# RECENT IMPROVEMENTS FOR SURFACE AND MICROPHYSICAL SCHEMES IN THE MESONH MESOSCALE MODEL

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## 1. INTRODUCTION

To study meteorological problems involving small scale phenomena, the use of a mesoscale (non-hydrostatic) model with an accurate set of parametrizations is crucial. The French community mesoscale model MesoNH (Lafore *etal* 2000 or http://www.aero.obs-mip.fr/mesonh/) has been recently upgraded by implementing new surface and microphysical schemes. This new set of parametrizations leads to improvements in simulating precipitation event over complex orography at fine scale, urban breeze associated with an urban heat island or biogenic fluxes over natural surface.

## 2 A 2-MOMENT WARM MICROPHYSICAL SCHEME WITH CCN ACTIVATION

### 2.1 Summary of the scheme

The original warm cloud scheme is extensively described in Cohard and Pinty (2000a), with first results shown in Cohard and Pinty (2000b). The scheme is grounded on the classical partition between cloud droplets ($D < 80\mu$m) and raindrops ($D > 80\mu$m) for which both mixing ratios ($r_c$ and $r_r$) and number concentrations ($N_c$ and $N_r$) are the respective prognostic variables. An assumption of the scheme is to consider generalized $\gamma$-functions as size distribution functions, and fixed dispersion coefficients $\alpha_x$ and $\nu_x$ (with $x \in \{c, r\}$),

$$\gamma_x = N\frac{\alpha_x}{\Gamma(\nu_x)}\lambda_x^{\alpha_x\nu_x}D^{\alpha_x\nu_x-1}exp\big(-(\lambda_x D)^{\alpha_x}\big) \quad (1)$$

$D$ is the drop/droplet diameter and $\lambda_x$, the slope parameter computed from the third and zeroth moments of (1) corresponding to $r$ and $N$. The microphysical scheme itself is sketched in Fig. 1. The heterogeneous nucleation (**HEN**) selects the formation of the first cloud droplets by CCN activation from the aerosol reservoir $N_a$. The reversible condensation/evaporation process (**CND/EVA**) results from an implicit adjustment to water saturation (no prediction of supersaturation).The growth of the raindrops is made through coalescence processes including the autoconversion (**AUT**), the accretion (**ACC**) and the self-collections (**SCOC, SCOR**).

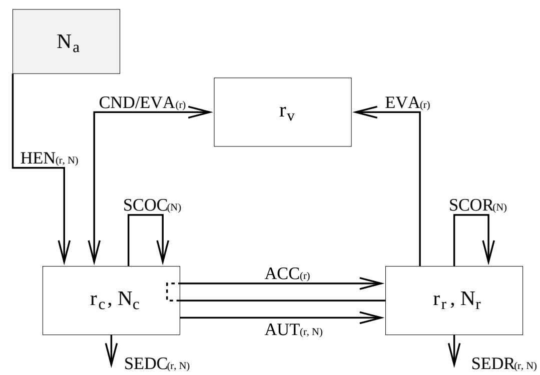


Fig 1. Warm microphysical processes included in the scheme (see text for the acronyms and explanations)

A raindrop breakup efficiency, with an exponential decrease with $D$, limits the SCOR ter m. The sedimentation terms (**SEDC, SEDR**) affect the concentrations and mixing ratios and so crudely account for size sorting phenomenon. Finally, the evaporation of the raindrops (**EVA**) is integrated from the vapor diffusion growth equation including the ventilation effect. It is important to recall that the bulk representation of the microphysical processes proceeds mostly from analytical integration using (1). This is also the case for the CCN activation scheme which is shortly described now.

