Quantifying changes in observed precipitation distributions globally

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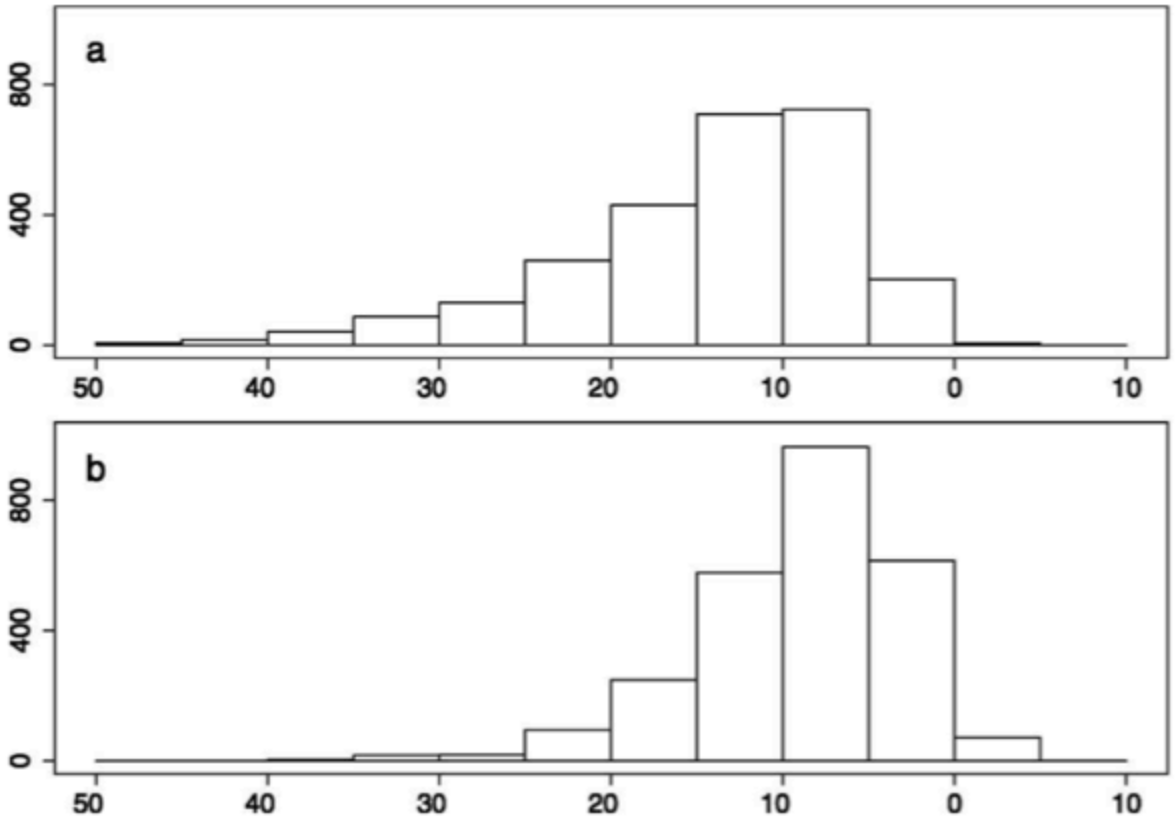
Motivation

- IPCC AR5 concluded:
  - There are *likely* more areas with increases in heavy precipitation events than decreases
  - … records show mixed and insignificant trends in global means

? Are the extremes increasing at the cost of fewer light events or does intensification happen throughout the distribution?

! We need to analyse PDFs of daily rainfall

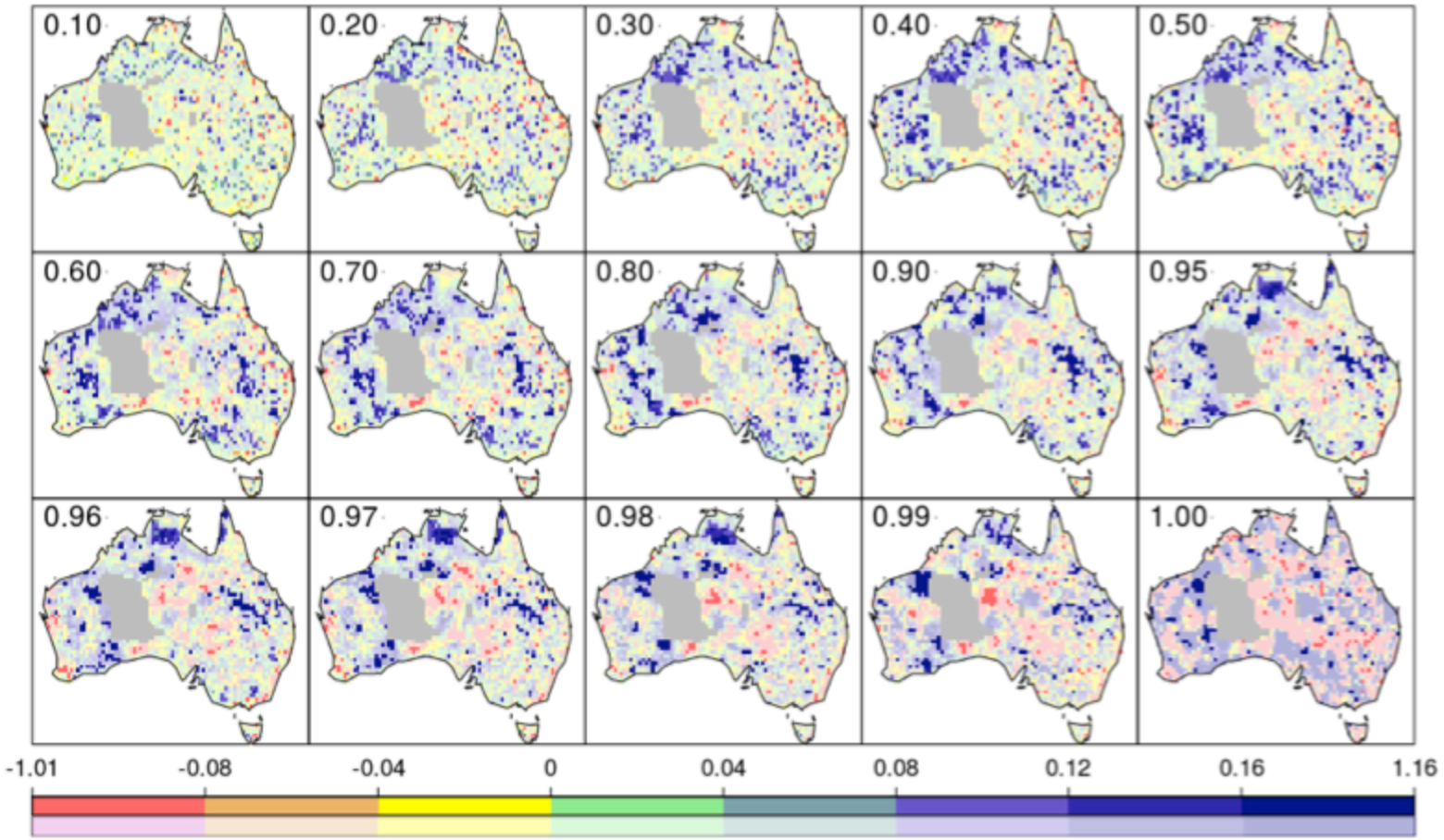
Analysing PDF changes based on quantile comparison



Histograms of two DJF daily minimum temperature distributions (°C)

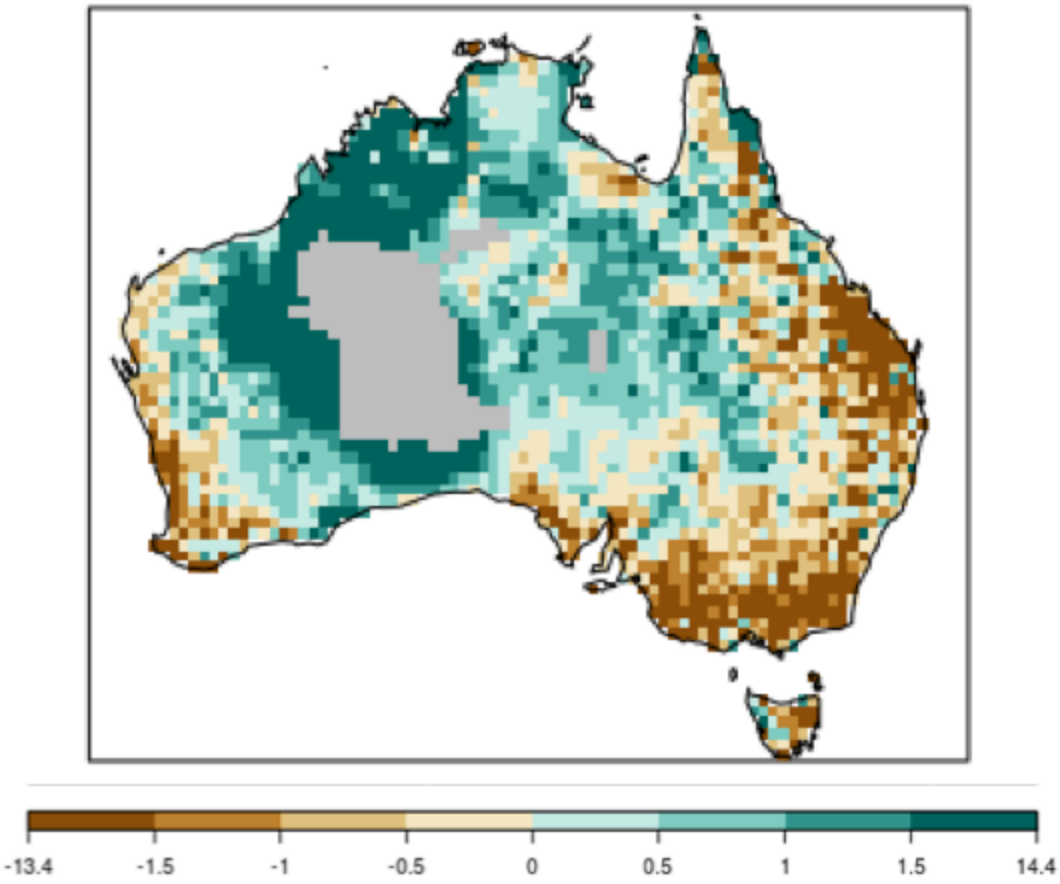
Ferro, C.A.T., Hannachi, A. & Stephenson, D.B., "Simple Nonparametric Techniques for Exploring Changing Probability Distributions of Weather". (2005) *Journal of Climate*, 18(21), pp.4344–4354.

Relative change in quantiles between 1958 – 1985 and 1986 – 2013



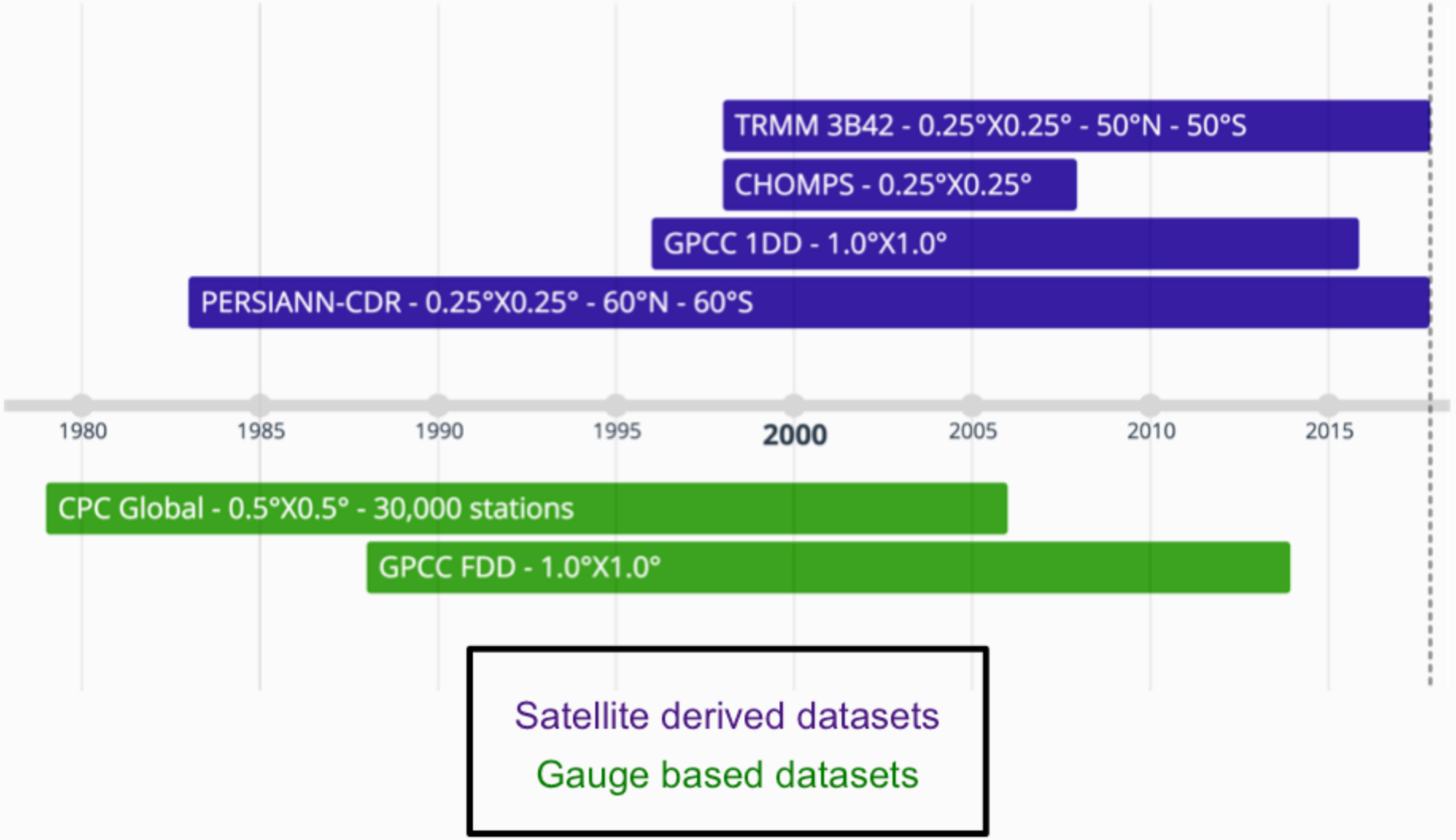
Contractor S, Markus G Donat, Lisa V Alexander, "Intensification of the daily wet day rainfall distribution across Australia". (2018) *Geophysical Research Letters,* Under Review

