

COSMO-DE-EPS: A Limited-area Ensemble Prediction System on the Convective Scale

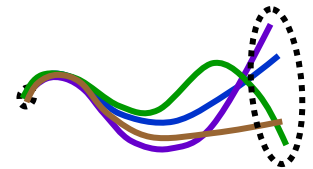
Susanne Theis, Christoph Gebhardt,
Marcus Paulat, Michael Buchhold, Roland Ohl

Deutscher Wetterdienst

Aims

Support beneficial use of COSMO-DE forecasts (2,8km):

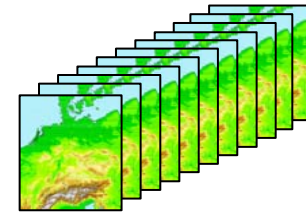
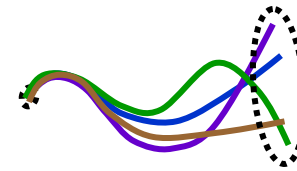
- acknowledge limited predictability of small scales
- quantify forecast uncertainty
- communicate forecast uncertainty



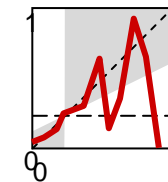
operational EPS in 2011

Overview

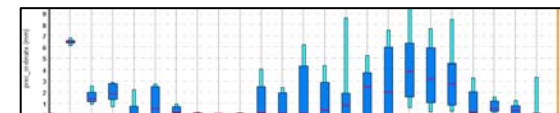
- implement perturbations in model, boundary and initial conditions



- verify ensemble forecasts
- post-process ensemble forecasts

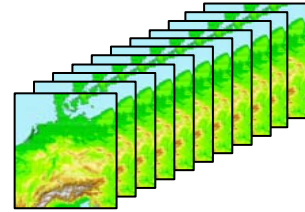
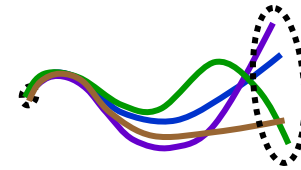


- visualization in NinJo

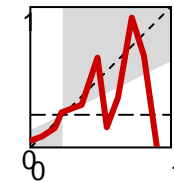


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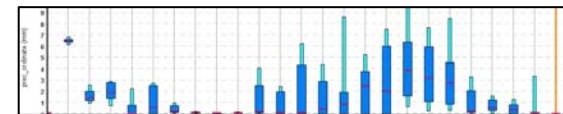
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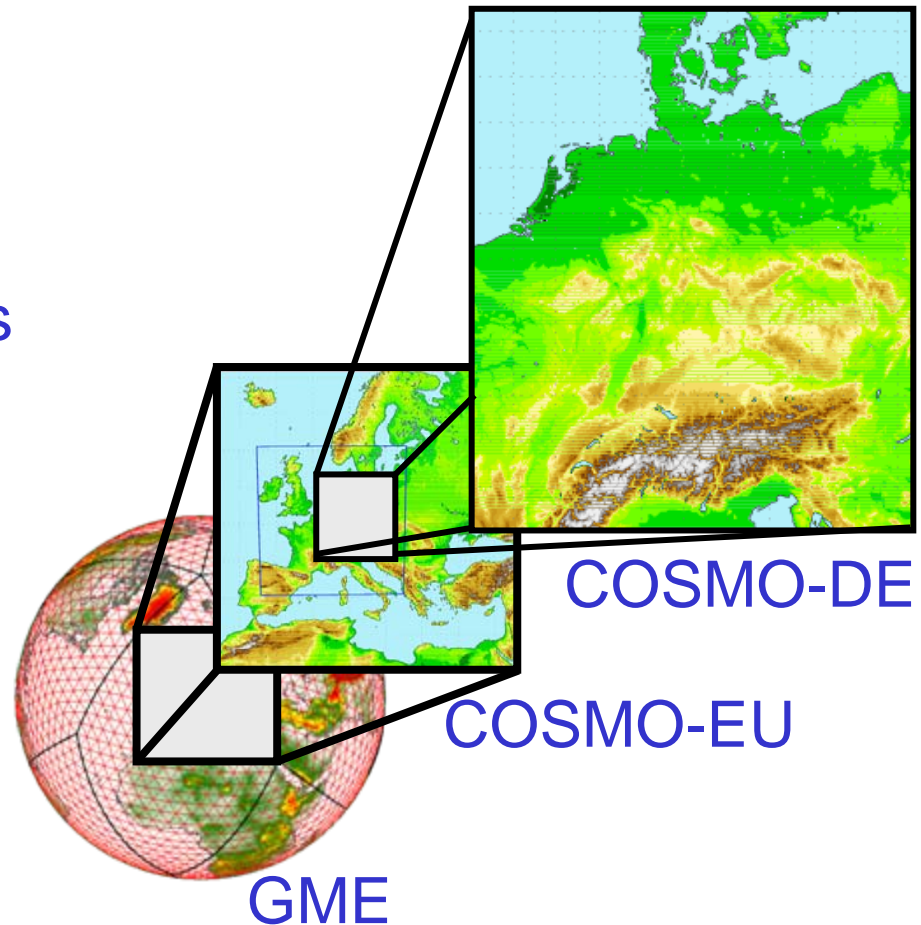


- visualization in NinJo



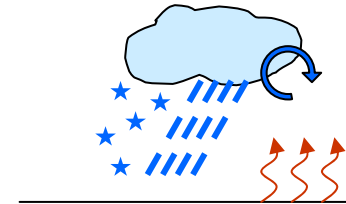
Model configuration COSMO-DE

- grid-spacing: 2,8 km
→ convective scale
- forecast lead time: 0-24 hours
- operational set-up

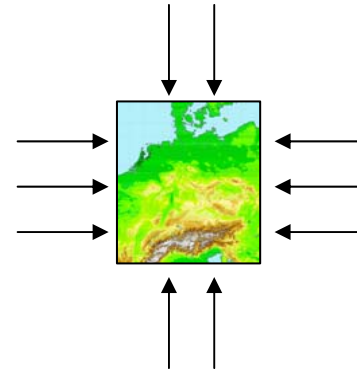


Perturbation Strategy

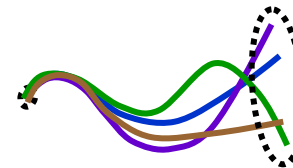
➤ perturbation of model physics



➤ perturbation of boundary conditions



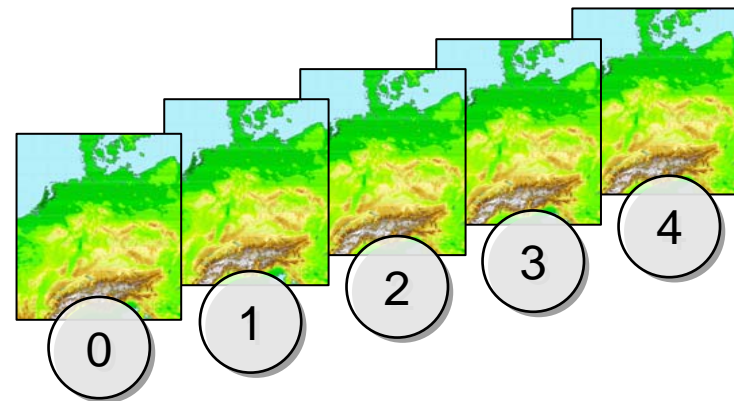
➤ perturbation of initial conditions



Perturbation of the model

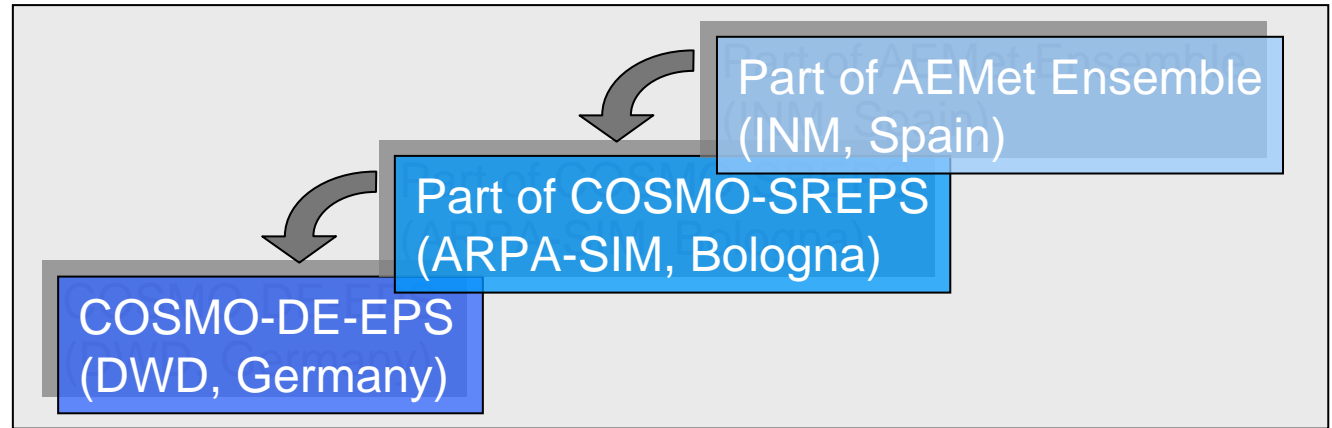
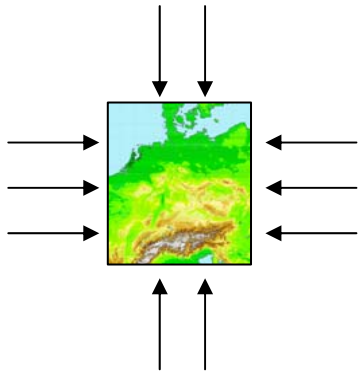


- alter parameters in parameterization schemes
- 5 different (fixed) configurations of model physics
- 5 slightly different model versions

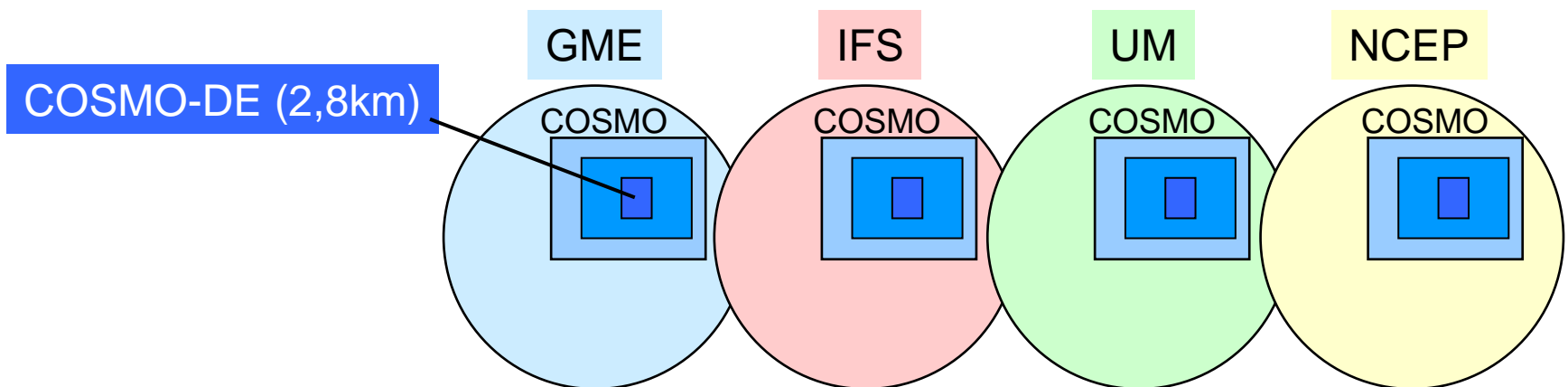
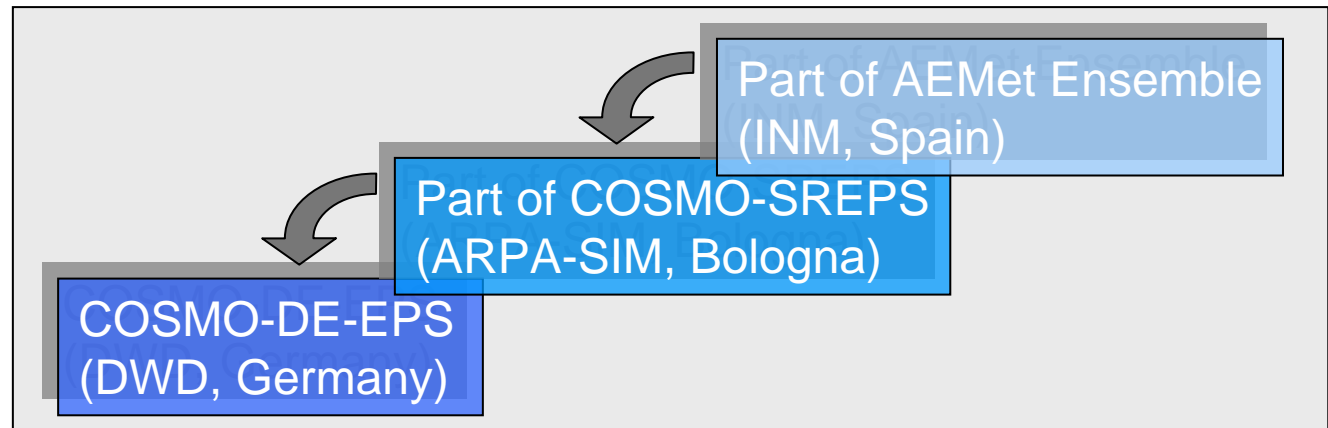
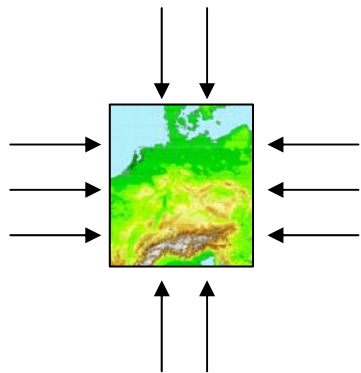


requires careful tuning

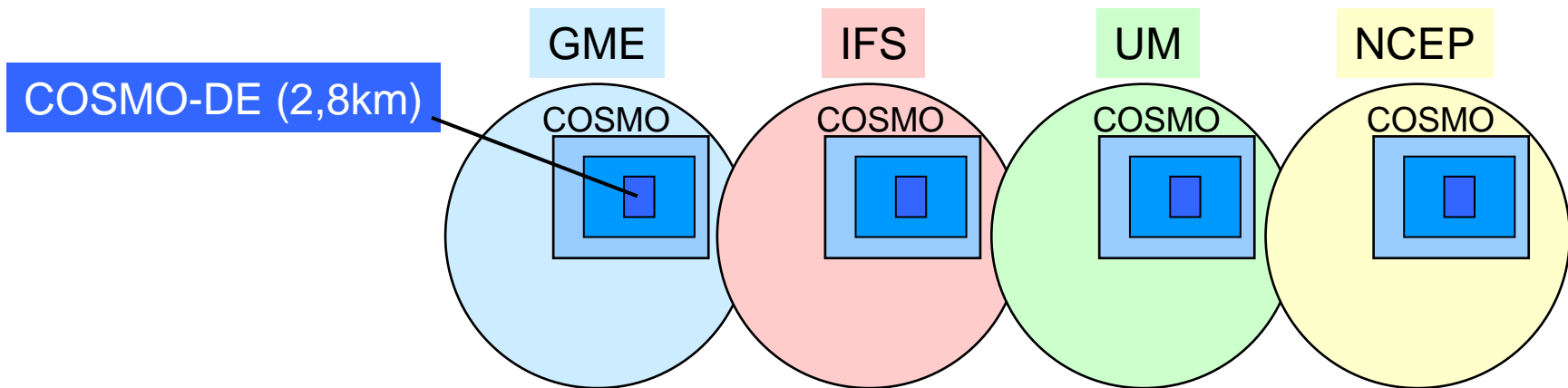
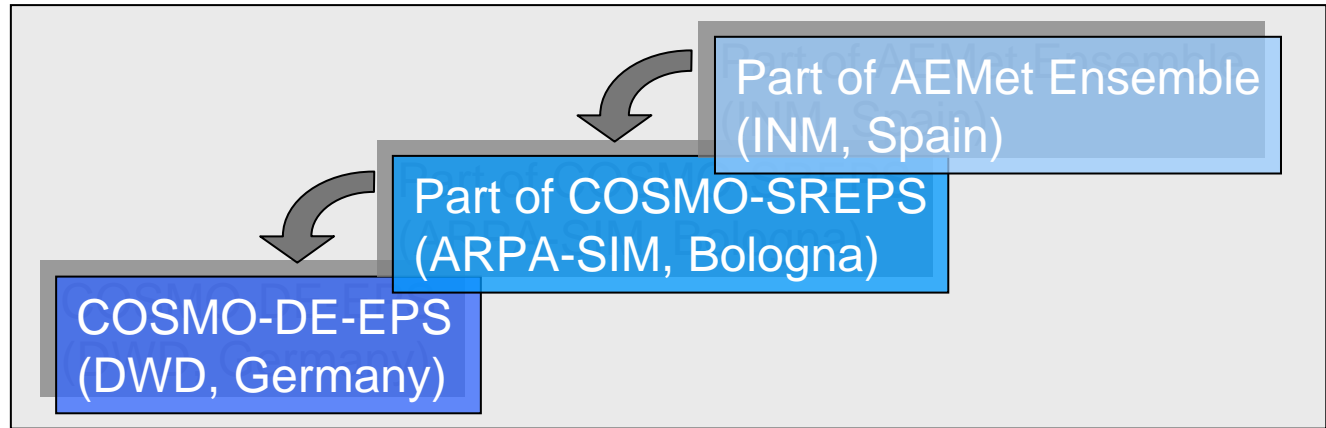
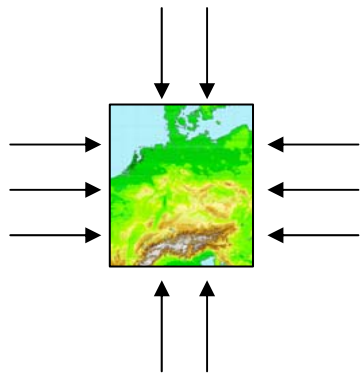
Perturbation of boundary conditions



Perturbation of boundary conditions

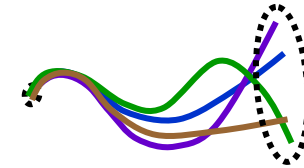


Perturbation of boundary conditions

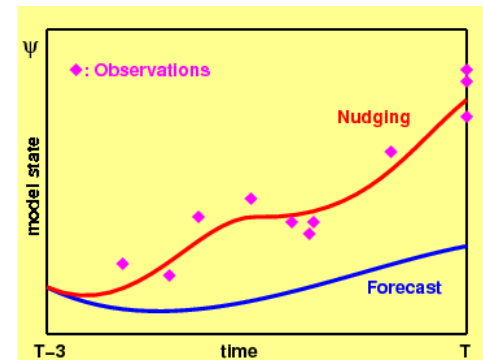


long-term Plan: take boundaries from ICON Ensemble

Perturbation of initial conditions



- first experiments: perturb “nudgecast”
 - correlation length of observation increments
 - geostrophic balance
 - divergent flow correlations



➤ current work:

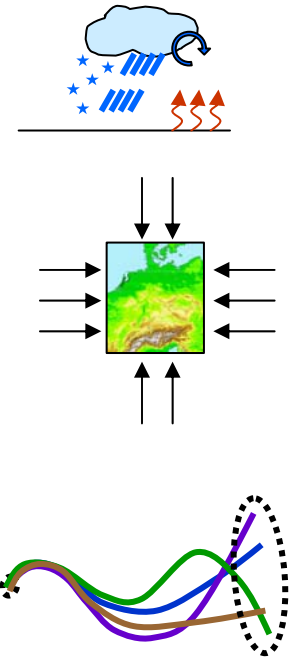
use differences between control and COSMO-SREPS as IC perturbations

➤ long-term plan:

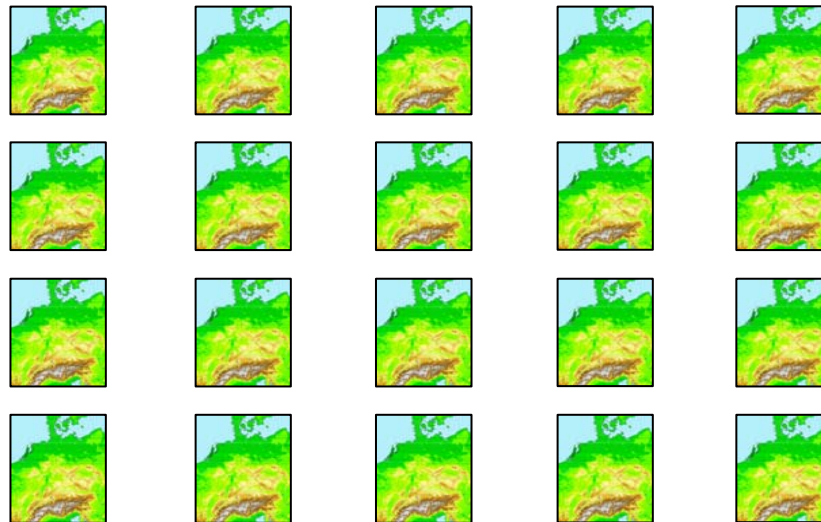
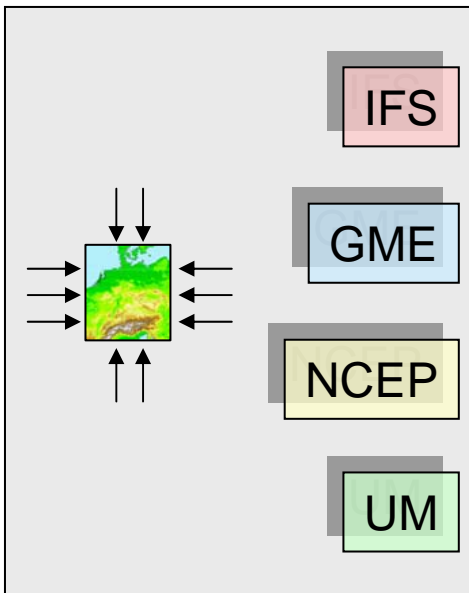
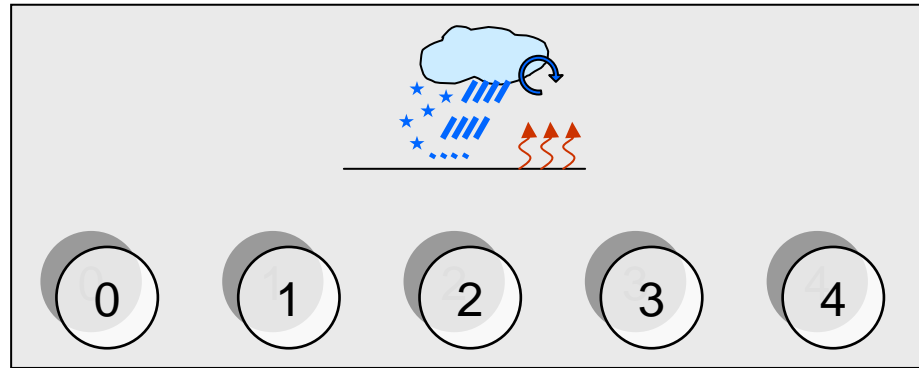
Ensemble Transform Kalman Filter (COSMO project KENDA)

