Five years of limited-area ensemble activities

at ARPA-SIM:

the COSMO-LEPS system

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Outline

- Introduction
- Methodology of COSMO-LEPS
- Verification results:
  - SYNOP on the GTS
  - high-resolution network
- Future plans

COSMO-LEPS (developed at ARPA-SIM)

- What is it?

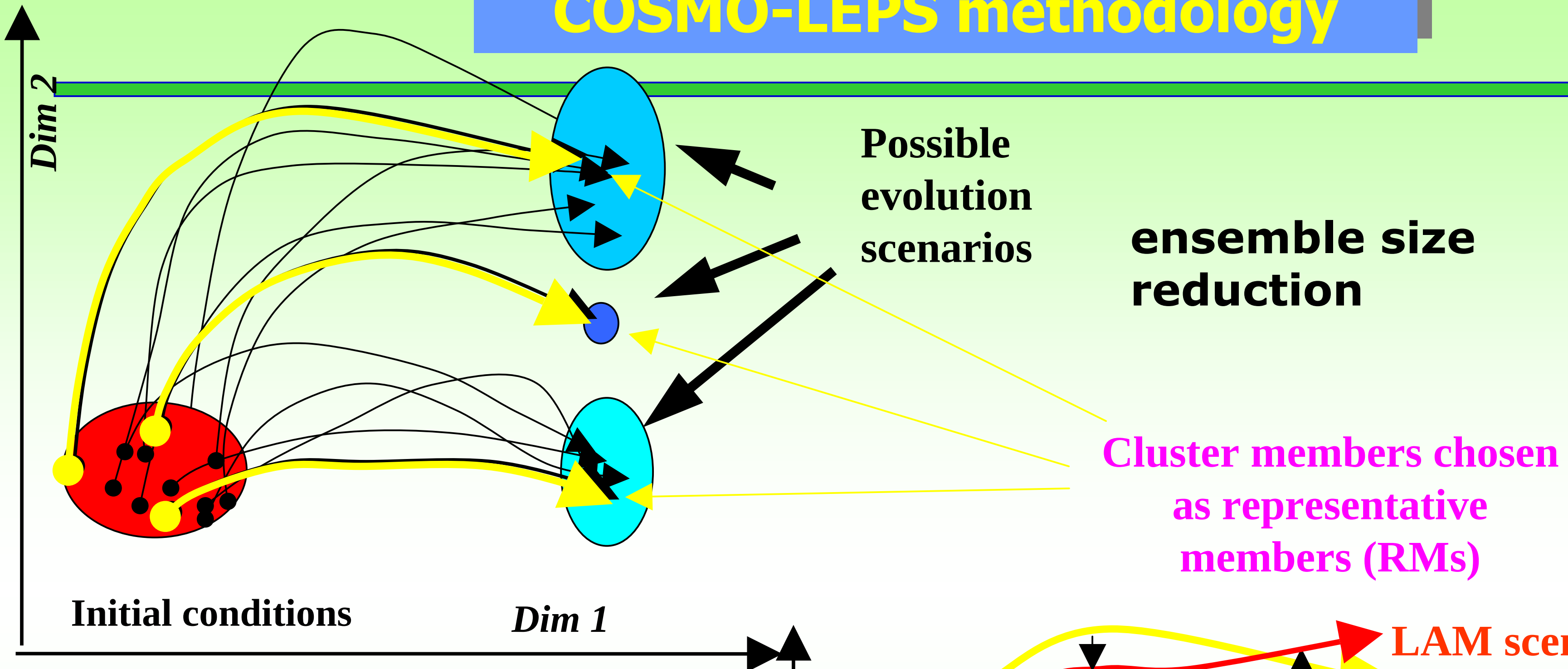
It is a **L**imited-area **E**nsemble **P**rediction **S**ystem (**LEPS**), based on COSMO-model and implemented within ***COSMO*** (***CO****nsortium for* ***S****mall-scale* ***MO****delling*, which includes Germany, Greece, Italy, Poland, Romania, Switzerland).

- 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 **severe** and **localised** weather events (heavy rainfall, strong winds, temperature anomalies, snowfall, …)

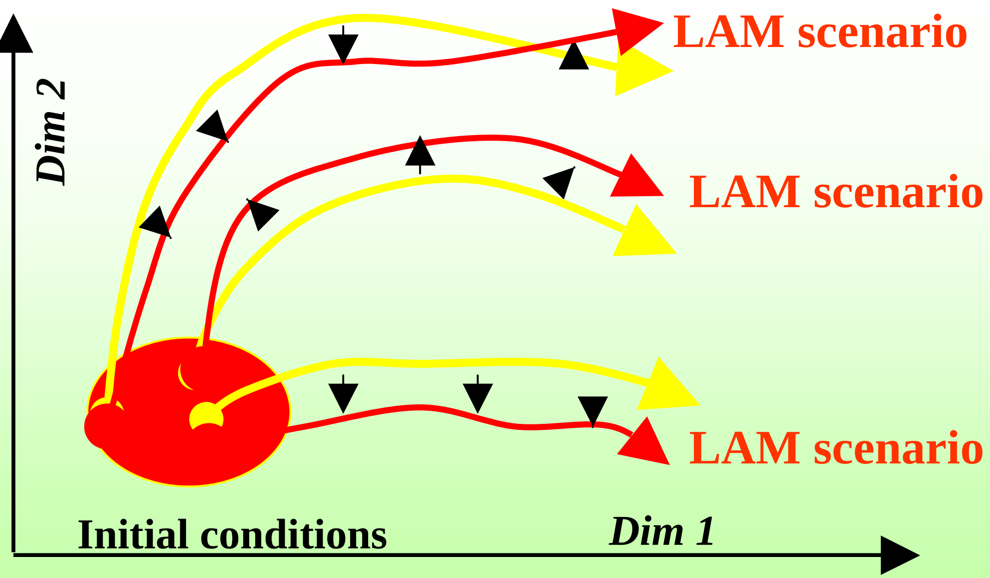
generation of COSMO-LEPS to improve the Late-Short (48hr) to Early-Medium (132hr) range forecast of severe weather events.

