Application and Verification of ECMWF Products 2021

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1. Summary of major highlights

ECMWF HRES model output from both 00 and 12 UTC runs is used as plotted fields in the forecasting department mainly for the medium range, as input to physical adaptation schemes, but also as boundary conditions for the Italian Air Force Local Area Models (COSMO-ME/IT and COSMO-ME/IT-EPS). Verification of ECMWF products is carried out at COMET for operational model T1279. Topical surface parameters and forecast ranges relevant to weather forecasters are considered.

2. Use and application of products

2.1 Direct Use of ECMWF Products

"Weather regime frequency ensemble forecast" and "Stratospheric temperature anomaly" are currently used for operational purposes.

Feedback on direct use of ECMWF products, including "Open Charts", in operational duties is reported in Appendix B.

2.2 Other uses of ECMWF output

2.2.1 Post-processing

The Metview module FLEXTRA is being used to trace radioactive cloud trajectories, running with 00 and 12 UTC ECMWF atmospheric model, in compliance with the National nuclear emergency plan.
The Metview module FLEXPART is being used both to run with 00 and 12 UTC ECMWF NWP atmospheric model and to download from MARS older model runs to trace contaminants dispersion in case of CBRN (chemical, biological, radiological and nuclear) incident/accident. The Metview module FLEXPART is being used both in forward mode, to trace contaminants trajectories and dispersion, and in backward mode, to trace residence time in past time. Procedures feeding from ECMWF dissemination system are planned in order to improve both timing and reliability.
Meteorological CBRN messages are generated in compliance to NATO directives and other agreements.
Thousands of maps are produced every day from both 00 and 12 UTC HRES and WAVE ECMWF models runs.
A dedicated Geographical Information System (GIS) platform is fed with both 00 and 12 UTC HRES and WAVE ECMWF models runs in order to provide GIS services to end users and exchange GIS services with other GIS platforms.

2.2.2 Derived fields

Thousands of meteograms are routinely produced over geographical sites within the 80°N-60°S area. At present meteograms are exported in PNG graphical format and in text or XML mode every 6 hours for the range T+0H to T+168H stepping in time. Meteograms are produced targeting to a general purpose use and, for this reason, the weather parameters included are numerous; among them: 2m temperature, 2m humidity, mean sea level pressure, total-high-medium-low cloud cover, convective precipitation, grid scale precipitation and 10 m wind. Despite the static mass production a web based system offering dynamic generation services of the same meteograms as above to the registered users is operational since 2011.
Based on the ECMWF models output, several derived parameters are routinely calculated as well. Using the deterministic operational model forecasts, the derived fields produced are for example:

- freezing level;
- wet bulb potential temperature;
- KO and other stability indexes;
- liquid water content;
- accumulated precipitation over fixed time interval;
- heat index (Steadman);
- wind-chill;
- tropopause height and maximum wind;
- 2m relative humidity.

A deterministic post-processing package known as Automatic Weather Interpretation (AWI) is also applied to ECMWF HRES model output fields. A series of multi-parameter decisional tree allows the determination of weather phenomena (drizzle, rain,

snow, thunderstorms, fog, etc.) as well as of the cloud type, the risk of icing, strong wind or heat waves. The AWI output are operationally used to establish weather impact over regions of interest.
Derived fields are also calculated using the ECMWF Wave Model output. The most important derived parameter is the sea state code, which is based on the primary wind wave height (Douglas Scale). Meteograms over sea geographical sites are exported in PNG graphical format and in text or XML mode too. For each site primary sea swell height, wind wave height, 10 m wind and wave direction behaviours are described from T+0H up to T+96H at 6H time resolution. Most of the sites are chosen according to buoys and tide gauges deployment. Some of them do not correspond to any physical instrument deployed and for this reason they are named as "virtual buoys". As above a web based system offering dynamic generation services of the same meteograms to the registered users is operational since 2011.
The production of some graphical outputs from the EPS forecast system, is carried out directly from ECMWF Servers using "ad hoc" built applications and Metview batch procedures. In particular, the following maps are created on a daily basis:

- Epsgrams and Plumes for 40 main Italian cities
- Probability maps on Europe from t+ 48 to t+168 (precipitation, wind, 850 hPa Temp)
- Tubes on Europe t+96 and t+168

Both ECMWF Wave Model and ECMWF Atmospheric Model outputs are used and suitably cropped, re-gridded and distributed according to agreements with specific users.

2.2.3 Modelling

For the COSMO-ME (Euro-mediterranean domain) deterministic run are currently used the BC from the 6hour older HRES run up to +84hours.

For the COSMO-ME EPS run are currently used 40 randomly selected members from the 6 hours older EPS run up to +84hours.

For the higher resolution models COSMO-IT and COSMO-IT-EPS the same BC from HRES as above are used, stopping at +54hours.

For the LETKF data assimilation cycle (first guess production) are currently used as BC the 6 hours older HRES run (forecasts up to +12hours) perturbed using 40 randomly selected members from the 12 hours older EPS run (ensemble forecasts up to +18hours).

For the 3DVAR analysis cycle (first guess production) are currently used the 6 hours older HRES run up to +12hours.

The Metview modules FLEXTRA and FLEXPART are currently used to download from MARS and code 00 and 12 UTC ECMWF atmospheric model runs, in order to trace contaminants dispersion in case of nuclear and chemical incident/accident.

3. Verification of ECMWF products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS), and other NWP models

Local weather parameters verified for locations *(see appendix A for plots)*

Objective scores are computed for ECMWF HRES 00 UTC run (d+1 to d+7) after collecting data retrieved from all available Italian Synop stations, using several stratifications. Plots have been produced for a number of parameters: 2m Temperature, 2m Dew Point Temperature, 10m Wind Speed, MSLP, Total Cloud Cover (ME, MAE, RMSE).
Cumulated precipitation quarterly event scores (POD/FAR, FBI, ETS) with respect to fixed thresholds and for d+1 to d+7 ranges, are computed.
For this report, data covering the 2-year period from JJA 2019 to MAM 2021 have been used for the verification of these parameters and only some selected results are presented in the next pages (see Appendix A), for ECMWF HRES 00 UTC run only.
In order to compute the scores, no interpolation from grid point to observation location is performed. The "nearest point" method is used, taking into account both the difference in altitude combined with the horizontal distance between a station and the corresponding grid point. Just for the accumulated precipitation field an averaged value over a fixed-radius circle is considered.
The reference software used for verification purposes is called VERSUS (VERification System Unified Survey), i.e. the official software used within COSMO model consortium as Common Verification Suite (CVS). The VERSUS system has been developed at Air Force Met service and it is based on DB architecture with a GUI. Through this tool, Conditional Verifications are also possible (cross conditions on different parameters).

A short note on the results is given below.
10m Wind Speed: a general small underestimation is shown in ME, less than 0.8 m/s in absolute value. MAE increases with the forecast time and its values are mainly comprised between 1.4 and 2.3 m/s. RMSE increases with the forecast time and its values are mainly comprised between 2.0 and 3.3 m/s.
2m Temperature: clear diurnal cycle in ME, MAE and RMSE, especially in winter. A general underestimation is shown in ME, especially during the night. MAE increases with the forecast time and its values are mainly comprised between 1.5 and 2.8 K. RMSE increases with the forecast time and its values are mainly comprised between 2.4 and 3.8 K.
12-h Cumulated Precipitation: regarding the bias (FBI) ECMWF model shows an overestimation for all the seasons for lower thresholds, while tends to underestimate the really higher ones. The discriminant threshold (i.e. FBI = 1) ranges, for example, from 02-10 mm/12h in Summer 2019 to 02-20 mm/12h in Fall 2020 (with a general worsening above 20-25 mm/12h). About the accuracy (ETS), all seasons exhibit the best results mainly for low thresholds and for the first 3-4 days of integration. For all thresholds there is a gradual decrease in accuracy with the integration time.

ECMWF model output compared to other NWP models *(see appendix A for plots)*

ECMWF HRES 00-UTC scores (ETS, FBI) for 12 hours cumulated precipitation have been calculated and graphically compared to those for the 00 UTC run of COSMO-ME model (5 Km resolution) up to step +72h over the italian synop stations. Results are shown in the Appendix A.
Respect to the FBI scores, COSMO-ME and ECMWF HRES show a similar tendency, with an overestimation for the lower thresholds and a general underestimation for the higher thresholds; COSMO-ME model shows better values that are lower and closer to 1 (e.g. for thresholds < 5 mm/12h around 0.6-2.0 in Summer 2019, 1.0-1.2 in Fall 2019, 0.9-1.3 in Winter 2019-20, 0.9-1.4 in Spring 2020) respect to the ECMWF model (e.g. for thresholds < 5 mm/12h around 0.7-3.0 in Summer 2019, 1.0-2.0 in Fall 2019, 0.9-2.0 in Winter 2019-20, 0.7-2.0 in Spring 2020) and more costant in function of the thresholds (at least up to 18-20 mm) . Accuracy, represented here through ETS score, tends to be similar, except for lower thresholds, for both models, for all seasons, showing a behaviour similar to that recorded in previous years.
A further comparison between the two models has been done in terms of mean error and root mean square error (ME,RMSE) for 2m temperature and 10m wind speed.
Results show a tendency of COSMO-ME to overestimate the 2m Temperature in Summer 2019/2020 and, for some time steps, in Fall 2020, opposite to the IFS behaviour; for Winter 2019-20 and 2020-21 both models have an underestimation attitude, with a counterphased trend, for the mean error; for Spring 2020 and 2021 COSMO-ME has a ME close to zero, with a slight overestimation attitude, while it is present a negative bias for ECMWF. Looking at the 10m Wind Speed comparison COSMO-ME model seems to slightly outperform the IFS in terms of ME, especially during daytime, except for Fall 2019 and Winter 2019-20, where the parameter is pretty similar for both models.

Monthly and seasonal reports on model verification results are made available to Intranet and Internet users as well as to Forecast and Applications divisions.

