CONSORTIUM FOR SMALL SCALE MODELING

COSMO

A sensitivity test to assess the impact of different soil moisture initializations on short range ensemble variability in COSMO model

Riccardo Bonanno, Nicola Loglisci

PIEMONTE

Arpa

Agenzia Regionale per la Protezione Ambientale

COSMO/CLM/ART User Seminar – Offenbach – 17-19 March 2014

Introduction

- A well-known problem with ensemble forecasts is their lack of variability between members, typically worse near the surface rather than higher in the troposphere.
- Surface condition uncertainties are seldom taken into account in ensemble systems, and ensemble forecasts typically use the same surface conditions for all members.
- However, the sensitivity of moist atmospheric processes to soil conditions has been demonstrated in numerous studies: Sutton et al. (2006), Aligo et al. (2007), Quintanar et al. (2008), Klüpfel et al. (2011)
- Considering all this studies, it's clear that it would be very important to integrate surface perturbations into an ensemble system to account for uncertainties in surface conditions and to increase the ensemble spread near the surface.
- In this regard, some techniques have been proposed in the recent years: Sutton and Hamill (2004), Wang et al. (2010), Hacker (2010), Lavaysse et al. (2013), Cloke et al (2012)

Aim of the study

- The goal of this study is to perform a sensitivity test to assess the behavior of COSMO model to different lower boundary initial conditions

- **COTEKINO** priority project
  - (**CO**smo **T**owards **E**nsembles at the **K**m-scale **IN O**ur countries)
  - aimed to develop a convection-permitting ensembles in our country.

- In fact, even if the sensitivity of the atmospheric moist processes to different soil condition initializations has been demonstrated in several studies previously mentioned, it can't be generalized to a completely different modeling system.

- Hence, it would be wise to verify a sensitivity in COSMO model before implementing soil moisture perturbations. The study of Klüpfel et al. (2011) for the West Africa lead us to imagine positive results also for our test.

Dataset

Different models with different spatial resolution have been chosen to ensure a good variability among the soil moisture fields used to initialize COSMO model for the sensitivity test.

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
Soil levels depth (cm)	1, 2, 6, 18, 54, 162, 486, 1458	7, 28, 100, 289	10, 40, 100, 200	10, 40, 100, 200	1, 2, 6, 18, 54, 162, 486, 1458

- NOAH LSM is driven by a Global Land Data Assimilation System (GLDAS).
- UTOPIA LSM (University of TOrino land Process Interaction in Atmosphere, Cassardo et al. (2006)) is a diagnostic one-dimensional land surface model (similar to TERRA LSM) developed at the University of Torino (driven by ECMWF analysis and TRMM precipitation gridded dataset)

Methodology:

Soil moisture preprocessing

1. The dependence of soil moisture on the soil texture of the original model is taken into account
   - ***Degree of saturarion*** :

   $$S = \frac{\eta_w}{\eta_s}$$

   η_w is the volumetric soil water content and η_s is the soil porosity of the original model depending on the spatial distribution of the soil texture

   - ***Soil moisture index*** **:** operational method used in INT2LM (l_smi=TRUE)

   $$SMI = \frac{\eta_w - \eta_{wp}}{\eta_{fc} - \eta_{wp}}$$

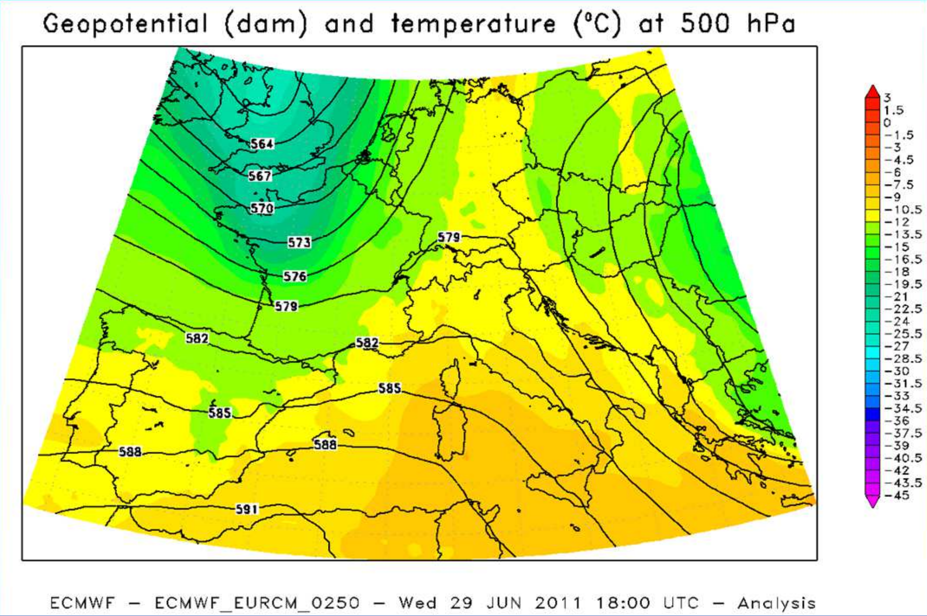
   η_{wp} and η_{fc} volumetric soil water content at the wilting point and field capacity

2. Rotation and spatial interpolation over finer COSMO 0.025° gri
3. Vertical interpolation of *S* over COSMO soil levels (1, 2, 6, 18, 54, 162, 486, 1458 cm)
4. The soil texture of COSMO at 0.025° model is taken into account:

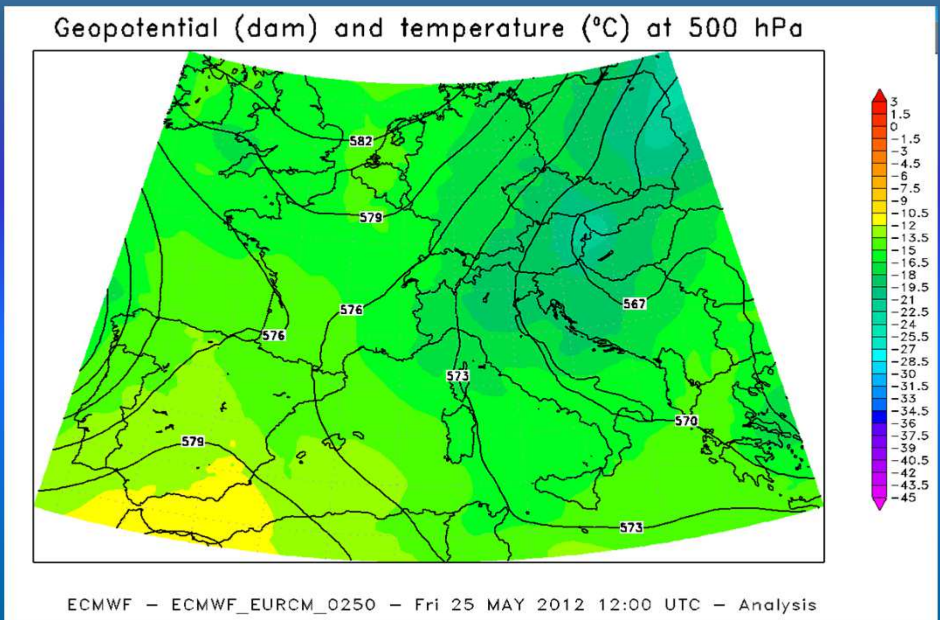
$$\eta_{w\ final} = S\ \eta_{s\ COSMO}$$

