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Application and verification of ECMWF products 2017

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1. Summary of major highlights

ECMWF HRES model output from both 12 and 00 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 and COSMO-ME-EPS). Verification of ECMWF products is carried out at COMET 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 ECMWF model output

2.1.1 Statistical adaptation

A statistical post-processing system, named SIBILLA (Statistical Integrated Bayesian Information from Large to Local Area), aiming at the refinement and downscaling of the ECMWF seasonal forecast model output through an artificial neural network adaptive approach is used. This system runs on a decade basis providing monthly and three-months outlooks of significant atmospheric variables over Italy.

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.
The Metview module FLEXTRA is being used to trace contaminant dispersion in case of nuclear, chemical or biological incident/accident.
Meteorological CBRN messages as well are generated and distributed according to NATO directives and other agreements.
The ECMWF model data are also used as boundary conditions in the following components of the operational short-range numerical forecasting system:

- Ensemble Kalman Filter (EnKF) Data Assimilation System based on the COMET-LETKF algorithm and the high-resolution non-hydrostatic model COSMO integrated over the Mediterranean-European region (40+1 members, 10km, 45 vertical levels);
- COSMO-ME EPS short-range ensemble prediction system initialized by the COMET-LETKF ensemble analysis and running twice a day (00 and 12 UTC) up to 72 hours;
- COSMO-ME deterministic model integrated up to 72 hours over the Mediterranean-European region (5km, 45 vertical levels), four times a day.

In the COMET-LETKF assimilation cycle and COSMO-ME EPS system the HRES and ENS ECMWF data are both used to generate the perturbed lateral boundary conditions. In particular, 40 randomly selected perturbations from ENS fields (ensemble member minus ensemble mean) are added to the most recent HRES fields. These HRES data are also used as boundary condition for the COSMO-ME deterministic model.)

2.1.3 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 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 being produced 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 ECMWF products

2.2.1 Use of Products

CNMCA uses ECMWF products from ecChart, ECMWF web-site and from our operational web-site, where most of the products are replotted for Italy area.
CNMCA mission is to to issue severe weather warnings and to support the National Civil Protection Department. Our main warnings usually are issued at 12.00UTC and not before 18-24 hours before the severe weather event begins.
At 10.00L the forecaster discuss his decisions about the warnings with the Civil Protection Department, unfortunately between end march to end October without using all the ENS products, because for example EFI are available after 10.00L. Anyway in this period, at 09.40, closed before the discussion we have short time only to see the total precipitation probability maps, which start to be available. Before issuing the warning at 12UTC we also look at EFI-SOT with model climate, CDF, ecChart, for example to have more detailed information (probe-window), the clickable charts at www.ecmwf.int, which are very useful to have together punctually ENS and HRES values in ENSgrams and maps.
We appreciate the ECMWF web-site cloud cover representation, which is the best way to show three cloud layer in a single map.

Finally extended forecasts are also used in the operational forecasting room to issue monthly forecasts available weekly on our public website www.meteoam.it.

2.2.2 Product requests

1. On www.ecmwf.int, EFI with more geographical domains.
2. Clickable chart: Prob total precipitation in 6 hours step 6 hours with threshold 15mm
3. On ecchart Probe for EFI with hundredths (i.e. EFI=0,79)
4. On ecchart regional boundaries
5. New GRIB parameter: maximum temperature at 2m in the last 24 hours

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS)

Local weather parameters verified for locations
Objective scores are computed for ECMWF HRES 12 and 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).

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 this report, data covering the 1-year period from JJA 2016 to MAM 2017 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, optimized by the "smaller" difference in altitude combined with the horizontal distance between a station and the corresponding grid point. 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 CNMCA centre (now named COMET) 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, around 1.5-2 m/s in spring and fall, 1.7-2.3 m/s in winter and 1.4-1.8 m/s in summer, with a tendency to slightly increase with forecast step.
2m Temperature: clear diurnal cycle in both ME and MAE especially in winter and spring. 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 2.4 K (reaching up to 2.9 K in winter).
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) is around 6-12 mm/12h in fall and spring, 03-10 mm/12h in summer and around 12-25 mm/12h in winter. 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.

3.1.2 ECMWF model output compared to other NWP models

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 (7 km resolution) for d+1 and d+2 over the Italian area. Results are shown in the Appendix A. COSMO-ME forecasts are also used in the air base weather offices and are generally available one hour before the ECMWF HRES forecasts.
Respect to the FBI scores, COSMO-ME and ECMWF show a similar behaviour, with an overestimation for the lower thresholds and a general underestimation for the higher thresholds; for the lower thresholds COSMO-ME model shows better values that are closer to 1 (around 1.4) respect than the ECMWF model (around 2.0), in all seasons. In general higher thresholds are underestimated with both ECMWF and COSMO-ME models, whereas the overestimation is less evident in COSMO-ME than in ECMWF model.
Accuracy, represented here through ETS score, tends to be slightly higher for COSMO-ME for lower thresholds for all seasons.

3.1.3 Post-processed products

3.1.4 End products delivered to users

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

3.2 Subjective verification

3.2.1 Subjective scores

3.2.2 Case studies

Case Study (COMET): Liguria, November 21st -23rd 2016
Warm Conveyor Belt (WCB) association role with orographically induced confluence lines, due to katabatic local or mesoscale effects, is here taken into a consideration in the aim of justifying atmospheric conditions responsible of intense and persistent rainfall over western Ligurian sites, particularly between Genoa and Savona, November 21st, 22nd, 23rd 2016. A primary role is here accorded to due to such relatively warm African air flux which, being unstabilized by humidity acquired moving over the sea, comes into a collision with already existing colder and drier air masses determining potentially unsettled atmospheric conditions. On the other hand, Convergence Line role is fundamental in quick and remarkable atmospheric unstabilizing. Convective phenomena so produced are depending from different air masses contrast as well as jet stream, classical carrier for shorter baroclinically induced Bjerknes waves, did not play any role in such a case.

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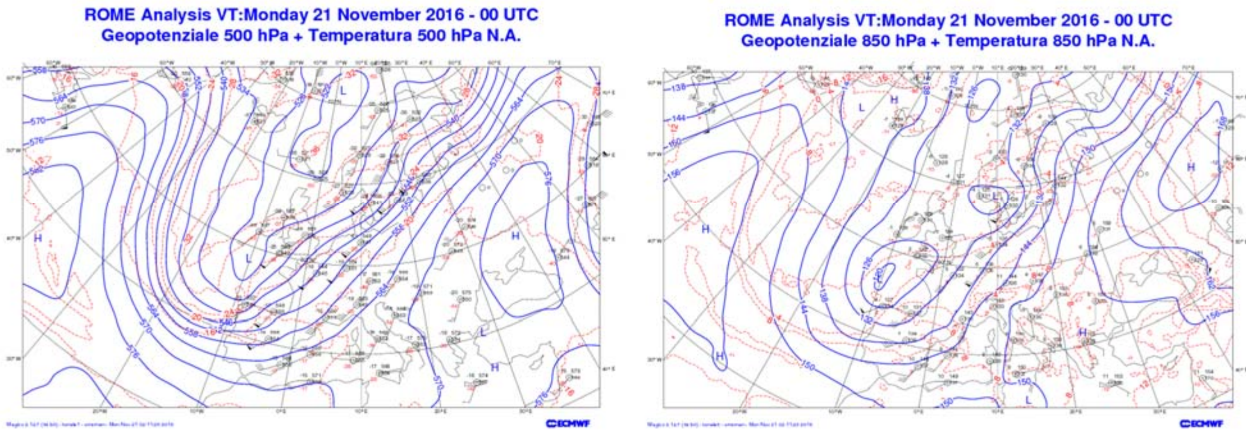

Fig. 1: Analysis chart (upper level and low level) on November 21st 2016, 00UTC. An upper level trough is evident corresponding to a ground frontogenesis with WCB prefrontal flow individuated by circulation and thermal advection.

