World Climate Research Programme's Grand Challenge in **Weather and Climate Extremes**

L. Alexander[1], G. Hegerl[2], S. Seneviratne[3], and X. Zhang[4]

[1]UNSW, Sydney, Australia; [2]U. Edinburgh, UK;
[3]ETH Zurich, Switzerland; [4]Environment Canada, Toronto, Canada

WCRP grand challenge on weather and climate extremes

- ***service perspective***: What are frequency and magnitudes of various impact-causing extremes in the near and long term?
- ***science perspective***: causes and mechanisms of variability and change in extremes, how to improve the prediction of change
- Implementation needs to be focused: areas with opportunity for rapid progress

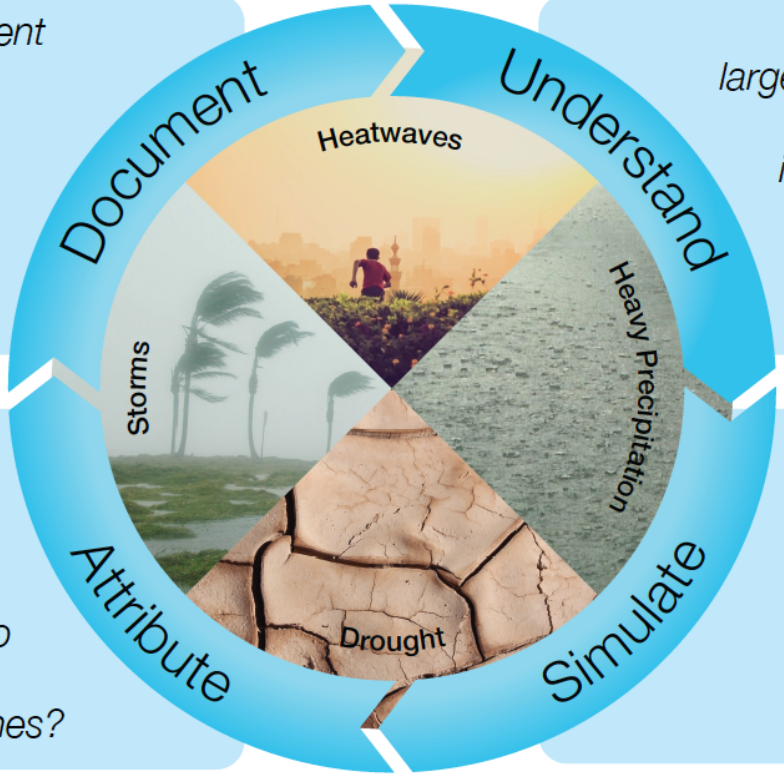
WCRP
World Climate Research Programme

GEWEX

4 main extremes, 4 over arching themes

Are existing observations sufficient to underpin the assessment of extremes?

What are the relative roles of large-scale, regional and local scale processes, as well as their interactions, for the formation of extremes?



What are the contributors to observed extreme events and to changes in the frequency and intensity of the observed extremes?

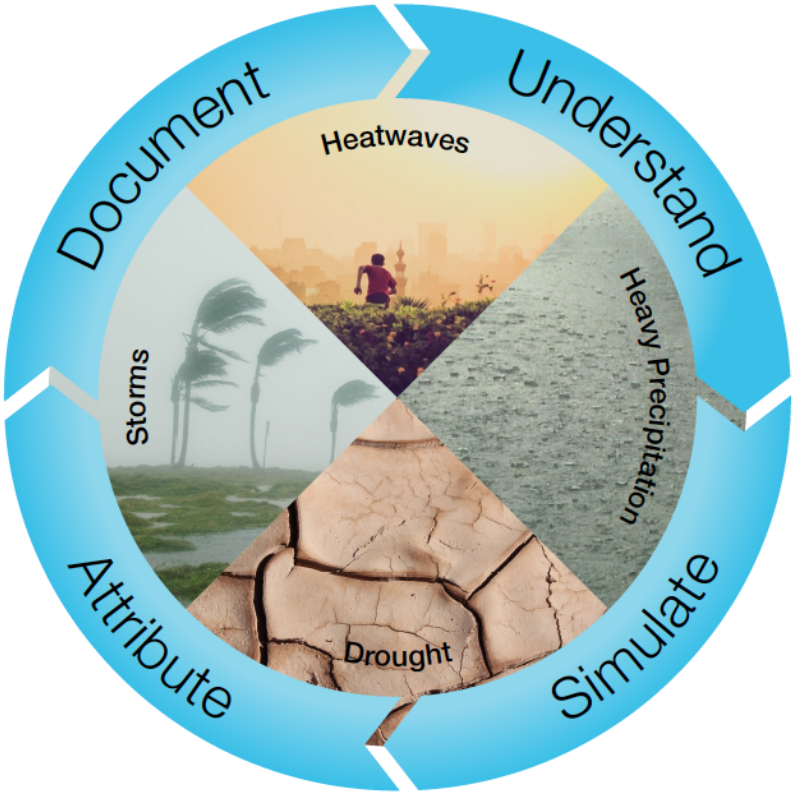
Are models able to reliably simulate extremes and their changes, and how can this be evaluated and improved?

