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MEDITERRANEAN OCEAN FORECASTING SYSTEM: TOWARD ENVIRONMENTAL PREDICTION

MFSTEP

# Project Deliverable Report D4

# WP10: Atmospheric Forcing and Air-Sea Interaction Studies

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|---|---|---|---|---|---|
| **Project title** | **MEDITERRANEAN OCEAN FORECASTING SYSTEM: TOWARD ENVIRONMENTAL PREDICTION** | | | | |
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| **Deliverable title** | **LAM2 model implemented in the Eastern Med. area** | | | | |
| **Work package** | **WP10 Atmospheric Forcing and Air-Sea Interaction Studies** | | | | |
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## 1) Introduction

This report describes the work performed under the scopes of deliverable 4 of WP10. This work package contains the necessary activities to create and deliver the atmospheric surface fields to the WP8 and WP9 ocean modelling community, and to define and perform the Severe Verification Period (SVP) intercomparison of atmospheric models. The aim of this sub-task (deliverable 4) is to implement the LAM2 modeling system with a grid increment of 10 km in the Mediterranean region in order to provide meteorological forecasts to the ocean modelers.

The IASA/AM&WFG group will utilize the nonhydrostatic SKIRON/Eta modelling system at high-resolution during the SVP and the Targeted Operational Period (TOP). The model output will become available through the MFSTEP-WP10 webpage (http://forecast.uoa.gr/mfstep/) and through a project dedicated ftp server.

## 2) The SKIRON/Eta modeling system

The SKIRON/Eta modeling system has been developed for operational use at the AM&WFG/IASA. The implementation of the system requires Unix computational environment and corresponding meteorological data input. The current version of the Eta model is appropriately coded in order to run on any parallel computer platform utilizing any number of processors (Kallos et al. 1997b). The system has been developed in order to operate as fully automatic.

The SKIRON/Eta system is based on the Eta/NCEP model. A detailed description of its characteristics and configurations is to be found in Kallos (1997), Nickovic et al. (1998), Papadopoulos et al. (2002) and others.

The model has several unique capabilities making it appropriate for regional/mesoscale simulations in regions with varying physiographic characteristics. It has the unique capability to use either a "step-mountain" vertical coordinate (Mesinger 1984) or the customary pressure or sigma (or hybrid) coordinate. The SKIRON/Eta modeling system is also including dust cycle capabilities. The hydrostatic version of the system is successfully used operationally in the University of Athens since 1997, as well as in applications of simulations of historical dust-storm events (Nickovic et al. 2001). During the last years, mercury cycle modules have also been incorporated to the SKIRON/Eta system providing forecasts of the concentration and deposition of mercury in Europe and USA (Kallos et al. 2001; Voudouri et al. 2003).

The main features of the system that was implemented in the Mediterranean region in the framework of MFSTEP project are briefly described in the following sections.

**2.1) Model geometry and dynamics**

- The model variables are represented on the staggered Arakawa E-grid. It has been shown by Winninghoff (1968) and Arakawa and Lamb (1977) that various horizontal grids simulate differently large and synoptic scale atmospheric processes. It was demonstrated that the grids E and C (and also the B grid which is equivalent to E) have advantages relative to the A and D grids. The grid separation related to the E grid is avoided by the use of a special technique (Mesinger 1973; Janjic 1974, 1979).
- For horizontal advection the cascade process of non-linear energy toward smaller scales is under control.
- The "step-mountain" Eta coordinate is used in the vertical. The schematic picture of the eta coordinate mountains, as well as the distribution of the variables in the vertical is shown in Figure 1.

