# Application and Verification of ECMWF Products 2013

*Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA)*

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## 1. Summary of major highlights

IFS deterministic model output from both 12 and 00 UTC runs is used at CNMCA as plotted fields in the forecasting department mainly for the medium range, as input to statistical (PPM type) and physical adaptation schemes, but also as initial and/or boundary conditions for CNMCA Local Area Models (7km COSMO-ME and very high resolution 2.8km COSMO-IT).Verification of ECMWF products are carried out at CNMCA for operational model T1279. Surface parameters and forecast ranges mainly used by weather forecasters are considered.

## 2. Use and application of products

### 2.1. Post-processing of model output.

#### 2.1.1. Statistical adaptation.

Statistical adaptation is involved in a Perfect Prog application currently being used named ARGO. The model is used to infer surface weather parameters such as precipitation, 2T, humidity, cloudiness, wind etc. over about one hundred geographical sites corresponding to the locations were the Italian network of weather stations is deployed and observations are available.

#### 2.1.2. Physical adaptation.

Physical adaptation is being used within the meteograms generation application. Routines selecting for each geographical site the most likely point among nearest grid points, make use of land/sea mask and elevation comparisons. Correction at all is being performed once the grid point has been chosen on the base of geophysical properties of the site.

#### 2.1.3. Post-processing products and derived fields.

Thousands of meteograms are routinely produced over geographical sites within the 80°N-60°S area. At present meteograms are being produced in PNG graphical format and in text mode every 6 hours for the medium range (up to T+72H stepping in time) and every 12 hours for the long range (T+72H 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.

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.

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 (Beaufort Scale). Metgrams (sometime you call them meteograms, others metgrams) over sea geographical sites are being produced too. For each site primary sea swell height, wind wave height, 10 m wind and wave direction behaviours are described from T+12H up to T+96H. 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".

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

## 2.2. **Use of products**

The ECMWF T1279L137 operational model is being used at CNMCA. Surface and upper air fields of the 00Z and 12Z runs are routinely downloaded on 0.25° horizontally spaced mesh for surface fields and on a 1.0° horizontally spaced mesh for upper air fields. The time step between two adjacent meteorological fields issued, is 6 hours from T+0h to T+168h and 12 hours between T+168h and T+240h forecast times.
The ECMWF products are classified in two main typologies: primary and secondary.
In the first one, parameter fields identified as synoptic tracers are considered, like Potential Vorticity at 300 Hpa and equivalent temperature at 850 hPa as well; they allow to localize and define the path of synoptic configurations, especially in cases where they are not well defined at 500 hPa maps.
In the second category belong all the maps concerning parameters which better summarize the related meteorological conditions (high, medium and low cloudiness, temperature, wind etc.). The fields are generally plotted in an overlapping mode, including satellite images; many combinations are used using proper tools. In this way the forecaster is able to detect the subjects of interest, like Conceptual Models.

Besides these maps, products from EPS and EFI are used for severe weather events detection and issuing of warnings.

Every month, according to the availability of the ECMWF model products, maps from System 3 Seasonal FC (ensemble mean, probability and climagrams) are subjectively analyzed to obtain an outlook for the next quarterly period. Along with a concise commentary, these maps are shown on the internal intranet website (available on request also for external users).

Finally monthly forecasts system is also used in the Operational Forecasting room even if not routinely.

## 3. Verification of products

### 3.1. **Objective verification**

#### *3.1.1. Direct ECMWF model output*

**(i) in the free atmosphere**

Some basic (MA, MAE or RMSE) verification statistical indices for the free atmosphere parameters (e.g wind, Temp, RH and geopotential at standard pressure level) are produced and compared to CNMCA COSMO-ME model output verification results,.

**(ii) of local weather parameters verified for locations**

Objective scores are computed for ECMWF 12 and 00 UTC run (d+1 to d+7) after collecting data retrieved from all available Italian Synop stations, using several stratifications. Graphics have been elaborated for a number of parameters: 2m Temperature, 2m dew point, 10m Wind Speed, MSLP, Tot Cloud Cover (ME, MAE).

Cumulated precipitation quarterly event scores (POD/FAR, FBI, KSS, ETS, ORSS, POD, FAR) with respect to fixed thresholds and for d+1 to d+7 ranges, are computed.

For the present document, data covering the period from DJF 2012/13 to SON 2013 have been used for the verification of these parameters and only some selected results are presented in the next pages, for ECMWF 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, optimised by the “smaller” difference in altitude combined with the horizontal distance between a station and the corresponding grid point. The software used for verification products is called VERSUS (VERification System Unified Survey) that replaced operationally the previous package Common Verification Suite (CVS) in mid 2008. This new system has been developed at CNMCA 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.

<u>24-h Cumulated Precipitation:</u> Model shows an overestimation for all the seasons for lower thresholds, while tends to underestimate the really higher ones. FBI score is overestimated for almost all the seasons and thresholds (FBI =1 only around 25 mm/24h), only in Autumn the overestimation is less evident (FBI =1 only around 10 mm/24h). Comparing these results with the previous year, overestimation appears to be slightly more evident for all the seasons. About the accuracy (ETS), all seasons exhibit the best results, mainly for low thresholds and for the first 3-5 days of integration. For all thresholds there is a gradual decrease in accuracy with integration time.

<u>2m Temperature</u>: clear diurnal cycle in both ME and MAE. It is clear a general underestimation especially during the night. MAE increases with the forecast time and its values are mainly comprised between 2 and 2,5°C (reaching up to 3,5°C in winter). It is clear a decrease in accuracy (higher MAE values) with integration time.

10m Wind Speed: Clear diurnal cycle for all the seasons for ME and MAE, especially during winter and summer. A general underestimation is shown in ME, but really small. MAE, around 1,5-2 m/s in summer and fall and 2-2,5 m/s in winter and spring, with a tendency to increase slightly with forecast time.

*3.1.2 ECMWF model output compared with CNMCA COSMO-ME limited area model.*

ECMWF 00-UTC scores (ETS, FBI) for 12 hours cumulated precipitation, have been calculated and graphically compared to those evaluated for Italian 00-UTC run non-hydrostatic LAM named COSMO-ME (7 km resolution) for d+1 and d+2. These scores are shown in the next pages on Italian area.

About FBI scores, COSMO-ME shows a better distribution and representation than ECMWF especially for almost all the thresholds for all the seasons. In general higher thresholds are underestimated with both IFS and COSMO-ME models, but clearly overestimation is less evident in COMSO-ME than in the IFS one.

Accuracy, represented here through ETS score, tends to be higher for COSMO-ME especially for lower thresholds and for all seasons.

*3.1.3 Post processed products.*

Metgrams, Automatic Weather Interpretation (AWI), Trajectories, Sounding Forecast

*3.1.4 End products delivered to users.*

Quarterly reports are made available to Intranet and Internet users as well as Forecasts and Research division.

