Deutscher Wetterdienst

Developing an Ensemble Prediction System: A Forecast Provider´s Perspective

Susanne Theis

Project COSMO-DE-EPS

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Overview

- Motivation for Project COSMO-DE-EPS
- Tasks within Project
- Current Status and Challenges

Motivation for the Project

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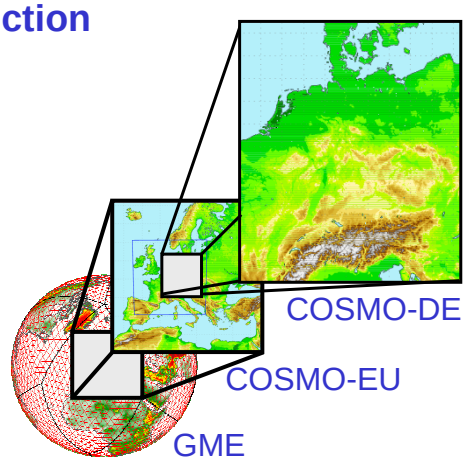
Numerical Weather Prediction Model COSMO-DE

- grid box size: 2,8 km
- without parametrization of deep convection
- assimilation of radar data
- lead time: 0-21 hours
- operational since April 2007



30th July 2009 Susanne Theis Project COSMO-DE-EPS

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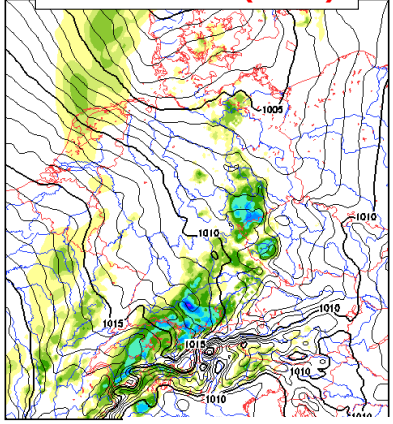
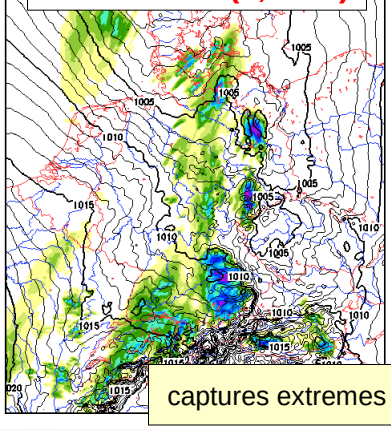
Benefits of COSMO-DE

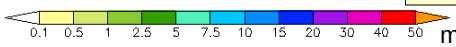
COSMO-EU (7 km)



COSMO-DE (2,8 km)



captures extremes



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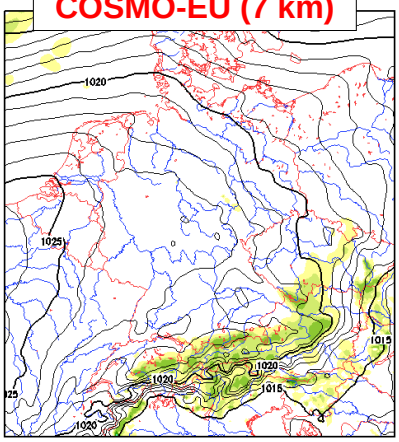
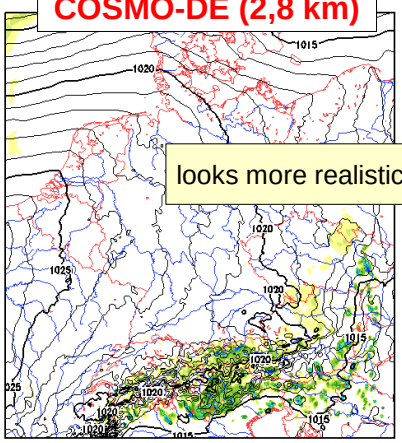
Benefits of COSMO-DE

COSMO-EU (7 km)

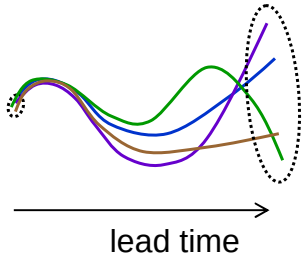


COSMO-DE (2,8 km)



looks more realistic

What about Deterministic Predictability?



Atmosphere is

a chaotic system

(Lorenz,1963)

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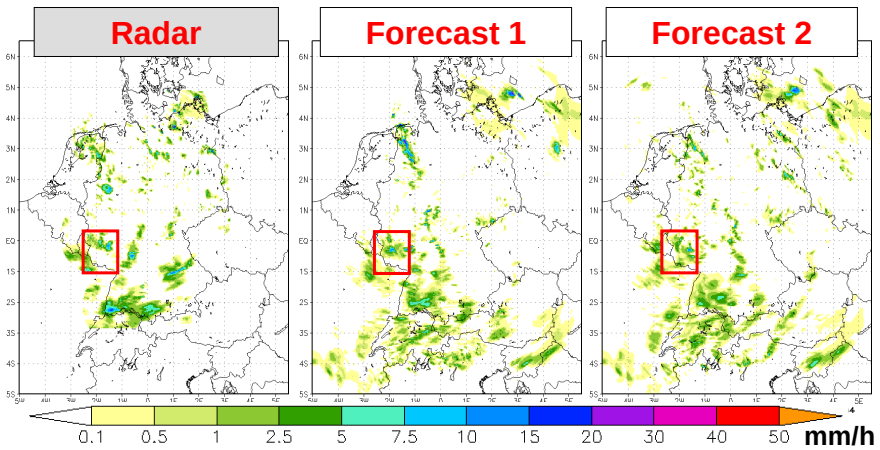
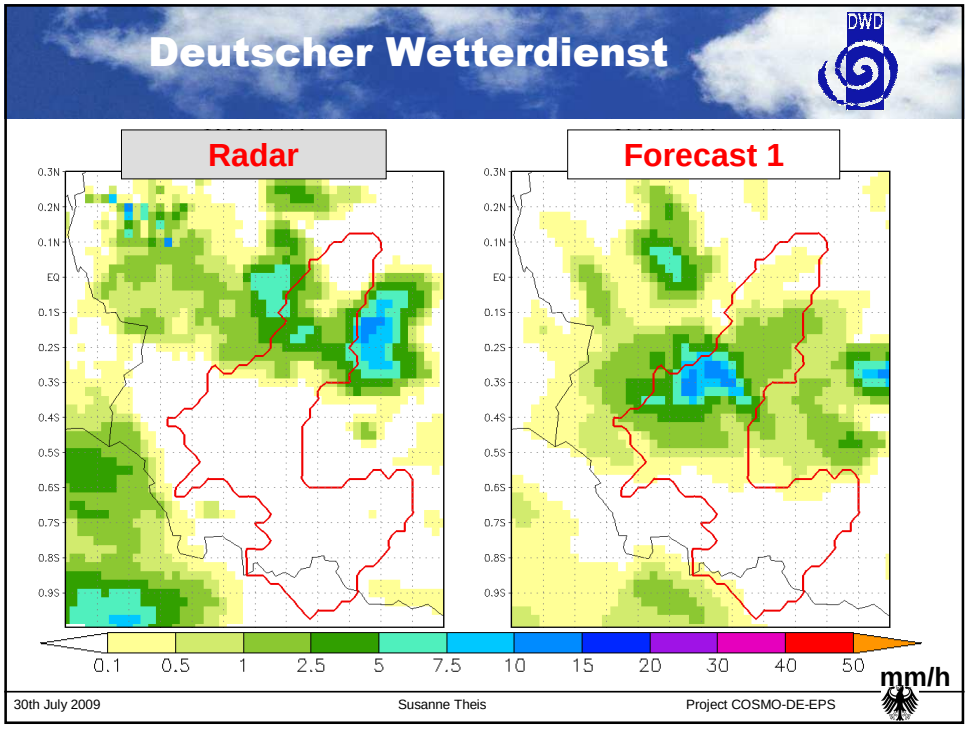
Example: tiny changes in the model → what happens?