Meshes well with WCRP strategic plan

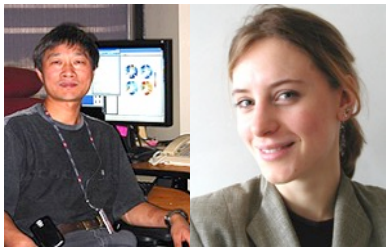
WMO IOC ICSU

Leads

Lisa Alexander | Ali Behrangi



Sonia Seneviratne | Olivia Martius | Robert Vautard



Xuebin Zhang | Fredi Otto

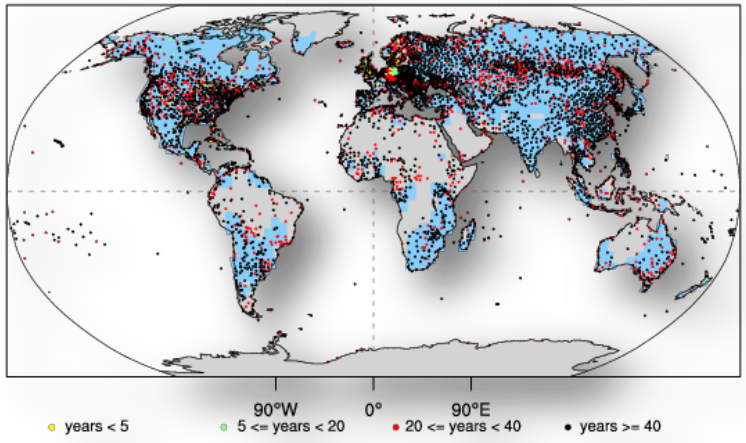
Gabi Hegerl | Jana Sillmann | Erich Fischer

Document

critical gaps exist in the amount, quality, consistency and availability of observations, especially for extremes

Interest in 'old extremes' eg in early records

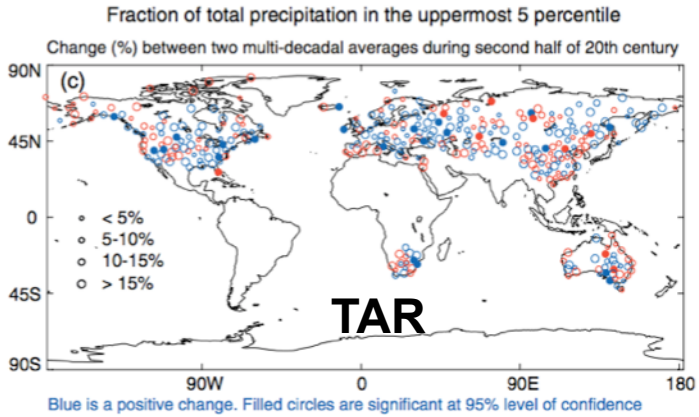
Sub-daily precip stations (HadISD) and SDII coverage (HadEX2)

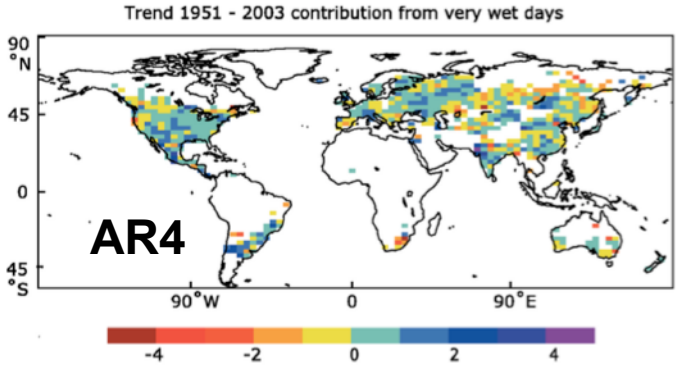


Source: Westra et al. 2014, Rev. Geophys.

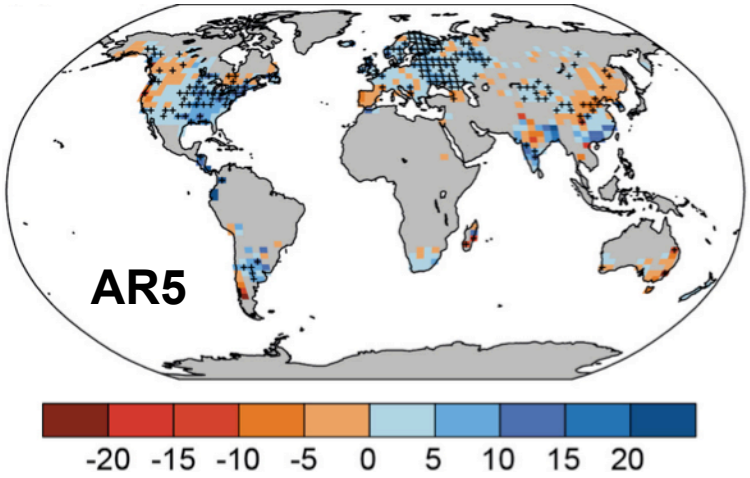
- Permanent destruction of old records
- More data undigitised than digitised (especially pre WWII)
- Many institutions unwilling or unable to exchange data
- Data quality and homogeneity
- *Also considers runoff observations*

IPCC assessments – data improvements?





