The reply to the anonymous referee #1 (RC1)

We are thankful to the referee for the detailed analysis of our study and for the constructive criticism. We agree with most of statements made by the referee and we took into account almost all of them while revising our paper.

Below, the actual comments of the referee are given in **`bold courier font and blue colour`**. The text added to the revised version of the manuscript is marked by red colour.

`The motivation of the study and the review of previous work is rather poor.`

We agree with the remark of the esteemed referee that the motivation is presented not enough clear. In the revised version of our manuscript, we restructured the introduction section and organised it as three subsections: Background, Motivation and Novelty. In these subsections we tried to specify all the reasons for doing the study on the LWP land-sea contrast. So, the new section describing motivation is the following:

1.2 Motivation

Primarily, the motivation for our efforts to investigate the LWP land-sea difference originated from our previous studies (Kostsov et al. 2018, 2019) which were devoted to the problem of validation of space-borne remote observations of cloud parameters by means of ground-based passive microwave remote sounding. In these studies microwave measurements were conducted over land but in a coastal area. It should be emphasized that ground-based microwave remote measurements of LWP are the most reliable and widely used tool for validation of observations of LWP from space, in particular by the instruments SEVIRI and AVHRR which measure reflected solar radiation (Roebeling et al., 2008ab; Greuell and Roebeling 2009). However, to the best of our knowledge, there were no validations of space-borne measurements over water areas and over water bodies covered by ice/snow. The importance of such validations arises from the fact that retrieval algorithms use a land-sea mask, and also they use a sea-ice and a snow mask. A misclassification in a mask can cause errors which propagate to higher-level products of the satellite observations. Such situation can occur in winter and during off-season. In winter, the LWP retrieval over highly reflective surfaces (snow and ice) becomes even more complicated problem (Musial et al., 2014), and, as a consequence, the retrieval errors can increase. The mechanism of the error amplification is described by Han et al. (1999) and Platnick et al. (2001): (1) multiple reflections occur between a cloud and underlying surface; (2) the increase in reflectance contributed by a cloud is relatively smaller in case of highly reflective underlying surface. The problem becomes more complicated due to the variability of the ice/snow properties. It has been noted by Platnick et al. (2001) that, as shown in a number of studies, the albedo of the sea ice is dependent on several factors, for example on the presence of air bubbles. Besides, if ice is covered with a snow layer greater than several centimetres the overall reflectance is dominated by this snow layer. Also, the melting process can cause the decreases in reflectance. The complexity of the problem of space-borne remote sensing of cloud parameters over different surfaces stimulated us to conceive the study in which the general features of the LWP land-sea contrast derived from satellite measurements could be summarised and analysed. In our opinion, the joint comprehensive analysis of the large LWP data sets derived from space-borne observations over various surfaces can be valuable for development of validation algorithms.

The importance of studying the LWP land-sea difference rather than the LWP values over land and water separately arises from the fact that inconsistency of data can be detected more easily in this way. The vivid example of detecting inconsistency in data by means of looking at the land-sea contrast of atmospheric parameter is an artefact in ozone column measurements by the TOMS (Total Ozone Mapping Spectrometer) instrument (Cuevas, 2001). Persistent year-to-year differences in total ozone between continents and oceans were found in the mean global ozone data which were averaged in time. This feature has been named GHOST (Global Hidden Ozone Structures from TOMS). Part of these differences appeared to be caused by truncation of the lower tropospheric column due to the topography and by permanent differences in tropopause height distribution. The remaining part (66%) has been found to be an artefact of the retrieval algorithm: the effects of the presence of UV-absorbing aerosols might have been accounted for not correctly. For examining the effect of each possible contribution to the observed difference, Cuevas (2001) selected the Iberian Peninsula region for a case study. The study by Cuevas (2001) was an encouraging example for us and additional stimulus to investigate common features of the LWP land-sea differences in Northern Europe with the aim to identify the natural effects and possible artefacts in measurements.

The second reason for making the present study was the lack of information on the LWP land-sea differences. Except the above mentioned works by Karlsson there were no special studies focused on the analysis of the LWP values over surfaces of various types in Northern Europe, in particular over land and water areas. Obviously, taking into account the diversity of properties of water bodies and the diversity of the features of local climate, we can expect that the LWP land-sea differences are highly variable in space and time. So far, not enough attention was paid to this interesting issue. In our view, this issue is important for development of regional weather and climate models from the perspective of more accurate simulations over water bodies and in neighbouring areas. As an example, the ICON model can be mentioned which has a special option for weather and climate simulations over lakes (ICON, 2021; ICON Tutorial, 2021).

The third motive to initiate the present study was the fact that so far not much attention was paid to the investigation of physical mechanisms which drive the LWP land-sea differences in Northern Europe. The reason for the differences in spring and summer has been suggested by Karlsson (2003): the inflow of cold water from melting snow and ice is cooling the near-surface atmospheric layer over the water bodies. As a result, in contrast to the land surface, this layer over the water bodies becomes very stable preventing the formation of clouds. This mechanism, however, does not explain the existence of the LWP land-sea difference during cold season when both land and water surfaces are covered with snow and ice. We would like to mention one more mechanism which has been suggested by an expert during an open discussion of the preprint of the present article (https://doi.org/10.5194/acp-2021-387-RC1, last access 29 March 2022):

‘In addition, during winter/spring, (dark) forest areas can absorb considerably more solar radiation than surrounding snow-covered ground or ice-covered water surfaces. This can also lead to updrafts and eventually cloud formation.’

