GOBIERNO DE ESPAÑA

MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

AEMet Agencia Estatal de Meteorología

Probabilistic Forecast of Severe Weather Events: The long way to the mesoscale

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Introduction

- Main Weather Forecast issues are related with Short-Range forecast of extreme events.
- Convection and convective precipitation are, roughly speaking, the most dangerous extreme weather events.
- Due to the small spatial and temporal scales of these events, forecast is very difficult.
- Increasing the horizontal and vertical resolutions of the numerical weather prediction models has been the traditional approach to improve the forecast of these events.
- But deterministic tools, like mesoscale NWP models, didn’t show the improvement expected in the last 20 years or so.

Uncertainty

- In the last 80’s and beginning of 90’s some studies show that the effects of the Chaos theory has to be taken into account in medium-range weather forecasting (ECMWF).
- Uncertainty of the weather forecast was introduced through probabilistic tools, like the Ensemble Prediction Systems, EPS (NCEP, ECMWF).
- At the same time mesoscale models with resolution below 5 Km (MM5) show similar behaviour when they were used to deal with convection.
- In the last years some experiments with mesoscale EPS have shown some skill in the information about the uncertainty of convective events.

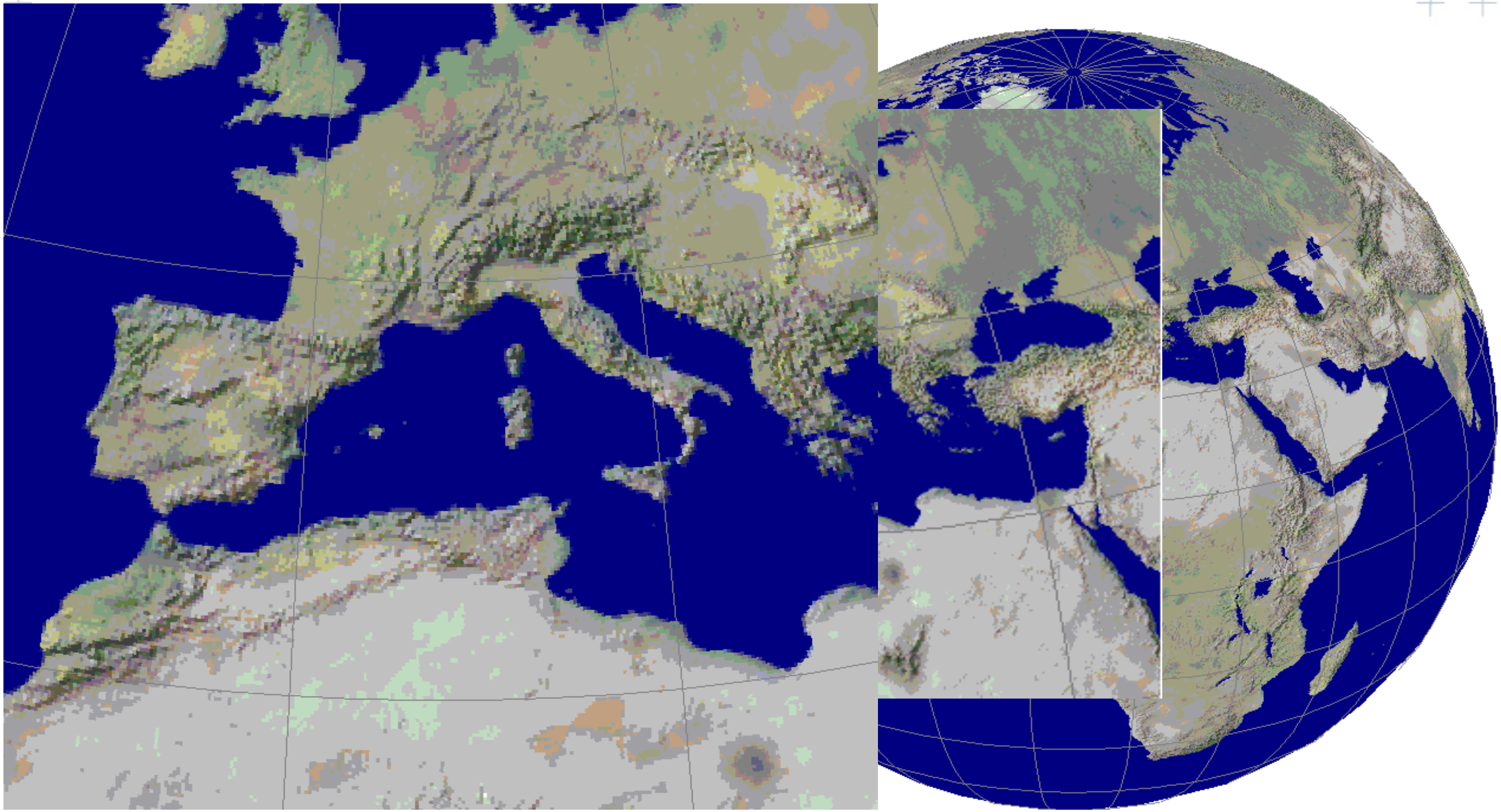
Mesoscale EPS

- Probabilistic tools has shown to be very useful in the forecast of extreme weather events.
- At medium-range the ECMWF Extreme Forecast Index (EFI) is being very wide used in the European Weather Services.
- At short- and very short-ranges Met Services in Europe and around the world are doing parallel tests of mesoscale EPS (convection-permitting resolution).
- The huge amount of computer resources needed to run operationally mesoscale EPS is one of the key aspects that has to be taken into account.
- Then a compromise among forecast length, domain size, number of members, periodicity of runs and so on are key aspects of those operational mesoscale EPS.

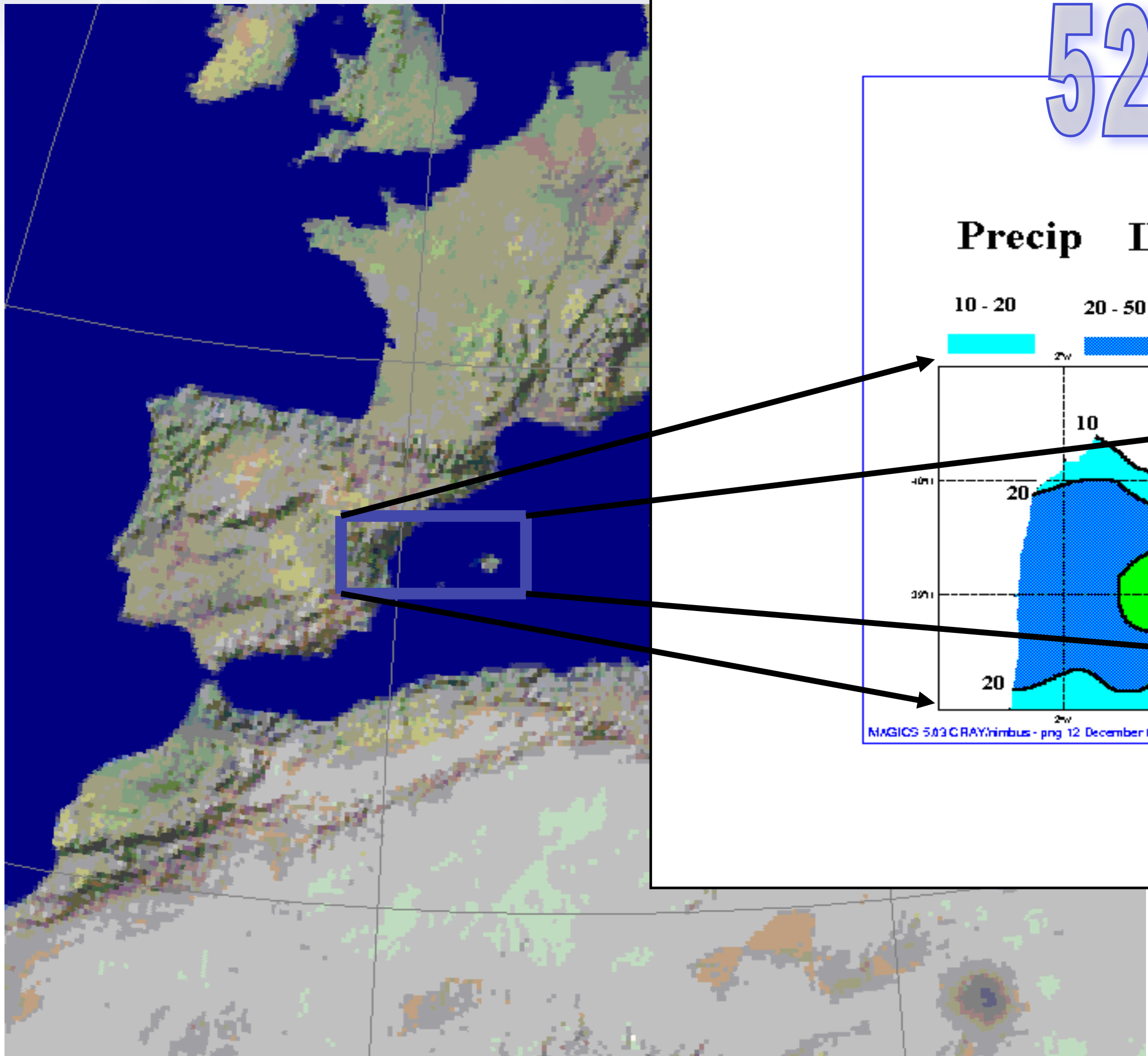
Examples in Spain

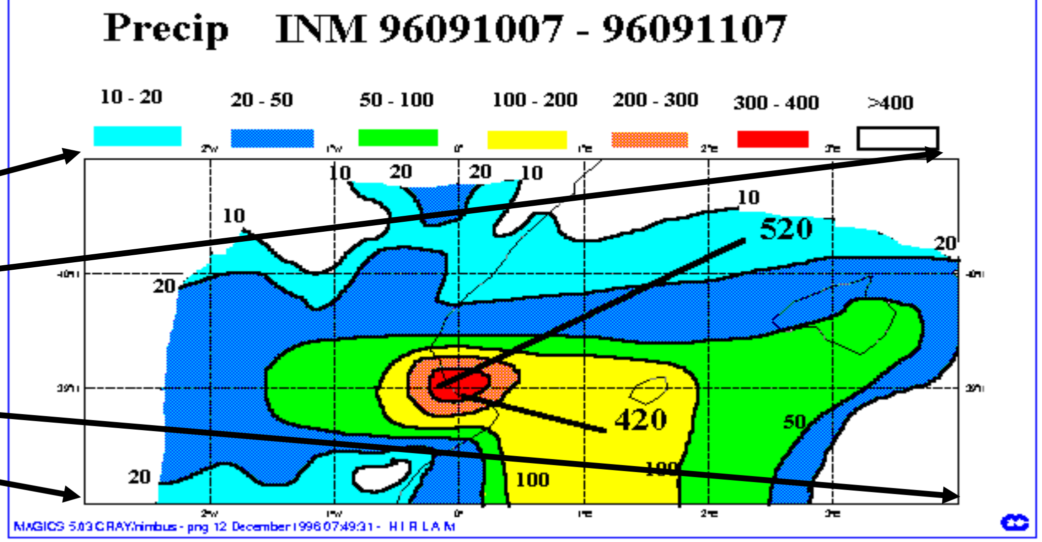
- Western Mediterranean is a close sea rounded by high mountains.
- In autumn sea is warmer than air.
- Several cases of more than 200 mm/few hours occurs every year.
- Some fast cyclogenesis like “tropical cyclones” also appears from time to time (called “medicanes” in the literature).
- Most of these severe precipitation events are an effect of deep convection.

Geographical Framework



520 mm/24 h




Precip INM 96091007 - 96091107
10 - 20
20 - 50
50 - 100
100 - 200
200 - 300
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520
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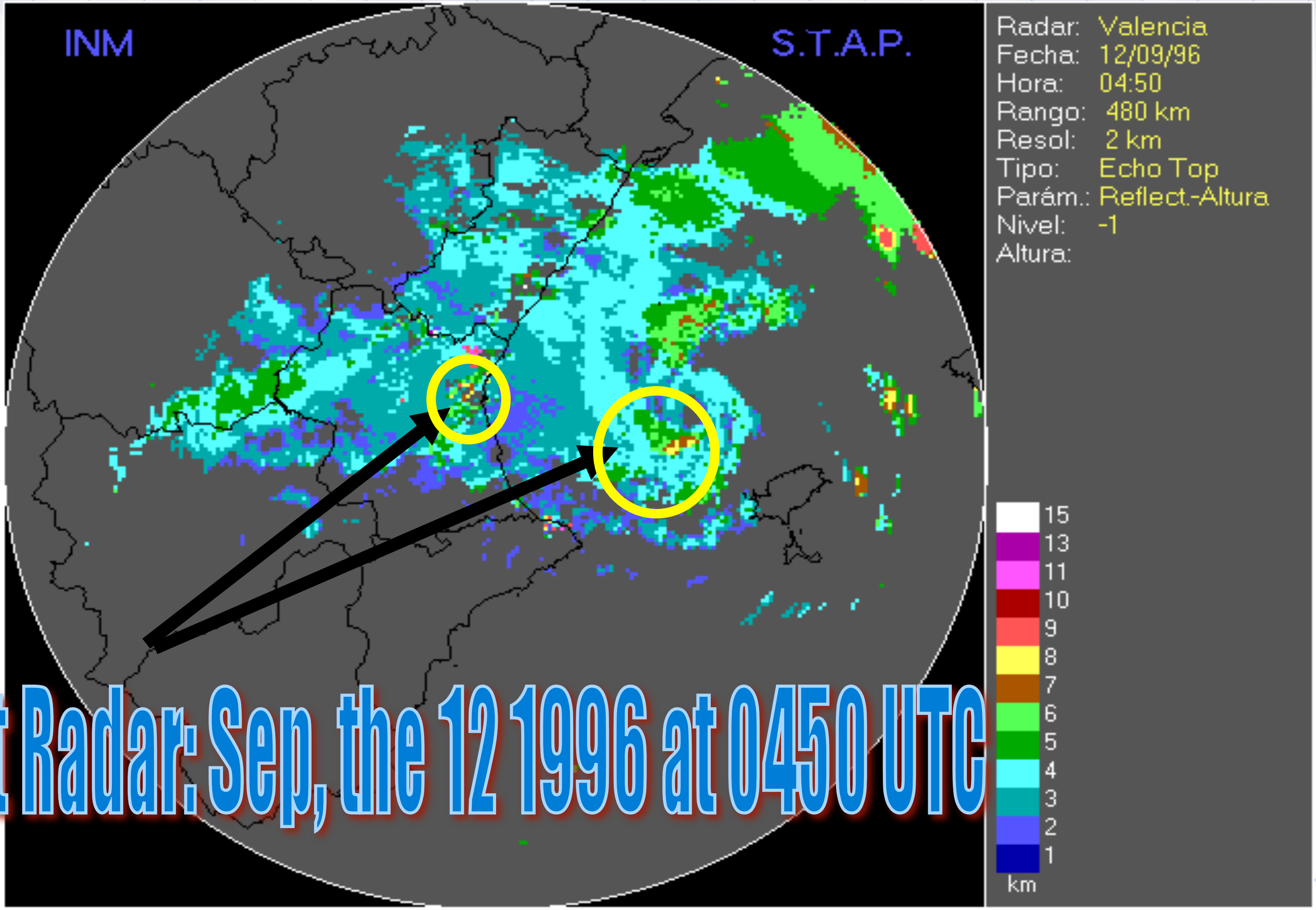
MAGICS 5.0.3 CRAY/nimbus - png 12 December 1996 07:49:31 - H I R L A M

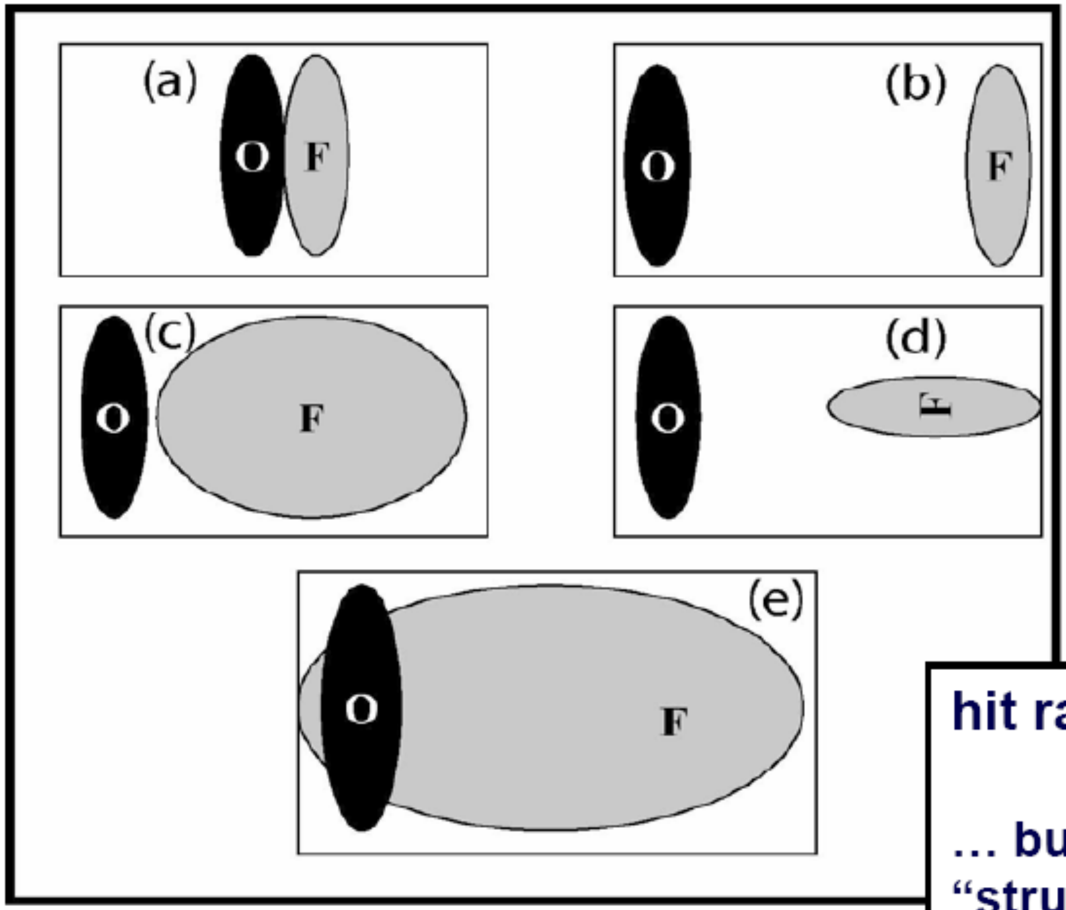


Met Radar: Sep, the 12 1996 at 0450 UTC

Mesoscale Deterministic Models

- Such events can be model with very high resolution NWP models.
- But phase errors in space and time make very difficult to use these models in operational environments.
- In particular, point-to-point objective verification tools normally give better skill to smoother-lower resolution models.
- New methods like SAL index are using to give proper opportunities to mesoscale models.
- The key question is how to properly compare 2 or 1 Km resolution models with outputs every few minutes, with observations at completely different scales (10-20 Km with recording every 24 hours or 50-100 Km recording every hour).

