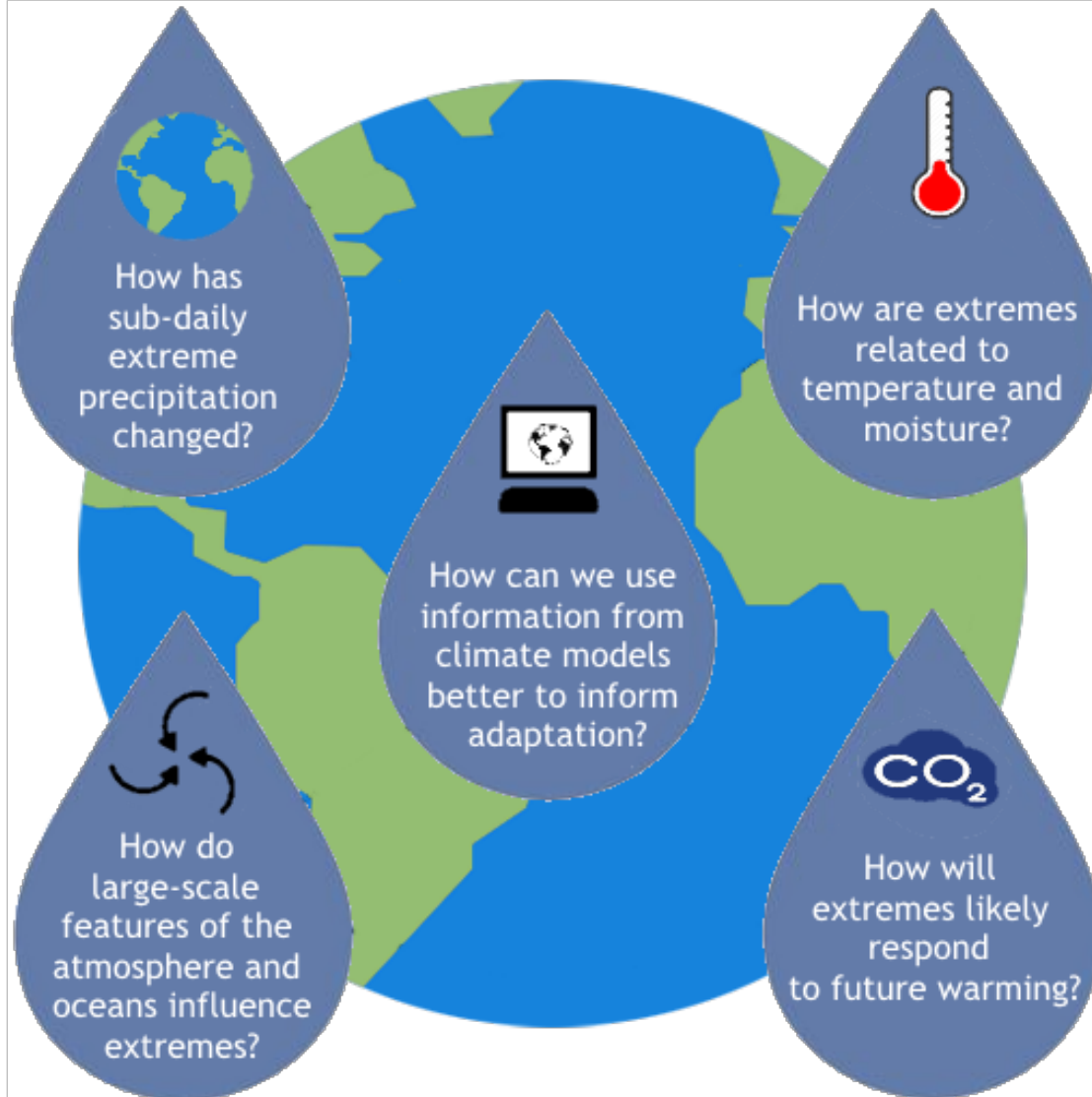Understanding changes in short-duration heavy rainfall under global warming: The GEWEX cross-cut on sub-daily rainfall extremes (INTENSE)

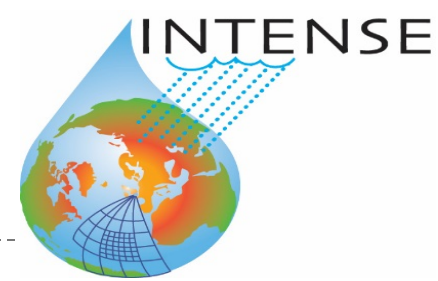## Prof Hayley Fowler

Newcastle University, UK

INTENSE research questions

How has sub-daily extreme precipitation changed?

How are extremes related to temperature and moisture?

How can we use information from climate models better to inform adaptation?

How do large-scale features of the atmosphere and oceans influence extremes?

How will extremes likely respond to future warming?

CO_2

Thanks to:

- Lizzie Kendon and team, Robert Dunn, Nigel Roberts (UK Met Office)

- Stephen Blenkinsop, Steven Chan, Liz Lewis, Selma Guerreiro, Xiao-Feng Li, Haider Ali (Newcastle University)

- INTENSE partners (especially Geert Lenderink, Seth Westra, Christoph Schär, Nicolina Ban, Jason Evans, Lisa Alexander, Renaud Barbero)

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

INTENSE Update

- 5 full-time PDRA's working on project at Newcastle University : Dr Stephen Blenkinsop, Dr Elizabeth Lewis, 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

- Development of dataset, QC method and now indices – **Elisabeth Lewis**

- Development of sub-hourly precipitation datasets– **Stephen Blenkinsop**

- Understanding trends in sub-daily precipitation extremes and preliminary analysis of dynamical and thermodynamic drivers – **Renaud Barbero (now at IRSTEA, France)/Geert Lenderink – Haider Ali soon to join us**

- Understanding large-scale drivers of sub-daily precipitation extremes – **Xiao-Feng Li**

- Understanding extreme rainfall processes using convection-permitting models – **Steven Chan/Lizzie Kendon**

