Limited-area ensemble activities at ARPA-SIMC: present status and future plans of the COSMO-LEPS system

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12th Workshop on Meteorological Operational Systems
Reading, 2-6 November 2009

Outline

- Introduction and present status.
- Use of observations:
  - time-series verification of COSMO-LEPS using SYNOP;
  - comparison of COSMO-LEPS and ECMWF EPS using a high-resolution network;
  - calibration of COSMO-LEPS.
- Present activity:
  - experimental suite at 7km;
  - COSMO-LEPS for TIGGE-LAM.
- Future plans.

COSMO-LEPS (developed at ARPA-SIMC)

- What is it?

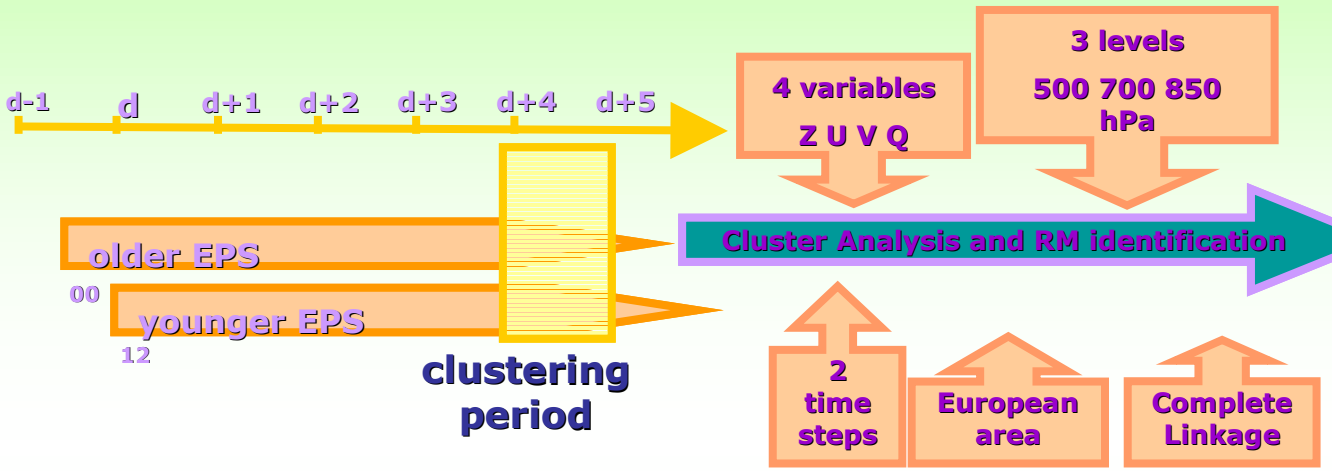
It is a **L**imited-area **E**nsemble **P**rediction **S**ystem (**LEPS**), based on COSMO-model and implemented within **COSMO** (**CO**nsortium for **S**mall-scale **Mo**delling, including Germany, Greece, Italy, Poland, Romania, Russia, Switzerland).

- Why?

It was developed to combine the advantages of global-model ensembles with the high-resolution details gained by the LAMs, so as to identify the possible occurrence of **high-impact** and **localised** weather events (heavy rainfall, strong winds, temperature anomalies, snowfall, …)

➔ **generation of COSMO-LEPS to improve the forecast of high-impact weather in the short and early-medium range (up to fc+132h)**

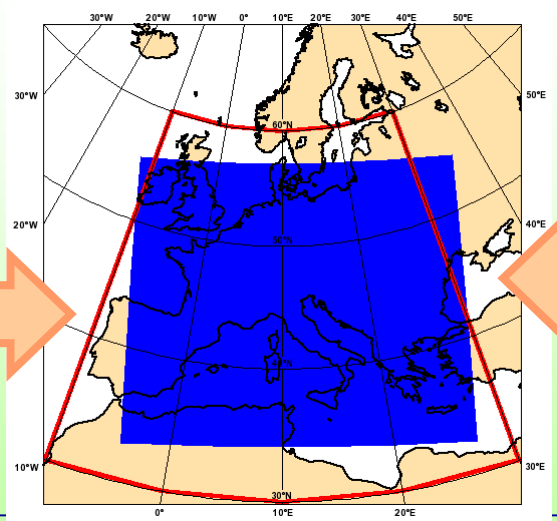
COSMO-LEPS suite @ ECMWF: present status



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

employing either Tiedtke or Kain-Fristch convection scheme (randomly choosen) + perturbations in turbulence scheme

COSMO-LEPS clustering area

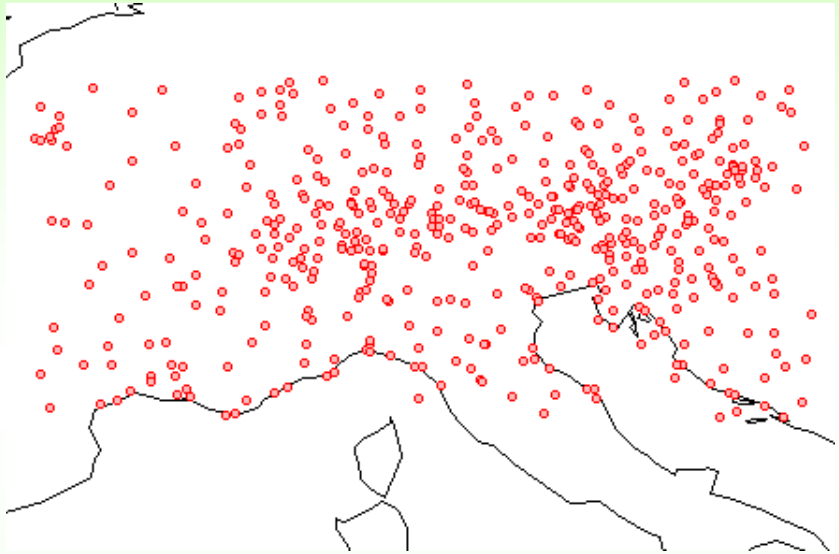


COSMO-LEPS Integration Domain

- suite runs as a "time-critical application" managed by ARPA-SIMC;
- Δx ~ 10 km; 40 ML; fc+132h;
- COSMO v4.7 since Feb09 (with Runge-Kutta + multi-layer soil scheme);
- computer time (6.0 million BU for 2009) provided by the COSMO partners which are ECMWF member states.

Time-series verification of COSMO-LEPS

- SYNOP on the GTS



Main features:

variable: 12h cumulated precip (18-06, 06-18 UTC);

period : from Dec 2002 to Jul 2009;

region: 43-50N, 2-18E **(MAP D-PHASE area);**

method: nearest grid point; no-weighted fcst;

obs: synop reports (about 470 stations/day);

fcst ranges: 6-18h, 18-30h, …, 102-114h, 114-126h;

thresholds: **1, 5, 10, 15,** *25, 50* **mm/12h**;

system: COSMO-LEPS;

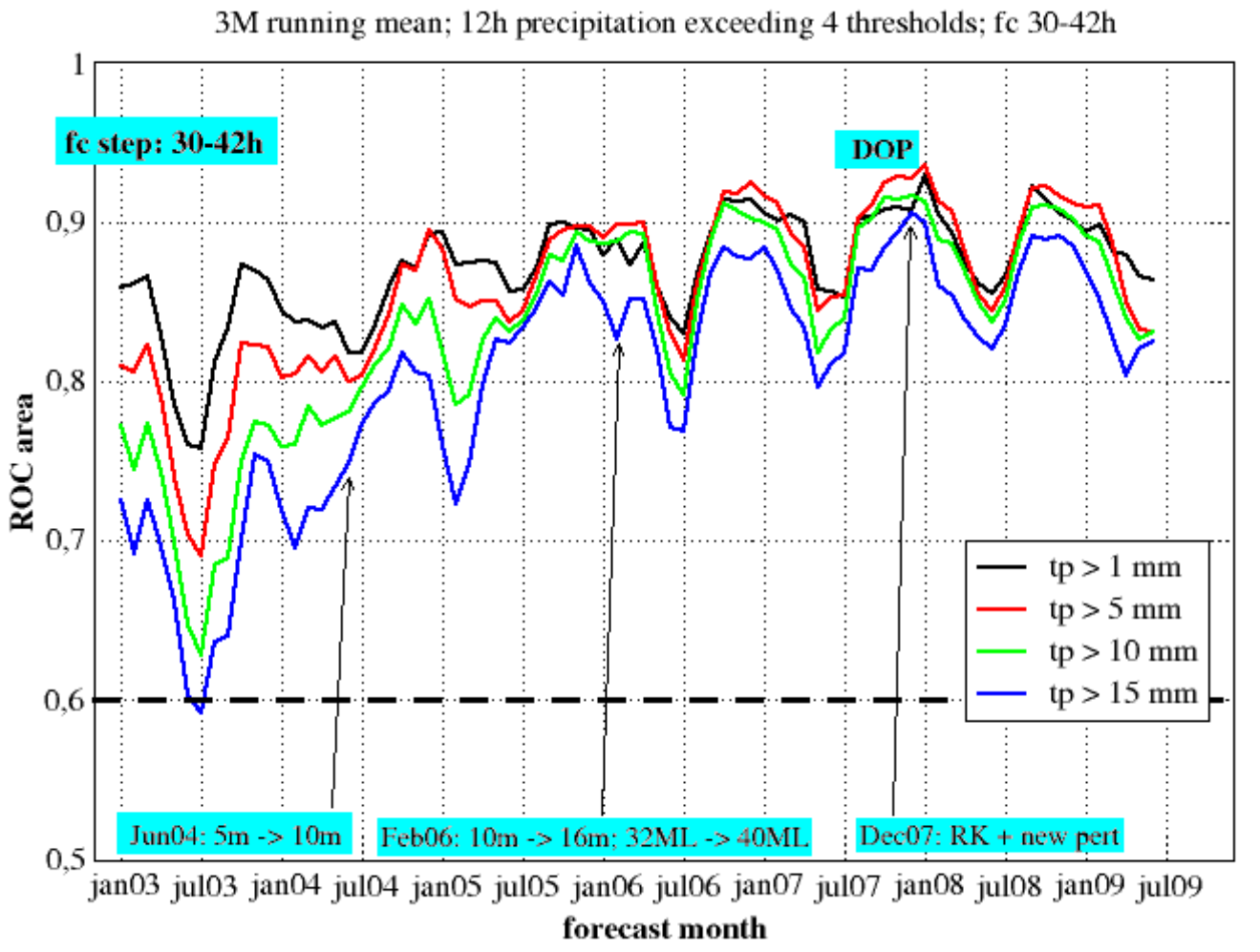
scores: **ROC area**, RPSS, Outliers, …

both monthly and seasonal scores were computed

ROC area: time series + seasonal scores

- Area under the curve in the HIT rate vs FAR diagram; the higher, the better …
- Performance of the system assessed as **time-series** and for the **last 5 summers** ("event" 10 mm/12h).