The sea breeze mechanism should be mentioned also. Indeed, strong sea breeze fronts initiate vertical currents that are usually marked by the development of cumulus clouds. The detailed review of recent studies of the sea breeze features can be found in the paper by Miller et al. (2003). However the sea breeze mechanism is not able to fully explain the diversity of land-ocean contrasts presented in our work. Indeed, the sea breeze can be the reason for the development of convective cloudiness in the frontal zone, with an inland penetration up to several tens of kilometers. But the results presented in our work demonstrate the systematic suppression of cloudiness over water bodies, with a relatively uniform distribution of cloudiness over the land surface, regardless of the distance from the coastline (see the map in Fig. 2, for example). The sea breeze phenomena certainly can complement another physical mechanism proposed by Karlsson (2003) and already mentioned above. However, both of these mechanisms – the sea breeze circulation and the influx of melt water – cannot explain the existence of the land-ocean contrasts during the cold season, when both land and water surfaces are covered with snow and ice.

In our opinion, the necessary prerequisite for identifying the prevailing physical mechanisms which drive the LWP land-sea differences in Northern Europe is the special detailed statistical analysis of the LWP data provided by the satellite instruments over various water bodies and over land near these water bodies during different seasons. In the present work we make a kind of such analysis.

Added references:

Cuevas, E., Gil, M., Rodriguez, J., Navarro, M., and Hoinka, K.P.: Sea-land total ozone differences from TOMS: GHOST effect, Journal of Geophysical Research, 106 (D21), 27745-27755, https://doi.org/10.1029/2001JD900246, 2001.

Miller, S.T.K., Keim, B.D., Talbot, R.W., Mao, H.: Sea breeze: Structure, forecasting, and impacts, Reviews of Geophysics, 41(3), https://doi.org/10.1029/2003RG000124, 2003.

An introduction into typical land-sea contrasts of clouds, wind and temperature and related studies would be necessary in the introduction.

We do not agree with the statement of the referee that the review of previous work is poor. There is not much information on the LWP land-sea differences in Northern Europe. Except the mentioned works by Karlsson there were no special studies focused on the analysis of the LWP values over surfaces of various types in Northern Europe, in particular over land and water areas. We agree to point that presenting typical land-sea contrasts of cloud parameters and meteorological parameters would be useful for a reader, but such information is absent. Moreover, let's not forget about the variety of water bodies and about the variety of orographic features and local climate of neighbouring land. How can we talk about "typical" values for all diverse cases? And there is one more argument: in fact, to reveal typical features of the LWP land-sea contrast in Northern Europe is exactly the goal of our study.

To me, the word "gradient" does not describe what you are analyzing. A gradient is the change of a quantity over a distance. In this case it would be LWP m^{-1} > hence the unit would have to be kg m^{-2} m^{-1} = kg m^{-3}. This would not be very useful, therefore I suggest to change the wording to "LWP difference". Also, your direction of the gradient is wrong. If you call it "Land-Sea gradient" your values would have to be negative.

In our preliminary short answer to the referee we have already written that the referee is perfectly right in his/her statement that we used the term "gradient" not in its rigorous meaning. Indeed, we investigated two types of the LWP land-sea difference which we called "short distance gradient" and "long distance gradient". This quantities in fact should have had the dimension kg m^{-2}/(20 km) and kg m^{-2}/(80 km). We omitted the denominators for simplicity, in order not to repeat them multiple times. We agree that it was not a good decision. In the revised version of our paper we do not use the term "gradient". Instead, we use the terms "difference" and "contrast". The latter one seems to be a good choice since the referee used the term "contrast" himself/herself.

Also, the use of the rigorous term "difference" (or "contrast") helps to avoid ambiguity with the sign of the quantity which is investigated. In the revised version of the paper we define it by Eq.(2) of the manuscript in the following way

$$d = W_{land} - W_{sea}, \qquad (2)$$

where W is the liquid water path value measured in the pixels selected over the land and water areas (as indicated by subscripts).

As a result, the land-sea contrast is expected to be positive, except the abnormal situations.

The limitation to 7 years of data is probably due to large amount of data. However, SEVIRI data are available for the time back to 2004/05. Why didn't you include some years before 2011?

Yes, the referee's guess about the large amount of data is correct, it was the first reason. And the second reason for starting with 2011 data was our plans for future research: in a separate study we planned to make comparisons of the LWP land-sea contrast derived from SEVIRI observations with the ground-based data from the HATPRO microwave instrument which started operation only in 2012.

Trends over 7 years have no statistical significance (e.g. Fig. 9). Excluding just the last year (2017) would already show completely different trends. By using a larger dataset (e.g. 2005-2020) you could test your hypothesis. I can imagine that single outliers can be caused by a dry/wet summer (low/high soil moisture), more or less sea-ice/snow cover, or windy conditions (sea/lake

temperatures are less stratified). Therefore, you have to show more proof for your "most important finding" (p.16, l. 474ff and p. 17, l. 515ff) . In the current version, to me there is no proof that another selection of years would not produce totally different trends.

When we made our study, the most recent version of SEVIRI data was available for 2017 and earlier years. We could not use the data provided by an older version of processing algorithm since the algorithm is constantly improved. At present (March 2022), when preparing the revised version of our paper we have no possibility to extend the data set for analysis due to the case of force majeure: the collaboration between Russian and German scientists is suspended because of current unprecedented tense political situation in the world. It is important to emphasize that our study is the result of collaborative work.