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DWD
Radar
Forecast 1
0.3N
0.2N
0.1N
EQ
0.1S
0.2S
0.3S
0.4S
0.5S
0.6S
0.7S
0.8S
0.9S
0.1
0.5
1
2.5
5
7.5
10
15
20
30
40
50
mm/h
30th July 2009
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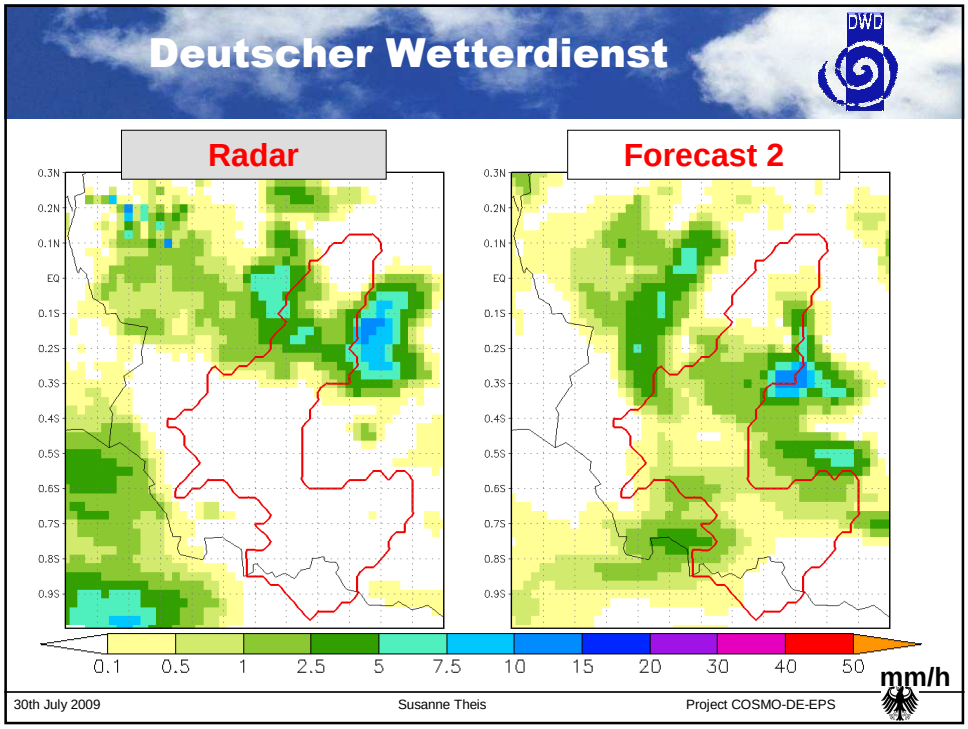
Deutscher Wetterdienst
DWD
Radar
Forecast 2
0.3N
0.2N
0.1N
EQ
0.1S
0.2S
0.3S
0.4S
0.5S
0.6S
0.7S
0.8S
0.9S
0.1
0.5
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2.5
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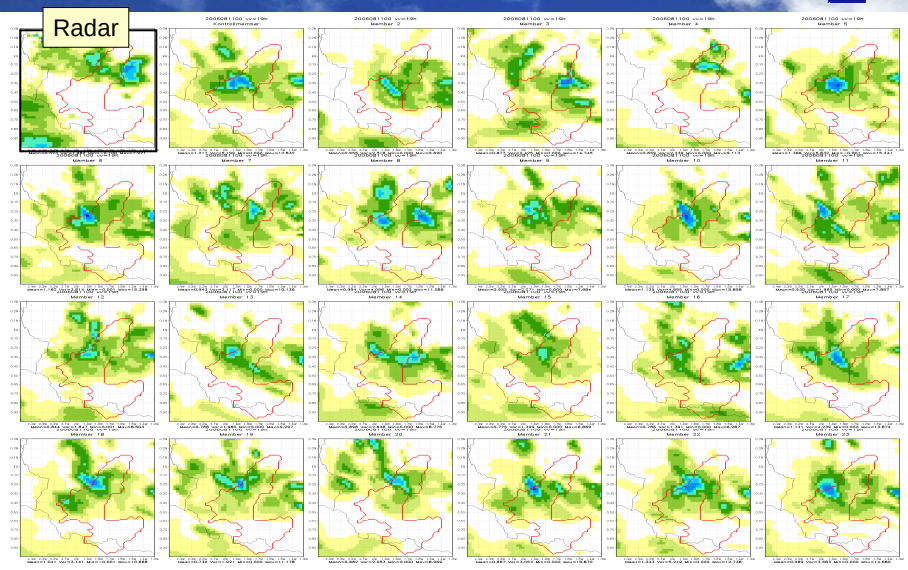

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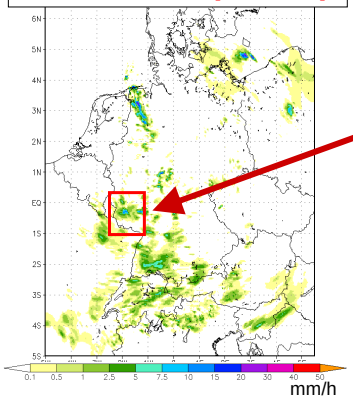
COSMO-DE (2,8 km)



Need for probabilistic approach

→ so that user really gets benefit

→ paradigm shift from deterministic to probabilistic prediction

Project COSMO-DE-EPS:
Development of a convection-allowing Ensemble Prediction System

Aims, Tasks, Scientists

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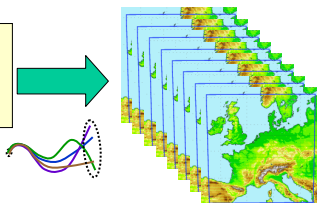
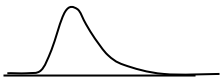
Setting up an Ensemble System

„variations“ in prediction system



several predictions
= „members“ of ensemble



ensemble products:

- probability density fct
- exceedance probs
- quantiles
- „spread“
- mean
- ...

→ *tremendous investment of computing power*

Aim of the Project

- simple approach leading to acceptable results
  (→ “good” probabilistic forecasts)

- technically fast & stable

- reach users

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Aim of the Project

How many ensemble members?

20 members, pre-operational

40 members, operational

When?

2010 pre-operational

2011 operational

Where the project starts from:

- **international state of the art**
  in convection-permitting EPS:
  some experiments, none with operational perspective

- **ensemble experience at DWD:**
  first “in-house” ensemble system

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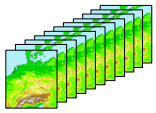
Who?

