Application and verification of ECMWF products 2022-23

Hellenic National Meteorological Service (HNMS)
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1. Summary of major highlights

The ECMWF products are widely used in HNMS and are essential tools for our daily forecast.

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 IFS-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 our limited area model ICON (**ICO**sahedral **N**onhydrostatic) is used in conjunction with the ECMWF products.

Daily verification is performed for the surface fields of the IFS products as well as for the high-resolution limited area model (ICON-GR 2.5km) that are used by the HNMS forecasters. The relative performance of the models is subject to intercomparison.

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2. Use and application of products

2.1 Direct use of ECMWF Products

The HNMS forecasting centre continues to use ECMWF products in conjunction with the products of its limited area models for the general 7-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.

The EPS products (plumes, meteograms, 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.

2.2 Other uses of ECMWF output

2.2.1 Derived fields

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

2.1.2 Modelling

ECMWF model output provides the lateral and boundary conditions for the execution of the daily simulations of the HNMS limited area model ICON-GR. As an option, ECMWF model output can also be used to provide the necessary input for the MOTHY air pollution trajectory model in the Eastern Mediterranean Sea. 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.

Finally, the ECMWF deterministic model provides the necessary initial conditions to drive a wave forecast model (WAM) as an alternative option to ICON-GR. 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 been implemented with the use of observations taking by the buoys positioned around the Greek Seas (POSEIDON system).

3. Verification of ECMWF products

In order to determine the quality of the NWP products at the Hellenic National Meteorological Service (HNMS), verification processes are applied based on tools developed through the **CO**nsortium for **S**mall-scale **MO**deling (COSMO). The first one is **VER**ification **S**ystem **U**nified **S**urvey (VERSUS), the development of which was coordinated by the Italian Meteorological Service, and MEC (Model equivalent Calculator) developed by DWD (Iriza et al, 2022).

For research reasons and special test cases, the spatial verification methods software package VAST (VERSUS Additional Statistical Techniques), developed by the COSMO consortium offers a number of neighbourhood verification tools and is mainly used for precipitation.

Monthly and seasonal verification is performed for the surface fields of the IFS products as well as for the high-resolution limited area model (ICON at 2.5km) that are used by the HNMS forecasters.

3.1 Objective verification

3.1.1 Surface data verification

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.

The continuous variables that are routinely verified are the 2m temperature, 2m dew point temperature, Mean Sea Level pressure, 10m wind speed and total cloud cover. For dichotomous 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. A selection of statistics for 6h is presented in the current report.

The RMSE and Bias scores are calculated for every forecast cycle, every 3 hours from the t+3 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 is performed for every season (JJA22-MAM23) and scores of our local model ICON-GR (2.5 km resolution) are also depicted on the graphs. The main findings are as follows:

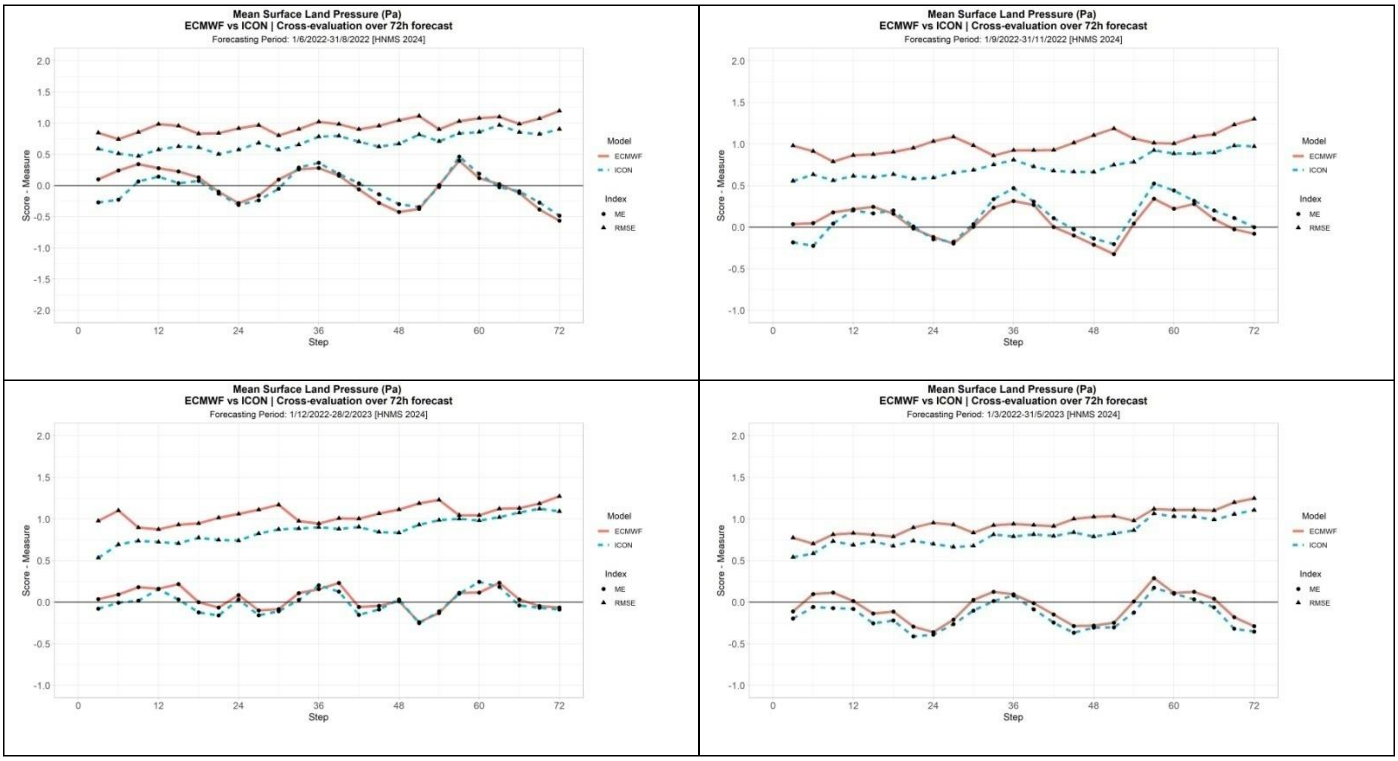


Fig. 1: MSLP scores RMSE, ME (y axis) for JJA22 (top left), SON22(top right), DJF23(bottom left), MAM23 (bottom right) with forecast time (x-axis).

