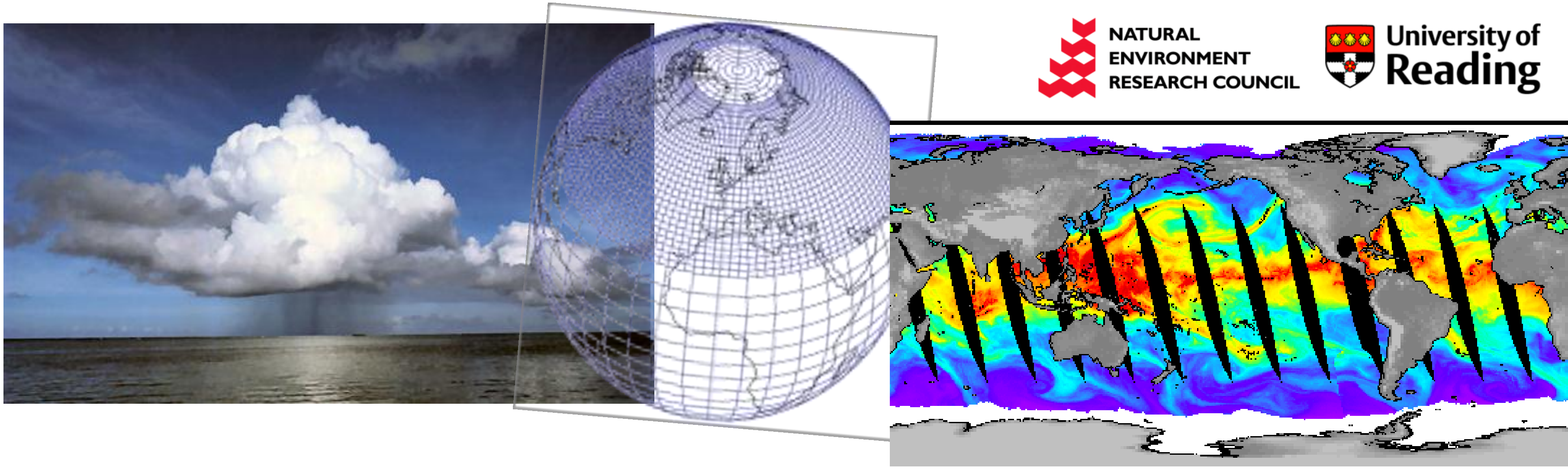

Climate change and the global water cycle

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Changing water cycle

Introduction

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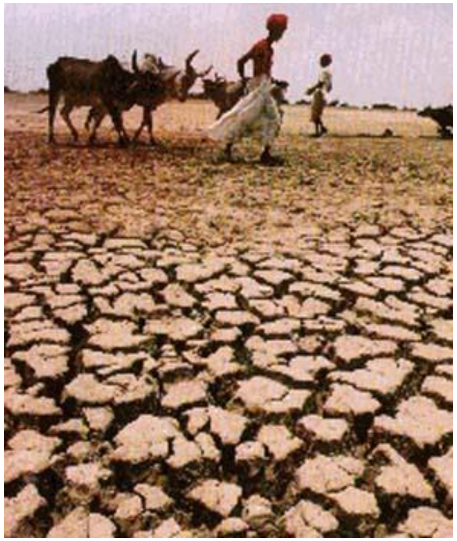
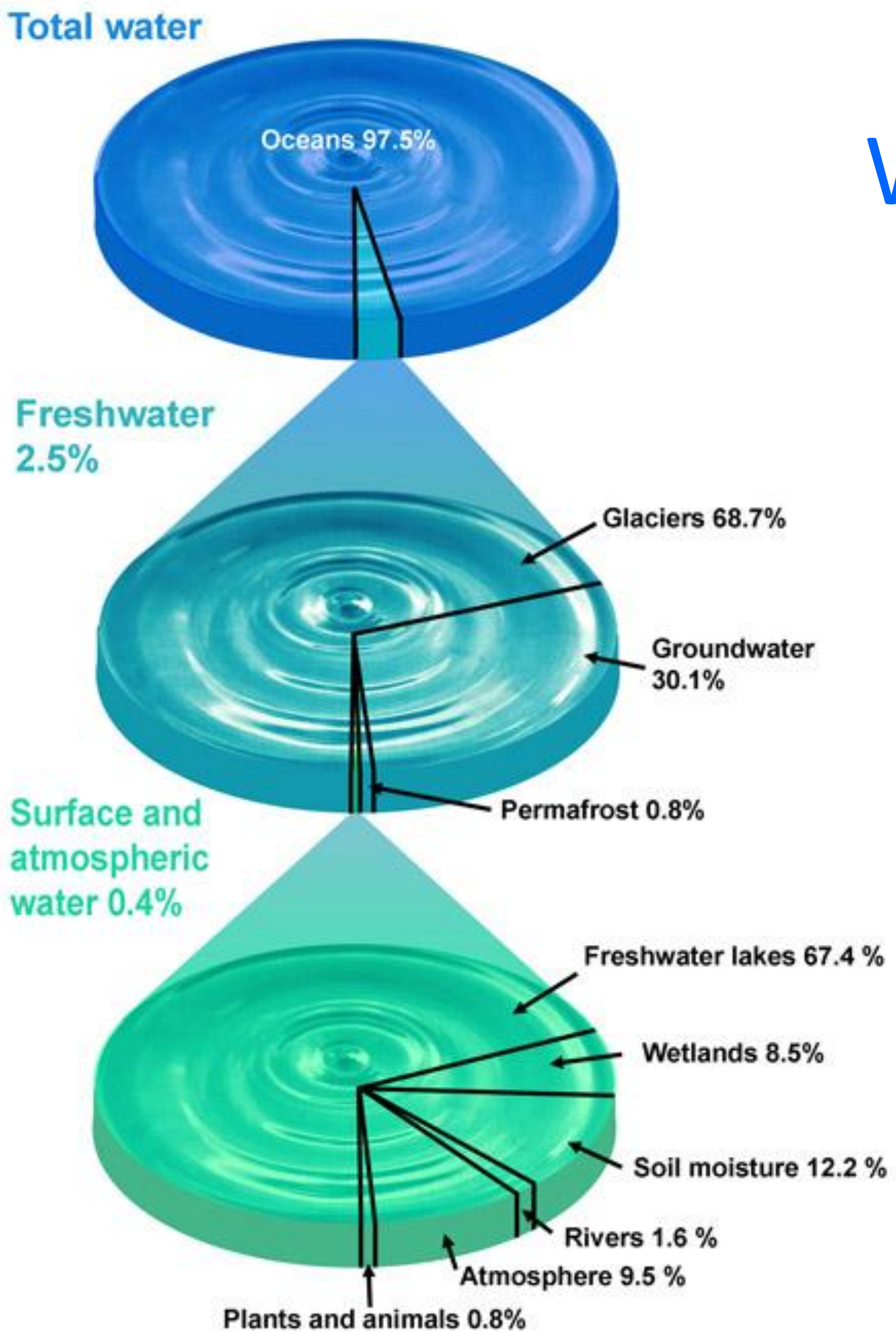
"Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems."
IPCC (2008) Climate Change and Water





