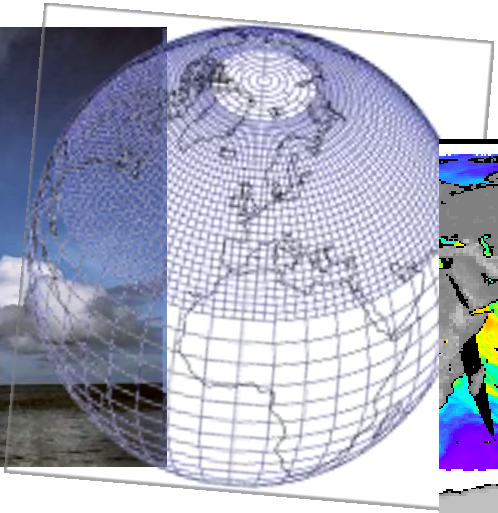

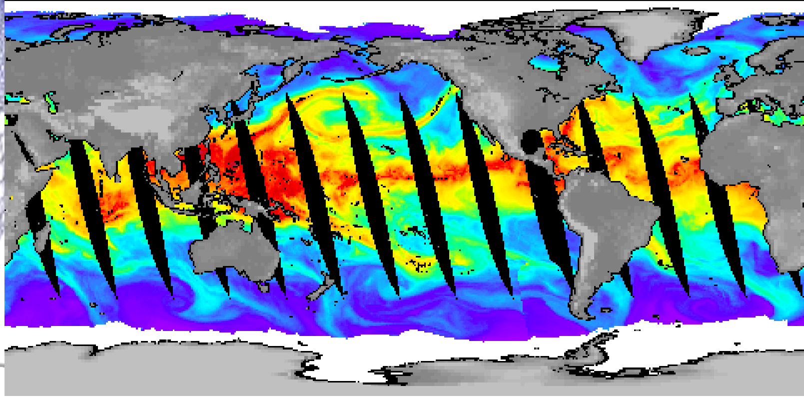

Climate change and the global water cycle

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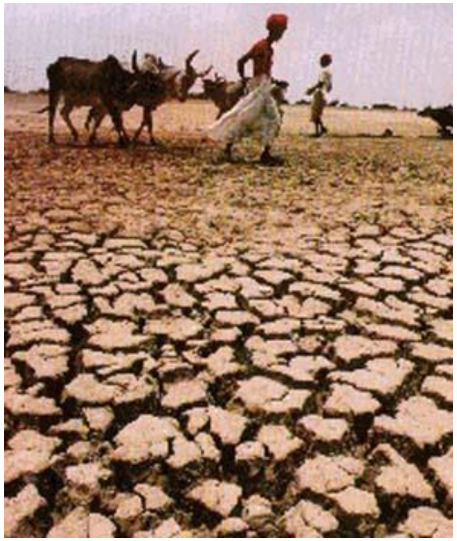
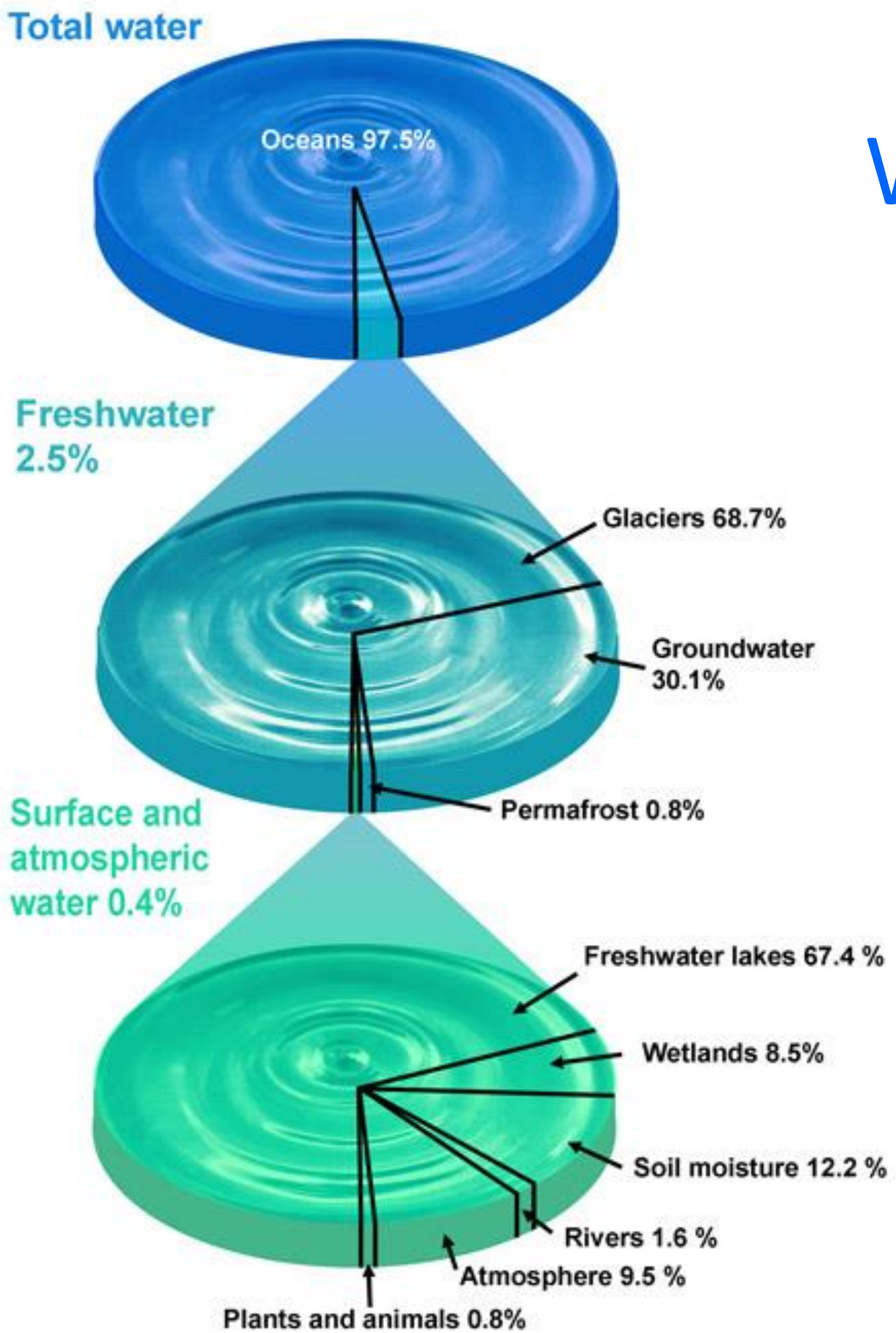
Climate-KIC – TheJourney. University of Reading 22nd August 2013