## 3.2 Subjective verification.

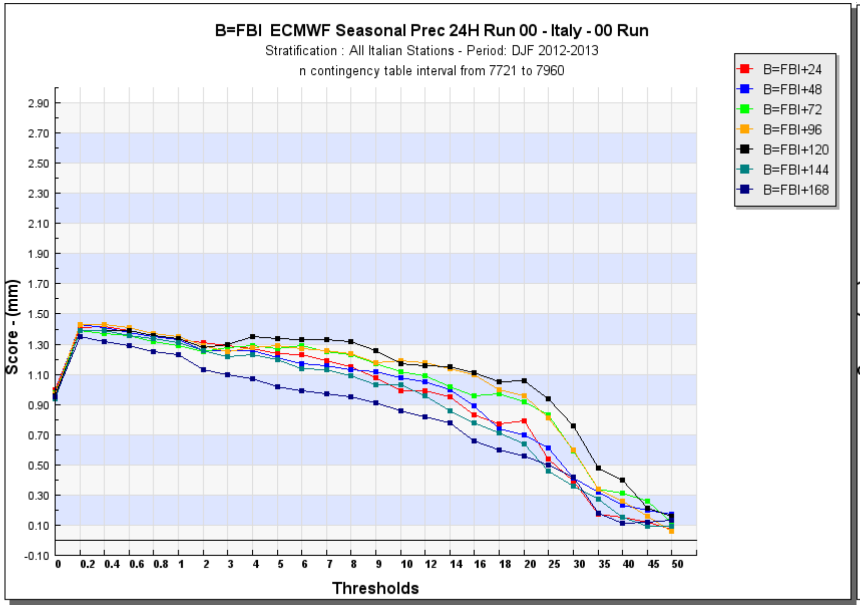
*3.2.1. Subjective scores: none*

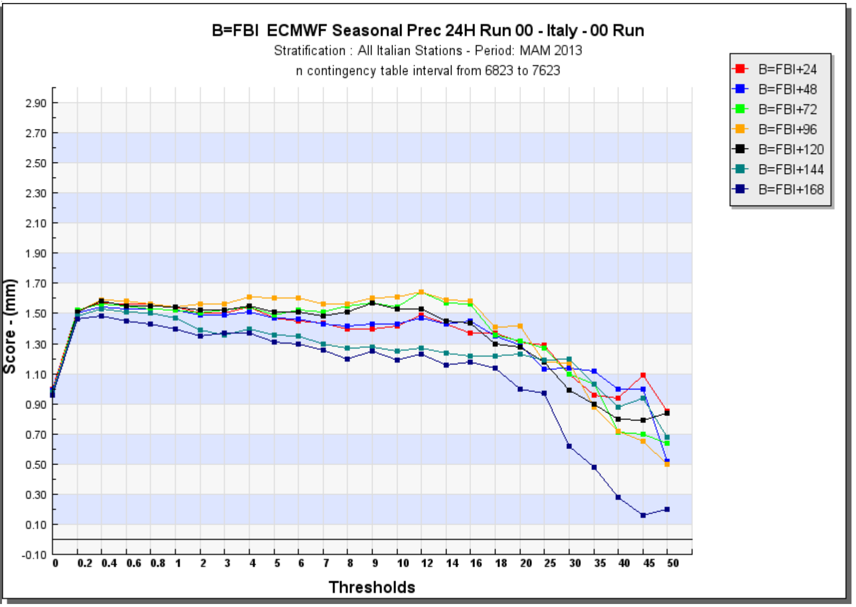
*3.2.2. Synoptic studies:*

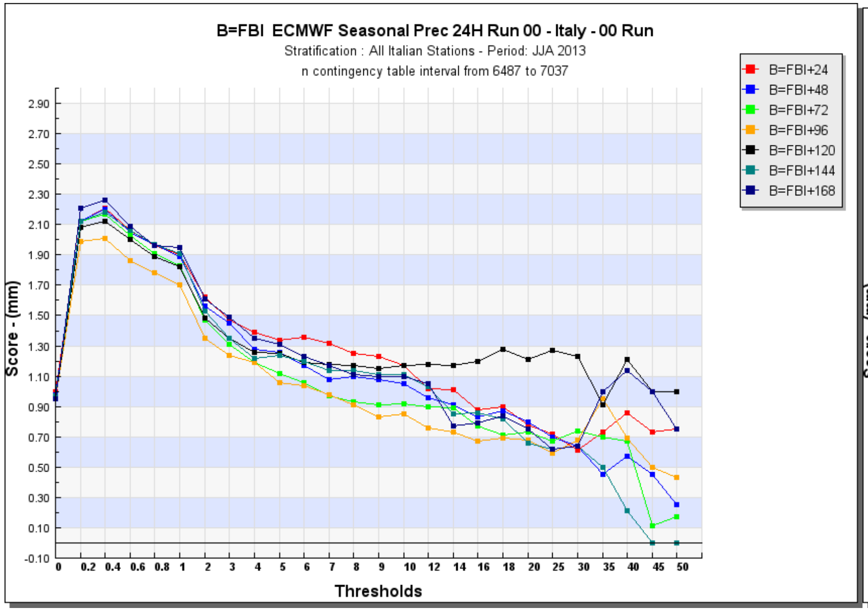
Synoptic studies regarding the floods over Sardinia November 18$^{th}$, 2013 have been treated and such results (which have been previously sent to Newsletter EUMETNET WGCEF) are shown in the next pages.

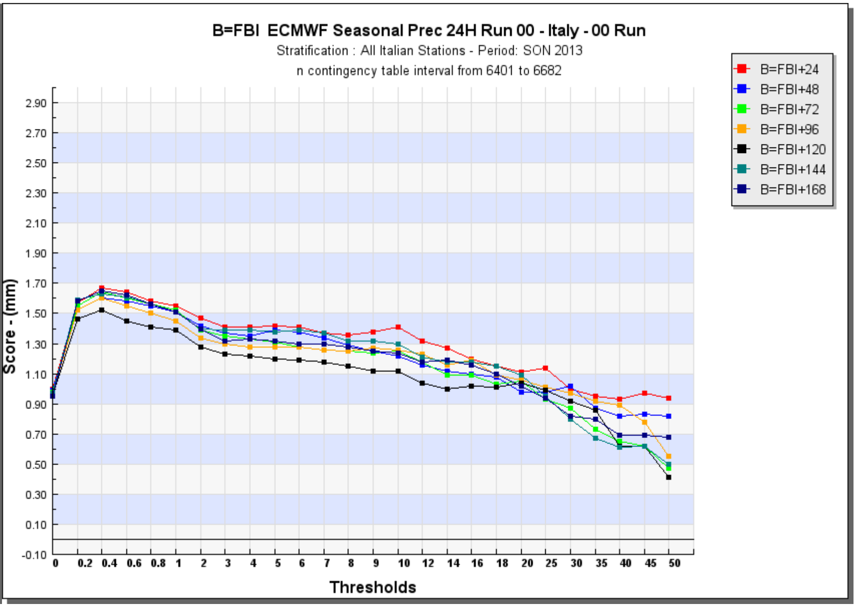
Moreover a collection of Ecmwf model Forecast Maps has been provided in order to underline how the model performance has been definitely high in such incident, having supplied a signal up to 96 hours in advance.

