MS/CS “Green Book’ Report 2024

Section 1: Background

* 1.1 Country
Serbia

* 1.2 Author(s)
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* 1.3 Organisation
RHMZ of Serbia

* Section 2: Summary of major highlights

Since January 2022. most graphical presentation on our workstations are based on MetView Python. There are more and more direct output or derived products on several new internal web pages for multiple ranges and areas.

Section 3: Forecast Products

3.1. Direct use of ECMWF forecast products

* a) Medium Range (e.g. for high impact weather forecasting)
The basic forecast products that Hydrometeorological Service of Serbia relies on in operational work is IFS, both deterministic and ensemble. GRIB products are used for graphical presentation (using MetView Python) and for BC for regional models WRF and NMMB. Forecasters are using ecChart on a daily basis.

* b) Extended Range (monthly)
Several graphs and products of extended range and re-forecast is in operational use. Raw extended range data is used for the calculations of percentiles for parameters like precipitation and temperature. Also anomalies are plotted and available to the forecasters.

* c) Long Range (seasonal)
Monthly anomalies of temperature and precipitation are presented on the maps. Raw ensemble data are also used for the running of NMMB regional seasonal forecast every month.

* d) CAMS and Fire-related output (ecCharts mainly)
During 2024 we started testing an experimental, non operational use of CAMS product from Copernicus. Concentration of aerosols and chemical species in digital form can be compared with the observations. Work on presenting maps and time series of UVBED is in progress.

3.2. Cycle 48r1

* a) <u>Positive</u> impacts of model cycle 48r1
None

* b) <u>Negative</u> impacts of model cycle 48r1
None

c) Systematic changes in forecast output since model cycle 48r1 was implemented

3.3: Derived Fields

A flexible and modular system in Python for monthly (extended range) forecast, using ecCode and Magics based on ECMWF's monthly reforecast and forecast data in order to have more flexibility regarding different monthly forecast time periods, precise values in each grid point for climatologically percentiles, possibility to extract values of different percentiles and forecast probabilities at any required point within area is built few years ago.

Methodology used for calculation of reforecast percentile values (10, 33, 50, 66, 90) and probabilities, is compatible with methodology used at ECMWF. The system became operational in 2022.

3.4: Artificial Intelligence (AI) / Machine Learning (ML) techniques

3.5: Dynamical Adaptation

ECMWF's boundary conditions are used for WRF-NMM, a Non-hydrostatic Mesoscale Model, horizontal resolution about 4 km since 2009. Also, NMMB, a Non-hydrostatic Multiscale Model on the B-grid, horizontal resolution about 4 km, is using IFS and running on Centre's supercomputer. Some verification results compared to ECMWF forecast are presented in chapter 4.1.

For hydrological purposes IFS is used as input for hydrological model HBV run. We have been using deterministic and ensemble ECMWF products for hydrological forecasts for Sava, Velika Morava and Drina river catchments for several years.

3.6: Data-driven (AI) models

*** a) ECMWF's real-time AI model initiative**
Still considering reliability and achievement of AI models.

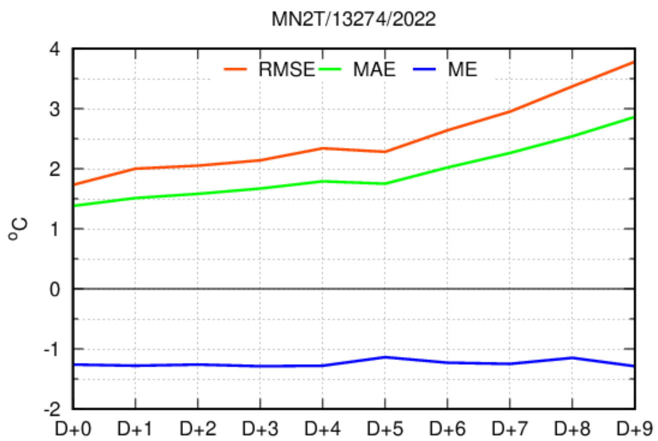
*** b) Use of AI forecasts for operational purposes**
None

