A Changing Character of Precipitation in a Warming World: Physical Drivers

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How will the water cycle change?

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

IPCC WGI (2013)
Physical Driver: Earth’s Energy Balance

Physical Driver: water vapour

- Physics: Clausius-Clapeyron

- Low-level water vapour concentrations increase with atmospheric warming at about 6-7%/K
Globally, in the present-day climate, temperature, moisture, and precipitation are strongly coupled.

Allan et al. (2014) Surv. Geophys
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

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

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

- Heavy rain follows moisture (~7%/K)
- Mean Precipitation linked to energy balance (~2-3%/K)
- Light Precipitation (-?%/K)

The Rich Get Richer...

- Wet regions become wetter, already dry regions drier
- Observations and detailed computer simulations (CMIP5)
- But wet/dry regions move around
e.g. Allan (2014) Nature Geosci.

Liu & Allan (2013) Environmental Research Letters
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?

Aerosol radiative forcing, internal variability and feedbacks involving land surface & ocean-atmosphere coupling all influence regional circulation & precipitation patterns.

Challenge: Regional projections

JJA

DJF
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 (~7%/K)
- Wet get wetter, dry get drier
  - More flooding, more drought?
  - But wet and dry regions don’t stay still...
- Regional projections are a challenge
  - Sensitive to small changes in atmospheric circulation