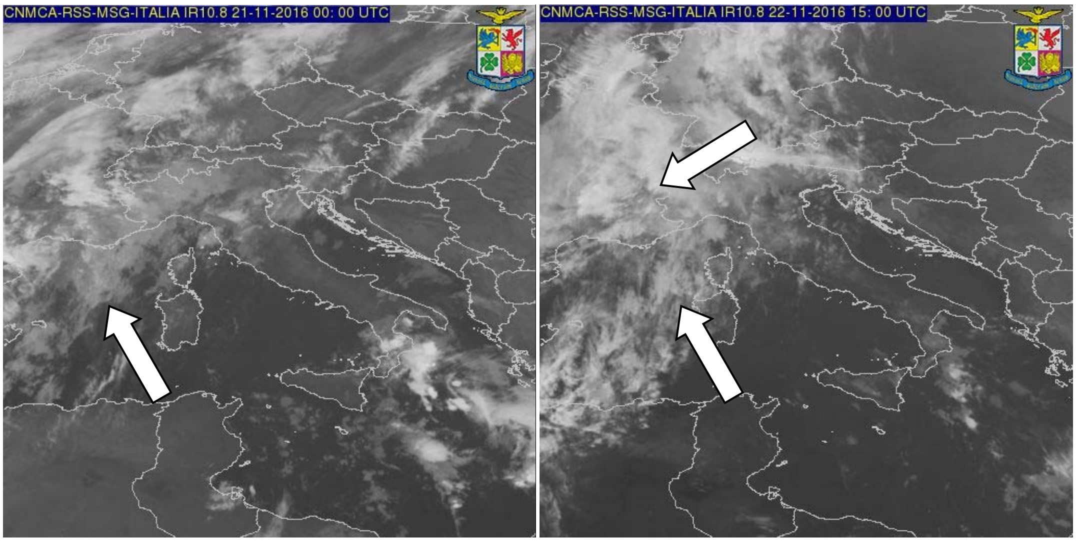

Fig. 2: Satellite IR cannel showing already on November 21st, 00.00 UTC, a prefrontal warm flow over Western Mediterranean region with un regular cloudiness. This means orographic thermodynamic processes are in progress. On November 22nd, 15 UTC a convergence line is evident, between Liguria and Southern Pedmont, where WCB is enforced by main wave trend to generate a tear off.

Analysis charts (figg 1, 2) show already on November 21st 2016, Euro-Atlantic scenery characterized by a mid latitude classic frontogenetic development, following a deep high level trough extending from Island down to Iberian Peninsula and near Atlantic area (fig 3), evident even in November 22nd analysis (fig 4).
This configuration is based on the presence of a strong block anticyclone over Russian area, limiting its zonal circulation, being fed (at lower levels) by a WCB with rearward behavior. It blows continental warm and dry African air all through Mediterranean sea which, having quite peculiar hygrometric characteristics, enhances the ordinary air mass unstabilizing process due to thermodynamic air mass and sea surface exchanges (fig 5). Such an air flow is going to acquire moderately unstable dump air features, slowly lifting up to produce an upper level thickness ridge. By the way a portion of such WCB is projected through Tuscan-Emilian Apennines orography, into a cooler and drier sector which it assumes characteristics of, initially as an anabatic wind suffering falling pressure and temperature and causing a part of its water vapor phase transition, then getting a rearward like rotation before coming down over Gulf of Genoa in form of heavy and dry air orographic falling wind which, overlying warm and humid air masses, unstabilizes low layers into a local dynamic depression reminding a monsoon development process (fig 6).

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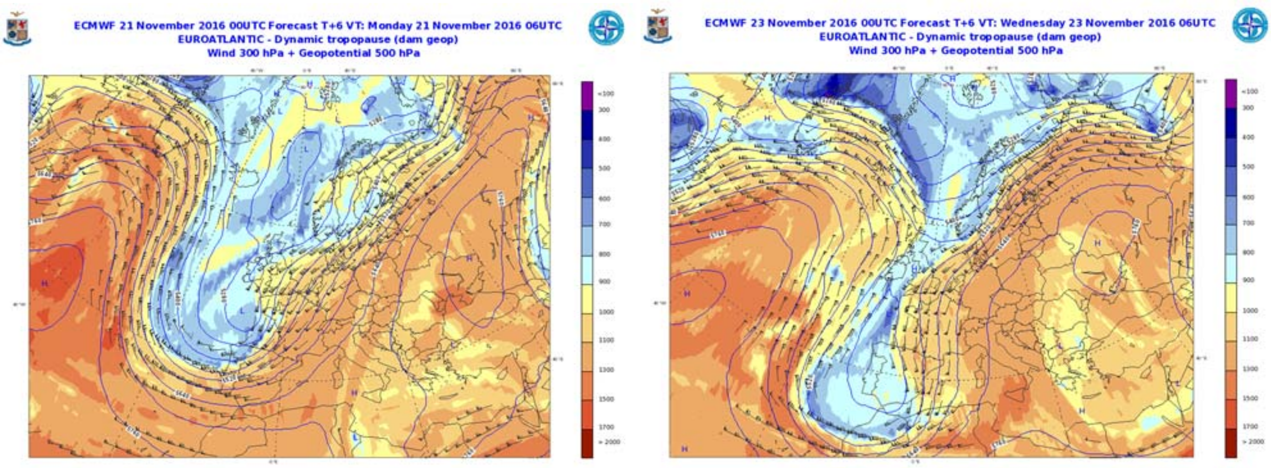


Fig. 3: Forecast charts (ECMWF global model, November 21st, 00.00UTC, T+6hours and November 23rd, 00.00UTC, T+6hours) for Dynamic Tropopause, showing jet stream different branches (300 hPa wind) and air mass movement being produced by upper level convergence/ divergence: Russian block anticyclone effect is noticeable, determining a tear off like configuration within the main part of tropopause anomaly assuring persistence of such synoptic subject influence

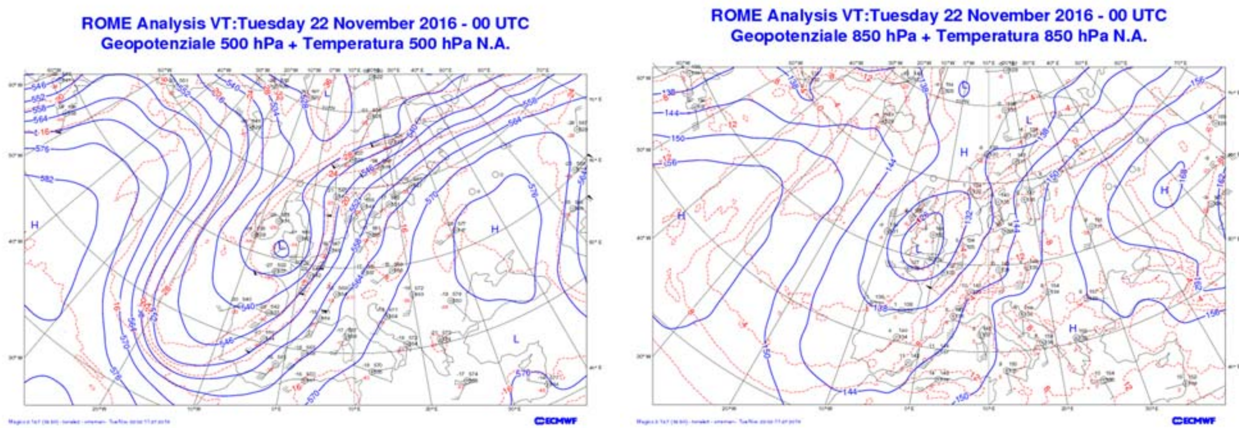


Fig. 4: Analysis chart (upper level and low level) on November 22nd 2016, 00UTC .

