



GEWEX/GHP annual meeting 2016

3rd-5th October, 2016, CNRS, Paris

European Research Council
Established by the European Commission

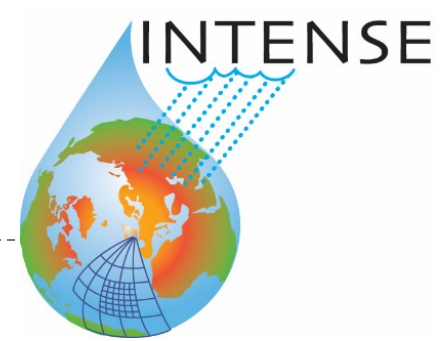
Understanding changes in short-duration heavy rainfall under global warming: The GEWEX cross-cut on sub-daily rainfall extremes (INTENSE)

Hayley Fowler

*Professor of Climate Change Impacts
Royal Society Wolfson Research Fellow
Newcastle University, UK*



GEWEX



Developing a consistent approach for quality control, including data homogenisation

Developing a comprehensive international repository for sub-daily data

**GEWEX
Cross-cut
sub-daily
rainfall
(INTENSE)**

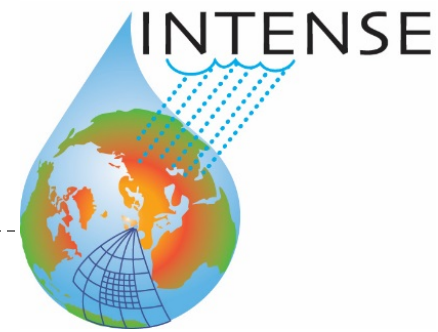
Analysis of new observed dataset – trends and understanding process mechanisms

CPM model intercomparisons using common diagnostics

State of the science on:
(a) sub-daily extremes: *Westra et al. 2014, Revs. Geophys.*
(b) CPM projections: *Kendon et al., BAMS, in press*

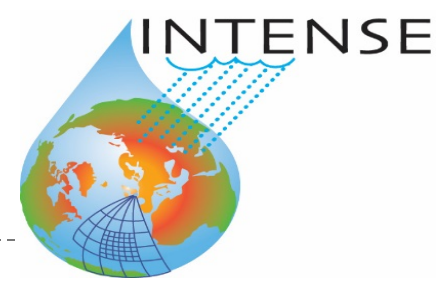
INTENSE: INTElligent use of climate models for adaptation to non-Stationary hydrological Extremes
(2M€ ERC Consolidators Grant)

INTENSE Key Research Questions



1. How has sub-daily maximum precipitation changed over the last century, across continents, climate regimes and seasons?
2. How does precipitation at different time-scales vary with atmospheric temperature and atmospheric moisture as the atmosphere warms?
3. How do large-scale atmospheric and oceanic features influence or modulate the observed changes in precipitation extremes, the clustering of extremes and the variability between 'drought' and 'flood' periods, in different climate regimes and seasons?
4. What is the influence of climate model resolution and structure on the simulation of precipitation extremes for different climate regimes and seasons?
5. What is likely the response to warming of precipitation and precipitation extremes at different time- scales across different climate regimes?
6. How can we use information from both high-resolution and coarse-resolution climate models in a more intelligent way to inform climate change adaptation decision making to better manage extreme hydrological events?

INTENSE Update



- 6 full-time PDRA's working on project at Newcastle University : Dr Stephen Blenkinsop, Dr Elizabeth Lewis, Dr Renaud Barbero, Dr Xiaofeng Li, Dr Selma Guerreiro and Dr Steven Chan (based at UK Met Office), Dr Geert Lenderink (part-time, KNMI, Netherlands) and team at UK Met Office led by Dr Lizzie Kendon
- Standard request letter and identified routes to data providers (with Lisa Alexander). Data provided for many countries – **Elisabeth Lewis**
- Development of quality control procedures for sub-daily precipitation using UK data – **Stephen Blenkinsop**
- Understanding trends in sub-daily precipitation extremes and preliminary analysis of dynamical and thermodynamic drivers – **Renaud Barbero/Geert Lenderink**
- Understanding extreme rainfall processes using convection-permitting models – **Steven Chan/Lizzie Kendon**
- Extent to which CPMs are needed for reliable future climate projections - paper in press in BAMS (Kendon et al. 2016).
- A gridded hourly rainfall product for the UK for 1991-2013
- **Website: <https://research.ncl.ac.uk/intense/>**

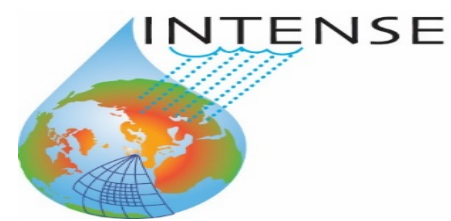
GEWEX-sponsored INTENSE workshop: “Sub-daily rainfall extremes: data, processes and modelling”, 13-15th Sep 2016



- **Aimed to:**

- Explore best practise for using sub-daily rainfall data, including quality control
- 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, and a model diagnostic set for CPMs
- 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

GEWEX-sponsored INTENSE workshop: “Sub-daily rainfall extremes: data, processes and modelling”, 13-15th Sep 2016



- **Outcomes:**

- 20 people attended from as far afield as Australia and the US, with many participants from Europe, and some using Skype to participate in the meeting.
- Participants agreed on a first set of sub-daily precipitation indices and a draft is to be circulated to all participants and members of the ETCCDI team in early October 2016.
- Agreed on first draft of set of common model diagnostics for CPMs to take to Trieste Flagship pilot study meeting.
- A written summary of the workshop will be submitted to GEWEX news and BAMS meetings reports.
- Paper is planned on the grand challenges in understanding sub-daily precipitation extremes.

