Application and verification of ECMWF products 2015

Hellenic National Meteorological Service (HNMS)
Flora Gofa, Dimitra Boukouvala and Panagiotis Skrimizeas

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 limited area model 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 model (COSMO-GR, WAM). 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 (JJA2014-MAM2015) 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

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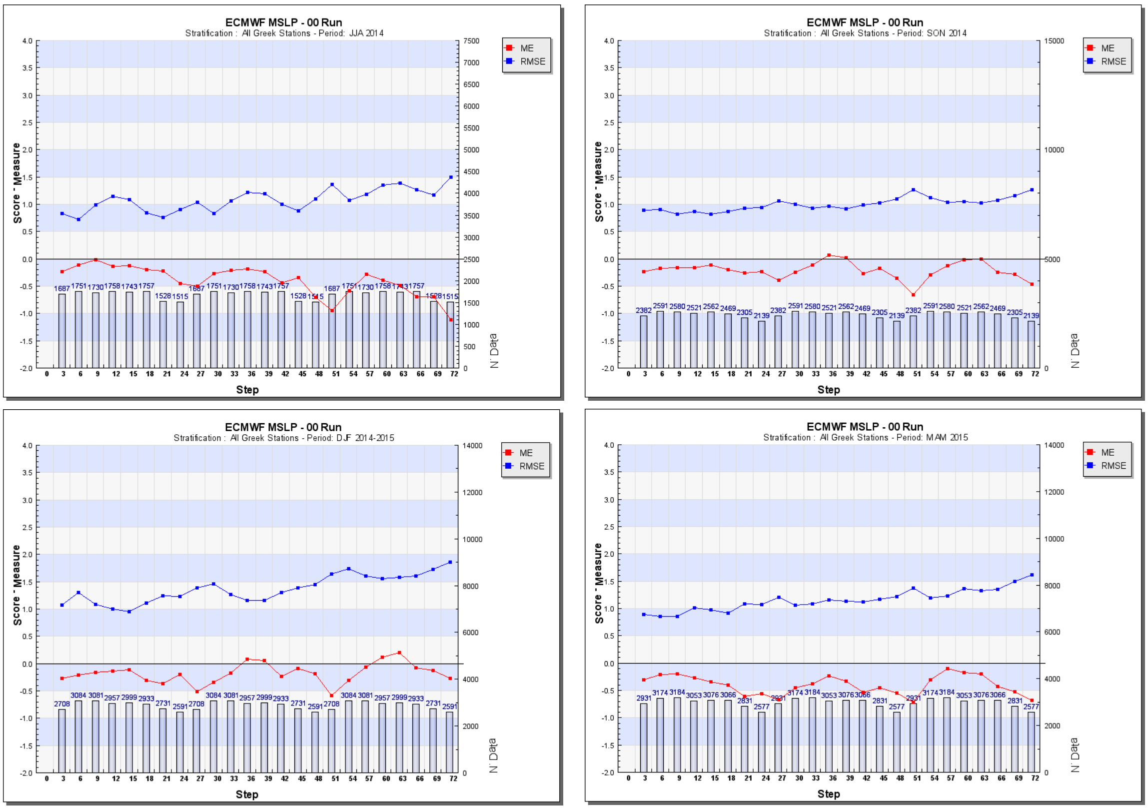
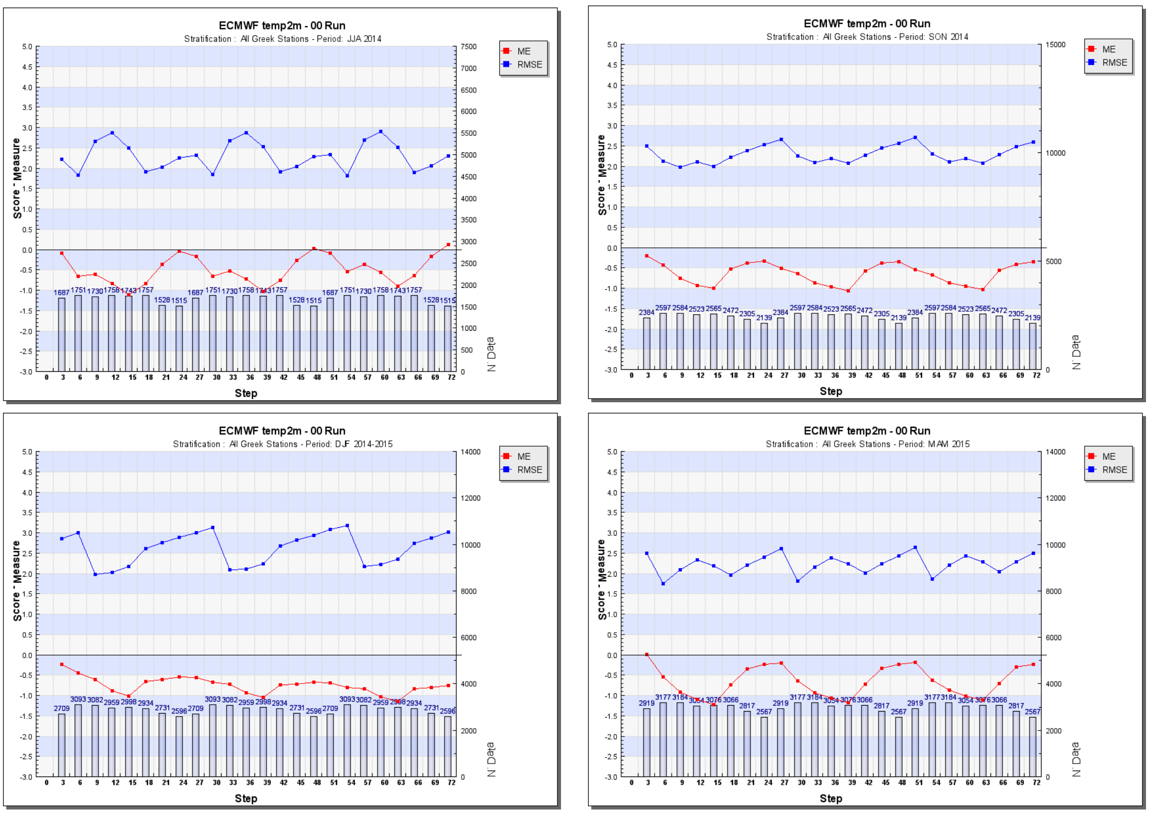