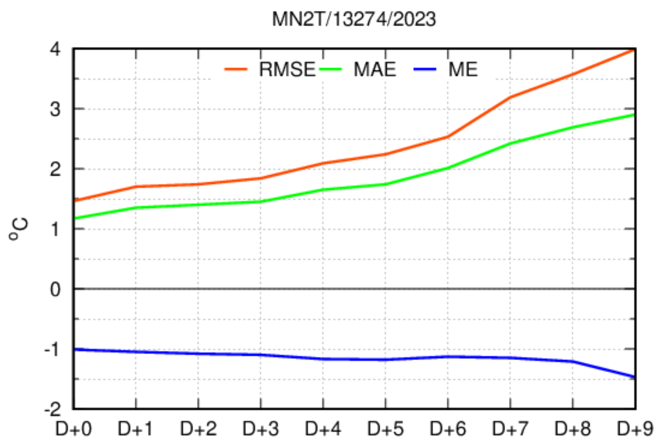
Section 4: Verification

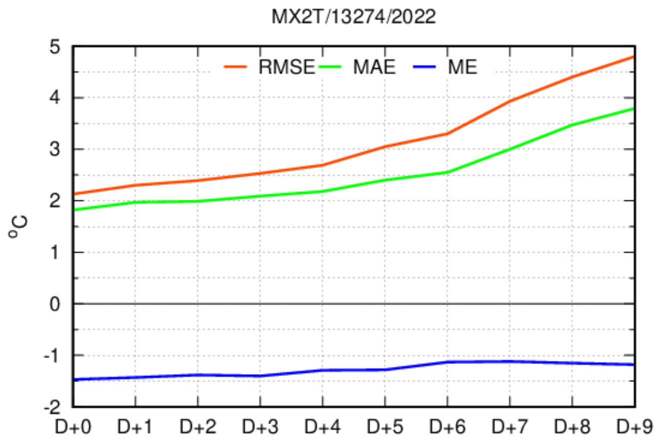
4.1 Raw model output from ECMWF, and other operational models/ensembles

a) Short Range and Medium Range

The 00 UTC run of ECMWF deterministic forecast is verified against SYNOP observations. Forecast data were taken from 0.1° x 0.1° grid, using grid points closest to chosen synoptic stations. Statistical scores presented here are related to station Beograd - Karađorđev park (13274).







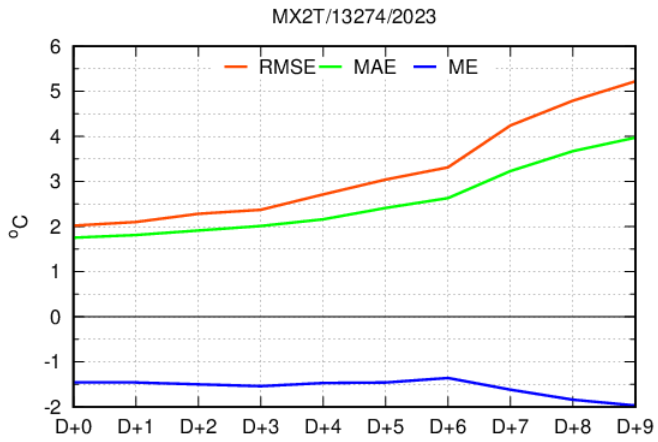


Fig.1-4 ME, MAE and RMSE of ECMWF 2 meter minimum and maximum temperature forecast (D+0 to D+9) as a function of forecast range (Beograd - Karađorđev park).

ME, MAE and RMSE of 2m minimum (18-06 UTC) temperature forecast during 2023 show an improvement compared to previous years up to D+6. For scores of 2m maximum (06-18 UTC) temperature forecast (Fig.3-4) there is a slight worsening up to D+6 compared to the 2020.

