Ensemble prediction at CoMet: status and future plans

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Operational Numerical Weather Prediction System

Ensemble Data Assimilation:

Operational since June 2011

7 km
49 v.l.

COMET-LETKF
(40+1 members)

Operational since nov 2018

2.2 km
65 v.l.

LETKF
(40+1 members)

Observations

RAOB (also 4D), PILOT, SYNOP, ISPRA rep., SHIP, BUOY, Wind Profilers, AMDAR-AIREP, Mode-S, MSG3-MET8 AMV, Metop scatt. winds, NOAA/Metop AMSUA/MHS and NPP/NOAA 20 ATMS radiances

ECMWF Boundary Conditions
(HRES, ENS also from BC Progr.)

Ensemble Analysis

Deterministic Analysis

Ensemble Prediction System:

7 km
20 m.

COSMO-ME EPS
00-12 UTC up to 72h

65 v.l.
20 m.

COSMO-IT EPS
00-12 UTC up to 48h

NETTUNO-ME EPS 3'
30 freq., 36 dir.
00 UTC up to 48h

Local Area Modeling:

5 km
45 v.l.

parameterized convection

2.2 km
65 v.l.

explicit convection

COSMO-ME
00-06-12-18 UTC
up to 72h

COSMO-IT
00-06-12-18
UTC up to
30/48h

NETTUNO-ME 3'
30 freq., 36 dir.
00-12 UTC up to
48h

NETTUNO-IT 1'
30 freq., 36 dir.
00-12 UTC up to
48h

Characteristics of the CoMet EPS system

❑ COSMO-ME EPS

- COSMO-ME EPS is operational on hybrid CPU/GPU architecture at COMET. Last version of the cosmo-code (optimized for GPU) is running since oct 2019 (*single precision, Tiedtke scheme*) .
- The COSMO model is integrated 20+1 times on the same domain of the COSMO-ME system with a grid spacing of 7 km, 45 vertical levels.
- The initial conditions are from the high resolution KENDA-LETKF *(40+1 m, 7 km, 49 vl)* system (da-cycle runs on double precision on CPU) and the lateral boundaries conditions are derived from the IFS-EPS members fields.
- It performs 72 h forecasts for the 00 and 12 UTC runs.

❑ COSMO-IT EPS

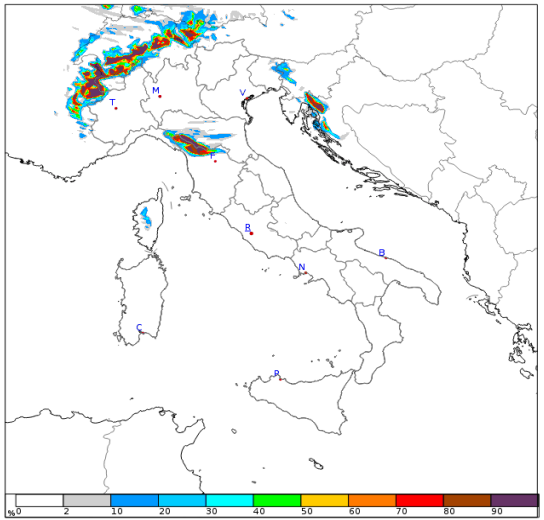
- COSMO-IT EPS is operational on hybrid CPU/GPU architecture at COMET. Since Jan 2020 the last version of the cosmo-code with *Becthold scheme* (optimized for GPU) is running *(single precision*).
- The COSMO model is integrated 20+1 times on the same domain of the COSMO-IT system with a grid spacing of 2.2 km, 576x701 grid points/layer and 65 vertical levels.
- The initial conditions are from the high resolution KENDA-LETKF *(40+1 m, 2.2 km, 65 vl)* system (da-cycle runs on double precision on CPU) and the lateral boundaries conditions are derived from the COSMO-ME EPS fields.
- It performs 48 h forecasts for the 00 and 12 UTC runs.

