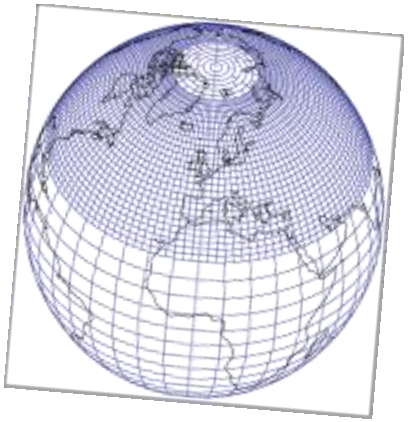

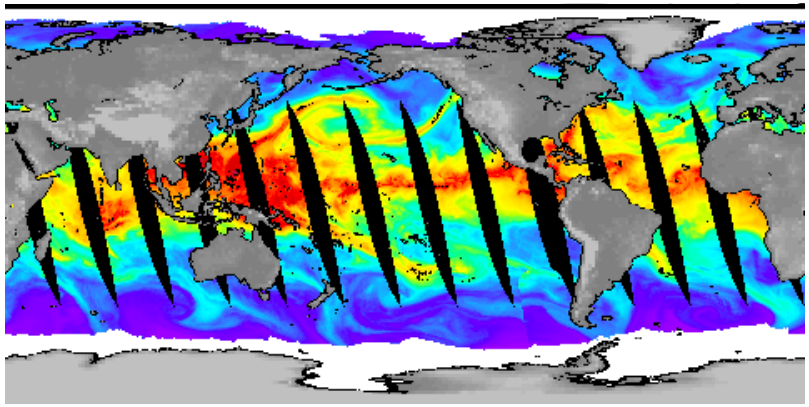

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HydrOlogical cYcle Understanding via Process-bAsed GlObal Detection, Attribution and prediction

Changing water cycle

Current changes in precipitation and moisture

Richard P. Allan, Chunlei Liu, Matthias Zahn

Department of Meteorology, University of Reading

Thanks to George Huffman, Viju John, Brian Soden, William Ingram

http://www.met.reading.ac.uk/~sgs02rpa

r.p.allan@reading.ac.uk

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Met Office

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How well do we understand current changes in precipitation and moisture?

- Seeking robust responses in the hydrological cycle that are:

  (1) physically understandable

  (2) observable
- Is Clausius Clapeyron a sufficient contraint for:
  - Low level water vapour amount?
  - The rich get richer (wetter, fresher)?
  - Heavier heavy rainfall?
- Global precipitation changes constrained by energy balance
  - Slow responses ($\kappa\Delta T$) and fast response to radiative forcing (F)
  - $L\Delta P \approx \kappa\Delta T - F(1-R)$
- Combine models and observations to understand system

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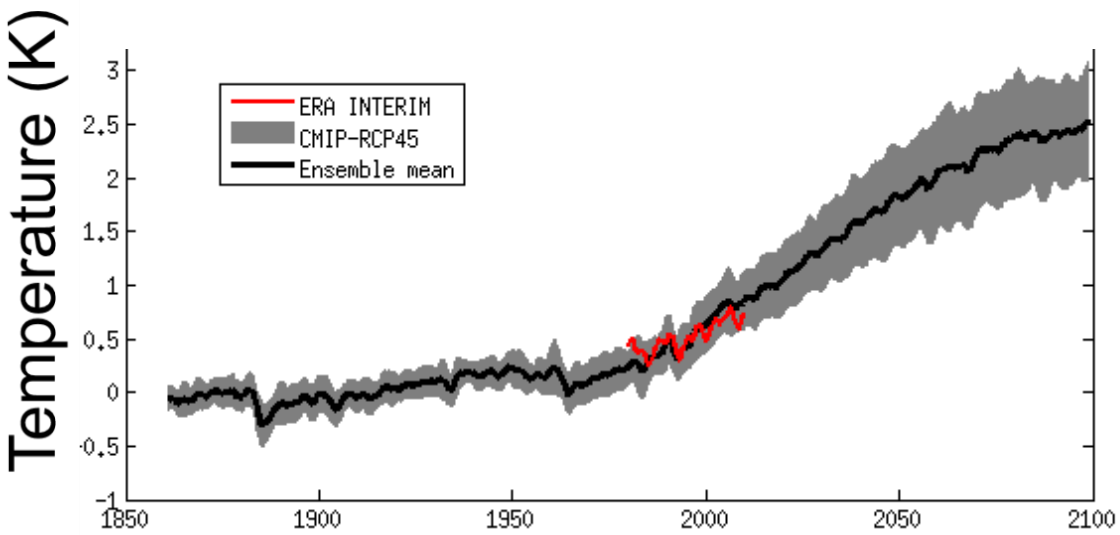
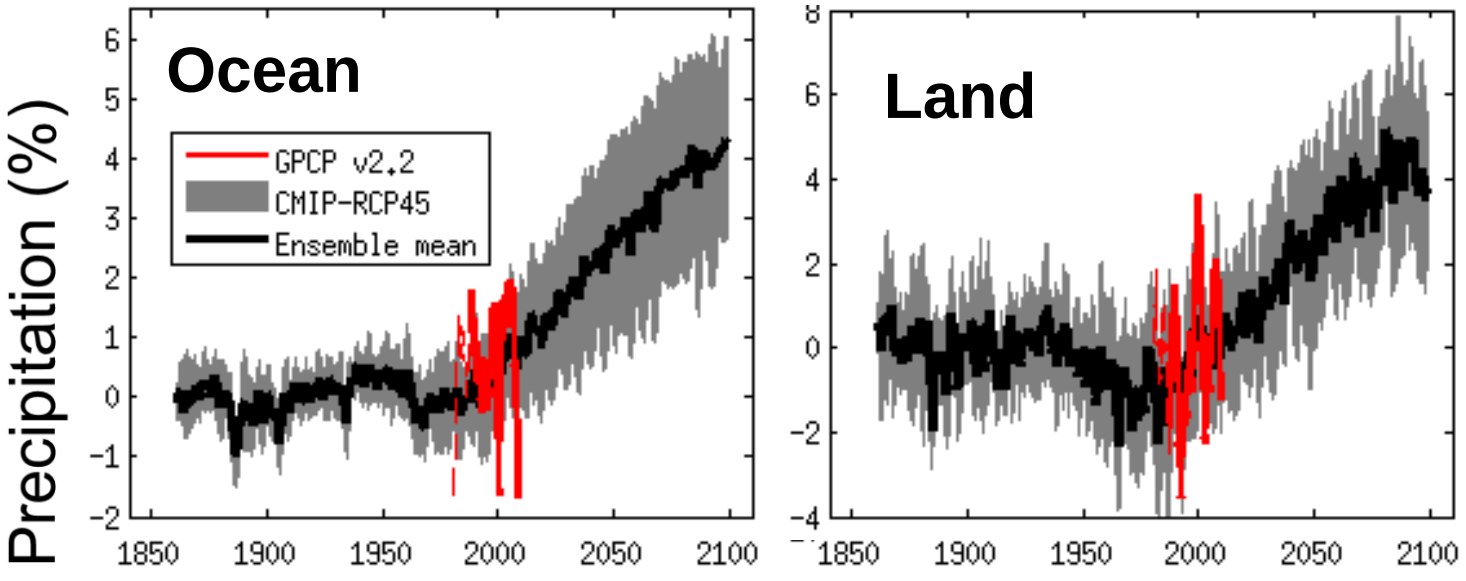
Changing water cycle