Problematic aspects of grid point based error scores



hit rate = 0

… but (a) is "better" than (b)-(d)

hit rate > 0

… but forecast has not the right "structure"

Davis et al. 2006 (MWR)

SAL

- Classical problem of double penalty
- Feature-oriented → ~ subjective verification
- E.g: SAL measure
  - S (Structure)
  - A (Amplitude)
  - L (Location)
- Perfect forecast: S = A = L = 0
- S requires patterns/objects definition, currently simple algorithms, need improvement

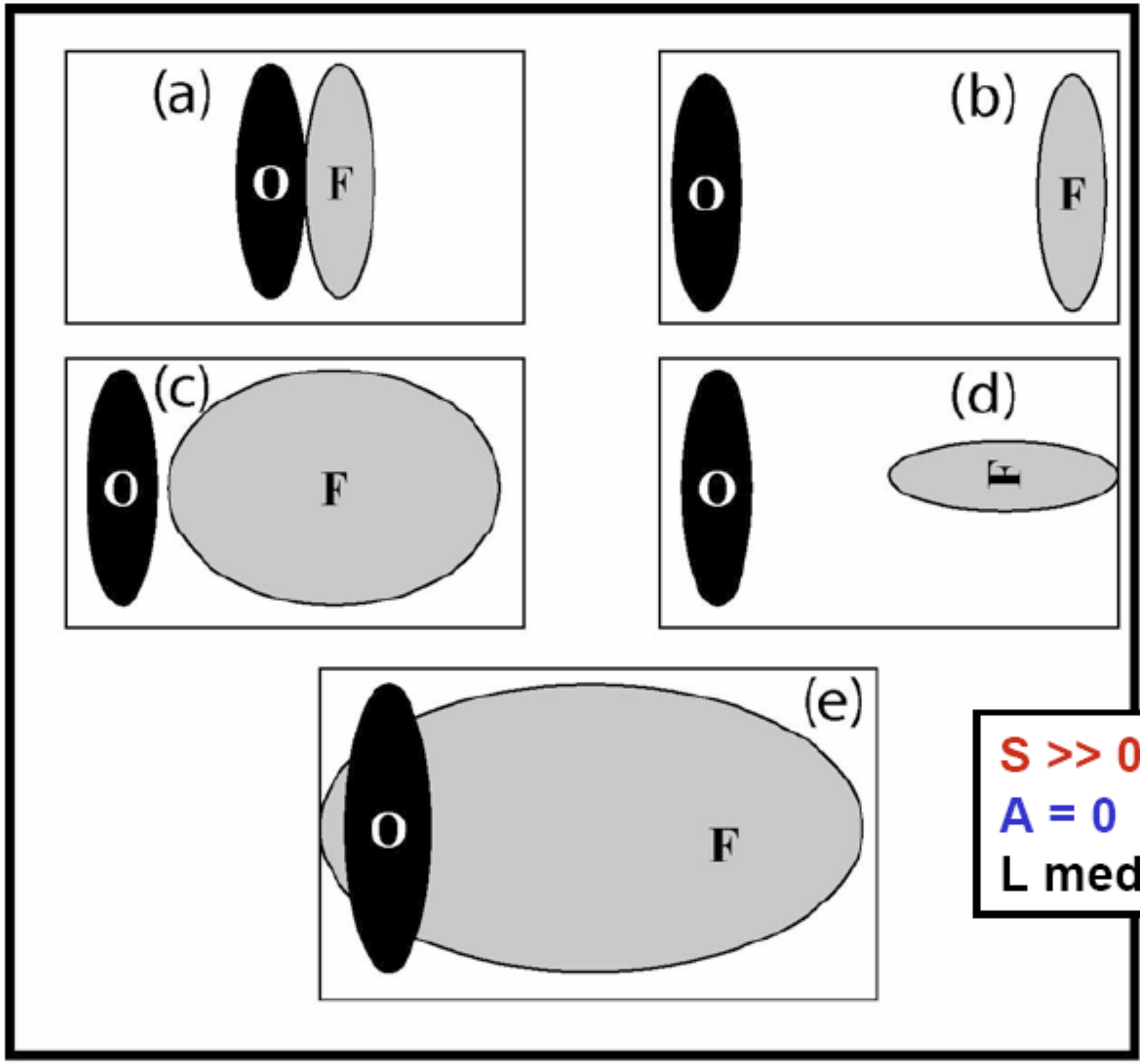
SAL

S:	Structure	-2 … objects too small or too peaked	0 … Perfect		+2 objects too large or too flat
A:	Amplitude	-2 … averaged QPF under-estimated	0 … Perfect		+2 averaged QPF over-estimated
L:	Location		0 … Perfect		+2 wrong location of Total Center of Mass (TCM) and / or of objects relative to TCM

SAL

S = 0
A = 0
L small

S > 0
A = 0
L medium



S = 0
A = 0
L large

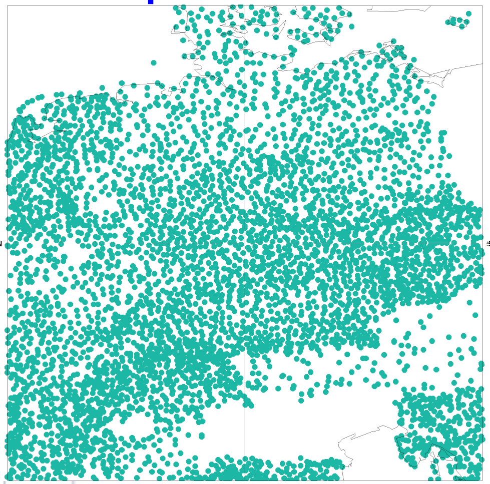
S = 0
A = 0
L large

S >> 0
A = 0
L medium

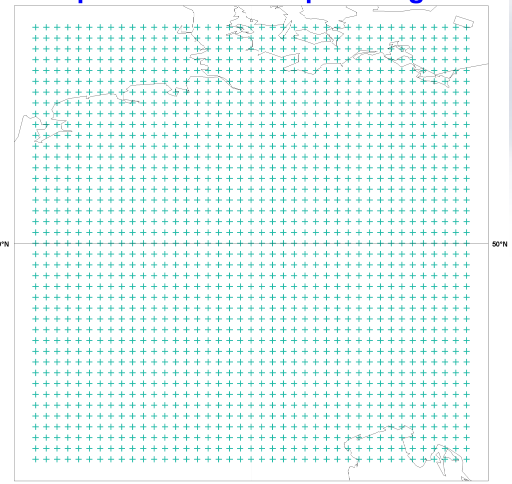
Davis et al. 2006

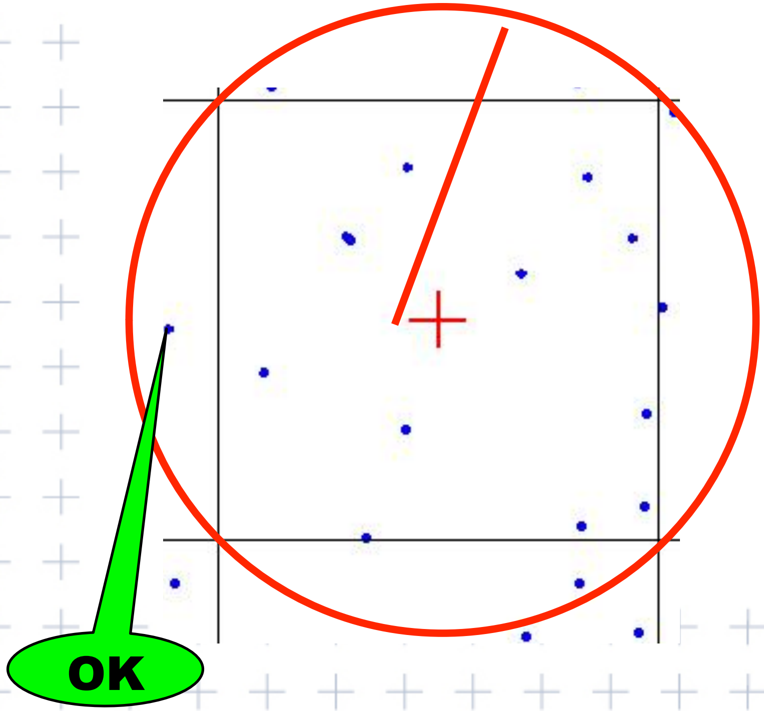
Up-scaling

Europe HR obs 2008



Europe HR obs 2008 up-scaling 0.25



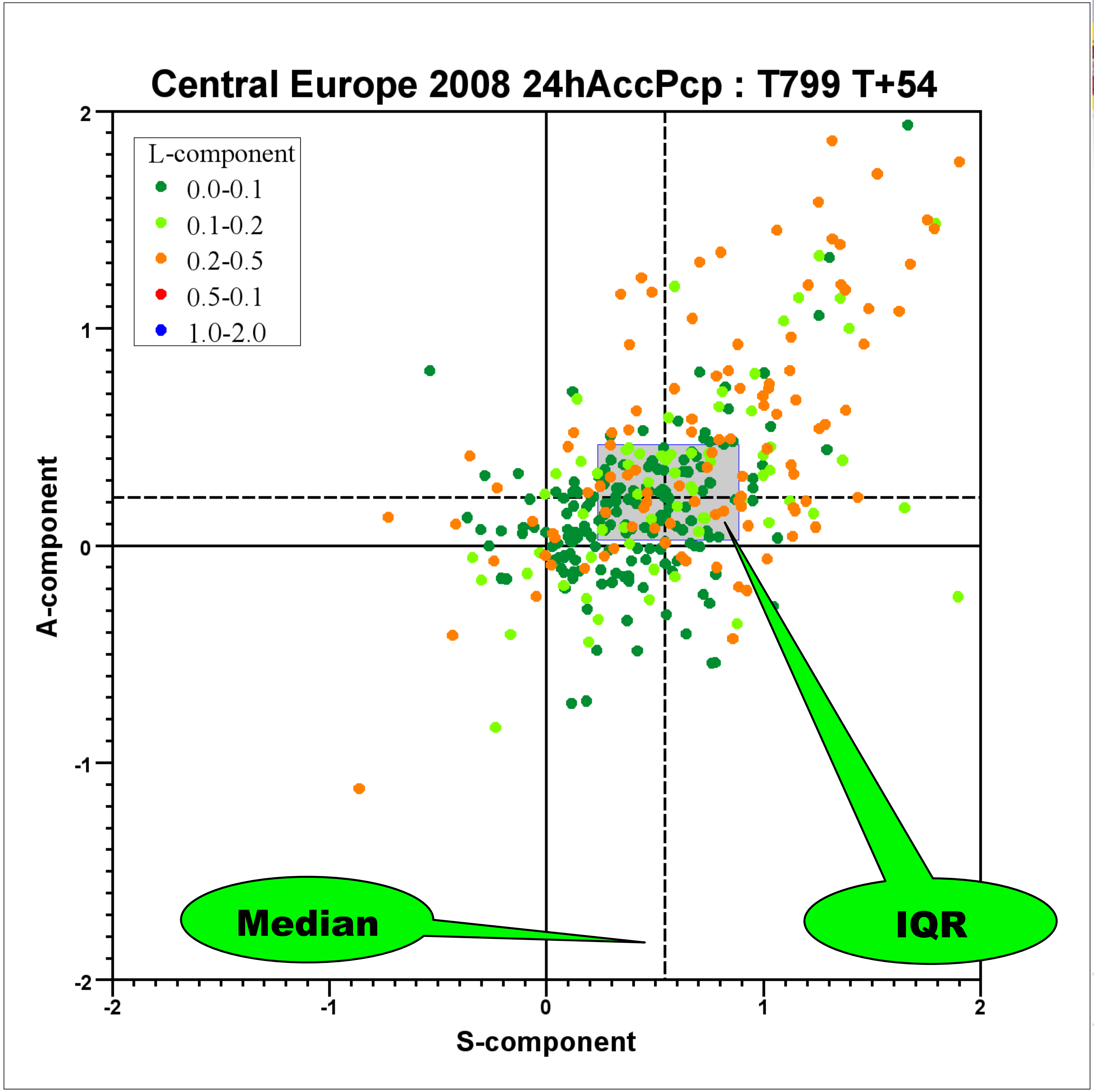


What is the **truth**?

Up-scaling Europe HR obs available at ECMWF: a first simple approach:

- For each grid point consider d
- obs r < d → ob considered
- $R = \sum r^{-\alpha} R_i / \sum r^{-\alpha}$ with e.g. $\alpha=2$
- Overcome missing data at most resolutions

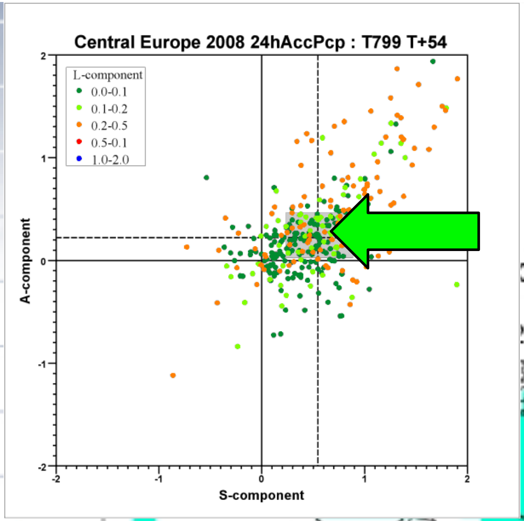
- In this work
  - Each model is compared with its own "natural up-scaling"
  - T799 with up-scaling 0.25
  - T399 with up-scaling 0.50



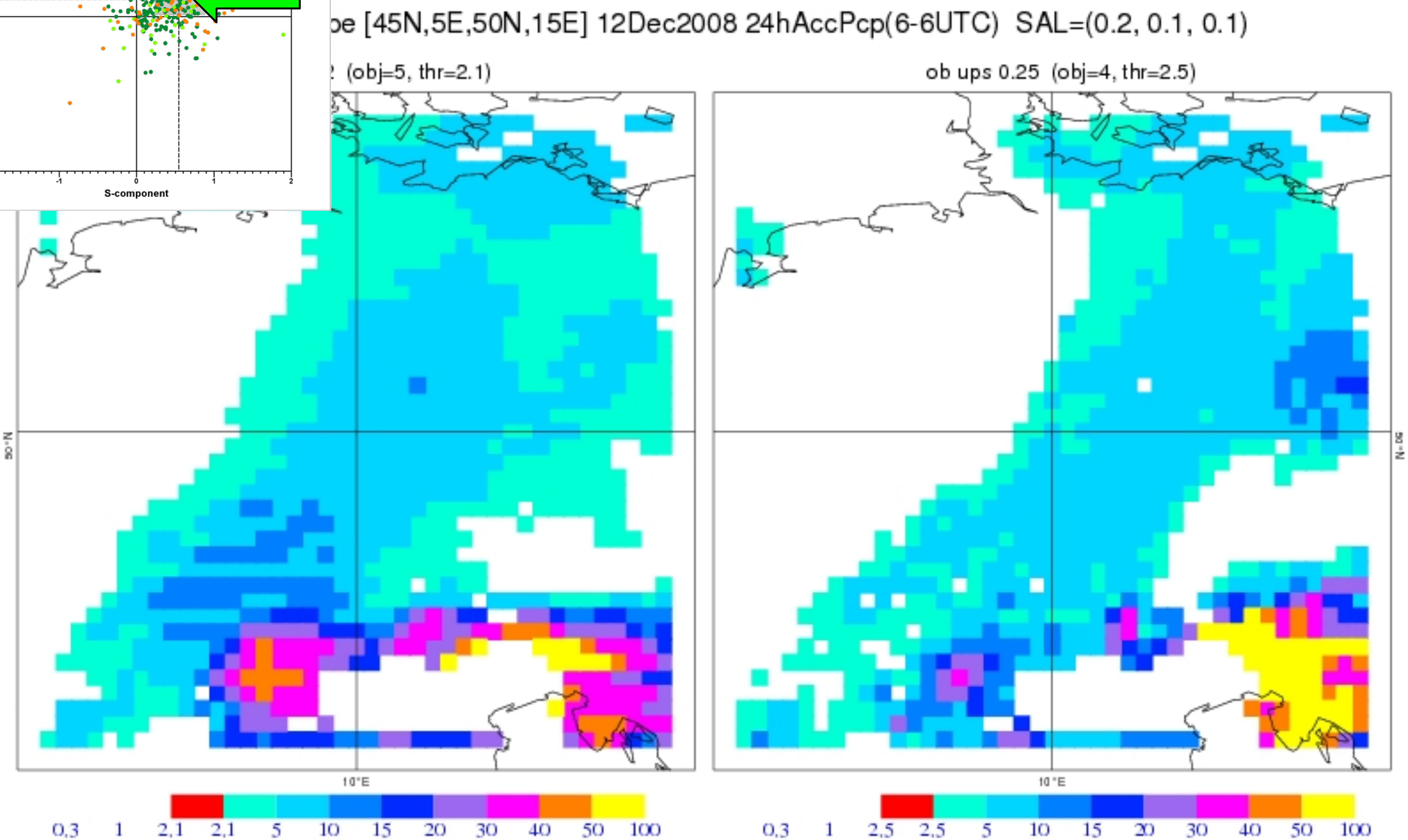
The SAL plot:

T799 D+2

Inside IQR



Central Europe 2008 24hAccPcp : T799 T+54
L-component
0.0-0.1
0.1-0.2
0.2-0.5
0.5-0.1
1.0-2.0
A-component
S-component

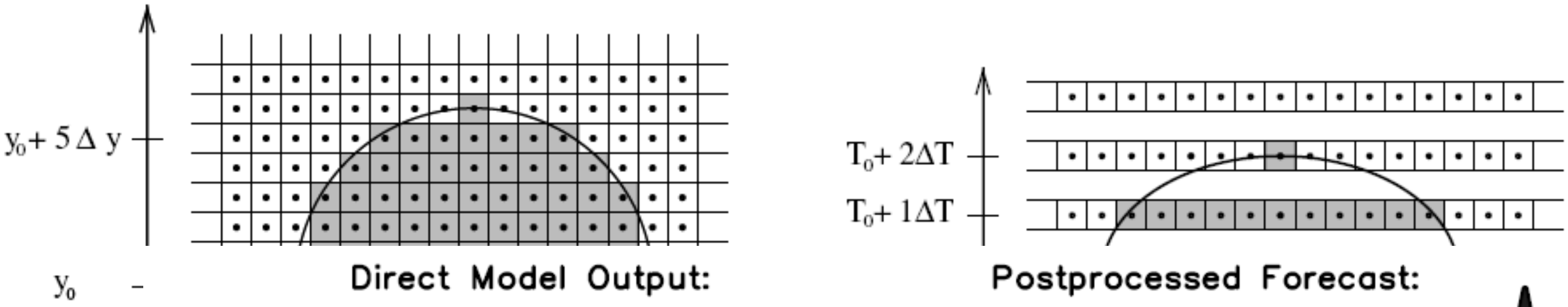


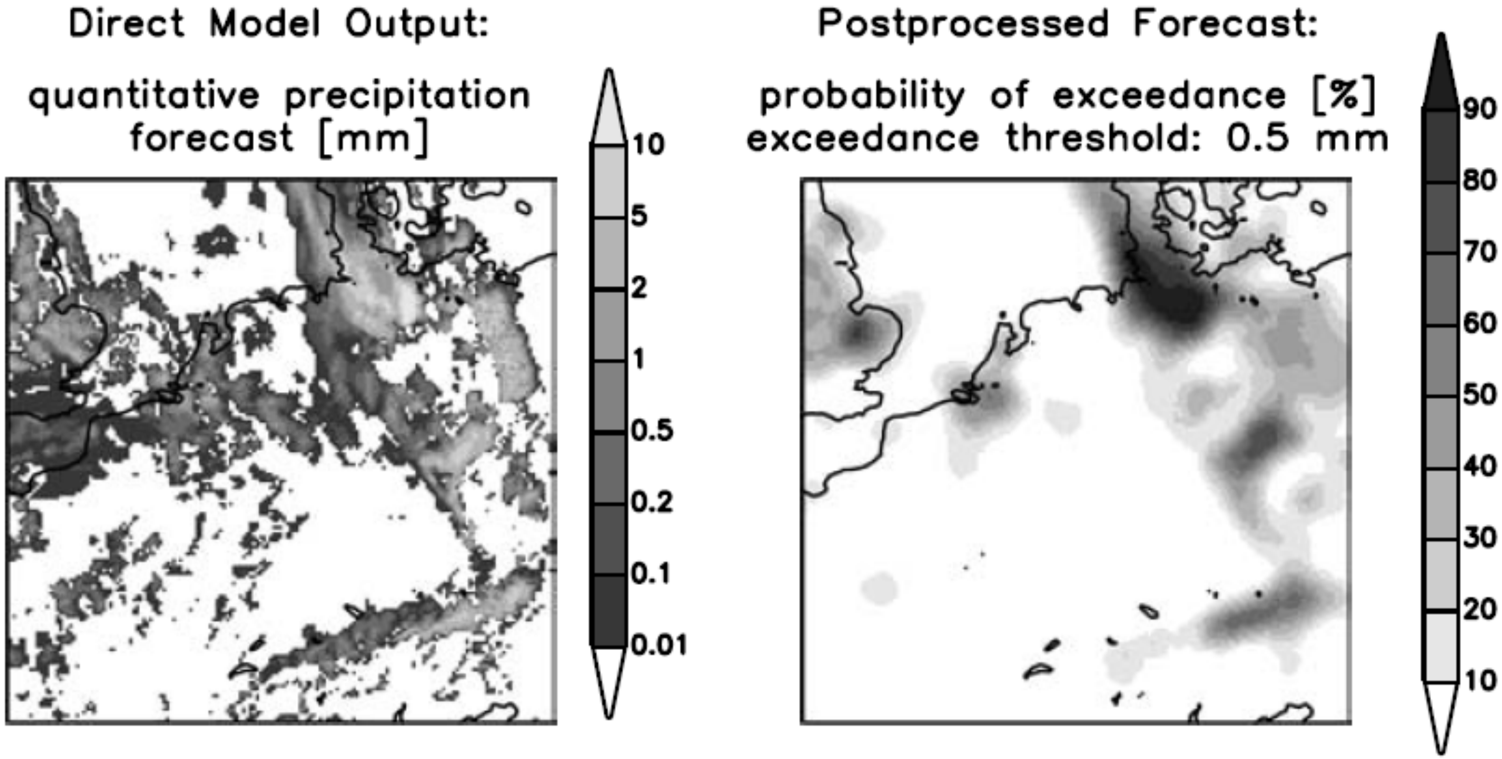
pe [45N,5E,50N,15E] 12Dec2008 24hAccPcp(6-6UTC) SAL=(0.2, 0.1, 0.1)
2 (obj=5, thr=2.1)
ob ups 0.25 (obj=4, thr=2.5)
10°E
50°N
0,3 1 2,1 2,1 5 10 15 20 30 40 50 100
0,3 1 2,5 2,5 5 10 15 20 30 40 50 100

Probabilistic tools from deterministic models

- To avoid the problem of computer resources needed to run a mesoscale EPS there are some techniques to get probabilities from deterministic numerical models.
- The **neighbourhood method** which consists in compute probabilities using data from grid-points around the target one:
  - Only in space giving a circle or an ellipse.
  - Or in space and time giving a ball or a bowl.

