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Parametrization of the subgrid-scale condensation in the operational french model AROME

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Clouds are a major element for the hydrological cycle and the Earth climatic system. In the atmosphere, the water can exist under three phases: water vapour, liquid water and ice. Each of them has a different impact on atmospheric processes such as the formation of precipitation or the radiative budget. A good representation of clouds is a quality condition for all numerical models. The main purpose of our study is to improve the cloud description in mesoscale numerical weather forecast models such as the operational model Arome or the research model Méso-NH which are currently used and developed at Météo-France.

With an horizontal resolution of 2.5 km (AROME resolution), thick stratiform clouds and deep cumulonimbus can be considered as resolved clouds but shallow cumulus and stratocumulus are still treated by subgrid processes. The objective of our work is on one hand to improve the cloud scheme for resolved clouds and on the other hand to develop a prognostic subgrid cloud scheme well suited for the Arome resolution.

At the scale of the "continuum", the cloud formation requires a thermodynamic equilibrium between the three phases of water. In numerical models, this process is parametrized. It is supposed that the water phases reach this thermodynamic equilibrium with a characteristic time scale much smaller than the time step. The cloud scheme is then reduced to an adjustment to saturation of a guess of the prognostic variables of the model. Two different numerical approaches are available in Méso-NH:

- The "all or nothing" adjustment supposes a quasi-homogeneous distribution of the thermodynamical parameters inside the grid and it prohibits any partial cloudiness. In theory, this method is only dedicated to the clouds well resolved by the horizontal and vertical grid sizes of the model.

- The subgrid condensation scheme deals with variations of temperature and humidity at scales lower than the grid size. The subgrid scheme should give the same results than the "all or nothing" scheme for resolved and homogeneous clouds. The scheme should also be able to produced cloud condensates and cloud cover when the mean grid variables are not saturated. Both the water cloud content and the cloud cover should depend on the variability of the thermodynamic parameters in the grid and on the distance to the saturation. This approach is necessary in an operational NWP model as it should be able to reproduce the impacts of all types of clouds on the mean prognostic variables of the model.

In a first stage, the "all or nothing" cloud adjustment scheme of Méso-NH was carefully improved and validated in order to constitute a good reference for resolved clouds both at meso-scale and in LES. One of the sensitive problems with the "all or nothing" scheme is the treatment of mixed phase clouds (cloud with supercooled liquid water). The code based on an approach proposed by Tao et al (1989) was cleaned up and the algorithm (Langlois, 1973) was optimized to produce more precise results.

In a second stage, we started the development of a new subgrid cloud scheme for AROME and Méso-NH. The idea is to implement a solution originally proposed by Tompkins (2002). At this scale, the internal variance of the thermodynamic variables is mainly linked with the shallow convection and the eddy diffusivity. The use of tunable beta function allows a flexible representation of the thermodynamical parameters and offers then a better chance to represent correctly a large range of clouds. The parameters of the beta functions may also be treated in a prognostic way for a better representation of the cloud life cycles.

Simulations in Cloud Resolving or LES modes for various clouds cases (shallow cumulus, transition Stratocumulus/Cumulus, cirrus,...) are used to calibrate the beta functions and their evolution in the NWP parametrization. The parametrization will be tested first with academic 1D, 2D and 3D cases before the final validation for real cases in Méso-NH and in the operational context of AROME.