5th International Conference on Fog, Fog Collection and Dew
Münster, Germany, 25–30 July 2010
FOGDEW2010-96

Study of fog characteristics by using the 1-D model COBEL at the airport of Thessaloniki, Greece

S. Stolaki, I. Pytharoulis and Th. Karacostas
Department of Meteorology and Climatology, School of Geology, Aristotle University of Thessaloniki, Greece
(sstolaki@geo.auth.gr / Fax: +30-2310-995392)

Abstract

An attempt is made to couple the one dimensional COBEL - ISBA (COuche Brouillard Eau Liquide - Interactions Soil Biosphere Atmosphere) model with the WRF numerical weather prediction model. This accomplishment will improve the accuracy of the short-term forecasting of fog events, which is of paramount importance -mainly to the airway companies, the airports functioning and the community as well- and will provide the means for the implementation of extensive studies of fog events forming at the "Macedonia" airport of Thessaloniki. Numerical experiments have been performed to study in depth the thermodynamic structure and the microphysical characteristics of the fog event that was formed on 6th of January 2010. Moreover, the meteorological conditions that prevailed during the formation of the fog event are also investigated. Sensitivity tests with respect to the initial conditions of temperature and relative humidity profiles have been performed to illustrate the model's performance. The numerical results have been thoroughly studied and the findings have been evaluated and discussed.

1. Introduction

Accurate and reliable information on expected visibility conditions at the airport of Thessaloniki-Greece, is of high importance, concerning safety and operational expenses for the airport and the airway companies. On the other hand, the life cycle of fog involves complex interactions among dynamical, turbulent, microphysical and radiative processes that are still not fully understood. Therefore, the implementation of an integrated weather-fog numerical model could be a very helpful tool, for understanding in depth the physical processes involved in the different stages of fog formation and consequently to accurately predict fog conditions. Several efforts have been made towards the forecast of low-visibility and fog conditions, either through the use of three-dimensional (3D) models ([5], [7], [8], [6], [11]), or the use of one-dimensional (1D) models ([1], [3], [2]).

The main objective on this work is to couple the 1D boundary layer model COBEL-ISBA (COuche Brouillard Eau Liquide - Interactions Soil Biosphere Atmosphere) with the version 3.1.1 of the WRF-ARW (Weather Research and Forecasting) regional non-hydrostatic atmospheric model, at the "Macedonia" airport of Thessaloniki (LGTS). High-resolution numerical experiments were performed in order to study the thermodynamic structure and the microphysical characteristics of the fog event that was formed on the 6th of January 2010 at the airport. This is an overview of a first attempt, with the means of a single column model, for a better understanding of the formation and dissipation of the fog event in Thessaloniki.

2. The COBEL-ISBA model

The COBEL model [developed in collaboration between the Laboratoire d'Aérologie-Université Paul Sabatier/Centre National de la Recherche Scientifique (CNRS) and Météo-France/Centre National de Recherches Météorologiques (CNRM)] is coupled with the land-surface scheme ISBA, as documented in [2] and it possesses a high vertical resolution, which consists of 30 levels between 0.5 and 1360 m, with 20 levels being below 200 m. ISBA is run with 7 levels in the ground, from 1 mm to 1.7 m below the surface level. The model input are the initial conditions and mesoscale forcings. The first are given by a two-step assimilation scheme, using local observations [2] consisting of: 2 m temperature and humidity, visibility and ceiling, temperature and humidity observations at 1, 5, 10 and 30 m from a measurement mast, radiative fluxes (short-wave and long-wave) at 2 and 45 m and soil temperature and water content at the surface, -10, -20, -30 and -40 cm. The available observations for the airport of Thessaloniki (40.52^{o}N, 22.96^{o}E) are very limited and consist of the operational half hour information provided by the station's METARs. Neither radiative fluxes data, nor mast measurements are available; therefore parts of the model code that make use of them have been deactivated. Mesoscale forcings are given by the WRF-ARW Numerical Weather Prediction (NWP) model. Since soil temperature and moisture observations were unavailable, the forecast values of the NWP model were used.

3. The WRF model

The non-hydrostatic Weather Research and Forecasting model with the Advanced Research dynamic solver (WRF-ARW Version 3.1.1) was utilized in the numerical experiments. It is a flexible, state-of-the-art numerical weather prediction system, designed to operate in both, research and operational mode ([9], [12]).

