Investigations on COSMO 2.8Km precipitation forecast

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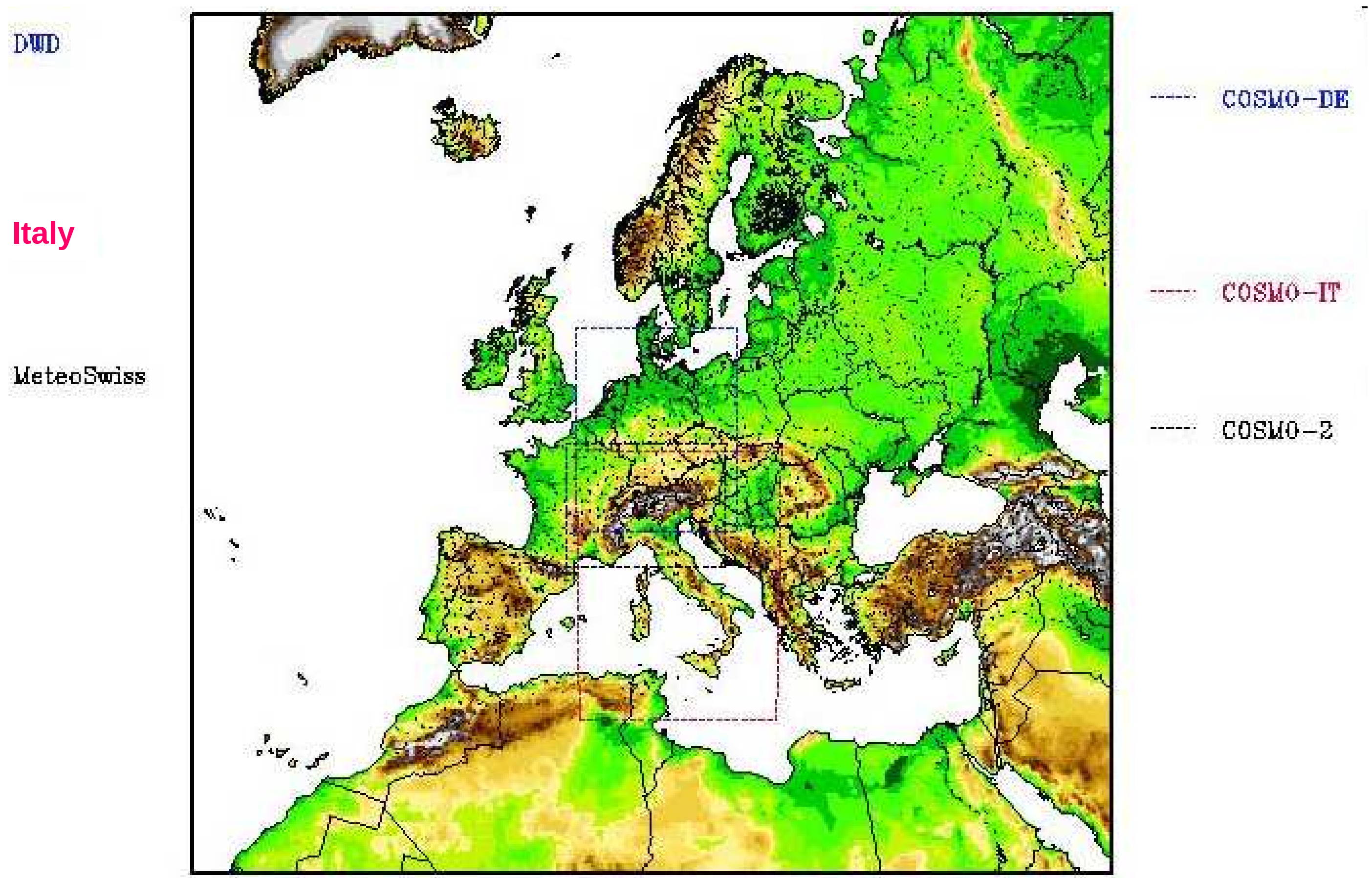
Outline

- Brief description of the COSMO-HR operational suites
- Which are the spatial scale/phenomena where COSMO-HR is most effective ? Scale dependant precipitation scores
- Understanding predictability limitations: absolute instability and convective equilibrium
- Few examples and case studies

Main characteristics of COSMO-HR operational suites

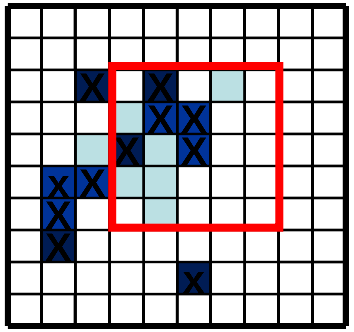
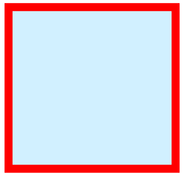
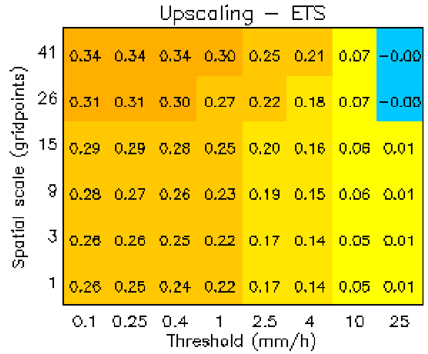
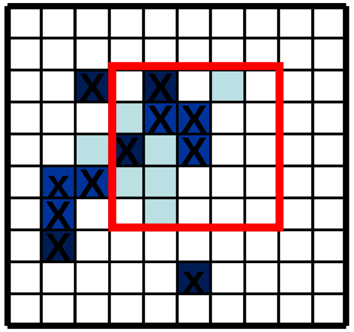
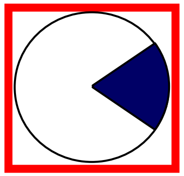
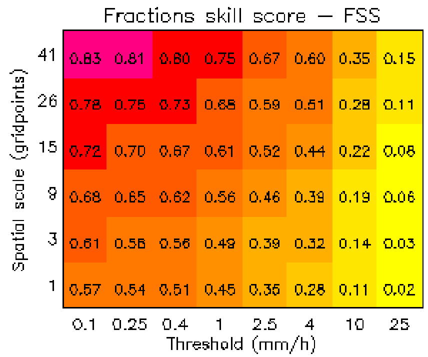
	DWD	MeteoSwiss	Italy (USAM ARPA EM – ARPA PIEM)
Domain Size (grid points)	421 x 461	520 x 350	447 x 532
Hor. Grid Spacing (degree / km)	0.025 / 2.8	0.02 / 2.2	0.025 / 2.8
Number of Layers	50	60	45
Time Step (sec)	25	20	25
Forecast Range (h)	21	24	48
Initial Time of Model Runs (UTC)	00, 03, 06, 09, 12, 15, 18, 21	00, 03, 06, 09, 12, 15, 18, 21	00, 12
Lateral Boundary Conditions	COSMO-EU	COSMO-7	COSMO-I7
LBC Update Frequency (h)	1	1	1
Initial State	Nudging + LHN	Nudging + LHN	COSMO-I7 AN
Initialization	None	None	None
External Analysis	SST, Snow Depth	SST(IFS), Snow Depth	None

Operational domains of COSMO-HR



Fuzzy Verification from MeteoSwiss: upscaling and fraction skill score

courtesy of Pierre Eckert and F. Ament, Pierre.Eckert@meteoswiss.ch

Method	Raw Data	Fuzzyfication	Score	Example result
Upscaling		Average 	Equitable threat score	
Fraction Skill Score (Roberts and Lean, 2005)		Fractional coverage 	Skill score with reference to worst forecast	

Upscaling ⇔ **mean** around a point / station

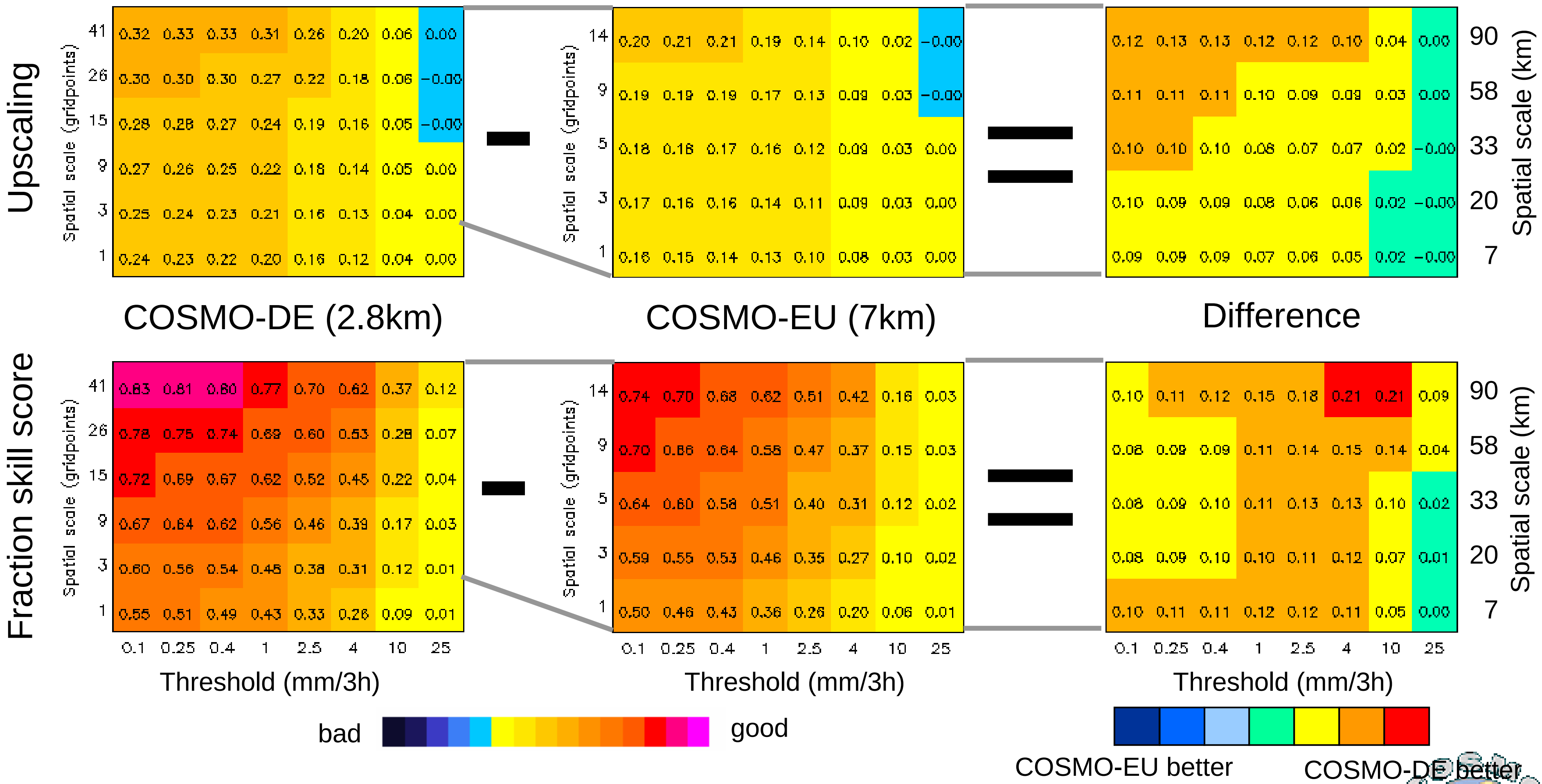
Fraction skill score ⇔ Compares fractional coverage in forecast with fractional coverage in observations

Fuzzy methods explanations

- ***Fuzzy (neighborhood) methods*** - relax the requirement for an exact match by evaluating forecasts in the local neighborhood of the observations.
- Fractions skill score (Roberts and Lean, 2008)
- ***Answers the question:*** *What are the spatial scales at which the forecast resembles the observations?*
- This approach directly compares the forecast and observed fractional coverage of grid-box events (rain exceeding a certain threshold, for example) in spatial windows of increasing size. These event frequencies are used directly to compute a Fractions Brier Score, a version of the more familiar (half) Brier score but now the observation can take any value between 0 and 1. The result can be framed as a Fractions Skill Score with the following properties:
- The Fractions Skill Score has a range of 0 (complete mismatch) to 1 (perfect match).
- If either there are no events forecast and some occur, or some occur and none are forecast the score is always 0.
- As the size of the squares used to compute the fractions gets larger, the score will asympotote to a value that depends on the ratio between the forecast and observed frequencies of the event. The closer the asymptotic value is to 1, the smaller the forecast bias.
- The score is most sensitive to rare events (or for small rain areas).

Fuzzy Verification: COSMODE – COSMOEU

JJA 2007, Verification against Swiss Radar Composite, 3 hourly accumulations



Moist Processes in Future High Resolution NWP Models June 15-17, 2009 Norrköping, Sweden
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Fuzzy Verification: COSMO2 – COSMO7

JJA 2007, Verification against Swiss Radar Composite, 3 hourly accumulations

Upscaling

COSMO-2 (2.2km) — Upscaling – ETS

Spatial scale (gridpoints) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
41	0.34	0.34	0.34	0.30	0.25	0.21	0.07	-0.00
26	0.31	0.31	0.30	0.27	0.22	0.18	0.07	-0.00
15	0.29	0.29	0.28	0.25	0.20	0.16	0.06	0.01
9	0.28	0.27	0.26	0.23	0.19	0.15	0.06	0.01
3	0.26	0.26	0.25	0.22	0.17	0.14	0.05	0.01
1	0.26	0.25	0.24	0.22	0.17	0.14	0.05	0.01

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COSMO-7 (7km) — Upscaling – ETS

Spatial scale (gridpoints) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
14	0.13	0.14	0.14	0.13	0.09	0.06	0.01	-0.00
9	0.13	0.14	0.14	0.12	0.09	0.06	0.02	-0.00
5	0.13	0.13	0.13	0.11	0.08	0.06	0.02	0.00
3	0.13	0.12	0.12	0.11	0.08	0.06	0.02	0.00
1	0.12	0.12	0.11	0.10	0.07	0.05	0.02	0.00

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Difference — Upscaling

Spatial scale (km) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
90	0.20	0.20	0.20	0.17	0.16	0.14	0.06	0.00
58	0.18	0.16	0.17	0.15	0.13	0.12	0.05	0.00
33	0.17	0.16	0.15	0.13	0.12	0.10	0.04	0.01
20	0.16	0.15	0.14	0.13	0.11	0.10	0.04	0.01
7	0.14	0.14	0.13	0.12	0.10	0.09	0.03	0.01

Fraction skill score

COSMO-2 (2.2km)

Spatial scale (gridpoints) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
41	0.83	0.81	0.80	0.75	0.67	0.60	0.35	0.15
26	0.78	0.75	0.73	0.68	0.59	0.51	0.28	0.11
15	0.72	0.70	0.67	0.61	0.52	0.44	0.22	0.08
9	0.68	0.65	0.62	0.56	0.46	0.39	0.19	0.06
3	0.61	0.58	0.56	0.49	0.39	0.32	0.14	0.03
1	0.57	0.54	0.51	0.45	0.35	0.28	0.11	0.02

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COSMO-7 (7km)

Spatial scale (gridpoints) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
14	0.65	0.61	0.59	0.51	0.38	0.29	0.10	0.01
9	0.62	0.58	0.55	0.47	0.35	0.26	0.09	0.01
5	0.56	0.52	0.49	0.42	0.30	0.22	0.08	0.01
3	0.52	0.48	0.45	0.38	0.27	0.20	0.07	0.01
1	0.45	0.41	0.38	0.31	0.21	0.15	0.05	0.01

