Application and verification of ECMWF products 2011

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1. Summary of major highlights

In order to determine the quality of the NWP products at the Hellenic National Meteorological Service (HNMS), a verification process is applied based on a tool that was developed through the **CO**nsortium for **S**mall-scale **MO**deling (COSMO). This operational conditional verification tool, known as **VER**ification **S**ystem **U**nified **S**urvey (VERSUS), the development of which was coordinated by the Italian Meteorological Service, is currently used by the HNMS for all verification activities concerning the weather forecast models.

The operational verification system at the HNMS has been expanded to include verification of NWP post-processed products such as Kalman filter derived min-max temperatures and dew point temperature as well as on-demand verification of ensemble forecasts produced by short-range ensemble prediction systems. Daily verification is performed for the surface and upper-air fields of the IFS products as well as for the two high-resolution limited area models (Eta/Skiron, COSMO-GR at 3 and at 7km) that are used by the HNMS forecasters. In addition, the relative performance of the models is subject to intercomparison.

2. Use and application of products

The medium-range weather forecasts at the HNMS are based primarily on the deterministic ECMWF forecast. Both the 00 UTC and 12 UTC cycles of the ECMWF forecasts are received daily in 0.25 deg resolution. For short-range forecasting and for observation of local characteristics of weather patterns in Greece, the output of the limited area models is used in conjunction with the ECMWF products.

The EPS products (plumes, epsgrams, ensemble probability maps) are retrieved daily from the ECMWF website and are of particular value to the HNMS forecasters, especially the d+4 to d+7 forecast where the value of the deterministic forecasts is substantially reduced). An increasingly popular ECMWF product at the HNMS is the Extreme Forecast Index (EFI) for temperature and precipitation. As a measure of the distance from the climatological value (mean), the EFI maps are directly related to severe weather events. The monthly (and weekly) anomalies and seasonal forecasts are not used operationally but only for consultative or research purposes.

2.1 Post-processing of model output

2.1.1 Statistical adaptation

The HNMS implements a method improving the temperature minimum and maximum forecast values for 50 locations in Greece (position of the stations) on a daily basis. This method uses a Kalman filtering technique, which is based on non-linear polynomials, incorporating all available quality-controlled observations in combination with the corresponding NWP data of the IFS model as well as from the two limited area models, namely Eta/Skiron and COSMO-GR. Application of the filter helps improve the temperature forecasts by eliminating possible systematic errors. The same technique is also used with the dew point temperature data (minimum and maximum) in order to correct biases related to relative humidity.

2.1.2 Physical adaptation

ECMWF model output provides the lateral and boundary conditions for the execution of the daily simulations of the HNMS limited area models (Eta/Skiron, COSMO-GR). As an option, ECMWF model output can also be used to provide the necessary input for the MOTHY trajectory model.

MOTHY is a sea pollution model (e.g. Daniel, 1996), which is applied in cases of oil spills in the eastern Mediterranean Sea, that HNMS is responsible for. It is based on the numerical weather predictions of the ECMWF model, either the 00:00 UTC cycle or the 12:00UTC cycle. The data used as input are the surface wind speed and the sea surface pressure, (and the two meters temperature as an option). The model provides the possible trajectories (locations) of oil (or floating objects) transport as well as the percentage of the oil spill that will reach the coast or the seabed. The HNMS operates MOTHY as part of the Marine Pollution Emergency Response Support System (MPERSS) for the Marine Pollution Incident (MPI) Area III East, which includes the eastern Mediterranean Sea.

Finally, the ECMWF deterministic model provides the necessary initial conditions to drive a wave forecast model (WAM) as an alternative option to COSMOGR. The wave forecast of the HNMS is based on the ECMWF version of the WAM (CYCLE 4) model. It is a third generation wave model which computes spectra of random short-crested wind-generated waves and is one of the most popular and well tested wave models. Verification of the calculated wave height and direction has recently been implemented with the use of observations taking by the buoys positioned around the Greek Seas (POSEIDON system).

2.1.3 Derived fields

A wide range of derived fields are produced from the ECMWF model outputs (e.g. meteograms) for visualisation and other applications at the forecasting center.

2.2 Use of products

As mentioned above, the HNMS forecasting centre uses ECMWF products in conjunction with the products of its limited area models for the general 6-day forecast that is provided to the public as well as for the sea state forecast for the Eastern Mediterranean and, finally, the forecast for aeronautical purposes. The IFS forecast products are also consulted by the forecaster on duty and used to complete the awareness report for the European MeteoAlarm website.

3. Verification of products

The forecasted values of weather parameters are compared with synoptic meteorological data from the HNMS' operational network of stations and a range of statistical scores is calculated on a daily, monthly and yearly basis. The surface verification is performed by using the SYNOP data from the most reliable surface stations, every 3 or 6 hours.

The continuous variables that are routinely verified are the 2m temperature, 2m dew point temperature, Mean Sea Level pressure, wind speed and cloud cover. For dichotomic parameters such as precipitation, the 6-, 12- and 24h-hour precipitation amounts are verified using indices from the respective contingency tables for the 72-hour forecast horizon. The thresholds for the precipitation amounts range from 0.2mm up to 30mm, accumulated in different time ranges.