Case studies

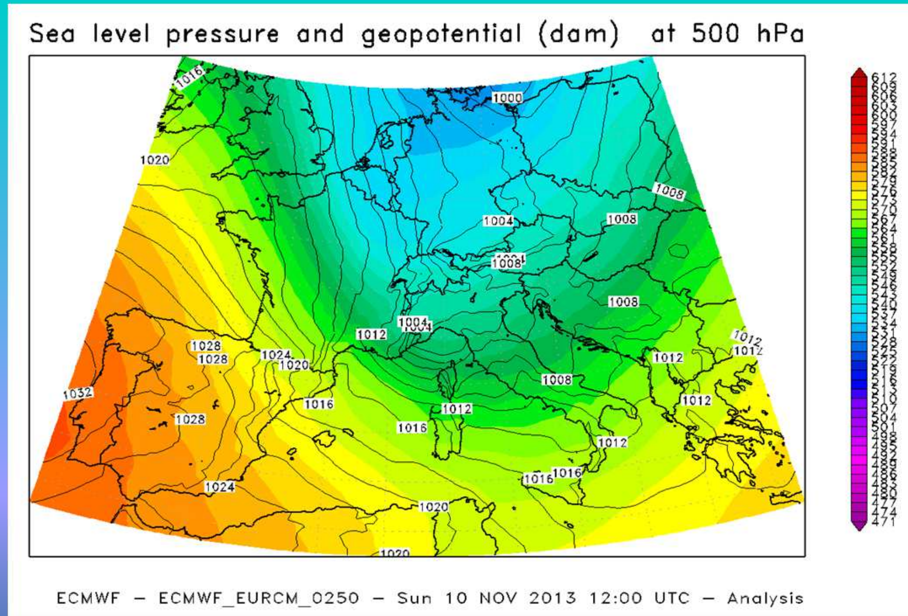
(1) 29-01-2011 00UTC - STRONG SYNOPTIC FORCING



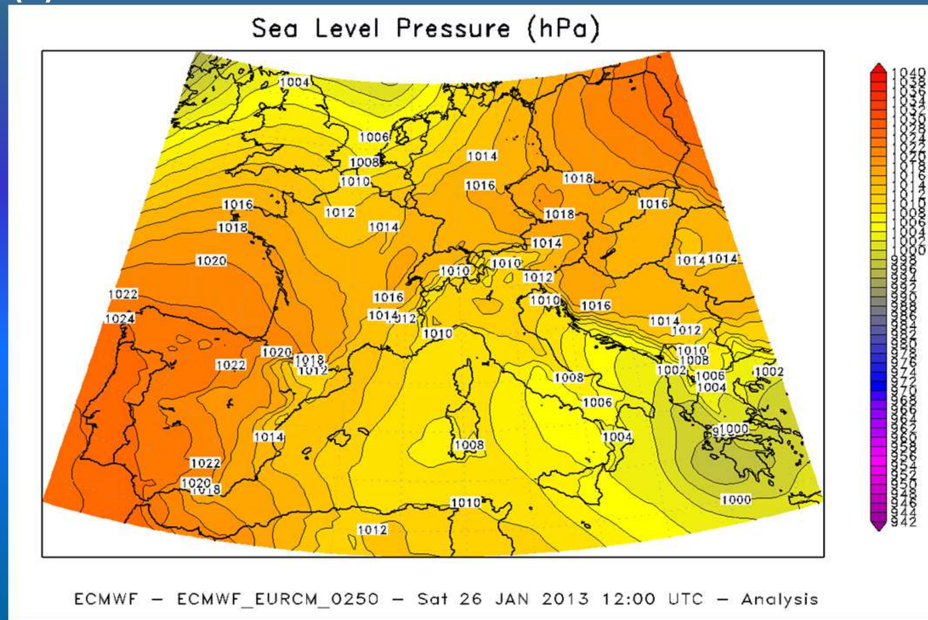
(2) 25-05-2012 00UTC - WEAK SYNOPTIC FORCING



(3) 10-11-2013 00UTC - STRONG KATABATIC WIND (FOEHN) OVER THE PO VALLEY

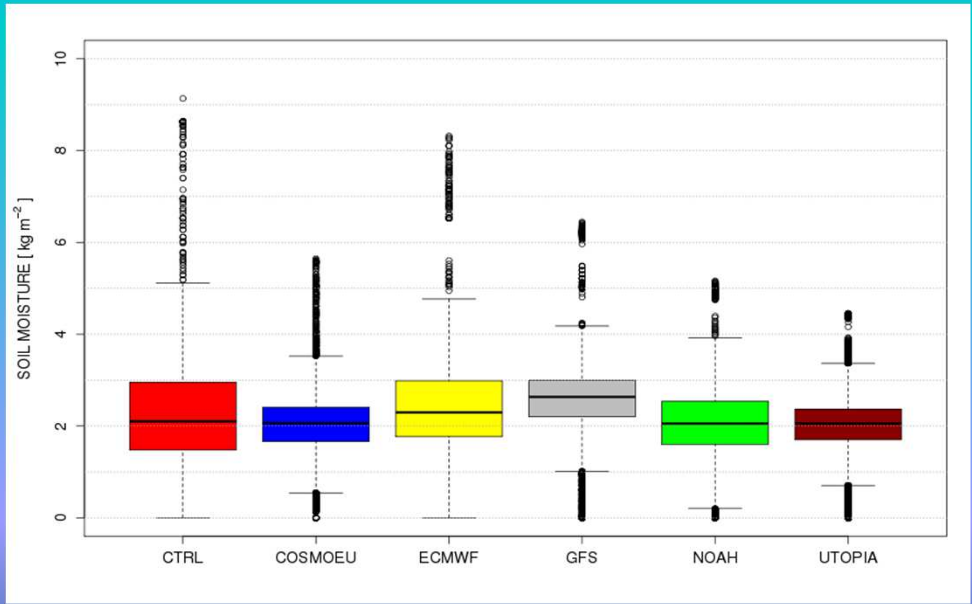


(4) 25-01-2013 12UTC – STABLE CONDITIONS

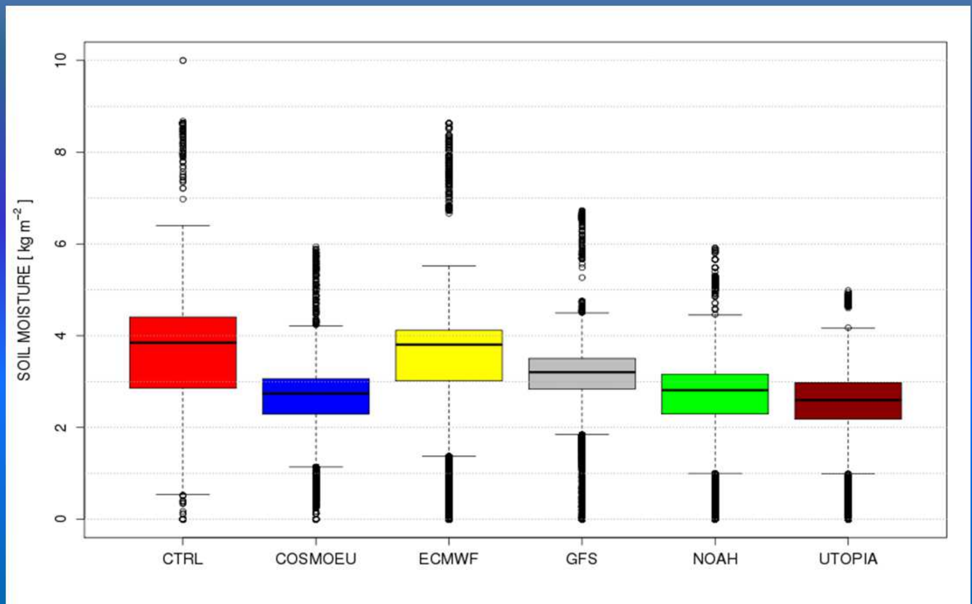


Boxplot of soil moisture fields (1 cm depth)

