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A CASE STUDY OF ONLINE ENVIRO-HIRLAM AND WRF-CHEM MODEL DURING AN AIR POLLUTION EPISODE IN ISTANBUL

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Abstract

The main objective of this study is to evaluate the performance of Online Enviro-HIRLAM and WRF-CHEM in air pollution atmospheric conditions in Istanbul in mid of January 2013. For this purposes we ran the model from 10 to 20 January of 2013, due to high PM10 values during 14-16 January, 2013. The assessment has been performed for selected relevant air pollution parameters (PM10), meteorological parameters, such as temperature, inversion, pressure, wind speed and relative humidity. Long range transportation is analysed by HYSPLIT model. The result also compares with measurement of air pollution parameter PM10. Results of this study are important especially for those involved in online meteorological and chemical modeling and decision-making.
Keywords: Air pollution, episode, online modeling, Enviro-HIRLAM, WRF-CHEM.

1. Introduction

Air quality levels in the urban area of megacities are a serious issue usually depends on some meteorological conditions. One of the important air pollution issues is to make forecasts of air quality levels to be able to take precautionary emergency measures usually urban areas. There have been numerous studies regarding air pollution and its various factors, such as emissions, meteorological parameters, topography, atmospheric chemical processes, solar radiation, emission source areas, related climatic characteristics, and seasonal variation (Erçelebi and Toros, 2009; Ozdemir and et al., 2011). The strategy of new generation integrated Meso-Meteorological and Atmospheric Chemical Transport Model systems suggest considering the urban air quality as a combination and integration, at least, of the following factors: air pollution, meteorological/ climatic conditions, and population exposure (Baklanov, 2008). Chemical weather forecasts of high quality will be highly valuable in air air pollution modeling. Toros el al. (2014) compared forecasts generated by HIRLAM and HARMONIE models and observations at meteorological stations in İstanbul area. They result show that HIRLAM and HARMONIE 24 h's forecasts are successful to predict possible episode conditions due to meteorological circumstances, and thus both models provide reliable weather input to an air pollution warning system.

In worldwide, Enviro-HIRLAM model is used for future scenarios. In Copenhagen, Enviro- HIRLAM model were tested and verified for 1.4 km horizontal resolution with simple (urban roughness and anthropogenic heat flux) and complex (building effects parameterizations) urbanization. Results of this study shows that, ‘‘for typical wind conditions, the differences for: wind at 10 m is less than 0.5 m s^{-1} (with a maximum up to 1.5, at midday); air temperature at 2 m is less than 0.25 ºC (with a maximum up to 0.5 ºC, at night time); and relative humidity is a few percent (with a maximum up to 5%, at midday). For low wind conditions, the differences for: wind at 10 m is more than 1 m/s (with a maximum up to 3 m s^{-1}, at night time); air temperature at 2 m is more

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than 0.5 ºC (with a maximum up to 1.5 ºC, at night time); relative humidity is a few percent with a maximum up to 7%, at midday'' (Mahura et al., 2009, p. 149).

WRF/Chem is the other useful model for air quality for multinational area. For instance, WRF/Chem model is ran for specify characterizations of chemical oxidants in Mexico City. Conclusion of this study shows, Chemical process are cause of diurnal ozone cycle. Oxidation of alkenes and aromatic HCs occurs in day time and NO removes this process in night time. Emissions and PBL height are effected diurnal cycles of CO and NOx. In Mexico City, ozone production is limited by HCs, therefore rises in HC emissions lead to O_3 rises, while increases in NOx emissions lead to O_3 decreases. When emissions of HC are increased, higher ozone maxima are occurred (Tie et al., 2006). AQMEII framework phase-2 exercise, Kong et al. (2014) for the dust case study, eight WRF-Chem and one WRF-CMAQ simulations were selected. Outcomes of this study are signal for interactions between chemistry and meteorology, exclusively ozone and aerosols in the online coupled models. Their case study on the Russian forest fire show that reducing planetry boundary layer height, surface temperature and downward short wave radiation respect for high levels of PM10 over the Moscow area.