7 scientists:

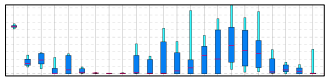
Michael Buchhold	permanent
Christoph Gebhardt	
Susanne Theis	
Zied Ben Bouallègue	time contracts
Roland Ohl	
Marcus Paulat	
Carlos Peralta	

Tasks within Project

- implementation of perturbations



- post-processing
- verification & diagnostics
- visualization
- early user feedback



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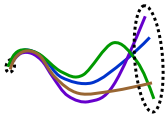
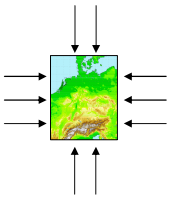
Implementation of Perturbations

Implementation of Perturbations



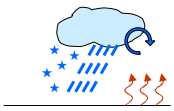
X



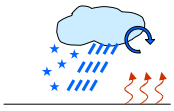
X

initial conditions boundary conditions model physics

Perturbation of the Model

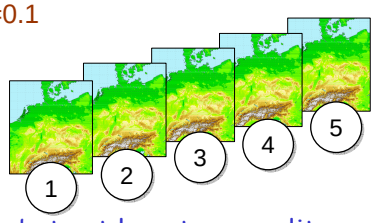


Perturbation of the Model



Alter parameters in physics parametrizations

1. entr_sc=0.0003 → entrain_sc=0.002
2. rlam_heat=1. → rlam_heat=10.
3. rlam_heat=1. → rlam_heat=0.1
4. …q_crit…
5. …tur_len…



requires careful tuning → affect forecast, but not long-term quality

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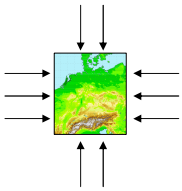
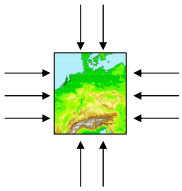
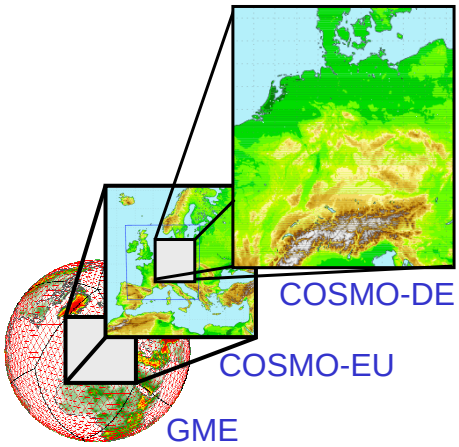
Perturbation of Boundary Conditions



Perturbation of Boundary Conditions

Reminder: operational chain





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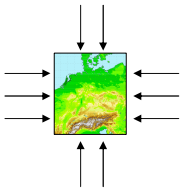
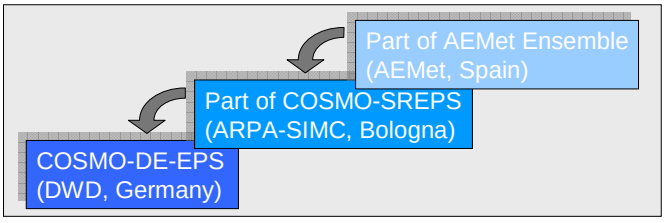
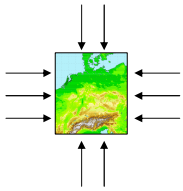
Perturbation of Boundary Conditions

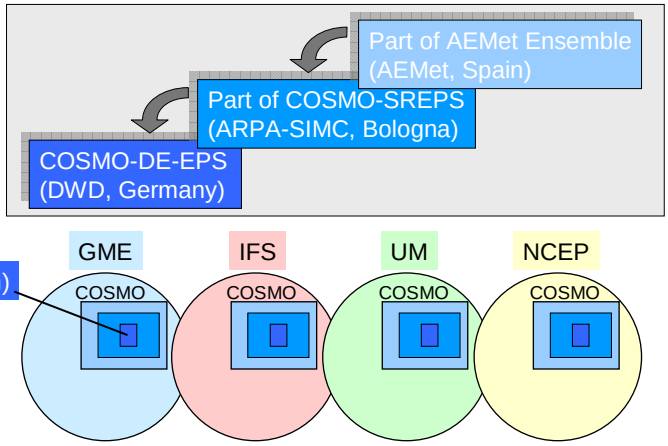




(Garcia-Moya et al., 2007)
(Marsigli et al., 2008)
(Gebhardt et al. 2009)

Perturbation of Boundary Conditions





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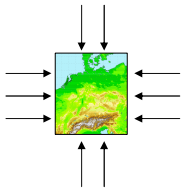
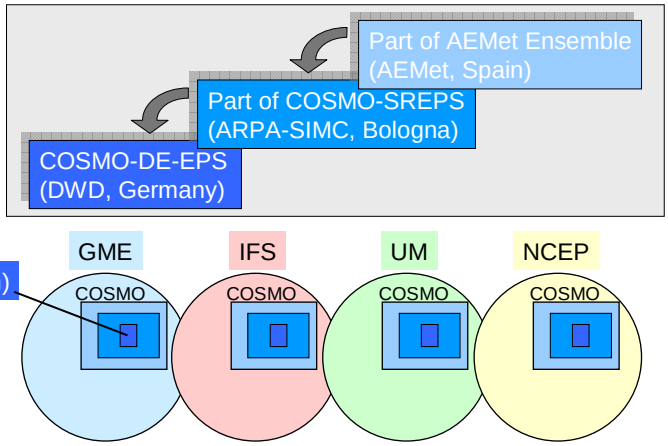
Perturbation of Boundary Conditions



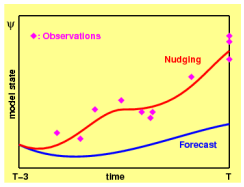


long-term Plan: take boundaries from ICON Ensemble

Perturbation of Initial Conditions

- first experiments:

  perturb “nudging” at forecast start



- **current work:**

  use differences between control and COSMO-SREPS

- plans:

  Ensemble Transform Kalman Filter (COSMO project KENDA)

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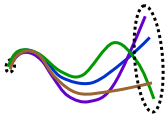
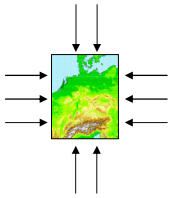
Current Experiments

- experimental set-up
- examples

Current Status



x



x

initial conditions | boundary conditions | model physics

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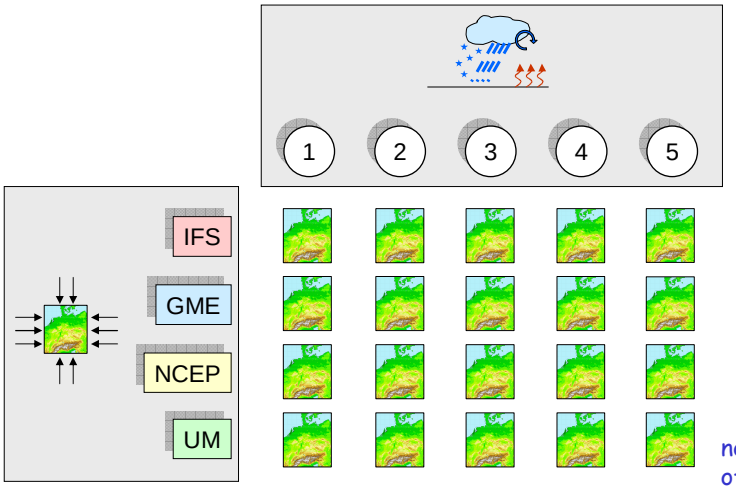
Current Experiments



no perturbation
of initial conditions

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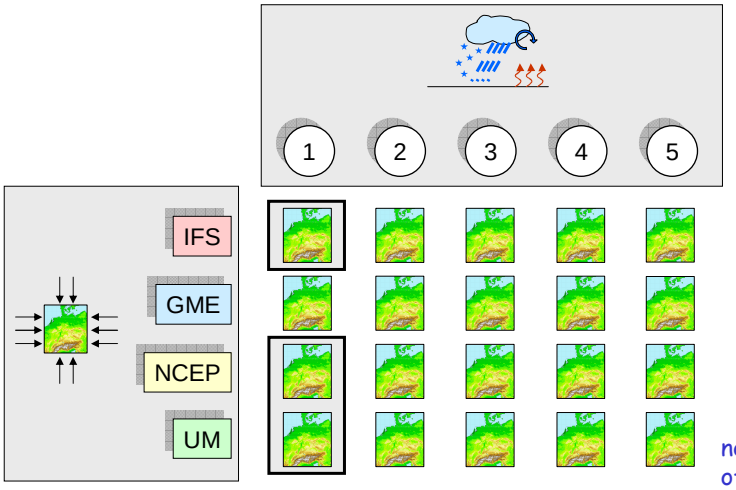
Current Experiments