COSMO-LEPS methodology

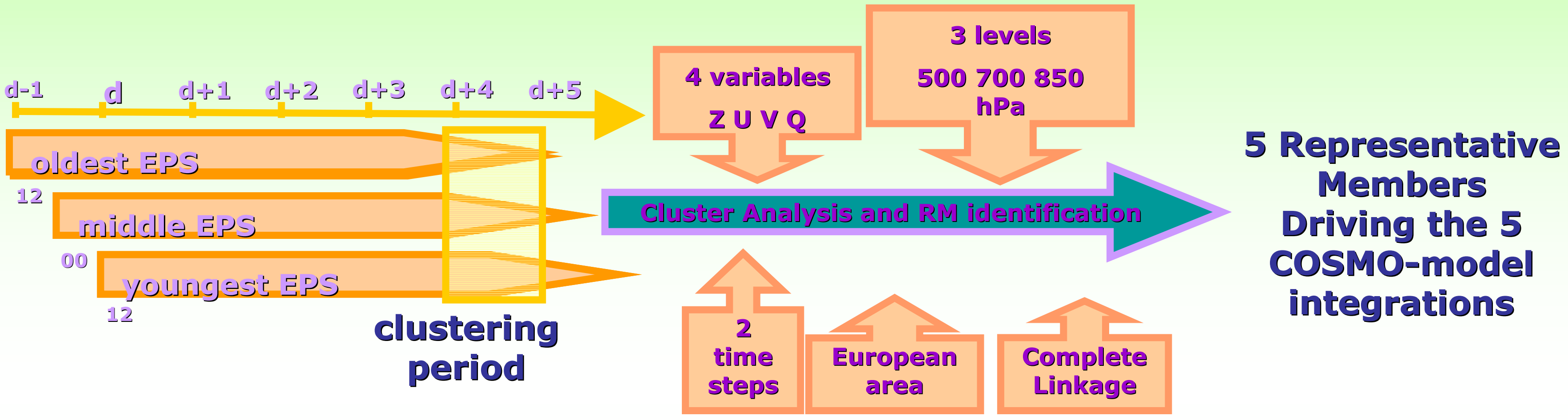


ensemble size reduction

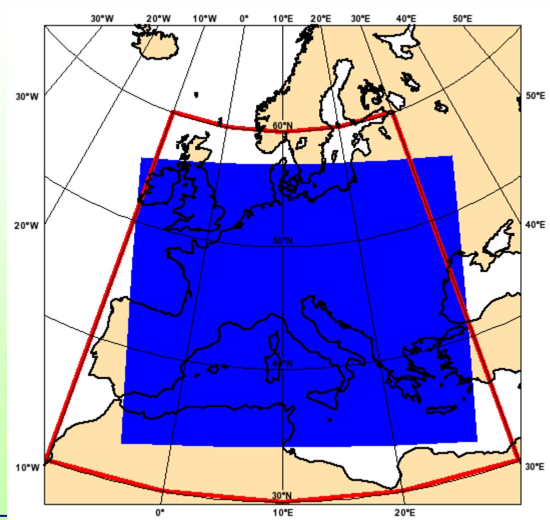
LAM integrations driven by RMs



The COSMO-LEPS suite @ ECMWF
November 2002 – May 2004



COSMO-LEPS clustering area



COSMO-LEPS Integration Domain

The COSMO-LEPS suite @ ECMWF
June 2004 – January 2006

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

middle EPS

00

youngest EPS

12

clustering period

4 variables

Z U V Q

3 levels

500 700 850 hPa

Cluster Analysis and RM identification

2 time steps

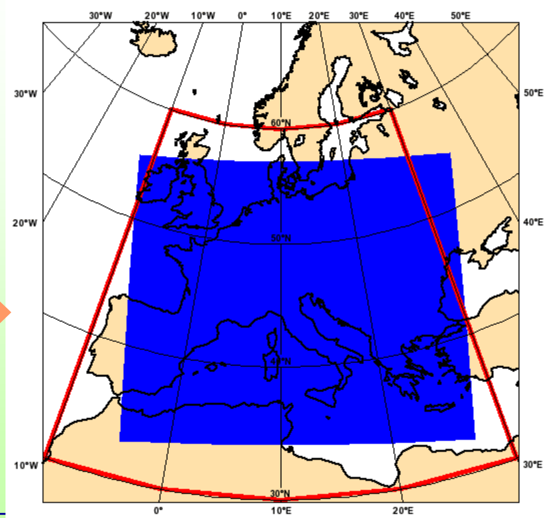
European area

Complete Linkage

10 Representative Members driving the 10 COSMO-model integrations

employing either Tiedtke or Kain-Fristch scheme randomly choosen

COSMO-LEPS clustering area

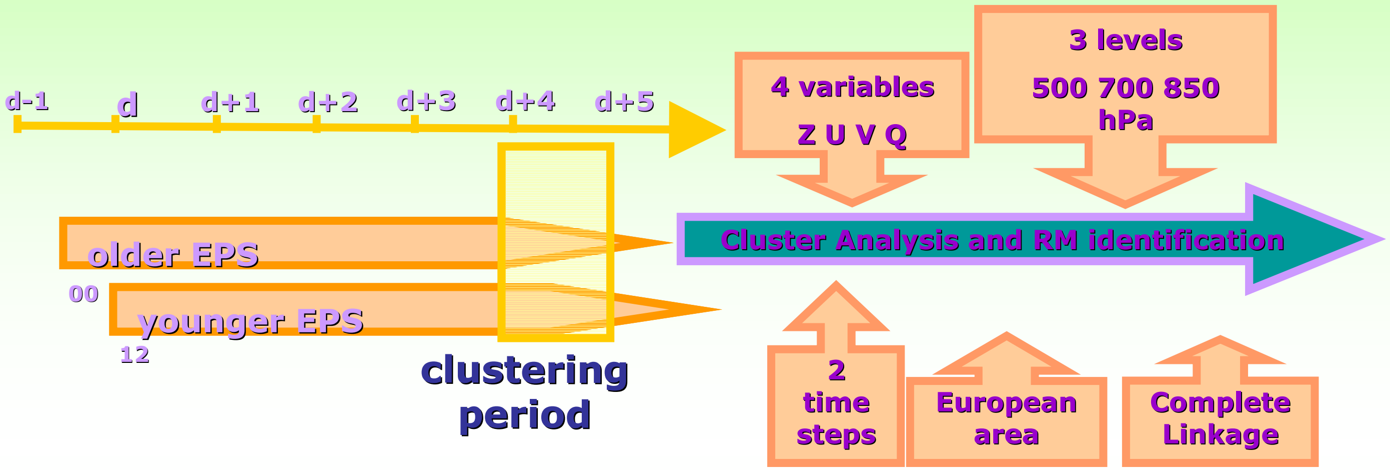


COSMO-LEPS Integration Domain

- Suite running in real time at ECMWF managed by ARPA-SIM;
- $\Delta x \sim 10$ km
- Fc length: 120h

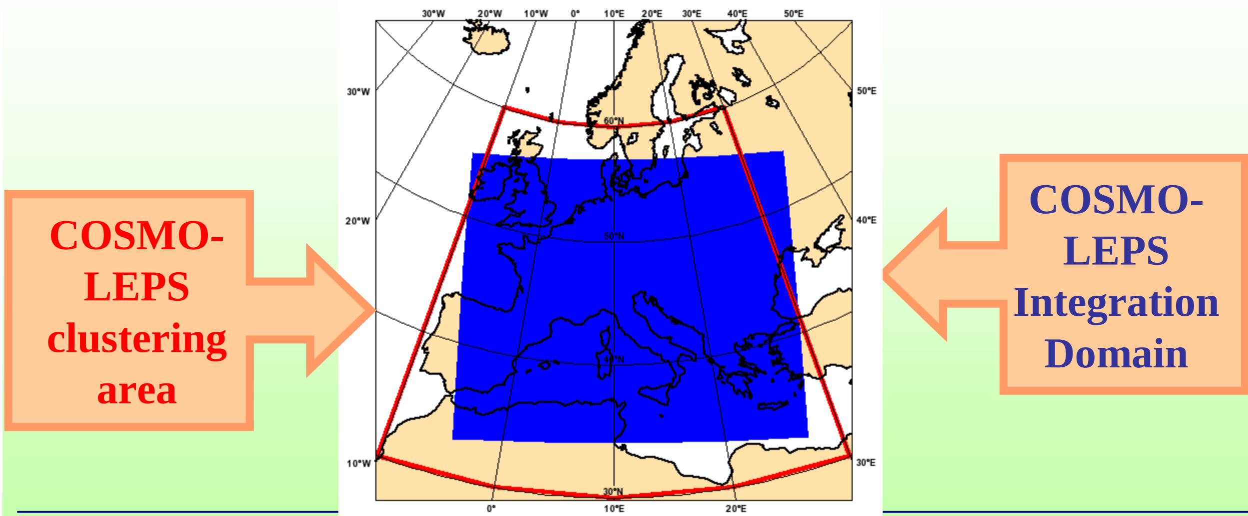
arpa SIM

COSMO-LEPS suite @ ECMWF
since February 2006



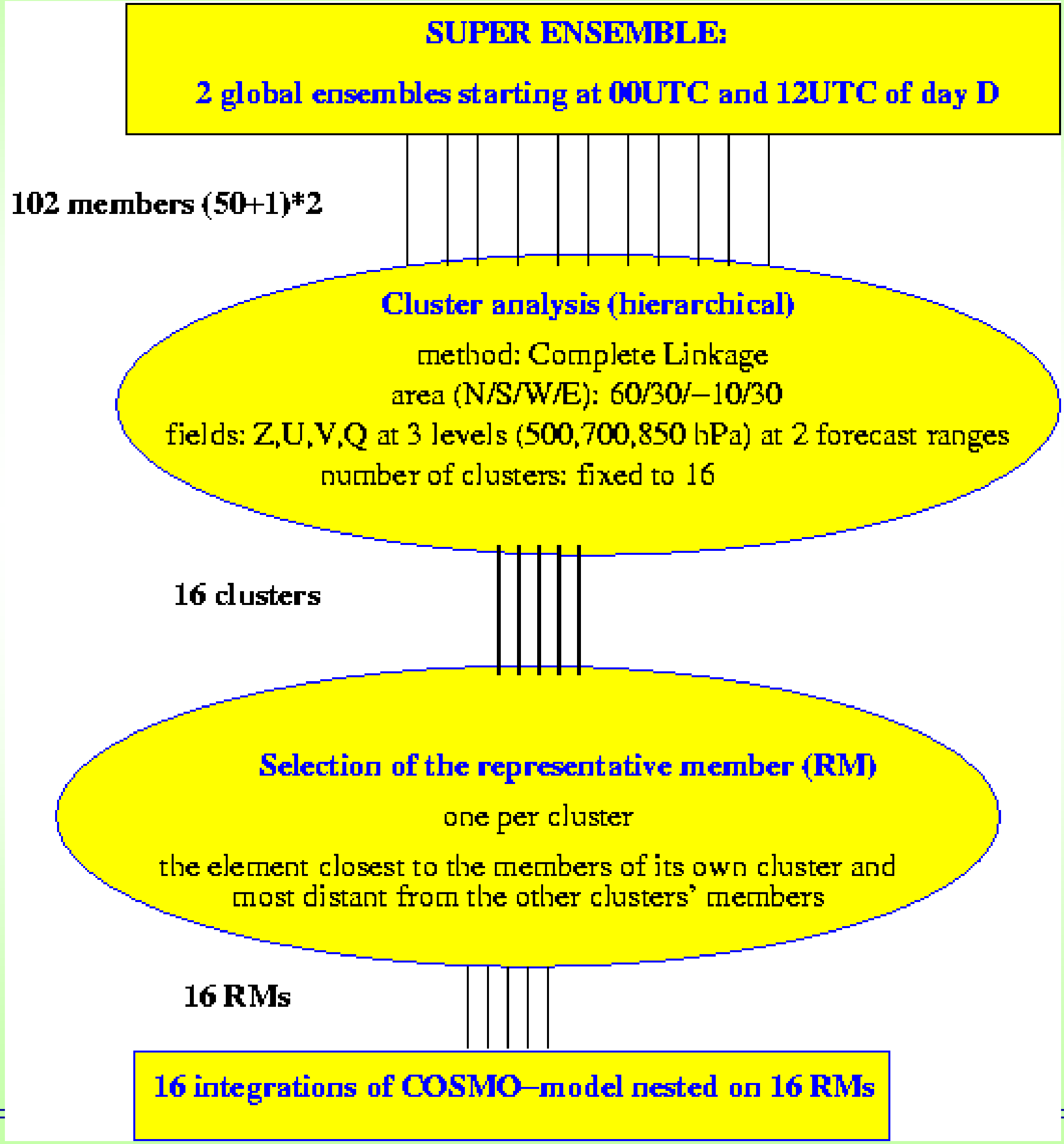
16 Representative Members driving the 16 COSMO-model integrations (weighted according to the cluster populations)