Perturbation Strategy: Current Experiments

- perturbation of model physics
and perturbation of boundary conditions
- experiments for several weeks & verification
- perturbation of initial conditions
- case studies with promising results

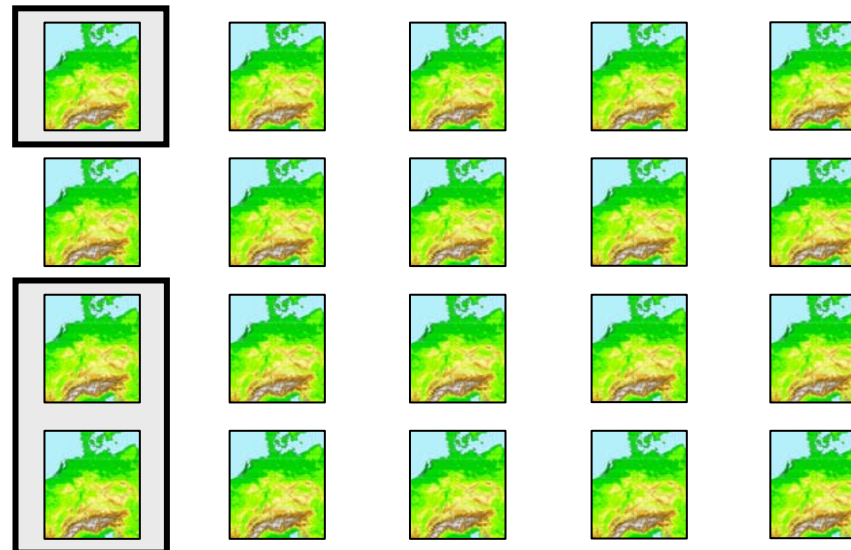
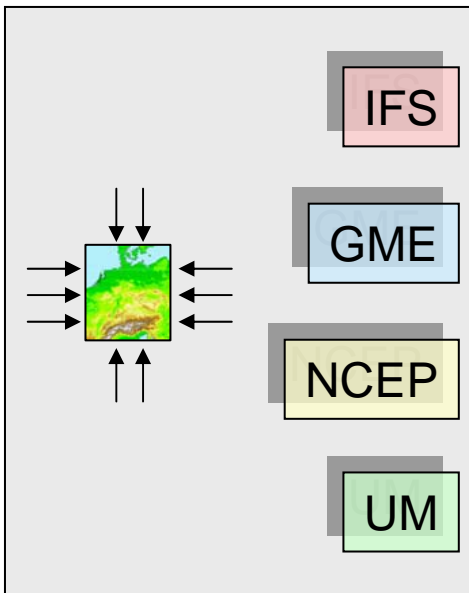
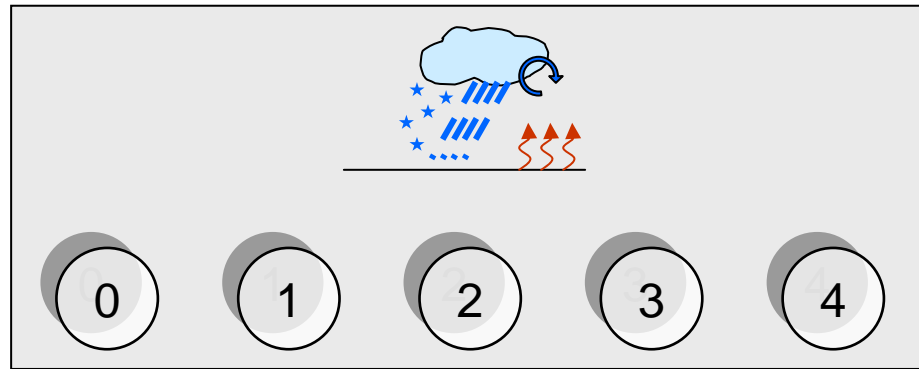


Experiments – physics and boundary perturbations



no perturbation
of initial conditions

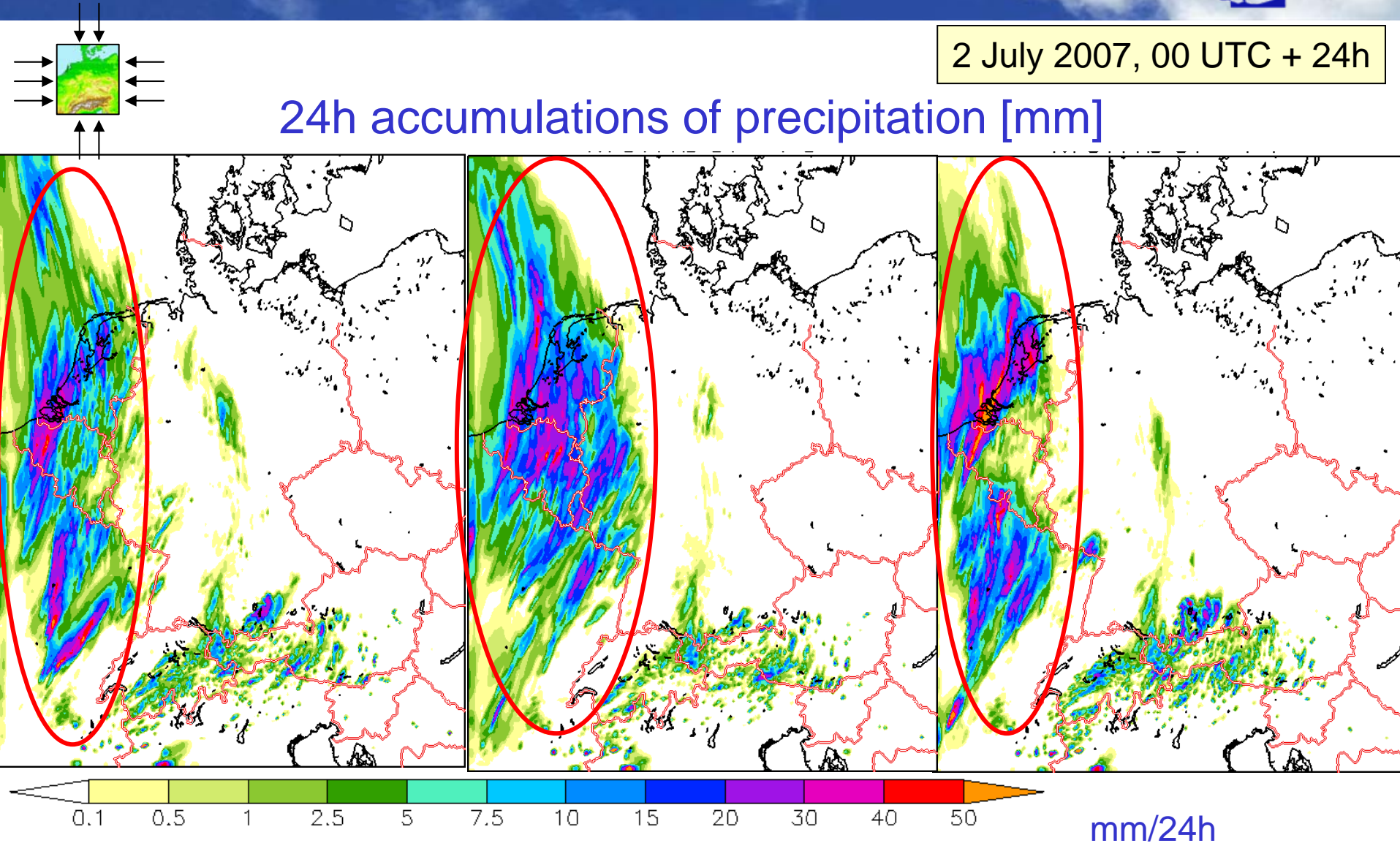
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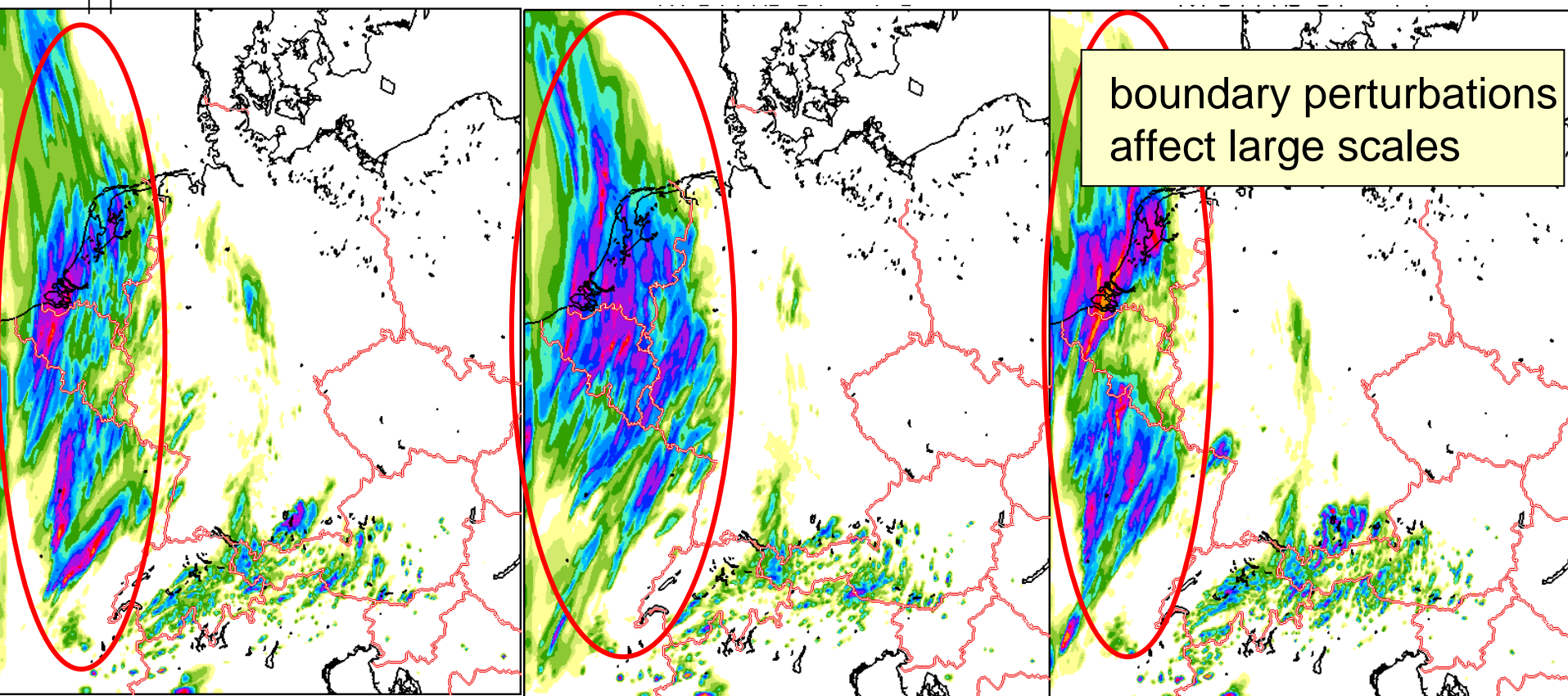
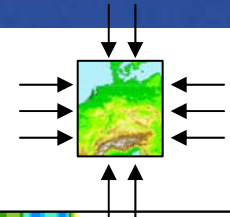
2 July 2007, 00 UTC + 24h

24h accumulations of precipitation [mm]



2 July 2007, 00 UTC + 24h

24h accumulations of precipitation [mm]

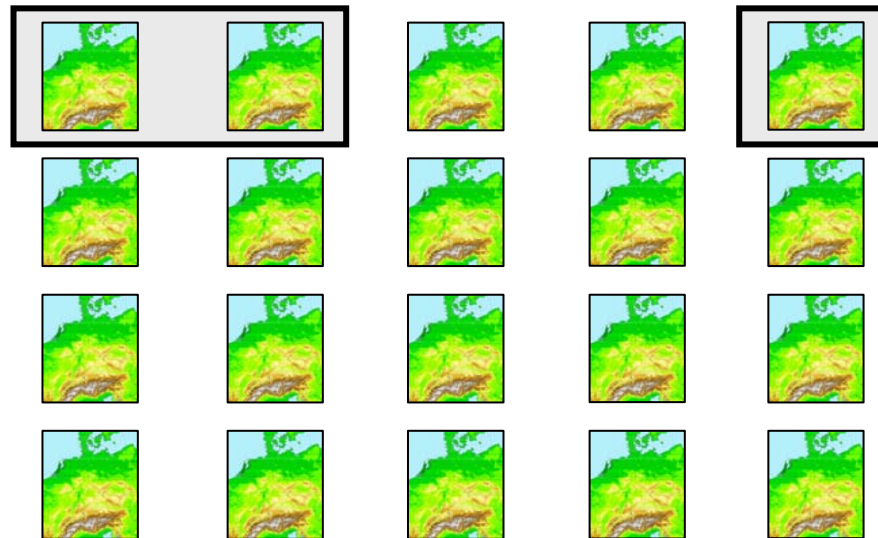
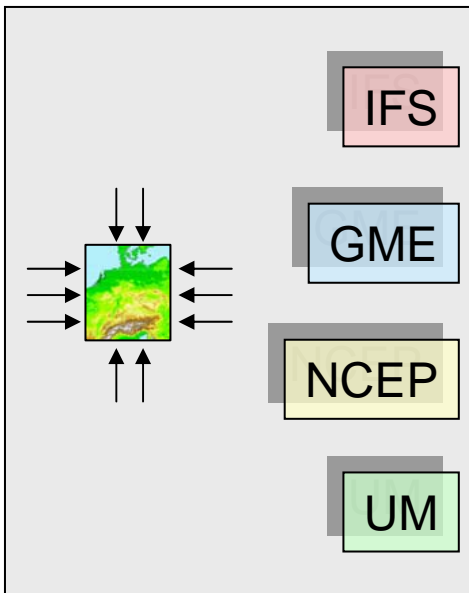
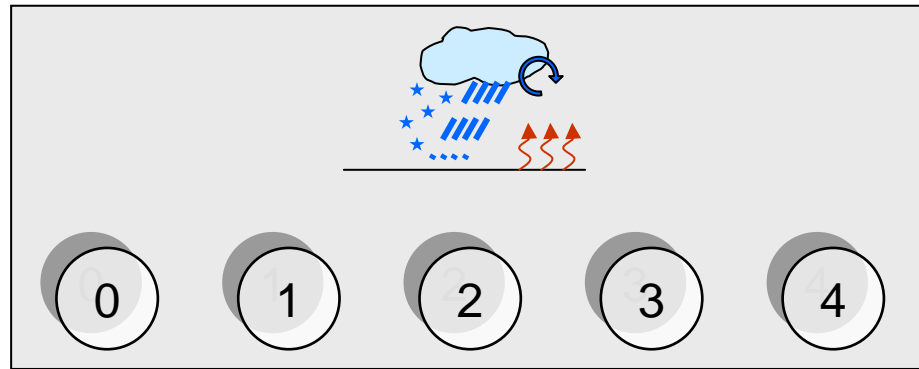


boundary perturbations affect large scales



mm/24h

Experiments – physics and boundary perturbations

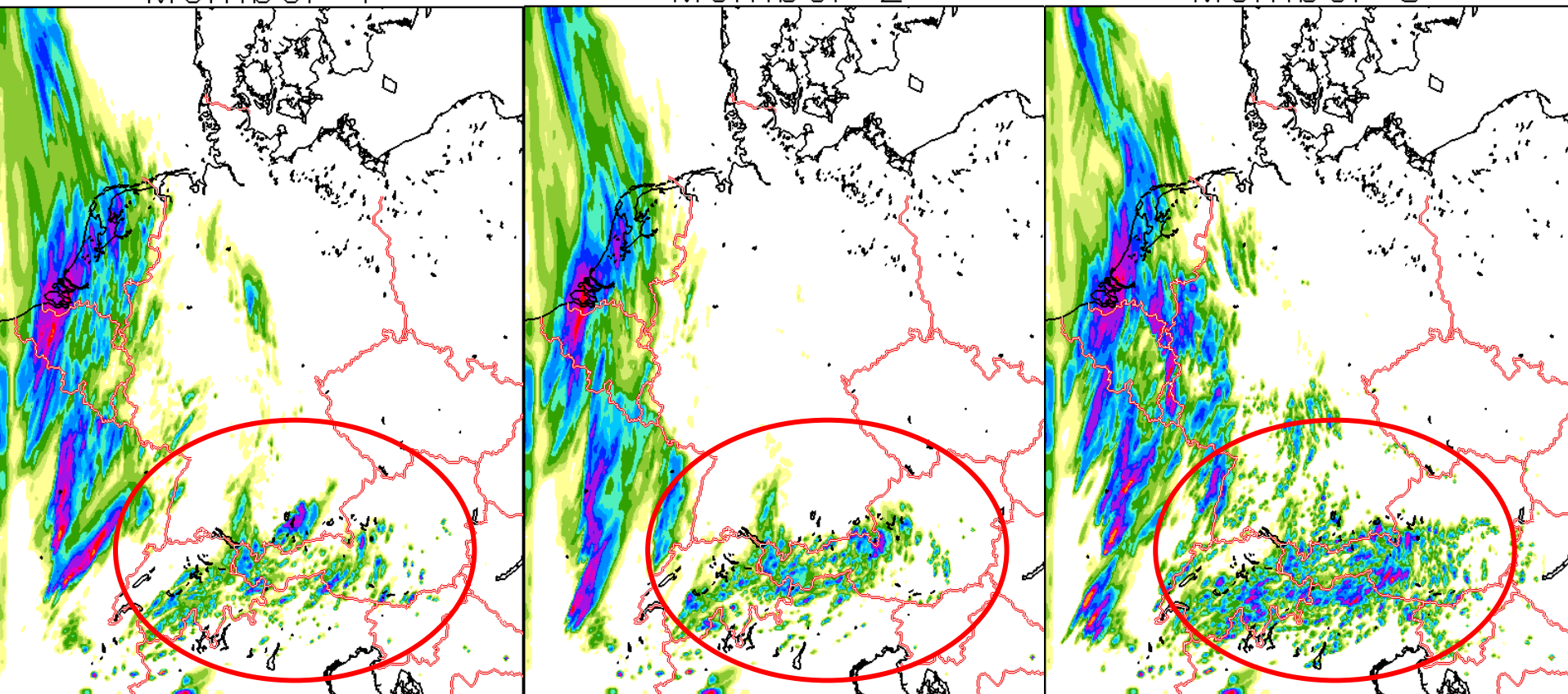


no perturbation
of initial conditions



2 July 2007, 00 UTC + 24h

24h accumulations of precipitation [mm]



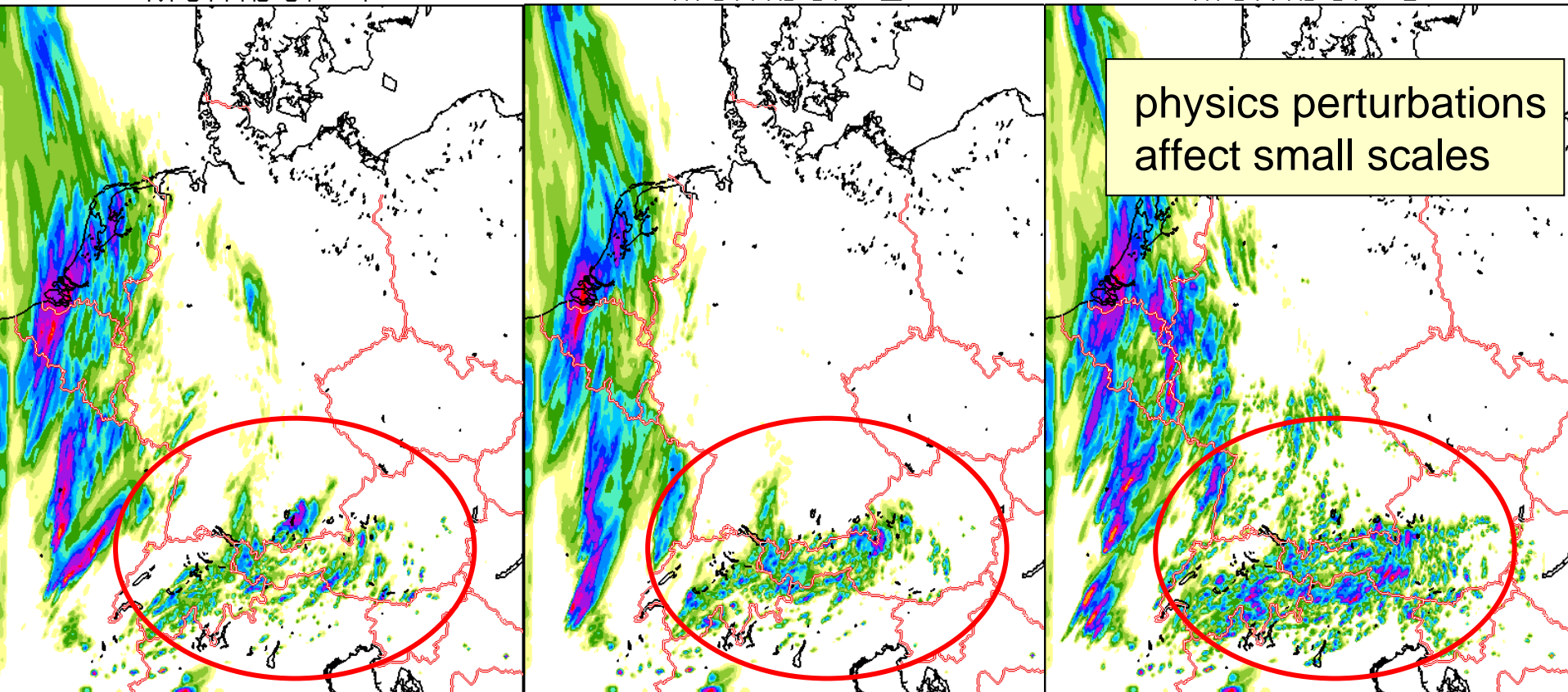
mm/24h





2 July 2007, 00 UTC + 24h

24h accumulations of precipitation [mm]