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Difference

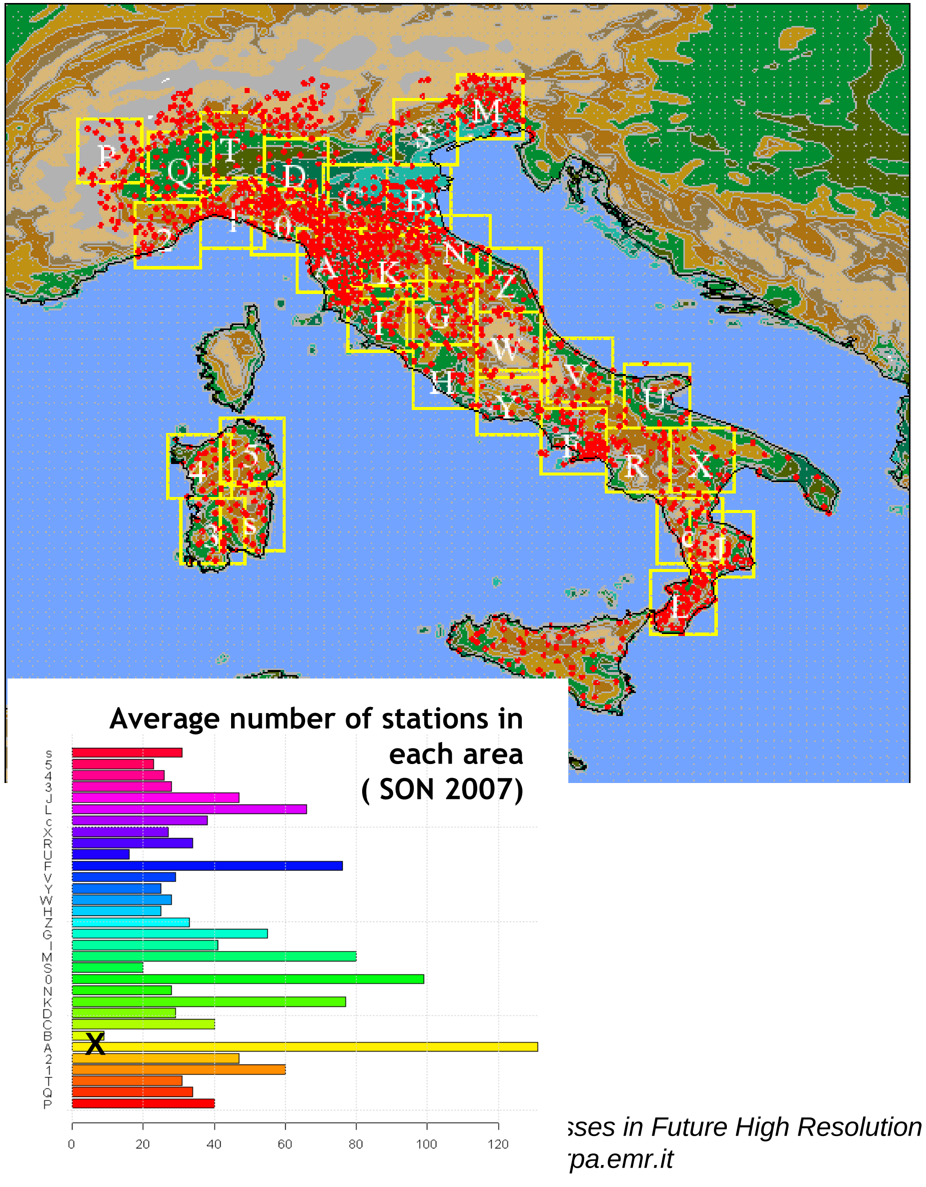
Spatial scale (km) \ Threshold (mm/3h)	0.1	0.25	0.4	1	2.5	4	10	25
90	0.18	0.20	0.21	0.24	0.29	0.31	0.25	0.13
58	0.16	0.16	0.18	0.21	0.24	0.25	0.19	0.09
33	0.17	0.16	0.18	0.20	0.22	0.22	0.15	0.07
20	0.16	0.17	0.17	0.18	0.20	0.20	0.12	0.05
7	0.16	0.17	0.17	0.18	0.18	0.17	0.09	0.03

bad — good

COSMO-7 better — COSMO-2 better

Precipitation box analysis verification ARPA-SIM

courtesy of M.S. Tesini, mstesini@arpa.emr.it

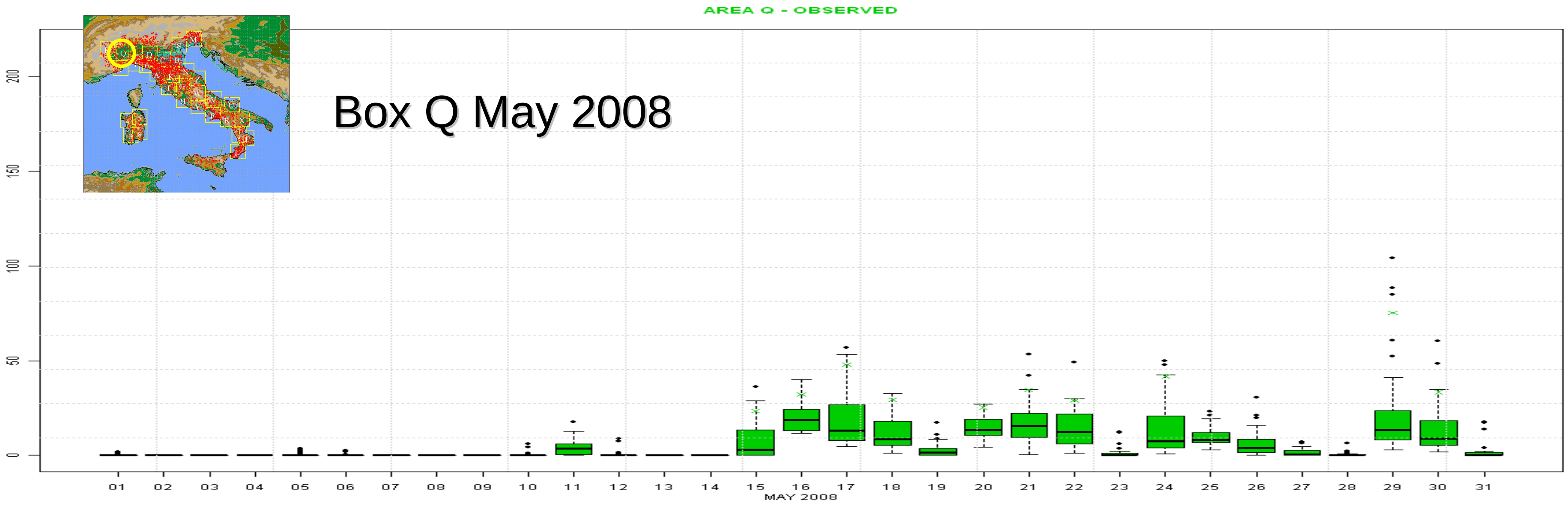


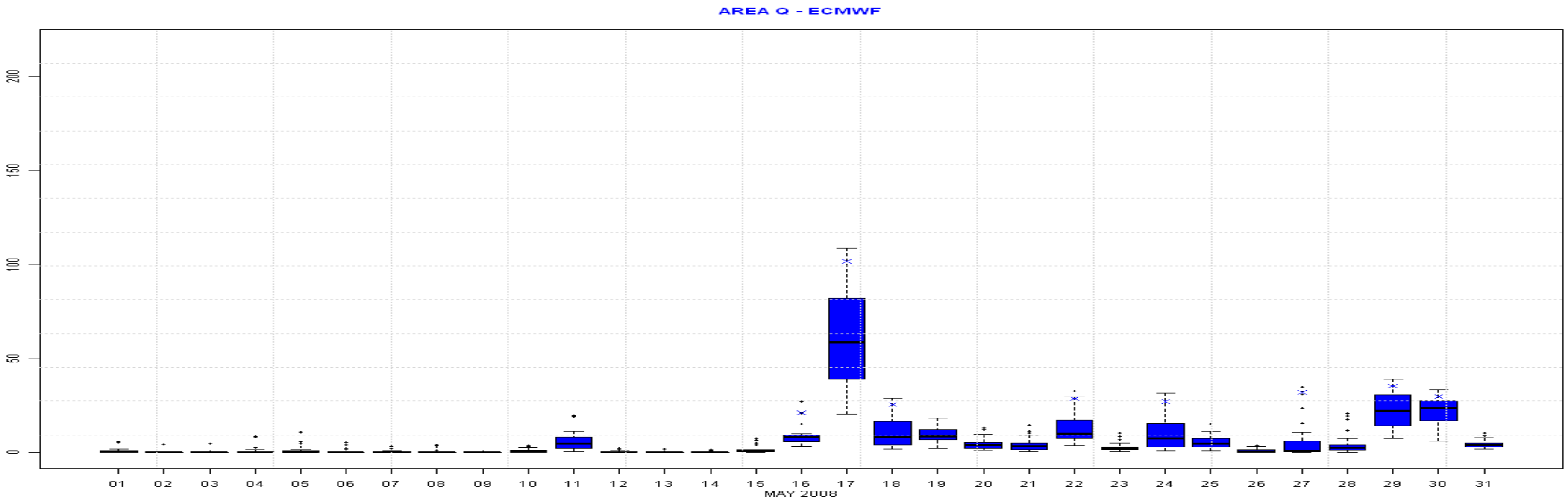
We devised a verification methodology by aggregating observed and predicted precipitation in boxes of 1°x 1° (labelled boxes in the map)

The choice of the size and position of the areas has been performed according to different rules:

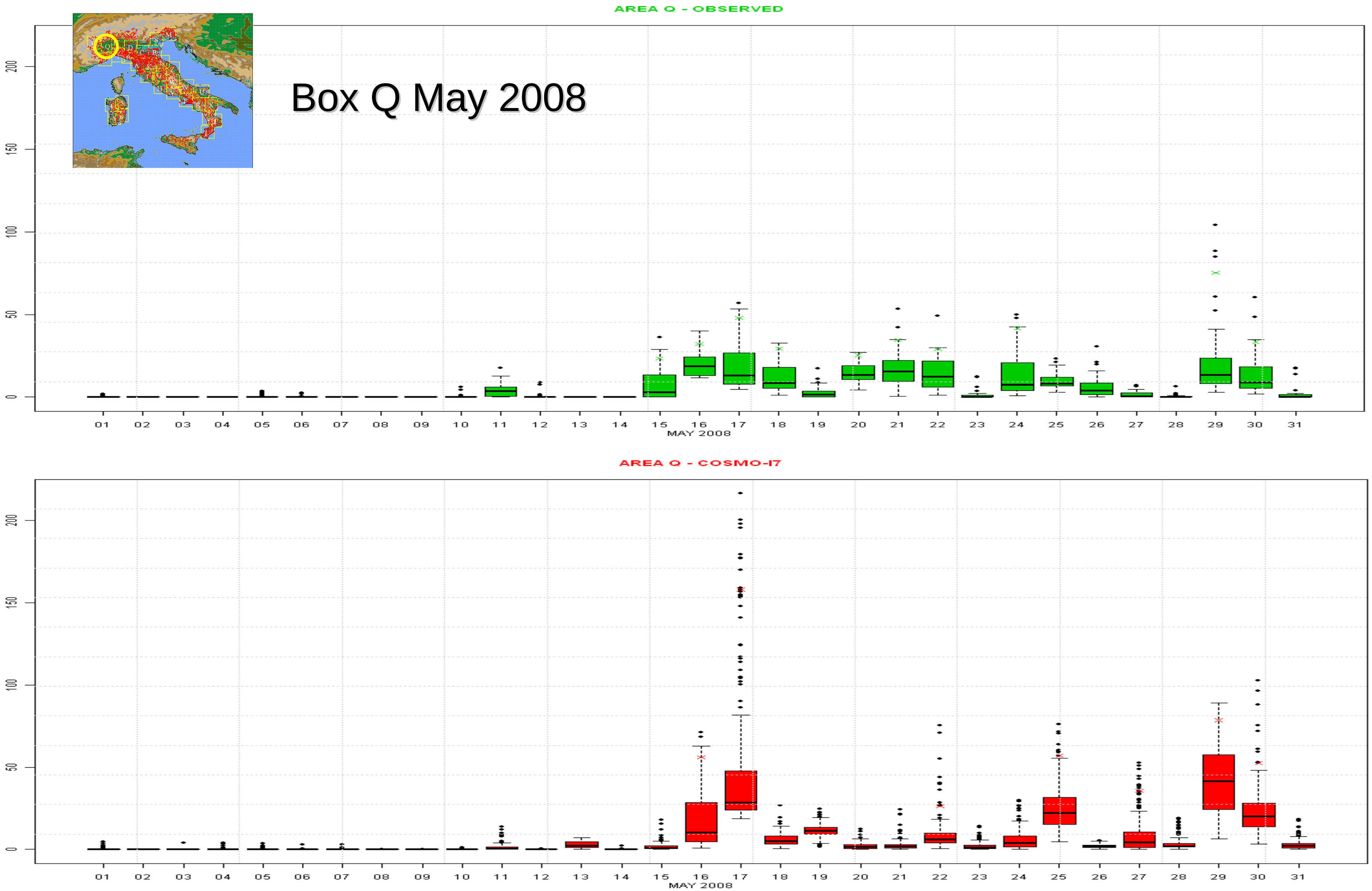
- boxes have to be enough large in order to contain a high number of observation points (ranging from 20 to over 100, depending on location and period of time considered)
- boxes have to be homogeneous as much as possible in terms of geographic-territorial characteristics