No improvement in coverage between IPCC Assessments



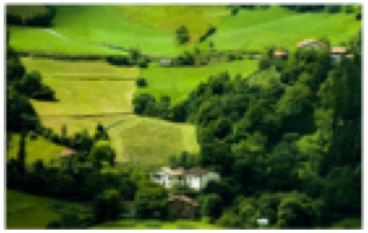
Big gains for small coordination effort between in situ, remote sensing, reanalysis communities

Understand

atmosphere

greenhouse gases

oceans

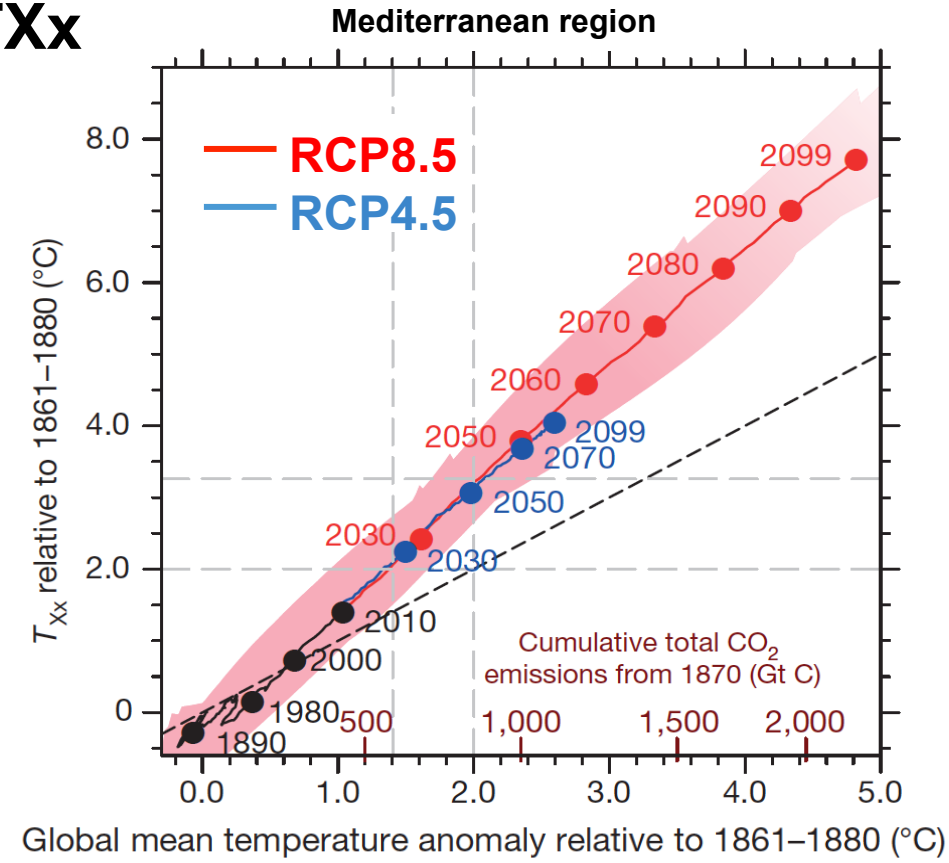


land

Interaction between large-scale phenomena (weather types, modes of variability) and regional-scale land-atmosphere feedbacks or forcing is critical

Understanding: Global scale vs regional scale drivers, role of land-atmosphere interactions

