STATISTICAL EVALUATION OF HIGH RESOLUTION MM5 SURFACE WINDS AND TEMPERATURES OVER COMPLEX TERRAIN

D. Rostkier-Edelstein[1], S. Berkovic, and R. Givati

Israel Institute for Biological Research

1. INTRODUCTION

This paper presents preliminary results of a project (Rostkier-Edelstein et al., 2003) with a twofold aim: 1. To test the ability of the Penn State/NCAR MM5 mesoscale model to reproduce the major features of the flow in a coastal area of complex terrain in Israel; 2. To statistically evaluate the model results versus observations (as opposed to a specific episode reproduction). To the best of our knowledge this is the first evaluation of this kind of MM5 model results at high resolution over Israel.

2. TERRAIN OF THE STUDIED AREA

Fig.1 shows the studied area as resolved by the 2 km resolution grid used in our simulations (see Sec. 4) and the location of the surface stations. All stations are located at urban areas at a height of about 6 to 10 meters above the roofs.

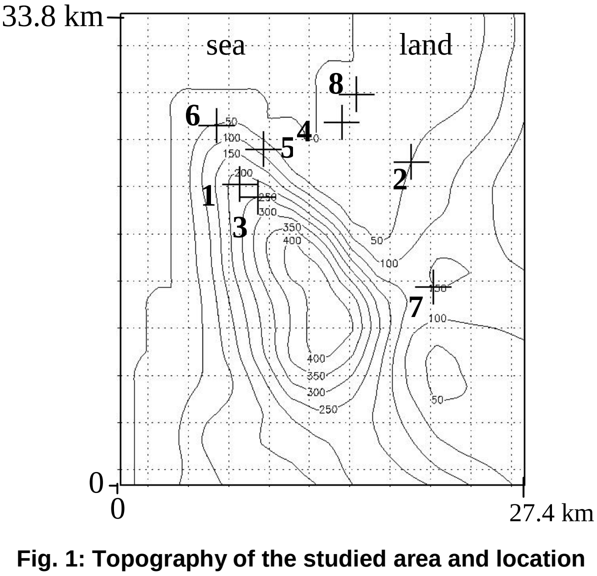

Fig. 1: Topography of the studied area and location of the surface observation stations. Heights are shown in meters.

3. SYNOPTIC AND MESOSCALE BACKGROUND

Our study focused on a summer period. Throughout the summer, the eastern Mediterranean is dominated by a Subtropical ridge extending from the north-African coast to the east, and by the Persian trough extending from the monsoonal low through the Persian Gulf to the northeast Mediterranean and Turkey (see e.g. Alpert et al., 1992). The mesoscale dynamics are dominated by the sea-land breeze mechanism and by mountain-valley circulation. (see e.g. Lieman and Alpert, 1993 and references therein)

4. MODEL SETUP

The standard PSU/NCAR MM5 model version 3.2 was configured using 4 nested domains with 1 way nesting interaction and with horizontal resolutions of 54, 18, 6 and 2 km (Fig. 2). The vertical resolution is of 26 levels with 11 levels between sigma 1.0 and 0.8. Forty-eight hour simulations initialized at 0 UTC were run for July 1994. The model employed the following physical options: 1) Grell cumulus scheme, 2) MRF boundary layer scheme, 3) Five-layer soil temperature model, 4) Dudhia simple ice microphysical scheme, and 5) Cloud-radiation scheme. The first guess and boundary conditions were provided from the GEOS-1 Multi Year Assimilation Data Mediterranean subset (Da-Silva and Alpert, 1996), with spatial resolution of 2° latitude by 2.5° longitude and temporal resolution of 6 hours; and from the AVHRR sea surface temperature data set, with spatial resolution of 0.5° latitude and longitude and averaged over 5 days (WOCE Satellite Data CD-ROM, Version 1.1). No objective analysis or data assimilation was done.

