Soutenance de thèse
14 avril 2022 à 14h
lieu: Navier- Salle Joël Noilhan

Improvement of liquid clouds shortwave optical properties parameterization

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Abstract

Simulating the radiative impact of clouds is challenging for atmospheric models, because cloud-radiation interactions are driven by the optical properties of individual cloud particles. These properties depend on the size of the particles and the frequency of light, two quantities not fully resolved in atmospheric models, implying that cloud optical properties need to be parameterized. In this thesis we focus on quantifying the uncertainties in shortwave (SW) cloud radiative impact due to the parameterization of the liquid clouds SW optical properties. Uncertainties are first due to the droplet size distribution (DSD) shape assumption required in two steps: 1) to estimate the cloud droplets effective radius (r_{eff}) from liquid water content (LWC) and droplet number concentration (N); 2) to compute the cloud single scattering properties (SSPs) as a function of r_{eff}. Uncertainties also arise from averaging SSPs over wide spectral bands. To assess these uncertainties, a set of new parameterizations allowing us to explicitly take into account various DSD shapes and spectral averaging methods are designed and implemented in the radiative code ecRad.

Using this updated version of ecRad, we perform offline simulations to compute the bulk radiative properties (reflectance, transmittance, absorptance) of various clouds (defined with given vertical profiles of LWC and N), including a homogeneous cloud, more realistic case studies, and outputs of a climate model. The results show that the transmittance/reflectance of the cloud can vary up to 20 % depending on the assumed DSD. Likewise, differences up to 20% are obtained for atmospheric heating rates. The impact of the DSD shape assumption on r_{eff} (resp. SSPs) estimation contributes to around 80% (resp. 20%) of the total uncertainty. Spectral averaging appears to be a lesser issue, except for atmospheric absorption. Overall, global SW cloud radiative effect can vary by 6 W m^{-2} depending on the assumed DSD shape, which is about 13 % of the best observational estimate.

To complement these offline simulations and investigate how differences in radiative forcing feed back on cloud evolution, the updated version of ecRad is implemented in the atmospheric model Meso-NH. In addition, the DSD shape assumed in ecRad is made consistent with the DSD shape assumed in the 2-moment microphysical scheme of Meso-NH, LIMA. 1D simulations of a stratocumulus cloud are performed with various DSD shapes affecting simultaneously LIMA, the r_{eff} estimation and the SSPs parameterization. The direct impact of the DSD on the simulated radiative impact is assessed, and the indirect effects that results from interactions of radiation with other components of the model are discussed as well. Throughout the simulation, the differences in radiative fluxes and heating rates progressively impact the vertical profiles of temperature, LWC and N, enhancing the feedback since r_{eff} depends on these two quantities. In these interactive simulations, the estimation of r_{eff} remains the main source of differences, and the obtained direct effects are in line with the offline simulations.

This work highlights that the estimation of r_{eff}, which is critical to accurately simulate the radiative impact of liquid clouds, should not be overlooked. Our approach paves the way for a more realistic coupling between cloud microphysics and radiation in atmospheric models.

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