(1) 29-01-2011 00UTC - STRONG SYNOPTIC FORCING



(2) 25-05-2012 00UTC - WEAK SYNOPTIC FORCING



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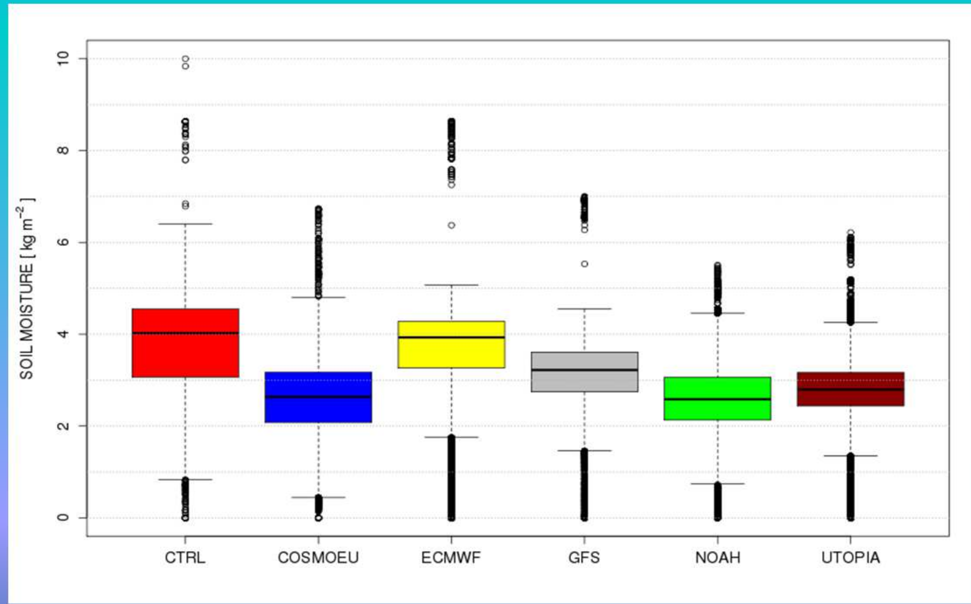
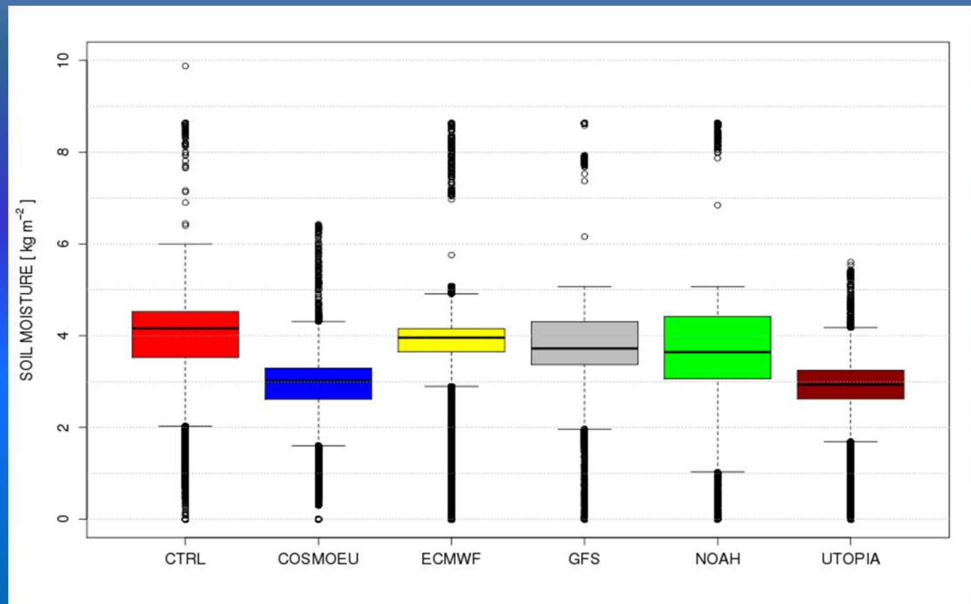


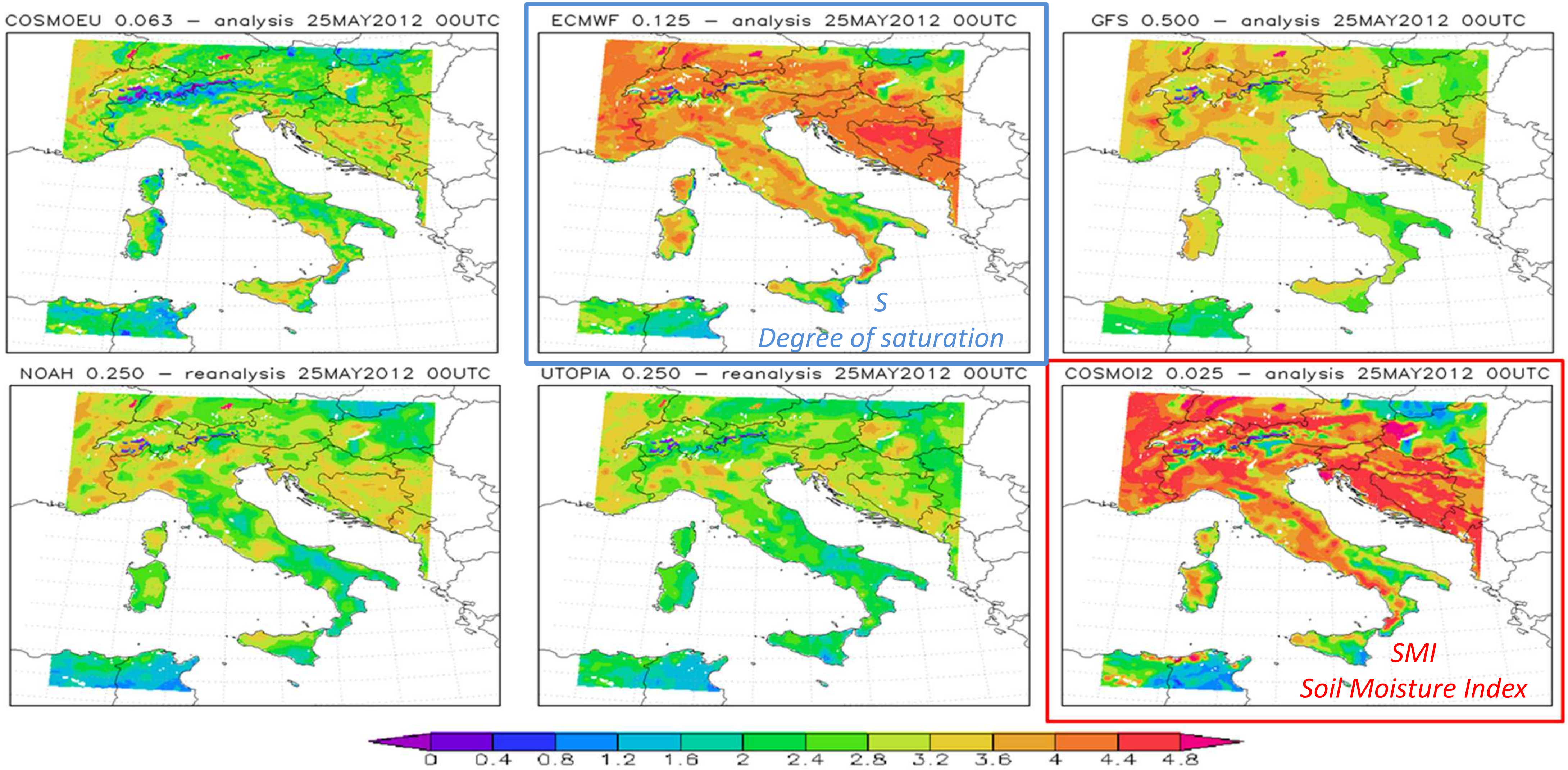
(4) 25-01-2013 12UTC – STABLE CONDITIONS