We agree, that our "most important finding" needs more convincing proof. Taking into account the very limited number of data points for multi-year trend analysis, in the revised version we are applying the Fisher criterion for estimating the significance of the linear regression for different locations and seasons. We removed Fig. 9 and added two tables instead, which present the characteristics used for the Fisher criterion. The new part of the Section 3 is the following:

Figs. 7 and 8 provide some indication of a positive temporal trend of the LWP land-sea contrast for several locations. Taking into account the very limited number of data points (only seven) available for multi-year trend analysis, we are applying the Fisher criterion for estimating the statistical significance of the linear regression for different locations and seasons. The algorithm of assessment of statistical significance was taken from the book by Bolshakov (1965). In order to estimate a robustness of a correlation coefficient for a number of data points less than 50 one can use the following function:

$$z = \frac{1}{2}\left[\mathbf{ln}(1+r) - \mathbf{ln}(1-r)\right] \qquad (3)$$

where r is a correlation coefficient. The values of z are normally distributed with the standard deviation:

$$\sigma_z = \frac{1}{\sqrt{n-3}} \qquad (4)$$

where n is the number of data points. In our case n=7 and so σ_z=0.5. For given value of r we calculate the corresponding value of z. Then we obtain the values of the correlation coefficient which correspond to the values $z-\sigma_z$ and $z+\sigma_z$ using the inversion of Eq. 3:

$$r_1 = \frac{\mathbf{exp}(2(z-\sigma_z))-1}{\mathbf{exp}(2(z-\sigma_z))+1} \qquad (5a)$$

$$r_2 = \frac{\mathbf{exp}(2(z+\sigma_z))-1}{\mathbf{exp}(2(z+\sigma_z))+1} \qquad (5b)$$

In such a way we obtain the limits of uncertainty of the correlation coefficient:

$$r_1 \le r \le r_2 \qquad (6)$$

The linear trend can be considered as statistically significant if the following relation is satisfied:

$$|r| \ge 3\sigma_r \qquad (7)$$

It was shown by Dlin (1958) that the lower limit of the correlation coefficient which satisfies Eq. 7 depends on the number of data points and can be calculated as follows:

$$r_{\mathbf{min}} = \frac{\sqrt{n+36}-\sqrt{n}}{6} \qquad (8)$$

In our case $r_{\min}$=0.65. Finally, comparing r_1 and $r_{\min}$ we can find out whether the linear trend is statistically significant:

$$\begin{aligned} r_1 &\ge r_{\mathbf{min}} \qquad significant \\ r_1 &< r_{\mathbf{min}} \qquad not \;\; significant \end{aligned} \qquad (9)$$

The relations (9) are valid for positive correlation coefficient r_1. For negative r_1, the minimal absolute value among r_1 and r_2 should be taken.

Tables 3 and 4 present the results of calculations of correlation coefficients for data pairs “time – LWP contrast” plotted in Figs. 7 and 8 for different locations and seasons. Also, other parameters relevant to assessment of statistical significance of linear trends are given. One can see that for all water bodies except Lake Ladoga the correlation coefficients are positive for both cold and warm seasons. However, there are only four cases which demonstrate robust statistical significance of the linear trend. For cold season, the significant trend is observed for Lake Onega (long-distance LWP difference) and for Lake Ilmen. For warm season, the significant trend is observed for Gulf of Riga (long-distance LWP difference) and for the Neva River Bay. These statistically significant trends are characterised by the following growth rates of the LWP contrast: 0.0064 kg m^{-2} yr^{-1} (Lake Onega), 0.0072 kg m^{-2} yr^{-1} (Lake Ilmen), 0.0014 kg m^{-2} yr^{-1} (Gulf of Riga), 0.0026 kg m^{-2} yr^{-1} (The Neva River Bay). The rates are larger for cold season. The detected growth rates require confirmation on the basis of expanded datasets. For the time being, no general conclusions could be made.

Table 3. Parameters (r, r_1, r_2, r_{min}) used for assessment of statistical significance (signif.: *yes* or *no*) of linear temporal trend of the LWP land-sea contrast for various locations. Cold season.

Water body	Data set	Cold season				
		r	r_1	r_2	r_{min}	Is trend significant?
1. Gulf of Riga	ML1-1	0.52	0.08	0.79	0.65	no
	ML1-2	0.32	-0.16	0.68		no
2. Gulf of Finland	ML2-1	0.32	-0.16	0.68		no
	ML2-2	0.53	0.09	0.80		no
3. Lake Ladoga	ML3-1	-0.10	-0.54	0.38		no
	ML3-2	0.56	0.13	0.81		no
4. Lake Onega	**ML4-1**	**0.90**	**0.74**	**0.96**		**yes**
	ML4-2	0.84	0.62	0.94		no
5. Lake Peipus	ML5	0.64	0.25	0.85		no
6. Lake Pihkva	ML6	0.43	-0.04	0.75		no
7. Lake Ilmen	**ML7**	**0.90**	**0.75**	**0.96**		**yes**
8. Lake Saimaa	ML8	0.31	-0.18	0.68		no
9. The Neva River bay	ML9	0.33	-0.16	0.69		no

Table 4. The same as Table 3 but for warm season.

