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Large scale and cloud scale dynamics and microphysics in the formation and evolution of a TTL cirrus : a case modelling study

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Cirrus clouds in the tropical tropopause layer (TTL) control dehydration of air masses entering the stratosphere and strongly contribute to the local radiative heating. In this study, we aim at understanding, through a real case simulation, the dynamics controlling the formation and life cycle of a cirrus cloud event in the TTL. We also aim at quantifying the chemical and radiative impacts of the clouds.

To do this, we use the Weather Research and Forecast (WRF) model to simulate a large scale TTL cirrus event happening in January 2009 (27-29) over the Eastern Pacific, which has been extensively described through satellite observations (Taylor et al., 2011).
Comparison of simulated and observed high clouds shows a fair agreement, and validates the reference simulation regarding cloud extension, location and life time. The simulation and Lagrangian trajectories within the simulation are then used to characterize the evolution of the cloud : displacement, Lagrangian life time and links with dynamics. The efficiency of dehydration by such clouds is also examined.

Sensitivity tests were performed to evaluate the importance of different microphysics schemes and initial and boundary conditions to accurately simulate the cirrus. As expected, both were found to have strong impacts. In particular, there were substantial differences between simulations using different initial and boundary conditions from atmospheric analyses (NCEP CFSR and ECMWF). This illustrates the primordial role of accurate vapour and dynamics for realistic cirrus modelling, on top of the need for appropriate microphysics.

Last, we examined the effects of cloud radiative heating. Long wave radiative heating in cirrus clouds has been invoked to induce a cloud scale circulation that would lengthen the cloud lifetime, and increase the size of its dehydration area (Dinh et al. 2010). To try to diagnose this, we have carried out simulations using different radiative schemes, including or suppressing the radiative effect of clouds, and different radiative conditions. For our simulations, although cloud radiative heating rates were similar to those of the idealized experiments described in the literature, we have found no strong influence of cloud radiative effect on cloud evolution or vertical transport. We explain our results by the wind shear and the temperature variability in Lagrangian trajectories, which limit the cloud lifetime in the simulations to a few hours, i.e. much less than the time required for a cloud-induced circulation to build.

Taylor, J.R., W.J. Randel and E. Jensen, 2011: Cirrus cloud-temperature interactions in the tropical tropopause layer: a case study. Atmos. Chem. Phys.

Dinh, T., D. R. Durran, and T. Ackerman, 2010: Maintenance of tropical tropopause layer cirrus. J. Geophys. Res.