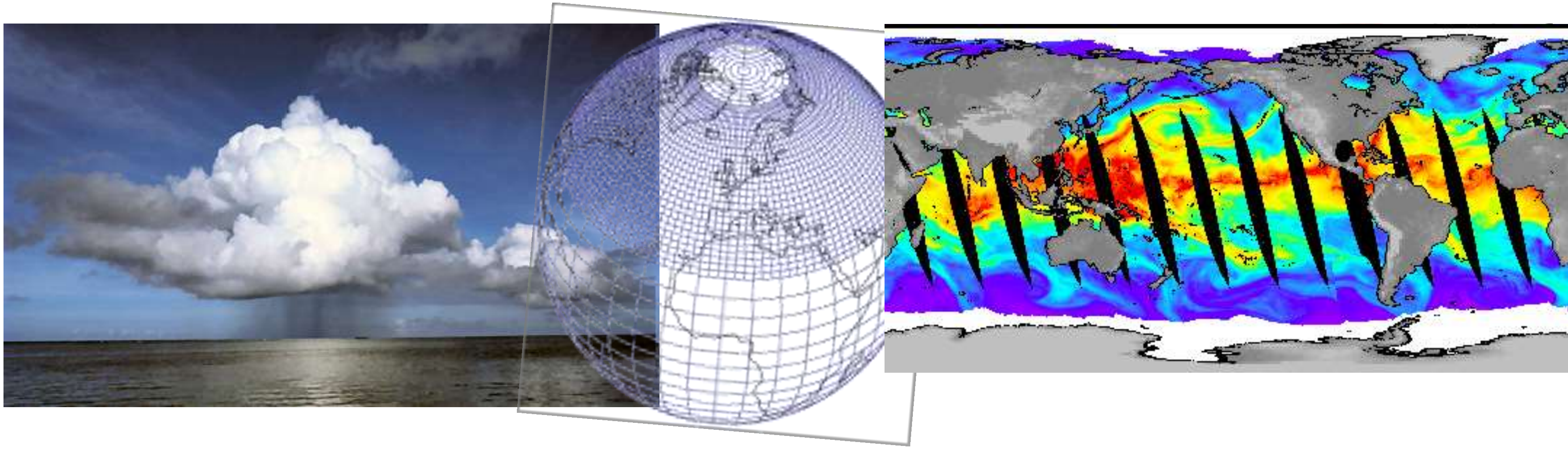

Climate change and meteorological drivers of widespread flooding in the UK

EA/Defra/NRW Research and Development (R&D) project board meeting, London, March 26 2015

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NERC SCIENCE OF THE ENVIRONMENT · Changing water cycle · Walker INSTITUTE · University of Reading

Meteorological drivers of widespread flooding in the UK

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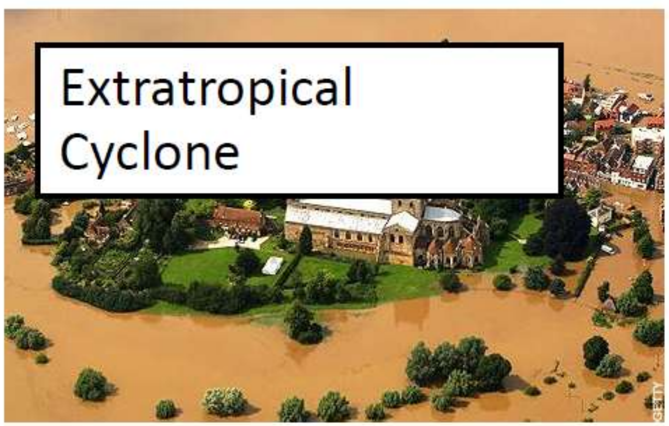
- Extreme seasonal rainfall e.g. winter 2013/14
  - Jet stream position/strength/characteristics, blocking
  - “Memory” in climate system e.g. remote sea surface temperature and ice coverage
  - Repeated rainfall & coastal inundation events
- Extreme weather events
  - “Atmospheric rivers”, convergence lines, “Spanish Plume”, wind storms, snow melt
- Impact of a warming climate
  - Increasing atmospheric water vapour
  - Changing characteristics of weather patterns