Neighborhood Approach





Roberts and Lean (2008); Theis et al (2005)

Neighborhood Approach - verification

Comparison with AEMET Multimodel SREPS using precipitation observations from the Spanish Climate Network

Deterministic forecast at
a space and time grid point
p=1

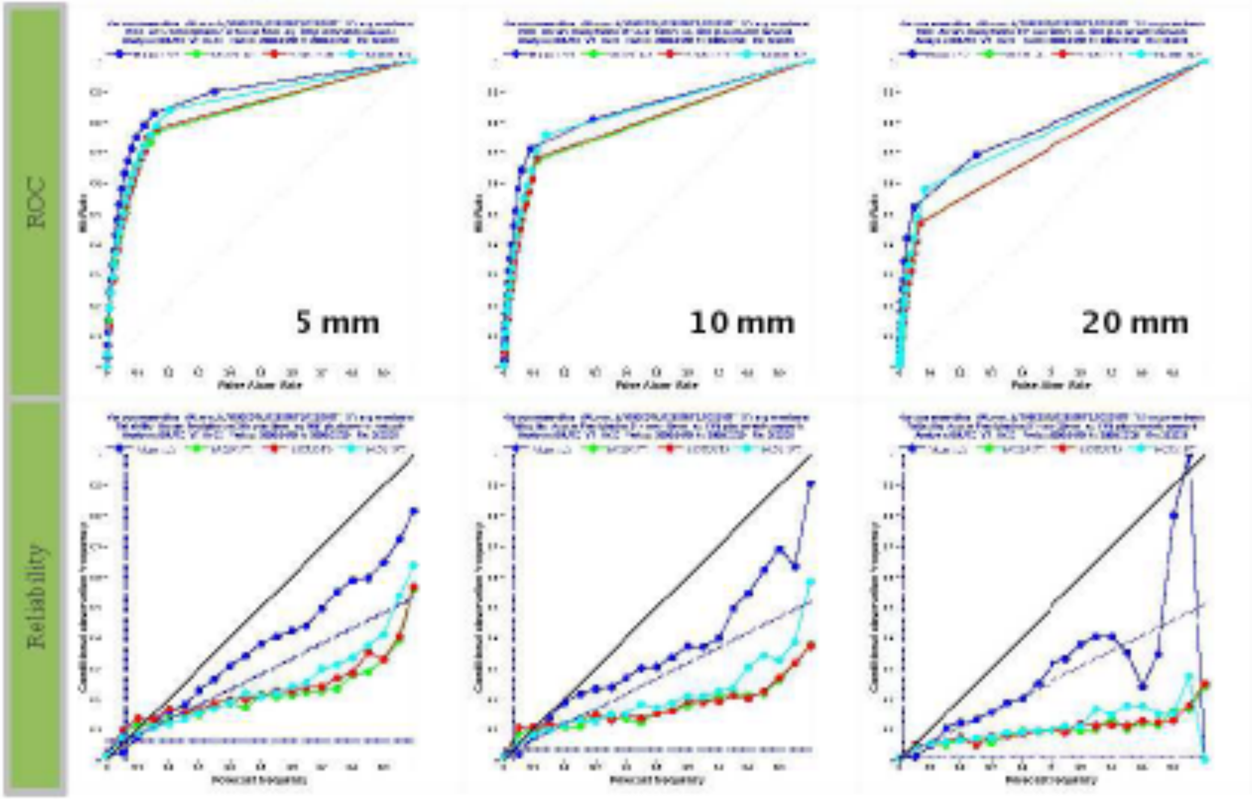
24 hours precipitation from HIRLAM 0.05°, H+06 to H+30 forecast

Results for the HIRLAM 0.05° set of experiments and H+30 forecast.

There are less differences in the ROC curves between Multimodel ensemble and diffusive method, although Multimodel ensemble shows much better reliability.

Relative value for Multimodel ensemble are clearly better than diffusive.

Verification is done with the INM observational network.



Blue – Multimodel

Red and Cyan – Neigh. Method

Hybrid Methods

- **The Concept of Hybrid EPS (Du, J., 2006)**
  - Each EPS member could be decomposed into two parts:

    EPS member = base + *perturbation*
  - The high-resolution model could be considered as better base:

    ***high resolution base* = deterministic forecast**
  - A new Hybrid Ensemble could be obtained exchanging the bases:

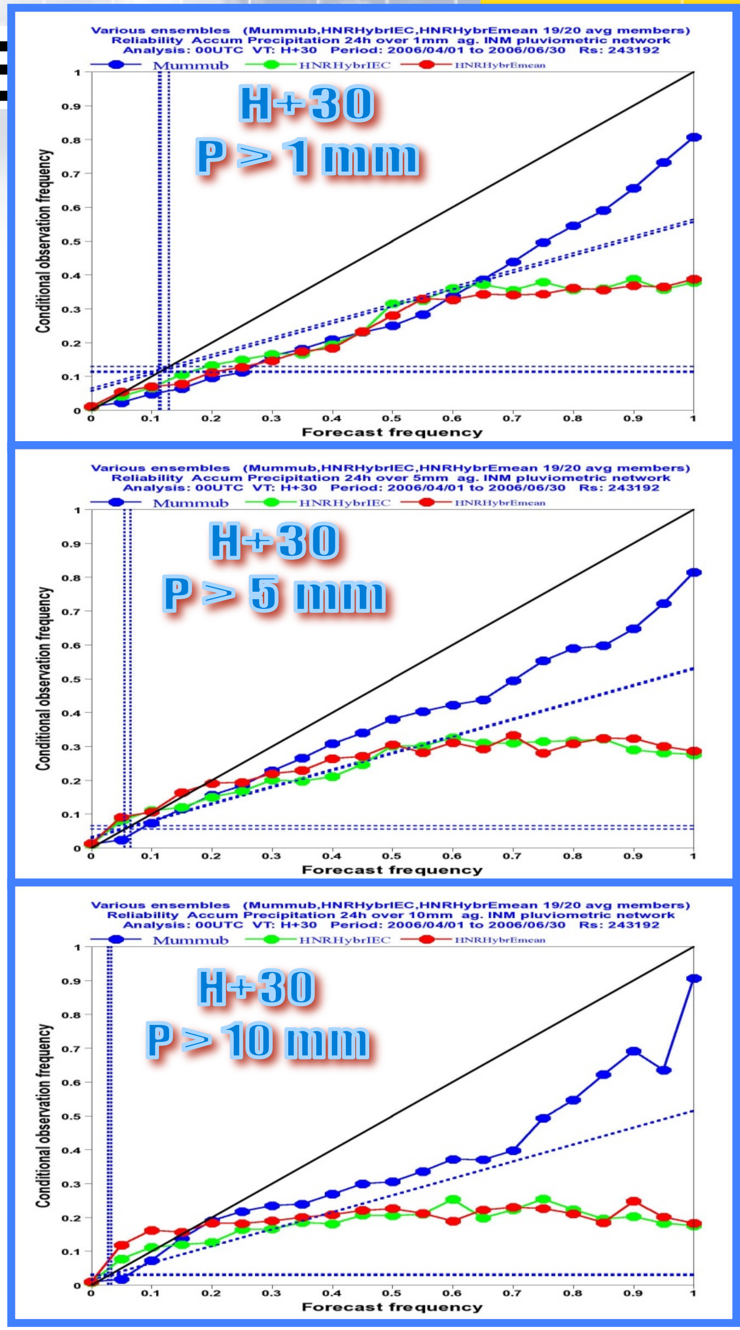
    Hybrid EPS member = high resolution base ± perturbation ("two side approach")
  - The **base** is the control member from EPS which is more close in dynamics and physics to the high resolution deterministic forecast

- Du, J., 2006: Hybrid Ensemble Prediction System: a New Ensembling Approach. Workshop on Predictability, Observations, and uncertainties in Geosciences, 13-15 March 2006, Tallahassee, Florida.
- [2] García-Moya, J.A. *et al.*, 2007: Multi-model Ensemble for Short-Range Predictability. 3rd International Verification Methods Workshop, ECMWF.
- [3] Santos, C. *et al.*, 2007: Performance of the INM Short Range Multi-Model ensemble using High-resolution Precipitation Observations. 3rd International Verification Methods Workshop, ECMWF.

Hybrid Methods - Example

- Two high resolution deterministic models are currently running at the Spanish Met Service (INM).
- A Short-Range Ensemble Prediction System (SREPS, García-Moya, J.A., *et al*., 2007) is daily running at INM as well, but a lower resolution.
- A goal could be combine both systems in order to improve the quality of the probability forecast, especially the precipitation forecast.
- A few Hybrid Ensemble has been developed and verified.
- Combine the spread or uncertainty information from the coarse EPS with the more detailed and higher accuracy deterministic model in order to form a more robust ensemble: the Hybrid Ensemble.

Hybrid Methods - E



Exp. Hirlam 0,05º

Blue – Multimodel
Red and Green – Hybrid

Pure EPS Methods

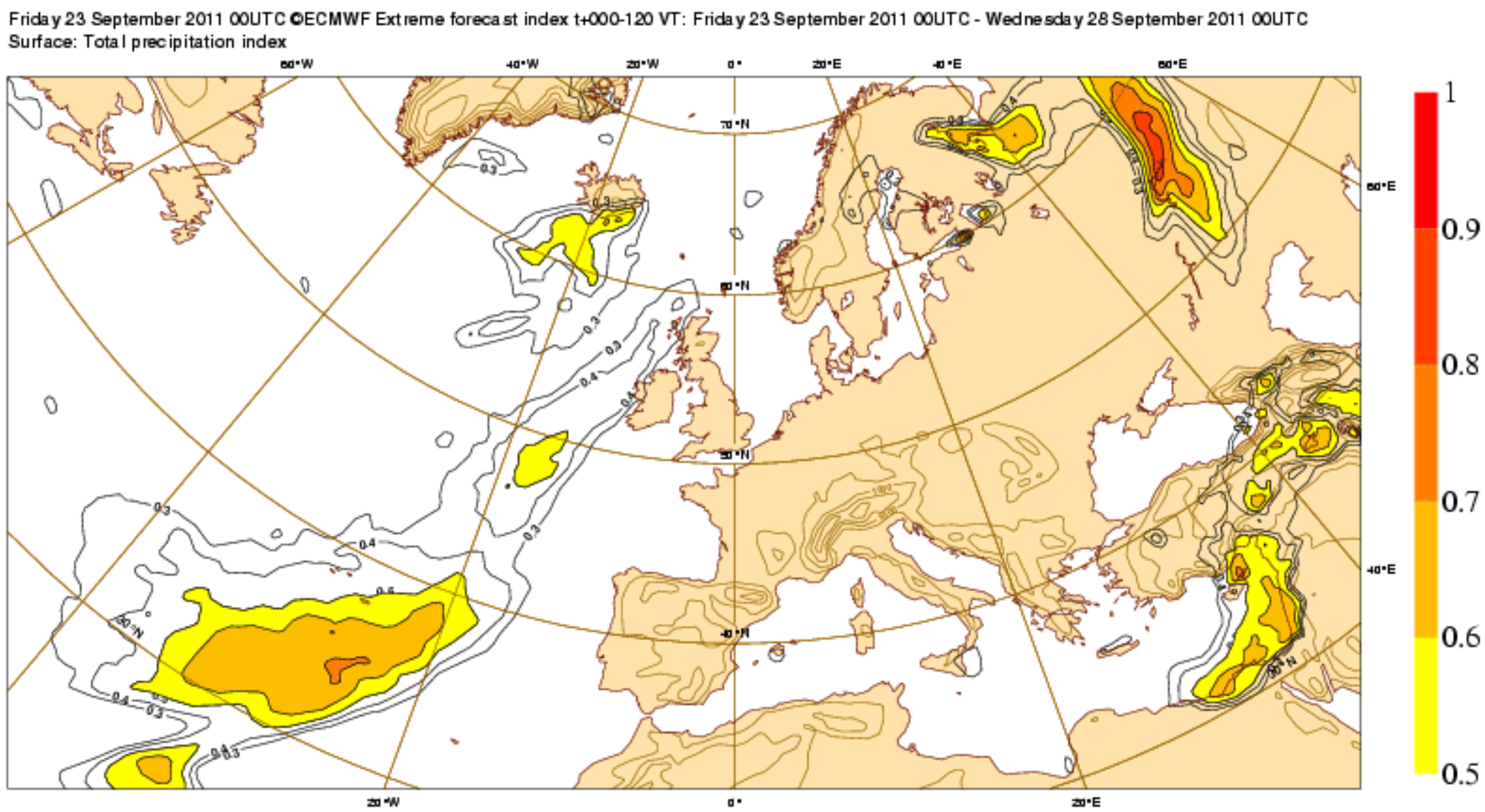
- Main goal:
  - Sampling phase space by taking into account:
    - Initial conditions perturbations.
    - Model errors, mainly Physics.
    - Boundary conditions perturbations.
- Validation and verification:
  - Spread (spread-skill diagram, Talagrand histogram).
  - Reliability (reliability diagram and sharpness).
  - Resolution (ROC curves).
  - Brier Skill Score.

Medium-Range Forecast - ECMWF

- Characteristics:
  - Initial condition perturbations: EDA + SVs.
  - Model errors: Physics Stochastic Scheme.
  - 51 members.
  - ~ 30 Km horizontal resolution.
- Goal:
  - Forecasting severe weather at medium-range.
- Tool:
  - Extreme Forecast Index (EFI).
  - Measures how far away from the model climate distribution the actual EPS forecast is.
  - It scales from -1 to 1 (all members reach respectively unprecedented small and unprecedented large values).
- Disadvantage:
  - Computing periodically (weekly) the climate of the numerical model for calibration.

EFI - Example

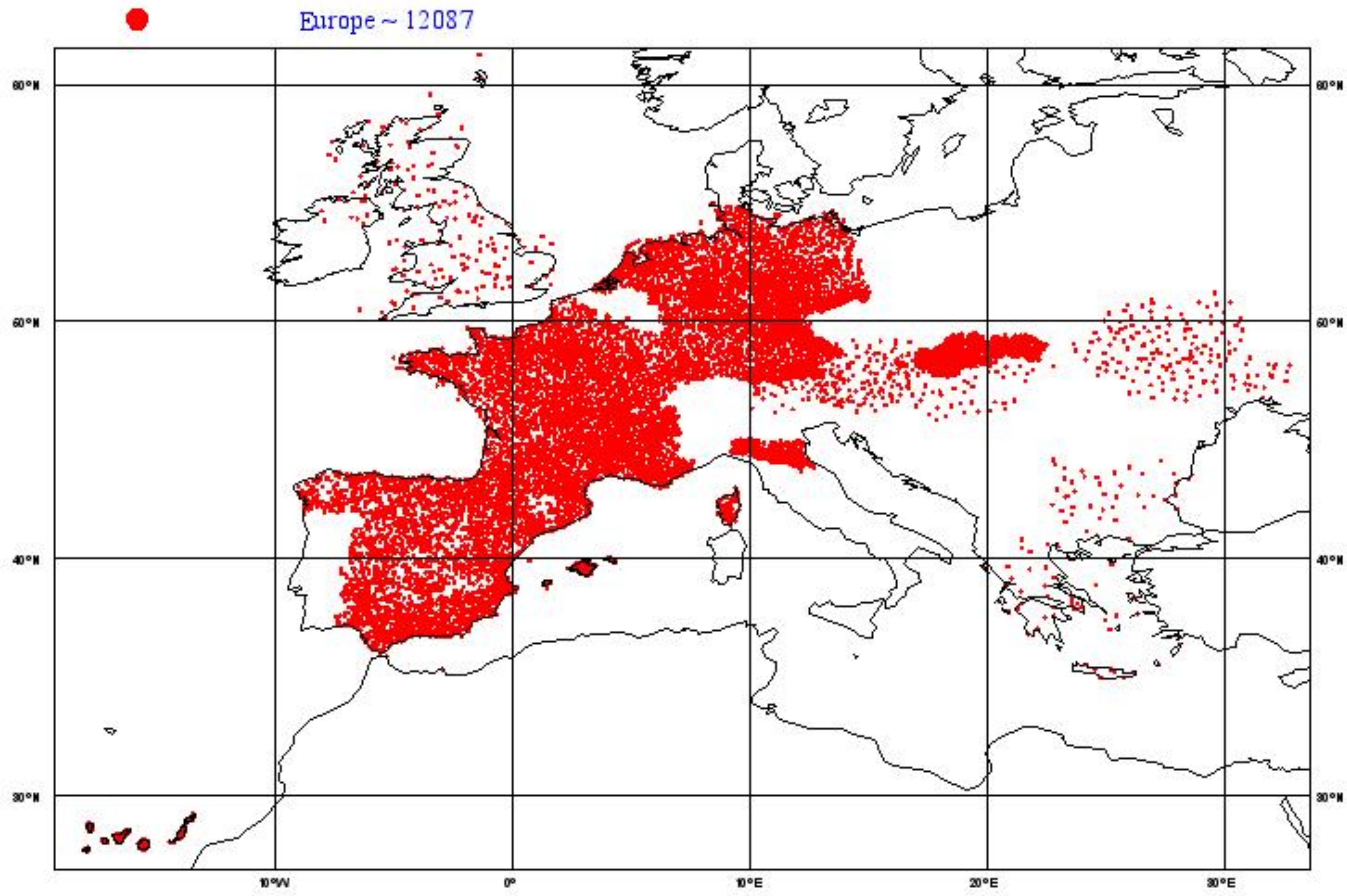
- Computing integrated EFI for wind (speed and gusts), temperature and precipitation.

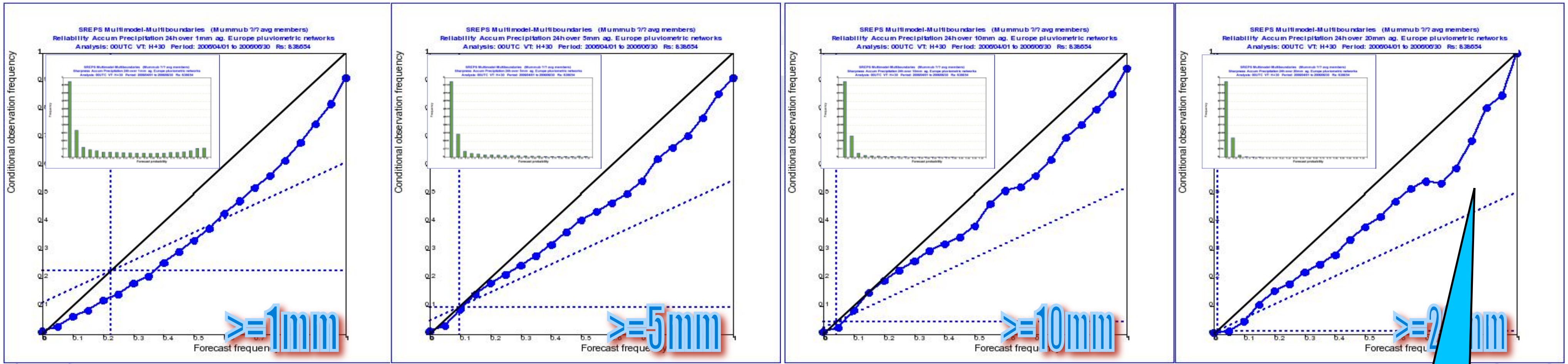


Short-Range – AEMET - SREPS

- Characteristics:
  - Initial and boundary condition perturbations: Downscaling Global Deterministic models (ECMWF, NCEP, CMC, JMA, GME).
  - Model errors: Multimodel (Hirlam, HRM, COSMO, UM, MM5)
  - 25 members.
  - ~ 25 Km horizontal resolution.
- Goal:
  - Forecasting severe weather at short-range.
- Tool:
  - Better spread-skill from multimodel technique.
  - Better PDF for precipitation.
  - Easy calibration through Bayesian Model Averaging (BMA).
- Disadvantage:
  - Difficult to maintain the system operationally (human resources needed).