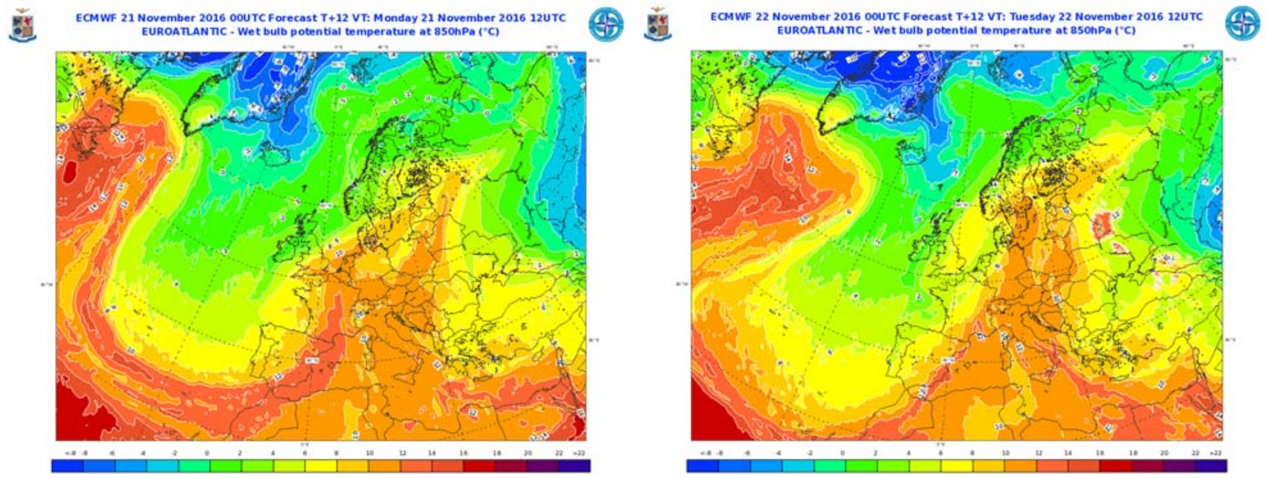


Fig. 5: Forecast charts (ECMWF global model, November 21st, 00.00UTC, T+12 hours and November 22nd, 00.00UTC, T+12 hours) for 850 hPa Potential Wet Bulb Temperature. Such parameter is a valid classic front and pseudofront tracker (even if its efficiency gets partially disabled during summer time over Mediterranean area). Different air masses and WCB branches are visible

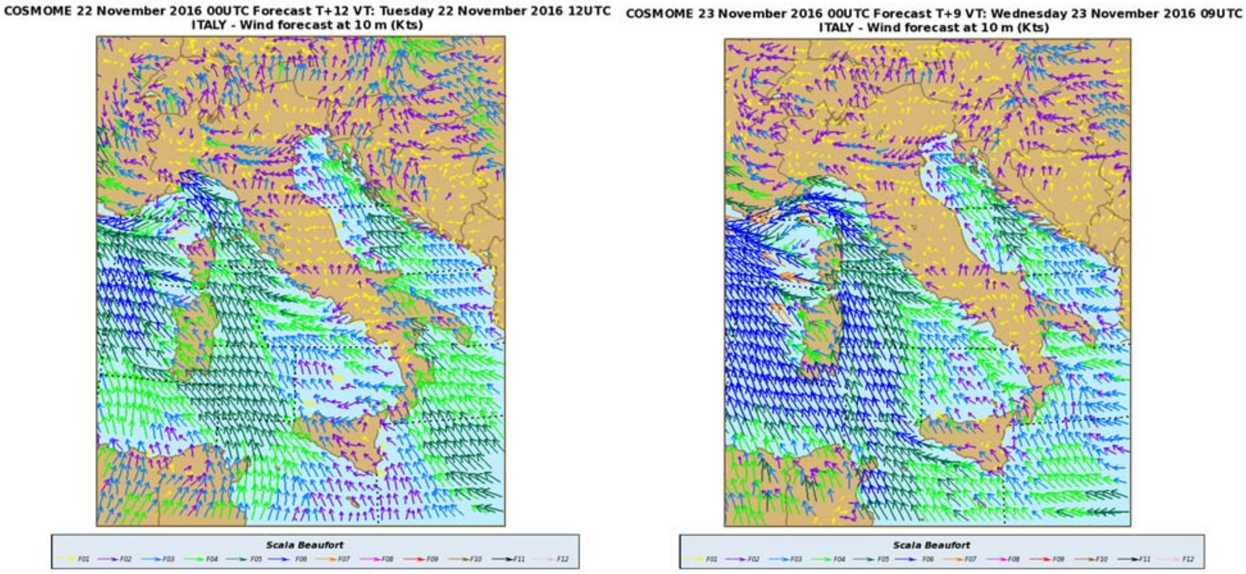


Fig. 6: Forecast charts (COSMO-ME local model, November 22nd, 00.00UTC T+12hours and November 23rd, 00.00UTC T+9hours) for 10m wind: convergence over Western Liguria and Provence is noticeable, by ascending air masses from southern sector and falling down from Apennines with a cyclonic like rotation

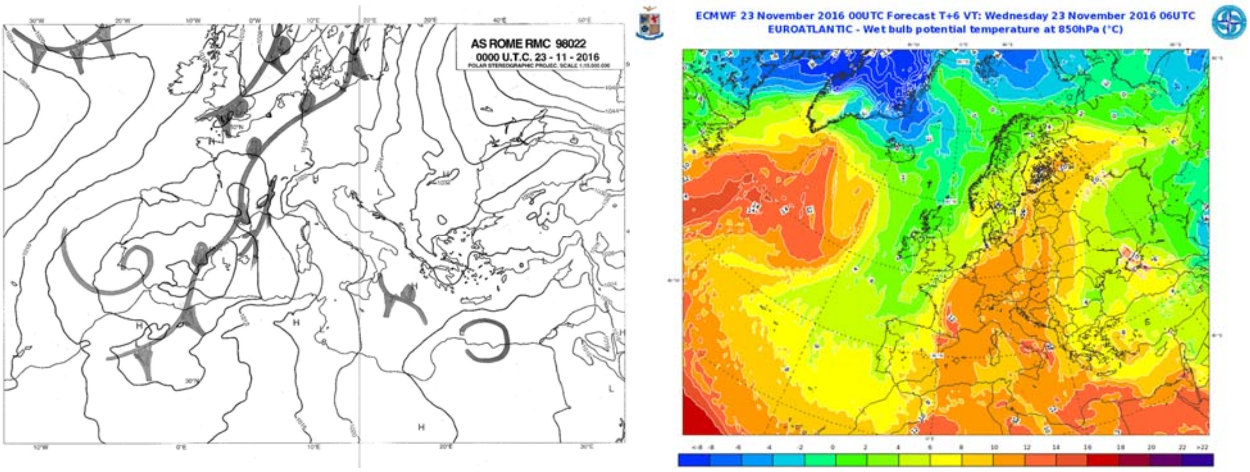


Fig. 7: Analysis chart on November 23rd 00 UTC with detected convergence line in prefrontal position over Liguria. Forecast chart ECMWF global model, November 23rd, 00.00UTC, T+6 hours, for 850 hPa Potential Wet Bulb Temperature: ground air masses played role is evident as synoptic wave advanced tear off stage.

Such upper and low level air masses circulation attitude is extending at a synoptic scale and at mesoscale for a few days time range because of the already mentioned anticyclone. In fact November 23rd, 00.00UTC analysis confirms a solid convergence line presence over Gulf of Genoa and Provence (fig 7), very active and represented as prefrontal with moderate wind. By the way fig.3 shows main waves at synoptic scale not interfering with this area tear off like circulation to November 24th at least.