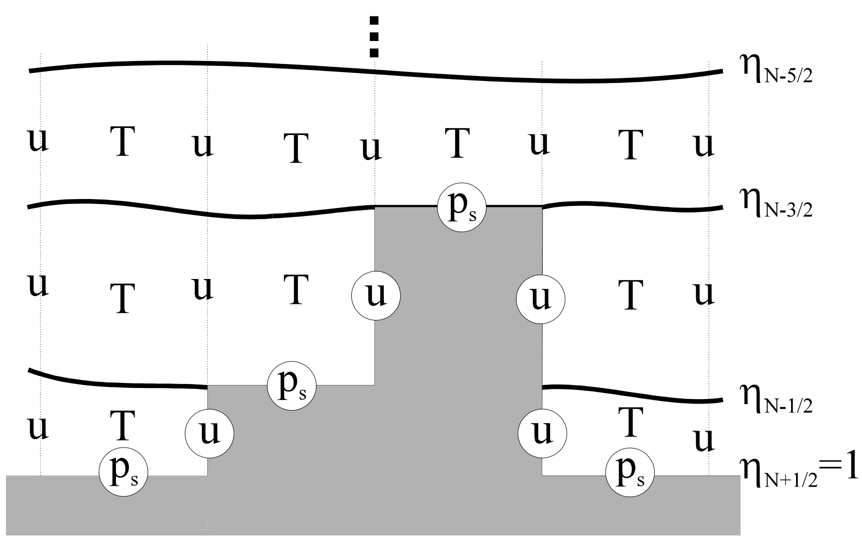


***Figure 1.*** *The eta vertical coordinate system and the distribution of the model variables in the vertical*

The eta coordinate system is proposed as a response to a problem related to the sigma terrain-following coordinate when applied to steep mountain areas. This problem appears as a result of the errors associated with the implied vertical interpolation of geopotential from sigma to pressure surfaces and can generate significant errors in the vicinity of the steep model mountains. In contrast to the sigma surfaces, the constant eta coordinate surfaces are quasi-horizontal in both mountainous and non-mountainous areas. Thus, it may be considered that the eta coordinate represents a more natural alternative to the widely used sigma system for ever-increasing horizontal and vertical model resolution, accompanied by a need to have more realistic model mountains.

- The arithmetic solution of the set of equations is performed in a grid point model using a finite difference scheme.
- A split-explicit scheme is used for time differencing. More specifically, a “forward-then-centered time” time differencing scheme is used for the horizontal advection. For the vertical advection of temperature, specific humidity, turbulent kinetic energy and horizontal momentum, the Euler-backward (Matsuno) scheme is used.
- The model includes the option to use either the hydrostatic assumption or nonhydrostatic dynamics. In the framework of the MFSTEP project the model physics will include nonhydrostatic dynamics (Janjic et al. 2001). The nonhydrostatic model appears to be computationally robust at all resolutions and efficient in NWP applications. The use of nonhydrostatic dynamics is an important improvement especially for high-resolution simulations in which the non-hydrostatic processes may exert a significant influence on the meteorological fields. In high-resolution simulations the nonhydrostatic model is generally more robust than the hydrostatic one and produces smoother solutions

**2.2) Physical parameterizations**

There is a large number of physical processes that cannot be explicitly modeled despite the high horizontal resolution that will be used in the MFSTEP forecasts. These processes must be included if an accurate representation of the atmospheric flow is expected. Hence, they are included in the model through parameterization schemes. In the SKIRON/Eta model there is a large number of such schemes:

- The boundary layer is parameterized using a 2.5 order closure scheme proposed by Mellor and Yamada (1982).

- A 2nd order closure scheme proposed by Mellor and Yamada is used to parameterize the surface layer.
- A viscous sublayer scheme is used over ground and water surfaces in order to improve the calculation of the surface fluxes. The method proposed by Zilitinkevich (1995) is used over ground points, specifying an effective roughness length as a function of the flow regime and of the grid-box orography variation. The viscous sublayer over water surfaces in the Skiron/Eta model is designed by matching the log profile of the considered variables with a separate viscous sublayer profile (Janjic 1994).
- The surface processes are parameterized using advanced schemes. The soil temperature and moisture are calculated at six layers extending from the surface down to 255cm. A data assimilation scheme for soil temperature and soil wetness has been recently developed.
- The parameterisation of the subgrid scale convective processes is allowed to use either the modified Betts-Miller-Janjic or the Kain-Fritsch approach. Both schemes take into account deep and shallow convection. In the framework of MFSTEP project, the model will be integrated using the Betts-Miller-Janjic convective parameterization which was extensively tested in pseudo-operational mode runs during the last months.
- The large-scale cloud and precipitation parameterization is based on the scheme of Zhao and Carr (1997). In this scheme cloud water and ice are prognostically calculated in the stratiform clouds. Precipitation is diagnosed directly from the cloud water/ice content. Two types of precipitation, rain and snow, are calculated in the scheme. Evaporation of clouds and precipitation and snow melting below the freezing level are allowed by the model.
- The radiative fluxes are calculated using the GFDL radiation scheme (e.g. Schwarzkopf and Fells 1991). Three radiatively active gases of the atmosphere (water vapour, carbon dioxide and ozone) are considered. The GFDL scheme takes into account the cloud information supplied by the parameterization of moist processes allowing random overlapping of clouds at various levels.