ITALY

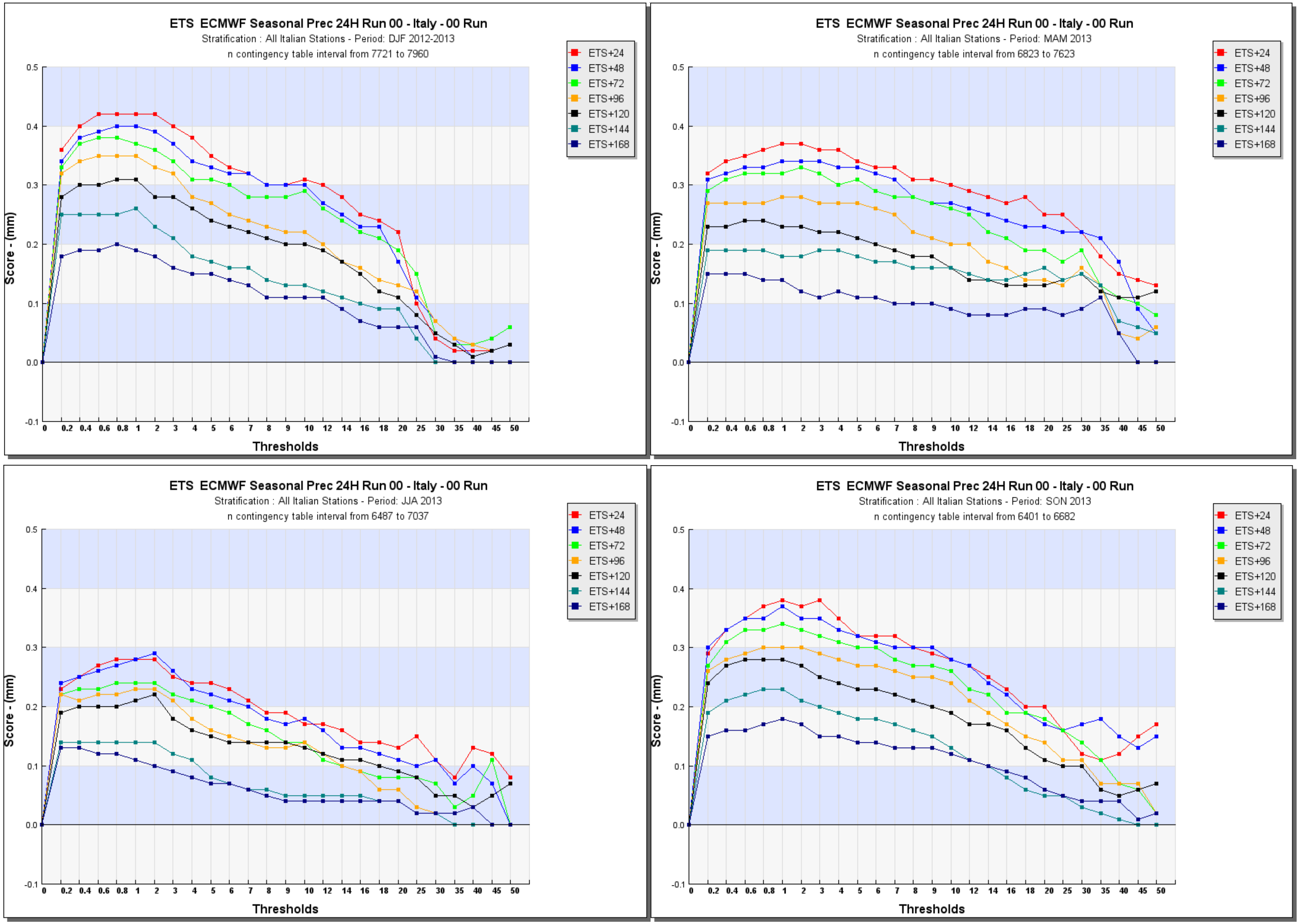


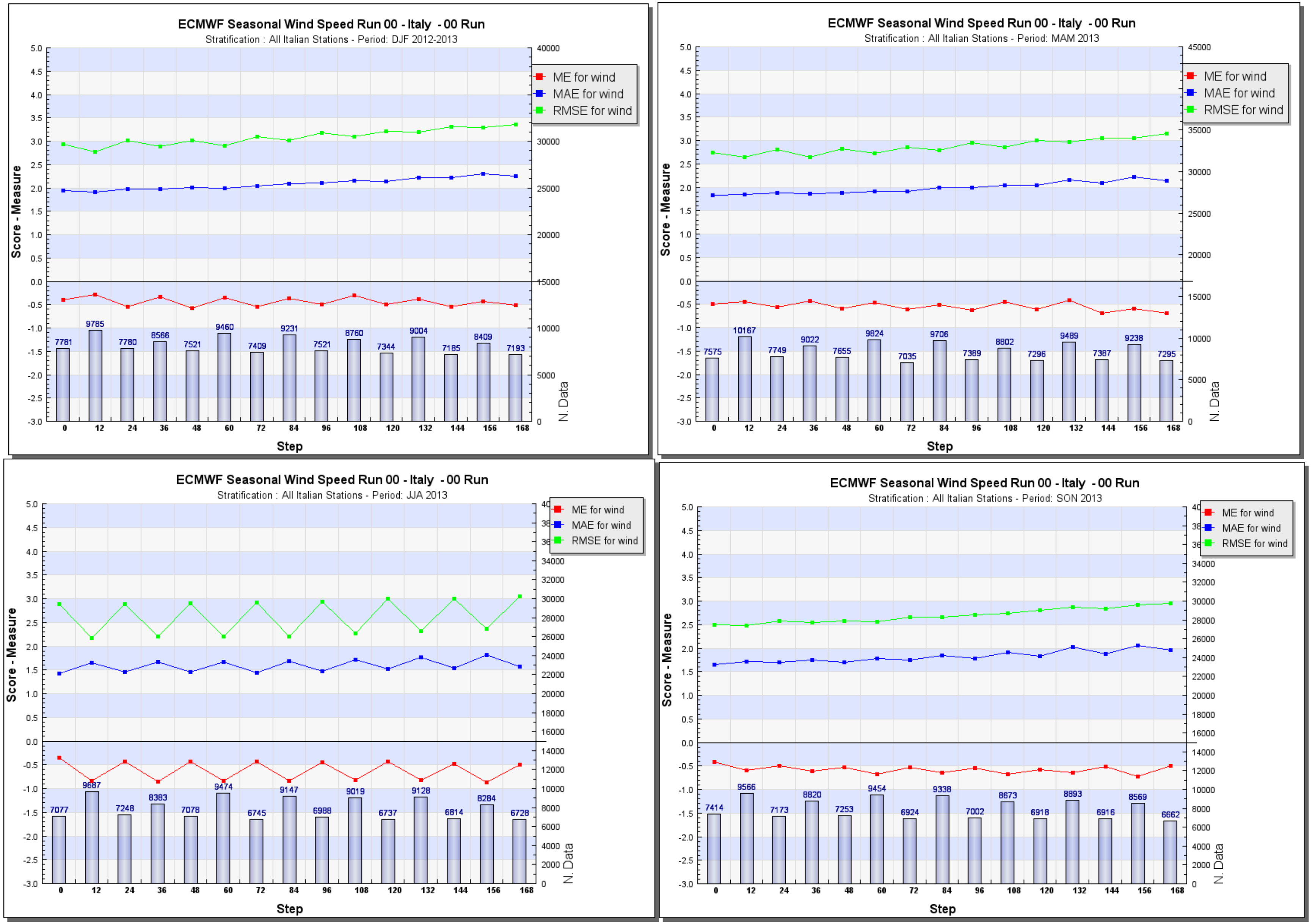



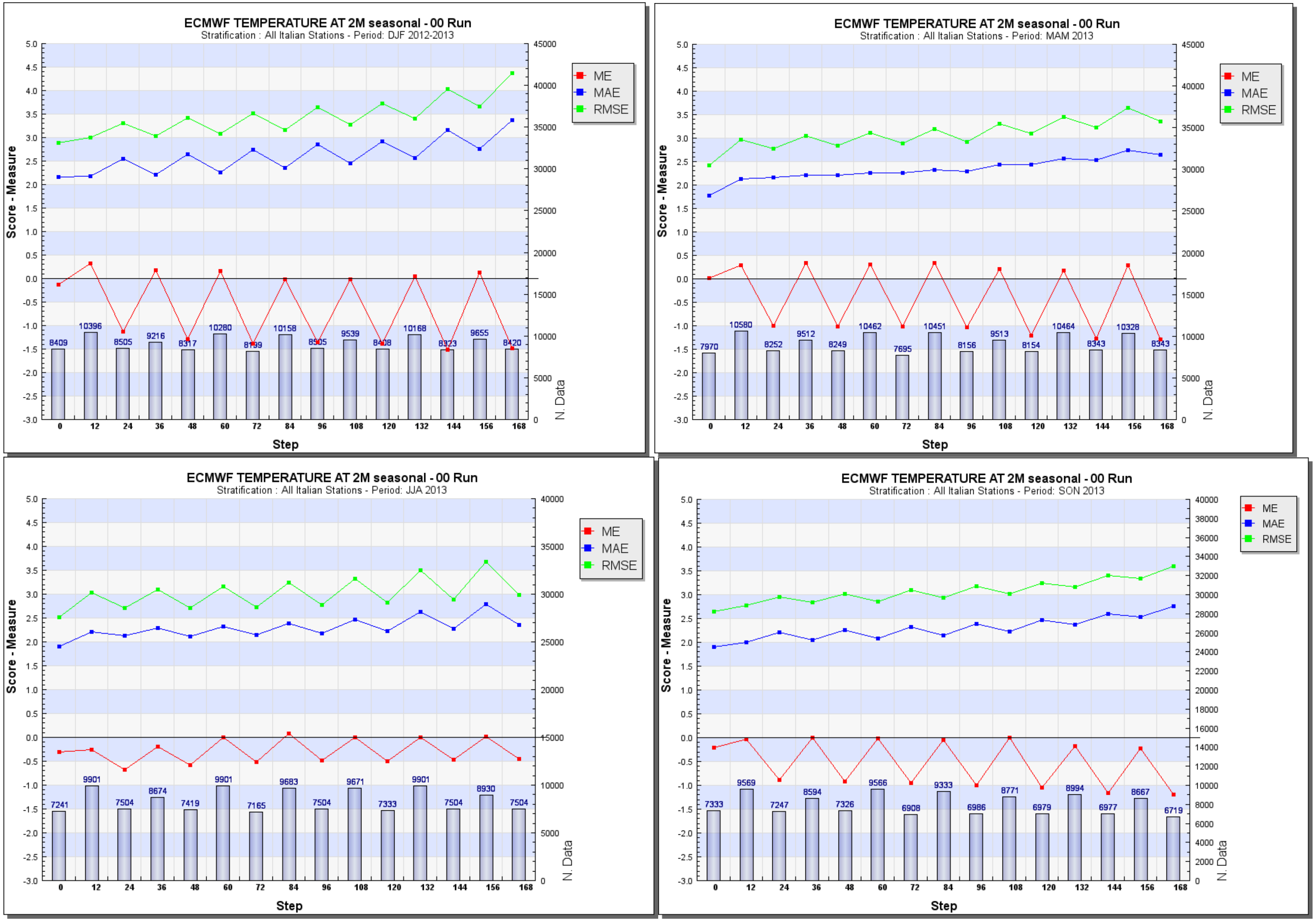

**IFS Precipitation in 24 hours - FBI score**



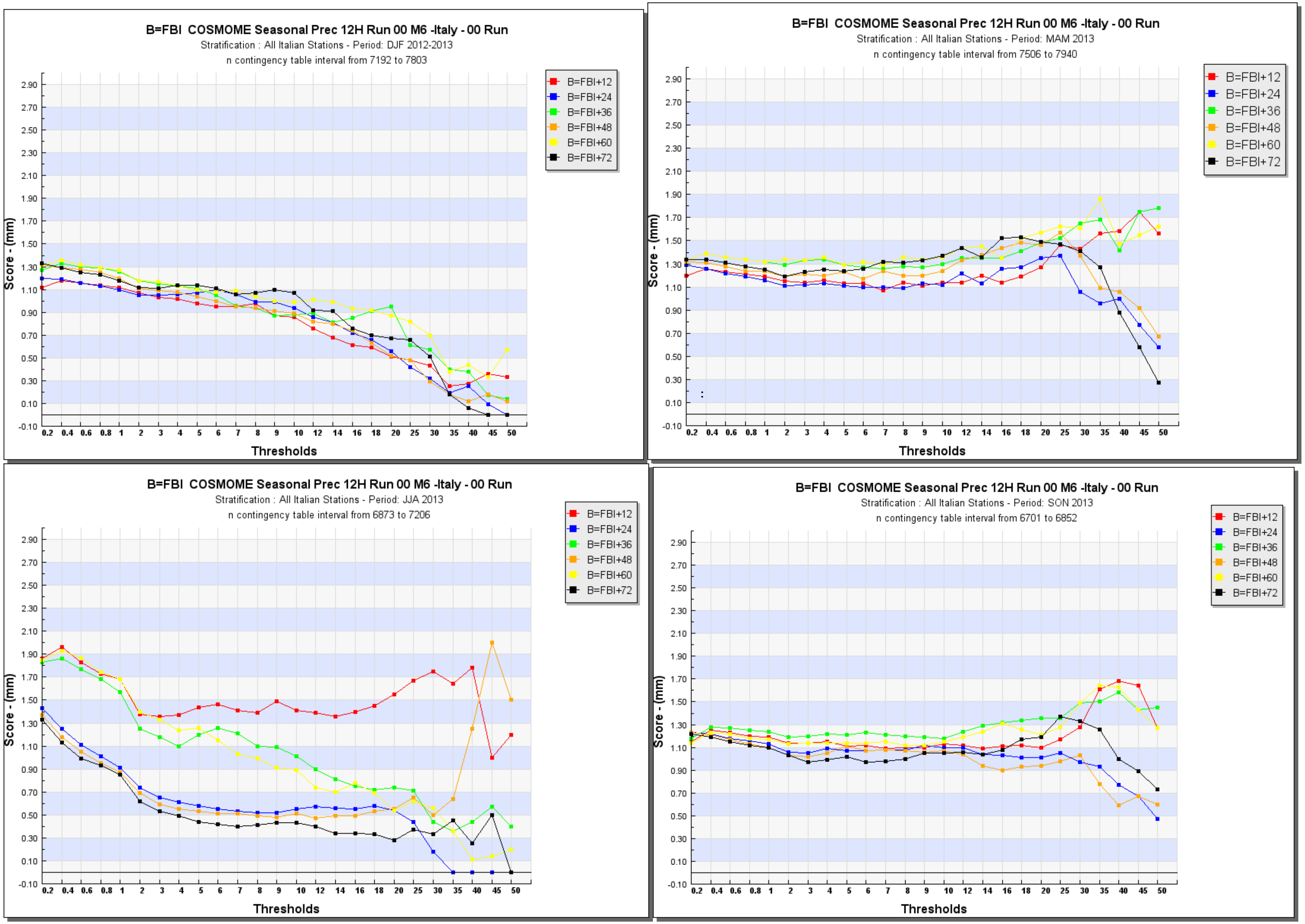

**IFS Precipitation in 24 hours - ETS score**



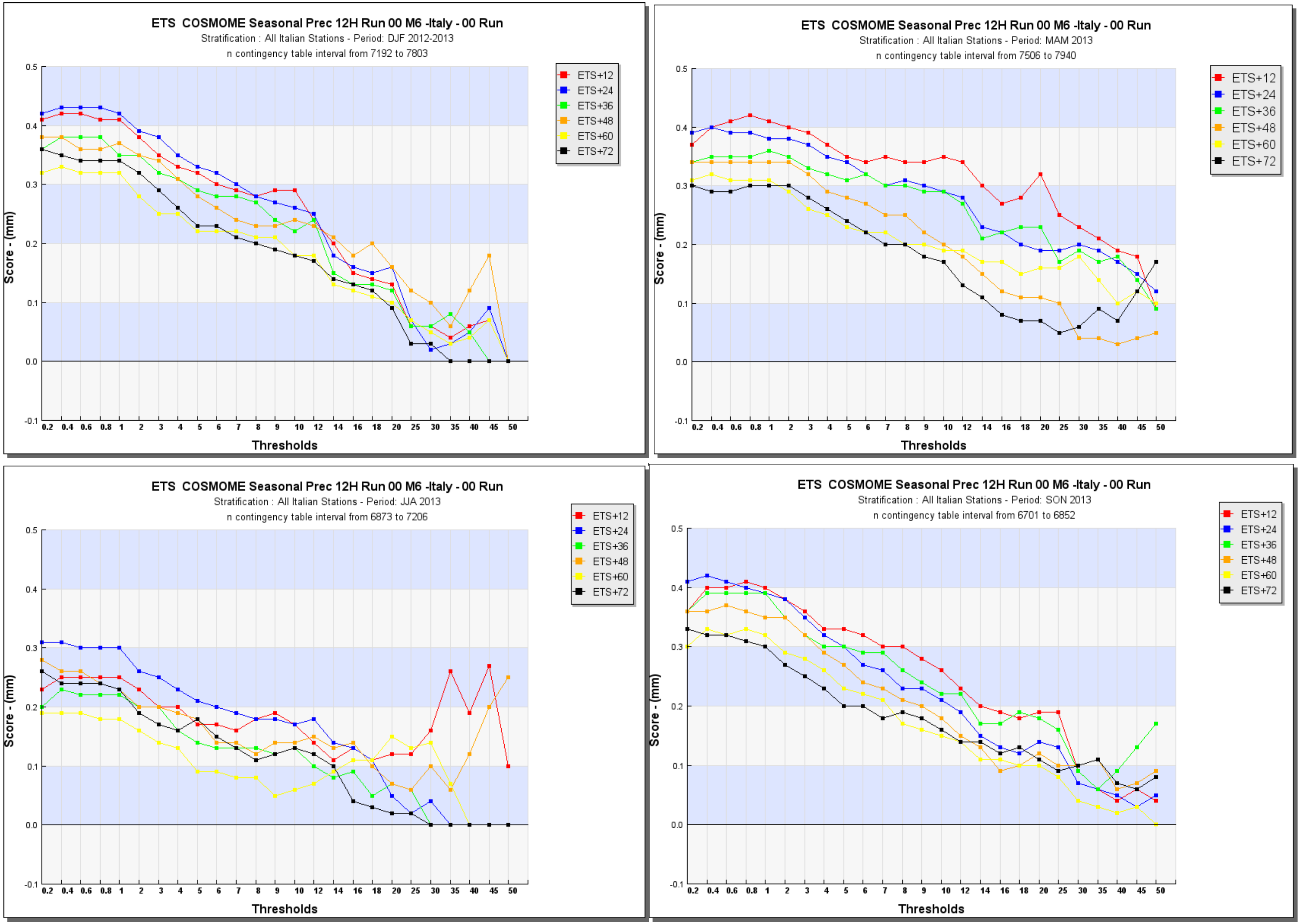

**IFS Wind Speed (Mean Absolute Error, Mean Error and Root MSE)**



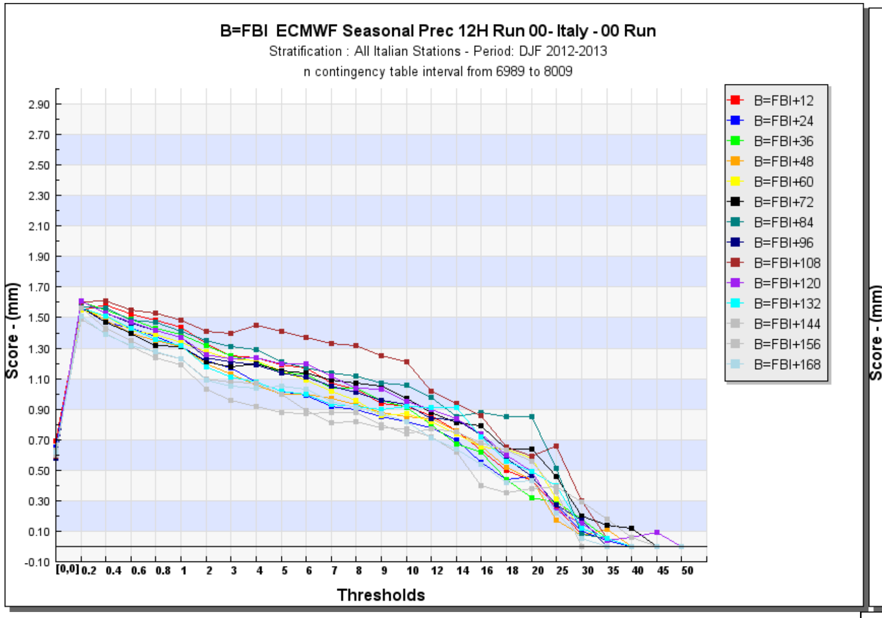

**IFS T2m (Mean Absolute Error, Mean Error, Root MSE)**

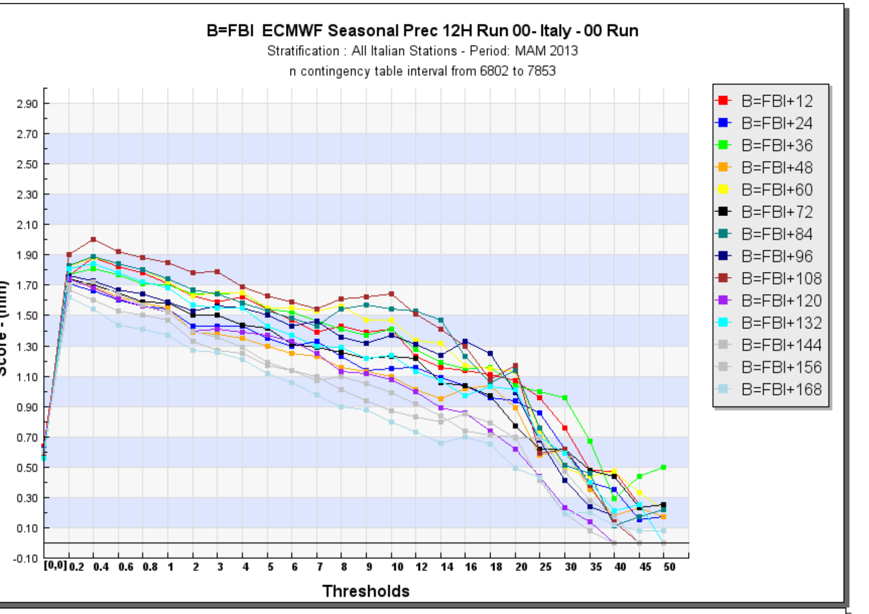


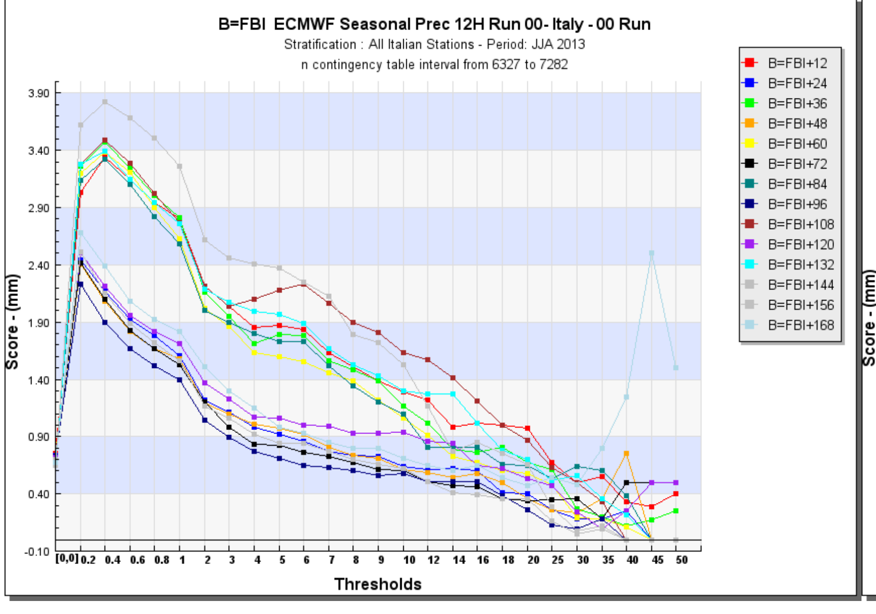

**COSMO-ME Precipitation in 12 hours - FBI score**

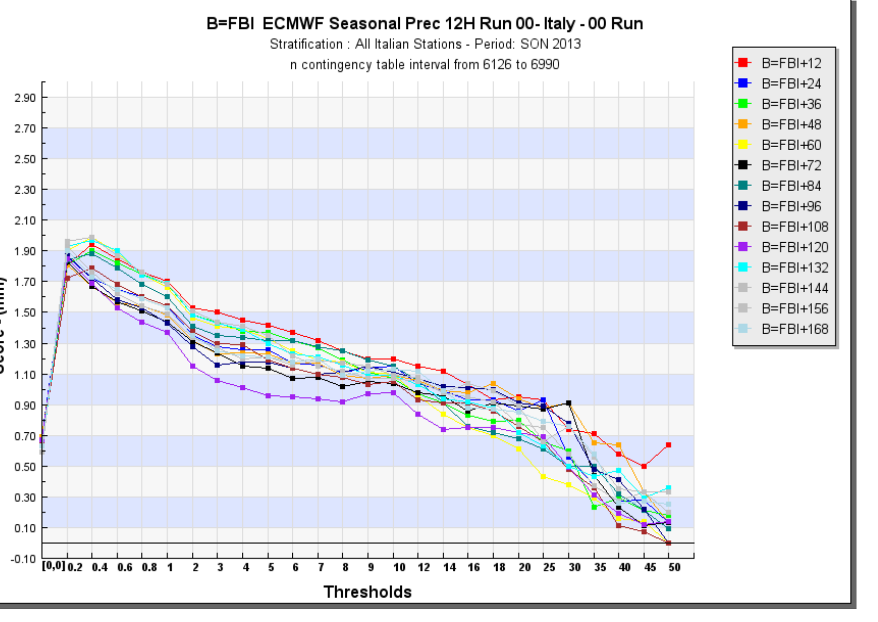



**COSMO-ME Precipitation in 12 hours - ETS score**

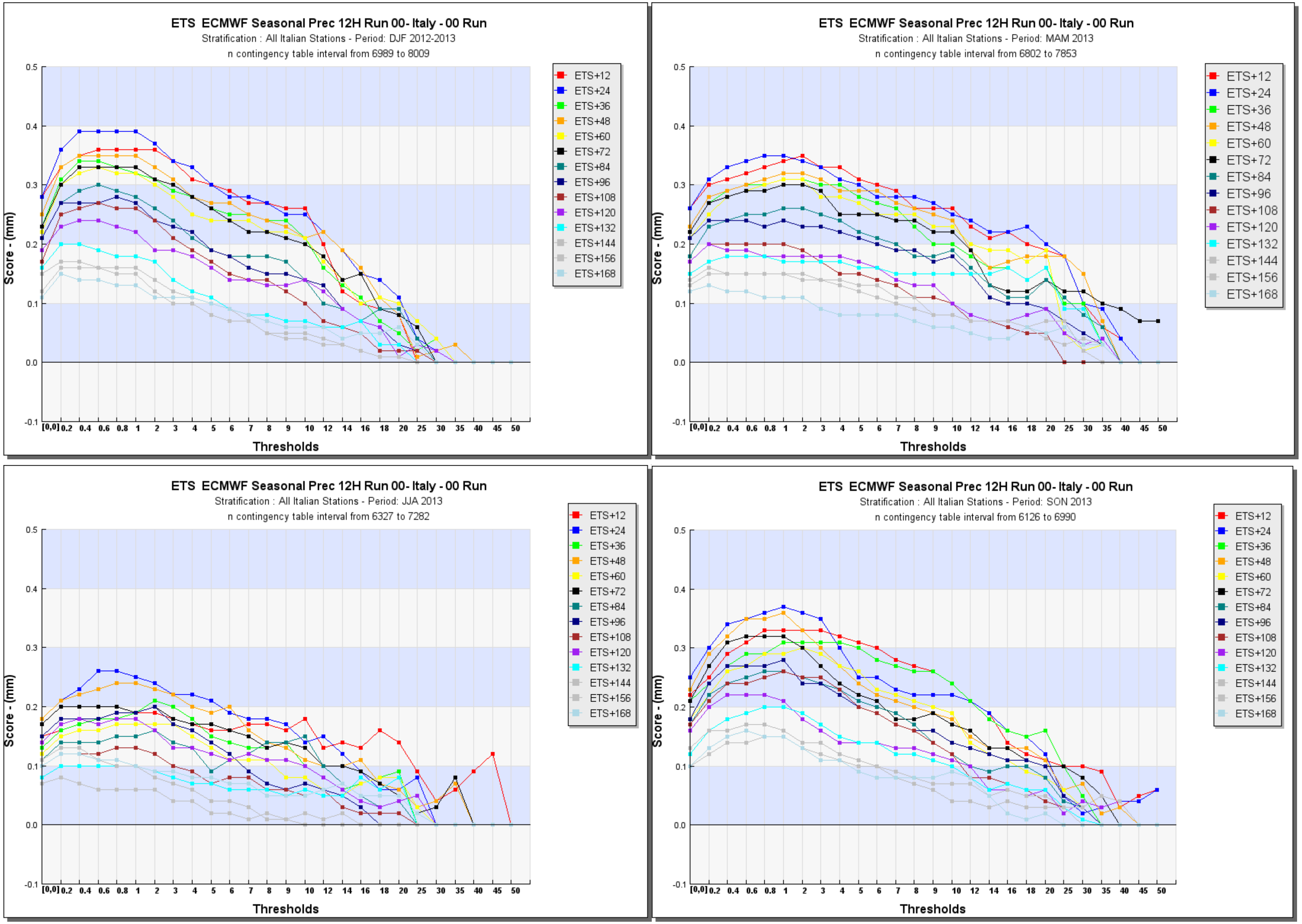