3.1.2 Post-processed products and end products delivered to users

NN

3.1.3 Monthly and Seasonal forecasts

NN

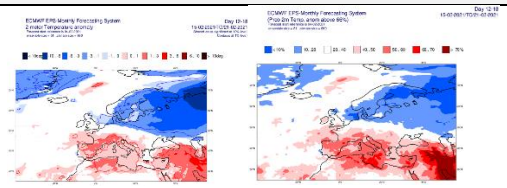
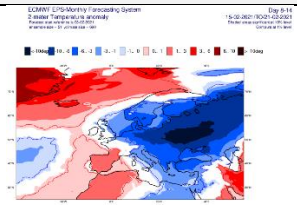
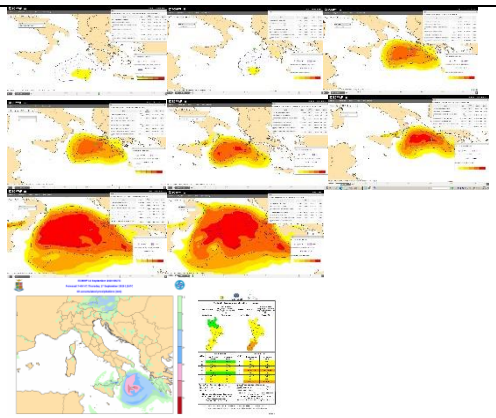
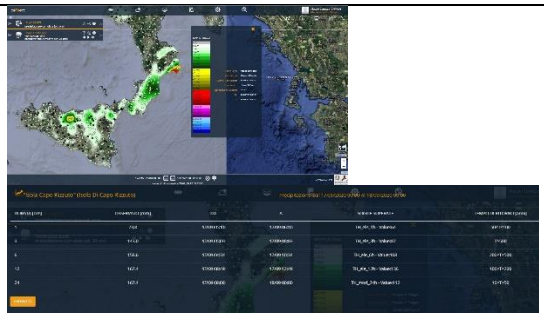
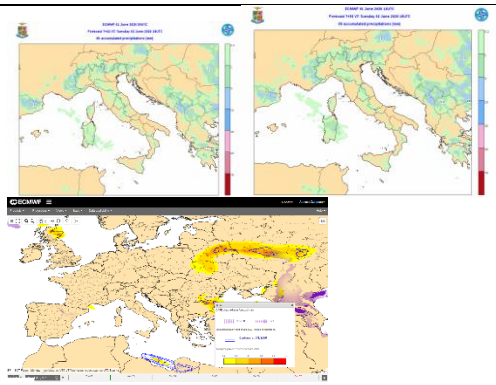
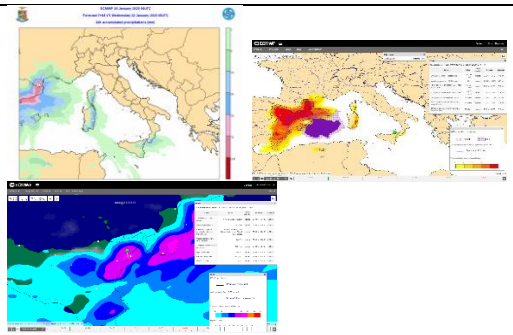
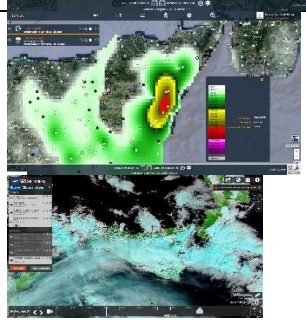
3.2 Subjective verification

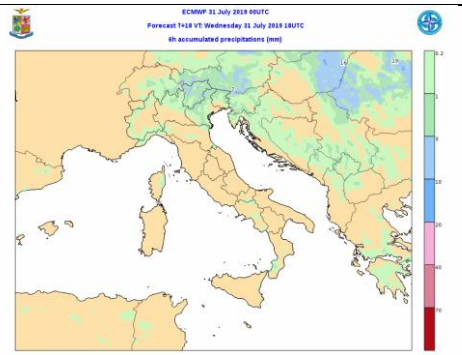
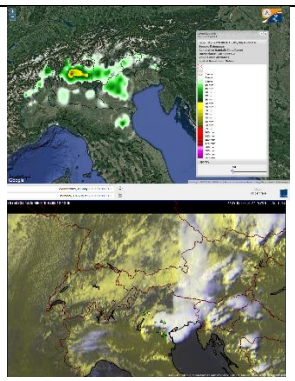
3.2.1 Subjective scores

NN

3.2.2 Case studies

A set of case studies is shortly attached here. Further feedbacks are enclosed in Appendix B.

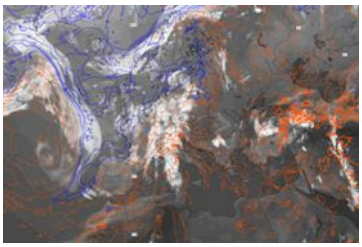
Case studies	Forecast	Observation
15-21 February 2021 Monthly forecast Forecast (reference start 04.02.2021) shows positive T2m anomaly with middle Prob 50-60% above 66%		 Forecast, reference start 08.02.2021, shows negative T2m anomaly
17 September 2020 05-08UTC Medicane “IANOS” **EFI precip** The correct position was forecasted too late **HRES precip underestimation** **Only yellow warning issued**		 Capo Rizzuto 73.8mm/1h 143mm/3h 05-08UTC
2 June 2020 16-18 UTC Widespread Severe Deep convection (multi&supercell) on Lombardia with large hail and high hail accumulation **ENS and HRES underestimation**		
21 January 2020 Heavy upslope rain Eastern Sicily, no deep convection **HRES & ENS Underestimation** **Max 34mm/24h**		 126mm/24h 20 18UTC – 21 18UTC

31 July 2019 12-14UTC Deep convection (supercell) brought large hail on Veneto **HRES & ENS Underestimation**		

4. Requests for additional output

Particular requests follow:

- We would like to have a cross section tool in ecChart, where we can plot “Equivalent potential temperature” surfaces like for example the cross section at http://eumetrain.org/ePort_MapViewer/index.html
- We would like to have a better style for the layer “850 hPa wet bulb potential temperature” - Contour (Multi-colour, Interval 2, available as in the following picture). With some more colours this layer would be more understandable.



- We would like to have a new ocean parameter called “storm surge”
- We would like to have the dashboard link in the following page https://apps.ecmwf.int/webapps/opencharts/
- We would like to have in the ENS meteogram (15 days with climate) the M-climate T2m minimum 99% line because it is unfortunately not visible.
- We would like to have the time step in the horizontal axis of every charts, where you can change the validity time, but also in the info panel “i” and in the “Valid time” drop down menu, which is under the “Base time” drop down menu and above the “Area” drop down menu. It is important to read the time step one time, because, as now, you can read it only when you do “download plot”.
- We would be interested in the production in ERA5 and SEAS of two additional fields: the 'visibility' and 'ceiling' fields, obviously also generating them for the respective reforecast datasets, in order to elaborate climatic statistics for these two important parameters from the point of view of aeronautical operations.

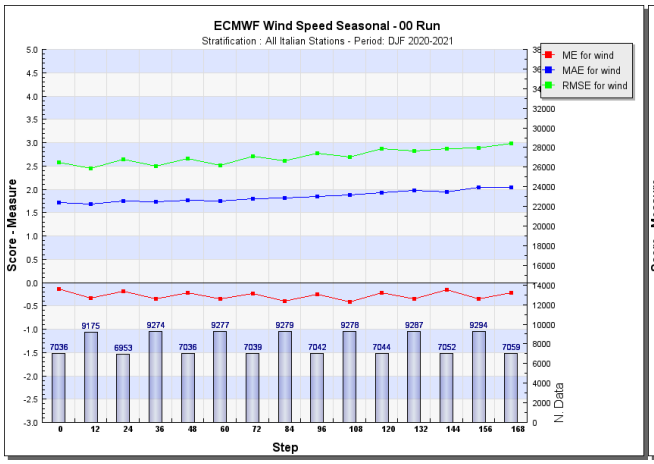
5. References to relevant publications

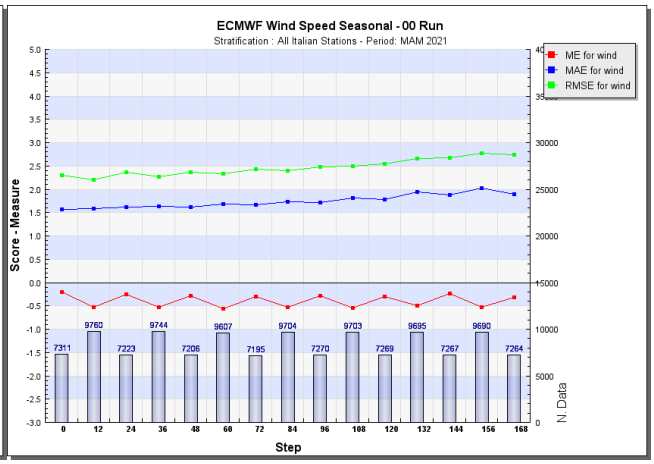
Plots of statistical scores from internal reports are enclosed in Appendix A.

Case studies and general remarks reported by the Forecasting Division are enclosed in Appendix B.

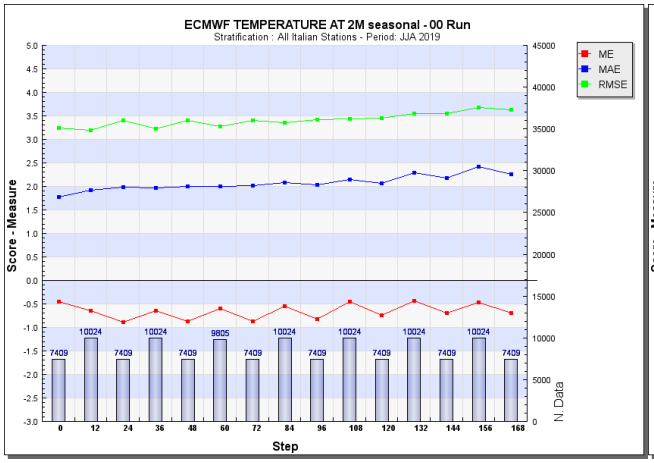
Appendix A of Report ECMWF 2021 – ITALY

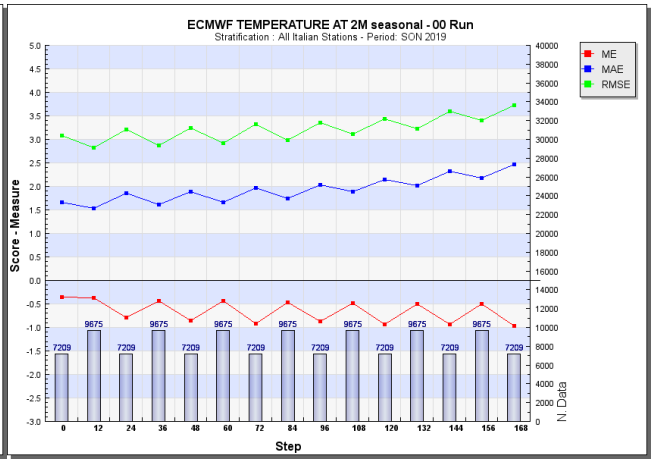
IFS 10m Wind Speed (Mean Absolute Error, Mean Error and Root MSE)