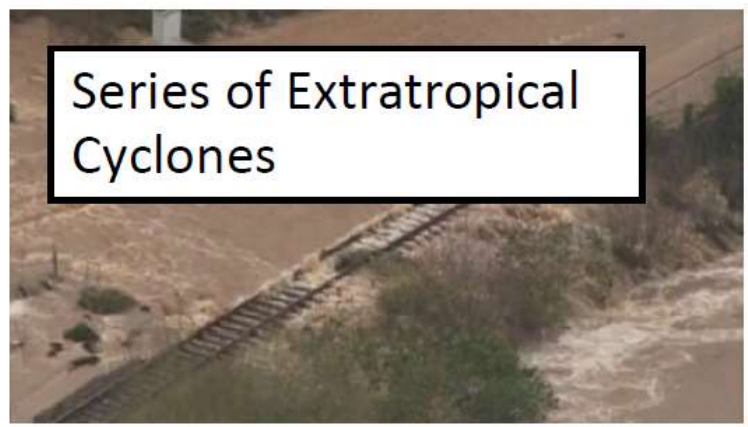
Flooding and extreme rainfall

Aug 2004 Boscastle

Nov 2009 Cockermouth



July 2007 Tewkesbury



Nov 2012 South-West Floods

Slide courtesy of Len Shaffrey, University of Reading

Global context: changing water cycle

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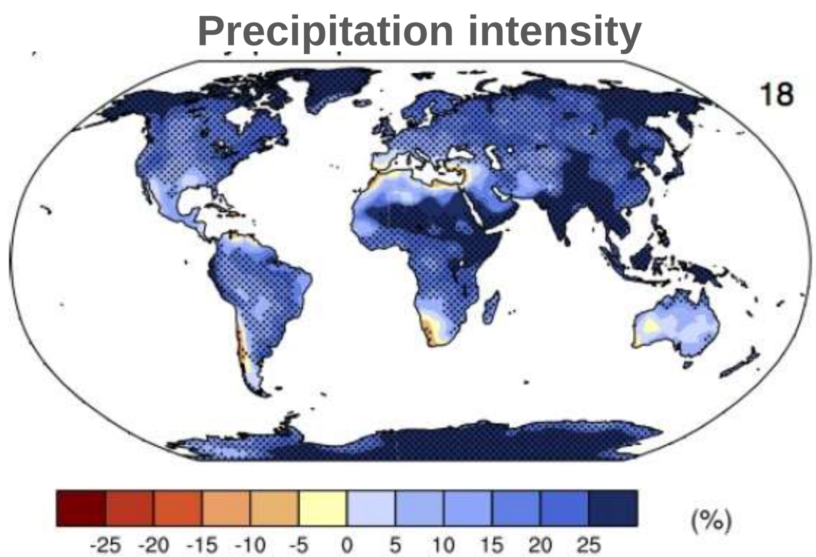
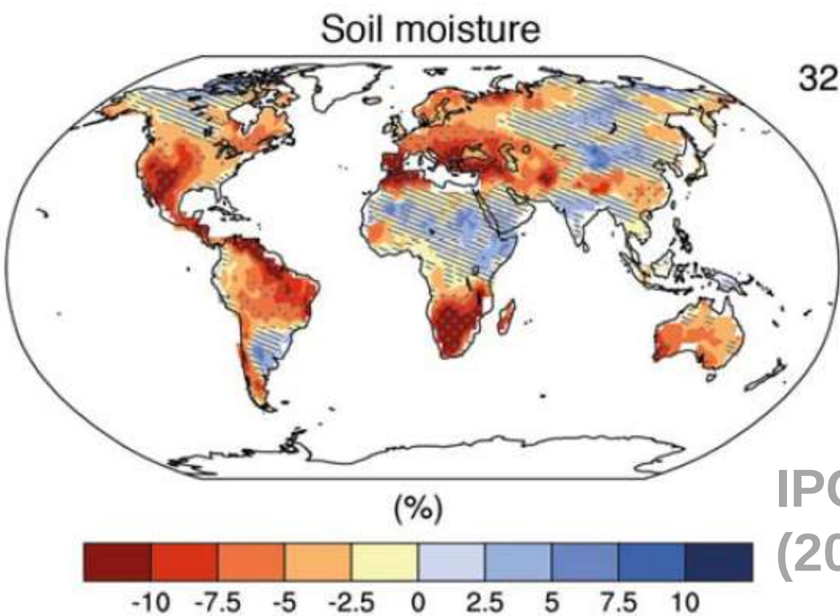
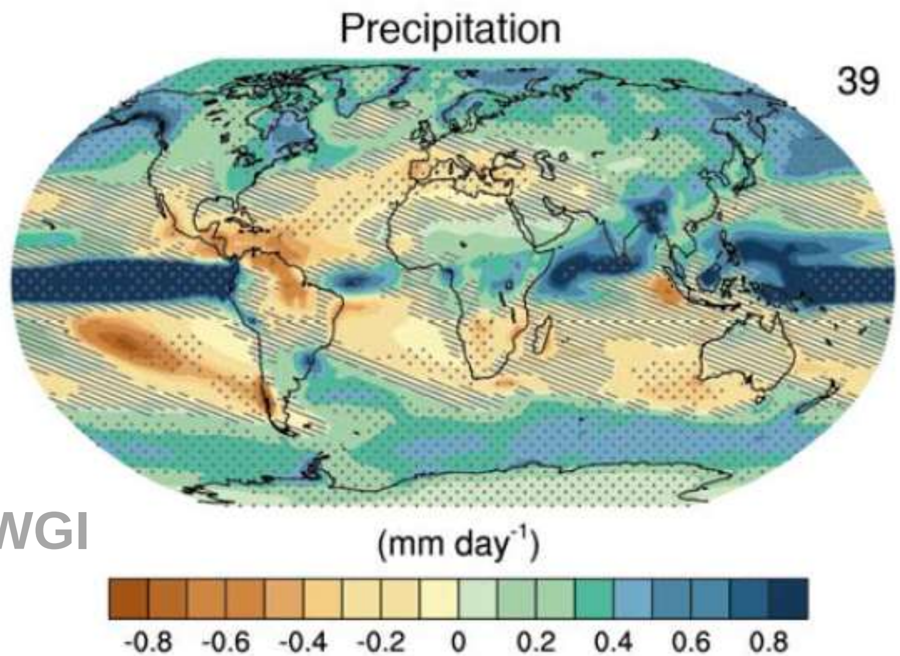


