HIGH RESOLUTION OPERATIONAL FORECASTING WITH MOLOCH FOR MAP DPHASE

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Abstract: In preparation to the MAP DPHASE activity, planned for summer-autumn 2007, the non-hydrostatic model MOLOCH has been implemented in order to operationally provide real-time, high resolution weather forecasts over the entire Alpine area. The model chain is based on the GFS model forecasts and comprise also the hydrostatic model BOLAM.

Keywords: *ICAM, convection resolving model, high resolution forecasts, Alps*

1. INTRODUCTION

The MAP DPHASE (**M**esoscale **A**lpine **P**rogramme, **D**emonstration of **P**robabilistic **H**ydrological and **A**tmospheric **S**imulation of flood **E**vents in the Alpine region) is a Forecast Demonstration Project (FDP) of the WWRP (World Weather Research Programme of WMO), aimed at demonstrating the ability of forecasting heavy precipitation and related flooding events over complex terrain, as gained from state-of-the-art atmospheric and hydrological models, new technologies and improved knowledge acquired during the MAP project. High resolution, convection resolving models are a component of the end-to-end forecasting system that will be run operationally for six months, starting from 1st June 2007, over the Alpine region.

At ISAC-CNR, a weather prediction chain for producing real-time, high resolution simulations in the range 0-48 hours has been recently implemented. The modelling chain, based on the 00 UTC GFS (Global Forecasting System - NCEP) global model forecasts at 0.5 degree horizontal resolution, will run once a day during the six months period of MAP DPHASE experiment. The chain comprises the hydrostatic model BOLAM (for a description see Davolio and Buzzi, 2004), which is driven directly by the global model, and the non-hydrostatic model MOLOCH, which is nested in cascade, using a 1-way nesting procedure. For BOLAM simulations the horizontal resolution is 0.11 degree in rotated coordinate (about 12 km); for MOLOCH is 0.02, corresponding to about 2.2 km (Tab. 1).

Table 1: Models configuration.

	Horizontal Resolution (degrees)	Grid points	Levels	Initial and boundary conditions
BOLAM	0.11 x 0.11	154 x 154	40	GFS forecast (0.5° resolution)
MOLOCH	0.02 x 0.02	340 x 290	50	BOLAM forecast (1-way nesting)

2. MODEL DESCRIPTION

The non-hydrostatic model MOLOCH has been developed at ISAC-CNR as a tool for very high resolution, short-range weather prediction and research studies. MOLOCH is based on the fully compressible set of equations with prognostic variables - pressure, temperature, specific humidity, horizontal and vertical velocity components, turbulent kinetic energy (TKE) and five water species (cloud water, cloud ice, rain, snow and graupel/hail) - represented on the lat-lon rotated Arakawa C grid.

Model dynamics is integrated in time with an implicit scheme for the vertical propagation of sound waves, while explicit, time-split schemes are implemented for the remaining terms. Horizontal wave propagation is forward-backward. An economical second-order forward-backward advection scheme (FBAS, Malguzzi e Tartaglione, 1999) is used in alternative with the more accurate, but computationally more expensive, Weighted Average Flux (WAF) advection scheme (Billet and Toro, 1997). The latter scheme, being non dispersive, allows using much smaller horizontal diffusion coefficients than the FBAS scheme.

Small horizontal fourth order diffusion is included to prevent energy accumulation on the shorter space scales.

The lower boundary condition over topography is imposed using a terrain following vertical coordinate system, in which the vertical coordinate ζ relaxes smoothly to horizontal surfaces away from the earth surface. ζ is implicitly defined as:

$$\zeta = H\left(1 - e^{-\frac{z - h\left(1 - \frac{\zeta}{H}\right)}{H}}\right),\ h(x,y) < z < \infty\ , \tag{1}$$

where $H = \frac{R_d T_0}{g}$ is the density scale height.

The physical scheme consists in cloud and precipitation microphysics, sub-grid turbulence parameterization, a soil model including vegetation and an atmospheric radiation scheme. The microphysical scheme is based on the parameterizations proposed by Drofa and Malguzzi (2004). The physical processes determining the time tendency of specific humidity, cloud water/ice and precipitating water/ice are divided into "fast" and "slow" ones. Fast processes involve transformations between specific humidity and cloud quantities and are computed every advection time step. Temperature is updated by imposing entropy conservation at constant pressure. Fall of precipitation is computed with the stable and dispersive backward-upstream scheme with terminal velocities depending on concentration. The turbulence scheme is based on a E-l closure where the subgrid turbulent kinetic energy (TKE) is predicted. Surface fluxes of momentum, specific humidity and temperature are computed by applying the classical Monin-Obukhov theory, with Businger (Holtslag) functions in the unstable (stable) case. The mixing length is computed from the TKE (Deardorff, 1980) in the stable atmosphere and from the Bougeault and Lacarrere (1989) method, modified by Zampieri (2004), in the unstable environment. A four-layer soil model describes the evolution of water and heat fluxes, including vegetation effects as evapotranspiration, rain and snow interception (Pressman, 1994). The computation of atmospheric radiation is based on a combined application of the Geleyn (Ritter and Geleyn, 1992) and ECMWF scheme (Morcrette et al, 1998).

