COTEKINO PP

Setting up COSMO EPS perturbing lower boundary conditions

Riccardo Bonanno, Nicola Loglisci

COSMO General Meeting - Eretria – 8-11 September 2014

Introduction

- In a previous study we performed a sensitivity test to assess the impact of different soil moisture initializations on short range ensemble variability in COSMO model using different soil moisture analysis from global, regional and land surface models.

Model	COSMO EU analysis	ECMWF analysis	GFS analysis	GLDAS – NOAH LSM reanalysis	UTOPIA LSM reanalysis
Resolution (°)	0.063	0.125	0.500	0.250	0.250

- Spread stronger in the spring/summer case studies with convective conditions, weaker in autumn season and nearly absent in stable winter conditions.

- Not only the surface, but also the upper levels in the troposphere are affected by soil moisture variability.

R. Bonanno, N. Loglisci, 2014: A sensitivity test to assess the impact of different soil moisture initializations on short range ensemble variability in COSMO model. **COSMO Newsletter no. 14**, 95-105 , Available at http://www.cosmo-model.org/content/model/documentation/newsLetters/newsLetter14/cnl14_11.pdf

Stochastic Pattern Generator

M Tsyrulnikov, I Mamay, D.Gayfulin - *HydroMetCenter of Russia*

***KENDA** Priority Project*

- The Generator is based on solution of a partial stochastic differential equation in spectral space on a 3-dimensional torus. Variance, spatial and temporal scales are tunable.

$$\left(\frac{\partial f}{\partial t} + \mu (1 - \lambda^2 \Delta)^q \right)^p f = \sigma \alpha$$

- *p* and *q* are external parameter, σ, λ and μ are parameters related to the desired variance, spatial and temporal correlation scale. α is the spatio-temporal white noise.

Streatching Function

Gaussian random noise

(Lavaysse et al, 2013, Charron et al, 2010)

$$F = \mu + S(f, \mu)(f - \mu)$$

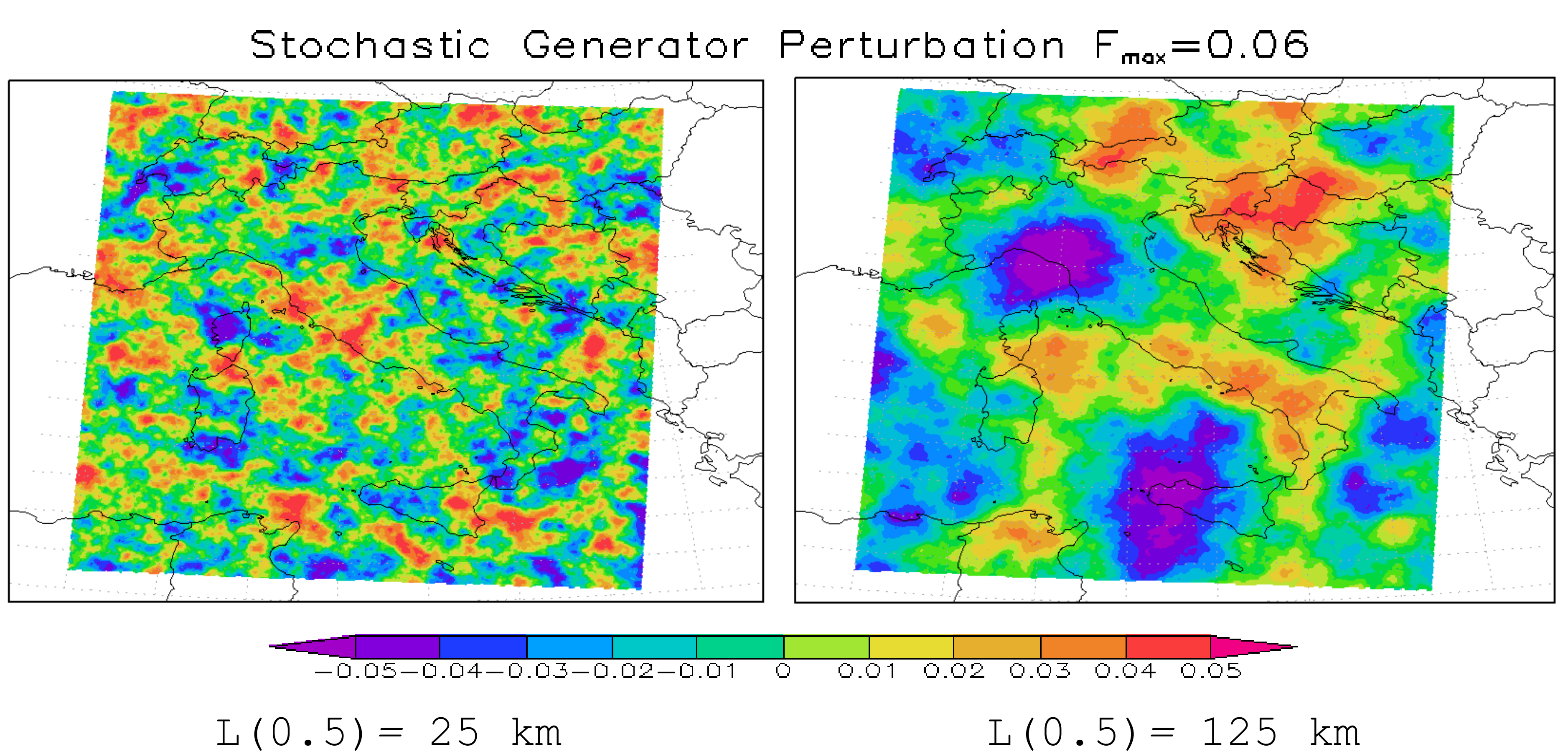
$$S(f,\mu) = 2 - \frac{1 - \exp\left[\beta \left(\frac{f - \mu}{f_{\max} - \mu} \right)^2 \right]}{1 - \exp(\beta)}$$

$$\beta \approx -1.27$$

Spatial correlation scale

$$\left(\frac{\partial f}{\partial t} + \mu(1-\lambda^2\Delta)^q\right)^p f = \sigma\alpha$$

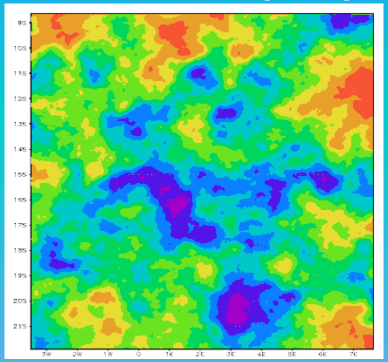
L(0.5) is defined as the distance at which the correlation function falls to 0.5. The value of *L(0.5)* has to be set in the configuration file to determine λ.



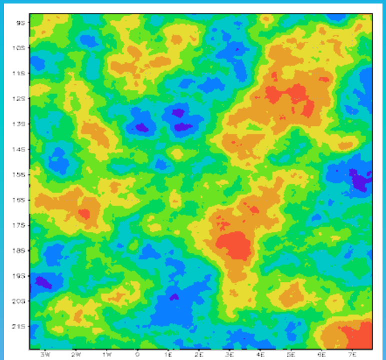
Stochastic Pattern Generator
L(0.5)=125 km

&

Stretching Function
$F_{max\ surf}$ = 0.06 m^3m^{-3} Bounds [-0.06, 0.06]

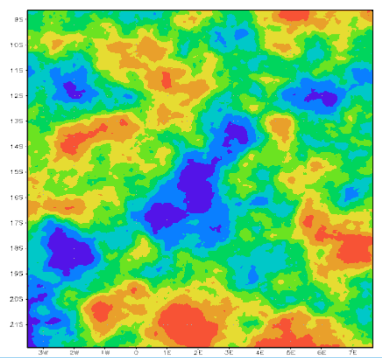


Perturbation ***F1***

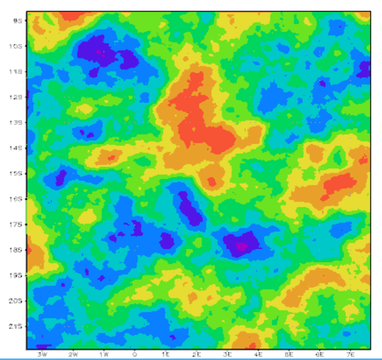


Perturbation ***F2***

....

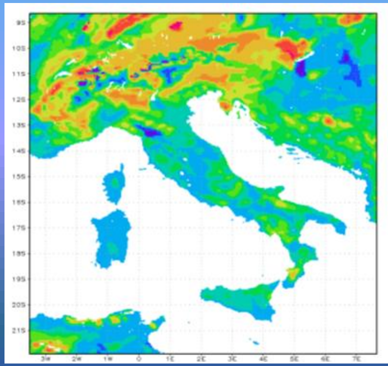


Perturbation ***F9***

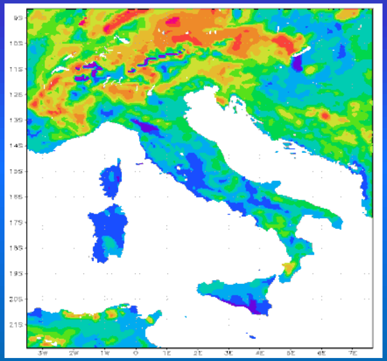


Perturbation ***F10***

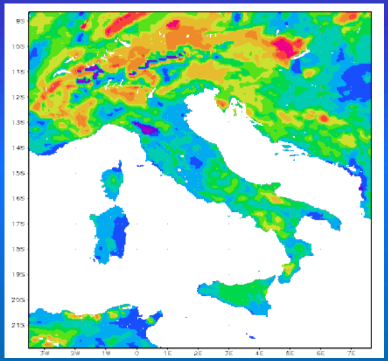
IFS soil moisture
INT2LM



Check with soil porosity **$0 \leq$ W_SO $\leq \eta_s$**

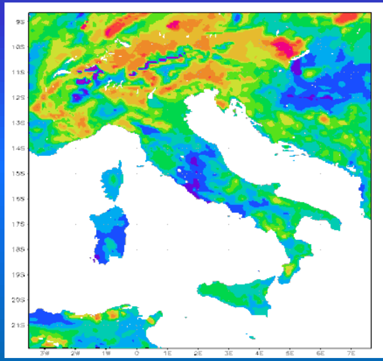


W_SO 1

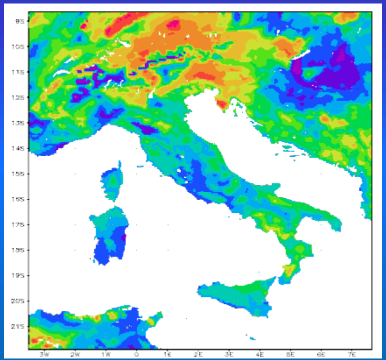


W_SO 2

....



W_SO 9



W_SO 10

Sensitivity to the characteristics of the perturbation

Intensity and Spatial correlation scale

Test	$F_{max\ surf}$ ($m^3\ m^{-3}$)	$F_{max\ root}$ ($m^3\ m^{-3}$)	*L(0.5)* (km)
1	0.06	0.04	25
2	0.06	0.04	125
3	0.06	0.04	225
4	0.06	0.04	425
5	0.08	0.06	125

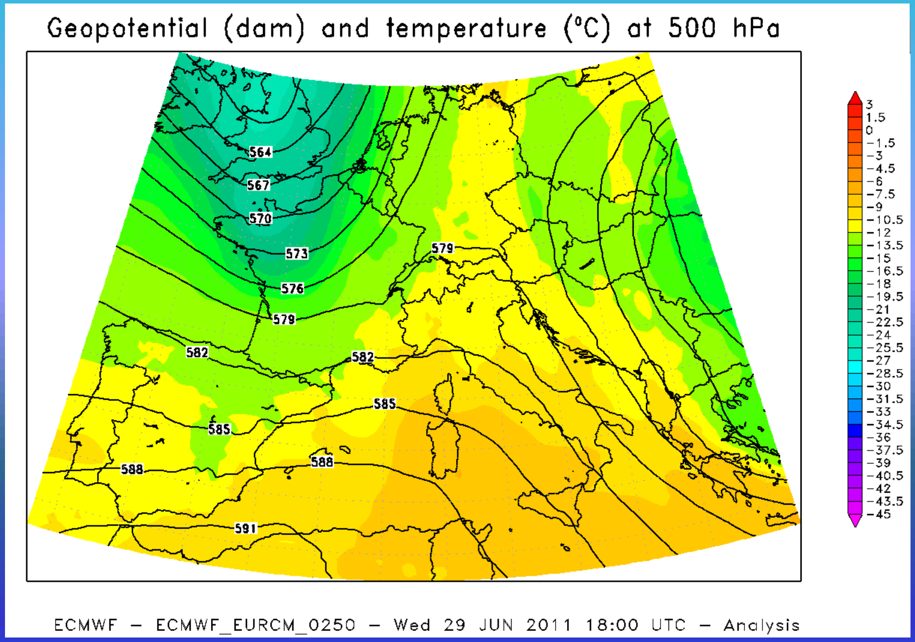
0.06 m^3m^{-3} for the surface layer and 0.04 m^3m^{-3} for root layers (Lavaysse et al., 2013, Mc Laughlin et al., 2006).

The higher values of the surface perturbation is motivated by the higher spatial and temporal variability of soil moisture in the superficial layer.