Europe pcp networks 2006





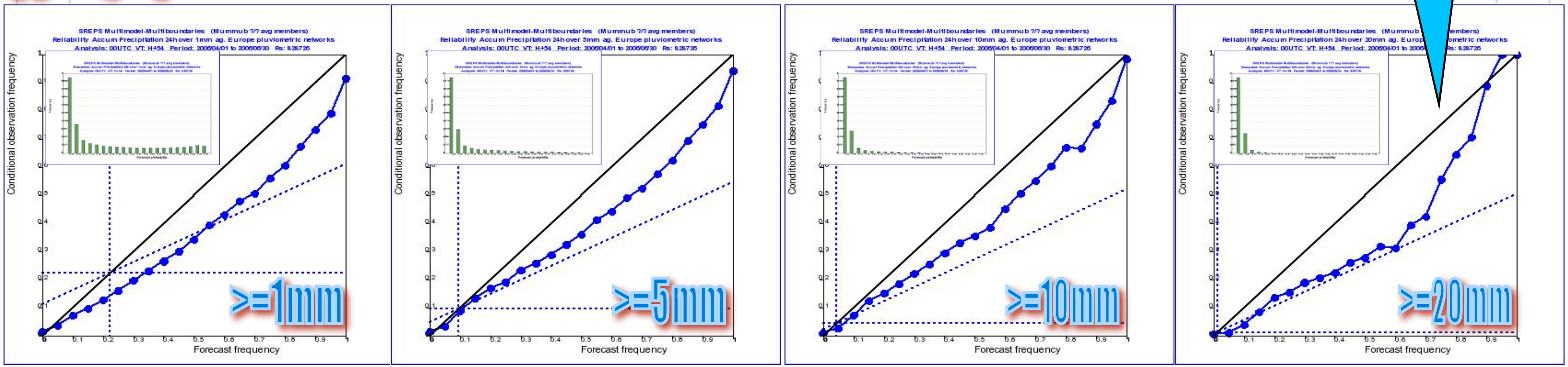
H+30

Joint

H+54

- Good reliability according to
  - thresholds (base rate)
  - forecast length

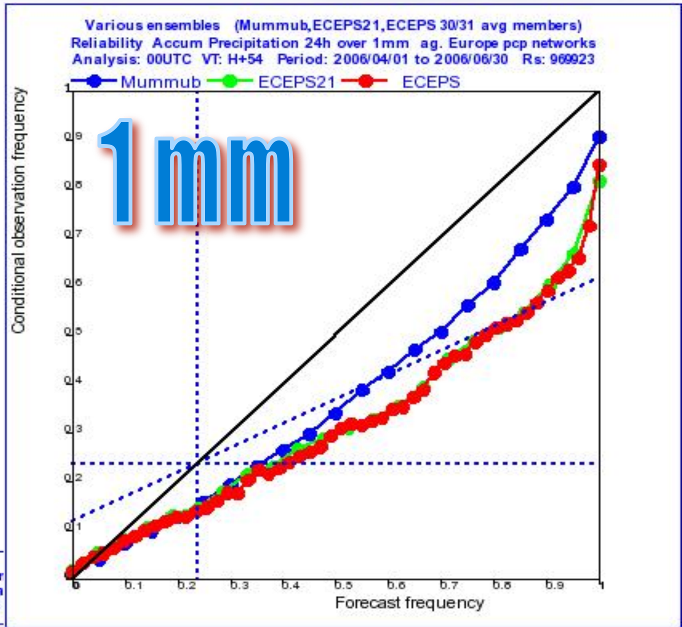
No Under-sampling

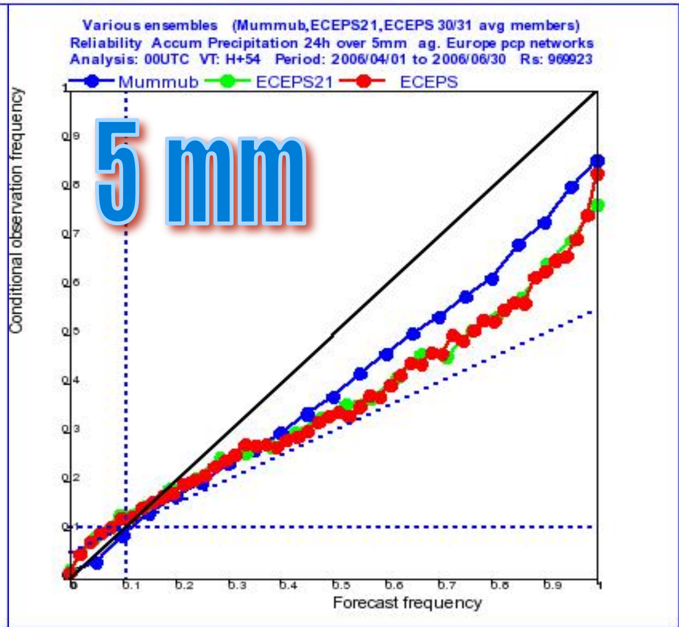


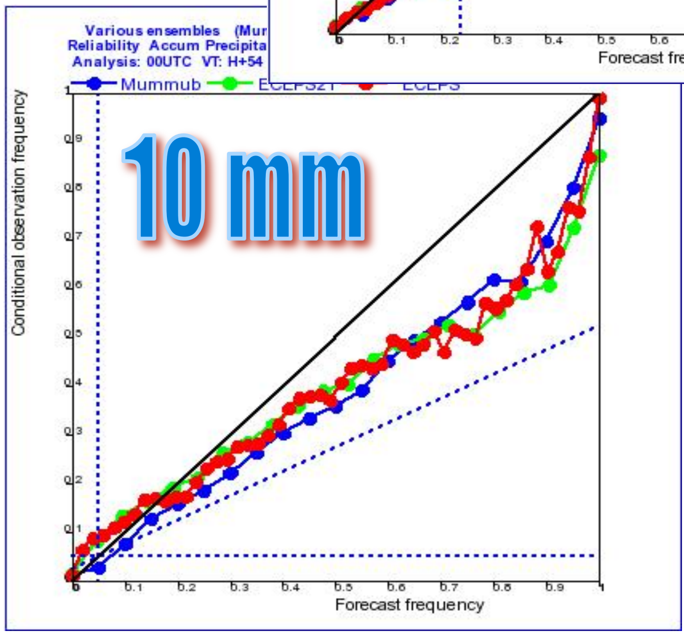
Comparison SREPS with ECMWF EPS

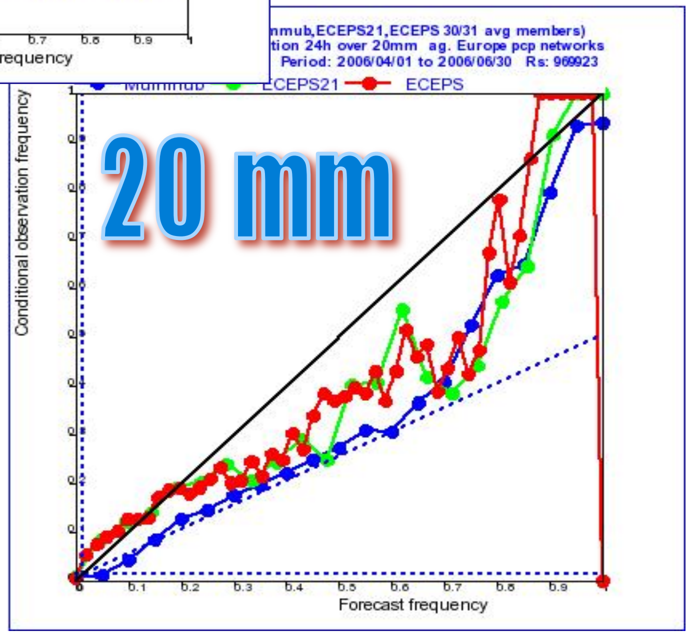
- Period: April to June 2006
- European Synop obs: **H+72**.
  - Mslp / v 10m / Precipitation
- European climate precipitation network: **H +54** (longest SREPS period matching observations).
  - 24 hours accumulated precipitation (from early morning to early morning).

Climate Obs – 24 h. Precip (1, 5, 10 & 20 mm)









Blue - SREPS

Green - ECMWF 21

Red - ECMWF 51

Climate Obs – 24 h. Precip (1, 5, 10 & 20 mm)

Brier Skill Score (BSS) Decomposition – 10^6 realizations

BSS [+]

Precip (mm)	Climatolog. Frequency	Uncertainty	MumMub	ECMWF 21	ECWMF 51
1	0.24	0.18	0.35	0.28	0.28
5	0.11	0.09	0.27	0.22	0.22
10	0.05	0.05	0.18	0.18	0.19
20	0.01	0.01	0.01	0.07	0.08

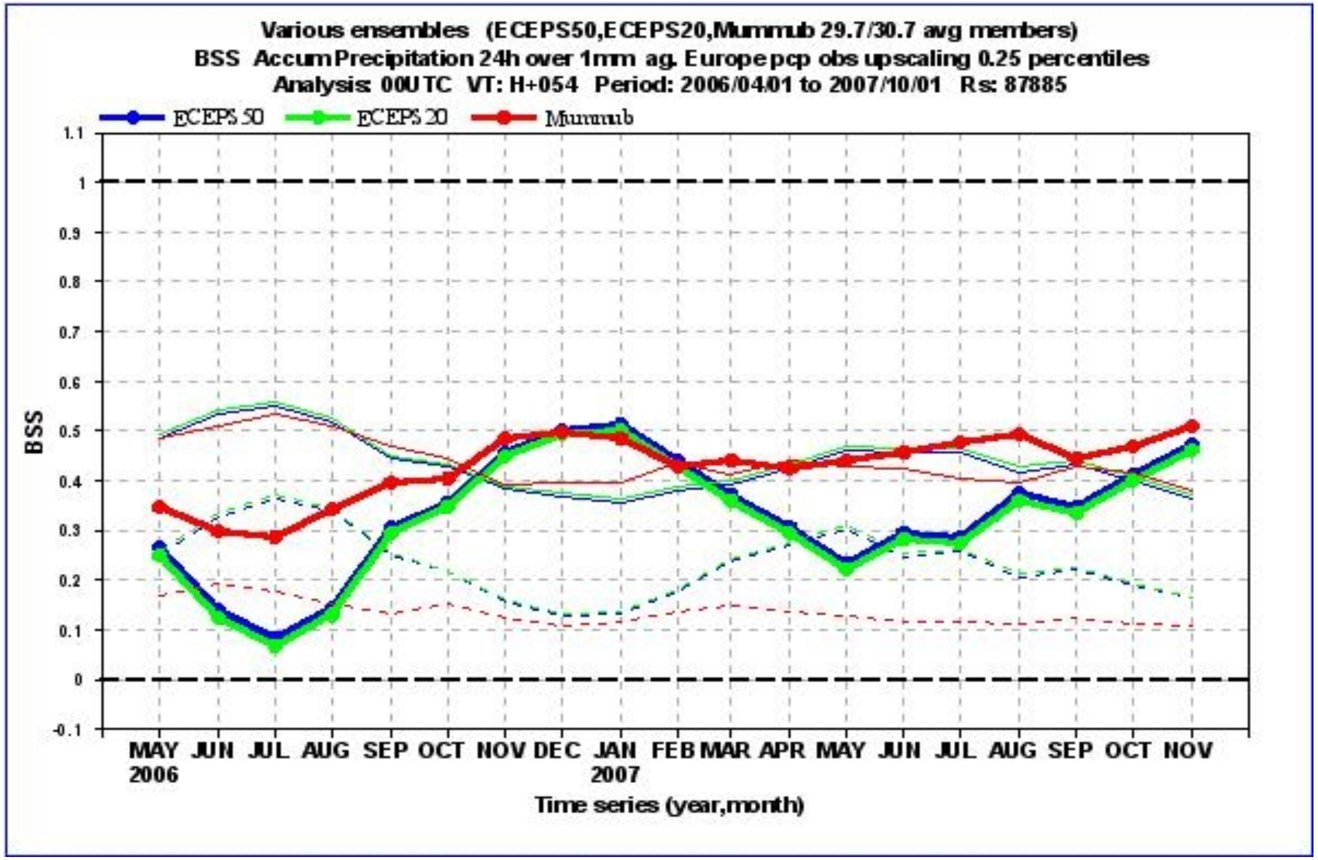
BSS Rel [-]

Precip (mm)	MumMub	ECMWF 21	ECWMF 51
1	0.06	0.13	0.14
5	0.03	0.08	0.08
10	0.03	0.03	0.03
20	0.07	0.02	0.02

BSS Res [-]

Precip (mm)	MumMub	ECMWF 21	ECWMF 51
1	0.59	0.59	0.59
5	0.70	0.70	0.70
10	0.79	0.79	0.78
20	0.91	0.91	0.90

24 hours accumulated precipitation from European climate network upscaled to 0.25 deg. Resolution - BSS



SREPS

ECMWF 51

ECMWF 21

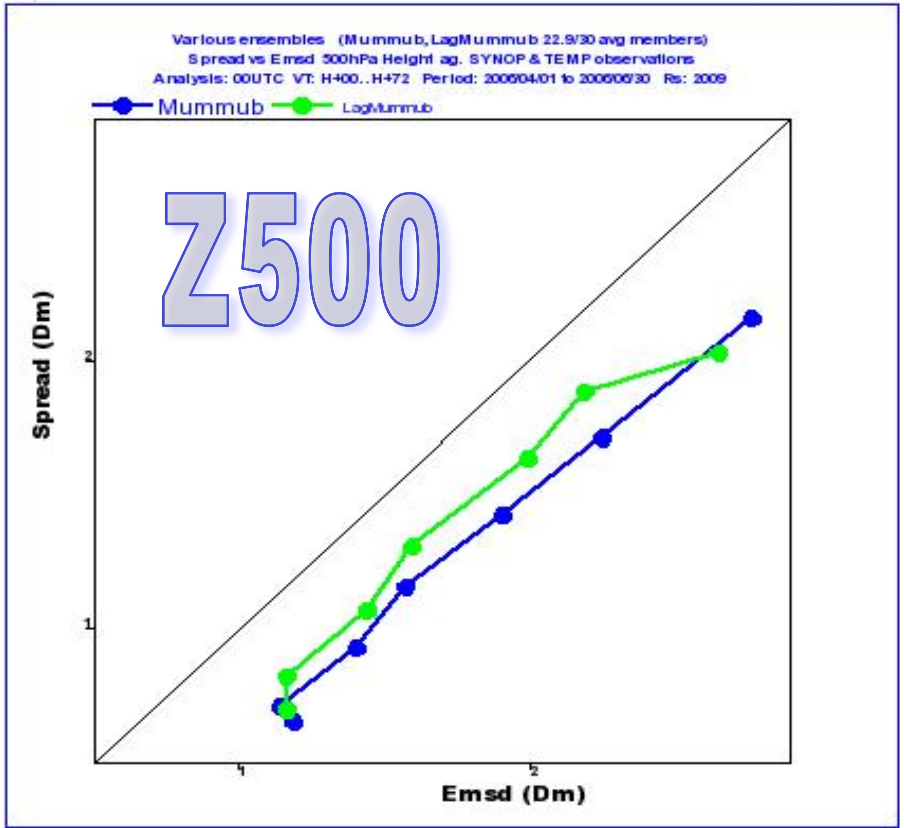
Time-Lagged Super-ensemble

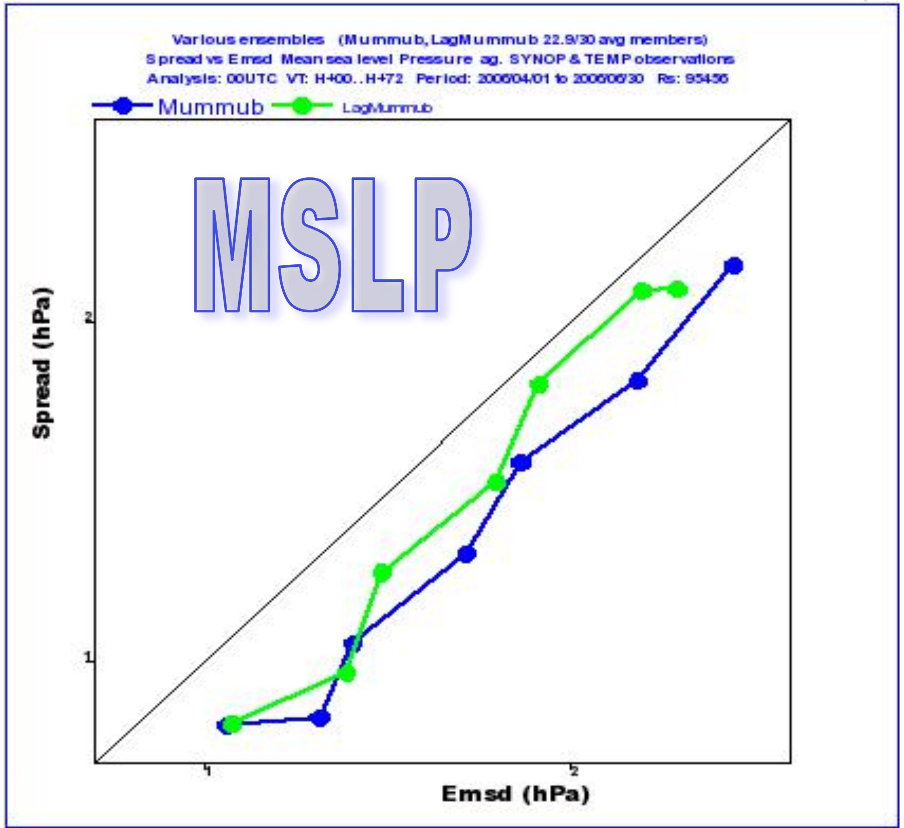
- How much predictability can be added by a time-lagged super-ensemble?
- 40 members super-ensemble (SE-SREPS) with the last two runs of SREPS (HH & HH-12).
- Verification against observations
- Cheap in terms of computer resources
- Just a different post-process

Spread-skill

Green - SE-SREPS

Blue - SREPS





BMA calibration

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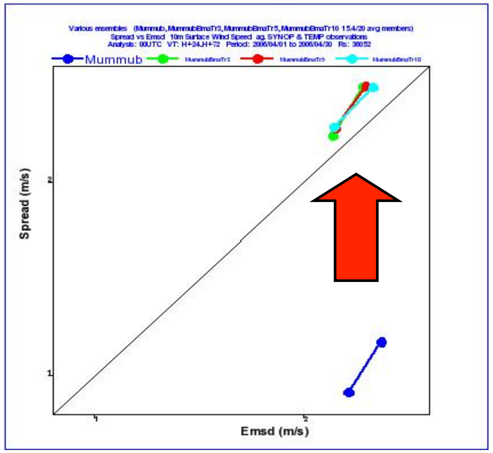
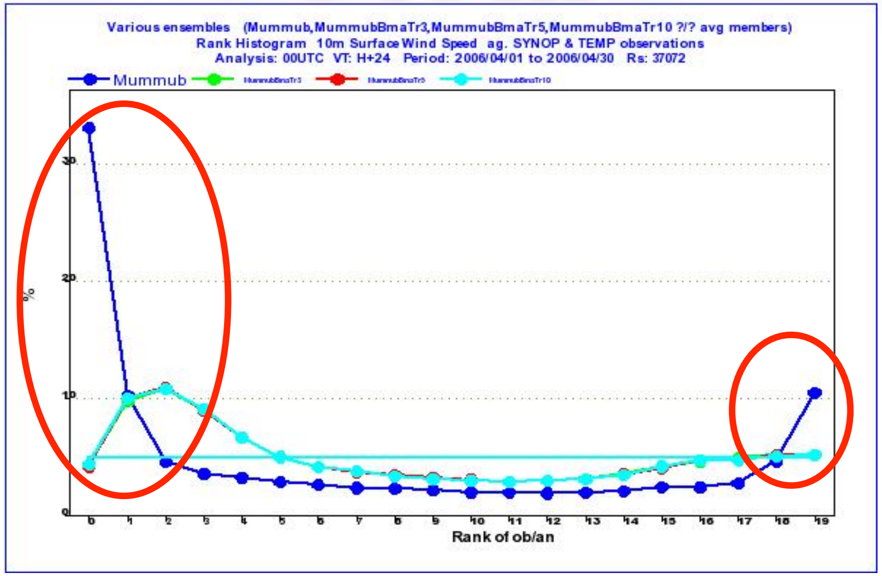
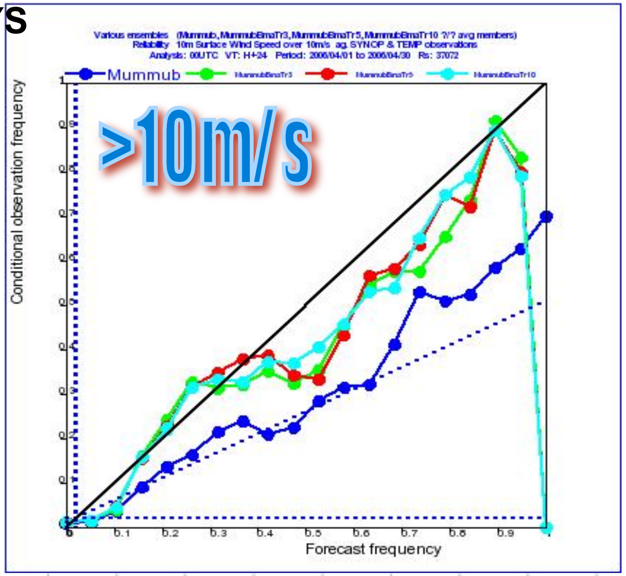
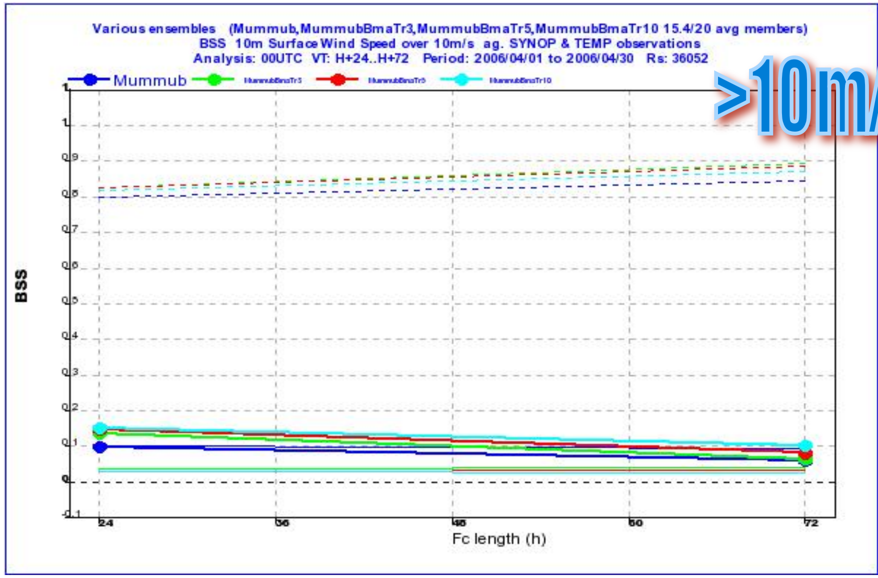
s10m

