Storm-permitting ensembles

Nigel Roberts, Giovanni Leoncini, Changui Wang, Emilie Carter and Humphrey Lean

Met Office @ Reading
Getting the forecast right

Bournemouth angry over wrong Bank Holiday weather forecast

A resident in Bournemouth was angry over the weather forecast for the Bank Holiday weekend. The forecast predicted sunny weather, but actually it was grey and wet.

The Met Office apologised for the inaccuracy, saying it was a one-off error. However, some residents in Bournemouth were not so forgiving, calling it a "disaster for planning summer activities."
Questions being asked

What is the nature of predictability and realism of convection in ‘storm-permitting’ models?

More resolution or a bigger ensemble?

How small an ensemble is sufficient?
Does higher resolution give more skilful forecasts?

Apparently not! Has it all been a waste of time?

April to Oct 2010
Equitable Threat Score (ETS)
Using gauges

M Mittermaier, N Roberts & S Thompson
submitted to Met Apps
Skill depends on the scale you look at

All hourly accumulation curves, threshold top 10%

Fractions skill score

Spatial scale (km)

1 km
We shouldn’t believe high-resolution at face value (at or near the grid scale)

Distribution of instability well predicted at larger scale

‘Unreliable’ Scale

Individual cell Locations ‘random’

Rainfall Probability

Courtesy of Peter Clark
Multi-resolution storm-permitting simulations

Emilie Carter
and
Humphrey Lean

Improvements and difficulties with increased resolution

500m at least 45 times more expensive than 1.5km. (200 times 2.2km)
100m ~25,000 times 2.2km

... very high-resolution model research still essential
We shouldn’t believe high-resolution at face value

What if distribution of instability is NOT well predicted at larger scale
2.2 km ensemble from summer 2012 (MOGREPS-UK) embedded within either MOGREPS-R (EU) (12 km) or MOGREPS-G (~30 km) ensemble.

36-hour forecasts

~12 members

New ensemble every 6 hours

Downscaling – starts from coarser-resolution fields

Neighbourhood products
Forecast variability
3rd August 2004

radar

12km from 09UTC 03

1km from 09UTC 03

T+ 4 to 9

T+ 19 to 24

Nigel Roberts
3rd August 2004
Importance of mesoscale dynamics

Water vapour imagery

16 UTC
3rd August 2004
Comparison of mesoscale dynamics

Upper-level vortex
Results: Different physics

Seonaid Dey and Giovanni Leoncini

FSS for precipitation hourly accumulations

FSS

- Values 0-1
- 1 = ‘perfect match’
- 0 = ‘totally different’
- Contours every 0.1, colours black at 0.0 to red at 1.0
- Graupel / convection scheme / timestep had little effect at reliable scales
Highest 6-hour totals

MOGREPS output  00 UTC 30/10/08  (top)
UKV 6-hour accumulations                  (bottom)

Computed on 4.5km grid – Changgui Wang

© Crown copyright   Met Office
All pixels exceeding critical thresholds

‘Extreme’ threshold for surface water flooding

1 in 30 years

1 in 10 years

40 mm in 6 hours

50 mm in 6 hours

Computed on 4.5km grid – Changgui Wang
Consequence of uncertainty in forecasting local weather (e.g. pdf for showers)

If a 5km storm can occur anywhere within 50km radius. Assuming discrete non-overlapping positions and only considering positional uncertainty:

Require at least 300 members. In reality 1000s for postcode probabilities.

But we don’t need an ensemble to produce a probability forecast

Nearby grid squares provide plausible alternative scenarios – and can therefore be treated as ensemble members

The so called ‘neighbourhood’ approach can be combined with an ensemble. (Theis et al 2005, UKMO, Schwartz et al 2009,2010)

How many members do we need now?
Comparison of ensemble sizes

- FSS adaptive
- 99.5th percentile

- RMS difference
  Odds
- 99.5th percentile

Number of members vs. FSS and RMS difference.
Comparison of ensemble sizes and resolution

Graphs showing the relationship between number of members and FSS (left) and RMS difference (right) for 1.5 km and 2.2 km resolution.
Storm-permitting ensemble - findings

High resolution crucial for predicting high-impact local weather
Important to represent mesoscale uncertainty (larger-scale flow)
Neighbourhood processing can effectively increase ensemble size and represent small-scale uncertainty
Neighbourhood processing can adapt to ensemble spread and scales of uncertainty
Ensemble size – a small ensemble can do a reasonable job if processed intelligently
Model resolution – 12-member 2.2 km ensemble is comparable or better than 6-member 1.5 km ensemble (except perhaps for most extreme situations)
Beware – resolution dependence can be crucial in some situations.
Need to understand biases. Incorporate physics uncertainties.
Thanks for listening.