TXx

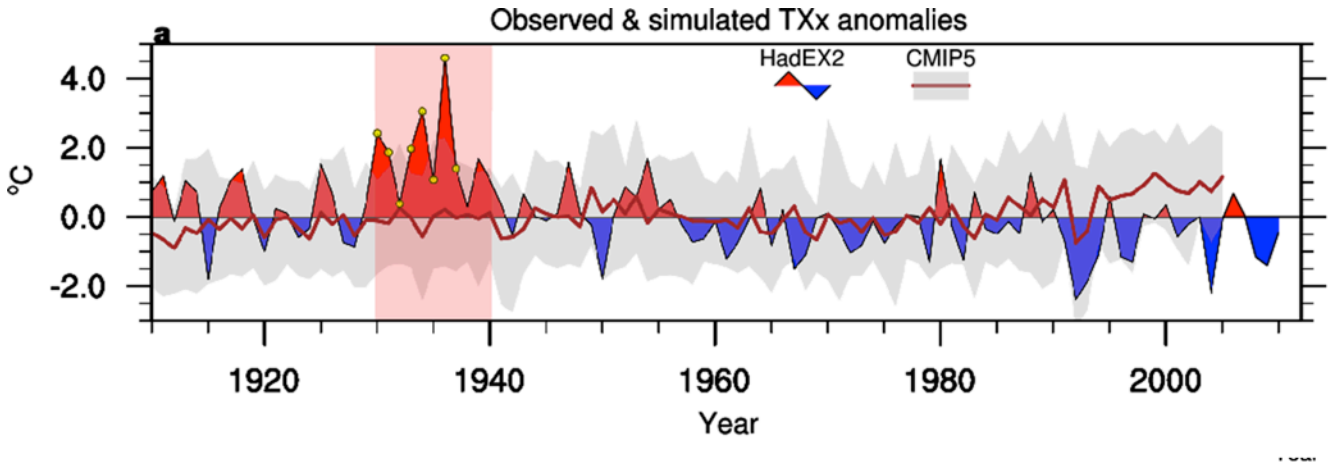


Source: Seneviratne et al. 2016, Nature

Daily maximum temperature linear with cumulative emissions, just like global mean temperature

Increase can be moderated by increasing/decreasing land drying

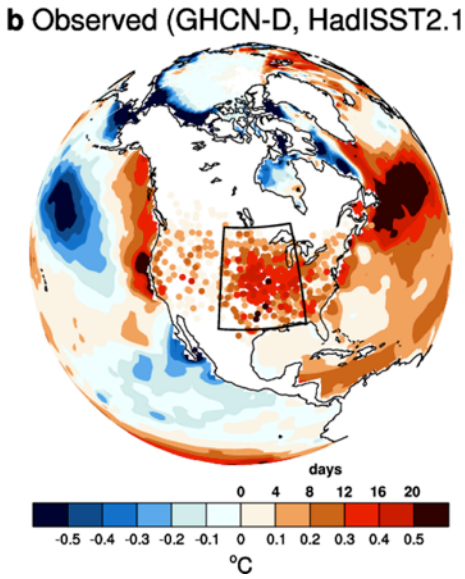
Case study: dustbowl heat waves

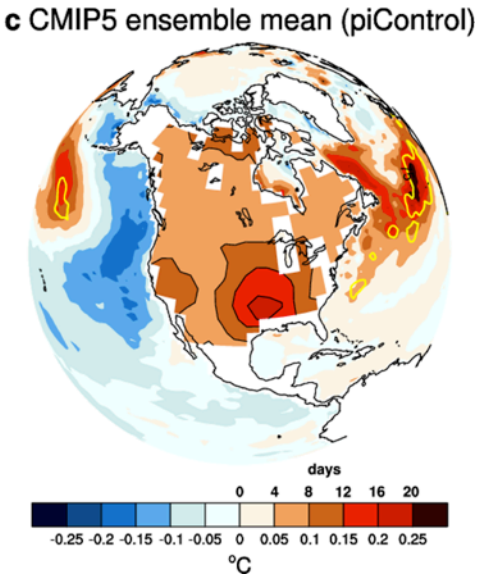


- Record heat in US great plains in 1930s, CMIP5 doesn't capture
- Coincided with Pacific and Atlantic SST patterns but magnitude not reproduced
- In targeted model simulations, devegetation can produce heat waves like this or larger

⇒ **Potential for enhanced or decreased heat wave activity when accounting vegetation feedbacks**

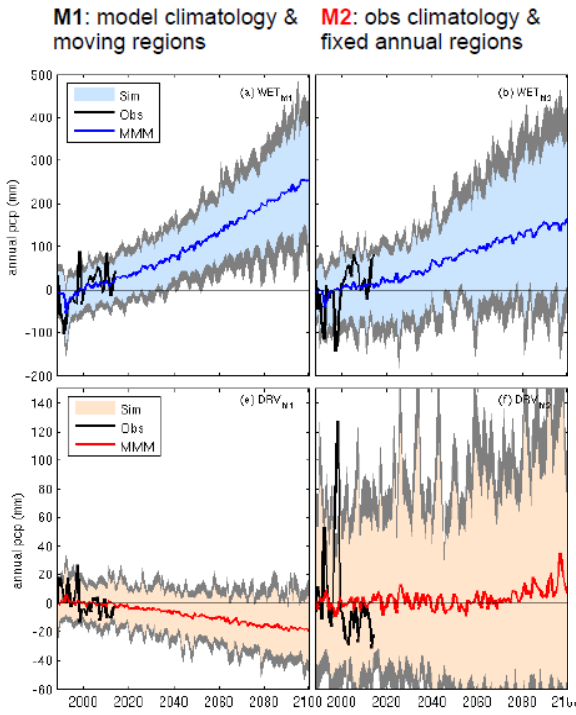
Cowan; et al, in review; and 2017





Wet vs dry contrast:

- Wet gets wetter dry gets drier ONLY if accounting for seasons, movement and placement of wet and dry regions (Polson et al2016; ERL)