The orography used in the simulations is derived from interpolation and smoothing of the 1 km resolution USGS Digital Elevation Model. Soil type data are interpolated from the global FAO/UNESCO dataset, available at 1/12°, resolution. Landcover/landuse data, that include vegetation type and cover, at about 1 km resolution, are derived from the Global Land Cover Facility.

The MOLOCH performance in cases of strong precipitation was already evaluated for a number of different case studies, including those related to MAP and characterized by heavy precipitation (Richard et al, 2002; Buzzi et al, 2004; Zampieri et al, 2005, Davolio et al, 2007; Richard et al, 2007). A pre-operational version is currently being tested in regional meteorological centres in Italy.

3. IMPLEMENTATION AND TESTING

The MOLOCH code can be run efficiently on parallel computer systems. At ISAC, MOLOCH is run on a Linux-based parallel system, composed by 8 dual-core nodes, for a total of 16 processors. A preliminary testing phase has been devoted to assess the PC-cluster performance in order to be able to produce the forecast in due time. The size of the integration domain has been set up accordingly. A grid of 340 x 290 grid points covers the entire Alpine area (Fig. 1).

The forecasting procedure starts at 06 LT with the download of the GFS data (00 UTC forecasts), available through the NOAA Operational Model Archive Distribution System - NOMADS (http://nomad3.ncep.noaa.gov). BOLAM is run for 48 hours with boundary conditions updated every 3 hours, and then MOLOCH is nested, starting from BOLAM forecast valid at 09 UTC, for a 39-hours run. Based on the current set up (Tab. 1 and Fig. 2), the forecast products are available within less than four hours from the beginning of the procedure.

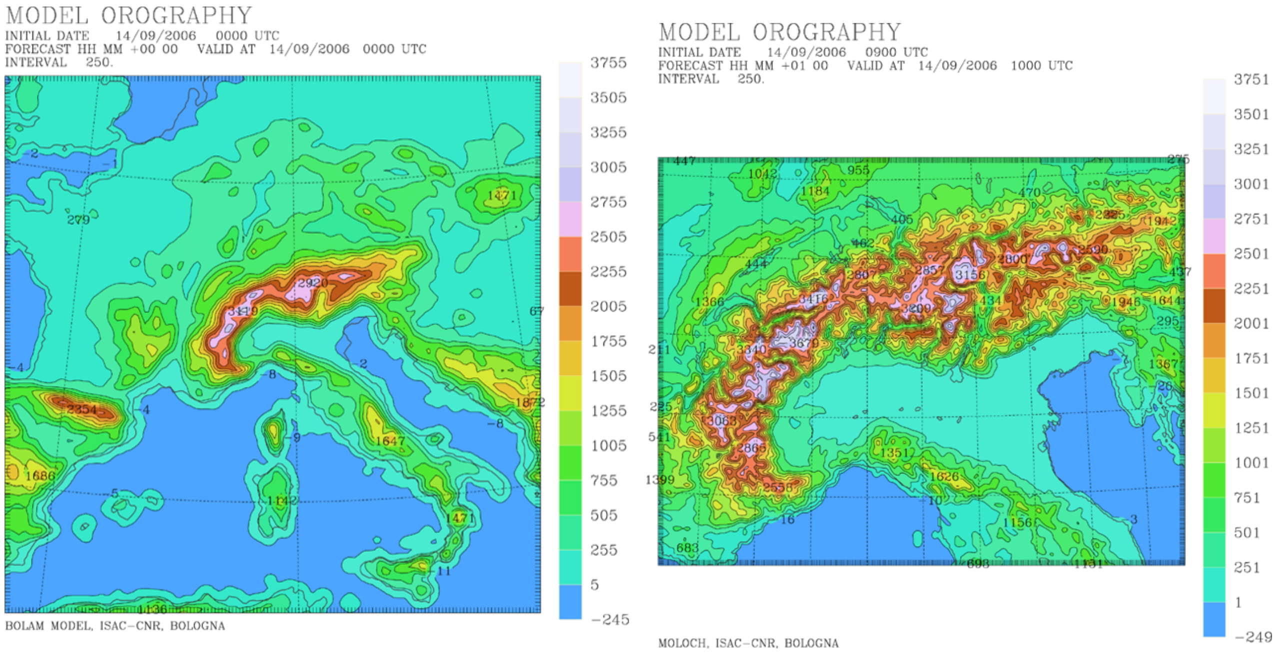

Figure 1: Left: BOLAM integration domain. Right: MOLOCH integration domain.