no perturbation
of initial conditions

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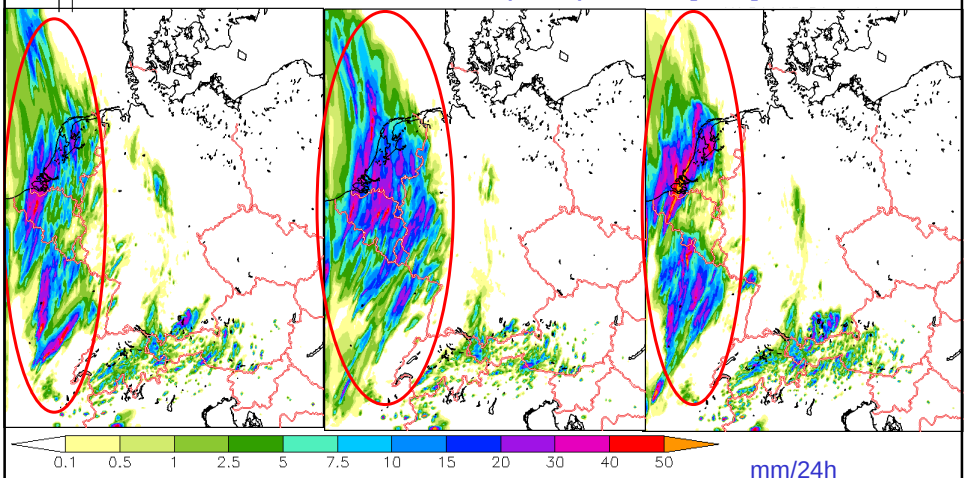
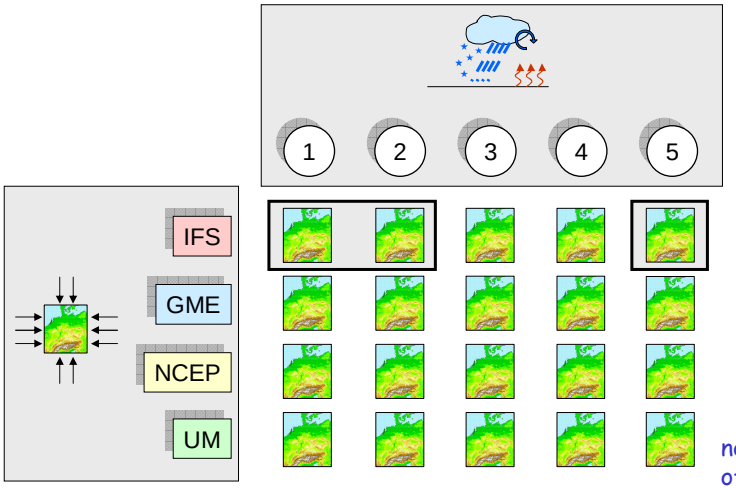
2 July 2007, 00 UTC + 24h

24h accumulations of precipitation [mm]



Current Experiments



no perturbation
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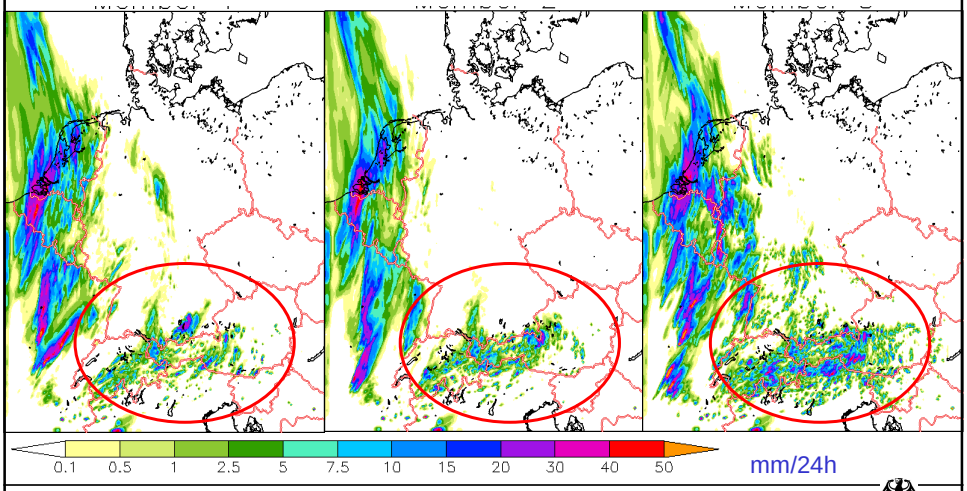

Ensemble Diagnostics

- how do perturbations affect the forecast?

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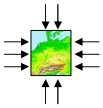
Effect of perturbations on precipitation



boundaries:

dominate after a few hours

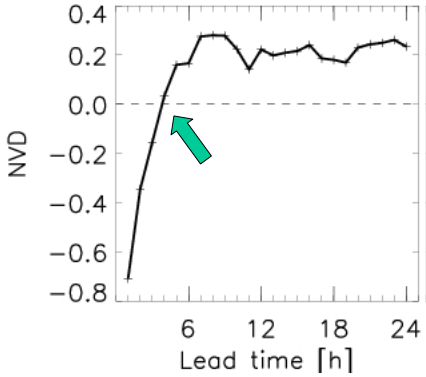
(not necessarily, also case-dependent)

physics:

dominate during first few hours

(Gebhardt et al., 2009)

Ensemble Dispersion (precipitation)



Normalized
Variance Difference

= variance (BC only)
- variance (PHY only)

normalized by
sum of variances

(Gebhardt et al., 2009)

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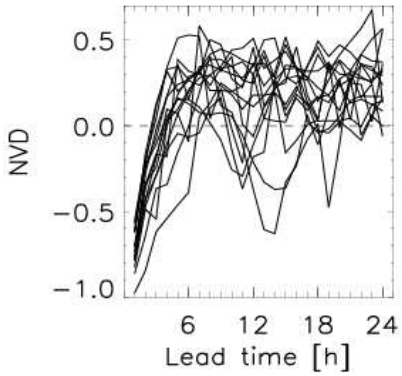
Ensemble Dispersion (precipitation)



for individual days

Normalized
Variance Difference

= variance (BC only)
- variance (PHY only)

normalized by
sum of variances

(Gebhardt et al., 2009)

Ensemble Verification

- how good is the Ensemble (at this stage)?

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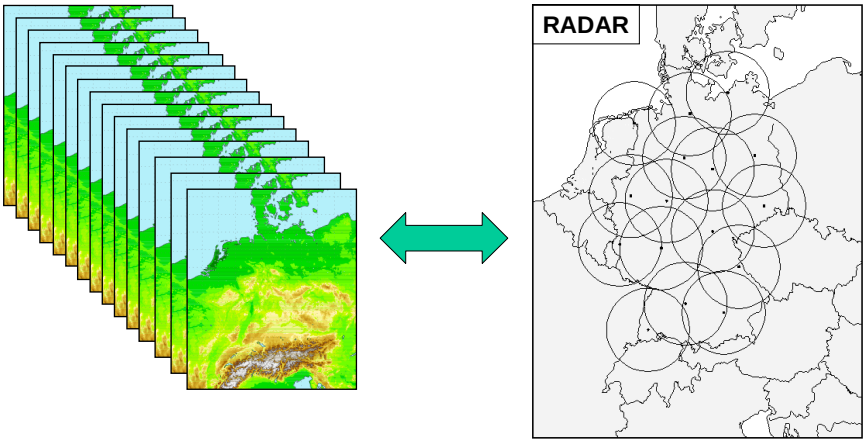
Verification Data Sets



