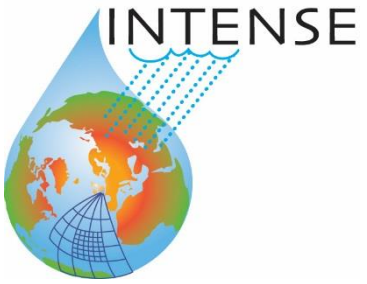
GEWEX Convection-Permitting Climate Modeling Workshop
6th-8th September, 2016, Boulder, CO,USA



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

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on behalf of Hayley J. Fowler
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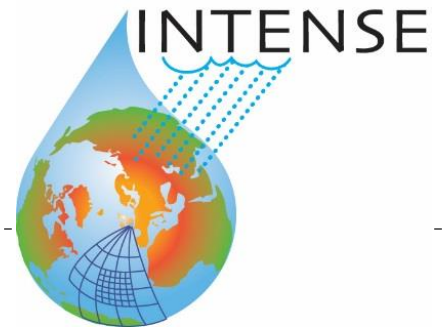
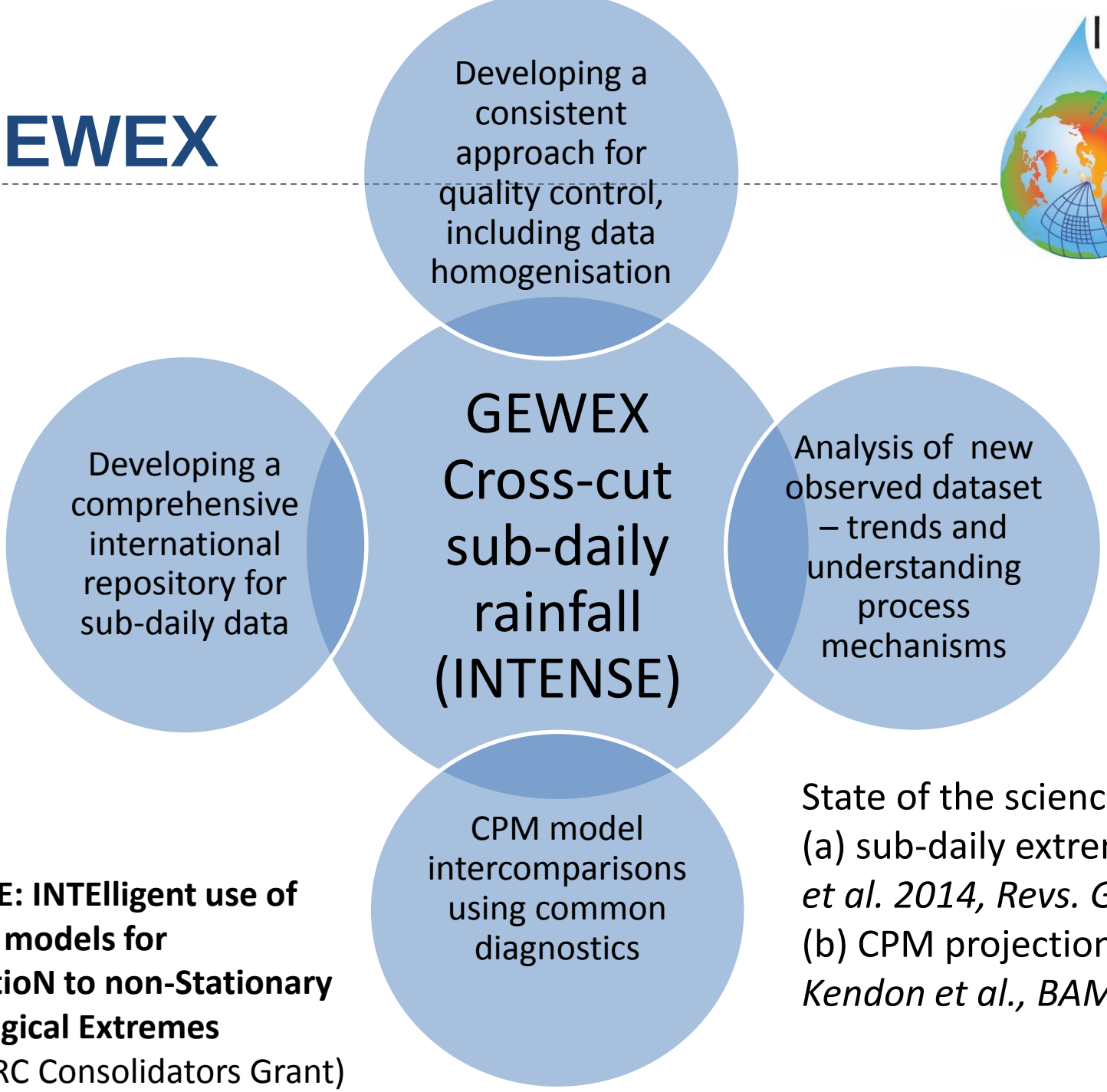
GEWEX

