LETTER

Which of satellite- or model-based estimates is closer to reality for aerosol indirect forcing?

In their contribution to PNAS, Penner et al. (1) used a climate model to estimate the radiative forcing by the aerosol first indirect effect (cloud albedo effect) in two different ways: first, by deriving a statistical relationship between the logarithm of cloud droplet number concentration, ln Nc, and the logarithm of aerosol optical depth, ln AOD (or the logarithm of the aerosol index, ln AI) for present-day and preindustrial aerosol fields, a method that was applied earlier to satellite data (2), and, second, by computing the radiative flux perturbation between two simulations with and without anthropogenic aerosol sources. They find a radiative forcing that is a factor of 3 lower in the former approach than in the latter [as Penner et al. (1) correctly noted, only their "inline" results are useful for the comparison]. This study is a very interesting contribution, but we believe it deserves several clarifications:

i) Contrary to their statement, the finding by Penner et al. (1), if it is correct, is only relevant to a single study where indirect forcing is estimated from satellite data alone (2). Studies that use satellite data to constrain aerosol-cloud relationships for present-day conditions (e.g., 3, 4) are unaffected by the problem identified by Penner et al. (1). In these studies, the relationships are not imposed as a parameterization directly and the model can simulate different relationships for preindustrial and present-day conditions. These studies also found a weak aerosol indirect forcing.

ii) We suspect that the results found by Penner et al. (1) are partly an artifact of them using monthly mean aerosol distributions to compute both AOD and Nc via the model parameterizations, with only meteorological fields varying at higher frequency. This strongly reduces the variability in input parameters compared with a method using instantaneous satellite data. As a test, we computed the regression slopes for 6 y of MODerate Resolution Imaging Spectroradiometer (MODIS) satellite data for the regions specifically examined by Penner et al. (1), that is, North America in June-July-August and December-January-February and Asia in March-April-May (Fig. 1). We found regression slopes for $\partial \ln Nc/\partial \ln AOD$ of 0.13, 0.16, and 0.16 when using instantaneous values but regression slopes of 0.09, 0.09, and 0.04 only when using monthly means, which is a factor of 2 difference on average. Using monthly means may thus be responsible for a large part of the discrepancy between the two methods.

iii) A main reason for the discrepancy between the two methods in the study of Penner et al. (1) is that the anthropogenic aerosols in their model contribute much more to the cloud condensation nuclei (CCN) concentration than to AOD. Regression slopes considering the relative change between present-day and preindustrial AOD even exceed 1 in many cases (figure 2A of ref. 1). However, observations compiled by Andreae (5) found that ln CCN scales with ln AOD for a large range of natural and anthropogenic conditions.

In conclusion, we believe that studies using satellite data for climate model evaluation and constraints are not refuted by the study by Penner et al. (1) and the method used for this assessment exaggerates the discrepancy between the radiative forcing estimates from statistical methods and bottom-up model parameterizations.

Johannes Quaas[a,1], Olivier Boucher[b], Nicolas Bellouin[c], and Stefan Kinne[d]

[a]*Institute for Meteorology, Universität Leipzig, 04103 Leipzig, Germany;* [b]*Laboratoire de Météorologie Dynamique, Centre National de la Recherche Scientifique, Université Pierre et Marie Curie, 75252 Paris Cedex 05, France;* [c]*Met Office Hadley Centre, Exeter EX1 3PB, United Kingdom; and* [d]*Max Planck Institute for Meteorology, 20146 Hamburg, Germany*

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[1]To whom correspondence should be addressed. E-mail: johannes.quaas@uni-leipzig.de.

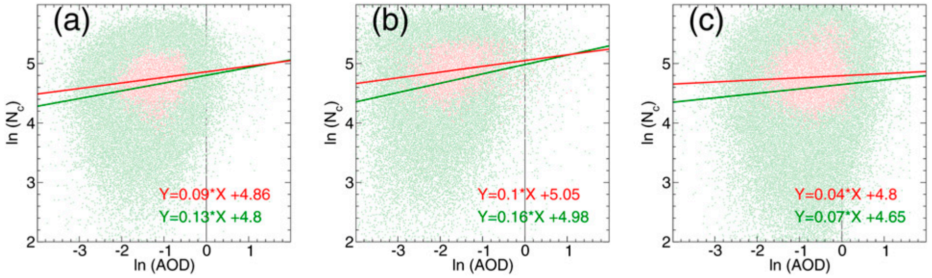

Fig. 1. Scatterplots and regression lines of ln Nc vs. ln AOD for North America, June-July-August (*A*); North America, December-January-February (*B*); and Asia, March-April-May (*C*). Daily instantaneous (green) and monthly mean (red) data from March 2000 through July 2006 MODerate Resolution Imaging Spectroradiometer (MODIS) data are shown, as in the report by Quaas et al. (2), as a 2.5° × 2.5° grid.