A prognostic large scale cloud and semi-Lagrangian precipitation scheme in ARPEGE and ALADIN models

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The large scale precipitation and the cloudiness schemes used operationally at Météo-France in the global ARPEGE and limited area ALADIN numerical weather prediction (NWP) models for short range forecasting include no storage of liquid and solid water. The large scale precipitation occurs when water vapor is above wet bulb water vapor and falls in one time step. A revised Kessler method is used for computing precipitation evaporation, melting and freezing. The diagnostic scheme for the "radiative" clouds link the cloudiness to the production of stratiform and convective precipitations, and to the existence of inversions. The cloudiness functionally depends on the diagnosed total cloud condensate (Xu and Randall, 1996). Used operationally since many years, these schemes have proved their robustness and utility for short range forecasting. However the use of more sophisticated microphysics is promising for improving the simulation of clouds, precipitations and surface conditions. Therefore the large scale cloud and precipitation scheme developed by Lopez (2002) has been tested and improved to be used in ARPEGE and ALADIN models (Bouyssel et al. 2005, Bouteloup et al. 2005).

Originally based on the addition of two prognostic quantities, namely the amount of cloud condensate (suspended liquid water plus ice) and the precipitation content (rain plus snow), the Lopez's scheme is based now on the addition of four prognostic quantities: the amount of cloud liquid water, ice cloud water, rain and snow. A prognostic treatment of precipitation has been chosen to provide a finer description of the temporal evolution of the vertical distribution of precipitation (especially snow) and, thus, of the effects of latent-heat release associated with sublimation and evaporation. The calculations of large scale condensation/evaporation and cloud fraction are based on a triangular probability-density functions (Smith, 1990). The width of this function is adjusted via a critical relative humidity threshold, above which clouds start to appear. An analytical formulation has been designed to describe the dependency of "critical relative humidity" with height and horizontal resolution. The partitioning of stratiform cloud condensate into cloud liquid water and cloud ice is diagnosed from the local temperature. The parameterized microphysical processes that involve precipitation are autoconversion, collection, evaporation/sublimation and melting. The autoconversion rate of cloud droplets (ice crystals) into precipitating drops (snowflakes), is given by the simple formulation of Kessler. The threshold coefficient for autoconversion of cloud ice to snow is function of temperature. Three types of collection processes are considered: accretion, aggregation and riming for which the classical continuous collection equation has been integrated over the Marshall-Palmer exponential particle spectra for specified distributions of particle fall speed and mass. Precipitation evaporation is calculated by integrating the equation that describes the evaporation of a single particle over the assumed spectra of particle number, mass, and fall speed. The fall of rain and snow are considered as specific processes, and are computed using a semi-Lagrangian approach, valid for the long NWP and GCM time-steps, that is separate from the standard semi-Lagrangian advection scheme used in ARPEGE and ALADIN models.

The scheme has been validated with an improved turbulence scheme which diffuses cloud conservative variables (moist static energy and total water content) and the operational ECMWF radiation scheme. These modifications are currently in pre-operational tests for weather forecasting and climate simulation with ARPEGE and ALADIN models. The benefits are an improvement of cloud representation (more high clouds and less medium clouds). The amount of precipitation is smoother spatially, with more precipitation on the leeside mountains and less on the windward mountains, both aspects being beneficial according to the current model biases. The use of a prognostic microphysics is expected to be also beneficial for the future assimilation of cloud satellite radiances and radar reflectivities, and the coupling of the future operational high resolution model (AROME).

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