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



- suite running as a "time-critical application" managed by ARPA-SIM;
- Δx ~ 10 km; 40 ML;
- COSMO-LM 3.20 since Nov06;
- fc length: 132h;
- Computer time (4.7 million BU for 2007) provided by the COSMO partners which are ECMWF member states.

Present methodology



Operational set-up

Core products:

➔ **16 *perturbed* COSMO-model runs (ICs and 3-hourly BCs from 16 EPS members) to *generate*, "via weights", probabilistic output (start at 12UTC; Δt = 132h);**

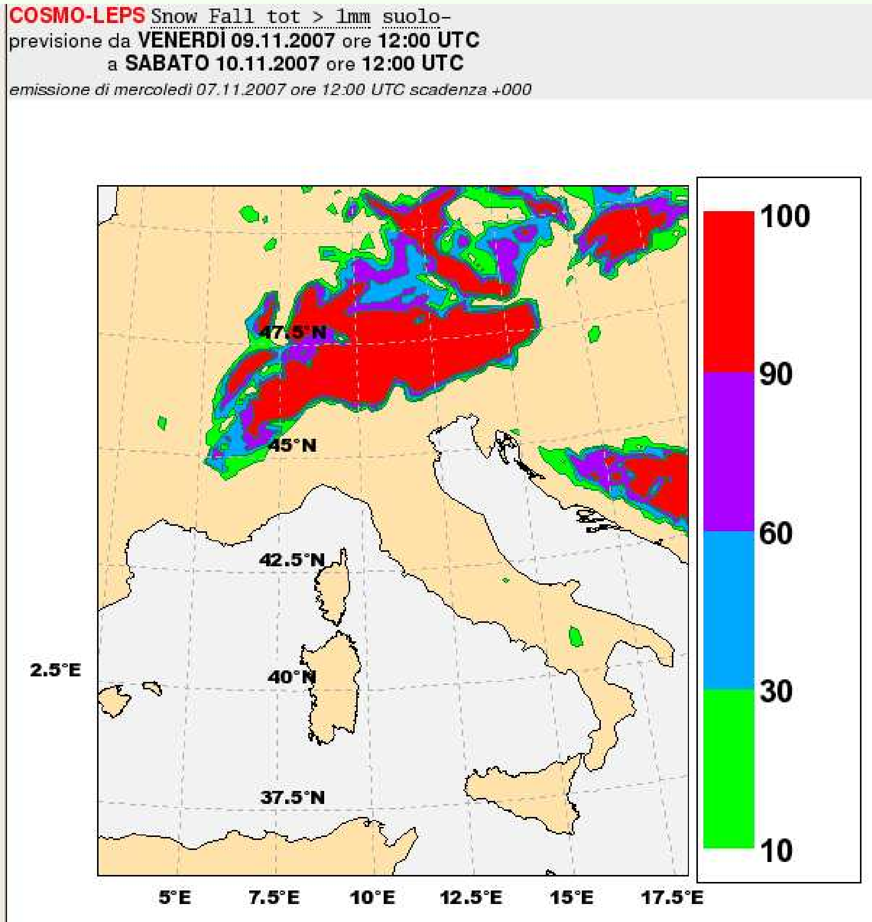
Additional products:

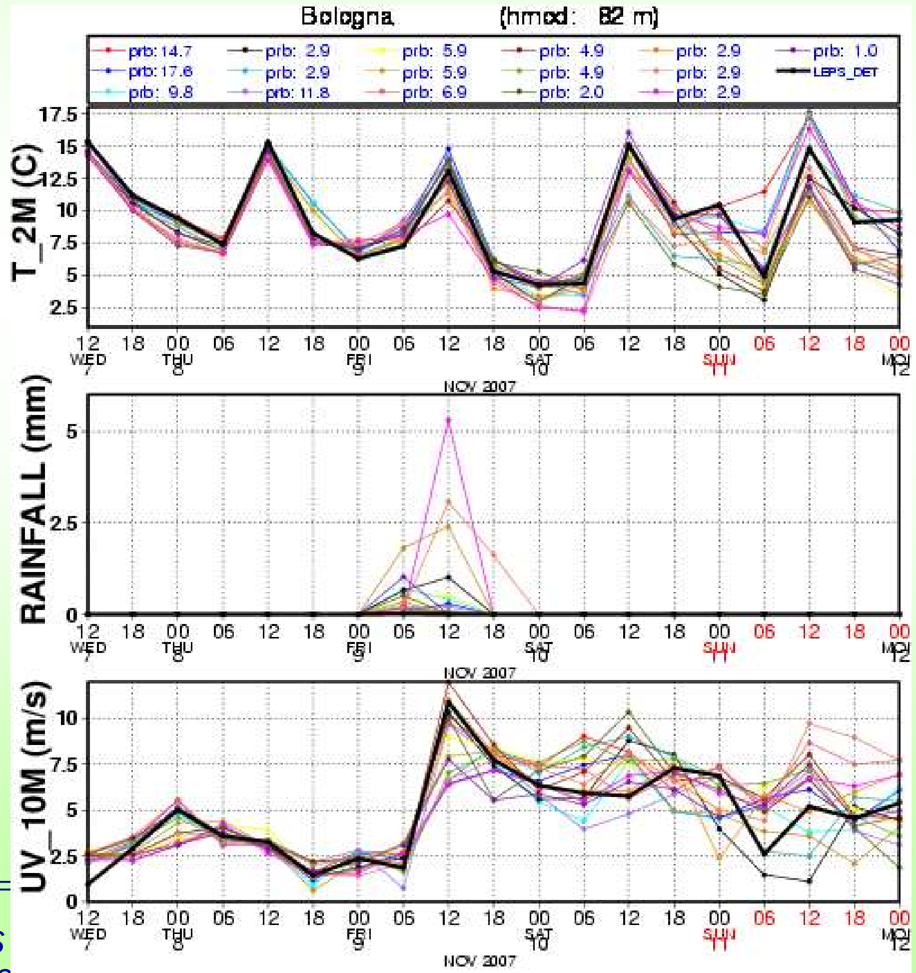
➔ 1 *deterministic* run (ICs and 3-hourly BCs from the high-resolution deterministic ECMWF forecast) to "join" deterministic and probabilistic approaches (start at 12UTC; Δt = 132h);

➔ 1 "*hindcast*" run (ICs and 3-hourly BCs from ECMWF analyses) to "downscale" ECMWF information (start at 00UTC; Δt = 36h).

Dissemination

- ➔ **probabilistic products**
- ➔ **deterministic products** (individual COSMO-LEPS runs)
- ➔ **derived probability products (EM, ES)**
- ➔ **meteograms over station points**





Objective verification of COSMO-LEPS

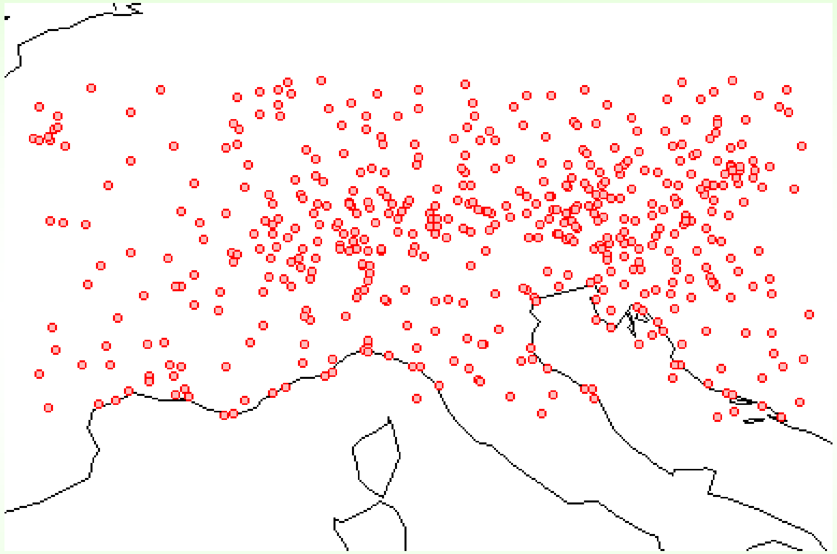
- SYNOP on the GTS (COSMO-LEPS only);
- high-res network (COSMO-LEPS vs ECMWF EPS).

