EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

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Deliverable D4.5 Evaluation to what extend aerosol-cloud-climate effects depend on the representation of cloud processes.

Responsible Partner: ETHZ

Partners involved: MPG, CNRS-IPSL

Delivery date: 48 months

Deliverable 4.5: Aerosol-Cloud-Climate Effects

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Aim: *A study evaluating the extent to which aerosol-cloud-climate effects depend on the representation of cloud processes.*

This deliverable has been addressed by two contributions. One launching a new multi-model intercomparison study the other through a paper analyzing aerosol forcing and which proposes a new, less negative, lower bound on the forcing. The first study, or group of studies, explores how aerosol-radiation interactions might be influenced by cloud radiative effects, the second looks at how cloud distributions affect estimates of aerosol-cloud interactions.

The first contribution is known as the Easy Aerosol Project. It involves looking at the response of models to prescribed aerosol forcing derived from a new aerosol climatology. The project was developed under EUCLIPSE and has been integrated into the World Climate Research Programme Grand Science Challenge on Clouds, Circulation and Climate Sensitivity. The project description is published on the WCRP website (Easy Aerosol), and is motivated by studies illustrating the potential of aerosols to change the large- scale atmospheric circulation, and with this the global patterns of precipitation. The aim is to better understand whether purported aerosol influences on the circulation changes reflect robust model behavior or are affected by uncertainties in the models' treatment of physical processes, particularly clouds. By subjecting comprehensive atmosphere general circulation models to the same set of idealized easy aerosol perturbations designed to mimic the gravest mode of the anthropogenic aerosol the Easy Aerosol project proposes to answer this question (Voigt et al., 2014b)

The easy aerosol project has motivated a related study to better understand how cloud feedbacks moderate inter-hemispheric albedo differences (Voigt et al., 2014a). In this problem four EUCLIPSE models were subjected to inter hemispheric perturbations in their clear sky albedo. All models showed a robust shift of the ITCZ into the darker (warmer) hemisphere, but the strength of the shift varied greatly with most of the variations being attributable to differences in cloud radiative forcing in regions of deep convection. This study is the first to show that aerosol driven circulation changes may be strongly modulated by the representation of clouds and convective processes.

In the second contribution new constraints were introduced to help reduce uncertainty in estimates of aerosol radiative forcing (Stevens, 2014). A simple analytic framework was introduced to help interpret the results of comprehensive modelling, within which the effective cloud fraction plays a critical role. This effective cloud fraction mediates aerosol-cloud interactions and describes the effective fraction of clouds that if perturbed by the mean aerosol forcing would give the same response as the total distribution of clouds perturbed by the pattern of the aerosol forcing. As such it accounts for covariances in the patterns of cloudiness and aerosol perturbations. A meta analysis of past modelling study, and three dimensional calculations using aerosol and cloud climatologies, suggest that the effective cloud fraction is about 0.1, or a factor of three smaller than assumed in earlier studies. But the uncertainty in this number is still quite large, and further reducing uncertainty in aerosol forcing requires a better understanding of covariability between cloudiness and

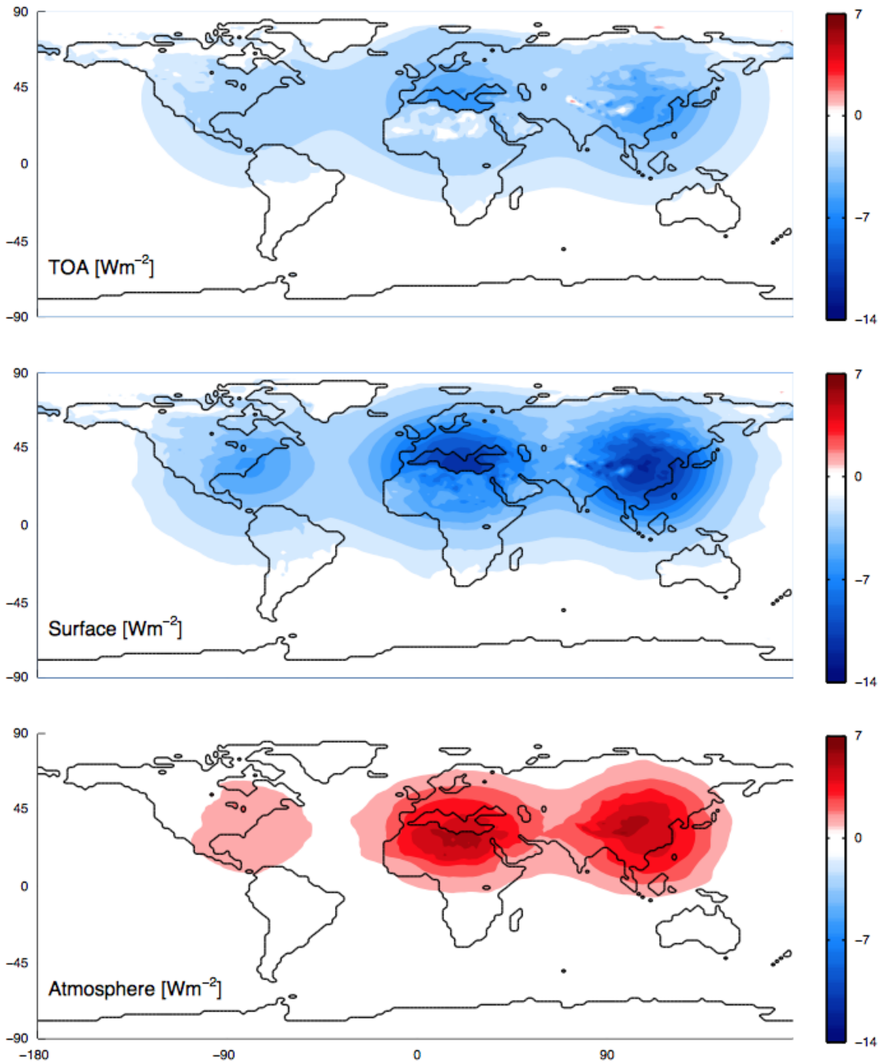

Figure 1: Time-mean change in clear-sky shortwave irradiances between the aerosol-free AMIP reference simulation (CLEAN) and the AMIP simulation with the three aerosol plumes (PLUMES). Taken from Fig.5 of Voigt et al. (2014b)

anthropogenic aerosol loading, particularly temporal co-variability and its modulation by precipitation processes.

References

Stevens, B., 2014: Rethinking the lower bound on aerosol radiative forcing. *Nature*, 1–19– in review.

Voigt, A., S. Bony, J.-L. Dufresne, and B. Stevens, 2014a: The radiative impact of clouds on the shift of the inter-tropical convergence zone. *Geophys. Res. Lett.*, 1–27– in press.

Voigt, A., B. Stevens, S. Bony, and O. Boucher, 2014b: Easy Aerosol - a modeling framework to study robustness and sources of uncertainties in aerosol-induced changes of the large-scale atmospheric circulation.