MS No.: acp-2020-555
Title: The Effect of Meteorological Conditions and Atmospheric Composition in the Occurrence and Development of New Particle Formation (NPF) Events in Europe
Author(s): Dimitrios Bousiotis et al.

RESPONSE TO REVIEWERS

The authors thank the reviewers for their insightful comments and have made many modifications in response, and to enhance the clarity of the paper.

Anonymous Referee #1

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A couple of decades ago, a number of studies tried to link meteorological variables and gas phase pollutants with NPF. In some cases, the analysis was concise enough to produce evidence that a certain physical parameter played a role in NPF at a specific site.

Since then, studies - mostly chamber-based - have provided evidence on the ruling mechanisms of nucleation and subsequent growth of newly formed particles. These are mainly related to the concentration of low vapor pressure compounds such as sulfuric acid, or ELVOC as well as agents that could stabilize the former (ammonia, amines, iodine) suggesting that NPF is dictated mainly by gas phase chemistry rather than meteorology. However, other parameters such as the ones investigated in this study, play a secondary yet important role. Therefore a summary of observations from European, or even better global sites, is always welcome. During the past 15 years more than 20 compilations of results related to atmospheric NPF have been published, the majority of which are summarized by Kerminen et al., 2018. Even though some of them (eg Kerminen et al., 2018, Lee et al 2019) provide insight on the parameters this study is also focusing on, none has gone been as detailed as the one presented in this work. Therefore, the compilation of results presented in this work are of interest to the community and would be worthwhile publishing if the manuscript was well written and the analysis provided informative and concise. I am afraid that this is not the case. After reading the article, I was disappointed not to find any information on seasonality for any of the parameters investigated even though multi year data were investigated.

RESPONSE: It is not clear by the comment what kind of analysis is expected (whether it is the seasonality of the parameters themselves or the seasonality of their effect). The seasonality of the parameters (which was found to favour mainly summer for the growth rate, while the results for the formation rate were more variable) is separately investigated in a previously published paper for the UK sites (Bousiotis et al., 2019) and for the rest of the sites in an already submitted manuscript (Bousiotis et al., 2020) and thus was not discussed in the present study (this is noted in 2.1). The seasonality of their effect was not studied in the present manuscript as this would extend its size too much. It is worth pointing out that the variables most affected by season such as temperature and insolation are considered in this paper, and to break down the data analysis according to season would involve a great deal of repetition.

Furthermore the authors fail to deliver any error metric whatsoever (deviation, error, confidence level). The lack of the most elementary statistical analysis was striking.
RESPONSE: Much of this information is included in the paper. Deviation errors are included in the SI figures for every subgroup of every variable studied (reporting these is unrealistic as they are over a thousand). R^2 is reported for every slope calculated of every variable studied on the figures. p-values are reported (when significant) for every variable in every site in tables 3 and 4. We have calculated, but not included, the error of the slope for every variable calculated using the normalised gradients, but have not included this as the normalised slopes do not have any significance other than their absolute value; we include only information on their trend.

The other striking feature is the poor use of English and terminology, which I explain thoroughly below. The use of English must be improved as there are many sentences that require revision.
RESPONSE: Many changes in terminology and corrections were applied throughout the manuscript to improve the level of English.

The major drawback is the generalizations and uncertain phrases used throughout the manuscript. The authors should be concise and specific instead.
RESPONSE: The manuscript was updated in many cases to reduce uncertainty (whenever there was enough confidence in the statements presented)

As an example in Line 69 (76) it is advised to name the places (exceptions) were NPF is hardly observed. A nice review can be found by Lee et al., 2019 (section 4.8).
RESPONSE: Exceptions where NPF events are not observed and references were added.

Example 2 Line 270: A few sites presented a strong correlation, which in all cases were background sites (either rural or urban). A few sites (which ones?) presented a strong correlation (nowhere in the manuscript strong, medium weak is defined. The reader has no idea what the author is discussing) which in all cases were background sites (either rural or urban; to the best of my knowledge rural sites are considered as background sites. What do the authors mean?). I assume that the authors are trying to point at urban kerbside sites with this sentence, yet I am not really sure what they mean. And the paragraph continues The relation (which one?) found in most cases (how many, percentage?) was positive (does this mean a positive slope? Where is it shown? In which table or graph?) apart from two roadsides (improper terminology) and GREUB, though due to the low (again low is not defined?) R2 these results cannot be used with confidence (and where do the authors draw the confidence line?). The above lines are just an example of improper phrasing used throughout the manuscript that make it very hard to follow. Similar examples can be found throughout the manuscript. A major drawback of this work is that many trends/relationships reported are not referred to any table or Figure and hence are hard to follow.
RESPONSE: References to the sites mentioned in each case as well as R^2 values were added throughout the manuscript to improve readability. References for the results were added in the

beginning of each section (to avoid repetition). Specific references for unusual trends were also added for the figures in the SI (figure numbering in SI was overhauled). References for SI figures for simple relationships were not added as they are covered by the slopes found in tables 3 and 4. Strong, weak and other characterisations of the correlations are now accompanied with either the R^2 or a range of the R^2.

NPF probability sounds to me as if you are trying to predict the occurrence of nucleation events. Based on Line 218 (Equations are not numbered!) a more suited term would be NPF frequency.
RESPONSE: The term NPF frequency is used within the text for the frequency of the events without taking into account any grouping of the data (into groups of condition ranges e.g NPF probability for RH in the range 60 – 65%). To separate these the term probability was used instead. Equation numbers were added.

The authors should consider adding reference formation and growth rates from other studies in their figures for comparison. I understand that this is not always possible (especially for formation rates) but is for the other two parameters in question.
RESPONSE: Similar to a previous comment, such an analysis was done in other studies either already submitted or published (Bousiotis et al., 2020; 2019).

Table 2 should also include growth rates for this study.
RESPONSE: The parameters of NPF are already reported in previously submitted studies (Bousiotis et al., 2020; 2019). The frequency and formation rate are reported here because they are used in the calculation of the normalised slopes, which is not done for the growth rate (see the methodology). Nevertheless, the growth rate and the number of NPF events for each site were added in Table 2.

The authors fail to summarize the seasonality of the parameters they are exploring even though they are having multi year data. This is very disappointing.
RESPONSE: This comment has already been addressed.

The statement in Lines 45-46 (49 – 50) is not true. Please read Kerminen et al., 2018 for example. That work which explicitly states the opposite.
RESPONSE: The sentence was rephrased into "without always following" to state that exceptions exist as pointed later in the Introduction part.

I have noted another case (Lines 98-99) (109 – 110) in the manuscript where the authors focus on the exceptions (which always exist) rather than the rule giving a very distorted view to the reader.
RESPONSE: In the text it is stated that "the negative effect of CS is widely accepted" and follows mentioning the exceptions found in the literature as "cases were found". This does not imply that the exceptions are anything more than that and it is essential that they are mentioned.

The introduction is very poor on references.
RESPONSE: More references were added in the introduction and throughout the manuscript

Lines 107-111 (118 – 123) should be rephrased. I cannot make sense of it at all.
RESPONSE: This sentence was included to show that the NPF events considered in our study were not driven by combustion products but by secondary formation. A parenthesis was added though which makes the sentence easier to understand.

Lines 82-84 (94 – 96). Please mention that increasing temperatures also have a negative effect as they increase the energy barrier the clusters have to overcome to become stable and grow in size.
RESPONSE: The comment has been added.

Kerminen, V. M., Chen, X., Vakkari, V., Petäjä, T., Kulmala, M. and Bianchi, F.: Atmo- spheric new particle formation and growth: Review of field observations, Environ. Res. Lett., 13(10), doi:10.1088/1748-9326, 2018.

Lee, S. H., Gordon, H., Yu, H., Lehtipalo, K., Haley, R., Li, Y. and Zhang, R.: New Particle Formation in the Atmosphere: From Molecular Clusters to Global Climate, J. Geophys. Res. Atmos., 124(13), 7098–7146, doi:10.1029/2018JD029356, 2019.

Anonymous Referee #2
Received and published: 26 September 2020
General comments
The focus of this study is to investigate the effect of meteorological conditions and atmospheric composition on the occurrence of new particle formation (NPF) events at 16 sites (rural, urban background and roadside) located in 6 European countries. The results are based on more than 85 years of meteorological and atmospheric composition data. The authors are using a binned linear regression to find correlations between parameters such as windspeed, temperature, pressure, or solar radiation intensity, ozone or volatile organic compounds mixing ratios to name a few, and the occurrence of NPF, particle growth and the formation rates. This is an interesting study and of interest to the community, however the following comments should be addressed before publishing. On many occasions the authors claim that certain variables are weakly or strongly correlated but do not provide any numbers or figure to support these statements. Please provide references to the exact figures in the manuscript or in the supplemental material (SM). This is an issue reappearing throughout the manuscript. Following on that, Figure S1 in SM contains many figures and only one caption. These figures are not marked with a number/letter. Please consider adding individual numbering (or introduce letters) so the respective figures corresponding to individual sites when being discussed in the manuscript could be easily found in SM.
RESPONSE: This is addressed in a later comment

It looks like the authors use terms frequency of NPF occurrence and NPF probability interchangeably. NPF probability doesn't really fit here since you do not predict NPF events. However, the NPF probability term is explained in the text and in the equation (line 191; also please number equations). In results, however, the authors are using term frequency of NPF occurrence (line 245). Please clarify, review the explanation in text and use the correct term throughout the manuscript. I assume what you want to use is NPF frequency.

RESPONSE: This is explained later

I understand you identify the number of days with NPF according to the method by Dal Maso et al. (2005) with additional certain criteria. It would be good to report the numbers of NPF events for each site (and season?). Please explain what days with "relevant data" are when calculating the frequency.

RESPONSE: Two additional papers analysing in detail the conditions of the NPF events at all the sites were either published (for UK) or were submitted (for the rest of the sites). This is noted in section 2.1. A figure has been added to the SI to show the seasonality.

If I understood correctly to calculate the frequency, you divide the number of days identified as NPF event-days by all days that you have data available or "relevant(?)" data available? I am curious how does the frequency changes when you use the number of all days with all data and not only with "relevant data available"? It would be good to mention this number somewhere in the manuscript or in the SM? Following on the above, please explain what is in e.g. line 191 "available data" and "given group"?

RESPONSE: The term "relevant data" refers to all the data available at each site and are considered in each analysis (and of course when those are available). At each site the data were almost in their entirety available and the limitation was in most cases the SMPS data (its availability for each site is reported in Table 1). The data is always considered only when they are available for each variable studied (by the code used in the analysis, as they were calculated one by one), so no hours of data with missing values were included. In other words, when e.g. temperature was studied only the hours with both SMPS and temperature data were considered.

More detail on the site selection criteria would be helpful. Do these sites belong to a network? How were these sites selected? In Line 120: the authors mention "geographical region and type of environment". I suggest adding more description on the sites (e.g. in SM), their characteristic and typical meteorological conditions, e.g. features they have in common/differences, number of NPF studied and identified.

RESPONSE: A justification for the sites chosen is given in the Site description section. As mentioned earlier, the analysis of the events, as well as the typical conditions for all the sites were given in two separate earlier papers.

Having this extensive dataset, I encourage the authors to discuss variability e.g. seasonal, site to site/regional. A figure where you plot frequency of NPF occurrence or number of NPF events for each station in each season (e.g. bar plot?) on (y axis), for each site type (x axis) would be helpful. Exploring e.g. seasonal variability would add value to the paper.
RESPONSE: This was already done in two earlier papers (Bousiotis et al., 2020; 2019).

Where there any limitations of the study? If yes, these should be discussed. Further, errors should be included.
RESPONSE: The study is pretty straightforward, and the only limitation was the lack of data for some variables at some sites e.g. SO_2 data was not available at all sites. A comment was added for this limitation at the end of 2.1 Site Description and Data Availability section.

Are there general trends for these three site types? Maybe you could discuss these more. It would be helpful to highlight (e.g. text in bold) data in Table S1 e.g. significant correlations.
RESPONSE: As explained in the response to the first comment, these are provided in other studies (Bousiotis et al., 2020; 2019). Stronger correlations were highlighted with bold numbers.

What is the importance of the result of this study? The authors could discuss it more e.g. in conclusion. I feel that is missing in the current version.
RESPONSE: The statement: "This study, apart from providing insights into the effect of a number of variables on the occurrence and development of NPF events in atmospheric conditions across Europe, also shows the differences that climatic, land use and atmospheric composition variations cause to those effects. Such variations are probably the cause of the differences found among previous studies." was added in the last paragraph of the text (838).

Please improve the language. It is critical to make the text more concise and clearer. It is hard to follow the line of thoughts at points. There are some repetitions and long sentences that could be shortened (e.g. lines: 76-82, 107-111, 325-330).
RESPONSE: Many changes were made in the manuscript to improve readability.

Specific comments
Line 38-62: in the abstract the authors could also mention: 85 years of data; how good these correlations are (r2)' mention "meteorological conditions" e.g. such as …
RESPONSE: The information that a combined dataset of 85 years was used was added (52). Added the highest R^2 values found for some variables (54 – 56). Added "(such as solar radiation and relative humidity)" (58)

Line 42 (46): "except at very clean air sites" – more information is needed to this statement. Something is missing. Please review or explain.
RESPONSE: This phrase has been removed.

Line 54 (60): What "higher values" means there exactly? Provide a number.
RESPONSE: Added the word "average". No values can be provided as what is implied by the results is that the importance of some variables becomes less as the average values (average conditions) become higher or lower, depending on the general trend.

Line 61- 62 (67-68): you could give these values in brackets
RESPONSE: No values were added as the text implies that one increases with the other simultaneously, similar to the meteorological conditions.
Line 97 (108): "negative effect" on?
"on the occurrence of the events" was added.

Line 99 (110): "average conditions"? What does it mean here?
RESPONSE: No change in the text. It means the average CS which is well covered with the term "average conditions" in this case.

Line 107-111 (118 – 123): hard to follow, please review and shorten
RESPONSE: Already mentioned by referee #1 and addressed.

Line 121 (133): please add references to the studies you refer to
RESPONSE: References were added

Line 122 (134): NPF probability? Or NPF occurrence? As mentioned above, probability doesn't really fit here
RESPONSE: NPF probability was not changed as every time it is mentioned it implies the results from the analysis/modelling that was done in this study. An explanation for this was provided (213)

Line 124 (138): I suggest calling this section: "2. Methods", 2.1 as is. 2.2 as is or similar. This way you can remove 2.2 Methods so it does not appear twice. In 2.1 the authors could mention which cities/countries/sites were used; which meteorological and atmospheric composition variables did you use in this study already at this point. Which stations had a full set of data and which only some etc. Maybe also mention which are dependent and which independent variables. And what do you consider relevant data days, what do you mean by available data: e.g. in line 189. Please be more specific upfront. You could also add information on how these sites were chosen? Any criteria you applied to select these? Are they belong to a network? Are they similar or different in any respect?
RESPONSE: Section naming was not changed as it is considered sensible for a chapter named "Data and Methods" to have section 1 named "Sites and data" and section 2 as "Methods". The countries and cities included in the study are mentioned. A list of the data available in each site is found in Table 1, as mentioned in the text. A justification for the sites chosen was also added. The sites do not belong to a single network and thus such information is not provided.

Line 127 (140): I feel that the number of events (1950) is already a result so it should go to the result section and not methods. Also, it is mentioned before the description of the NPF selection method itself.
RESPONSE: The number of events was moved to the beginning of the Results section

Line 131 (142): it is also referring to the result. I suggest moving this sentence to the result section.
RESPONSE: The reference for the Table with results was moved to the beginning of the Results section.

Line 136-143 (156 – 165): please add more details to the approach taken in this study. What "Ia" exactly refers to and which additional criteria was used (line 142).
RESPONSE: The process of NPF event extraction was rewritten and more details were added for the approach taken (156 – 169).

Line 137 (158): add size range of the nucleation mode you consider in your study
RESPONSE: Added "(smaller than 20 nm in diameter)".

Line 139 (160): you could mention confidence level in the brackets
RESPONSE: Changed to level of certainty to avoid misunderstandings.

Line 151 (178): add "respectively" after "particles". You could already mention there Fuchs correction factor and keep it explained below.
RESPONSE: Added the word "respectively" (178). Second was not mentioned to avoid repetition and flow distraction.

Line 149 (176): Formulas need to be numbered
RESPONSE: Equation numbers were added

Line 188 (216): given group? please explain
RESPONSE: The NPF probability is calculated for the range of data in a specific group (time range, range of a given variable ex. for relative humidity from 50 to 55% etc.). Text was slightly modified to reflect this better.

Line 191 (219): Again: I am not sure I follow this equation: what are these groups? Is it just a number of days with NPF that was accompany by all relevant data? From explanation you seem only to take days with NPF that were accompanied by relevant data.
RESPONSE: For the analysis done, data was separated into smaller groups as mentioned earlier. Thus, the term probability is considered more appropriate than frequency. This is clearly stated in the text.

Line 196 (224): low significance? Please give a number
RESPONSE: The results found from the analysis of raw data, due to the large spread, almost never provided with any significant result (the R^2 was always very low). A single number cannot be provided as the results are numerous. The word “statistical” was added.

Line 212 (241): extreme values? Please give a number
RESPONSE: As previous. The cases that extreme values that biased the results were many. For example, an extreme value of wind speed (a single very windy day with no event) would result in an NPF probability of zero for that wind speed range. This though would result in biasing the whole analysis by a very limited range of data.

Line 239 (268): Results and Discussion? You could include here sentence in line 126: You mention 1950 events studied, could you provide information on how many were identified? It would be helpful if authors mention that in the paper a summary of data can be found in the manuscript and in the SM data/results for individual sites is presented.
RESPONSE: The sentence mentioned (the number of events extracted) was moved to the Results section as suggested. The events studied were those that all the work was focused on. While other, less clear events (without the expected growth, advected, uncertain etc.) were also extracted, they were considered only as exceptions or special cases in previous works. For further information about the events for each site as well as the comparative study between them, references were added in the Site Description section.

Line 245 (277): what is relevant data? Please explain more clearly in methods section and refer to it. Diagnostic features – wouldn’t these be better in methods?
RESPONSE: Added “depending on the variable studied”. Relevant data refer to the data available depending on the variables studied, e.g. to find the frequency of NPF events, the days with available SMPS data were only considered. These diagnostic features are used to present the results in Table 2 and thus were not moved to Methods.

Line 252 (286): “slopes and R2” please use correct terms for these or more careful description
RESPONSE: Changed to the terms gradient (instead of slope) and coefficient of determination for R^2.

Line 261 (296): very strong? Please provide references to the exact figures in the figures/supplemental material when discussing results
RESPONSE: In this case very strong correlations were considered for $R^2 > 0.75$ as explained in the parenthesis (and a clarification is added to any characterised correlation). The correlations (whether weak or strong) are found in Tables 3 and 4 (references added). References to the figures in the SI

are not needed when discussing slopes and R^2 and were only referenced when variable/unusual trends were found.

Line 279 (315): low? Please give a number and refer to the figure. Also, you placed all figures in the SM under Figure 1. Maybe it would be better for the reader to have them split into different figure numbers or a,b,c,d? This way it would be easier to find the one you describe at the very moment.

RESPONSE: The value of the R^2 was added in a parenthesis. Also, changed the numbering scheme for the figures in SI. References to figures in the SI that present results not in the tables (i.e. variable trends) were added in the text.

Line 296 (333): reference?

RESPONSE: A reference was added

Line 301-303 (339): why? Could you explain? When describing results maybe worth mentioning these for various site specifics? Anything in common?

RESPONSE: A possible explanation was added "This may be due to the different seasonality of the events found for the Greek sites (being more balanced within a year), as there was increased probability of NPF events for the seasons with higher RH compared to other sites, making it a less important factor for their occurrence."

Line 369 (414): which factors remain constant?

RESPONSE: Added the word "meteorological"

Line 377 (420): reference?

RESPONSE: References for this are found in the introduction

Line: 398 (441 - 443): maximum? Low?

RESPONSE: Maximum changed to greatest. Low wind speeds changed to "close to zero wind speeds".

Line 420 (464): Ethesian: add few words what these are could be added

RESPONSE: A brief description has been added ("a pressure system that develops in the region every summer").

Table 3: what is a "p value"? has it been defined somewhere? In tables: the authors could use bold text to highlight significant correlations? So these patterns/trends could be clearly seen?

RESPONSE: Added the definition of p-value (line 286). Used bold text for all correlation $r > 0.50$

Figures: no need to mention in each caption "of the present studies"

RESPONSE: The phrase was removed

Line 433 (479): you could already mention here which pollutants (such as. . .) are studied and described in the upcoming sections.
Added the chemical compounds studied in a parenthesis
Line 752 (806): “at higher values”?
Changed to “at sites with higher average values”

Line 755 (810): “meteorological conditions” such as?
“such as temperature or relative humidity” was added

Line 756-757 (812): is that the only explanation? How about chemistry/composition at such type of site? Anything else that might play a role?
RESPONSE: Added “compared to the urban environments and the more complex chemical interactions found there”
Line 782-783 (840): seems out of place here; it would be more suitable at the beginning of conclusion section or removed.
RESPONSE: Moved the sentence to the start of the Conclusions section (line 796).

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-555, 2020
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RESPONSE: Additionally, four authors were added in the list of authors

Table 1 was updated

Bousiotis, D., Pope, F. D., Beddows, D. C., Dall’Osto, M., Massling, A., Nøjgaard, J. K., Nørdstrom, C., Niemi, J. V., Portin, H., Petäjä, T., Perez, N., Alastuey, A., Querol, X., Kouvarakis, G., Vratolis, S., Eleftheriadis, K., Wiedensohler, A., Weinhold, K., Merkel, M., Tuch, T., and Harrison, R. M.: An Analysis of New Particle Formation (NPF) at Thirteen European Sites, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-414, in review, 2020.

Bousiotis, D., Dall'Osto, M., Beddows, D. C. S., Pope, F. D., and Harrison, R. M.: Analysis of new particle formation (NPF) events at nearby rural, urban background and urban roadside sites, Atmos. Chem. Phys., 19, 5679–5694, https://doi.org/10.5194/acp-19-5679-2019, 2019.

The Effect of Meteorological Conditions and Atmospheric Composition in the Occurrence and Development of New Particle Formation (NPF) Events in Europe

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ABSTRACT

Although new particle formation (NPF) events have been studied extensively for some decades, the mechanisms that drive their occurrence and development are yet to be fully elucidated. Laboratory studies have done much to elucidate the molecular processes involved in nucleation, but this knowledge has yet to be conclusively linked to NPF events in the atmosphere~~, except at very clean air sites~~. There is great difficulty in successful application of the results from laboratory studies to real atmospheric conditions, due to the diversity of atmospheric conditions and observations found, as NPF events occur almost everywhere in the world without always following a clearly defined trend of frequency, seasonality, atmospheric conditions or event development. The present study seeks common features in nucleation events by applying a binned linear regression over an extensive dataset from 16 sites of various types (combined dataset of 85 years from rural and urban backgrounds as well as roadside sites~~s~~) in Europe. At most sites, a clear positive relation is found between the solar radiation intensity (up to $R^2 = 0.98$), temperature (up to $R^2 = 0.98$) and atmospheric pressure (up to $R^2 = 0.97$) with the ~~frequency~~ probability of NPF events, while relative humidity (RH) presents a negative relation (up to $R^2 = 0.95$) with NPF event~~-~~ probability~~frequency~~. Wind speed presents a less consistent relationship which appears to be heavily affected by local conditions. While some meteorological variables (such as the solar radiation intensity and RH) appear to have a crucial effect on the occurrence and characteristics of NPF events, especially at rural sites, it appears that their role becomes less marked when at higher average values.

The analysis of chemical composition data presents interesting results. Concentrations of almost all chemical compounds studied (apart from O_3) and the Condensation Sink (CS) have a negative relationship with NPF event probability, though areas with higher average concentrations of SO_2 had higher NPF event probability. Particulate Organic Carbon (OC), Volatile Organic Compounds (VOCs) and particulate phase sulphate consistently had a positive relation with the growth rate of the newly formed particles. As with some meteorological variables, it appears that at increased concentrations of pollutants or the CS, their influence upon NPF probability is reduced.

1. INTRODUCTION

New Particle Formation (NPF) events are an important source of particles in the atmosphere (Merikanto et al., 2009; Spracklen et al., 2010), which are known to have adverse effects on human health (Schwartz et al., 1996; Politis et al., 2008; Kim, et al., 2015) as well as affecting the optical and physical properties of the atmosphere (Makkonen et al., 2012; Seinfeld and Pandis, 2012). While they occur almost everywhere in the world (Dall’Osto et al., 2018; Kulmala et al., 2017; O’Dowd et al., 2002; Wiedensohler et al., 2019; Chu et al., 2019; Kerminen et al., 2018), with some exceptions mentioned in the literature in forest (Lee et al., 2016; Pillai et al., 2013; Rizzo et al., 2010) or high-elevation sites (Bae et al., 2010; Hallar et al., 2016), great diversity is found in the atmospheric conditions within which they take place. Many studies have been done in a large number of different types of locations (urban, traffic, regional background) around the world and differences were found in both the seasonality and intensity of NPF events. To an extent this variability is due to the mix of conditions that are specific to each location, which blurs the general understanding of the conditions that are favourable for the occurrence of NPF events (Berland et al., 2017; Bousiotis et al., 2020). For example, solar radiation is considered as one of the most important factors in the occurrence of NPF events (Kulmala and Kerminen, 2008; Kürten et al., 2016; Pikridas et al., 2015; Salma et al., 2011), as it is needed for the photochemical reactions that lead to the formation of sulphuric acid (Petäjä et al., 2009; Cheung et al., 2013)~~,~~. Sulphuric acid ~~which~~ is considered as the main component of the formation and growth of the initial clusters (Iida et al., 2008; Stolzenburg et al., 2020; Weber et al., 1995). Nevertheless,~~; although~~ in many cases~~,~~

NPF events did not occur in the seasons with the highest insolation (Park et al., 2015; Vratolis et al., 2019). Similarly, uncertainty exists over the effect of temperature (Yli-Juuti et al., 2020; Stolzenburg et al., 2018). H~~h~~igher temperatures are considered favourable for the growth of the newly formed particles as increased concentrations of both Biogenic Volatile Organic Compounds (BVOCs) and Anthropogenic Volatile Organic Compounds (AVOCs) (Yamada, 2013; Paasonen et al., 2013) and their oxidation products (Ehn et al., 2014) are associated to~~with~~ the growth of the particles. The negative effect of increasing temperatures in increasing the energy barriers the clusters have to overcome to become stable and grow in size though should not be overlooked (Kürten et al, 2018; Zhang et al., 2012). This appears to be true in most cases, as higher growth rates are found in most cases in the local summer (Nieminen et al., 2018), although the actual importance of those VOCs in the occurrence of NPF events is still not fully elucidated, with oxidation mechanisms still under intense research (Tröstl et al., 2016; Wang et al., 2020). The effect of other meteorological variables is even more complex, with studies presenting mixed results on the effect of the wind speed and atmospheric pressure. Extreme values of those variables may be favourable for the occurrence of NPF events, as they are associated with increased mixing in the atmosphere, but at the same time suppress due to increased dilution of precursors (Brines et al., 2015; Rimnácová et al., 2011; Shen et al., 2018; Siakavaras et al., 2016), or favour them due to a reduced condensation sink (CS).

The effect of atmospheric composition on NPF events is also a puzzle of mixed results. While the negative effect of the increased CS on the occurrence of the events is widely accepted (Kalkavouras et al., 2017 ; Kerminen et al., 2004; Wehner et al., 2007), cases are found when NPF events occur on days with higher CS compared to average conditions (Größ et al., 2018; Kulmala et al., 2005). Sulphur dioxide (SO_2), which is one of the most important contributors to many NPF pathways, in most studies was found in lower concentrations on NPF event days compared to average conditions (Alam et al., 2003; Bousiotis et al., 2019), although there are studies that have reported the opposite (Woo et al., 2001; Charron et al., 2008). Additionally, in a combined study of NPF events in China, events were found to be more probable under sulphur-rich conditions rather than sulphur-poor (Jayaratne et al., 2017). Similar is the case with the BVOCs and AVOCs, which present great variability depending the area studied (Dai et al., 2017), and their contribution in the growth of the particles is not fully understood yet. Until recently, it was considered unlikely for NPF events, as they are considered in the present study~~,~~ (deriving from secondary formation not associated with traffic related processes such as dilution of the exhaust), to occur within the complex urban environment due to the increased presence of compounds, mainly associated with combustion processes, which would suppress the survival of the newly formed particles within this type of environment (Kulmala et al., 2017). Despite thiast though, NPF events were found to occur within even the most polluted areas and sometimes with high formation and growth rates (Bousiotis et al., 2019; Yao et al., 2018).

It is evident that while a general knowledge of the role of the meteorological and atmospheric variables has been achieved, there is great uncertainty over the extent and variability of their effect (and for some of them even their actual effect) in the mechanisms of NPF in real atmospheric conditions, especially in the more complex urban environment (Harrison, 2017). The present study, using an extensive dataset from 16 sites in six European countries, attempts to elucidate the effect of several meteorological and atmospheric variables not only in general, but also depending on the geographical region or type of environment. While studies with multiple sites have been reported in the past (Dall'Osto et al., 2018; Kulmala et al., 2005; Rivas et al., 2020), to the authors' ~~our~~ knowledge this is the first study that focuses directly on the effect of these variables upon the probability of NPF events as well as the formation and growth rates of newly formed particles in real atmospheric conditions.

2. DATA AND METHODS

2.1 Site Description and Data Availability

The present study uses a total of more than 85 years of hourly data from 16 sites from six countries of Europe of various land usage and climates ~~from which 1950 NPF events were extracted and studied~~. It was considered very important that at least a rural and an urban site would be available from each country to study the differences between the different land usage on NPF events throughout Europe. The sites were chosen to cover the greatest possible ~~area~~extent of the European continent, with sites from both northern, central and southern Europe, as well as from western and eastern. The sites are located in the UK (London and Harwell), Denmark (Copenhagen greater area), Germany (Leipzig greater area), Finland (Helsinki and Hyytiälä), Spain (Barcelona and Montseny – a site in a mountainous area) and Greece (Athens and Finokalia). Unfortunately, not all sites had available data for all the variables studied, which to an extent~~d~~ may bias some of the results. An extended analysis of the typical and NPF event~~s'~~ conditions, seasonal variations and trends at these sites for the same period is found in other studies (Bousiotis et al., 2019; 2020). A list of the available data and a brief description for each site is found in Table 1 (for the ease of reading the sites are named by the country of the site followed by the last two letters which refer to the type of site, being RU for rural/regional background, UB for urban background and RO for roadside site), while a map of the sites is found in Figure 1. ~~The NPF frequency and formation rate for each site is found in Table 2.~~

2.2 Methods

2.2.1 NPF events selection

NPF events were selected using the method proposed by Dal Maso et al (2005). A~~s of this, a~~n NPF event is ~~considered~~ identified ~~when a new mode of particles appears~~by the appearance of a new mode or particles in the nucleation mode (smaller than 20 nm in diameter), which prevails for some hours and shows signs of growth. The events can then be classified into classes I and II according to the level of ~~confidence~~certainty, while class I events can be further classified to Ia and Ib. E~~, with Ia~~ events having both a clear formation of a ~~by~~ new mode of particles ~~at~~in the smallest size bins available (thus excluding possible advected events) as well as a distinct and persistent growth of the new mode of particles for at least 3 hours were classified as Ia, while Ib consists of rather clear events that fail though by at least one of the criteria set. Additionally, for the roadside sites, a formation of particles in the nucleation mode accompanied ~~with~~by a significant increase of the concentrations of pollutants was not considered as an NPF event, as it may be associated ~~to~~with mechanisms other than the secondary formation. In the present study, only the events of class Ia were considered with the additional criterion of at least 1 nm h^{-1} growth for at least 3 hours.

2.2.2 Calculation of condensation sink, growth rate, formation rate, and NPF event probability

The condensation sink (CS) is calculated according to the method proposed by Kulmala et al., (2001) as:

$$CS = 4\pi D_{vap} \sum \beta_M \, r \, N \qquad (1)$$

where r and N is the radius and number concentration of the particles respectively and D_{vap} is the diffusion coefficient calculated as (Poling et al., 2001):

$$D_{vap} = 0.00143 \cdot T^{1.75} \frac{\sqrt{M_{air}^{-1} + M_{vap}^{-1}}}{P\left(D_{x,air}^{\frac{1}{3}} + D_{x,vap}^{\frac{1}{3}}\right)^2} \qquad (2)$$

for T = 293 K and P = 1013.25 mbar. M and D_x are the molar mass and diffusion volume for air and sulphuric acid. β_M is the Fuchs correction factor calculated as (Fuchs and Sutugin, 1971):

$$\beta_M = \frac{1 + K_n}{1 + \left(\frac{4}{3a} + 0.377\right) K_n + \frac{4}{3a} {K_n}^2} \qquad (3)$$

where K_n is the Knudsen number, calculated as $K_n = 2\lambda_m/d_p$ where λ_m is the mean free path of the gas.

Growth rate (GR) is calculated as (Kulmala et al., 2012):

$$GR = \frac{D_{P_2} - D_{P_1}}{t_2 - t_1} \qquad (4)$$

for the size range between the minimum available particle diameter up to 30 nm (50 nm for the UK sites due to the higher minimum particle size available). The time window used for the calculation of the growth rate was from the start of the event until a) growth stopped, b) GMD reached the upper limit set or c) the day ended.

The formation rate J was calculated using the method proposed by (Kulmala et al., 2012) as:

$$J_{d_p} = \frac{dN_{d_p}}{dt} + CoagS_{d_p} \times N_{d_p} + \frac{GR}{\Delta d_p} \times N_{d_p} + S_{losses} \qquad (5)$$

where $CoagS_{dp}$ is the coagulation rate of particles of diameter d_p, calculated as (Kerminen et al., 2001):

$$CoagS_{d_p} = \int K(d_p, d'_p)\, n(d'_p) dd'_p \cong \sum_{d'_p=d_p}^{d'_p=max} K(d_p, d'_p)\, N_{d_p} \qquad (6)$$

$K(d_p, d'_p)$ is the coagulation coefficient of particles with diameters d_p and d'_p, while S_{losses} accounts for additional loss terms (i.e. chamber wall losses), which are not applicable in the present study. For the present study, the formation rate of particles of diameter of 10 nm was calculated for uniformity (16 nm for the UK sites), though most sites had data for particle sizes below 10 nm.

The NPF probability, used instead of NPF frequency when modelled results are presented, was calculated by the number of NPF event days divided by the number of days with available data in the given group (temporal, variable range wind direction sector etc.). The results presented in this study were also normalised according to the data availability, as:

$$NPF_{probability} = \frac{N_{NPF\ event\ days\ for\ group\ of\ days\ X}}{N_{days\ with\ available\ data\ for\ group\ of\ days\ X}}$$

2.2.3 Calculation of the ~~slope~~ gradient and intercept for the variables used

Due to the large datasets available and the great spread of the values, a direct comparison between a given variable and any of the characteristics associated with NPF events (NPF probability, growth rate and formation rate) always provided results with low statistical significance. As a result, an alternative method which can provide a reliable result without the ~~noise~~ dispersion of the large datasets was used in the present study, to investigate the relationships between the variables which are considered to be associated with the NPF events. For this, a timeframe which is more directly associated with the NPF events typically observed in the mid-latitudes was chosen. For NPF probability and GR the timeframe between 05:00 to 17:00 Local Time (LT) was chosen, which is considered the time when the vast majority of NPF events take place and further develop with the growth of the particles. For the formation rate a smaller timeframe was chosen, 09:00 to 15:00 LT ~~(Local Time)~~ which is ± 3 hours from the time of the maximum formation rate found for almost all sites (12:00 LT). This was done to exclude as far as possible the effect of the morning rush at the roadside sites~~s~~, as well as only to include the time window when the formation rate is mostly relevant to NPF events (negative values that are more probable outside this timeframe and are not associated ~~to~~with the formation of the particles would bias the results).

F~~Specifically, f~~or the CS the timeframe 05:00 to 10:00 LT was chosen. This was done to avoid including the direct effect of the NPF events (the contribution of newly formed particles to CS), as well as to provide results for the conditions which either promote or suppress the characteristics studied, which specifically for the CS are more important before the start of the events. The extreme values (very high or very low) which bias the results only carrying a very small piece (forming bins of very small size) of information were then removed, though 90% of the available data ~~were~~ was used for all the variables. The data left was separated into smaller bins and a minimum of 10 bins was required for each variable (for example if the difference between the minimum and the maximum relative humidity (RH) is 70%, then 14 bins each with a range of 5% were formed). The variables of interest were then averaged for each bin and plotted, and a linear relation was considered for each one of them.

The ~~slope~~ gradient of these linear relations (a_N, a_G and a_J for NPF probability, growth rate and formation rate J_{10} accordingly) found in this analysis should be used with great caution as apart from the atmospheric conditions (local and meteorological as well as atmospheric composition) it is also affected by the variable in question (e.g. a greater NPF probability will provide a greater ~~slope~~gradient), resulting in giving the same trend for all the atmospheric variables tested; the sites with the higher values of these variables (NPF probability and formation rate) always had greater ~~slope~~ gradient values and vice versa. In order to remove the effect of the variable in question (NPF probability or formation rate – growth rate will provide an ~~untrustworthy~~ unreliable result as it is calculated in a different range for each site due to the lower available size of particles), the ~~slopes~~ gradients were normalised by dividing them by their respective variable (e.g. divide the ~~slope~~ gradient of the NPF probability with the NPF ~~probability~~frequency), providing with a new normalised slope (a_N* for NPF probability or a_J* for the formation rate) that will have no significance other than its absolute value, which can be used for direct comparisons:

$$a_N^* = \frac{a_N}{\text{NPF}\,\%}$$

Where a_N is the ~~slope~~ gradient of the relation between the given variable and NPF ~~probability~~ frequency (NPF %)

$$a_J^* = \frac{a_J}{J_{10}}$$

Where a_J is the ~~slope~~ gradient of the relation between the given variable and the formation rate of 10 nm particles J_{10} (J_{16} for the UK sites).

3. RESULTS

In this study NPF events are generally observed as particles grow from a smaller size (typically 3-16~~5~~ nm depending on the size detection limit of instruments used) to 30 nm or larger. They therefore reflect the result both of nucleation, which creates new particles of 1-2 nm (not detected with the instruments used in this study), and growth to larger sizes. In analysing NPF events, we therefore consider three diagnostic features:

- the ~~frequency~~ probability of events occurring (i.e. days with an event divided by total days with relevant data, depending on the variable and range studied),
- the rate of particle formation at a given size (J_{10} in this case),
- the growth rate of particles from the lower measurement limit to 30 nm (or 50 nm for the UK sites).

From the analysis of the extended dataset a total of 1952 NPF events were extracted and studied. The NPF frequency, growth and formation rate for each site is found in Table 2. The seasonal variation of NPF events is found in ~~f~~Figure S14.

3.1 Meteorological Conditions

The ~~slopes~~ gradients, coefficients of determination (~~and~~ R^2) and the p-values (deriving from one-way ANOVA test) from the analysis of the meteorological variables, as well as the average conditions of these variables are found in Table 3. The results for each site and variable are found in f~~F~~igures S1 – S5.

3.1.1 Solar radiation intensity

As mentioned earlier, solar radiation intensity is considered ~~as~~ to be one of the most important variables in NPF occurrence, as it contributes to the production of H_2SO_4 which is a main component of the initial clusters and participates in the early growth of the newly formed particles.

Hidy et al. (1994) reported up to six times higher SO_2 oxidation rates into H_2SO_4 in typical summer conditions compared to winter~~)~~. For almost all sites this relation is confirmed with very strong correlations (R^2 > 0.75) between the intensity of solar radiation and the probability for NPF events to occur.~~,~~ The relationship between the solar radiation and NPF probability was positive at all sites and only three sites (FINUB, SPARU and GREUB) presented weak correlations (R^2 <~~below~~ 0.40). Weaker correlations were found for the southern European sites, which might be associated with the higher averages for solar radiation intensity, or the interference of other processes (such as coinciding with increased CS by recirculation of air masses (Carnerero et al., 2019)), possibly making it less of an important factor for these areas.

The relationship of solar radiation ~~to~~ with the growth rate was weaker in all cases and did not present a clear trend. Only some rural background sites (GERRU, FINRU and GRERU) ~~A few sites~~ presented a strong correlation (R^2 > 0.50).~~, which in all cases were background sites (either rural or urban).~~ The relationship found in most cases was positive apart from two roadside sites (GERRO and UKRO)~~s~~ and two urban background sites (GREUB and UKUB), though due to the low R^2 (< 0.10) these results cannot be ~~used~~ considered with confidence. It seems though that the solar radiation intensity is probably a more important factor at background sites rather than at roadside sitess, where possibly local conditions (such as local emissions) are more important (Olin et al, 2020). Finally, the formation rate has a positive relationship with the solar radiation intensity, with relatively strong correlations in most areas (R^2 > 0.50). The correlations were stronger at the rural background sites compared to the roadside sites~~s~~, which further underlines the increased importance of this factor at this type of site. A negative relationship between the solar radiation intensity and the formation rate was found at the GRERU site but the R^2 is very low ($R^2 = 0.05$).

Plotting the normalised ~~slopes~~ gradients for NPF event probability a_N^* with the average solar radiation intensity at each site (Figure 2) a negative relationship is found ($R^2 = 0.62$), with the southern areas (those with higher average solar intensity) having smaller a_N* compared to those in higher latitudes (and thus with a lower average solar radiation). This may indicate that while solar radiation is a deciding factor in the occurrence of an NPF event, when in greater intensity its role becomes relatively less important, a finding that was also implied by Wonaschütz et al. (2015). Additionally, the a_J* was found to be higher at all rural sites compared to their respective roadside sites~~s~~ (and urban background sites for all but the Greek and German ones), making it a more important factor at this type of site (Figure 3).

3.1.2 Relative humidity

Relative humidity is considered to have a negative effect on the occurrence of NPF events (Jeong et al., 2010; Hamed et al., 2011; Park et al., 2015; Dada et al., 2017; Li et al., 2019). While water in the atmosphere is one of the main compounds needed for the formation of the initial clusters either on the binary or ternary nucleation theory (Henschel et al., 2016; Korhonen et al., 1999; Mirabel and Katz, 1974), ~~in~~ under atmospheric conditions it may also play a negative role suppressing the number concentrations of new particles by increasing aerosol surface area (Li et al. 2019). Consistent with this, a negative relationship of the RH with NPF probability was found for all the sites of this study with very high R^2 for almost all of them ($R^2 > 0.80$). This is not simple to interpret as solar radiation intensity, temperature, RH and CS are not independent variables, since an increase in temperature of an air mass due to increased solar radiation will be associated with reduced RH, which in turn affects the CS. The sites in Greece presented lower R^2 compared to the other sites while, GRERU was found to have the weakest correlation ($R^2 = 0.22$). This may be due to the different seasonality of the events found for the Greek sites (being more balanced within a year), as there was increased frequency of NPF events for the seasons with higher RH compared to other sites, making it a less important factor for their occurrence. Growth rate on the other hand had a variable relationship, either positive or negative, with only a handful of background sites having strong correlations. T ~~Among these t~~he German background sites as well as FINRU, which were among the sites with the highest average RH (average RH for GERRU is 81.9%, GERUB is 78.7% and FINUB is 80.1%) presented a negative relationship between the RH and growth rate.~~, while~~ DENRU (average RH at 75.7%) had a positive relationship, which might indicate that the relationship between these two variables may vary depending upon the RH range. Formation rate also appears to have a negative relationship with the RH, though this relationship was significant ($R^2 > 0.40$) for only 6 sites, which once again in most cases are sites with higher RH average conditions. Along with the results of the growth rate this might indicate that the RH becomes a more important factor in the development of NPF events as its values increase.

The normalised ~~slopes~~ gradients once again provide some additional information. Regarding the NPF probability, it is found that the a_N^* was more negative at rural sites compared to roadside sites~~s~~. This indicates that the RH has a smaller effect at roadside sites~~s~~, as other variables, such as the atmospheric composition, are probably more important within the complex environment in this type of site~~s~~. Additionally, the relationship between a_N^* and average RH at the sites had a negative relationship (R^2 = 0.46), which further shows that the RH becomes a more important factor at higher values (Figure 4). Furthermore, at the sets of rural and roadside sites with R^2 higher than 0.40 for the relation between RH and the formation rate (UK and German sites), it was found that the a_J^* was more negative at the rural sites which indicates that the RH is a more important factor at rural sites compared to their respective roadside sites~~s~~.

3.1.3 Temperature

Temperature can have both a direct and indirect effect in the development of NPF events, as it is directly associated with the abundance of both biogenic~~-~~ and anthropogenic volatile carbon, which is an important group of compounds whose oxidation products can participate in nucleation itself (Lehtipalo et al., 2018; Rose et al., 2018), as well as in the growth of newly formed particles.~~, while~~ I~~i~~t may ~~affect~~ also have a negative effect on the particle size distributions or number concentrations through other processes such as particle evaporation. Most of the sites of the present study presented a strong relationship of NPF probability with temperature, which in most cases was positive, though in many cases (such as the Danish, ~~Spanish and Finnish~~Finnish and Spanish sites – figures S2b, d and e) there seems to be a peak in the NPF probability at some temperature, after which a decline starts (though being at the higher end does not greatly affect the results). Sites with smaller R^2 (weaker association with temperature), were mainly those that have a seasonal variation that favoured seasons other than summer. These sites not only had weaker relationship of NPF probability with temperature, but in most cases had a negative relationship (background sites in Finland, Spain and Greece). The Finnish sites, having the lowest average temperatures and a sufficient amount of data below zero temperature, show at all three sites the possible presence of a peak in the NPF event probability for temperatures below zero (Figure S2d). This seems to be the cause of the weak relations found there and they seem to be associated with the formation rate J_{10}, which also seems to have an increasing trend below zero degrees (Figure S2p). This may depend on the nucleation mechanism occurring, as cluster evaporation rates of sulphuric acid clusters are sensitive to the ternary stabilising compound present (Olenius et. al., 2017) ~~be the result of increased stability of molecular clusters at lower temperatures~~, as well as the possible enhancement of growth mechanisms ~~in~~ at lower temperatures (below 5°C) by other chemical compounds in the atmosphere (i.e. nitric acid and ammonia) as found by Wang et al., (2020). Laboratory experiments show that the characteristics of organic aerosol forming from alpha-pinene is governed by gas phase oxidation (e.g. Ye et al. 2019). In the real atmosphere, the higher temperature enhances the amount of biogenic vapours (e.g. Paasonen et al. 2013)~~,~~ and, although the oxidation can be more efficient ~~in~~

at higher temperatures, the lower temperatures favour formation of more non-volatile compounds (Quéléver et al., 2019; Stolzenburg et al. 2018; Ye et al. 2019~~; Stolzenburg et al. 2018~~).

Growth rate had a more uniform trend, with almost all sites having a positive relationship with temperature (apart from GERRO, though with $R^2 = 0.00$). This relationship was very strong for most sites ($R^2 > 0.60$ for 10 sites), which is also confirming the summer peak found for the growth rate at most of these sites in other studies (Bousiotis et al., 2020; 2019). A rather strong relationship ($R^2 > 0.50$) with temperature was also found for the formation rate for most sites, and was positive for almost all sites (apart from FINRO with $R^2 = 0.01$ and the Greek sites with $R^2 < 0.47$). As with the NPF probability, in general the sites with a seasonal variation of events that favoured summer had the strongest relationship (high R^2) of the ~~formation rate~~temperature with ~~temperature~~formation rate, which might indicate that this variable, either through its direct or indirect effect is an important one for the seasonal variability of NPF events in a given area.

The normalised ~~slopes~~ gradients for this variable did not present a clear trend among the areas studied, other than presenting greater a_N* for the sites with a summer peak in their NPF event seasonal variation. As with other meteorological variables, the importance of this variable became smaller with increased values in the average conditions for both the NPF probability (Figure 5) and J_{10}, though these relationships were not significant (biased by the very low average temperatures and different behaviour of the variables at the Finnish sites, without which the relation becomes a lot clearer as ~~pointed~~ indicated in Figure S13~~2~~). The variation though within the sites of the same area (different sites in same country / region) appears to directly follow the variability of temperature, showing that the temperature directly affects the occurrence of NPF events when other meteorological factors remain constant, having a negative trend for all countries but Finland. The a_J^* though is found to be greater (positively or negatively) at the rural background sites than at the other two types of sites at all areas studied, showing that it is a more important factor for the formation rate at this type of site compared to others (Figure 6).

3.1.4 Wind speed

Wind speed may have both a positive and a negative effect on the occurrence of NPF events. On one hand, it may promote NPF events by the increased mixing of the condensable compounds in the atmosphere as well as by reducing the CS. O~~, while o~~n the other hand, high wind speeds may suppress NPF events due to increased dilution. It should be considered that the variability found is also affected by the specific conditions found at each site. The wind speed measurements in many cases, especially in urban sites, can be biased by the local topography or specific conditions found at each site, thus representing the local conditions for this variable rather than the regional ones. Similarly, measurements of wind speed at well sited meteorological stations may be more representative of regional conditions, than of those affecting the sites of nucleation measurement. The sites in this study presented mixed results, both in the importance as well as the effect of the wind speed variability. Three different behaviours were found in the variation of NPF event probability and wind speed which appear to be associated with local conditions as they are almost uniformly found among the sites within close proximity. Some sites presented a steady increase of NPF event probability with wind speed (Danish sites, ~~as well as~~ UKUB, FINRU, SPAUB and GRERU), while others were found to steadily decline with increasing wind speeds (German sites – it should be noted that the German sites are the only ones that are located at a great distance from the sea), while some were found to reach a peak and then decline, which also leads to smaller R^2 (UKRU, UKRO, SPARU and to a lesser extent GREUB – figures S4a, e and f). The reasons for these differences between the sites are very hard to distinguish as apart from the wind speed the origin and the characteristics of these air masses play a crucial role. Following this, it appears that NPF probability is very low or zero for wind speeds close to calm for the sites with an increasing trend (as well as those that have a peak and decline after), while the opposite is observed for the German sites where the maximum NPF probability is found for very low wind speeds (fig. S4c).

Similarly, the effect of different wind speeds upon the growth rate also varied a lot, though it was found to be negative in all the cases where R^2 was higher than 0.50 (UKUB, DENRU, DENRO, GERRU, GERUB and GREUB). Finally, the formation rate was found to have a significant correlation ($R^2 > 0.40$) only at two sites (UKRO and DENRU), probably indicating that the variability of the wind speed either does not affect this variable or its effect is rather small.

The normalised ~~slopes~~ gradients did not have any notable relation to either the NPF probability or the formation rate further confirming that the effect of the different wind speeds is not due to its variability only, but it is also influenced by the characteristics of the incoming air masses as well as specific local conditions found at each site.

3.1.5 Pressure

In almost all the sites with available data (apart from the Spanish), the NPF probability presented a positive relationship with high significance at all types of sites. The greater significance found at the rural sites (apart from SPARU) indicates the increased importance of meteorological conditions in the occurrence of NPF events at this type of site. The growth rate also presented a similar picture, with positive relationships at all the background sites of this study except the ones in Greece ($R^2 > 0.71$) and FINUB (though with low R^2 at 0.02). This is probably associated with the seasonal variation found in Greece where higher growth rates were found in summer, a period when increased wind speeds and lower atmospheric pressure was found due to the Etesians, a pressure system that develops in the region every summer (Kalkavouras et al., 2017). An interesting finding is the negative ~~slopes~~ gradients found at all the roadside sites~~s~~, though the significance of these results is relatively low ($R^2 < 0.43$) and always lower compared to the rural sites. The effects of pressure above are not likely to be important. Once again however, this is not an independent variable and higher pressure in summer tends to be associated with higher insolation and temperatures and lower RH. Since most events occur in the warmer months of the year, this is probably the explanation for the apparent effects of pressure. The formation rate presented relationships of low significance ($R^2 < 0.47$) for the sites of this study. Due to this, pressure should not be an important factor for the formation rate at any type of site.

The normalised ~~slopes~~ gradients did not present any clear trends, even for the NPF probability for which the results presented significant relations at almost all sites.

3.2 Atmospheric Composition

The ~~slopes~~ gradients,~~and~~ R^2 and p-values from the analysis of a number of air pollutants (SO_2, NO_x, O_3, organic compounds, sulphate and ammonia) and the ~~condensation sink~~CS, as well as the average conditions of these variables are found in Table 4. The results for each site and variable are found in Figures S6 – S12~~1~~.

3.2.1 Sulphur dioxide (SO_2)

Sulphur dioxide, as a precursor of H_2SO_4, is considered as one of the main components ~~that~~ associated ~~to~~with~~participate in~~ the NPF process. According to nucleation theories and observations, H_2SO_4 is the most important compound from which the initial clusters are formed, as well as one of the candidate compounds for the initial steps of particle growth (Kirkby et al., 2011; Nieminen et al., 2010; Sipila et al., 2010; Stolzenburg et al., 2020). As H_2SO_4 in the atmosphere is produced from oxidation reactions of SO_2 it would be expected that increased concentrations of the latter would be associated with increased values for all the variables associated with the NPF process.

Contrary to this though, the relationship of SO_2 concentrations with NPF probability was found to be negative at all the sites in this study with available data. This relationship was relatively strong ($R^2 > 0.50$) in most areas with an increased significance at roadside sites~~s~~ compared to their respective rural sites. As this is a negative relationship, this may indicate that SO_2 is in sufficient concentrations for H_2SO_4 formation, thus not suppressing the occurrence of NPF events, as well as showing that in increased concentrations, it is a more important factor (or surrogate for a factor) in preventing the occurrence of NPF events within the urban environment, as ~~probably~~ higher SO_2 is likely associated with increased co-emitted particle pollution and hence CS. The growth rate on the other hand, presented mixed results and the significance of the relationships is low in most cases, which makes these results ~~untrustworthy~~unreliable. Finally, the relationship of SO_2 concentrations with the formation rate was found to be positive at all sites but SPARU and FINRU (which had the lowest concentrations across the sites ~~of this study~~with available data). The significance of this relationship was rather low ($R^2 < 0.40$) for all but the roadside sites~~s~~. This suggests that higher H_2SO_4 concentrations favour ~~increased~~ greater formation rates (i.e. more particles can be formed), rather than necessarily promoting nucleation itself because of the competing effect of condensation onto the pre-existing particle population.

The normalised ~~slopes~~ gradients a_N^* were found to be more negative at the background sites compared to their respective roadside sites~~s~~, as well as being less negative in the UK (where SO_2 is in greater abundance) compared to the other sites with relatively significant relationships. Plotting the average SO_2 concentrations with the normalised ~~slopes~~ gradients a_N^* for the all sites (though not all had significant relations), a positive relationship with relatively high R^2 (when the extreme values from Marylebone Road-UKRO are removed) is found which might indicate that while increased concentrations are a negative factor in NPF event occurrence at a given site, in general the sites with higher SO_2 concentrations on average present higher probability for NPF events (Figures 7a and 7b). This appears to be in agreement with Dall'Osto et al. (2018) who discussed the variable role of SO_2 depending on its concentrations. No significant relations were found for the values of a_J^* as in most cases these relationships were rather weak.

3.2.2 Nitrogen oxides or nitrogen dioxide (NO_x or NO_2)

NO_x and NO_2 are directly associated with pollution, which can be a limiting factor for NPF events as it increases the CS and may suppress the events (An et al., 2015), though with the reduction of SO_2 concentrations achieved the last couple of decades, there is a possibility for oxidation products of NO_x to become an important component for NPF (Wang et al., 2020). For almost all sites (apart from GRERU) with available data a negative relationship between the NPF probability and NO_x concentrations (or NO_2 depending on the available data) ~~concentrations (depending on what data was available)~~ was found. Similarly, for all the sites but SPARU and GRERU, the correlations were strong with $R^2 > 0.43$. The rural background sites had a weaker relationship between the two variables compared to the urban sites, which is probably associated with them having rather low concentrations and variability of NO_x (or NO_2) ~~and variability~~, making the variations of this factor less important. Growth rate had weaker correlations with NO_x and different trends between the sites, either being positive or negative. The variable effect of NO_x ~~NOX~~ on particle growth, shifting HOMs~~'~~ volatility, was previously discussed by Yan et al. (2020). While variability was found for the background sites, all roadside sites~~s~~ regardless of the strength of the relationship had a positive relation between NO_x and the growth rate. This may indicate the different components associated with the growth process at each type of site which, as found in other studies, can be related to compounds associated with combustion processes that take place within the urban environment (Guo et al., 2020; Wang et al., 2017a). The formation rate presents few cases of strong relationships, with variable trends (positive and negative). While much effort was made to isolate the effect of NPF events by taking a shorter time frame before the event, the effect of local pollution is still included, especially at the urban sites (which probably explains the positive effect found).

The normalised ~~slopes~~ gradients do not provide a significant result for the relationship of this variable with either the probability of the events or the formation rate. The only noteworthy points are the more negative a_N^* at the rural background sites compared to the roadside sites~~s~~ in all the areas studied, which shows the increased importance of a clean environment for NPF events to occur in areas where condensable compounds are in lesser abundance, such as a rural environment. Additionally, the negative ~~slopes~~ gradients found at all the roadside sites, which increases the confidence that the events extracted at the roadside sites~~s~~ are not pollution incidents but NPF events. However, it appears that traffic pollution favours higher particle growth rates, although the components responsible for this effect are unknown.

3.2.3 Ozone (O_3)

Ozone is typically the result of atmospheric photochemistry and is itself a source of hydroxyl radical through photolysis, or ozonolysis of alkenes both during daytime and night-time (Fenske et al., 2000). It might therefore be expected to act as an indicator of photochemical activity which promotes the oxidation of SO_2 and VOCs. Ozone concentrations may be directly related to the solar radiation intensity as well as the pollution levels in the area studied, and O_3 is considered as a positive factor in the occurrence of NPF events (Woo et al., 2001; Berndt et al., 2006). As with~~for~~ the solar radiation intensity, there is a strong relationship between O_3 concentration and the probability for NPF events. This positive relationship was found to be stronger for the sites in northern Europe ($R^2 > 0.51$), while it was not significant ($R^2 < 0.38$) for the sites ~~from~~ in southern Europe (Spanish sites and GRERU), possibly indicating that O_3 is a less important factor at the southern sites. Specifically for the Spanish sites which have the highest average concentrations of O_3 with some extreme values (Querol et al., 2017), the relationship of O_3 concentrations with the NPF probability presents a unique trend (Figure S8d), having a clear peak then a steady decline at both sites (though at different O_3 concentrations), which is also responsible for the low correlations found (this trend seems to also occur at SPARU for the growth rate and to a lesser extent for the formation rate as well, though for different O_3 concentration ranges – figures S8i and n). The specific variability found at the Spanish sites was also studied by Carnerero et al., (2019). For sites with a marked seasonal variation in ozone, associations with NPF may be artefactual due to correlations with other variables such as temperature, RH and solar radiation intensity.

Unlike the solar radiation intensity though, the growth rate presents a negative relationship at the sites where the relationship between these two variables was significant (UKRU, UKUB, DENUB and FINRU), which might either be an indication of a polluted background that may have a negative effect in the growth of the newly formed particles (though the trends found for NO_x indicate differently) or specific chemical processes which cannot be identified due to the lack of detailed chemical composition data. A significant relationship between O_3 and the formation rate was only found for two ~~a few~~ sites (UKRO and DENRO, though the trends become a lot clearer if some values are removed from the extreme lower or higher end). This way the relationships become strong, but positive, for some areas and negative for some others without any clear trend (type or location of the site, O_3 concentrations etc.). No clear relationship between these two variables was found as the sites with strong relationship have both positive (DENRO) and negative (UKRO) relationships and as a result no confident conclusions can be drawn.

As the correlations found were strong the normalised ~~slopes~~ gradients for NPF probability, when plotted against the average concentrations of O_3, present a negative correlation with relatively high R^2 (0.64), indicating that the O_3 is a more important factor in the occurrence of NPF events when in lower concentrations (Figure 8). Finally, though with a low level of confidence for the southern sites, the a_N^* were smaller at the southern sites compared to those in the north, up to one order of magnitude between ~~the~~ FINRU (furthest north rural background) and GRERU (furthest south rural background).

3.2.4 Organic compounds

3.2.4.1 Particulate organic carbon (OC)

Organic carbon (OC) compounds ~~are considered as components with importance in the growth of newly formed particles~~in the secondary aerosol typically enter the particles via condensational processes, with a role that becomes increasingly important as the size of the particles becomes larger (Nieminen et al., 2010; Zhang et al., 2012; Shrivastava et al., 2017). Particulate OC, the data for which ~~are~~ is available in the present study, can be associated with pollution, especially in the urban environment. Only a few of the sites of the present study were found to have a relatively strong negative relationship ($R^2 > 0.50$) of particulate OC with the NPF probability (UKUB, UKRO and DENRU). Regardless though of the strength of this relationship, all other sites (apart from FINRU) had a negative relationship between these two variables as well, consistent with increased concentrations of particulate OC being associated with increased pollution, which elevate the CS, ~~is a~~ suppressing ~~factor in~~ the occurrence of NPF events. Growth rate on the other hand was found to have a ~~slight~~ positive relationship ($R^2 > 0.40$) for most of the sites. This relationship appeared to be stronger (higher R^2) at the roadside sites~~s~~ with available data compared to their respective rural background sites. The relationship between particulate OC and the growth rate was positive at all the sites with available data regardless of their significance showing that, despite its effect in the occurrence of NPF events, it is still a favourable variable for the growth of the particles. The formation rate was found to have a significant relationship with particulate OC concentrations at half of the sites with available data (UKUB, UKRO, DENRU, DENRO).

The normalised ~~slopes~~ gradients for this variable did not present any noteworthy relations with either the type of site or the concentrations of OC at a given site.

3.2.4.2 Volatile organic compounds (VOCs)

Many volatile organic compounds have been found to be associated with the NPF process. Benzene, toluene, ethylbenzene, m-~~+~~p-xylene, o-xylene and trimethylbenzenes have been reported to be able to form Highly Oxygenated Organic Molecules (HOMs) in flow tubes (Wang et al., 2017a; Molteni et al., 2018), which may act as contributors to particle nucleation and/or growth. Xylenes, and to a lesser extent trimethylbenzenes, are the most efficient at forming HOMs. Benzene and toluene are less efficient and will form more volatile HOMs. These HOMs may all be too volatile to form new particles, though this is not yet confirmed. Chamber studies involving H_2SO_4 and trimethylbenzene oxidation products were associated with high formation rates when measuring $J_{1.5}$ (Metzger et al., 2010). All these HOMs though will be sufficiently involatile to contribute to particle growth. Those with higher oxygen content or carbon number will be classed as LVOC and if they dimerise, they will form ELVOC (Bianchi et al., 2019). Monoterpenes can also form HOMs which drive both the formation (Ehn et al., 2014; Riccobono et al., 2014) and growth (Tröstl et al., 2016), while isoprene can act as a sink for hydroxyl radical (Kiendler-Scharr et al., 2009) and is not as effective in HOM and secondary organic aerosol formation compared to monoterpenes (McFiggans et al., 2019).

Volatile organic compound data were available for three of the sites of this study (Table S2). Two of the sites with VOC data were from the rural background and the roadside site in the UK. Most of the compounds are associated with combustion sources and were found to have a negative relationship with NPF event occurrence at both sites, with high R^2 ($R^2 > 0.50$) in most cases. Additionally, isoprene, which may have either biogenic or anthropogenic sources (Wagner and Kuttler, 2014) was also found to have a negative relationship with NPF event occurrence at Marylebone Road-UKRO, though with low R^2 (0.07). This result is in line with the VOCs being strongly correlated with particulate OC (which presented a negative relationship with NPF event probability, as discussed in Section 3.2.4.1), as well as with the CS (which also presented a negative relationship with NPF event probability, as mentioned in Section 3.2.6), further associating these compounds with combustion emissions.

Growth rate was found to have a positive relationship with VOCs in almost all cases for both UK sites. Few exceptions were found (with only 1,3 butadiene having a relatively high R^2) which presented a negative relationship with the growth rate in rural Harwell-UKRU. Finally, the formation rate presented a different behaviour between the two sites. At ~~Harwell~~ UKRU, the relationship was unclear in most cases, with a group of VOCs presenting a negative relationship with the formation rate (ethane, ethene, propane, 1,3 butadiene, toluene, ethylbenzene, o-xylene and 1,2,4 trimethylbenzene – with $R^2 > 0.40$), two VOCs presented a rather clear positive relationship with the formation rate (iso-pentane and 2-methylbenzene) and the rest of the VOCs had an unclear relationship. At ~~Marylebone Road~~ UKRO though, VOCs presented a positive relationship with the formation rate (for particles of diameter 16 nm). This is probably due to the fact that these VOCs are associated with pollution emissions (as mentioned earlier) and though a smaller time window was chosen to avoid including the effect of the morning rush hour traffic, this is very difficult in the traffic polluted environment of Marylebone Road ~~UKRO~~.

As Hyytiälä (FINRU) is a rural background site far from the direct effect of combustion emissions, different VOCs were measured, which mainly originate from biogenic sources rather than anthropogenic ones. The results were mixed and less clear compared to those from the UK sites (mainly due to the smaller dataset), and three groups were found depending on their relationship with NPF probability. The first group, including acetonitrile, acetic acid and m~~M~~ethyl e~~E~~thyl k~~K~~etone (MEK) presented a slight positive relationship. The second group presented a negative relationship, with the VOCs in this group being ~~MEK,~~ monoterpenes, methacroleine, benzene, isoprene and toluene (only the last two have $R^2 > 0.50$). Finally, the third group included VOCs that presented a peak and then a decline for higher concentrations including methanol, and acetone. Two groups of VOCs were found depending on their relationship with the growth rate. The ones with a positive relationship being methanol, acetonitrile, acetone, acetic acid, isoprene, MEKmethacroleine, monoterpenes and toluene, while acetaldehyde, MEK and benzene had a negative relationship, with relatively high R^2 in most cases. Finally, the results with the formation rate were unclear with only a handful presenting weak ($R^2 < 0.21$) positive (methanol, acetic acid and benzene) or negative (MEK) relationships that do not appear to be significant. The normalised slopes gradients cannot be used for VOCs as there are very few sites with available data.

3.2.5 Sulphate (SO_4^{-2})

Sulphate (SO_4^{2-}) is a major secondary constituent of aerosols. Secondary SO_4^{2-} aerosols largely arise from either gas phase reaction between SO_2 and OH, or in the aqueous phase by the reaction of SO_2 and O_3 or H_2O_2, or NO_2 (Hidy et al., 1994). In environments where SO_4^{2-} chemistry is dominant (i.e. remote areas), SO_4^{2-} and ammonium (bi) sulphate ($(NH_4)_2SO_4$ and NH_4HSO_4) particles are a large relative contributor to aerosol mass, while this contribution is lower in environments where other emissions are also significant (i.e. urban areas where the secondary NO_3^- relative contribution is a lot higher). While not well established, a possible relationship of SO_4^{2-}-containing compounds and variables of NPF events was found in previous studies (Beddows et al., 2015; Minguillón et al., 2015; Wang et al., 2017b). In the present study, only a few sites had SO_4^{2-} data available, for PM_1 (FINRU), $PM_{2.5}$ (Danish sites) or PM_{10} (rest of the sites). While this data cannot be considered as directly associated with the ultrafine particles, for two sites with available AMS data for ultrafine particles, the direct comparison between SO_4^{2-} aerosol in PM and in the range of particles of about

50 nm, very high correlations were found (results not included). For all the sites with available data the NPF probability presented a negative relationship. The significance of this relationship was found to be relatively high ($R^2 > 0.50$) only for background sites (apart from GERRU, which has rather low concentrations and probably different mechanisms for the NPF events). Similarly, the growth rate presented a ~~more~~ significant relationship ($R^2 > 0.40$) for the same background sites (apart from FINRU), though this relationship was found to be positive at all sites regardless of its significance. Finally, the formation rate did not present a clear trend as it was found to have both negative and positive relationships for different sites. This relationship was significant only for two rural sites (UKRU and DENRU) and as a result no ~~assumptions~~ conclusions can be ~~made~~reached.

The normalised ~~slopes~~ gradients cannot be used for any analysis on sulphate as the measurements available are from different particle size ranges.

3.2.6 Gaseous ammonia (NH_3)

Ammonia (NH_3) can be an important compound in the nucleation process according to the ternary theory (Kirkby et al., 2011; Napari et al., 2002). It was found that elevations in NH_3 concentrations can lead to elevations to NPF rate (Lehtipalo et al., 2018) and it was also found to be an important factor for NPF event occurrence even when stronger bases are present in high concentrations (Glasoe et al., 2015). No significant variation was found though between event and non-event days in a previous study in Harwell - ~~Harwell~~ UKRU (Bousiotis et al., 2019). Data for gaseous ammonia

~~were~~ was only available for ~~Harwell~~ UKRU and presented a positive relationship with NPF probability, until reaching a peak point. Further increase in NH_3 concentrations presented a decline with NPF probability (Figure S11a), which might be due to its association with increased pollution levels. ~~Interesting though is that i~~It presented a clear positive relationship with both the growth rate (though it also appears to decline at high concentrations) and the formation rate, consistent with its well-established role in accelerating both of these processes (Kirkby et al. 2011; Stolzenburg et al., 2020).

3.2.7 Condensation sink (CS)

The CS is a measure of the rate at which molecules will condense onto pre-existing aerosols (Lehtinen et al., 2003). It is highly dependent on the number and size of the particles in the atmosphere and as a result it is expected to be affected by both the local emissions within the urban environment as well as the formation and growth of the particles due to NPF events. As a result, for the specific metric a time frame before the events are in full development was chosen (05:00 to 10:00 LT) to avoid including the effect of the NPF events and provide a picture of the atmospheric conditions that preceded the NPF events. With this data, the NPF probability presented very strong relationships with the condensation sink. Two groups of sites were found though; those which had a positive relationship and those with a negative relationship. In the first group are the sites in Germany and Greece while all others had a negative relationship. This grouping follows the trend between the countries, the sites of which presented a greater ~~(the ones with the positive slopes)~~ or smaller CS on NPF event days (having positive or negative gradients respectively), though it is unknown what causes this behaviour (at the German sites and GREUB it may be associated with the very high formation rates on NPF event days). While the ~~slopes~~ gradients from this analysis cannot be used for direct comparisons, a trend was found for which the ~~slopes~~ gradients were more positive or negative at the rural sites compared to their respective roadside sites~~s~~, which might indicate the greater importance of the variability of the CS at the rural sites in the occurrence of NPF events.

The growth rate was positively correlated with the CS for most of the sites, with strong relationships (~~high~~ R^2 > 0.40) for about half of them. As the CS is a metric of pre-existing particles, it is also associated with the level of pollution in a given area. The increased significance and ~~slope~~ gradient found at the rural sites probably indicates the importance of enhanced presence of condensable compounds in a cleaner environment, which in many cases are associated with the moderate presence of pollution. The formation rate was also found to have a positive relationship with the CS. This relationship was more significant at the roadside sites~~s~~ of this study, a result which to some extent is biased by the presence of increased traffic emissions found in the timeframe chosen. While to an extent, increased presence of condensable compounds can be favourable for greater formation rates, this result should be considered with great caution.

The normalised ~~slopes~~ gradients a_N^* followed a similar trend as those found with the initial analysis. These ~~slopes~~ gradients were found to be more positive or negative, depending on the trend of the given area, at the rural sites compared to their roadside sitess. The urban background sites did not always have a uniform behaviour (though in UK, Denmark and Finland these were between the rural site and the roadside site), due to their more diverse character compared to the other two types of sites.

3.3 Association of the Effect of the Variables

The Pearson correlation coefficients for the variables studied on each site are found in Table S1. The relatively strong relationship between the solar radiation intensity, temperature and O_3 found, as well as their anticorrelation with the RH may lead to the conclusion that not all these factors play a role in NPF events, but their visible effect is the result of their relationship with each other. There is a similar case with the association of the CS and NO_x (or NO_2), and OC, as well as SO_2, especially at urban sites. However, the factors affect different outcomes differently, as for example the solar radiation intensity does not seem to be as important a factor for the growth rate as temperature, or O_3 does not seem to be strongly associated with either the formation or the growth rate. This is further established by the fact that some of these variables do not correlate well at the southern sites, but still appear to be associated with either the probability of NPF events or the growth or nucleation rate. The effects of all of these factors have been demonstrated in both laboratory and atmospheric studies in the past and were discussed earlier in this paper. By the analysis provided in the present study, the effect of each of these variables is further established, providing an association of each one of these variables with either the formation or the growth mechanism. However, RH does not seem to be a consistent factor in any mechanism, and it appears that its effect is dependent on location specific conditions, although it was the variable with the most consistent relation with NPF event probability at almost all sites.

3.4 Relationship to a previous- multi-station European study

The findings of our study in respect of the background sites show many similarities with the conclusions drawn in the previous multi-station study in Europe by Dall'Osto et al. (2018) despite the two studies using several different sampling stations as well as some in common. Both studies point towards the influence of variables such as solar radiation intensity and CS upon the occurrence of NPF events. The previous study suggested that different compounds participate in the growth of the particles, depending on the area considered. Thus, for northern and southern sites the growth of the particles is suggested to be driven mainly by organic compounds, while for the sites in central Europe sulphate plays a more important role. These findings are confirmed by the present study, as the growth rate was found to correlate better with organic compounds for the rural sites in Finland and Greece, while SO_4^{2-} presented a stronger relationship with the growth rate for the Danish and German sites (the latter presented high ~~slope~~ gradient values but low R^2 due to a decline at higher SO_4^{2-} concentrations – figure S10i, probably associated with NPF events being suppressed by increased pollution). The growth of the particles at the rural background site in the UK, characterised as "Overlap" in the previous study, was found to be strongly associated with both organic compounds and sulphate, consistent with it being in the central group.

The seasonality of NPF events at northern sites was hard to explain in the previous study, and the possible effect of low temperature was considered. In the present study, the Finnish background sites presented a double-peak relationship of NPF probability with temperature, with one of the peaks being below zero degrees. This might point to the possibility of different compounds driving the events for different temperature ranges, as well as the increased nucleation rate of H_2SO_4 at lower temperatures (Kirkby et al., 2011; Yan et al., 2018), which makes the occurrence of NPF events more probable at lower temperatures in a region with low SO_2 concentrations.

4. CONCLUSIONS

The present study attempts to explain the effect of several meteorological and atmospheric variables on the occurrence and development of NPF events, by using a large-scale dataset. More than 85 site-years of data from 16 sites from six countries in Europe were analysed for NPF events. A total of 1952~~0~~ NPF events with consequent growth of the newly formed particles were extracted and with the use of binned linear regression, the relationship between three variables associated with NPF events (NPF event probability, formation and growth rate) with meteorological conditions and atmospheric composition was studied. Among the meteorological conditions, solar radiation intensity, temperature and atmospheric pressure presented a positive relationship with the occurrence of NPF events~~ occurrence~~, ~~and~~ either promoting the formation or growth rate. ~~Relative humidity~~RH presented a negative relationship with NPF event probability which in most cases was associated with it being a limiting factor on particle formation at higher average values. Wind speed on the other hand presented variable results, appearing to depend on the location of the sites rather than their type. This shows that while wind speed can be a factor in NPF event occurrence, the origin of the incoming air masses also plays a very important role. In most cases, meteorological conditions, such as temperature or RH appeared to be more important factors in NPF event occurrence at rural sites compared to urban sites, suggesting that NPF events are driven more by them at this type of site compared to urban environments and the more complex chemical interactions found there. Additionally, while some meteorological variables appeared to play a crucial role in the occurrence of NPF events, this role appears to become less important at higher values when a positive relation was found (or lower when a negative relation was found).

The results for the levels of atmospheric pollutants presented a more interesting picture as most of these, which appear to be either directly or indirectly associated with the NPF process were found to have negative relationships with NPF probability. This is probably due to the fact that increased concentrations of such compounds are associated with more polluted conditions, which are a limiting factor in the occurrence of NPF events, as was found with the negative relationship between the CS and NPF probability in most cases. Thus, SO_2, NO_x (or NO_2), particulate OC and SO_4^{2-} concentrations were negatively correlated with NPF probability in most cases. Average SO_2 concentrations ~~though~~ appeared to correlate positively with the normalised NPF event probability ~~slopes~~ gradients with a relatively significant correlation, indicating that while increasing concentrations have a negative impact in the occurrence of NPF events at a given site, in general sites with higher SO_2 concentrations have higher probability for NPF events. ~~On the other hand though~~Conversely, these compounds in many cases had a positive relationship (not always though with high significance) with the other variables considered. Thus, particulate OC (and VOCs where data ~~were~~ was available) and SO_4^{2-} consistently had a positive relationship with the growth rate, while SO_2 was positively associated with both the formation and growth rate in most cases. Finally, O_3 was positively correlated with NPF event probability at all sites in this study, though it presented variable results with the other two variables. As with some meteorological conditions it was found that at sites with increased concentrations of O_3, its importance as a factor was decreased, which to ~~an~~ some extent can be related with the high CS associated with peak summer O_3 days in southern Europe.

~~The present study attempts to explain the effect of several meteorological and atmospheric variables on the occurrence and development of NPF events, by using a large-scale dataset.~~ It should be noted that the variables considered are in many cases inter-related (e.g. temperature and RH) and this considerably complicates ~~considerably~~ the interpretation in terms of causal factors. Large datasets are very useful in providing ~~with~~ more uniform results by removing the possible bias of short period extremities, which may lead to wrong assumptions. This study, apart from providing insights into the effect of a number of variables on the occurrence and development of NPF events in atmospheric conditions across Europe, also shows the differences that climatic, land use and atmospheric composition variations cause to those effects. Such variations are probably the cause of the differences found among previous studies. Following from this, the importance of a high-resolution measurement network, both ~~site~~ spatially and ~~timewise~~ temporally is underlined, as it can help in elucidating the mechanisms of new particle formation in the real atmosphere.

DATA ACCESSIBILITY

Data supporting this publication are openly available from the UBIRA eData repository at https://doi.org/

AUTHOR CONTRIBUTIONS

The study was conceived and planned by RMH who also contributed to the final manuscript, and DB who also carried out the analysis and prepared the first draft of the manuscript. AM, JKN, CN, JVN, HP, NP, AA, GK, SV and KE have provided with the data for the analysis. JB provided help with analysis of the data. FDP provided advice on the analysis. MDO, XQ and TP contributed to the final manuscript.

COMPETING INTERESTS

The authors have no conflict of interests.

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REFERENCES

Aalto, P., Hämeri, K., Becker, E. D. O., Weber, R., Salm, J., Mäkelä, J. M., Hoell, C., O'Dowd, C. D., Karlsson, H., Hansson, H., Väkevä, M., Koponen, I. K., Buzorius, G. and Kulmala, M.: Physical characterization of aerosol particles during nucleation events, Tellus, Ser. B Chem. Phys. Meteorol., 53(4), 344–358, doi:10.3402/tellusb.v53i4.17127, 2001.

Alam, A., Shi, J. P. and Harrison, R. M.: Observations of new particle formation in urban air, J. Geophys. Res. Atmos., 108(D3), n/a-n/a, doi:10.1029/2001JD001417, 2003.

An, J., Wang, H., Shen, L., Zhu, B., Zou, J., Gao, J. and Kang, H.: Characteristics of new particle formation events in Nanjing, China: Effect of water-soluble ions, Atmos. Environ., 108, 32–40, doi:10.1016/j.atmosenv.2015.01.038, 2015.

Bae, M.-S., Schwab, J. J., Hogrefe, O., Frank, B. P., Lala, G. G. and Demerjian, K. L.: Characteristics of size distributions at urban and rural locations in New York, Atmos. Chem. Phys. Discuss., 10(1), 69–108, doi:10.5194/acpd-10-69-2010, 2010.

Beddows, D. C. S., Harrison, R. M., Green, D. C. and Fuller, G. W.: Receptor modelling of both particle composition and size distribution from a background site in London, UK, Atmos. Chem. Phys., 15(17), 10107–10125, doi:10.5194/acp-15-10107-2015, 2015.

Berland, K., Rose, C., Pey, J., Culot, A., Freney, E., Kalivitis, N., Kouvarakis, G., Cerro, J. C., Mallet, M., Sartelet, K., Beckmann, M., Bourriane, T., Roberts, G., Marchand, N., Mihalopoulos, N. and Sellegri, K.: Spatial extent of new particle formation events over the Mediterranean Basin from multiple ground-based and airborne measurements, Atmos. Chem. Phys., 17(15), 9567–9583, doi:10.5194/acp-17-9567-2017, 2017.

Berndt, T., Böge, O. and Stratmann, F.: Formation of atmospheric H2SO4H2O particles in the absence of organics: A laboratory study, Geophys. Res. Lett., 33(15), 2–6, doi:10.1029/2006GL026660, 2006.

Bianchi, F., Kurtén, T., Riva, M., Mohr, C., Rissanen, M. P., Roldin, P., Berndt, T., Crounse, J. D., Wennberg, P. O., Mentel, T. F., Wildt, J., Junninen, H., Jokinen, T., Kulmala, M., Worsnop, D. R., Thornton, J. A., Donahue, N., Kjaergaard, H. G. and Ehn, M.: Highly oxygenated organic molecules (HOM) from gas-phase autoxidation involving peroxy radicals: A key contributor to atmospheric aerosol, Chem. Rev., 119, 3472–3509, doi:10.1021/acs.chemrev.8b00395, 2019.

Bigi, A. and Harrison, R. M.: Analysis of the air pollution climate at a central urban background site, Atmos. Environ., 44(16), 2004–2012, doi:10.1016/j.atmosenv.2010.02.028, 2010.

Birmili, W., Weinhold, K., Rasch, F., Sonntag, A., Sun, J., Merkel, M., Wiedensohler, A., Bastian, S., Schladitz, A., Löschau, G., Cyrys, J., Pitz, M., Gu, J., Kusch, T., Flentje, H., Quass, U., Kaminski, H., Kuhlbusch, T. A. J., Meinhardt, F., Schwerin, A., Bath, O., Ries, L., Wirtz, K. and Fiebig, M.: Long-term observations of tropospheric particle number size distributions and equivalent black carbon mass concentrations in the German Ultrafine Aerosol Network (GUAN), Earth Syst. Sci. Data, 8(2), 355–382, doi:10.5194/essd-8-355-2016, 2016.

Bousiotis, D., Pope, F. D., Beddows, D. C., Dall'Osto, M., Massling, A., Nøjgaard, J. K., Nørdstrom, C., Niemi, J. V., Portin, H., Petäjä, T., Perez, N., Alastuey, A., Querol, X., Kouvarakis, G., Vratolis, S., Eleftheriadis, K., Wiedensohler, A., Weinhold, K., Merkel, M., Tuch, T., and Harrison, R. M.: An Analysis of New Particle Formation (NPF) at Thirteen European Sites, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-414, in review, 2020.
Bousiotis, D., Pope, F. D., Dall'Osto, M., Massling A., Nøjgaard, J. K., Nørdstrom C., Niemi J. V., Portin H., Petäjä T., Perez, N., Alastuey, A., Querol, X., Kouvarakis, G.,Vratolis, S., Eleftheriadis, K., and Harrison, R. M.: An Analysis of new particle formation (NPF) at several European Sites, Atmos. Chem. Phys., submitted, 2020

Bousiotis, D., Osto, M., Beddows, D. C. S., Pope, F. D. and Harrison, R. M.: Analysis of new particle formation (NPF) events at nearby rural, urban background and urban roadside sites, Atmos. Chem. Phys., 19, 5679-5694, 2019.

Brines, M., Dall'Osto, M., Beddows, D. C. S., Harrison, R. M., Gómez-Moreno, F., Núñez, L., Artíñano, B., Costabile, F., Gobbi, G. P., Salimi, F., Morawska, L., Sioutas, C. and Querol, X.: Traffic and nucleation events as main sources of ultrafine particles in high-insolation developed world cities, Atmos. Chem. Phys., 15(10), 5929–5945, doi:10.5194/acp-15-5929-2015, 2015.

Carnerero, C., Pérez, N., Petäjä, T., Laurila, T. M., Ahonen, L. R., Kontkanen, J., Ahn, K. H., Alastuey, A. and Querol, X.: Relating high ozone, ultrafine particles, and new particle formation episodes using cluster analysis, Atmos. Environ. X, 4(October), doi:10.1016/j.aeaoa.2019.100051, 2019.

Charron, A. and Harrison, R. M.: Primary particle formation from vehicle emissions during exhaust dilution in the roadside atmosphere, Atmos. Environ., 37(29), 4109–4119, doi:10.1016/S1352-2310(03)00510-7, 2003.

Charron, A., Birmili, W. and Harrison, R. M.: Fingerprinting particle origins according to their size distribution at a UK rural site, J. Geophys. Res. Atmos., 113(7), 1–15, doi:10.1029/2007JD008562, 2008.

Charron, A., Degrendele, C., Laongsri, B. and Harrison, R. M.: Receptor modelling of secondary and carbonaceous particulate matter at a southern UK site, Atmos. Chem. Phys., 13(4), 1879–1894, doi:10.5194/acp-13-1879-2013, 2013.

Cheung, H. C., Chou, C. C.-K., Huang, W.-R. and Tsai, C.-Y.: Characterization of ultrafine particle number concentration and new particle formation in an urban environment of Taipei, Taiwan, Atmos. Chem. Phys., 13(17), 8935–8946, doi:10.5194/acp-13-8935-2013, 2013.

Chu, B., Kerminen, V., Bianchi, F., Yan, C., Petäjä, T. and Kulmala, M.: Atmospheric new particle formation in China, Atmos. Chem. Phys., 19 , 115–138, doi:10.5194/acp-2018-612, 2019

~~Costabile, F., Birmili, W., Klose, S., Tuch, T., Wehner, B., Wiedensohler, A., Franck, U., Konig, K. and Sonntag, A.: Spatio-temporal variability and principal components of the particle number size distribution in an urban atmosphere, Atmos. Chem. Phys., 9(9), 3163–3195, doi:10.5194/acp-9-3163-2009, 2009.~~

Dada, L., Paasonen, P., Nieminen, T., Buenrostro Mazon, S., Kontkanen, J., Peräkylä, O., Lehtipalo, K., Hussein, T., Petäjä, T., Kerminen, V. M., Bäck, J. and Kulmala, M.: Long-term analysis of clear-sky new particle formation events and nonevents in Hyytiälä, Atmos. Chem. Phys., 17(10), 6227–6241, doi:10.5194/acp-17-6227-2017, 2017.

Dai, L., Wang, H., Zhou, L., An, J., Tang, L., Lu, C., Yan, W., Liu, R., Kong, S., Chen, M., Lee, S. and Yu, H.: Regional and local new particle formation events observed in the Yangtze River Delta region, China, J. Geophys. Res., 122(4), 2389–2402, doi:10.1002/2016JD026030, 2017.

Dal Maso, M., Kulmala, M., Riipinen, I., Wagner, R., Hussein, T., Aalto, P. P. and Lehtinen, K. E. J.: Formation and growth of fresh atmospheric aerosols: Eight years of aerosol size distribution data from SMEAR II, Hyytiälä, Finland, Boreal Environ. Res., 10(5), 323–336, doi:10.1016/j.ijpharm.2012.03.044, 2005.

Dall'Osto, M., Beddows, D. C. S., Asmi, A., Poulain, L., Hao, L., Freney, E., Allan, J. D., Canagaratna, M., Crippa, M., Bianchi, F., De Leeuw, G., Eriksson, A., Swietlicki, E., Hansson, H. C., Henzing, J. S., Granier, C., Zemankova, K., Laj, P., Onasch, T., Prevot, A., Putaud, J. P., Sellegri, K., Vidal, M., Virtanen, A., Simo, R., Worsnop, D., O'Dowd, C., Kulmala, M. and Harrison, R. M.: Novel insights on new particle formation derived from a pan-european observing system, Sci. Rep., 8(1), 1–11, doi:10.1038/s41598-017-17343-9, 2018.

Dall'Osto, M., Querol, X., Alastuey, A., O'Dowd, C., Harrison, R. M., Wenger, J. and Gómez-Moreno, F. J.: On the spatial distribution and evolution of ultrafine particles in Barcelona, Atmos.

Chem. Phys., 13(2), 741–759, doi:10.5194/acp-13-741-2013, 2013.

Dall'Osto, M., Beddows, D. C. S., Pey, J., Rodriguez, S., Alastuey, A., M. Harrison, R. and Querol, X.: Urban aerosol size distributions over the Mediterranean city of Barcelona, NE Spain, Atmos. Chem. Phys., 12(22), 10693–10707, doi:10.5194/acp-12-10693-2012, 2012.

Ehn, M., Thornton, J. A., Kleist, E., Sipilä, M., Junninen, H., Pullinen, I., Springer, M., Rubach, F., Tillmann, R., Lee, B., Lopez-Hilfiker, F., Andres, S., Acir, I. H., Rissanen, M., Jokinen, T., Schobesberger, S., Kangasluoma, J., Kontkanen, J., Nieminen, T., Kurtén, T., Nielsen, L. B., Jørgensen, S., Kjaergaard, H. G., Canagaratna, M., Maso, M. D., Berndt, T., Petäjä, T., Wahner, A., Kerminen, V. M., Kulmala, M., Worsnop, D. R., Wildt, J. and Mentel, T. F.: A large source of low-volatility secondary organic aerosol, Nature, 506(7489), 476–479, doi:10.1038/nature13032, 2014.

~~Engler, C., Rose, D., Wehner, B., Wiedensohler, A., Bruggermann, E., Gnauk, T., Spindler, G., Tuch, T. and Birmili, W.: Size distributions of non-volatile particle residuals (Dp <800 nm) at a rural site in Germany and relation to air mass origin, Atmos. Chem. Phys., 7, 5785–5802, 2007.~~

Fenske, J. D., Hasson, A.S., Paulson, S. E., Kuwata, K. T., Ho, A., Houk, K. N.: The Pressure Dependence of the OH Radical Yield from Ozone Alkene Reactions J Phys Chem A, 104 7821, 2000

Fuchs, N. A. and Sutugin, A. G.: Highly dispersed aerosols, Top. Curr. Aerosol Res., 1, doi:https://doi.org/10.1016/B978-0-08-016674-2.50006-6, 1971.

Glasoe, W. a, Volz, K., Panta, B., Freshour, N., Bachman, R., Hanson, D. R., Mcmurry, P. H. and Jen, C.: Sulfuric acid nucleation: An experimental study of the effect of seven bases, , 1933–1950, doi:10.1002/2014JD022730, 2015.

Größ, J., Hamed, A., Sonntag, A., Spindler, G., Manninen, H. E., Nieminen, T., Kulmala, M., Hõrrak, U., Plass-Dülmer, C., Wiedensohler, A., and Birmili, W.: Atmospheric new particle formation at the research station Melpitz, Germany: connection with gaseous precursors and meteorological parameters, Atmos. Chem. Phys., 18, 1835–1861, https://doi.org/10.5194/acp-18-1835-2018, 2018.
~~Größ, J., Hamed, A., Sonntag, A., Spindler, G. and Manninen, H. E.: Atmospheric new particle formation at the research station Melpitz , Germany : connection with gaseous precursors and meteorological parameters, , 1835–1861, doi:10.5194/acp-18-1835-2018, 2018.~~

Guo, S., Hu, M., Peng, J., Wu, Z., Zamora, M. L., Shang, D., Du, Z., Zheng, J., Fang, X., Tang, R., Wu, Y., Zeng, L., Shuai, S., Zhang, W., Wang, Y., Ji, Y., Li, Y., Zhang, A. L., Wang, W., Zhang, F., Zhao, J., Gong, X., Wang, C., Molina, M. J. and Zhang, R.: Remarkable nucleation and growth of ultrafine particles from vehicular exhaust, Proc. Nat. Acad. Sci. U. S. A., 117(7), 3427–3432, doi:10.1073/pnas.1916366117, 2020.

Hallar, A. G., Petersen, R., McCubbin, I. B., Lowenthal, D., Lee, S., Andrews, E. and Yu, F.: Climatology of new particle formation and corresponding precursors at storm peak laboratory, Aerosol Air Qual. Res., 16(3), 816–826, doi:10.4209/aaqr.2015.05.0341, 2016.

Hamed, A., Korhonen, H., Sihto, S. L., Joutsensaari, J., Jrvinen, H., Petäjä, T., Arnold, F., Nieminen, T., Kulmala, M., Smith, J. N., Lehtinen, K. E. J. and Laaksonen, A.: The role of relative humidity in continental new particle formation, J. Geophys. Res. Atmos., 116(3), 1–12, doi:10.1029/2010JD014186, 2011.

Harrison, R. M.: Urban atmospheric chemistry: A very special case for study, npj Clim. Atmos. Sci., 1(1), 5, doi:10.1038/s41612-017-0010-8, 2017.

Henschel, H., Kurtén, T., Vehkamäki, H.: Computational study on the effect of hydration on new particle formation in the sulfuric acid/ammonia and sulfuric acid/dimethylamine systems, J. Phys. Chem. A 2016, 120, 11, 1886–1896, 2016.

Hidy, G. M.: Atmospheric sulfur and nitrogen oxides, Academic Press, ISBN: 9781483288666, 1994

Hietikko, R., Kuuluvainen, H., Harrison, R. M., Portin, H., Timonen, H., Niemi, J. V and Rönkkö, T.: Diurnal variation of nanocluster aerosol concentrations and emission factors in a street canyon, Atmos. Environ., 189, 98–106, doi:10.1016/j.atmosenv.2018.06.031, 2018.

Iida, K., Stolzenburg, M. R., McMurry, P. H. and Smith, J. N.: Estimating nanoparticle growth rates from size-dependent charged fractions: Analysis of new particle formation events in Mexico City, J. Geophys. Res. Atmos., 113(5), 1–15, doi:10.1029/2007JD009260, 2008.

Järvi, L., Hannuniemi, H., Hussein, T., Junninen, H., Aalto, P., Hillamo, R., Mäkelä, T., Keronen, P. and Siivola, E.: The urban measurement station SMEAR III : Continuous monitoring of air pollution and surface – atmosphere interactions in Helsinki , Finland, 14(April), 86–109, 2009.

Jayaratne, R., Pushpawela, B., He, C., Li, H., Gao, J., Chai, F. and Morawska, L.: Observations of particles at their formation sizes in Beijing, China, Atmos. Chem. Phys., 17(14), 8825–8835, doi:10.5194/acp-17-8825-2017, 2017.

Jeong, C.-H. H., Evans, G. J., McGuire, M. L., Y.-W. Chang, R., Abbatt, J. P. D. D., Zeromskiene, K., Mozurkewich, M., Li, S.-M. M., Leaitch, W. R., Chang, R. Y.-W., Abbatt, J. P. D. D., Zeromskiene, K., Mozurkewich, M., Li, S.-M. M. and Leaitch, W. R.: Particle formation and growth at five rural and urban sites, Atmos. Chem. Phys., 10(16), 7979–7995, doi:10.5194/acp-10-7979-2010, 2010.

Kalkavouras, P., Bossioli, E., Bezantakos, S., Bougiatioti, A., Kalivitis, N., Stavroulas, I., Kouvarakis, G., Protonotariou, A. P., Dandou, A., Biskos, G., Mihalopoulos, N., Nenes, A. and Tombrou, M.: New particle formation in the southern Aegean Sea during the Etesians: Importance for CCN production and cloud droplet number, Atmos. Chem. Phys., 17(1), 175–192, doi:10.5194/acp-17-175-2017, 2017.

Kerminen, V., Lehtinen, K. E. J., Anttila, T., Kulmala, M., Lehtinen, K. E. J., Anttila, T. and Kulmala, M.: Dynamics of atmospheric nucleation mode particles : a timescale analysis, Tellus, 56B, 135–146, doi:10.3402/tellusb.v56i2.16411, 2004.

Kerminen, V. M., Pirjola, L. and Kulmala, M.: How significantly does coagulational scavenging limit atmospheric particle production?, J. Geophys. Res. Atmos., 106(D20), 24119–24125, doi:10.1029/2001JD000322, 2001.

Kerminen, V. M., Kulmala, M., Worsnop, D. R., Wildt, J. and Mentel, T. F.: A large source of low-volatility secondary organic aerosol, Nature, 506(7489), 476–479, doi:10.1038/nature13032, 2014.

Ketzel, M., Wåhlin, P., Kristensson, A., Swietlicki, E., Berkowicz, R., Nielsen, O. J. and Palmgren, F.: Particle size distribution and particle mass measurements at urban, near-city and rural level in the Copenhagen area and Southern Sweden, Atmos. Chem. Phys. Discuss., 3(6), 5513–5546, doi:10.5194/acpd-3-5513-2003, 2004.

Kiendler-Scharr, A., Wildt, J., Dal Maso, M., Hohaus, T., Kleist, E., Mentel, T. F., Tillmann, R., Uerlings, R., Schurr, U. and Wahner, A.: New particle formation in forests inhibited by isoprene emissions, 461, 381–384, 2009.

Kim, K. H., Kabir, E. and Kabir, S.: A review on the human health impact of airborne particulate matter, Environ. Int., 74, 136–143, doi:10.1016/j.envint.2014.10.005, 2015.

Kirkby, J., Curtius, J., Almeida, J., Dunne, E., Duplissy, J., Ehrhart, S., Franchin, A., Gagné, S., Ickes, L., Kürten, A., Kupc, A., Metzger, A., Riccobono, F., Rondo, L., Schobesberger, S., Tsagkogeorgas, G., Wimmer, D., Amorim, A., Bianchi, F., Breitenlechner, M., David, A., Dommen, J., Downard, A., Ehn, M., Flagan, R. C., Haider, S., Hansel, A., Hauser, D., Jud, W., Junninen, H., Kreissl, F., Kvashin, A., Laaksonen, A., Lehtipalo, K., Lima, J., Lovejoy, E. R., Makhmutov, V., Mathot, S., Mikkilä, J., Minginette, P., Mogo, S., Nieminen, T., Onnela, A., Pereira, P., Petäjä, T., Schnitzhofer, R., Seinfeld, J. H., Sipilä, M., Stozhkov, Y., Stratmann, F., Tomé, A., Vanhanen, J., Viisanen, Y., Vrtala, A., Wagner, P. E., Walther, H., Weingartner, E., Wex, H., Winkler, P. M., Carslaw, K. S., Worsnop, D. R., Baltensperger, U. and Kulmala, M.: Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation, Nature, 476(7361), 429–435, doi:10.1038/nature10343, 2011.

Korhonen, P., Kulmala, M., Laaksonen, A., Viisanen, Y., Mcgraw, R. and Seinfeld, J. H.: Ternary nucleation of H2SO4, NH3 and H2O in the atmosphere, J. Geophys. Res., 104(D21), 26349–26353, 1999.

Kulmala, M., Petäjä, T., Mönkkönen, P., Koponen, I. K., Dal Maso, M., Aalto, P. P., Lehtinen, K. E. J. and Kerminen, V.-M.: On the growth of nucleation mode particles: source rates of condensable vapor in polluted and clean environments, Atmos. Chem. Phys. Discuss., 4(5), 6943–6966, doi:10.5194/acpd-4-6943-2004, 2005.

Kulmala, M. and Kerminen, V. M.: On the formation and growth of atmospheric nanoparticles, Atmos. Res., 90(2–4), 132–150, doi:10.1016/j.atmosres.2008.01.005, 2008.

Kulmala, M., Kerminen, V.-M. M., Petäjä, T., Ding, A. J. and Wang, L.: Atmospheric gas-to-particle conversion: Why NPF events are observed in megacities?, Faraday Discuss., 200, 271–288, doi:10.1039/c6fd00257a, 2017.

Kulmala, M., Petäjä, T., Nieminen, T., Sipilä, M., Manninen, H. E., Lehtipalo, K., Dal Maso, M., Aalto, P. P., Junninen, H., Paasonen, P., Riipinen, I., Lehtinen, K. E. J., Laaksonen, A. and Kerminen, V. M.: Measurement of the nucleation of atmospheric aerosol particles, Nat. Protoc., 7(9), 1651–1667, doi:10.1038/nprot.2012.091, 2012.

Kulmala, M., Petäjä, T., Mönkkönen, P., Koponen, I. K., Dal Maso, M., Aalto, P. P., Lehtinen, K. E. J. and Kerminen, V.-M.: On the growth of nucleation mode particles: source rates of condensable vapor in polluted and clean environments, Atmos. Chem. Phys. Discuss., 4(5), 6943–6966, doi:10.5194/acpd-4-6943-2004, 2005.

Kulmala, M., Dal Maso, M., Mäkelä, J. M., Pirjola, L., Väkevä, M., Aalto, P., Miikkulainen, P., Hämeri, K. and O'Dowd, C. D.: On the formation, growth and composition of nucleation mode particles, Tellus, Ser. B Chem. Phys. Meteorol., 53(4), 479–490, doi:10.3402/tellusb.v53i4.16622, 2001.

Kürten, A., Li, C., Bianchi, F., Curtius, J., Dias, A., Donahue, N. M., Duplissy, J., Flagan, R. C., Hakala, J., Jokinen, T., Kirkby, J., Kulmala, M., Laaksonen, A., Lehtipalo, K., Makhmutov, V., Onnela, A., Rissanen, M. P., Simon, M., Sipilä, M., Stozhkov, Y., Tröstl, J., Ye, P., and McMurry, P. H.: New particle formation in the sulfuric acid–dimethylamine–water system: reevaluation of CLOUD chamber measurements and comparison to an aerosol nucleation and growth model, Atmos.

Chem. Phys., 18, 845–863, https://doi.org/10.5194/acp-18-845-2018, 2018.

Kürten, A., Bergen, A., Heinritzi, M., Leiminger, M., Lorenz, V., Piel, F., Simon, M., Sitals, R., Wagner, A. C. and Curtius, J.: Observation of new particle formation and measurement of sulfuric acid, ammonia, amines and highly oxidized organic molecules at a rural site in central Germany, Atmos. Chem. Phys., 16(19), 12793–12813, doi:10.5194/acp-16-12793-2016, 2016.

Lee, S.-H. H., Uin, J., Guenther, A. B., de Gouw, J. A., Yu, F., Nadykto, A. B., Herb, J., Ng, N. L., Koss, A., Brune, W. H., Baumann, K., Kanawade, V. P., Keutsch, F. N., Nenes, A., Olsen, K., Goldstein, A. and Ouyang, Q.: Isoprene suppression of new particle formation: Potential mechanisms and implications, J. Geophys. Res. Atmos., 121(24), 14,621-14,635, doi:10.1002/2016JD024844, 2016.

Lehtinen, K. E. J., Korhonen, H., Dal Maso, M. and Kulmala, M.: On the concept of condensation sink diameter, Boreal Environ. Res., 8(4), 405–411, 2003.

Lehtipalo, K., Yan, C., Dada, L., Bianchi, F., Xiao, M., Wagner, R., Stolzenburg, D., Ahonen, L. R., Amorim, A., Baccarini, A., Bauer, P. S., Baumgartner, B., Bergen, A., Bernhammer, A., Breitenlechner, M., Brilke, S., Buchholz, A., Mazon, S. B., Chen, D., Chen, X., Dias, A., Dommen, J., Draper, D. C., Duplissy, J., Ehn, M., Finkenzeller, H., Fischer, L., Frege, C., Fuchs, C., Garmash, O., Gordon, H., Hakala, J., He, X., Heikkinen, L., Heinritzi, M., Helm, J. C., Hofbauer, V., Hoyle, C. R., Jokinen, T., Ojdanic, A., Onnela, A., Passananti, M., Petäjä, T., Piel, F., Sarnela, N., Schallhart, S., Schuchmann, S., Sengupta, K. and Simon, M.: Multicomponent new particle formation from sulfuric acid , ammonia , and biogenic vapors, , (3), 1–10, 2018.

Li, X., Chee, S., Hao, J., Abbatt, J. P. D., Jiang, J. and Smith, J. N.: Relative humidity effect on the formation of highly oxidized molecules and new particles during monoterpene oxidation, Atmos. Chem. Phys., 19(3), 1555–1570, doi:10.5194/acp-19-1555-2019, 2019.

Makkonen, R., Asmi, A., Kerminen, V. M., Boy, M., Arneth, A., Hari, P. and Kulmala, M.: Air pollution control and decreasing new particle formation lead to strong climate warming, Atmos. Chem. Phys., 12(3), 1515–1524, doi:10.5194/acp-12-1515-2012, 2012.

McFiggans, G., Mentel, T. F., Wildt, J., Pullinen, I., Kang, S., Kleist, E., Schmitt, S., Springer, M., Tillmann, R., Wu, C., Zhao, D., Hallquist, M., Faxon, C., Le Breton, M., Hallquist, Å. M., Simpson, D., Bergström, R., Jenkin, M. E., Ehn, M., Thornton, J. A., Alfarra, M. R., Bannan, T. J., Percival, C. J., Priestley, M., Topping, D. and Kiendler-Scharr, A.: Secondary organic aerosol reduced by mixture of atmospheric vapours, Nature, 565(7741), 587–593, doi:10.1038/s41586-018-0871-y, 2019.
Merikanto, J., Spracklen, D. V., Mann, G. W., Pickering, S. J. and Carslaw, K. S.: Impact of nucleation on global CCN, Atmos. Chem. Phys., 9(21), 8601–8616, doi:10.5194/acp-9-8601-2009,

2009.

McFiggans, G., Mentel, T. F., Wildt, J., Pullinen, I., Kang, S., Kleist, E., Schmitt, S., Springer, M., Tillmann, R., Wu, C., Zhao, D., Hallquist, M., Faxon, C., Le Breton, M., Hallquist, Å. M., Simpson, D., Bergström, R., Jenkin, M. E., Ehn, M., Thornton, J. A., Alfarra, M. R., Bannan, T. J., Percival, C. J., Priestley, M., Topping, D. and Kiendler-Scharr, A.: Secondary organic aerosol reduced by mixture of atmospheric vapours, Nature, 565(7741), 587–593, doi:10.1038/s41586-018-0871-y, 2019.

Merikanto, J., Spracklen, D. V., Mann, G. W., Pickering, S. J. and Carslaw, K. S.: Impact of nucleation on global CCN, Atmos. Chem. Phys., 9(21), 8601–8616, doi:10.5194/acp-9-8601-2009, 2009.

Metzger, A., Verheggen, B., Dommen, J., Duplissy, J., Prevot, A. S. H., Weingartner, E., Riipinen, I., Kulmala, M., Spracklen, D. V., Carslaw, K. S. and Baltensperger, U.: Evidence for the role of organics in aerosol particle formation under atmospheric conditions, Proc. Nat. Acad. Sci., 107(15), 6646–6651, doi:10.1073/pnas.0911330107, 2010.

Minguillón, M. C., Brines, M., Pérez, N., Reche, C., Pandolfi, M., Fonseca, A. S., Amato, F., Alastuey, A., Lyasota, A., Codina, B., Lee, H. K., Eun, H. R., Ahn, K. H. and Querol, X.: New particle formation at ground level and in the vertical column over the Barcelona area, Atmos. Res., 164–165, 118–130, doi:10.1016/j.atmosres.2015.05.003, 2015.

Mirabel, P. and Katz, J. L.: Binary homogeneous nucleation as a mechanism for the formation of aerosols, J. Chem. Phys., 60(3), 1138–1144, doi:10.1063/1.1681124, 1974.

Mølgaard, B., Birmili, W., Clifford, S., Massling, A., Eleftheriadis, K., Norman, M., Vratolis, S., Wehner, B., Corander, J., Hämeri, K. and Hussein, T.: Evaluation of a statistical forecast model for size-fractionated urban particle number concentrations using data from five European cities, J. Aerosol Sci., 66, 96–110, doi:10.1016/j.jaerosci.2013.08.012, 2013.

Molteni, U., Bianchi, F., Klein, F., El Haddad, I., Frege, C., Rossi, M. J., Dommen, J. and Baltensperger, U.: Formation of highly oxygenated organic molecules from aromatic compounds, Atmos. Chem. Phys., 18(3), 1909–1921, doi:10.5194/acp-18-1909-2018, 2018.

Napari, I., Noppel, M., Vehkamäki, H. and Kulmala, M.: An improved model for ternary nucleation of sulfuric acid-ammonia-water, J. Chem. Phys., 116(10), 4221–4227, doi:10.1063/1.1450557, 2002.

Nieminen, T., Kerminen, V.-M., Petäjä, T., Aalto, P. P., Arshinov, M., Asmi, E., Baltensperger, U., Beddows, D. C. S., Beukes, J. P., Collins, D., Ding, A., Harrison, R. M., Henzing, B., Hooda, R., Hu, M., Hõrrak, U., Kivekäs, N., Komsaare, K., Krejci, R., Kristensson, A., Laakso, L., Laaksonen, A., Leaitch, W. R., Lihavainen, H., Mihalopoulos, N., Németh, Z., Nie, W., O 'dowd, C., Salma, I., Sellegri, K., Svenningsson, B., Swietlicki, E., Tunved, P., Ulevicius, V., Vakkari, V., Vana, M., Wiedensohler, A., Wu, Z., Virtanen, A., Kulmala, M., O'Dowd, C., Salma, I., Sellegri, K., Svenningsson, B., Swietlicki, E., Tunved, P., Ulevicius, V., Vakkari, V., Vana, M., Wiedensohler, A., Wu, Z., Virtanen, A., Kulmala, M., O ’dowd, C., Salma, I., Sellegri, K., Svenningsson, B., Swietlicki, E., Tunved, P., Ulevicius, V., Vakkari, V., Vana, M., Wiedensohler, A., Wu, Z., Virtanen, A. and Kulmala, M.: Global analysis of continental boundary layer new particle formation based on long-term measurements, Atmos. Chem. Phys. Discuss, 5194, 2018–304, doi:10.5194/acp-2018-304, 2018.

Nieminen, T., Lehtinen, K. E. J. and Kulmala, M.: Sub-10 nm particle growth by vapor condensation-effects of vapor molecule size and particle thermal speed, Atmos. Chem. Phys., 10(20), 9773–9779, doi:10.5194/acp-10-9773-2010, 2010.

O’Dowd, C. D., Jimenez, J. L., Bahreini, R., Flagan, R. C., Seinfeld, J. H., Hameri Kaarle, Pirjola, L., Kulmala, M., Jennings, S. G. and Hoffmann, T.: Marine aerosol formation from biogenic iodine emissions, Lett. to Nat., 417(June), 1–5, doi:10.1038/nature00773.1.2.3.4.5.6.7.8.9.10., 2002.

Olenius, T., Halonen, R., Kurten, T., Henschel, H., Maatta, O. K., Ortega, I. K., Jen, C., Vehkamäki, H. and Riipinen, I.: New particle formation from sulfuric acid amines: Comparison of monomethylamine, dimethylamine, and trimethylamine, J. Geophys. Res. Atmos., 7103–7118, doi:10.1002/2017JD026501, 2017.

Olin, M., Kuuluvainen, H., Aurela, M., Kalliokoski, J., Kuittinen, N., Isotalo, M., Timonen, H. J., Niemi, J. V., Rönkkö, T., and Dal Maso, M.: Traffic-originated nanocluster emission exceeds H2SO4-driven photochemical new particle formation in an urban area, Atmos. Chem. Phys., 20, 1–13, https://doi.org/10.5194/acp-20-1-2020, 2020.

Paasonen, P., Asmi, A., Petäjä, T., Kajos, M. K., Äijälä, M., Junninen, H., Holst, T., Abbatt, J. P. D., Arneth, A., Birmili, W., Van Der Gon, H. D., Hamed, A., Hoffer, A., Laakso, L., Laaksonen, A., Richard Leaitch, W., Plass-Dülmer, C., Pryor, S. C., Räisänen, P., Swietlicki, E., Wiedensohler, A., Worsnop, D. R., Kerminen, V. M. and Kulmala, M.: Warming-induced increase in aerosol number concentration likely to moderate climate change, Nat. Geosci., 6(6), 438–442, doi:10.1038/ngeo1800, 2013.

Park, M., Yum, S. S. and Kim, J. H.: Characteristics of submicron aerosol number size distribution and new particle formation events measured in Seoul, Korea, during 2004–2012, Asia-Pacific J. Atmos. Sci., 51(1), 1–10, doi:10.1007/s13143-014-0055-0, 2015.

Petäjä, T., Mauldin, R. L., Kosciuch, E., McGrath, J., Nieminen, T., Paasonen, P., Boy, M., Adamov, A., Kotiaho, T. and Kulmala, M.: Sulfuric acid and OH concentrations in a boreal forest site, Atmos. Chem. Phys., 9(19), 7435–7448, doi:10.5194/acp-9-7435-2009, 2009.