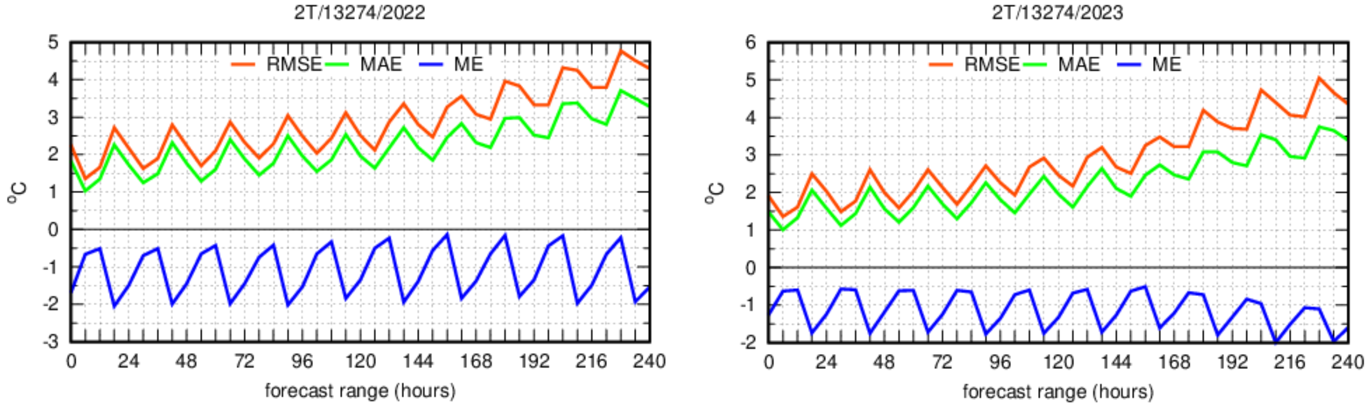


Fig.5-6 ME, MAE and RMSE of ECMWF 2 meter temperature forecast as a function of forecast range (Beograd - Karađorđev park).

Figures 5 and 6 show scores for 2 meter temperature forecast. Diurnal cycle for ME during 2023 is weaker than previous years. MAE and RMSE are lower after 168 h forecast.

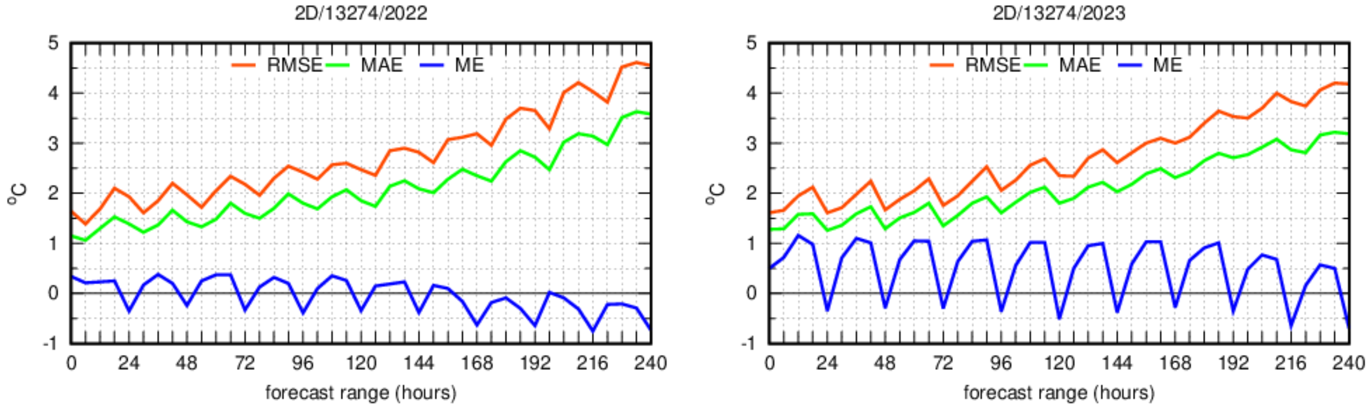


Fig.7-8 ME, MAE and RMSE of ECMWF 2 meter dew point temperature forecast as a function of forecast range (Beograd - Karađorđev park).

