A METEOROLOGICAL BASED VALIDATION OF ARPS DURING ESCOMPTE 2001: A CASE STUDY FROM IOP2A AND IOP2B

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INTRODUCTION

Because of the importance of meteorology to air quality, meteorological fields produced by mesoscale models require a proper validation before use in air quality modeling. These models need numerous input data, with a deciding role not only for the quality of the data, but also for the spatial and temporal resolution. Simulations with meteorological models optimize the spatial and temporal resolution needed for air quality and chemistry-transport models. Therefore, a validation of meteorological parameters and energy fluxes is of great concern.
From that perspective, the Atmospheric Regional Prediction System (ARPS), a non-hydrostatic mesoscale meteorological model, is run for the Marseille-Berre Pond region (France). The ARPS model is run at a spatial and temporal resolution of 1km and 1h respectively and its performance is mainly validated with observations of temperature, wind speed and direction and vapour pressure collected during the ESCOMPTE (Expérience sur Site pour COntaindre les Modèles de Pollution atmospherique et de Transport d'Emissions) campaign (Cros et al., 2004) (Figure 1). Field measurements are described, followed by a description of the mesoscale model ARPS. The next section compares the model results with the measurements. The last section deals with sensitivity tests describing the influence of increasing sea surface temperature on mesoscale meteorological model outputs.

FIELD MEASUREMENTS

Measurements were taken from the ESCOMPTE database from 20 June 2001 to 26 June 2001, during the intensive IOP2a & b measurement period, which is characterized by dry and warm air masses (high pressure conditions), developing sea breezes and low wind speeds. The proximity of the Mediterranean Sea and the mountains surrounding the region make the geographically setting extremely complex (Cros et al, 2004; Lemonsu et al, 2004). Therefore, three fixed surface stations are used, namely the measurements sites of Marseille Centre, Trets and Meyrargues (Figure 1). They are selected because of their diversity in respect to location, surface characteristics and measurement heights (Table 1).

Table 1: Characteristics of measurement stations used for the validation of ARPS.

Site	Coordinates		Height asl (m)	Soil cover
Marseille Centre	43.30°N	5.379°E	70	Central Urban Site – Roof of CAA (gravel)
Trets	43.267°N	5.419°E	264	Grass terrain in municipal stadium
Meyrargues	43.39°N	5.32°E	196	Maize field

In Marseille Centre, a pneumatic tower was installed on the roof of CAA (Administrative Court of Appeal). Data used for this study are temperature, wind speed and direction, vapour pressure and heat fluxes, with turbulent fluxes determined by the Eddy Covariance method (Grimmond et al, 2004; Lemonsu et al, 2004). For the Meyrargues region, measurements are taken in a maize field located 30km North of Marseille over an area of 13ha. The surrounding areas were cropland in a flat terrain, the Durance Valley. A standard meteorological station provided the meteorological measurements whereas fluxes are estimates from the covariance between the vertical wind speed measured with a 3D sonic anemometer (solent 1012R2, Gill Instruments, UK) (Michou et al, 2005). For Trets, only wind speed and direction, air temperature and vapour pressure are available, measured on a grass terrain of the municipal stadium.