**2.3) Surface characteristics**

High resolution topography, vegetation and soil data are used. The topography and vegetation data are available from USGS with a resolution of 30x30 arc sec, with the later following the SiB classification (Dorman and Sellers 1989; Table 1). For soil textural class the UNEP/FAO dataset

(2x2 arc min) is used after its conversion from soil type to soil textural ZOBLER classes (Zobler 1986; Table 2).

| Type | Vegetation/land | Albedo | $Z_0$ | $RC_{min}$ | $R_{gl}$ | hs |
|---|---|---|---|---|---|---|
| 1 | Broadleaf-evergreen trees (tropical forest) | 0.11 | 2.653 | 150 | 30 | 41.69 |
| 2 | Broadleaf-deciduous trees | 0.19 | 0.826 | 100 | 30 | 54.53 |
| 3 | Broadleaf and needleleaf trees (mixed forest) | 0.16 | 0.563 | 125 | 30 | 51.93 |
| 4 | Needleleaf-evergreen trees | 0.13 | 1.089 | 150 | 30 | 47.35 |
| 5 | Needleleaf-deciduous trees (larch) | 0.19 | 0.854 | 100 | 30 | 47.35 |
| 6 | Broadleaf trees with groundcover (savanna) | 0.19 | 0.856 | 70 | 65 | 54.53 |
| 7 | Groundcover only (perennial) | 0.19 | 0.075 | 40 | 100 | 36.35 |
| 8 | Broadleaf shrubs with perennial groundcover | 0.29 | 0.238 | 300 | 100 | 42.00 |
| 9 | Broadleaf shrubs with bare soil | 0.29 | 0.065 | 400 | 100 | 42.00 |
| 10 | Dwarf trees and shrubs with groudcover (tundra) | 0.14 | 0.076 | 150 | 100 | 42.00 |
| 11 | Bare soil | 0.15 | 0.011 | 999 | 999 | 999 |
| 12 | Cultivations (the same parameters as the type 7) | 0.19 | 0.075 | 40 | 100 | 36.35 |
| 13 | Glacial | 0.15 | 0.011 | 999 | 999 | 999 |

***Table 1.*** *Sib vegetation types*

| Type | Soil type | $SMC_{max}$ | $\Psi_{sat}$ | b | $SMC_d$ | SATDK ($10^{-5}$) |
|---|---|---|---|---|---|---|
| 1 | Coarse | 0.421 | 0.04 | 4.26 | 0.07 | 1.41 |
| 2 | Medium | 0.464 | 0.62 | 8.72 | 0.14 | 0.20 |
| 3 | Fine | 0.468 | 0.47 | 11.55 | 0.22 | 0.10 |
| 4 | Coarse-medium | 0.434 | 0.14 | 4.74 | 0.08 | 0.52 |
| 5 | Coarse-fine | 0.406 | 0.10 | 10.73 | 0.18 | 0.72 |
| 6 | Medium-fine | 0.465 | 0.26 | 8.17 | 0.16 | 0.25 |
| 7 | Coarse-medium-fine | 0.404 | 0.14 | 6.77 | 0.12 | 0.45 |
| 8 | Organic matter | 0.439 | 0.36 | 5.25 | 0.10 | 0.34 |
| 9 | Land ice | 0.421 | 0.04 | 4.26 | 0.07 | 1.41 |

***Table 2.*** *Zobler soil types*

The model also allows the use of high resolution NCEP SST data of 0.5 degrees, high-resolution NESDIS snow and ice cover data and US Air Force snow depth analysis data. These products are available daily in standard WMO grib format.