- MULTIMODEL
- BMA 3 T. DAYS
- BMA 5 T. DAYS
- BMA 10 T. DAYS









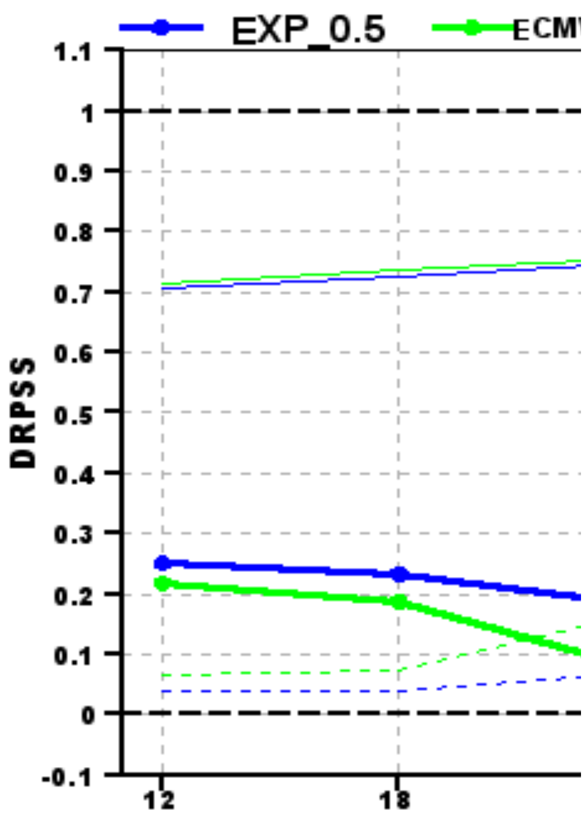
But resolution matters - GLAMEPS

- Characteristics:
  - Initial and boundary condition perturbations: Downscaling Targeted ECMWF EPS.
  - Model errors: Multimodel (Hirlam – Two convection schemes, ALADIN)
  - 51 members.
  - ~ 10 Km horizontal resolution.
- Goal:
  - Forecasting severe weather at short-range.
- Tool:
  - Keeping some multimodel benefits.
  - Easy calibration through Bayesian Model Averaging (BMA).
- Disadvantage:
  - Computer resources needed to run the system operationally.

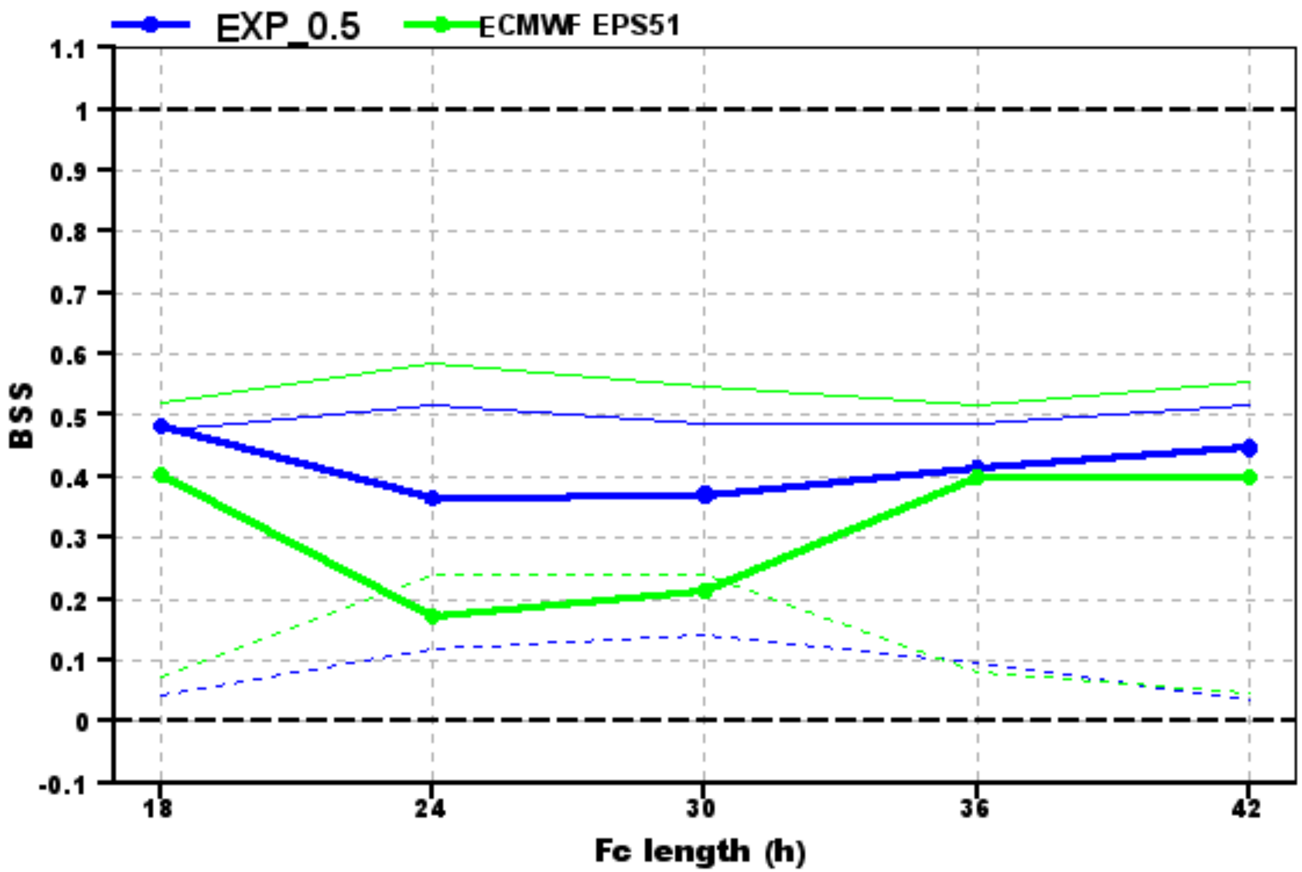
Verification GLAMEPS.org

Aug-Sept-Oct 2010

DRPSS 12-42h, 6h Precip

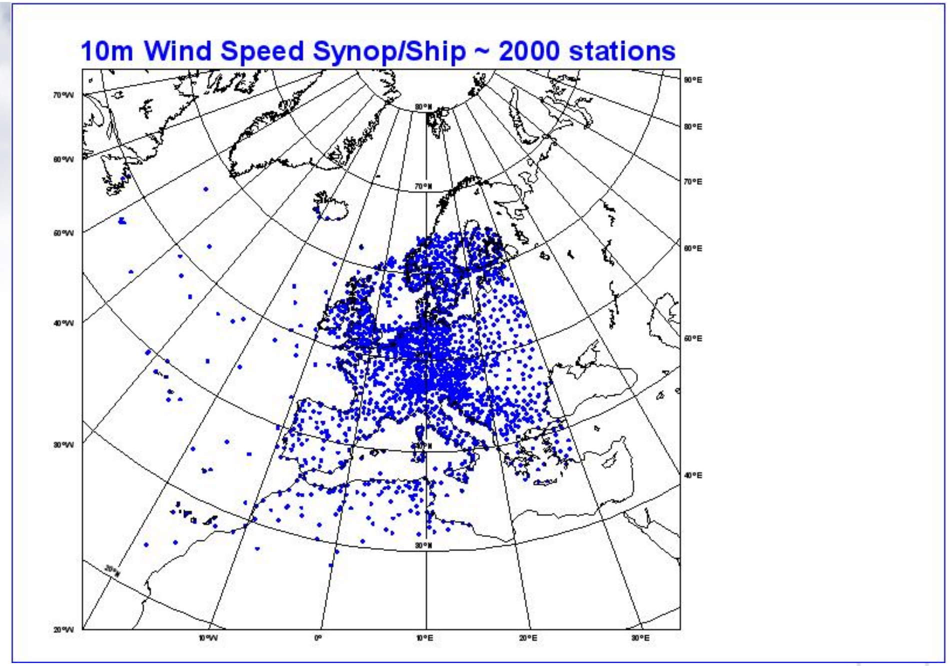


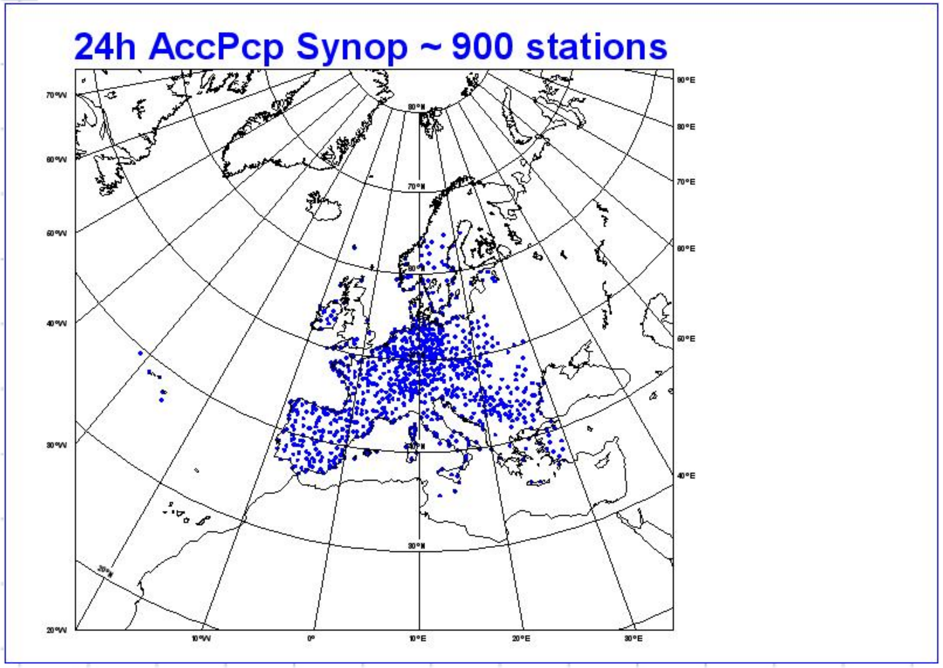
BSS 12h Acc. Precip.

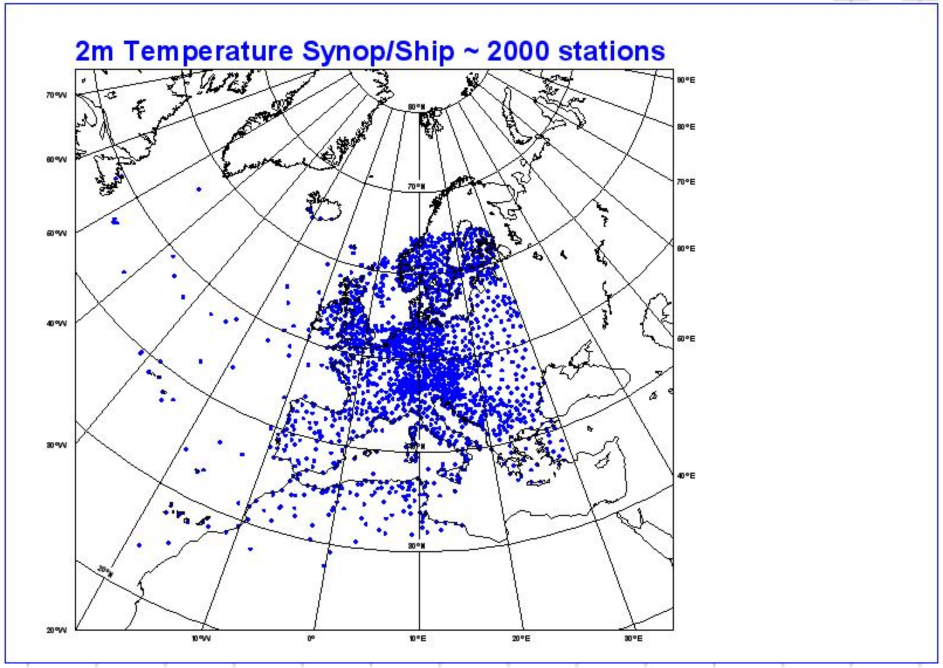


Observations

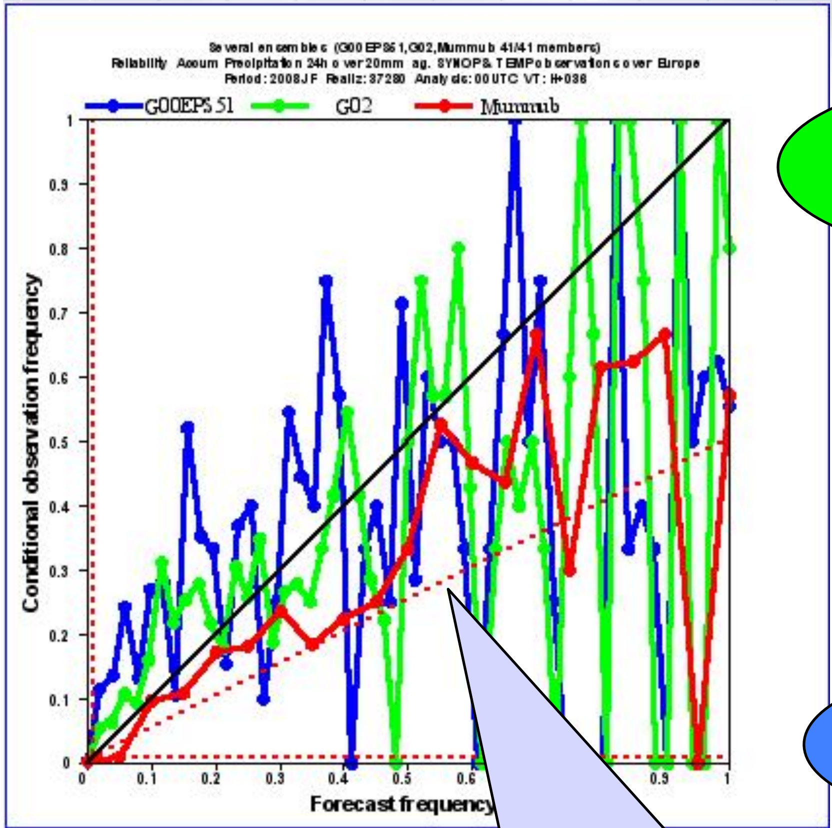
- Only available forecast steps 12,18,24,30,32,36,48 for GLAMEPS EXP_2.0
- Thus climatological network not feasible (6/to/30)
- **SYNOP/SHIP** available (pcp 18/to/36)