Fig.1: RMSE and Bias scores for MSLP (above) and 2m Temperature (below) from the IFS model (00UTC run) calculated and presented for every season



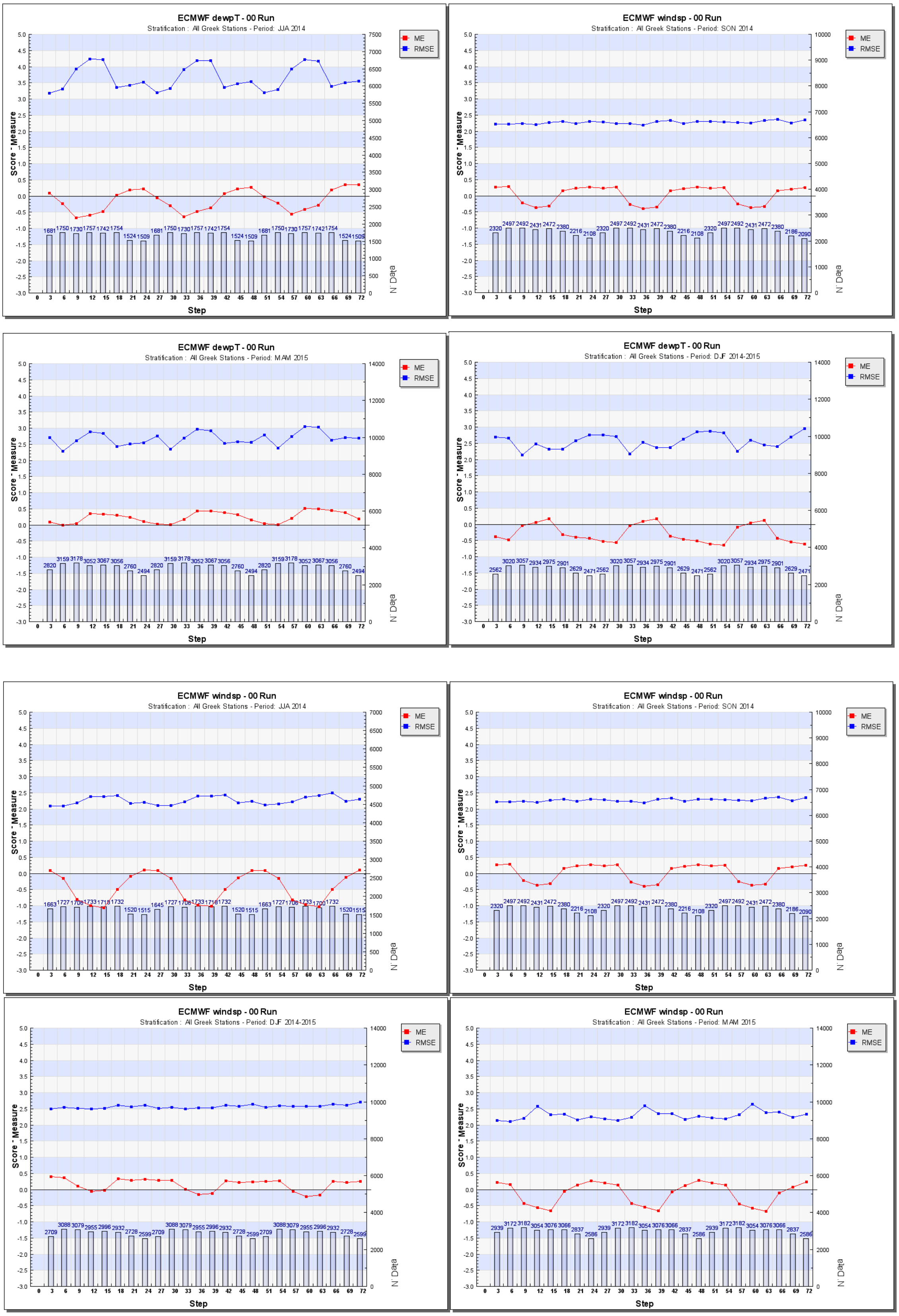


Fig.2: RMSE and Bias scores for 2m Dew Point Temp (above) and 10m Wind speed (below) from the IFS model (00UTC run) calculated and presented for every season

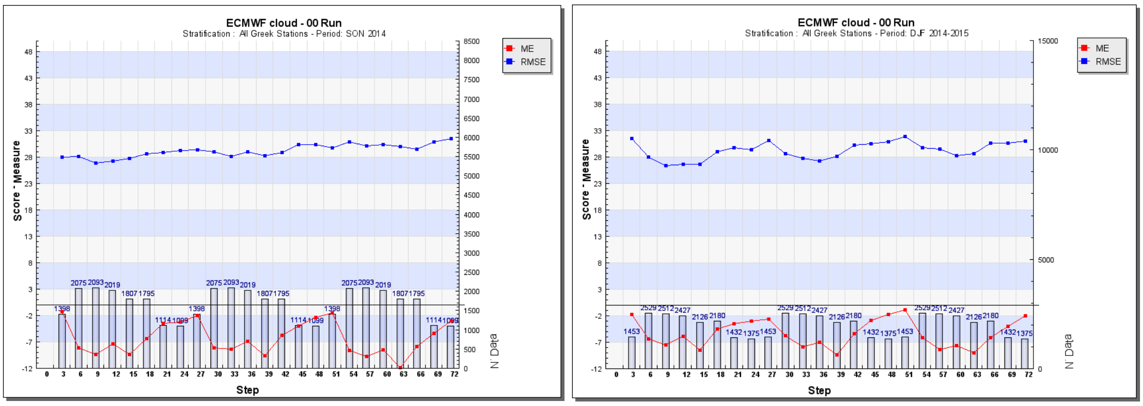


Fig.3: RMSE and Bias scores for Cloud Cover from the IFS model (00UTC run) – Fall and Winter (above)