Example

2° case study: weak forcing: upper level through moving westward from the east Europe

1° layer soil moisture [kg m^{-2}] (1 cm depth)



Simulations and Results

- Once soil fields were available and ready to initialize COSMO model, a number of simulations were carried out to study the response of the model itself to different soil moisture initialization.

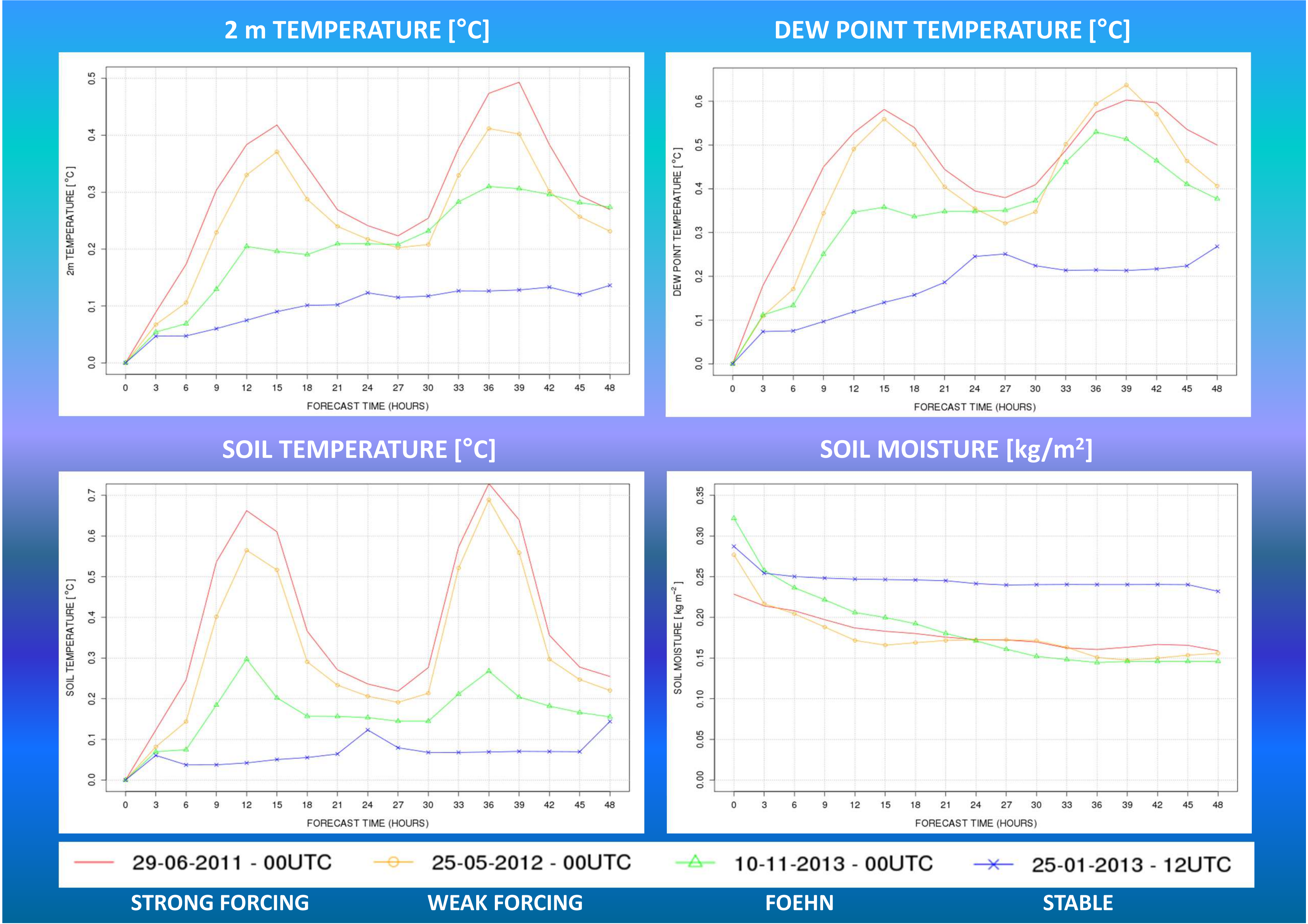
- Being 4 the case studies considered and 5 the different soil moisture analyses (+ 1 of control), we obtained 24 different COSMO runs.

