Application of a non-hydrostatic mesoscale meteorological model to the Aveiro Region, Portugal

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ABSTRACT

A meteorological campaign was performed around the Aveiro lagoon with the aim of studying the developmemt of the sea breeze circulation. The mesoscale meteorological model MEMO, is being applied to this region. The results of a simulation without geostrophic forcing are presented.

INTRODUCTION

During the last 5 years, the University of Aveiro has directed a significant interest towards the analysis of regional air quality problems[1]. The major goal is the study of atmospheric dispersion patterns and particularly the analysis of photochemical pollution episodes, through the application of adequate dispersion modeling techniques at an interregional scale.

The Urban Airshed Model has been used to analyse photochemical air quality in the area of Lisbon. Preliminaries episode simulations have been carried out and reported[2,3]. Emissions and meteorological inputs for this simulation were relatively crude; maximum simulated ozone concentrations were considerably lower than those observed. The analysis of these results stresses the need of focussing the research activities on a few items:

- in order to incorporate mesoscale atmospheric circulations it is necessary to obtain a more detailed meteorological information than the available in dispersion models pre-processors;

- models at this scale require very detailed emission data. Available emission data has to be temporally, spatially and chemically discretized in order to comply with the requirements of these models;

- most models were developed for the study of urban air pollution, underestimating the effects of natural emissions and the existence of natural (rural and forest) atmospheric chemistry mechanisms. Natural emissions might have a crucial role on photo-oxidant formation in Southern Europe;

- most of the air quality monitoring stations of Portugal are located in the vicinities or in the interior of industrial complexes, strongly affected by their emissions.

Current effort is focused on the generation of improved meteorological inputs. In fact, dispersion grid models require a gridded representation of meteorology (wind, temperature and vertical mixing conditions) within a space/time modeling domain. Routine meteorological observations in high-smog areas are frequently insufficient to represent complex mesometeorological patterns. Mesoscale meteorological models represent these patterns through direct simulation of atmospheric physical processes. These models can provide continuous, physically realistic meteorological fields for input to dispersion grid models.

MODELING REGION

In order to avoid the complexity of the Lisbon region it was decided to select, as a first stage for the application of mesoscale meteorological models in Portugal, an area with a simpler coastline and terrain. As a result of this, the Aveiro region was selected due to its topographical characteristics and surface meteorological data availability.

The region under study is a coastal area in the central part of Portugal.The topography (see figure 1) is dominated by a large lagoon which extends around 35 km in the North-South direction. The western part of this region, surrounding the Aveiro lagoon, is relatively flat. The eastern part of the domain is characterized by rough terrain that follows 3 small mountain ranges: Serra da Arada (reaching 1119 m above sea level), Talhadas (804 m) and Serra do Caramulo (1071 m). The topography is also affected by the river Vouga which cuts a deep valley between the Serra de Arada e Talhadas. This valley is clearly seen in figure 2.

METEOROLOGICAL CAMPAIGN

A meteorological campaign was conducted between August 24th and September 10th 1992 in the Aveiro region. A measurement network (see figure 2) was in continuous operation throughout this period.

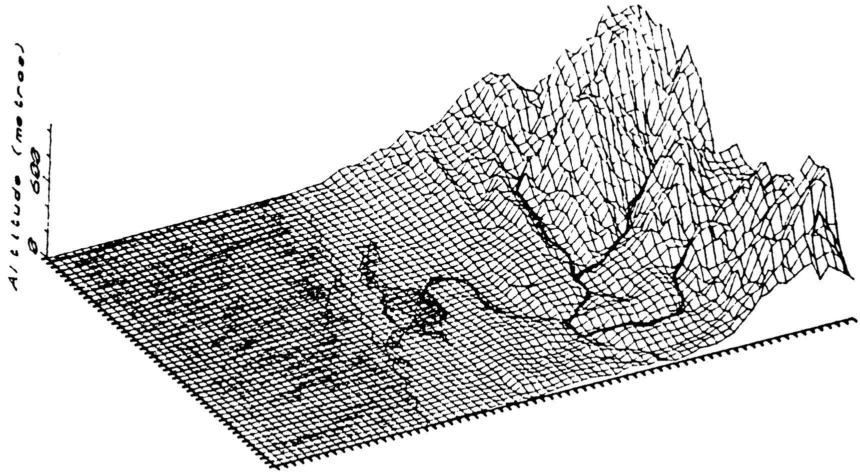

Figure 1. Topographic view of the Aveiro region. Greyish areas represent water (the ocean, the lagoon and the rivers)