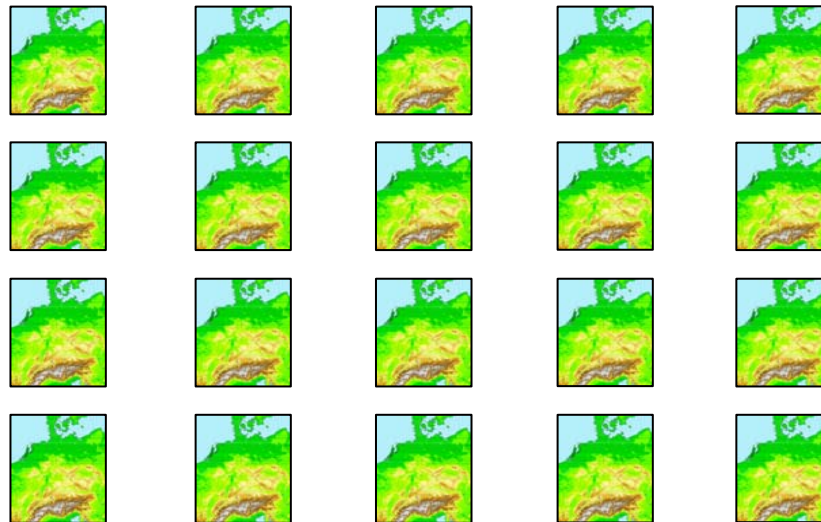
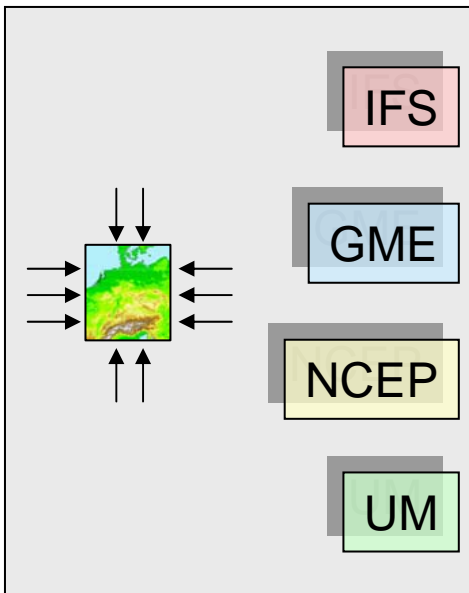
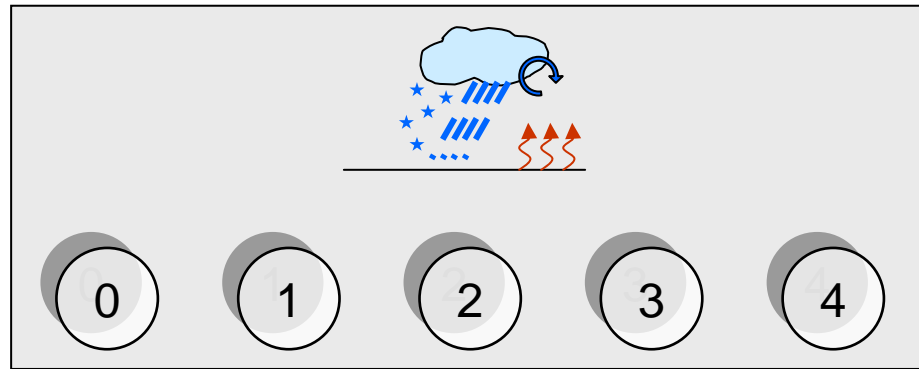
physics perturbations affect small scales



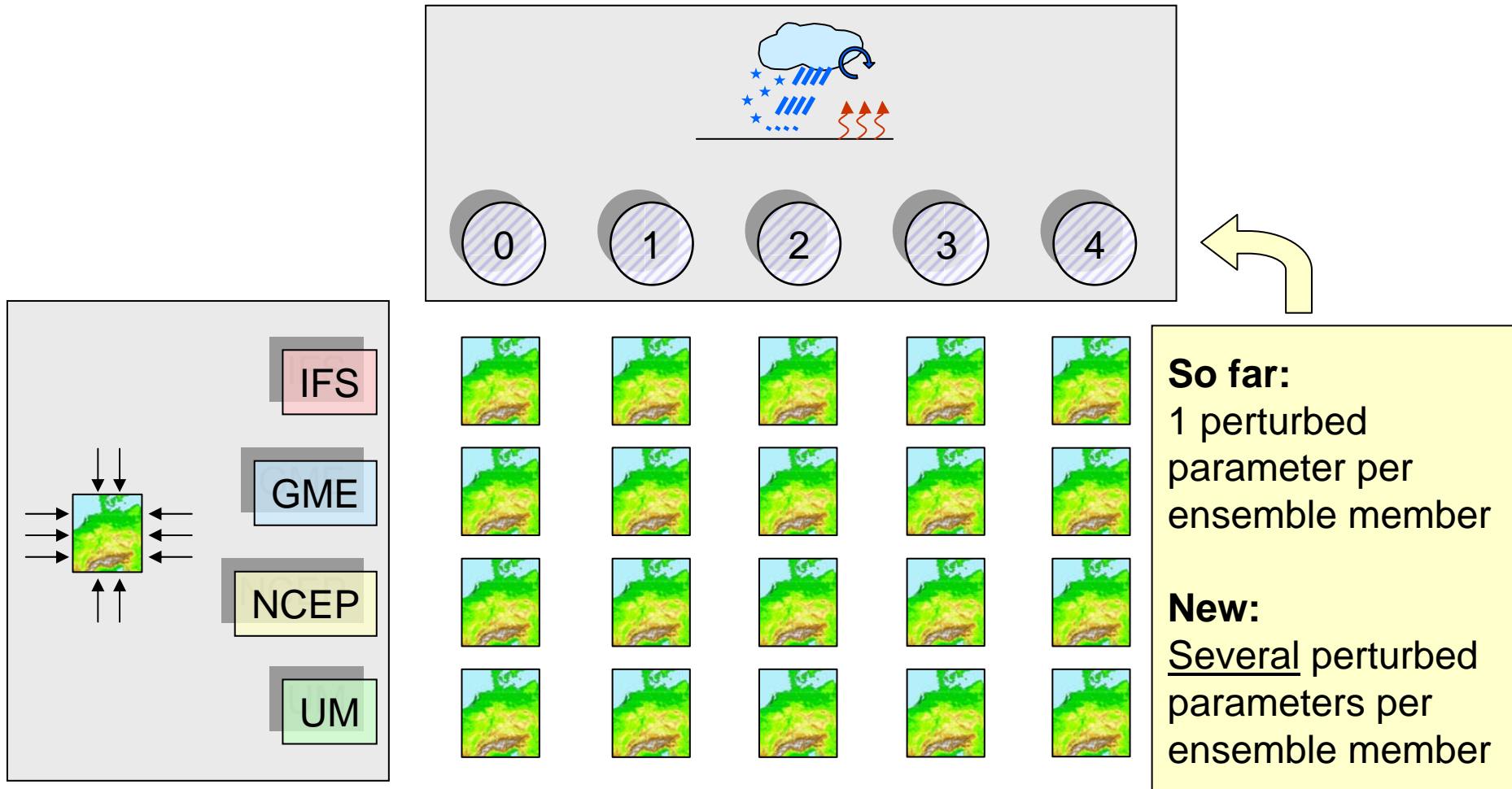
mm/24h



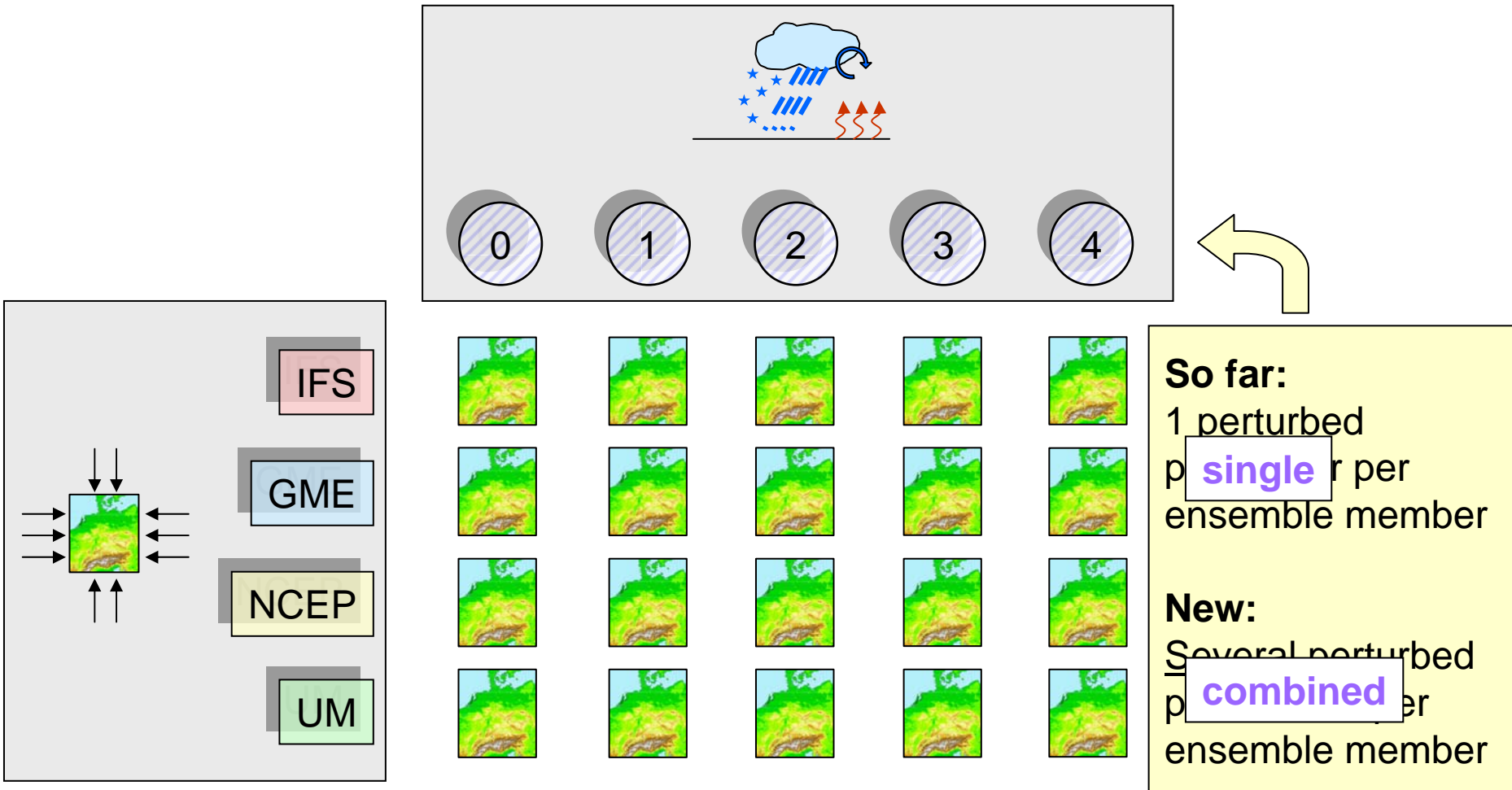
Experiments – physics and boundary perturbations



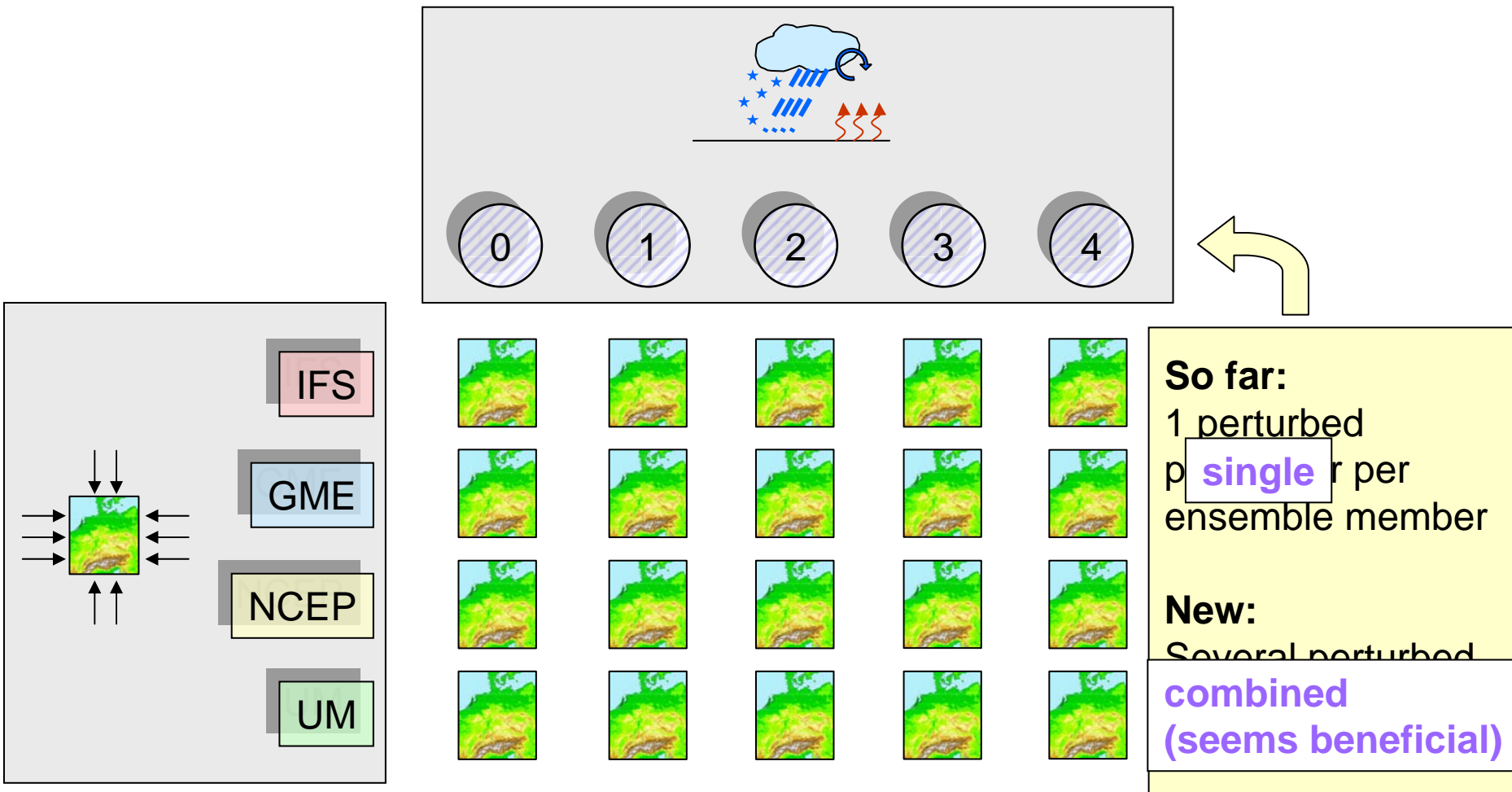
Experiments – physics and boundary perturbations



Experiments – physics and boundary perturbations



Experiments – physics and boundary perturbations



Conclusions - physics and boundary perturbations

-  boundaries → large spatial scales



physics → small spatial scales

- boundary perturbations usually dominate, but not always (not shown)

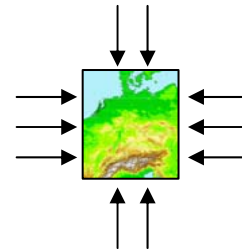


- combining several physics perturbations seems beneficial
- set-up of physics perturbations required careful tuning

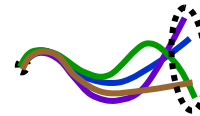
Perturbation Strategy: Future Plans

- increase duration of experiments → more data

- manage missing boundary conditions
(technical)

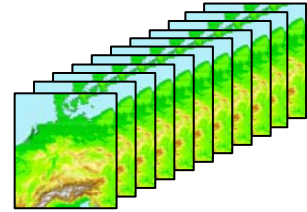
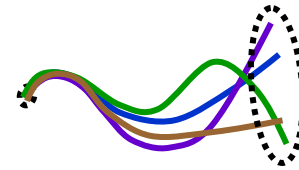


- initial condition perturbations:
promising ideas, more experiments

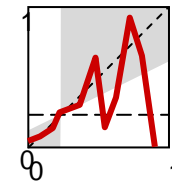


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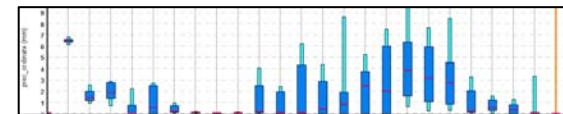
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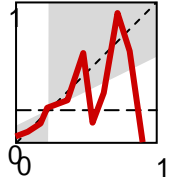
- **verify ensemble forecasts**
- post-process ensemble forecasts



- visualization in NinJo

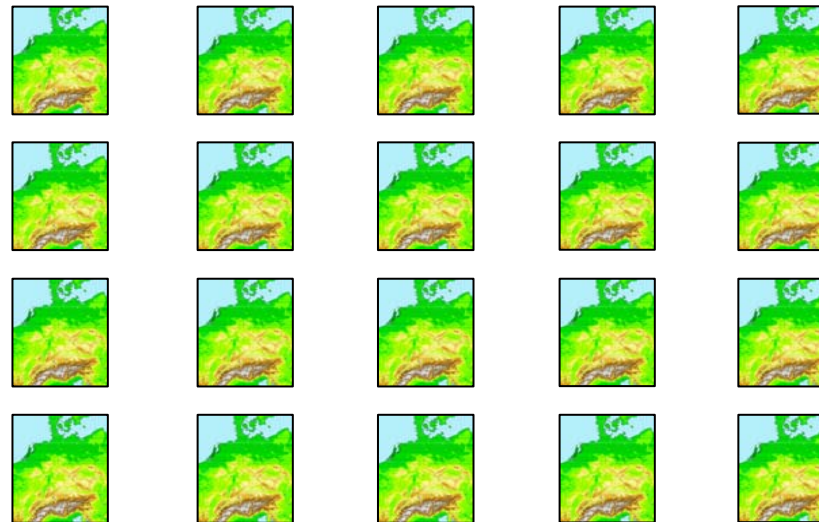
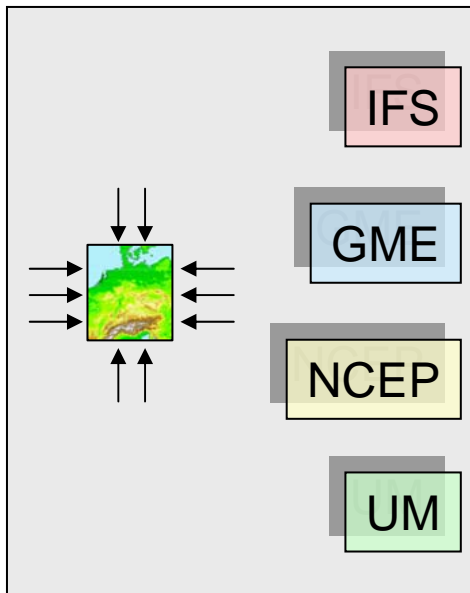
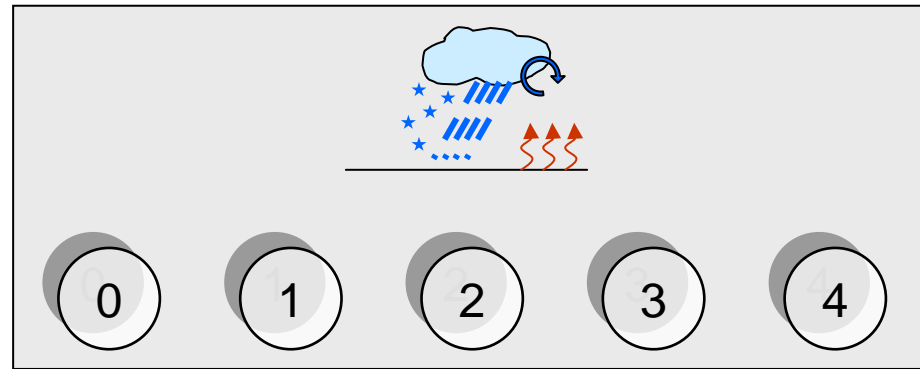


Verify Ensemble Forecasts

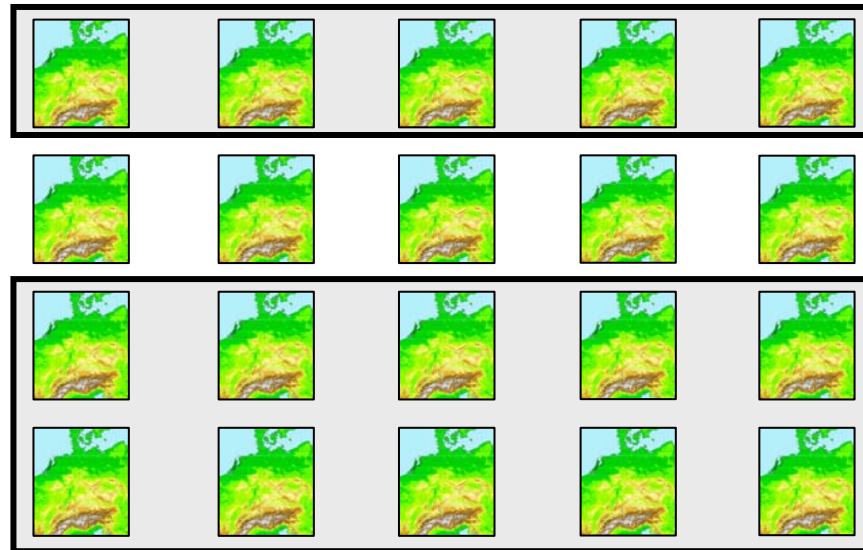
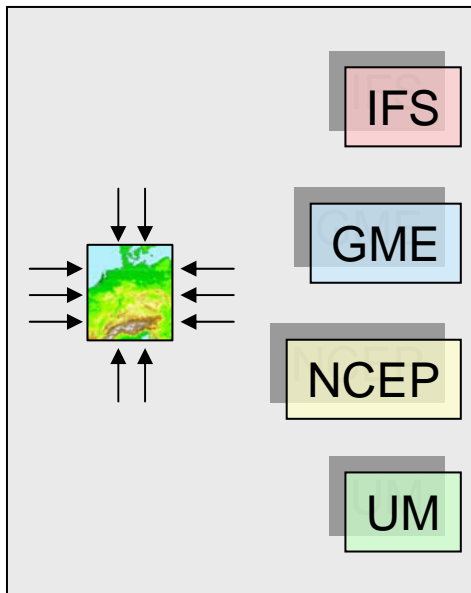
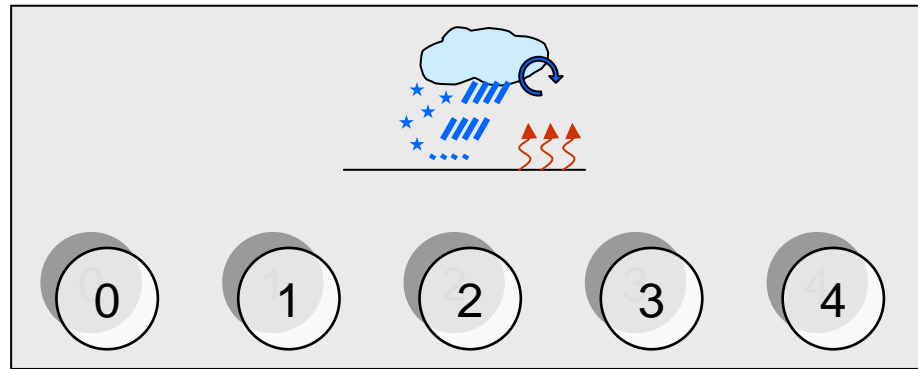


- develop tool for probabilistic verification ✓
 - contains data handling, score calculation, visualization
 - covers all traditional verification scores:
 - Brier Score, Talagrand, ROC, Reliability, Spread-Skill, ...
 - compares against SYNOP and radar observations
 - includes scale-dependent verification
 - can handle large data sets
- assess individual members and the entire ensemble