- **Website: https://research.ncl.ac.uk/intense/**

# So far, collected hourly data from ~25,000 stations...
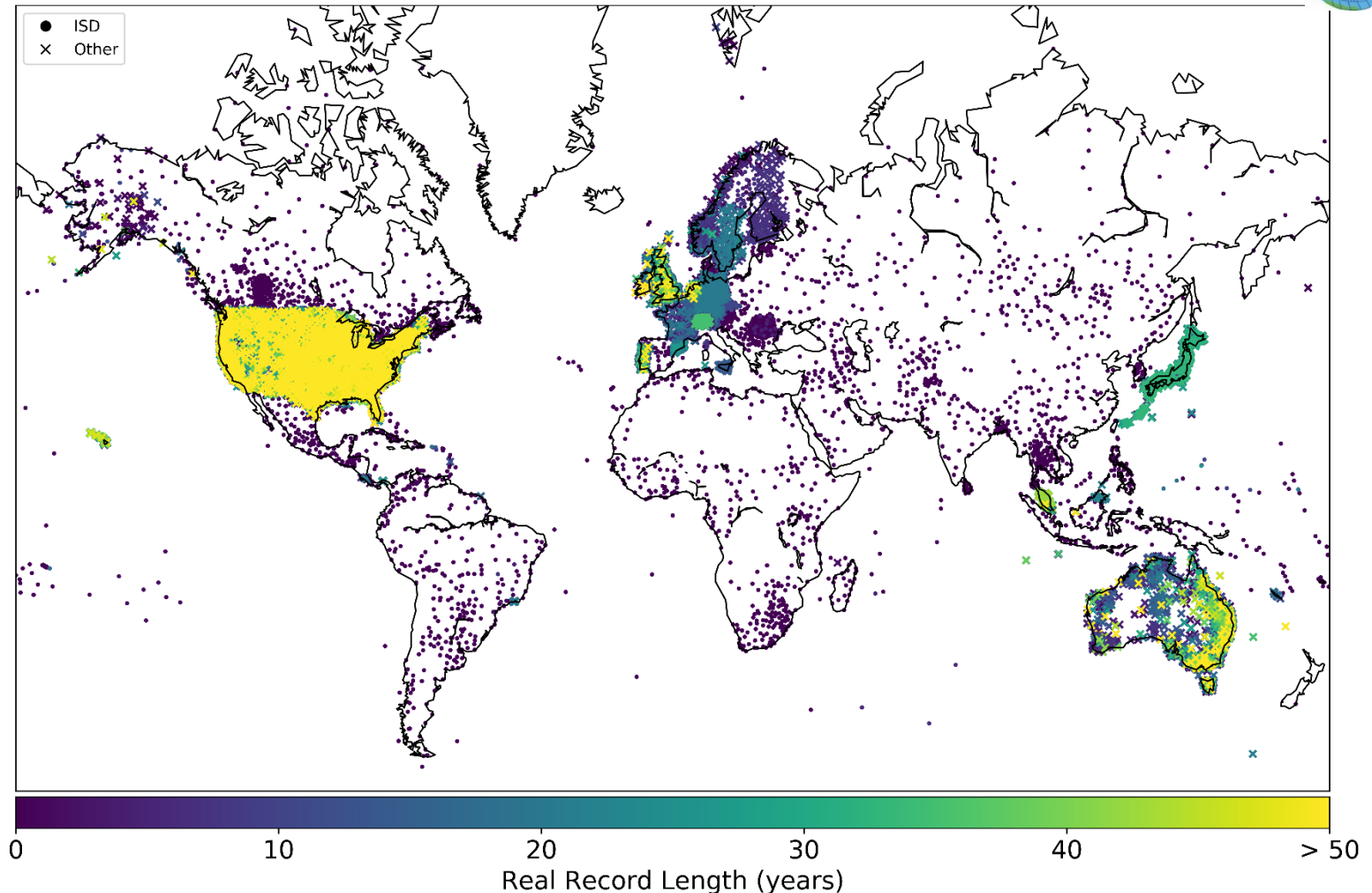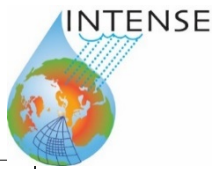
National datasets: UK, US, Canada, Brazil, France, Germany, Spain, Portugal, Italy, Philippines, India, Norway, Sweden, The Netherlands, Finland, Australia, Kenya, Indonesia, Slovenia, Costa Rica, Argentina, Switzerland, Austria, Hungary, Panama, Ireland, Japan, Malaysia, Singapore, Dominica, Trinidad & Tobago

So far, collected hourly data from ~25,000 stations...

Real Record Length (years)
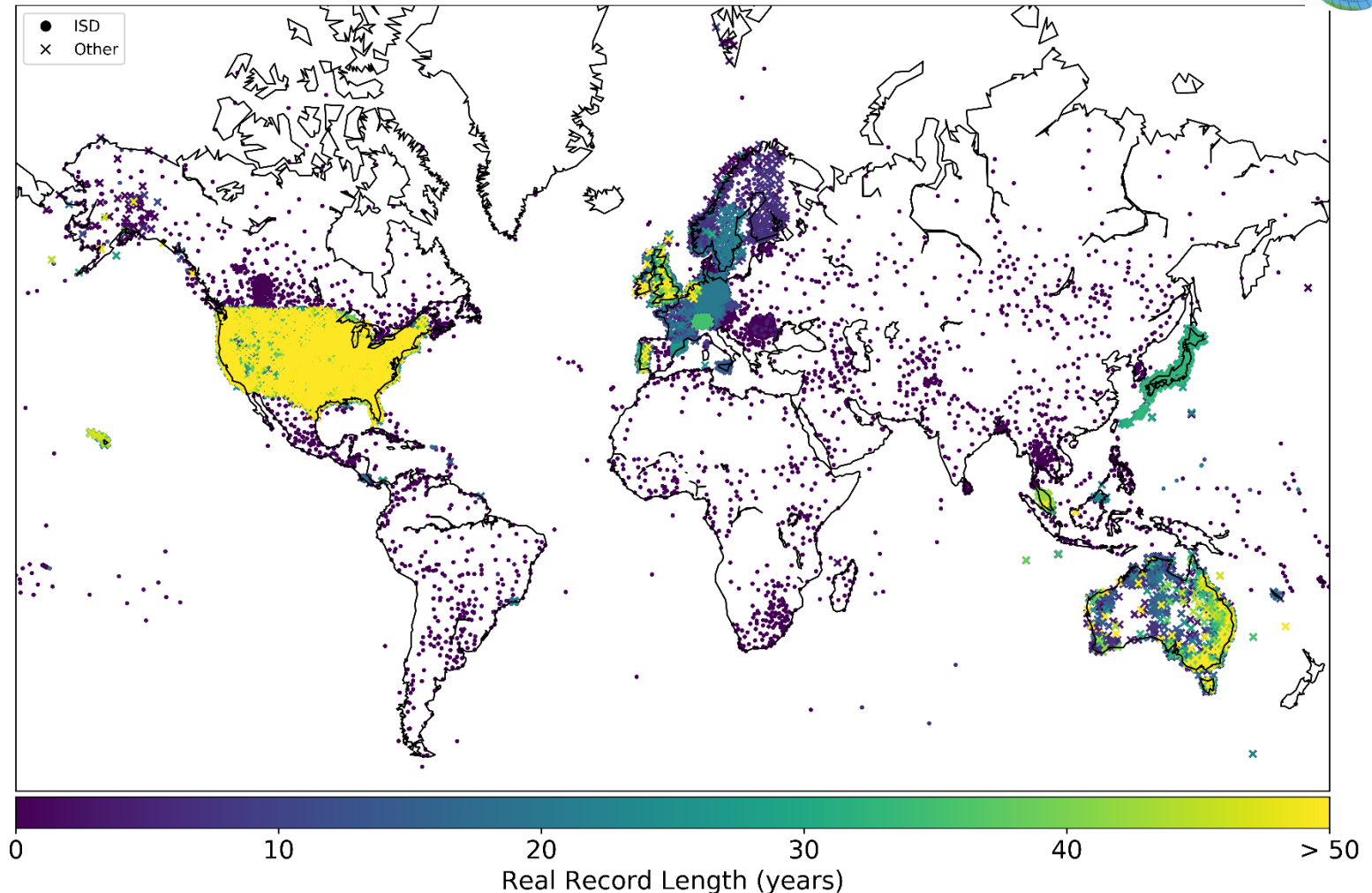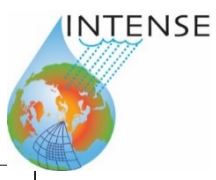
Global dataset: HadISD, approx. 10,000 stations (varying data quality, more useful data at 3h and 6h), freely available <u>sub-daily</u> precipitation data. Plus access to additional datasets (i.e. E Europe, China) to calculate indices.