Pikridas, M., Sciare, J., Freutel, F., Crumeyrolle, S., Von Der Weiden-Reinmüller, S. L., Borbon, A., Schwarzenboeck, A., Merkel, M., Crippa, M., Kostenidou, E., Psichoudaki, M., Hildebrandt, L., Engelhart, G. J., Petäjä, T., Prévôt, A. S. H., Drewnick, F., Baltensperger, U., Wiedensohler, A., Kulmala, M., Beekmann, M. and Pandis, S. N.: In situ formation and spatial variability of particle number concentration in a European megacity, Atmos. Chem. Phys., 15(17), 10219–10237, doi:10.5194/acp-15-10219-2015, 2015.

Pillai, P., Khlystov, A., Walker, J. and Aneja, V.: Observation and analysis of particle nucleation at a forest site in southeastern US, Atmosphere (Basel)., 4(2), 72–93, doi:10.3390/atmos4020072, 2013.

Poling, B. E., Prausnitz, J. M. and O'Connell, J. P.: The properties of gases and liquids, 5th ed., McGraw-Hill Education., 2001.

Politis, M., Pilinis, C. and Lekkas, T. D.: Ultrafine particles (UFP) and health effects. Dangerous. Like no other PM? Review and analysis, Glob. Nest J., 10(3), 439–452, 2008.

Quéléver, L. L. J., Kristensen, K., Normann Jensen, L., Rosati, B., Teiwes, R., Daellenbach, K. R., Peräkylä, O., Roldin, P., Bossi, R., Pedersen, H. B., Glasius, M., Bilde, M. and Ehn, M.: Effect of temperature on the formation of highly oxygenated organic molecules (HOMs) from alpha-pinene ozonolysis, Atmos. Chem. Phys., 19(11), 7609–7625, doi:10.5194/acp-19-7609-2019, 2019.

Querol, X., Gangoiti, G., Mantilla, E., Alastuey, A., Minguillón, M. C., Amato, F., Reche, C., Viana, M., Moreno, T., Karanasiou, A., Rivas, I., Pérez, N., Ripoll, A., Brines, M., Ealo, M., Pandolfi, M., Lee, H. K., Eun, H. R., Park, Y. H., Escudero, M., Beddows, D., Harrison, R. M., Bertrand, A., Marchand, N., Lyasota, A., Codina, B., Olid, M., Udina, M., Jiménez-Esteve, B. B., Jiménez-Esteve, B. B., Alonso, L., Millán, M. and Ahn, K. H.: Phenomenology of high-ozone episodes in NE Spain, Atmos. Chem. Phys., 17(4), 2817–2838, doi:10.5194/acp-17-2817-2017, 2017.

Riccobono, F., Schobesberger, S., Scott, C. E., Dommen, J., Ortega, I. K., Rondo, L., Almeida, J., Amorim, A., Bianchi, F., Breitenlechner, M., David, A., Downard, A., Dunne, E. M., Duplissy, J., Ehrhart, S., Flagan, R. C., Franchin, A., Hansel, A., Junninen, H., Kajos, M., Keskinen, H., Kupc, A., Makhmutov, V., Mathot, S., Nieminen, T., Onnela, A., Petäjä, T., Tsagkogeorgas, G., Vaattovaara, P., Viisanen, Y., Vrtala, A. and Wagner, P. E.: Oxidation Products of biogenic atmospheric particles, Science, 717, 717–722, doi:10.1126/science.1243527, 2014.

Rimnácová, D., Ždímal, V., Schwarz, J., Smolík, J. and Rimnác, M.: Atmospheric aerosols in suburb of Prague: The dynamics of particle size distributions, Atmos. Res., 101(3), 539–552,

doi:10.1016/j.atmosres.2010.10.024, 2011.
Rose, C., Zha, Q., Dada, L., Yan, C., Lehtipalo, K., Junninen, H., Mazon, S. B., Jokinen, T., Sarnela, N., Sipilä, M., Petäjä, T., Kerminen, V. M., Bianchi, F. and Kulmala, M.: Observations of biogenic ion-induced cluster formation in the atmosphere, Sci. Adv., 4(4), 1–10, doi:10.1126/sciadv.aar5218, 2018.

Rivas, I., Beddows, D. C. S., Amato, F., Green, D. C., Järvi, L., Hueglin, C., Reche, C., Timonen, H., Fuller, G. W., Niemi, J. V, Pérez, N., Aurela, M., Hopke, P. K., Alastuey, A., Kulmala, M., Harrison, R. M., Querol, X. and Kelly, F. J.: Source apportionment of particle number size distribution in urban background and traffic stations in four European cities, Environ. Int., 135, 105345, doi:10.1016/j.envint.2019.105345, 2020.

Rizzo, L. V., Artaxo, P., Karl, T., Guenther, A. B. and Greenberg, J.: Aerosol properties, in-canopy gradients, turbulent fluxes and VOC concentrations at a pristine forest site in Amazonia, Atmos. Environ., 44(4), 503–511, doi:10.1016/j.atmosenv.2009.11.002, 2010.

Salma, I., Borsòs, T., Weidinger, T., Aalto, P., Hussein, T., Dal Maso, M. and Kulmala, M.: Production, growth and properties of ultrafine atmospheric aerosol particles in an urban environment, Atmos. Chem. Phys., 11(3), 1339–1353, doi:10.5194/acp-11-1339-2011, 2011.

Schwartz, J., Dockery, D. W. and Neas, L. M.: Is Daily Mortality Associated Specifically with Fine Particles?, J. Air Waste Manag. Assoc., 46(10), 927–939, doi:10.1080/10473289.1996.10467528, 1996.

Seinfeld, J. H. and Pandis, S. N.: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Editio., John Wiley & Sons, Inc, New Jersey, Canada, 2012.

Shen, X., Sun, J., Kivekäs, N., Kristensson, A., Zhang, X., Zhang, Y., Zhang, L., Fan, R., Qi, X., Ma, Q. and Zhou, H.: Spatial distribution and occurrence probability of regional new particle formation events in eastern China, Atmos. Chem. Phys., 18(2), 587–599, doi:10.5194/acp-18-587-2018, 2018.

Shrivastava, M., Cappa, C. D., Fan, J., Goldstein, A. H., Guenther, A. B., Jimenez, J. L., Kuang, C., Laskin, A., Martin, S. T., Ng, N. L., Petaja, T., Pierce, J. R., Rasch, P. J., Roldin, P., Seinfeld, J. H., Shilling, J., Smith, J. N., Thornton, J. A., Volkamer, R., Wang, J., Worsnop, D. R., Zaveri, R. A., Zelenyuk, A. and Zhang, Q.: Recent advances in understanding secondary organic aerosol: Implications for global climate forcing, Rev. Geophys., 55(2), 509–559, doi:10.1002/2016RG000540, 2017.

Siakavaras, D., Samara, C., Petrakakis, M. and Biskos, G.: Nucleation events at a coastal city during the warm period: Kerbside versus urban background measurements, Atmos. Environ., 140, 60–68, doi:10.1016/j.atmosenv.2016.05.054, 2016.

Sipila, M., Berndt, T., Petaja, T., Brus, D., Vanhanen, J., Stratmann, F., Patokoski, J., Mauldin III, R. L., Hyvarinen, A. P., Lihavainen, H. and Kulmala, M.: The Role of Sulfuric Acid in Atmospheric Nucleation, Science, 327, 1243–1246, doi:10.1126/science.1180315, 2010.

Spracklen, D. V., Carslaw, K. S., Merikanto, J., Mann, G. W., Reddington, C. L., Pickering, S., Ogren, J. A., Andrews, E., Baltensperger, U., Weingartner, E., Boy, M., Kulmala, M., Laakso, L., Lihavainen, H., Kivekäs, N., Komppula, M., Mihalopoulos, N., Kouvarakis, G., Jennings, S. G., O'Dowd, C., Birmili, W., Wiedensohler, A., Weller, R., Gras, J., Laj, P., Sellegri, K., Bonn, B., Krejci, R., Laaksonen, A., Hamed, A., Minikin, A., Harrison, R. M., Talbot, R. and Sun, J.: Explaining global surface aerosol number concentrations in terms of primary emissions and particle formation, Atmos. Chem. Phys., 10(10), 4775–4793, doi:10.5194/acp-10-4775-2010, 2010.

Stolzenburg, D., Simon, M., Ranjithkumar, A., Kürten, A., Lehtipalo, K., Gordon, H., Ehrhart, S., Finkenzeller, H., Pichelstorfer, L., Nieminen, T., He, X.-C., Brilke, S., Xiao, M., Amorim, A., Baalbaki, R., Baccarini, A., Beck, L., Bräkling, S., Caudillo Murillo, L., Chen, D., Chu, B., Dada, L., Dias, A., Dommen, J., Duplissy, J., El Haddad, I., Fischer, L., Gonzalez Carracedo, L., Heinritzi, M., Kim, C., Koenig, T. K., Kong, W., Lamkaddam, H., Lee, C. P., Leiminger, M., Li, Z., Makhmutov, V., Manninen, H. E., Marie, G., Marten, R., Müller, T., Nie, W., Partoll, E., Petäjä, T., Pfeifer, J., Philippov, M., Rissanen, M. P., Rörup, B., Schobesberger, S., Schuchmann, S., Shen, J., Sipilä, M., Steiner, G., Stozhkov, Y., Tauber, C., Tham, Y. J., Tomé, A., Vazquez-Pufleau, M., Wagner, A. C., Wang, M., Wang, Y., Weber, S. K., Wimmer, D., Wlasits, P. J., Wu, Y., Ye, Q., Zauner-Wieczorek, M., Baltensperger, U., Carslaw, K. S., Curtius, J., Donahue, N. M., Flagan, R. C., Hansel, A., Kulmala, M., Lelieveld, J., Volkamer, R., Kirkby, J., and Winkler, P. M.: Enhanced growth rate of atmospheric particles from sulfuric acid, Atmos. Chem. Phys., 20, 7359–7372, https://doi.org/10.5194/acp-20-7359-2020, 2020.

Stolzenburg, D., Fischer, L., Vogel, A. L., Heinritzi, M., Schervish, M. and Simon, M., Wagner, A. C., Dada, L., Ahonen, L. R., Amorim, A., Baccarini, A., Bauer, P. S., Baumgartner, B., Bergen, A., Bianchi, F., Breitenlechner, M., Brilke, S., Buenorstro Mazon, S., Chen, D., Dias, A., Draper, D. C., Duplissy, J., El Haddad, I., Finkenzeller, H., Frege, C., Fuchs, C., Garmash, O., Gordon, H., He, X., Helm., J., Hofbauer, V., Hoyle, C. R., Kim, C., Kirkby, J., Kontkanen, J., Kürten, A., Lampilahti, J., Lawler, M., Lehtipalo, K., Leiminger, M., Mai, H., Mathot, S., Mentler, B., Molteni, U., Nie, W., Nieminen, T., Nowak, J. B., Ojdanic, A., Onnela, A., Passananti, M., Petäjä, T., Quéléver, L. L. J., Rissanen, M. P., Sarnela, N., Schallhart, S., Tauber, C., Tome, A., Wagner, R., Wang, M., Weitz, L., Wimmer, D., Xiao, M., Yan, C., Ye, P., Zha, Q., Baltensperger, U., Curtius, J., Dommen, J., Flagan, R. C., Kulmala, M., Smith, J. N., Worsnop, D. R., Hansel, A., Donahue, N. M., Winkler, P. M.: Rapid growth of organic aerosol nanoparticles over a wide tropospheric temperature range, PNAS , 115(37), doi:10.1073/pnas.1807604115, 2018.

~~Stolzenburg, D., Fischer, L., Vogel, A. L., Heinritzi, M., Schervish, M. and Simon, M., Wagner, A. C., Dada, L., Ahonen, L. R., Amorim, A., Baccarini, A., Bauer, P. S., Baumgartner, B., Bergen, A., Bianchi, F., Breitenlechner, M., Brilke, S., Buenorstro Mazon, S., Chen, D., Dias, A., Draper, D. C., Duplissy, J., El Haddad, I., Finkenzeller, H., Frege, C., Fuchs, C., Garmash, O., Gordon, H., He, X., Helm., J., Hofbauer, V., Hoyle, C. R., Kim, C., Kirkby, J., Kontkanen, J., Kürten, A., Lampilahti, J., Lawler, M., Lehtipalo, K., Leiminger, M., Mai, H., Mathot, S., Mentler, B., Molteni, U., Nie, W., Nieminen, T., Nowak, J. B., Ojdanic, A., Onnela, A., Passananti, M., Petäjä, T., Quéléver, L. L. J., Rissanen, M. P., Sarnela, N., Schallhart, S., Tauber, C., Tome, A., Wagner, R., Wang, M., Weitz, L., Wimmer, D., Xiao, M., Yan, C., Ye, P., Zha, Q., Baltensperger, U., Curtius, J., Dommen, J., Flagan, R. C., Kulmala, M., Smith, J. N., Worsnop, D. R., Hansel, A., Donahue, N. M., Winkler, P. M.: Rapid growth of organic aerosol nanoparticles over a wide tropospheric temperature range, PNAS , 115(37), doi:10.1073/pnas.1807604115, 2018.~~

Tröstl, J., Chuang, W. K., Gordon, H., Heinritzi, M., Yan, C., Molteni, U., Ahlm, L., Frege, C., Bianchi, F., Wagner, R., Simon, M., Lehtipalo, K., Williamson, C., Craven, J. S., Duplissy, J., Adamov, A., Almeida, J., Bernhammer, A. K., Breitenlechner, M., Brilke, S., Dias, A., Ehrhart, S., Flagan, R. C., Franchin, A., Fuchs, C., Guida, R., Gysel, M., Hansel, A., Hoyle, C. R., Jokinen, T., Junninen, H., Kangasluoma, J., Keskinen, H., Kim, J., Krapf, M., Kürten, A., Laaksonen, A., Lawler, M., Leiminger, M., Mathot, S., Möhler, O., Nieminen, T., Onnela, A., Petäjä, T., Piel, F. M., Miettinen, P., Rissanen, M. P., Rondo, L., Sarnela, N., Schobesberger, S., Sengupta, K., Sipilä, M., Smith, J. N., Steiner, G., Tomè, A., Virtanen, A., Wagner, A. C., Weingartner, E., Wimmer, D., Winkler, P. M., Ye, P., Carslaw, K. S., Curtius, J., Dommen, J., Kirkby, J., Kulmala, M., Riipinen, I., Worsnop, D. R., Donahue, N. M. and Baltensperger, U.: The role of low-volatility organic compounds in initial particle growth in the atmosphere, Nature, 533(7604), 527–531, doi:10.1038/nature18271, 2016.

Vratolis, S., Gini, M. I., Bezantakos, S., Stavroulas, I., Kalivitis, N., Kostenidou, E., Louvaris, E., Siakavaras, D., Biskos, G., Mihalopoulos, N., Pandis, S. N. N., Pilinis, C., Papayannis, A. and Eleftheriadis, K.: Particle number size distribution statistics at City-Centre Urban Background, urban background, and remote stations in Greece during summer, Atmos. Environ., 213(May), 711–726, doi:10.1016/j.atmosenv.2019.05.064, 2019.

Wagner, P. and Kuttler, W.: Biogenic and anthropogenic isoprene in the near-surface urban atmosphere - A case study in Essen, Germany, Sci. Total Environ., 475, 104–115, doi:10.1016/j.scitotenv.2013.12.026, 2014.

Wang, D., Fu, Q., Geng, F., Li, L., Wang, H., Qiao, L., Yang, X., Chen, J., Kerminen, V. M., Petäjä, T., Worsnop, D. R., Kulmala, M. and Wang, L.: Atmospheric new particle formation from sulfuric acid and amines in a Chinese megacity, Science, 361(6399), 278–281, doi:10.1126/science.aao4839, 2018.

Wang, S., Wu, R., Berndt, T., Ehn, M. and Wang, L.: Formation of Highly Oxidized Radicals and Multifunctional Products from the Atmospheric Oxidation of Alkylbenzenes, , doi:10.1021/acs.est.7b02374, 2017a.

Wang, Z., Wu, Z., Yue, D., Shang, D., Guo, S., Sun, J., Ding, A., Wang, L., Jiang, J., Guo, H., Gao, J., Cheung, H. C., Morawska, L., Keywood, M. and Hu, M.: New particle formation in China: Current knowledge and further directions, Sci. Total Environ., 577, 258–266, doi:10.1016/j.scitotenv.2016.10.177, 2017b.

Wang, F., Ketzel, M., Ellermann, T., Wåhlin, P., Jensen, S. S., Fang, D. and Massling, A.: Particle number, particle mass and NO_x emission factors at a highway and an urban street in Copenhagen, Atmos. Chem. Phys., 10(6), 2745–2764, doi:10.5194/acp-10-2745-2010, 2010.

Wang, M., Kong, W., Marten, R., He, X. C., Chen, D., Pfeifer, J., Heitto, A., Kontkanen, J., Dada, L., Kürten, A., Yli-Juuti, T., Manninen, H. E., Amanatidis, S., Amorim, A., Baalbaki, R., Baccarini, A., Bell, D. M., Bertozzi, B., Bräkling, S., Brilke, S., Murillo, L. C., Chiu, R., Chu, B., De Menezes, L. P., Duplissy, J., Finkenzeller, H., Carracedo, L. G., Granzin, M., Guida, R., Hansel, A., Hofbauer, V., Krechmer, J., Lehtipalo, K., Lamkaddam, H., Lampimäki, M., Lee, C. P., Makhmutov, V., Marie, G., Mathot, S., Mauldin, R. L., Mentler, B., Müller, T., Onnela, A., Partoll, E., Petäjä, T., Philippov, M., Pospisilova, V., Ranjithkumar, A., Rissanen, M., Rörup, B., Scholz, W., Shen, J., Simon, M., Sipilä, M., Steiner, G., Stolzenburg, D., Tham, Y. J., Tomé, A., Wagner, A. C., Wang, D. S., Wang, Y., Weber, S. K., Winkler, P. M., Wlasits, P. J., Wu, Y., Xiao, M., Ye, Q., Zauner-Wieczorek, M., Zhou, X., Volkamer, R., Riipinen, I., Dommen, J., Curtius, J., Baltensperger, U., Kulmala, M., Worsnop, D. R., Kirkby, J., Seinfeld, J. H., El-Haddad, I., Flagan, R. C. and Donahue, N. M.: Rapid growth of new atmospheric particles by nitric acid and ammonia condensation, Nature, 581(7807), 184–189, doi:10.1038/s41586-020-2270-4, 2020.

Weber, R. J., McMurry, P. H., Eisele, F. L. and Tanner, D. J.: Measurement of expected nucleation precursor species and 3-500-nm diameter particles at Mauna Loa Observatory, Hawaii, J. Atmos. Sci., 52(12), 2242–2257, doi:10.1175/1520-0469(1995)052<2242:MOENPS>2.0.CO;2, 1995.

Wehner, B., Siebert, H., Stratmann, F., Tuch, T., Wiedensohler, A., Petäjä, T., Dal Maso, M. and Kulmala, M.: Horizontal homogeneity and vertical extent of new particle formation events, Tellus, Ser. B Chem. Phys. Meteorol., 59(3), 362–371, doi:10.1111/j.1600-0889.2007.00260.x, 2007.

Wiedensohler, A., Ma, N., Birmili, W., Heintzenberg, J., Ditas, F., Andreae, M. O. and Panov, A.: Infrequent new particle formation over the remote boreal forest of Siberia, Atmos. Environ., 200, 167–169, doi:10.1016/j.atmosenv.2018.12.013, 2019.

Wonaschütz, A., Demattio, A., Wagner, R., Burkart, J., Zíková, N., Vodička, P., Ludwig, W., Steiner, G., Schwarz, J. and Hitzenberger, R.: Seasonality of new particle formation in Vienna, Austria - Influence of air mass origin and aerosol chemical composition, Atmos. Environ., 118, 118–126, doi:10.1016/j.atmosenv.2015.07.035, 2015.

Woo, K. S., Chen, D. R., Pui, D. Y. H. H. and McMurry, P. H.: Measurement of Atlanta aerosol size distributions: Observations of lutrafine particle events, Aerosol Sci. Technol., 34, 75–87, doi:10.1080/02786820120056, 2001.

Yamada, H.: Contribution of evaporative emissions from gasoline vehicles toward total VOC emissions in Japan, Sci. Total Environ., 449, 143–149, doi:10.1016/j.scitotenv.2013.01.045, 2013.

Yan, C., Nie, W., Vogel, A. L., Dada, L., Lehtipalo, K., Stolzenburg, D. and Wagner, R.: Size-dependent influence of NOx on the growth rates of organic aerosol particles, , Sci. Adv., 6, 1–10, 2020.

Yan, C., Dada, L., Rose, C., Jokinen, T., Nie, W., Schobesberger, S., Junninen, H., Lehtipalo, K., Sarnela, N., Makkonen, U., Garmash, O., Wang, Y., Zha, Q., Paasonen, P., Bianchi, F., Sipilä, M., Ehn, M., Petäjä, T., Kerminen, V.-M., Worsnop, D. R. and Kulmala, M.: The role of H_2SO_4-NH_3 anion clusters in ion-induced aerosol nucleation mechanisms in the boreal forest, Atmos. Chem. Phys., 18, 13231–13243, doi:10.5194/acp-18-13231-2018, 2018.

~~Yan, C., Nie, W., Vogel, A. L., Dada, L., Lehtipalo, K., Stolzenburg, D. and Wagner, R.: Size-dependent influence of NOx on the growth rates of organic aerosol particles, , Sci. Adv., 6, 1–10, 2020.~~

Yao, L., Garmash, O., Bianchi, F., Zheng, J., Yan, C., Kontkanen, J., Junninen, H., Mazon, S. B., Ehn, M., Paasonen, P., Sipilä, M., Wang, M., Wang, X., Xiao, S., Chen, H., Lu, Y., Zhang, B., Wang, M., Chen, D., Xiao, M., Ye, Q., Stolzenburg, D., Hofbauer, V., Ye, P., Vogel, A. L., Mauldin, R. L., Amorim, A., Baccarini, A., Baumgartner, B., Brilke, S., Dada, L., Dias, A., Duplissy, J., Finkenzeller, H., Garmash, O., He, X. C., Hoyle, C. R., Kim, C., Kvashnin, A., Lehtipalo, K., Fischer, L., Molteni, U., Petäjä, T., Pospisilova, V., Quéléver, L. L. J., Rissanen, M., Simon, M., Tauber, C., Tomé, A., Wagner, A. C., Weitz, L., Volkamer, R., Winkler, P. M., Kirkby, J., Worsnop, D. R., Kulmala, M., Baltensperger, U., Dommen, J., El-Haddad, I. and Donahue, N. M.: Photo-oxidation of Aromatic Hydrocarbons Produces Low-Volatility Organic Compounds, Environ. Sci. Technol., 54(13), 7911–7921, doi:10.1021/acs.est.0c02100, 2020.

Yao, L., Garmash, O., Bianchi, F., Zheng, J., Yan, C., Kontkanen, J., Junninen, H., Mazon, S. B., Ehn, M., Paasonen, P., Sipilä, M., Wang, M., Wang, X., Xiao, S., Chen, H., Lu, Y., Zhang, B., Wang, D., Fu, Q., Geng, F., Li, L., Wang, H., Qiao, L., Yang, X., Chen, J., Kerminen, V. M., Petäjä, T., Worsnop, D. R., Kulmala, M. and Wang, L.: Atmospheric new particle formation from sulfuric acid and amines in a Chinese megacity, Science, 361(6399), 278–281, doi:10.1126/science.aao4839, 2018.

Ye, J., Abbatt, J. P. D., Chan, A. W.H., Novel pathway of SO_2 oxidation in the atmosphere: reactions with monoterpene ozonolysis intermediates and secondary organic aerosol, Atmos. Chem. Phys., 18, 5549-5565, 2018

Yli-Juuti, T., Mohr, C. and Riipinen, I.: Open questions on atmospheric nanoparticle growth, Commun. Chem., 3(1), 2–5, doi:10.1038/s42004-020-00339-4, 2020.

Zhang, R., Khalizov, A., Wang, L., Hu, M. and Xu, W.: Nucleation and growth of nanoparticles in the atmosphere, Chem. Rev., 112(3), 1957–2011, doi:10.1021/cr2001756, 2012.

TABLE LEGENDS

Table 1: Location and data availability of the sites.

Table 2: Frequency (and number of NPF events), growth and formation rate of NPF events~~ for the sites of the study~~.

Table 3: Normalised ~~slopes~~ gradients (non-normalised for growth rate), R^2 and p-values (- for values >0.05) for the relationship between meteorological conditions and NPF event variables.

Table 4: Normalised gradients~~slopes~~ (non-normalised for growth rate), R^2 and p-values (- for values >0.05) for the relationship between atmospheric composition variables and NPF event variables.

FIGURE LEGENDS

Figure 1: Map of the sites of the present study.

Figure 2: Relation of average downward incoming solar radiation (K↓) and normalised gradients~~slopes~~ a_N^*~~ for the sites of the present study~~.

Figure 3: Normalised gradients~~slopes~~ a_J^* for K↓ ~~for the sites of the present study~~ (*UK sites are calculated with solar irradiance).

Figure 4a: Relationship of average relative humidity and normalised gradients~~slopes~~ a_N^*~~ for the sites of the present study~~.

Figure 4b: Relationship of average relative humidity and normalised gradients~~slopes~~ a_N^* ~~for the sites of the present study~~ (SPAUB not included).

Figure 5: Relationship of average temperature and normalised gradients~~slopes~~ a_N^*~~ for the sites of the present study~~.

Figure 6: Normalised gradients~~slopes~~ a_J^* for temperature~~ for the sites of the present study~~.

Figure 7a: Relationship of average SO_2 concentrations and normalised gradients~~slopes~~ a_N^*~~ for the sites of the present study~~.

Figure 7b: Relationship of average SO_2 concentrations and normalised gradients~~slopes~~ a_N^* ~~for the sites of the present study~~ (UKRO not included).

Figure 8: Relationship of average O_3 concentrations and normalised gradients~~slopes~~ a_N^* ~~for the sites of the present study~~.

Table 1: Location and data availability of the sites.

Site	Location	Available data	Meteorological data location	Data availability	Reference
UKRU	Harwell Science Centre, Oxford, 80 km W of London, UK (51° 34’ 15” N; 1° 19’ 31” W)	SMPS (16.6 - 604 nm, 76.5% availability), NO_x, SO_2, O_3, OC, SO_4^{2-}, gaseous ammonia	On site	2009 - 2015	Charron et al., 2013
UKUB	North Kensington, 4 km W of London city centre, UK (51° 31’ 15” N; 0° 12’ 48” W)	SMPS (16.6 - 604 nm, 83.3% availability), NO_x, SO_2, O_3, OC, SO_4^{2-}	Heathrow airport	2009 - 2015	Bigi and Harrison, 2010
UKRO	Marylebone Road, London, UK (51° 31’ 21” N; 0° 9’ 16” W)	SMPS (16.6 - 604 nm, 74.3% availability), NO_x, SO_2, O_3, OC, SO_4^{2-}	Heathrow airport	2009 - 2015	Charron and Harrison, 2003
DENRU	Lille Valby, 25 km W of Copenhagen, (55° 41’ 41” N; 12° 7’ 7” E) (2008 – 6/2010) Risø, 7 km north of Lille Valby, (55° 38' 40" N; 12° 5' 19" E) (7/2010 – 2017)	DMPS and CPC (5.8 - 700 nm, 68.3% availability), NO_x, SO_2, O_3, OC, SO_4^{2-}	H.C. Ørsted – Institute station	2008 – 2017	Ketzel et al., 2004
DENUB	H.C. Ørsted – Institute, 2 km NE of the city centre, Copenhagen, Denmark (55° 42’ 1” N; 12° 33’ 41” E)	DMPS and CPC (5.8 - 700 nm, 61.4% availability), NO_x, O_3	On site	2008 – 2017	Wang et al., 2010
DENRO	H.C. Andersens Boulevard, Copenhagen, Denmark (55° 40’ 28” N; 12° 34’ 16” E)	DMPS and CPC (5.8 - 700 nm, 65.7% availability), NO_x, SO_2, O_3, OC, SO_4^{2-}	H.C. Ørsted – Institute station	2008 – 2017	Wang et al., 2010
GERRU	Melpitz, 40 km NE of Leipzig, Germany (51° 31’ 31.85” N; 12° 26’ 40.30” E)	TDMPS with CPC (4.8 - 800 nm, 87.2% availability), OC, SO_4^{2-}	On site	2008 – 2011	Birmili et al., 2016
GERUB	Tropos, 3 km NE from the city centre of Leipzig, Germany (51° 21’ 9.1” N; 12° 26’ 5.1” E)	TDMPS with CPC (3 - 800 nm, 90.4% availability)	On site	2008 – 2011	Birmili et al., 2016
GERRO	Eisenbahnstraße, Leipzig, Germany (51° 20’ 43.80” N; 12° 24’ 28.35” E)	TDMPS with CPC (4 - 800 nm, 68.3% availability)	Tropos station	2008 – 2011	Birmili et al., 2016
FINRU	Hyytiälä, 250 km N of Helsinki, Finland (61° 50’ 50.70” N; 24° 17’ 41.20” E)	TDMPS with CPC (3 – 1000 nm, 98.2% availability), NO_x, SO_2, O_3, VOCs	On site	2008 – 2011 & 2015 – 2018	Aalto et al., 2001
FINUB	Kumpula Campus 4 km N of the city centre, Helsinki, Finland (60° 12’ 10.52” N; 24° 57’ 40.20” E)	TDMPS with CPC (3.4 - 1000 nm, 99.7% availability)	On site	2008 – 2011 & 2015 – 2018	Järvi et al., 2009
FINRO	Mäkelänkatu street, Helsinki, Finland (60° 11’ 47.57” N; 24° 57’ 6.01” E)	DMPS (6 - 800 nm, 90.0% availability), NO_x, O_3	Pasila station and on site	2015 – 2018	Hietikko et al., 2018
SPARU	Montseny, 50 km NNE from Barcelona, Spain (41° 46’ 45” N; 2° 21’ 29” E)	SMPS (9 – 856 nm, 53.7% availability), NO_2, SO_2, O_3	On site	2012 - 2015	Dall’Osto et al., 2013
SPAUB	Palau Reial, Barcelona, Spain (41° 23’ 14” N; 2° 6’ 56” E)	SMPS (11 – 359 nm, 88.1% availability), NO_2, SO_2, O_3	On site	2012 – 2015	Dall’Osto et al., 2012
GRERU	Finokalia, 70 km E of Heraklion, Greece (35° 20’ 16.8” N; 25° 40’ 8.4” E)	SMPS (8.77 - 849 nm, 85.0% availability), NO_2, O_3, OC	On site	2012 – 2018	Kalkavouras et al., 2017
GREUB	“Demokritos”, 12 km NE from the city centre, Athens, Greece (37° 59’ 41.96” N; 23° 48’ 57.56” E)	SMPS (10 – 550 nm, 88.0% availability)	On site	2015 – 2018	Mølgaard et al., 2013

~~Site~~ | ~~Location~~ | ~~Available data~~ | ~~Meteorological data location~~ | ~~Data availability~~ | ~~Reference~~

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UKRU	Harwell Science Centre, Oxford, 80 km W of London, UK (51o 34' 15" N; 1o 19' 31" W)	SMPS (16.6 - 604 nm, 76.5% availability), NOx, SO2, O3, OC, SO42-, gaseous ammonia	On site	2009 - 2015	Charron et al., 2013
UKUB	North Kensington, 4 km W of London city centre, UK (51o 31' 15" N; 0o 12' 48" W)	SMPS (16.6 - 604 nm, 83.3% availability), NOx, SO2, O3, OC, SO42-	Heathrow airport	2009 - 2015	Bigi and Harrison, 2010
UKRO	Marylebone Road, London, UK (51o 31' 21" N; 0o 9' 16" W)	SMPS (16.6 - 604 nm, 74.3% availability), NOx, SO2, O3, OC, SO42-	Heathrow airport	2009 - 2015	Charron and Harrison, 2003
DENRU	Lille Valby, 25 km W of Copenhagen, (55o 41' 41" N; 12o 7' 7" E) (2008 – 6/2010) Risø, 7 km north of Lille Valby, (55° 38' 40" N; 12° 5' 19" E) (7/2010 – 2017)	DMPS and CPC (5.8 - 700 nm, 68.3% availability), NOx, SO2, O3, OC, SO42-	H.C. Ørsted – Institute station	2008 – 2017	Ketzel et al., 2004
DENUB	H.C. Ørsted – Institute, 2 km NE of the city centre, Copenhagen, Denmark (55o 42' 1" N; 12o 33' 41" E)	DMPS and CPC (5.8 - 700 nm, 61.4% availability), NOx, O3	On site	2008 – 2017	Wang et al., 2010
DENRO	H.C. Andersens Boulevard, Copenhagen, Denmark (55o 40' 28" N; 12o 34' 16" E)	DMPS and CPC (5.8 - 700 nm, 65.7% availability), NOx, SO2, O3, OC, SO42-	H.C. Ørsted – Institute station	2008 – 2017	Wang et al., 2010
GERRU	Melpitz, 40 km NE of Leipzig, Germany (51o 31' 31.85" N; 12o 26' 40.30" E)	TDMPS with CPC (4.8 - 800 nm, 87.2% availability), OC, SO42-	On site	2008 – 2011	Engler et al., 2007
GERUB	Tropos, 3 km NE from the city centre of Leipzig, Germany (51o 21' 9.1" N; 12o 26' 5.1" E)	TDMPS with CPC (3 - 800 nm, 90.4% availability)	On site	2008 – 2011	Costabile et al., 2009
GERRO	Eisenbahnstraße, Leipzig, Germany (51o 20' 43.80" N; 12o 24' 28.35" E)	TDMPS with CPC (4 - 800 nm, 68.3% availability)	Tropos station	2008 – 2011	Birmili et al., 2016
FINRU	Hyytiälä, 250 km N of Helsinki, Finland (61o 50' 50.70" N; 24o 17' 41.20" E)	TDMPS with CPC (3 – 1000 nm, 98.2% availability), NOx, SO2, O3, VOCs	On site	2008 – 2011 & 2015 – 2018	Aalto et al., 2001
FINUB	Kumpula Campus 4 km N of the city centre, Helsinki, Finland (60o 12' 10.52" N; 24o 57' 40.20" E)	TDMPS with CPC (3.4 - 1000 nm, 99.7% availability)	On site	2008 – 2011 & 2015 – 2018	Järvi et al., 2009
FINRO	Mäkelänkatu street, Helsinki, Finland (60o 11' 47.57" N; 24o 57' 6.01" E)	DMPS (6 - 800 nm, 90.0% availability), NOx, O3	Pasila station and on site	2015 – 2018	Hietikko et al., 2018
SPARU	Montseny, 50 km NNE from Barcelona, Spain (41o 46' 45" N; 2o 21' 29" E)	SMPS (9 – 856 nm, 53.7% availability), NO2, SO2, O3	On site	2012 – 2015	Dall'Osto et al., 2013
SPAUB	Palau Reial, Barcelona, Spain (41o 23' 14" N; 2o 6' 56" E)	SMPS (11 – 359 nm, 88.1% availability), NO2, SO2, O3	On site	2012 – 2015	Dall'Osto et al., 2012
GRERU	Finokalia, 70 km E of Heraklion, Greece (35o 20' 16.8" N; 25o 40' 8.4" E)	SMPS (8.77 - 849 nm, 85.0% availability), NO2, O3, OC	On site	2012 – 2018	Kalkavouras et al., 2017
GREUB	"Demokritos", 12 km NE from the city centre,	SMPS (10 – 550 nm, 88.0% availability)	On site	2015 – 2018	Mølgaard et al., 2013

	Athens, Greece (37o 59' 41.96" N; 23o 48' 57.56" E)				

Table 2: Frequency (and number of NPF events), growth and formation rate of NPF events ~~for the sites of the study~~.

Site	Frequency of NPF events (%)	GR (nm h-1)	J_{10} (N cm^{-3} s^{-1})
UKRU	7.0 (160)~~7.0~~	3.4*	8.69E-03**
UKUB	7.0 (156)~~7.0~~	4.2*	1.42E-02**
UKRO	6.1 (120)~~6.1~~	5.5*	3.75E-02**
DENRU	7.9 (176)~~7.9~~	3.19	2.57E-02
DENUB	5.8 (116)~~5.8~~	3.19	2.40E-02
DENRO	5.4 (117)~~5.4~~	4.45	8.07E-02
GERRU	17.1 (164)~~17.1~~	4.34	9.18E-02
GERUB	17.5 (169)~~17.5~~	4.24	1.02E-01
GERRO	9.0 (62)~~9.0~~	5.17	1.38E-01
FINRU	8.7 (190)~~8.7~~	2.91	1.19E-02
FINUB	5.0 (110)~~5.0~~	2.87	2.49E-02
FINRO	5.1 (49)~~5.1~~	3.74	6.94E-02
SPARU	12 (68)~~12~~	3.87	1.54E-02
SPAUB	13.1 (97)~~13.1~~	3.71	2.12E-02
GRERU	6.5 (116)~~6.5~~	3.68	4.90E-03
GREUB	8.5 (82)~~8.5~~	3.4	4.41E-02

* GR up to 50 nm calculated

** J_{16} calculated

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Table 3: Normalised ~~slopes~~ gradients (non-normalised for growth rate), R^2 and p-values (- for values >0.05) for the relation between meteorological conditions and NPF event variables.

Downward shortwave solar radiation K↓ (W m^{-2})										
Site	**a_N* (W^{-1} m^2)**	**R^2**	**p**	**a_G**	**R^2**	**p**	**a_J* (W^{-1} m^2)**	**R^2**	**p**	**Averag**
UKRU*	**1.21E-03**	0.94	<0.001	6.53E-05	0.11	-	**6.28E-04**	0.93	<0.001	443
UKUB*	**6.81E-04**	0.90	<0.001	-8.26E-05	0.10	-	1.49E-04	0.19	-	448
UKRO*	**8.69E-04**	0.98	<0.001	-7.75E-06	0.00	-	**2.66E-04**	0.64	<0.005	464
DENRU	**2.22E-03**	0.88	<0.001	4.24E-04	0.20	-	**1.38E-03**	0.64	<0.001	115
DENUB	**1.87E-03**	0.91	<0.001	1.47E-04	0.03	-	8.98E-04	0.48	<0.01	115
DENRO	**2.46E-03**	0.95	<0.001	1.27E-04	0.01	-	**6.77E-04**	0.50	<0.005	117
GERRU	**2.87E-03**	0.98	<0.001	**9.88E-04**	0.72	<0.01	**1.45E-03**	0.81	<0.001	130
GERUB	**3.18E-03**	0.97	<0.001	**7.28E-04**	0.51	<0.005	**1.53E-03**	0.69	<0.001	114
GERRO	**2.40E-03**	0.95	<0.001	-5.89E-04	0.09	-	**9.95E-04**	0.59	<0.005	114
FINRU	**2.63E-03**	0.76	<0.001	**1.01E-03**	0.57	<0.01	**2.04E-03**	0.82	<0.001	91.5
FINUB	1.38E-03	0.37	-	1.81E-04	0.08	-	8.99E-04	0.25	-	111
FINRO	**1.76E-03**	0.59	<0.005	9.15E-04	0.34	<0.005	4.45E-04	0.03	-	114
SPARU	3.46E-04	0.35	<0.05	5.68E-04	0.13	-	**1.97E-03**	0.74	<0.001	162
SPAUB	**5.92E-04**	0.58	<0.05	6.98E-04	0.23	-	**1.58E-03**	0.81	<0.001	180
GRERU	**4.10E-04**	0.52	<0.001	**7.14E-04**	0.55	<0.001	-6.30E-04	0.05	-	201
GREUB	3.49E-04	0.31	-	-1.10E-04	0.02	-	8.97E-04	0.34	<0.05	183

* Global solar irradiation measurements in kJ m^{-2}

Relative Humidity (%)										
Site	**a_N* (%$^{-1}$)**	**R^2**	**p**	**a_G**	**R^2**	**p**	**a_J* (%$^{-1}$)**	**R^2**	**p**	**Averag**
UKRU	**-5.89E-02**	0.85	<0.001	1.69E-03	0.02	-	**-3.35E-02**	0.85	<0.001	79.7
UKUB	**-3.42E-02**	0.94	<0.001	8.23E-03	0.24	-	-5.66E-03	0.19	-	75.3
UKRO	**-5.09E-02**	0.85	<0.001	7.03E-03	0.25	-	-1.49E-02	0.46	<0.05	74.5
DENRU	**-3.90E-02**	0.95	<0.001	**9.42E-03**	0.74	<0.001	5.45E-04	0.00	-	75.7
DENUB	**-3.14E-02**	0.94	<0.001	3.64E-03	0.06	-	2.57E-03	0.00	-	75.7
DENRO	**-3.64E-02**	0.95	<0.001	-1.21E-02	0.22	-	-3.91E-03	0.10	-	75.7
GERRU	**-5.08E-02**	0.88	<0.001	**-1.30E-02**	0.72	<0.001	**-2.46E-02**	0.91	<0.001	81.9
GERUB	**-5.35E-02**	0.86	<0.001	**-6.34E-03**	0.67	<0.001	**-2.25E-02**	0.86	<0.001	78.7
GERRO	**-2.83E-02**	0.90	<0.001	3.98E-03	0.05	-	**-1.72E-02**	0.81	<0.001	78.7
FINRU	**-4.48E-02**	0.94	<0.001	**-7.07E-03**	0.65	<0.001	**-2.16E-02**	0.87	<0.001	80.1
FINUB	**-5.89E-02**	0.95	<0.001	1.04E-02	0.26	-	-6.52E-03	0.18	-	76.5
FINRO	**-3.34E-02**	0.92	<0.001	-1.47E-03	0.01	-	7.39E-03	0.10	-	71.1
SPARU	**-1.54E-02**	0.90	<0.001	-4.67E-03	0.08	-	-7.12E-03	0.14	-	66.4
SPAUB	**-4.84E-02**	0.93	<0.001	**2.43E+02**	0.50	<0.01	-9.83E-03	0.19	-	69.2
GRERU	-7.72E-03	0.22	-	1.06E-02	0.06	-	-1.83E-01	0.15	-	70.0
GREUB	**-1.42E-02**	0.62	<0.001	2.83E-03	0.06	-	4.85E-04	0.00	-	60.5

Temperature (°C)										
Site	**a_N* (°C^{-1})**	**R^2**	**p**	**a_G**	**R^2**	**p**	**a_J* (°C^{-1})**	**R^2**	**p**	**Average**
UKRU	**1.10E-01**	0.93	<0.001	**7.85E-02**	0.94	<0.001	**8.72E-02**	0.84	<0.001	10.6
UKUB	**9.04E-02**	0.98	<0.001	**1.39E-01**	0.96	<0.001	**6.34E-02**	0.73	<0.005	11.8
UKRO	**8.22E-02**	0.98	<0.001	**3.51E-02**	0.52	<0.05	4.32E-02	0.44	<0.05	12.1
DENRU	**6.68E-02**	0.83	<0.001	1.54E-02	0.08	-	**6.68E-02**	0.92	<0.001	9.80
DENUB	**2.50E-02**	0.45	<0.05	2.40E-02	0.33	-	3.05E-02	0.45	<0.05	9.82
DENRO	**6.64E-02**	0.88	<0.001	3.51E-03	0.00	-	**2.96E-02**	0.58	<0.005	10.0
GERRU	**7.27E-02**	0.92	<0.001	**5.65E-02**	0.92	<0.001	**5.37E-02**	0.93	<0.001	10.3

GERUB	**8.20E-02**	0.93	<0.001	**3.38E-02**	0.62	<0.001	**4.28E-02**	0.54	<0.005	11.1
GERRO	**5.08E-02**	0.89	<0.001	-3.33E-03	0.00	-	1.61E-02	0.11	-	11.1
FINRU	-2.01E-02	0.17	-	**1.13E-01**	0.79	<0.001	**4.27E-02**	0.72	<0.001	4.79
FINUB	-4.21E-03	0.00	-	**7.42E-02**	0.83	<0.001	1.67E-02	0.28	-	6.52
FINRO	**6.24E-02**	0.65	<0.005	**9.28E-02**	0.87	<0.001	-1.09E-02	0.05	-	7.72
SPARU	-2.51E-02	0.41	<0.05	**1.23E-01**	0.92	<0.001	**9.11E-02**	0.71	<0.001	13.9
SPAUB	-3.43E-03	0.02	-	**6.67E-02**	0.66	<0.005	1.18E-02	0.08	-	18.2
GRERU	**-4.66E-02**	0.75	<0.001	**1.74E-01**	0.75	<0.001	-9.45E-02	0.47	<0.05	18.2
GREUB	-1.00E-02	0.25	-	**4.67E-02**	0.62	<0.005	-2.85E-02	0.20	-	17.6

Wind Speed (m s^{-1})										
Site	a_N* (m^{-1} s)	R^2	p	a_G	R^2	p	a_J* (m^{-1} s)	R^2	p	Averag
UKRU	5.72E-02	0.20	-	-3.04E-02	0.07	-	6.87E-03	0.00	-	3.96
UKUB	**1.72E-01**	0.87	<0.001	**-1.91E-01**	0.71	<0.001	3.56E-03	0.00	-	4.16
UKRO	6.34E-02	0.19	-	3.21E-02	0.02	-	7.28E-02	0.45	<0.005	4.14
DENRU	**1.08E-01**	0.88	<0.001	**-2.33E-01**	0.74	<0.001	1.28E-01	0.44	<0.01	4.17
DENUB	**1.50E-01**	0.90	<0.001	-3.33E-02	0.10	-	8.31E-02	0.19	-	4.17
DENRO	**1.65E-01**	0.89	<0.001	-1.51E-01	0.49	<0.001	9.08E-03	0.00	-	4.16
GERRU	**-1.06E-01**	0.57	<0.005	**-2.26E-01**	0.83	<0.001	-5.32E-03	0.00	-	2.58
GERUB	**-1.27E-01**	0.52	<0.01	**-1.41E-01**	0.60	<0.005	-3.32E-02	0.04	-	2.33
GERRO	**-2.40E-01**	0.56	-	-2.54E-01	0.38	-	-1.30E-01	0.22	-	2.33
FINRU	**1.62E-01**	0.63	<0.005	-1.29E-01	0.16	<0.05	7.99E-02	0.07	-	1.31
FINUB	-3.17E-02	0.08	-	7.26E-02	0.20	<0.05	-9.74E-02	0.17	-	3.43
FINRO	**8.62E-02**	0.51	<0.05	-1.60E-01	0.32	<0.05	-1.86E-01	0.32	-	4.26
SPARU	-2.20E-02	0.02	-	3.80E-01	0.31	-	5.74E-02	0.02	-	0.94
SPAUB	**2.90E-01**	0.93	<0.001	7.71E-02	0.24	-	-5.90E-02	0.05	-	2.05
GRERU	**4.37E-02**	0.54	<0.001	1.01E-01	0.36	<0.005	1.73E-03	0.00	-	6.06
GREUB	-1.13E-01	0.47	<0.01	**-1.88E-01**	0.50	<0.005	-3.78E-02	0.01	-	1.87

Atmospheric Pressure (mbar)										
Site	a_N* (mbar^{-1})	R^2	p	a_G	R^2	p	a_J* (mbar^{-1})	R^2	p	Avera
UKRU	**4.26E-02**	0.83	<0.005	**3.93E-02**	0.58	<0.005	2.95E-02	0.47	<0.05	1007
UKUB	**1.90E-02**	0.50	-	1.17E-02	0.05	<0.05	4.16E-03	0.04	-	1011
UKRO	**6.33E-02**	0.95	<0.001	-1.21E-01	0.40	-	-2.98E-02	0.17	-	1013
GERRU	**5.10E-02**	0.97	-	**8.95E-02**	0.85	<0.001	2.16E-02	0.21	-	1007
GERUB	**6.27E-02**	0.97	-	**4.00E-02**	0.76	-	2.00E-02	0.37	<0.05	995.
GERRO	**4.57E-02**	0.79	-	-9.61E-02	0.43	-	-2.80E-02	0.21	-	995.
FINRU	**3.46E-02**	0.88	<0.001	**2.90E-02**	0.57	<0.001	1.05E-02	0.14	-	985.
FINUB	**2.61E-02**	0.55	<0.005	-3.57E-03	0.02	-	4.38E-03	0.05	-	1004
FINRO	**4.91E-02**	0.70	-	-2.67E-02	0.17	-	1.43E-02	0.26	-	1008
SPARU	-2.02E-02	0.09	-	4.79E-02	0.14	-	2.89E-02	0.08	-	939.
SPAUB	-2.83E-02	0.44	<0.05	1.86E-02	0.08	-	1.68E-02	0.21	-	1006
GRERU	6.00E-02	0.46	<0.001	-1.50E-01	0.73	-	8.14E-02	0.33	-	1014
GREUB	9.42E-03	0.10	<0.05	-1.00E-01	0.71	-	1.58E-02	0.04	-	1015
~~Downward shortwave solar radiation K↓ (W m^{-2})~~										
~~Site~~	~~a_N* (W^{-1} m^2)~~	~~R^2~~	~~p~~	~~a_G~~	~~R^2~~	~~p~~	~~a_J* (W^{-1} m^2)~~	~~R^2~~	~~p~~	~~Average~~

UKRU*	1.21E-03	0.94	<0.001	6.53E-05	0.11	-	6.28E-04	0.93	<0.001	443
UKUB*	6.81E-04	0.90	<0.001	-8.26E-05	0.10	-	1.49E-04	0.19	-	448
UKRO*	8.69E-04	0.98	<0.001	-7.75E-06	0.00	-	2.66E-04	0.64	<0.005	464
DENRU	2.22E-03	0.88	<0.001	4.24E-04	0.20	-	1.38E-03	0.64	<0.001	115
DENUB	1.87E-03	0.91	<0.001	1.47E-04	0.03	-	8.98E-04	0.48	<0.01	115
DENRO	2.46E-03	0.95	<0.001	1.27E-04	0.01	-	6.77E-04	0.50	<0.005	117
GERRU	2.87E-03	0.98	<0.001	9.88E-04	0.72	<0.01	1.45E-03	0.81	<0.001	130
GERUB	3.18E-03	0.97	<0.001	7.28E-04	0.51	<0.005	1.53E-03	0.69	<0.001	114
GERRO	2.40E-03	0.95	<0.001	-5.89E-04	0.09	-	9.95E-04	0.59	<0.005	114
FINRU	2.63E-03	0.76	<0.001	1.01E-03	0.57	<0.01	2.04E-03	0.82	<0.001	91.5
FINUB	1.38E-03	0.37	-	1.81E-04	0.08	-	8.99E-04	0.25	-	111
FINRO	1.76E-03	0.59	<0.005	9.15E-04	0.34	<0.005	4.45E-04	0.03	-	114
SPARU	3.46E-04	0.35	<0.05	5.68E-04	0.13	-	1.97E-03	0.74	<0.001	162
SPAUB	5.92E-04	0.58	<0.05	6.98E-04	0.23	-	1.58E-03	0.81	<0.001	180
GRERU	4.10E-04	0.52	<0.001	7.14E-04	0.55	<0.001	-6.30E-04	0.05	-	201
GREUB	3.49E-04	0.31	-	-1.10E-04	0.02	-	8.97E-04	0.34	<0.05	183

* Solar irradiation measurements

Relative Humidity (%)										
Site	**a_N* (%$^{-1}$)**	**R^2**	**p**	**a_G**	**R^2**	**p**	**a_J* (%$^{-1}$)**	**R^2**	**p**	**Average**
UKRU	-5.89E-02	0.85	<0.001	1.69E-03	0.02	-	-3.35E-02	0.85	<0.001	79.7
UKUB	-3.42E-02	0.94	<0.001	8.23E-03	0.24	-	-5.66E-03	0.19	-	75.3
UKRO	-5.09E-02	0.85	<0.001	7.03E-03	0.25	-	-1.49E-02	0.46	<0.05	74.5
DENRU	-3.90E-02	0.95	<0.001	9.42E-03	0.74	<0.001	5.45E-04	0.00	-	75.7
DENUB	-3.14E-02	0.94	<0.001	3.64E-03	0.06	-	2.57E-03	0.00	-	75.7
DENRO	-3.64E-02	0.95	<0.001	-1.21E-02	0.22	-	-3.91E-03	0.10	-	75.7
GERRU	-5.08E-02	0.88	<0.001	-1.30E-02	0.72	<0.001	-2.46E-02	0.91	<0.001	81.9
GERUB	-5.35E-02	0.86	<0.001	-6.34E-03	0.67	<0.001	-2.25E-02	0.86	<0.001	78.7
GERRO	-2.83E-02	0.90	<0.001	3.98E-03	0.05	-	-1.72E-02	0.81	<0.001	78.7
FINRU	-4.48E-02	0.94	<0.001	-7.07E-03	0.65	<0.001	-2.16E-02	0.87	<0.001	80.1
FINUB	-5.89E-02	0.95	<0.001	1.04E-02	0.26	-	-6.52E-03	0.18	-	76.5
FINRO	-3.34E-02	0.92	<0.001	-1.47E-03	0.01	-	7.39E-03	0.10	-	71.1
SPARU	-1.54E-02	0.90	<0.001	-4.67E-03	0.08	-	-7.12E-03	0.14	-	66.4
SPAUB	-4.84E-02	0.93	<0.001	2.43E+02	0.50	<0.01	-9.83E-03	0.19	-	69.2
GRERU	-7.72E-03	0.22	-	1.06E-02	0.06	-	-1.83E-01	0.15	-	70.0
GREUB	-1.42E-02	0.62	<0.001	2.83E-03	0.06	-	4.85E-04	0.00	-	60.5
Temperature (ºC)										
Site	**a_N* (ºC^{-1})**	**R^2**	**p**	**a_G**	**R^2**	**p**	**a_J* (ºC^{-1})**	**R^2**	**p**	**Average**
UKRU	1.10E-01	0.93	<0.001	7.85E-02	0.94	<0.001	8.72E-02	0.84	<0.001	10.6
UKUB	9.04E-02	0.98	<0.001	1.39E-01	0.96	<0.001	6.34E-02	0.73	<0.005	11.8
UKRO	8.22E-02	0.98	<0.001	3.51E-02	0.52	<0.05	4.32E-02	0.44	<0.05	12.1
DENRU	6.68E-02	0.83	<0.001	1.54E-02	0.08	-	6.68E-02	0.92	<0.001	9.80
DENUB	2.50E-02	0.45	<0.05	2.40E-02	0.33	-	3.05E-02	0.45	<0.05	9.82
DENRO	6.64E-02	0.88	<0.001	3.51E-03	0.00	-	2.96E-02	0.58	<0.005	10.0
GERRU	7.27E-02	0.92	<0.001	5.65E-02	0.92	<0.001	5.37E-02	0.93	<0.001	10.3
GERUB	8.20E-02	0.93	<0.001	3.38E-02	0.62	<0.001	4.28E-02	0.54	<0.005	11.1
GERRO	5.08E-02	0.89	<0.001	-3.33E-03	0.00	-	1.61E-02	0.11	-	11.1
FINRU	-2.01E-02	0.17	-	1.13E-01	0.79	<0.001	4.27E-02	0.72	<0.001	4.79
FINUB	-4.21E-03	0.00	-	7.42E-02	0.83	<0.001	1.67E-02	0.28	-	6.52

FINRO	6.24E-02	0.65	<0.005	9.28E-02	0.87	<0.001	-1.09E-02	0.05	-	7.72
SPARU	-2.51E-02	0.41	<0.05	1.23E-01	0.92	<0.001	9.11E-02	0.71	<0.001	13.9
SPAUB	-3.43E-03	0.02	-	6.67E-02	0.66	<0.005	1.18E-02	0.08	-	18.2
GRERU	-4.66E-02	0.75	<0.001	1.74E-01	0.75	<0.001	-9.45E-02	0.47	<0.05	18.2
GREUB	-1.00E-02	0.25	-	4.67E-02	0.62	<0.005	-2.85E-02	0.20	-	17.6

Wind Speed (m s^{-1})										
Site	a_N* (m^{-1} s)	R^2	P	a_G	R^2	P	a_J* (m^{-1} s)	R^2	P	Average
UKRU	5.72E-02	0.20	-	-3.04E-02	0.07	-	6.87E-03	0.00	-	3.96
UKUB	1.72E-01	0.87	<0.001	-1.91E-01	0.71	<0.001	3.56E-03	0.00	-	4.16
UKRO	6.34E-02	0.19	-	3.21E-02	0.02	-	7.28E-02	0.45	<0.005	4.14
DENRU	1.08E-01	0.88	<0.001	-2.33E-01	0.74	<0.001	1.28E-01	0.44	<0.01	4.17
DENUB	1.50E-01	0.90	<0.001	-3.33E-02	0.10	-	8.31E-02	0.19	-	4.17
DENRO	1.65E-01	0.89	<0.001	-1.51E-01	0.49	<0.001	9.08E-03	0.00	-	4.16
GERRU	-1.06E-01	0.57	<0.005	-2.26E-01	0.83	<0.001	-5.32E-03	0.00	-	2.58
GERUB	-1.27E-01	0.52	<0.01	-1.41E-01	0.60	<0.005	-3.32E-02	0.04	-	2.33
GERRO	-2.40E-01	0.56	-	-2.54E-01	0.38	-	-1.30E-01	0.22	-	2.33
FINRU	1.62E-01	0.63	<0.005	-1.29E-01	0.16	<0.05	7.99E-02	0.07	-	1.31
FINUB	-3.17E-02	0.08	-	7.26E-02	0.20	<0.05	-9.74E-02	0.17	-	3.43
FINRO	8.62E-02	0.51	<0.05	-1.60E-01	0.32	<0.05	-1.86E-01	0.32	-	4.26
SPARU	-2.20E-02	0.02	-	3.80E-01	0.31	-	5.74E-02	0.02	-	0.94
SPAUB	2.90E-01	0.93	<0.001	7.71E-02	0.24	-	-5.90E-02	0.05	-	2.05
GRERU	4.37E-02	0.54	<0.001	1.01E-01	0.36	<0.005	1.73E-03	0.00	-	6.06
GREUB	-1.13E-01	0.47	<0.01	-1.88E-01	0.50	<0.005	-3.78E-02	0.01	-	1.87

Atmospheric Pressure (mbar)										
Site	a_N* (mbar^{-1})	R^2	P	a_G	R^2	P	a_J* (mbar^{-1})	R^2	P	Average
UKRU	4.26E-02	0.83	<0.005	3.93E-02	0.58	<0.005	2.95E-02	0.47	<0.05	1007.7
UKUB	1.90E-02	0.50	-	1.17E-02	0.05	<0.05	4.16E-03	0.04	-	1011.7
UKRO	6.33E-02	0.95	<0.001	-1.21E-01	0.40	-	-2.98E-02	0.17	-	1012
GERRU	5.10E-02	0.97	-	8.95E-02	0.85	<0.001	2.16E-02	0.21	-	1007.0
GERUB	6.27E-02	0.97	-	4.00E-02	0.76	-	2.00E-02	0.37	<0.05	995.5
GERRO	4.57E-02	0.79	-	-9.61E-02	0.43	-	-2.80E-02	0.21	-	995.5
FINRU	3.46E-02	0.88	<0.001	2.90E-02	0.57	<0.001	1.05E-02	0.14	-	985.1
FINUB	2.61E-02	0.55	<0.005	-3.57E-03	0.02	-	4.38E-03	0.05	-	1004.4
FINRO	4.91E-02	0.70	-	-2.67E-02	0.17	-	1.43E-02	0.26	-	1008.8
SPARU	-2.02E-02	0.09	-	4.79E-02	0.14	-	2.89E-02	0.08	-	939.3
SPAUB	-2.83E-02	0.44	<0.05	1.86E-02	0.08	-	1.68E-02	0.21	-	1006.3
GRERU	6.00E-02	0.46	<0.001	-1.50E-01	0.73	-	8.14E-02	0.33	-	1014.5
GREUB	9.42E-03	0.10	<0.05	-1.00E-01	0.71	-	1.58E-02	0.04	-	1015.7

Table 4: Normalised ~~slopes~~ gradients (non-normalised for growth rate), R^2 and p-values (- for values >0.05) for the relation between atmospheric composition variables and NPF event variables.

SO_2 ($\mu g\ m^{-3}$)										
Site	a_N* ($\mu g^{-1}\ m^3$)	R^2	p	a_G	R^2	p	a_J* ($\mu g^{-1}\ m^3$)	R^2	p	Average
UKRU	-1.97E-01	0.38	<0.05	-6.17E-02	0.02	-	3.30E-01	0.06	-	1.64
UKUB	-2.57E-01	0.62	<0.001	1.93E-02	0.00	-	4.18E-01	0.40	-	2.04
UKRO	-1.03E-01	0.82	<0.001	6.90E-02	0.34	<0.01	8.43E-02	0.77	<0.001	7.46
DENRU	-9.77E-01	0.53	<0.05	2.84E+00	0.37	-	4.38E-01	0.09	-	0.52
DENRO	-4.20E-01	0.91	<0.001	6.42E-01	0.54	<0.005	5.66E-01	0.62	<0.001	0.97
FINRU	-5.66E-01	0.05	-	-1.42E+00	0.19	-	-6.30E-02	0.00	-	0.09
SPARU	-3.62E-01	0.74	<0.001	-1.33E-01	0.02	-	-3.55E-02	0.01	-	0.95
SPAUB	-2.93E-02	0.04	-	4.12E-01	0.59	-	1.07E-01	0.29	-	1.99

NO_x or NO_2 (ppb)										
Site	a_N* (ppb^{-1})	R^2	p	a_G	R^2	p	a_J* (ppb^{-1})	R^2	p	Average
UKRU	-4.99E-02	0.67	<0.005	4.52E-02	0.58	<0.05	-4.51E-02	0.70	<0.005	11.7
UKUB	-8.75E-03	0.83	<0.001	-3.97E-04	0.00	-	-1.09E-02	0.43	<0.05	53.6
UKRO	-3.22E-03	0.72	<0.001	1.44E-03	0.39	<0.05	2.19E-03	0.66	<0.001	299
DENRU	-9.41E-02	0.43	<0.005	-4.89E-03	0.00	<0.001	-6.47E-02	0.55	<0.01	5.42
DENUB	-4.99E-02	0.68	<0.001	2.85E-02	0.26	-	8.55E-04	0.00	-	10.5
DENRO	-5.10E-03	0.75	<0.001	1.10E-02	0.69	<0.001	8.33E-03	0.88	<0.001	68.5
FINRU	-7.27E-01	0.54	<0.001	-2.74E-01	0.11	-	1.95E-01	0.05	-	0.72
FINRO	-6.24E-03	0.68	<0.001	1.70E-03	0.12	-	3.25E-03	0.03	-	88.1
SPARU*	-1.53E-02	0.05	-	2.54E-02	0.01	-	1.25E-01	0.21	-	3.26
SPAUB*	-2.59E-02	0.62	<0.005	2.23E-02	0.70	<0.001	2.57E-03	0.01	-	31.4
GRERU*	3.01E-01	0.19	-	-1.40E+00	0.75	<0.001	5.23E-01	0.13	-	0.52

* NO_2 measurements

O$_3$ (ppb)										
Site	a_N* (ppb^{-1})	R^2	p	a_G	R^2	p	a_J* (ppb^{-1})	R^2	p	Average
UKRU	2.27E-02	0.88	<0.001	-4.89E-02	0.53	<0.005	-3.53E-03	0.01	-	54.4
UKUB	1.37E-02	0.87	<0.001	-3.45E-02	0.68	<0.001	-5.95E-03	0.05	-	39.3
UKRO	7.46E-02	0.95	<0.001	-1.06E-02	0.09	-	-2.44E-02	0.63	<0.005	16.2
DENRU	4.97E-02	0.92	<0.001	-1.32E-02	0.15	-	1.23E-02	0.08	-	30.1
DENUB	5.85E-02	0.84	<0.001	-1.69E-02	0.58	-	2.77E-02	0.32	<0.05	28.2
DENRO	6.42E-02	0.51	<0.05	1.39E-02	0.03	-	3.24E-02	0.91	<0.05	31.1
FINRU	6.76E-02	0.77	<0.05	-4.23E-02	0.60	-	3.92E-02	0.37	<0.05	27.4
FINRO	2.38E-02	0.91	<0.001	6.11E-03	0.24	-	-1.83E-02	0.29	-	37.1
SPARU	1.57E-02	0.02	-	4.34E-02	0.11	-	1.31E-02	0.31	-	75.9
SPAUB	7.99E-03	0.38	<0.05	-5.83E-03	0.30	-	-1.13E-03	0.01	-	54.9
GRERU	7.55E-03	0.04	-	3.68E-02	0.17	-	-3.01E-02	0.15	-	49.5

Particulate Organic Carbon (μg m^{-3})										
Site	a_N* (μg^{-1} m^3)	R^2	p	a_G	R^2	p	a_J* (μg^{-1} m^3)	R^2	p	Average
UKRU	-3.30E-02	0.00	-	1.13E+00	0.42	<0.005	2.13E-01	0.16	-	1.96
UKUB	-2.76E-01	0.59	<0.005	6.63E-01	0.58	<0.05	2.19E-01	0.55	<0.05	3.63
UKRO	-3.78E-01	0.89	<0.001	8.12E-01	0.57	<0.005	4.60E-01	0.75	<0.001	6.24
DENRU	-4.44E-01	0.75	<0.001	2.24E-01	0.11	-	-3.17E-01	0.68	<0.01	1.48
DENRO	-7.80E-02	0.11	-	1.10E+00	0.77	<0.005	4.02E-01	0.81	<0.005	2.59
GERRU	-1.26E-01	0.24	-	1.35E-01	0.09	-	3.14E-02	0.03	-	2.18
FINRU	2.27E-02	0.00	-	3.39E-01	0.60	<0.005	-3.46E-01	0.16	-	1.78
GRERU	-2.08E-01	0.11	-	7.87E-01	0.41	<0.05	8.94E-01	0.11	-	1.58

Sulphate (μg m^{-3})										
Site	a_N* (μg^{-1} m^3)	R^2	p	a_G	R^2	p	a_J* (μg^{-1} m^3)	R^2	p	Average
UKRU[1]	-2.62E-01	0.57	<0.001	7.34E-01	0.77	<0.001	7.99E-01	0.44	<0.05	1.97
UKUB[1]	-3.57E-01	0.89	<0.001	9.28E-01	0.44	<0.01	9.72E-01	0.16	-	1.58
UKRO[1]	-6.05E-02	0.24	-	3.04E-01	0.34	<0.05	-6.22E-02	0.04	-	1.98
DENRU[2]	-7.81E-01	0.34	<0.05	1.02E+00	0.60	<0.05	-1.03E+00	0.63	<0.01	0.52
DENRO[2]	-8.23E-01	0.28	-	1.99E+00	0.22	-	2.82E-01	0.12	-	0.55
GERRU[1]	-3.37E-02	0.00	-	5.89E-01	0.11	-	-4.89E-02	0.01	-	0.92
FINRU[3]	-1.18E+00	0.65	<0.001	2.35E-01	0.09	-	-2.53E-01	0.17	-	1.02

[1] Measurements in PM_{10}
[2] Measurements in $PM_{2.5}$
[3] Measurements in PM_1

Condensation Sink (s^{-1})										
Site	a_N* (s)	R^2	p	a_G	R^2	p	a_J* (s)	R^2	p	Average
UKRU	-2.28E+02	0.72	<0.001	2.64E+02	0.60	<0.001	7.58E+01	0.22	-	3.38E-03
UKUB	-1.66E+02	0.78	<0.001	2.49E+02	0.41	<0.05	1.73E+02	0.35	<0.05	7.41E-03
UKRO	-4.03E+01	0.75	<0.001	2.33E+01	0.18	-	8.94E+01	0.91	<0.001	2.12E-02
DENRU	-4.48E+01	0.91	<0.001	6.90E+01	0.49	<0.05	5.37E+01	0.24	-	9.46E-03
DENUB	-3.78E+01	0.75	<0.001	3.58E+01	0.25	-	1.55E+01	0.56	<0.005	1.42E-02
DENRO	-1.06E+01	0.73	<0.001	2.53E+01	0.56	<0.005	2.72E+01	0.79	<0.001	3.10E-02
GERRU	1.54E+02	0.86	<0.001	1.33E+02	0.56	<0.001	6.67E+01	0.63	<0.001	7.02E-03
GERUB	3.59E+01	0.56	<0.005	3.63E+01	0.17	-	4.74E+01	0.75	<0.001	9.11E-03
GERRO	3.89E+01	0.22	<0.05	-2.21E+01	0.03	<0.005	3.54E+01	0.45	<0.005	1.20E-02
FINRU	-1.80E+02	0.59	<0.005	4.01E+02	0.74	<0.001	4.98E+01	0.10	-	2.32E-03
FINUB	-1.51E+02	0.63	<0.005	8.14E+01	0.31	-	2.01E+02	0.41	<0.05	6.34E-03
FINRO	-6.99E+01	0.77	<0.001	-1.56E+01	0.05	-	2.42E+02	0.83	<0.001	8.96E-03
SPARU	-2.15E+02	0.65	<0.005	1.86E+01	0.00	-	8.60E+01	0.47	<0.05	5.49E-03
SPAUB	-1.18E+02	0.65	<0.005	3.74E+01	0.38	<0.05	9.51E+01	0.52	<0.01	1.00E-02
GRERU	4.33E+00	0.00	-	2.86E+02	0.70	<0.001	1.77E+02	0.56	<0.005	4.66E-03
GREUB	1.64E+02	0.65	<0.001	9.31E+01	0.28	<0.05	1.73E+02	0.83	<0.001	7.55E-03

SO_2 (µg m^{-3})										
Site	a_N* (µg^{-1} m^3)	R^2	p	a_G	R^2	p	a_J* (µg^{-1} m^3)	R^2	p	Average
UKRU	-1.97E-01	0.38	<0.05	-6.17E-02	0.02	-	3.30E-01	0.06	-	1.64
UKUB	**-2.57E-01**	0.62	<0.001	1.93E-02	0.00	-	4.18E-01	0.40	-	2.04
UKRO	**-1.03E-01**	0.82	<0.001	6.90E-02	0.34	<0.01	**8.43E-02**	0.77	<0.001	7.46
DENRU	**-9.77E-01**	0.53	<0.05	2.84E+00	0.37	-	4.38E-01	0.09	-	0.52
DENRO	**-4.20E-01**	0.91	<0.001	**6.42E-01**	0.54	<0.005	**5.66E-01**	0.62	<0.001	0.97
FINRU	-5.66E-01	0.05	-	-1.42E+00	0.19	-	-6.30E-02	0.00	-	0.09
SPARU	**-3.62E-01**	0.74	<0.001	-1.33E-01	0.02	-	-3.55E-02	0.01	-	0.95
SPAUB	-2.93E-02	0.04	-	**4.12E-01**	0.59	-	1.07E-01	0.29	-	1.99

NO_x or NO_2 (ppb)										
Site	a_N* (ppb^{-1})	R^2	p	a_G	R^2	p	a_J* (ppb^{-1})	R^2	p	Average
UKRU	**-4.99E-02**	0.67	<0.005	**4.52E-02**	0.58	<0.05	**-4.51E-02**	0.70	<0.005	11.7
UKUB	**-8.75E-03**	0.83	<0.001	-3.97E-04	0.00	-	-1.09E-02	0.43	<0.05	53.6
UKRO	**-3.22E-03**	0.72	<0.001	1.44E-03	0.39	<0.05	**2.19E-03**	0.66	<0.001	299
DENRU	-9.41E-02	0.43	<0.005	-4.89E-03	0.00	<0.001	**-6.47E-02**	0.55	<0.01	5.42
DENUB	**-4.99E-02**	0.68	<0.001	2.85E-02	0.26	-	8.55E-04	0.00	-	10.5
DENRO	**-5.10E-03**	0.75	<0.001	**1.10E-02**	0.69	<0.001	**8.33E-03**	0.88	<0.001	68.5
FINRU	**-7.27E-01**	0.54	<0.001	-2.74E-01	0.11	-	1.95E-01	0.05	-	0.72
FINRO	**-6.24E-03**	0.68	<0.001	1.70E-03	0.12	-	3.25E-03	0.03	-	88.1
SPARU*	-1.53E-02	0.05	-	2.54E-02	0.01	-	1.25E-01	0.21	-	3.26
SPAUB*	**-2.59E-02**	0.62	<0.005	**2.23E-02**	0.70	<0.001	2.57E-03	0.01	-	31.4
GRERU*	3.01E-01	0.19	-	**-1.40E+00**	0.75	<0.001	5.23E-01	0.13	-	0.52

* NO_2 measurements

O3 (ppb)										
Site	a_N* (ppb^{-1})	R^2	p	a_G	R^2	p	a_J* (ppb^{-1})	R^2	p	Avera
UKRU	**2.27E-02**	0.88	<0.001	**-4.89E-02**	0.53	<0.005	-3.53E-03	0.01	-	54.
UKUB	**1.37E-02**	0.87	<0.001	**-3.45E-02**	0.68	<0.001	-5.95E-03	0.05	-	39.
UKRO	**7.46E-02**	0.95	<0.001	-1.06E-02	0.09	-	**-2.44E-02**	0.63	<0.005	16.
DENRU	**4.97E-02**	0.92	<0.001	-1.32E-02	0.15	-	1.23E-02	0.08	-	30.
DENUB	**5.85E-02**	0.84	<0.001	**-1.69E-02**	0.58	-	2.77E-02	0.32	<0.05	28.
DENRO	**6.42E-02**	0.51	<0.05	1.39E-02	0.03	-	**3.24E-02**	0.91	<0.05	31.
FINRU	**6.76E-02**	0.77	<0.05	**-4.23E-02**	0.60	-	3.92E-02	0.37	<0.05	27.
FINRO	**2.38E-02**	0.91	<0.001	6.11E-03	0.24	-	-1.83E-02	0.29	-	37.
SPARU	1.57E-02	0.02	-	4.34E-02	0.11	-	1.31E-02	0.31	-	75.
SPAUB	7.99E-03	0.38	<0.05	-5.83E-03	0.30	-	-1.13E-03	0.01	-	54.
GRERU	7.55E-03	0.04	-	3.68E-02	0.17	-	-3.01E-02	0.15	-	49.

Particulate Organic Carbon (µg m^{-3})										
Site	a_N* (µg^{-1} m^3)	R^2	p	a_G	R^2	p	a_J* (µg^{-1} m^3)	R^2	p	Averag
UKRU	-3.30E-02	0.00	-	1.13E+00	0.42	<0.005	2.13E-01	0.16	-	1.96
UKUB	**-2.76E-01**	0.59	<0.005	**6.63E-01**	0.58	<0.05	**2.19E-01**	0.55	<0.05	3.63
UKRO	**-3.78E-01**	0.89	<0.001	**8.12E-01**	0.57	<0.005	**4.60E-01**	0.75	<0.001	6.24
DENRU	**-4.44E-01**	0.75	<0.001	2.24E-01	0.11	-	**-3.17E-01**	0.68	<0.01	1.48
DENRO	-7.80E-02	0.11	-	**1.10E+00**	0.77	<0.005	**4.02E-01**	0.81	<0.005	2.59
GERRU	-1.26E-01	0.24	-	1.35E-01	0.09	-	3.14E-02	0.03	-	2.18
FINRU	2.27E-02	0.00	-	**3.39E-01**	0.60	<0.005	-3.46E-01	0.16	-	1.78
GRERU	-2.08E-01	0.11	-	7.87E-01	0.41	<0.05	8.94E-01	0.11	-	1.58

Sulphate (µg m^{-3})										
Site	a_N* (µg^{-1} m^3)	R^2	p	a_G	R^2	p	a_J* (µg^{-1} m^3)	R^2	p	Avera
UKRU[1]	**-2.62E-01**	0.57	<0.001	**7.34E-01**	0.77	<0.001	7.99E-01	0.44	<0.05	1.97
UKUB[1]	**-3.57E-01**	0.89	<0.001	9.28E-01	0.44	<0.01	9.72E-01	0.16	-	1.58
UKRO[1]	-6.05E-02	0.24	-	3.04E-01	0.34	<0.05	-6.22E-02	0.04	-	1.98
DENRU[2]	-7.81E-01	0.34	<0.05	**1.02E+00**	0.60	<0.05	**-1.03E+00**	0.63	<0.01	0.52
DENRO[2]	-8.23E-01	0.28	-	1.99E+00	0.22	-	2.82E-01	0.12	-	0.55
GERRU[1]	-3.37E-02	0.00	-	5.89E-01	0.11	-	-4.89E-02	0.01	-	0.92
FINRU[3]	**-1.18E+00**	0.65	<0.001	2.35E-01	0.09	-	-2.53E-01	0.17	-	1.02

[1] Measurements in PM_{10}
[2] Measurements in $PM_{2.5}$
[3] Measurements in PM_1

Condensation Sink (s^{-1})										
Site	a_N* (s)	R^2	p	a_G	R^2	p	a_J* (s)	R^2	p	Average
UKRU	**-2.28E+02**	0.72	<0.001	**2.64E+02**	0.60	<0.001	7.58E+01	0.22	-	3.38E-03
UKUB	**-1.66E+02**	0.78	<0.001	2.49E+02	0.41	<0.05	1.73E+02	0.35	<0.05	7.41E-03
UKRO	**-4.03E+01**	0.75	<0.001	2.33E+01	0.18	-	**8.94E+01**	0.91	<0.001	2.12E-02
DENRU	**-4.48E+01**	0.91	<0.001	6.90E+01	0.49	<0.05	5.37E+01	0.24	-	9.46E-03
DENUB	**-3.78E+01**	0.75	<0.001	3.58E+01	0.25	-	1.55E+01	0.56	<0.005	1.42E-02
DENRO	**-1.06E+01**	0.73	<0.001	**2.53E+01**	0.56	<0.005	**2.72E+01**	0.79	<0.001	3.10E-02
GERRU	**1.54E+02**	0.86	<0.001	**1.33E+02**	0.56	<0.001	**6.67E+01**	0.63	<0.001	7.02E-03

GERUB	**3.59E+01**	0.56	<0.005	3.63E+01	0.17	-	**4.74E+01**	0.75	<0.001	9.11E-03
GERRO	3.89E+01	0.22	<0.05	-2.21E+01	0.03	<0.005	3.54E+01	0.45	<0.005	1.20E-02
FINRU	**-1.80E+02**	0.59	<0.005	**4.01E+02**	0.74	<0.001	4.98E+01	0.10	-	2.32E-03
FINUB	**-1.51E+02**	0.63	<0.005	8.14E+01	0.31	-	2.01E+02	0.41	<0.05	6.34E-03
FINRO	**-6.99E+01**	0.77	<0.001	-1.56E+01	0.05	-	**2.42E+02**	0.83	<0.001	8.96E-03
SPARU	**-2.15E+02**	0.65	<0.005	1.86E+01	0.00	-	8.60E+01	0.47	<0.05	5.49E-03
SPAUB	**-1.18E+02**	0.65	<0.005	3.74E+01	0.38	<0.05	**9.51E+01**	0.52	<0.01	1.00E-02
GRERU	4.33E+00	0.00	-	**2.86E+02**	0.70	<0.001	**1.77E+02**	0.56	<0.005	4.66E-03
GREUB	**1.64E+02**	0.65	<0.001	9.31E+01	0.28	<0.05	**1.73E+02**	0.83	<0.001	7.55E-03

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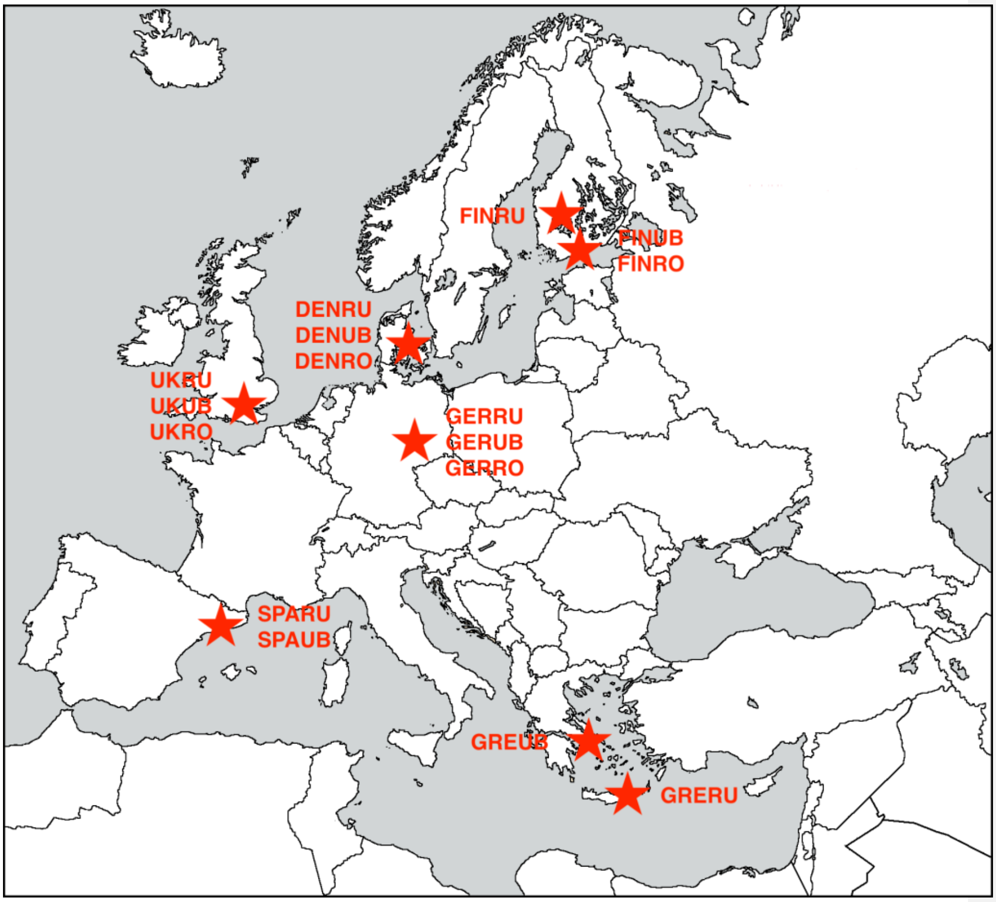


Figure 1: Map of the sites of the present study.

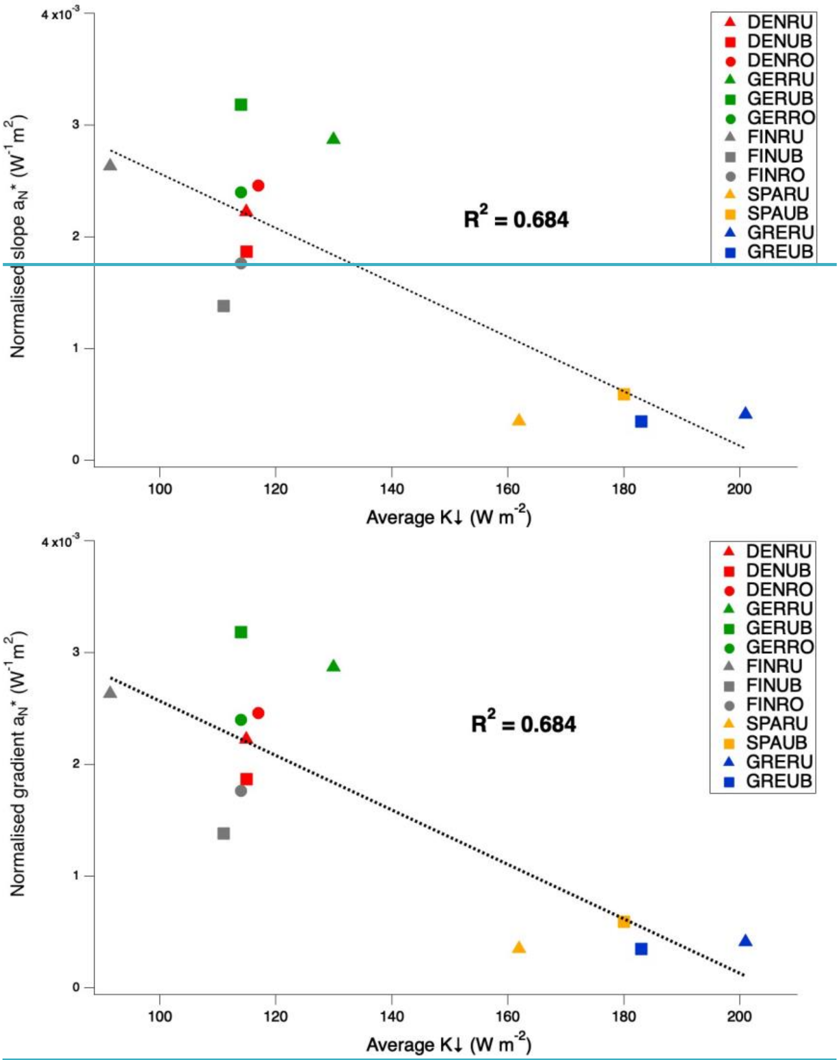


Figure 2: Relationship of average downward incoming solar radiation (K↓) and normalised gradientsslopes a_N^* for the sites of the present study.

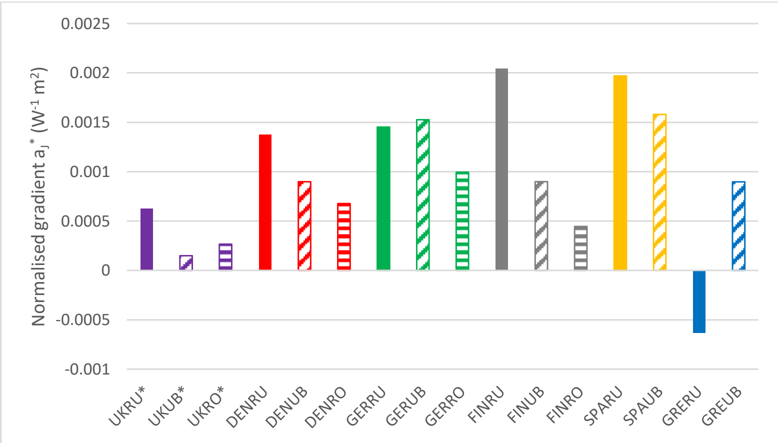


Figure 3: Normalised slopes a_J^* for K↓ ~~for the sites of the present study~~ (*UK sites are calculated with solar irradiance).

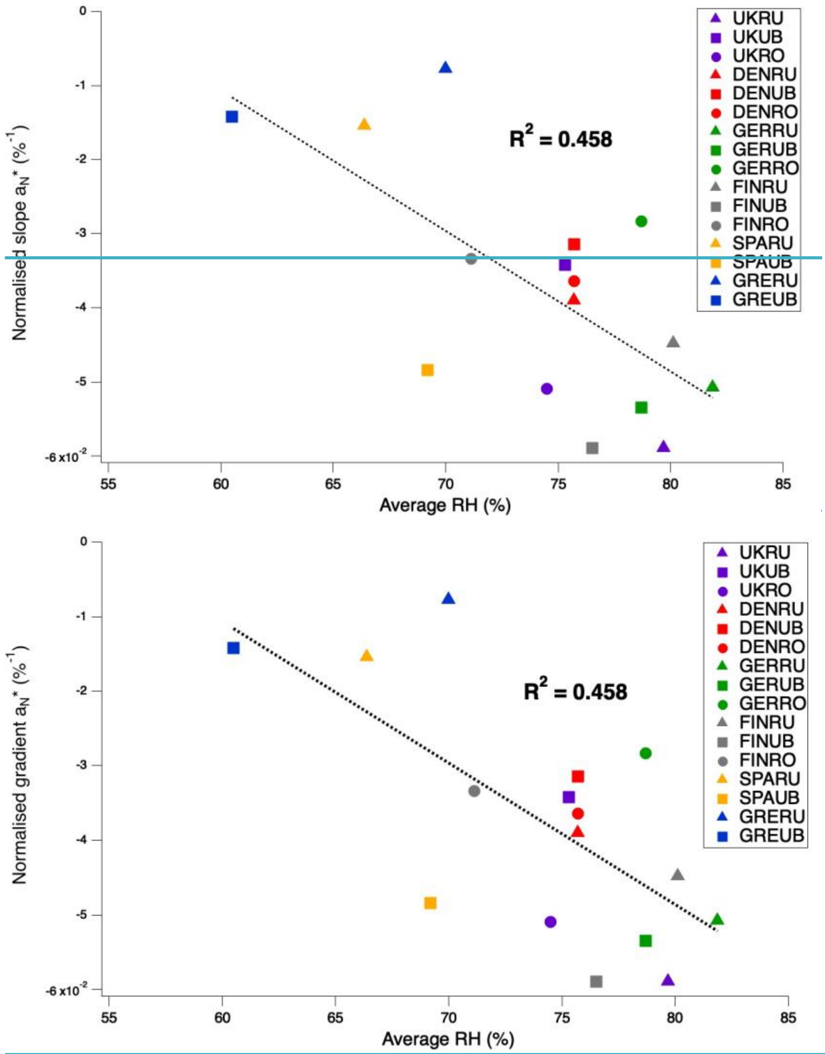


Figure 4: Relationship of average relative humidity and normalised ~~slopes~~ gradients a_N^* ~~for the sites of the present study~~.

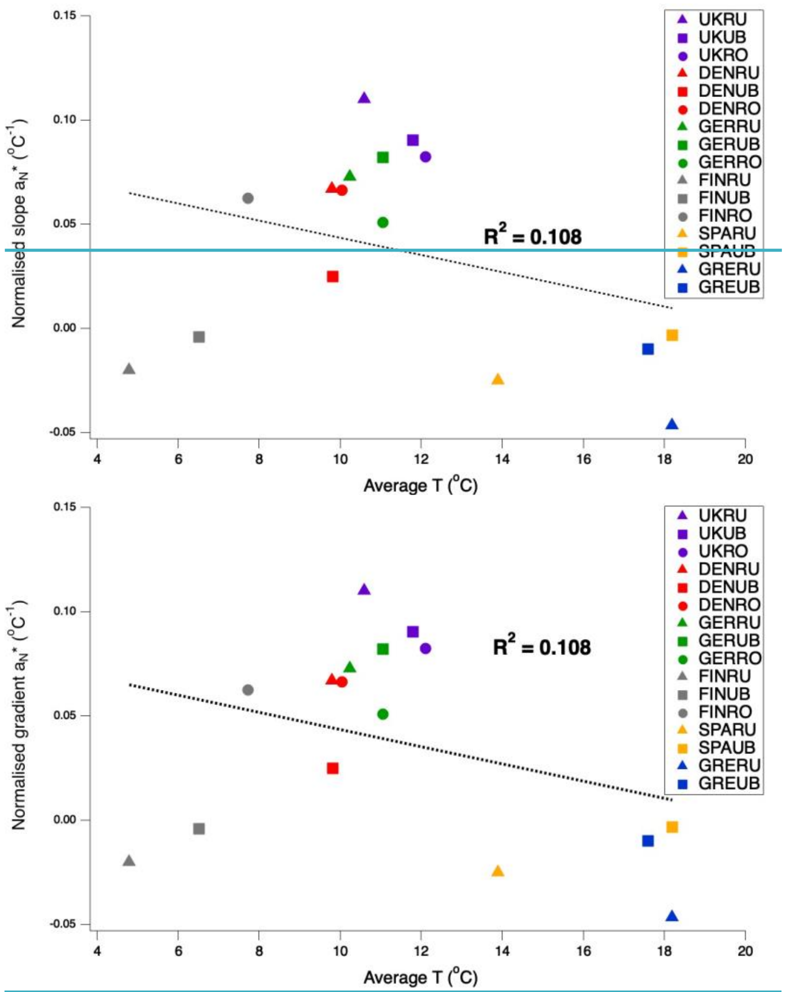


Figure 5: Relationship of average temperature and normalised slopes gradients a_N^* for the sites of the present study.

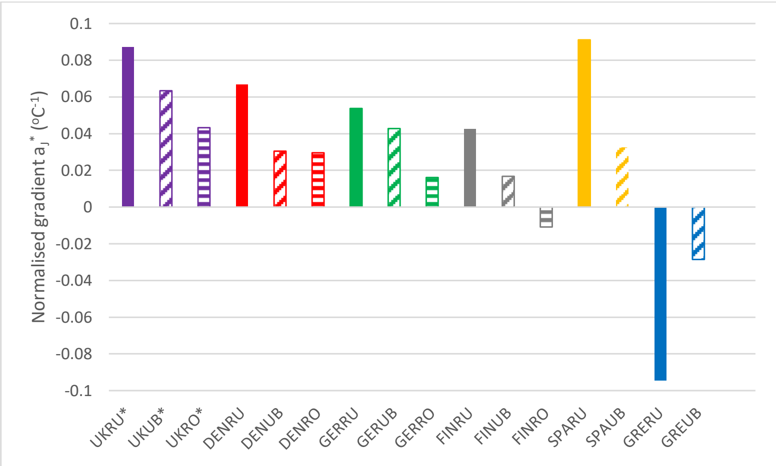
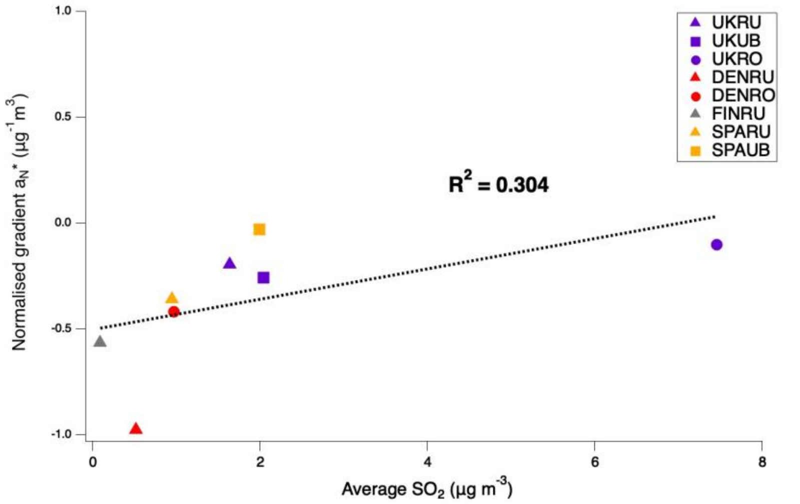


Figure 6: Normalised ~~slopes~~ gradients a_J^* for temperature ~~for the sites of the present study~~.



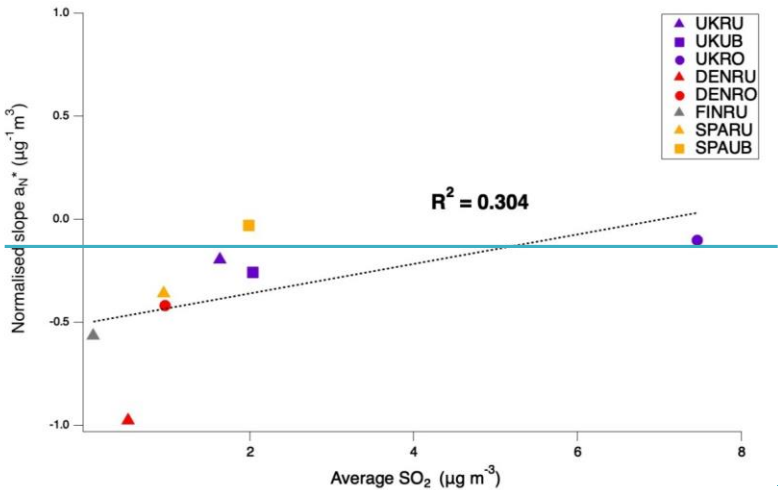


Figure 7a: Relationship of average SO_2 concentrations and normalised slopes gradients a_N^* for the sites of the present study.

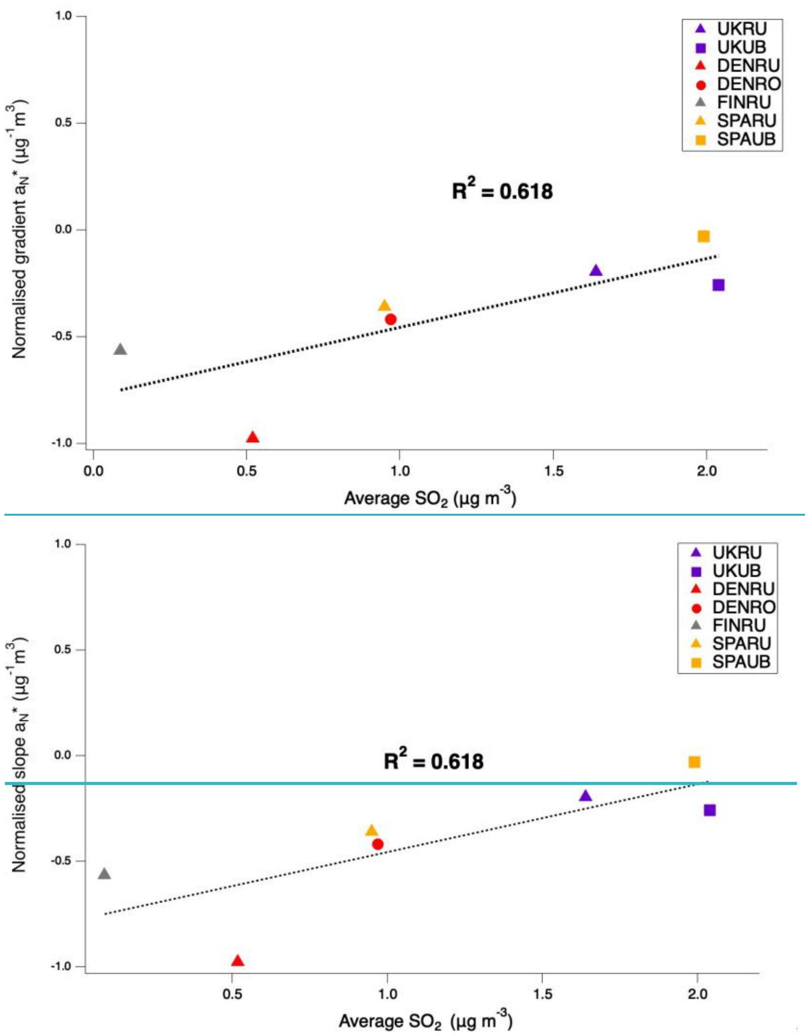


Figure 7b: Relationship of average SO_2 concentrations and normalised ~~slopes~~ gradients a_N^* ~~for the sites of the present study~~ (UKRO not included).

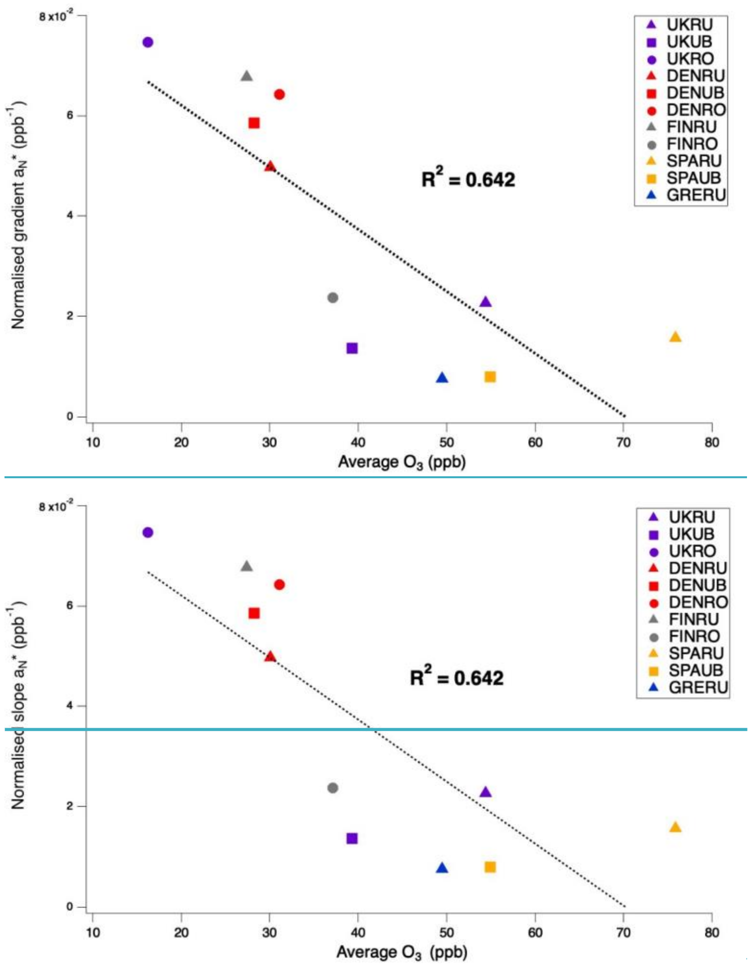


Figure 8: Relationship of average O_3 concentrations and normalised ~~slopes~~ gradients a_N^* ~~for the sites of the present study~~.

SUPPLEMENTARY INFORMATION

The Effect of Meteorological Conditions and Atmospheric Composition in the Occurrence and Development of New Particle Formation (NPF) Events in Europe

Dimitrios Bousiotis, James Brean, Francis Pope, Manuel Dall'Osto, Xavier Querol, Andres Alastuey, Noemi Perez, Tuukka Petäjä, Andreas Massling, Jacøb Klenø Nøjgaard, Claus Nørdstrom, Giorgos Kouvarakis, Stergios Vratolis, Konstantinos Eleftheriadis, Jarkko V. Niemi, Harri Portin, Alfred Wiedensohler, Kay Weinhold, Maik Merkel, Thomas Tuch and Roy M. Harrison

Table S1: Correlation matrices of the meteorological and atmospheric variables.

UKRU	SR	RH	T	WS	P	SO_2	NOx	O_3	OC	SO_4^{2-}	CS
SR	**1.00**	**-0.70**	**0.55**	0.12	0.13	0.05	-0.12	0.45	0.07	0.05	0.00
RH	**-0.70**	**1.00**	**-0.55**	-0.29	-0.10	-0.10	0.20	**-0.59**	0.01	-0.04	0.01
T	**0.55**	**-0.55**	**1.00**	0.12	0.09	-0.01	-0.26	0.37	0.15	0.11	-0.03
WS	0.12	-0.29	0.12	**1.00**	-0.42	0.04	-0.19	0.41	-0.29	-0.12	-0.32
P	0.13	-0.10	0.09	-0.42	**1.00**	-0.07	0.03	-0.09	0.13	0.15	0.23
SO_2	0.05	-0.10	-0.01	0.04	-0.07	**1.00**	0.05	0.06	0.03	0.37	0.31
NOx	-0.12	0.20	-0.26	-0.19	0.03	0.05	**1.00**	**-0.58**	0.48	0.16	**0.54**
O_3	0.45	**-0.59**	0.37	0.41	-0.09	0.06	**-0.58**	**1.00**	-0.30	-0.07	-0.34
OC	0.07	0.01	0.15	-0.29	0.13	0.03	0.48	-0.30	**1.00**	0.37	**0.59**
SO_4^{2-}	0.05	-0.04	0.11	-0.12	0.15	0.37	0.16	-0.07	0.37	**1.00**	0.44
CS	0.00	0.01	-0.03	-0.32	0.23	0.31	**0.54**	-0.34	**0.59**	0.44	**1.00**

UKUB	SR	RH	T	WS	P	SO_2	NOx	O_3	OC	SO_4^{2-}	CS
SR	**1.00**	**-0.70**	**0.53**	0.22	0.07	0.08	-0.15	0.47	0.01	0.02	-0.14
RH	**-0.70**	**1.00**	**-0.56**	-0.22	-0.19	-0.08	0.20	**-0.66**	-0.10	-0.01	0.08
T	**0.53**	**-0.56**	**1.00**	0.21	-0.05	-0.05	-0.38	**0.52**	-0.12	0.01	-0.18
WS	0.22	-0.22	0.21	**1.00**	-0.33	-0.16	-0.44	0.41	-0.43	-0.25	**-0.50**
P	0.07	-0.19	-0.05	-0.33	**1.00**	0.18	0.22	-0.06	0.31	0.25	0.26
SO_2	0.08	-0.08	-0.05	-0.16	0.18	**1.00**	0.44	-0.16	0.29	0.40	0.39
NOx	-0.15	0.20	-0.38	-0.44	0.22	0.44	**1.00**	**-0.56**	**0.57**	0.29	**0.79**
O_3	0.47	**-0.66**	**0.52**	0.41	-0.06	-0.16	**-0.56**	**1.00**	-0.14	-0.14	-0.40
OC	0.01	-0.10	-0.12	-0.43	0.31	0.29	**0.57**	-0.14	**1.00**	0.46	**0.63**
SO_4^{2-}	0.02	-0.01	0.01	-0.25	0.25	0.40	0.29	-0.14	0.46	**1.00**	0.36
CS	-0.14	0.08	-0.18	**-0.50**	0.26	0.39	**0.79**	-0.40	0.63	0.36	**1.00**

UKRO	SR	RH	T	WS	P	SO_2	NOx	O_3	OC	SO_4^{2-}	CS
SR	**1.00**	**-0.68**	**0.51**	0.11	0.15	0.14	0.17	0.16	-0.03	0.03	0.06
RH	**-0.68**	**1.00**	-0.49	-0.14	-0.24	0.01	-0.01	-0.35	0.09	-0.01	0.06
T	**0.51**	-0.49	**1.00**	0.16	0.21	0.18	0.15	-0.02	0.02	0.01	0.15
WS	0.11	-0.14	0.16	**1.00**	-0.34	0.17	0.17	0.08	-0.16	-0.19	-0.05
P	0.15	-0.24	0.21	-0.34	**1.00**	-0.10	-0.05	0.04	0.15	0.08	0.01
SO_2	0.14	0.01	0.18	0.17	-0.10	**1.00**	**0.91**	**-0.65**	0.36	-0.13	**0.72**
NOx	0.17	-0.01	0.15	0.17	-0.05	**0.91**	**1.00**	-0.63	0.34	-0.04	**0.81**
O_3	0.16	-0.35	-0.02	0.08	0.04	**-0.65**	-0.63	**1.00**	-0.43	0.02	**-0.64**
OC	-0.03	0.09	0.02	-0.16	0.15	0.36	0.34	-0.43	**1.00**	0.24	0.47
SO_4^{2-}	0.03	-0.01	0.01	-0.19	0.08	-0.13	-0.04	0.02	0.24	**1.00**	0.18
CS	0.06	0.06	0.15	-0.05	0.01	**0.72**	**0.81**	**-0.64**	0.47	0.18	**1.00**

DENRU	SR	RH	T	WS	SO_2	NOx	O_3	OC	SO_4^{2-}	CS
SR	**1.00**	**-0.56**	0.44	0.07	-0.05	-0.12	0.43	-0.04	-0.09	0.05
RH	**-0.56**	**1.00**	-0.39	0.02	0.02	0.17	**-0.54**	0.01	0.18	-0.08
T	0.44	-0.39	**1.00**	-0.18	-0.09	-0.19	0.37	-0.13	-0.06	0.22
WS	0.07	0.02	-0.18	**1.00**	0.02	-0.28	0.22	-0.09	0.02	-0.32
SO_2	-0.05	0.02	-0.09	0.02	**1.00**	0.18	-0.06	0.48	**0.51**	0.34
NOx	-0.12	0.17	-0.19	-0.28	0.18	**1.00**	**-0.58**	0.34	0.22	**0.54**
O_3	0.43	**-0.54**	0.37	0.22	-0.06	-0.58	**1.00**	-0.17	-0.18	-0.17
OC	-0.04	0.01	-0.13	-0.09	0.48	0.34	-0.17	**1.00**	0.65	**0.58**
SO_4^{2-}	-0.09	0.18	-0.06	0.02	**0.51**	0.22	-0.18	**0.65**	**1.00**	0.41
CS	0.05	-0.08	0.22	-0.32	0.34	**0.54**	-0.17	**0.58**	0.41	**1.00**

DENUB	SR	RH	T	WS	NOx	O_3	CS
SR	**1.00**	**-0.55**	0.45	0.06	-0.02	0.39	0.04
RH	**-0.55**	**1.00**	-0.40	-0.02	0.15	**-0.58**	-0.04
T	0.45	-0.40	**1.00**	-0.13	-0.11	0.40	0.18
WS	0.06	-0.02	-0.13	**1.00**	-0.37	0.26	-0.35
NOx	-0.02	0.15	-0.11	-0.37	**1.00**	-0.59	**0.55**
O_3	0.39	**-0.58**	0.40	0.26	-0.59	**1.00**	-0.23
CS	0.04	-0.04	0.18	-0.35	**0.55**	-0.23	**1.00**

DENRO	SR	RH	T	WS	SO_2	NOx	O_3	OC	CS
SR	**1.00**	**-0.55**	0.30	0.21	0.37	0.29	0.41	0.00	0.26
RH	**-0.55**	**1.00**	-0.45	-0.09	-0.26	-0.17	-0.42	-0.20	-0.29
T	0.30	-0.45	**1.00**	0.04	0.22	0.12	0.25	0.39	0.41
WS	0.21	-0.09	0.04	**1.00**	-0.16	-0.12	0.53	-0.19	-0.12
SO_2	0.37	-0.26	0.22	-0.16	**1.00**	**0.80**	0.01	0.31	**0.62**
NOx	0.29	-0.17	0.12	-0.12	**0.80**	**1.00**	-0.02	0.20	**0.67**
O_3	0.41	-0.42	0.25	0.53	0.01	-0.02	**1.00**	-0.01	0.05
OC	0.00	-0.20	0.39	-0.19	0.31	0.20	-0.01	**1.00**	0.36
CS	0.26	-0.29	0.41	-0.12	**0.62**	**0.67**	0.05	0.36	**1.00**

GERRU	SR	RH	T	WS	P	OC	SO_4^{2-}	CS
SR	**1.00**	**-0.70**	**0.55**	0.20	0.13	-0.07	-0.07	0.02
RH	**-0.70**	**1.00**	**-0.61**	-0.31	-0.12	0.08	0.10	-0.01
T	**0.55**	**-0.61**	**1.00**	0.01	0.11	-0.34	-0.29	-0.11
WS	0.20	-0.31	0.01	**1.00**	-0.24	-0.14	-0.09	-0.35
P	0.13	-0.12	0.11	-0.24	**1.00**	0.11	0.13	0.23
OC	-0.07	0.08	-0.34	-0.14	0.11	**1.00**	0.83	**0.65**
SO_4^{2-}	-0.07	0.10	-0.29	-0.09	0.13	0.83	**1.00**	**0.52**
CS	0.02	-0.01	-0.11	-0.35	0.23	**0.65**	**0.52**	**1.00**

GERUB	SR	RH	T	WS	P	CS
SR	**1.00**	**-0.72**	**0.55**	0.25	0.16	-0.06
RH	**-0.72**	**1.00**	**-0.61**	-0.32	-0.17	0.10
T	**0.55**	**-0.61**	**1.00**	0.05	0.11	-0.20
WS	0.25	-0.32	0.05	**1.00**	-0.21	-0.31
P	0.16	-0.17	0.11	-0.21	**1.00**	0.21
CS	-0.06	0.10	-0.20	-0.31	0.21	**1.00**

GERRO	SR	RH	T	WS	P	CS
SR	**1.00**	**-0.65**	**0.50**	0.19	0.14	0.05
RH	**-0.65**	**1.00**	**-0.72**	-0.14	-0.16	0.03
T	**0.50**	**-0.72**	**1.00**	-0.03	0.16	-0.14
WS	0.19	-0.14	-0.03	**1.00**	-0.15	-0.34
P	0.14	-0.16	0.16	-0.15	**1.00**	0.19
CS	0.05	0.03	-0.14	-0.34	0.19	**1.00**

FINRU	SR	RH	T	WS	P	SO_2	NOx	O_3	OM	SO_4^{2-}	CS
SR	**1.00**	**-0.67**	**0.50**	0.11	0.11	0.00	-0.24	0.30	-0.05	-0.14	0.09
RH	**-0.67**	**1.00**	**-0.56**	-0.21	-0.27	-0.12	0.31	**-0.55**	0.00	0.17	-0.20
T	**0.50**	**-0.56**	**1.00**	0.01	0.03	-0.20	-0.28	-0.14	0.27	-0.20	0.28
WS	0.11	-0.21	0.01	**1.00**	0.17	0.11	0.13	0.35	-0.20	-0.20	-0.07
P	0.11	-0.27	0.03	0.17	**1.00**	0.00	-0.08	-0.08	0.34	0.12	0.19
SO_2	0.00	-0.12	-0.20	0.11	0.00	**1.00**	0.18	0.09	NA	NA	0.21
NOx	-0.24	0.31	-0.28	0.13	-0.08	0.18	**1.00**	-0.24	NA	NA	0.12
O_3	0.30	**-0.55**	-0.14	0.35	-0.08	0.09	-0.24	**1.00**	NA	NA	0.02
OM	-0.05	0.00	0.27	-0.20	0.34	NA	NA	NA	**1.00**	0.43	0.61
SO_4^{2-}	-0.14	0.17	-0.20	-0.20	0.12	NA	NA	NA	0.43	**1.00**	0.18
CS	0.09	-0.20	0.28	-0.07	0.19	0.21	0.12	0.02	0.61	0.18	**1.00**

FINUB	SR	RH	T	WS	P	CS
SR	**1.00**	**-0.54**	0.45	0.05	0.09	0.00
RH	**-0.54**	**1.00**	-0.35	0.04	-0.23	-0.01
T	0.45	-0.35	**1.00**	-0.02	-0.01	0.00
WS	0.05	0.04	-0.02	**1.00**	-0.26	0.00
P	0.09	-0.23	-0.01	-0.26	**1.00**	0.00
CS	0.00	-0.01	0.00	0.00	0.00	**1.00**

FINRO	SR	RH	T	WS	P	NOx	O_3	CS
SR	**1.00**	**-0.58**	0.47	0.03	0.08	0.05	0.20	0.09
RH	**-0.58**	**1.00**	-0.29	-0.05	-0.24	0.02	-0.34	0.01
T	0.47	-0.29	**1.00**	-0.07	-0.02	-0.08	0.18	0.05
WS	0.03	-0.05	-0.07	**1.00**	-0.25	-0.29	0.41	-0.32
P	0.08	-0.24	-0.02	-0.25	**1.00**	0.10	-0.09	0.13
NOx	0.05	0.02	-0.08	-0.29	0.10	**1.00**	-0.61	**0.75**
O_3	0.20	-0.34	0.18	0.41	-0.09	**-0.61**	**1.00**	-0.51
CS	0.09	0.01	0.05	-0.32	0.13	**0.75**	-0.51	**1.00**

SPARU	SR	RH	T	WS	P	SO_2	NO2	O_3	CS
SR	**1.00**	**-0.45**	**0.50**	0.38	0.09	0.10	-0.02	0.34	0.34
RH	**-0.45**	**1.00**	-0.29	-0.20	-0.24	-0.08	0.05	-0.48	-0.06
T	**0.50**	-0.29	**1.00**	0.16	0.24	0.07	-0.05	0.54	0.47
WS	0.38	-0.20	0.16	**1.00**	-0.16	0.13	-0.02	0.25	0.10
P	0.09	-0.24	0.24	-0.16	**1.00**	-0.15	0.12	0.09	0.14
SO_2	0.10	-0.08	0.07	0.13	-0.15	**1.00**	0.14	0.19	0.25
NO_2	-0.02	0.05	-0.05	-0.02	0.12	0.14	**1.00**	-0.02	0.42
O_3	0.34	-0.48	0.54	0.25	0.09	0.19	-0.02	**1.00**	0.44
CS	0.34	-0.06	0.47	0.10	0.14	0.25	0.42	0.44	**1.00**

SPAUB	SR	RH	T	WS	P	SO_2	NO2	O_3	CS
SR	**1.00**	-0.43	0.44	0.18	0.03	0.25	-0.09	0.32	0.00
RH	-0.43	**1.00**	-0.04	-0.23	-0.16	-0.12	0.10	-0.23	0.16
T	0.44	-0.04	**1.00**	-0.14	0.11	0.35	-0.07	0.38	0.11
WS	0.18	-0.23	-0.14	**1.00**	-0.26	-0.08	-0.34	0.32	-0.43
P	0.03	-0.16	0.11	-0.26	**1.00**	0.13	0.15	-0.10	0.10
SO_2	0.25	-0.12	0.35	-0.08	0.13	**1.00**	0.20	0.13	0.16
NO_2	-0.09	0.10	-0.07	-0.34	0.15	0.20	**1.00**	**-0.66**	**0.59**
O_3	0.32	-0.23	0.38	0.32	-0.10	0.13	**-0.66**	**1.00**	-0.35
CS	0.00	0.16	0.11	-0.43	0.10	0.16	**0.59**	-0.35	**1.00**

GRERU	SR	RH	T	WS	P	NO_2	O_3	OC	CS
SR	**1.00**	-0.30	0.33	0.02	-0.11	0.36	0.19	0.09	0.18
RH	-0.30	**1.00**	-0.25	-0.27	0.20	-0.20	-0.12	-0.06	0.08
T	0.33	-0.25	**1.00**	0.00	**-0.53**	0.02	**0.54**	0.35	0.46
WS	0.02	-0.27	0.00	**1.00**	-0.21	-0.03	0.15	0.14	0.11
P	-0.11	0.20	**-0.53**	-0.21	**1.00**	-0.10	-0.35	-0.24	-0.09
NO_2	0.36	-0.20	0.02	-0.03	-0.10	**1.00**	0.00	0.01	-0.02
O_3	0.19	-0.12	**0.54**	0.15	-0.35	0.00	**1.00**	**0.50**	**0.62**
OC	0.09	-0.06	0.35	0.14	-0.24	0.01	**0.50**	**1.00**	0.47
CS	0.18	0.08	0.46	0.11	-0.09	-0.02	**0.62**	0.47	**1.00**

GREUB	SR	RH	T	WS	P	CS
SR	**1.00**	**-0.55**	0.48	0.47	-0.15	0.04
RH	**-0.55**	**1.00**	**-0.67**	-0.30	0.18	-0.07
T	0.48	**-0.67**	**1.00**	0.20	**-0.51**	-0.06
WS	0.47	-0.30	0.20	**1.00**	-0.15	-0.21
P	-0.15	0.18	**-0.51**	-0.15	**1.00**	0.16
CS	0.04	-0.07	-0.06	-0.21	0.16	**1.00**

Table S2: ~~Slopes~~ Gradients and R^2 for the ~~relation~~relationship between VOCs and NPF events variables.