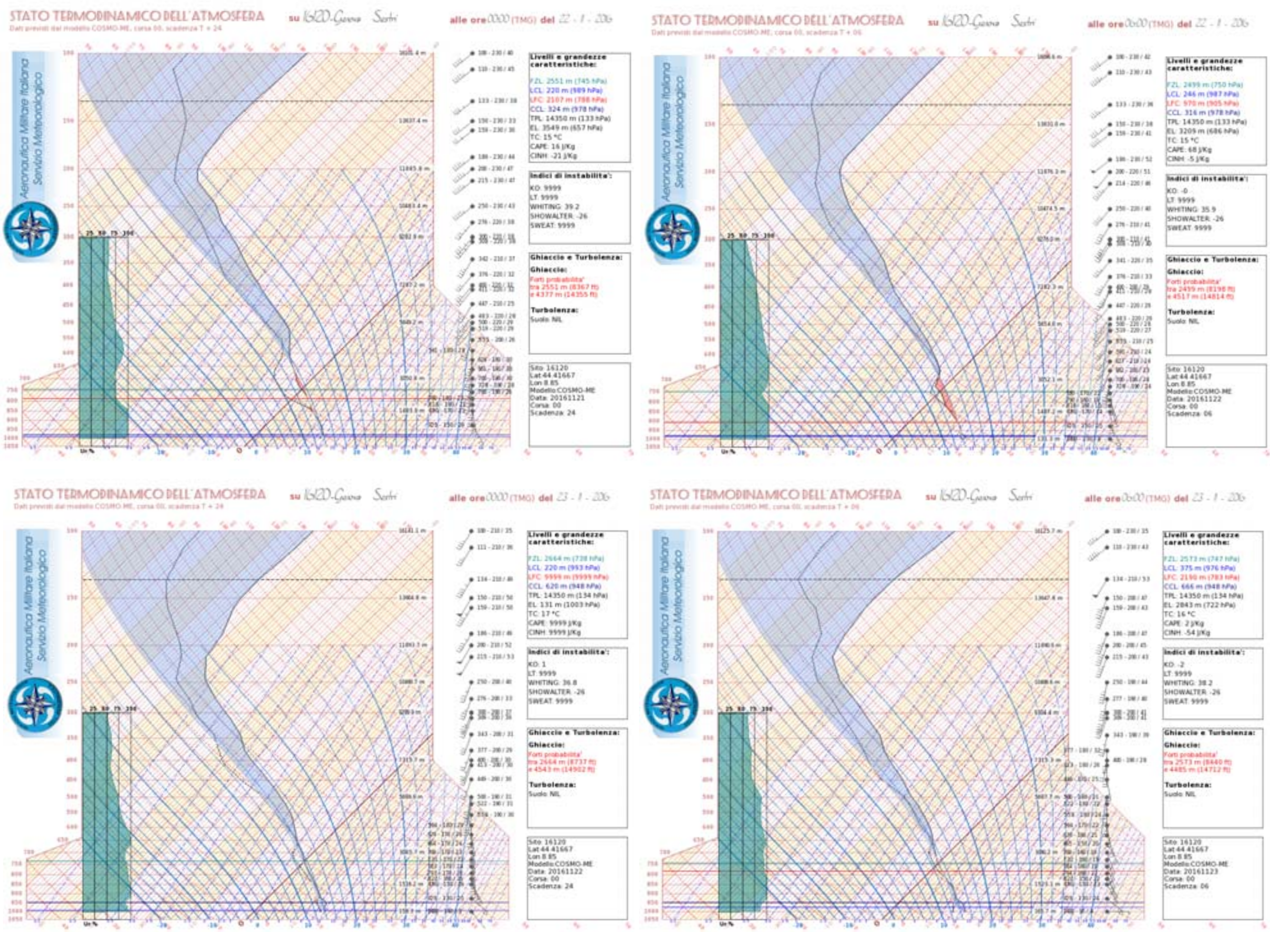


Fig. 8: Forecast Thermodynamic Sounding (COSMO-ME local model) night November 21st-22nd and night November 21nd-22rd over Genova Sestri on Herloffson nomogram. Showalter convective instability index value looks quite negative under 850 hPa level; CAPE value not excessive but air column saturated since lower levels.

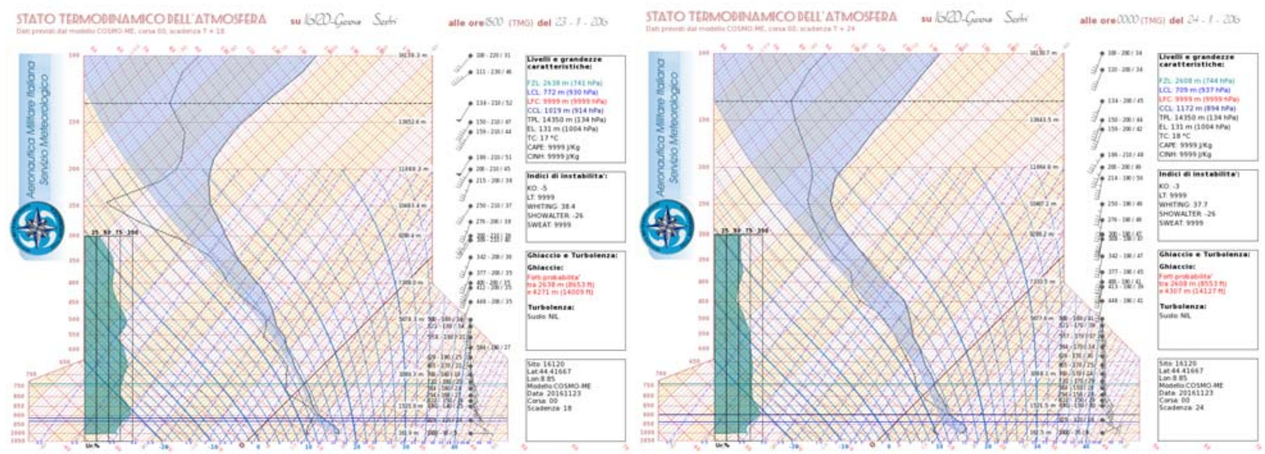


Fig. 9: Forecast Thermodynamic Sounding (COSMO-ME local model) on November 23rd over Genova Sestri on Herloffson nomogram. Instability index KO fall is evident with values showing high tropospheric instability.

The above described situation determinates a local depression as resulting from Herloffson nomogram (figg 8, 9), with a relatively reduced size CAPE air column is humidity saturated and ice formation probability is high (thermal zero between 800 and 950 hPa). Thermodynamic Sounding is showing, by some indexes, air mass attitude to get quite convectively unstable. Showalter index, objective instability evaluation (with confidence for next 6-12 hours), looks definitely negative diagnosticating severe thunderstorms possibility (limited in hygrometric state on top air column though). Whiting index, air mass instability evaluation by thermal and hygrometric values test in low troposphere (between 850 and 500 hPa), shows moving values between 36 and 38, which means severe thunderstorm like activity "very high" probability (values exceeding 30). KO index (consistently lower layers humidity and saturation testing by potential equivalent temperature measurement, being constant within adiabatic processes) November 21st and 22nd is between 1 and -2 (thunderstorm possibility/ probability) but on November 23rd dropping down to -5 (severe thunderstorm probability with hail), which means thunderstorm matrix is changing: it is the phase when classic frontogenesis is overlying to instability line enhancing phenomena again. The same index is currently recognized as tornadoes development possibility detector (values less than -6).

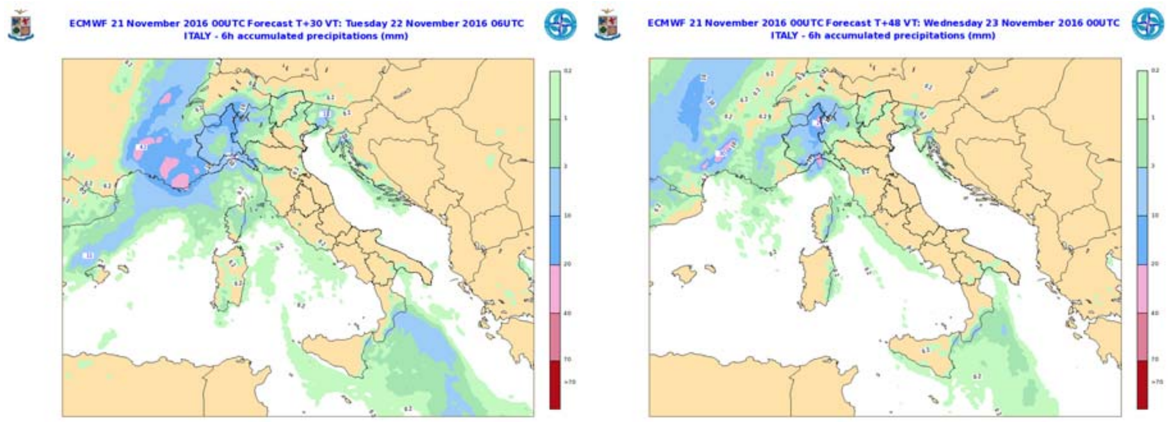


Fig. 10: ECMWF global model Forecast chart 6hours Accumulated Precipitation, November 21st, 00.00UTC, respectively from T+24 to T+30 and from T+42 to T+48 hour: what is noticeable is that the main phenomenology is located within a strip west side of Genoa, exactly where instability line lies.

