A high-resolution data assimilation system for Mediterranean high-impact weather events: AROME West-MED.

METEO FRANCE
Toujours un temps d'avance

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

CNRM/GAME

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Motivation

The Western Mediterranean region is regularly affected by high-impact weather events such as Heavy Precipitating Events (HPE) and flash-flooding, cyclogenesis and strong winds. The contribution of fine-scale processes has been identified as a reason for the still low ability to predict such high-impact weather events. High-resolution deterministic modelling systems resolving explicitly atmospheric deep convection improve the representation of high-impact weather systems [*Ducrocq et al.*, 2002].

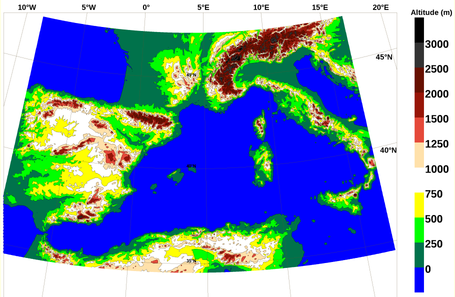
The new French operational high-resolution modelling system AROME (2.5 km) has been adapted over a large domain covering Western Mediterranean from Portugal to Sicily and from Atlas to the Northern Alps. Such large domain allows to better represent the influence of the major mountain ranges of the western Mediterranean region (Atlas, Pyrenees, Alps, Massif Central, etc.) on the atmospheric circulation as well as the contribution of the Sea to humidity and stability in the lower layers.

The main characteristics of the AROME West-MED data assimilation system and forward model are presented here. Most of the dynamic, physical and data assimilation characteristics are the same as in AROME-France. Some parameters have been recalculated to adapt to the new domain, especially for the data assimilation system configuration. The AROME West-MED simulation of the 1st November 2008 HPE is discussed below to show the capability of this new version of AROME to reproduce Mediterranean high-impact weather events.

Domain characteristics

AROME-WMED is a Limited Area Model (LAM) with a 2.5 km-grid covering the western part of the Mediterranean Sea (see the figure below) coupled hourly with the ALADIN-FRANCE model forecast (9.6 km horizontal grid mesh [Radnóti *et al.*, 1995]) on its lateral boundaries.

AROME-WMED describes the atmosphere up to about 1 hPa with 41 vertical levels.



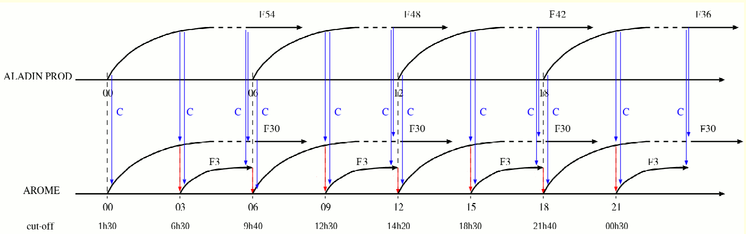
Dynamics

AROME-WMED, as AROME-France, uses a non-hydrostatic extension of the ALADIN equations [*Bubnova et al.*, 1995]. The Laprise-type formulation uses the hybrid hydrostatic pressure terrain-following as vertical coordinate and is discretised with a semi-lagrangian semi-implicit scheme. The prognostic variables are the two wind components, surface pressure, temperature, the six water species contents – specific humidity, cloud water, rain water, cloud ice cristal, snow and graupel, uni-dimensional TKE (Turbulent Kinetic Energy), vertical divergence and departure of the pressure from hydrostatism.

Data assimilation

AROME-WMED has its own data assimilation system, based on a 3D-Var scheme with an incremental formulation [*Courtier et al.*, 1994] inherited from ALADIN [*Fischer et al.*, 2005].

The AROME-WMED background error covariances are based on a multivariate formulation [*Berre*, 2000] and have been estimated using an ensemble-based method [*Berre et al.*, 2006] with a six-member ensemble of AROME-WMED 3-hour forecasts over a 30-day period. In comparison with larger-scale background errors, they have smaller horizontal correlations and increased standard deviations for model parameters representing small scale structures, such as temperature in low layers [*Brousseau et al.*, 2008]. No observation-errors correlation is taken into account.



As in AROME-France, the 3D-Var data assimilation system is carried out using a 3-hour forward intermittent cycle. A cycle consists in computing the analysis using observations within a ±1h30 assimilation window and a 3-hour forecast to serve as first-guess for the next cycle. The two wind components, temperature, specific humidity and surface pressure are analysed. Other model fields are directly cycled from the previous guess. 30-h forecast can be run from each cycle.