Changes in number of wet days between 1958 - 1985 and 1986 - 2013



Contractor S, Markus G Donat, Lisa V Alexander, “Intensification of the daily wet day rainfall distribution across Australia”. (2018) *Geophysical Research Letters,* Under Review

Timeline of existing datasets



REGEN

Rainfall Estimates on a GriddEd Network

A global gridded dataset of daily precipitation

1950 - 2013 daily precipitation

Global land coverage

1.0° grid resolution

Three Data Sources

- GHCN-Daily 103,631 stations
- GPCC ~100,000 stations
- Other ~1000 stations

Automated Quality Control

Basic integrity checks

- Checks for repetition
- Checks for duplication between time periods
- World record exceedance checks

Automated Quality Control

Outlier checks

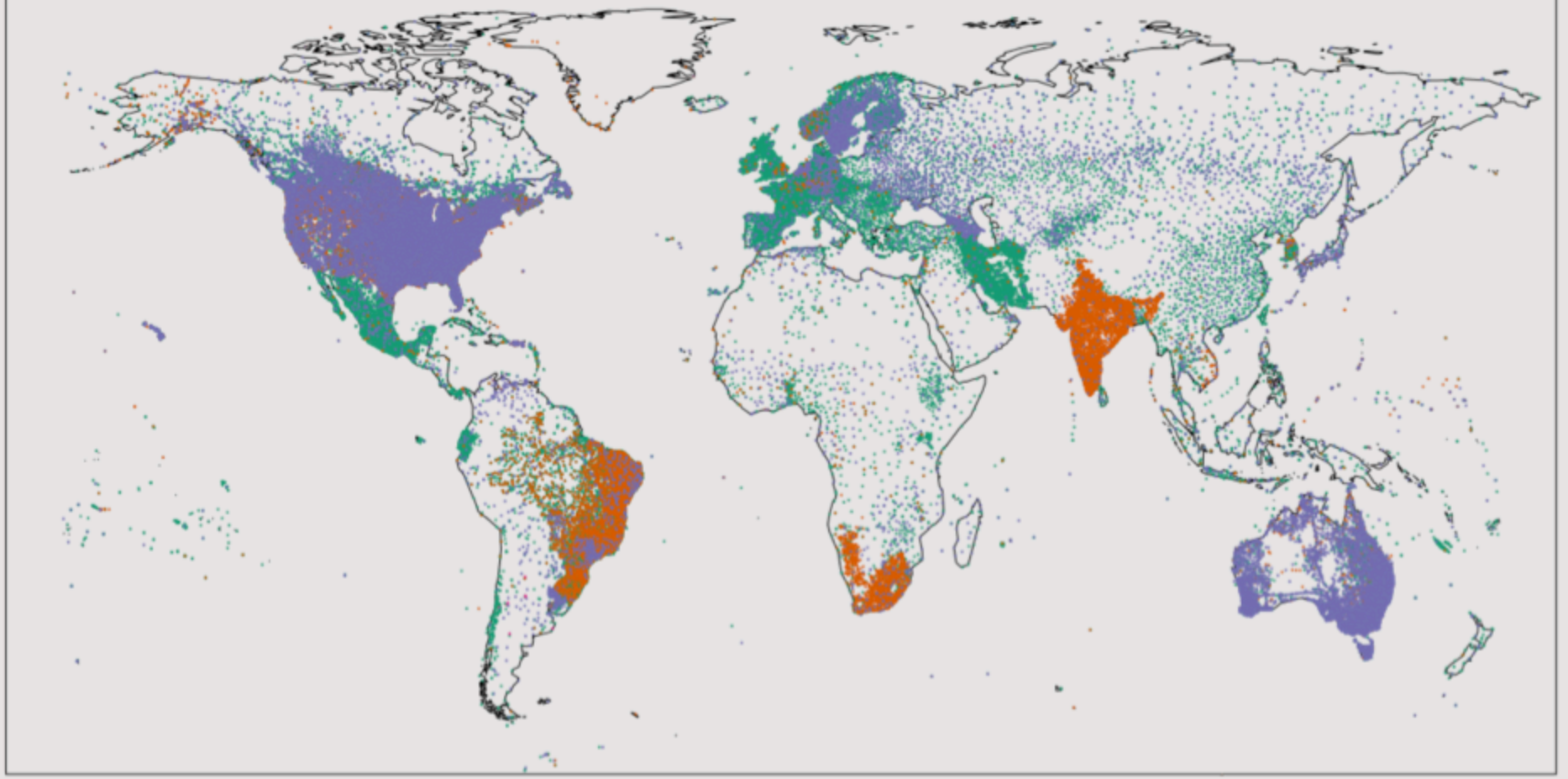
- Gap checks in distribution tails
- Climatological outlier checks

Automated Quality Control

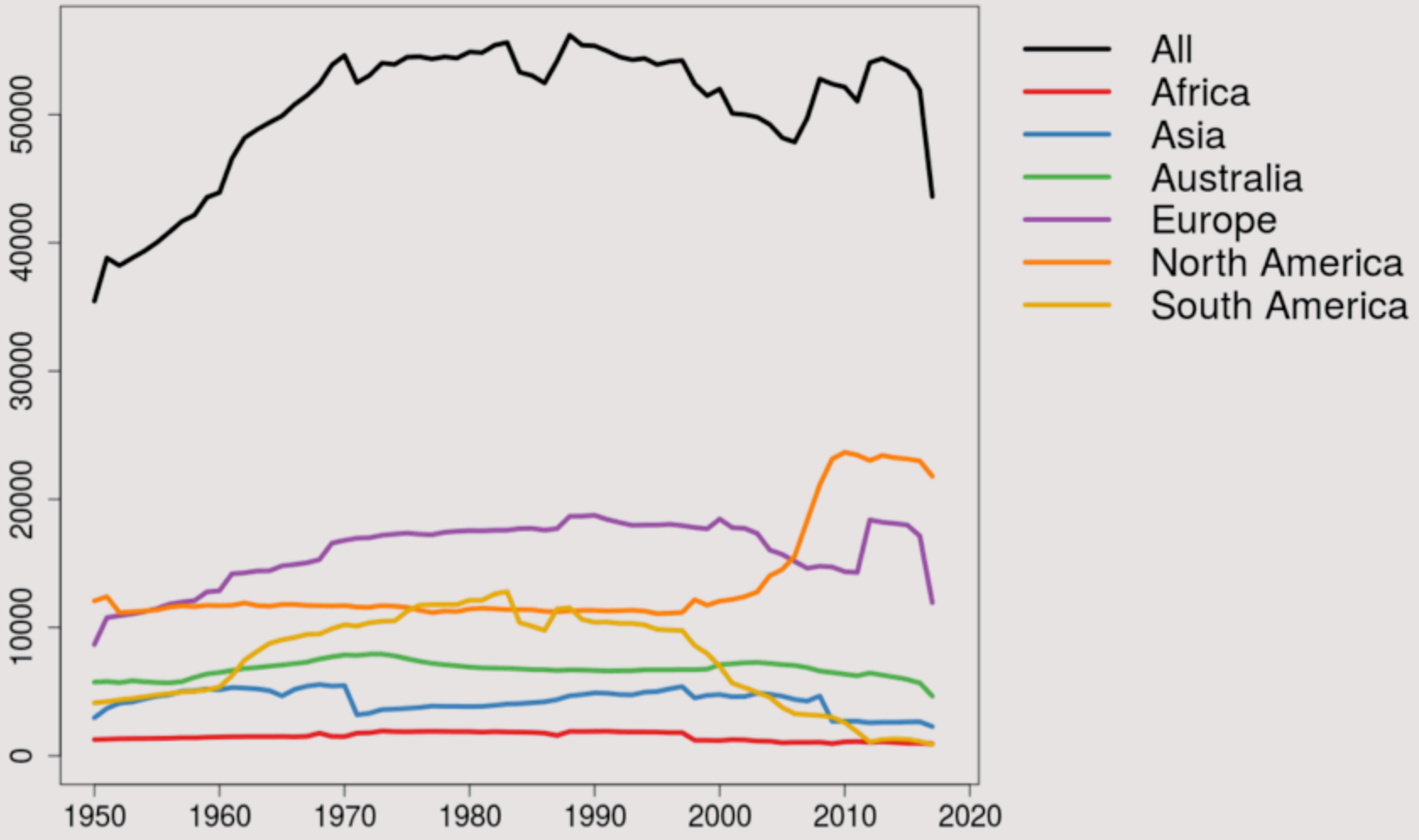
Spatial consistency checks

- Spatial regression checks
- Spatial corroboration checks

135,142 station between 1950 and 2013



Number of Stations by Region



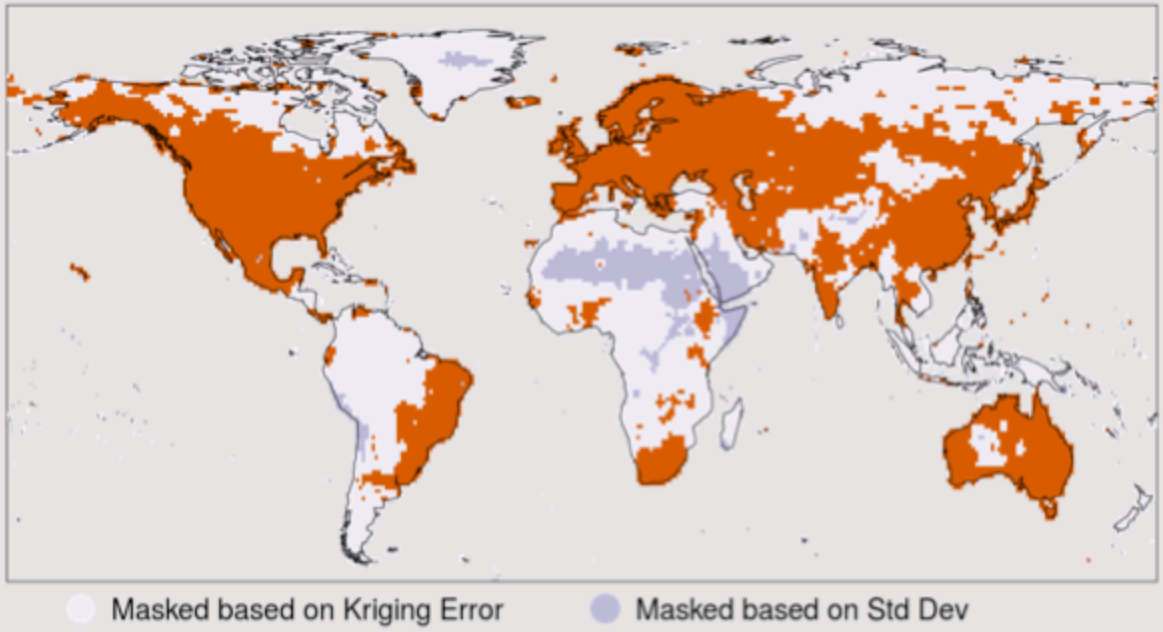
We provide:

- Daily precipitation per grid

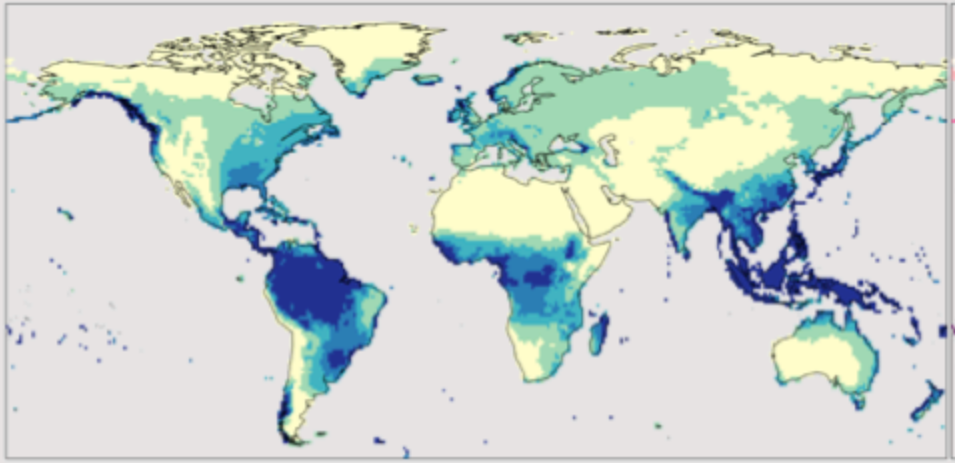
AND

Uncertainty Information:

- Standard deviation per grid
- Kriging error
- Number of stations per grid
- Data quality mask

