Online Air Quality Developments Undertaken within the NMMB Multiscale Model at the Barcelona Supercomputing Center

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DEVELOPMENT OF A NEW FULLY ON-LINE CHEMICAL MULTISCALE MODEL

NMMB/BSC-CTM is a new chemical weather prediction system for short term forecast, currently under development at the Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS) in collaboration with several research institutions. The model is able to simulate the tropospheric gas-phase photochemistry (Jorba et al., 2010) and includes the dust processes of NMMB/BSC-DUST (Pérez et al., 2008, 2011; Haustein et al., 2011).

The meteorological core of the model is the new NMMB (Janjic, 2005; Janjic and Black, 2007), an evolution of the NCEP WRF-NMM model.

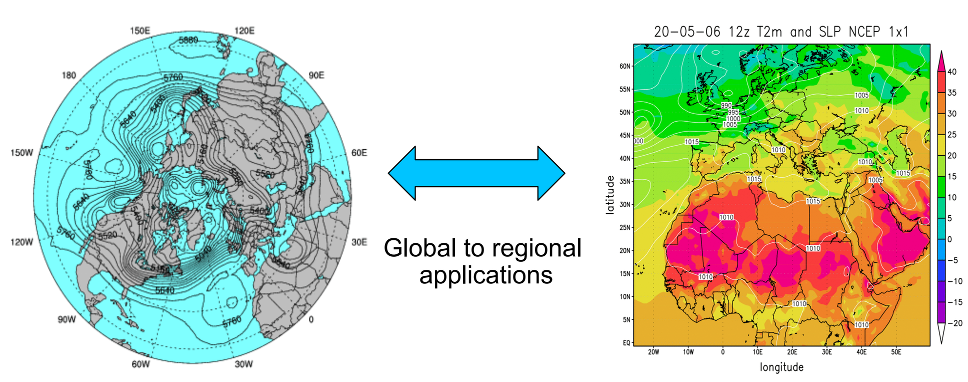
Gas-phase photochemistry, dust processes, and meteorology are on-line coupled in order to describe feedback interactions, such as direct radiative effect and photolysis feedback.

THE NONHYDROSTATIC MULTISCALE MODEL ON THE B GRID (NMMB) – THE ATMOSPHERIC DRIVER

- NMMB can be regarded as an upgrade of the WRF Non-hydrostatic Mesoscale Model WRF-NMME, which is operationally used at NCEP as the North American Mesoscale (NAM) model.
- Its unified non-hydrostatic dynamical core allows both regional and global simulations with consistent dynamics and physics.

Among the various parameterization schemes used by the NMMB, here we give particular attention to those that are involved in the coupling with gas-phase photochemistry and dust processes:

- Mellor-Yamada-Janjic (MYJ) turbulence (Janjic, 2001)
- Ferrier microphysics and grid-scale clouds (Ferrier et al., 2002)
- Adjustment moist convection scheme and clouds of Betts-Miller-Janjic (BMJ) (Janjic, 1994)
- Radiative scheme: GFDL SW/LW, RRTM SW/LW (coupling with aerosols only allowed for RRTM SW)