Projected precipitation response



Response
~2%/K



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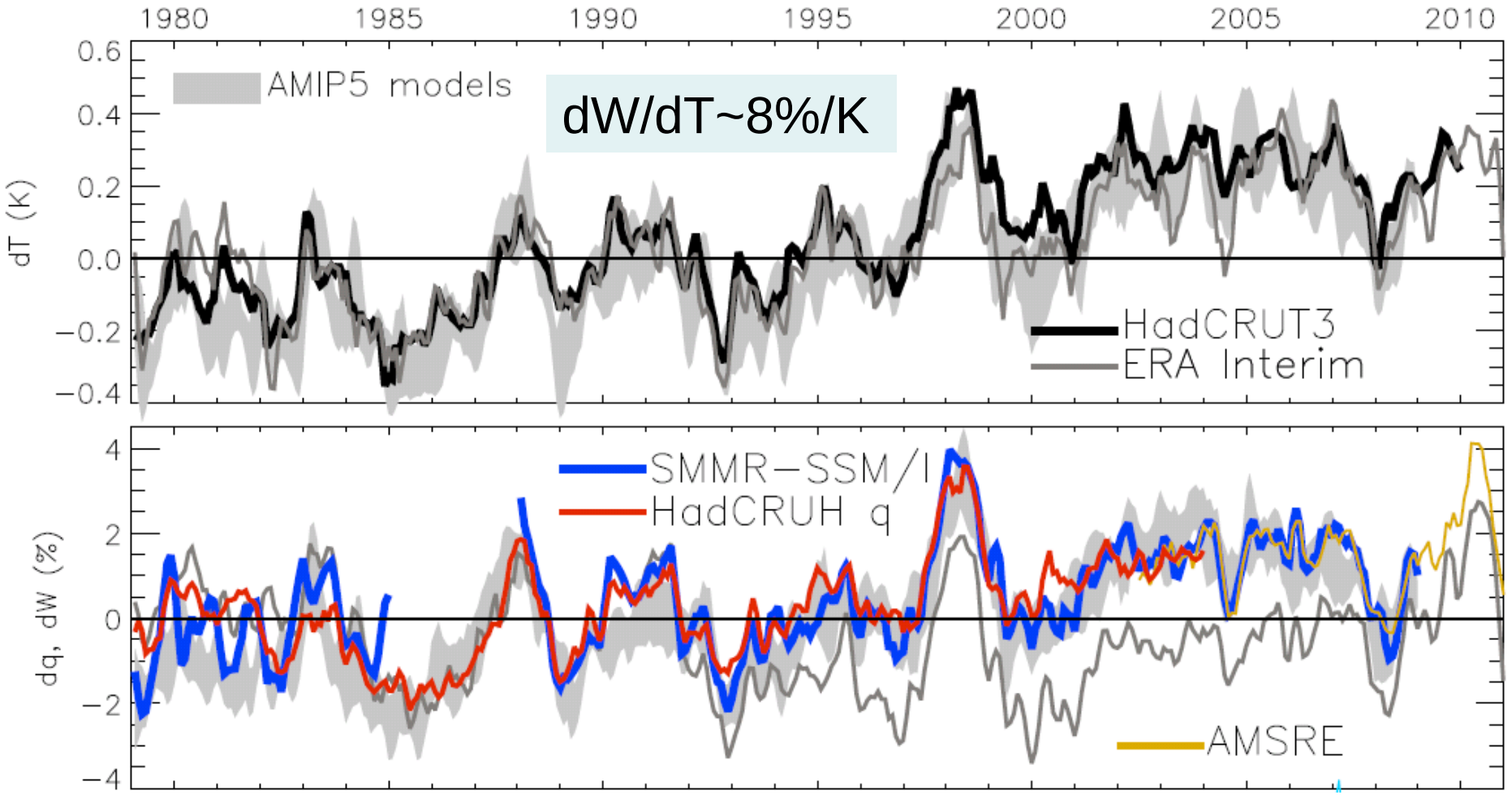
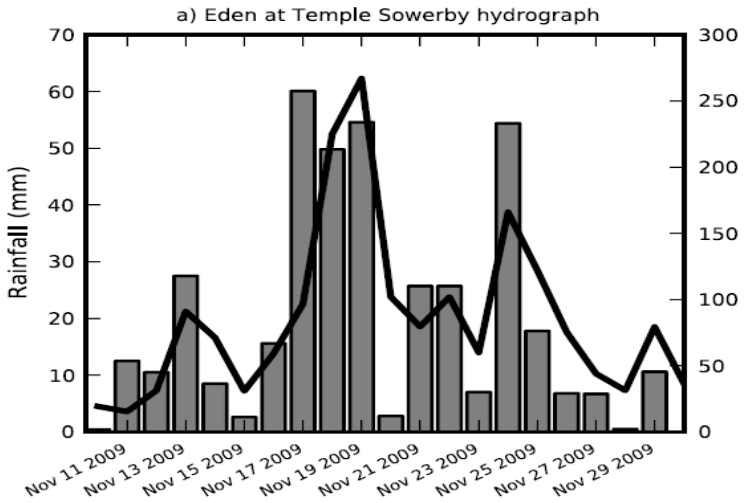
Current changes in global water vapour

