Application and verification of ECMWF products 2012

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1. Summary of major highlights

- The ECMWF deterministic runs had the lowest average RMSE for temperature forecast compared with all the other models used by the IMS.
- ECMWF deterministic runs used by INCA (Integrated Nowcasting through Comprehensive Analysis) together with automatic station data yield a corrected analysis and nowcasting up to 6 hours.
- Statistical adaptation of ECMWF forecast, using bias correction of 7 days before a given forecast, significantly improves the forecast.
- The seasonal (3 months) precipitation hit score for Israel is about 50%.

2. Use and application of products

Including medium-range deterministic and ensemble forecasts, monthly forecast, seasonal forecast

2.1 Post-processing of model output

2.1.1 Statistical adaptation

2.1.2 Physical adaptation

ECMWF deterministic model output is ingested to INCA (Integrated Nowcasting through Comprehensive Analysis) high resolution nowcasting system (Haiden et. al. 2011). The system combines data from the NWP model (downscaled to 1 km resolution) with 85 AWS (Automatic Weather Station) observations. The ECMWF weighting function increases linearly from 0 to 1 in the time interval between analysis (+0 hr) and +6 hr forecast.

Fig. 1 presents the average Root Mean Squared Error (RMSE) and Mean Bias Error (MBE=model-observed) for both ECMWF and INCA 2m temperature for up to six hour forecast for 2011. It can be seen that INCA eliminates the ECMWF analysis bias of 2ºC and improves the nowcast skill.

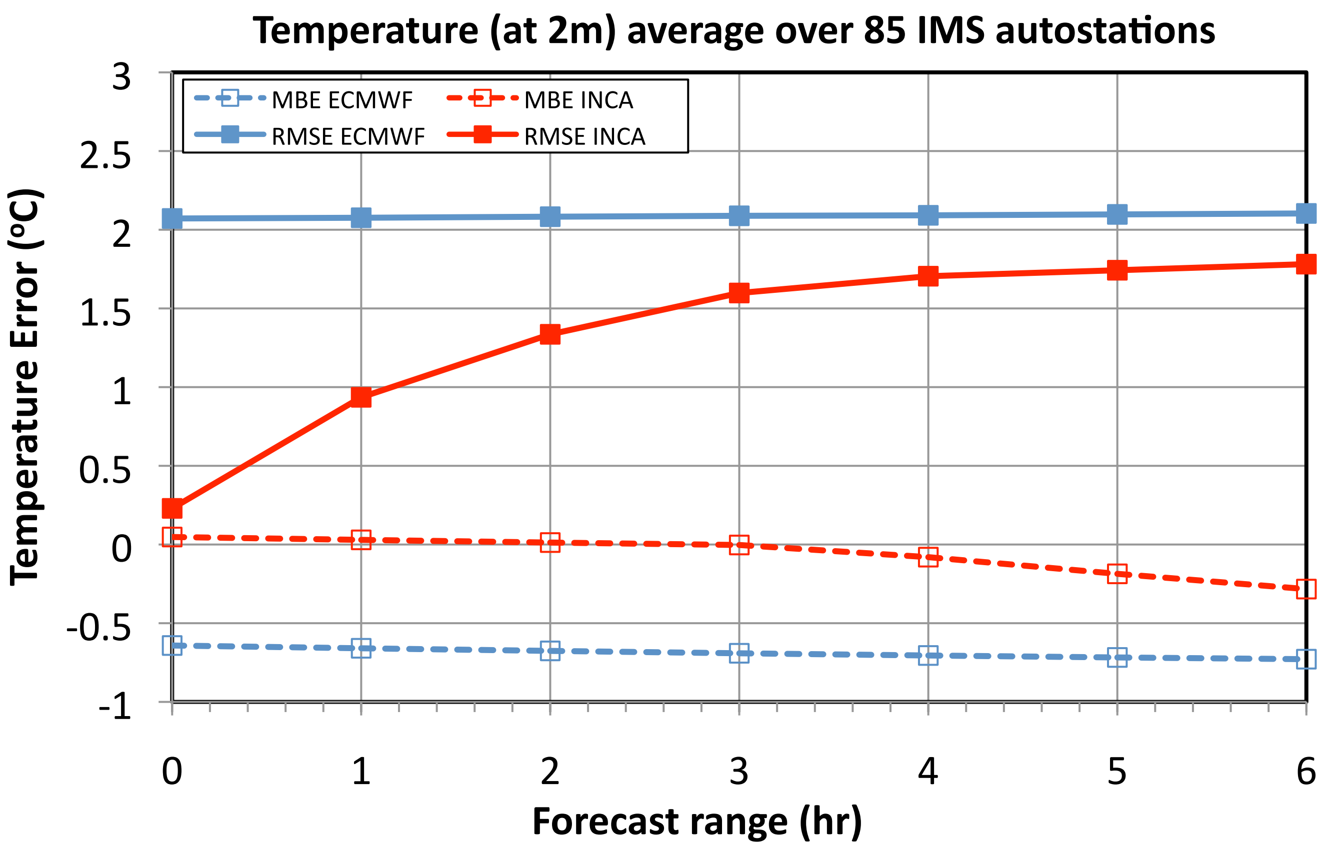

Figure 1 Average RMSE and MBE of ECMWF and INCA for the temperature analysis (forecast hour = 0) and the following first 6 hours calculated with 85 weather stations for every hour of year 2011 (8760 hour).

2.1.3 Derived fields

An advanced interface was developed, allowing, by a simple click, to present multi parameter meteograms at various grid points, representing 51 meteorological stations over Israel. An example of that interface is presented in Fig. 2.

