SIMULATION OF A HIGH IMPACT WEATHER EVENT OVER ISRAEL WITH THE WRF-RTFDDA SYSTEM – A CASE STUDY

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1. INTRODUCTION

Numerical weather prediction (NWP) over Israel is a challenging goal. The geographical nature of the region, mainly characterized by the sea-land interfaces along the Mediterranean and Red-Sea coasts, complex topography along the west and north regions and a mosaic of land characteristics including different types of vegetations, urban and dessert areas, results in complex mesoscale and microscale flows. In addition, the synoptic flow patterns of the region lead to a wide variety of weather regimes that have been widely characterized and classified (see e.g., Alpert *et al.*, 2004 and references therein). As a result, NWP over the region implies a multi-scale problem that ranges from the synoptic to the meso-beta and gamma scales. Therefore, the use of an advanced mesoscale model in a nested configuration is a requirement in this case.

The data assimilation procedure is an essential component of a NWP system, as forecast skill relies critically on, among other things, the model initial conditions. In the area of Israel and its surroundings, surface and upper air in-situ observations are sparse, both over the Mediterranean Sea and over land areas (see Figs. 1 and 3). A competent data assimilation (DA) system applied to this area should be capable of assimilating other than in-situ direct observations. Techniques such as optimal analyses and nudging are limited to the assimilation of observations of state variables (e.g., surface and upper air in-situ observations) or retrievals of model variables from remote sensing observations (e.g., satellite radiances, GPS radio-occultations, radar reflectivity). Variational and ensemble (Kalman) filter based techniques are capable of assimilating remotely sensed data without the need of retrieving (in many cases ambiguously) model variables. The direct assimilation of radiances, for instance, has been demonstrated to improve model skill to a larger extent than the use of retrievals. However, variational techniques are not mature enough to deal with the fine resolutions (grid sizes of less than 10 km) required to skillfully model the flow over the area of interest, for they rely on large scale balance constraints. And, ensemble (Kalman) filter techniques have not yet been implemented in mesoscale models with such fine resolution.

On meso-beta and -gamma scales, nudging techniques have proven to be the most effective operationally, in particular in the lower troposphere. Probably, a hybrid system which encompasses variational DA for coarse resolutions together with nudging DA techniques for fine resolutions would be the optimal present solution to achieve our goal. However, no operational system with those characteristics has been developed and implemented yet.

In the last few years NCAR/RAL has developed an observation-nudging-based rapid-cycling four dimensional DA and forecast (RTFDDA) system (Cram *et al.*, 2001) for the Army Test and Evaluation Command (ATEC). The system, based on MM5 is running operationally at five Army test ranges. Moreover, the system is relocatable and been used operationally at more than 20 sites over the globe. During the last two years, the WRF model has been adopted for RTFDDA (Liu *et al.*, 2005) and an observation nudging capability was implemented in the community WRF. The system allows multiple nests, making it possible to cope with multi-scale needs. The system is capable of assimilating non-conventional observations using the nudging scheme, including ship and buoy observations, observations from GTS/WMO; NOAA/NESDIS satellite winds derived from cloud, water vapor and IR imageries; NOAA/FSL ACARS, AMDAR, TAMDAR and other aircraft reports; NOAA/FSL NPN (NOAA Profiler Network) and CAP (Cooperative Agencies Profilers) profilers; the 3-hourly cloud-drifting winds and water-vapor-derived winds from NOAA/NESDIS and NASA QuikScat sea

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surface winds.

Based on the above, the WRF-RTFDDA system is an attractive candidate to be applied for the area of interest. The WRF-RTFDDA was run over the Israel region to simulate an extreme-weather event. The following sections describe the model run configuration, the event's weather conditions, a preliminary verification of the model results, and a summary of the work.