Operational post-processing *(Fieldextra)*

COSMOIT_EPS 13 February 2020 00UTC

Forecast T+24 VT: Friday 14 February 2020 00UTC

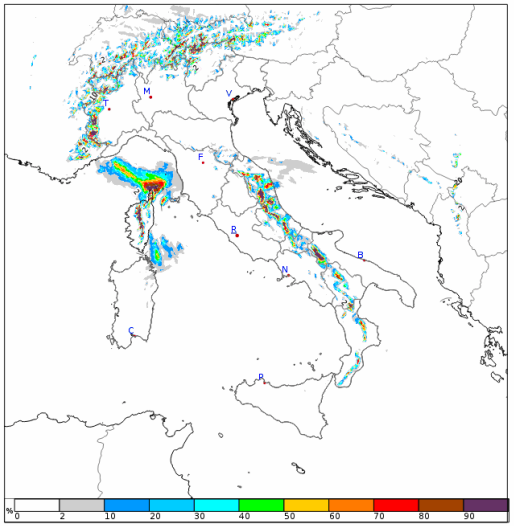
6h accumulated total precipitation probability > 10 mm



COSMOIT_EPS 10 February 2020 00UTC

Forecast T+30 VT: Tuesday 11 February 2020 06UTC

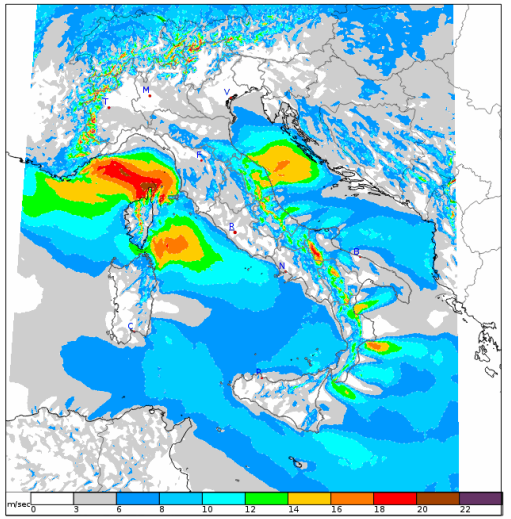
6h - 10 m max wind speed probability > 55 Kts



COSMOIT_EPS 10 February 2020 00UTC

Forecast T+30 VT: Tuesday 11 February 2020 06UTC

10 m Wind speed uncertainty (2 x Standard Deviation) m/sec



Pre-Operational post-processing

SRNWP-EPS phase III (APSU PP)

EPS_2	Develop products for postprocessing using specifically outputs from LAM ensemble systems and devoted to high impact weather forecasting (e.g. gusts, icing, fog, severe convection, wind storms, turbulence). Products should be defined by EPS_req0 (*members needs*) and from the outcome of the Post-processing Module

Post processing of standard model output through different methods has been implemented in the existing code in order to allow icing and turbulence forecast at different levels

Icing available methods:
- Liquid water content approach
Bernt Olofsson, "A new algorithm to estimate aircraft icing in theHIRLAM model," Meteorol. Appl. 10, pp. 111-114, 2003.
- **Adwice method**
Frank Kalinka, "The In-flight icing warning system ADWICE for European airspace – Current structure, recent improvements and verification Resaults," Meteorologische Zeitscrhift , vol. 24, no. 4, pp. 441-455, 2017.

(CAT) Turbulence available methods:
-**Eddy dissipation parameter**
(Matthias Raschendorfer, DWD, https://www.dwd.de/DE/fachnutzer/luftfahrt/download/vortraege/kundenforum/2014/04_turbulenzvorhersagen.pdf?__blob=publicationFile&v=2)
- Ellrod index

Icing methods:

- **LWC approach**

$$LWC[g/m^3] = \frac{(p * q_c * 1000.0)}{R_d * T * \left[1.0 + \left(\left(\frac{R_v}{R_d} - 1\right) * q_v\right) - q_c - q_{rs}\right]}$$

- **LWC HIRLAM approach**

$$A = 5 + ln(LWC)$$

w [cm/s]	< 0	$0 - 10$	$10 - 20$	$20 - 30$	> 30
Index B	$A - 1$	$A + 1$	$A + 2$	$A + 3$	$A + 4$

