Examples of Verification of the LM Results Vs. Synoptic Observations and Vertical Soundings

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Introduction

The goal of weather forecast is to reproduce all the physical processes occurring in the atmosphere together with time extrapolation of them. Numerical models, developed for many years, try to get with their results as close as possible to real meteorological situations and to elongate the period of a forecast. Direct model output (DMO) is used for many other applications (PPP - Post Processed Products), including graphical presentations, meteograms, statistical corrections (e.g. Kalman's filter) and dedicated End Products (EP) for end-users. Numerical weather forecast, obtained from COSMO-LM model is the basis for IMWM meteorologists. It is also the basis for many other forecasts like hydrological or bio-meteorological. Extremely important issue for the proper interpretation and further post-processing is the knowledge of errors of the forecast. The quality of 72-hour mesoscale forecast of DWD model for Poland was estimated through comparison of forecast results to routine meteorological observations at surface (meteorological) stations (see Fig.1) as well as to upper-air soundings, carried out at three Polish stations, located in Leba, Legionowo and Wroclaw. The location of a selected station in a particular grid square may have a big influence on a quality of forecast for this station. For example, the elevation of mountain station (calculated for the model needs) may differ and it does from a real one. In turn for station located at a seacoast influence of a neighboring sea may be also a crucial factor.

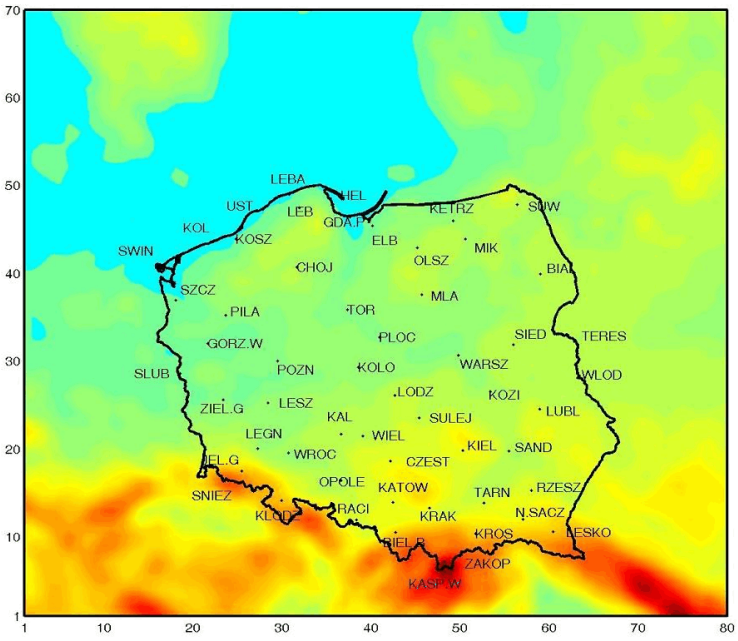

Figure 1: Locations of meteorological (surface) stations in Poland.

Figure 2: Aerological (upper-air) stations in Europe. Arrows indicate locations of Polish stations selected for comparison.

Results

The results of COSMO-LM were compared to actual values, observed at the stations. Data from regular model grid were interpolated to locations of selected meteorological stations. Following meteorological elements were concerned:

- Temperature at 2 m above ground level;
- Dew point temperature at 2 m a.g.l;
- Air pressure at sea level;
- Wind speed at 10m a.g.l.

Verification was carried out for midnight forecast for 0, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66 and 72 hours ahead. The following scores were calculated:

Mean Error (ME, BIAS)

$$\frac{1}{N}\sum_{i=1}^{N}(for_i - obs_i)$$

Root Mean Square Error (RMSE)

$$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(for_i - obs_i)^2}$$

Mean error (average over one month) may be interpreted as a systematic forecast error and thus may be considered during further processing. Root mean square error is a pattern describing the range of deviation. Results of this verification are shown in the following pictures.