Box Q May 2008

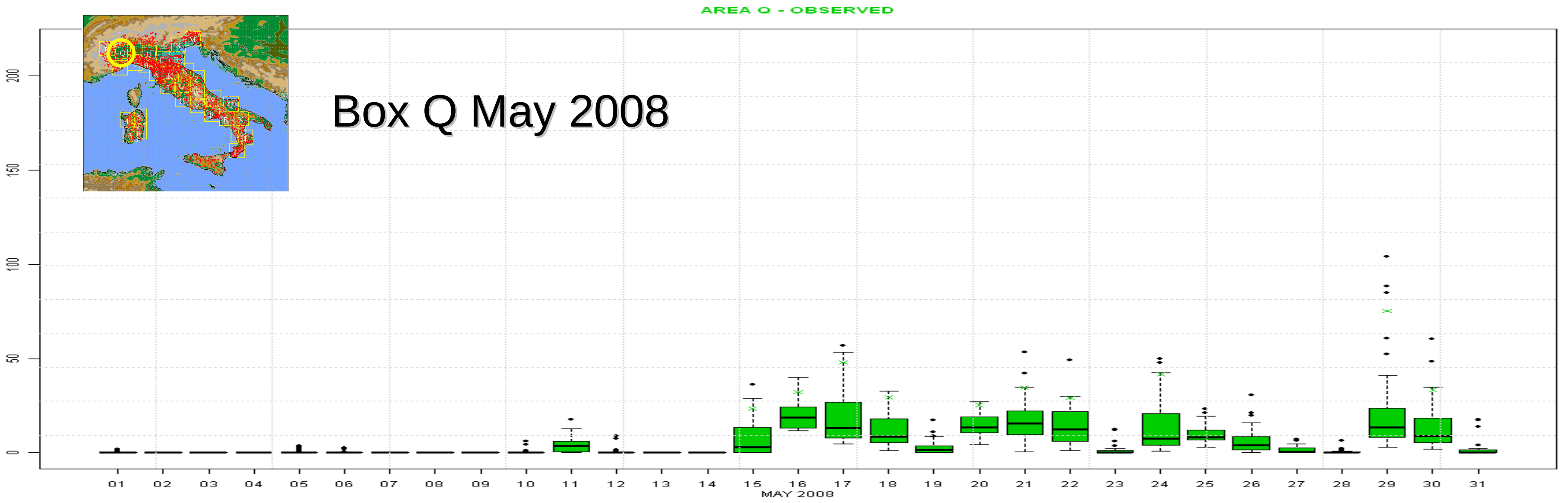


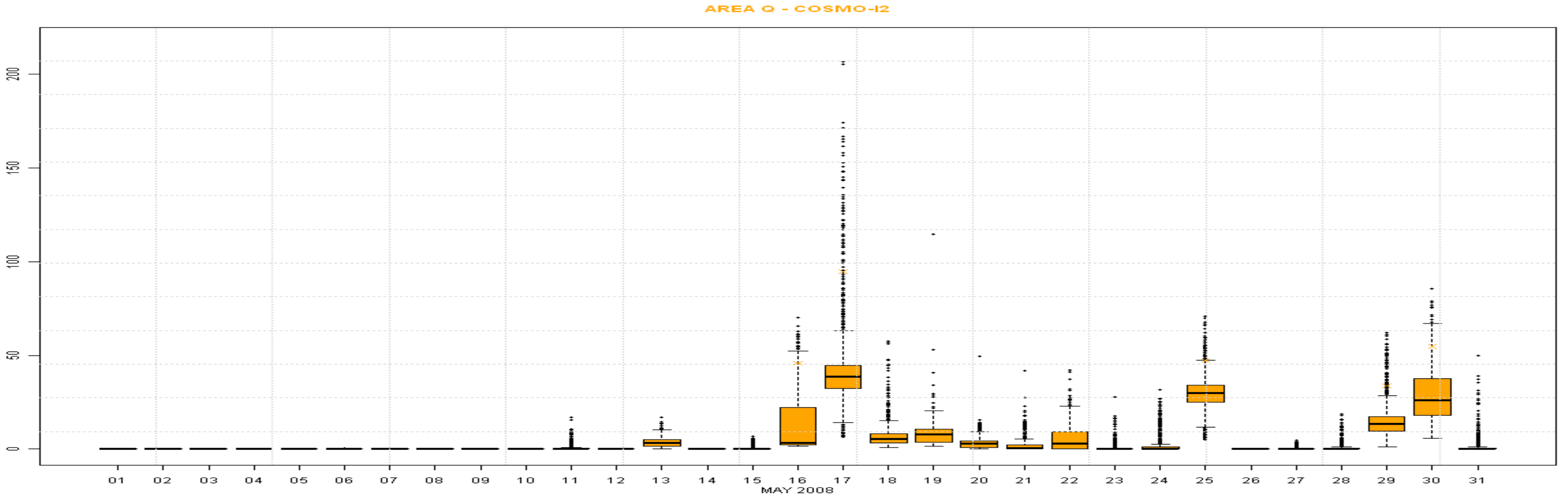


Box Q May 2008



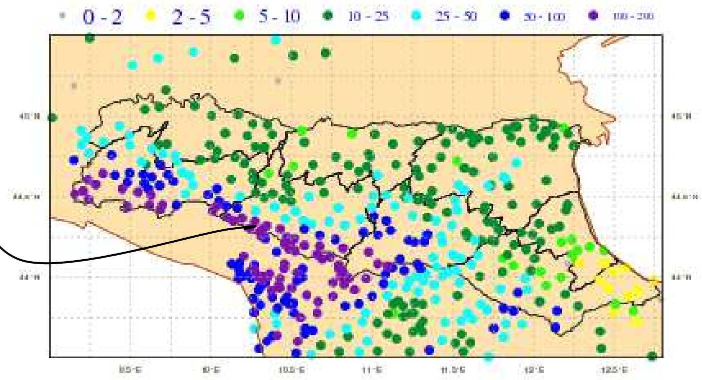
Box Q May 2008





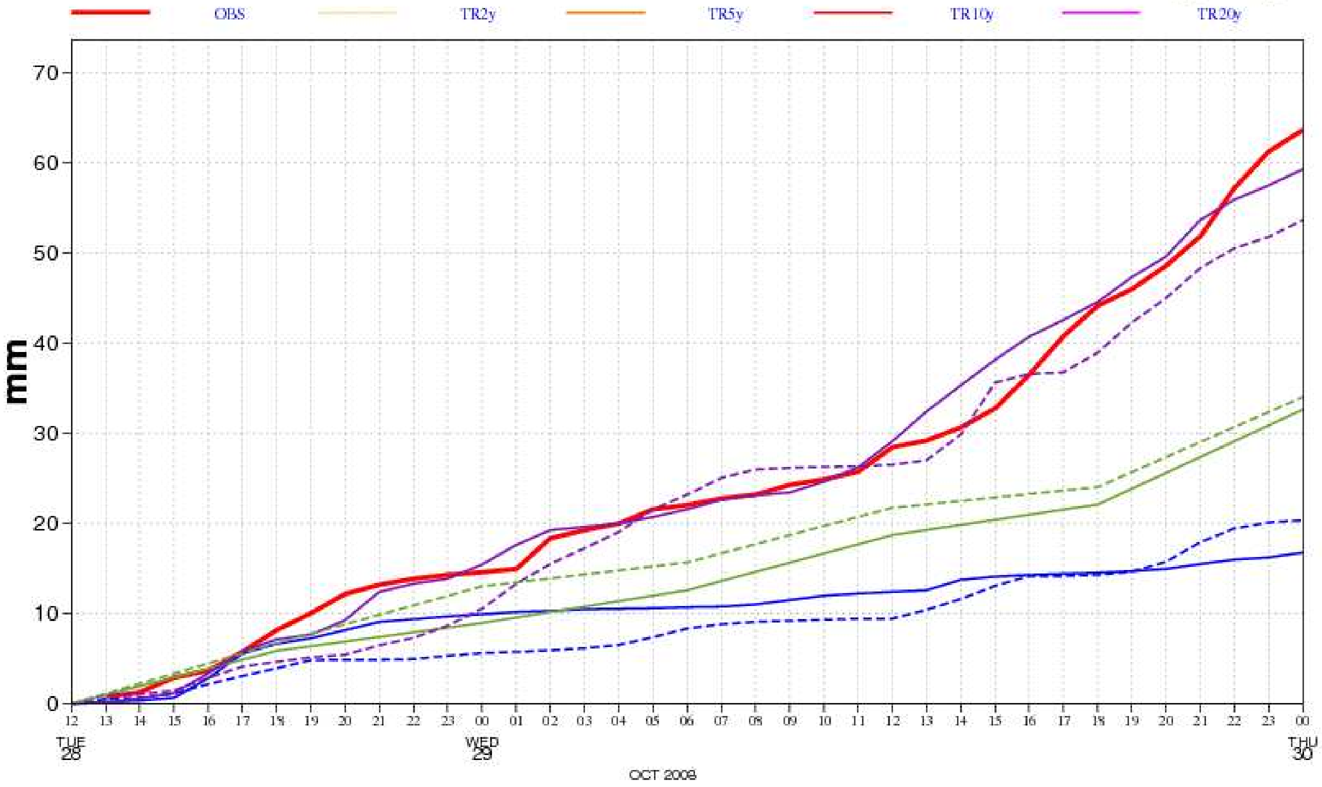
Heavy rain over the Appenines mountains
orographic forcing and embedded convection in a strong southerly

Operational precipitation forecasts from different mode



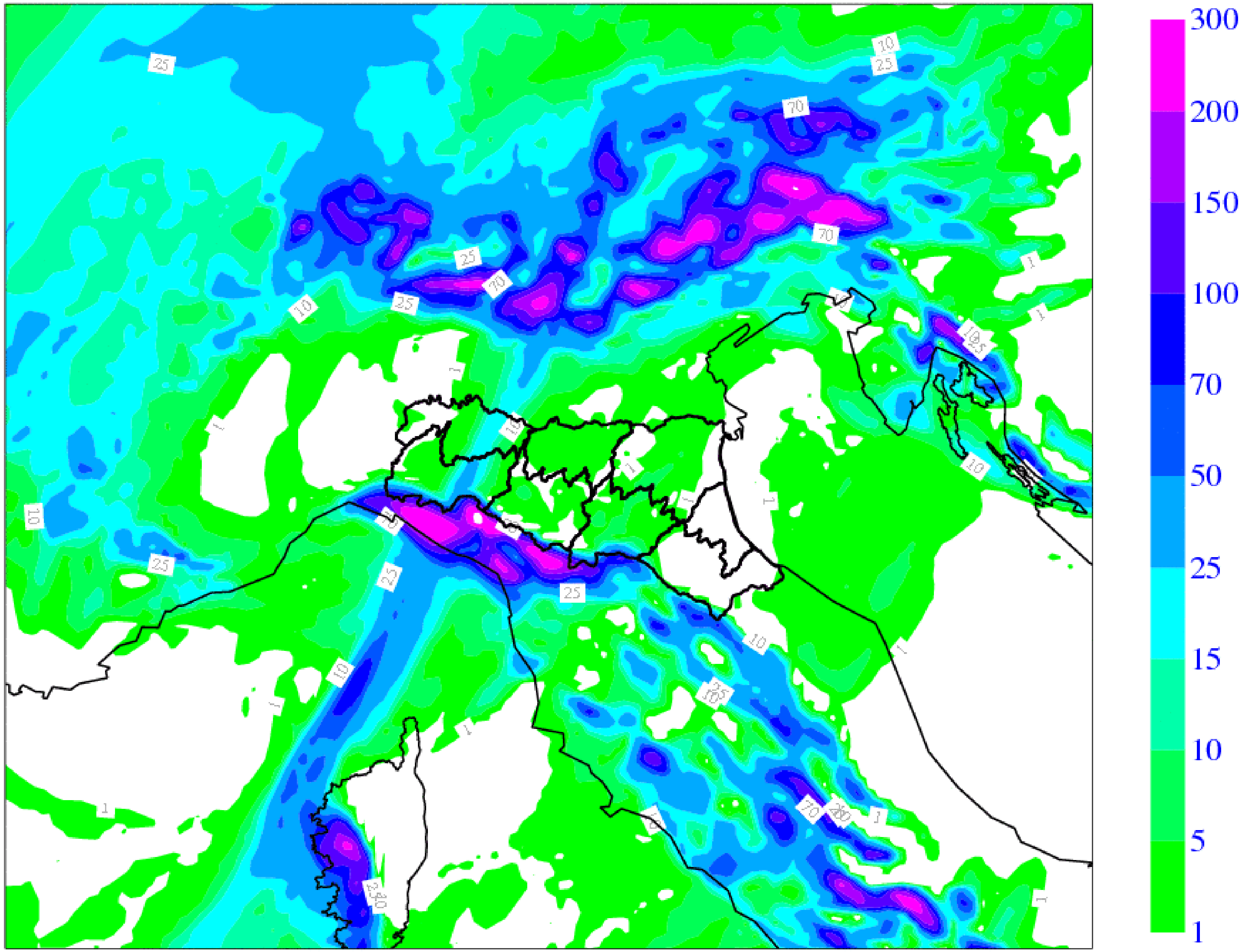
Averaged precip over warning area E (3000Km2)

PRECIPITAZIONE OSSERVATA E PREVISTA SULLA MACRO AREA - E -
osservazioni e tempi di ritorno (TR) riferiti a 24h
I2 : 410 grid-points, I7 : 67grid-points, OBS: 45

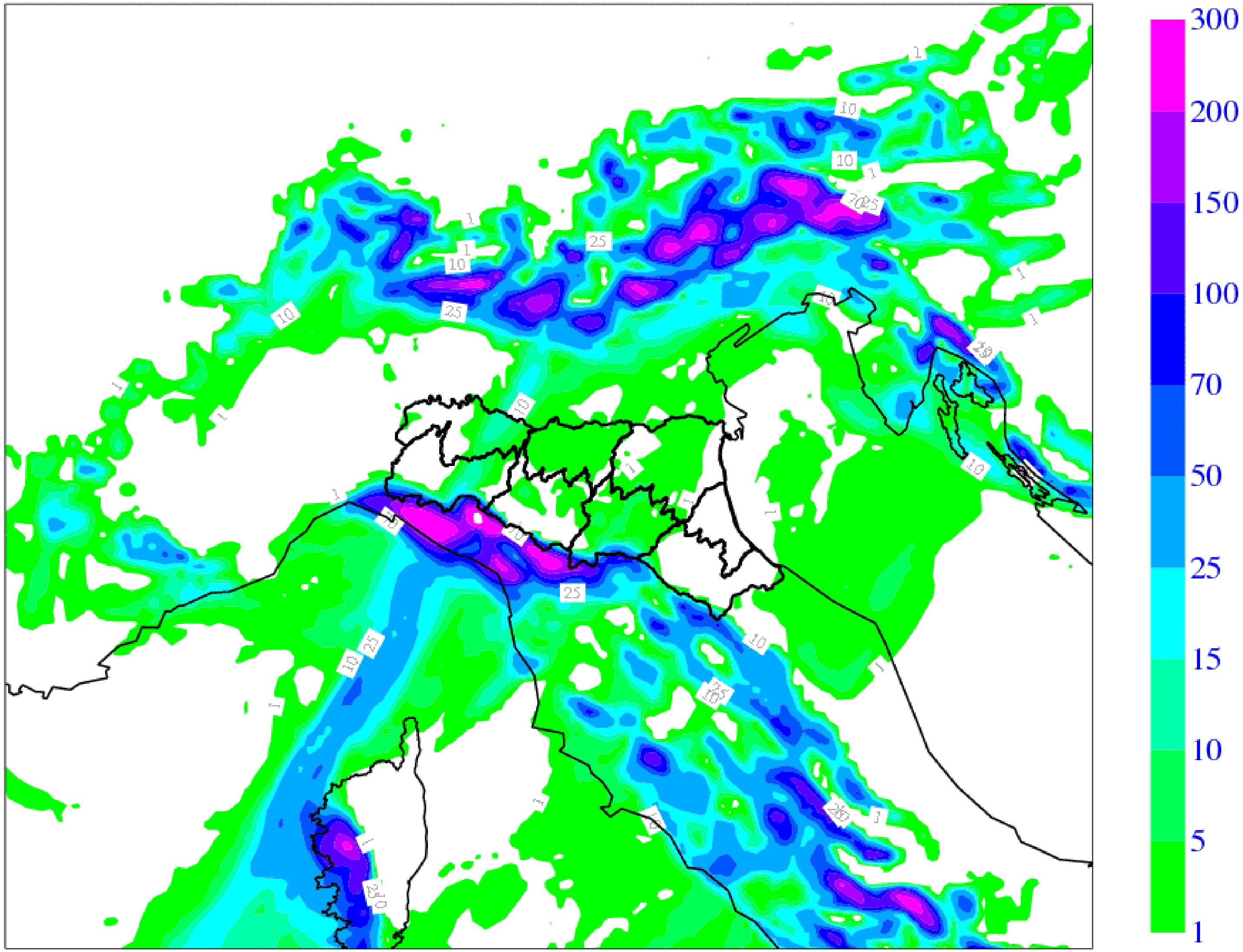


I7: 2008102812
I2: 2008102812
ECMWF: 2008102812

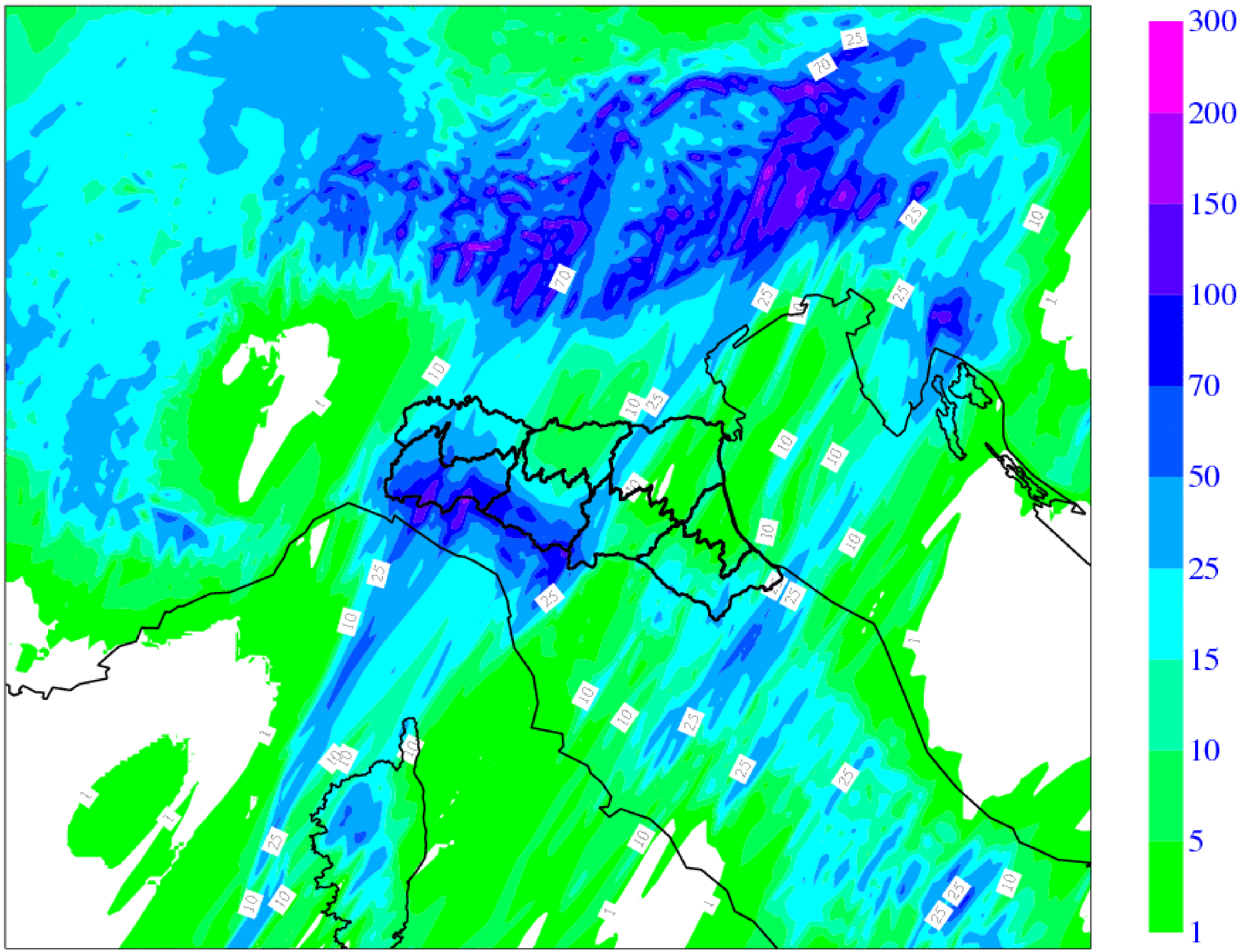
COSMOI7 – Acc total precip Fc+12 – Fc+36 29/10 00-24UTC



COSMOI7 – Acc Conv precip Fc+12 – Fc+36 29/10 00-24UTC



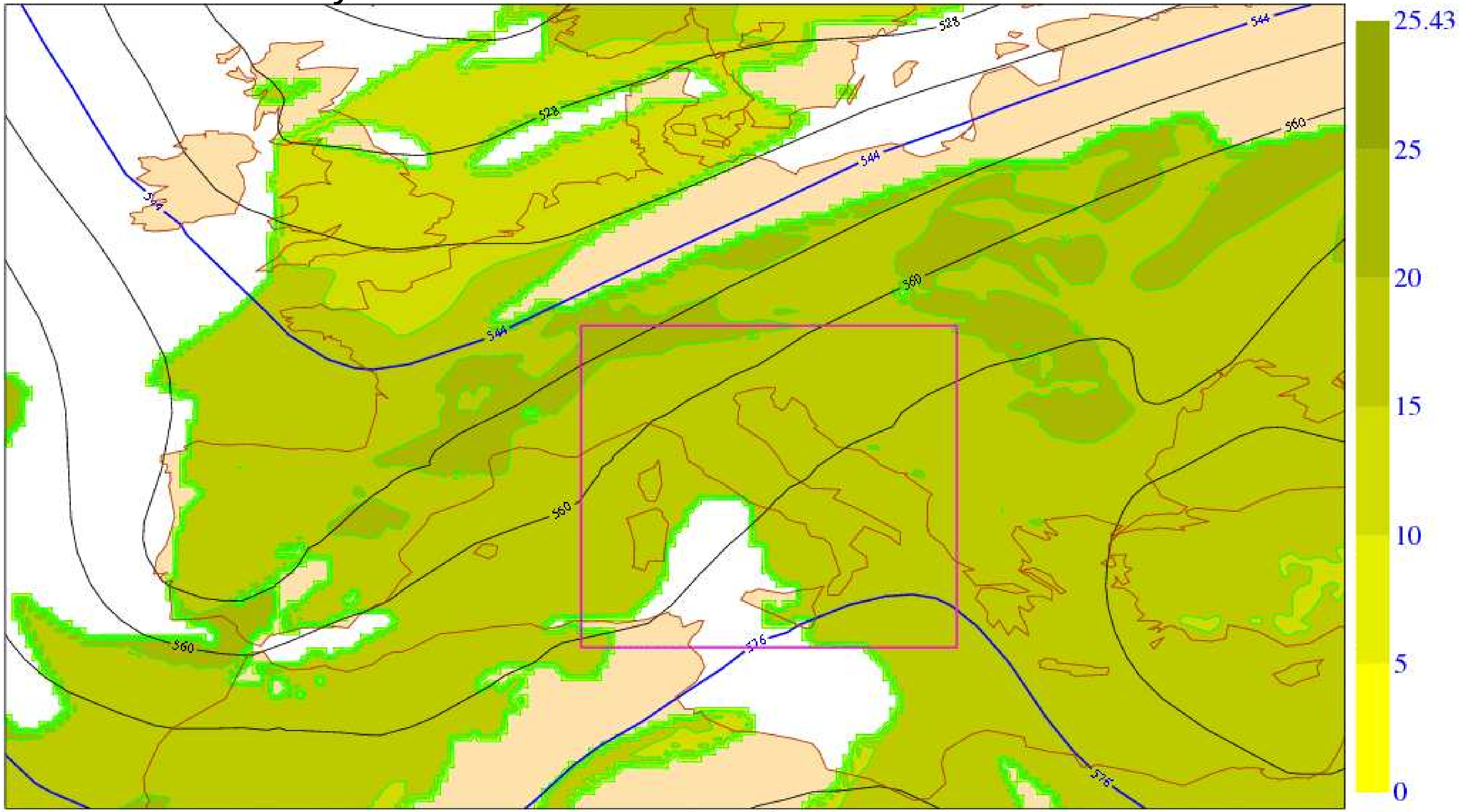
COSMOI2 – Acc total precip Fc+12 – Fc+36 29/10 00-24UTC



Heavy rain over the Appenines mountains flow: despite relevant presence of convection and instability the COSMOI2 forecast was very accurate, why?