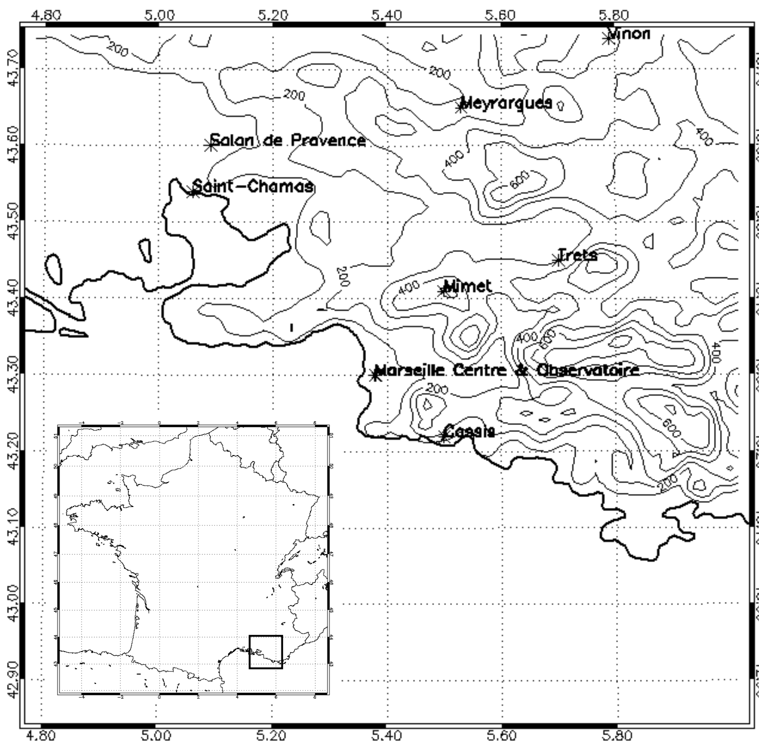

Fig. 1: Orographic map (height isocontours) of the ARPS simulation area, with some measurement stations.

MESOSCALE MODEL ARPS

The Advanced Regional Prediction System (ARPS) is a non-hydrostatic mesoscale meteorological model developed at the Center for Analysis and Predictions of Storms (CAPS) at the University of Oklahoma (Xue et al, 2000,2001). At Vito, an advanced land surface scheme (De Ridder & Schayes, 1997) was incorporated in ARPS to study the impact of land use changes on atmospheric circulations and pollutant dispersion. This land surface scheme calculates the interactions between the land surface and the atmosphere, including the effect of vegetation (represented using the big-leaf approach) and soils on the partitioning of incident radiant energy between the turbulent fluxes of sensible and latent heat, and the heat storage flux. Terrain heterogeneity within a model grid cell is accounted for by separately calculating energy fluxes for bare soil and vegetation, obtaining the grid-average flux as a weighted mean using fractional occurrence of each weight. For better modelling urban areas, the land scheme model is upgraded by De Ridder and Lefebre (2003). Cities are presented as bare soil, though with the appropriate values for the albedo, thermal admittance and roughness. Furthermore, urban surfaces are considered impermeable for rainfall. The most fundamental change of the land surface scheme consists of the incorporation of Brusaert's (1975) temperature roughness parameterisation.

RESULTS

Temperature modelling results are overall in good agreement with observations (Figure 2). The height-corrected temperature record shows an overestimation of the model during daytime in Meyrargues and Marseille Centre, and again during night time, especially for Marseille Centre, probably due to the urban environment. Diurnal wind direction cycles are well simulated, with north-westerly wind directions, turning to southwest due to a reinforcement of sea breezes, resulting in a north-easterly wind early in the morning. Overall wind direction trends for Marseille Centre are in good agreement with observations, although certain direction shifts aren't well captured by the model. This could be due to local scale turbulence caused by the high buildings of the residential area of the city where the measurements are taken (Grimmond et al, 2004). Wind speeds are low as a result of the synoptic weather situation dominated by high pressure and a weak surface pressure gradient. A comparison of simulated vapour pressure with measurements from the ESCOMPTE campaign shows that there is a rather large discrepancy during the second half of the study period. This problem is probably linked to a changing synoptic airflow from the 24th of June and more importantly, to an abrupt increase of the Mediterranean's SST (Sea Surface Temperature).

