Understanding changes in short-duration heavy rainfall under global warming: The GEWEX cross-cut on sub-daily rainfall extremes (INTENSE)

Marie Ekström, CSIRO

on behalf of Hayley J. Fowler
Professor of Climate Change Impacts
Royal Society Wolfson Research Fellow
Newcastle University, UK
Developing a consistent approach for quality control, including data homogenisation

Analysis of new observed dataset – trends and understanding process mechanisms

Developing a comprehensive international repository for sub-daily data

CPM model intercomparisons using common diagnostics

State of the science on:
(b) CPM projections: Kendon et al., BAMS, in press

INTENSE: INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes (2M€ ERC Consolidators Grant)
First regional CPM simulations at 1.5km resolution over UK

- First climate simulations at convection permitting scales
- Span southern England and Wales at 1.5km resolution.
- Driven by 12km European RCM, which is in turn driven by ERA-interim or 60km HadGEM3.
- Explicitly represents convection without need for parameterisation scheme.
- Runs completed to date:
  - Reanalysis driven run (1989-2008)
  - 13y control (1996-2009) and 13y future (~2100) RCP8.5 climate change experiments
  - SINGAPORE experiment
  - NORTHERN UK experiment
Summary of projections from very high resolution models

<table>
<thead>
<tr>
<th>Changes which are likely to be robust from coarser to higher resolution models, driven by large-scale changes inherited from global climate model</th>
<th>Changes for which representation of the local storm dynamics, or high resolution orography, is important</th>
</tr>
</thead>
<tbody>
<tr>
<td>=&gt; Confidence in coarse resolution climate model projections</td>
<td>=&gt; Need for very high resolution (km-scale) model for accurate projections</td>
</tr>
<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>Increases in multi-hourly 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>

Kendon et al, BAMS, in press
Observed temperature dependency: model validation

- The relationship between local surface air temperature and 99 percentile of JJA daily 1-hr maximum rainfall. Left column shows observations.
- Note decline in scaling in higher temperature in the future simulation.

Chan et al, 2016, Nature Geoscience
Changes in RH

- Relationship between 99th percentile of rainfall and non-local maximum 850-hPa wet-bulb potential temperature ($\Theta_w$).
- The decline of scaling at high temperatures in the future simulation disappears when we account for humidity changes.

Chan et al, 2016, Nature Geoscience
• Increase of MSLP over northern Europe.
• Consistent with dynamical changes, there is a 50% decline in rainfall probability for both 1.5-km and 12-km simulations.
• Change in storm dynamics and thermodynamics important – consistent with observational study of Wasko et al. (2016).
• Change in dominant precipitation type (Berg et al. 2013).

Chan et al, 2016, Nature Geoscience
Shorter duration events as temperature increases (Utsumi et al. 2011)?

- Rainfall composites for peak 10-min intensity > 99 percentile.
- (a) 10-min intensity
- (b) accumul. since t-300

Chan et al, ERL, in revision
INTENSE: Sub-daily precipitation data collection so far...

- UK, US, Canada, Brazil, France, Germany, Spain, Portugal, Italy, Israel, Philippines, India, Norway, Sweden, The Netherlands, Finland, New Zealand, Australia, Kenya, Indonesia, Slovenia, Costa Rica, Argentina, Switzerland, Austria, Hungary, Turkey, Bangladesh, Panama, Russia, Ireland, Japan, Malaysia, Singapore, Some Africa, Some SE Asia,
- Global datasets: HadISD, ISD, NOAA, MSWEP, NLDAS-2, InERG, EuMETGRD,
Trends in Seasonal Max data in US

Seasonal Maximum P (1-h)  \hspace{1cm} Seasonal Maximum P (24-h)

Winter

Spring

Summer

Fall

Seasonal Maximum Precipitation

% of samples w/ positive trends

1-h P  \hspace{1cm} 24-h P

Barbero et al., GRL, in revision
Trends in Seasonal frequencies of extremes in US

95th (wet hours) 95th (wet days)