Greater loss of predictability occurs over moist convectively unstable regions that are able to propagate energy against the mean flow. From linear analysis of absolute instability we see that for $U > U_{crit} = Nm^2/(m^2+k^2)*\text{sqrt}\ /(m^2+k^2)$ upstream propagation of gravity waves is inibithed, growing perturbation are flushed away by lateral boundary condition, increase of predictability. "Predictability Mistery " by ***Hohenegger et al. 2006 Mon. Wea. Rev.***

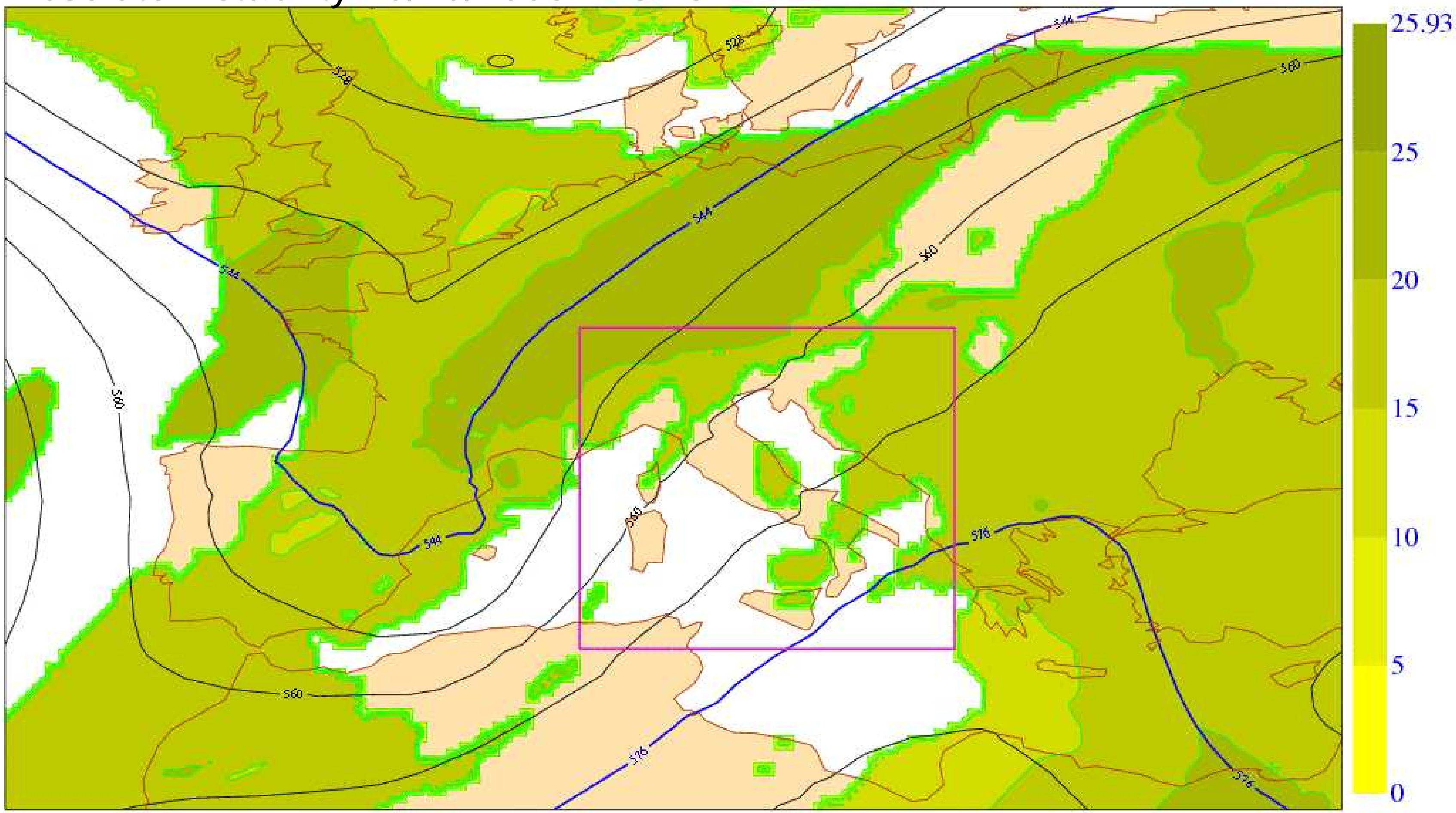
Absolute instability 28/10/2008 12UTC



Heavy rain over the Appenines mountains

On this day very high precip were recorded, in the order of 150-200 mm/24h with peaks during convective events of 30mm/h

Absolute instability 29/10/2008 12UTC



Absolute instability as defined in Hohenegger et al. 2006 Mon. Wea. Rev.*

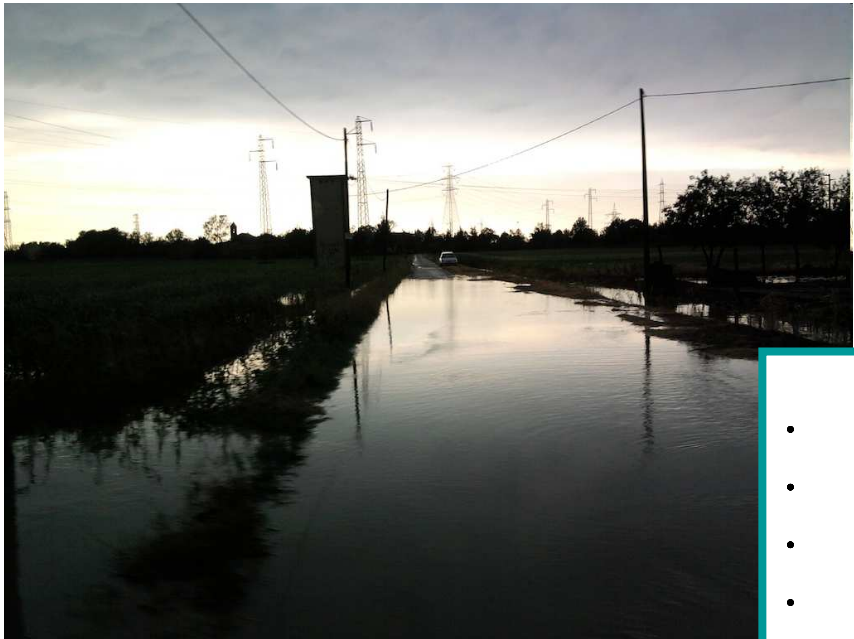
some conclusions so far…..

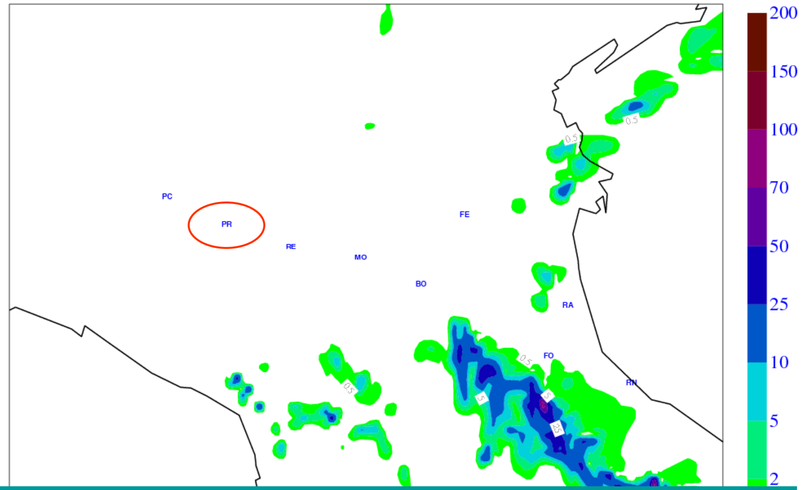
- Precipitation scores increase with box size
- Overall better results for very high-res models for moderate-high precipitations intensity
- This suggest that the benefits of very high-res models is rather to see in situations with strong synoptic forcing, flow interaction with orography, embedded convection. Strongest impact at scales of 30 to 50 km. Not always convection is a limiting factor.
- This is confirmed by experience and case studies. On those cases COSMO2 is often better than COSMO7 due excessive convective precip upwind to the orography of the latter. Some time there is also an excessive feedback of parametrized convection in to the dynamics (also observed in severe cases in ECMWF model).
- *What about weakly forced convection ?* We present a case study over N-Italy illustrating this situation.

A case of non equilibrium convection:

building up of CAPE over longer time-scales, high spatial variability of CIN values, convection enhanced by cold pools from previous systems (Done et al. 2006 QJR Meteorol. Soc.)