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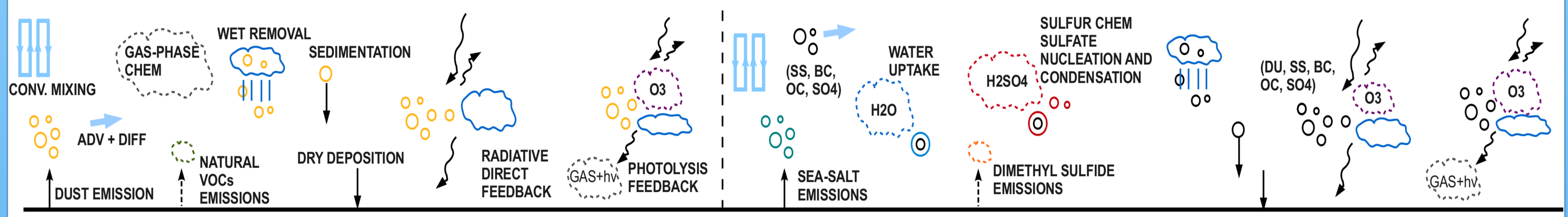
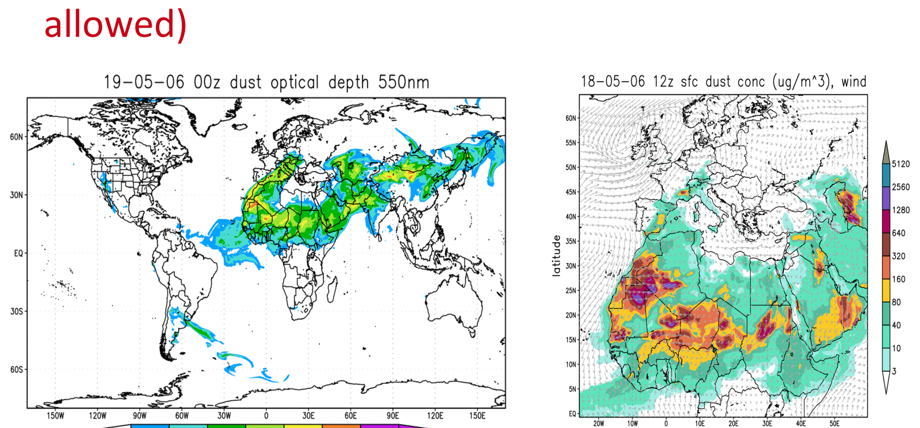
ON-LINE PROCESSES AND FEEDBACKS IMPLEMENTED IN NMMB/BSC-CTM AND PLANNED FUTURE DEVELOPMENTS...



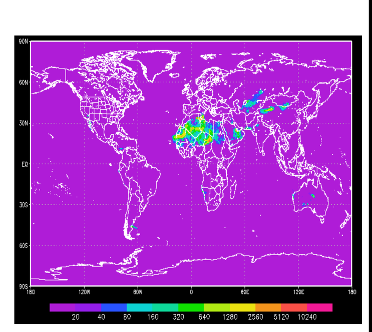
NMMB/BSC-DUST: the mineral dust aerosol model

- A new model for the mineral dust cycle fully embedded within NMMB.
- Dust aerosol is described within 8 transport bins in the range 0.1 – 10 µm and a sub-bin invariant lognormal approach.
- 4 soil population modes are involved in the parametrization of emissions.
- Several dust processes implemented, such as physically-based emissions due to sandblasting, transport, sedimentation, dry deposition, in- and below-cloud scavenging, dust convective mixing (following the adjustment approach of BMJ)

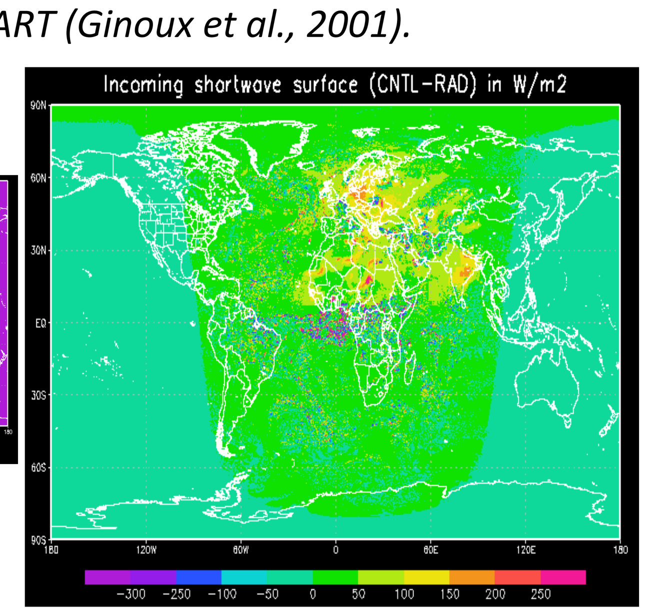
- RRTMN SW/LW radiative scheme implemented and coupled with the NMMB clouds
- Dust optical properties (optical thickness, single-scattering albedo, asymmetry factor) parameterized and coupled with the RRTMN scheme (coupling allowed)