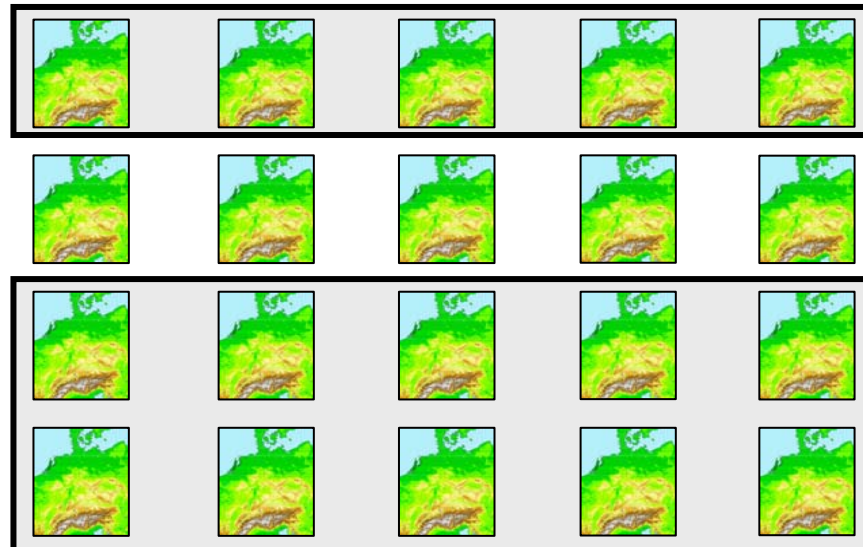
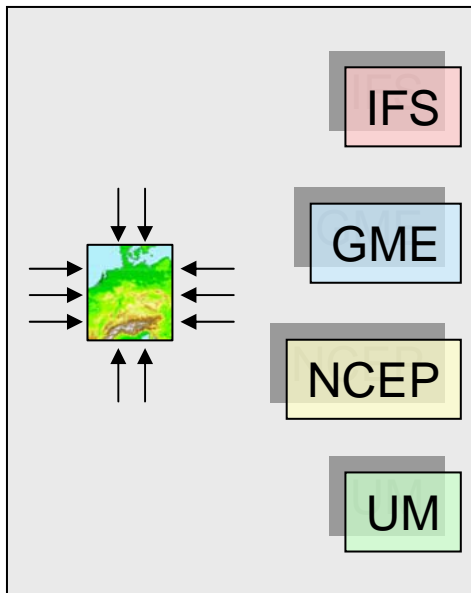
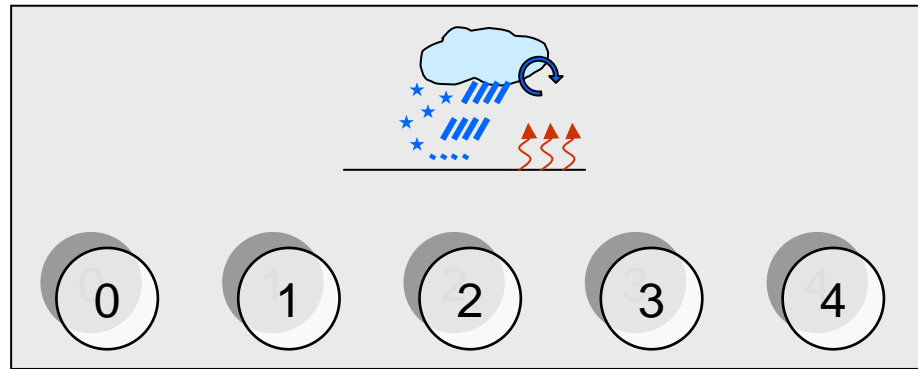
Verification of Physics and Boundary Ensemble



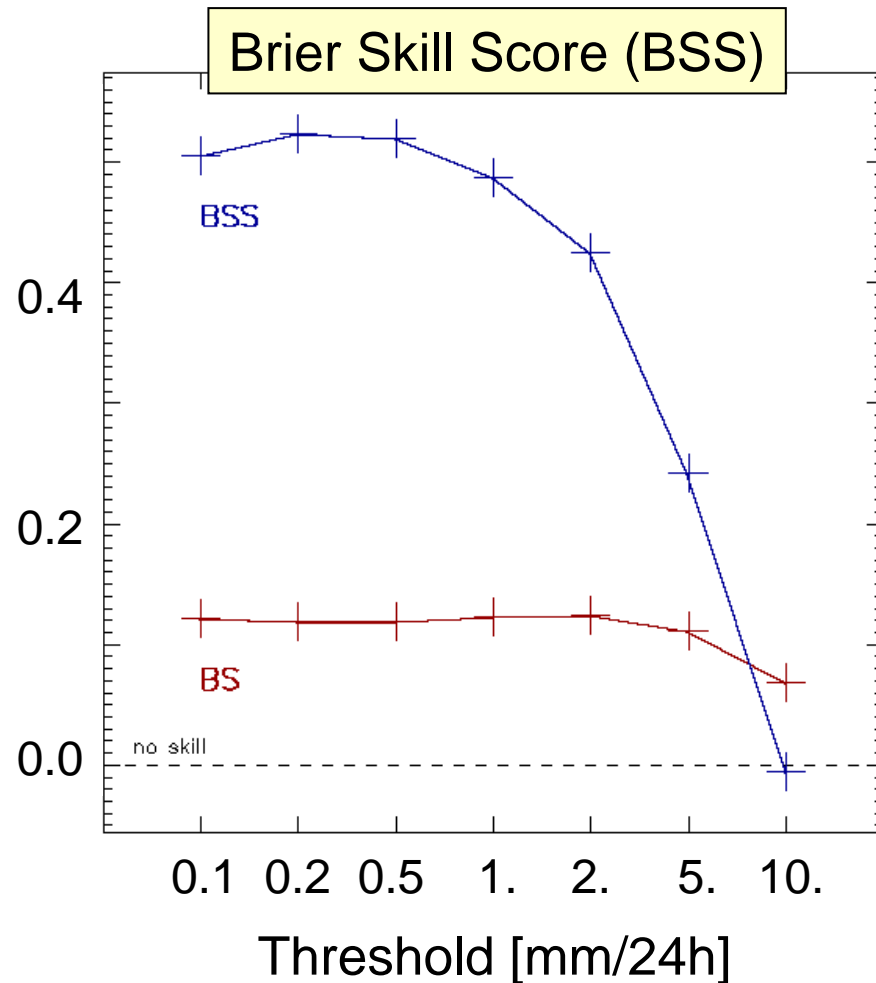
Verification of Physics and Boundary Ensemble



Verification of Physics and Boundary Ensemble



Period:
1 July – 16 Sep 2008
when all 15 members
available
(60% of days)



Forecast:

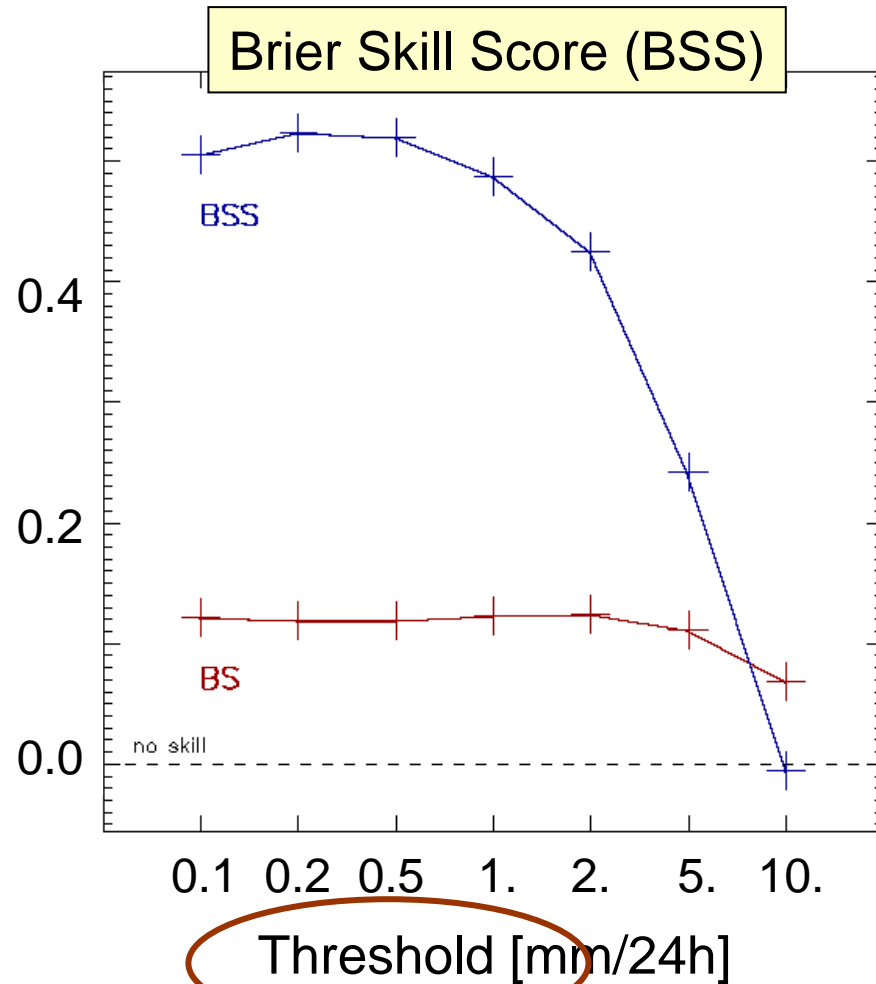
Probability that
24h precipitation > threshold

Observation:

Radar Data
24h precipitation > threshold
YES/NO

Reference Forecast:

Climatology from Period



Forecast:

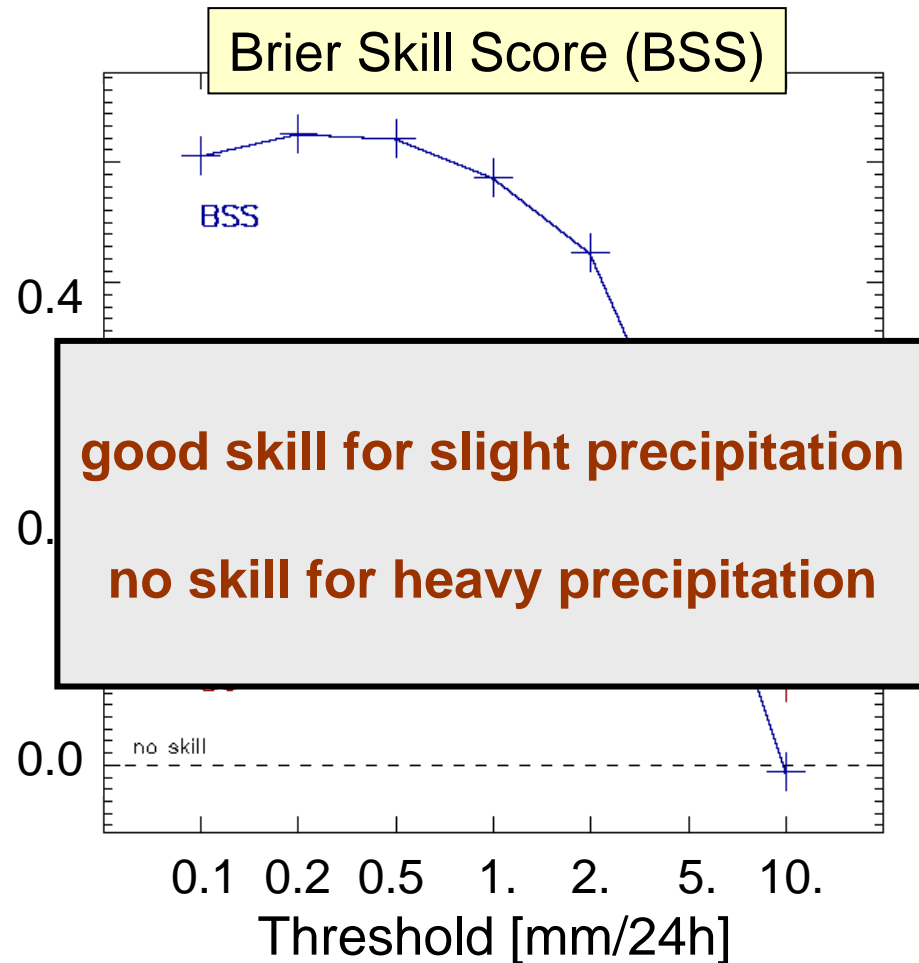
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Forecast:

Probability that
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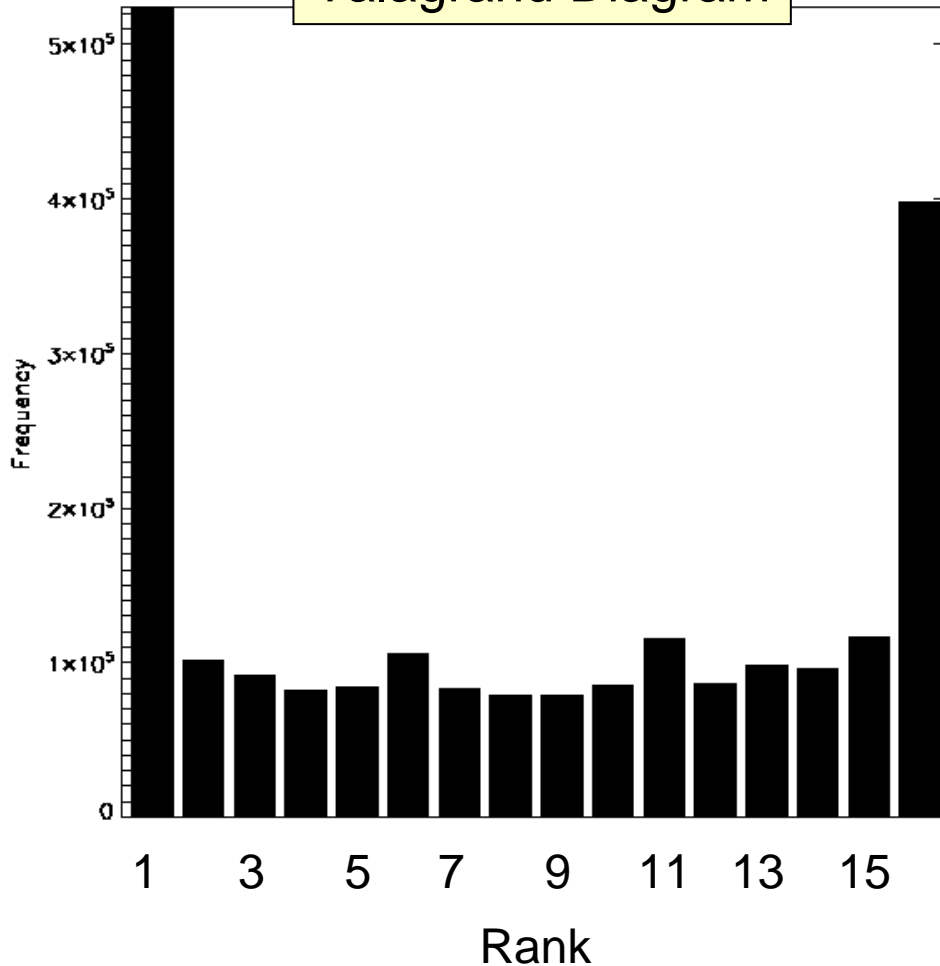
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Reference Forecast:

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Talagrand Diagram



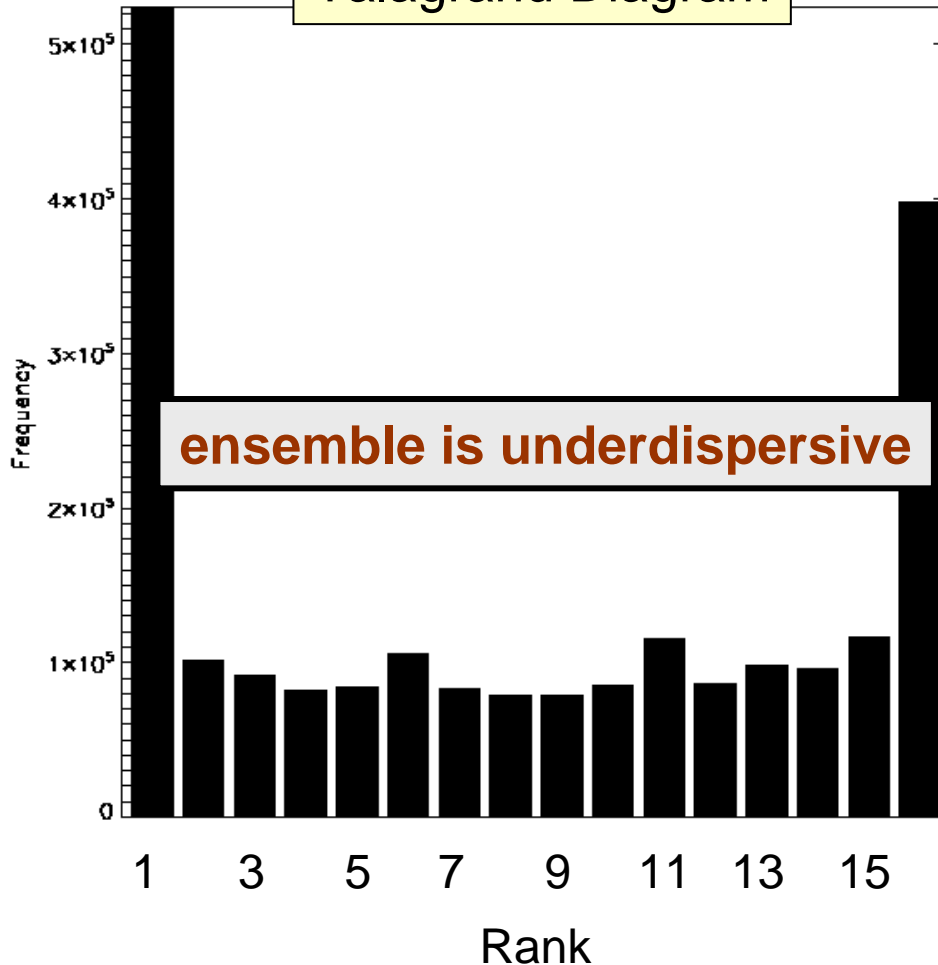
Forecast:

Individual Members
24h precipitation amounts

Observation:

Radar Data
24h precipitation amounts

Talagrand Diagram



Forecast:

Individual Members
24h precipitation amounts

Observation:

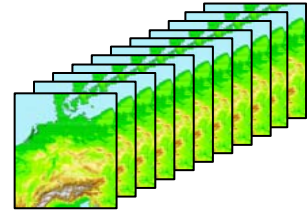
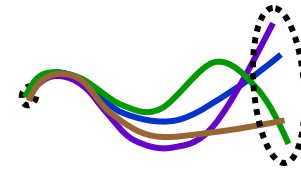
Radar Data
24h precipitation amounts

Conclusions from Verification

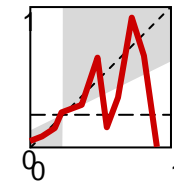
- ensemble forecasts have skill
but not yet for heavy precipitation
- ensemble forecasts are underdispersive
- ensemble needs further improvement
 - include initial condition perturbations
 - apply statistical postprocessing

Overview

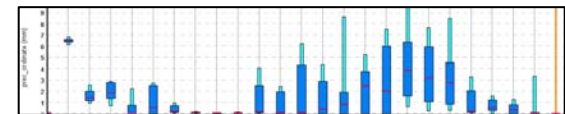
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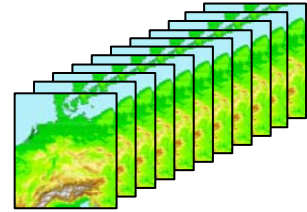
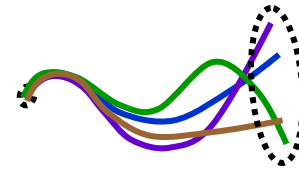


- visualization in NinJo

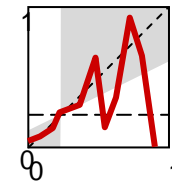


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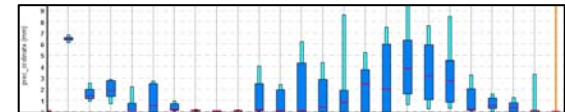
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- visualization in NinJo



Visualization in NinJo

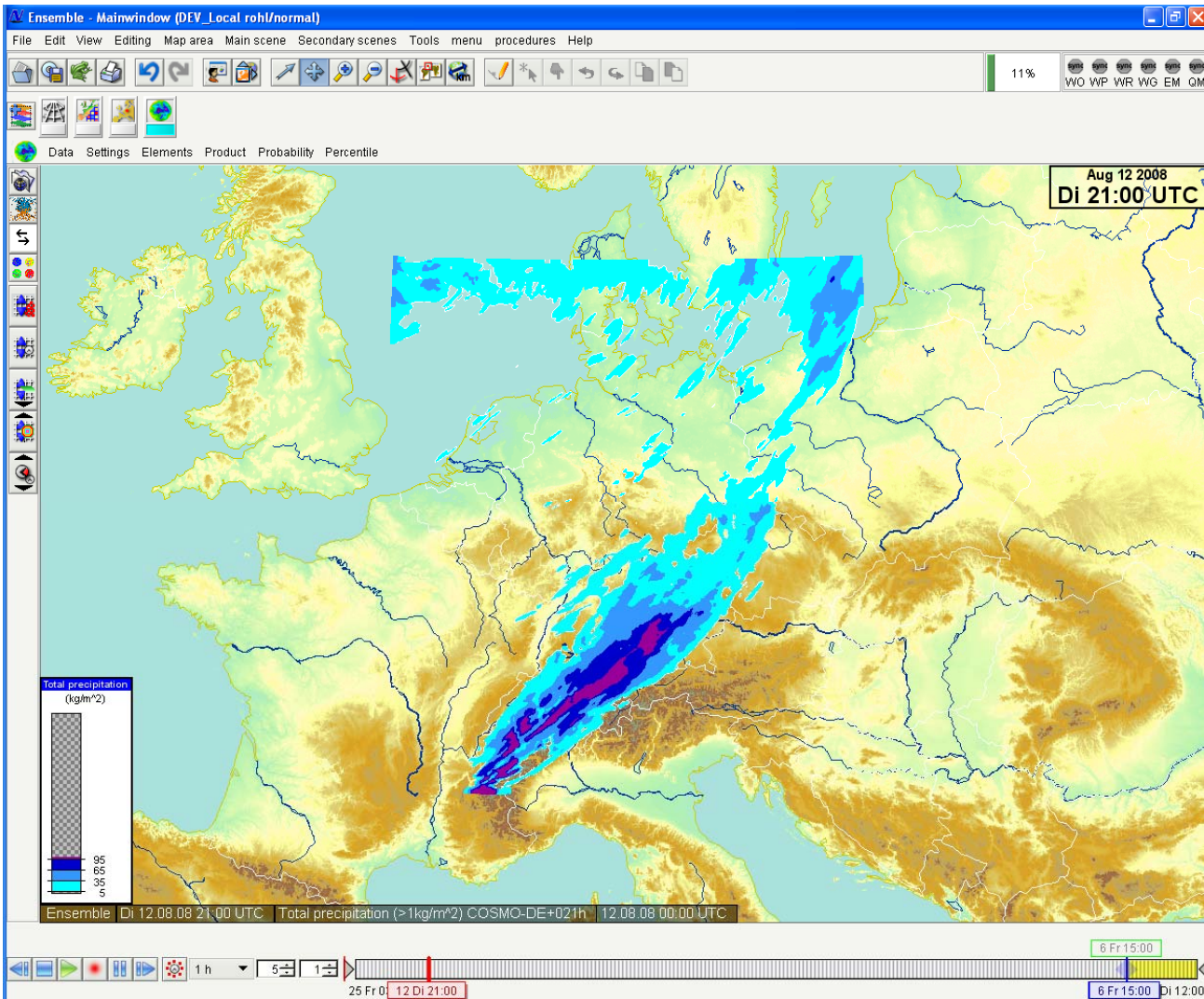
NinJo = visualization tool for forecasters



Visualization is part of the project:
end-to-end approach!