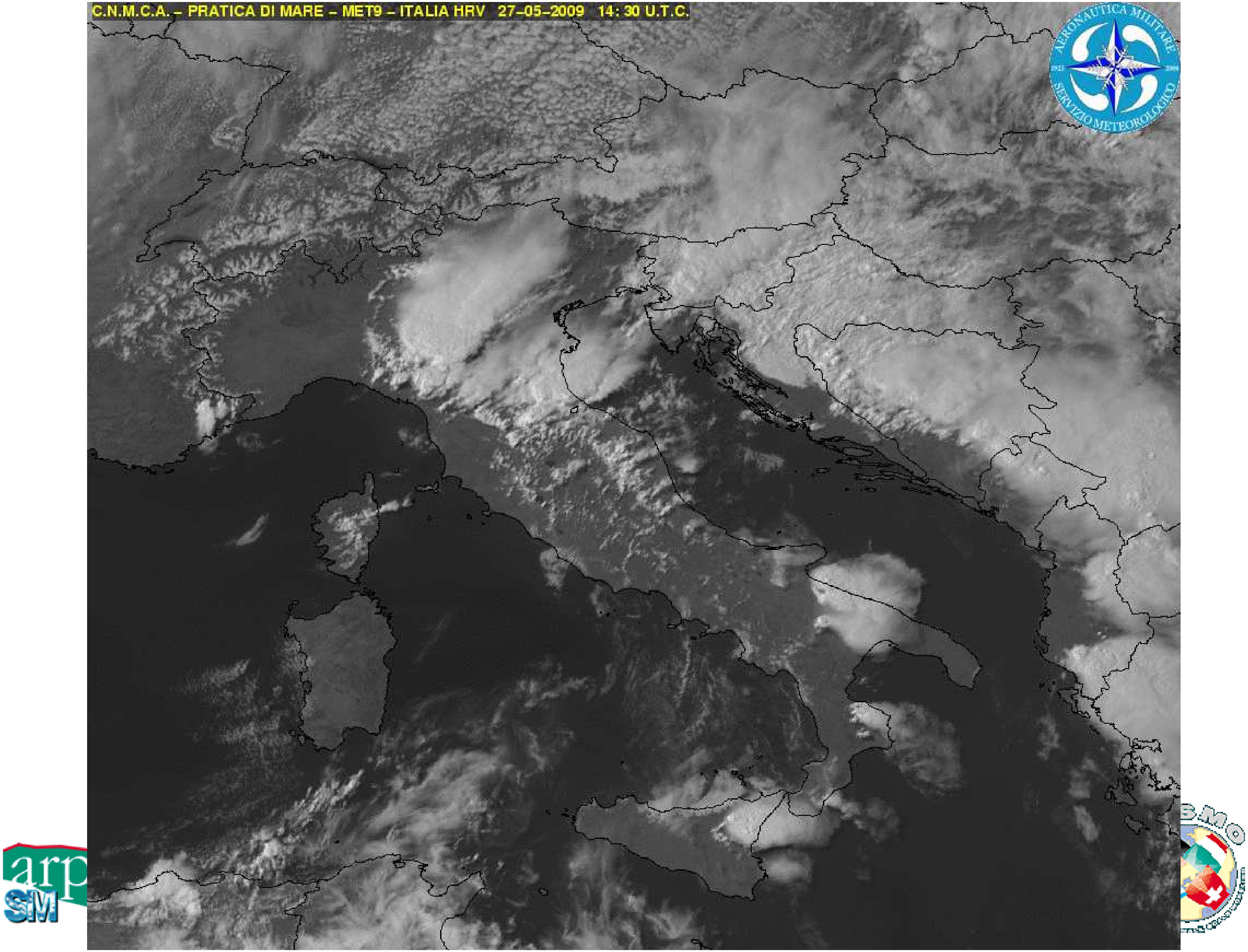
Floodings outside Parma 27/05/2009

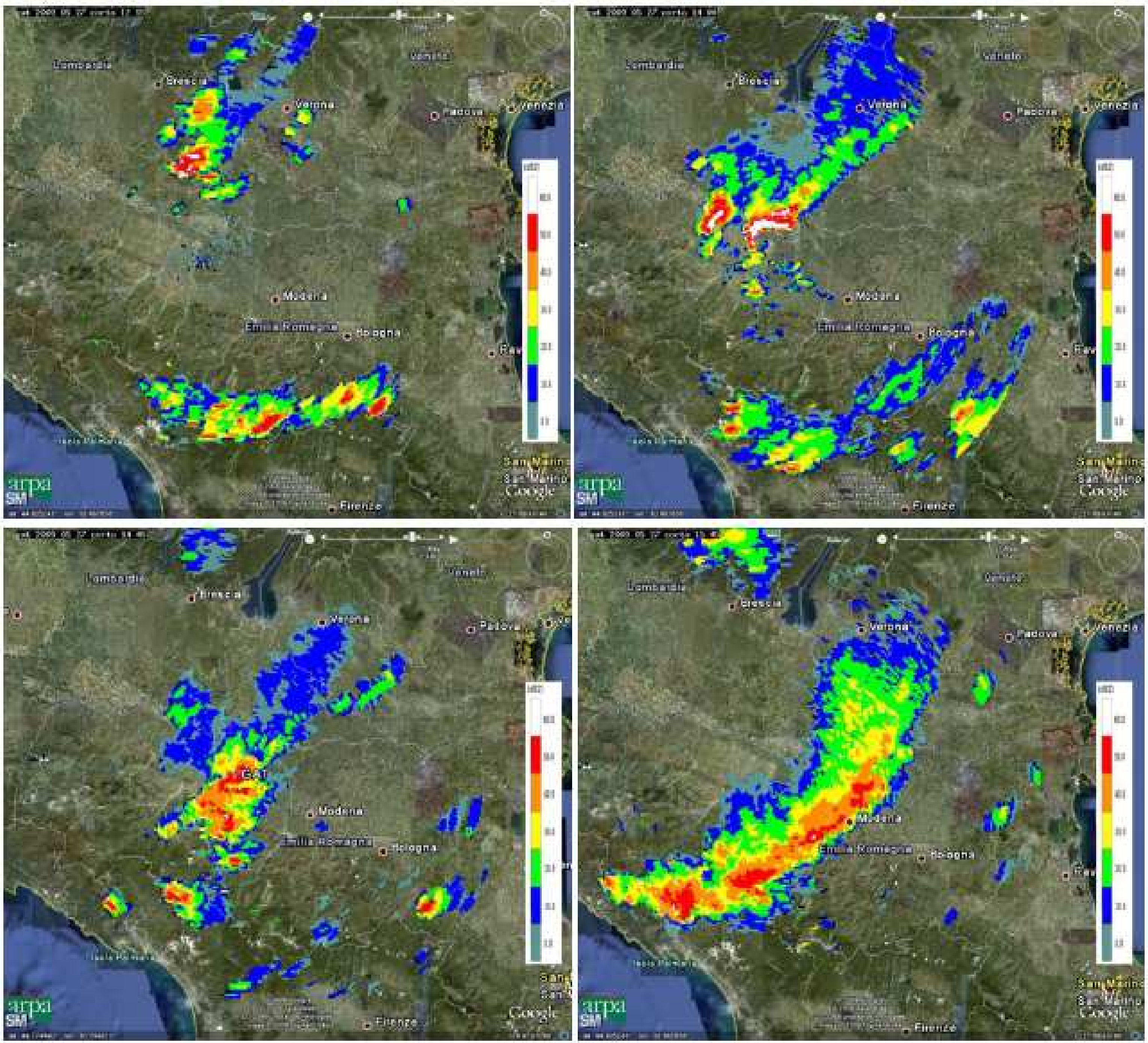




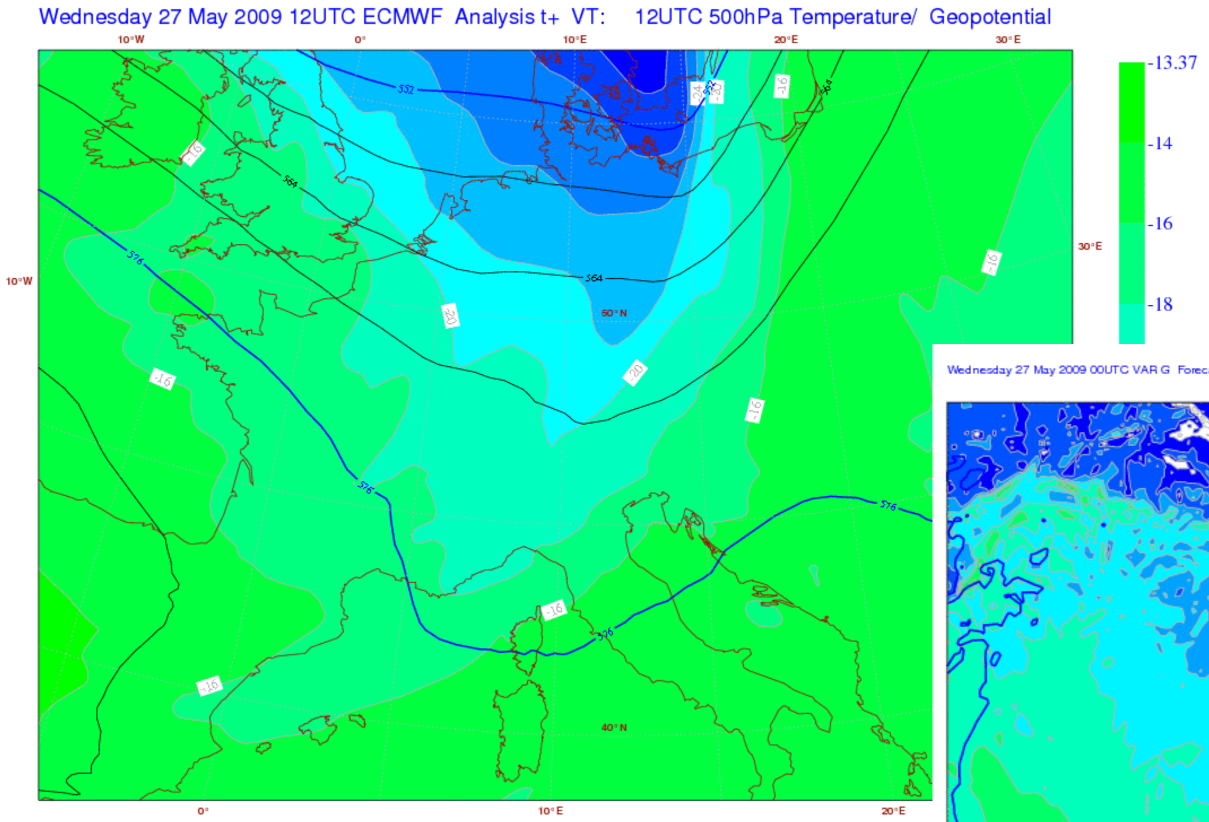
Observed precipitation in 15 minutes

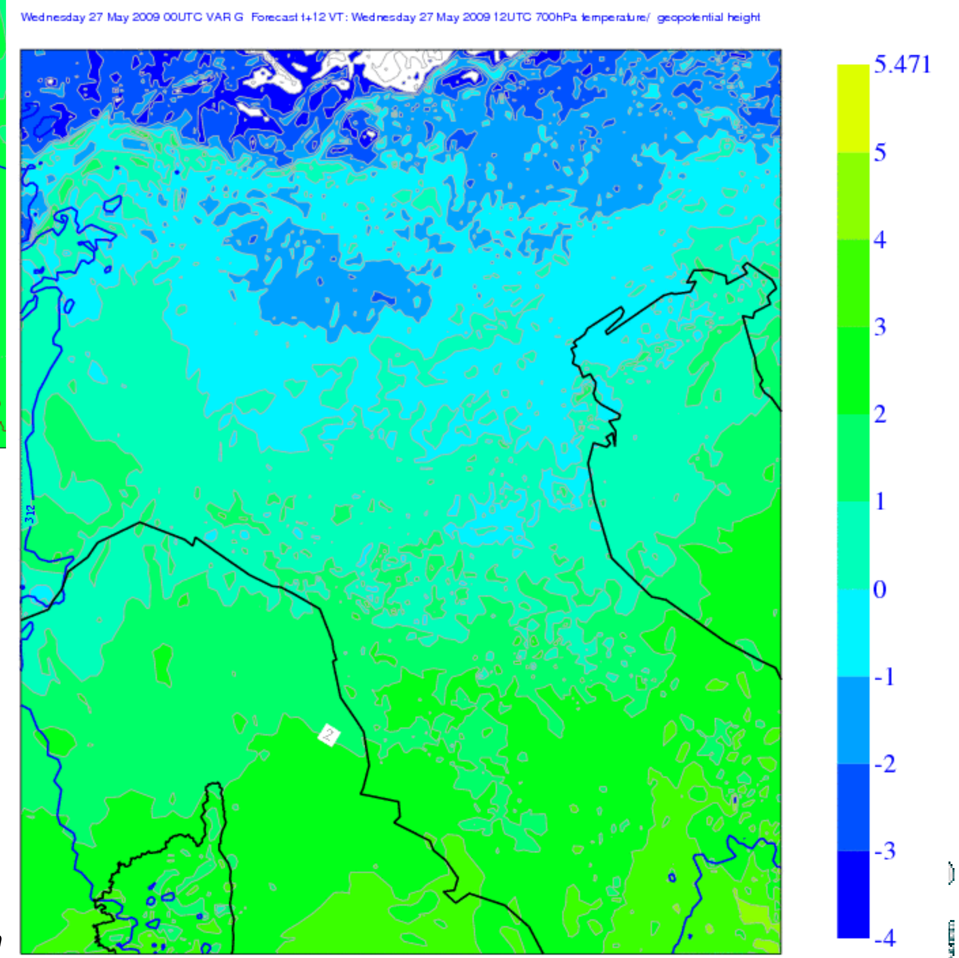
27/05/2009 – 14:00	Colorno (PR)	21.2
27/05/2009 – 14:45	Parma T. P. (PR)	29.4
27/05/2009 – 14:45	Parma (PR)	31.4
27/05/2009 – 15:15	Casatico – Langhirano (PR)	36.8
27/05/2009 – 15:45	Collagna (RE)	20.2
27/05/2009 – 16:00	Ligonchio (RE)	30
27/05/2009 – 16:00	Collagna (RE)	25


C.N.M.C.A. – PRATICA DI MARE – MET9 – ITALIA HRV 27–05–2009 14: 30 U.T.C.
AERONAUTICA MILITARE
SERVIZIO METEOROLOGICO

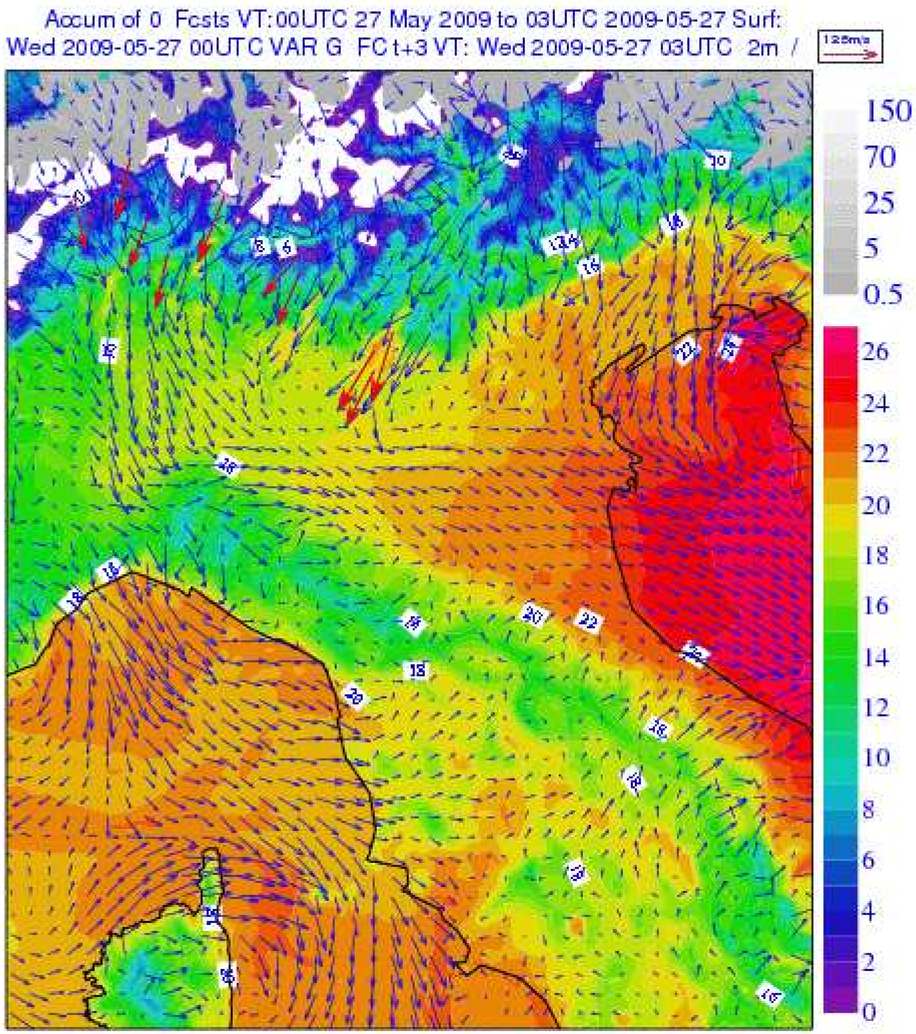

Lombardia
Brescia
Verona
Veneto
Padova
Venezia
Modena
Emilia Romagna
Bologna
San Marino
Firenze
Google
arpa SM