2. WRF-RTFDDA SET UP.

Three domains, with grid sizes of 30, 10 and 3.33-km, were used in the numerical study, and the fine meshes were two-way nested in the coarser domains. The fine mesh domain is 450X850 km^2, covering Israel, and neighboring areas and coastal regions. The WRF-RTFDDA system was cycled at 6 hour intervals, generating hourly analyses and forecasts for nearly 4 days, from 00Z Feb. 6 to 18Z Feb. 9, 2006. The following observations were assimilated:

1. Two kinds of upper air observations:
   a. Radiosondes at fixed locations, available either once or twice a day depending on their location. Fig. 1 is a typical example of radiosonde-sounding availability near Israel.
   b. AMDAR aircrafts observations along commercial flight legs, mostly during the day. Fig. 2 shows a typical map of AMDAR observations within the finest domain.
2. Two kinds of surface observations:
   a. Standard WMO surface stations (Metar, Synop, etc.) available at hourly to six hourly time resolutions.
   b. NASA QuikScat sea surface winds, over water only, available twice a day.
   Fig. 3 shows a representative example of surface observations used in this work.

The suite of physical parameterizations used to run WRF is described in Liu *et al.*, 2005. No tuning of the DA parameters for the specific region was performed. The system was run using the parameter values employed for the operational ATEC-ranges.

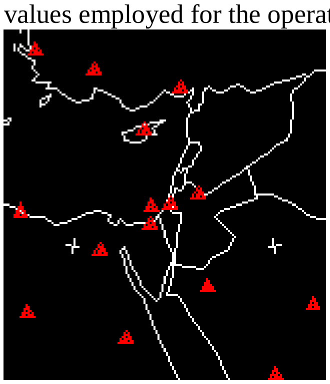

Fig. 1: A representative map of available WMO radiosonde-soundings in the area.

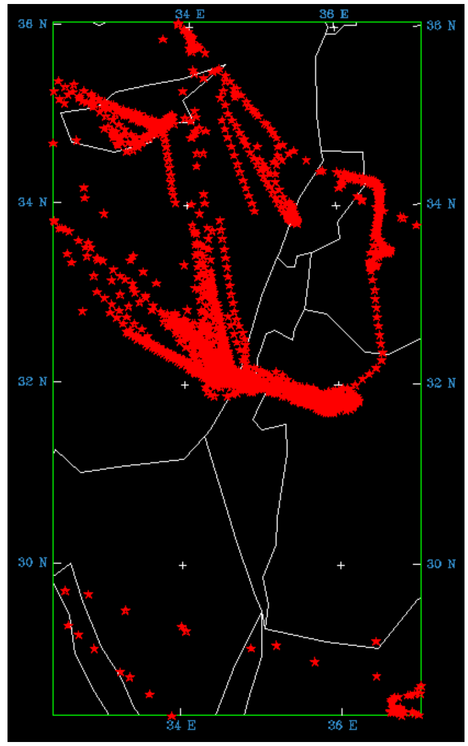

Fig.2: A representative map of available AMDAR aircrafts observations in the 3.3 km resolution domain.

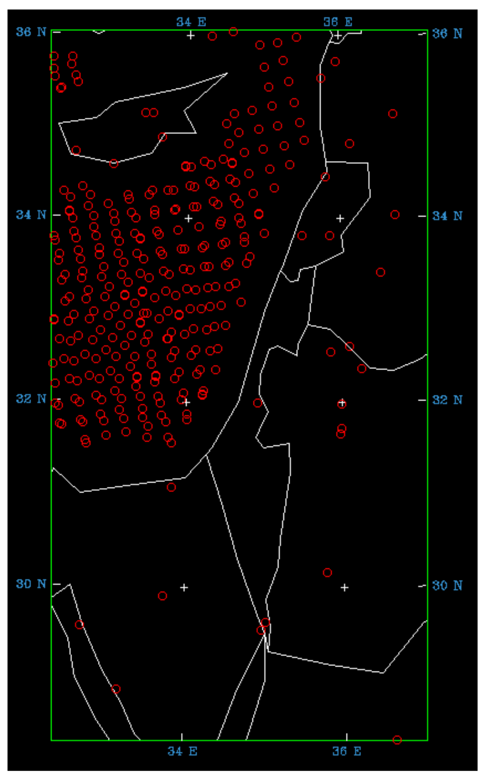

Fig. 3: A representative map of available WMO surface observations and NASA QuikScat sea surface winds in the 3.3 km resolution domain.