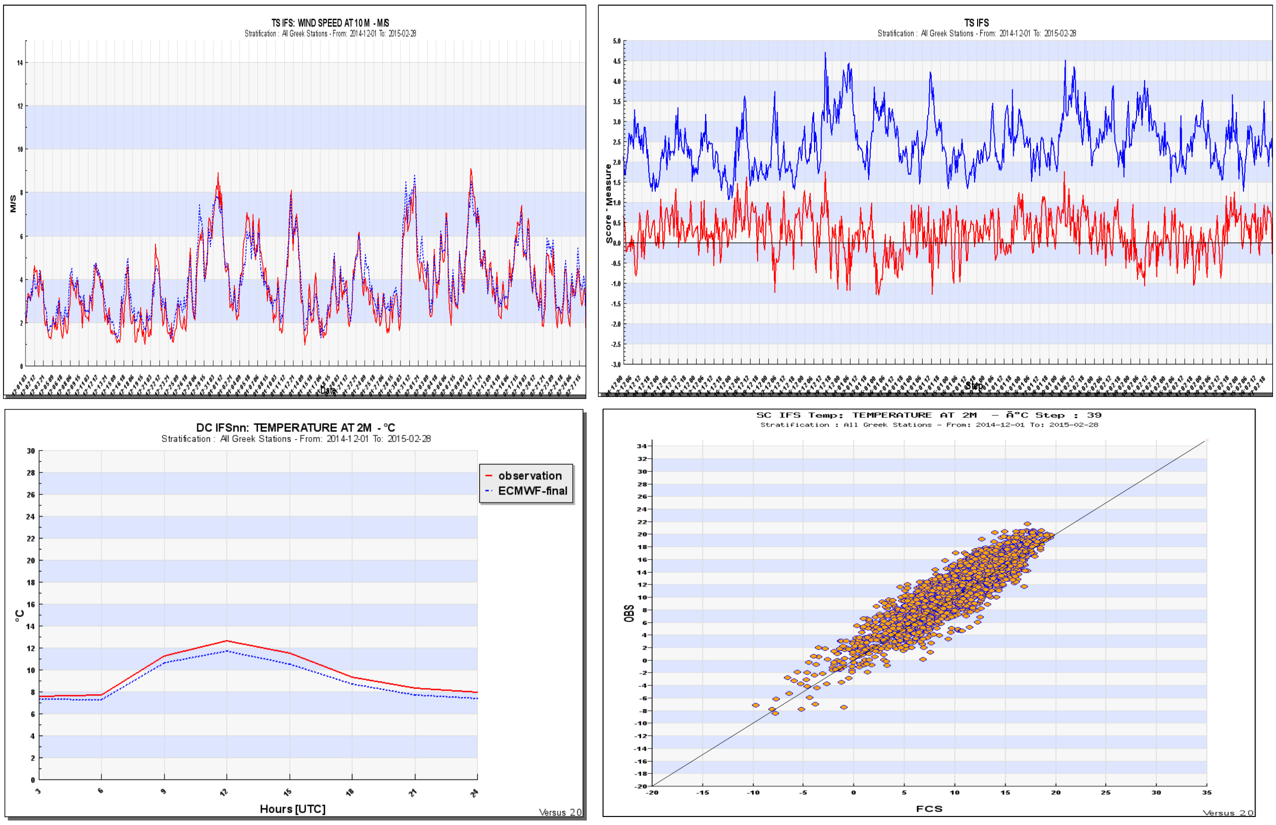


Fig.4: Time Series for fcst-obs and for ME, RMSE for wind speed (winter). DC and scatter plot for 2mT for winter 2015.

Dew Point Temperature*:* The DPT is underestimated by the model for all seasons except spring. 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:
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, but the representation chosen for this report are the Performance Diagrams (PD). PD summarizes the SR (that is FAR-1), POD, FBI, and TS. Dashed lines repre-sent bias scores with labels on the outward extension of the line, while labeled solid contours are TS. Sampling uncertainty, if any, is given by the crosshairs. A perfect, or better, forecast will lie on, or towards, the upper right corner of the diagram.