Weak synoptic forcing, cold air advection at upper levels north of the Alps

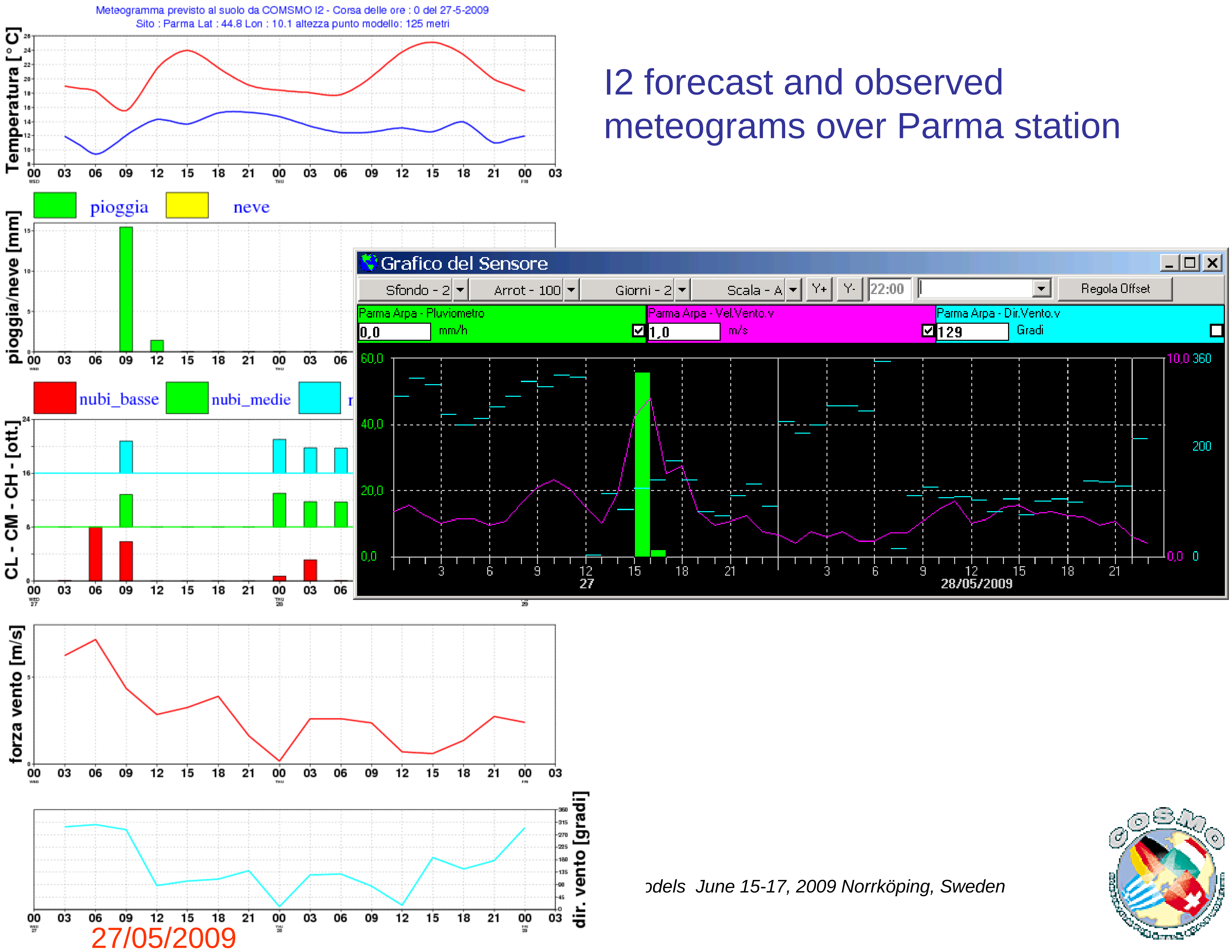


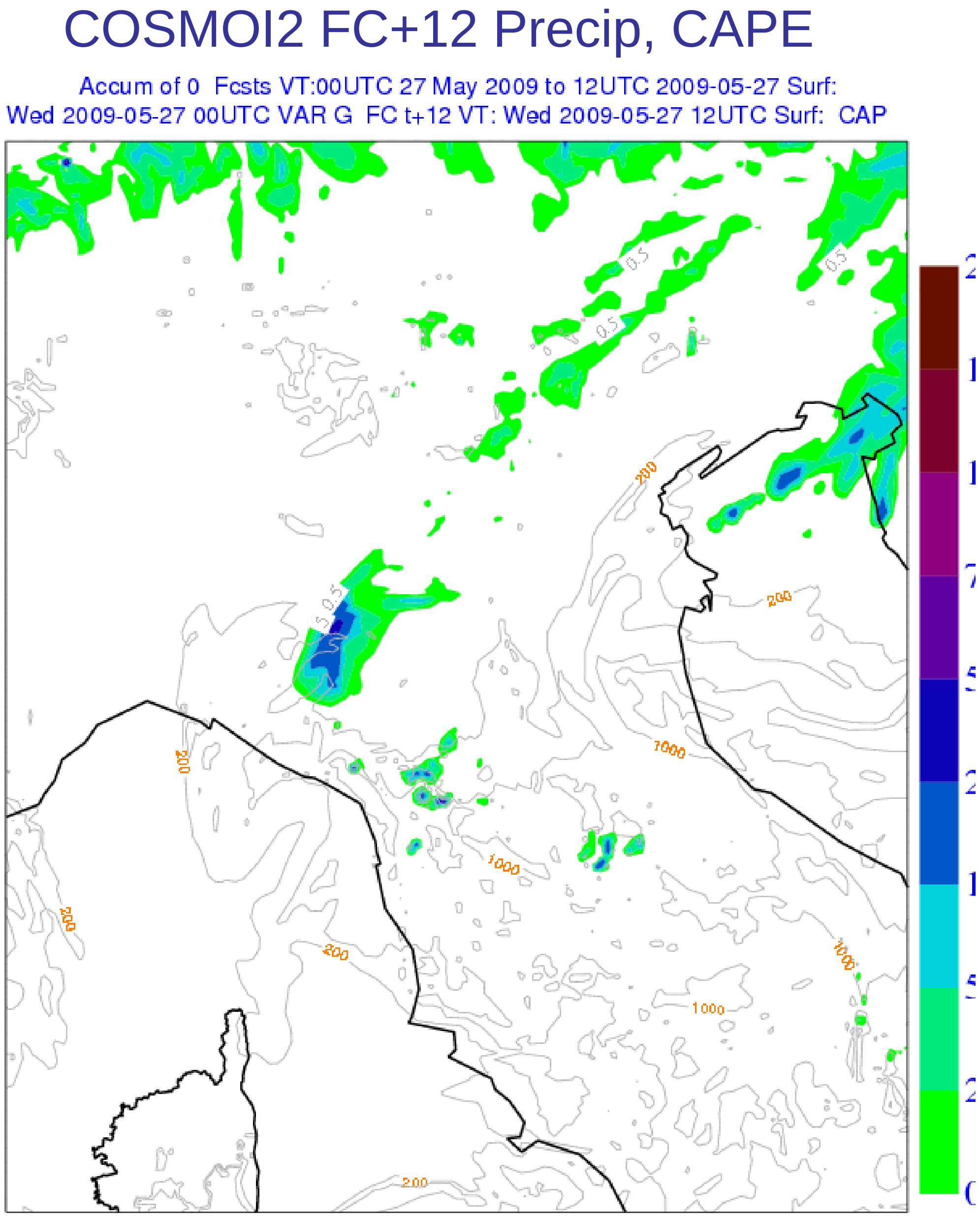


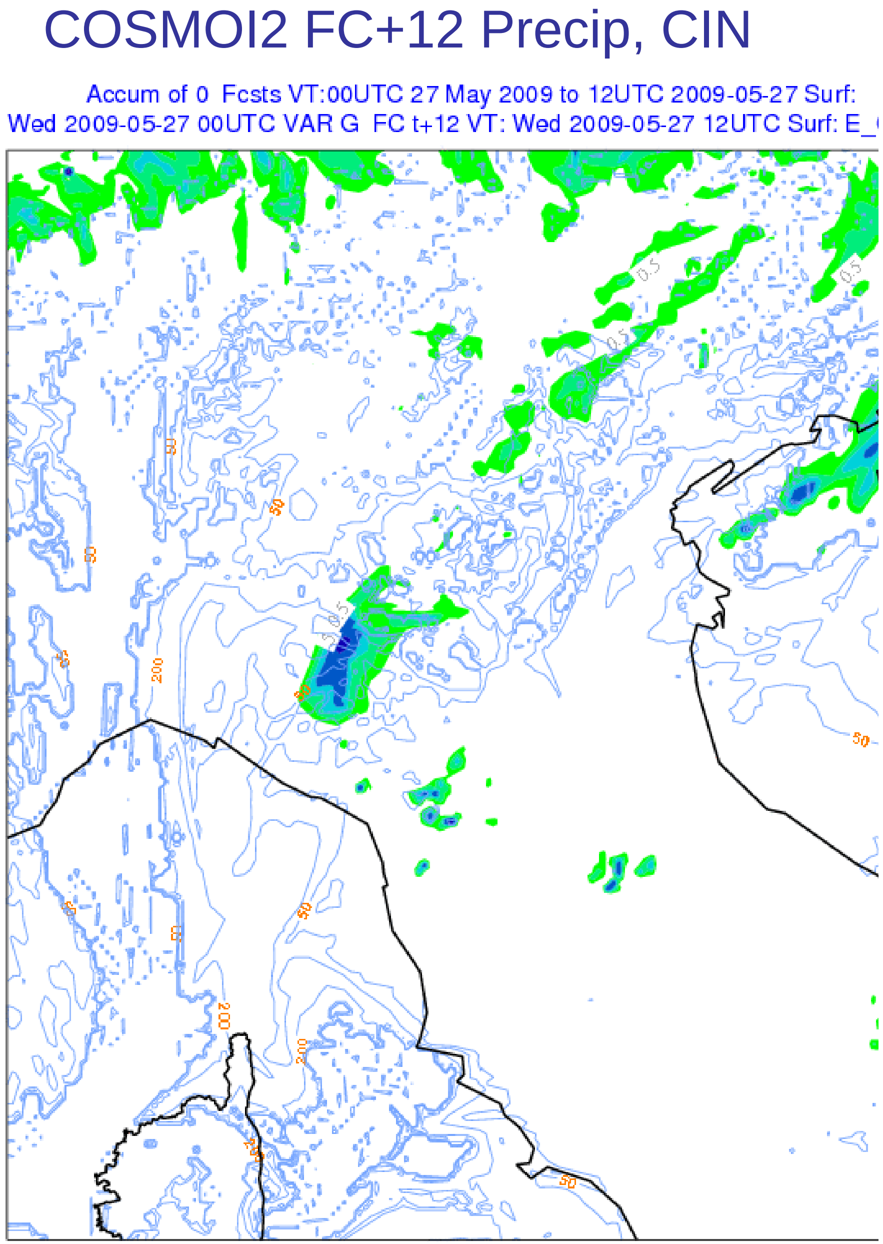
Hourly animation of COSMOI2 forecast of Precip (grey), 2mT,10m wind



I2 forecast and observed meteograms over Parma station




COSMOI2 FC+12 Precip, CAPE
Accum of 0 Fcsts VT:00UTC 27 May 2009 to 12UTC 2009-05-27 Surf:
Wed 2009-05-27 00UTC VAR G FC t+12 VT: Wed 2009-05-27 12UTC Surf: CAP

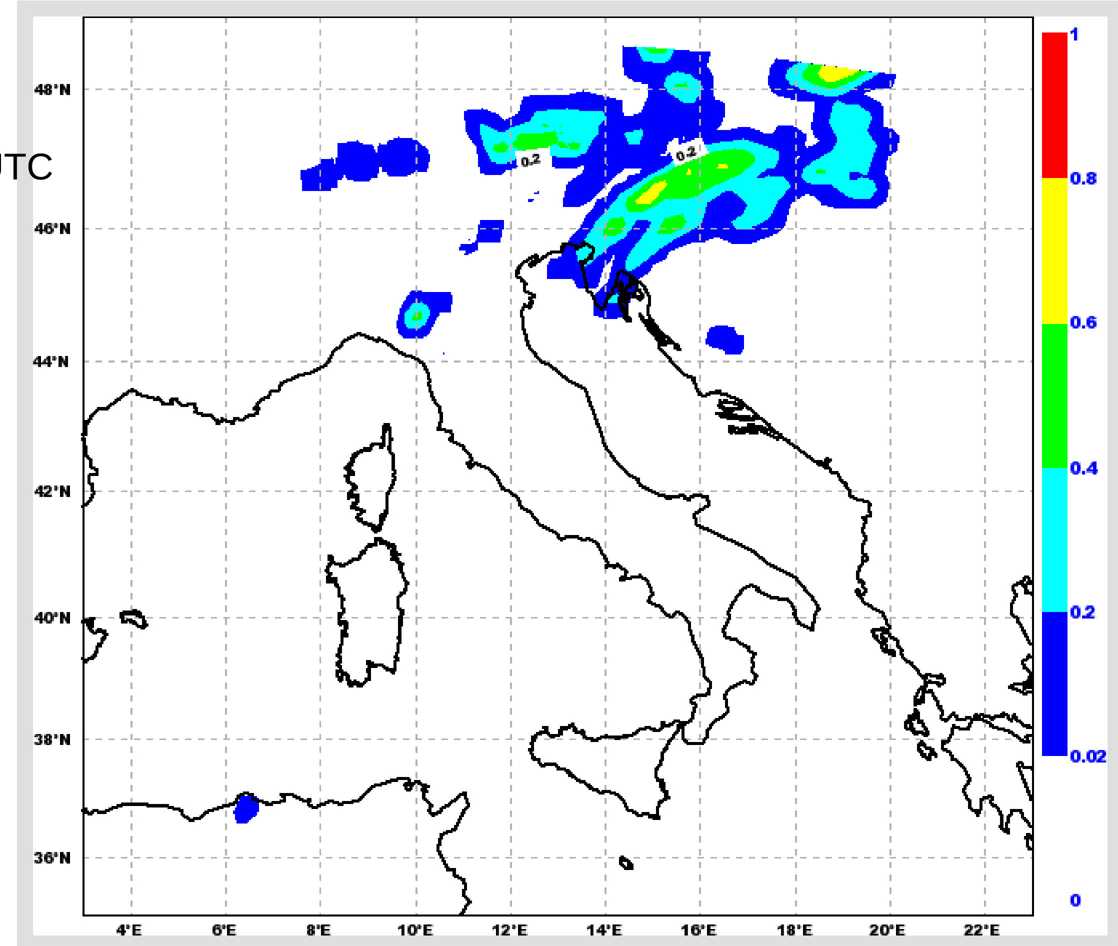

COSMOI2 FC+12 Precip, CIN
Accum of 0 Fcsts VT:00UTC 27 May 2009 to 12UTC 2009-05-27 Surf:
Wed 2009-05-27 00UTC VAR G FC t+12 VT: Wed 2009-05-27 12UTC Surf: E_

How to improve ?....statistical postprocessing

Probability precipitation forecast (PPF): for each grid point a frequency is computed counting how many grid points in the neighborhood (6 grid-points) and in time(2h) are above a defined threshold

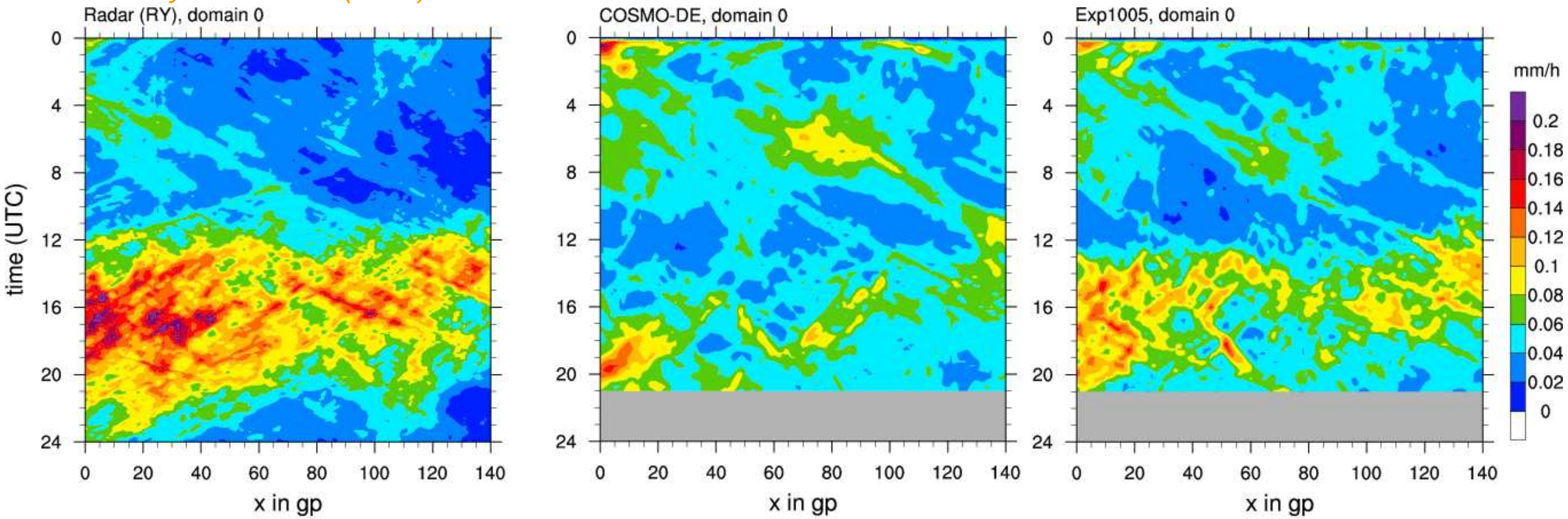
COSMOI2 PPF
27052009 valid at 09 UTC

1h TP > 10mm



How to improve ?....better physical description of PBL

Hovmöller diagrams of (latitudinal average over Germany) precipiation rate, 1 May to 9 June 2008,
Courtesy of A. Seifert (DWD)



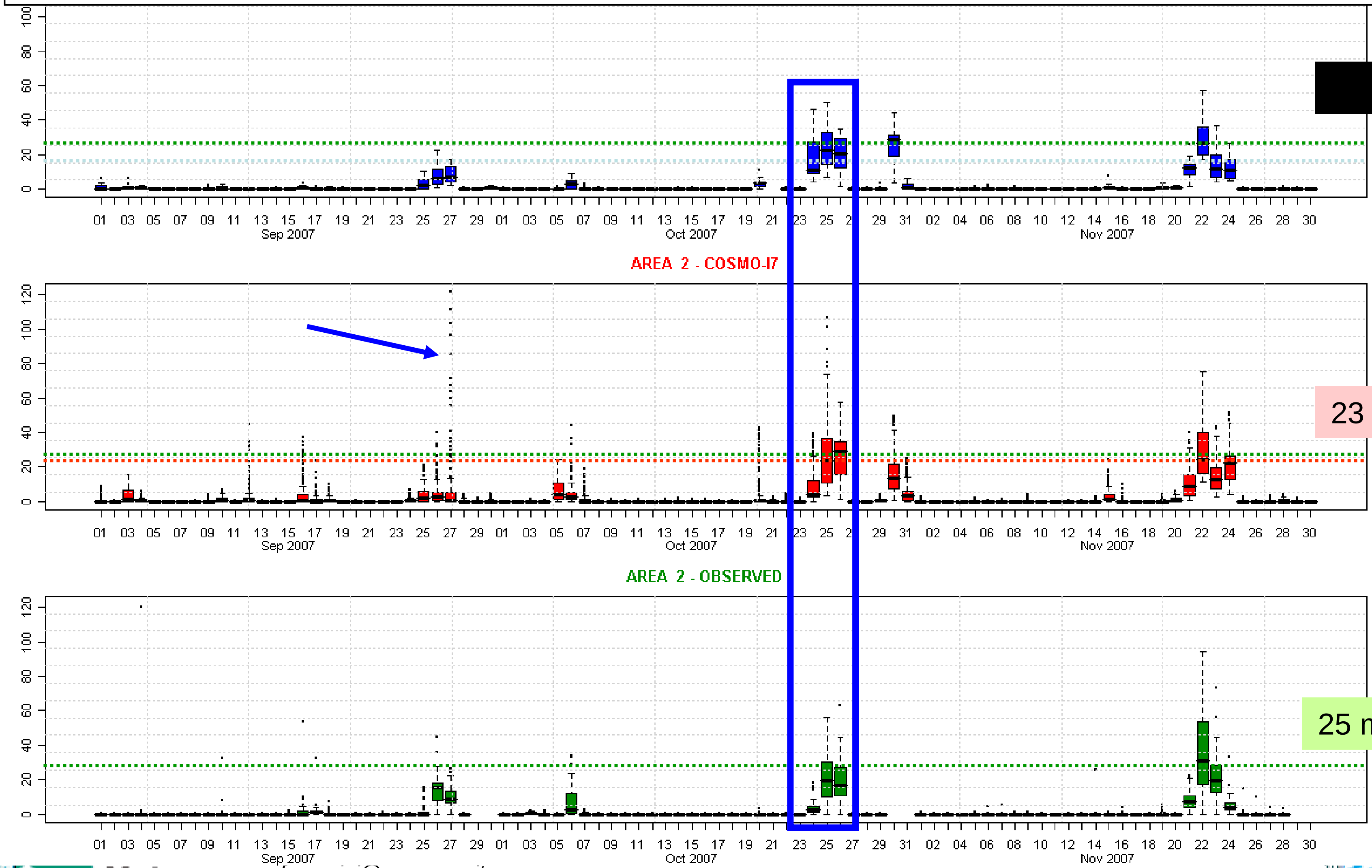
- COSMO2 has a very limited diurnal cycle, the afternoon maximum was very weak.
- Modified PBL parameters (see exp) had some positive impact like a reduced nocturnal drizzle and better afternoon maximum. However improvement were not uniform.
- DWD introduced turlen=150m together with a modification of the subgrid cloudiness q_krit=1.6, clc_diag=0.5. For Germany this change has a quite positive impact, with more small scale convection, which is in many cases more realistic. Also the diurnal cycle has been improved. A negative impact is an increase in the 2m-temperature. However there is still a tendency underestimate the frequency of convective systems.
- At MeteoSwiss they find a negative impact of the reduced mixing length getting to much convection over the Alps.They have now operationally introduced turlen=250m combined with q_krit=1.6, clc_diag=0.5.

Final summary

- Despite the clear benefit of running NWP models at convective-scale resolutions for the representations of local effects, weakly forced convection is still problematic with a general underestimation by COSMO2
- A not correct representation of nocturnal PBL evolution could have a negative effect on diurnal convection preventing or anticipating the triggering. (sensitivity on PBL parameters, micrometeorological field campaign)
- More sophisticated microphysics schemes could help in the correct representation of life cycle and organization of deep convection, especially for the formation of downdrafts and of cold pools. (implementations of the new Seifert and Beheng hierarchical two-moment scheme)
- Running different implementations of the model may represents a great potential for diagnostic investigation. However it is difficult to exploit this potential due to the limited exchange of data between the different operational centre and by the restrictions of archiving large volumes of data.

