EVALUATION OF THE HIRLAM AND HARMONIE NUMERICAL WEATHER PREDICTION MODELS DURING AN AIR POLLUTION EPISODE

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Abstract

We analyse the severe air quality episode in the Istanbul Metropolitan Area during 18–20 November 2009 using the HIRLAM and HARMONIE numerical weather prediction models and the HYSPLIT trajectory model. The HYSPLIT trajectory model result shows that the sources of this episode were local. The weather situation leading to this episode is analysed using meteorological observations. During the episode, a high pressure system over northwest Turkey, including Istanbul, led to the formation of an exceptionally strong ground-based temperature inversion which, combined with the low temperature and the heating, led to increased pollution levels.

Keywords: Air pollution episode, İstanbul, HIRLAM, HARMONIE, HYSPLIT

Introduction

Air pollution has increased during last century due to increasing use fossil sources for energy demand. Increases have usually occurred over populated cities, where air pollution has become a worldwide public health and environmental problem. Important issues include decreasing the air pollution for a long period for environmental sustainability and short-term forecasting of air quality levels as a precaution for emergency preparedness and information systems. Meteorological conditions affect the concentration, distribution, and transportation of pollution and also precipitate the source of pollution; usually we use more fossil fuel for heating in cold weather situations, and the 24-hour forecast of HIRLAM and HARMONIE can forecast these situations (Toros et al., 2013).

Study Area and Data

Istanbul is one of the world's megacities, with nearly 14 million inhabitants according to the 2012 figures. The city (41^{o}N, 29^{o}E) is located on two continents, Asia and Europe, with a total area of almost 6,000 km^2. The climate of Istanbul is usually Mediterranean, being warm and dry in summer and cold and wet in winter. The prevailing wind is from the north. Istanbul, as a centre for industry, commerce, culture and tourism, is the heart of Turkey. Features of numerics, physics and analysis/initialisation of the HIRLAM and HARMONIE models for the current study are listed in Table 1.

Figure 1. Map of the Greater Istanbul Area showing the locations of meteorological and air quality monitoring stations

Table 1. Summary of the HIRLAM and HARMONIE model setup

Model feature	HIRLAM	HIRLAM	HIRLAM	HARMONIE
Experiment	HL_{11}/EC_{25}	$HL_{2.5}/EC_{25}$	$HL_{2.5}/HL_{11}$	$HM_{2.5}/EC_{25}$
Exp. begin time YYYYMMDDHH (UTC)	2009111600	2009111600	2009111606	2009111600
Version	7.2.1	7.2.1	7.2.1	Cy35h1.3
Horizontal resolution (km)	11	2.5	2.5	2.5
Vertical levels	60	60	60	60
System of coordinates	Rotated lat/lon	Rotated lat/lon	Rotated lat/lon	Unrotated
Boundaries	ECMWF(EC_{25})	ECMWF(EC_{25})	HL_{11}	ECMWF(EC_{25})
Nodes in x	438	406	406	400
Nodes in y	400	400	400	400
Coordinates of modeling domains (lon; lat)	-19.9S,-22.0W,20N,21.7E	-4.39S,-4.46W,4.39N,4.46E	-4.39S,-4.46W,4.39N,4.46E	28.8W;41.0N (central point)
Coordinates of South pole	-50.0;30	-49.0;28.8	-49.0;28.8	
Time step fc (s)	360	80	80	60
Time step lower resolution DA (s)	1800	396	240	-
Land surface scheme	ISBA	ISBA	ISBA	SURFEX
Forecast length (h)	48	24	24	24
Data assimilation	4DVAR	4DVAR	4DVAR	3DVAR
Dynamics	Hydrostatic	Hydrostatic	Hydrostatic	Non-hydrostatic
Physics	HIRLAM	HIRLAM	HIRLAM	AROME

Results and Discussion

There is a substantial variation in daily PM_{10} concentrations in Istanbul due to emission sources and meteorological conditions. As seen in Figure 2, the concentrations started to increase on 18 November and reached their maximum on 19 November.