Mean Sea Level Pressure: (Fig. 1). A slight propagation of the error (RMSE) with forecast time is evident for all seasons. RMSE IFS-ECMWF values are slightly higher than ICON-GR. A diurnal RMSE variation with higher values at night is shown. IFS-ECMWF bias values indicate a slight MSLP underestimation at night and overestimation in warm hours, mostly apparent in JJA, SON and MAM in contrast to DJF, when bias diurnal variation is weak with values closer to zero. Bias variation of ICON-GR is similar to IFS-ECMWF.

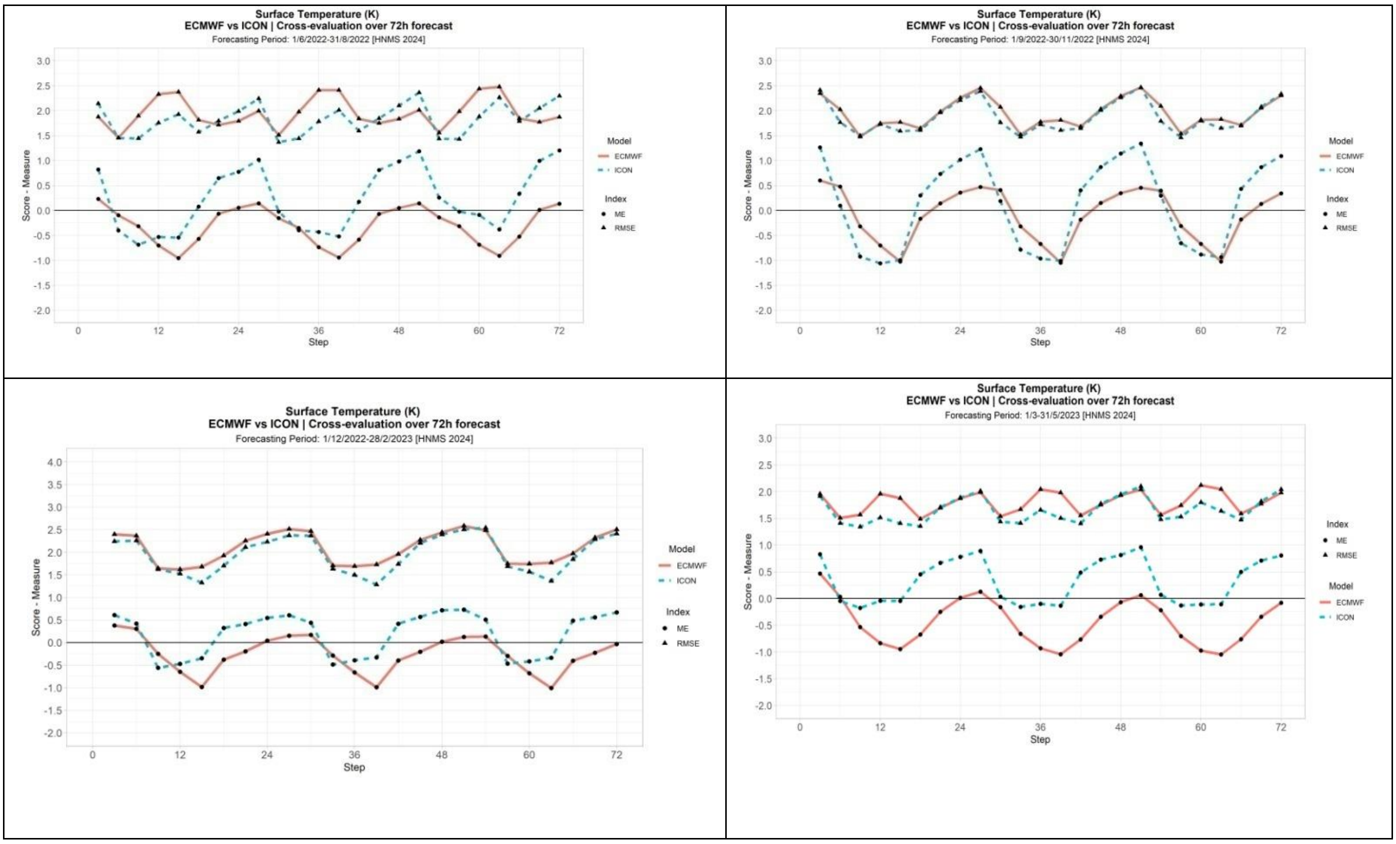


Fig. 2: T2m scores RMSE, ME (y axis) for JJA22 (top left), SON22 (top right), DJF23(bottom left), MAM23 (bottom right) with time (x-axis).

2m Temperature: There is a daily bias variation with underestimation in warm hours for all seasons and slight overestimation at night mostly seen in SON season. (Fig.2) The variation of ICON-GR model bias is more shifted to positive values and T2m is overestimated at night. RMSE score is around 2K for all seasons with maximum values at night. ICON-GR RMSE score is comparable to IFS-ECMWF.