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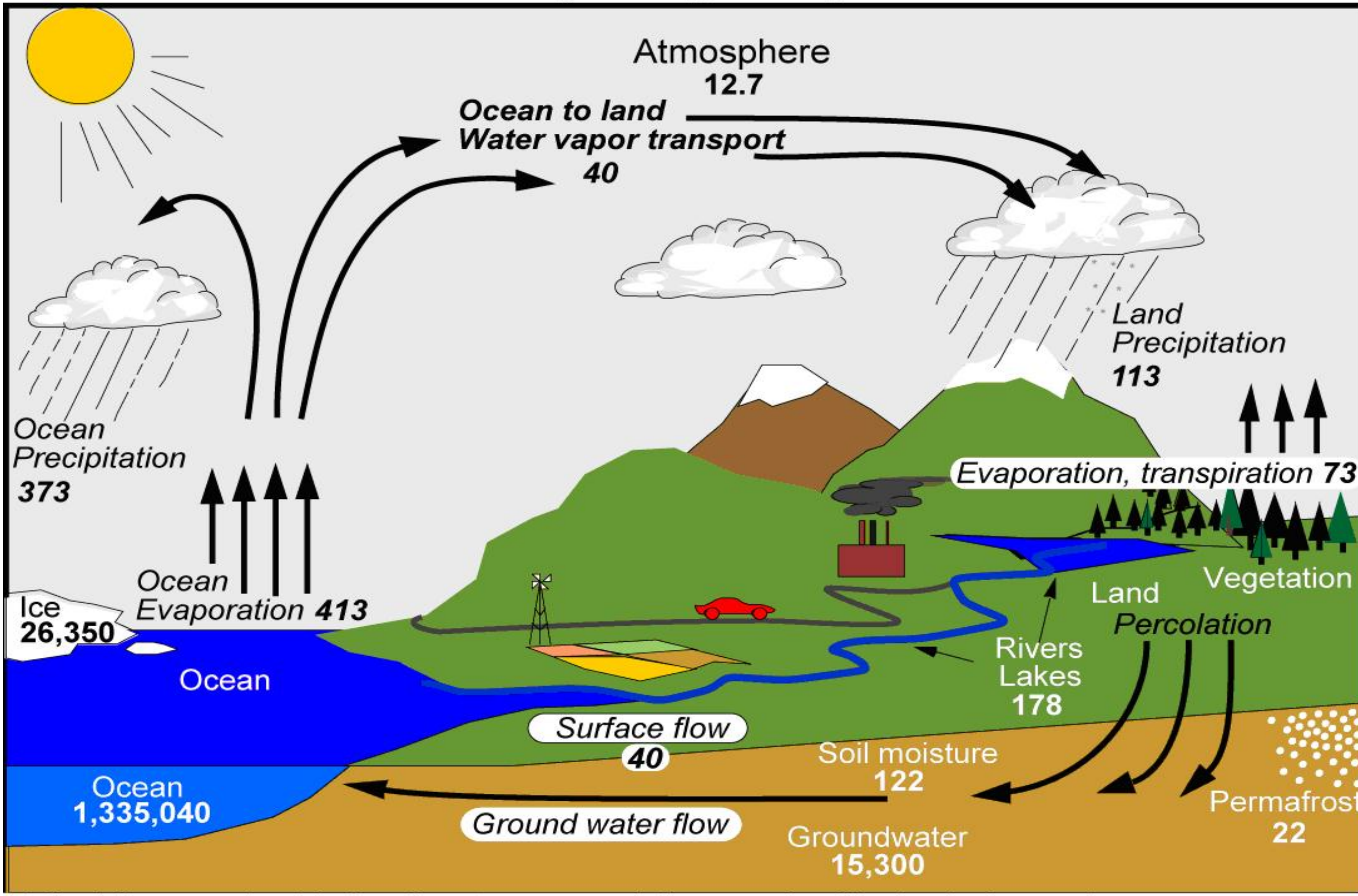
Water resources

- Most water on Earth is salty
- Most fresh water is locked away in glaciers or is deep in the ground
- Water that is usable depends strongly on the water cycle