**IFS Precipitation in 12 hours - FBI score**




**IFS Precipitation in 12 hours - ETS score**

# Flooding over Sardinia November 18th, 2013

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## 1. Abstract

The November 18, 2013 flooding in Sardinia has left 17 casualties behind, with extensive and severe damage to public and private assets.
Media coverage, trying to provide details about this storm, described it as a cyclone; this kind of simplification creates ambiguity to the public opinion that associates the term to tropical latitudes extreme weather, such as Atlantic hurricanes (or Pacific typhoons). The extra tropical cyclones that usually cross the Mediterranean Sea are featured by a low pressure system (L), in connection with fronts. A front is a leading edge of air masses with distinctly different thermal characteristics (blue identifies the cold front, red the warm one, as shown in Fig. 1). [1]

**Fig.1 Stages of development of an extra-tropical cyclone**

Below, a detailed description of the extreme event occurred over Sardinia will be provided; although outstanding, it presents features typical of mid-latitude disturbances.

## 2. Synoptics

On Sunday, November 17, a wide Atlantic high pressure area dominated Central Europe keeping the main disturbances at much higher latitudes (60°N), then slightly bended over Eastern Europe towards the Black Sea.
Due to such pattern, the vortex located between the southern portion of Iberian Peninsula and Sardinia strengthened in its isolation, as shown in Fig.2.

**Fig.2 Analysis at 500 hPa over the Euro-Atlantic Area**

The cut-off on Sunday was located over southern Spain, and ended its regressive phase (i.e., its movement from east to west) temporarily moving over the Strait of Gibraltar. This brought a moderate increase of the geopotential heigh and a southerly flow across southern Italy, with a temporary improvement of weather conditions over Italy.
At D+1, i.e. Monday November 18, the low pressure system moved towards the Balearic Islands, and its dynamically more active eastern area reached eastern Sardinia as well as southern Sicily, northern Italy and the Tyrrhenian areas. The upper level southerly flow over Sardinia coupled with a strong confluence of winds in the lower troposphere. Numerical weather prediction models, both at the global (ECMWF ) and regional scale (COSMO-ME[2]) on Sunday November 17 forecast heavy rain for Monday, with higher amount of cumulated precipitation primarily over the southern and the eastern portions of the island (Fig.3).

