Sujet de thèse Rayonnement GMME

Encadrement : F. Couvreux (HDR), Q. Libois

Titre : Sensibilité de la prévision numérique du temps au traitement des flux radiatifs

Context :

Radiative fluxes are key drivers of the climate. Hence balancing the Earth radiative budget in climate models is essential to obtain realistic simulations, which would otherwise quickly derive. On the contrary, the role of radiation is much less obvious at shorter time scales, in particular for numerical weather prediction where frequent observations prevent the models from deriving too much. Compared to other variables such as air temperature or humidity, radiative fluxes have been largely overlooked in the past, and persistent biases in models have not been tackled as priority as in climate models. Radiative fluxes are known to be central in specific situations such as the formation and life cycle of stratocumulus and fog, but how instantaneous errors or permanent biases do impact forecasts in a more general context remains poorly quantified. Few sensitivity studies have investigated the impact of radiation errors on cloud formation, precipitation or turbulence. Before considering to refine existing radiative codes, in particular by implementing more realistic but also more expensive 3D parameterizations (e.g. Jakub and Mayer, 2015), it is necessary to better understand the fundamental role of radiation in NWP.

Objectives :

This thesis aims at better understanding the role and impact of radiation in numerical weather prediction, that is at short temporal horizons compared to climate simulations. It will treat both the shortwave (SW) and longwave (LW) components of radiation, and will investigate the distinct roles of radiative surface fluxes, which drive the surface energy balance, and vertical profiles of heating and cooling rates, which have been much less studied. First, sensitivity studies will be performed where biases or noise will be added to these radiative quantities, with various intensity and frequency. The objective is to test the stability of the atmosphere to such perturbations, which are meant to mimic the current uncertainties in radiative fluxes. The latter either result from an imperfect parameterization of atmospheric radiative transfer or from a poor representation of atmospheric components that drive it, primarily clouds. A central question is to estimate how long it takes for a radiation perturbation to have significant consequences on the mean atmospheric state? Second, different configurations will be explored, where the radiative code will be called more or less frequently, and at various spatial resolutions. This will provide valuable information about the relevant temporal and spatial scales for radiation to operate and will help to design the next generation of radiative codes. Finally, the impact of horizontal heterogeneities will be investigated (Lohou and Patton, 2014), by manipulating the surface fields or vertical profiles of radiative quantities, to see whether such instantaneous heterogeneities (resulting for instance from moving cloud shadows or surface albedo heterogeneities) drive cloud patterns, or whether they are smoothed through longer time scales averaging. This remains a debated question (e.g. Jakub and Mayer, 2017). To this end the sensitivity to spatial averaging, translation, or random redistribution of the fields will be tested. The above mentioned impacts will be measured from various perspectives, including traditional scores used to rate models. A particular focus will be put on the impact on cloud properties, including cloud fraction, water content and lifetime. The work will be based on kilometric AROME (Seity et al., 2011) simulations where clouds remain partly unresolved, but will also investigate the role of radiation at smaller spatial scales in ideal reference LES simulations performed with Meso-NH (Lac et al., 2018), covering a variety of atmospheric situations. Both models will be used with the radiative code ecRad (Hogan and Bozzo, 2018).

References:

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