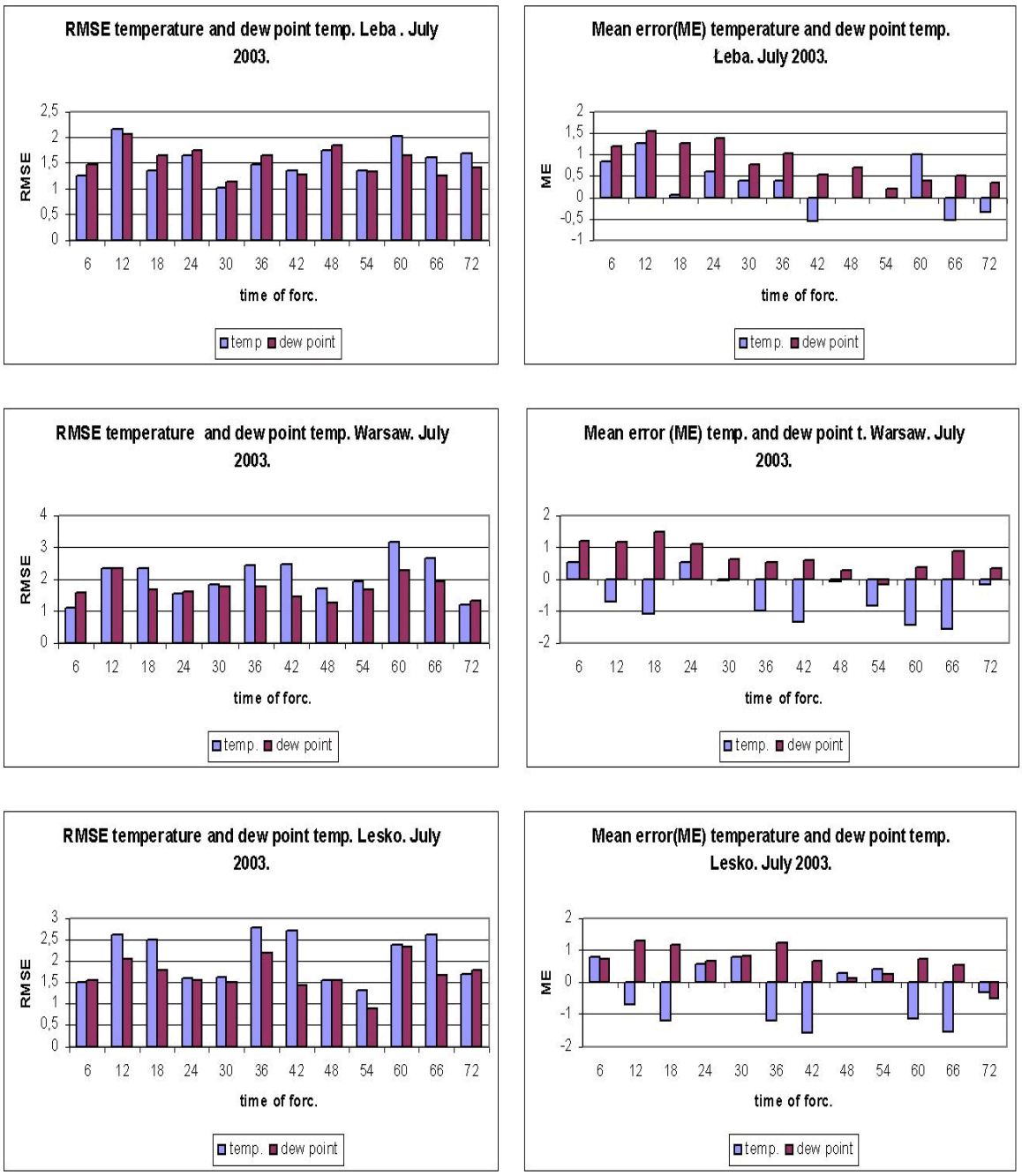

Figure 3: RMSE (left) and ME (right) of temperature and dew point temperature at 2m a.g.l for selected Polish meteorological stations.

