Severe storms and operational LAM simulations

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Outline

- Limited area model operational suite at ARPA-SIM
- The value of limited area models
- Precautionary notes on the use of limited area models
- Research and future plans

The COSMO Model

The COSMO model (formerly named Lokal-Modell) is a nonhydrostatic limited-area atmospheric prediction model formerly developed at DWD. It is based on the primitive thermo-hydrodynamical equations describing compressible flow in a moist atmosphere.

From 1999 the development of this models has been carried out in the framework of COSMO (COnsortium for Small scale MOdelling) composed by the national meteorological services of :Germany, Greece, Italy, Poland, Romania, Switzerland.

The Italian suite of COSMO model has been denominated COSMO-LAMI.

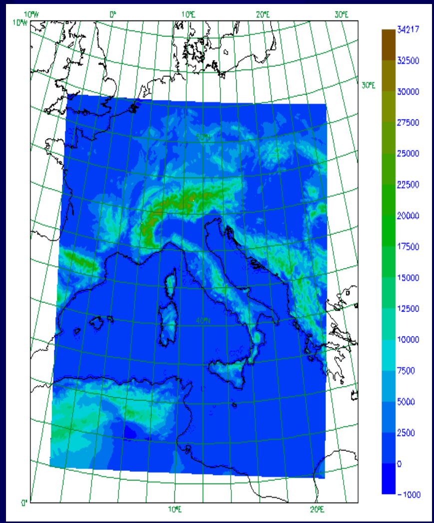
It has been designed in collaboration with ARPA-Piemonte and UGM

It is managed by ARPA-SIM Emilia-Romagna

It runs at Cineca and as back-up at ARPA-SIM

The products are distributed at the national Civil Protection and others environmental bodies and regional weather services

COSMO LAMI 7 Km



2 run per day starting at 00 and 12 UTC

Forecast length + 72 hours

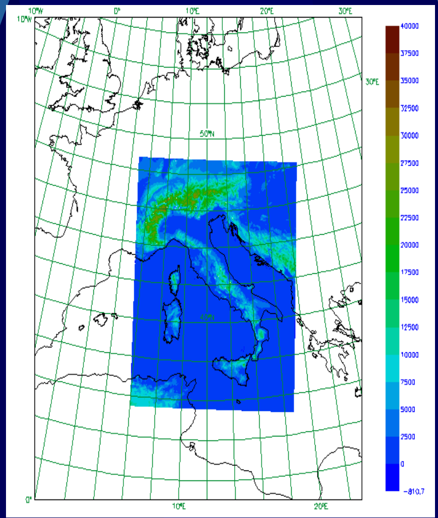
Horizontal resolution about 7 km

40 vertical levels

3-hourly boundary conditions from IFS/ECMWF forecast

Initial Conditions from COSMO LAMI continuous assimilation cycle based on nudging

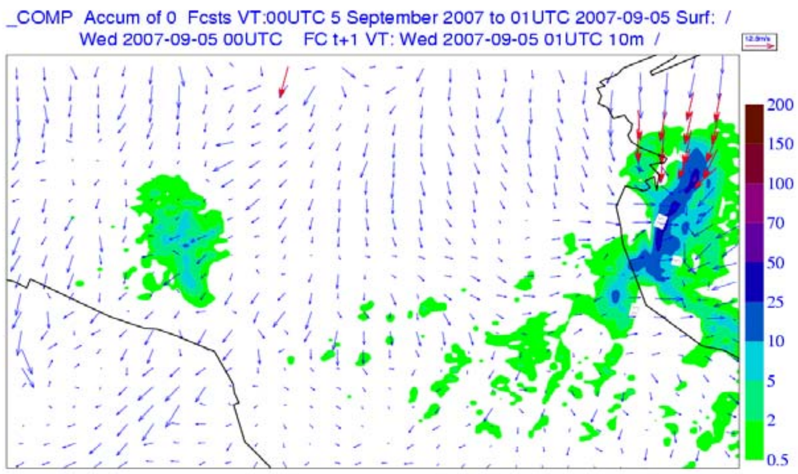
COSMO LAMI 2.8 Km



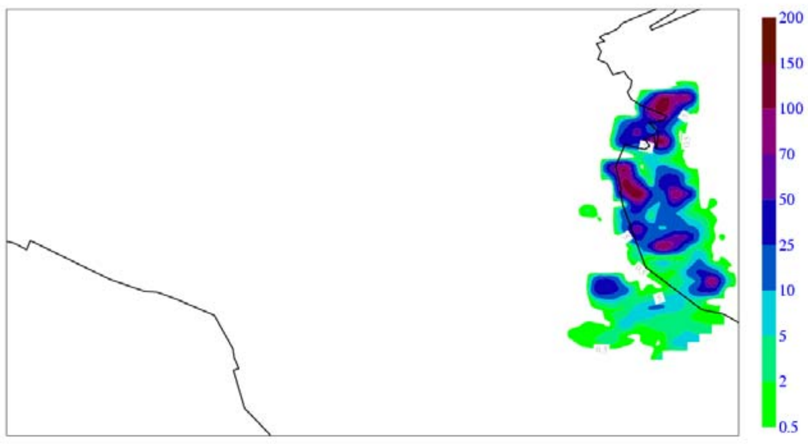
- 1 run per day starting at 00
- Forecast length + 48 hours
- Horizontal resolution about 2.8 km
- 45 vertical levels
- hourly boundary conditions from COSMO LAMI 7 km forecast
- Initial Conditions from COSMO LAMI 7 continuous assimilation cycle based on nudging

An example of LAMI 2.8 Km performance

6h forecast



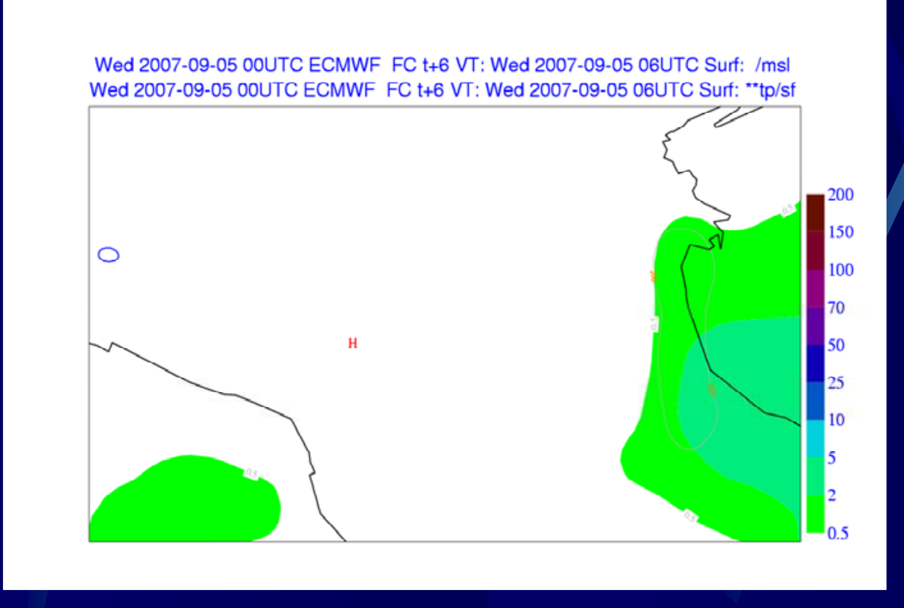
Observed rain rate from SPC radar



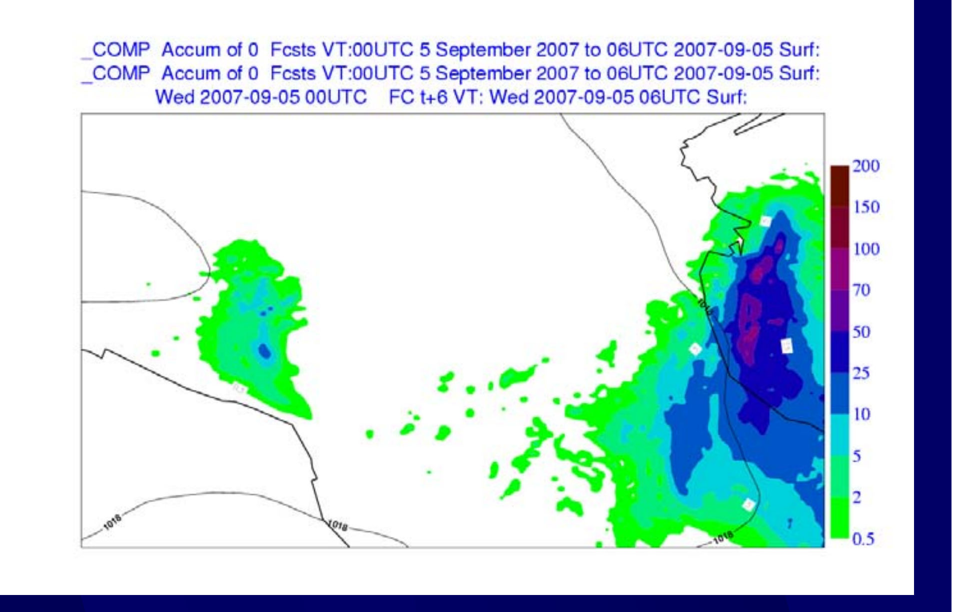
The added value of limited area models

patterns are more realistic……..