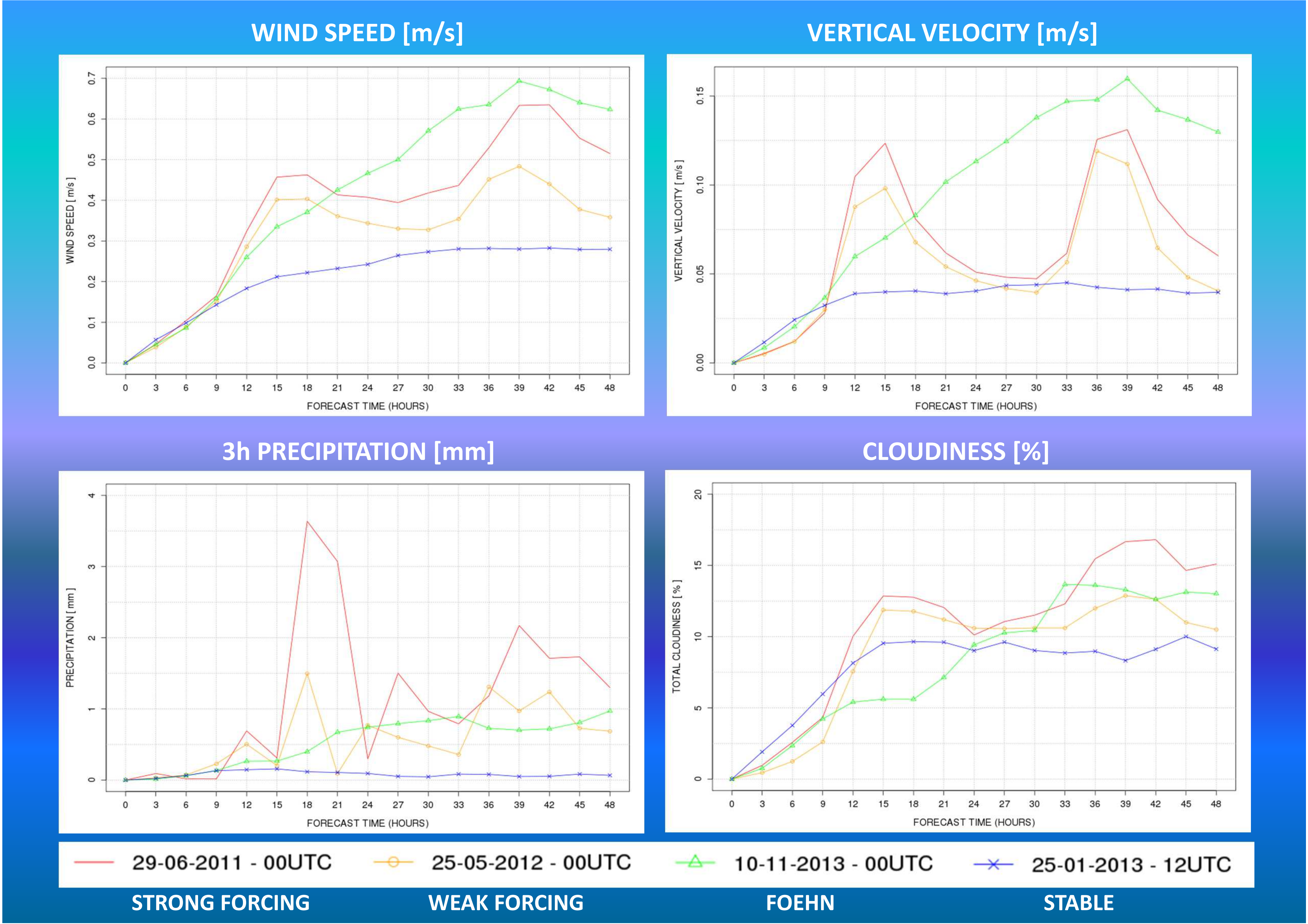
- For the model runs, COSMO model version 5.0 was used with an horizontal resolution of 0.025° (about 2.8 km).

- The variables that we opted to analyze for each case study are: 2 meters temperature and dew point, 10 meters wind speed (module), vertical velocity (w) at an altitude of about 1000 m, total precipitation, cloud cover, soil temperature and moisture

Analysis of the results:

1. Temporal evolution of the spread averaged over the whole domain
2. Spatial distribution of spread at a chosen time of the forecast

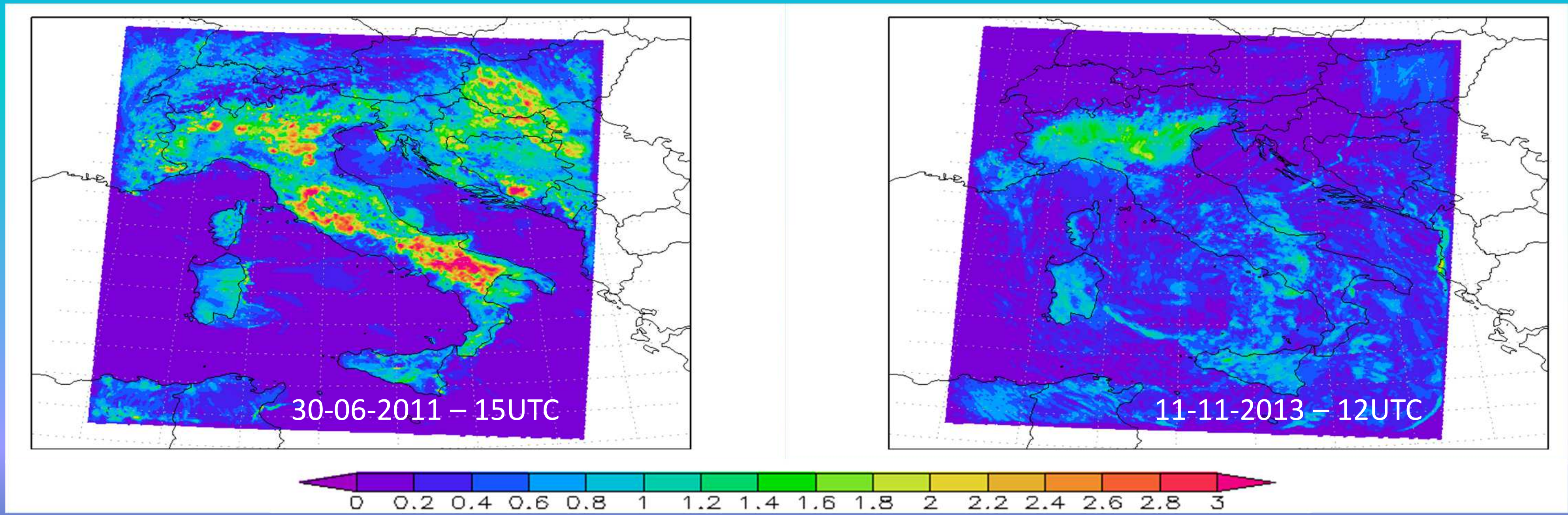

2 m TEMPERATURE [°C]
2m TEMPERATURE [°C]
FORECAST TIME (HOURS)
DEW POINT TEMPERATURE [°C]
DEW POINT TEMPERATURE [°C]
FORECAST TIME (HOURS)
SOIL TEMPERATURE [°C]
SOIL TEMPERATURE [°C]
FORECAST TIME (HOURS)
SOIL MOISTURE [kg/m²]
SOIL MOISTURE [kg m⁻²]
FORECAST TIME (HOURS)
29-06-2011 - 00UTC
25-05-2012 - 00UTC
10-11-2013 - 00UTC
25-01-2013 - 12UTC
STRONG FORCING
WEAK FORCING
FOEHN
STABLE


WIND SPEED [m/s]
WIND SPEED [m/s]
FORECAST TIME (HOURS)
VERTICAL VELOCITY [m/s]
VERTICAL VELOCITY [m/s]
FORECAST TIME (HOURS)
3h PRECIPITATION [mm]
PRECIPITATION [mm]
FORECAST TIME (HOURS)
CLOUDINESS [%]
TOTAL CLOUDINESS [%]
FORECAST TIME (HOURS)
29-06-2011 - 00UTC
25-05-2012 - 00UTC
10-11-2013 - 00UTC
25-01-2013 - 12UTC
STRONG FORCING
WEAK FORCING
FOEHN
STABLE

