The changing character of rainfall at convection permitting scales

Lizzie Kendon

Thanks to: Nigel Roberts and Steven Chan
Benefits of high resolution in NWP

- Use of ‘convection-permitting’ models is now common practice in numerical weather prediction (NWP)

- Explicitly represented convection
  - Diurnal cycle, showers coming inland, organisation, convective outflows, back-building, realistic rates

- Better local topography
  - Sea breeze convergence, elevated heating, valley cooling, localised fog, orographic enhancement of rain, peninsular shower bands

Improved representation of convective storms in 1.5km forecast model

5-hour rainfall accumulations for (a) radar, (b) 1.5km forecast model, (c) 12km forecast model

Case study: 27th July 2013; Courtesy: Nigel Roberts
Improved representation of orographic rain at kilometre-scale

Rain gauge observations and model forecasts

Model orography

Case study: Carlisle flood, Jan 2005
First regional climate simulations at 1.5km resolution over UK

1) First climate simulations at convection permitting scales run over *southern UK*, as part of CONVEX project.

- Driven by 12km European RCM, which is in turn driven by ERA-interim or 60km GCM.
- Runs completed:
  - Reanalysis driven run (1989-2008)
  - 13y control (1996-2009) and future (~2100) climate change experiments

2) Climate simulations, with identical set up, now complete for *northern UK*, as part of NUTCAT project
Daily precipitation (1990-2004)

Obs
- Rain gauge
- 1.5km-gauge
- 12km-gauge

Bias
- Rain gauge
- 1.5km-gauge
- 12km-gauge

Mean precip

Dry day occurrence

Heavy precip
Future changes in heavy rainfall at hourly timescale

**Observations**

**Model bias**

**Future change**

Winter

12km model – radar

12km future change

1.5km model – radar

1.5km future change

Summer

12km model – radar

12km future change

1.5km model - radar

1.5km future change
Duration-intensity characteristics of rainfall

Southern UK, Winter

Duration-intensity characteristics of rainfall

Southern UK, Summer

Changes in rainfall intensity across space and time scales

Winter

<table>
<thead>
<tr>
<th>Bias (%)</th>
<th>wet_avg djf</th>
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<tbody>
<tr>
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<td>-11 -13 -14</td>
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<tr>
<td>daily</td>
<td>-12 -15 -22</td>
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<tr>
<td>6hrly</td>
<td>-9 -14 -22</td>
</tr>
<tr>
<td>hrly</td>
<td>16 11 -3 -11</td>
</tr>
<tr>
<td>10min</td>
<td>-11 50km</td>
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<thead>
<tr>
<th>Change (%)</th>
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<tr>
<td>pentad</td>
<td>32 32 32 30</td>
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<tr>
<td>daily</td>
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<tr>
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<tr>
<td>hrly</td>
<td>28 28 29 26</td>
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<tr>
<td>10min</td>
<td>26 12km</td>
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</table>

Summer

<table>
<thead>
<tr>
<th>Bias (%)</th>
<th>wet_avg jja</th>
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<td>pentad</td>
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<tr>
<td>daily</td>
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<tr>
<td>6hrly</td>
<td>17 13 -26 5</td>
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<tr>
<td>hrly</td>
<td>35 25 -26 11</td>
</tr>
<tr>
<td>10min</td>
<td>-21 50km</td>
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<tr>
<td>pentad</td>
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<td>daily</td>
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<tr>
<td>6hrly</td>
<td>-20 -19 -17 -3 13 0</td>
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<tr>
<td>hrly</td>
<td>21 20 20 9 17 5</td>
</tr>
<tr>
<td>10min</td>
<td>24 23 22 15 15 15</td>
</tr>
</tbody>
</table>
Change in extremes in winter

Chan et al, 2014, ERL
Change in extremes in summer

Chan et al, 2014, ERL
Temperature-precipitation scaling

Chan et al, Nature Geosci., accepted
Resolution dependence of UK projections

<table>
<thead>
<tr>
<th>Changes which are robust from coarser to higher resolution RCM, driven by large-scale changes inherited from driving GCM</th>
<th>Changes for which representation of the local storm dynamics, or high resolution orography, is important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease in summertime mean rainfall</td>
<td>Intensification of hourly rainfall in summer</td>
</tr>
<tr>
<td>Increase in wintertime mean rainfall</td>
<td>Changes in hourly and daily summertime extremes</td>
</tr>
<tr>
<td>Increase in heavy rainfall in winter</td>
<td>Changes in rainfall extremes over steep orography in winter</td>
</tr>
<tr>
<td>Large decrease in rainfall occurrence in summer</td>
<td>Changes in rainfall duration</td>
</tr>
</tbody>
</table>

Similar results found for 2.2km simulations over Alps using COSMO-CLM (Ban et al, 2015, GRL)
Summary

• Convection-permitting models simulate realistic hourly rainfall characteristics, unlike coarser RCMs, giving us confidence in their ability to project future changes.

• Future projections of increases in UK winter rainfall are robust from coarser to higher resolution models.

• Convection-permitting model shows an intensification of hourly rainfall in summer not seen at coarser resolution.
  ➢ Significantly more events exceeding high thresholds (30mm/h) indicative of flash flooding.

• Convection-permitting model captures present-day scaling between temperature and precipitation intensity, and indicates this cannot simply be extrapolated into the future.

• Accurate representation of the local storm dynamics is essential for predicting changes to convective extremes.

• Similar results obtained for 2.2km COSMO-CLM over Alps compared to 1.5km MetUM over southern UK.
Future outlook

• Convection-permitting climate change simulations to date:
  ➢ 1.5km UK (Kendon et al 2014); 2.2km Alps (Ban et al 2015), 2.8km SW Germany (Fosser et al submitted)

• How robust are changes in hourly rainfall extremes in convection-permitting models?
  ➢ Need for coordinated modelling experiments to assess uncertainties (H2020 EURO-CORDEX)
  ➢ 2.2km pan-European climate simulations

• UKCPnext
  ➢ First probabilistic projections at km-scales