Introduction

"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

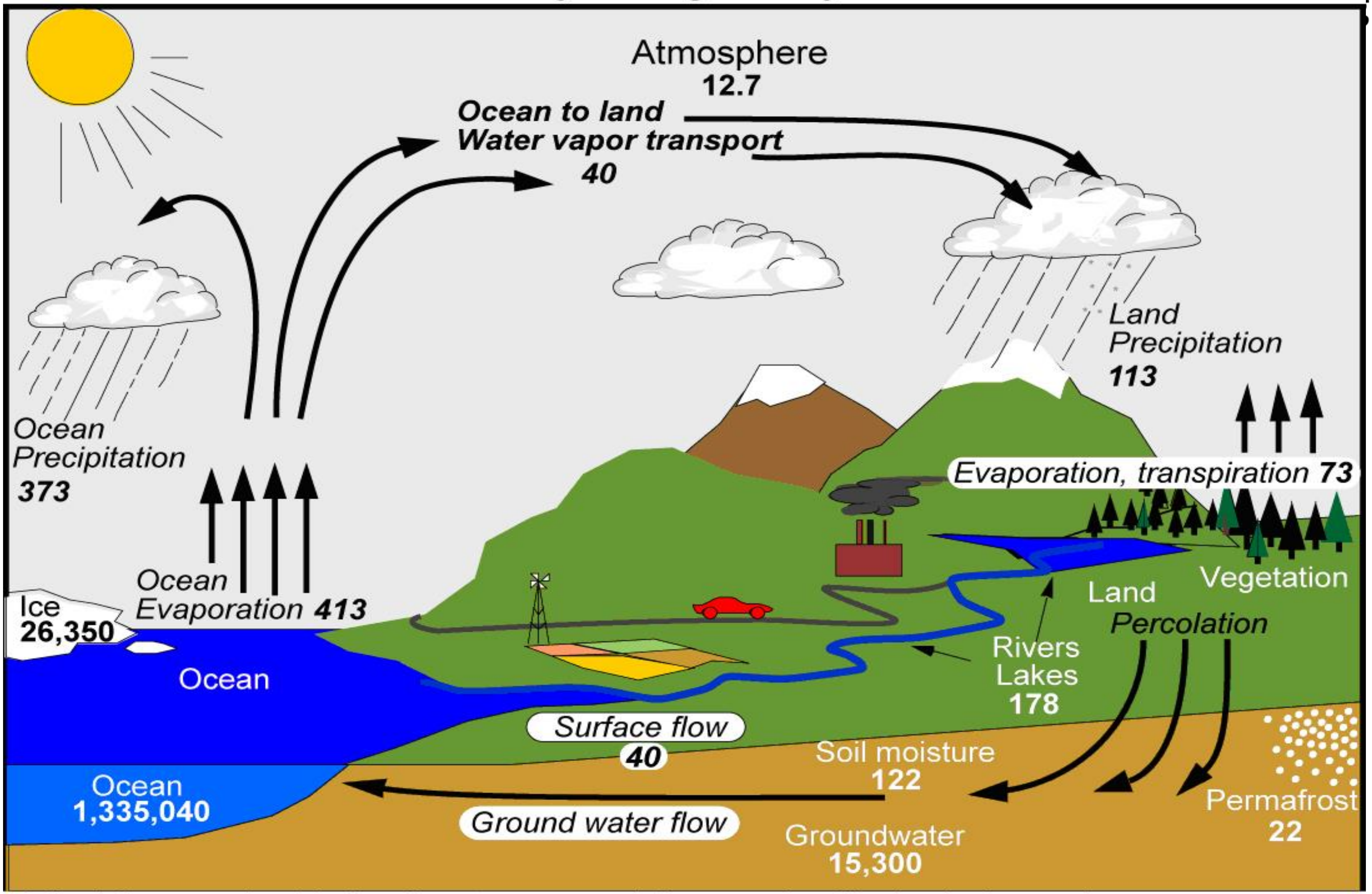


Water resources



- 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

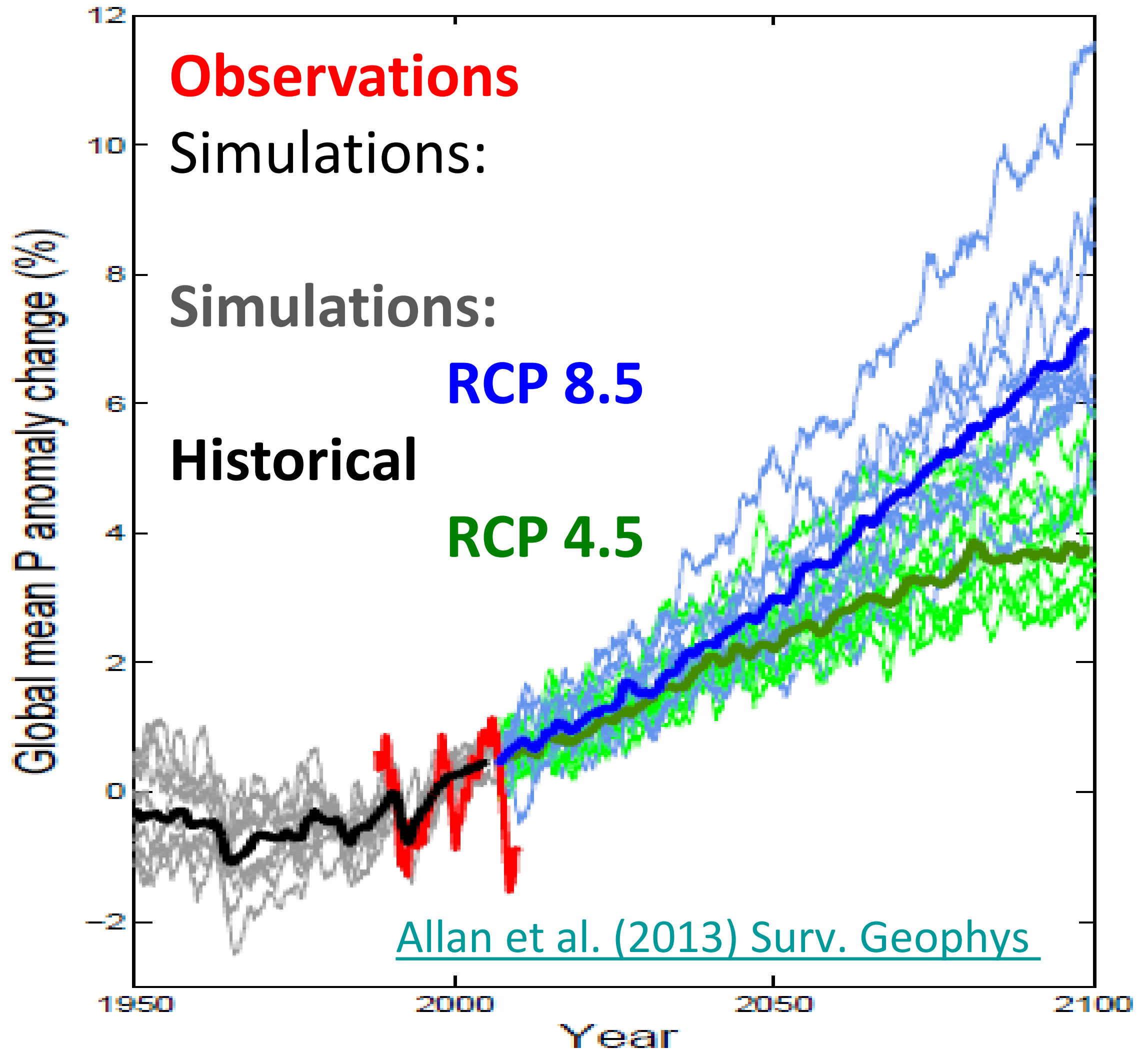
Hydrological Cycle



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

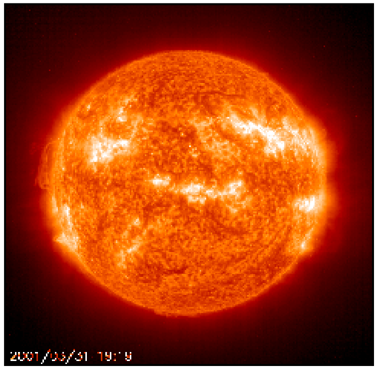
[Kevin Trenberth and co-authors (2007) J Hydromet]

How will global precipitation respond to climate change?