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

The ECMWF deterministic forecasts are verified against the synoptic observations. The RMSE and Bias scores are calculated for every forecast cycle, every 6 hours from the t+6 to the t+120 forecast hour (here presented up to 72h) for every synoptic station, indicating the degree to which the forecast values differ from the observations. The scores, which are averaged over all stations, are presented below. The verification was performed for every season and the main findings are as follows:

Mean Sea Level Pressure: For MSLP (Fig. 1), a propagation of the error (RMSE) with forecast time is evident for all seasons. Larger errors were calculated for the winter period (1-3 mb) and smaller errors for the summer (1-1.5 mb).

2m Temperature: A clear diurnal cycle of the Bias values is a characteristic of all seasons (Fig. 1). The model underpredicts the temperature values in all seasons to up to 1.5°C. The error values reach up to 3.0 $^{\circ}$C during midday hours, while the average error for the other periods is approximately 2.5 $^{\circ}$C.

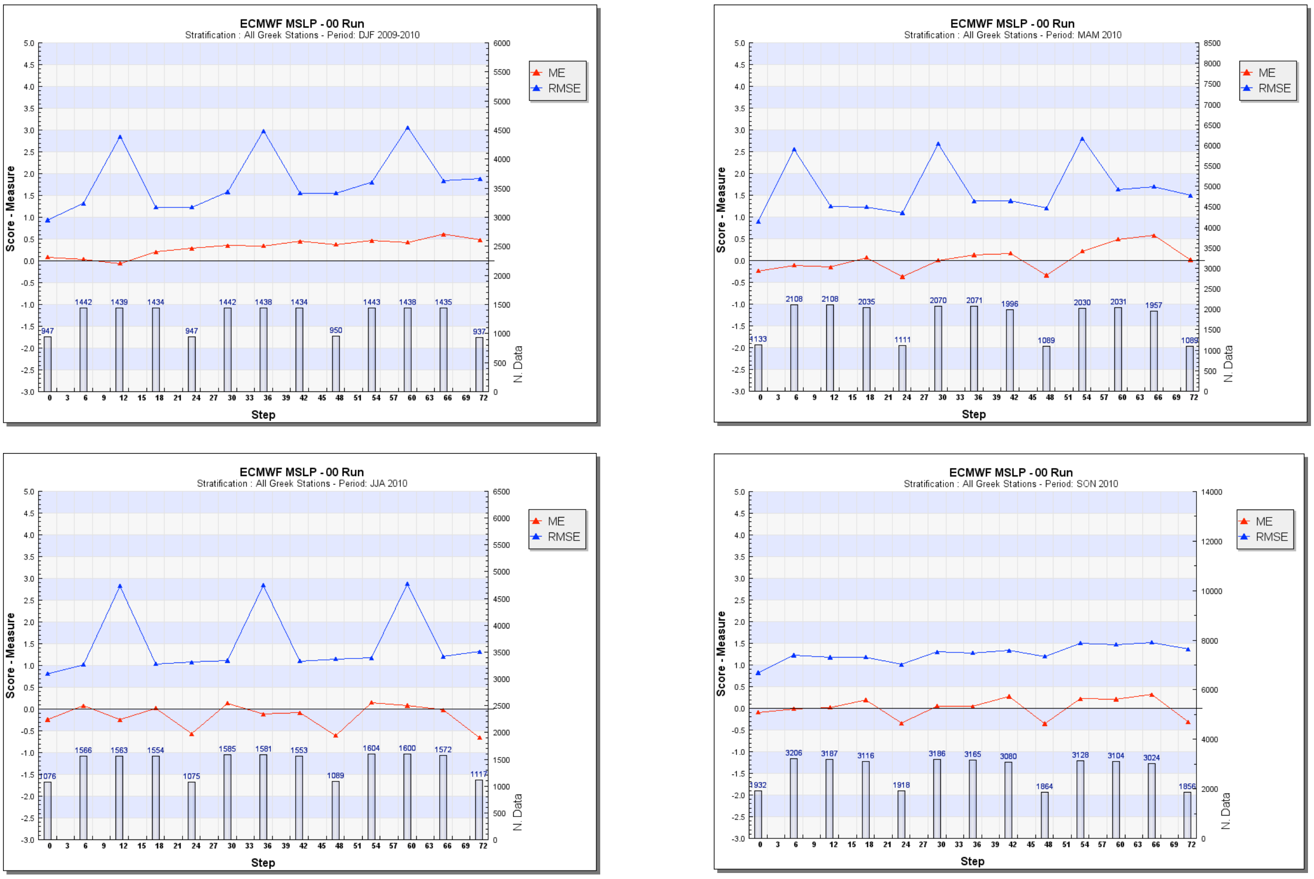
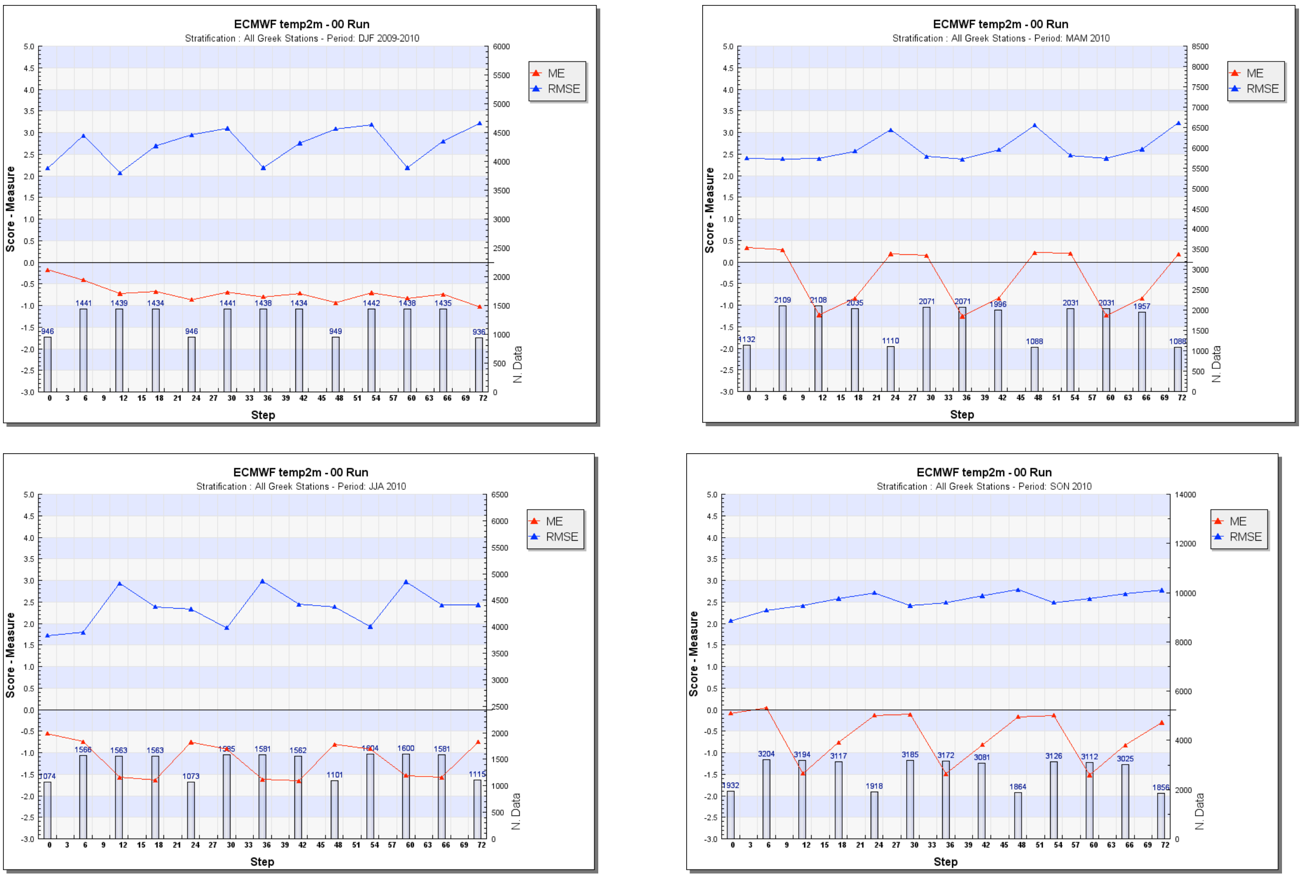