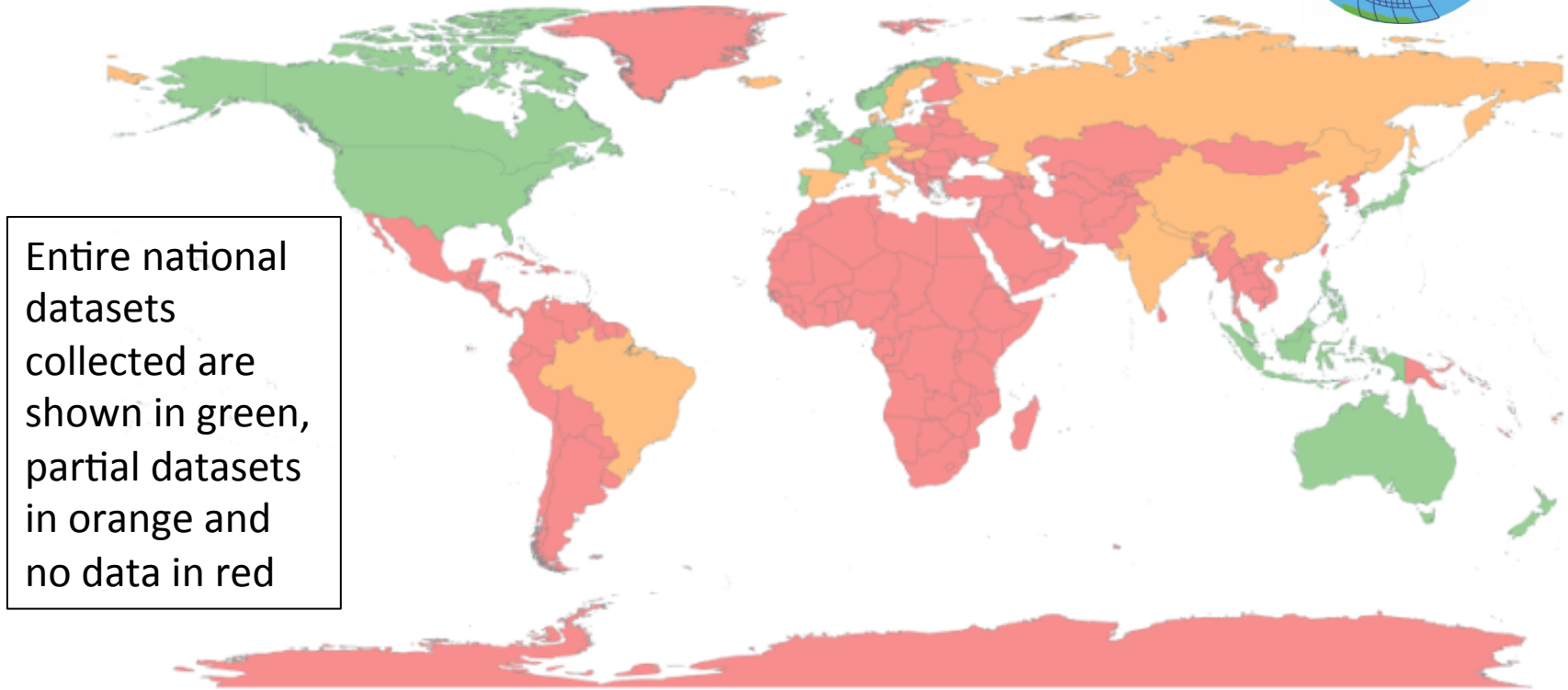
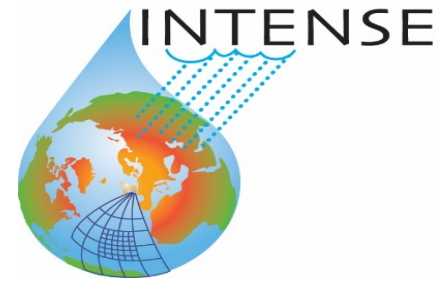
GEWEX-sponsored meeting on CPM held at NCAR, Boulder, CO, US from 6-8th September 2016.



- **Outcomes:**

- more than 70 researchers from 13 countries
- Missing observational datasets were identified as a main challenge in enhancing convection permitting modeling. The INTENSE project was presented at the workshop and the potential benefits of the global hourly precipitation data collection for model development and evaluations were discussed.
- Main outcome of the meeting was that the convection-permitting climate modeling community should aim for more collaborations to prevent the duplication of research and to make results more comparable. INTENSE could play an important role in the latter by developing a set of sub-daily precipitation indices and metrics that can be adopted by the community.
- special issue in a peer-reviewed journal on CPM and blog to foster communication and exchange of ideas related to high-resolution climate information.

INTENSE: Sub-daily precipitation data collection so far...



Entire national datasets collected are shown in green, partial datasets in orange and no data in red

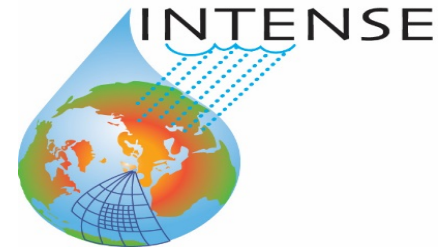
- UK, US, Canada, Brazil, France, Germany, Spain, Portugal, Italy, Israel, Philippines, India, Norway, Sweden, The Netherlands, Finland, New Zealand, Australia, Kenya, Indonesia, Slovenia, Costa Rica, Argentina, Switzerland, Austria, Hungary, Turkey, Bangladesh, Panama, Russia, Ireland, Japan, Malaysia,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



Sub-daily indices

- **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.**

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

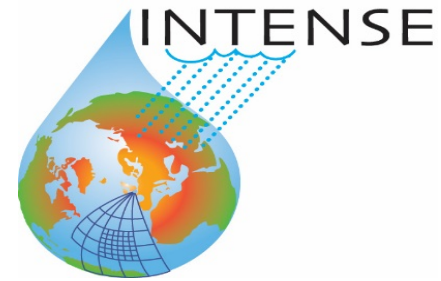
Statistical test of consistency with nearby gauges but problematical for extremes in summer/autumn therefore only partially applied

Multiple QC flags applied to each hour for each test

Automated rule base to define exclusions

For example:

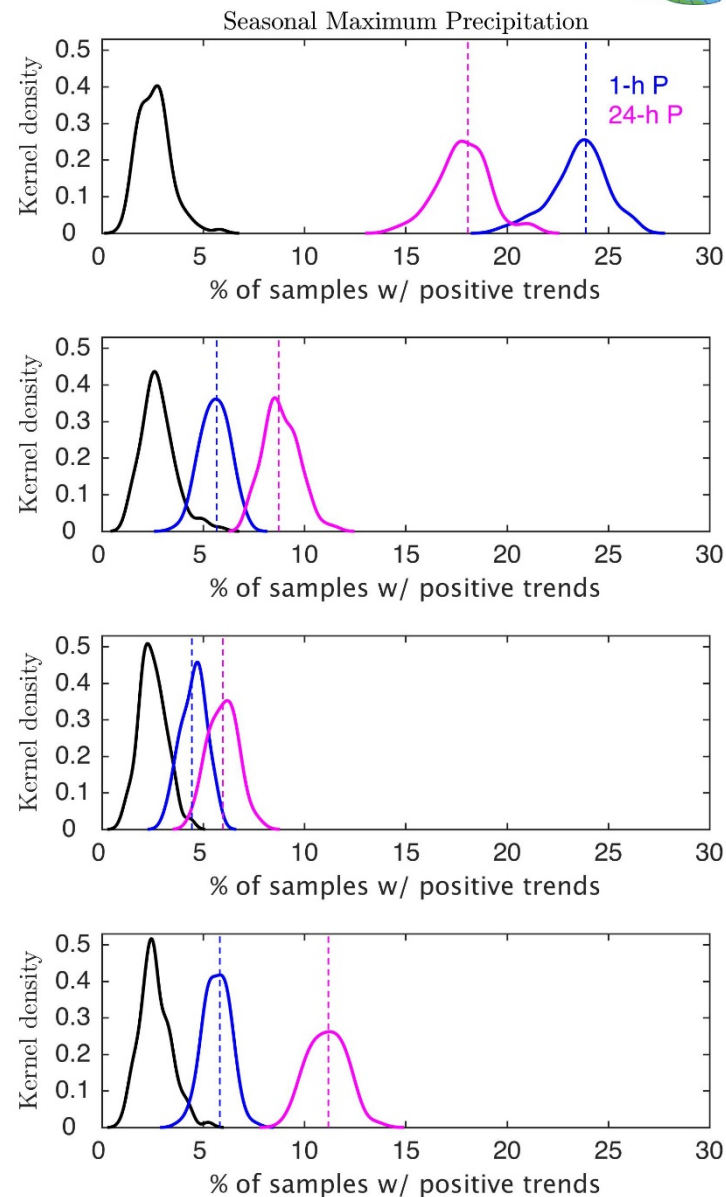
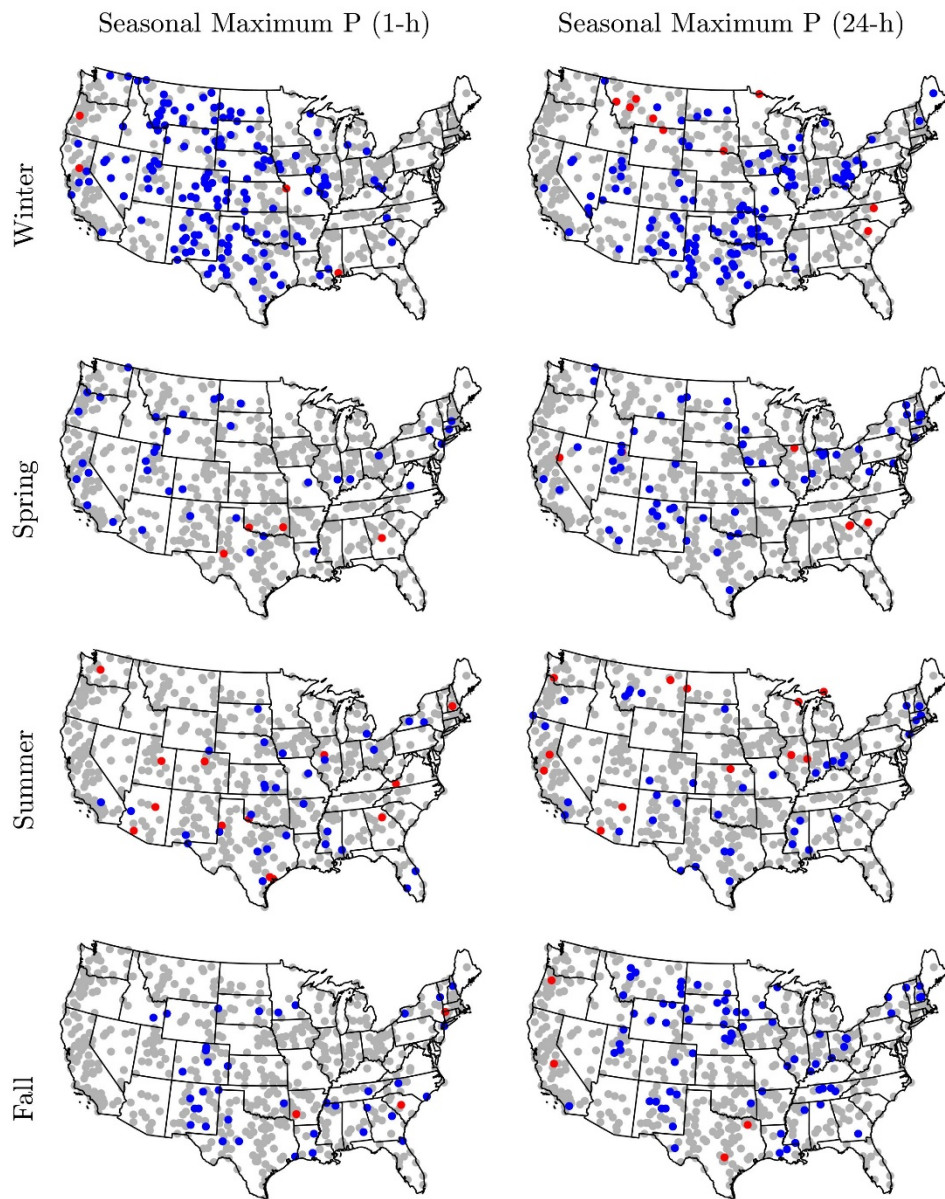
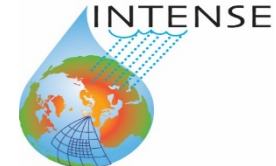
- all implausible hourly totals
- “large” hourly totals if in winter at 9am after ≥ 23 dry hours
- “large” hourly totals if after gauge non-operation (long dry spell)



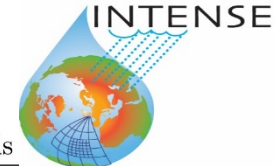
We should be able to adapt most of these checks to work globally...using CLIMDEX daily indices

