Limited Area Ensemble Systems

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OUTLINE of the presentation

- Introduction
- Operational systems
- Research systems
- Comments and concluding remarks

Why Limited Area Ensemble Prediction?

- Global Ensemble Prediction Systems
  - have become extremely important tools to tackle the problem of predictions beyond day 2
  - are usually run at a coarser resolution with respect to deterministic global predictions → skill in forecasting intense and localised events is currently still limited.

Why Limited Area Ensemble Prediction? (2)

As regards high resolution deterministic forecast in the short range, where limited-area models play the major role, a "satisfactory" QPF is still one of the major challenges. The same can be said for other local parameters.

This is due, among other reasons, to the inherently low degree of predictability typical of severe and localised events.

Probabilistic/Ensemble approach is so required also for the short range at higher resolution

From Global EPS to LAM EPS

- In the Limited-area ensemble systems, tailored for the short range, perturbations must be already "active" during the first hours of integration

- The characteristic of the LAM ensemble are strongly dependent by the lateral boundaries forcing.

- Due to the "regional" application of these Limited Area Ensembles, methodologies can be different in different geographycal regions.

A pratical consideration:

Global EPS ~ Big Centres

Limited Area EPS ~ (also) Relatively Small Centres

Limited Area Ensemble Systems

Conceptually simple approaches

- Dynamical downscaling of Global EPS:
  improvement of the forecast essentially due to the increased resolution of LAMs

- Multi-Model Multi-Analysis:
  the use of different models and different analyses systems allows an efficient way to account for analyses and model errors.

Limited Area Ensemble Systems

Other methodologies

- Perturbations on the Initial conditions (analysis errors):
  - SV, Breeding, EnKF, ETKF
- Perturbation of the model trajectories (model errors):
  - Pert. of tendencies
  - Perturbation of model parameters
  - Different physical schemes

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NCEP SREF System: prior to Aug. 17 2004

The ***1st operational*** regional ensemble system in the world Implemented officially at **NCEP in April 2001** – Du and Tracton 2001

Multi-model (Eta and RSM), multi-analysis (gdas and edas), multi-ICs (breeding) and multi-physics (BMJ, KF and SAS):

Eta_BMJ (5) -- ctl + 2 breeding pair from edas
Eta_KF (5) -- ctl + 2 breeding pair from edas
RSM_SAS (5) – ctl + 2 breeding pair from gdas
(15 members in total)

48km, 63h fcst lead time twice per day (09z and 21z), large North American domain

- RSM Regional Spectral Model
- EDAS Eta Data Assimilation System
- GDAS Global Data Assimilation System
- BMJ Betts Miller Janic
- KF Kain Fritsch
- SAT SATurated moisture profiles
- DET full cloud DETrainement
- SAS Simple Arakawa Shubert
- RAS Relaxed Arakawa Shubert

Two problems (related to each other):

- ***too small IC pert size in summer while too big occasionally in winter when atmosphere is extremely unstable***
- ***clustering by model, too small spread in warm season***

NCEP SREF System: after Aug. 17 2004

•**From 3 convective schemes (BMJ, KF and SAS) to 6 schemes:**

Eta_BMJ (3): ctl + 1 breeding pair
Eta_SAT (2): 1 breeding pair

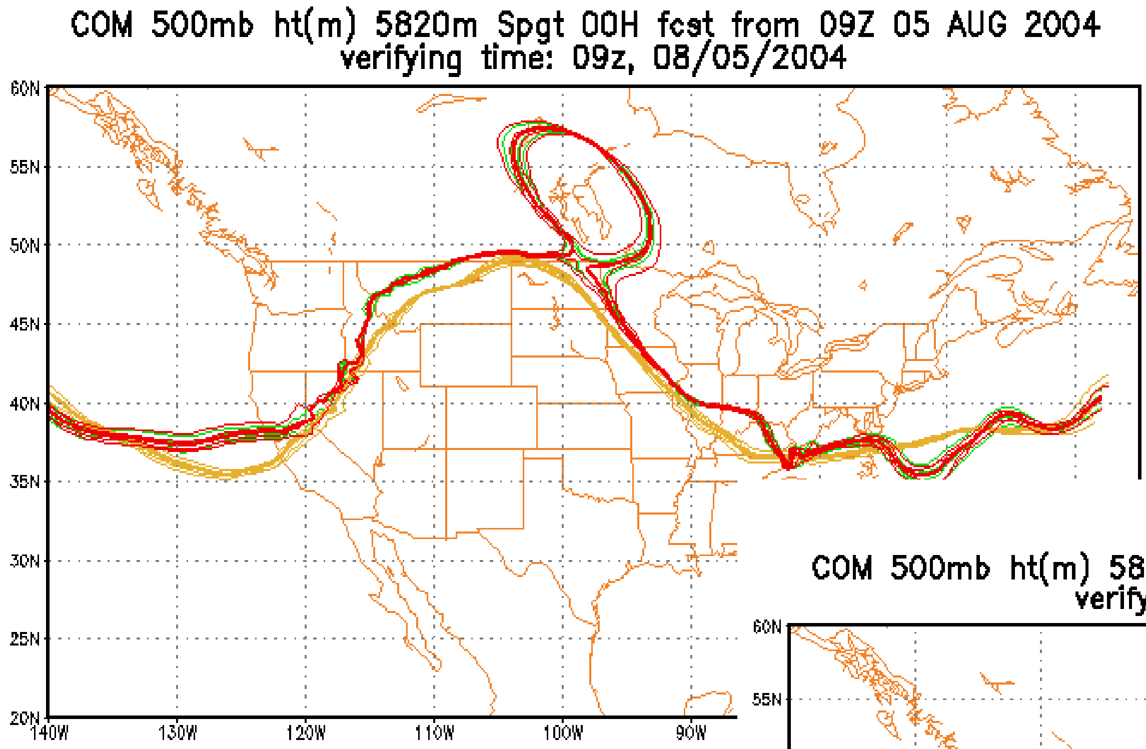
Eta_KF (3): ctl + 1 breeding pair
Eta_DET (2): 1 breeding pair

RSM_SAS (3): ctl + 1 breeding pair
RSM_RAS (2): 1 breeding pair
(15 members in total)

•**New scaling on breeding (prevent IC pert. size from being too small in summer and from being too big in winter but always consistent with typical error size possibly in analysis)**

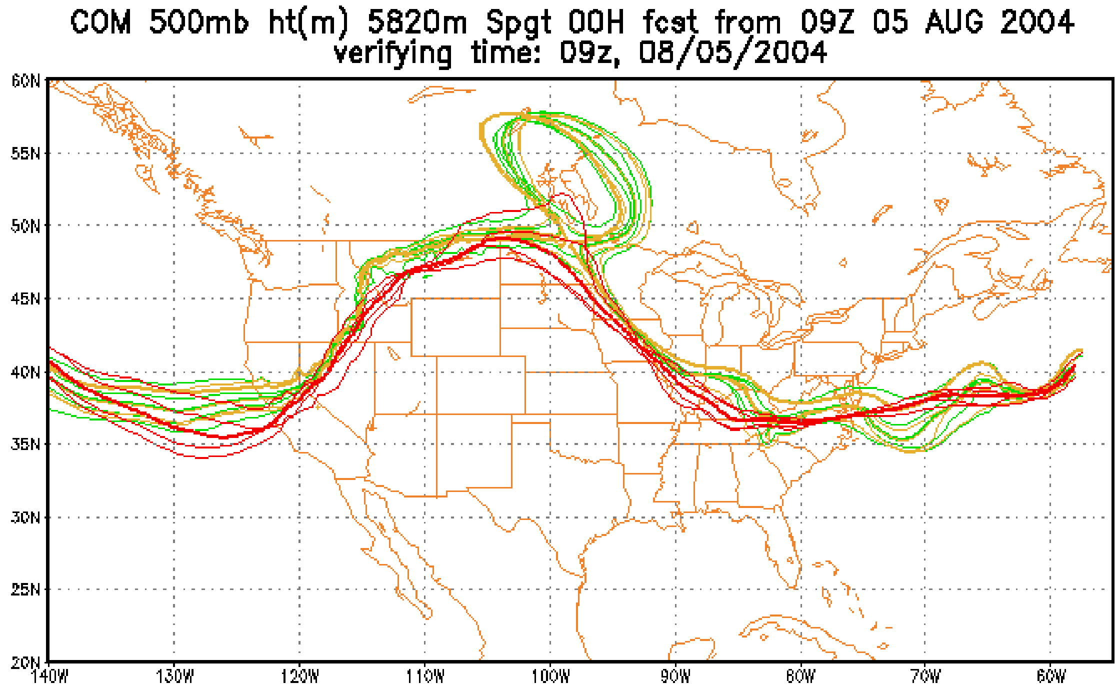
•**From 48km to 32km**

- RSM Regional Spectral Model
- EDAS Eta Data Assimilation System
- GDAS Global Data Assimilation System
- BMJ Betts Miller Janic
- KF Kain Fritsch
- SAT SATurated moisture profiles
- DET full cloud DETrainement
- SAS Simple Arakawa Shubert
- RAS Relaxed Arakawa Shubert



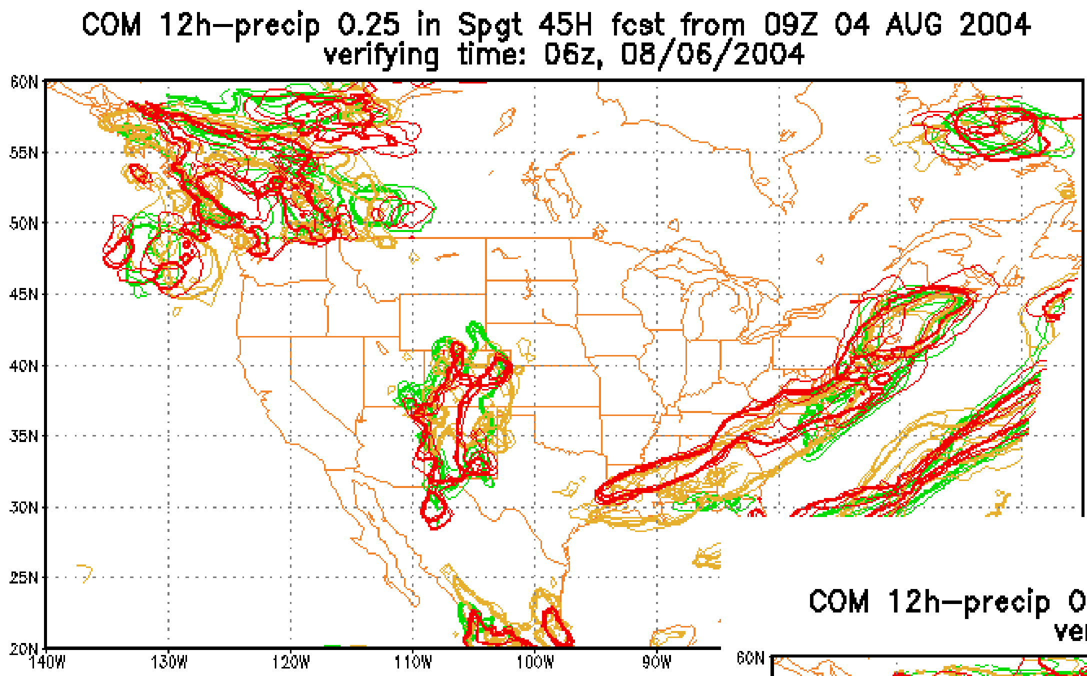
OPS SREF: too small IC perturbation size in summer time!

NCEP SREF System
NCEP SREF SYSTEM
after Aug 17, 2004:

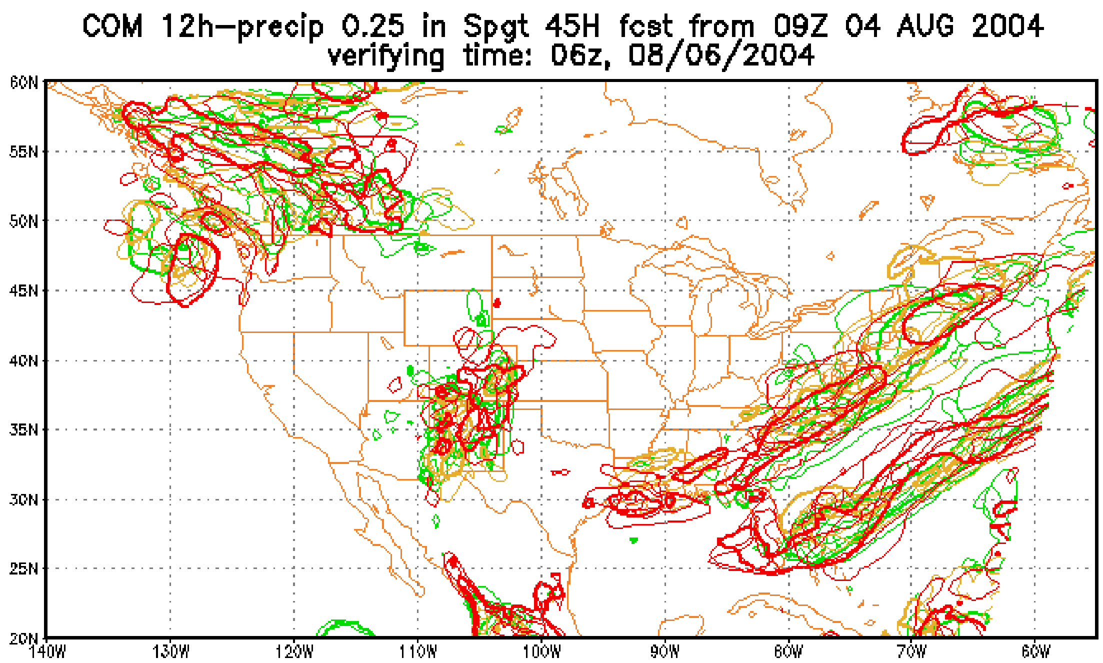


NCEP SREF System
NCEP SREF SYSTEM
prior to Aug. 17, 2004

PAR SREF: IC perturbation size increased!



NCEP SREF System
NCEP SREF SYSTEM
after Aug 17, 2004:



OPS SREF: clustering by model leads to too small spread especially in summer!

NCEP SREF System
NCEP SREF SYSTEM
prior to Aug. 17, 2004

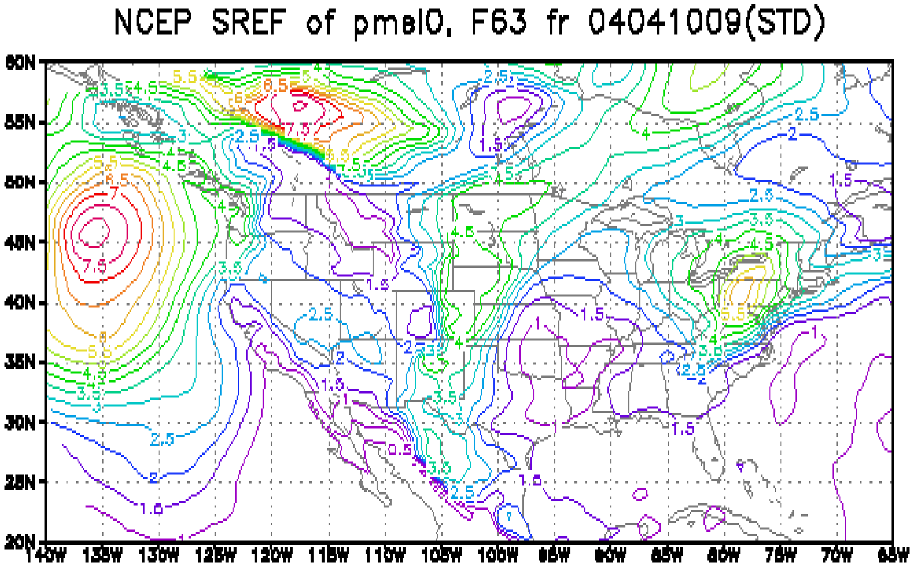
PAR SREF: clustering by model disappeared!

Why ensemble spread increased from old to new SREF System significantly?

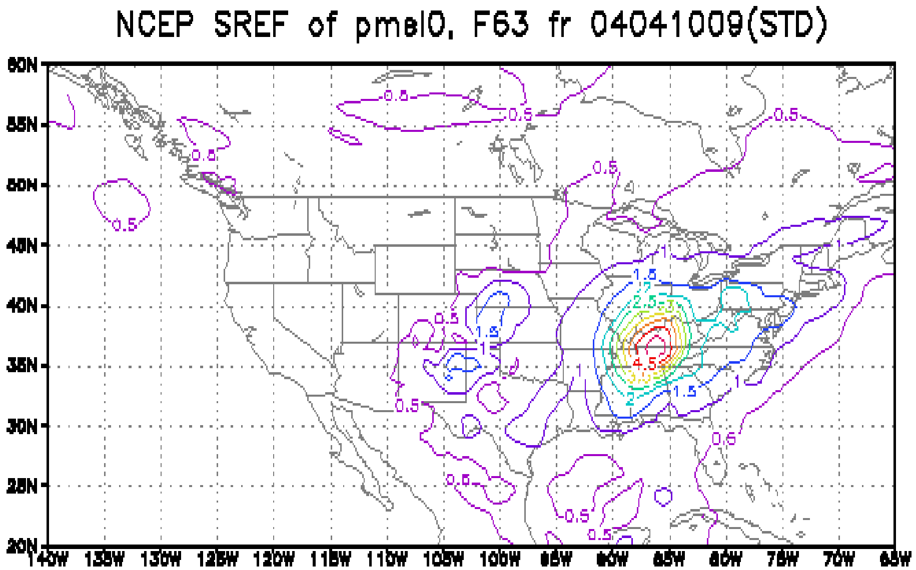
(1) IC perturbation size increased a lot during warm season (primary reason);

(2) Warm season is more convective which is sensitive to convective scheme diversity more (secondary reason);

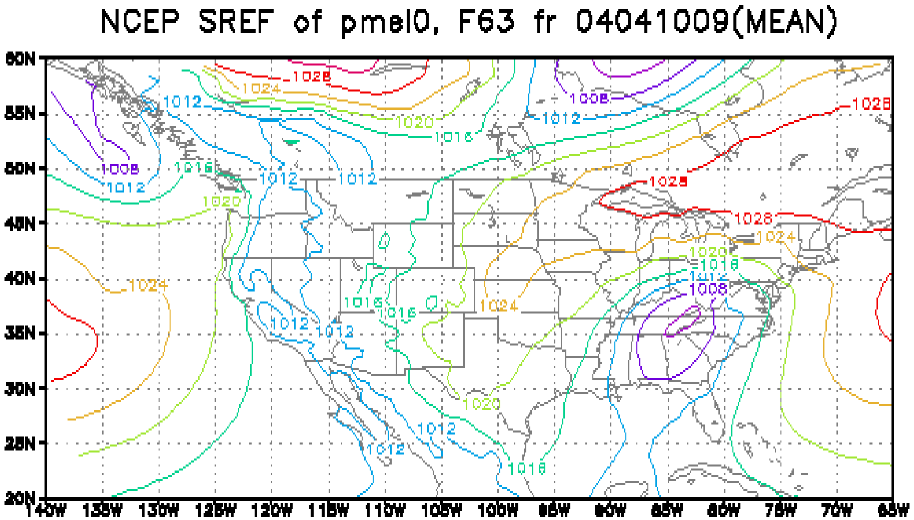
(3) Ensemble spread is, in general, much more sensitive to IC pert than to physics diversity for atmospheric-circulation related fields as demonstrated by the following exp.