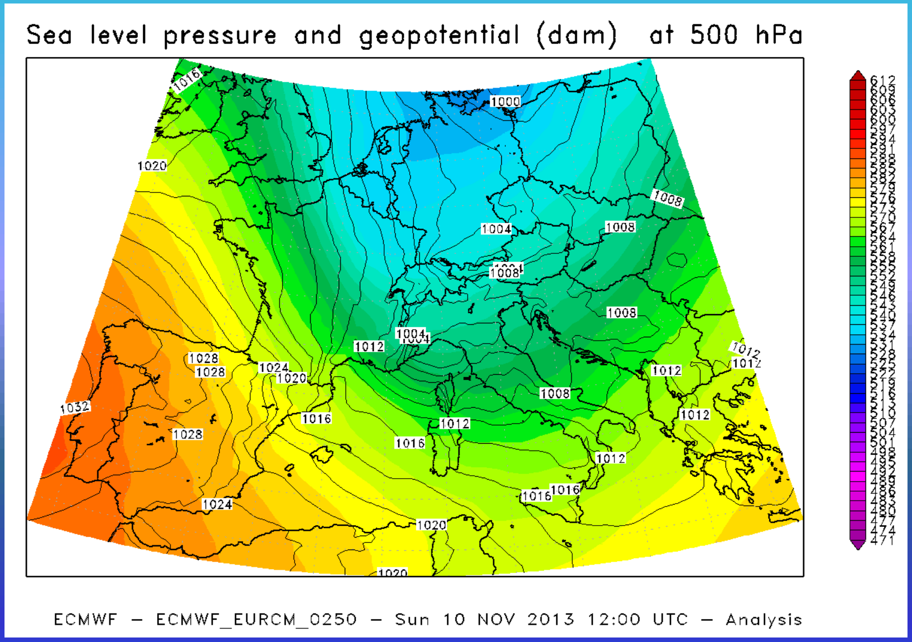
These values are comparable of smaller than errors of the operational soil moisture analysis at ECMWF (bias = −0.081 $m^3\ m^{-3}$, RMSE = 0.113 $m^3\ m^{-3}$ over the period 2008-2010, Albergel et al. (2012) or ECMWF Newsletter No. 133, Autumn 2012)

Case studies

(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING



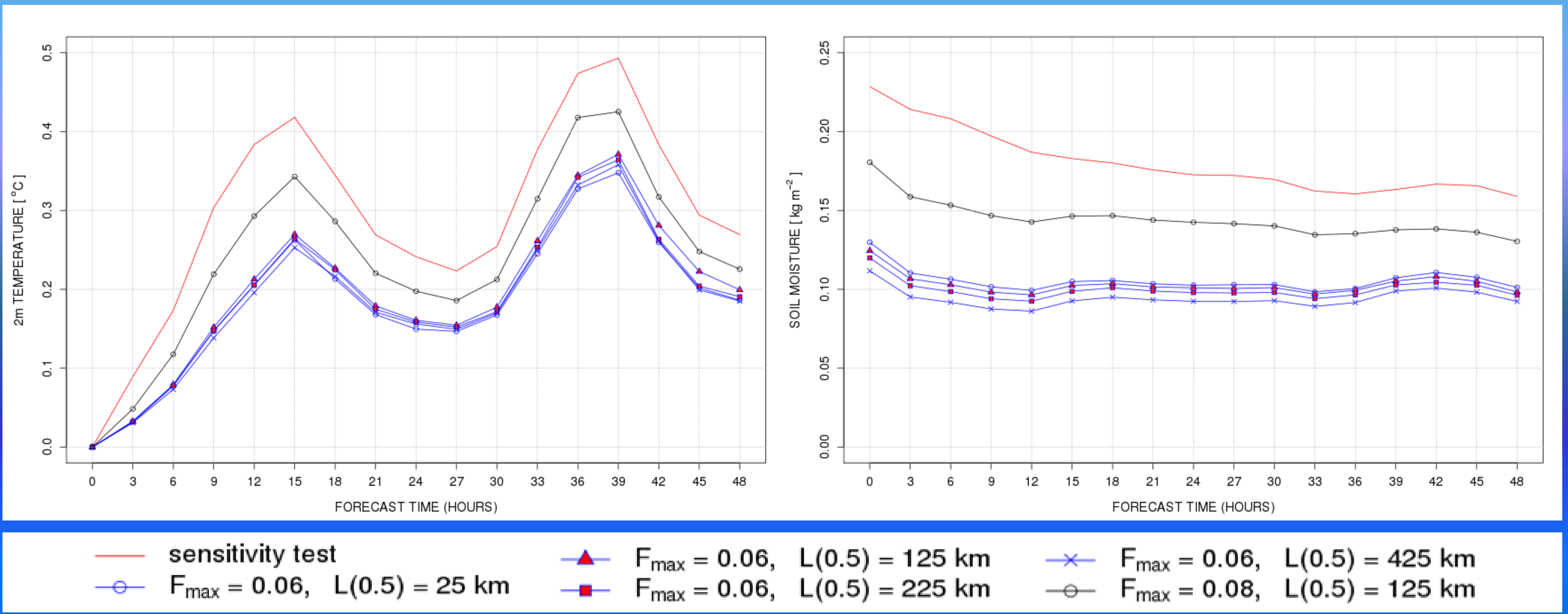
(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA



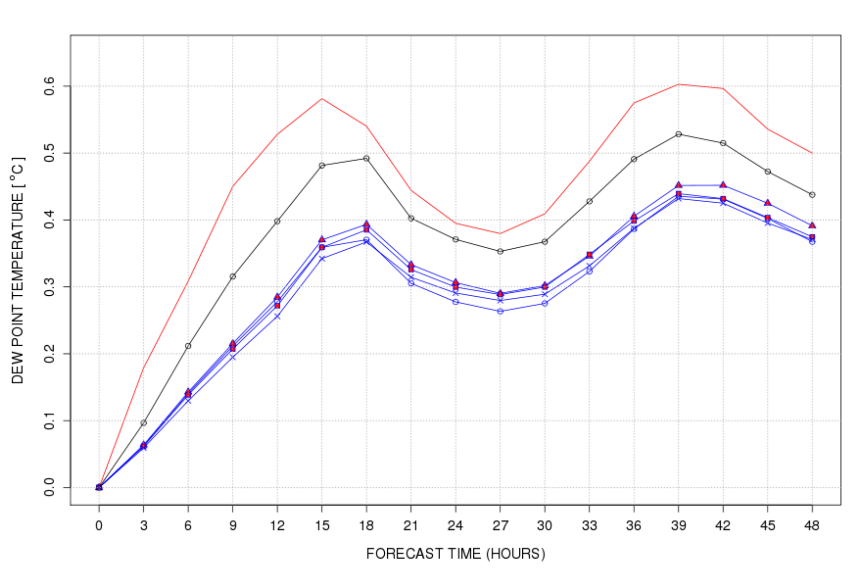
Sensitivity to the characteristics of the perturbation

1° case study: 29/06/2011

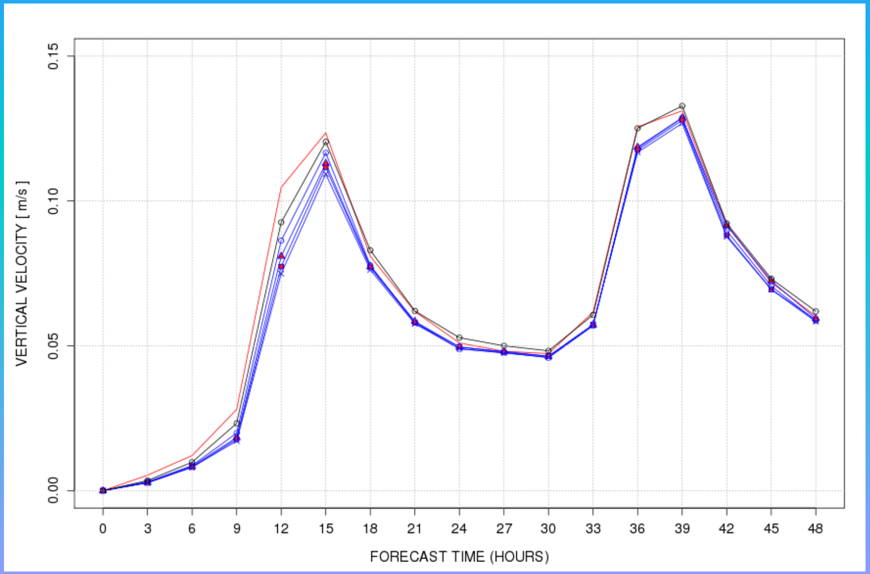
2m TEMPERATURE [°C] **SOIL MOISTURE [kg/m²]**



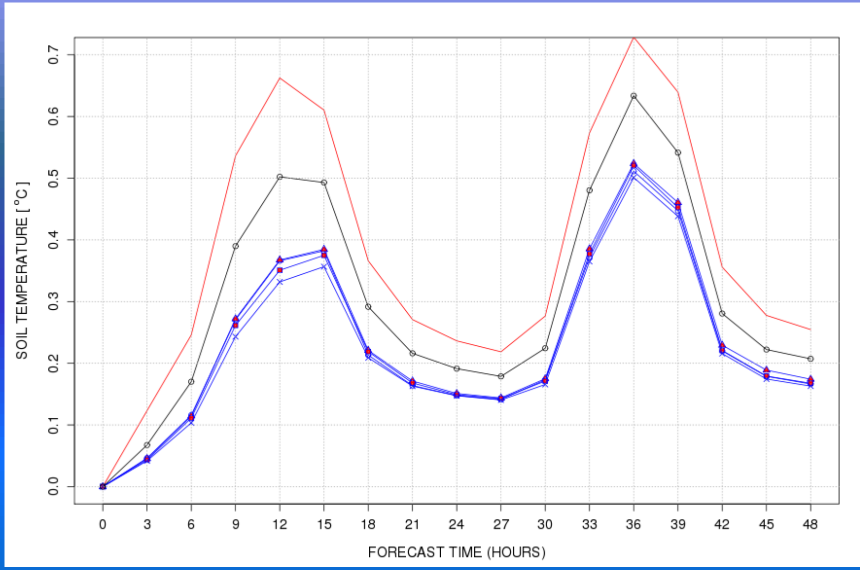
DEW POINT TEMPERATURE [°C]



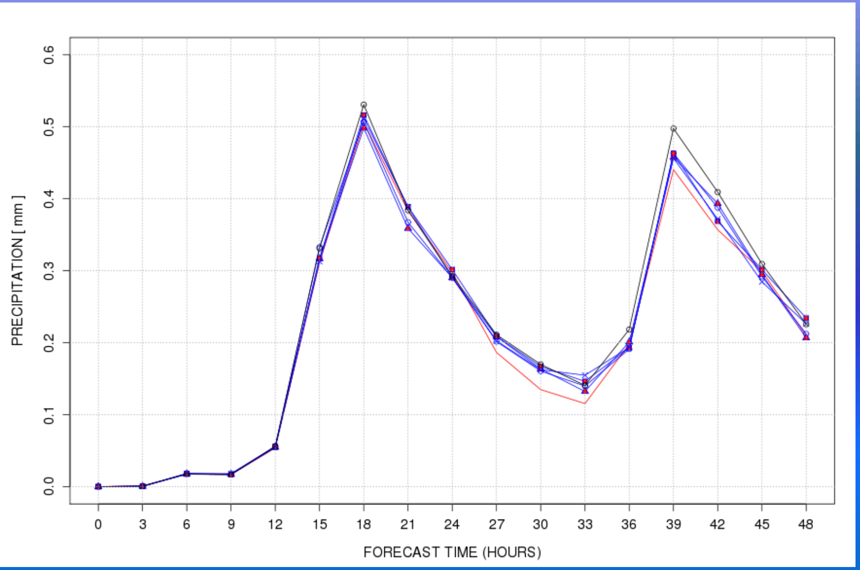
VERTICAL VELOCITY [m/s]



SOIL TEMPERATURE [°C]



3h PRECIPITATION [mm]



sensitivity test
$F_{max} = 0.06$, $L(0.5) = 25$ km
$F_{max} = 0.06$, $L(0.5) = 125$ km
$F_{max} = 0.06$, $L(0.5) = 225$ km
$F_{max} = 0.06$, $L(0.5) = 425$ km
$F_{max} = 0.08$, $L(0.5) = 125$ km

Comparison with the spread of an ensemble system with IC e BC perturbations: COSMO LEPS

Variables considered: *2m Temperature* T_{2m} , *Dew Point Temperture* T_{d}, *Precipitation P, Wind Speed* $\sqrt{U^2 + V^2}$

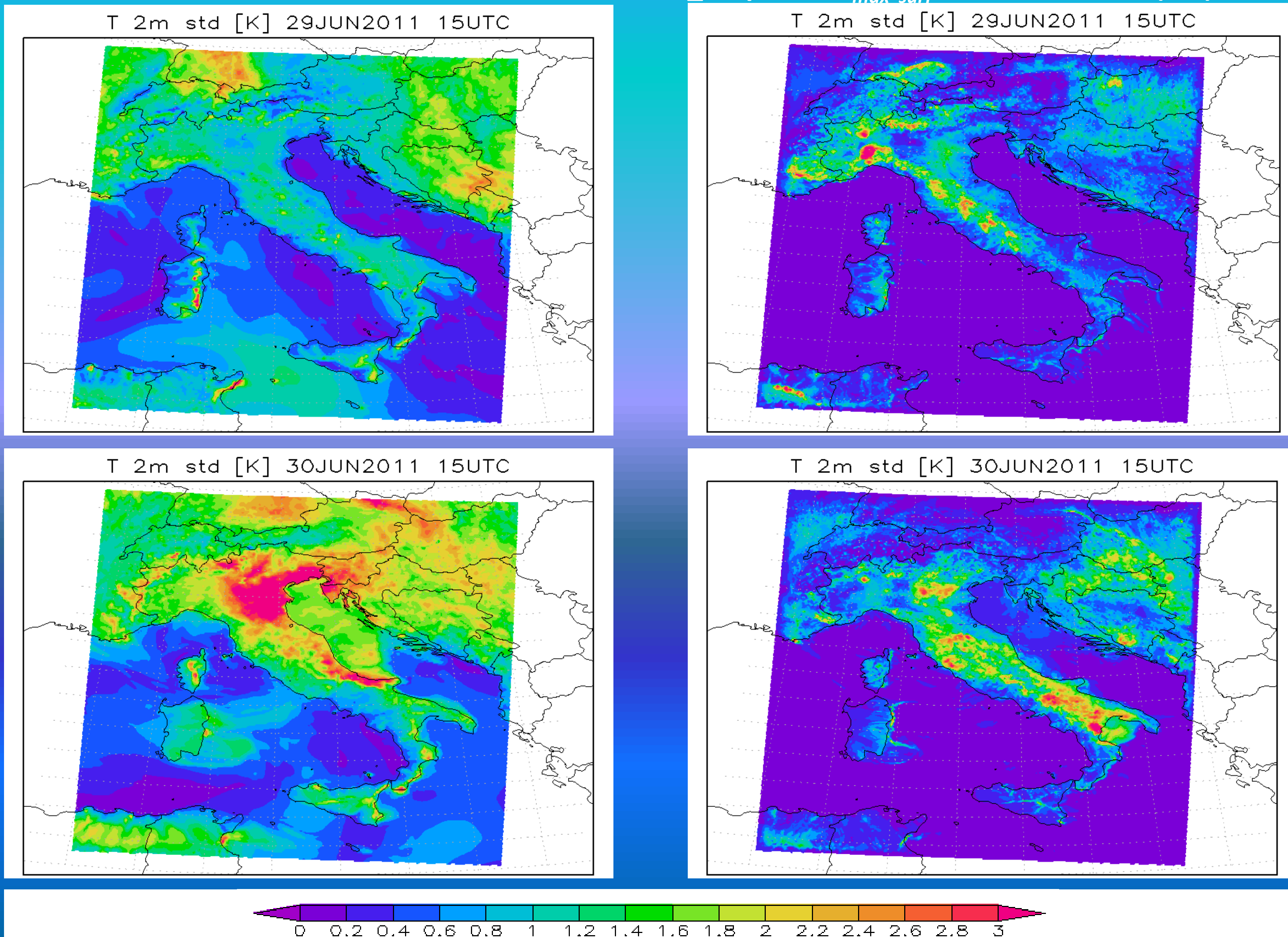
Case study:

- *29-06-2011 00UTC – Strong synoptic forcing (cold front)*
- *10-11-2013   00 UTC – Strong winds (Foehn + Mistral) and low pressure system over Tyrrhenian sea*

Settings: $L(0.5) = 125$ km, $F_{max\ surf} = 0.08$, $F_{max\ root} = 0.06\ m^3\ m^{-3}$

2m Temperature – case study 29062011 00 UTC

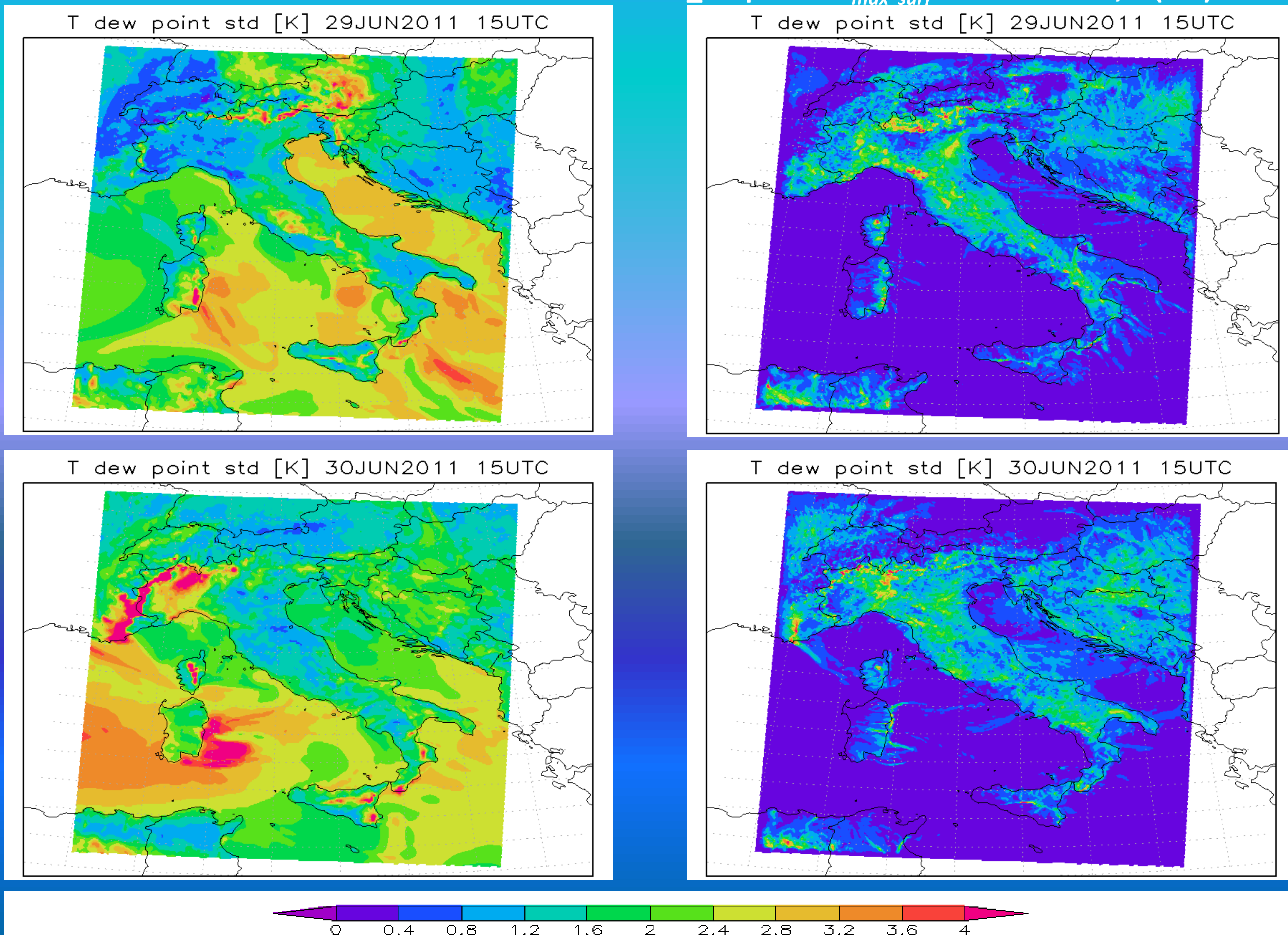
COSMO LEPS – run 28062011 12 UTC | **W_SO pert. – $F_{max\_surf} = 0.08\ m^3\ m^{-3}$, L(0.5) = 125 km**



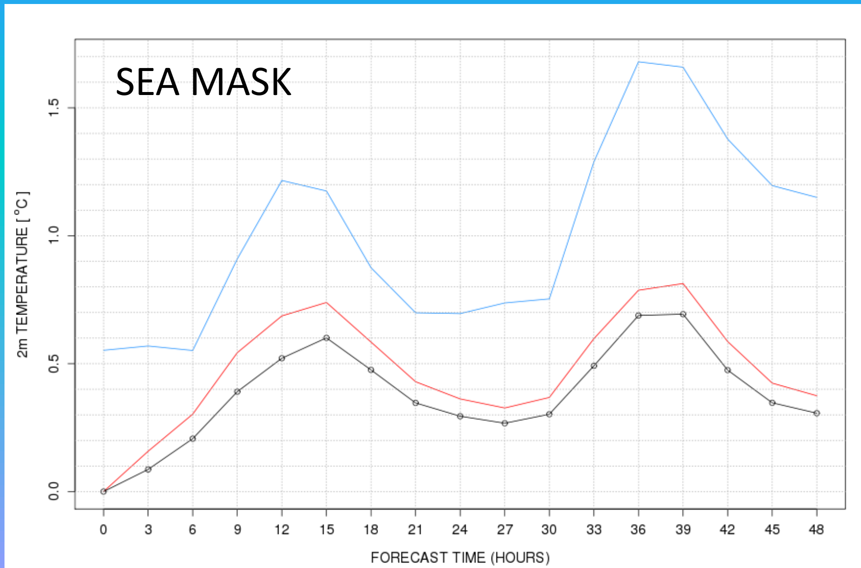
Dew Point Temperature – case study 29062011 00 UTC

COSMO LEPS – run 28062011 12 UTC

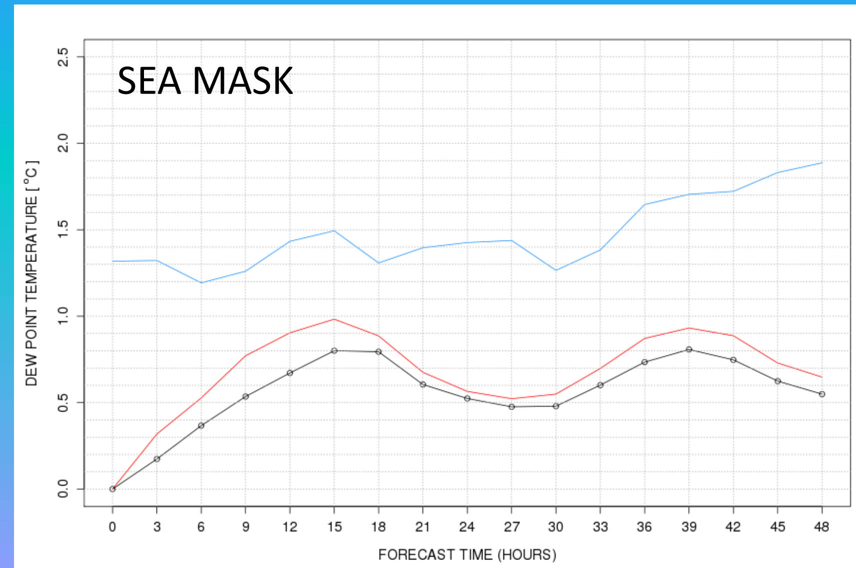
W_SO pert. – F_{max_surf} = 0.08 $m^3\ m^{-3}$, L(0.5) = 125 km



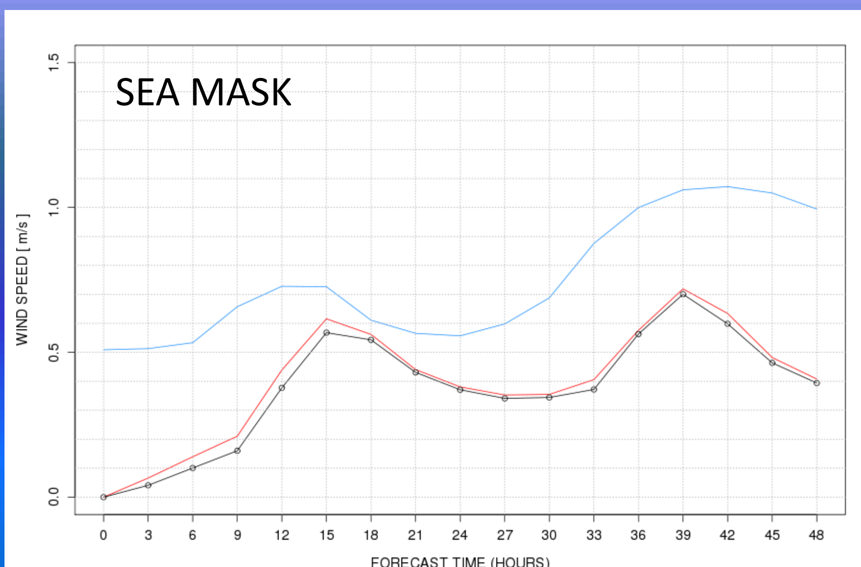
2 m TEMPERATURE [°C]



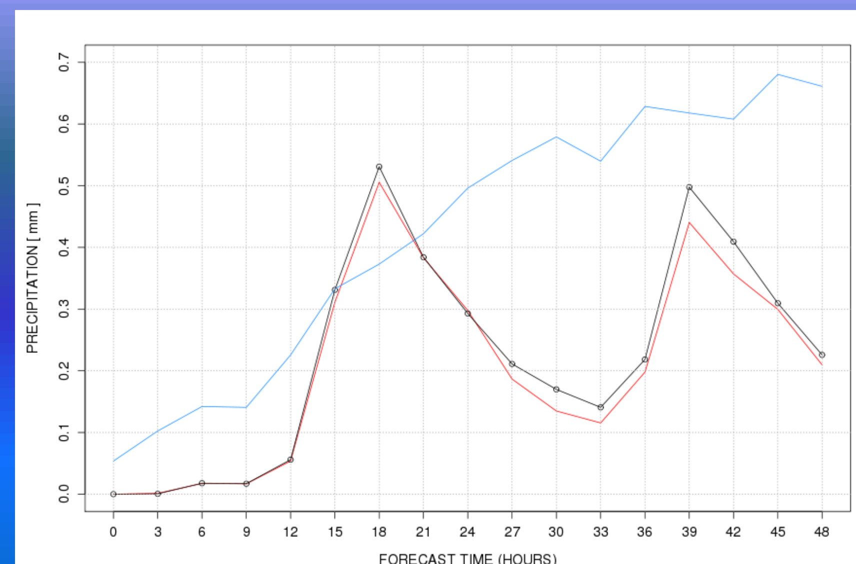
DEW POINT TEMPERATURE [°C]



WIND SPEED [m/s]

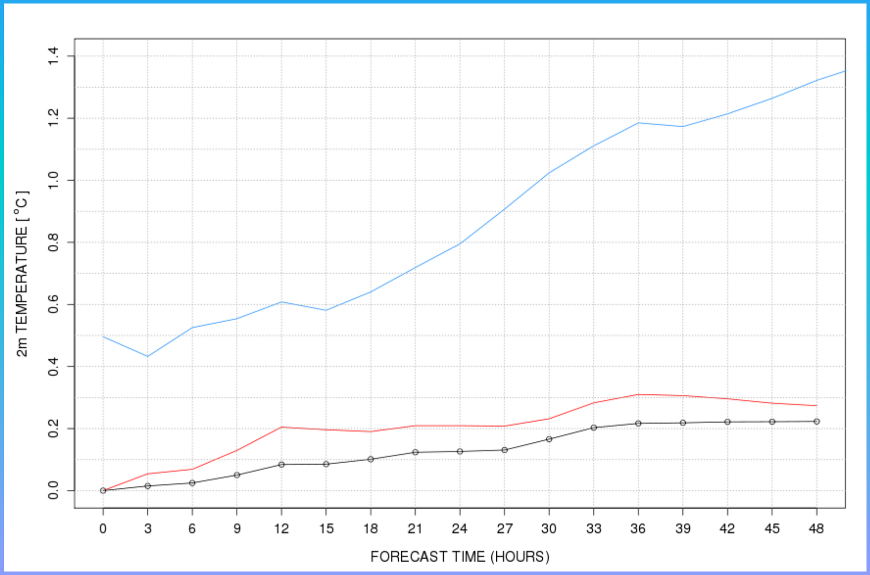


3h PRECIPITATION [mm]

