

Interactive comment on “No statistically significant effect of a short-term decrease in the nucleation rate on atmospheric aerosols” by E. M. Dunne et al.

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Review of “No statistically significant effect of a short-term decrease in the nucleation rate on atmospheric aerosols” by Dunne et al.

This paper explores the physical connection between cosmic rays, ions, aerosol nucleation and CCN to determine if there is a causal link between cosmic rays and clouds through an aerosol-microphysics pathway. The authors focus on the short-term (~ 10 day) Forbush decreases (FD's) of cosmic rays to the troposphere, where recently published papers have published conflicting results on a cosmic-ray/cloud connection. Because the authors are using a global microphysics model, which can compare simula-

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tions with FDs to those without FDs, they can predict the change in CCN due to the change in nucleation directly. However, the authors additionally used advanced statistics to determine if a connection between cosmic rays and CCN via the nucleation pathway could even be detected in atmospheric data.

The paper concludes that the cosmic-ray/CCN connection is too weak to have an important effect on clouds. Furthermore, the changes in CCN due to the changes in cosmic rays (via the nucleation pathway) should not even be statistically detectable in the real world (where control simulations are not possible). The authors leave open the possibility that sub-grid aerosol microphysics, which can't be resolved by the model, may possibly have some role in affecting clouds, and they also leave open the possibility of another mechanism (not involving aerosol nucleation) affecting clouds.

The paper is generally well-written, within the scope of ACP. It deserves to be published in ACP once several comments have been addressed.

P15375 L8: Regarding the small change in the total solar irradiance being too small to change clouds: there is a feedback mechanism in the Hadley cell that is proposed to increase subtropical clouds for a small reduction in solar irradiance.

Meehl G.A., J.M. Arblaster, G.W. Branstator and H. van Loon, 2008: A coupled air-sea response mechanism to solar forcing in the Pacific region, *J. Climate*, 21, 2883-2897.

P15376 L19-21: An additional significant reason why the fractional change in nucleation is always greater than the fractional change in CCN is that the likelihood of a nucleated particle surviving to become a CCN (survival probability) decreases with increasing nucleation rates. This decrease in survival probability is because of slower growth (more competition for condensable material) and more coagulation at faster nucleation rates. This is discussed in Pierce and Adams (2009b).

P15378 L1-3: Laken et al. (2009) did claim that the delay was too long, but I've never agreed with this. Mean growth rates in the free troposphere are often ~ 1 nm/hr or less.

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Therefore, it could take at least 4 days for CCN to be formed in the free troposphere, so if the FT is where the action is, this delay is expected.

P15378 L9-12: Can you add a quick statement as to how Laken et al. (2010) was able to rule out ion-induced nucleation through the statistical analysis?

P15382 L23 through end-of-paragraph: It would be useful to add a statement here about how much ion concentrations (or ion-formation rates) change during a FD. The way the paragraph is currently written might lead a novice reader to assuming that your choice of 15% reduction might have something to do with the 15% of nucleation being calculated to be ion induced (as cited earlier); however, you are actually assuming that 100% of nucleation is ion induced and that the ion concentrations decrease by 15% during a FD.

Also in this paragraph, you should mention that these estimates are for a forested continental boundary-layer site and that this may not be representative for the fraction of nucleation that is ion induced in other regions of the atmosphere (I believe you now have estimates of this in your modelling work that you presented in the CLOUD workshop).

Equation 1: The formula for the AE is flipped (the AOD stuff should be on top) and needs a negative sign. As the equation stands now, Rayleigh-scattering particles would have an AE of -0.25 rather than 4.

Equation 2: Technically the right-hand side does not exactly equal the left-hand side, or else X_{ij} in Eqn. 3 would be 0. It would be more clear to change Y_{ij} in Eqn. 2 to Y_{ij_fit} .

Table 2: What are S1 and S2 in the table? I assume that they should be S_c and S_R . What are the primes? I assume that the not-primed data is unperturbed and the primed is perturbed, but there is no discussion of this.

Figure 4b: Maybe my eyes are playing tricks on me, but it REALLY looks like the 30

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days of the 12 months are correlated with each other, even in the unperturbed data. It looks like the 12 points move up and down in unison as you move across the day-of-month. I bet if you calculated the correlation coefficient between the lowest point for each day-of-month with the highest point for each day-of-month, you get an r-value much greater than 0. Why should there be any correlation between the upper values with the lower values? Is this something that is a relic of the de-trending? I'm quite confused.

P15392 L14: "Perturbed data points are no more likely to fall outside the confidence interval than unperturbed." Are you applying the confidence interval of the unperturbed data to the perturbed data? This seems like the right test to do (since the perturbed data will have more variance and thus a larger confidence interval). However, it might not matter which confidence interval you use since the difference between the perturbed and unperturbed is so small.

P15393 L8: "Responses of CN and CCN are compared in Figs. 4 and 5." CCN are in 4 and CN in 5 so maybe say "responses of CCN and CN."

P15393 L11: "The response in CN10 is strongest at the surface because the nucleation rate in the boundary layer $J_{BLN} = A [H_2SO_4]$ is higher than in the free troposphere, so the 15 % decrease in the nucleation rate has a larger effect." True, but I would guess that nucleation contributes to a higher fraction of the CN10 in the FT than it contributes to the fraction CN10 than in the boundary layer (since primary emissions are emitted directly into the BL). I guess the nucleation-rate difference wins out overall though?

P15393 L17: "At 10–15 km the model predicts that the concentrations of CN10 and CCN70 increase slightly in response to a decrease in nucleation rate." Is this shown in some figure or table? I couldn't find it.

Table 3: "Table 3 shows the proportion of unperturbed and perturbed grid boxes for which the variation between days is found to be statistically significantly greater than the residual variance in that grid box." Can you split to show the % for the unperturbed

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and the % for the perturbed? It would be interesting to know if there is a difference.

P15394 L15 and L17: "Figure 4" should be Figure 8.

Figure 8: How many total model levels are there again?

Figure 8b: relative difference (%) or absolute difference (units)?

P15395 L5-7: I think it would be better to say "all concluded that there were no significant correlations." Saying "all concluded that the observed correlations were not causally linked to Forbush decreases" sounds like they did find significant correlations found them to not be linked through physics (i.e. the cosmic-ray change did not directly cause the cloud change); however, these studies didn't look at the physics. This is a matter of being clear on the difference between correlation and causality.

P15395 L16-19: Similar to an earlier comment: Need to state how much ions change during a FD and also state that these observations are for a continental BL.

Writing comments

Use "that" before restrictive phrases and clauses (e.g. "He drove away in the car that was red." The sentence implies that there was more than one car, and he specifically left in the red one). Use ", which" (note the comma) before nonrestrictive phrases and clauses (e.g. "He drove away in the car, which was red." This implies that there was only one car, and it just happened to be red.). There are several places in the paper where these are not done correctly (either "which" where there should be a "that" or "which" where there should be a ", which").

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