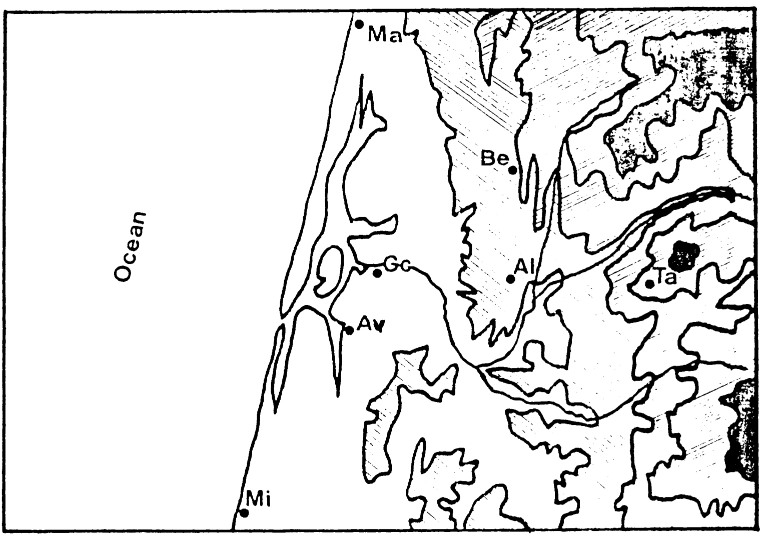

Figure 2. Geographic features of the region of Aveiro. Topographical isolines are shown for 0, 50, 100, 200, 400 and 800 m. The location of the meteorological measurements sites is also represented. (1 cm = 6 km)

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Surface stations
Surface measurements were performed on 5 stations surrounding the Aveiro lagoon:

Cacia (Cc) - Altitude 4m. Hourly measurements of wind (W), temperature (T) and humidity (H) at 10 and 30 m.

Bemposta (Be) - Altitude 230 m. Hourly measurements of W at 12 m.

Talhadas (Ta) - Altitude 350 m. Half-hourly measurements of W, T and H on a 8.5 m mast.

Maceda (Ma) - Altitude 5m. Hourly climatological data between 0600 and 1800 LST.

Mira (Mi) - Altitude 5 m. Continuous wind measurement on a 10 m mast.

Vertical soundings
In addition to the surface network outlined above, vertical profiles of wind were obtained in 2 locations:

Aveiro (Av) - Altitude 5 m. Doppler sodar, used for measuring the wind profiles in the first few hundred meters. Radiosoundings (W, T and H) were made at 0900, 1200, 1700 and 2000 LST. During typical sea-breeze days pilot balloons at 1030 and 1400 LST were released.

Albergaria (Al) - Altitude 100 m. Doppler sodar measurements and release of pilot balloons at 0900, 1200, 1700 and 2000 LST.

MESOSCALE METEOROLOGICAL MODELING

The model selected consists of the non-hydrostatic prognostic mesoscale model MEMO[4,5], developed by the University of Karlsruhe.

For the calculation of the wind field a modeling domain of 72x48x6 km was chosen. Two different horizontal resolution with a grid spacing of 2 and 4 km leading to 36x24 and 18x12 horizontal grid points were considered. In the vertical direction the grid consists of 20 layers and is non-equidistant with a minimum spacing of 20 m near the ground. The timestep is 15 s for the 2 km grid simulation and 30 s for the 4 km grid simulation.

The MEMO model
Within MEMO, the conservation equations in the atmosphere for momentum, mass and scalar quantities as potential temperature, turbulent kinetic energy and specific humidity are solved numerically. The result shown in this paper

were obtained with the model version using the Boussinesq approximation. For the calculation of the turbulent diffusion, K-theory is applied. The exchange coefficients for momentum and scalars are computed with an one-equation turbulence model. At roughness height z_0 similariry theory is applied where u^* and θ^* are calculated from the Businger equations.