So far, collected hourly data from ~25,000 stations...
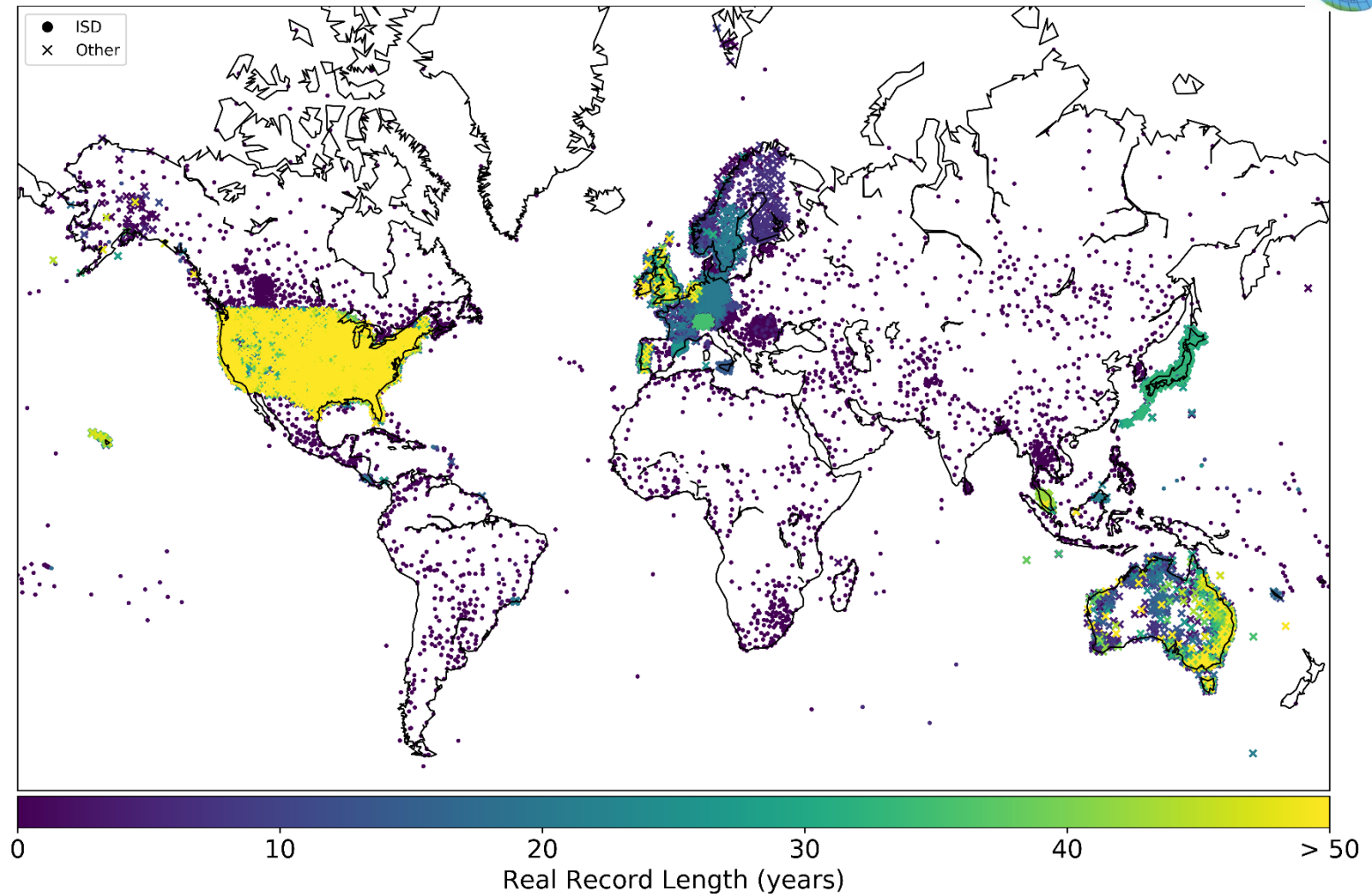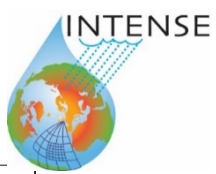
See talk by Liz Lewis on Wed at 13:30: Creating a global sub-daily precipitation data set in **S4. Sub-daily Rainfall Extremes**

1. Quality control of hourly data
(Blenkinsop et al, 2017; IJC & Lewis et al., submitted)

2. Adapt checks to work globally using CLIMDEX daily indices and DWD daily dataset (Lewis et al, in prep)

Site specific tests

• rain gauge metadata,
• implausible large values (1h & 24h records)
• Monthly maximum 1-day precipitation
• long dry periods due to gauge malfunction
• accumulated totals (often at 9am)
• repeated values
• Change in resolution
• Duplicate records

Nearby gauge comparisons

• Statistical test of consistency with nearby gauges but problematical for extremes in summer/autumn therefore only partially applied
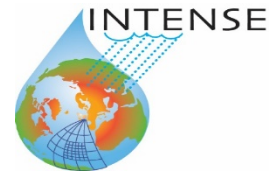
Multiple QC flags applied to each hour for each test

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)

# Produce new sub-daily precipitation indices from new global dataset

INTENSE

- **Rx1hr** Monthly maximum 1-hour precipitation
- **Rx3hr** Monthly maximum 3-hour precipitation
- **Rx6hr** Monthly maximum 6-hour precipitation
- **Rx1hrP** Percent of daily total that fell in the Monthly maximum 1-hour precipitation

Monthly maximum indices

- **LW1H** Monthly likely wettest hour within a day
- **LD1H** Monthly likely driest hour within a day
- **DLW1H** Dispersion around Monthly likely wettest hour within a day
- **S1HII** Simple hourly precipitation intensity index
- **CW1H** Maximum length of wet spell

Diurnal cycle indices

- **R10mm1hr** Monthly count of hours when PRCP ≥ 10mm
- **R20mm1hr** Monthly count of hours when PRCP ≥ 20mm
- **Rxmm1hr** Annual count of hours when PRCP ≥ nnmm, nn is a user defined threshold