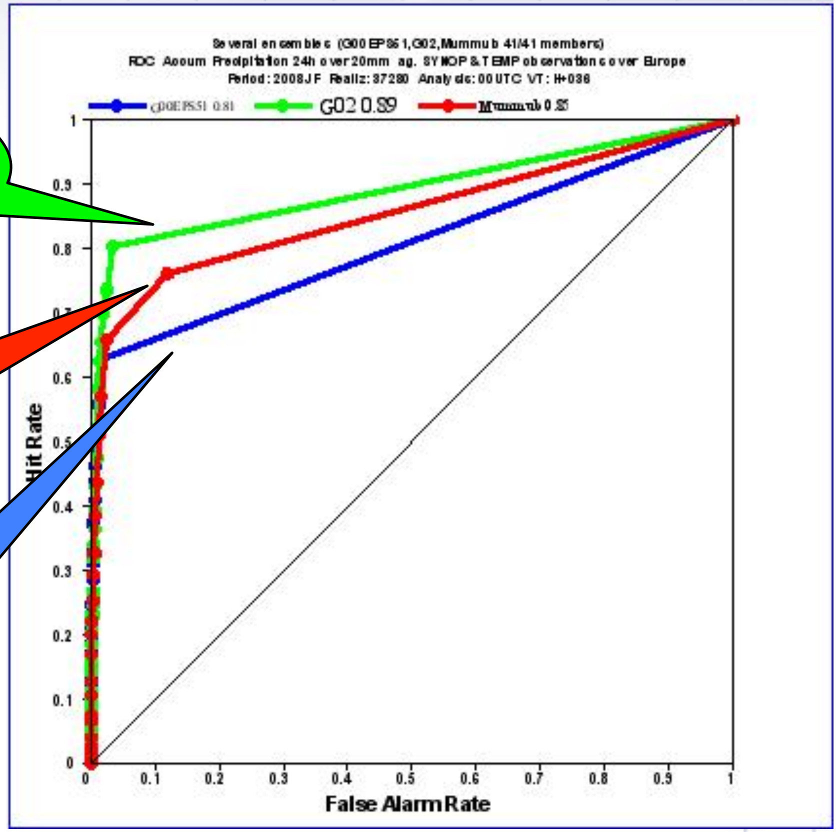






24hAccPcp > 20mm





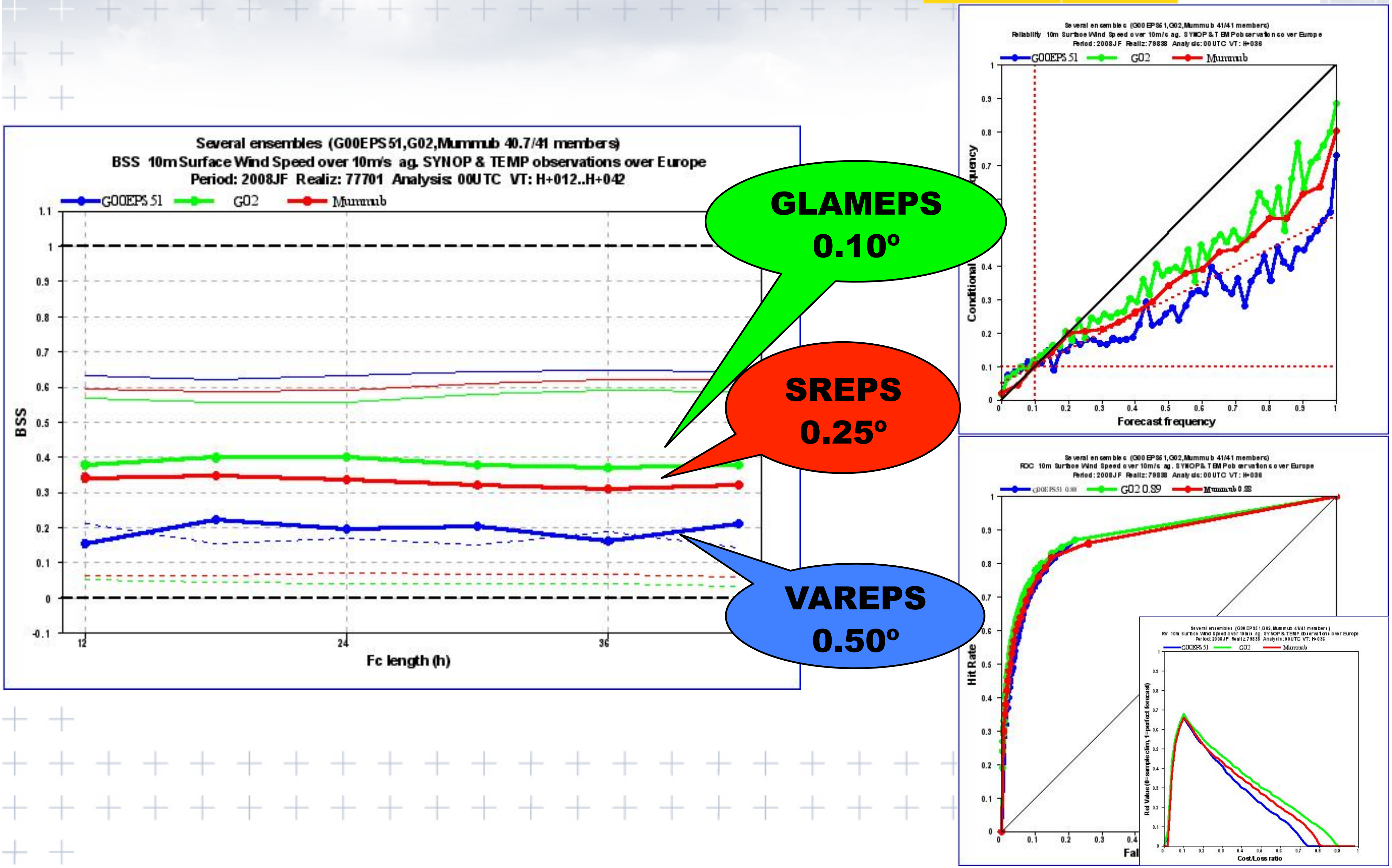
GLAMEPS 0.10º

SREPS 0.25º

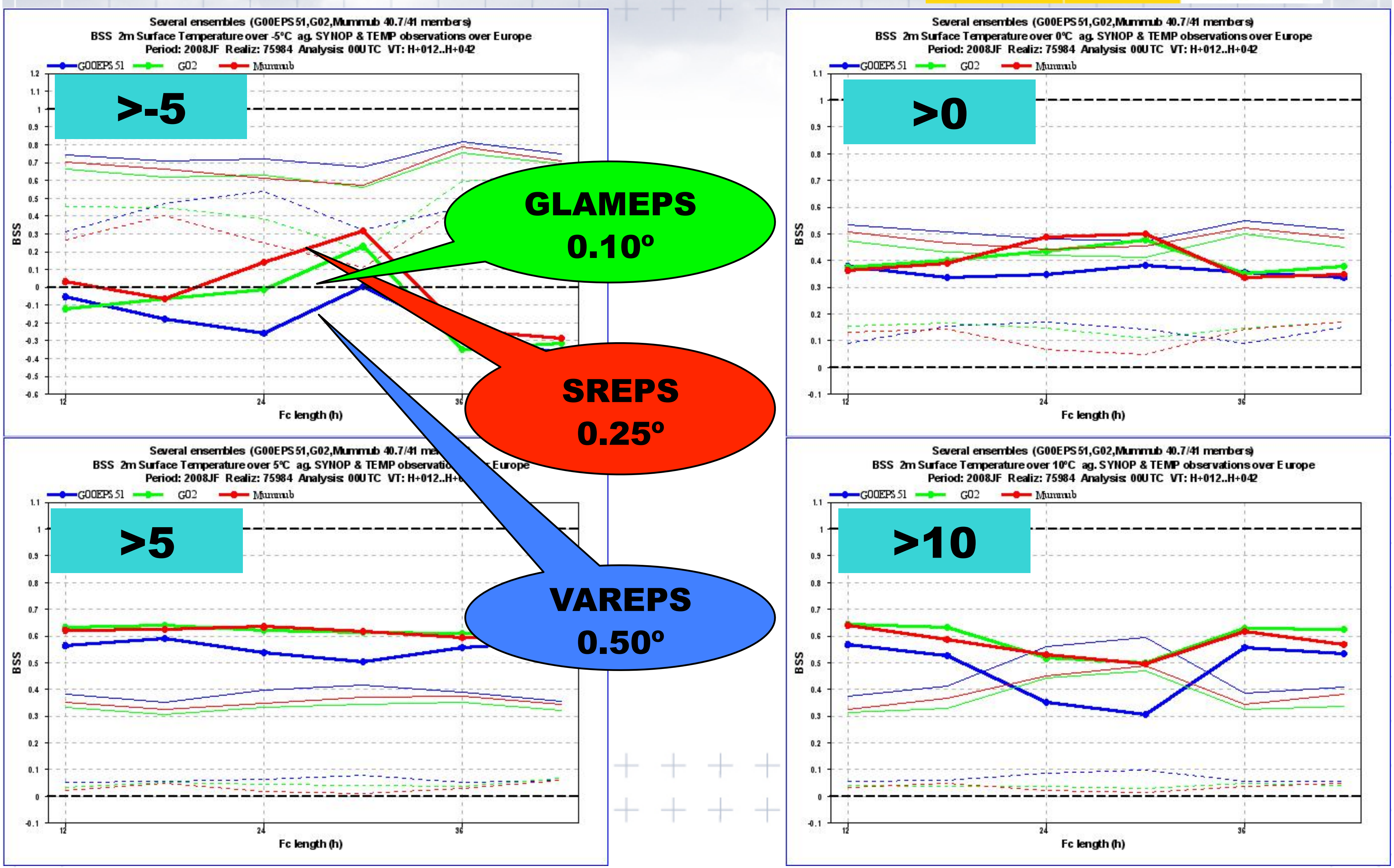
VAREPS 0.50º

Strong undersampling

10mWindSpeed > 10m/s



2mTemperature



Mesoscale EPS

- Characteristics:
  - Initial and boundary condition perturbations: Downscaling lower resolution EPS or deterministic global models.
  - Model errors, perturbations in Physics:
    - Stochastic Physics
    - Stochastic parameters
    - Multi-Physics
  - Domain: very small (normally one country).
  - 15-20 members.
  - ~ 2 Km horizontal resolution.
  - Running 4 to 8 times a day up to 24 or 36 hours.
- Goal:
  - Forecasting severe weather at short- and very short-range (nowcasting).
- Tool:
  - Convective-permitting EPS.
  - Using mesoscale NWP models.
- Disadvantage:
  - Computer resources needed to run the system operationally are huge.
  - Objective verification very difficult due to the high resolution.

Mesoscale EPS – Example - UKMO

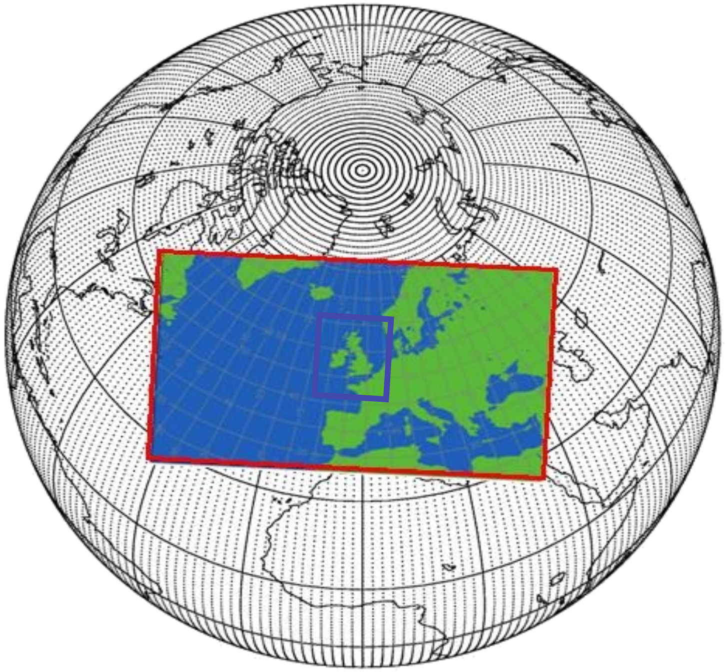
Plan to routinely run a 2.2 km ensemble from 2012 (MOGREPS-UK), embedded within MOGREPS-R (EU) (18 km -> 12 km) ensemble.

36-hour forecasts

12 members

6-hour cycling

Downscaling – No high-resolution initial perturbations or forecast perturbations to start with



Case study experiments

24 members 1.5 & 2.2 km

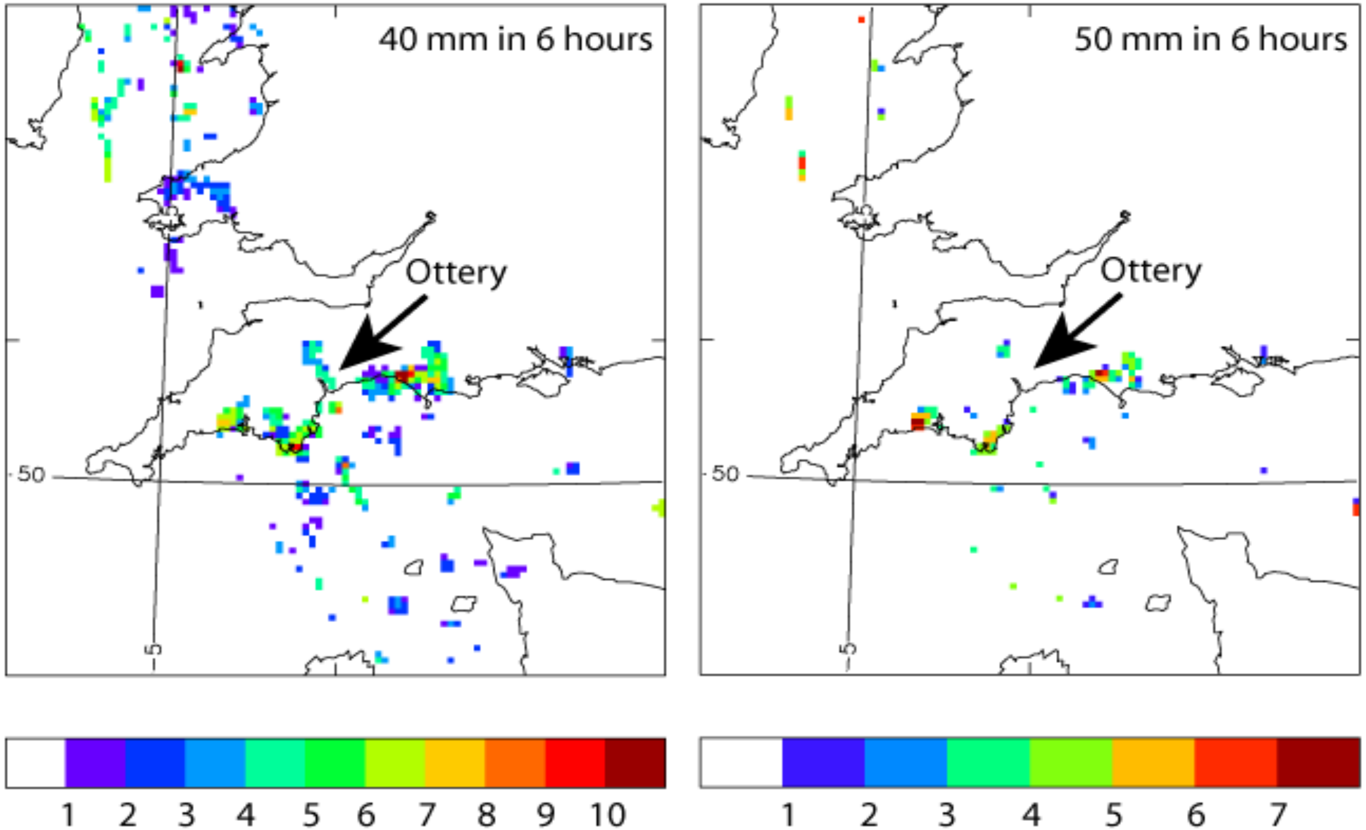
Courtesy of Nigel Roberts and UKMO

All pixels exceeding critical thresholds

‘Extreme’ threshold for
surface water flooding

1 in 10
years

1 in 30
years

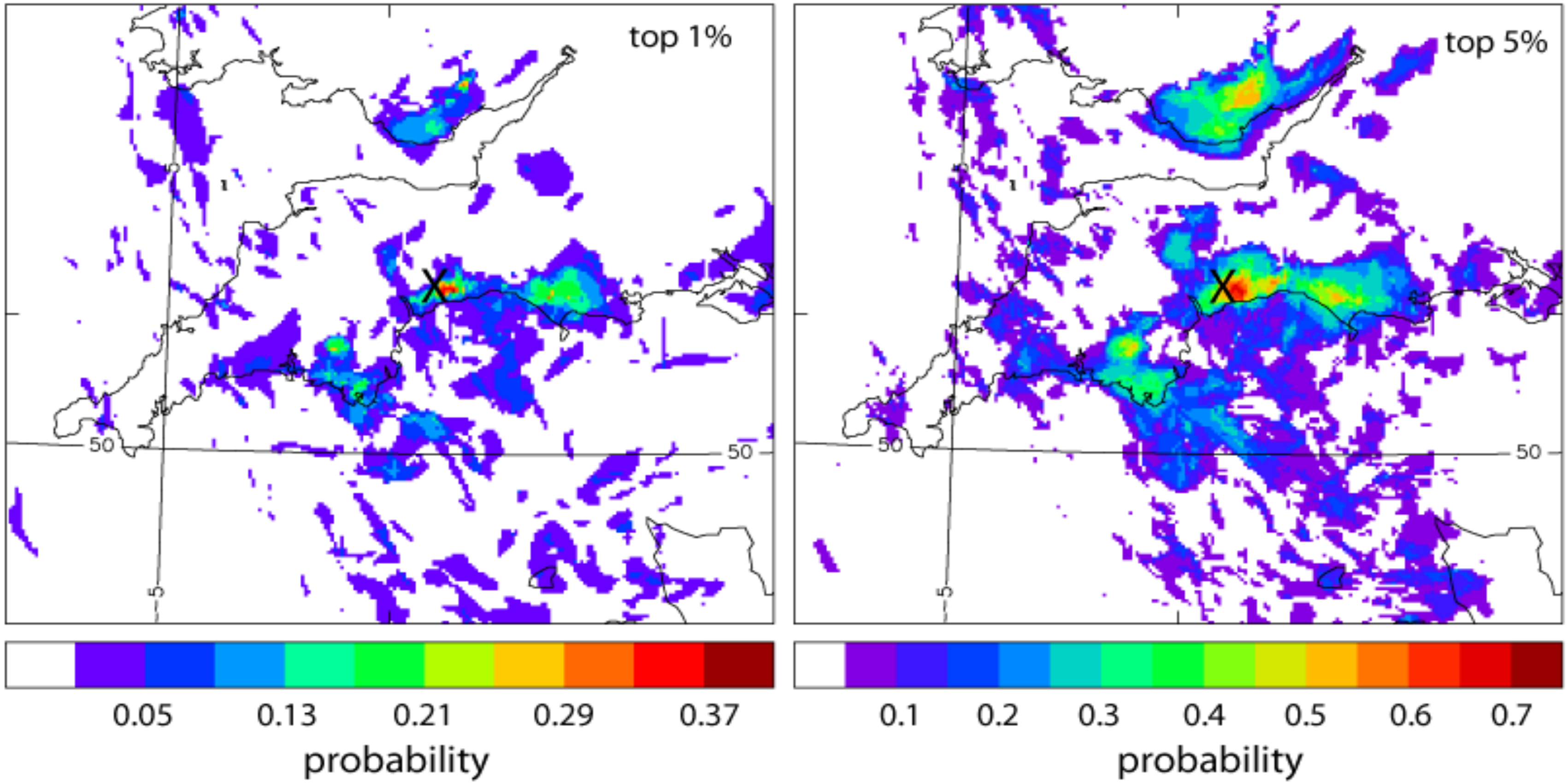


Computed on 4.5km grid – Changgui Wang

Courtesy of Nigel Roberts and UKMO

Ottery-St-Mary flood event

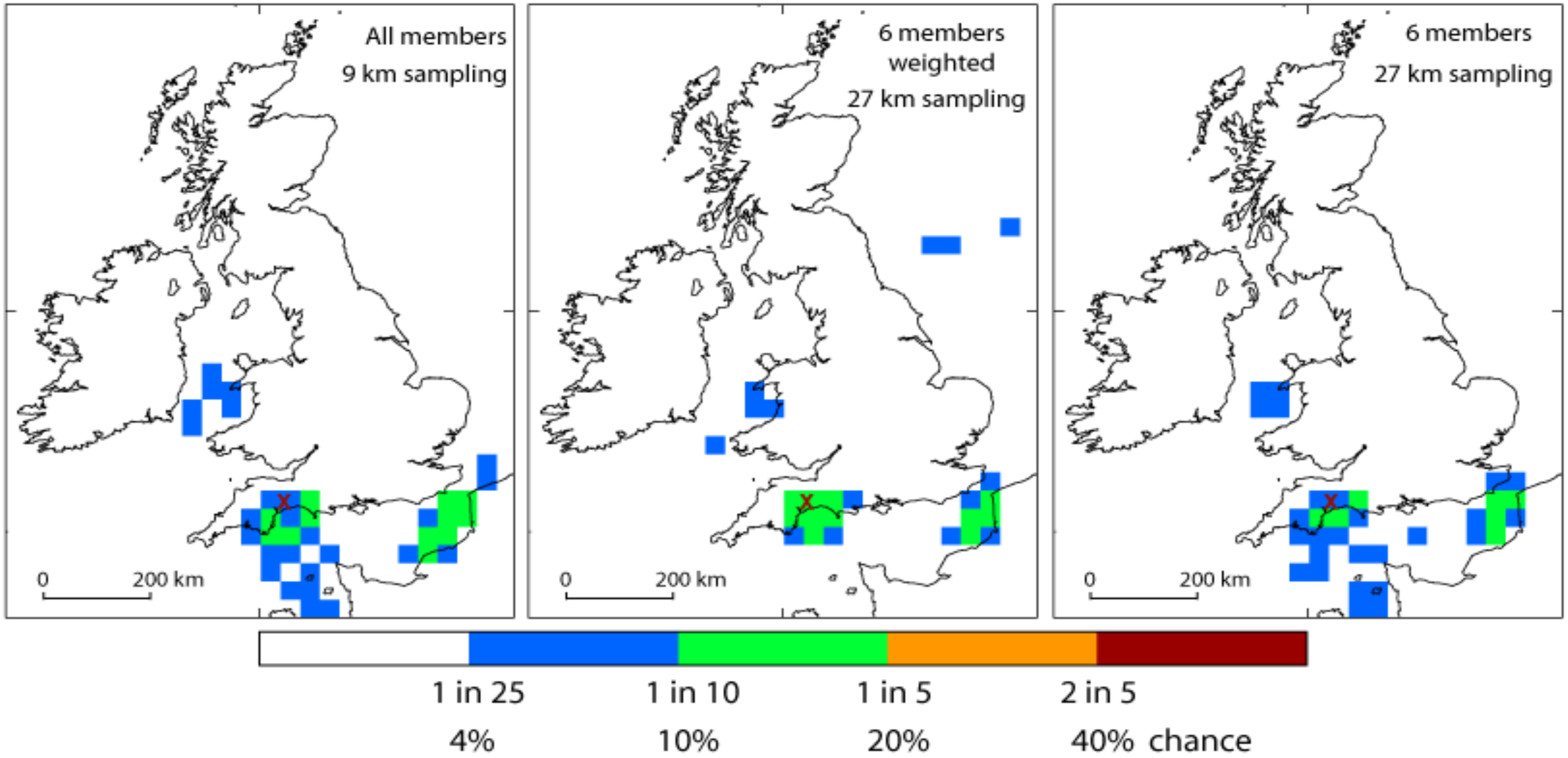
Probability of getting the top 1% or 5% of rainfall amounts.
Peak values exceeded extreme rainfall thresholds.
Produced from 24 forecasts from the 1.5 km UKV model. X marks Ottery.