- **ADWICE**:

Vertical profile of temperature T and dewpoint temperature T_D are used to identify different icing scenarios

4 scenarios are detected:

- **General Scenario**
- **Covective Scenario**
- **Stratiform Scenario**
- **Freezing Scenario**

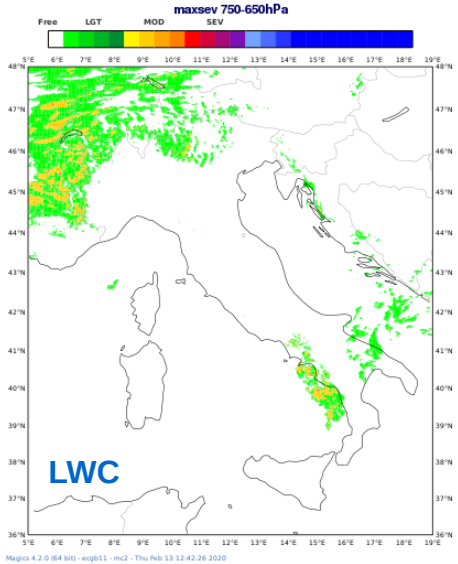
$$I = \sum_x w_x F_x$$

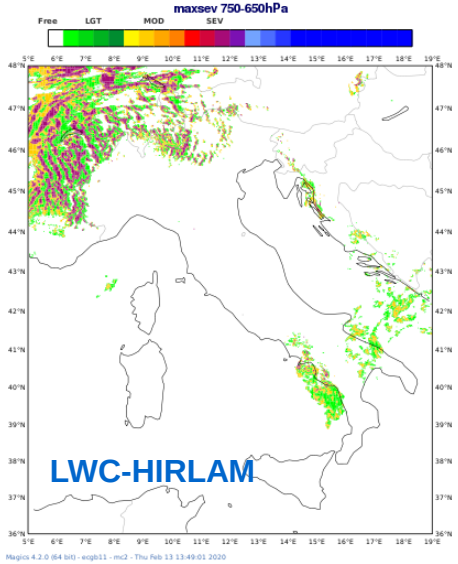
w_x weighting factor

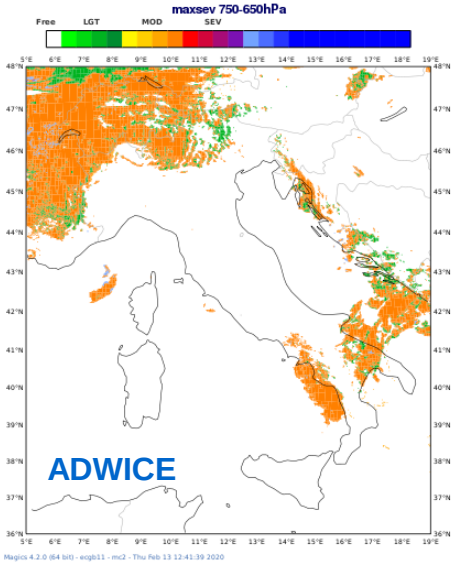
F_x fuzzy membership functions

Threshold	Icing Intensity level
$I = 0$	No Icing
$0 < I < 0.4$	Light
$0.4 \leq I < 0.7$	Moderate
$0.7 \leq I \leq 1$	Severe