Verification package includes the traditional probabilistic scores:

- **Brier Skill Score** (Wilks, 1995)
- **ROC area** (Mason and Graham, 1999)
- Cost-loss Curve (Richardson, 2000)
- **Percentage of Outliers** (Buizza, 1997)
- **Ranked Probability Skill Scores** (Wilks, 1995)
- Rank histograms (Wilks, 1995)

Objective verification of COSMO-LEPS

➢ **SYNOP on the GTS (COSMO-LEPS only);**



Main features:

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

period: from Dec 2002 to Sep 2007;

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;

both (58) monthly and (19) seasonal scores are computed.

work is in progress for verification over the full domain (1500 stations)

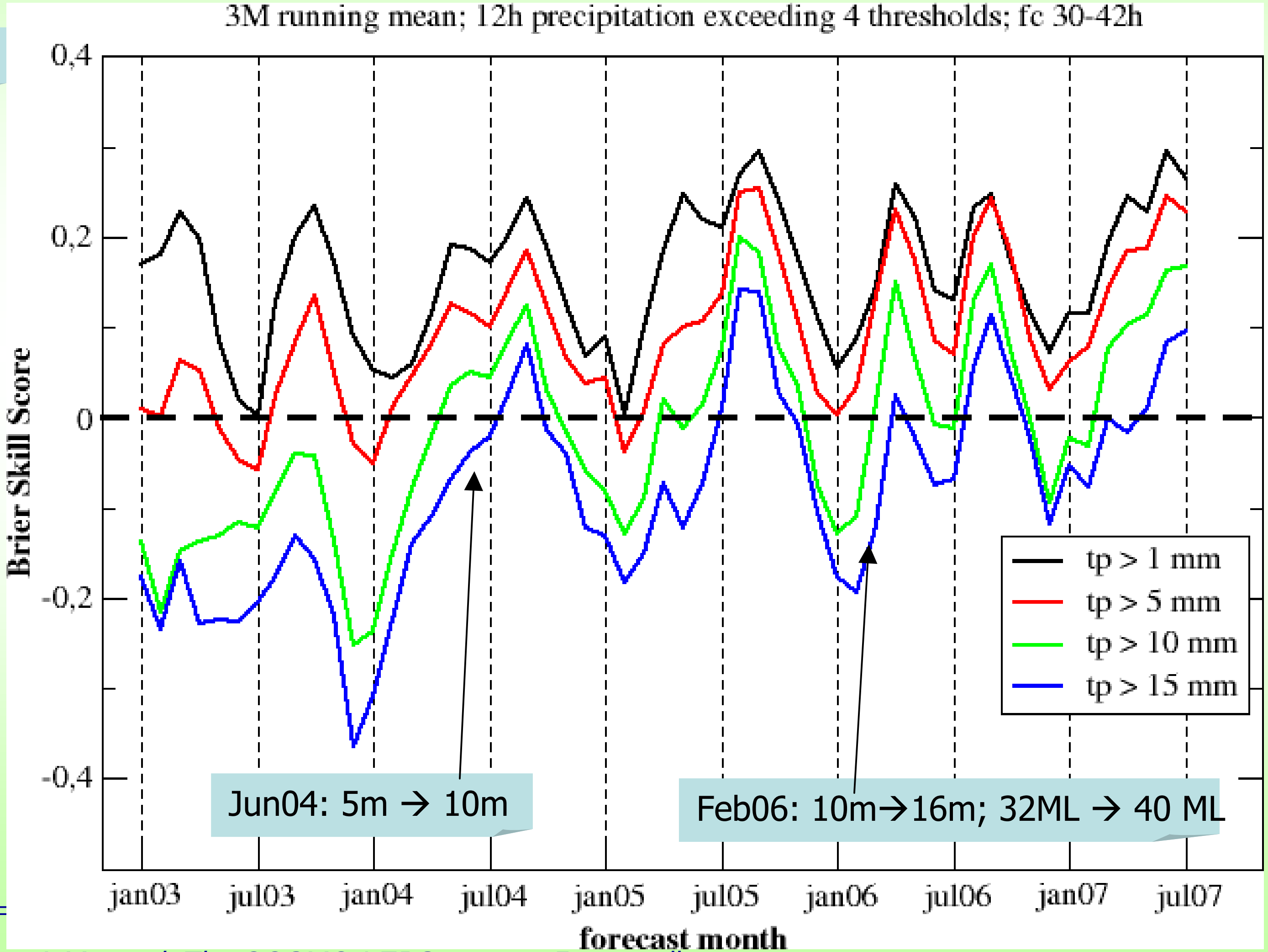
Time series of Brier Skill Score

- BSS is written as 1-BS/BS_{ref}. **Sample climate** is the reference system. Useful forecast systems if BSS > 0.
- BS measures the mean squared difference between forecast and observation in probability space.
- Equivalent to MSE for deterministic forecast.

BSS

fc step: 30-42h

- improvement of performance **detectable** for all thresholds along the years;
- still problems with high thresholds, but good trend in 2007.



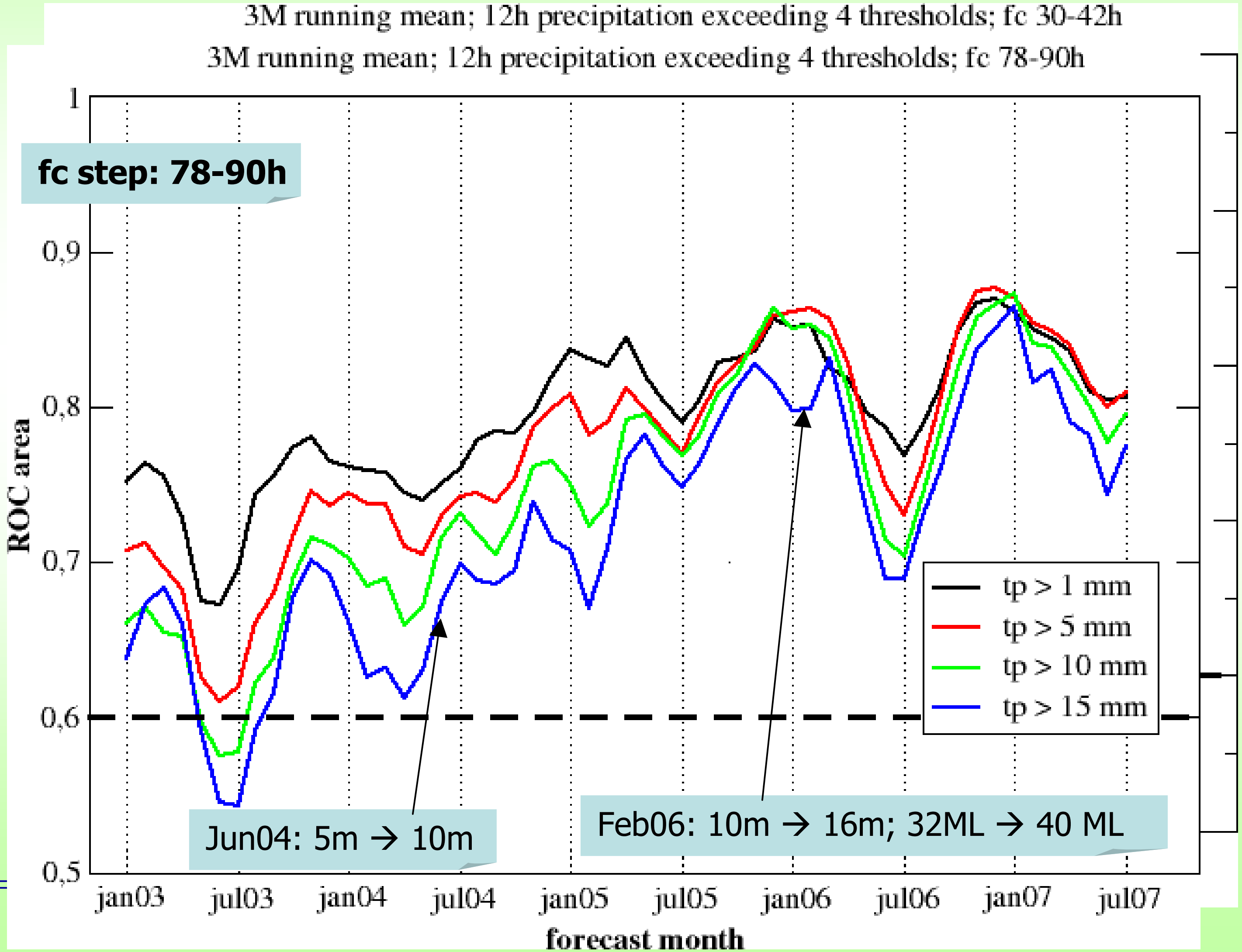
Time series of ROC area

- Area under the curve in the HIT rate vs FAR diagram.
- Valuable forecast systems have ROC area values > 0.6.