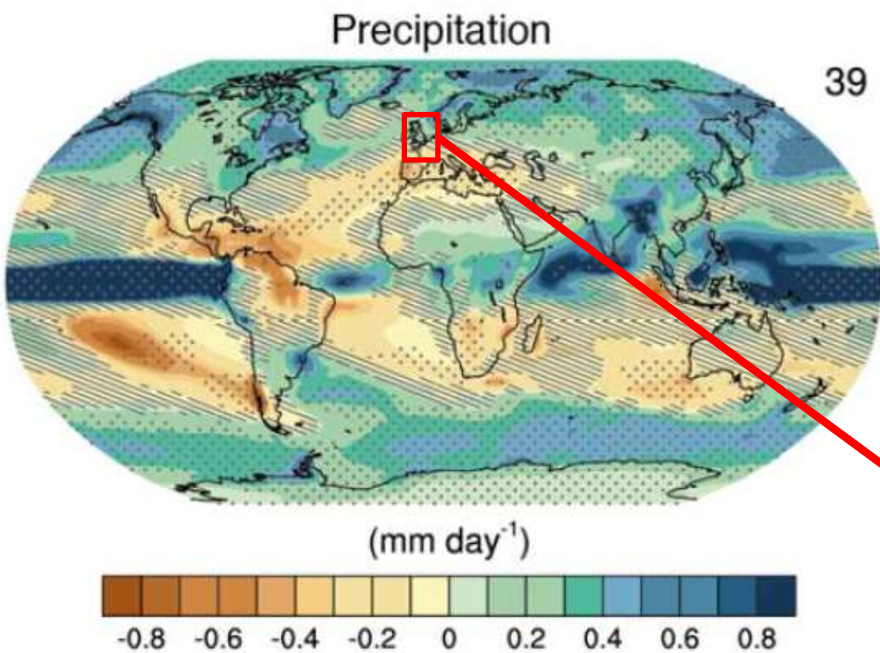


- Increased Precipitation
- More Intense Rainfall
- More droughts
- Wet regions get wetter, dry regions get drier?