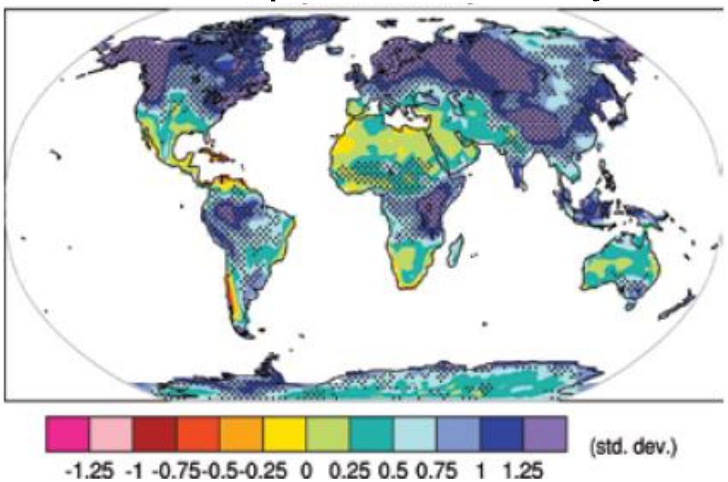
Allan et al. (2013) Surv. Geophys

See also Hawkins & Sutton (2010) Clim. Dyn

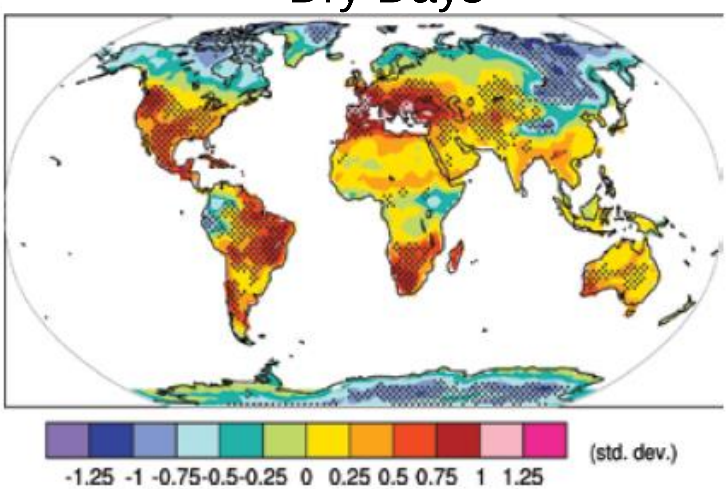


Climate model projections

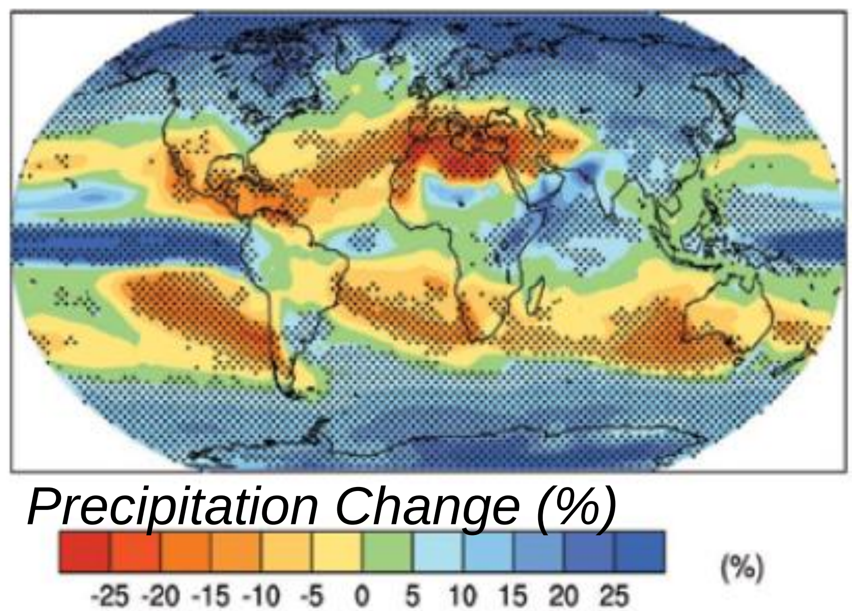
Precipitation Intensity



Dry Days



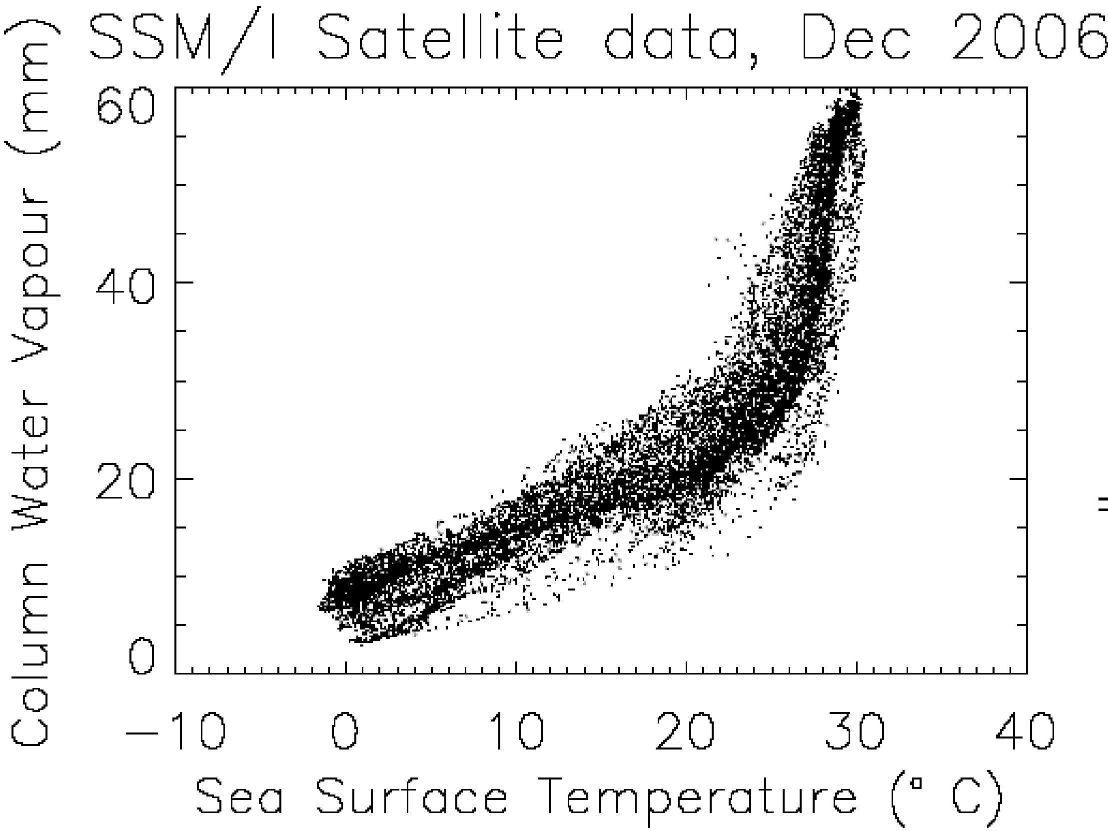
- Increased Precipitation
- More Intense Rainfall
- More droughts
- Wet regions get wetter, dry regions get drier?
- Regional projections??



Precipitation Change (%)

IPCC WGI (2007)