ECMWF T799 FC T+6, Precipitation



LAMI 2.8 Km FC T+6, Precipitation



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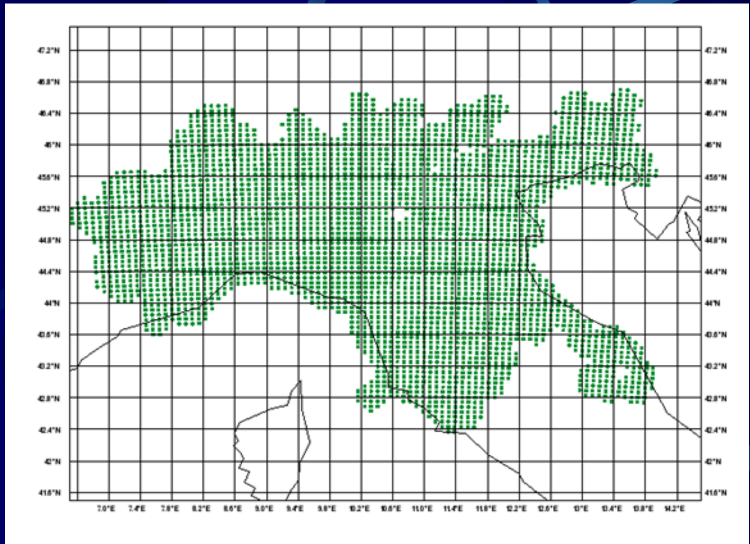
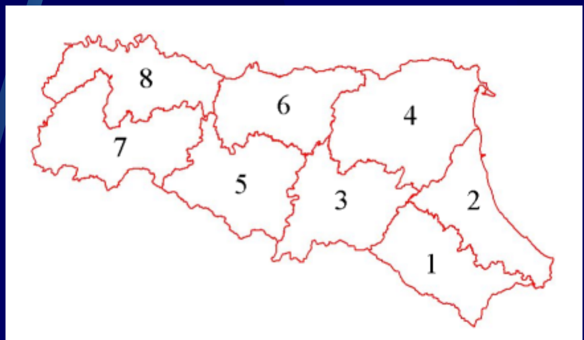
.....but sometimes may be wrong in space and in time:
The benefit of precipitation aggregation

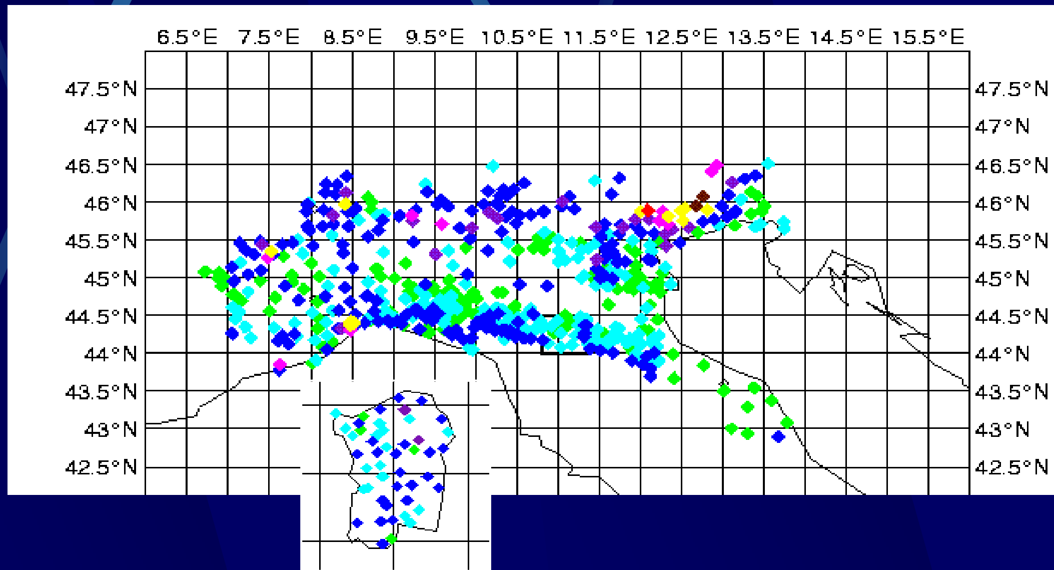


LAMI 7Km grid-points distribution
over verification boxes of 0.5°x0.5°



Warning areas of Emilia-Romagna

observation distribution
over verification boxes of 0.5°x0.5°



Scores definition

EVENT FORECAST	EVENT OBSERVED		
	YES	NO	*marginal totals*
YES	HIT (A)	False Alarm (B)	*fc YES*
NO	Miss (C)	correct rejection (D)	*fc NO*
marginals totals	*obs SI*	*obs NO*	*sum totals*

$$TS = \frac{a}{a + b + c} \qquad FAR = \frac{b}{a + b}$$

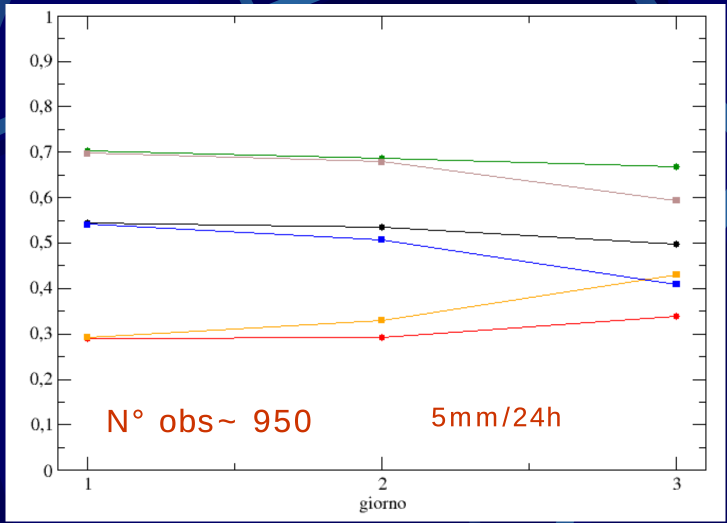
$$POD = \frac{a}{a + c} \qquad BS = \frac{a + b}{a + c}$$

Perfect forecast : TS, BS, POD = 1 FAR = 0

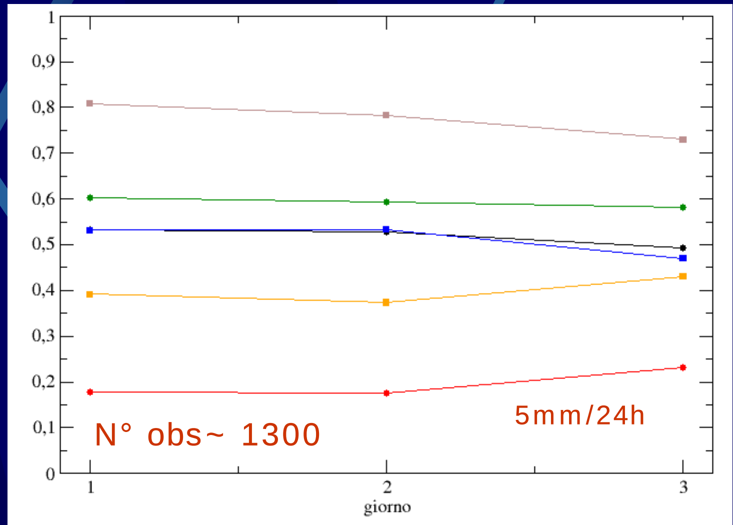
Verification of 24h accumulated precipitation aggregated over boxes of 0.5°x0.5°