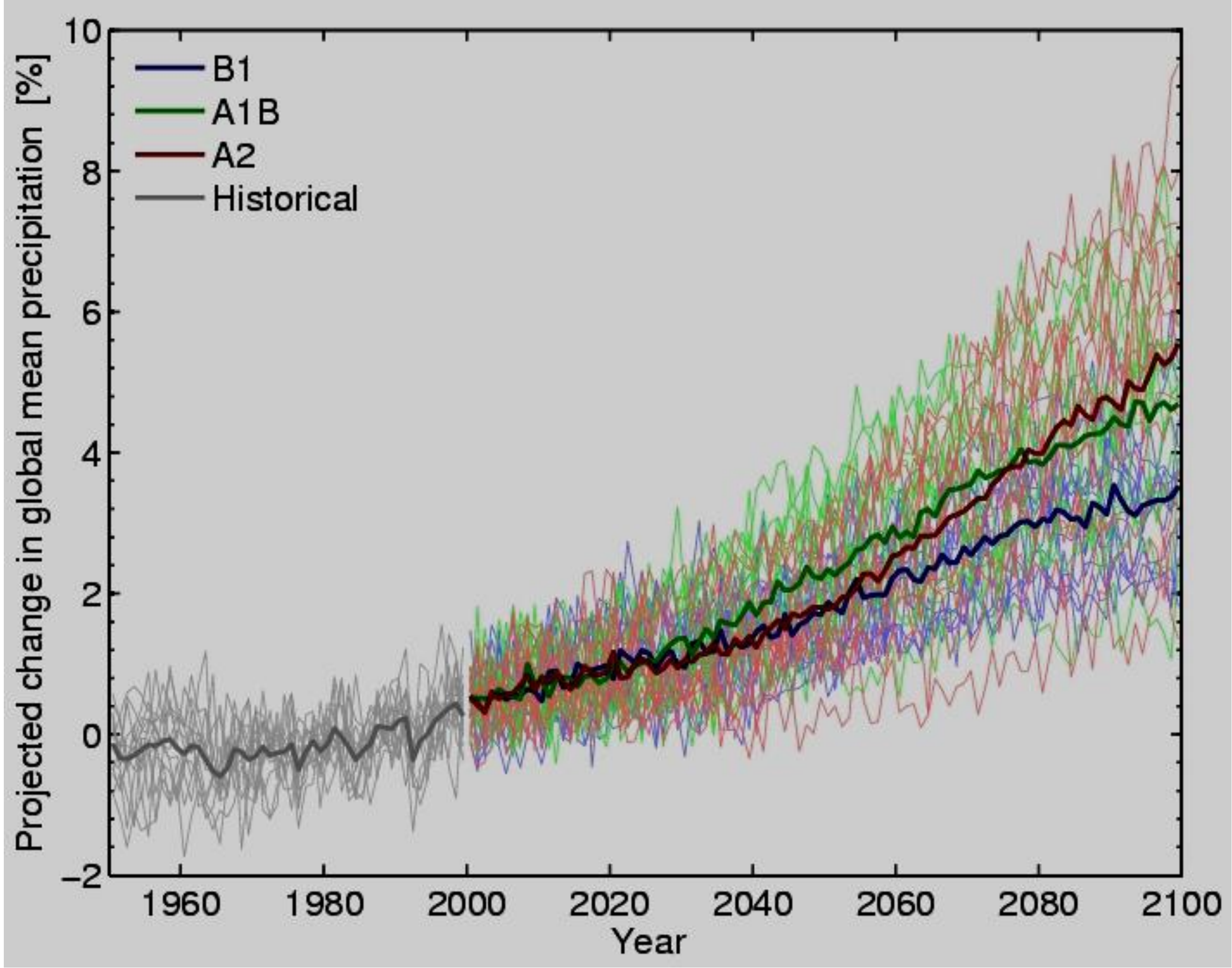
Hydrological Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Kevin Trenberth and co-authors (2007) J Hydromet

How will the global water cycle respond to climate change?



Hawkins and Sutton (2010) Clim. Dyn.