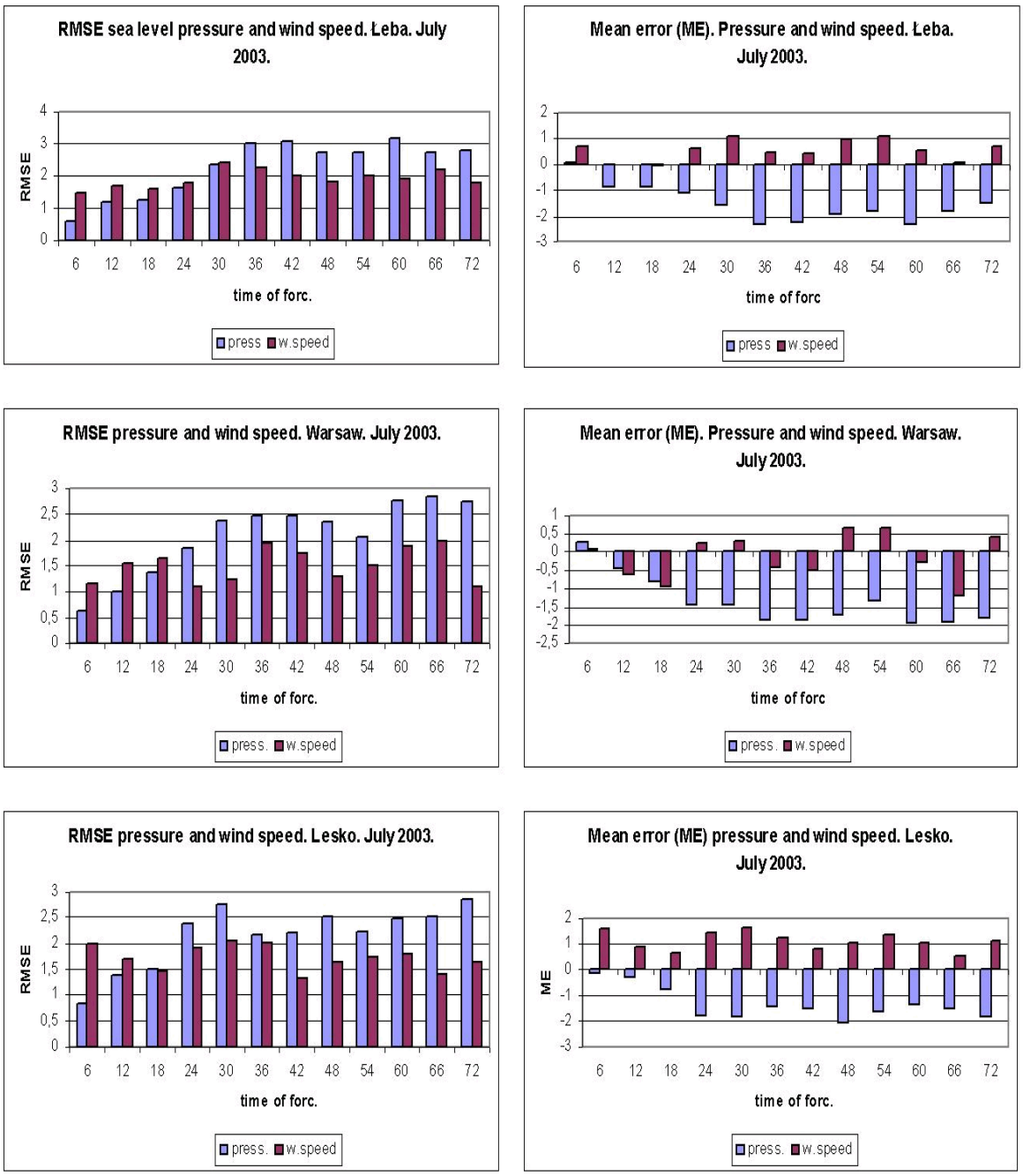

Figure 4: RMSE (left) and ME (right) of sea-level pressure and wind speed for selected Polish meteorological stations.