ROC

- the positive impact of increasing the ensemble size in 2004 is **evident** for all thresholds and for different forecast ranges.

- poor performance of the system in Spring and Summer 2006 (both quite dry), despite upgrades.



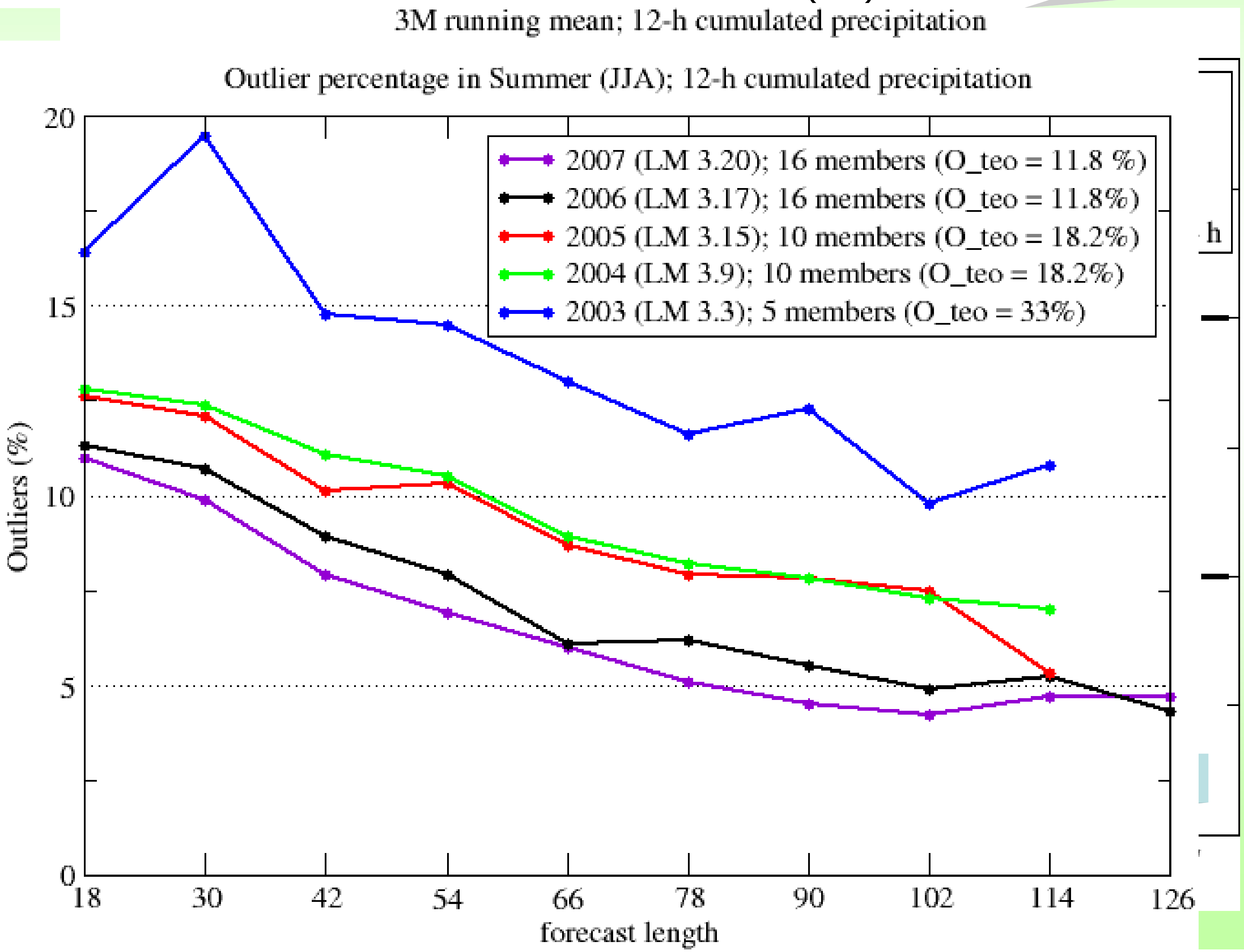
Outliers: time series + seasonal scores

- How many times the analysis is out of the forecast interval spanned by the ensemble members.
- … the lower the better …
- Performance of the system assessed as time series and for 5 different Summers (JJA).

OUTL

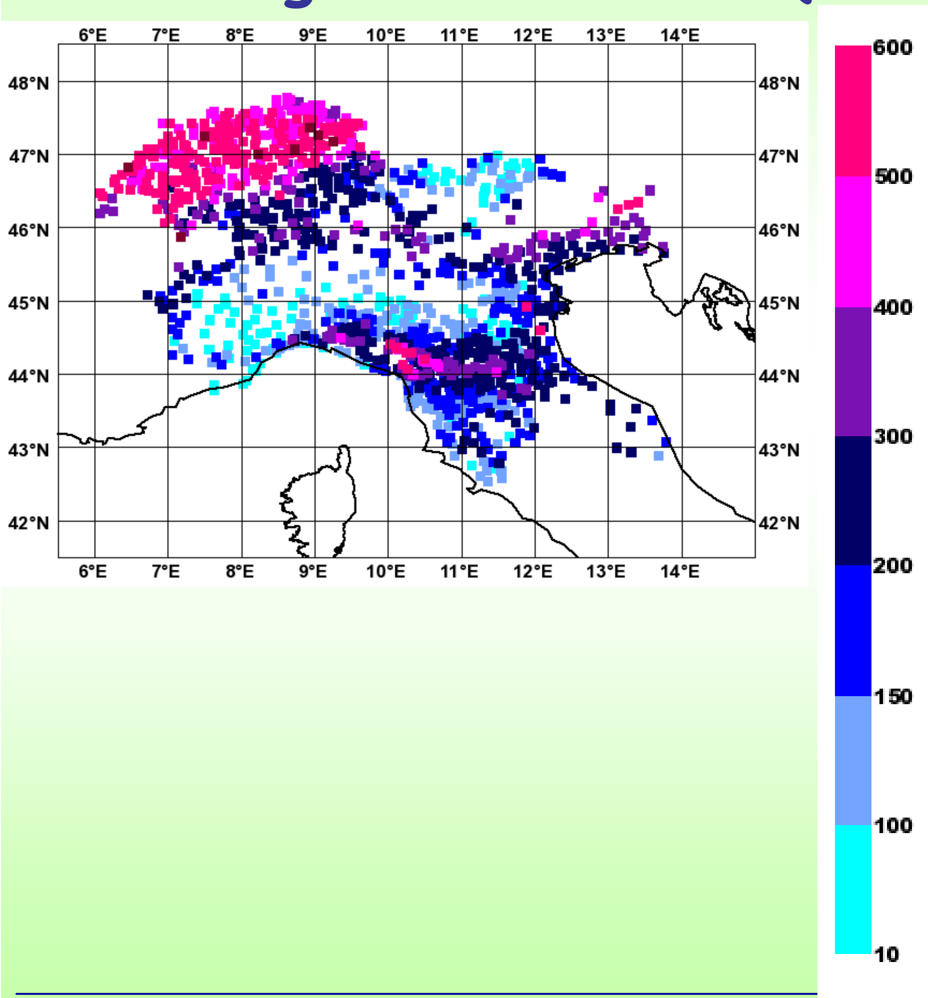
- Evident seasonal cycle (more outliers in winter), but overall reduction of outliers in the years.

- Reduction of outliers from one Summer to the other, related to the increase of ensemble size (more evident for the 5 to 10 increase).
- Need to take into account the different statistics for each season (JJA 2003 less rainy than the others).



Objective verification of COSMO-LEPS

- high-res network (COSMO-LEPS vs ECMWF EPS).