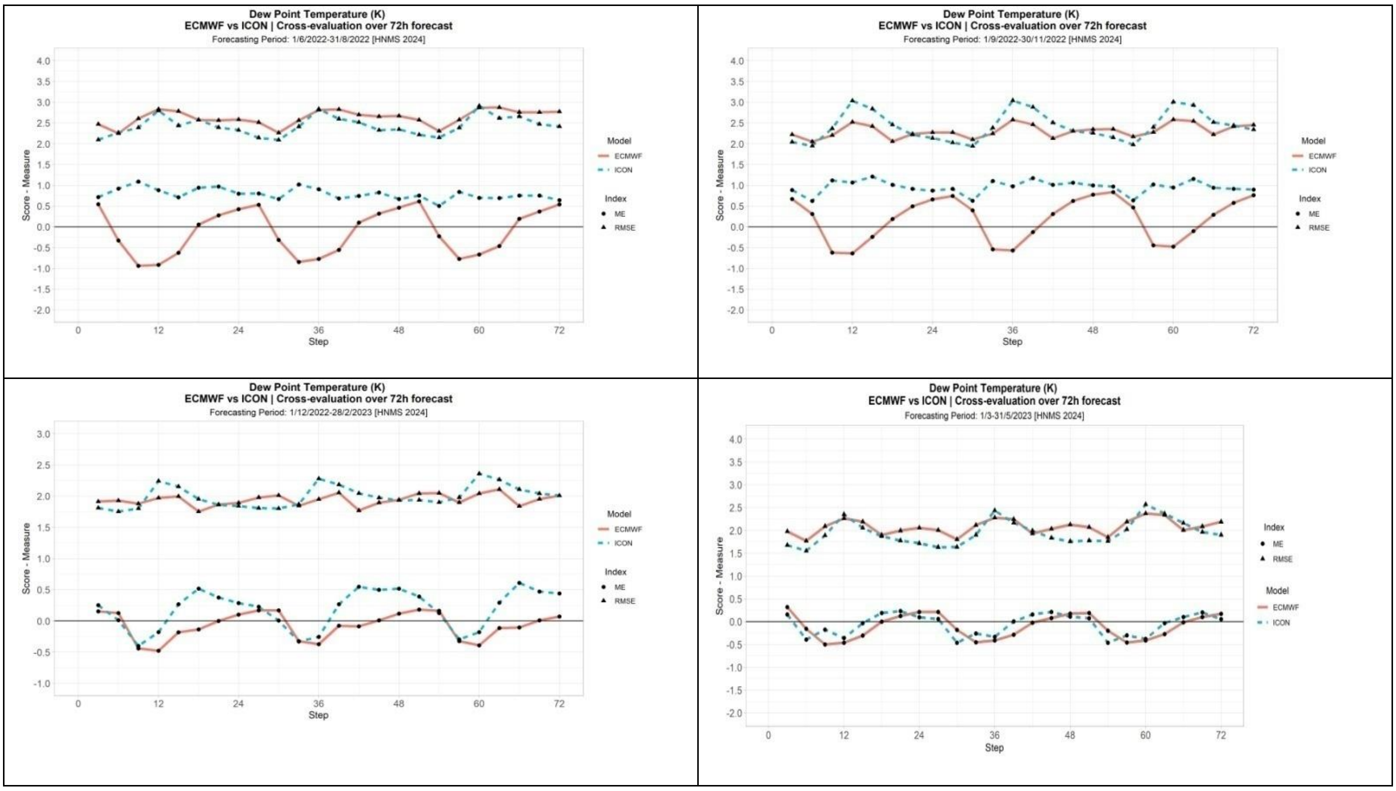


Fig. 3: Td2m scores RMSE, ME (y axis) for JJA22 (top left), SON22 (top right), DJF23 (bottom left), MAM23 (bottom right) with time (x-axis).

2m Dew Point Temperature*:* The diurnal cycle is evident in the bias values of IFS-ECMWF, where 2mTd is underestimated in warm hours and overestimated at night especially in JJA and SON seasons. In DJF and MAM seasons, bias values are closer to zero. ICON-GR constantly overestimates 2mTd in warm seasons (JJA, SON) in contrast to IFS diurnal cycle. RMSE scores for both models show a weak diurnal variability with higher values in the daytime (2K) peaking in warm hours.

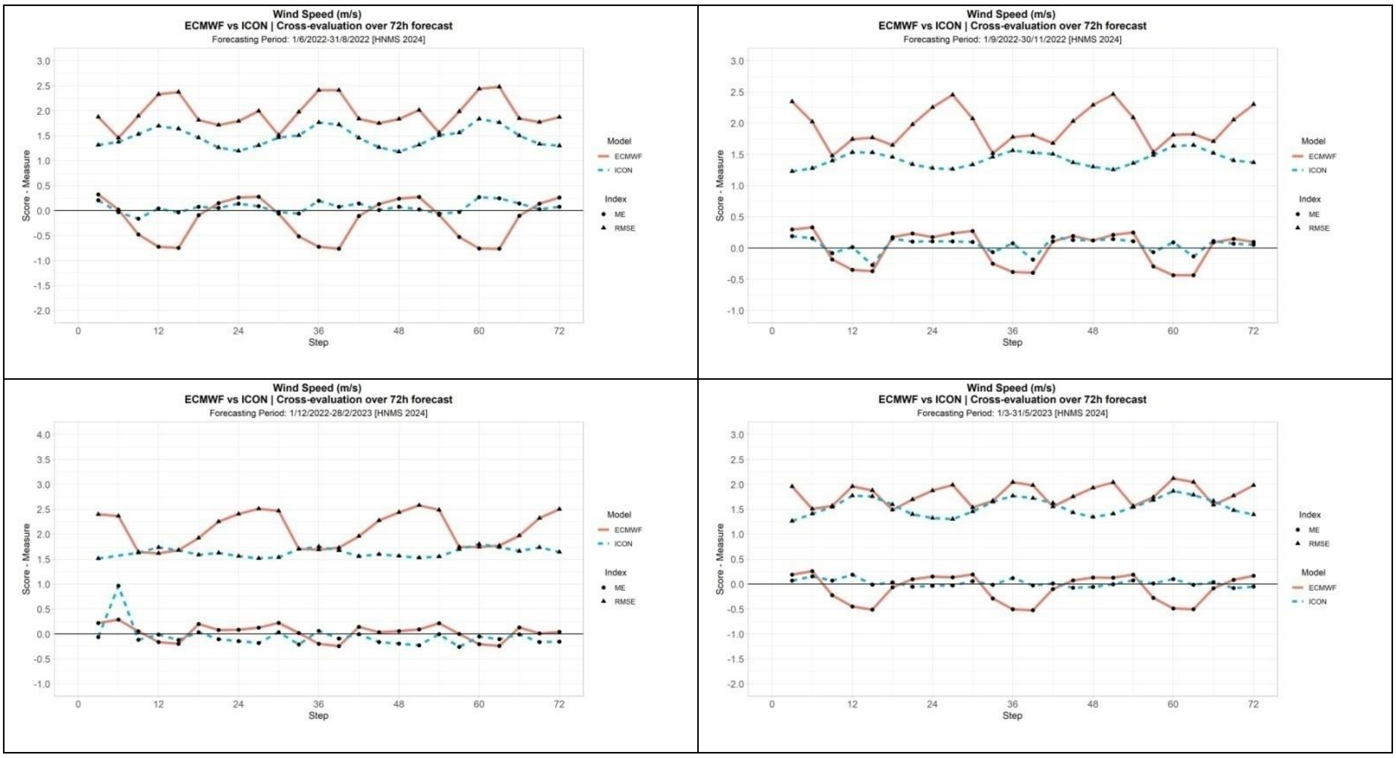


Fig. 4: 10m Wind Speed scores RMSE, ME (y axis) for JJA22 (top left), SON22 (top right), DJF23 (bottom left), MAM23 (bottom right) with time (x-axis).