The SST dataset is produced on a 0.5° (latitude-longitude) grid by an optimum interpolation analysis of the most recent 24-hours receipts of buoy and ship data, satellite-retrieved SST data and SSTs derived from satellite-observed sea ice coverage. The SKIRON/Eta modeling system has also been prepared to use alternatively the lower resolution (1°) NCEP SST dataset and the 0.5° ECMWF SSTs. It has been shown that the use of the high resolution SSTs by ETA model resulted to improved forecasts of storm track and precipitation over Eastern US (Thiebaux et al. 2003). Sensitivity tests performed by the SKIRON/Eta model during the pseudo-operational mode runs indicated the superiority of the 0.5° SSTs. The importance of high resolution SST data in high resolution modeling in the Mediterranean region will be investigated extensively in MFSTEP project.

## 2.4) Model domain

The computational model domain will cover the whole Mediterranean Region and part of Central Europe (Figure 2). In the horizontal, a grid increment of 0.1 degrees is applied. The coverage of each sub-area depends on the horizontal grid increment, which in our case is of about 10x10 $km^2$. Because of the high horizontal resolution a timestep of 30 sec is used. In the vertical, 38 levels are used stretching from the ground to the model top at 25 mb (corresponding approximately to 25 km) or optionally to 50 mb (~20 km). The large number of vertical levels is expected to provide a good vertical representation of the physical processes especially within the atmospheric boundary layer.

The computational domain was chosen to extend to the west much further than the original dissemination[1] domain because it is well known that during all seasons synoptic systems or air-masses originating over western Mediterranean (Gulf of Genova, Atlas mountains etc.) strongly affect the weather of eastern Mediterranean (e.g. Kallos et al., 1997a).

Sensitivity experiments using different domains showed the superiority of the domain of Figure 2. The use of smaller domains did not allow many low pressure systems emerging from western Mediterranean to develop fully. In this case the LAM predictions depended strongly on the lateral boundary conditions that were provided by the coarser model. Therefore fields which are important to the ocean modelers, such as the wind speed or the precipitation, were usually under estimated. The errors were mainly associated with the intensity and not with the track. On the other hand, simulations with domains larger than that of Figure 2 were not always associated with better forecasts but they required significantly more integration time. The integration time is going to be a very important parameter in the operational phase of MFSTEP.

[1] According to the Description of Work the SKIRON/Eta model was planned to provide meteorological forecasts in the Mediterranean region east of 18°E. In the beginning of the TOP period, IASA, Meteo-France and CHMI decided that both SKIRON/Eta and Alladin models will provide forecasts for the whole Mediterranean and Black sea regions.