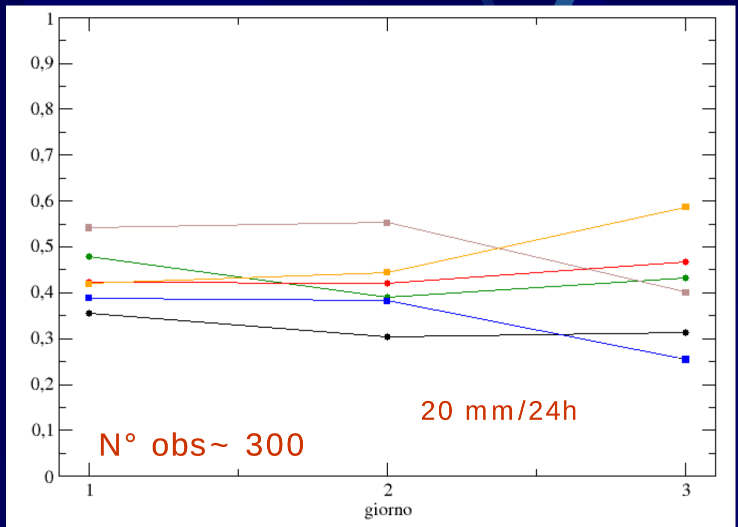
TS ECMWF12
POD ECMWF12
FAR ECMWF12
TS LAMI OPE
POD LAMI OPE
FAR LAMI OPE

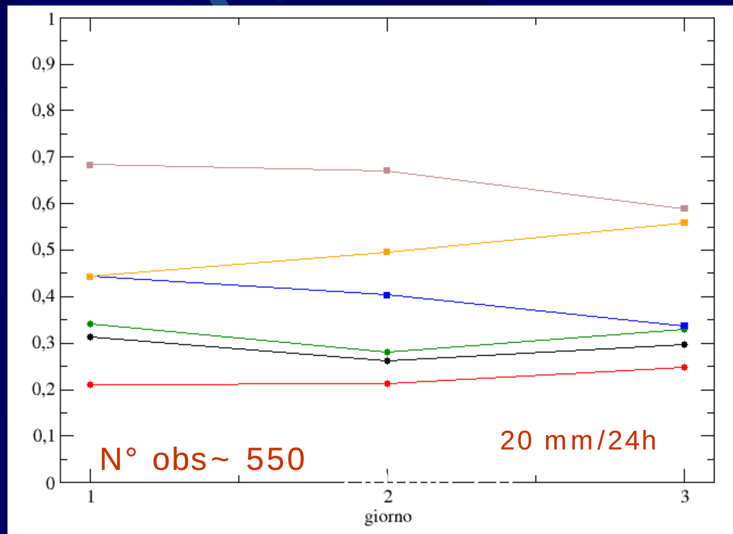
VALORE MEDIO



VALORE MASSIMO



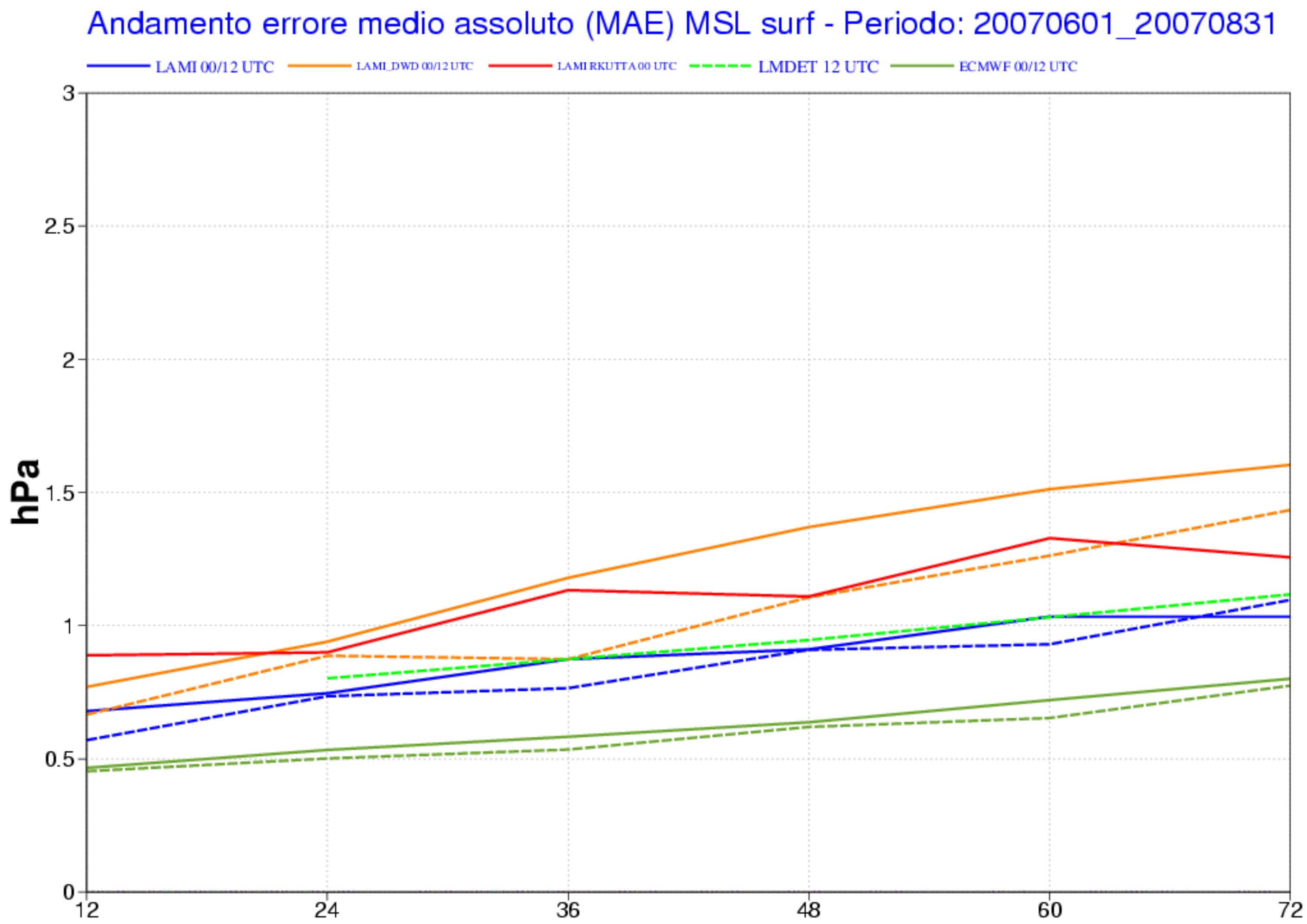




Sensitivity to the dimension of the box shows that the optimum size, reducing the positioning error, is around 7 times the horizontal resolution of the LAMs.