Deterministic output



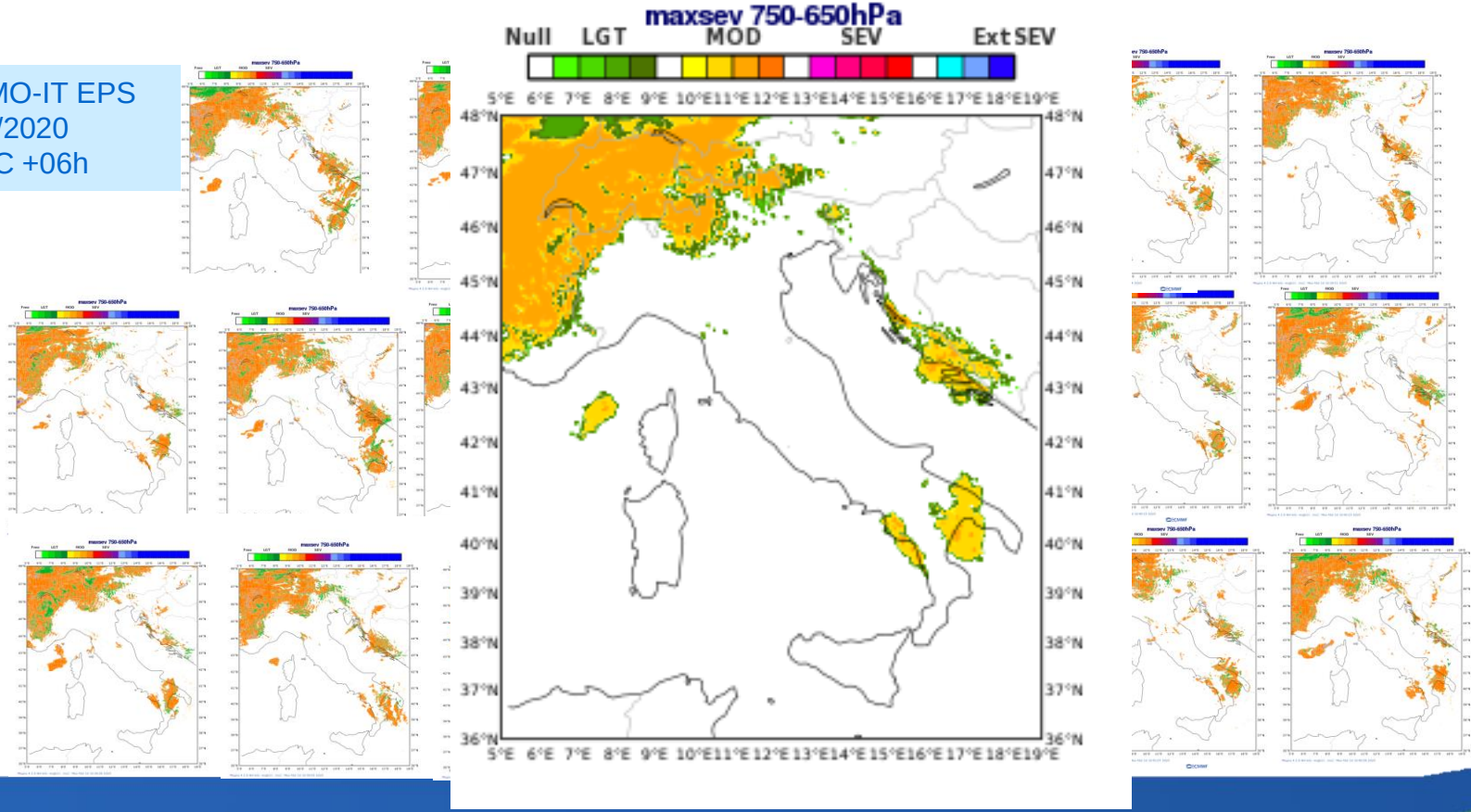




COSMO-IT EPS, 10/02/2020 00UTC run +06h

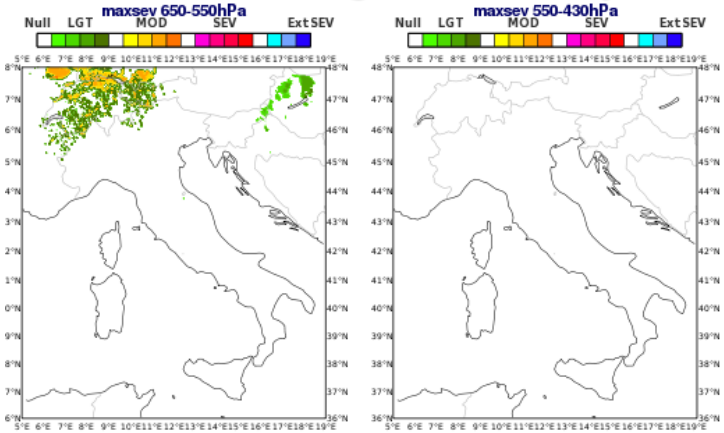
Ensemble outputs and «most probable» icing intensity