Climate model projections

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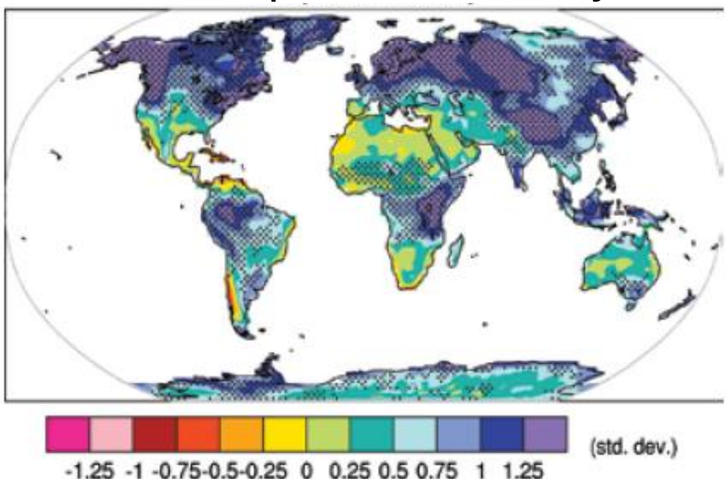
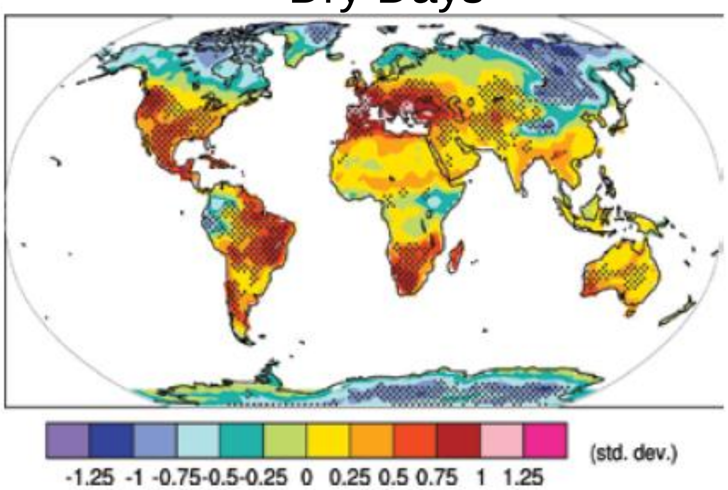
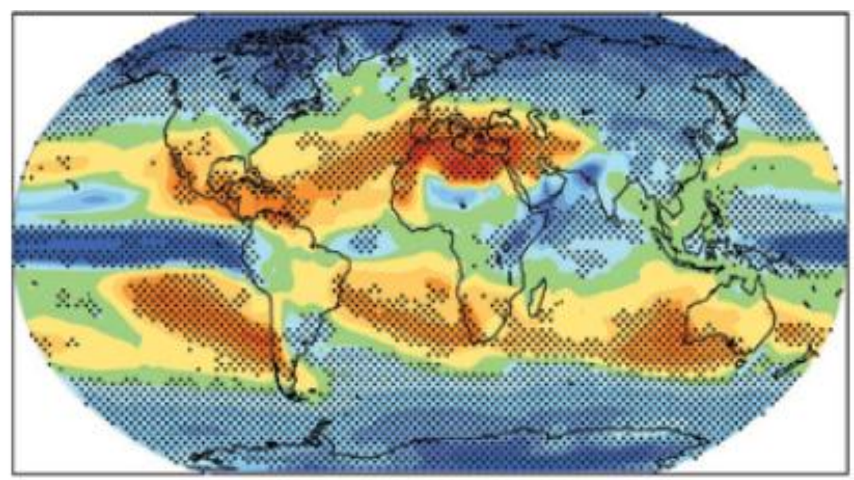
Precipitation Intensity



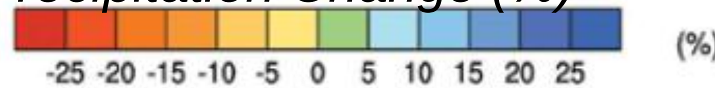
Dry Days



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

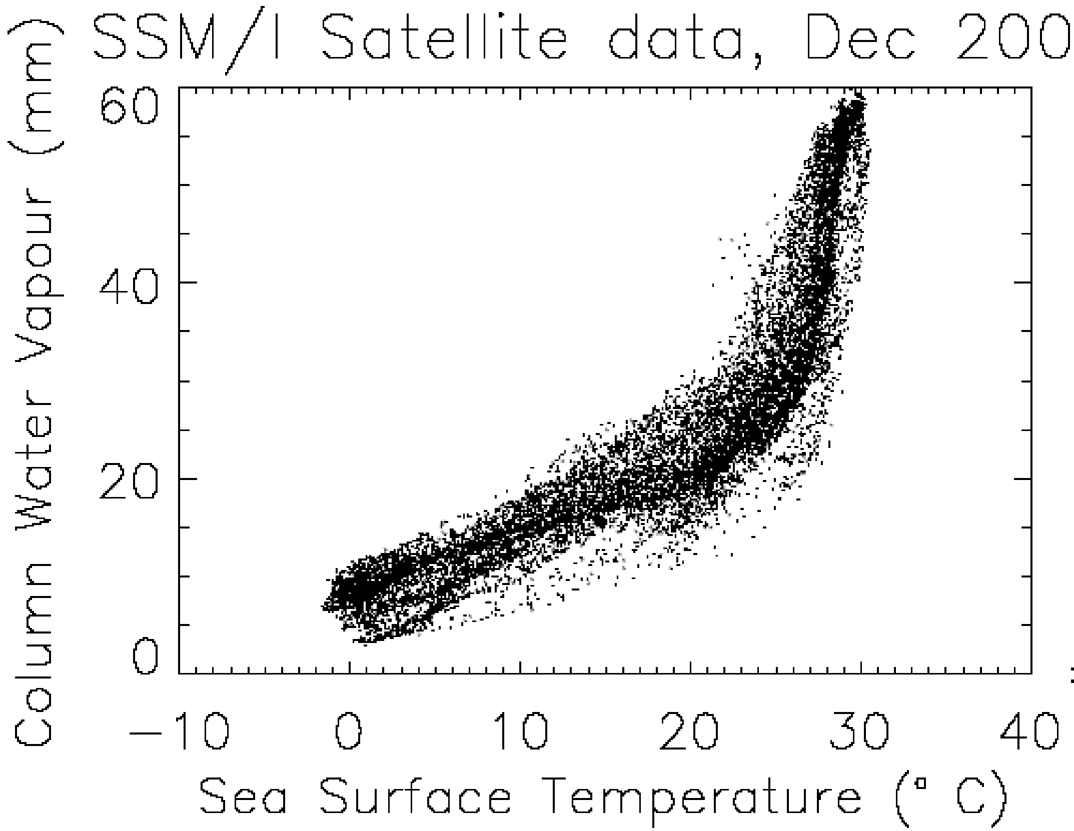


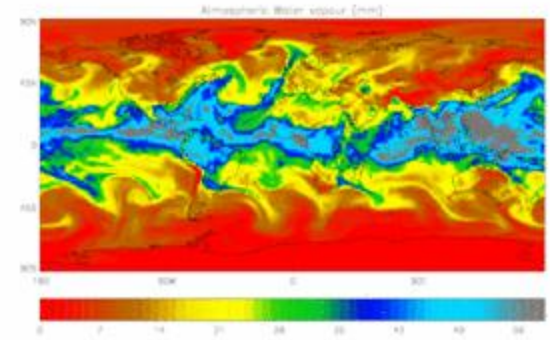
Precipitation Change (%)