For 2 meter dew point temperature forecast ME diurnal cycle during 2023 is stronger than previous years while MAE and RMSE are lower after 120 h forecast.

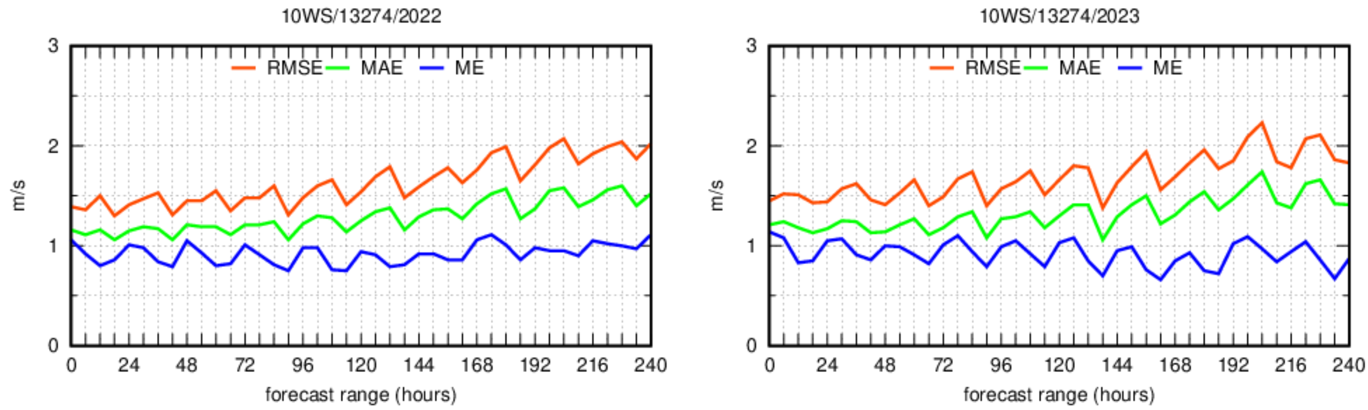


Fig.9-10 ME, MAE and RMSE of ECMWF 10 meter wind speed forecast as a function of forecast range (Beograd - Karađorđev park).

MAE and RMSE for 10 meter wind speed forecast are similar as previous years. There are local maxima at noon (12 UTC) and local minima at evening (18 UTC). ME shows diurnal cycle contrary to 2020.