### 2.2 The CCN activation scheme

The scheme (Cohard et al., 1998) is based upon the concept of activation spectrum relating the cumulative number of activated CCN to the water vapor supersaturation field $s$. The originality of the scheme relies on an elaborate function to shape activation spectra $N_{CCN}(s)$ in the place of classical power laws. The

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$N_{CCN}(s)$ function, expressed by

$$N_{CCN}(s) = Cs^k F(\mu, \frac{k}{2}, \frac{k}{2} + 1; -\beta s^2) \qquad (2)$$

where F is the hypergeometric function and $[C, k, \mu, \beta]$, four adjustable coefficients, has two remarkable properties. First, the number of activated CCN can be computed with (2) following the formulation of Twomey (see Pruppacher and Klett, 1997) for which a analytical integration can be obtained. Secondly, the mathematical expression (2) with a finite limit as $s$ goes to infinity, adheres closely to activation spectra produced by lognormally distributed aerosols. Exploiting further this property, Cohard et al. (2000c) were able to calibrate the four tunable coefficients of (2), from known properties of aerosol populations (modal radius $\overline{r}$, standard deviation $\ln(\sigma)$, concentration $N_a$, solubility, etc...). So the CCN activation scheme provides an estimate of $N_c$ from the computed vertical velocity field (source of supersaturation) together with specified aerosol properties. This makes the "CCN sensitive" scheme powerful for 3D real case studies at small scale.

## 2.3 Fine scale simulation of precipitating bands

South-East facing slopes of the Massif Central, the Cevennes ridge in France (see Fig. 2 for a geographical location), are exposed to intense precipitation events that can lead locally to severe flash flooding. The meteorological situation at the origin of these events is well understood.

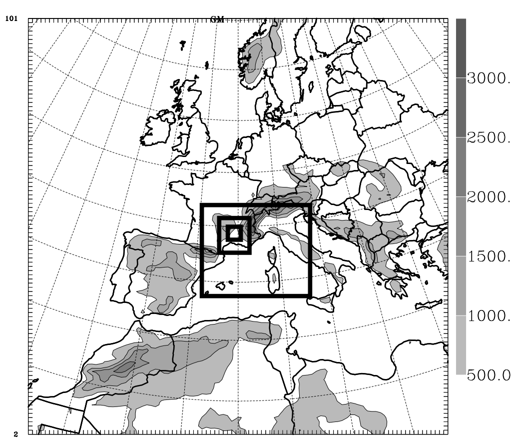


Fig 2: Domains ($\sim 100^2 \times 45$ each) of the interactively nested simulations at 50, 10, 2 and 1 km resolution, respectively. The height contours are every 500 m

The precipitation forms after a forced ascent of warm moist air flowing from the Mediterranean sea in response to an eastward moving upper level trough approaching the French Atlantic coast. A first investigation of this phenomenom has been made during the fall seasons of 1986-1988 by French hydrologists to estimate the feasability of integrating over small scale watersheds rainfall rates derived from radar reflectivities. The radar observations (example in Fig. 3) indicate that the cloud tops remain below the freezing level.

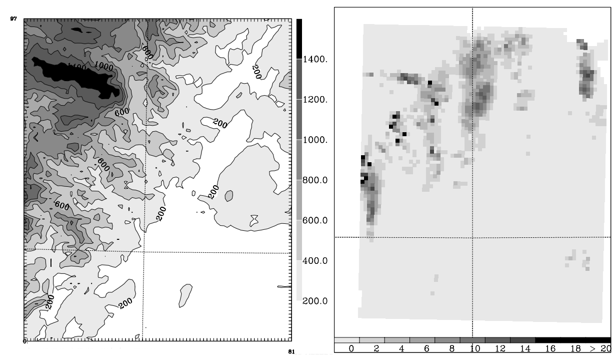


Fig 3: 1 km scale relief with contours every 200 m (left). Mean radar rainfall rates between 11:00 and 12:00 (right)

Due to small scale topographical features superimposed on the main slope of the terrain (Fig. 3), precipitations over the Cevennes ridge are often organized in narrow bands that evolve with a time scale of one hour, approximately. The purpose of this work is to test the sensitivity of these bands to the aerosol load of the incoming maritime airmass at high horizontal resolution.