Water body	Data set	Warm season				
		r	r_1	r_2	r_{min}	Is trend significant?
1. Gulf of Riga	**ML1-1**	**0.92**	**0.79**	**0.97**	0.65	**yes**
	ML1-2	0.69	0.33	0.87		no
2. Gulf of Finland	ML2-1	0.55	0.12	0.81		no
	ML2-2	0.30	-0.19	0.67		no
3. Lake Ladoga	ML3-1	0.73	0.40	0.89		no
	ML3-2	-0.46	-0.76	0.01		no
4. Lake Onega	ML4-1	0.38	-0.10	0.71		no
	ML4-2	0.02	-0.45	0.48		no
5. Lake Peipus	ML5	0.53	0.08	0.79		no
6. Lake Pihkva	ML6	0.45	-0.02	0.75		no
7. Lake Ilmen	ML7	0.61	0.20	0.84		no
8. Lake Saimaa	ML8	0.65	0.27	0.86		no
9. The Neva River bay	ML9	**0.92**	**0.79**	**0.97**		**yes**

Two references have been added accordingly:

> Bolshakov, V.D., Theory of observational errors with basics of probability theory. “Nedra” Publishing, Moscow, 184 P., 1965, (in Russian).
>
> Dlin, A.M., Mathematical statistics in engineering, “Sovetskaya nauka” Publishing, Moscow, 1958, (in Russian).

Taking into account the results of the assessment of the statistical significance of detected trends, we reworded item 3) of the conclusion:

3) The interesting finding is the positive trend of the LWP contrast during 2011-2017 for all considered measurement locations and for both cold and warm seasons with only one exception: Lake Ladoga. Despite the very limited number of data points, the statistical significance of positive linear trends has been confirmed for Lake Onega and Lake Ilmen (cold season) and for Gulf of Riga and the Neva River bay (warm season). These statistically significant trends are characterised by the following growth rates of the LWP contrast: 0.0064 kg m^{-2} yr^{-1} (Lake Onega), 0.0072 kg m^{-2} yr^{-1} (Lake Ilmen), 0.0014 kg m^{-2} yr^{-1} (Gulf of Riga), 0.0026 kg m^{-2} yr^{-1} (The Neva River Bay). The rates are larger for cold season. However, the obtained results require confirmation on the basis of extended data sets before any general conclusions could be made.

We also reworded the last phrases of the paper. The revised text is the following:

> Nevertheless, to our opinion, the most interesting findings of the present work are the positive long-term (7-year) trend of the magnitude of the LWP land-sea contrast (statistically significant for four measurement locations) and the so-called “August anomaly”: the absence of the LWP difference in August if compared to June and July. It should be emphasised that this "August anomaly" is strictly limited to Gulf of Finland.

Accordingly, we changed the text in the abstract:

> The interesting finding is the positive trend of the land-sea LWP difference detected within the time period 2011-2017 which appeared to be statistically significant for four water bodies (lakes Onega and Ilmen, Gulf of Riga and the Neva River bay).

For the comparison with reanalysis data, I wonder whether the model grid boxes that you chose are really fully placed over sea or land, respectively? In addition, the effective resolution of processes in an atmospheric model is always coarser than the nominal grid spacing.

Spatial resolution of the reanalysis data is already discussed in detail in Section 6, second paragraph:
"In the present study we consider the ERA-Interim and Era5 reanalyses…"
Position of grid points is shown in Fig. 17. In order to avoid a situation when a reader can be misled, we explicitly indicate in caption and in the text that grid points Fig. 17 are relevant to Era5. We also make a note in the text that grid boxes of Era5 have been selected in a way to be fully placed over sea or land:

> It should be noted that grid boxes of Era5 have been selected in a way to be fully placed over sea or land. It was possible since long distance LWP differences are considered.

And we mention that for Era Interim, due to coarser original spatial resolution, the original grid boxes (before interpolation to 28km-grid) can contain a small portion of the "wrong" surface: sea for a land grid box and land for a sea grid box:

> One should keep in mind that for Era Interim, due to coarser original spatial resolution, the original grid boxes (before interpolation to 28km-grid) can contain a small portion of the "wrong" surface: sea for a land grid box and land for a sea grid box.

Also, we placed a scale (100 km bar) in Fig. 17 and added the information to axes:

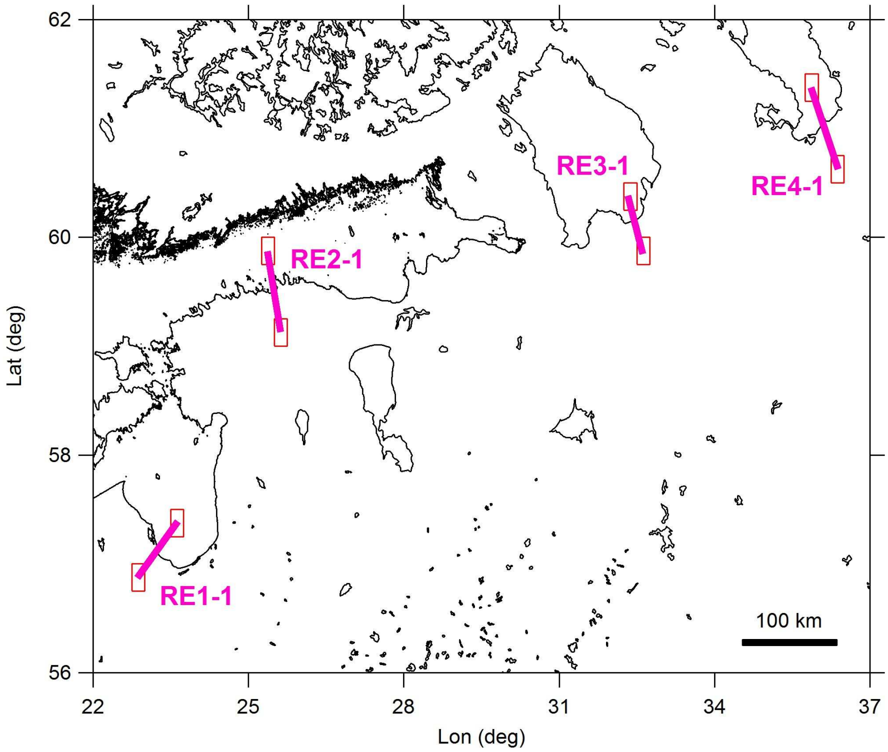


Figure 17: The map showing the geographical location of the Era5 reanalysis grid points used for the calculations of the LWP land-sea contrast. Vector shoreline data: (GSHHG, 2017).