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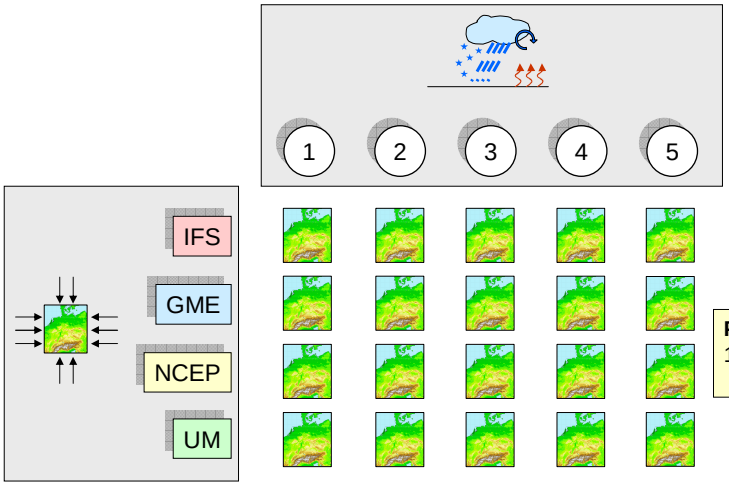
Verification Data Sets (Ensemble Forecasts)



Period:
1 July – 16 Sep 2008

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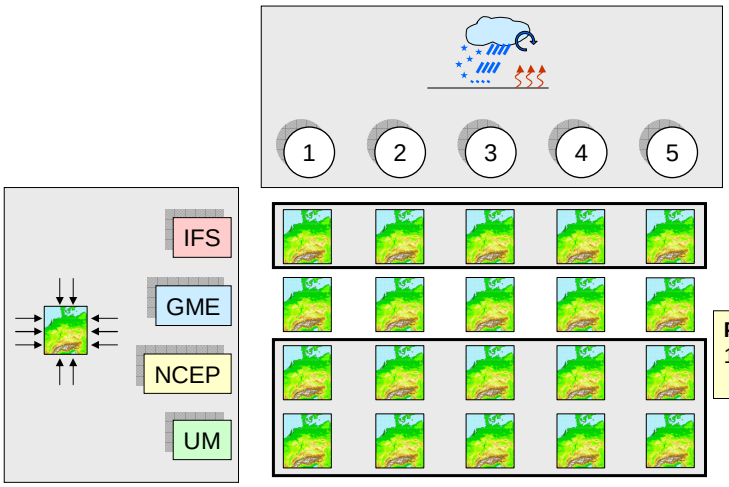
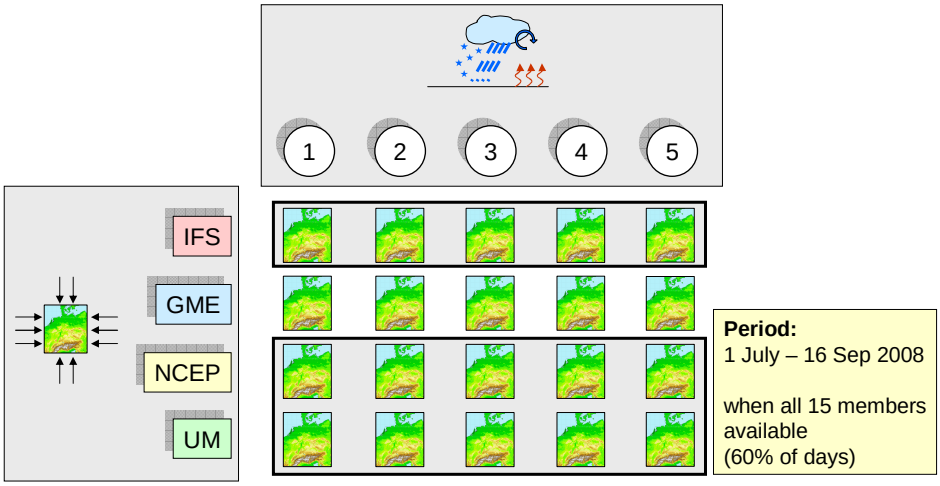
Verification Data Sets (Ensemble Forecasts)



Period:
1 July – 16 Sep 2008

Verification Data Sets (Ensemble Forecasts)



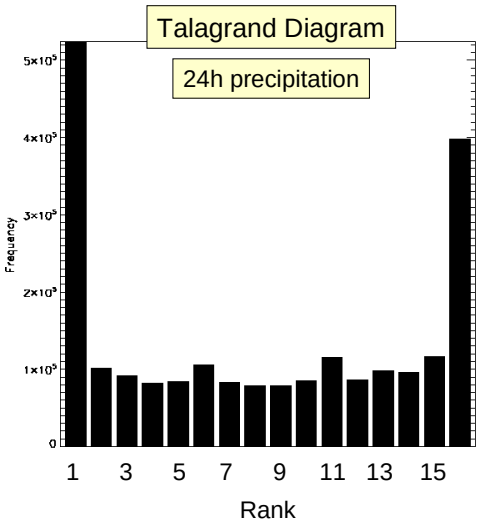
Period:
1 July – 16 Sep 2008

when all 15 members available
(60% of days)

Probabilistic Verification Measures

Traditional:

- Brier Score, Brier Skill Score
- ROC curve
- Reliability Diagram
- Talagrand Diagram



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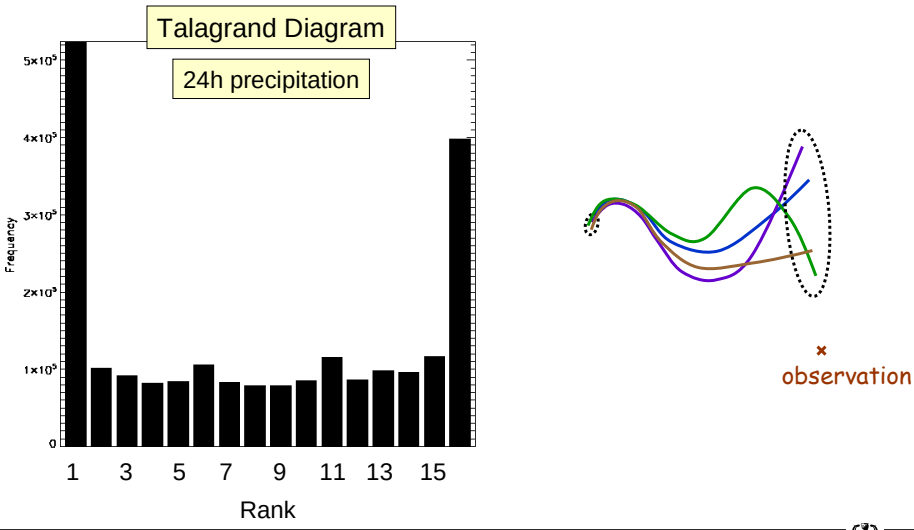

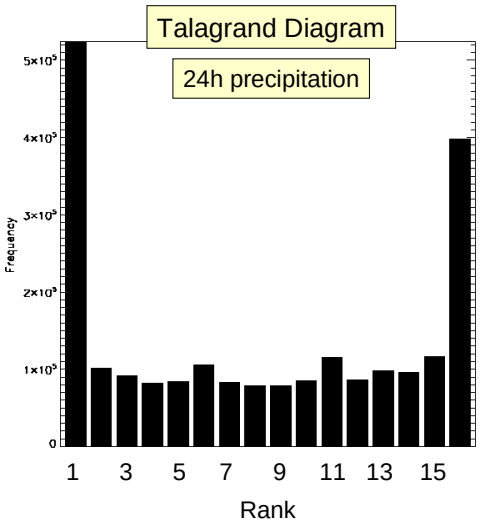

- **underdispersive !**
- add IC perturbations and statistical PP !
- also look into more spread measures

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Future Plan:

Statistical Postprocessing

Statistical Postprocessing (just starting)

Aim:

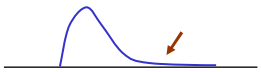
improve quality of ensemble products

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

Focus:

Precipitation

1. exceedance probabilities (“30% probability of heavy rain”)
2. entire pdf, extremes?