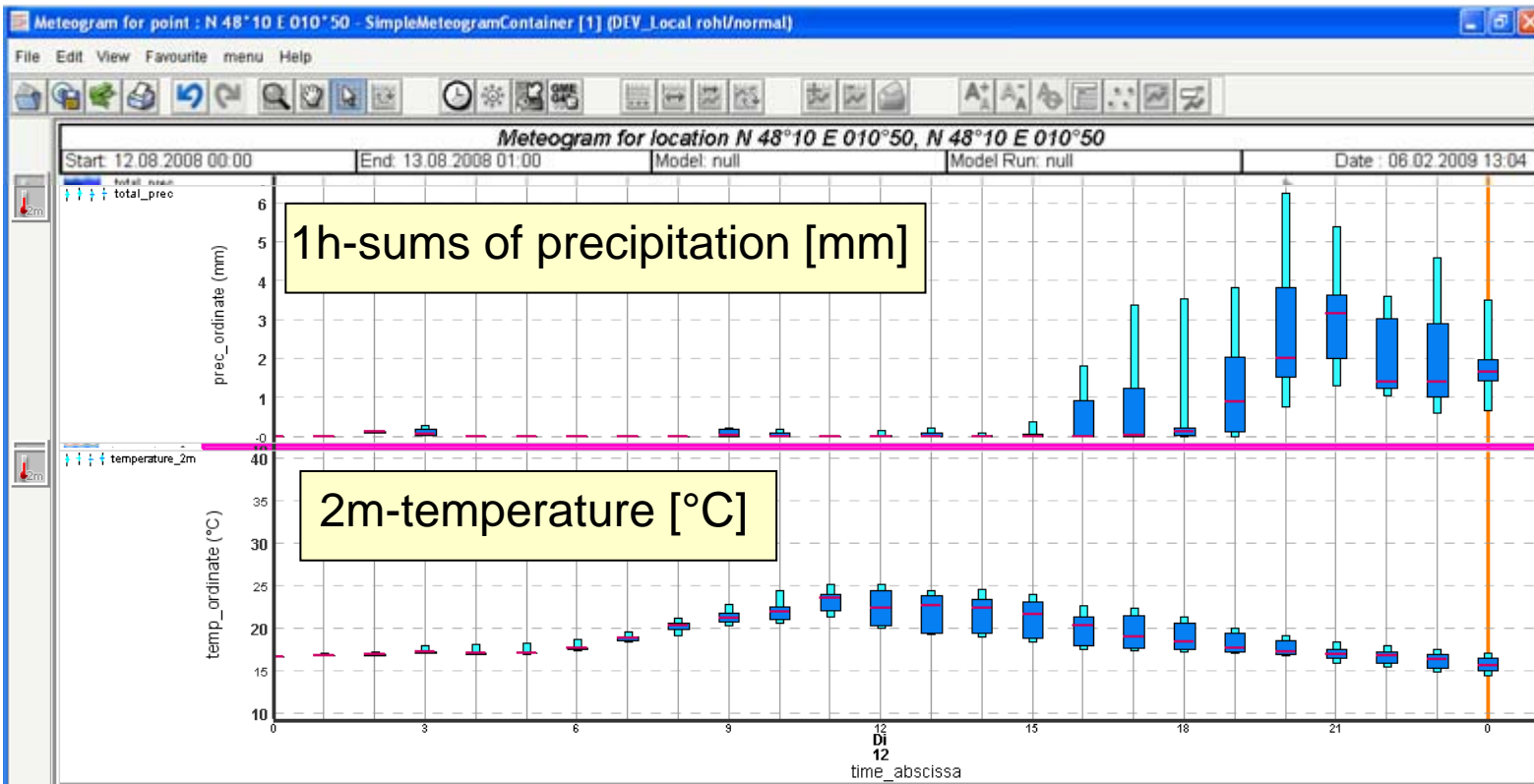
Challenge of ensemble visualization:

- amount of data
- good communication of complex matters



Exceedance Probabilities in %

Probability of RR > 1 mm/h

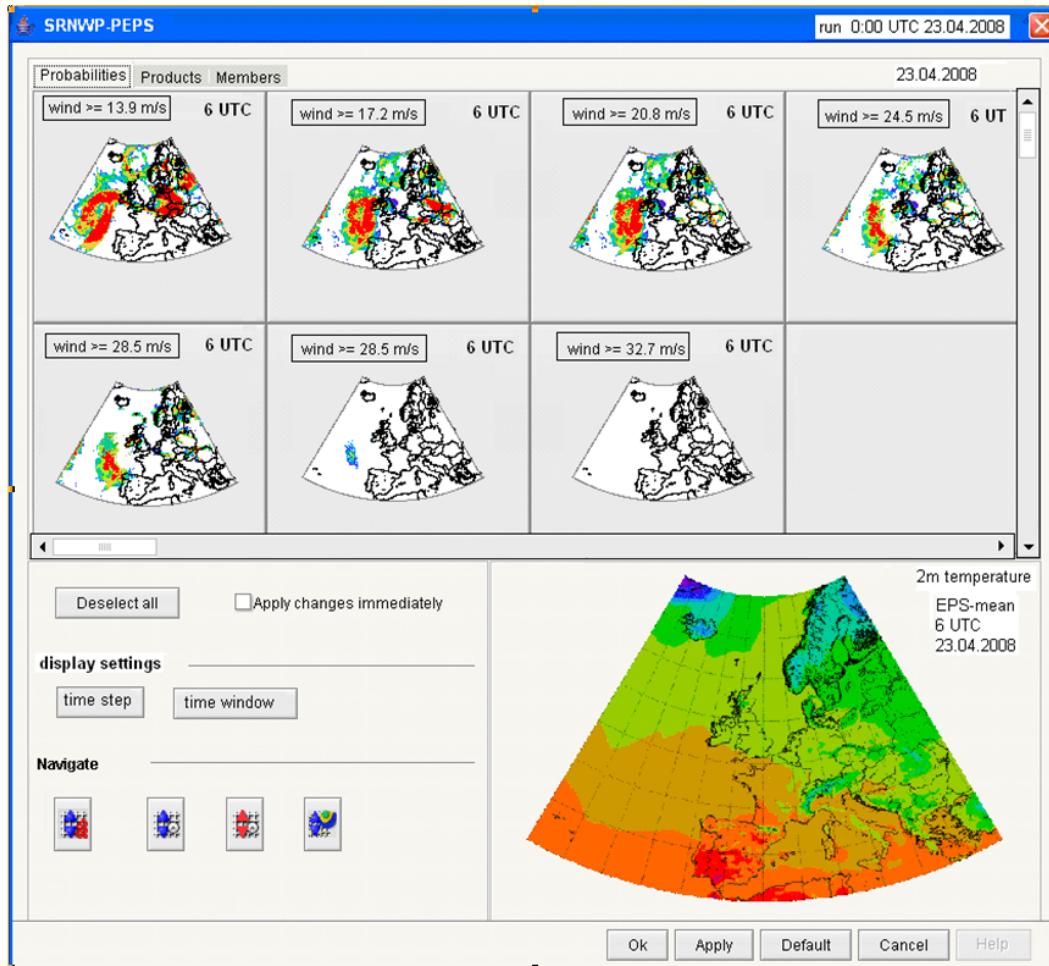


Quantiles



range of
90% probability

Further Plans: Ensemble Navigation Window (draft)



also possible to
look at individual members

Summary

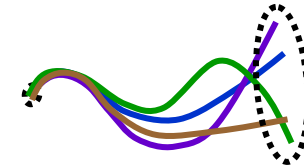
- physics & boundary perturbations:
technical set-up ready, several weeks of experiments
- refinement of physics perturbations:
combination of perturbations in each ensemble member
- initial conditions perturbations: new idea, first experiments
- verification tool: ready, demonstrates quality of ensemble
- postprocessing: just starting, aims & concept defined
- visualization: first version ready



Extra Slides

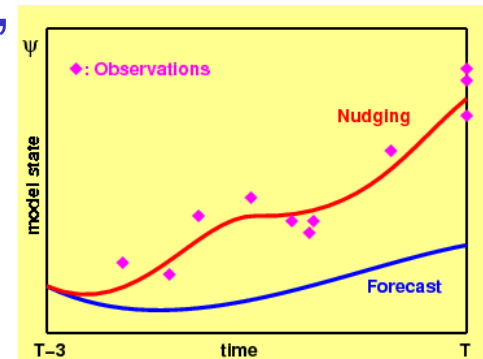


Perturbation of initial conditions



➤ first experiments: perturb “nudgecast”

- correlation length of observation increments
- geostrophic balance
- divergent flow correlations



➤ current work:

use differences between control and COSMO-SREPS as IC perturbations

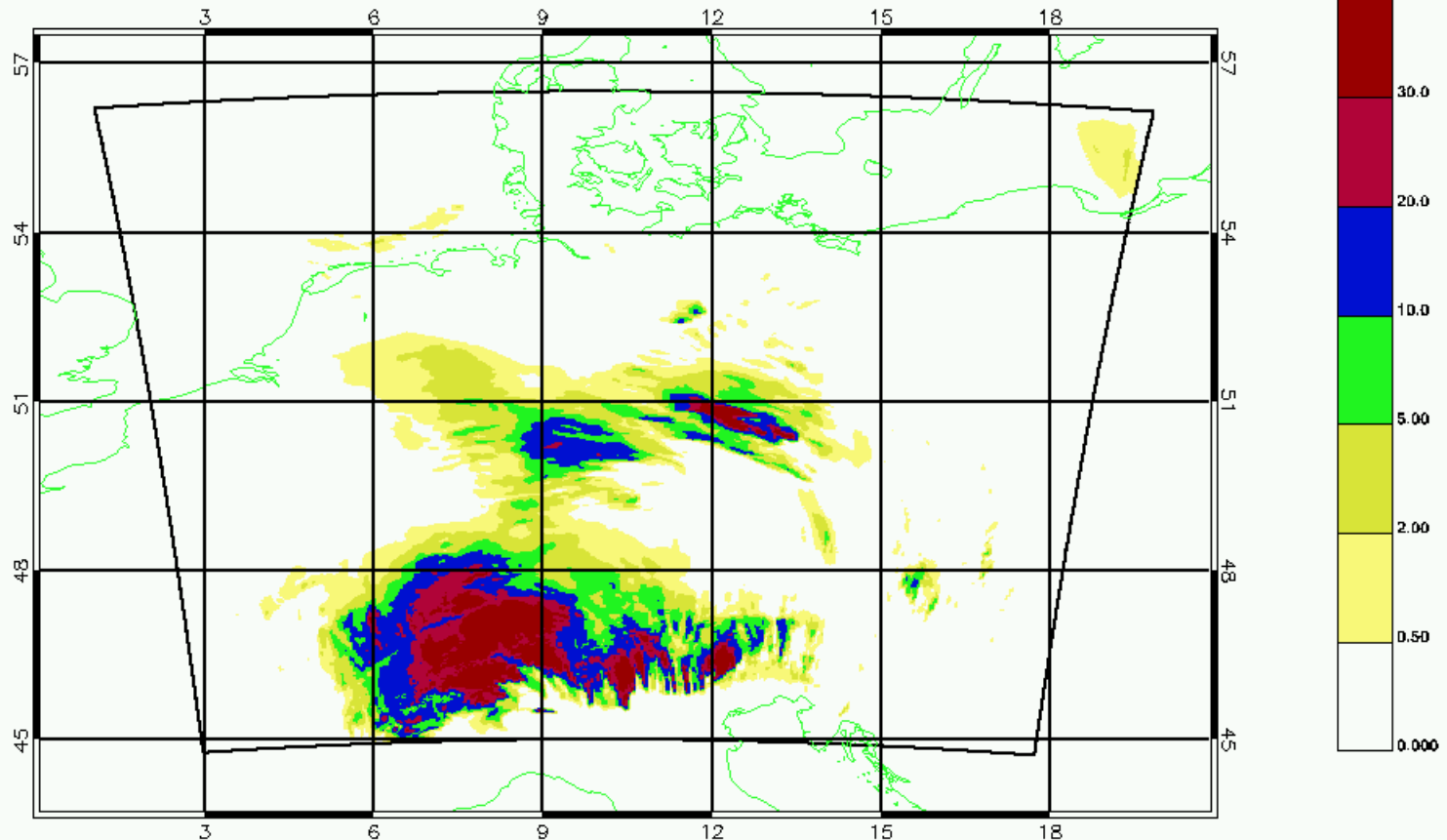
➤ long-term plan:

Ensemble Transform Kalman Filter (COSMO project KENDA)

Unperturbed 18-24UTC precipitation, 8 Aug 2007

tot_prec ref 07080812 vv 06-12

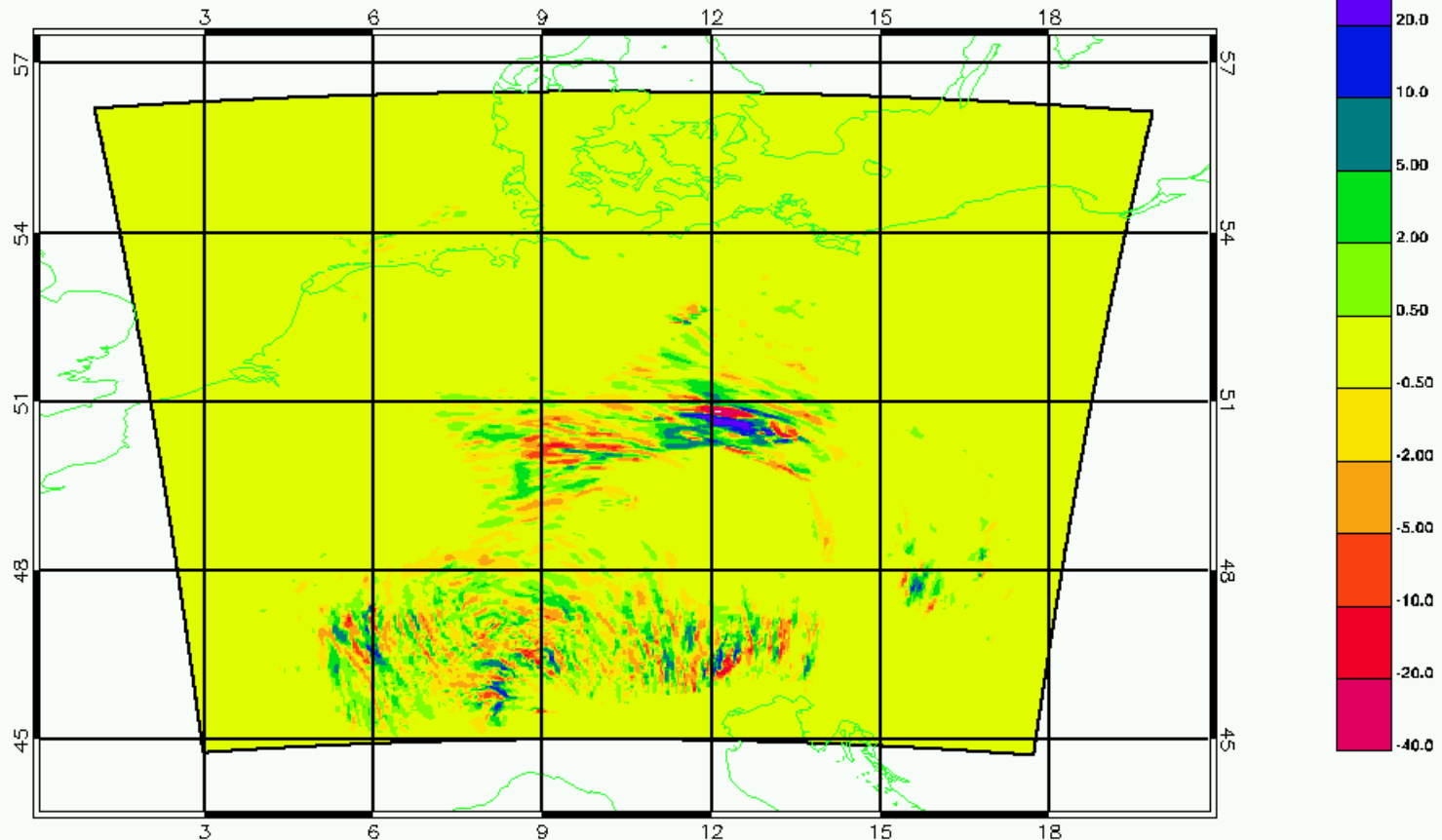
mean: 2.23 std: 6.86 min: 0.00 max: 85.81



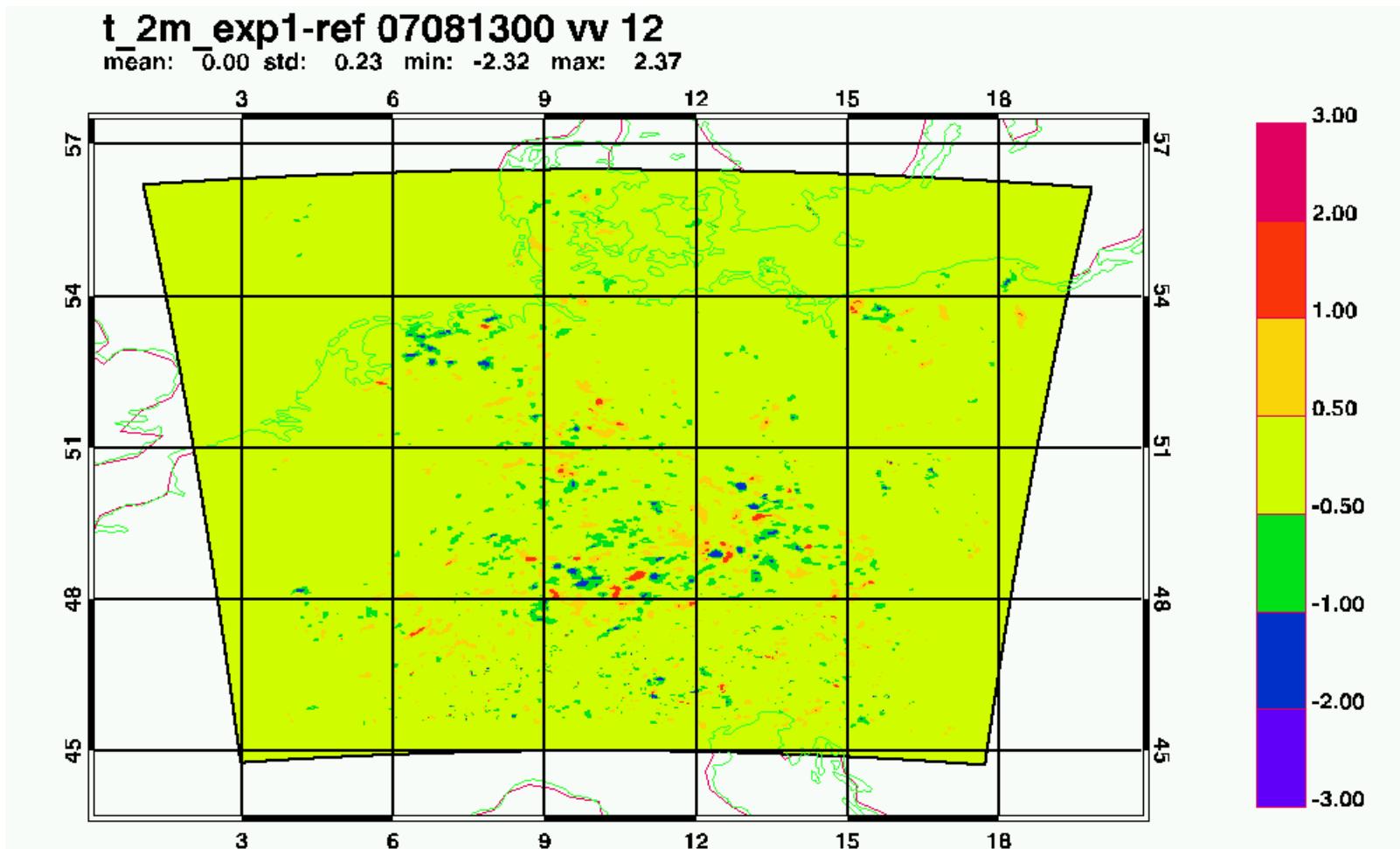
forecast perturbations 18-24UTC precipitation, 8 Aug 2007

tot_prec exp1-ref 07080812 vv 06-12

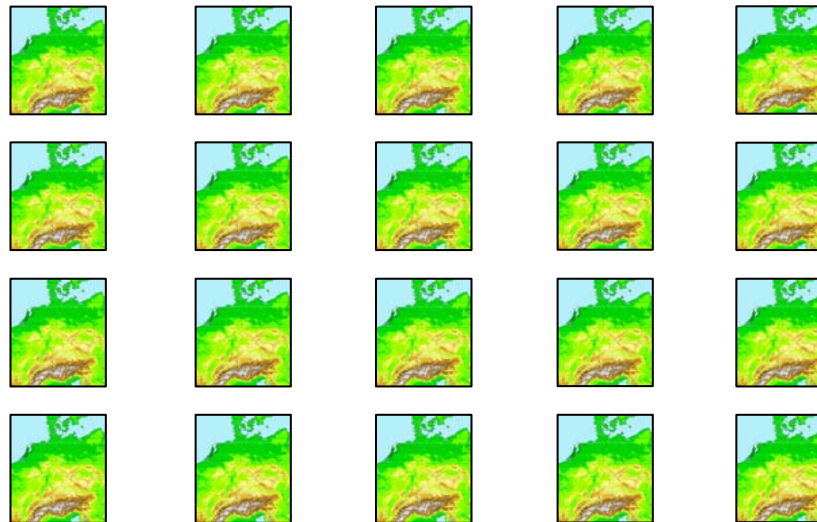
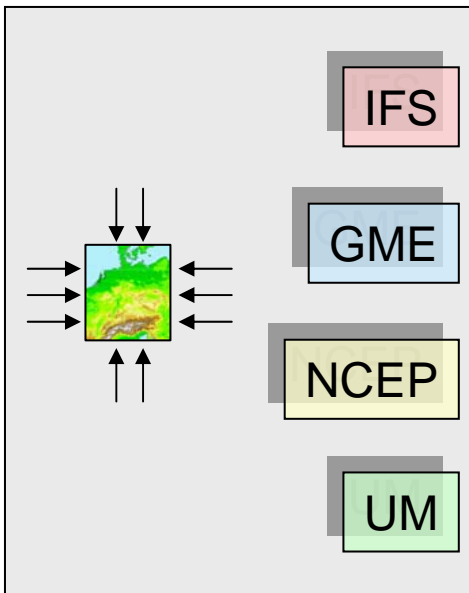
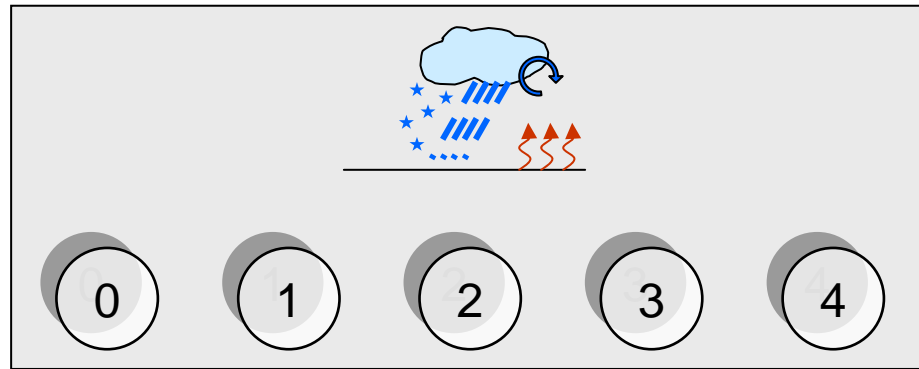
mean: 0.02 std: 1.44 min: -46.68 max: 65.45