The AROME data assimilation system uses the following data, which are all subjected to various quality control checks (selection of stations, levels and channels; flow-dependent background departure check; redundancy check; horizontal and vertical thinning of data denser than the model grid; etc.) and bias correction:
- surface observations from land stations, buoys and ships (surface pressure and wind are assimilated, as well as 2m humidity and temperature from land stations),
- aircraft measurements at cruise level and during ascent/descent phases (temperature and wind are assimilated),
- vertical soundings from radiosondes, pilot balloons and dropsondes (temperature, wind and humidity are assimilated),
- wind from European wind profiler radars, satellite scatterometers (Quikscat, Metop/ASCAT and ERS2/AMI) and Atmospheric Motion Vectors derived from geostationary satellites (Meteosat, GOES, and MTSAT),
- doppler wind from French Doppler radars,
- European (EGVAP) ground-based GPS measurements (zenith total delays are assimilated),
- cloud-free temperature and humidity sensitive satellite radiances from polar-orbiting infrared and microwave radiometers (HIRS, AMSU, MHS and SSMI) and from the geostationary imager SEVIRI - channels sensitive to low levels are only used over sea. A current development will enable the full-resolution assimilation of SSMI data.

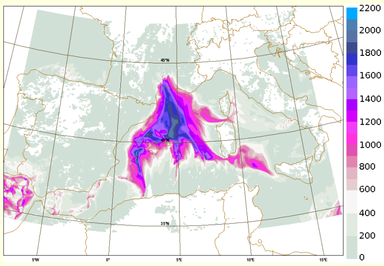
Physical parameterisations

The AROME physical package is inherited from the physical parameterisations of the Meso-NH research model [*Lafore et al.*, 1998]. Thanks to the high horizontal resolution, deep convection is explicitly resolved. The prognostic equations of the six water species (water vapour, cloud water, rain water, ice cristal, snow and graupel) are governed by a bulk mixed microphysical scheme [*Pinty and Jabouille*, 1998]. The shallow convection is parameterised according to the Eddy Diffusivity Kain Fritsch (EDKF) scheme [*Pergaud et al.*, 2007]. The turbulence parameterisation is uni-dimensional, based on a TKE equation with a 1.5-order closure [*Cuxart et al.,* 2000] and the radiative scheme adopts the RRTM parameterization [*Mlawer et al.*, 1998].

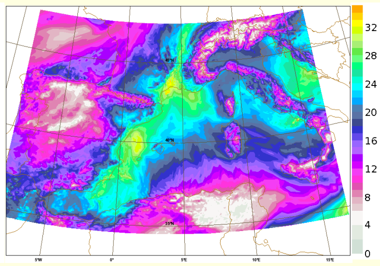
Surface parameters are computed through a two-way coupling with the externalised surface model SURFEX. The surface energy exchanges are parameterised according four different schemes depending on the surface types (nature surfaces, urban areas, ocean or lake) included in the grid mesh. The natural land surfaces are handled by the Interactions Soil-Biosphere-Atmosphere (ISBA) scheme [*Noilhan and Mahfouf*, 1996], whereas surface energy exchanges over urban surfaces are parameterised according to the Town Energy Balance (TEB) scheme [*Masson*, 2000]. Turbulent air-sea fluxes are estimated according to the ECUME parameterisation.

The 1st November 2008 HPE case

Cape (J) at 00 UTC, 02 Nov. 2008 – 18 h **AROME-WMED** forecast starting from the 06 UTC, 01 Nov. 2008 analysis

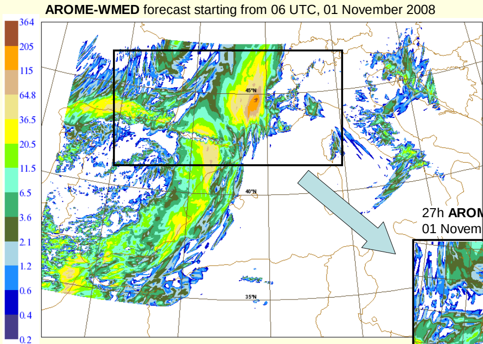


IWV (kg/m²) at 00 UTC, 02 Nov. 2008 – 18 h **AROME-WMED** forecast starting from the 06 UTC, 01 Nov. 2008 analysis



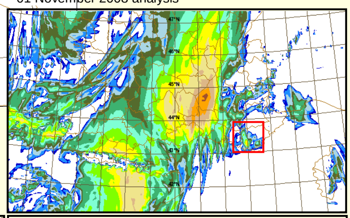
In this AROME-WMED simulation, the inflow of unstable Mediterranean air coming from as South as West-Sicilia or North-Algeria is well captured thanks to the large domain. This inflow is a key ingredient in the development of Mediterranean HPE. Its high-resolution description with AROME-WMED is therefore a real improvement as confirmed by the following 24h cumulated precipitation forecasts and observations.