UKRU	a_N	R^2	a_{GR}	R^2	a_J	R^2
benzene	-3.37E-01	0.88	1.24E+00	0.16	-5.99E-03	0.07
ethane	-5.42E-02	0.88	-4.79E-01	0.26	-4.61E-03	0.77
ethene	-1.65E-01	0.83	2.64E+00	0.60	-1.70E-02	0.57
ethylbenzene	-7.01E-01	0.79	6.78E+00	0.41	-5.77E-02	0.63
iso.butane	-2.06E-01	0.75	1.41E+00	0.70	-5.62E-03	0.11
iso.octane	-5.23E-01	0.45	1.09E+01	0.80	9.32E-03	0.11
iso.pentane	-1.96E-01	0.74	2.36E+00	0.58	2.36E-02	0.72
m.p.xylene	-2.92E-01	0.86	3.21E+00	0.68	-1.98E-02	0.35
n.butane	-1.67E-01	0.79	1.04E+00	0.44	1.43E-02	0.11
n.heptane	-9.63E-01	0.80	1.36E+01	0.73	-1.46E-02	0.13
n.hexane	-1.21E+00	0.84	6.82E+00	0.67	1.33E-02	0.11
n.pentane	-3.71E-01	0.67	3.49E+00	0.64	-8.97E-03	0.06
o.xylene	-5.34E-01	0.71	8.59E+00	0.86	-1.81E-02	0.42
propane	-7.77E-02	0.76	1.97E-01	0.24	-4.28E-03	0.49
propene	-1.50E-01	0.67	-4.01E-01	0.02	6.20E-03	0.08
toluene	-1.48E-01	0.79	1.88E+00	0.81	-9.26E-03	0.43
1.2.4.trimethylbenzene	-4.36E-01	0.46	5.38E+00	0.29	-4.78E-02	0.68
1.3.butadiene	-1.17E+00	0.40	-1.68E+01	0.71	-7.55E-02	0.66
1.butene	-9.39E-02	0.03	-4.77E+00	0.25	-1.99E-02	0.07
2.methylpentane	-7.66E-01	0.77	8.49E+00	0.57	4.56E-02	0.64

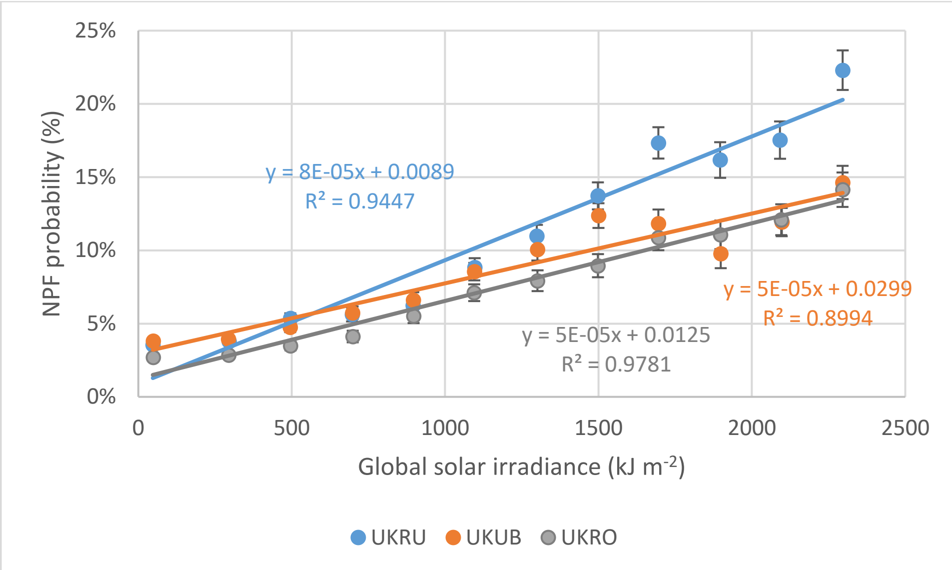
FINRU	a_N	R^2	a_{GR}	R^2	a_J	R^2
Acetaldehyde	-1.04E-01	0.05	-2.16E+00	0.69	1.23E-02	0.07
Aceticacid	1.19E-01	0.13	5.88E+00	0.77	3.33E-02	0.21
Acetolnitrite	-1.02E+00	0.13	1.33E+01	0.59	6.62E-02	0.18
Acetone	-4.63E-02	0.08	3.38E+00	0.74	5.85E-03	0.19
Benzene	-4.46E-01	0.11	-2.02E+01	0.83	-4.13E-02	0.02
Ethanol	4.04E-02	0.06	1.31E+00	0.10	4.77E-03	0.10
Isoprene	-3.17E+00	0.51	1.59E+01	0.87	-1.50E+00	0.31
MEK	6.45E-01	0.34	-8.03E+00	0.36	2.95E-02	0.03
Methacrolein.MVK	-5.15E+00	0.45	3.75E+01	0.66	2.92E-02	0.02
Methanol	1.68E-02	0.05	1.48E+00	0.75	3.48E-03	0.12
Monoterpenes	-1.17E-01	0.38	2.84E+00	0.56	1.11E-03	0.00
Toluene	-4.25E+00	0.59	2.88E+01	0.80	-5.55E-02	0.13

~~**UKRO**~~	~~a_N~~	~~R^2~~	~~a_{GR}~~	~~R^2~~	~~a_J~~	~~R^2~~
~~benzene~~	~~-1.03E-01~~	~~0.68~~	~~1.36E+00~~	~~0.80~~	~~4.42E-02~~	~~0.78~~
~~cis.2.butene~~	~~-1.93E-01~~	~~0.59~~	~~8.33E-01~~	~~0.02~~	~~1.70E-01~~	~~0.48~~
~~ethane~~	~~-2.45E-02~~	~~0.53~~	~~2.99E-02~~	~~0.06~~	~~2.28E-03~~	~~0.14~~
~~ethene~~	~~-4.59E-02~~	~~0.69~~	~~5.74E-01~~	~~0.83~~	~~2.50E-02~~	~~0.97~~
~~ethylbenzene~~	~~-7.13E-02~~	~~0.87~~	~~1.22E+00~~	~~0.77~~	~~3.59E-02~~	~~0.41~~
~~ethyne~~	~~-8.43E-02~~	~~0.74~~	~~1.23E+00~~	~~0.75~~	~~4.22E-02~~	~~0.64~~
~~iso.butane~~	~~-4.70E-02~~	~~0.55~~	~~6.07E-01~~	~~0.78~~	~~1.79E-02~~	~~0.92~~
~~iso.octane~~	~~-7.53E-02~~	~~0.80~~	~~2.14E+00~~	~~0.78~~	~~7.35E-02~~	~~0.67~~
~~iso.pentane~~	~~-1.10E-02~~	~~0.70~~	~~2.64E-01~~	~~0.72~~	~~1.00E-02~~	~~0.82~~
~~isoprene~~	~~-2.75E-02~~	~~0.07~~	~~4.34E-01~~	~~0.01~~	~~2.24E-03~~	~~0.00~~
~~m.p.xylene~~	~~-1.99E-02~~	~~0.91~~	~~3.81E-01~~	~~0.56~~	~~1.47E-02~~	~~0.64~~
~~n.butane~~	~~-2.17E-02~~	~~0.61~~	~~2.58E-01~~	~~0.78~~	~~4.07E-03~~	~~0.17~~
~~n.heptane~~	~~-1.53E-01~~	~~0.75~~	~~2.51E+00~~	~~0.80~~	~~1.15E-01~~	~~0.82~~
~~n.hexane~~	~~-1.10E-01~~	~~0.63~~	~~2.86E+00~~	~~0.75~~	~~8.28E-02~~	~~0.74~~
~~n.octane~~	~~-2.64E-01~~	~~0.55~~	~~7.06E+00~~	~~0.72~~	~~2.73E-01~~	~~0.98~~
~~n.pentane~~	~~-5.44E-02~~	~~0.53~~	~~1.03E+00~~	~~0.80~~	~~2.99E-02~~	~~0.86~~
~~o.xylene~~	~~-4.69E-02~~	~~0.88~~	~~9.58E-01~~	~~0.65~~	~~4.37E-02~~	~~0.86~~
~~propane~~	~~-3.16E-02~~	~~0.68~~	~~1.95E-01~~	~~0.32~~	~~1.01E-02~~	~~0.90~~
~~propene~~	~~-6.69E-02~~	~~0.87~~	~~1.15E+00~~	~~0.85~~	~~3.55E-02~~	~~0.78~~

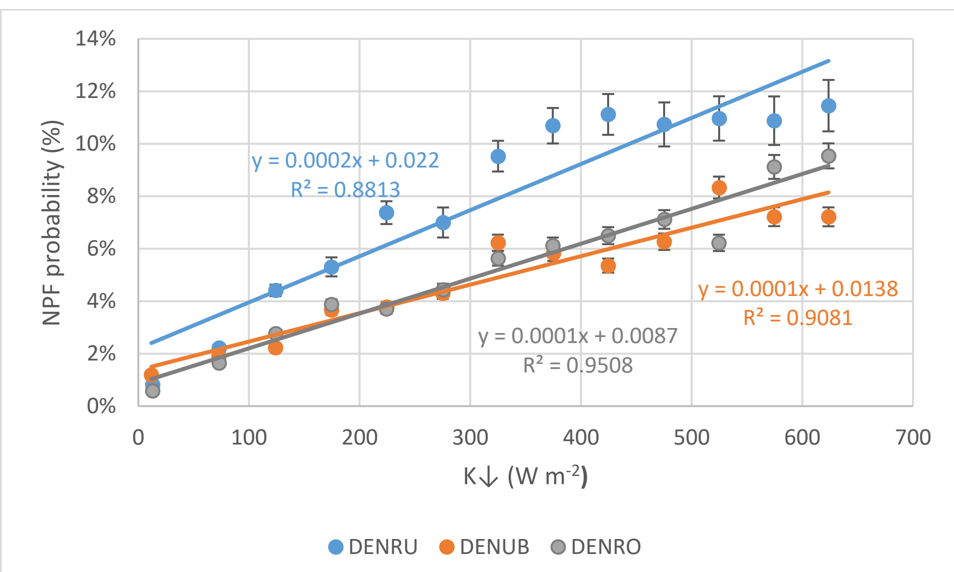
toluene	-1.22E-02	0.84	2.76E-01	0.74	1.15E-02	0.85
trans.2.butene	-2.63E-01	0.72	3.16E+00	0.35	1.41E-01	0.60
trans.2.pentene	-1.67E-01	0.73	2.69E+00	0.31	1.16E-01	0.52
1.2.3.trimethylbenzene	-1.45E-01	0.78	3.31E+00	0.66	1.28E-01	0.81
1.2.4.trimethylbenzene	-4.89E-02	0.85	7.64E-01	0.43	3.26E-02	0.46
1.3.5.trimethylbenzene	-8.62E-02	0.77	1.56E+00	0.67	6.65E-02	0.64
1.3.butadiene	-1.78E-01	0.81	2.99E+00	0.44	9.04E-02	0.26
1.butene	-2.18E-01	0.38	2.51E+00	0.25	1.24E-01	0.64
1.pentene	-2.43E-01	0.52	6.92E+00	0.37	3.00E-01	0.82
2.methylpentane	-3.73E-02	0.68	8.57E-01	0.67	2.83E-02	0.80

UKRO	a_N	R^2	a_{GR}	R^2	a_J	R^2
benzene	-1.03E-01	0.68	1.36E+00	0.80	4.42E-02	0.78
cis.2.butene	-1.93E-01	0.59	8.33E-01	0.02	1.70E-01	0.48
ethane	-2.45E-02	0.53	2.99E-02	0.06	2.28E-03	0.14
ethene	-4.59E-02	0.69	5.74E-01	0.83	2.50E-02	0.97
ethylbenzene	-7.13E-02	0.87	1.22E+00	0.77	3.59E-02	0.41
ethyne	-8.43E-02	0.74	1.23E+00	0.75	4.22E-02	0.64
iso.butane	-4.70E-02	0.55	6.07E-01	0.78	1.79E-02	0.92
iso.octane	-7.53E-02	0.80	2.14E+00	0.78	7.35E-02	0.67
iso.pentane	-1.10E-02	0.70	2.64E-01	0.72	1.00E-02	0.82
isoprene	-2.75E-02	0.07	4.34E-01	0.01	2.24E-03	0.00
m.p.xylene	-1.99E-02	0.91	3.81E-01	0.56	1.47E-02	0.64
n.butane	-2.17E-02	0.61	2.58E-01	0.78	4.07E-03	0.17
n.heptane	-1.53E-01	0.75	2.51E+00	0.80	1.15E-01	0.82
n.hexane	-1.10E-01	0.63	2.86E+00	0.75	8.28E-02	0.74
n.octane	-2.64E-01	0.55	7.06E+00	0.72	2.73E-01	0.98
n.pentane	-5.44E-02	0.53	1.03E+00	0.80	2.99E-02	0.86
o.xylene	-4.69E-02	0.88	9.58E-01	0.65	4.37E-02	0.86
propane	-3.16E-02	0.68	1.95E-01	0.32	1.01E-02	0.90
propene	-6.69E-02	0.87	1.15E+00	0.85	3.55E-02	0.78
toluene	-1.22E-02	0.84	2.76E-01	0.74	1.15E-02	0.85
trans.2.butene	-2.63E-01	0.72	3.16E+00	0.35	1.41E-01	0.60
trans.2.pentene	-1.67E-01	0.73	2.69E+00	0.31	1.16E-01	0.52
1.2.3.trimethylbenzene	-1.45E-01	0.78	3.31E+00	0.66	1.28E-01	0.81
1.2.4.trimethylbenzene	-4.89E-02	0.85	7.64E-01	0.43	3.26E-02	0.46
1.3.5.trimethylbenzene	-8.62E-02	0.77	1.56E+00	0.67	6.65E-02	0.64
1.3.butadiene	-1.78E-01	0.81	2.99E+00	0.44	9.04E-02	0.26
1.butene	-2.18E-01	0.38	2.51E+00	0.25	1.24E-01	0.64
1.pentene	-2.43E-01	0.52	6.92E+00	0.37	3.00E-01	0.82
2.methylpentane	-3.73E-02	0.68	8.57E-01	0.67	2.83E-02	0.80

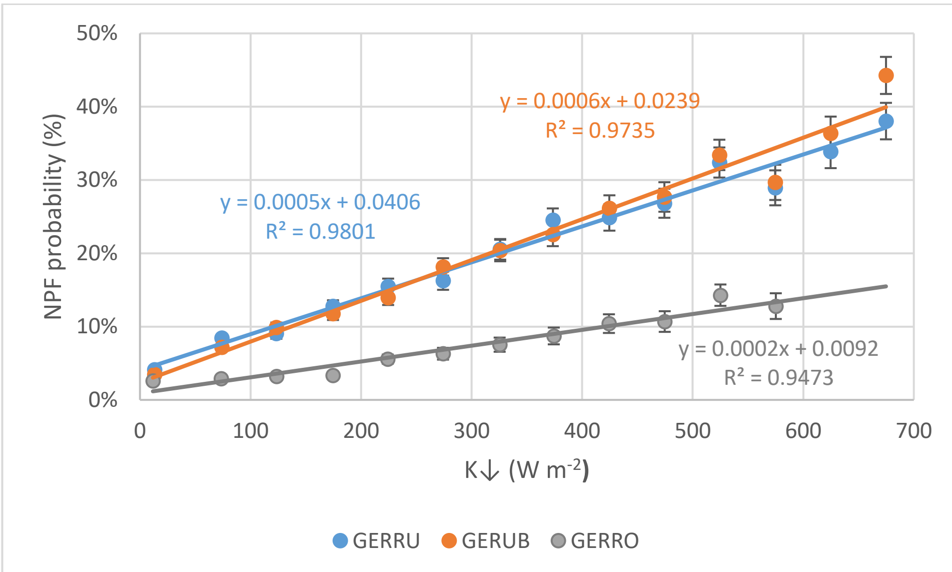
Figure S1: Relationship of solar radiation with NPF variables.



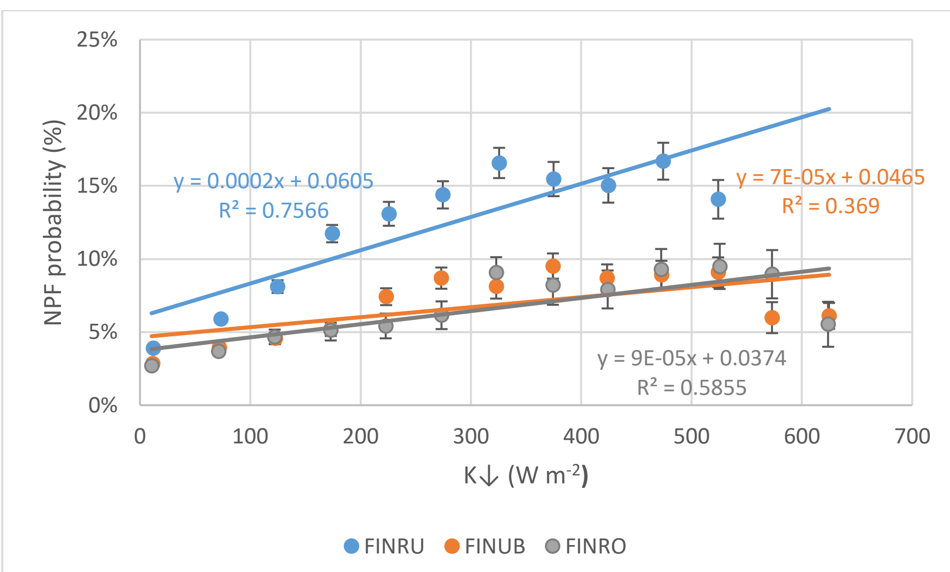
(a)



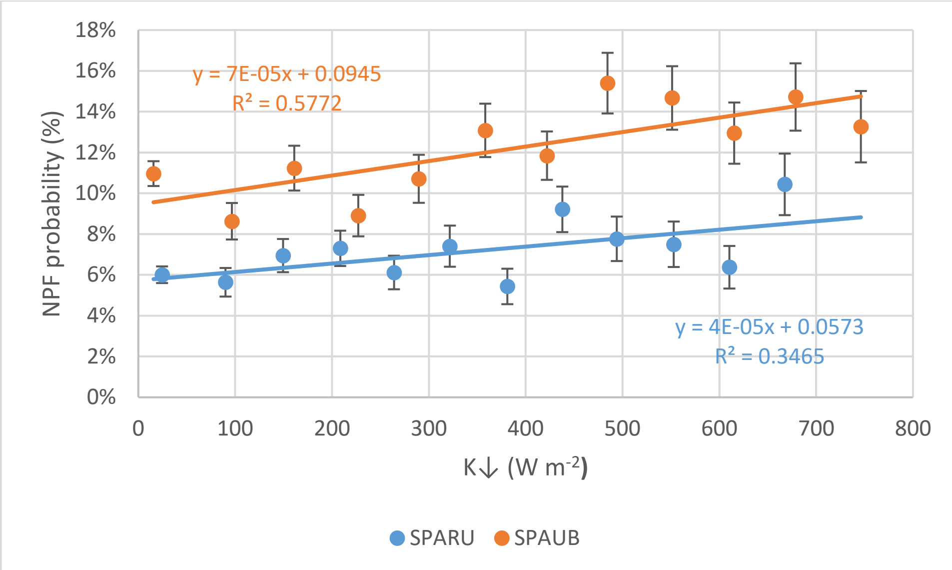
(b)


NPF probability (%)
50%
40%
30%
20%
10%
0%
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0006x + 0.0239
R² = 0.9735
y = 0.0005x + 0.0406
R² = 0.9801
y = 0.0002x + 0.0092
R² = 0.9473
GERRU
GERUB
GERRO

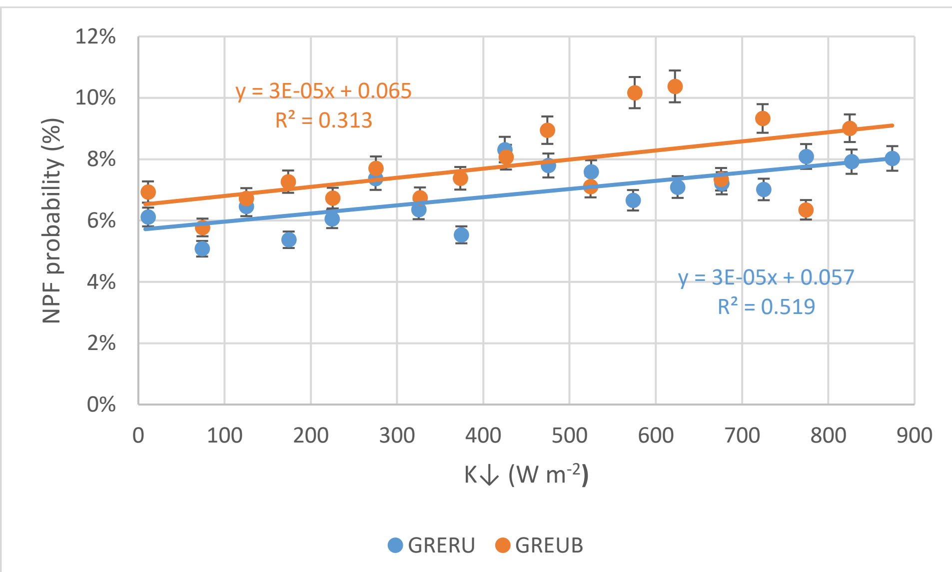
(c)


NPF probability (%)
25%
20%
15%
10%
5%
0%
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0002x + 0.0605
R² = 0.7566
y = 7E-05x + 0.0465
R² = 0.369
y = 9E-05x + 0.0374
R² = 0.5855
FINRU
FINUB
FINRO

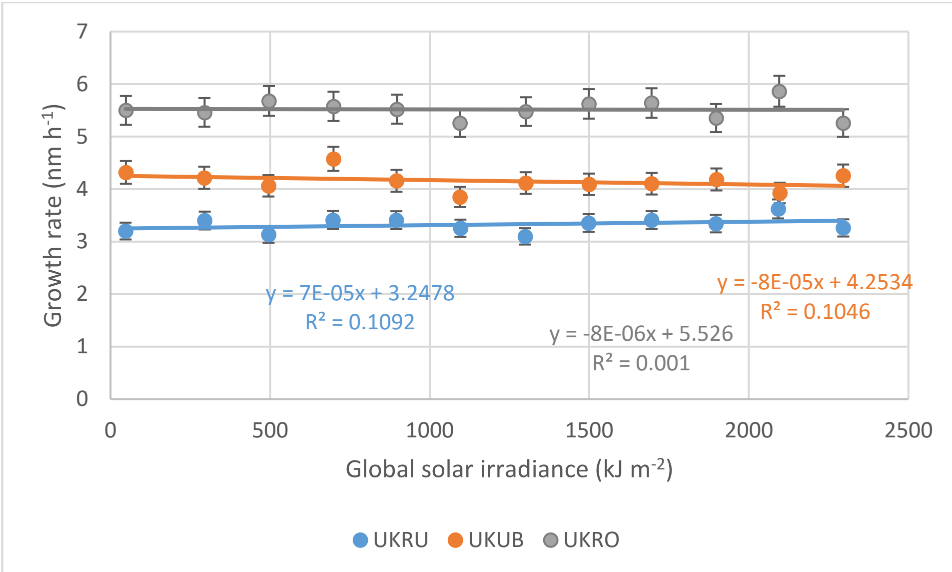
(d)


y = 7E-05x + 0.0945
R² = 0.5772
y = 4E-05x + 0.0573
R² = 0.3465
NPF probability (%)
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
100
200
300
400
500
600
700
800
K↓ (W m-2)
SPARU
SPAUB

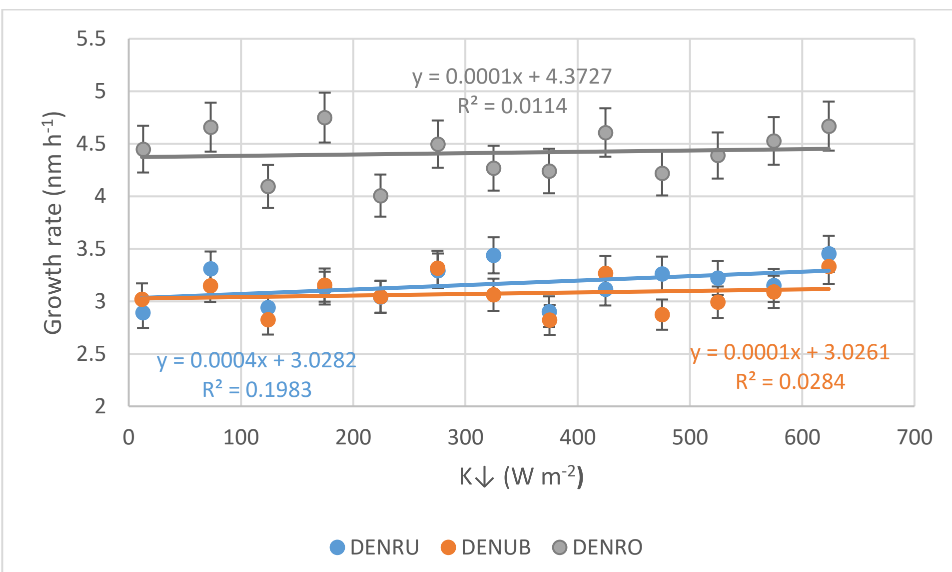
(e)


y = 3E-05x + 0.065
R² = 0.313
y = 3E-05x + 0.057
R² = 0.519
NPF probability (%)
12%
10%
8%
6%
4%
2%
0%
0
100
200
300
400
500
600
700
800
900
K↓ (W m-2)
GRERU
GREUB

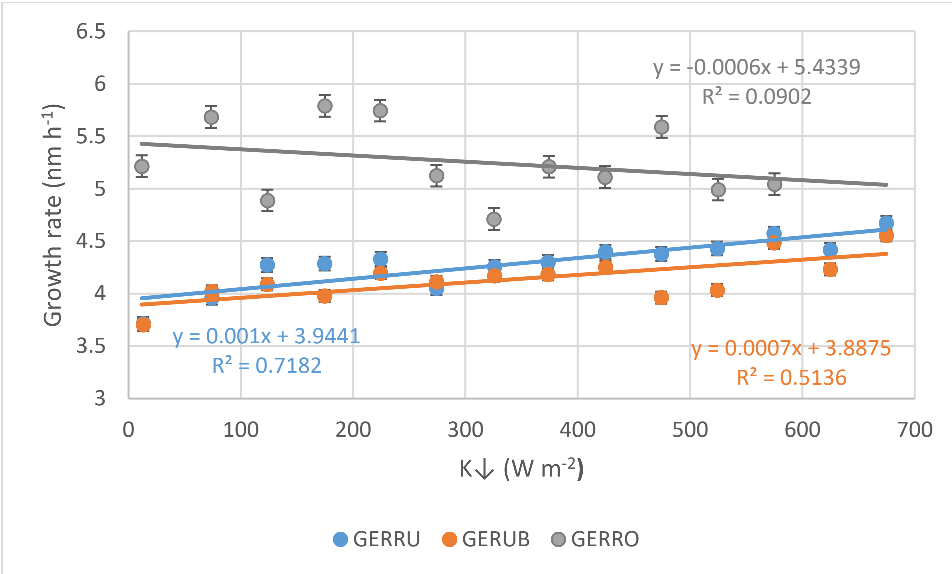
(f)


Growth rate (nm h-1)
Global solar irradiance (kJ m-2)
y = 7E-05x + 3.2478
R² = 0.1092
y = -8E-06x + 5.526
R² = 0.001
y = -8E-05x + 4.2534
R² = 0.1046
UKRU UKUB UKRO

(g)

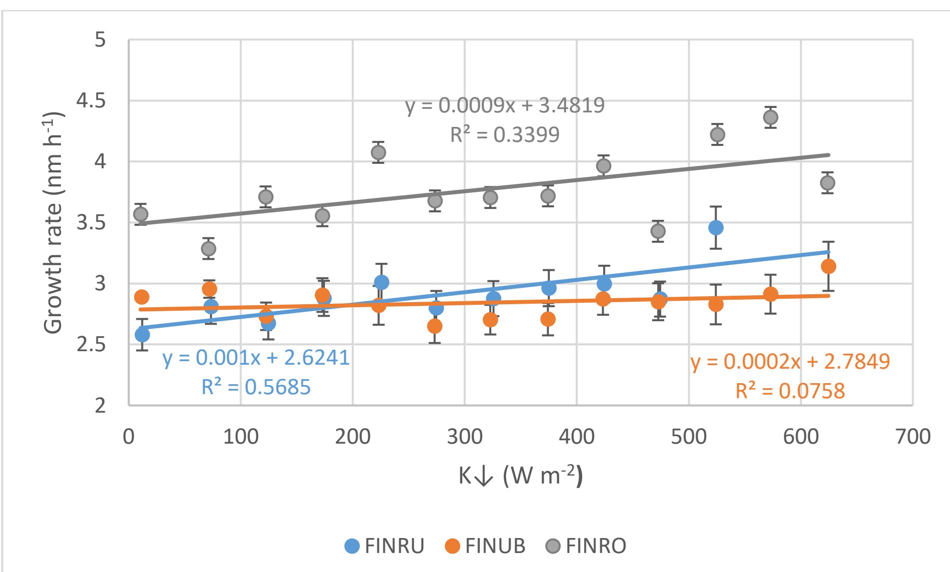

Growth rate (nm h-1)
K↓ (W m-2)
y = 0.0001x + 4.3727
R² = 0.0114
y = 0.0004x + 3.0282
R² = 0.1983
y = 0.0001x + 3.0261
R² = 0.0284
DENRU DENUB DENRO

(h)



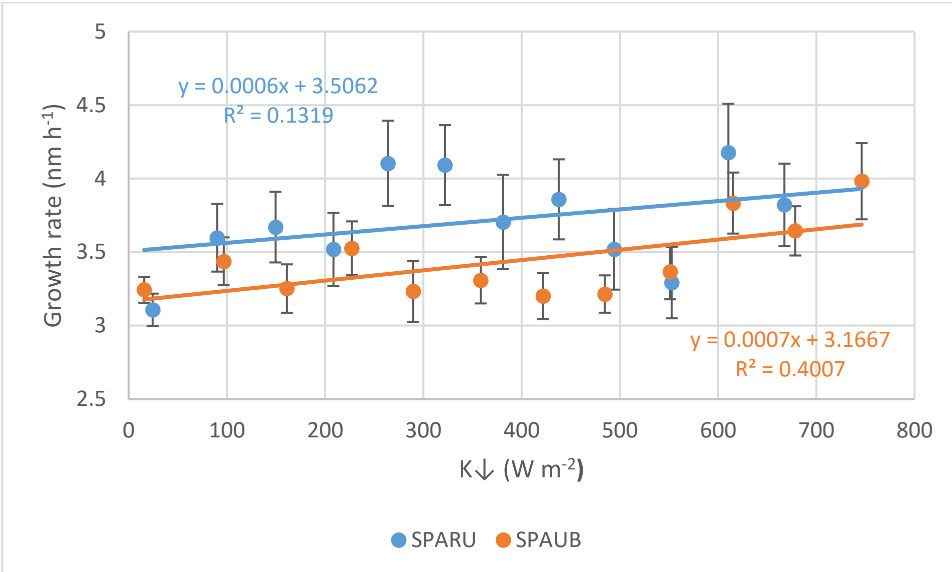
y = -0.0006x + 5.4339
R² = 0.0902
y = 0.001x + 3.9441
R² = 0.7182
y = 0.0007x + 3.8875
R² = 0.5136
Growth rate (nm h-1)
K↓ (W m-2)
GERRU
GERUB
GERRO

(i)

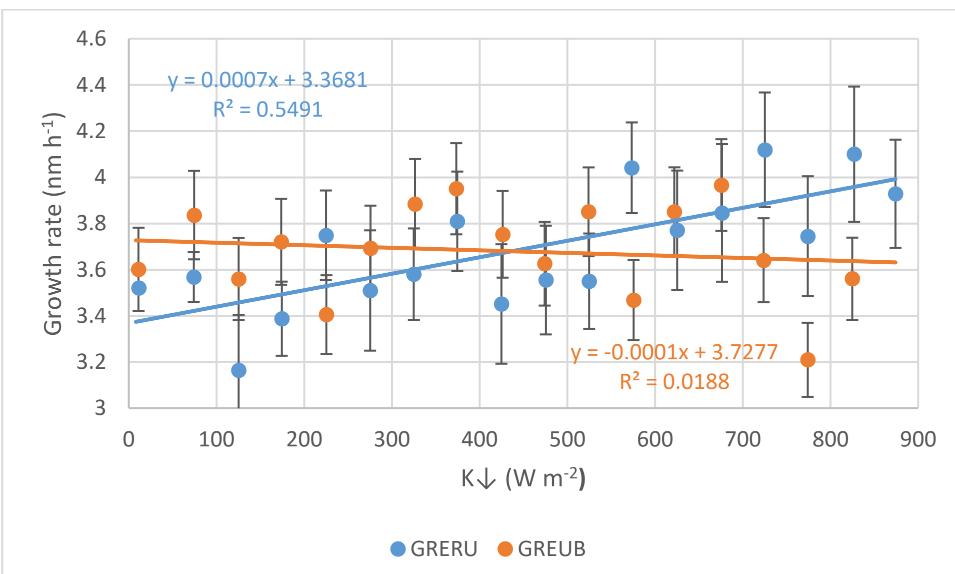


y = 0.0009x + 3.4819
R² = 0.3399
y = 0.001x + 2.6241
R² = 0.5685
y = 0.0002x + 2.7849
R² = 0.0758
Growth rate (nm h-1)
K↓ (W m-2)
FINRU
FINUB
FINRO

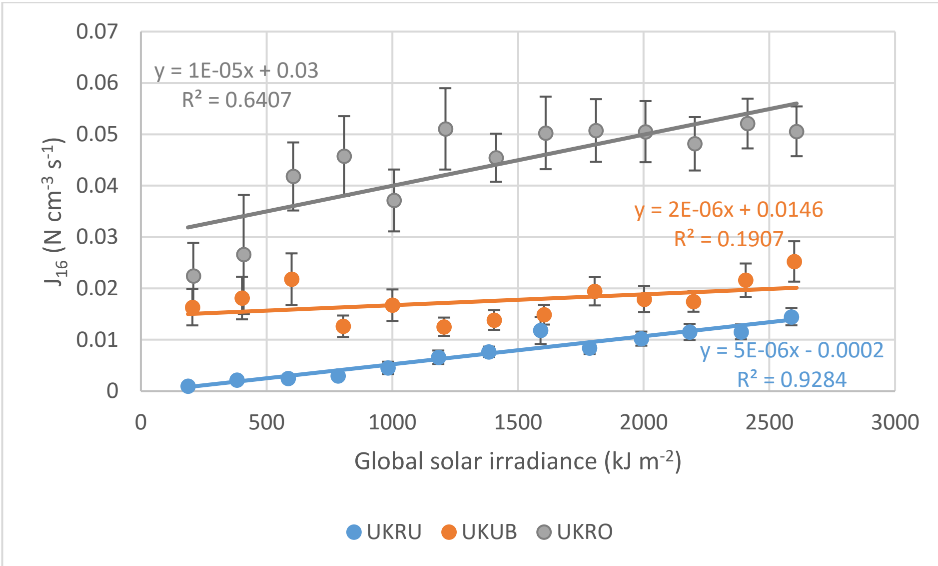
(j)


y = 0.0006x + 3.5062
R² = 0.1319
y = 0.0007x + 3.1667
R² = 0.4007
Growth rate (nm h-1)
5
4.5
4
3.5
3
2.5
0
100
200
300
400
500
600
700
800
K↓ (W m-2)
SPARU
SPAUB

(k)

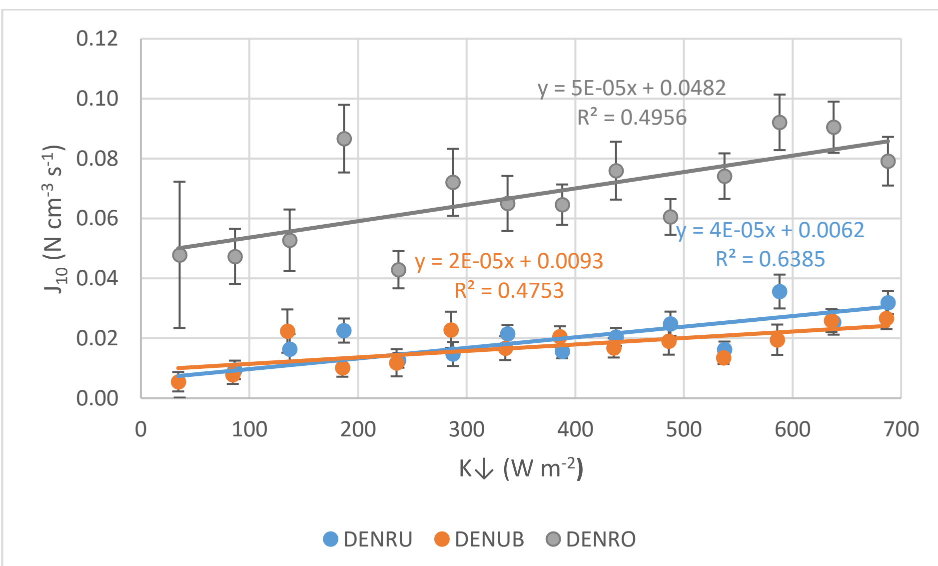

y = 0.0007x + 3.3681
R² = 0.5491
y = -0.0001x + 3.7277
R² = 0.0188
Growth rate (nm h-1)
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
0
100
200
300
400
500
600
700
800
900
K↓ (W m-2)
GRERU
GREUB

(l)



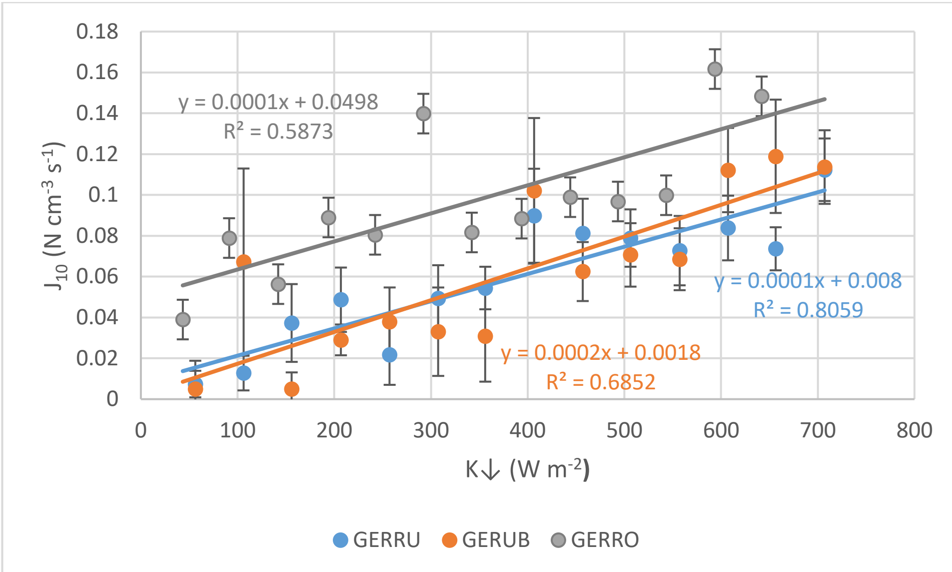
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
J16 (N cm-3 s-1)
Global solar irradiance (kJ m-2)
y = 1E-05x + 0.03
R² = 0.6407
y = 2E-06x + 0.0146
R² = 0.1907
y = 5E-06x - 0.0002
R² = 0.9284
UKRU
UKUB
UKRO

(m)



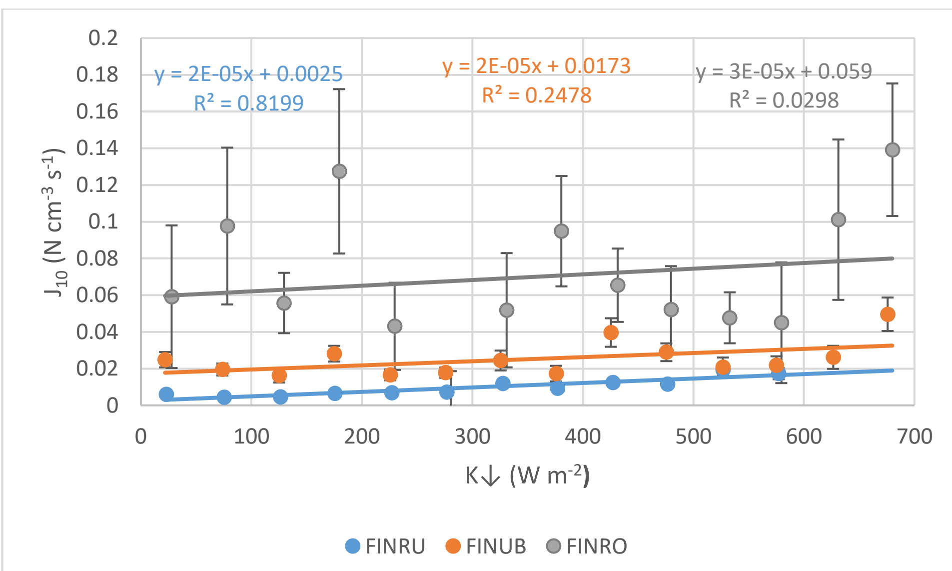
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
100
200
300
400
500
600
700
J10 (N cm-3 s-1)
K↓ (W m-2)
y = 5E-05x + 0.0482
R² = 0.4956
y = 4E-05x + 0.0062
R² = 0.6385
y = 2E-05x + 0.0093
R² = 0.4753
DENRU
DENUB
DENRO

(n)



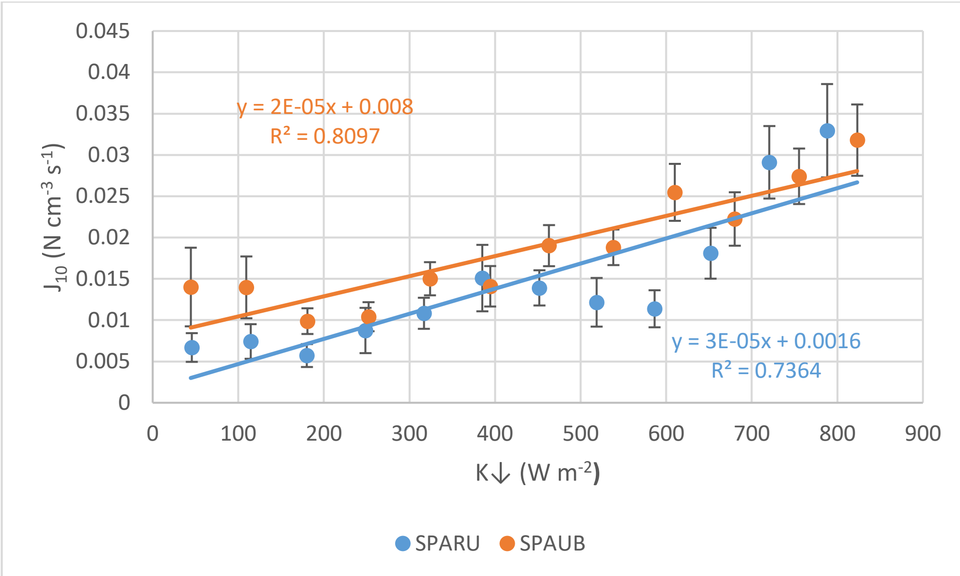
y = 0.0001x + 0.0498
R² = 0.5873
y = 0.0001x + 0.008
R² = 0.8059
y = 0.0002x + 0.0018
R² = 0.6852
J10 (N cm-3 s-1)
K↓ (W m-2)
GERRU
GERUB
GERRO

(o)

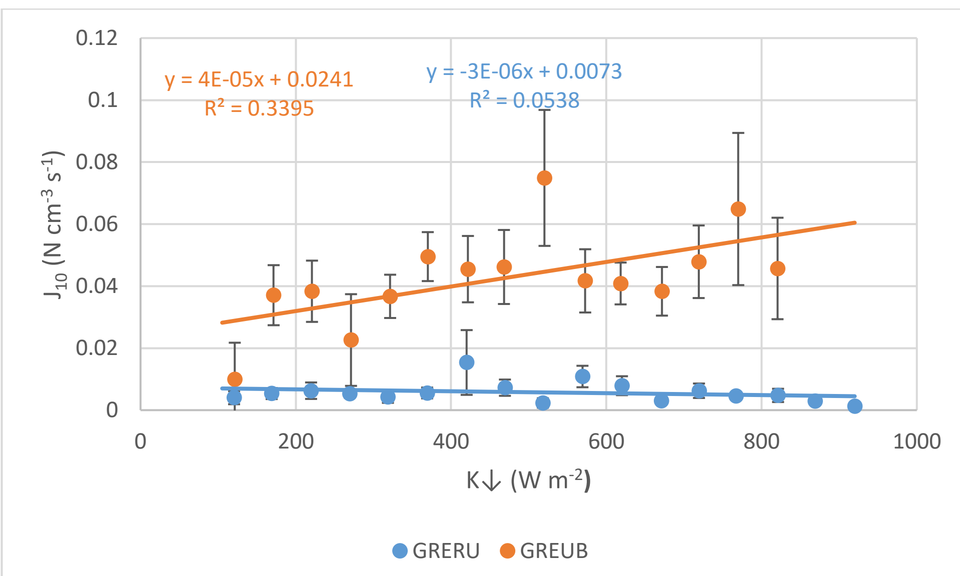


y = 2E-05x + 0.0025
R² = 0.8199
y = 2E-05x + 0.0173
R² = 0.2478
y = 3E-05x + 0.059
R² = 0.0298
J10 (N cm-3 s-1)
K↓ (W m-2)
FINRU
FINUB
FINRO

(p)

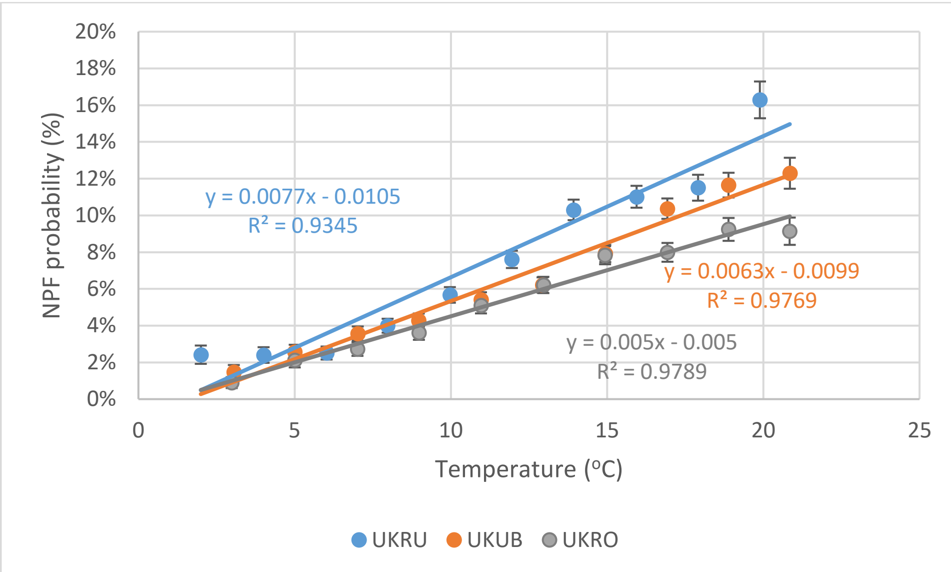

0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
J10 (N cm-3 s-1)
y = 2E-05x + 0.008
R² = 0.8097
y = 3E-05x + 0.0016
R² = 0.7364
0
100
200
300
400
500
600
700
800
900
K↓ (W m-2)
SPARU
SPAUB

(q)

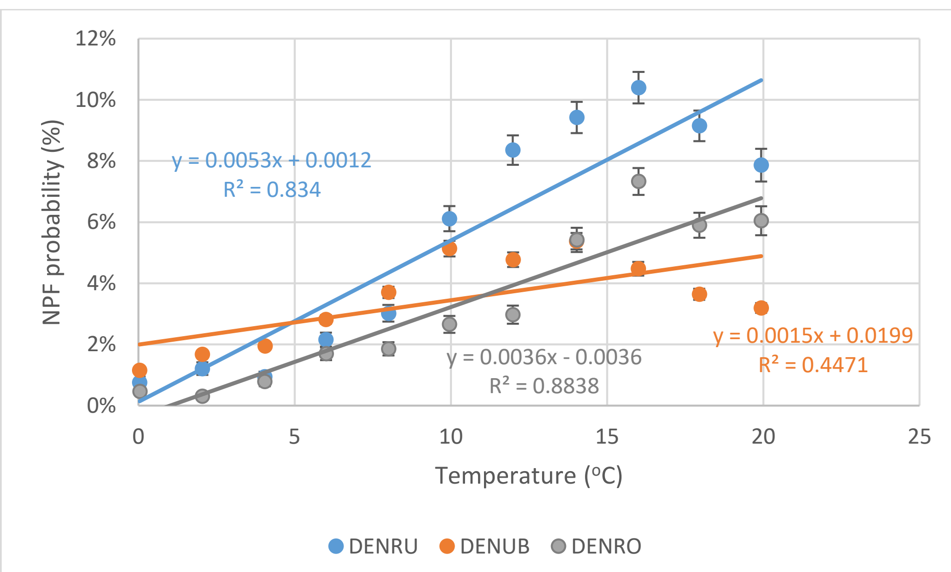

0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
y = 4E-05x + 0.0241
R² = 0.3395
y = -3E-06x + 0.0073
R² = 0.0538
0
200
400
600
800
1000
K↓ (W m-2)
GRERU
GREUB

(r)

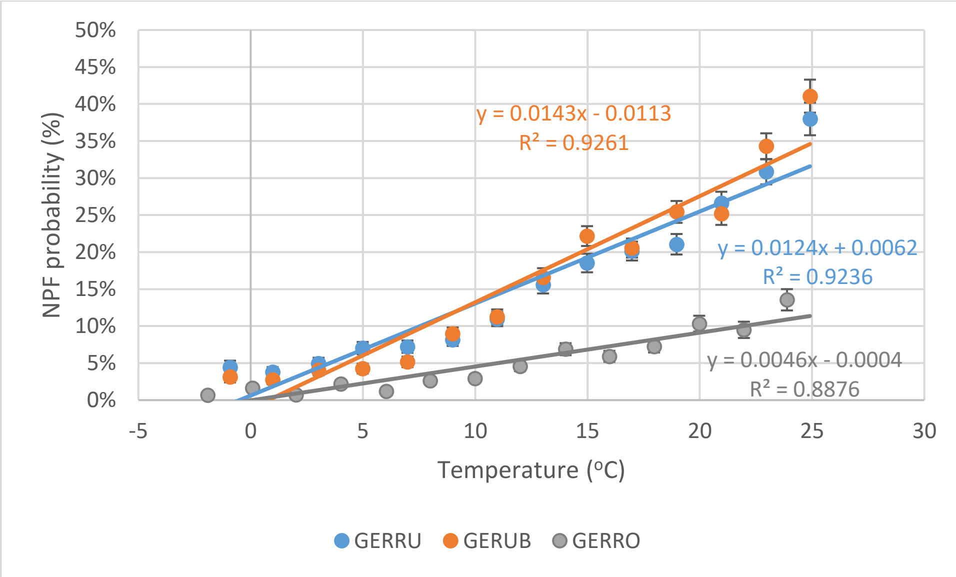
Figure S2: Relationship of temperature with NPF variables.



(a)

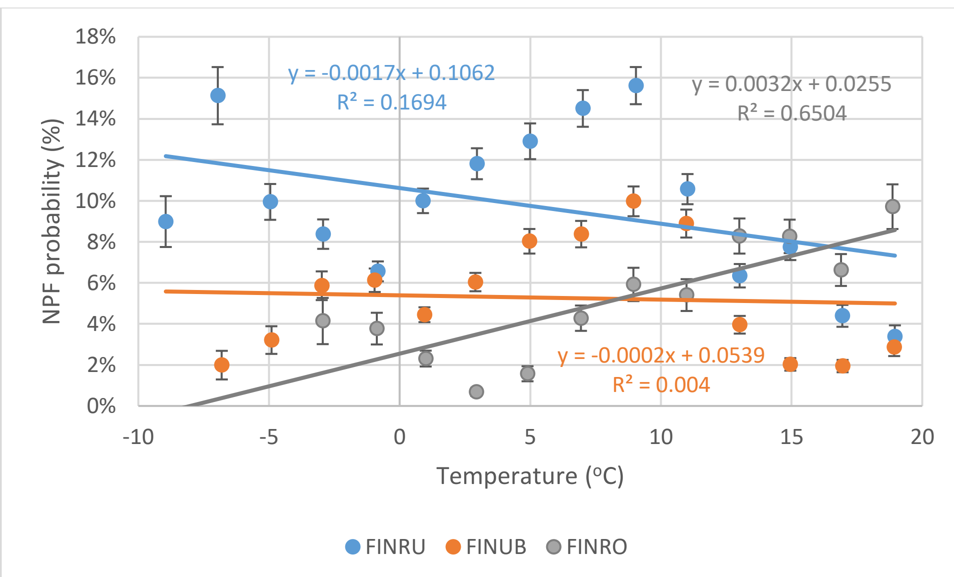


(b)



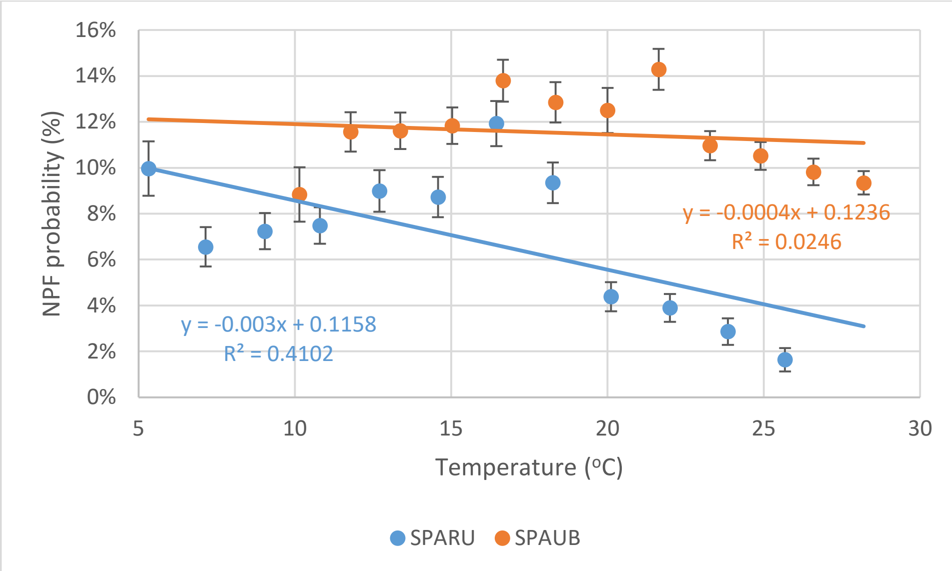
NPF probability (%)
Temperature (ºC)
y = 0.0143x - 0.0113
R² = 0.9261
y = 0.0124x + 0.0062
R² = 0.9236
y = 0.0046x - 0.0004
R² = 0.8876
GERRU
GERUB
GERRO

(c)

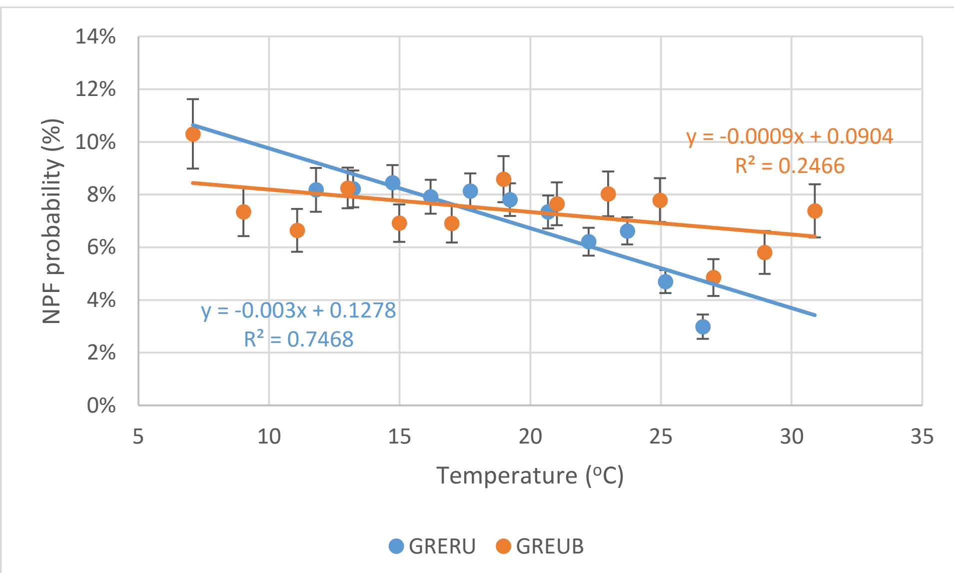


NPF probability (%)
Temperature (ºC)
y = -0.0017x + 0.1062
R² = 0.1694
y = 0.0032x + 0.0255
R² = 0.6504
y = -0.0002x + 0.0539
R² = 0.004
FINRU
FINUB
FINRO

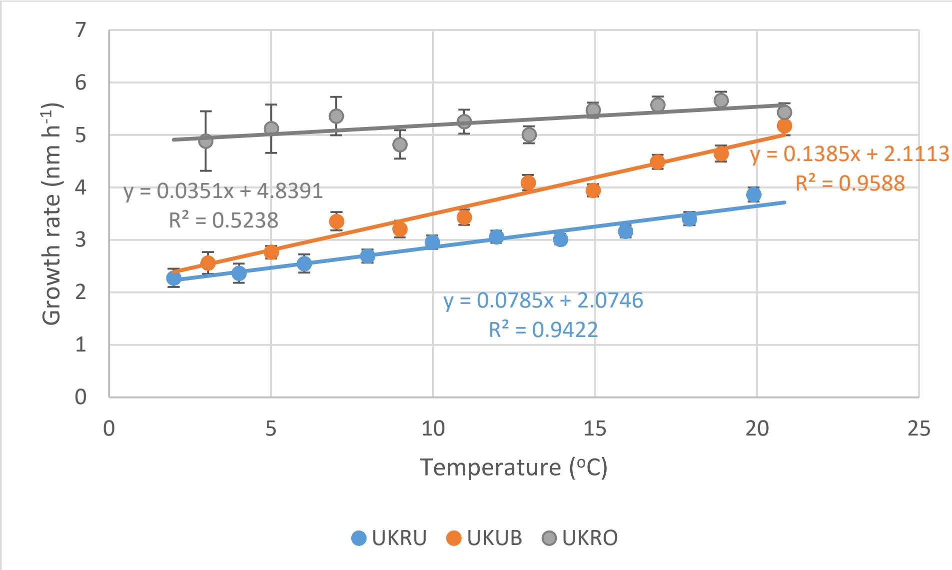
(d)


16%
14%
12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
5
10
15
20
25
30
Temperature (°C)
y = -0.0004x + 0.1236
R² = 0.0246
y = -0.003x + 0.1158
R² = 0.4102
SPARU
SPAUB

(e)

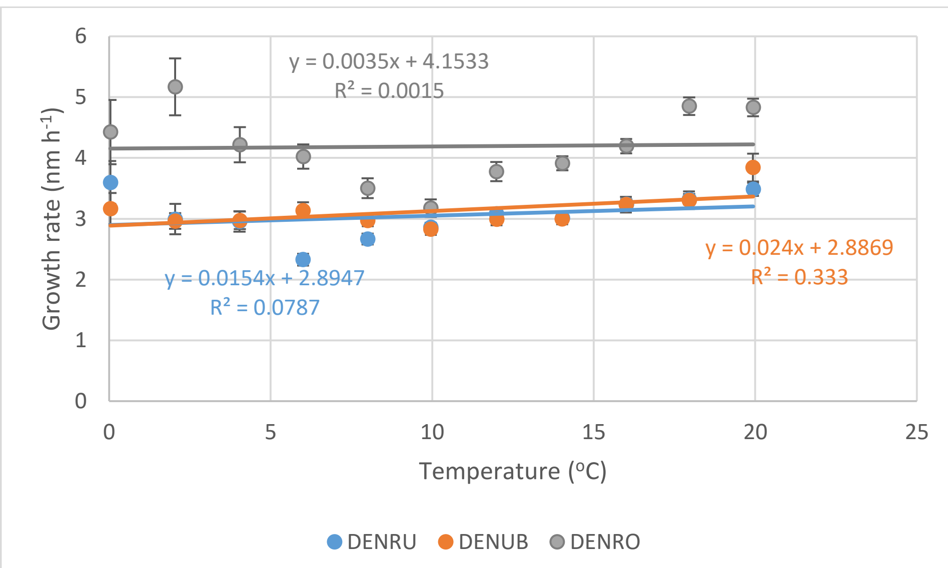

14%
12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
5
10
15
20
25
30
35
Temperature (°C)
y = -0.0009x + 0.0904
R² = 0.2466
y = -0.003x + 0.1278
R² = 0.7468
GRERU
GREUB

(f)



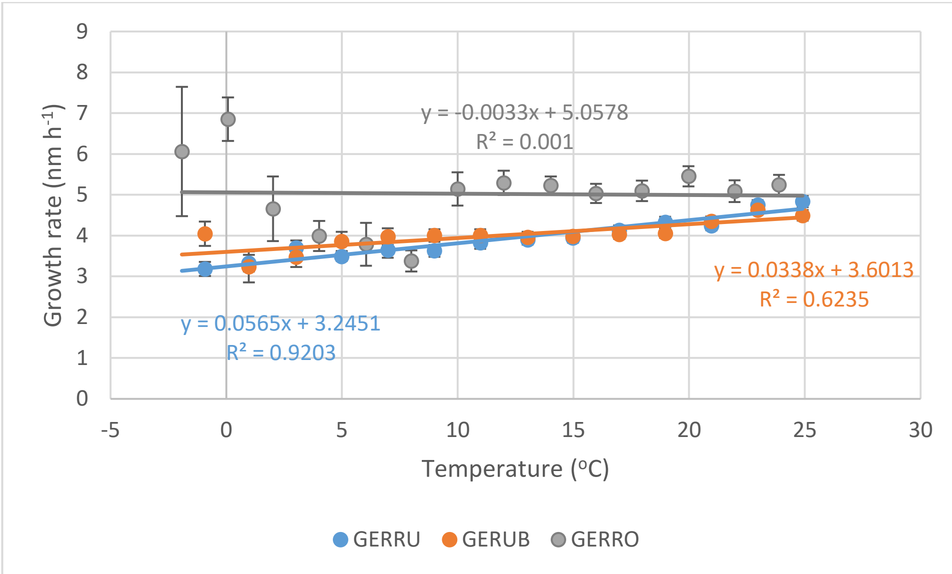
y = 0.0351x + 4.8391
R² = 0.5238
y = 0.1385x + 2.1113
R² = 0.9588
y = 0.0785x + 2.0746
R² = 0.9422
Growth rate (nm h-1)
Temperature (°C)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
UKRU
UKUB
UKRO

(g)



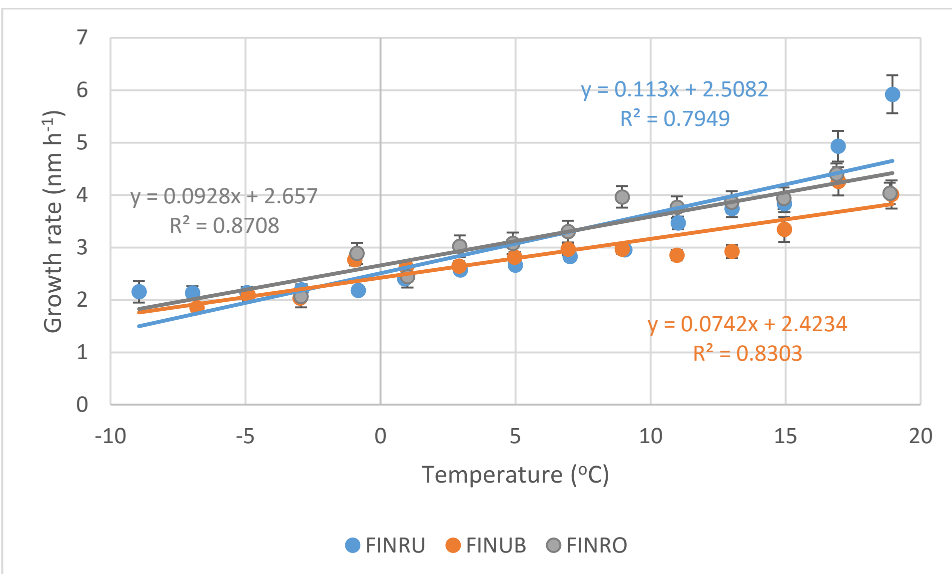
y = 0.0035x + 4.1533
R² = 0.0015
y = 0.0154x + 2.8947
R² = 0.0787
y = 0.024x + 2.8869
R² = 0.333
Growth rate (nm h-1)
Temperature (°C)
0
1
2
3
4
5
6
0
5
10
15
20
25
DENRU
DENUB
DENRO

(h)



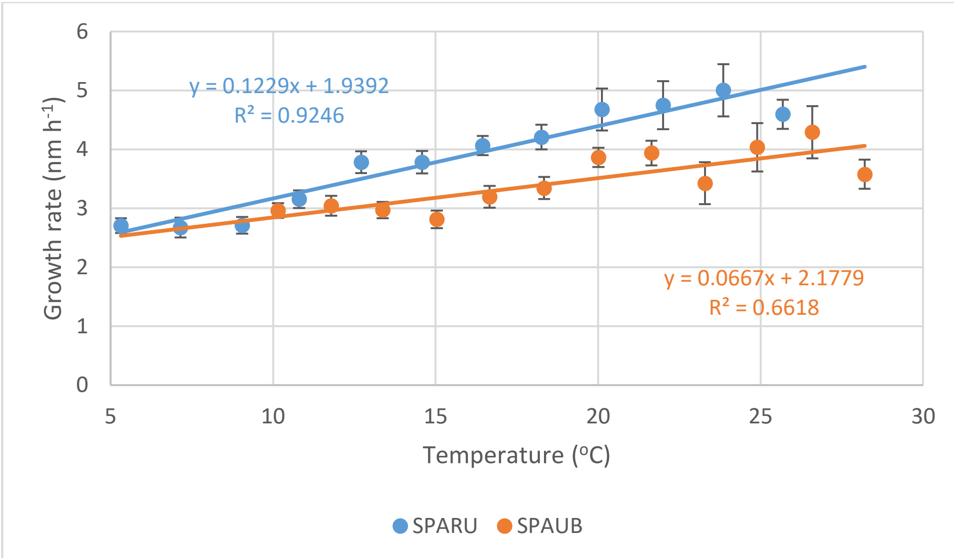
Growth rate (nm h-1)
Temperature (°C)
y = -0.0033x + 5.0578
R² = 0.001
y = 0.0338x + 3.6013
R² = 0.6235
y = 0.0565x + 3.2451
R² = 0.9203
GERRU
GERUB
GERRO

(i)



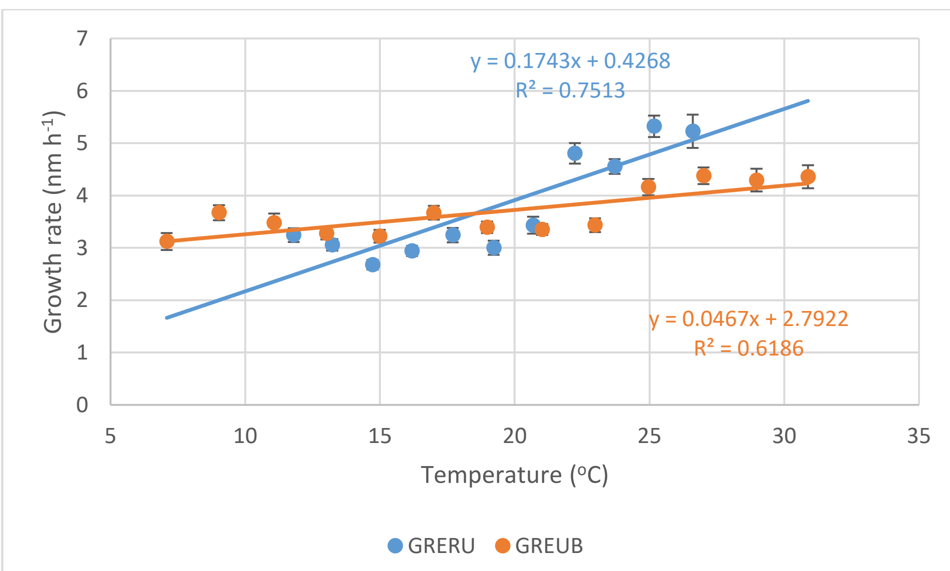
Growth rate (nm h-1)
Temperature (°C)
y = 0.113x + 2.5082
R² = 0.7949
y = 0.0928x + 2.657
R² = 0.8708
y = 0.0742x + 2.4234
R² = 0.8303
FINRU
FINUB
FINRO

(j)



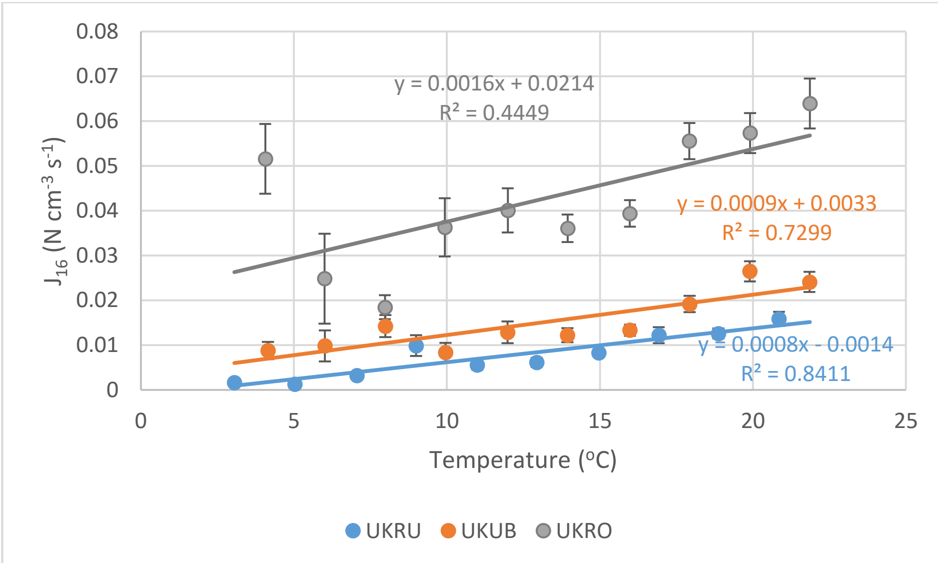
y = 0.1229x + 1.9392
R² = 0.9246
y = 0.0667x + 2.1779
R² = 0.6618
Growth rate (nm h-1)
Temperature (°C)
SPARU
SPAUB

(k)



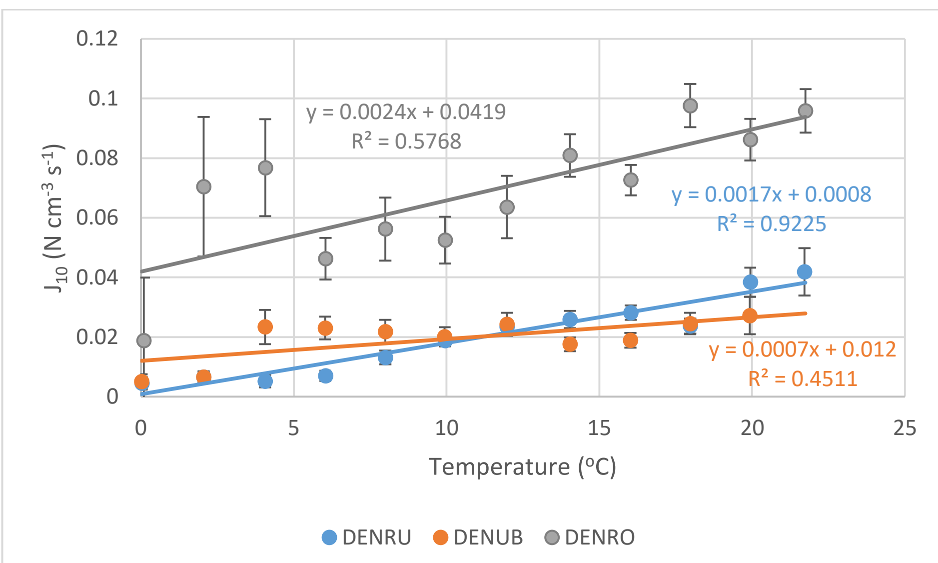
y = 0.1743x + 0.4268
R² = 0.7513
y = 0.0467x + 2.7922
R² = 0.6186
Growth rate (nm h-1)
Temperature (°C)
GRERU
GREUB

(l)



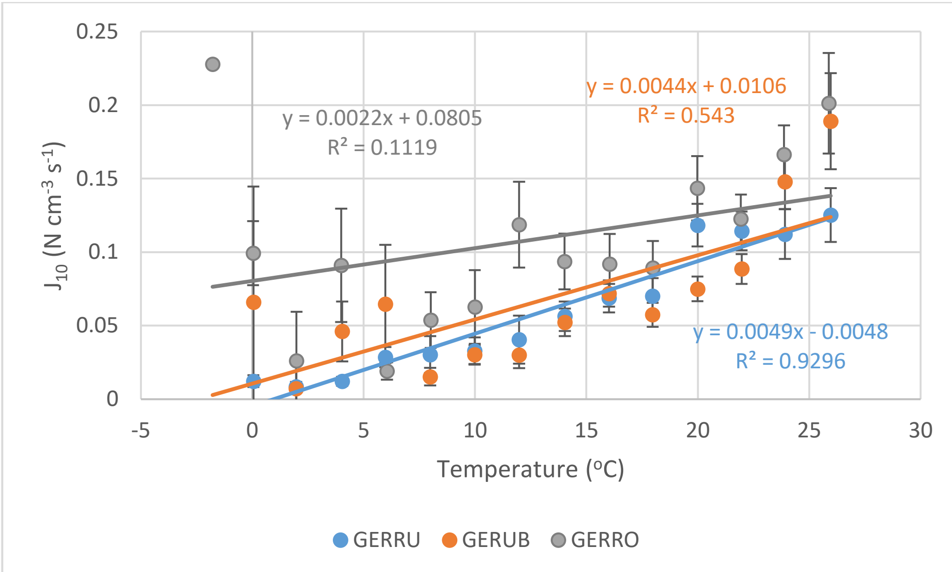
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J16 (N cm-3 s-1)
0
5
10
15
20
25
Temperature (oC)
y = 0.0016x + 0.0214
R² = 0.4449
y = 0.0009x + 0.0033
R² = 0.7299
y = 0.0008x - 0.0014
R² = 0.8411
UKRU
UKUB
UKRO

(m)



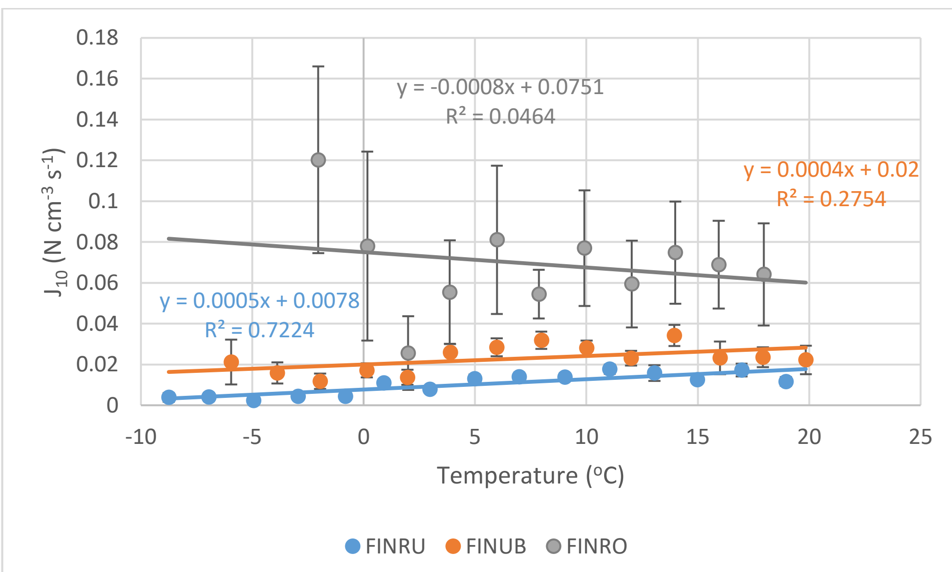
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
0
5
10
15
20
25
Temperature (oC)
y = 0.0024x + 0.0419
R² = 0.5768
y = 0.0017x + 0.0008
R² = 0.9225
y = 0.0007x + 0.012
R² = 0.4511
DENRU
DENUB
DENRO

(n)



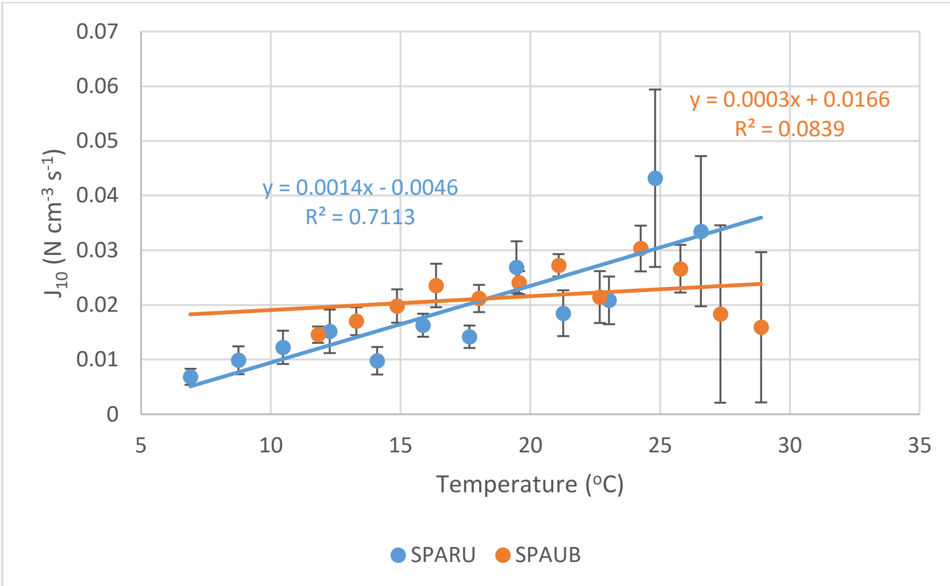
0.25
0.2
0.15
0.1
0.05
0
-5
0
5
10
15
20
25
30
J_{10} (N cm^{-3} s^{-1})
Temperature (°C)
y = 0.0022x + 0.0805
R^2 = 0.1119
y = 0.0044x + 0.0106
R^2 = 0.543
y = 0.0049x - 0.0048
R^2 = 0.9296
GERRU
GERUB
GERRO

(o)

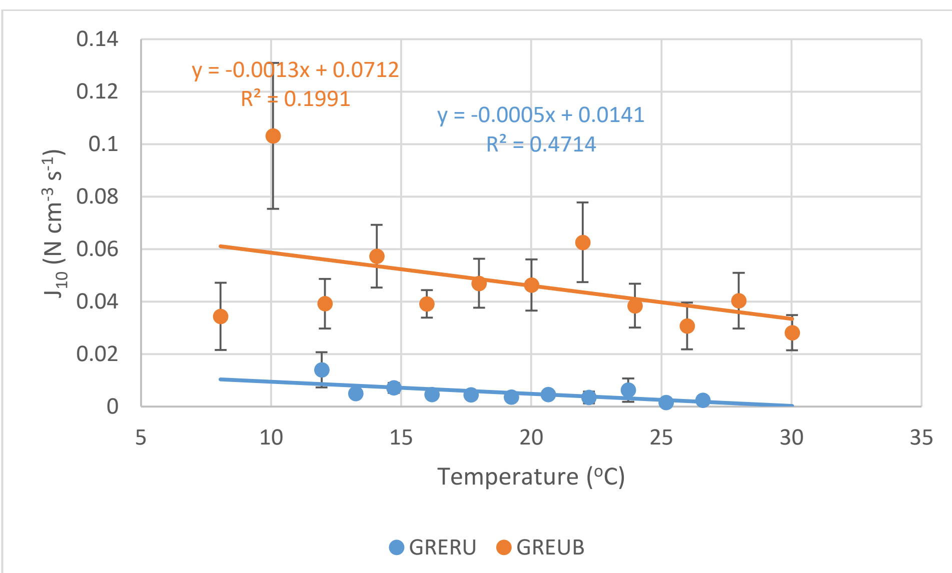


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-10
-5
0
5
10
15
20
25
J_{10} (N cm^{-3} s^{-1})
Temperature (°C)
y = -0.0008x + 0.0751
R^2 = 0.0464
y = 0.0004x + 0.02
R^2 = 0.2754
y = 0.0005x + 0.0078
R^2 = 0.7224
FINRU
FINUB
FINRO

(p)

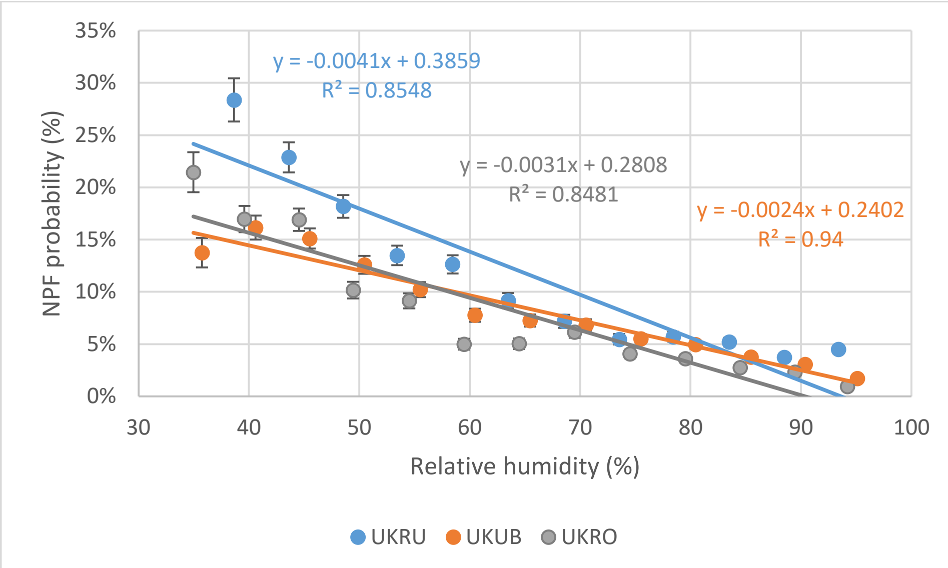

y = 0.0003x + 0.0166
R² = 0.0839
y = 0.0014x - 0.0046
R² = 0.7113
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J10 (N cm-3 s-1)
5
10
15
20
25
30
35
Temperature (ºC)
SPARU
SPAUB

(q)

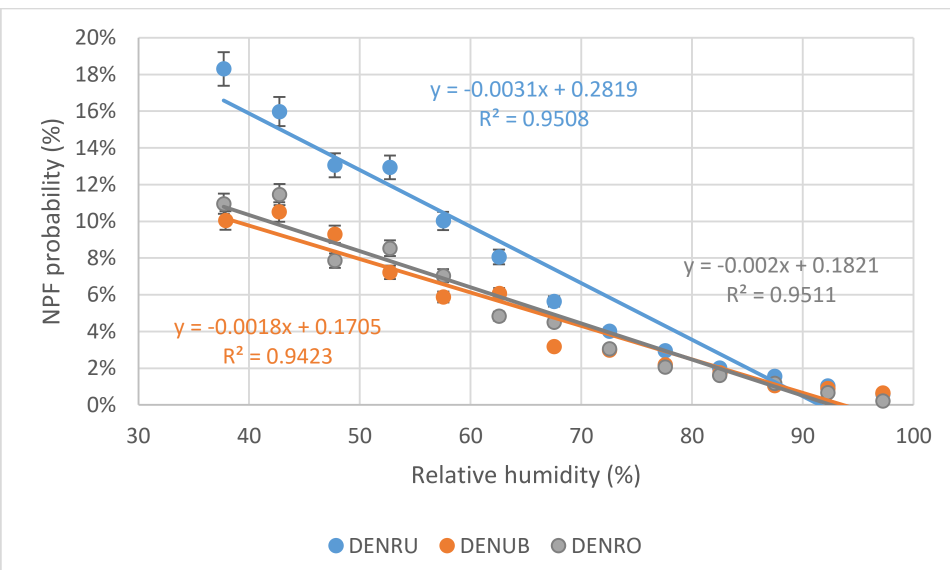

y = -0.0013x + 0.0712
R² = 0.1991
y = -0.0005x + 0.0141
R² = 0.4714
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
5
10
15
20
25
30
35
Temperature (ºC)
GRERU
GREUB

(r)

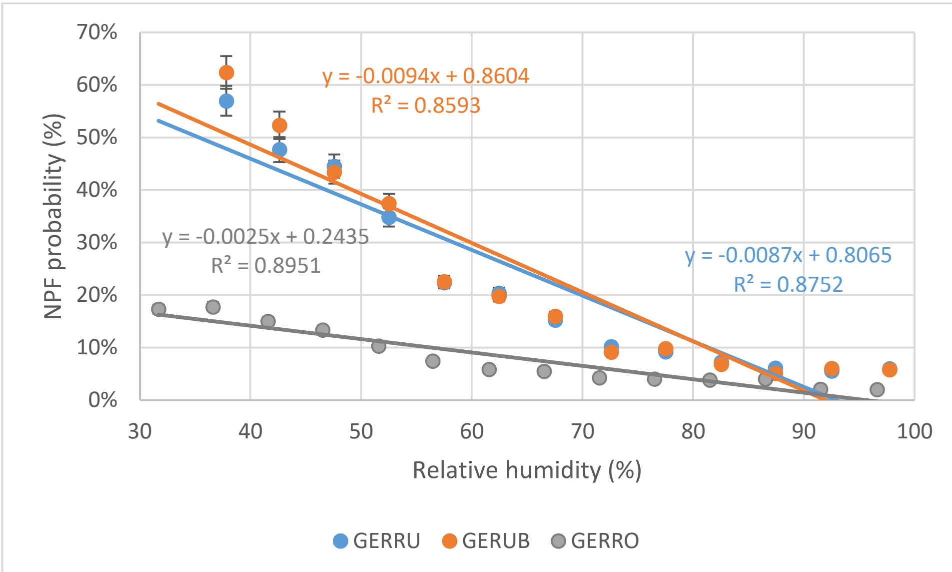
Figure S3: Relationship of relative humidity with NPF variables.



(a)

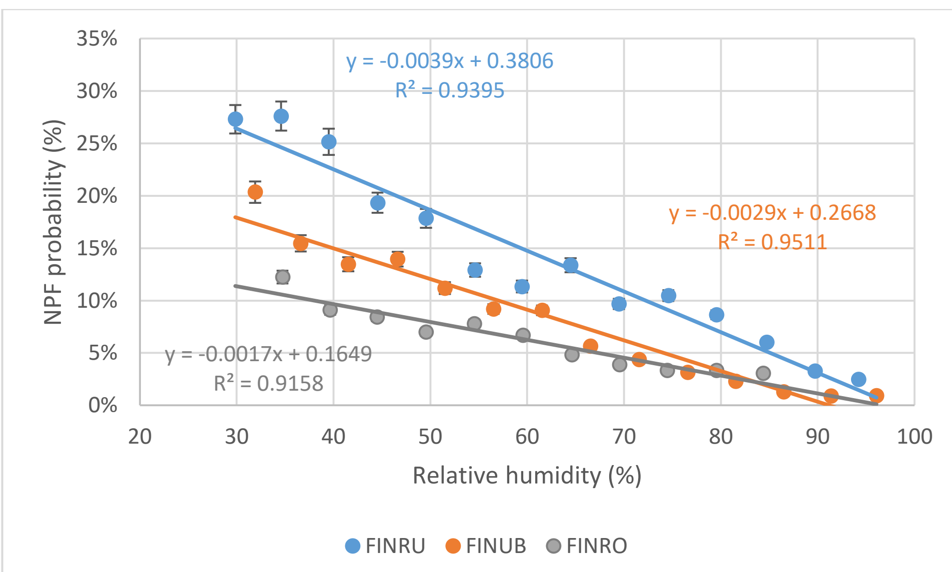


(b)



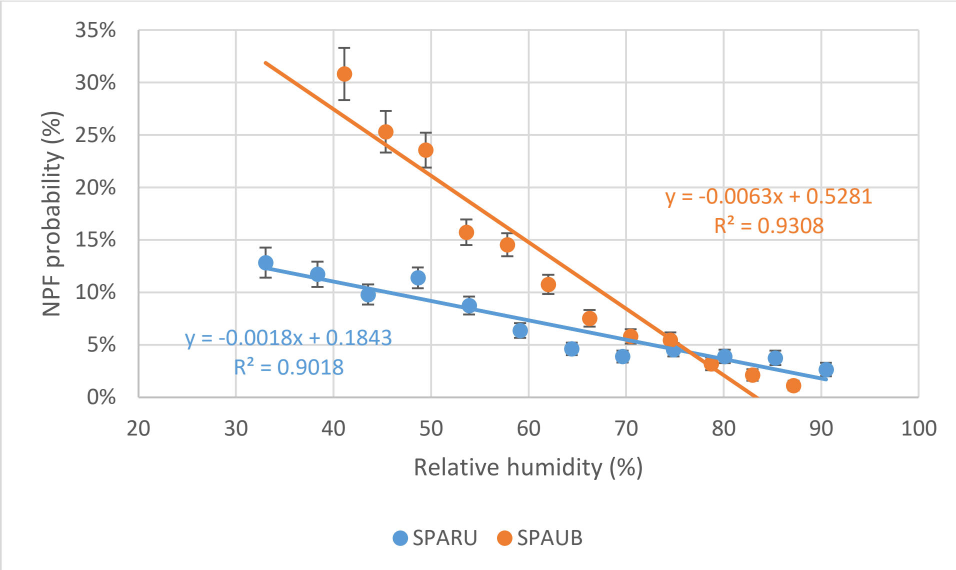
y = -0.0094x + 0.8604
R² = 0.8593
y = -0.0025x + 0.2435
R² = 0.8951
y = -0.0087x + 0.8065
R² = 0.8752
70%
60%
50%
40%
30%
20%
10%
0%
NPF probability (%)
30 40 50 60 70 80 90 100
Relative humidity (%)
GERRU
GERUB
GERRO

(c)



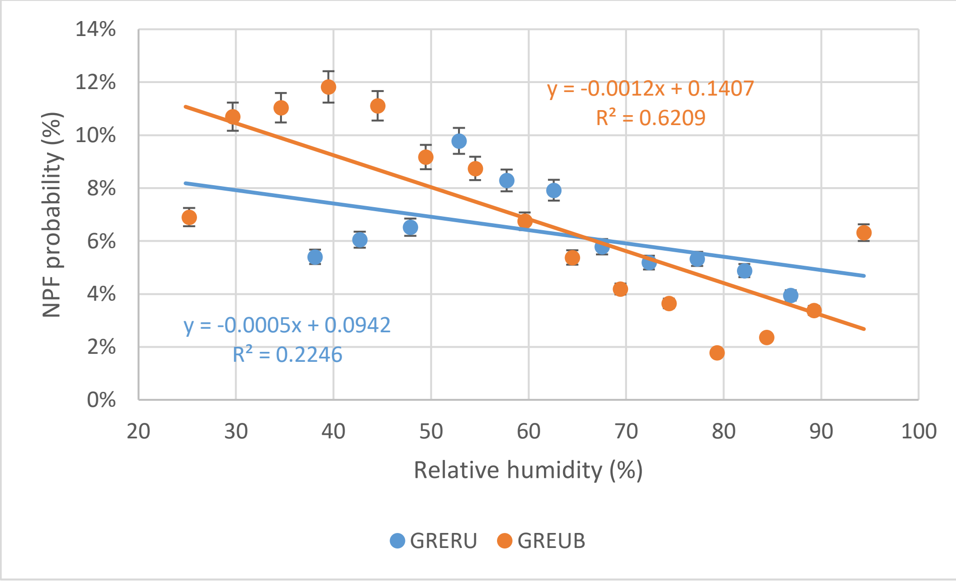
y = -0.0039x + 0.3806
R² = 0.9395
y = -0.0029x + 0.2668
R² = 0.9511
y = -0.0017x + 0.1649
R² = 0.9158
35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
20 30 40 50 60 70 80 90 100
Relative humidity (%)
FINRU
FINUB
FINRO

(d)



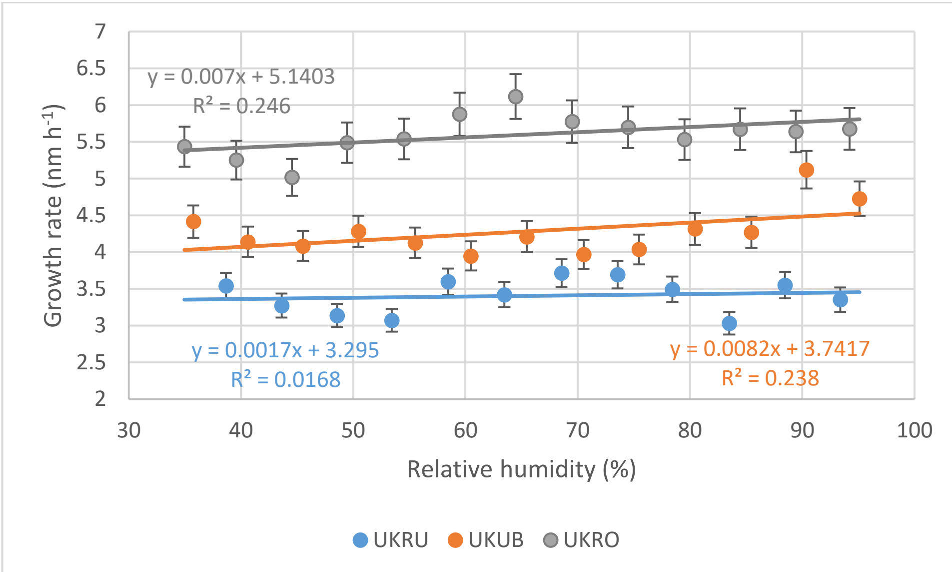
NPF probability (%)
35%
30%
25%
20%
15%
10%
5%
0%
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0063x + 0.5281
R² = 0.9308
y = -0.0018x + 0.1843
R² = 0.9018
SPARU
SPAUB

(e)

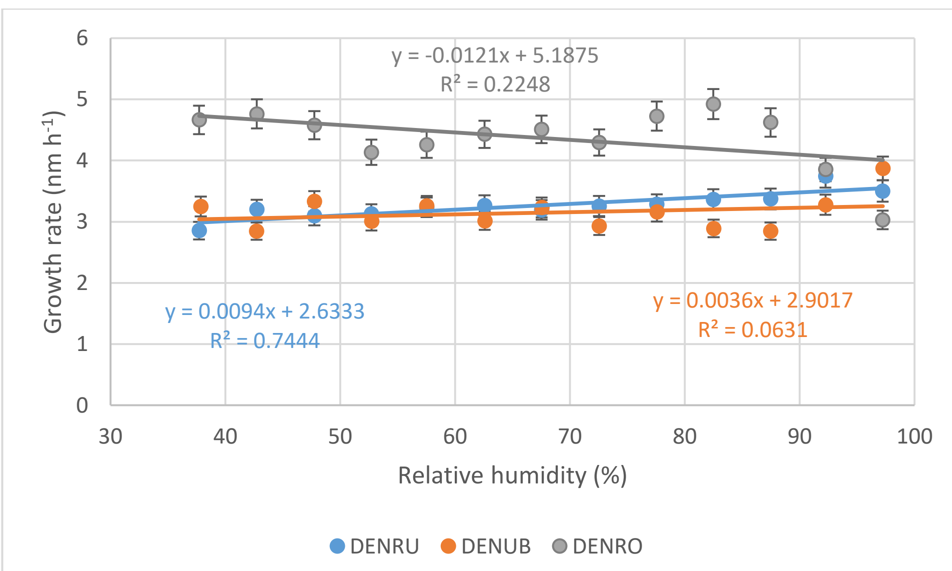


NPF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0012x + 0.1407
R² = 0.6209
y = -0.0005x + 0.0942
R² = 0.2246
GRERU
GREUB

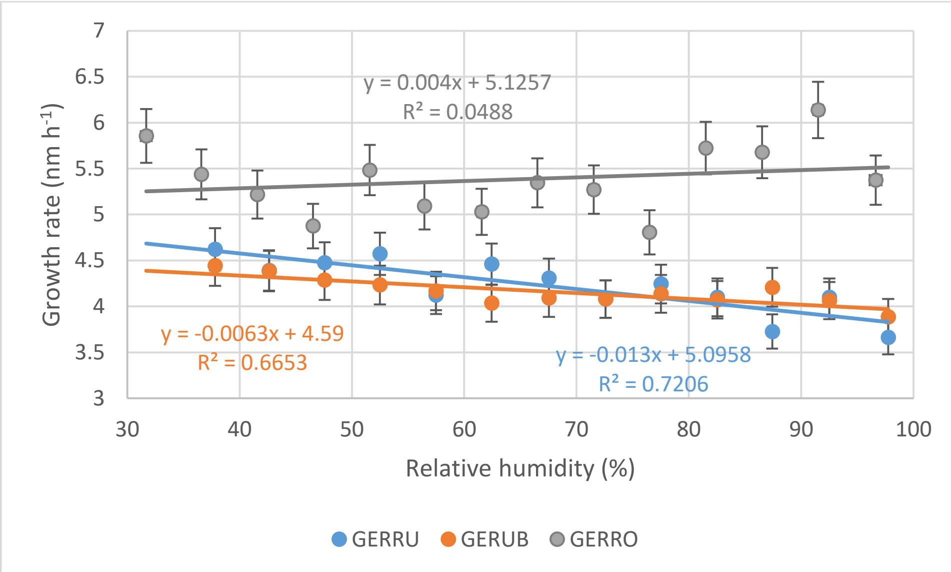
(f)


y = 0.007x + 5.1403
R² = 0.246
y = 0.0017x + 3.295
R² = 0.0168
y = 0.0082x + 3.7417
R² = 0.238
Growth rate (nm h-1)
Relative humidity (%)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
30
40
50
60
70
80
90
100
UKRU
UKUB
UKRO

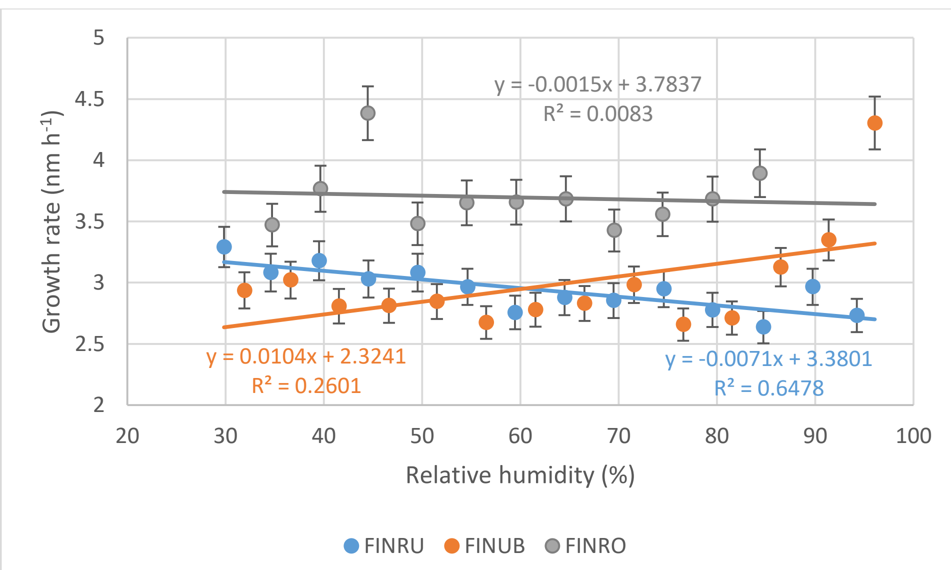
(g)


y = -0.0121x + 5.1875
R² = 0.2248
y = 0.0094x + 2.6333
R² = 0.7444
y = 0.0036x + 2.9017
R² = 0.0631
Growth rate (nm h-1)
Relative humidity (%)
6
5
4
3
2
1
0
30
40
50
60
70
80
90
100
DENRU
DENUB
DENRO

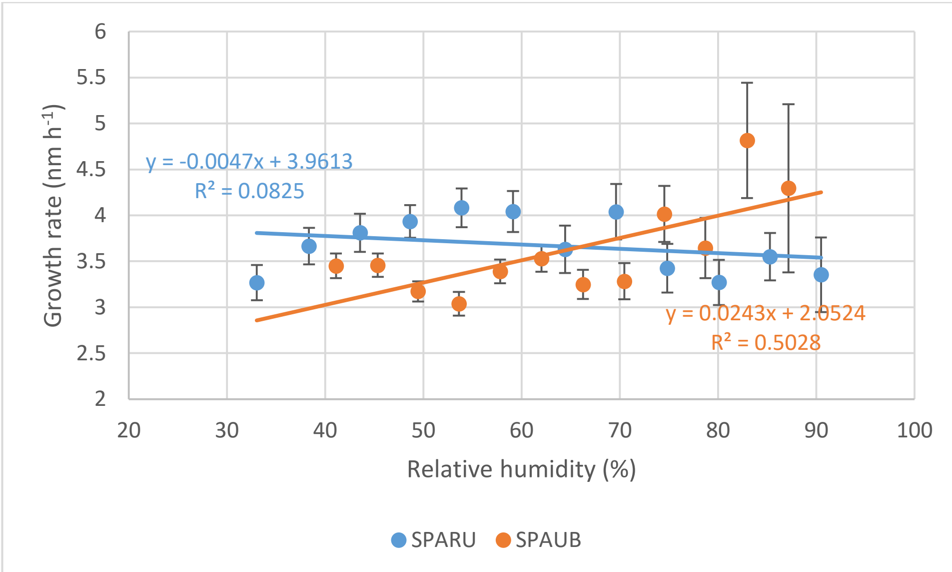
(h)


7
6.5
6
5.5
5
4.5
4
3.5
3
Growth rate (nm h-1)
30
40
50
60
70
80
90
100
Relative humidity (%)
y = 0.004x + 5.1257
R² = 0.0488
y = -0.0063x + 4.59
R² = 0.6653
y = -0.013x + 5.0958
R² = 0.7206
GERRU
GERUB
GERRO

(i)

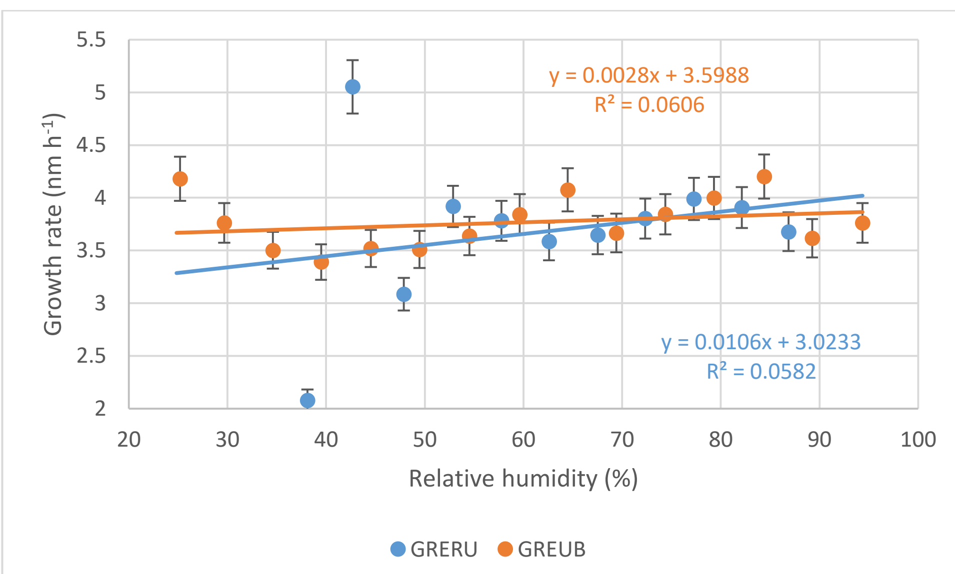

5
4.5
4
3.5
3
2.5
2
Growth rate (nm h-1)
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0015x + 3.7837
R² = 0.0083
y = 0.0104x + 2.3241
R² = 0.2601
y = -0.0071x + 3.3801
R² = 0.6478
FINRU
FINUB
FINRO

(j)



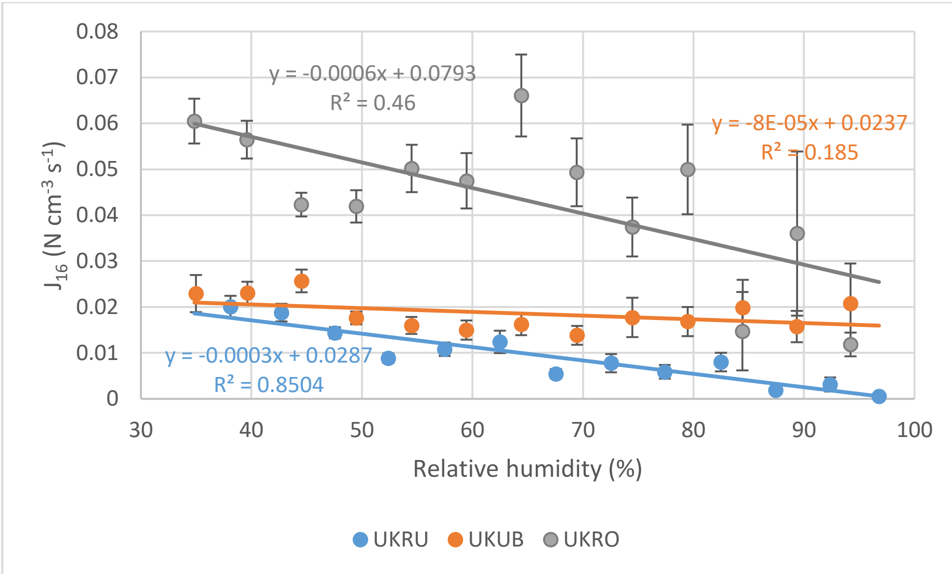
Growth rate (nm h-1)
Relative humidity (%)
y = -0.0047x + 3.9613
R² = 0.0825
y = 0.0243x + 2.0524
R² = 0.5028
SPARU
SPAUB

(k)



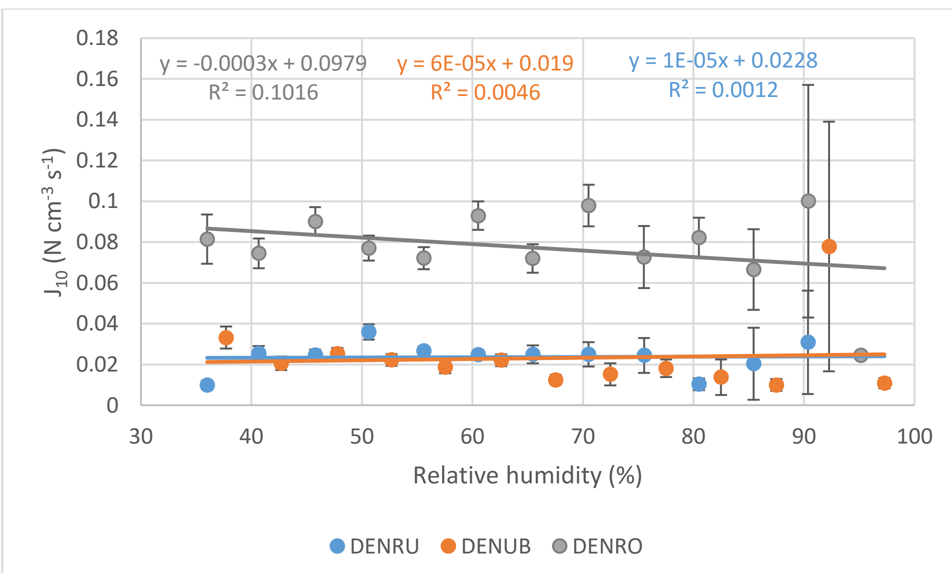
Growth rate (nm h-1)
Relative humidity (%)
y = 0.0028x + 3.5988
R² = 0.0606
y = 0.0106x + 3.0233
R² = 0.0582
GRERU
GREUB

(l)



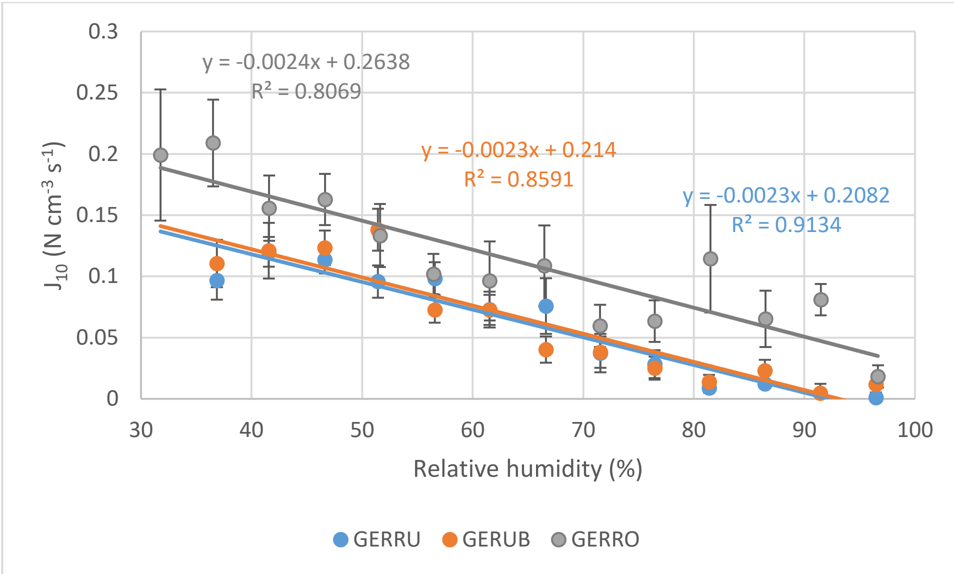
y = -0.0006x + 0.0793
R² = 0.46
y = -8E-05x + 0.0237
R² = 0.185
y = -0.0003x + 0.0287
R² = 0.8504
J16 (N cm-3 s-1)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
30
40
50
60
70
80
90
100
Relative humidity (%)
UKRU
UKUB
UKRO

(m)

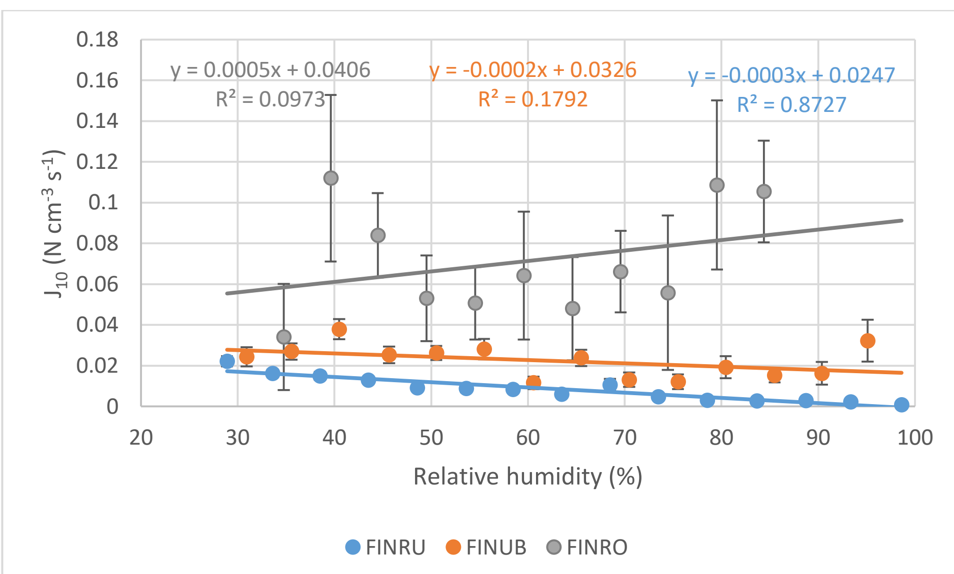


y = -0.0003x + 0.0979
R² = 0.1016
y = 6E-05x + 0.019
R² = 0.0046
y = 1E-05x + 0.0228
R² = 0.0012
J10 (N cm-3 s-1)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
30
40
50
60
70
80
90
100
Relative humidity (%)
DENRU
DENUB
DENRO

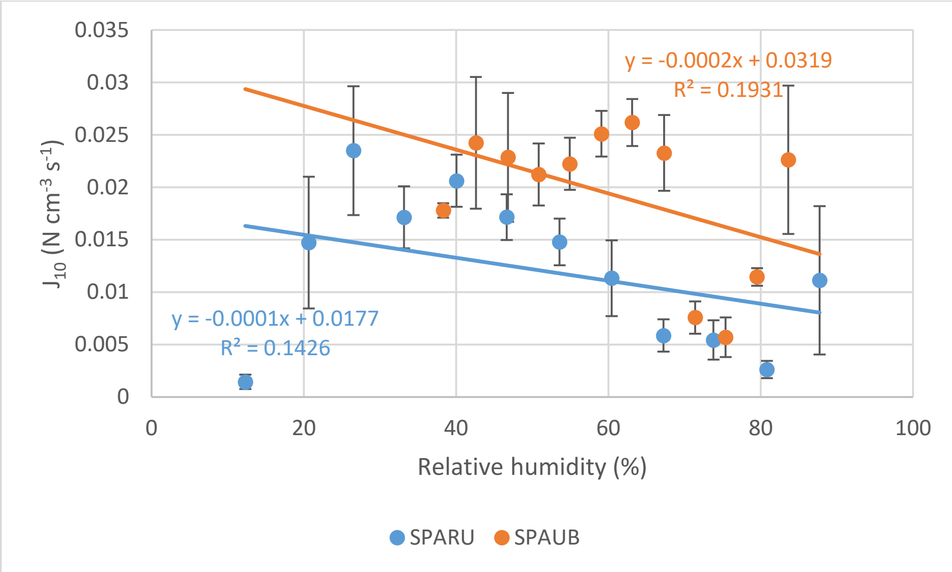
(n)


y = -0.0024x + 0.2638
R² = 0.8069
y = -0.0023x + 0.214
R² = 0.8591
y = -0.0023x + 0.2082
R² = 0.9134
J10 (N cm-3 s-1)
0
0.05
0.1
0.15
0.2
0.25
0.3
30
40
50
60
70
80
90
100
Relative humidity (%)
GERRU
GERUB
GERRO

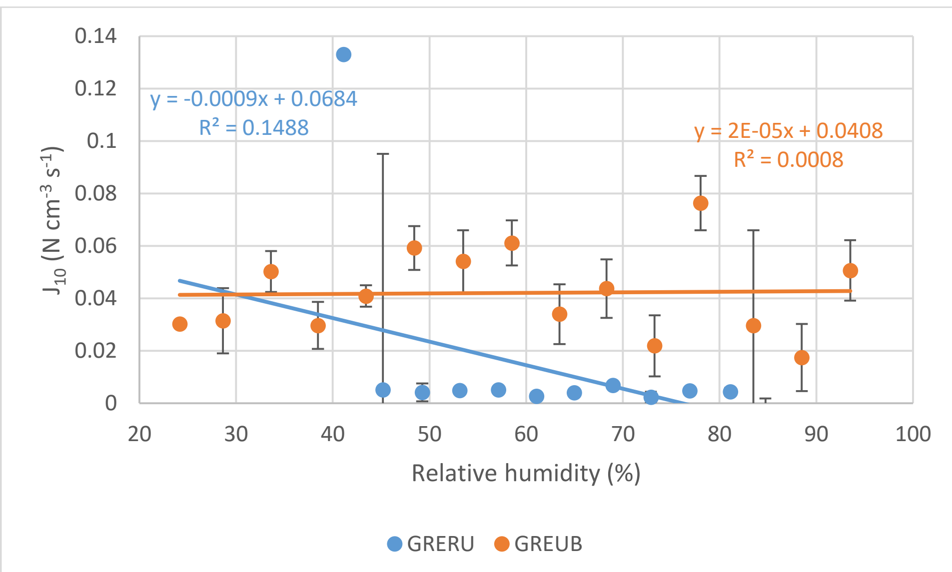
(o)


y = 0.0005x + 0.0406
R² = 0.0973
y = -0.0002x + 0.0326
R² = 0.1792
y = -0.0003x + 0.0247
R² = 0.8727
J10 (N cm-3 s-1)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
20
30
40
50
60
70
80
90
100
Relative humidity (%)
FINRU
FINUB
FINRO

(p)

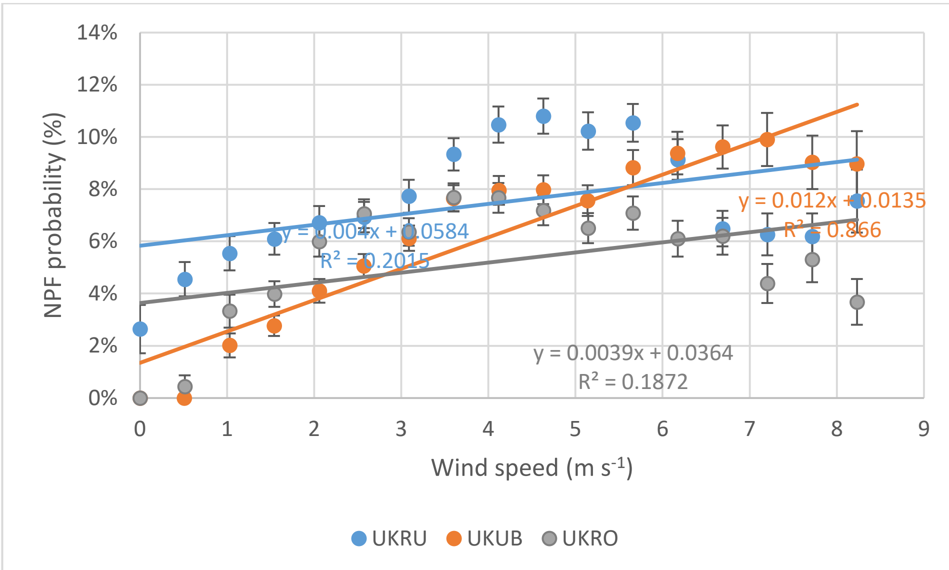

y = -0.0002x + 0.0319
R² = 0.1931
y = -0.0001x + 0.0177
R² = 0.1426
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
J10 (N cm-3 s-1)
0
20
40
60
80
100
Relative humidity (%)
SPARU
SPAUB

(q)

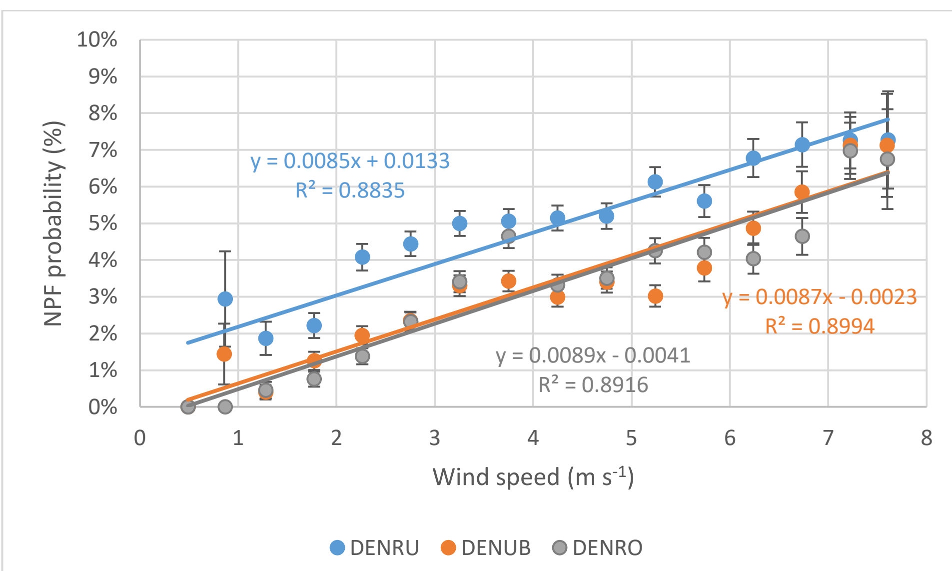

y = -0.0009x + 0.0684
R² = 0.1488
y = 2E-05x + 0.0408
R² = 0.0008
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
20
30
40
50
60
70
80
90
100
Relative humidity (%)
GRERU
GREUB

(r)

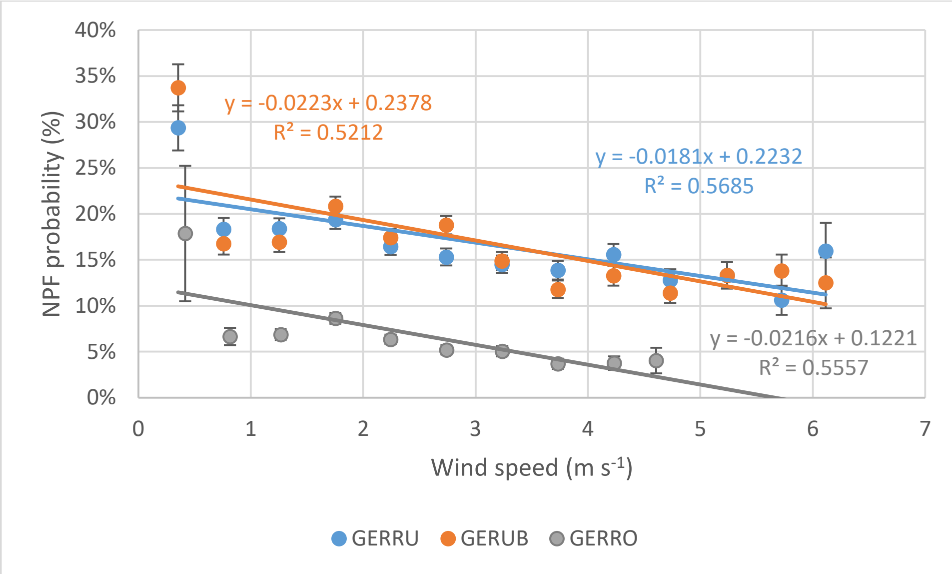
Figure S4: Relationship of wind speed with NPF variables.



