Flooding over Sardinia November 18th, 2013

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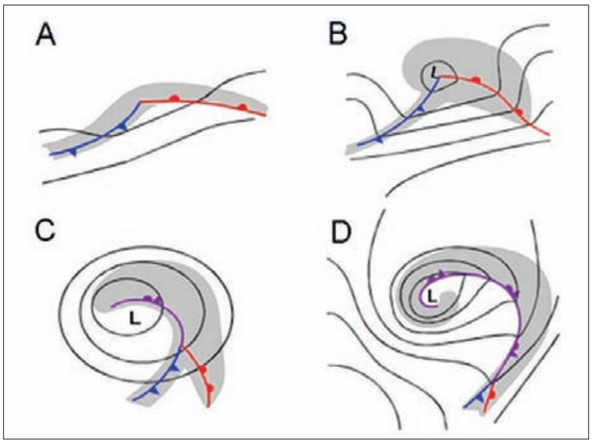
Abstract

The November 18th, 2013 flooding in Sardinia left 17 casualties, 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 in the minds of the public, who associate the term with the extreme weather of tropical latitudes, such as Atlantic hurricanes (or Pacific typhoons). But the extra tropical cyclones that usually cross the Mediterranean Sea are characterised 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).



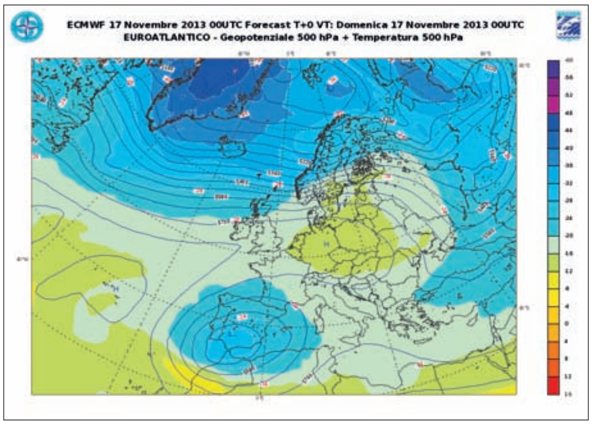
▲ *Figure 1: stages of development of an extra-tropical cyclone.*

Below, a detailed description of the extreme event which occurred over Sardinia is provided; although severe, it presents many features typical of mid-latitude disturbances.

Synoptics

On Sunday, November 17th, a large Atlantic high pressure area dominated Central Europe keeping the main disturbances at much higher latitudes (60°N) before steering them down over Eastern Europe towards the Black Sea.

Due to this pattern, the vortex located between the southern portion of the Iberian Peninsula and Sardinia strengthened in its isolation, as shown in Fig.2.