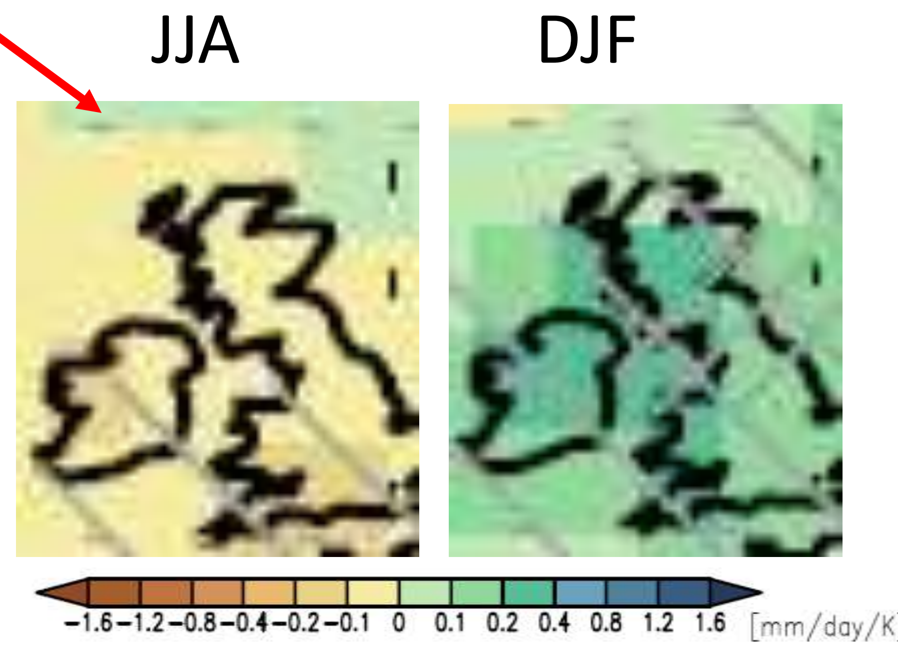


IPCC WGI (2013)

Challenge: Regional projections



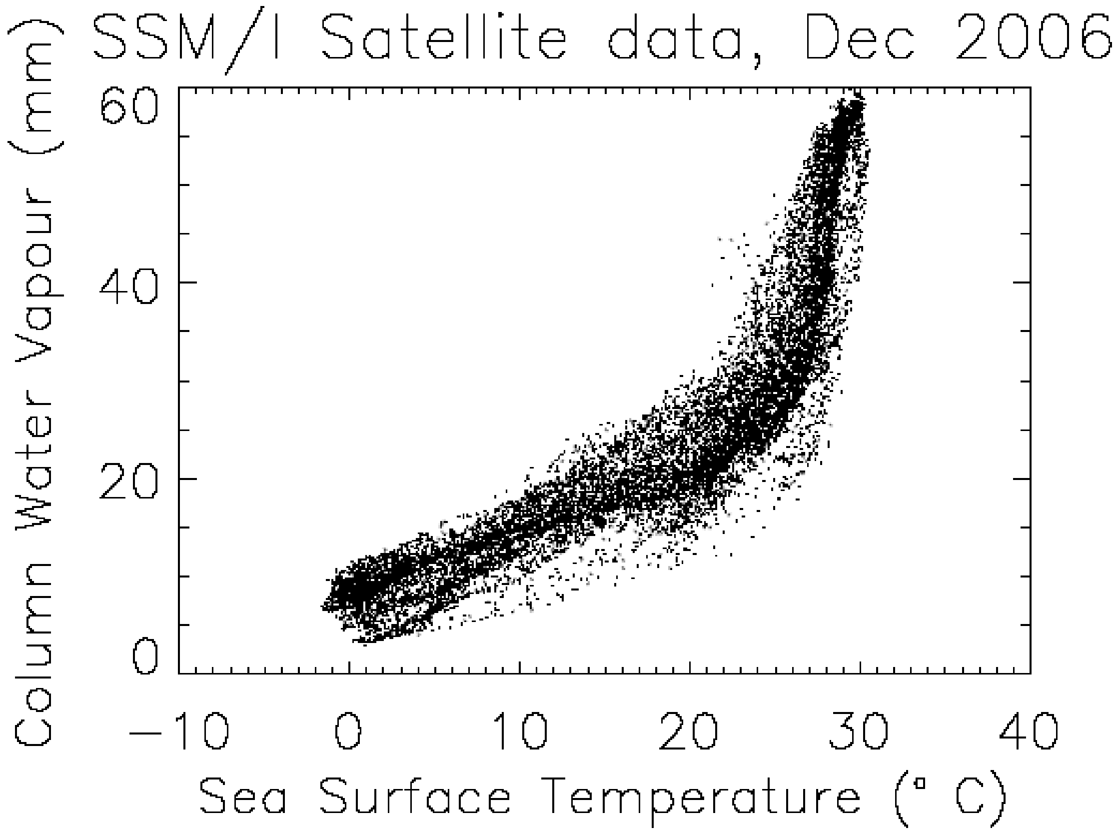
Shifts in atmospheric circulation are crucial to regional changes in water resources and risk yet this is the most challenging aspect of climate prediction