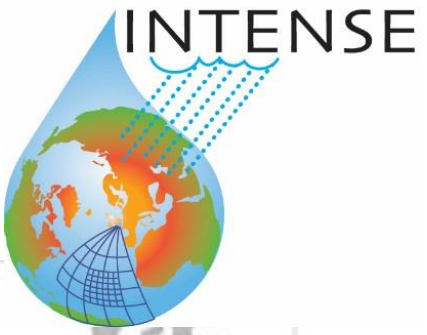


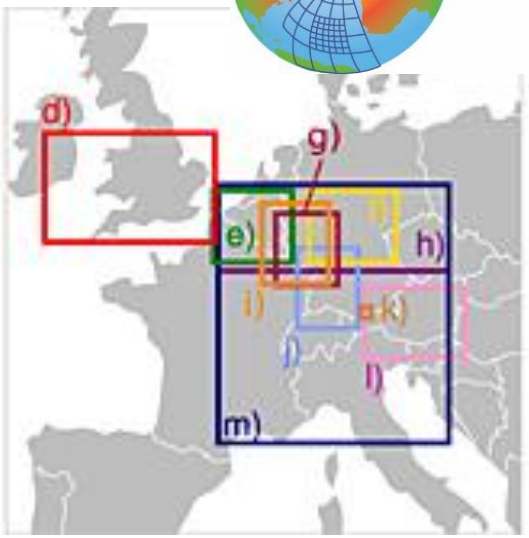


INTENSE: INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes
(2M€ ERC Consolidators Grant)

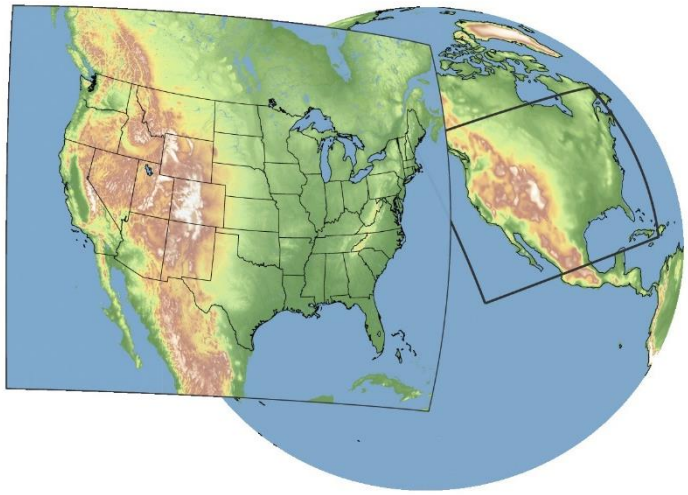
State of the science on:
(a) sub-daily extremes: *Westra et al. 2014, Revs. Geophys.*
(b) CPM projections:
Kendon et al., BAMS, in press

First regional CPM simulations at 1.5km resolution over UK

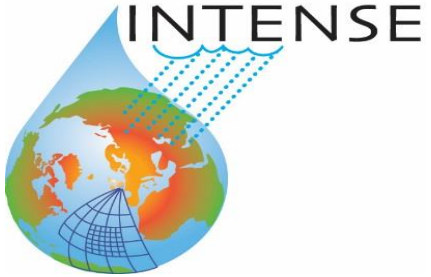




- First climate simulations at convection permitting scales
- Span southern England and Wales at 1.5km resolution.
- Driven by 12km European RCM, which is in turn driven by ERA-interim or 60km HadGEM3.
- Explicitly represents convection without need for parameterisation scheme.
- Runs completed to date: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