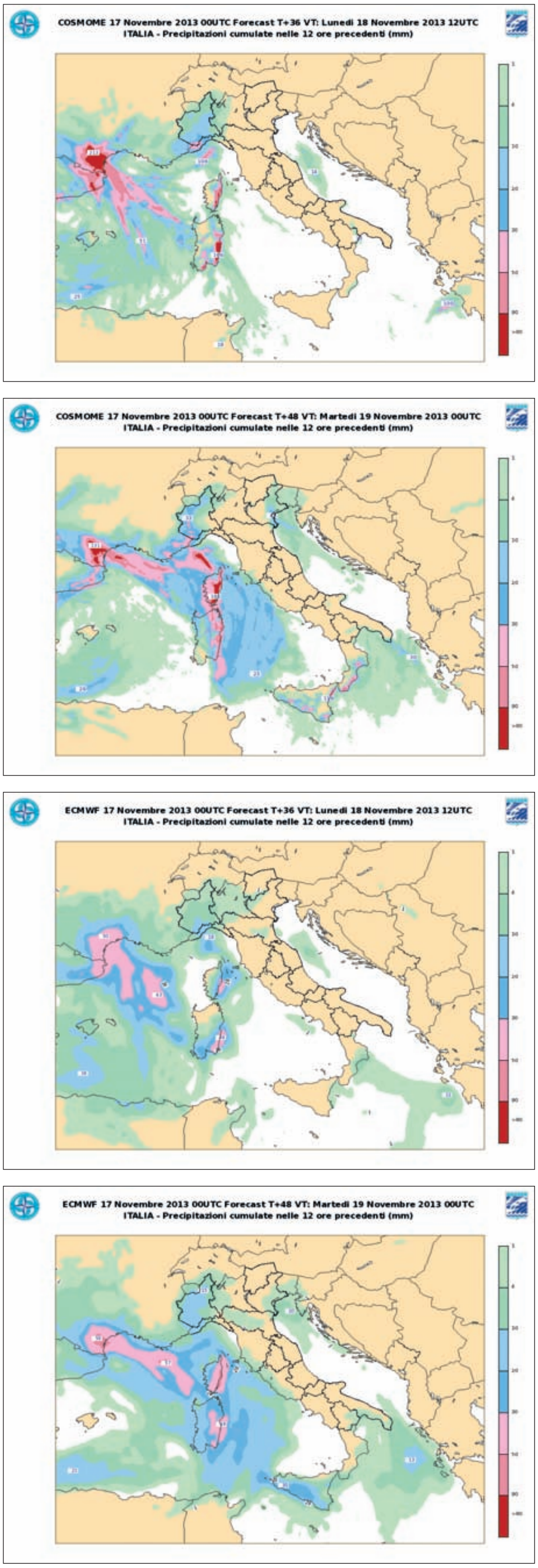


▲ *Figure 2: analysis at 500 hPa over the Euro-Atlantic Area.*

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 height and a southerly flow across southern Italy, with a temporary improvement of weather conditions over Italy.

At D+1, i.e. Monday November 18th, 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 17th forecast heavy rain for Monday, with higher amount of accumulated precipitation primarily over the southern and the eastern portions of the island (Fig.3).

Figure 3: rainfall predicted by ECMWF and COSMO-ME model.



A strong indication of heavy thunderstorms was present in the Supercell Detection Index (SDI2 [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).