LAMI 7Km => boxes of 50 Km
LAMI 2.8Km => boxes 20 Km

Verification and comparison of the different LAM suites



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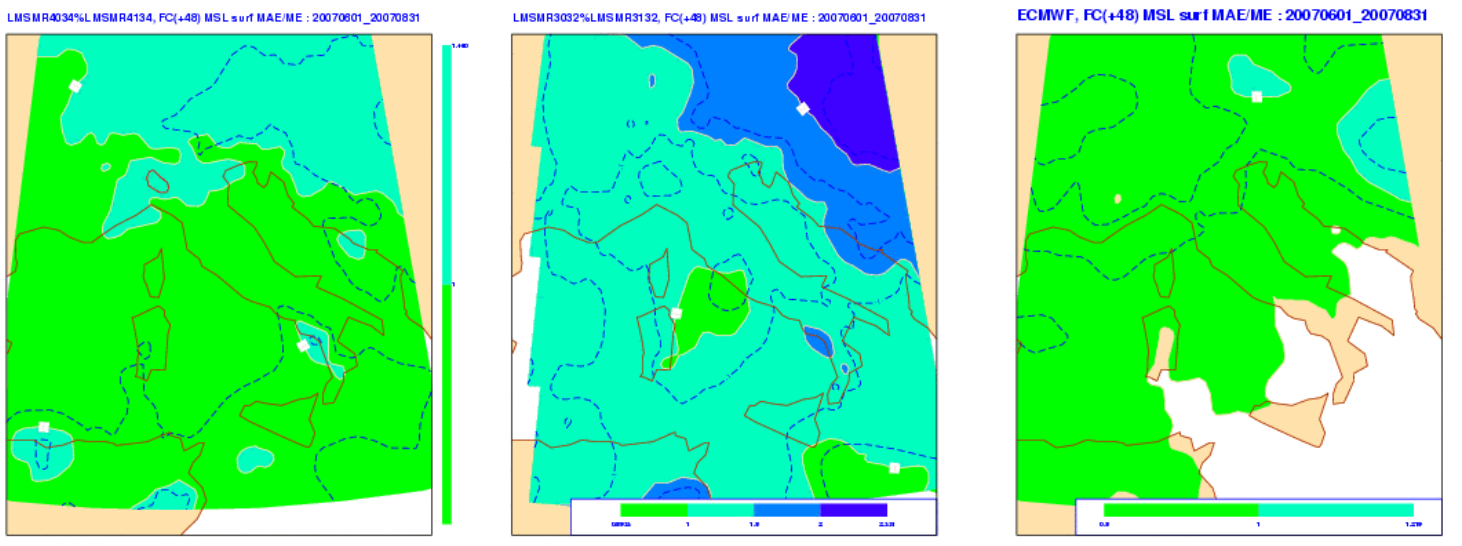
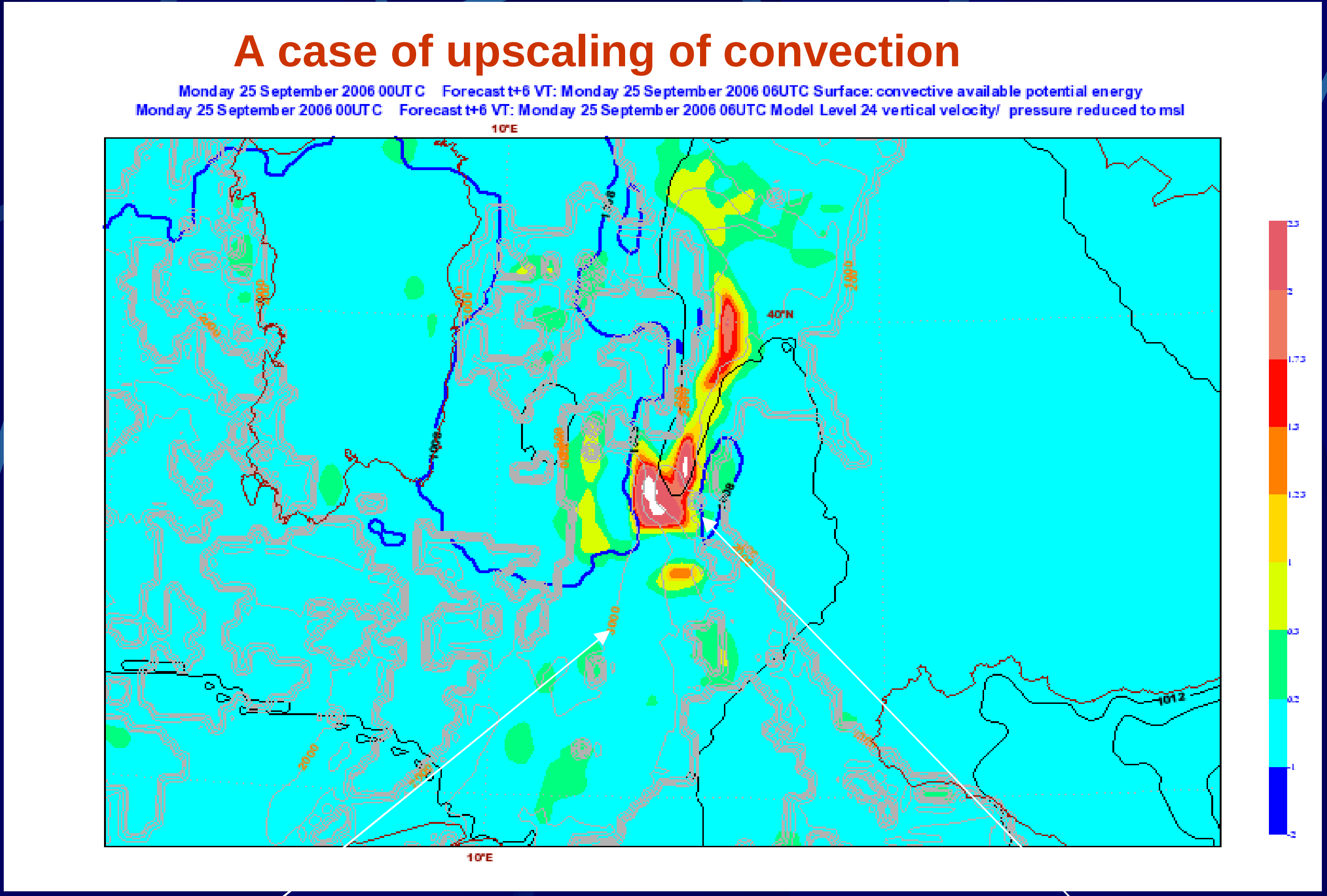
Verification and comparison of the different LAM suites



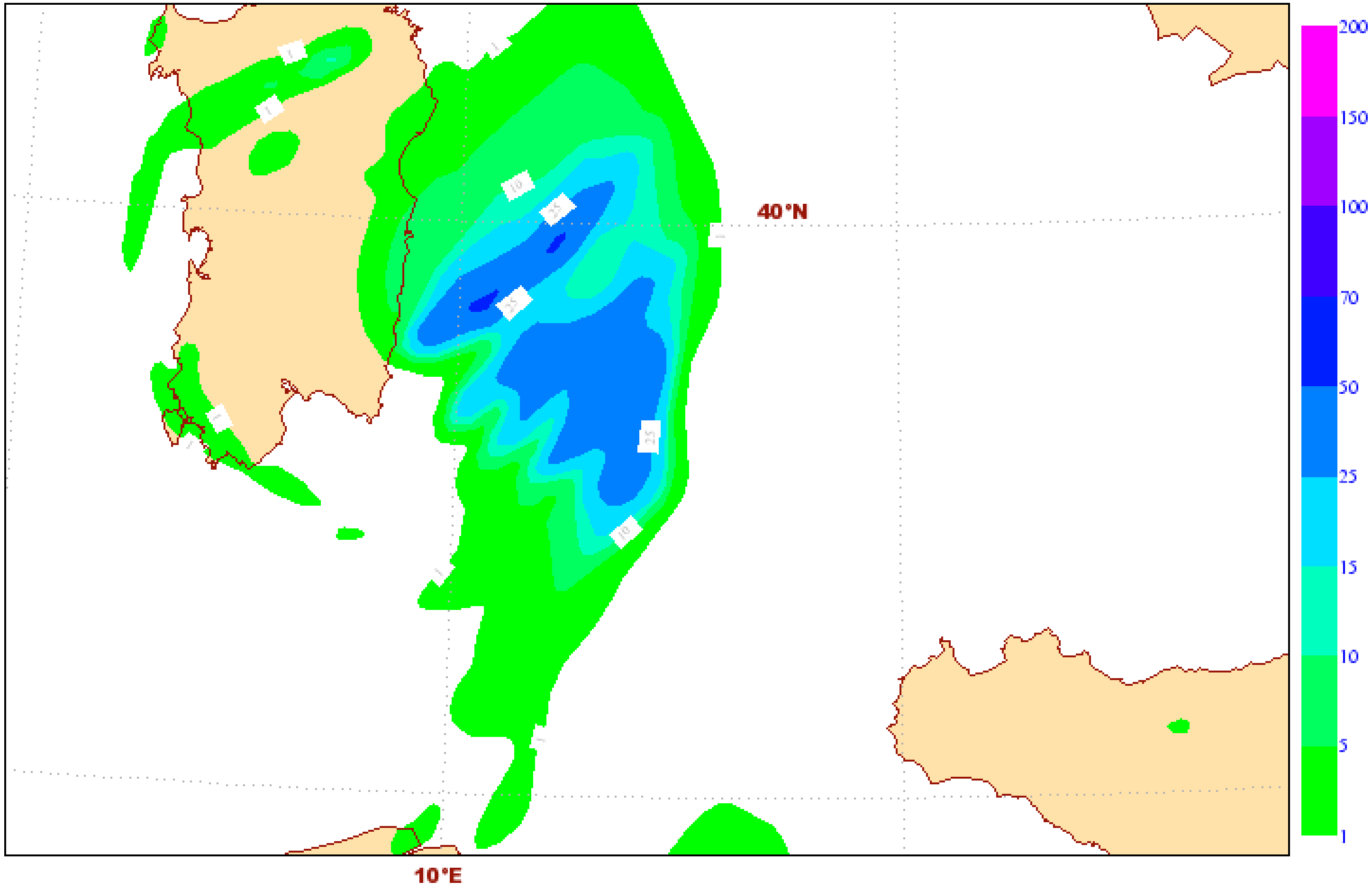
However objective verification is not sufficient, subjective inspection of fields is essential for diagnostic