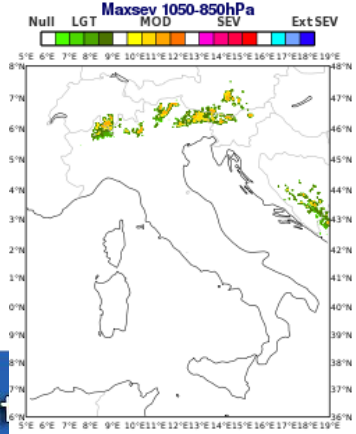
COSMO-IT EPS
10/02/2020
00UTC +06h

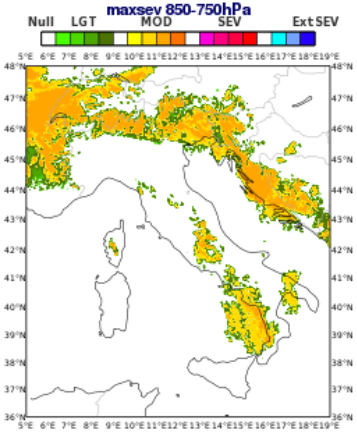


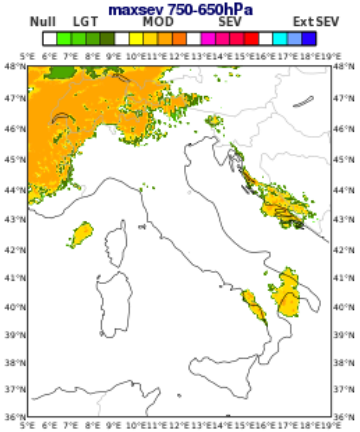
«Most probable» icing intensity at different fligh levels

COSMO-IT EPS
10/02/2020
00UTC +06h









«Turbulence CAT» Product

EDP

$$EDP = \sqrt[3]{EDR + \alpha DTKE}$$

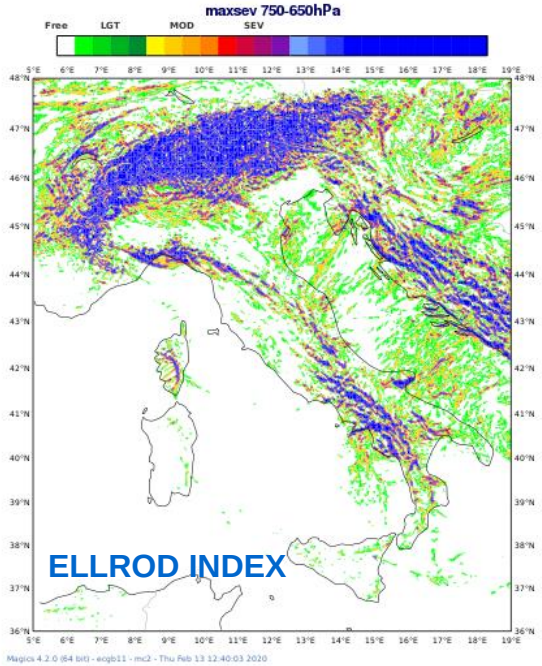
- EDR *Eddy Dissipation Rate (direct model output if available)*
- $\alpha = 1$
- DTKE *Turbulent Kinetic Energy (direct model output if available, optional correction)*