Another study for Marmara region is made for defining of air pollution sources at high resolution, estimating of pollution concentrations under the meteorological conditions. Calpuff model is used for air quality modeling to compare with the observation data in the area. According to the sensitivity analysis performed the sulfur content, if the reduction of the sulfur content of the ECA (Emission Control Area) limit, pollutant concentrations has been identified to reduce (Kılıc et al., 2014).

In Istanbul, air quality modeling scenarios are developed based on diffrent situations. For example, air pollution scenary on Bosphorus after than Channel Istanbul Project is investigated by researhers. In this study, ISCST3 model of USEPA is used for dispersion of SO_2, NO_X, CO and PM10. The model results are evaluated; it was found that the current annual and hourly throat highest level of air quality resulting from the traffic right on the throat and sore throat as part Şisli and Sarıyer district consists of a few hundred meters of the edge of the interior locations (Tuna and Elbir, 2013). These studies show represents, air quality modeling studies providing high accuracy results.

For this purposes we considered an investigation of air quality in Istanbul. One of the important air pollution issues is to make short-term forecasts of air quality levels to be able to take precautionary emergency measures. This paper presents a study of an air pollution episode from the perspective of online meteorological and chemical models for the synoptic meteorology, air pollution distribution and long-range transport from out side the study area.

Enviro-Hirlam (High Resolution Limited Area Model) for period from 10 till 20 January 2013, when an episode with high concentration of PM10 was observed, with ECMWF meteorology and TNO emission dataset as initial/ boundary conditions (IC/BCs and WRF-CHEM model runs with Enviro-HIRLAM for the same period of time, with GFS IC/BC and RETRO/EDGAR and GOCART background emissions. The model runs were performed for episode of high PM10 concentrations during. January 10-20 of 2013. The evaluation was done for both meteorological parameters and aerosol compounds. The Enviro-HIRLAM was run in parallel with the HYSPLIT model to assess long-range pathways of aerosol precursors. The modelling results were compared with groundbased observations.

2. Study Area, Data and Methods

2.1. Study Area

İstanbul, as a biggest megacity in the world with a population more than 14 million inhabitants according to the 2013 census (TUIK, 2014). İstanbul is the largest city in Turkey, with 18% of Turkey's total population living in İstanbul. In terms of culture, tourism, industry, commercialization, financial capital of Turkey and social media İstanbul is the heart of Turkey. It has complex topography that includes valleys, hills and the Bosporus where a narrow and deep strait that connects the Sea of Marmara with the Black Sea divides the city. Istanbul has two parts and also seperates the European and Asian Continents, (Figure 1). The city (41^{o}N, 29^{o}E) is located between Asia and Europe, covering 5.315 km^2. The Trans-Europe Motorway (TEM) passes through İstanbul via the Fatih Sultan Mehmet Bridge. Roughly 5 million (35 %) people live on the Asian side in 2013 census, and 9 million (65 %) on the European side. Istanbul has a Mediterranean climate with usually warm and dry in summer and cold and wet in winter. The warm season is May till September and the cold season is October till April. Climatological wind directions are north to northeast (N to NE) and south-southwest to southwest (SSW to SW).

Figure 1. The air quality observation stations in the İstanbul Metropolitan Area.

2.2. Air Pollution Observed Data

There are ten air quality measurement stations in the region that are operated by the İstanbul Greater Metropolitan Environment Department and the Ministry of Environment and Forestry of Turkey (Figure 1). PM10 concentrations were measured using the standard Beta gauge measurement Method ISO 10473 of the MP101M analyzer.

2.3. Enviro-HIRLAM

The Enviro-HIRLAM v.7.4 model with new aerosol microphysics scheme M7 (Vignati at al., 2004) and simple tropospheric sulphur chemistry (Nuterman et al. 2013) has been applied for air quality forecast over the city of

Istanbul. The modelling domain with horizontal resolution of 0.11° x 0.11° and the following boundaries -4.39S, -4.46W, 4.39N, 4.46E was nested to ECMWF-IFS (0.25° x 0.25°) numerical weather prediction global data. Chemical intial and boundary concentration was taken from MACC (IFS-MOZART), (Chenevez et al, 2004; Baklanov et al, 2008; Korsholm et al, 2009).