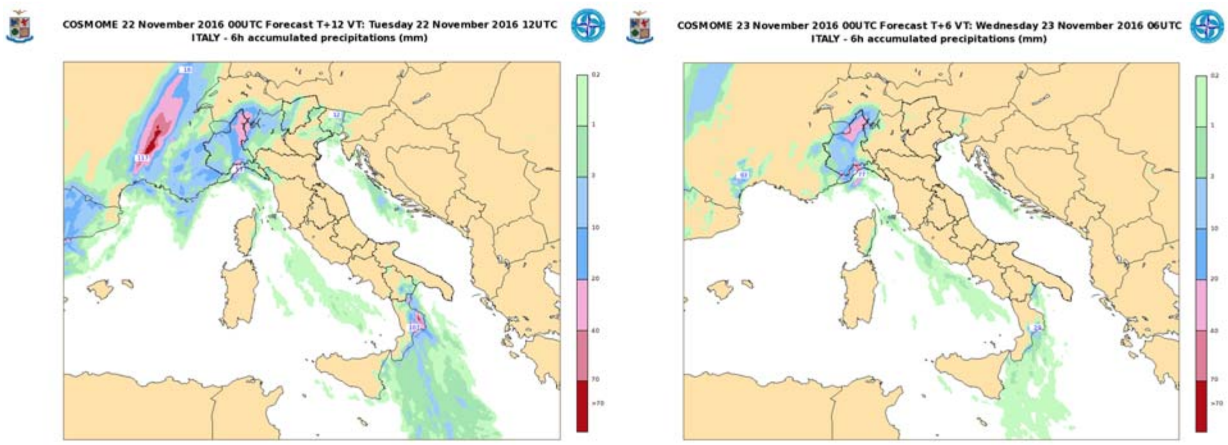


Fig. 11: COSMO-ME local model Forecast chart 6hours Accumulated Precipitation, November 22nd, 00.00UTC, from T+6 to T+12 hours, and November 23rd, 00.00UTC,from T+0 to T+6 hours: main phenomenology is confirmed to lie within the same strip west side of Genoa. Rainfall within WCB looks low or moderate as no forcing terms are present there.

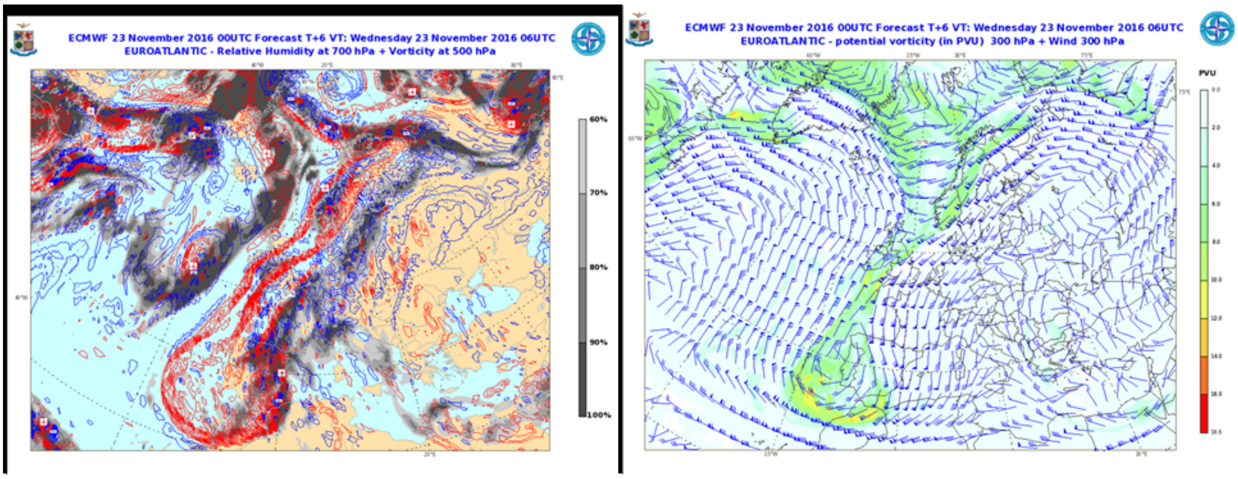


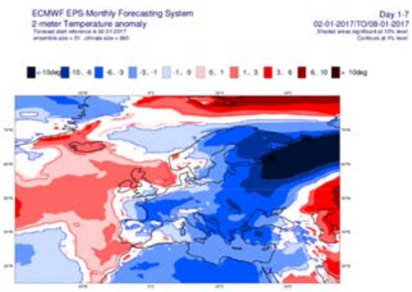
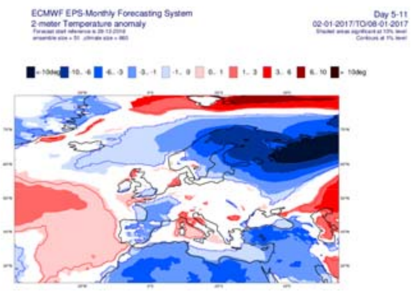
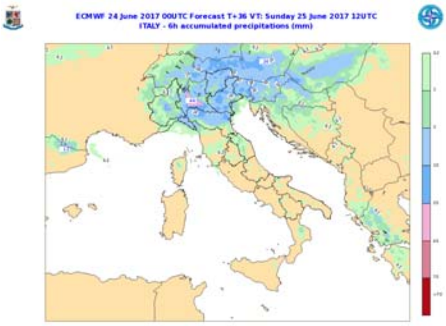
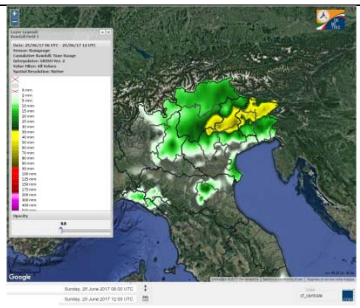
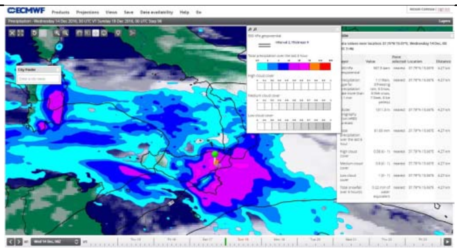
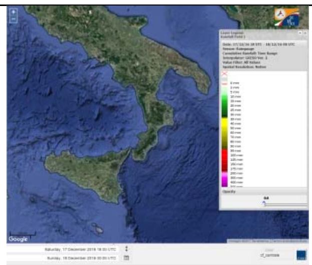
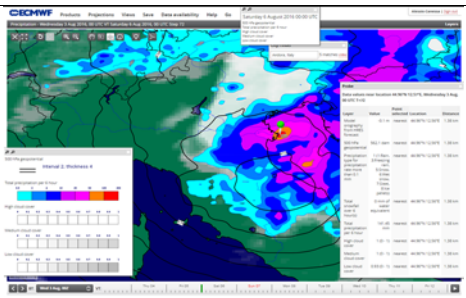
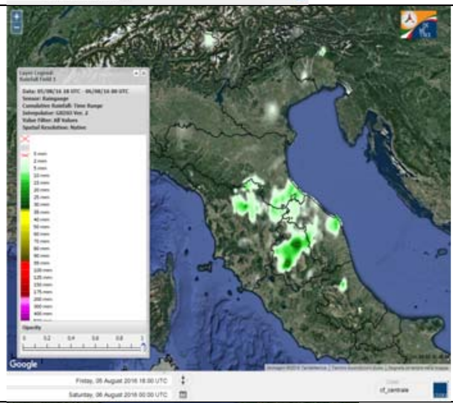
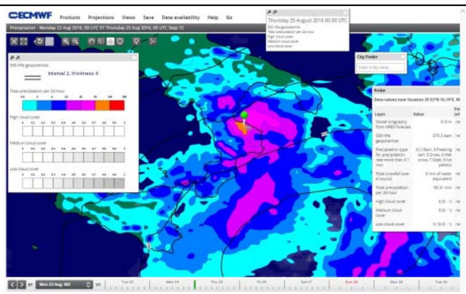
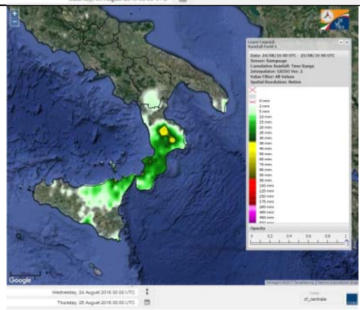
Fig 12: Forecast charts (ECMWF global model, November 23rd, 00.00UTC, T+6hours) respectively for 700 hPa Relative humidity / 500 hPa Vorticity and 300 hPa Potential Vorticity and Wind