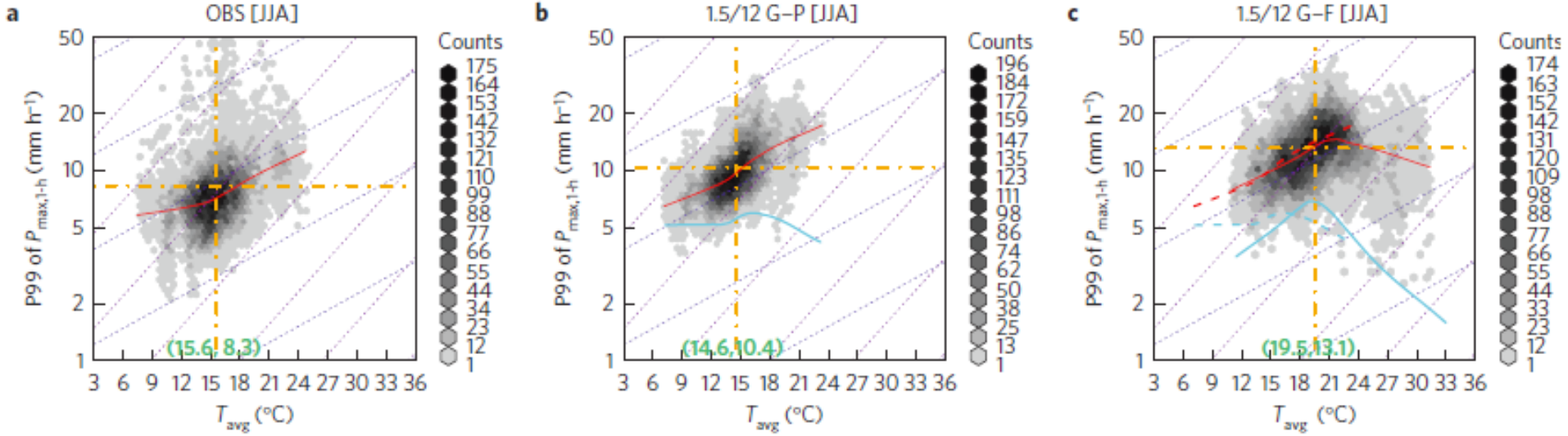
Summary of projections from very high resolution models



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**	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**
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

Kendon et al, BAMS, in press

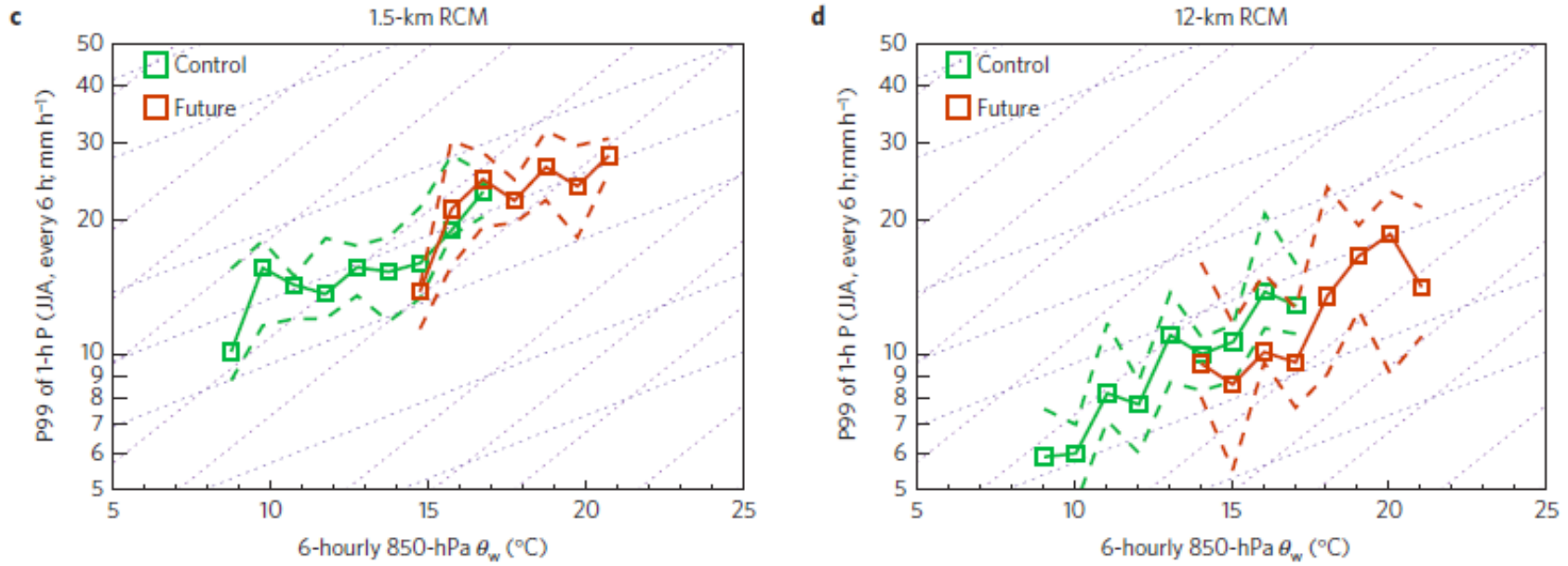
Observed temperature dependency: model validation



