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

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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
Overview

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Model configuration COSMO-DE

- grid-spacing: 2.8 km → convective scale
- forecast lead time: 0-24 hours
- operational set-up
Peturbation 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

- COSMO-DE-EPS (DWD, Germany)
- Part of COSMO-SREPS (ARPA-SIM, Bologna)
- Part of AEMet Ensemble (INM, Spain)
Perturbation of boundary conditions

COSMO-DE-EPS (DWD, Germany)

Part of COSMO-SREPS (ARPA-SIM, Bologna)

Part of AEMet Ensemble (INM, Spain)

COSMO-DE (2,8km)

GME

IFS

UM

NCEP
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)
Peturbation 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
Experiments – physics and boundary perturbations

0 1 2 3 4

no perturbation of initial conditions
24h accumulations of precipitation [mm]

2 July 2007, 00 UTC + 24h

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24h accumulations of precipitation [mm]

2 July 2007, 00 UTC + 24h

boundary perturbations affect large scales
Experiments – physics and boundary perturbations

no perturbation of initial conditions
24h accumulations of precipitation [mm]

2 July 2007, 00 UTC + 24h
24h accumulations of precipitation [mm]

physics perturbations affect small scales
Experiments – physics and boundary perturbations
Experiments – physics and boundary perturbations

So far:
1 perturbed parameter per ensemble member

New:
Several perturbed parameters per ensemble member
Experiments – physics and boundary perturbations

So far:
1 perturbed parameter per ensemble member

New:
Several perturbed parameters per ensemble member
Experiments – physics and boundary perturbations

So far:
1 perturbed parameters per ensemble member

New:
Several perturbed parameters per ensemble member (seems beneficial)
Conclusions - physics and boundary perturbations

• boundaries $\rightarrow$ large 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 \(\rightarrow\) more data

• manage missing boundary conditions (technical)

• initial condition perturbations:
  promising ideas, more experiments
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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)
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Brier Skill Score (BSS)

Forecast:
Probability that 24h precipitation > threshold

Observation:
Radar Data
24h precipitation > threshold
YES/NO

Reference Forecast:
Climatology from Period

Threshold [mm/24h]
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Brier Skill Score (BSS)

**Forecast:**
Probability that 24h precipitation > threshold

**Observation:**
Radar Data
24h precipitation > threshold
YES/NO

**Reference Forecast:**
Climatology from Period
**Brier Skill Score (BSS)**

**Forecast:**
Probability that 24h precipitation > threshold

**Observation:**
Radar Data
24h precipitation > threshold YES/NO

**Reference Forecast:**
Climatology from Period

*good skill for slight precipitation*

*no skill for heavy precipitation*
Talagrand Diagram

**Forecast:**
Individual Members
24h precipitation amounts

**Observation:**
Radar Data
24h precipitation amounts
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Talagrand Diagram

Forecast:
Individual Members
24h precipitation amounts

Observation:
Radar Data
24h precipitation amounts

ensemble is underdispersive
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
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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
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Exceedance Probabilities in %

Probability of RR > 1 mm/h
1h-sums of precipitation [mm]

2m-temperature [°C]

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
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
forecast perturbations 18-24UTC precipitation, 8 Aug 2007
forecast perturbations 12 UTC 2m-temperature, 13 Aug 2007
Experiments – physics and boundary perturbations

IFS

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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

boundary perturbations dominate
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
So far:
1 perturbed parameter per ensemble member

New:
Several perturbed parameters per ensemble member

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

spread [K]

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

forecast hour

0 3 6 9 12 15 18 21

“single“

“combined“ (revised)

1-11 July 2007, 0-24 h
spread of 1h-precipitation (spatio-temporal mean)

1-11 July 2007, 0-24 h
spread of 2m-temperature (spatio-temporal mean)

1-15 July 2007, 0-24 h

"single"  "combined" (first try)
spread of 2m-temperature (spatio-temporal mean)

- Large spread due to unrealistic members??
- "single" (first try)
- "combined"
Attention: physics perturbation set-up requires careful tuning

Long-term quality check of individual ensemble members

- 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

Hit Rate vs. False Alarm Rate

Area = 0.90

"combined"

Relative Operating Characteristic

Hit Rate vs. False Alarm Rate

Area = 0.92
Verification results for 24 hours precipitation

threshold: 1mm/24h

„single“

Reliability Diagram

„combined“

Reliability Diagram
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Verification results for 24 hours precipitation

„single“
Brier (Skill) Score

„combined“
Brier (Skill) Score

Score

Threshold in mm/24h

BSS

BS

no skill
Verification results for 2m-temperature 12UTC

threshold: 25°C

ROC

Reliability

Relative Operating Characteristic

Reliability Diagram

area=0.94
Threshold: 0.1mm/24h

ROC area = 0.90
Threshold: 10mm/24h

ROC area = 0.85
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
   
   + spatio-temporal neighbourhood
   + lagged average ensemble

2. Bayesian Model Averaging
   
   cooperation with Univ. Bonn

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calibration of probabilities

 enhancement sample

→ entire pdf