The role of water vapour

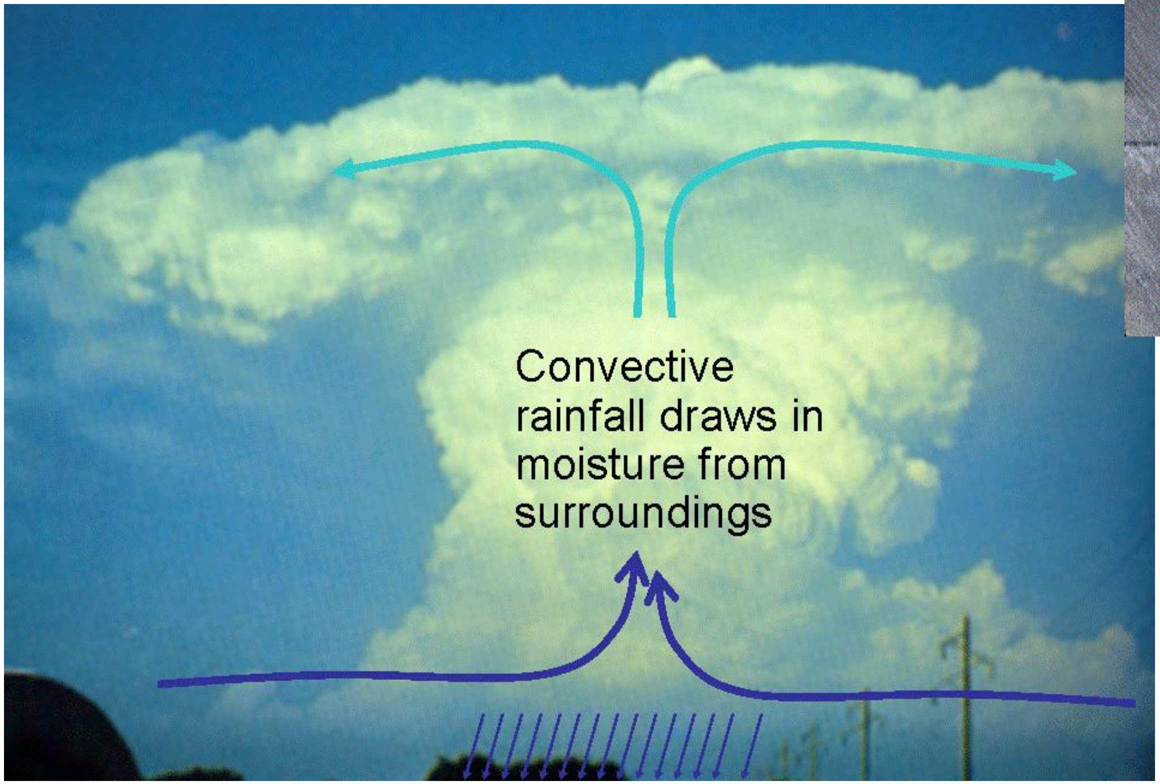


$$\frac{1}{e_s}\frac{de_s}{dT} = \frac{L}{R_v T^2}$$

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

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

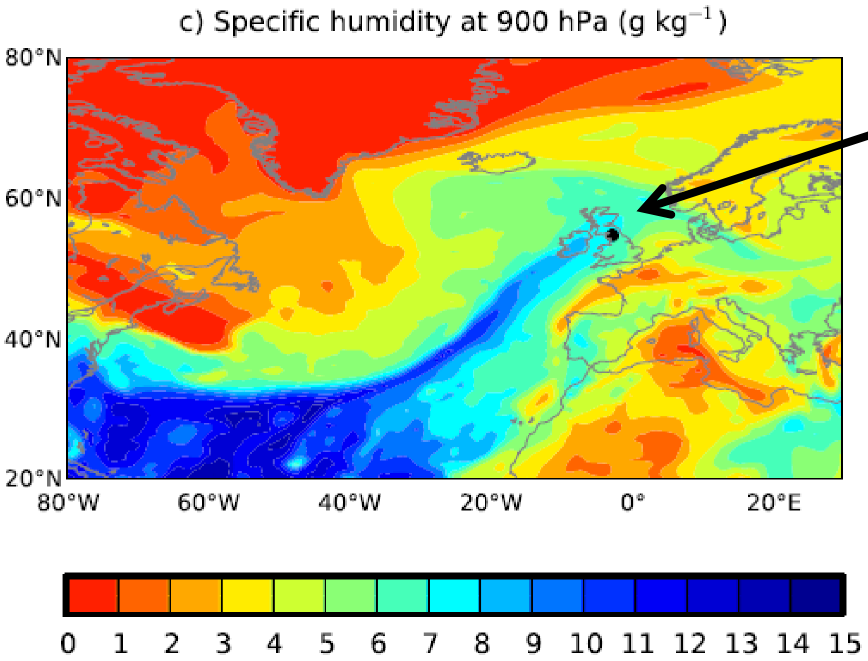
Extreme Precipitation

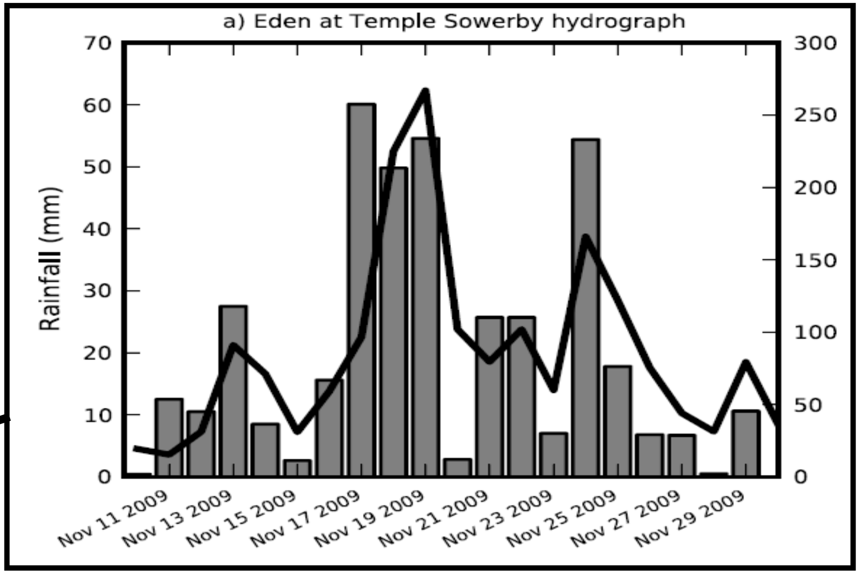


- Large-scale rainfall events fuelled by moisture convergence
  - e.g. Trenberth et al. (2003) *BAMS*
- Intensification of rainfall with global warming
  - *e.g. Allan and Soden (2008) Science*

Extreme precipitation & mid-latitude flooding

UK winter flooding linked to "Atmospheric Rivers" (ARs)
e.g. Nov 2009 Cumbria floods