- 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.

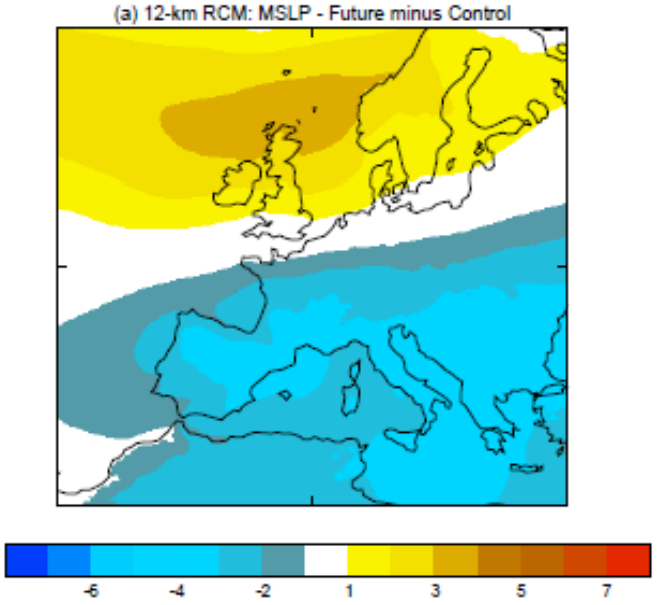
Chan et al, 2016, Nature Geoscience

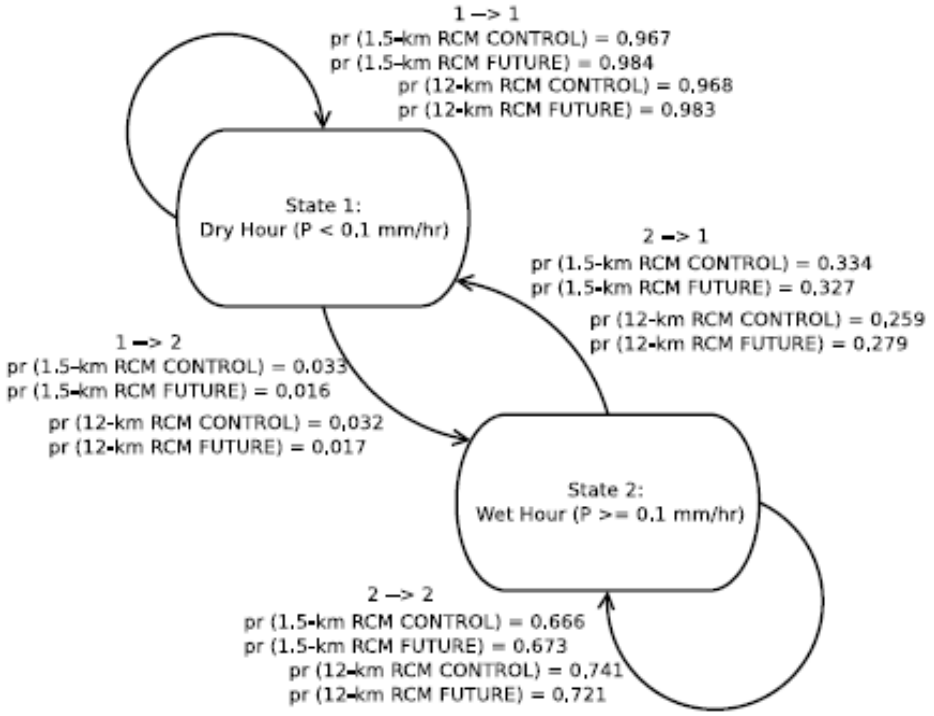
Changes in RH



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

Chan et al, 2016, Nature Geoscience

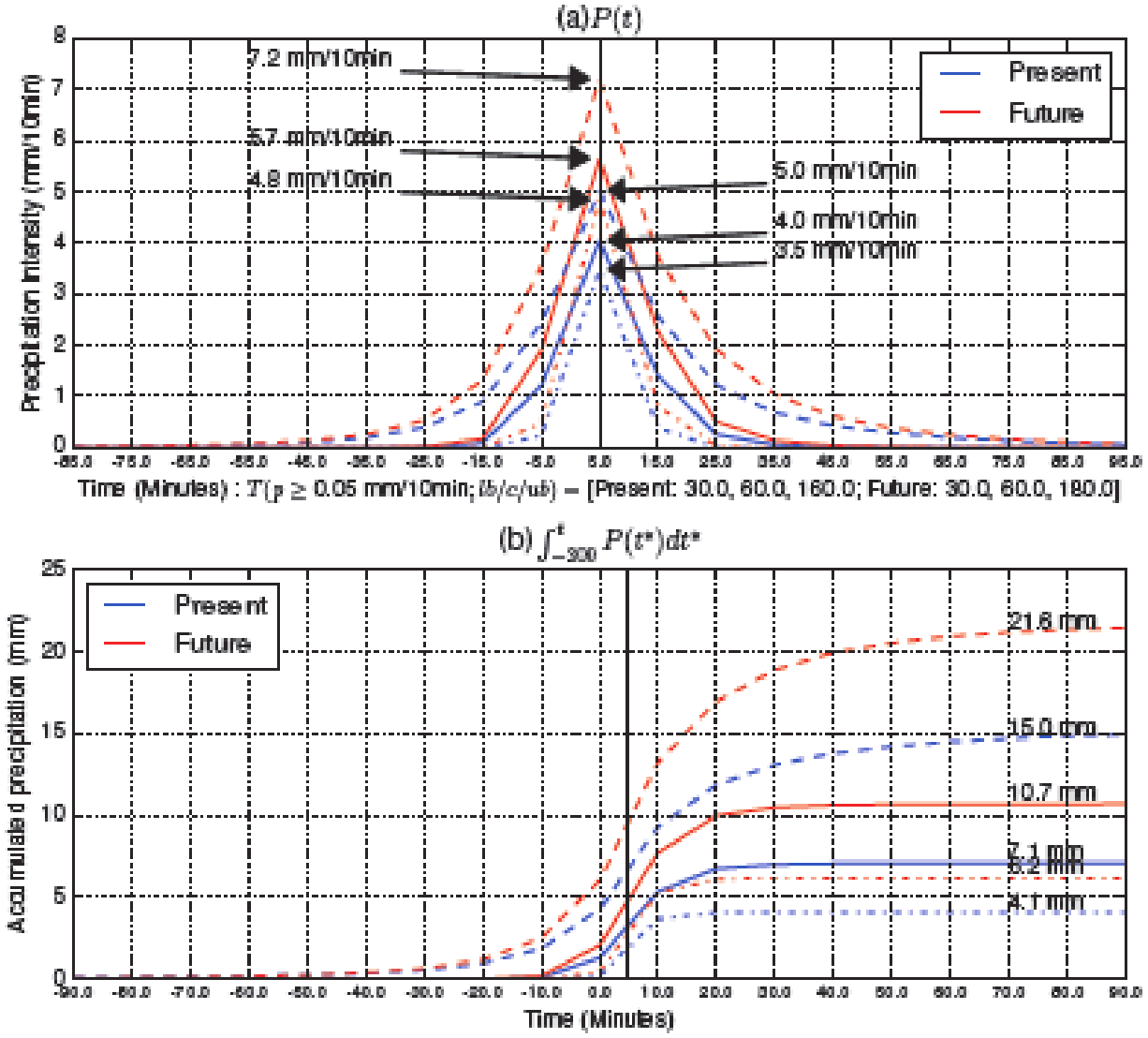




- Increase of MSLP over northern Europe.
- Consistent with dynamical changes, there is a 50% decline in rainfall probability for both 1.5-km and 12-km simulations
- Change in storm dynamics and thermodynamics important – consistent with observational study of Wasko et al. (2016)
- Change in dominant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