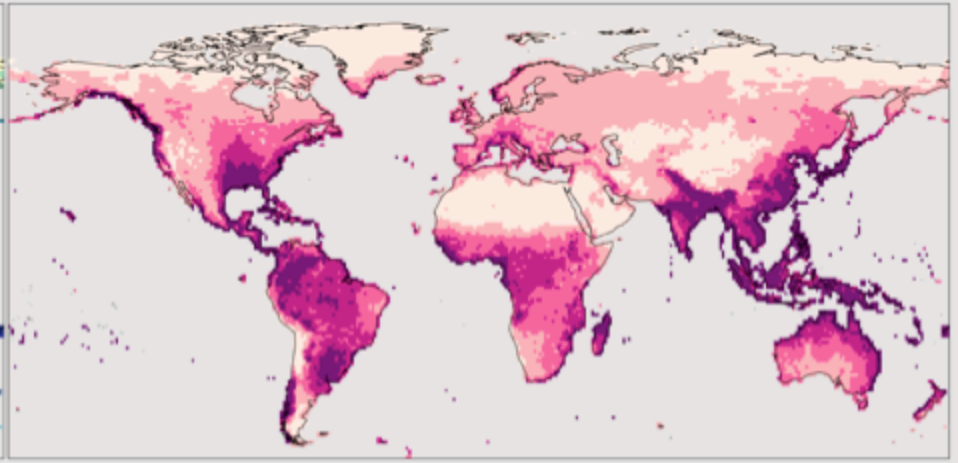


Annual precipitation totals and RX1DAY



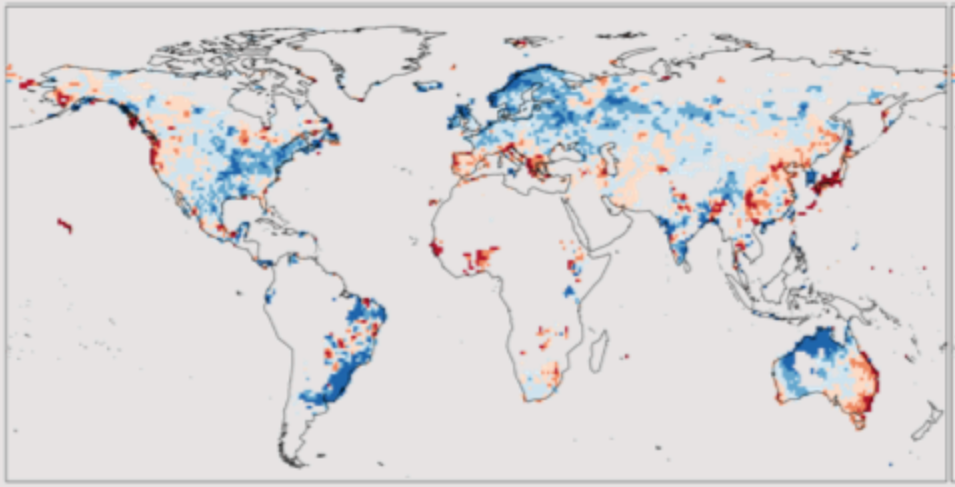
REGEN V1.1 Average total annual precipitation 1950-2013 (mm/year)

0 400 800 1200 1600



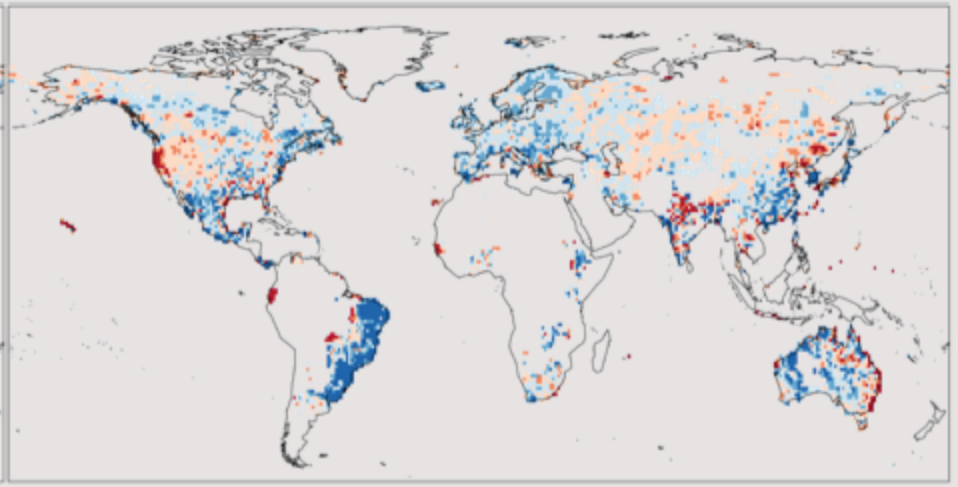
REGEN V1.1 Average annual maximum precipitation 1950-2013 (mm/year)

0 15 30 45 60



REGEN V1.1 annual total precipitation trends 1950-2013 (mm/year)

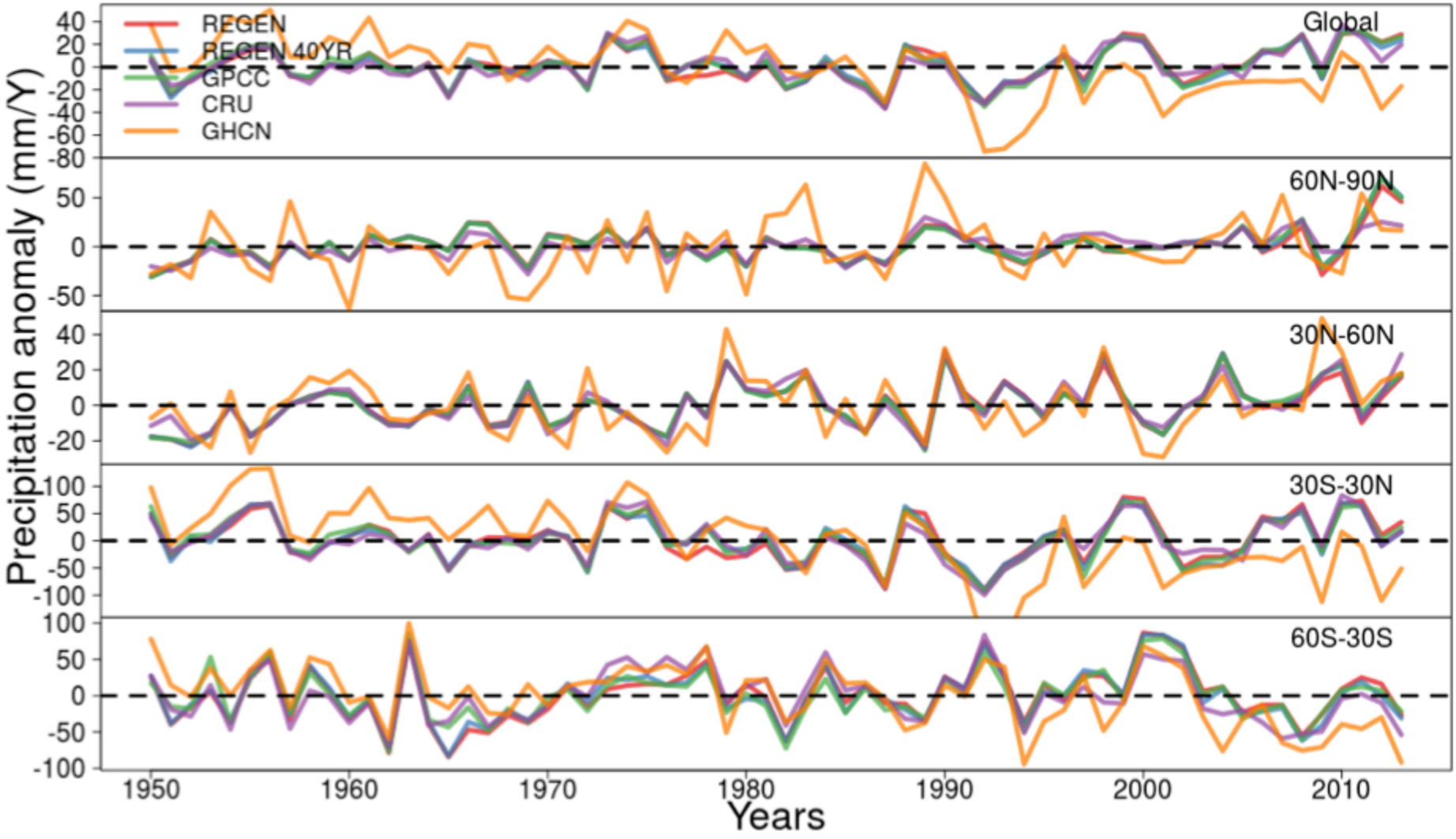
-2 -1 0 1 2



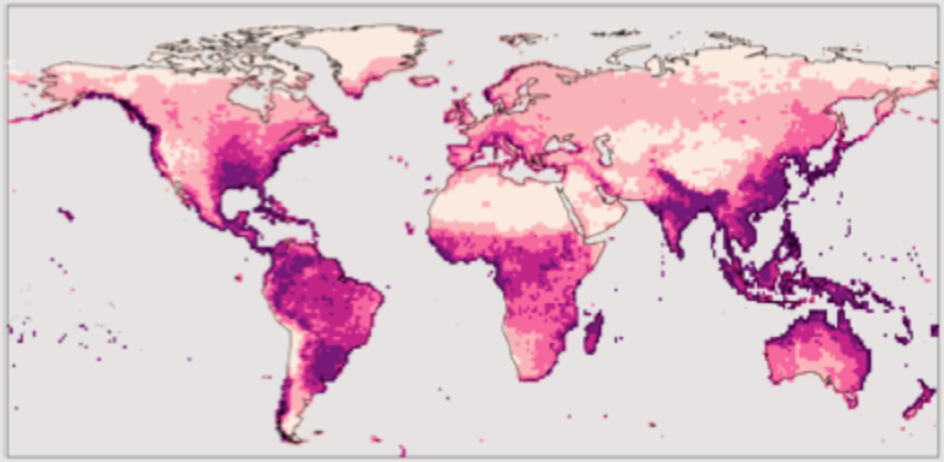
REGEN V1.1 annual maximum precipitation trends 1950-2013 (mm/year)

-0.2 -0.1 0 0.1 0.2

Comparison with monthly datasets

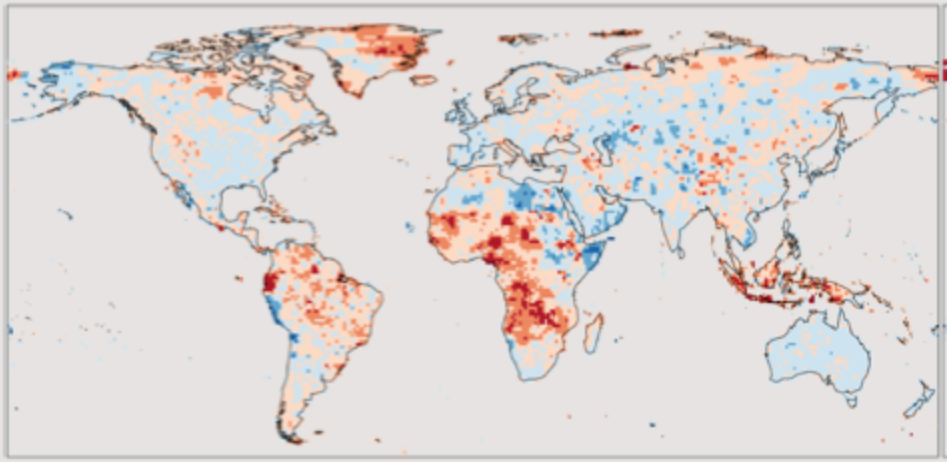


Comparison with daily global datasets



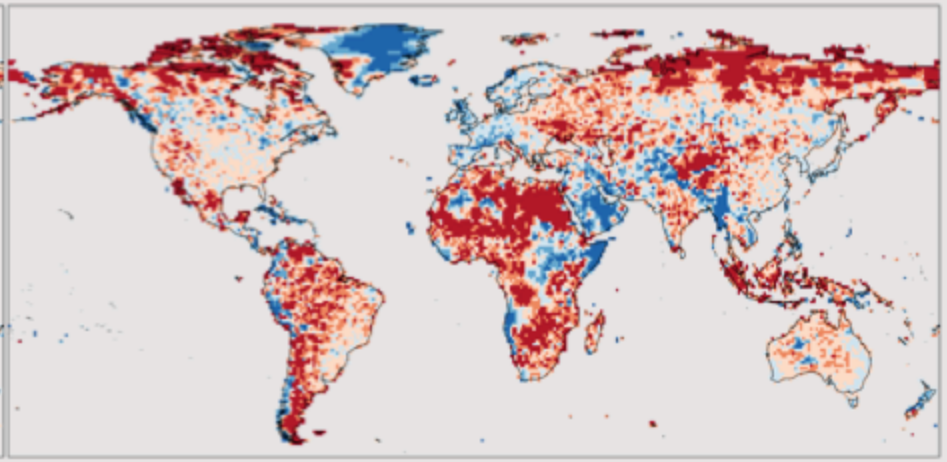
REGEN V1.1 Averaged annual maximum precipitation 1988-2013 (mm/year)

0 15 30 45 60



Percentage diff between REGEN and GPCC-FDD Avg max prcp 1988-2013

-30% -15% 0% 15% 30%



Percentage diff between REGEN and CPC_Glb Avg max prcp 1988-2013

-30% -15% 0% 15% 30%

Conclusion

- We present REGEN – a global dataset of daily precipitation from 1950 to 2013
- Provides uncertainty information and mask based on data quality for better confidence in extremes analysis
- Compares well with existing high quality datasets on various temporal scales and across various regions
- Next steps: quantify changes in entire distribution of daily precipitation including extremes across global locations