Main features:

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

period: MAM 2006;

region: Switzerland, Italy (North of 43N);

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, 5, 10, 20, 30 mm/24h;**

systems:

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

- reduced EPS (16m, 50 km, 60 ML)

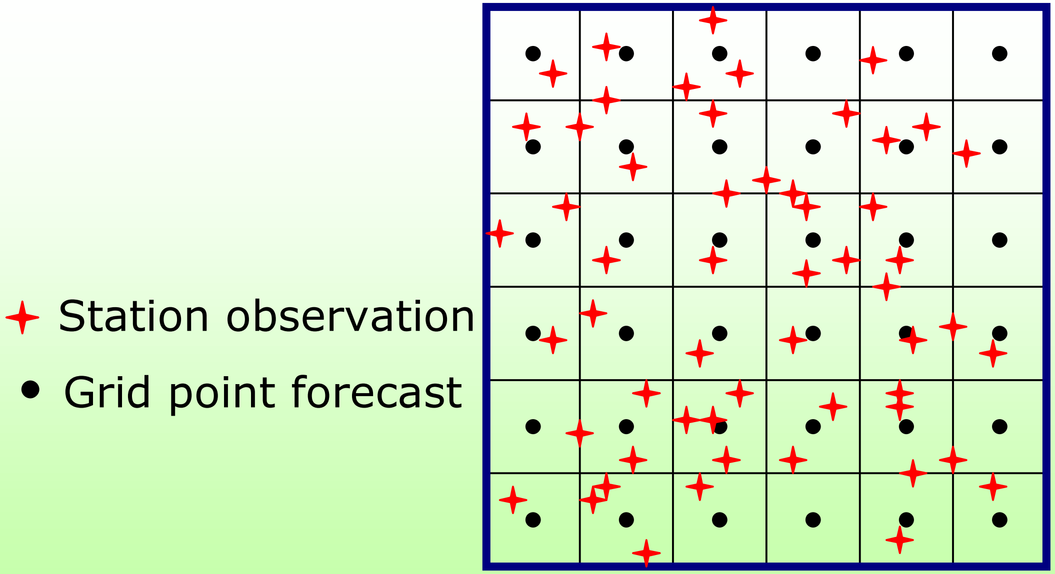
- full EPS (51m, 50 km, 60 ML)

Verification of the distributions

The verification has been made in terms of:

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

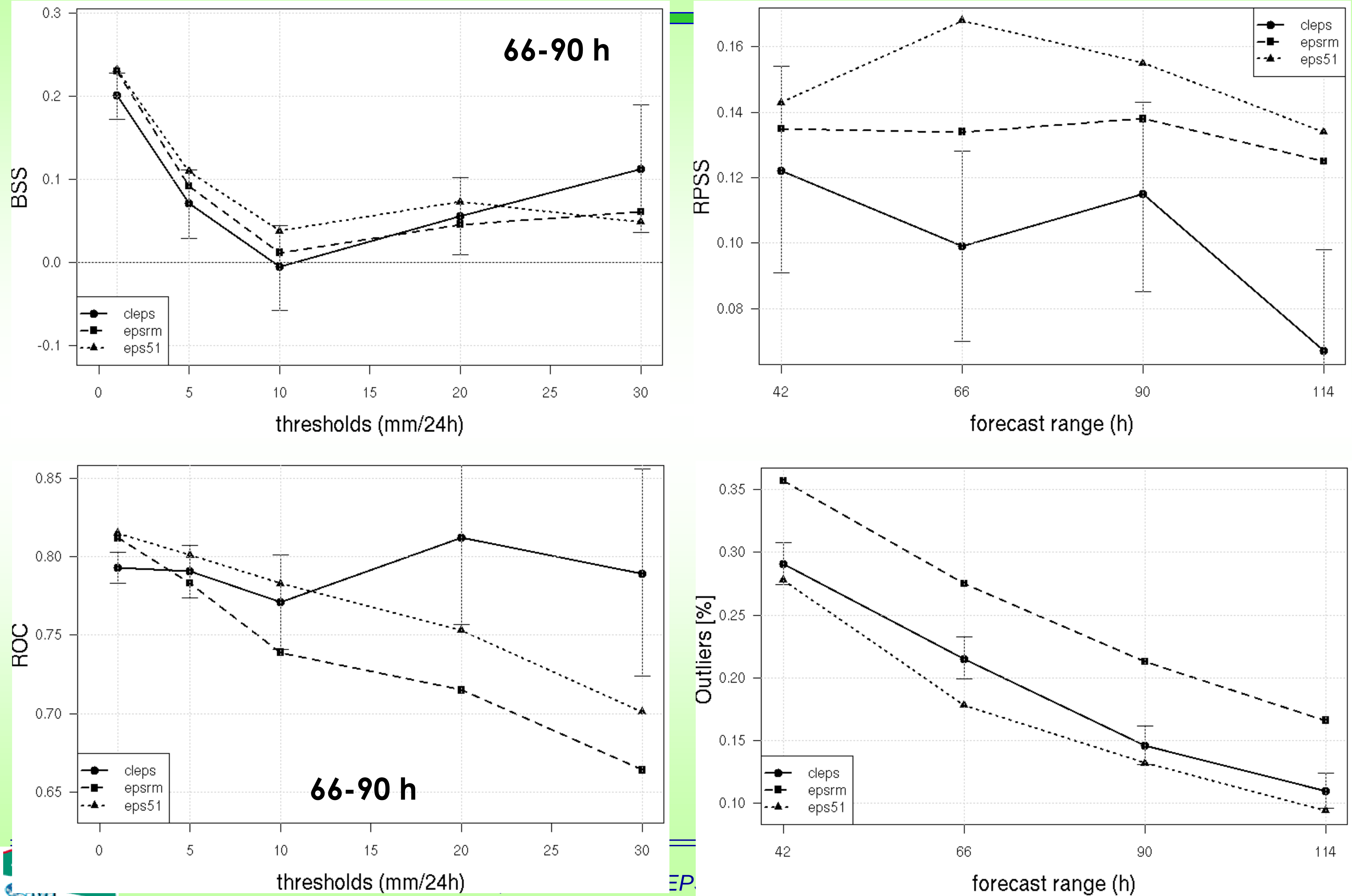
in a box



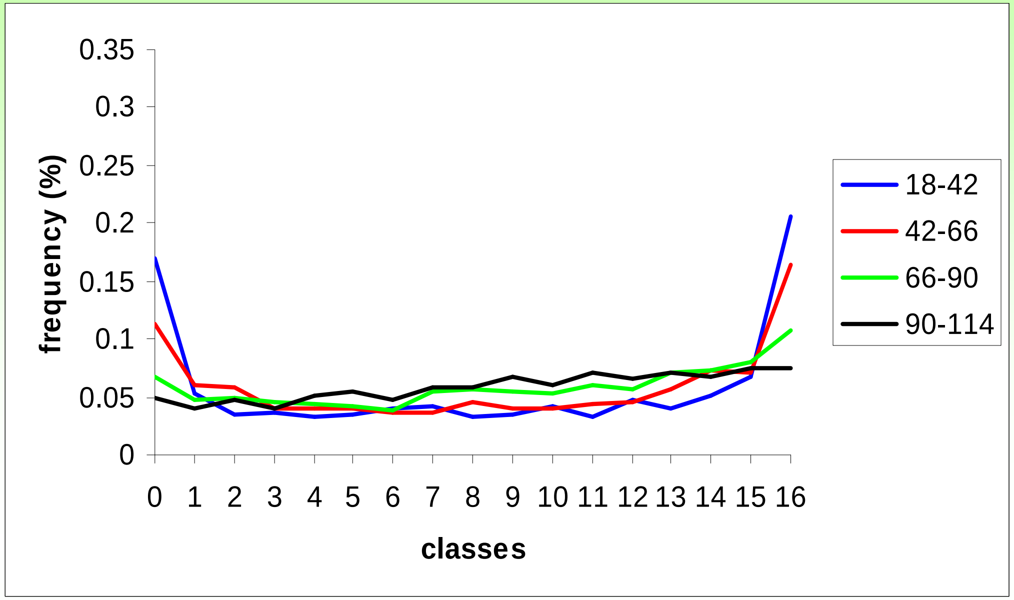
two measures of precipitation:

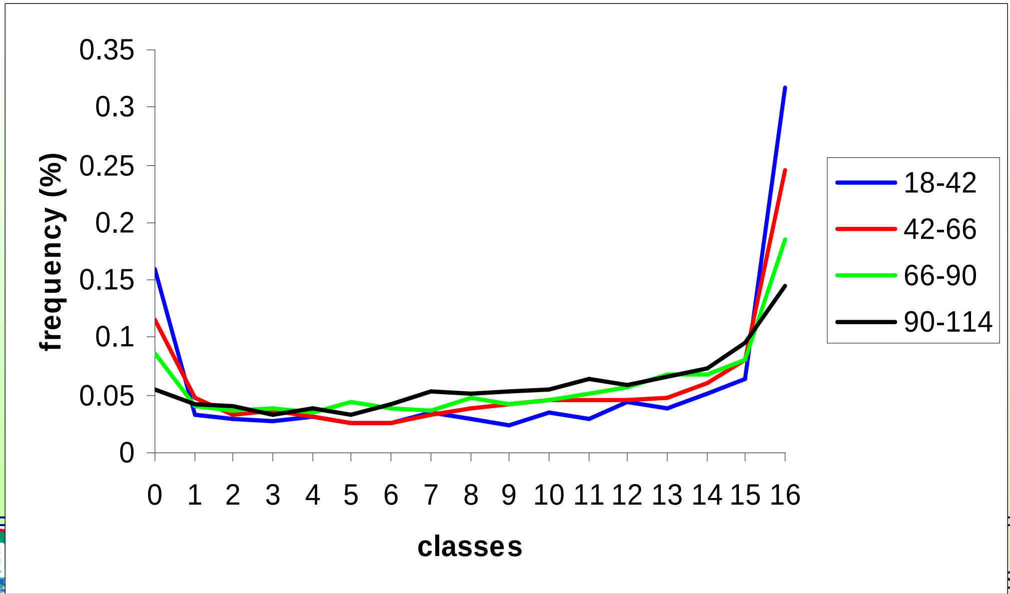
- the cumulative volume of water deployed over a specific region;
- the rainfall peaks occurring within the same region.