Chan et al, 2016, Nature Geoscience

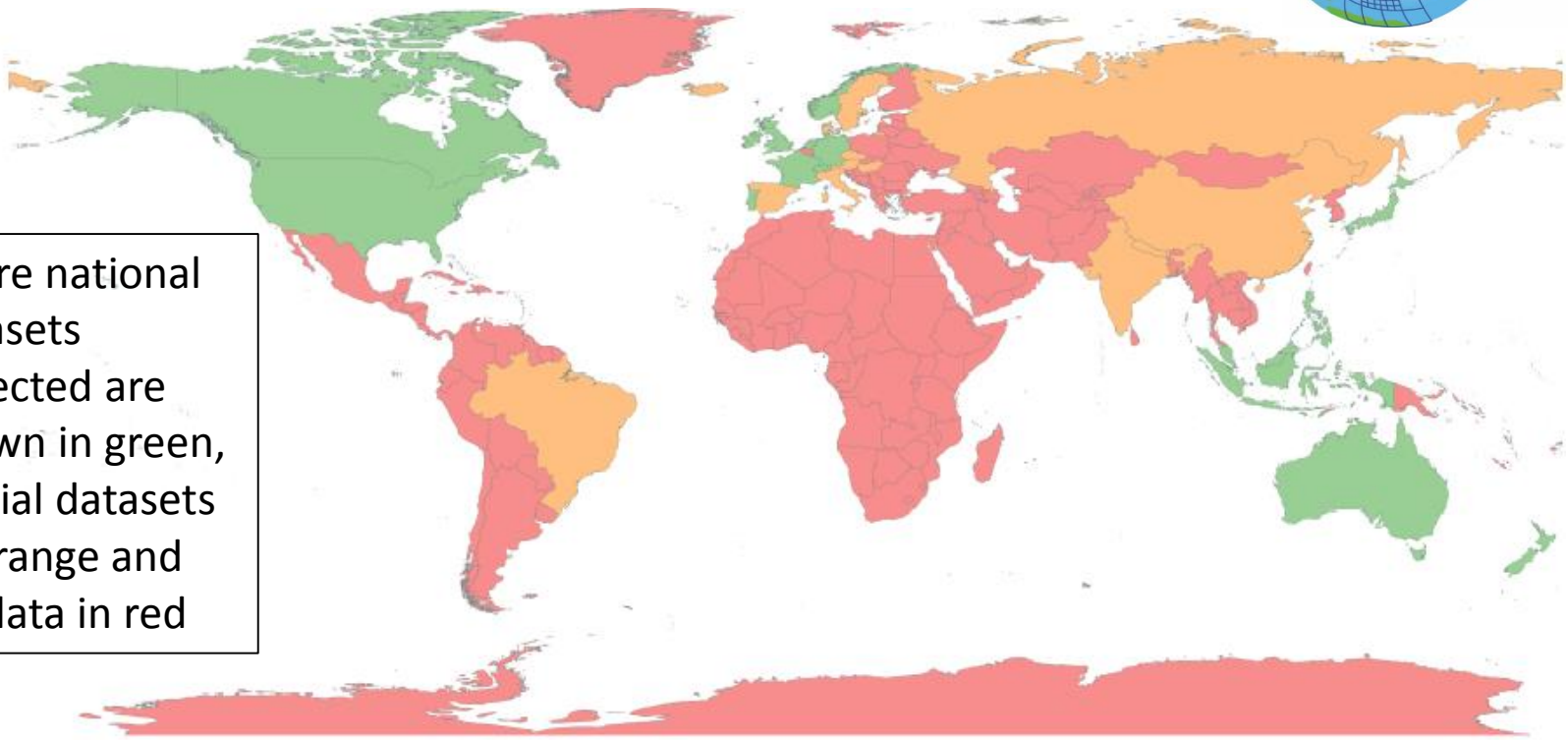
Shorter duration events as temperature increases (Utsumi et al. 2011)?