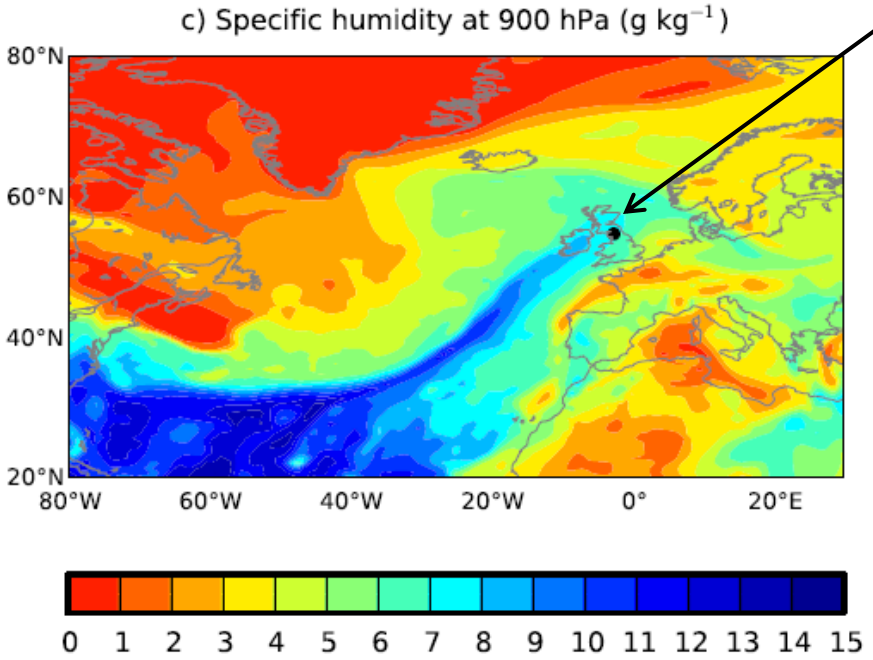


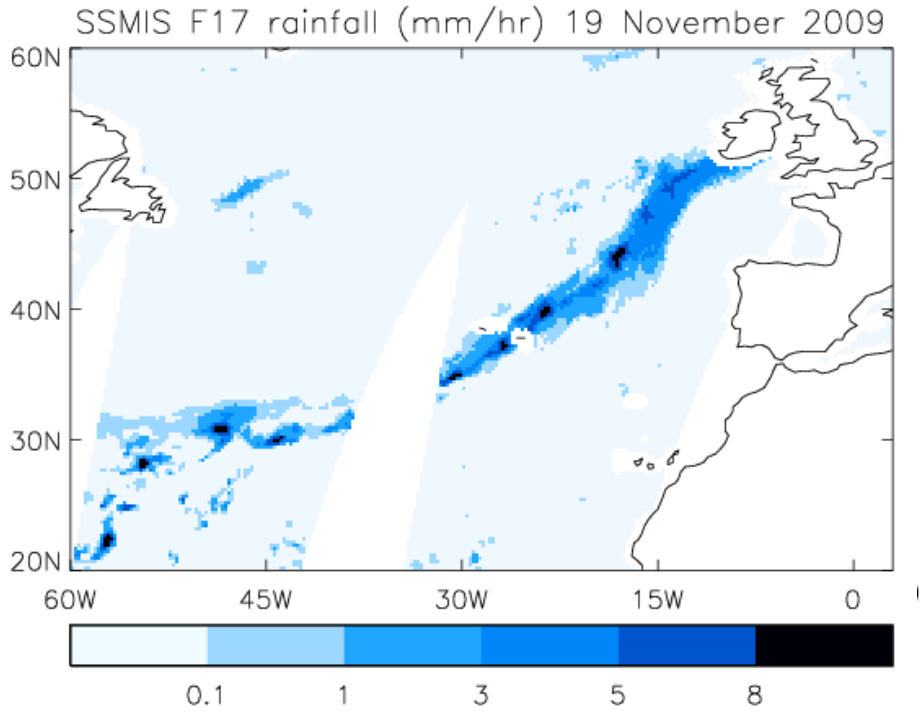
Updated from O'Gorman et al. (2012) Surv. Geophys; see also John et al. (2009) GRL

Extreme precipitation & mid-latitude flooding

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



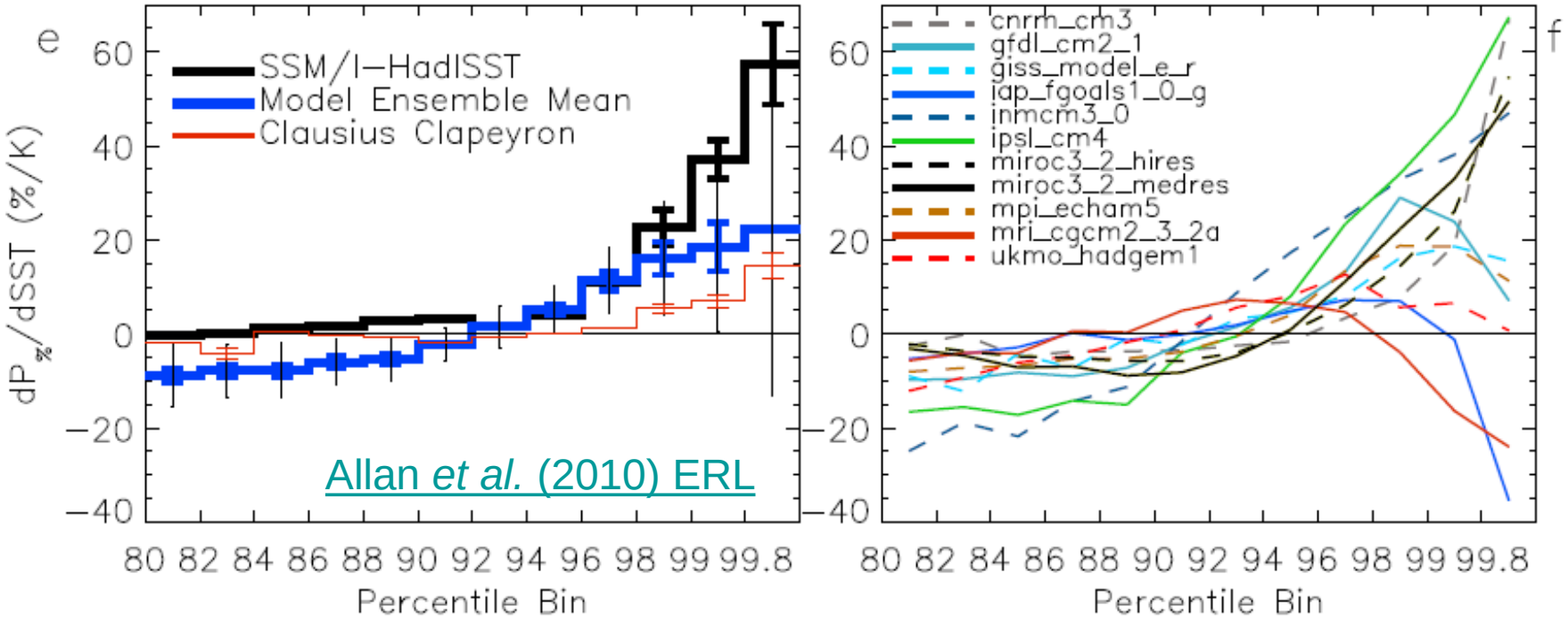




Lavers et al. (2011) Geophys. Res. Lett.

Increase in intense rainfall with tropical ocean warming

- SSM/I satellite observations at upper range of substantial model spread (see also O'Gorman and Schneider 2009 PNAS)



Turner and Slingo (2009) ASL: dependence on convection scheme?