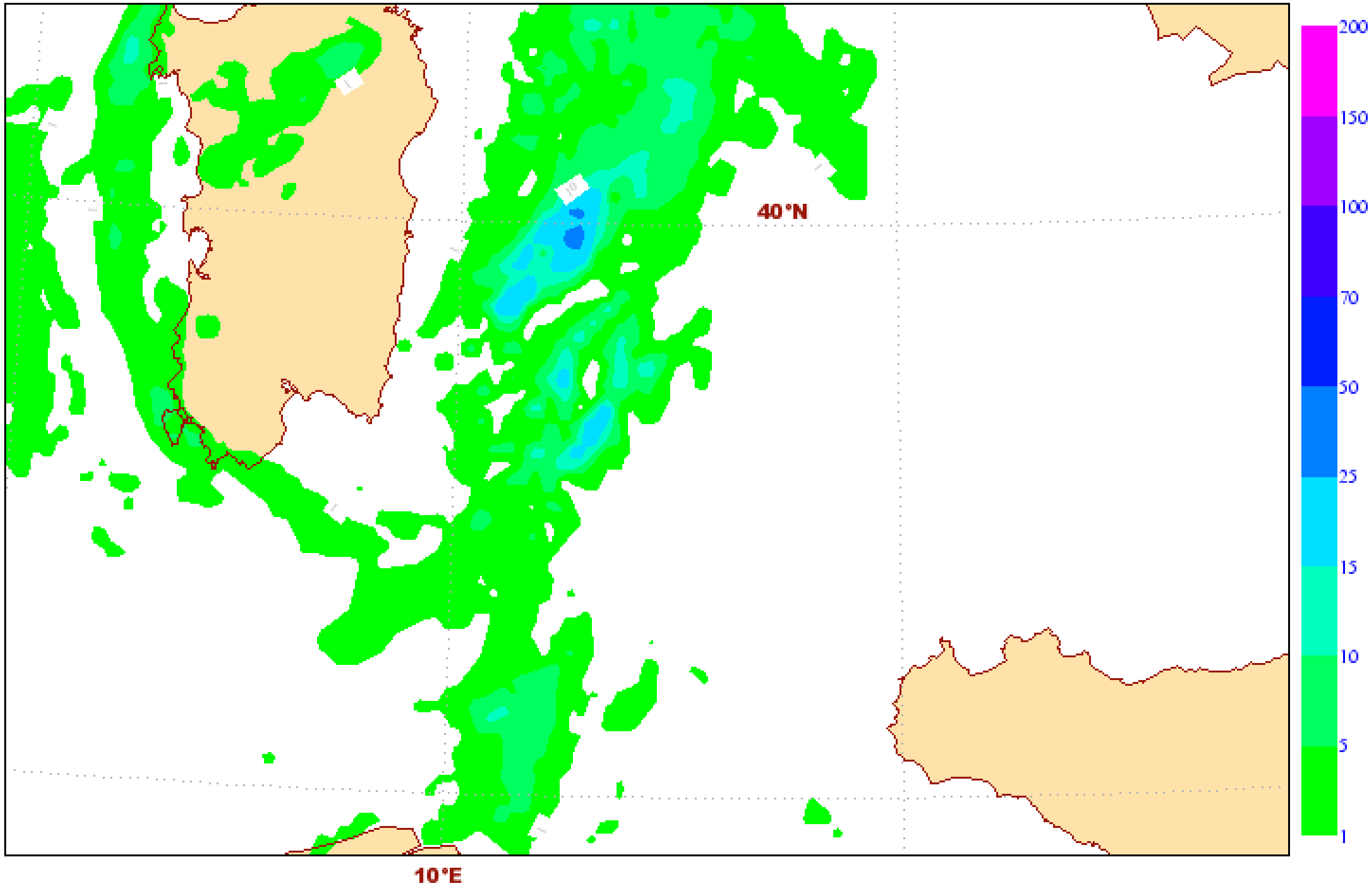
Very high CAPE ~3000 J/Kg

Unrealistic updraft, 4/5 grid points with w at 3500 m (model level 24) greater than 2 m/s

3h large-scale precipitation 25092006 00UTC (t+3 / t+6)

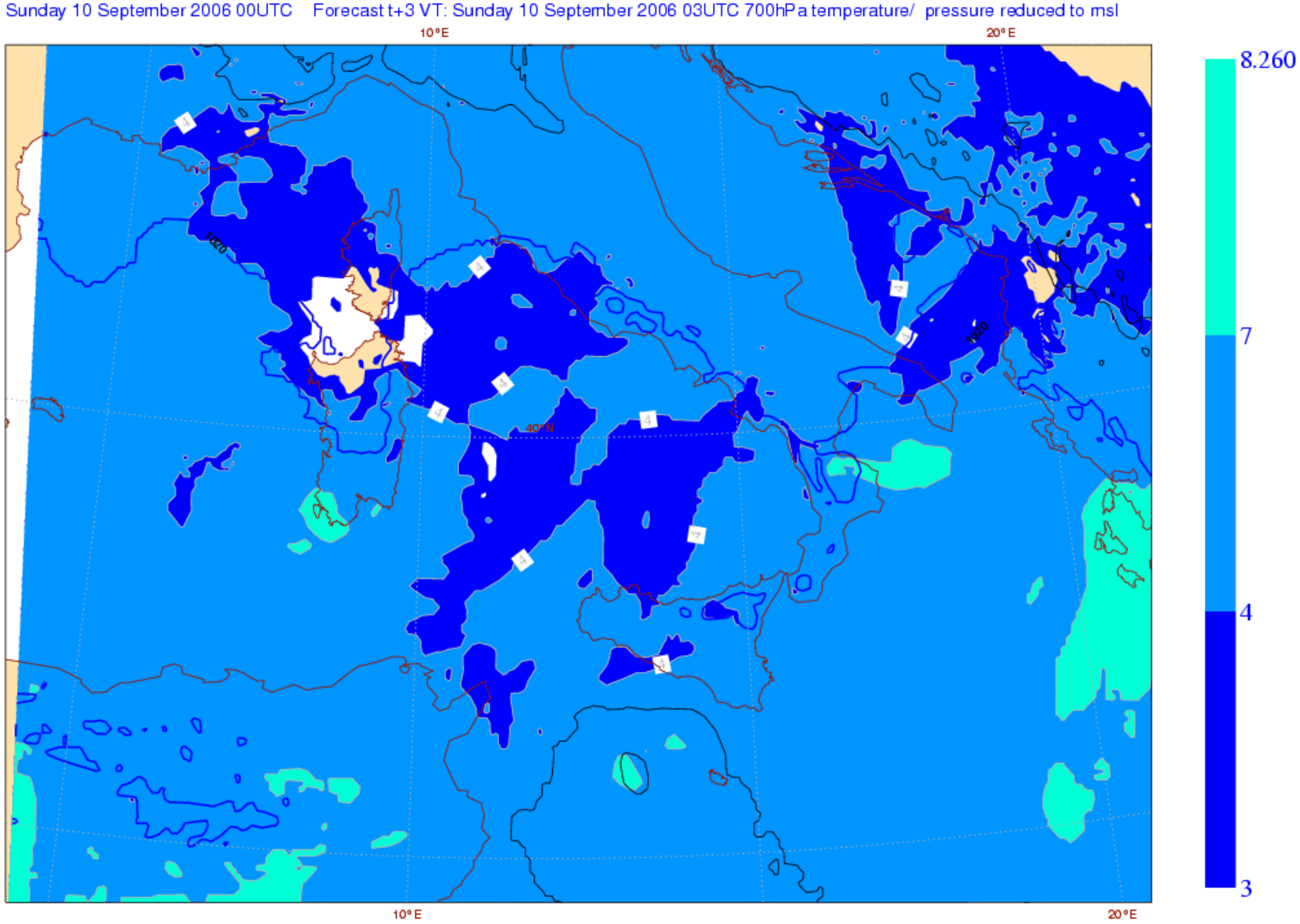


3h convective precipitation 25092006 00UTC (t+3 / t+6)