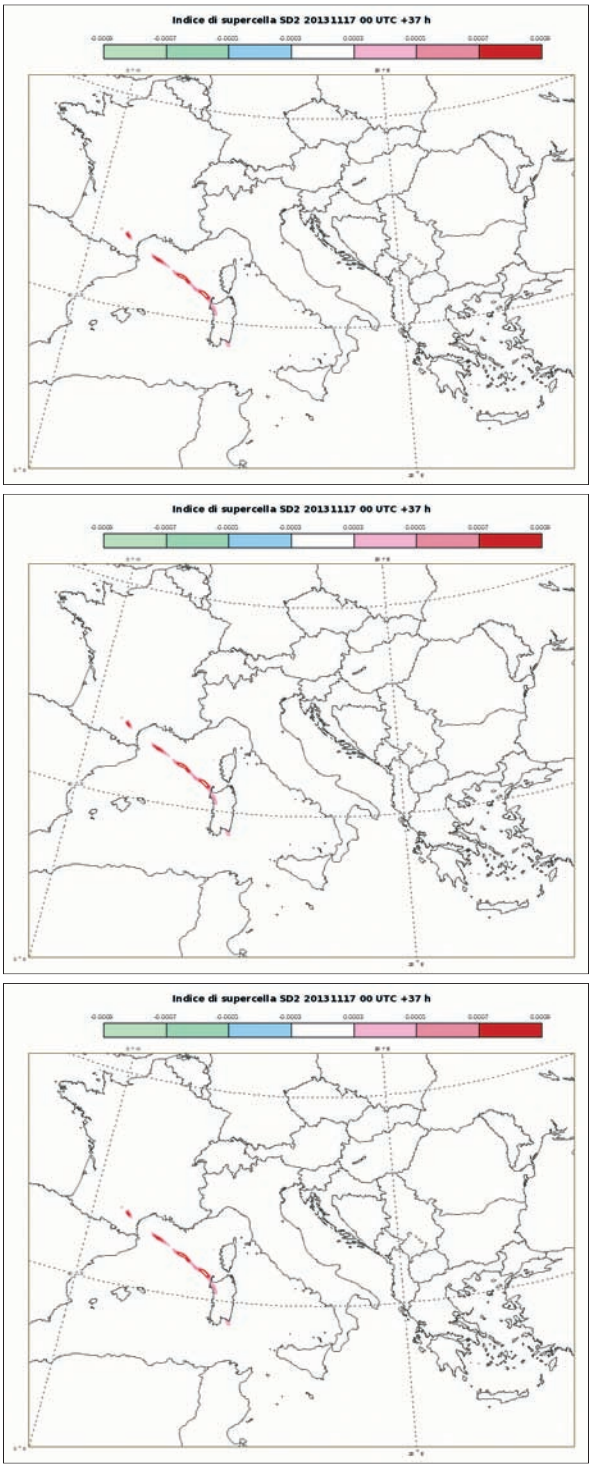


Figure 4: SD2 Index output Cosmo IT Run November 18, 2013 00 UTC VT +13-15 h.

A)

$$SDI_{1,ij} = \rho_{ij} \cdot \overline{\zeta_{ij}} \qquad \rho_{ij} = \frac{\langle w'\zeta' \rangle}{\left(\langle w'^2 \rangle_{ij} \langle \zeta'^2 \rangle_{ij}\right)^{1/2}} \qquad \zeta_{ij} = (\nabla\, x\, v)_z$$

B)

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

Where ρij is the velocity-vorticity correlation and ςij is the vertically averaged vorticity.

