Limited-area ensembles:
finer grids & shorter lead times

Susanne Theis
COSMO-DE-EPS project leader
Deutscher Wetterdienst
Thank You

Neill Bowler et al. (UK Met Office)
Andras Horányi et al. (Hungarian Meteorological Service)
Trond Iversen and Jørn Kristiansen (Norwegian Meteorological Institute)
Chiara Marsigli and Tiziana Paccagnella (ARPA SIMC)
Olivier Nuissier et al. (Meteo France)
Axel Seifert (Deutscher Wetterdienst)
Presentation Overview

⇒ introduction to limited-area ensembles

⇒ finer grids – what do they promise?

⇒ predictability issues

⇒ constructing limited-area ensembles

⇒ probability maps – aim at finest grid?
Introduction to
Limited-Area Ensembles
Limited-area ensembles

- computing resources are limited

- compromise between
  grid size / number of members / model complexity
  etc
Limited-area ensembles

- computing resources are limited

- compromise between grid size / number of members / model complexity etc.
Limited-area ensembles

- driven by members of global ensemble
- „dynamical downscaling ensemble“
- plus other perturbations
- today in Europe:
  more than 10 different ensemble systems

(Marsigli et al. 2005, Frogner et al. 2006, Bowler et al. 2008, etc)
Limited-area ensembles in Europe („large“ domains)

<table>
<thead>
<tr>
<th>system</th>
<th>grid size</th>
<th>lead time</th>
<th>father EPS (global)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOGREPS-R</td>
<td>18 km</td>
<td>2.25 days</td>
<td>MOGREPS-G</td>
</tr>
<tr>
<td>COSMO-LEPS *</td>
<td>7 km</td>
<td>5.5 days</td>
<td>ECMWF EPS selection</td>
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<td>GLAMEPS</td>
<td>13 km</td>
<td>1.75 days</td>
<td>ECMWF EPS (v0: EuroTEPS)</td>
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<td>LAMEPS #</td>
<td>12 km</td>
<td>2.5 days</td>
<td>ECMWF / EuroTEPS</td>
</tr>
<tr>
<td>ALADIN-HUNEPS *</td>
<td>12 km</td>
<td>2.5 days</td>
<td>PEARP</td>
</tr>
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<tr>
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<td>7 km</td>
<td>2 days</td>
<td>multi-model</td>
</tr>
<tr>
<td>AEMET-SREPS</td>
<td>0.25°</td>
<td>3 days</td>
<td>multi-model</td>
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<tr>
<td>+ SRNWP-PEPS</td>
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Limited-area ensembles in Europe („small“ domains)

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<th>lead time</th>
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<tr>
<td>MOGREPS-UK</td>
<td>2.2 km</td>
<td>yes</td>
<td>1.5 days</td>
<td>development</td>
</tr>
<tr>
<td>AROME-EPS</td>
<td>2.5 km</td>
<td>yes</td>
<td>1.5 days</td>
<td>development</td>
</tr>
<tr>
<td>COSMO-DE-EPS</td>
<td>2.8 km</td>
<td>yes</td>
<td>21 hours</td>
<td>running</td>
</tr>
<tr>
<td>DMI-EPS</td>
<td>0.05°</td>
<td>no</td>
<td>1.5 days</td>
<td>running</td>
</tr>
<tr>
<td>UMEPS</td>
<td>4km</td>
<td>no</td>
<td></td>
<td>research</td>
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Limited-area ensembles in Europe („small“ domains)

MOGREPS-UK

COSMO-DE-EPS

AROME-EPS
- HyMeX campaign
- future operational

rough projection
Finer Grids

- what do they promise?
Finer Grids

- what do they promise?

Examples from ALADIN-HUNEPS, COSMO-LEPS, UMEPS
Benefit shown by verification (ALADIN-HUNEPS)


Figure 5 (right)

Latest developments around the ALADIN operational short-range ensemble prediction system im Hungary

grid size: 12 km
Benefit shown by verification (ALADIN-HUNEPS)

Horányi et al. (2011),
Tellus 63A: 642-651.
DOI: 10.1111/j.1600-0870.2011.00518.x
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Latest developments around the ALADIN operational short-range ensemble prediction system in Hungary

grid size: 12 km

schematic reproduction of some features in original figure
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Benefit shown by verification (ALADIN-HUNEPS)

"At 2m (...) ALADIN HUNEPS limited area ensemble significantly improves in quality with decreasing values of RMSE (this being due to the higher resolution limited area model and with a better description of the corresponding surface)."