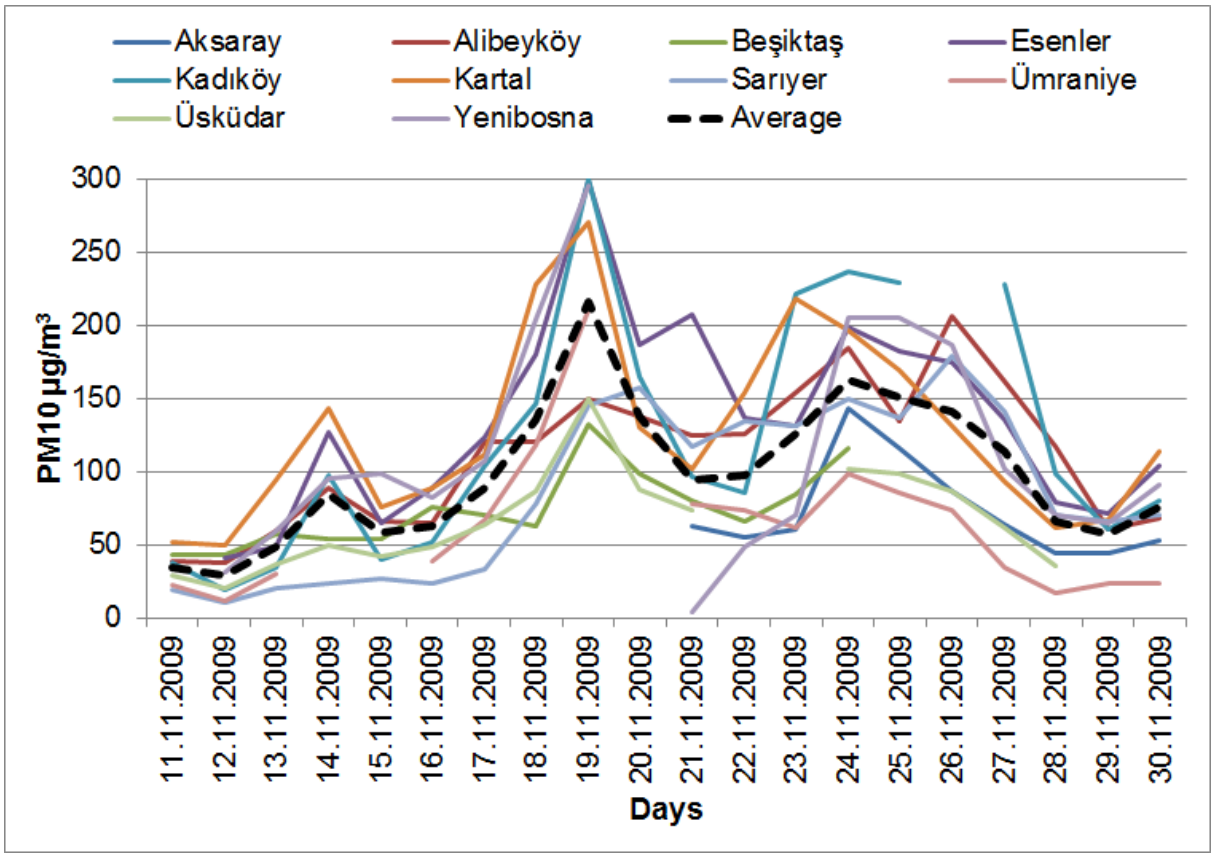

Figure 2. Daily PM10 concentrations at the Istanbul municipality stations

The three-day HYSPLIT backward trajectories show that the air parcels originated from the Black Sea (Figure 3). It can be concluded that there was no long-range transport of dust, e.g. from the Sahara Desert, during this episode; therefore, this pollution episode most likely resulted from the local accumulation of particles.

