Application and verification of ECMWF products 2013

Hellenic National Meteorological Service (HNMS)
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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.

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. The operational verification system at the HNMS has been expanded to include verification of ensemble forecasts derived by -range ensemble prediction systems as well as wave model forecasts.

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 the current 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 (JJA2012-MAM2013) and the main findings are as follows:

Mean Sea Level Pressure: For MSLP (Fig. 1), a slight propagation of the error (RMSE) with forecast time is evident for all seasons. The ME error values exhibit an underprediction for almost all seasons.

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 °C during winter, while the average error for the other periods is approximately 2.5 °C. The daily cycle (DC) of 2mT values indicates this underestimation of temperature that is more evident during summer at noon times from the scatter plot.

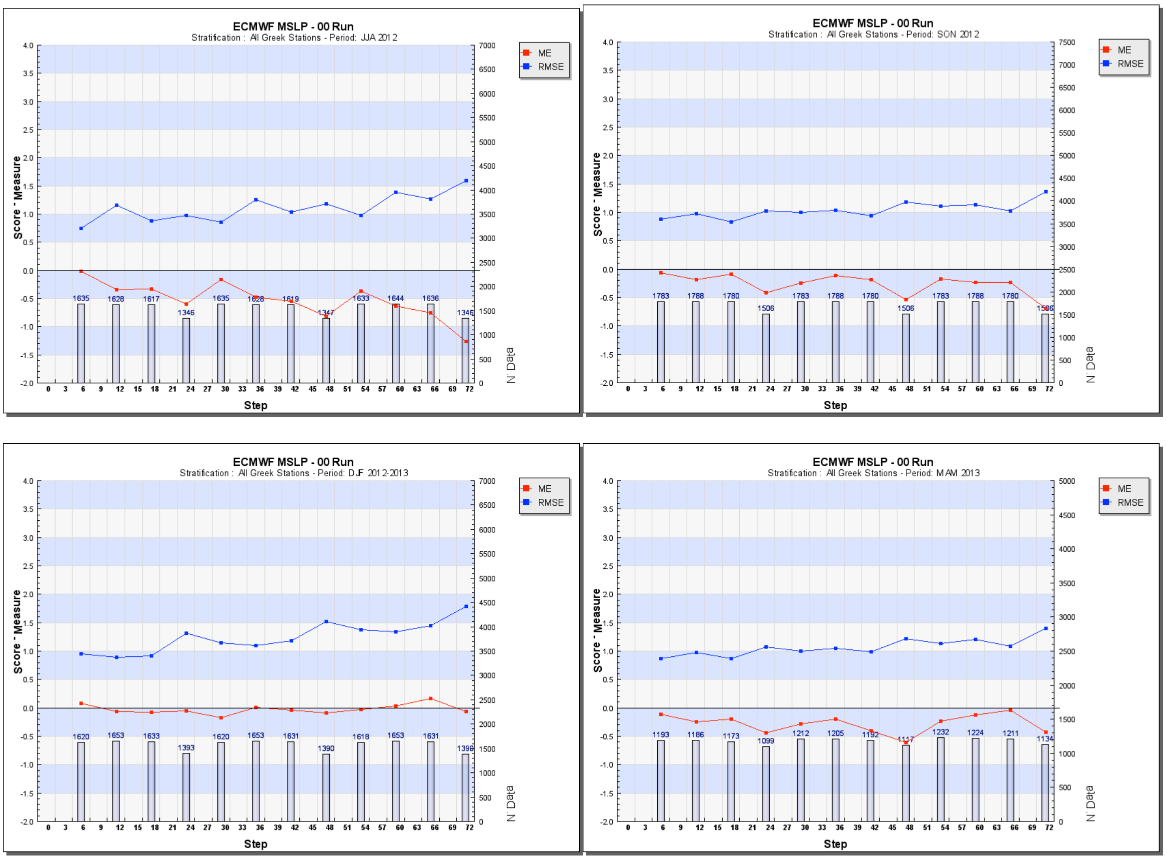
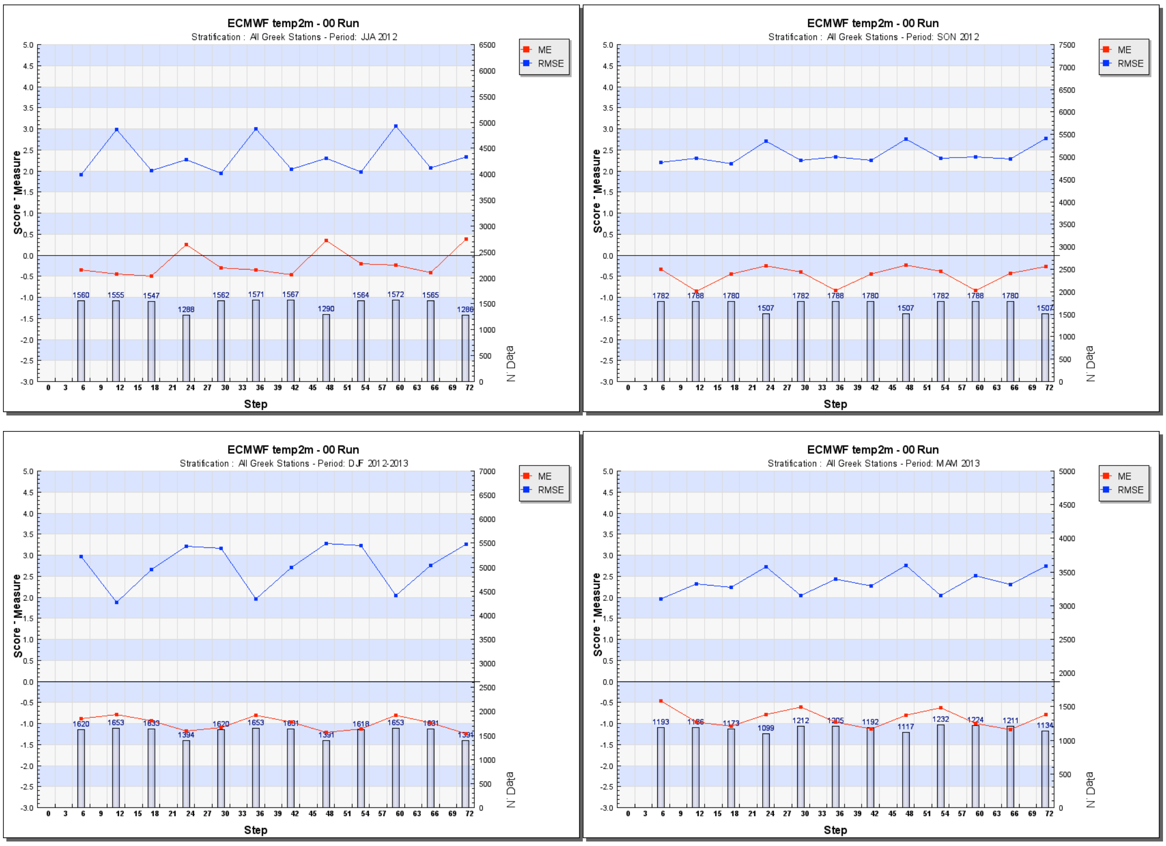