IC-ensemble spread (SLP at 63h)

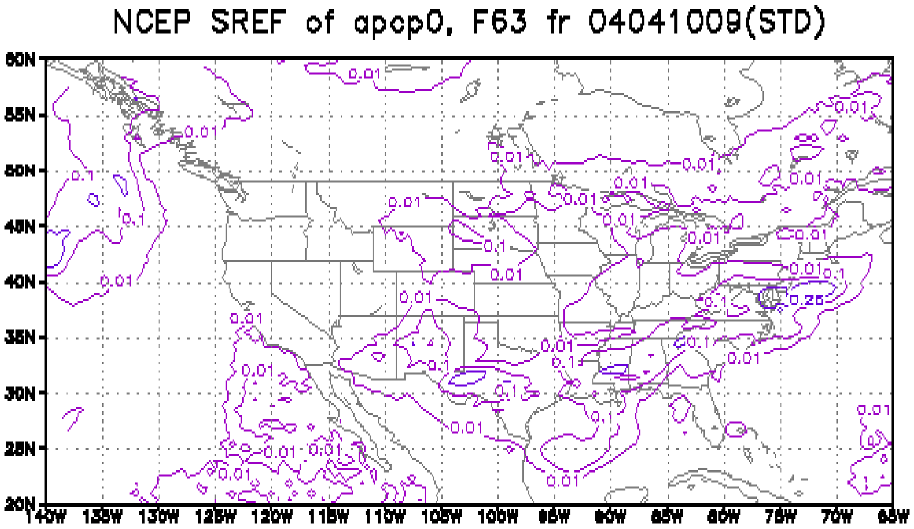


PHY-ensemble spread (SLP at 63h)

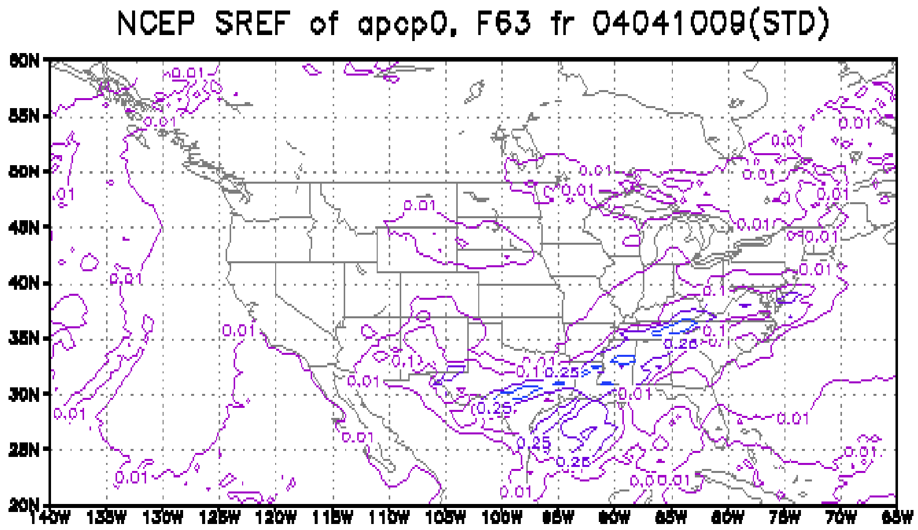


PHY-ensemble mean 63h fcst (SLP)

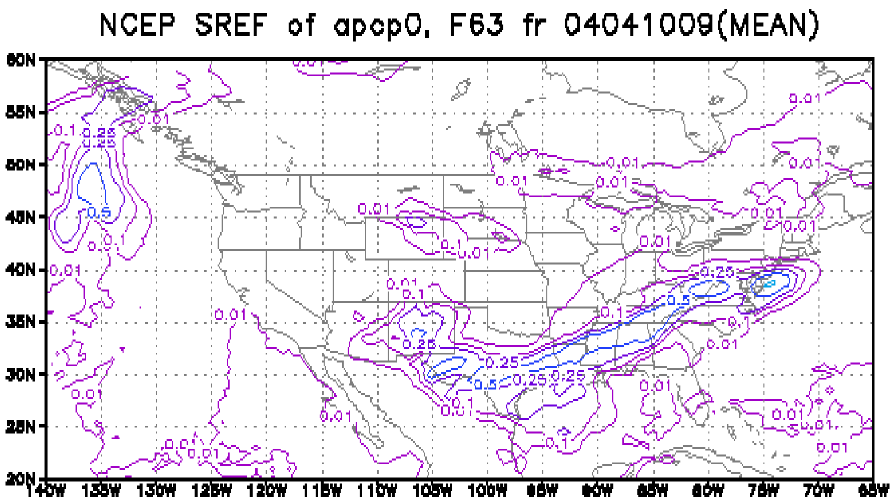
More sensitive to IC pert than PHY Diversity in general except for the Cyclone region where is more convective



IC-ensemble spread (12h-apcp at 63h)

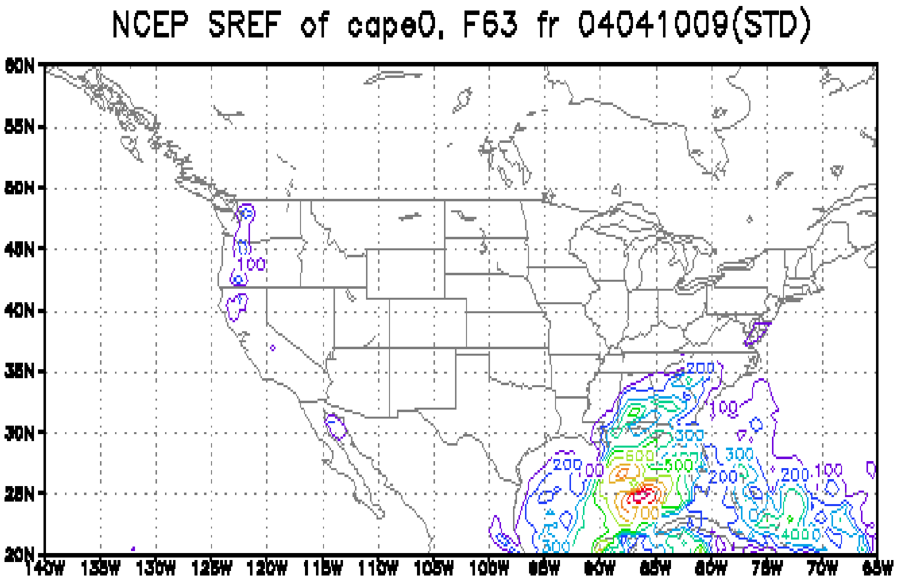


PHY-ensemble spread (12h-apcp at 63h)

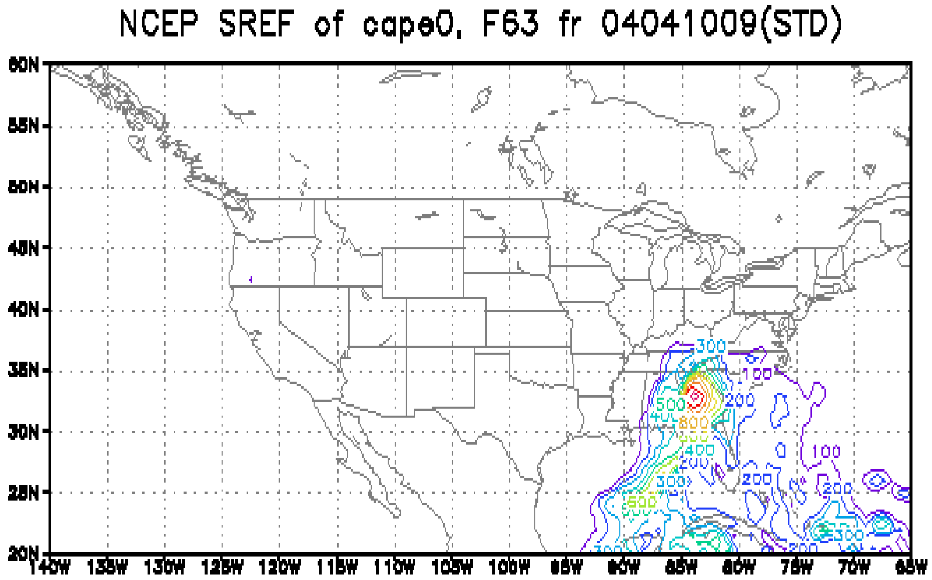


PHY-ensemble mean 63h fcst (12h-apcp)

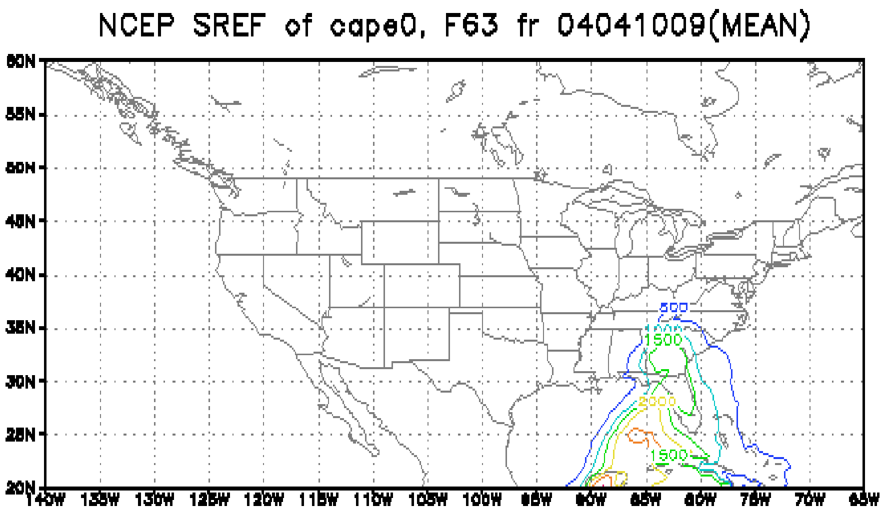
Similar sensitivity to both IC pert and to PHY Diversity for precip in general.
PHY diversity enhances sensitivity in Convective areas.



IC-ensemble spread (CAPE at 63h)



PHY-ensemble spread (CAPE at 63h)



PHY-ensemble mean 63h fcst (CAPE)

Equally sensitive to IC pert and PHY Diversity for CAPE (focusing different Sub-regions though)

NCEP SREF System What's Happening?

Jun Du EMC/NCEP/NOAA

1. Increase from 2 to 4 cycles per day and extend forecast lead time from 63 hr to 87 hr

2. Expand output domain to cover Alaska, Hawaii and Puerto Rico

3. Regime-dependant bias correction

4. Add 5-6 new WRF members

5. Improve IC perturbation scheme

6. Perturb land-surface states

Kamal Puri

At BMRC, in addition to the global EPS, a regional EPS has been developed based on the Limited Area Prediction System (LAPS) with emphasis on severe weather prediction.

Regional EPS:

- 16 members
- Domain 65S - 17N; 65E - 185E
- Resolution 0.5 degrees x 0.5 degrees, 29 levels
- Integration period 72 hours, once per day from 12Z analyses

Limited Area Ensemble System
at
Bureau of Meteorology Research Centre –Australia
Kamal Puri

- **Initial perturbations: random perturbations of observations** during data assimilation; if a tropical cyclone is present then the TC bogus data is perturbed by displacing the cyclone, reducing or increasing the size and drift velocity of the cyclone

- **Stochastic physics,** following the ECMWF approach is used. Also half the members use the CAPE closure for convection and the other half use moist convergence

- Boundary conditions are obtained from the global EPS in order to allow for uncertainties at the boundaries

SRNWP-PEPS

a regional multi-model ensemble in Europe

www.dwd.de/PEPS

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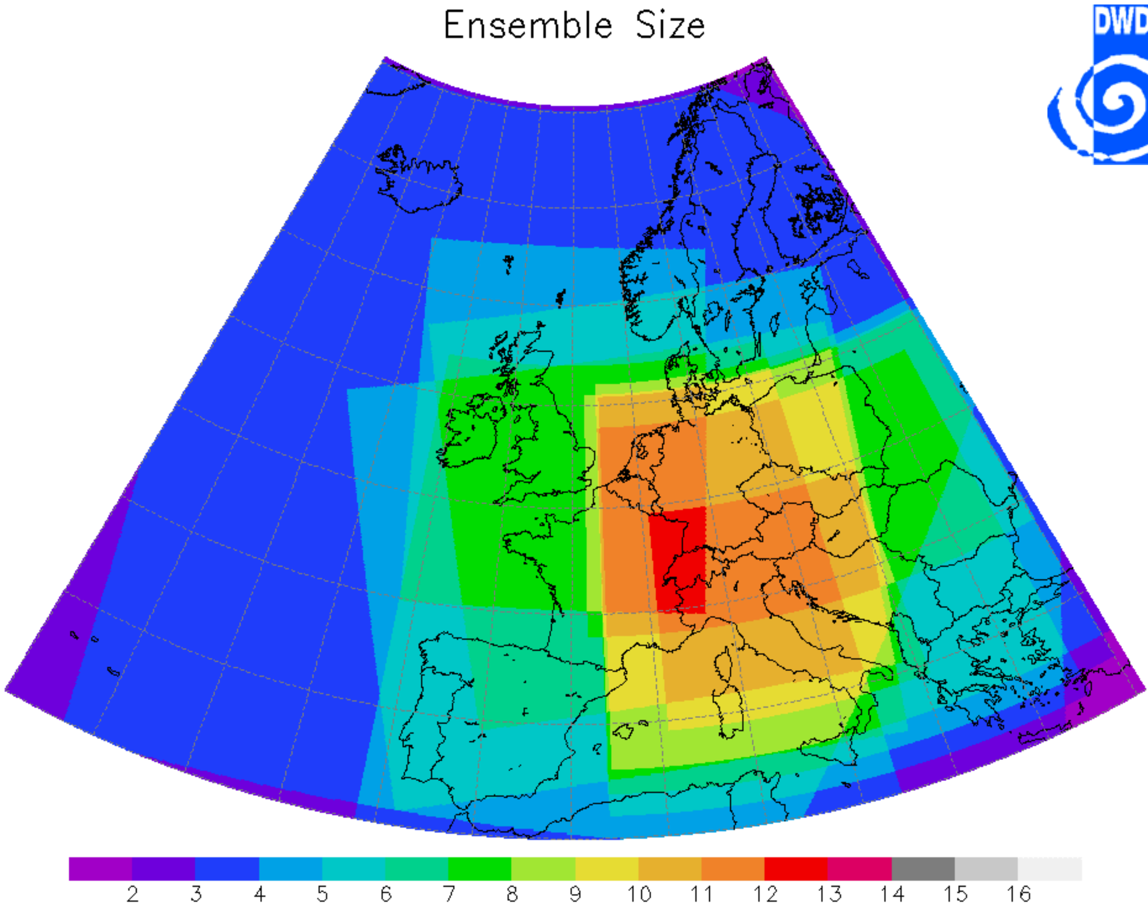
January 2005: 19 members

(1)	Austria	ALADIN-LACE (8 km)	ARPEGE
(2)	Czech Repub	ALADIN-LACE (9 km)	ARPEGE
(3)	Croatia	ALADIN-LACE (9 km)	ARPEGE
(4)	Hungary	ALADIN-LACE (11 km)	ARPEGE
(5)	Slovakia	ALADIN-LACE (11 km)	ARPEGE
(6)	France	ALADIN (11 km)	ARPEGE
(7)	Belgium	ALADIN (15 km)	ARPEGE
(8)	Slovenia	ALADIN (9.5 km)	ARPEGE
(9)	UK	UM-LAM (12 km)	UM-global
(10)	UK	UM-EU (20 km)	UM-global
(11)	Denmark	HIRLAM (16 km)	ECMWF
(12)	Finland	HIRLAM (22km)	ECMWF
(13)	Netherlands	HIRLAM (22 km)	ECMWF
(14)	Spain	HRLAM (22 km)	ECMWF
(15)	Ireland	HRLAM (16 km)	ECMWF
(16)	Norway	HRLAM (11 km)	ECMWF
(17)	Switzerland	aLMo (7 km)	ECMWF
(18)	Italy	LM	GME
(19)	Germany	LM (7 km)	GME