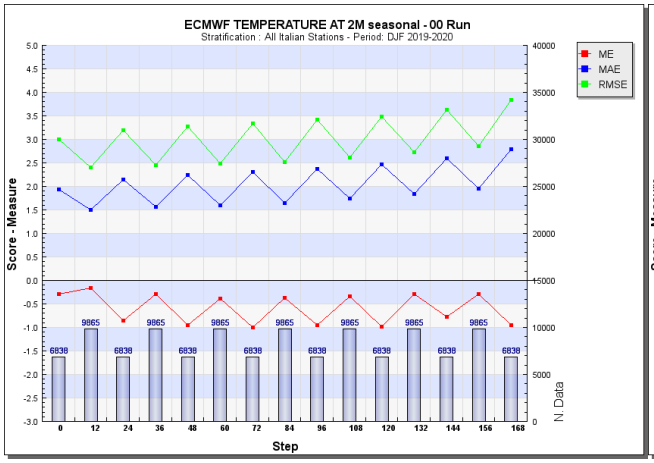


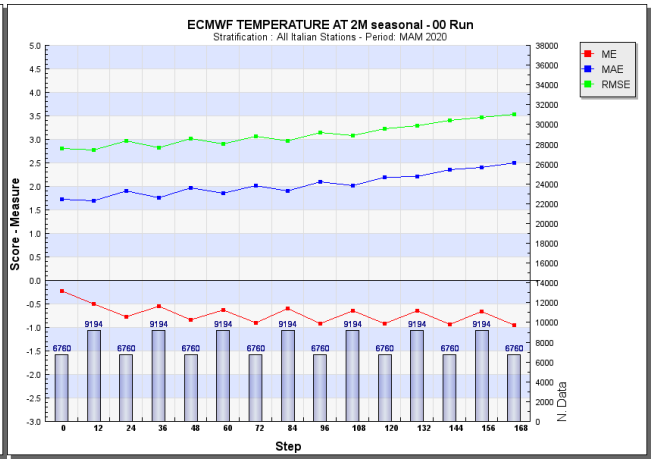


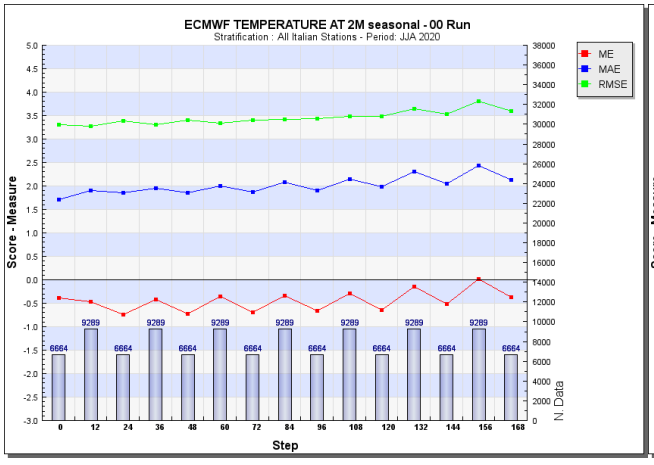
IFS 2m Temperature (Mean Absolute Error, Mean Error and Root MSE)

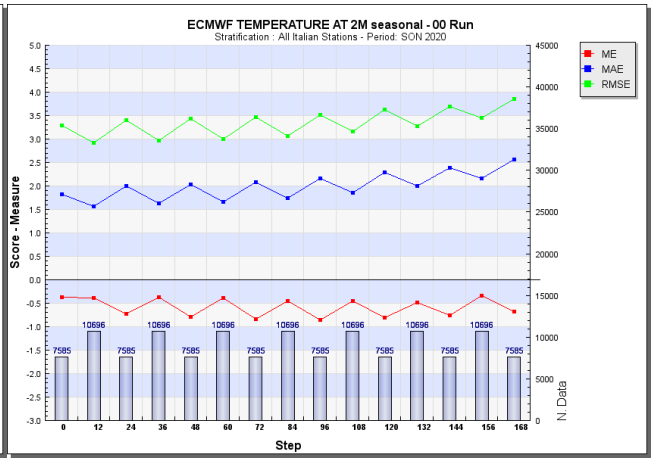


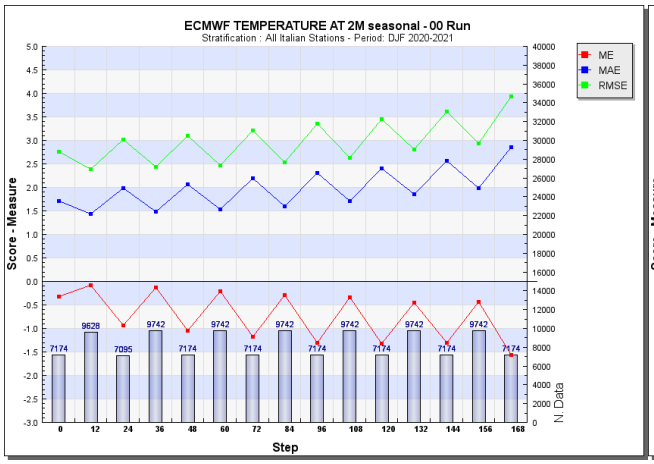


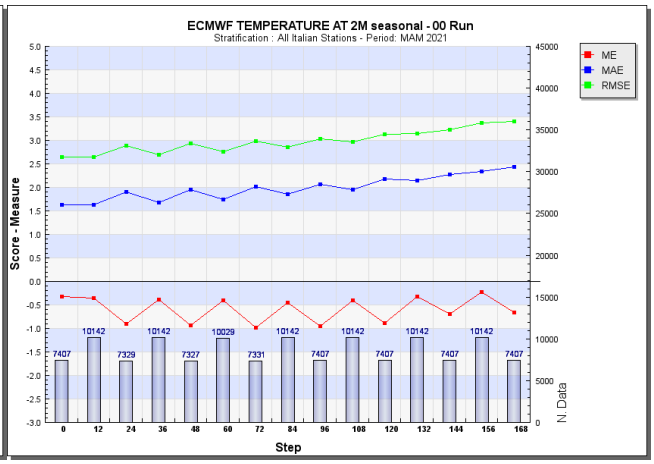




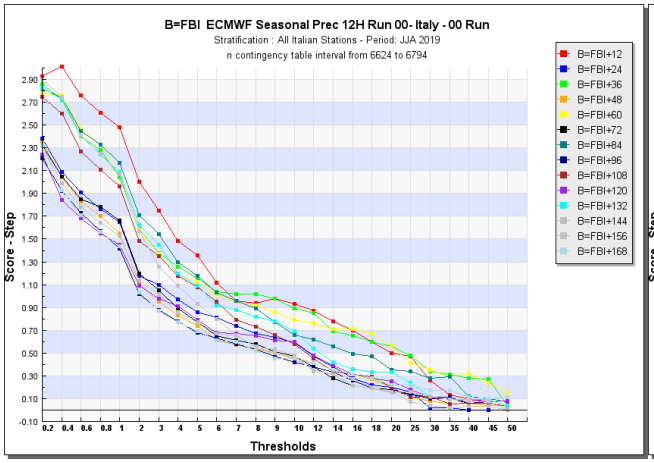


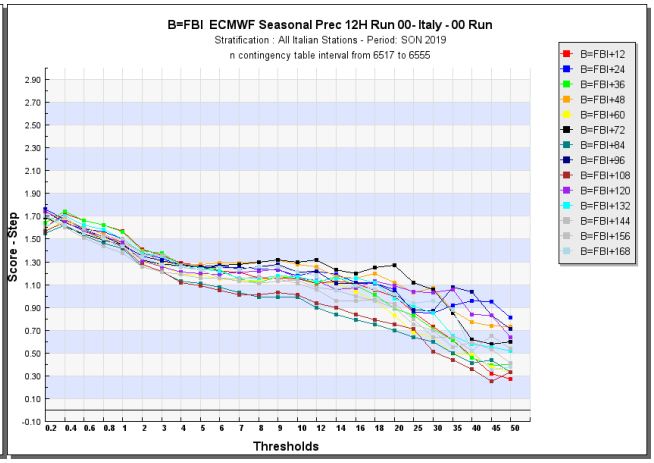


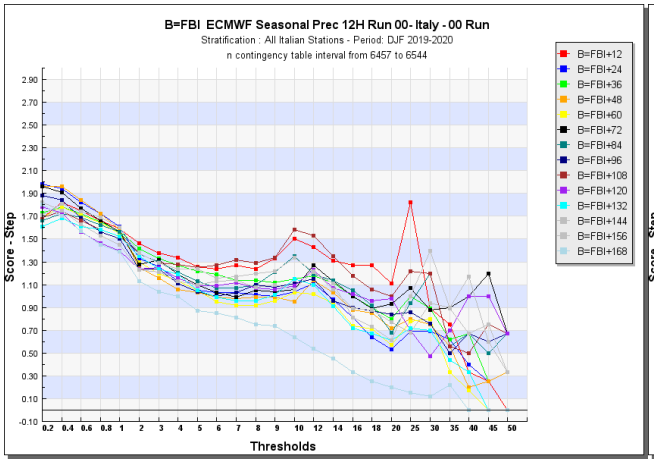


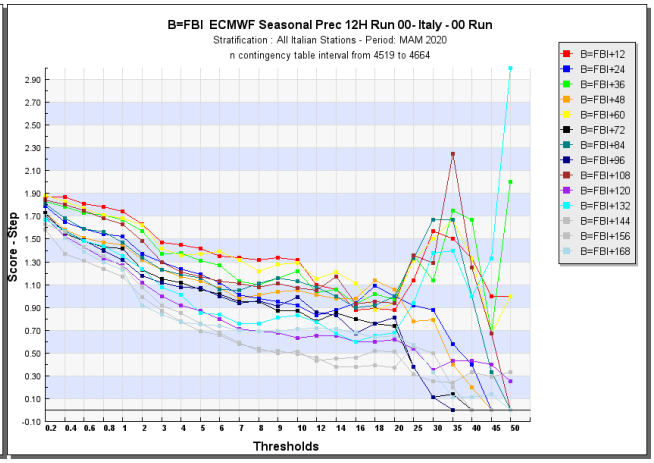


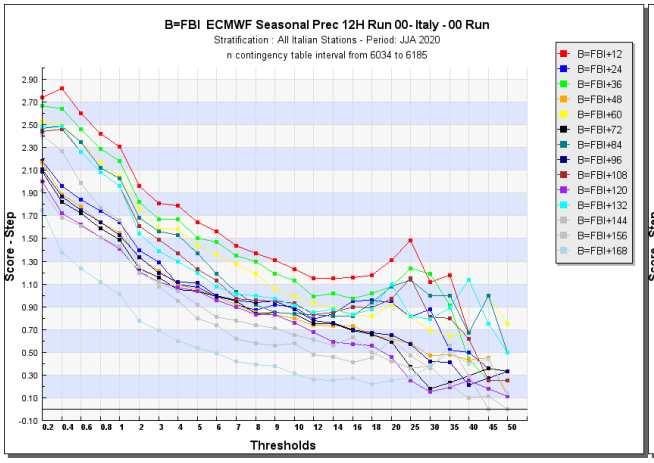
IFS Precipitation in 12 hours - FBI score