2.4. WRF-CHEM

We used online air quality model WRF/Chem version 3.5 for this study. WRF/Chem is a version of WRF coupled “online” with a chemistry model where meteorological
and chemical components of the model are predicted simultaneously (Grell et al., 2005)
WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with Chemistry. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with the meteorology. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry. The development of WRF-Chem is a collaborative effort among the community.

We carried out simulations using the Weather Research and Forecasting model with Chemistry (WRF-CHEM) v3.5 to examine the meteorological conditions and to produce estimates of PM10 over Istanbul for 10-20 January 2013. The three nested domains was setup using 18, 6 and 2 km horizontal grid spacing with (90x90), (115x115) and (130x130) grid points in 1st, 2nd and 3rd domains, respectively. The each domain was run using one way nesting option after preparing the results from the mother domain as an input to subsequent inner domain. 34 vertical levels were used with the lowest layer depth of 15 m above the surface and extending to 15 km at the model top. The model was configured using the model options after many tests to find optimal model parameters and was initialized using global emissions data available publicly. The local emissions database is still in works and is not available to use in the model instead of global data. The estimated PM10 concentrations were compared against the observed conditions. This work shows the first attempt of using WRF-CHEM in Turkey to estimate the pollutant concentrations instead of using other air pollution models such as WRF/CMAQ combination. At the time of constructing this abstract, the model runs were still being conducted and the results will be discussed at the conference.

Table 1. Summary of the Enviro-HIRLAM and WRF-CHEM model setup.

Model feature	Enviro-HIRLAM	WRF-CHEM
Exp. begin time (UTC)	2013011000	2013011000
Exp. finish time (UTC)	2013012000	2013012000
Version	7.4	3.5
Horizontal resolution (km)	11	11
Vertical levels	60	28
System of coordinates	Rotated lat/lon	Rotated lat/lon
Nodes in x	438	406
Nodes in y	400	400
Modeling domains (lon; lat)	-4.39S,-4.46W,4.39N,4.46E	-4.39S,-4.46W,4.39N,4.46E

Coordinates of South pole	-50.0;30	-49.0;28.8
Time step fc (s)	360	80
Time step lower resolution DA (s)	1800	396
Dynamics	Hydrostatic	Hydrostatic
Physics	HIRLAM	HIRLAM
Land surface scheme	ISBA	ISBA
Forecast length (h)	48	24
Data assimilation	4DVAR	4DVAR
Boundaries	ECMWF (EC25)	GFS

2.5 HYSPLIT

In this study, we used web-version of HYSPLIT trajectory model driven by meteorological reanalysis data from Global Data Assimilation System (GDAS, http://ready.arl.noaa.gov/HYSPLIT.php). Multiple backward and forward trajectories of air parcels arriving/departing to/from İstanbul have been computed for 3-days of Mediterranean air mass transport.

The Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed by the National Oceanic and Atmospheric Administration’s (NOAA) Air Resources Laboratory (ARL). HYSPLIT compute a wide range of backward and forward trajectory processes. In this study, we used the web-version of the HYSPLIT trajectory model using Global Data Assimilation System (GDAS) meteorological data for 3 day backward trajectories for air parcels arriving over İstanbul. The Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed by the National Oceanic and Atmospheric Administration’s (NOAA) Air Resources Laboratory (ARL). It is a system that can compute a wide range of backward and forward trajectory processes, including simple air parcel trajectories up to complex dispersion and deposition simulations. The dispersion of a pollutant is calculated by assuming either puff or particle dispersion. The model's default configuration assumes a 3-dimensional (3-D) particle distribution (Draxler and Rolph, 2012; Rolph, 2012). We used the web-version of the HYSPLIT trajectory model using Global Data Assimilation System (GDAS) meteorological data. The model generated 72-h (3 day) backward trajectories for air parcels arriving over İstanbul.