Frequency/threshold indices

- **PRCPTOT1hr** Annual total precipitation in wet hours

General indices

Lewis et al, in prep

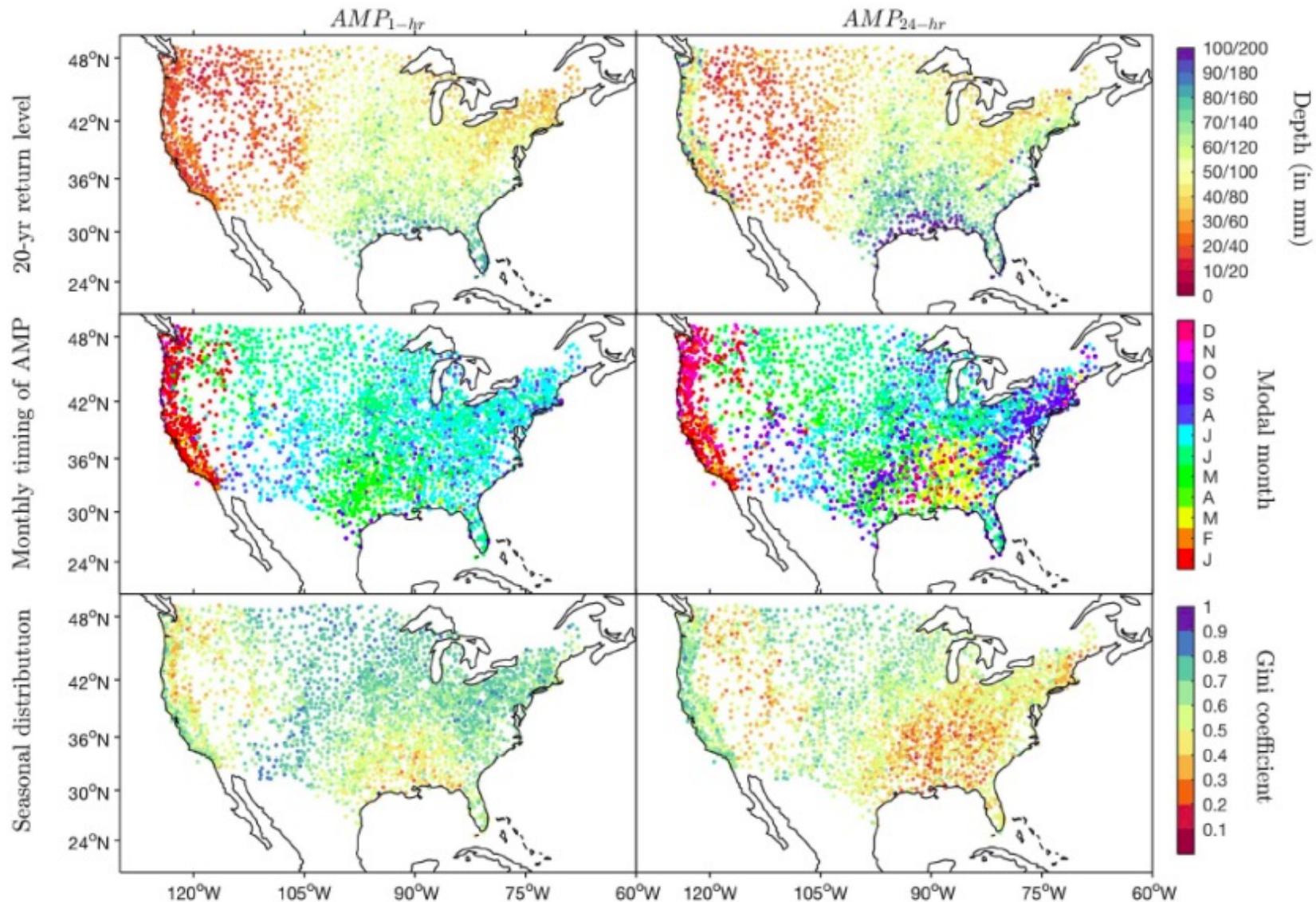# Assessing hourly rainfall climatology