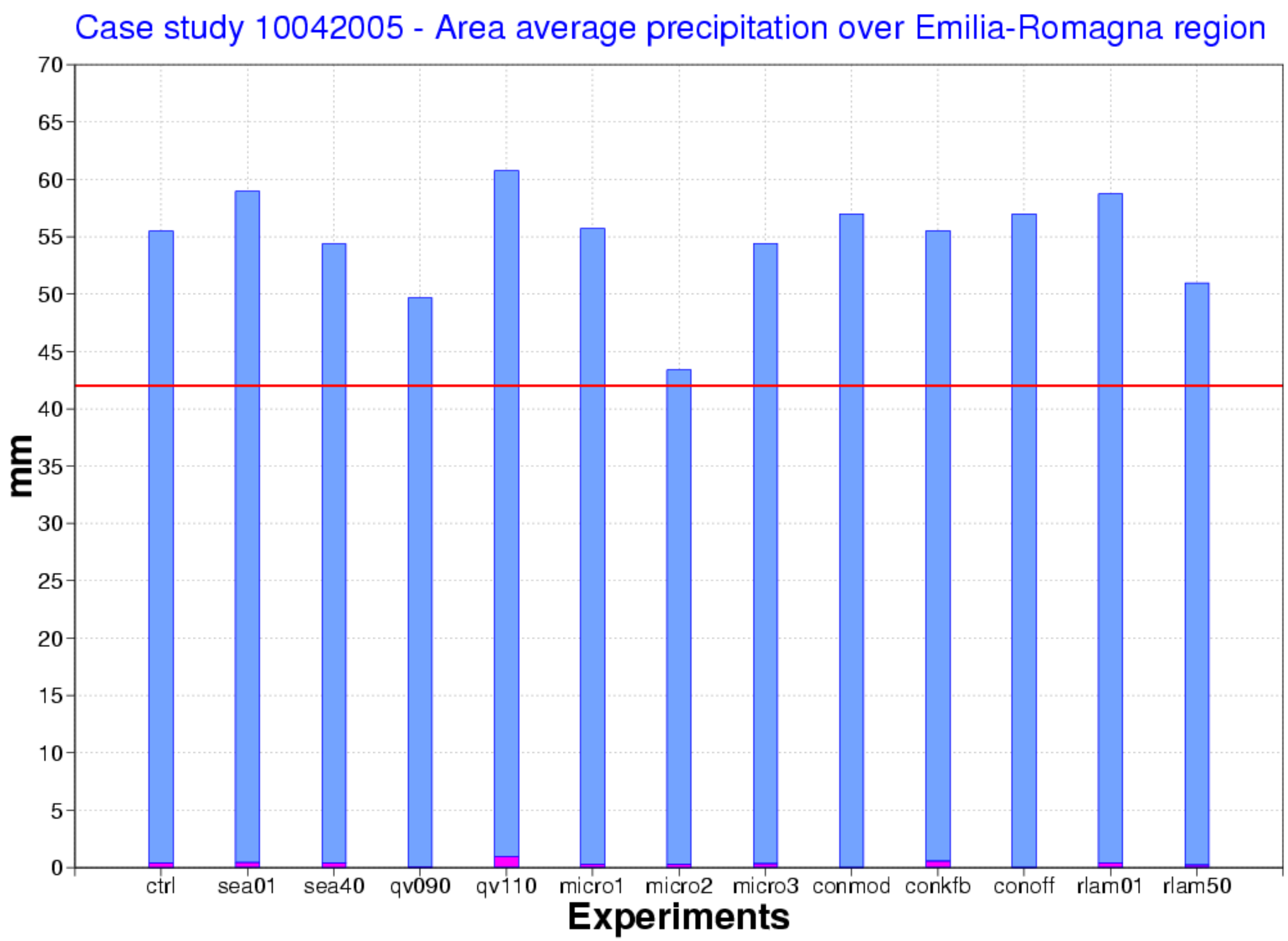


Can we learn from model errors ?

a virtual hurricane in the Med Sea



Efforts to improve precipitation forecast of COSMO model : QPF project



COSMO-LEPS

It is a **L**imited-area **E**nsemble **P**rediction **S**ystem (**LEPS**), based on the limited area model of the **COSMO** Consortium

It has been designed to improve the capability of forecasting severe local events in the time range 48 C132 hours by performing a dynamical downscaling of some selected members of ECMWF EPS

The new COSMO-LEPS suite @ ECMWF since February 2006

d-1 d d+1 d+2 d+3 d+4 d+5

00 UTC EPS

12 UTC EPS

clustering period

4 variables
Z U V Q

3 levels
500 700 850 hPa

Cluster Analysis and RMs identification

2 time steps

Europe an area

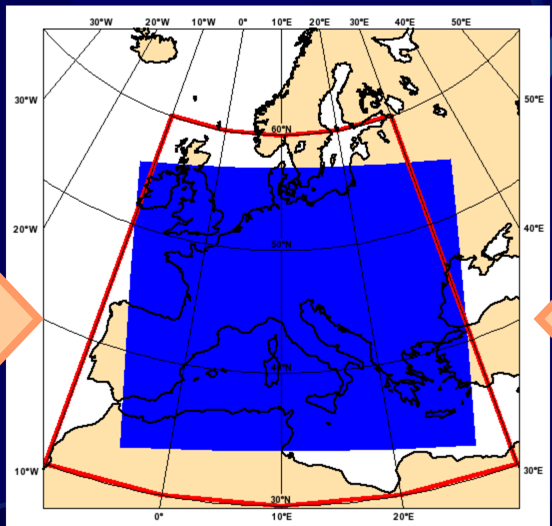
Complete Linkage

16 Representative Members driving the 16 COSMO model integrations (weighted according to the cluster populations)

&

Employing either Tiedtke or Kain-Fristch moist convection scheme (randomly choosen)

COSMO-LEPS clustering area



COSMO-LEPS Integration Domain

- suite running as a "time-critical application" managed by ARPA-SIM;
- Δx ~ 10 km; 40 ML;
- LM_3.17 since 1/2/2006;
- fc length: 132h;
- Computer time (4 million BU for 2006) provided by the COSMO partners which are ECMWF member states.

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COSMO-LEPS products

Products disseminated to the COSMO–countries

probabilistic products:

- 24h rainfall exceeding 20, 50, 100, 150 mm;
- 72h rainfall exceeding 50, 100, 150, 250 mm;
- 24h snowfall exceeding 1, 5, 10, 20 "cm";
- $UVmax_{10m}$ in 24h above 10, 15, 20, 25 m/s;
- $Tmax_{2m}$ in 24h above 20, 30, 35, 40 ^{0}C;
- $Tmin_{2m}$ in 24h below -10, -5, 0, +5 ^{0}C;
- min height of 0 ^{0}C isotherm in 24h below 1500, 1000, 700, 300 m;
- max–CAPE in 24h above 2000, 2500, 3000, 3500 J/kg;
- min Showalter Index in 24h below 0, -2, -4, -6;

deterministic products (for each LM run):

- 24–hour cumulated rainfall; mean–sea–level pressure, Z700, T850;

meteograms (over a number of station points):

- T_{2m}, rainfall, 10m wind speed.

about 4 GB a day

Products delivered at about 1 UTC to most of COSMO weather services.

New products:

Ensemble Mean

and

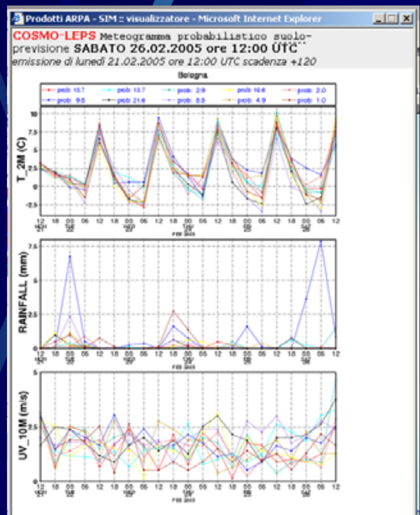
Ensemble Standard Deviation

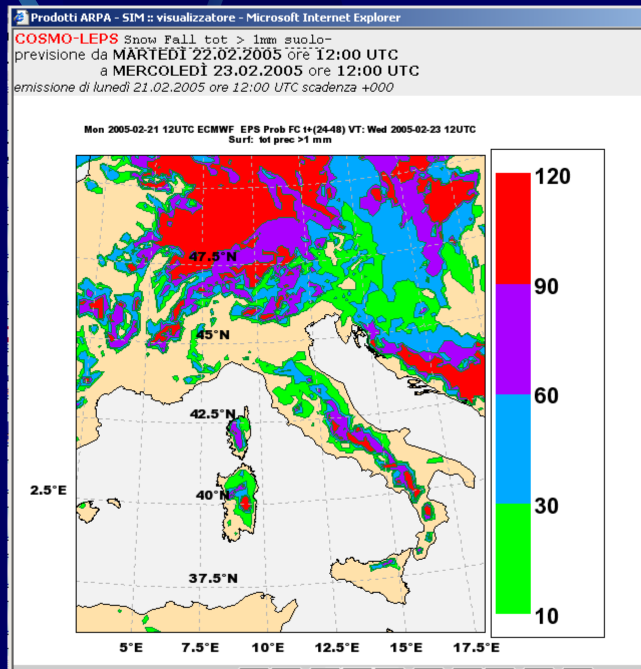
for

Z700 - T850 - MSLP - T2M - UV10M - TP

fc+0h to fc+132h every 3 hours

EM and ES are calculated **without** considering the weights relative to each integration