The simulations are carried out with the MésoNH model (Lafore et al., 1998) and its full physical package. The initial (14 Nov. 1986, 00Z) and the lateral boundary conditions of the large scale run at 50 km, are obtained from 6 hour analyses from ECMWF. A 1-way interactive grid-nesting strategy is adopted for the 10, 2 and 1 km scale simulations (Fig. 2) to allow for a maximum refreshment rate of the boundary conditions at high resolution. The simulations at 50 and 10 km are made with a standard Kessler scheme while those at 2 and 1 km are made with the advanced 2-moment scheme and assuming ammonium sulphate aerosols with $N_a = 66$ cm$^{-3}$, $\overline{r} = 0.133$ $\mu$m and $\ln(\sigma) = 0.4835$. The continuous downscaling of the mesoscale flow and of the cloud system is thus carefully maintained at 1 km.

A series of 4 experiments are performed with increasing aerosol concentrations ($N_a$, $N_a \times 2$, $N_a \times 4$ and $N_a \times 6$). This is a first attempt to illustrate the sensitivity of orographically triggered warm rainfall to the upstream CCN concentration. Results are summarized in Fig. 4 where the accumulated precipitation over the 10-14Z period of time are mapped for each experiment.

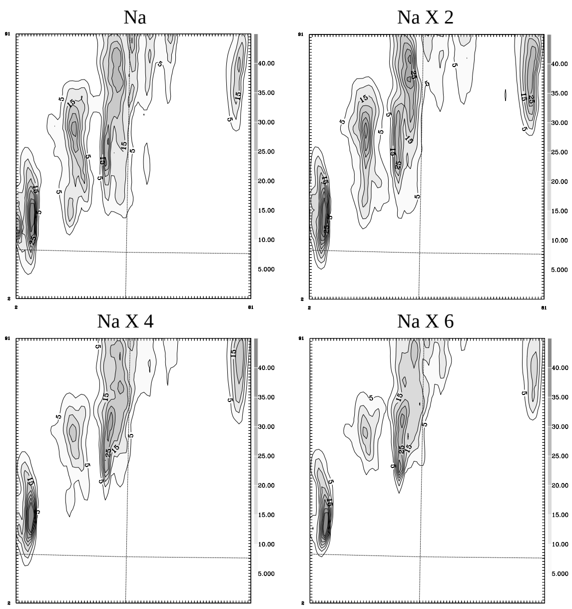


Fig 4: The 1 km scale rainfalls in the 10-14Z interval

The comparison between Figs 3 and 4 shows that the precipitating rainbands are simulated at the right location. This is due to the strong impact of small scale features in the 1 km scale orography because an additionnal experiment performed with the Kessler scheme at the same scale lead to a similar position of the rainbands. Turning now to the microphysical impact of the aerosol concentration, one can notice first that as expected, there is a continuous decrease of the domain averaged amount of rain from the $N_a$ case to the $N_a \times 6$ case because clouds with high droplet concentrations are less efficient to precipitate. A careful inspection of Fig. 4 reveals that in case of a higher concentration of aerosols, the precipitations form more downstream because the rain drops need more time to grow. It seems also that some rainbands are less affected by this effect. In conclusion, this study seems to demonstrate that kilometer scale orographic precipitation have some sensitivity to the aerosol load of the incoming airmass. This has to be annalysed in greater detail for other aerosol properties.

## 3. The Town Energy Budget (TEB)

### 3.1 Presentation

The TEB scheme (Masson 2000) aims to parametrize town-atmosphere dynamics and thermodynamic interactions. It should parametrize both the urban surface and the roughness sublayer, so that the atmospheric model only sees a constant flux layer as its lower boundary. Spatial averaging of the town characteristics leads to a generalization of local canyon geometry instead of the usual bare soil formulation currently used to represent cities in atmospheric models. This relatively simple description of the town geometry is compensated by a complete physical package. TEB simulates three energy budgets for wall, roads and roofs with forcasting three different temperatures representative of the three surface. The physics of the scheme are relatively complete :

- interception of snow and water
- longwave computations, infrared trapping effect
- shortwave computation, reflections, shadow
- momentum fluxes (with an urban roughness)
- sensible and latent fluxes, dew
- storage fluxes domestic heating
- anthropogenic fluxes (car traffic, factories)

The scheme is aimed to be as general as possible to represent any city in the world for any time or weather condition (heat island, urban wake, water evaporation after rainfall, snow effects ...).