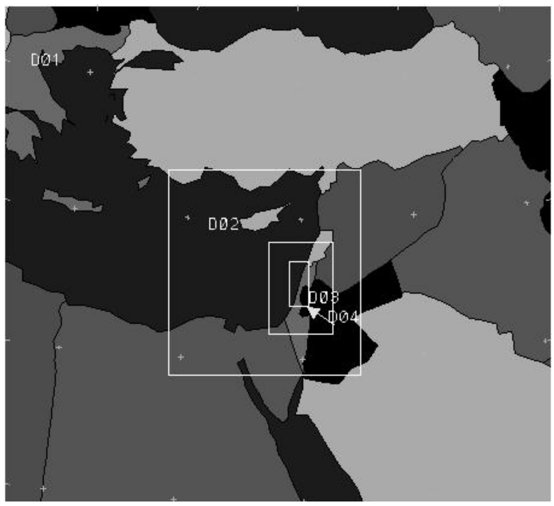

Fig. 2: 54, 18, 6 and 2 km MM5 modeling domains.

[1]Corresponding author address: Dorita Rostkier-Edelstein, Dept. of Math., IIBR, POB 19 Ness-Ziona 74100 Israel
Email: rostkier@ iibr.gov.il

5. RESULTS

Model variables were output every hour. 10 minutes averaged observations of wind and temperature, collected during July 1994, at model output times were used for the evaluation. The evaluation is done by comparison of simulated and observed monthly averaged daily cycle of temperatures (Fig. 3) and of wind speeds (Fig. 4), monthly averaged wind vectors (Fig. 5) and wind speed and wind direction distributions (Fig. 6). The model output at 2 km resolution and about 15 m above the surface, after 24 hours of spin up, is presented for comparison. We emphasize the evaluation is done for each of the stations independently and not averaged over the whole set, in order to test the validity of the model in different terrain areas. The most important findings may be summarized as follows:

1. The model was able to reproduce rather well the wind direction distribution (Fig. 6): the most frequent octants and the most infrequent octants are mostly the same in the simulations and in the observations, in some cases the most frequent octants are shifted by 45° clockwise; 2. Average simulated wind speeds (Fig. 4) correctly show the observed diurnal cycle in most of the stations, but the model fails to reproduce the enhanced speeds observed especially at high terrain elevation stations; 3. Average simulated temperatures (Fig. 3) are in agreement with the diurnal observed cycle at most of the stations, thereby showing the effect of topography and distance from the coast; 4. Simulated wind hodographs (Fig. 5) show a similar pattern to the observed ones, showing differences between high and low topography stations, but are rotated clockwise by about 30° in most stations (root mean square errors of 45°-50° have been reported in various works dealing with MM5 simulations at high horizontal resolutions, see e.g. Hanna and Yang, 2001).

The evaluation shows that in some cases correct prediction of temperatures does not guaranty correct wind prediction: for example at some stations the model succeeds to predict the temperature correctly but fails to predict the correct wind speeds (e.g. stations 1 and 3).

The study shows that the performance of the model is different according to the characteristics of the terrain. Therefore, it stresses the need of detailed evaluations and verification in areas of complex terrain (as opposed to an evaluation averaged over the whole set of observation stations in the studied domain) as the discrepancies between the model results and the observations in some parts of the domain may be of critical importance. The evaluation shows the difference in the timing of the diurnal cycle encountered in some cases between model results and observations.

6. FURTHER WORK

We suggest the following approaches in order to optimize model results in the present case: 1. Increase horizontal and vertical resolutions; 2. Improve initial guess and lateral boundary conditions by objective analysis and perform assimilation of data from stations at locations with different terrain characteristics; 3. Adapt land use parameters to the specific area; 4. Include an urban surface layer and/or urban boundary layer parameterization (e.g. Otte and Lacser, 2001); 5. Use true horizontal diffusion scheme in the integration of the equations of motion (e.g. Zangl, 2002); 6. Check sensitivity to SST data, especially the effect on the strength of the sea-land breeze.

