Climate change and the global water cycle

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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
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?

Observations

Simulations:

- RCP 8.5
- Historical
- RCP 4.5

Allan et al. (2013) Surv. Geophys

Climate model projections

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

IPCC WGI (2007)
The role of water vapour

- **Physics:** Clausius-Clapeyron

- Low-level water vapour concentrations increase with atmospheric warming at about 6-7%/K
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


Climate change response: intensification of AR events
Contrasting precipitation response expected

- Heavy rain follows moisture (~7%/K)
- Mean Precipitation linked to energy balance (~3%/K)
- Light Precipitation (-?%/K)

The Rich Get Richer...

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

Liu & Allan (2013)
*Environmental Research Letters*
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?