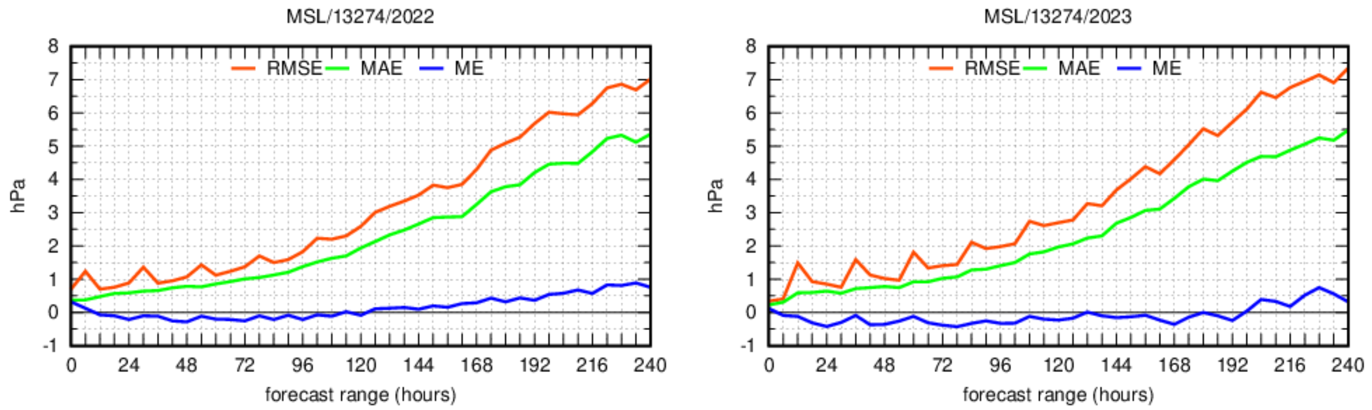


Fig.11-12 ME, MAE and RMSE of ECMWF mean sea level pressure forecast as a function of forecast range (Beograd - Karađorđev park).

For mean sea level pressure forecast a slight propagation of the errors with forecast time is evident. RMSE shows small picks at noon (12 UTC).

ECMWF model output is compared with regional NWP models operational in HMS of Serbia.

Models are WRF-NMM and NMMB with different initial and boundary conditions (IFS, GFS). Meteorological variables verified every six hours are mean sea level pressure, temperature at 2 m and wind speed at 10 m. 24 hour precipitation amount and occurrence with different precipitation thresholds are verified too. Only the 00 UTC run is considered, up to 72 hours of forecast.

For model intercomparison, verification is done over the largest common domain of the participating models (47.38/10.65/40.37/25.25). 39 synoptic stations are chosen, 33 land and 6 mountain stations. Half of them are in Serbia. Observations are from BUFR data and the nearest grid point to the station is used. Height adjustment is not used. Unfortunately, every year there are less and less synop stations active during the night.

Numerical weather prediction operational models intercompared here:
ECNMM WRF-NMM v3.5.1 with BC from IFS ECMWF. Horizontal resolution is about 4 km (0.05° x 0.05°).
NMMB4 NMMB nested in NMMB12 (with BC from NMMB global model with IC from GFS NCEP). Horizontal resolution is about 4 km (0.042° x 0.036°).
NMMBEC NMMB with BC from IFS ECMWF operational on ATOS. Horizontal resolution is about 4 km (0.042° x 0.036°).
ECMWF IFS model of ECMWF. Horizontal resolution is about 9 km (0.1° x 0.1°).

Comparison of the forecast quality of ECMWF model and our three operational NWP models is presented in figs. 7-16. Seasonal averaged values for mean sea level pressure, 2 meter temperature and 10 meter wind speed 36h (midday) forecast and 24 hour precipitation occurrence are taken in consideration