Fig.1: RMSE and Bias scores for MSLP (above) and 2m Temperature (below) from the IFS model (00UTC run) calculated and presented for every season



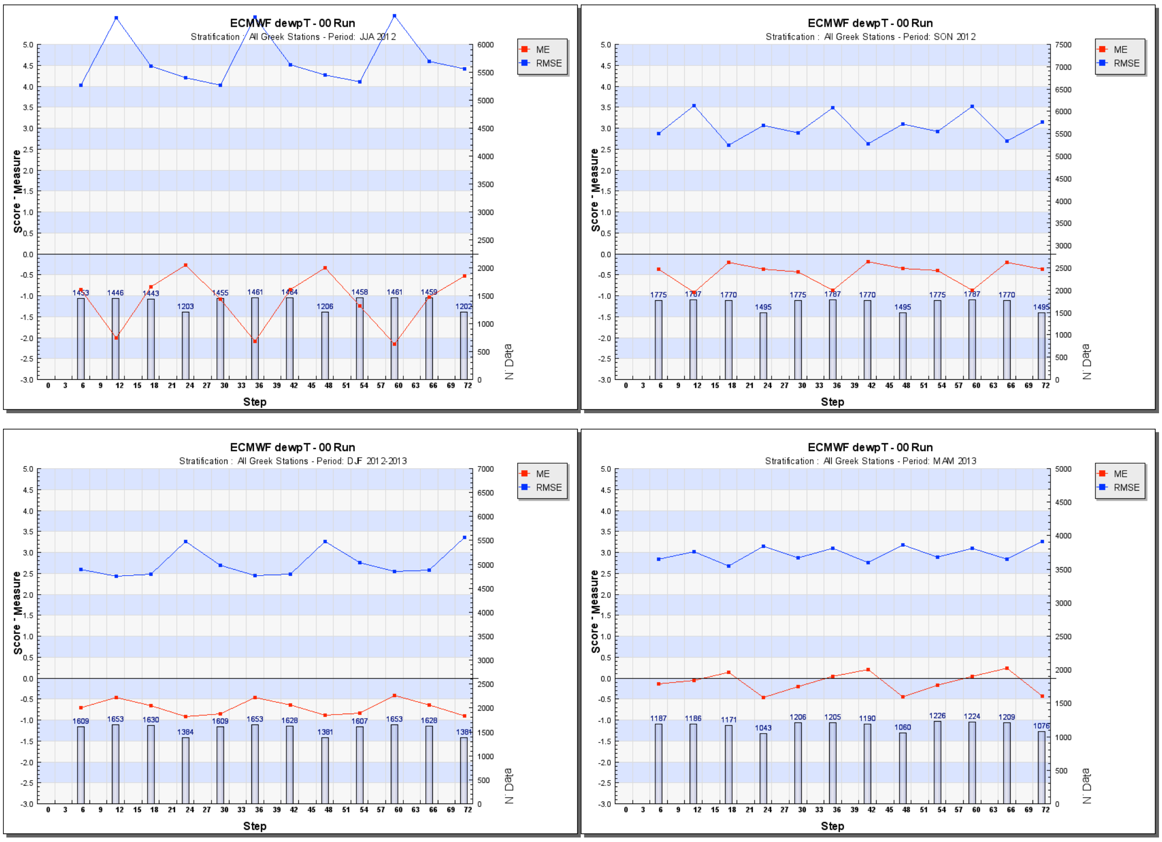
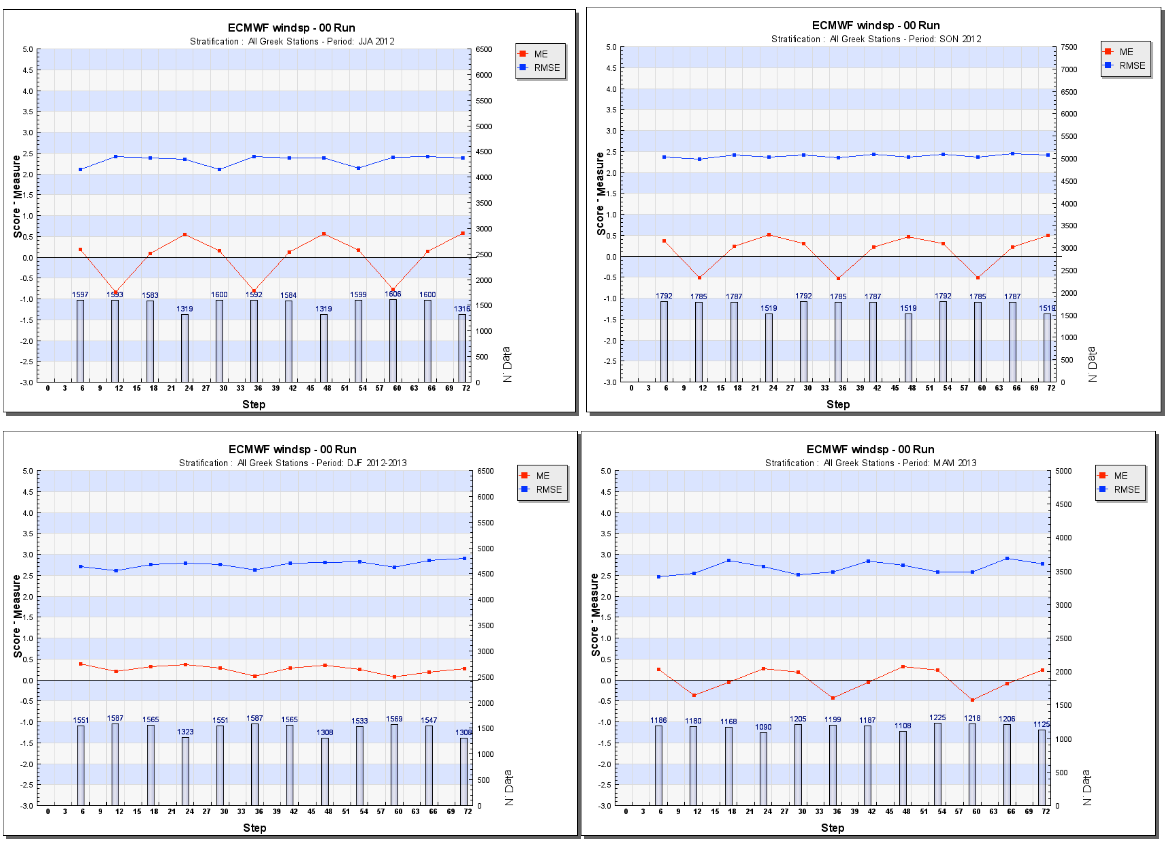