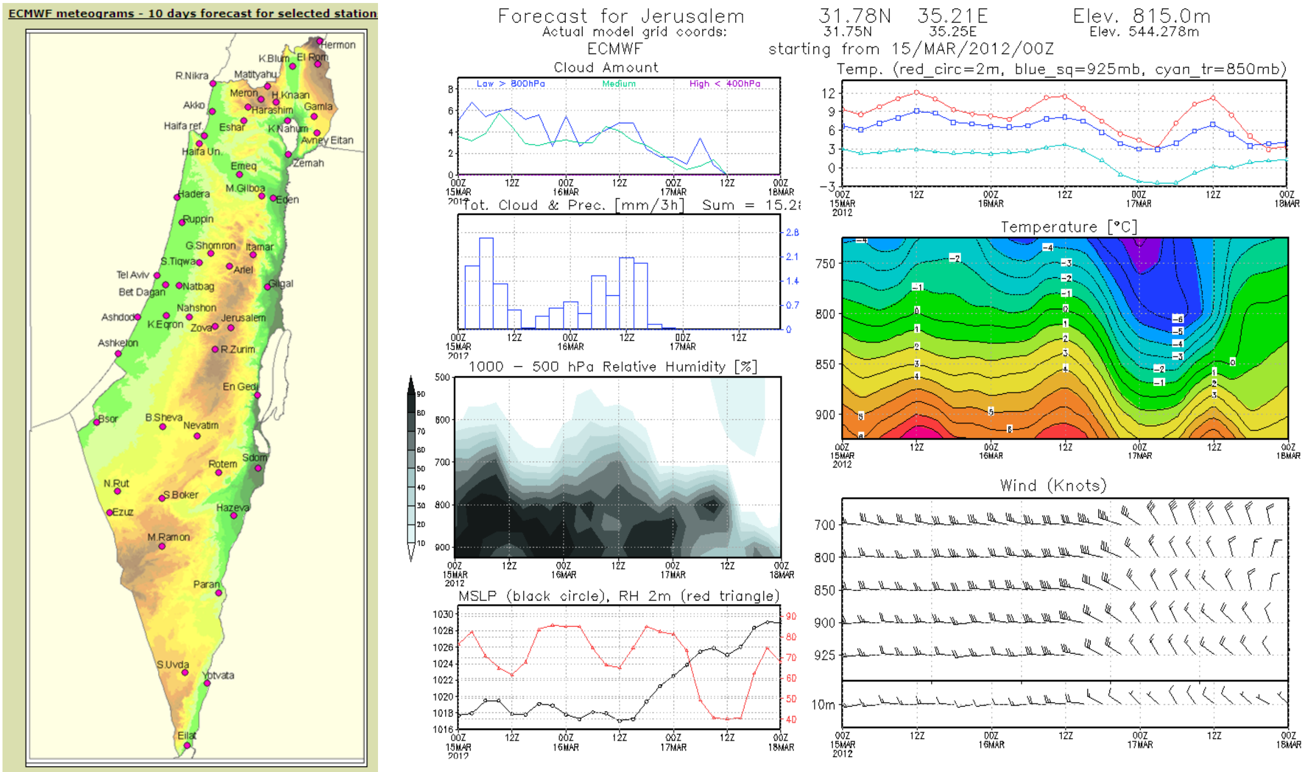

Figure 2 A map of the 51 stations, where multi parameter meteograms are available by a click.

2.2 Use of products

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

Israel has a Mediterranean climate with long, hot, rainless summers and relatively short, cool, rainy winters. The characteristics of the Israeli Climate are caused by Israel's location between the subtropical arid areas of the Sahara and the Arabian deserts, and the subtropical humid areas of the Levant and Eastern Mediterranean. The climate conditions are highly variable within the state and dependent locally on altitude, latitude, and the proximity to the Mediterranean Sea.

Here we present the ECMWF verification analysis performed over the period Nov 11, 2011 – Jul 31, 2012 at two metrological stations: Bet Dagan (near Tel Aviv) and Jerusalem. These two stations represent the Israeli Mediterranean climate region. Bet Dagan climate is highly affected by the sea, whereas Jerusalem climate is affected by both the sea and the topography of the central highlands. At the next table we summarize the characteristics of these two stations:

	Longitude	Latitude	Height (m)	Distance from the coast (km)	Distance from the nearest grid point (km)	Height of the nearest grid point (m)
Bet Dagan	34.814E	32.007N	35	7.6	5.81	63.8
Jerusalem	35.197E	31.770N	765	50.6	5.49	544.3

The verification analysis was performed for the meteorological parameters: temperature (at 2 meters), wind (at 10 meters) and precipitation (accumulated over 6 hours). For each of these parameters. Figs. 3,4,5 present the Mean Bias Error (MBE, calculated as Forecast - Observed) and the Root Mean Square Error (RMSE) as function of the forecast range of the ECMWF (12 GMT + 0 hours till 12 GMT + 240 hours, with time steps of 6 hours). MBE and RMSE are presented by dashed and solid lines, respectively.

a. <u>Temperature forecast verification</u>

Temperature forecast verification is presented on Fig. 3.