How will position of jet streams & monsoons respond to warming?

Regional heating/cooling effects from aerosol particle pollution and feedback loops involving the land and sea surface become important

Physical Driver: water vapour

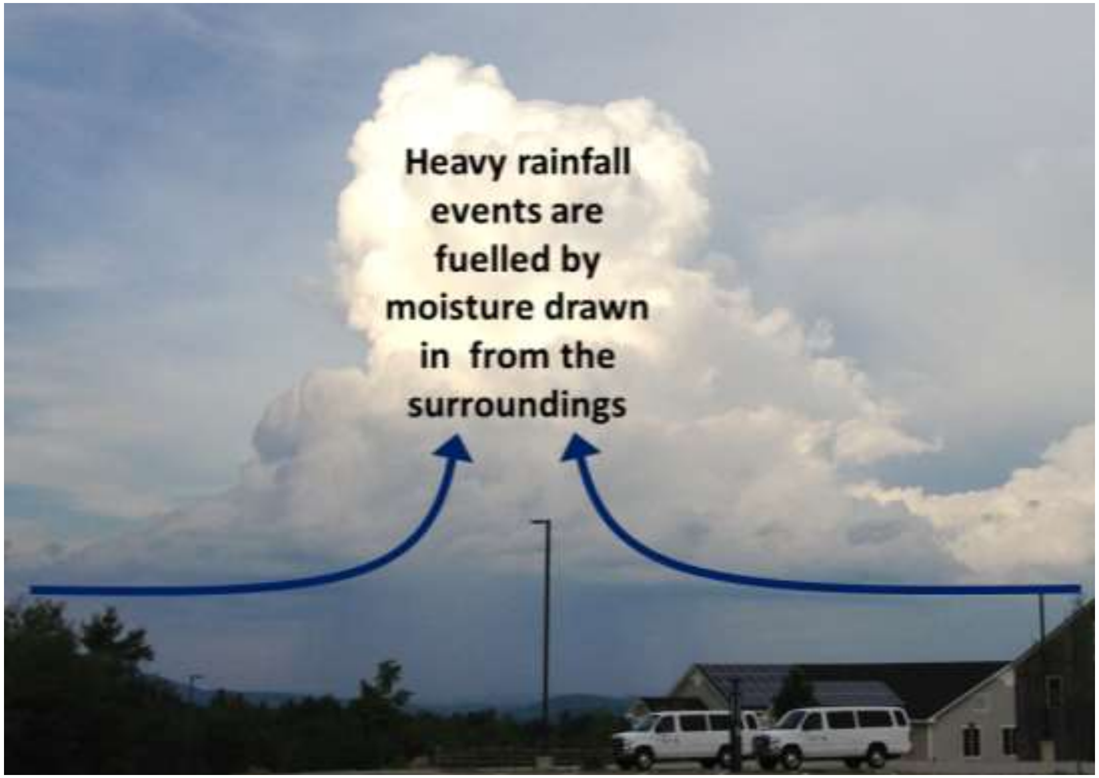


$$\frac{1}{e_s}\frac{de_s}{dT} = \frac{L}{R_v T^2}$$

$$= \begin{cases} 0.14K^{-1} & T = 200K \\ 0.07K^{-1} & T = 273K \\ 0.06K^{-1} & T = 300K \end{cases}$$