I would consider analysing more surface variables for specific days, such as air temperature at some coastal stations, sea surface temperature, diurnal wind patterns (sea breeze), etc. With that, your hypotheses, such as the "August anomaly" could be strongly improved.

We are thankful to the referee for this insightful comment. Indeed, the "August anomaly" was quite unexpected phenomenon which required explanation. When we made the present study and revealed this feature we made some attempts to investigate it in more detail. However, it appeared that these activities required separate quite large amount of efforts, in particular the efforts to analyse surface variables, as the esteemed referee suggests. Such work seemed to go beyond the scope of the present study. Therefore, we decided to limit our efforts by several model runs to have the impression how the LWP land-sea contrasts are reproduced. But there was also another reason to postpone the analysis of surface variables. After completing the present study, we intensively worked on the problem of assessment of the LWP land-sea contrast by ground-based spectral-angular microwave observations at the coastline of the Neva River bay. There was a hope that this work could provide a direct proof of this feature and give a new big stimulus for detailed investigation of the observed effects, in particular "August anomaly" which was observed by the SEVIRI instrument at this location also. Now this work is completed and the preprint has been published in Atmospheric Measurement Techniques Discussions:

Kostsov, V., Ionov, D., and Kniffka, A.: Retrieval of the land-sea contrast of cloud liquid water path by applying a physical inversion algorithm to combined zenith and off-zenith ground-based microwave measurements, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-415, in review, 2022.

The effect of "August anomaly" was not confirmed by the ground-based observations. Therefore, at present we are coming round to the opinion that "August anomaly" can be an artefact of the SEVIRI measurements. The argument in favour of this hypothesis is, first, the immediacy of the transition from large contrast to zero contrast and, second, the fact that this transition occurs exactly in the beginning of August at all examined locations in the Gulf of Finland. In the end of Section 4 we added some speculations about this possible reason of the anomaly:

> The revealed effect can be called "August anomaly". The similarity of results obtained for different locations in the Baltic Sea can lead to the conclusion about possible common physical mechanisms that drive the LWP land-sea difference in the entire Baltic Sea region considered in the present study. In order to explain this effect one can suggest collecting and analysing sets of surface variables, such as air temperature at some coastal stations, sea surface temperature, diurnal wind patterns (sea breeze), etc. However, such data search and analysis seem to form separate quite large research activity which goes beyond the scope of the present study. Therefore, in the present study we limit our efforts by several model runs to have the impression how the LWP land-sea contrasts are reproduced (see Section 7 below).
>
> One more important notice should be made. While the preprint of the present article was in review during an open discussion phase after submission to the journal "Atmospheric Chemistry and Physics", we intensively worked on the problem of assessment of the LWP land-sea contrast by ground-based spectral-angular microwave observations at the coastline of the Neva River bay. In this separate work, the physical inversion algorithm was used for processing ground-based measurements. Earlier, we used the regression algorithm (Kostsov et al., 2020). Subsequently, the physical inversion algorithm was selected as more accurate, if compared to regression approach, and the most suitable for error estimation and quality control. There was a hope that this work and new more accurate results could provide a direct independent proof of "August anomaly" which was clearly observed by the SEVIRI instrument at the location of ground-based microwave measurements (the Neva River bay). Now this work is completed and the preprint has been published in Atmospheric Measurement Techniques Discussions (Kostsov et al., 2022). The effect of "August anomaly" was not confirmed by the ground-based observations. Therefore, at present we

are coming round to the opinion that “August anomaly” can be an artefact of the SEVIRI measurements. The arguments in favour of this hypothesis are, first, the immediacy of the transition from large LWP contrast to very low contrast (just within a couple of days) and, second, the fact that this transition occurs exactly in the beginning of August at all examined locations in the Gulf of Finland. It is unlikely that natural meteorological processes change so sharply and synchronically at different places in the Baltic Sea. So, we assume that “August anomaly” can be an artefact which reflects certain algorithmic features in the SEVIRI data. If this hypothesis were confirmed, then we would have the situation similar to situation with the TOMS instrument described in the Introduction section when the observed features of the land-sea difference in total ozone turned out to be an artefact and helped to identify an error and to correct a data processing algorithm.

The number of figures should be reduced, or more figures should be combined to one large figure (e.g. Figs. 4-6).