Box 2 aut2007

90th percentile of “climatological” pdf



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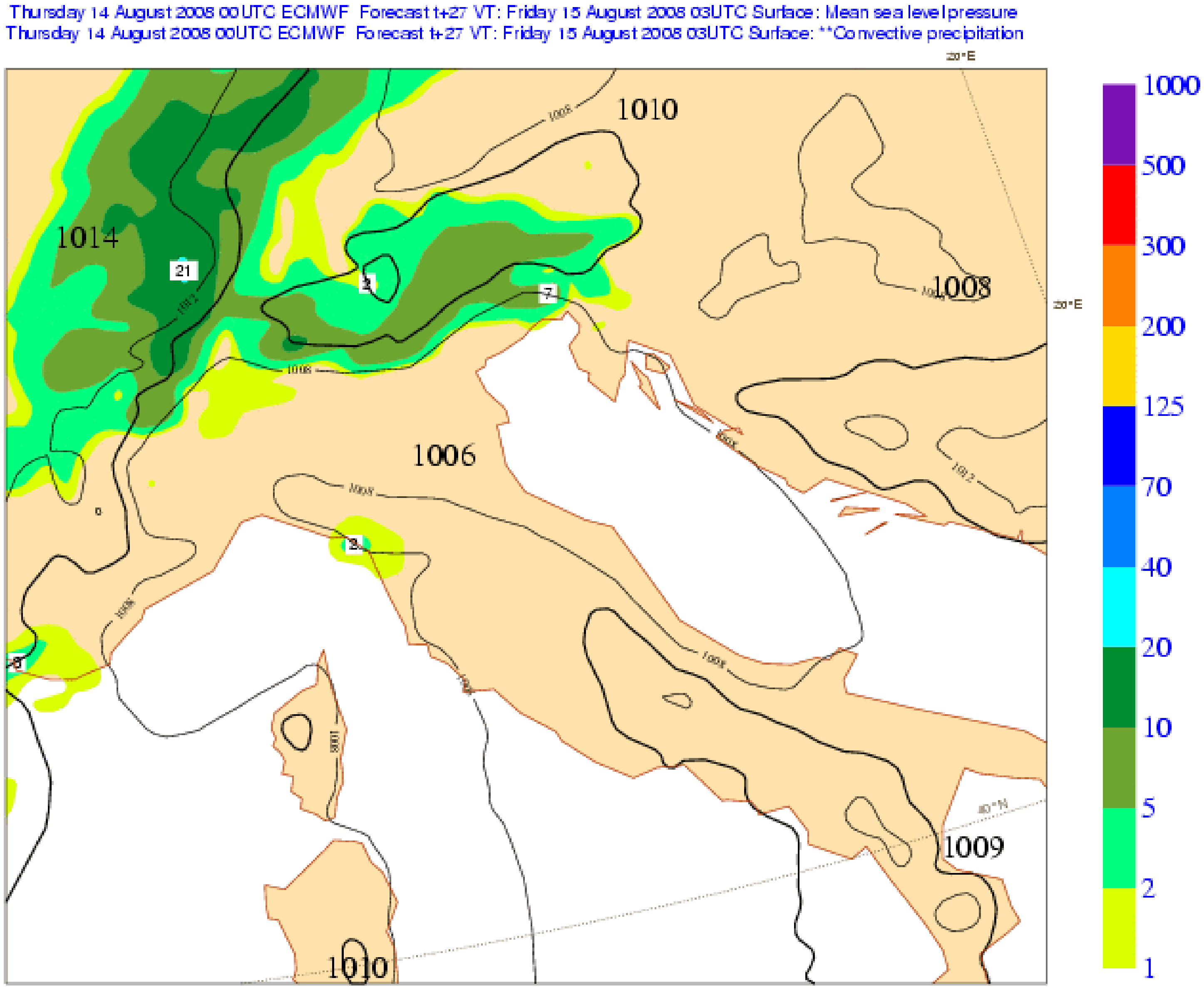
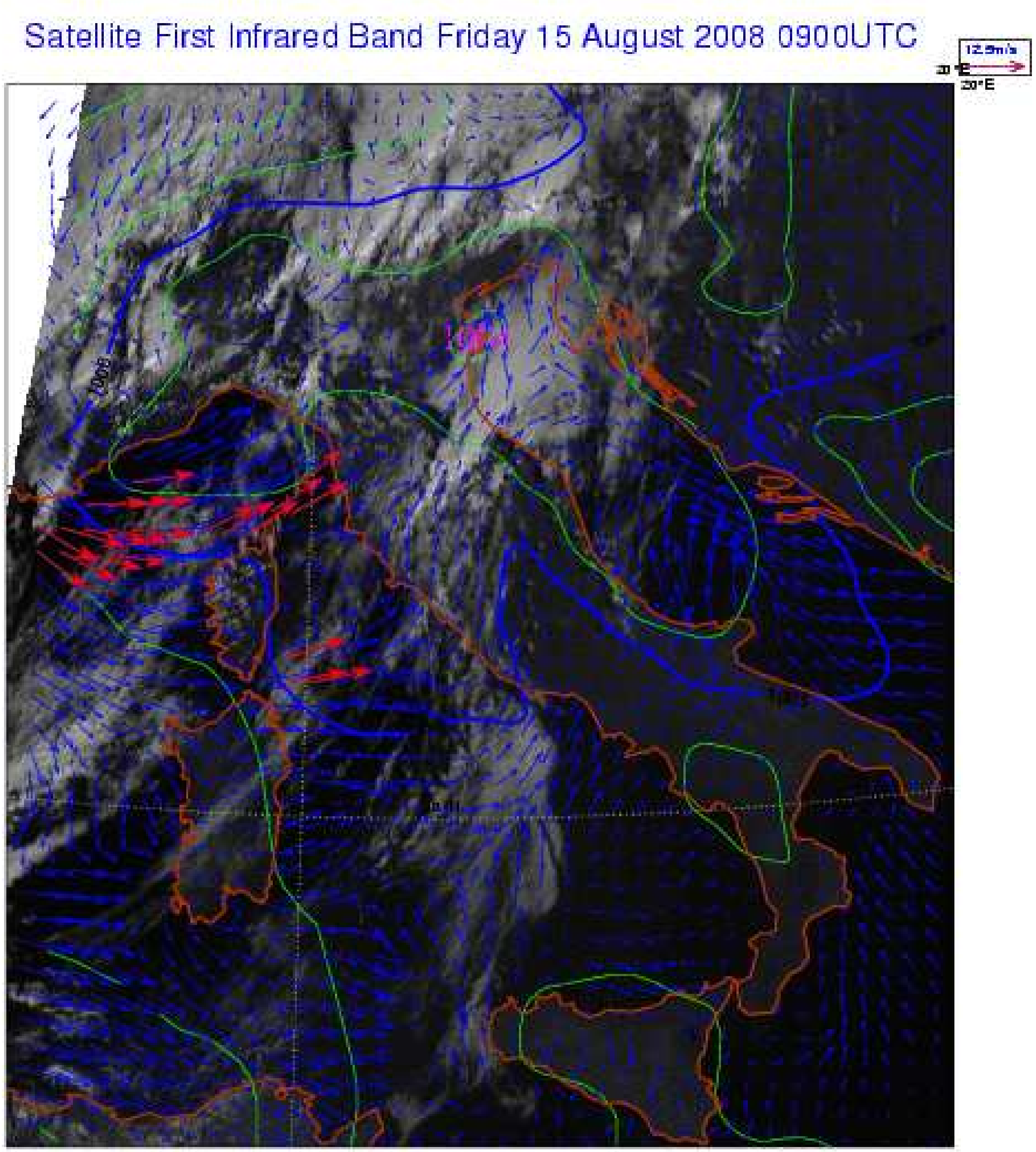
23 mm/24

25 mm/24

Midsummer storm false alarm (15/08/2008)

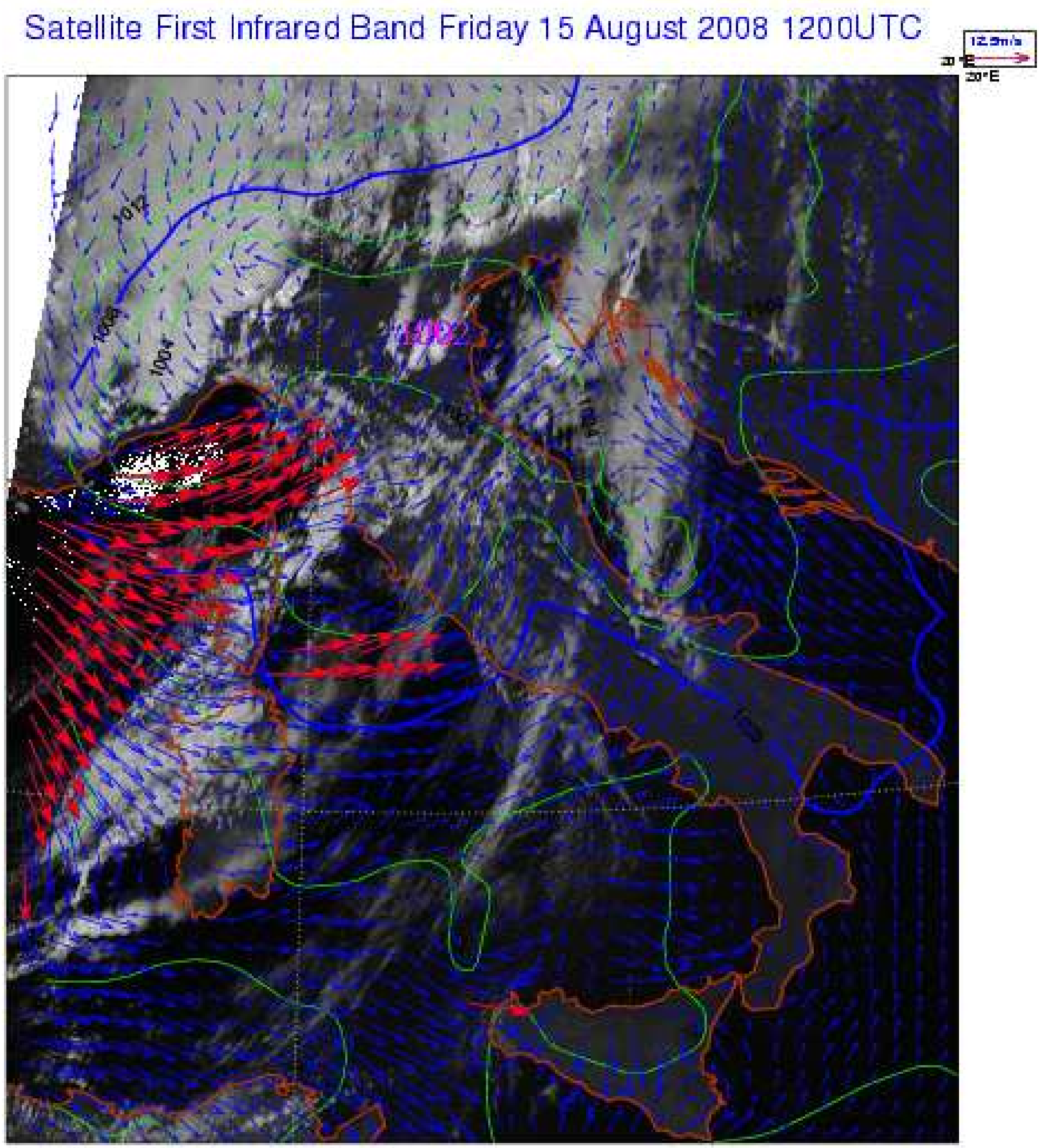
ECMWF: excessive feedback from parametrized convection on to the dynamics (?)





Midsummer storm false a
(15/08/2008)

Analysis



Midsummer storm false a
(15/08/2008)
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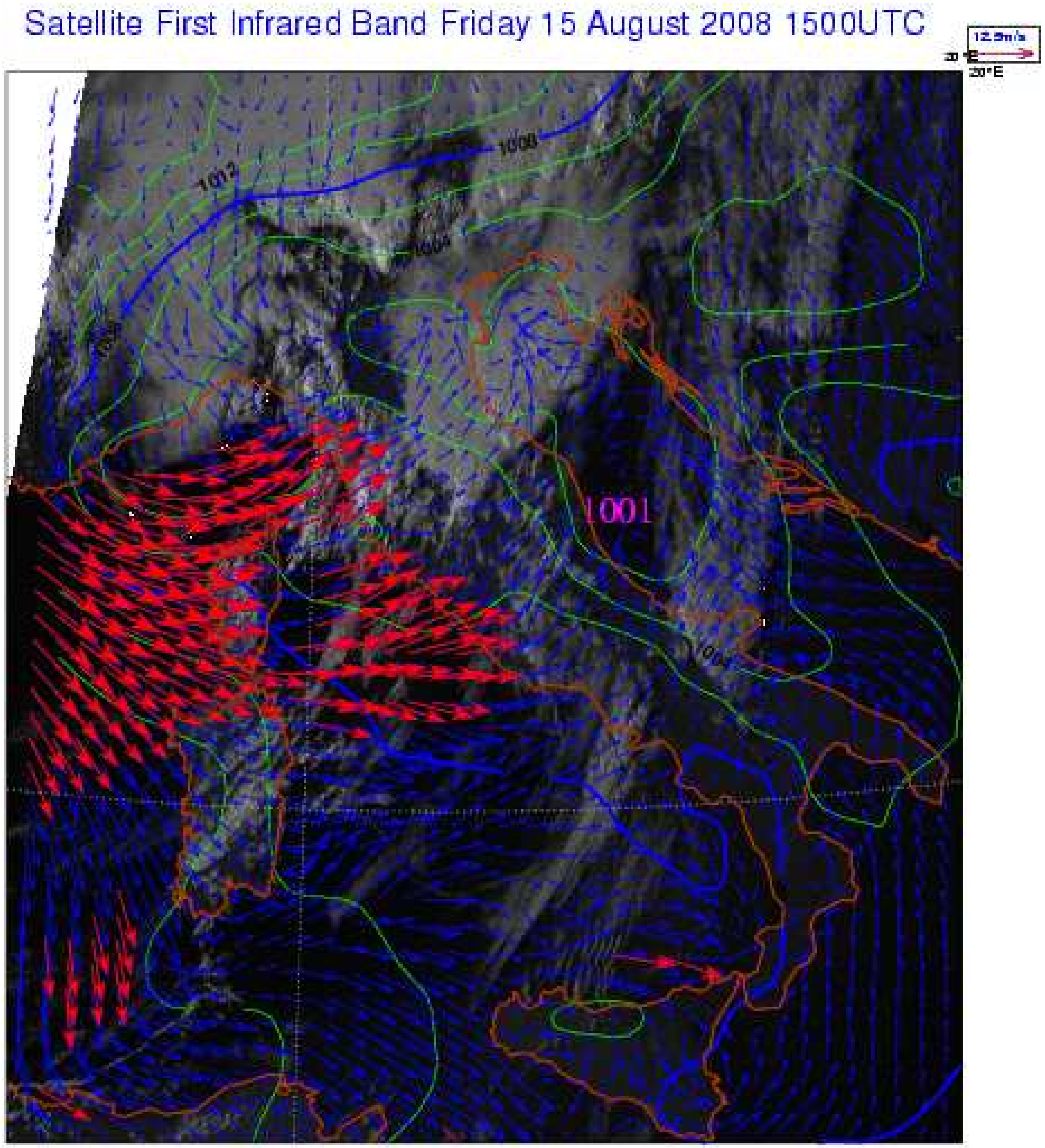
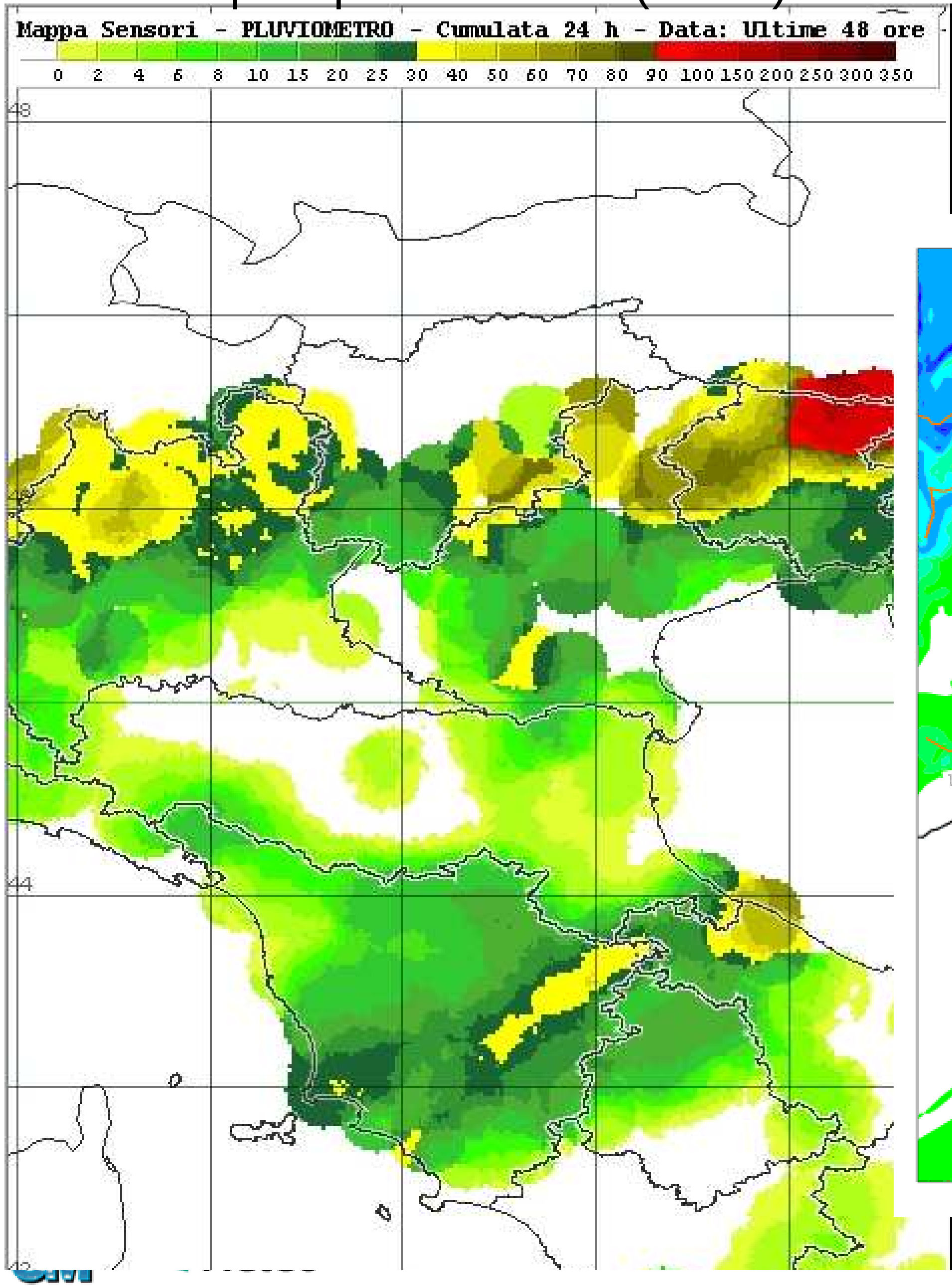
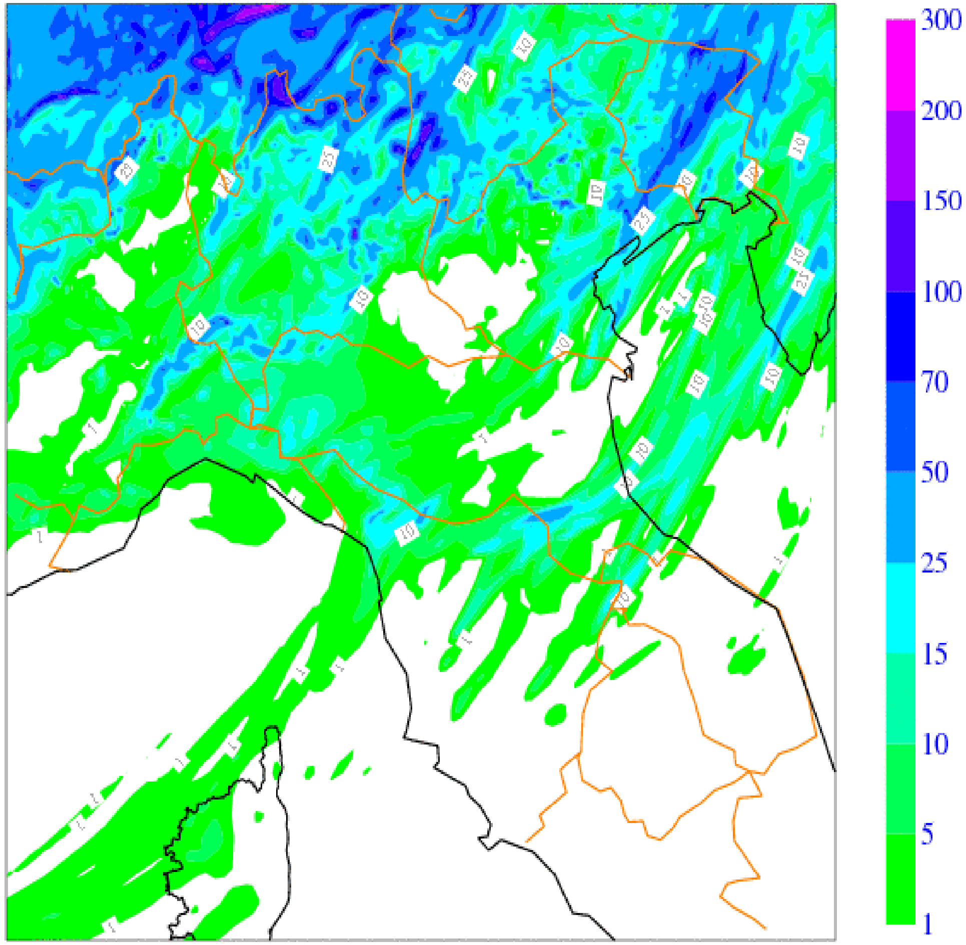