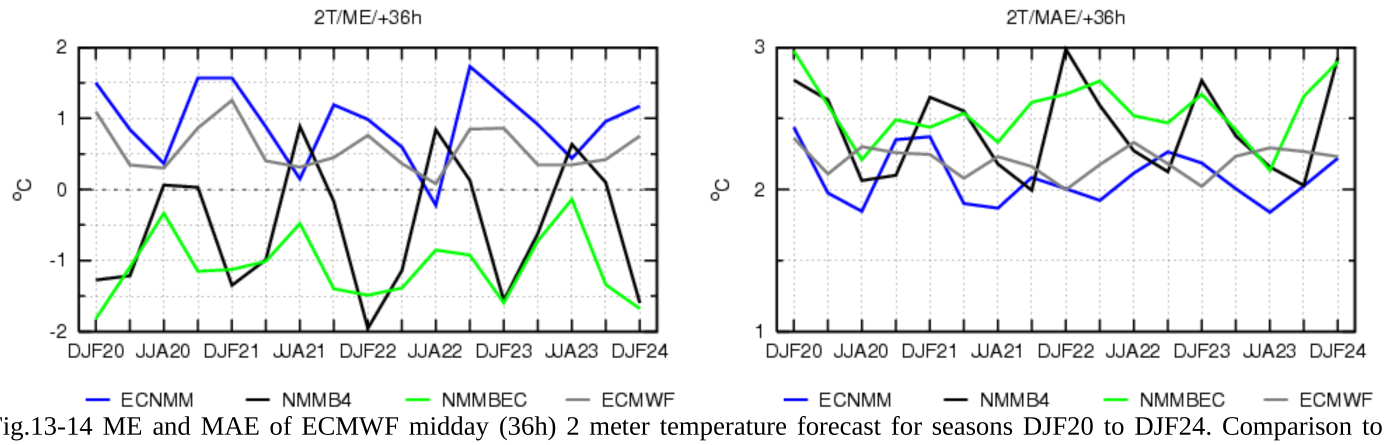


Fig.13-14 ME and MAE of ECMWF midday (36h) 2 meter temperature forecast for seasons DJF20 to DJF24. Comparison to operational NWP models forecast.

ME of ECMWF forecast for 2 metre temperature has the smallest amplitude among all other NWP models (Fig. 13). Values of MAE of ECNMM are comparable with these values for ECMWF (Fig. 14).

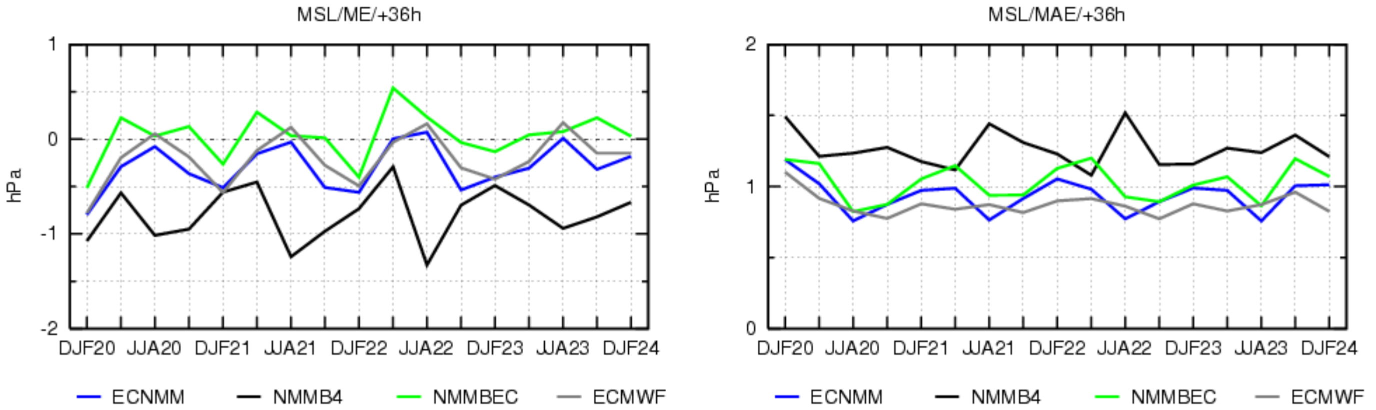


Fig.15-16 ME and MAE of ECMWF midday (36h) mean sea level pressure forecast for seasons DJF20 to DJF24. Comparison to operational NWP models forecast.

Values of ME of ECNMM are comparable with these values for ECMWF. MAE for mean sea level pressure forecast shows an advantage of ECMWF (Fig. 15-16).