Fig.2: RMSE and Bias scores for 2m Dew Point Temp (above) and 10m Wind speed (below) from the IFS model (00UTC run) calculated and presented for every season



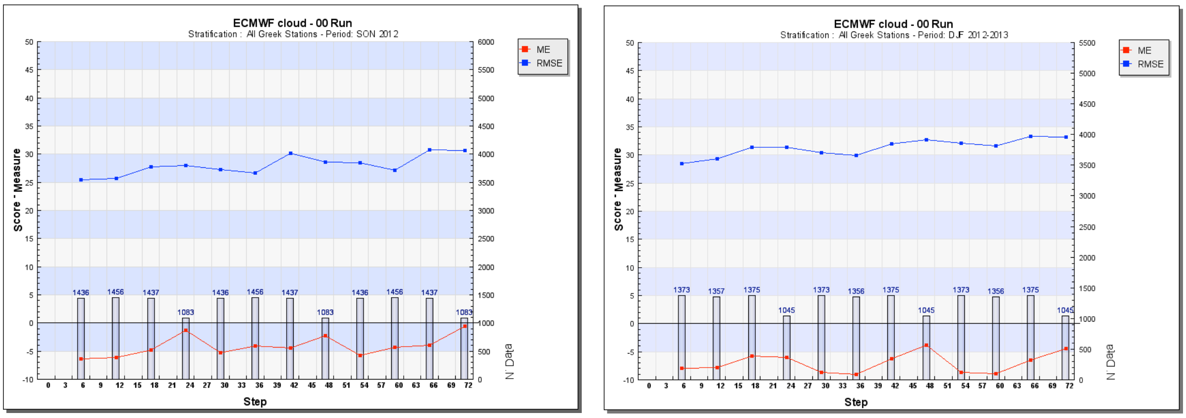


Fig.3: RMSE and Bias scores for Cloud Cover from the IFS model (00UTC run) – Fall and Winter (above)