- Improvement of performance **detectable** for all thresholds along the years;
- Good performance during DOP 2007 and some positive impact after 2007 system upgrades.
- Scores in 2009 similar to those of last year (slight worsening for the highest threshold).



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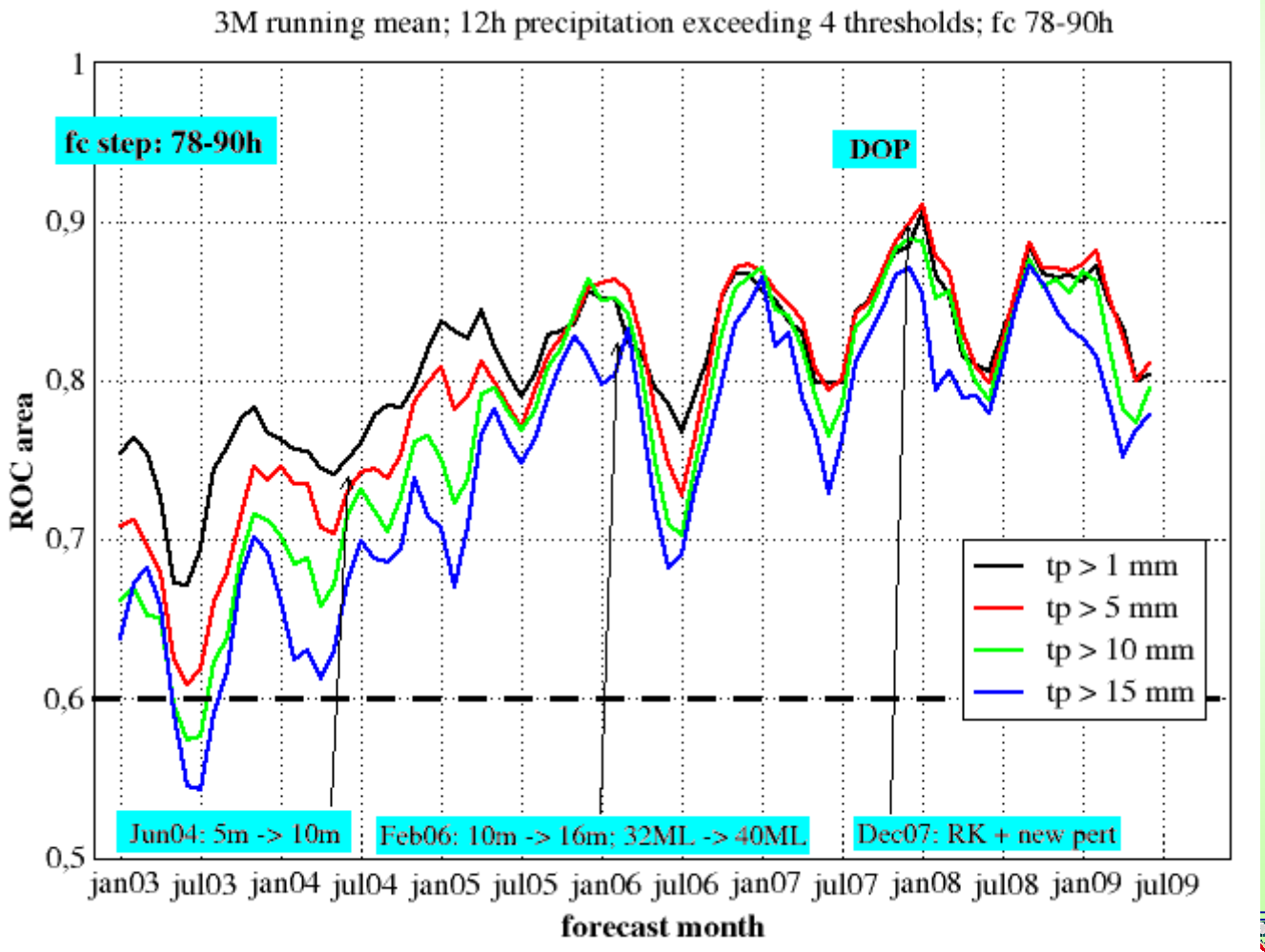

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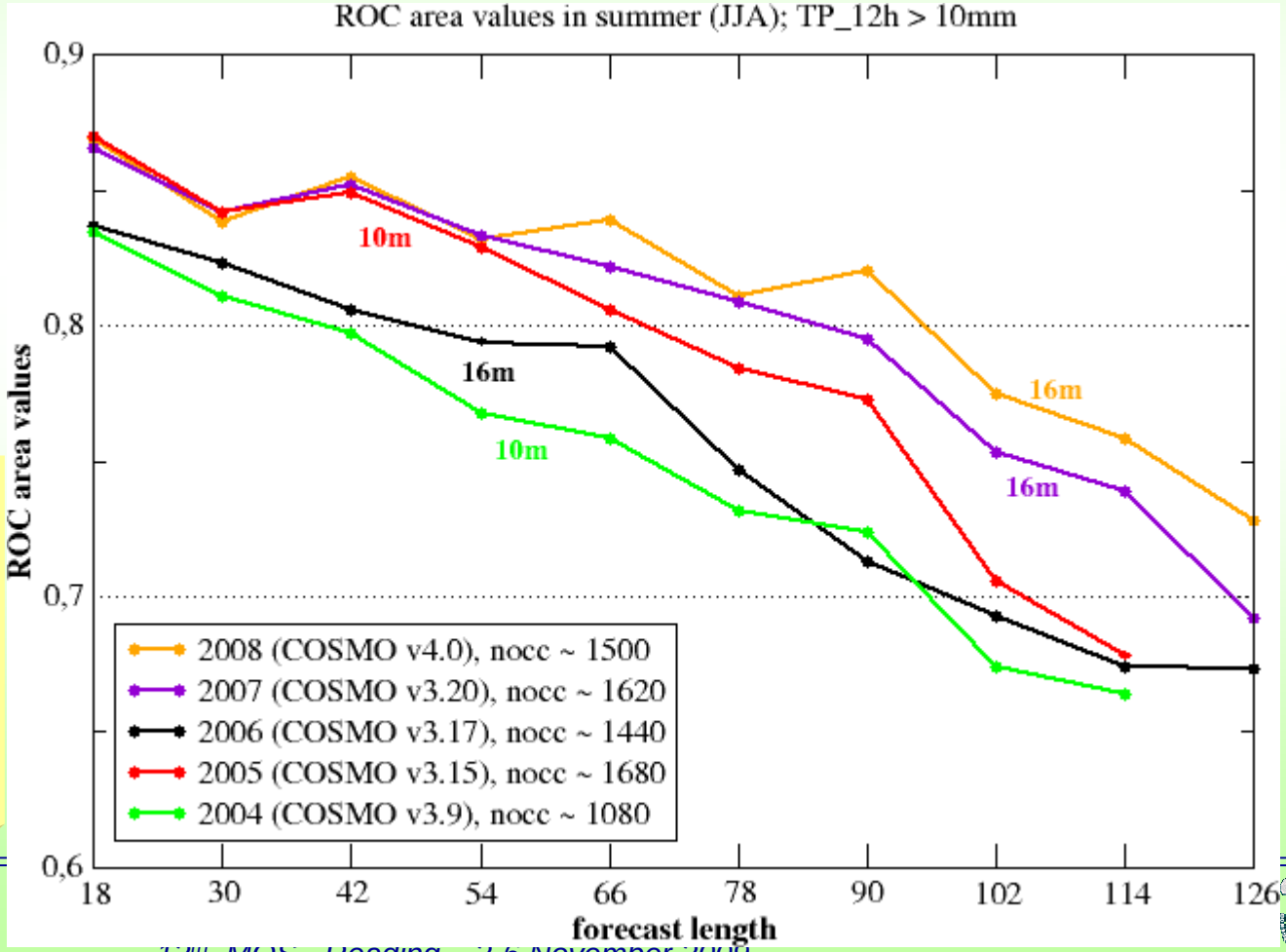
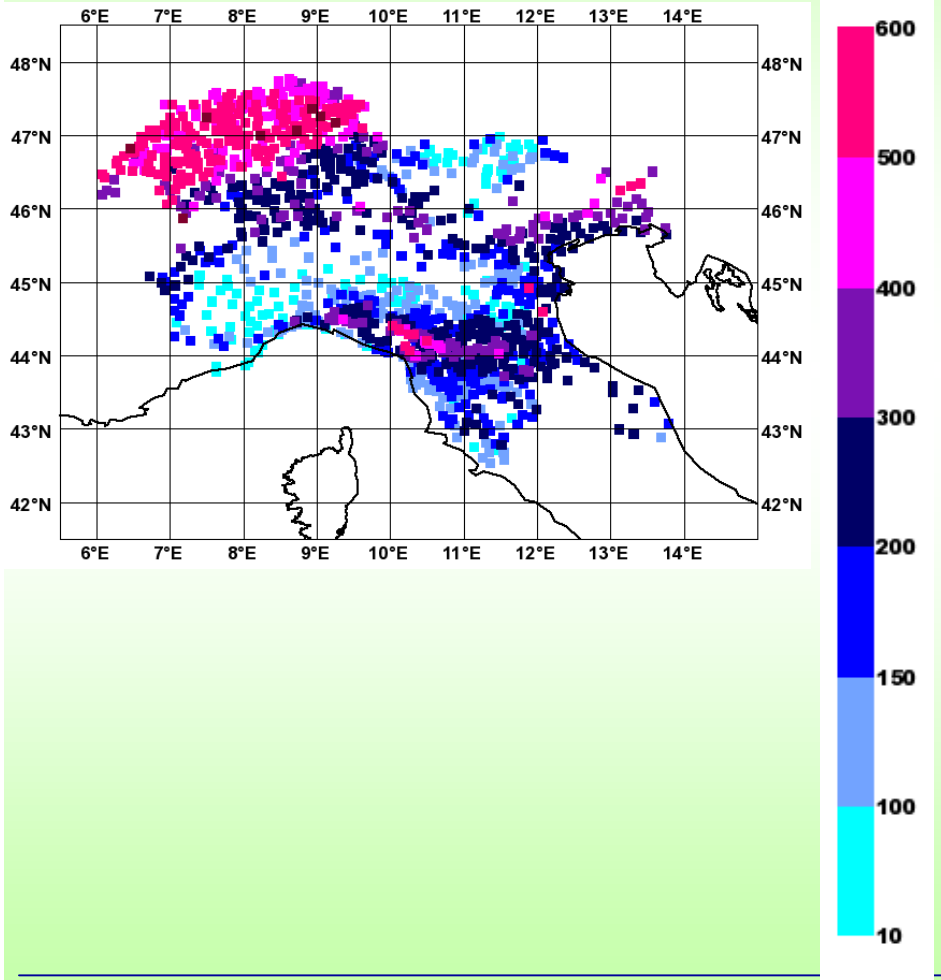