The direct radiative effect due to the presence of aerosols is shown below. No aerosols in the CNTL simulation, while the RAD simulation includes on-line forecasted dust and off-line climatologic aerosols (sea-salt, black carbon, organic matter, and sulfate) from GOCART (Ginoux et al., 2001).

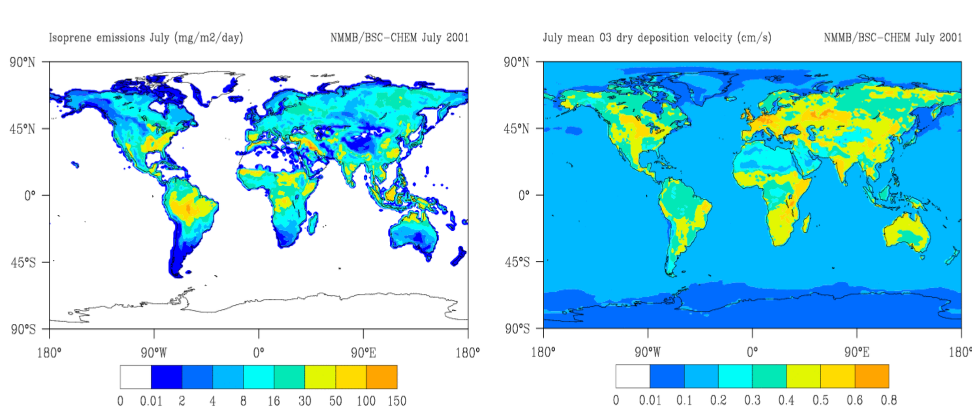


Dust surface concentration in µg/m^3

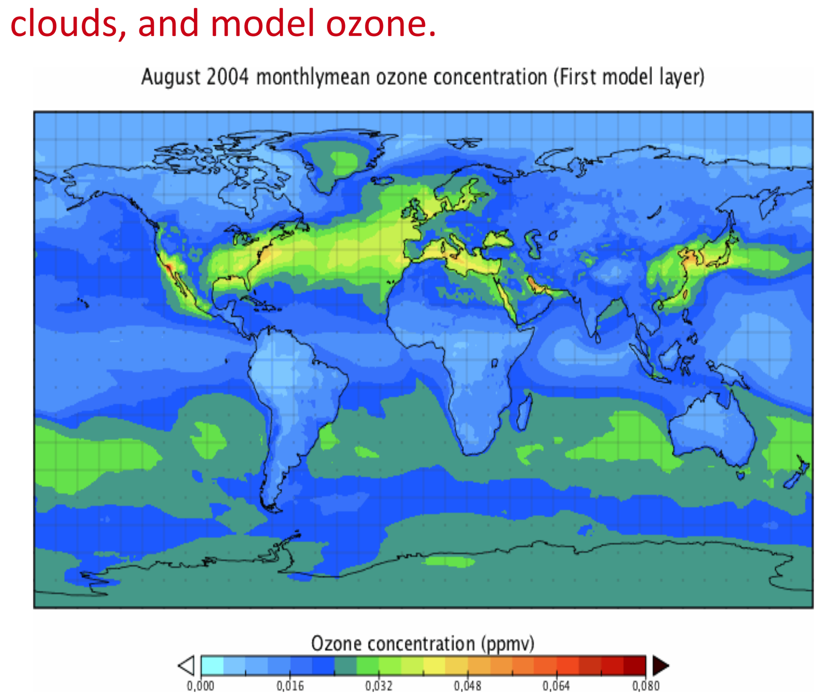


NMMB/BSC-CTM: adding tropospheric gas-phase chemistry

- Extending the NMMB/BSC-DUST model towards tropospheric gas-phase chemistry.
- Wide range of application from global to sub-synoptic scales.
- Modular implementation within NMMB. Chemistry solved after NMMB physics with the same timestep.
- The advection, horizontal and vertical diffusion solved with the NMMB numerical schemes.
- Dust processes of NMMB/BSC-DUST included and feedback interactions allowed.
- Several gas-phase processes implemented, such as on-line natural emissions from MEGAN model (Guenther et al., 2006), transport, dry deposition, clouds scavenging and wet deposition.



- Both the CBM-IV (Gery et al., 1989) and CB05 (Yarwood et al., 2005) lumped-structure gas-phase photochemical mechanisms implemented and on-line coupled with the NMMB meteorology
- Fast-J photolysis scheme (Wild et al., 2000) implemented. Fast-J is able to describe the coupling with clouds, aerosols, and absorbers. Currently, the photolysis scheme is coupled with NMMB grid-scale clouds, and model ozone.



FUTURE DEVELOPMENTS

- Improvement and upgrade of the numerics and the physics of the chemistry part of the model: gas-phase, dry deposition, cloud chemistry, aqueous-phase chemistry, linear stratosphere chemistry, etc.