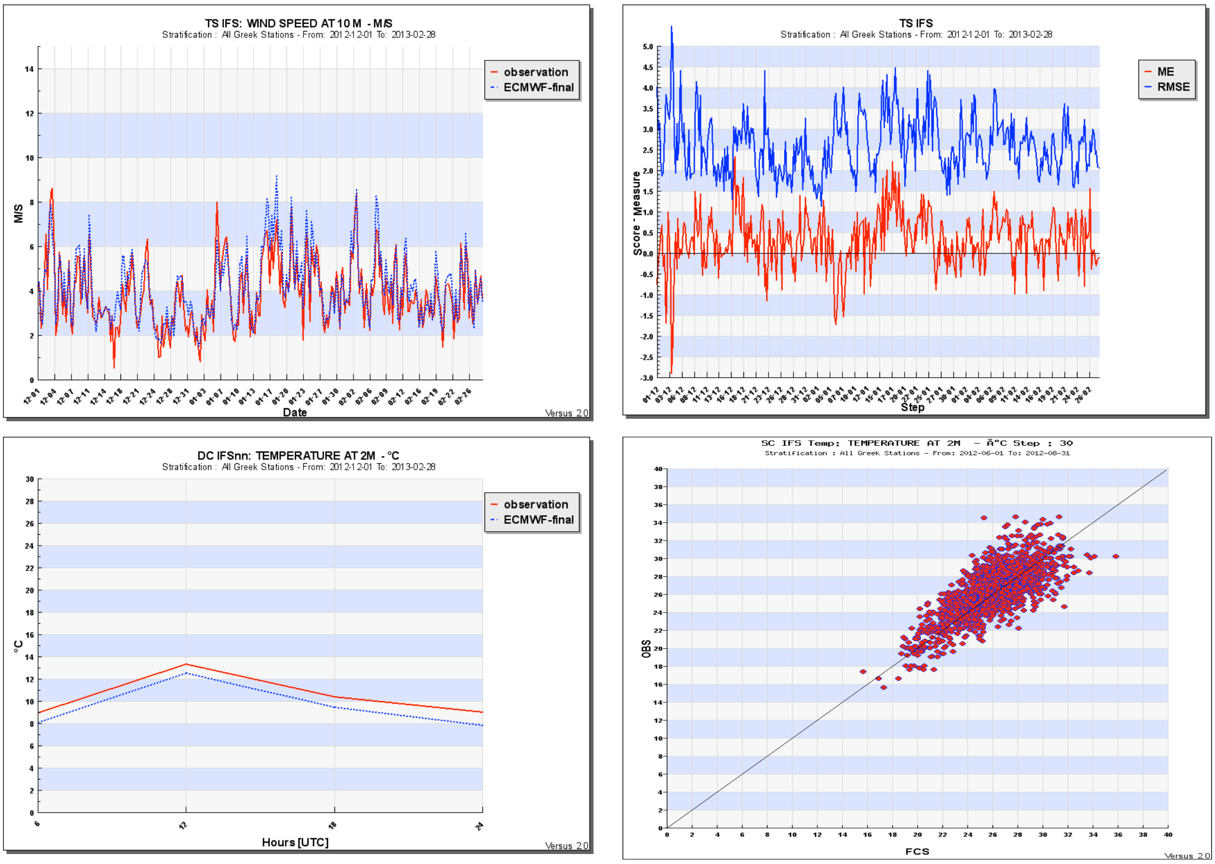


Fig.4: Time Series for fcst-obs and for ME, RMSE for wind speed (winter). DC and scatter plot for 2mT for two seasons.

Dew Point Temperature*:* The DPT is undererestimated by the model for all seasons. The diurnal cycle is evident in the Bias values. Very large RMSE values for the summer (Fig. 2).

10m Wind Speed: The RMSE behaviour and values are almost constant for all seasons with values around 2.5-3 m/s with a clear daily cycle in the Bias values (Fig. 2). The slight overestimation of wind is also apparent in the Time Series (TS) plots of obs-fcst pairs and of the statistical scores (Fig.4).

Cloud Cover: A general underestimation of cloud cover percentage is apparent in all seasons (only SON and DJF listed here) 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 (not shown) when weather conditions are more stable and cloud cover amount is in general decreased (Fig.3).