The governing equations are solved in terrain-following coordinates. The model MEMO includes an efficient numerical scheme for the calculation of the atmospheric radiative heating/cooling rates and of the radiative fluxes at ground level for both clear and polluted or cloudy atmosphere. The land surface temperature is computed from the surface heat budget equation. For the calculation of the soil temperature, a one-dimensional heat conduction equation for the soil is solved. Water temperature is kept constant during a simulation.

Meteorological situation analysed

At the moment of the preparation of this paper the data set containing the information obtained during the meteorological campaign was not yet available for processing. As a result of this, this work covers the simulation of a typical day with weather favorable for the development of a sea breeze. Under typical Summer conditions the the weather is dominated by the high pressure system of the Azores and the formation of the Iberian thermal low. It is important to indicate that the surface winds generated as a result of the formation of the thermal low have been observed to be ageostrophic for most occasions.[6]

The simulations were performed for a 20 hr period starting at 0400. A very weak synoptic wind was defined (u_g=0.1 m/s, v_g=0.1 m/s) in order to analyse the effect of the mesoscale forcing. This wind was kept constant during the whole simulation.

Simulation results

Simulations with a horizontal resolution of 2 and 4 km have been performed. Surface wind fields for these two runs at 1000 and 1200 LST are shown in figures 3 to 6.

A qualitative comparison of both resolutions show that the 4x4 km resolution does not seem very adequate to simulate the wind field in this region. Nevertheless, the main features of the sea/land breeze system are resolved and the coarser simulation can be used as a fast working tool, when working in relatively small computers.

The 2x2 km resolution run enhances the effect of the lagoon in the sea breeze front penetration (see figure 5). It seems that the lagoon acts as an important heat reservoir and that the model "sees" it as a concavity of the coastline. At 1200 (see figure 6) the sea breeze is well developed and a

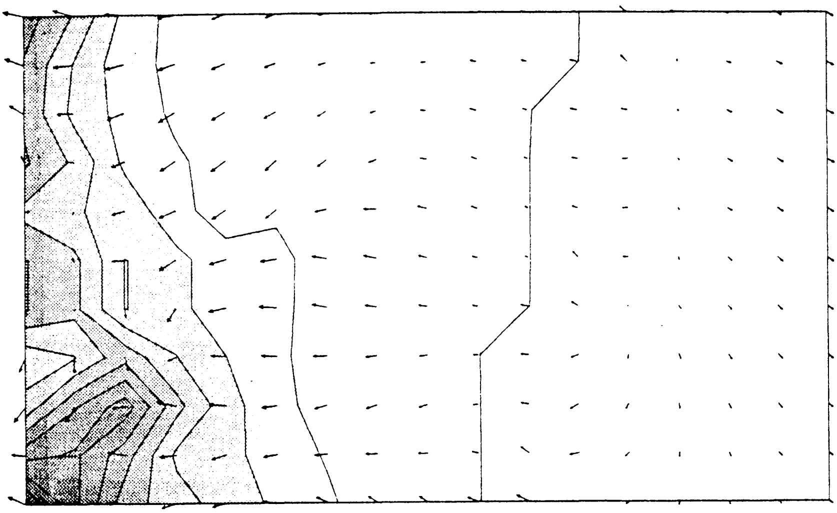

Figure 3. Computed surface wind field with 4 km resolution at 1000 LST.

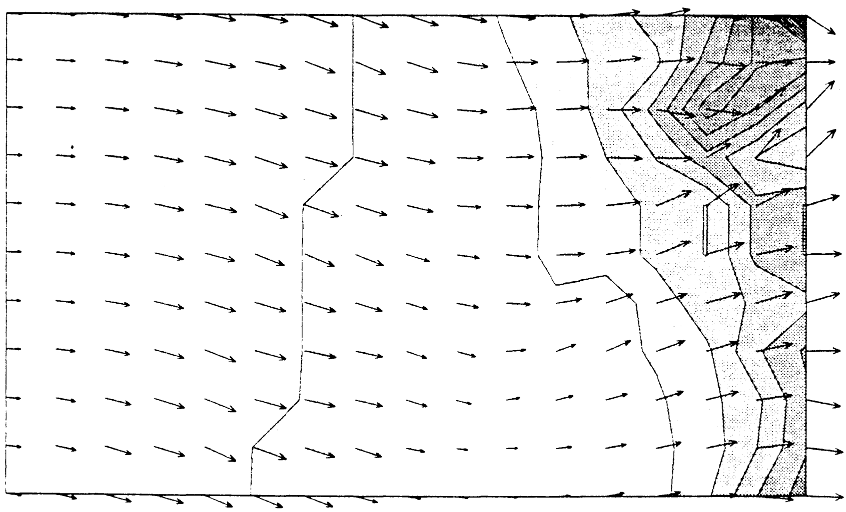

Figure 4. Computed surface wind field with 4 km resolution at 1200 LST.