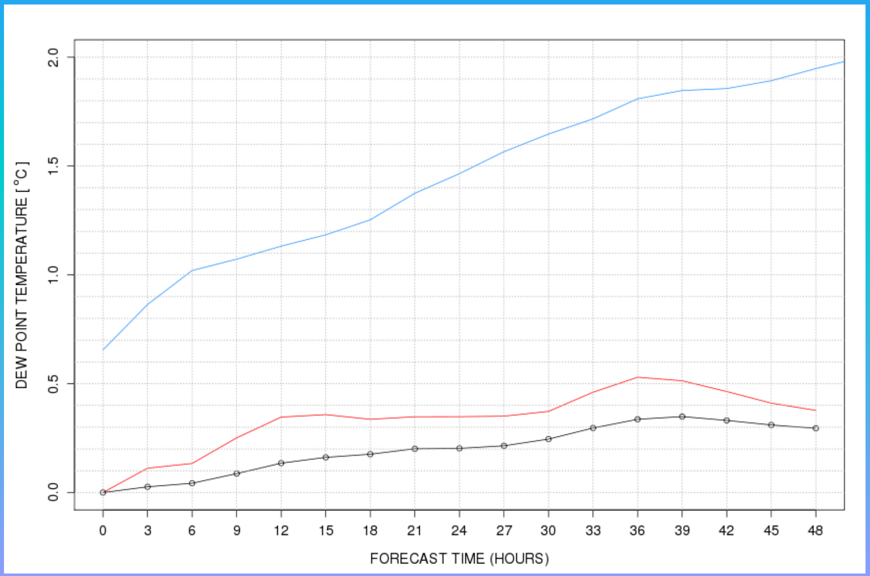


COSMO LEPS run: 28062011 12UTC   sensitivity test F_{max} = 0.08, L(0.5) = 125 km

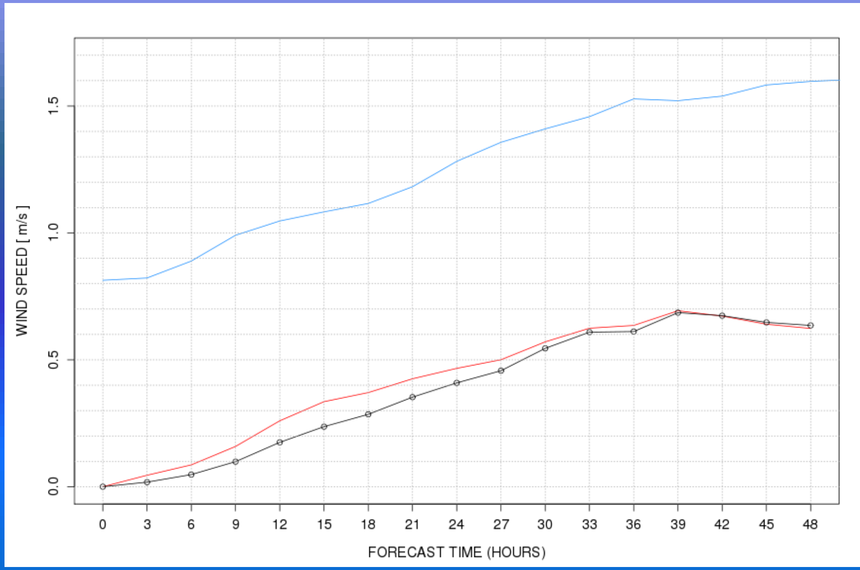
2 m TEMPERATURE [°C]



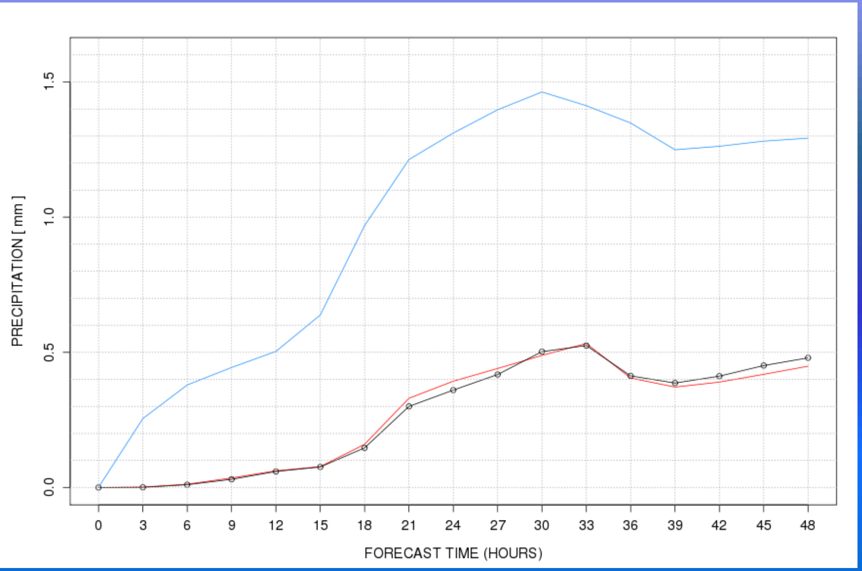
DEW POINT TEMPERATURE [°C]



WIND SPEED [m/s]



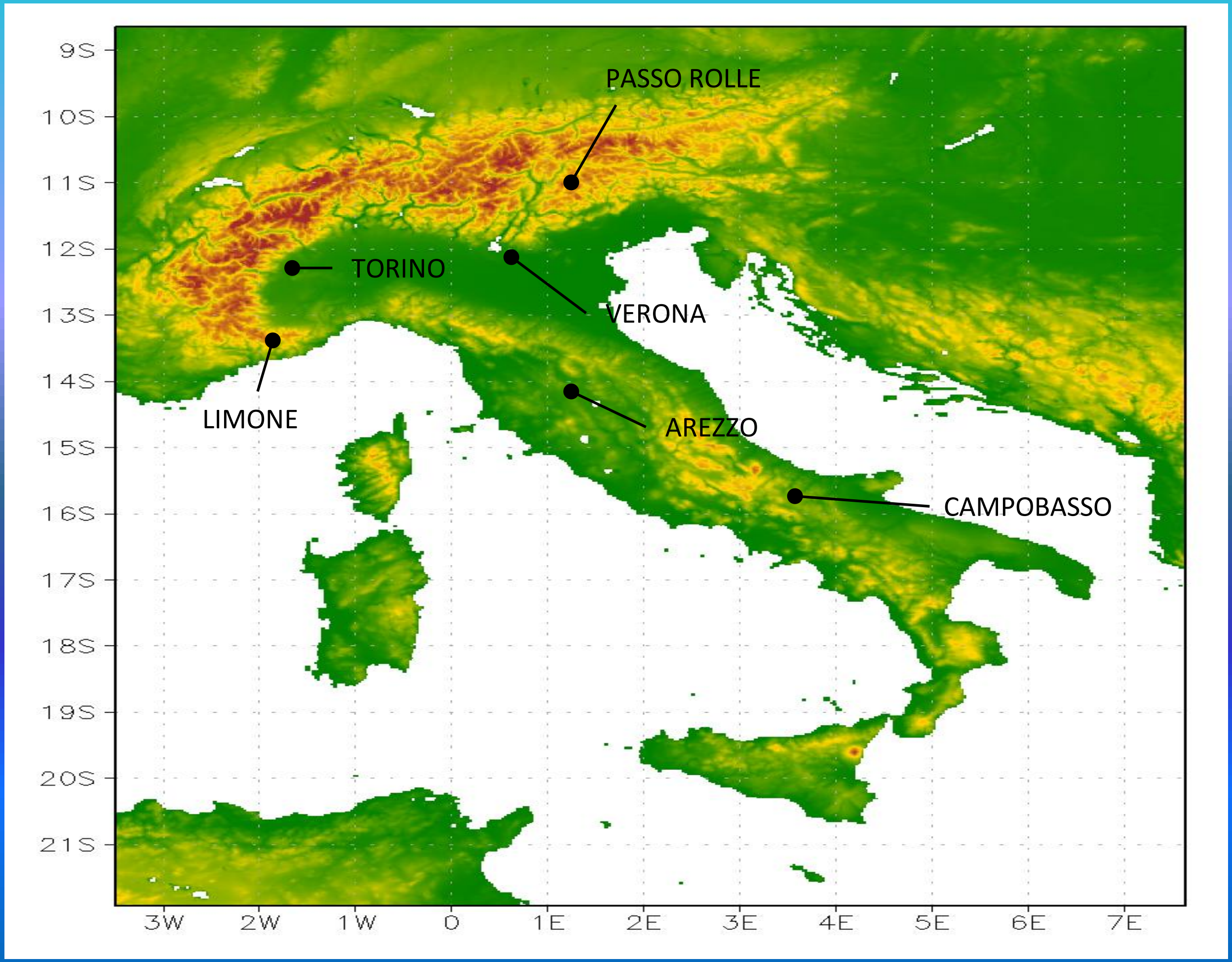
3h PRECIPITATION [mm]



COSMO LEPS run: 28062011 12UTC — sensitivity test — $F_{max} = 0.08$, $L(0.5) = 125$ km

Comparison with observations (SYNOP) 1° case study – 29/06/2011

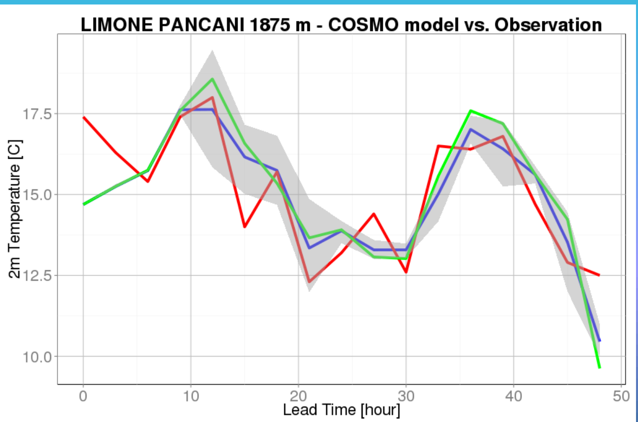
W_SO pert. – $F_{max\ surf}$ = 0.08 $m^3\ m^{-3}$, L(0.5) = 125 km

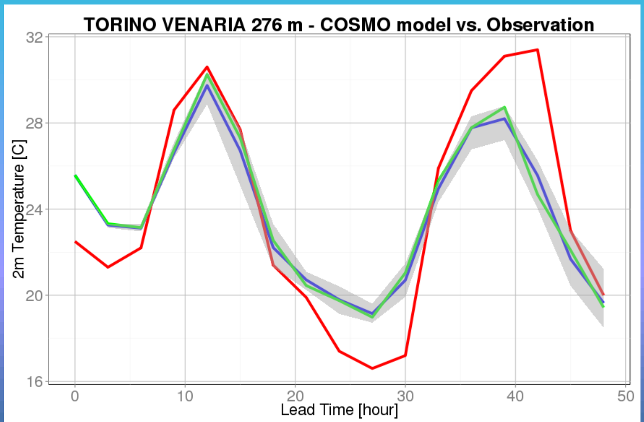


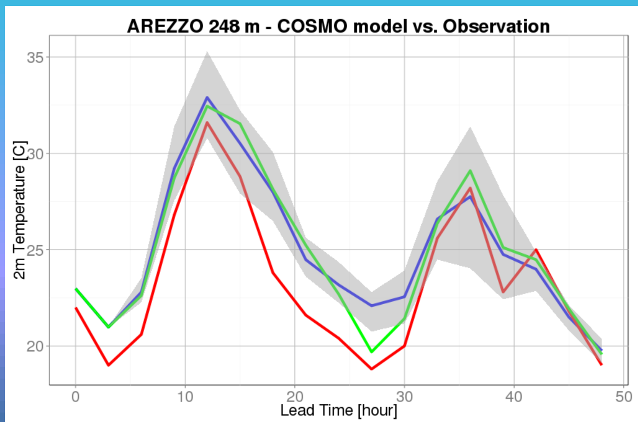
Comparison with observations (SYNOP)
1° case study – 29/06/2011

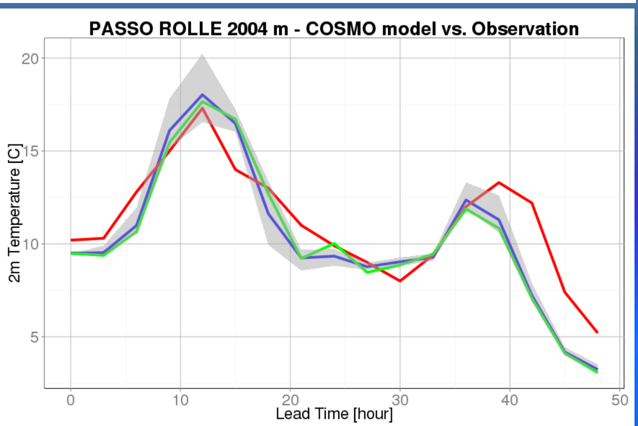
2m Temperature

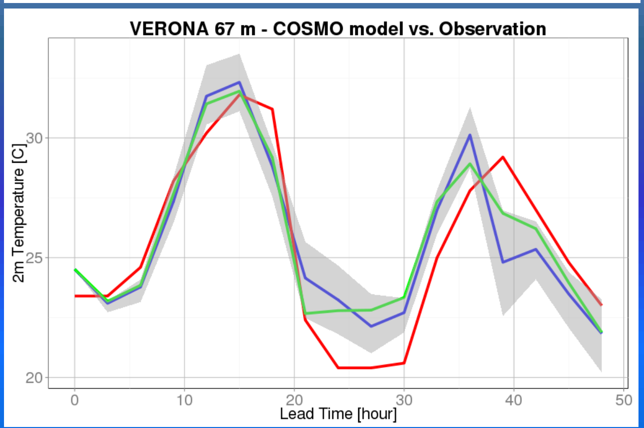
ALPS | PO VALLEY | CENTRAL ITALY

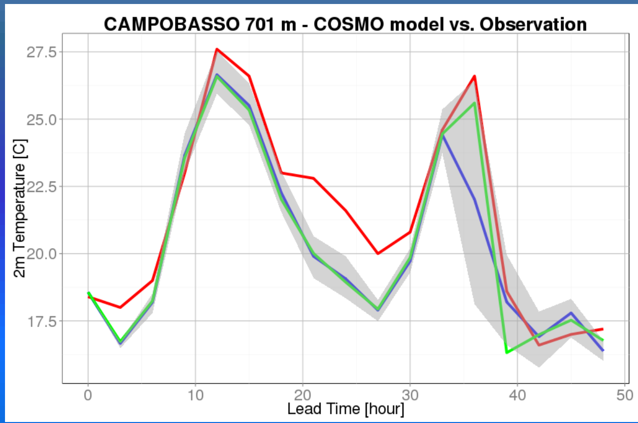










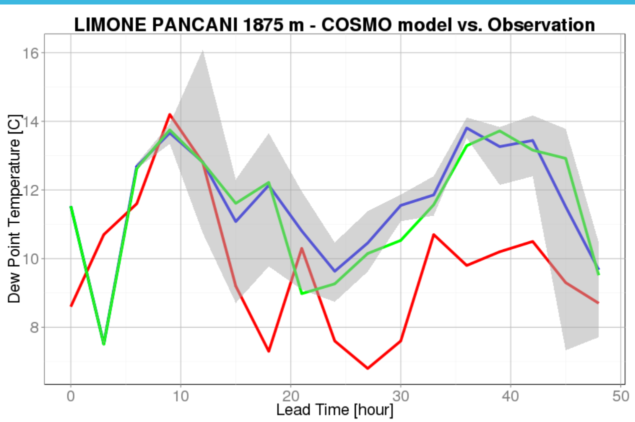


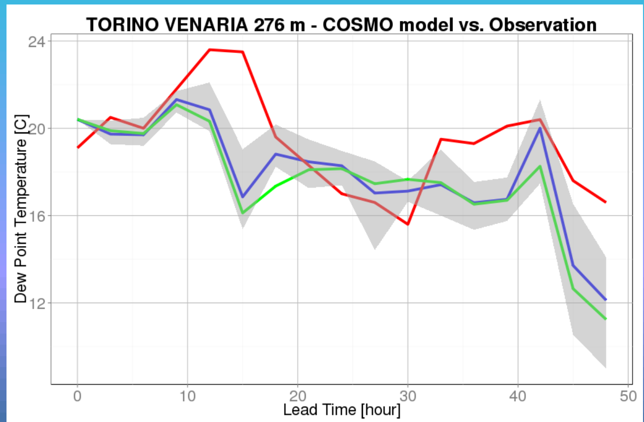
observations — ensemble mean — control run — prediction bounds (5th and 95th percentile)