10m Wind Speed: Bias values show slight underestimation of 10m wind speed in warm hours especially in JJA. At night bias is very close to zero with only slightly positive values. The daily variation is very weak in DJF season with almost no bias for both models. RMSE values are higher at night (2m/s) except for JJA when the maxima occur in warm hours. ICON-GR bias and RMSE values are better than IFS-ECMWF.

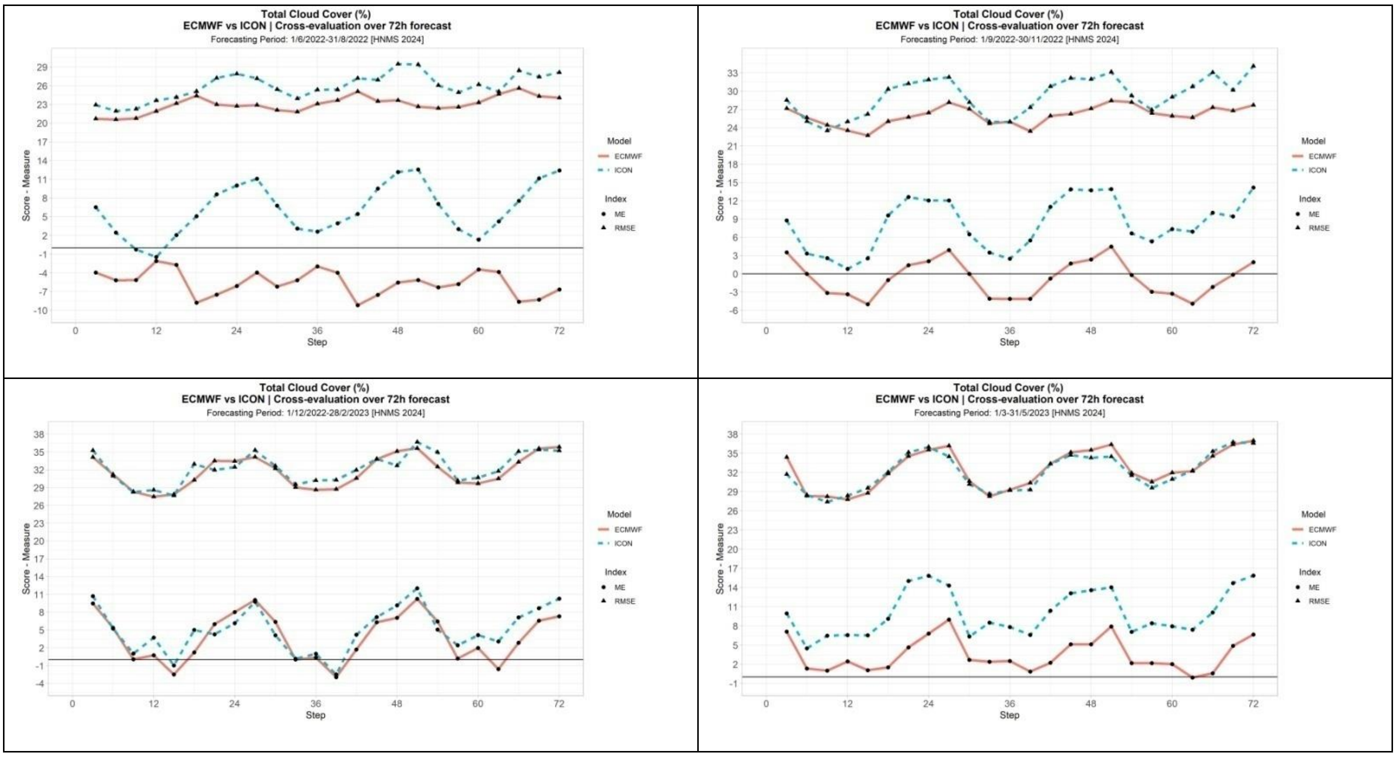


Fig. 5: 10m TCC scores RMSE, ME (y axis) for JJA22 (top left), SON22 (top right), DJF23 (bottom left), MAM23 (bottom right) with time (x-axis).

Cloud Cover: A general slight underestimation of cloud cover percentage from IFS-ECMWF model (Fig.5) is mainly seen in warm seasons, especially in JJA with a relatively weak bias daily cycle. During the cooler seasons (DJF, MAM), TCC is mainly overestimated especially at night. ICON-GR has a tendency of overestimation in all seasons, while both models give similar results in DJF season. RMSE shows maxima at night mainly during cooler seasons, when the values are similar to ICON-GR, while in the warmer seasons (JJA, SON), RMSE score for ICON-GR is higher.

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 behaviour. Verification is based on categorical scores that use contingency tables for specific thresholds. For this report, the most common categorical scores Equitable Threat Score (ETS), FBI (Frequency Bias), FAR (False Alarm Ratio) and POD (Probability of Detection).of 6h-hourly accumulated precipitation amounts are presented, for thresholds of 0.2,1,5,10mm.