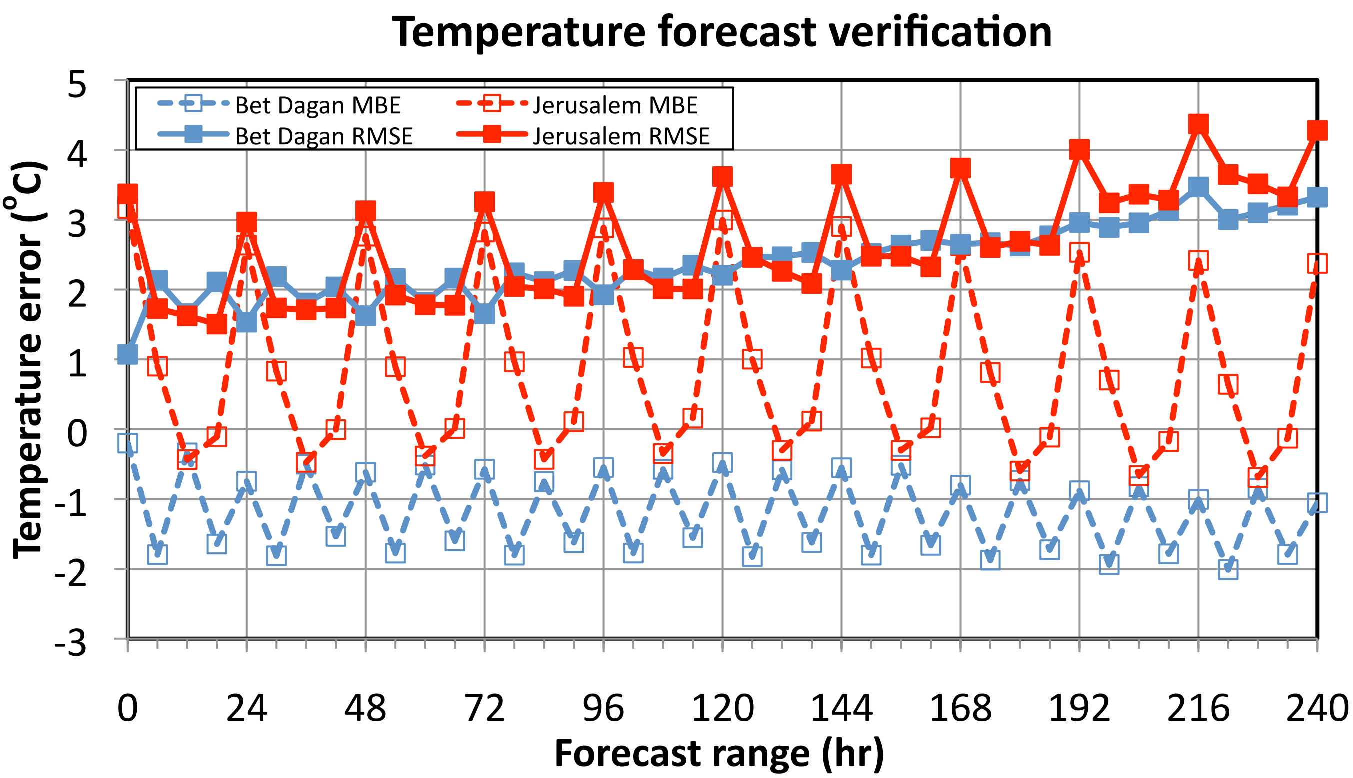

Figure 3 Temperature forecast verification of ECMWF over Israel for the period Nov 11, 2011 – Jul 31, 2012, based on 12Z runs.

One can see that the absolute value of MBE is smaller than 3°C and the RMSE is smaller than 5°C. As expected, the RMSE increases with the forecast range, but this increase is relatively small (from about 2 °C to 3-4 °C). In Bet Dagan, the temperature forecast is better than in Jerusalem. It might be explained by the wrong approximation of the height of Jerusalem which was done by ECMWF, due to its resolution limitations. It might be of an interest to mention, that in both scores (MBE and RMSE) there are oscillations as a function of the forecast hour. In Jerusalem these oscillations are more significant, and one can obviously see that at noon (12Z) the errors are larger than at night (0Z).

b. Wind forecast verification

Wind forecast verification is presented on Fig. 4. For each forecast range both the wind speed error

$|\vec{W}|_{forecast} - |\vec{W}|_{obs}$ and the wind vector error $\vec{W}_{forecast} - \vec{W}_{obs}$

were calculated during the entire period. The MBE was calculated from the set of wind speed errors, so it represents the mean wind speed bias error, while RMSE was obtained from the set of wind vector errors (reflects both wind speed and wind direction errors spread). These two scores were obtained for each of the two stations (Bet Dagan and Jerusalem), and are presented on Fig. 4.

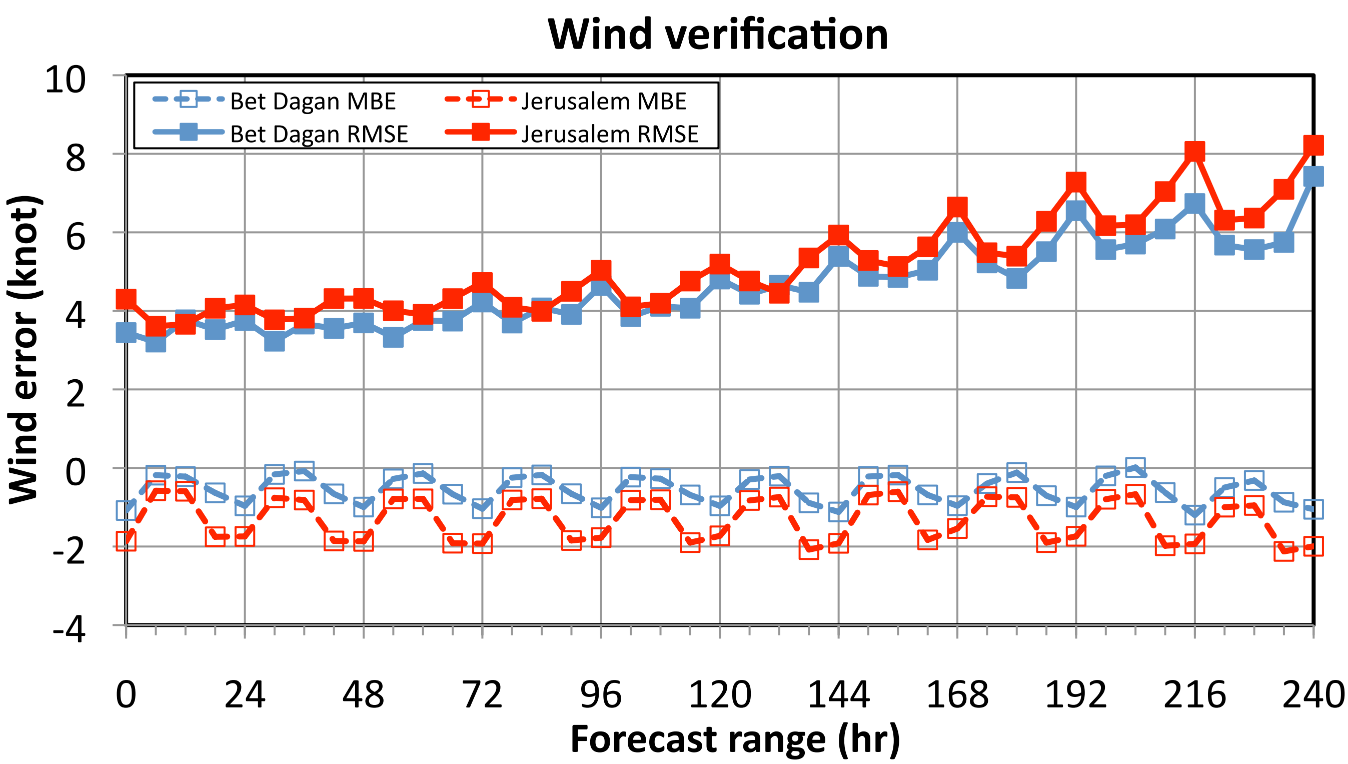

Figure 4 Wind forecast verification of ECMWF over Israel for the period Nov 11, 2011 – Jul 31, 2012, based on 12Z runs.