- For seasonal scores, need to account for the different statistics of each summer (JJA 2004 less rainy than the others).
- Best performance for JJA 2008, more evident for longer ranges.

Comparison of COSMO-LEPS and ECMWF EPS

- high-resolution network



Main features:

variable: 24h cumulated precip (06-06 UTC);

period: MAM 2009;

region: Switzerland, Northern Italy;

method: BOXES (1.0 x 1.0);

obs: COSMO network (1400 stations x day);

fcst ranges: 18-42h, 42-66h, 66-90h, 90-114h;

thresholds: **1, 10, 20, 30,** 50, 100 **mm/24h;**

systems:

- COSMO-LEPS (16m, 10 km, 40 ML)

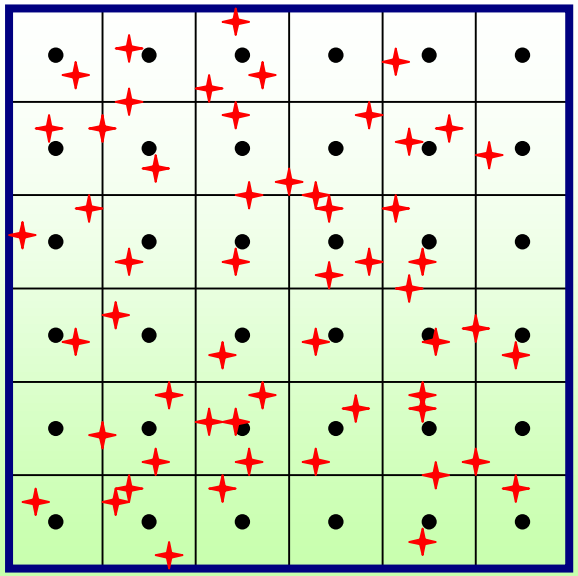
- full EPS (51m, 50 km, 62 ML)

Verification of the distributions

The verification has been made in terms of:

- **Average value**
- **Maximum value**
- 50th percentile (Median)
- 75th, 90th, 95th percentiles

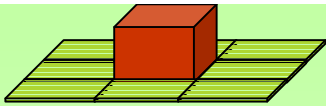
} in a box

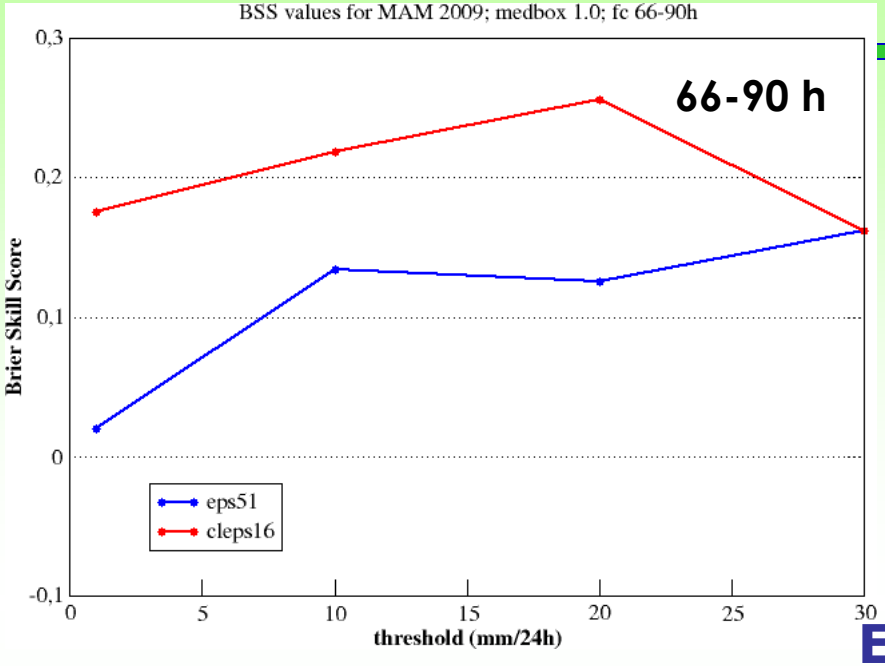


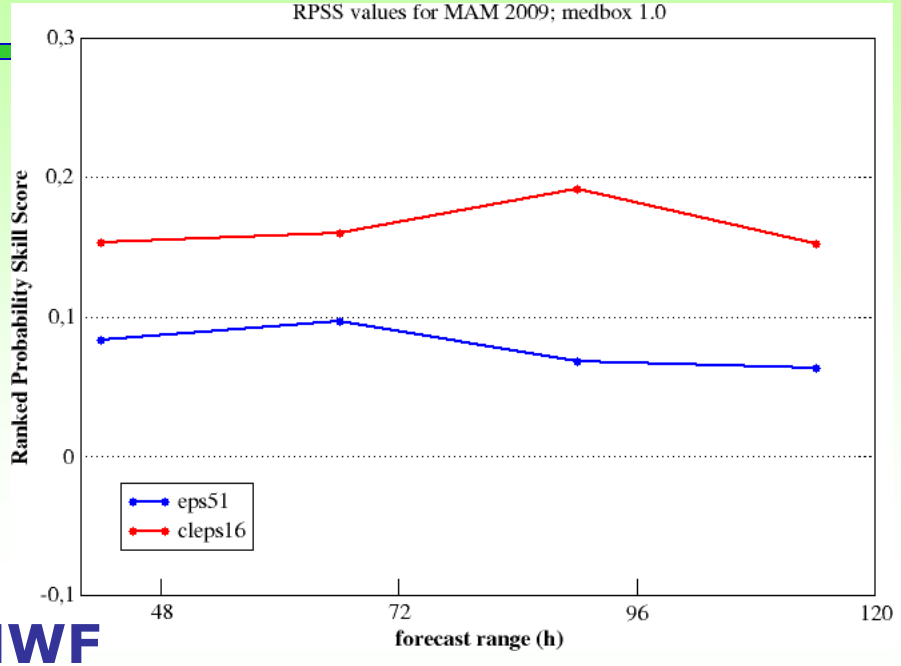
two measures of precipitation:

- the cumulative volume of water deployed over a specific region;
- the rainfall peaks occurring within the same region.

MAM09 **Average values** (boxes 1.0 x 1.0)