Precipitation for each weather class:
With the aim of gaining a better understanding of model behavior for the various types of weather that influence our area, a subjective classification was adopted that is based mainly on the basic circulation patterns that the forecasters at HNMS come across in their daily experience. The aim of the study is to identify weather situation-

dependent weaknesses and strengths of the IFS model. This tailor-made classification scheme comprises 12 different weather classes which describe the synoptic situation of the 500hPa at 12 UTC on a daily basis, with a geographical focus on the Greek region. These classes roughly separate the different weather situations into advective classes (e.g. *'northwest'*, *'southeast'*) and the accompanied convective classes *'anticyclonic'* and *'cyclonic'*. Each of these categories is related to specific weather phenomena, the intensity and amplitude of which depend greatly on the season. The categories used are presented in Fig. 5 with an example of the graphical representation of the circulation. The time period covered by the study was 1 December 2009 to 30 June 2013.

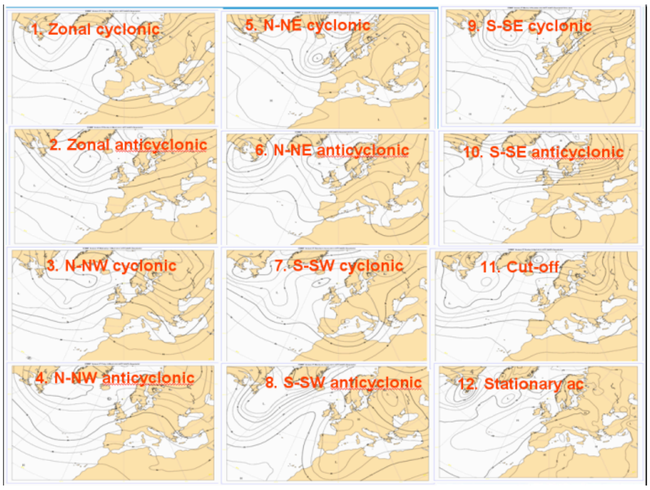


Fig.5: Graphical representation of the weather classes used.

Table 1 shows the relative percentage of days that fall into each weather category. Particular attention must be given to gathering large enough samples to provide trustworthy verification results, i.e. interpretation of verification results for classes 'N-NE' and 'S-SE' for both convective classes is limited.

Table 1. Percentage of days in each weather regime (total number of days 1248)

Zonal C	Zonal AC	N-NW C	N-NW AC	N-NE C	N-NE AC	S-SW C	S-SW AC	S-SE C	S-SE AC	Cut-off low	Stat/ry AC
21	15	10	3	4	2	15	6	1	1	14	7

Precipitation is commonly accepted as the most difficult weather parameter to correctly predict in terms of its spatial and temporal structure due to its stochastic behavior and any connection with specific weather systems is greatly appreciated by forecasters. The 12h-hour precipitation amounts were verified for this study and the thresholds for the precipitation amounts ranged from 0.2mm up to 30mm accumulated over each time interval. For each threshold a number of scores were calculated that provide insight into model behaviour, the most representative of which are shown in Fig. 6.

The 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 indicates over-forecast) while the Equitable Threat Score (ETS) is a measure of the fraction of correctly predicted events, adjusting for random hits (range: -1/3-1, perfect score=1). The results indicate that the IFS model performs well for the thresholds corresponding to small amounts of precipitation, but it fails to accurately predict large rainfall events. In cases that there was precipitation during a substantial number of days, FBI index results indicate that there is an overprediction for the lower thresholds during all cyclonic circulations, independent of the origin of the system, meaning that the model was giving us more often precipitation than truly occurred. On the other hand, the model underforecasts precipitation during heavy rainfall events (>8mm), especially during anticyclone circulations. The ETS index, which provides a measure of the general performance of the model, reduces dramatically as the precipitation threshold increases. After measuring this index for all the statistically significant weather classes, it was discovered that precipitation forecasts were more successful for weather systems originating from the south-west, but this behavior can only be better understood if a seasonal analysis is performed. POD scores (usually higher for coarser resolution models), follow the same results for each weather class.