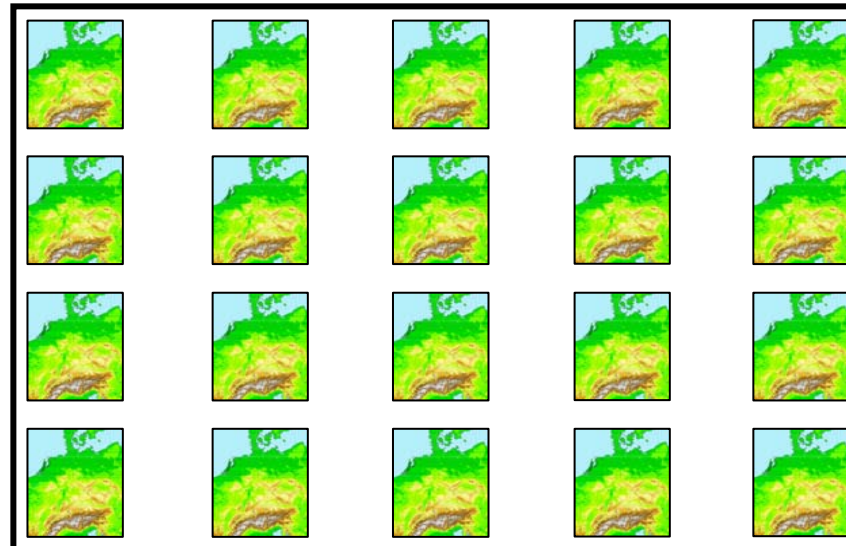
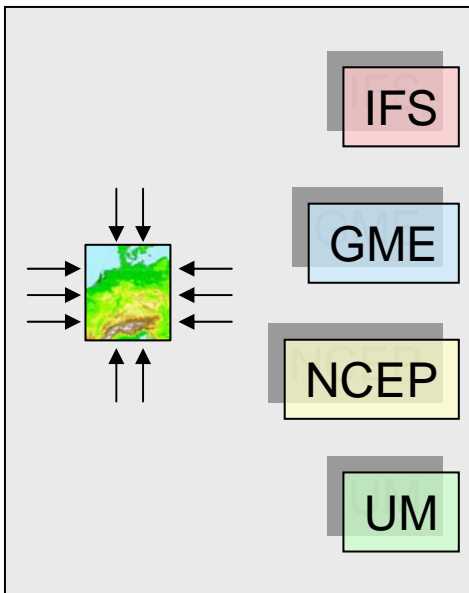
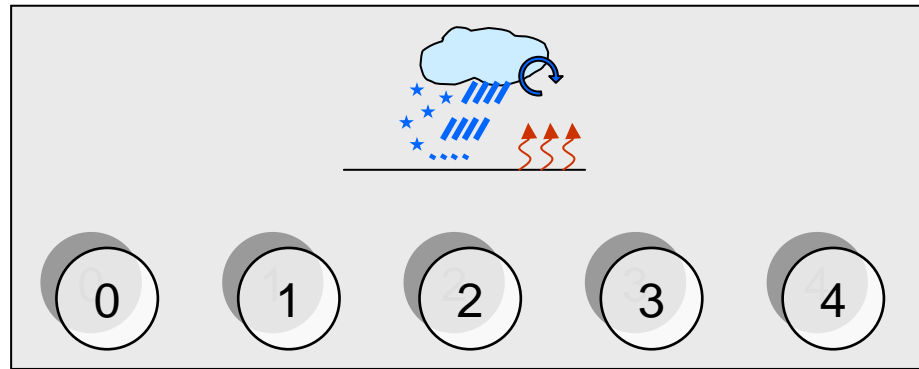
forecast perturbations 12 UTC 2m-temperature, 13 Aug 2007



Experiments – physics and boundary perturbations

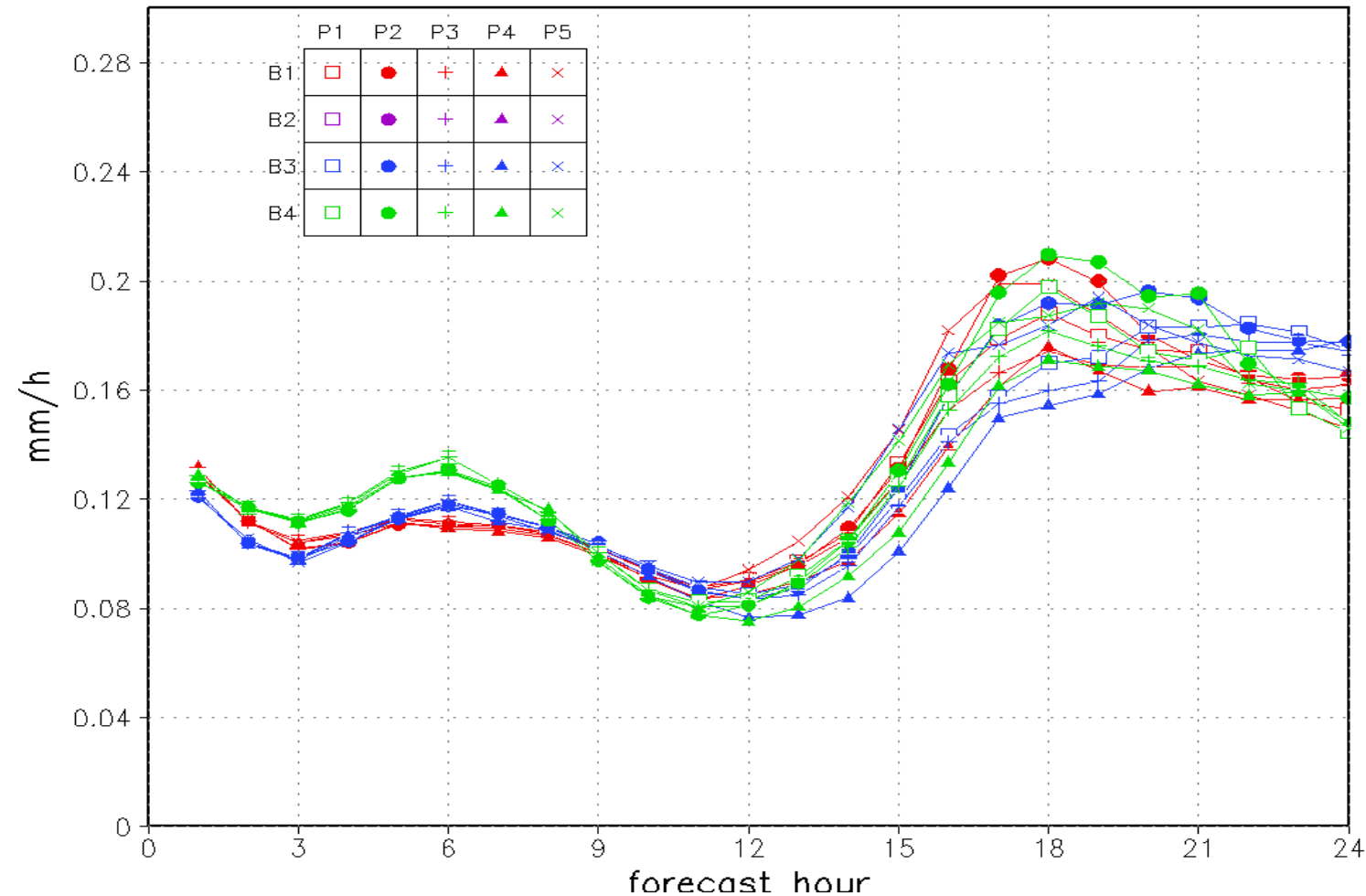


Experiments – physics and boundary perturbations



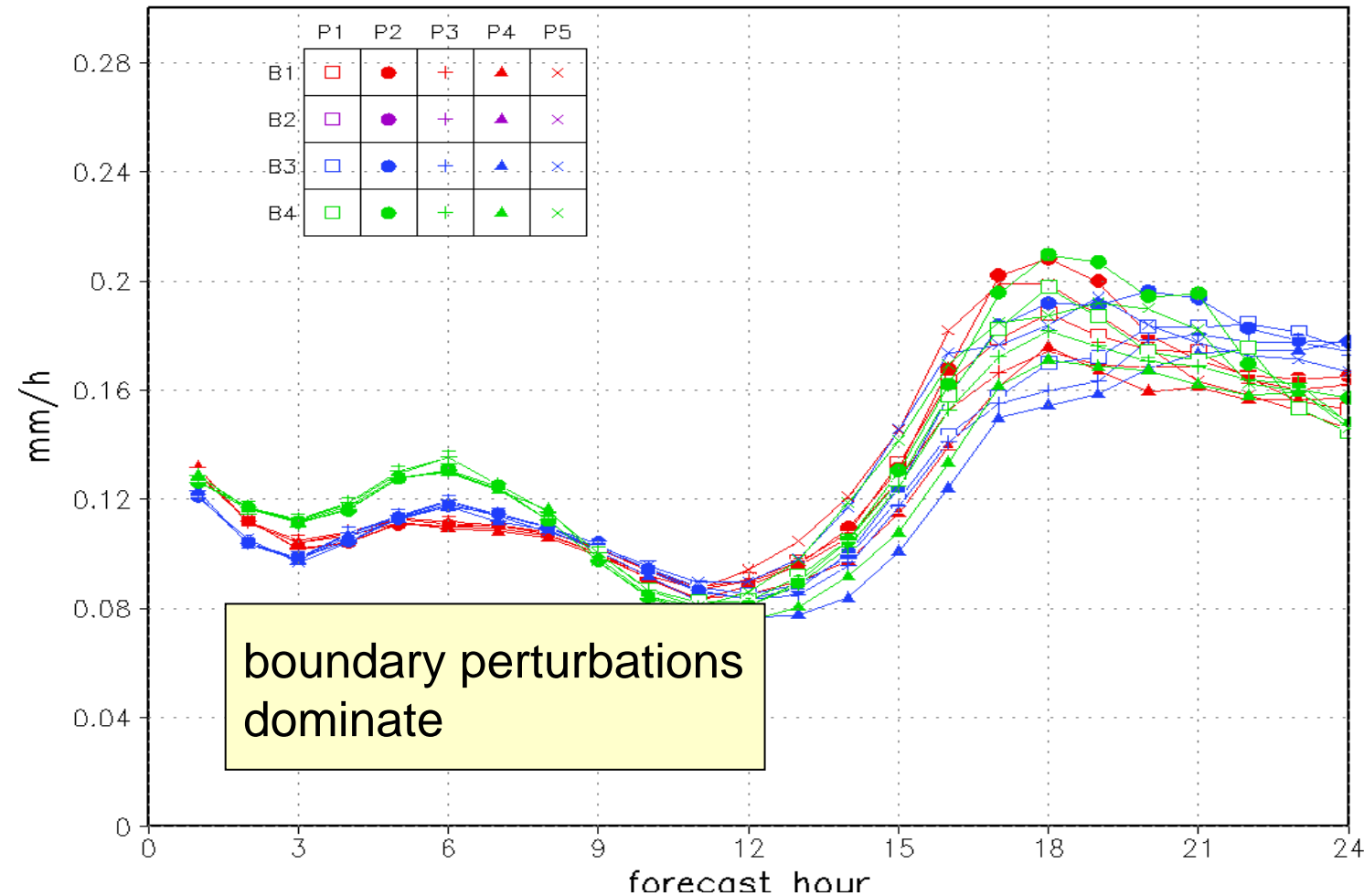
hourly precipitation (spatio-temporal mean)

1-9 July 2007, 0-24 h



hourly precipitation (spatio-temporal mean)

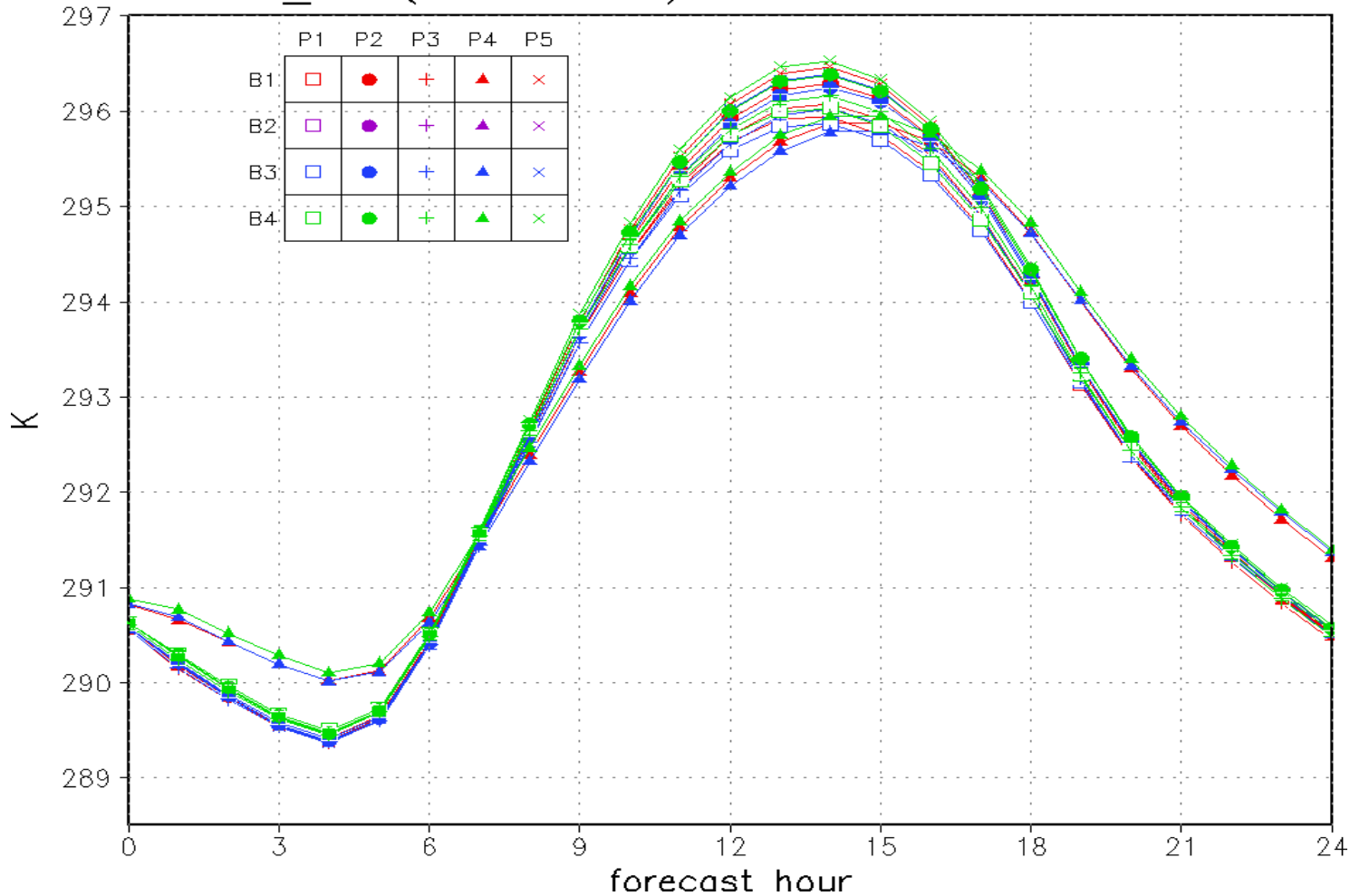
1-9 July 2007, 0-24 h





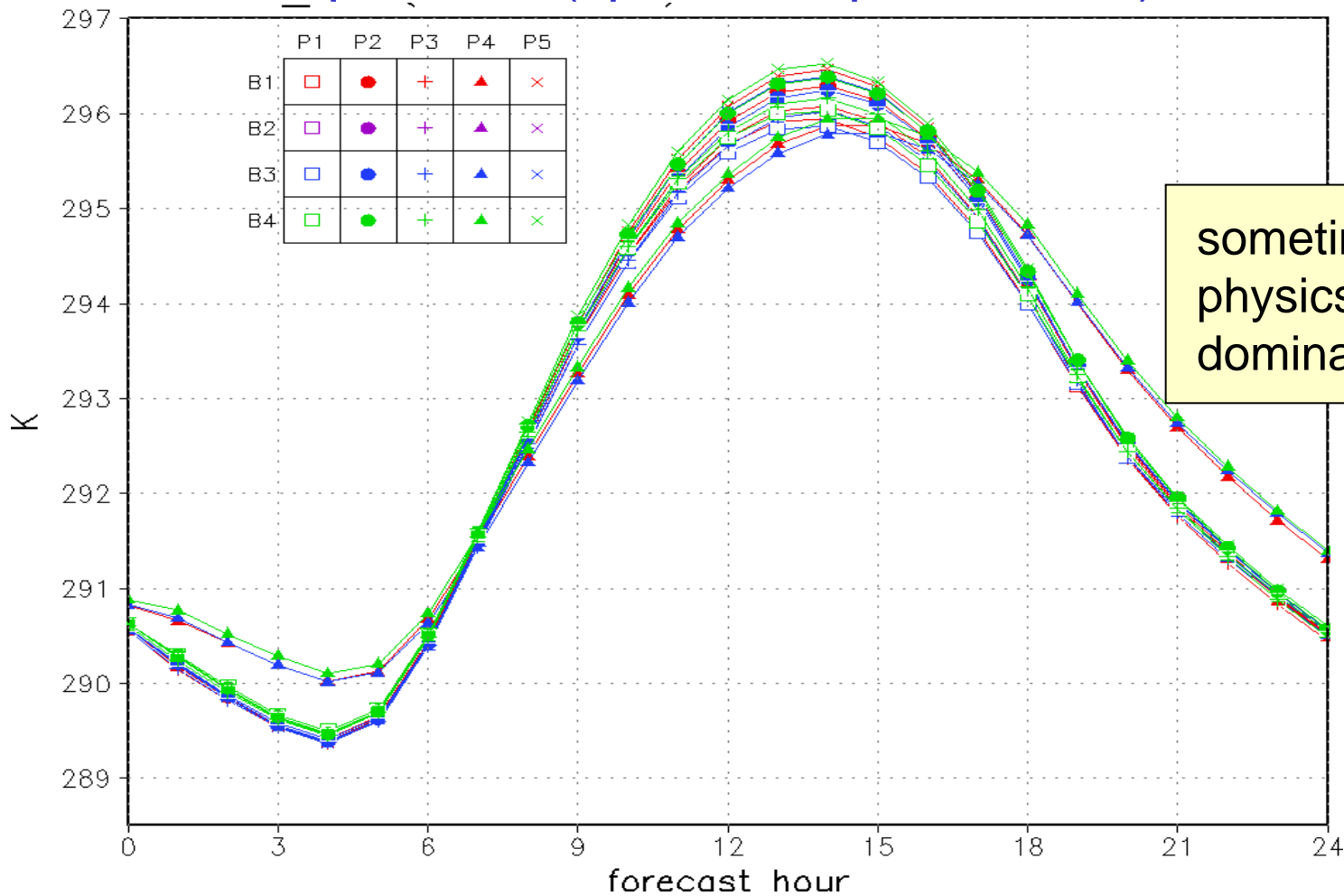
2m-temperature (spatio-temporal mean)

1-9 July 2007, 0-24 h



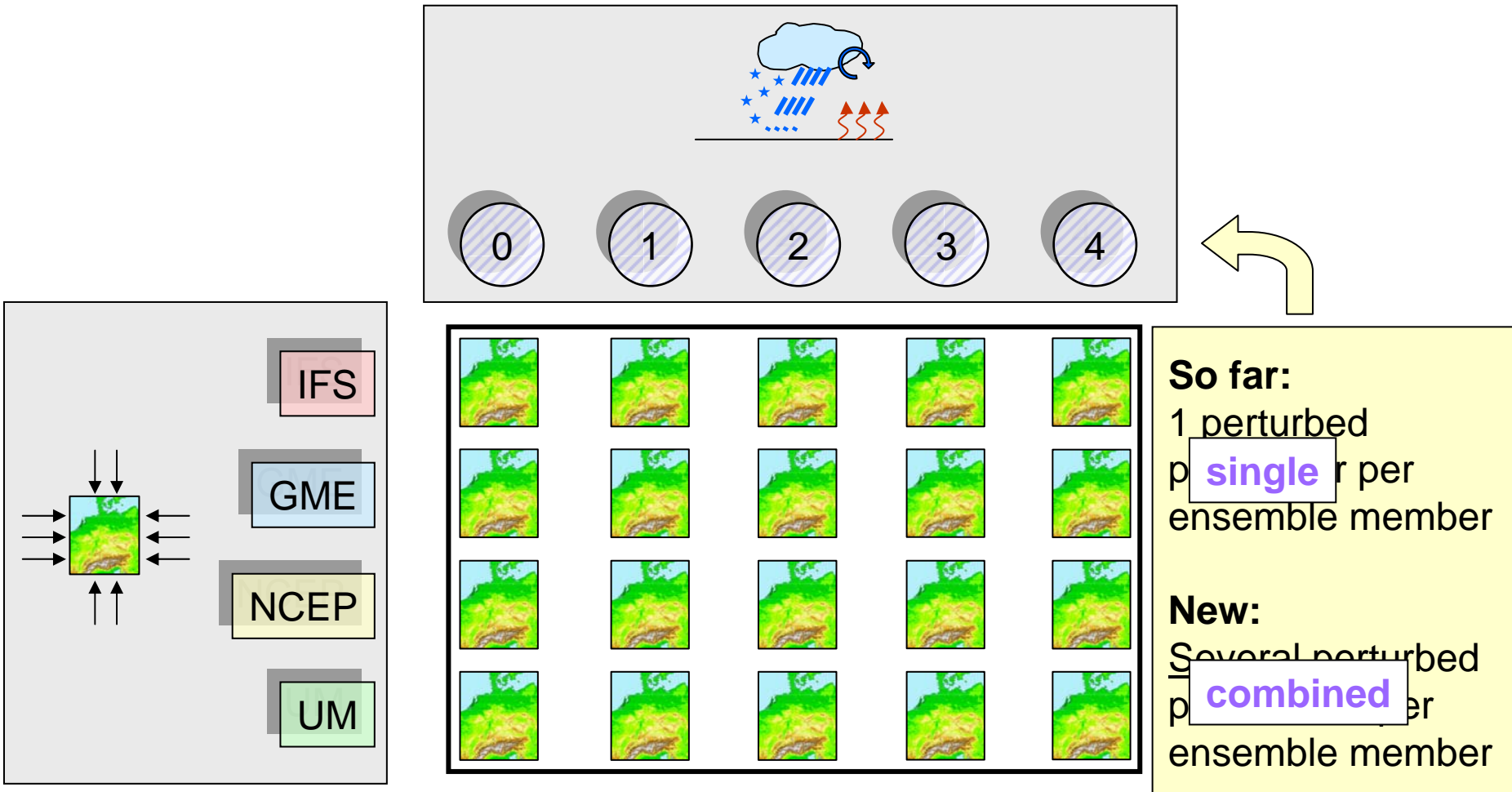
2m-temperature (spatio-temporal mean)