Figure 1 RMSE and Bias scores for MSLP (above) and 2m Temperature (below) from the IFS model (00UTC run) calculated and presented for every season



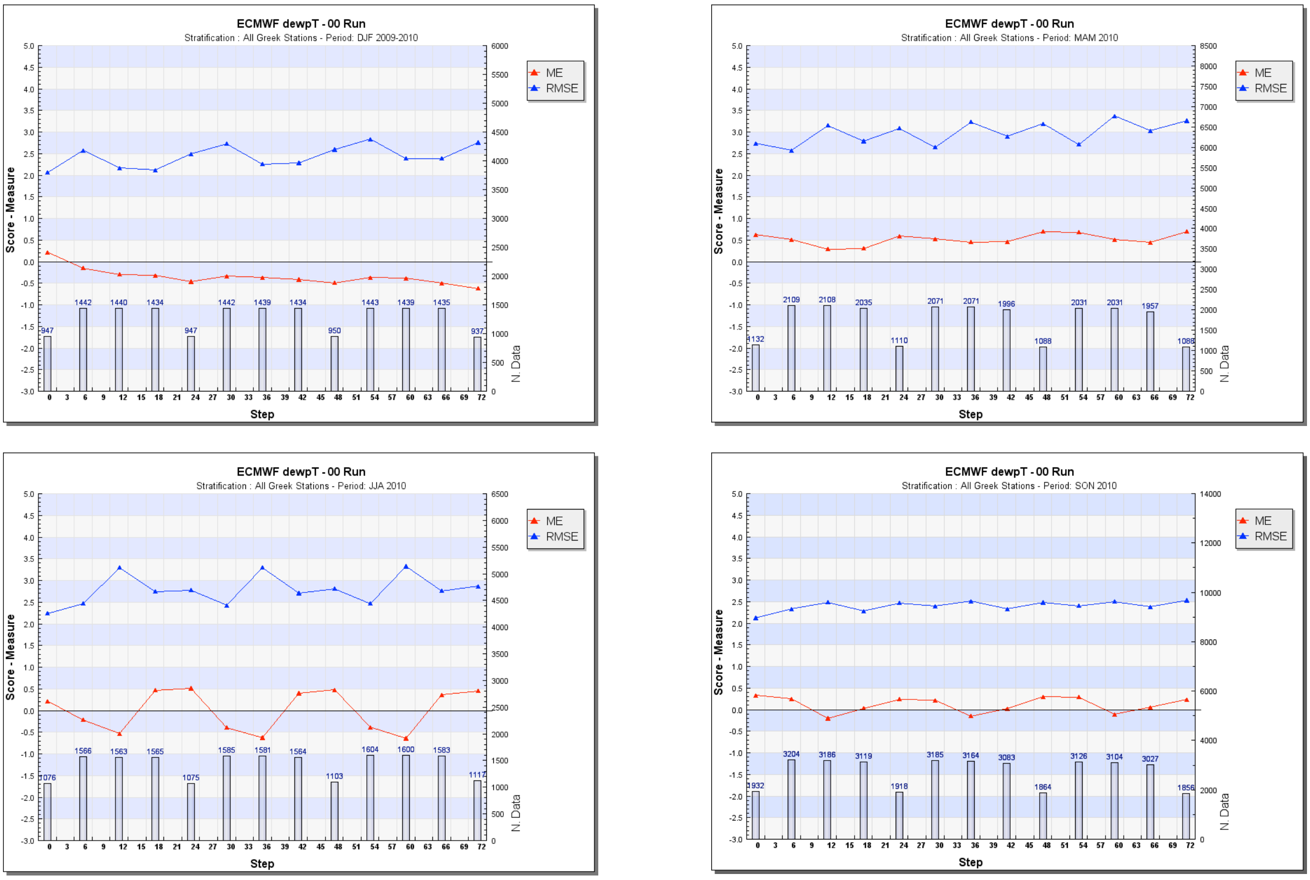
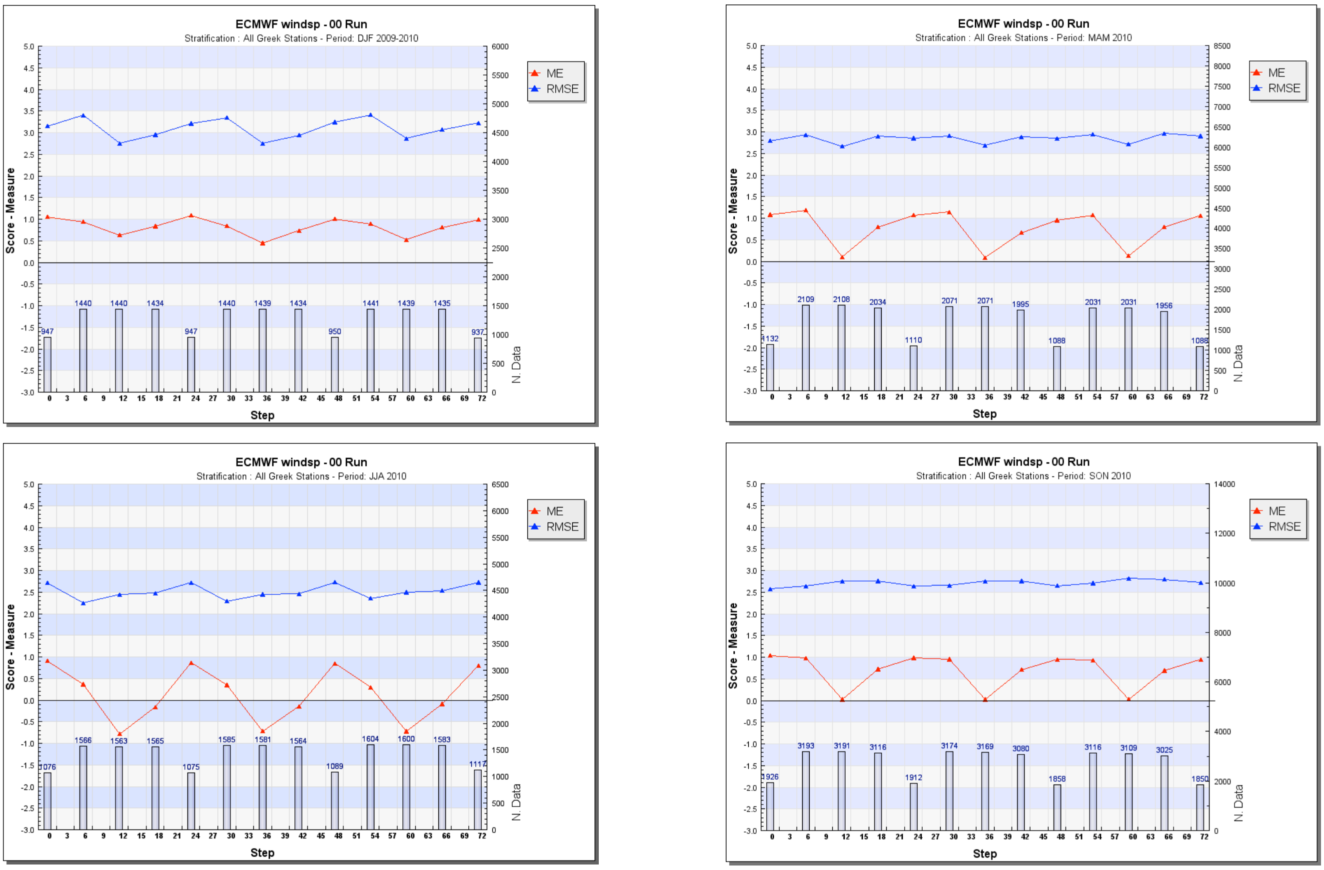