Wet Flags		Dry Flags
Threshold based	Non-threshold based	Threshold based
QC1- record 1hr total	QC2- daily accumulations	QC4- long dry spells
QC1.1- seasonal record	QC2b.1- consecutive daily accumulations	QC11- Neighbourhood checks
QC10- Neighbourhood checks	QC3- Monthly accumulations	
	QC5- Frequent tips	
	QC6- Consecutive identical values	
	QC9- manual flags	

Trends in Seasonal Max data in US



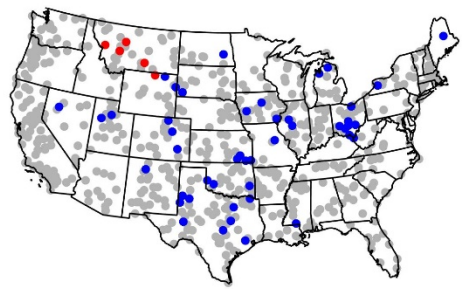
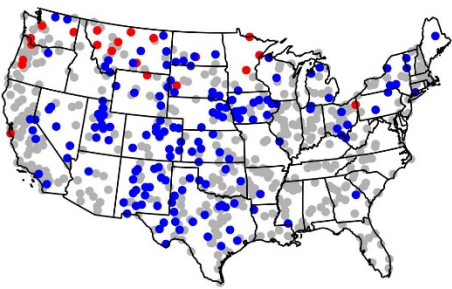
Trends in Seasonal frequencies of extremes in US



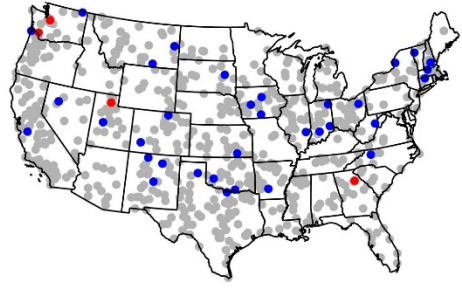
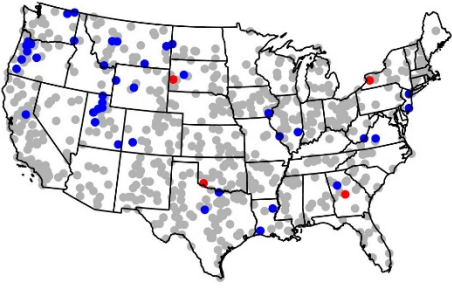
95th (wet hours)

95th (wet days)

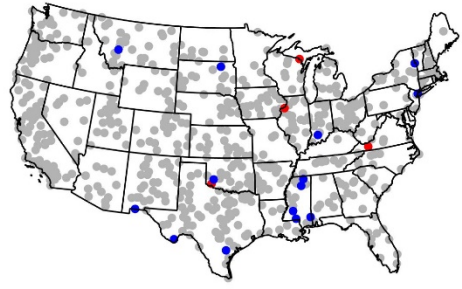
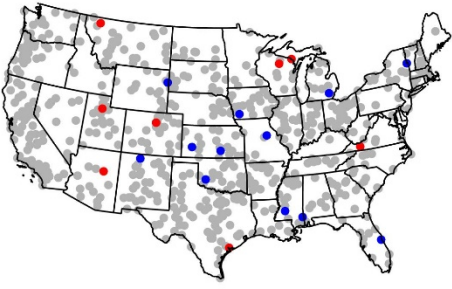
Winter



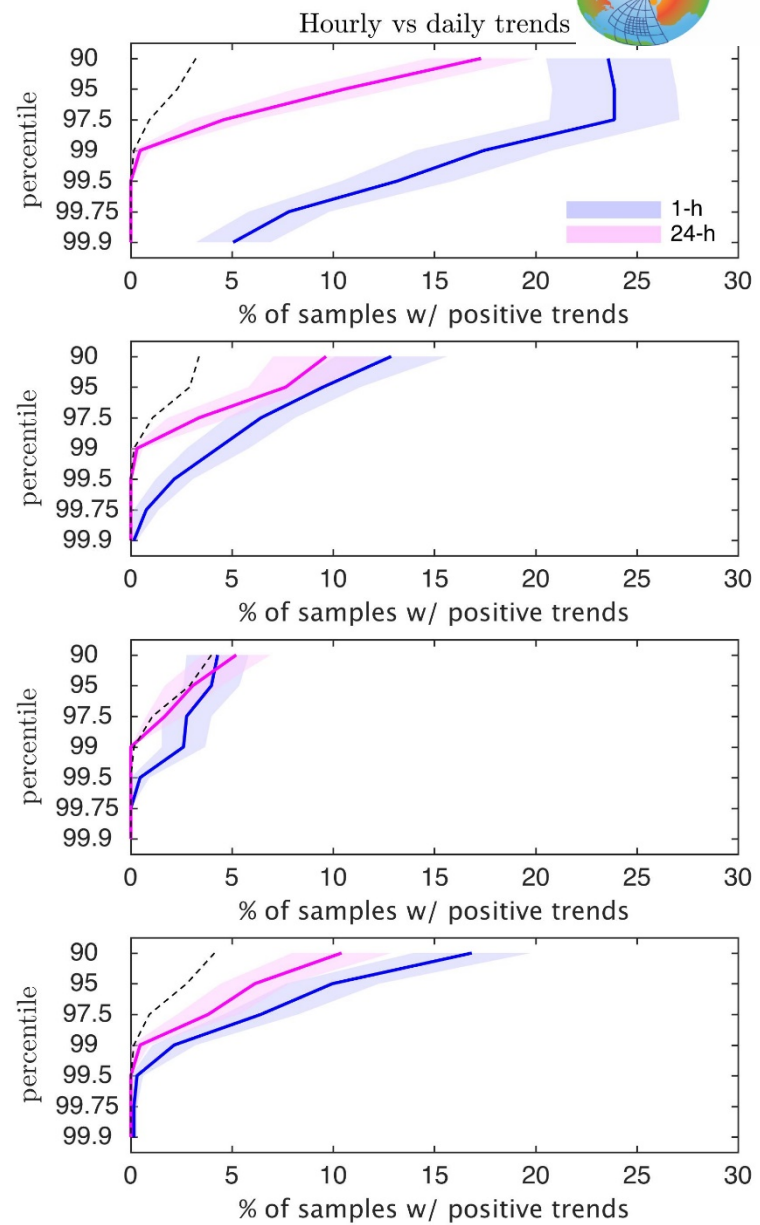
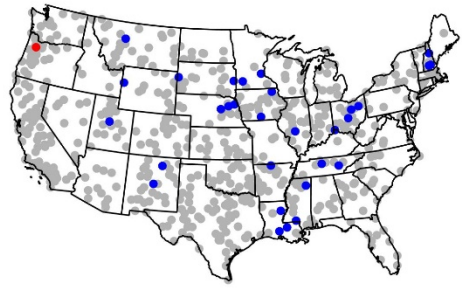
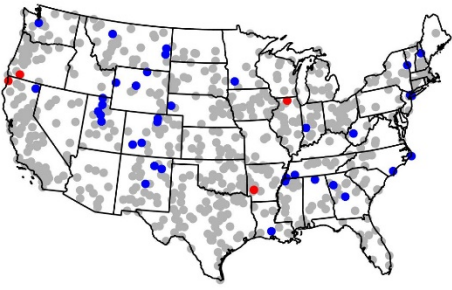
Spring