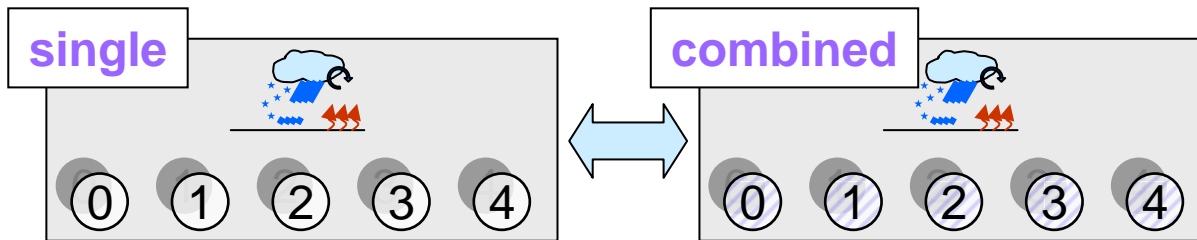
1-9 July 2007, 0-24 h



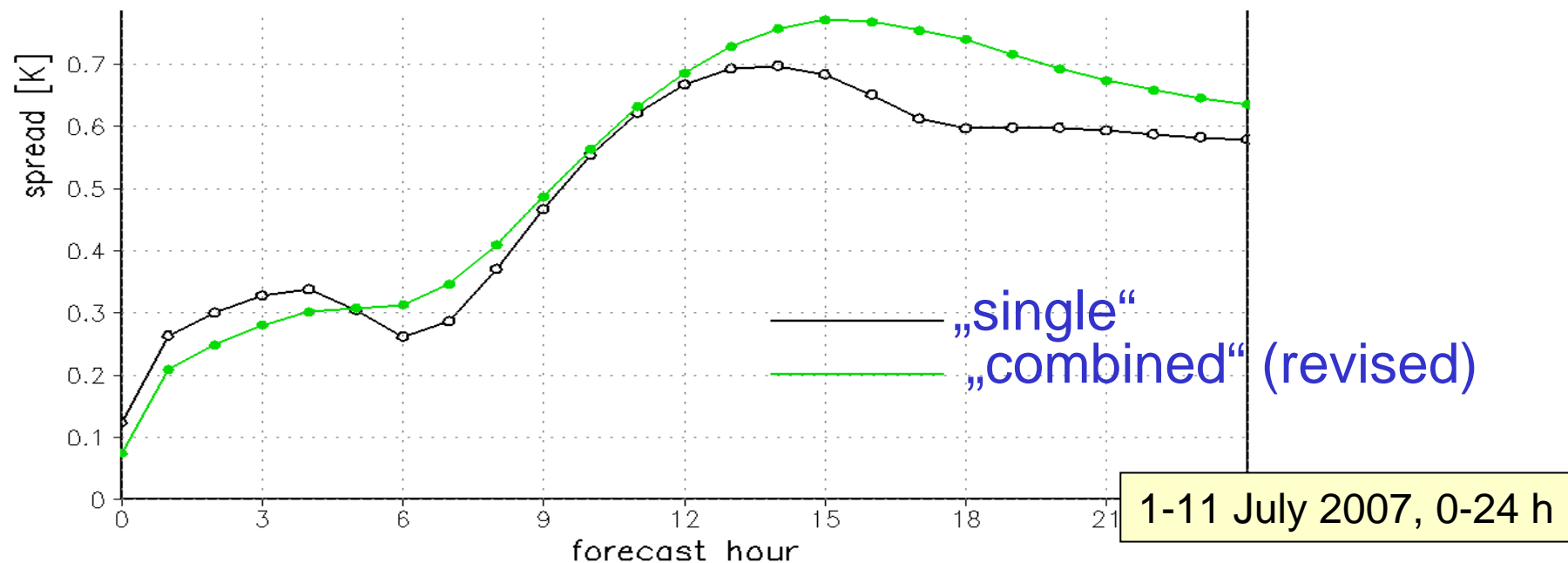
sometimes physics perturbations dominate

Experiments – physics and boundary perturbations



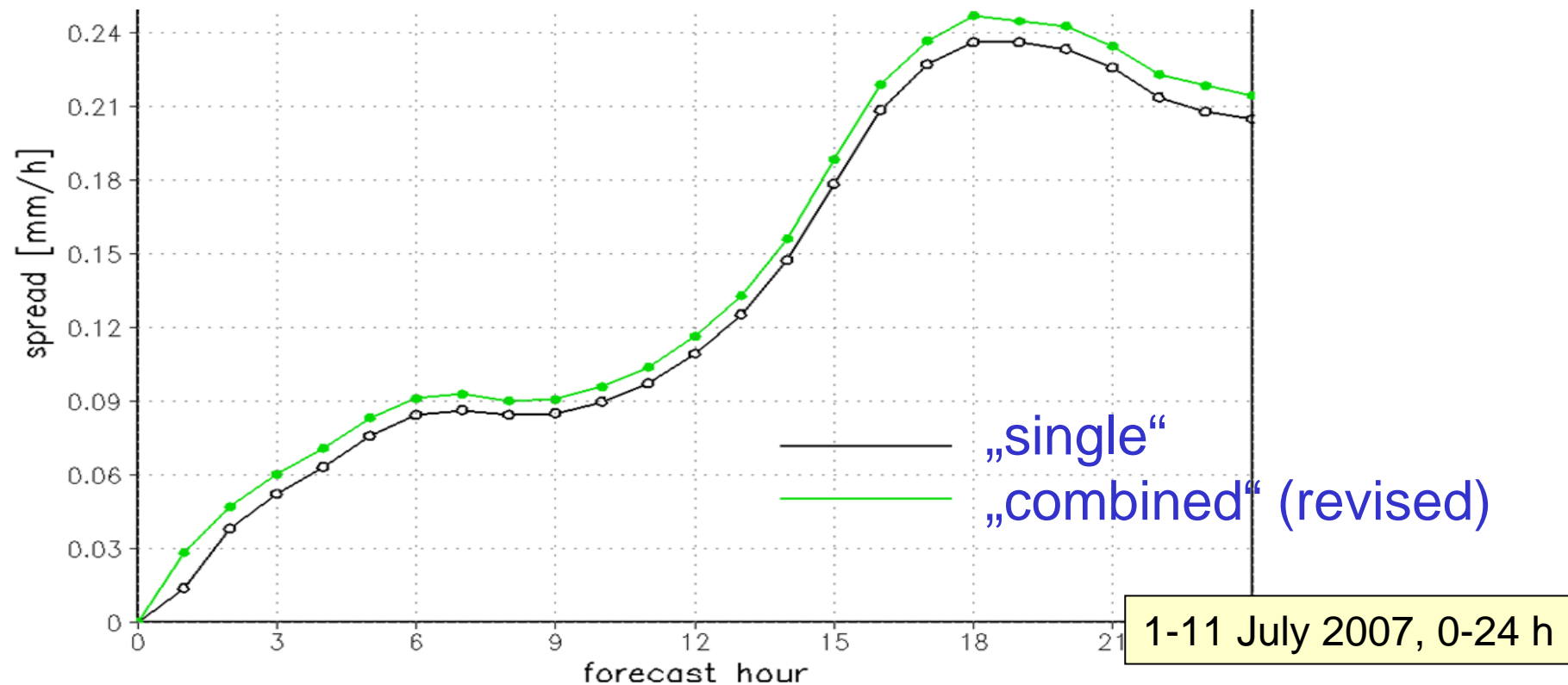


spread of 2m-temperature (spatio-temporal mean)



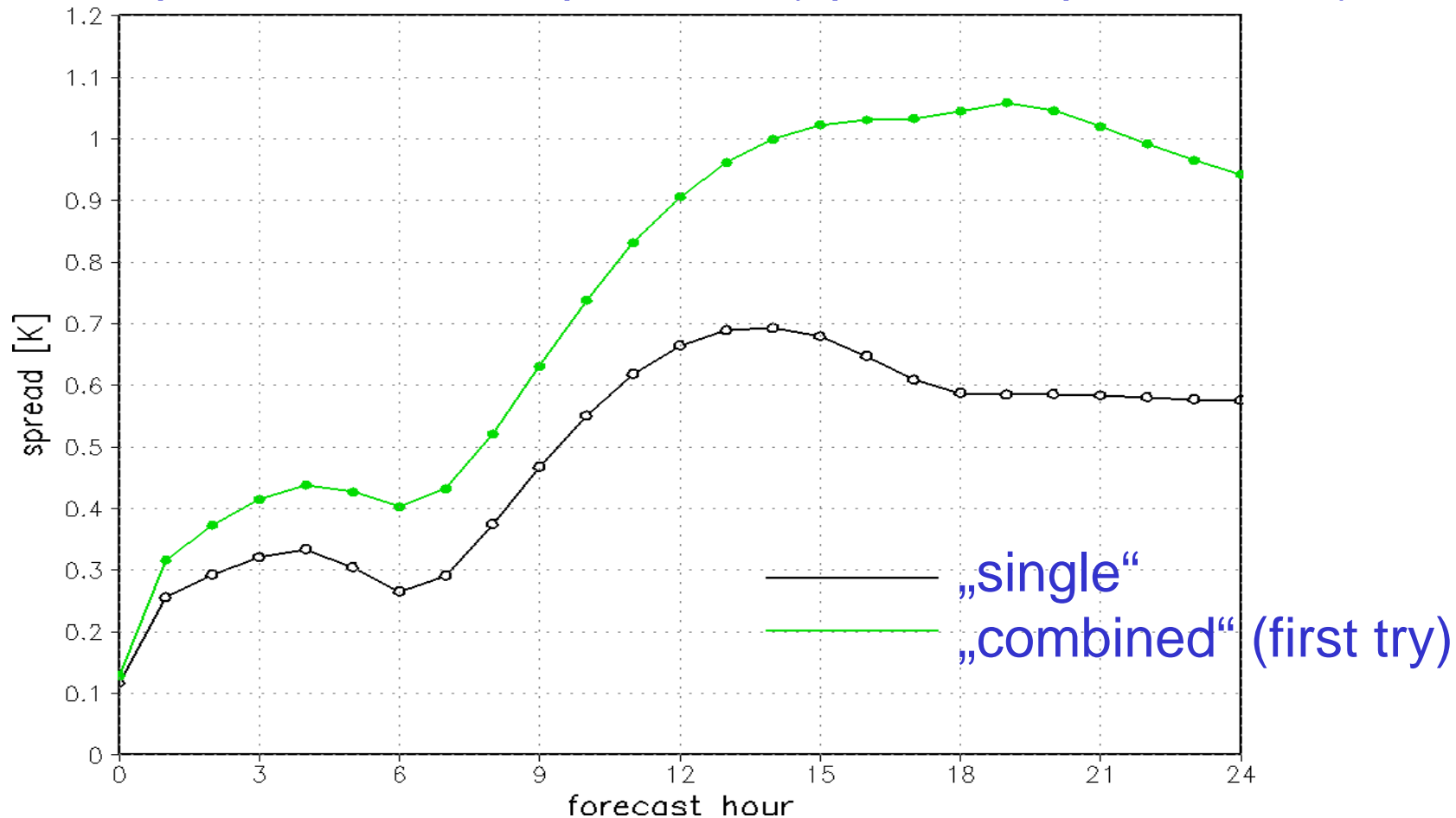
1-11 July 2007, 0-24 h

spread of 1h-precipitation (spatio-temporal mean)



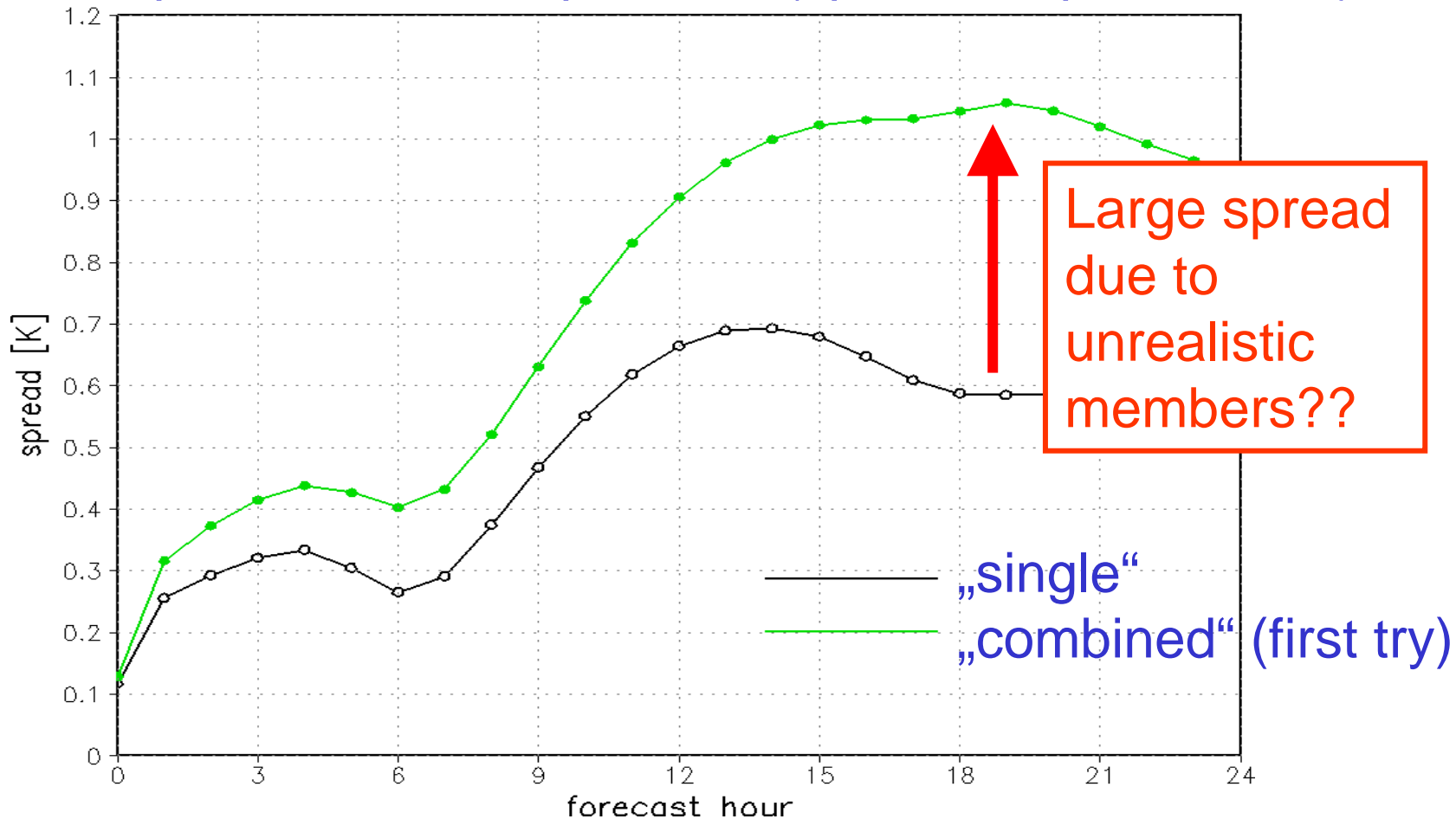
1-15 July 2007, 0-24 h

spread of 2m-temperature (spatio-temporal mean)



1-15 July 2007, 0-24 h

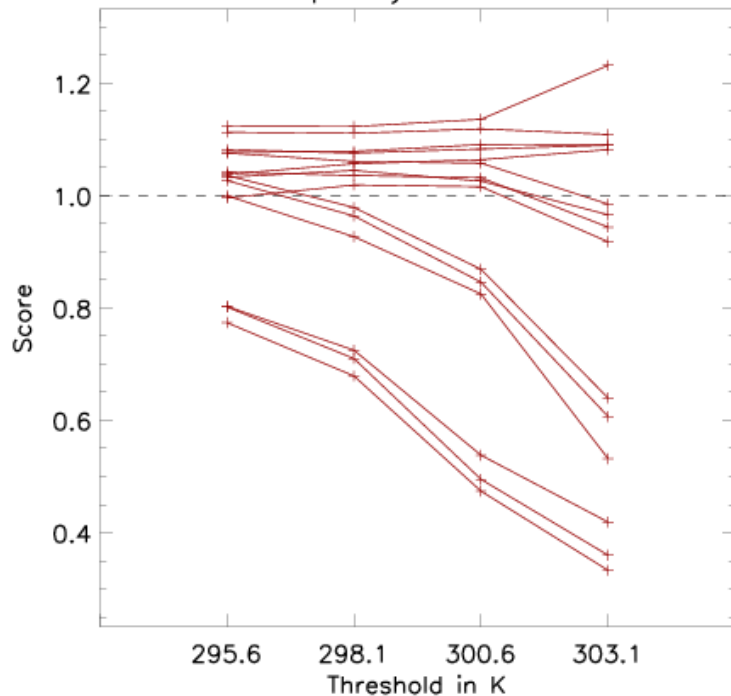
spread of 2m-temperature (spatio-temporal mean)



Attention:
physics perturbation set-up requires careful tuning

Long-term quality check of
individual ensemble members

Frequency Bias Index



first attempt
of physics perturbation set-up

Some members: bad quality

→ required a revision of
perturbation set-up

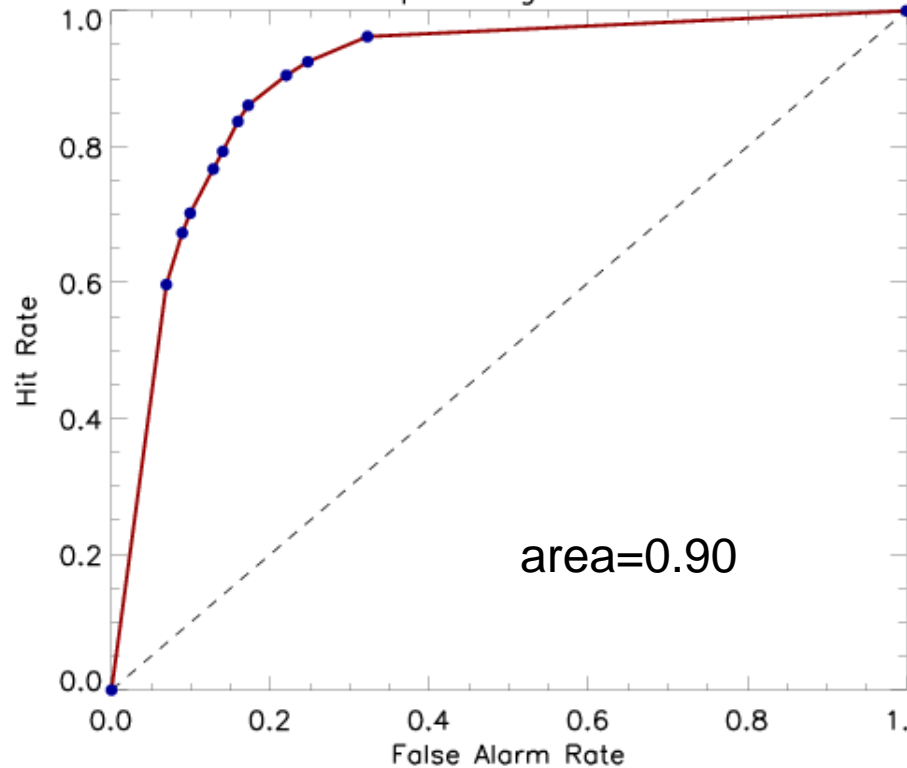
→ successful (not shown)