Figure 5 (right)

Latest developments around the ALADIN operational short-range ensemble prediction system im Hungary

grid size: 12 km
Figure 5 (right) Latest developments around the ALADIN operational short-range ensemble prediction system in Hungary

Benefit shown by verification (ALADIN-HUNEPS)

- 2m-temperature, RMSE of ens.mean
- Temperature °C
- Grid size: 12 km

Benefit: near-surface variables

Benefit shown by verification (COSMO-LEPS)

Marsigli et al. (2008), Meteorol. Appl. 15: 125-143. DOI: 10.1002/met.65 Figure 7(e)

A spatial verification method applied to the evaluation of high-resolution ensemble forecasts

grid size: 10 km
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A spatial verification method applied to the evaluation of high-resolution ensemble forecasts

verification of precipitation

roc area

limited-area

grid size: 10 km

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Benefit shown by verification (COSMO-LEPS)

Marsigli et al. (2008), Meteorol. Appl. 15: 125-143. DOI: 10.1002/met.65 Figure 7(e)

A spatial verification method applied to the evaluation of high-resolution ensemble forecasts

„COSMO-LEPS has the skill in forecasting the occurrence of precipitation peaks over an area, irrespective of the exact location.“
Benefit shown by verification (COSMO-LEPS)

Marsigli et al. (2008), Meteorol. Appl. 15: 125-143.
DOI: 10.1002/met.65
Figure 7(e)

A spatial verification method applied to the evaluation of high-resolution ensemble forecasts

Benefit: precipitation peaks
The „Polar Low Example“ (UMEPS)

Kristiansen et al. (2011),
Tellus 63A: 585-604.
DOI: 10.1111/j.1600-0870.2010.00498.x
Figure 7 (c) (d)

High-resolution ensemble prediction of a polar low development

grid size: 4 km
The „Polar Low Example“ (UMEPS)

About polar lows:

- frequently accompanied by severe weather
- moist convective processes are important
- prediction of polar lows often fails
- example indicates added value of a high-resolution ensemble

Kristiansen et al. (2011), Tellus 63A: 585-604. DOI: 10.1111/j.1600-0870.2010.00498.x

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High-resolution ensemble prediction of a polar low development

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Probability [%] of wind speed > 25 m/s

LAMEPS

grid size: 12 km

UMEPS

grid size: 4 km

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High-resolution ensemble prediction of a polar low development

Benefit:
improved representation of processes leading to severe weather
Benefit of ensembles with finer grids

- improved representation of **atmospheric processes**: subsynoptic, mesoscale, convective

- improved forecasts of **near-surface variables**: precipitation, 2m-temperature, wind gusts

- improved forecasts of **severe weather**

*(Horanyi et al. 2011) (Iversen et al. 2011) (Marsigli et al. 2008) (Bowler et al. 2008) etc*
Entering Key Applications

- probabilistic forecasts of **severe weather**, near-surface variables, for short lead times:
  - weather warnings
  - flood warnings
  - aviation
  - wind energy
  - etc
Predictability Issues
Predictability Issues

General Remarks

„Supercell Example“ by COSMO-DE-EPS
Finer Grids – gain in predictability?
Finer Grids – gain in predictability?

→ not necessarily!
scale diagram

predictability

characteristic time scale

characteristic length scale

1 week
1 hour
100 m 10 km 1000 km

synoptic
convective

lead time
Uncertainties in small scales grow faster \((\text{Lorenz 1969})\)
Finer Grids – gain in predictability?

- **smaller scales** usually possess shorter life cycles, **faster error growth**, shorter predictability limits

- high-resolution model simulations are expected to contain a **larger degree of randomness**

- this **can offset the benefits** due to a smaller model grid box size if forecast uncertainties are not addressed explicitly *(e.g. Mass et al. 2002)*
Finer Grids – gain in predictability?