Midsummer storm false a
(15/08/2008)
Analysis

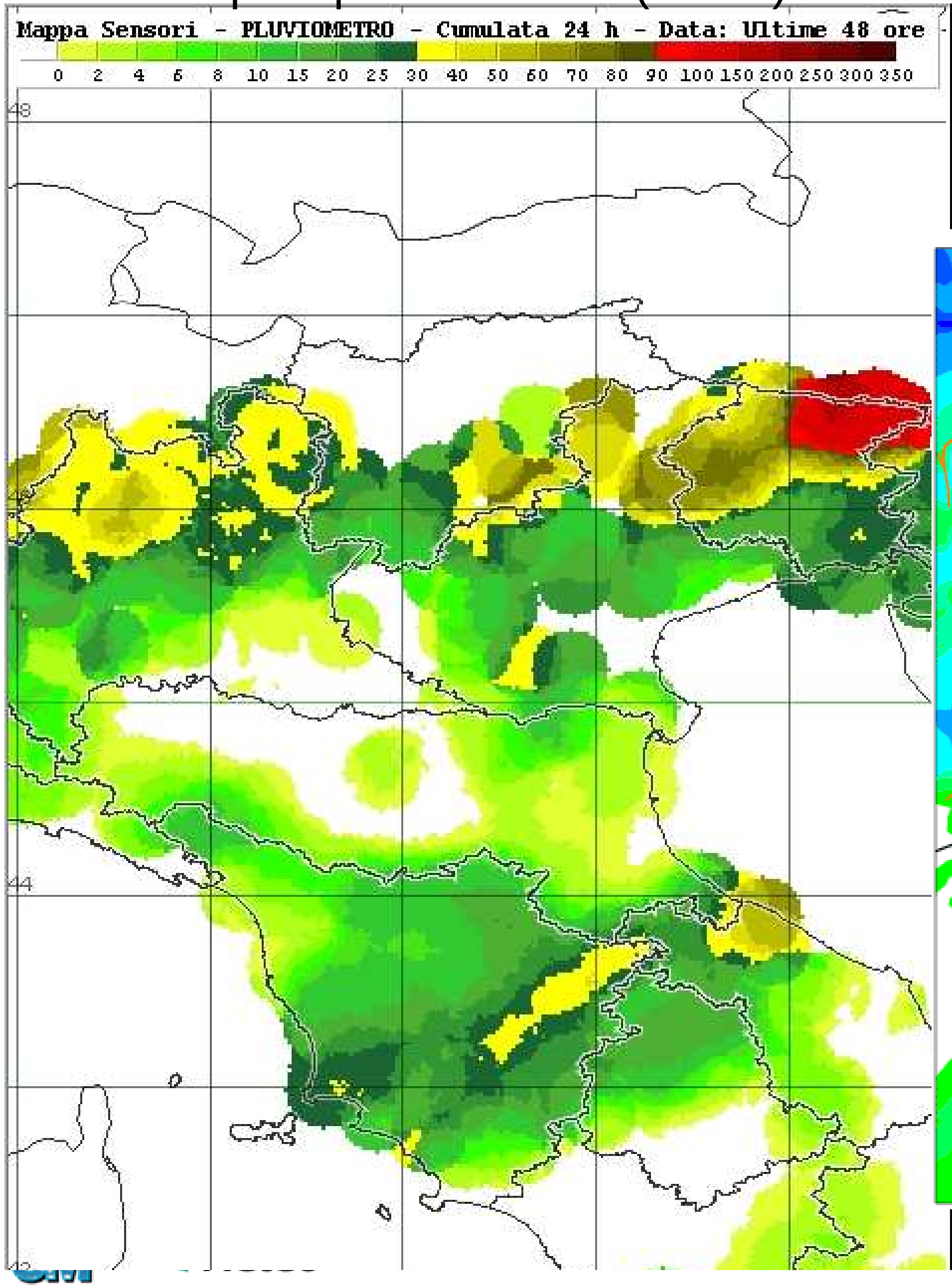
Observed precipitation 15/08 (00-24)



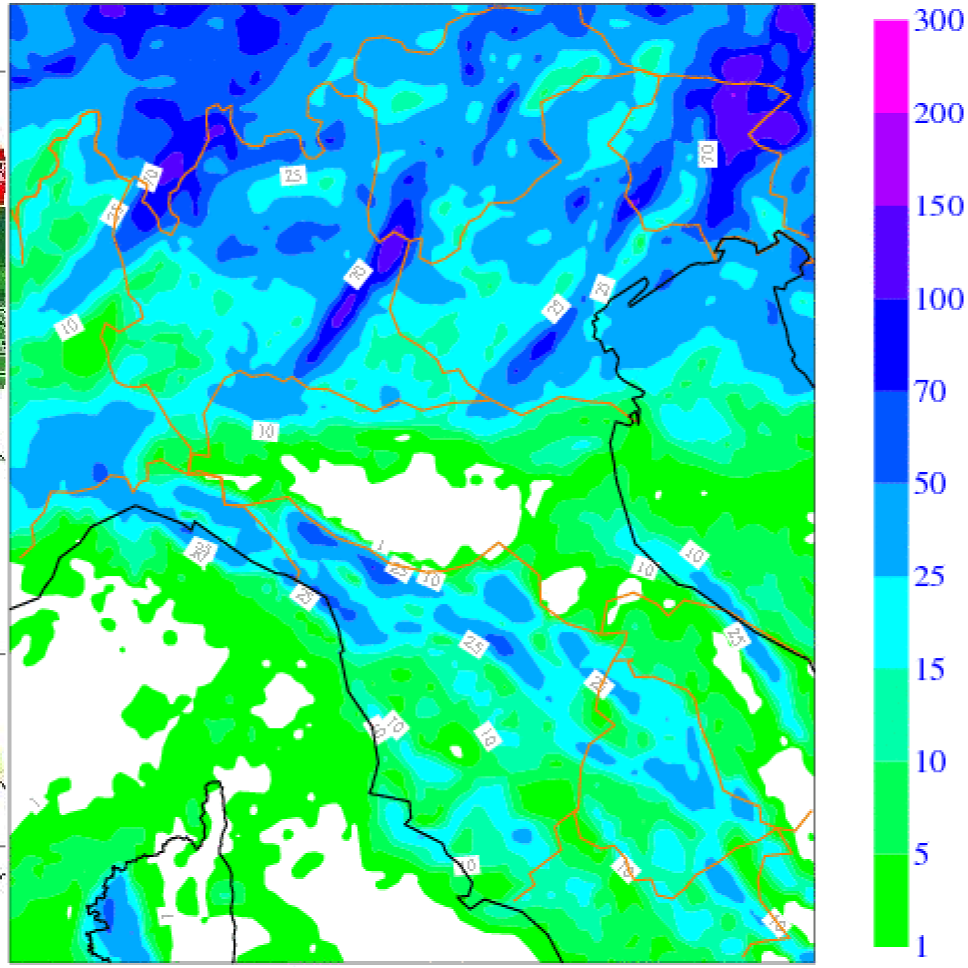
I2 14/08 12UTC 24h precip Fc+12-Fc+36

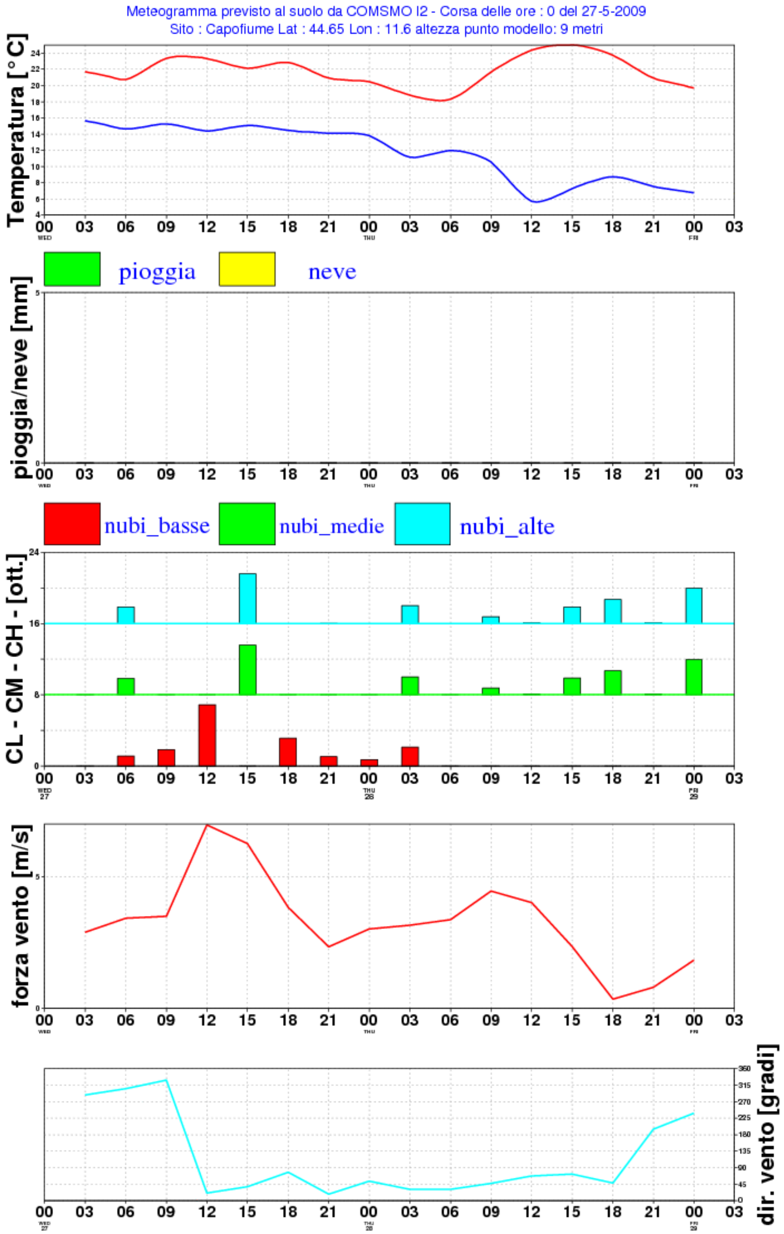


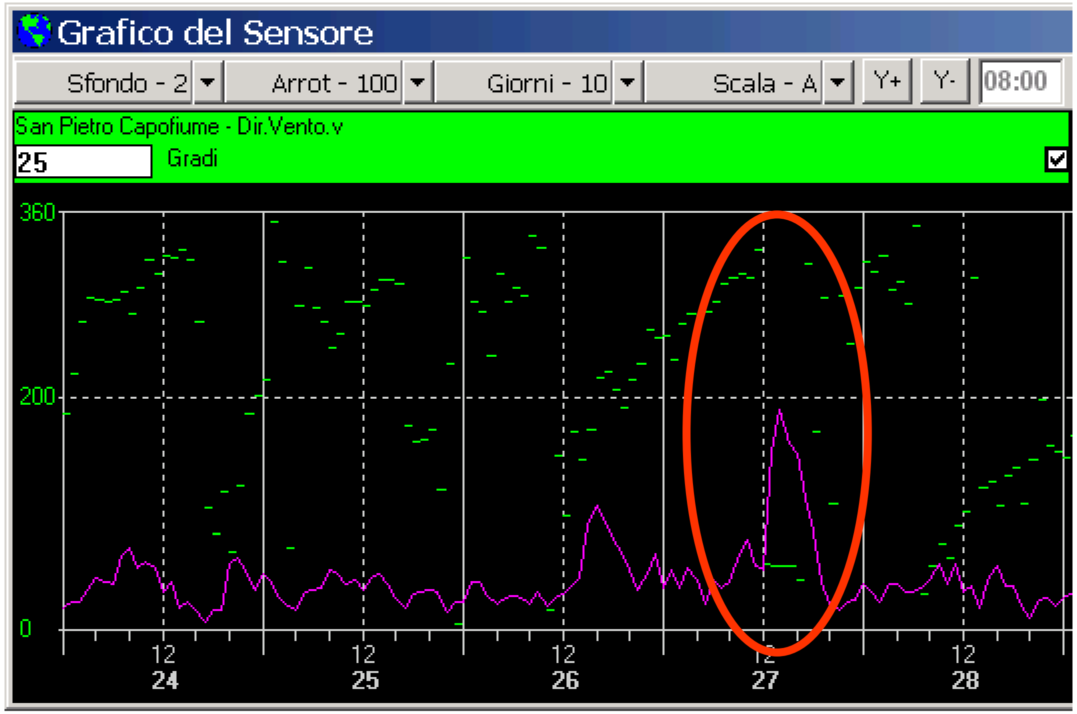
Observed precipitation 15/08 (00-24)



I7 14/08 12UTC 24h precip Fc+12-Fc+36







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