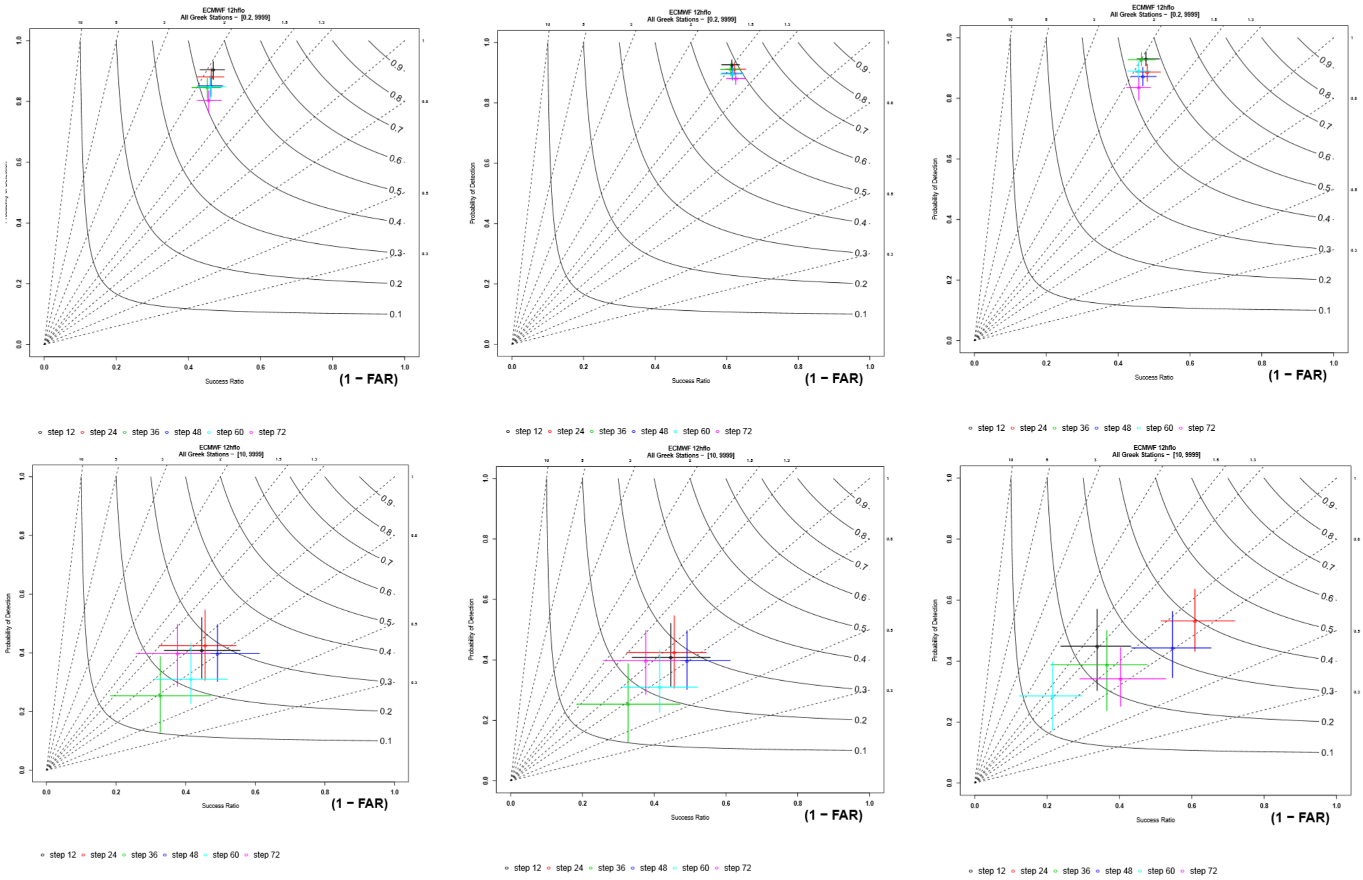
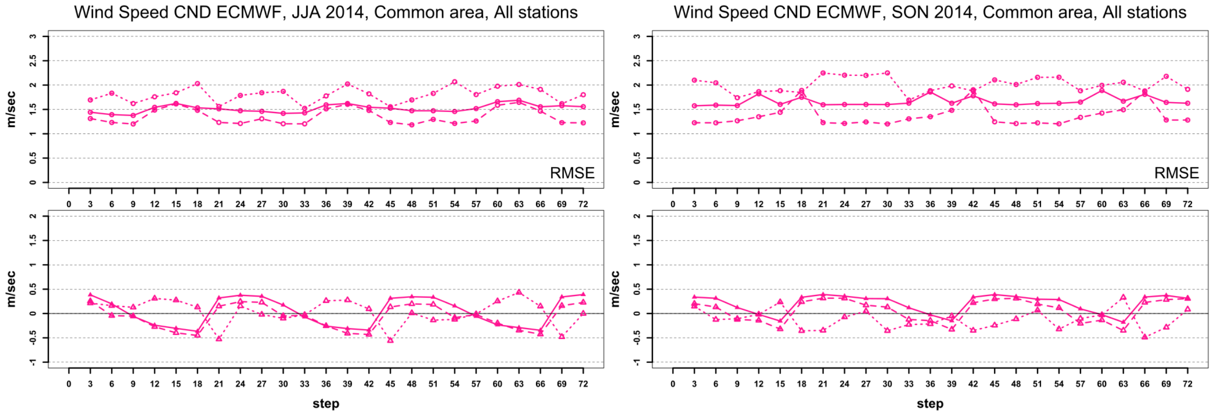


Fig.5: Performance diagrams: Fall-Winter-Spring (left to right) for thresholds >0.2mm(upper row), >10mm/12h (lower row)

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. PD graphs indicate that there is an overprediction for the lower thresholds meaning that the model was giving more often precipitation than truly occurred. On the other hand, the model underforecasts precipitation during heavy rainfall events (>10mm). In general, the performance of IFS model deteriorates with increasing precipitation threshold