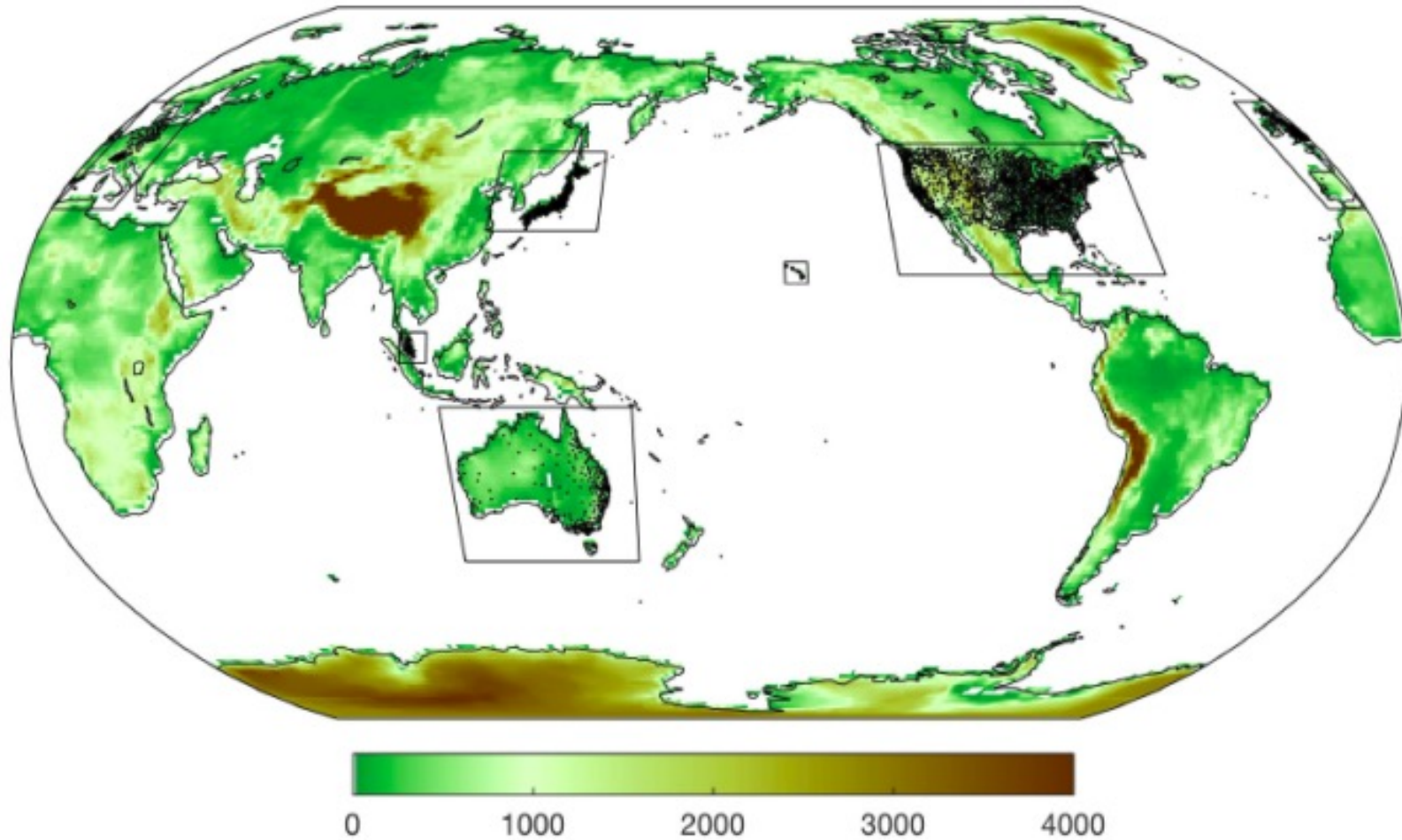
Assessing hourly rainfall climatology
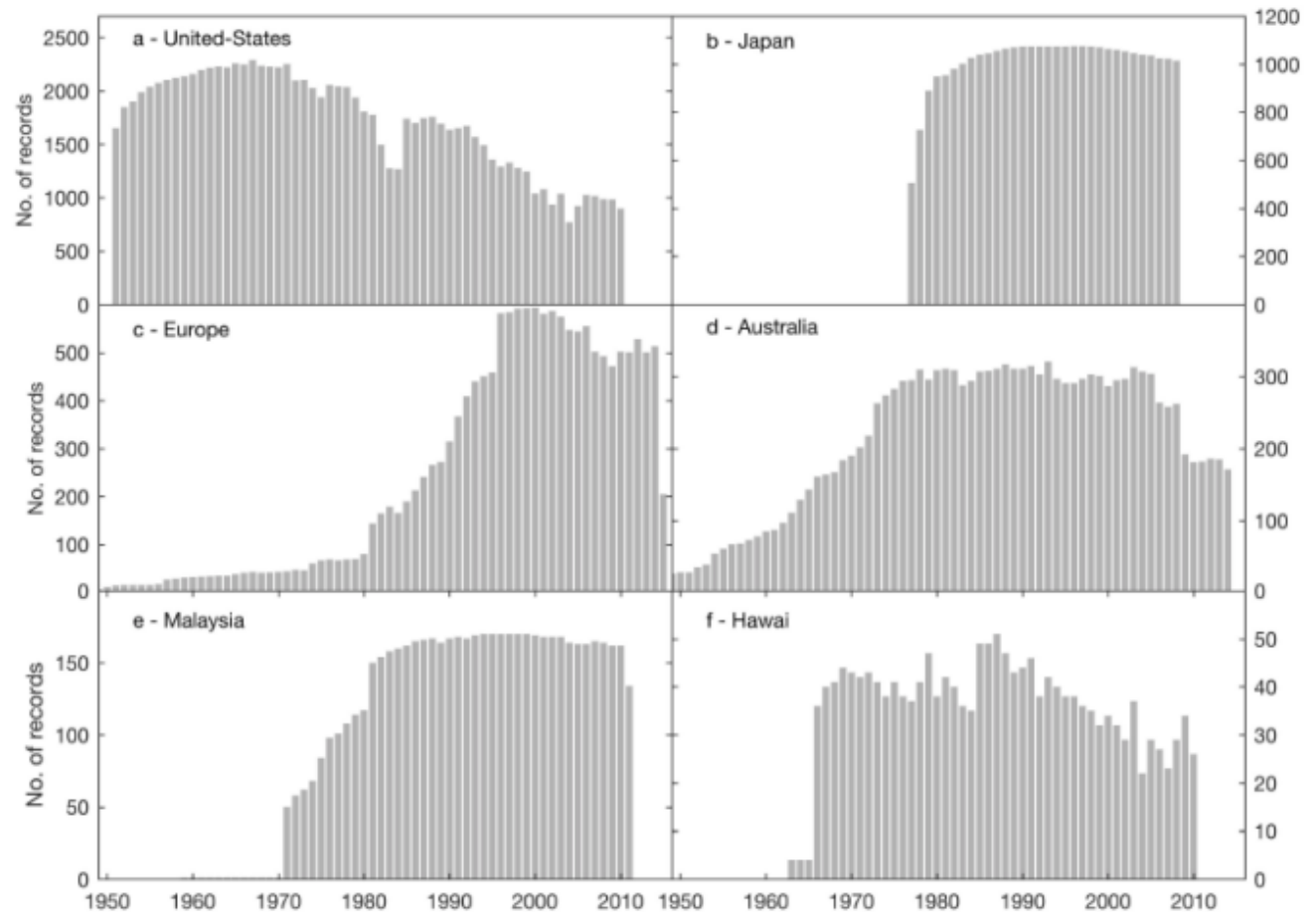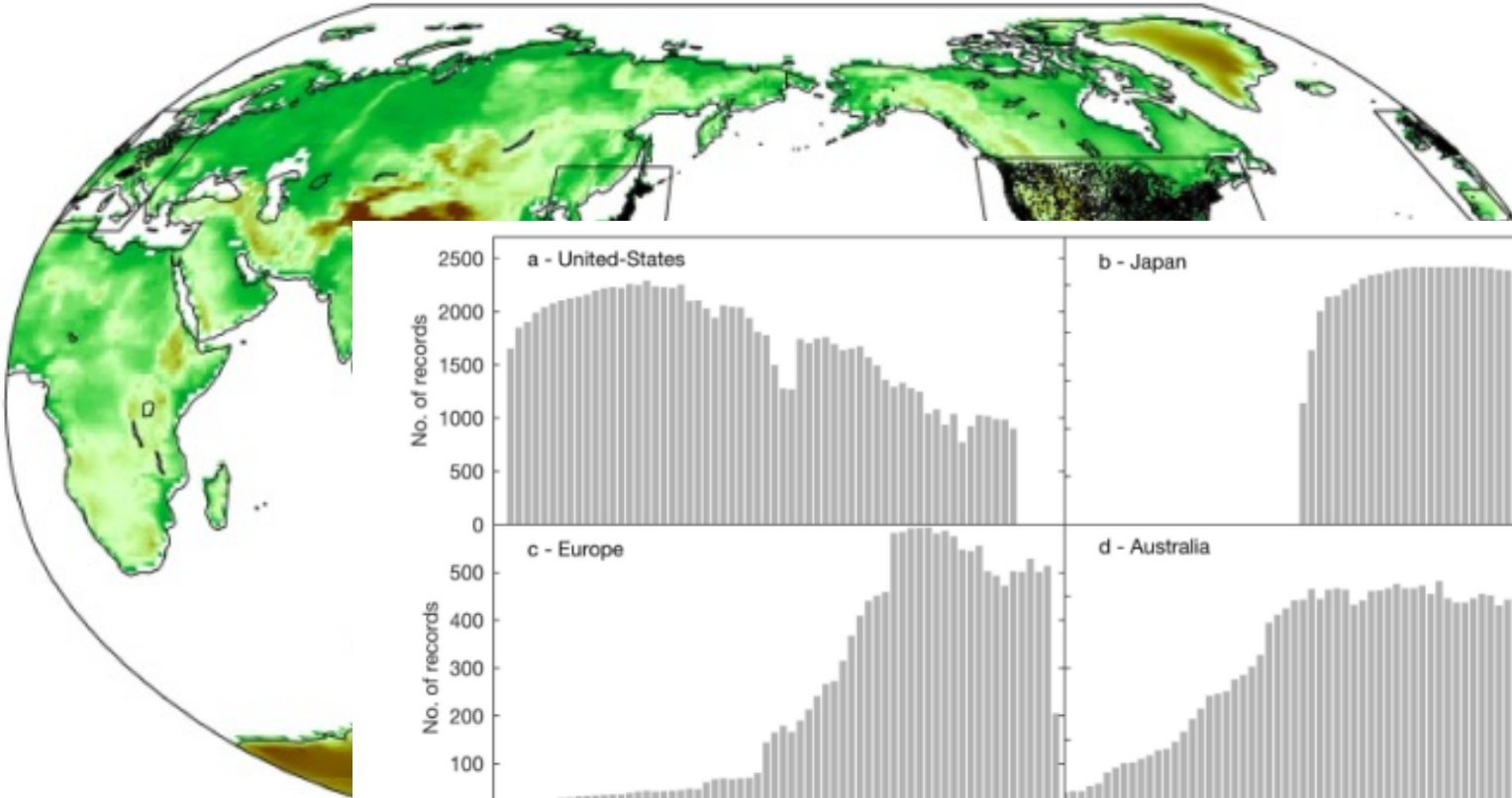
Example metrics: 20yr RL, monthly timing