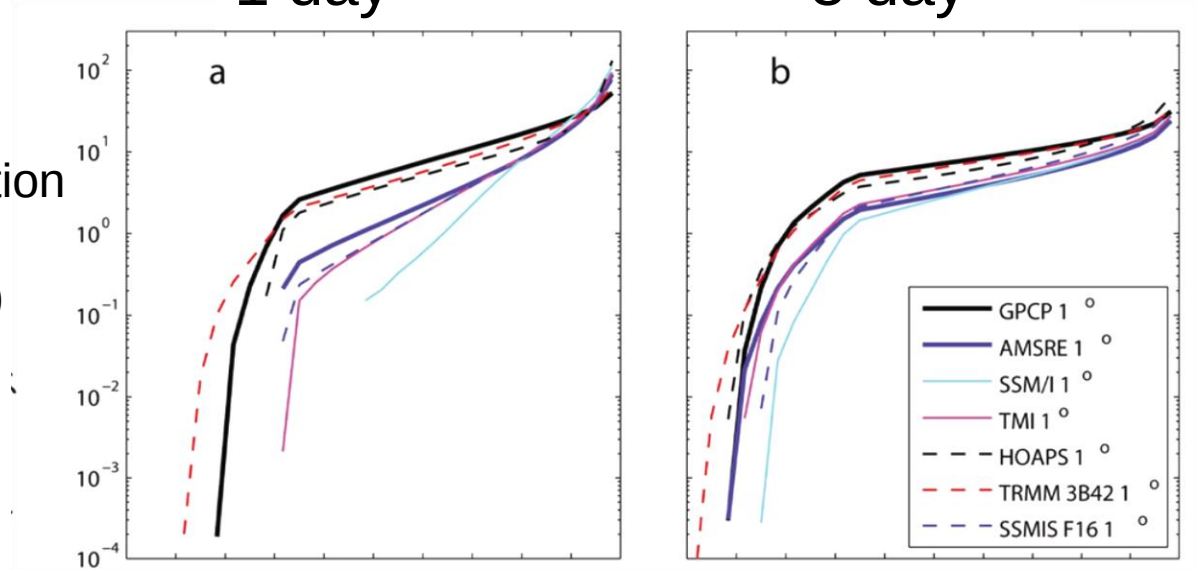
Observational evidence of changes in intensity/duration (Zolina et al. 2010 GRL)

Links to physical mechanisms/relationships required (Haerter et al. 2010 GRL)

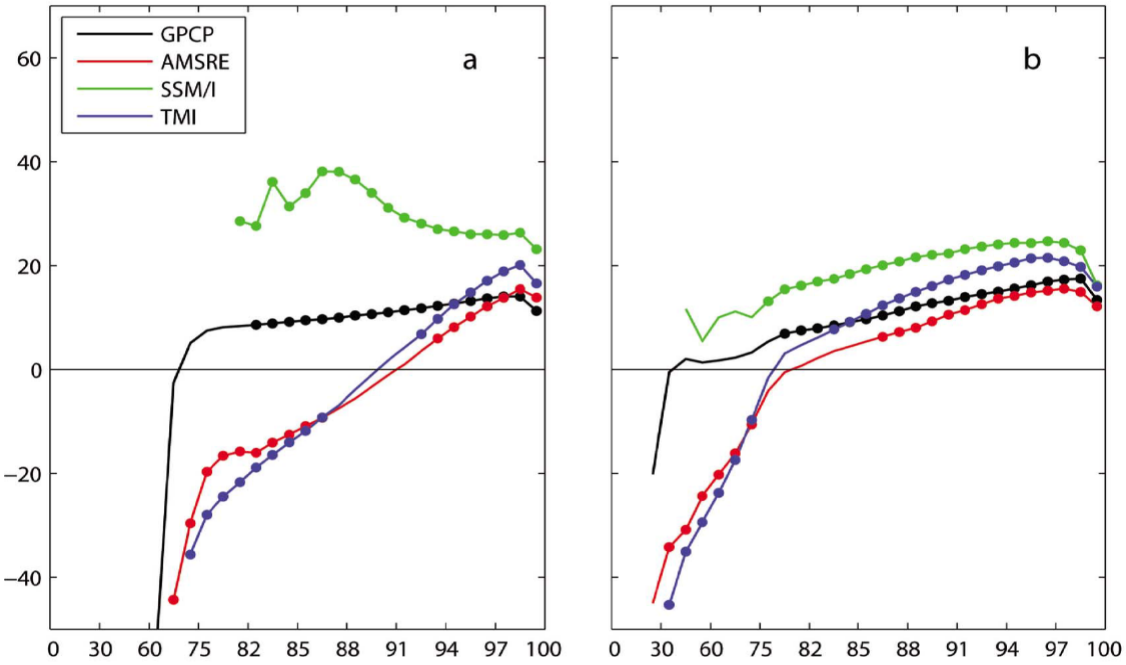
1 day

5 day

Precipitation intensity (mm/day)



Precipitation intensity change with mean surface temperature (mm/day)



Precipitation intensity distributions & responses between datasets (tropical oceans)

Liu & Allan (2012) JGR

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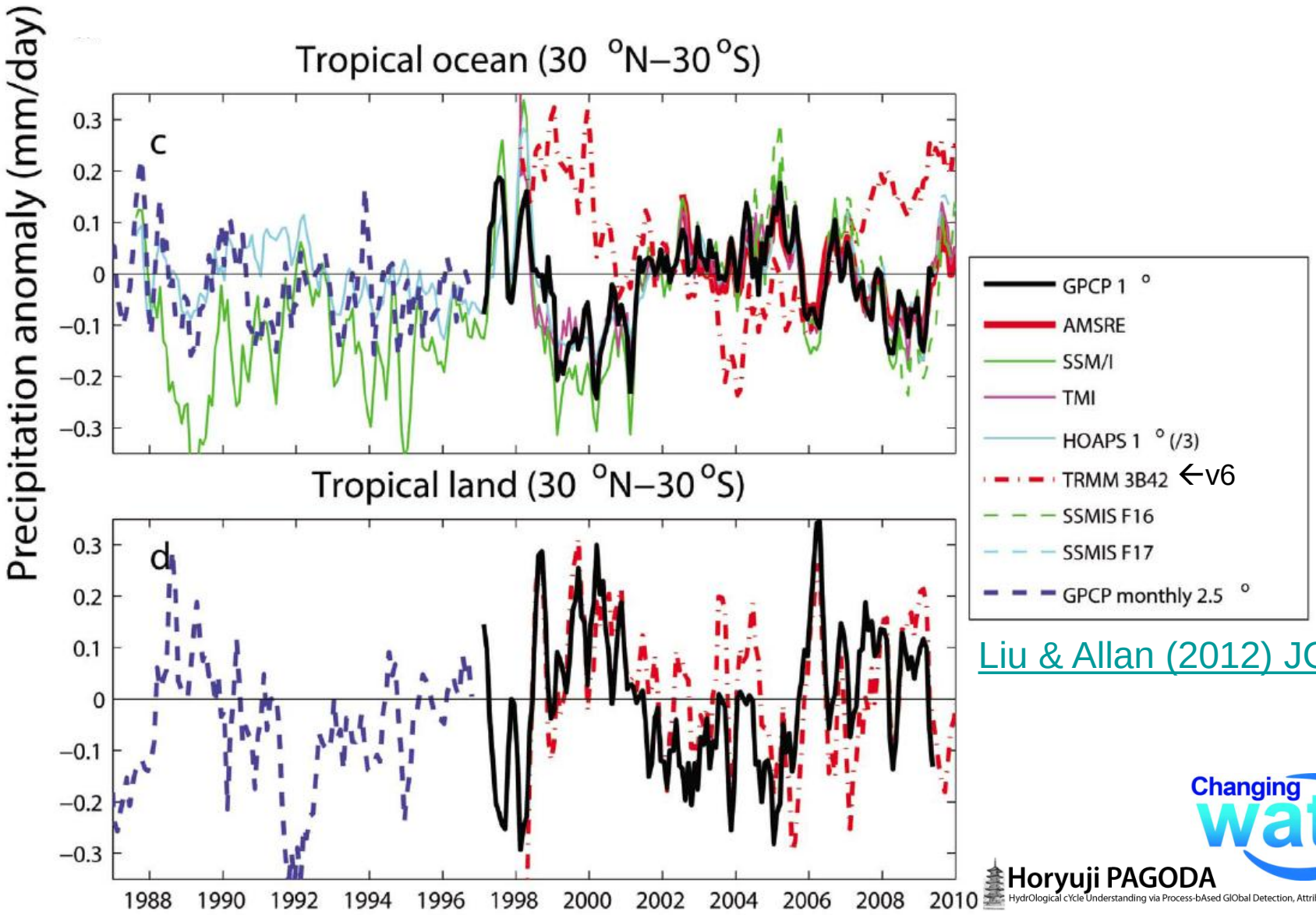
Comparing precipitation products