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Statistical Postprocessing (just starting)

Envisaged Methods:

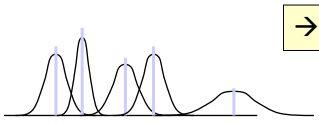
1. Logistic Regression calibration of probabilities

+ spatio-temporal neighbourhood
+ lagged average ensemble

enhance sample

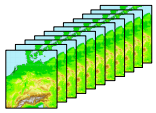
2. Bayesian Approach → entire pdf

cooperation with P.Friederichs



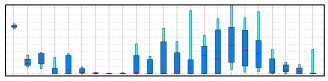
As a Reminder: Tasks within Project

- implementation of perturbations



- post-processing
- verification & diagnostics

- visualization
- early user feedback



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„Side Issue“:

Technical Challenges

- **fast run-time**
  → current problems with new supercomputer

- **stable (> 99.9%)**
  → current problems with new supercomputer
  → availability of forecasts at lateral boundaries (technical & political)

- **maintenance**
  → documentation, readability, portability, simple handling, …

- **fit into existing computing environment**
  → existing scripts and structures, data base, data formats, …

- **interaction with the technical infrastructure**
  → introduce GRIB2
  → improve bandwidth for international data transfer
  → problem reports about new supercomputer

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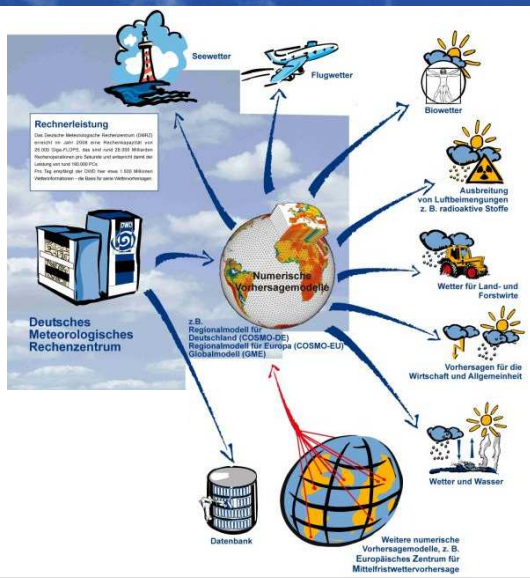
Reaching the User



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Reaching the user (= “serve mankind”)

- make ensemble forecast **accessible**
- choose a **good format** and reduce information

- work towards **acceptance**
- work towards **correct (useful) interpretation**
- work towards integration into **decision making**

- **increase trust** in forecast provider

  (by doing the “right thing” = probabilistic forecasts)

Visualization in NinJo

- make forecasts accessible
- choose formats

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Visualization in NinJo

NinJo = visualization tool for forecasters

Challenge:

- amount of data
- good communication of complex matters
- must fit into an existing system (NinJo)

1 computer scientist, 4 years (Roland Ohl)

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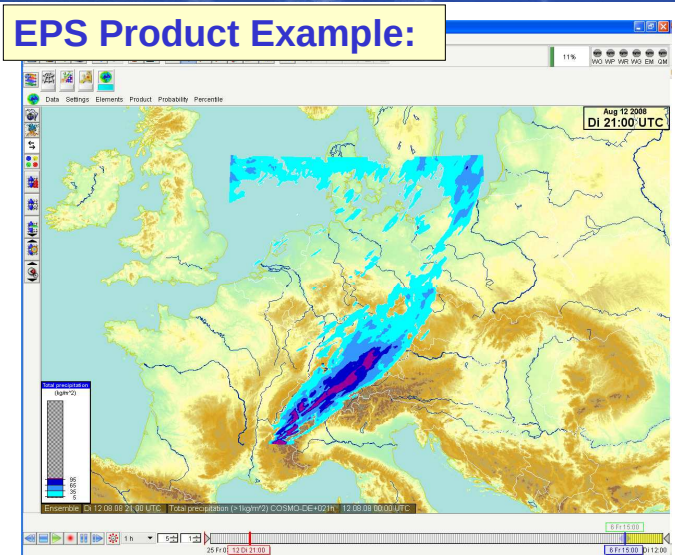
EPS Product Example:



Exceedance Probabilities in %

Probability of RR > 1 mm/h

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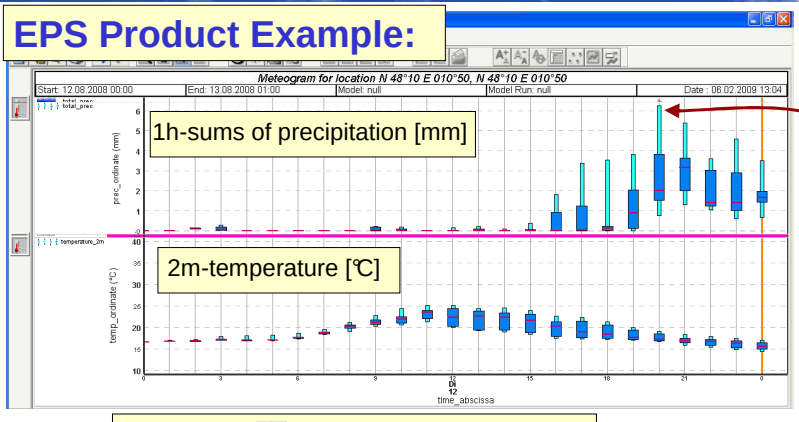
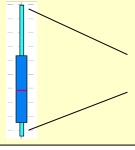
EPS Product Example:



1h-sums of precipitation [mm]

2m-temperature [℃]

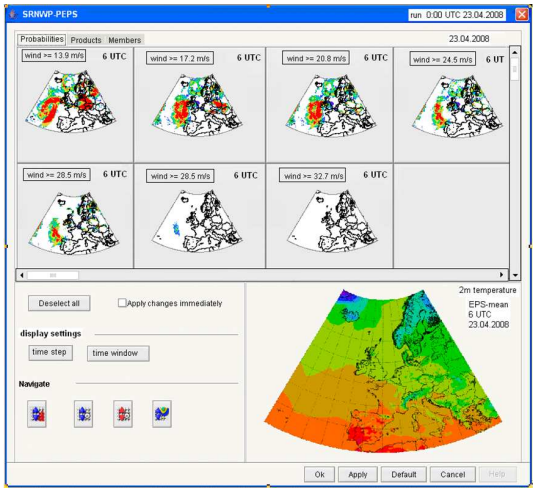
Quantiles



range of 80% probability (= uncertainty)

10% probability (= risk): interesting for some users

Further Plans: Ensemble Navigation Window (draft)



also possible to
look at individual members

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Early User Feedback

- work towards acceptance
- work towards useful interpretation

Early User Feedback

- Forecasters (DWD)

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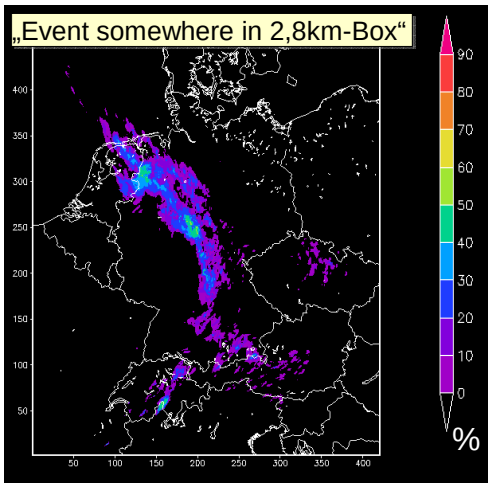
EPS Product Example: Probability Maps