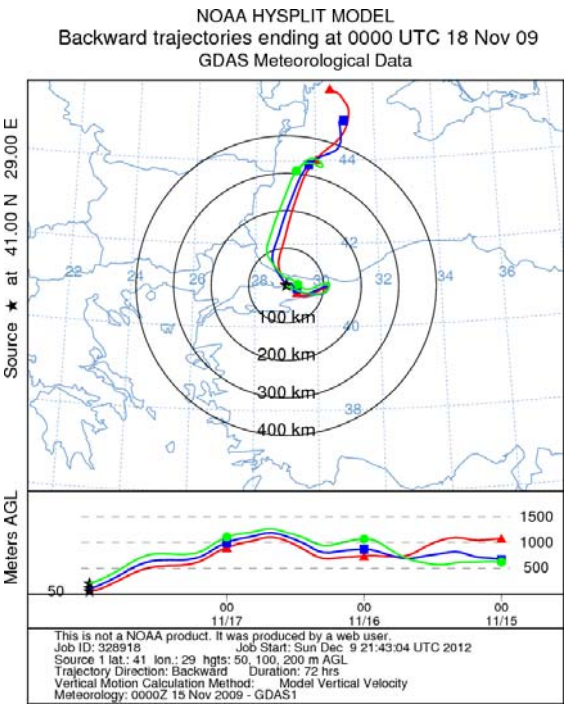

Figure 3. HYSPLIT 72-hour backward trajectories for air parcels arriving over the Greater Istanbul area on 0000 UTC 18 November 2009.

We chose to investigate the weather situation using operational versions of the limited area numerical weather models HIRLAM and HARMONIE. The forecasts are compared to observations at meteorological stations in the area. Figure 4 shows the 24-hour forecasts produced by the HIRLAM (1st–3rd columns of panels) and HARMONIE (4th column) models run with different horizontal resolutions (ranging from 11 to 2.5 km) and boundary conditions (from ECMWF and HIRLAM model outputs) for the minimum air temperature at 2 m (1st row), 10 m wind speed (2nd row), relative

humidity at 2 m (3rd row) and precipitation (4th row) on 18 November 2009, 0000 UTC.

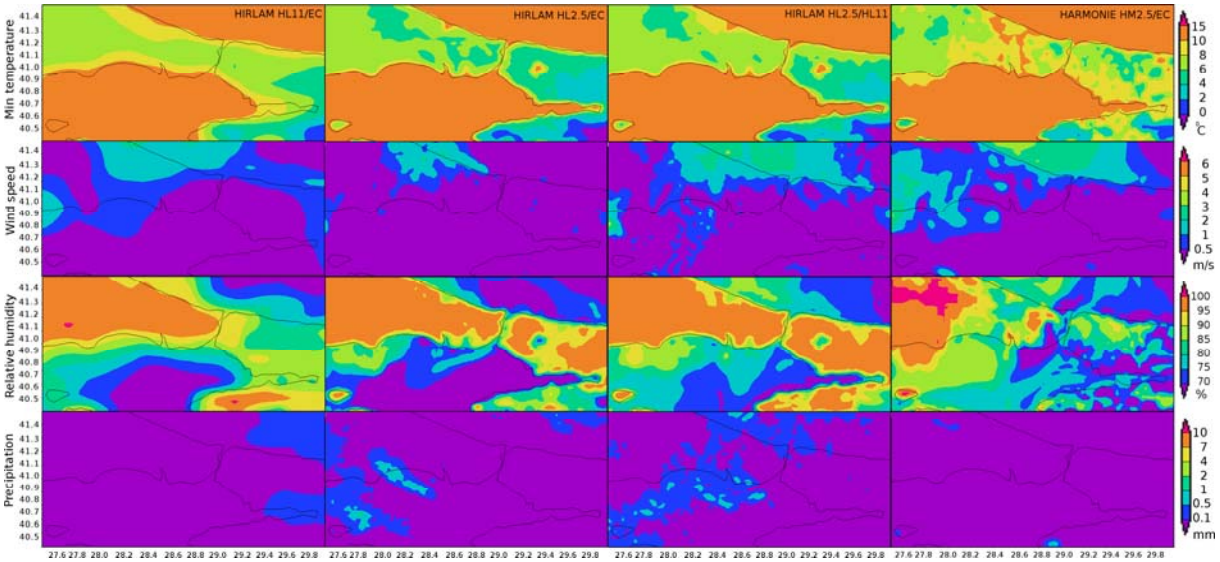

Figure 4. The 24-hour forecasts produced by the HIRLAM (1st–3rd columns) and HARMONIE (4th column) models

Conclusion

The episode was formed during strong inversion, high pressure, light winds and cold air. There was no long-range transport from the Sahara desert so there was not a high demand for heating of residences. Accuracy in forecasting air pollution levels depends critically on the ability of the numerical weather prediction models to compute the relevant meteorological parameters. We have therefore tested the performance of the limited area weather forecasting model HIRLAM and HARMONIE. The 24-hour forecast from HIRLAM and HARMONIE was able to predict the low temperature, low wind speed, high relative humidity and precipitation.

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References

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