Following the advice of the referee we combined Figs. 4-6 to one figure which shows only typical distributions of the LWP land-sea contrast:

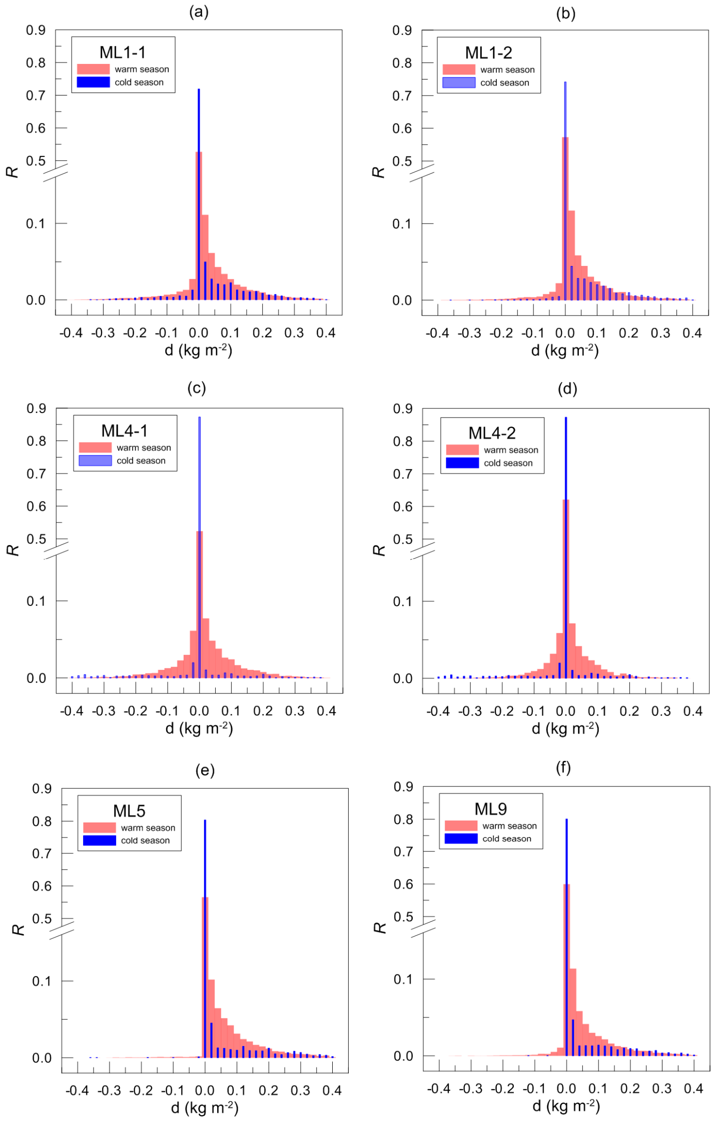


Figure 4: Typical statistical distributions (in terms of relative frequency of occurrence R) of the LWP land-sea contrast values for different measurement locations and seasons. Please note that for better visibility the vertical axes are broken and have different scaling in the lower and upper part.

The text which describes the distributions has been changed accordingly.

Fig. 9 has been removed. Instead, the results of the assessment of statistical significance of trends have been added (already described above).

Figs. 10 and 11 have been combined in one Fig. 7, only typical cases are demonstrated now:

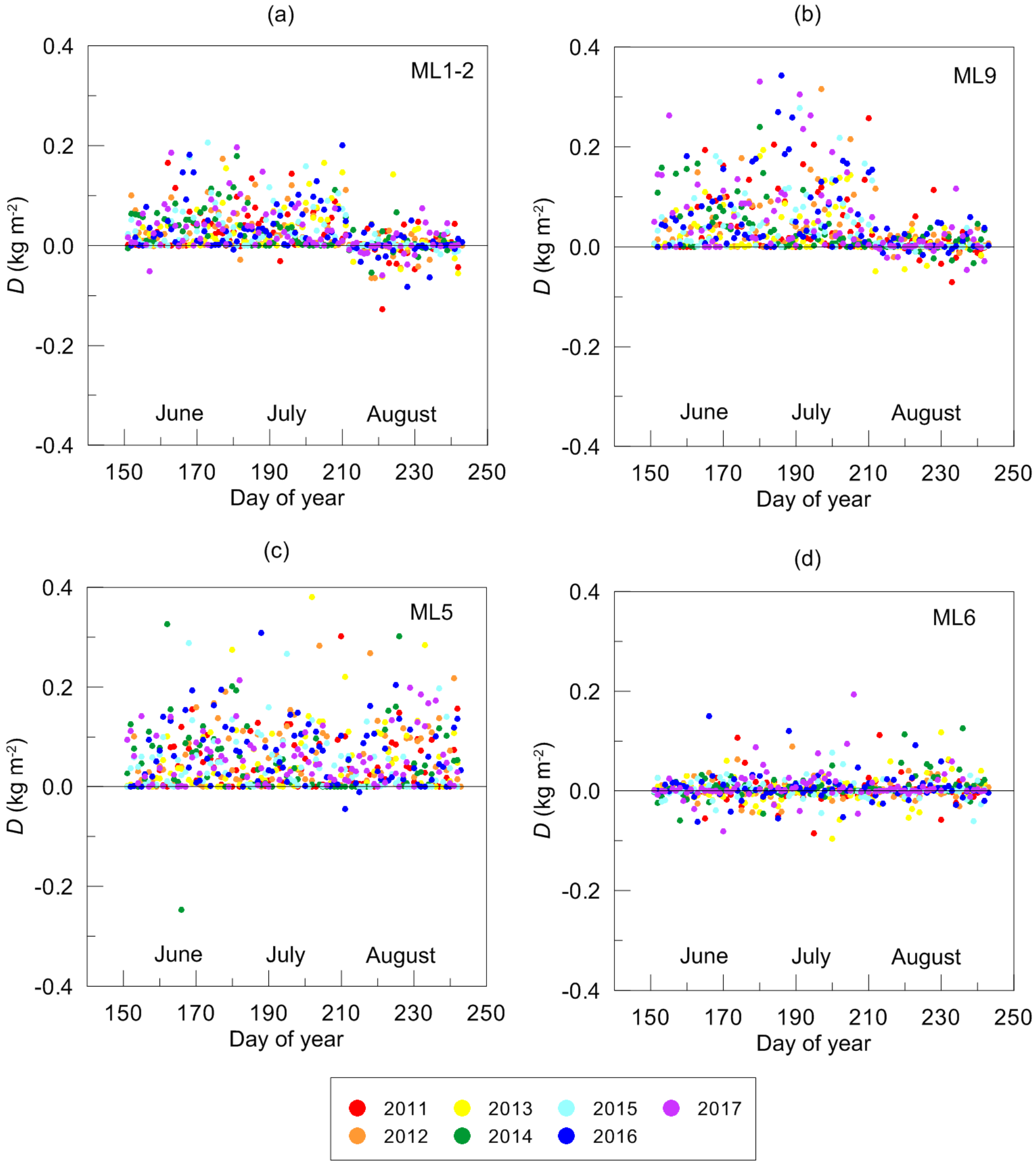


Figure 7: Intra-seasonal variability of the daily-mean LWP land-sea contrast for measurement locations ML1-2, ML2-2, and ML9 (warm season, seven years of observations – see the legend).

The text has been changed accordingly.

We removed Fig. 15 where diurnal features of the LWP contrast are similar to features presented in Fig. 14 and mentioned in the text that the only one exception from common behaviour is the location ML13 in August.

Finally, we managed to decrease the number of Figures by 5: from 23 to 18.

Please provide scales to your maps (esp. Fig. 17)

In the revised version the scales (100 km bars) are provided in all figures with maps with only few exceptions for the maps generated by the ICON model on the latitude-longitude grid with equal steps in degrees. In these maps, distance between objects may be slightly distorted which does not influence the quality of demonstration of the results.

Specific comments:

p.3, l. 78: In addition, during winter/spring, (dark) forest areas can absorb considerably more solar radiation than surrounding snow-covered ground or ice-covered water surfaces. This can also lead to updrafts and eventually cloud formation.

We are thankful to the referee for this remark and we included it in the text:

> Also, we would like to mention one more mechanism which has been suggested by an expert during an open discussion of the preprint of the present article (https://doi.org/10.5194/acp-2021-387-RC1, last access 29 March 2022):
>
> > *'In addition, during winter/spring, (dark) forest areas can absorb considerably more solar radiation than surrounding snow-covered ground or ice-covered water surfaces. This can also lead to updrafts and eventually cloud formation.'*

p.4, l. 121-122: What do you mean by "simultaneously and not simultaneously"? Do you want to say "cases where both land and water or any of them are clear sky"?

Yes, exactly. We corrected the text in the following way:

> The data selected for analysis include all clear sky cases where both land and water or any of them are clear sky.

p.10, l. 281 ff: Which time zone did you use for "local time"? UTC+2? If so, please mention it here!

We are grateful to the referee for this remark. Indeed, we missed to clarify the important issue about time that we used. We added the following information in the beginning of Section 5 (diurnal features):

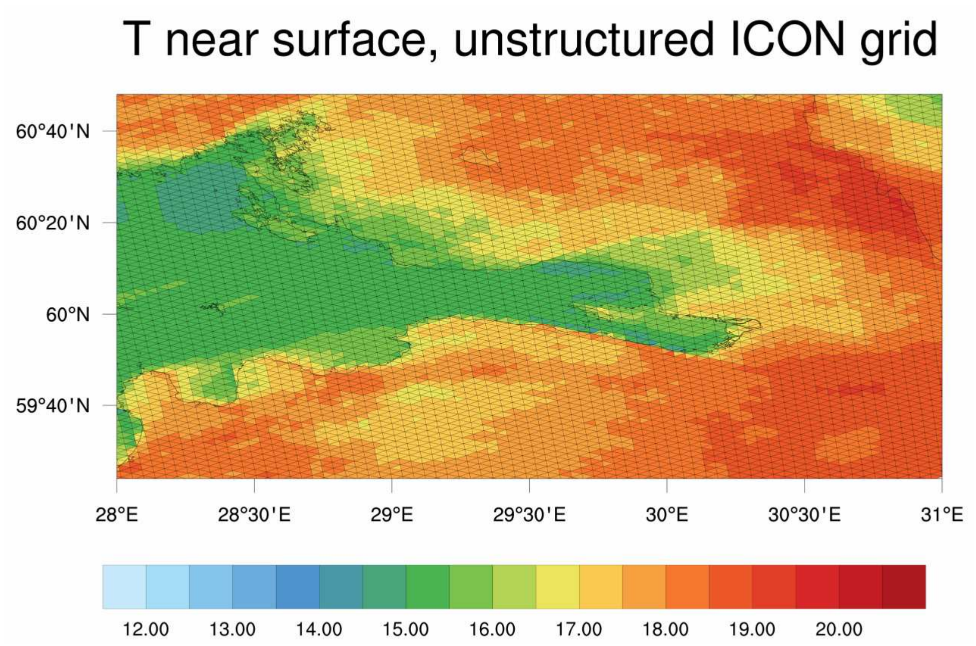
> It is important to note that for each location the time of SEVIRI measurements was converted to local solar time using geographical longitude. It means that for each location the 12 h moment on the time scale exactly corresponds to local noon.

p. 13, l. 380 ff: I am missing some information about the setup of the ICON-LEM model: What is the resolution? Which initial profiles did you use? What is happening at the domain boundaries?