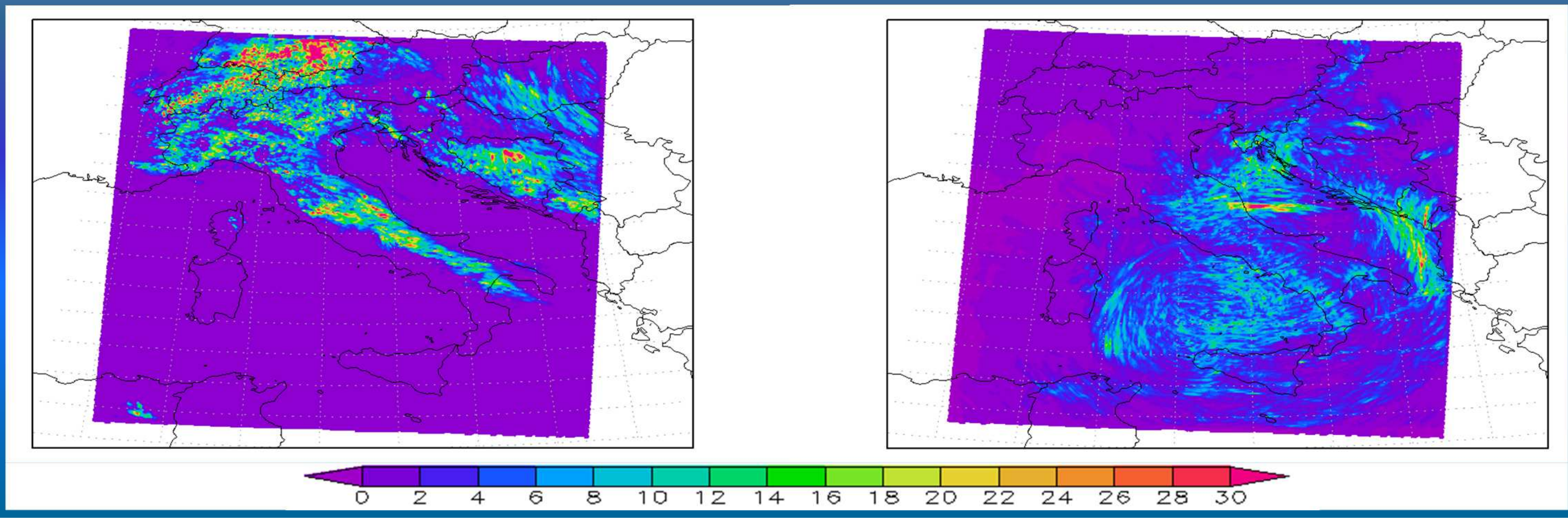
Spatial distribution of spread - 2m temperature

(1) 29-01-2011 00UTC - STRONG SYNOPTIC FORCING

(3) 10-11-2013 00UTC - FOEHN OVER THE PO VALLEY



Spatial distribution of spread – 48h cumulated precipitation



Conclusions

- In this 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.
- Spread stronger in the spring/summer case studies with convective conditions, weaker in autumn season and less appreciable in stable winter conditions
- To assess if the spread obtained in our test is significant it would be wise to compare these values with those coming from an ensemble obtained perturbing only the initial atmospheric conditions.
- Numerical instability: some simulations concerning another case study similar to the 3rd one presented here failed. Also this case study consisted in a foehn condition in the northwestern Italian Alps with strong winds.
- This fact remind us how important is to take into account the numerical stability of the model when perturbing soil moisture with a certain technique.

Future developments

Perturbation technique

1. Lavaysse et al. (2013) : two-dimensional random function on the sphere correlated in space to perturb soil moisture and temperature

2. Implemented in Matlab. A first tested was just completed with the case study of strong synoptic forcing (29-06-2011 00UTC). First results will be presented in the COTEKINO PP session.

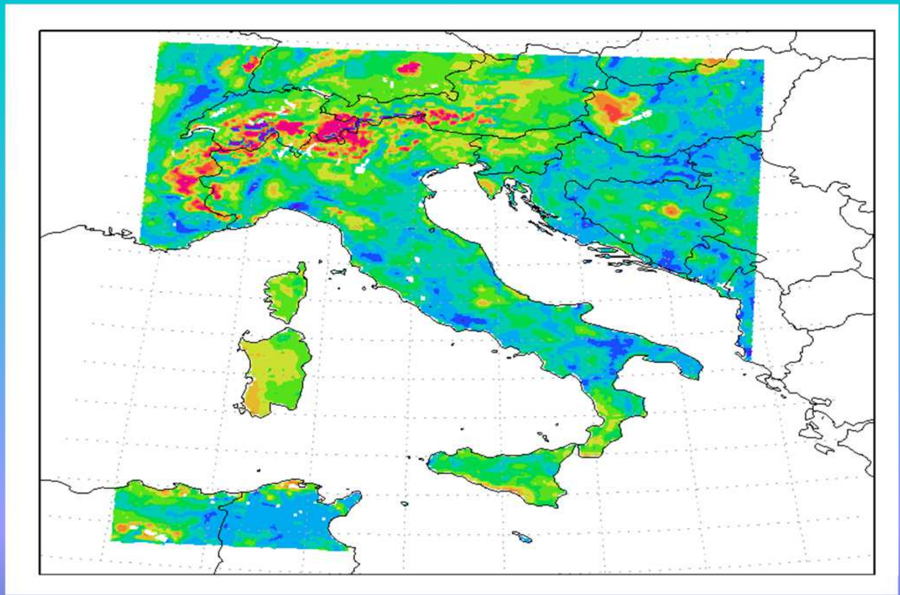
3. Test with more case studies (already used for the sensitivity test)

4. Test of other techniques in case of non satisfactory results
   - CONSENS Priority Project : empirical orthogonal function (EOF), technique inspired by the work of Sutton and Hamill, 2004
   - Perturbation of some soil scheme parameters (Cloke et al (2012) used in the ECMWF seasonal forecasting system)
   - Method based on differences between two soil moisture analyses (COSMO-EU and COSMO-DE, technique implemented by DWD and under test)

Thank you for your attention!

Initial soil moisture spread: spatial distribution

(1) 29-01-2011 00UTC - STRONG SYNOPTIC FORCING



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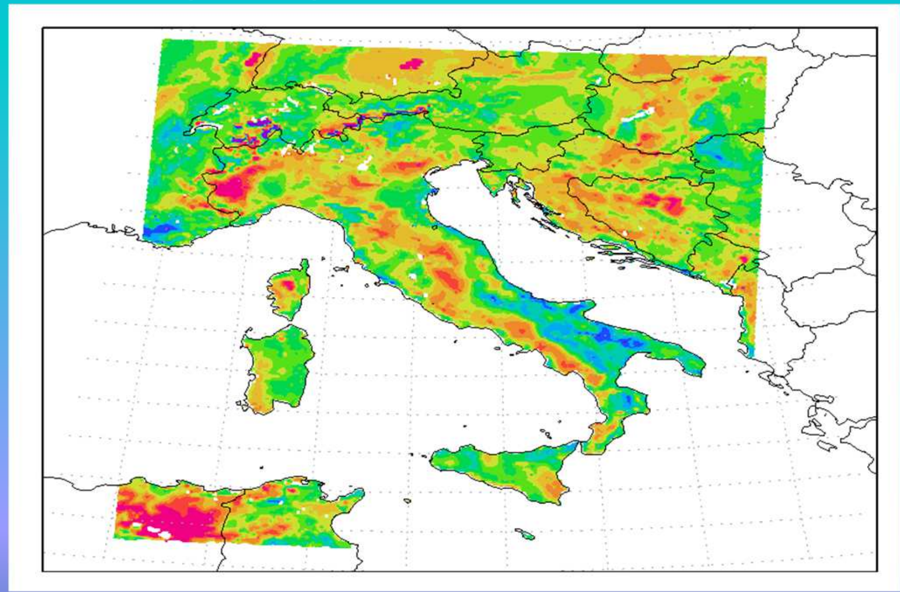