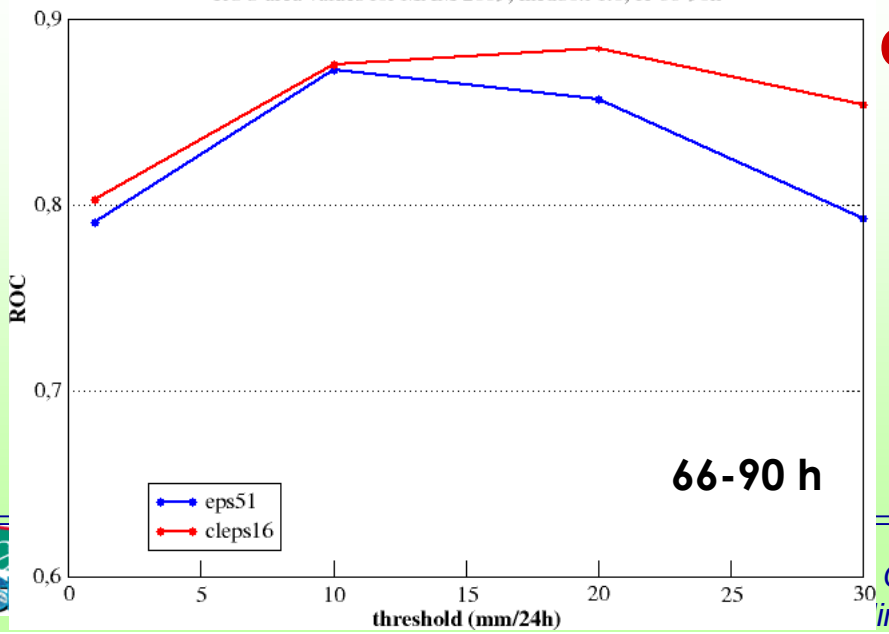


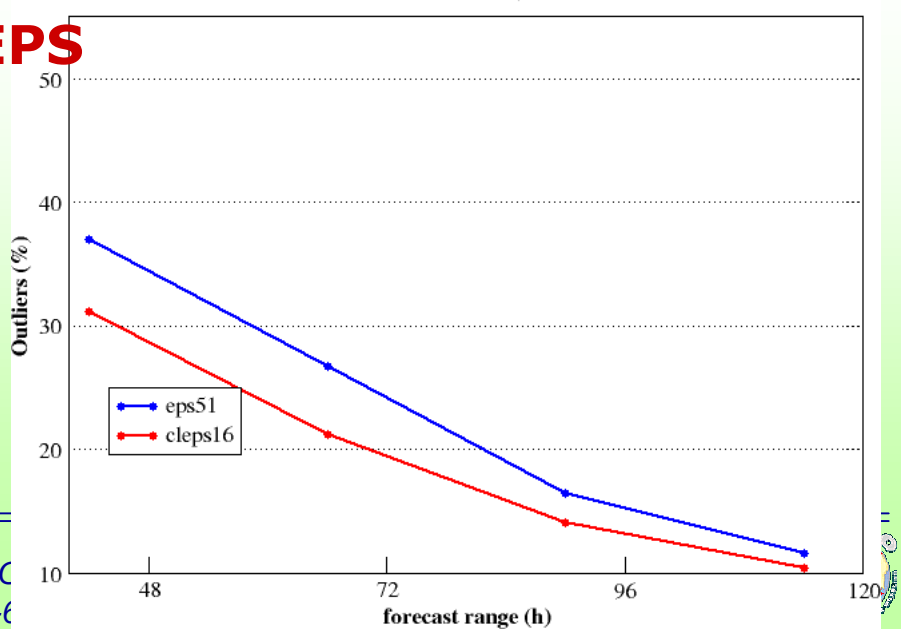




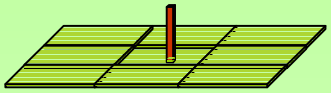
ECMWF

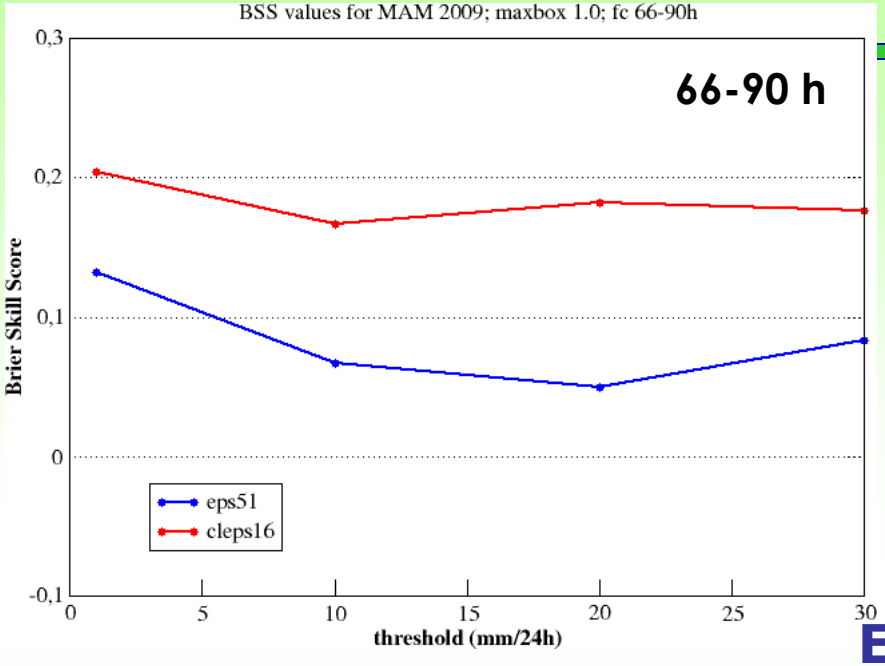
CLEPS

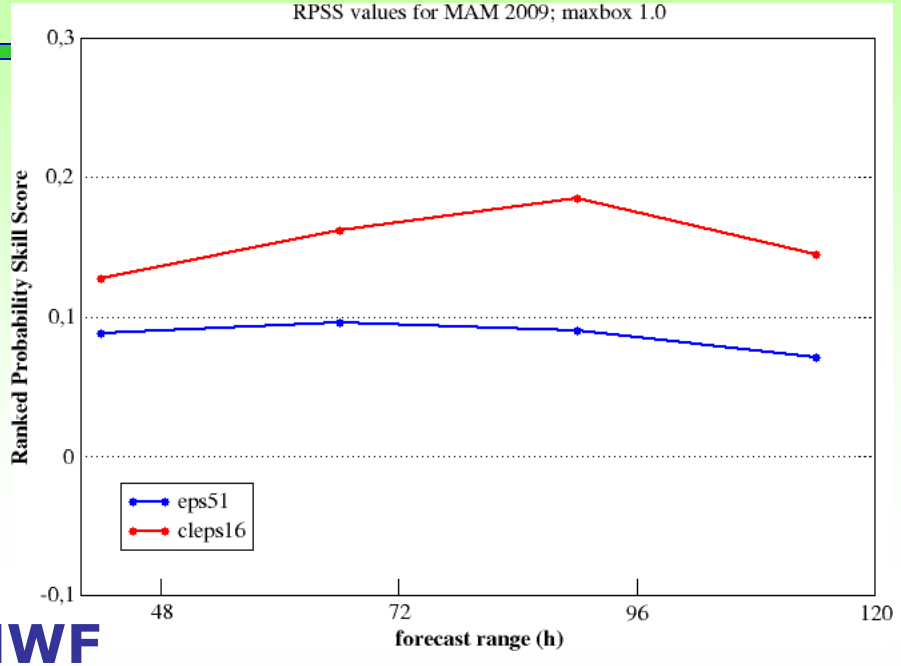




MAM09 **Maximum values** (boxes 1.0 x 1.0)