Ensemble Generation

PEPS grid with a grid spacing of 0.0625° (~7 km) covering Europe



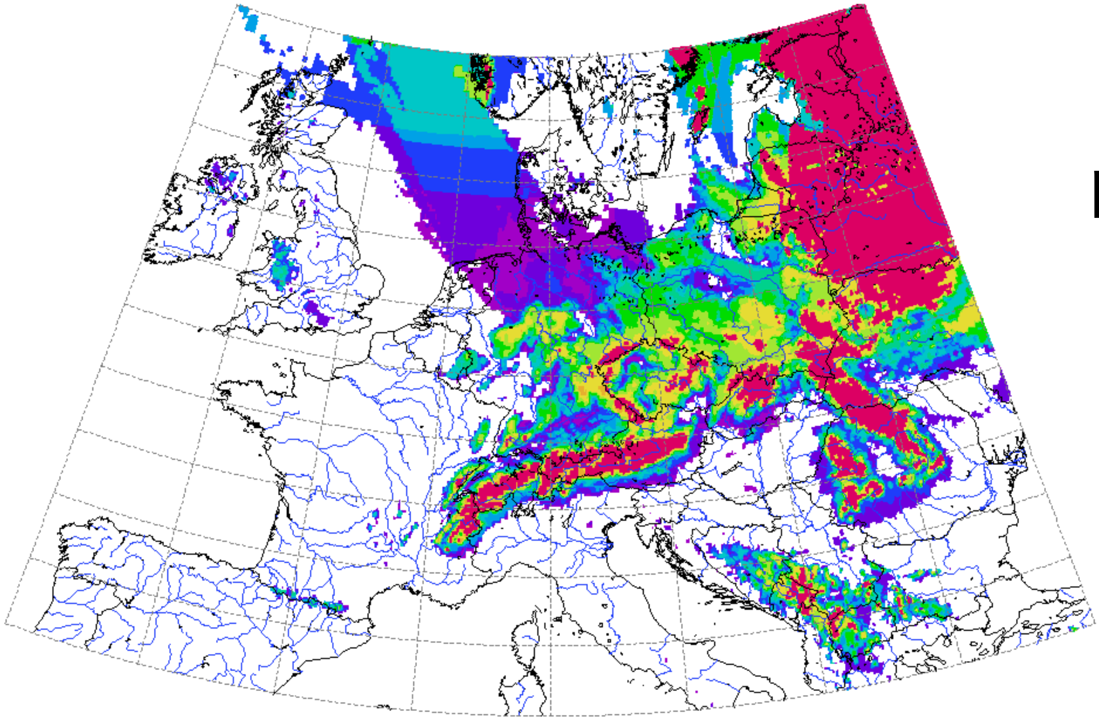
Method

$$P_i(x > T) = \frac{Number\ of\ forecasts\ x\ exceeding\ T\ at\ i}{N_i}$$

where N_i is the total number of forecasts at grid point i and T is a threshold

The ensemble size depends on location and every PEPS grid point has its own probability distribution

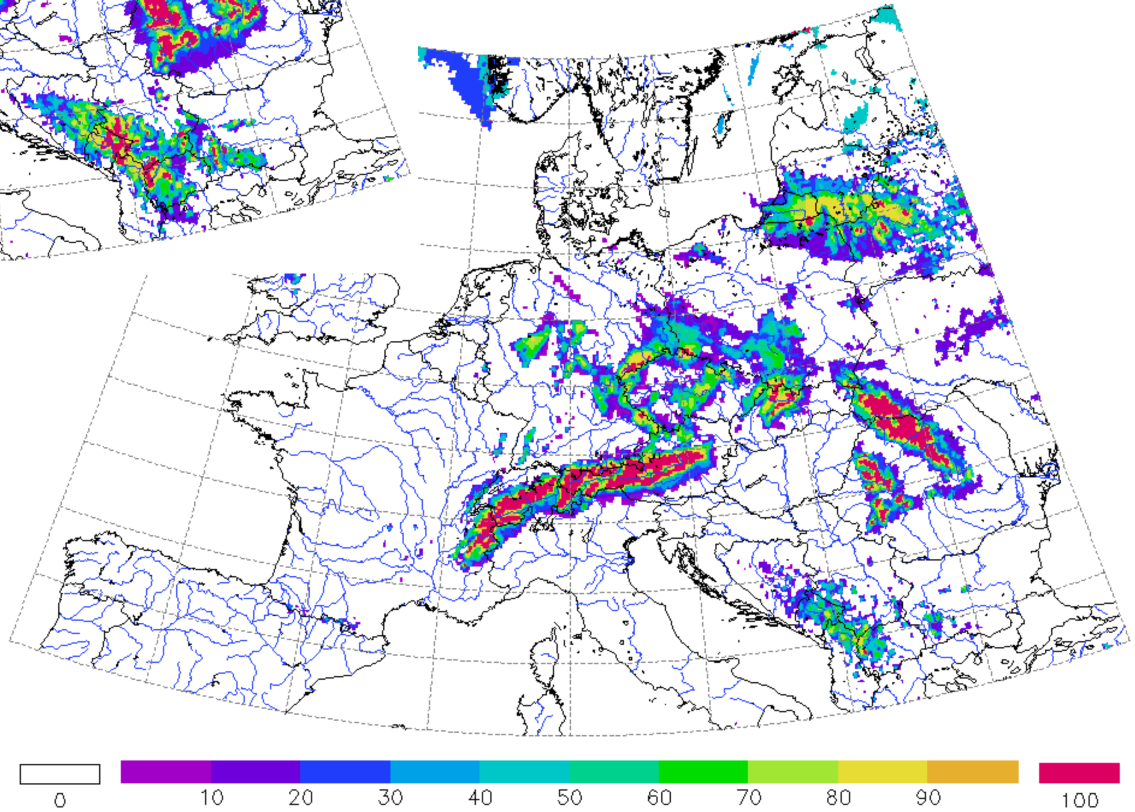
probability of 24 h total snow > 1 cm [%]



probability forecasts

21/01/2005 00 UTC +06...30

24 h total snow > 5 cm [%]



The SRNWP-PEPS project

SRNWP-PEPS runs operationally since December 2004
(Distribution of forecasts to the contributing NWS)

SRNWP-PEPS workshop 6th April 2005, ARPA-SIM, Italy

- **products**
- **ensemble calibration**
- **validation**
- **further developement**
- **status and rights of use**

International projects which use or may use SRNWP-PEPS forecasts

- **EURORISK Prev.I.EW windstorms workpackage**
- **MAP D-Phase (Mesoscale Alpine Program)**

COSMO-LEPS

C.Marsigli, A.Montani, F.Nerozzi, T.Paccagnella, S.Tibaldi

ARPA-SIM

with the support of:
ECMWF (Umberto Modigliani) and
COSMO partners

The methodology was originally developed in cooperation with R.Buizza and F.Molteni. Thanks also to H. Hersbach.

2 related ECMWF Special Projects ongoing:

- SPITLAEF in cooperation with UGM
- SPCOLEPS in cooperation with Meteo-Swiss

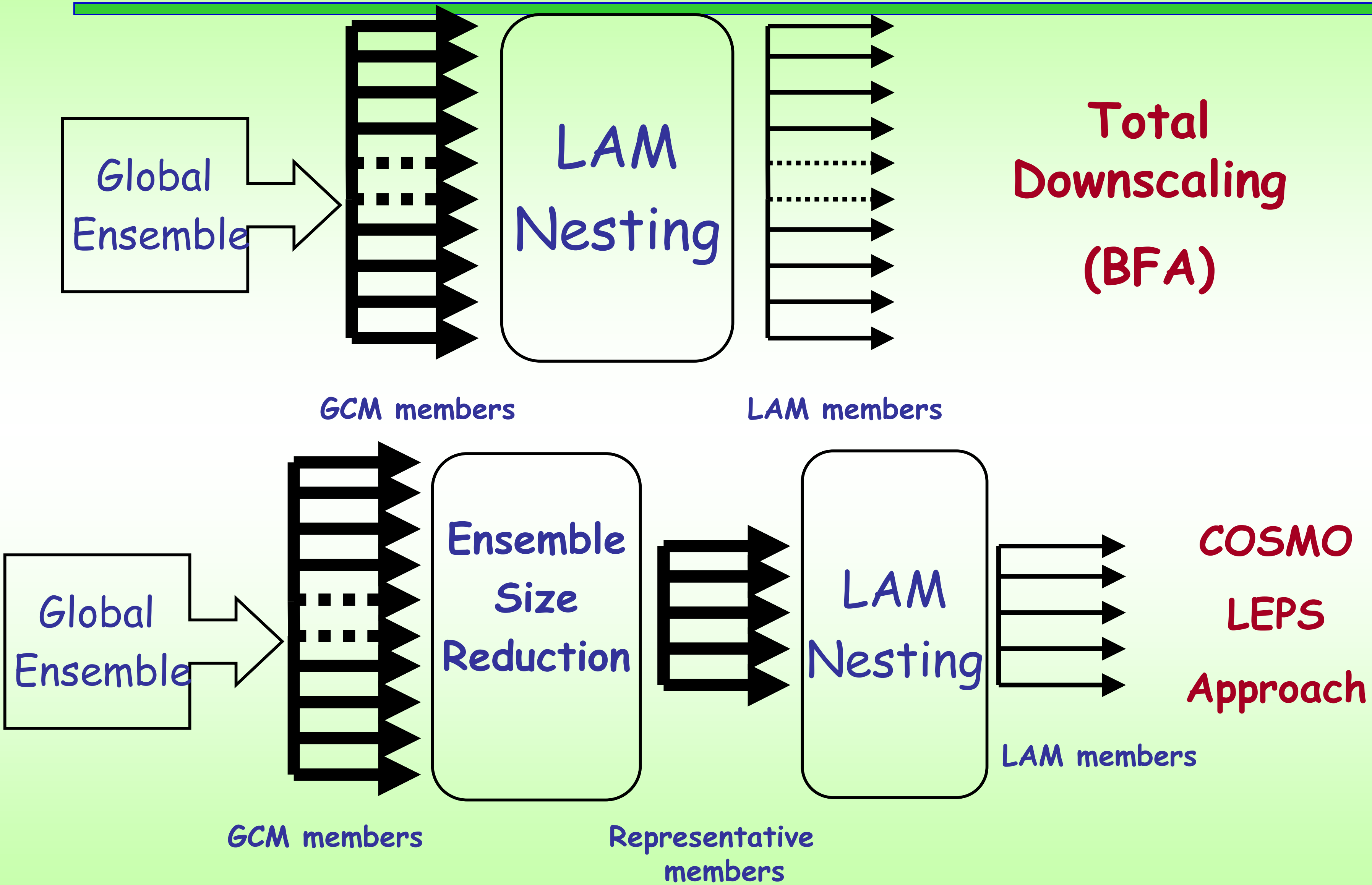
COSMO-LEPS

COSMO-LEPS has been designed

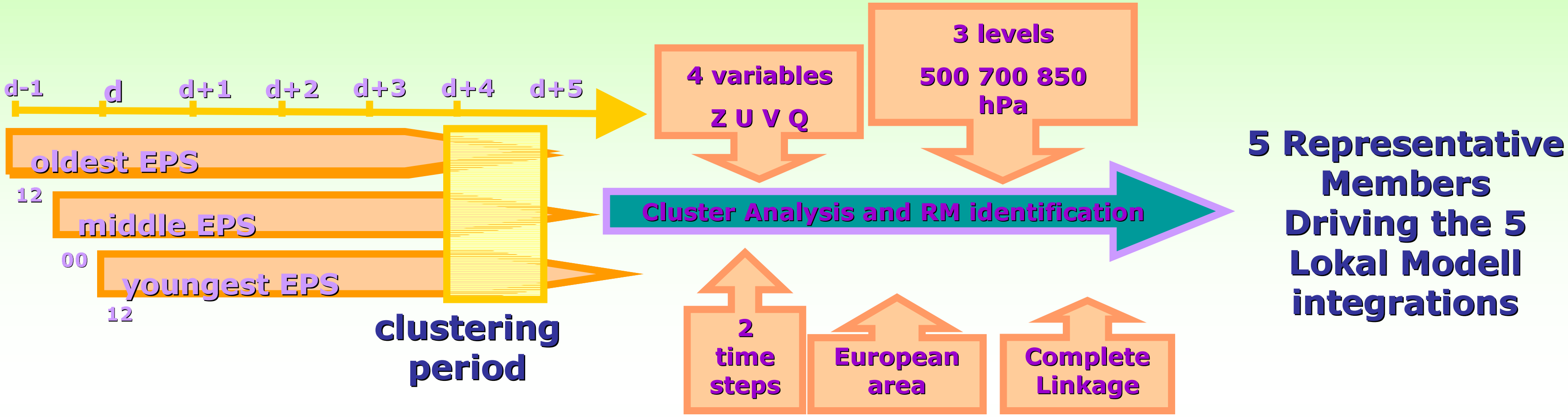
- to improve forecasting capability of extreme events (mainly precipitation) with probabilistic support

- in the Late- Short (48hr) ÷ Early Medium (120hr) range

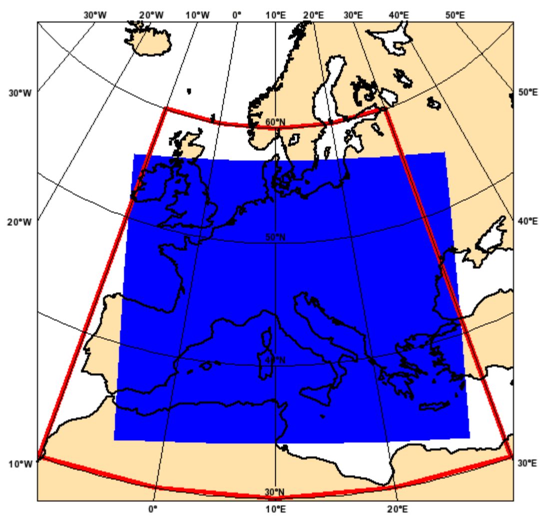
Downscaling



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

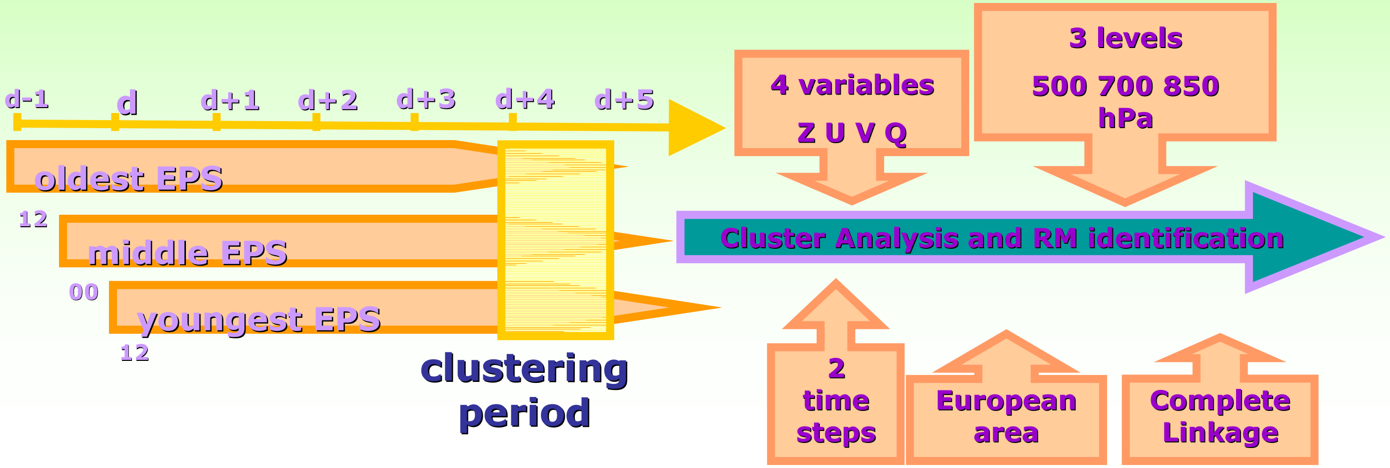


COSMO-LEPS clustering area



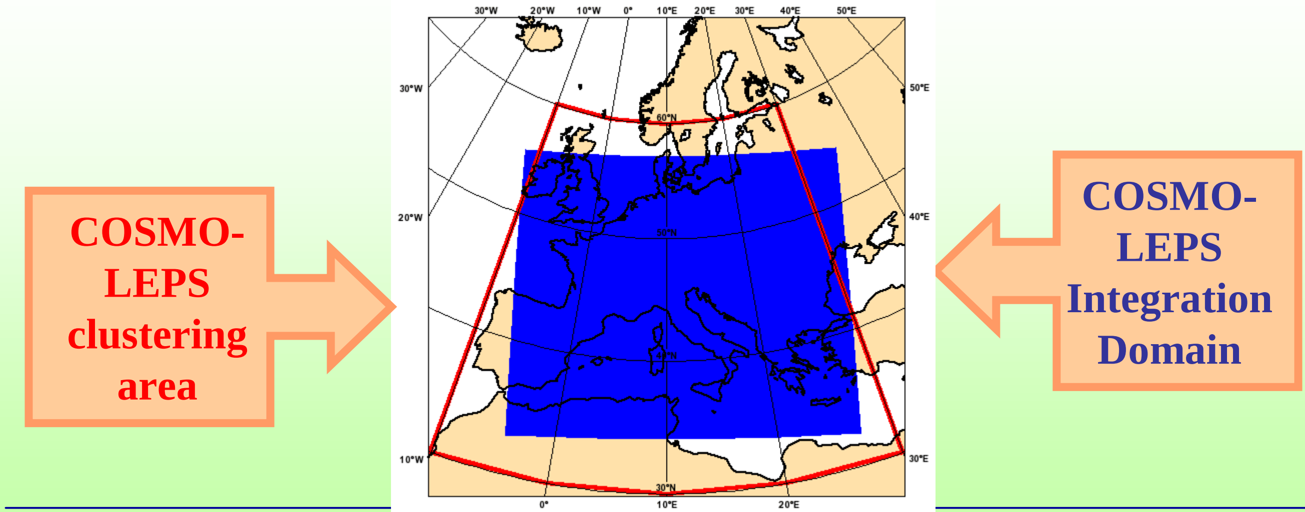
COSMO-LEPS Integration Domain

The COSMO-LEPS suite @ ECMWF since June 2004



10 Representative Members Driving the 10 Lokal Modell integrations

Employing Tiedtke or Kain-Fristch scheme randomly



- Suite running on real time at ECMWF managed by ARPA-SIM;
- Δx ~ 10 km
- Fc length: 120h

COSMO-LEPS

Real time products

Products disseminated to the COSMO–countries

probabilistic products:

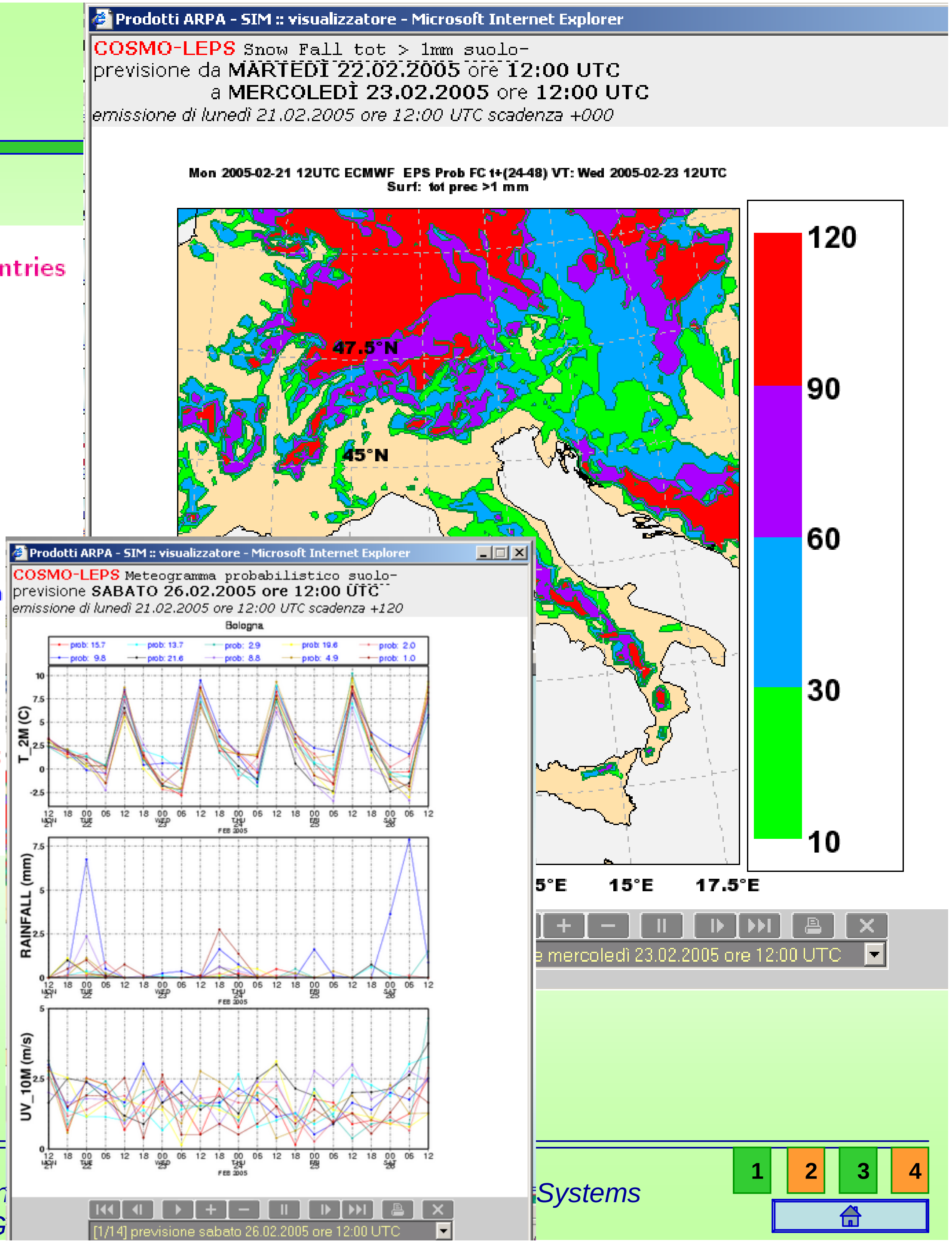
- 24h rainfall exceeding 20, 50, 100, 150 mm;
- 72h rainfall exceeding 50, 100, 150, 250 mm;
- 24h snowfall exceeding 1, 5, 10, 20 "**cm**";
- $UVmax_{10m}$ in 24h above 10, 15, 20, 25 m/s;
- $Tmax_{2m}$ in 24h above 20, 30, 35, 40 ^{o}C;
- $Tmin_{2m}$ in 24h below -10, -5, 0, +5 ^{o}C;
- min height of 0 ^{o}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.

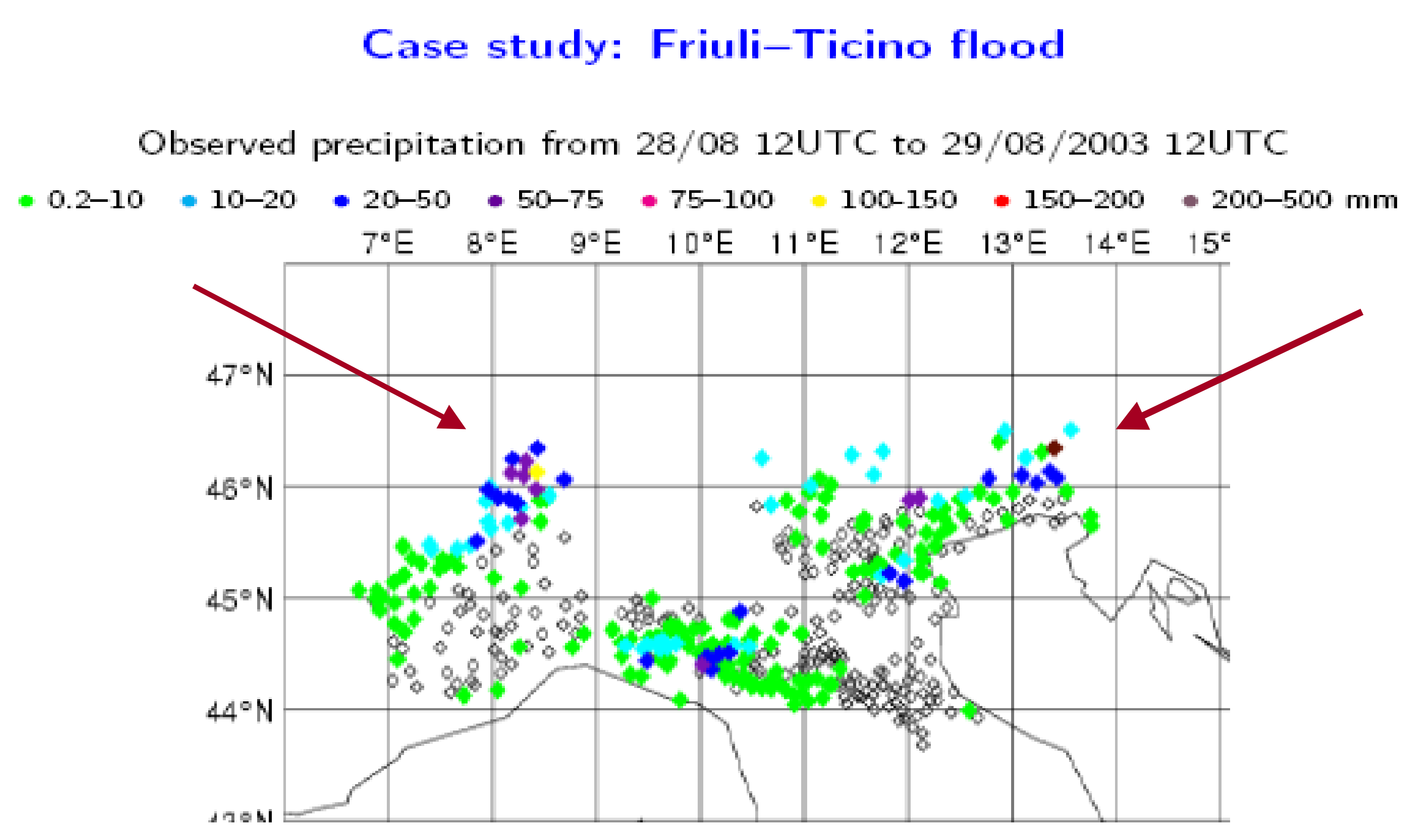


Operational COSMO-LEPS ~ Operational EPS

S.E. 153
5 RMs

"Friuli case"

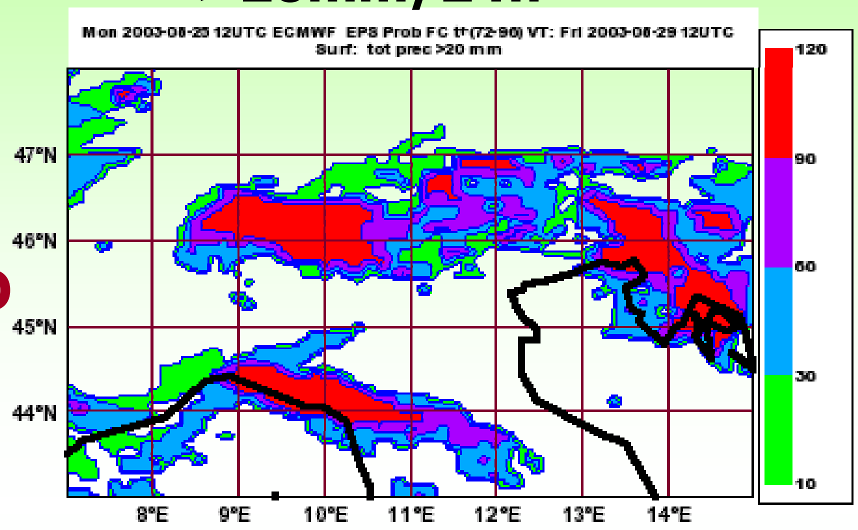
The youngest
EPS

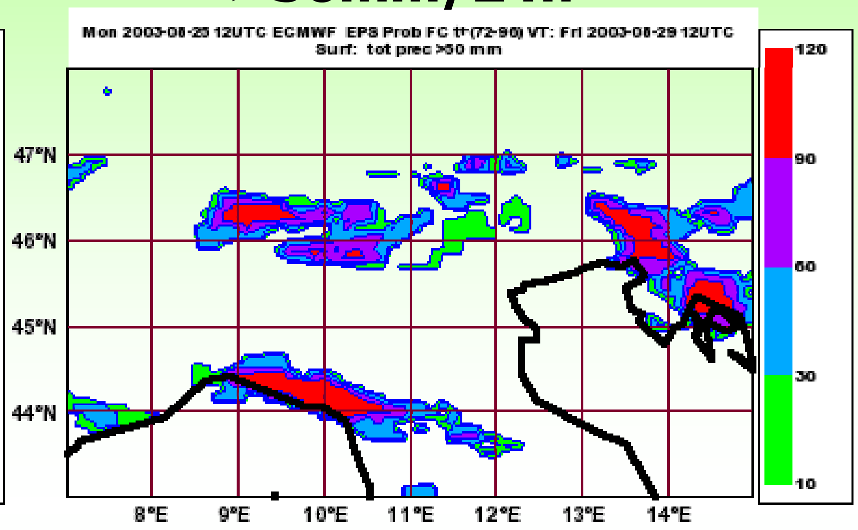


Operational COSMO-LEPS ~Operational EPS : Friuli case probability maps – fc. range +96

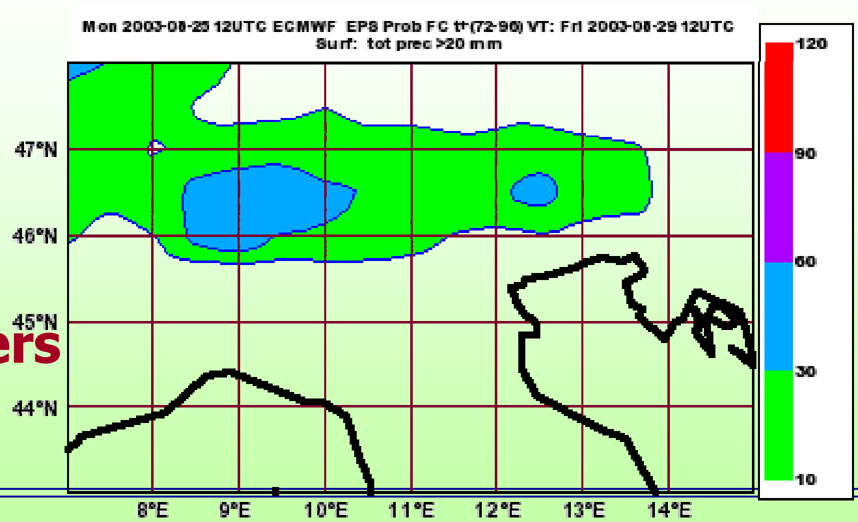
>20mm/24h **>50mm/24h**

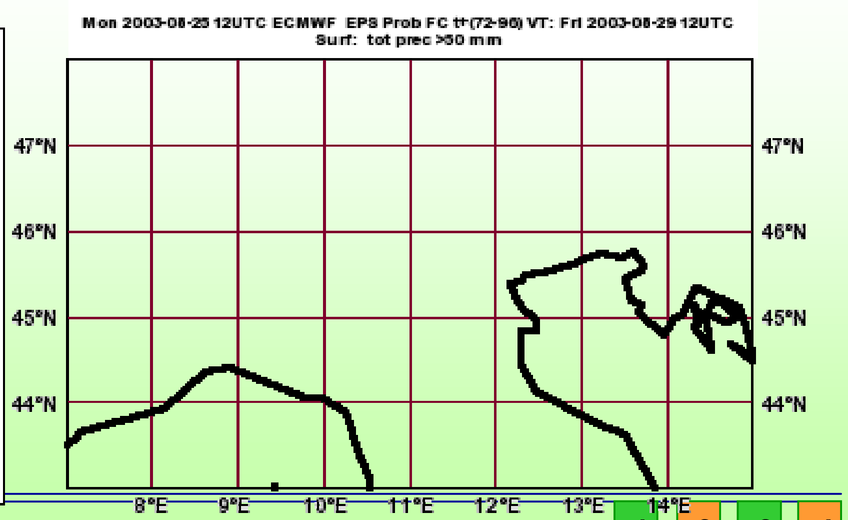
COSMO LEPS





EPS 51 members





COSMO-LEPS

past and ongoing activities

EVALUATION OF THE METHODOLOGY
With respect to:

- ENSEMBLE SIZE REDUCTION
- SUPER-ENSEMBLE SIZE
- CLU… reas) (ongoing)
- IM… OF…
- AD… AL…

Just something will be shown !!!