Thank You

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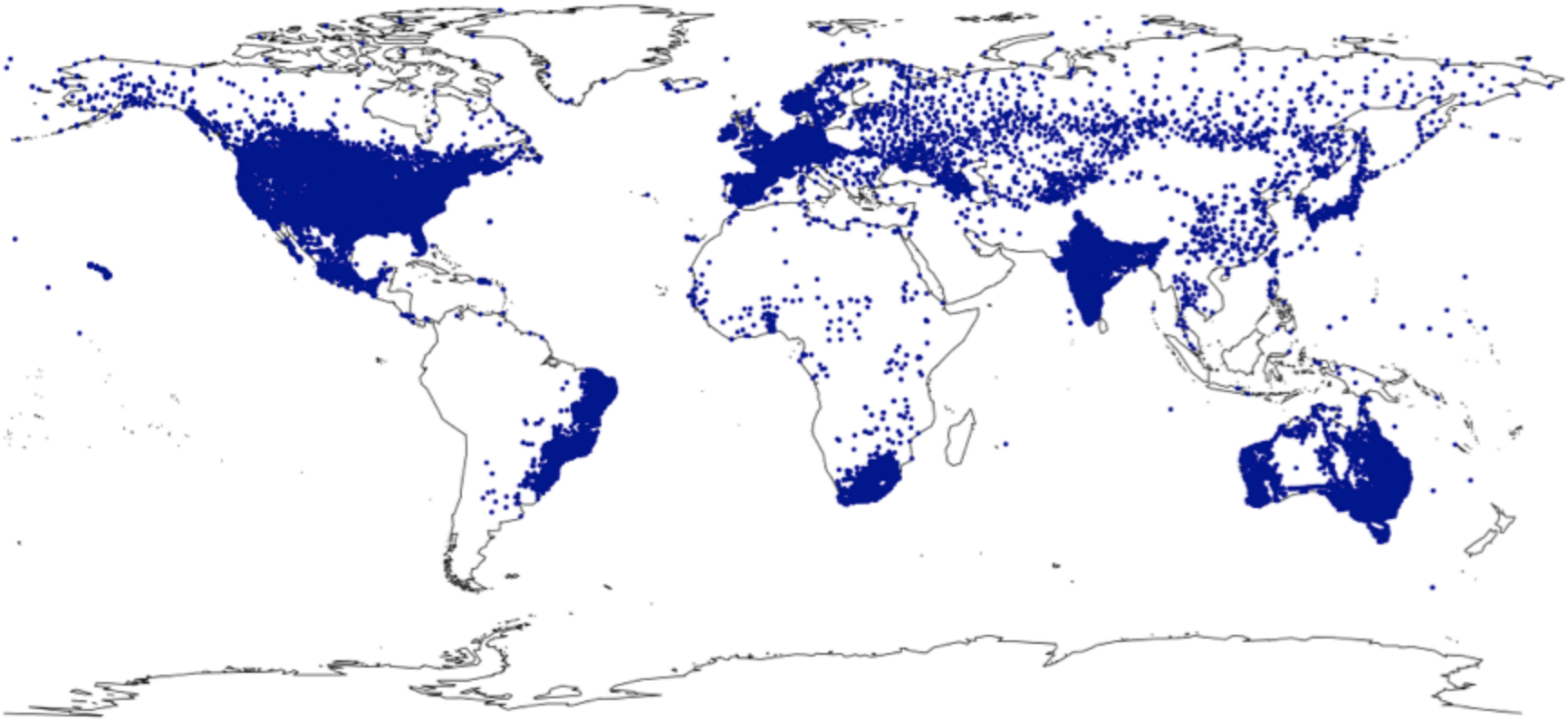
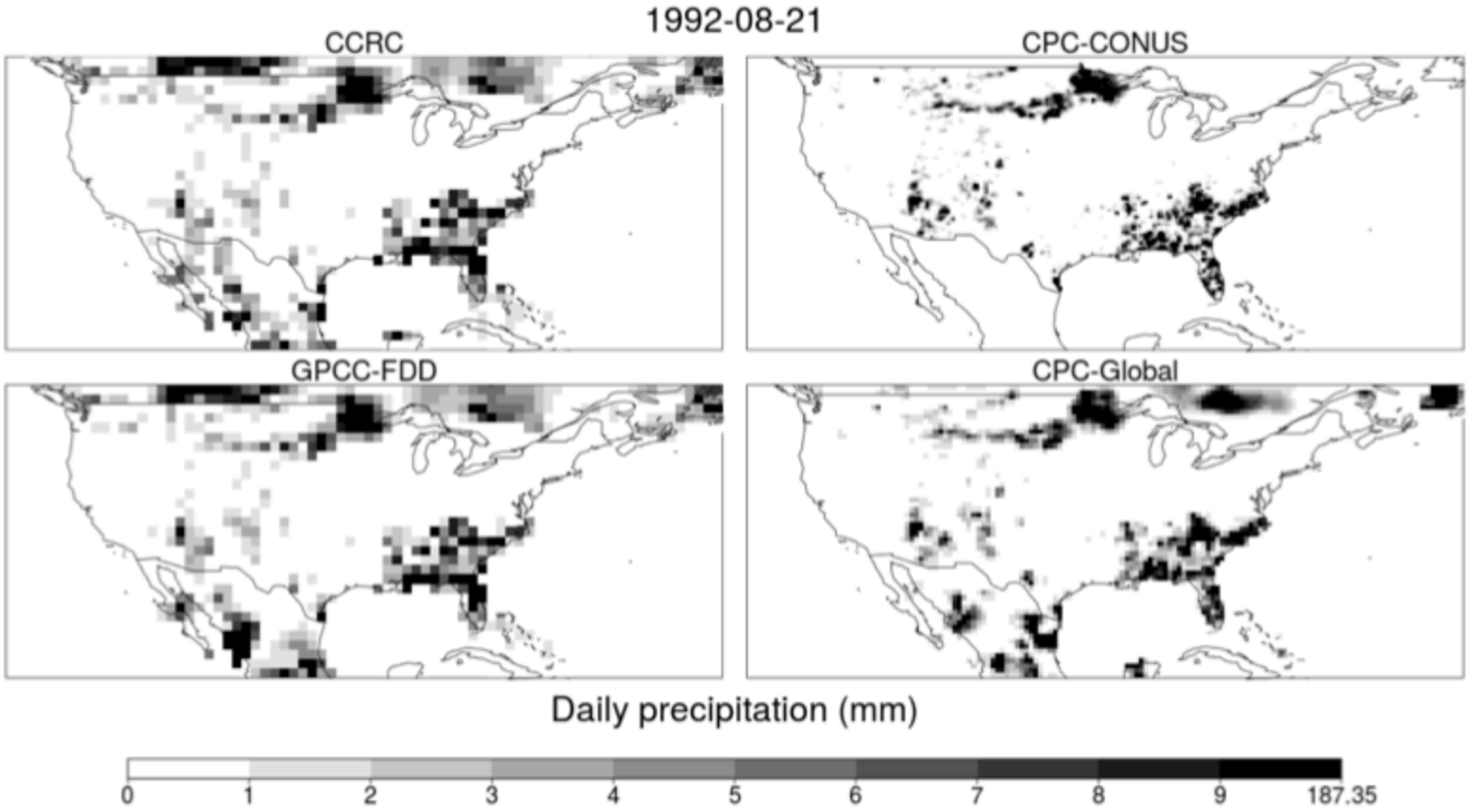
Comparison with regional datasets

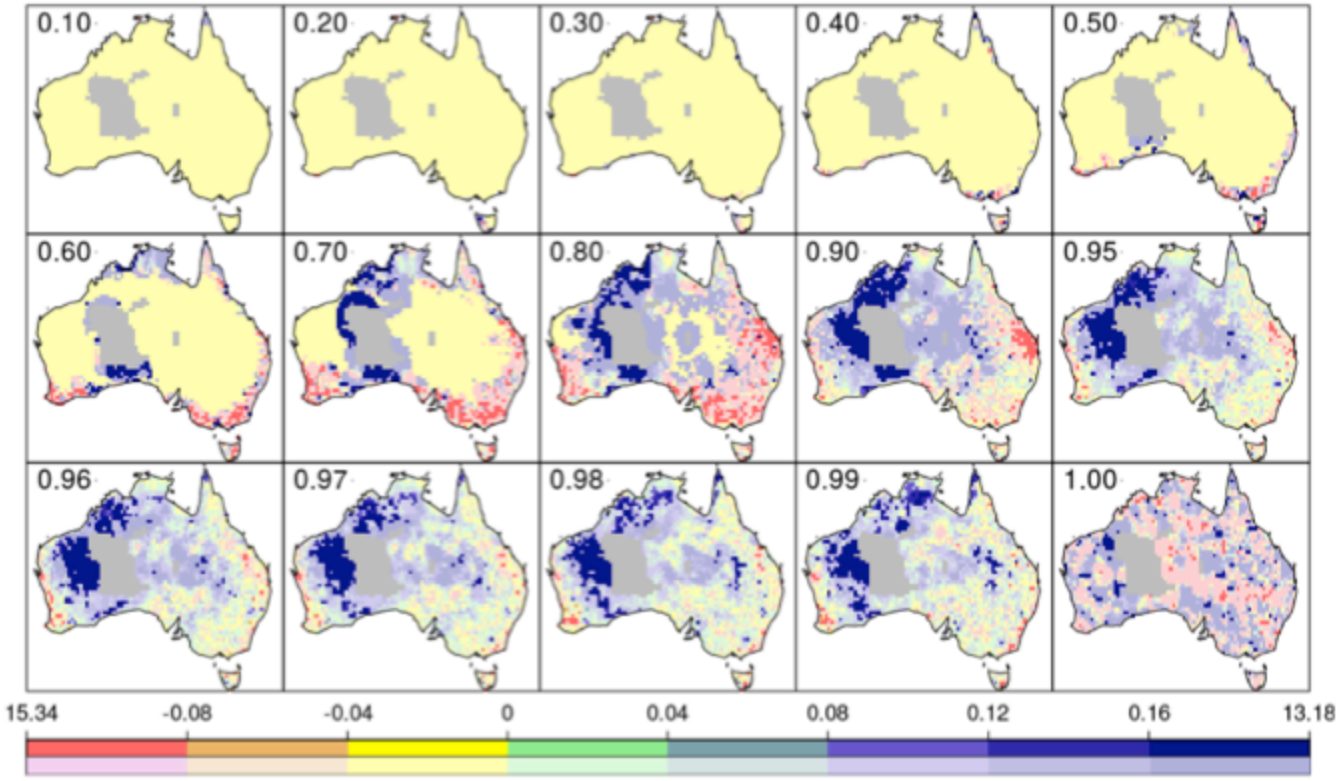
1950



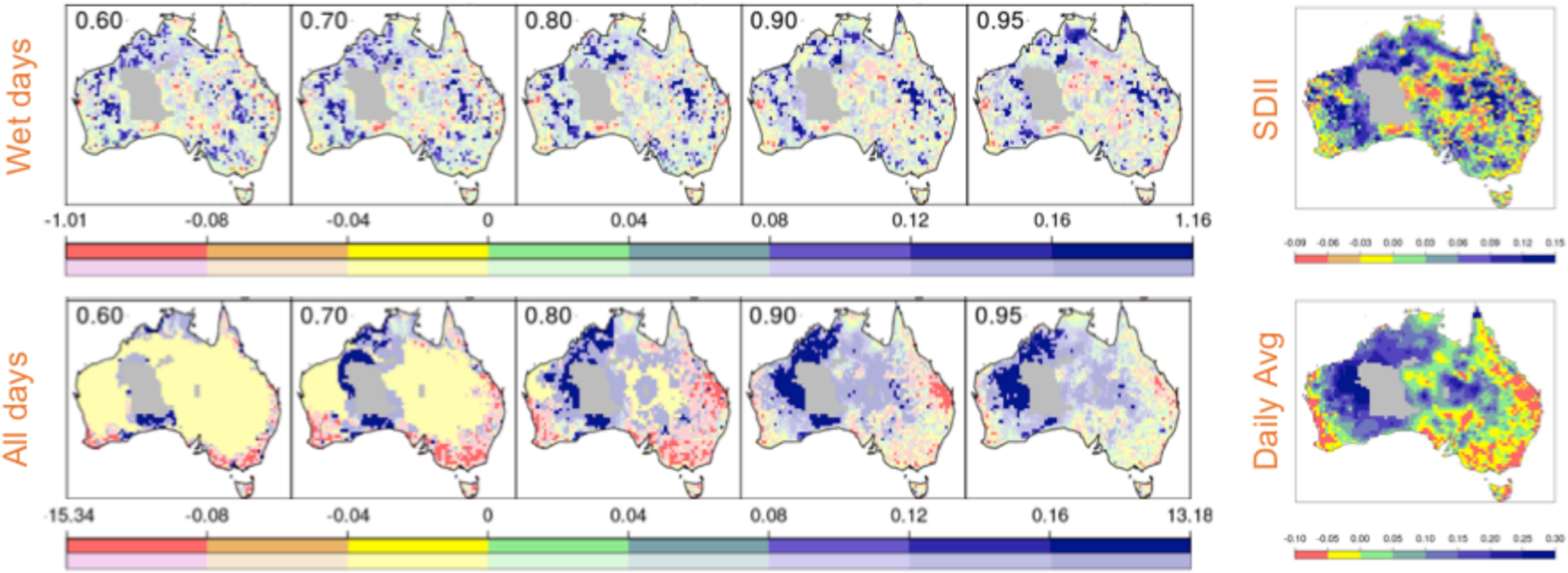
Hurricane Andrew Aug 1992



All day quantile changes



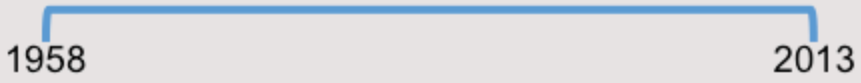
Wet day and all day quantile change vs SDII and Daily Average