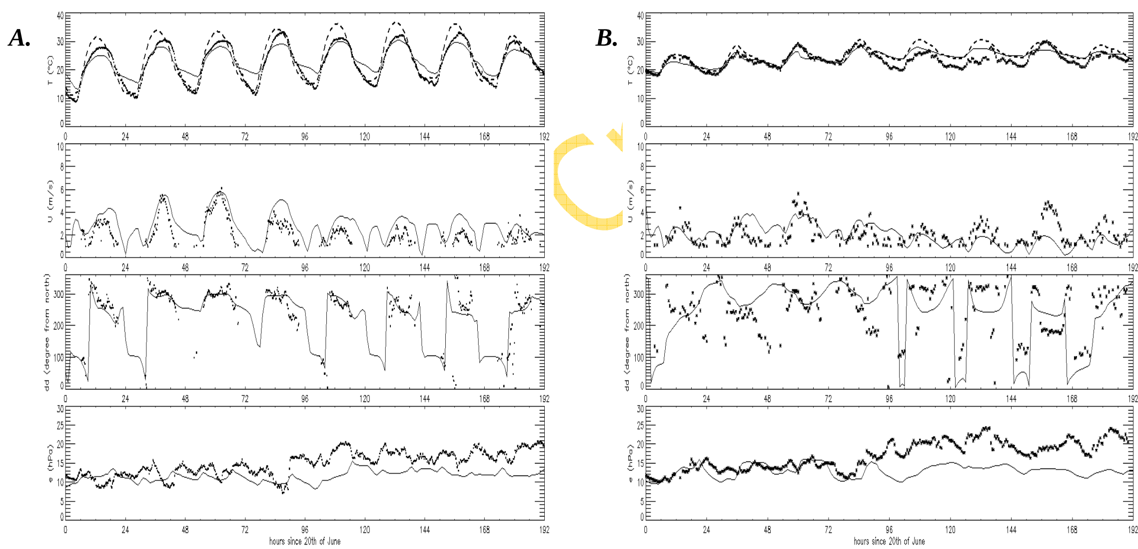

Fig. 2: Comparison between observed and simulated values for air temperature, wind speed and direction and vapour pressure for Meyrargues (A) and Marseille Centre (B). Black dots are measurements, full black lines are the simulated values and dashed line is height correction for temperature using the Monin-Obukhov similarity theory.

In case of Marseille Centre, no observations were made for the anthropogenic heat flux (Q_f), which is a function of vehicles, energy within buildings and energy released as part of metabolism (Grimmond et al, 2004). Therefore, diurnal patterns of Q_f were assigned based on recently made estimates for several U.S (Sailor and Lu, 2004) and other large Asian and European cities (Ichinose et al, 1998; Klysik, 1996). Values are assigned as follows: night time value of 15 W/m², daytime value of 50 W/m² and two peaks of 75 W/m², timed by values of CO_2 measured in Marseille (Grimmond et al, 2004). The corrections are added to ARPS' output for the Marseille measurement station, which doesn't take into account Q_f. The storage heat flux Q_s is calculated as a residual from the observations. Comparison with measurements results (Figure 3) in a good net radiation simulation for both measurement locations, with a slight underestimation for the last day of the Meyrargues measurements and the whole Marseille Centre period. The latter reveals itself in an underestimation of the sensible heat (Q_h). Thermal urban characteristics might not be fully captured with the mesoscale model which can result in an overestimation of Q_s and underestimation of Q_h. Differences between the rural and urban measurement sites are very well captured by the ground storage flux and the latent heat flux, although simulated latent fluxes for Meyrargues are somewhat lower than observations, probably caused by a shortage of water vapour. This could be linked to an abrupt increase of some °C of the Mediterranean's SST.