(a)

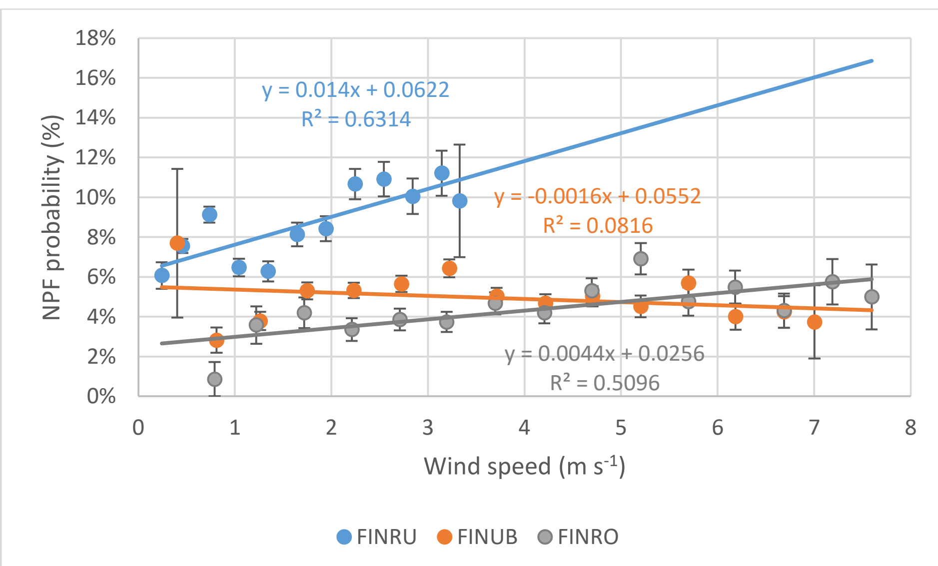


(b)



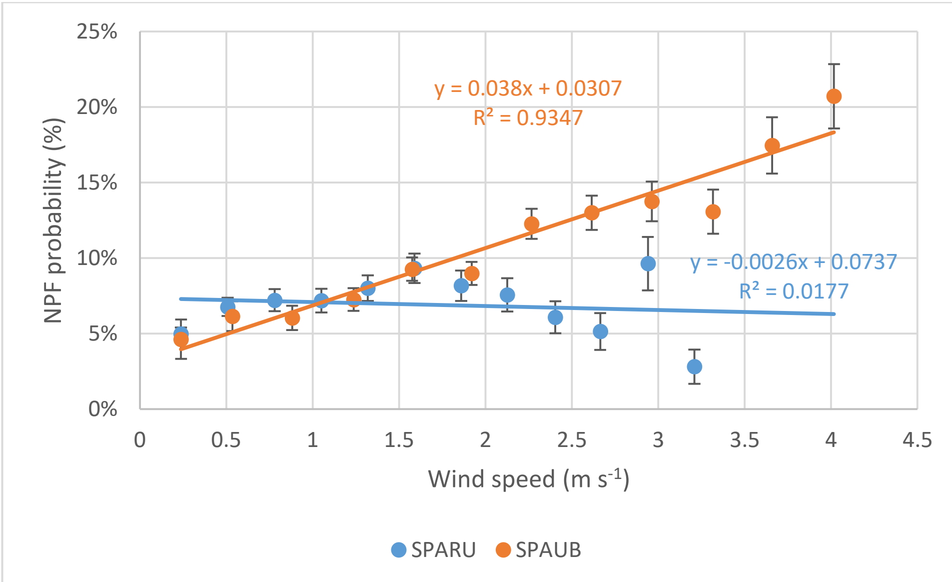
40%
35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
0
1
2
3
4
5
6
7
Wind speed (m s-1)
y = -0.0223x + 0.2378
R² = 0.5212
y = -0.0181x + 0.2232
R² = 0.5685
y = -0.0216x + 0.1221
R² = 0.5557
GERRU
GERUB
GERRO

(c)

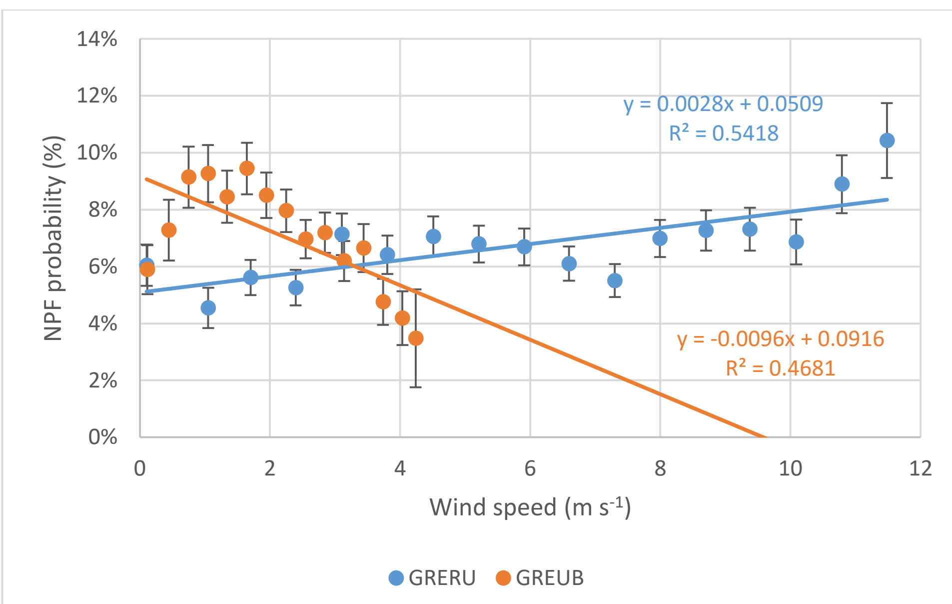


18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
0
1
2
3
4
5
6
7
8
Wind speed (m s-1)
y = 0.014x + 0.0622
R² = 0.6314
y = -0.0016x + 0.0552
R² = 0.0816
y = 0.0044x + 0.0256
R² = 0.5096
FINRU
FINUB
FINRO

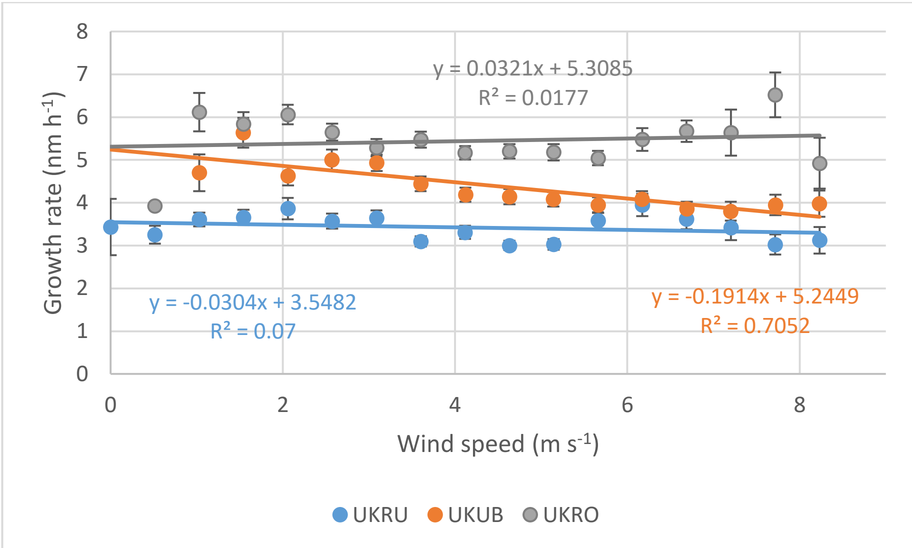
(d)


NPF probability (%)
25%
20%
15%
10%
5%
0%
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Wind speed (m s-1)
y = 0.038x + 0.0307
R² = 0.9347
y = -0.0026x + 0.0737
R² = 0.0177
SPARU
SPAUB

(e)

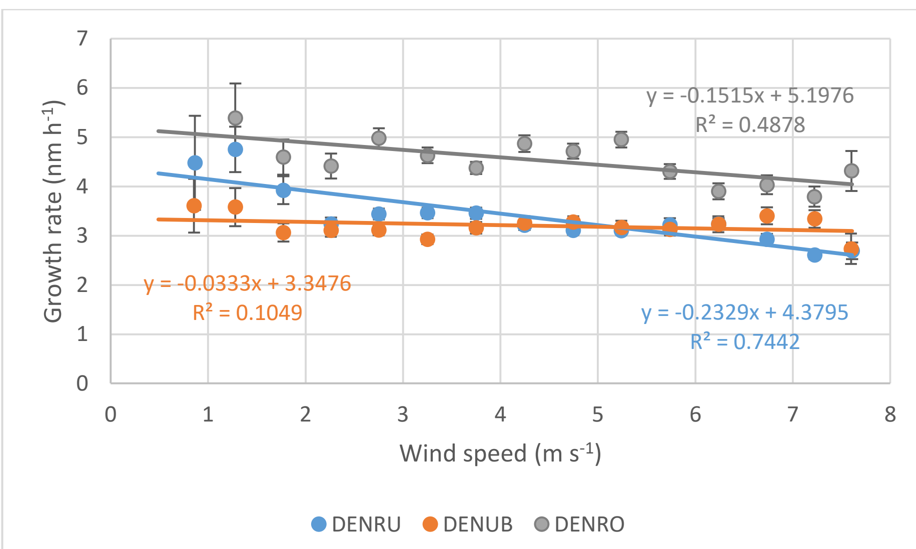

NPF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
0
2
4
6
8
10
12
Wind speed (m s-1)
y = 0.0028x + 0.0509
R² = 0.5418
y = -0.0096x + 0.0916
R² = 0.4681
GRERU
GREUB

(f)



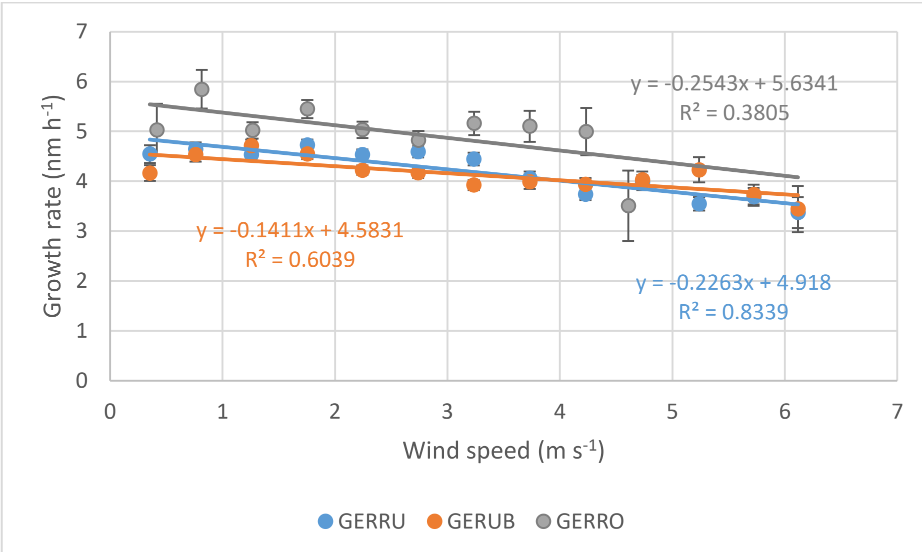
y = 0.0321x + 5.3085
R² = 0.0177
y = -0.0304x + 3.5482
R² = 0.07
y = -0.1914x + 5.2449
R² = 0.7052
Growth rate (nm h-1)
Wind speed (m s-1)
0
1
2
3
4
5
6
7
8
0
2
4
6
8
UKRU
UKUB
UKRO

(g)



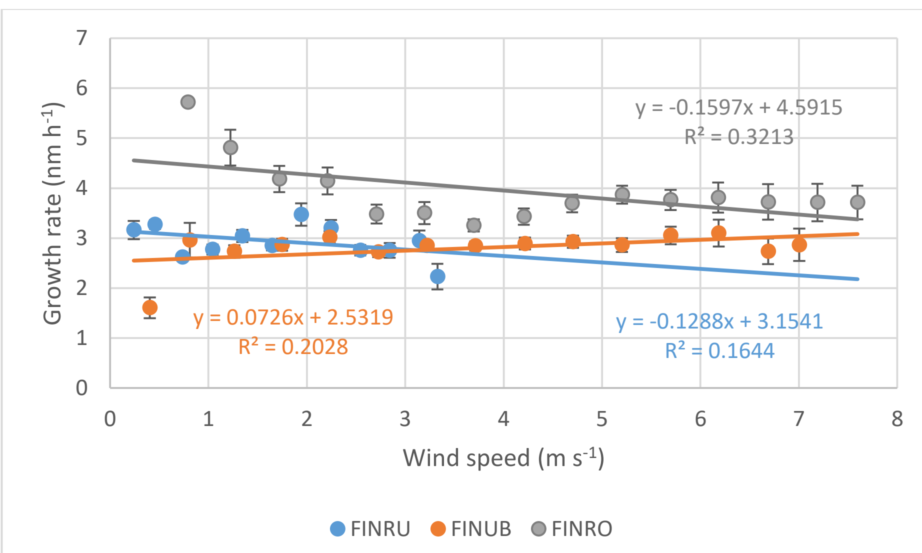
y = -0.1515x + 5.1976
R² = 0.4878
y = -0.0333x + 3.3476
R² = 0.1049
y = -0.2329x + 4.3795
R² = 0.7442
Growth rate (nm h-1)
Wind speed (m s-1)
0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
7
8
DENRU
DENUB
DENRO

(h)



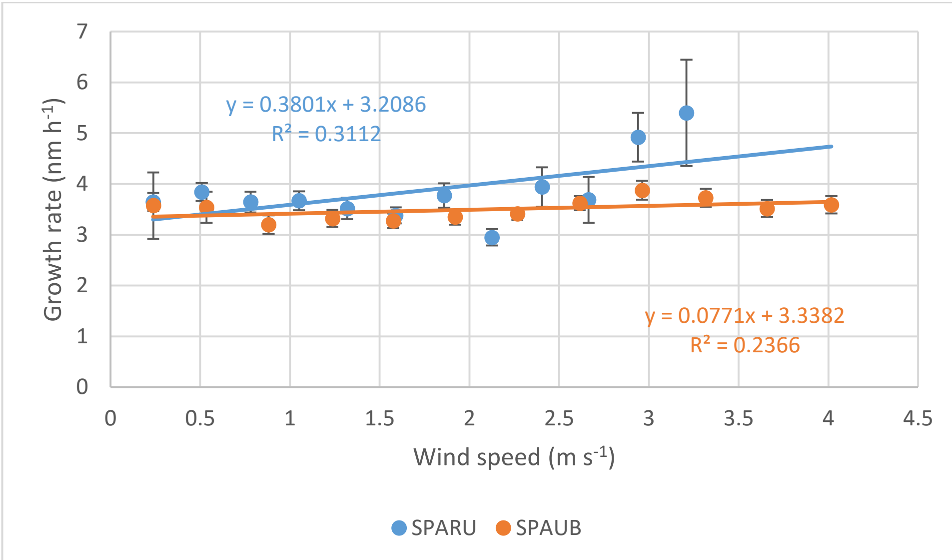
Growth rate (nm h-1)
Wind speed (m s-1)
y = -0.2543x + 5.6341
R² = 0.3805
y = -0.1411x + 4.5831
R² = 0.6039
y = -0.2263x + 4.918
R² = 0.8339
GERRU
GERUB
GERRO

(i)

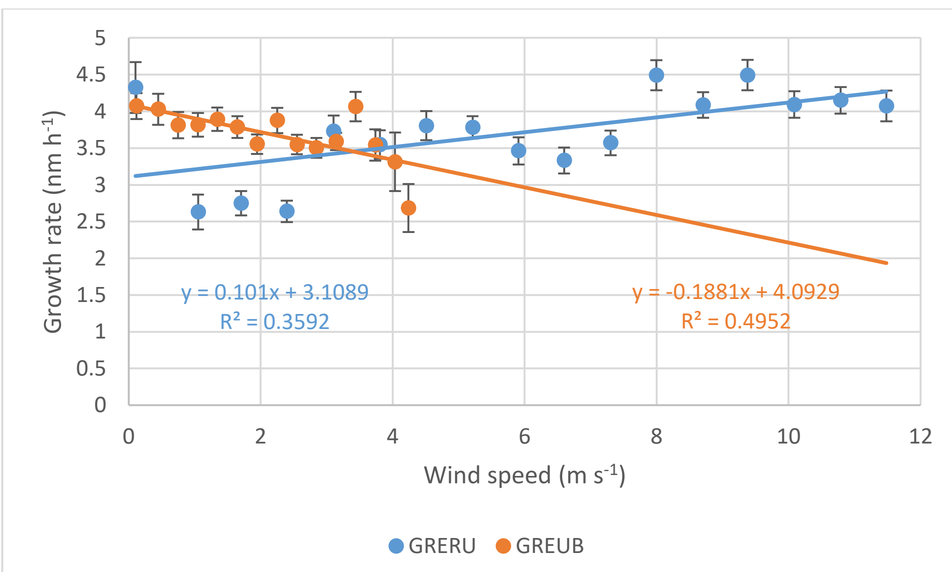


Growth rate (nm h-1)
Wind speed (m s-1)
y = -0.1597x + 4.5915
R² = 0.3213
y = 0.0726x + 2.5319
R² = 0.2028
y = -0.1288x + 3.1541
R² = 0.1644
FINRU
FINUB
FINRO

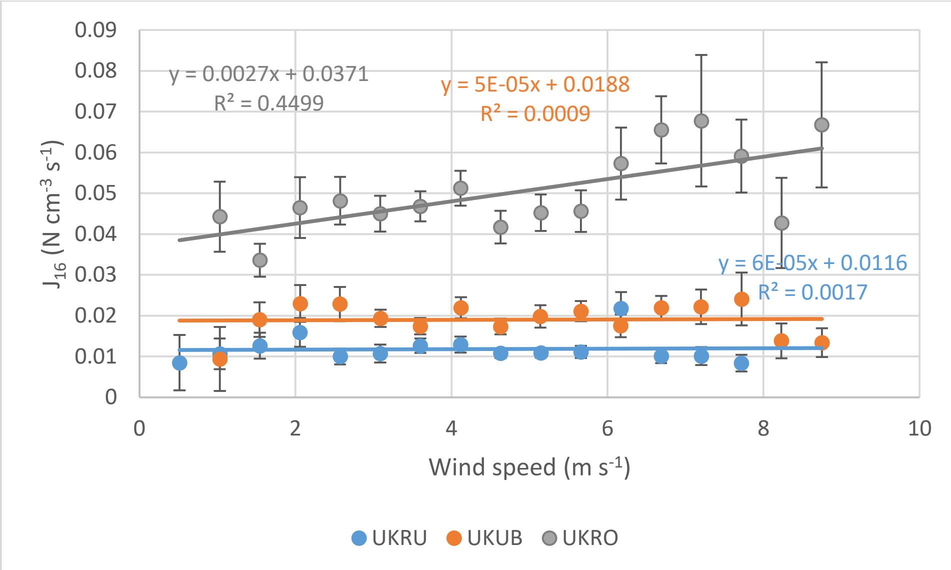
(j)


Growth rate (nm h-1)
Wind speed (m s-1)
y = 0.3801x + 3.2086
R² = 0.3112
y = 0.0771x + 3.3382
R² = 0.2366
SPARU
SPAUB

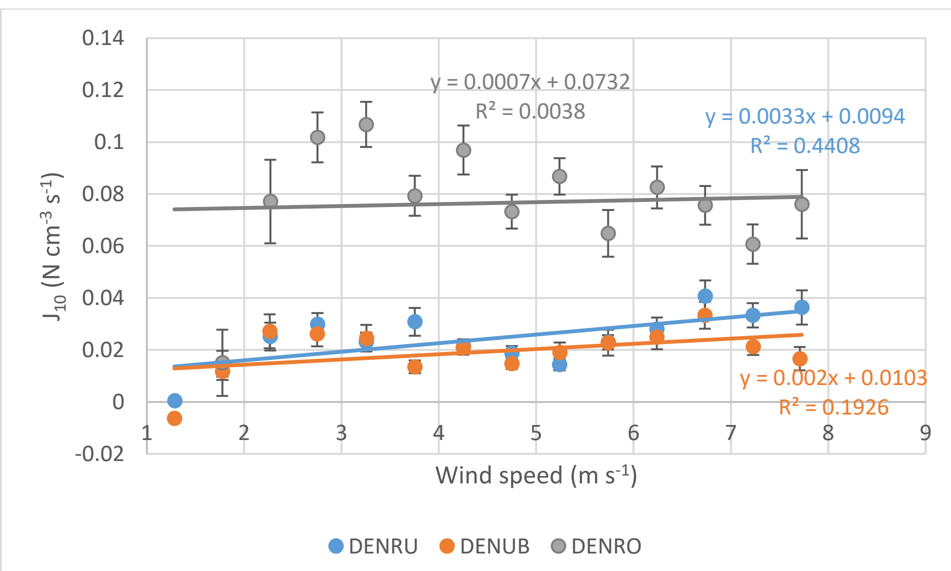
(k)


Growth rate (nm h-1)
Wind speed (m s-1)
y = 0.101x + 3.1089
R² = 0.3592
y = -0.1881x + 4.0929
R² = 0.4952
GRERU
GREUB

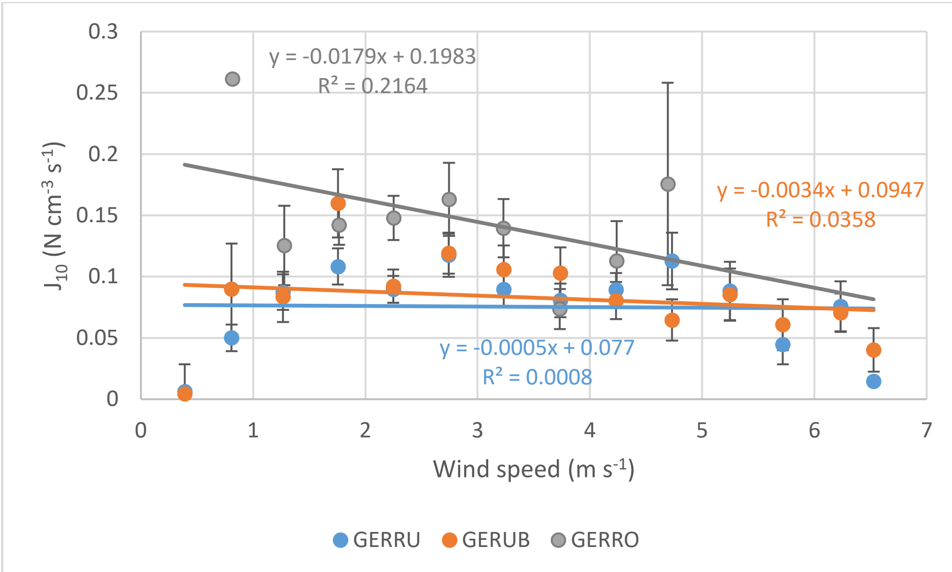
(l)


0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
J16 (N cm-3 s-1)
Wind speed (m s-1)
y = 0.0027x + 0.0371
R² = 0.4499
y = 5E-05x + 0.0188
R² = 0.0009
y = 6E-05x + 0.0116
R² = 0.0017
UKRU
UKUB
UKRO

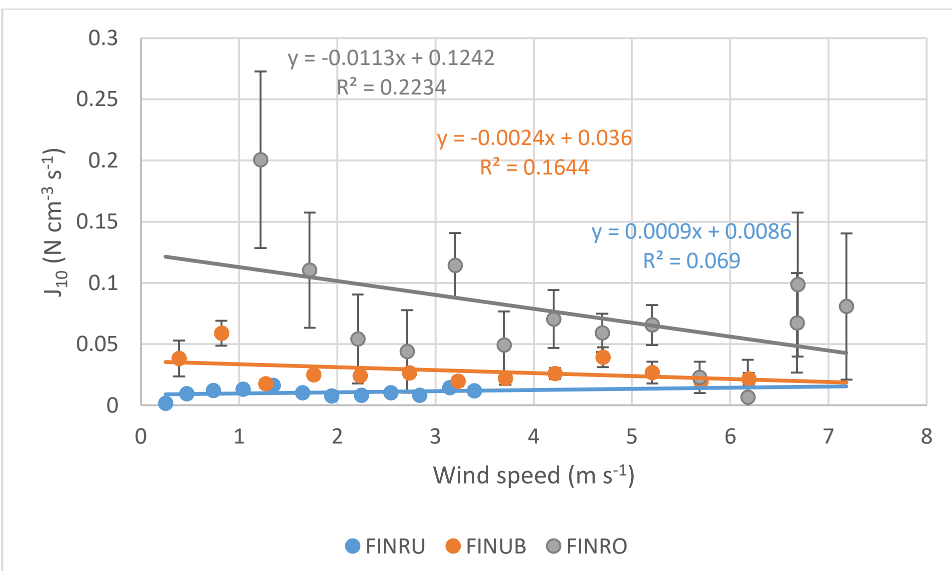
(m)


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
1
2
3
4
5
6
7
8
9
J10 (N cm-3 s-1)
Wind speed (m s-1)
y = 0.0007x + 0.0732
R² = 0.0038
y = 0.0033x + 0.0094
R² = 0.4408
y = 0.002x + 0.0103
R² = 0.1926
DENRU
DENUB
DENRO

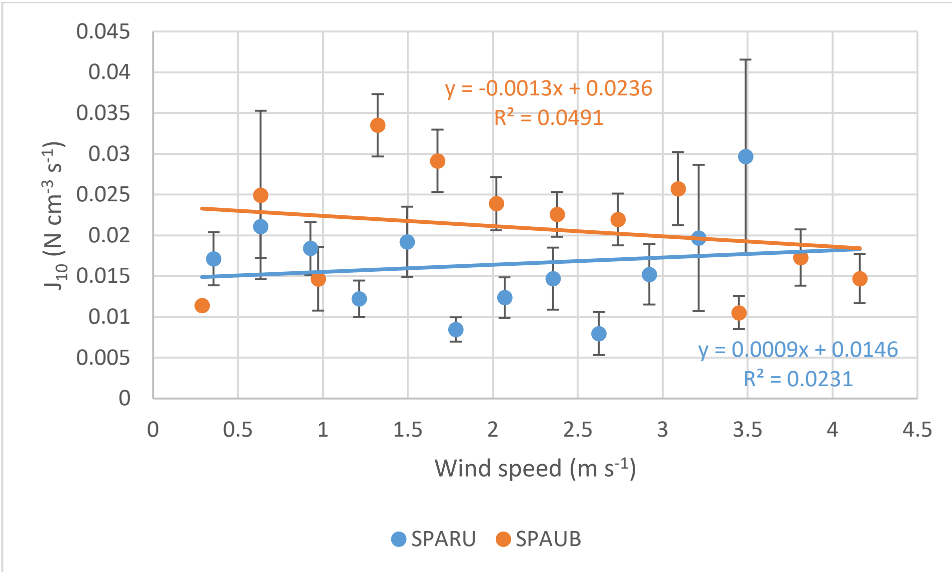
(n)


0.3
0.25
0.2
0.15
0.1
0.05
0
J_{10} (N cm^{-3} s^{-1})
y = -0.0179x + 0.1983
R² = 0.2164
y = -0.0034x + 0.0947
R² = 0.0358
y = -0.0005x + 0.077
R² = 0.0008
0
1
2
3
4
5
6
7
Wind speed (m s^{-1})
GERRU
GERUB
GERRO

(o)

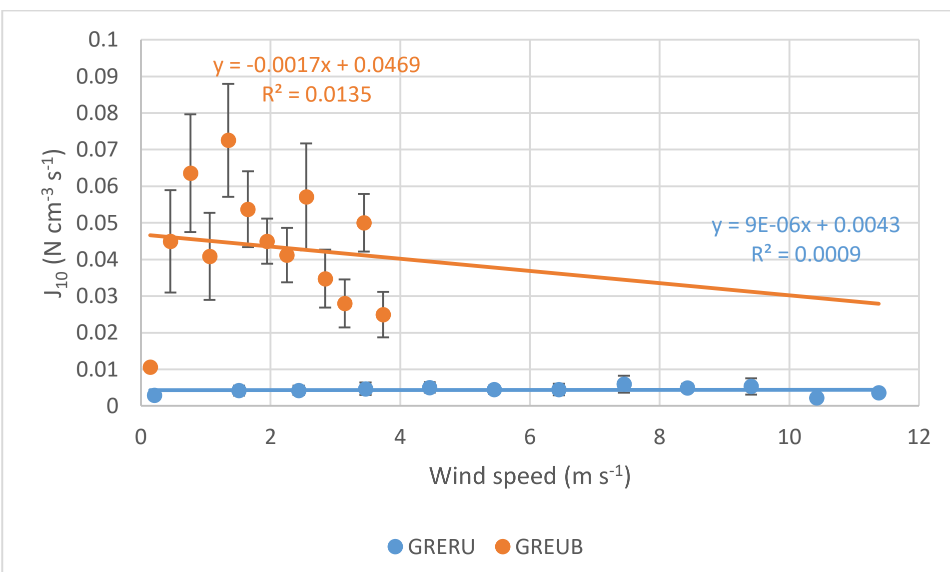

0.3
0.25
0.2
0.15
0.1
0.05
0
J_{10} (N cm^{-3} s^{-1})
y = -0.0113x + 0.1242
R² = 0.2234
y = -0.0024x + 0.036
R² = 0.1644
y = 0.0009x + 0.0086
R² = 0.069
0
1
2
3
4
5
6
7
8
Wind speed (m s^{-1})
FINRU
FINUB
FINRO

(p)



0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
J_{10} (N cm^{-3} s^{-1})
Wind speed (m s^{-1})
y = -0.0013x + 0.0236
R^2 = 0.0491
y = 0.0009x + 0.0146
R^2 = 0.0231
SPARU
SPAUB

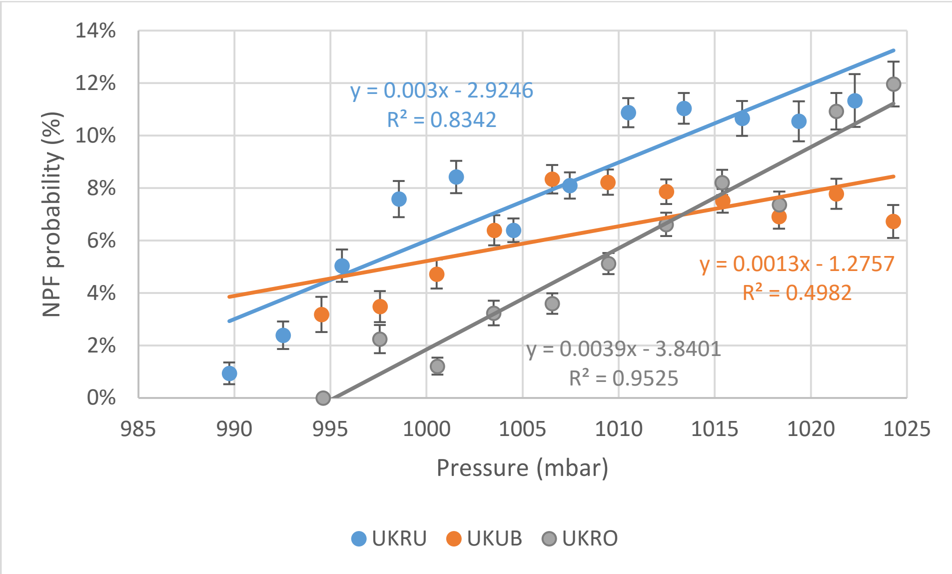
(q)



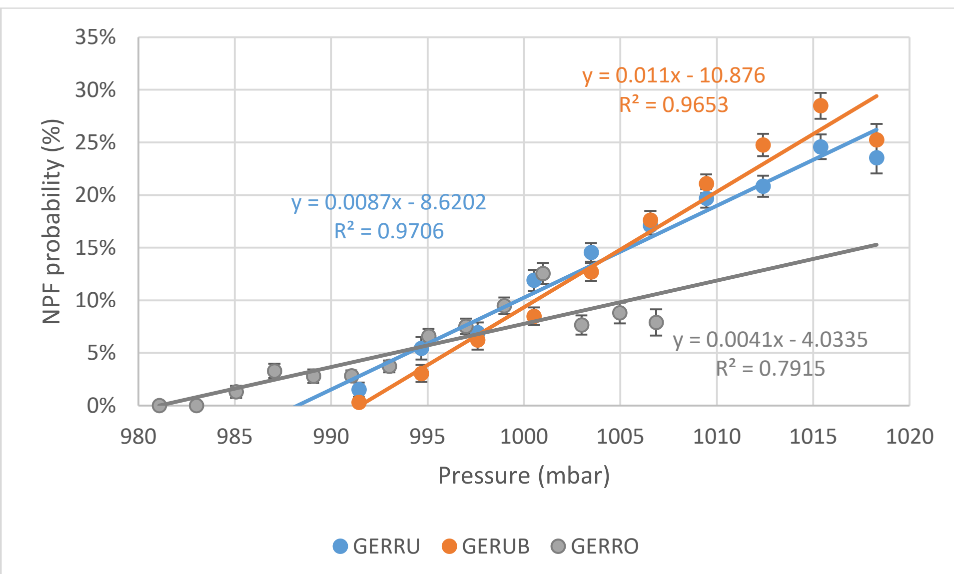
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12
J_{10} (N cm^{-3} s^{-1})
Wind speed (m s^{-1})
y = -0.0017x + 0.0469
R^2 = 0.0135
y = 9E-06x + 0.0043
R^2 = 0.0009
GRERU
GREUB

(r)

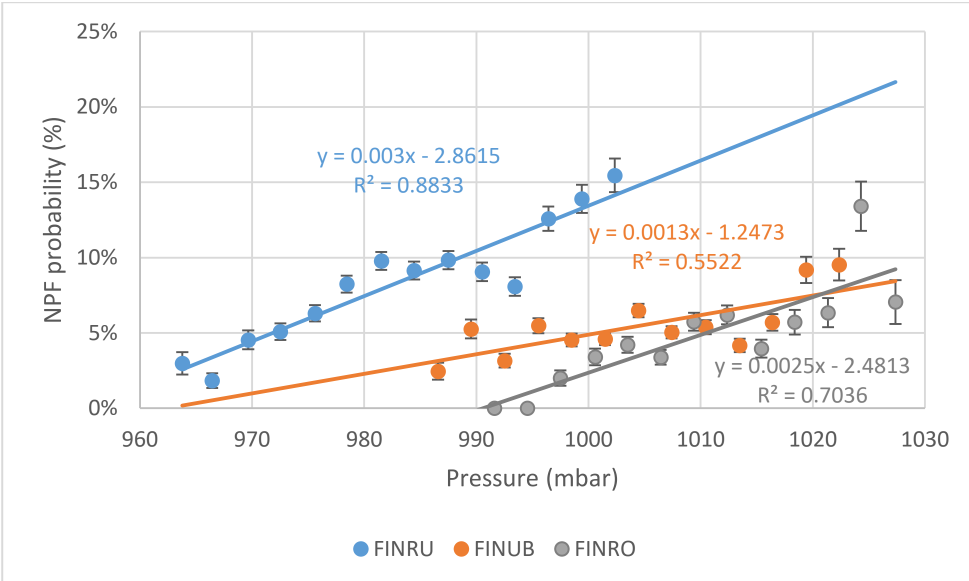
Figure S5: Relationship of atmospheric pressure with NPF variables.



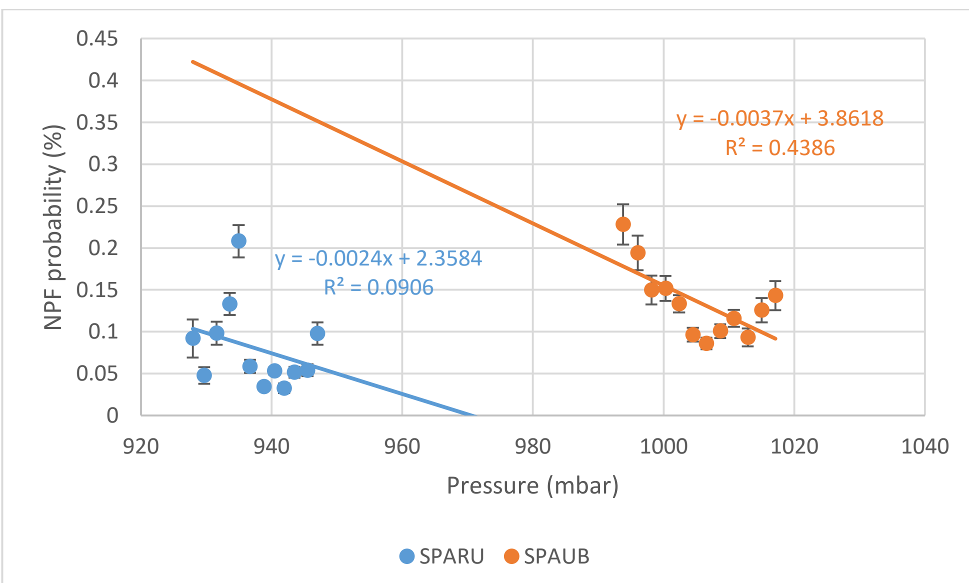
(a)



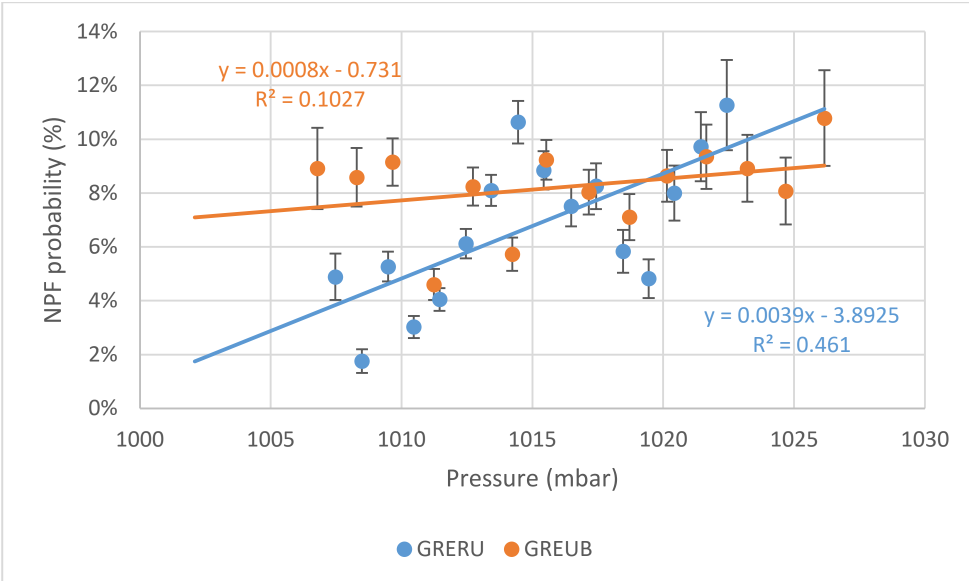
(b)


NPF probability (%)
25%
20%
15%
10%
5%
0%
960
970
980
990
1000
1010
1020
1030
Pressure (mbar)
y = 0.003x - 2.8615
R² = 0.8833
y = 0.0013x - 1.2473
R² = 0.5522
y = 0.0025x - 2.4813
R² = 0.7036
FINRU
FINUB
FINRO

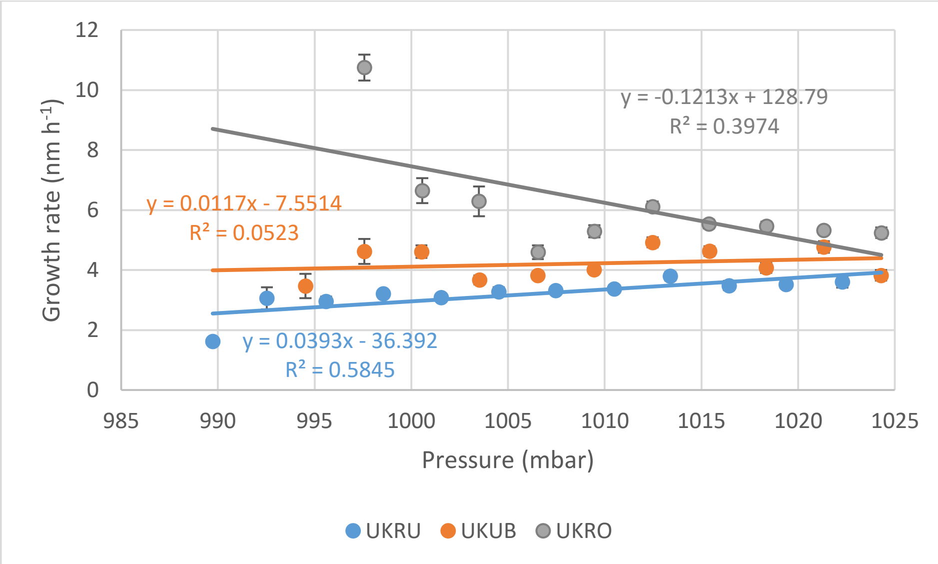
(c)


NPF probability (%)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
920
940
960
980
1000
1020
1040
Pressure (mbar)
y = -0.0037x + 3.8618
R² = 0.4386
y = -0.0024x + 2.3584
R² = 0.0906
SPARU
SPAUB

(d)

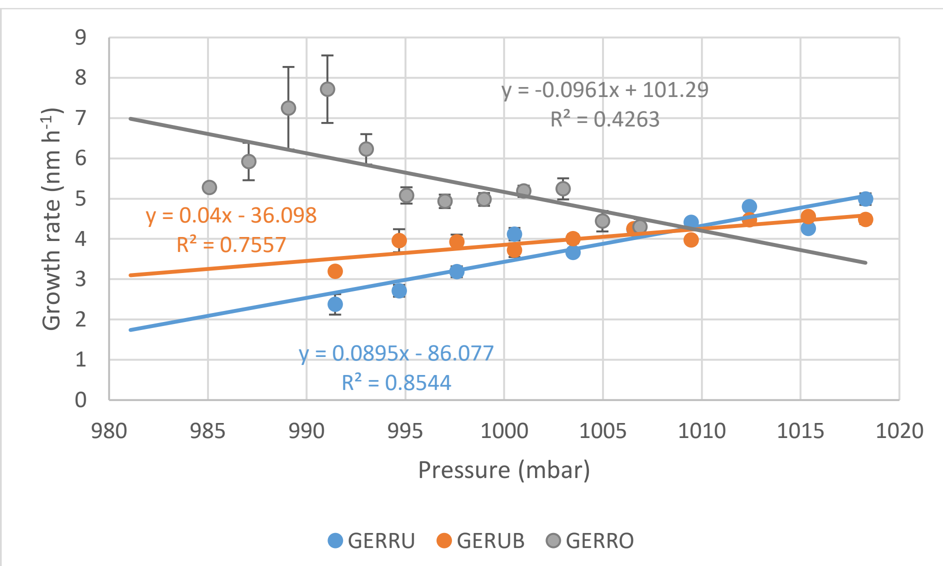

y = 0.0008x - 0.731
R² = 0.1027
y = 0.0039x - 3.8925
R² = 0.461
NPF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
GRERU
GREUB

(e)



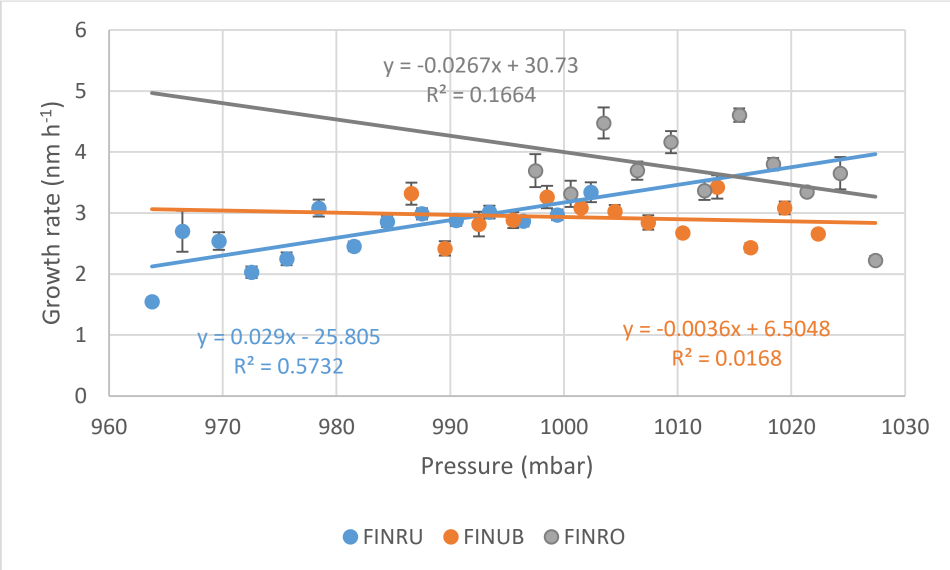
y = -0.1213x + 128.79
R² = 0.3974
y = 0.0117x - 7.5514
R² = 0.0523
y = 0.0393x - 36.392
R² = 0.5845
Growth rate (nm h-1)
Pressure (mbar)
0
2
4
6
8
10
12
985
990
995
1000
1005
1010
1015
1020
1025
UKRU
UKUB
UKRO

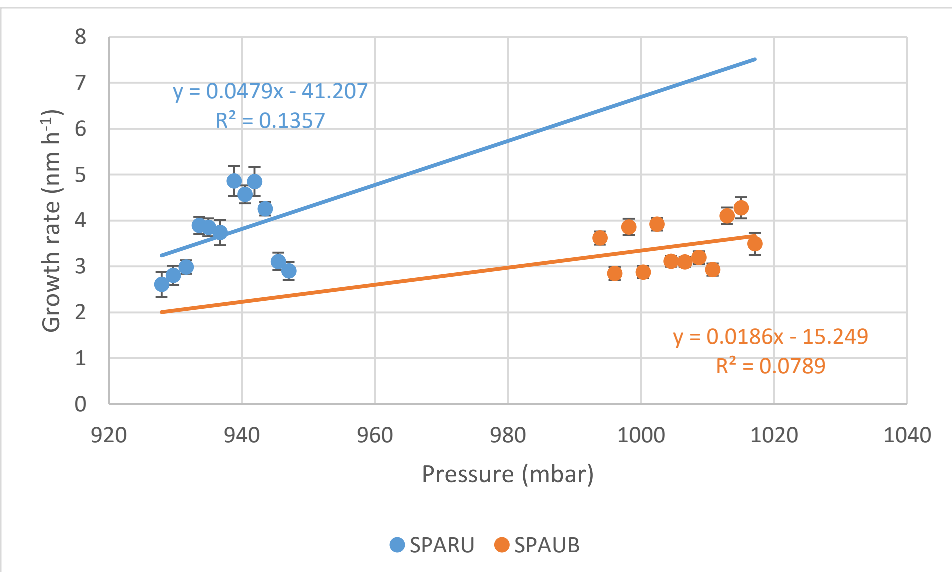
(f)

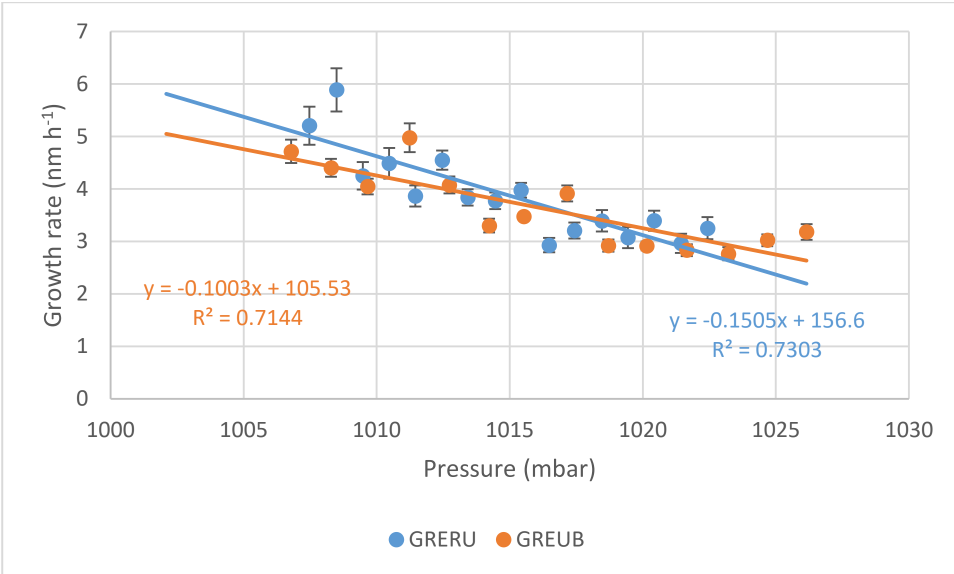


y = -0.0961x + 101.29
R² = 0.4263
y = 0.04x - 36.098
R² = 0.7557
y = 0.0895x - 86.077
R² = 0.8544
Growth rate (nm h-1)
Pressure (mbar)
0
1
2
3
4
5
6
7
8
9
980
985
990
995
1000
1005
1010
1015
1020
GERRU
GERUB
GERRO

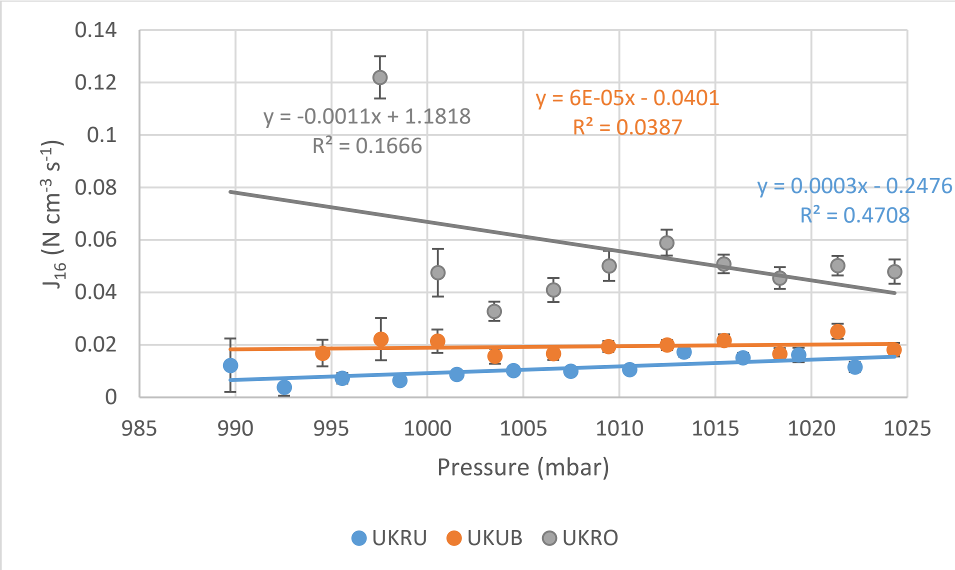
(g)


y = -0.0267x + 30.73
R² = 0.1664
y = 0.029x - 25.805
R² = 0.5732
y = -0.0036x + 6.5048
R² = 0.0168
Growth rate (nm h-1)
Pressure (mbar)
0
1
2
3
4
5
6
960
970
980
990
1000
1010
1020
1030
FINRU
FINUB
FINRO
(h)

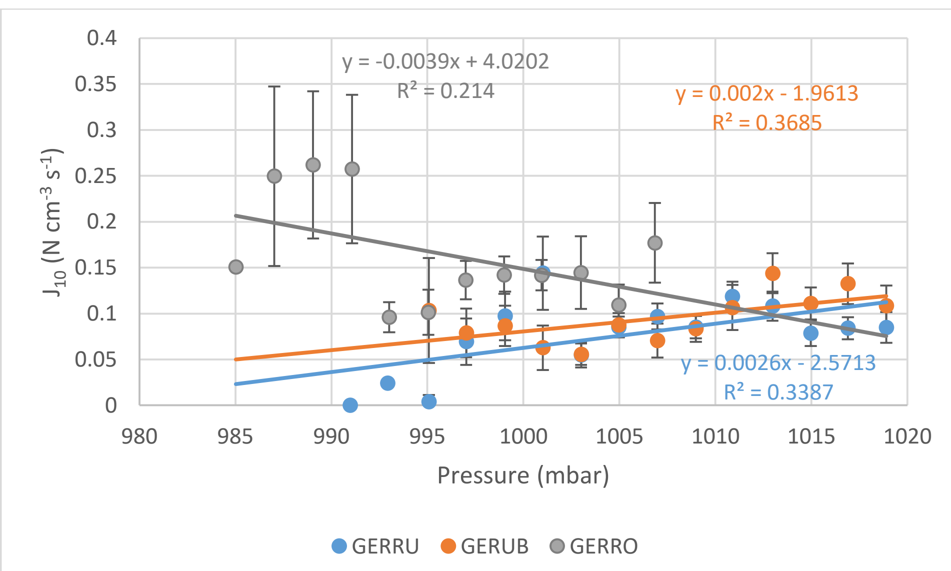

y = 0.0479x - 41.207
R² = 0.1357
y = 0.0186x - 15.249
R² = 0.0789
Growth rate (nm h-1)
Pressure (mbar)
0
1
2
3
4
5
6
7
8
920
940
960
980
1000
1020
1040
SPARU
SPAUB
(i)


Growth rate (nm h-1)
7
6
5
4
3
2
1
0
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
y = -0.1003x + 105.53
R² = 0.7144
y = -0.1505x + 156.6
R² = 0.7303
GRERU
GREUB

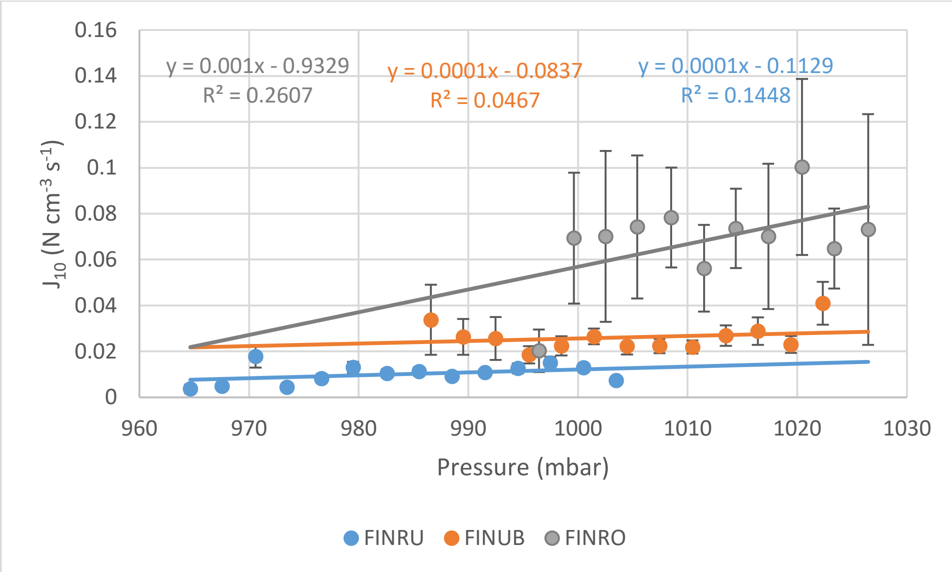
(j)


y = -0.0011x + 1.1818
R² = 0.1666
y = 6E-05x - 0.0401
R² = 0.0387
y = 0.0003x - 0.2476
R² = 0.4708
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
985
990
995
1000
1005
1010
1015
1020
1025
J16 (N cm-3 s-1)
Pressure (mbar)
UKRU
UKUB
UKRO

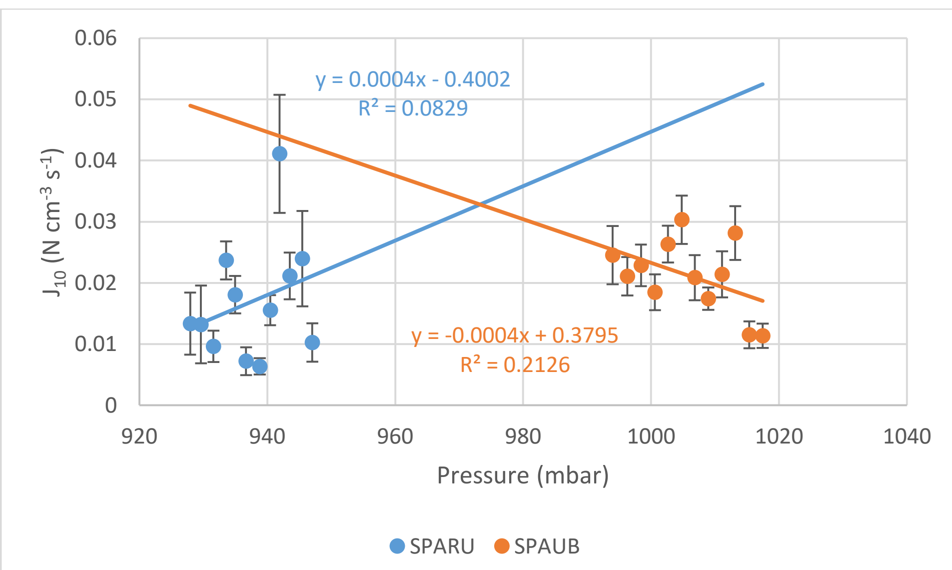
(k)


y = -0.0039x + 4.0202
R² = 0.214
y = 0.002x - 1.9613
R² = 0.3685
y = 0.0026x - 2.5713
R² = 0.3387
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
980
985
990
995
1000
1005
1010
1015
1020
J10 (N cm-3 s-1)
Pressure (mbar)
GERRU
GERUB
GERRO

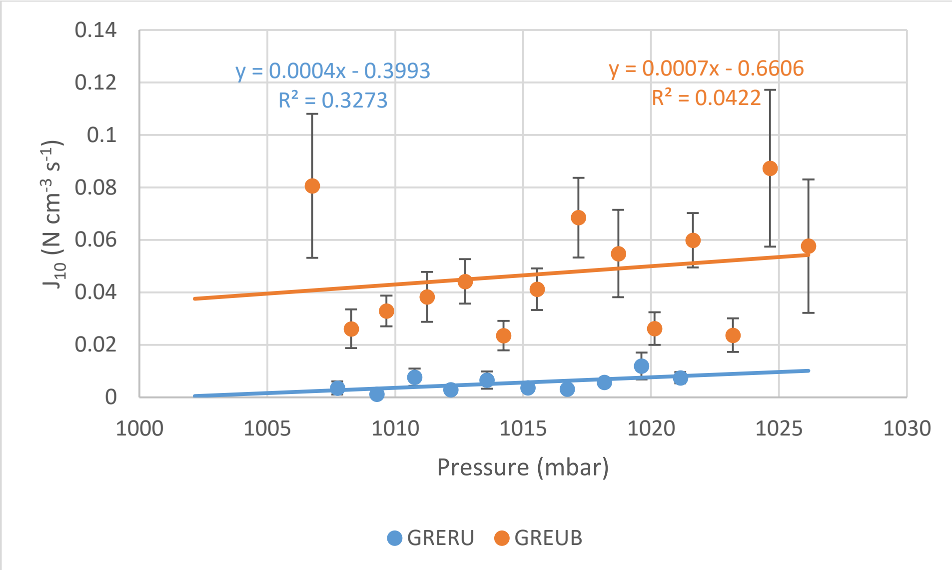
(l)


y = 0.001x - 0.9329
R² = 0.2607
y = 0.0001x - 0.0837
R² = 0.0467
y = 0.0001x - 0.1129
R² = 0.1448
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
960
970
980
990
1000
1010
1020
1030
Pressure (mbar)
FINRU
FINUB
FINRO

(m)

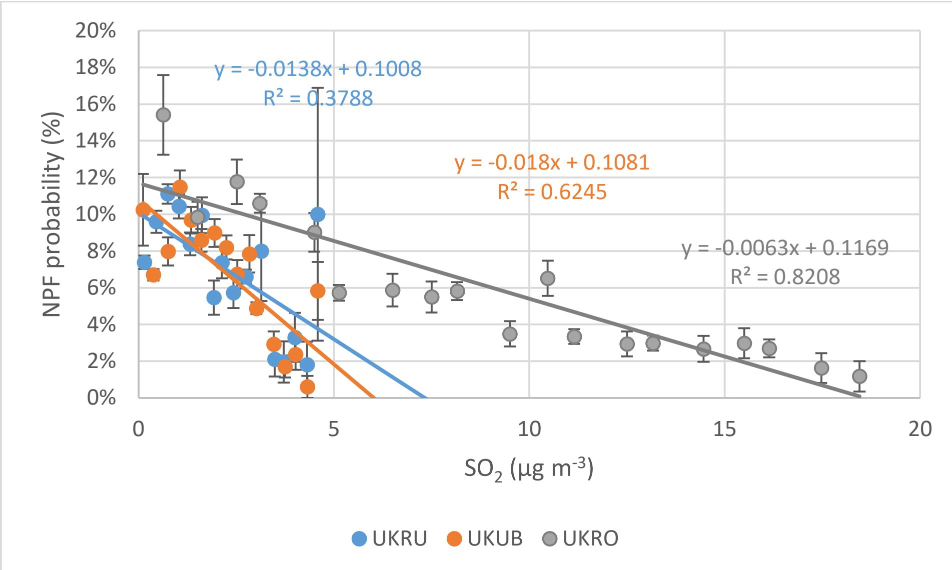

y = 0.0004x - 0.4002
R² = 0.0829
y = -0.0004x + 0.3795
R² = 0.2126
0.06
0.05
0.04
0.03
0.02
0.01
0
J10 (N cm-3 s-1)
920
940
960
980
1000
1020
1040
Pressure (mbar)
SPARU
SPAUB

(n)

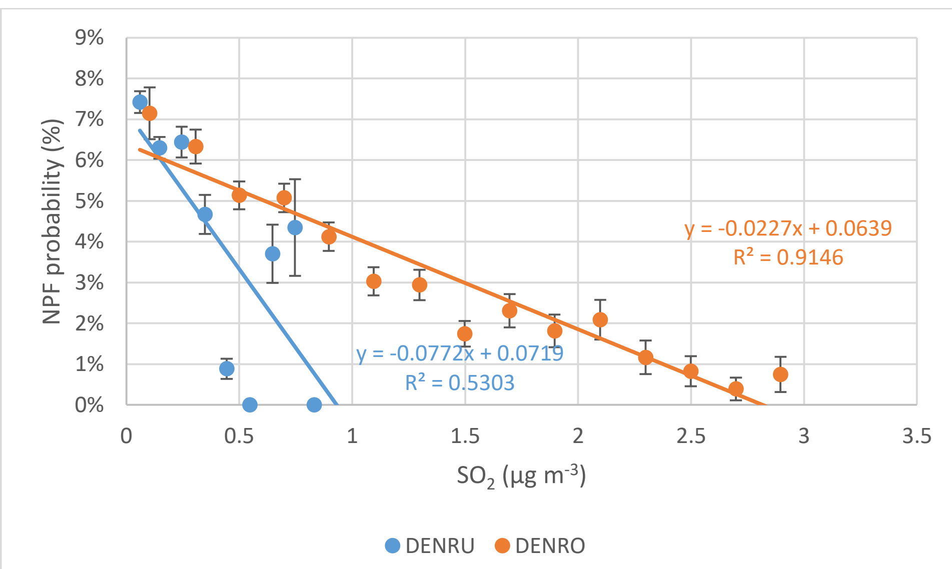

y = 0.0004x - 0.3993
R² = 0.3273
y = 0.0007x - 0.6606
R² = 0.0422
J10 (N cm-3 s-1)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
GRERU
GREUB

(o)

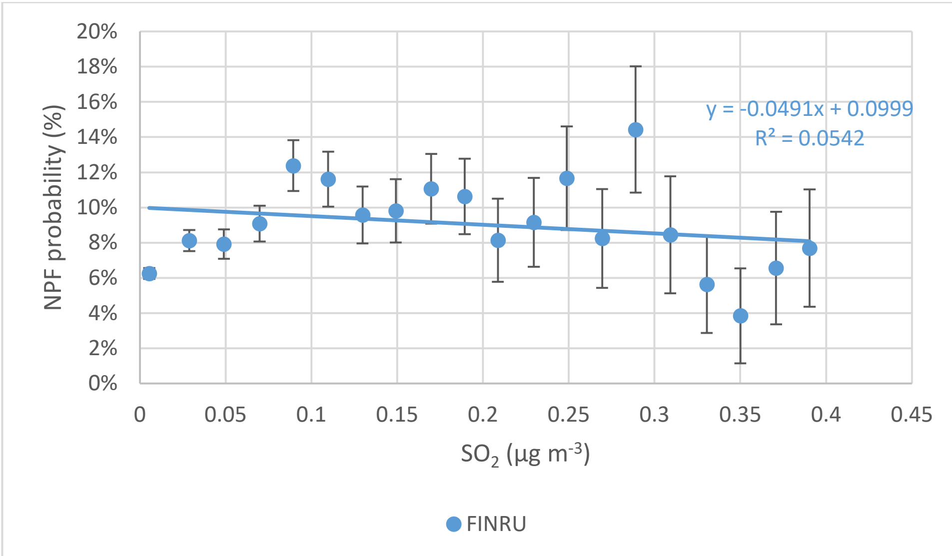
Figure S6: Relationship of SO_2 concentration with NPF variables.



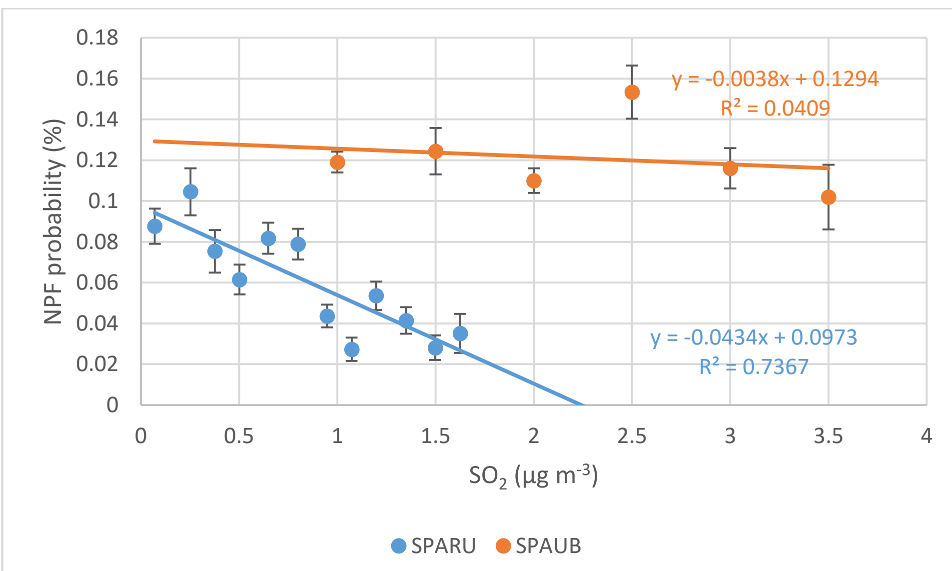
(a)



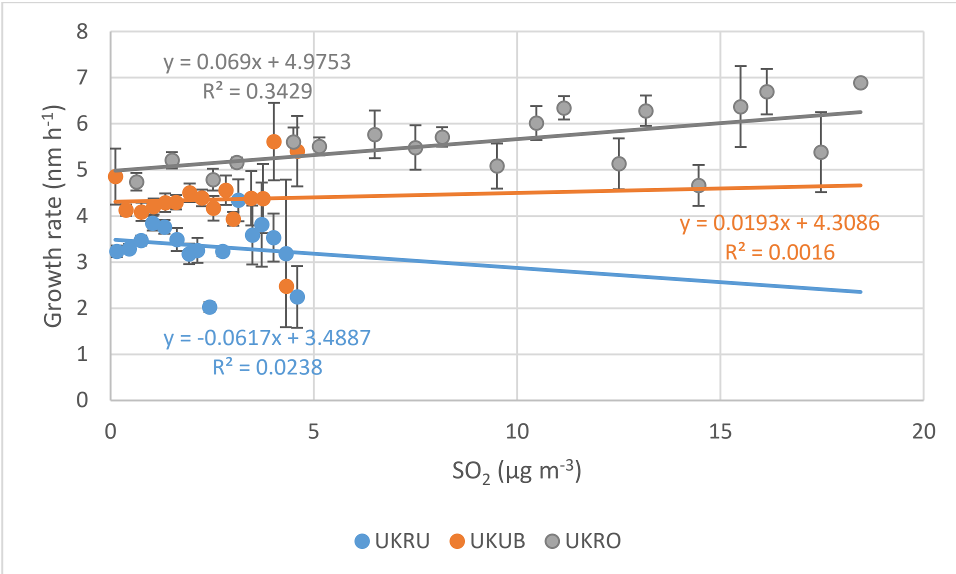
(b)


20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
NPF probability (%)
SO2 (µg m-3)
y = -0.0491x + 0.0999
R² = 0.0542
FINRU

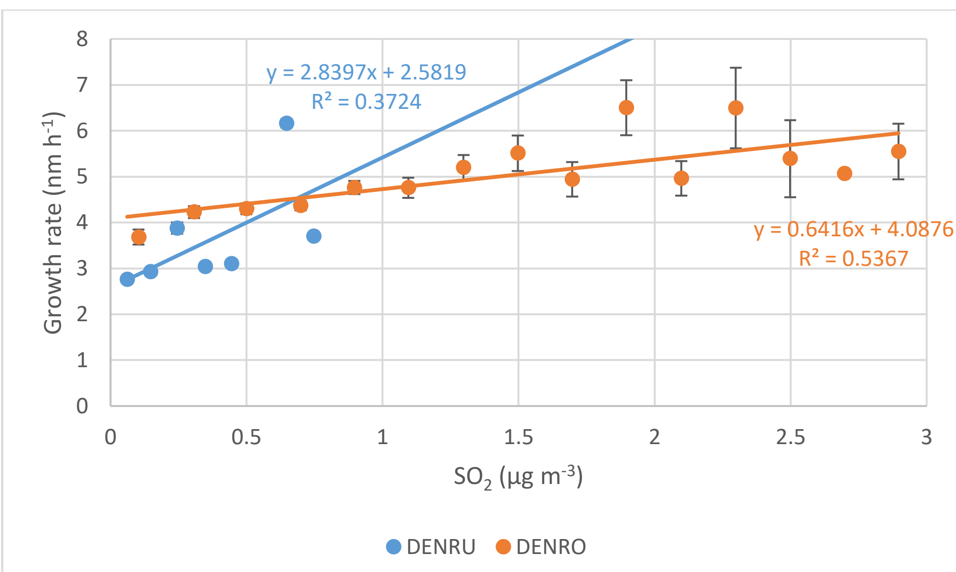
(c)


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
3.5
4
NPF probability (%)
SO2 (µg m-3)
y = -0.0038x + 0.1294
R² = 0.0409
y = -0.0434x + 0.0973
R² = 0.7367
SPARU
SPAUB

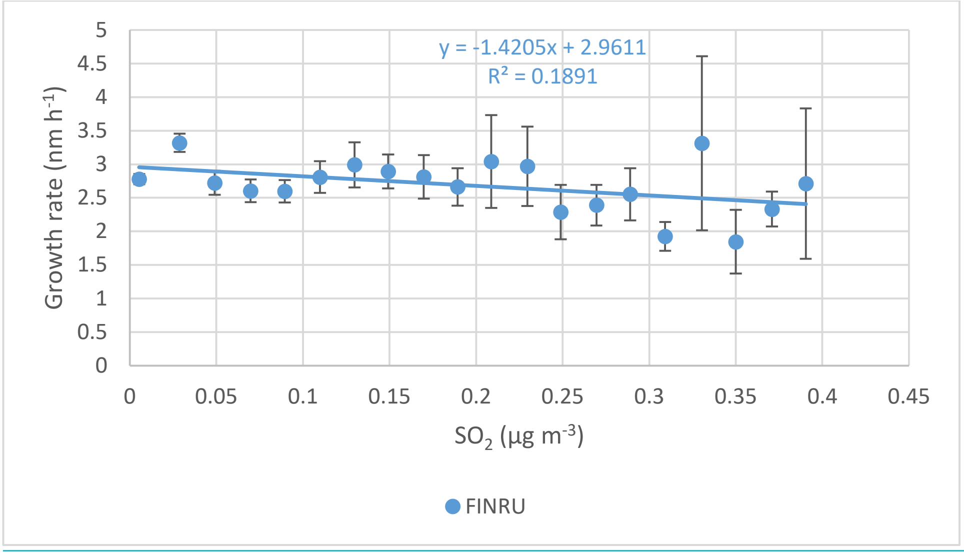
(d)


y = 0.069x + 4.9753
R² = 0.3429
y = 0.0193x + 4.3086
R² = 0.0016
y = -0.0617x + 3.4887
R² = 0.0238
Growth rate (nm h-1)
SO2 (µg m-3)
0
5
10
15
20
1
2
3
4
6
7
8
UKRU
UKUB
UKRO

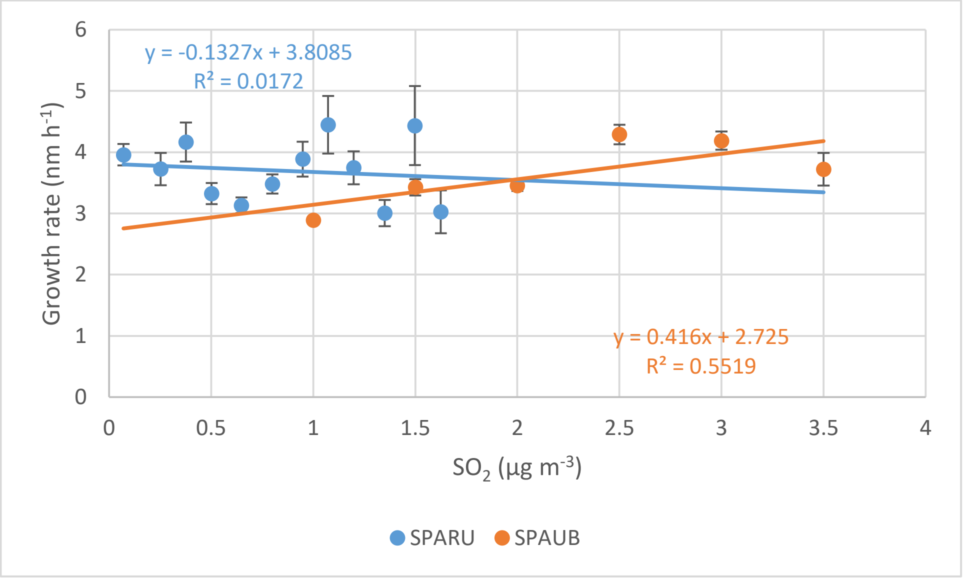
(e)


y = 2.8397x + 2.5819
R² = 0.3724
y = 0.6416x + 4.0876
R² = 0.5367
Growth rate (nm h-1)
SO2 (µg m-3)
0
0.5
1
1.5
2
2.5
3
4
5
6
7
8
DENRU
DENRO

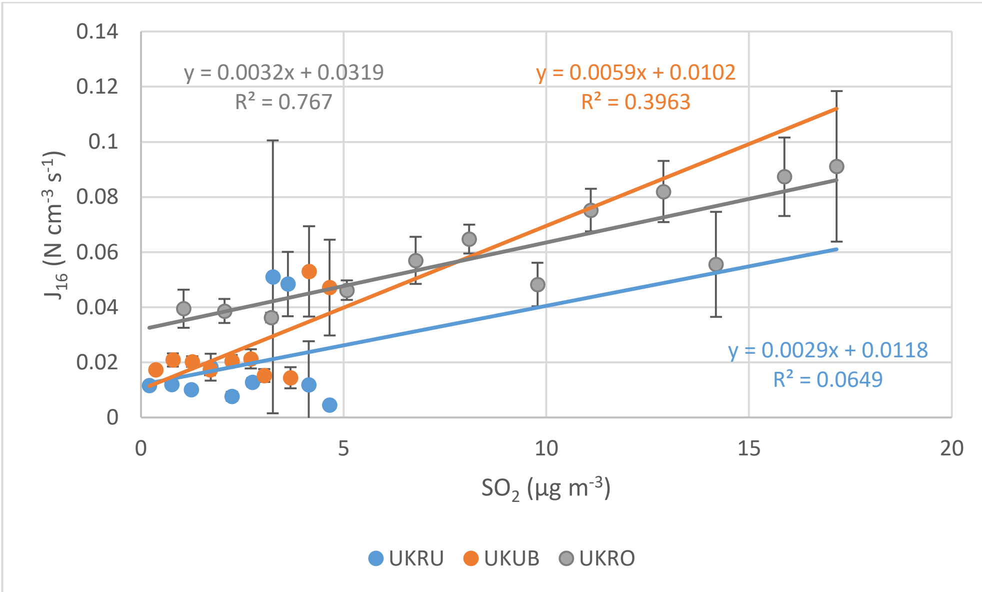
(f)


y = -1.4205x + 2.9611
R² = 0.1891
Growth rate (nm h-1)
SO2 (μg m-3)
FINRU

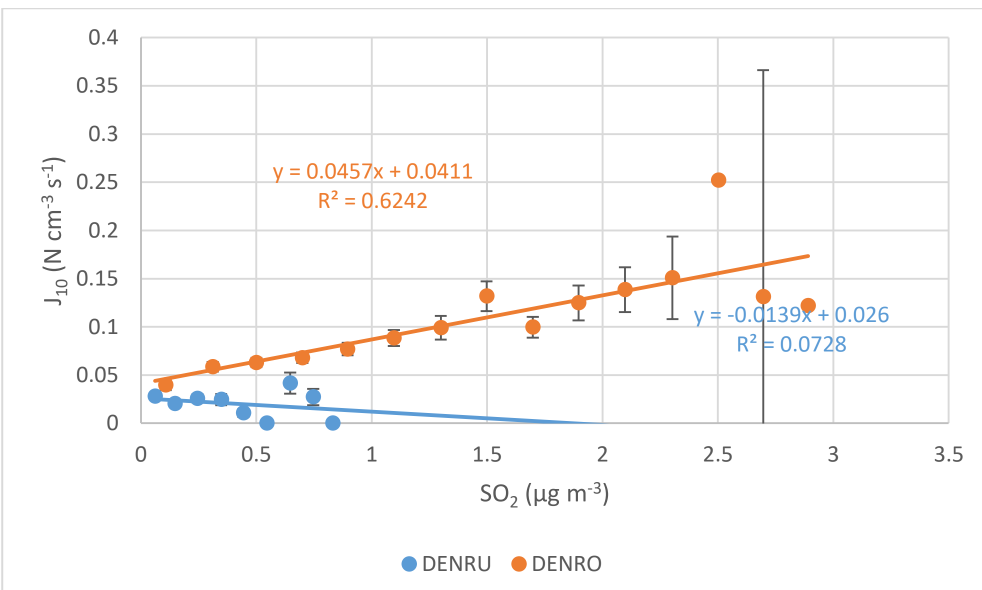
(g)


y = -0.1327x + 3.8085
R² = 0.0172
y = 0.416x + 2.725
R² = 0.5519
Growth rate (nm h-1)
SO2 (μg m-3)
SPARU
SPAUB

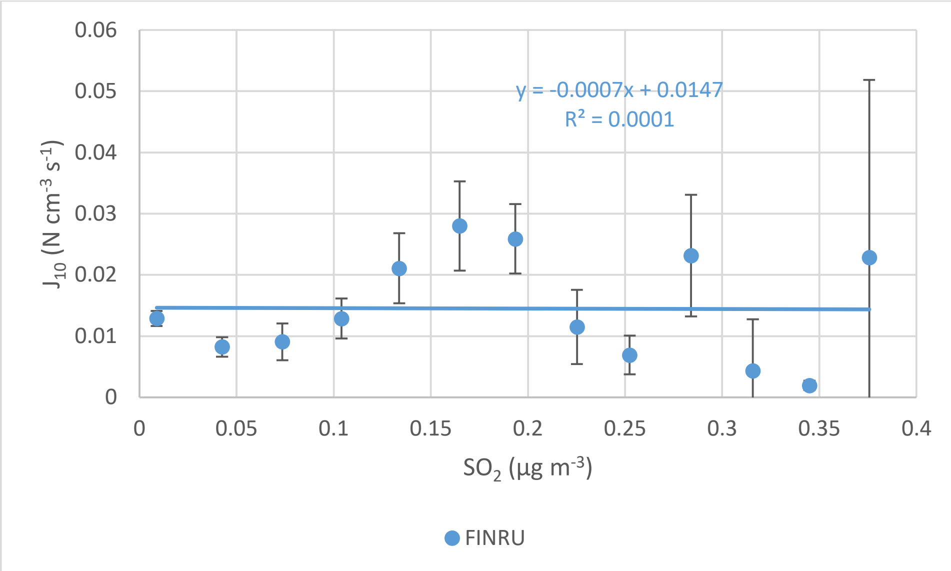
(h)


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J16 (N cm-3 s-1)
y = 0.0032x + 0.0319
R² = 0.767
y = 0.0059x + 0.0102
R² = 0.3963
y = 0.0029x + 0.0118
R² = 0.0649
0
5
10
15
20
SO2 (µg m-3)
UKRU
UKUB
UKRO

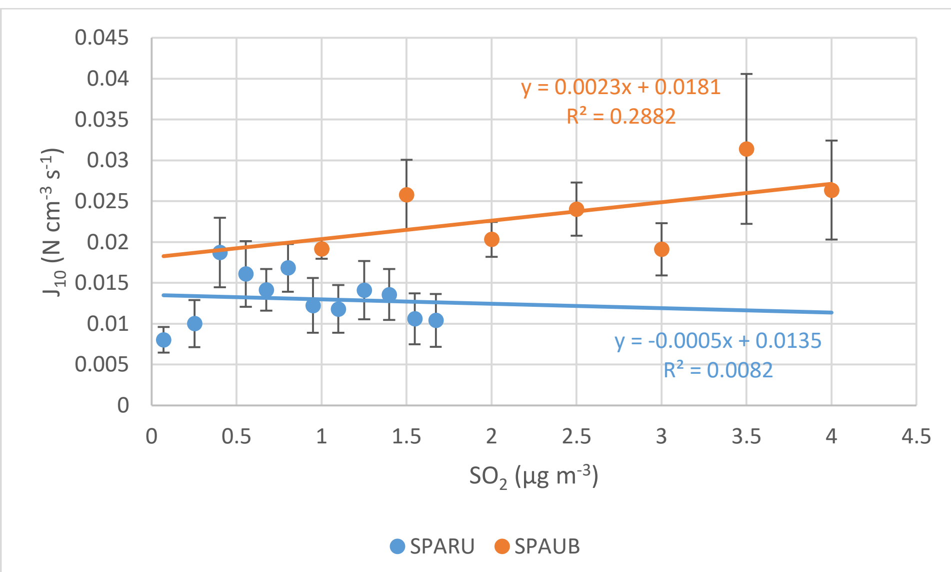
(i)


0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
J10 (N cm-3 s-1)
y = 0.0457x + 0.0411
R² = 0.6242
y = -0.0139x + 0.026
R² = 0.0728
0
0.5
1
1.5
2
2.5
3
3.5
SO2 (µg m-3)
DENRU
DENRO

(j)

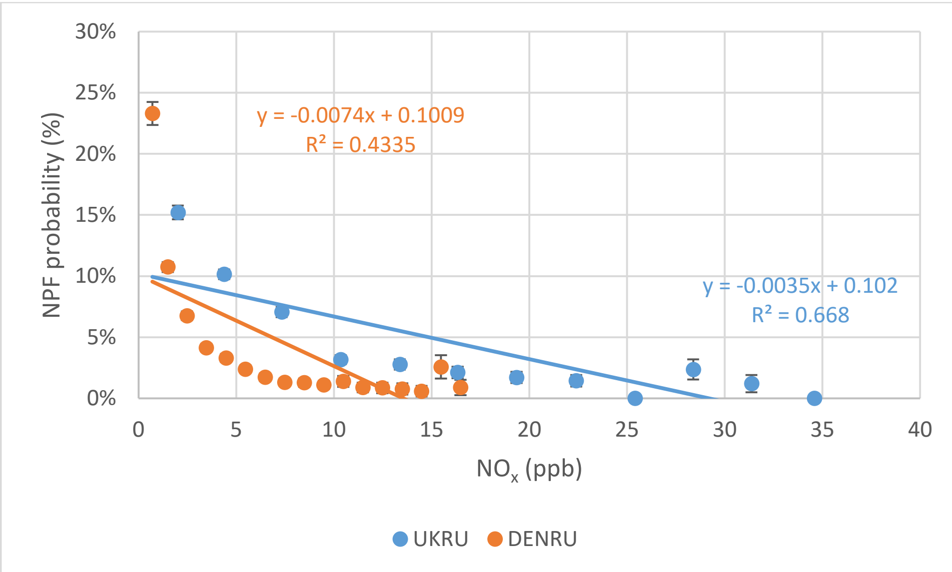

0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
J10 (N cm-3 s-1)
SO2 (µg m-3)
y = -0.0007x + 0.0147
R² = 0.0001
FINRU

(k)

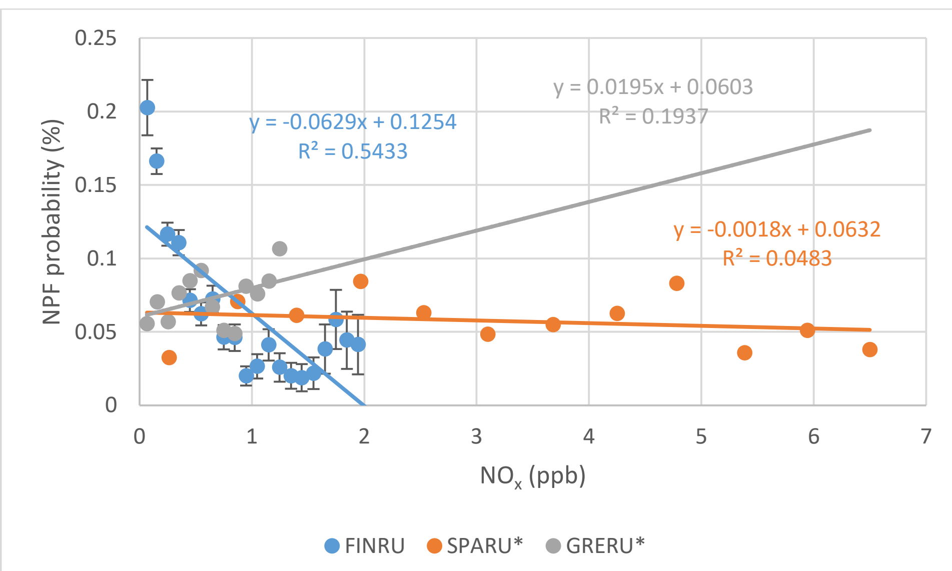

0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
J10 (N cm-3 s-1)
SO2 (µg m-3)
y = 0.0023x + 0.0181
R² = 0.2882
y = -0.0005x + 0.0135
R² = 0.0082
SPARU
SPAUB

(l)

Figure S7: Relationship of NO_2 / NO_x concentration with NPF variables.