IPCC WGI (2007)

The role of water vapour

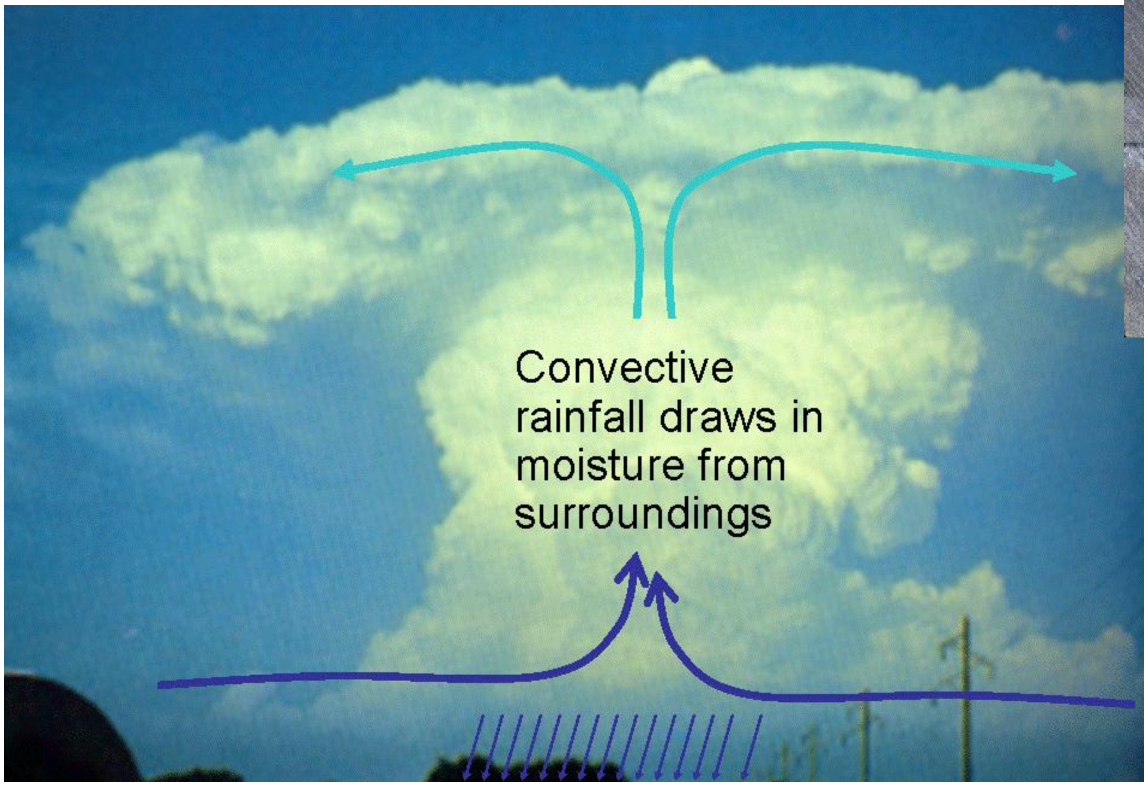




$$\frac{1}{e_s}\frac{de_s}{dT} = \frac{L}{R_v T^2} = \begin{cases} 0.14K^{-1} & T = 200K \\ 0.07K^{-1} & T = 273K \\ 0.06K^{-1} & T = 300K \end{cases}$$