MAM06 **Average values** (boxes 1.0 x 1.0)



MAM06 **Average values** (boxes 1.0 x 1.0)

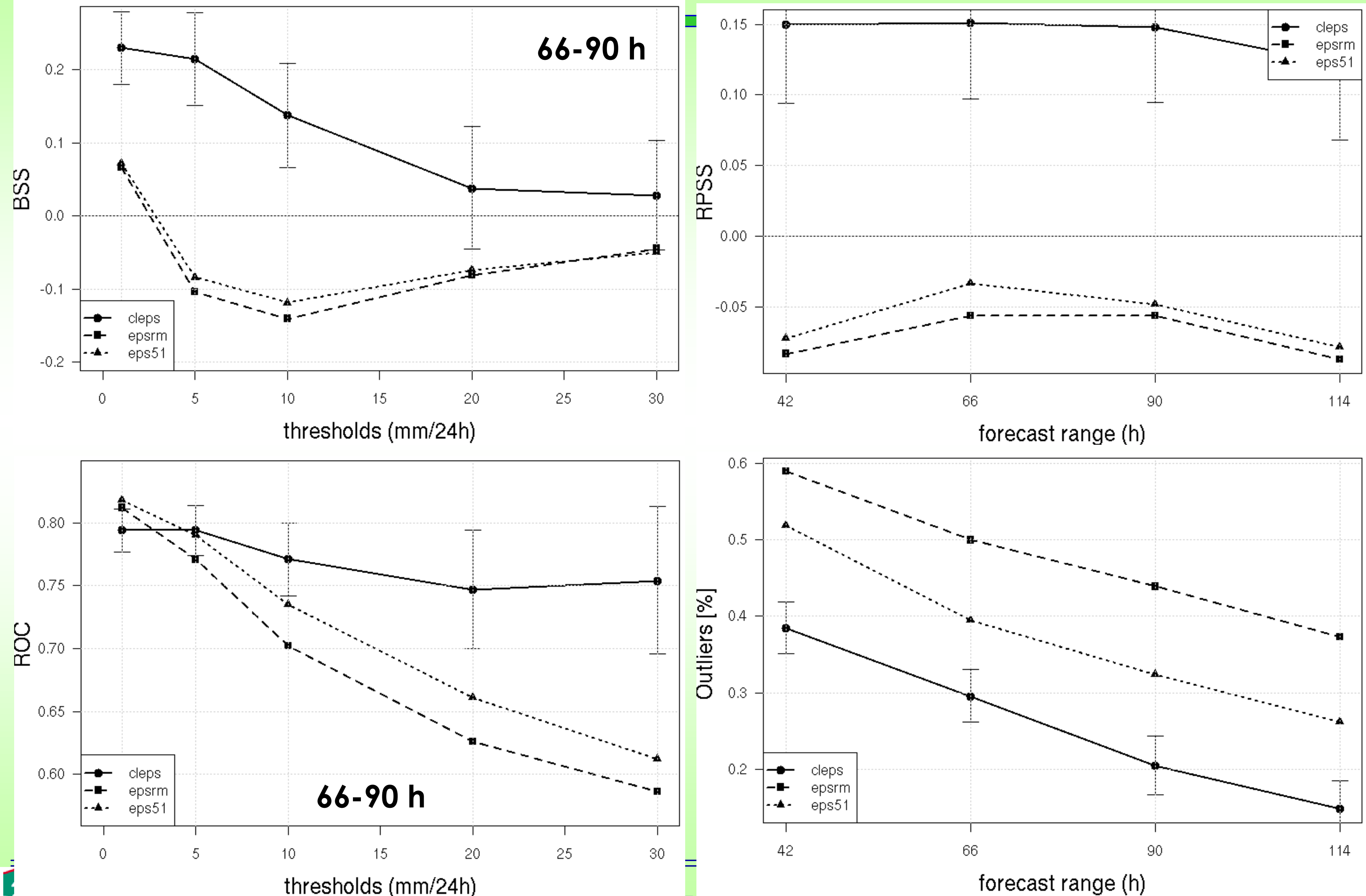




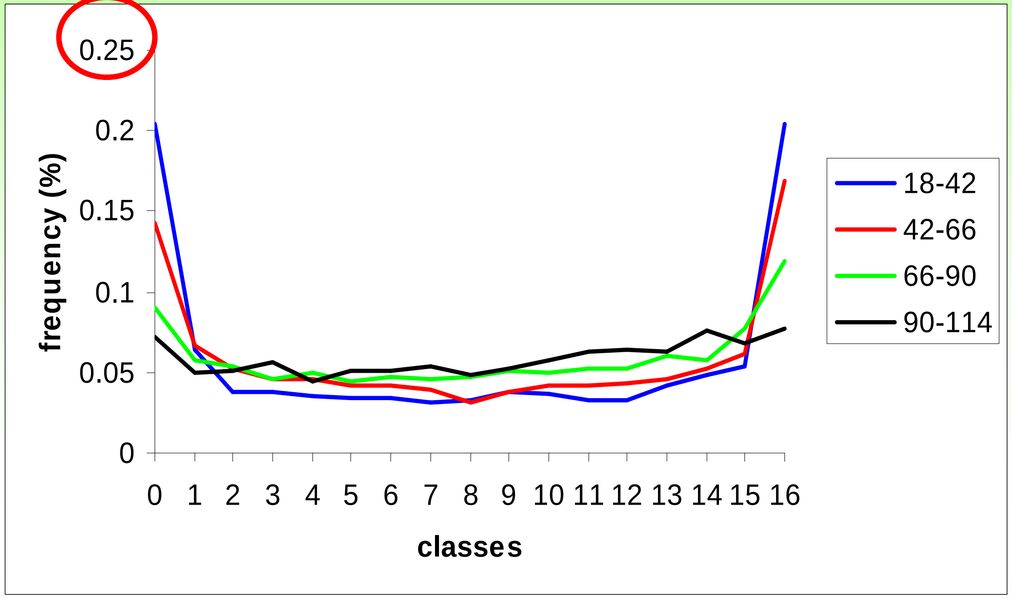
COSMO-LEPS

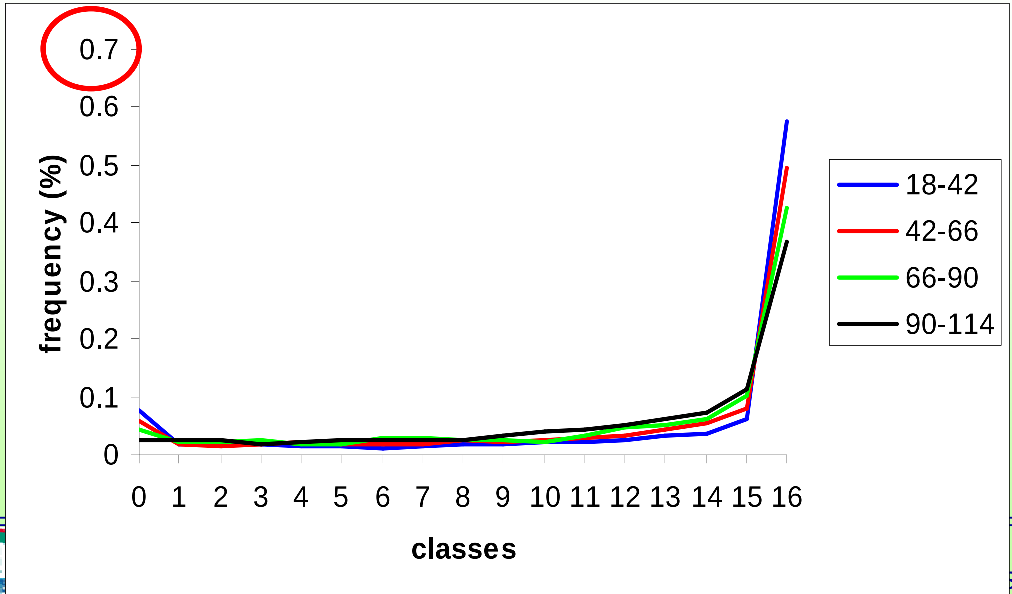
16-MEMBER EPS

MAM06 **Maximum values** (boxes 1.0 x 1.0)