7. REFERENCES

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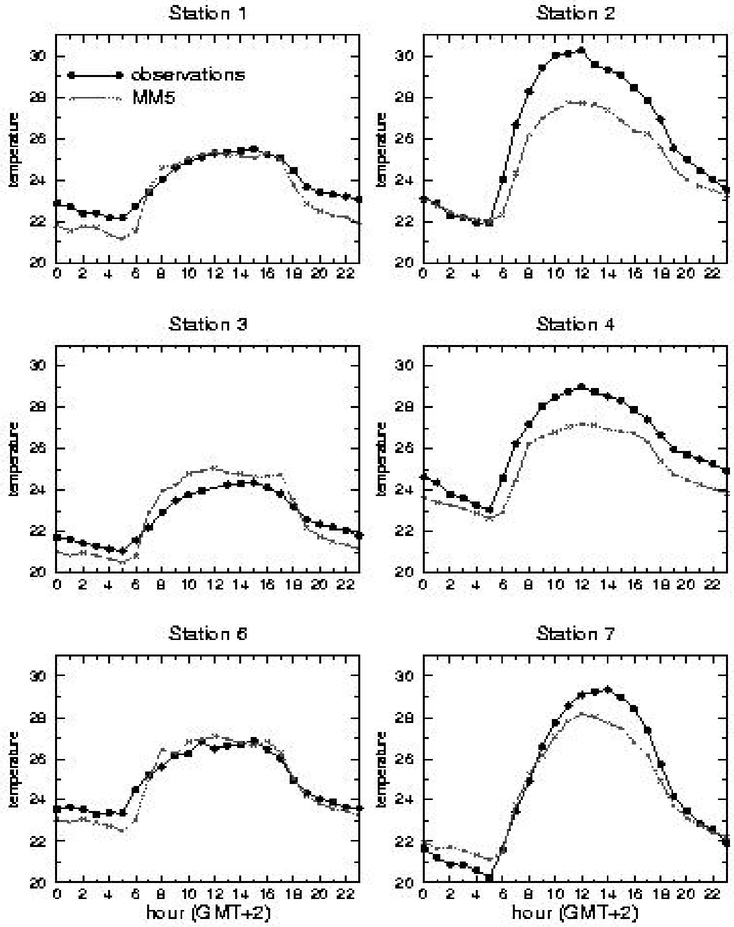

Fig. 3: Monthly averaged observed and model temperatures (in Celsius degrees) as a function of the local standard time for 6 of the stations (no temperature measurements were available for stations 5 and 8). Full lines and circles: observations. Dotted lines and crosses: model results.