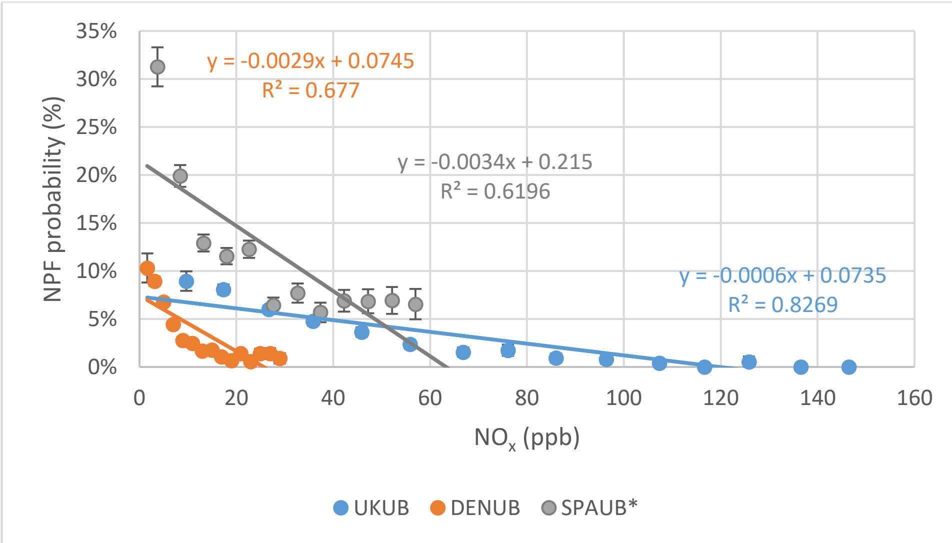


(a)



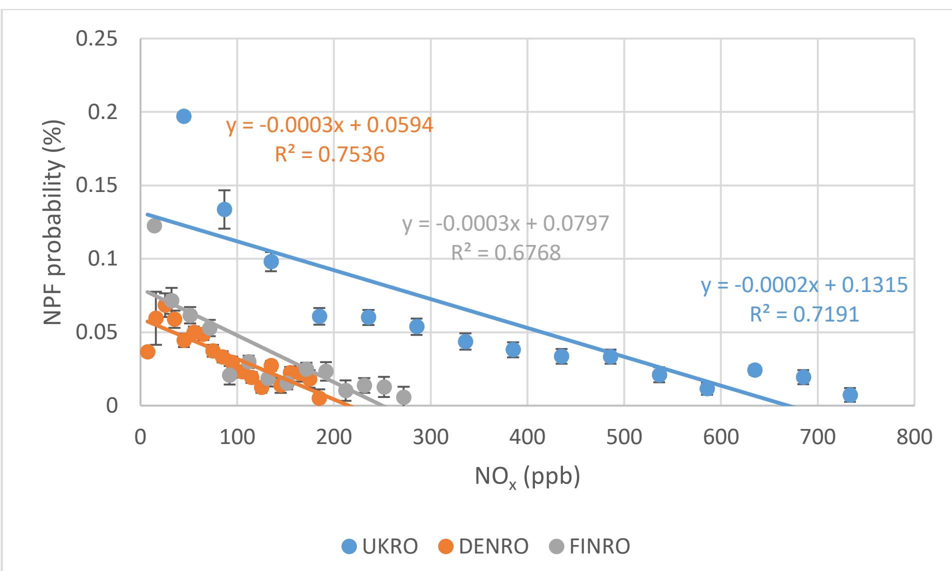
(b)

***NO_2 for SPARU and GRERU**

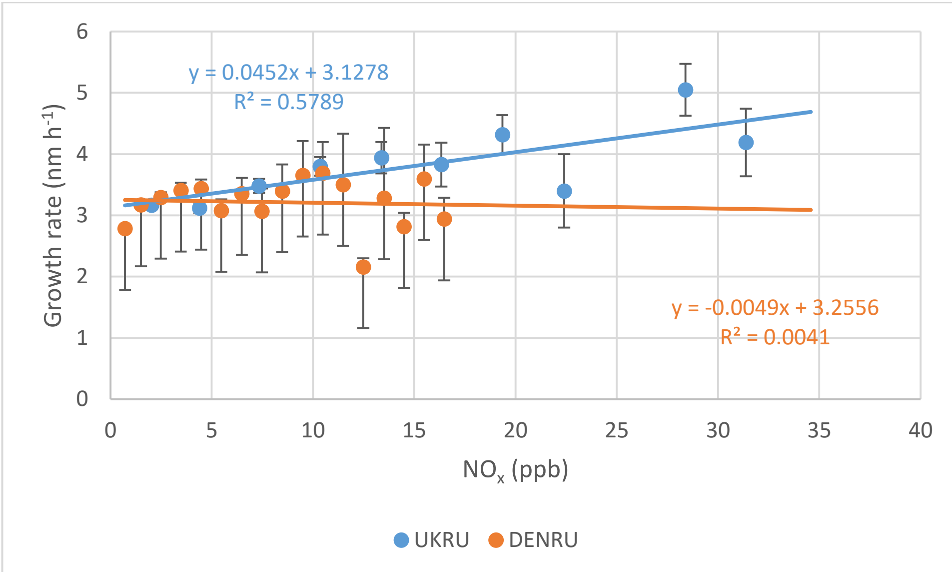


(c)

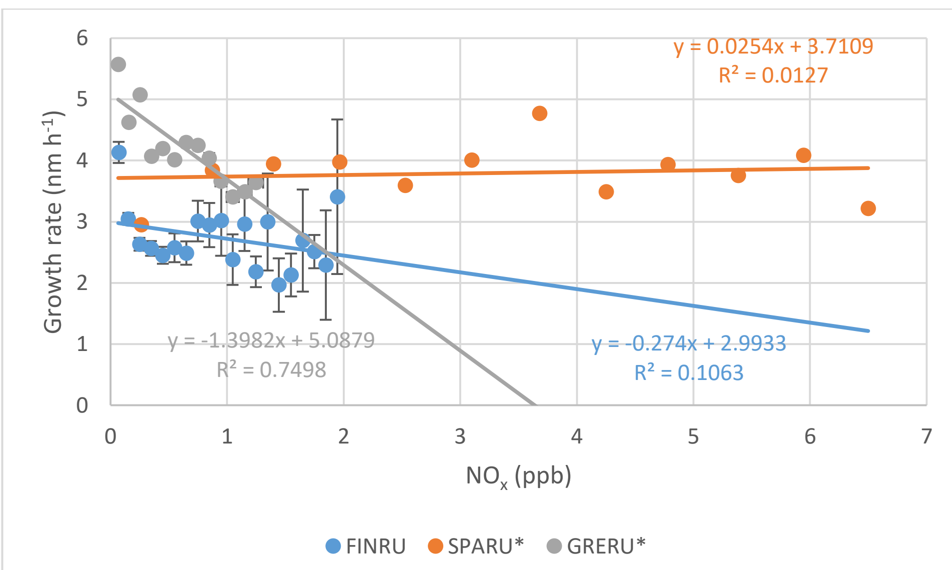
***NO_2 for SPAUB**



(d)

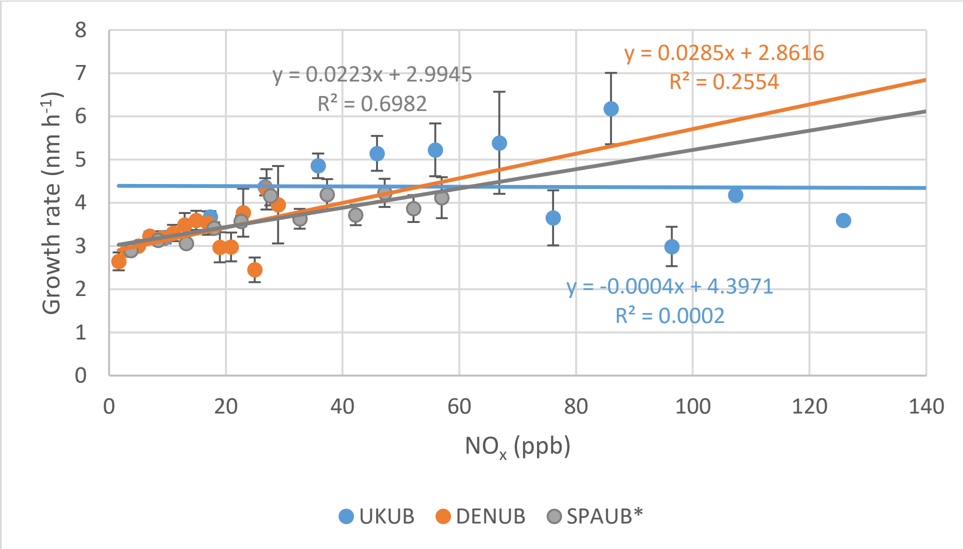


(e)



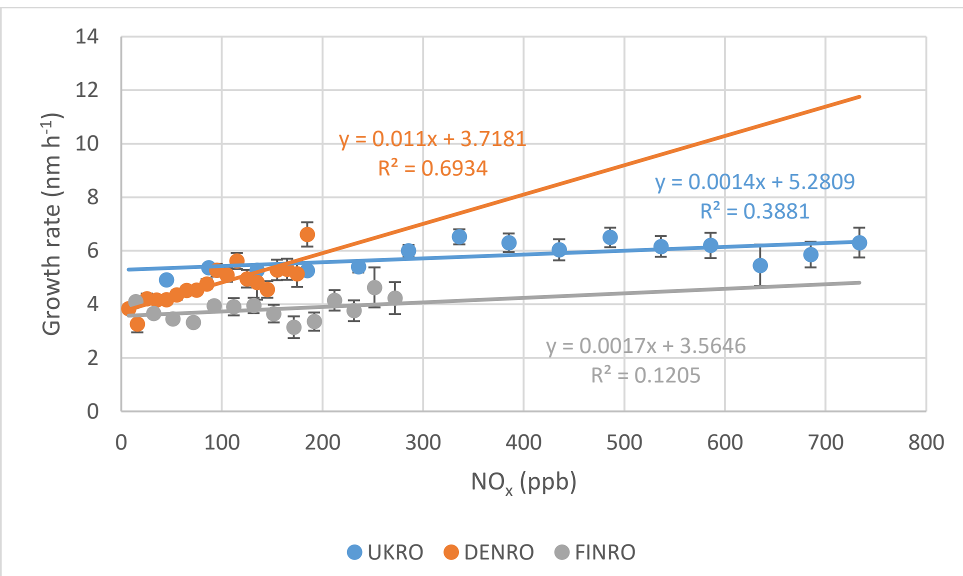
(f)

*NO_2 for SPARU and GRERU

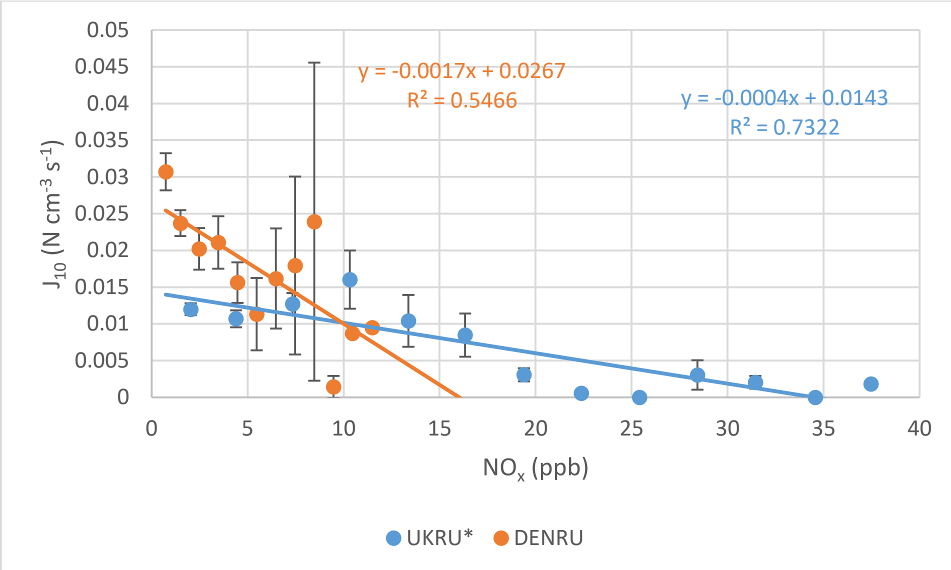


(g)

***NO_2 for SPAUB**

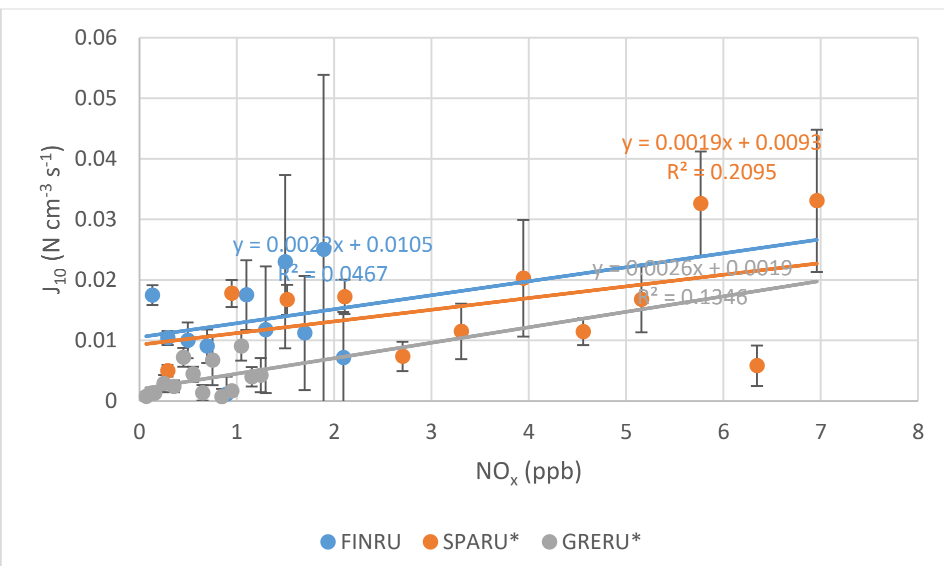


(h)



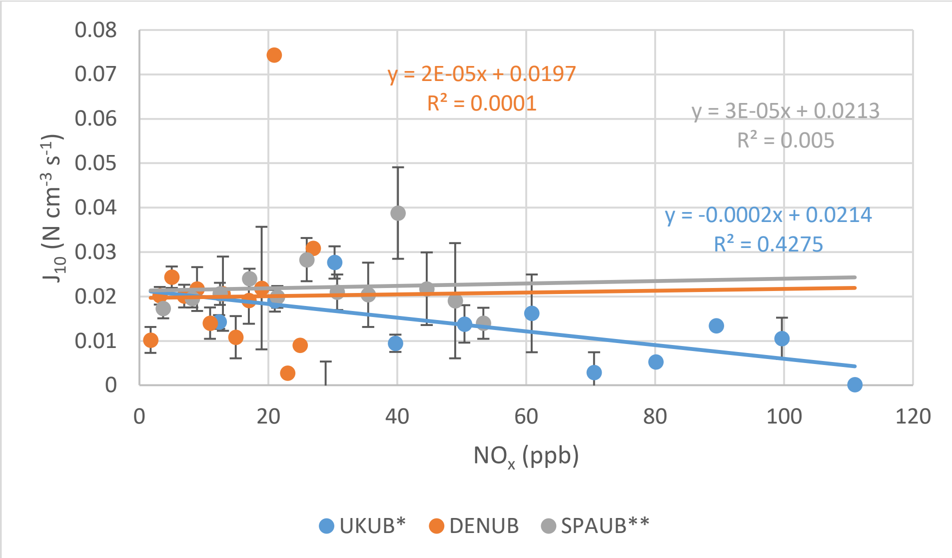
(i)

***J16 for UKRU**



(j)

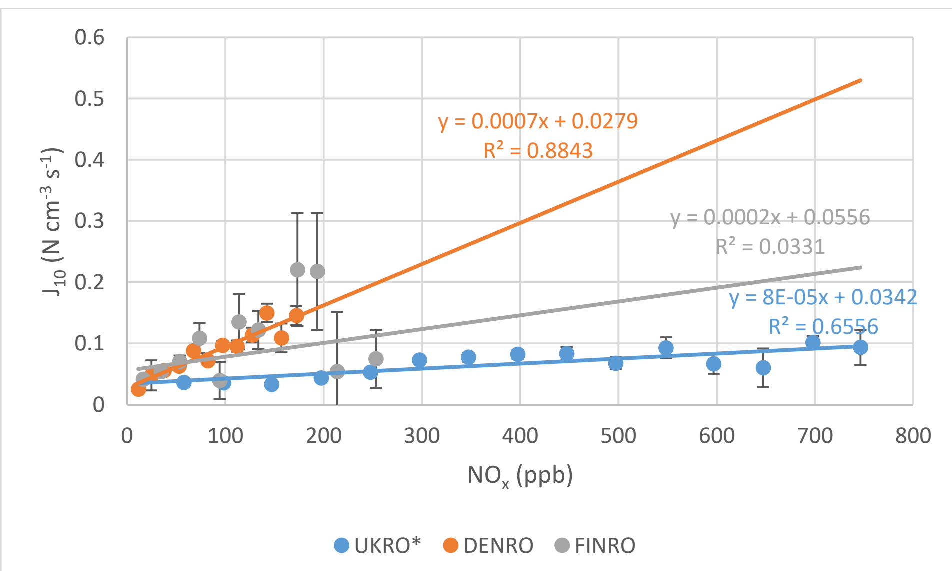
***NO_2 for SPARU and GRERU**



(k)

J_{16} for UKUB

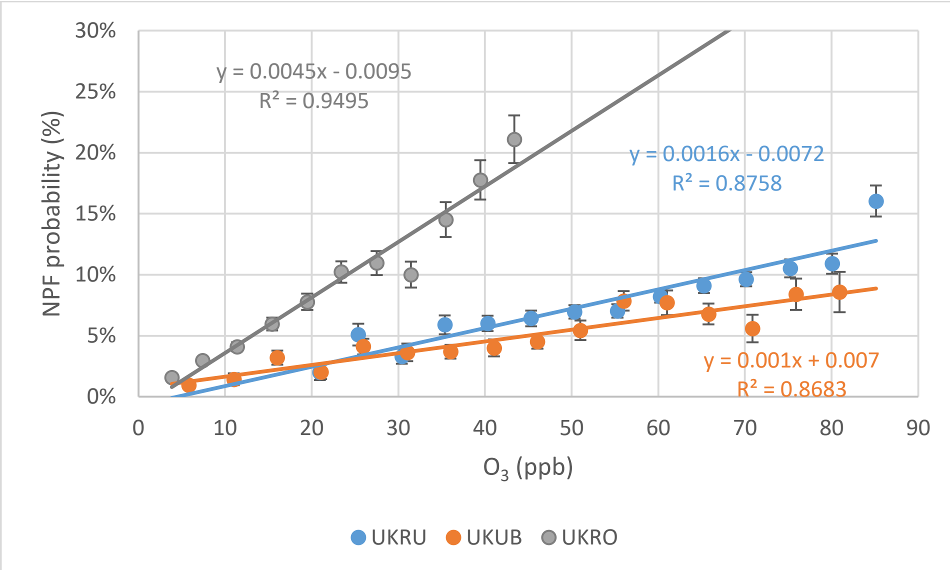
***** NO_2 for SPAUB**



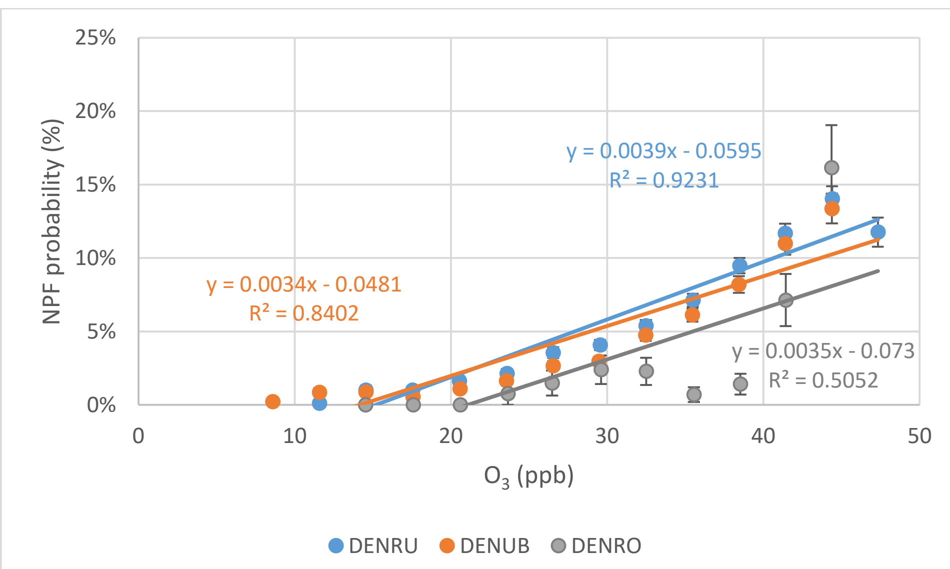
(l)

J_{16} for UKRO

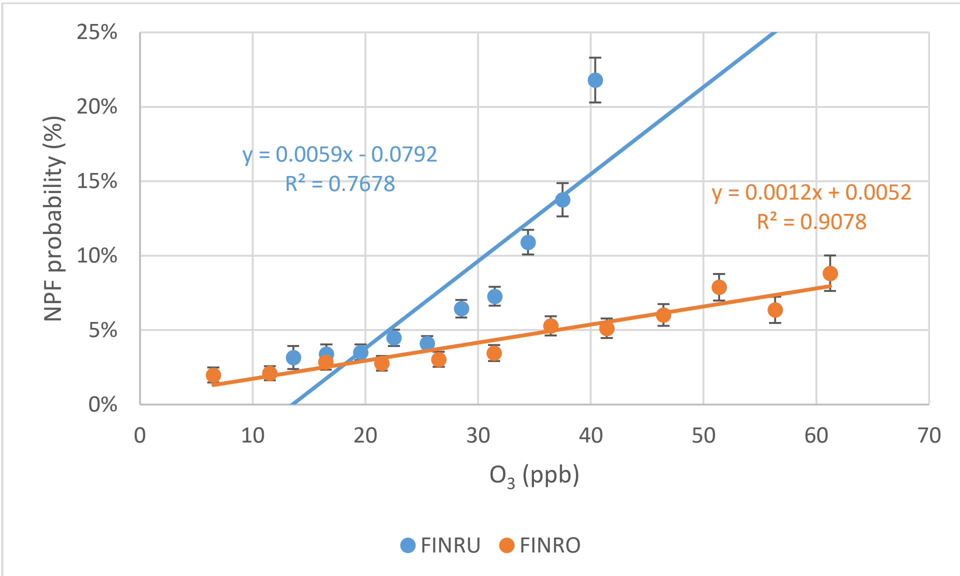
Figure S8: Relationship of O_3 concentration with NPF variables.



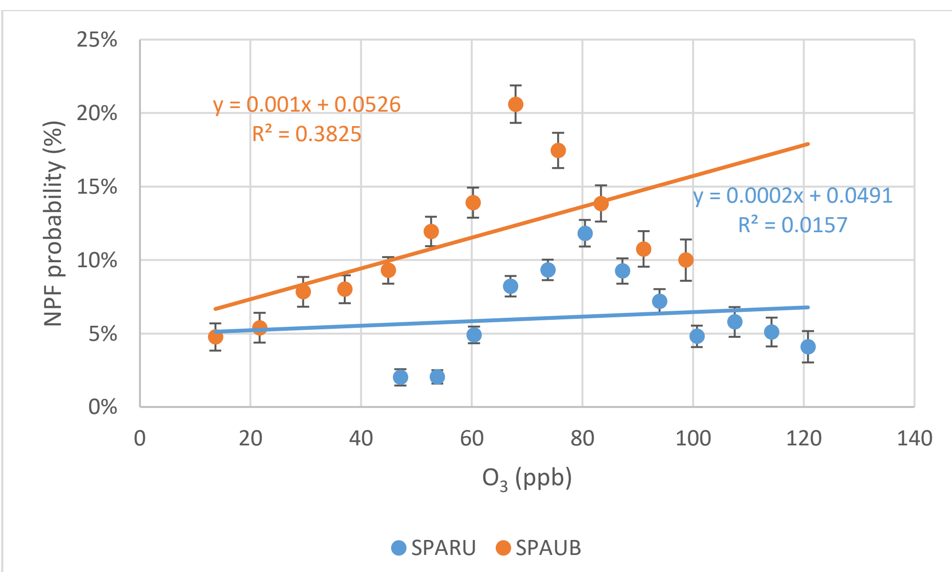
(a)



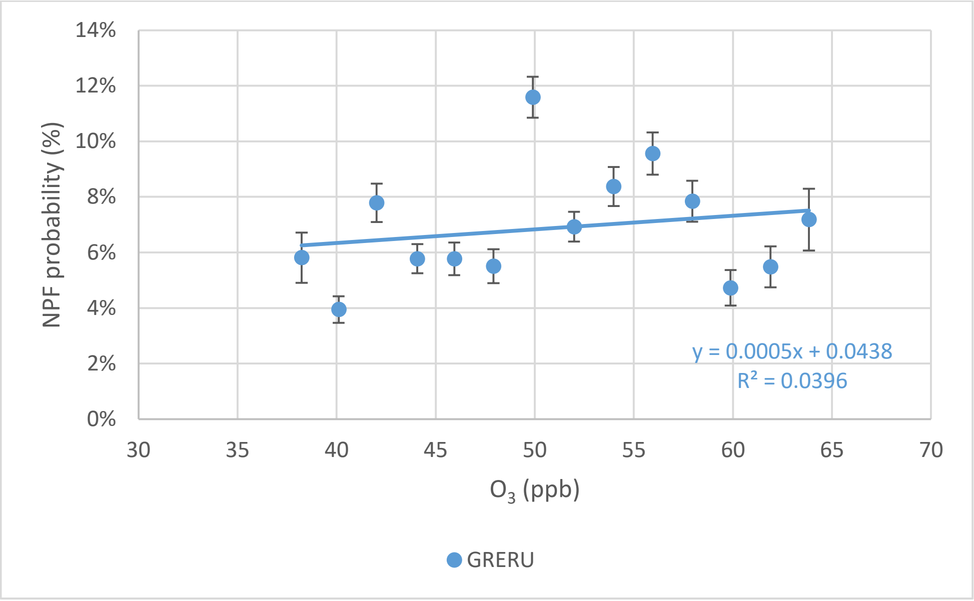
(b)


25%
20%
15%
10%
5%
0%
0
10
20
30
40
50
60
70
NPF probability (%)
O3 (ppb)
y = 0.0059x - 0.0792
R² = 0.7678
y = 0.0012x + 0.0052
R² = 0.9078
FINRU
FINRO

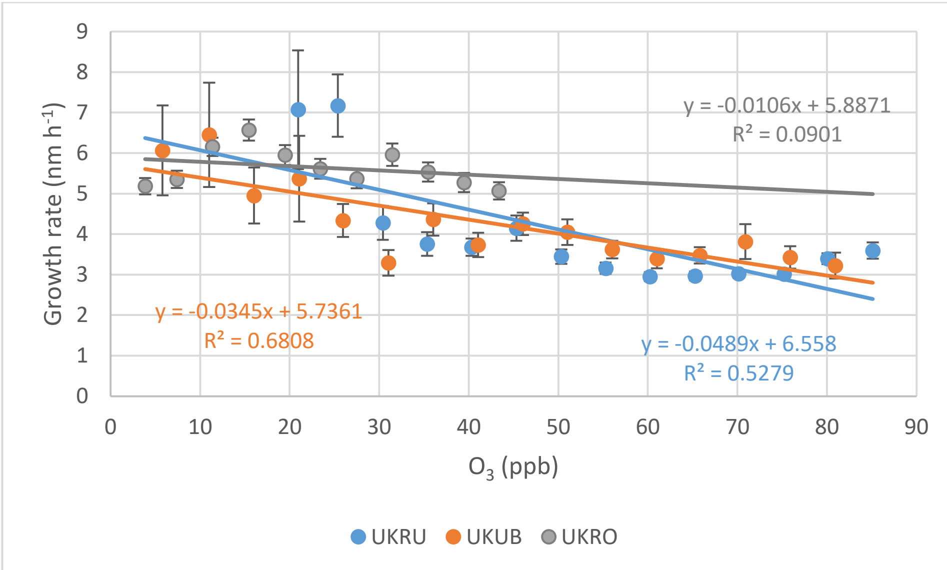
(c)


25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
140
NPF probability (%)
O3 (ppb)
y = 0.001x + 0.0526
R² = 0.3825
y = 0.0002x + 0.0491
R² = 0.0157
SPARU
SPAUB

(d)

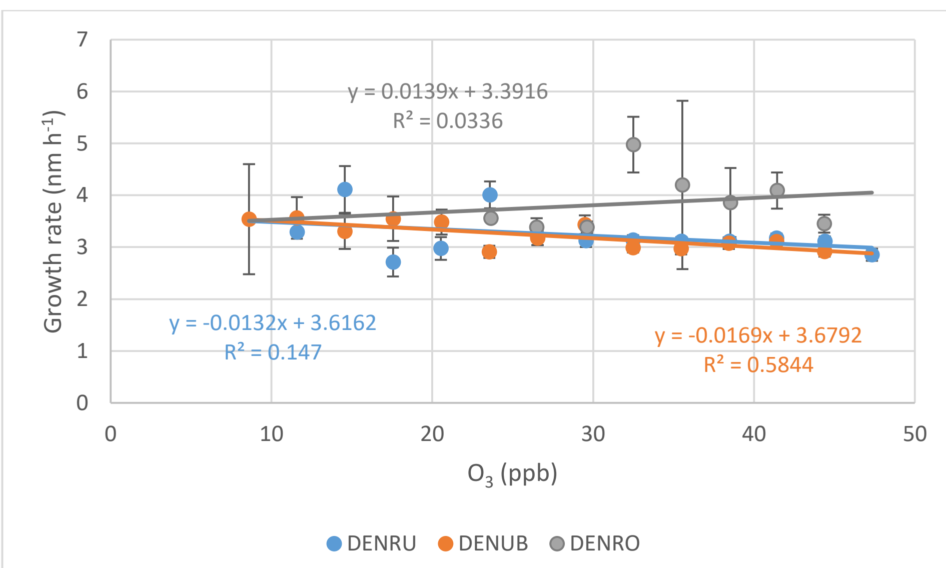

14%
12%
10%
8%
6%
4%
2%
0%
30
35
40
45
50
55
60
65
70
NPF probability (%)
O_3 (ppb)
y = 0.0005x + 0.0438
R^2 = 0.0396
GRERU

(e)



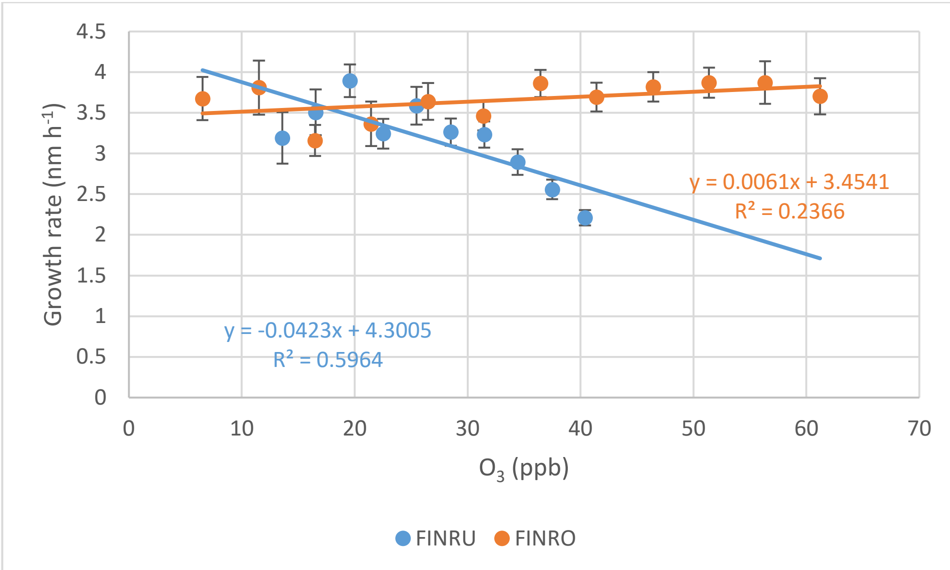
Growth rate (nm h-1)
O3 (ppb)
y = -0.0106x + 5.8871
R² = 0.0901
y = -0.0345x + 5.7361
R² = 0.6808
y = -0.0489x + 6.558
R² = 0.5279
UKRU
UKUB
UKRO

(f)

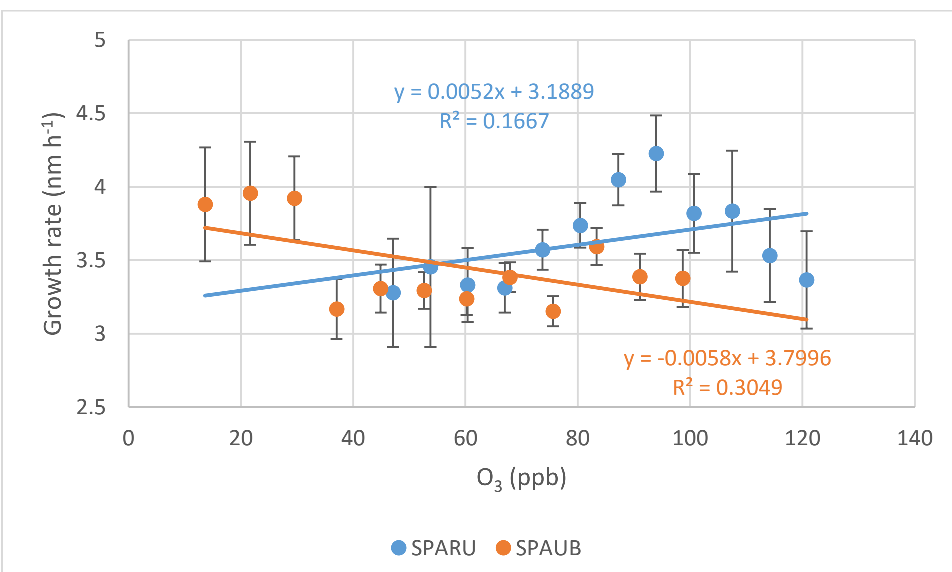


Growth rate (nm h-1)
O3 (ppb)
y = 0.0139x + 3.3916
R² = 0.0336
y = -0.0132x + 3.6162
R² = 0.147
y = -0.0169x + 3.6792
R² = 0.5844
DENRU
DENUB
DENRO

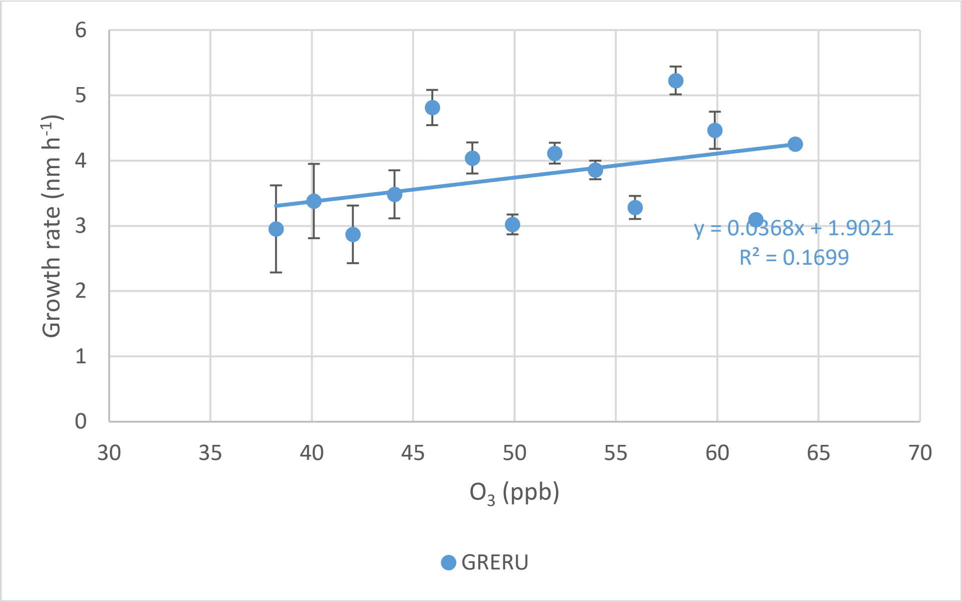
(g)


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Growth rate (nm h-1)
0
10
20
30
40
50
60
70
O3 (ppb)
y = 0.0061x + 3.4541
R² = 0.2366
y = -0.0423x + 4.3005
R² = 0.5964
FINRU
FINRO

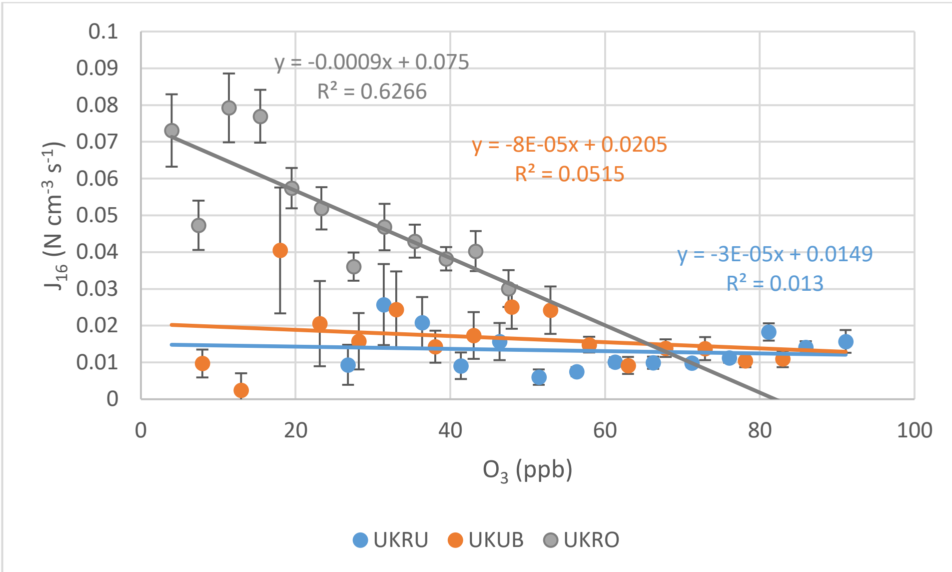
(h)


5
4.5
4
3.5
3
2.5
Growth rate (nm h-1)
0
20
40
60
80
100
120
140
O3 (ppb)
y = 0.0052x + 3.1889
R² = 0.1667
y = -0.0058x + 3.7996
R² = 0.3049
SPARU
SPAUB

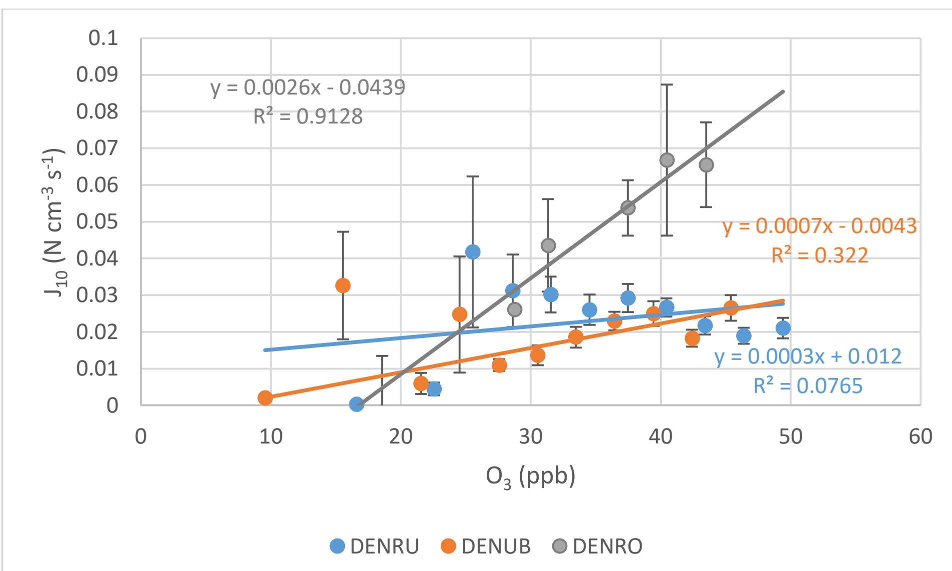
(i)


6
5
4
3
2
1
0
Growth rate (nm h-1)
30
35
40
45
50
55
60
65
70
O3 (ppb)
y = 0.0368x + 1.9021
R² = 0.1699
GRERU

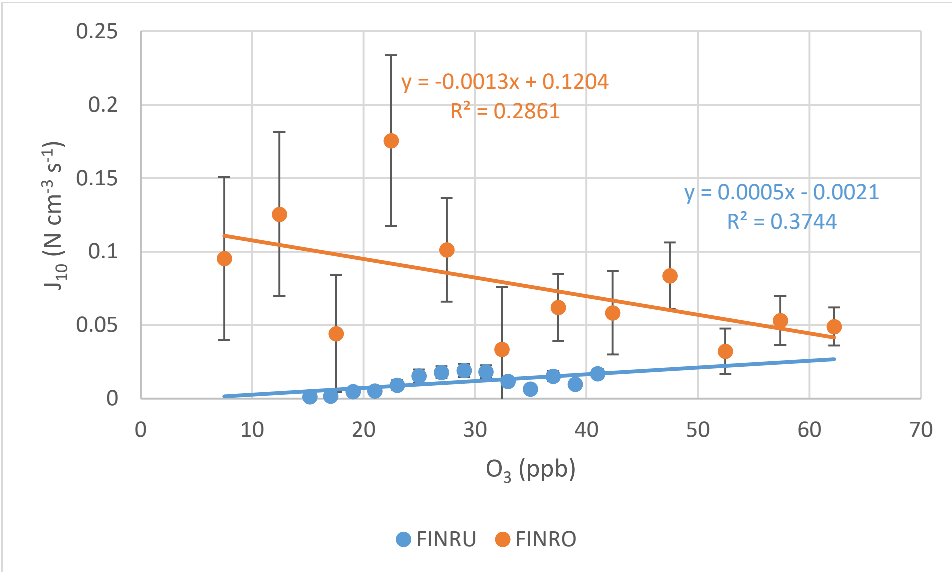
(j)


0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
J16 (N cm-3 s-1)
O3 (ppb)
y = -0.0009x + 0.075
R² = 0.6266
y = -8E-05x + 0.0205
R² = 0.0515
y = -3E-05x + 0.0149
R² = 0.013
UKRU
UKUB
UKRO

(k)

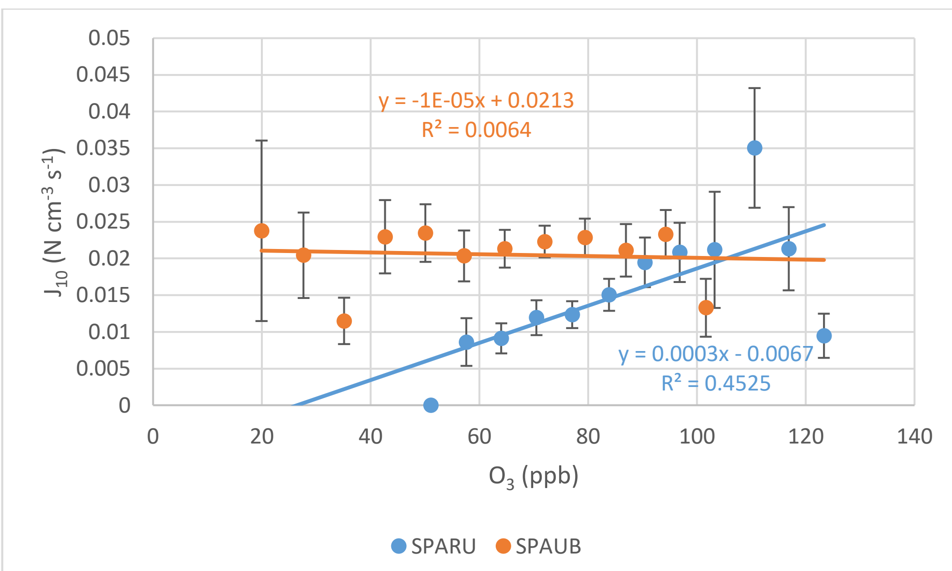

0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
10
20
30
40
50
60
J10 (N cm-3 s-1)
O3 (ppb)
y = 0.0026x - 0.0439
R² = 0.9128
y = 0.0007x - 0.0043
R² = 0.322
y = 0.0003x + 0.012
R² = 0.0765
DENRU
DENUB
DENRO

(l)



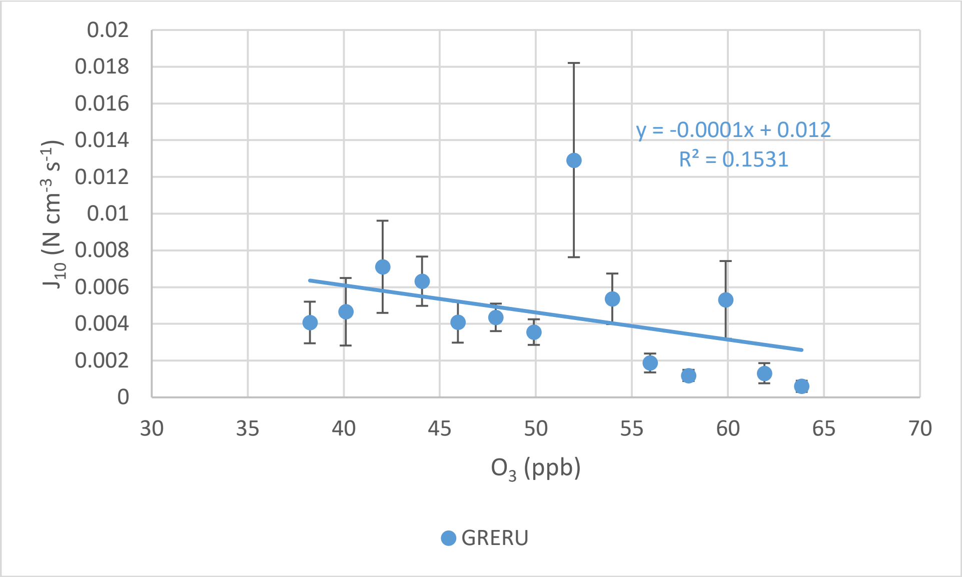
y = -0.0013x + 0.1204
R² = 0.2861
y = 0.0005x - 0.0021
R² = 0.3744
J10 (N cm-3 s-1)
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
O3 (ppb)
FINRU
FINRO

(m)



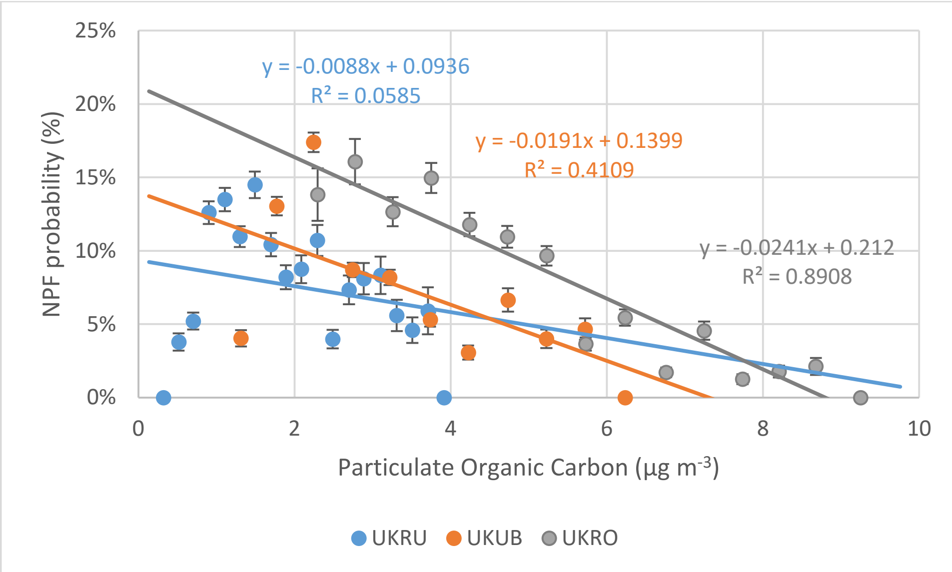
y = -1E-05x + 0.0213
R² = 0.0064
y = 0.0003x - 0.0067
R² = 0.4525
J10 (N cm-3 s-1)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
140
O3 (ppb)
SPARU
SPAUB

(n)

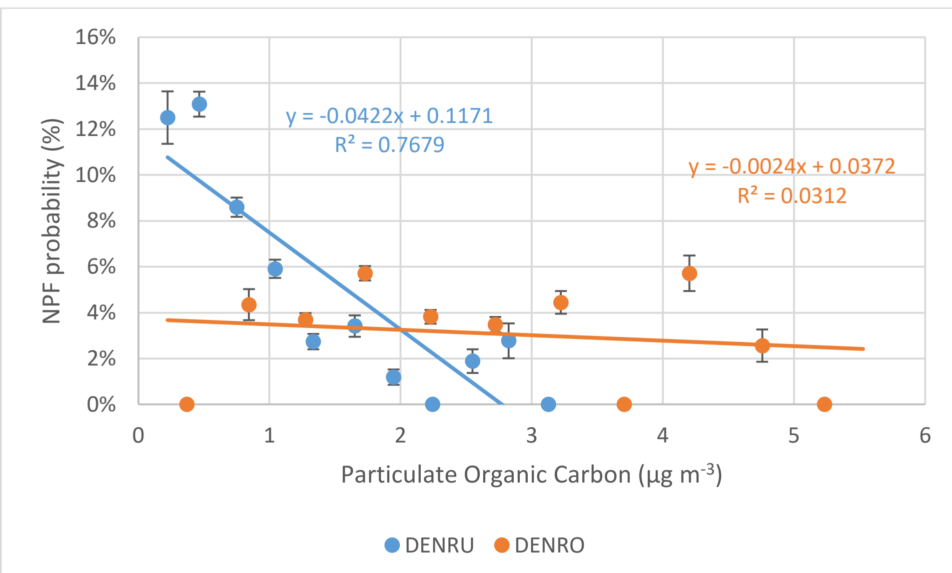

0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
J10 (N cm-3 s-1)
30
35
40
45
50
55
60
65
70
O3 (ppb)
y = -0.0001x + 0.012
R² = 0.1531
GRERU

(o)

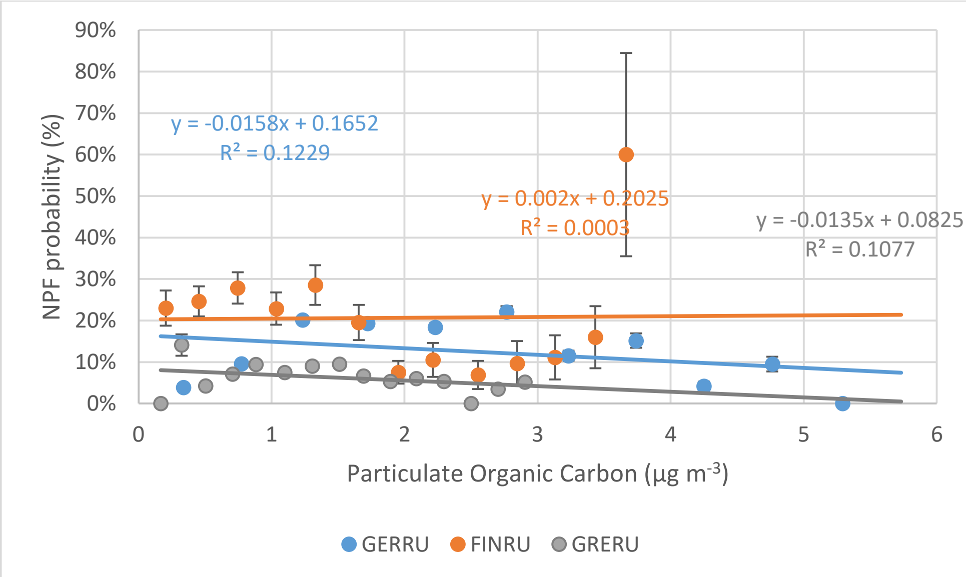
Figure S9: Relationship of particulate organic carbon concentration with NPF variables.



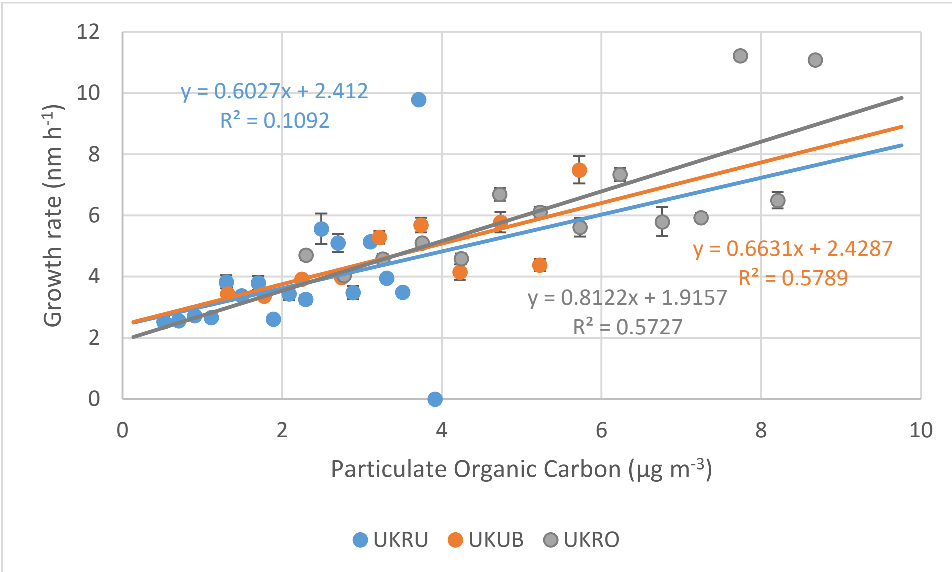
(a)



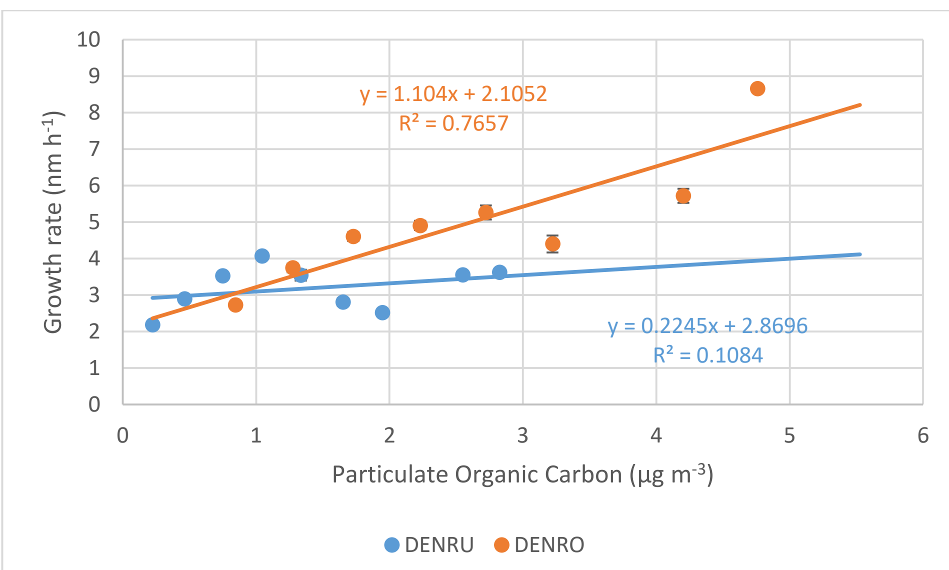
(b)


NPF probability (%)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
Particulate Organic Carbon (µg m-3)
y = -0.0158x + 0.1652
R² = 0.1229
y = 0.002x + 0.2025
R² = 0.0003
y = -0.0135x + 0.0825
R² = 0.1077
GERRU
FINRU
GRERU

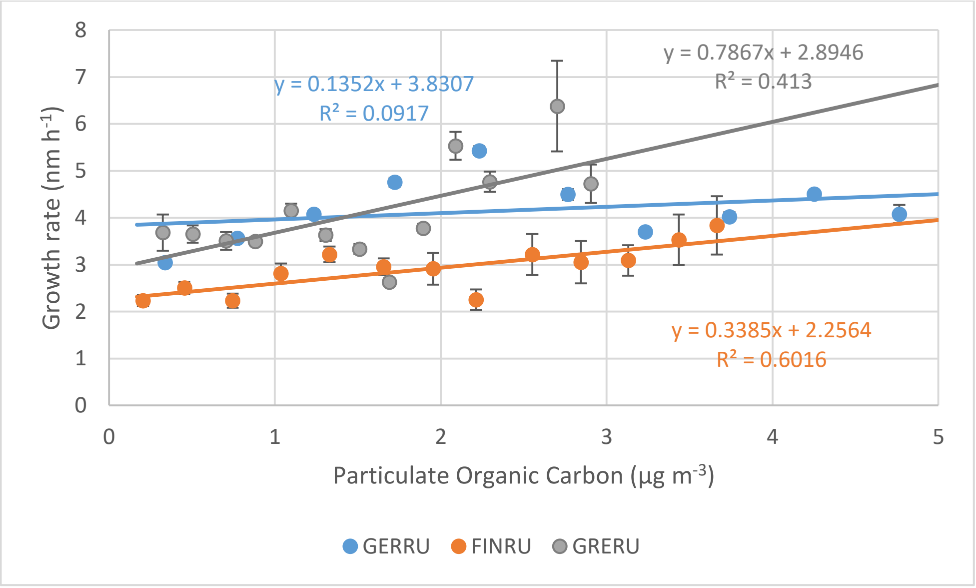
(c)

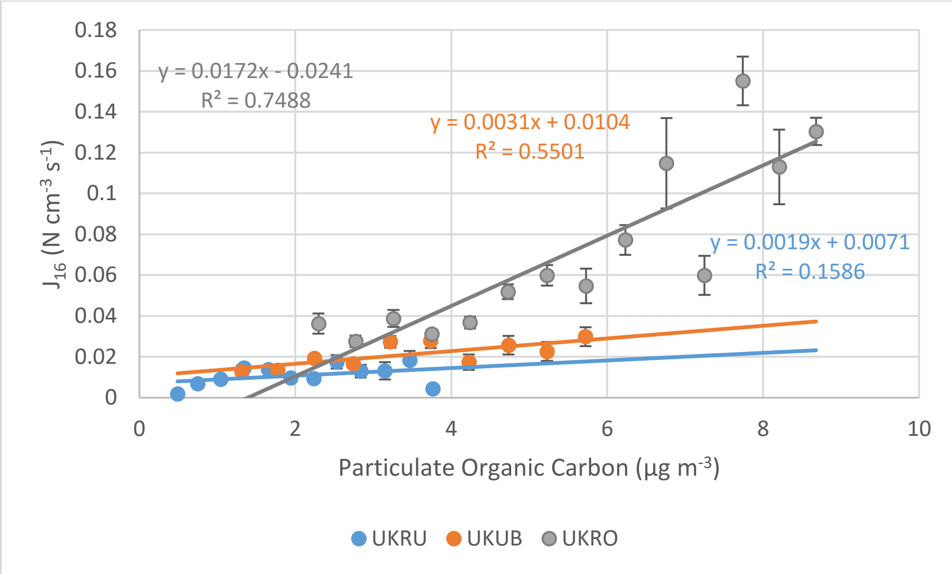

y = 0.6027x + 2.412
R² = 0.1092
y = 0.6631x + 2.4287
R² = 0.5789
y = 0.8122x + 1.9157
R² = 0.5727
Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
UKRU
UKUB
UKRO

(d)

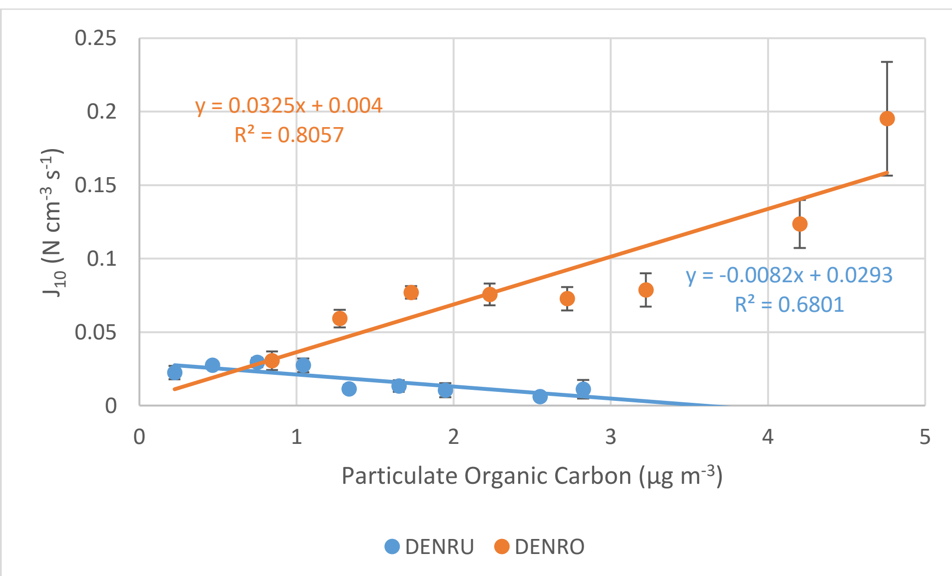

y = 1.104x + 2.1052
R² = 0.7657
y = 0.2245x + 2.8696
R² = 0.1084
Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
DENRU
DENRO

(e)

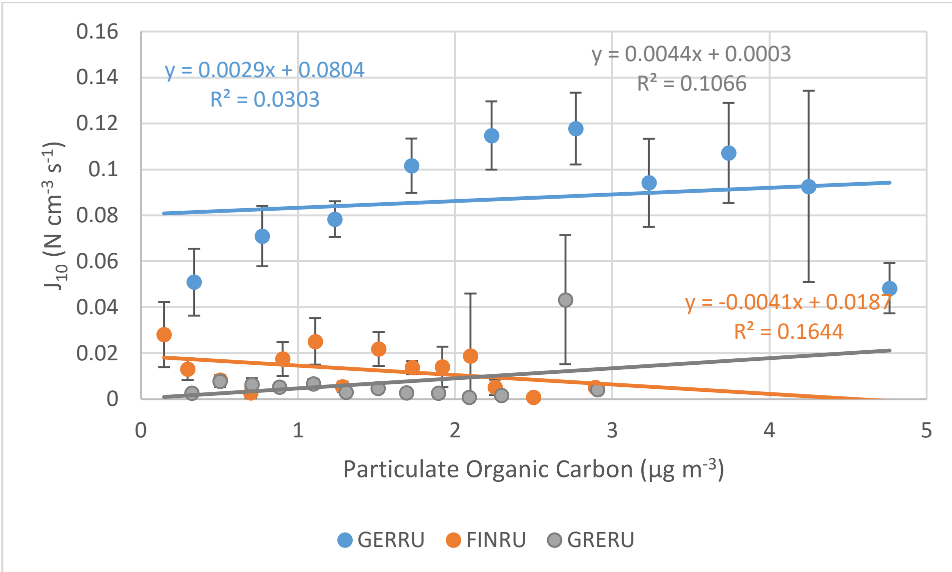

y = 0.7867x + 2.8946
R² = 0.413
y = 0.1352x + 3.8307
R² = 0.0917
y = 0.3385x + 2.2564
R² = 0.6016
Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
GERRU
FINRU
GRERU
0
1
2
3
4
5
6
7
8
(f)


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
2
4
6
8
10
y = 0.0172x - 0.0241
R² = 0.7488
y = 0.0031x + 0.0104
R² = 0.5501
y = 0.0019x + 0.0071
R² = 0.1586
J16 (N cm-3 s-1)
Particulate Organic Carbon (µg m-3)
UKRU
UKUB
UKRO

(g)

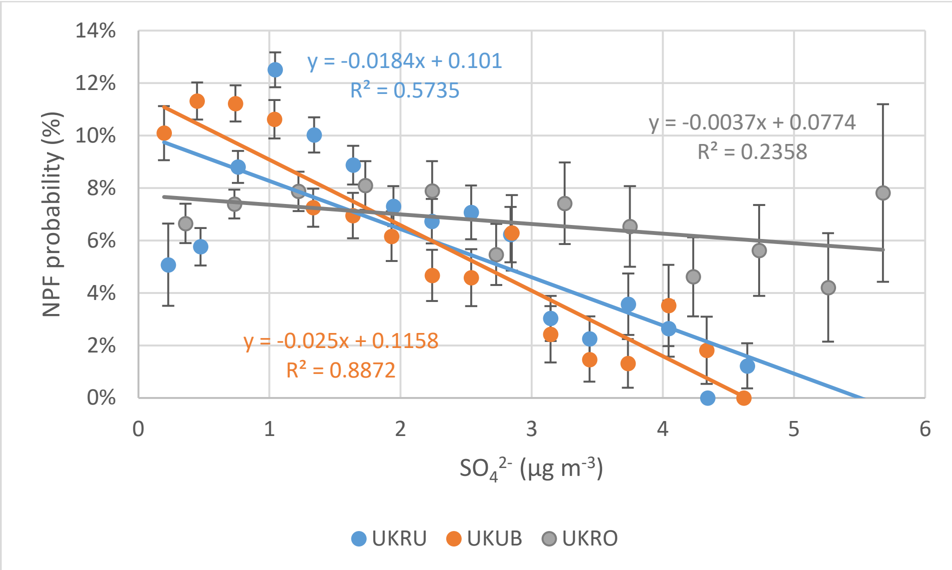

0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
y = 0.0325x + 0.004
R² = 0.8057
y = -0.0082x + 0.0293
R² = 0.6801
J10 (N cm-3 s-1)
Particulate Organic Carbon (µg m-3)
DENRU
DENRO

(h)

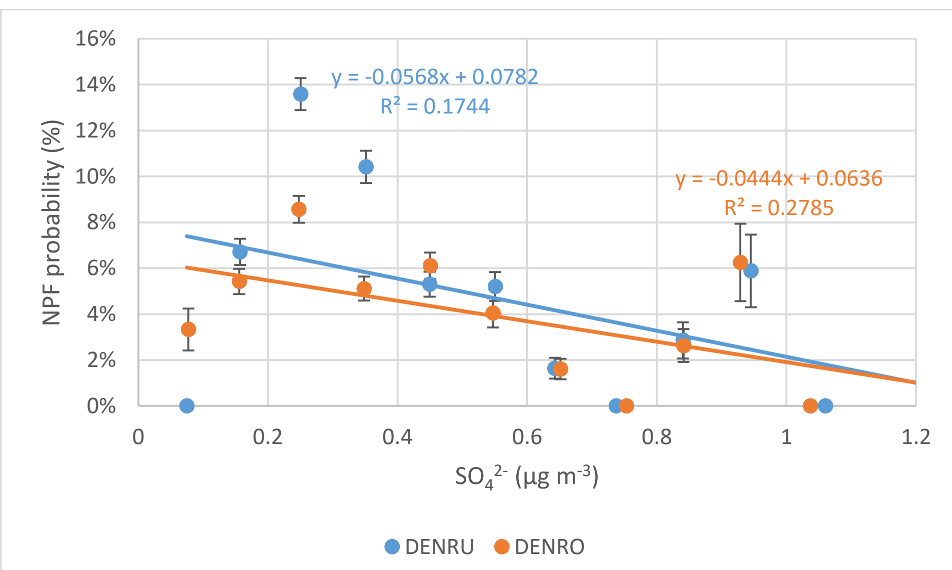

y = 0.0029x + 0.0804
R² = 0.0303
y = 0.0044x + 0.0003
R² = 0.1066
y = -0.0041x + 0.0187
R² = 0.1644
J10 (N cm-3 s-1)
Particulate Organic Carbon (µg m-3)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
GERRU
FINRU
GRERU

(i)

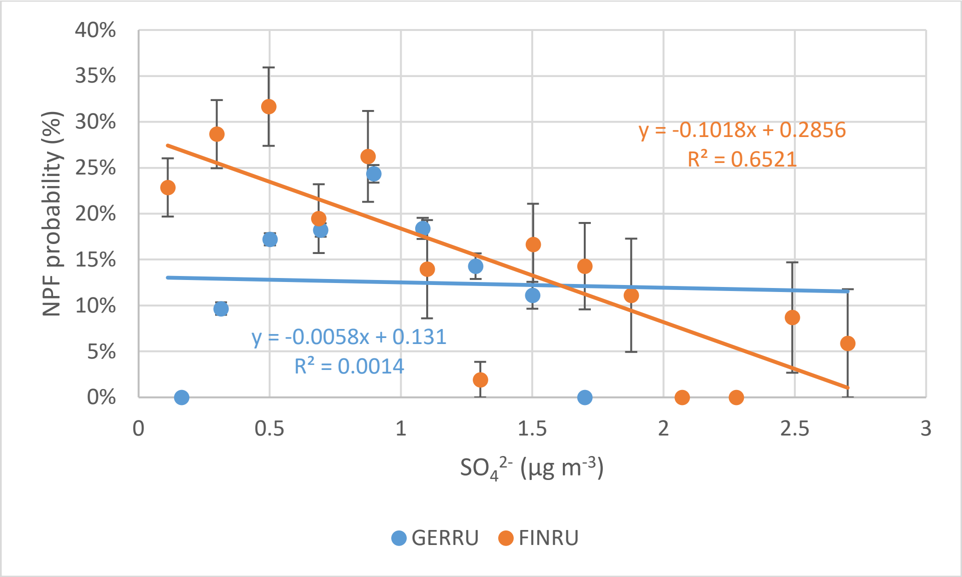
Figure S10: Relationship of SO_4^{2-} concentration with NPF variables.



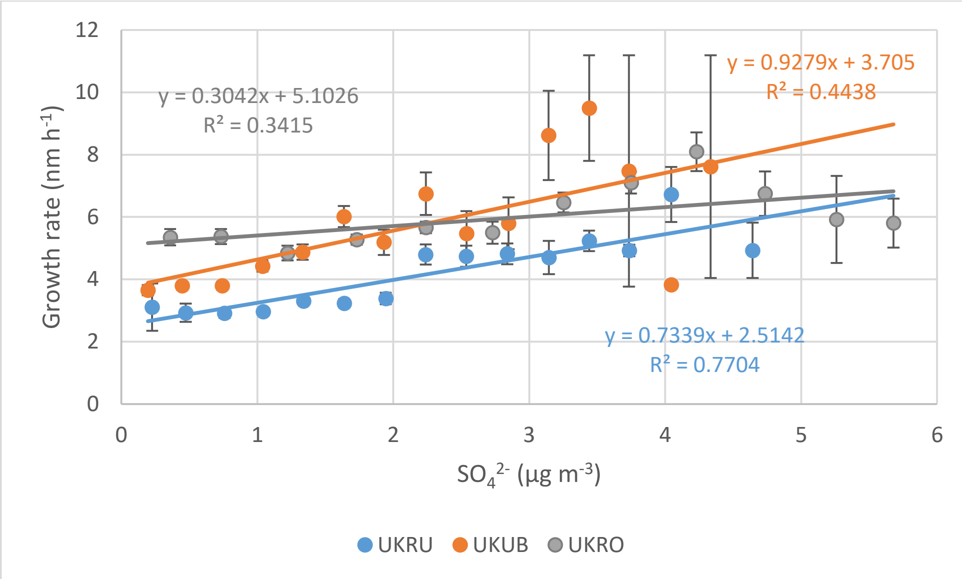
(a)



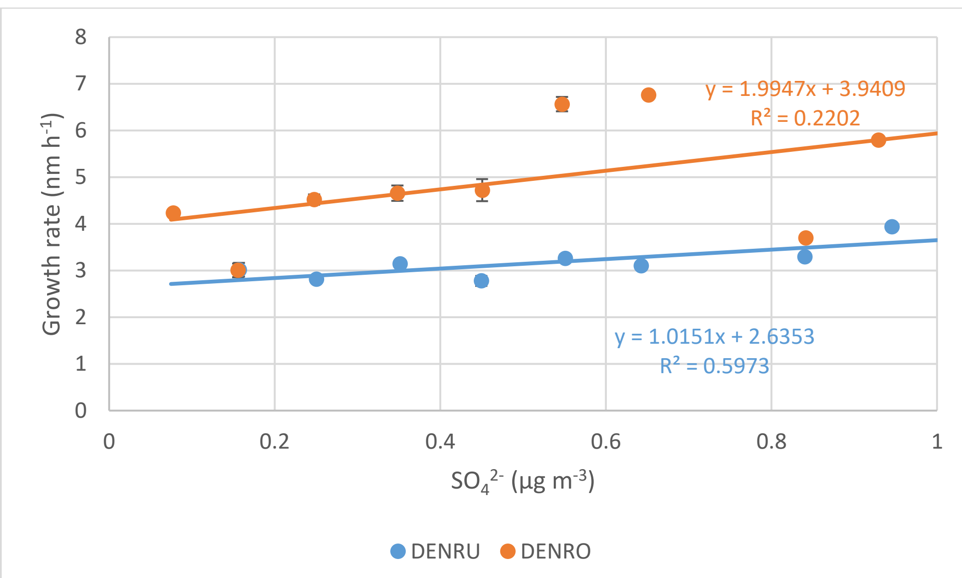
(b)


40%
35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
0
0.5
1
1.5
2
2.5
3
SO_4^{2-} (μg m^{-3})
y = -0.1018x + 0.2856
R^2 = 0.6521
y = -0.0058x + 0.131
R^2 = 0.0014
GERRU
FINRU

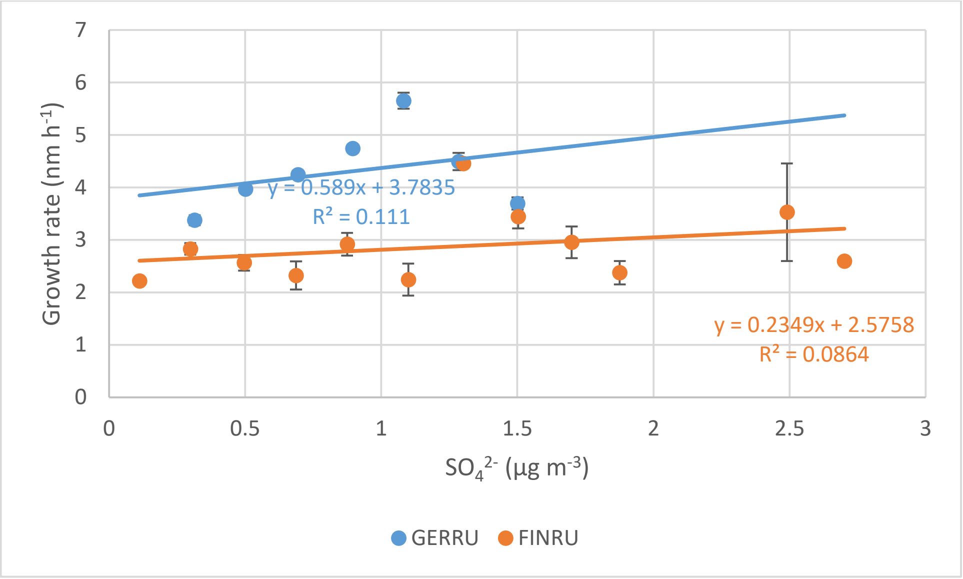
(c)


12
10
8
6
4
2
0
Growth rate (nm h-1)
y = 0.3042x + 5.1026
R² = 0.3415
y = 0.9279x + 3.705
R² = 0.4438
y = 0.7339x + 2.5142
R² = 0.7704
0
1
2
3
4
5
6
SO4 2- (µg m-3)
UKRU
UKUB
UKRO

(d)

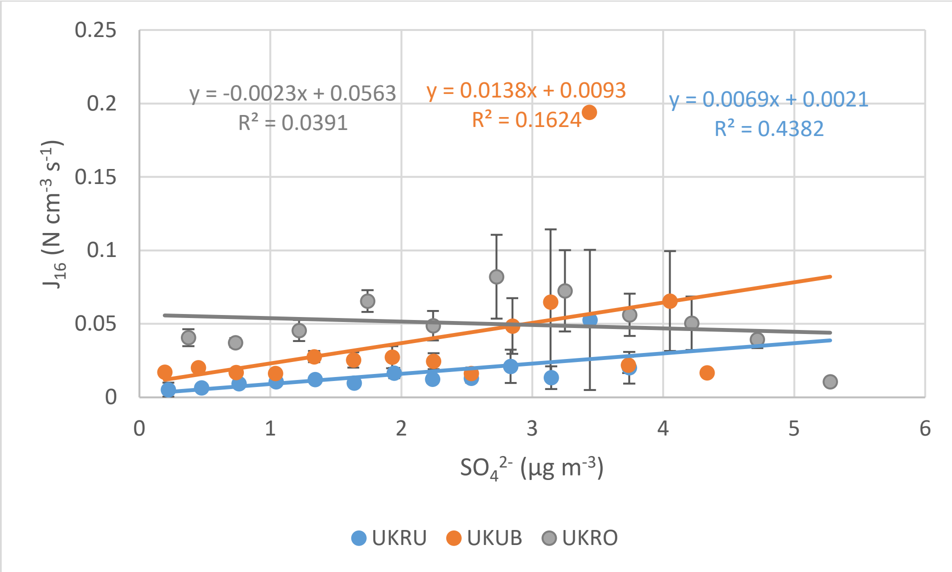

8
7
6
5
4
3
2
1
0
Growth rate (nm h-1)
y = 1.9947x + 3.9409
R² = 0.2202
y = 1.0151x + 2.6353
R² = 0.5973
0
0.2
0.4
0.6
0.8
1
SO4 2- (µg m-3)
DENRU
DENRO

(e)

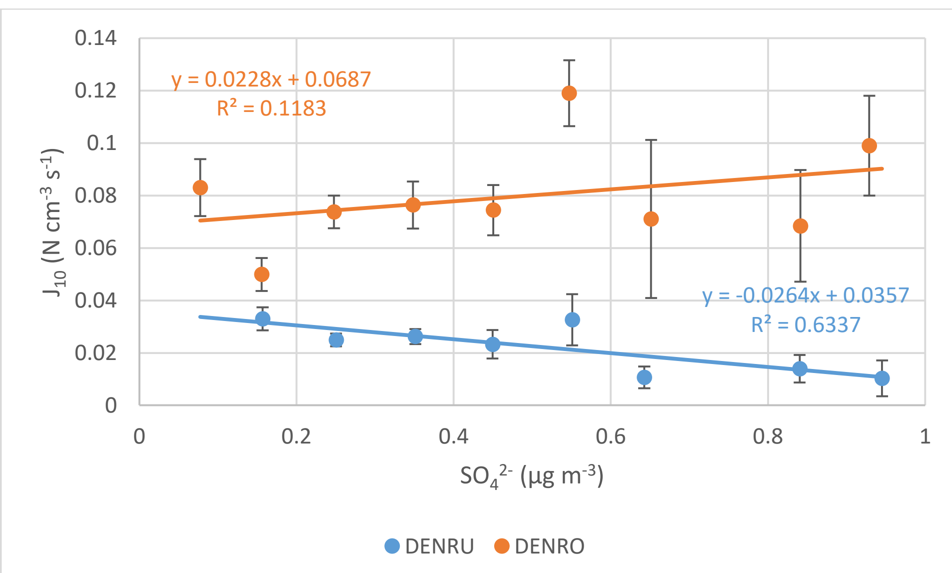


7
6
5
4
3
2
1
0
Growth rate (nm h-1)
0
0.5
1
1.5
2
2.5
3
SO4 2- (μg m-3)
y = 0.589x + 3.7835
R² = 0.111
y = 0.2349x + 2.5758
R² = 0.0864
GERRU
FINRU

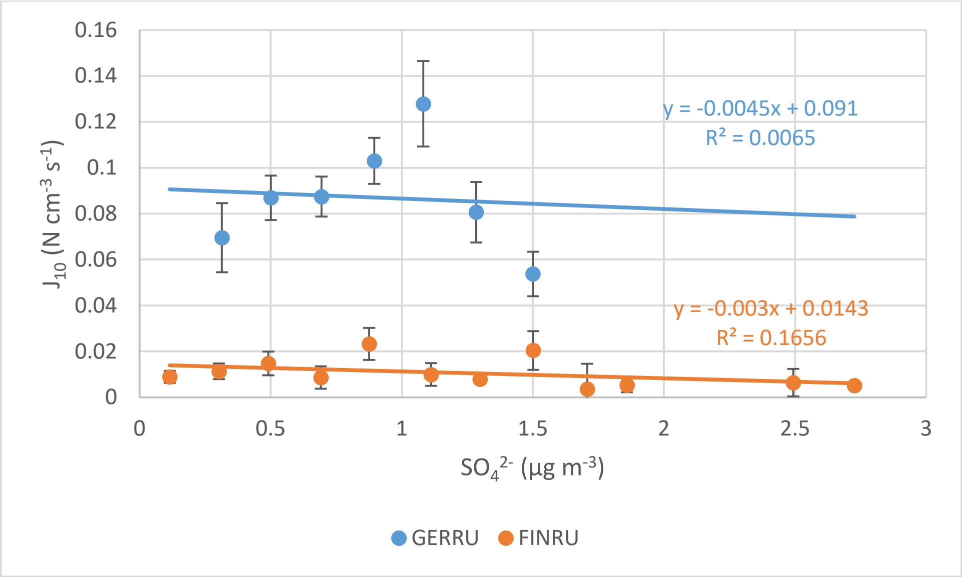
(f)


0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
y = -0.0023x + 0.0563
R² = 0.0391
y = 0.0138x + 0.0093
R² = 0.1624
y = 0.0069x + 0.0021
R² = 0.4382
J16 (N cm-3 s-1)
SO42- (μg m-3)
UKRU
UKUB
UKRO

(g)

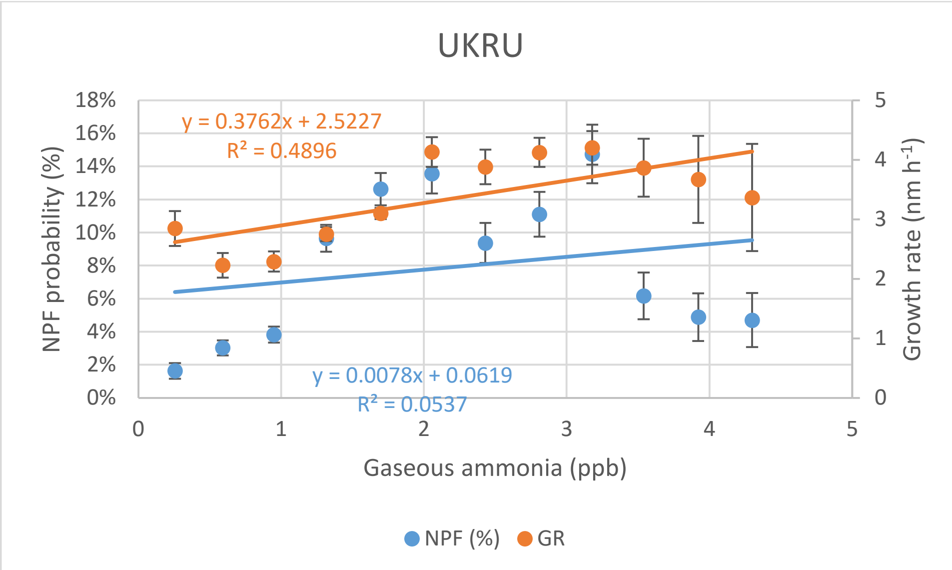

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
y = 0.0228x + 0.0687
R² = 0.1183
y = -0.0264x + 0.0357
R² = 0.6337
J10 (N cm-3 s-1)
SO42- (μg m-3)
DENRU
DENRO

(h)

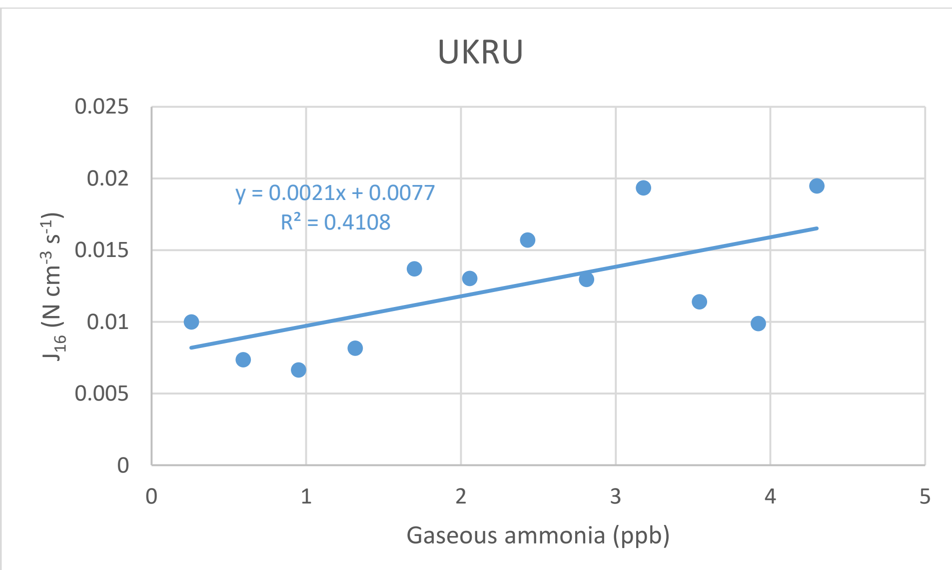

0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J_{10} (N cm^{-3} s^{-1})
0
0.5
1
1.5
2
2.5
3
SO_4^{2-} (μg m^{-3})
y = -0.0045x + 0.091
R^2 = 0.0065
y = -0.003x + 0.0143
R^2 = 0.1656
GERRU
FINRU

(i)

Figure S11: Relationship of gaseous ammonia concentration with NPF variables.

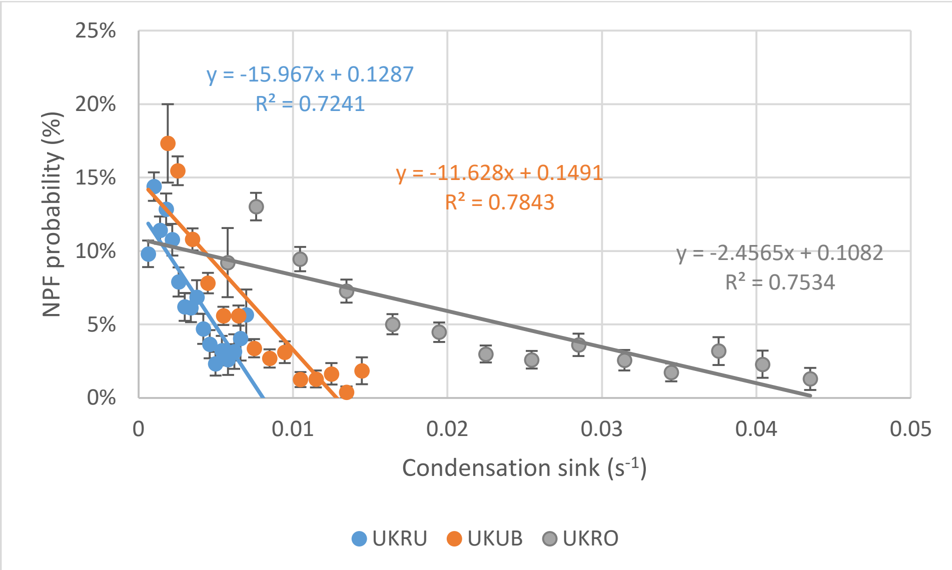


(a)

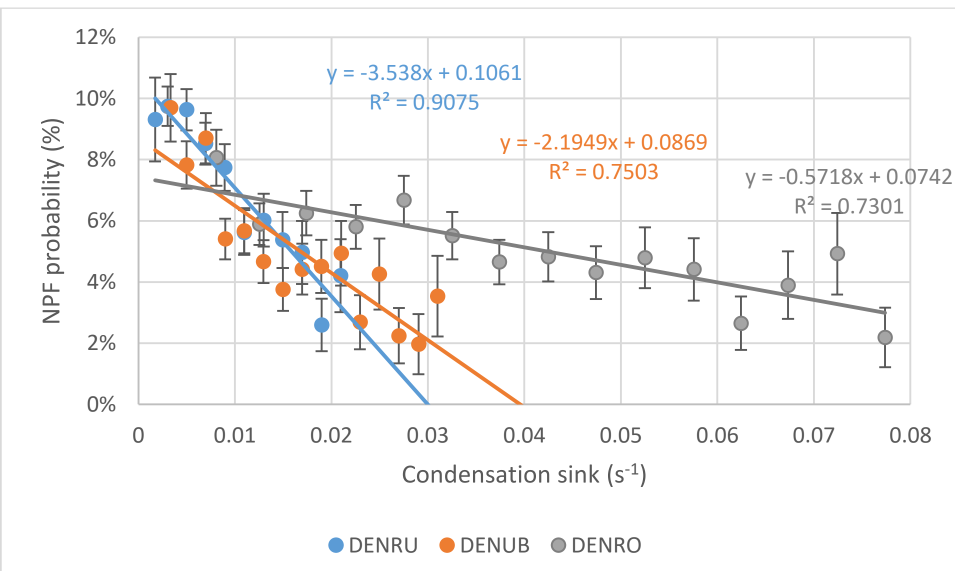


(b)

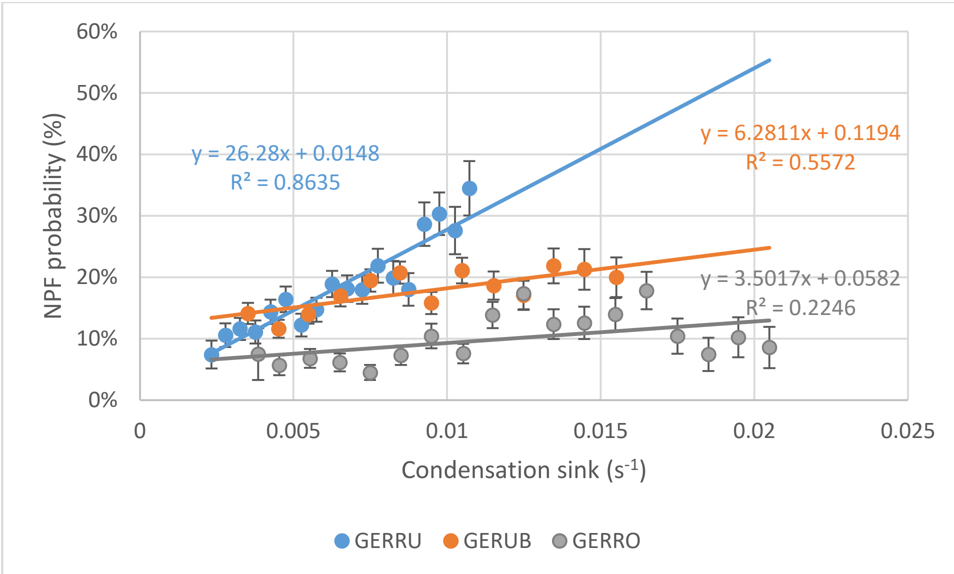
Figure S12: Relationship of the condensation sink with NPF variables.



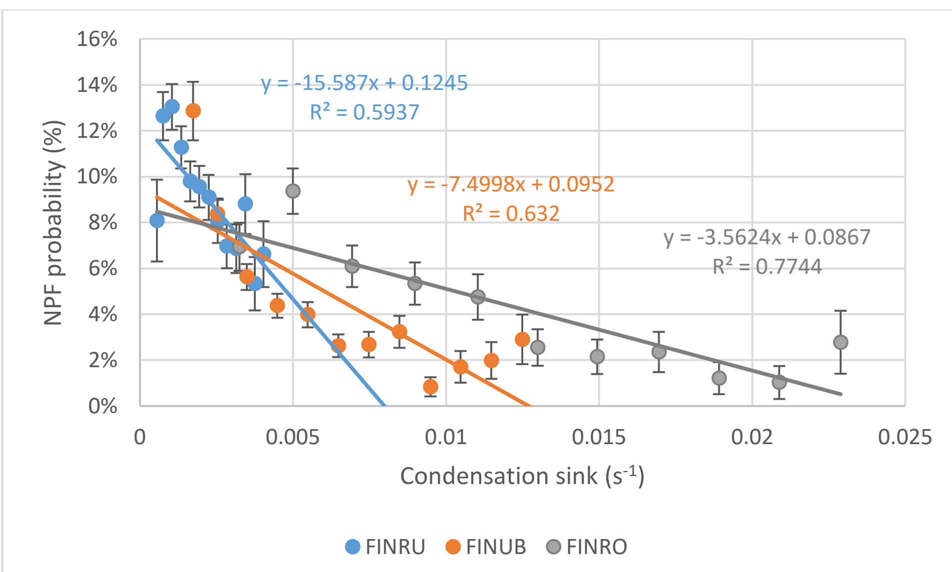
(a)



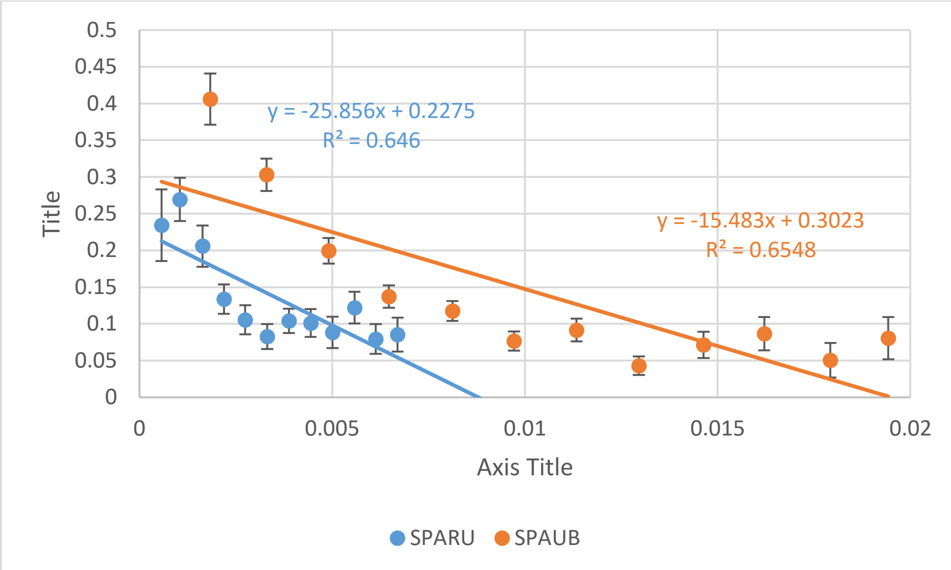
(b)


NPF probability (%)
60%
50%
40%
30%
20%
10%
0%
0
0.005
0.01
0.015
0.02
0.025
Condensation sink (s-1)
y = 26.28x + 0.0148
R² = 0.8635
y = 6.2811x + 0.1194
R² = 0.5572
y = 3.5017x + 0.0582
R² = 0.2246
GERRU
GERUB
GERRO

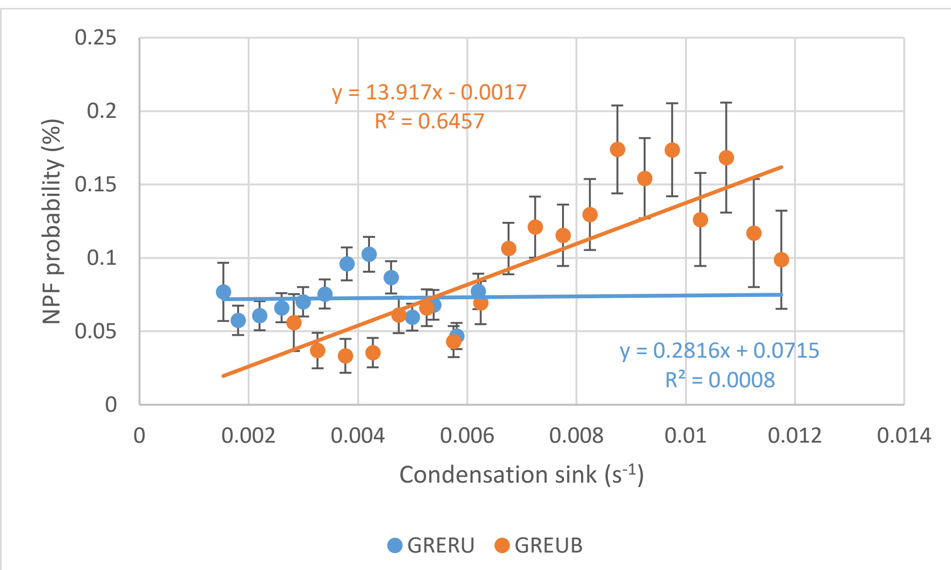
(c)


NPF probability (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
0.005
0.01
0.015
0.02
0.025
Condensation sink (s-1)
y = -15.587x + 0.1245
R² = 0.5937
y = -7.4998x + 0.0952
R² = 0.632
y = -3.5624x + 0.0867
R² = 0.7744
FINRU
FINUB
FINRO

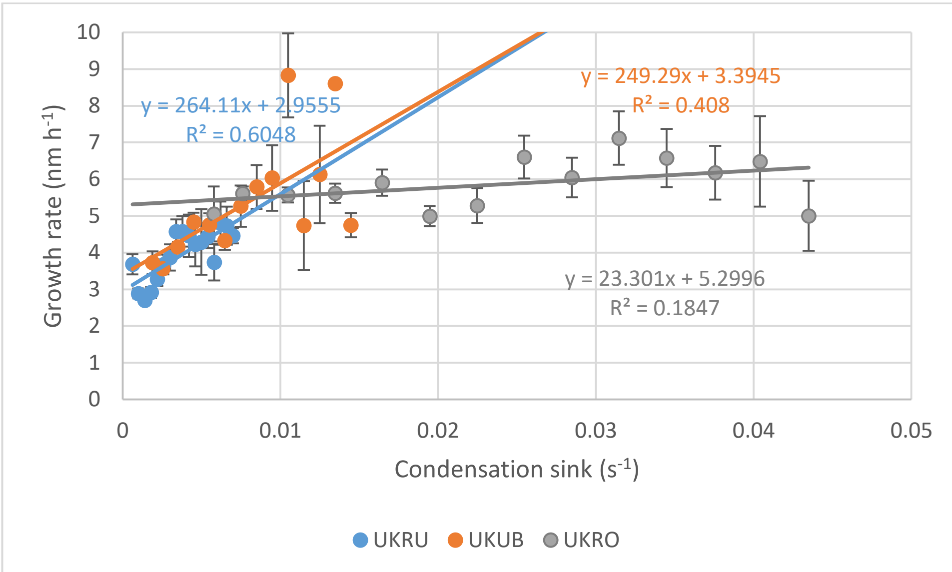
(d)


y = -25.856x + 0.2275
R² = 0.646
y = -15.483x + 0.3023
R² = 0.6548
Title
Axis Title
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.005
0.01
0.015
0.02
SPARU
SPAUB

(e)

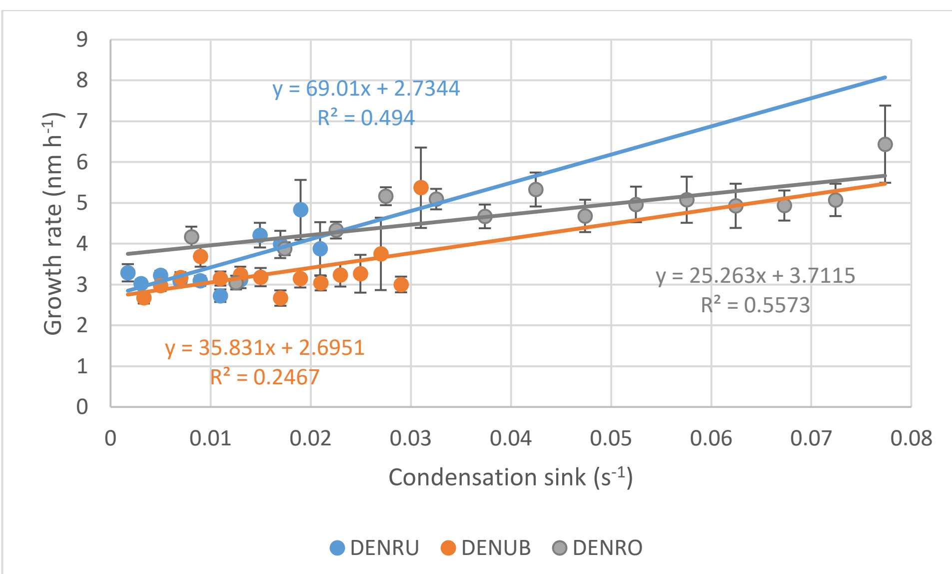

y = 13.917x - 0.0017
R² = 0.6457
y = 0.2816x + 0.0715
R² = 0.0008
NPF probability (%)
Condensation sink (s⁻¹)
0.25
0.2
0.15
0.1
0.05
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
GRERU
GREUB

(f)



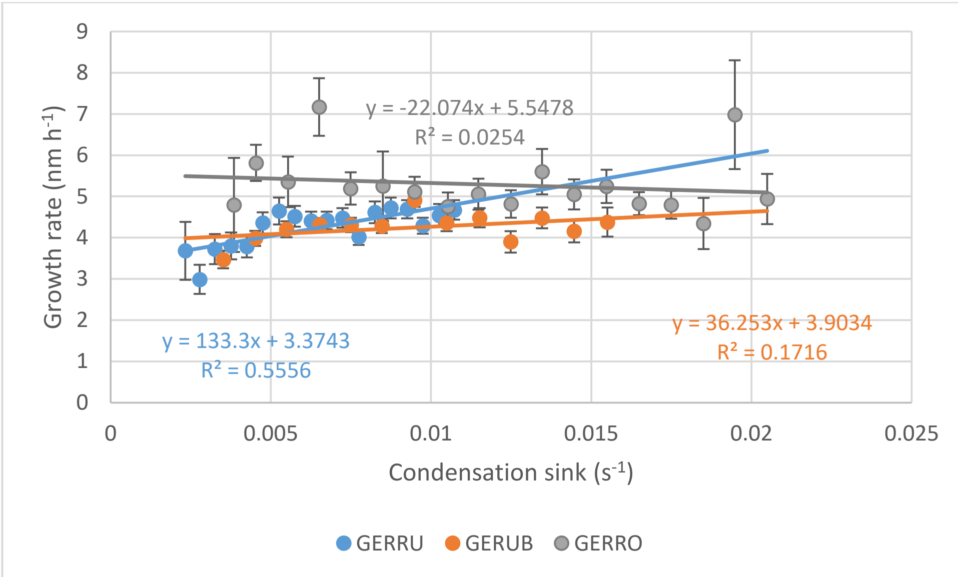
Growth rate (nm h-1)
Condensation sink (s-1)
y = 264.11x + 2.9555
R² = 0.6048
y = 249.29x + 3.3945
R² = 0.408
y = 23.301x + 5.2996
R² = 0.1847
UKRU
UKUB
UKRO
0 1 2 3 4 5 6 7 8 9 10
0 0.01 0.02 0.03 0.04 0.05

(g)



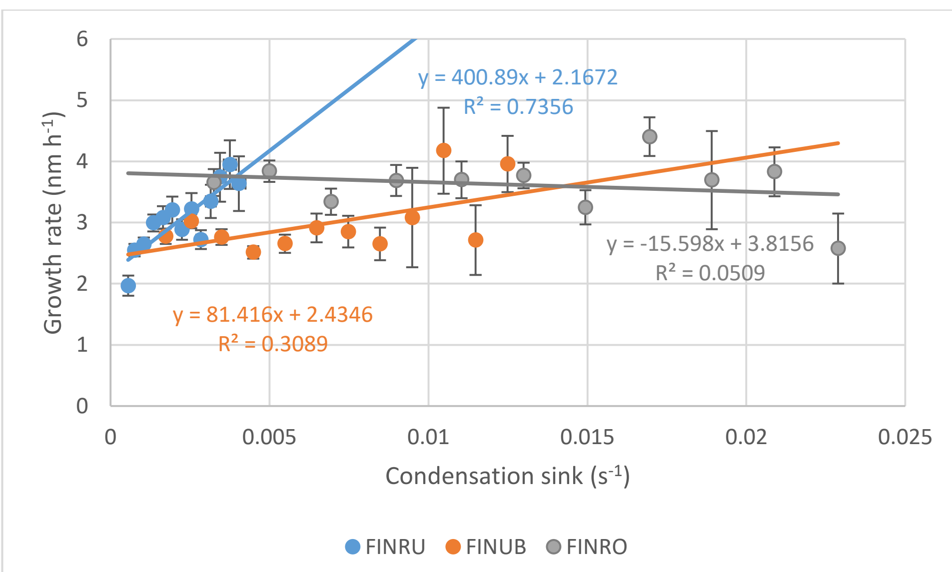
Growth rate (nm h-1)
Condensation sink (s-1)
y = 69.01x + 2.7344
R² = 0.494
y = 25.263x + 3.7115
R² = 0.5573
y = 35.831x + 2.6951
R² = 0.2467
DENRU
DENUB
DENRO
0 1 2 3 4 5 6 7 8 9
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08

(h)



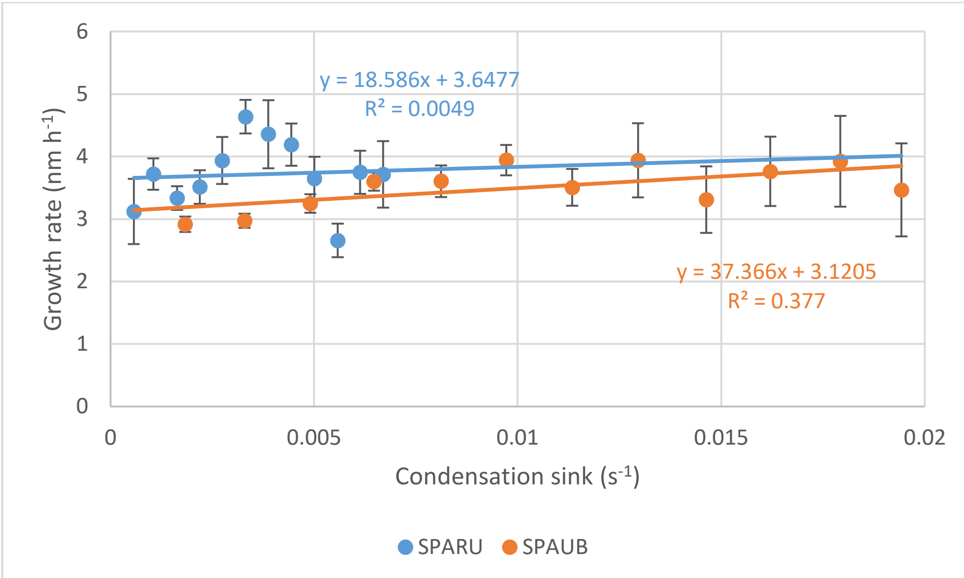
Growth rate (nm h-1)
Condensation sink (s-1)
y = -22.074x + 5.5478
R² = 0.0254
y = 133.3x + 3.3743
R² = 0.5556
y = 36.253x + 3.9034
R² = 0.1716
0 1 2 3 4 5 6 7 8 9
0 0.005 0.01 0.015 0.02 0.025
GERRU GERUB GERRO

(i)

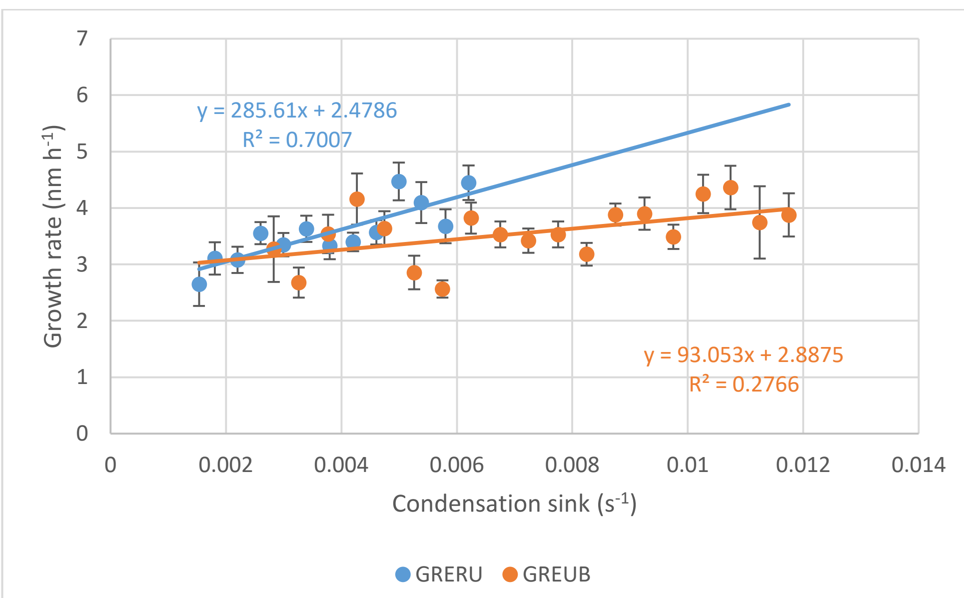


Growth rate (nm h-1)
Condensation sink (s-1)
y = 400.89x + 2.1672
R² = 0.7356
y = -15.598x + 3.8156
R² = 0.0509
y = 81.416x + 2.4346
R² = 0.3089
0 1 2 3 4 5 6
0 0.005 0.01 0.015 0.02 0.025
FINRU FINUB FINRO

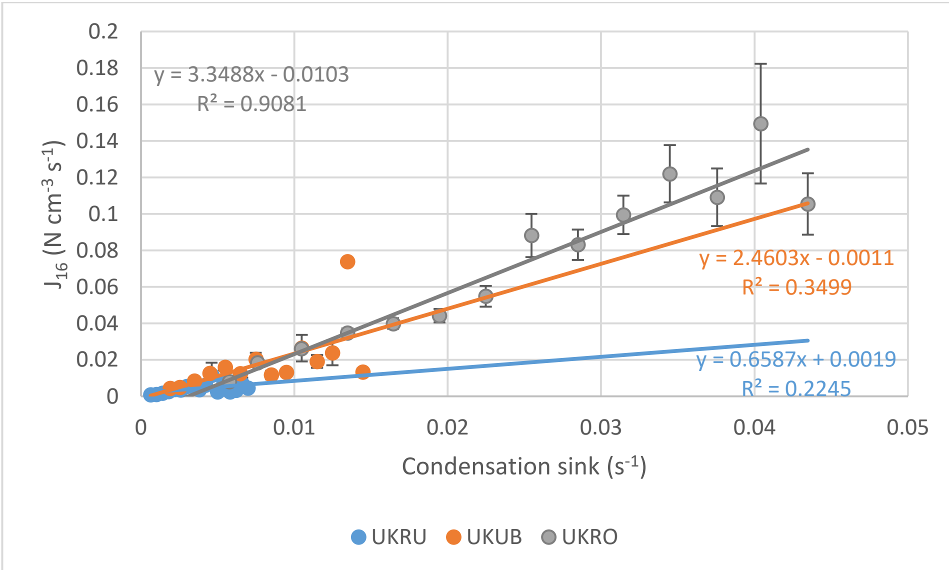
(j)


y = 18.586x + 3.6477
R² = 0.0049
y = 37.366x + 3.1205
R² = 0.377
Growth rate (nm h-1)
Condensation sink (s-1)
SPARU
SPAUB

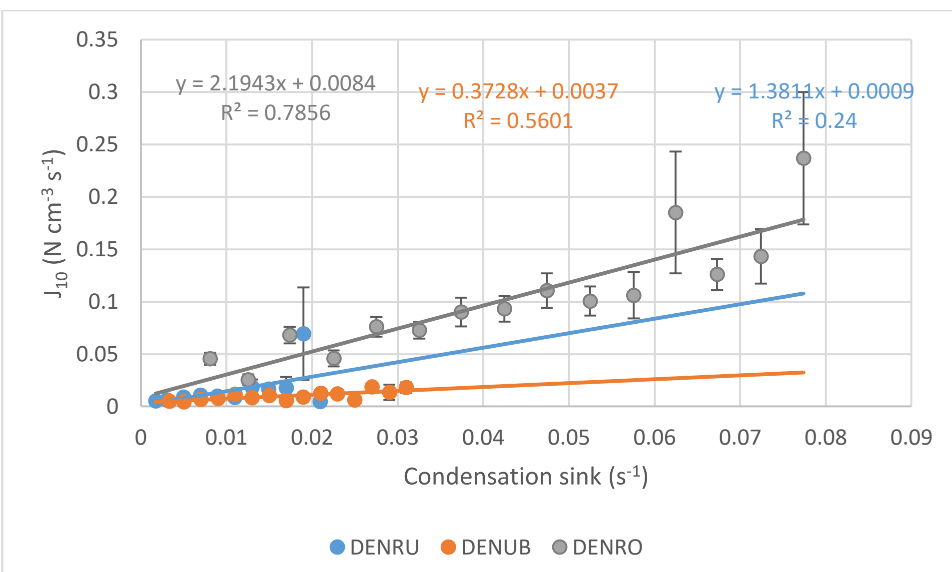
(k)


y = 285.61x + 2.4786
R² = 0.7007
y = 93.053x + 2.8875
R² = 0.2766
Growth rate (nm h-1)
Condensation sink (s-1)
GRERU
GREUB

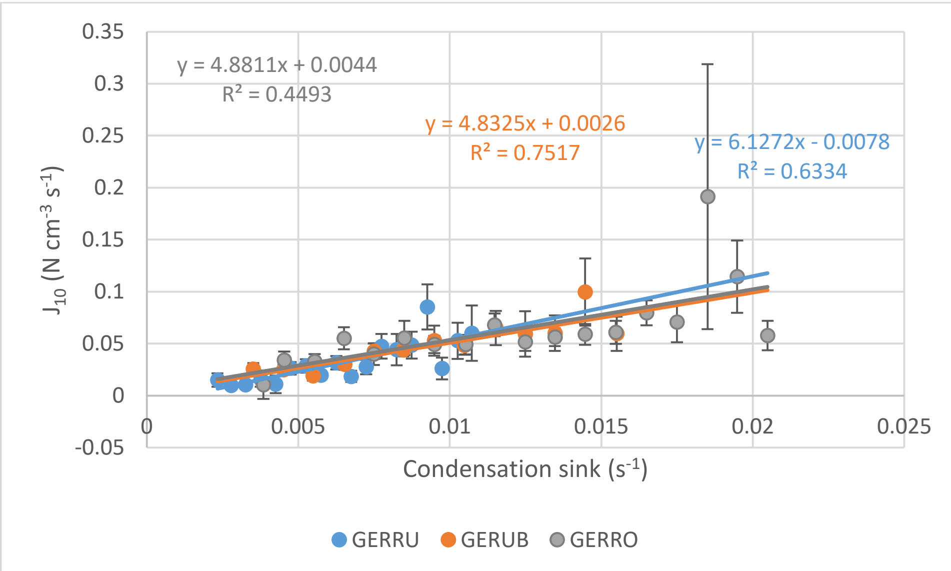
(l)


y = 3.3488x - 0.0103
R² = 0.9081
y = 2.4603x - 0.0011
R² = 0.3499
y = 0.6587x + 0.0019
R² = 0.2245
J16 (N cm-3 s-1)
Condensation sink (s-1)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.01
0.02
0.03
0.04
0.05
UKRU
UKUB
UKRO

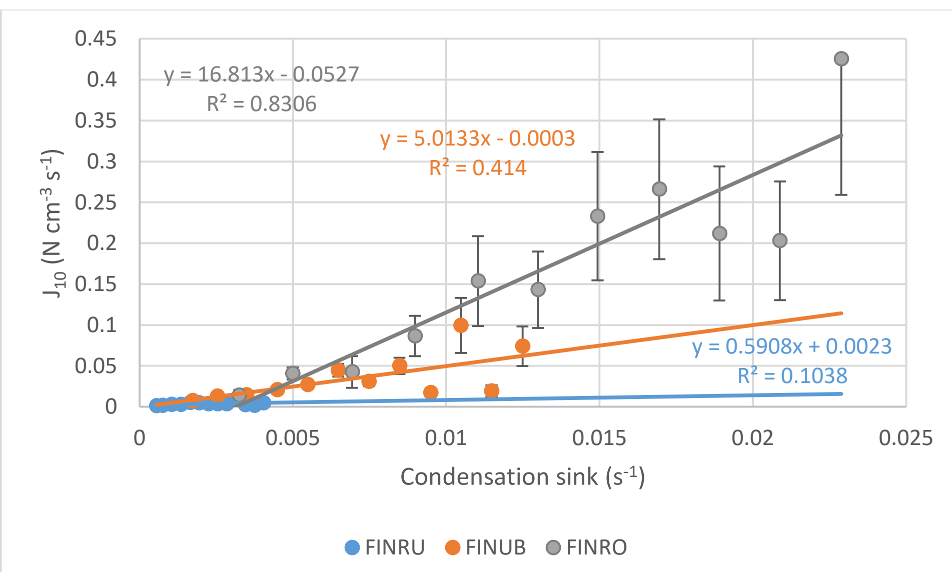
(m)


y = 2.1943x + 0.0084
R² = 0.7856
y = 0.3728x + 0.0037
R² = 0.5601
y = 1.3811x + 0.0009
R² = 0.24
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
DENRU
DENUB
DENRO

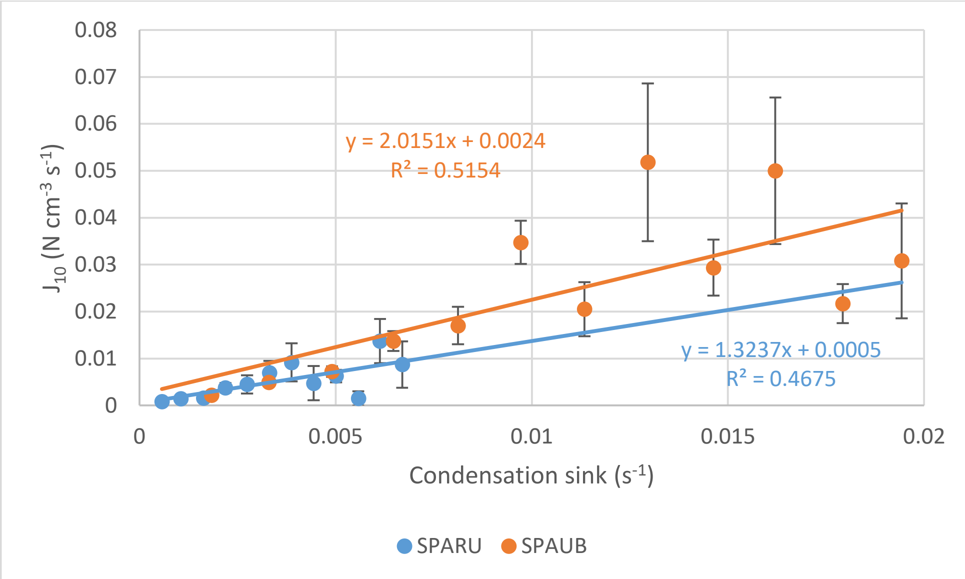
(n)


y = 4.8811x + 0.0044
R² = 0.4493
y = 4.8325x + 0.0026
R² = 0.7517
y = 6.1272x - 0.0078
R² = 0.6334
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
0.005
0.01
0.015
0.02
0.025
GERRU
GERUB
GERRO

(o)

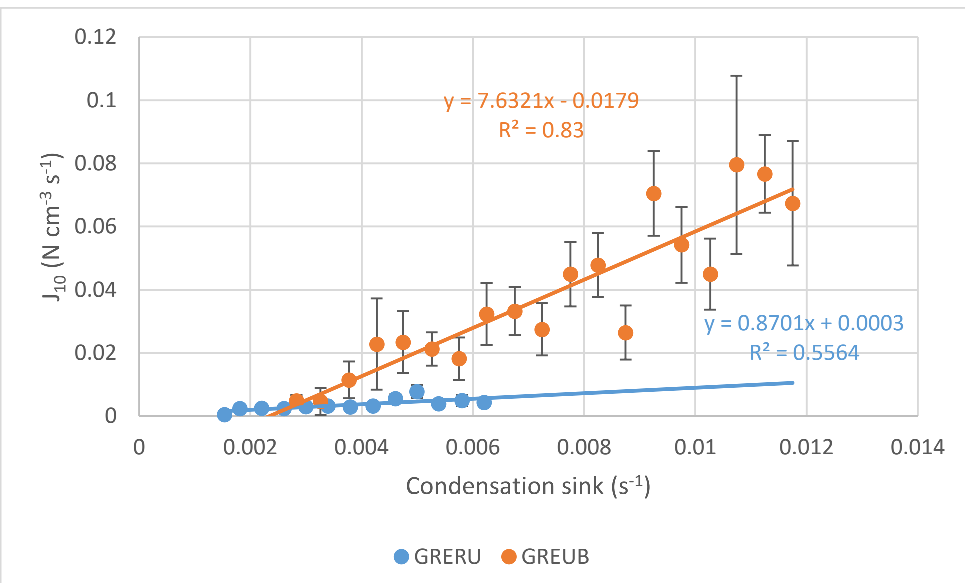

y = 16.813x - 0.0527
R² = 0.8306
y = 5.0133x - 0.0003
R² = 0.414
y = 0.5908x + 0.0023
R² = 0.1038
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.005
0.01
0.015
0.02
0.025
FINRU
FINUB
FINRO

(p)



0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J10 (N cm-3 s-1)
y = 2.0151x + 0.0024
R² = 0.5154
y = 1.3237x + 0.0005
R² = 0.4675
0
0.005
0.01
0.015
0.02
Condensation sink (s-1)
SPARU
SPAUB

(p)



0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
y = 7.6321x - 0.0179
R² = 0.83
y = 0.8701x + 0.0003
R² = 0.5564
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Condensation sink (s-1)
GRERU
GREUB

(q)

Figure S13: Relationship of average temperature and normalised gradients a_N^* for all but the Finnish sites.