Liu & Allan (2012) JGR

Changing water cycle

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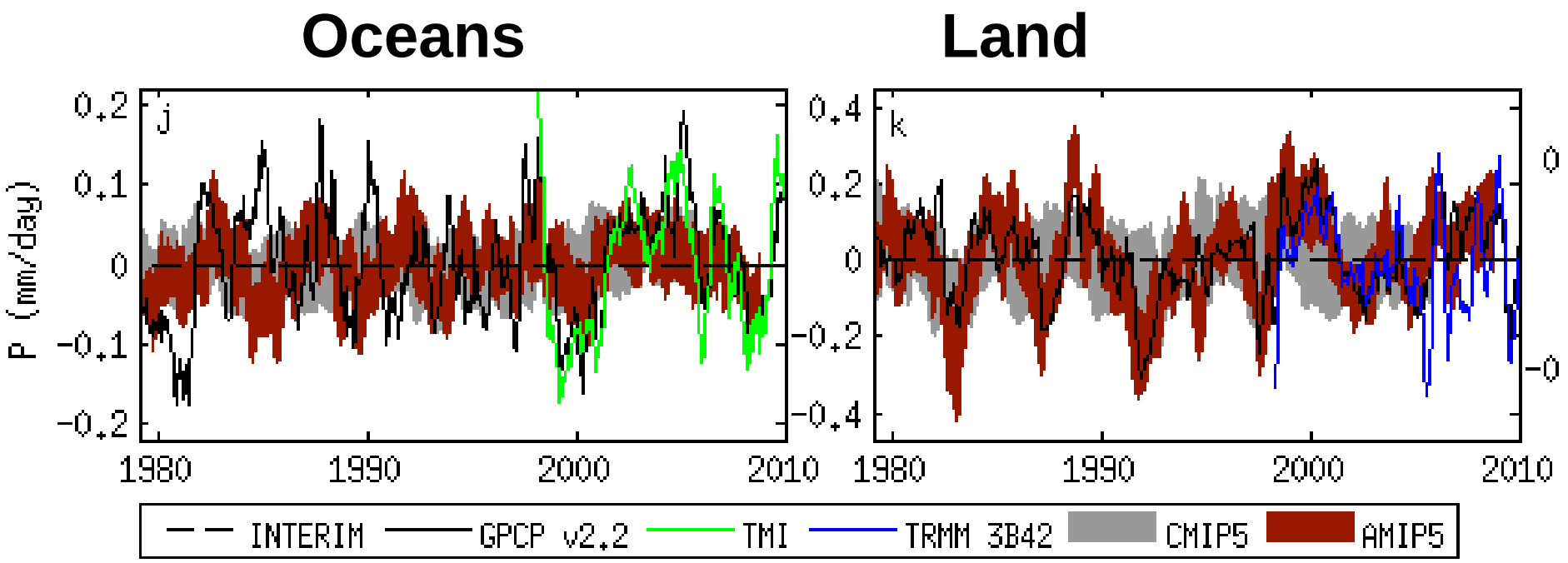
Current changes in tropical precipitation in CMIP5 models & satellite-based observations

Note realism of atmosphere-only AMIP model simulations



[Liu, Allan, Huffman (2012) GRL in press]