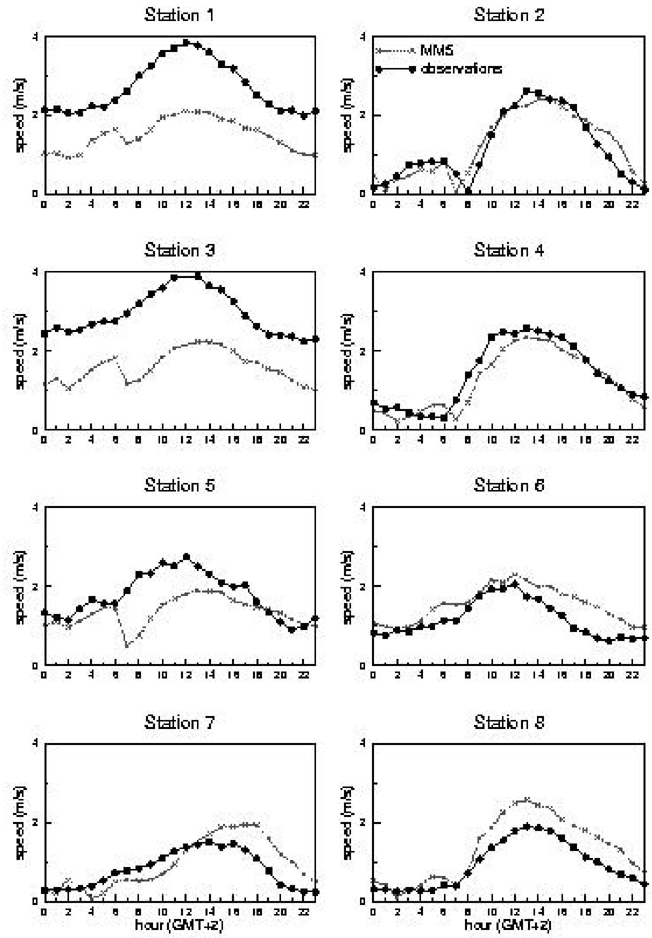

Fig. 4: Monthly averaged observed and model wind speeds (in m/s) as a function of the local standard time for the eight stations. Full lines and circles: observations. Dotted lines and crosses: model results.

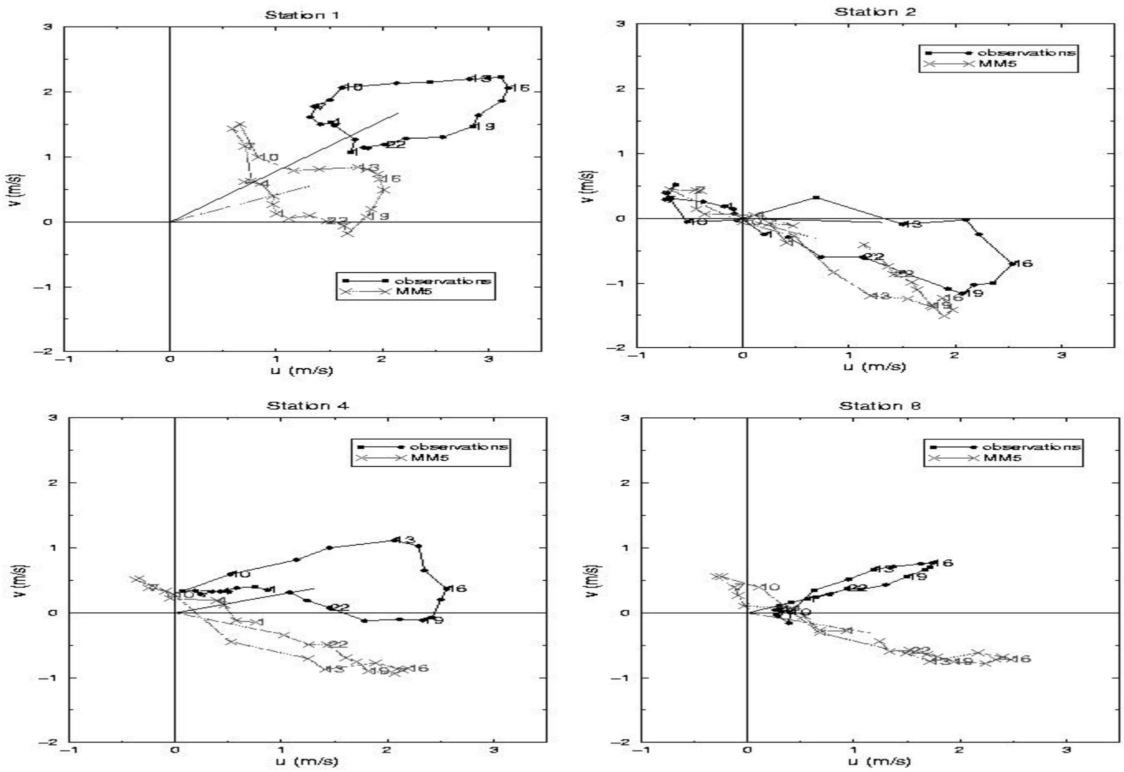

Fig. 5: Monthly averaged hodographs for 4 of the stations: Each point represents the head of the averaged wind vector at the specific hour of the day (local standard time). Straight lines starting at the origin represent the 24 hours monthly averaged wind vectors, positive u for westerly winds, positive v for southerly winds. Full lines and circles: observations. Dotted lines and crosses: model results.