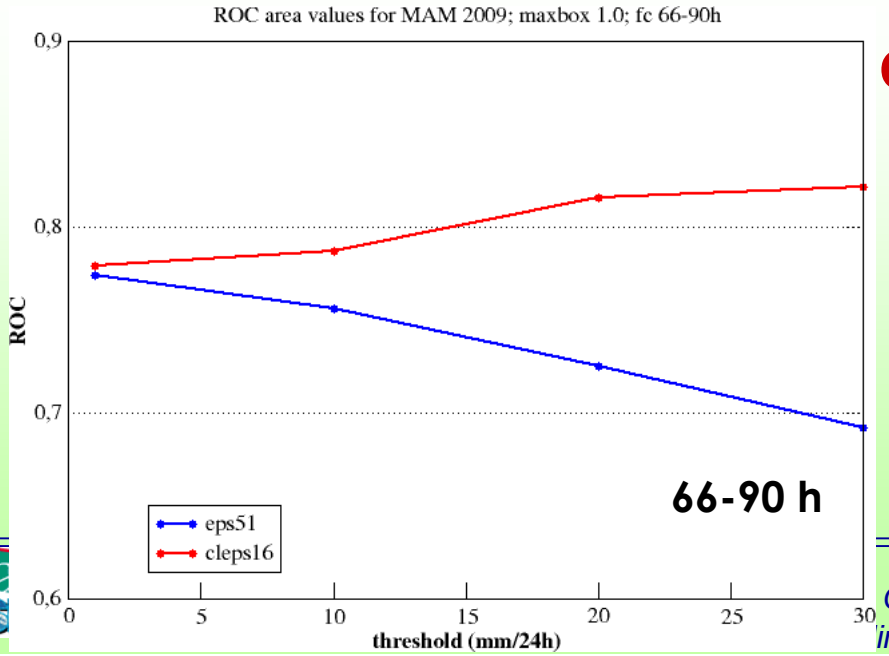


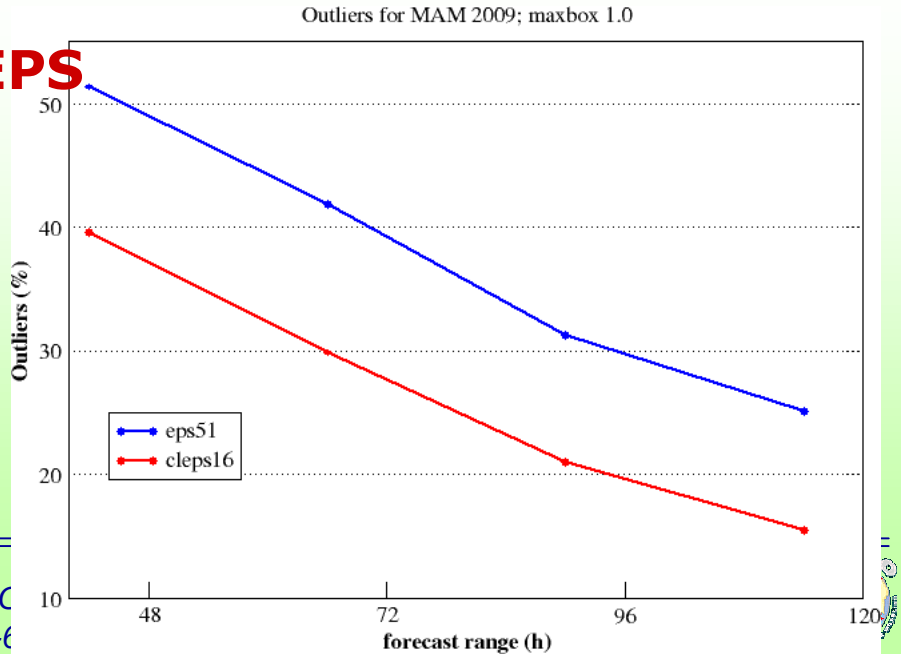




ECMWF

CLEPS



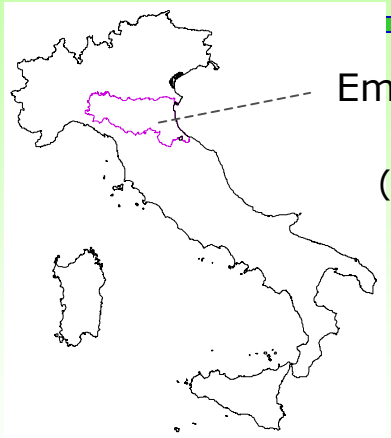


Calibration of COSMO-LEPS

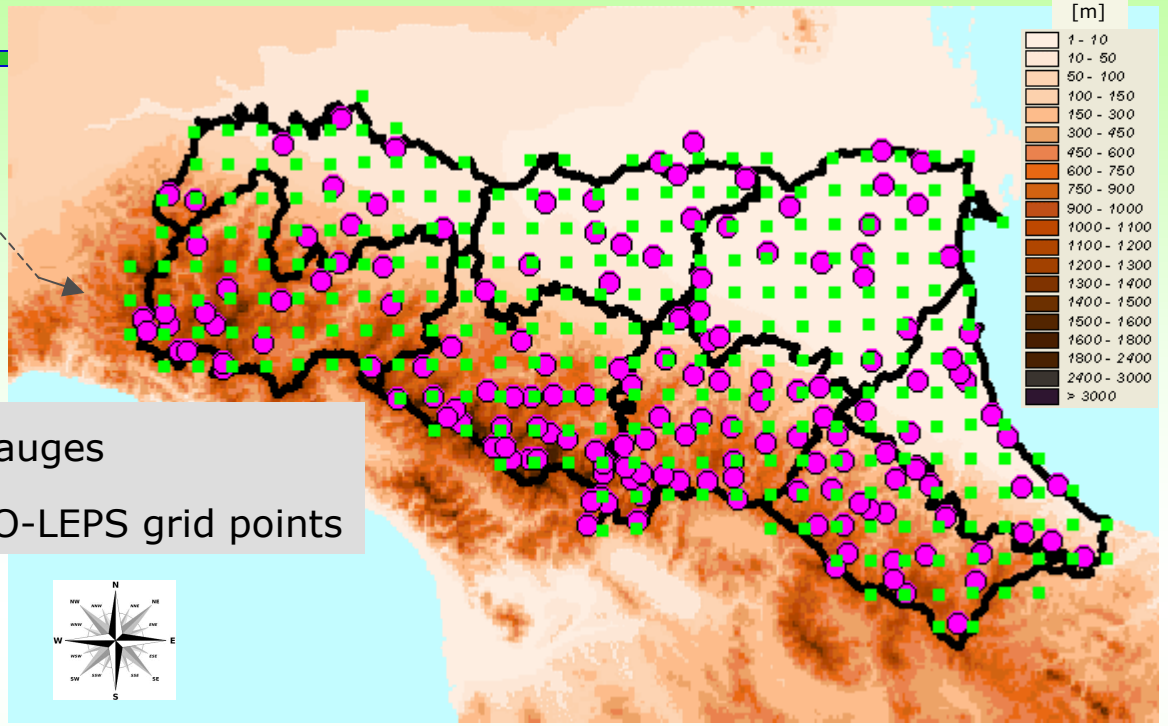
Why? To improve COSMO-LEPS quantitative precipitation forecasts (QPFs), so as to provide calibrated QPFs **to be** mainly **used as an input to hydrologic models.**

➔ need to develop and apply a calibration strategy to the ensemble output

Calibration strategy – data collection



Emilia-Romagna Region
(~22000 km^2)



158 rain-gauges

281 COSMO-LEPS grid points

- **Observations**
  - Emilia-Romagna Region
  - 24-h precipitation (08-08 UTC), 1970-2007
- **COSMO-LEPS reforecasts (performed by MeteoSwiss)**
  - 30 years: 1971-2000
  - 1 member, nested on 6-hourly ERA40 analyses, COSMO v4.0
  - 1 run every third day (+90h)
- **COSMO-LEPS operational QPFs**
  - 5 years: 2003-2007

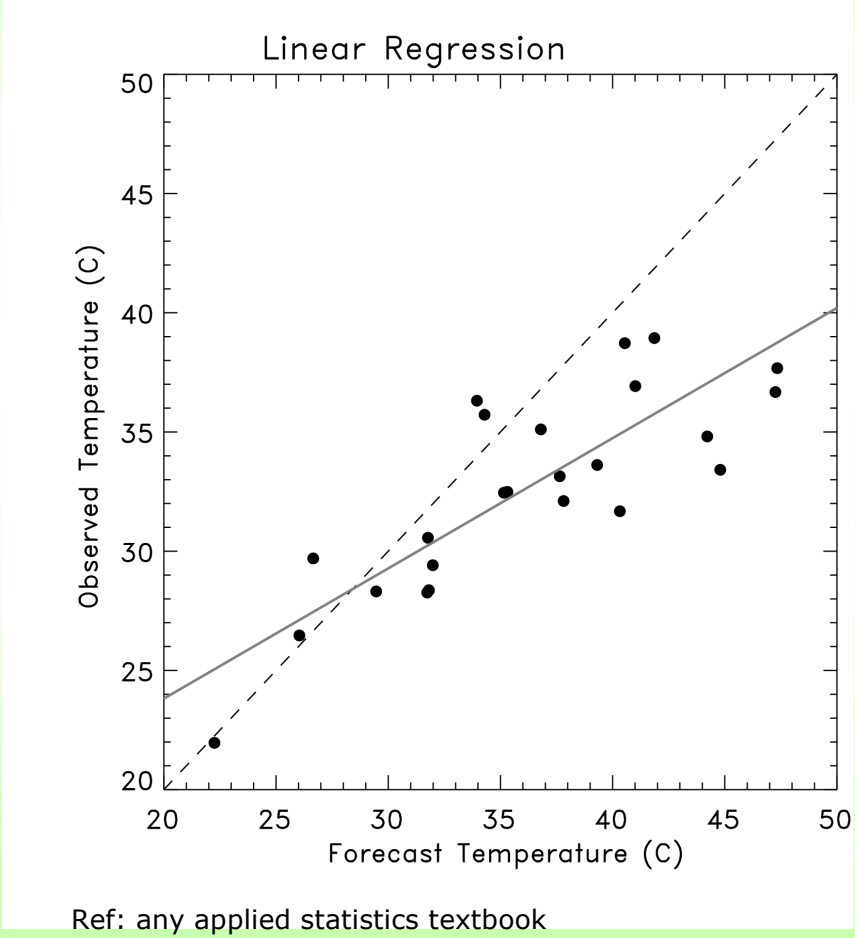
Calibration strategy – methodologies

- Choice of methodologies which enable a calibration of 24-h QPFs, not only of the probabilities of exceeding a threshold.

- Tested methods:
  - Cumulative Distribution Function (CDF) based corrections
  - **Linear Regression**
  - Analogues (based on the similarity of forecast precipitation fields)

Calibration strategy – methodologies

Linear Regression



Ref: any applied statistics textbook

For each model grid point:

x-axis: COSMO-LEPS reforecasts

y-axis: historical observations

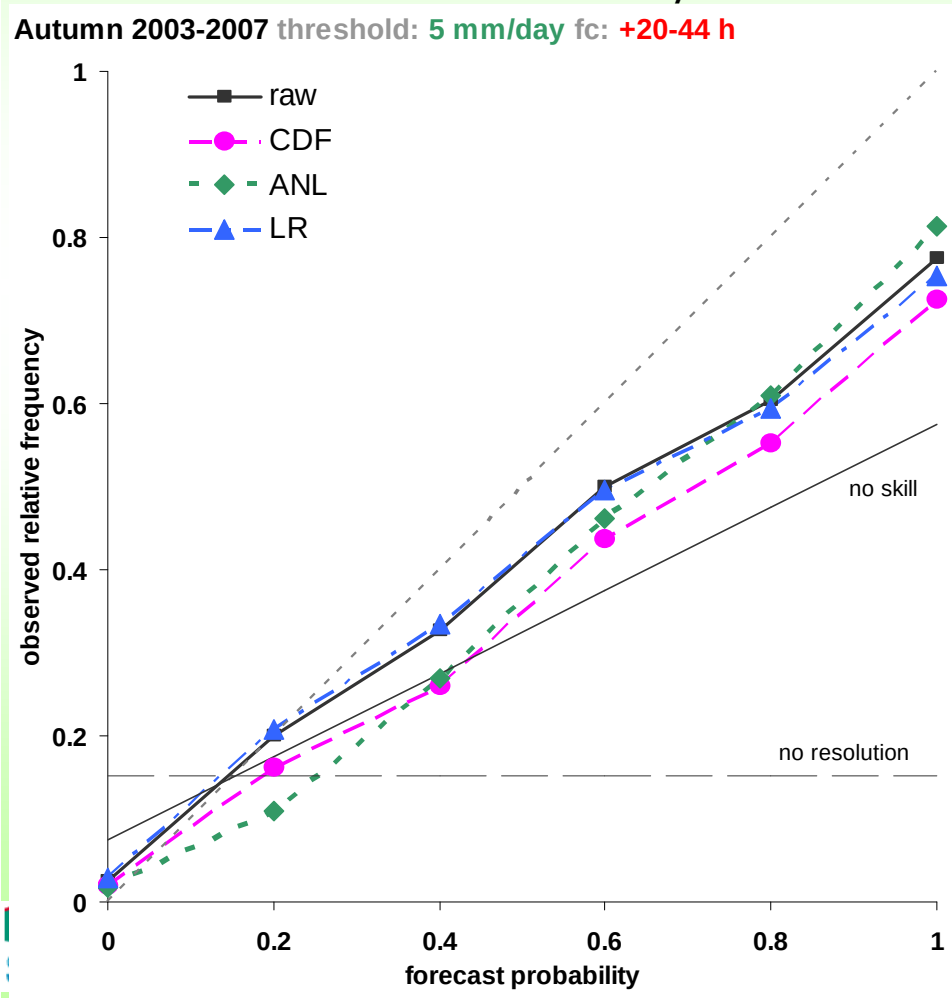
$$y_i = \beta_0 + \beta_1 x_i$$

Calibration strategy – first results

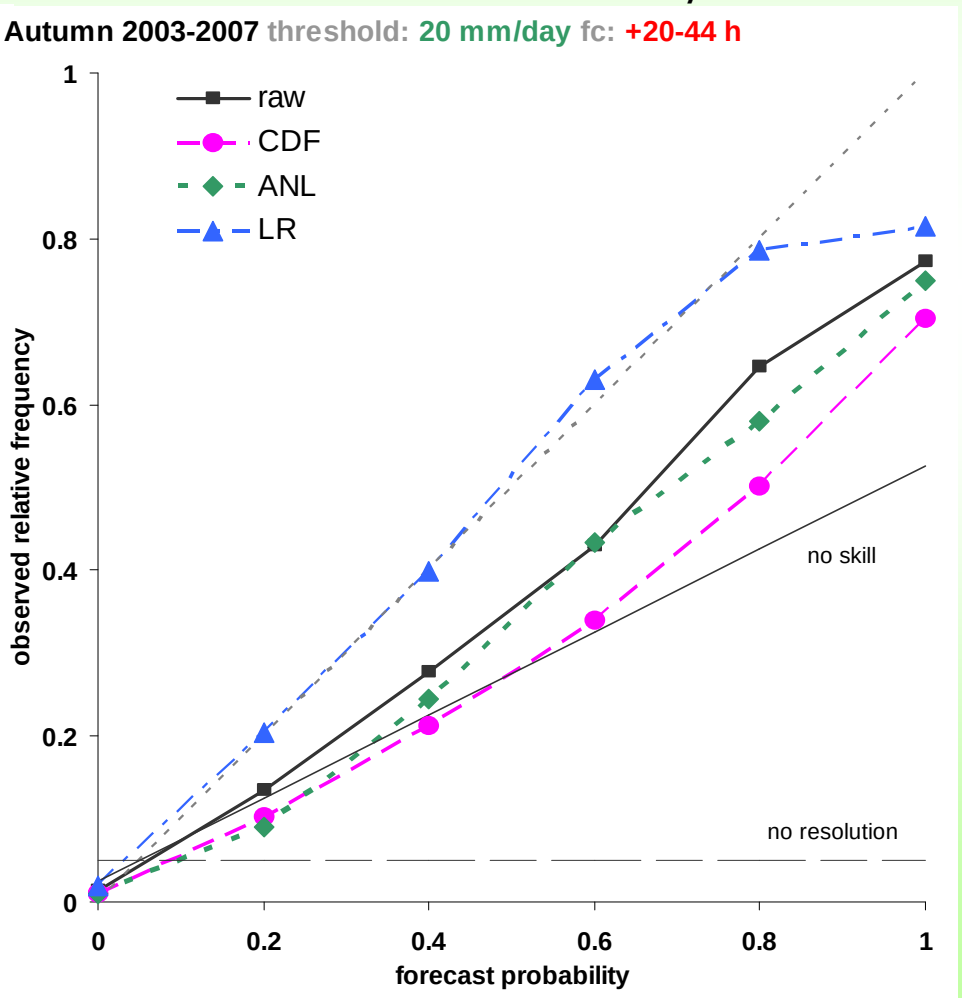
total area

Attributes Diagram
method comparison
season: autumns 2003-2007
(lead time: +20-44 h)

threshold: 5 mm/24 h



threshold: 20 mm/24 h

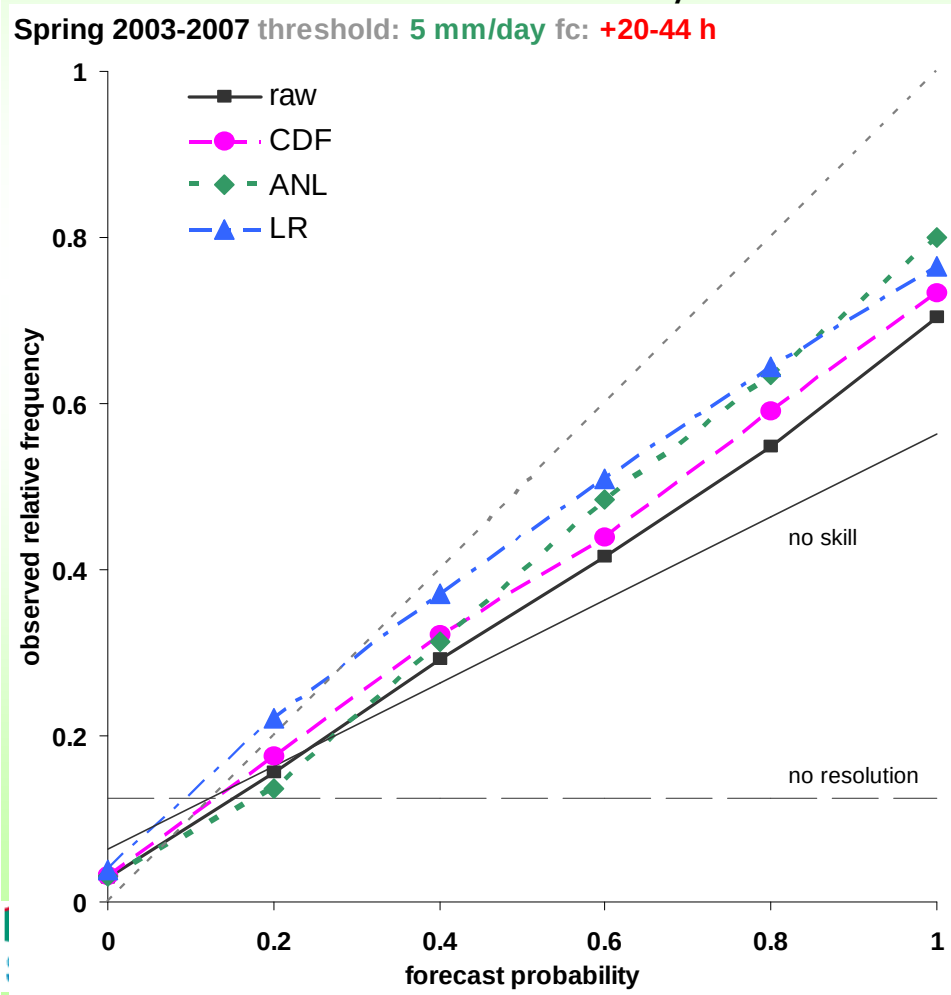


Calibration strategy – first results

total area

Attributes Diagram
method comparison
season: spring 2003-2007
(lead time: +20-44 h)

threshold: 5 mm/24 h



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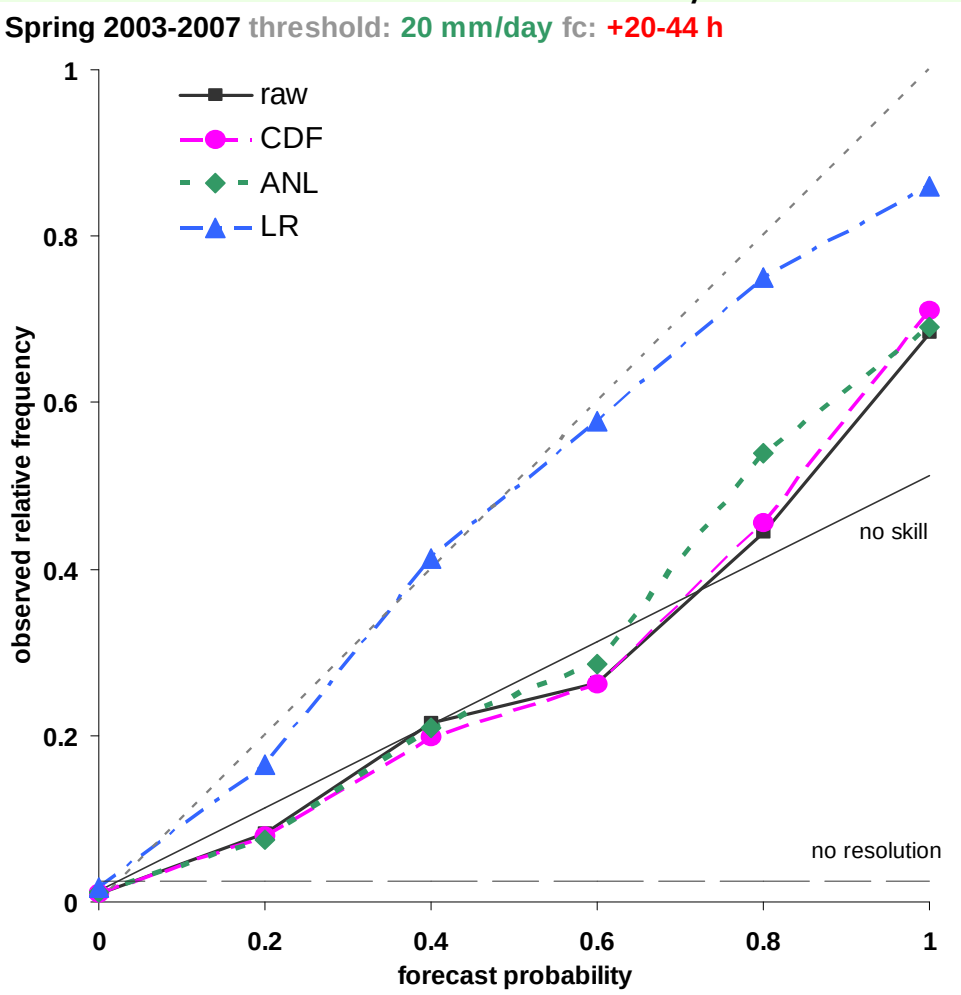


Present activity

1) Implementation of COSMO-LEPS at 7 km 

2) COSMO-LEPS for TIGGE-LAM 

Implementation of COSMO-LEPS at 7 km

Why? - to improve the forecast of near-surface parameters
- to keep the "resolution gap" vs ECMWF EPS

Present system

Δx = 10 km
Δz = 40 ML
Δt = 90 s
ngp = 306x258x40 = 3.157.920
fcst range = 132h
cost = 570 BU x run
elapsed time = 25 min/run
initial conditions: interpolated from EPS members

New system (COSMO-LEPS_7)

Δx = 7 km
Δz = 40 ML
Δt = 60 s
ngp = 511x415x40 = 8.482.600
fcst range = 132h
cost = **2100** BU x run
elapsed time = 48 min/run
initial conditions: interpolated from EPS members merged with surface and soil-layer fields produced at DWD for COSMO-EU