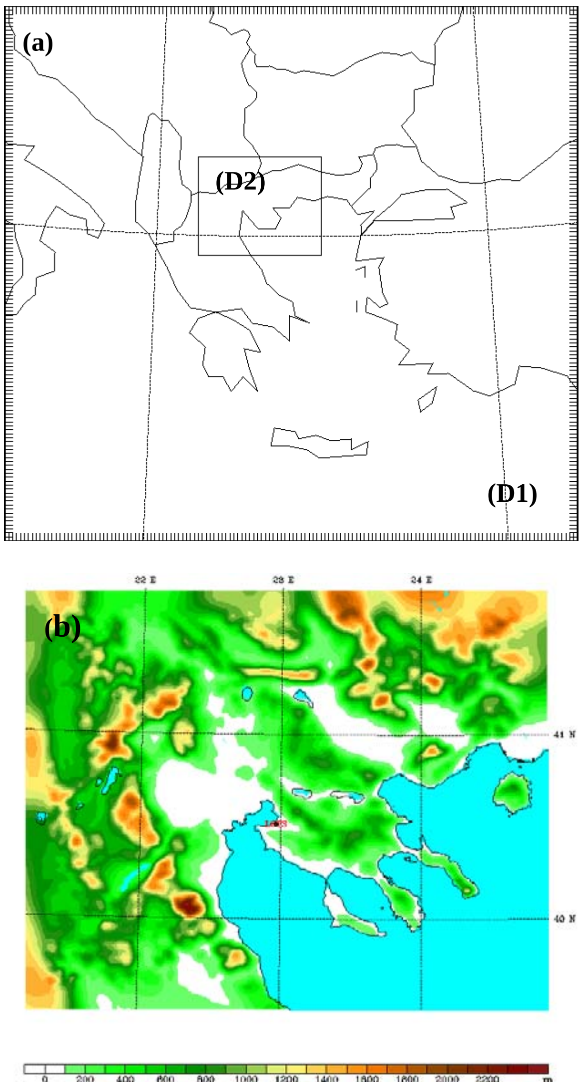

Figure 1. (a) The two nests used by WRF-ARW in the numerical experiments. (b) The topography of the inner domain (D02) and the location of the airport.

Two interactive model domains (Figure 1a) covering Balkans and the wider area of Macedonia (Figure 1b) at horizontal grid-spacings of 10km x 10km (D1) and 2km x 2km (D2), respectively, utilizing the staggered Arakawa C grid. Fine-resolution data (30''x30'') were used in the definition of topography, land use and soil type. Six-hourly ECMWF analyses at a horizontal resolution of $0.25^o x 0.25^o$ were used as initial and lateral boundary conditions for the coarse domain, while the fine inner domain was two-way nested to the larger one. The sea-surface temperatures were also derived from the ECMWF analysis and were kept fixed to their initial values throughout the simulations. In the vertical, 38 sigma levels (up to 50 hPa) were used by both nests. The GFDL scheme, the Monin-Obukhov (Eta), Mellor-Yamada-Janjic, the NOAH Unified model and the Ferrier Eta scheme were used in both nests to represent longwave/shortwave radiation, surface layer, boundary layer processes, soil physics and microphysics, respectively. Cumulus convection was parameterized only in the coarse nest by the Betts-Miller-Janjic scheme.

Among the NWP mesoscale forcings that COBEL requires are the downward shortwave and longwave radiation under clear skies at the ground. In order to get the former, the GFDL shortwave radiation scheme was used. However, the latter is not provided by the NWP, therefore, it was estimated though the equation provided by [4] formula. This formula was chosen among others.

4. The fog event of 6th January 2010

Thessaloniki's International Airport is located 15 km south-southeast of city-center in a fog-prone coastal region with several geomorphological complexities (valley, mountain, coastline, urban and rural areas). The existence of the nearby Anthemountas valley and of the Chortiatis mountain (~1200 m) are of high importance, since a breeze, originated within the valley, descends from the slopes of the surrounding hills to the airport area, transferring already formed fog or providing the area with cold air from the valley [10].

On the 6th of January 2010, fog that extended to an area covering the whole airport and the surroundings -that is up to a radius of 5 km- formed and was quite thick, with estimated minimum visibility reaching 100 m (Figure 2). The fog event started at 05:20 UTC and ended at 10:50 UTC. According to the surface synoptic conditions (Figure 3), northern Greece was influenced by an upper air low pressure system that resulted in a warm front affecting the region, while the airport area was mainly influenced by the warm sector of the front. A variable direction light breeze was prevailing a few hours before the fog onset.