Left side: wet and dry part of tropics and subtropics in satellite data (black) and multimodel mean and range; wet/dry selected each season and per model
2nd panel: wet and dry fixed in time and seasonally

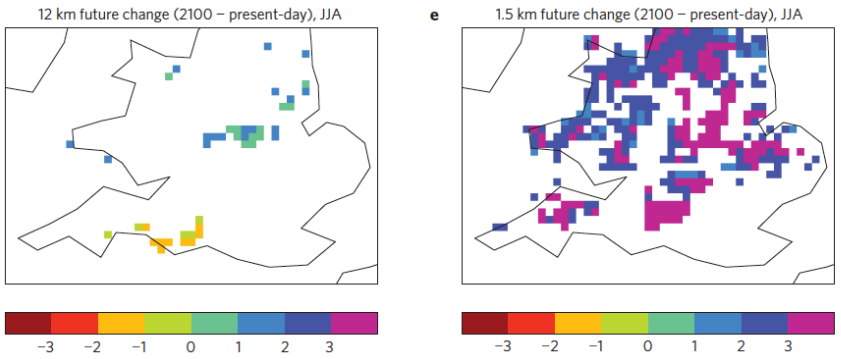
=> Not suitable over land and not useful for prediction

Simulate

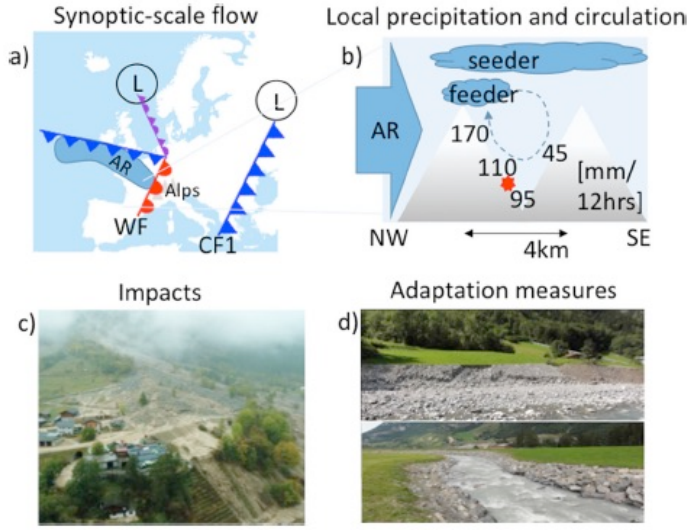
How use both statistical methods for tails and knowledge about mechanisms/ storylines?

What phenomena are credible in simulations (GCM, RCM) and how can models be improved?

How can high resolution and large ensembles be used together to better sample tail and processes?