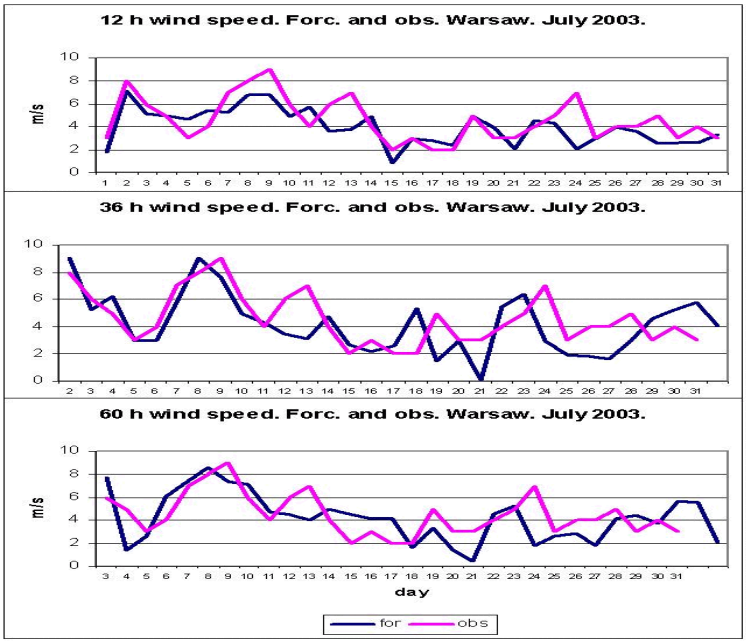

Figure 5: Wind speed - forecast and observations in Warsaw, July 2003. Upper panel - forecast for 12 hours, middle - for 36 hours and lower - for 60 hours ahead.

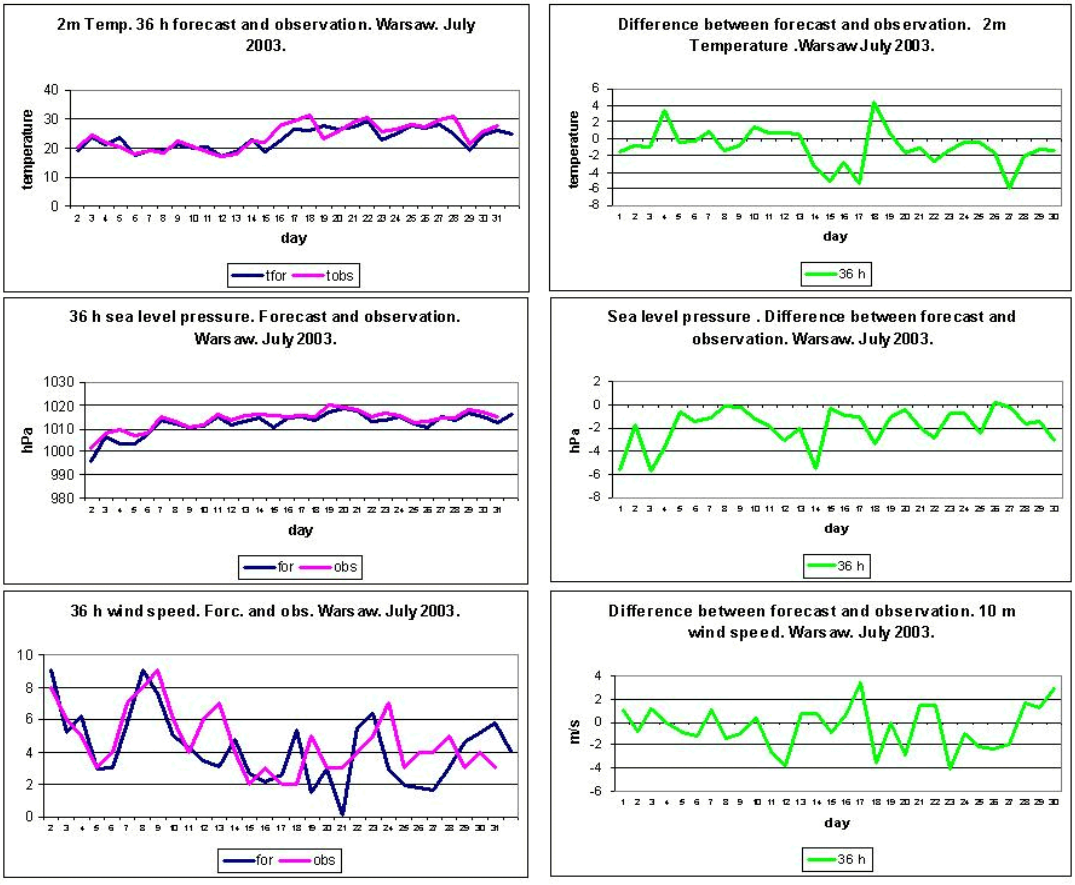

Figure 6: Air temperature, pressure and wind speed - forecast, observations and difference between them in Warsaw, July 2003. Forecast valid for 36 hours ahead.