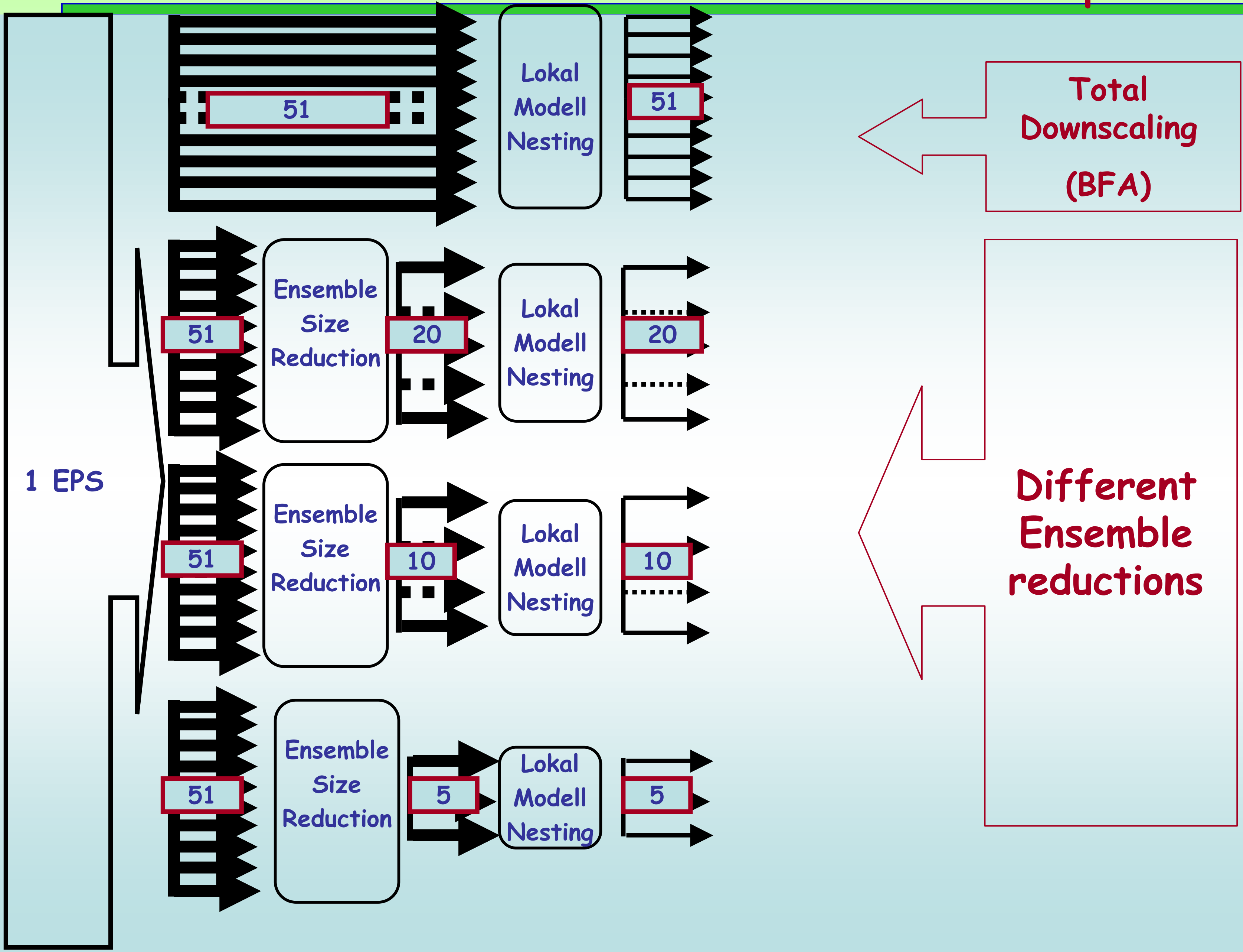
C… TE… S

- A… DE… A…
- EV… L… TE…
- EVALUATED OVER DIFFERENT GEOGRAPH… REGIONS
- EVALUATED FOR TWO DIFFERENT CONV… ON SCHEMES

SUBJECTIVE VERIFICATION OF COSMO-LEPS

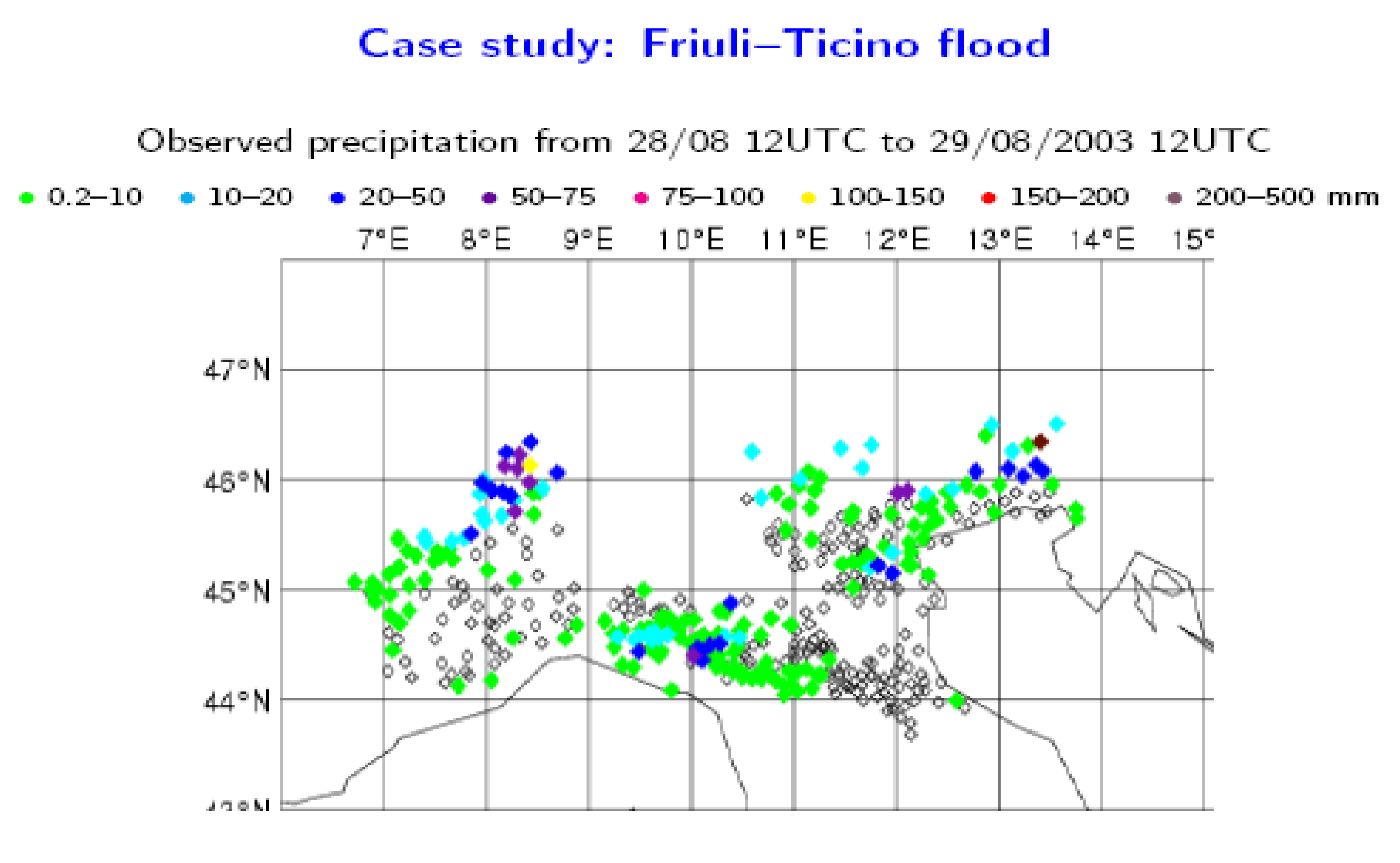
- FORECASTERS OF SOME COSMO PARTNERS

ENSEMBLE SIZE REDUCTION:
Friuli and Piedmont case studies set-up



ENSEMBLE SIZE REDUCTION

IMPACT EVALUATED ON CASE STUDIES (1)



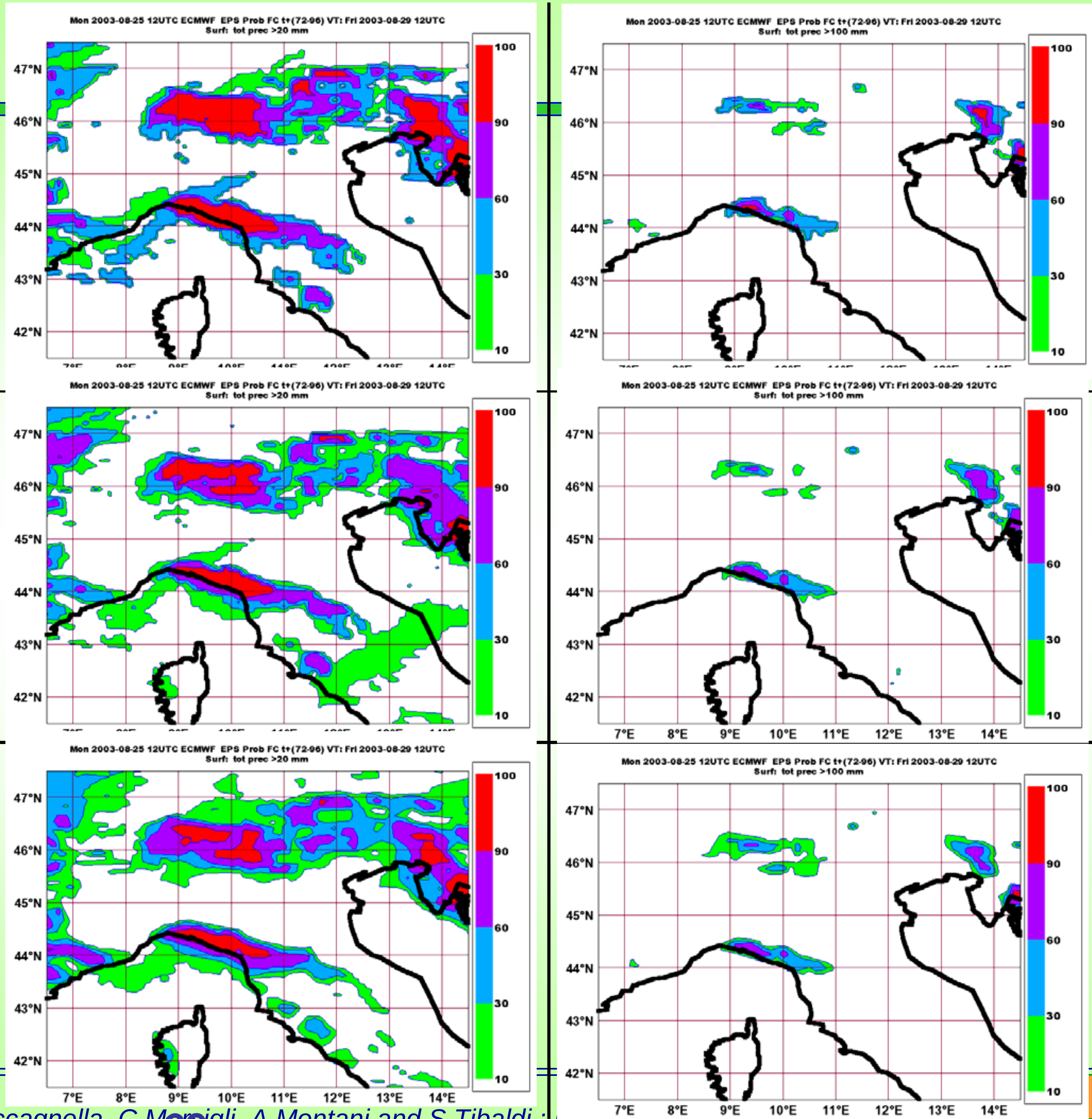
2003082512 Friuli

(+72-+96)

5 RMs

10 RMs

All 51



20 mm

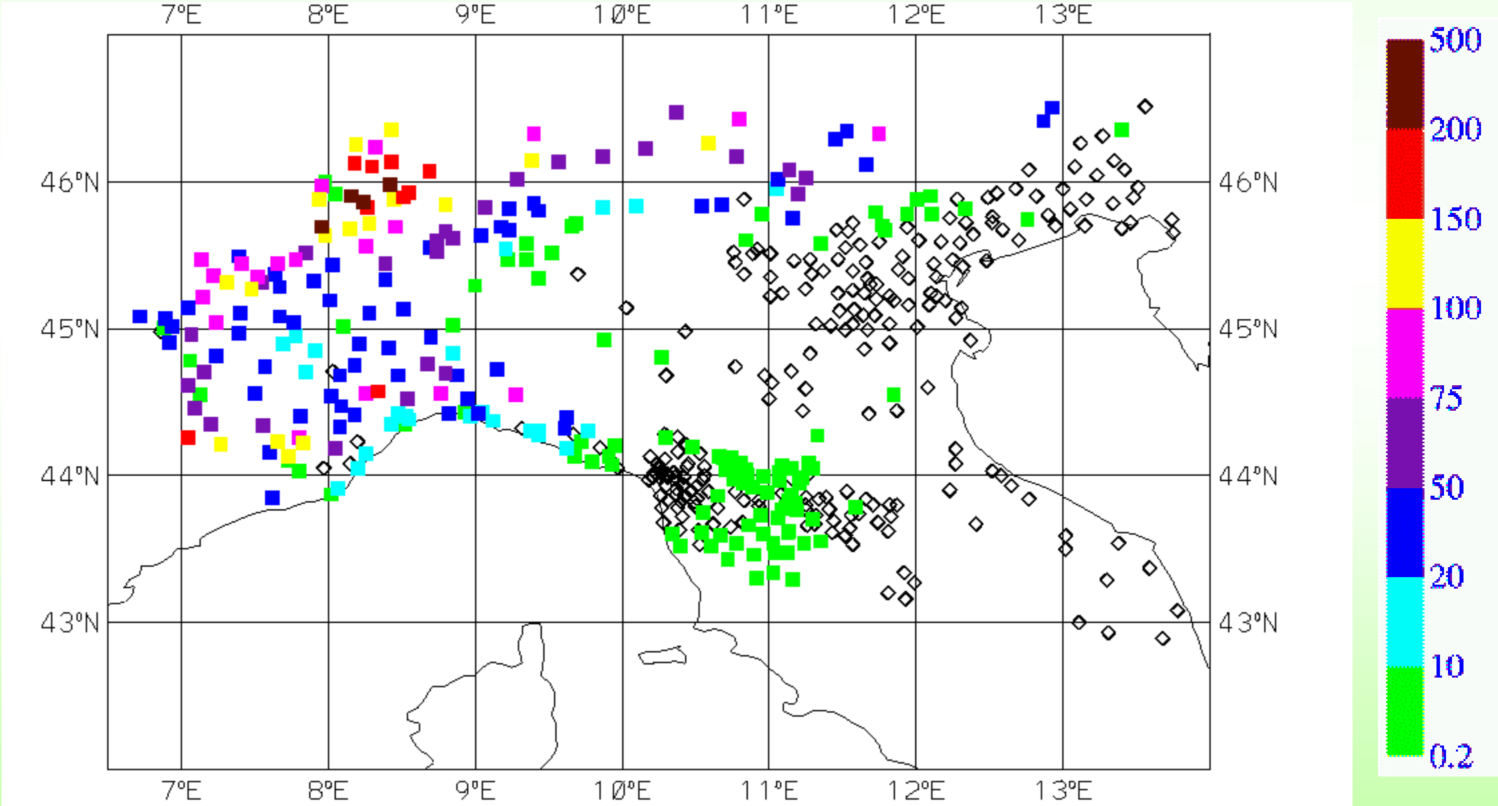
100 mm

ENSEMBLE SIZE REDUCTION

IMPACT EVALUATED ON CASE STUDIES (2)