3. Results and Discussion

In order to meteorologically evaluate the episode, the corresponding synoptic maps and radiosonde measurements were analysed, including pressure, wind, precipitation, and relative humidity observations. The synoptic situation during 14 January 2013 is presented in Figure 2. A surface high pressure system is bigger than 1025 hPa İstanbul and the 500 hPa map shows a ridge, leading to divergence and subsidence.

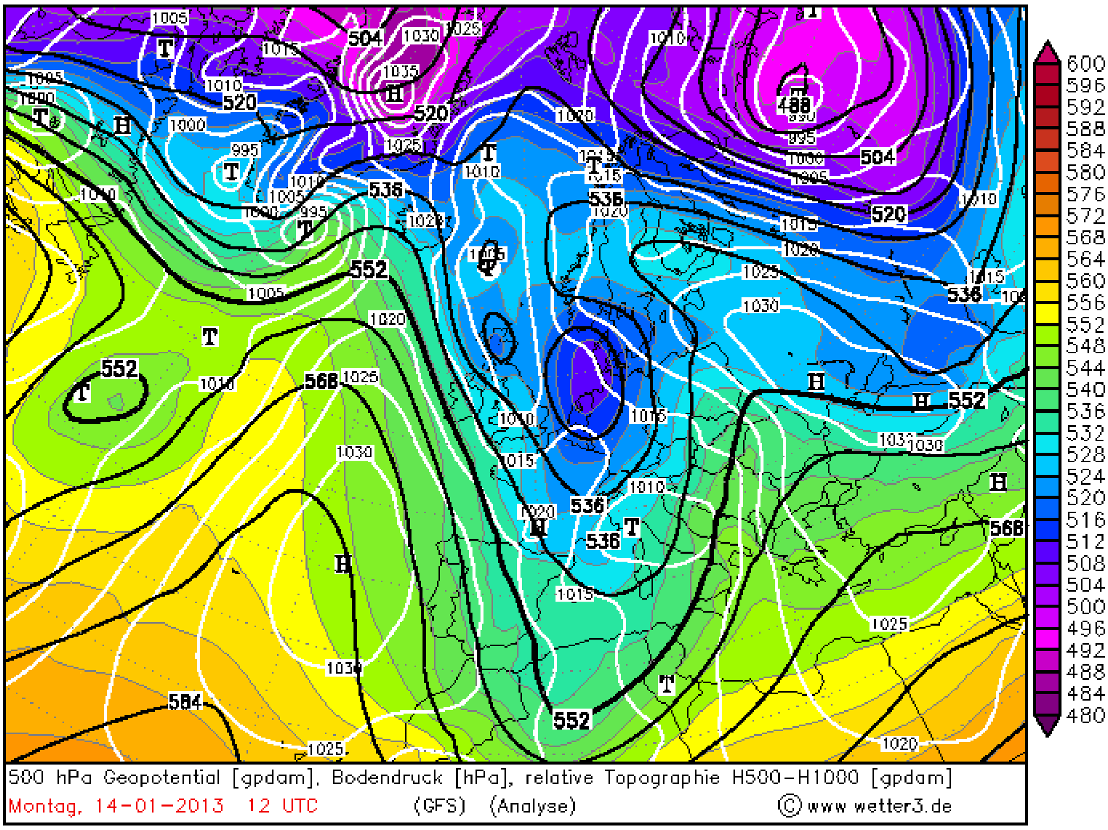

Figure 2. Weather chart showing the 500 hPa analysis map for 1200 UTC, 14 January 2013.

During the STSM several experiments were done on ITU HPC clusters to evaluate model performance and integretability of the new version. Seminars with colleagues from ITU were also organized with focus on implementation and using of Enviro-HIRLAM and WRF-Chem. During the STSM, we discussed issues of preparing and pre-processing data sets, such as initial/ boundary conditions (IC/BCs). Experiments for a period for 10 till 20 January 2013 have been designed and tested with both Enviro-HIRLAM and WRF-Chem models and analyzed for both meteorological conditions and air pollution situations in the Istanbul metropolitan area. The models' results have been visualized.

