(1) GLOBO – Global Bologna model: Global Hydrostatic Numerical Weather Prediction model
BOLAM – Bologna Limited Area Model: Hydrostatic Numerical Weather Prediction model at limited area
MOLOCH – Model Local: Non-hydrostatic Numerical Weather Prediction model at limited area

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(3) Available modes for the model runs: Research and Operational

(4) Components & processes: Atmosphere, Pedosphere & Physical

(5) Brief models description

GLOBO is a hydrostatic meteorological model, operating over the entire globe, developed at CNR-ISAC (Bologna). The prognostic variables are the wind components *u* and *v*, the absolute temperature *T*, the surface pressure p_S, the specific humidity *q* and the turbulent kinetic energy *TKE*. The water cycle for stratiform precipitation is described by means of five additional prognostic variables: cloud ice, cloud water, rain, snow and graupel.
The model prognostic variables are distributed in the vertical on a non-regular Lorenz grid, with higher resolution in the atmospheric boundary layer near the lower surface. The vertical discretization is based on a hybrid vertical coordinate system, in which the terrain-following *sigma* coordinate (p/p_S) gradually tends to a pure pressure coordinate with increasing height above the ground. The relaxing factor from *sigma* to *p* is prescribed as a function of the orography height in the domain. The horizontal discretization is based on a staggered Arakawa-C grid (Arakawa and Lamb, 1977), in geographical coordinates (latitude-longitude). The advection scheme presently implemented is the Weighted Average Flux scheme (WAF, Billet and Toro, 1997).
The temporal integration scheme is *split-explicit*, *forward-backward* for the gravity modes. The horizontal diffusion scheme is of the second order for all the prognostic variables, except for surface pressure. Local and vertically integrated divergence is slightly diffused to control internal and external gravity wave modes.
Model includes the following parametrization schemes of physical processes.
- Microphysical processes parametrization: nucleation of cloud water and ice particles, condensation/sublimation, evaporation, freezing, melting of cloud particles, autoconversion of cloud particles into precipitation particles, sublimation/condensation, riming/collection/accretion, melting evaporation of rain, snow, graupel particles, thermodynamic feedback based on enthalpy conservation.
- Deep moist convection parametrization. The Kain–Fritsch scheme (Kain and Fritsch, 1990) is used.
- Turbulence and orographic drag parametrization. The parametrization is based on the similarity theory (Monin and Obukhov, 1955) to surface layer approximation. The mixing-length based turbulence closure model, widely used to compute the ABL (Atmospheric Boundary Layer) fluxes for atmospheric modelling, is applied to parameterize the turbulent vertical diffusion of momentum,

heat and moisture. The turbulence closure is of order 1.5 (E-l scheme, Zampieri et al, 2005), in which the TKE is predicted. To take into account buoyancy effects for a stratified ABL, the Blackadar (1962) mixing length is used together with stability functions that depend on the Richardson number. For the unstable ABL case, a modified version of the non-local mixing length of Bougeault and Lacarrere (1989) is applied. The roughness length is computed as a function of vegetation and of sub-grid orography variance. Over the sea, a Charnock (1955) roughness is introduced, which takes into account the wave height as a function of the surface wind speed. The sea surface temperature (SST) is computed, depending on latent and sensible heat fluxes and radiative fluxes, using a simple slab ocean model in which the analysed distribution of SST is used a relaxation reference value.
A parameterization of the orographic wave drag, associated with the deceleration of the mean flow passing over orography, is applied.
- “Pochva” parametrization is used for soil, vegetation ans snow cover thermodynamic processes and for exchange with the air (prediction of surface fluxes of heat and water vapor, prediction of temperature and water content at soil levels). The number of soil levels is different for temperature and water content and it changes depending on the depth of annual temperature oscillation dampening and water table depth. A dynamic multi-layer scheme is used for snow cover simulation, predicting mass, temperature and density at each snow level.
- Parametrization of atmospheric radiation processes. It is computed with a combined application of the Ritter and Geleyn scheme (Ritter and Geleyn, 1992) e and the ECMWF scheme (Morcrette, 1991; Mlawer et al., 1997).
The daily operation run (7 day forecast) of the GLOBO model are performed (since 2008) in the framework of weather forecasting for Italian Civil Protection Department. At present GLOBO is run employing a grid step of 19 km in mid-latitudes, and with 60 atmospheric levels. An ensemble of lower-resolution GLOBO forecasts is also employed to obtain an experimental probabilistic (ensemble) monthly prediction issued once per week under joint WWRP/WCRP Subseasonal-to-Seasonal Prediction (S2S) project (http://s2sprediction.net/).

BOLAM is the first model that was developed at ISAC, beginning in the 90's. It is a limited-area hydrostatic numerical weather prediction model. It shares with GLOBO the equations for the dynamical component and the physical parameterizations. In domain grid definition the equator can be taken to be any great circle on the Earth in order to minimize grid anisotropy over the limited area of the simulation (rotated coordinate system). The lateral boundary conditions are applied on a number (typically 8) of grid point rows, using a relaxation scheme (Leheman, 1993) that efficiently absorbs wave energy, helping in reducing spurious reflection by the lateral boundaries.
The daily operation run (3 day forecast) of the BOLAM model is performed (since 2005) in the framework of weather forecasting for Italian Civil Protection Department. At present it is being run with a grid size of 0.075 degrees (8.3 km) in rotated geographical coordinates, with 60 atmospheric levels. BOLAM runs start at 00:00 UTC of each day.

MOLOCH is capable of producing forecasts with high spatial detail, allowing an explicit representation of convective phenomena. It integrates the non-hydrostatic, fully compressible equations for the atmosphere.
It integrates the set of atmospheric equations with prognostic variables (pressure p, absolute temperature T, specific humidity q, horizontal (u, v) and vertical (w) components of wind velocity,

turbulent kinetic energy TKE and five water species, see below), represented on the latitude-longitude, optionally rotated, Arakawa C-grid (Arakawa and Lamb, 1977) .

A hybrid terrain following coordinate *zita*, relaxing smoothly to horizontal surfaces away from the earth surface, is employed. Model dynamics are integrated in time with an implicit scheme for the vertical propagation of sound waves, while explicit, time-split schemes are implemented for the time integration of the remaining terms of the equations of motion. Three dimensional advection is computed using the Eulerian Weighted Average Flux scheme (Billet and Toro, 1997). Horizontal second order diffusion and a small divergence damping are included to prevent energy accumulation on the shorter space scales.

MOLOCH use the same physical processes parametrization as GLOBO and BOLAM, excluding deep convection parametrization.

The daily operation run (2 day forecast) of the MOLOCH model are performed (since 2007) in the framework of weather forecasting for Italian Civil Protection Department. At present it is being run with a grid size of 0.0113 degrees (1.25 km) in rotated geographical coordinates, with 60 atmospheric levels. MOLOCH runs start at 00:03 UTC of each day.

Forecast results of all three models are available in web-page
http://www.isac.cnr.it/dinamica/projects/forecasts/

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