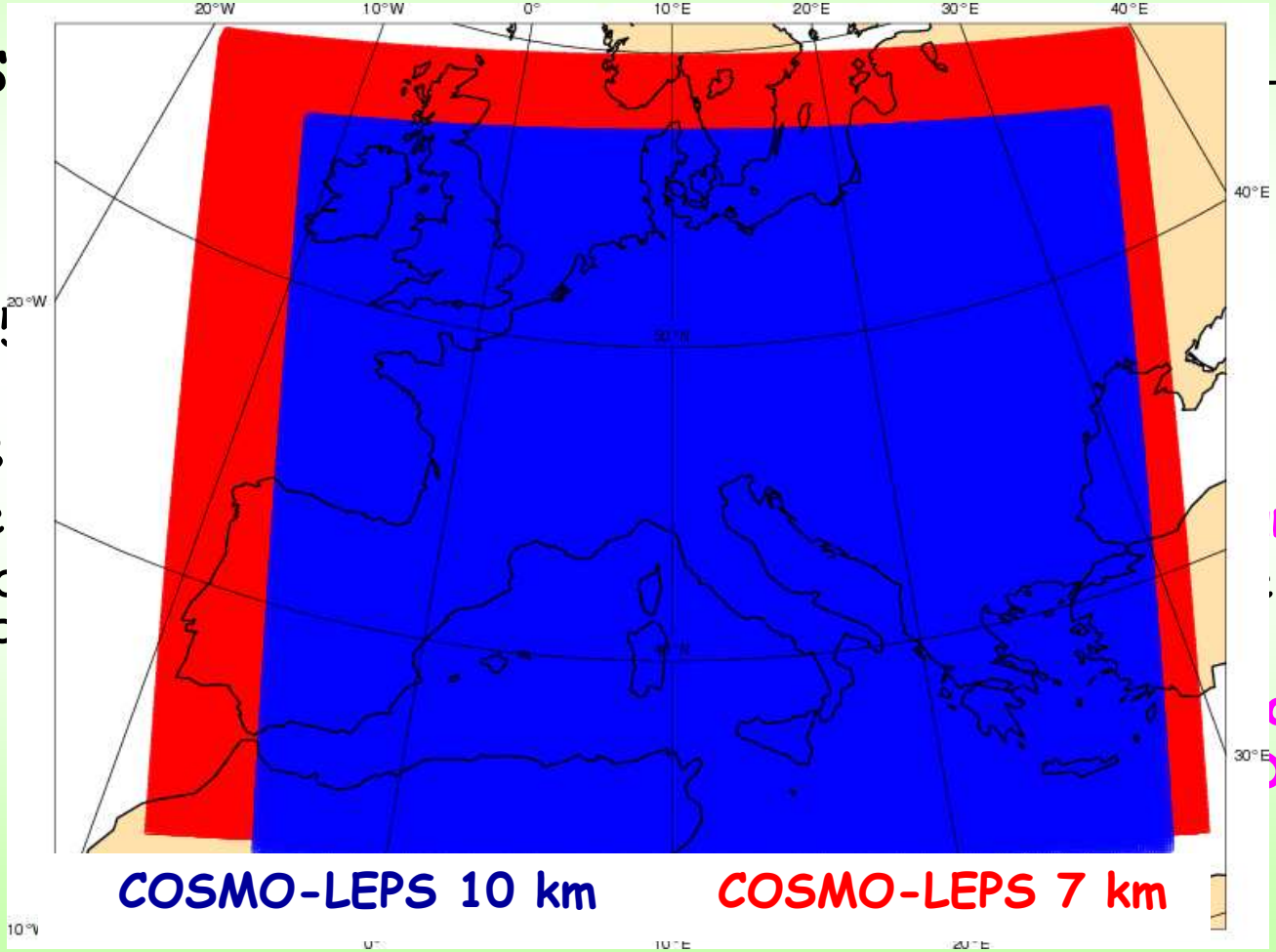
COSMO-LEPS_7 running in e-suite since 24 May 09 (no merging yet)

Implementation of COSMO-LEPS at 7 km

Why? - to improve the forecast of near-surface parameters
- to keep the "resolution gap" vs ECMWF EPS

Pres -LEPS_7)

Δx = 10 km
Δz = 40 ML
Δt = 90 s
ngp = 306x2!
fcst range =
cost = 570 B .600
elapsed time
initial conc n
from EF rpolated
merged
oil-layer
WD for



COSMO-LEPS_7 running in e-suite since 24 May 09 (no merging yet)

COSMO-LEPS_10 (oper) **vs COSMO-LEPS_7** (exp)

- Observations: SYNOP reports over either MAP D-PHASE region (450 reports/day) or the FULL-DOMAIN (1400 reports/day).
- Method: nearest grid point; no-weighted fcst.

• Deterministic verification of T2M ensemble mean

- Variable: 2-metre temperature.
- Period: 3 months, from 24/5 to 24/8/2009.
- Forecast ranges: fc+6h, fc+12h, …, fc+132h.
- Scores: root-mean-square error, bias.

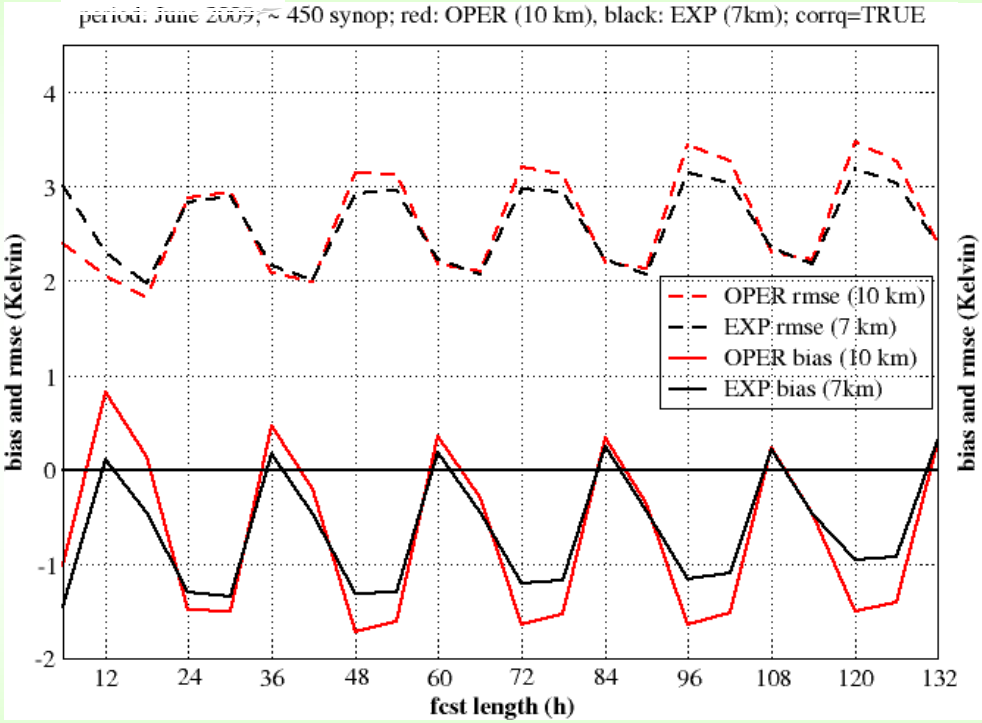
• Probabilistic verification of 12-hour cumulated precipitation

- Variable:12h cumulated precipitation (18-06, 06-18 UTC).
- Period: 2 months, June and July 2009.
- Forecast ranges: fc 6-18h, fc 18-30h, …, fc 114-126h.
- Scores: ROC area, BSS, RPSS, Outliers.
- Thresholds: 1, 5, 10, 15, 25, 50 mm/12h.

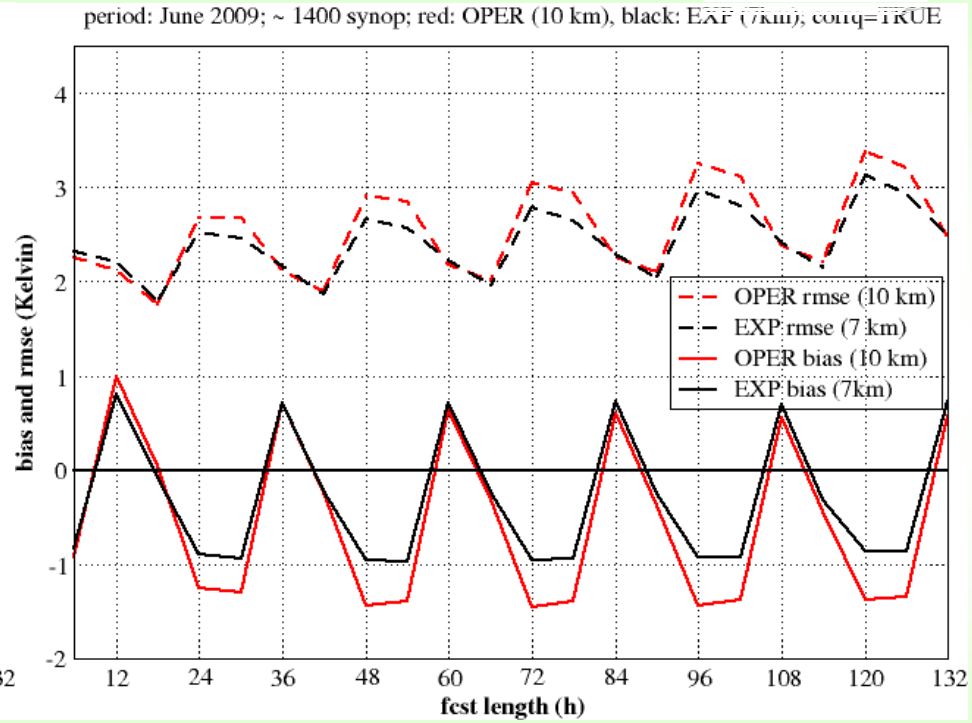
Bias and rmse of T2M Ensemble Mean

- Consider bias and rmse **for June 2009**.
- T2m forecasts are corrected with height.