AROME-WMED forecast starting from 06 UTC, 01 November 2008

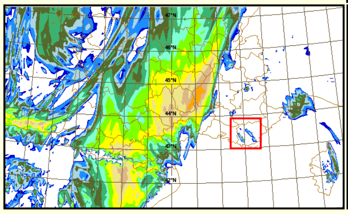


Both AROME-WMED and AROME-France simulations of the 1st November 2008 HPE are realistic. AROME-WMED one is slightly more convective. It is performing better in simulating:
- better located and orientated precipitation areas,
- a maximum of precipitation closer to the observations,
- isolated eastern cells (red square).

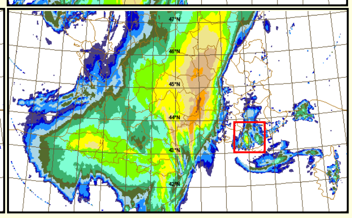
27h **AROME-WMED** forecast starting from the 06 UTC, 01 November 2008 analysis



24 h cumulated rain (mm) at 09 UTC, 02 November 2008



27h **AROME-France** forecast starting from the 06 UTC, 01 November 2008 analysis



Radar **observations**

Conclusions and outlooks

Up to now, AROME-WMED data assimilation and forward modelling system has been set up and evaluated on two HPE cases. A further study has shown even more promising results when assimilating more SSM/I data.
It is foreseen that this system will run in real-time during the HyMeX SOPs. Up to this time, studies will be carried out to improve the AROME-WMED configuration especially by fostering the integration of new research developments (surface data assimilation, additional observations assimilation such as satellite hyperspectral infrared radiances, radar reflectivity, new land cover data, etc.). The possibility of a two-way coupling of AROME-WMED with a 1D ocean model according to Lebeaupin et al (2009) will be investigated. Future work will also evaluate a coupling with the upcoming 15-km horizontal resolution version of the ARPEGE NWP operational system or other larger scale models.

References

Berre L. (2000), Estimation of synoptic and mesoscale forecast error covariances in a limited area model, *Mon. Weather Rev.*, *128*(3), 644-667.
Berre L., S.E. Stefanescu and M.B. Pereira (2006), The representation of the analysis effect in three error simulation techniques, *Tellus*, *58A*(2), 196-209.
Brousseau, P., F. Bouttier, G. Hello, Y. Seity, C. Fischer, L. Berre, T. Montmerle, L. Auger and S. Malardel (2008), A prototype convective-scale data assimilation system for operation: the AROME-RUC, *Hirlam tech. report N.68 - SRNWP workshop on data assimilation*, 23-30, Norrköping, Sweden.
Bubnová R., G. Hello, P. Bénard and J.-F. Geleyn (1995), Integration of the Fully Elastic Equations Cast in the Hydrostatic Pressure Terrain-Following Coordinate in the Framework of the ARPEGE/Aladin NWP System, *Mon. Wea. Rev.*, *123*(2), 515–535.
Courtier P., J.-N. Thépaut and A. Hollingsworth (1994), A strategy for operational implementation of 4D-Var using an incremental approach, *Q. J. R. Meteorol. Soc.*, *120*(519), 1367-1387.
Ducrocq, V., D. Ricard, J.-P. Lafore. and F. Orain (2002), Storm-scale numerical rainfall prediction for five precipitating events over France: on the importance of the initial humidity field, *Wea. Forecasting*, **17**, 1236-1256
Fischer C., T. Montmerle, L. Berre, L. Auger and S.E. Stefanescu (2005), An overview of the variational assimilation in the ALADIN/France numerical weather prediction system, *Q. J. R. Meteorol. Soc.*, *131*(613), 3477-3492.
Lafore J.-P., J. Stein, N.Asencio, P.Bougeault, V.Ducrocq, J.Duron, C.Fischer, P.Héreil, P.Mascart, V.Masson, J.-P.Pinty, J.-L.Redelsperger, E.Richard & J.Vilà-Guerau (1998), The Meso-NH Atmospheric Simulation System. Part I: adiabatic formulation and control simulations, *Ann. Geophys.*, *16*, 90-109.
Radnóti G., R. Ajjaji, R. Bubnová, M. Caian, E. Cordoneanu, K. von der Emde, J.-D. Gril, J. Hoffman, A. Horányi, S. Issara, V. Ivanovici, M. Janousek, A. Joly, P. LeMoigne and S. Malardel (1995), The spectral limited area model ARPEGE-ALADIN, *Proc. PWPR Rep. Series 7, WMO TD*, *699*, 111-118.

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