Analysis of results showed that both Enviro-HIRLAM and WRF-Chem models produced PM10 concentrations up to 10 and 6 times lower compared with measurements, correspondingly. Spatial distribution of PM10 looks reasonable for both models (see below Figures 3, 4, 5). Perhaps problem with initial condition of emissions, which is present some time averaged value.

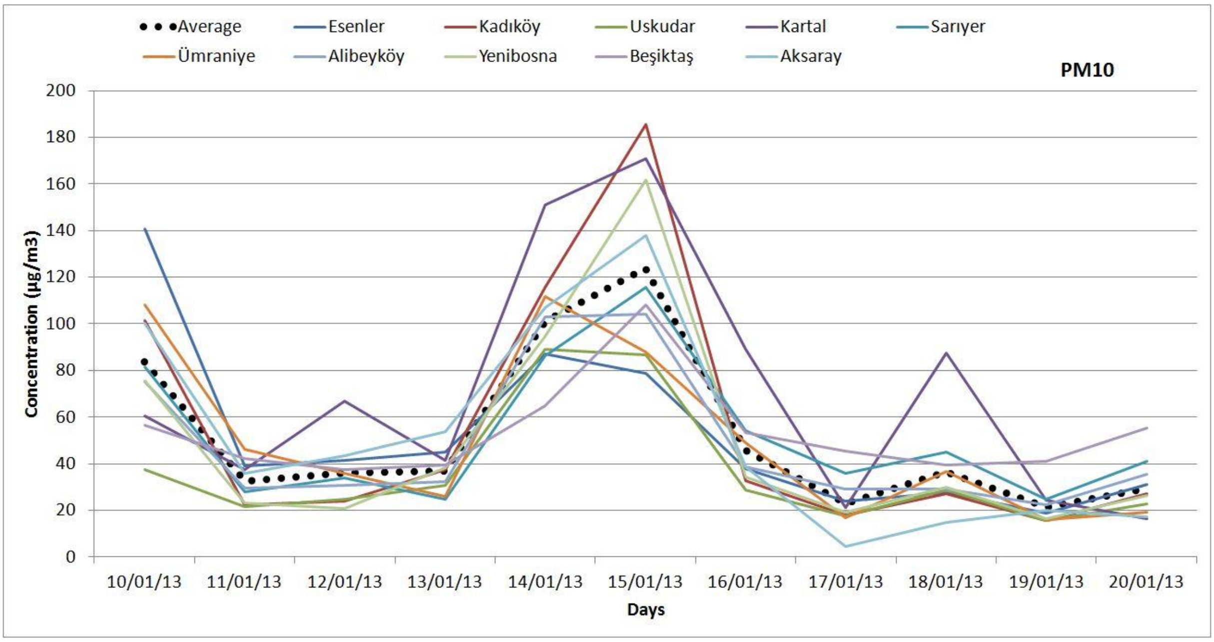

Figure 3. Time-series of daily PM10 concentrations from 10 Jan till 20 2013 at selected air quality stations within the İstanbul metropolitan area.