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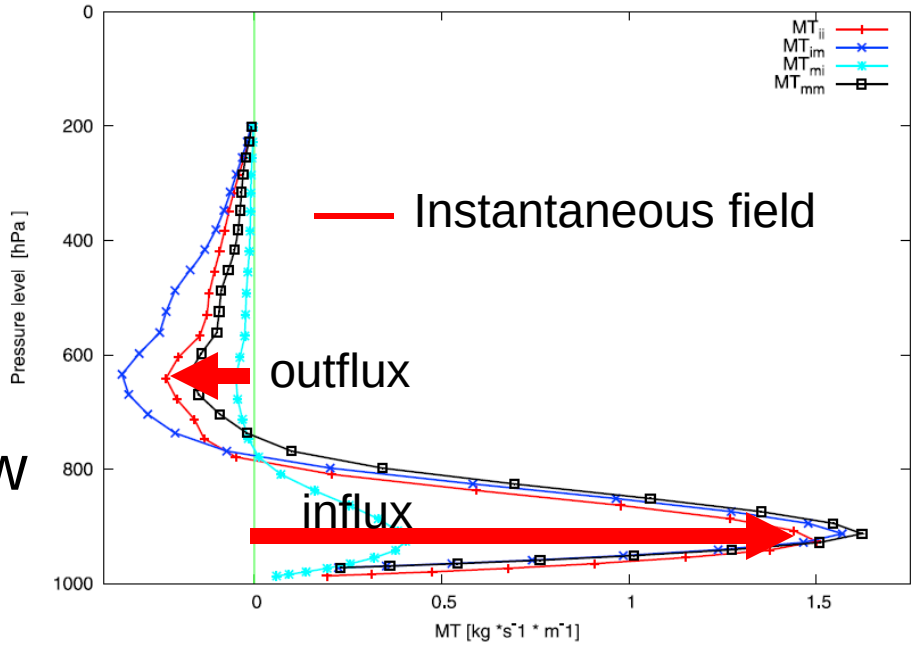
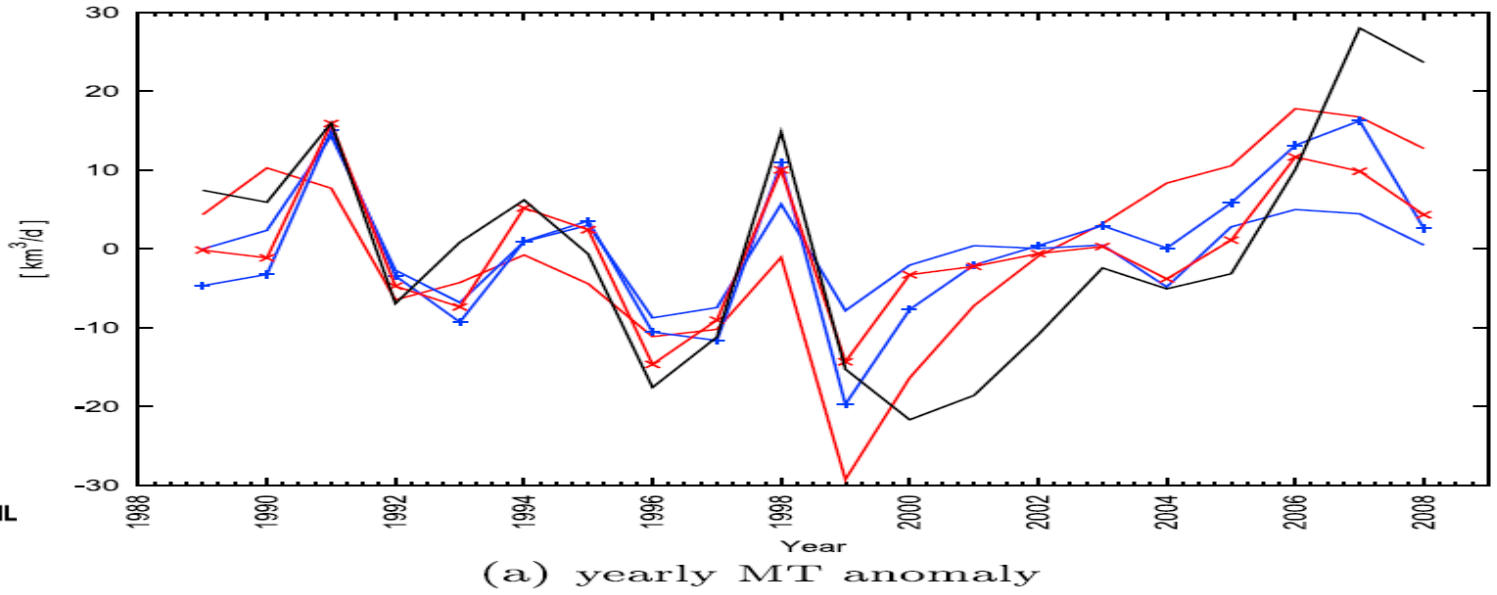
Changing tropical moisture transports

- Moisture transport into tropical ascent region
- Significant mid-level outflow
- 2000s: increases in inflow or drift in ERA Interim?





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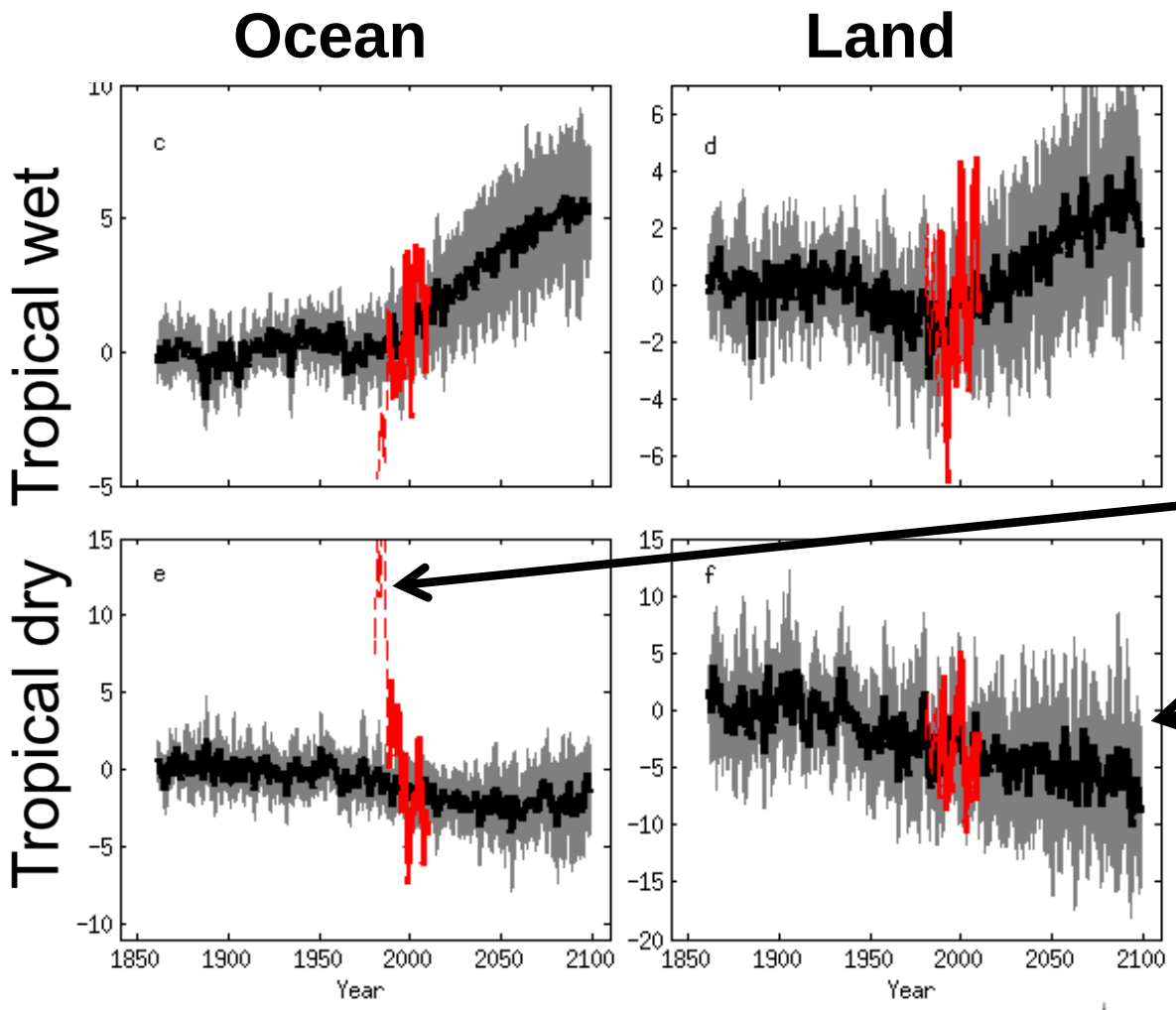
PREPARE project