The interpretation of classical verification results with regard to systematic deficiencies in the model's simulation of specific processes is also far from trivial. Even though obvious weaknesses of the model may be identified, determining the reasons behind these failures is hampered by the integral properties of the classical approach, i.e. the averaging over spatial (and temporal) domains without consideration of specific details of the atmospheric and/or surface situation. The verification of forecast products in conjunction with the existence of additional criteria that are to be met will hereafter be considered as “conditional verification” (CV). The primary purpose of CV is the systematic evaluation of model performance in order to reveal typical shortcomings and their root causes. The typical approach to CV consists of the selection of one or more forecast products and one or more mask variables, which are used to define thresholds for the product verification. At HNMS, CV applications are inserted in the operational verification routine on an annual basis for all NWP limited area models. Some of these tests are extended to the model that provides the IC/BC conditions (IFS is our case) in order to be able to indentify model performance trends that are inherited. Below an example is given from the IFS wind speed errors with variable roughness length (RL) conditions for all seasons. As it is shown (Fig.6), in all cases RMSE error is reduced in conditions of high RL, an indication that is exerted also analyzing COSMO-7 model (not shown).



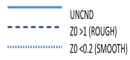
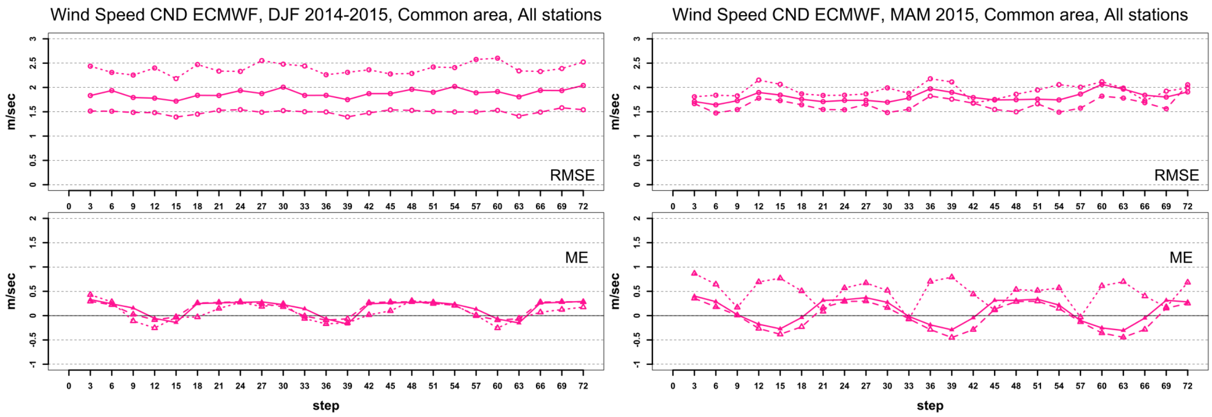


Fig.6: RMSE for Wind speed unconditioned and in high (>1m) or low (<0.2m) Z0 conditions



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)

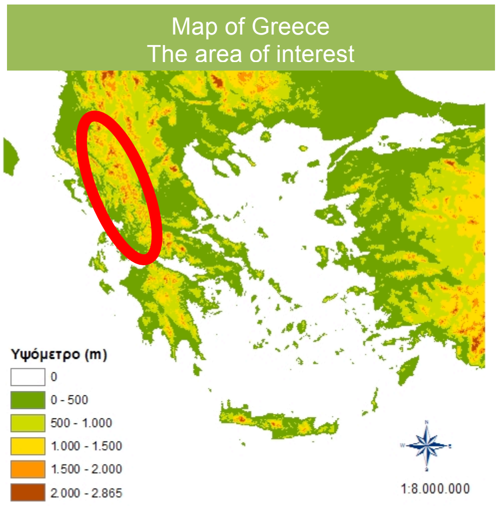
3.2.2 Case Studies

Stochastic forecasts and extreme weather events. The case study of intense and devastating rains over NW Greece during the period 30 Jan-1Feb 2015

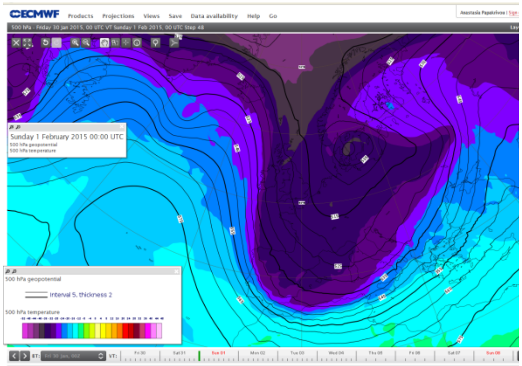
Anastasia Papakrivou and Panagiotis Skrimizeas

