Use of global climate models and satellite observations to understand cloud – climate interactions

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Global climate models are the main tools to understand the Earth's climate and climate changes at a large scale. It is recognised that cloud processes play a central role in the Earth system particularly due to their influence on the energy balance and the hydrological cycle. However, many cloud-related processes and their interaction with climate is not understood properly and not satisfactorily represented in models.

Satellite data may be of crucial importance due to their large-scale and long-term observation capabilities of various parameters related to clouds, radiation, and aerosols. However, substantial uncertainties inherent in the retrieval of climate parameters need to be taken into account.

Statistics derived from satellite data are very useful tools to analyse cloud-related processes and to evaluate the representation of cloud processes ("parameterization") in climate models.

As an example, I have looked at the relationship between cloud-top temperature and the thermodynamic phase of cloud particles as derived from satellite data in order to improve the representation of the distinction of condensed water into ice and liquid water as a function of local temperature in a climate model (Doutriaux-Boucher and Quaas, Geophys. Res. Lett. 2004).

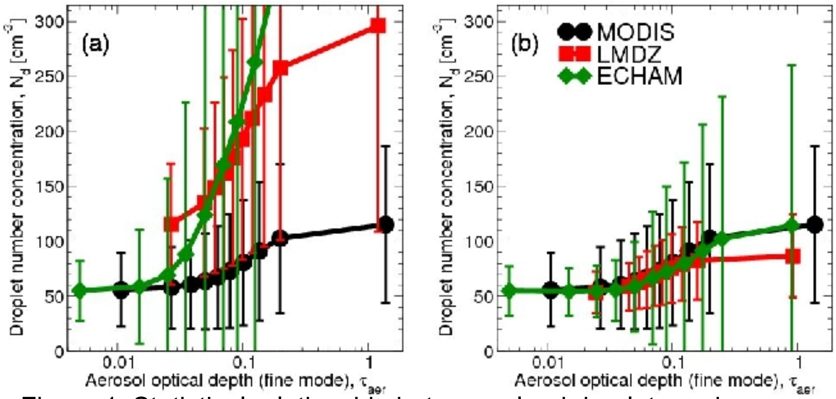

Figure 1. Statistical relationship between cloud droplet number concentration and aerosol concentration as seen by satellite data (MODIS) and two global climate models (LMDZ and ECHAM) with (a) the standard models and (b) improved representation of aerosol indirect effects (from Quaas et al., Atmos. Chem. Phys. 2006).

Similarly, the relationship of the cloud droplet effective radius (or cloud droplet number concentration) and aerosol concentration (Fig. 1) reflects the "indirect effects" by which aerosols, particularly anthropogenic pollutants, alter cloud properties and ultimately planetary albedo. I have used such relationships in several studies to constrain the representation of such effects in climate models (Quaas et al., J. Geophys. Res. 2004; Quaas and Boucher, Geophys. Res. Lett. 2005; Dufresne et al., Geophys. Res. Lett. 2005; Quaas et al., Atmos. Chem. Phys. 2006) and to infer an estimate of the resulting climate forcing from satellite data (Quaas et al., J. Geophys. Res. 2008).

International model intercomparison projects help to get further insights into uncertainties and the importance of particular processes for climate. I contributed (and continue to do so) to various such projects analysing cloud-climate feedbacks (Ringer et al., Geophys. Res. Lett. 2006) and aerosol-cloud interactions (Menon et al., J. Geophys. Res. 2003; Penner et al., Atmos. Chem. Phys. 2006). Currently, I am organising a study within the AEROCOM project to evaluate aerosol-cloud interactions in various climate models with satellite data.