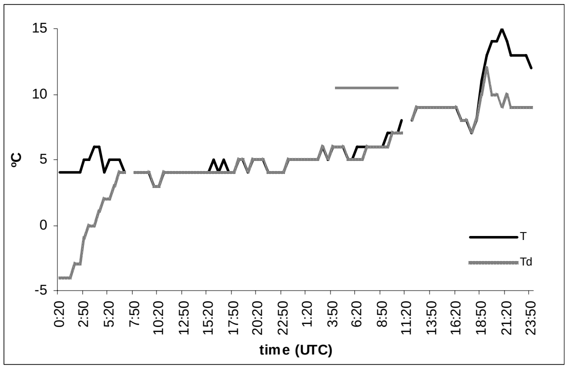

Figure 2. Temporal evolution of the 2 m temperature, dew point temperature for 5-6 January 2010. The fog period is highlighted with a grey line.

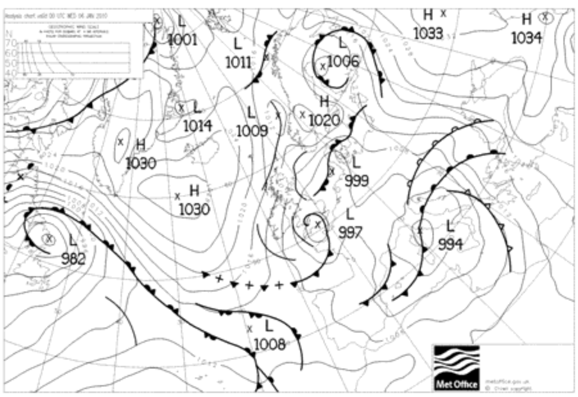

Figure 3. Surface synoptic conditions on the 6th January 2010, 00UTC.

4. Results

One of the first tasks, in order to successfully forecast the occurrence of fog at the airport of Thessaloniki, was the coupling of the COBEL-ISBA model with the WRF-ARW. To achieve this, an interface between the two models was developed, that vertically interpolates 16 meteorological fields, needed as mesoscale forcings for the initialization of COBEL, from the WRF vertical sigma level format into the COBEL format (the 15 required height levels above ground are at: 20, 50, 100, 250, 500, 750, 1000, 1250, 1500, 2000, 2500, 3000, 4000, 5000, 6000 m). The WRF data used in the interpolation correspond to 1h frequency forecasts, with initialization time on the 05/01/2010 at 1200 UTC. The simulation of COBEL was initialized at 1800 UTC on 05/01/2010 (before the fog onset) and a 24h forecast was produced. Moreover, the initial fog thickness was set a fixed value, since no radiative fluxes measurements were available.

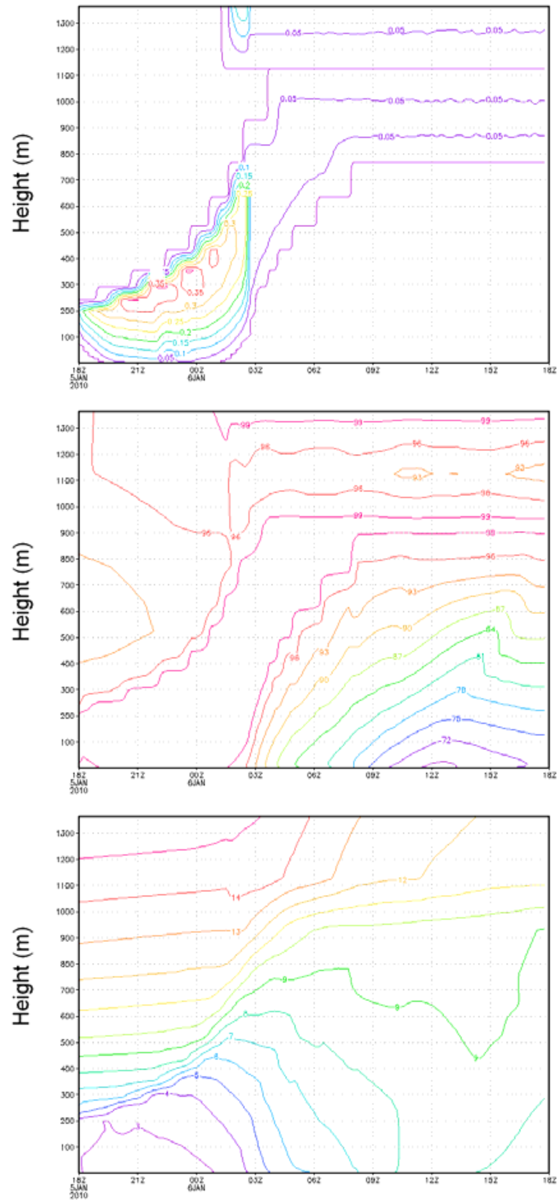

Figure 4. Time-height cross sections of the liquid water mixing ratio (gkg^{-1}), relative humidity (%) and potential temperature (^{o}C) by COBEL-ISBA, initialized at 1800 UTC, 06/01/2010.