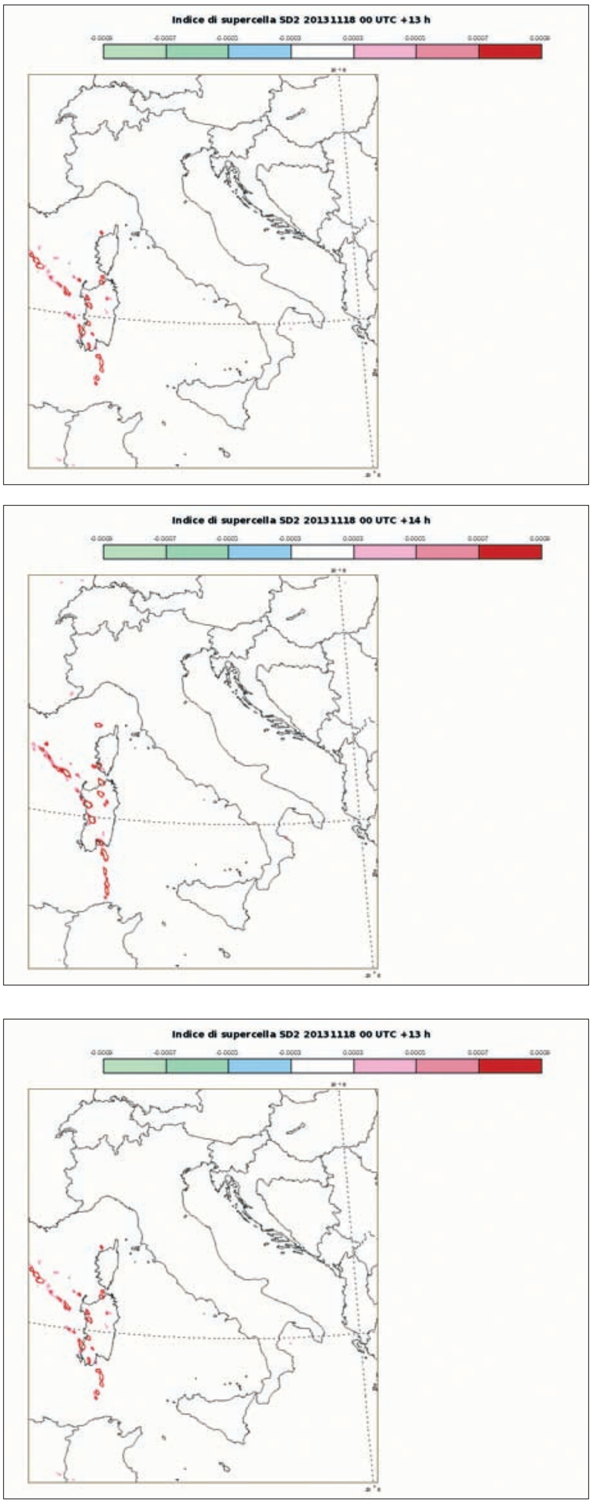


Figure 4: SD2 Index output Cosmo IT Run November 18, 2013 00 UTC VT +13-15 h.

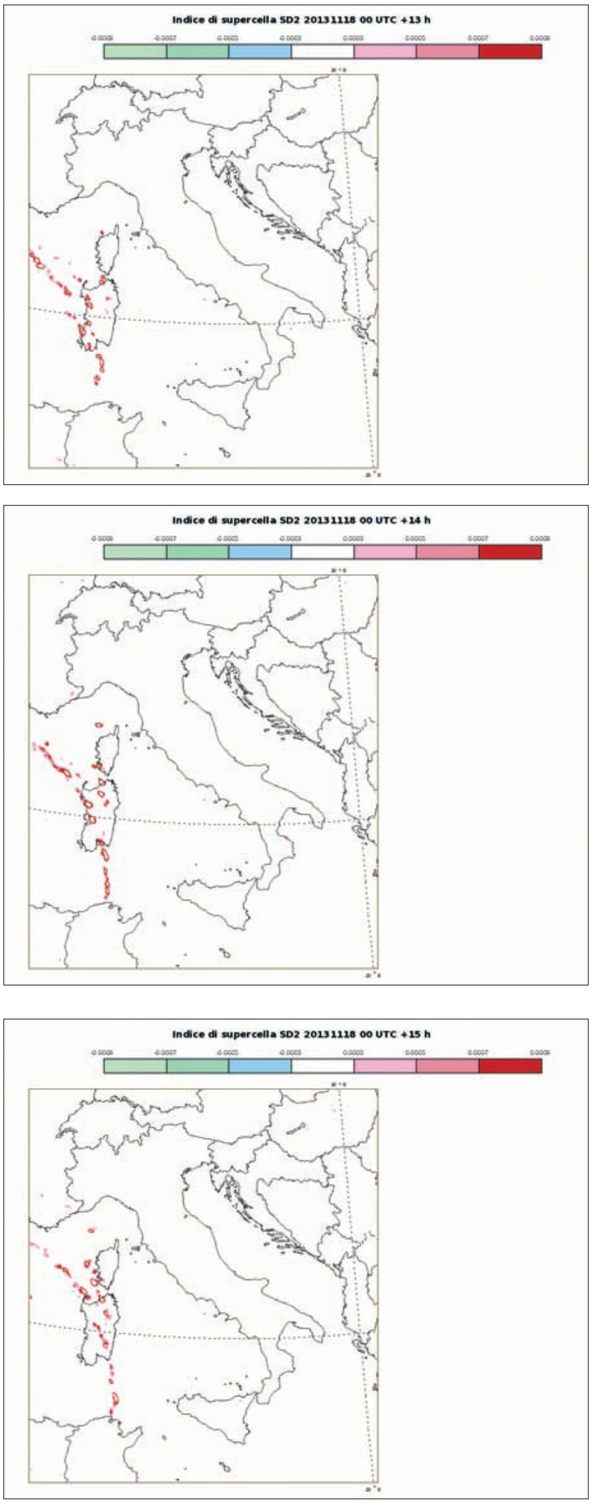


Figure 5: SD2 Index output Cosmo Me Run November 17, 2013 00 UTC VT +37-39 h.

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” outlined the characteristic of severe storm cells, which in these cases are usually organized in lines lasting several hours.