Courtesy of Nigel Roberts and UKMO

Probability of an 'extreme' event within 36x36km squares

Traditional clustering method found wanting – weighted sampling should be better

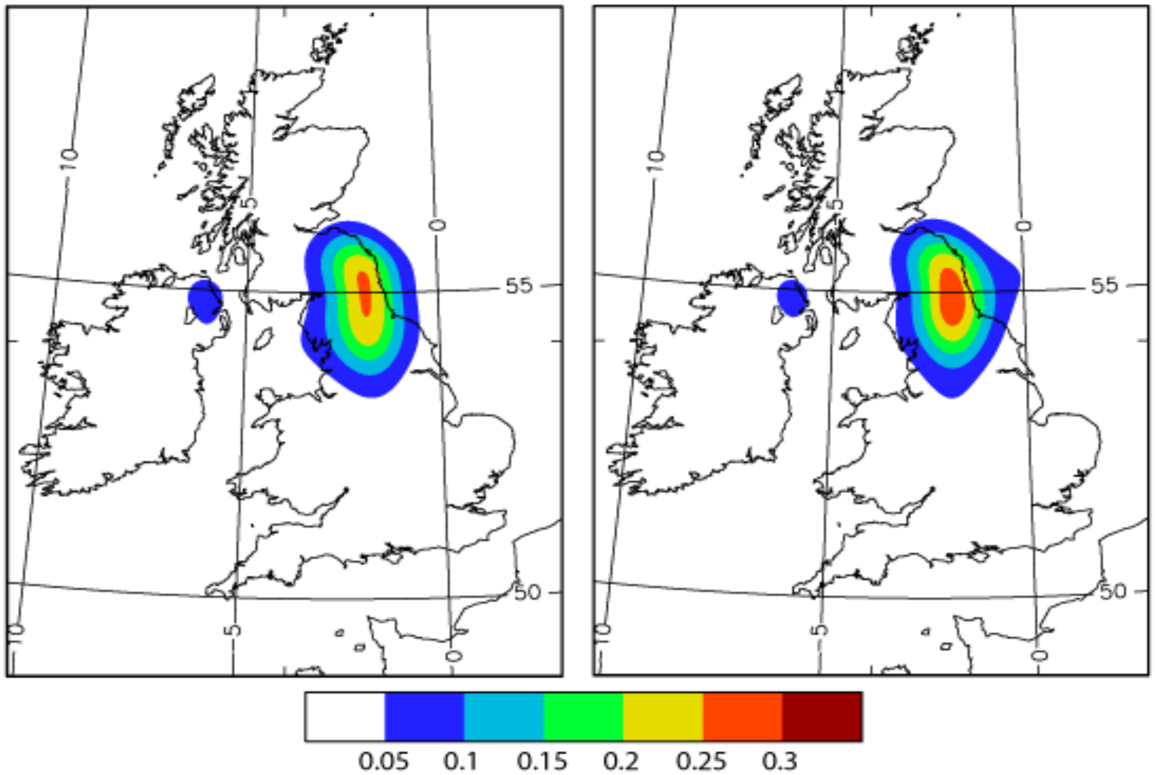


Courtesy of Nigel Roberts and UKMO

Morpeth flood event 5-6 Sept 2008

Probability of exceeding 50mm in 17 hours

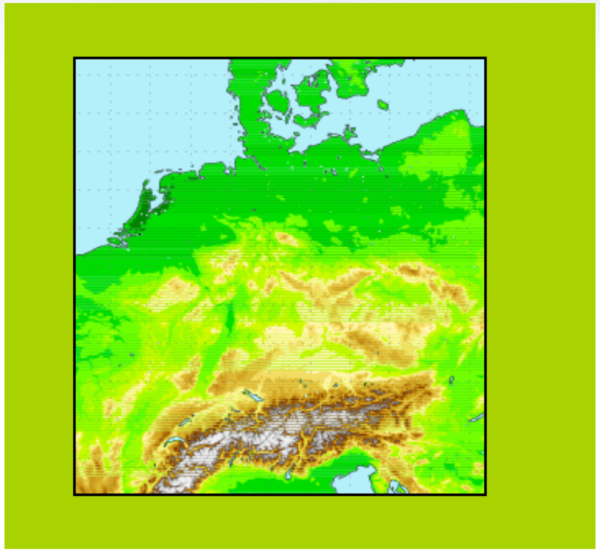
UKV 24 members 2.2km 24 members



Courtesy of Nigel Roberts and UKMO

Mesoscale EPS – Example - DWD

- **pre-operational phase has started:**
  Dec 9th, 2010
- **pre-operational setup:**
  - 20 members
  - grid size: 2.8 km
    convection-permitting
  - lead time: 0-21 hours,
    8 starts per day (00, 03, 06,... UTC)
  - variations in
    physics, initial conditions, lateral boundaries



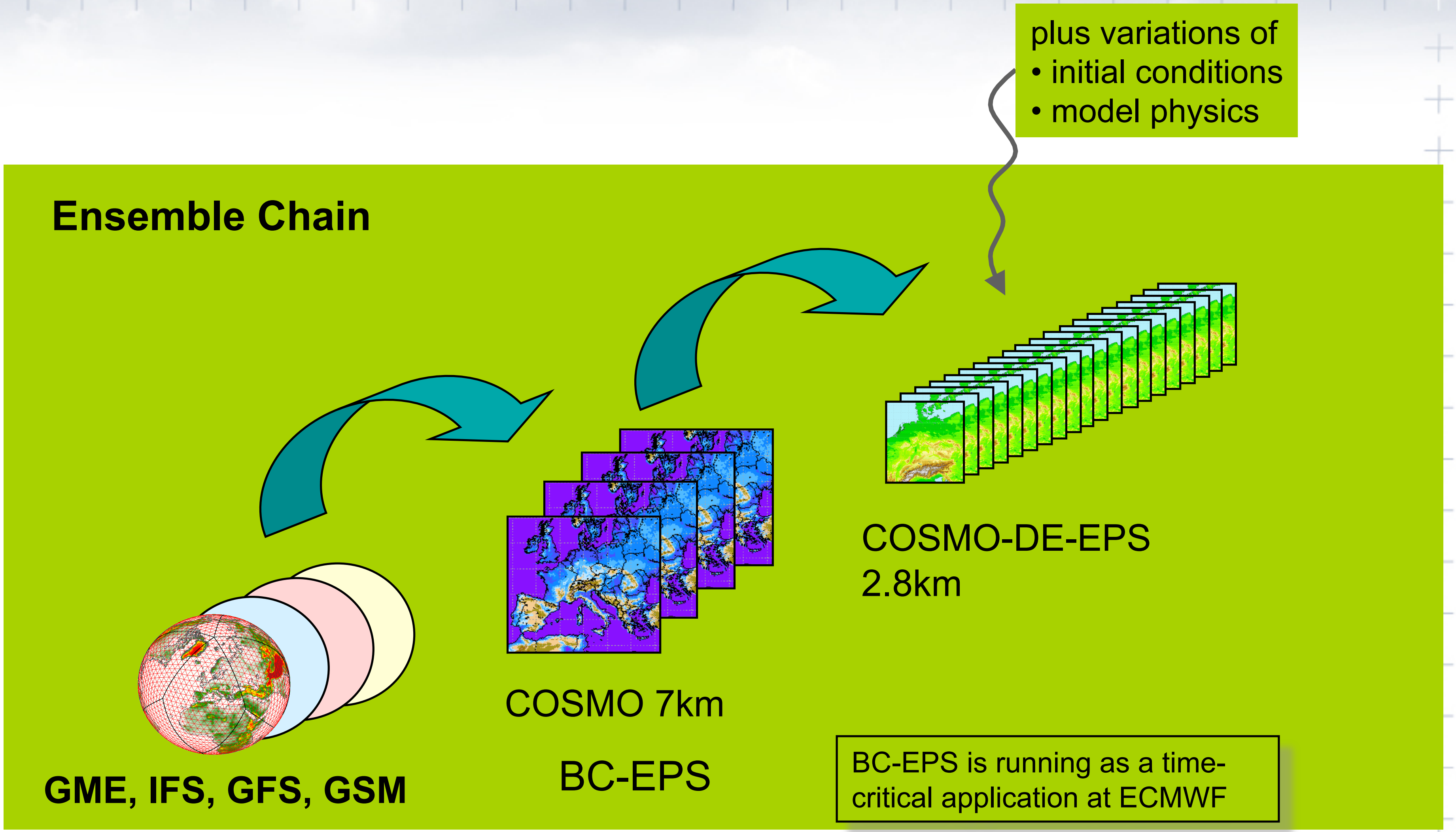
model domain

Perturbation Methods

Lateral Boundaries	Initial Conditions	Model Physics
“multi-model”	**“multi-model”**	**“multi-configuration”**
driven by different global models	different global models are used to modify COSMO-DE initial conditions	different configurations of the COSMO-DE model

Courtesy of Susanne Theis and DWD

Mesoscale EPS – Example - DWD



Courtesy of Susanne Theis and DWD

COSMO-DE-EPS plans (2011-2014)

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AEMet Agencia Estatal de Meteorología

- upgrade to 40 members, redesign

2011

reach operational status

2012

- statistical post-processing

2013

- initial conditions by LETKF
- lateral boundary conditions by ICON EPS

Courtesy of Susanne Theis and DWD

The „Supercell Example“

- COSMO-DE: convection-permitting model (2.8 km)
- can **explicitly simulate severe storms,**
  but **deterministic forecasts** of individual cells
  are not possible with 12 h lead time
- i.e. the **model provides a possible scenario**
  for the development of individual convective cells
- in this example: visualized by
  - simulated radar reflectivity
  - the **supercell detection index (SDI)**
  Wicker et al. (2005)

by
Axel Seifert

with Thomas Hanisch,
Christoph Gebhardt,
Zied Ben Bouallegue,
Michael Buchold

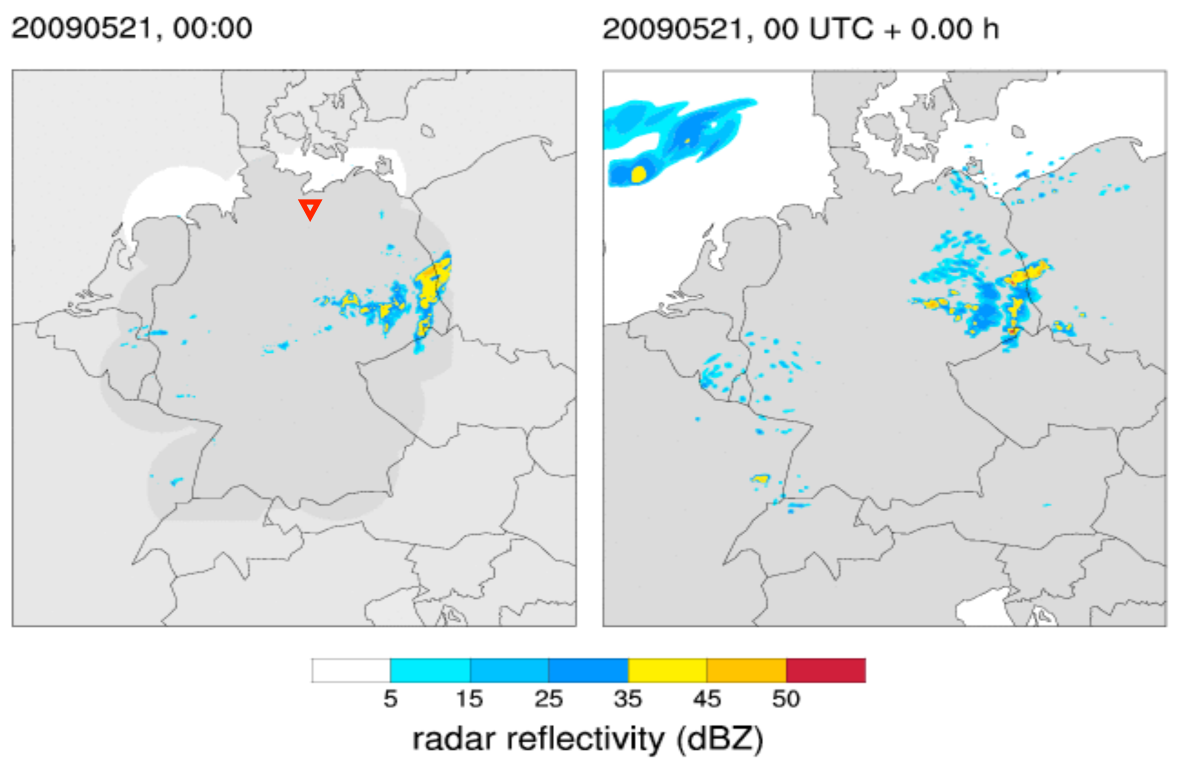
Deutscher Wetterdienst

Courtesy of Susanne Theis and DWD

The „Supercell Example“

21 May 2009

observed by radar **forecast by COSMO-DE**



- F2 tornado ▽ near “Plate” close to the Baltic coast 16:20 UTC
- the forecast ○ shows many ‘SDI events’ in that region

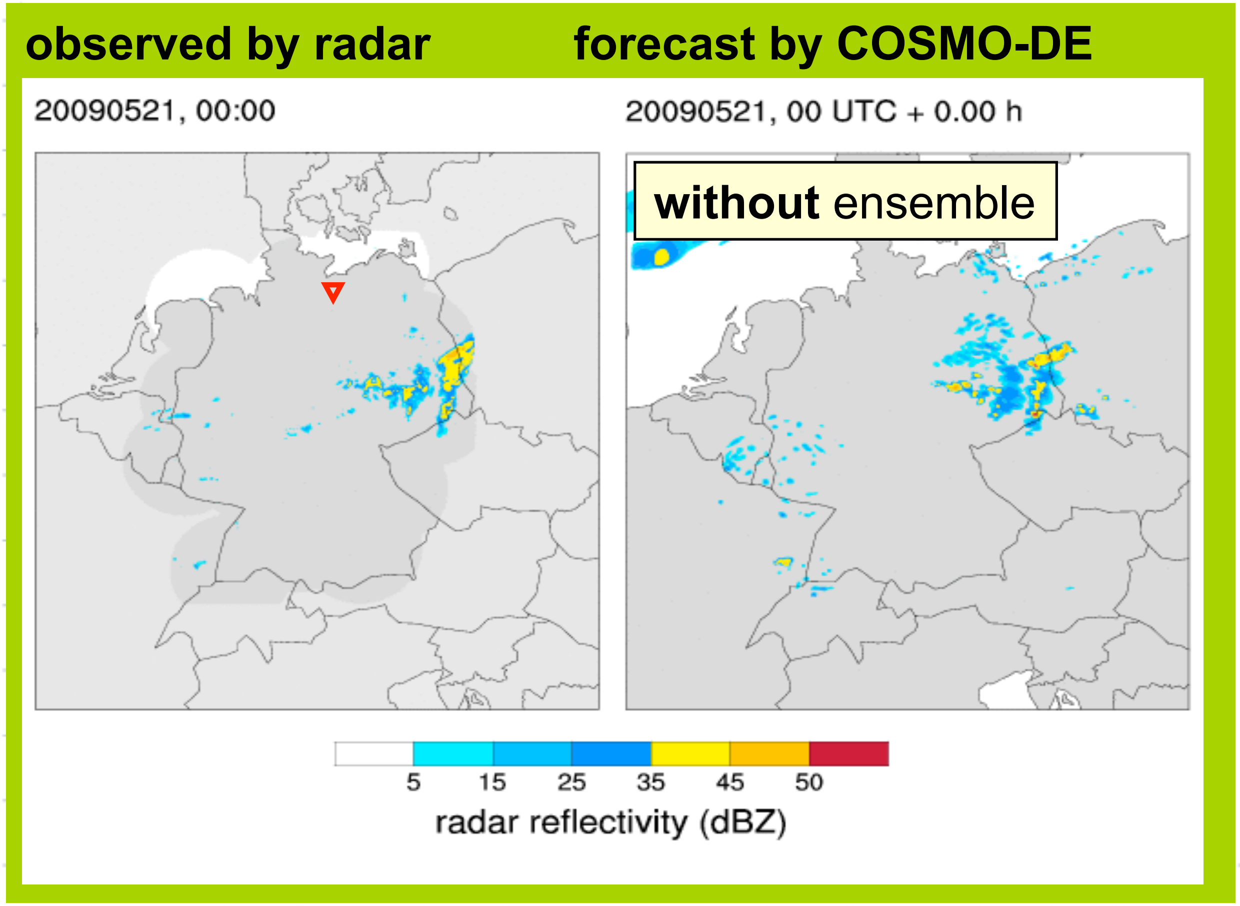
by
Axel Seifert

Deutscher Wetterdienst

Courtesy of Susanne Theis and DWD

The „Supercell Example“

21 May 2009



- F2 tornado ▽ near “Plate” close to the Baltic coast 16:20 UTC
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by
Axel Seifert

Deutscher Wetterdienst

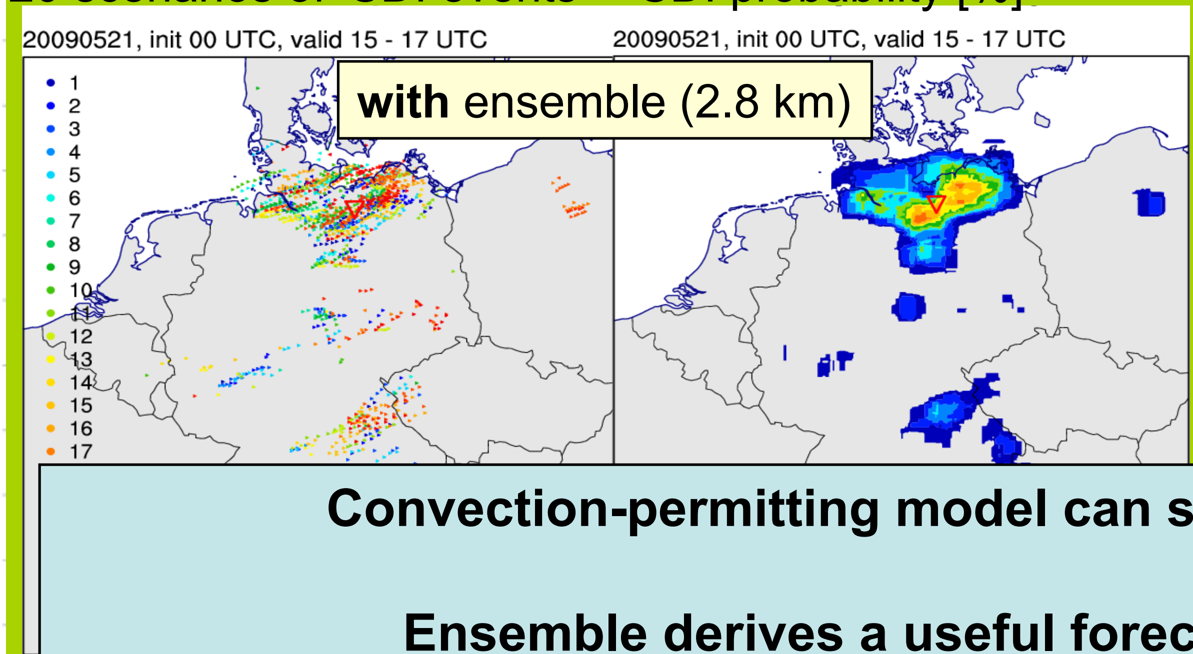
Courtesy of Susanne Theis and DWD

The „Supercell Example“

21 May 2009

forecast by COSMO-DE-EPS *(Gebhardt et al., 2011)*

20 scenarios of ‘SDI events’ SDI probability [%]



- ensemble provides 20 scenarios
- combined in a probability product
- useful guidance

Convection-permitting model can simulate process.

Ensemble derives a useful forecast guidance.

Courtesy of Susanne Theis and DWD

Mesoscale EPS – Example – CAPS – SPC
HWT Spring Experiment (http://hwt.nssl.noaa.gov/Spring_2011/index.php)

- Characteristics:
  - Initial condition perturbations: EDA using radar
  - Boundary condition perturbations: downscaling from SREF.
  - Model errors, perturbations in Physics:
    - Multimodel (WRF/NMM, WRF/ARW, ARPS)
    - Multi-Physics
  - Domain: CONUS
  - 50 members.
  - ~ 4 Km horizontal resolution.
  - Running 00 UTC up to 36 hours.
- Goal:
  - Forecasting severe weather at short- and very short-range (nowcasting):
    - Severe convection.
    - Convective initiation.
    - QPF
- Tool:
  - Convective-scale EPS.
  - Using mesoscale NWP models (WRF and ARPS).