3. EVENT WEATHER: FEB 7, 18Z – FEB 9, 12Z, 2006

During the evening of Feb 7 2006, a surface Cyprus Low located over the Mediterranean Sea to the west of Cyprus caused southerly to south-easterly surface winds over Israel. At 500 hPa, the area was dominated by a deep trough to the west of Israel. Medium and high clouds over Israel caused local rains during the night hours.

On Feb 8 2006 surface pressure maps showed a pronounced gradient, which strengthened the south-westerly surface winds. The strong winds caused heavy haze and even sand storms over the whole country. The haze was advected from the Sinai Peninsula and North-Africa. It severely limited the visibility, in some areas to less than 1 km. Medium and high clouds covered Israel. The 500 hPa trough over Israel deepened during the night. The lower levels over Israel were dominated by the Cyprus low's cold front, which caused westerly winds. As a result, well developed low clouds penetrated inland, along with rain, and the haze gradually disappeared.

On Feb 9 2006 surface maps showed that Israel was dominated by the cold air mass of the Cyprus low. The 500 hPa level showed a deep trough, together with a mass of cold air (-25° C). Weather conditions were characterized by rain and Cb cells.

4. MODEL RESULTS

In this section, we examine model results and compare them to observations. The purpose of this verification study is to illustrate the potential of using such a relocatable DA and forecasting system in this region. Further discussion on the optimization process needed to convert this system into a powerful forecast tool for this region will be discussed in Section 5.

Screen- and anemometer-height variables, analyzed and forecasted by the model, were compared to observations at several locations in Israel. Fig. 4 shows the location of three stations that were used in the comparison. The stations are located at different distances from the coast, and at different altitudes. The station named "c" was assimilated into the model, the other two were not. Four variables were examined: wind speed, wind direction, temperature and relative humidity. Fig. 5 shows observed, analyzed and forecasted wind speeds as a function of time for the three stations. Fig. 6 shows a similar comparison for temperatures. Results for wind direction and relative humidity will be discussed in the poster. The plots show good agreement between the model-analyzed and forecasted variables and the observations. The model captured both: a. the effect of the synoptic flow dominated by the surface Cyprus Low and by the 500 hPa trough; and b. the effect of local characteristics at each of the station locations. Fig. 6 shows that the model reproduced the temperature decrease caused by the synoptic processes at all stations, and in addition it captured the lower-temperature regime that characterizes station "b" (station "b" is located at a significantly higher altitude relative to the other two). Fig. 5 shows clearly that the model followed the high wind speed episodes that characterized the event. The difference should be noted between station "b", characterized by a roughly steady high wind-speed episode; and the two other stations, which show a high wind-speed episode with two wind-speed maxima. However, the model overestimated the high wind speeds at station "b". Little difference is found between analyses and forecasted results, indicating the benefit of the "spun-up" analyses of the continuous FDDA process. Similar verification results are observed for station "c", which was assimilated by the model, and the other two stations that were not.