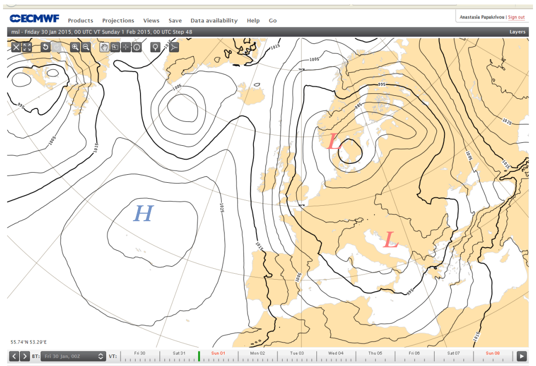
Nowadays there is a profound increase in the number of natural disasters attributed to extreme weather events which is significantly impeding progress towards sustainable development. The most common approach for the classification of an impending weather event as "probably extreme", presupposes that at least one of its defining meteorological parameters is expected to exceed some predefined thresholds. These thresholds are relative to the region of occurrence, and thus its climate, rendering this a purely meteorological topic.

As however, the severity of the impacts of extreme weather events depends strongly on the level of vulnerability and exposure of the local societies to these events (IPCC, 2011), it is the decision makers who, except the meteorologists, also need to take action and properly manage and exploit meteorological information. Thus, taking into account the social, economic and other constraints decision makers are called to act in, except of being accurate in space and time predictions, forecasts need to give further, quantitative information concerning the risk level of an impending weather event. Such a forecast, presented in an appropriate way leading to a clear interpretation, would be an extremely useful tool, particularly in the phase of preparedness. In this paper, we test the effectiveness of the ECMWF stochastic weather forecasts and demonstrate their utility in decision-making, under the supervision of an experienced weather forecaster. To do so, we use as case study the region of Arta in northwest Greece, which experienced intense and devastating rains during the period January 30 - February 1 2015.



Synoptic Situation





In the upper atmosphere (500hPa), the strong northerly airflow over Western Europe, feeds Western Mediterranean Sea with cold air mass, which, enriched with moisture, move over Greece due to the strong southwest flow over central and eastern Mediterranean Sea. At the surface (MSLP), a deepening low pressure centre over northwest Greece.

Probabilistic approach

According to the meteoalarm color code, “orange” for West Greece means that the 12hr accumulated precipitation is expected to exceed 50 mm. This is why charts illustrating the probability of the 12hr accumulated precipitation to exceed 50mm, are thought to be a useful tool in the phase of preparedness. In addition, considering an apparent increase of the region vulnerability, due to the significant rainfall observed during the previous days, we decided the parallel use of charts with the probability of the 12hr accumulated precipitation to exceed 30mm, a significant lower height. Using ecCharts, we synthesized forecasting maps showing the probability of the 12hr accumulated precipitation to exceed the defined thresholds (three runs: 30/01 00UTC, 30/01 12UTC, 31/01 00UTC).

These probabilities are shown in the Table below:

	P(%) > 30mm			P(%) > 50mm		
	Time before the event					
Forecast valid	36hr	24hr	12hr	36hr	24hr	12hr
31/1- 18UTC	35-65	65-95	100	0-35	0-35	0-35
31/1- 21UTC	65-95	100	100	35-65	0-35	35-65
1/2- 00UTC	100	100	100	35-65	35-65	65-95
1/2- 03UTC	100	100	100	65-95	65-95	100
1/2- 06UTC	100	100	100	35-65	35-65	65-95
1/2- 09UTC	65-95	100	100	35-65	35-65	35-65
1/2- 12UTC	65-95	65-95	65-95	0-35	0-35	0-35
run based on	30/00UTC	30/12UTC	31/00UTC	30/00UTC	30/12UTC	31/00UTC