Lifecycle

By the morning of November 18th, all Italian western sea areas were affected by the humid and unstable southerly flow connected to the low pressure system located over the western Mediterranean. At the same time, in the upper troposphere the vortex was centred between Spain and Morocco. Additionally, a southwesterly branch of the jet-stream affected the whole northern portion of the African coast as well as Sicily (Fig.6).

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

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

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

On Monday afternoon the cyclone moved eastwards causing the storm that affected the Campidano area

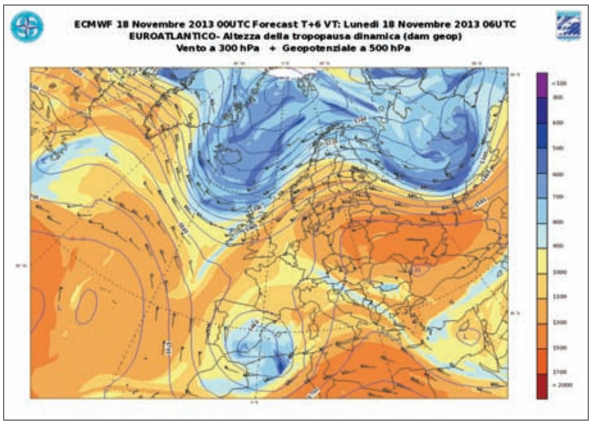


Figure 6: dynamic Tropopause from ECMWF November 18 06 UTC.

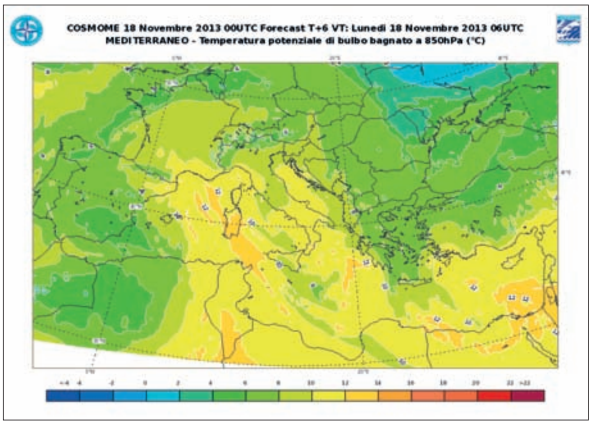


Figure 7: wet Bulb Potential Temperature at 850 hPa (aw) November 18 at 06 UTC.

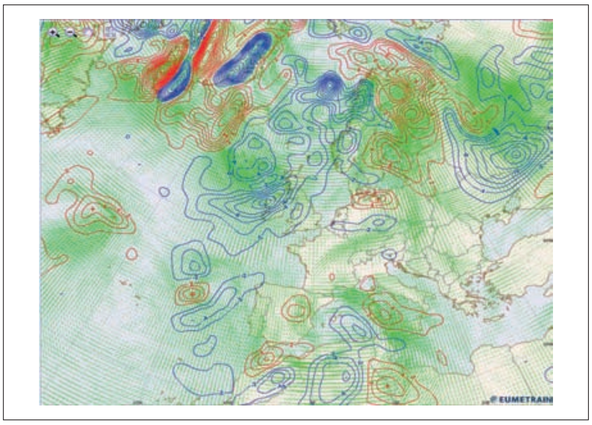


Figure 8: d850 hPa wind and 700 hPa thermal advection (cold blue, warm red) November 18 at 06 UTC.

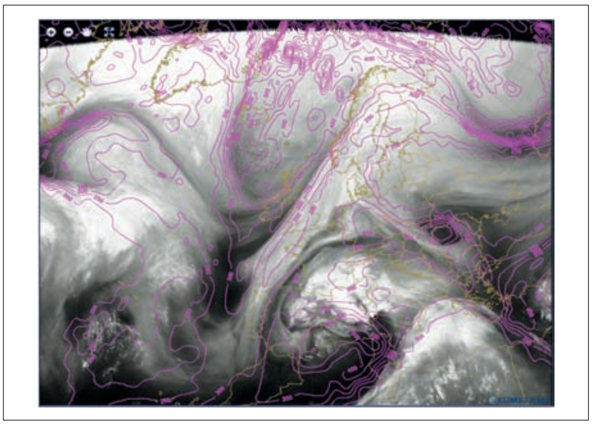


Figure 9: MSG3 WV6.2 and Dynamic Tropopause November 18 at 12 UTC.