We added this information to Section 7:

> For each single day, ICON was running with a global setting and a refined nest over the study region with the horizontal resolution of about 2.5 km and triangular grid. The study region is shown in Fig. 15b. A border zone of about 30 km of the study region was excluded from the analysis since it was used as a nudging zone for the lateral boundary data. These data are needed to force the large scale flow on the limited aread grid once per hour and are stored as global fields. The reliable input data for modelling were taken from archives which were available for 2015 and later. Modelling of a single day required processing of about 130 Gbyte of input data. The high resolution limited area mode which we used for simulations is not suitable for climate time scale studies, therefore we simulated single days only.

In order just to give the impression about the resolution, in the plot below we present the temperature of the lowest model level on the original triangular grid:



Since the article is already nearly overloaded with plots, we did not add this figure in the revised version.

Table 1: What's the percentage of days which were used for the analysis? Is there a significant inter-annual difference?

We are grateful to the referee for the advice to check the percentage of days used for the analysis. Indeed, it should be done in order to identify possible data gaps which may influence the results of the analysis. We calculated for each month the percentage of days which were used for the analysis. The results are presented below in two Tables for warm and cold seasons:

Table Percentage1. The percentage of days which were used for the analysis. Calculations for each month. Warm season. Data sets (locations) ML1-ML9.

Data set / Month	ML1-1	ML1-2	ML2-1	ML2-2	ML3-1	ML3-2	ML4-1	ML4-2	ML5	ML6	ML7	ML8	ML9
Jun-2011	97	100	100	100	93	93	87	90	100	100	97	97	97
Jul-2011	87	90	97	97	90	97	100	100	100	100	100	100	100
Aug-2011	94	97	87	100	97	94	97	97	97	100	94	90	94
Jun-2012	97	100	93	97	90	97	93	93	93	100	93	93	97
Jul-2012	97	97	97	100	97	100	100	100	97	94	97	94	94
Aug-2012	90	97	87	94	97	97	90	94	100	100	97	90	97
Jun-2013	97	100	100	100	97	100	97	97	97	100	100	93	97
Jul-2013	94	100	100	100	94	100	100	94	100	100	100	97	100
Aug-2013	94	100	90	97	90	94	97	97	100	100	100	97	100
Jun-2014	100	100	93	93	97	97	90	97	97	93	100	83	90
Jul-2014	94	94	100	100	97	97	94	100	97	100	97	97	100
Aug-2014	87	90	81	90	94	94	97	90	84	100	90	94	97
Jun-2015	93	100	97	100	100	100	100	100	100	100	100	97	100
Jul-2015	97	94	97	97	97	94	94	97	94	97	97	94	97
Aug-2015	100	100	100	100	97	97	97	97	97	100	97	97	100
Jun-2016	90	97	87	97	93	97	100	100	93	100	100	100	93
Jul-2016	97	100	94	100	87	90	90	94	94	97	94	90	100
Aug-2016	94	100	90	97	97	97	97	97	94	97	94	84	87
Jun-2017	93	97	90	93	90	93	87	87	90	100	90	83	87
Jul-2017	97	97	94	94	100	100	90	97	90	97	94	94	94
Aug-2017	97	97	87	90	90	97	94	100	97	90	100	90	94

Table Percentage2. The percentage of days which were used for the analysis. Calculations for each month. Cold season. Data sets (locations) ML1-ML9.

Data set Month	ML1-1	ML1-2	ML2-1	ML2-2	ML3-1	ML3-2	ML4-1	ML4-2	ML5	ML6	ML7	ML8	ML9
Feb-2011	64	71	43	46	36	39	25	25	50	61	57	29	36
Mar-2011	90	94	87	90	90	94	84	71	94	94	94	97	97
Feb-2012	55	55	41	38	34	38	24	24	38	55	55	28	34
Mar-2012	94	97	90	90	90	94	90	94	94	94	97	97	94
Feb-2013	64	64	36	39	21	32	14	14	39	61	57	18	29
Mar-2013	94	94	97	100	94	90	90	90	97	90	94	97	100
Feb-2014	39	43	29	32	21	32	11	11	36	54	50	18	29
Mar-2014	84	90	71	81	71	77	68	71	77	90	87	81	77
Feb-2015	61	64	32	32	29	29	21	21	46	64	54	25	43
Mar-2015	84	87	81	87	74	81	81	81	87	90	90	94	84
Feb-2016	55	59	28	31	31	38	24	28	38	55	55	24	34
Mar-2016	87	87	90	94	90	87	81	81	87	94	87	77	94
Feb-2017	50	50	21	25	21	21	18	25	36	46	46	21	29
Mar-2017	81	84	84	90	90	97	84	87	87	84	77	97	87

One can see that for June, July and August (warm season) and for March (cold season) and all years of observations there are no data gaps and there is no any noticeable inter-annual difference for all locations. For February (cold season), the percentage considerably differs from location to location, but for a single location the inter-annual difference is not considerable. In order not to overload the article, we decided not to include these tables in the revised version. Instead, we added the following text in the revised version of our article after the analysis of Table 1 in the end of Section 2:

> In order to identify possible data gaps which may influence the results of the analysis we calculated for each month the percentage of days which were used for the analysis. These calculations have shown that for June, July and August (warm season) and for March (cold season) and all years of observations there are no data gaps and there is no any noticeable inter-annual difference for all locations. Also, there is no any noticeable difference between the calculated quantities for different locations: they are mostly within the interval 80%-100%. For February (cold season), the percentage considerably differs from location to location within the interval 10-70%, but for a single location the inter-annual difference is not considerable.

In conclusion, we would like to thank once again the referee for valuable remarks and suggestions which we sincerely appreciate.

Vladimir Kostsov,
corresponding author