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Forecasts must be addressed in a probabilistic framework
The „Supercell Example“ (COSMO-DE-EPS)

by
Axel Seifert

with Thomas Hanisch,
Christoph Gebhardt,
Zied Ben Bouallègue,
Michael Buchhold

Deutscher Wetterdienst
The „Supercell Example“ (COSMO-DE-EPS)

- 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 Bouallègue, Michael Buchhold

Deutscher Wetterdienst
The „Supercell Example“ (COSMO-DE-EPS)

F2 tornado near “Plate” close to the Baltic coast
16:20 UTC

by
Axel Seifert

Deutscher Wetterdienst
The „Supercell Example“ (COSMO-DE-EPS)

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

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The “Supercell Example“ (COSMO-DE-EPS)

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The „Supercell Example“ (COSMO-DE-EPS)

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

20 scenarios of ‘SDI events’

ensemble provides 20 scenarios

20090521, init 00 UTC, valid 15 - 17 UTC

with ensemble (2.8 km)

by
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Deutscher Wetterdienst
The „Supercell Example“ (COSMO-DE-EPS)

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

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The „Supercell Example“ (COSMO-DE-EPS)

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 accounts for limited predictability and derives useful guidance.
Constructing limited-area ensembles
- same as global?
Finer grids: revision of ensemble techniques

- focus on **short lead times**
- account for **uncertainties coming from the driving model**
- introduce **uncertainties in the relevant scales and processes**
- some techniques are **not applicable anymore**
- high demand of computing resources
Finer grids: revision of ensemble techniques

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*new scientific challenges*
Probability maps: aim at finest grid?
Probability maps: aim at finest grid?

forecast provider  user
Probability maps: aim at finest grid?

- convection-permitting ensembles have a grid size of 1-3 km

- we can produce probability maps for this grid size
Probability maps: aim at finest grid?

Example: 15 May 2011 12 UTC

RADAR observation
Probability maps: aim at finest grid?

Forecast:
Probability of precipitation
11-12 UTC

derived from COSMO-DE-EPS 2.8 km
Probability maps: aim at finest grid?

Forecast:
Probability of precipitation
11-12 UTC

on the same grid as the model:
2.8 km

derived from COSMO-DE-EPS 2.8 km
Probability maps: aim at finest grid?

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Probability maps: aim at finest grid?

**Forecast:**
Probability of precipitation
11-12 UTC

on a larger grid than the model: 28 km

-derived from COSMO-DE-EPS 2.8 km
Probability maps: aim at finest grid?

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Probability maps: aim at finest grid?

→ think about scale of interest

→ “alert areas”

COSMO-DE-EPS example by DWD
S. Theis, C. Gebhardt, Z. Ben Bouallègue, M. Buchhold
Probability maps: aim at finest grid?

- think about scale of interest

- “alert areas”

  e.g. UK Met Office: MOGREPS-W

  derives area warnings from MOGREPS-R (18 km)
Probability maps: aim at finest grid?

- think about scale of interest

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  e.g. UK Met Office: MOGREPS-W

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*COSMO-DE-EPS example by DWD*

S. Theis, C. Gebhardt, Z. Ben Bouallègue, M. Buchhold

End product not necessarily on finest grid

Beneficial if underlying ensemble is on finest grid
Probability maps: aim at finest grid?

- users must know and understand the reference area of probabilities

*COSMO-DE-EPS example by DWD*
S. Theis, C. Gebhardt, Z. Ben Bouallègue, M. Buchhold
Probability maps: aim at finest grid?

- users must know and understand the reference area of probabilities

(Epstein, 1966)
(Murphy, 1980)
and (Gigerenzer et al., 2005)

…“reference class”

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…“reference class”

Users (and providers) must achieve “risk literacy”
Summary

- **ensembles are going to finer grids**
  - improved representation of atmospheric processes,
    improved forecasts of near-surface weather, severe weather
  - even less deterministic predictability → increased need for ensembles
  - new challenges for ensemble techniques

- **implication for ensemble applications**
  - entering key applications
  - end products on scale of interest, not necessarily on finest grid
  - „risk literacy“ is essential