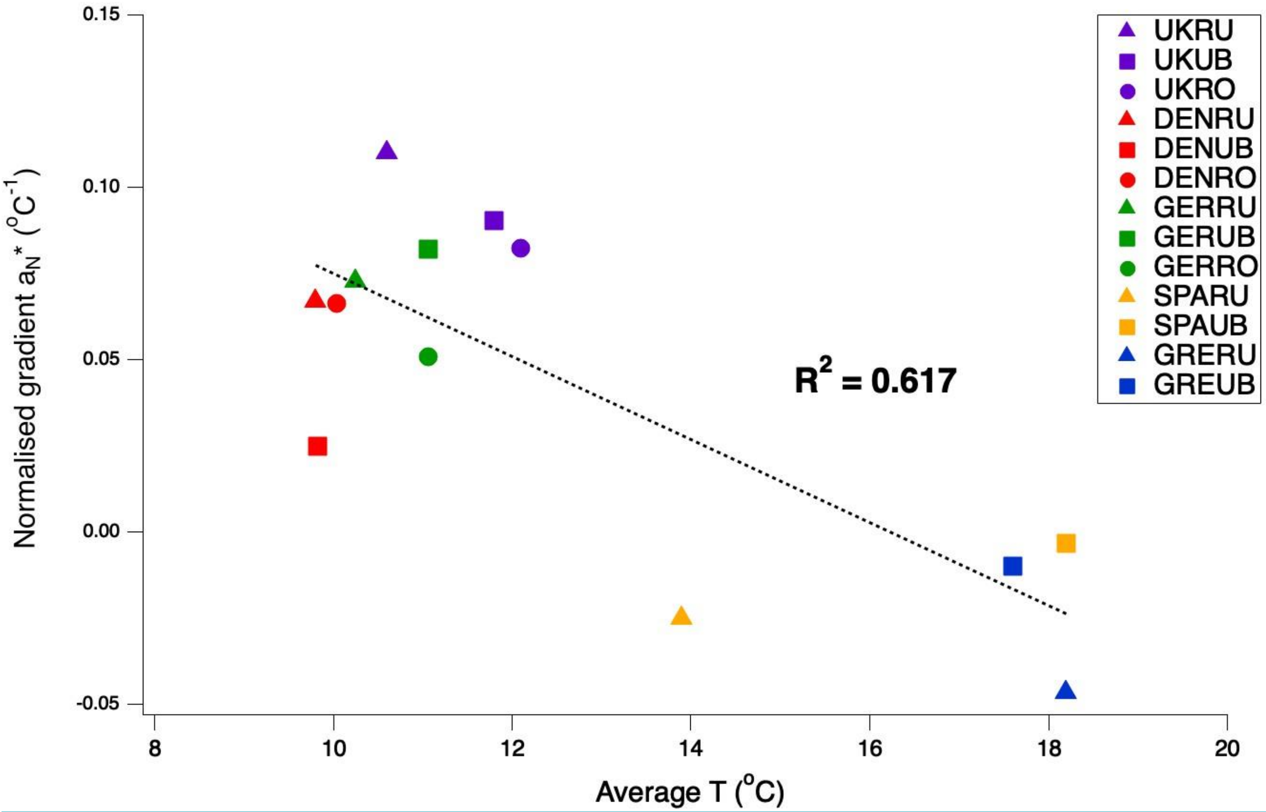
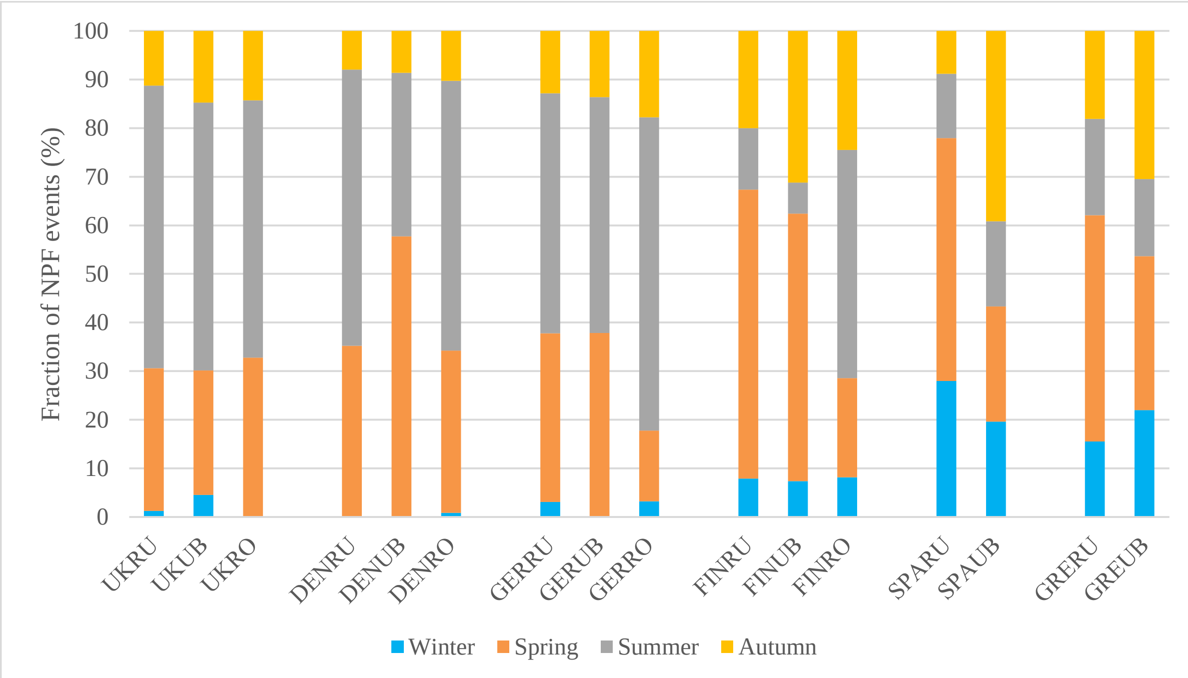
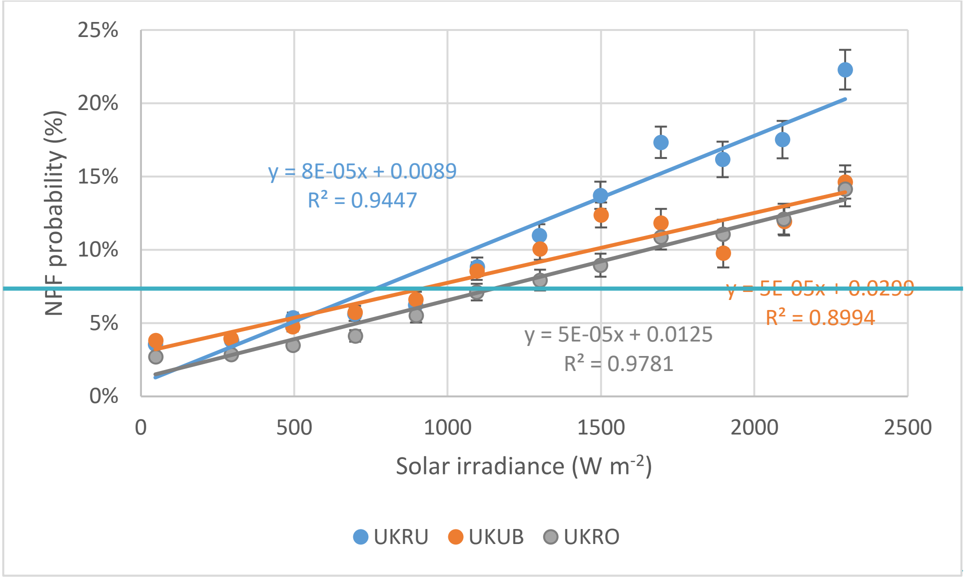
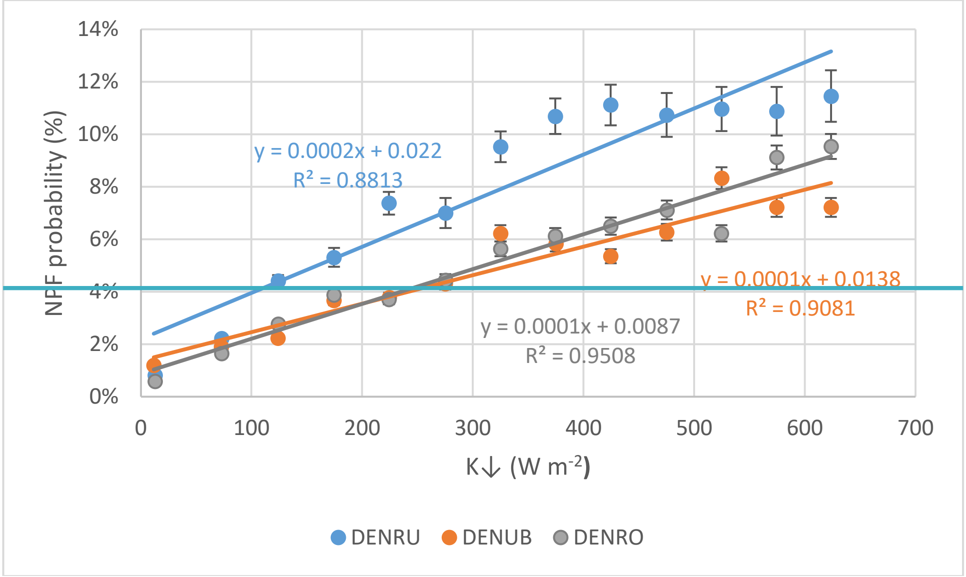


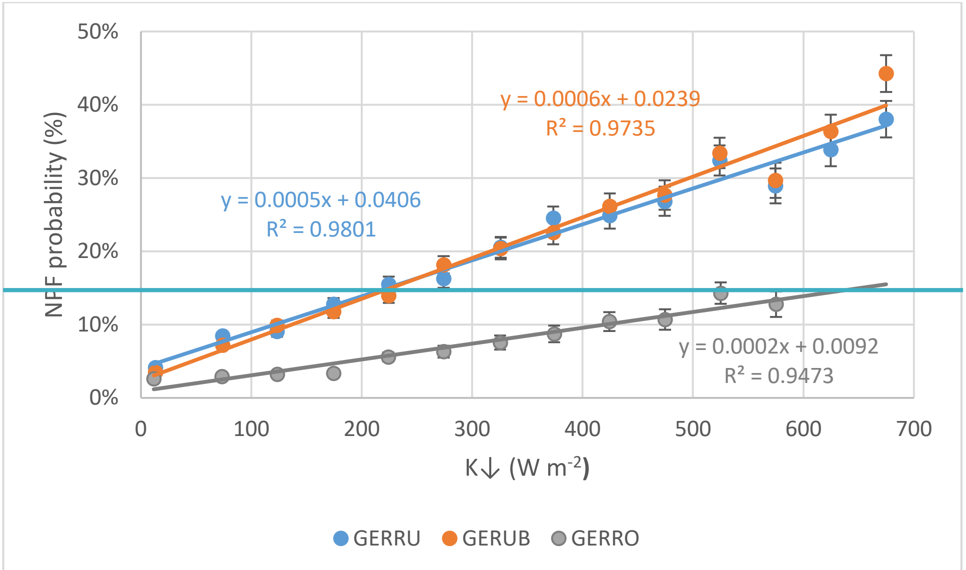
Figure S14: Seasonal variation of NPF events

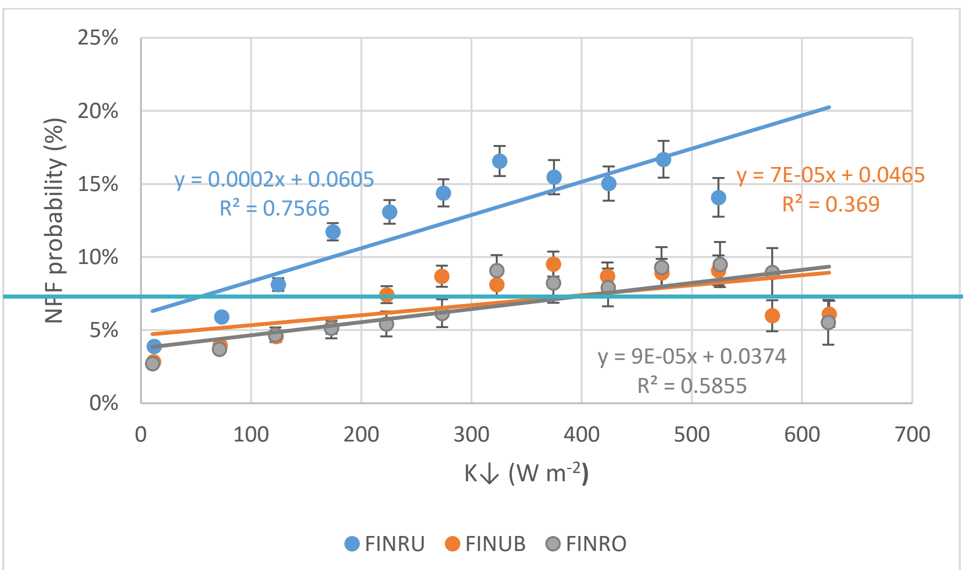


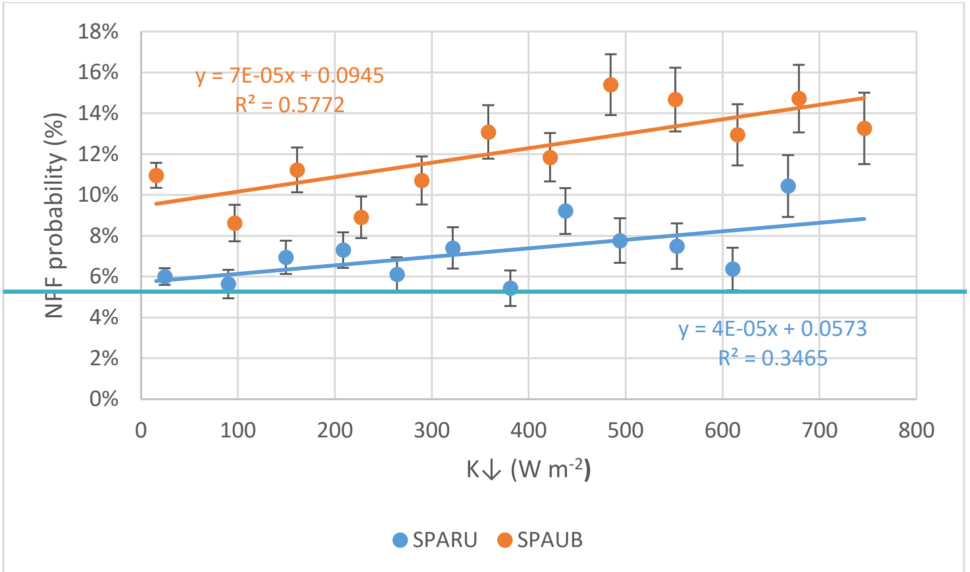
~~**Figure S1:** Relation of meteorological and atmospheric variables with NPF variables for all sites of the present study.~~


25%
20%
15%
10%
5%
0%
NFF probability (%)
0
500
1000
1500
2000
2500
Solar irradiance (W m-2)
y = 8E-05x + 0.0089
R² = 0.9447
y = 5E-05x + 0.0299
R² = 0.8994
y = 5E-05x + 0.0125
R² = 0.9781
UKRU
UKUB
UKRO

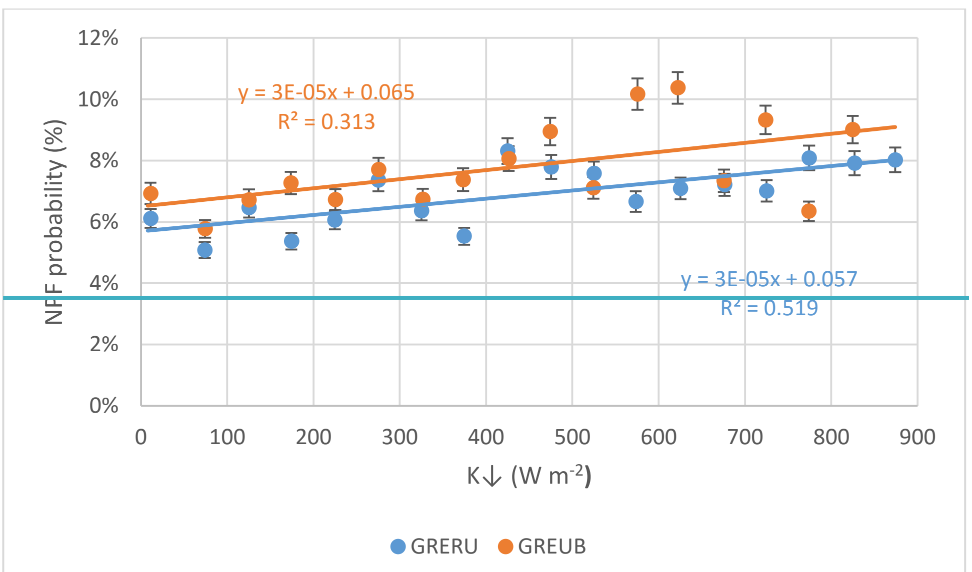

14%
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0002x + 0.022
R² = 0.8813
y = 0.0001x + 0.0138
R² = 0.9081
y = 0.0001x + 0.0087
R² = 0.9508
DENRU
DENUB
DENRO


NFF probability (%)
50%
40%
30%
20%
10%
0%
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0006x + 0.0239
R² = 0.9735
y = 0.0005x + 0.0406
R² = 0.9801
y = 0.0002x + 0.0092
R² = 0.9473
GERRU
GERUB
GERRO

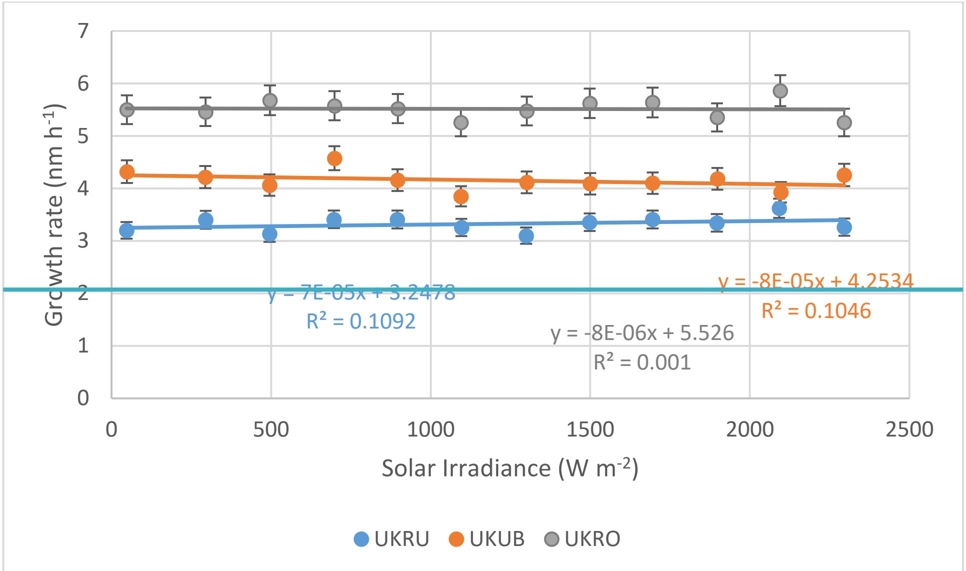

NFF probability (%)
25%
20%
15%
10%
5%
0%
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0002x + 0.0605
R² = 0.7566
y = 7E-05x + 0.0465
R² = 0.369
y = 9E-05x + 0.0374
R² = 0.5855
FINRU
FINUB
FINRO

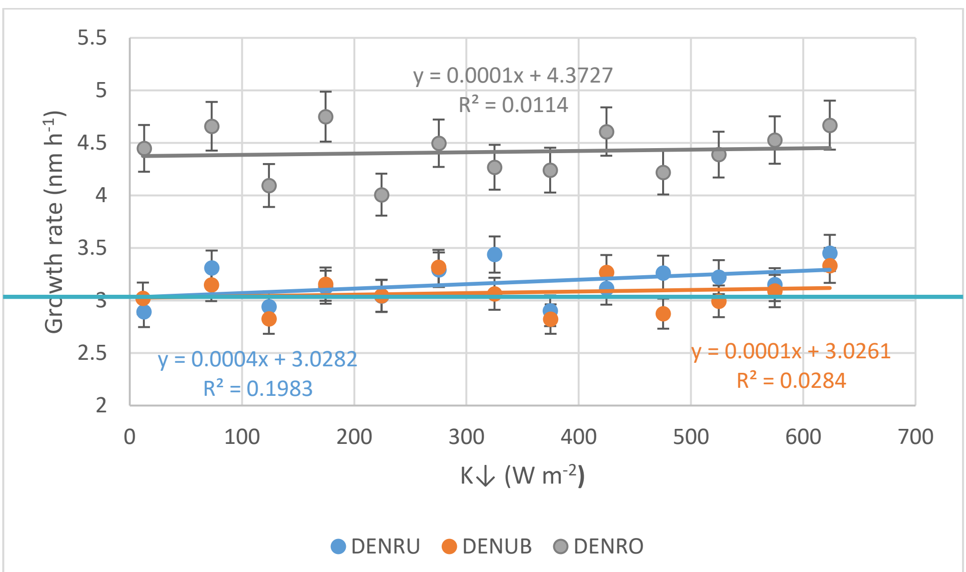


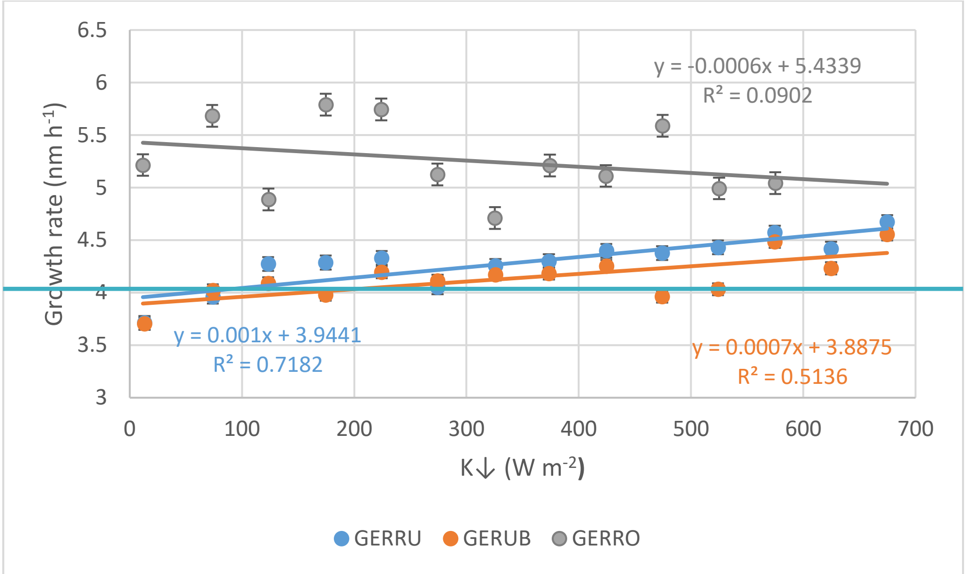
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
y = 7E-05x + 0.0945
R² = 0.5772
y = 4E-05x + 0.0573
R² = 0.3465
0
100
200
300
400
500
600
700
800
K↓ (W m-2)
SPARU
SPAUB



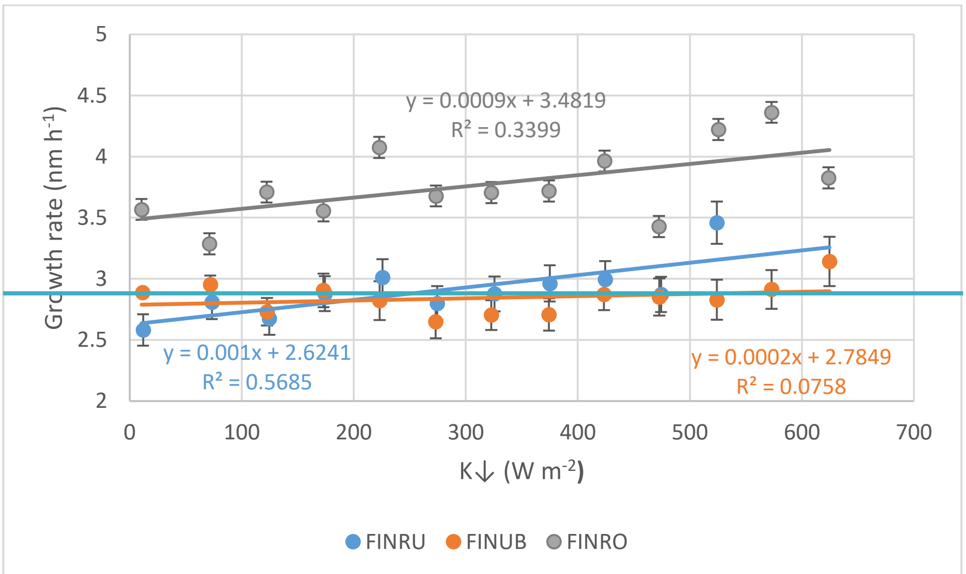
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
y = 3E-05x + 0.065
R² = 0.313
y = 3E-05x + 0.057
R² = 0.519
0
100
200
300
400
500
600
700
800
900
K↓ (W m-2)
GRERU
GREUB


Growth rate (nm h-1)
Solar Irradiance (W m-2)
y = 7E-05x + 3.2478
R² = 0.1092
y = -8E-05x + 4.2534
R² = 0.1046
y = -8E-06x + 5.526
R² = 0.001
UKRU
UKUB
UKRO

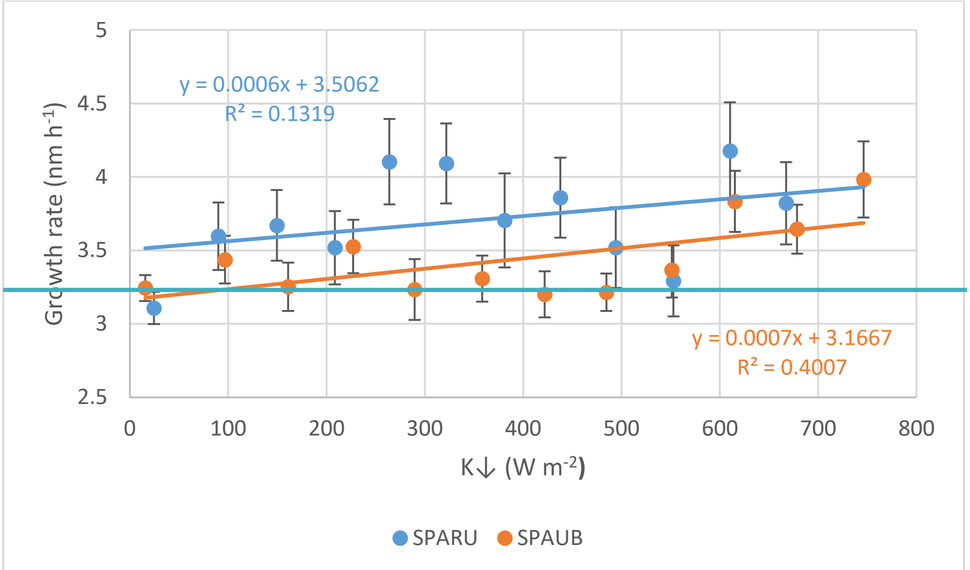

Growth rate (nm h-1)
K↓ (W m-2)
y = 0.0001x + 4.3727
R² = 0.0114
y = 0.0004x + 3.0282
R² = 0.1983
y = 0.0001x + 3.0261
R² = 0.0284
DENRU
DENUB
DENRO

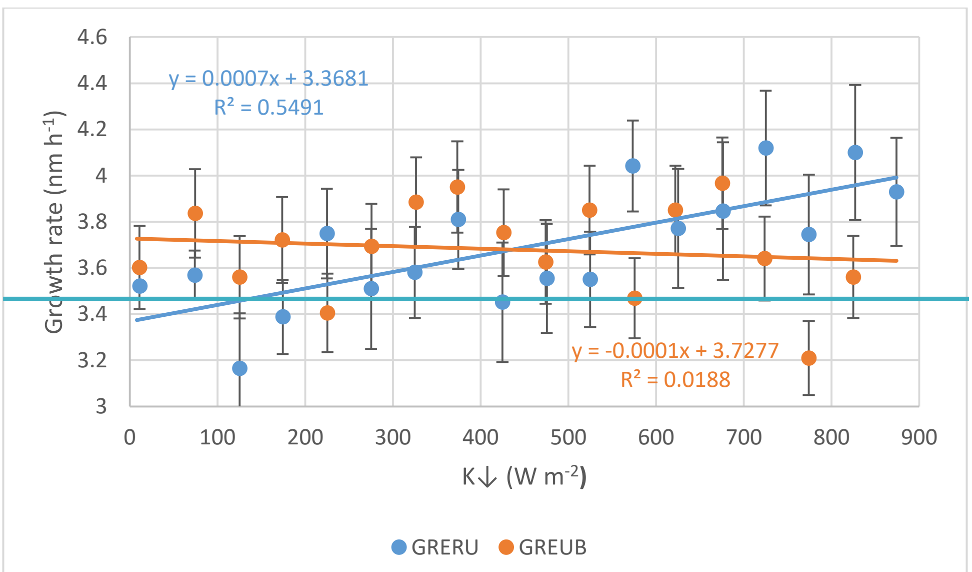


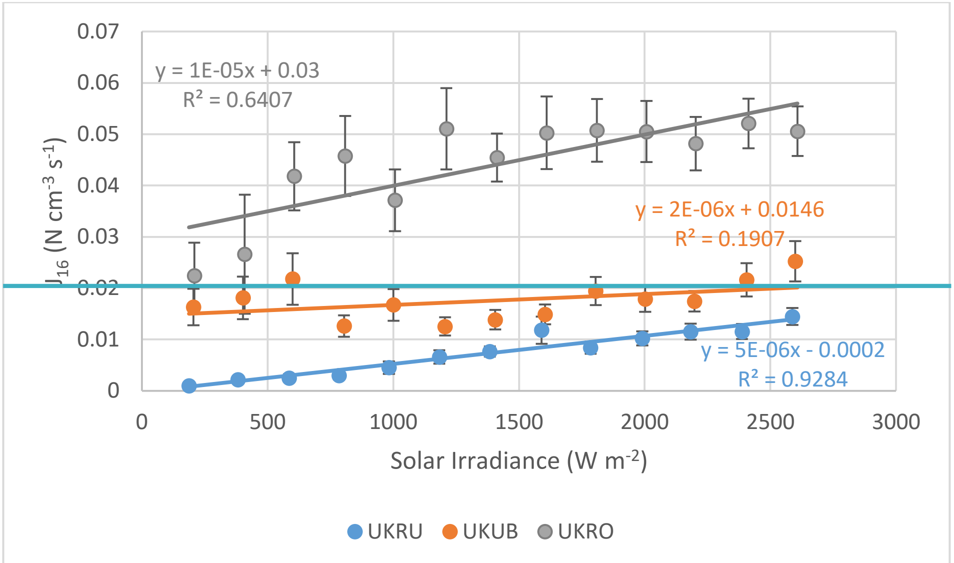
Growth rate (nm h-1)
6.5
6
5.5
5
4.5
4
3.5
3
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = -0.0006x + 5.4339
R² = 0.0902
y = 0.001x + 3.9441
R² = 0.7182
y = 0.0007x + 3.8875
R² = 0.5136
GERRU
GERUB
GERRO

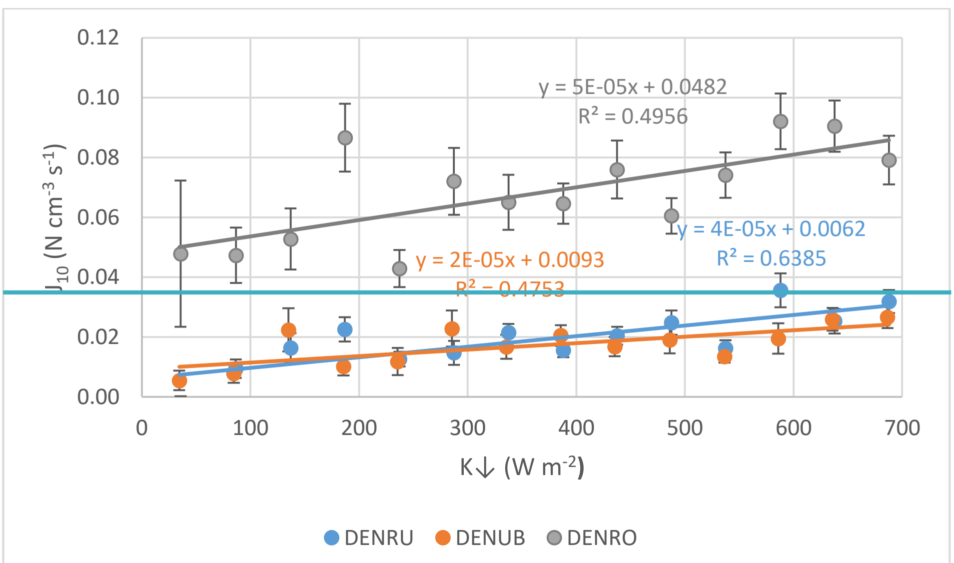


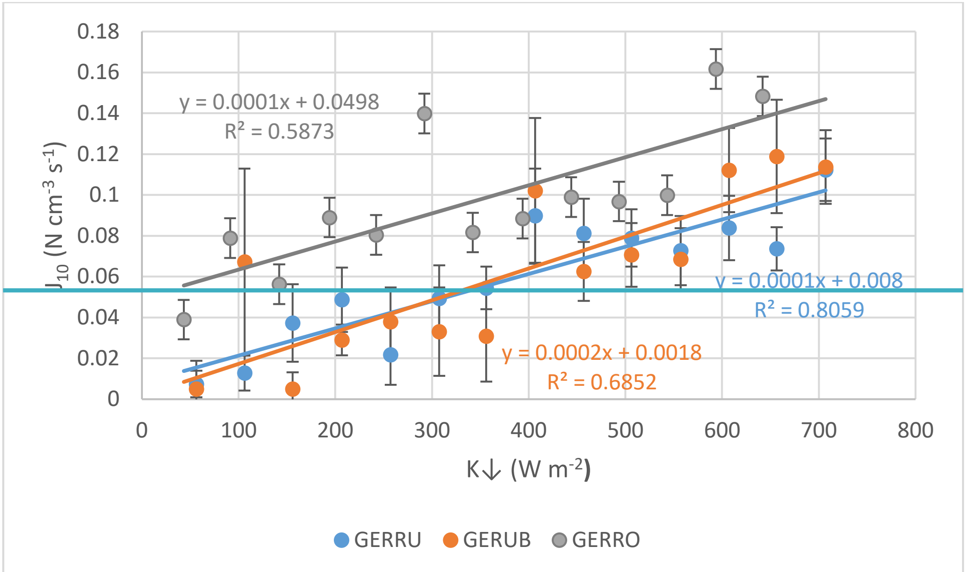
Growth rate (nm h-1)
5
4.5
4
3.5
3
2.5
2
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 0.0009x + 3.4819
R² = 0.3399
y = 0.001x + 2.6241
R² = 0.5685
y = 0.0002x + 2.7849
R² = 0.0758
FINRU
FINUB
FINRO

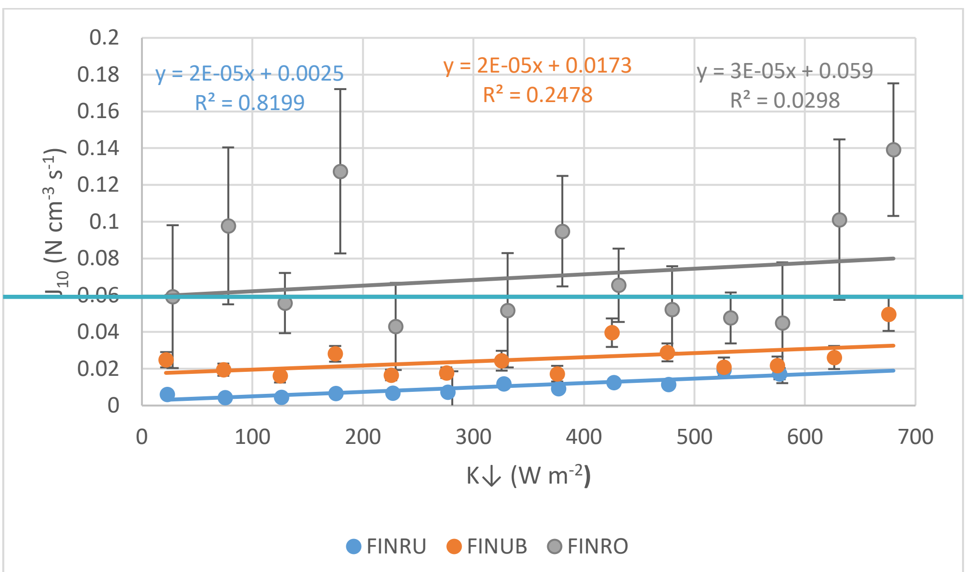

y = 0.0006x + 3.5062
R² = 0.1319
y = 0.0007x + 3.1667
R² = 0.4007
Growth rate (nm h-1)
K↓ (W m-2)
SPARU
SPAUB

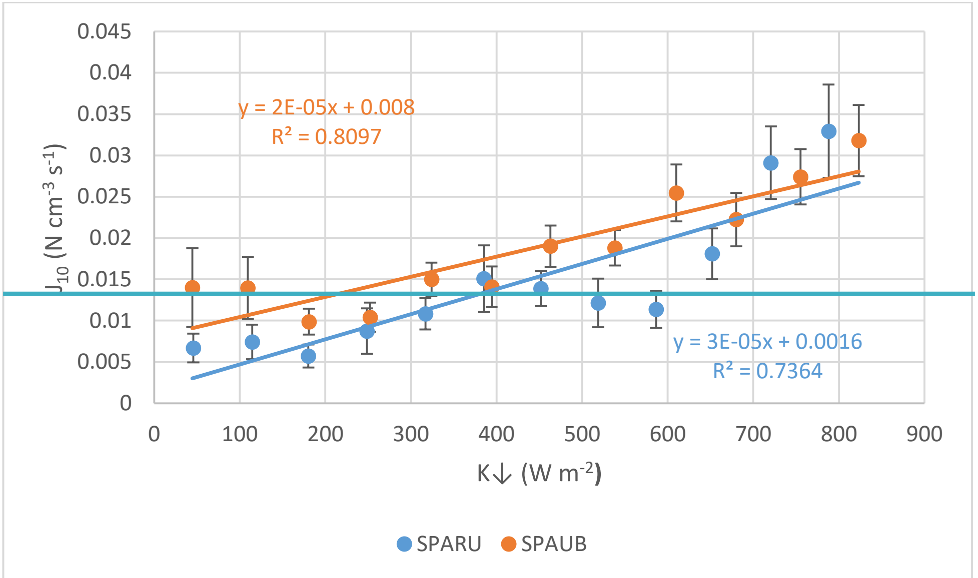

y = 0.0007x + 3.3681
R² = 0.5491
y = -0.0001x + 3.7277
R² = 0.0188
Growth rate (nm h-1)
K↓ (W m-2)
GRERU
GREUB

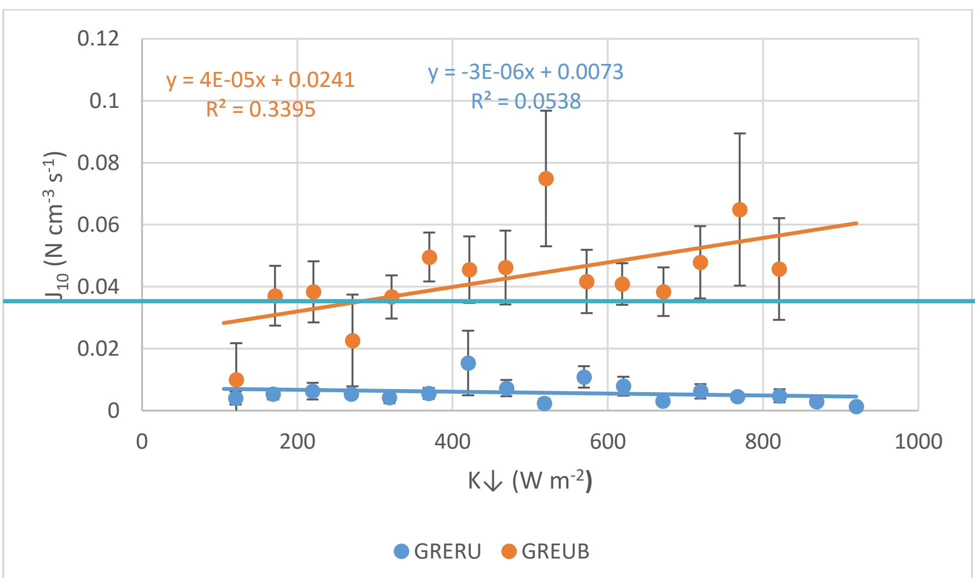

0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
J16 (N cm-3 s-1)
Solar Irradiance (W m-2)
y = 1E-05x + 0.03
R² = 0.6407
y = 2E-06x + 0.0146
R² = 0.1907
y = 5E-06x - 0.0002
R² = 0.9284
UKRU
UKUB
UKRO

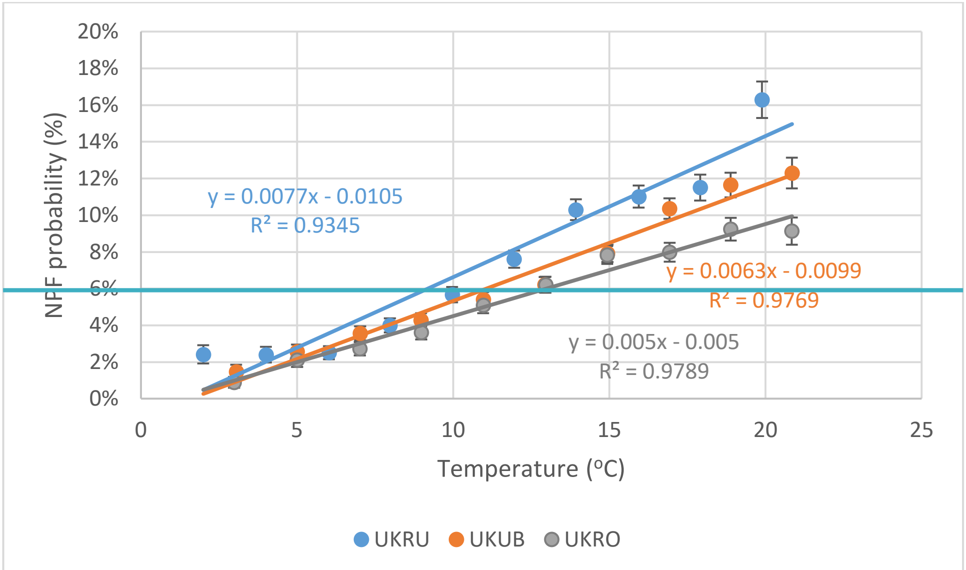

0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
100
200
300
400
500
600
700
J10 (N cm-3 s-1)
K↓ (W m-2)
y = 5E-05x + 0.0482
R² = 0.4956
y = 4E-05x + 0.0062
R² = 0.6385
y = 2E-05x + 0.0093
R² = 0.4753
DENRU
DENUB
DENRO

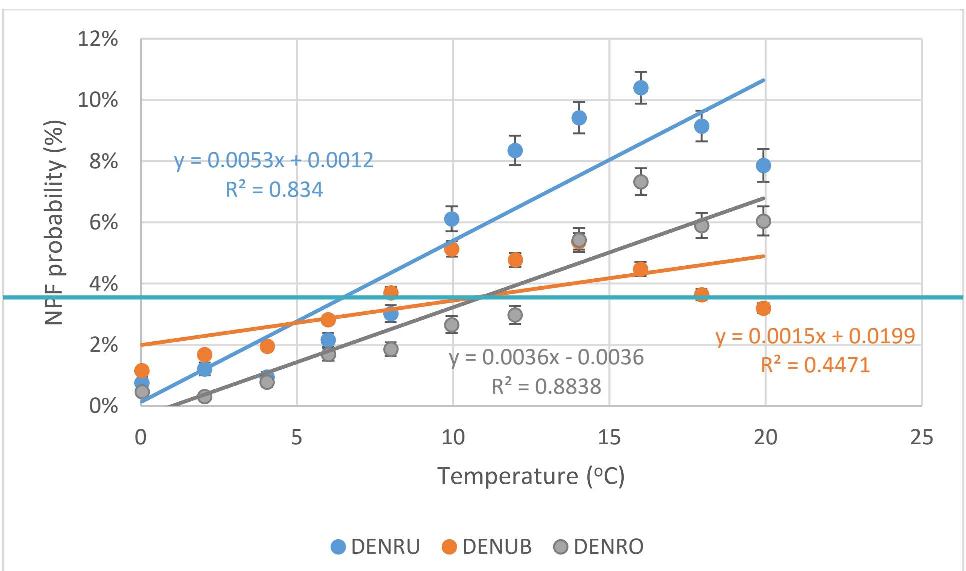

0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
0
100
200
300
400
500
600
700
800
K↓ (W m-2)
y = 0.0001x + 0.0498
R² = 0.5873
y = 0.0001x + 0.008
R² = 0.8059
y = 0.0002x + 0.0018
R² = 0.6852
GERRU
GERUB
GERRO

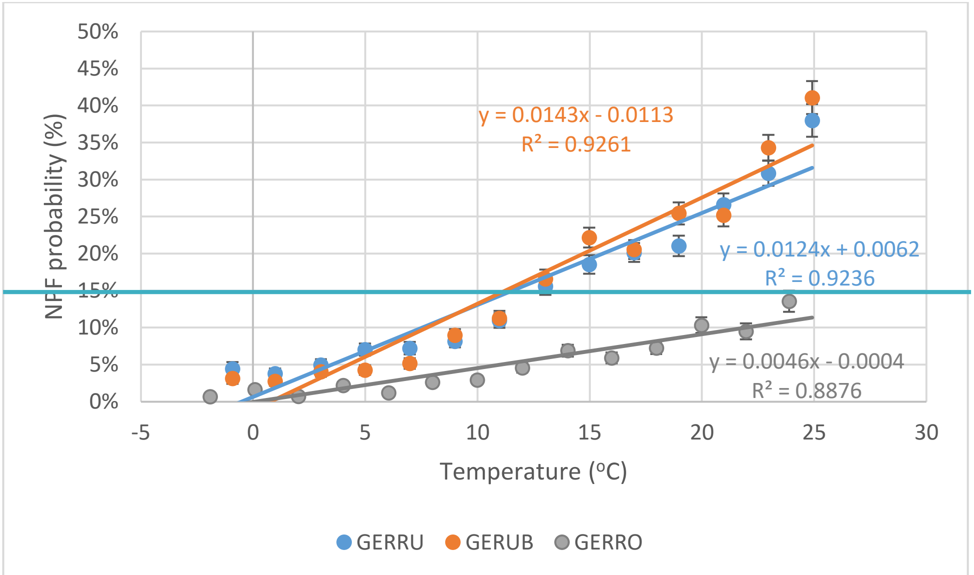

0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
0
100
200
300
400
500
600
700
K↓ (W m-2)
y = 2E-05x + 0.0025
R² = 0.8199
y = 2E-05x + 0.0173
R² = 0.2478
y = 3E-05x + 0.059
R² = 0.0298
FINRU
FINUB
FINRO


y = 2E-05x + 0.008
R² = 0.8097
y = 3E-05x + 0.0016
R² = 0.7364
J10 (N cm-3 s-1)
K↓ (W m-2)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
100
200
300
400
500
600
700
800
900
SPARU
SPAUB

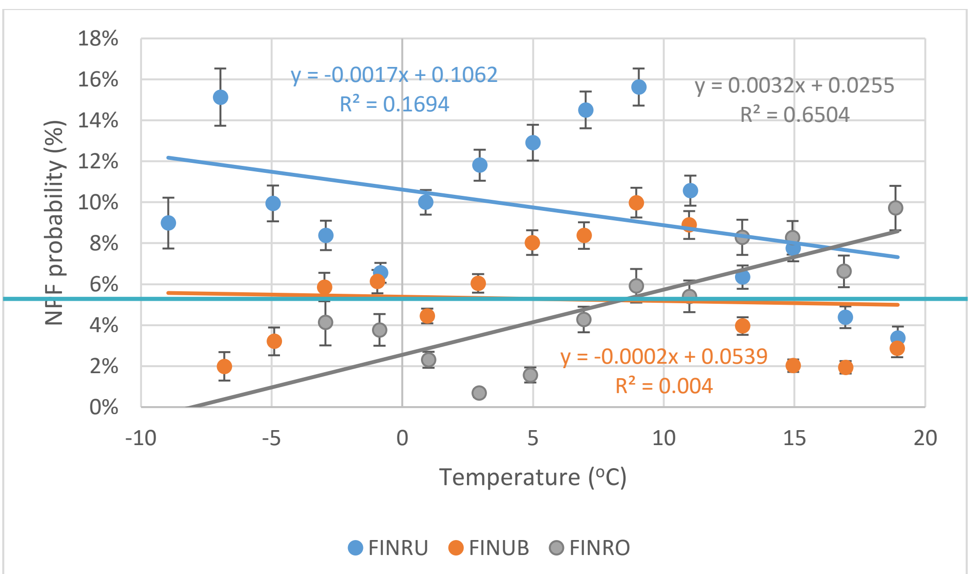

y = 4E-05x + 0.0241
R² = 0.3395
y = -3E-06x + 0.0073
R² = 0.0538
J10 (N cm-3 s-1)
K↓ (W m-2)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
GRERU
GREUB


NPF probability (%)
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
5
10
15
20
25
Temperature (ºC)
y = 0.0077x - 0.0105
R² = 0.9345
y = 0.0063x - 0.0099
R² = 0.9769
y = 0.005x - 0.005
R² = 0.9789
UKRU
UKUB
UKRO

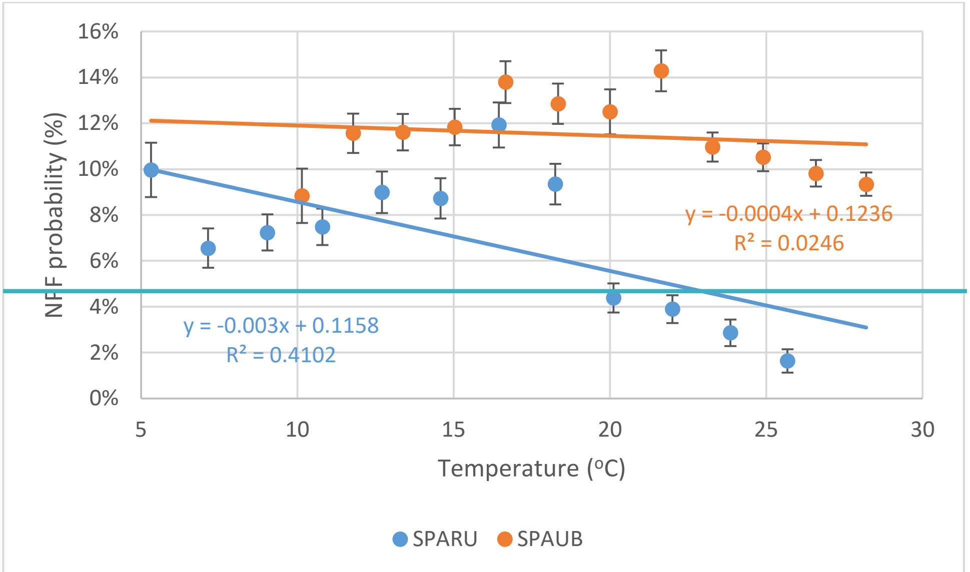

NPF probability (%)
12%
10%
8%
6%
4%
2%
0%
0
5
10
15
20
25
Temperature (ºC)
y = 0.0053x + 0.0012
R² = 0.834
y = 0.0036x - 0.0036
R² = 0.8838
y = 0.0015x + 0.0199
R² = 0.4471
DENRU
DENUB
DENRO

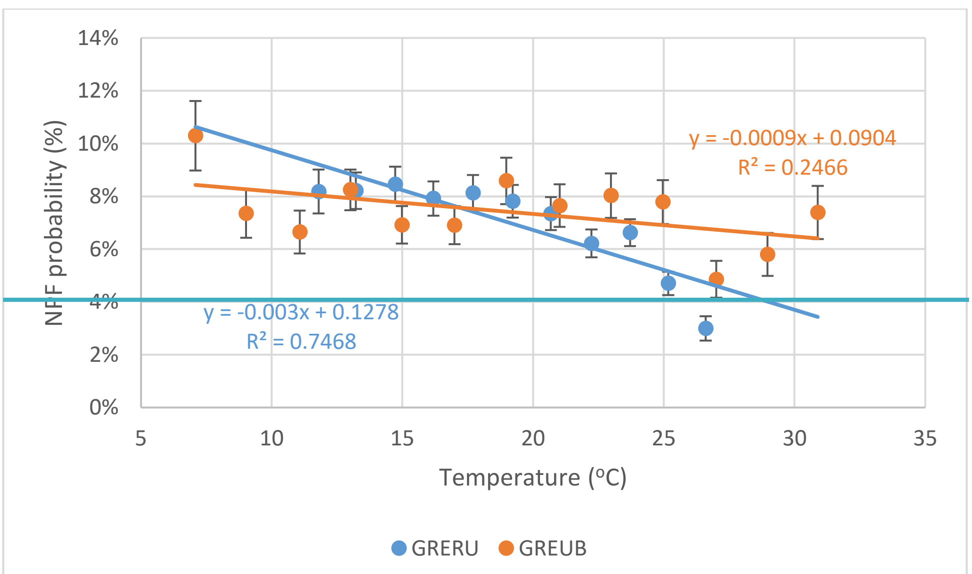


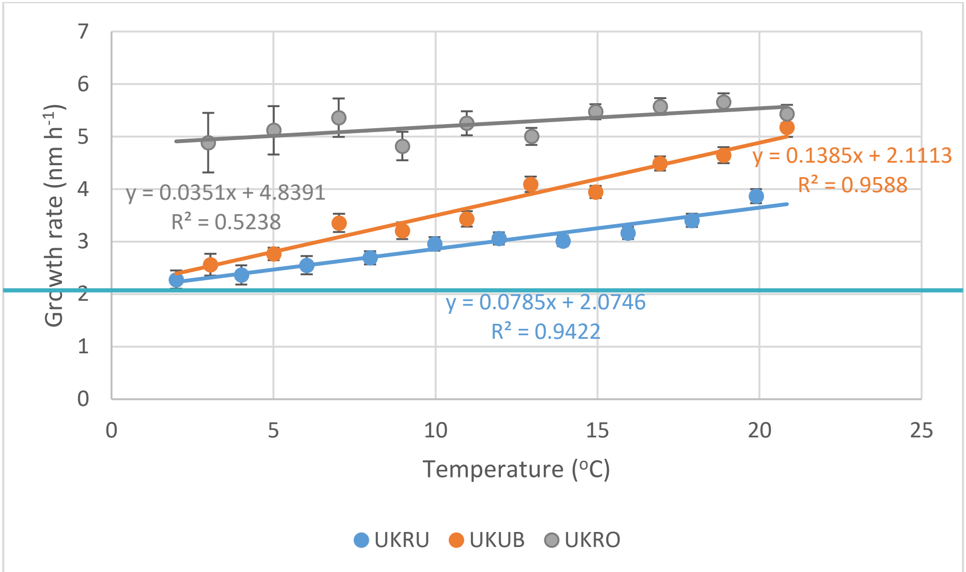
NFF probability (%)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-5
0
5
10
15
20
25
30
Temperature (ºC)
y = 0.0143x - 0.0113
R² = 0.9261
y = 0.0124x + 0.0062
R² = 0.9236
y = 0.0046x - 0.0004
R² = 0.8876
GERRU
GERUB
GERRO

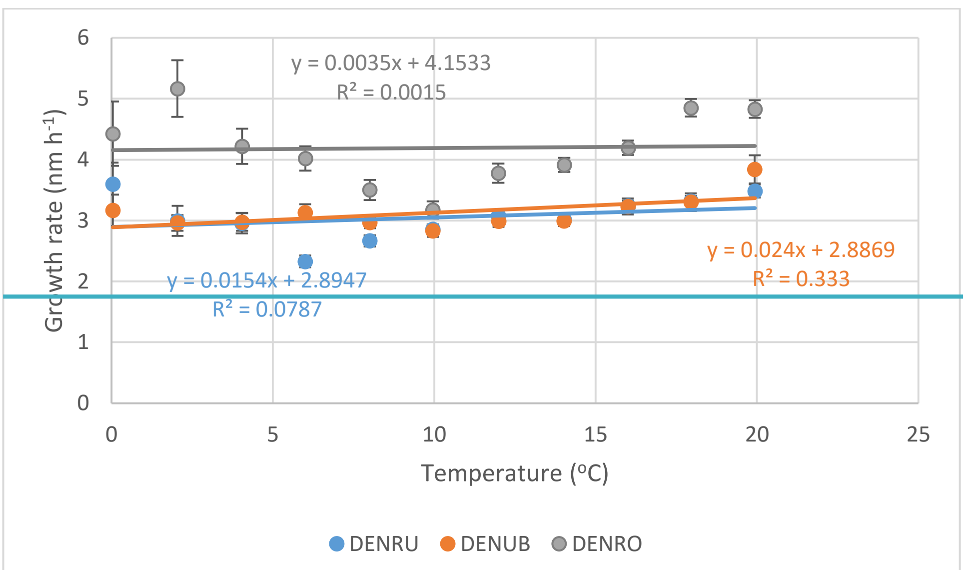


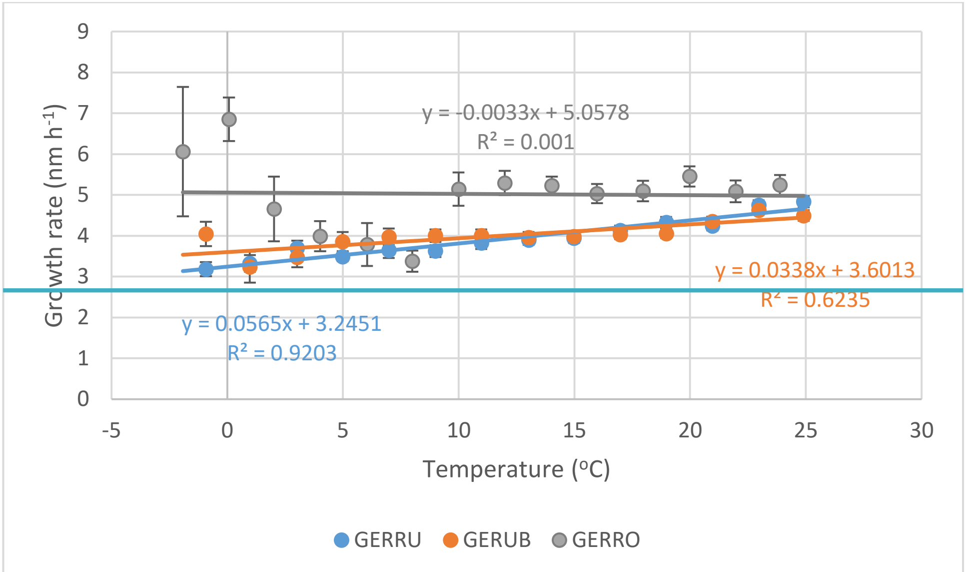
NFF probability (%)
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
-10
-5
0
5
10
15
20
Temperature (ºC)
y = -0.0017x + 0.1062
R² = 0.1694
y = 0.0032x + 0.0255
R² = 0.6504
y = -0.0002x + 0.0539
R² = 0.004
FINRU
FINUB
FINRO

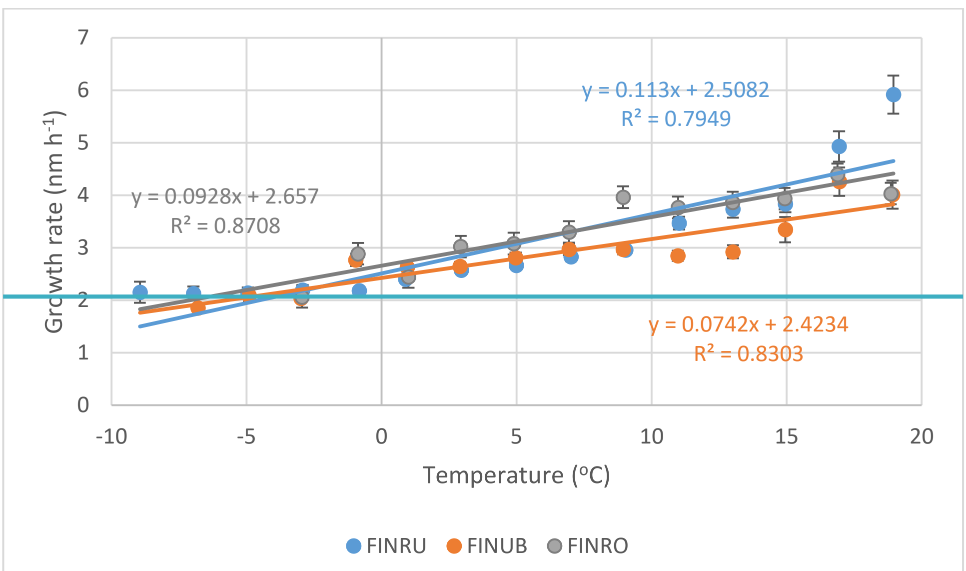

16%
14%
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
5
10
15
20
25
30
Temperature (ºC)
y = -0.0004x + 0.1236
R² = 0.0246
y = -0.003x + 0.1158
R² = 0.4102
SPARU
SPAUB

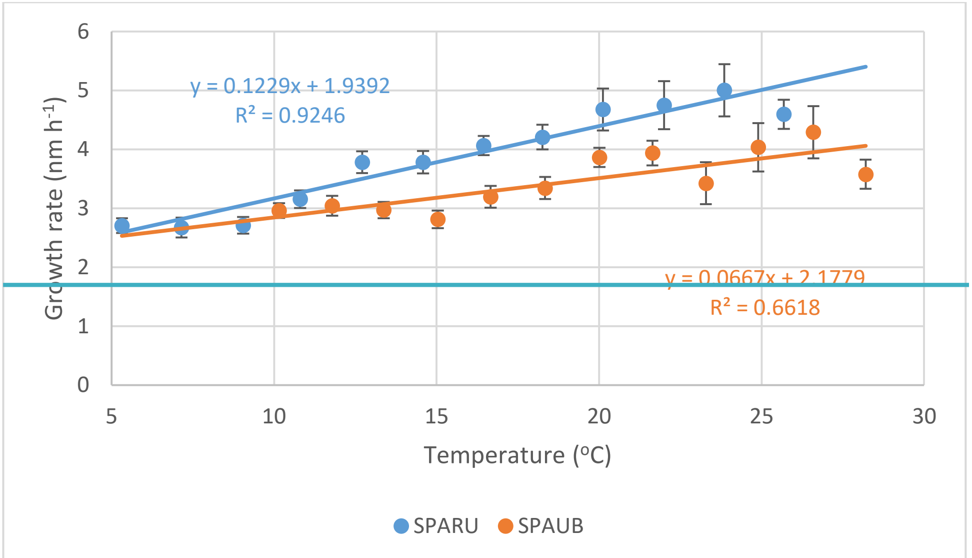

14%
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
5
10
15
20
25
30
35
Temperature (ºC)
y = -0.0009x + 0.0904
R² = 0.2466
y = -0.003x + 0.1278
R² = 0.7468
GRERU
GREUB

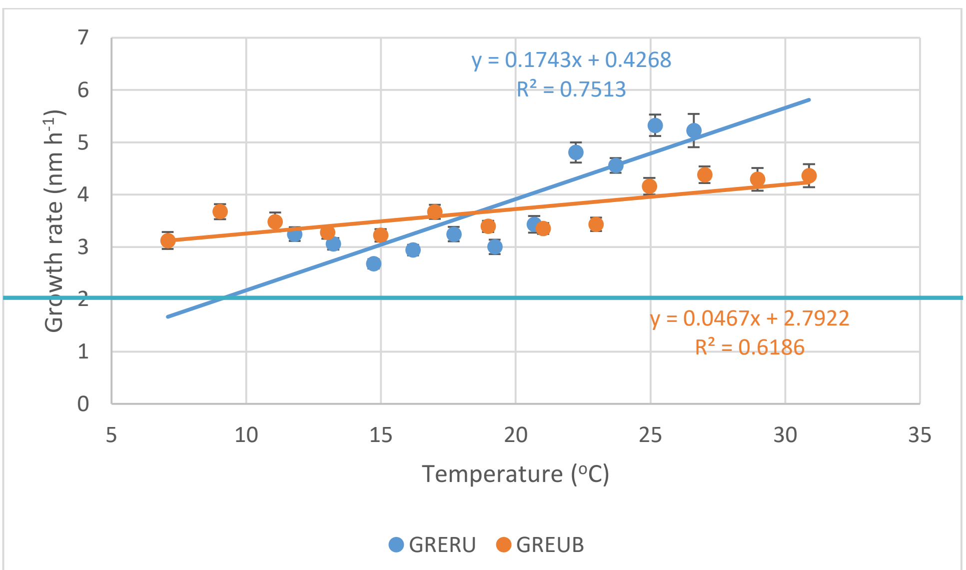

Growth rate (nm h-1)
Temperature (oC)
y = 0.0351x + 4.8391
R² = 0.5238
y = 0.1385x + 2.1113
R² = 0.9588
y = 0.0785x + 2.0746
R² = 0.9422
UKRU
UKUB
UKRO

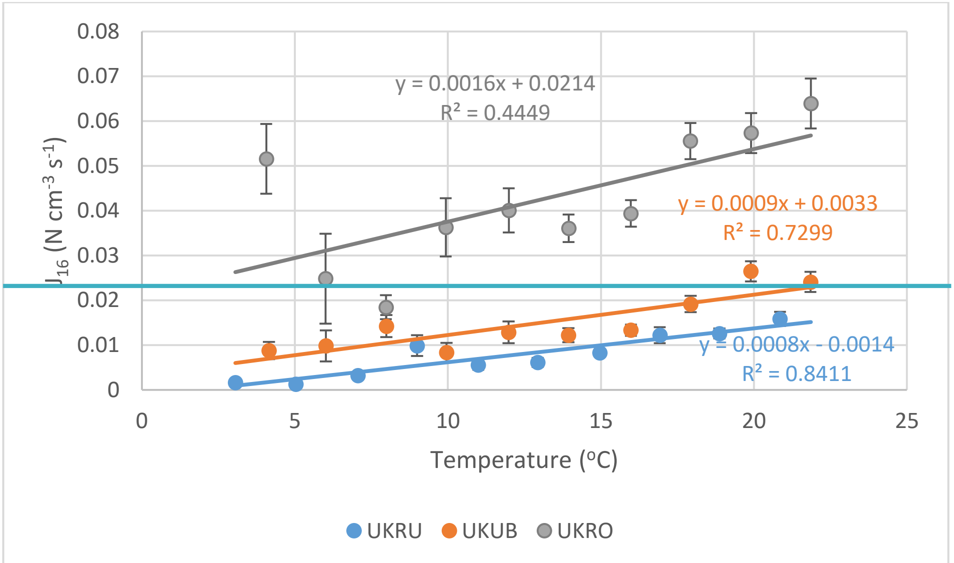

Growth rate (nm h-1)
Temperature (oC)
y = 0.0035x + 4.1533
R² = 0.0015
y = 0.024x + 2.8869
R² = 0.333
y = 0.0154x + 2.8947
R² = 0.0787
DENRU
DENUB
DENRO

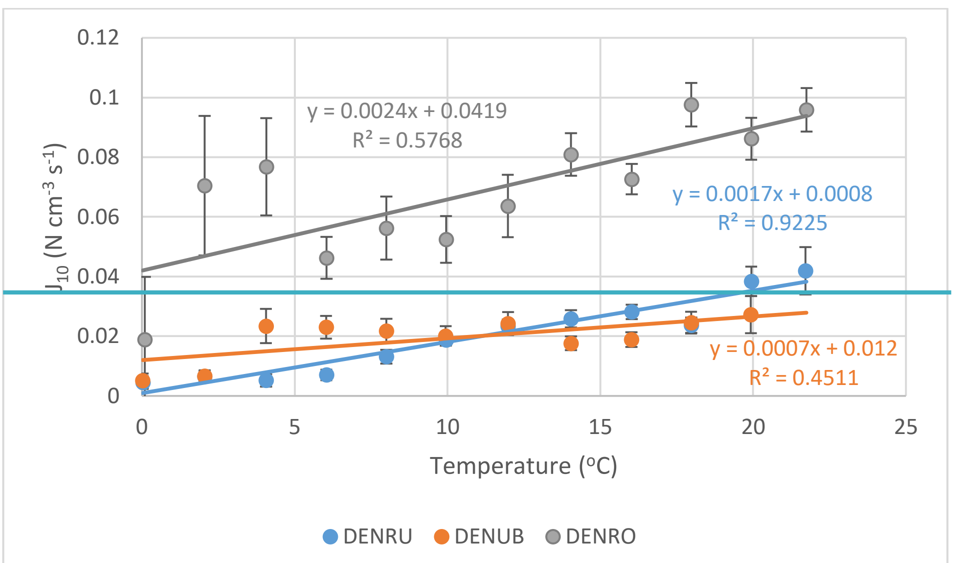

Growth rate (nm h-1)
Temperature (°C)
y = -0.0033x + 5.0578
R² = 0.001
y = 0.0338x + 3.6013
R² = 0.6235
y = 0.0565x + 3.2451
R² = 0.9203
GERRU
GERUB
GERRO

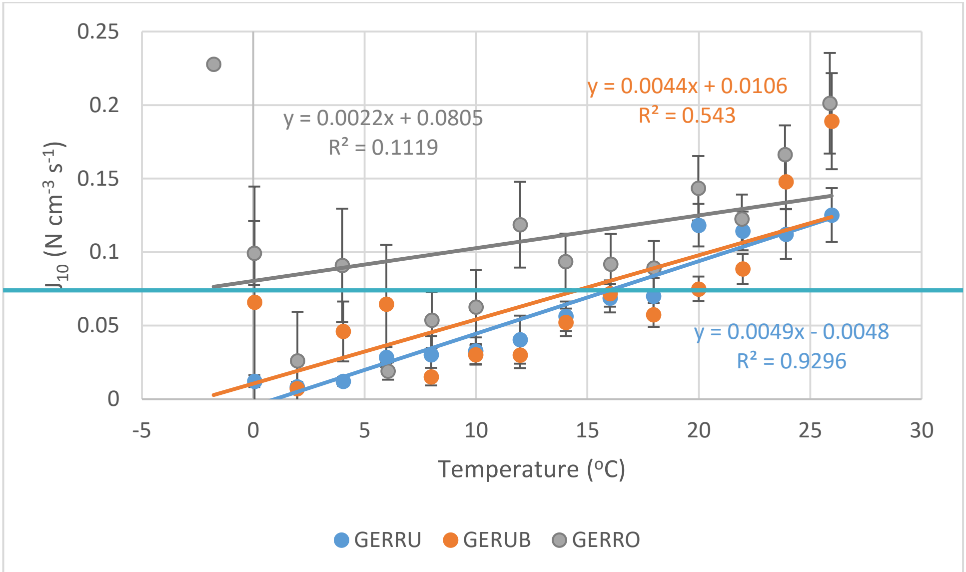

Growth rate (nm h-1)
Temperature (°C)
y = 0.113x + 2.5082
R² = 0.7949
y = 0.0928x + 2.657
R² = 0.8708
y = 0.0742x + 2.4234
R² = 0.8303
FINRU
FINUB
FINRO


y = 0.1229x + 1.9392
R² = 0.9246
y = 0.0667x + 2.1779
R² = 0.6618
Growth rate (nm h-1)
Temperature (°C)
SPARU
SPAUB

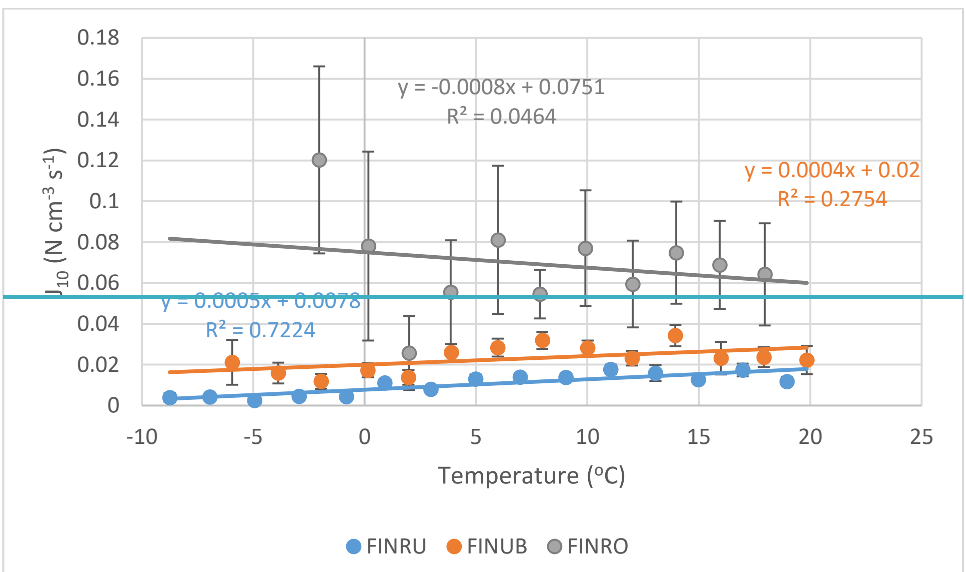

y = 0.1743x + 0.4268
R² = 0.7513
y = 0.0467x + 2.7922
R² = 0.6186
Growth rate (nm h-1)
Temperature (°C)
GRERU
GREUB


0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J_{16} (N cm^{-3} s^{-1})
y = 0.0016x + 0.0214
R² = 0.4449
y = 0.0009x + 0.0033
R² = 0.7299
y = 0.0008x - 0.0014
R² = 0.8411
0
5
10
15
20
25
Temperature (°C)
UKRU
UKUB
UKRO

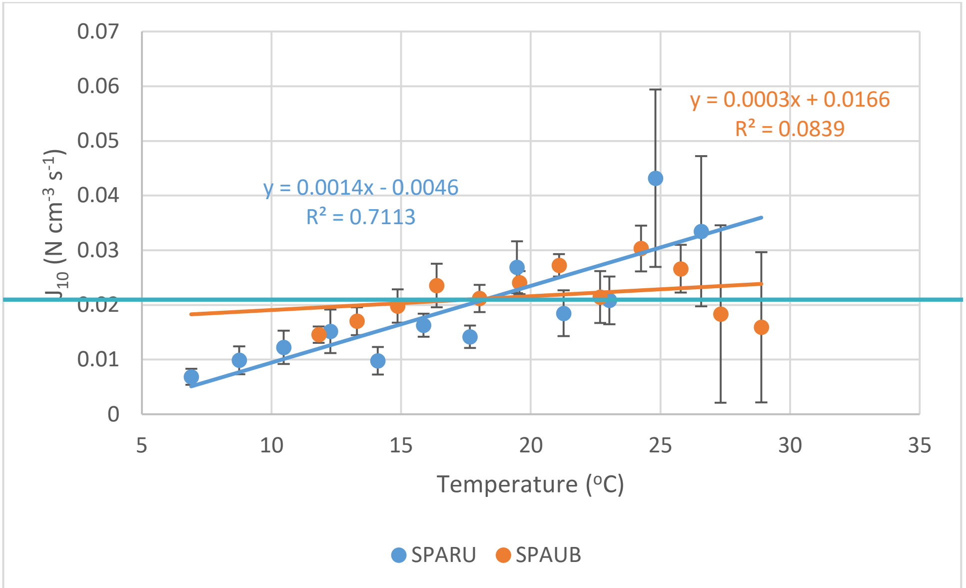

0.12
0.1
0.08
0.06
0.04
0.02
0
J_{10} (N cm^{-3} s^{-1})
y = 0.0024x + 0.0419
R² = 0.5768
y = 0.0017x + 0.0008
R² = 0.9225
y = 0.0007x + 0.012
R² = 0.4511
0
5
10
15
20
25
Temperature (°C)
DENRU
DENUB
DENRO

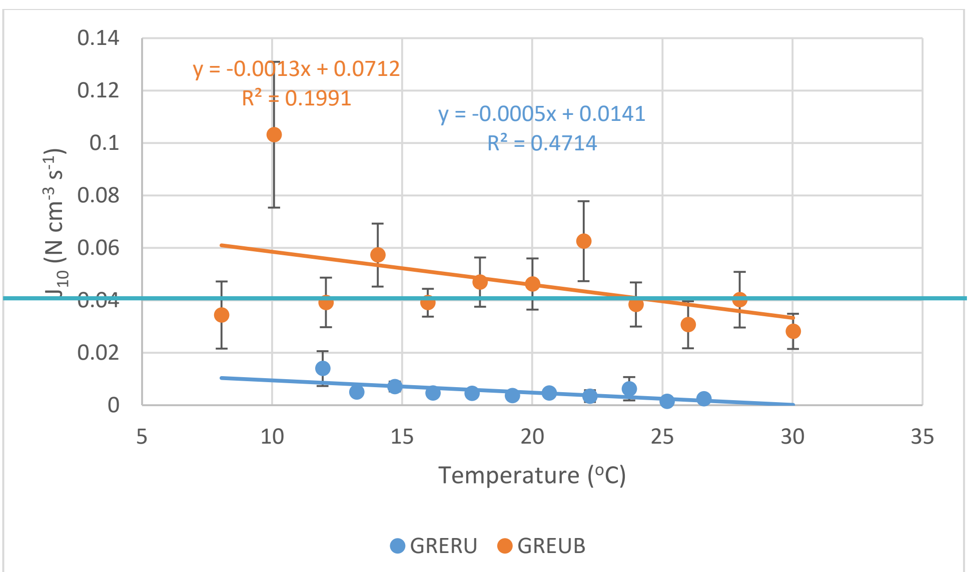


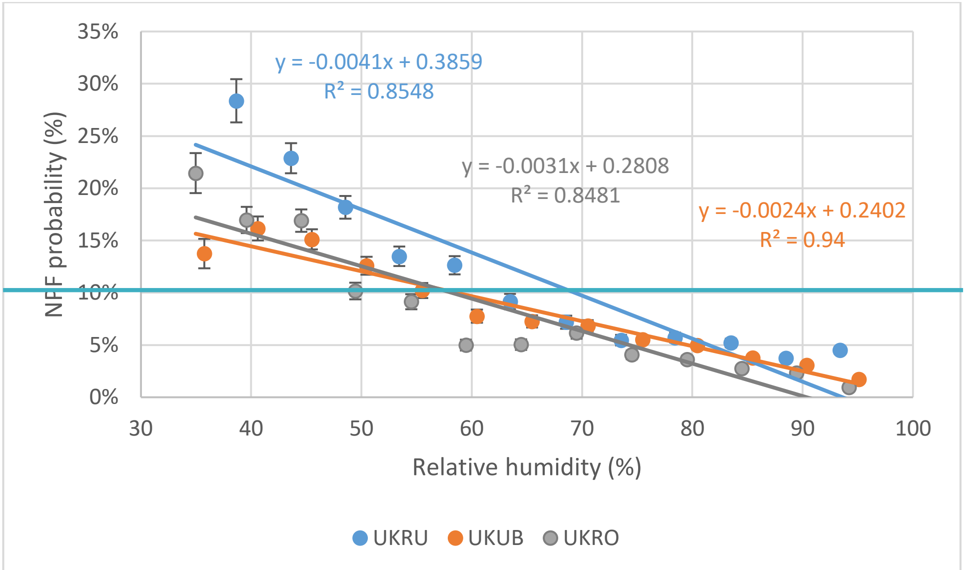
0.25
0.2
0.15
0.1
0.05
0
-5
0
5
10
15
20
25
30
J10 (N cm-3 s-1)
Temperature (oC)
y = 0.0022x + 0.0805
R² = 0.1119
y = 0.0044x + 0.0106
R² = 0.543
y = 0.0049x - 0.0048
R² = 0.9296
GERRU
GERUB
GERRO

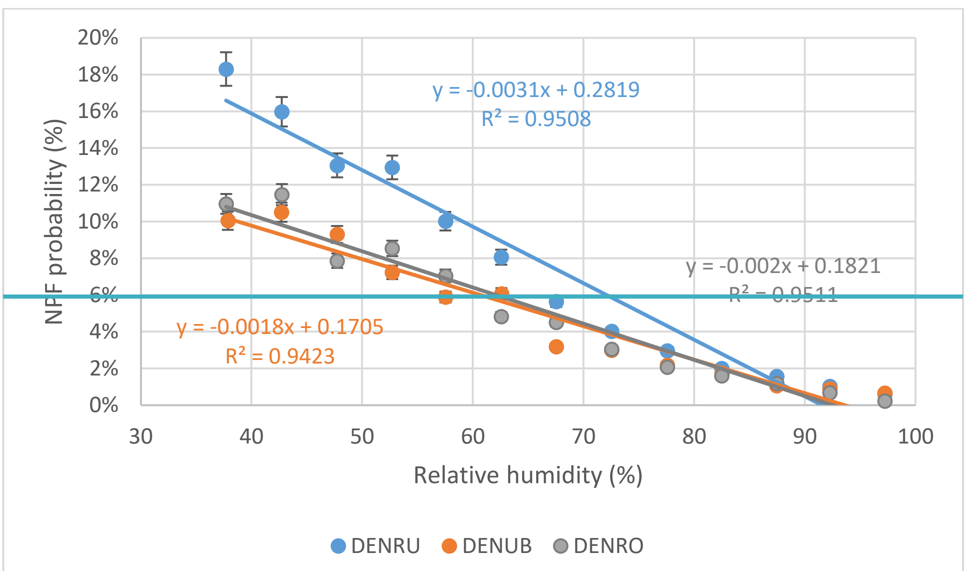


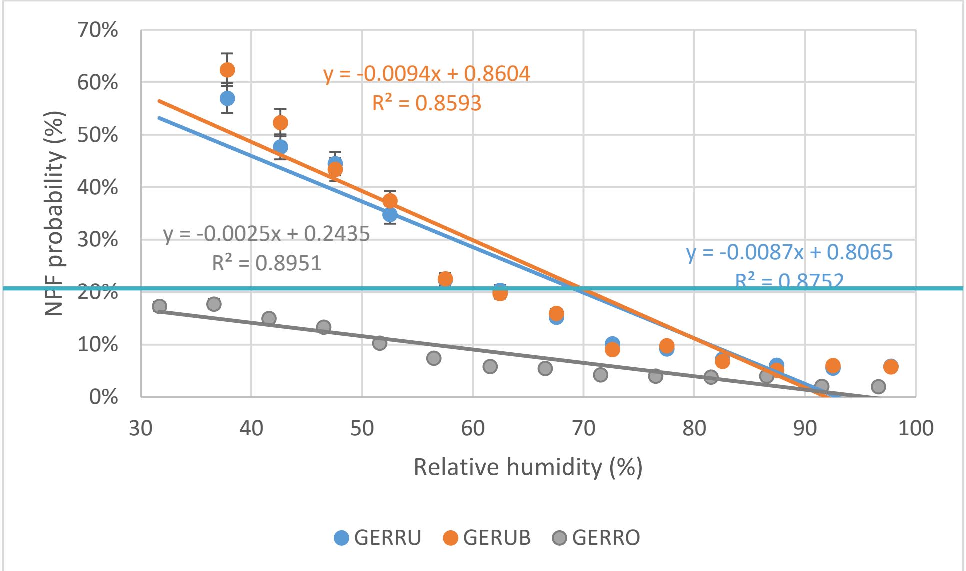
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-10
-5
0
5
10
15
20
25
J10 (N cm-3 s-1)
Temperature (oC)
y = -0.0008x + 0.0751
R² = 0.0464
y = 0.0004x + 0.02
R² = 0.2754
y = 0.0005x + 0.0078
R² = 0.7224
FINRU
FINUB
FINRO


y = 0.0003x + 0.0166
R² = 0.0839
y = 0.0014x - 0.0046
R² = 0.7113
J10 (N cm-3 s-1)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5
10
15
20
25
30
35
Temperature (oC)
SPARU
SPAUB

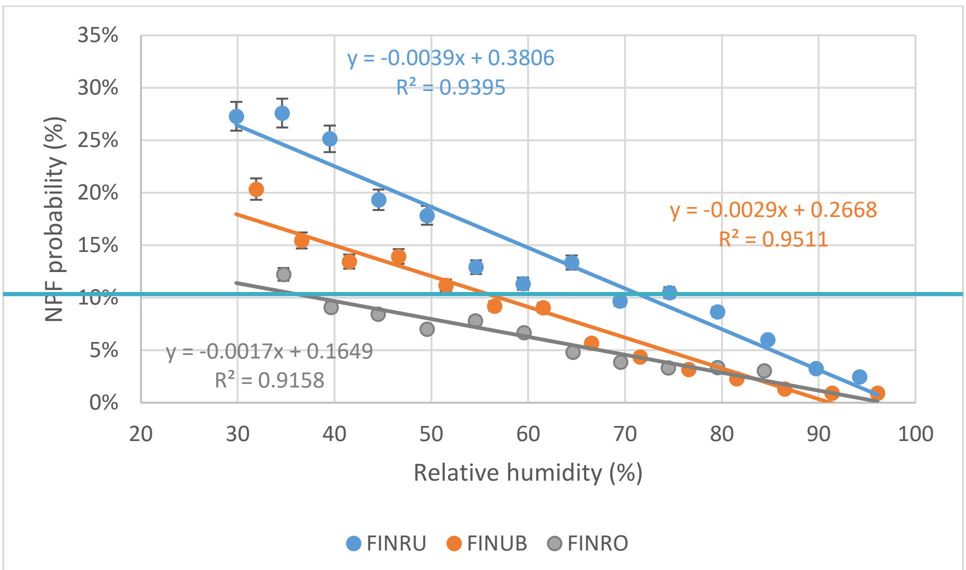

y = -0.0013x + 0.0712
R² = 0.1991
y = -0.0005x + 0.0141
R² = 0.4714
J10 (N cm-3 s-1)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
5
10
15
20
25
30
35
Temperature (oC)
GRERU
GREUB


35%
30%
25%
20%
15%
10%
5%
0%
NFF probability (%)
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0041x + 0.3859
R² = 0.8548
y = -0.0031x + 0.2808
R² = 0.8481
y = -0.0024x + 0.2402
R² = 0.94
UKRU
UKUB
UKRO

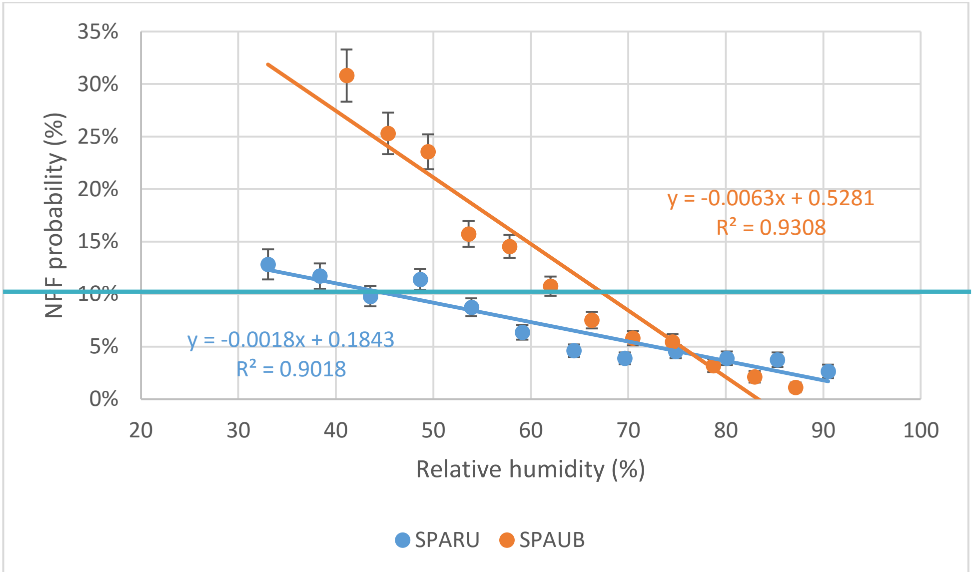

20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
NFF probability (%)
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0031x + 0.2819
R² = 0.9508
y = -0.002x + 0.1821
R² = 0.9511
y = -0.0018x + 0.1705
R² = 0.9423
DENRU
DENUB
DENRO

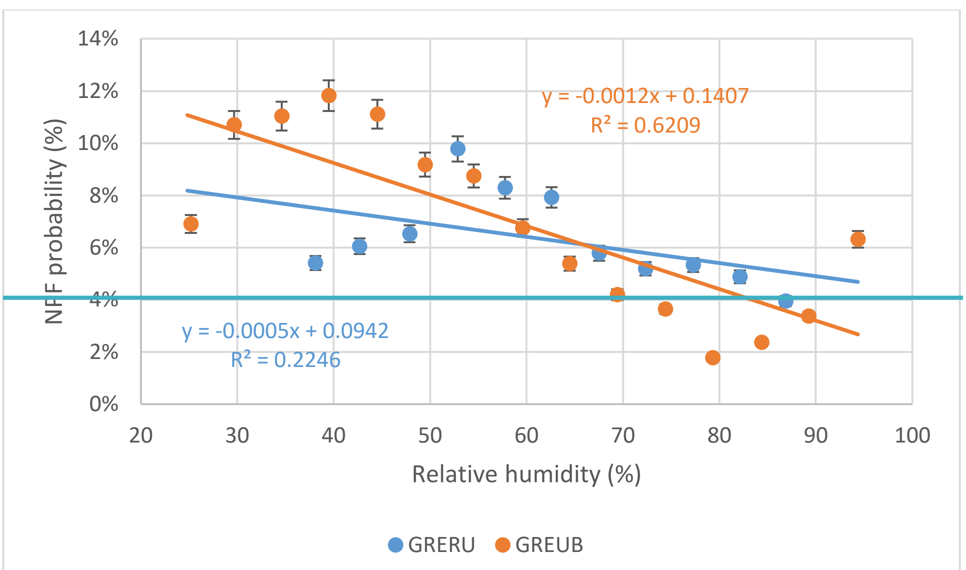


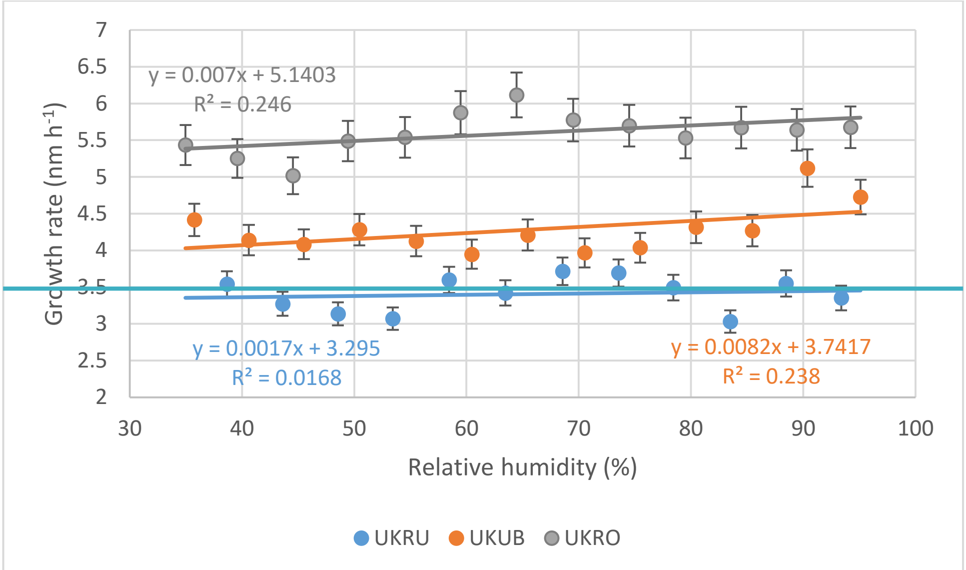
70%
60%
50%
40%
30%
20%
10%
0%
NPF probability (%)
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0094x + 0.8604
R² = 0.8593
y = -0.0025x + 0.2435
R² = 0.8951
y = -0.0087x + 0.8065
R² = 0.8752
GERRU
GERUB
GERRO

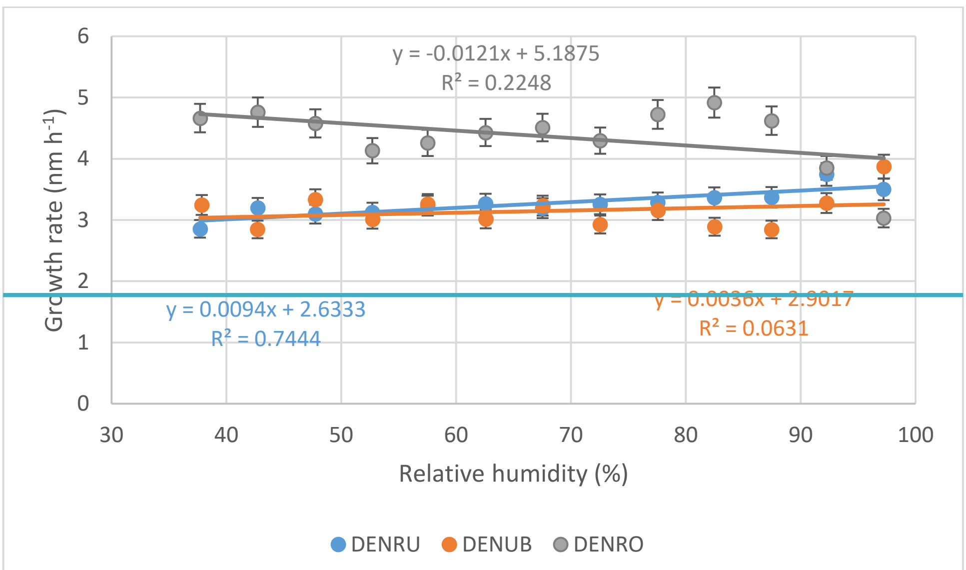


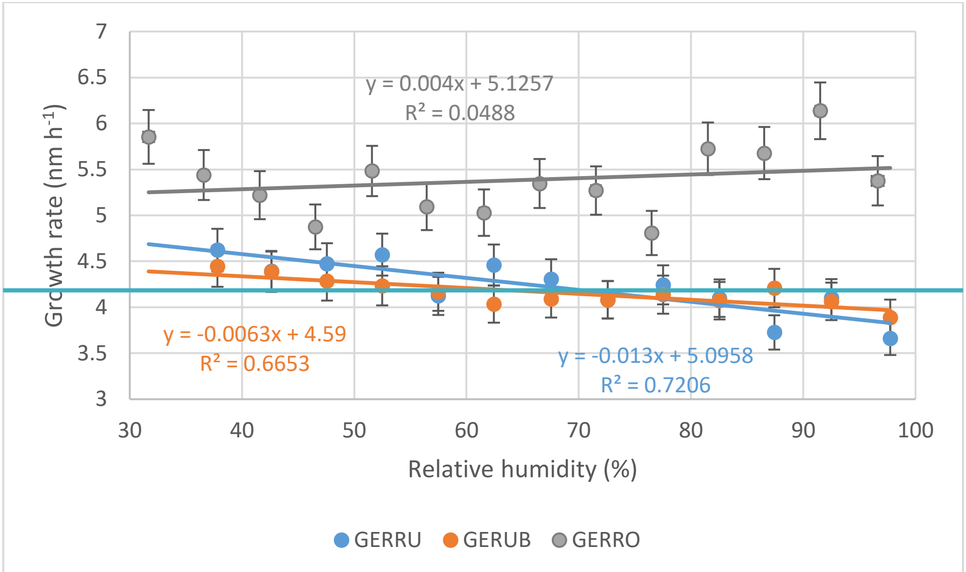
35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0039x + 0.3806
R² = 0.9395
y = -0.0029x + 0.2668
R² = 0.9511
y = -0.0017x + 0.1649
R² = 0.9158
FINRU
FINUB
FINRO

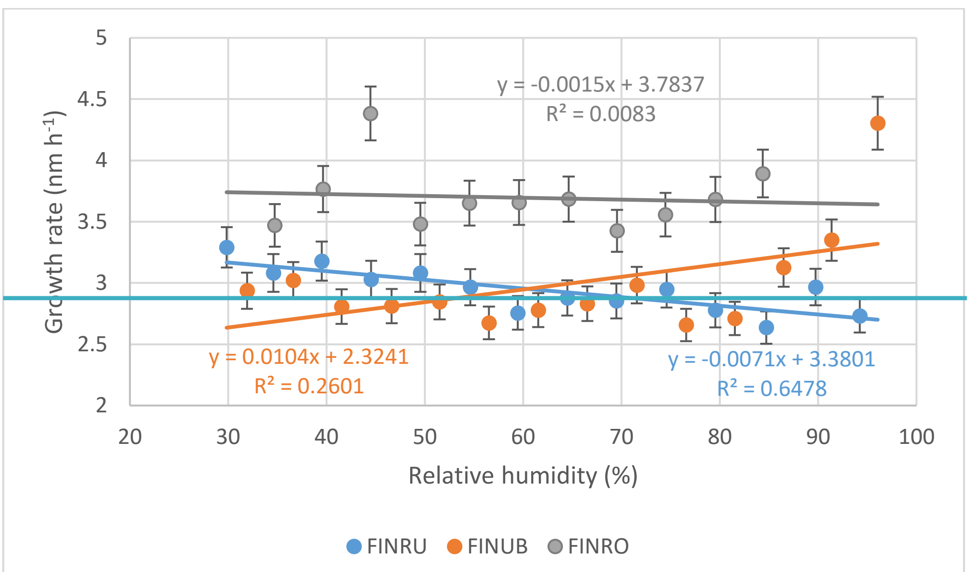

NFF probability (%)
35%
30%
25%
20%
15%
10%
5%
0%
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0063x + 0.5281
R² = 0.9308
y = -0.0018x + 0.1843
R² = 0.9018
SPARU
SPAUB

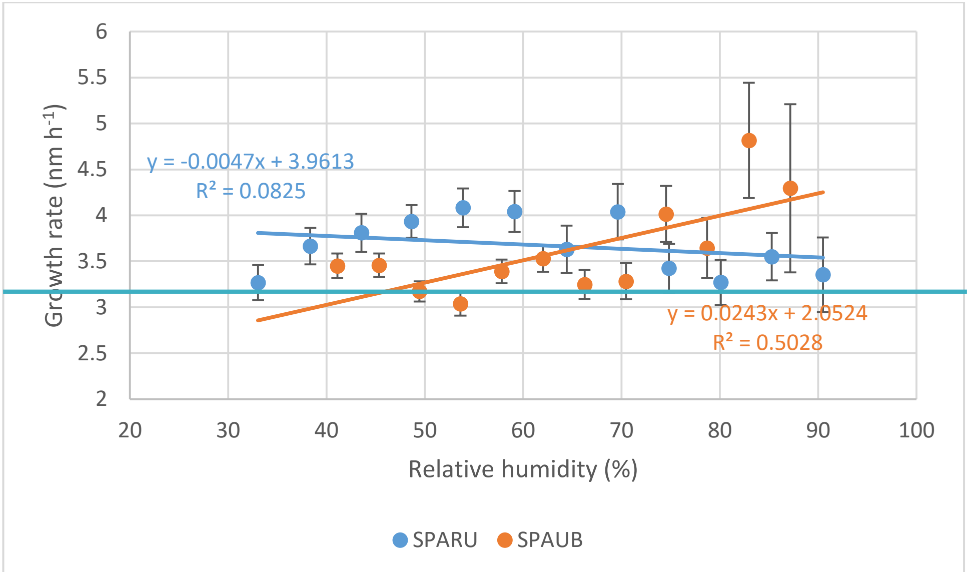

NFF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0012x + 0.1407
R² = 0.6209
y = -0.0005x + 0.0942
R² = 0.2246
GRERU
GREUB

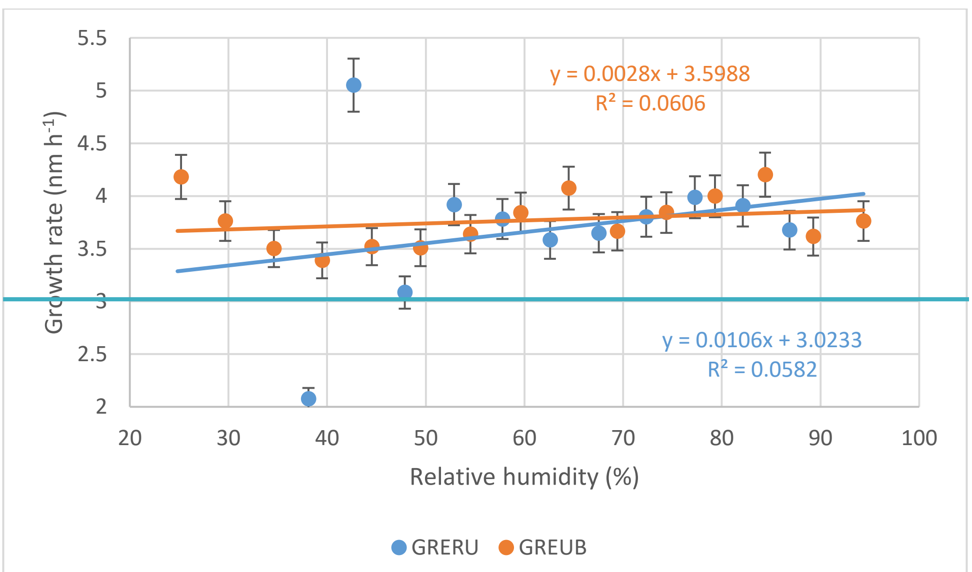

y = 0.007x + 5.1403
R² = 0.246
y = 0.0017x + 3.295
R² = 0.0168
y = 0.0082x + 3.7417
R² = 0.238
Growth rate (nm h-1)
Relative humidity (%)
UKRU
UKUB
UKRO

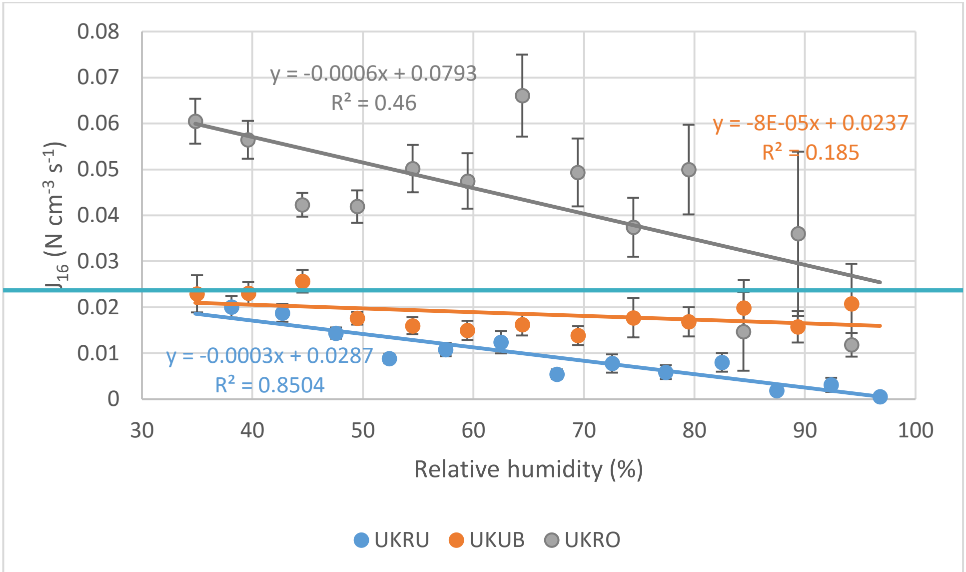

y = -0.0121x + 5.1875
R² = 0.2248
y = 0.0094x + 2.6333
R² = 0.7444
y = 0.0036x + 2.9017
R² = 0.0631
Growth rate (nm h-1)
Relative humidity (%)
DENRU
DENUB
DENRO

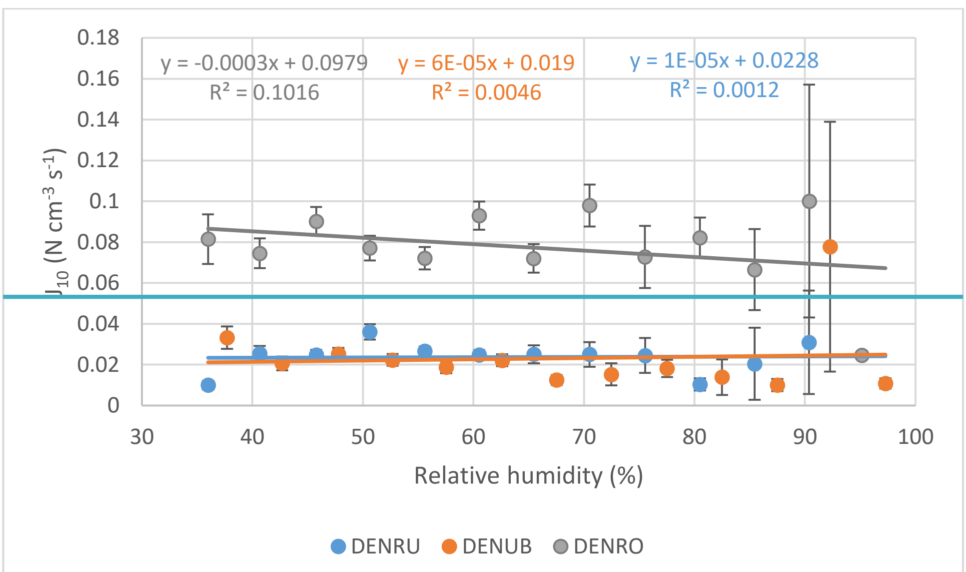

Growth rate (nm h-1)
Relative humidity (%)
y = 0.004x + 5.1257
R² = 0.0488
y = -0.0063x + 4.59
R² = 0.6653
y = -0.013x + 5.0958
R² = 0.7206
GERRU
GERUB
GERRO

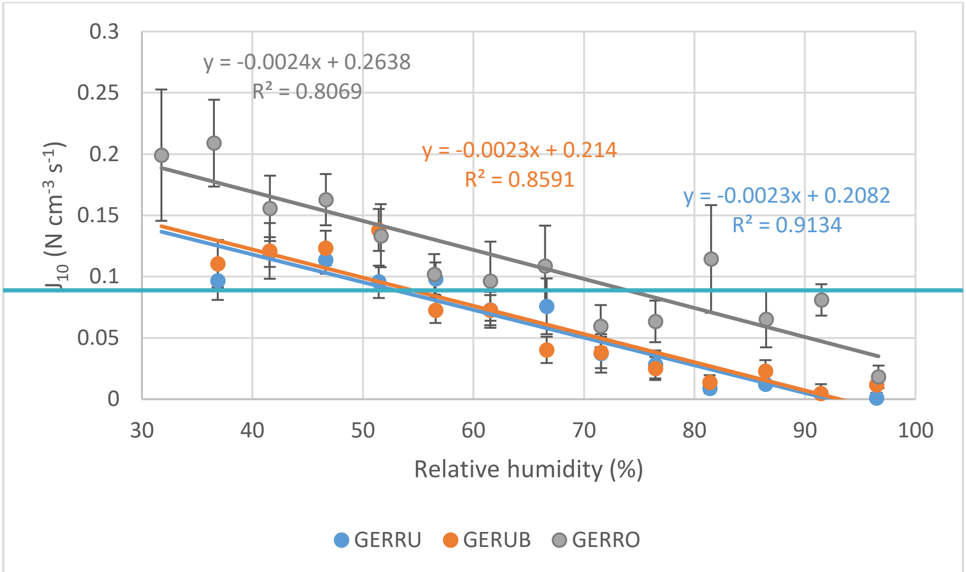

Growth rate (nm h-1)
Relative humidity (%)
y = -0.0015x + 3.7837
R² = 0.0083
y = 0.0104x + 2.3241
R² = 0.2601
y = -0.0071x + 3.3801
R² = 0.6478
FINRU
FINUB
FINRO


Growth rate (nm h-1)
Relative humidity (%)
y = -0.0047x + 3.9613
R² = 0.0825
y = 0.0243x + 2.0524
R² = 0.5028
SPARU
SPAUB

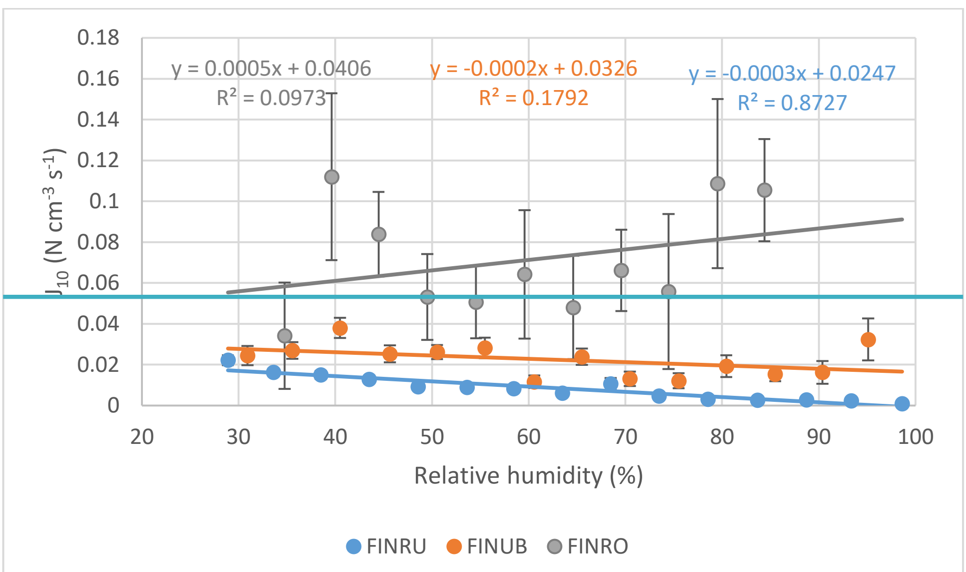

Growth rate (nm h-1)
Relative humidity (%)
y = 0.0028x + 3.5988
R² = 0.0606
y = 0.0106x + 3.0233
R² = 0.0582
GRERU
GREUB


0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J16 (N cm-3 s-1)
y = -0.0006x + 0.0793
R² = 0.46
y = -8E-05x + 0.0237
R² = 0.185
y = -0.0003x + 0.0287
R² = 0.8504
30
40
50
60
70
80
90
100
Relative humidity (%)
UKRU
UKUB
UKRO

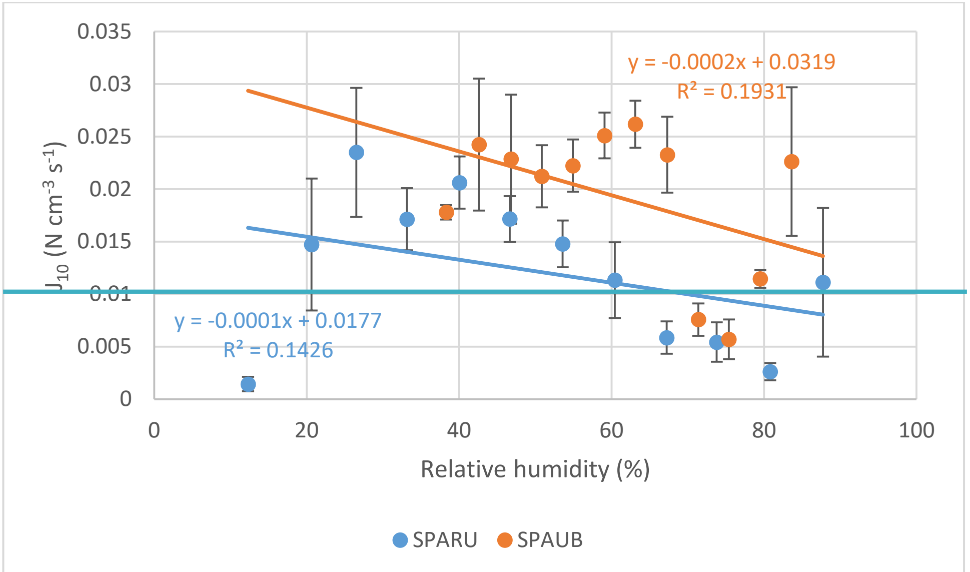

0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
y = -0.0003x + 0.0979
R² = 0.1016
y = 6E-05x + 0.019
R² = 0.0046
y = 1E-05x + 0.0228
R² = 0.0012
30
40
50
60
70
80
90
100
Relative humidity (%)
DENRU
DENUB
DENRO