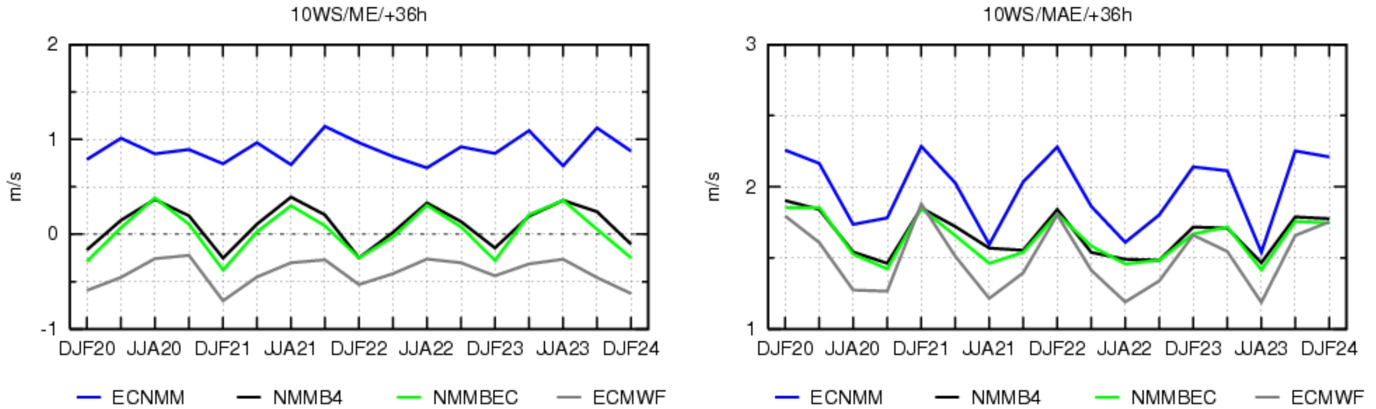


Fig.17-18 ME and MAE of ECMWF midday (36h) 10 meter wind speed forecast for seasons DJF20 to DJF24. Comparison to operational NWP models forecast.

ME shows an underestimation of ECMWF for 10 meter wind speed forecast. ECMWF has the best MAE score compared to other models' score during all seasons. Error is the smallest during summer and the largest during winter (Fig. 17-18).
It can be noticed that amplitudes of ME of ECMWF forecasts (Fig. 13, 15, 17) decrease since 2021

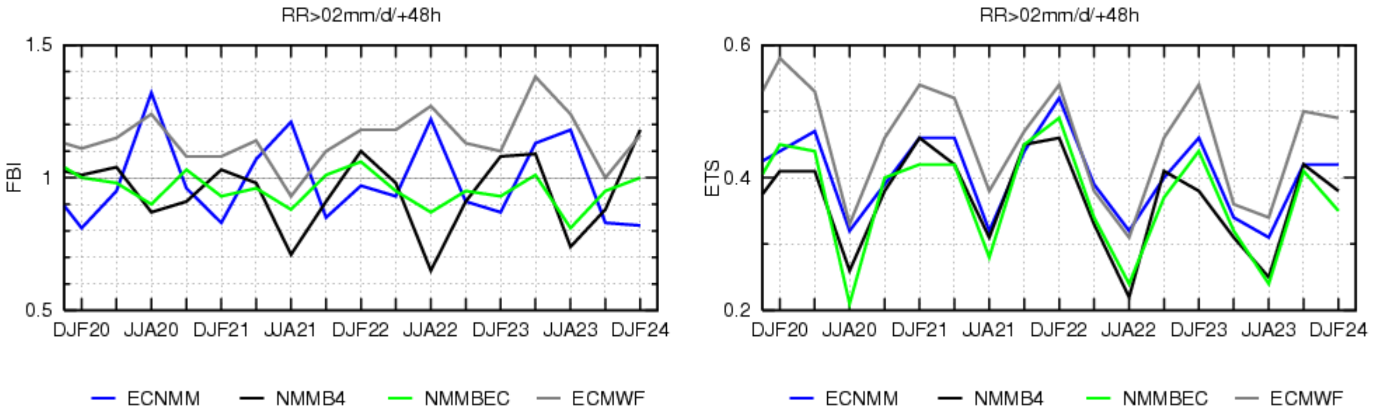
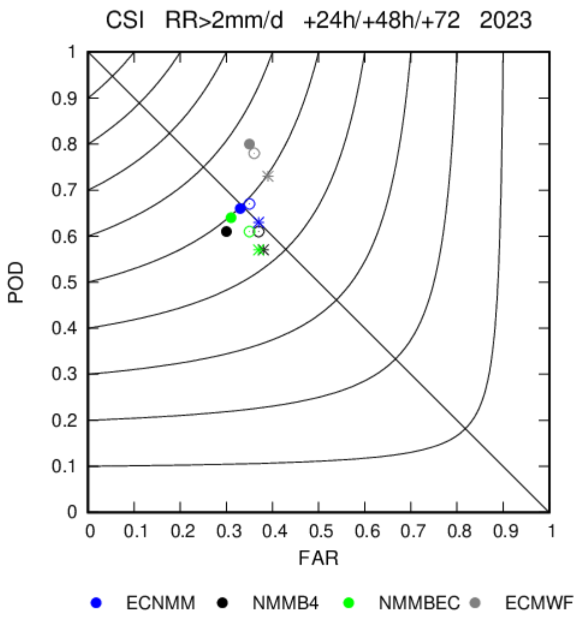