Figure 2 RMSE and Bias scores for 2m Dew Point Temp (above) and 10m Wind speed (below) from the IFS model (00UTC run) calculated and presented for every season



Dew Point Temperature: The DPT is slightly overestimated by the model for almost all seasons, apart from the winter. The diurnal cycle is evident in the Bias values. The average error is higher for spring and summer (up to 3.5°C) but almost constant (2.5-3 °C) the rest of the year (Fig. 2).

10m Wind Speed: The RMSE behaviour and values are almost constant for all seasons with values around 2.5-3 m/s. A general overestimation is shown in all graphs and a clear daily cycle was detected in the Bias values (Fig. 2).

Cloud Cover: A general underestimation of cloud cover percentage is apparent in all seasons as well as a clear daily cycle of the ME. The RMSE values were quite high with a much better performance during the summer season when weather conditions are more stable and cloud cover amount is in general decreased (Fig.3).

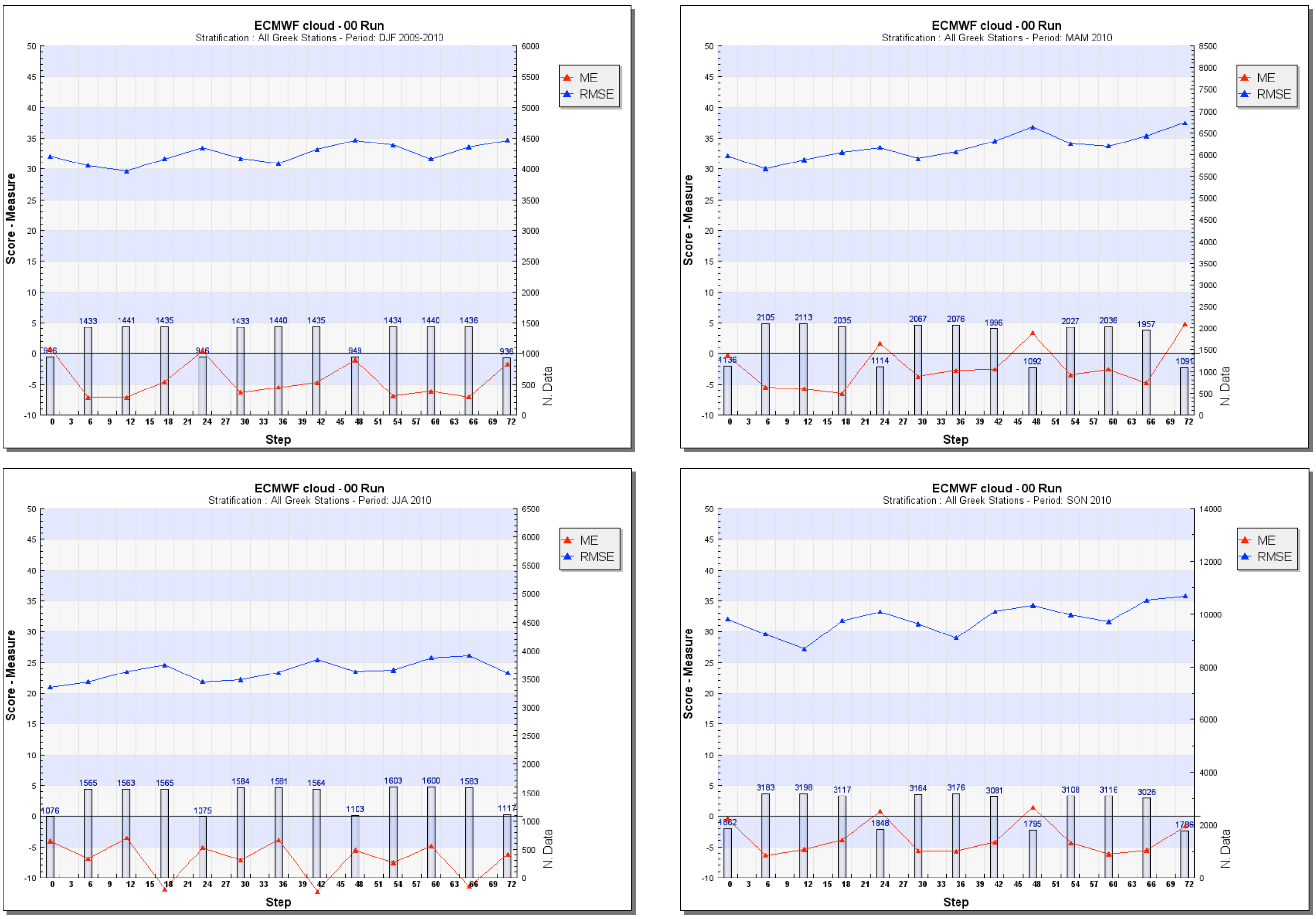


Figure 3 RMSE and Bias scores for Cloud Cover from the IFS model (00UTC run) calculated and presented for every season

Precipitation: For each threshold a number of scores were calculated providing insight into model behaviour and the most representative results shown in the following graphs are: Probability Of Detection of event (POD) (range: 0-1, perfect score=1) indicates the proportion of observed events correctly forecasted, False Alarm Rate (FAR) (range: 0-1, perfect score=0) indicates the proportion of the wrongly forecasted rainfall events, and Frequency Bias (FBI) is a measure of comparison between the frequency of forecasts to the frequency of occurrences (range: 0-∞, perfect score=1, FBI>1 the system overforecasts). Only the verification indices for the 12-hour accumulated amounts are presented here for the fall and winter seasons.

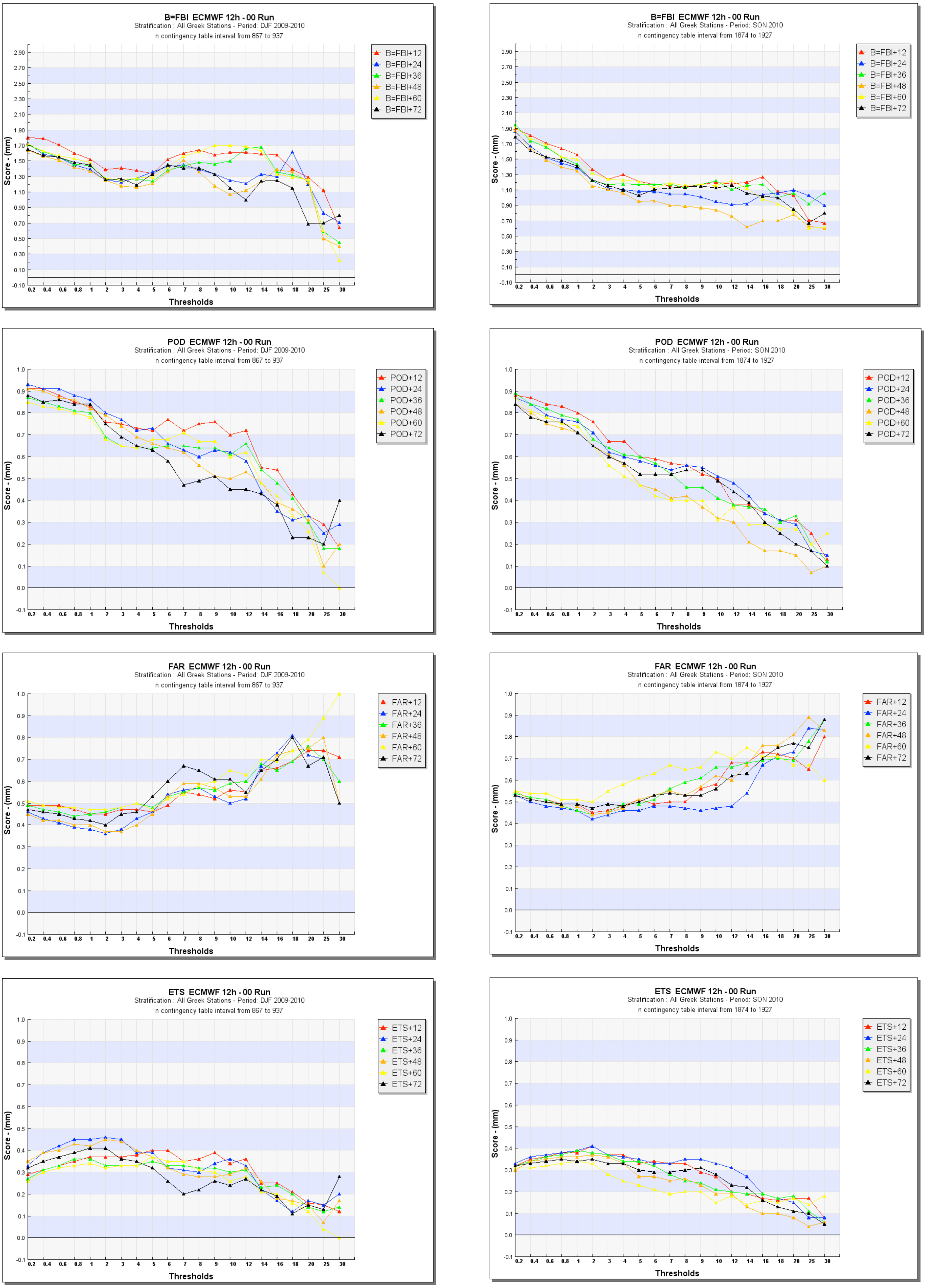


Figure 4 Statistical scores for the 12-hour accumulated precipitation forecast for fall and winter