The absolute value of MBE is smaller than 2 knots and the RMSE is smaller than 8 knots. As expected, the RMSE is increasing with the forecast range. In Bet Dagan, the wind forecast is slightly better than in Jerusalem. Again, it could be explained by the coarse representation of the height of Jerusalem, due to ECMWF resolution limitations. Interesting to mention, that as in Fig. 3, in both scores (MBE and RMSE) there are diurnal oscillations. During the day (12Z) there is a systematic bias as the modelled wind is about 2 knots weaker than the observed one. During the night (00Z) the bias is smaller, and the RMSE is smaller as well.

c. <u>Precipitation forecast verification</u>

Precipitation forecast verification is presented on Fig. 5. For each forecast range we have calculated the error $P_{forecast}$-P_{obs} of the accumulated precipitation over the last 6 hours (from the previous forecast range to the current), during the entire time period. From this data, the MBE and RMSE were obtained for each of the two stations, and are presented on Fig. 5. Note that over Israel, most of the year there is no precipitation, and the precipitation forecasts show zeros. Therefore, in order to reflect the precipitation forecasts quality, we have ignored the error $P_{forecast}$-P_{obs} if both $P_{forecast}$ and P_{obs} were less than 0.5mm/6hr.

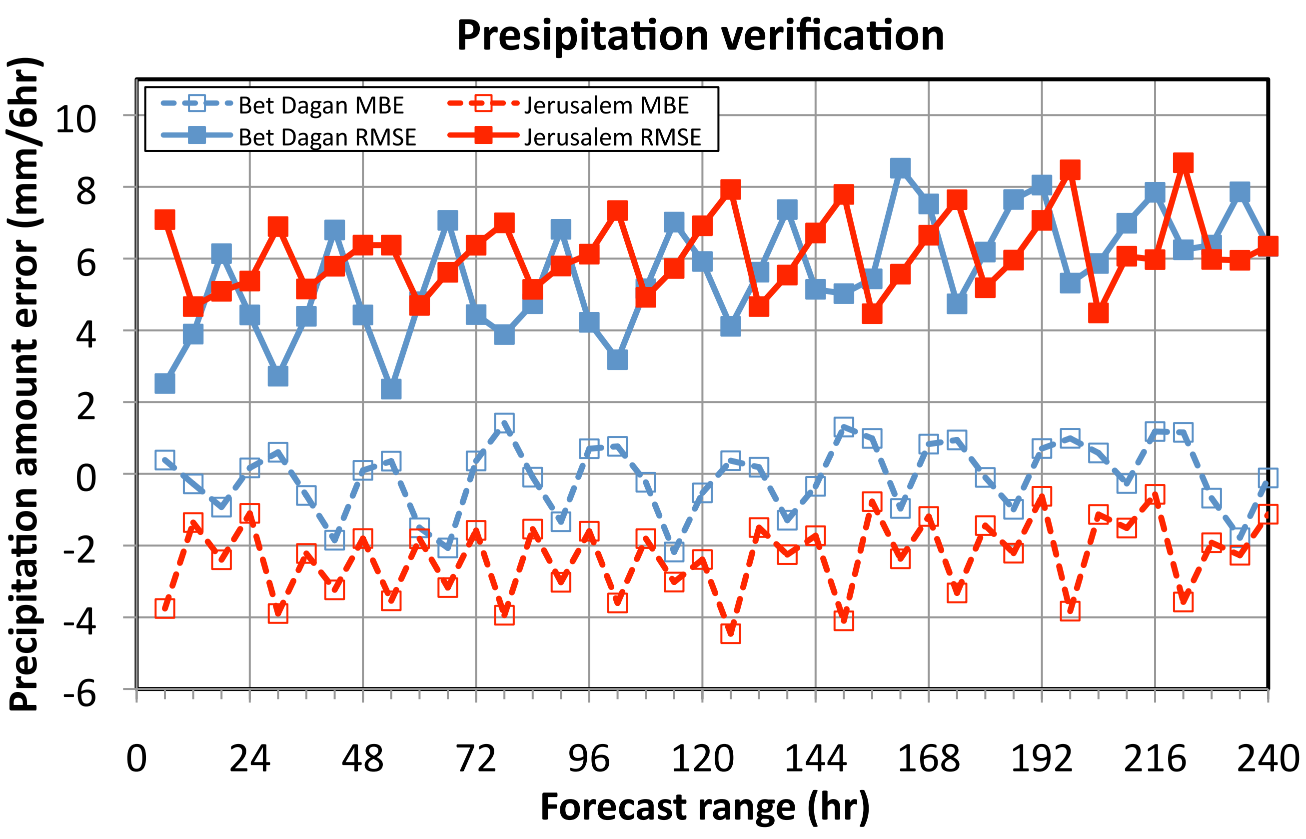

Figure 5 Precipitation forecast verification of ECMWF over Israel for the period Nov 11, 2011 – Jul 31, 2012, based on the 12Z runs.

Important to mention, that the total precipitation predicted by ECMWF at Bet Dagan for the period of Nov 11, 2011 – Jul 31, 2012 (using forecasts of 12Z + 6 hours till 12Z + 24 hours) was 561 mm, and the measured value was 562 mm, which is an extremely successful hit. On the contrary, over Jerusalem, the total predicted value was 319 mm while the measured value was 612 mm. Indeed, one can see on Fig. 5, that the MBE at Jerusalem is negative (about -0.5 mm/6hr), in contrast to a nearly zero MBE at Bet Dagan. Moreover, on Fig. 6 we present the ECMWF forecast verification of the precipitation accumulated over the period Nov 11, 2011 – Jul 31, 2012, at four parts of a day: 12-18Z, 18-00Z, 00-06Z, and 06-12Z, at Bet Dagan (BD) and Jerusalem (JR).