**Fig.3 Rainfall predicted by ECMWF and COSMO-ME model**

A strong indication of heavy thunderstorms was present in the Supercell Detection Index ($SDI_2$ [3] maps) of the November 2013 00 UTC 13-15 h forecast of the very high resolution model COSMO-IT [1] (2.8 km) (Fig.4).
The SDI2 index is defined as the correlation of vorticity and vertical velocity weighted by the mean vertical velocity in the atmospheric column (see boxes A, B below). The signal was also evident in the COSMO-ME SDI2 maps (Fig.5) of the previous day 00UTC run (November 17, 2013), despite the coarse model resolution (7 km).

A

$$\rho_{ij} = \frac{\langle w'\zeta'\rangle}{\left(\langle w'^2\rangle_{ij}\langle \zeta'^2\rangle_{ij}\right)^{1/2}}$$

$$SDI_{1,ij} = \rho_{ij} \cdot \overline{\zeta_{ij}}$$

$$\zeta_{ij} = (\nabla\, x\, v)_z$$

B

$$SDI_{2,ij} = \begin{cases} \rho_{ij}\left|\overline{\zeta_{ij}}\right| : w \geq 0 \\ 0 : w \leq 0 \end{cases}$$

Where $\rho_{ij}$ is the velocity-vorticity correlation and $\zeta_{ij}$ is the vertically averaged vorticity.

**Fig.4 SD2 Index output Cosmo IT Run November 18, 2013 00 UTC VT +13-15 h**

After the analysis of all mentioned data a weather warning for persistent, heavy, thundery and locally extreme rainfall over southern and eastern areas of Sardinia was issued on Sunday. The adjective "persistent" outlines the characteristic of severe storm cells, which in these cases are usually organized in lines lasting several hours.

**Fig.5 SD2 Index output Cosmo Me Run November 17, 2013 00 UTC VT +37-39 h**

## 3. Lifecycle

On November 18, all Italian western seas were affected since morning by the humid and unstable southerly flow connected to the low pressure system placed over western Mediterranean; at the same time, in the upper troposphere the minimum was placed between Spain and Morocco; additionally, a southwesterly branch of the jet-stream affected the whole northern portion of African coast as well as Sicily (Fig.6).

**Fig.6 Dynamic Tropopause from ECMWF November 18 06 UTC**

At lower levels an intense southeasterly flow, featured by a strong warm advection from the Strait of Sicily, converged with distinctly southerly winds over Sardinia Channel associated with the extra-tropical cyclone placed on Balearic Islands (Figg.7-8-9-10).

**Fig.7 Wet Bulb Potential Temperature at 850 hPa ($\theta_{aw}$) November 18 at 06 UTC**

**Fig.8 850 hPa wind and 700 hPa thermal advection (cold blue, warm red) November 18 at 06 UTC**

**Fig.9 MSG3 WV6.2 and Dynamic Tropopause November 18 at 12 UTC**

**Fig.10 Surface Analysis November 18 at 12 UTC**

All the above mentioned items brought to a strong convergence at the lower layers which, coupled to an upper level trough (evident on the VP height chart = 1.5), led to a significant convective development along two distinct confluence lines, as clearly showed by radar images (Fig 11).

**Fig.11 Radar echoes November 18, 2013 at 12.30 (A) and at 15.00 (B)**

The polar satellite image in the visible channel (Fig.12) highlights the two lines clearly showing the structure of cumulonimbus clouds.

**Fig12 NOAA POES VIS 0.8 µm 18th november 2013 at 13.00 UTC**

On Monday afternoon the cyclone moved eastwards causing the storm that affected the Campidano area (a large valley of Sardinia extending from Cagliari to Oristano Gulf) to weaken, while severe thunderstorm activity continued throughout the eastern sector, as highlighted by the picture showing the composite radar-lightning-IR 10.8 µm (Fig. 13).

**Fig.13 Radar-Lightning-IR 10.8 µm November 18, 2013 at 17.00 UTC (a) 19.00 UTC (b)**

The convergence line at 19:00 UTC left Sardinia, moving eastwards and reached the Tyrrhenian Sea.

Fig.14, obtained by overlaying the RGB airmass image at 18:00UTC with the thermal front parameter (TFP), shows the cold front that leaves Sardinia, as shown in surface analysis as well (Fig.15).

**Fig.14 MSG3 RGB airmass and TFP November 18, 2013 at 18.00 UTC**

**Fig.15 Surface Analysis November 18, 2013 at 18.00 UTC**

The convergence line, deployed all along the warm sector, overtook the island, leaving on the ground an extreme amount of precipitation.
Fig. 16 shows the cumulated rainfall over Sardinia, collected thanks to the raingauge network owned by Italian Civil Protection Department; matching these data with the daily extreme rainfall (fig. 17), this event proves its exceptional feature.

**Fig. 16 Total Cumulated Rainfall on November 18, 2013 over Sardinia from Civil Protection Obs Network**
**Fig. 17 Daily extreme rainfall from Italian NWS climatological archive.**

## 4. Final Remarks

The flood event that affected Sardinia on November 18 showed the following characteristics:

- The amount of rainfall must be considered extreme, due to values remarkably larger than climatic datasets ones.
- The synoptic scenario showed a large vortex almost completely isolated from the main flow (cut-off) whose evolution was simulated in a reliable and consistent way by the numerical models used by the Italian Met Service, both at global (ECMWF) and regional scale (COSMO-ME).
- Supercell Detection index gave a good prognostic signal of severe convection lines.
- The considerable rainfall was due to a strong pre-frontal and very unstable flow: risk of flooding over western and northwestern Italy (Sardinia, Liguria, Piedmont, northern Tuscany) is considerably high when this feature occurs coupled to a cut-off coming from the Iberian Peninsula or when it develops inside a broad and deep trough over Western Europe (the so-called V-shaped trough).

**References:**

- [1] Satrep Manual http://www.eumetrain.org/satmanu/SatManu/main.htm
- [2] http://cosmo-model.org/content/tasks/operational/usam/default.htm
- [3] http://www.cosmo-model.org/content/model/documentation/techReports/docs/techReport17.pdf

Here are a collection of rainfall ECMWF Forecast Maps showing how such incident has been detected correctly.

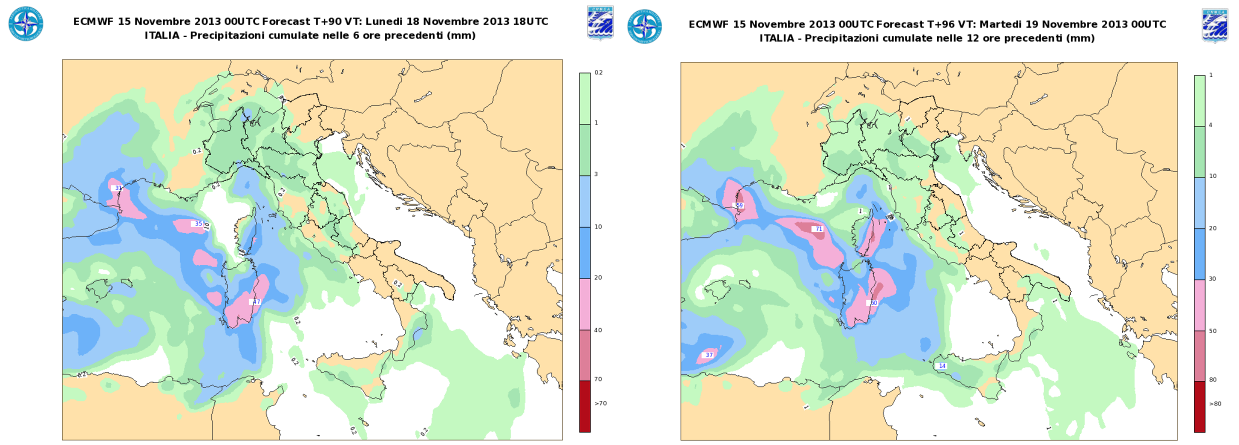


***Fig 1*** *15th nov 2013, 00 UTC run, ECMWF cumulated rainfall previous 6 hours Forecast (T+90) and previous 12 hours Forecast (T+96)*