Zahn and Allan (2011) JGR see also Sohn and Park (2010) JGR

CMIP5 projections: wet regions get wetter, dry regions get drier



Pre 1988 GPCP ocean data does not contain microwave data

Robust drying of dry tropical land

Allan et al. (2010) ERL.; Liu and Allan *in prep*

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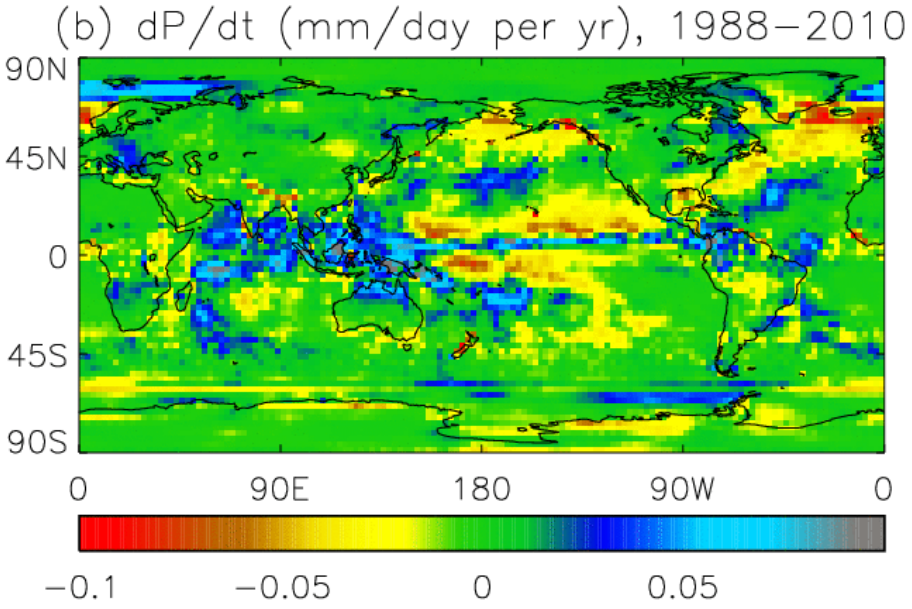
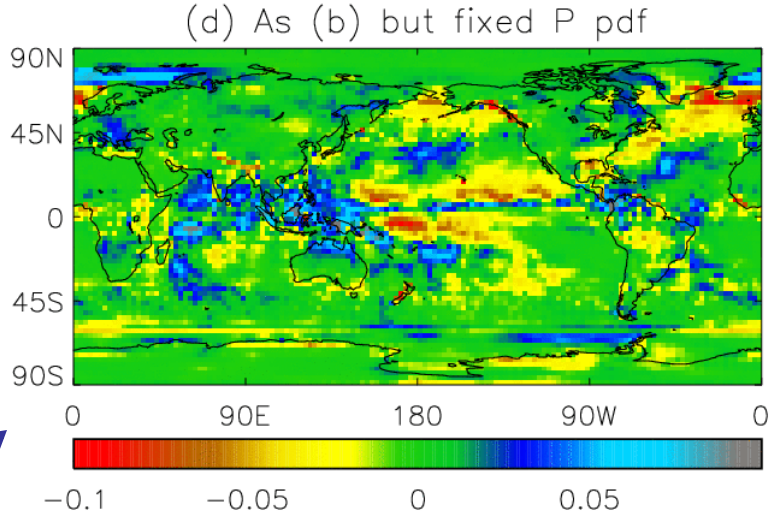
Separating dynamical / thermodynamic trends

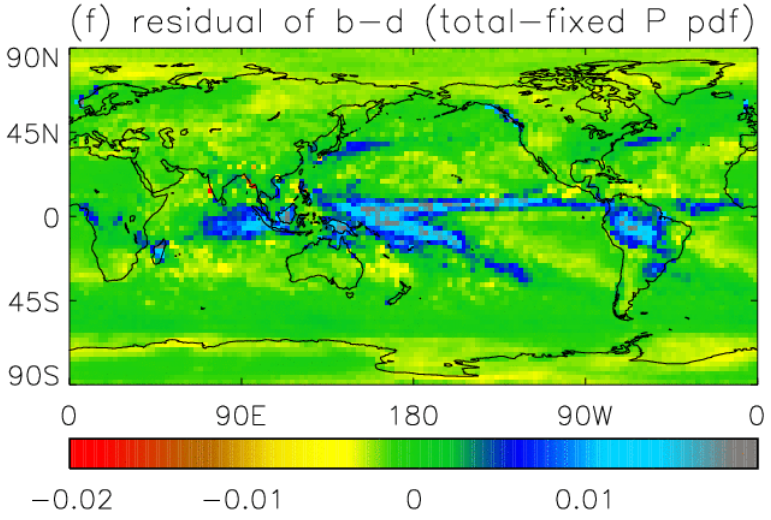




Top: fixed P intensity PDF

Bottom: residual (total trend minus fixed PDF)

We are currently applying this technique to CMIP5 models



Open Issues for discussion

- **Trends are meaningless** especially for short periods (decadal variability)…unless physical basis…or comparing datasets…ok, they're quite useful
- **Regional trends** are overwhelmed by changes in atmospheric circulation
- **Mechanisms for decadal variability** are unclear (oscillations, climate shifts, forced responses)

- The **diversity of approaches for inter-calibration** and inter-comparison is valuable
- The **sampling issue** is a non-issue solved by model to satellite approach…but this is non trivial.
- **You are the weakest link!** Calibration, orbital drift, sensor decay, retrieval assumptions, …

- Current **reanalyses are inadequate** for ocean-wide decadal changes
- Should we have **observing system-specific reanalyses**? e.g. UTH,P,..?

Open Issues for discussion

- The **observing system remains inadequate** for monitoring precipitation change over the ocean.
- **Models underestimate** precipitation response…
  Observations overestimate precipitation response?
- **Models overestimate** mean precipitation…
  Observations underestimate mean precipitation?
- **Testing understanding of what?** Models or the observing system?
- **Beyond 'blob' plot**: process-level understanding (just fine words?)

- Why has the **land RH** declined recently?
- What explains **stalled ocean surface warming**?
- Can **precipitation changes be directly attributed to radiative forcing,** separate to slow response to surface warming?
- We are at a pivotal point in the climate record…

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Changes in net atmospheric radiative cooling and precipitation