All these rainfall incidents have been well forecast as short–medium range by global mode since run 00.00UTC on November 21st (fig 10): more precisely precipitation affected Pedmont Apenninian side, Asti and Cuneo area on November 21st (in the morning), with a wide space distribution although resulting not too heavy (upwind WCB branch over Apenninian area phase); severe rainfall thunderstorm like with lightnings have been detected the following night November 21st and 22nd (between 00.00 and 02.00 am, local time), limited over a few local Ligurian areas and particularly over Orba Valley, extended from Asti surroundings down south to Voltri, just west side of Genoa (much less rainfall occurred anywhere else). Such activity resulted persistent with some heavy intensity phenomena all day long on November 22nd up to reach a night exceptional relevance (electric activity consistency was concentrate dover the right Orba Valley profile) with severe phenomena till the whole following morning, on November 23rd (about 600mm rainfall have been locally recorded within these three days). All described incidents have been forecast then as very short range by local model COSMO-ME, because of its specific of showing less default humidity at the lower thresholds, differently from ECMWF model, and resulting more sensible with heavy and quick rainfall, up to T+36 hours (figg 10, 11). On November 23rd and, even more, on November 24th, a classic front overlied the scenery with scattered precipitations associated, starting from upwind Alpine and Apenninian sides but then again over Western Liguria (as clear by thermodynamic sounding KO index in fig 9), and still thunderstorm like activity, dynamic this time, going on to next day when phenomena disappeared. November 25th is the time when such configuration comes to its end leaving space to a new circulation phase, characterized by a classic dynamic and cold, typically unstable frontogenesis, with spreading rainfall, sometime thunderstorm like. It is evident from fig 12 (even fig 3, right) the main synoptic wave still suffers Russian anticyclone block, so accumulating energy determines a tear off which develops then into a cut off configuration, physiological phases for such kind of subjects. This phase occurs at high levels because of a jet branch detachment with relative PVU anomaly, refilled by absolute vorticity advection inducing ground cyclonic rotation as WCB rearward rotation. WCB warm flow penetrates a cold dry air mass making it unstable (main concept in the theory of Baroclinic 2 Level Model). Next cut off phase leads to accumulated Energy progressive exhaustion and phenomena ceasing.

The intense precipitations, mainly thunderstorm like, being affecting Western Liguria between November 21st and 24th took their origin from an air masses contrast: specifically a warm humid flow moving into a preexistent colder dry environment with forcing term given by cold and dry mountain katabatic winds. This determined potentially unstable atmosphere stratification which allowed ascending air movement. Precipitations can be associated initially to WCB presence and the following amplificating tear off within colder air mass but, more specifically, to the prefrontal confluence line pseudo monsoon cell like structured activated by spiral pressure minimum low circulation generated over western Gulf of Genoa sector by katabatic winds incidence with WCB. The whole precipitation have been widely forecast by ECMWF global model, with more than acceptable good quality at short-medium time range, although some specifics, as said, regard very low and extremely high thresholds, and a warning has been issued together with Civil Protection. The same rainfall regime has been monitored by COSMO-ME local model within very short-short time. In this case study WCB importance has been underlined as a conceptual model, and convergence lines well, as a conceptual model too, in the context of different air masses contrast which, as demonstrated, outlooks absolute relevance about mesoscale incidents, to increase knowledge in the frame of wider circulation situations.

Other Case Studies (CNMCA)

We have noticed that the total precipitation's maxima per 6 hours are much bigger than in the past, with sometimes peaks close or even bigger to the observed precipitation maxima.

Case studies		
The monthly forecast for the second week Day 5-11 (2-8 january 2017) was wrong over Italy (warm anomaly instead of cold anomaly).		
	Precipitation forecast	**Observed precipitation**
25 june 2017 06-12UTC Over Veneto region HRES+36h and ENS underestimation max 20mm/6h forecast Prob 5-35% >15mm/6h 60-100mm/6h observed		
17-18 december 2016 18-00UTC Eastern Sicily HRES+96h and ENS overestimation max 61,65mm/6h forecast Prob 63% >10mm/6h 0mm/6h observed		
5-6 august 2016 18-00 UTC Emilia-Romagna e Marche HRES+48h+96h Overestimation ENS low prob max 141,45mm/6h forecast 0mm/6h observed		
24 august 2016 00-24 UTC Calabria HRES+72h Overestimation max 95mm/24h forecast max 50-60mm/24h observed		

4. Feedback on ECMWF "forecast user" initiatives

As last year we invite comment on whether you use the following, on how useful you find them, and on any changes you would like to see:

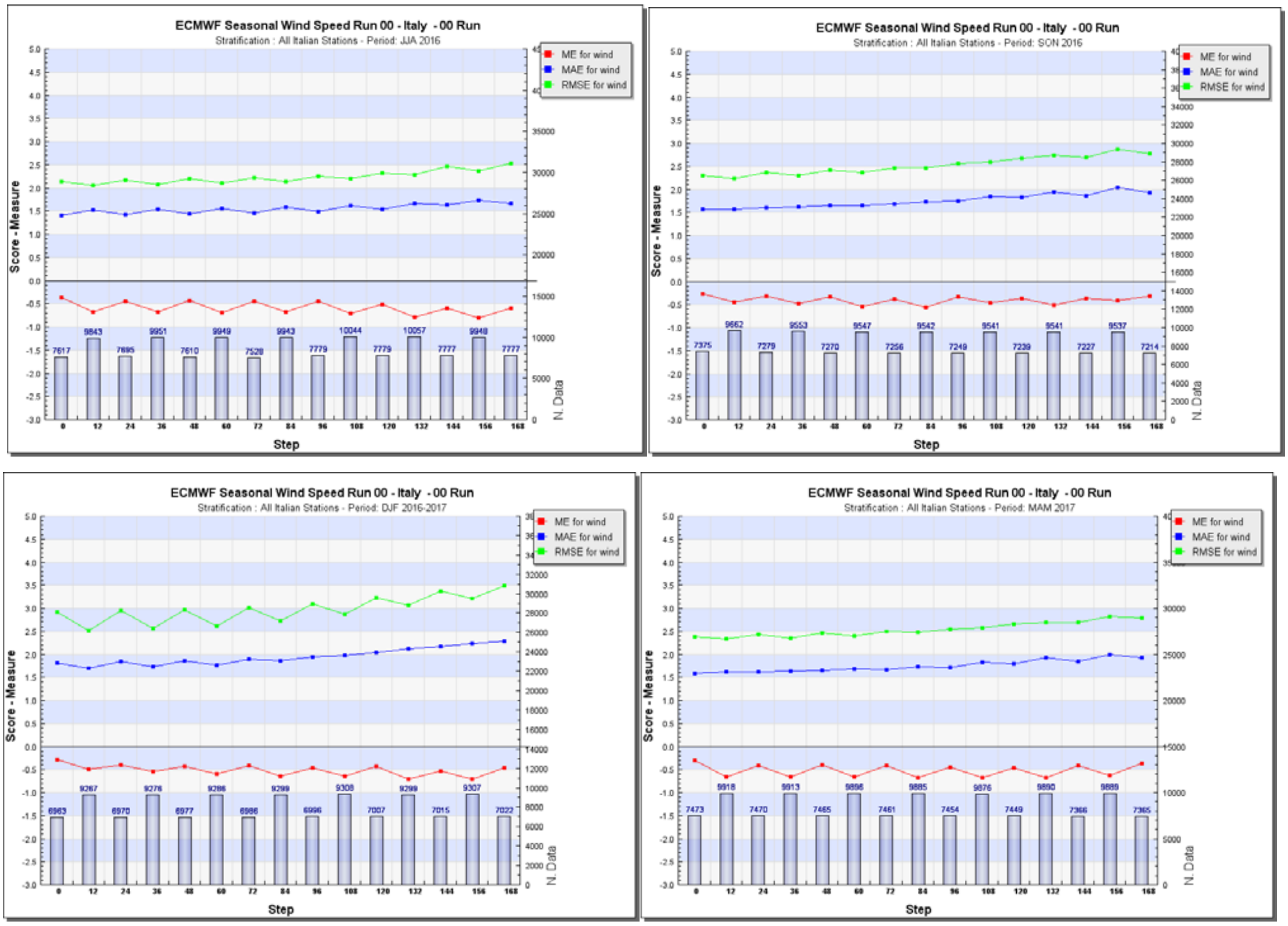
- "Known IFS forecast issues" page – (https://software.ecmwf.int/wiki/display/FCST/Known+IFS+forecasting+issues)
- "Severe event catalogue" (https://software.ecmwf.int/wiki/display/FCST/Severe+Event+Catalogue).