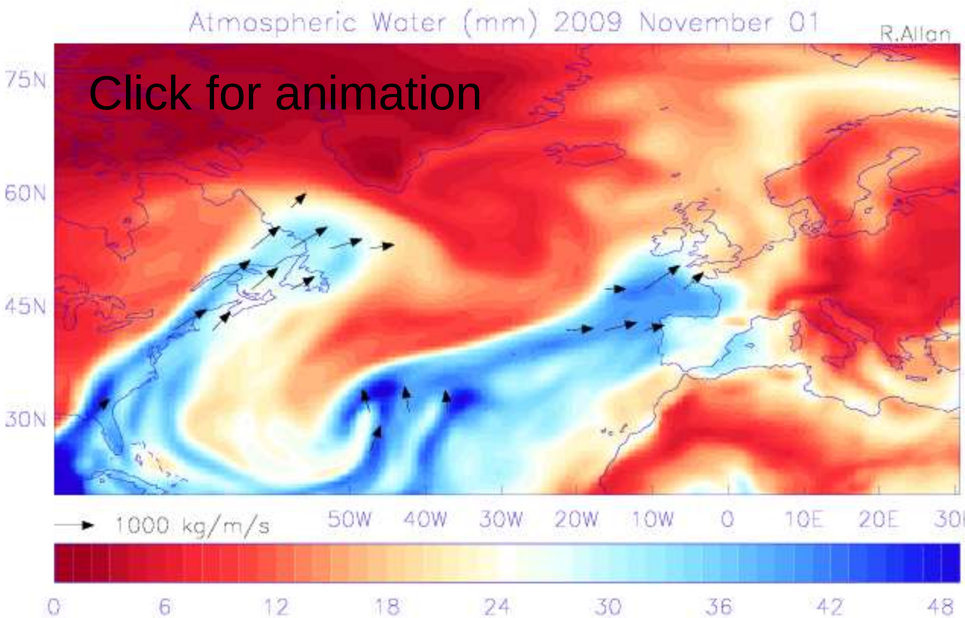
- Physics: Clausius-Clapeyron
- Low-level water vapour concentrations increase with atmospheric warming at about 6-7%/K
  - Wentz and Shabel (2000) *Nature*; Raval and Ramanathan (1989) *Nature*

Extreme Precipitation



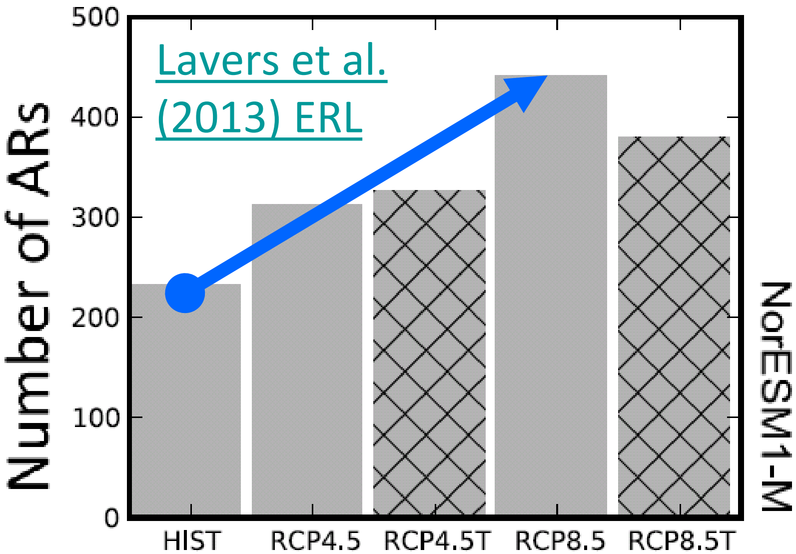
- Large-scale rainfall events fuelled by moisture convergence
  - e.g. Trenberth et al. (2003) *BAMS*
- Intensification of rainfall with global warming 7%/K or more?
  - *e.g. Allan and Soden (2008) Science ; Kendon et al. (2014) Nature Climate*