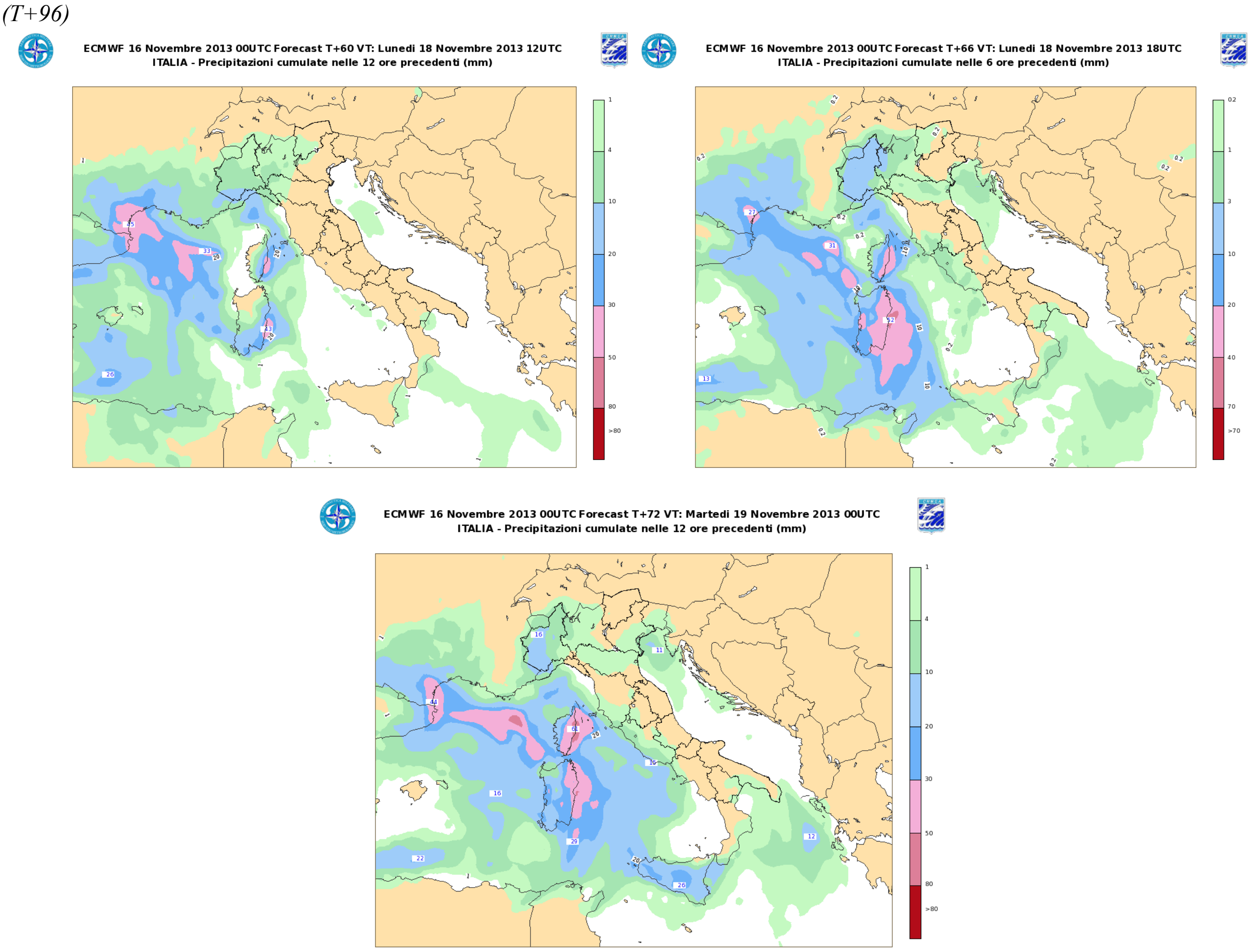


***Fig 2*** *16th nov 2013, 00 UTC run, ECMWF cumulated rainfall previous 12 hours Forecast (T+60), previous 6 hours Forecast (T+66), previous 12 hours Forecast (T+72)*

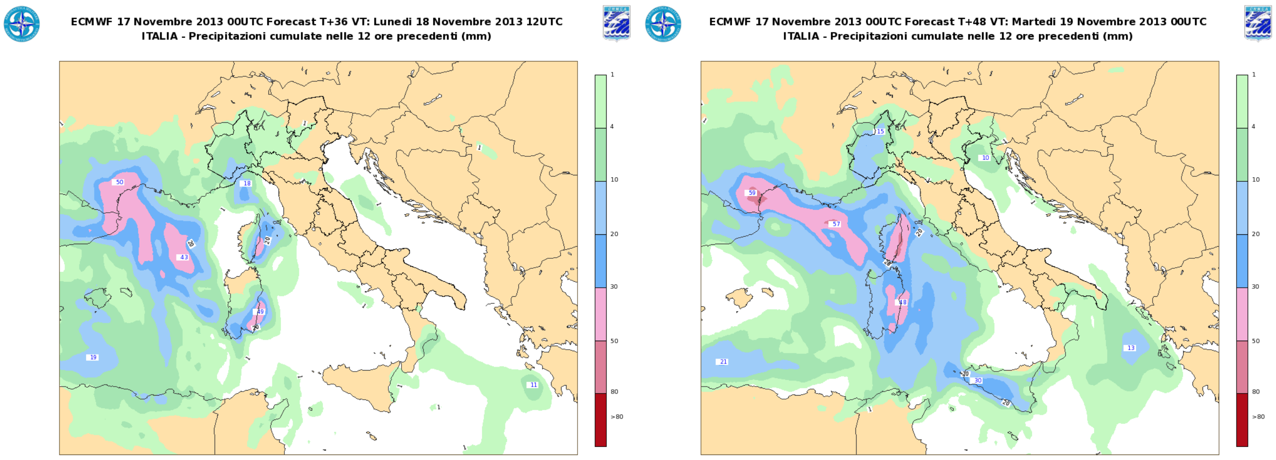


***Fig 3*** *17th nov 2013, 00 UTC run, ECMWF cumulated rainfall previous 12 hours Forecast (T+36), previous 12 hours Forecast (T+42)*

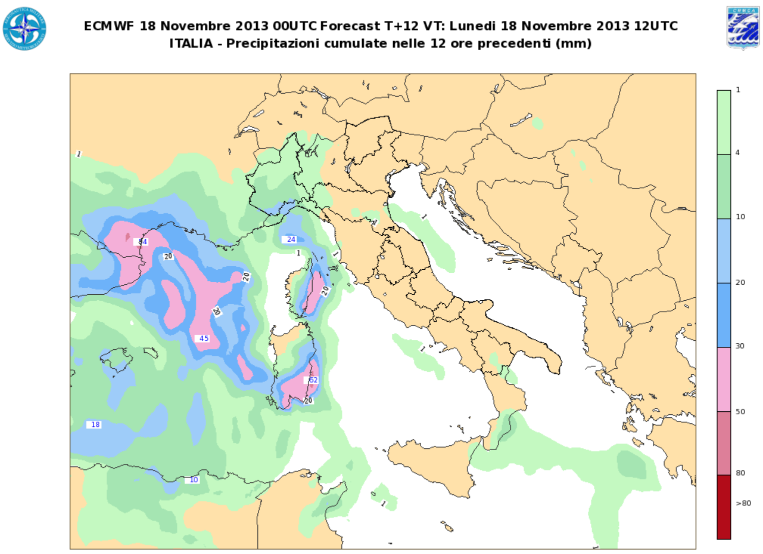


***Fig 4*** *18th nov 2013, 00 UTC run, ECMWF cumulated rainfall previous 12 hours Forecast (T+12)*