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

Chan et al, ERL, in revision

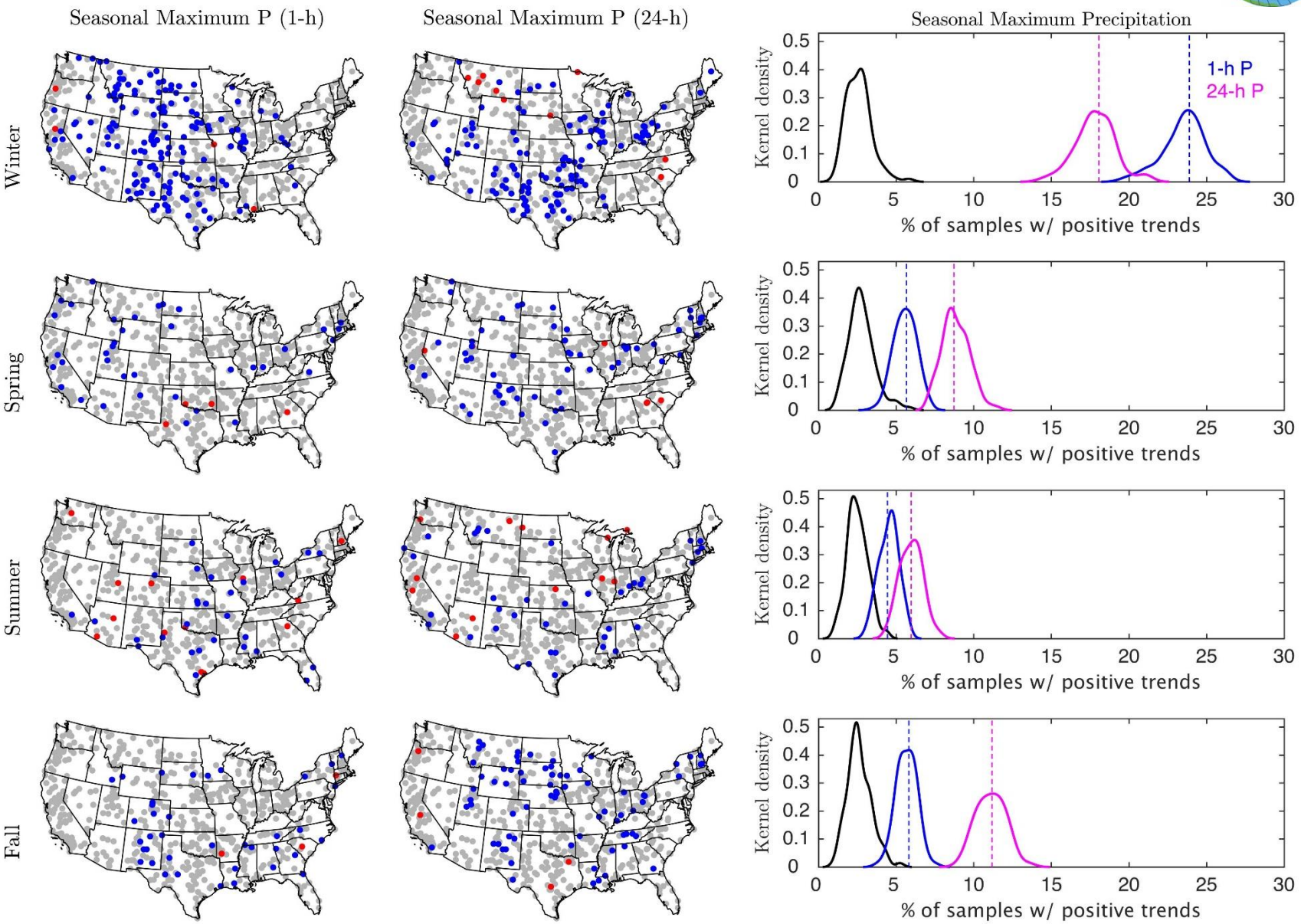
INTENSE: Sub-daily precipitation data collection so far…