Summer

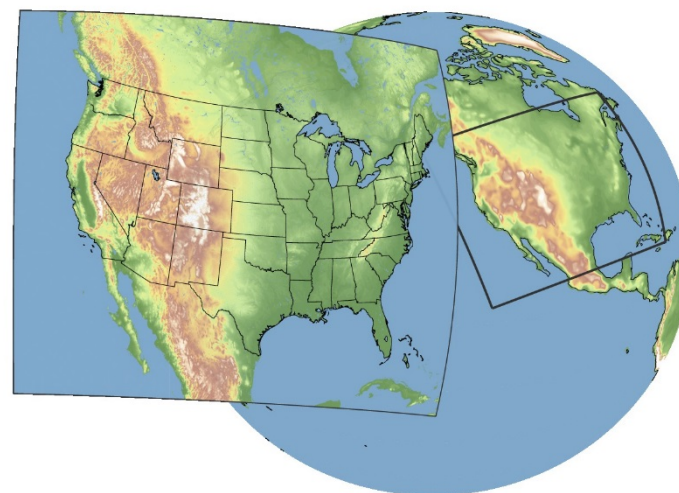
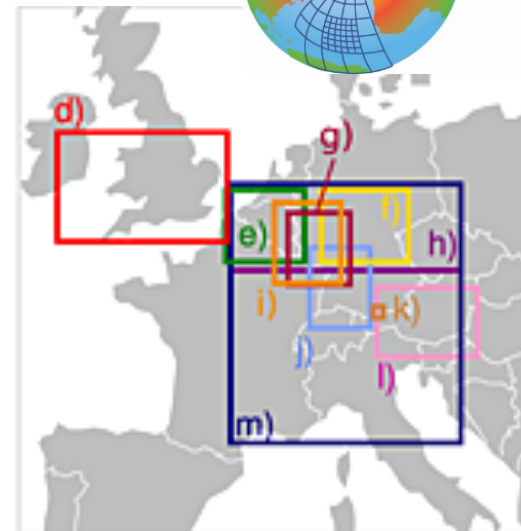
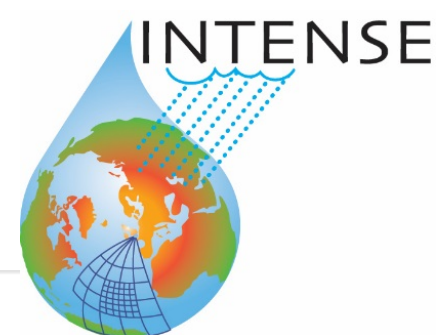


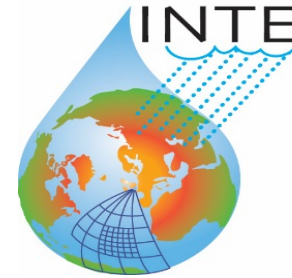
Fall



First comparison of CPM climate projections at high resolution

- Now many CPM runs: southern England, Northern England, Alps, Germany, US, Greater Sydney, Singapore etc.
- Planned runs in China and runs in progress at 2.2km over European domain (comparison study ETH Zurich – Schar – and UK Met Office – Kendon/INTENSE)
- CORDEX Flagship pilot study to compare CPMs over common domain – KO meeting Trieste 3-4th November. Likely domain – Alps.
- Common model diagnostic set and observed sub-daily indices under development

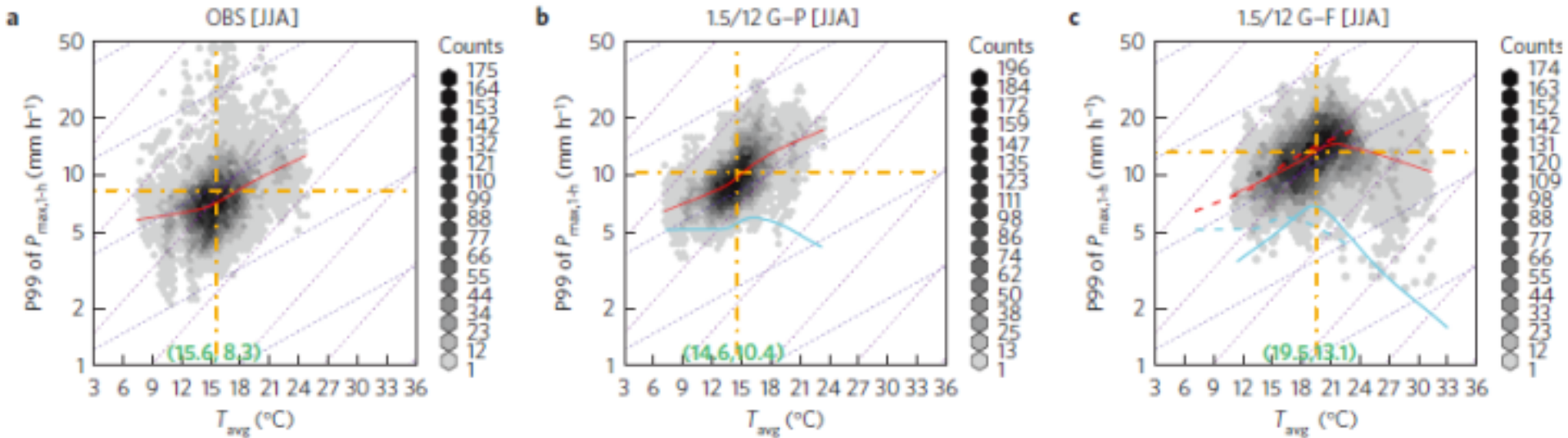
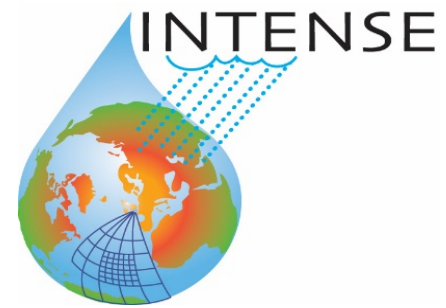