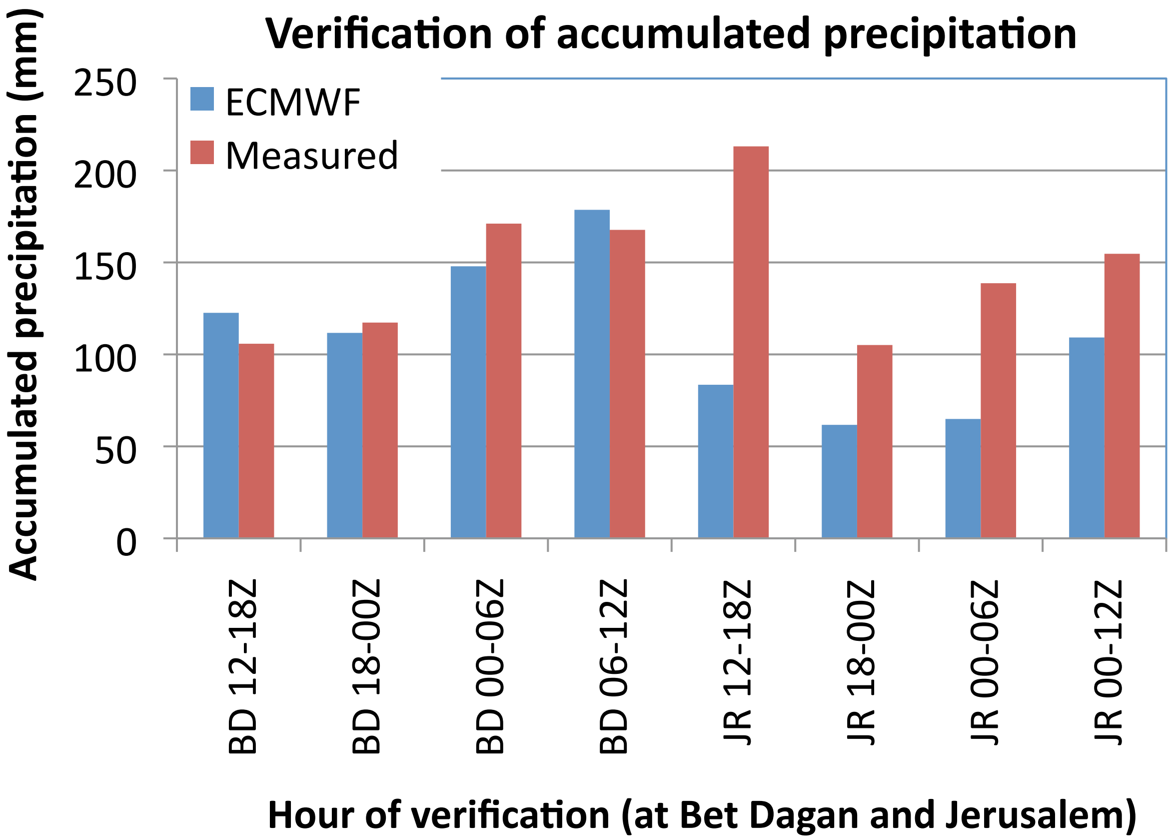

Figure 6 ECMWF forecast verification of the precipitation accumulated during the period Nov 11, 2011 – Jul 31, 2012, at 12-18Z, 18-00Z, 00-06Z, and 06-12Z, at Bet Dagan (BD) and Jerusalem (JR).

Again, one can see a good agreement between the predicted and the measured accumulated precipitation at Bet Dagan, but at Jerusalem the results are not as good (Fig. 6).

The under-prediction of ECMWF precipitation over Jerusalem could be again explained by the coarse resolution. Moreover, major part of the cloudiness over Israeli central and north highlands (and particularly Jerusalem) are orographic. Unfortunately, orographic convection is forecasted as a sub-grid process in ECMWF, maybe not sufficient.

d. <u>System 4 Seasonal verification</u>

Fig. 7 shows one month lead (from November) of ECMWF seasonal re-forecasting for DJF average precipitation in northern and central Israel. The hit score of the ECMWF forecast was only 40%. The hit score for two month lead (from October) was surprisingly better and reached 47%. If using the ensemble average instead of median the hit score raises to 50%.

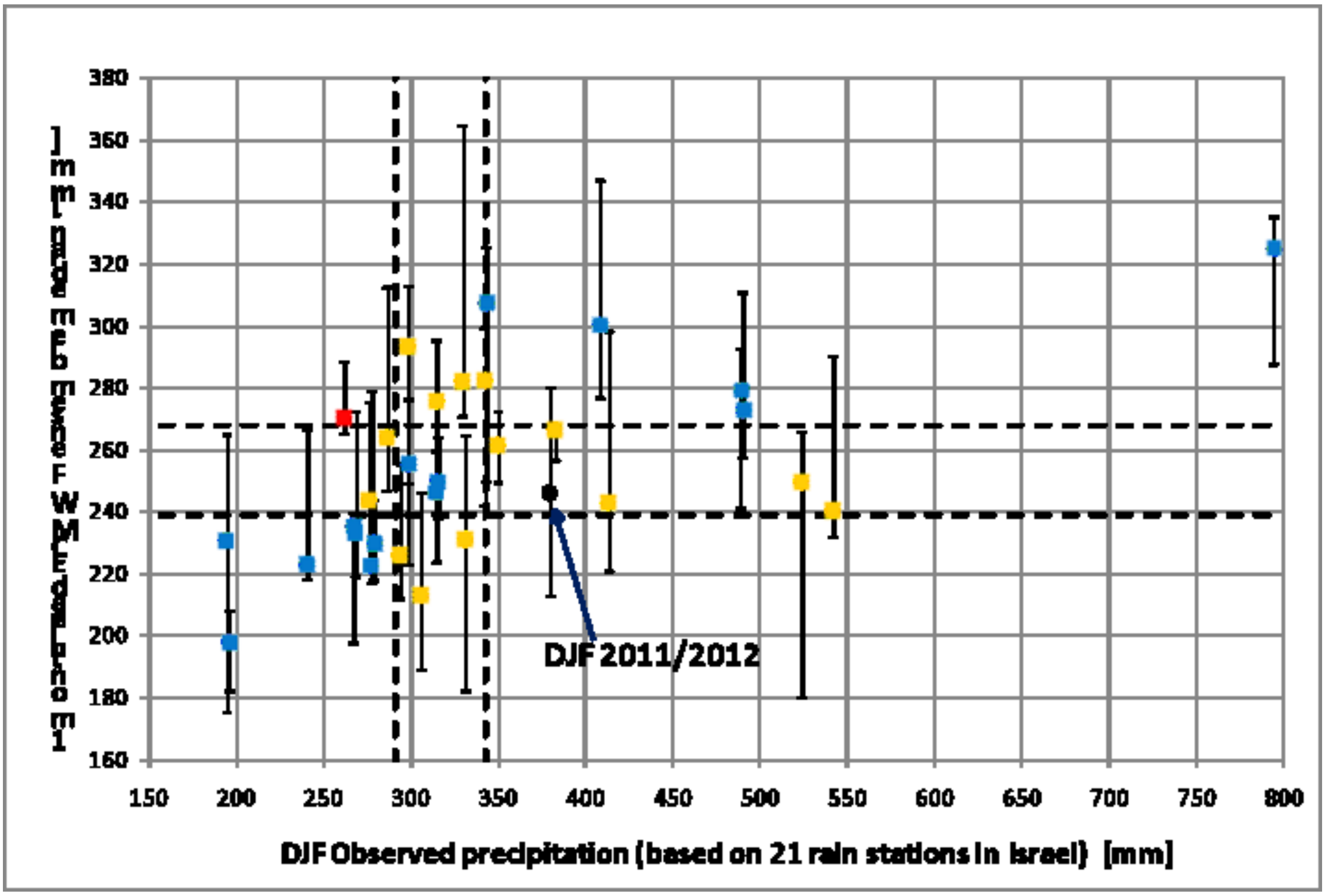

Figure 7 The ensemble median vs. average of 21 rain stations in northern and central Israel. The error lines show the middle 33% probability range of the ensemble (5 members in the middle of 15 ensemble members). The dashed lines show the middle tercile thresholds of both the ECMWF and observed precipitation. The blue dots are hits, the yellow false and the red bust (2 categories between observed and forecast). 2012 operational forecast with the 51 members is indicated in black.