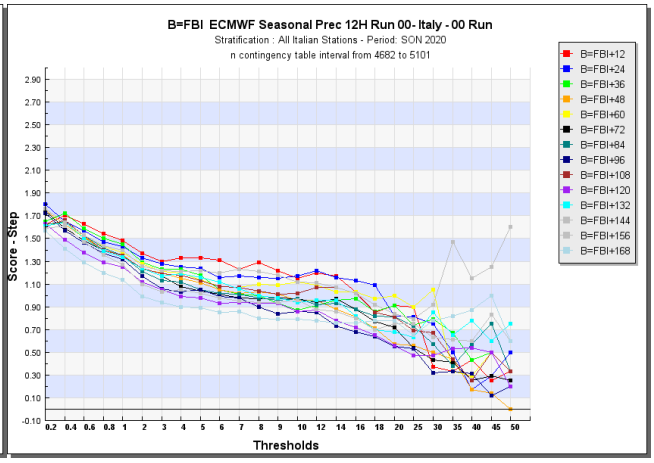


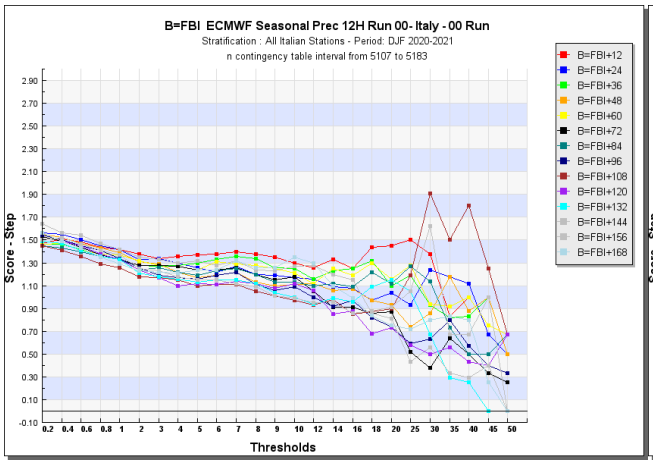


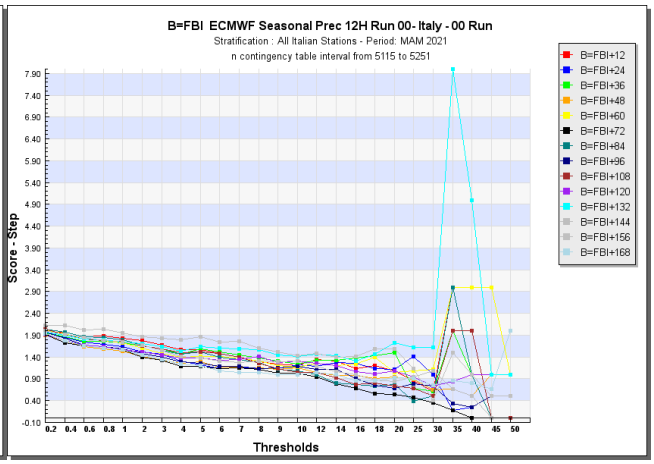




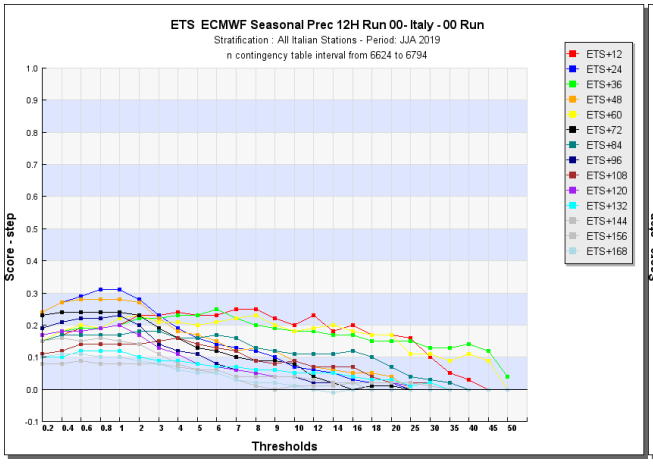


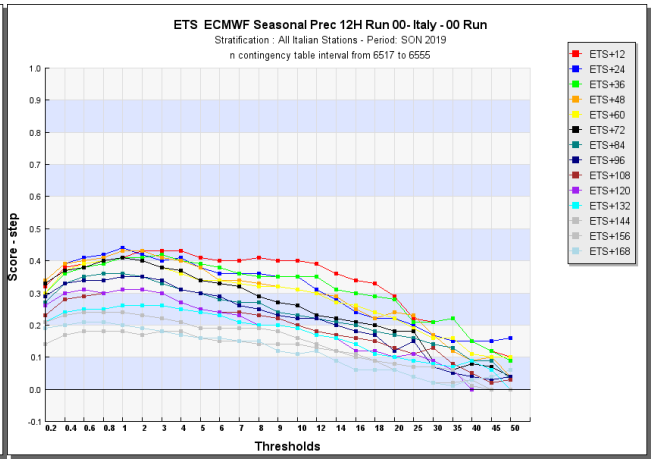


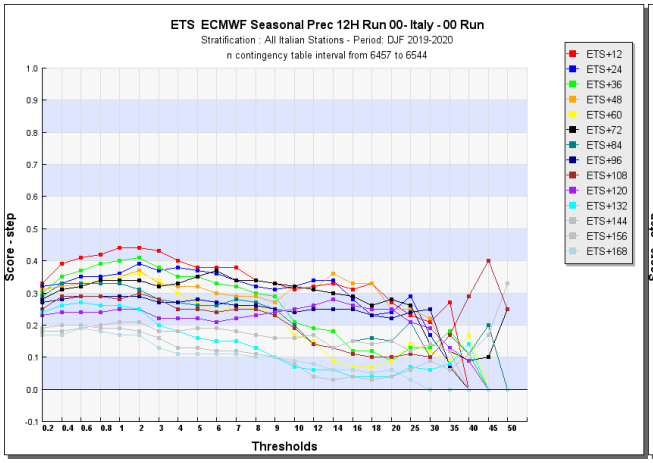


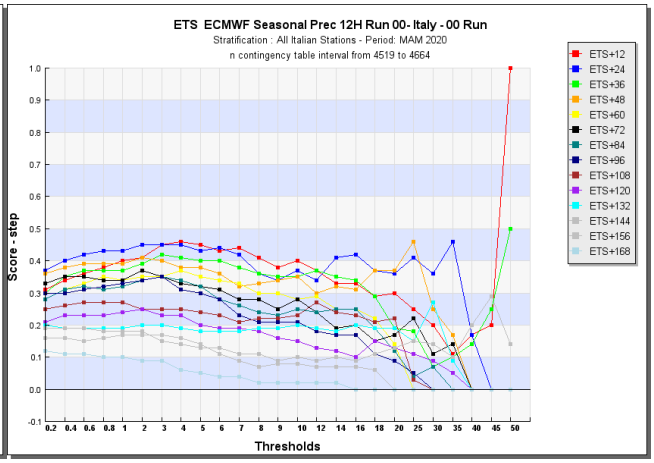


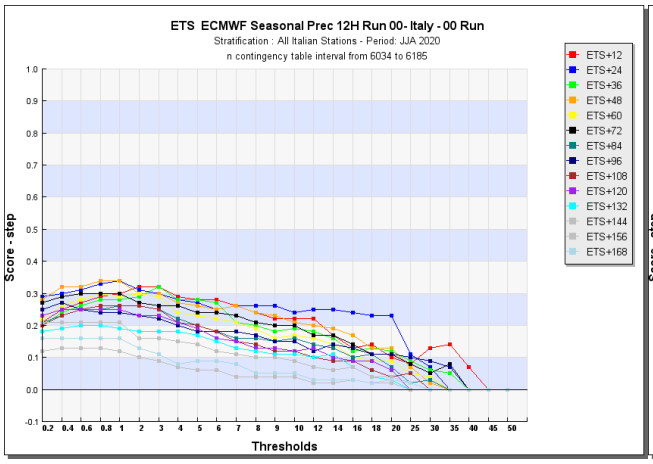
IFS Precipitation in 12 hours - ETS score