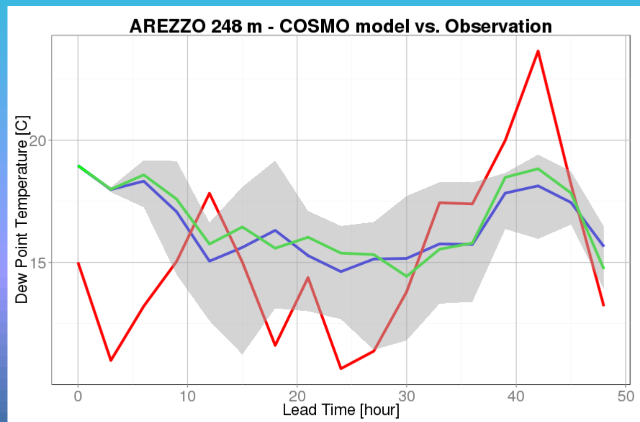
Comparison with observations (SYNOP)
1° case study – 29/06/2011

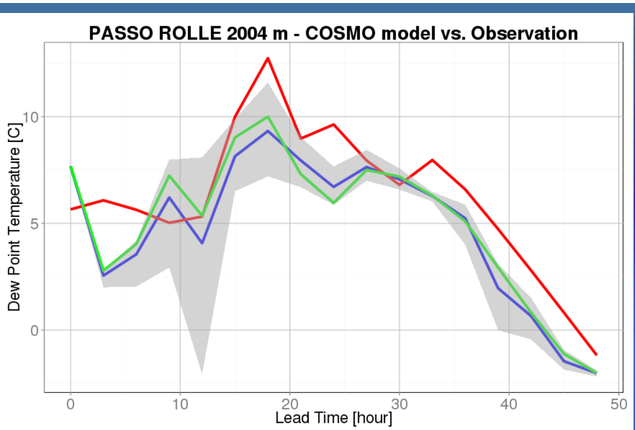
Dew Point Temperature

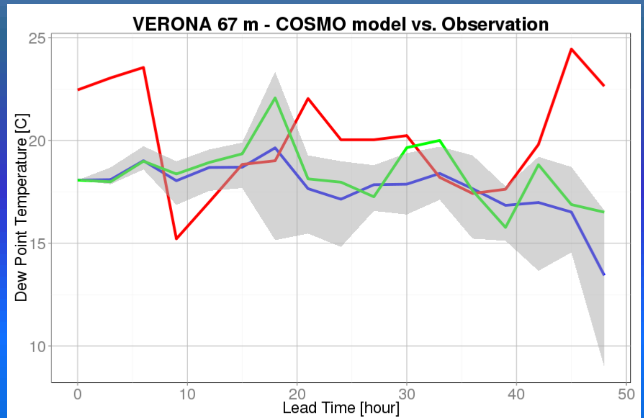
ALPS | PO VALLEY | CENTRAL ITALY

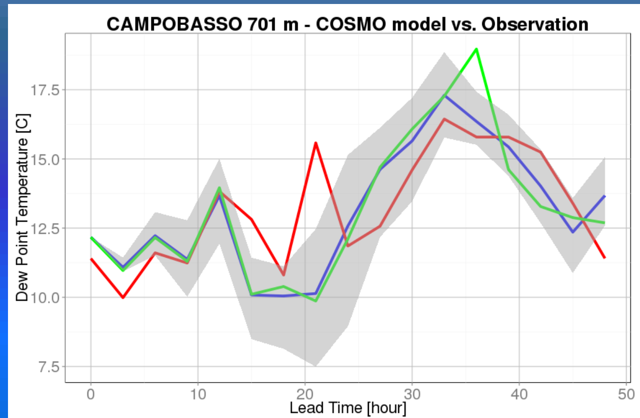












observations — ensemble mean — control run — prediction bounds (5th and 95th percentile)

Conclusions

1. Low sensitivity with respect to the spatial length scale and higher sensitivity to the intensity of the perturbation.
2. COSMO EU soil moisture initialization lead to higher values of spread (considering the same value of the intensity of the perturbation F_{max}) for both the case studies.
3. Weak sensitivity of COSMO model to the perturbation of some external parameters like Leaf Area Index, Roughness Length and Plant Cover.
4. Non additive effect when perturbing all the external parameters together (in this case, the contribution to the spread is similar to the contribution obtained by perturbing a single parameter)
5. Complete perturbation (external parameters + soil moisture) doesn't have in general a positive effect in the spread production.
6. Lower values of spread (but not negligible!) compared to the case of an ensemble system with IC and BC perturbation (COSMO LEPS). Sometimes strong contribution coming from sea surface.
7. Locally, considering the comparison with SYNOP observations, reasonable values of spread can be noticed.

Future developments

1. Assess the sensitivity of the COSMO model to the perturbation of the soil temperature. The perturbation technique will be inspired by the same used for the soil moisture

2. Definition of the ‘final’ perturbation technique that includes the perturbation of the soil moisture and eventually of the soil temperature.

3. Implementations of the algorithm in an ensemble systems for testing (eg COSMO-IT-EPS).

4. Comparison with observations to evaluate quantitatively the skill of the complete ensemble system with IC + BC + LBC perturbation. For this purpose one or more interesting case studies of Hymex Project will be considered.

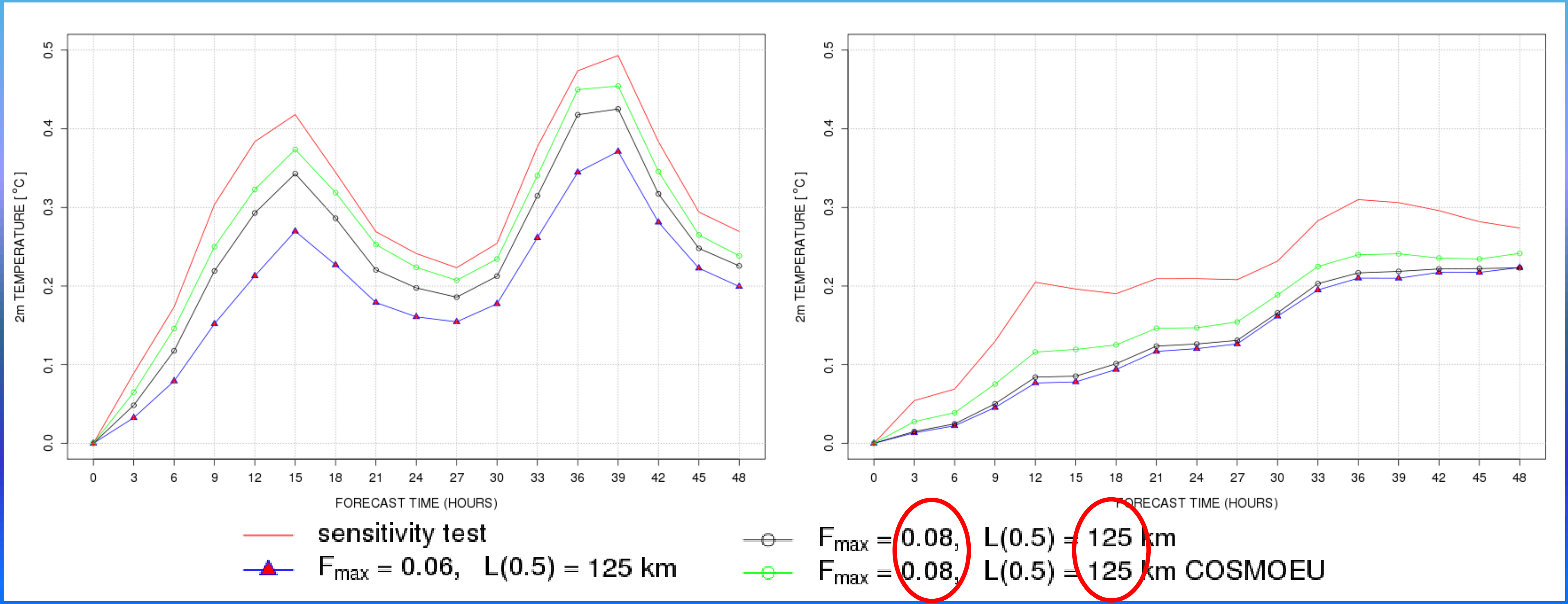
Thank you for your attention!

Change in the original soil moisture analysis

COSMO EU vs. IFS

(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA



2m TEMPERATURE [°C]

External parameters perturbation:

Leaf Area Index, Roughness Length and Plant Cover

- Multiplicative perturbation (Lavaysse et al. 2013)
- Choice based on the assumption that the errors are proportional to the values of the considered variable.
- For Plant Cover perturbation is assumed to be lower when the values of plant cover are close to the limits (0 or 1)
  - Simmetric perturbation centered at 0.5 is used
- Same spatial length scale for all the variables considered (L(0.5)=125 km)

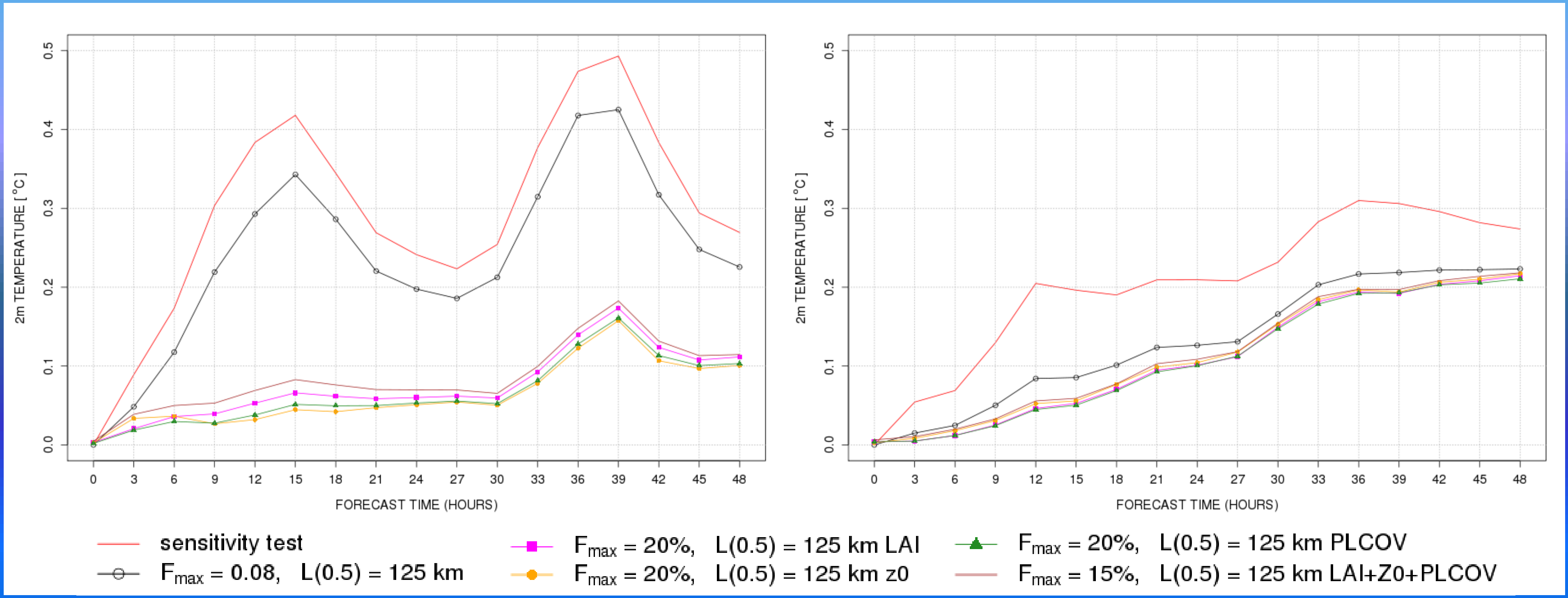
Variables	Layer	Type of perturbation	Intensity F_{max}	Boundaries
Leaf Area Index		x	0.2; 1.8 – 20%	[0; [
Roughness Length		x	0.2; 1.8 – 20%	[0; [
Plant Cover		x	0.2; 1.8 – 20% (centered at 0.5)	[0; 1]
Soil moisture	Surface	+	± 0.06 (0.08) $m^3 m^{-3}$	[0; 1], porosity
	Root zone	+	± 0.04 (0.06) $m^3 m^{-3}$	[0; 1], porosity