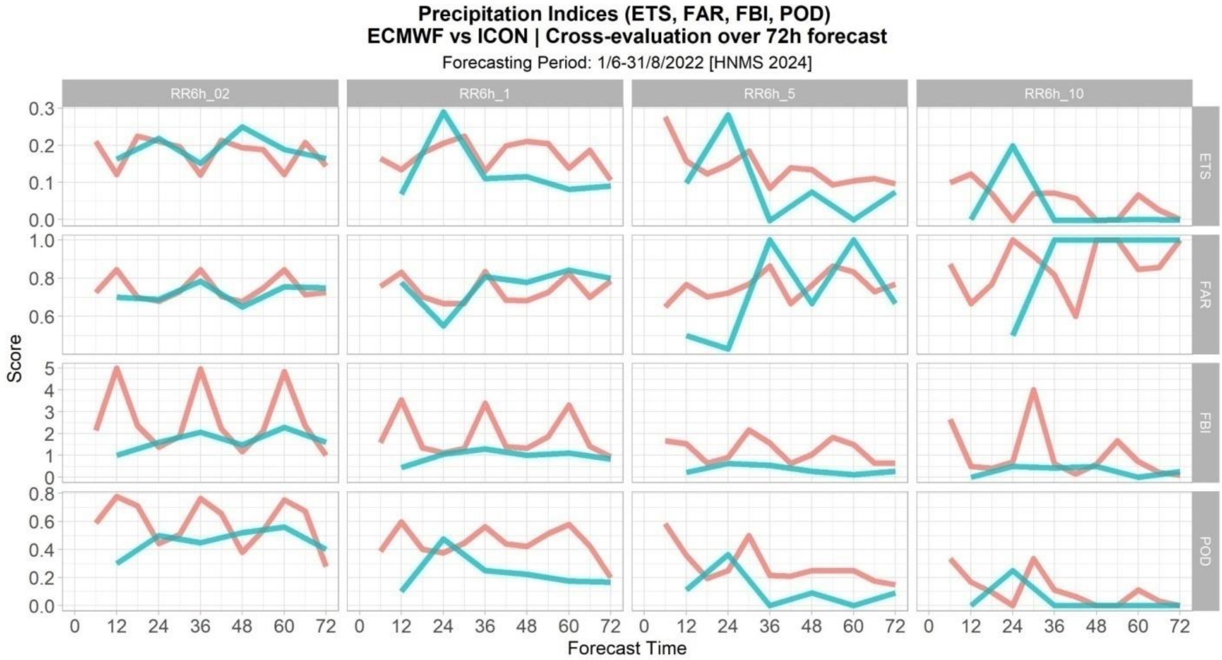


Fig.6 : Scores for 6h precipitation with forecast time (x axis): ETS, FAR, FBI, POD for threshold 0.2, 1, 5,10mm on for JJA 22(y-axis). Red line represents IFS-ECMWF, blue line ICON-GR.