Water vapour and mid-latitude flooding



- Future increase in moisture explains most (but not all) of intensification of AR events
  - Confident in the mechanisms and physics involved

- UK winter flooding linked to strong moisture transport events
  - Cumbria November 2009 (Lavers et al. 2011 GRL)
  - "Atmospheric Rivers" (ARs) in warm conveyor

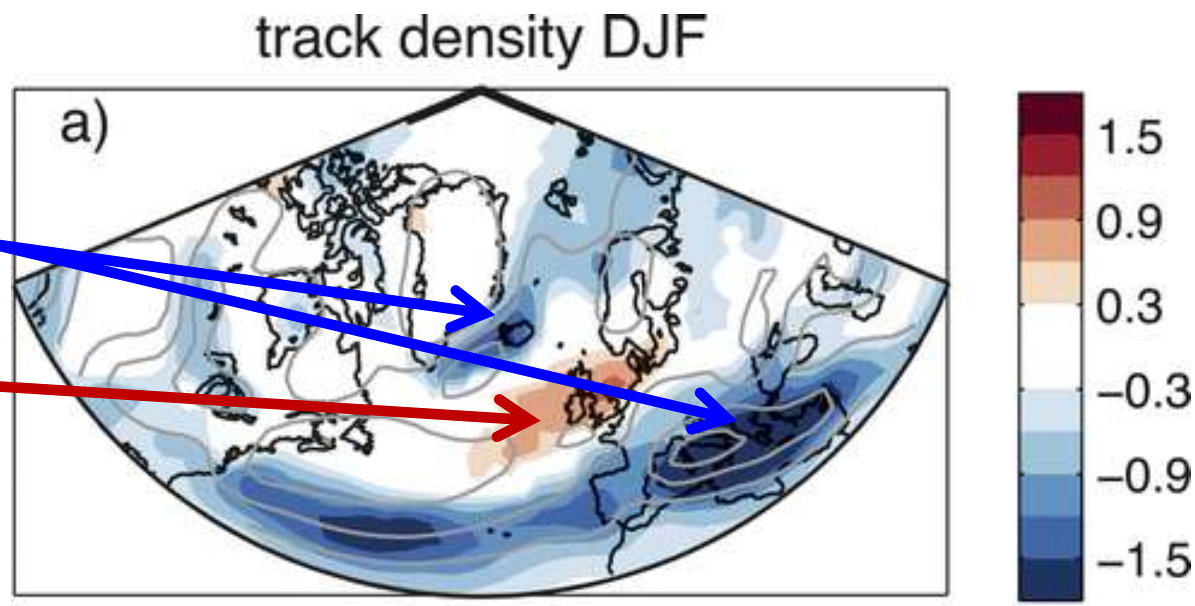


Projected changes in storms

Changes in storm frequency (2070-2100 minus 1980-2005) from climate model projections for a high-range emissions scenario.