External parameters perturbation:

Leaf Area Index, Roughness Length and Plant Cover

(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA



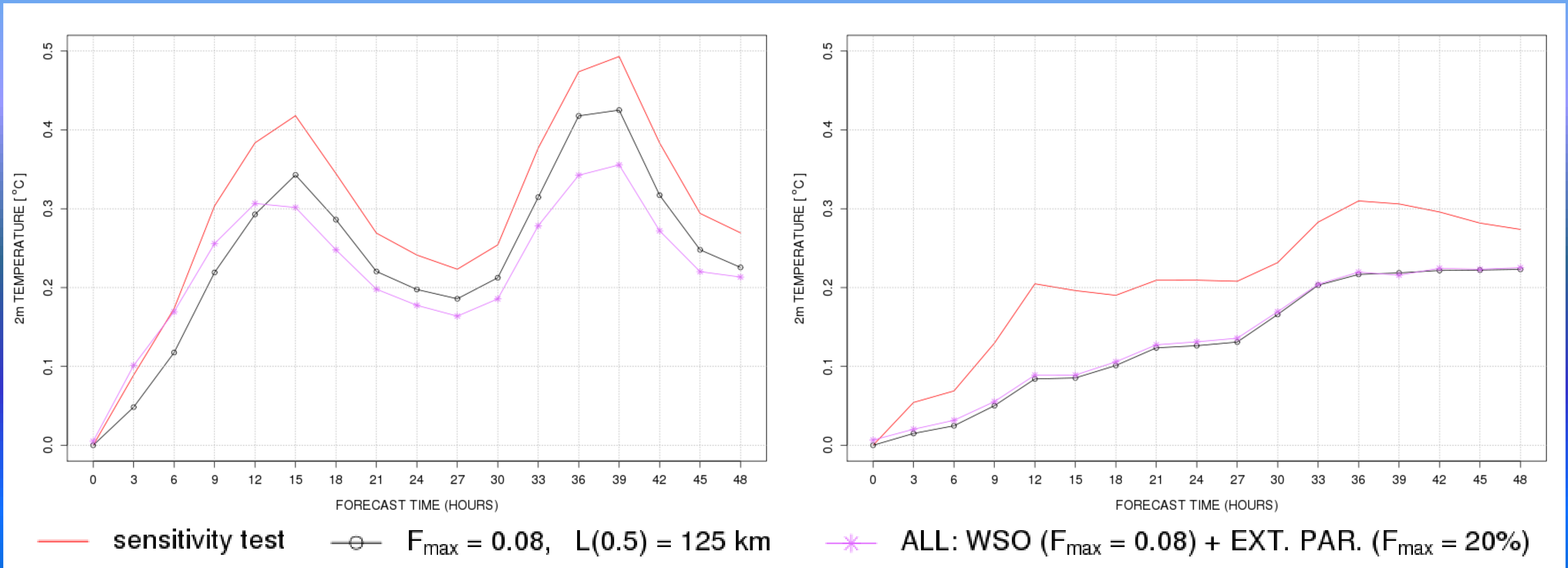
2m TEMPERATURE [°C]

Complete Perturbation

- external parameters: F_{max} = 20%, $L(0.5)$ = 125 km
- soil moisture: $F_{max\ surf}$ = 0.08 $m^3\ m^{-3}$, $L(0.5)$ = 125 km

(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA

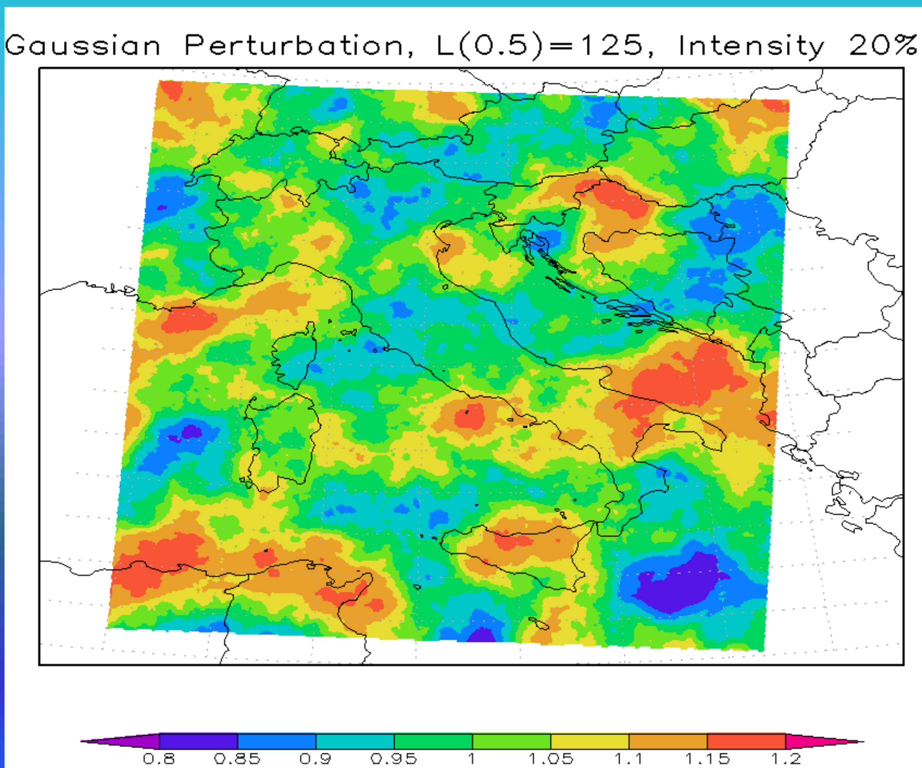


2m TEMPERATURE [°C]

Alternative stretching function

Uniform (Li et al., 2008, McLaughlin et al., 2006)

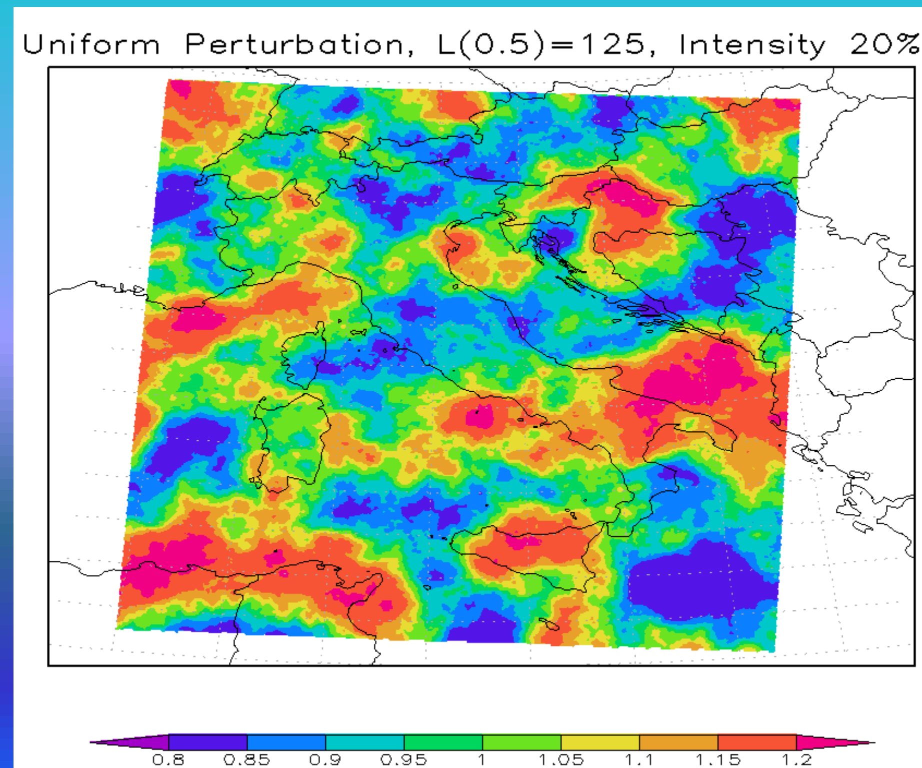
Gaussian



$$F = \mu + S(f,\mu)(f-\mu)$$

$$S(f,\mu) = 2 - \frac{1-\exp\left[\beta\left(\frac{f-\mu}{f_{\max}-\mu}\right)^2\right]}{1-\exp(\beta)} \qquad \beta \approx -1.27$$

Uniform

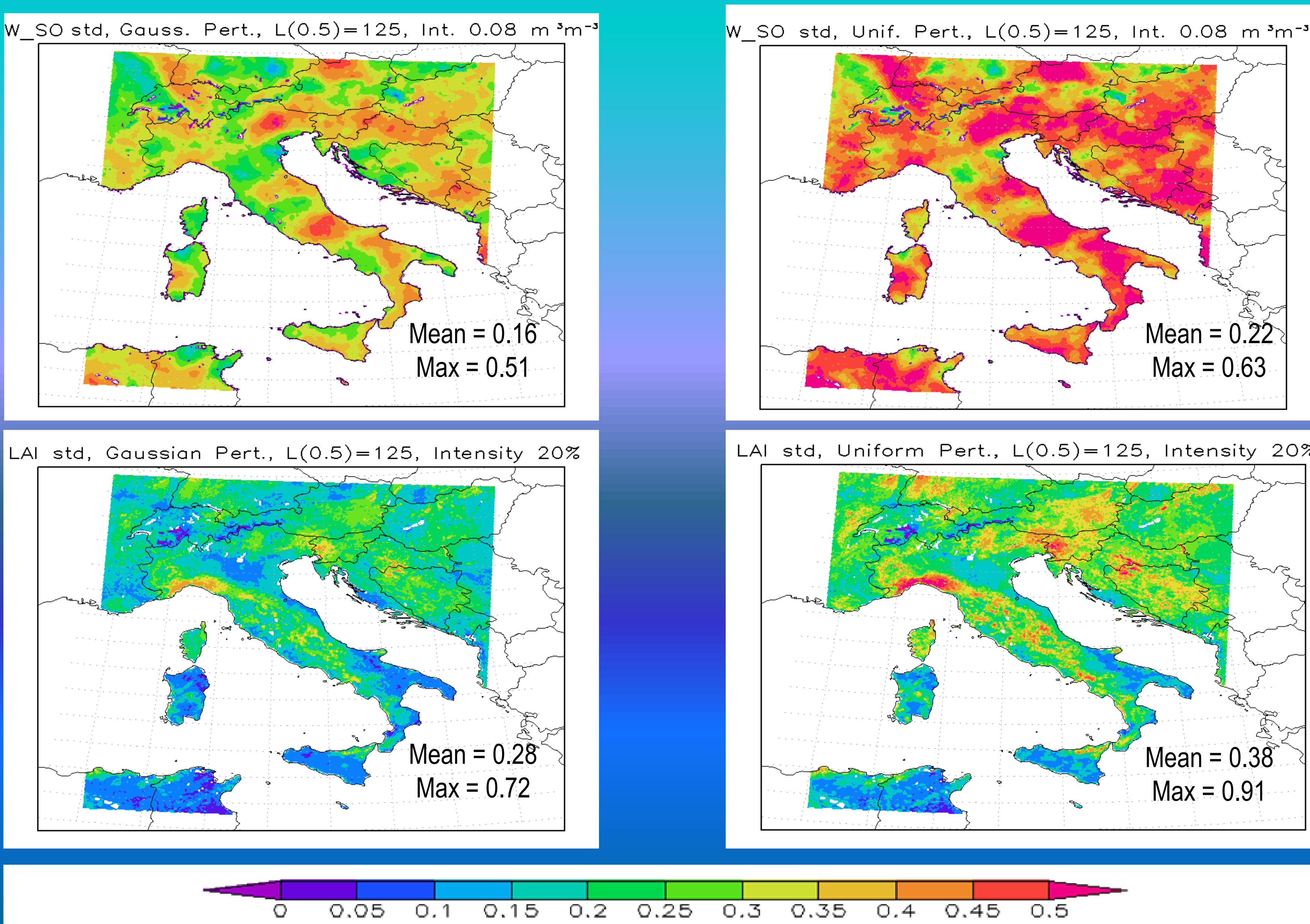


$$F = \mu + \frac{f_{\max} - f_{\min}}{2}\, erf\left(\frac{f-\mu}{\sigma\sqrt{2}}\right)$$

Alternative stretching function

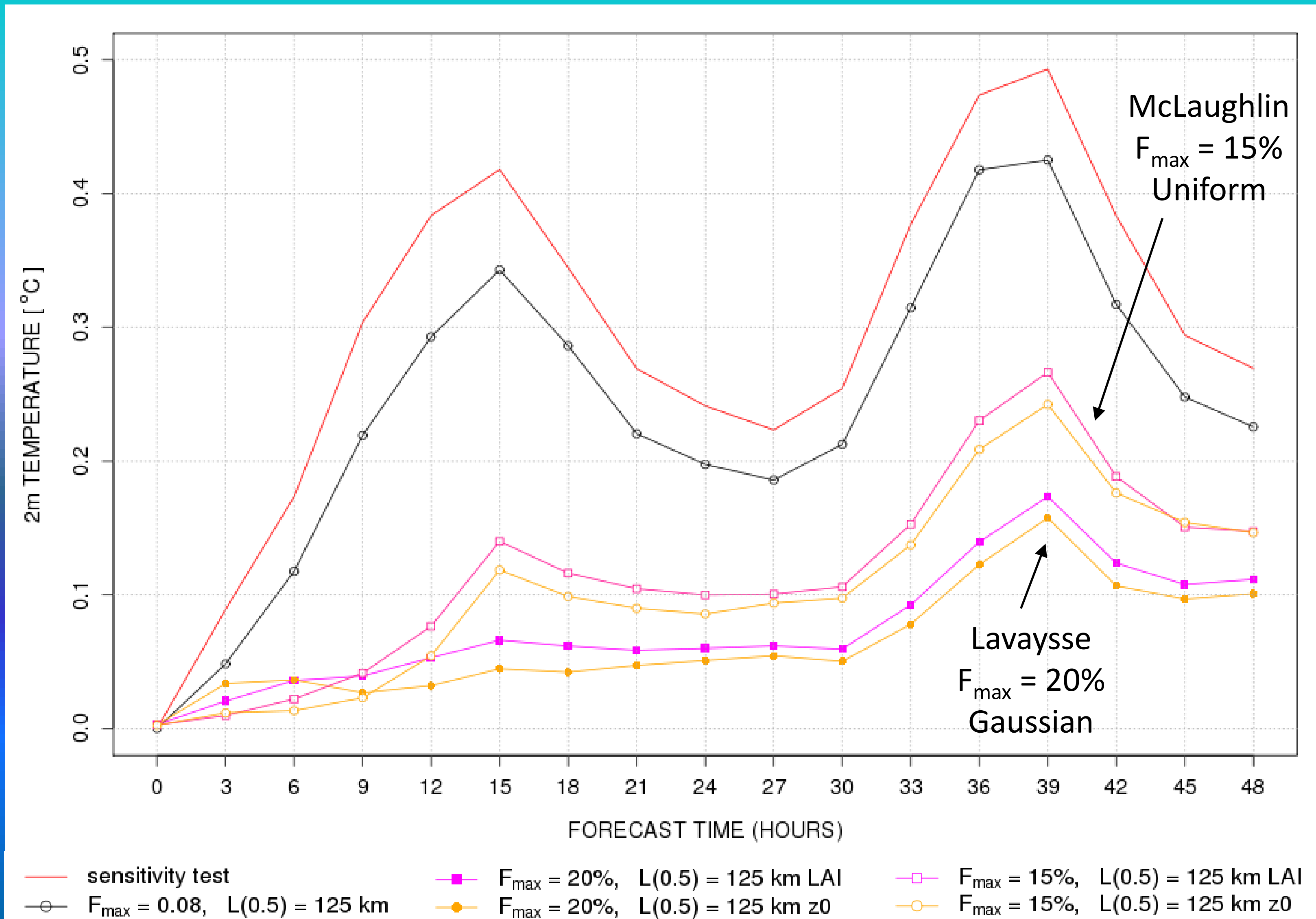
Gaussian

Uniform



External parameters perturbation:

