Laboratoire : Centre National de Recherches Météorologiques

Titre du stage : Sensitivity of large-eddy simulations of boundary-layer clouds to the treatment of radiative fluxes

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Sujet du stage :

Context :

Radiative fluxes are known to be key for the development and life cycle of boundary-layer clouds (Wood, 2012). These fluxes largely depend on the physical properties and geometry of the clouds, and are thus very complex. However, in most atmospheric models they are treated in a much simpler way, because neighboring columns are not accounted for to compute radiative fluxes. This means for instance that shadows are cast underneath the clouds and clouds are assumed to be infinitely large. These crude assumptions are referred to as independent column approximation (ICA) and plane parallel hypothsis (PPH). In the last decade, a variety of refined radiative transfer models have been developed to better account for the horizontal exchanges of radiation. These models are more accurate, but it comes at the expense of computational challenges (Jakub and Mayer, 2016). Whether such refined models should be implemented in atmospheric models thus remains a topical question. To help answering this question, this work aims at investigating the sensitivity of numerical simulations of clouds to the treatment of radiative fluxes.

Objectives :

This study will focus on a variety of large-eddy simulations (LES) of boundary-layer clouds, including cumulus, stratocumulus, and transitions from stratocumulus to cumulus. These simulations will be performed with various configurations of the radiative transfer parameterization. These will include the traditional ICA/PPH treatment of radiation, the translation of shortwave (SW) surface fluxes to mimic cloud remote shading, the homogeneization of surface fluxes by spatial averaging at various scales, the random spatial redistribution of surface fluxes, the scaling and offsetting of the fluxes etc. Both the SW and longwave (LW) fluxes will be manipulated in this procedure, as well as the vertical profiles of heating rates. The frequency at which the radiation scheme is called will also be varied.

This set of simulations will then be analyzed to investigate the impact of radiation on the simulated cloud fields. The following quantities will be examined in details : cloud fraction, altitude, liquid water content, size distribution, spatial organization and lifetime, as well as the characteristics of the thermal plumess, which are the roots of boundary-layer clouds.. This will help identify which fluxes (surface or in cloud) primarily impact cloud characteristics, and whether the spatial distribution of radiative fluxes is critical for the establishment and life cycle of clouds.

References :

Jakub, F., & Mayer, B. (2016). 3-D radiative transfer in large-eddy simulations-experiences coupling the TenStream solver to the UCLA-LES. *Geoscientific Model Development*, (4), 1413-1422.

Wood, R. (2012). Stratocumulus clouds. *Monthly Weather Review*, *140*(8), 2373-2423.