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New diagnostics to assess the representation of upper-tropospheric cloud systems in climate models

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Organized deep convection creates cloud systems with stratiform cirrus anvils of the size of several thousands km2. Up to now the relation between these UT anvils and convective intensity is not yet well understood and poorly represented in climate models. Progress has been hampered by the difficulty to represent ice cloud processes and the organization of convection itself, as well as by a lack of key measurements that directly connect the smaller deep convective towers to the much larger cirrus anvils.

We investigate the representation of UT cloud systems in the LMDZ general circulation model (GCM), in particular its sensitivity to different parametrizations of bulk ice crystal diameter and fall speed, with the ultimate objective to improve the representation of the life cycle of the cirrus in the GCM and better quantify their radiative effect and their impact on climate.

The good spectral resolution of Infrared Sounders allows a reliable cirrus identification, down to an infrared optical depth of 0.1, both day and night. LMD has developed a 15 year- climatology from the Atmospheric InfraRed Sounder (AIRS), being part of the A-Train, and a 10-year climatology from the Infrared Atmospheric Sounding Interferometers (IASI). Recently, these cloud data have been further used to build mesoscale upper tropospheric cloud systems by applying a spatial composite technique on cloud pressure. Convective cores, cirrus anvil and thin cirrus within these systems are then distinguished by cloud emissivity. This made it possible to link horizontal anvil structure to convective intensity. It seems that colder convective systems (linked to stronger convection) include relatively more thin cirrus in / around their anvils.

This novel cloud system approach and in particular this observational behaviour are used to evaluate processes linked to UT cloud systems in the LMDZ GCM. To compare the LMDZ GCM outputs with these observations, we first use a 'satellite observation simulator' that determines from the model outputs the cloud properties which correspond to those retrieved from the IR sounders. In a second step, we adapt the UT cloud system approach to the spatial resolution of the model.

We present in particular the sensitivity of the parameterization of three parameters to the relationships between convective strength and anvil properties: ice crystal diameter, bulk ice fall velocity and the detrained fraction of convective condensate, the two latter ones determining the cirrus lifetime. We show that these parameters strongly impact the sizes of the UT cloud systems and the ratio of thin cirrus to total anvils, as well as their dependence on convective depth. We consider different schemes of detrainment, effective ice crystal size and ice fall speed and we try to select the parametrizations that are the most suitable to reproduce the main characteristics of the observed UT cloud systems.