### 3.2 Simulation of urban mesoscale effects

During anticyclonic situations, it is important to well understand the urban influence on the boundary layer because most of pollution events happen in such situation. The urbanization of the surface induces atmospheric changes like urban heat island (which represents the difference between air temperature in city and surrounding).

An anticyclonic situation (the 12th of July, 1994) has been simulated over the city of Paris (France). The MesoNH model has been integrated during 48 hours, from the 11th, 12 utc to the 13th,12UTC. The surface fluxes are computed by TEB over the urbanized areas and by the ISBA scheme over the vegetated areas. The other physical parametrizations used in the simulation are turbulence, radiation and warm microphysics. A two-way grid nesting is used to increase the horizontal resolution over Paris (1 km), while the coarser model uses a grid mesh of 5 km. The results of the simulations are compared to meteorological stations inside and around Paris (Fig 5).

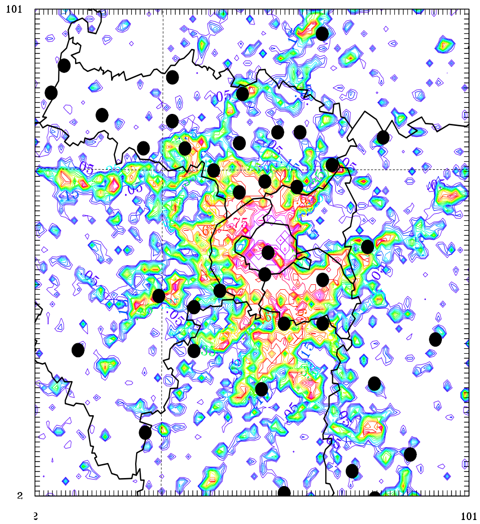

Fig 5: Model urbanized area, with meteorological stations

The model temperatures are in good agreement with the observations for all degrees of urbanization and both for night or day (Fig 6). The St-Jacques tower station is located in down town at 40 meters of height. The Urban Heat island (UHI) is correctly simulated (within 1 degree of the observations), larger during the night as observed.

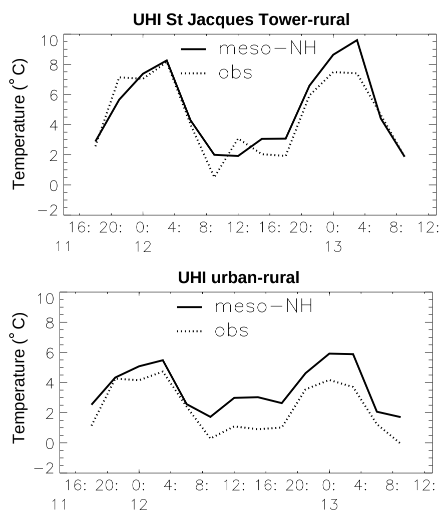


Fig 6: Observed and Simulated Urban Heat Island (top: between Paris center and countryside, bottom: between all dense urban area and countryside)

Once the model is validated, it is used as a numerical laboratory to explore and quantify the urban effects on the atmosphere. During the day, an urban breeze appears. It is caused by the sensible turbulent heat flux released by the city, and the associated urban heat island. It creates a mean vertical movement above Paris. However, to discriminate between urban and other effects, a new simulation is run, in which the urban areas are removed. This 'rural' simulation is compared to the 'reference' simulation presented above. The simulated 10m wind fields in both simulations are shown in Fig. 7 (top). The difference between these two wind fields clearly shows a strong convergence around Paris (Fig. 7, middle). This convergence is therefore present only when the urban areas are taken into account. It reaches 5 m/s on the 10m wind. As a consequence, a divergence appears at the boundary layer top (Fig. 7, bottom). This divergence reaches in this case 9m/s, and extends to more than 50km from Paris.