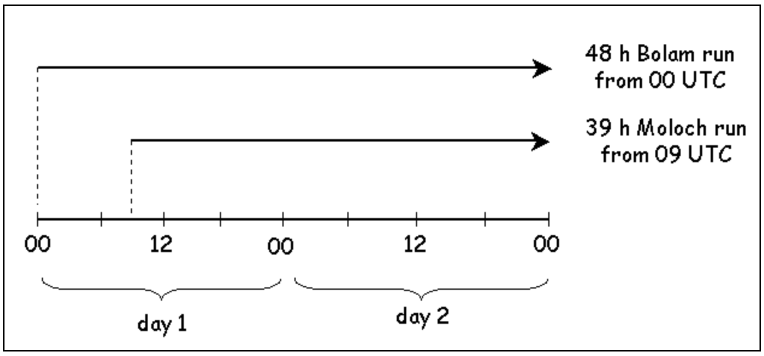

Figure 2: Current set up of the modelling chain.

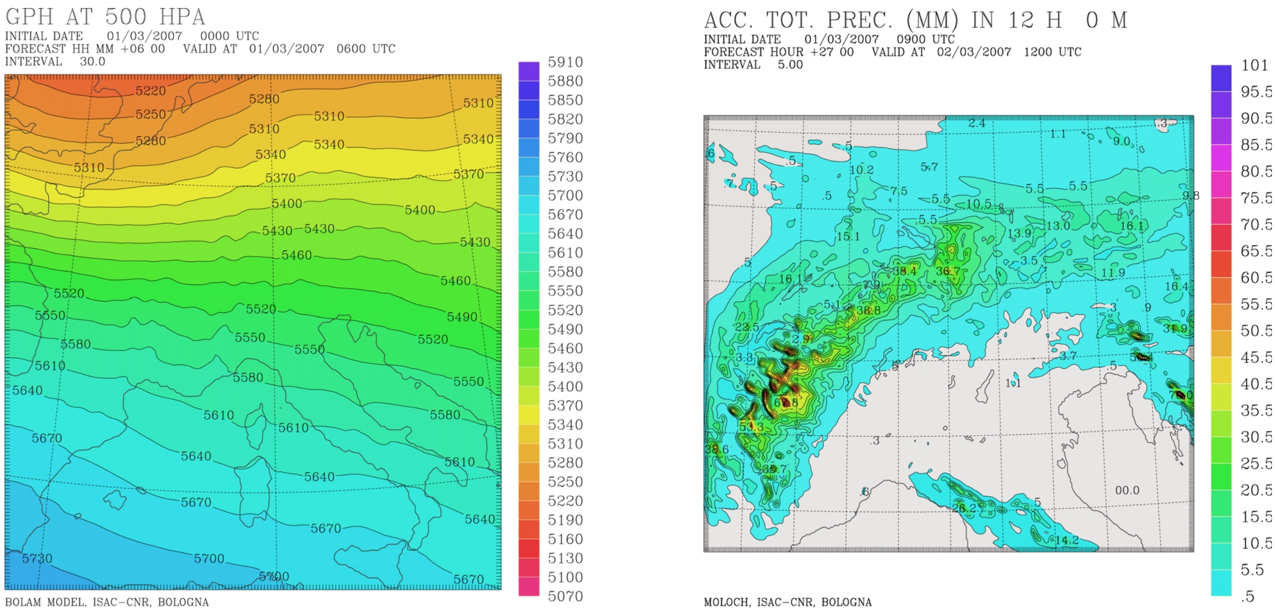

Figure 3: Left: Geopotential height at 500 hPa. Initial condition for BOLAM, valid at 00 UTC, 1 Mar. 2007. Right: 12 hours accumulated precipitation at 12 UTC, 2 Mar. 2007, as forecasted by MOLOCH.

A post-processing procedure has been implemented in order to provide the hourly output fields in GRIB format, that is the common format among all the MAP DPHASE partners. Moreover, a suitable interface using the GRADS graphical package generates both graphical output and alert files, the latter needed by the project warning system. An automatic procedure transfers the output products to the project data base.

Between 26 February and 3 March 2007, the first "dry run" of MAP DPHASE took place. With the aim of preliminary testing the distributed end-to-end forecasting system, operational simulations have been performed for a week. Prevailing and persistent zonal westerly flow in the middle troposphere (Fig. 3), prevented the occurrence of intense precipitation over the Alpine area. However, the north-western slopes of the Alps, exposed to the prevailing flow, experienced moderate amount of orographic rainfall and snowfall (Fig. 3).

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