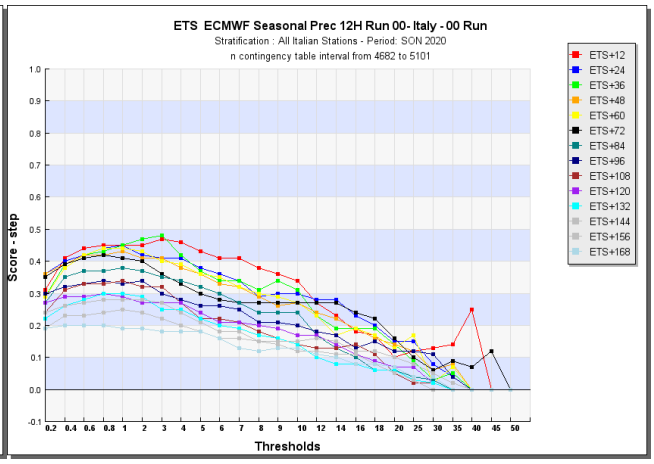


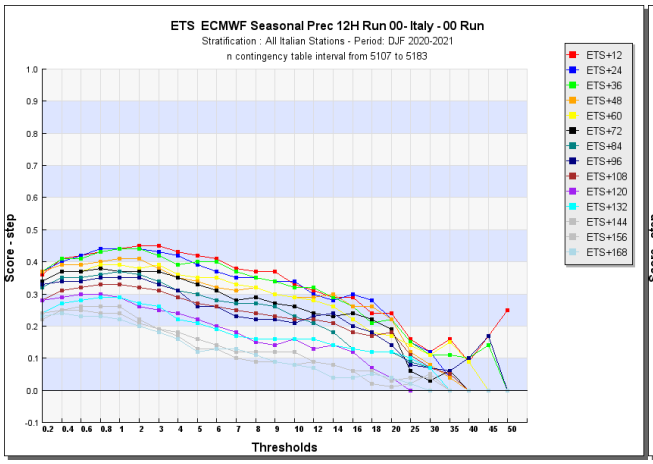


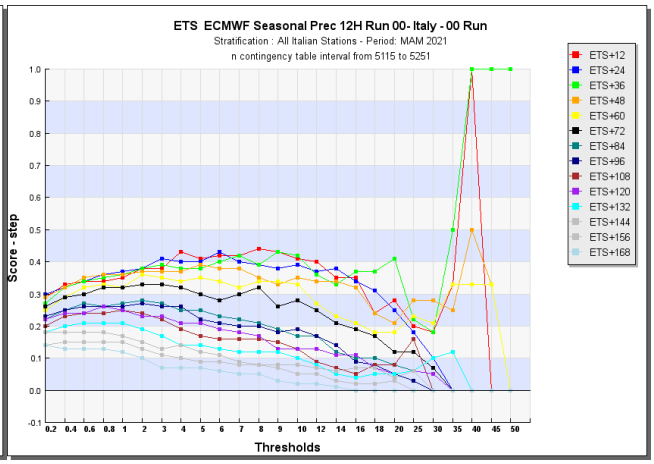




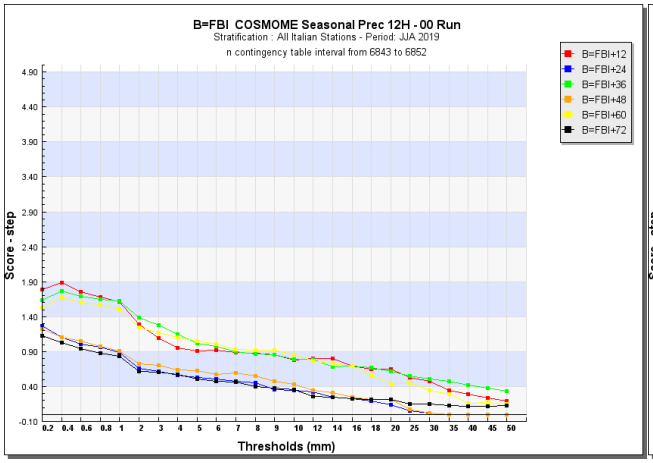


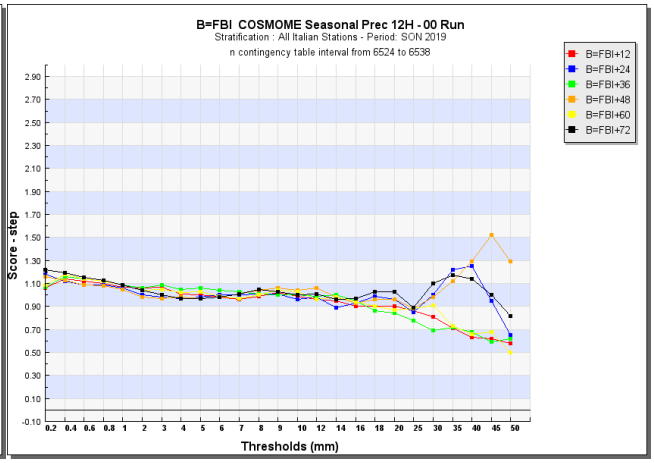


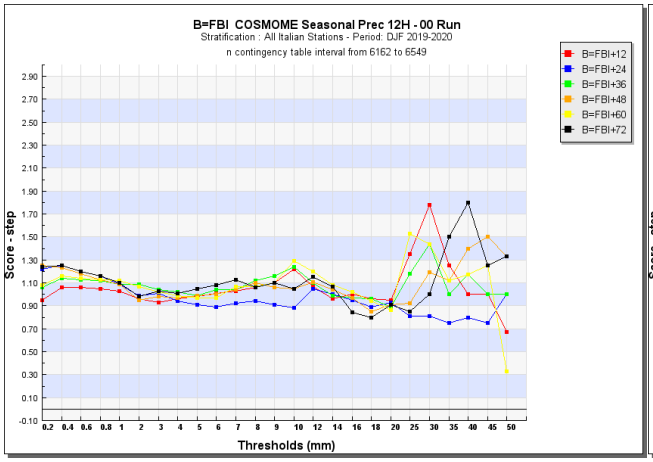


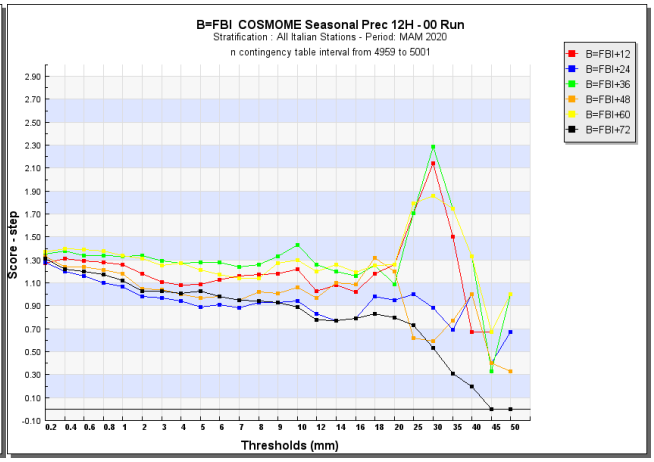


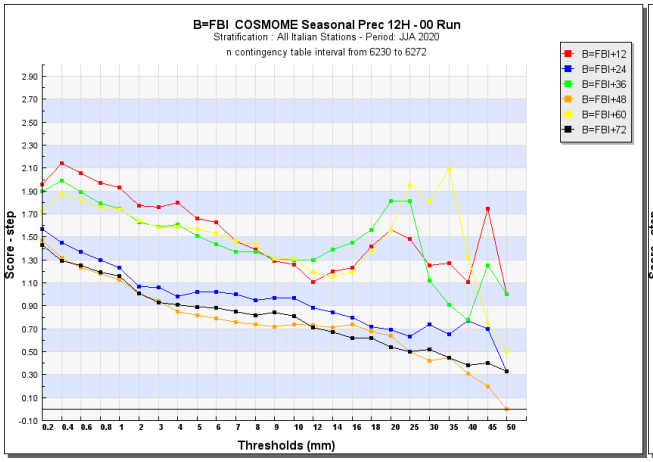
COSMO-ME Precipitation in 12 hours - FBI score

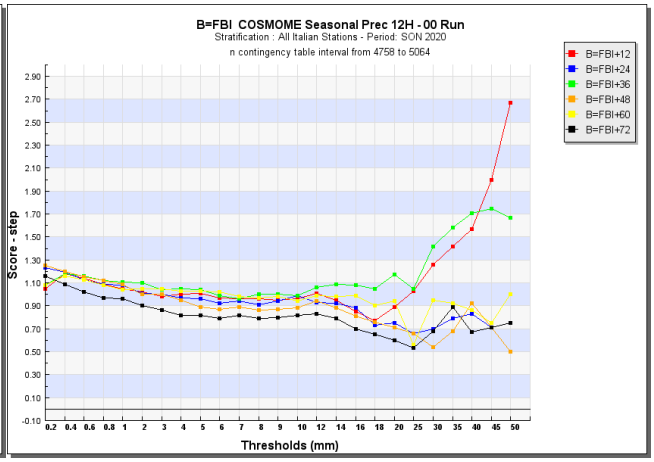


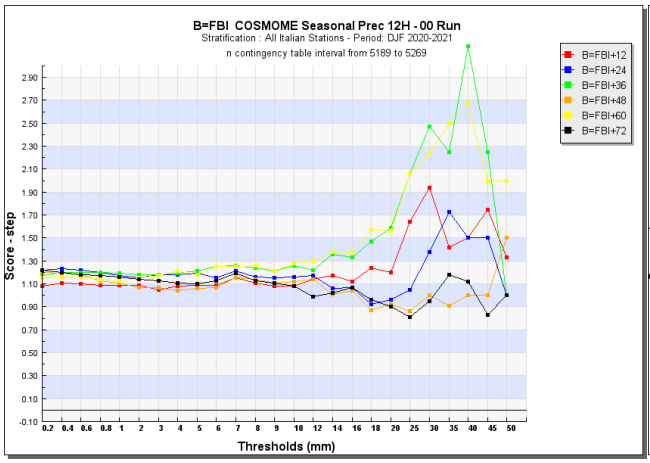


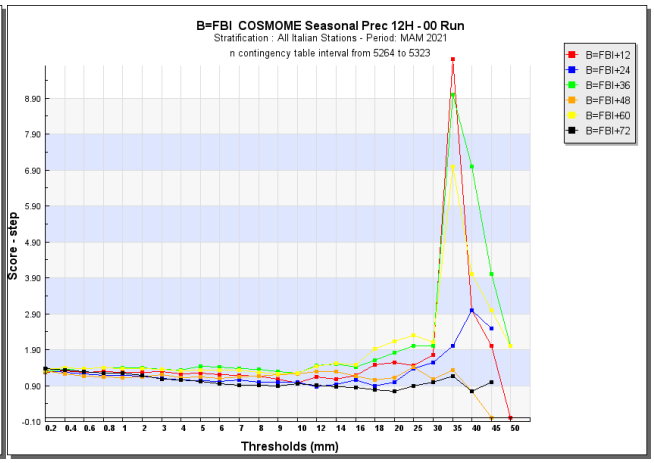




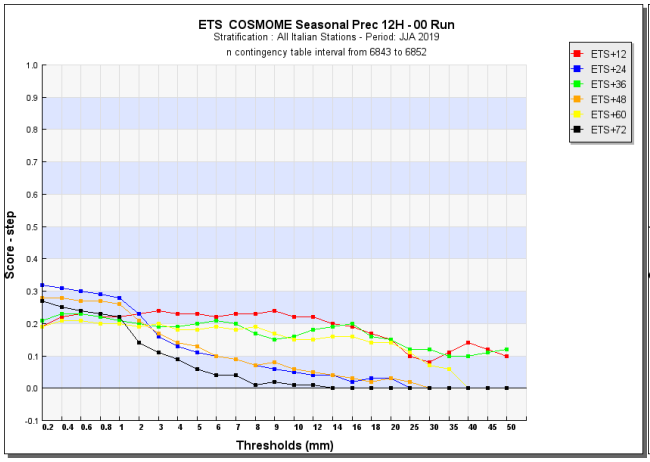


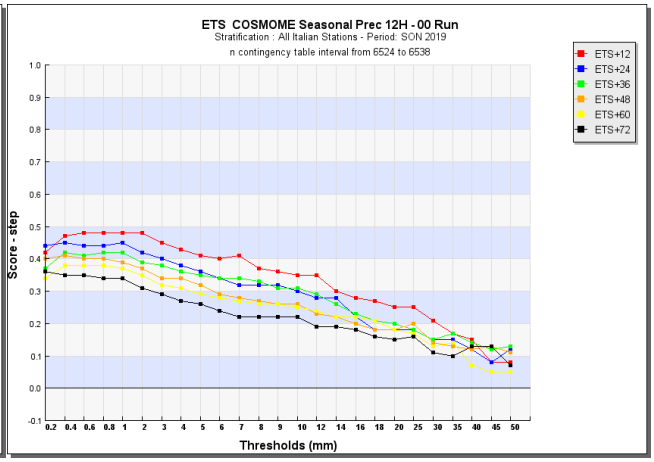


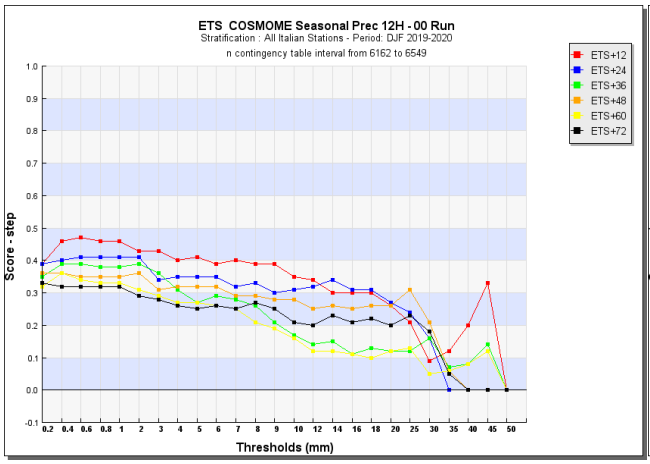


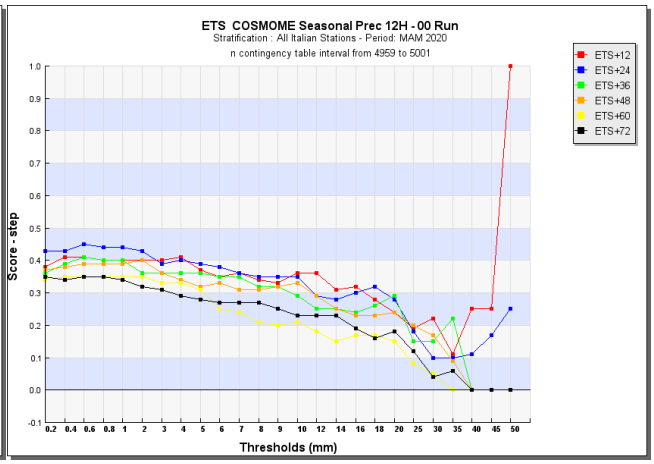


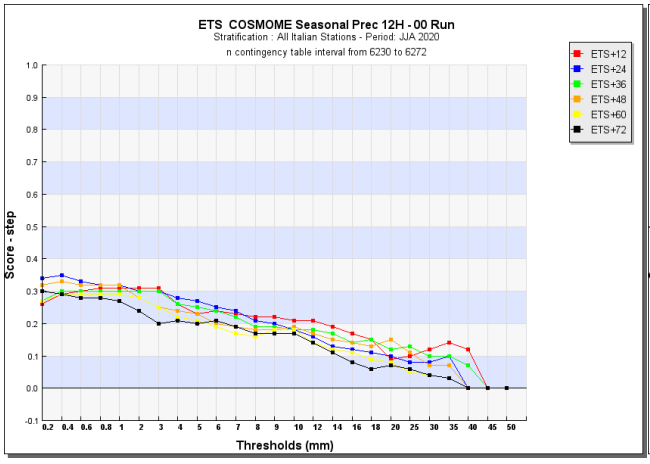
COSMO-ME Precipitation in 12 hours - ETS score