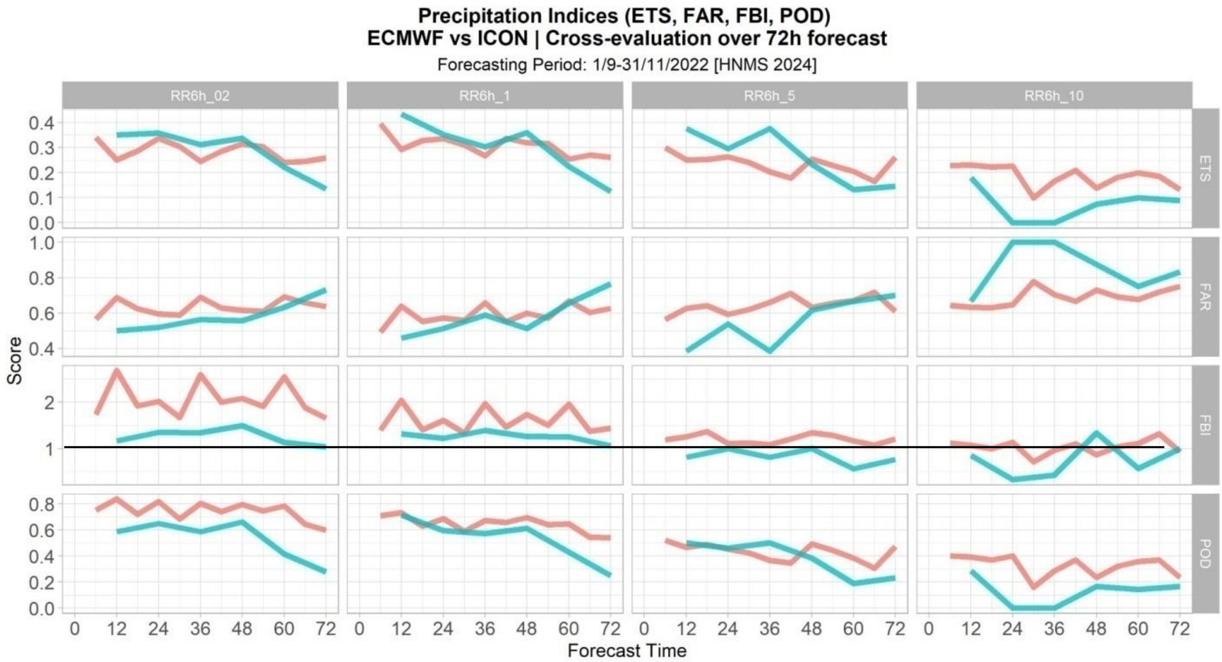


Fig. 7: Same as Fig.6 but for SON 2022

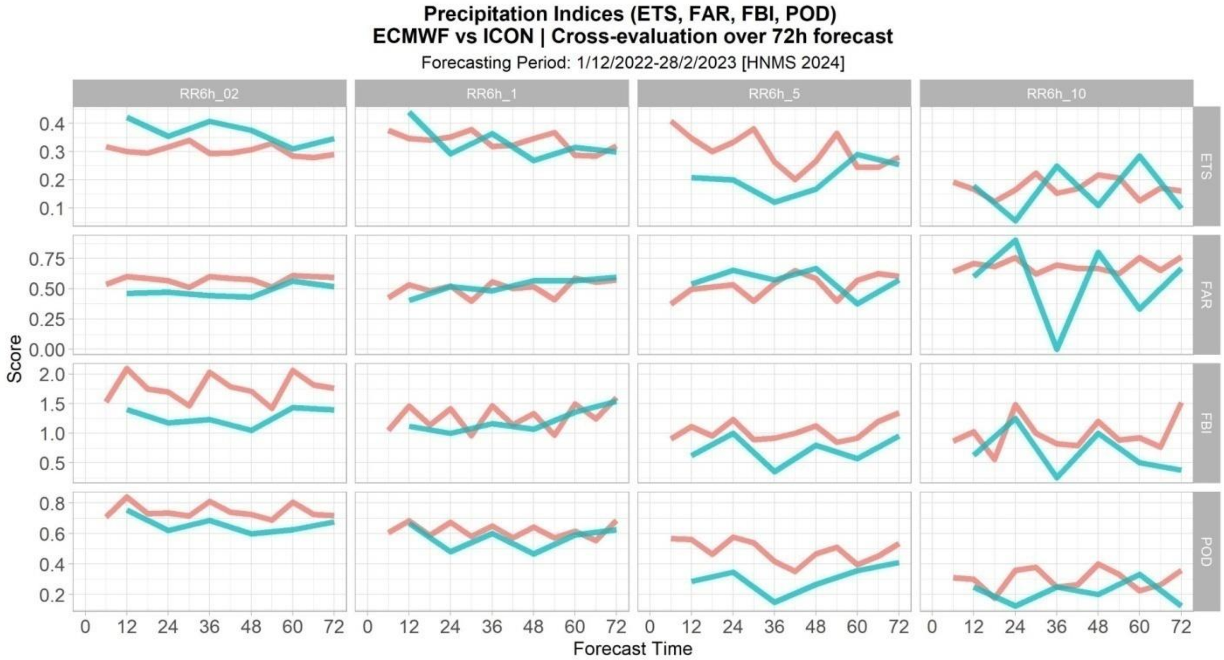


Fig 8: Same as Fig.6 but for DJF 2022-23

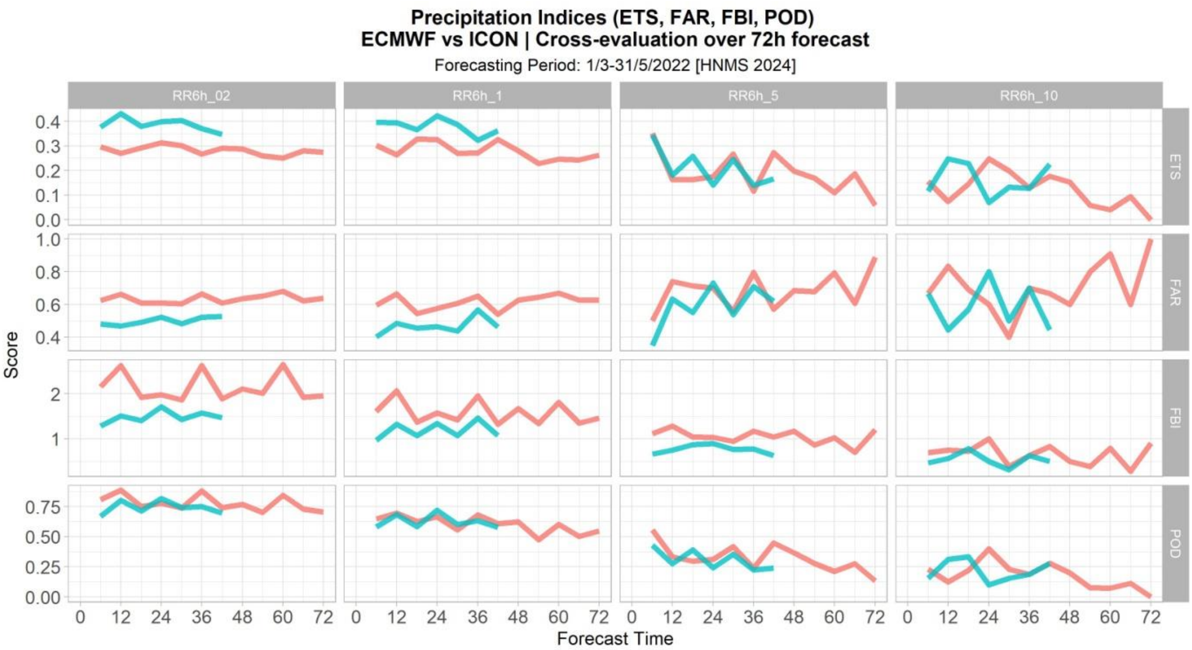


Fig 9: Same as Fig.6 but for MAM 2022

FBI: Overestimation of low thresholds precipitation events with a clear diurnal cycle in warm seasons especially JJA. For higher thresholds, FBI decreases and the diurnal variability weakens (less in JJA), FBI for ICON-GR is better for lower thresholds, while for higher ones, there is a tendency of events underestimation. Therefore, for higher thresholds IFS-ECMWF performs better.

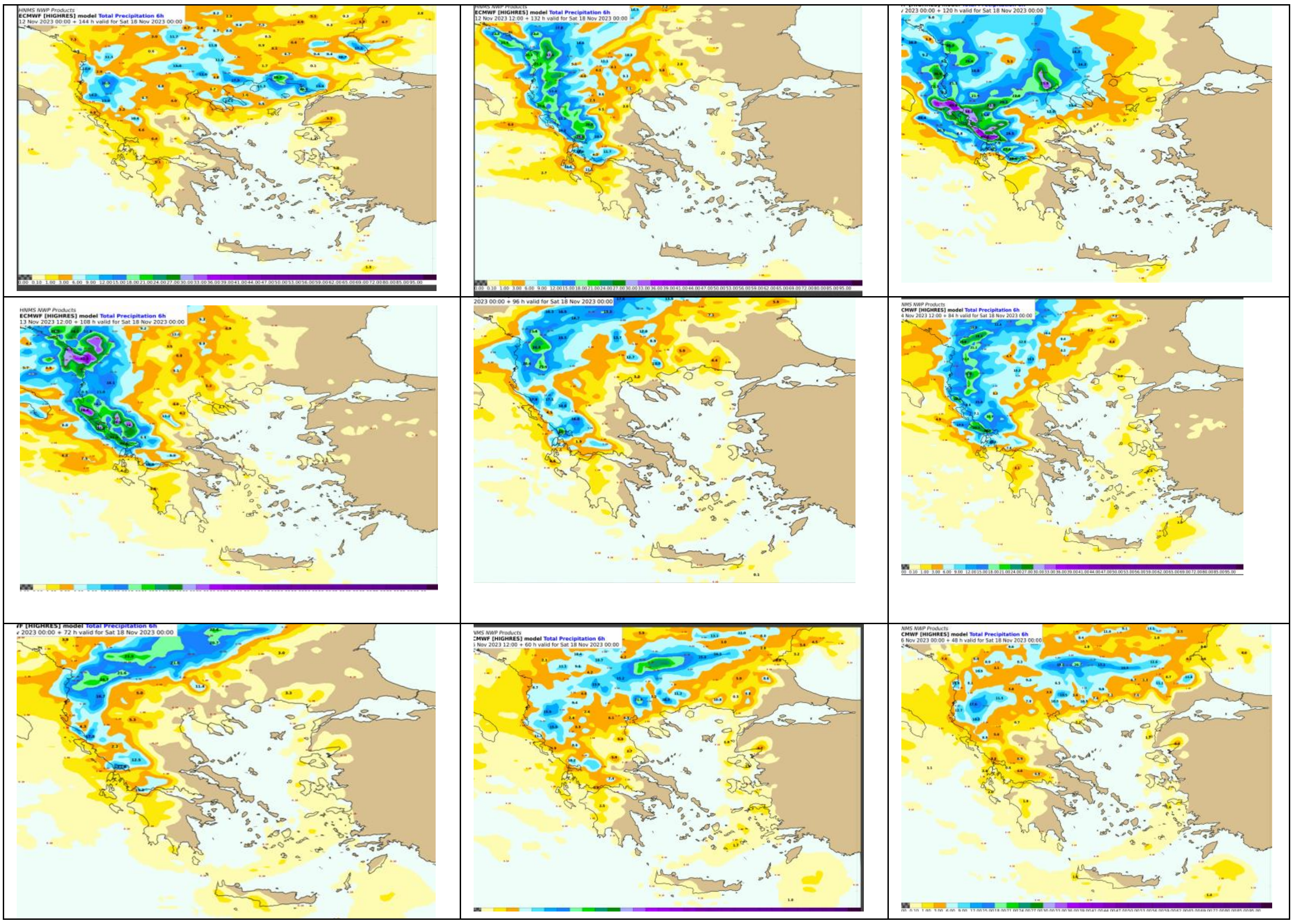
POD: IFS-ECMWF POD score is higher for lower thresholds, with diurnal cycle and maxima in JJA in warm hours. In cool seasons diurnal variability is minimal and POD reaches its higher values. POD values drop with increasing threshold and forecast time. POD IFS values are higher than ICON-GR in all seasons.