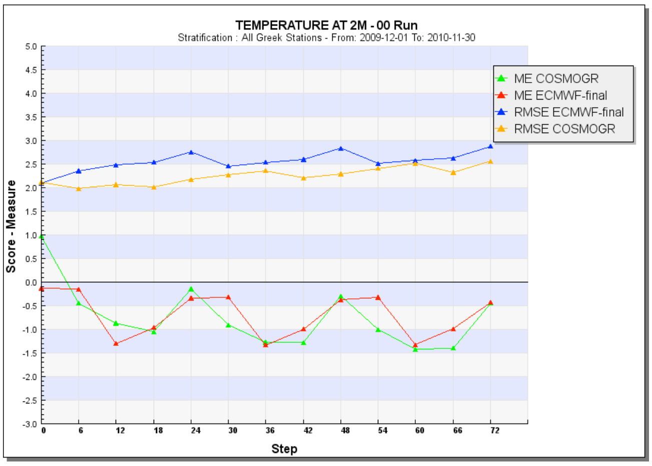
The results indicate that the IFS model performs better for the thresholds corresponding to small amounts of precipitation, but it fails to accurately predict large rainfall events. This is evident from all the aforementioned scores as they tend to worsen when precipitation amounts greater than 5mm in 12h are examined. It should be noted that the sample size was considerably smaller for higher precipitation thresholds, which can influence the reliability of the derived values.

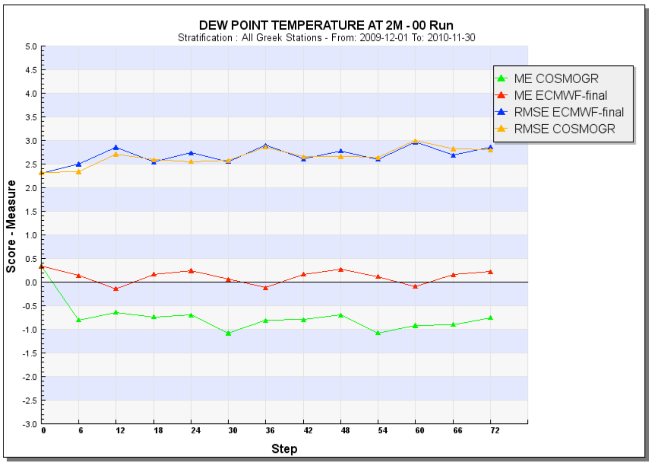
In detail, POD values exceed 70% for almost all forecast periods for thresholds smaller than 3mm/12h but decrease substantially for higher thresholds. The exact opposite behaviour in observed for the FAR index with 40-50% occurrences of false alarms when rainfall amounts less than 5mm are examined, a number that is quite high, indicating a general overestimation of rainfall events. The same conclusion can be drawn when analysing the FBI index. For almost all the precipitation amounts (up to 15-20mm/12h) and for all forecast times, there is an overestimation of rainfall for both seasons and only in the very high thresholds do the values drop below 1. The ETS score, which is a measure of accuracy adjusting for random chance hits, exhibits better performance, again, for the lower thresholds and similar behaviour for both seasons as the precipitation is mainly induced by well-defined synoptic perturbations.

3.1.2 ECMWF model output compared to other NWP models

The HNMS operates two high-resolution Numerical Weather Prediction (NWP) systems (COSMO-GR and Eta/Skiron) that provide detailed deterministic forecasts for an extended area around Greece on a daily basis. The operational domain of COSMO-GR covers an area with a longitude range of 45° and a latitude range of 24.5° with 35 vertical levels and a horizontal resolution of 0.0625° (~7 km). More recently, a higher resolution version of the model is also operated (~2.5 km), providing a more detailed forecast.

Comparison of the performance of the ECMWF model with the COSMO-GR is done on a regular basis. Average statistical indices over the course of a year are calculated and presented in this report. As indicated in the plots of the RMSE for the dew point temperature (DPT), the models give similar results for the 72-hour forecast with higher underestimation of the DPT by the COSMOGR model. The wind speed and the 2m temperature forecasts exhibit lower errors, as expected with the use of the higher resolution model, while for MSLP the IFS model has on average better performance (Fig. 5).