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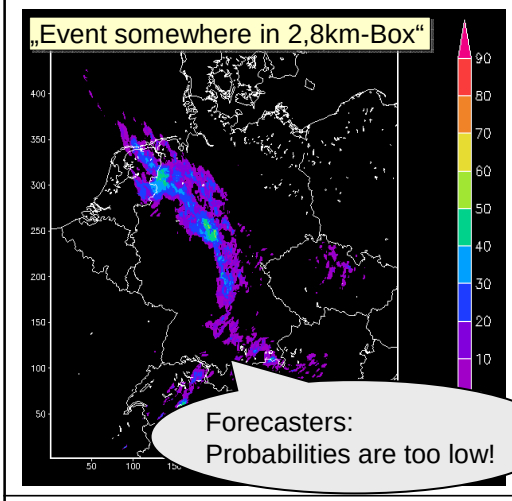
EPS Product Example: Probability Maps



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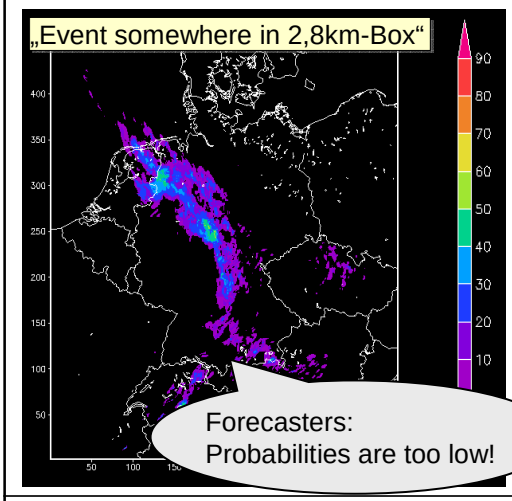


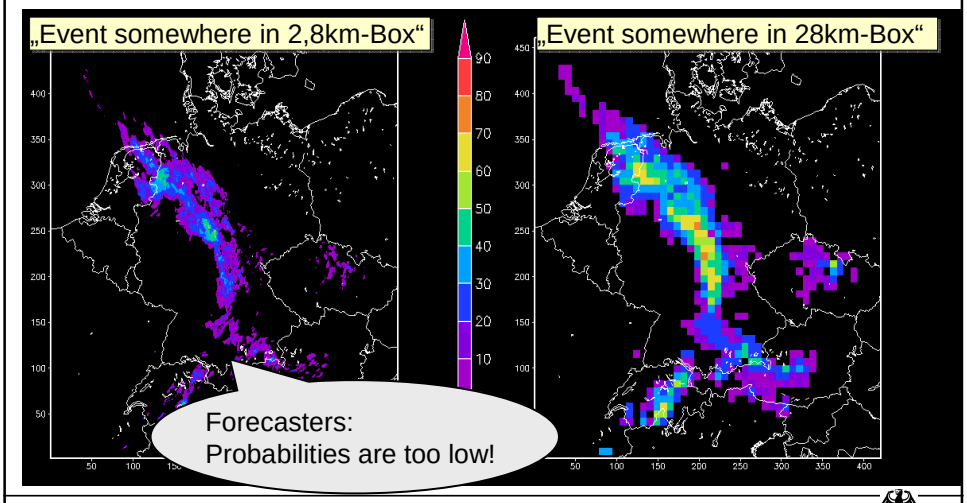
Reason:

Forecasters are used to larger reference regions

→ Experiment:

present probabilities on coarser grid

EPS Product Example: Probability Maps



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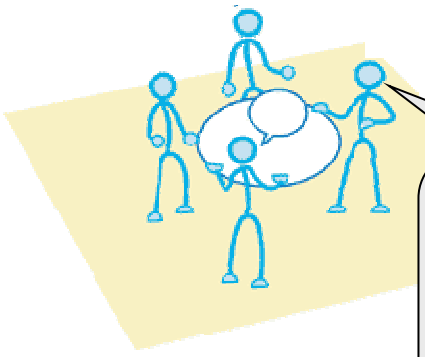
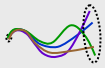
Early User Feedback

- Hydrologists

This is me, talking to some hydrologists



- atmosphere is chaotic system



- limited predictability
- specify uncertainties
- better than giving out wrong forecasts

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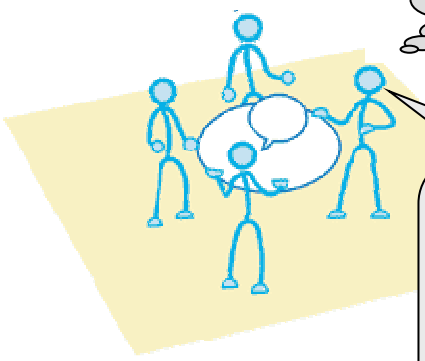
This is me, talking to some hydrologists

this will increase trust, because I am doing the right thing



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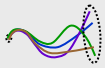

- limited predictability
- specify uncertainties
- better than giving out wrong forecasts

Deutscher Wetterdienst

Why don‘t you put all efforts into **improving your model**?

Please point out the **best member** in your ensemble!

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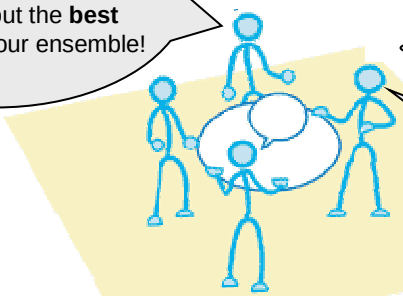
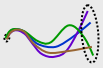


- atmosphere is chaotic system 
- limited predictability
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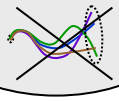
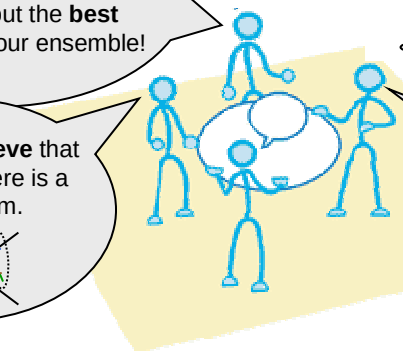
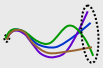
I **do not believe** that the atmosphere is a chaotic system. 