FAR: Diurnal cycle in warm seasons especially in JJA with higher values at noon especially for low thresholds. FAR becomes irregular and increases with higher thresholds. Fewer false alarms in DJF where no diurnal cycle is apparent. FAR IFS-ECMWF values are higher than ICON-GR for low thresholds and comparable for higher thresholds.

ETS: ICON-GR score is higher than IFS-ECMWF for low thresholds in DJF and MAM and comparable for both models in JJA and SON, with JJA maxima in warm hours and values dropping with increasing thresholds and lead time for all seasons. ETS for higher thresholds are comparable for both models.

3.2 Case Study with different runs of the deterministic model.

The evolution of the deterministic precipitation IFS-ECMWF 6h forecast with different initial forecast times for 18/11/23 00UTC are shown below (Fig.10). The general precipitation estimation of the area was satisfactory even in runs of 6 days before, as it was predicted on the western and north eastern parts of the country. However, the latest runs more precisely reflected the observed precipitation distribution with the higher values finally observed over the north eastern parts of the country and lower values over the west.



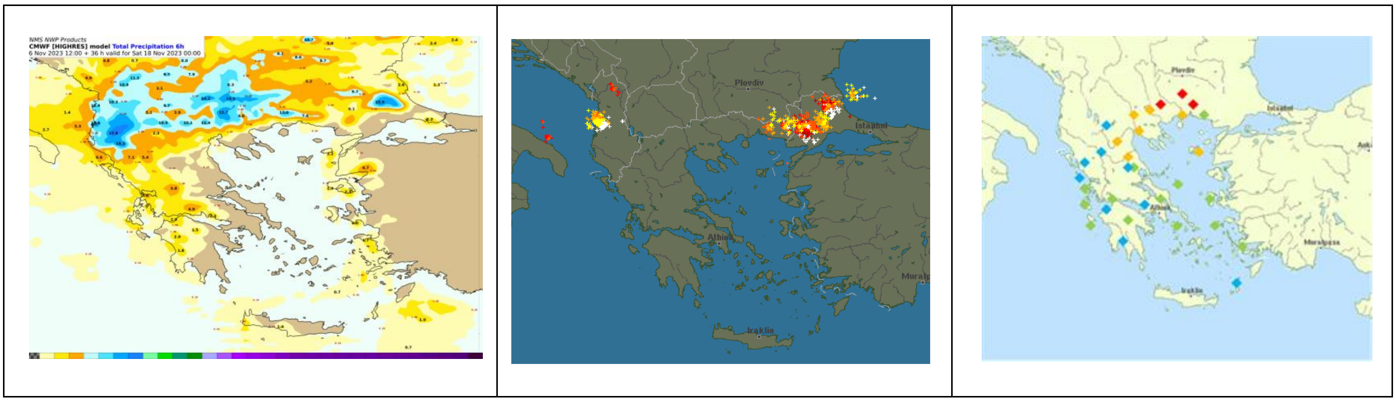


Fig. 10 : 18/11/23 00 UTC 6h precipitation forecast evolution from top left to right (+144,+132,+120,+108,+96,+84,+72,+60,+48,+36) hours, lightning map (blitzorung.org) and 12h precipitation observations map: green (1-3mm),blue(3-5mm), yellow(5-10mm), red (>10mm)

The synoptic conditions of 500hpa (Fig.11) showed a trough with cool air masses (-20ºC) over the country which slightly differs in position at different forecast times, located over western parts in initial runs.