Summary of projections from very high resolution models

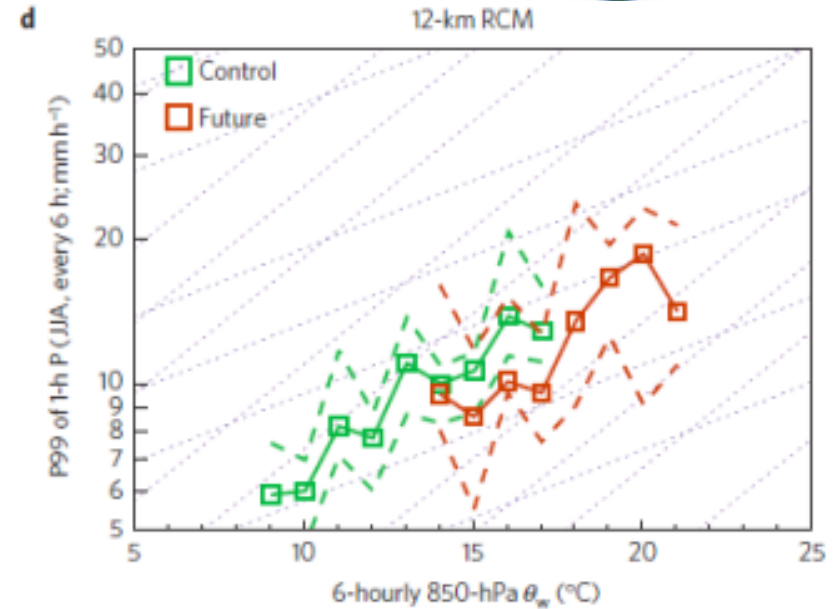
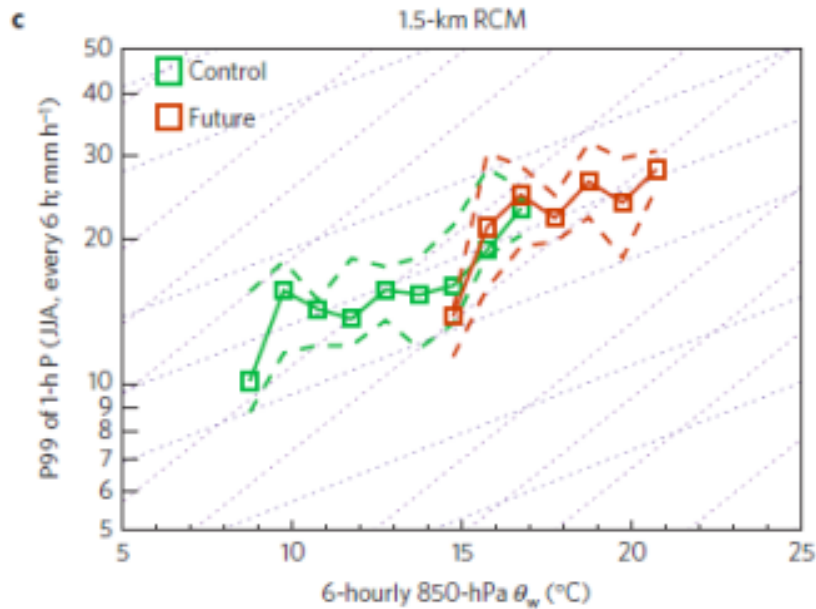
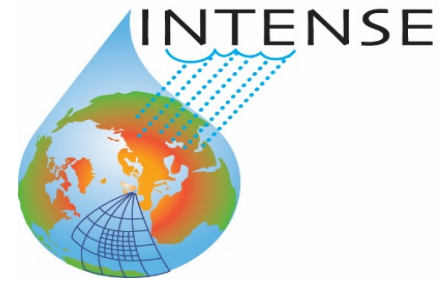
<p>Changes which are likely to be robust from coarser to higher resolution models, driven by large-scale changes inherited from global climate model => Confidence in coarse resolution climate model projections</p>	<p>Changes for which representation of the local storm dynamics, or high resolution orography, is important => Need for very high resolution (km-scale) model for accurate projections</p>
Decrease in summertime mean rainfall	Intensification of hourly rainfall in summer
Increase in wintertime mean rainfall	Changes in hourly and daily summertime extremes
Increase in heavy rainfall in winter	Increases in multi-hourly rainfall extremes over steep orography in winter
Large decrease in rainfall occurrence in summer	Changes in rainfall duration