Source: Kendon et al. 2014, Nature Climate Change

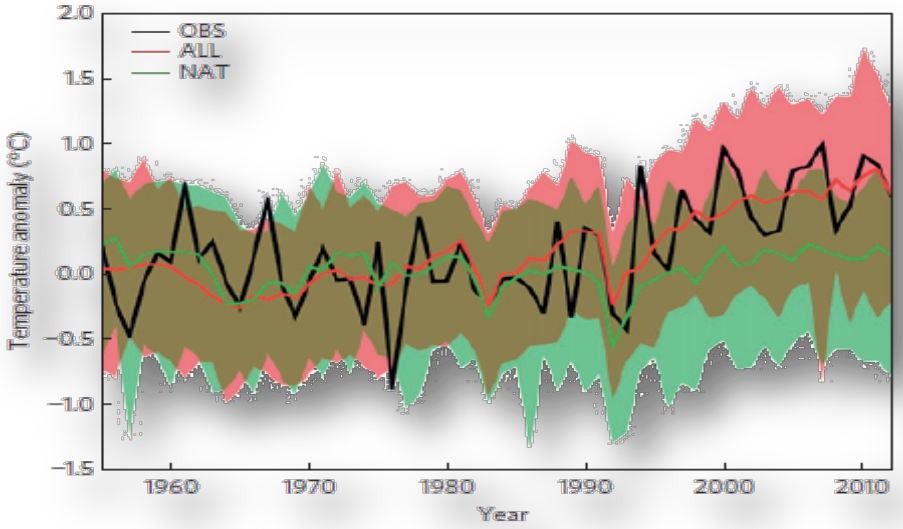


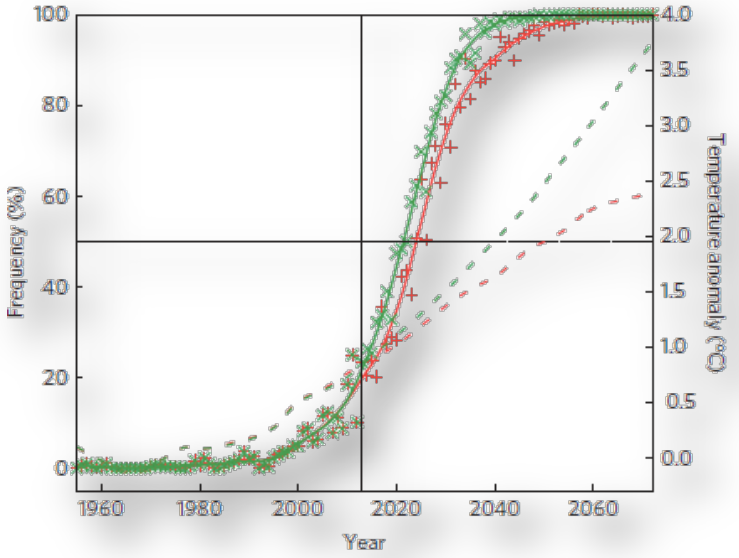
Source: Shepherd et al., DOI: http://dx.doi.org/10.1007/s10584-018-2317-9

Attribute

Challenge: understand extent to which humans are responsible for changes in extremes and the likelihood of individual extreme weather events - example: East China Heatwave more likely with human influences