Winter

Spring

Summer

Fall

Hourly vs daily trends

% of samples w/ positive trends

percentile

90 95
97.5
99
99.5
99.75
99.9

0 5 10 15 20 25 30

0 5 10 15 20 25 30

0 5 10 15 20 25 30

0 5 10 15 20 25 30

Barbero et al., GRL, in revision
Quality control of hourly data

*Blenkinsop et al. IJC in press (DOI: 10.1002/joc.4735)*

**Site specific tests**
- For example:
  - rain gauge metadata,
  - implausible large values (1h & 24h tested)
  - “frequent tipping”
  - long dry periods due to gauge malfunction
    - accumulated totals (often at 9am)
    - repeated values
    - comparison with 24h gridded data

**Nearby gauge comparisons**
- Statistical test of consistency with nearby gauges but problematical for extremes in summer/autumn therefore only partially applied

**Multiple QC flags applied to each hour for each test**

**Automated rule base to define exclusions**
- For example:
  - all implausible hourly totals
  - “large” hourly totals if in winter at 9am after ≥23 dry hours
  - “large” hourly totals if after gauge non-operation (long dry spell)
We should be able to adapt most of these checks to work globally...using CLIMDEX daily indices

<table>
<thead>
<tr>
<th>Wet Flags</th>
<th>Dry Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold based</strong></td>
<td><strong>Non-threshold based</strong></td>
</tr>
<tr>
<td>QC1- record 1hr total</td>
<td>QC2- daily accumulations</td>
</tr>
<tr>
<td>QC1.1- seasonal record</td>
<td>QC2b.1- consecutive daily accumulations</td>
</tr>
<tr>
<td>QC10- Neighbourhood checks</td>
<td>QC3- Monthly accumulations</td>
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<tr>
<td></td>
<td>QC5- Frequent tips</td>
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<td>QC6- Consecutive identical values</td>
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<td></td>
<td>QC9- manual flags</td>
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</tbody>
</table>
Summary (1)

• CPM enables a more process based understanding of climate change and identification of aspects of coarser resolution model projections which are robust
  - Changes in seasonal mean rainfall are robust
  - Changes in heavy winter rainfall are robust (expect perhaps for daily extremes over mountains)
  - Changes in the duration and intensity of summertime rain underestimated at coarse resolution

• Summer rainfall intensities increase with temperature but are moderated by changes in circulation patterns and CPMs do not show same changes for sub-hourly extremes as observed in limited studies.
Summary (2)

• INTENSE is collecting a global database of sub-daily (mostly hourly) observations of rainfall. These will be quality controlled using methods developed on UK data (and adapted to local circumstances using the CLIMDEX daily indices)

• Data will be held at an approved data centre (TBD) where freely distributable, and sub-daily seasonal/monthly indices will be developed for all stations which will be freely downloadable. Other station metrics could be calculated.

• The indices will be made available through a dedicated web site which will also indicate data availability and links to data providers and licensing arrangements etc.
Outlook

• GEWEX-sponsored INTENSE workshop next week in Newcastle, UK on “Sub-daily rainfall extremes: data, processes and modelling”, 13-15th September, 2016

• Aims to:
  – Explore best practise for using sub-daily rainfall data
  – Examine current research theories around processes affecting sub-daily rainfall extremes (mainly observations)
  – Identify a set of sub-daily extreme rainfall indices useful to a wide variety of users
  – Discuss progress on convection-permitting models and the current gaps in our understanding, and how to best combine observational and modelling studies
  – Plan the next steps in this area, including a publication from the workshop
Further thoughts/Challenges

• Km-scale GCMs? Need intercomparison studies, improved evaluation methods, set of common diagnostics, analysis of additional variables
• Seasonal analyses not annual to better explore T-P scaling, and linking to large-scale atmospheric drivers
• Improved observational datasets and analysis of trends/changes
• Evaluation of processes using models to inform observational studies – how do we use models to explore and understand processes we cannot observe?
• The INTENSE project website:
  https://research.ncl.ac.uk/intense/aboutintense/

Prof. Hayley Fowler: h.j.fowler@ncl.ac.uk
Contributors

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