Fewer storms over Mediterranean and Iceland.
<u>UK: Little signal.</u>

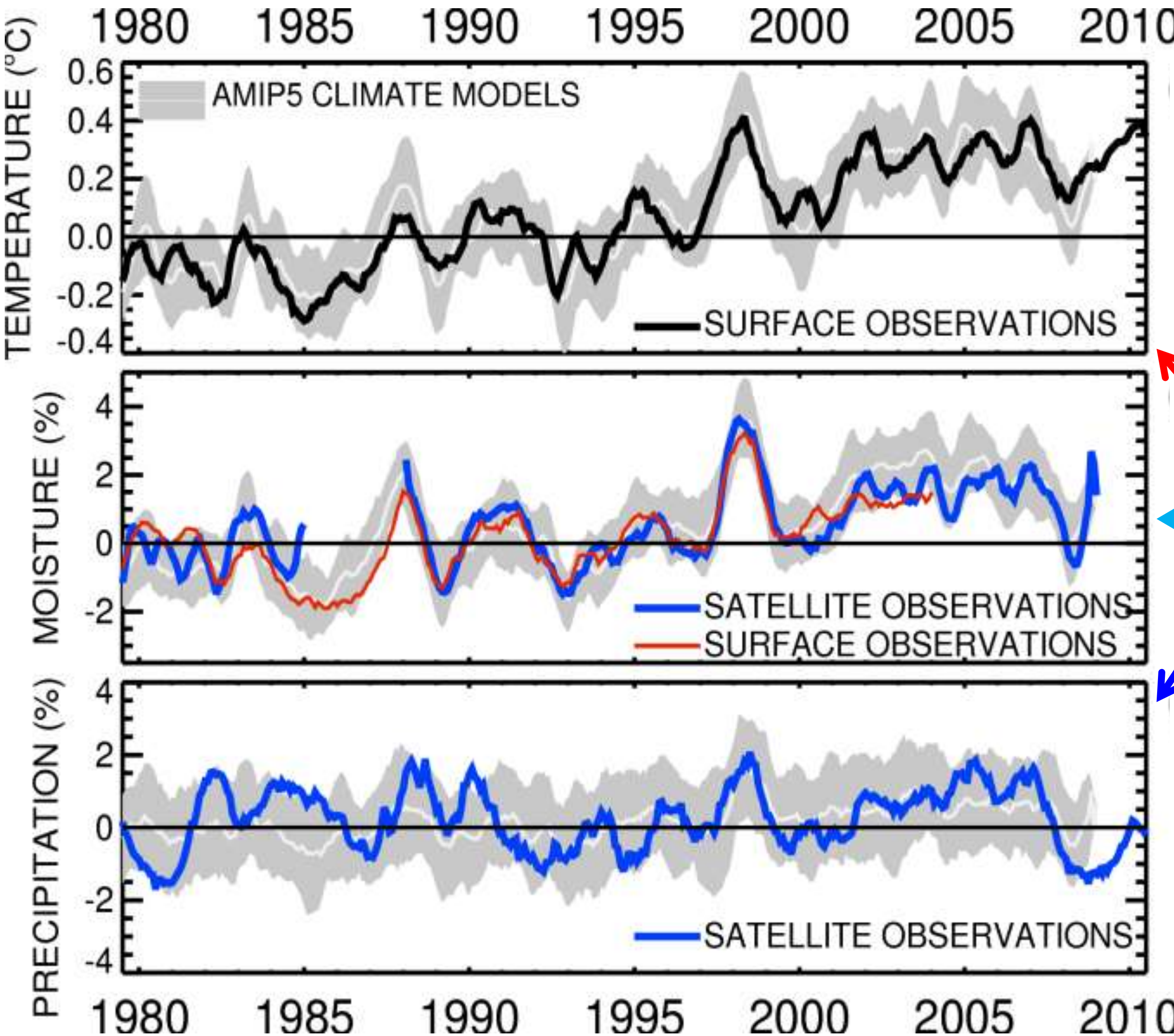
Robust signal: more extreme precipitation from all storms.



[Zappa et al. 2013 J. Clim.]

Conclusions

- Global precipitation will rise with warming ~2%/K
  - Constrained by energy budget of atmosphere and surface
- Heavy rainfall becomes more intense
  - Fuelled by increased water vapour & moisture convergence ~7%/K
- Regional projections are a challenge
  - Sensitive to small changes in atmospheric circulation
  - When atmosphere conspires to generate heavy and/or prolonged rainfall, it will be more intense in a warmer environment
- Sea level rise, due to warming oceans and melting land ice, will exacerbate coastal flooding
- Snow melt events are likely to decrease in importance



Globally, in the present-day climate, temperature, moisture and precipitation are strongly coupled

Allan et al. (2014) Surv. Geophys

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Changing water cycle

Horyuji PAGODA
HydrOlogical cYcle Understanding via Process-bAsed GlObal Detection, Attribution and prediction