(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 m (Fig. 13).

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

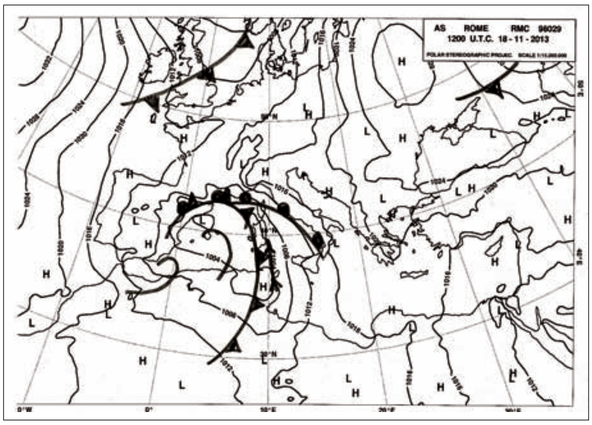


Figure 10: surface Analysis November 18th at 12 UTC.

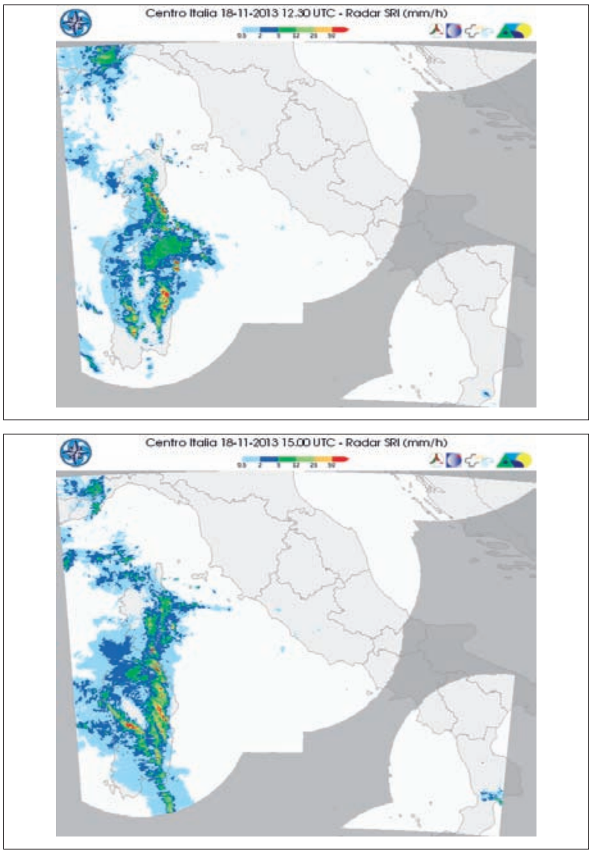


Figure 11: radar echoes November 18th, 2013 at 12.30 (A) and at 15.00 (B).