MAM06 **Maximum values** (boxes 1.0 x 1.0)





COSMO-LEPS

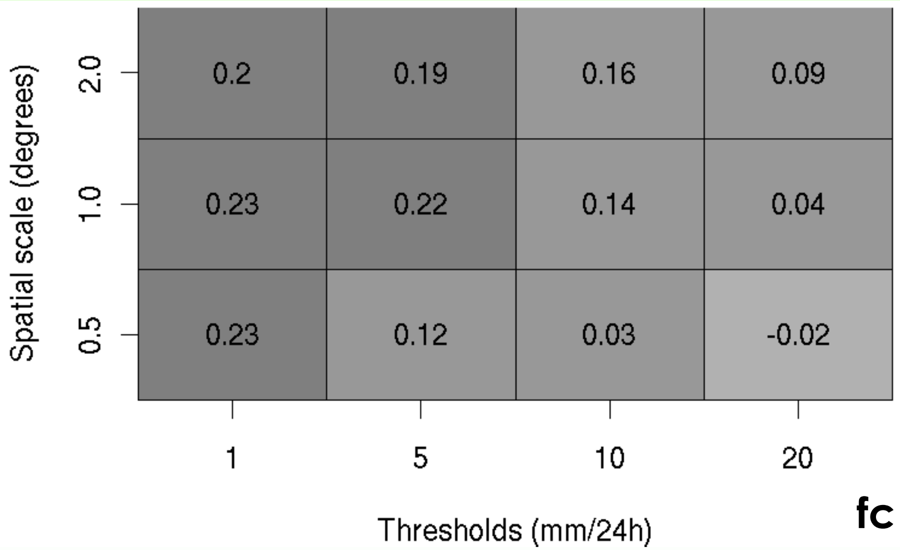
16-MEMBER EPS

MAM06

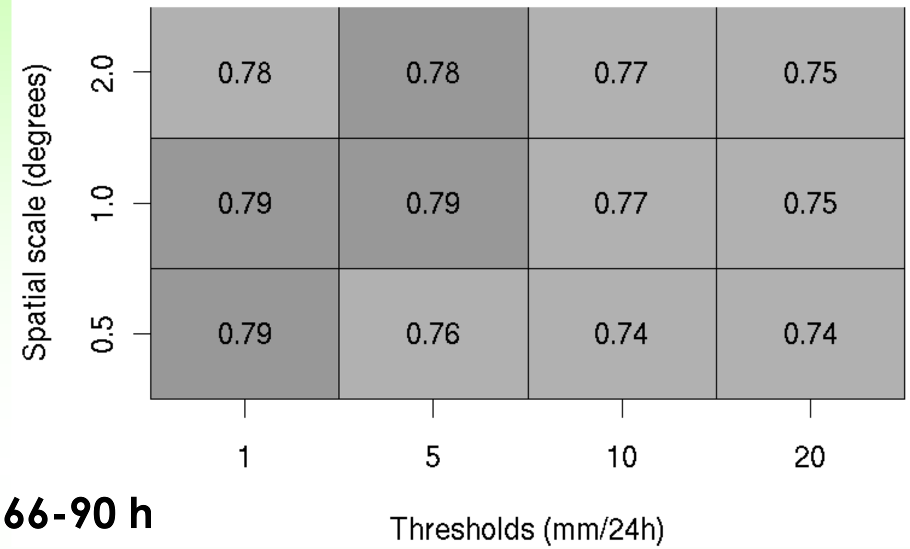
Scale-intensity (max)

cleps

BSS

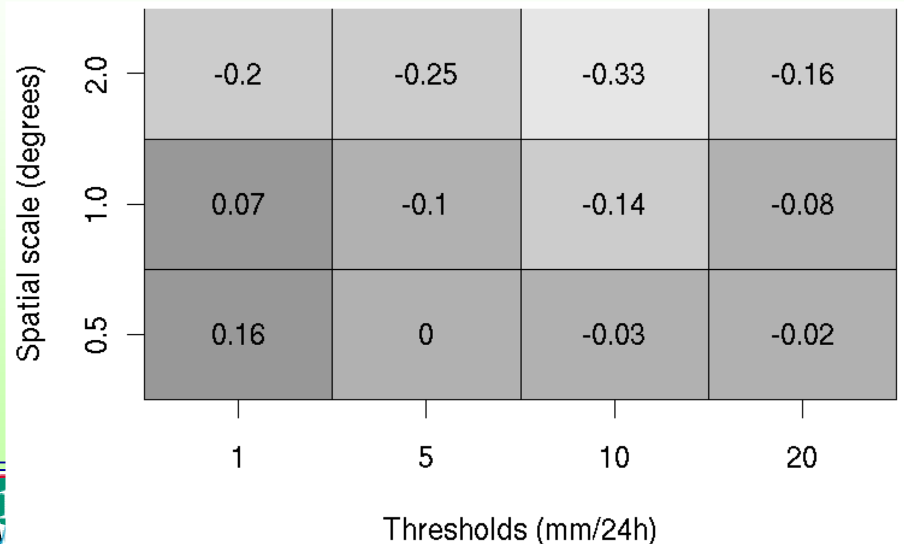


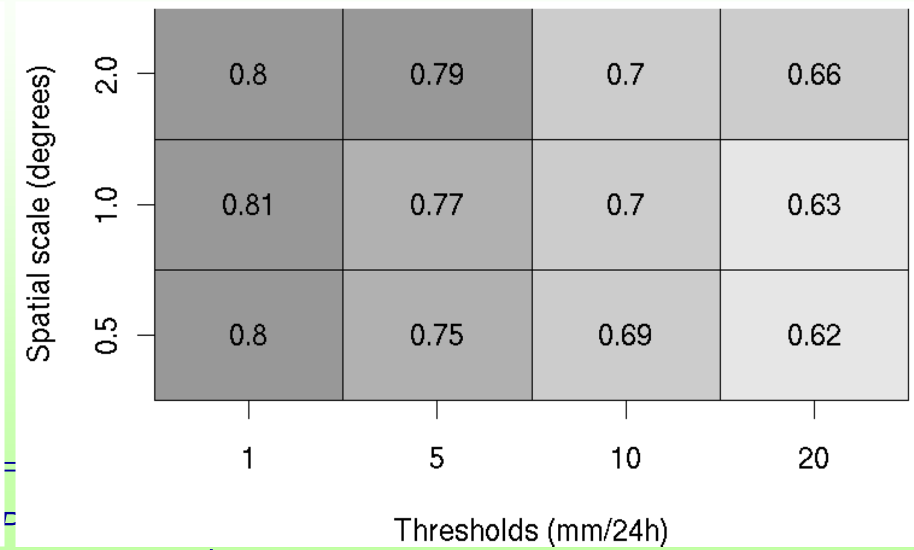
ROC



fc 66-90 h

epsrm





Main results

- Since November 2002, COSMO-LEPS system has been running on a daily basis.
- Since December 2005, COSMO-LEPS is a “member-state time-critical application”.
- COSMO-LEPS products are routinely used in met-ops rooms across COSMO community, in EC Projects (e.g. Windstorms PREVIEW) as well as in field campaigns of meteorological experiments (e.g. COPS, MAP D-PHASE).

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);
  - although some deficiency in the skill of the system were identified after the system upgrades occurred on February 2006 (from 10 to 16 members; from 32 to 40 model levels + EPS upgrade), **scores are encouraging throughout 2007.**

- **High-res verification shows better scores of COSMO-LEPS with respect to EPS in forecasting precipitation maxima within boxes.**

Future plans

- **Verification vs synop:**
  - **assess performance over the full domain,**
  - **consider other variables (2m temperature, 10m wind speed, 10m wind gust).**
- **Implement "weighted" derived probability products:**
  - **weighted ensemble mean and weighted ensemble standard deviation.**
- **Introduce physics perturbations to improve spread/skill relation.**
- **"Think about" increasing horizontal resolution to 7 km.**
- **Calibrate COSMO-LEPS fcsts using reforecasts (F. Fundel , Meteoswiss).**
- **Implement "TIGGE-LAM compliant" COSMO-LEPS which runs on different domains, on different boundary conditions** (relocatable COSMO-LEPS).
- **Develop "hybrid" clustering technique** (take boundary conditions from a "grand-global" ensemble provided by mixing ECMWF-EPS and UKMO-MOGREPS).

Thank you !