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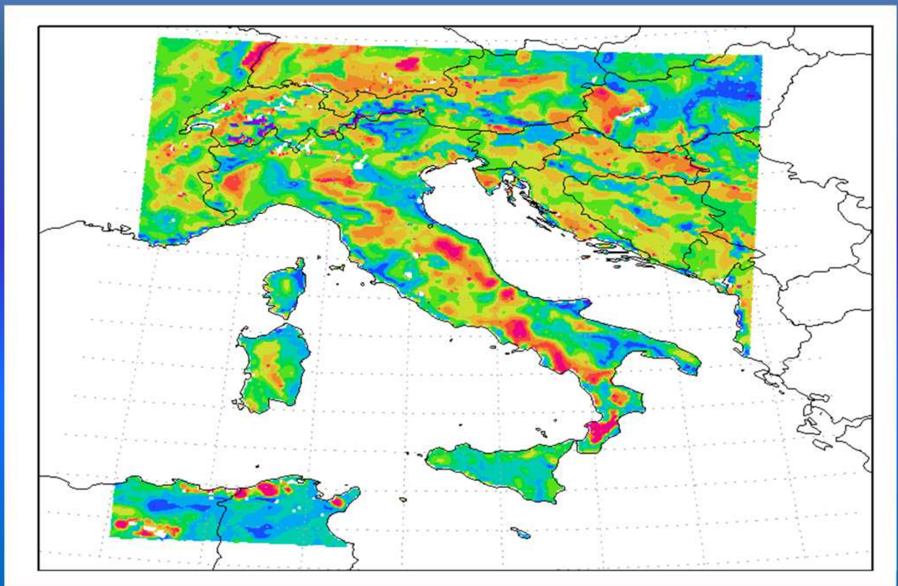
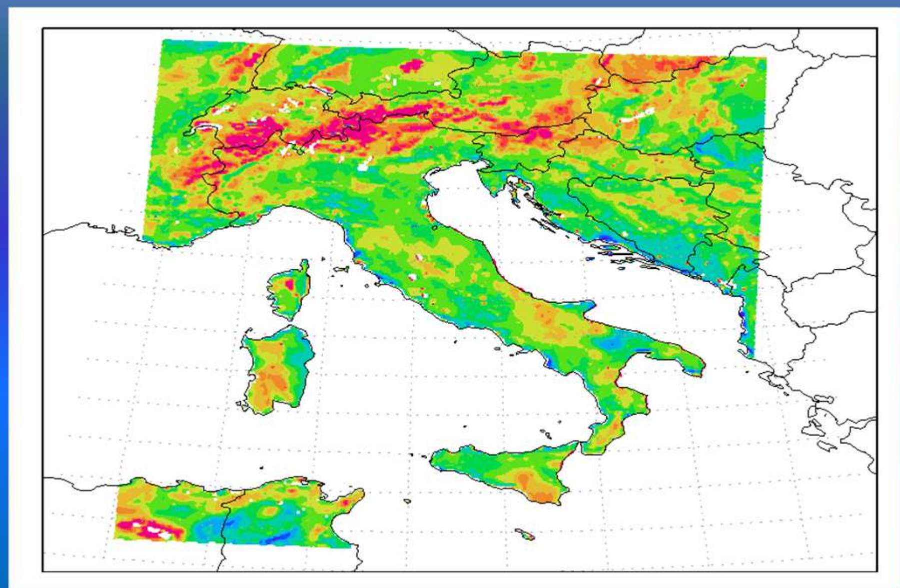
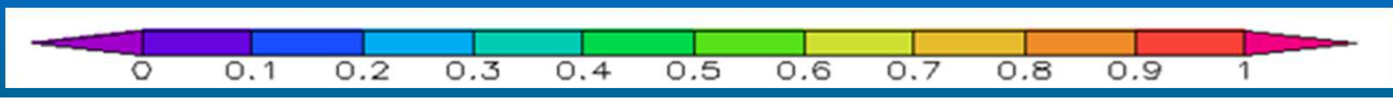
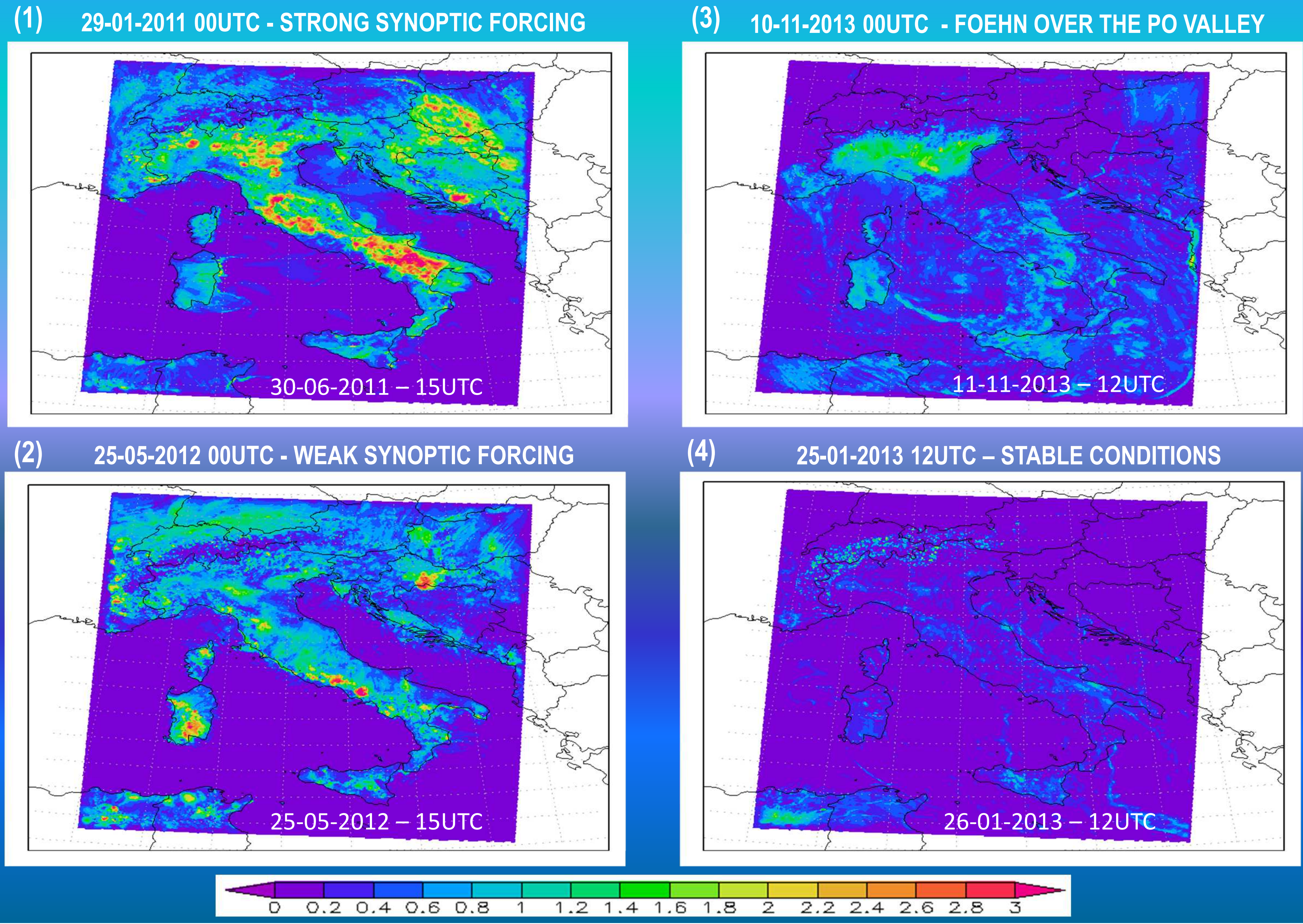