Observed temperature dependency: model validation

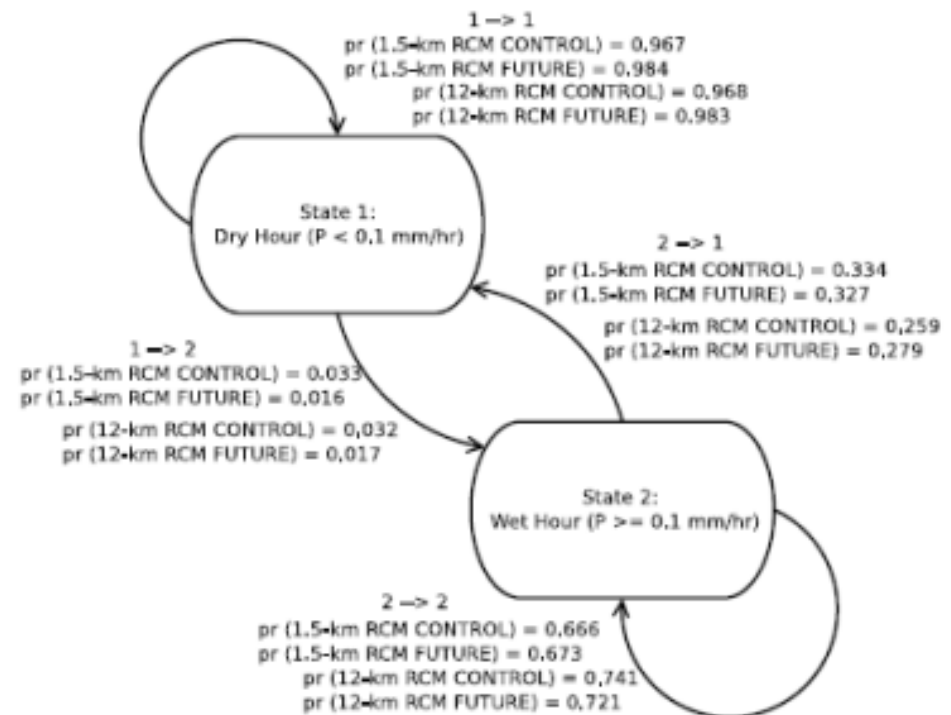
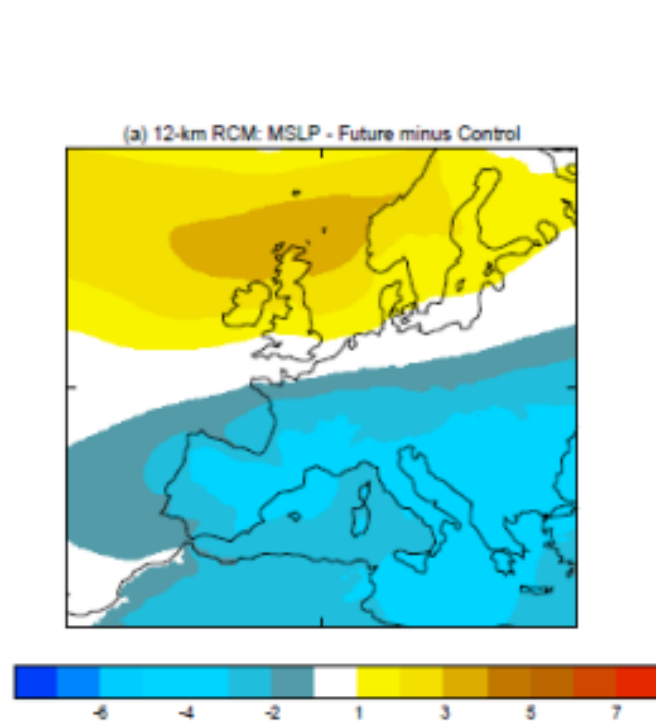


- The relationship between local surface air temperature and 99 percentile of JJA daily 1-hr maximum rainfall. Left column shows observations
- Note decline in scaling in higher temperature in the future simulation.

Changes in RH

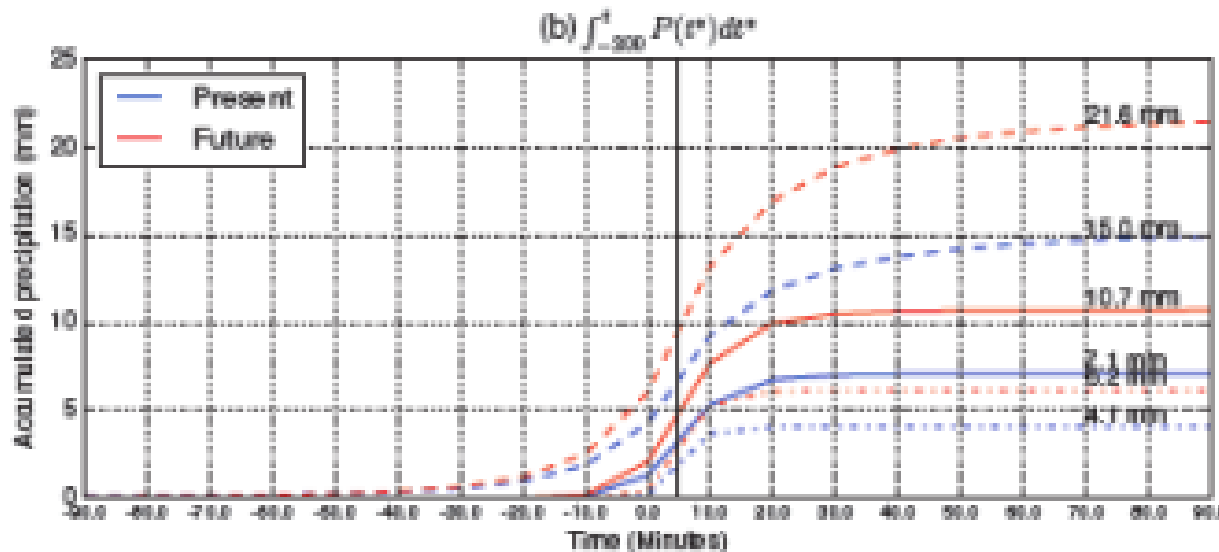
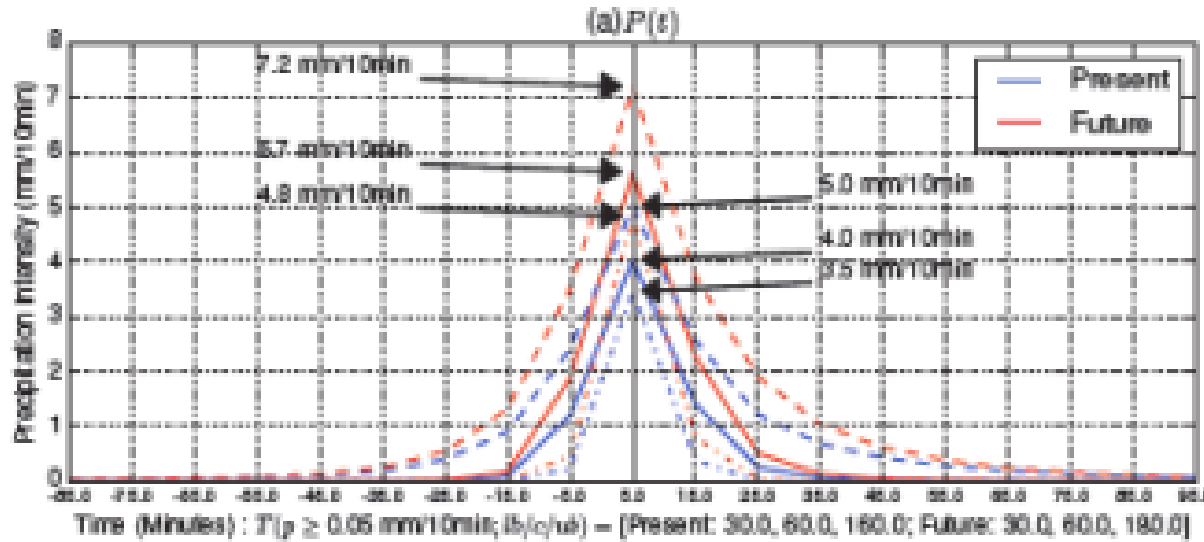
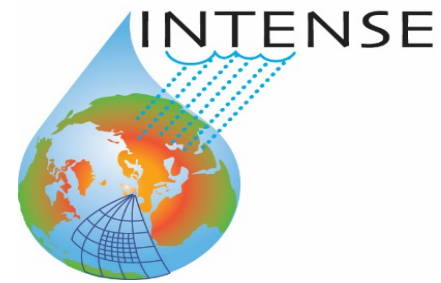