3.1.2 ECMWF model output compared to other NWP models

Here we present the temperature (at 2m) verification analysis of 8 IMS models:

- IFS 0.125NX0.125E degrees resolution,
- UKMO 0.833NX0.555E degrees resolution,
- COSMO-ME (Italy) 0.0625NX0.0625E degrees resolution,
- GFS 1NX1E degrees resolution,
- WRF 0.11NX0.11E degrees resolution (WRF model with a domain centred at Israel, based on the GFS global model),
- COSMO-IL 0.0625NX0.0625E degrees resolution (COSMO model with a domain centred at Israel, based on the GME global model),
- HRM 0.125NX0.125E degrees resolution (DWD model with a domain centred at Israel, based on the GME global model),
- GME 0.36NX0.36E degrees resolution.

The analysis was performed over the period Nov 11, 2011 – Jul 31, 2012 at Bet Dagan. On Figs. 8 and 9 we present the Mean Bias Error (MBE) and the Root Mean Square Error (RMSE) as function of the forecast range (12 GMT + 0 hours till 12 GMT + 240 hours, with time steps of 6 hours). For each forecast range the temperature error $T_{forecast}$-T_{obs} was calculated during the entire time period. From this data, the MBE and RMSE were obtained.

The ECMWF deterministic runs had the lowest RMSE for temperature forecast compared to all the other models used by the IMS. The Root Mean Square Error, averaged over the first 60 hours of forecast at Bet Dagan meteorological station, is the minimal for IFS (1.87^{o}C), compared to UKMO: 2.1^{o}C, GFS: 2.44^{o}C, GME: 2.56^{o}C, COSMO-ME: 1.98^{o}C, COSMO-IL: 2.15^{o}C, HRM: 2.44^{o}C, WRF: 2.36^{o}C. Although, the 60-hours averaged Mean Bias Error is not the optimal for IFS (-1.08^{o}C), compared to UKMO: -1.11^{o}C, COSMO-ME: -0.8^{o}C, GFS: -1.3^{o}C, WRF: -0.02^{o}C, COSMO-IL: -1.12^{o}C, HRM: -1.53^{o}C, GME: -1.87^{o}C.

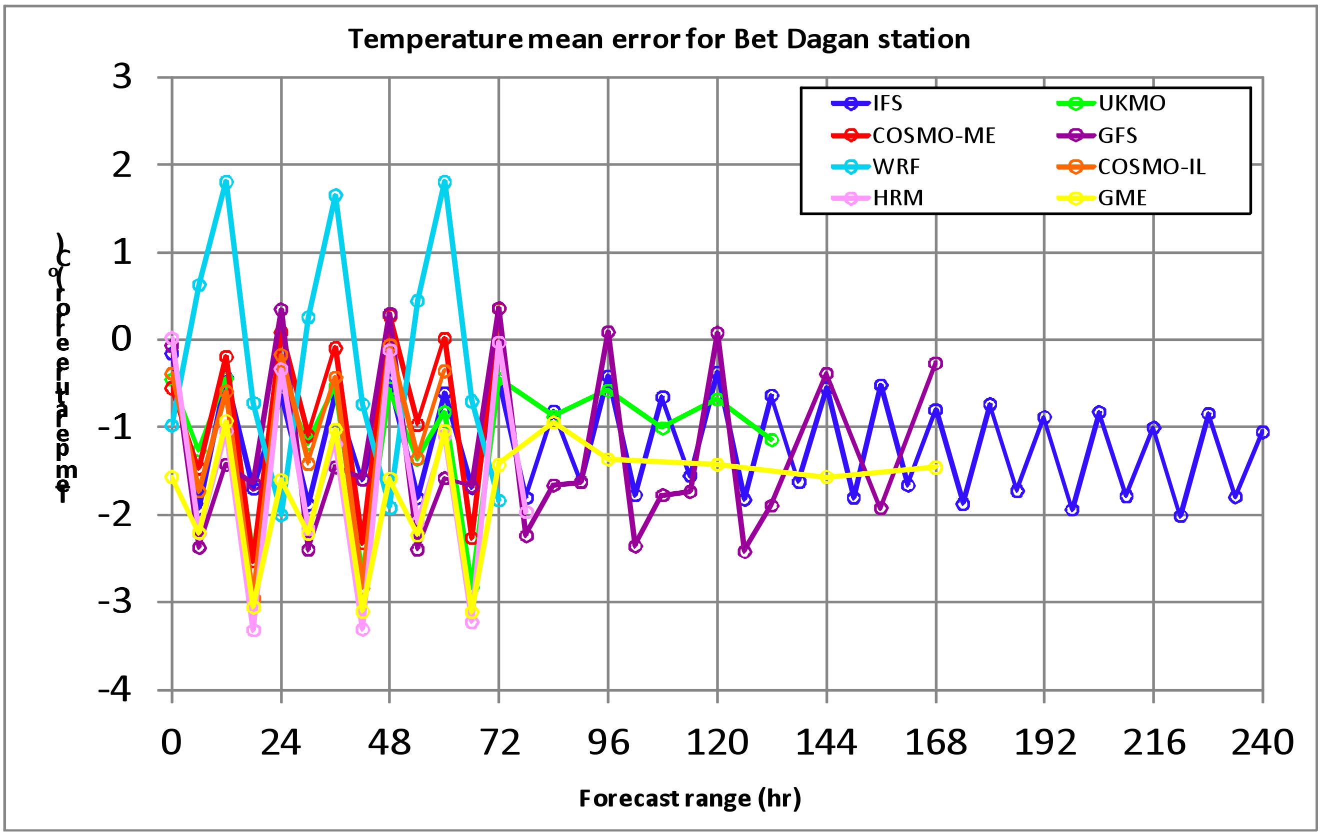

Figure 8 Temperature MBE verification of 8 IMS models at Bet Dagan (near Tel-Aviv) for the period Nov 11, 2011 – Jul 31, 2012, based on the 12Z runs.