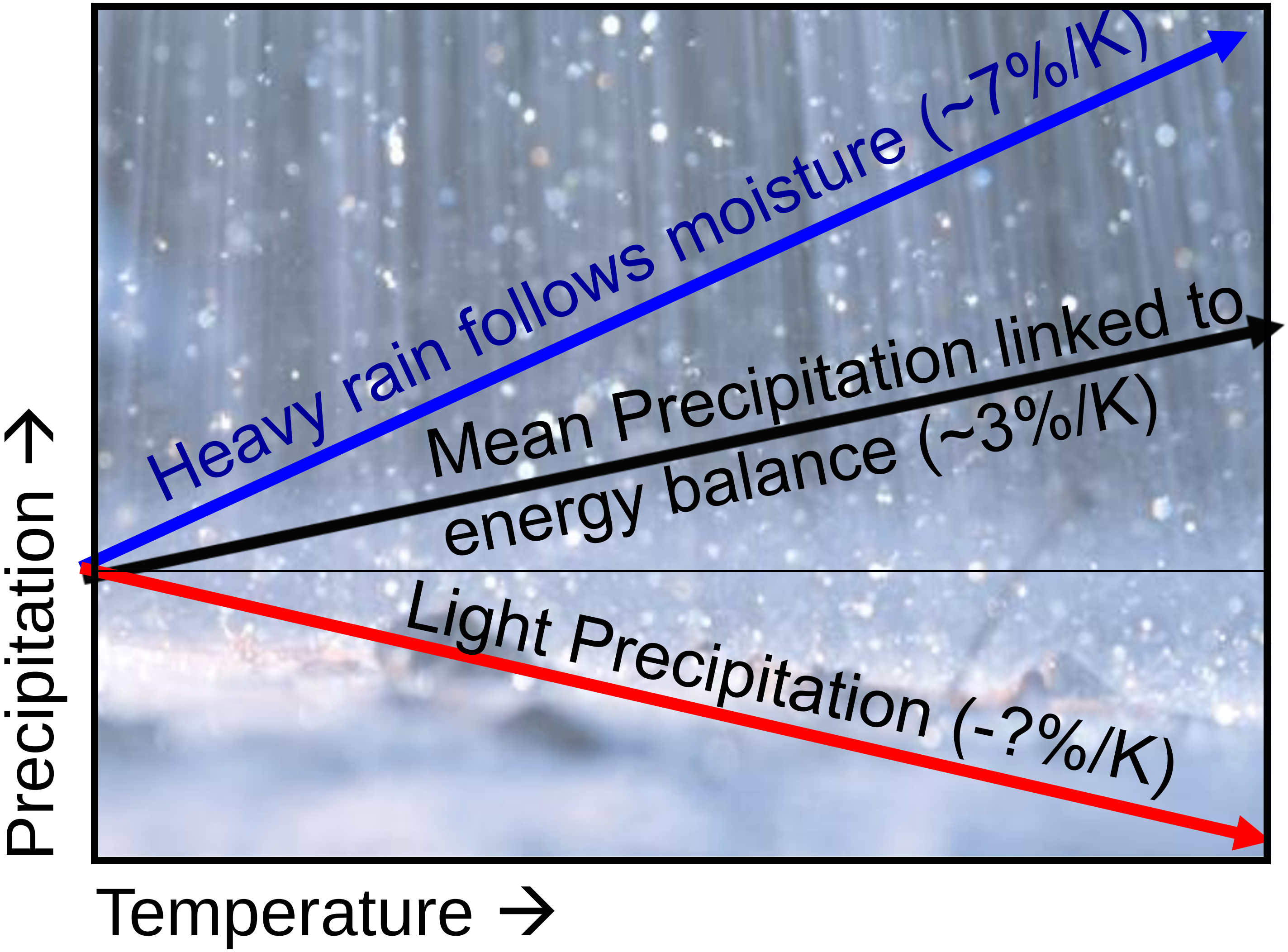


Lavers et al. (2011) Geophys. Res. Lett.

Climate change response: intensification of AR events