Barbero et al, in prep

Example metrics: diurnal cycle
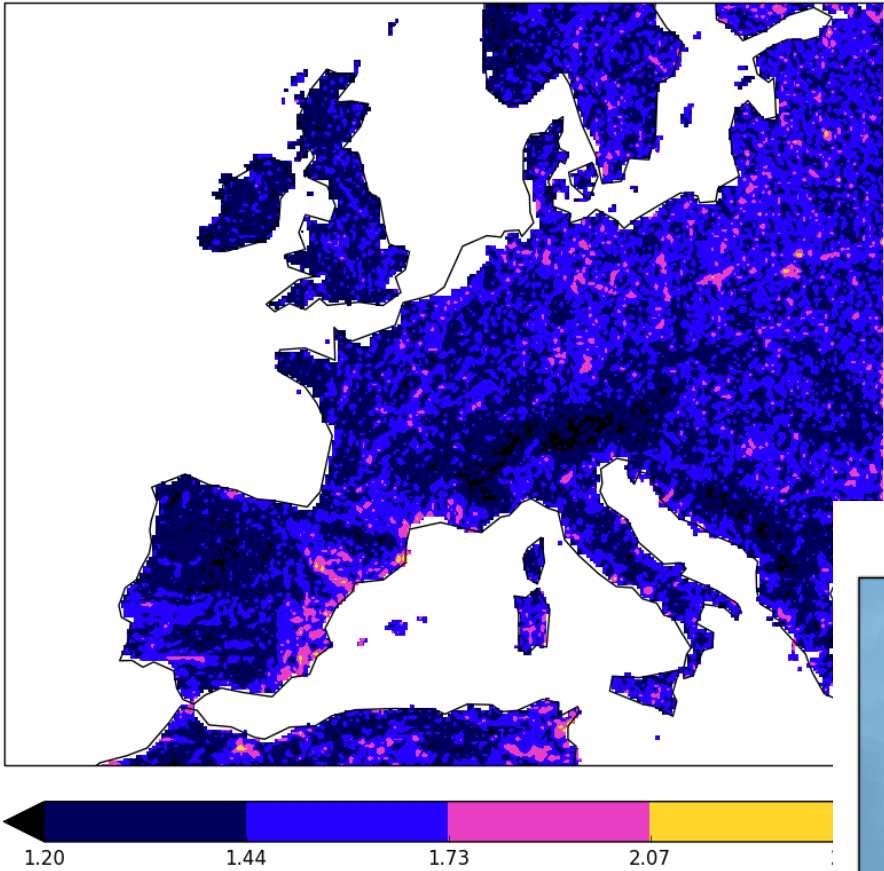

Barbero et al, in prep
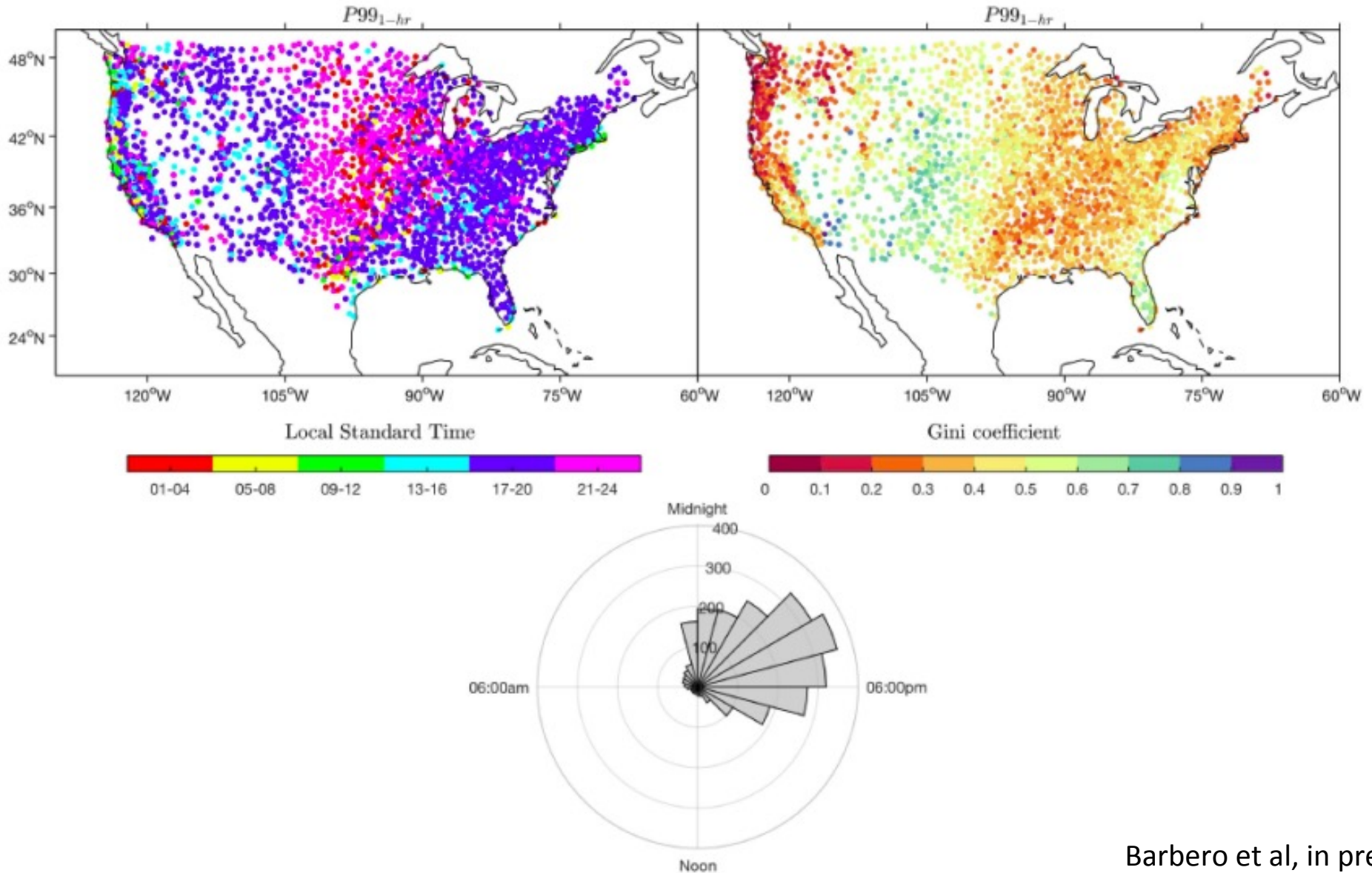
Large-scale drivers in the US
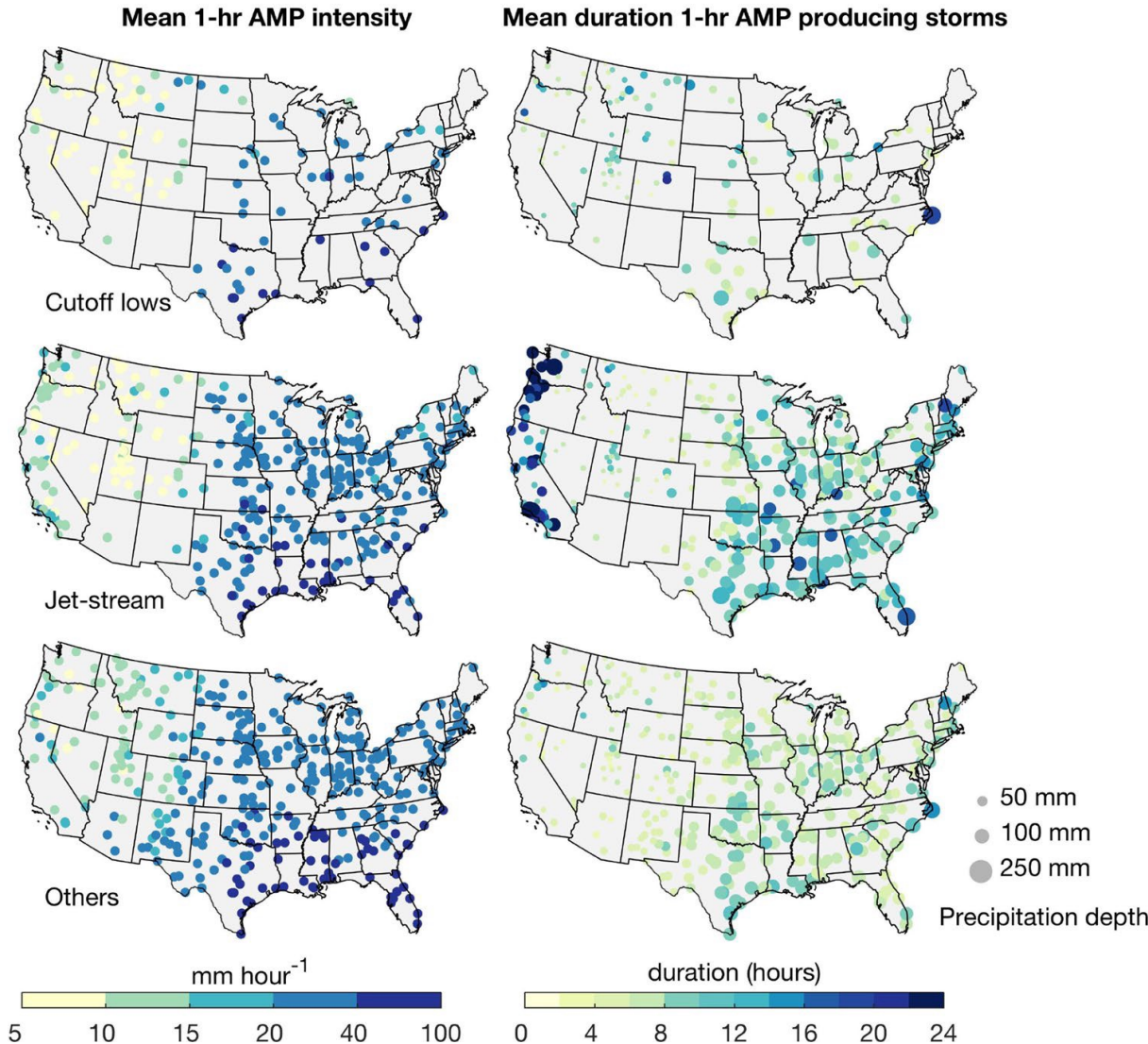
Left: mean intensity of 1-h annual maximum precipitation (AMP) attributed to cutoff lows, jet-stream and other processes.