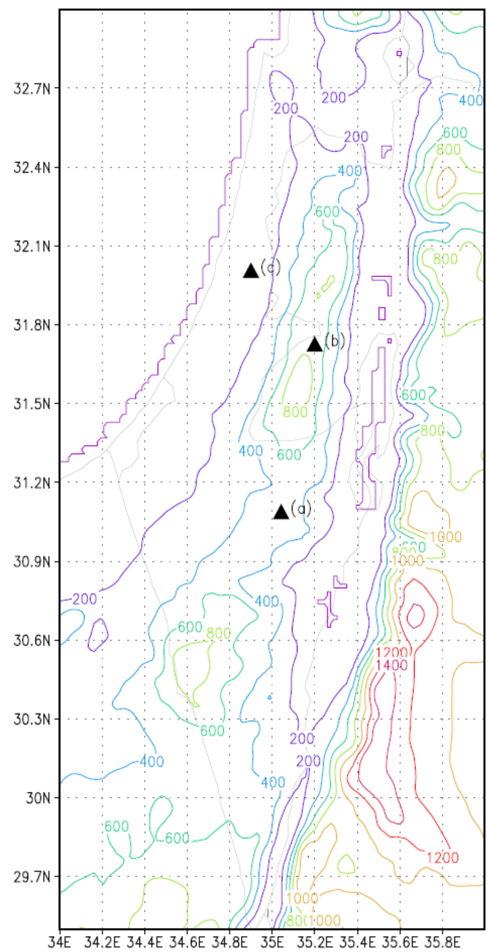

Fig. 4: Location of the surface stations used to analyze the model results (triangles). Contours show the model topography as resolved in the 3 km resolution domain.

A comparison between model hourly accumulated precipitation maps, radar reflectivity and satellite images will be presented in the poster.

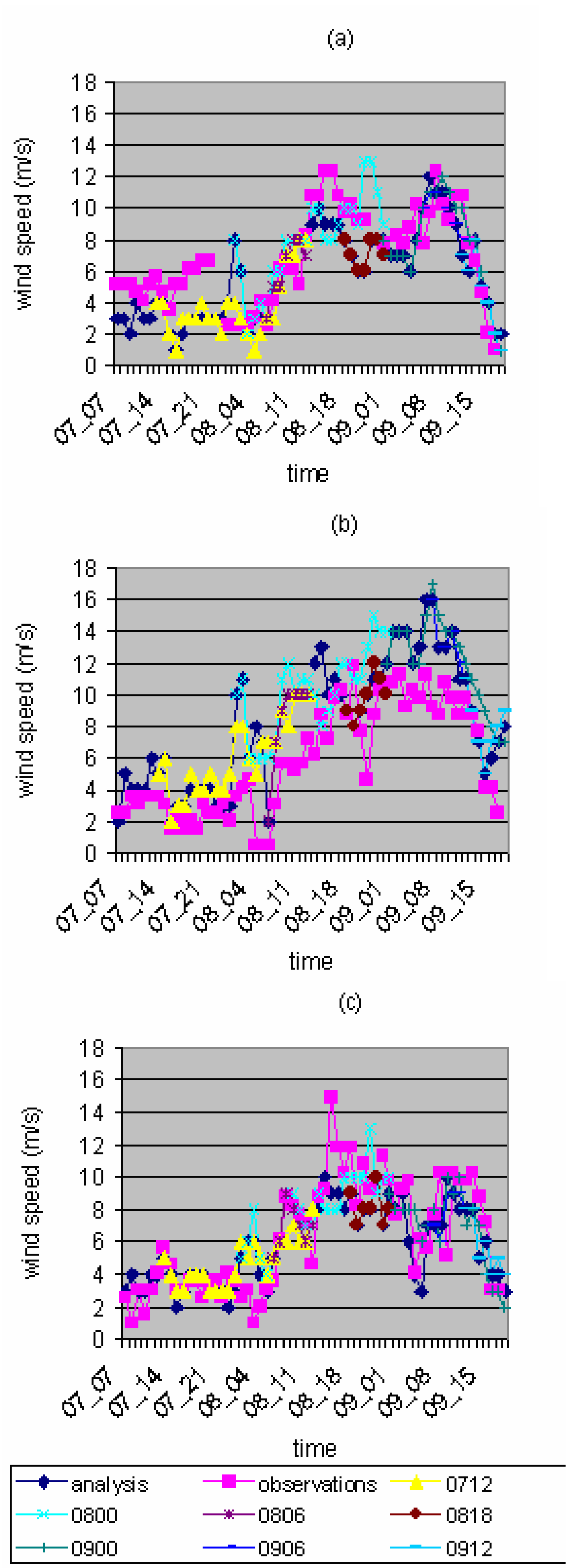

Fig.5: Time series of anemometer-height wind speeds at three stations. Shown: observations, model analyses, and model forecasts. Model forecasts identified by their starting hour and date, e.g., "0712" stands for Feb 7 12Z.