Lavers et al. (2013) Environ. Res. Lett.

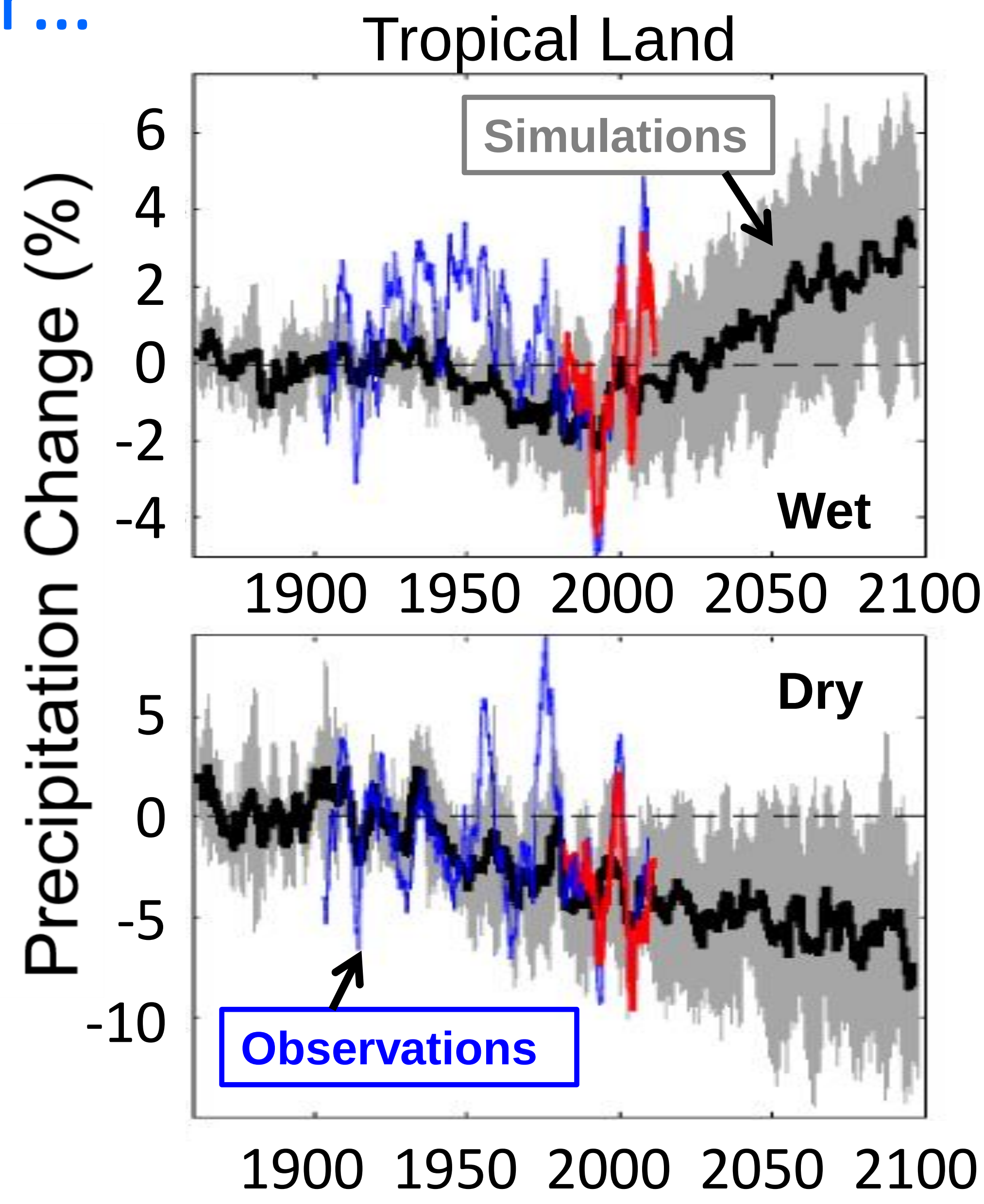
Contrasting precipitation response expected