- atmosphere is chaotic system 
- limited predictability
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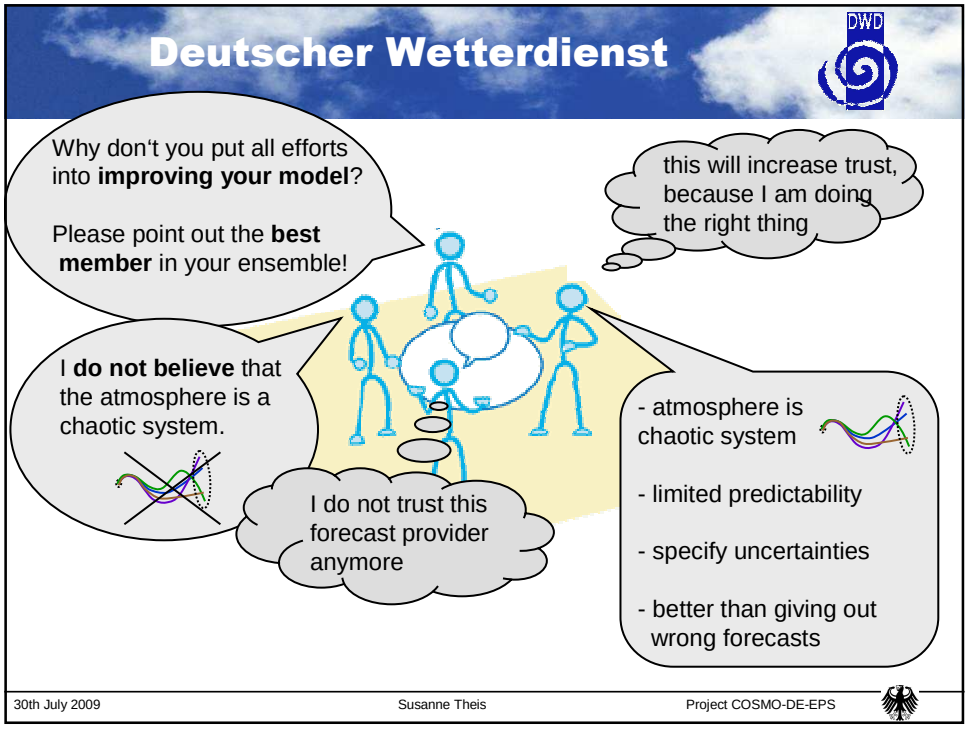
Deutscher Wetterdienst
DWD
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this will increase trust, because I am doing the right thing
I **do not believe** that the atmosphere is a chaotic system.
I do not trust this forecast provider anymore
- atmosphere is chaotic system
- limited predictability
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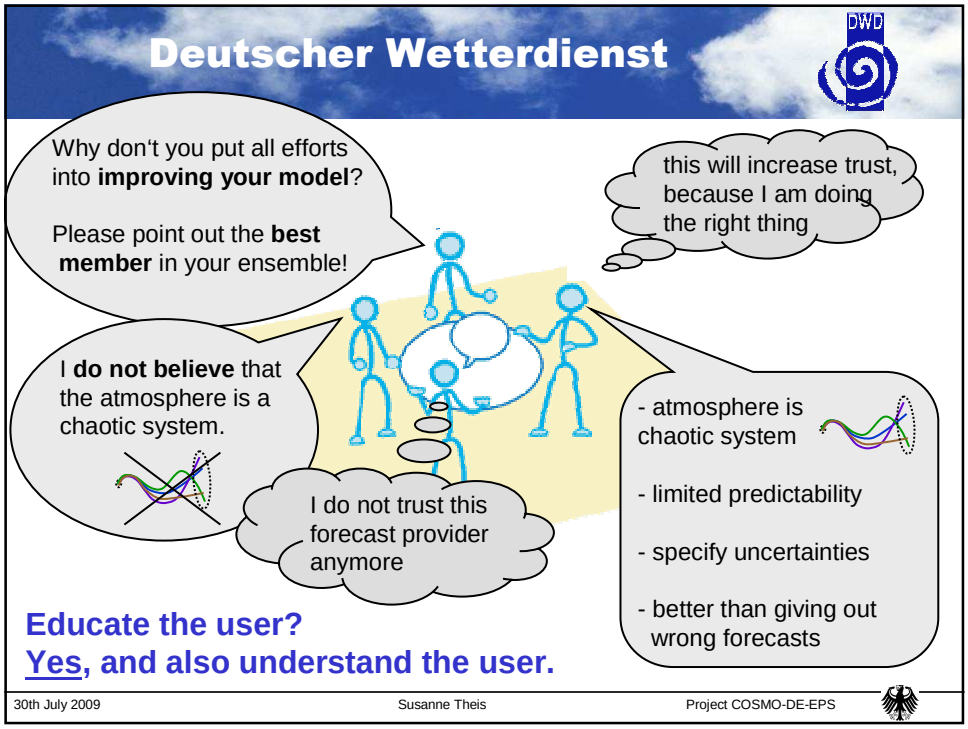
- better than giving out wrong forecasts
30th July 2009
Susanne Theis
Project COSMO-DE-EPS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I do not trust this forecast provider anymore
- atmosphere is chaotic system
- limited predictability
- specify uncertainties
- better than giving out wrong forecasts
Educate the user?
Yes, and also understand the user.
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Project COSMO-DE-EPS

Research about the Users

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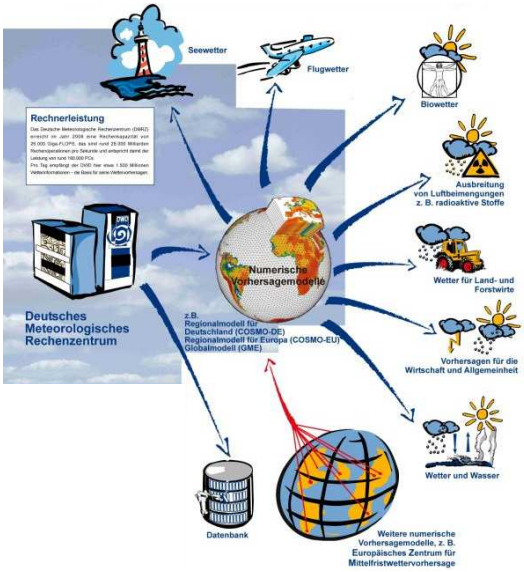

Center of Attention:
The **Model**

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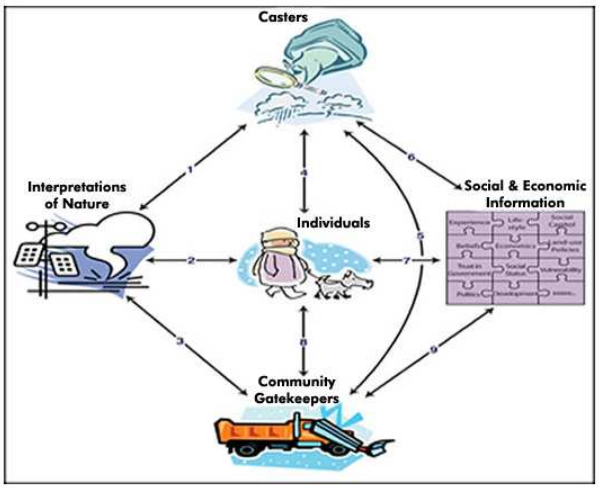

Center of Attention:
The **Human Being**

*(WAS*IS Workshop, 2005)*

Literature about perception of ensemble forecasts:

Demeritt, D., Cloke, H., Pappenberger, F., Thielen, J., Bartholmes, J. and M.-H. Ramos (2007): Ensemble predictions and perceptions of risk, uncertainty, and error in flood forecasting. Environmental Hazards 7, 115-127.

Gigerenzer, G., Hertwig, R., van den Broek, E., Fasolo, B. and K.V.Katsikopoulos (2005): „A 30% Chance of Rain Tomorrow": How does the public understand probabilistic weather forecasts? Risk Analysis 25(3), 623-629.

Joslyn, S., Pak, K., Jones, D., Pyles, J. and E. Hunt (2007): The ef…istic information on threshold forecasts. Weather and Forecasting 22, 804-812.

Morss, R.E., Demuth, J.L. and J.K. Lazo (2008): Co…certainty in Weather Forecasts: A Survey of the U.S. Public. Weather and Forecasting 23, 974-991.

Morss, R.E., Wilhelmi, V.W., Downt… Gruntfest (2005): Flood risk, uncertainty, and scientific information for decision making: Lessons from an interdi…ct. Bulletin of the American Meteorological Society 86(11), 1593-1601.

National Research Co…ompleting the Forecast: Characterizing and Communicating Uncertaintiy for Better Decisions Using Weather and Cli…ecasts. National Academies Press, 124 pp.

Roulston, M.S., Bolton, G.E., Kleit, A.N. and A.L. Sears-Collins (2006): A laboratory study of the benefits of including uncertainty information in weather forecasts. Weather and Forecasting 21, 116-122.

extremely interesting for me

Back to the Project COSMO-DE-EPS: Summary and Challenges

Deutscher Wetterdienst

Summary of Project COSMO-DE-EPS

- setting up an ensemble with a complex NWP model
- one of the first convection-permitting ensembles (with operational perspective)
- simple approach first, improve later („just do it“)
- covering all parts of forecast chain (perturbations, products, postprocessing, verification, users)

Challenges (Forecast Provider's Perspective)

- **"describe nature":**
  try to be scientifically appropriate → probabilistic approach
- **"provide forecasts":**
  technical requirements: fast, stable, maintainable
- **"serve mankind":**
  convey benefits to the real world