As far as upper-air verification is concerned, it was done in 12-hour intervals, namely 12, 24, 36, 48, 60, and 72 hour of forecast with similar scores. The following meteorological elements (at standard pressure levels 1000, 850, 700, 500, 400, 300, 250 and 200hPa) were considered:

- Temperature;
- Relative humidity;
- Height of standard pressure level(s);
- Wind speed.

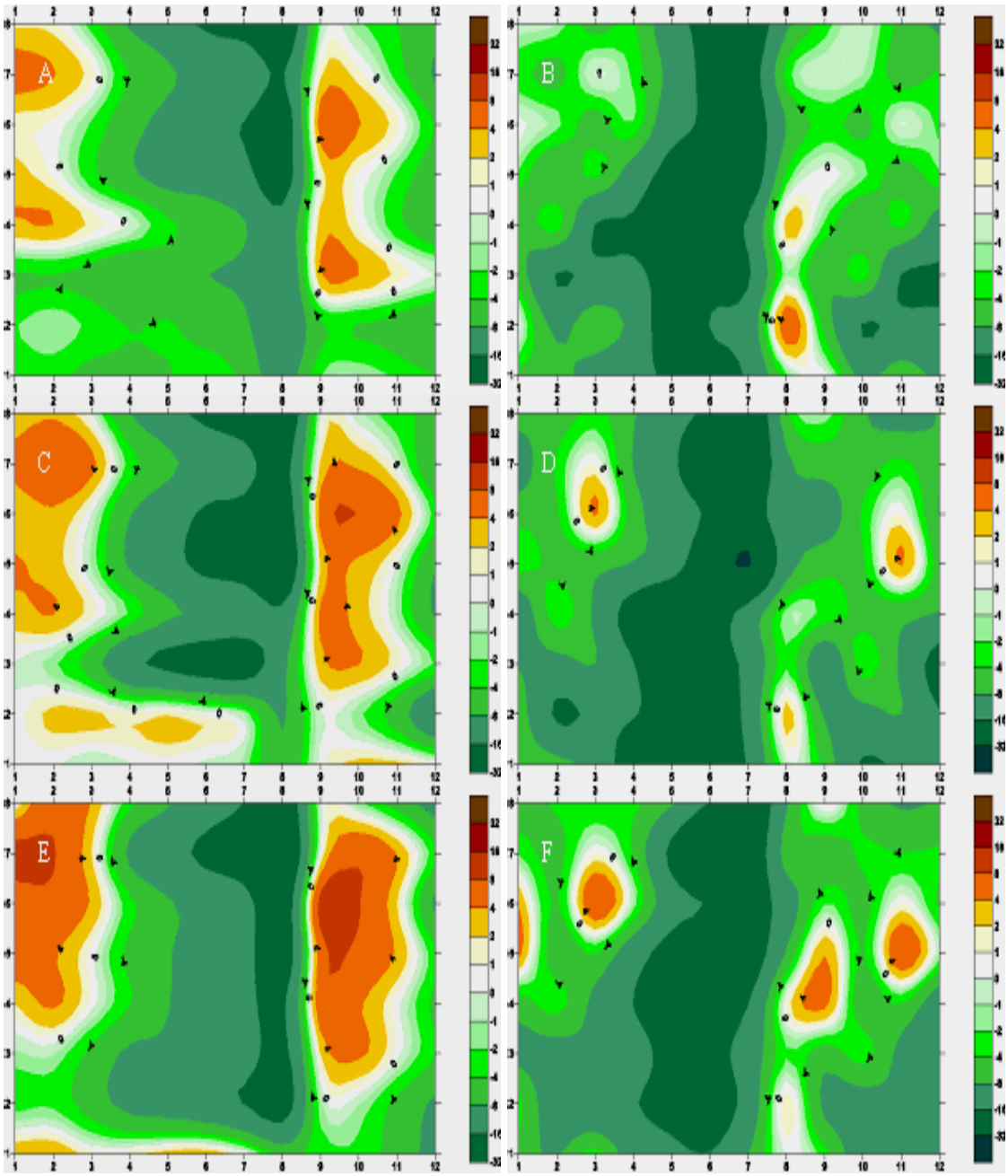

Figure 7: Monthly mean ME at standard pressure levels (1000, 850, 700, 500, 400, 300, 250 and 200 hPa). Left column - height of pressure level, right - relative humidity (forecast valid for 12 hours ahead). Comparison with upper-air soundings at: A and B - Leba station, C and D - Legionowo station, E and F - Wroclaw station. X-axis - months, Y-axis - pressure levels.