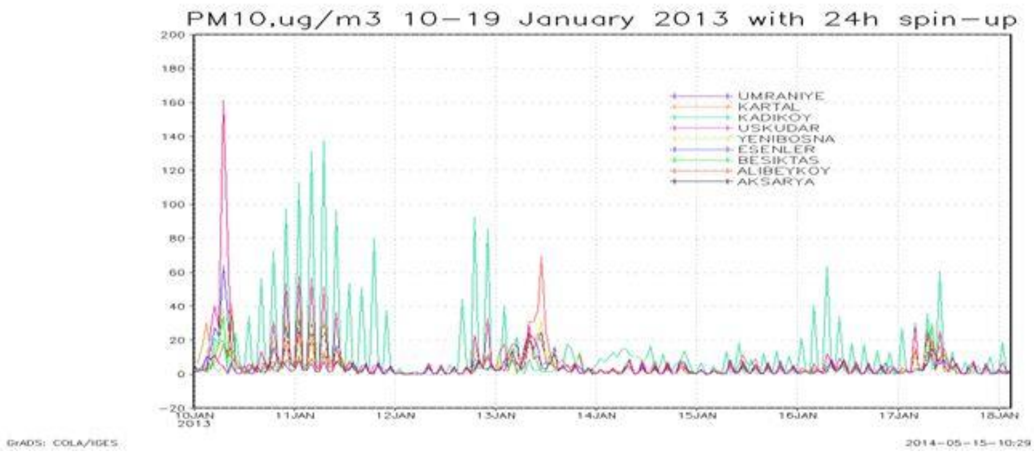

Figure 4. Enviro-HIRLAM simulated concentration of PM10 (ug/m3) during 10-20 January 2013.

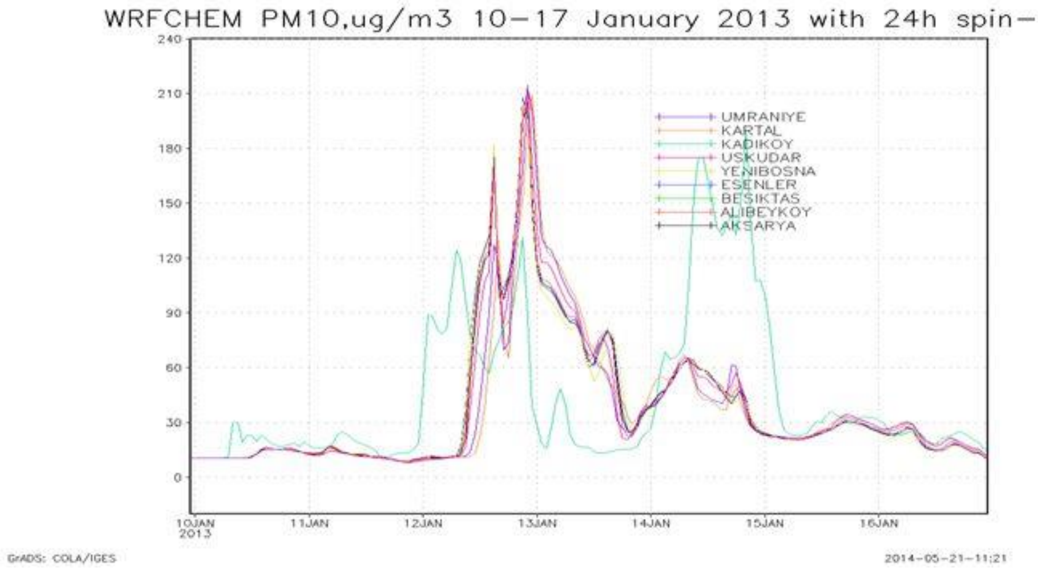

Figure 5. WRF-Chem simulated concentration of PM10 (ug/m3) during 10-20 January 2013.