Application to Australia (under review)

Application to Australia

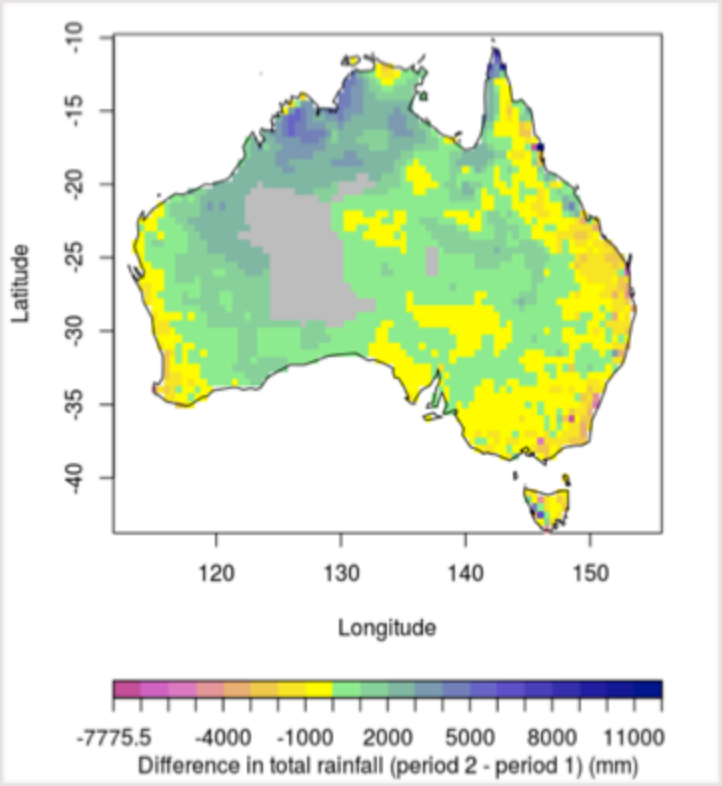
- Gridded daily rainfall data



Application to Australia

- Gridded daily rainfall data

Changes in total rainfall between 1958 - 1985 and 1986 - 2013



Yellow/pink grids indicate decreases whereas green/blue grids indicate increases. The grey shading in the centre indicates areas that were masked out.

Key Points

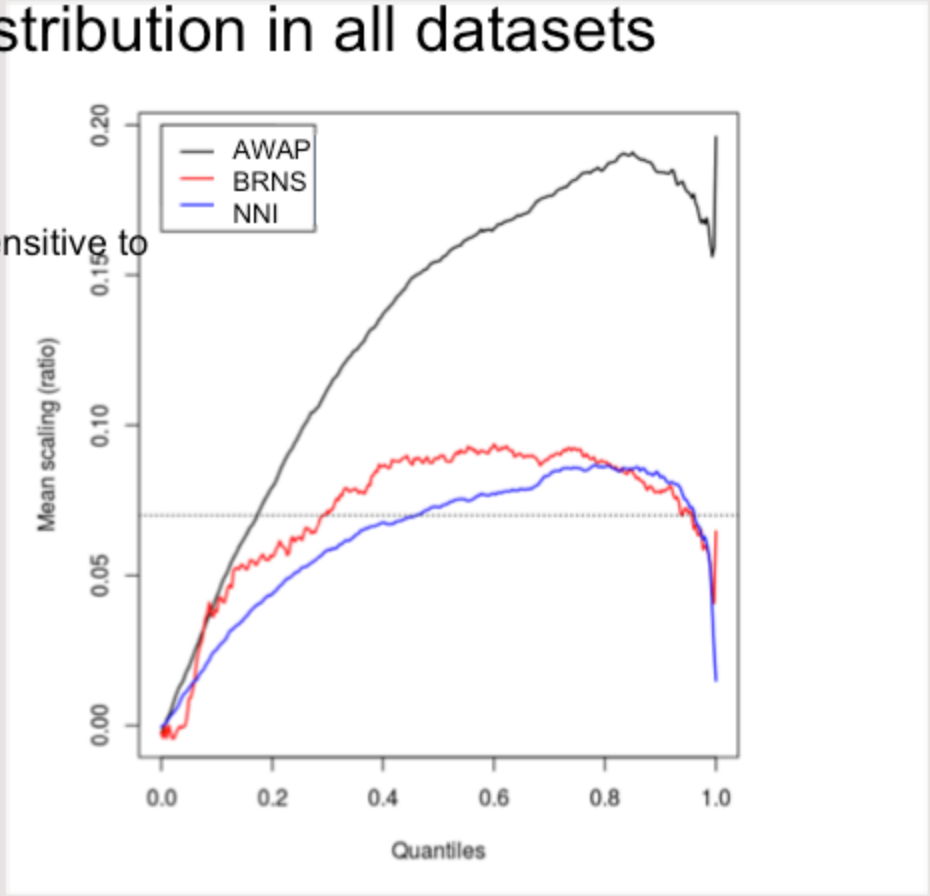
- We investigated changes to the **entire probability distribution** of daily rainfall across Australia from 1958 to 2013.

- Wet day **rainfall has intensified** throughout the distribution and exhibits a homogeneous spatial pattern of intensification.

- Changes in total rainfall are related to **changes in frequency but not intensity** in wet days.

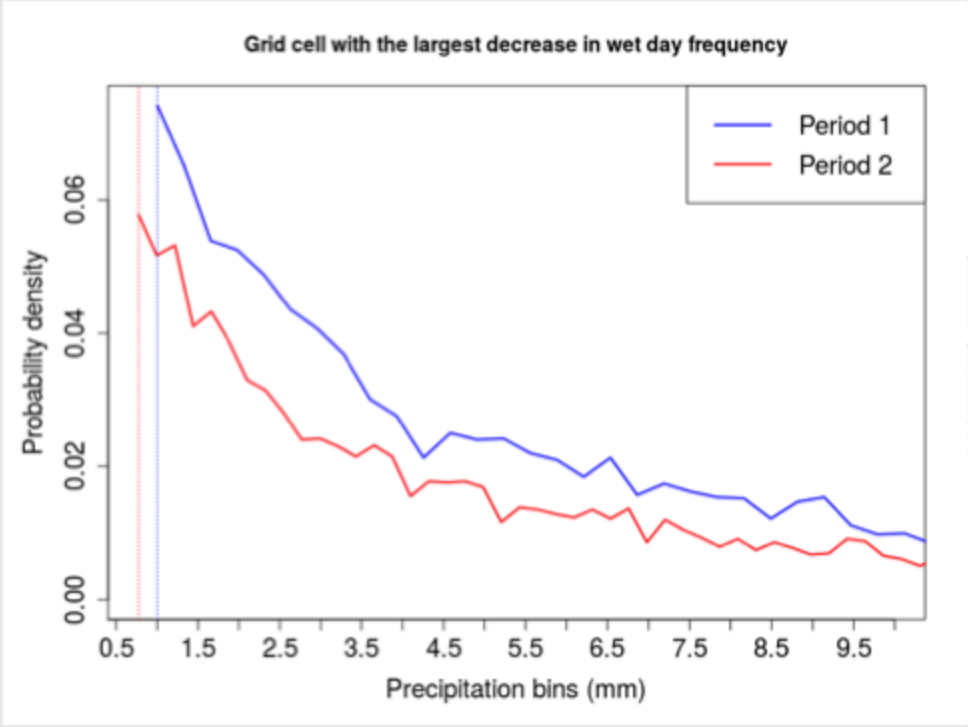
Intensification throughout the distribution in all datasets

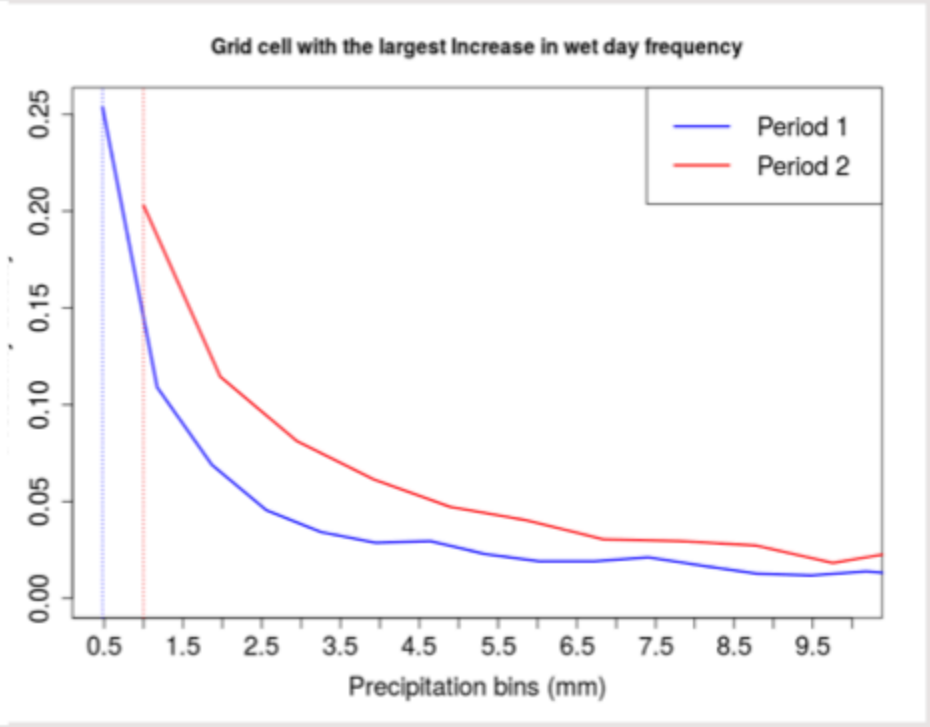
However, amount of intensification sensitive to underlying station network



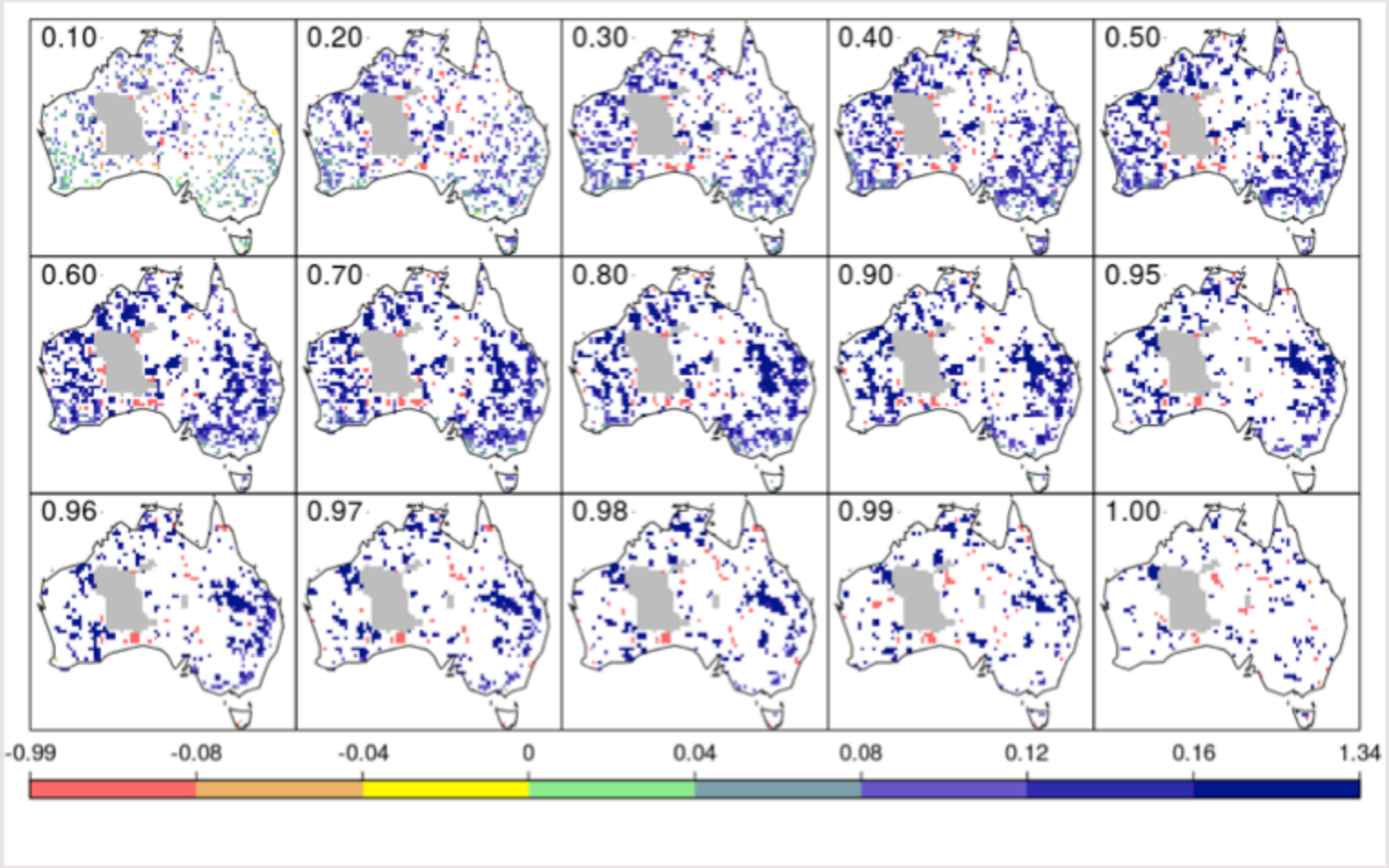
The dotted horizontal line represents a rough estimate of the expected C-C scaling (7%). All grids including non significant were used for the scaling calculation. Black, blue and red colours refer to AWAP, Barnes and Natural Neighbour Interpolation data respectively.