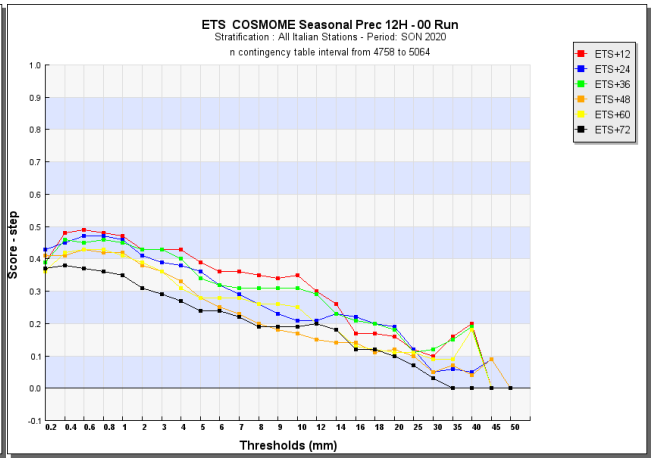


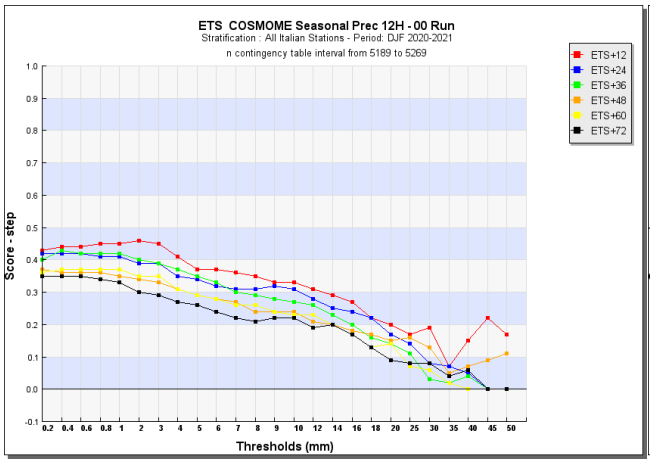


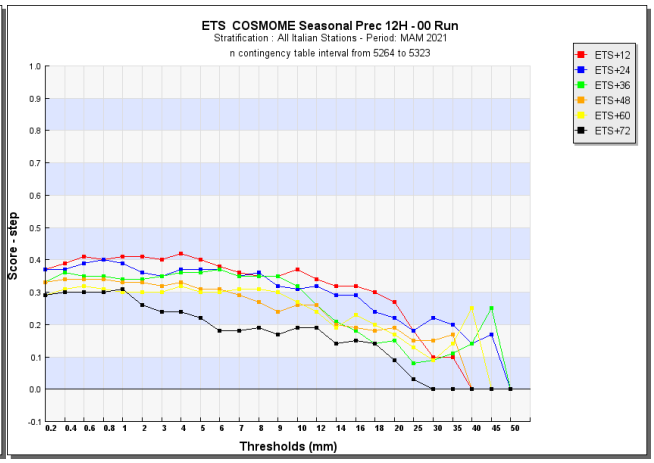




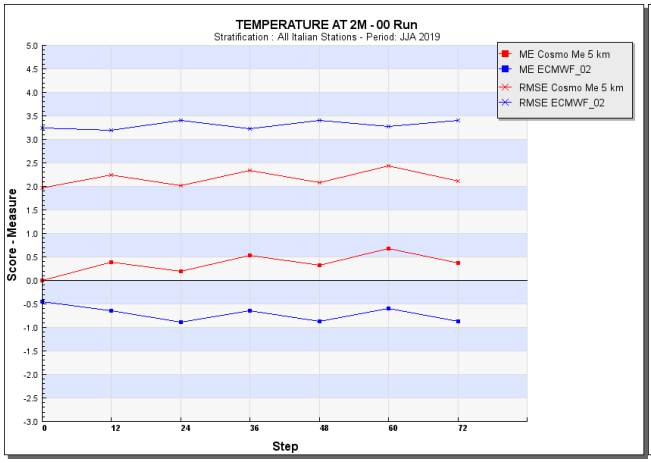


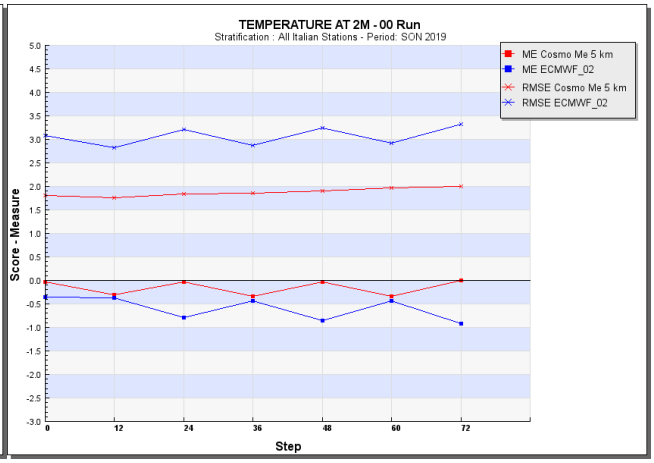


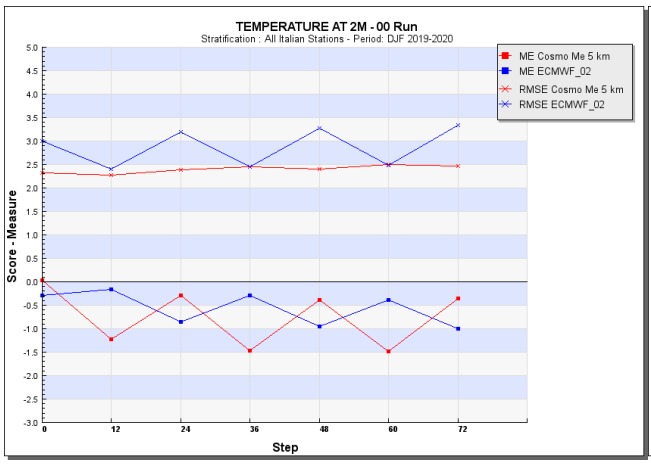


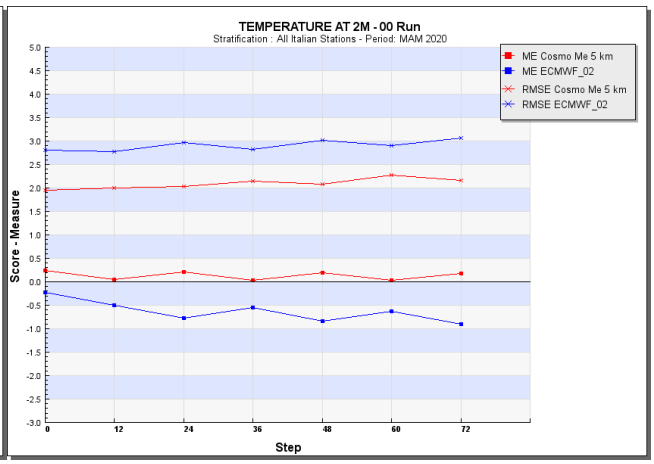


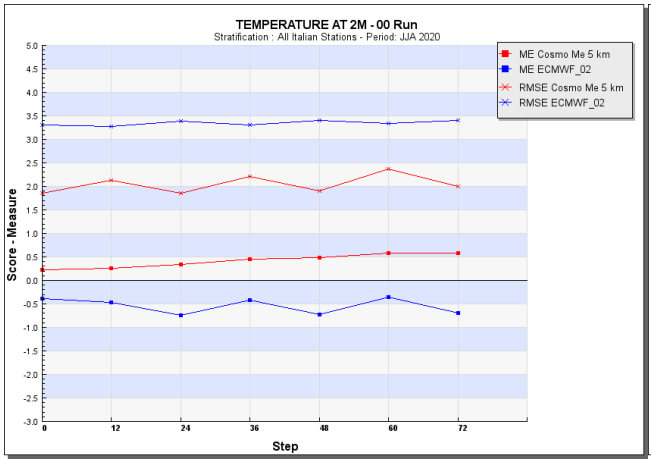
IFS – COSMO-ME comparison: 2m Temperature