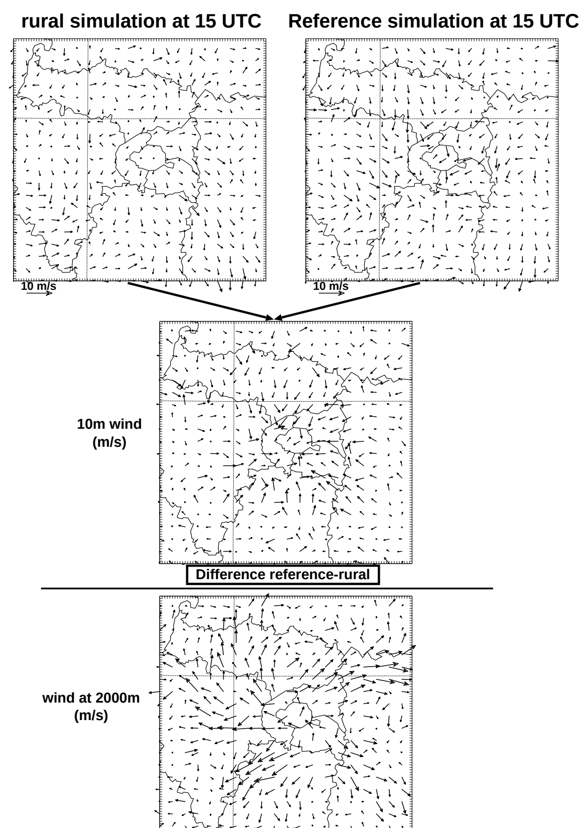


Fig 7: Evidence of urban breeze. Top: convergence at 10m. Bottom divergence at 2000m of altitude.

### 3.3 Patch approach

Atmospheric chemistry modeling require the study of surface-atmosphere interaction processes such as dry depositions or biogenic hydrocarbon emissions. Such processes strongly depends on sub-grid surface types, which can be characterized by contrasted micro-climates (e.g. forest/grassland/rock). In order to better describe such specificities in MESO-NH, the surface scheme has been modified to define explicitly different set of surface parameters (LAI, roughness, ....) adapted to main surface types in each grid cell. Furthermore, the corresponding sub-grid surface energy budgets are calculated with the surface scheme at each time steps of the atmospheric simulation. Energetic fluxes issued from such defined surface partitions are then explicitly averaged at the grid cell-level before "returning" to the atmosphere. This "patch approach", opposite to the classical "aggregated approach", allows for example to distinguish a "forest temperature" from the "grid cell surface temperature". For biogenic emissions, which are mainly due to forests, this differentiation is very sensitive, reaching 30 to 60 % of the predicted biogenic fluxes. This influence is of course stronger when the landscape heterogeneity scale is small with regard to the grid cell size.

By refining the surface description, the patch approach may concerns other types of surface atmosphere interactions as chemical species deposition, CO2 absorption, other types of biogenic emission (NOX, CH4), or the hydrological cycle.

## 4. CONCLUSIONS

The study presented in this paper aims to show that 3D real case simulations of orographically forced precipitating rainbands can be achieved at high resolution using a two-moment warm microphysical scheme that explicitly incorporates the activation of the CCN. An important result is that changing the CCN activation spectrum of typical maritime airmasses may induce a significant change in the precipitation patterns. These modifications, commensurate to the scale of the watersheds, are attributable to the different autoconversion efficiencies that result from variations of the CCN activation spectra in the microphysical scheme. This parametrization will be extended to take into account the ice hydrometeors.

The TEB scheme used in a 3D simulation simulates a realistic heat urban island over Paris. This scheme will be used to analyse data which will be collected during the ESCOMPTE experimental campaign in summer 2001 over the city of Marseille (France).

It will be useful to quantify the impact of patch approach not only for biogenic fluxes but also for sensible and latent fluxes which directly affect the atmosphere behaviour. Indeed, in presence of strong subgrid variability of land surface, the aggregation of parameters as roughness lenght can become inconsistant, the patch approach being more physical.

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