Right: average duration (shading) and average precipitation depth (circle size) of 1-h AMP producing storms.
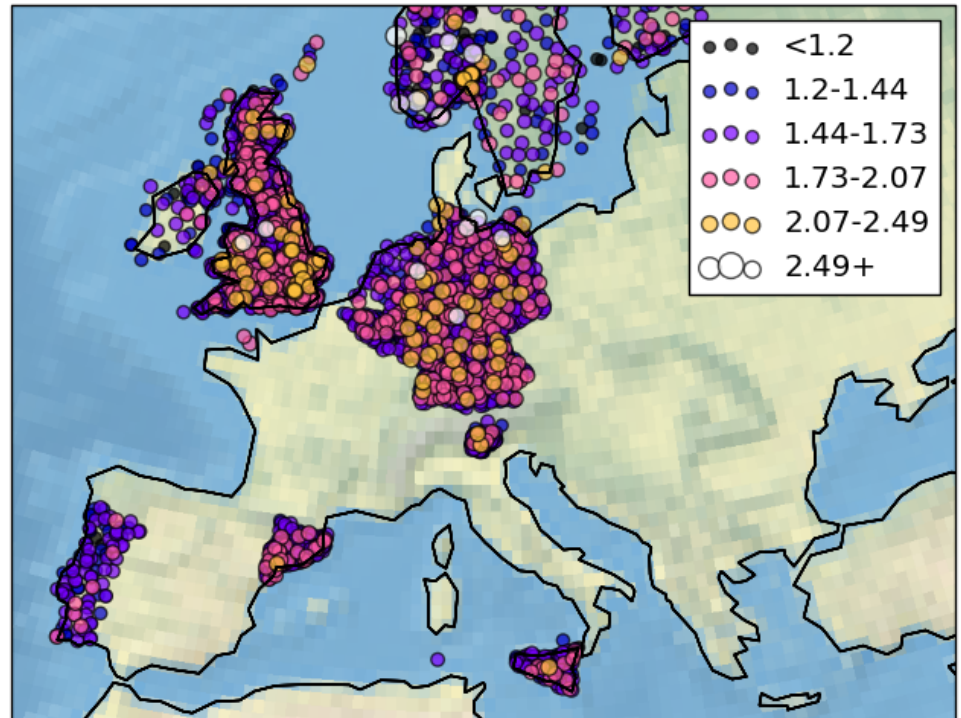
Barbero et al, 2018

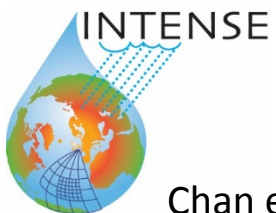z(10)/z(2); estimated from top-30 hourly events
mean = 1.439±0.192

Modelled and observed 10y growth factors from POT3 series

Hindcast has a lower 10-y growth factor for hourly extremes than the gauges
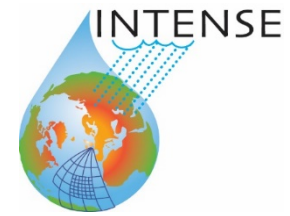