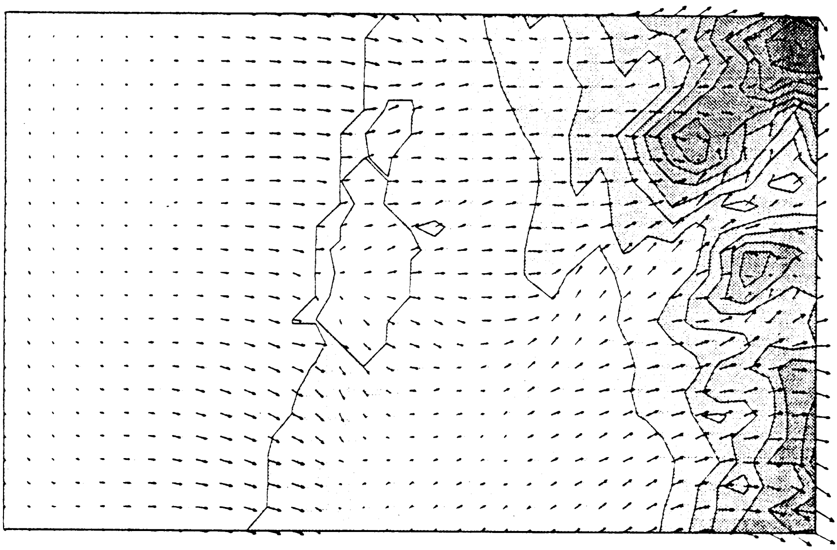

Figure 5. Computed surface wind field with 2 km resolution at 1000 LST.

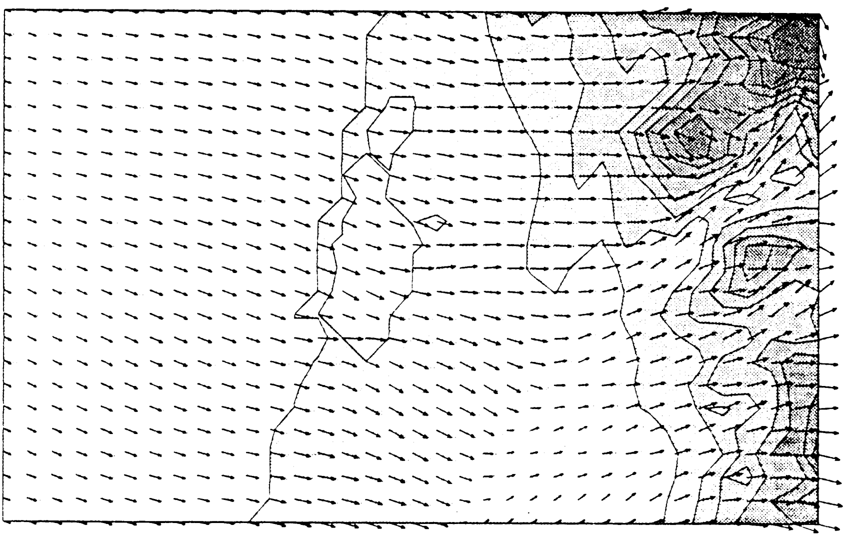

Figure 6. Computed surface wind field with 2 km resolution at 1200 LST.

chanelling effect on the Vouga valley is visible.

CONCLUSIONS

In this paper is described a meteorological campaign performed in the region of Aveiro, Portugal. The main aim of the campaign was the study of sea breeze development. Due to a delay in the processing of the data measured during the meteorological campaign it is not possible at the moment to compare the simulation results with real data.

Simulation results with different horizontal resolutions (2 and 4 km) are presented for a typical Summer day with no geostrophic forcing. The comparison of both resolutions plots show that the 4 km resolution can be used as a first and fast analysis in a mesoscale modeling study.

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