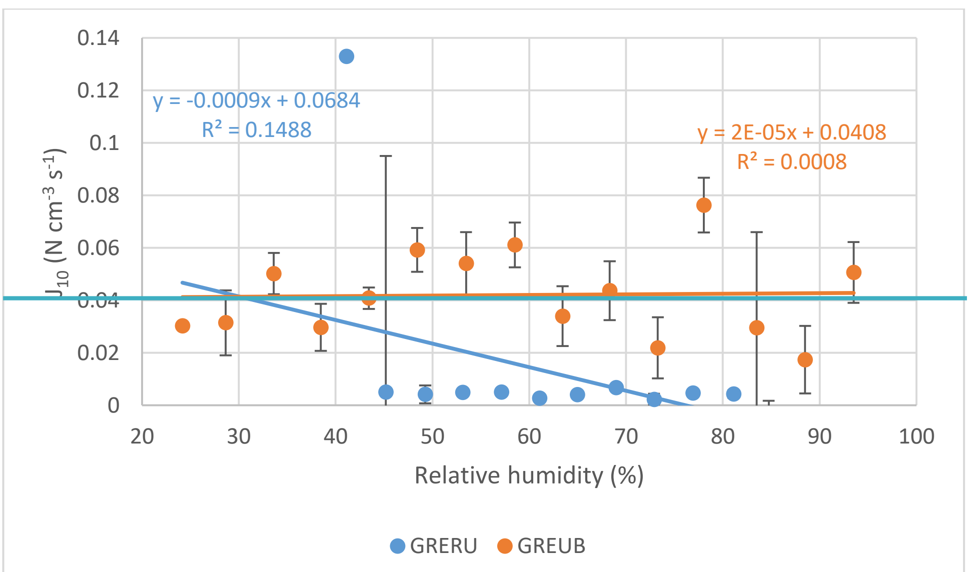
0.3
0.25
0.2
0.15
0.1
0.05
0
30
40
50
60
70
80
90
100
J10 (N cm-3 s-1)
Relative humidity (%)
y = -0.0024x + 0.2638
R² = 0.8069
y = -0.0023x + 0.214
R² = 0.8591
y = -0.0023x + 0.2082
R² = 0.9134
GERRU
GERUB
GERRO



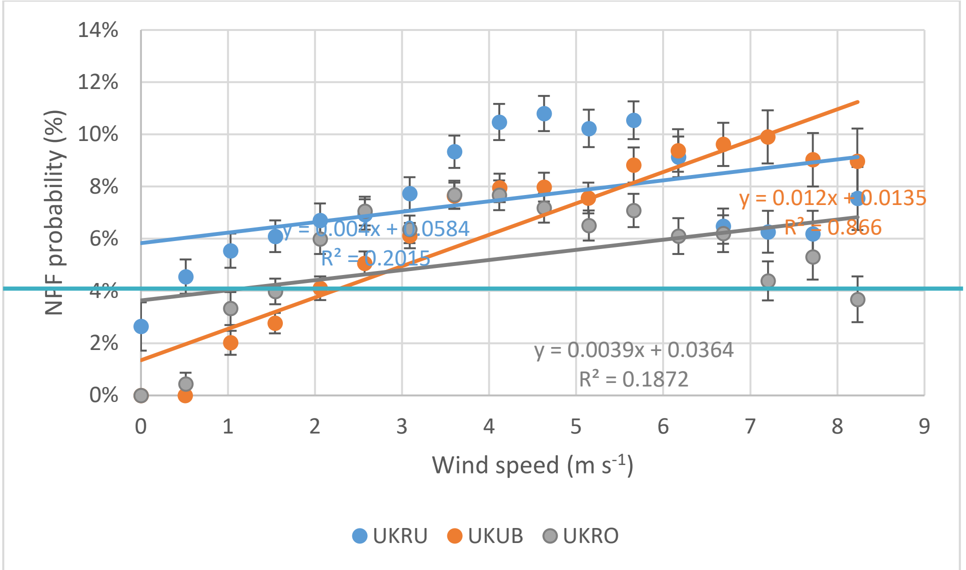
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
20
30
40
50
60
70
80
90
100
J10 (N cm-3 s-1)
Relative humidity (%)
y = 0.0005x + 0.0406
R² = 0.0973
y = -0.0002x + 0.0326
R² = 0.1792
y = -0.0003x + 0.0247
R² = 0.8727
FINRU
FINUB
FINRO

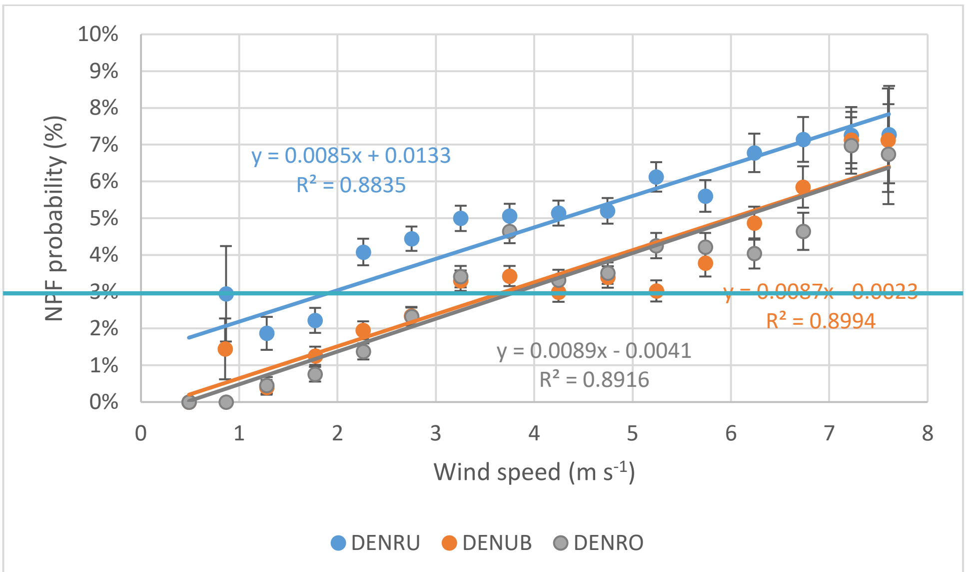


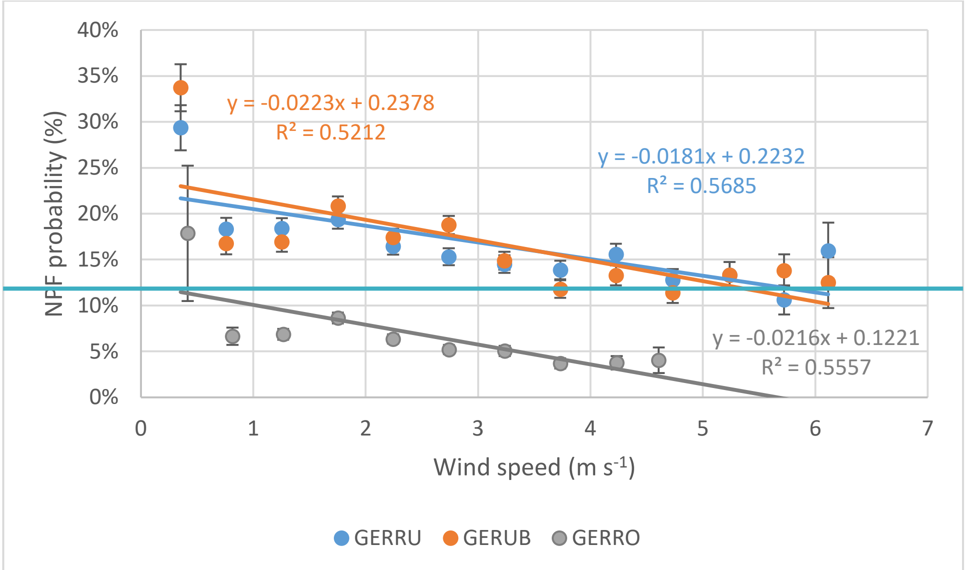
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
J_{10} (N cm^{-3} s^{-1})
0
20
40
60
80
100
Relative humidity (%)
y = -0.0002x + 0.0319
R^2 = 0.1931
y = -0.0001x + 0.0177
R^2 = 0.1426
SPARU
SPAUB

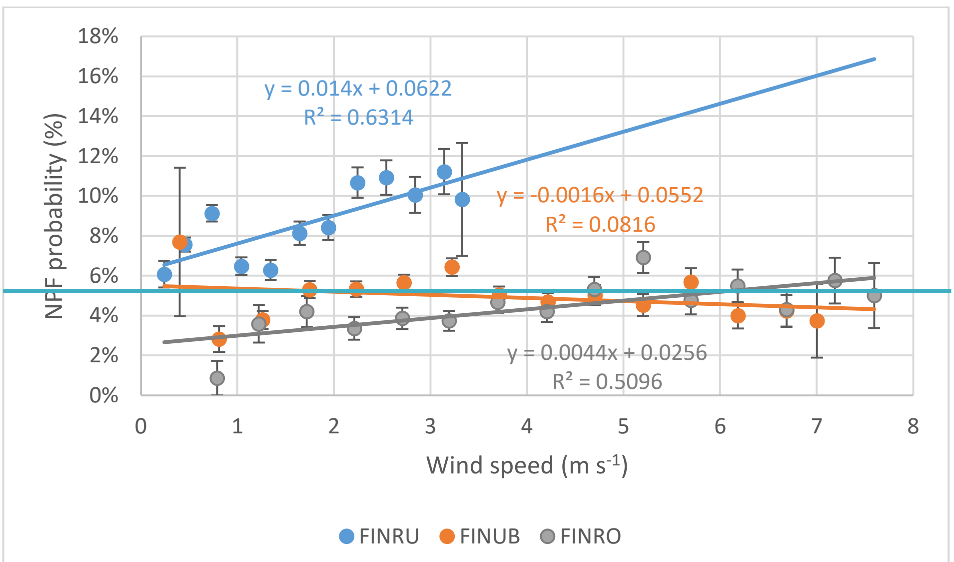


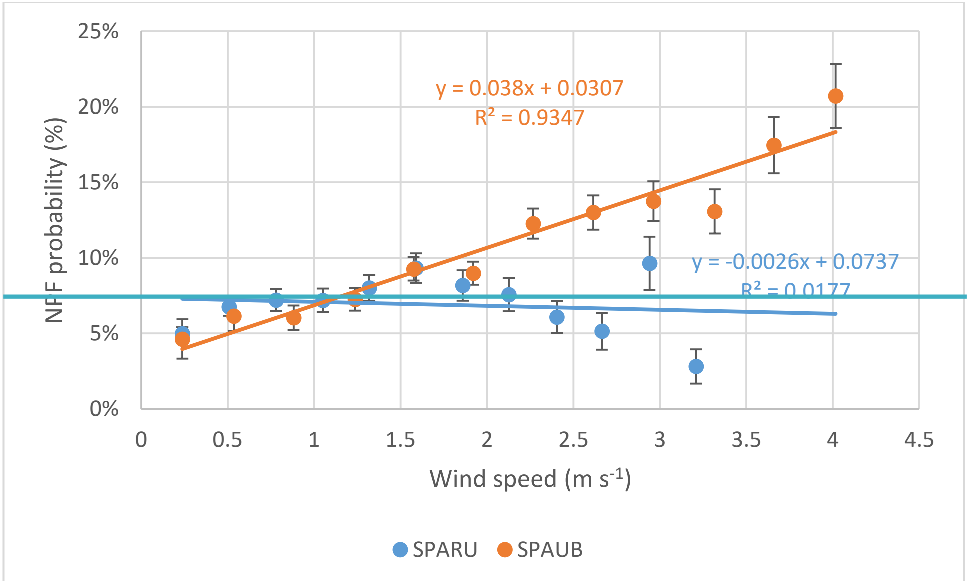
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J_{10} (N cm^{-3} s^{-1})
20
30
40
50
60
70
80
90
100
Relative humidity (%)
y = -0.0009x + 0.0684
R^2 = 0.1488
y = 2E-05x + 0.0408
R^2 = 0.0008
GRERU
GREUB


NFF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
7
8
9
Wind speed (m s-1)
y = 0.004x + 0.0584
R² = 0.2015
y = 0.012x + 0.0135
R² = 0.866
y = 0.0039x + 0.0364
R² = 0.1872
UKRU
UKUB
UKRO

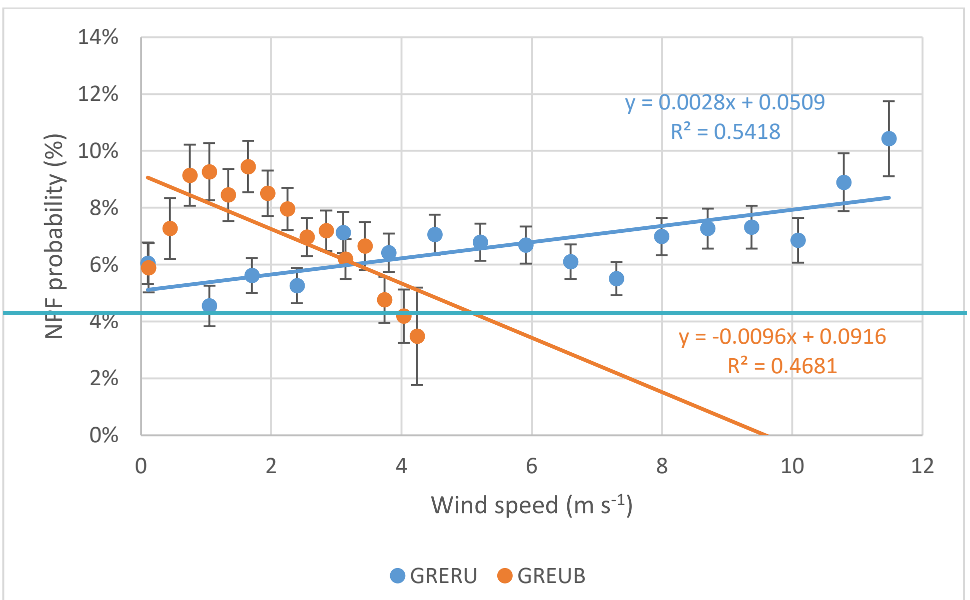

NFF probability (%)
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
1
2
3
4
5
6
7
8
Wind speed (m s-1)
y = 0.0085x + 0.0133
R² = 0.8835
y = 0.0087x - 0.0023
R² = 0.8994
y = 0.0089x - 0.0041
R² = 0.8916
DENRU
DENUB
DENRO


NPF probability (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
1
2
3
4
5
6
7
Wind speed (m s-1)
y = -0.0223x + 0.2378
R² = 0.5212
y = -0.0181x + 0.2232
R² = 0.5685
y = -0.0216x + 0.1221
R² = 0.5557
GERRU
GERUB
GERRO

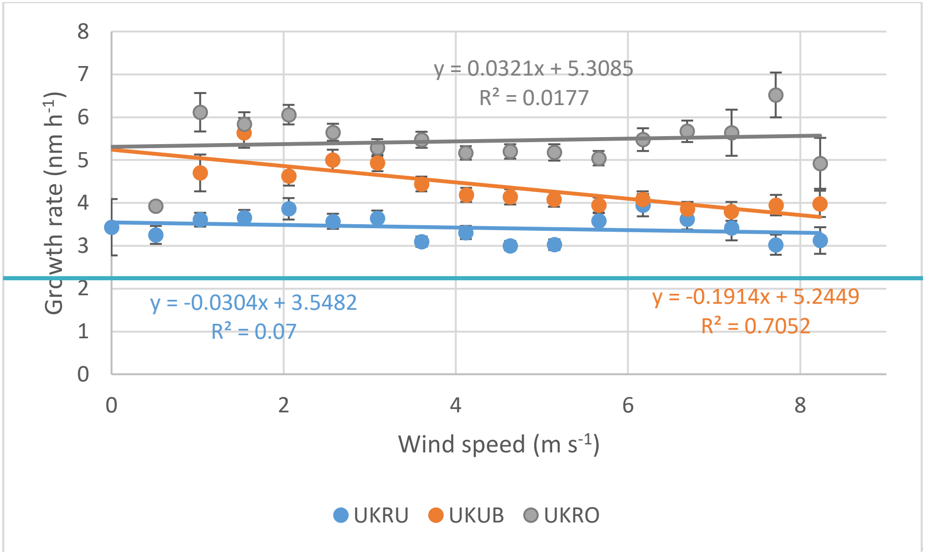

NPF probability (%)
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
7
8
Wind speed (m s-1)
y = 0.014x + 0.0622
R² = 0.6314
y = -0.0016x + 0.0552
R² = 0.0816
y = 0.0044x + 0.0256
R² = 0.5096
FINRU
FINUB
FINRO

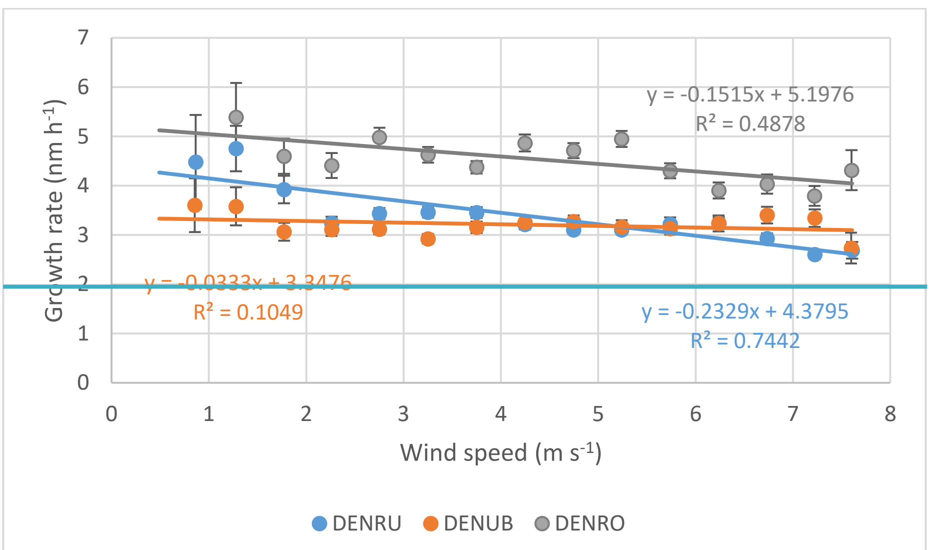


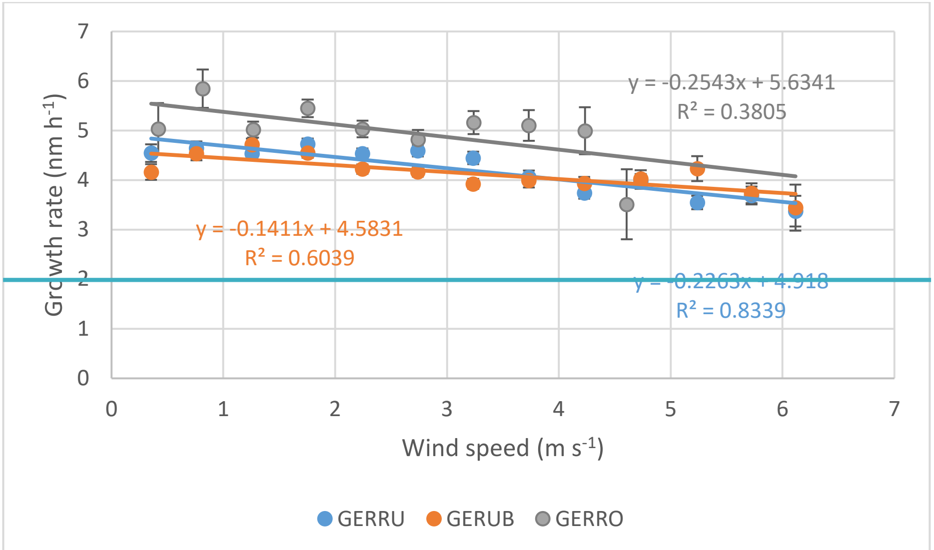
NFF probability (%)
25%
20%
15%
10%
5%
0%
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Wind speed (m s-1)
y = 0.038x + 0.0307
R² = 0.9347
y = -0.0026x + 0.0737
SPARU
SPAUB

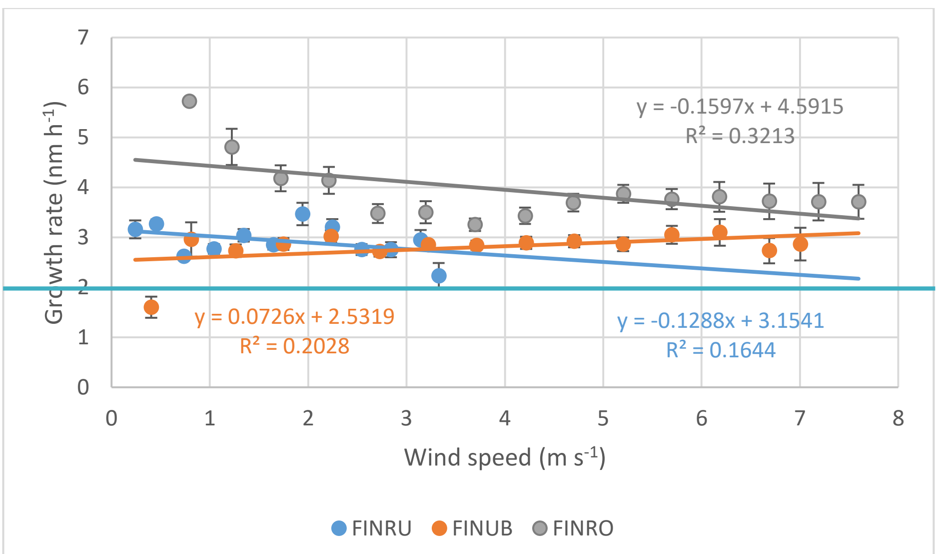


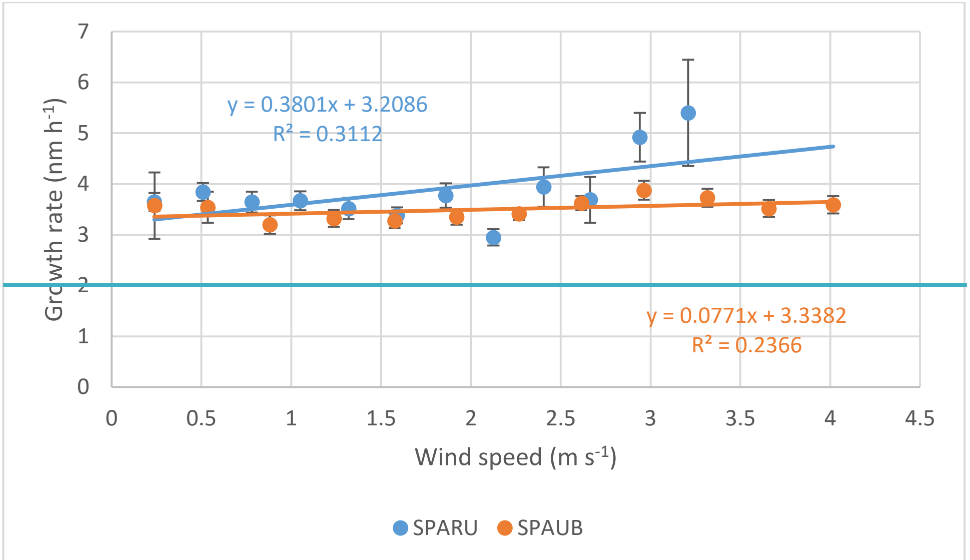
NFF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
0
2
4
6
8
10
12
Wind speed (m s-1)
y = 0.0028x + 0.0509
R² = 0.5418
y = -0.0096x + 0.0916
R² = 0.4681
GRERU
GREUB

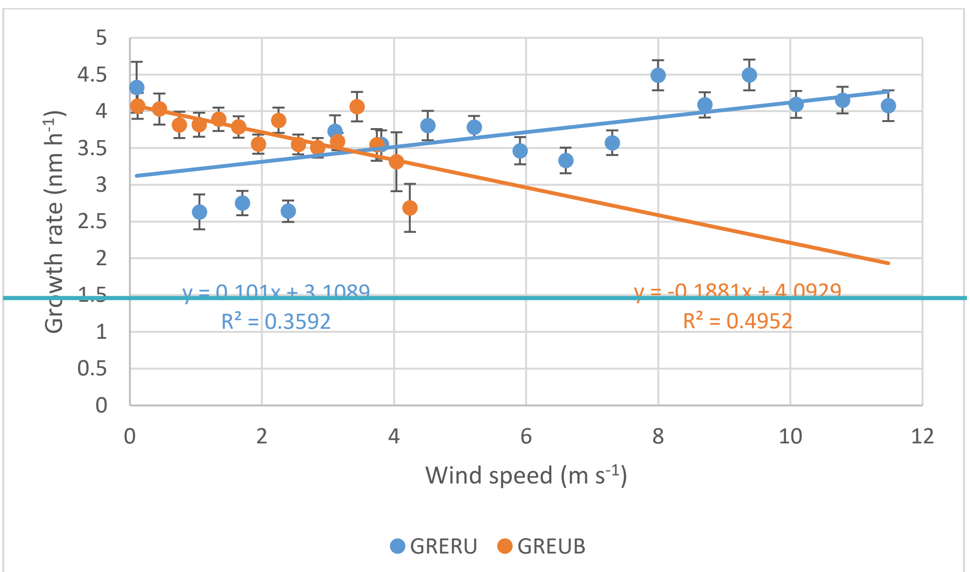

y = 0.0321x + 5.3085
R² = 0.0177
y = -0.0304x + 3.5482
R² = 0.07
y = -0.1914x + 5.2449
R² = 0.7052
Growth rate (nm h-1)
Wind speed (m s-1)
UKRU UKUB UKRO

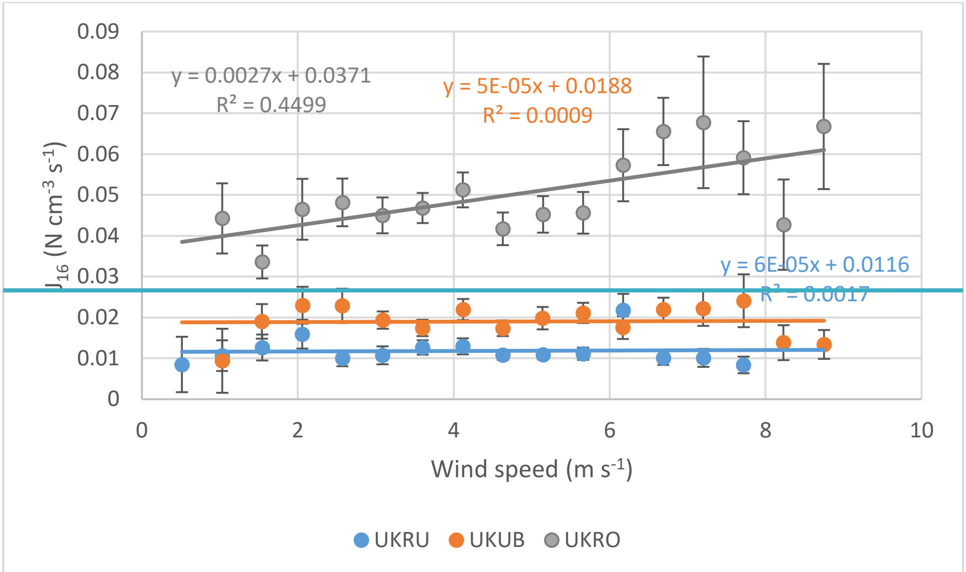

y = -0.1515x + 5.1976
R² = 0.4878
y = -0.0333x + 3.3476
R² = 0.1049
y = -0.2329x + 4.3795
R² = 0.7442
Growth rate (nm h-1)
Wind speed (m s-1)
DENRU DENUB DENRO

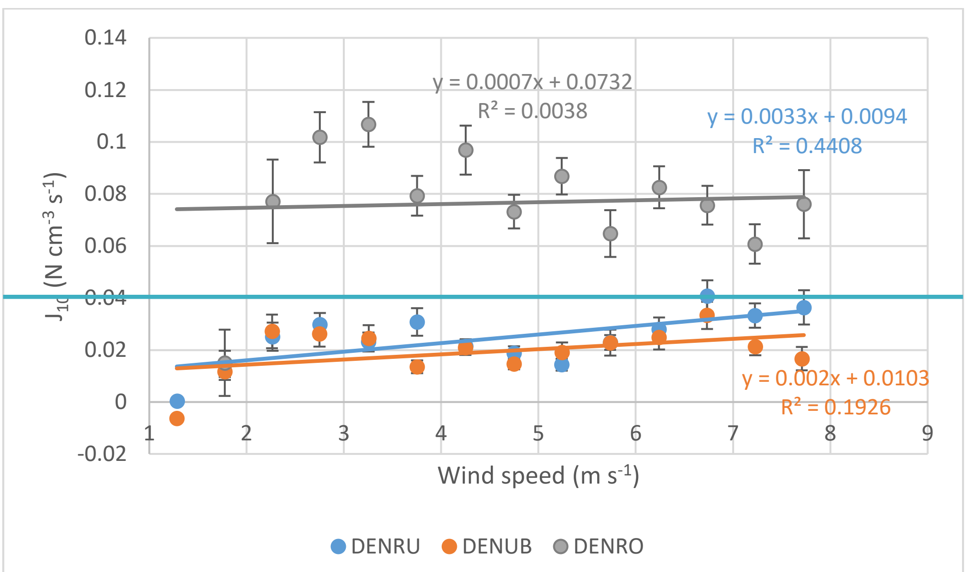

Growth rate (nm h-1)
Wind speed (m s-1)
y = -0.2543x + 5.6341
R² = 0.3805
y = -0.1411x + 4.5831
R² = 0.6039
y = -0.2263x + 4.918
R² = 0.8339
GERRU
GERUB
GERRO

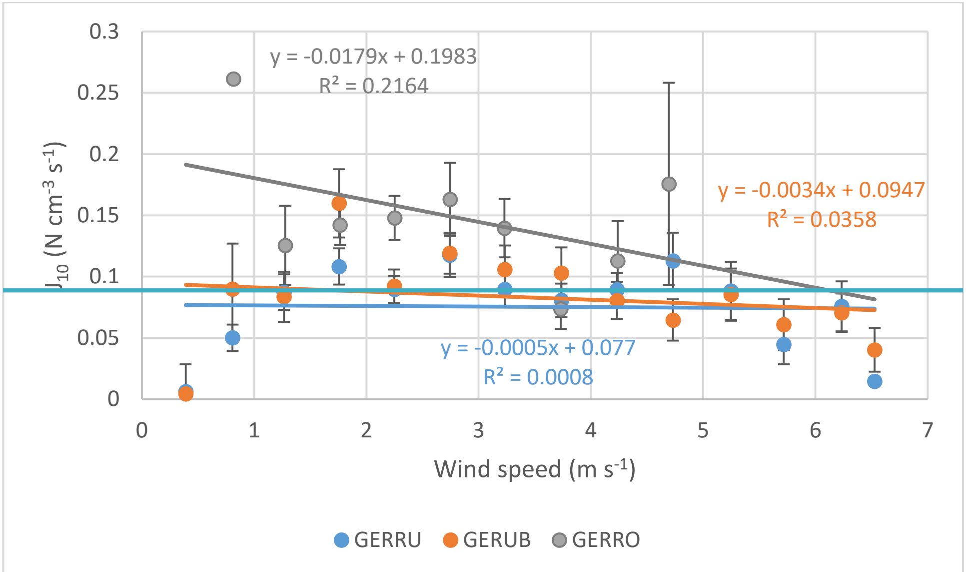

Growth rate (nm h-1)
Wind speed (m s-1)
y = -0.1597x + 4.5915
R² = 0.3213
y = 0.0726x + 2.5319
R² = 0.2028
y = -0.1288x + 3.1541
R² = 0.1644
FINRU
FINUB
FINRO


y = 0.3801x + 3.2086
R² = 0.3112
y = 0.0771x + 3.3382
R² = 0.2366
Growth rate (nm h-1)
Wind speed (m s-1)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
1
2
3
4
5
6
7
SPARU
SPAUB

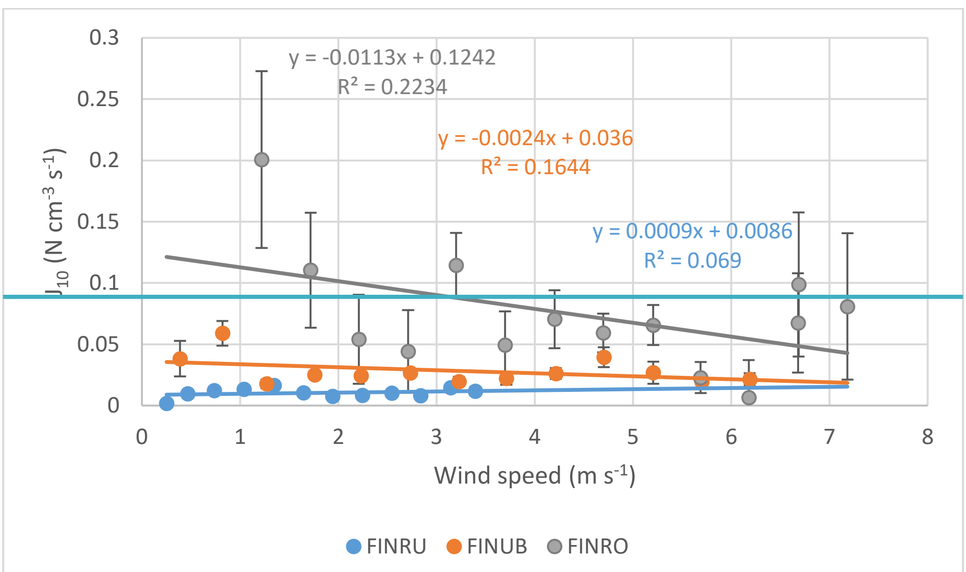

y = 0.101x + 3.1089
R² = 0.3592
y = -0.1881x + 4.0929
R² = 0.4952
Growth rate (nm h-1)
Wind speed (m s-1)
0
2
4
6
8
10
12
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
GRERU
GREUB


0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
J16 (N cm-3 s-1)
Wind speed (m s-1)
y = 0.0027x + 0.0371
R² = 0.4499
y = 5E-05x + 0.0188
R² = 0.0009
y = 6E-05x + 0.0116
R² = 0.0017
UKRU
UKUB
UKRO

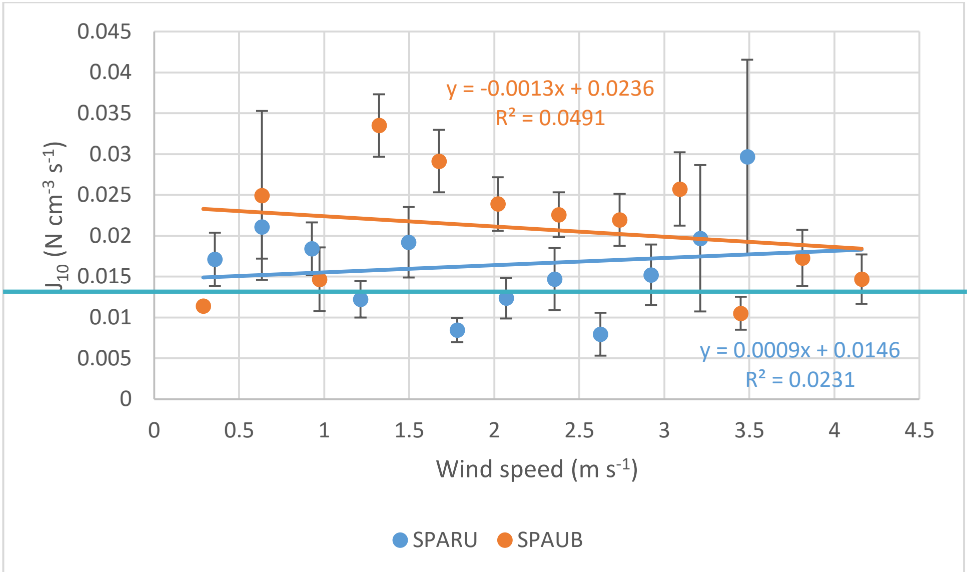

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
1
2
3
4
5
6
7
8
9
J10 (N cm-3 s-1)
Wind speed (m s-1)
y = 0.0007x + 0.0732
R² = 0.0038
y = 0.0033x + 0.0094
R² = 0.4408
y = 0.002x + 0.0103
R² = 0.1926
DENRU
DENUB
DENRO

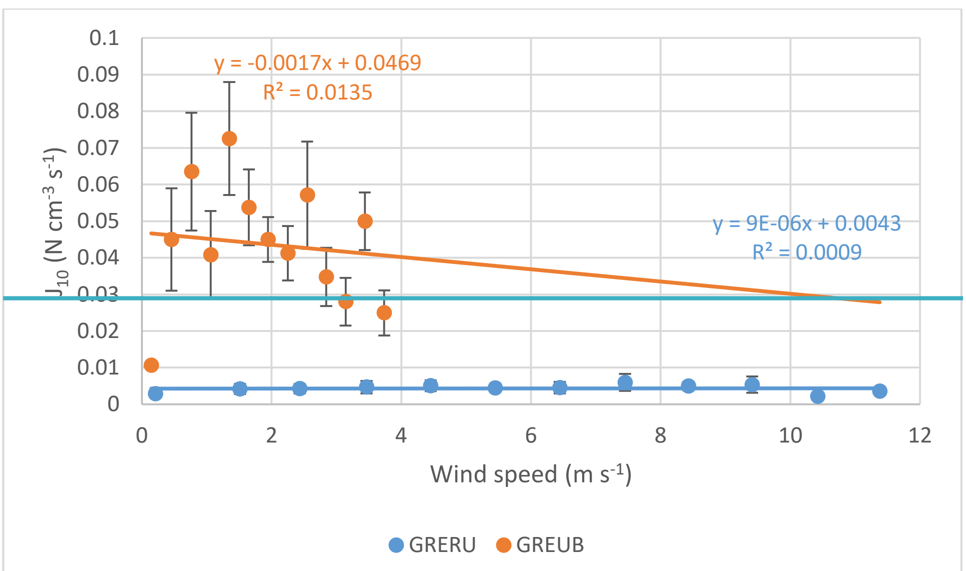


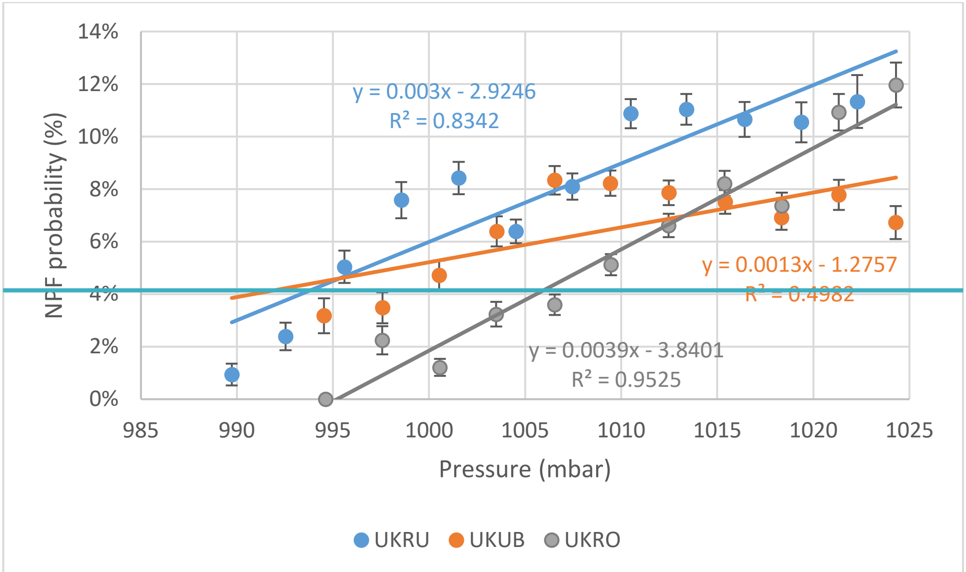
y = -0.0179x + 0.1983
R² = 0.2164
y = -0.0034x + 0.0947
R² = 0.0358
y = -0.0005x + 0.077
R² = 0.0008
J10 (N cm-3 s-1)
Wind speed (m s-1)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
GERRU
GERUB
GERRO

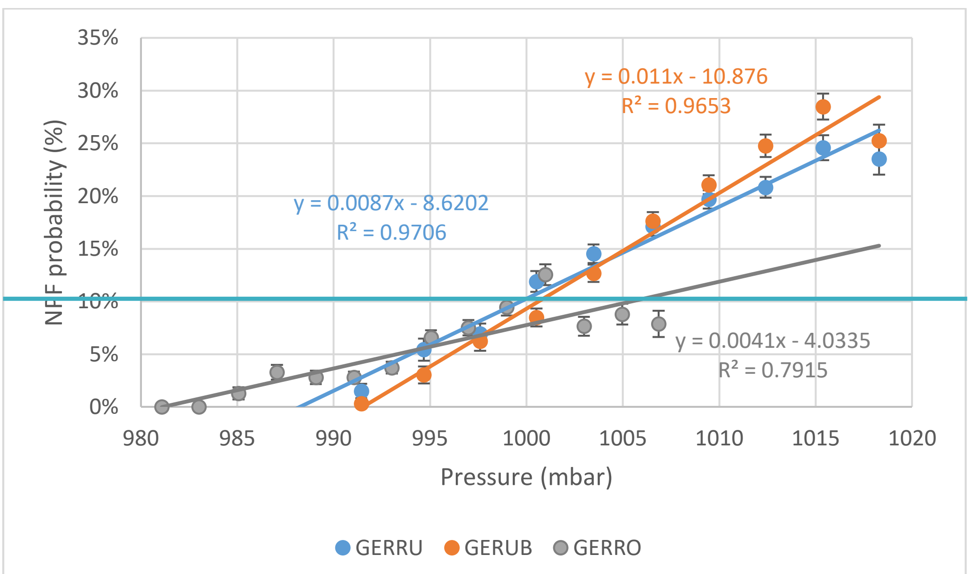


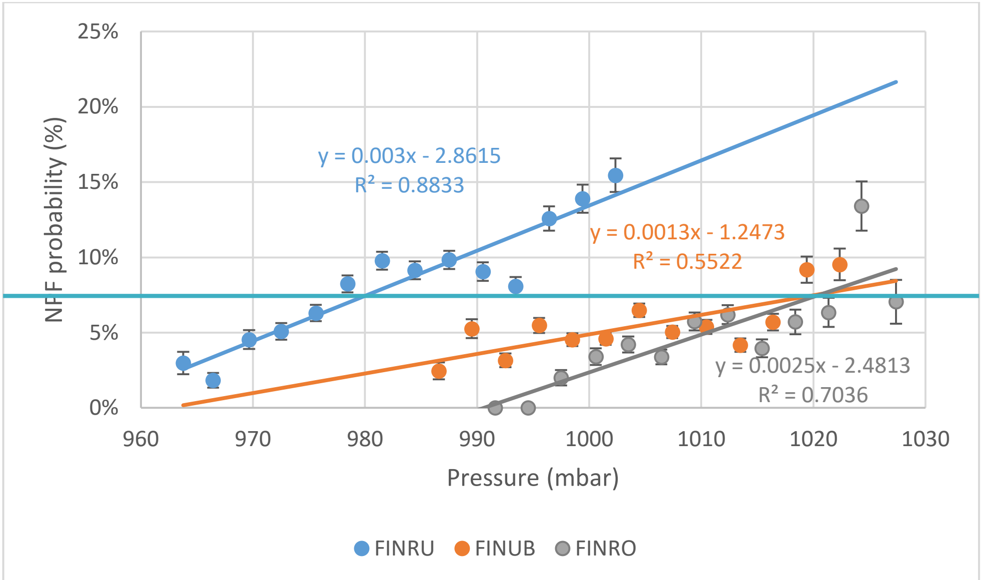
y = -0.0113x + 0.1242
R² = 0.2234
y = -0.0024x + 0.036
R² = 0.1644
y = 0.0009x + 0.0086
R² = 0.069
J10 (N cm-3 s-1)
Wind speed (m s-1)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
FINRU
FINUB
FINRO

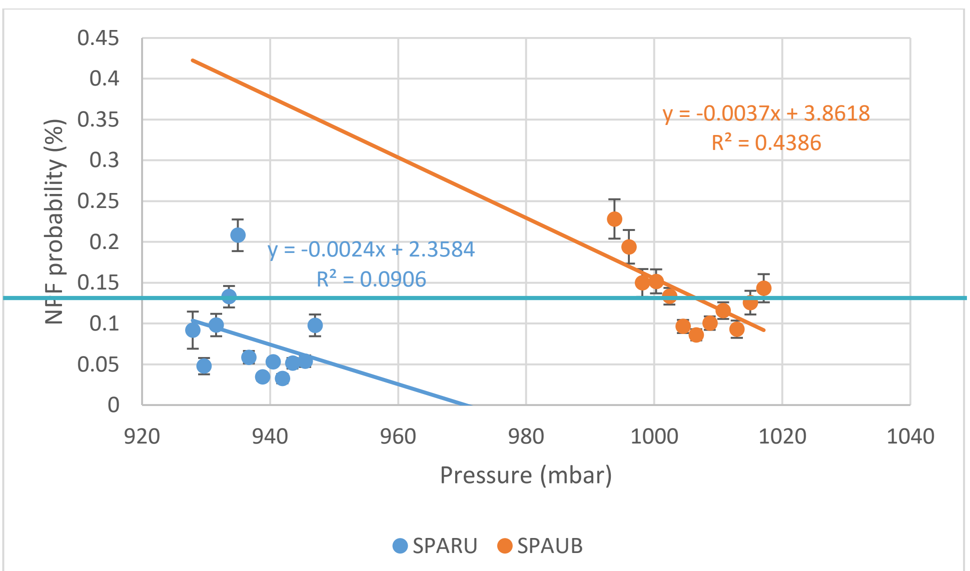

y = -0.0013x + 0.0236
R² = 0.0491
y = 0.0009x + 0.0146
R² = 0.0231
J10 (N cm-3 s-1)
Wind speed (m s-1)
SPARU
SPAUB

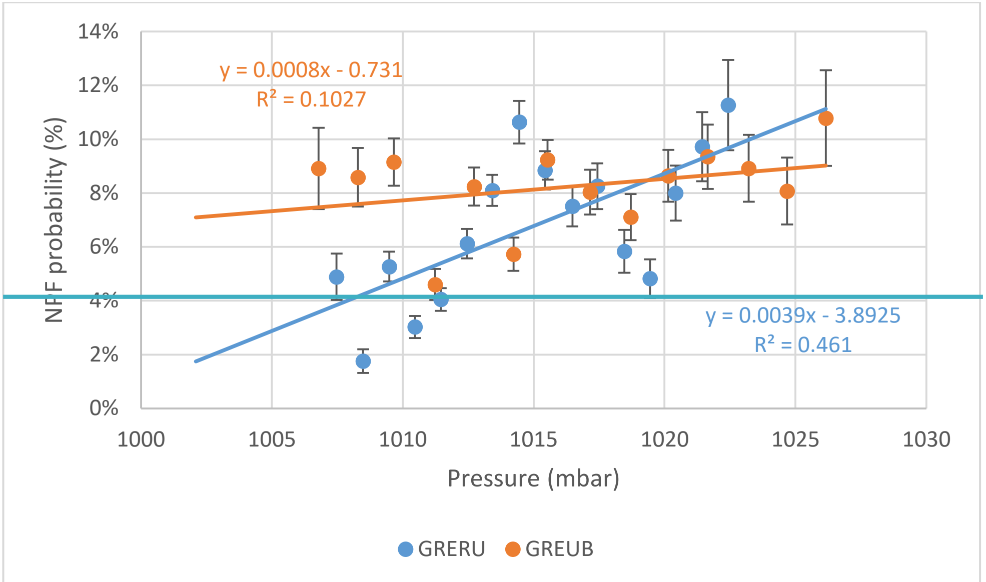

y = -0.0017x + 0.0469
R² = 0.0135
y = 9E-06x + 0.0043
R² = 0.0009
J10 (N cm-3 s-1)
Wind speed (m s-1)
GRERU
GREUB

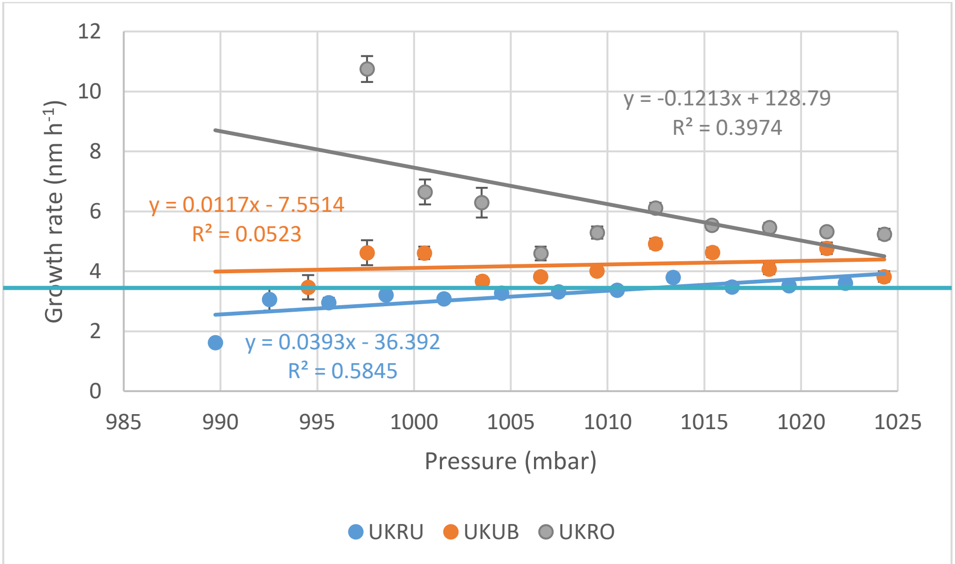

14%
12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
985
990
995
1000
1005
1010
1015
1020
1025
Pressure (mbar)
y = 0.003x - 2.9246
R² = 0.8342
y = 0.0013x - 1.2757
R² = 0.4982
y = 0.0039x - 3.8401
R² = 0.9525
UKRU
UKUB
UKRO

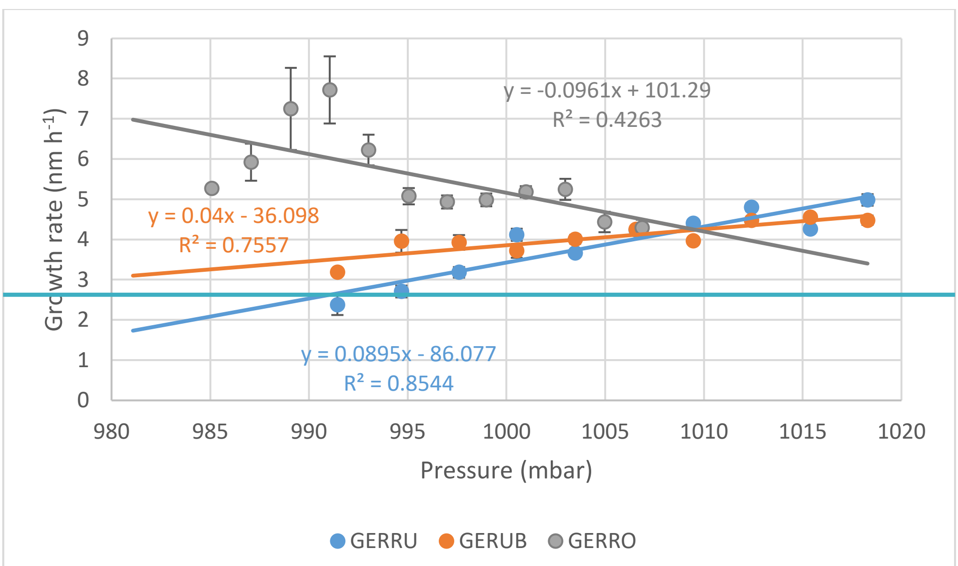

35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
980
985
990
995
1000
1005
1010
1015
1020
Pressure (mbar)
y = 0.011x - 10.876
R² = 0.9653
y = 0.0087x - 8.6202
R² = 0.9706
y = 0.0041x - 4.0335
R² = 0.7915
GERRU
GERUB
GERRO

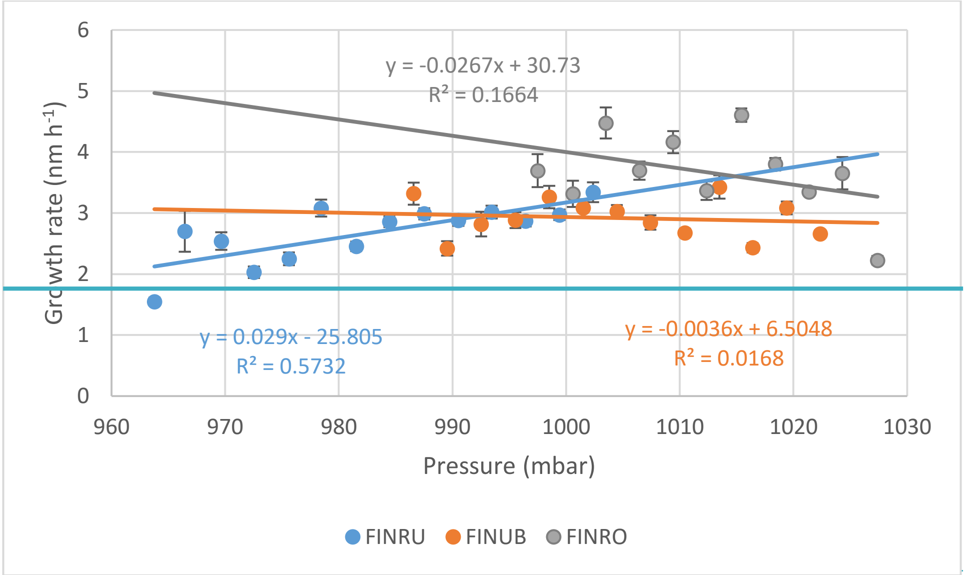

NFF probability (%)
25%
20%
15%
10%
5%
0%
960
970
980
990
1000
1010
1020
1030
Pressure (mbar)
y = 0.003x - 2.8615
R² = 0.8833
y = 0.0013x - 1.2473
R² = 0.5522
y = 0.0025x - 2.4813
R² = 0.7036
FINRU
FINUB
FINRO

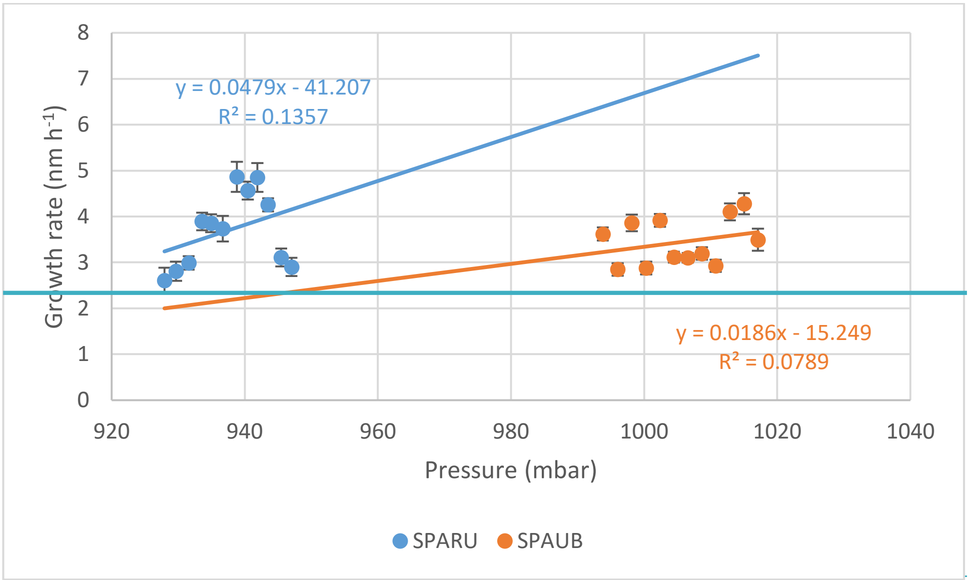

NFF probability (%)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
920
940
960
980
1000
1020
1040
Pressure (mbar)
y = -0.0037x + 3.8618
R² = 0.4386
y = -0.0024x + 2.3584
R² = 0.0906
SPARU
SPAUB

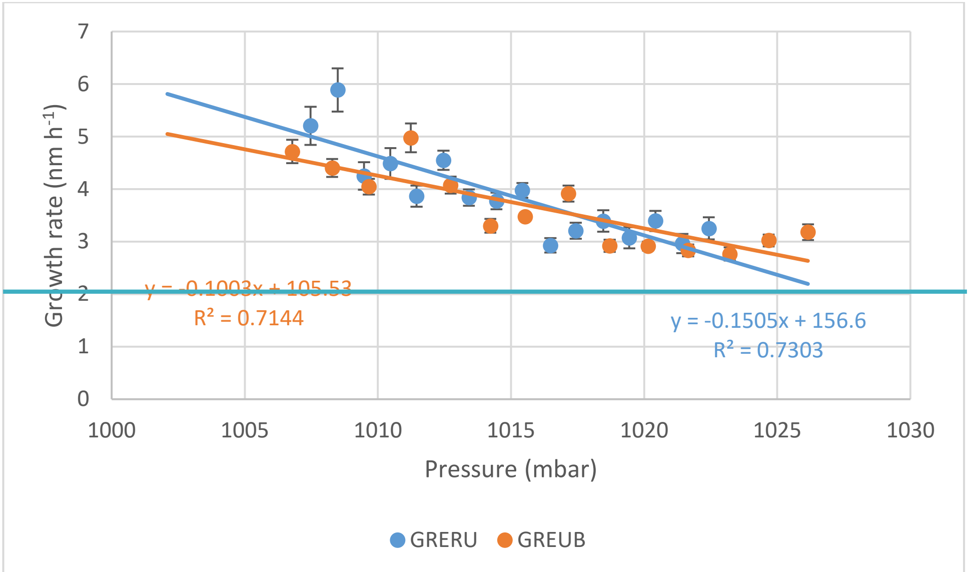

y = 0.0008x - 0.731
R² = 0.1027
y = 0.0039x - 3.8925
R² = 0.461
NPF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
GRERU
GREUB


12
10
8
6
4
2
0
Growth rate (nm h-1)
985
990
995
1000
1005
1010
1015
1020
1025
Pressure (mbar)
y = -0.1213x + 128.79
R² = 0.3974
y = 0.0117x - 7.5514
R² = 0.0523
y = 0.0393x - 36.392
R² = 0.5845
UKRU
UKUB
UKRO

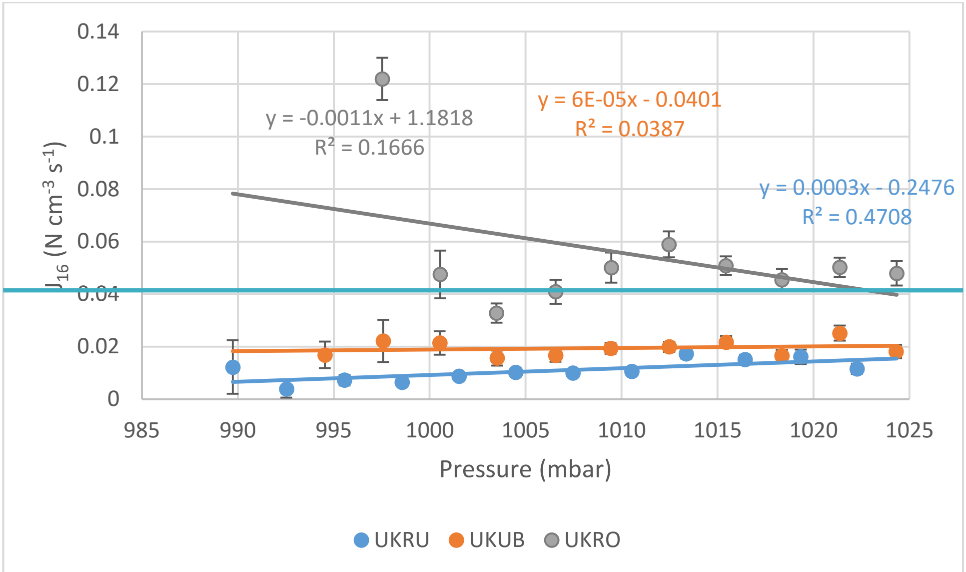

9
8
7
6
5
4
3
2
1
0
Growth rate (nm h-1)
980
985
990
995
1000
1005
1010
1015
1020
Pressure (mbar)
y = -0.0961x + 101.29
R² = 0.4263
y = 0.04x - 36.098
R² = 0.7557
y = 0.0895x - 86.077
R² = 0.8544
GERRU
GERUB
GERRO

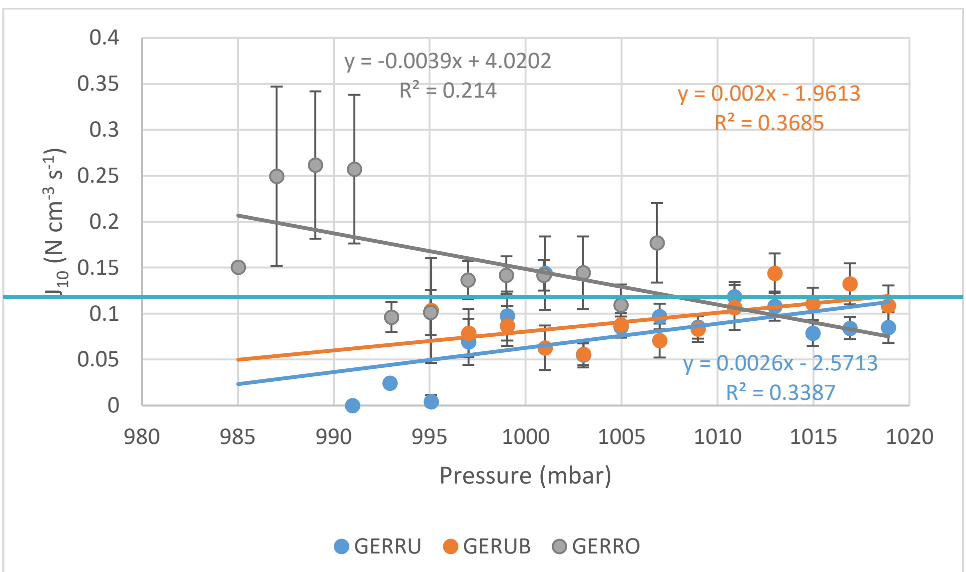

y = -0.0267x + 30.73
R² = 0.1664
y = 0.029x - 25.805
R² = 0.5732
y = -0.0036x + 6.5048
R² = 0.0168
Growth rate (nm h-1)
Pressure (mbar)
FINRU
FINUB
FINRO

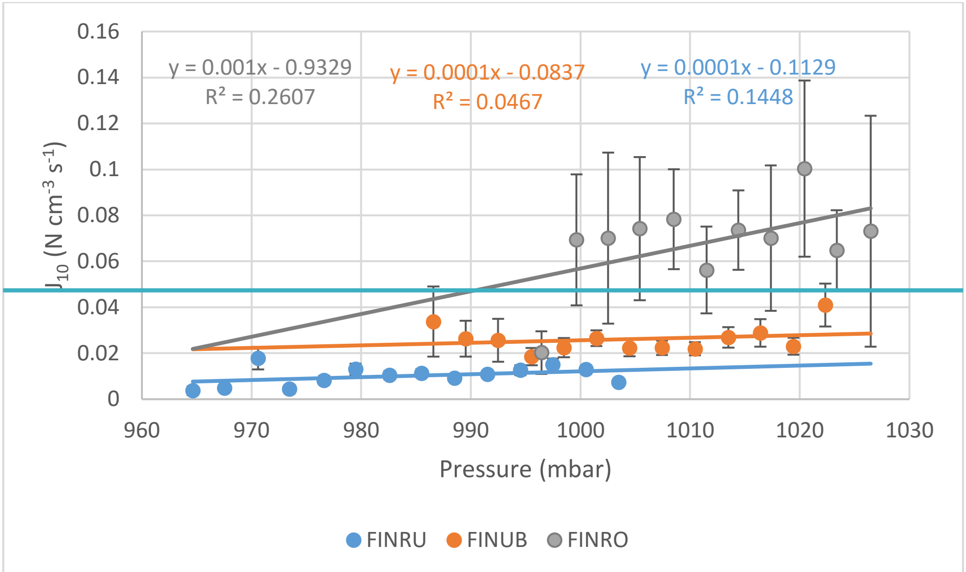

y = 0.0479x - 41.207
R² = 0.1357
y = 0.0186x - 15.249
R² = 0.0789
Growth rate (nm h-1)
Pressure (mbar)
SPARU
SPAUB

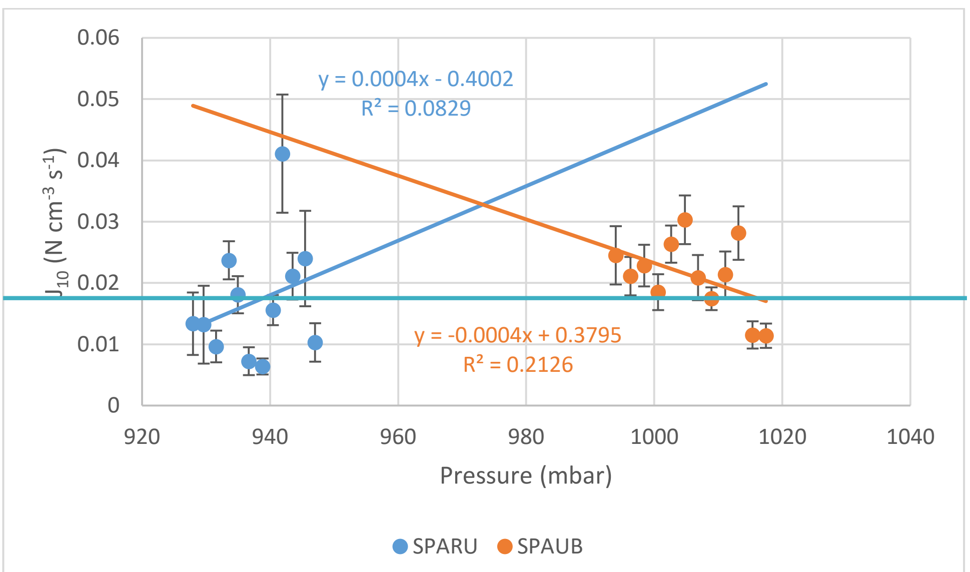


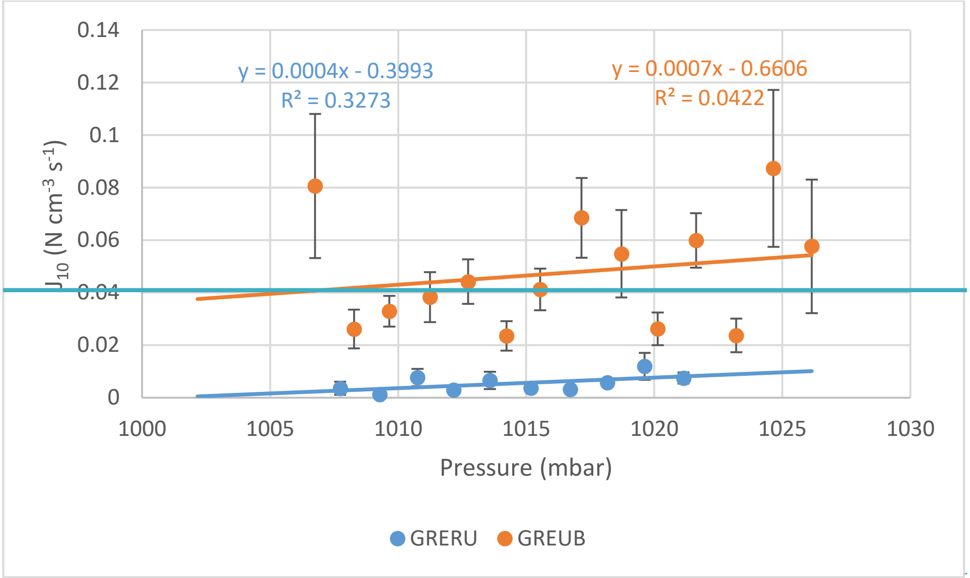
Growth rate (nm h-1)
7
6
5
4
3
2
1
0
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
y = -0.1003x + 105.53
R² = 0.7144
y = -0.1505x + 156.6
R² = 0.7303
GRERU
GREUB

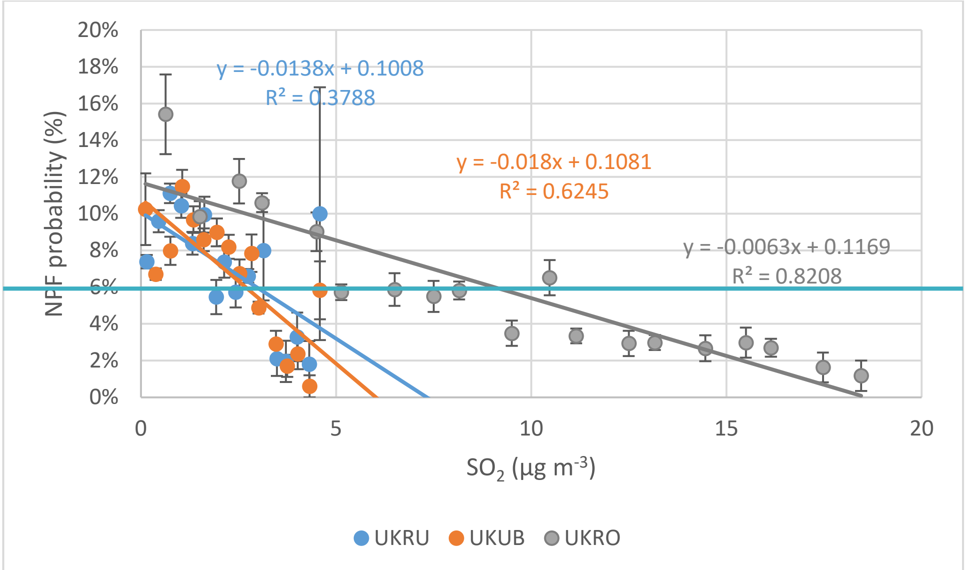

y = -0.0011x + 1.1818
R² = 0.1666
y = 6E-05x - 0.0401
R² = 0.0387
y = 0.0003x - 0.2476
R² = 0.4708
J16 (N cm-3 s-1)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
985
990
995
1000
1005
1010
1015
1020
1025
Pressure (mbar)
UKRU
UKUB
UKRO


y = -0.0039x + 4.0202
R² = 0.214
y = 0.002x - 1.9613
R² = 0.3685
y = 0.0026x - 2.5713
R² = 0.3387
J10 (N cm-3 s-1)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
980
985
990
995
1000
1005
1010
1015
1020
Pressure (mbar)
GERRU
GERUB
GERRO

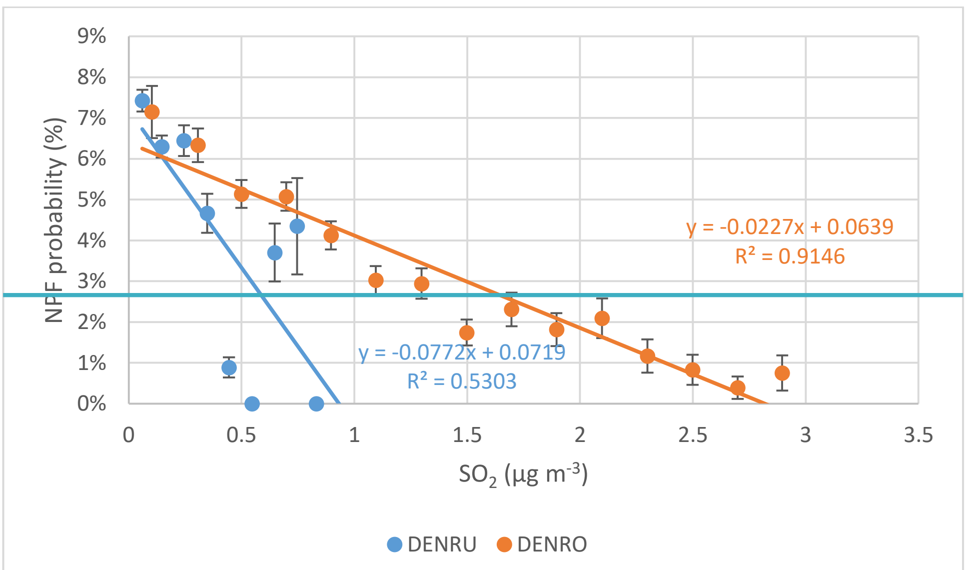

0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
960
970
980
990
1000
1010
1020
1030
Pressure (mbar)
y = 0.001x - 0.9329
R² = 0.2607
y = 0.0001x - 0.0837
R² = 0.0467
y = 0.0001x - 0.1129
R² = 0.1448
FINRU
FINUB
FINRO


0.06
0.05
0.04
0.03
0.02
0.01
0
J10 (N cm-3 s-1)
920
940
960
980
1000
1020
1040
Pressure (mbar)
y = 0.0004x - 0.4002
R² = 0.0829
y = -0.0004x + 0.3795
R² = 0.2126
SPARU
SPAUB

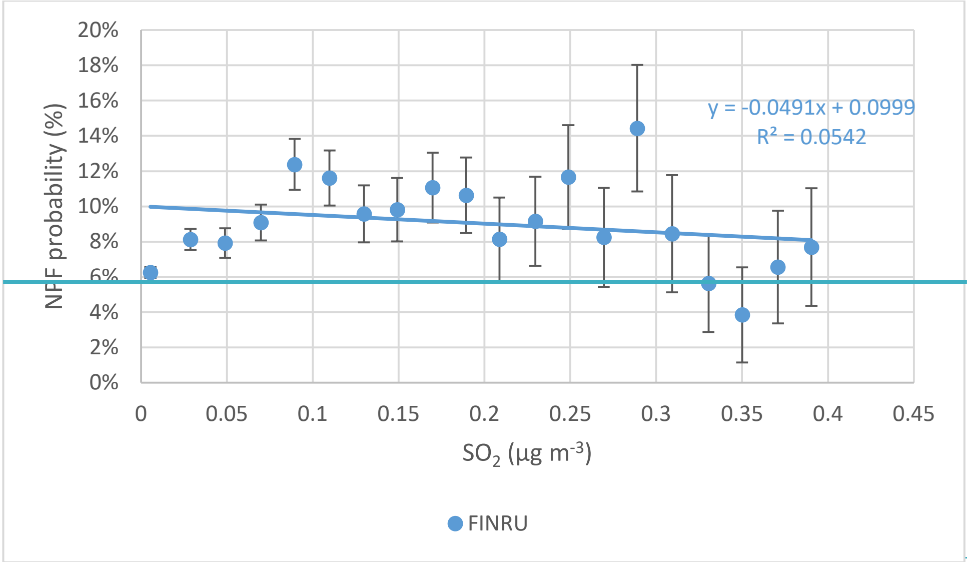

y = 0.0004x - 0.3993
R² = 0.3273
y = 0.0007x - 0.6606
R² = 0.0422
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
1000
1005
1010
1015
1020
1025
1030
Pressure (mbar)
GRERU
GREUB



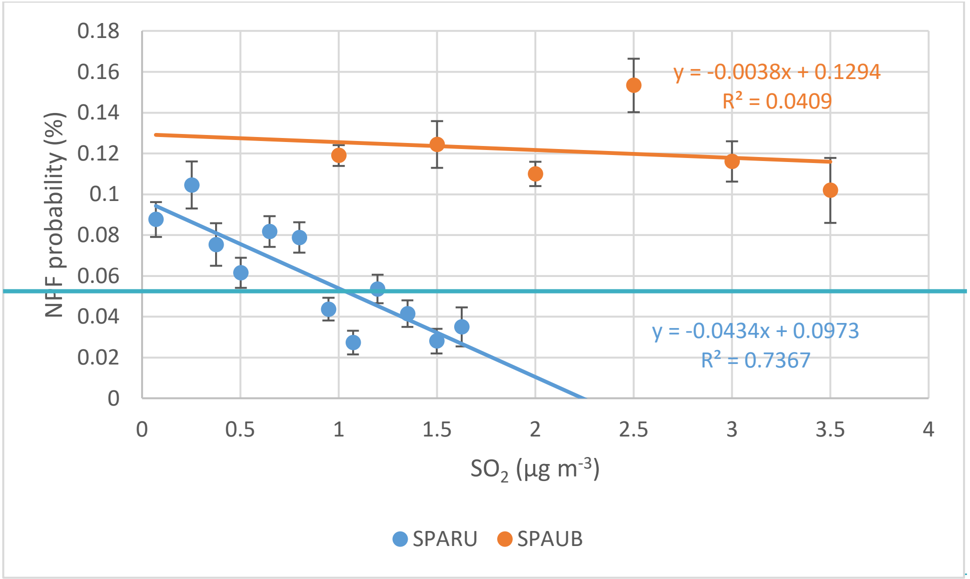
NPF probability (%)
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
5
10
15
20
SO2 (µg m-3)
y = -0.0138x + 0.1008
R² = 0.3788
y = -0.018x + 0.1081
R² = 0.6245
y = -0.0063x + 0.1169
R² = 0.8208
UKRU
UKUB
UKRO



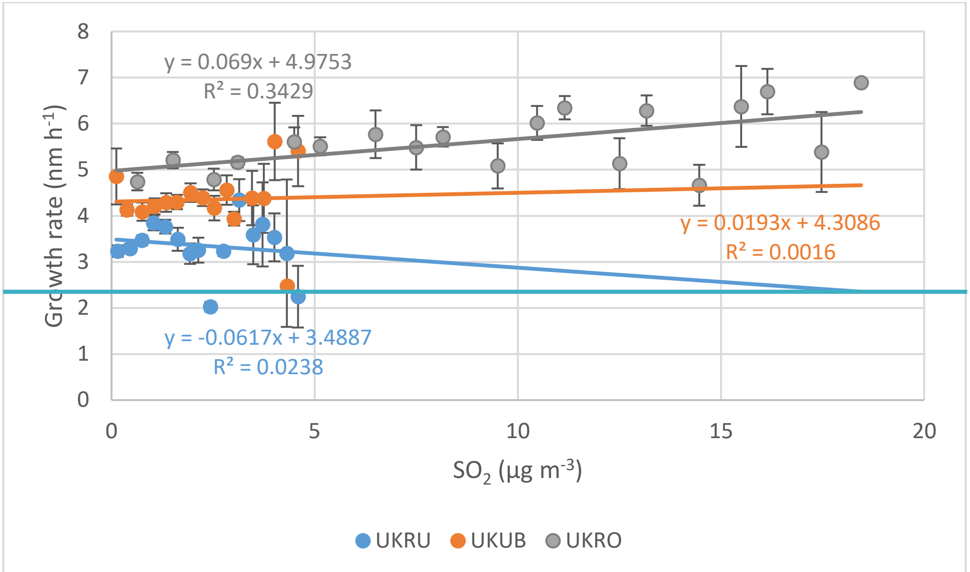
NPF probability (%)
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
0.5
1
1.5
2
2.5
3
3.5
SO2 (µg m-3)
y = -0.0227x + 0.0639
R² = 0.9146
y = -0.0772x + 0.0719
R² = 0.5303
DENRU
DENRO

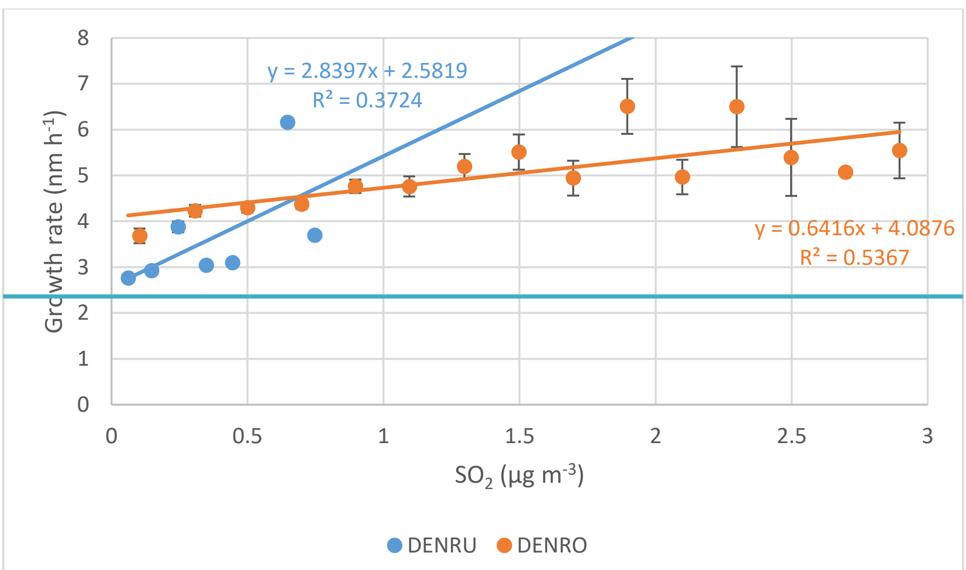


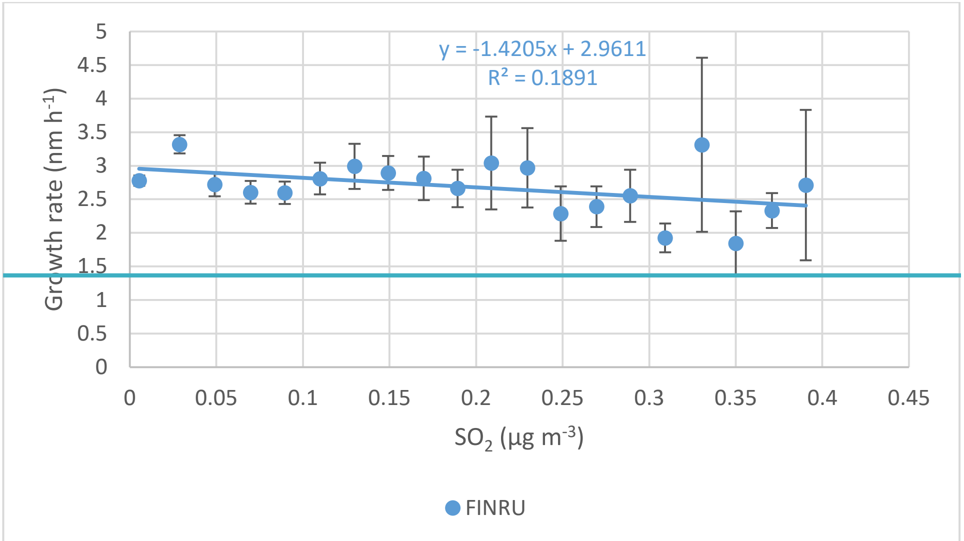
NFF probability (%)
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
SO2 (µg m-3)
y = -0.0491x + 0.0999
R² = 0.0542
FINRU

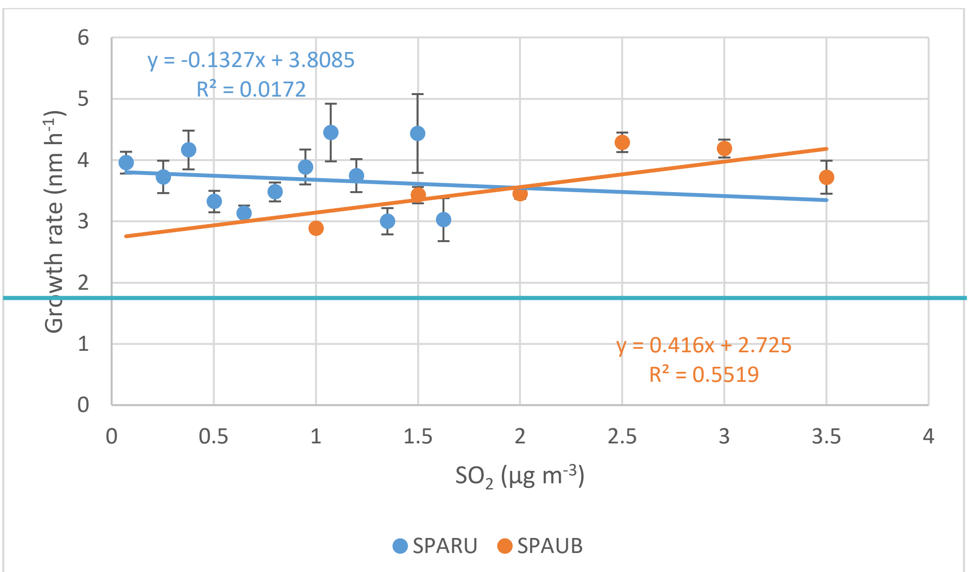


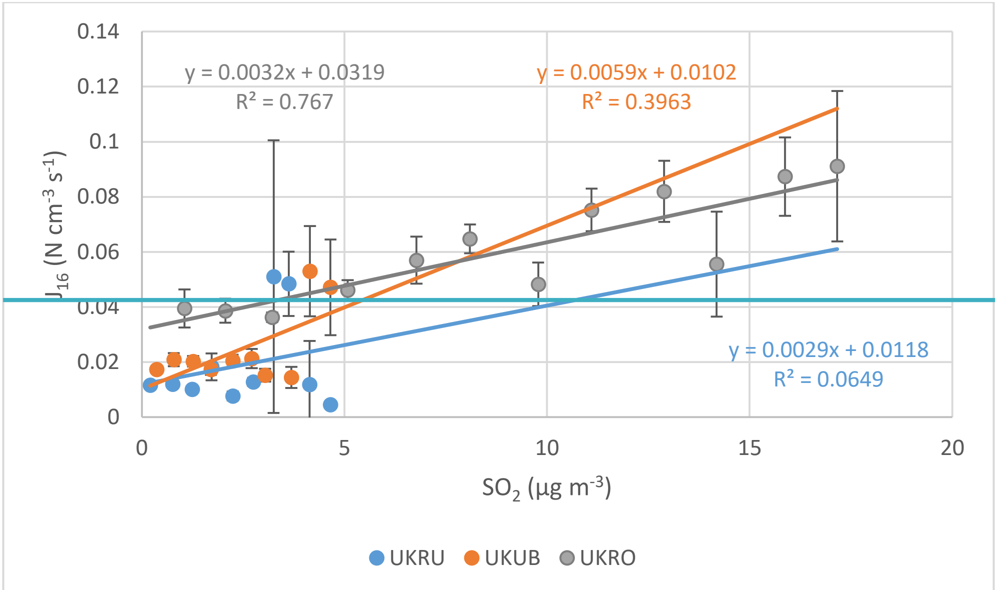
NFF probability (%)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
3.5
4
SO2 (µg m-3)
y = -0.0038x + 0.1294
R² = 0.0409
y = -0.0434x + 0.0973
R² = 0.7367
SPARU
SPAUB

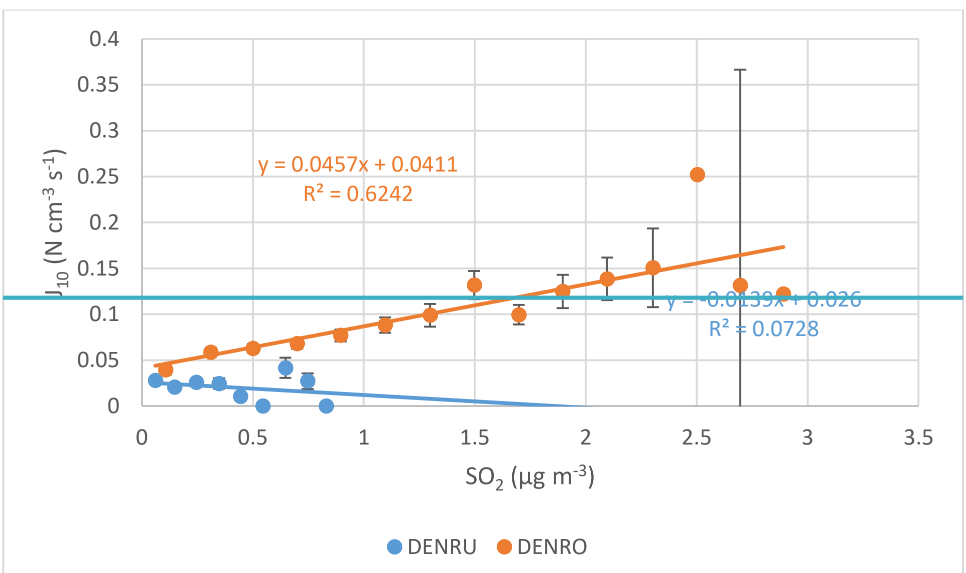

Growth rate (nm h-1)
SO2 (µg m-3)
y = 0.069x + 4.9753
R² = 0.3429
y = 0.0193x + 4.3086
R² = 0.0016
y = -0.0617x + 3.4887
R² = 0.0238
0
1
2
3
4
5
6
7
8
0
5
10
15
20
UKRU
UKUB
UKRO

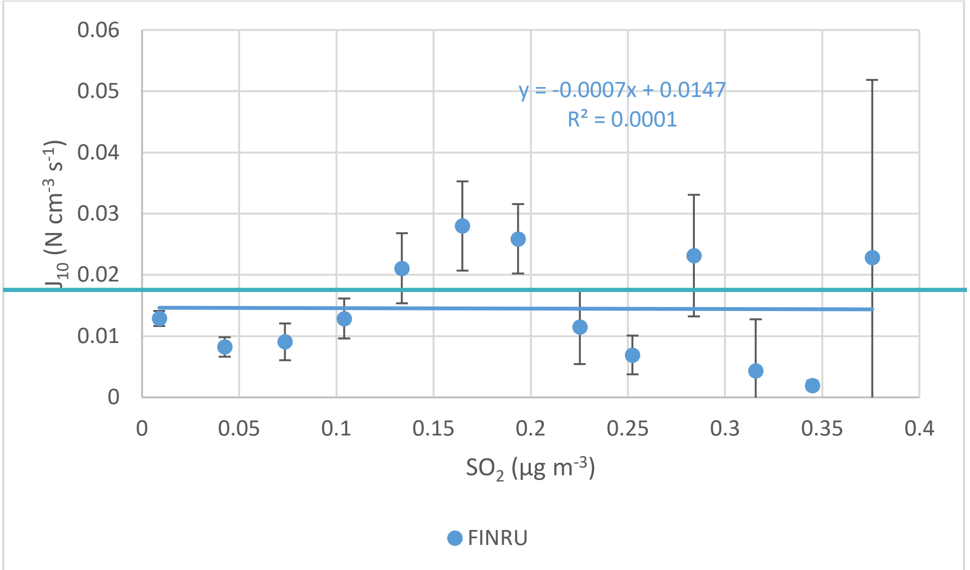

Growth rate (nm h-1)
SO2 (µg m-3)
y = 2.8397x + 2.5819
R² = 0.3724
y = 0.6416x + 4.0876
R² = 0.5367
0
1
2
3
4
5
6
7
8
0
0.5
1
1.5
2
2.5
3
DENRU
DENRO


y = -1.4205x + 2.9611
R² = 0.1891
Growth rate (nm h-1)
SO2 (µg m-3)
FINRU

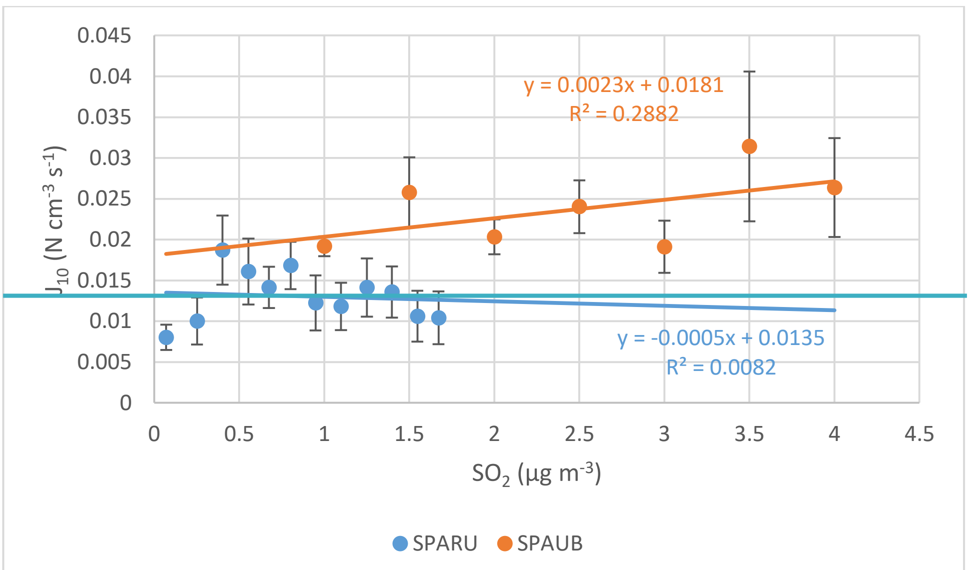

y = -0.1327x + 3.8085
R² = 0.0172
y = 0.416x + 2.725
R² = 0.5519
Growth rate (nm h-1)
SO2 (µg m-3)
SPARU
SPAUB


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J16 (N cm-3 s-1)
y = 0.0032x + 0.0319
R² = 0.767
y = 0.0059x + 0.0102
R² = 0.3963
y = 0.0029x + 0.0118
R² = 0.0649
0
5
10
15
20
SO2 (μg m-3)
UKRU
UKUB
UKRO

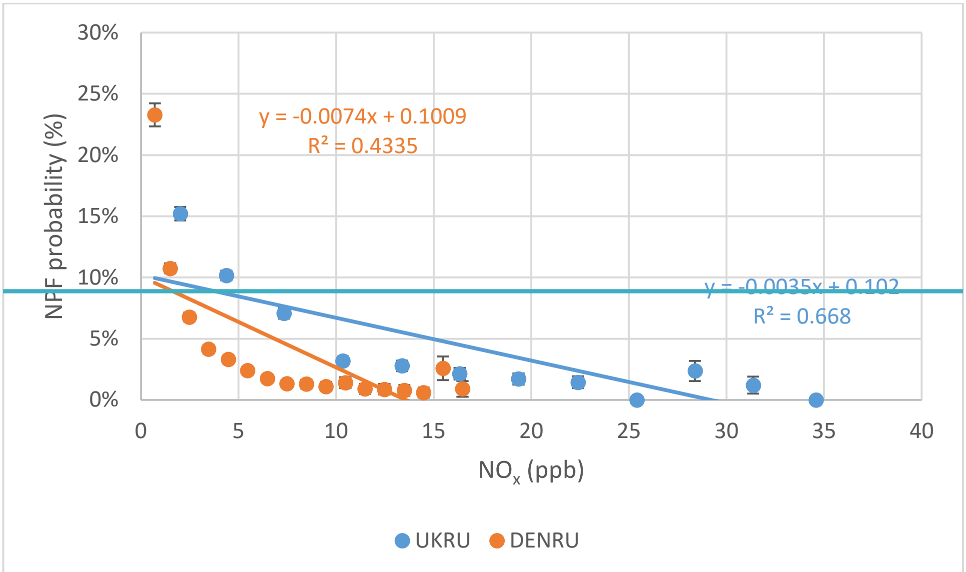

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
J10 (N cm-3 s-1)
y = 0.0457x + 0.0411
R² = 0.6242
y = -0.0139x + 0.026
R² = 0.0728
0
0.5
1
1.5
2
2.5
3
3.5
SO2 (μg m-3)
DENRU
DENRO

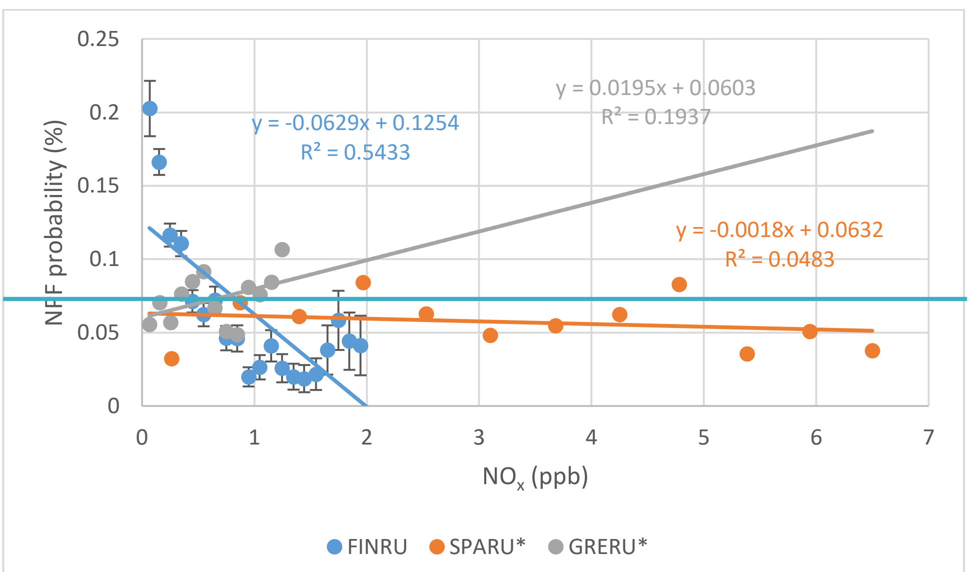


0.06
0.05
0.04
0.03
0.02
0.01
0
J_{10} (N cm^{-3} s^{-1})
y = -0.0007x + 0.0147
R^2 = 0.0001
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
SO_2 (µg m^{-3})
FINRU

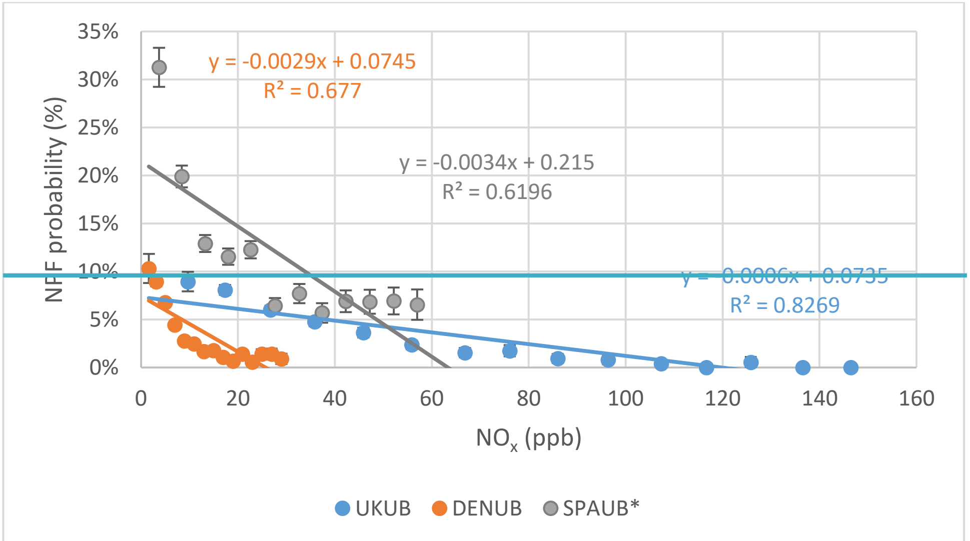


0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
J_{10} (N cm^{-3} s^{-1})
y = 0.0023x + 0.0181
R^2 = 0.2882
y = -0.0005x + 0.0135
R^2 = 0.0082
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
SO_2 (µg m^{-3})
SPARU
SPAUB