PDFs of distributions of all day quantiles restricted to wet days

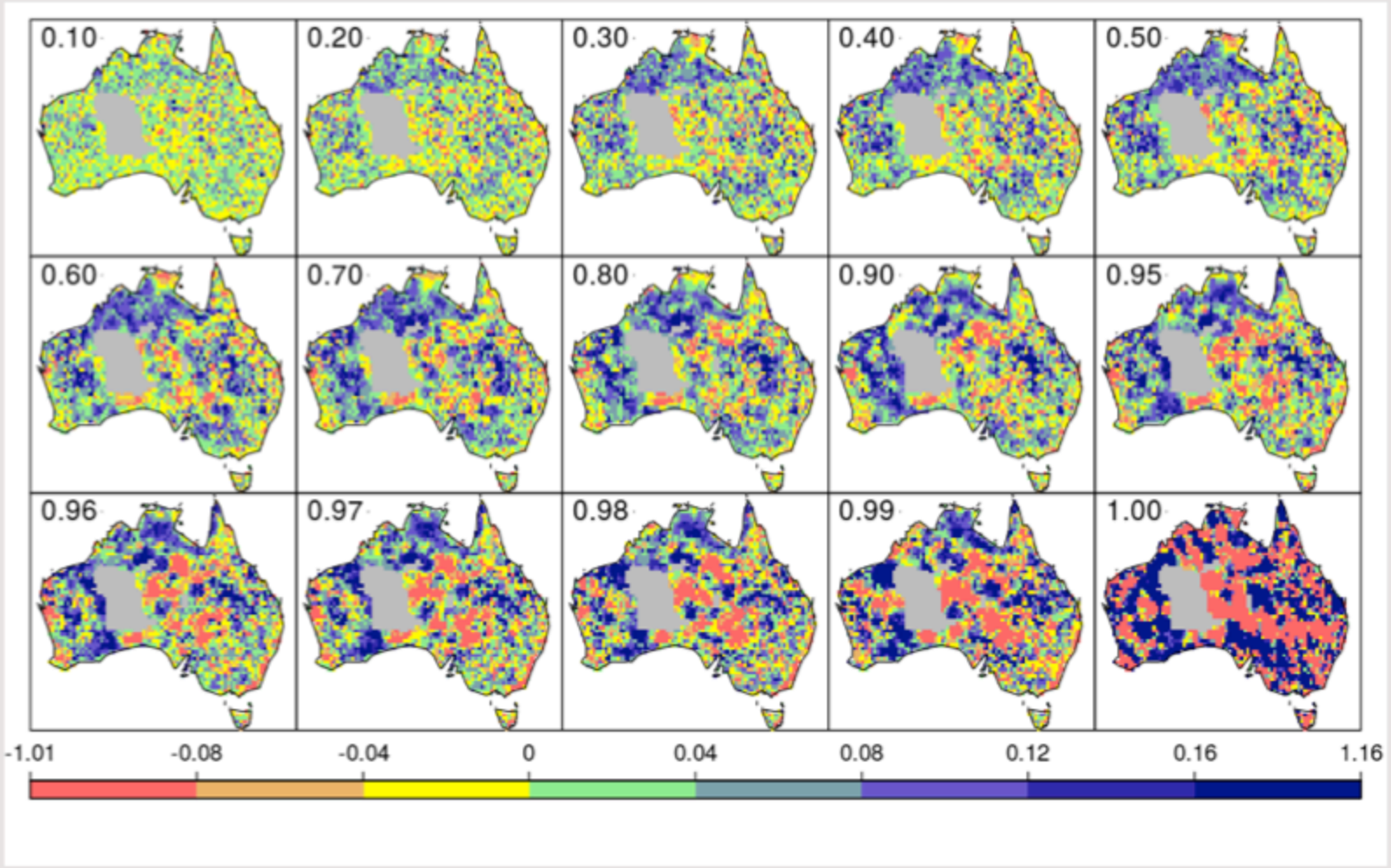




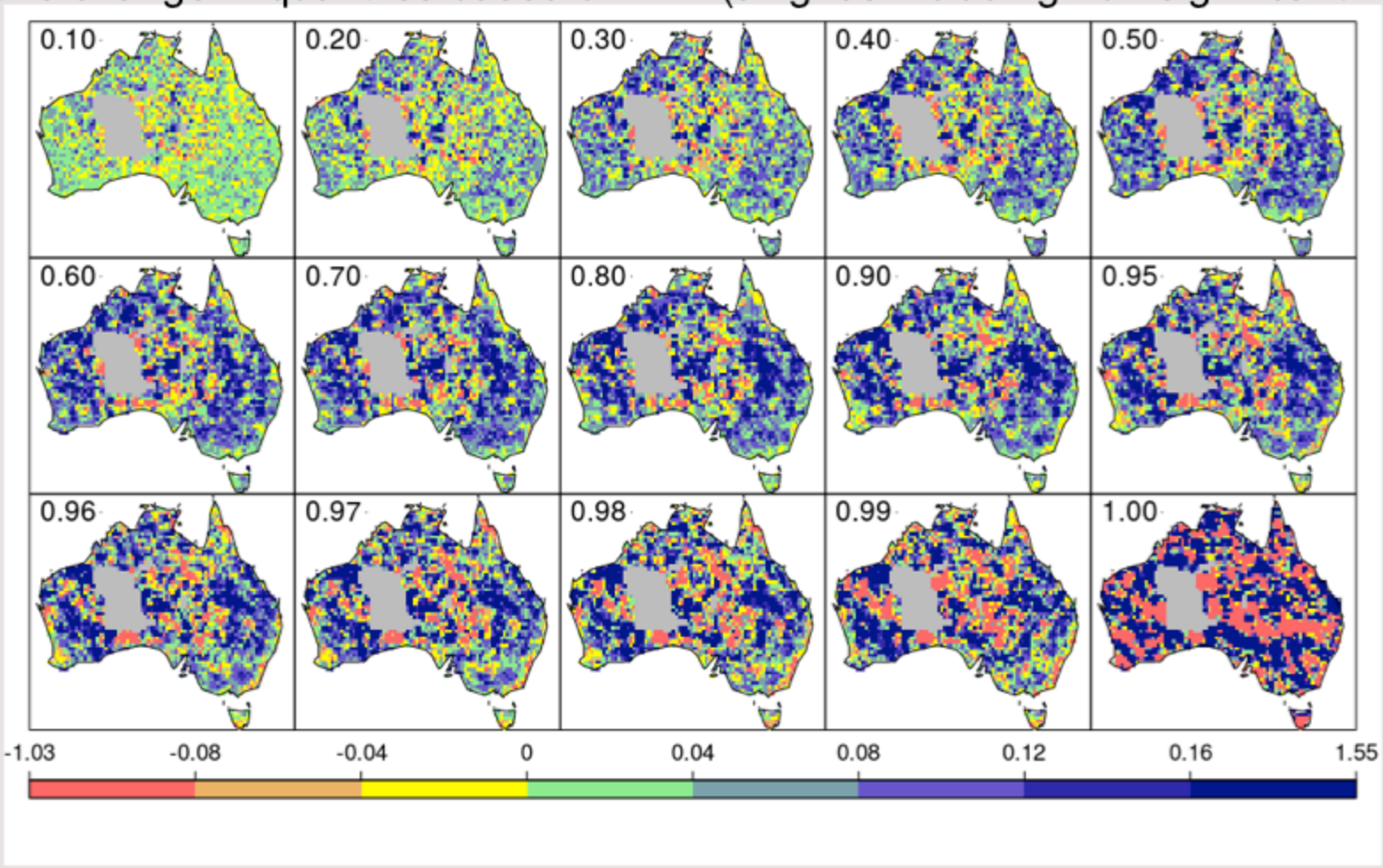
Relative change in quantiles based on AWAP



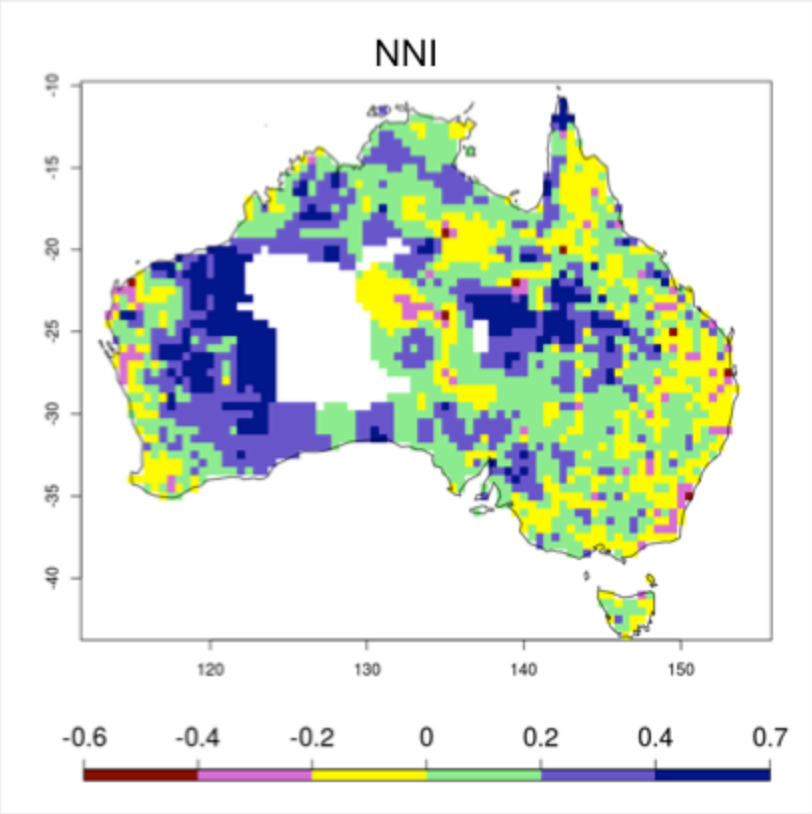
Relative change in quantiles based on AWAP (all grids including non-significant