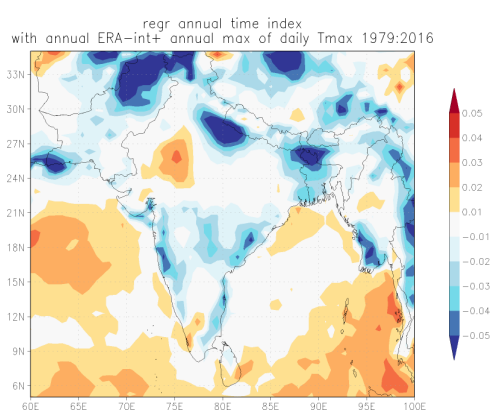
2013 Summer East China Heatwave



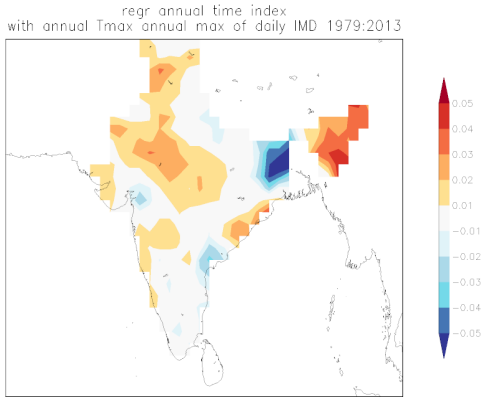


Trends in TXx in South Asia are poorly represented in CMIP5

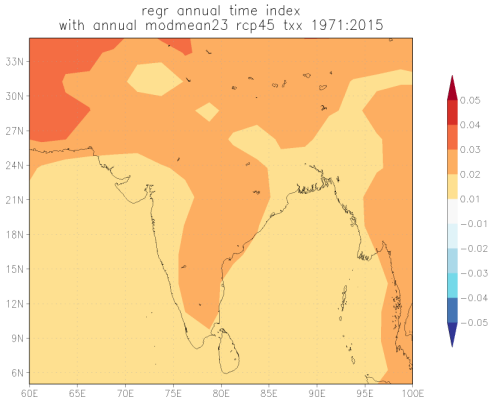
ERA-interim



IMD analysis



CMIP5 models

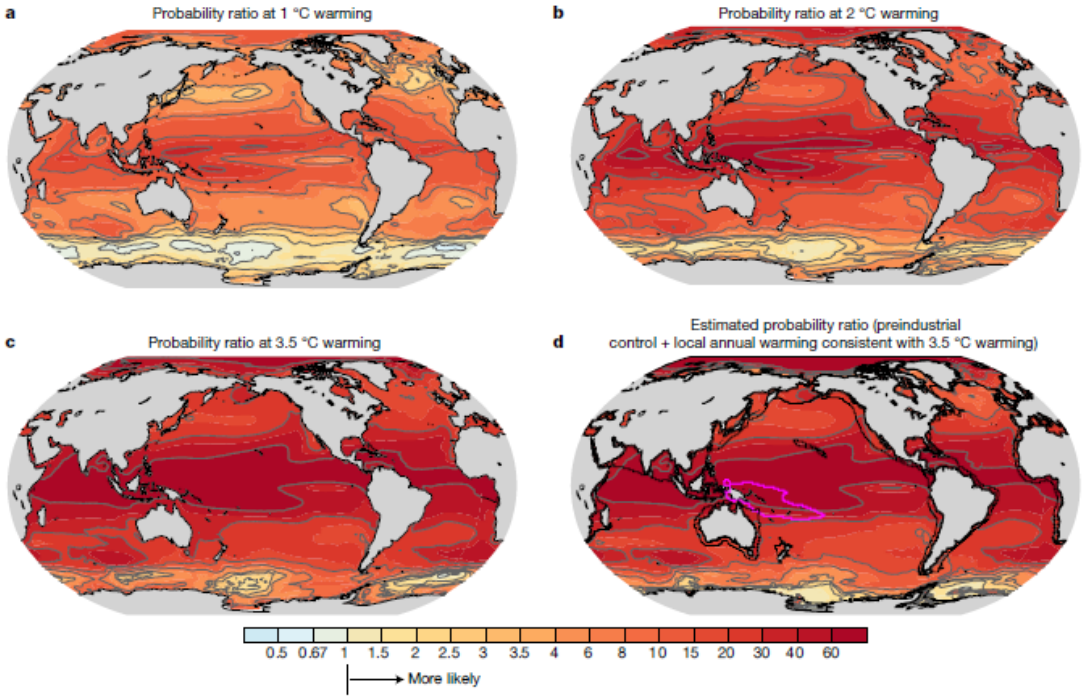


Trends in TXx are overestimated in India by CMIP5 GCMs possibly due to no irrigation, or deficient aerosol effects
van Oldenborgh et al, NHESS, 2018

Similarly: evaporation change due to warming impactful in regions with irrigation => questions on water use and sustainability (Philip et al., submitted)

Dramatic increase in probability of Marine Heat waves

Froehlicher et al nature 2018: – probability ratio already multiples of preindustrial by 1 degree for exceeding 99th percentile



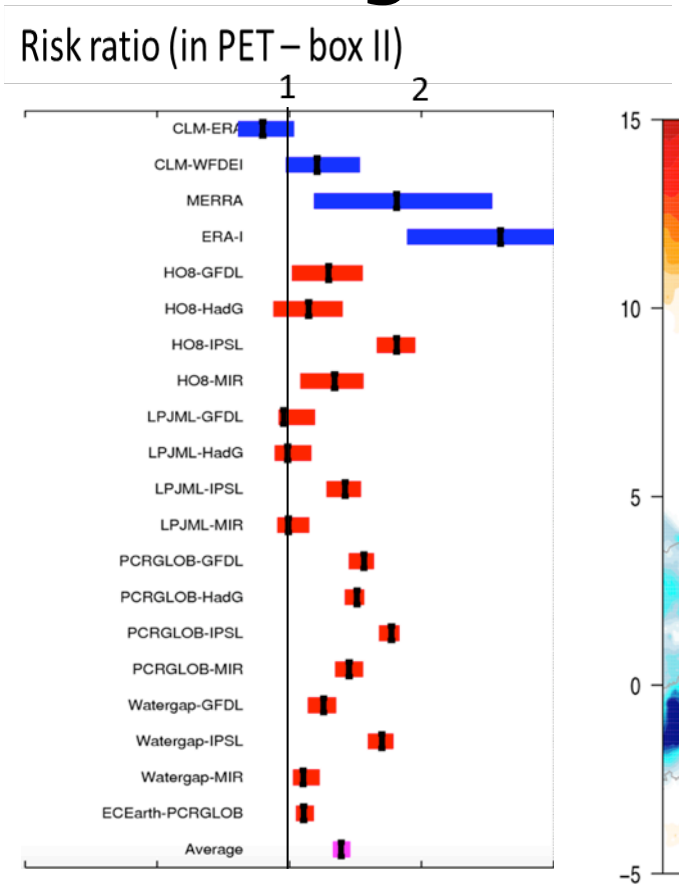
Looking forward

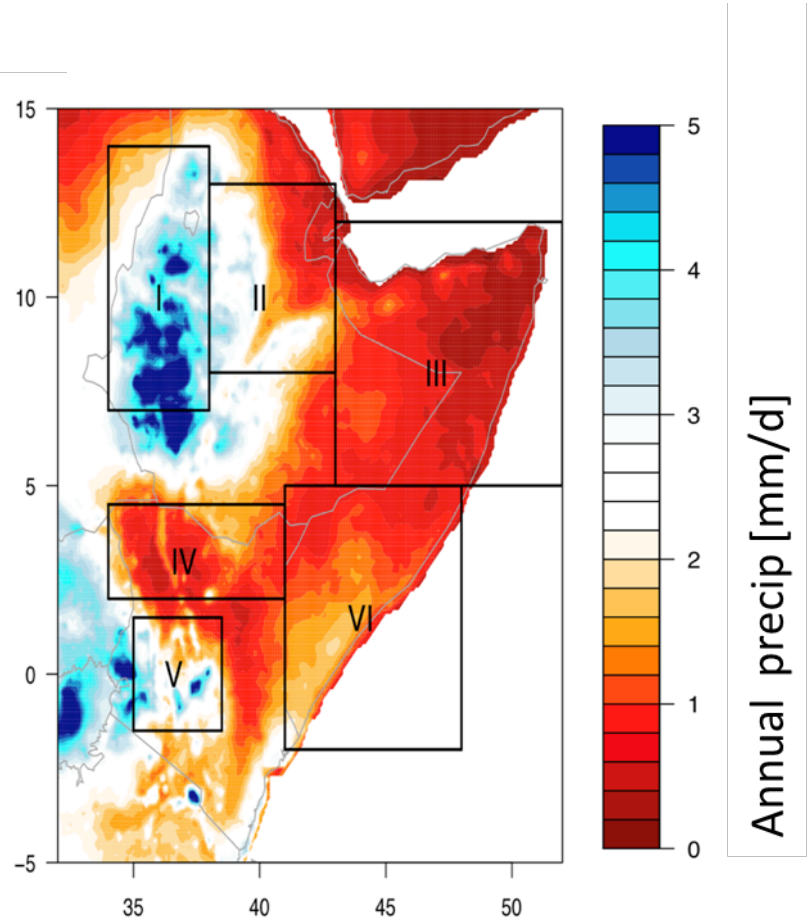
- Questions remain (data, process understanding, modelling, detection and attribution)
- Inclusion of compound events
- Development of guidance documents on future projection of extremes to be released after the conclusion of IPCC WGI AR6 report
- Completion of guidance document on suitability of rainfall datasets for studying extremes and the coordination of input into IPWG and IPCC (both latter: Alexander)
- 'old extremes' to test methods and processes
- What gives skill to decadal predictions – forcing for sure do initial conditions add beyond 1-2yrs?