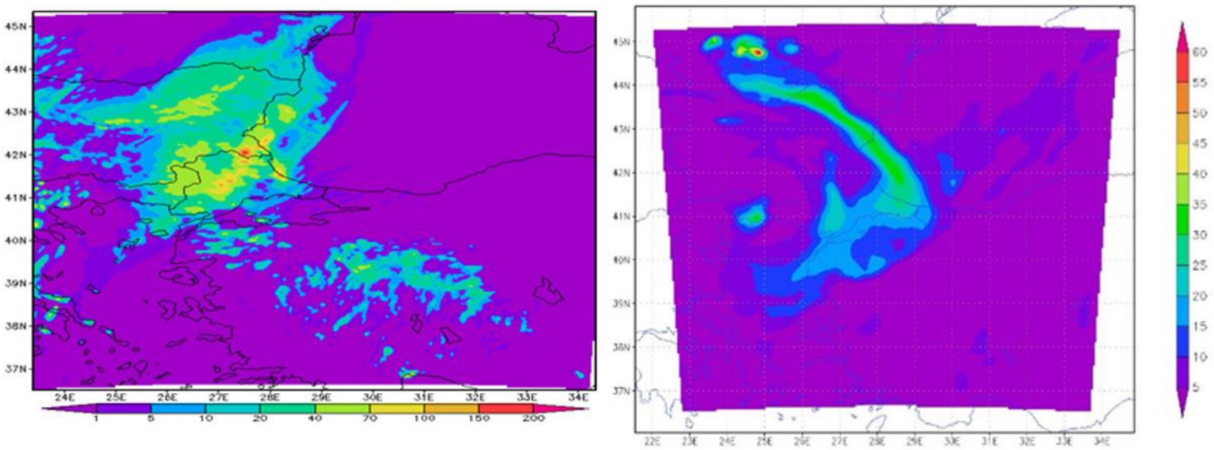

Figure 6. Distribution PM10 simulated by Enviro-HIRLAM (left column) and WRF-Chem (right column).

The HYSPLIT backward trajectories show the pathways of air parcels arrived to İstanbul metropolitan area three days prior to 12 UTC January 15. The air parcels originate from southern Europe (Figure 7). Thus, high PM_{10} values mainly resulted from remote or local anthropogenic sources. The Enviro-HIRLAM model output shows that there were two peaks, the first during January 14-15, and the second in January 16. During these periods the city of Istanbul was influenced by high-pressure system and weak wind speed. The Jet stream was located over the west of Istanbul.