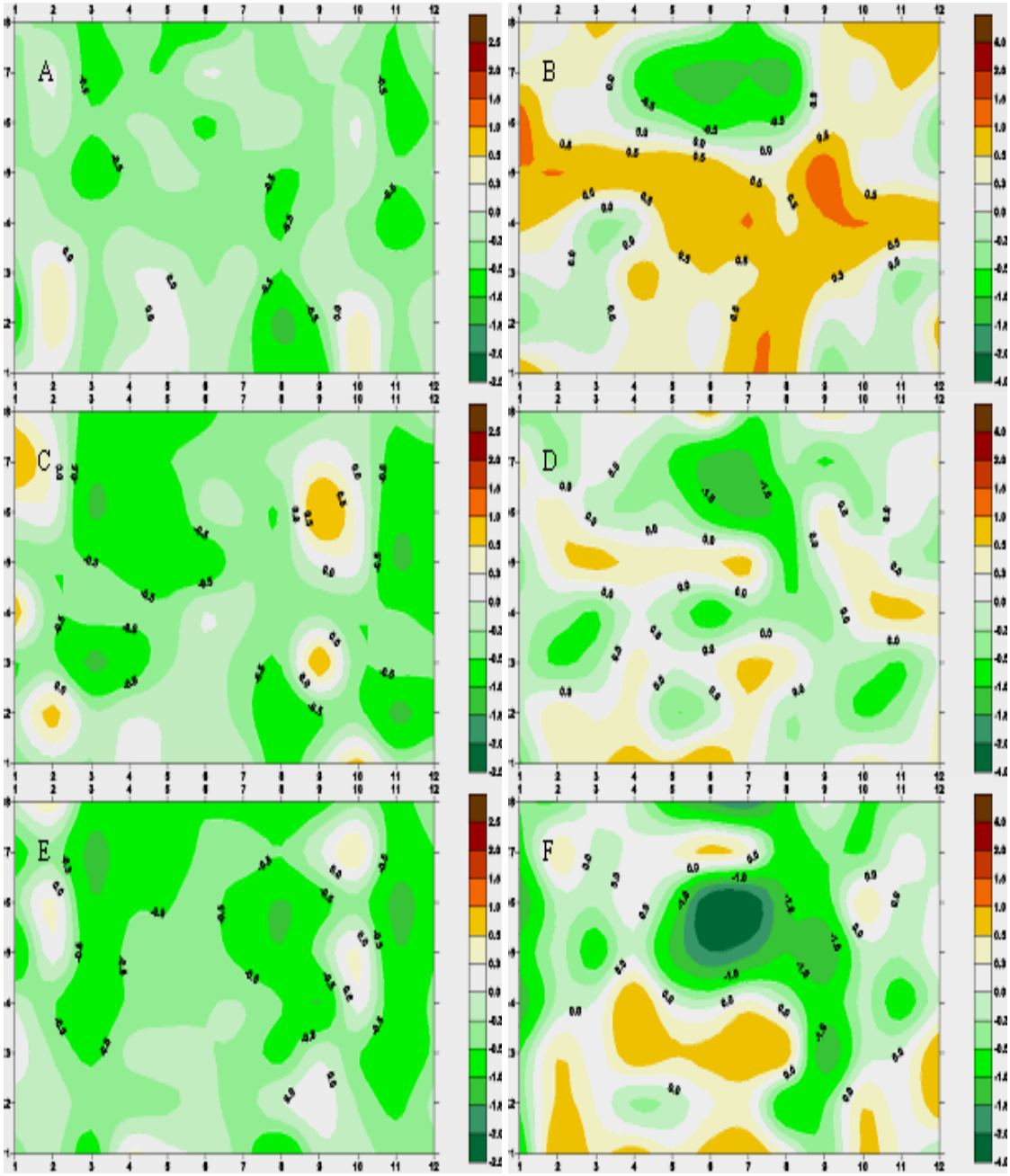

Figure 8: Monthly mean ME at standard pressure levels (1000, 850, 700, 500, 400, 300, 250 and 200 hPa). Left column - temperature, right - wind speed (forecast valid for 12 hours ahead). Comparison with upper-air soundings at: A and B - Leba station, C and D - Legionowo station, E and F - Wroclaw station. X-axis - months, Y-axis - pressure levels.