- 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*

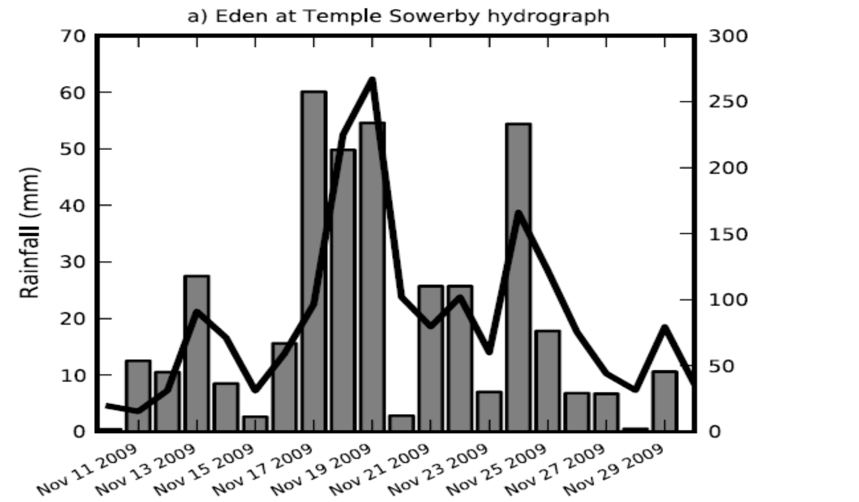
Extreme Precipitation

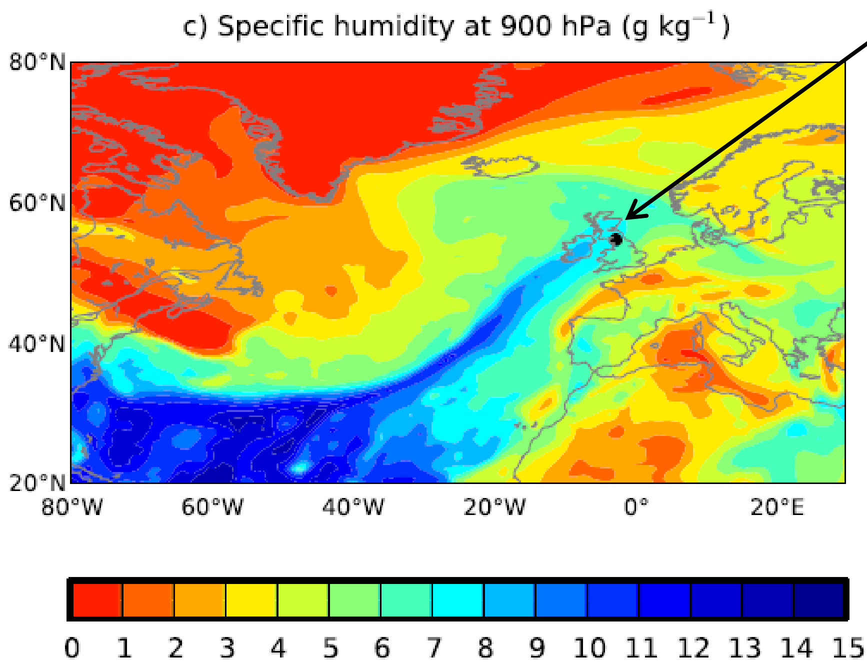


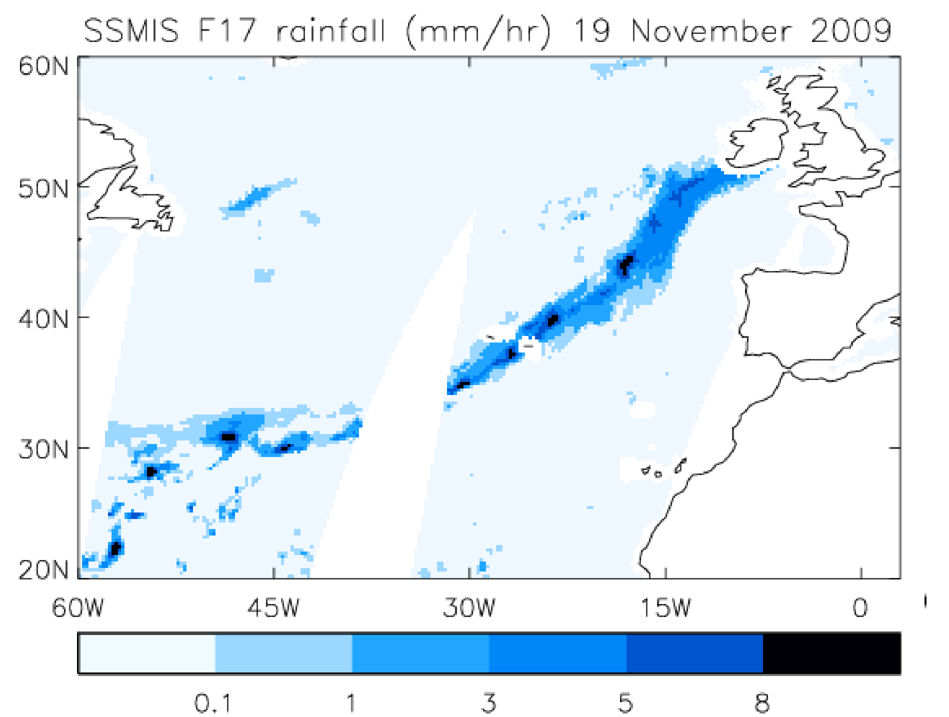
- Large-scale rainfall events fuelled by moisture convergence
  - e.g. Trenberth et al. (2003) *BAMS*
- Intensification of rainfall with global warming
  - *e.g. Allan and Soden (2008) Science*

Extreme precipitation & mid-latitude flooding

- Links UK winter flooding to moisture conveyor events
  e.g. Nov 2009 Cumbria floods