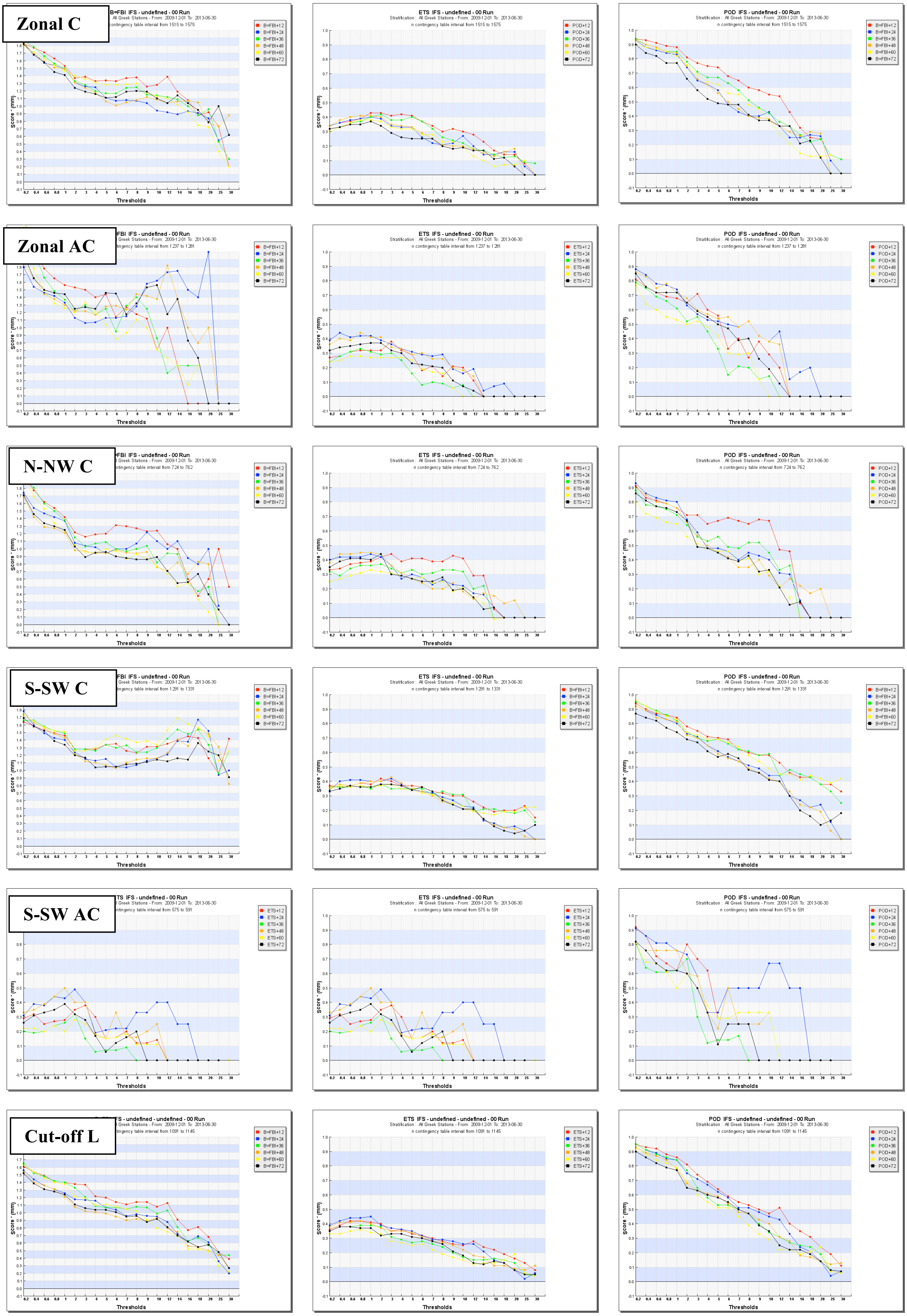


Fig.6: Statistical scores for the 12-hour accumulated precipitation forecast for fall and winter

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-GR7 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 (COSMOGR3).

Comparison of the performance of the ECMWF model with the COSMO-GR7 and COSMO-GR3 is done on a regular basis. Average statistical indices over every season are calculated and presented in this report. For MSLP, the IFS model gives lower errors and less propagation with time as for the two local models. On the other hand, IFS performs worse with respect to wind speed and temperature, and with the highest values of error in different timesteps than the two COSMO models that as expected have similar behaviour (Fig.7).

Fig.7: RMSE and Bias scores for 2m Temp, 10m Wind Speed and MSLP averaged over all two seasons.

3.1.3 Post-processed products

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