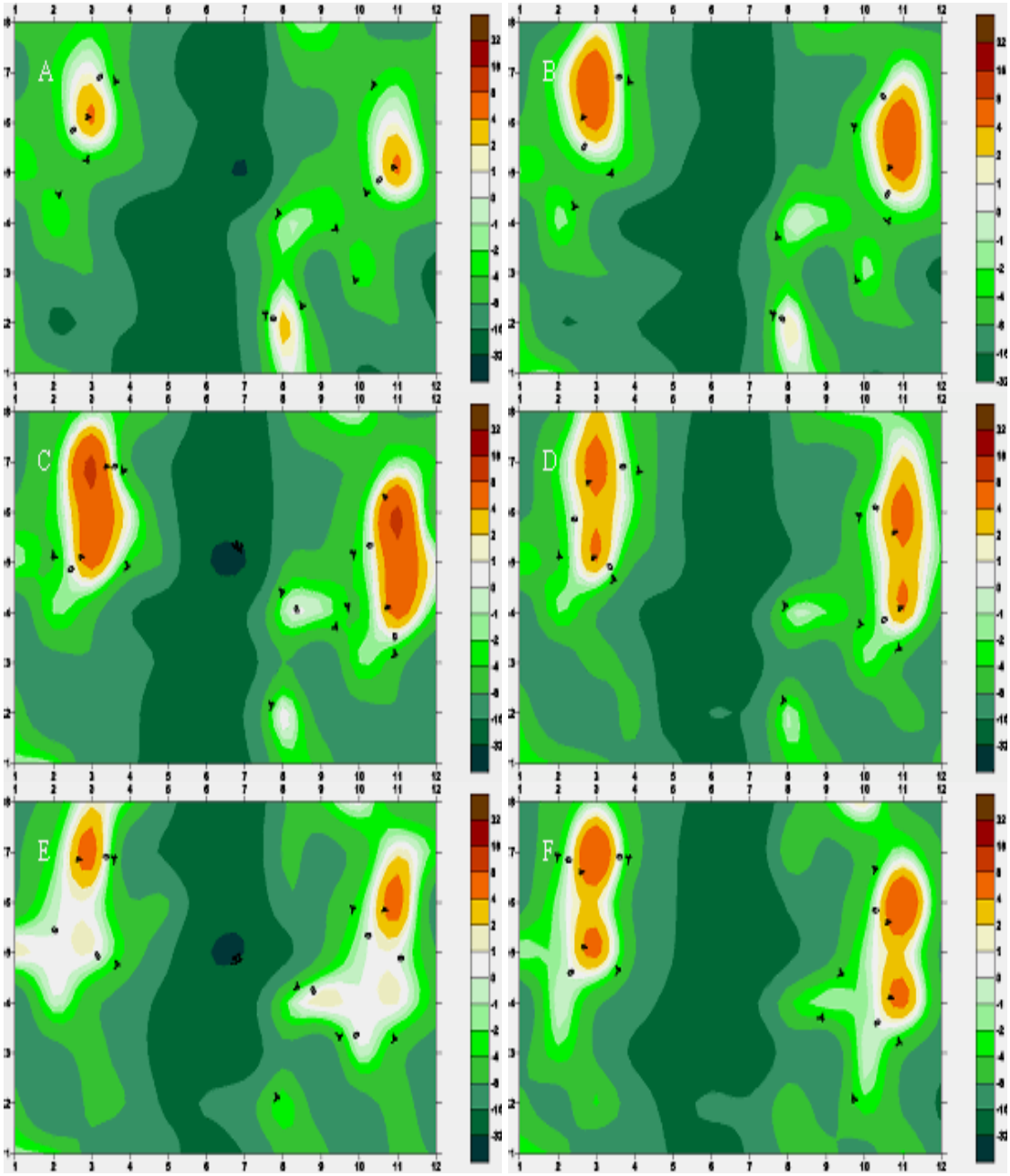

Figure 9: Monthly mean ME of relative humidity at standard pressure levels (1000, 850, 700, 500, 400, 300, 250 and 200 hPa). Comparison with upper-air soundings at: Legionowo station. Forecasts valid for: A - 12 hours, B - 24 hours, C - 36 hours, D - 48 hours, E - 60 hours, F - 72 hours ahead. X-axis - months, Y-axis - pressure levels.