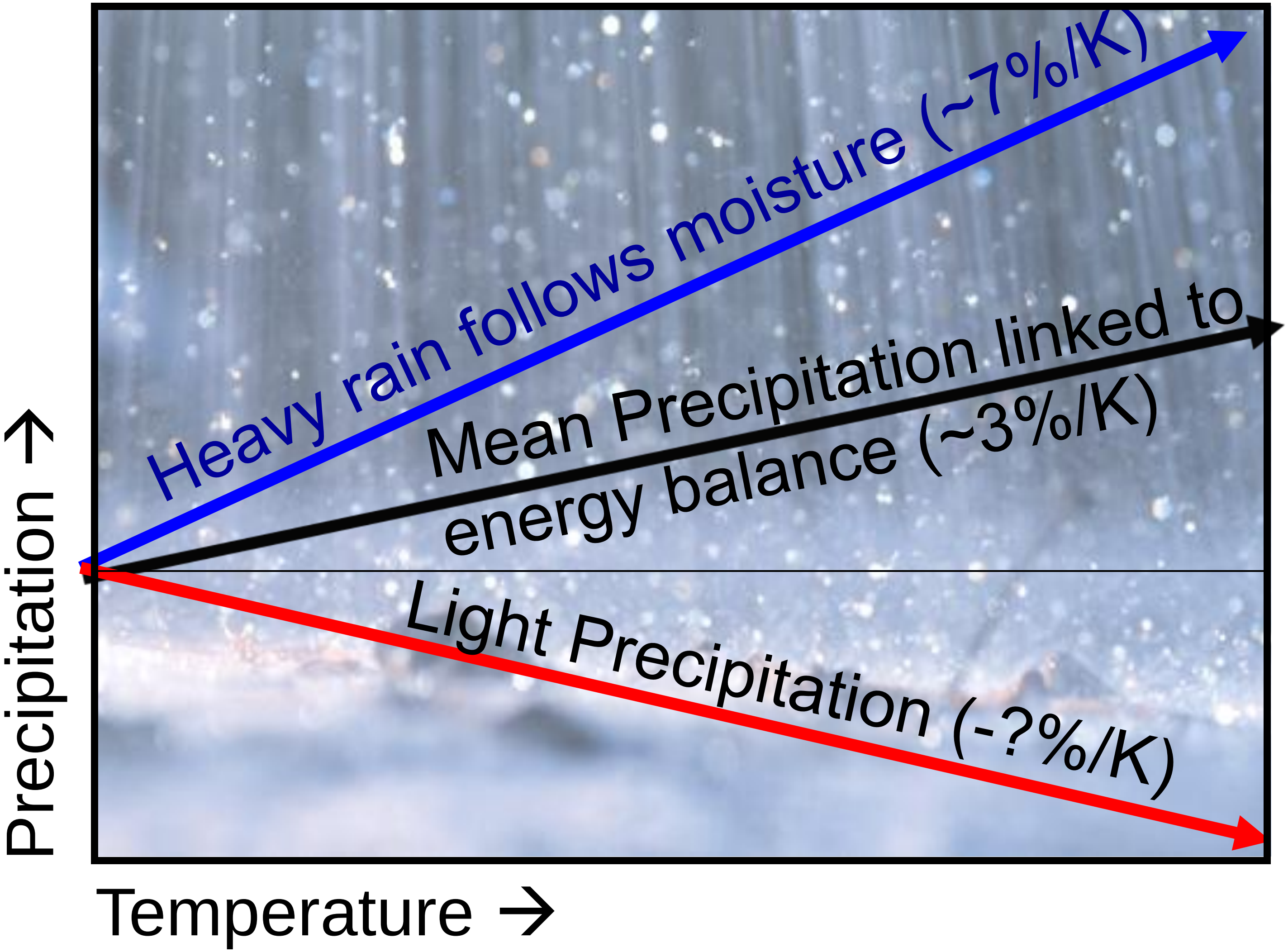






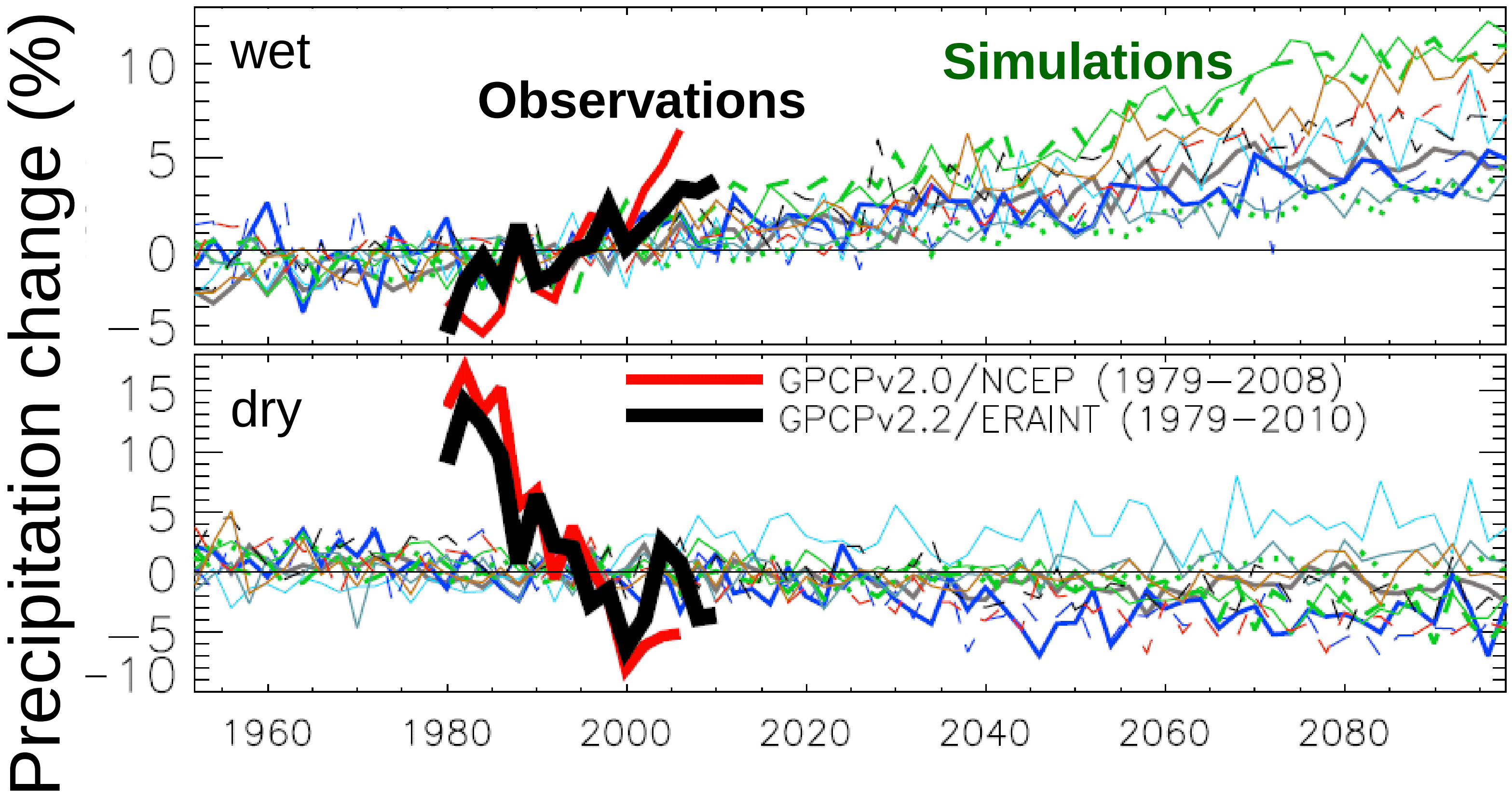
Lavers et al. (2011) Geophys. Res. Lett.