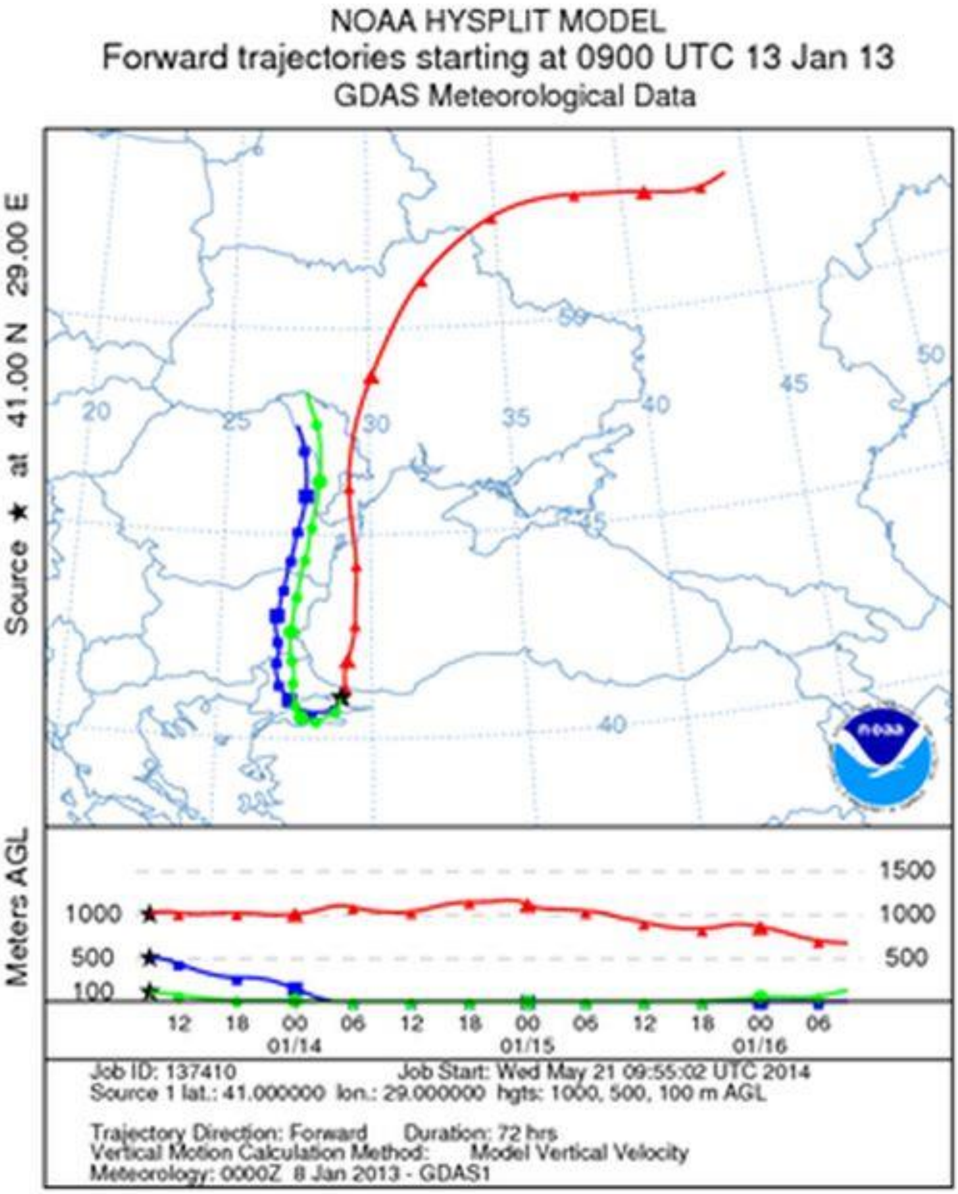

Figure 7. HYSPLIT 72 hour backward trajectories for air parcels arriving over the İstanbul.

4. Concluding Remarks

In this study, we present an analysis and evaluation of an air pollution episode of PM_{10} concentrations that occurred during mid of January 2013 in the Greater İstanbul Area. The surface meteorology during the episode was characterised by cold air, strong inversions, high pressure, and light winds. Application of the HYSPLIT trajectory model is showed that the sources of air pollution were not long-range transport from the Saharan Desert; thus, the high PM_{10} concentrations during the episode most likely originated from the increased heating of residences due to the low temperatures. Accuracy in forecasting air pollution levels critically depends on the ability of NWP models to compute relevant meteorological parameters such as temperature, wind speed, pressure and relative humidity. Thus, we tested the performance of the limited area weather forecasting models HIRLAM and HARMONIE with respect to this pollution episode. Our results showed that the 24-h forecasts from HIRLAM and HARMONIE correctly forecast the low temperatures, the low wind speed, the high relative humidity, high pressure and the precipitation accumulation during this episode. For dispersion modeling this is not very relevant, but it makes the meteorological output less suitable to forecast source strength, as residential heating is probably an important source.

Our results are promising for the improvement of 24 hours air quality forecasts for big cities such as İstanbul, and will hopefully benefit model developer teams, the health care system, early warning systems, and general population of İstanbul by encouraging governmental policy makers to take action and decrease the sources of air pollution in order to ultimately improve air quality. It is possible to choose more station to evaluate this kind of NWP model result for megacities like İstanbul for better forecast distribution in future studies.

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Analysis of Rainfall Hazard in the City of Algeria

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Abstract

The design of sewerage systems is directly related to rainfall, which has a highly random character.
Showers are usually described by three characteristics: intensity, volume and duration. Several studies considered only in two of the three models. The objective of our work is to perform an analysis of the impact of three variables on housing costs of sewerage, responsible for misbehavior, origin of urban flooding.
30 events were considered events for the longest, most rushed and most intense period which runs from 1986 - 2001. We built the IDF curves and heavy projects double symmetrical triangles associated with this selection.
A simulation of the operation, with the model canoe, sewage from the city of Annaba (Algeria) in the three rain solicitation project, double triangles associated with events considered.It appears that the sewage of the city of Annaba, in terms of charging, is much more sensitive to rain most precipitous, and the more intense causing loadings and last the longest. Further analysis of all the rain and the field measurements are underway to confirm the test simulations.

KEYWORDS: rand rainfall, intensity, volume, duration, sewerage, design, simulation, flood, CANOE.

1. Introduction

Rainfall is a very important component of the hydrological cycle. Climate observations necessary for the development of climatologically study, in the series of observations and hyetographs of showers were acquired from the ANRH (National Agency of Water Resources) and ONM (national Meteorology Office).

2. Materials and methods

2.1 Study area

The study region is located in northeast of Algeria, north of Mediterranean between 07 degree 27 and 07 degree 45 north of latitude and 36 degree 36 and 36 degree 55 west of longitude. Annaba region has low measurement network density formed of ten rain gauges in an area of approximately 1429 km2 (fig.1).