Different streatching functions



Impact of surface perturbation on upper levels of atmosphere

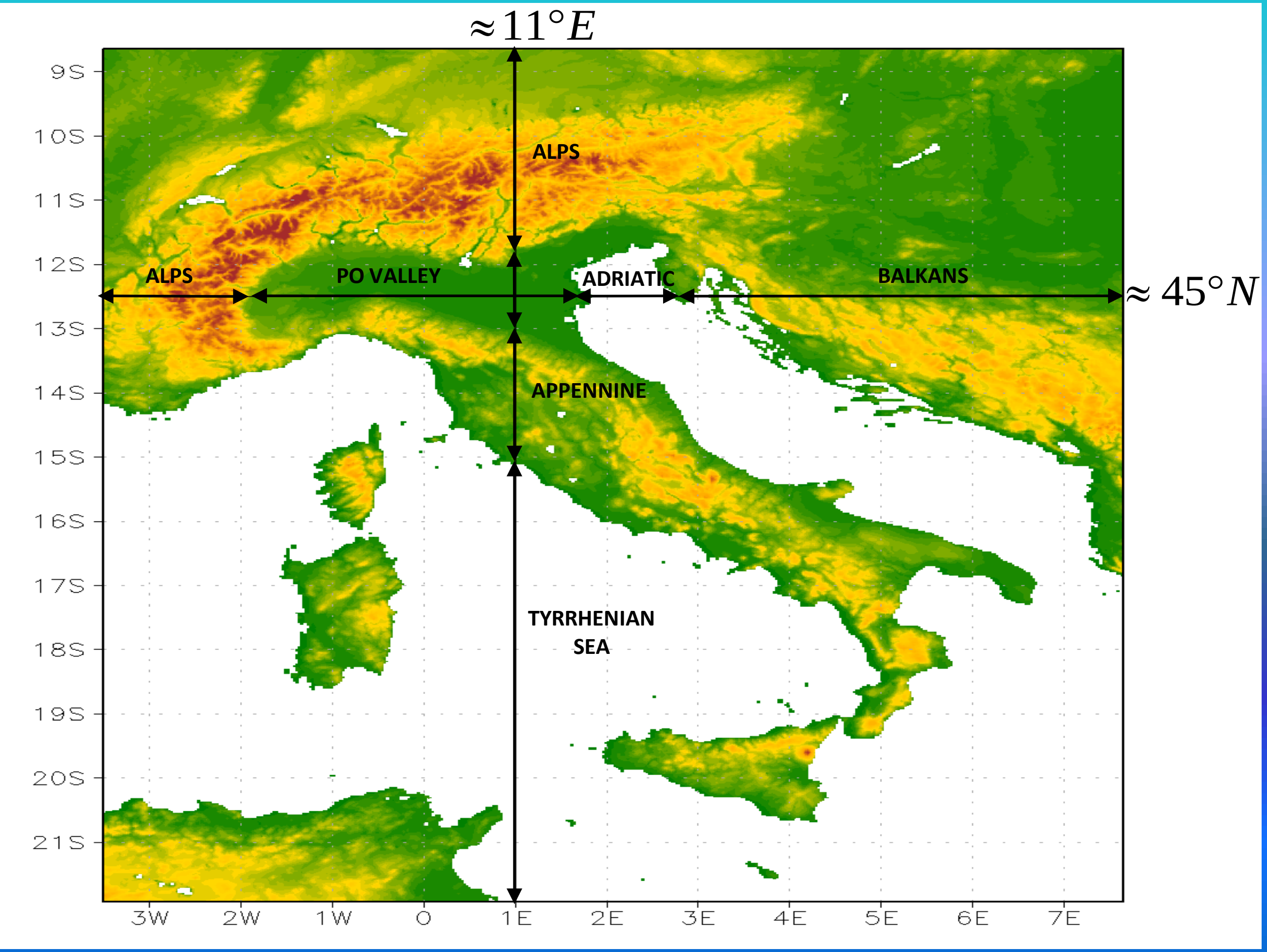
Variables considered: *Temperature* T, *Specific Humidity* Q_v, *Vertical Velocity* W, *Wind Speed* $\sqrt{U^2+V^2}$

Case study:

- *29-06-2011 00UTC – Strong synoptic forcing (cold front)*
- *10-11-2013 00 UTC – Strong winds (Foehn + Mistral) and low pressure system over Tyrrhenian sea*

Settings: $L(0.5) = 125$ km, $F_{max\ surf} = 0.08$, $F_{max\ root} = 0.06\ m^3\ m^{-3}$

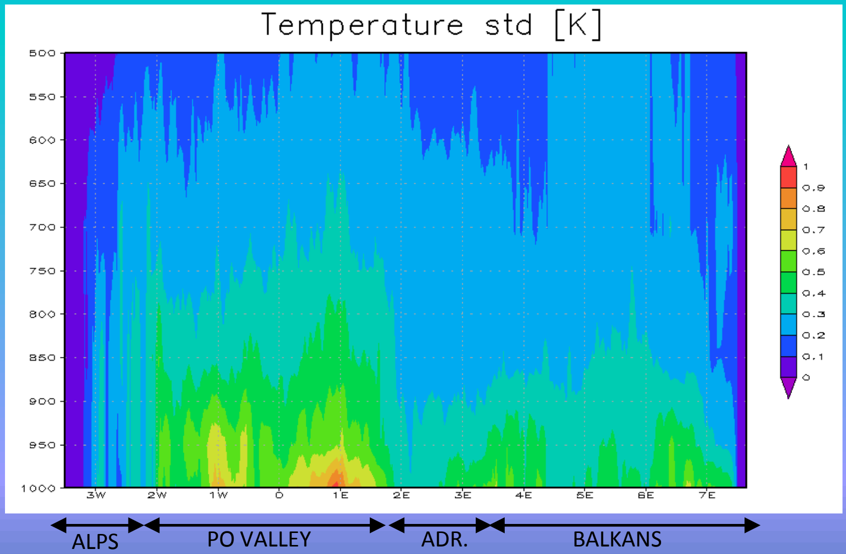
Impact of surface perturbation on upper levels of atmosphere

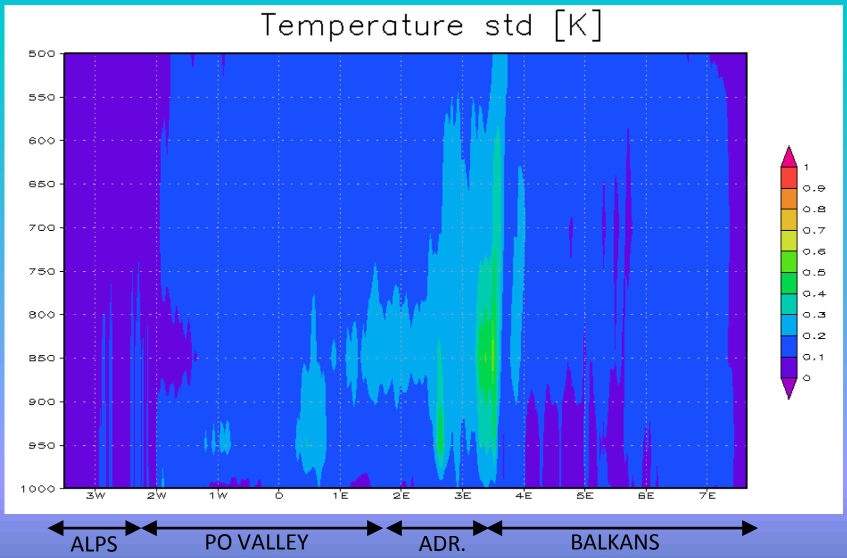


(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

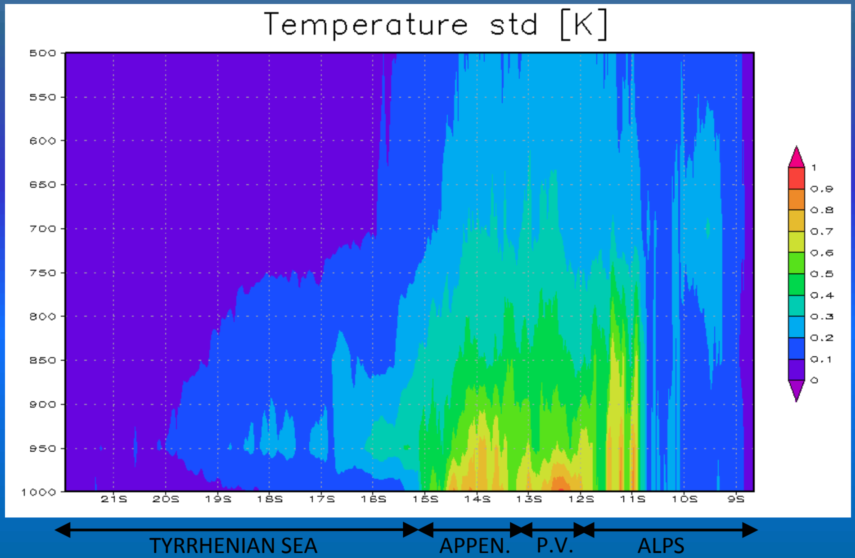
(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA

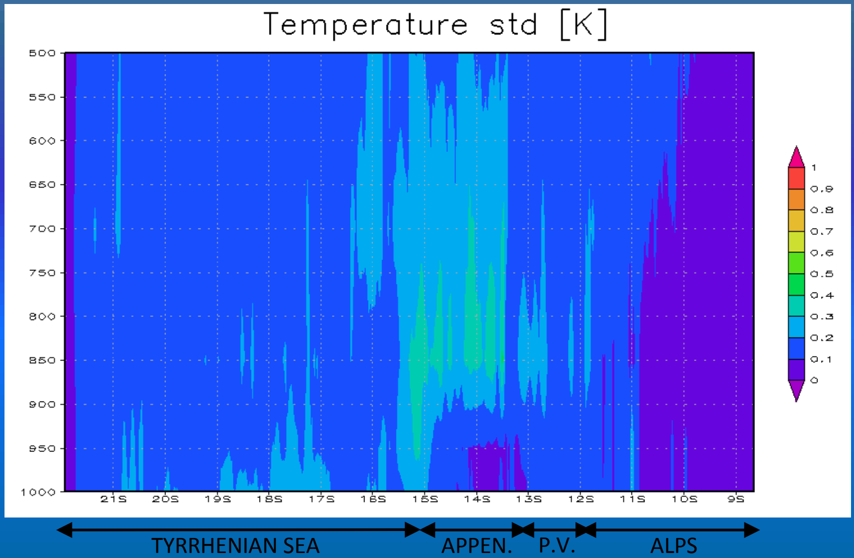
Temperature, Z(hPa) vs. lon, lat =-12.5° (≈ 45°N) , time mean