Both pages are very interesting and useful, but hard to find from the webpage www.ecmwf.int.

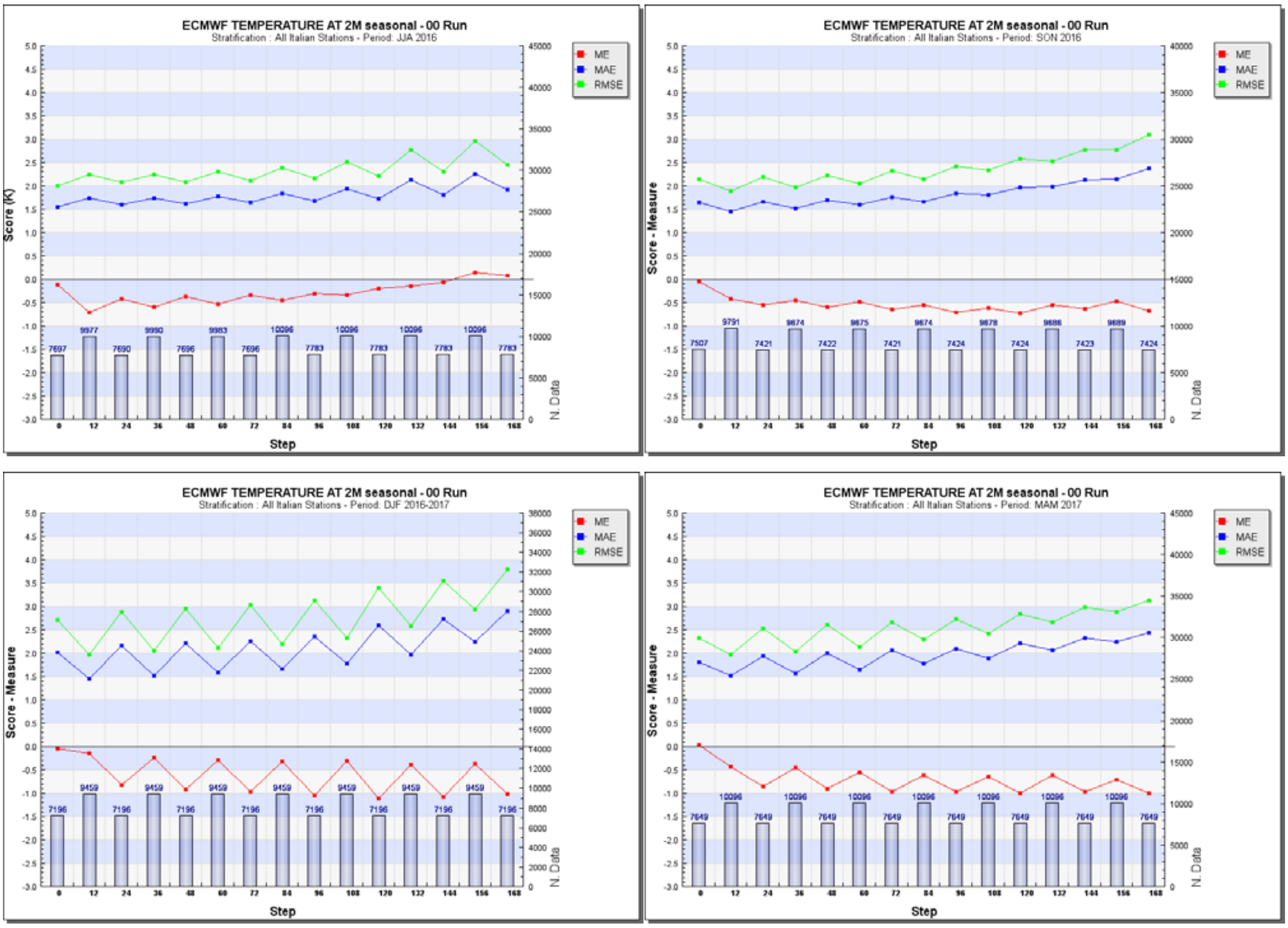
5. References to relevant publications

Appendix A of Report ECMWF 2017 -- ITALY

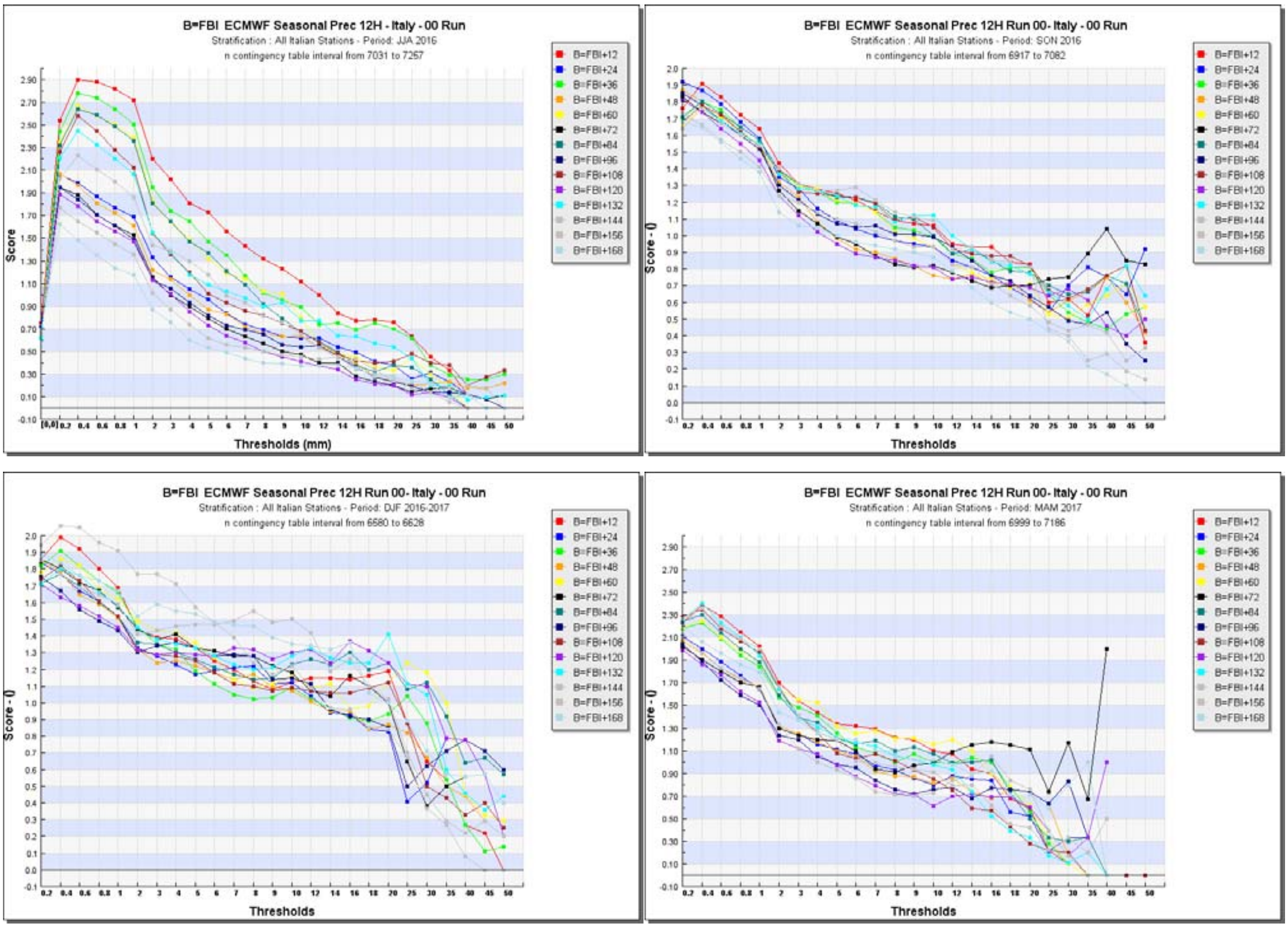
IFS 10m Wind Speed (Mean Absolute Error, Mean Error and Root MSE)