Fig.19-20 FBI and ETS of ECMWF 24h precipitation forecast (48h) for seasons DJF20 to DJF24. Threshold is 2mm/24h. Comparison to operational NWP models forecast

Values of ECMWF's FBI have the smallest amplitude but they are the largest for threshold of 2mm/24h among all other NWP models (Fig. 19) except in summer 2020.

Regarding ETS, evaluation of precipitation forecast is similar for all the models mostly with minimum skill in summer and maximum in winter or spring. ECMWF's ETS score is better than the other models' ETS score (Fig. 20).



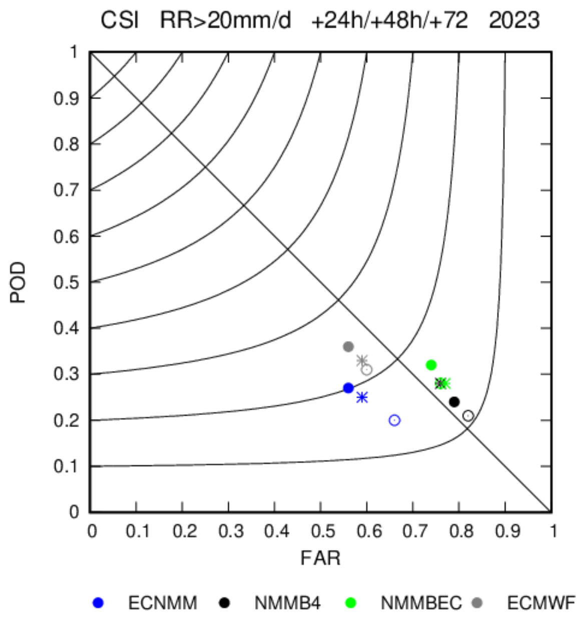


Fig.21-22 CSI contours as a function of FAR and POD for 24h/48h/72h 24h precipitation forecast. Thresholds are 2mm/24h and 20mm/24h. Comparison to operational NWP models forecast

ECMWF 24h precipitation forecast for 24h (dots), 48h (circles) and 72h (asterisks) has the best results for CSI for both thresholds 2mm/24h and 20mm/24h. For the first threshold (2mm/24h) there is an overestimation of precipitation amount and for the second threshold (20mm/24h) an underestimation of precipitation amount. NMMBEC shows an overestimation of precipitation amount for threshold of 20mm

b) Extended Range (Monthly) and Long Range (Seasonal)

4.2 Post-processed products and/or tailored products delivered to users

4.3 Subjective verification

4.4 Case Studies

a) Case Study 1

b) Case Study 2

Section 5: Output Requests

a) Product request 1:

b) Product request 2:

Section 6: References

Section 7: Additional comments and Feedback