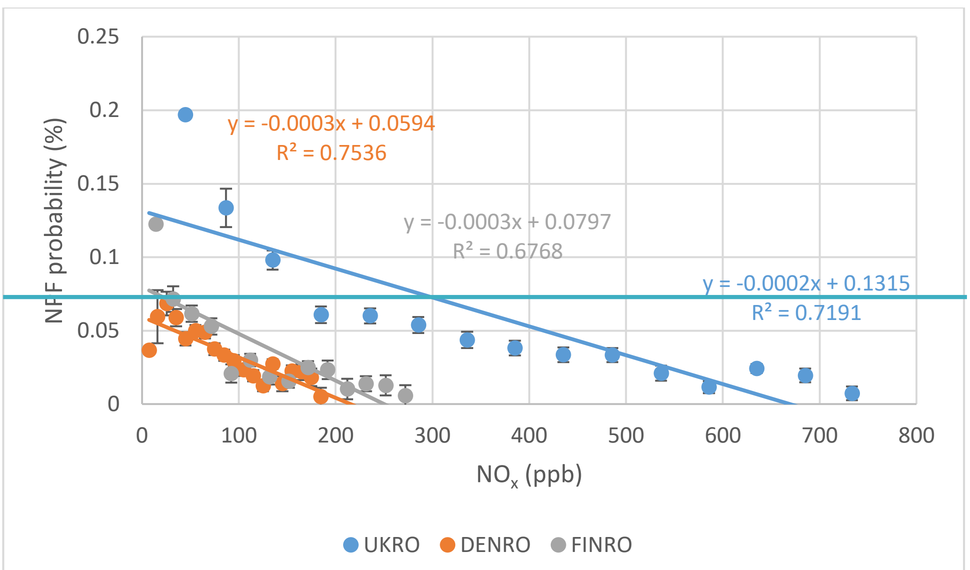


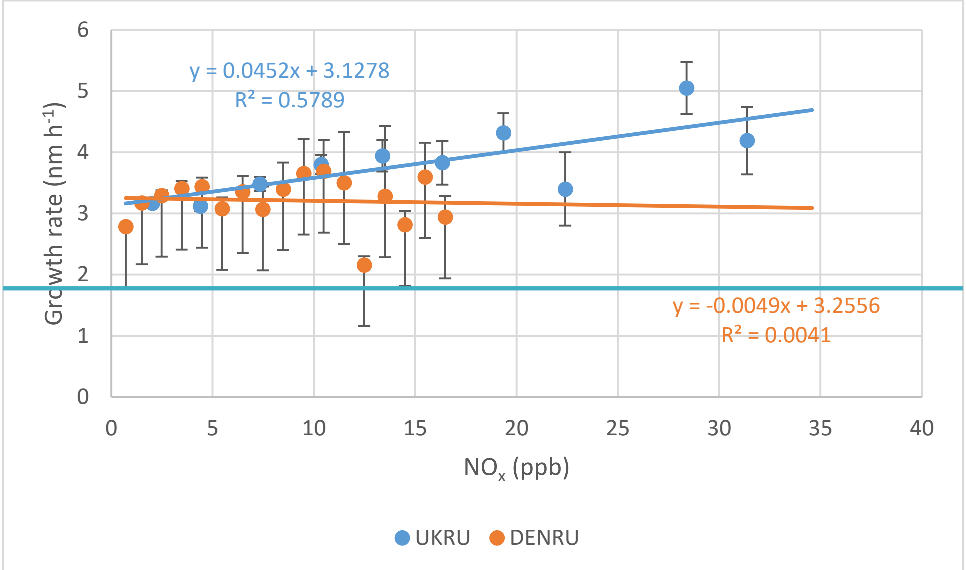


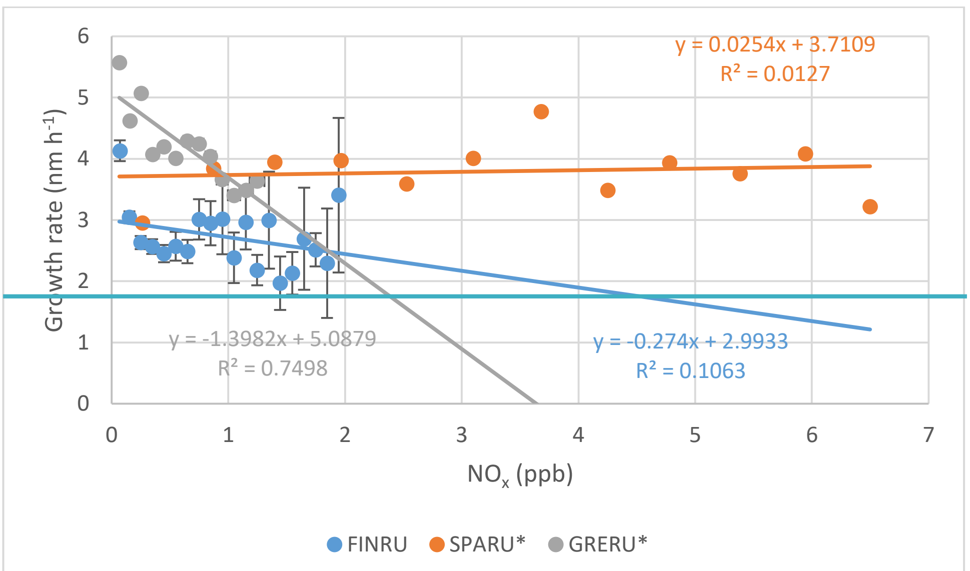
~~*NO_2 for SPARU and GRERU~~



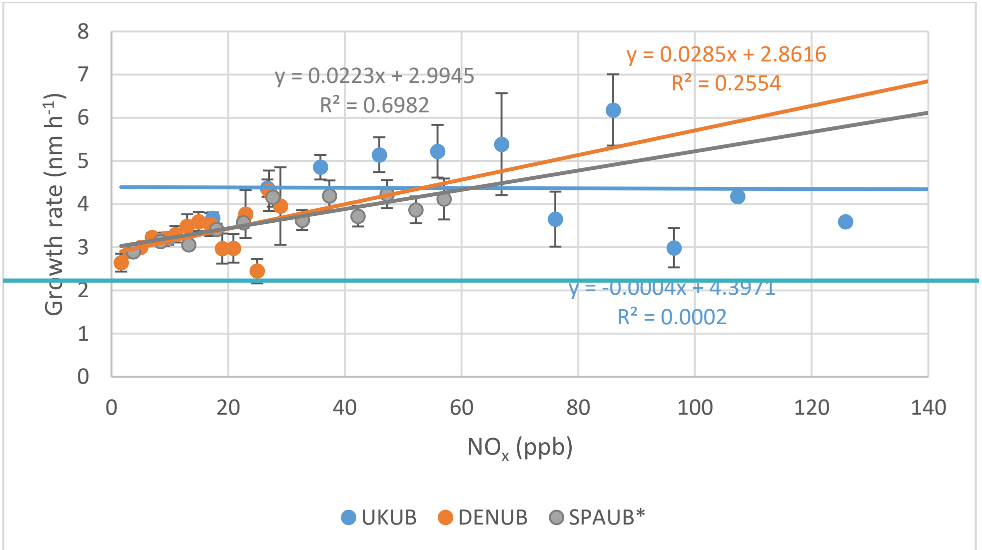
~~*NO_2 for SPAUB~~



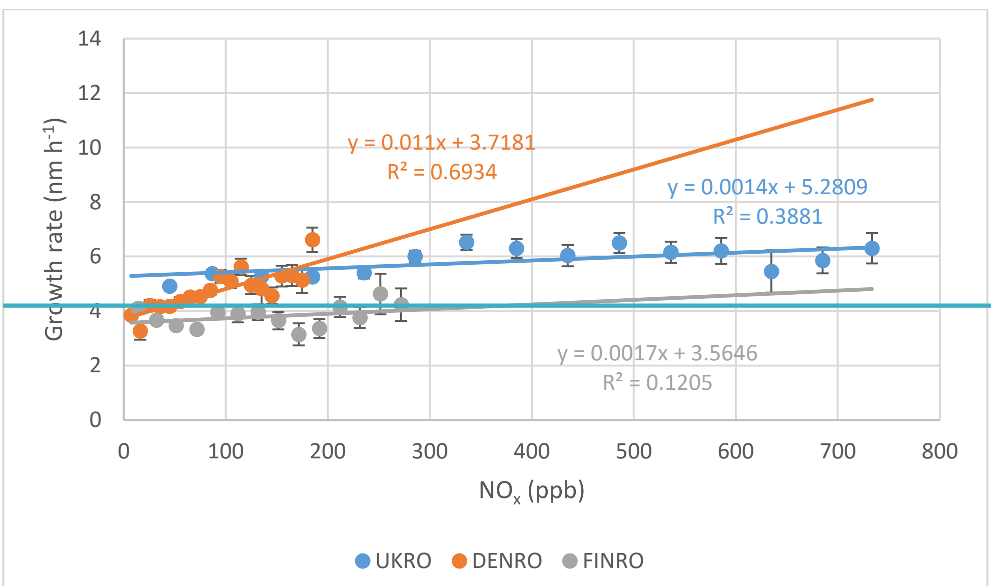


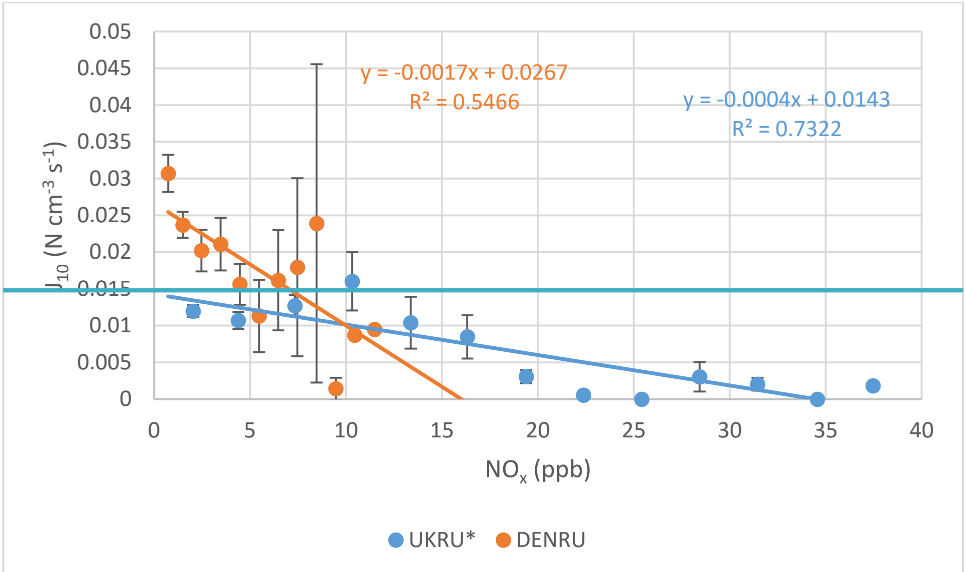


~~*NO_2 for SPARU and GRERU~~

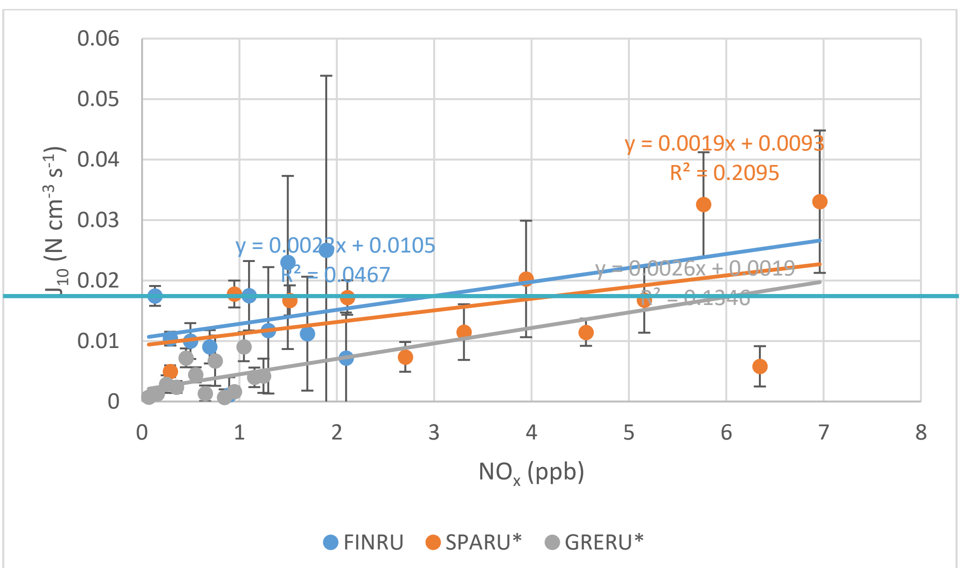


~~*NO_2 for SPAUB~~

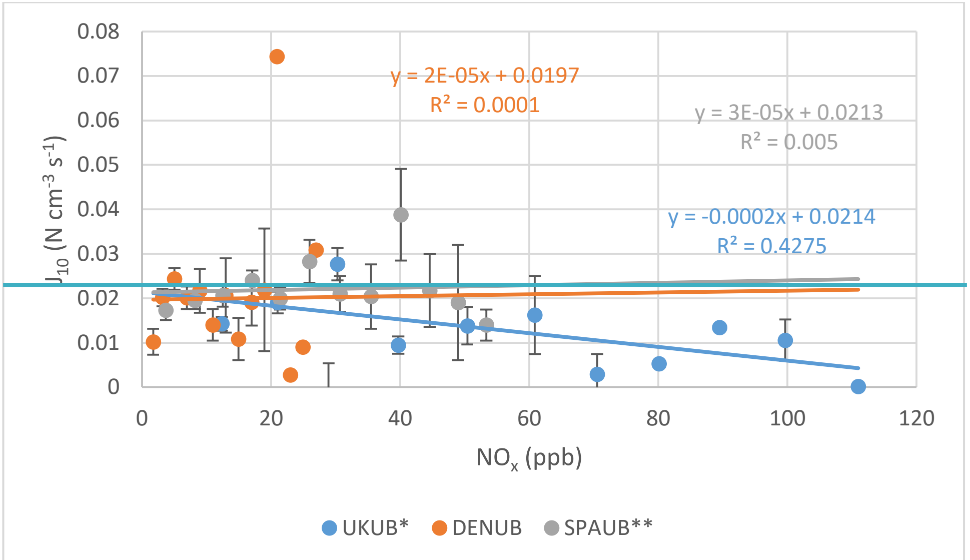




*J_{16} for UKRU

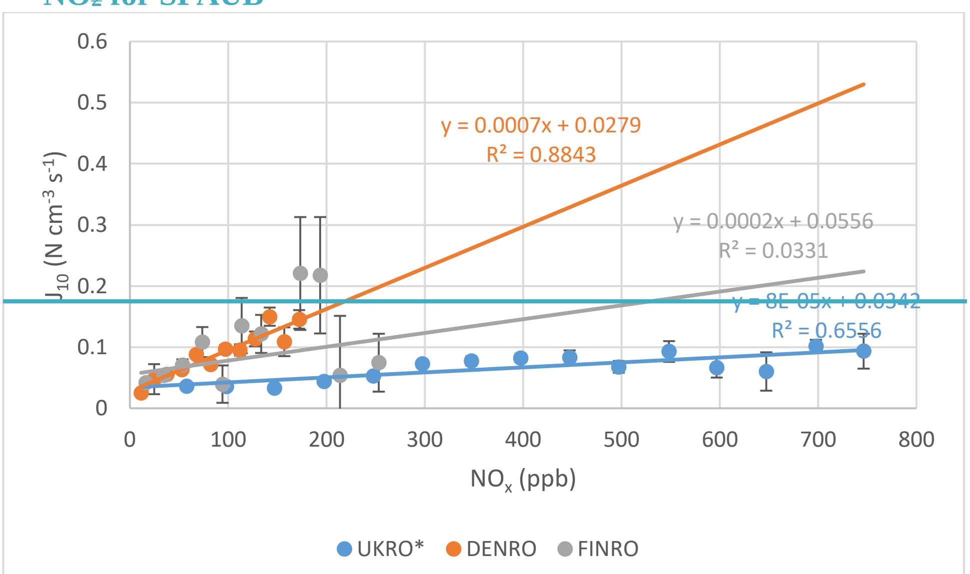


*NO_2 for SPARU and GRERU

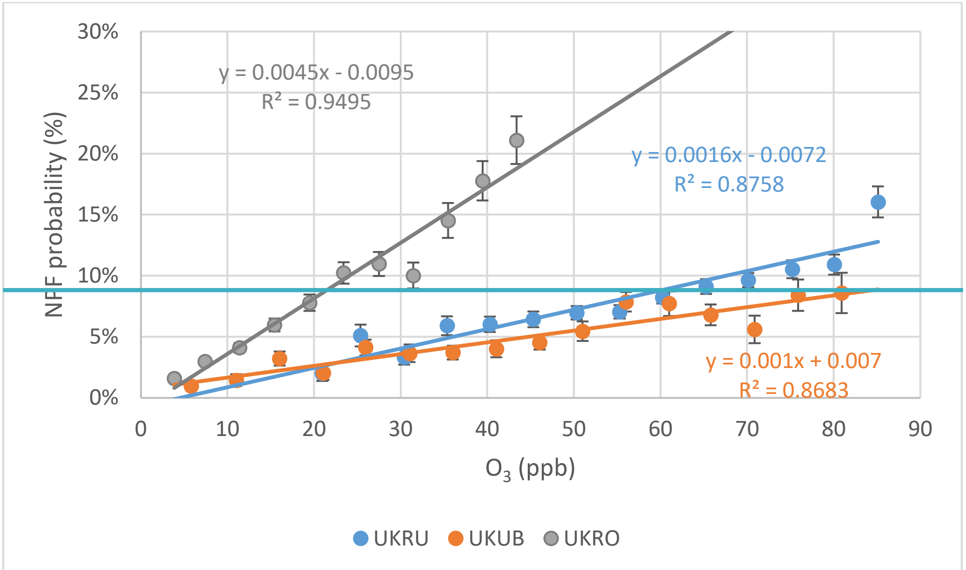


~~*J_{16} for UKUB~~

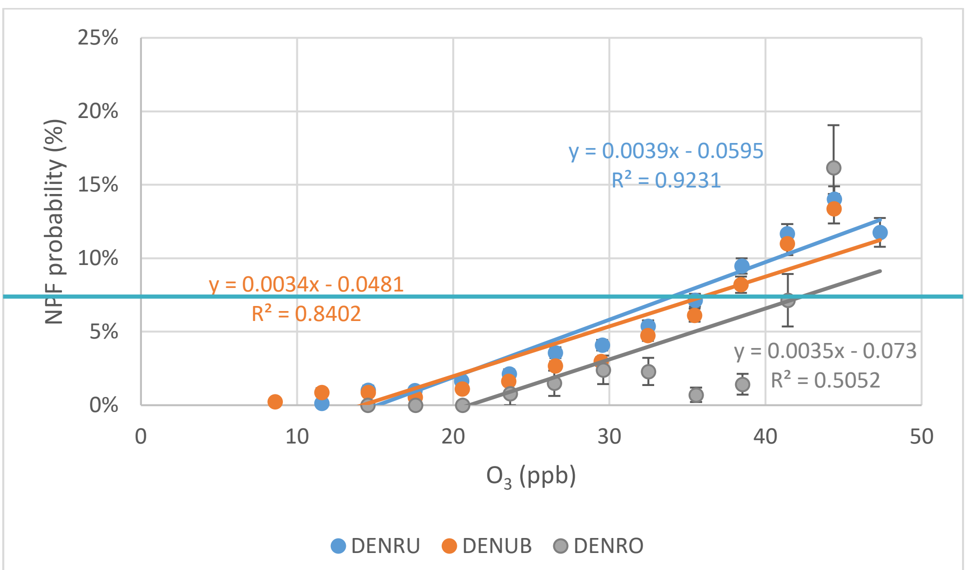
~~** NO_2 for SPAUB~~



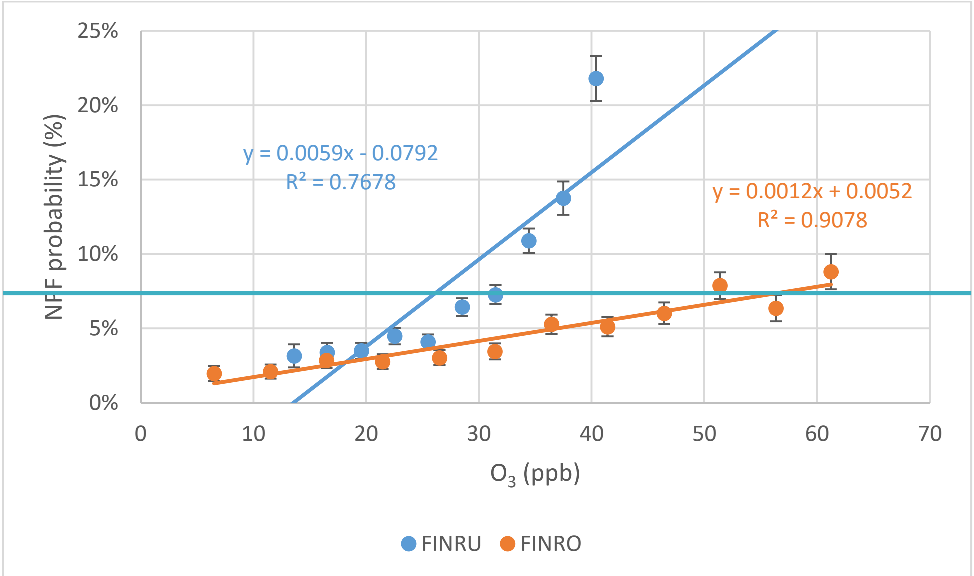
~~*J_{16} for UKRO~~

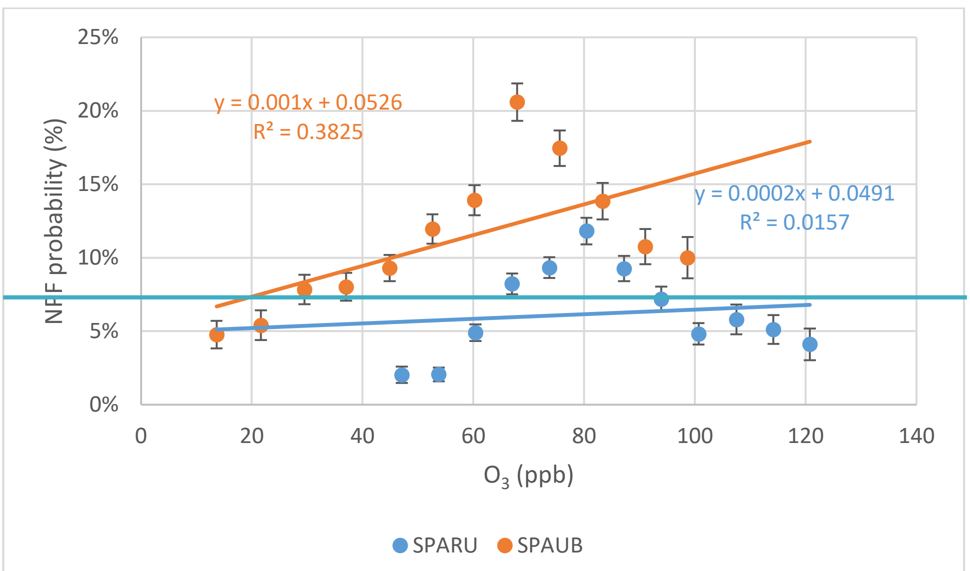


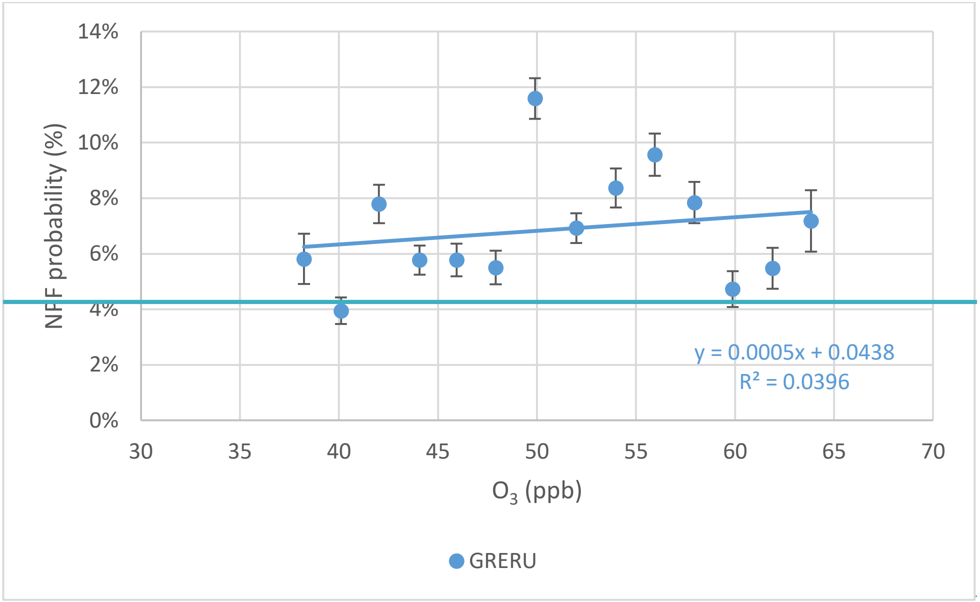
y = 0.0045x - 0.0095
R² = 0.9495
y = 0.0016x - 0.0072
R² = 0.8758
y = 0.001x + 0.007
R² = 0.8683
NFF probability (%)
30%
25%
20%
15%
10%
5%
0%
0
10
20
30
40
50
60
70
80
90
O3 (ppb)
UKRU
UKUB
UKRO

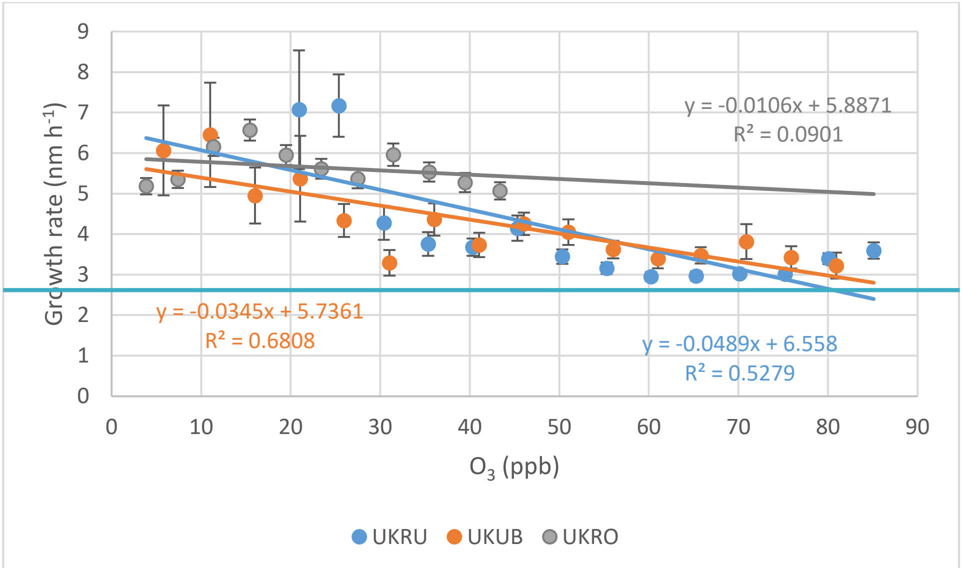


y = 0.0039x - 0.0595
R² = 0.9231
y = 0.0034x - 0.0481
R² = 0.8402
y = 0.0035x - 0.073
R² = 0.5052
NFF probability (%)
25%
20%
15%
10%
5%
0%
0
10
20
30
40
50
O3 (ppb)
DENRU
DENUB
DENRO

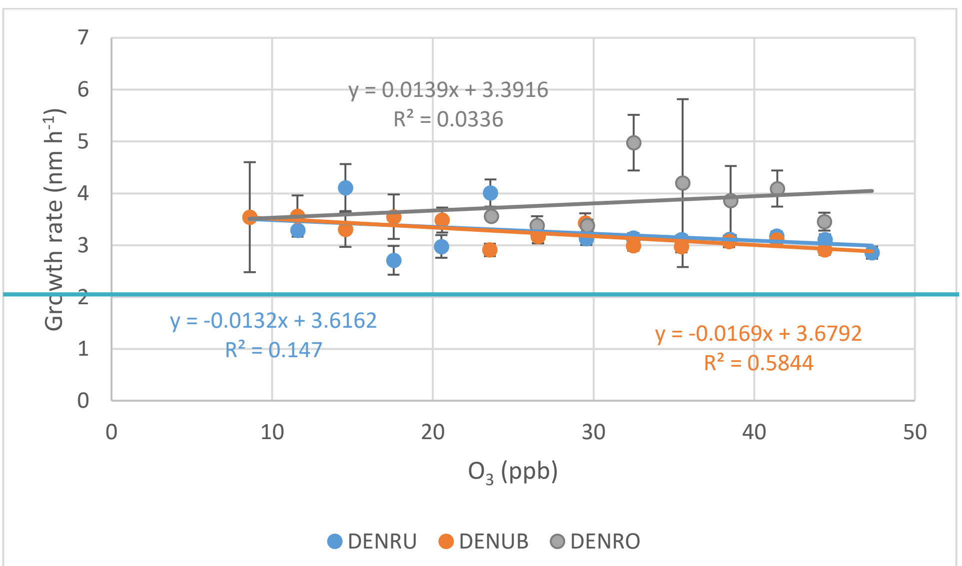

25%
20%
15%
10%
5%
0%
NFF probability (%)
y = 0.0059x - 0.0792
R² = 0.7678
y = 0.0012x + 0.0052
R² = 0.9078
0
10
20
30
40
50
60
70
O3 (ppb)
FINRU
FINRO


25%
20%
15%
10%
5%
0%
NFF probability (%)
y = 0.001x + 0.0526
R² = 0.3825
y = 0.0002x + 0.0491
R² = 0.0157
0
20
40
60
80
100
120
140
O3 (ppb)
SPARU
SPAUB

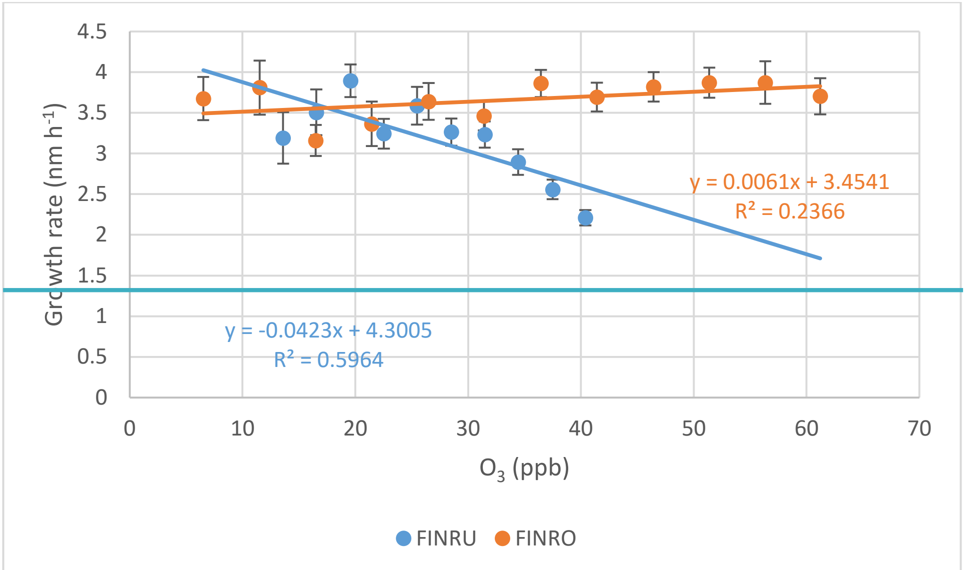

NFF probability (%)
14%
12%
10%
8%
6%
4%
2%
0%
30
35
40
45
50
55
60
65
70
O3 (ppb)
y = 0.0005x + 0.0438
R² = 0.0396
GRERU

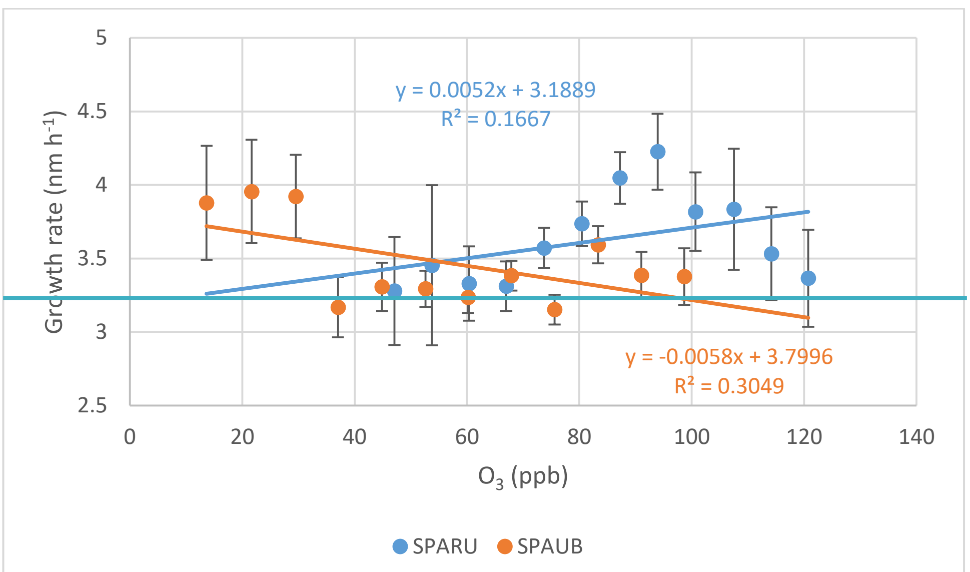


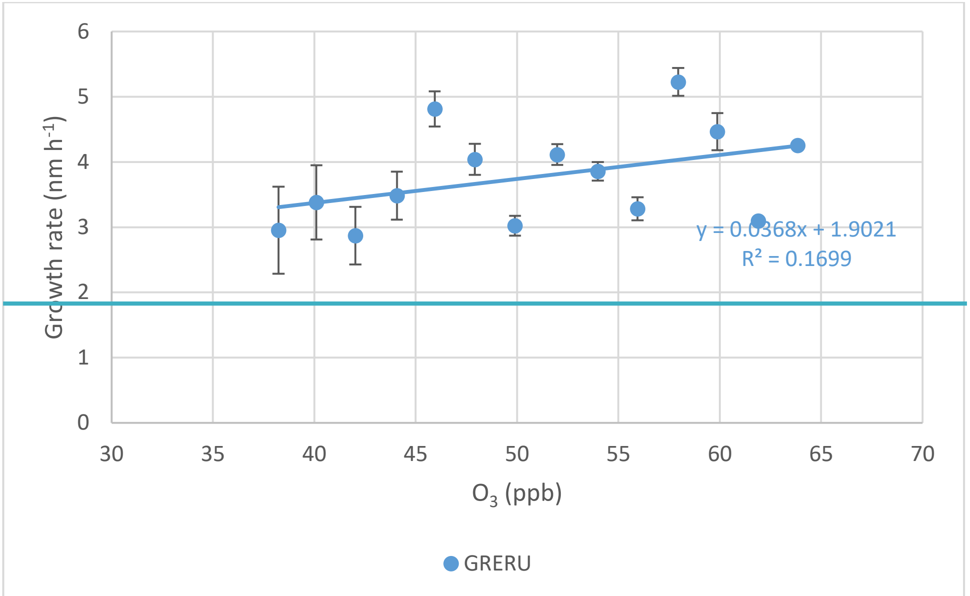
Growth rate (nm h-1)
O3 (ppb)
y = -0.0106x + 5.8871
R² = 0.0901
y = -0.0345x + 5.7361
R² = 0.6808
y = -0.0489x + 6.558
R² = 0.5279
UKRU
UKUB
UKRO

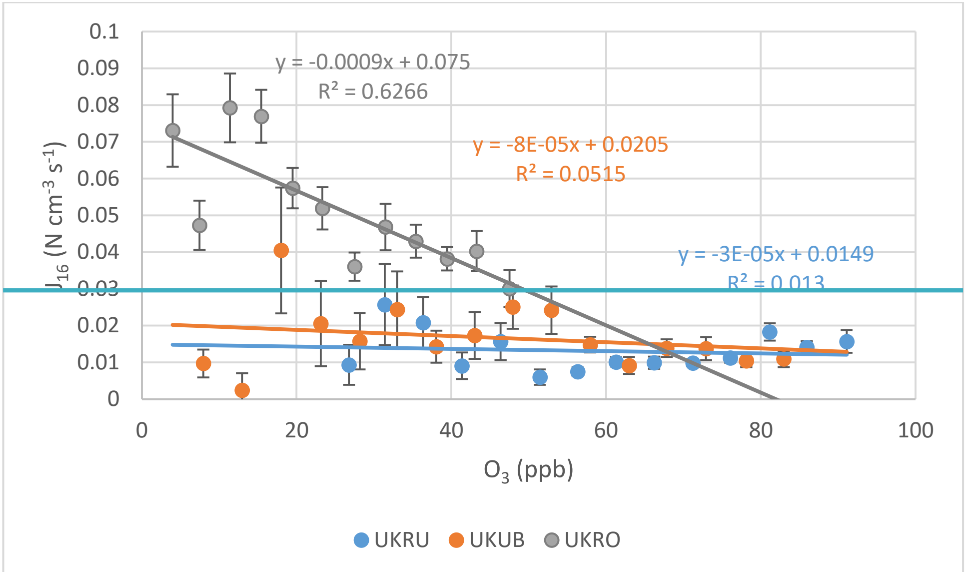


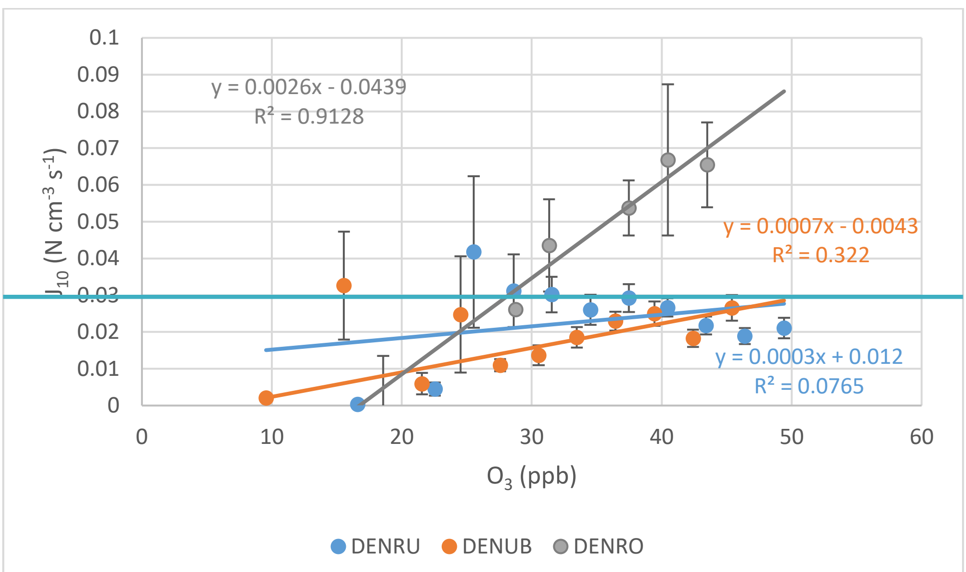
Growth rate (nm h-1)
O3 (ppb)
y = 0.0139x + 3.3916
R² = 0.0336
y = -0.0132x + 3.6162
R² = 0.147
y = -0.0169x + 3.6792
R² = 0.5844
DENRU
DENUB
DENRO

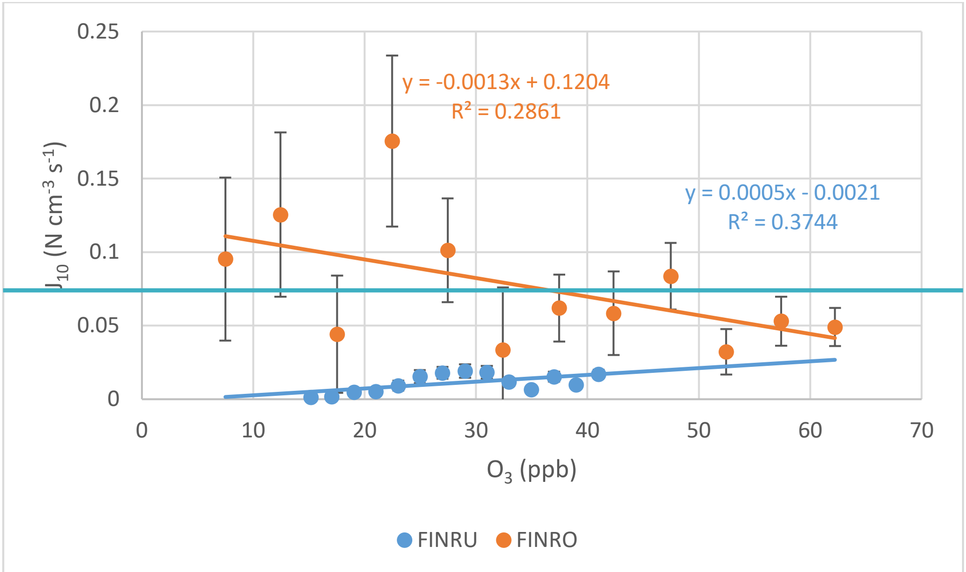

4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Growth rate (nm h-1)
0
10
20
30
40
50
60
70
O3 (ppb)
y = 0.0061x + 3.4541
R² = 0.2366
y = -0.0423x + 4.3005
R² = 0.5964
FINRU
FINRO

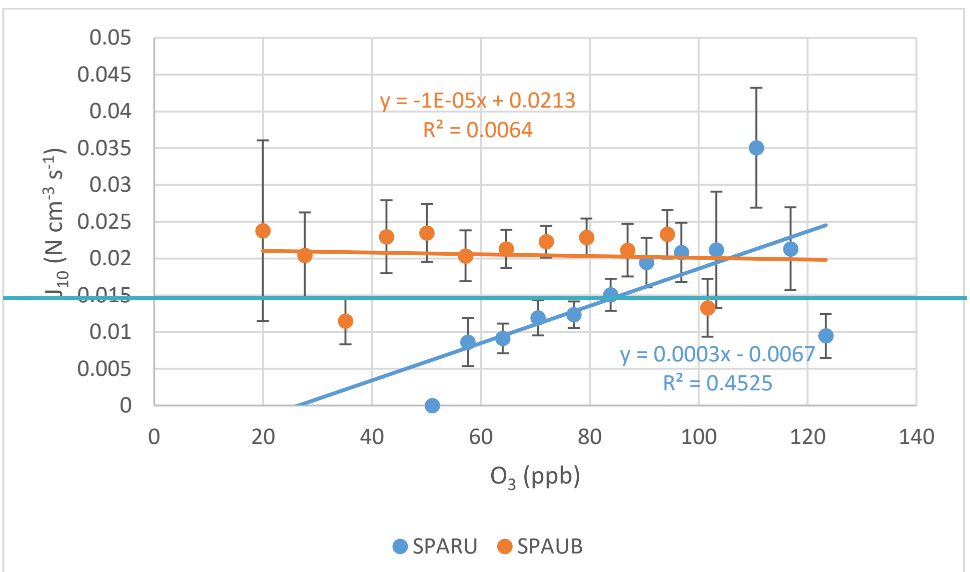

5
4.5
4
3.5
3
2.5
Growth rate (nm h-1)
0
20
40
60
80
100
120
140
O3 (ppb)
y = 0.0052x + 3.1889
R² = 0.1667
y = -0.0058x + 3.7996
R² = 0.3049
SPARU
SPAUB

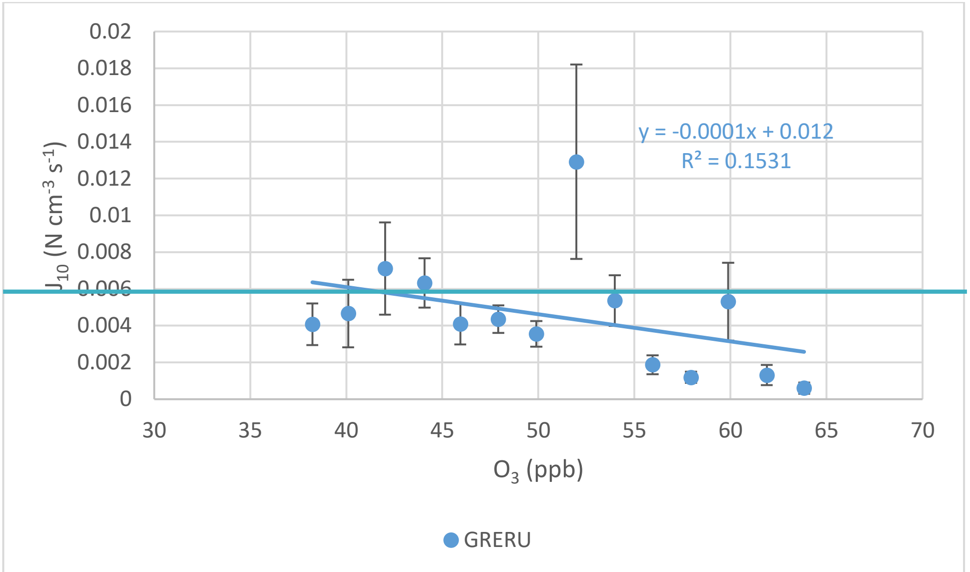

Growth rate (nm h-1)
0
1
2
3
4
5
6
30
35
40
45
50
55
60
65
70
O3 (ppb)
y = 0.0368x + 1.9021
R² = 0.1699
GRERU


0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J_{16} (N cm^{-3} s^{-1})
y = -0.0009x + 0.075
R² = 0.6266
y = -8E-05x + 0.0205
R² = 0.0515
y = -3E-05x + 0.0149
R² = 0.013
0
20
40
60
80
100
O_3 (ppb)
UKRU
UKUB
UKRO

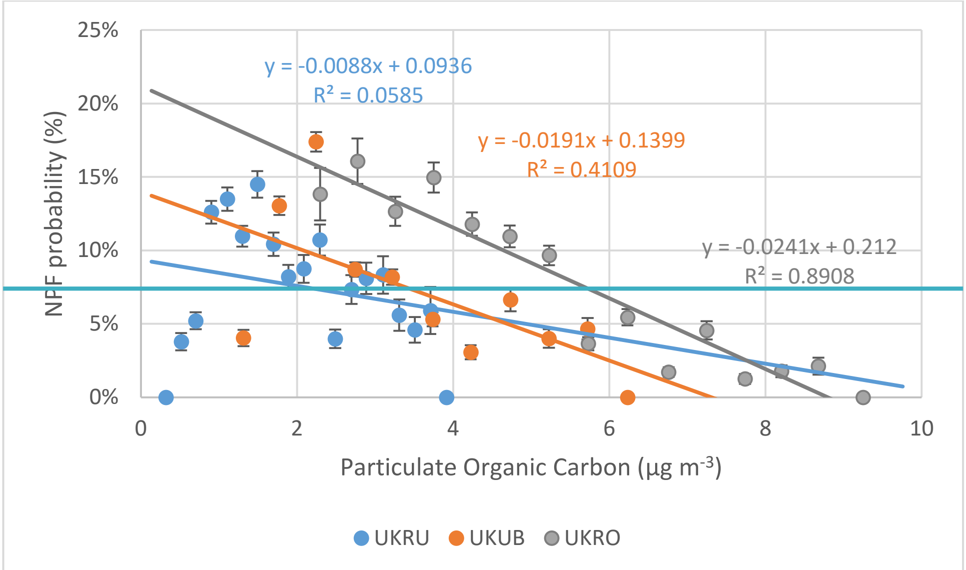

0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J_{10} (N cm^{-3} s^{-1})
y = 0.0026x - 0.0439
R² = 0.9128
y = 0.0007x - 0.0043
R² = 0.322
y = 0.0003x + 0.012
R² = 0.0765
0
10
20
30
40
50
60
O_3 (ppb)
DENRU
DENUB
DENRO


0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
J10 (N cm-3 s-1)
O3 (ppb)
y = -0.0013x + 0.1204
R² = 0.2861
y = 0.0005x - 0.0021
R² = 0.3744
FINRU
FINRO

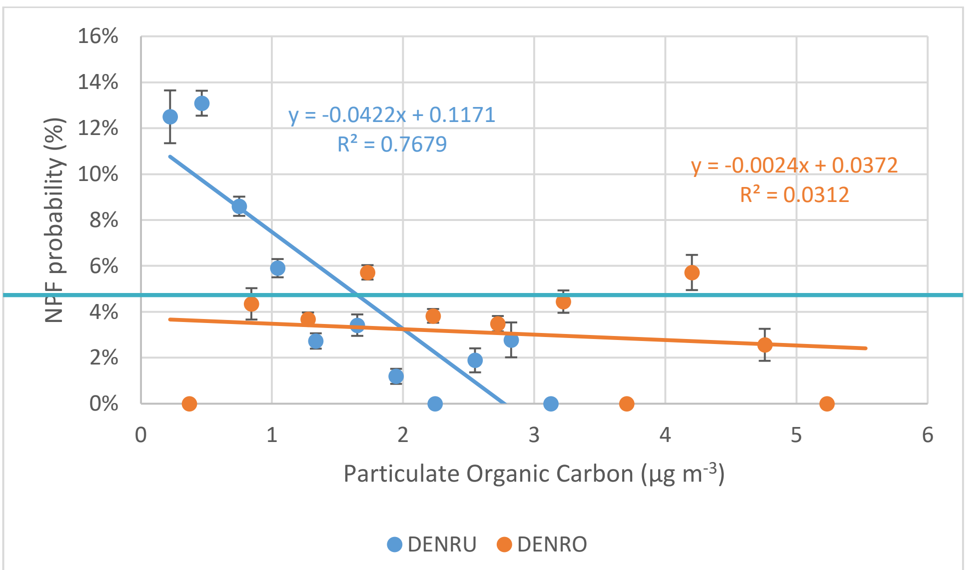

0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
140
J10 (N cm-3 s-1)
O3 (ppb)
y = -1E-05x + 0.0213
R² = 0.0064
y = 0.0003x - 0.0067
R² = 0.4525
SPARU
SPAUB



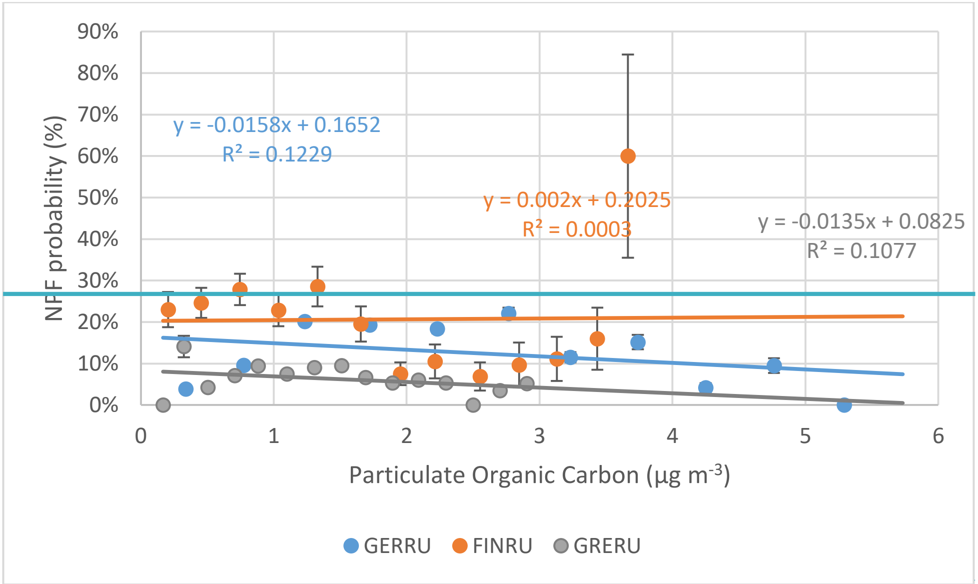
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
30
35
40
45
50
55
60
65
70
J10 (N cm-3 s-1)
O3 (ppb)
y = -0.0001x + 0.012
R² = 0.1531
GRERU



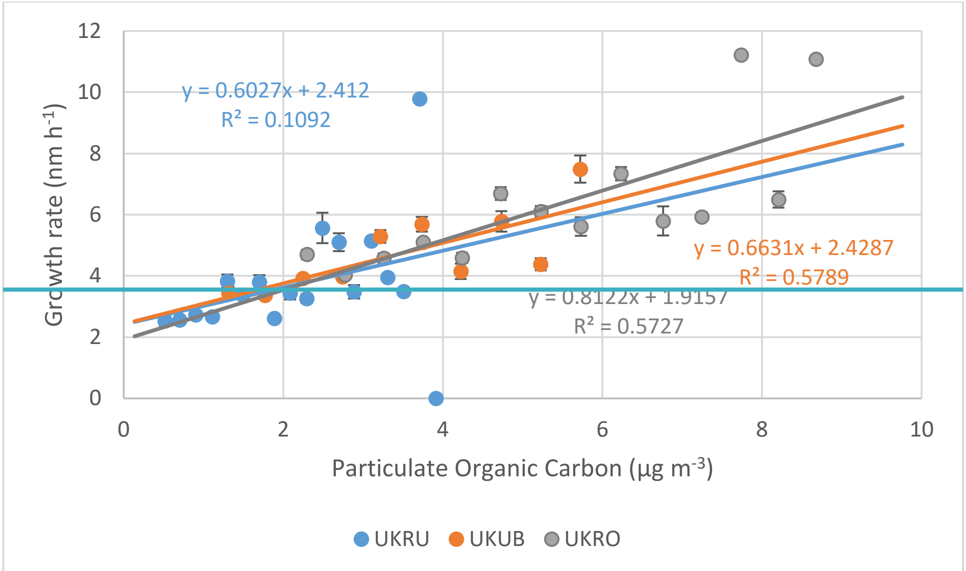
NPF probability (%)
25%
20%
15%
10%
5%
0%
0
2
4
6
8
10
y = -0.0088x + 0.0936
R² = 0.0585
y = -0.0191x + 0.1399
R² = 0.4109
y = -0.0241x + 0.212
R² = 0.8908
Particulate Organic Carbon (µg m-3)
UKRU
UKUB
UKRO

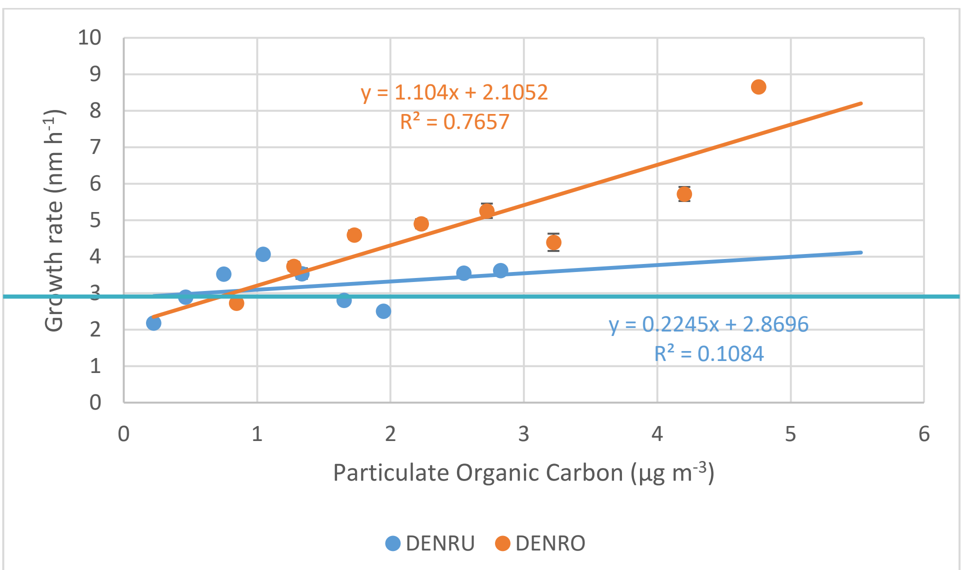


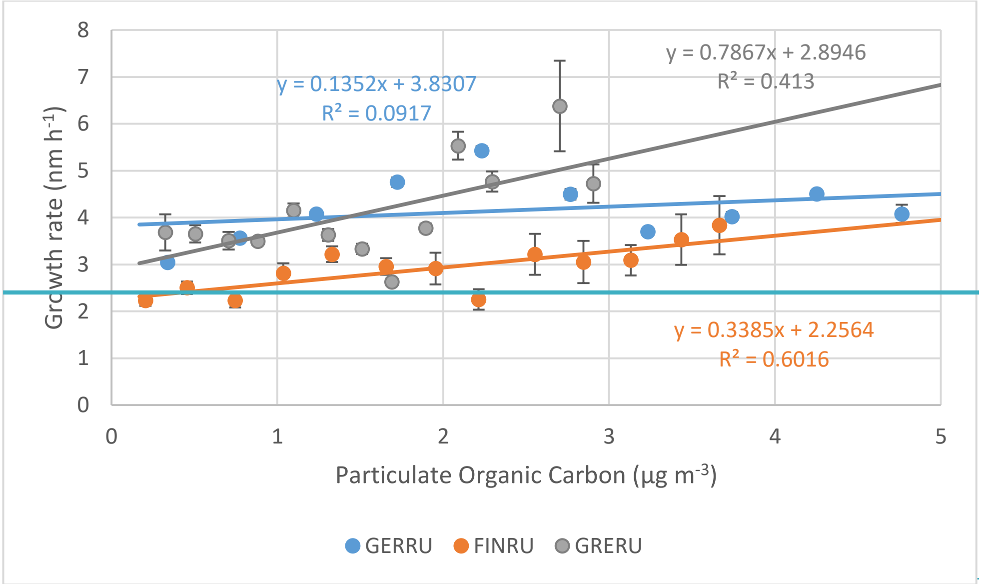
NPF probability (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
y = -0.0422x + 0.1171
R² = 0.7679
y = -0.0024x + 0.0372
R² = 0.0312
Particulate Organic Carbon (µg m-3)
DENRU
DENRO

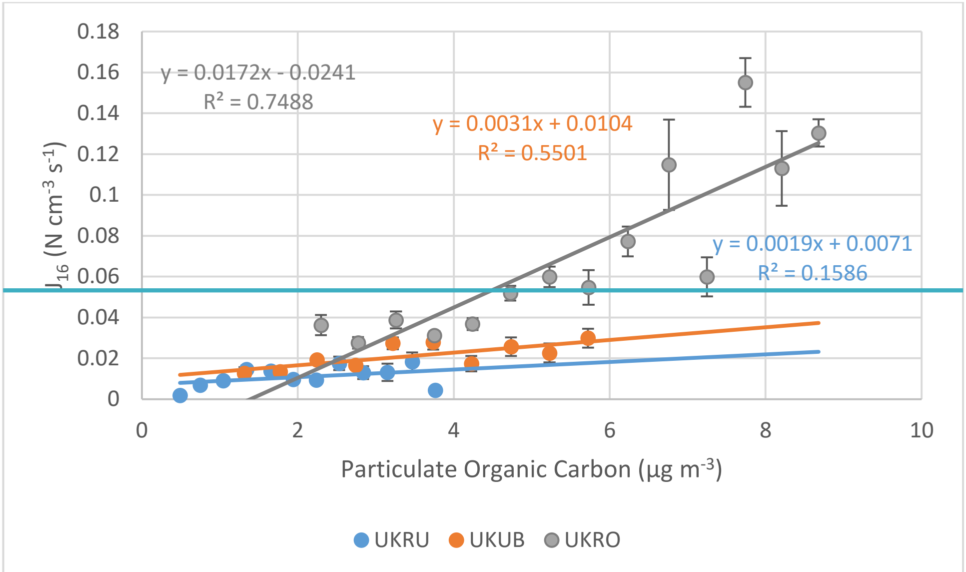


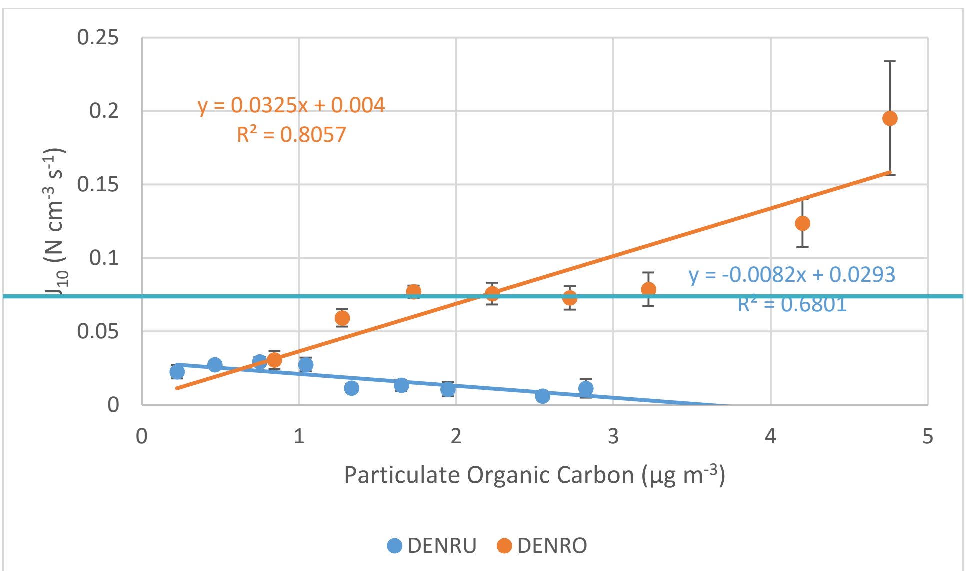
NFF probability (%)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
Particulate Organic Carbon (µg m-3)
y = -0.0158x + 0.1652
R² = 0.1229
y = 0.002x + 0.2025
R² = 0.0003
y = -0.0135x + 0.0825
R² = 0.1077
GERRU
FINRU
GRERU

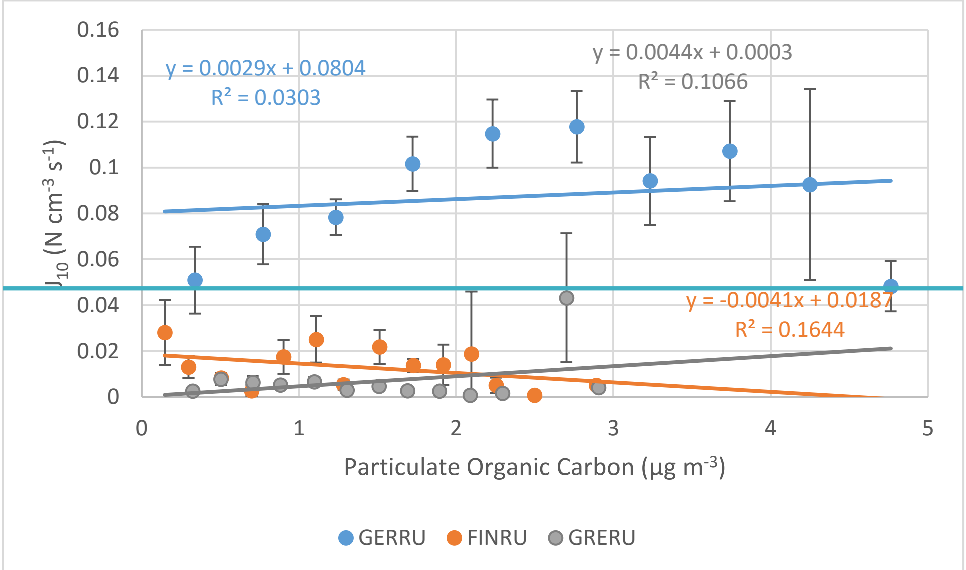

y = 0.6027x + 2.412
R² = 0.1092
y = 0.6631x + 2.4287
R² = 0.5789
y = 0.8122x + 1.9157
R² = 0.5727
Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
UKRU
UKUB
UKRO

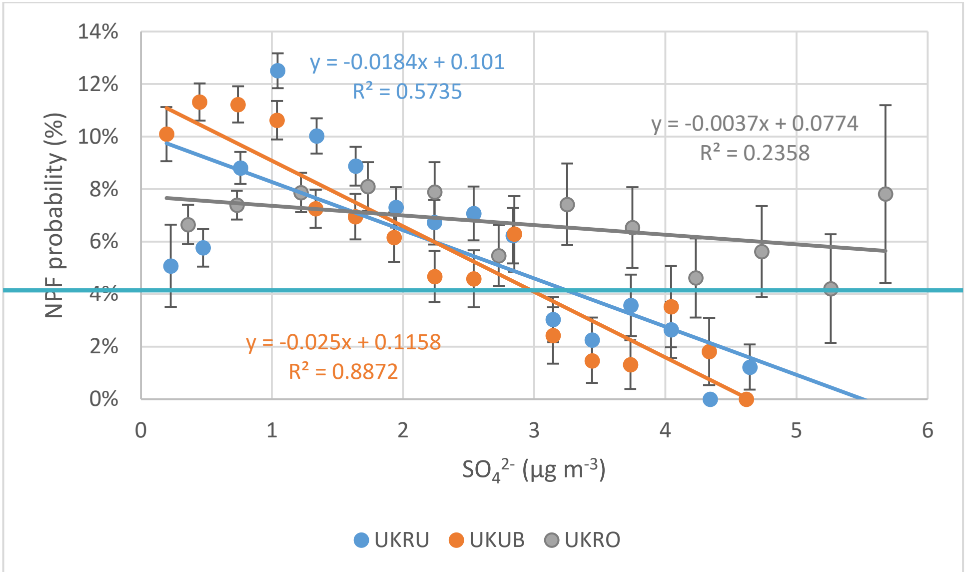

y = 1.104x + 2.1052
R² = 0.7657
y = 0.2245x + 2.8696
R² = 0.1084
Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
DENRU
DENRO

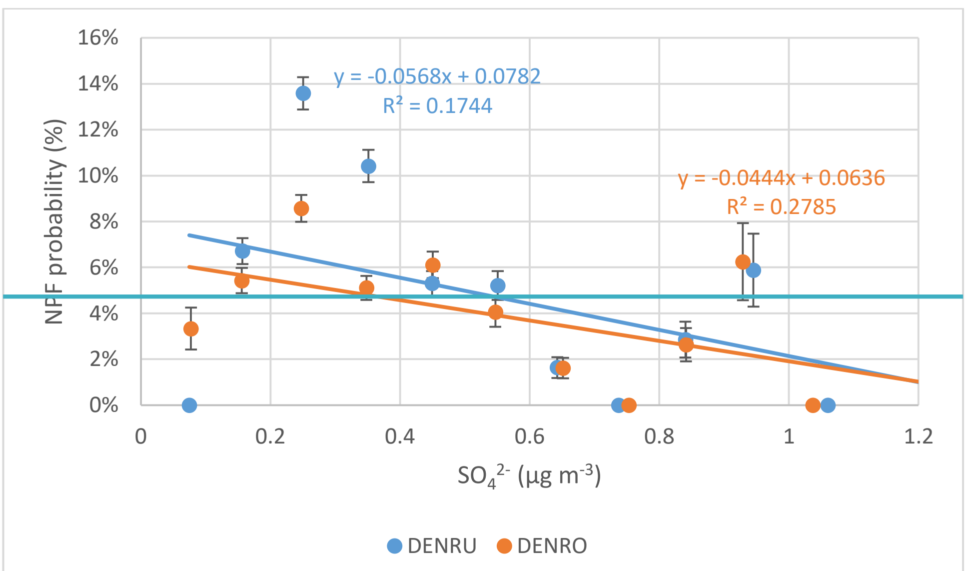

Growth rate (nm h-1)
Particulate Organic Carbon (µg m-3)
y = 0.1352x + 3.8307
R² = 0.0917
y = 0.7867x + 2.8946
R² = 0.413
y = 0.3385x + 2.2564
R² = 0.6016
GERRU
FINRU
GRERU

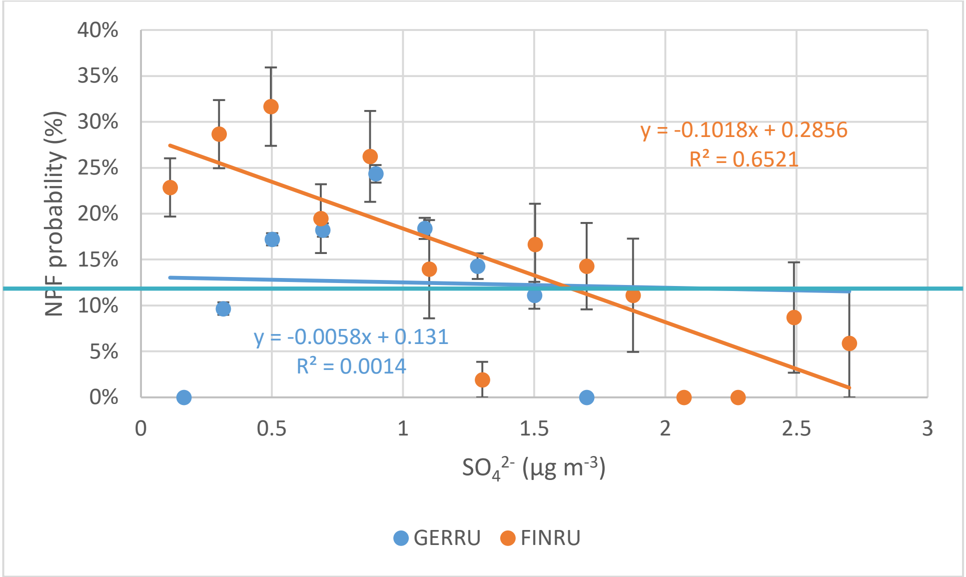

0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
2
4
6
8
10
J_{16} (N cm^{-3} s^{-1})
Particulate Organic Carbon (µg m^{-3})
y = 0.0172x - 0.0241
R^2 = 0.7488
y = 0.0031x + 0.0104
R^2 = 0.5501
y = 0.0019x + 0.0071
R^2 = 0.1586
UKRU
UKUB
UKRO

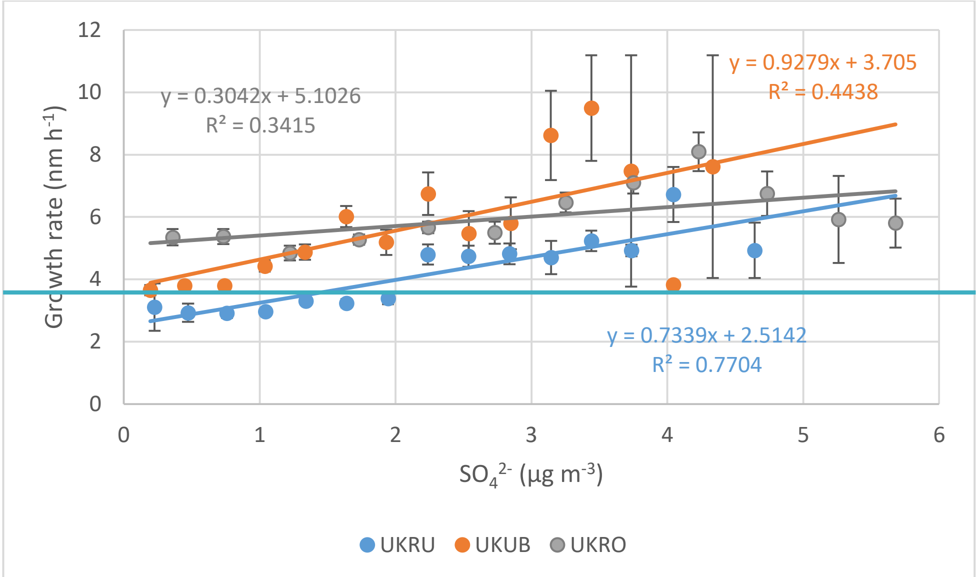

0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
J_{10} (N cm^{-3} s^{-1})
Particulate Organic Carbon (µg m^{-3})
y = 0.0325x + 0.004
R^2 = 0.8057
y = -0.0082x + 0.0293
R^2 = 0.6801
DENRU
DENRO

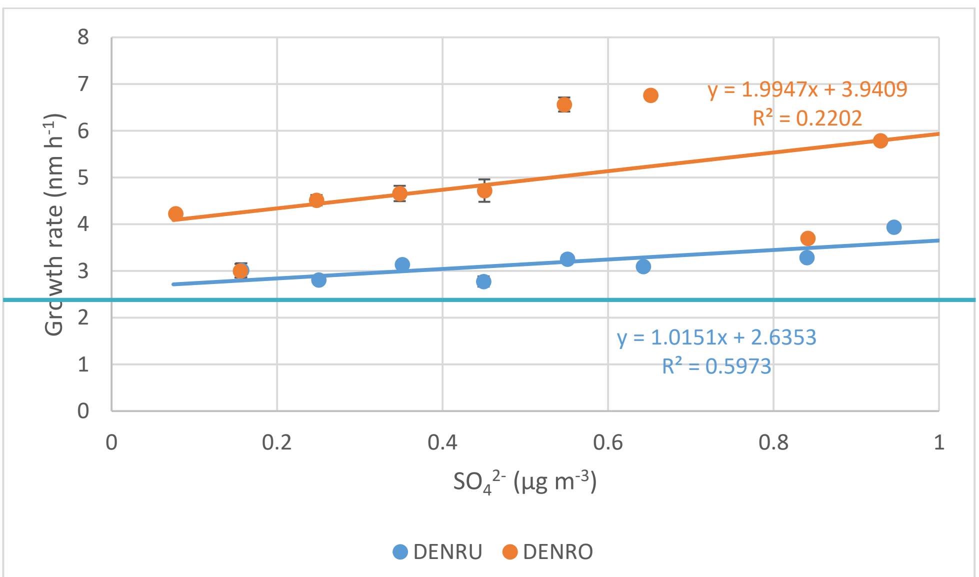

y = 0.0029x + 0.0804
R² = 0.0303
y = 0.0044x + 0.0003
R² = 0.1066
y = -0.0041x + 0.0187
R² = 0.1644
J10 (N cm-3 s-1)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
4
5
Particulate Organic Carbon (µg m-3)
GERRU
FINRU
GRERU

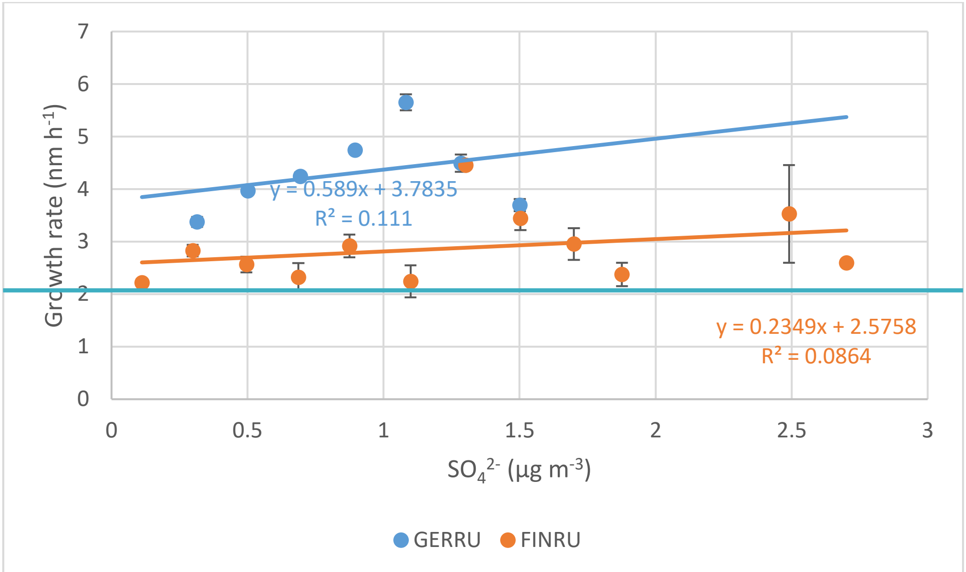

y = -0.0184x + 0.101
R² = 0.5735
y = -0.0037x + 0.0774
R² = 0.2358
y = -0.025x + 0.1158
R² = 0.8872
NPF probability (%)
SO4 2- (µg m-3)
UKRU
UKUB
UKRO

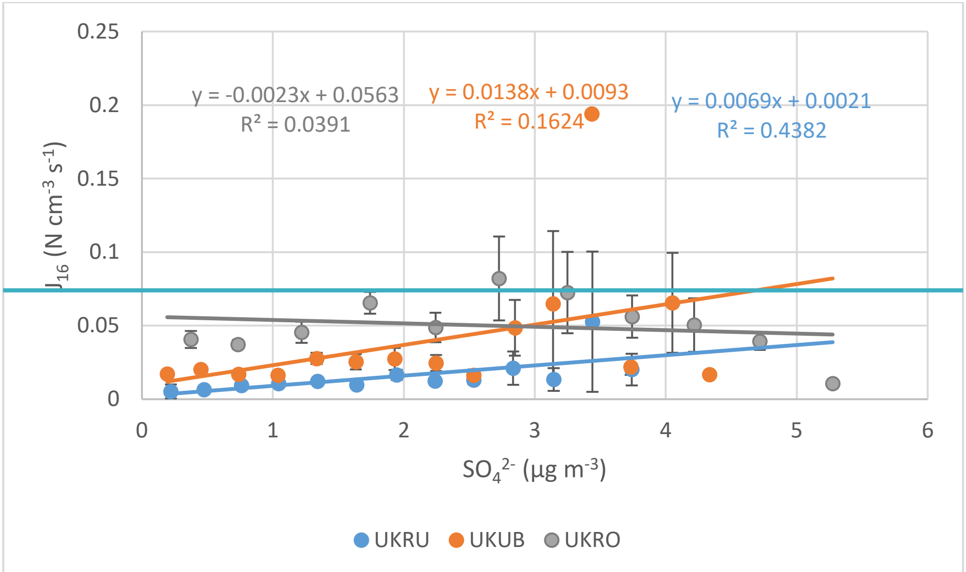

y = -0.0568x + 0.0782
R² = 0.1744
y = -0.0444x + 0.0636
R² = 0.2785
NPF probability (%)
SO4 2- (µg m-3)
DENRU
DENRO


40%
35%
30%
25%
20%
15%
10%
5%
0%
NPF probability (%)
0
0.5
1
1.5
2
2.5
3
SO4 2- (µg m-3)
y = -0.1018x + 0.2856
R² = 0.6521
y = -0.0058x + 0.131
R² = 0.0014
GERRU
FINRU

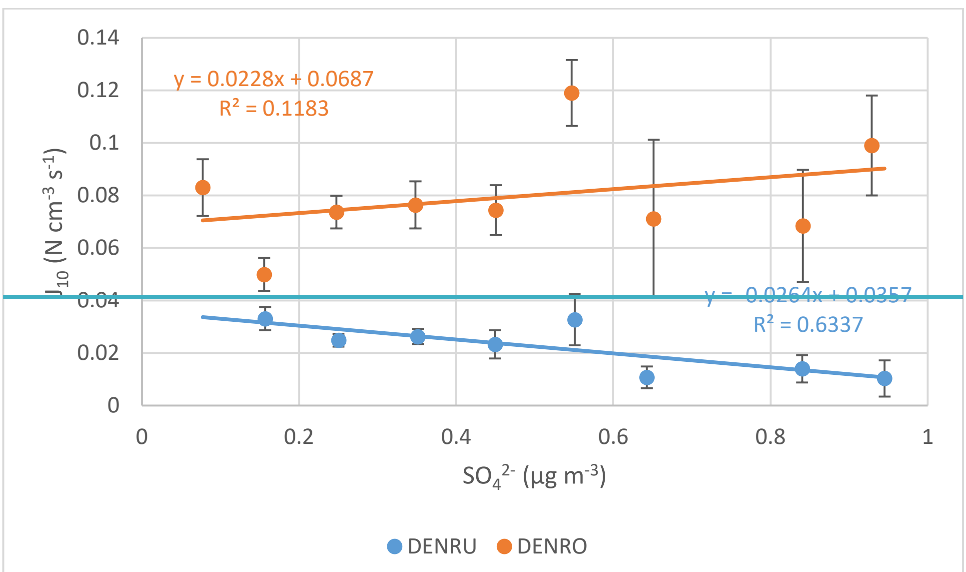

Growth rate (nm h-1)
12
10
8
6
4
2
0
0
1
2
3
4
5
6
SO42- (µg m-3)
y = 0.3042x + 5.1026
R² = 0.3415
y = 0.9279x + 3.705
R² = 0.4438
y = 0.7339x + 2.5142
R² = 0.7704
UKRU
UKUB
UKRO


Growth rate (nm h-1)
8
7
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
SO42- (µg m-3)
y = 1.9947x + 3.9409
R² = 0.2202
y = 1.0151x + 2.6353
R² = 0.5973
DENRU
DENRO

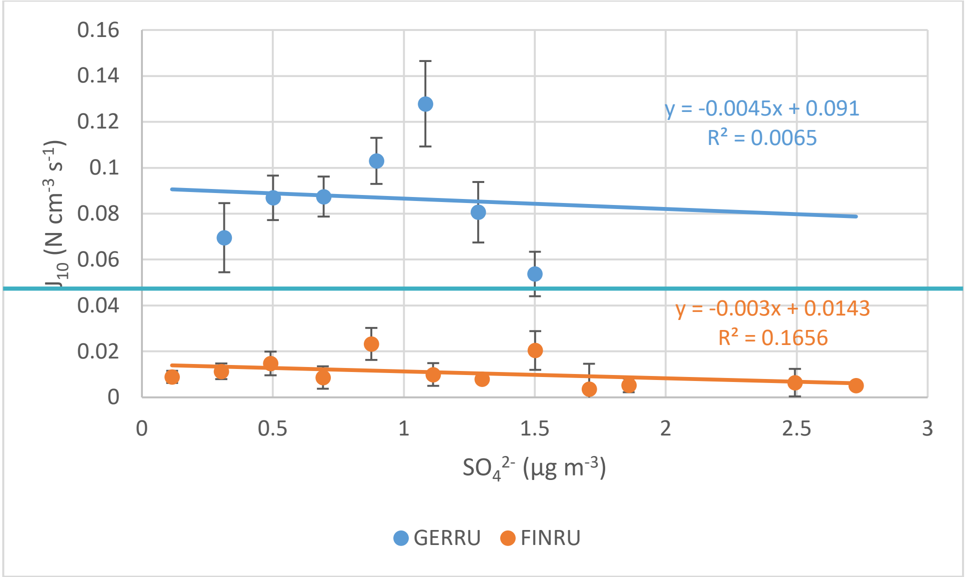

Growth rate (nm h-1)
SO42- (µg m-3)
y = 0.589x + 3.7835
R² = 0.111
y = 0.2349x + 2.5758
R² = 0.0864
GERRU
FINRU
0
1
2
3
4
5
6
7
0
0.5
1
1.5
2
2.5
3

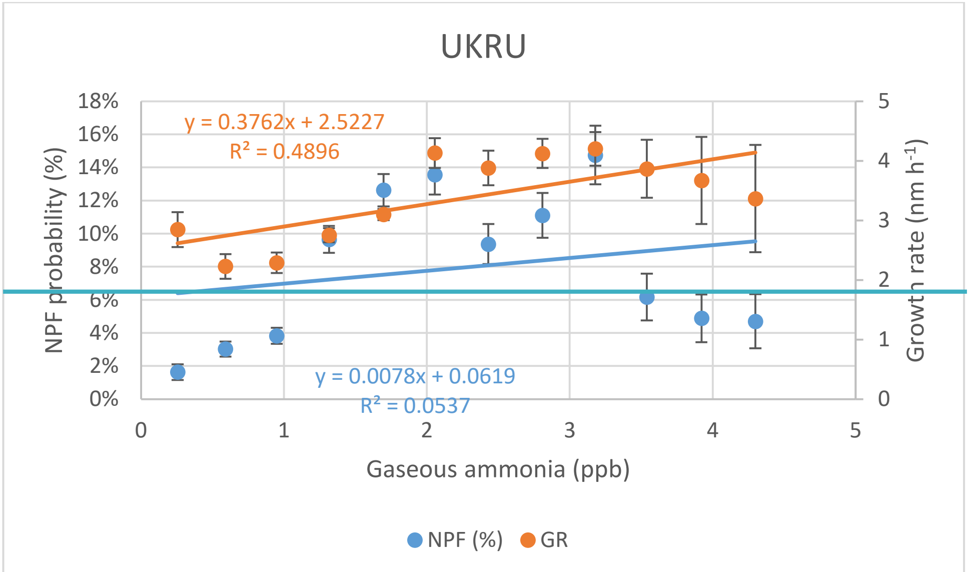


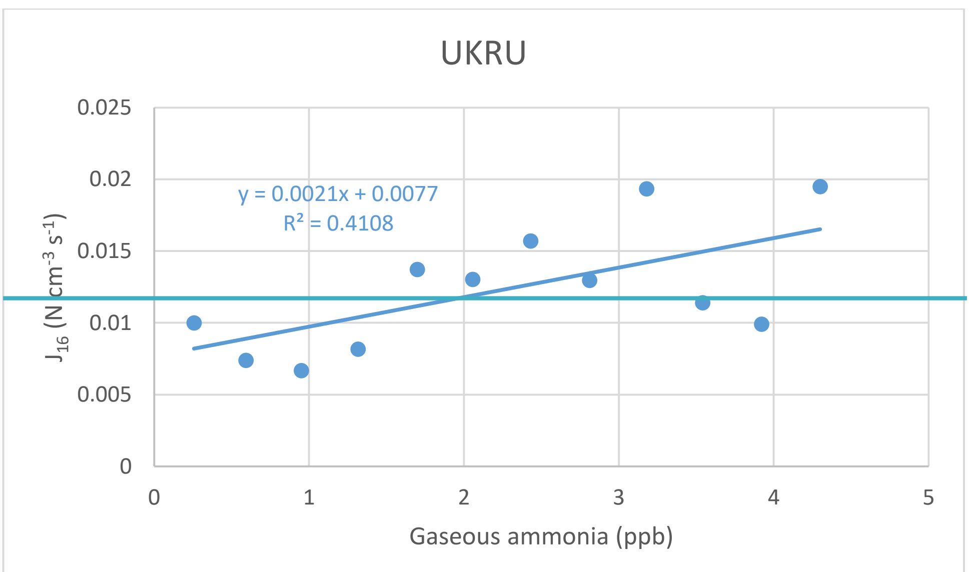
0.25
0.2
0.15
0.1
0.05
0
y = -0.0023x + 0.0563
R² = 0.0391
y = 0.0138x + 0.0093
R² = 0.1624
y = 0.0069x + 0.0021
R² = 0.4382
J16 (N cm-3 s-1)
0
1
2
3
4
5
6
SO4 2- (µg m-3)
UKRU
UKUB
UKRO

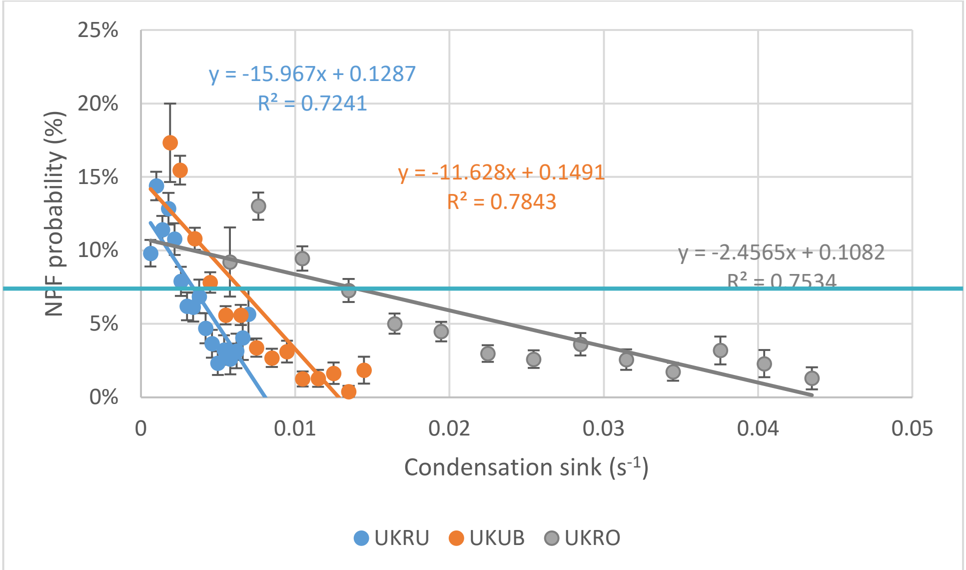


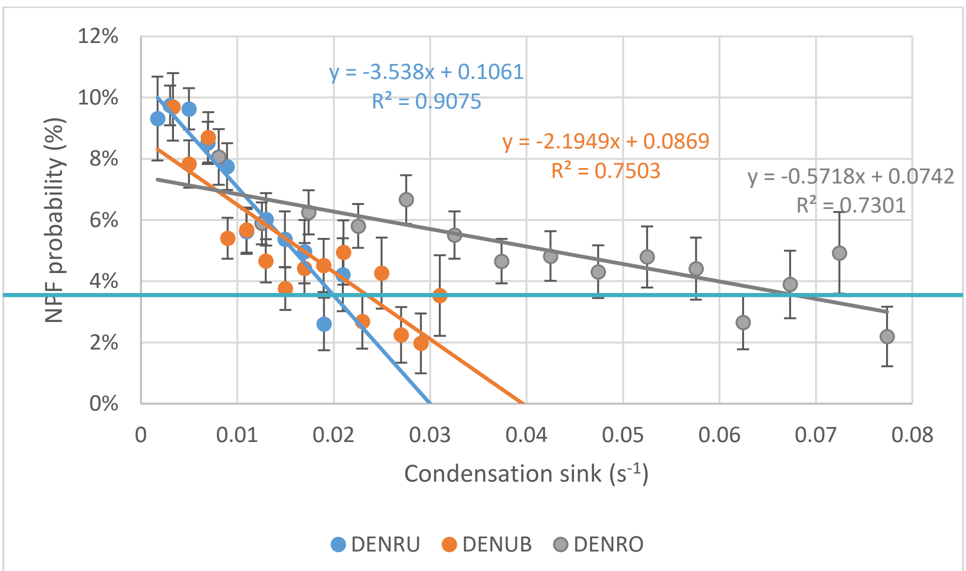
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
y = 0.0228x + 0.0687
R² = 0.1183
y = 0.0264x + 0.0357
R² = 0.6337
J10 (N cm-3 s-1)
0
0.2
0.4
0.6
0.8
1
SO4 2- (µg m-3)
DENRU
DENRO

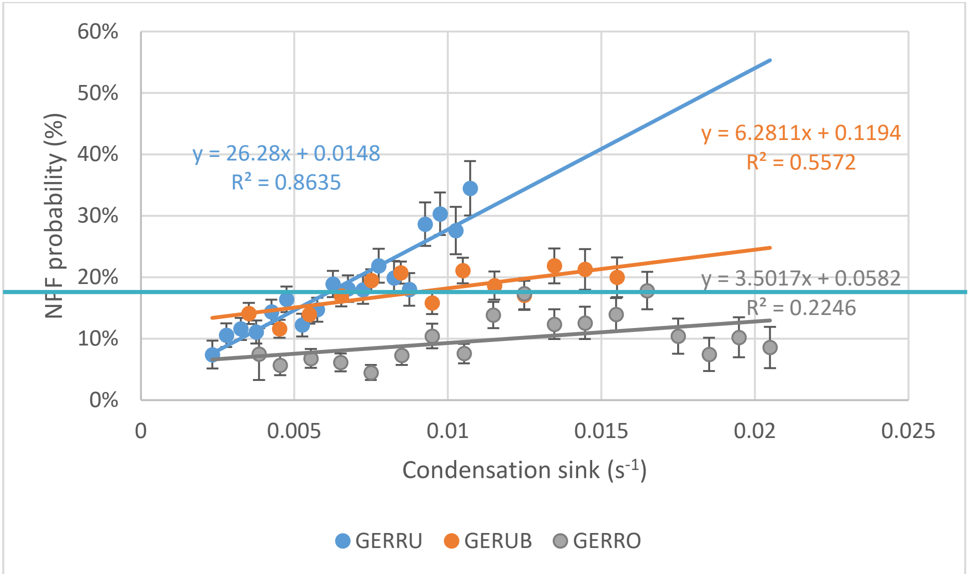

0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
0
0.5
1
1.5
2
2.5
3
SO42- (µg m-3)
y = -0.0045x + 0.091
R² = 0.0065
y = -0.003x + 0.0143
R² = 0.1656
GERRU
FINRU

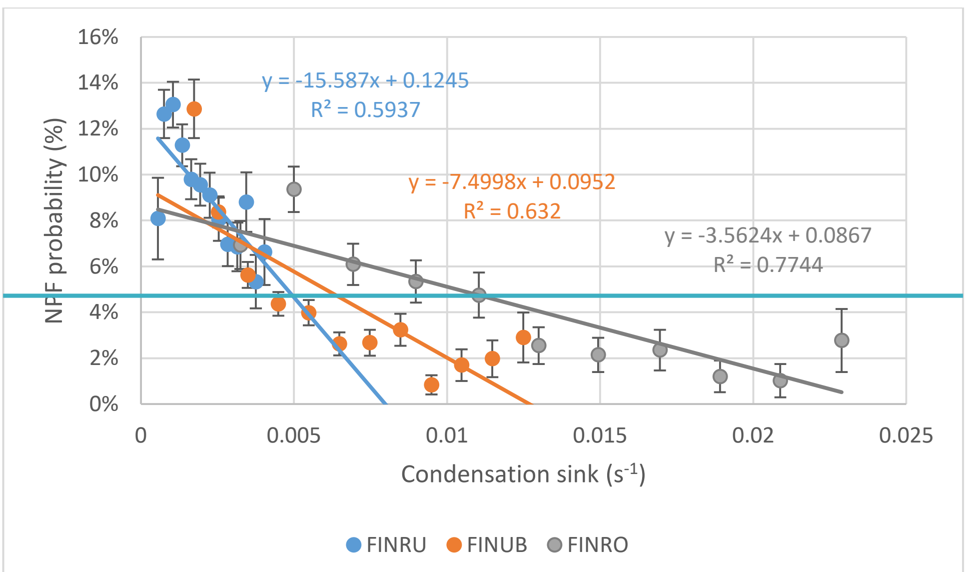

UKRU
NPF probability (%)
Growth rate (nm h-1)
y = 0.3762x + 2.5227
R² = 0.4896
y = 0.0078x + 0.0619
R² = 0.0537
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
5
4
3
2
1
0
0
1
2
3
4
5
Gaseous ammonia (ppb)
NPF (%)
GR

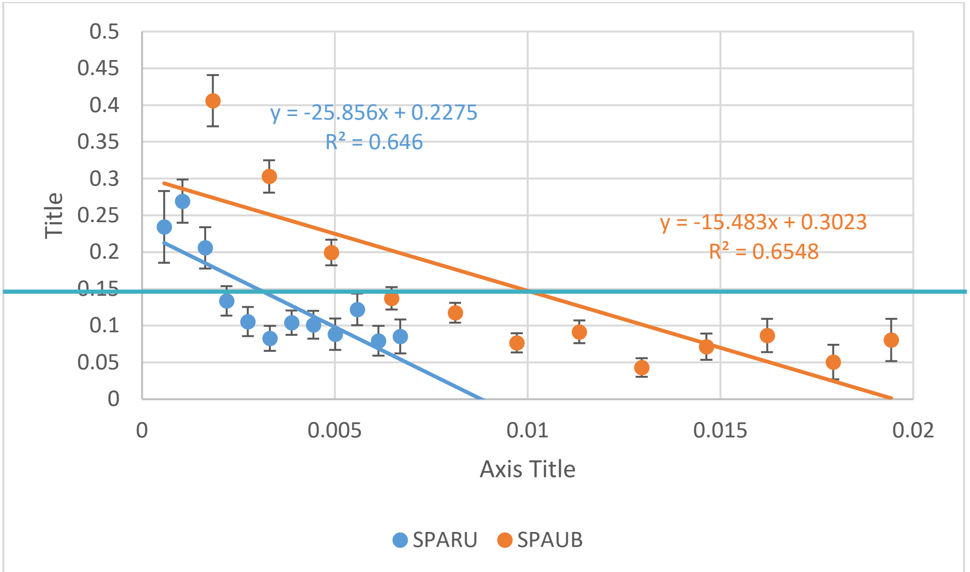

UKRU
J16 (N cm-3 s-1)
y = 0.0021x + 0.0077
R² = 0.4108
0.025
0.02
0.015
0.01
0.005
0
0
1
2
3
4
5
Gaseous ammonia (ppb)

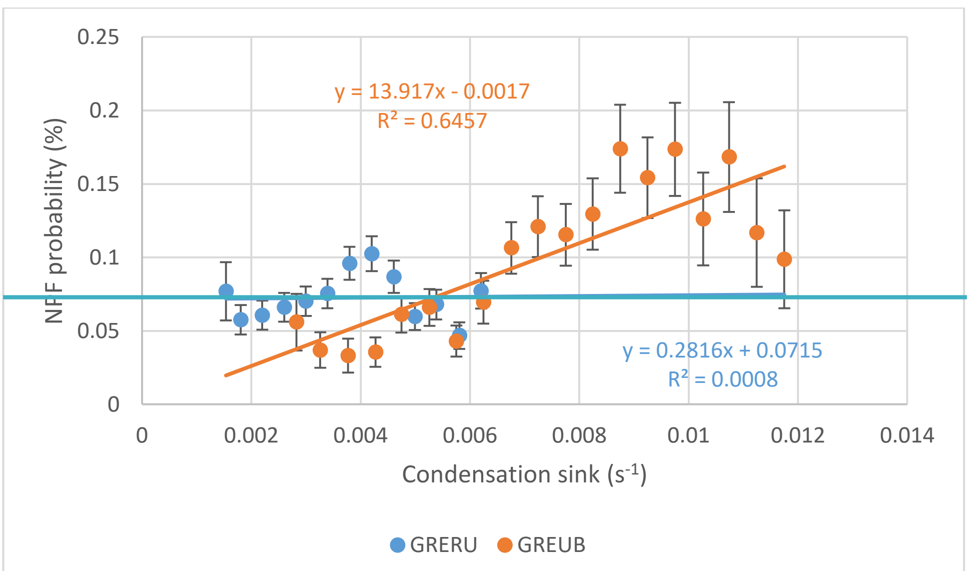

25%
20%
15%
10%
5%
0%
NPF probability (%)
y = -15.967x + 0.1287
R² = 0.7241
y = -11.628x + 0.1491
R² = 0.7843
y = -2.4565x + 0.1082
R² = 0.7534
0
0.01
0.02
0.03
0.04
0.05
Condensation sink (s-1)
UKRU
UKUB
UKRO

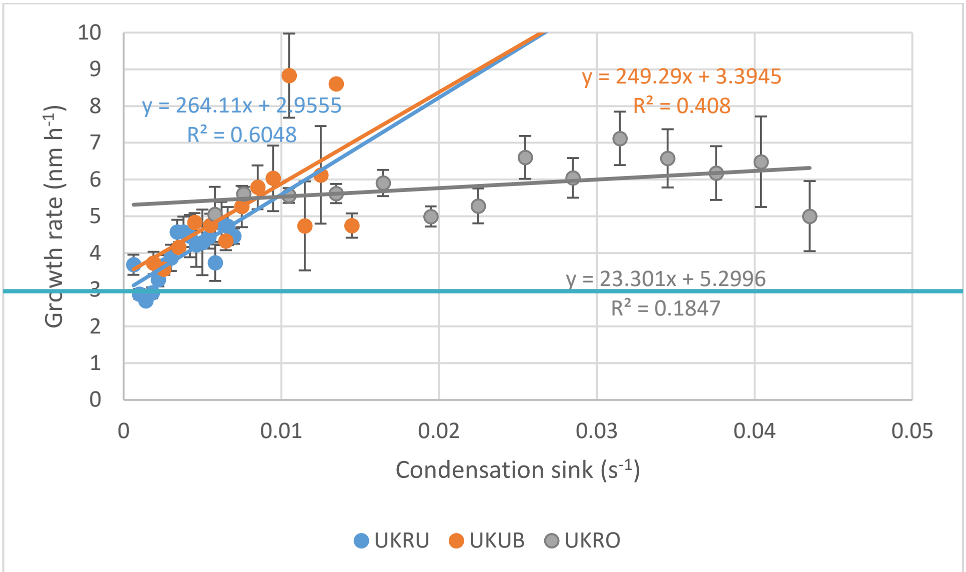

12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
y = -3.538x + 0.1061
R² = 0.9075
y = -2.1949x + 0.0869
R² = 0.7503
y = -0.5718x + 0.0742
R² = 0.7301
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Condensation sink (s-1)
DENRU
DENUB
DENRO

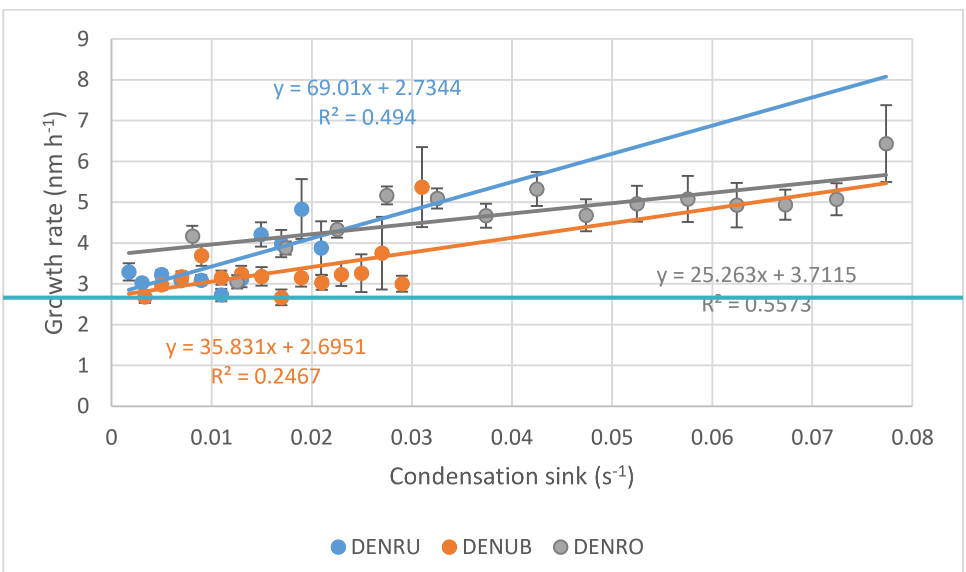

60%
50%
40%
30%
20%
10%
0%
NPF probability (%)
y = 26.28x + 0.0148
R² = 0.8635
y = 6.2811x + 0.1194
R² = 0.5572
y = 3.5017x + 0.0582
R² = 0.2246
0
0.005
0.01
0.015
0.02
0.025
Condensation sink (s-1)
GERRU
GERUB
GERRO

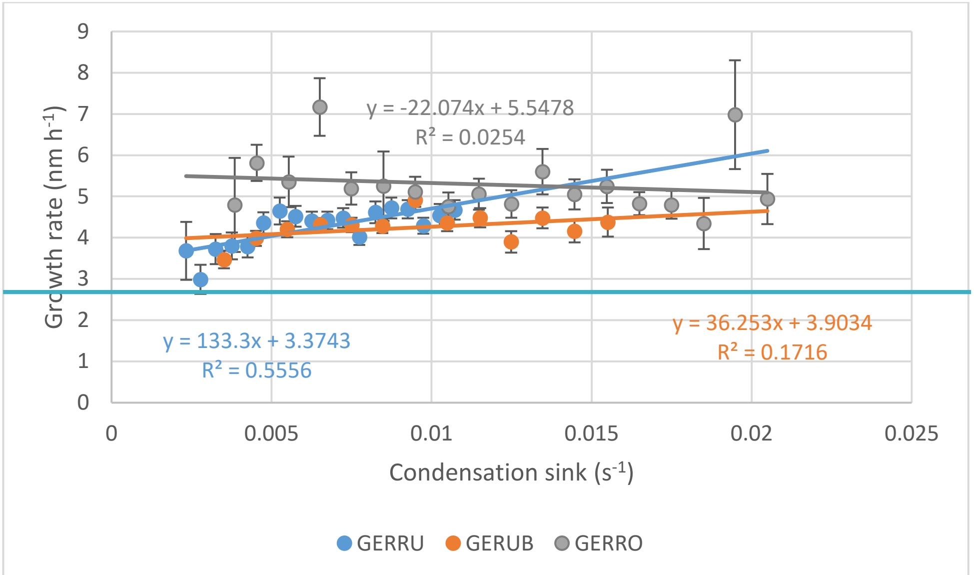

16%
14%
12%
10%
8%
6%
4%
2%
0%
NPF probability (%)
y = -15.587x + 0.1245
R² = 0.5937
y = -7.4998x + 0.0952
R² = 0.632
y = -3.5624x + 0.0867
R² = 0.7744
0
0.005
0.01
0.015
0.02
0.025
Condensation sink (s-1)
FINRU
FINUB
FINRO


0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Title
0
0.005
0.01
0.015
0.02
Axis Title
y = -25.856x + 0.2275
R² = 0.646
y = -15.483x + 0.3023
R² = 0.6548
SPARU
SPAUB

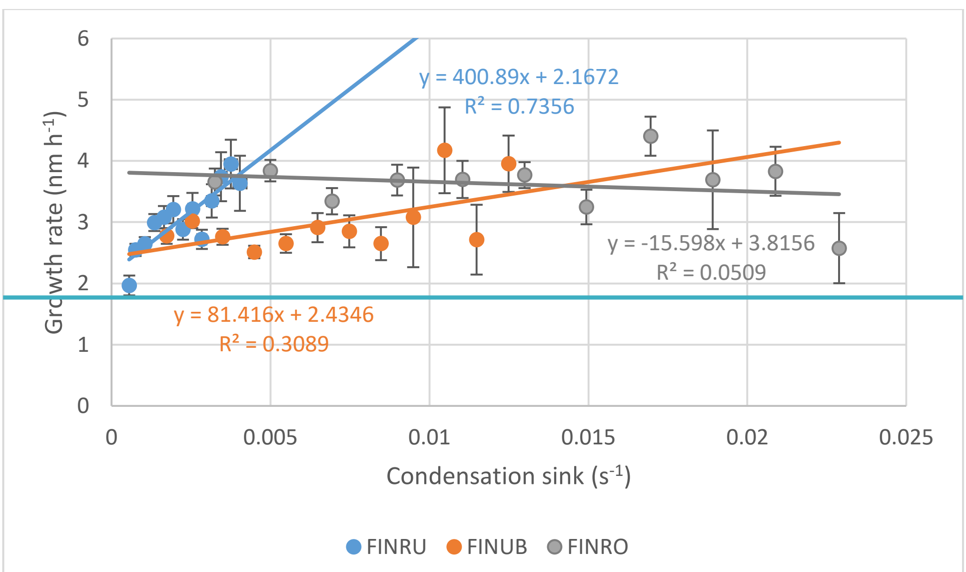

0.25
0.2
0.15
0.1
0.05
0
NFF probability (%)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Condensation sink (s-1)
y = 13.917x - 0.0017
R² = 0.6457
y = 0.2816x + 0.0715
R² = 0.0008
GRERU
GREUB


Growth rate (nm h-1)
Condensation sink (s-1)
y = 264.11x + 2.9555
R² = 0.6048
y = 249.29x + 3.3945
R² = 0.408
y = 23.301x + 5.2996
R² = 0.1847
0
1
2
3
4
5
6
7
8
9
10
0
0.01
0.02
0.03
0.04
0.05
UKRU
UKUB
UKRO

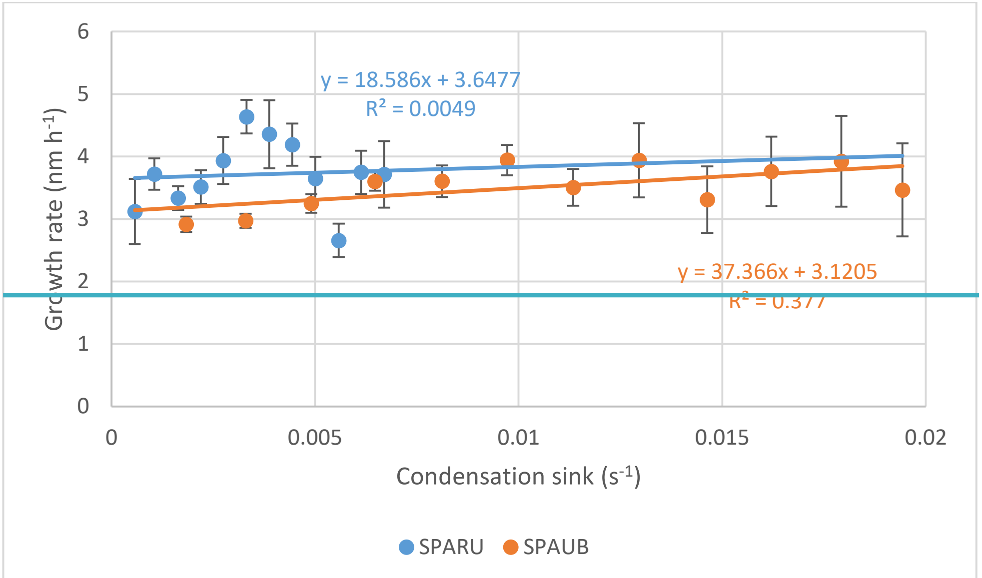

Growth rate (nm h-1)
Condensation sink (s-1)
y = 69.01x + 2.7344
R² = 0.494
y = 25.263x + 3.7115
y = 35.831x + 2.6951
R² = 0.2467
0
1
2
3
4
5
6
7
8
9
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
DENRU
DENUB
DENRO

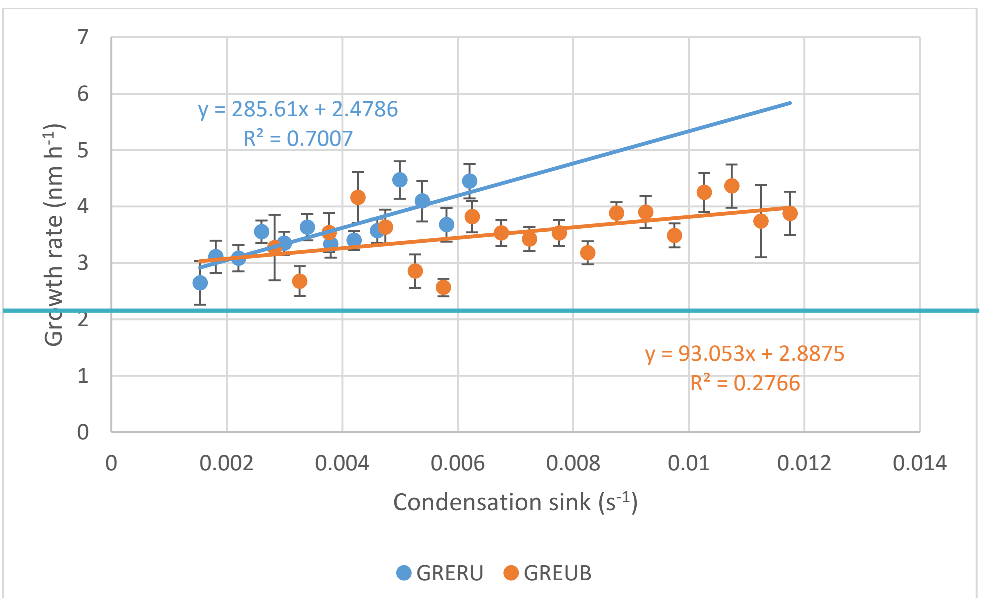


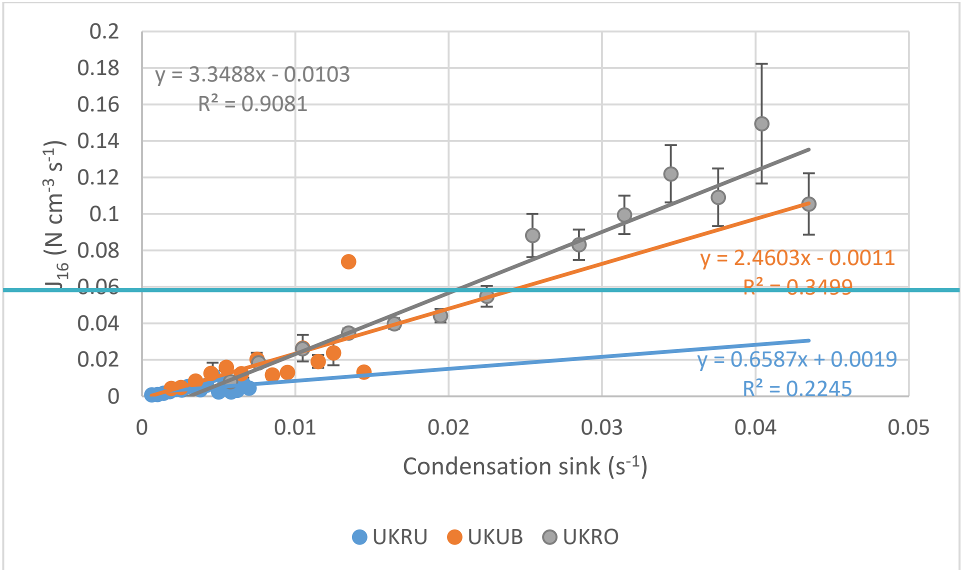
Growth rate (nm h-1)
Condensation sink (s-1)
y = -22.074x + 5.5478
R² = 0.0254
y = 133.3x + 3.3743
R² = 0.5556
y = 36.253x + 3.9034
R² = 0.1716
GERRU
GERUB
GERRO

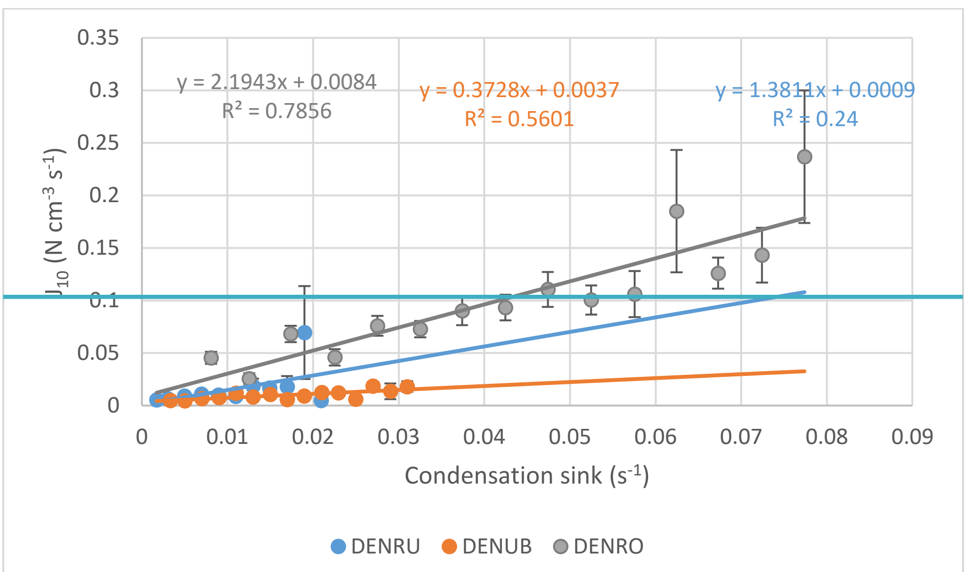


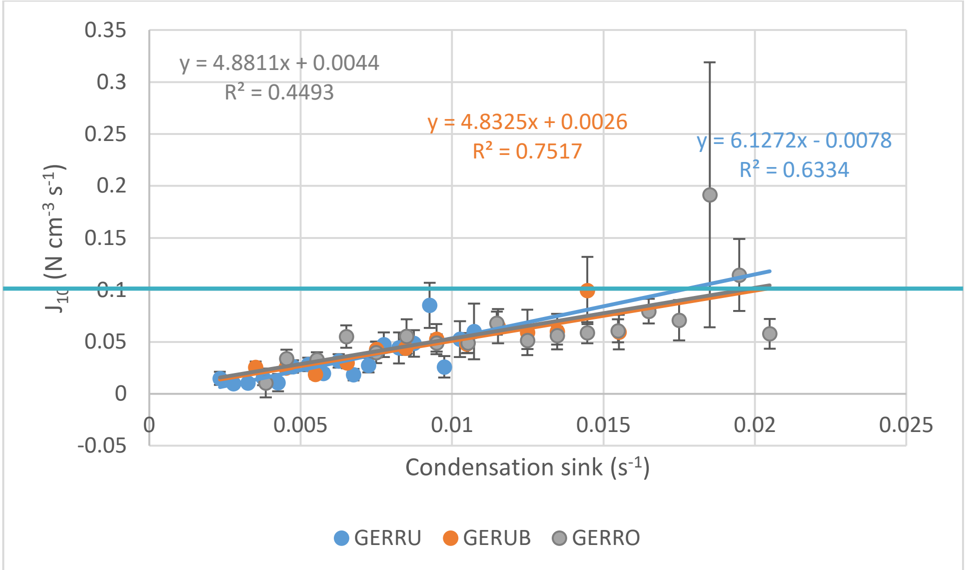
Growth rate (nm h-1)
Condensation sink (s-1)
y = 400.89x + 2.1672
R² = 0.7356
y = -15.598x + 3.8156
R² = 0.0509
y = 81.416x + 2.4346
R² = 0.3089
FINRU
FINUB
FINRO

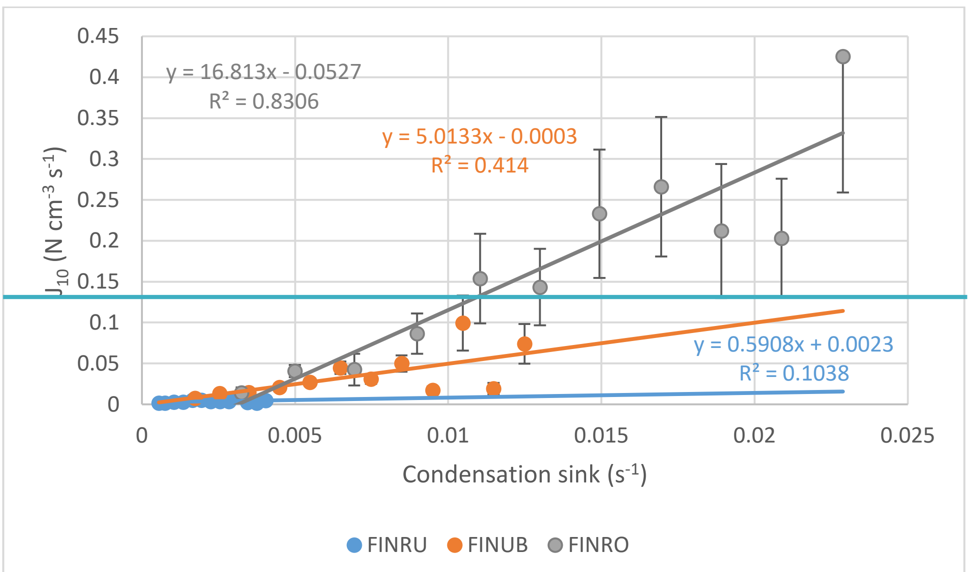

y = 18.586x + 3.6477
R² = 0.0049
y = 37.366x + 3.1205
R² = 0.377
Growth rate (nm h-1)
Condensation sink (s-1)
0
1
2
3
4
5
6
0
0.005
0.01
0.015
0.02
SPARU
SPAUB

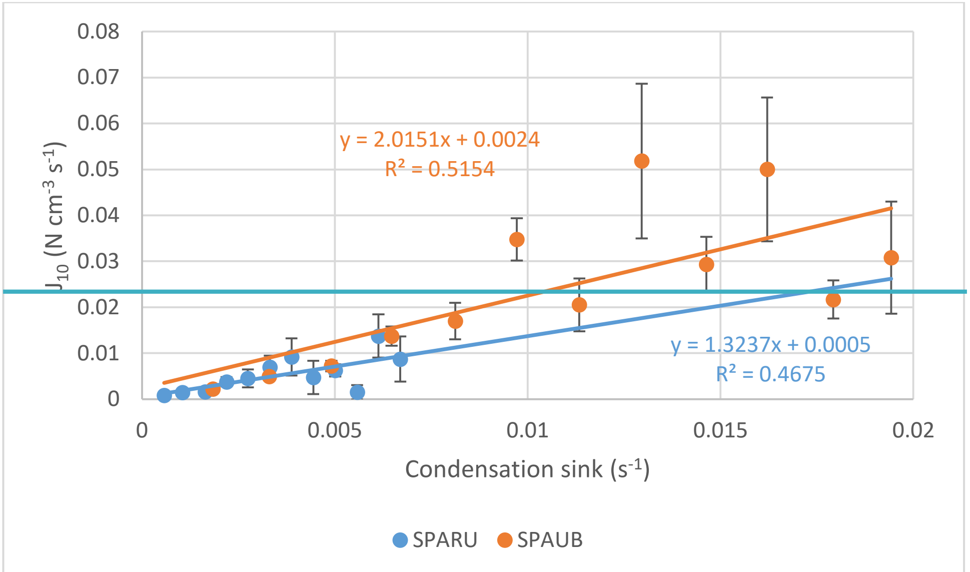

y = 285.61x + 2.4786
R² = 0.7007
y = 93.053x + 2.8875
R² = 0.2766
Growth rate (nm h-1)
Condensation sink (s-1)
0
1
2
3
4
5
6
7
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
GRERU
GREUB


y = 3.3488x - 0.0103
R² = 0.9081
y = 2.4603x - 0.0011
R² = 0.3499
y = 0.6587x + 0.0019
R² = 0.2245
J16 (N cm-3 s-1)
Condensation sink (s-1)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.01
0.02
0.03
0.04
0.05
UKRU
UKUB
UKRO


y = 2.1943x + 0.0084
R² = 0.7856
y = 0.3728x + 0.0037
R² = 0.5601
y = 1.3811x + 0.0009
R² = 0.24
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
DENRU
DENUB
DENRO


y = 4.8811x + 0.0044
R² = 0.4493
y = 4.8325x + 0.0026
R² = 0.7517
y = 6.1272x - 0.0078
R² = 0.6334
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
0.005
0.01
0.015
0.02
0.025
GERRU
GERUB
GERRO


y = 16.813x - 0.0527
R² = 0.8306
y = 5.0133x - 0.0003
R² = 0.414
y = 0.5908x + 0.0023
R² = 0.1038
J10 (N cm-3 s-1)
Condensation sink (s-1)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.005
0.01
0.015
0.02
0.025
FINRU
FINUB
FINRO


0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J10 (N cm-3 s-1)
y = 2.0151x + 0.0024
R² = 0.5154
y = 1.3237x + 0.0005
R² = 0.4675
0
0.005
0.01
0.015
0.02
Condensation sink (s-1)
SPARU
SPAUB

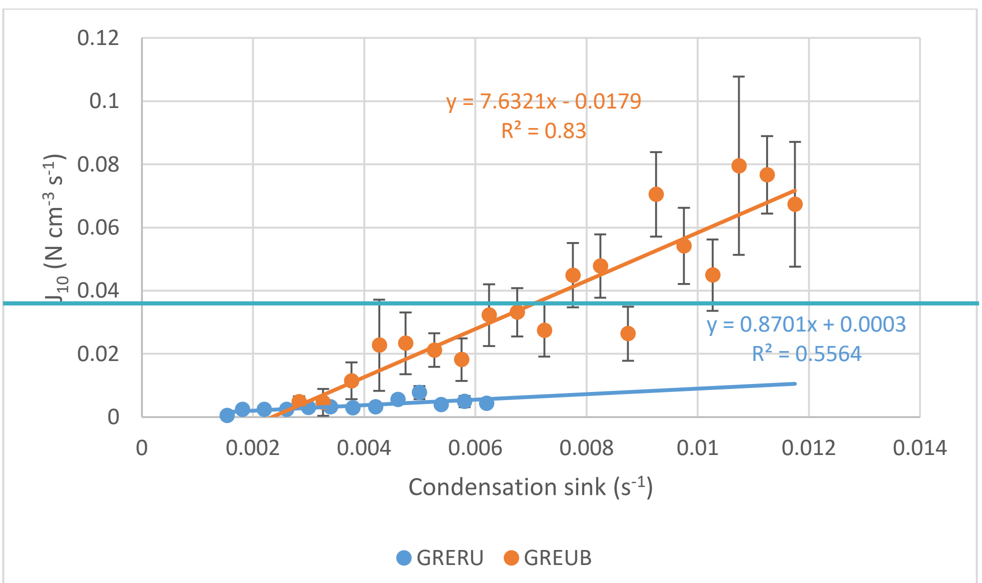

0.12
0.1
0.08
0.06
0.04
0.02
0
J10 (N cm-3 s-1)
y = 7.6321x - 0.0179
R² = 0.83
y = 0.8701x + 0.0003
R² = 0.5564
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Condensation sink (s-1)
GRERU
GREUB

Figure S2: ~~Relation of average temperature and normalised slopes a_N^* for all but the Finnish sites.~~