MAPDOM



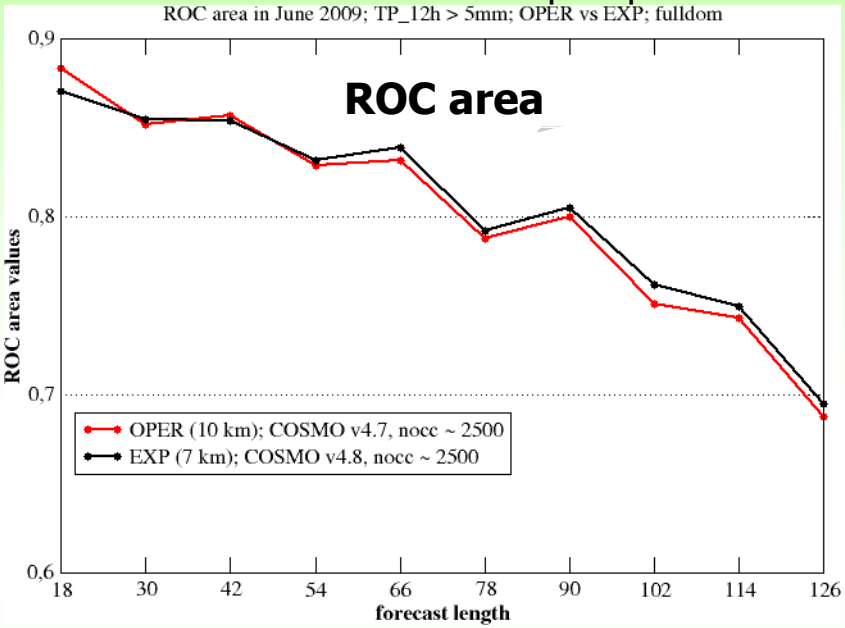
FULLDOM

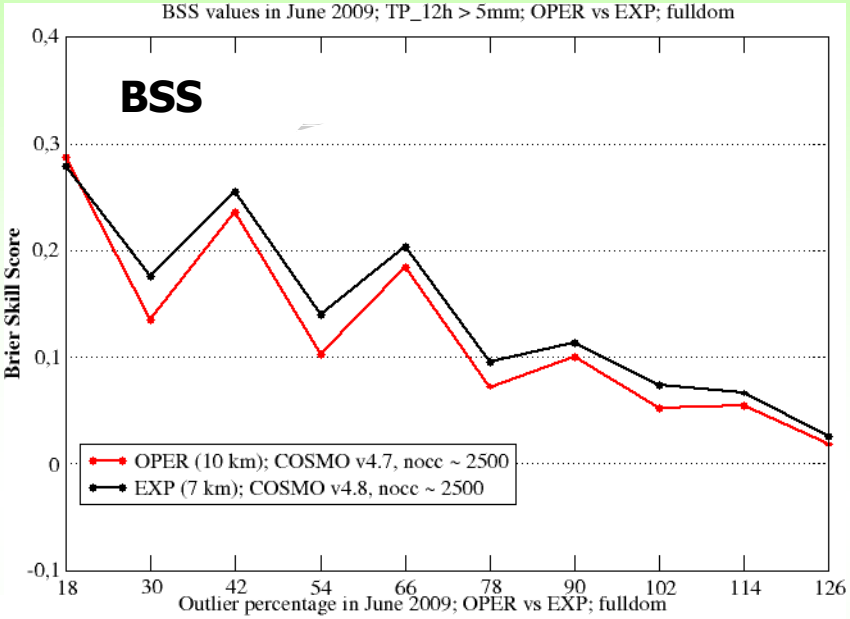


- **Bias closer to zero and lower rmse for the 7-km suite.**
- **Improvement** is not "massive", but **detectable** for all forecast ranges, especially for **day-time** verification.
- For both models, lower rmse over the FULL domain in comparison with the MAP D-PHASE domain.
- The signal is stable (similar scores for 1-month or 3-month verification).

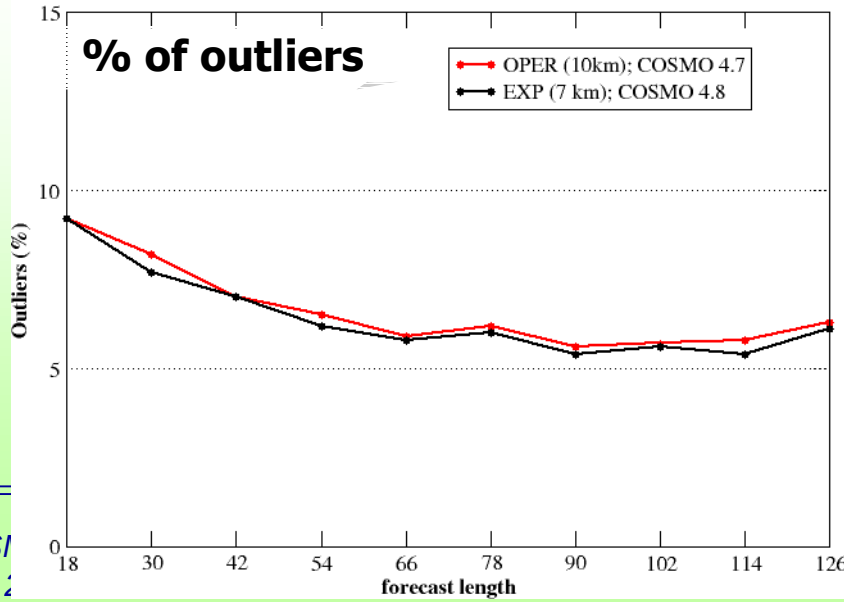
ROC area, BSS, OUTL for 12-hour tp (FULLDOM)

- Consider the event "5 mm of precipitation in 12 hours" for ROC area and BSS **in June 2009.**





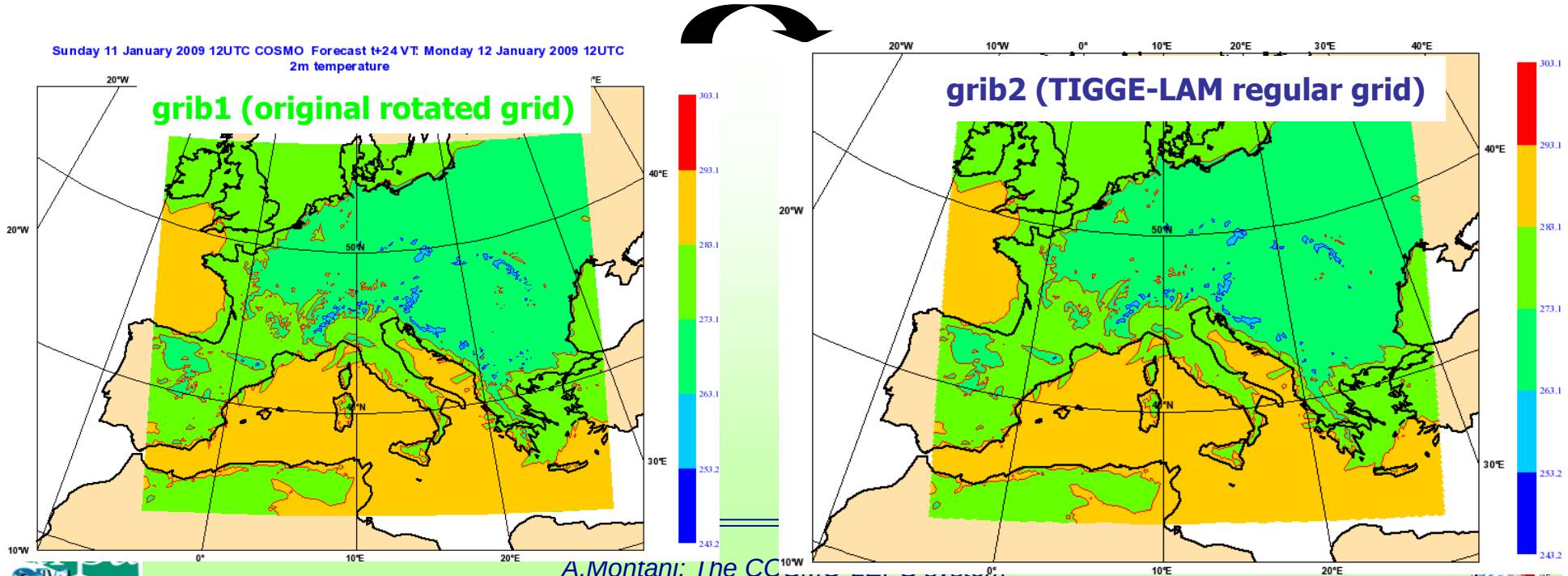
- Slightly better results for the 7-km suite, but **the gap is very small.**
- Percentage of outliers almost not reduced.
- The improvement is detectable for all forecast ranges.
- Need to consider also rainy seasons.



COSMO-LEPS for TIGGE-LAM

Products:

- "high-priority" parameters (tp, t2m, td2m, u10, v10, gust10, mslp, *orog*, *lsm*) operationally generated for each ensemble member from fc+0h to fc+132h every 3h;
- produced, in GRIB2 format, over a regular lat/lon grid (0.1x0.1);
- already archived at ARPA-SIMC; **soon** archived at ECMWF.



Main results

Time-series verification scores cannot disentangle improvements related to COSMO-LEPS upgrades from those due to better EPS boundaries; nevertheless, positive trends can be identified:

- increase in ROC area scores and reduction in outliers percentages;
- positive impact of increasing the population from 5 to 10 members (June 2004);
- some deficiencies in the skill of the system were identified after the system upgrades occurred on February 2006 (from 10 to 16 members; from32 to 40 model levels);
- system upgrades of December 2007 brought small but positive impact.

High-res verification shows better scores of COSMO-LEPS with respect to EPS in forecasting both average and maximum precipitation values within boxes.

As for calibration,

- both ensemble skill and calibration impact are quite variable, depending on the season and the geographical area;
- Linear Regression improves the ensemble reliability especially for higher thresholds;
- smaller (greater) impact of calibration in autumn (spring).

Future plans

- **COSMO-LEPS_7km** (operational on 1 December):
  - use the soil moisture analysis fields provided by DWD;
  - tune old perturbations and introduce new ones;
- **COSMO-LEPS for TIGGE-LAM**:
  - implement coding, post-processing and archiving of COSMO-LEPS output files in GRIB2 format;
  - develop "hybrid" clustering mixing ECMWF EPS and UKMO MOGREPS.
- Support calibration and verification.
- Carry on collaboration within research project (e.g. SAFEWIND).
- Towards the end of 2010, start to think about
  - COSMO-LEPS_2.8km
  - COSMO-LEPS with 20 members

Thank you for the attention!