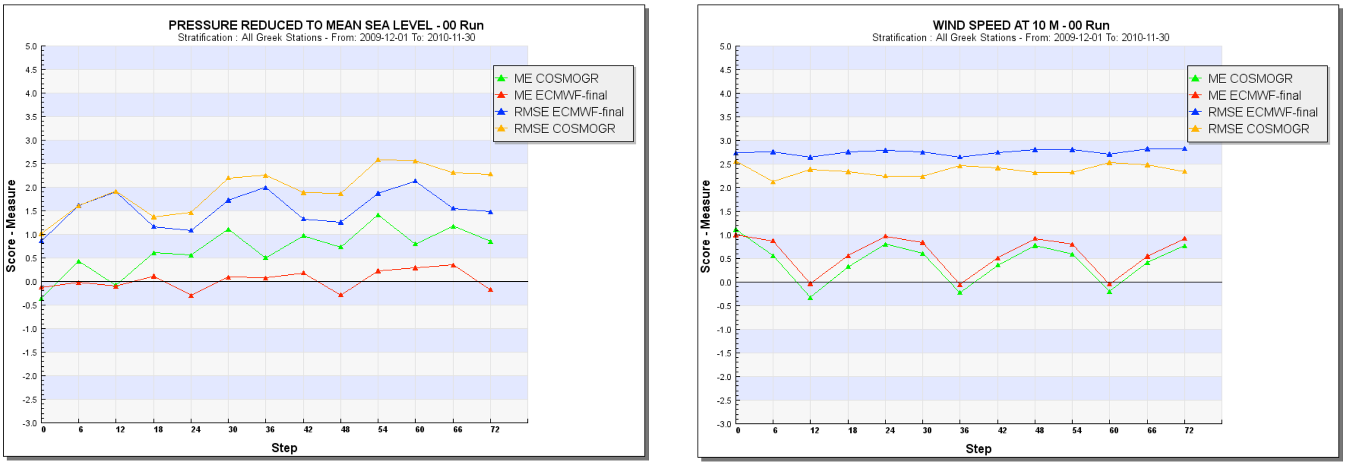


Figure 5 RMSE and Bias scores for 2m Temp, dew point Temp, MSLP and 10m Wind Speed averaged over all the year over all stations

Another way of verifying IFS model includes the use of a Conditional Verification (CV) tool that has been employed for the first time at HNMS. Through the selection of one or several forecast products and one or several 'mask variables' that are used to define thresholds for the product verification, it is possible to explore the performance of the model under specific conditions and investigate the interdependency of several weather parameters. A number of conditions were applied to the verification of weather parameters, and a small example of which is presented in this report. The T2m forecasts were verified in accordance with the observed cloud cover conditions. The results in Fig. 6 show that the model performs better (lower RMSE) in overcast (total cloud cover >75%) than in clear conditions (total cloud cover <25%) , especially during the winter. Clouds regulate the amount of solar radiation reaching the surface and can therefore heavily influence temperature near the ground.

Figure 6 RMSE and Bias scores for 2m Temp for clear sky and overcast cloud conditions averaged for every season

In general, the model has a cold bias for all the seasons with a very strong diurnal cycle of the forecast error. This bias decreases substantially under total cloud cover, highlighting the relationship between these two parameters.

3.1.3 Post-processed products

The reliability of the filtered results described above is statistically evaluated at the end of each month and season (e.g. Fig. 6). The frequency of the appearance of mean errors higher than 2ºC is diminished for all seasons for all the models to which the filter was applied and shows a remarkably symmetrical distribution of the Bias.

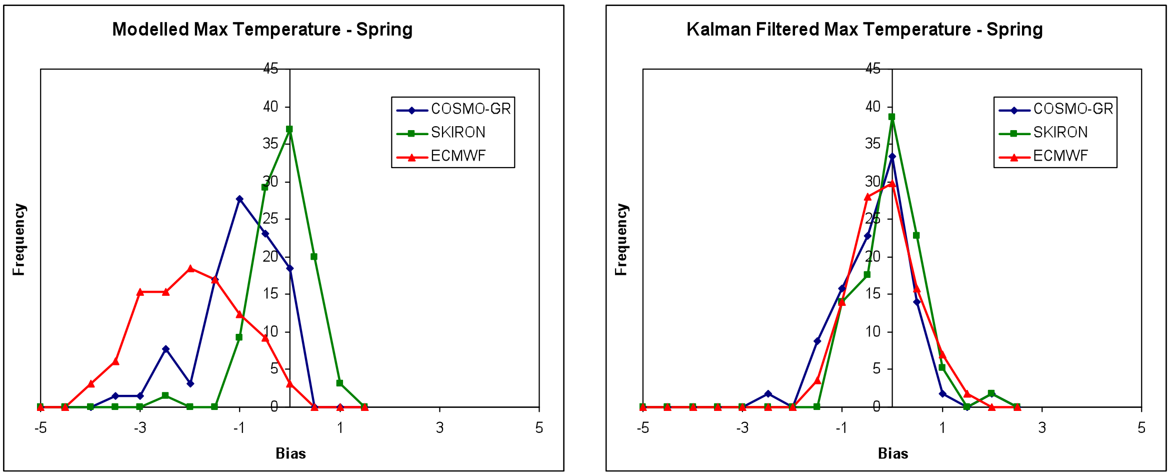


Figure 7 Bias of maximum spring temperature related with the frequency of its appearance for all stations before (left) and after (right) the application of Kalman filtering.

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