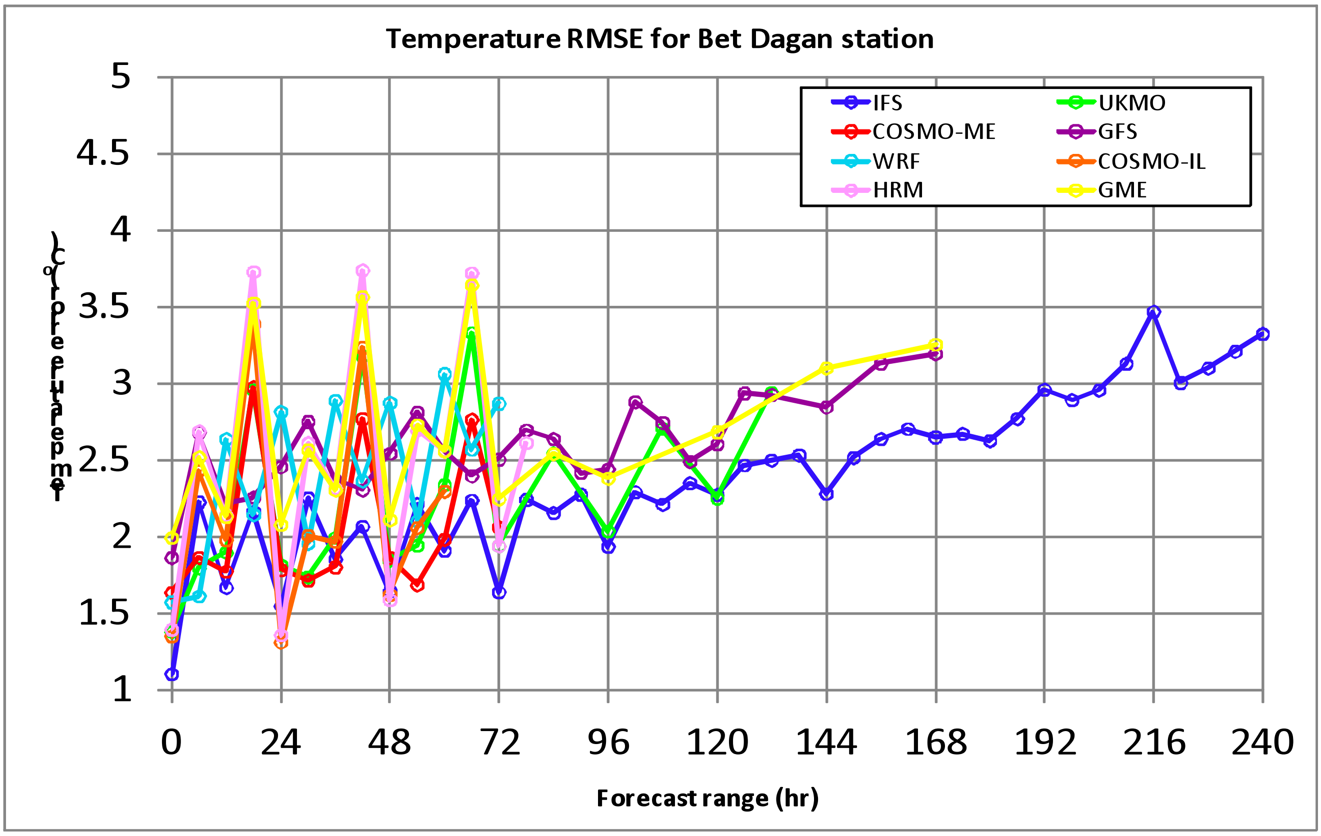

Figure 9 Temperature RMSE verification of 8 IMS models at Bet Dagan for the period Nov 11, 2011 – Jul 31, 2012, based on the 12Z runs.

3.1.3 Post-processed products

Statistical adaptation

Here we present the ECMWF temperature (at 2m) verification analysis after statistical adaptation of the model output, performed over the period Nov 11, 2011 – Jul 31, 2012 at the meteorological station of Bet Dagan (near Tel Aviv). Bet Dagan station characteristics and climate is described in Sec. 3.1.1.

As described in Sec. 3.1.1, we have calculated the Mean Bias Error (MBE) and the Root Mean Square Error (RMSE) as a function of the forecast range (12 GMT + 0 hours till 12 GMT + 240 hours, with time steps of 6 hours). For each forecast range the temperature error $T_{forecast}$-T_{obs} was calculated during the entire time period. From this data, the MBE and RMSE were obtained, and are presented in black on Figs 10 and 11, respectively. Moreover, for each forecast range, and for each day (of the entire period) we have calculated the temperature error $T_{forecast}$-T_{obs} subtracting the bias (MBE) of the previous day, of the last 7 days, or of the last 30 days. As a result, new temperature errors were obtained for each forecast range and for each day. From this data, new MBE and RMSE sets were calculated, and are presented on Figs. 10 and 11, respectively, where blue, green, and red lines represent 1-day, 7-days, and 30-days bias corrections, respectively.