Verification results for 24 hours precipitation

threshold: 1mm/24h

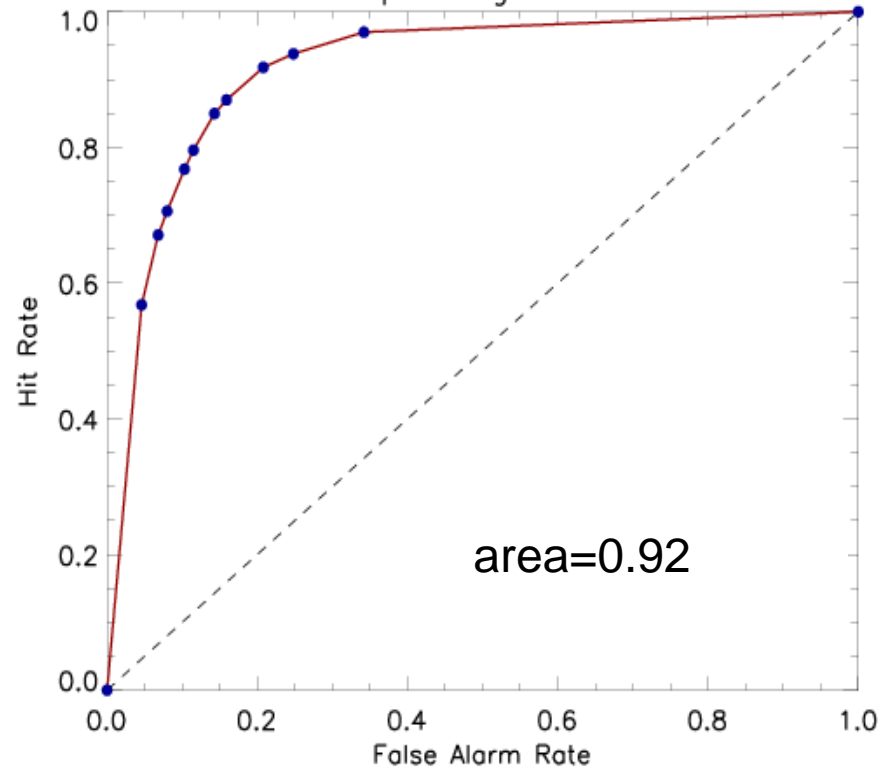
„single“

Relative Operating Characteristic



„combined“

Relative Operating Characteristic

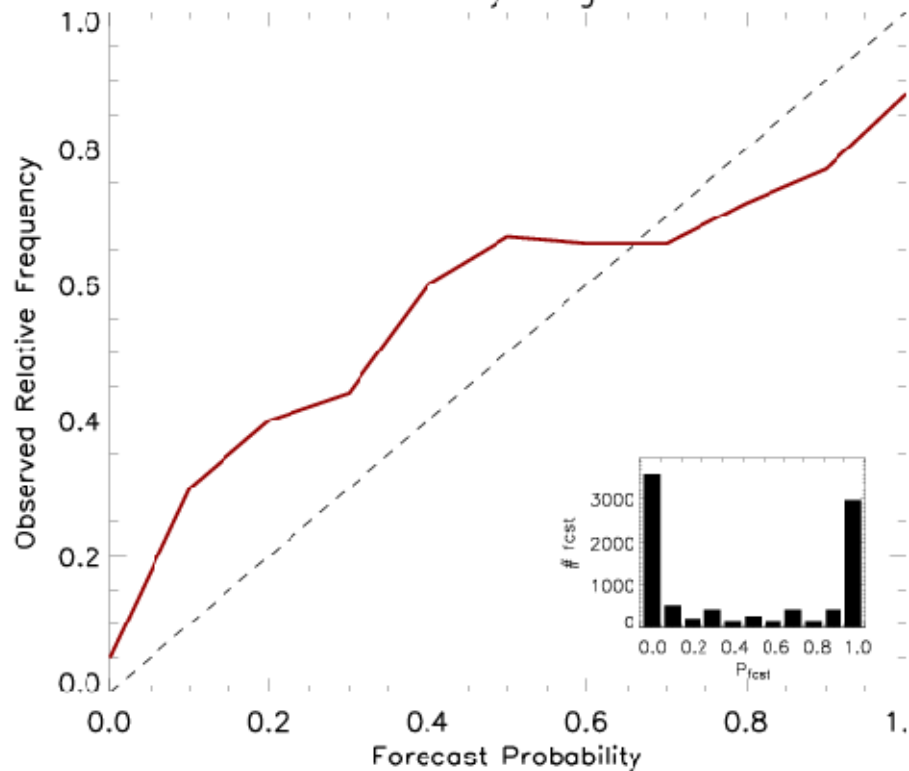


Verification results for 24 hours precipitation

threshold: 1mm/24h

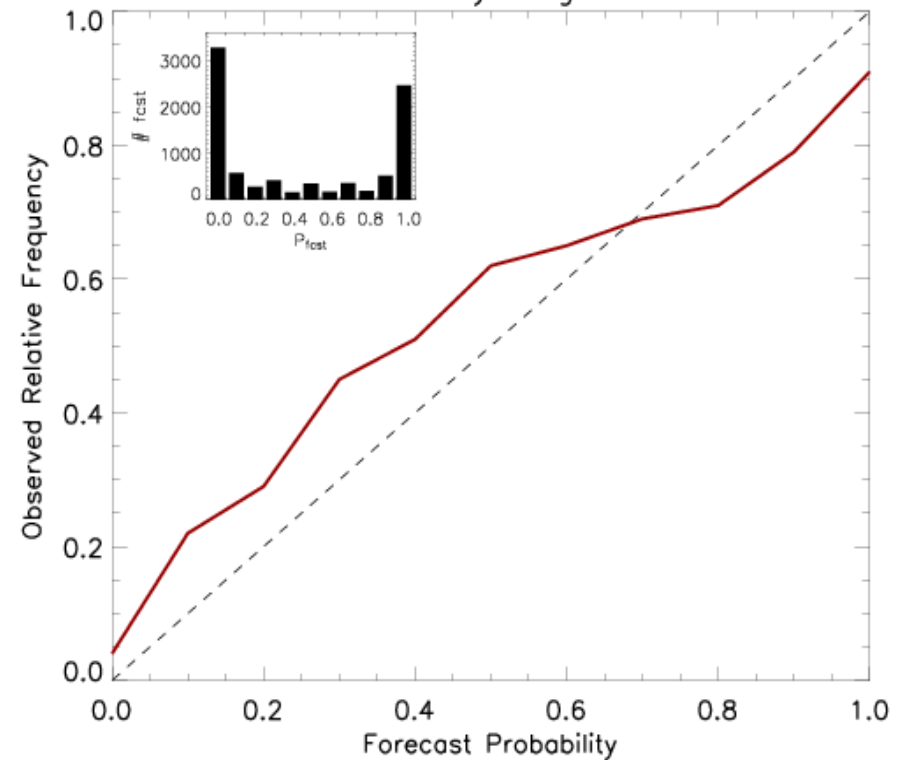
„single“

Reliability Diagram



„combined“

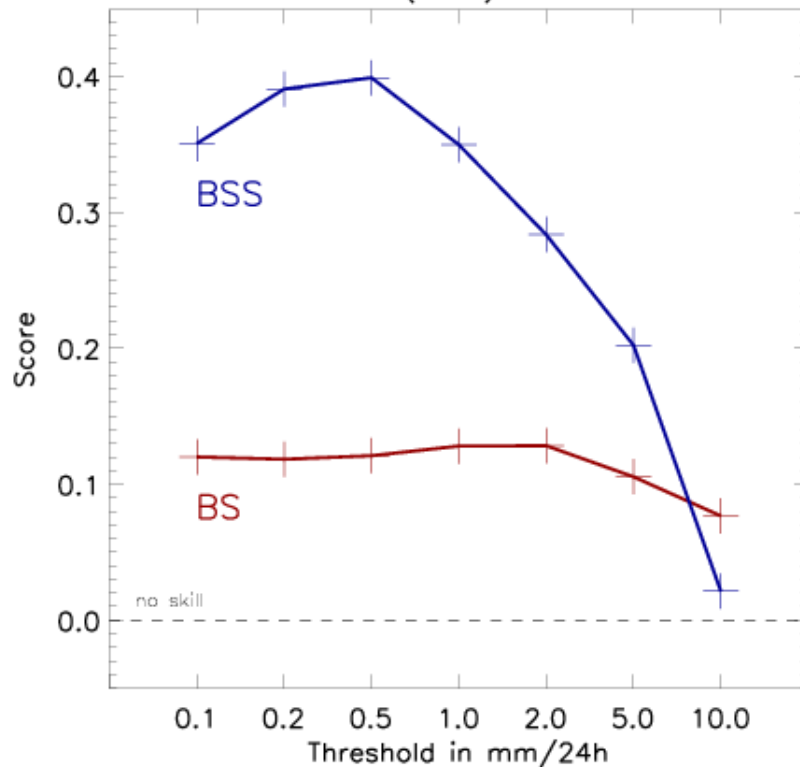
Reliability Diagram



Verification results for 24 hours precipitation

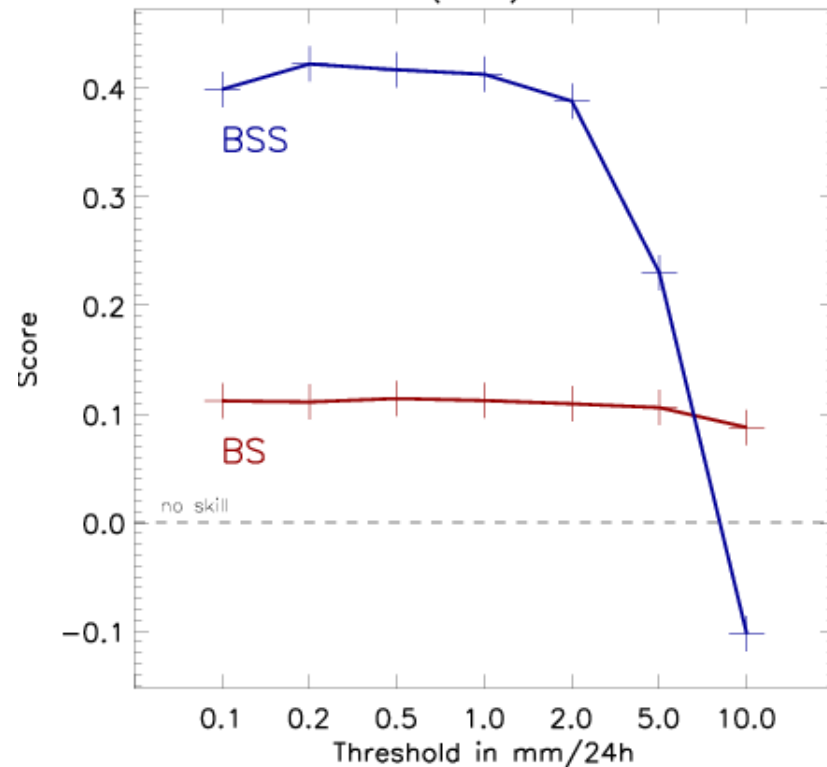
„single“

Brier (Skill) Score



„combined“

Brier (Skill) Score

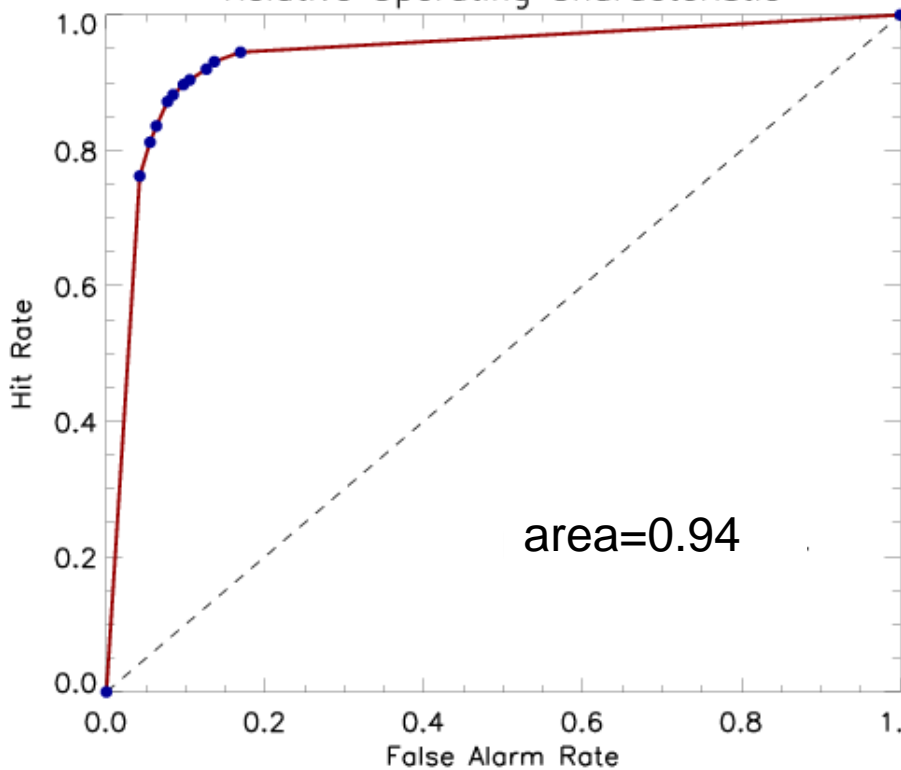


Verification results for 2m-temperature 12UTC

threshold: 25°C

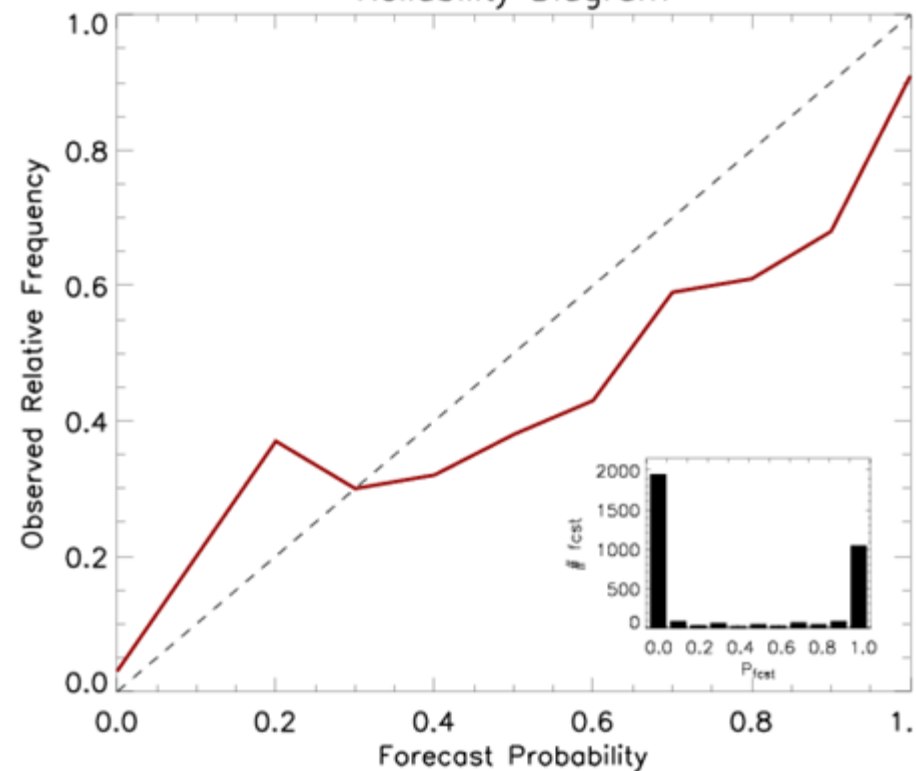
ROC

Relative Operating Characteristic

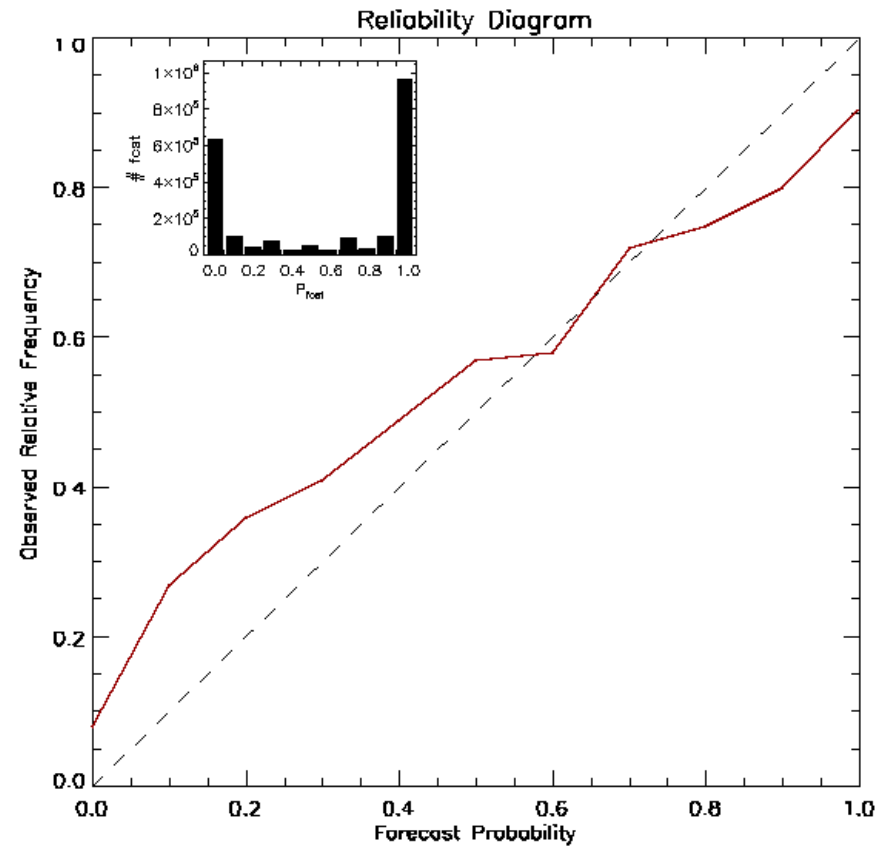
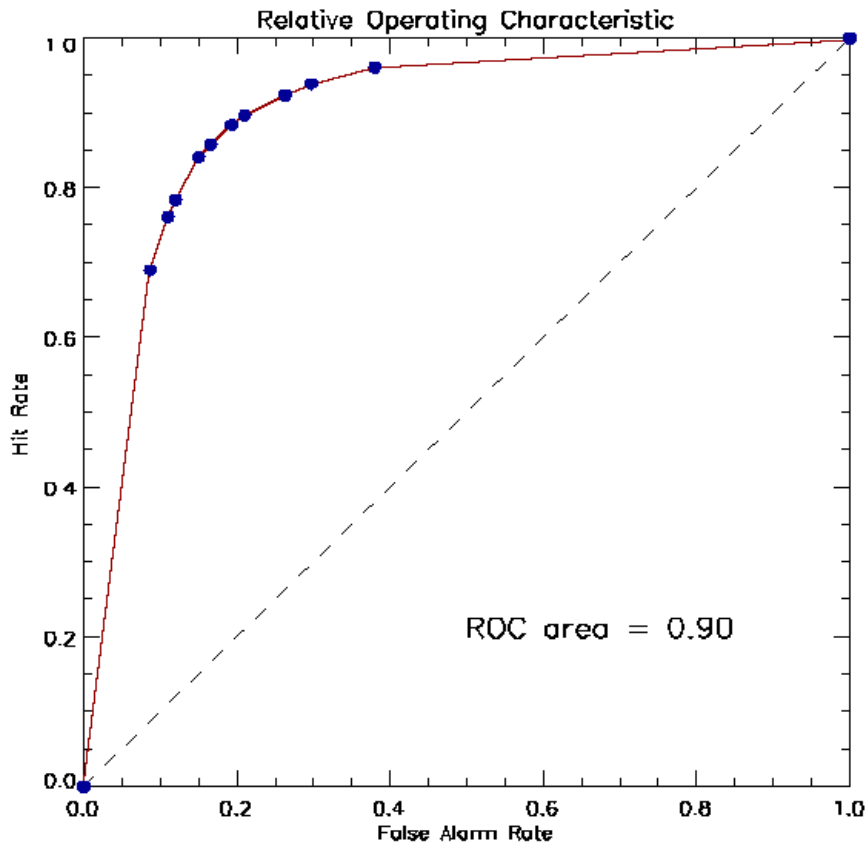


Reliability

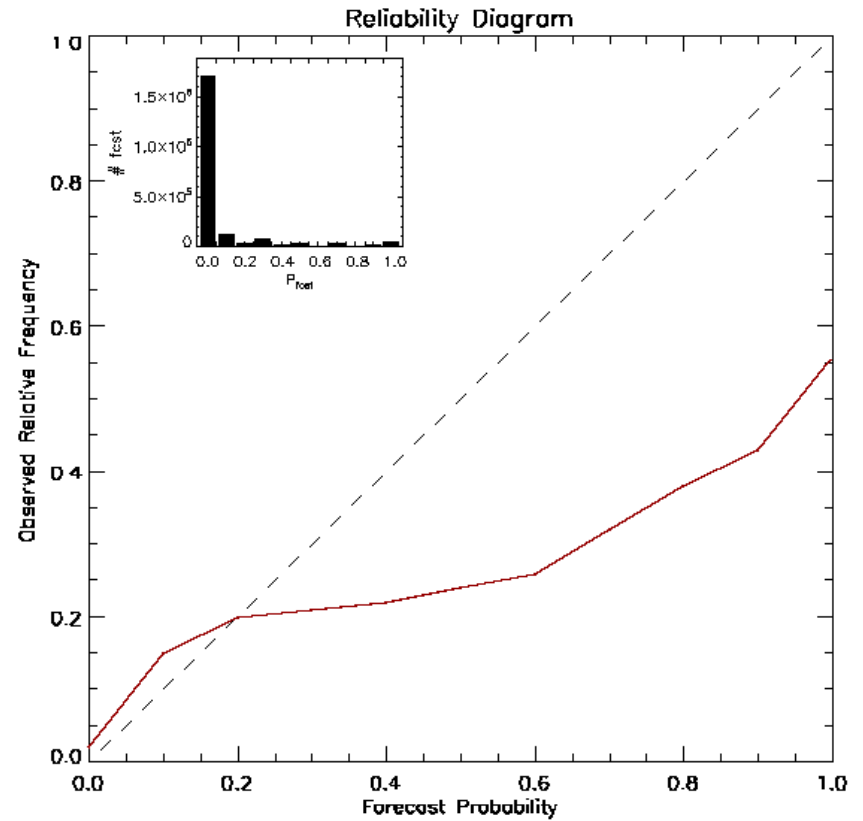
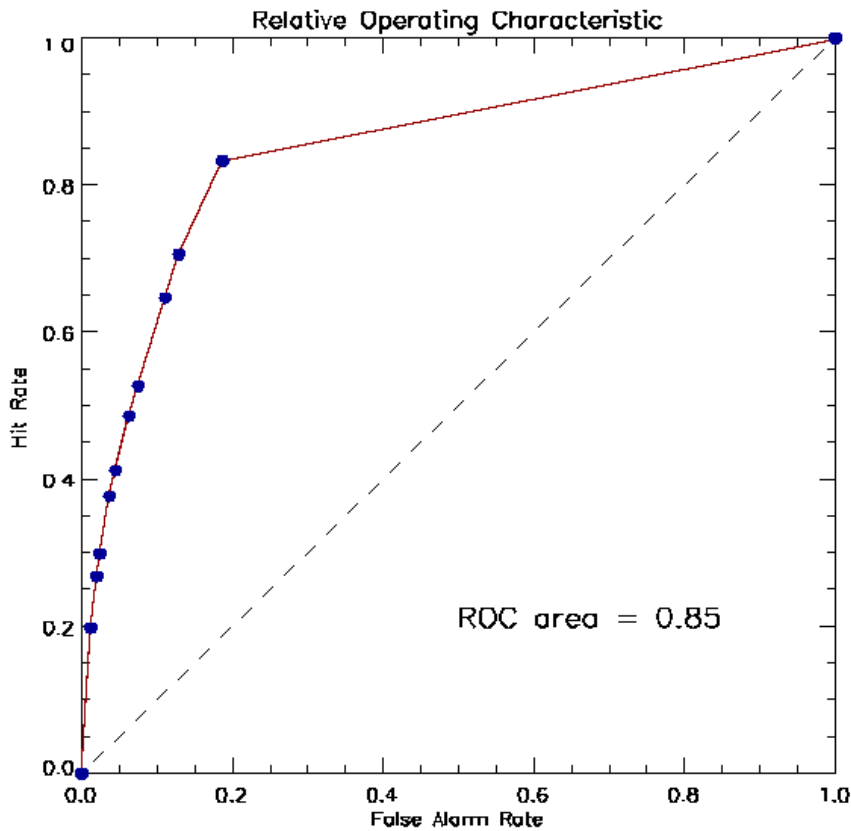
Reliability Diagram



Threshold: 0.1mm/24h



Threshold: 10mm/24h



Statistical Postprocessing (just starting)

Aim:

improve quality of ensemble products

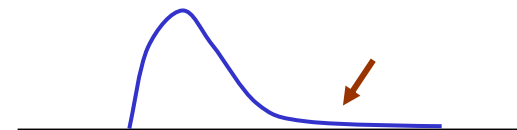
(probabilities, quantiles, mean, entire pdf, extremes,...)

Focus:

Precipitation

1. exceedance probabilities (“30% probability of heavy rain”)

2. entire pdf, extremes?



Statistical Postprocessing (just starting)

Envisaged Methods:

1. Logistic Regression

calibration of probabilities

- + spatio-temporal neighbourhood
- + lagged average ensemble



enhance sample

2. Bayesian Model Averaging

cooperation with Univ.Bonn

→ entire pdf