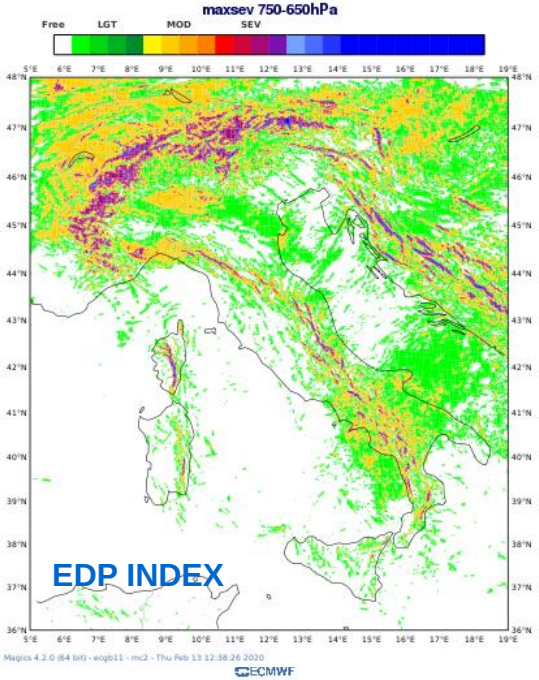
Ellrod cat index

$$EI = VWS * (DEF + CVG) = VWS * \left(\sqrt{(DSH^2 + DST^2)} + CVG\right)$$

Parameter	Acronym	Formula
VWS	Vertical wind shear	$\frac{\partial \omega}{\partial z}$
DEF	Total deformation	$\sqrt{(DSH^2 + DST^2)}$
DSH	Shearing deformation	$\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$
DST	Stretching deformation	$\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$
CVG	Convergence	$-\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$