Observed precipitation between 15-11-2002 12UTC and 16-11-2002 12 UTC

Piedmont case

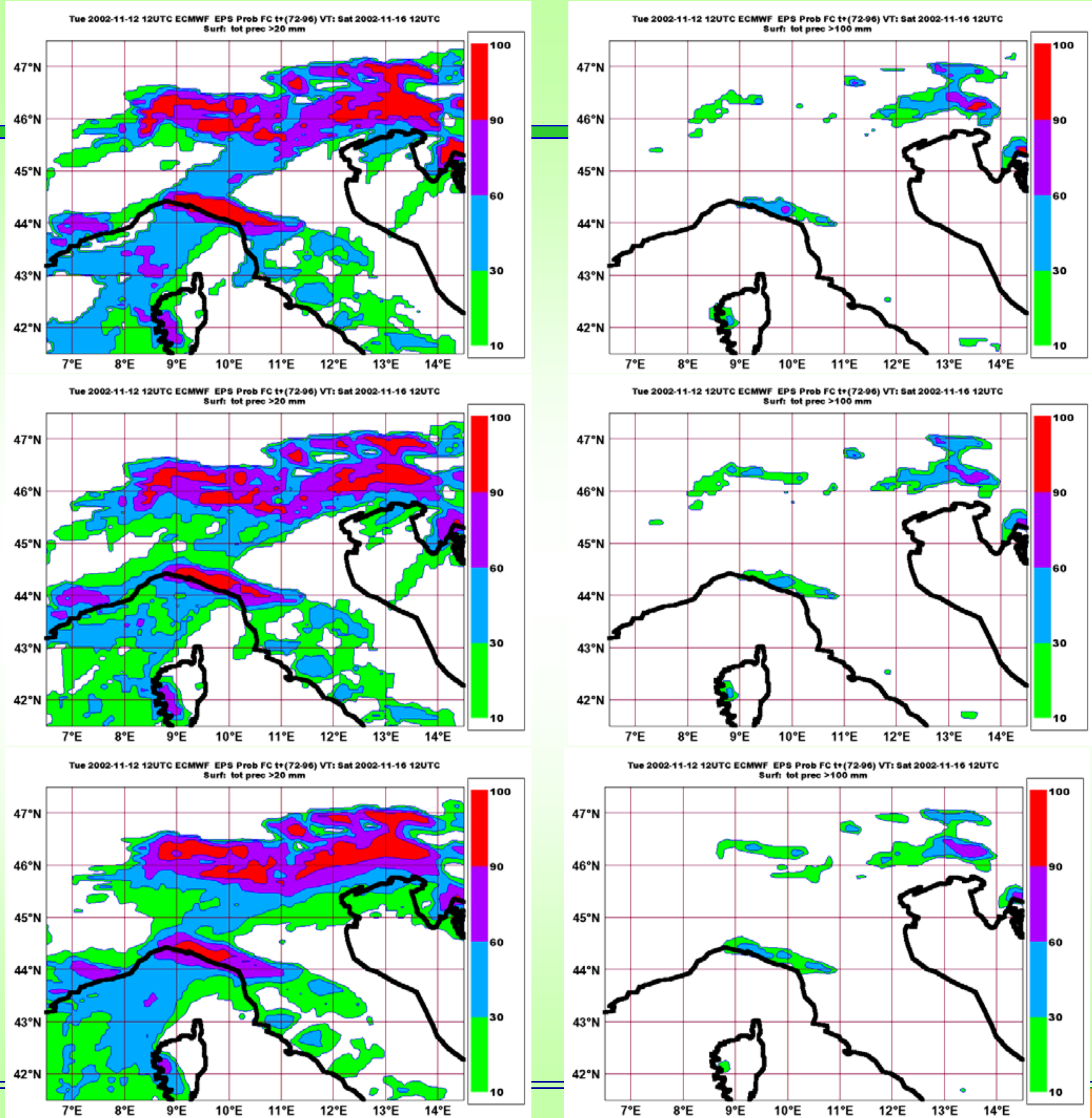


2002111212
Piedmont

5 RMs

10 RMs

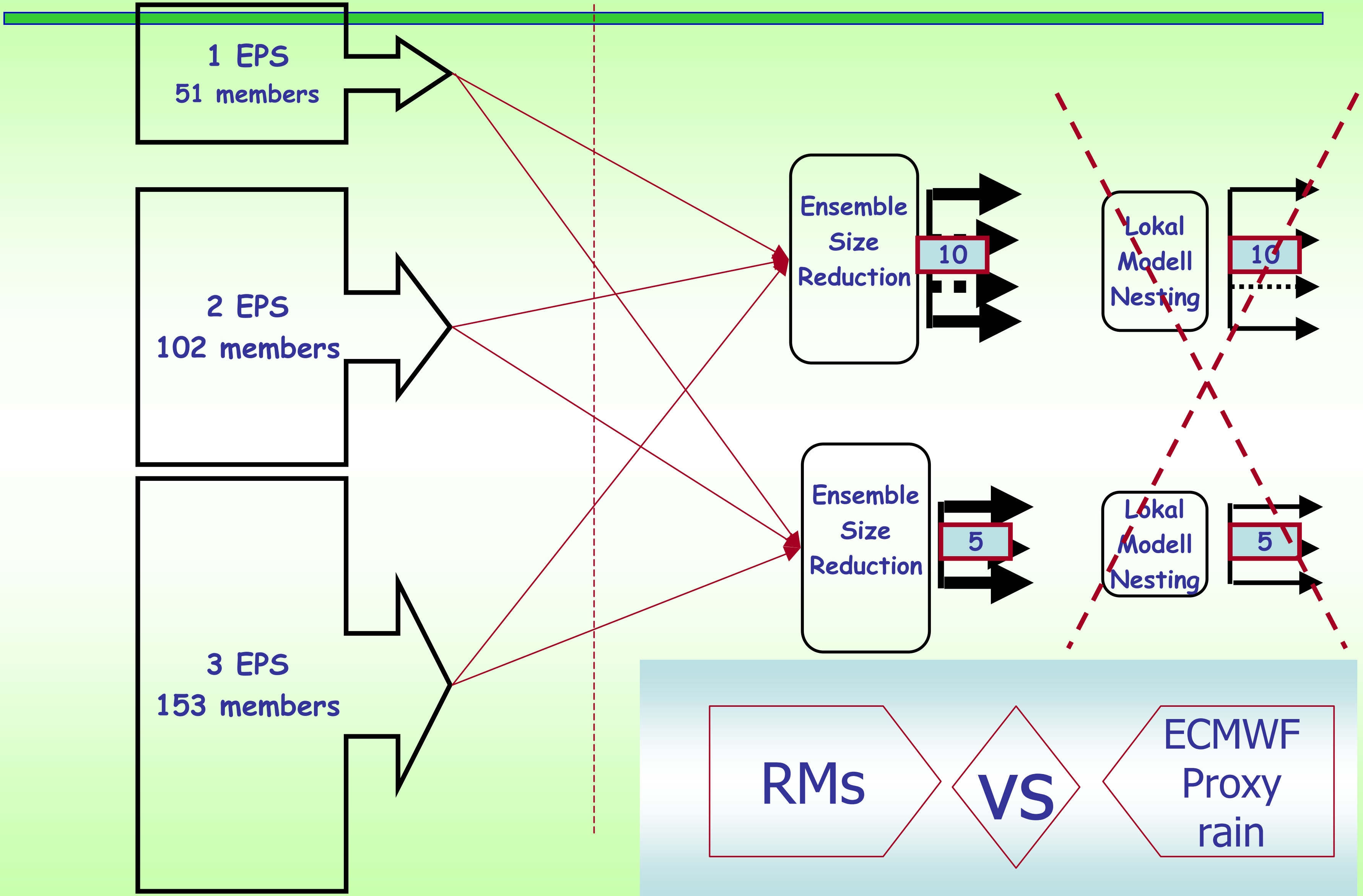
All 51



20 mm

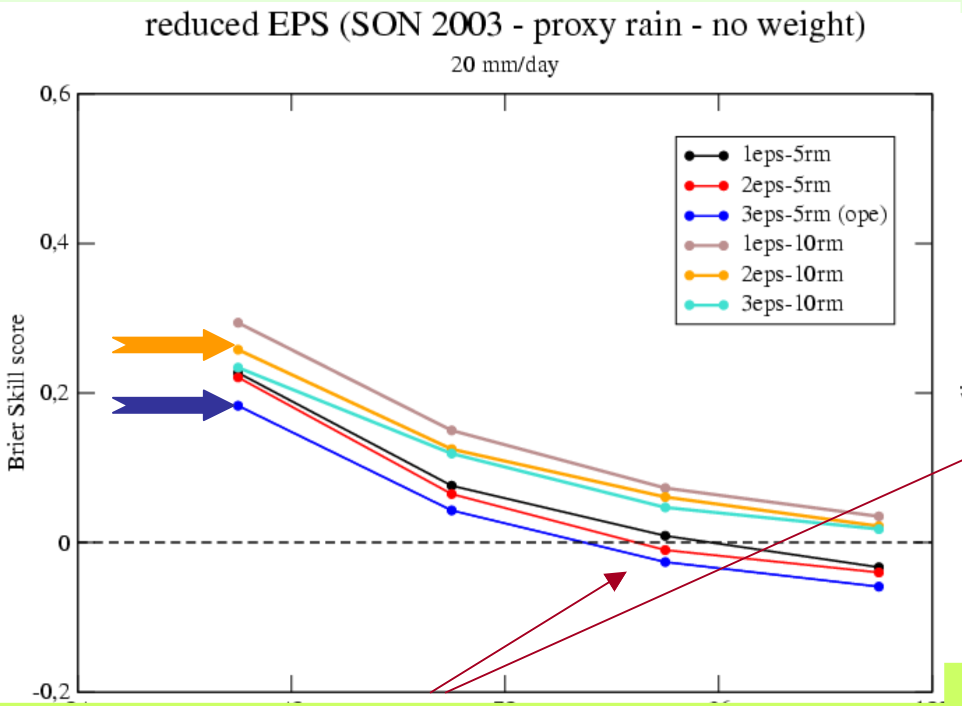
150 mm

EVALUATION OF
S.E. SIZE & ENSEMBLE SIZE REDUCTION

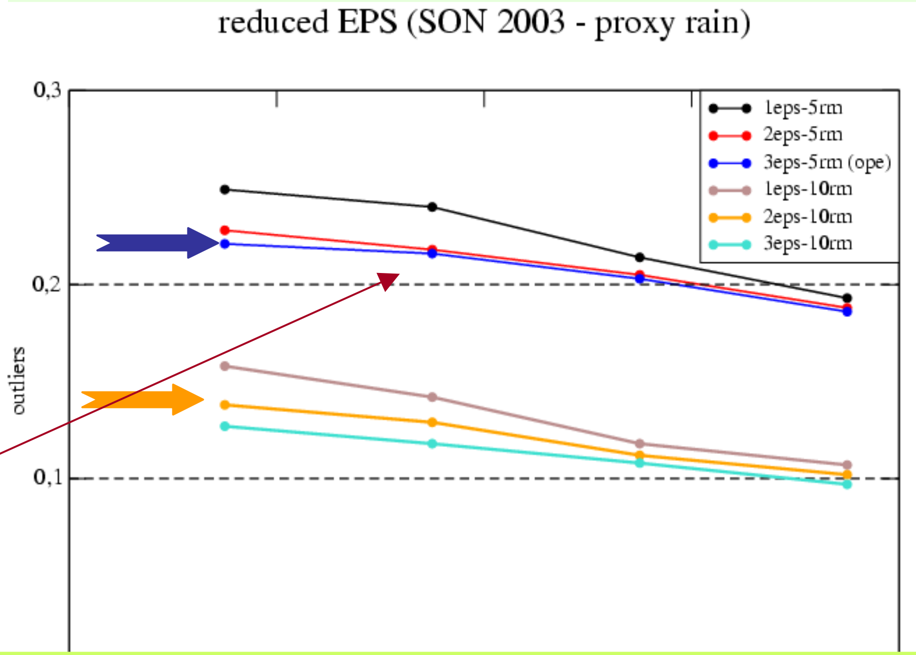


EVALUATION OF
S.E. SIZE & ENSEMBLE SIZE REDUCTION (2)

BSS



outliers



- Regarding the 5-RM ensembles results would seem to suggest that the use of just two EPS in the super-ensemble can be a good compromise, permitting to decrease the percentage of outliers significantly with respect of using just 1 EPS but leading only to a small decrease of the skill.

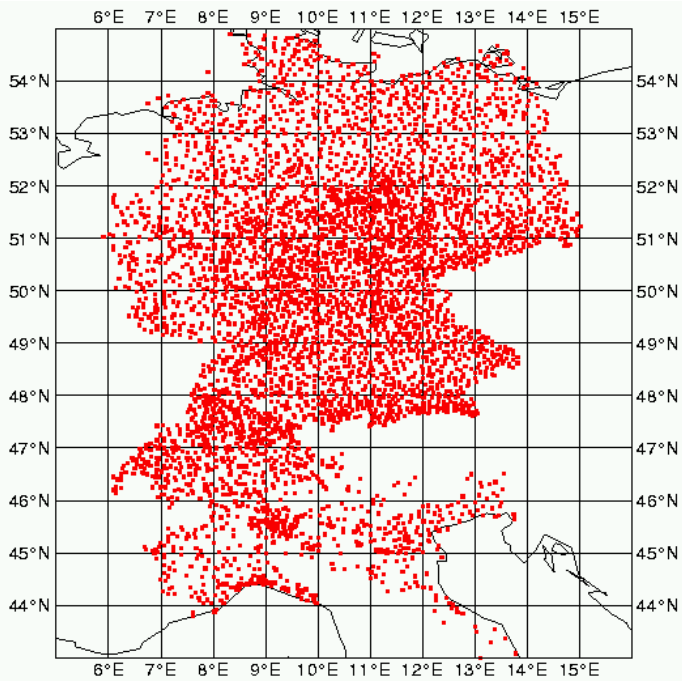
- Regarding the impact of the ensemble size, the difference between each 5-member ensemble and the correspondent 10-member ensemble is remarkable.The impact of doubling the ensemble size is almost the same for every configuration and is larger than impact of changing the number of EPSs on which the Cluster Analysis is performed (2 or 3).

OBJECTIVE VERIFICATION OF COSMO-LEPS

In the last period the verification package is being developed keeping into account two measure of precipitation:

- the cumulative volume of water deployed over a specific region
- the rainfall peaks which occur within this region

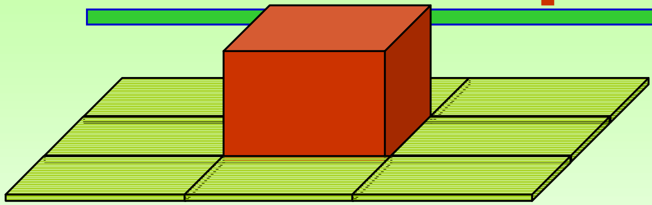
COSMO observations



Verification package includes the traditional probabilistic scores:

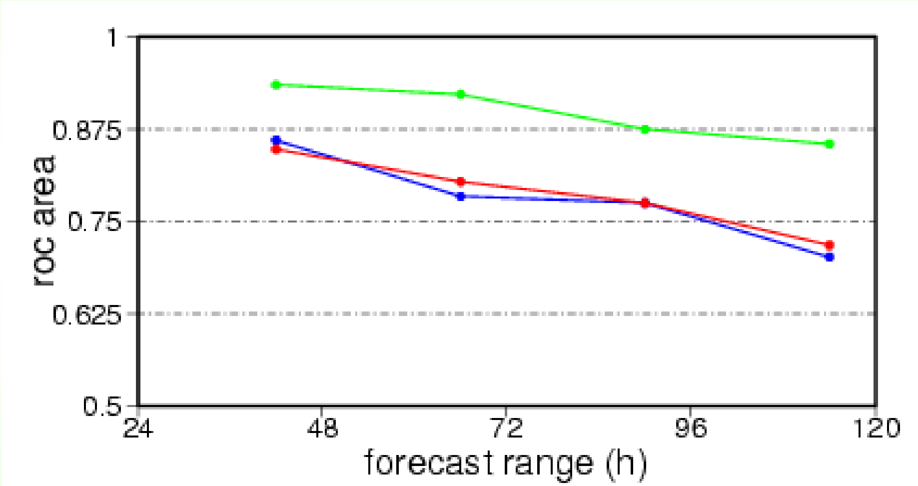
- •Brier Skill Score (Wilks, 1995)
- •ROC area (Mason and Graham, 1999)
- •Cost-loss Curve (Richardson, 2000)
- •Percentage of Outliers (Buizza, 1997)

Precipitation: average on 1.5 x 1.5 boxes

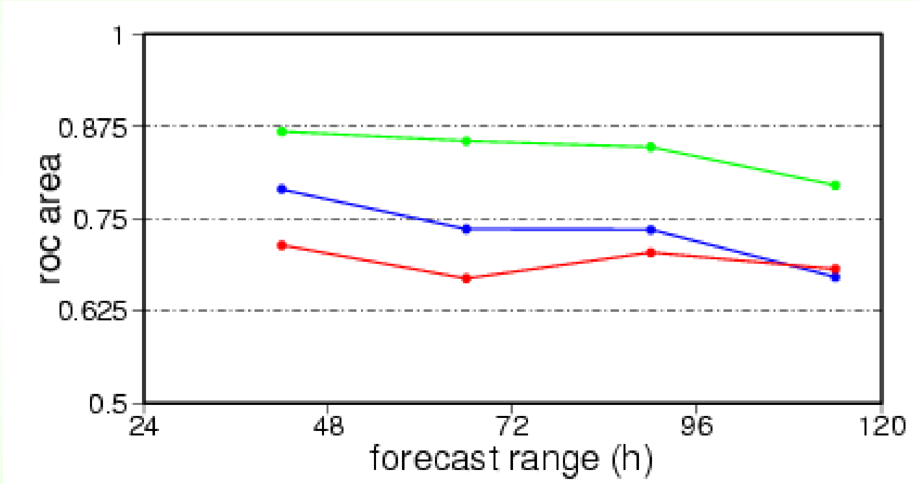


ROC area

tp > 10mm/24h



tp > 20mm/24h



COSMO-LEPS (blue)

5-MEMBER EPS (red)

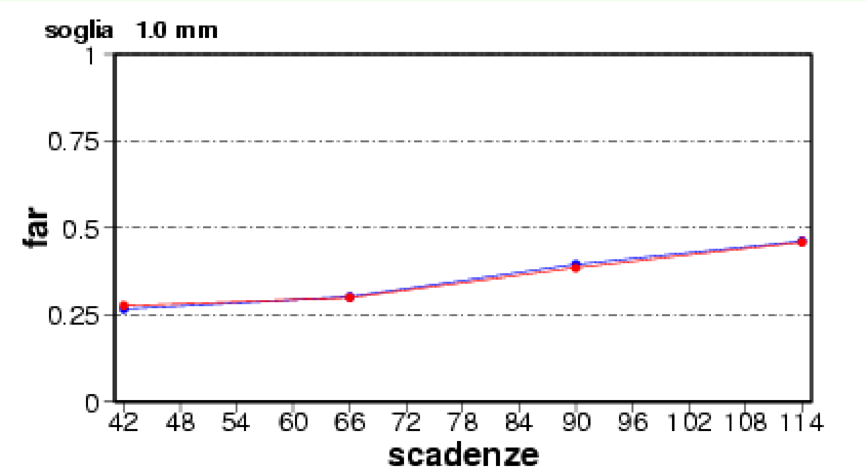
51-MEMBER EPS (green)

- As regards AVERAGE precipitation above these two threshols EPS is the best.
- Worsening due to the ensemble reduction
- Positive impact of LM downscaling

COSMO-LEPS vs ECMWF 5 RM

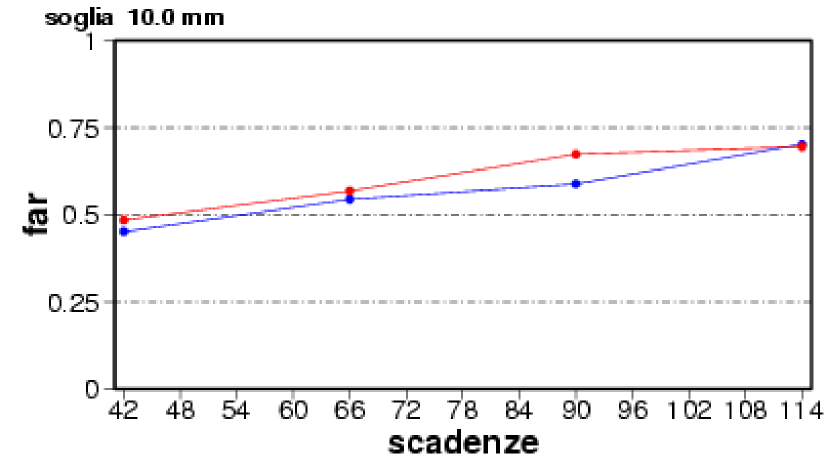
detscores average on 1.5 x 1.5 boxes

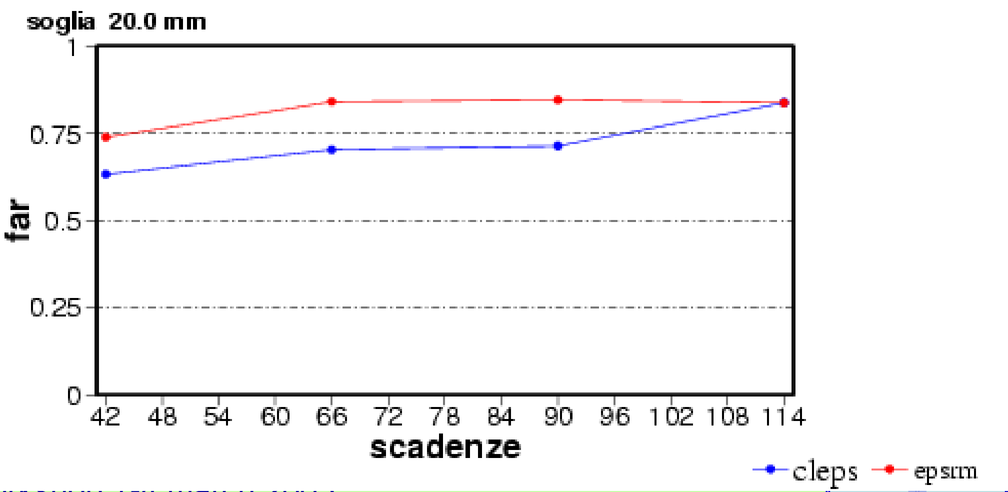
false alarm rate



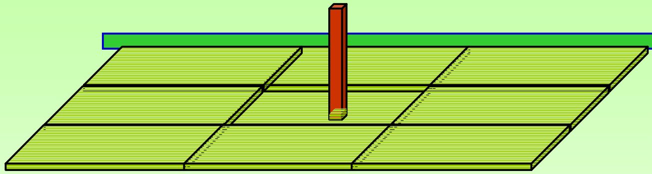
		observed	
		yes	no
forecast	yes	a	b
	no	c	d

$$FAR = \frac{b}{a+b}$$





maxima on 1.5 x 1.5 boxes



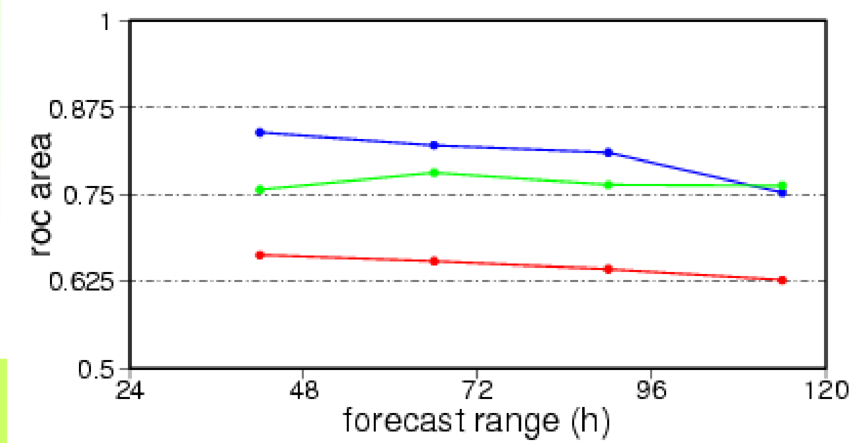
ROC area

COSMO-LEPS

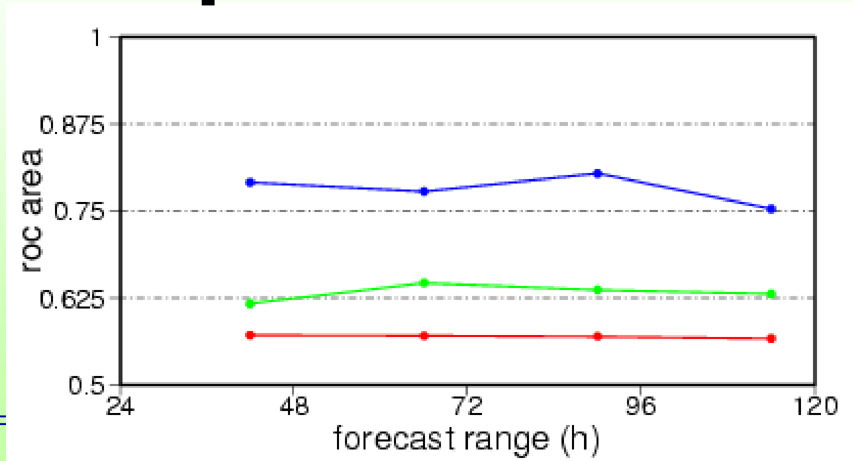
5-MEMBER EPS

51-MEMBER EPS

tp > 20mm/24h



tp > 50mm/24h



- **COSMO-LEPS is more skilful in forecasting correctly high precipitation values over a rather large area.**

Number of occurrences (about 600 and 150 for the 20 and 50 mm thresholds, respectively).