- Implementation of the other global relevant aerosol species, i.e. sea-salt (SS), black (BC) and organic carbon (OC), and sulfate (SO4), in addition to dust (DU). Several aerosol processes will be implemented in the model such as physically-based emissions, water-uptake, dry and wet removal, convective mixing, sulfur chemistry, etc.
- Evaluation tasks of the system on global and regional configurations.

- It is planned to couple the radiative scheme with all the considered aerosol species to simulate the aerosol radiative effect.
- It is planned to couple the model ozone prediction with the radiative scheme of NMMB.
- It is panned to couple the photolysis scheme with the model clouds, ozone, and aerosol species (DU, SS, BC, OC, SO4).

METEOROLOGY, GAS-PHASE CHEMISTRY, AND AEROSOLS ON-LINE INTERACTIONS TAKEN INTO CONSIDERATION BY NMMB/BSC-CTM AND ITS FUTURE DEVELOPMENTS

$$\partial_t Q_{i,j} + (\vec{v}\cdot\vec{\nabla}) Q_{i,j} = \sum_k \frac{dQ_{i,j}}{dt}(u^*, \vec{q}_w, \vec{c}_g, \dots)\Big|_{aero,k}$$

$$\partial_t \rho_{d,a} + \vec{\nabla}(\rho_{d,a}\vec{v}) = 0$$

$$\partial_t \vec{v} + (\vec{v}\cdot\vec{\nabla})\vec{v} = -f\vec{k}\times\vec{v} - \vec{\nabla}\Phi - \frac{1}{\rho_a}\vec{\nabla}p + \frac{d\vec{v}}{dt}\Big|_{turb}$$

$$\partial_t T + (\vec{v}\cdot\vec{\nabla})T = \sum_k \frac{dT}{dt}(I_\lambda, \dots)\Big|_{diab,k} + \frac{dT}{dt}\Big|_{turb}$$

$$\partial_t q_{w,\eta} + (\vec{v}\cdot\vec{\nabla}) q_{w,\eta} = \sum_k \frac{dq_{w,\eta}}{dt}\Big|_{water,k}$$

$$p\alpha = RT$$

$$\partial_t c_{g,\gamma} + (\vec{v}\cdot\vec{\nabla}) c_{g,\gamma} = \frac{dc_{g,\gamma}}{dt}(\vec{c}_g, I_\lambda, \dots)\Big|_{photochem,k} + \dots$$

$$\frac{dI_\lambda}{dt} = f(I_\lambda, \tau_\lambda^{aero}, \omega_\lambda^{aero}, g_\lambda^{aero}, \dots)$$

Radiative Transfer Eq.

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