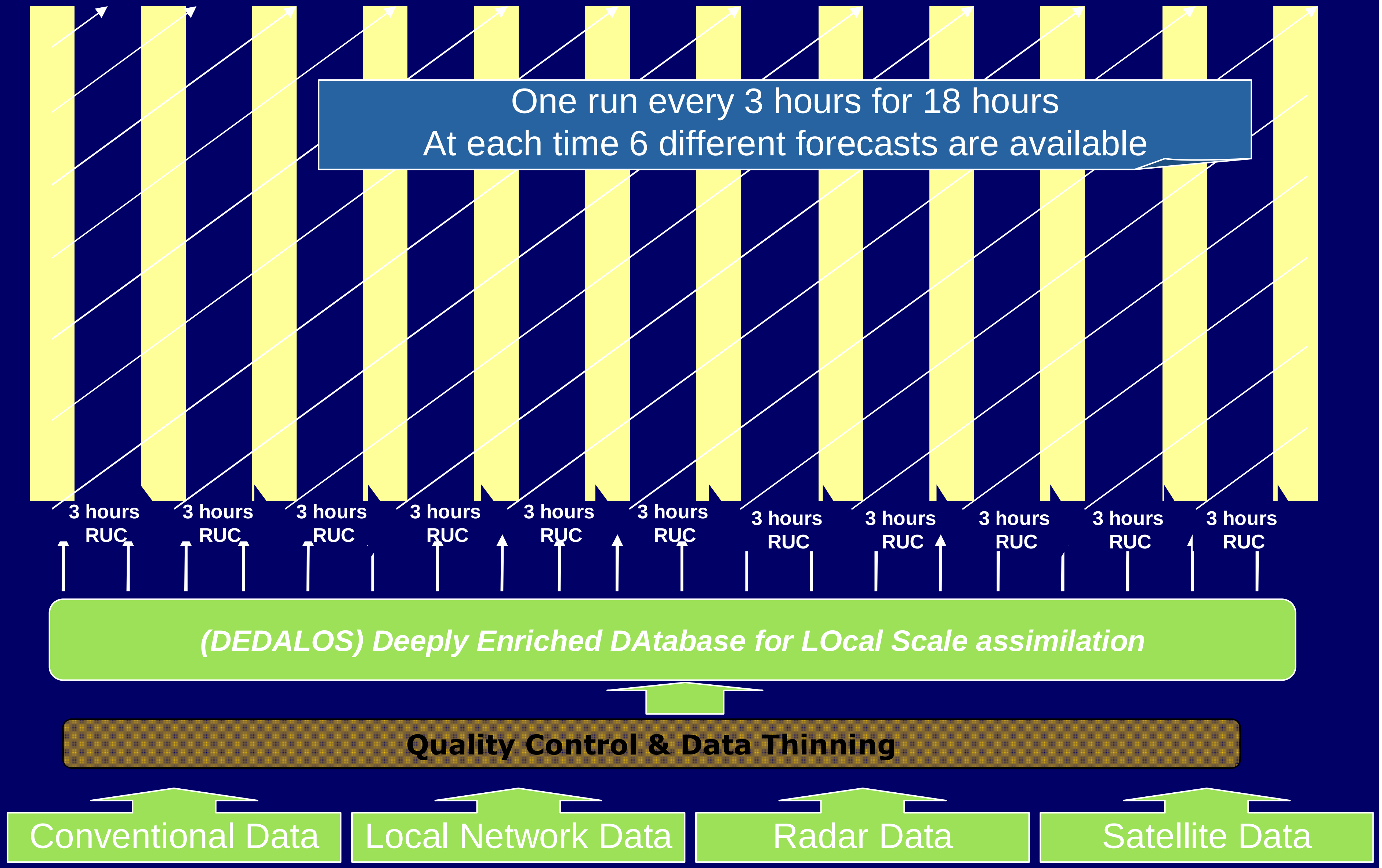




Reaserch and future plans: COSMO LAMI

- ❑ Operational implementation of 12 UTC run of LAMI 2.8 Km
- ❑ Implementation of data assimilation on LAMI 2.8 of conventional obs and MSG channels based on 1-Dvar approach
- ❑ Implementation of LAMI RUC (rapid update cycle)

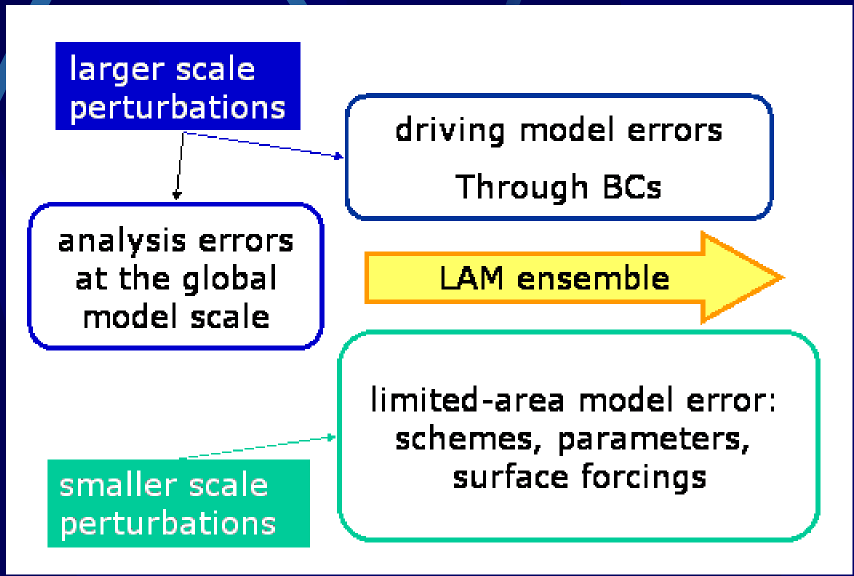
COSMO LAMI RUC



Future plans: COSMO SREPS

- **COSMO-LEPS mainly designed for the 2-5 days range**
- **The spread is coming only from EPS initial and boundary conditions (uncertainties related to larger scale analysis errors)**

- **COSMO-SREPS has been thought as a limited-area ensemble system for the short-range:**
  - add more spread in the short-range
    - initial and boundary condition from a Multi-Model Multi-Boundary ensemble (INM SREPS)
    - take into account also small scale uncertainty related to LM errors



IFS – ECMWF global

LM at 25 km on IFS

GME – DWD global

LM at 25 km on GME

UM – UKMO global

LM at 25 km on UM

AVN – NCEP global

LM at 25 km on NCEP

by INM Spain

1-month test: autumn 2006 (21 cases)

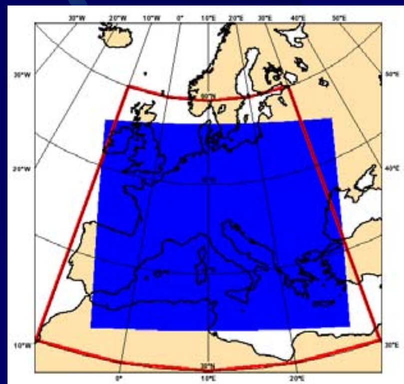
P1: control (ope)

P2: conv. scheme (KF)