Contrasting precipitation response expected



e.g. Allen and Ingram (2002) *Nature*; Allan (2011) *Nature*

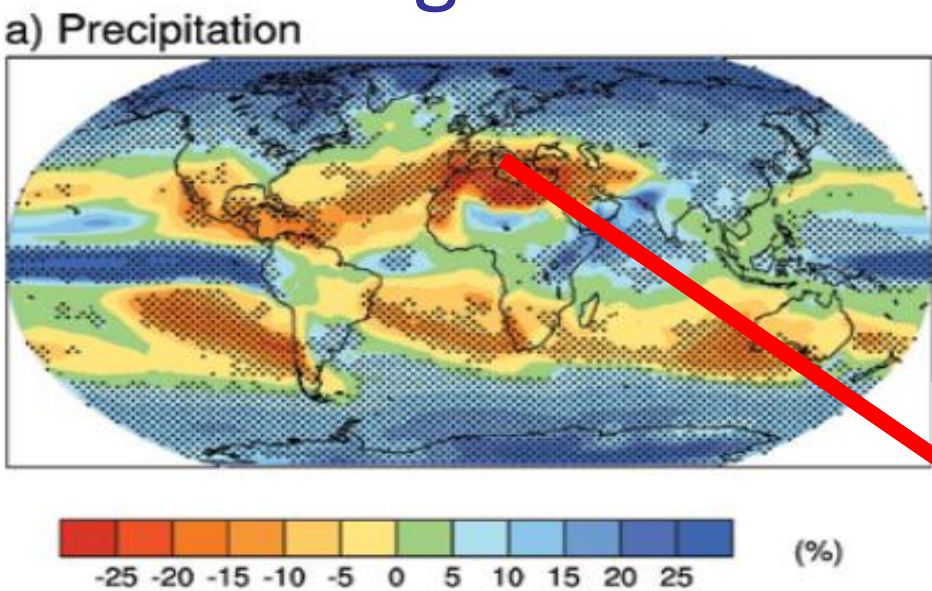
Contrasting precipitation response in wet and dry regions of the tropical circulation



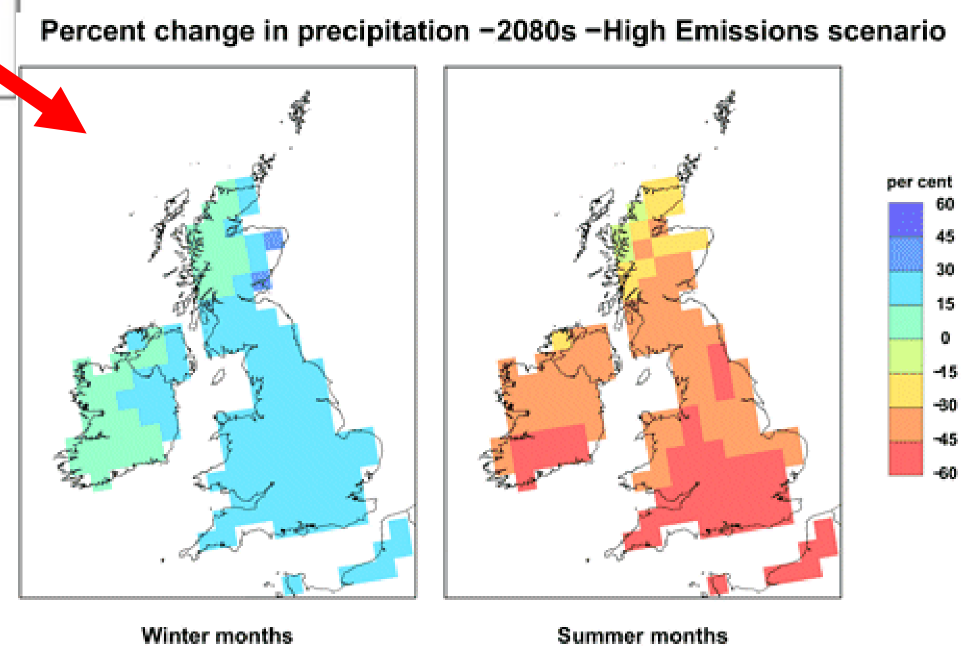
Sensitivity to reanalysis dataset used to define wet/dry regions

Updated from Allan *et al.* (2010) *Environ. Res. Lett.*; see also Liu et al. (2012) *GRL*

One of the largest challenges remains improving predictability of regional changes in the water cycle…



Changes in circulation systems are crucial to regional changes in water resources and risk yet predictability is poor.



How will catchment-scale runoff and crucial local impacts and risk respond to warming?

What are the important land-surface and ocean-atmosphere feedbacks which determine the response?

Conclusions

- Global precipitation will rise with warming ~2%/K
  - Constrained by energy budget
- Heavy rainfall becomes more intense
  - Fuelled by increased water vapour (~7%/K)
- Wet get wetter, dry get drier
  - More flooding, more drought ?
- Regional projections are a challenge
  - Sensitive to small changes in atmospheric circulation
- How do we make large-scale projections relevant for small scale impacts?