Challenges questions

- Interaction with other WCRP groups with extremes angles: ensure crossfertilization and use of a coordinated approach
- ETCCDI is no more
- Implementation is heavily relying on in kind support; need continued WCRP support for grand challenges (financially and programmatically)
- Thank you!

Changes in evaporation with warming





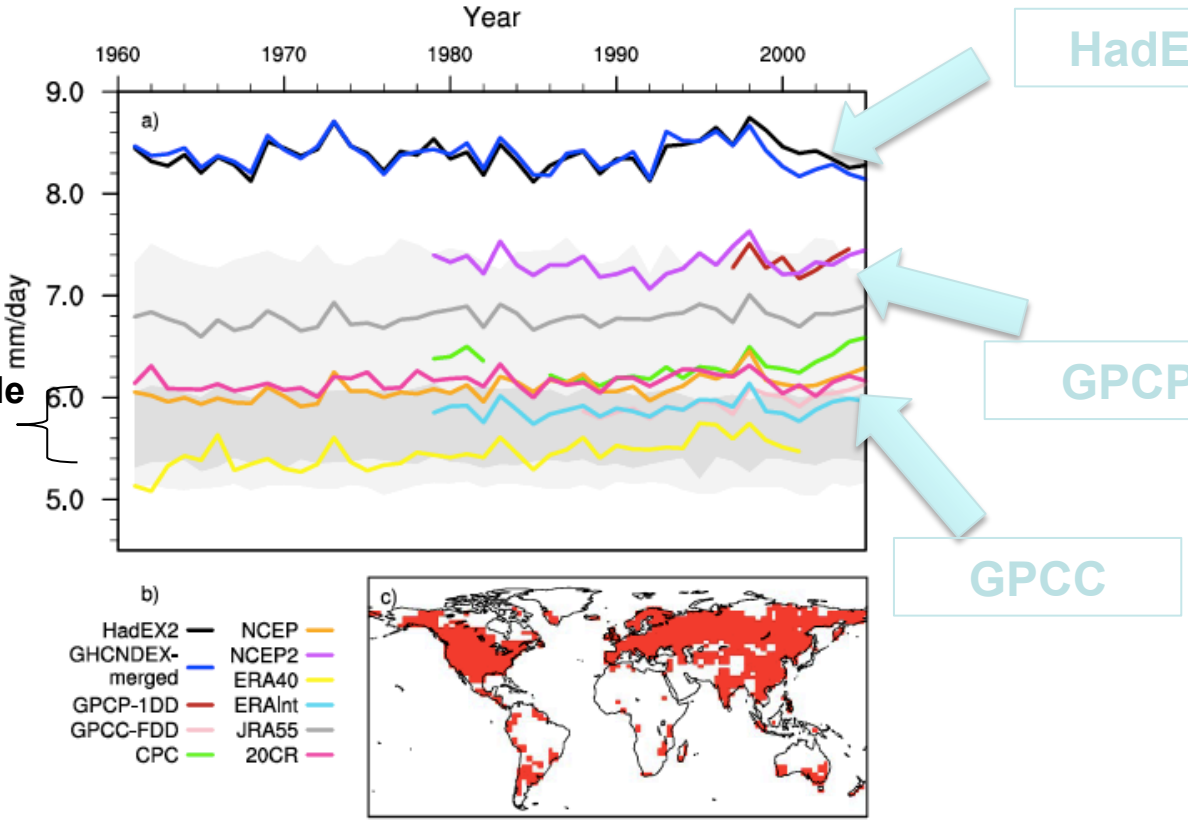
Evaporation reduced water input, but only where irrigated

The *dreary state* of precipitation observations

Full obs/ reanalyses range

Full CMIP5 range

Interquartile CMIP5 range



Source: Herold et al. 2016

~3mm/day difference

in annual estimates of daily precipitation intensity

Masked to where all datasets have data