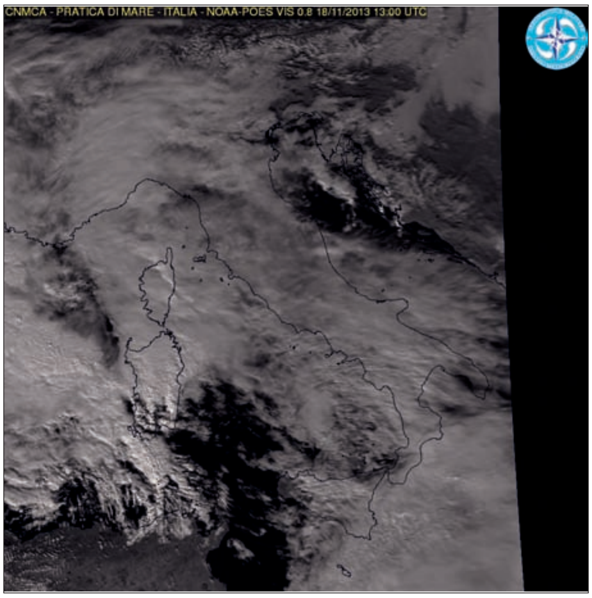


Figure 12: NOAA POES VIS 0.8 m 18th november 2013 at 13.00 UTC.

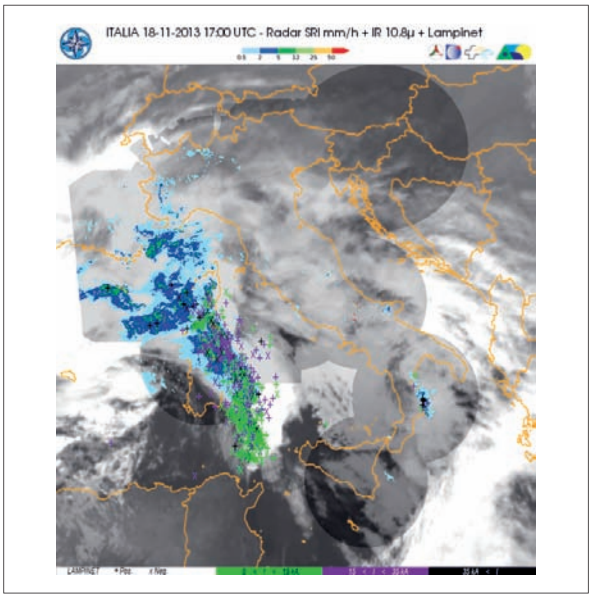


Figure 13: NOAA POES VIS 0.8 m 18th november 2013 at 13.00 UTC.

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

The convergence line, deployed all along the warm sector, overtook the island, leaving on the ground an extreme amount of precipitation.

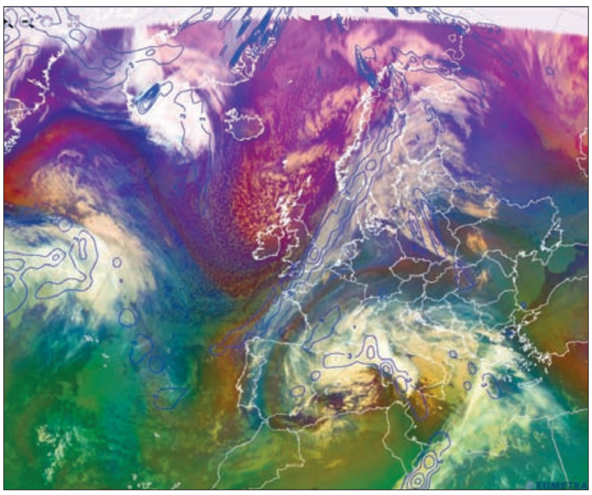


Figure 14: MSG3 RGB airmass and TFP November 18th, 2013 at 18.00 UTC.

Figure 16: total Accumulated Rainfall on November 18th, 2013 over Sardinia from Civil Protection Obs Network.