Deterministic output

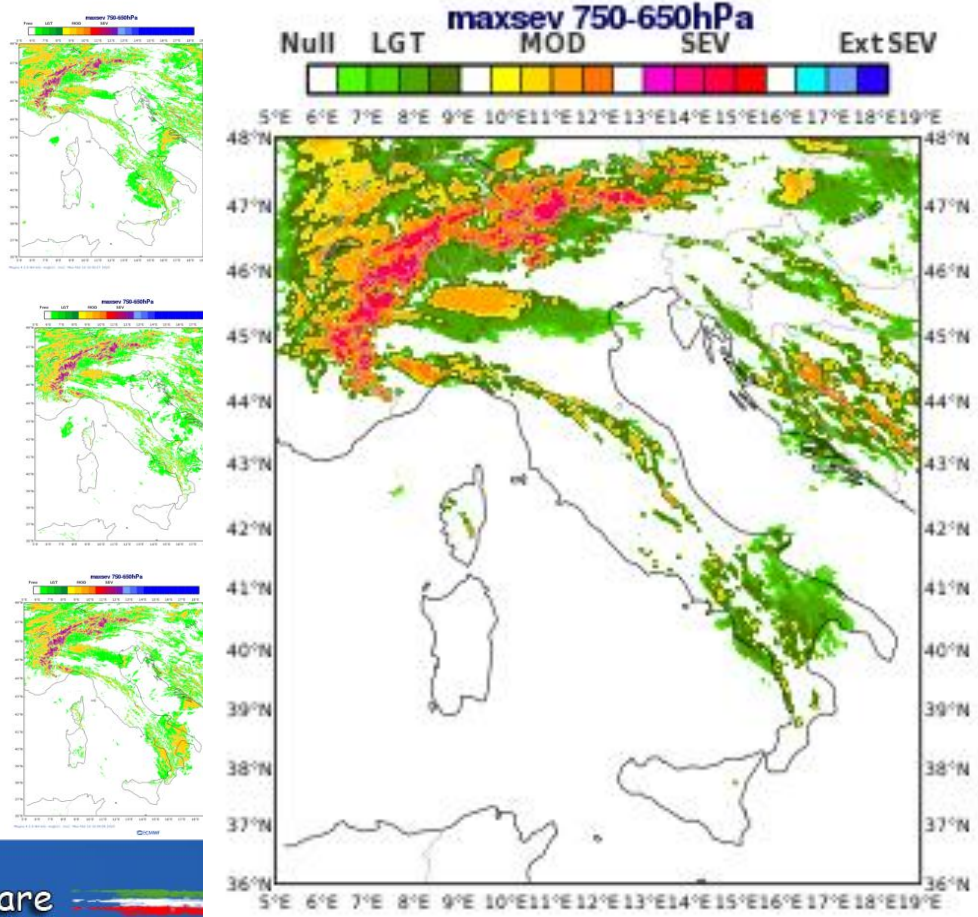




COSMO-IT EPS, 10/02/2020 00UTC run +06h

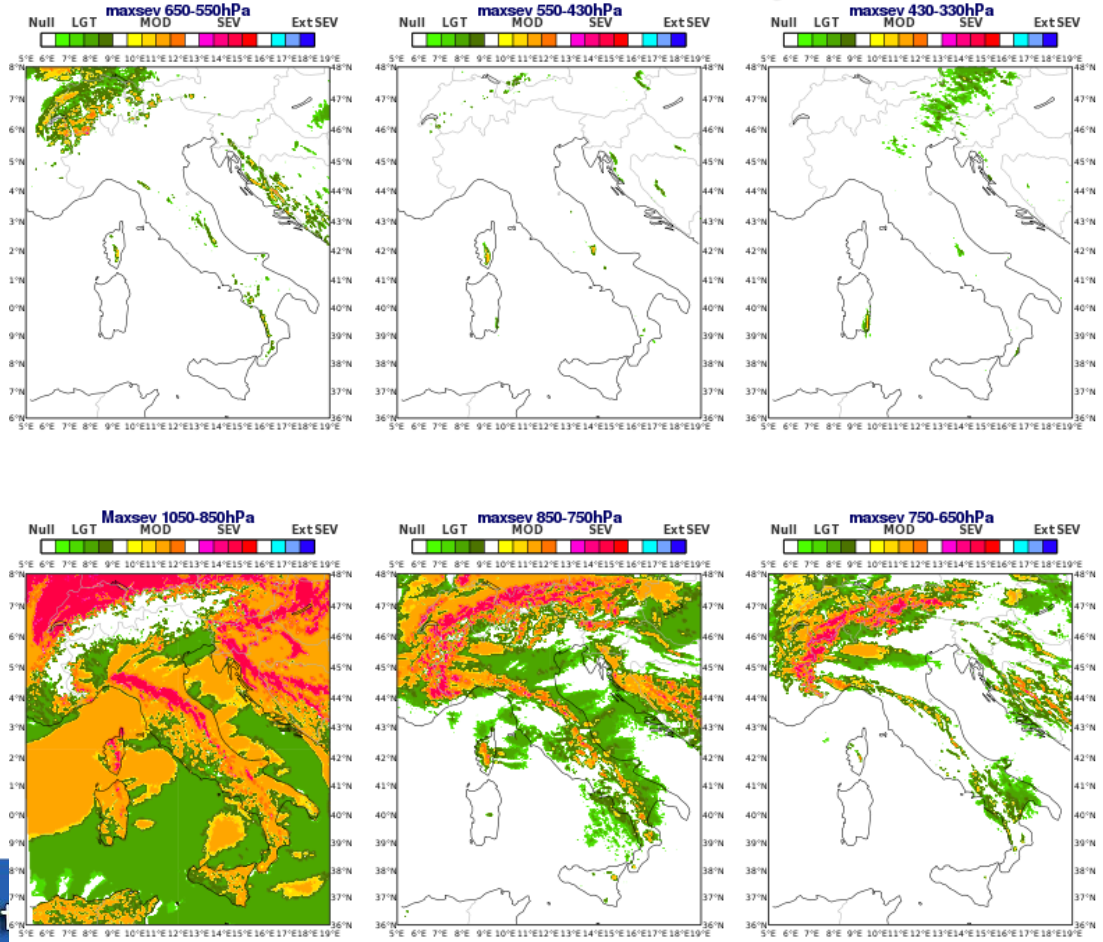
Ensemble outputs and «most probable» turbulence intensity

COSMO-IT EPS
10/02/2020
00UTC +06h



«Most probable» turbulence intensity at different fligh levels

COSMO-IT EPS
10/02/2020
00UTC +06h



Conclusions and future plans

- COSMO-IT EPS is now operational on hybrid CPU/GPU architecture. We need to reduce timing of model run with Bechtold's scheme, we expect a speed up with the new version of the cosmo-code (GRIDTOOLS)
- New products for mountain waves forecast and related turbulence are under investigation