e.g. Run 30/01 1200 UTC

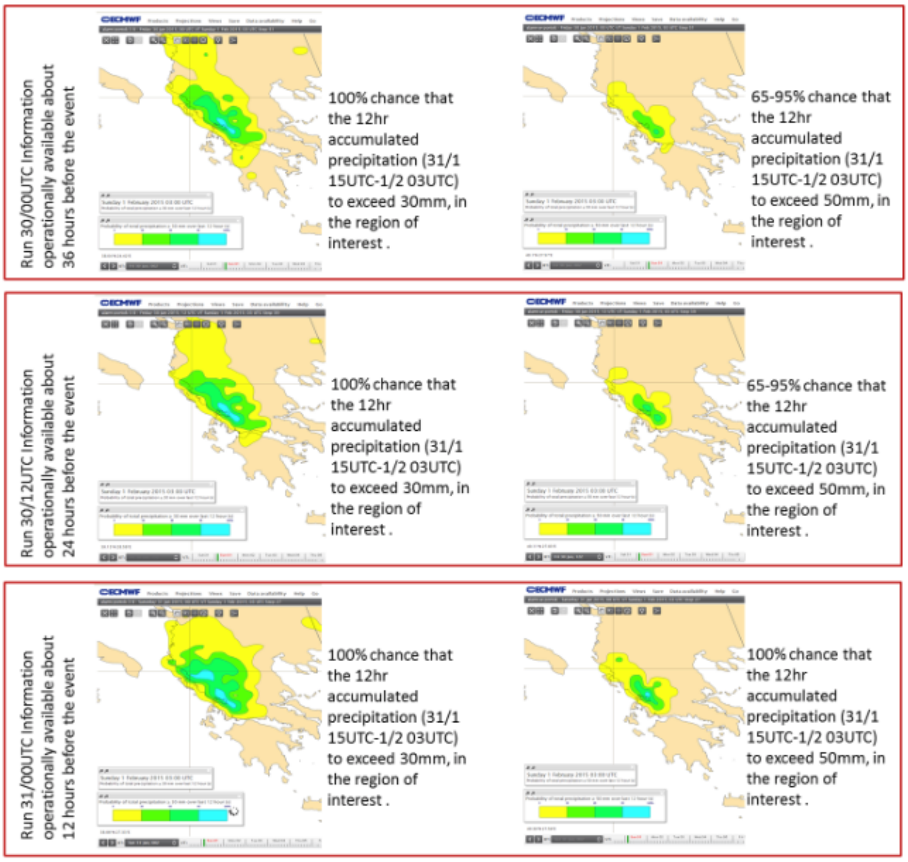
65-95% chance the 12hr accumulated precipitation (31/01 06UTC - 31/01 18UTC) to exceed 30mm, in the region of interest.

0-35% chance the 12hr accumulated precipitation (31/01 06UTC - 31/01 18UTC) to exceed 50mm, in the region of interest.

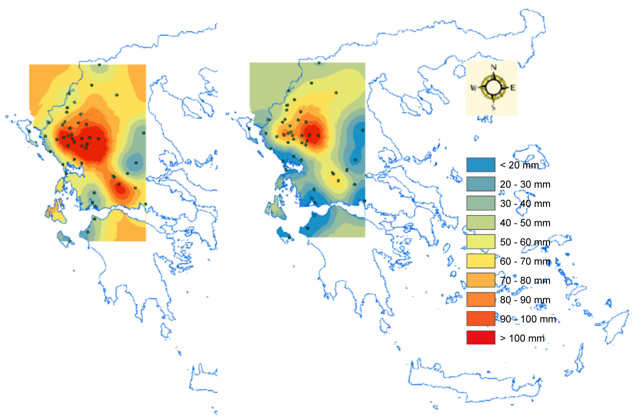
This information was operationally available about 24 hours before the event to be completed.

The crucial twelve hours: 31/1 15UTC – 01/02 03UTC

For this time period, the maps below show the spatial distribution of the probabilities for the three consecutive runs (30/00UTC-30/12UTC-31/00UTC). The following parameters are evident: a) the spatial consistency, b) the certainty for exceeding the 30mm threshold, in all three runs, in the area of interest, and c) the significant probability for exceeding the 50mm threshold in the first two runs turns to certainty in the last one.



Evaluation - the spatiotemporal observed accumulated precipitation



Precipitation data from both, HNMS and NOA meteorological station networks were used for evaluation purposes.

Spatial analysis of the 24hr precipitation on January 31 (on the left) and February 1 (on the right).

Conclusions

- The predictive guidance on the probability of exceeding the predetermined thresholds is evaluated positively.
- The period of the exacerbation of the event was successfully determined.
- The spatial distribution of probability is assessed positively.

The use of stochastic (ensemble) forecasts is proved to be the necessary added value to the till now supplied meteorological information. ecCharts, provides the ability for targeted analysis and synthesis of meteorological information and thus for tailor made products to fit operational needs and as a result to more effective management of natural disasters related to extreme weather events.