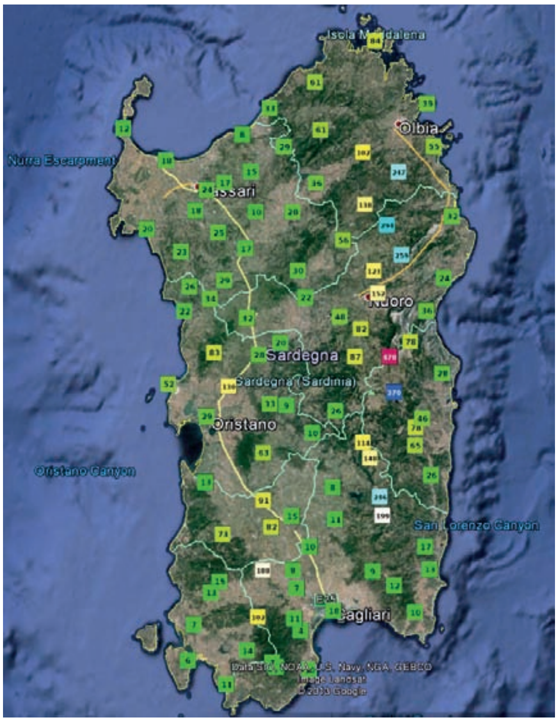


Fig. 16 shows the cumulative rainfall over Sardinia, collected thanks to the raingauge network owned by the Italian Civil Protection Department. Matching these data with the daily extreme rainfall (fig. 17) proves the exceptional nature of the event.

Final Remarks

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

- The amount of rainfall must be considered extreme, being much larger than climatic values.

- 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).

- The 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: the risk of flooding over western and northwestern Italy (Sardinia, Liguria, Piedmont, northern Tuscany) is 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).

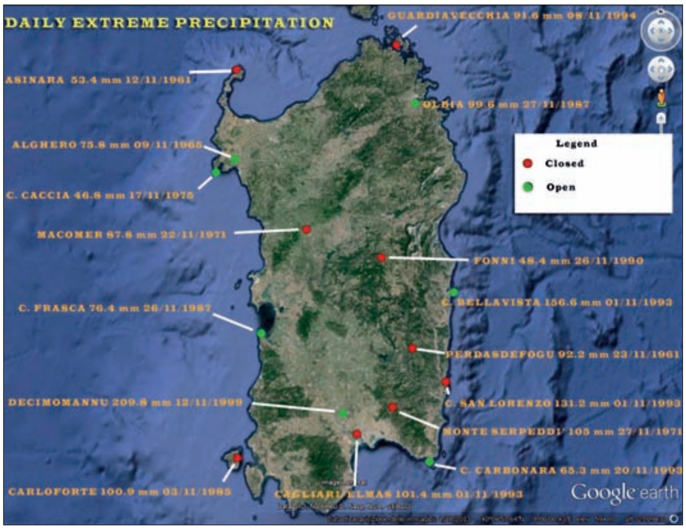


Figure 17: daily extreme rainfall from Italian NWS climatological archive.

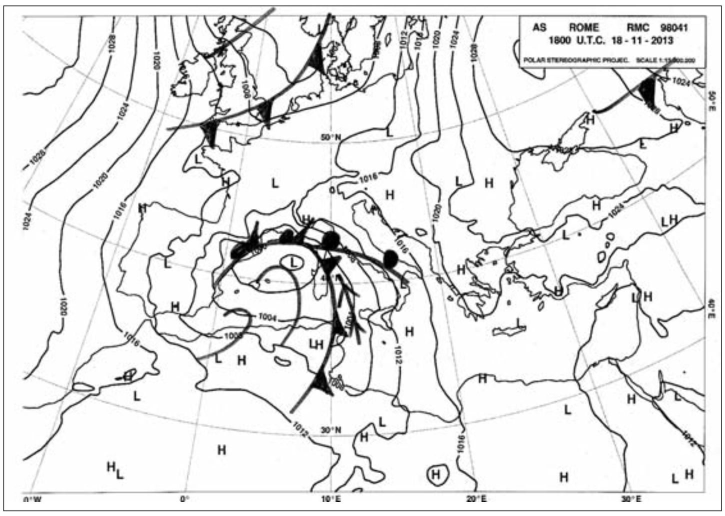


Figure 15: surface Analysis November 18th, 2013 at 18.00 UTC.

References:

[1] Satrep Manual
http://www.eumetrain.org/satmanu/SatManu/main.htm

[2]
http://cosmomoel.org/content/tasks/operational/usam/ default.htm

[3]
http://www.cosmo-model.org/content/model/documentation/ techReports/docs/techReport17.pdf