Temperature, Z(hPa) vs. lat , lon =1.0° (≈ 11°E), time mean

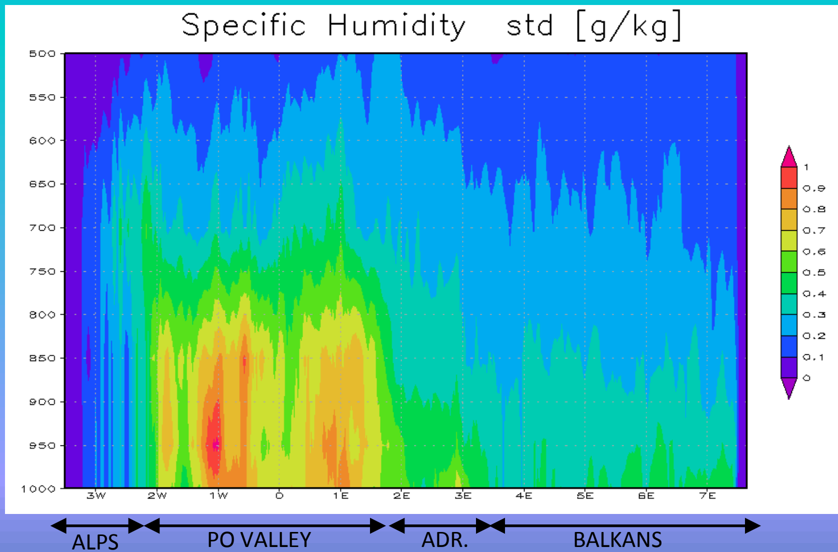


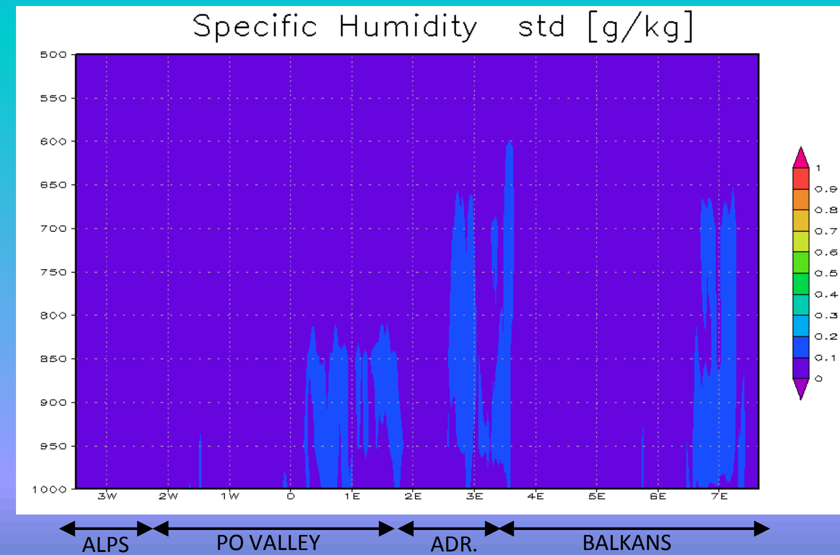


(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

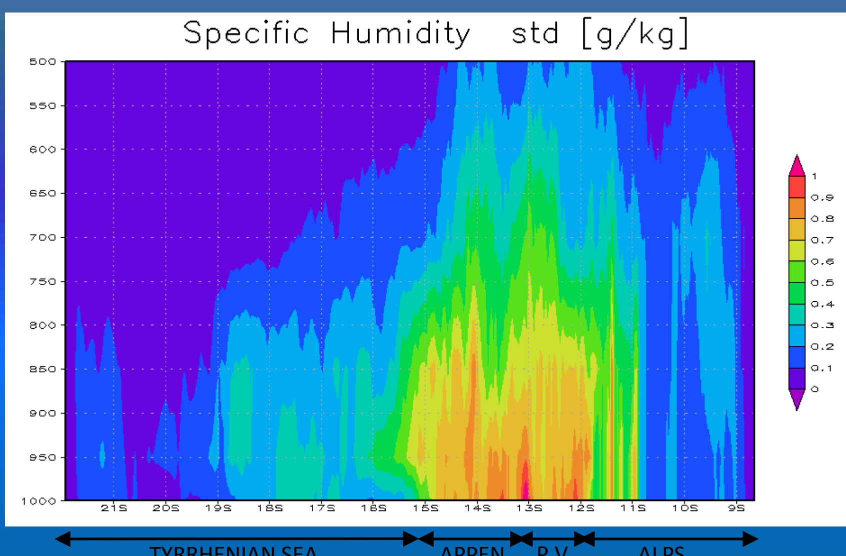
(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA

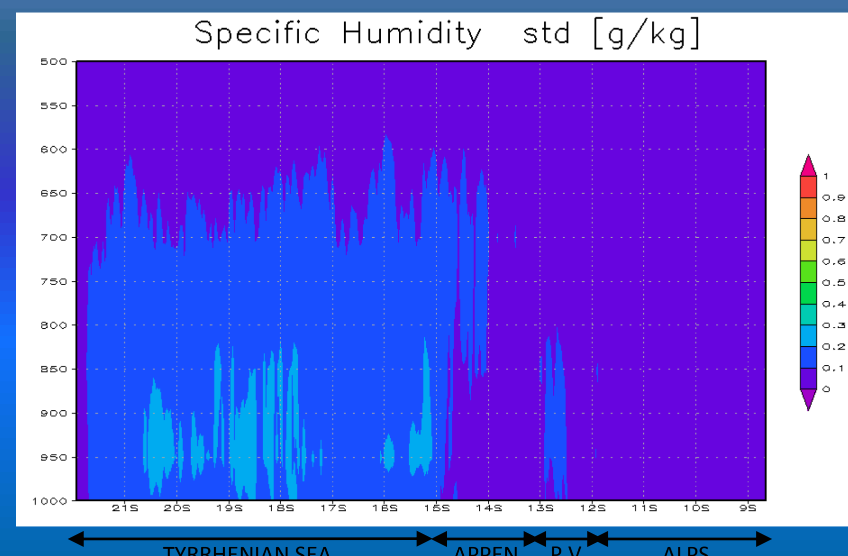
Specific Humidity, Z(hPa) vs. lon, lat =-12.5° (≈ 45°N) , time mean





Specific Humidity, Z(hPa) vs. lat , lon =1.0° (≈ 11°E), time mean

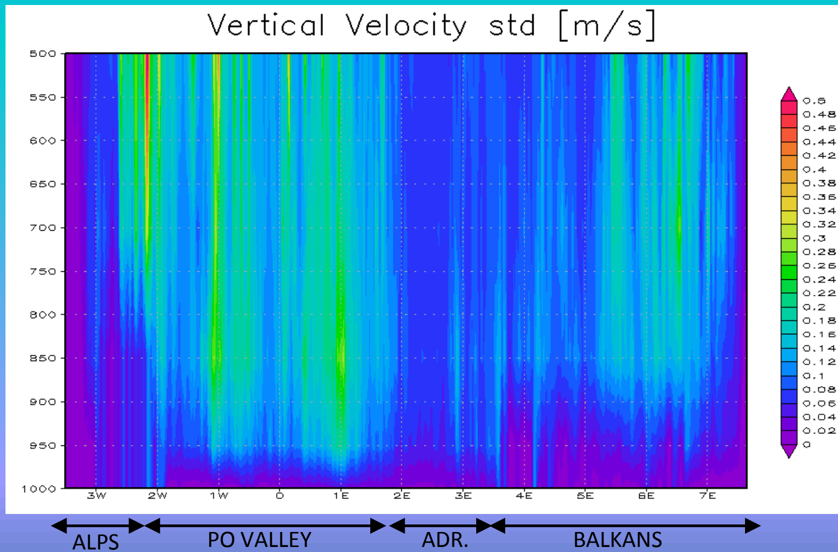


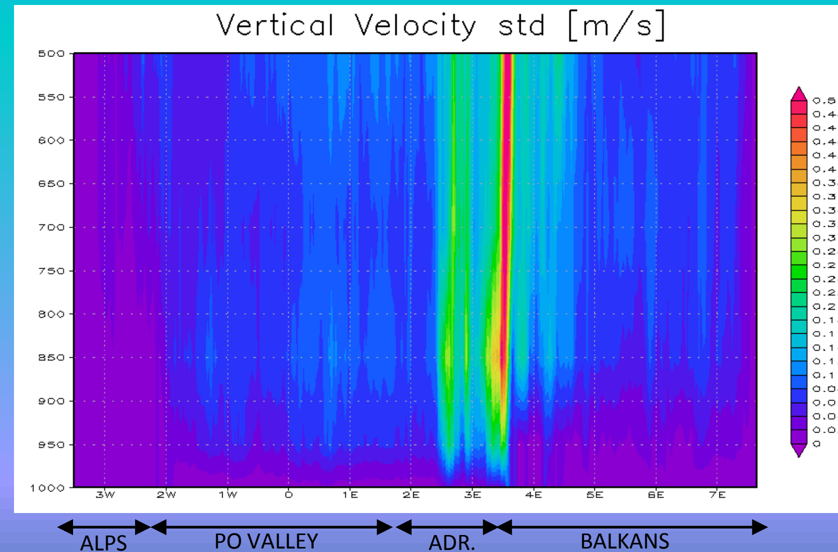


(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

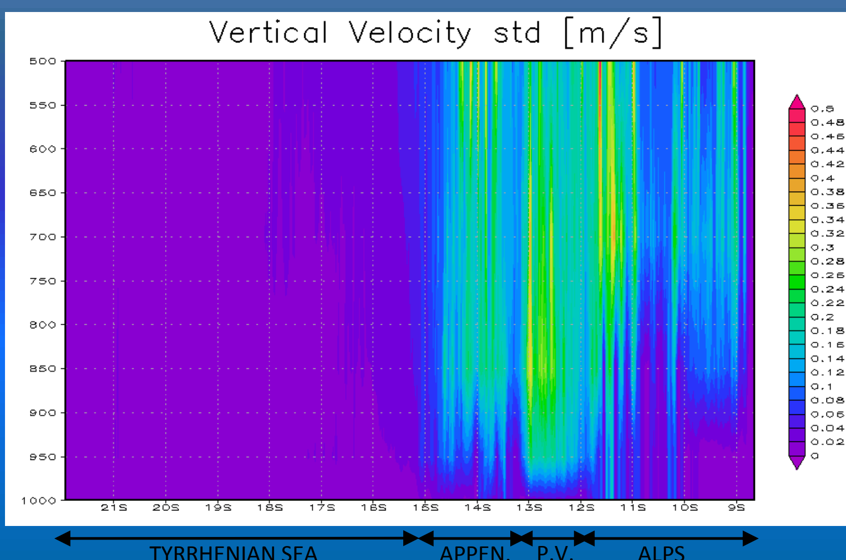
(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA

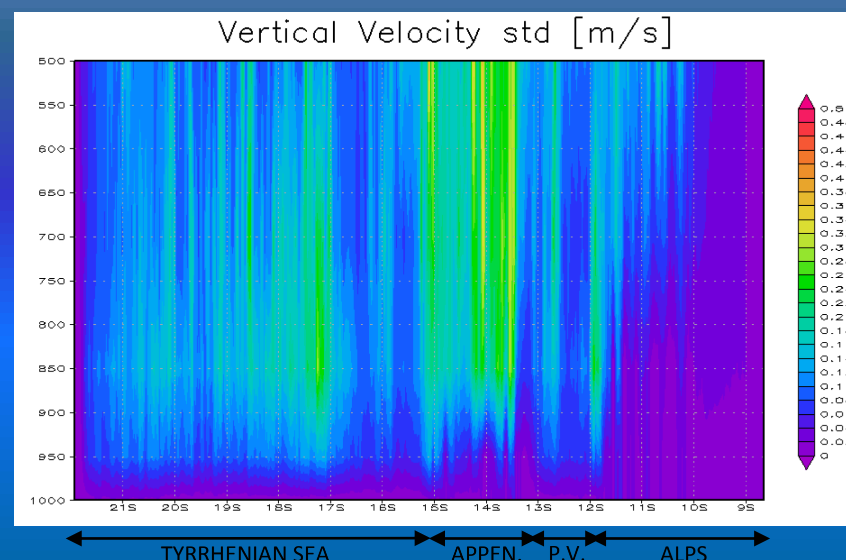
Vertical Velocity, Z(hPa) vs. lon, lat =-12.5° (≈ 45°N) , time mean





Vertical Velocity, Z(hPa) vs. lat , lon =1.0° (≈ 11°E), time mean

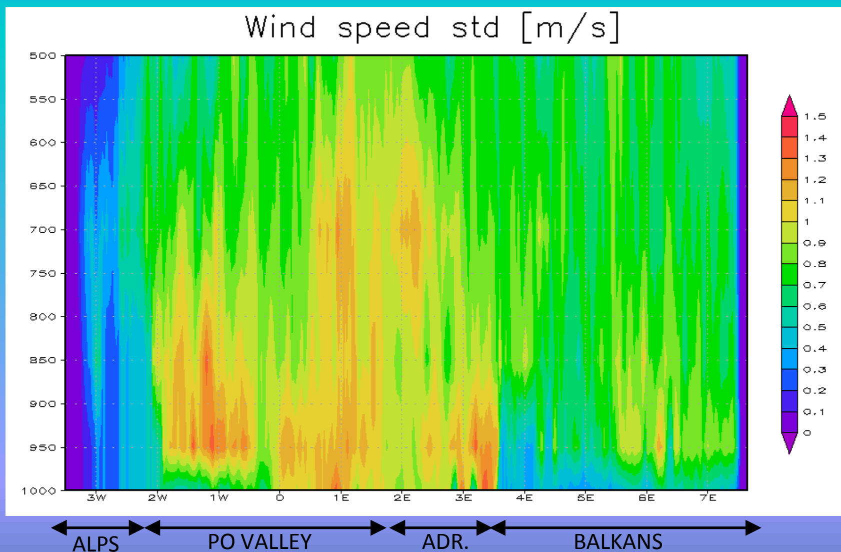


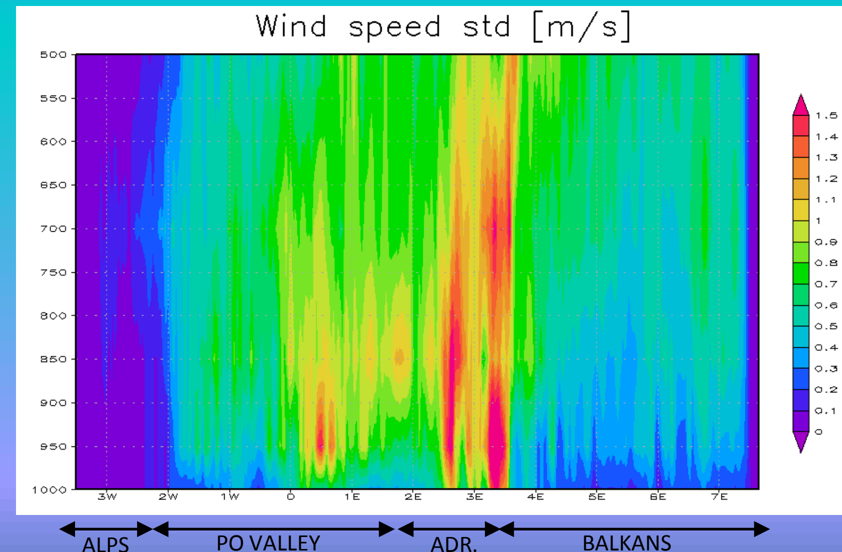


(1) 29-06-2011 00UTC - STRONG SYNOPTIC FORCING

(2) 10-11-2013 00UTC - STRONG WINDS (FOEHN + MISTRAL) AND LOW LEVEL PRESSURE OVER TYRRHENIAN SEA

Wind Speed, Z(hPa) vs. lon, lat =-12.5° (≈ 45°N) , time mean





Wind Speed, Z(hPa) vs. lat , lon =1.0° (≈ 11°E), time mean