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

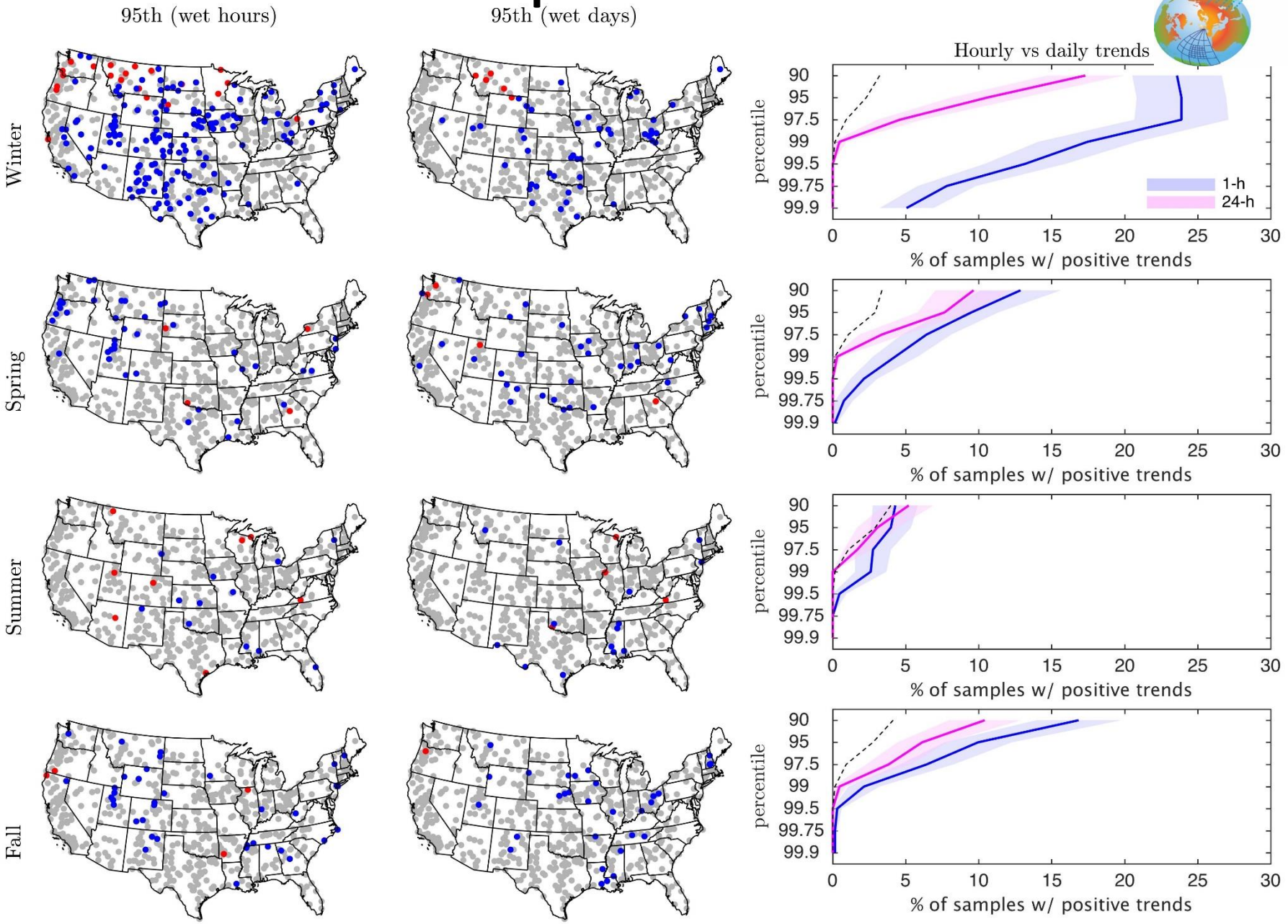
- UK, US, Canada, Brazil, France, Germany, Spain, Portugal, Italy, Israel, Philippines, India, Norway, Sweden, The Netherlands, Finland, New Zealand, Australia, Kenya, Indonesia, Slovenia, Costa Rica, Argentina, Switzerland, Austria, Hungary, Turkey, Bangladesh, Panama, Russia, Ireland, Japan, Malaysia,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

Trends in Seasonal Max data in US



Barbero et al., GRL, in revision

Trends in Seasonal frequencies of extremes in US



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

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	

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**
- **<u>Aims to:</u>**
  - 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/

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Contributors

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- Lizzie Kendon and team (Met Office Hadley Centre)
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