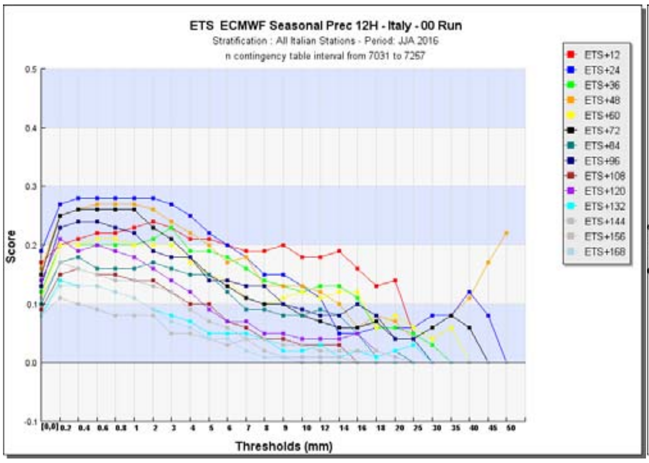
IFS 2m Temperature (Mean Absolute Error, Mean Error and Root MSE)

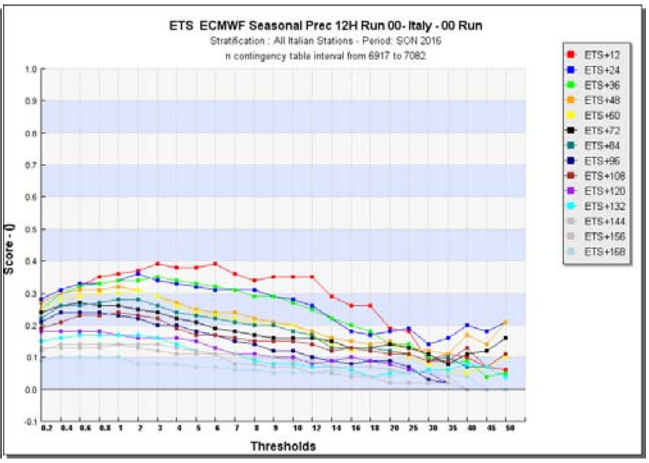


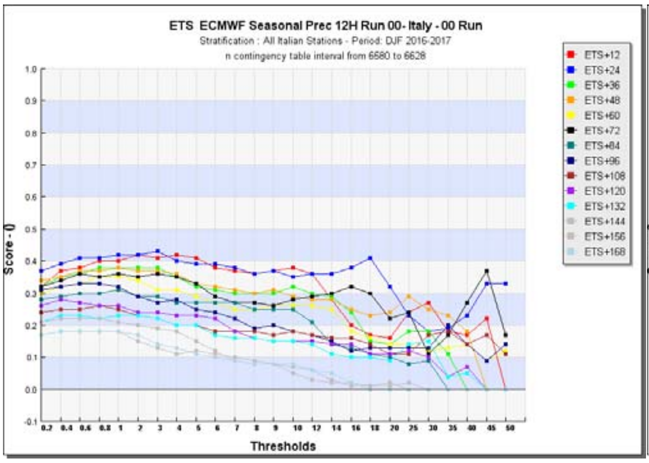
IFS Precipitation in 12 hours - FBI score

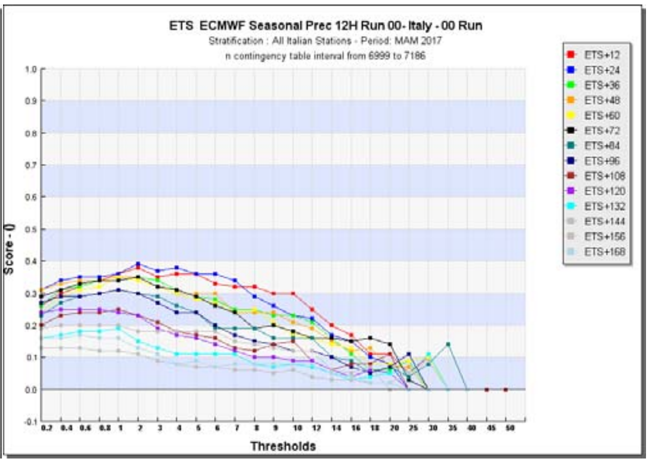


IFS Precipitation in 12 hours - ETS score

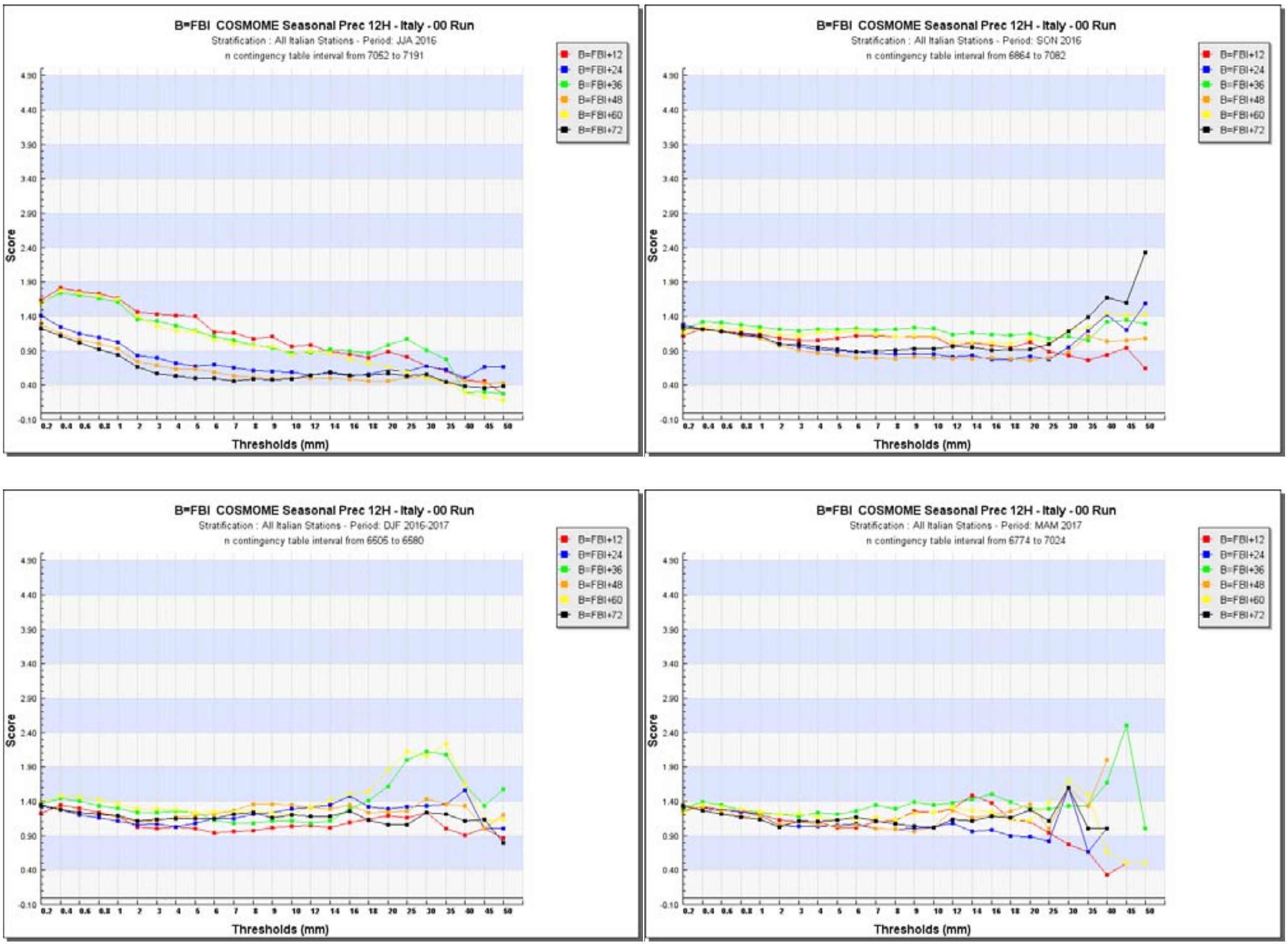








COSMO-ME Precipitation in 12 hours - FBI score



ITALY

COSMO-ME Precipitation in 12 hours - ETS score