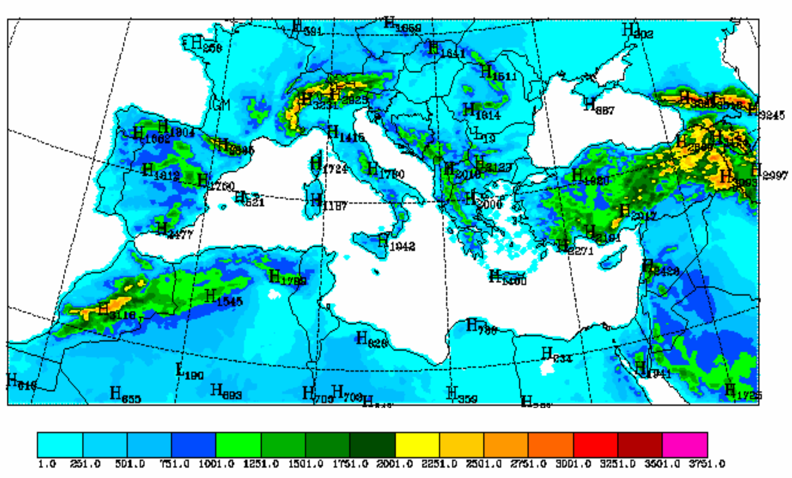

*Figure 2. The topography of the computational model domain of Skiron.*

**2.5) Initial and Boundary conditions**

During the TOP SKIRON/Eta and Aladin models will produce 120-hour forecasts initialized every Wednesday from the 0000 UTC ARPEGE analyses. In SKIRON/Eta the initialization of the soil moisture content and the soil temperature will be performed using the 24-hour forecast of the run of the previous day. It needs to be noted that everyday IASA will integrate the model for 3-days using the ARPEGE analyses and forecasts as initial and boundary conditions in order to update the soil properties on a daily basis. The sea-surface temperature field will be forced by the daily 0.5° latitude x 0.5° longitude NCEP SSTs and it will remain fixed to its initial value throughout each simulation. The lateral boundary conditions will be based on the ARPEGE forecasts and will be updated every 3 hours. The ARPEGE analyses and forecasts that will be used for initial and lateral boundary conditions will be provided by Meteo-France at a horizontal resolution of 0.25x0.25 degrees. The fine resolution of the initial data is expected to be an important factor of these forecasts because it will reduce the spin-up time of the LAMs.

IASA has produced special algorithms to pre-process the boundary conditions provided by Meteo-France. The boundary conditions that will be used for the daily SKIRON/Eta forecasts (except from Wednesday) are provided in a frame based format. Figure 3 illustrates the 96-hour forecast of geopotential height (gpm) from 0000UTC on 6/10/03 provided by ARPEGE in frame format. These algorithms have been tested extensively since it is well known that the boundary conditions are very important in limited area modeling.

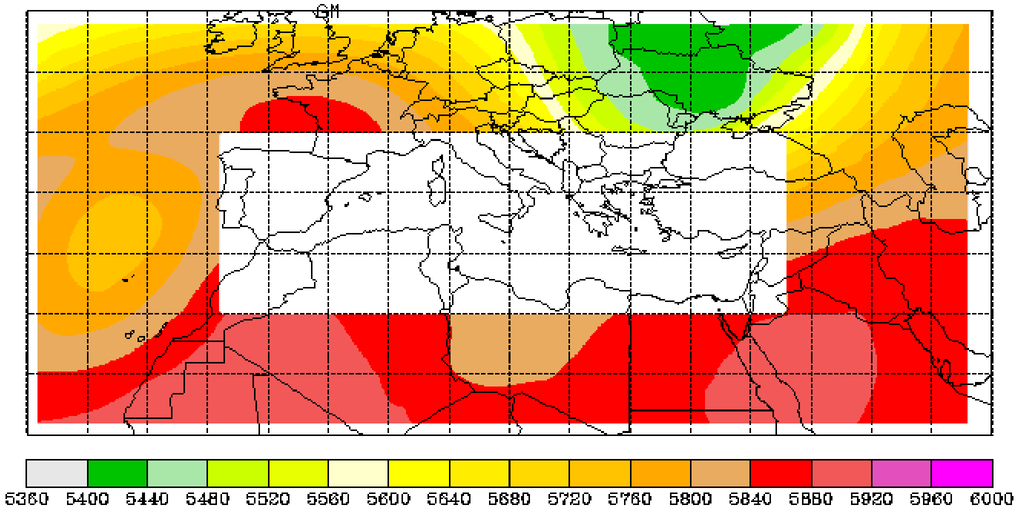


***Figure 3.*** *96-hour forecast of geopotential height (gpm) provided by ARPEGE model in Frame format. Initial time: 0000 UTC, 6/10/03.*

The high-resolution SKIRON/Eta modelling system will run parallel at the computer facilities of IASA. Specifically, a cluster of ten (10) dual-CPU nodes based on ATHLON-1900 processors will be used and has been configured in order to handle large data storage, namely a RAID 4:1 system handling approximately 350 GBYTE of data on line. The system will be exclusively available for the scope of the project. The system is connected to a high-speed network (1 Gbit/sec the slowest network section). The SKIRON/Eta modeling system will run parallel in order to achieve the highest performance.

The setup of the nonhydrostatic SKIRON/Eta modelling system has finished and all the hardware/software components have been tested in a pseudo-operational mode. The performance of the model is currently tested through the Scientific Verification Period hindcasts and it will be documented extensively in the following months.

## 3) Future Work

The works planned for the first half of 2004 are firstly the finalization of the production of the SVP hindcasts using the nonhydrostatic SKIRON/Eta modeling system and the verification of the model. IASA together with Meteo France and CHMI will also produce operationally and distribute the necessary high resolution forecasting products to the partners as raw data and graphics. Finally, the effects of high resolution SSTs on the model performance will be investigated in cooperation with UAT.

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