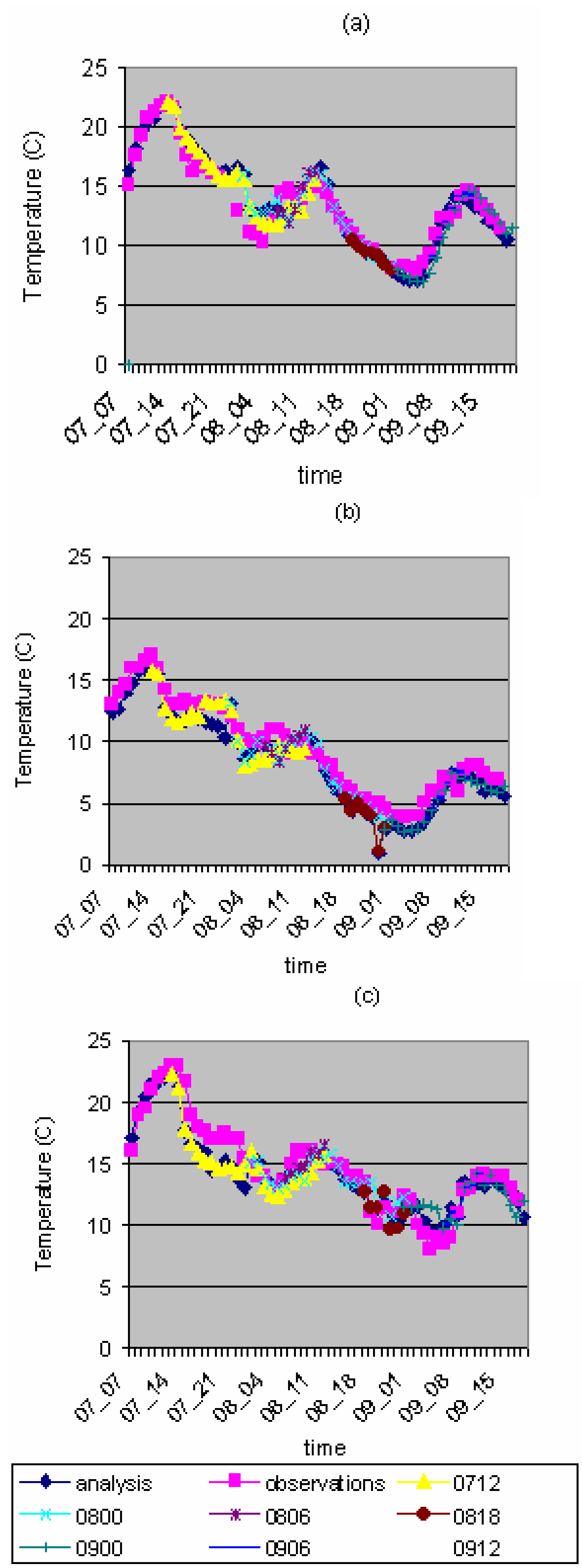

Fig.6: Same as Fig. 5 for screen height temperatures.

5. SUMMARY

The feasibility of using the NCAR/RAL WRF-RTFDDA system at a high horizontal resolution, including assimilation of conventional and non-conventional observations, over the Israel area was studied for a high-impact weather event. The model results showed good agreement with observations. This first numerical experiment shows the potential of using the system over this region. Yet, a comprehensive study is required to optimize the system for the region. The research should include, among others, studies to evaluate the model system performance on different weather regimes and seasonal evolutions, and asses the relative impact of the different components of the system on the forecasts, i.e., the DA procedure (including the use of variational assimilation schemes), the different types of observations, the horizontal and vertical resolutions, and the physical-process parameterizations schemes.

6. REFERENCES

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