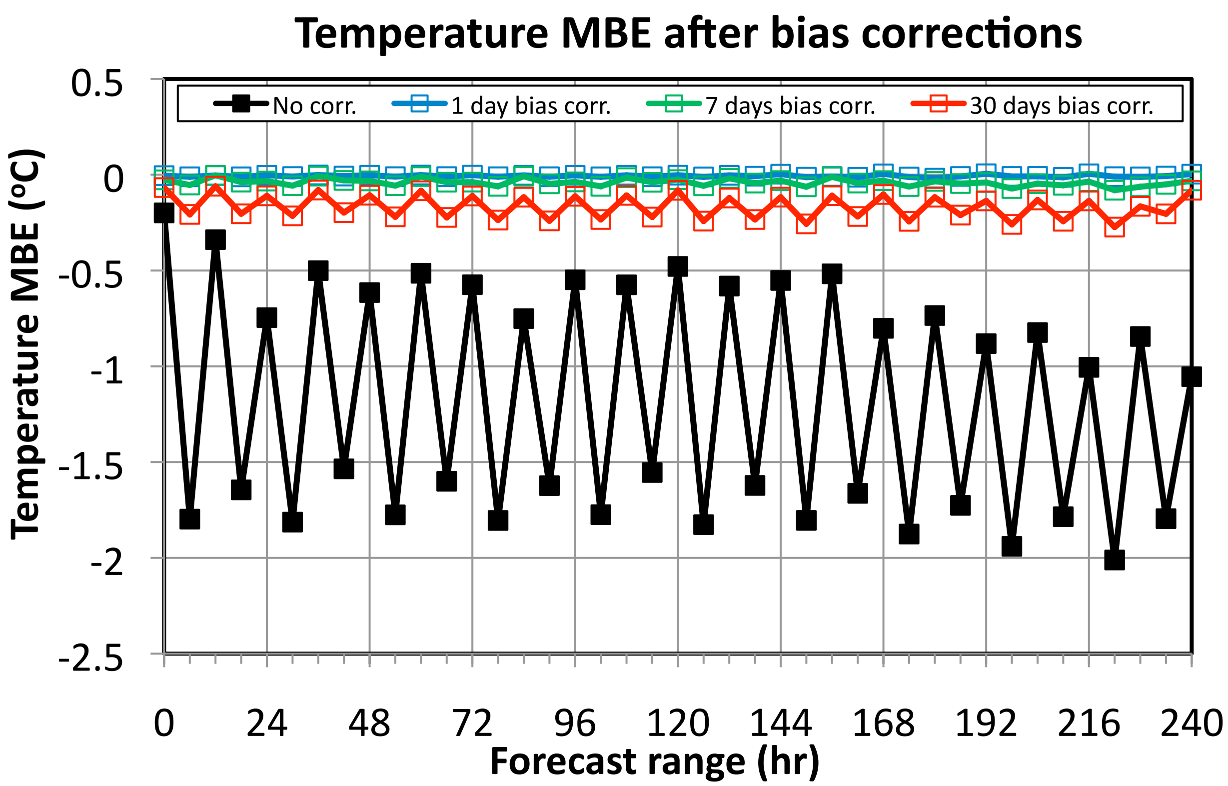

Figure 10 Temperature MBE verification at Bet Dagan for the period Nov 11, 2011 – Jul 31, 2012, before bias correction (black), after 1-day bias correction (blue), after 7-days bias correction (green), and after 30-days bias correction (red).

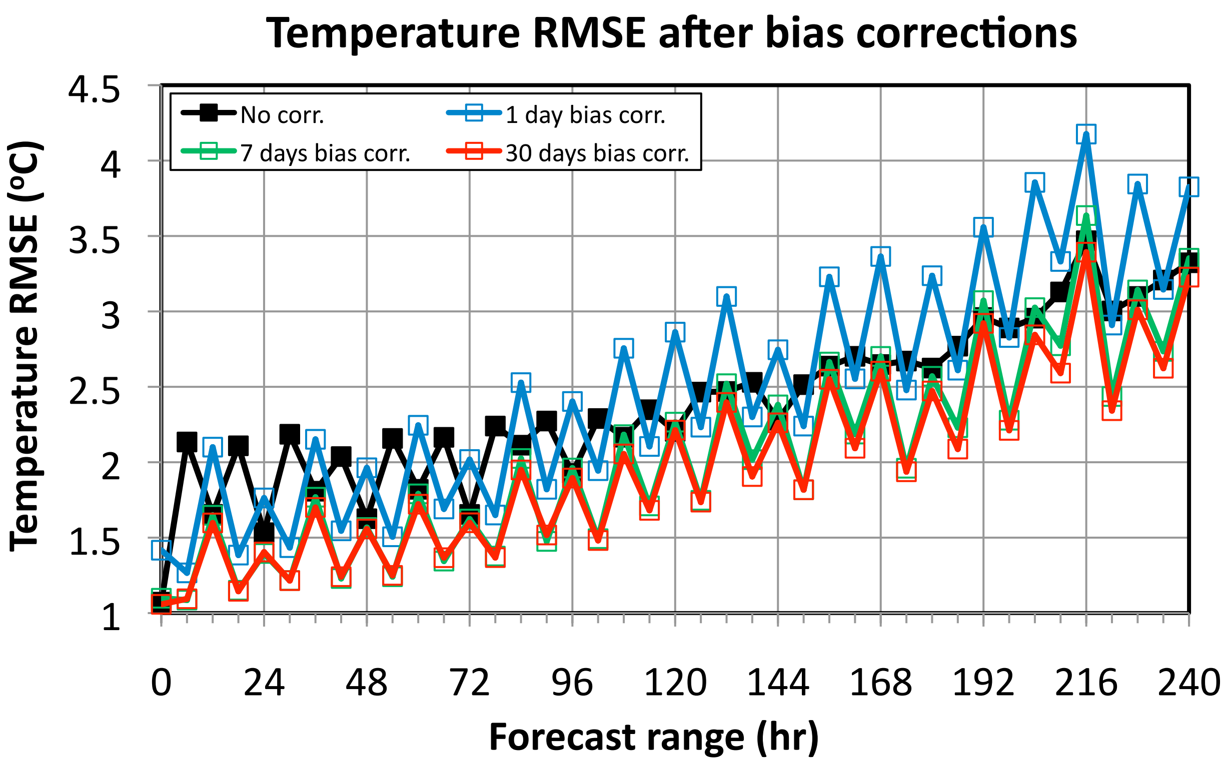

Figure 11 Temperature RMSE verification at Bet Dagan for the period Nov 11, 2011 – Jul 31, 2012, before bias correction (black), after 1-day bias correction (blue), after 7-days bias correction (green), and after 30-days bias correction (red).

One can see that the statistical adaptation of the model forecast, using bias correction of few days before a given forecast, significantly improves the forecast. Taking into account both MBE and RMSE verification results (Figs. 10 and 11), it seems optimal to correct the model results subtracting the bias of the previous 7 days. This conclusion also makes sense from the physical point of view, since the typical time scale of the synoptic events is about one week.

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

3.2.2 Synoptic studies

Including evaluation of the behaviour of the model

4. References to relevant publications

Haiden, T., A. Kann, C. Wittmann, G. Pistotnik, B. Bica, C. Gruber, 2011: The Integrated Nowcasting through Comprehensive Analysis (INCA) System and Its Validation over the Eastern Alpine Region. *Wea. Forecasting*, **26**, 166–183.