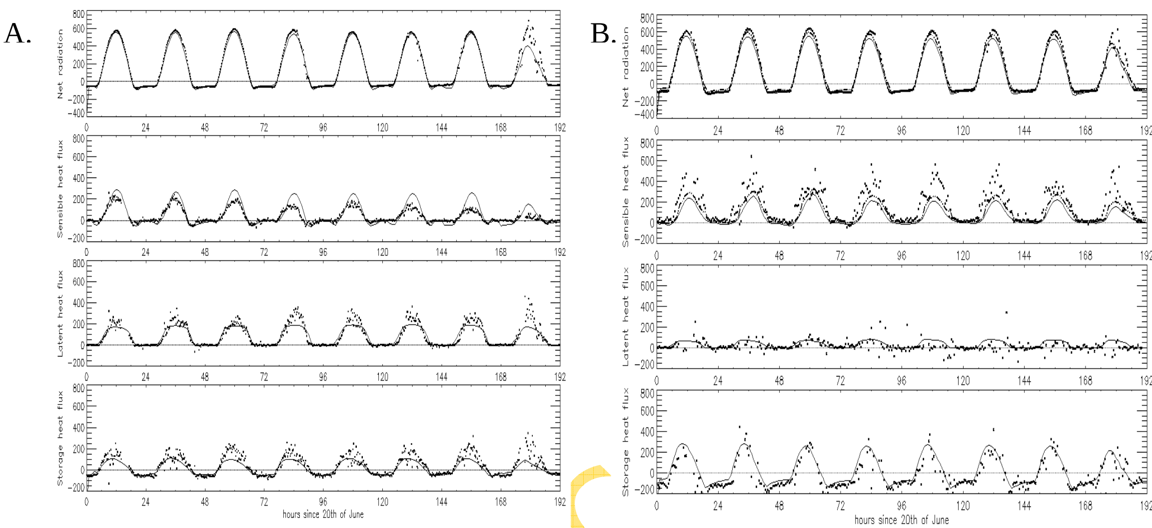

Fig.3: Energy balance fluxes for Meyrargues (A) and Marseille Centre (B). Black dots are measurements; full black lines are the simulated values and dot-dashed lines represents fluxes with anthropogenic heat correction.

SENSITIVITY STUDIES

AVHRR pathfinder images show a rapid change in SST, with an increase up to 2°C between 20 and 28 of June (Figure 4). Possibly this increase is partly responsible for the increase in water vapour pressure during the second half of this measurement period. SSTs in this simulation are integrated by means of a monthly averaged value, which doesn't contain the rapid changes. A re-run is started, first with an overall SST increase of 2°C. In case of significant effect, a second re-run will be done this time accounting for daily SST variability in order to improve the simulated humidity. Another re-run is planned with a modified parameterization of the thermal characteristics for the soil layer, which could result in a higher ground flux Q_s and a higher sensible heat flux Q_h.

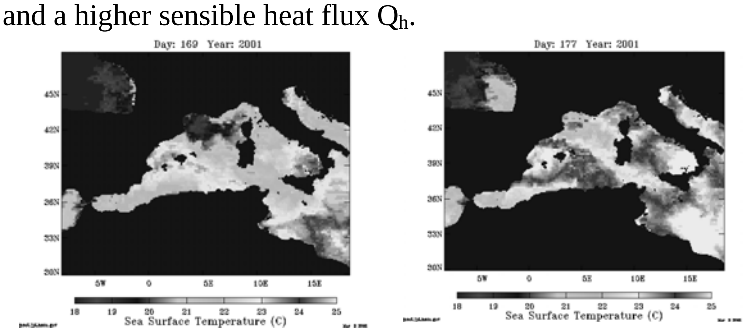

Fig. 4: Increase of the Sea Surface Temperature in the western part of the Mediterranean Sea Between 20 June 2001 (day 169) and 28 June 2001 (day 177).

CONCLUSIONS

Modeling results from the non-hydrostatic mesoscale meteorological model ARPS are overall in good agreement with observations, both for synoptic parameters as for heat fluxes. This validation is meaningful because of its importance before usage in air quality modeling, as well as the shown importance of good input of initial SST. Therefore, short-term SST fluctuations are planned to be fully integrated in future mesoscale modelling, in order to improve simulated humidity and other linked parameters.

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