- Relationship between 99th percentile of rainfall and non-local maximum 850-hPa wet-bulb potential temperature (θ_w).
- The decline of scaling at high temperatures in the future simulation disappears when we account for humidity changes.

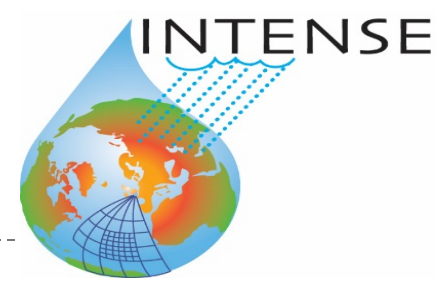


- Increase of MSLP over northern Europe.
- Consistent with dynamical changes, there is a 50% decline in rainfall probability for both 1.5-km and 12-km simulations
- Change in storm dynamics and thermodynamics important – consistent with observational study of Wasko et al. (2016)
- Change in dominant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

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



INTENSE planned activities

Database

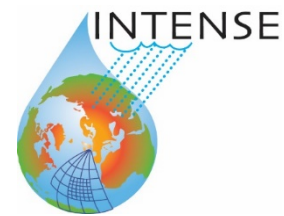
- Continued data acquisition strategy and initiatives on a regional basis to update and expand the existing database. Thought given to where to host data and development of new indices for sub-daily precipitation.
- Continue to support the development of quality control measures for sub-daily precipitation data including release of common QC code.
- Construction and analysis of a comprehensive UK sub-hourly (10-15 minute) dataset is planned using UK rain gauge data.

Research

- A global scale analysis of the extreme precipitation-temperature relationship will be undertaken using sub-daily datasets gathered by INTENSE.
- Global scale analysis of trends in sub-daily extreme precipitation
- Intensity-Duration-Frequency (IDF) curves generation for UK and global datasets
- Further develop the working group on very high resolution models and common analyses of model outputs.
- First analyses of large-scale drivers of sub-daily extreme precipitation
- Initiation of efforts to explore how sub-hourly in situ and satellite observations can help each other.
- Session proposed at the EGU 2017 on “Development and analysis of sub-daily rainfall datasets: characteristics, change and drivers of extremes”.

INTENSE publications

- Chan, S.C., Kendon, E.J., Roberts, N.M., Fowler, H.J., Blenkinsop, S. The characteristics of summer sub-hourly rainfall in a high-resolution convective permitting model. **Environmental Research Letters**, in press.
- Kendon, E.J., Ban, N., Roberts, N.M., Roberts, M.J., Chan, S. Fowler, H.J., Fosser, G., Evans, J. and Wilkinson, J. Using new high resolution models to assess the reliability of regional climate projections. **Bulletin of the American Meteorological Society**, in press.
- Blenkinsop, S., Lewis, E., Chan, S., Fowler, H.J. 2016. Quality control of an hourly rainfall dataset and climatology of extremes for the UK. **International Journal of Climatology**, DOI: 10.1002/joc.4735.
- Chan, S.C., Kendon, E.J., Roberts, N.M., Fowler, H.J., Blenkinsop, S. 2016: Downturn in scaling of UK extreme rainfall with temperature for future hottest days. **Nature Geoscience**, 9, 24–28, DOI: 10.1038/NGEO2596.
- Hegerl, G.C, Black, E., Allan, R.P., Ingram, W.J., Polson, D., Trenberth, K.E., Chadwick, R.S., Arkin, P.A., Sarojini, B.B., Becker, A., Dai, A., Durack, P.J., Easterling, D., Fowler, H.J., Kendon, E.J., Huffman, G.J., Liu, C., Marsh, R., New, M., Osborn, T.J., Skliris, N., Stott, P.A., Vidale, P.L., Wijnffels, S.E., Wilcox, L.J., Willett, K.M., Zhang, X. 2015: Challenges in Quantifying Changes in the Global Water Cycle. **Bulletin of the American Meteorological Society**, 96, 1097–1115, doi: <http://dx.doi.org/10.1175/BAMS-D-13-00212.1>
- Blenkinsop, S, Chan, S, Kendon, E.J, Roberts, N.M., Fowler, H.J. 2015. Temperature influences on intense UK hourly precipitation and dependency on large-scale circulation. **Environmental Research Letters**, 10, 054021, doi:10.1088/1748-9326/10/5/054021.
- Westra, S., Fowler, H.J., Evans, J.P., Alexander, L.V., Berg, P., Johnson, F., Kendon, E.J., Lenderink, G. and Roberts, N.M. 2014. Future changes to the intensity and frequency of short-duration extreme rainfall. **Reviews of Geophysics**, 52(3), 522–555 DOI: 10.1002/2014RG000464.



Contributors

Thanks to:

- Lizzie Kendon and team (Met Office Hadley Centre)
- Nigel Roberts (MetOffice@Reading)
- Stephen Blenkinsop, Renaud Barbero, Steven Chan, Liz Lewis, Selma Guerreiro, Xiao-Feng Li (Newcastle University)
- INTENSE partners