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

The Rich Get Richer…

- Wet regions become wetter, already dry regions drier
- Observations and detailed computer simulations (CMIP5)



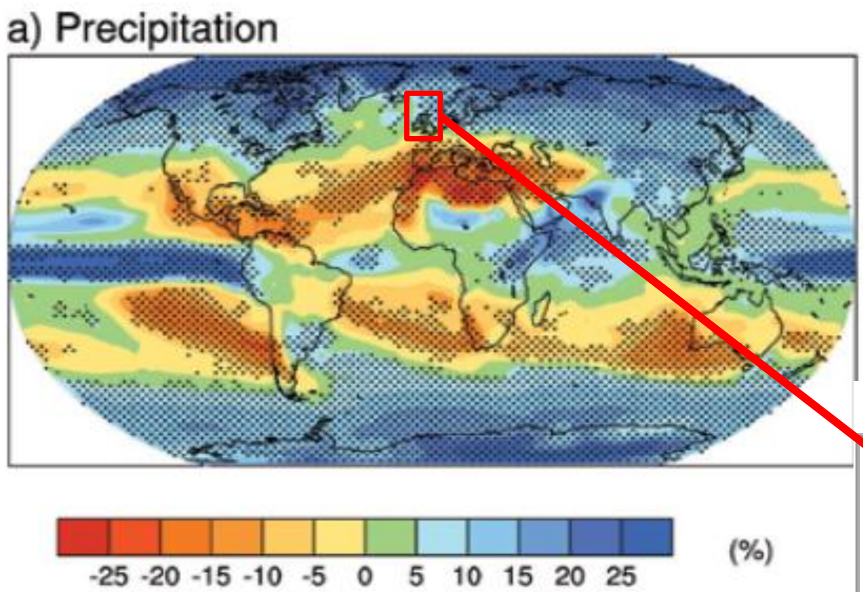
Liu & Allan (2013)
Environmental Research Letters

NATURAL ENVIRONMENT RESEARCH COUNCIL

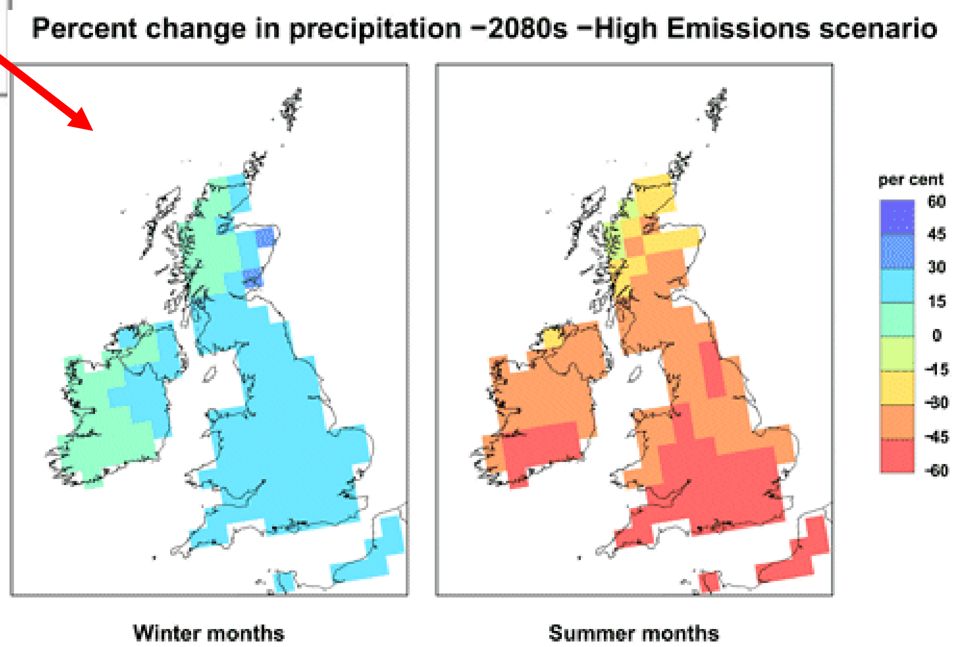
Changing water cycle

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

Challenge: Regional projections



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 ~2-3%/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?