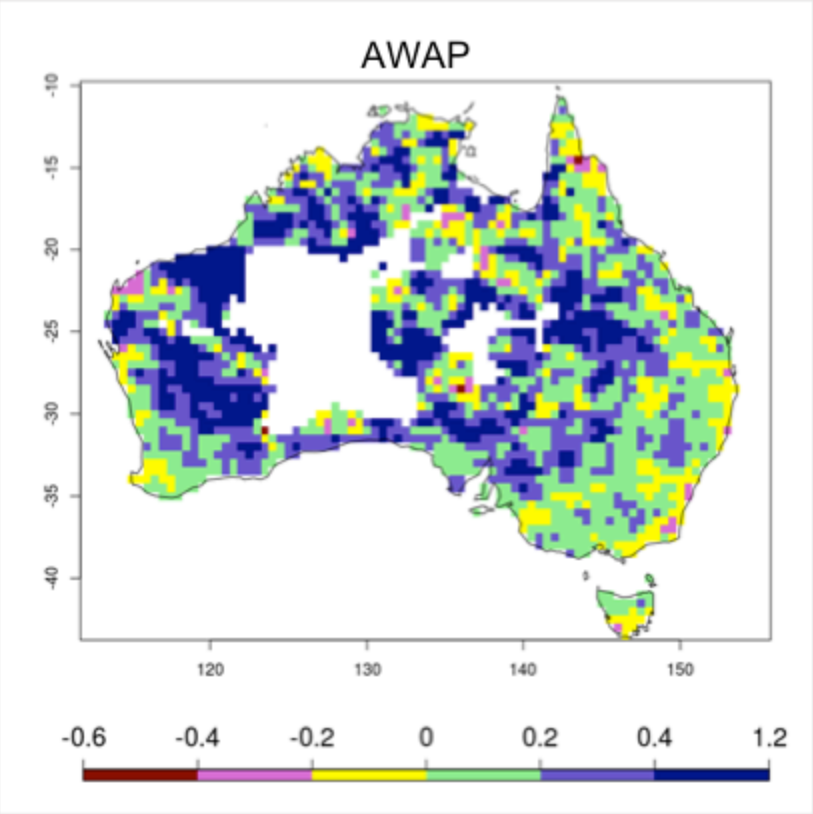


Relative change in quantiles based on NNI (all grids including non-significant



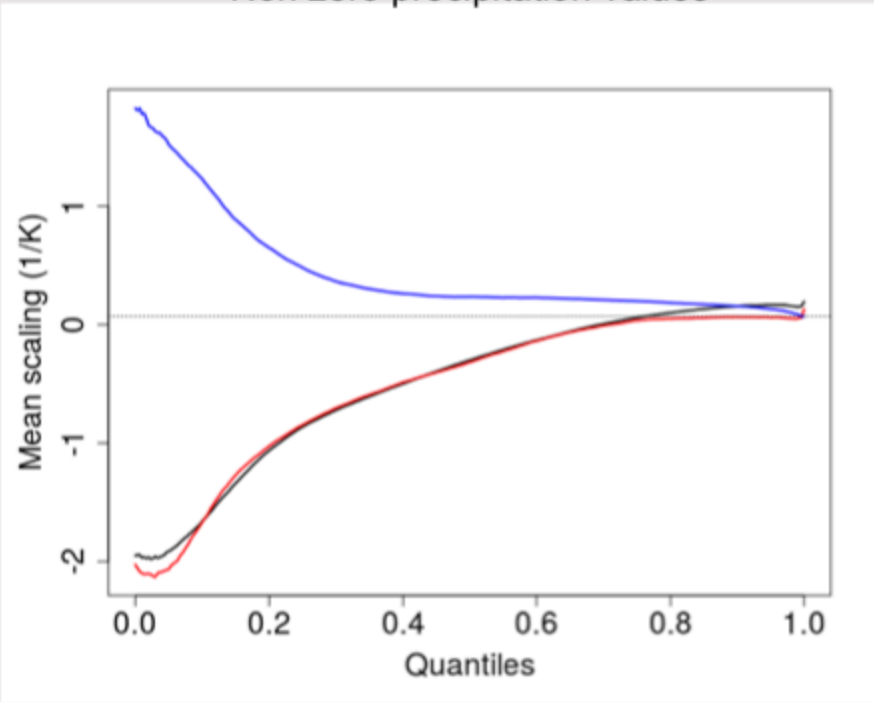
RX1DAY scaling by dataset



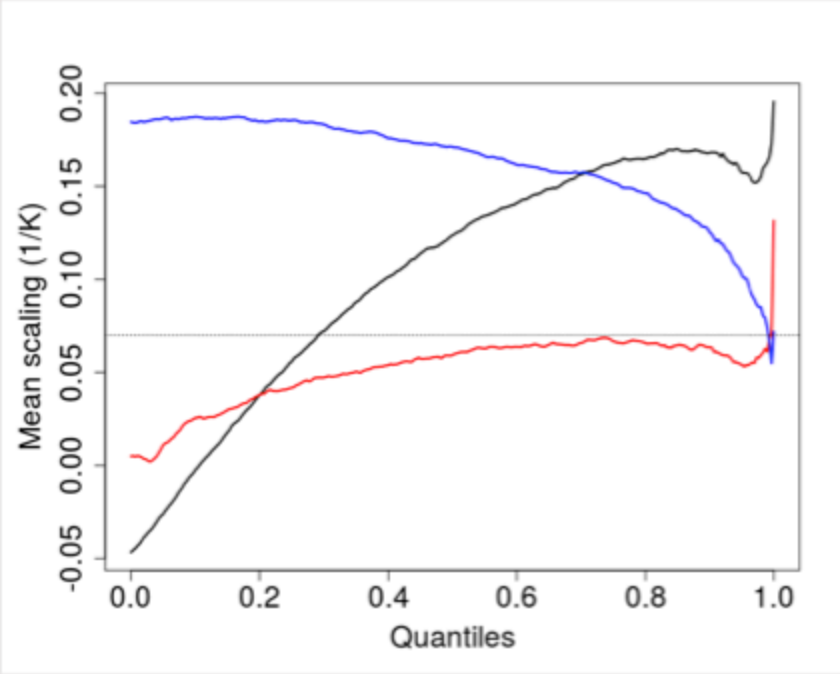


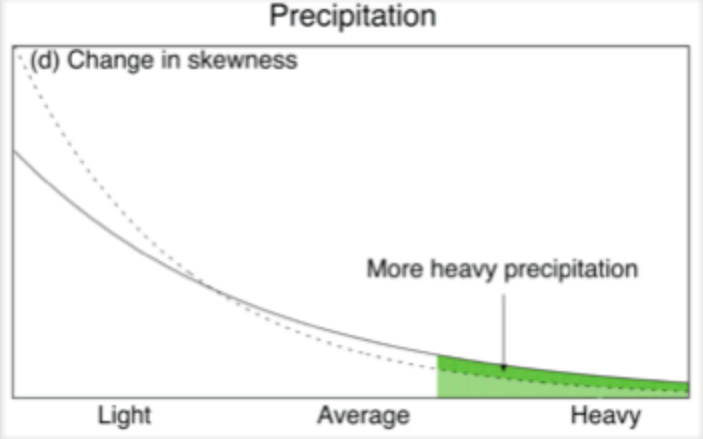
Scaling based on all day distributions

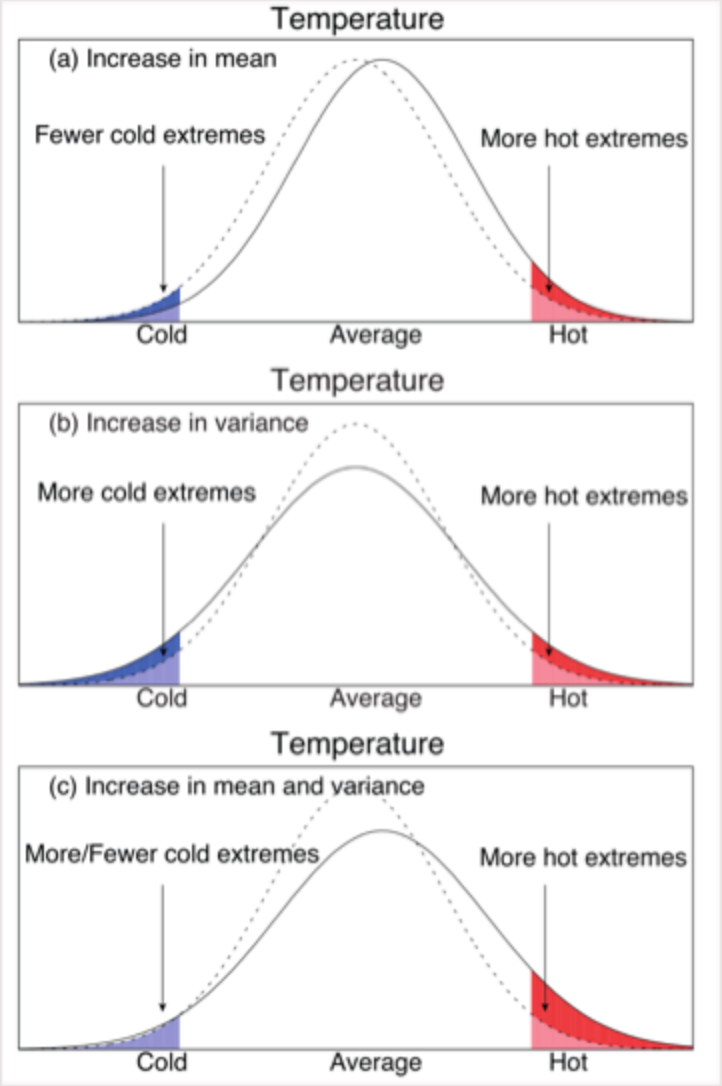
Non zero precipitation values



Wet day precipitation values




Precipitation
(d) Change in skewness
More heavy precipitation
Light
Average
Heavy


Temperature
(a) Increase in mean
Fewer cold extremes
More hot extremes
Cold
Average
Hot
Temperature
(b) Increase in variance
More cold extremes
More hot extremes
Cold
Average
Hot
Temperature
(c) Increase in mean and variance
More/Fewer cold extremes
More hot extremes
Cold
Average
Hot

Why are changes in precipitation observations so elusive?

- Statistical framework
- Observational datasets

ID	*Indicator name*	*Indicator definitions*	*Units*
TXx	Max Tmax	Monthly maximum value of daily maximum temperature	℃
TNx	Max Tmin	Monthly maximum value of daily minimum temperature	℃
TXn	Min Tmax	Monthly minimum value of daily maximum temperature	℃
TNn	Min Tmin	Monthly minimum value of daily minimum temperature	℃
TN10p	Cool nights	Percentage of time when daily minimum temperature < 10th percentile	%
TX10p	Cool days	Percentage of time when daily maximum temperature < 10th percentile	%
TN50p	Warm nights	Percentage of time when daily minimum temperature > 50th percentile	%
TX50p	Warm days	Percentage of time when daily maximum temperature > 50th percentile	%
TN90p	Warm nights	Percentage of time when daily minimum temperature > 90th percentile	%
TX90p	Warm days	Percentage of time when daily maximum temperature > 90th percentile	%
DTR	Diurnal temperature range	Monthly mean difference between daily maximum and minimum temperature	℃
FD0	Frost days	Annual count when daily minimum temperature < 0°C	days
SU25	Summer days	Annual count when daily maximum temperature > 25°C	days
TR20	Tropical nights	Annual count when daily minimum temperature > 20°C	days
WSDI*	Warm spell duration indicator	Annual count when at least 6 consecutive days of maximum temperature > 90th percentile	days
CSDI*	Cold spell duration indicator	Annual count when at least 6 consecutive days of minimum temperature < 10th percentile	days
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
RX5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	The ratio of total annual precipitation to the number of wet days (≥ 1 mm)	mm/day
R10mm	Number of heavy precipitation days	Annual count when precipitation > 10 mm	days
R20mm	Number of very heavy precipitation days	Annual count when precipitation > 20 mm	days
CDD*	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	days
CWD*	Consecutive wet days	Maximum number of consecutive days when precipitation ≥ 1 mm	days
R95p	Very wet days	Annual total precipitation from days > 95th percentile	mm
R99p	Extremely wet days	Annual total precipitation from days > 99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total precipitation from days ≥ 1 mm	mm

Alexander, L. V et al., 2007. Trends in Australia's climate means and extremes: a global context. Australian Meteorological Magazine, 56(March), pp.1–18.

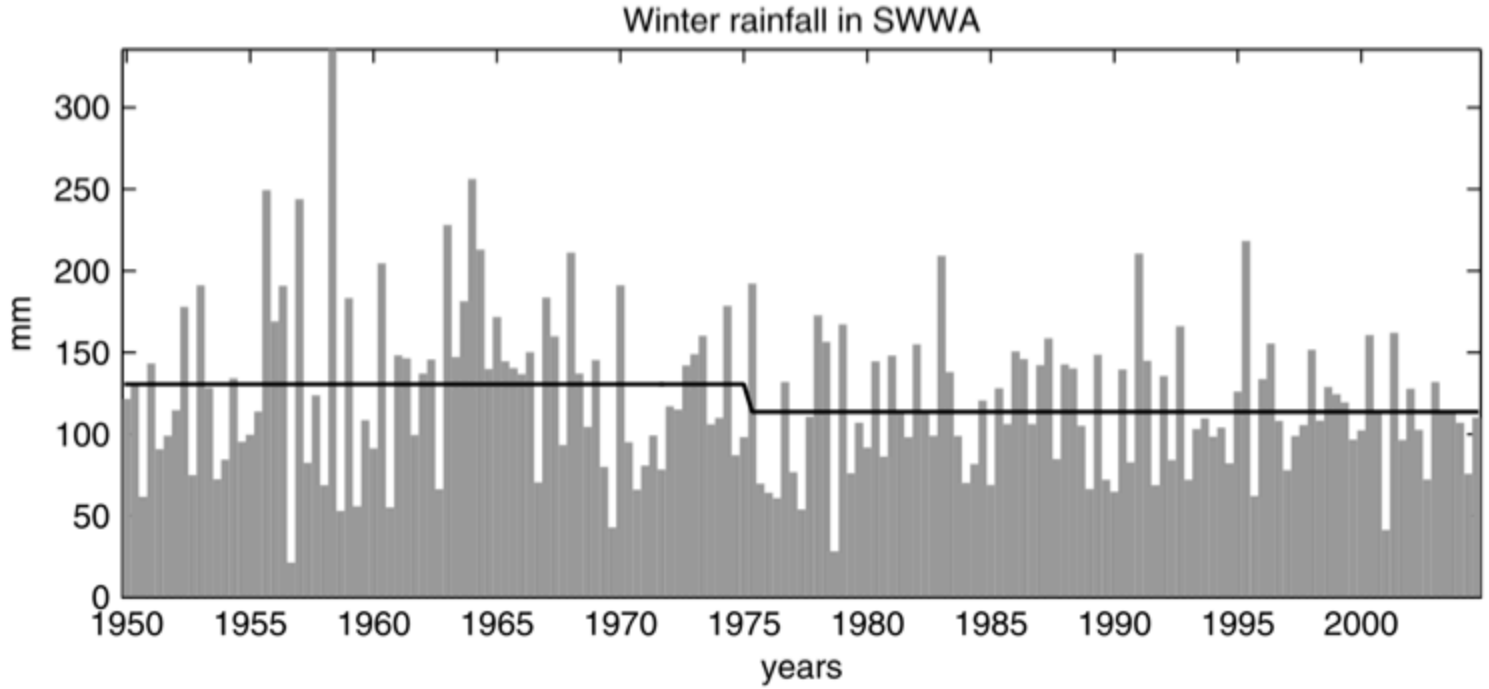


Figure 2. Winter precipitation over the SWWA region during 1950–2006. Overlaid is the mean winter rainfall before and after 1975.

Taschetto, A.S. & England, M.H., 2009. An analysis of late twentieth century trends in Australian rainfall. *International Journal of Climatology*, 29(6), pp.791–807.