Forecast Configurations of Three Years

- Spring 2007: 10-member WRF-ARW, 4 km, 33 h, 21Z start time, NAM+SREF ICs. 5 members physics perturbations only, 5 with Phy+IC+LBC perturbations. Single 2 km grid. 2/3 CONUS (Xue et al.; Kong et al.; 2007 NWP conf.)
- Spring 2008: larger domain, 00Z start, Phy+IC+LBC pert for all. Radar Vr and Z data assimilation for 4 and 2 km grids! (Xue et al.; Kong et al. 2008 SLS Conf.)
- Spring 2009: 20 members, 4 km, 3 models (ARW, NMM, ARPS), mixed physics/IC/LBCs. +Single 1 km grid. Radar DA (3DVAR +cloud analysis) on native grids. 30 h forecasts from 0Z (Xue et al.; Kong et al. 2009 NWP Conf.)
- About 1.5 months each spring season from mid-April through early June

t = 3 h

OBS

1 km with radar

4 km with radar

4 km no radar

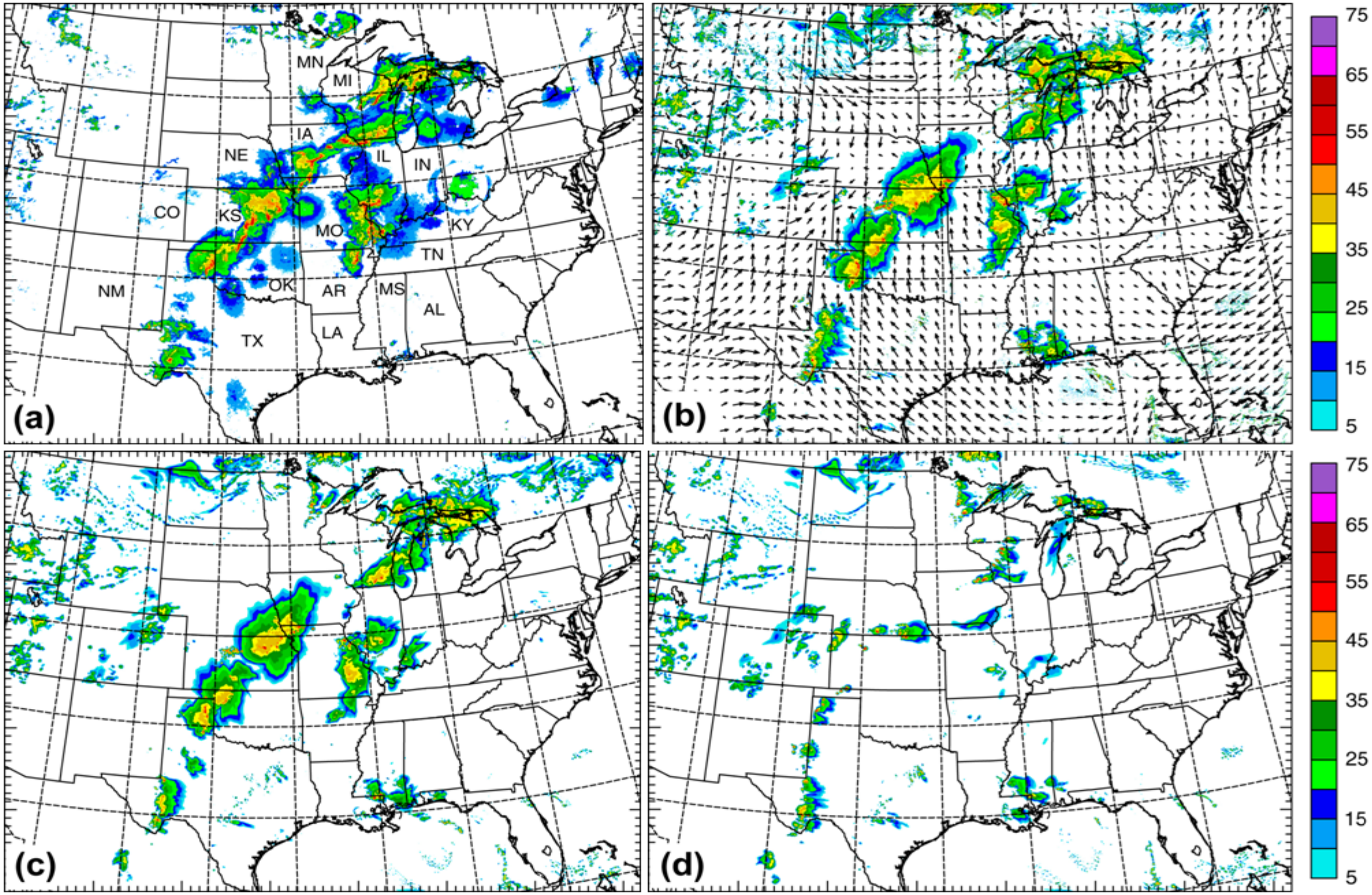


Fig. 1. Observed composite radar reflectivity (a), and 3-hour forecasts of the same field valid at 0300 UTC, May 26, 200, from (b) the 1-km forecast with radar data assimilation, (c) 4-km control forecast with radar data assimilation, and (d) 4-km forecast without radar data. For forecast domain is shown.

May 26, 2008 case

t = 9 h

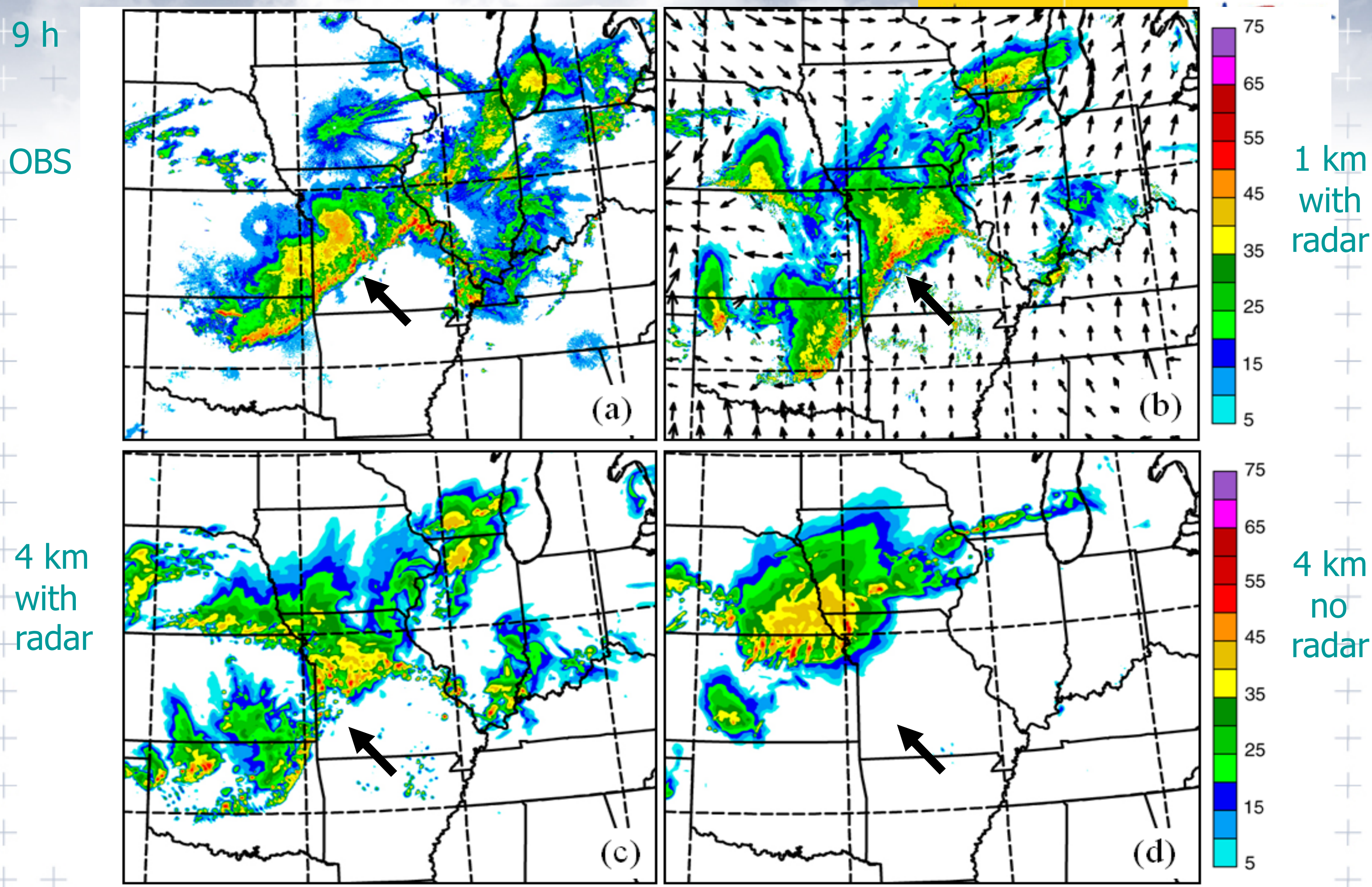
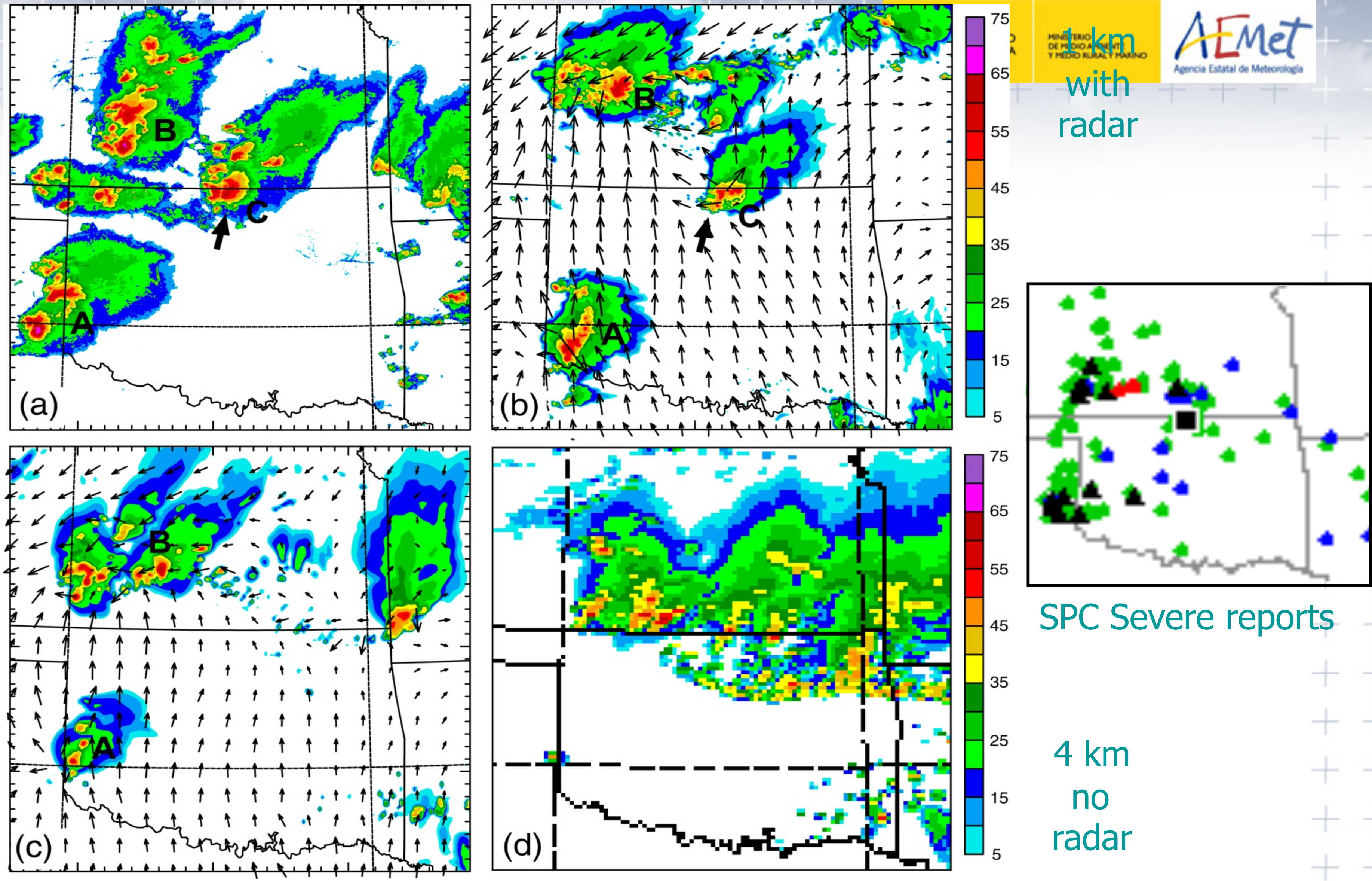


Fig. 2. As Fig. 1 but valid at 0900 UTC, 26 May 2008, corresponding to 9 hour forecast time, and for a zoomed-in domain.

t =23h

OBS

1 km with radar



SPC Severe reports

4 km with radar

4 km no radar

Fig. 3. As Fig. 1 but valid at 2300 UTC, 26 May 2008, corresponding to 23 hour forecast time, and for a further zoomed-in domain.

ETSs of hourly precipitation at 0.10 inch threshold for 26 May 2008 case

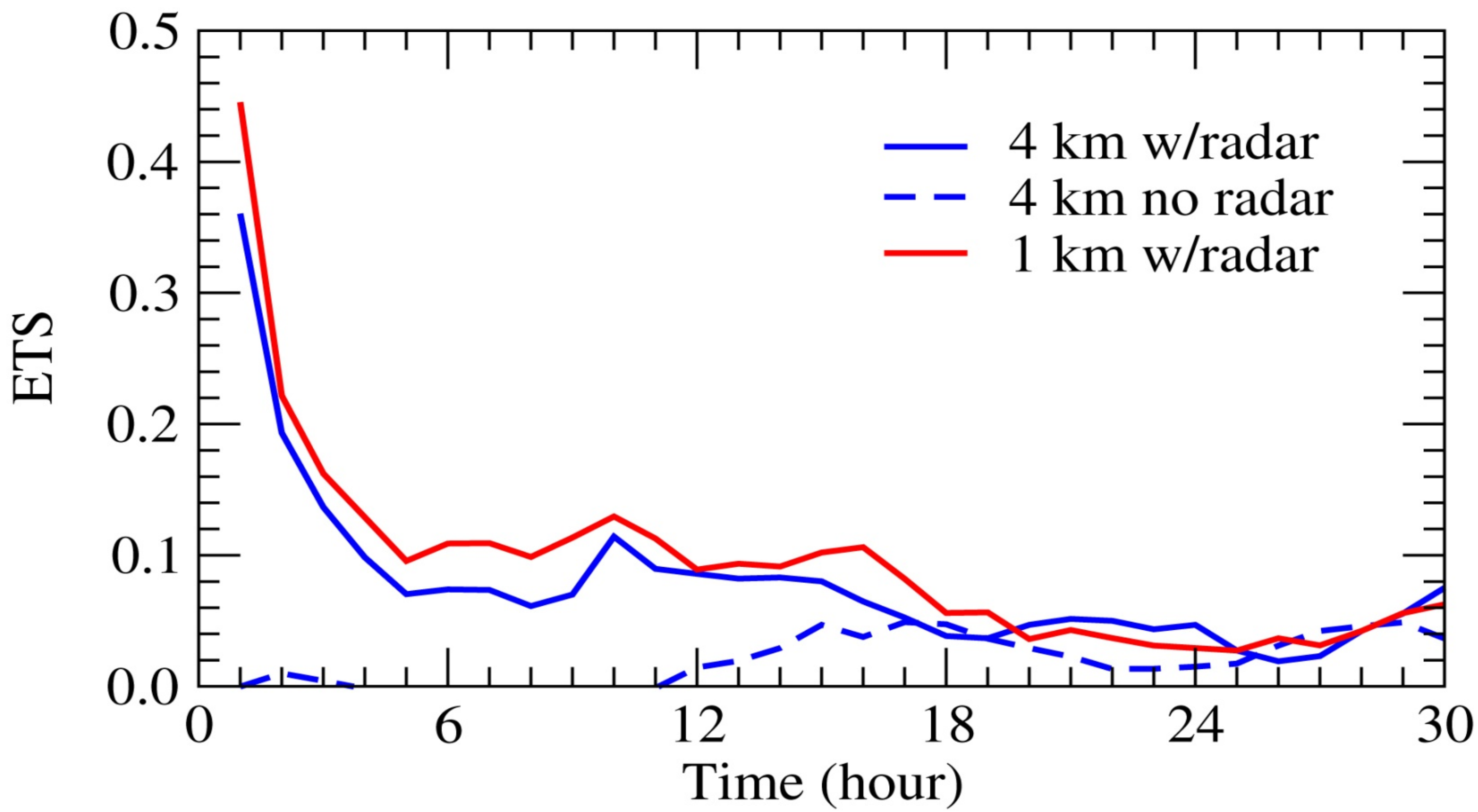


Table 1. Configurations of the ARW members of 4-km ensemble. NAMa and NAMf refer to 12 km NAM analysis and forecast, respectively. ARPSa refers to ARPS 3DVAR analysis.

ARW

member	IC	LBC	Radar	MPhys	SWRad	LSM	**PBL**
arw_cn	00Z ARPSa	00Z NAMf	yes	Thompson	Goddard	Noah	MYJ
arw_c0	00Z NAMa	00Z NAMf	no	Thompson	Goddard	Noah	MYJ
arw_n1	arw_cn – em_pert	SREF em-n1	yes	Ferrier	Goddard	Noah	YSU
arw_p1	arw_cn + em_pert	SREF em-p1	yes	WSM6	Dudhia	Noah	MYJ
arw_n2	arw_cn – nmm_pert	SREF nmm-n1	yes	Thompson	Dudhia	RUC	MYJ
arw_p2	arw_cn + nmm_pert	SREF nmm-p1	yes	WSM6	Dudhia	Noah	YSU
arw_n3	arw_cn – etaKF_pert	SREF etaKF-n1	yes	Thompson	Dudhia	Noah	YSU
arw_p3	arw_cn + etaKF_pert	SREF etaKF-p1	yes	Ferrier	Dudhia	Noah	MYJ
arw_n4	arw_cn – etaBMJ_pert	SREF etaBMJ-n1	yes	WSM6	Goddard	Noah	MYJ
arw_p4	arw_cn + etaBMJ_pert	SREF etaBMJ-p1	yes	Thompson	Goddard	RUC	YSU

* For all members: long wave radiation = RRTM; cumulus parameterization = None

Table 2. Configurations for NMM members of the 4-km ensemble

NMM

member	IC	LBC	Radar	MPhys	LWRad	SWRad	LSM	PBL
nmm_cn	00Z ARPSa	00Z NAMf	yes	Ferrier	GFDL	GFDL	Noah	MYJ
nmm_c0	00Z NAMa	00Z NAMf	no	Ferrier	GFDL	GFDL	Noah	MYJ
nmm_n1	*nmm_cn – em_pert*	*SREF em-n1*	*yes*	*Thompson*	*RRTM*	*Dudhia*	*Noah*	*MYJ*
nmm_p1	nmm_cn + em_pert	SREF em-p1	yes	WSM6	GFDL	GFDL	RUC	MYJ
nmm_n2	nmm_cn – nmm_pert	SREF nmm-n1	yes	Ferrier	RRTM	Dudhia	Noah	YSU
nmm_p2	nmm_cn + nmm_pert	SREF nmm-p1	yes	Thompson	GFDL	GFDL	RUC	YSU
nmm_n3	nmm_cn – etaKF_pert	SREF etaKF-n1	yes	WSM6	RRTM	Dudhia	Noah	YSU
nmm_p3	*nmm_cn + etaKF_pert*	*SREF etaKF-p1*	*yes*	*Thompson*	*RRTM*	*Dudhia*	*RUC*	*MYJ*
nmm_n4	nmm_cn – etaBMJ_pert	SREF etaBMJ-n1	yes	WSM6	RRTM	Dudhia	RUC	MYJ
nmm_p4	nmm_cn + etaBMJ_pert	SREF etaBMJ-p1	yes	Ferrier	RRTM	Dudhia	RUC	YSU

* For all members: cumulus parameterization = None. nmm_n1 and nmm_p3 (shaded) were removed from the list after the first week of experiment because they took too long to complete, reducing the NMM ensemble size from 10 to 8.

Table 3. Configurations of the ARPS members of the 4-km ensemble

ARPS

member	IC	LBC	Radar	MPhys	LWRad	SWRad	LSM	PBL	SGS turb
arps_cn	00Z ARPSa	00Z NAMf	yes	Lin	Goddard	Goddard	2-layer	TKE	3D TKE
arps_c0	00Z NAMa	00Z NAMf	no	Lin	Goddard	Goddard	2-layer	TKE	3D TKE

* For all members: cumulus parameterization = None

Future: A Dream System of Convective-scale NWP (from Dr. Xue - CAPS)

- Ensemble Kalman filter DA every 5 minutes at ~1 km resolution;
- ~1 km ensemble forecasts launched every ~30 min up to 6 hours;
- Reduced (~4 km) resolution ensemble forecasts up to 72 hours;
- Deterministic forecasts from ensemble mean analyses at up to 250 m resolution; and at reduced resolutions beyond 6 hours;
- Explicit forecasts from MCS down to tornado vortex scales, with probability estimates.
- An NSF sustained-petaflops machine (IBM Power7) with over 200,000 cores to come online in 2011 – are we ready?

Conclusions

GOBIERNO DE ESPAÑA | MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO | AEMet Agencia Estatal de Meteorología

- Mesoscale NWP models are able to replicate severe weather events (SWE).
- But model errors grow faster at higher resolutions.
- Uncertainty of Mesoscale NWP models and predictability of SWE make very difficult to use a deterministic approach.
- Phase errors can make deterministic information useless.
- EPS and probabilistic tools are useful to improve the forecast of SWE.
- Increasing resolution improves EPS results.
- Although computer resources involved in mesoscale EPS are huge, this tool will become very important in the coming future in the SWE forecasting process.
- But lot of questions have to be answered before going to operational activities…

Sorry, I have no time left to tell you about...

Thank you for your attention.

jgarciamoyaz@aemet.es

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