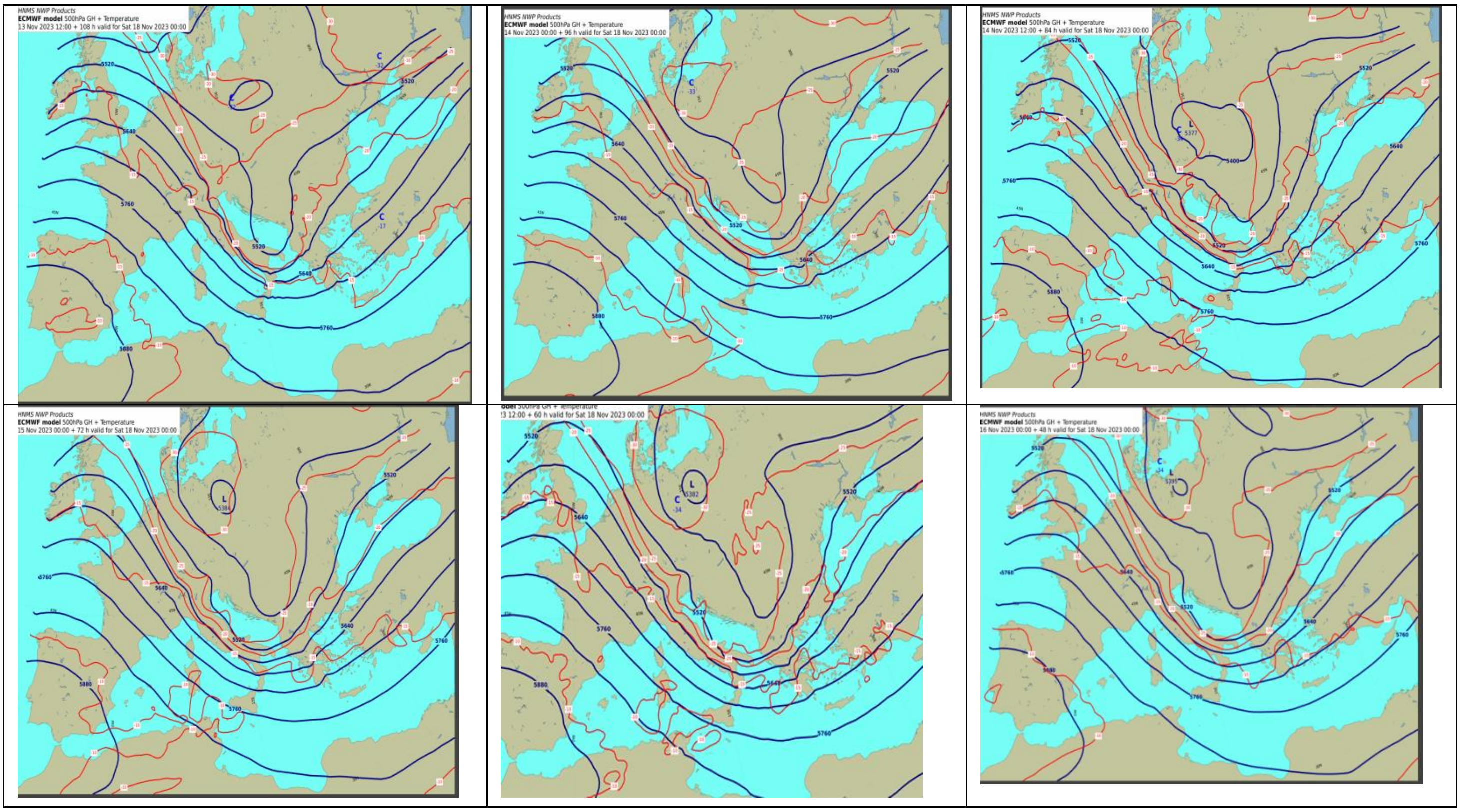


Fig. 11: 500hPa forecasts for 18/11/23 00 UTC for +108+96,+84,+72,+60,+48 hours (from left top to the right)

At the surface (Fig.12), low pressures centered over the country are combined with frontal activity. The MSLP surface forecast at different forecast initial times is given below, with the center of the low being forecasted over Western parts in runs (+ 120,+108), resulting in overforecast of the precipitation over the west. As forecast approaches real time, the low position is closer to the synoptic conditions.

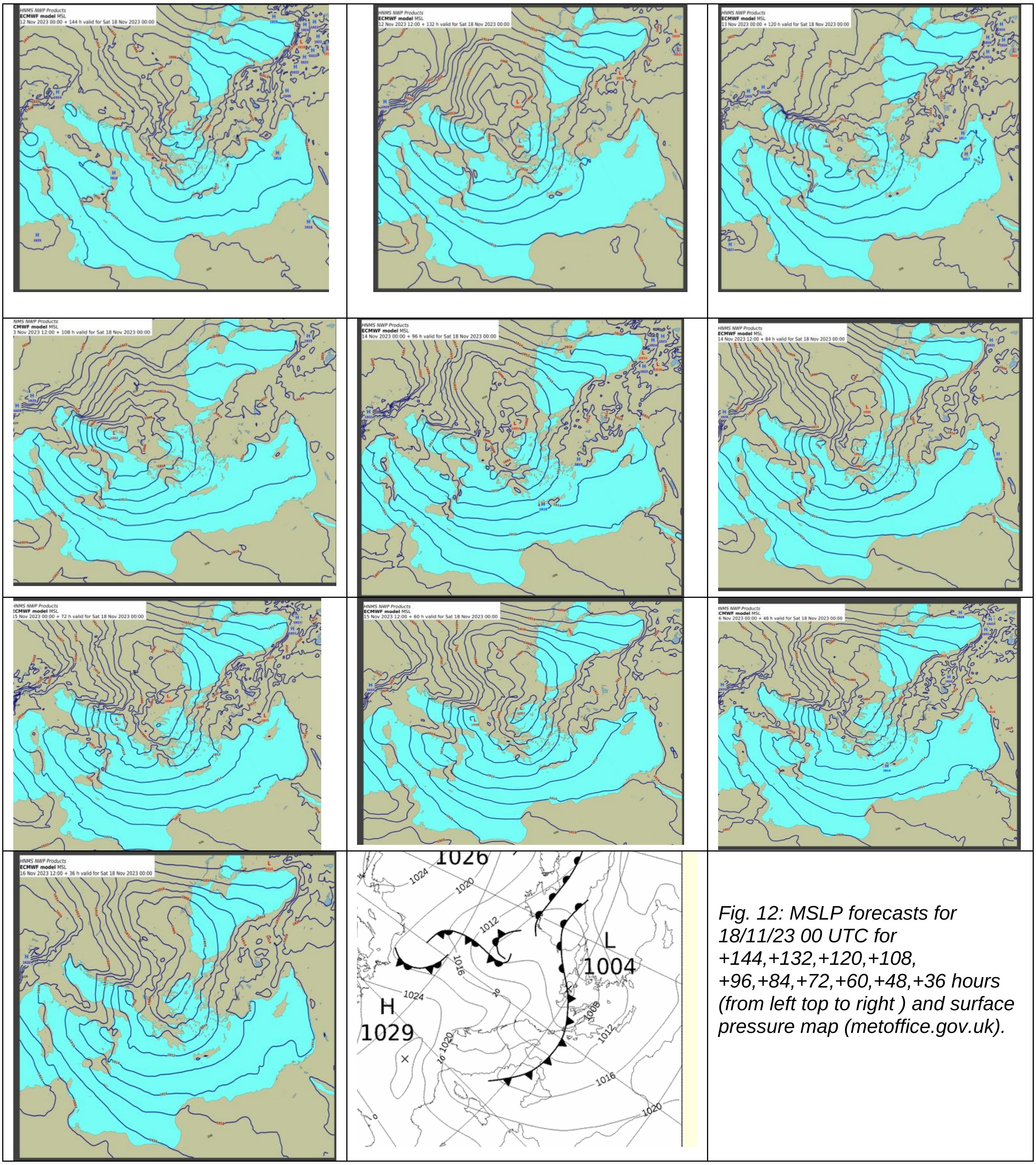


Fig. 12: MSLP forecasts for 18/11/23 00 UTC for +144,+132,+120,+108, +96,+84,+72,+60,+48,+36 hours (from left top to right) and surface pressure map (metoffice.gov.uk).

References

Iriza A. et al. (2022). Consortium for Small-Scale Modelling The COSMO Priority Project CARMA: Common Area with Rfdbk/MEC Application Final Report (www.cosmo-model.org)