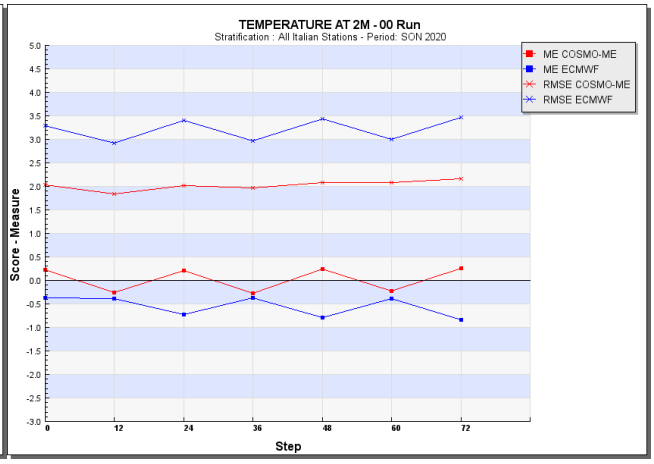


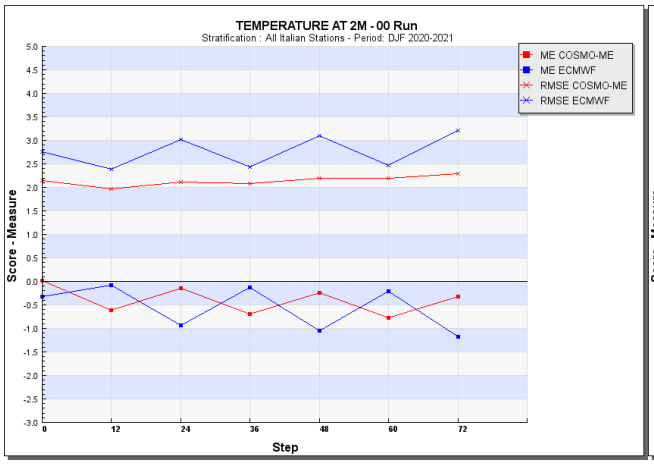


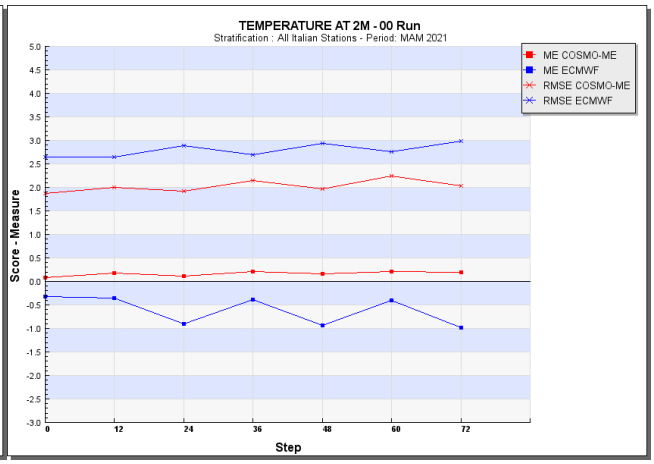




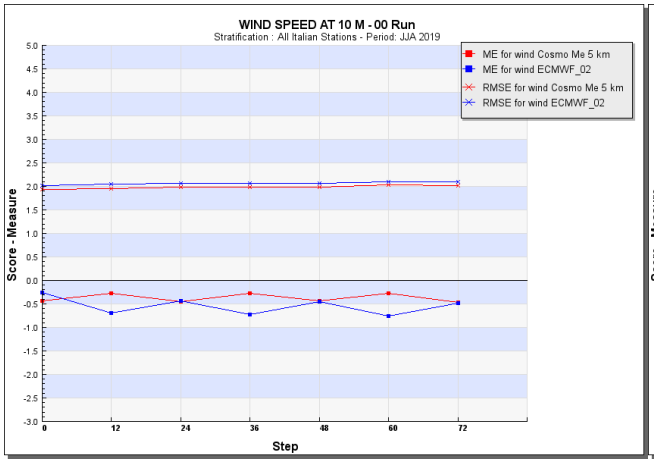


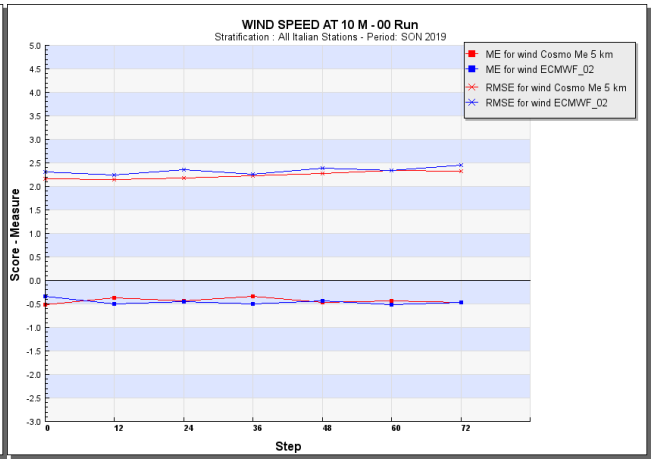


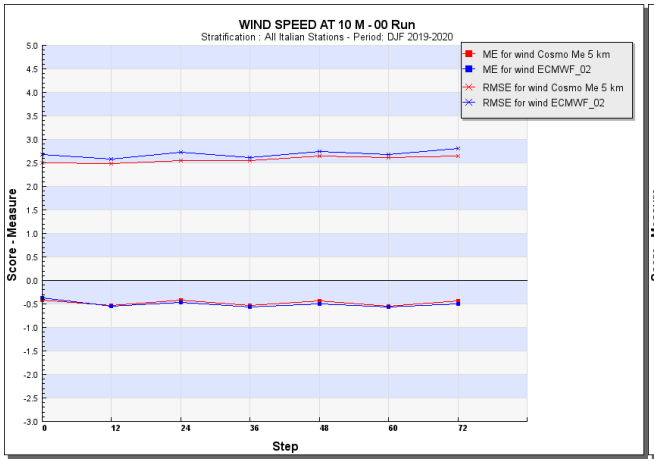


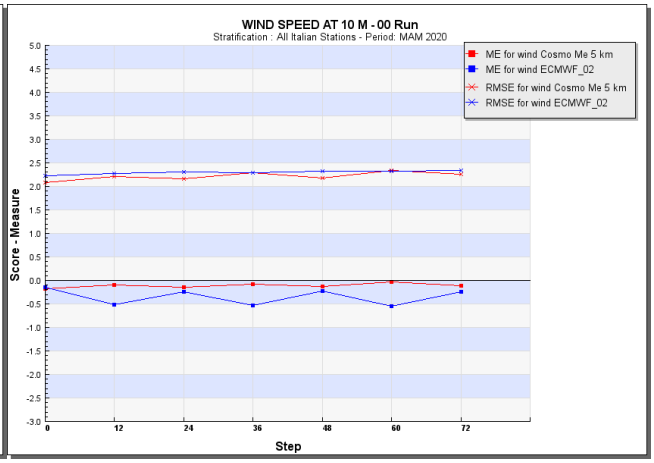


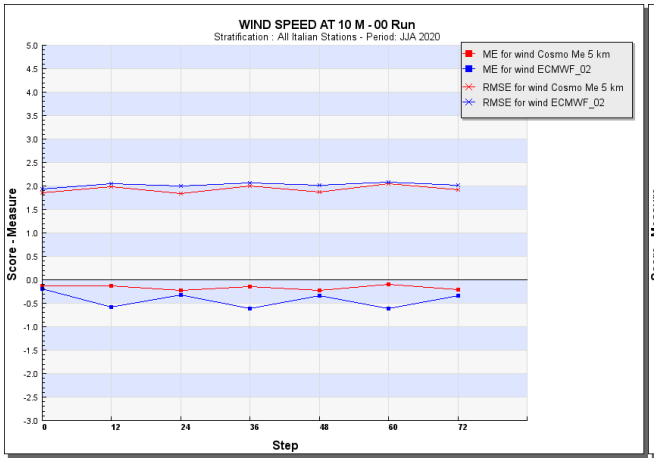
IFS – COSMO-ME comparison: 10m Wind Speed

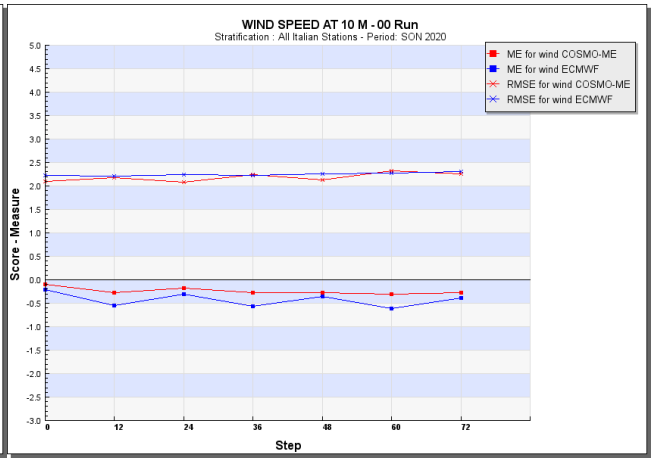


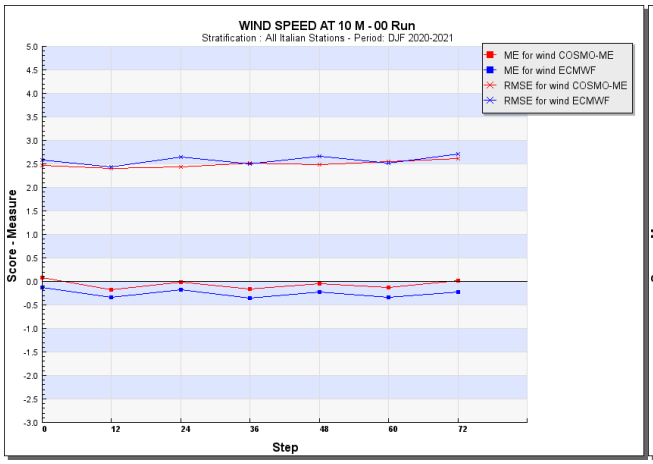


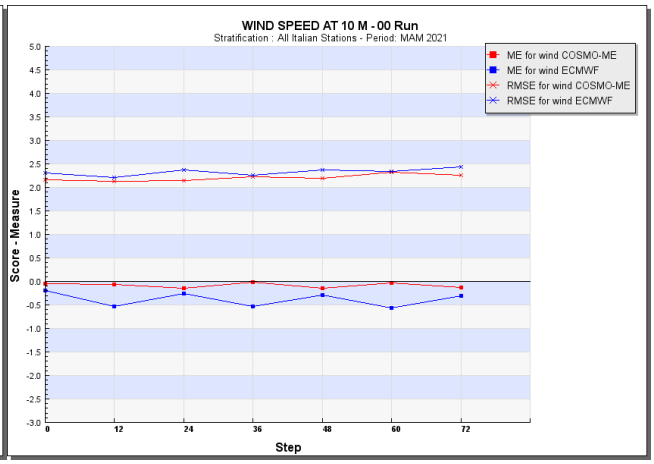









WIND SPEED AT 10 M - 00 Run
Stratification : All Italian Stations - Period: DJF 2020-2021
ME for wind COSMO-ME
ME for wind ECMWF
RMSE for wind COSMO-ME
RMSE for wind ECMWF
Score - Measure
Step

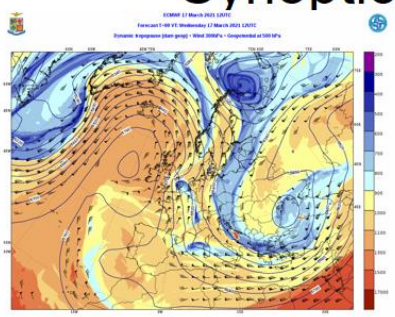

WIND SPEED AT 10 M - 00 Run
Stratification : All Italian Stations - Period: MAM 2021
ME for wind COSMO-ME
ME for wind ECMWF
RMSE for wind COSMO-ME
RMSE for wind ECMWF
Score - Measure
Step

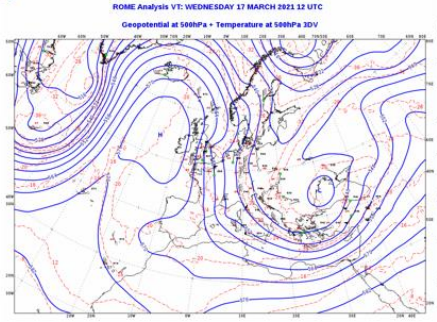
Appendix B of Report ECMWF 2021 – ITALY

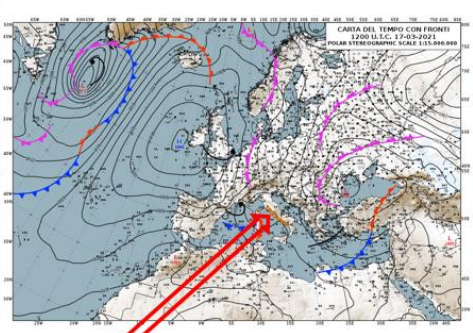
B1. Case Study#1

17th March 2021
Dry line over Central Italy

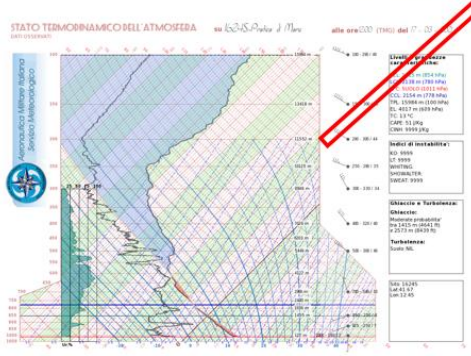
Synoptics

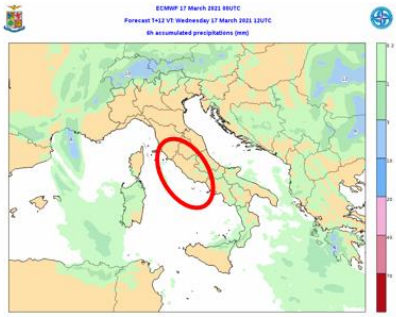




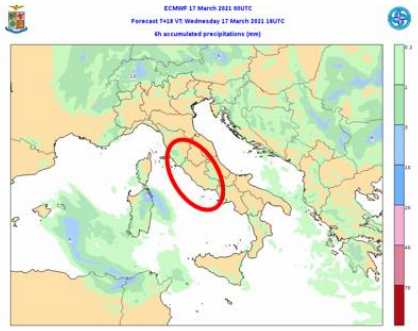


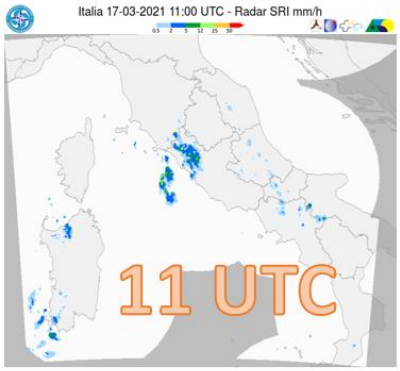
- **Wide cold trough over estearn Europe;**
- **Low over Tyrrenian sea;**
- **Low level southwesterny flow over Central Italy.**