Some comments

- Positive impact of COSMO-LEPS with respect to EPS in forecasting precipitation maxima
- Good performance of the ensemble size reduction technique (on case studies)
- The use of two EPS and 10 Representative Members seems to be the best configuration

And (not shown):

- No positive impact of the weighting procedure as regards high resolution precipitation
- No relevant impact on using either Tiedke or KF convection scheme
- Differences in the scores computed in different areas (results still too preliminary but supporting the idea that Limited Area Ensemble System set-up should be designed taking into account the specificity of the region)

COSMO-LEPS

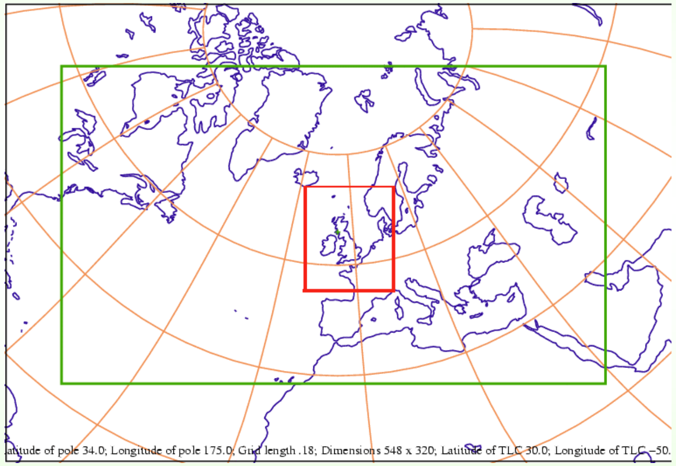
future plans

- COSMO_LEPS suite as "time-critical" application at ECMWF: stronger involvement of ECMWF in the operational management of the system.
- Participation to EURORISK-PREVIEW project:
  - integration domain will be enlarged to include northern Europe
  - Clustering on different areas will be tested to better focus on different scenarios (Central-North & Central-Mediterranean)
- Partecipation to MAP D-PHASE project:
  - Further downscaling (around 2 km h.r.) on specific areas where severe events are likely to occur (→ methodology to be evaluated also for the TIGGE); introduction of model perturbations to reveal uncertainty on smaller scales
- Clustering on different time ranges and different variables will be tested
- Verification will be further developed → more probabilistic approach

Met Office

Outline of LAMEPS Plans

- Nested Ensemble based on European Mesoscale model
  - 24km grid-length
  - Around 16 members
  - Run to T+72
- ETKF global and LAM (12 hours cycle)
- Perturbed physics parameters
  - research into stochastic physics
    - » Stochastic Convective Vorticity (SCV)
    - » Random Parameters (RP)
- Integrated with observation targeting
- Multi-model ensemble through collaboration

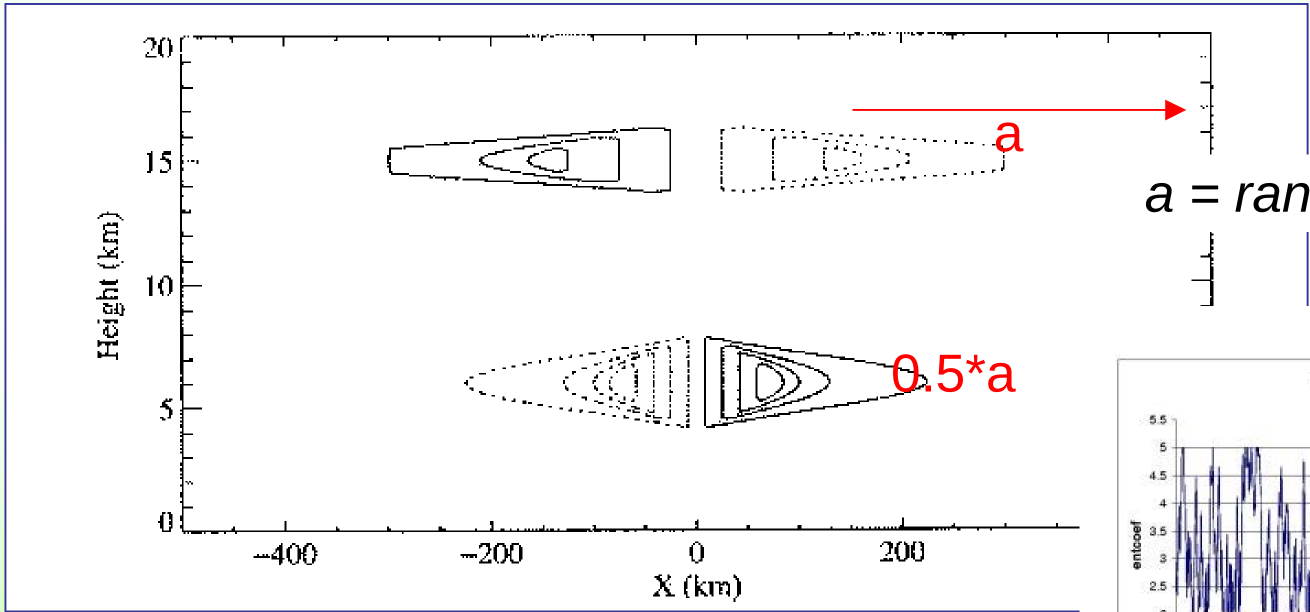


UK LAMEPS

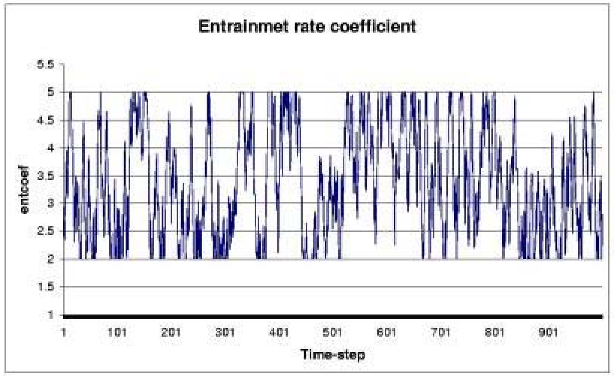
Ken Mylne

Stochastic Convective Vorticity (SCV)

The SCV represent potential vorticity dipoles associated with MCSs



a = random f(CAPE)*



Scale of vortices perturbed randomly

These parameters are treated as stochastic variables, and, each 3-h, their values are calculated using a first-order auto regression model:

$$P_t=\mu+r(P_{t-1}-\mu)+\varepsilon \quad \text{with } r = 0.95$$

Parameter	Scheme	min/std/Max
Entraiment rate	CONVECTION	2 / 3 / 5
Cape timescale	CONVECTION	30 / 30 / 120
Rhcrit	LRG. S. CLOUD	0.6 / 0.8 / 0.9
Cloud to rain (land)	LRG. S. CLOUD	1E-4/8E-4/1E-3
Cloud to rain (sea)	LRG. S. CLOUD	5E-5/2E-4/5E-4
Ice fall	LRG. S. CLOUD	17 / 25.2 / 33
Flux profile param.	BOUNDARY L.	5 / 10 / 20
Neutral mixing length	BOUNDARY L.	0.05 / 0.15 / 0.5
Gravity wave const.	GRAVITY W.D.	1E-4/7E-4/7.5E-4
Froude number	GRAVITY W.D.	2 / 2 / 4

Stochastic Physics Summary

- **Substantial impact on surface variables** in the short-range (72-h):
  - PMSL (up to 5 hPa)
  - T2M (up to 9°C)
  - PREC (up to 40% of control values)

- **RP** is the largest contributor to the impacts

- Flow dependency: seeding perturbations on large scale and extracting energy from background flow

- Neutral impact on climate, but still able to have a substantial impact on large-scale features on seasonal time-scales

Project Progress

- **Milestone:** Implementation of demonstration ensemble based on NAE model for assessment by forecasters (August 2005)
  - Global ensemble near completion
  - NAE has been run with perturbed LBCs & ICs
  - Project initiated to oversee operational implementation
    - Global – June 2005
    - NAE – July 2005
  - Product and Verification plan written

- We are on target to meet the milestone

NORLAMEPS

A Limited Area Ensemble Prediction System for Norway

Inger-Lise Frogner, Hilde Haakenstad and Ole Vignes, met.no

TEPS:

TEPS (at 12 UTC) is running at ECMWF daily and uses the operational cycle

- **SV calculations 30 minutes**
- **TEPS ensembles 2 h**

TEPS is the same as EPS from ECMWF

- **Targeted to Northern Europe**
- **Run for 90 hours**
- **20+1 members**

NORLAMEPS

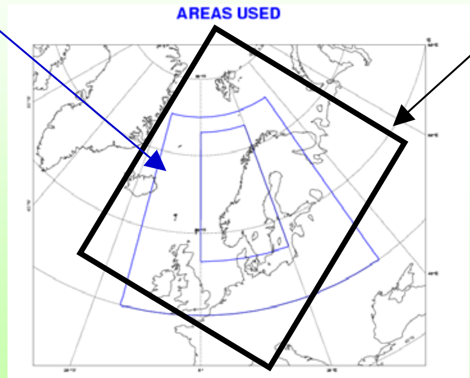
combination of LAMEPS and TEPS. Gives 41 + 1 members

LAMEPS:

Semi oper. from Feb. 2005

- **HIRLAM with 20 + 1 members. Resolution ~20 km / 40 levels**
- **ICs and BCs from TEPS (TL255/L40)**
- **The system is now running at 18UTC (6 hours old IC perturbations from TEPS) and run for 72h, it may be extended to 84h later**

The focus when developing and testing the system has been on "extreme" weather events, especially heavy precipitation.



NORLAMEPS

Inger-Lise Frogner, Hilde Haakenstad and Ole Vignes, met.no

RESULTS

- **Verification over 54 random cases in all four seasons in 2003**
  - EPS good for small precip. rates (10mm/24h)
  - NORLAMEPS better than EPS for larger precip. rates (25 mm/24h)

- **Verification for autumn (14 days). Including an episode of very heavy rain**

  High prec 25 mm/24 hours
  - NORLAMEPS is clearly the best system of the four
  - Improvement of TEPS (20 members) over EPS (50 members)

The results are for the pre-operational NORLAMEPS (i.e. lower resolution (~28km/30 levels) and old physics package) for Norway

NORLAMEPS

Inger-Lise Frogner, Hilde Haakenstad and Ole Vignes, met.no

FUTURE

- Include simple model physics perturbations
- Play with the optimisation time for the singular vectors. See this in connection with the age of the perturbations put into the system (18 h at present time)
- Extend system to more parameters
- Monitor the performance of TEPS vs. EPS, if TEPS performs better → feedback with ECMWF
- Move to higher resolution
- Forcing singular vectors – is it possible and suitable to use it in NORLAMEPS?

Ensemble System:

- 4 models around 0.25 deg in lat/lon and 40 vertical levels.
- 4 boundary conditions.
- 4 last ensembles (16 member ensemble every 6 hours: HH, HH-6, HH-12, HH-18).

- Time-lagged Super-Ensemble of 64 members every 6 hours.
- 72 hours forecast four times a day (00, 06, 12 y 18 UTC).

Multi-Model

- Hirlam.
- HRM, from DWD
- MM5
- Unif. Model UKMO

BCs 4 global determ. models:

- ECMWF.
- UKMO (UK Met Office).
- AVN (NCEP).
- GME, DWD

ROAD MAP

- Research to find best ensemble for the Short Range: March 2003- December 2004.
- Daily run non-operational: February 2005 – September 2005.
- Full operations: September 2005 (upgrade from Cray X1 with 60 PEs to Cray X1e with 120 Pes).

Preliminary results were very promising in terms of correlation between spread and error of the ensemble mean

FUTURE

- Verification software

  (ROC curves, cost-loss curves, …)

  (verification of the probabilistic forecast of precipitation using INM climatological network)

- Post process software (targeting clustering).

- Bayesian model averaging for improvement in calibration and better skill for weighted average.

Limited Area Ensemble Systems

OUTLINE of the presentation

- Introduction
- Operational systems
- Research systems
- Comments and concluding remarks

Long term objectives

- *Find a better way to account for uncertainties of the model, perhaps by introducing parameterizations that are inherently stochastic*
- *Develop a regional ensemble Kalman filter (stretched grid or limited area model)*
- *Compare the singular vector approach and a (still to be built) regional EnKF for regional ensemble predictions*

Some remarks

- Still a lot of fine tuning to perform and variants to test:
  - Try different truncations and time scales for Markov chains
  - Find suitable parameters/tendencies to perturb
  - Try SVs on the LAM grid based on rotational norm

Environnement Canada
Division de la recherche en météorologie
Environment Canada
Meteorological Research Branch

Status of the Canadian Regional Ensemble Prediction System

Martin Charron (MRB), Lubos Spacek (MRB) and Li Xiaoli (McGill)

- *Domain is North America (resolution 28 km)*
- *The aim is ensemble 2-day forecasts with 20 members from a limited-area model*
- *For now, based on downscaling of targeted singular vectors*
  - *Initial norm is global*
  - *Final norm is located over a domain covering North America*
- *For now, convection is also perturbed*
- *Ensemble of oundary conditions come from a global model (res. 150 km) perturbed by the singular vectors*

Environnement Canada
Division de la recherche en météorologie
Environment Canada
Meteorological Research Branch

Wind prediction ensemble experiments with DMI-HIRLAM

Kai Sattler and Henrik Feddersen, Danish Meteorological Institute (DMI)

- Work part of the national project *Wind power prediction by ensemble forecasting* (ORDRE-101295, FU2101)
- 1st ensemble approach (HIRLAM-51) based on downscaling all 51 members of the ECMWF-EPS
- 2nd ensemble approach (HIRLAM-PE) with 5 different parameterization schemes for condensation/ convection (boundaries from ECMWF-control)
- Model nesting setup:

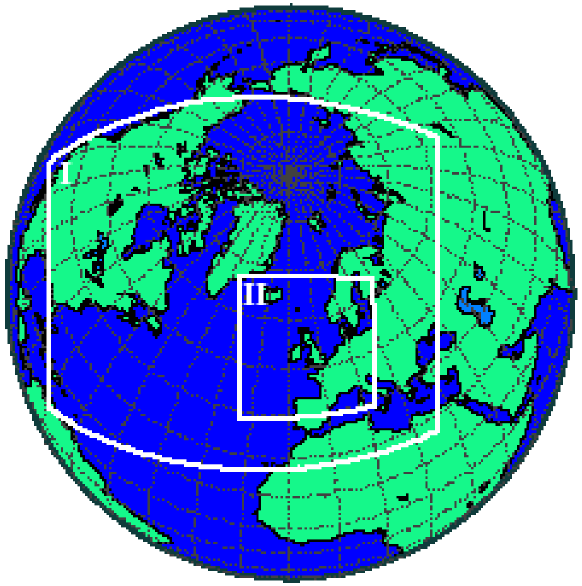
ECMWF-EPS T_L255L31

↓

I: DMI-HIRLAM 131x144L31, 0.6°

↓

II: DMI-HIRLAM 146x138L31, 0.2°



- Simulation period: 2002-12-08 to 2003-03-30
- Lead time: 0 - 72 hours
- Quasi real time integrations (Daily simulations run within 24 h)

Future

- involve high resol. data assimilation and initial perturbation + model error in one ensemble desired

LAMEPS HMS

Andras Horanji

- The system is based on ALADIN
- Nested in PEACE
- Dynamical Adaptation: no data assimilation
- Hor. Res.: 12km – Vert. Res.: 37 levels
- 10+1 ensemble members
- Forecasts for 54 hours

What is the effect of different target domains and optimization times in the global singular vector computation?