(4) 25-01-2013 12UTC – STABLE CONDITIONS





Spatial distribution of spread - 2m temperature



Spatial distribution of spread – 48h cumulated precipitation

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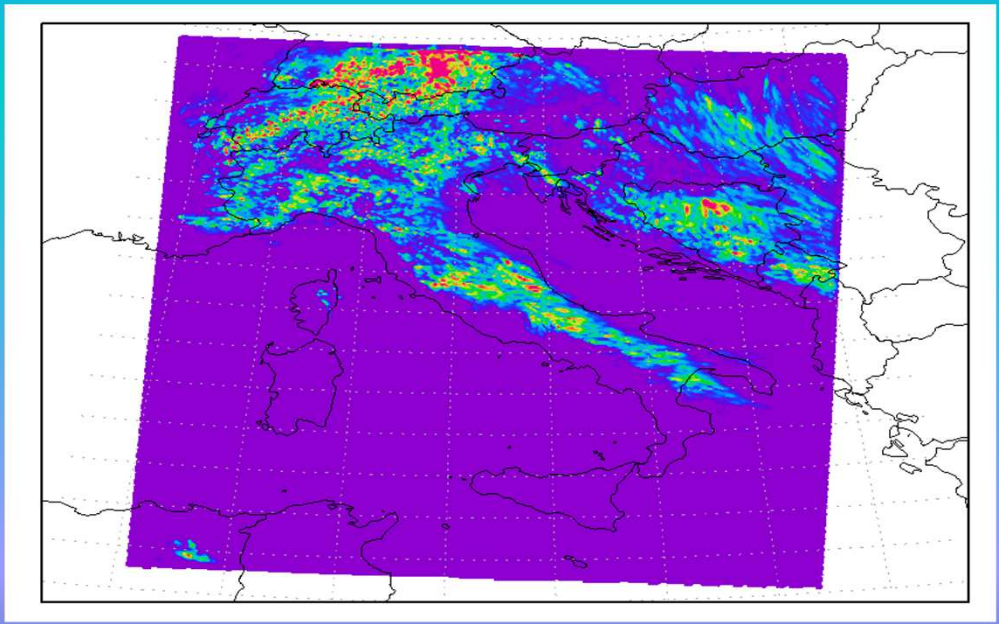
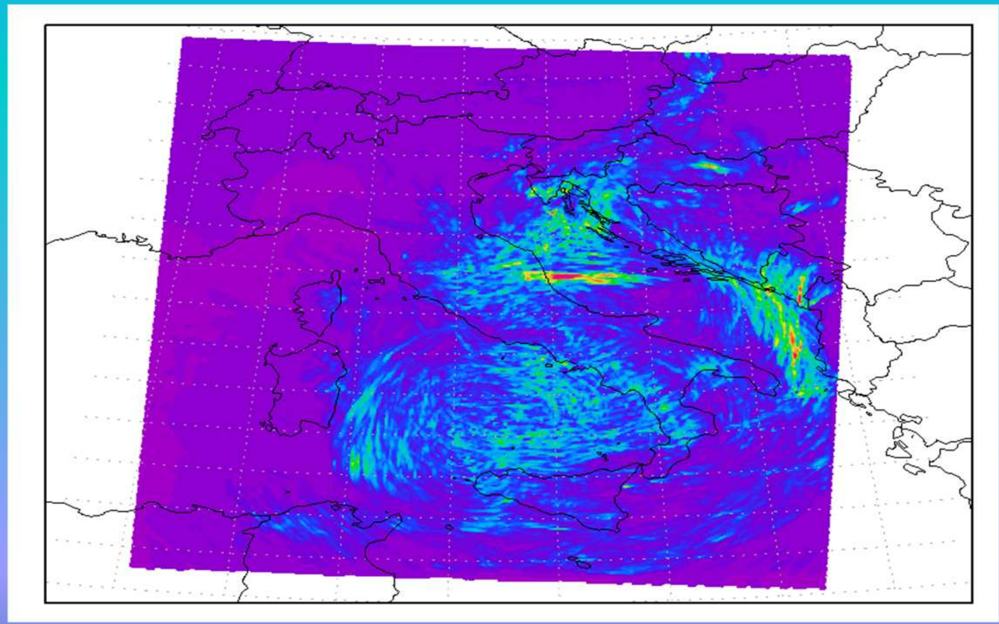


(3) 10-11-2013 00UTC - FOEHN OVER THE PO VALLEY



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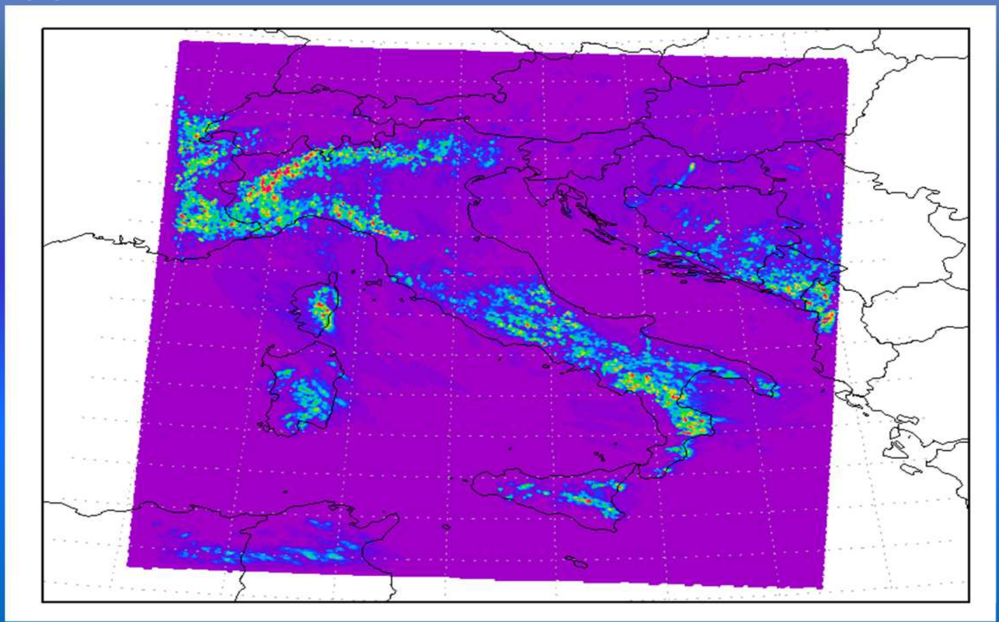

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