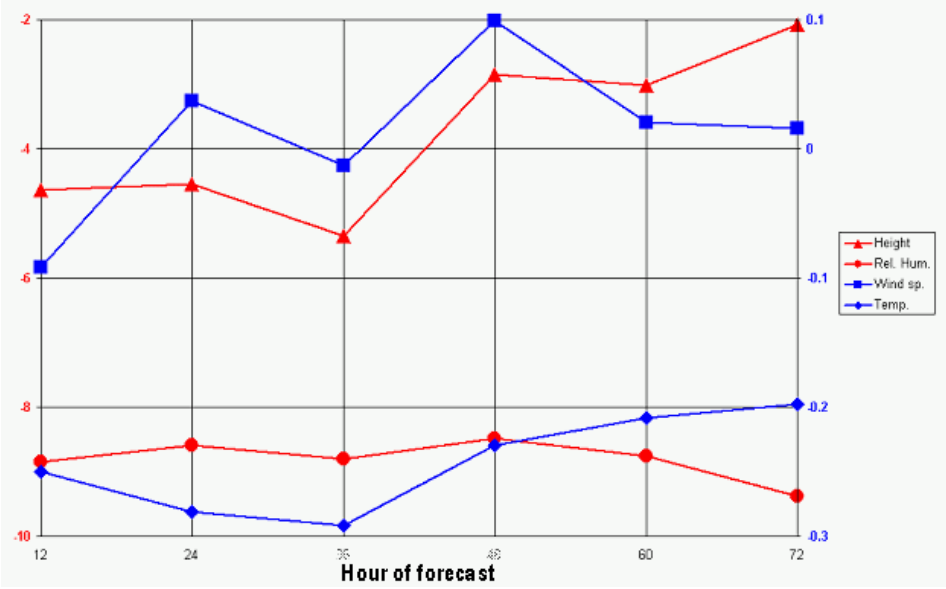

Figure 10: Annual average ME for height of pressure levels (m, left Y-axis), relative humidity (%, left Y-axis), wind speed (m/s, right Y-axis) and temperature (°C, right Y-axis) for forecast up to 72 hours ahead.

Discussion

A) Surface Parameters

RMSE for air temperature (and dew point) shows clear diurnal tendency. Large errors are observed for 12 and 18 hours (daytime) of forecast. For nighttime, error is significantly smaller (Warsaw and Lesko). Similar tendency can be seen for wind speed, and value of an error is considerably smaller for nighttime than for daytime. The tendency for air pressure is notably different. RMSE, very small in the beginning of the forecast, increases with the time of forecast.

In Warsaw, considered as typical station in middle Poland, monthly mean error is almost zero for nighttime of the forecast (0- and 6 hour) and is very small (and less than zero) for daytime (12- and 18 hour of forecast). Similar character of error can be seen at Lesko. For dew point temperature, almost all errors are positive while the opposite situation occurs for air pressure. All the errors are rather small for the beginning of the entire forecast and time courses (of forecast and observations) are very similar. The forecast of wind speed for very close to the real values, at least as July 2003 is concerned.

B) Upper-Air Soundings Conclusion that can be derived from the results gained is that the forecast is "surprisingly good" for temperature and wind speed and, moreover, that model is "too wet". Indeed, especially close to ground level, ME for both temperature and wind speed is very small, approximately ± 1 degree and $\pm$ 1m/s, respectively. The poorest (still interesting, however) situation appears in case of relative humidity, where - especially during a summer season - ME appears to be greater than 30%, which makes the value of relative error of about 50%. Furthermore, the quality of forecast of relative humidity (and only this forecast) decreases monotonously with time. For other parameters this tendency - naturally expected - is not so clearly seen.