P3: turb. parameter 1

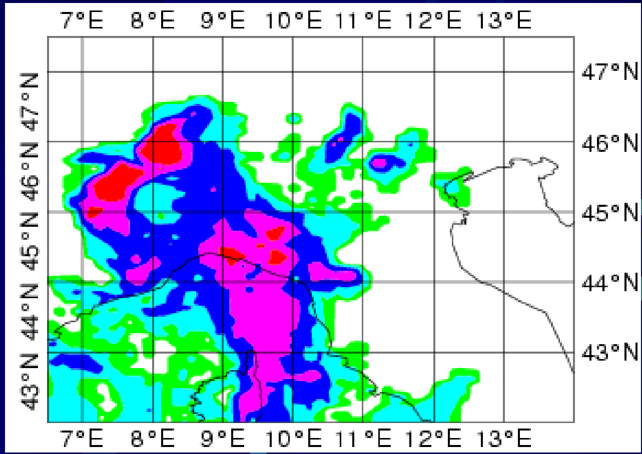
P4: turb. parameter 2

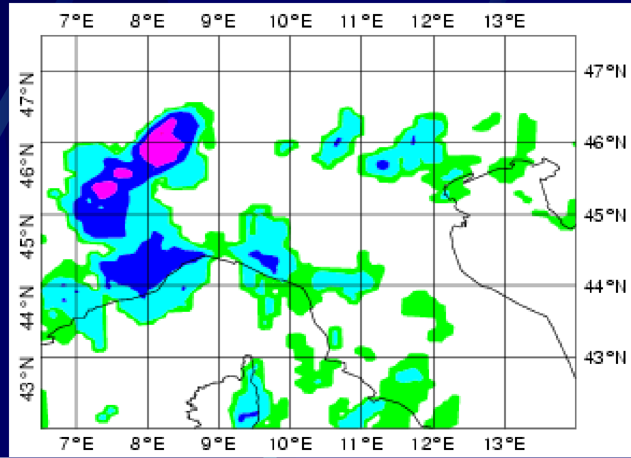
16 LM runs at 10 km

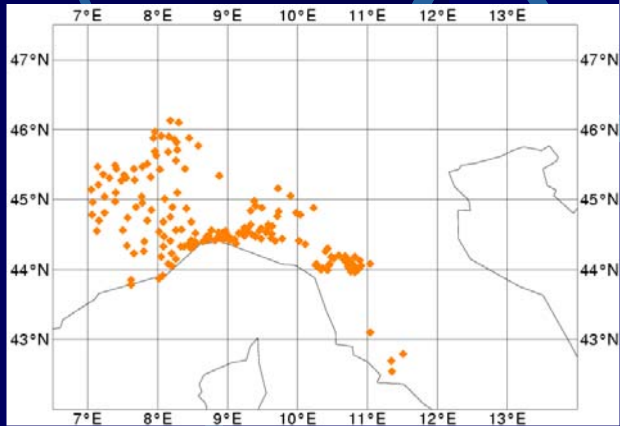


14 sep

> 50 mm/24h







24-48

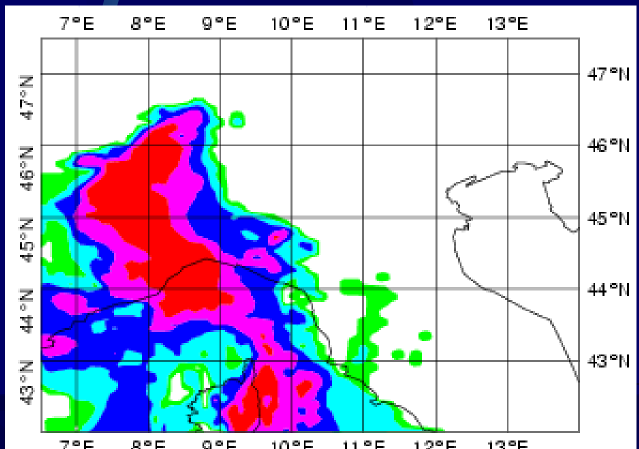
COSMO-SREPS

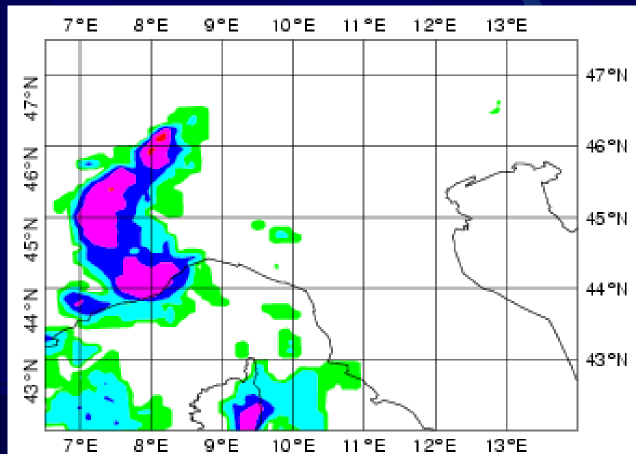
0-24

36-60

COSMO-LEPS

12-36





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Thanks for your attention

The COSMO model: *Dynamics and Numerics*

Numerics	
Grid structure:	Arakawa C (horizontal) Lorenz vertical staggering
Spatial discretization:	Second order horizontal and vertical differencing
Time integration:	Leapfrog (horizontally explicit, vertically implicit) time-split integration including extension proposed by Skamarock and Klemp 1992. Additional options for: - a two time-level Runge-Kutta split-explicit scheme (Wicker and Skamarock, 1998) - a three time level 3-D semi-implicit scheme (Thomas et al., 2000) - **a two time level 3rd-order Runge-Kutta scheme (regular or TVD) with various options for high-order spatial discretization (Foerster and Doms, 2004)**
Numerical smoothing:	4th order linear horizontal diffusion with option for a monotonic version including an orographic limiter (Doms, 2001); Rayleigh-damping in upper layers; 3-d divergence damping and off-centering in split steps.
Lateral Boundaries:	1-way nesting using the lateral boundary formulation according to Davies (1976). Options for: - boundary data defined on lateral frames only; - periodic boundary conditions Driving models: GME, IFS/ECMWF or LM.

Dynamics	
Basic equations:	Non-hydrostatic, fully compressible primitive equations; no scale approximations; advection form; subtraction of a stratified dry base state at rest.
Prognostic variables:	Horizontal and vertical Cartesian wind components, temperature, pressure perturbation, specific humidity, cloud water content. Options for additional prognostic variables: cloud ice, turbulent kinetic energy, rain, snow and **graupel** content.
Diagnostic variables:	Total air density, precipitation fluxes of rain and snow.
Coordinates:	Rotated geographical coordinates (λ,φ) and a generalized terrain-following coordinate ς. Vertical coordinate system options: – Hybrid reference pressure based σ-type coordinate (default) – Hybrid version of the Gal-Chen coordinate – Hybrid version of the SLEVE coordinate (Schaer et al. 2002)

The COSMO model: *Physics*

Physics	
Grid-scale Clouds and Precipitation:	Cloud water condensation /evaporation by saturation adjustment. Cloud Ice scheme HYDCI (Doms,2002). Further options: - prognostic treatment of rain and snow (Gassman,2002; Baldauf and Schulz, 2004, for the leapfrog integration scheme) - **a scheme including graupel content as prognostic variable** - the previous HYDOR scheme: precipitation formation by a bulk parameterization including water vapour, cloud water, rain and snow (rain and snow treated diagnostically by assuming column equilibrium) - a warm rain scheme following Kessler
Subgrid-scale Clouds:	Subgrib-scale cloudiness based on relative humidity and height. A corresponding cloud water content is also interpreted.
Moist Convection:	Mass-flux convection scheme (Tiedtke) with closure based on moisture convergence. Further options: - a modified closure based on CAPE within the Tiedtke scheme - The Kain-Fritsch convection scheme

Physics	
Vertical Diffusion:	Diagnostic K-closure at hierarchy level 2 by default. Optional: - a new level 2.5 scheme with prognostic treatment of turbulent kinetic energy; effects of subgrid-scale condensation and evaporation are included and the impact from subgrid-scale thermal circulations is taken into account.
Surface Layer:	Constant flux layer parameterization based on the Louis (1979) scheme (default). Further options: - a new surface scheme including a laminar-turbulent roughness sublayer
Soil Processes:	Two-layer soil model) including snow and interception storage; climate values are prescribed as lower boundary conditions; Penman-Monteith plant transpitration. Optional: - a new multi-layer soil model including melting and freezing (Schrodin and Heise, 2001
Radiation:	δ-two stream radiation scheme after Ritter and Geleyn (1992) for short and longwave fluxes; full cloud-radiation feedback

The COSMO model: other aspects

Initial Conditions:
Interpolated from GME, IFS/ECMWF or LM. Nudging analysis scheme (see Table 2). Diabatic or adiabatic digital filtering initialization (DFI) scheme (Lynch et al., 1997).
Boundary Conditions:
One way nesting by Davies boundary relaxation scheme;
Physiographical data Sets:
Mean orography derived from the GTOPO30 data set(30"x30") from USGS. Prevailing soil type from the DSM data set (5'x5')of FAO. Land fraction, vegetation cover, root depth and leaf area index from the CORINE data set. Roughness length derived from the GTOPO30 and CORINE data sets.
Code:
Standard Fortran-90 constructs. Parallelization by horizontal domain decomposition. Use of the MPI library for message passing on distributed memory machines.

The COSMO model: computing aspects

IBM Power5 o Linux cluster del Cineca

- **128 dedicated CPUs**
  - **run 00: ~ 5h**
  - **run 12: ~ 1h**
- **256 GB ram**
- **~ 1 TFlop/s**
- **5 TB disk space required**
- **3 TB storage**

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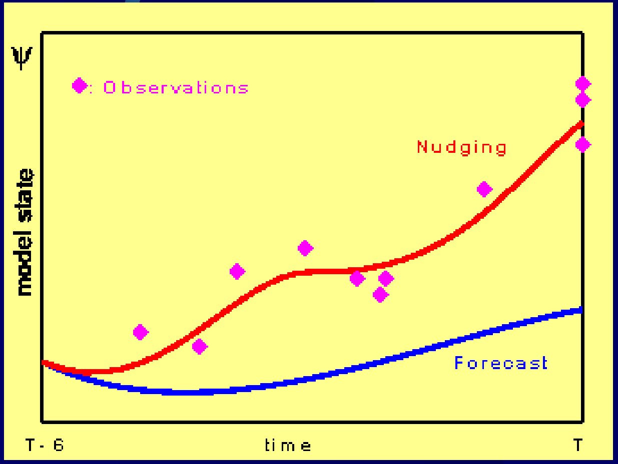
COSMO LAMI INITIAL CONDITION

Thus, the so-called nudging equation describes a continuous adaptation of the model values towards the observed values during the forward integration of the model.



Data Assimilation for LM	
Method:	Nudging towards observations
Implementation:	Continuous cycle
Realization:	Identical analysis increments used during 6 advection time steps
Balance	1. hydrostatic temperature increments (up to 400 hPa) balancing 'near-surface' pressure analysis increments 2. geostrophic wind increments balancing 'near-surface' pressure analysis increments 3. upper-air pressure increments balancing total analysis increments hydrostatically
Nudging coefficient	6.10^{-4} s^{-1} for all analyzed variables except pressure $1.2\ 10^{-3}$ s^{-1} for “near-surface” pressure
Analyzed variables	horizontal wind vector, potential temperature, relative humidity, 'near-surface' pressure (i.e. at the lowest model level)
Spatial analysis	Data are analyzed vertically first, and then spread laterally along horizontal surfaces.Vertical weighting: approximately Gaussian in log(p); horizontal weighting: isotropic as function of distance.