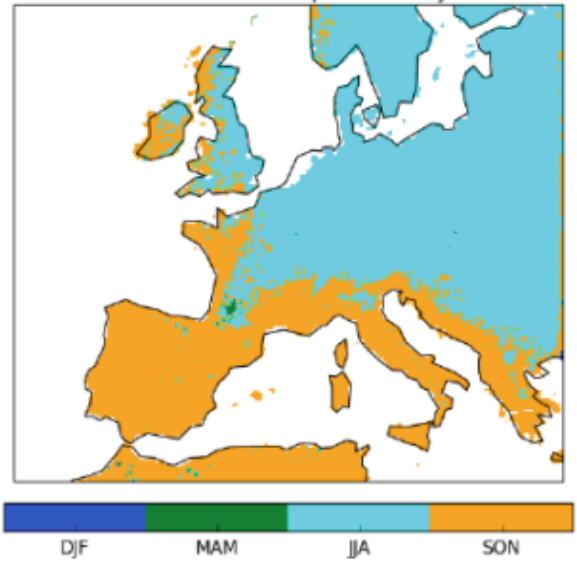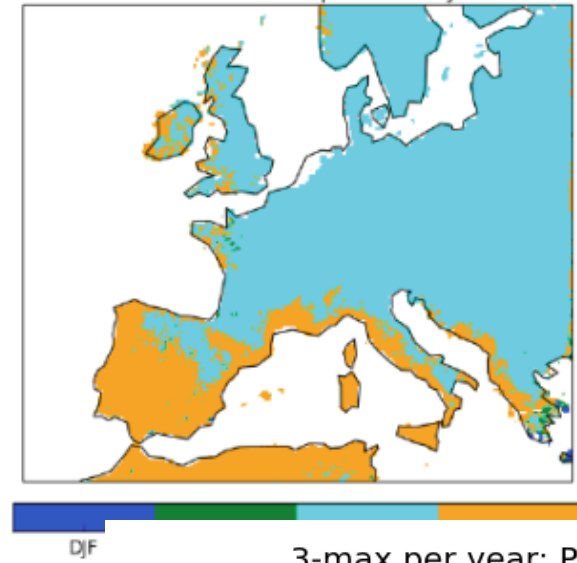3-max per year: daily max hr precip Z(10)/Z(2)
mean = 1.537±0.256

●●●	<1.2
●●●	1.2-1.44
●●●	1.44-1.73
●●●	1.73-2.07
○○○	2.07-2.49
○○○	2.49+

New results from CPM simulations

INTENSE

Chan et al, in prep

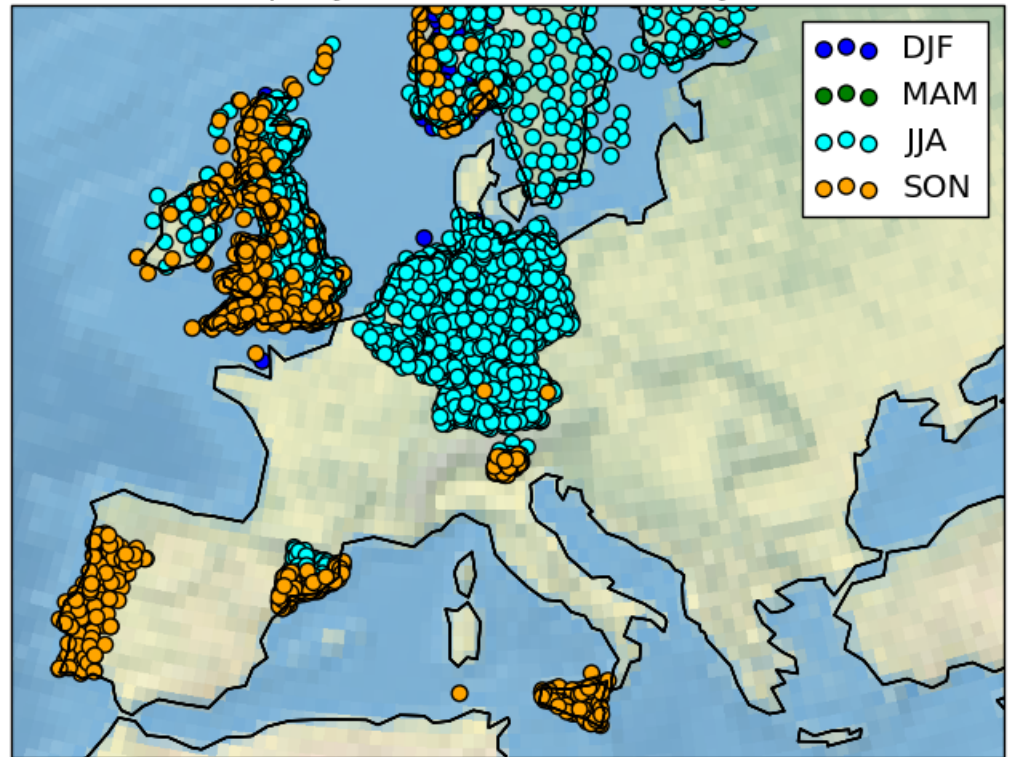UKMO Hindcast

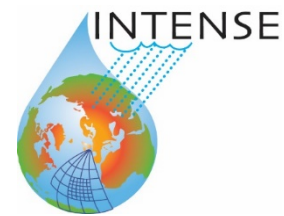
ETH Hindcast

INTENSE

DJF   MAM   JJA   SON

DJF

3-max per year: Peak Season - daily max hr

DJF
MAM
JJA
SON

Peak season for POT3 series

Hindcast seasonality matches well with that of hourly extremes from gauges

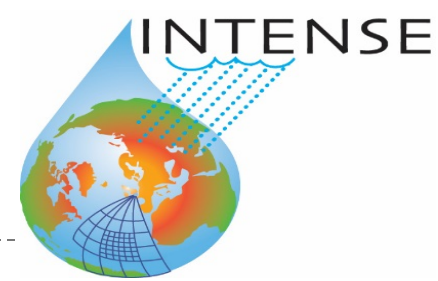New results from CPM simulations

Chan et al, in prep

Summary

We have collected a global sub-daily precipitation dataset, and applied automated quality control

- We have ~16,000 gauge records > 1yr data, ~11,000 > 10yr data

- We will develop sub-daily extreme precipitation indices at the station-level and gridded indices to be hosted on the DWD and CLIMDEX websites (end 2018)

- We will develop a set of climate model evaluation metrics/indices for assessment of high resolution simulations (end 2018) and satellite data products

- We are testing model evaluation metrics using European-scale simulations but happy to provide metrics to additional modelling groups for testing and use in model evaluation.

- DWD will host the hourly gauge data (most not public) and an associated website with metadata (in progress).

There is great potential for further analysis and development of scientific studies using this new dataset

INTENSE planned activities

Database

- Work with DWD to develop website for hosting indices; explore provision of data to Copernicus
- Release of common QC code

Research

- Global scale analysis of extreme precipitation-temperature relationship
- Global scale analysis of trends in sub-daily extreme precipitation
- Intensity-Duration-Frequency (IDF) curves generation for global datasets
- Develop common analyses of model outputs and observed indices for model evaluation
- First efforts to explore sub-hourly in situ and satellite observations
- Concentration of analysis in Tropics and comparison to CPM model outputs
- Further analysis and separation of large-scale and thermodynamic drivers influence

Meetings

- Discussion meeting proposal at Royal Society submitted