The time-height cross sections of the liquid water mixing ratio, the relative humidity and the potential temperature simulated by COBEL-ISBA are presented in Figure 4. The integrated WRF and COBEL-ISBA modeling system did not manage to predict accurately the onset time of the fog event. Nevertheless, the high values of existing relative humidity and of the liquid water mixing ratio, are strong evidences of fog forming potentially on that day. Moreover, the values of the liquid water mixing ratio (0.05-0.35 gkg^{-1}), are found to be of the same magnitude as the ones in the literature for COBEL-ISBA outputs. Finally, the potential temperature cross section depictes a typical stable nocturnal boundary layer around 0000 UTC.

5. Summary and Conclusions

This study demonstrates the first attempt that has been made in order to simulate a fog event that occurred at the airport of Thessaloniki. For first time COBEL-ISBA model is used in a fog prone area of Greece, as a forecasting tool, coupled with WRF NWP model. The high values of liquid water mixing ratio and relative humidity indicate the ability of the model to simulate the potential of fog formation. However, the integrated WRF and COBEL-ISBA modeling system did not manage to simulate accurately the onset time of the fog event. Other model experiments regarding the study of the thermodynamic and microphysical structure of fog, as well as sensitivity tests in respect of the initial model conditions, are under way and will be presented during the 5th International Conference on Fog, Fog Collection and Dew, in Germany.

Acknowledgements

The authors would like to thank Météo-France/Centre National de Recherches Météorologiques (CNRM) for providing the 1D COBEL-ISBA local forecast system. Many thanks are also given to Dr. T. Bergot and Dr. S. Remy for their valuable help and support in accomplishing the adaptation and run of COBEL-ISBA at the area of Thessaloniki's airport.

References

[1] Bergot, T., and Guédalia, D.: Numerical forecasting of radiation fog. Part I: Numerical model and sensitivity tests. Mon. Wea. Rev., Vol. 122, pp. 1218–1230, 1994.

[2] Bergot, T., Carrer, D., Noilhan, J., and Bougeault, P.: Improved site specific numerical prediction of fog and low clouds: a feasibility study. Weather and Forecasting, Vol. 20, pp. 627–646, 2005.

[3] Bott, A., and Trautmann, T.: PAFOG-a new efficient forecast model of radiation fog and low-level stratiform clouds, Atmos. Res., Vol. 64, pp. 191-203, 2002.

[4] Brutsaert, W.: On a derivable formula for long-wave radiation from clear skies, Water Resour. Res., Vol.11, pp. 742-744, 1975.

[5] Clark, D.A.: The 2001 demonstration of automated cloud forecast guidance products for San-Francisco international airport. Proc.10th Conf. on Aviation, Range,and Aerospace Meteorology, AMS, 2002.

[6] Hikari, S., Kundan, L.S., Akira, K., Akikazu, K., and Yoshio, I.: Fog simulation using a mesoscale model in and around the Yodo River Basin, Japan. J. Environ. Sci., Vol. 20, pp. 838-845, 2008.

[7] Koračin, D.I., Businger, J.A., Dorman, C.E., and Lewis, J.M.: Formation, evolution, and dissipation of coastal sea fog, Bound.-Layer Meteor., Vol. 117, pp. 447–478, 2005.

[8] Müller, M.D., Masbou, M., Bott, A., Janjic, Z.: Fog prediction in a 3D model with parametrized microphysics. Proc. WWRP Int. Symp. on Nowcasting and Very Short-Range Forecasting. 6.26, 2005. http://www.meteo.fr/cic/wsn05/resumes longs/6.26-96.pdf

[9] Skamarock, W.C., Klemp, J.B., Dudhia, J., Gill, D.O., Barker, D.M., Duda, M.G., Huang, X-Y, Wang, W., and Powers, J.G.: A description of the Advanced Research WRF Version 3.NCAR/TN-475+STR, pp. 113, 2008.

[10] Stolaki, S.N., Kazadzis, A.S., Foris, D.V., Karacostas, T.S. Fog characteristics at the airport of Thessaloniki, Greece, Nat. Hazards Earth Syst. Sci., Vol. 9, pp.1541-1549, 2009.

[11] Tang, Y.M., Capon, R., Forbes, R., and Clark, P.:fog prediction using a very high resolution numerical weather prediction model forced with a single profile, Meteorol. Appl., Vol. 16, pp. 129-141, 2009.

[12] Wang, W., Bruyère, C., Duda, M., Dudhia, J., Gill, D., Lin, H-C, Michalakes, J., Rizvi, S., and Zhang, X: ARW Version 3 Modelling System's User Guide, NCAR-MMM, pp. 312, 2010.