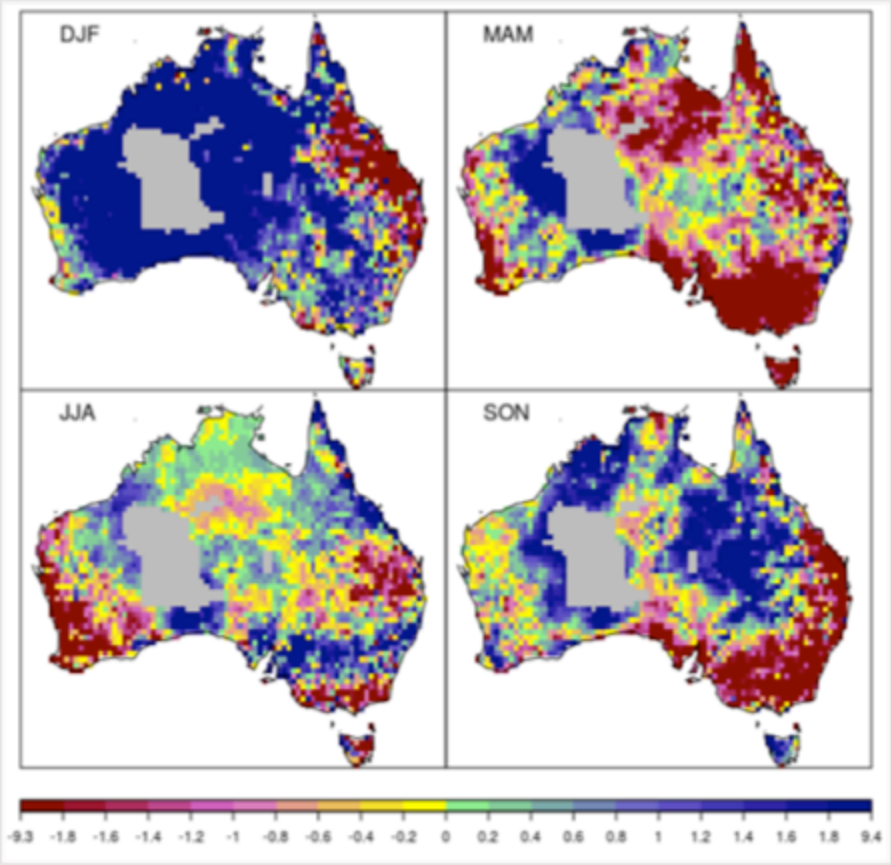
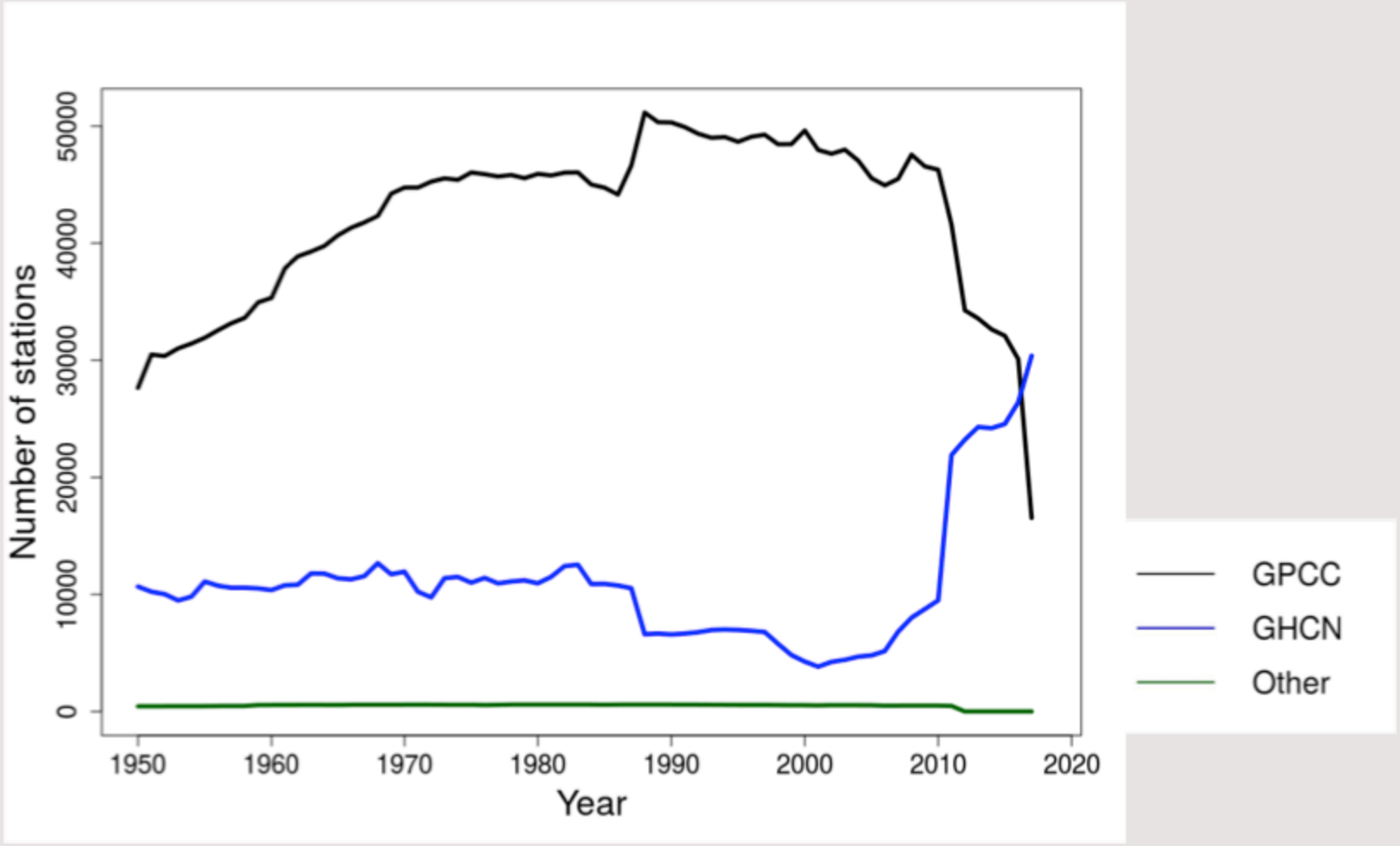


Figure: Same as the previous slide but showing seasonal changes in proportions of wet days between 1958 - 1985 and 1986 - 2013.

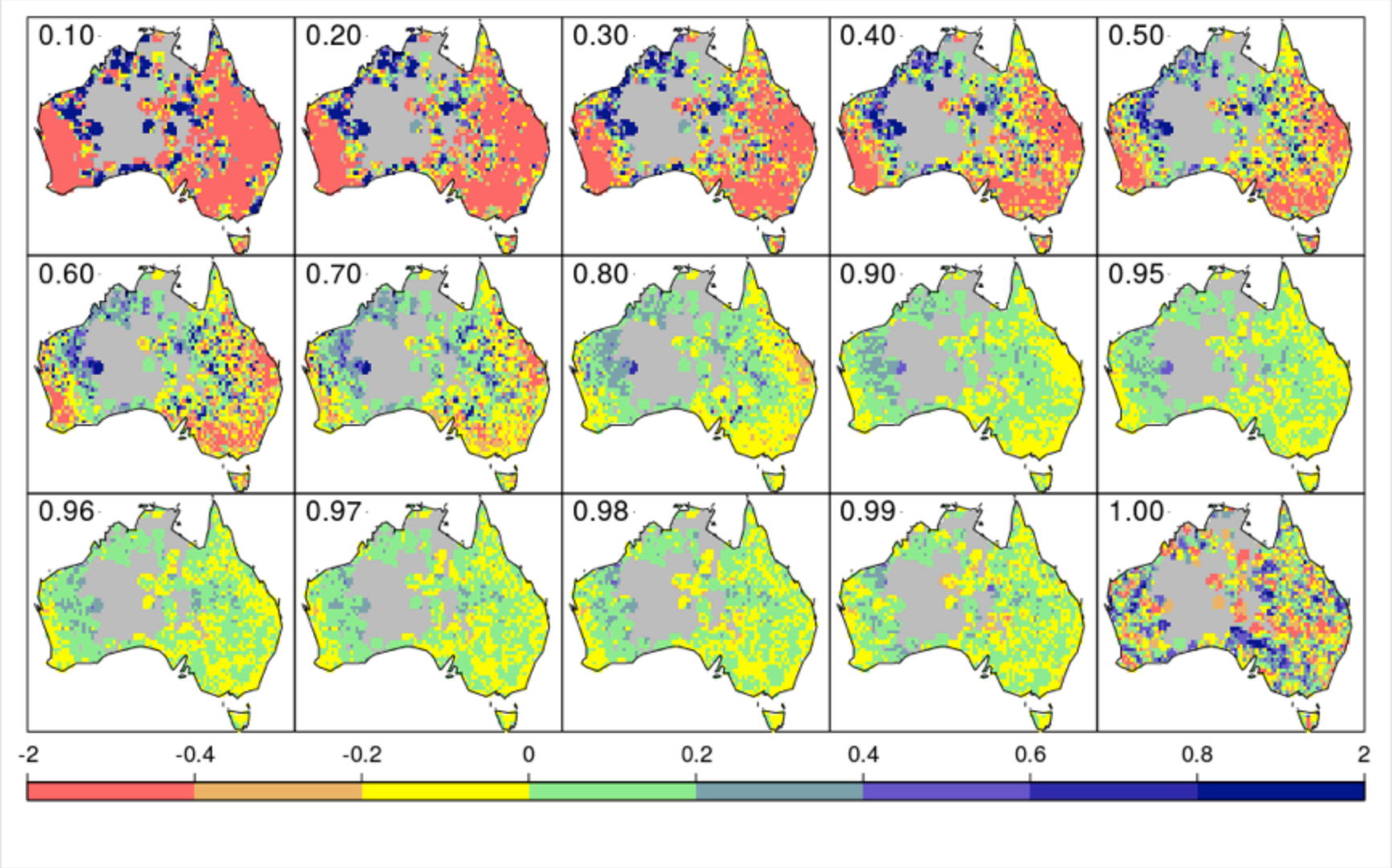

Number of stations
0
10000
20000
30000
40000
50000
1950
1960
1970
1980
1990
2000
2010
2020
Year
GPCC
GHCN
Other

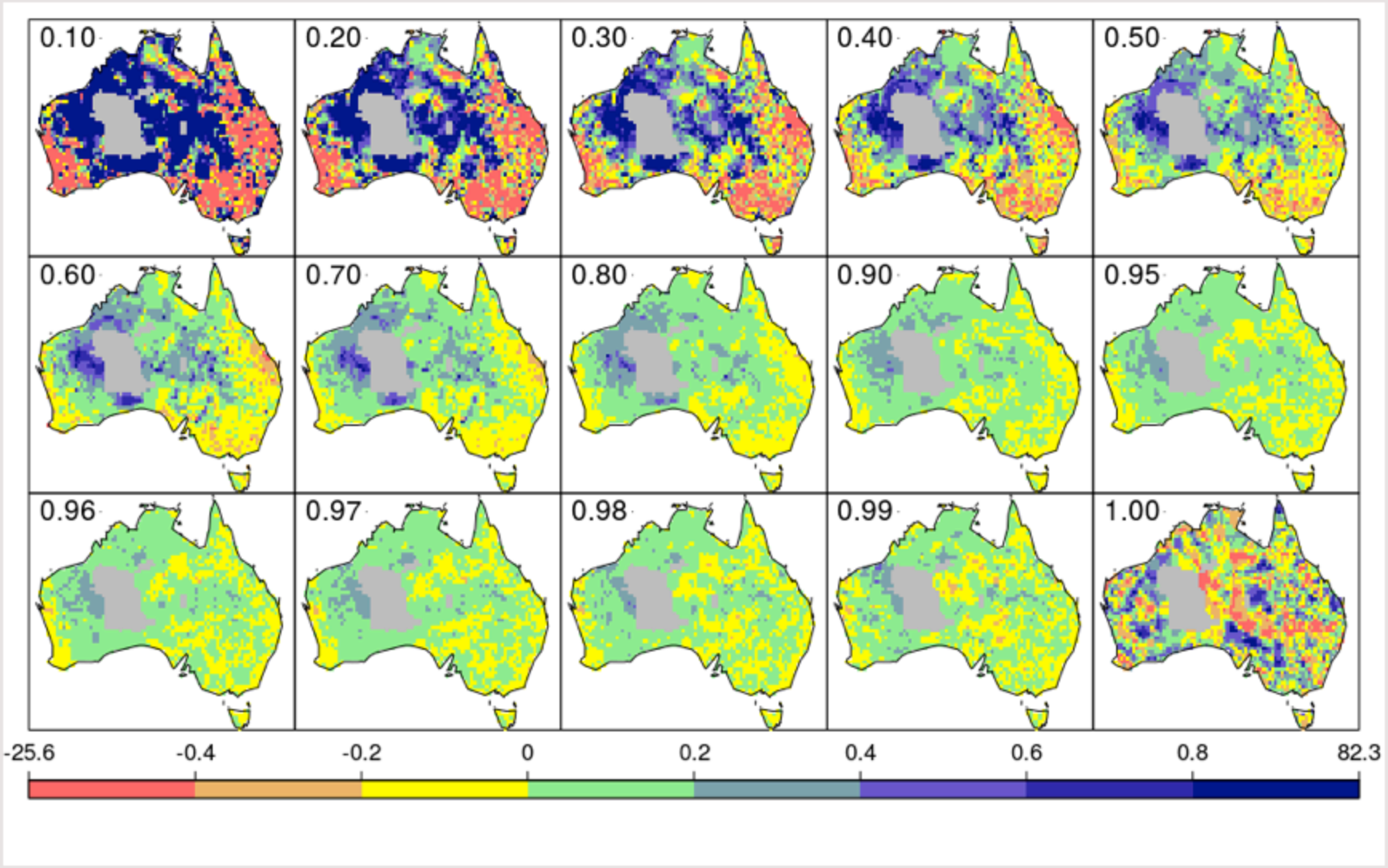
*"Confidence in precipitation change averaged over global land areas since 1901 is **low prior to 1951 and medium afterwards**. Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (medium confidence before and high confidence after 1951). For other latitudes area-averaged long-term positive or negative trends have **low confidence**"*

- IPCC Summary for Policy Makers 2013

"...it is likely that since 1951 there have been statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases, but there are strong regional and subregional variations in the trends."

- IPCC AR5 Chapter 2 2013


0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0.95
0.96
0.97
0.98
0.99
1.00
-2
-0.4
-0.2
0
0.2
0.4
0.6
0.8
2


0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0.95
0.96
0.97
0.98
0.99
1.00
-25.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
82.3