Sensitivity experiments

Case studies (for 4 different meteorological situations)

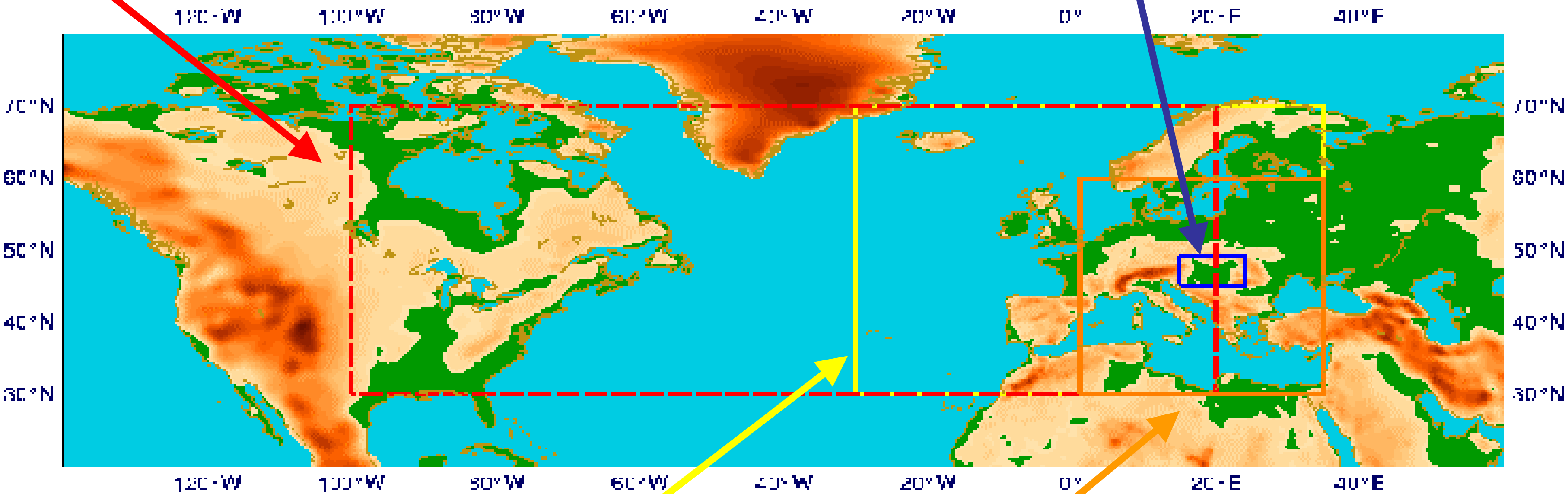
Experiment for a longer period (10 days)

LAMEPS HMS (3)

Large sensitivity in terms of **optimization area** (smaller domains bigger spread) and for **optimization time (**24h bigger spread)

Atlantic Ocean and Western Europe (target domain 1.)

Hungary (target domain 4.)



Central+East+South Europe (target domain 3.)

Europe (target domain 2.)

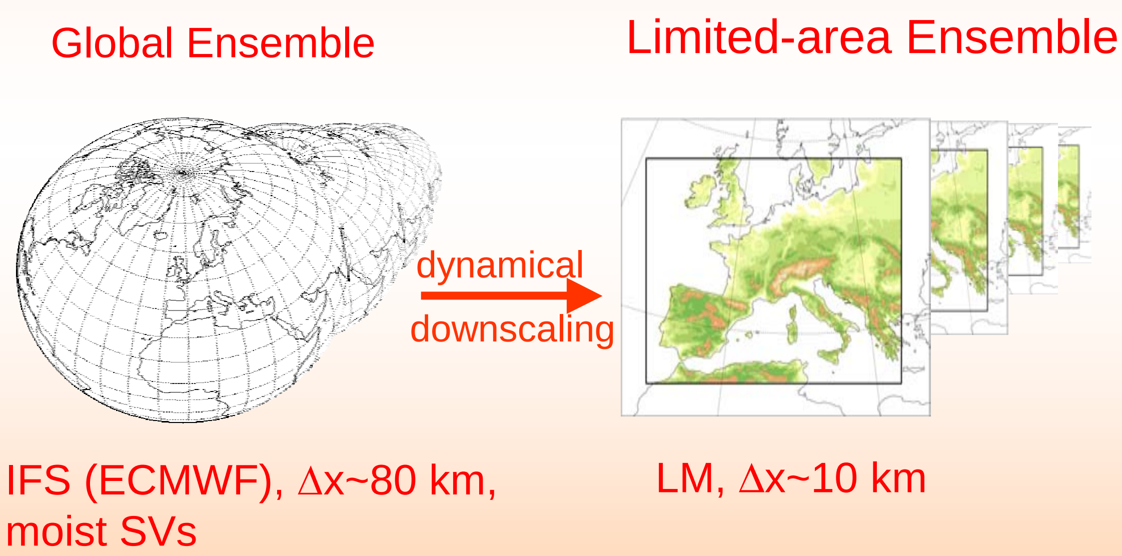
Future plans:

- Continue the sensitivity studies to obtain a bigger sample of cases
- Other methods are also planned:
  - Experiments with ALADIN EPS coupled with representative members obtained from the clustering of ECMWF EPS (as COSMO-LEPS)
  - Experiments with the computation of local (ALADIN native) perturbations

METEO_SWISS
COSMO-LEPS using ECMWF EPS with "moist" SVs

Andrè Walser

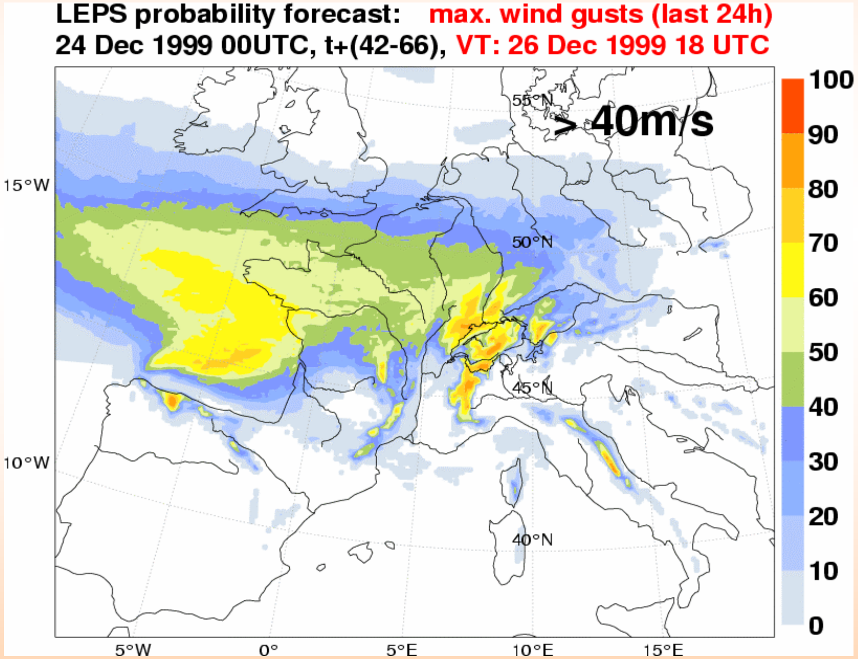
- Motivation: Improvement of early warning for extreme weather events
- Setup for case studies:



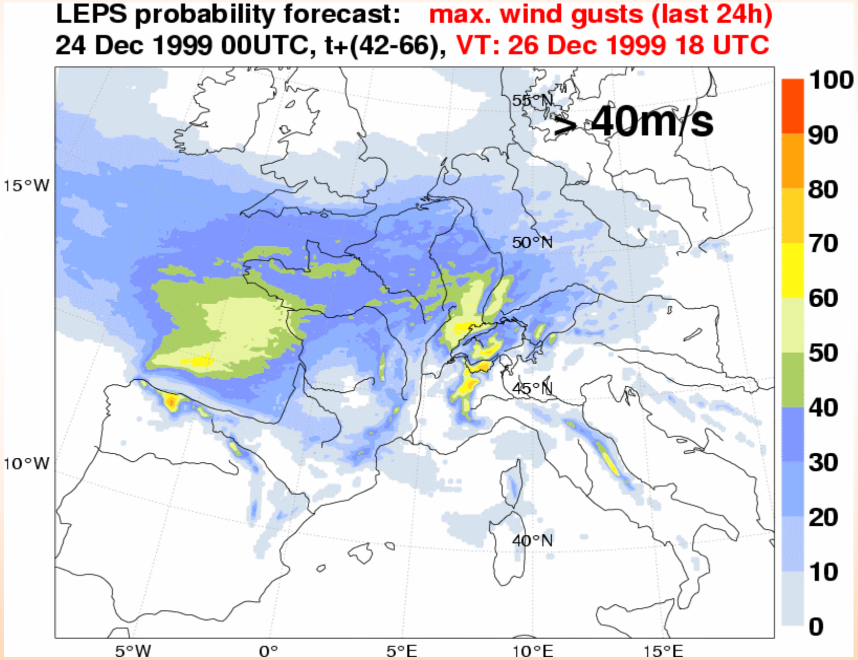
- 51 ensemble members
- LM with 10 km grid-spacing and 32 levels
- **72-h forecasts**
- **IFS members use„ moist" singular vectors**

LEPS forecast: max. wind gusts for storm Lothar

"moist" SVs



opr SVs



Multimodel-Multinalysis Mesoscale Ensemble (MusE)

P. A. Chessa, C. Dessy, G. Ficca , C. Castiglia (SAR)
and *M. Marrocu, I. Di Piazza* (CRS4)

Pre-operational setup

- Models → BOLAM - MM5 - RAMS
- I.C. and B.C. → AVN 12Z - ECMWF 12Z
- Area and Resol. → 13.5/34-24.5/54.5 ** 0.25°
- Forecast time range → +72h (step:6h)
- Period → 15/10/2002 to 15/04/2003

Results

- Superensemble techniques appear to work for parameters as temperature, geopotential height, wind intensity and mslp. For variables like precipitation a different approach has to be used.

- Using a learning period a tuned ensemble mean works in a similar way as the superensemble: both ameliorate the best model and in the worst cases (i. e. very high spread) tend to be very close to it. This make them the natural candidates as control forecasts.

- Applying a multilinear regression in the learning period a unique, positive *global* coefficient, for each model and for each forecast time step, can be found for the models producing *sensible* forecasts. Therefore they are liable to bring a relationship with the weights needed to build probabilistic forecasts. This global coefficients might also be used to change the ensemble size dinamically: i.e. ruling out the models producing the worst forecasts during the learning period.

Multimodel-Multinalysis Mesoscale Ensemble (MusE)

Future plans

- Design and assessment of probabilistic forecasts (under way)
- Set up (six months) of an operational ensemble composed by:
  - BOLAM – MM5 – RAMS models;
  - as I.C. and B.C. the 00-06-12-18Z AVN and the 12Z ECMWF runs
  - Euro-atlantic area; 0.18° spatial resolution; up to 72-9669 h of integration with output every 3h.

  This makes a 15 member ensemble to be run on a 16 nodes (Intel Xeon bi-processors) cluster. The estimated time of integrations about 9 to 12 hours.
- Extension of the ensemble size and increase of spatial resolution using a bigger cluster at CRS4 (12-18 months).

SUPERENSEMBLE

Massimo Milelli

The Multimodel SuperEnsemble method requires several model outputs, which are weighted with an adequate set of weights calculated during the so-called training period (Krishnamurti et. al., 2000).

We use the following operational runs of the 0.0625° resolution version of LM (00UTC runs)

- **Local Area Model Italy -** **LAMI** (UGM, ARPA-SIM, ARPA Piemonte)
- **Lokal Modell -** **LM** (Deutscher Wetterdienst)
- **aLpine Model -** **aLMo** (MeteoSwiss)

We evaluate the model performances with respect to our regional high resolution network.

Here presented are the results of 2m temperature forecasts, compared with the measurements of 201 stations, divided in altitude classes (<700 m, 700-1500 m, >1500 m).

Results

- Direct Model Output 2m temperature forecasts show a notable degradation in the Alpine region

- The Multimodel improves the forecasts in high mountains locations, both in bias and RMSE and its performances are similar to those from Kalman filter

Work in progress...

Extension of the Multimodel method to other parameters: humidity, precipitations…..

Mathias Rotach (Meteo-Swiss)

FDP : instrument of WWRP

General Goals

Demonstrate ability for improved forecast of heavy precipitation in the alps

→ High-resolution atmospheric modelling

→ **ensemble forecast technique**

→Include assimilation schemes/Radar data

→ Coupling hydro/meteo models

End users involved (end user needs, e.g. probabilistic forecasts)

Evaluation protocols (yet to be determined)

Strategy for D-PHASE…. (Forecast Demonstration Period)

Demonstration of Probabilistic Hydrological and Atmospheric Simulation of Flooding Events in the Alps

Atmosphere - Multi-component approach:

1. **Local EPS systems (COSMO-LEPS**, LAMEPS, PEPS,..)
   → 3-5 days probabilistic forecast
   → likelihood of 'event'
2. **'standard' deterministic models resolution (1-3km)**
   → short-range, targeted
   → coupled hydrological models
   → latest radar information assim
3. A possible **'micro-LEPS'** made up man's EPS from the above
   → probabilistic information on hy patterns.

Hydrosphere:

1. Hydrological models
   → distributed
   → coupled

Model	resolution	Forecast period	group
COSMO-LEPS	10km	48-120h	ARPA-SIM, MeteoSwiss, DLR
LAMEPS	25km		UK Met Office
PEPS	7km	48h	EUMETNET NWP
GEM-LAM	10km		Env. Ca
aLMo	2.2	18h	MeteoSwiss
UM	3-4km		UK Met Office
LM-K	2.8		DWD
MOLOCH	> 2.5km	24-36h	ISAC-CNR
LAMI	7km/1km		ARPA-SIM
Arôme	2.5km		Météo F
'Atm model'	1km		Env. Ca
ALADIN-Austria	9.6		ZAMG

End users:
→ civil protection
→ river/lake management

Present Situation Operational and Quasi Op. Systems	Status	Runs /day	Hor.Res.	Lead Time (hr)	n° Memb.	MA	Multi Model	Pert. on the initial state	Pert. on the trajectory	Downsc. and BCs
NCEP-SREF	OPE	2	32 km	63	15	Edas/ gdas	ETA RSM	Breeding	6 Phys. schemes conv.	GFS-EPS
BMRC	OPE	1	0.5°	72	16			Pert. Obs.	Stoc.Phys (tenden.) Schemes	BMRC-EPS
SRNWP_PEPS	OPE	4	Variable 7÷22	30	18	(18)	18 mod.			det GCM
COSMO-LEPS	Real Time	1	10 km	120	10					ECMWF-EPS
CMC-EPS	Q.O.	1	28 km	48	20 ☆				Pert. Phys. Conv.	CMC-EPS
NOR LAMEPS	Q.O.	1	20 km	72	41			SV		TEPS
UK Met Office	Q.O.	1	24 km	72	16			ETKF	Param.	UKMO-EPS
INM-SREPS	Q.O.	4	~0.25°	72	64		4 mod.			4 det GCM

Present Situation Research Systems	Status	Runs /day	Hor.Res.	Lead Time (hr)	n° Memb	MA	Multi Model	Pert. On The In. State	Pert. On The trajectory	Downsc. and BCs
DMI-HIRLAM	RES	1	0.6°-0.2°	72	51 / 5				No/ Param	EPS/ CTRL
HMS LAMEPS	RES	1	12 km	54	11					PEACE
SWISS LEPS	RES	Supporting COSMO-LEPS mainly in testing MSV impact and different clustering times								
SARD_MME	RES		0.25°	72	6	AVN 12UTC ECMWF 12UTC	SE 3 mod: MM5 BOLAM RAMS			AVN IFS
PIED_SE	RES		7 km		3		SE LM aLMo LAMI			LM and LAMI take BCs from GME aLMo takes BCs from IFS
MAP D-phase	RES		diff.	Up to 120			4 LEPS and 8 models			

PLANS Operational and Quasi Op. Systems	Status	Runs/day	H.Res.	Lead Time	N° Members	MA	MM	Pert. On The In. State	Pert. On The trajectory	Downsc. and BCs.	other
NCEP-SREF		4		87h	5-6 more			Impr.	Land.surf. Pert.		Larger domain Bias correction
BMRC											
SRNWP_PEPS	Developments will be defined at the next SRNWP-PEPS workshop Bologna April 2005										
COSMO-LEPS	Ope								Pert. Phys. Param.		Clustering on different domains and time windows Verification
CMC-EPS								Opt. SV Regional EnKF	Pert. Param. Tend. & New In.Stoc. Phys.		
NOR LAMEPS			higher	84h				Opt. SV	Phys. FSV?		
UK Met Office	Ope										Verification
INM-SREPS	Ope										Ver.& Post. Pr

PLANS Research Systems	Status	Runs/day	H.Res.	Lead Time	N° Members	MA	MM	Pert. On The In. State	Pert. On The trajectory	Downsc. and BCs	other
DMI-HIRLAM								yes	yes		
HMS LAMEPS								yes		+ EPS	
SWISS LEPS	Developments will be planned also considering COSMO-LEPS plans										
SARD_MME	OPE		0.18° Higher is planned		15	AVN 00,06,12,18UTC ECMWF 12UTC	SE 3 mod: MM5 BOLAM RAMS			AVN ECMWF	
PIED_SE											Extension to more parameters
MAP D-phase											

Concluding remarks: (1)

- A lot of activity about the development of Limited Area Systems has been doing in recent years
- Several systems are already running on operational basis → the positive results are leading to a further development of the systems
- Big effort on optimisation of perturbations (both on the initial state and on the trajectory), some hints:
  - ✓ The amount of spread depends on the considered variable → hints on the perturbation type (SREF - Du et al.)
  - ✓ Good impact of random parameter perturbations on surface variables (UK-LAMEPS - Mylne et al.)

Concluding remarks: (2)

- Interesting experiences will be available in the near future as regards multi-model approach→ combination methodologies are under development
- Limited area ensemble will also provide valuable contribution to mesoscale data assimilation systems to define the "error of the day" → mesoscale data assimilation schemes at few km resolution must support data from local networks with appropriate error statistics

Concluding remarks: (3)

- A lot of the present activities/projects in this area can provide a good starting point for TIGGE :
  - Downscaling of Global EPS in regions where severe events are likely to occur
  - Multi-model: how to combine members from different models
  - Verification/validation strategies
    - The strong dependency on the spatial and temporal scale must be considered. Verification and validation should include methodologies suitable to highlight the quality of the systems considering the users requirements.
  - Optimisation of perturbations for specific regions
  - Peculiarities of the different systems implemented in different geographycal regions

Announcement

The 2nd SRNWP workshop on
Short Range Ensemble
will be held in
Bologna
7-8 April 2005

If you are interested e-mail to
workshopsim@smr.arpa.emr.it

Thank You !