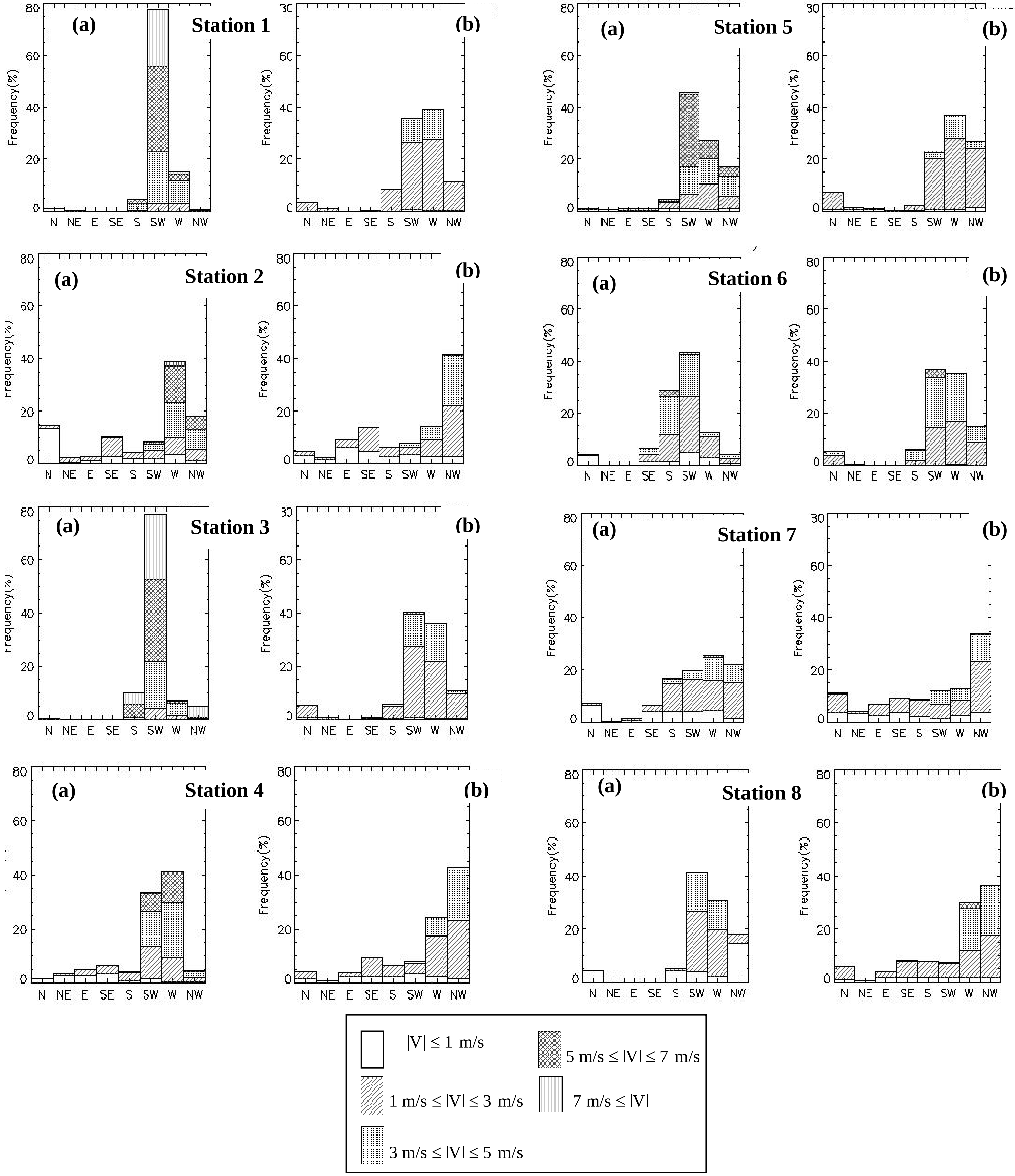

Fig. 6: Distributions of wind direction into octants and wind speeds into 5 categories. (a) Observations. (b) MM5 results.