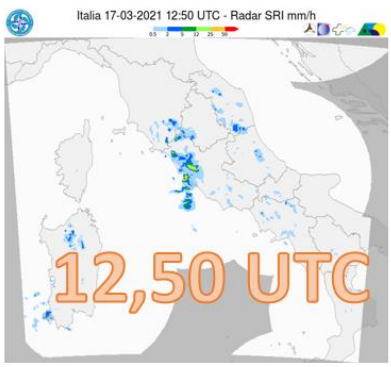


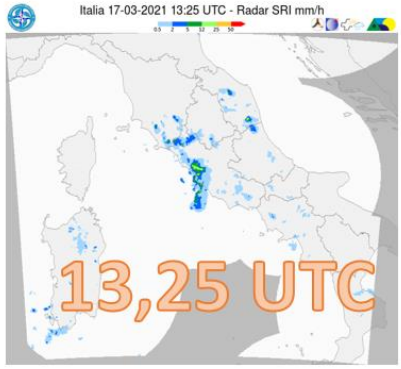


ECMWF total precipitation
17th march - 00 UTC run
VT: 17th jan
06-12UTC (left)
12-18UTC (right)



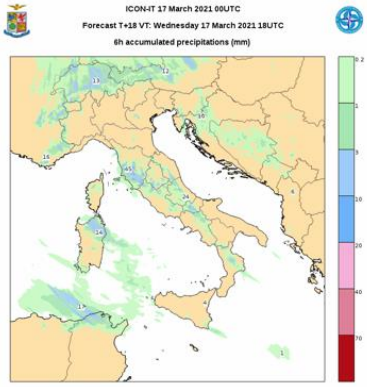


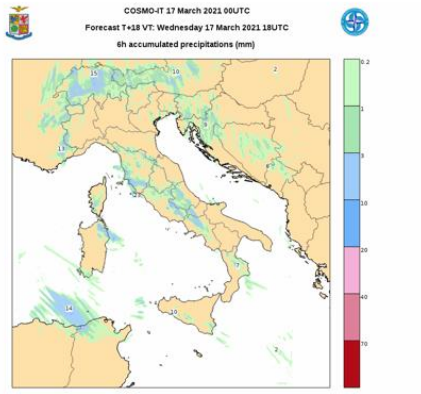




REMARKS

- Mismatch of precipitation over Latium;
- Convective event, no orographic forcing;
- Local models as well (COSMO, ICON) didn't see precipitations.

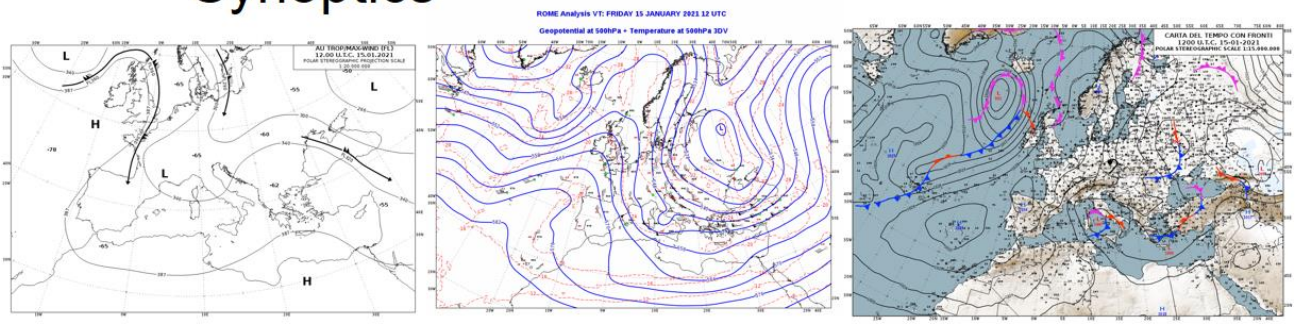




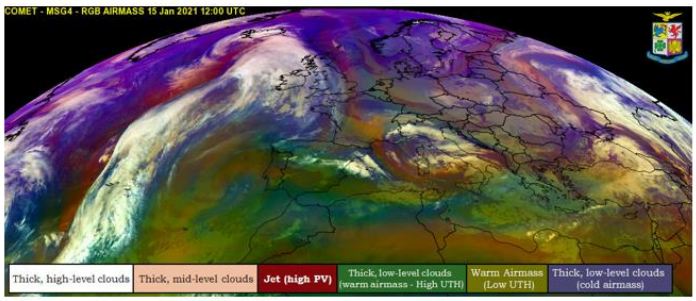
B2. Case Study#2

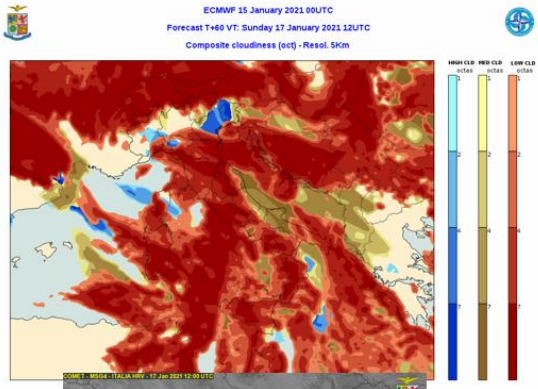
17th January 2021
Light rain/snow over Italy

Synoptics

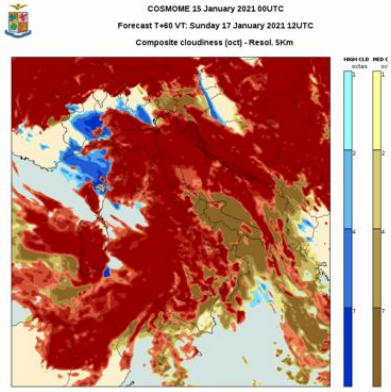


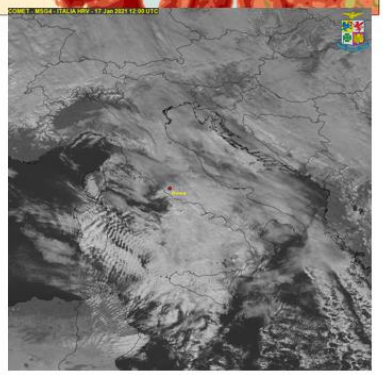
- **Wide trough over estearn Europe;**
- **Low over Tyrrenian sea;**
- **Low level eastern flow over Northern Italy.**





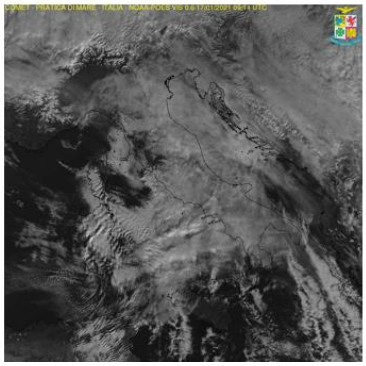
ECMWF vs COSMO
Composite Cloudiness
15th jan - 00 UTC run
VT: 17th jan 12UTC

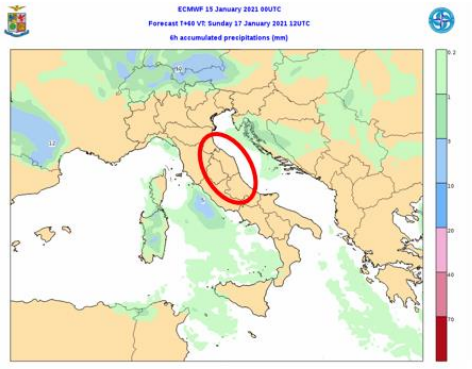




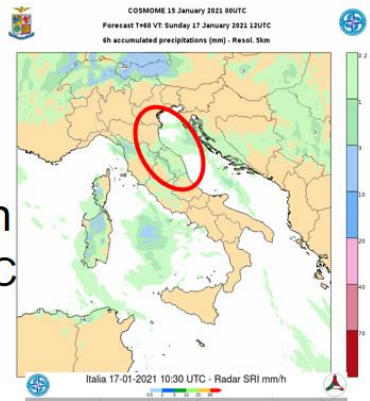
MET HRV 12 UTC

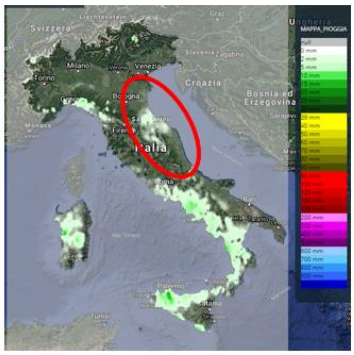
NOAA POES 09,14 UTC





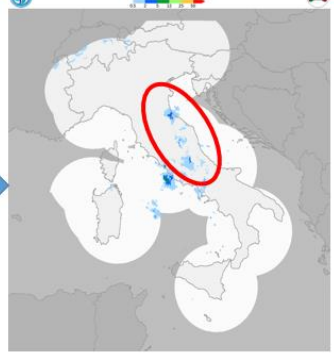
ECMWF vs COSMO
15th jan - 00 UTC run
VT: 17th jan 06-12UTC





Obs rainfall (06-12)

RADAR SRI 10,30 UTC



REMARKS

- Underestimation of precipitation over circled area (Romagna and Marche);
- Good cloudiness forecast by ECMWF and COSMO.

CONSIDERATIONS

- Light precipitation (rain + snow)
- Good cloudiness forecast, but probably lack of precipitable water
- Very unusual; tipically ECMWF overestimates coastal light precipitation

B3. GENERAL REMARKS TO BE REPORTED ABOUT ECMWF OPEN CHARTS

For short and medium range weather forecasting operational duties, the following products from ECMWF web site (authenticated users area) are envisaged as very valuable:

- **RAIN AND MEAN SEA LEVEL PRESSURE**; the representation is very clear, emphasizing the main frontal systems, both actual and developing, allowing a smart and quick synoptical picture on the Euro-Mediterranean area. The surface pressure plot provides useful information for marine meteorological support (Meteomar bulletins).
- **TOTAL CLOUD COVER**; outlook of the composite cloud coverage, provides hints on the daily cycle evolution of the clouds, supporting e.g. weather forecasting addressed to general public.
- **GEOPOTENTIAL 500 HPA AND TEMPERATURE AT 850 HPa**; classical chart of medium troposphere really valuable for the identification and the prognosis of air masses and synoptical subjects.

Furtherly, the opportunity of creation “on-the-fly” of metgrams by mouse-clicking on the chart is extremely beneficial for the forecaster, providing him with a synthetic overview of the weather parameters as total cloudiness, total precipitation, 10m wind speed and 2m temperature.

To be mentioned the importance of derived products as **SIMULATED SATELLITE IMAGES** and **EFI (extreme forecast index)**.

Finally, the possibility of easy changing the geographical scenario of interest is highly beneficial.