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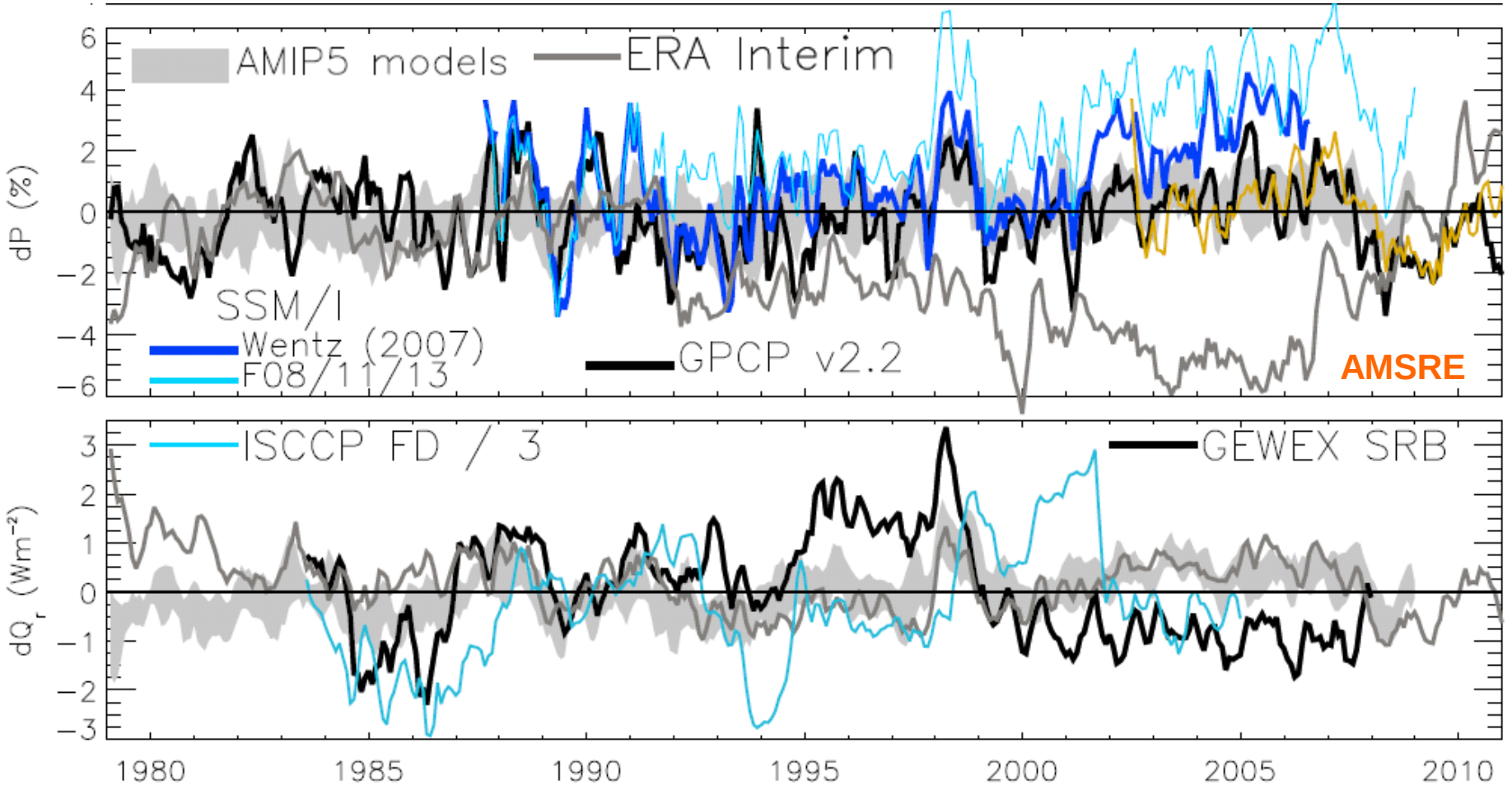
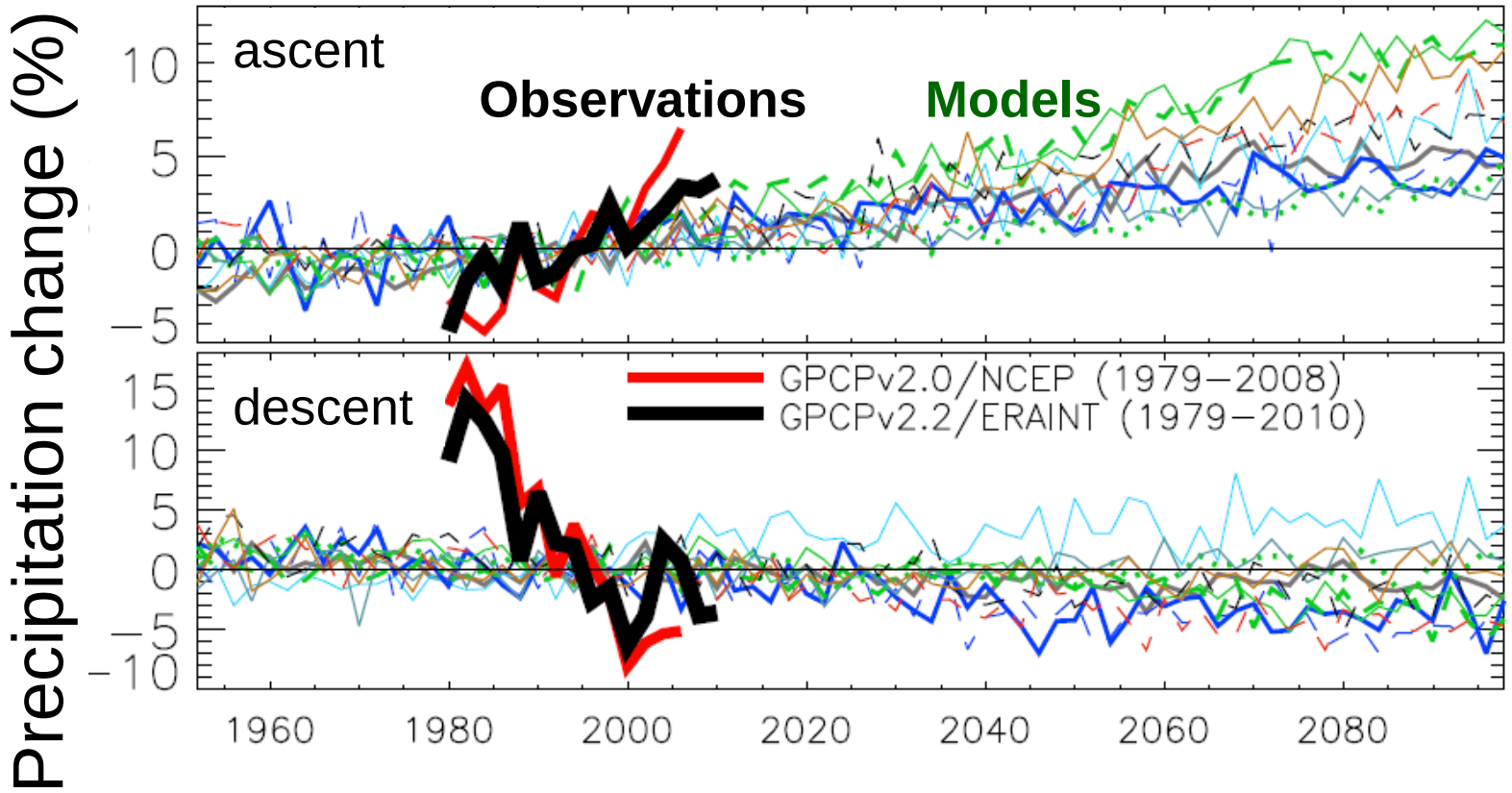


Updated from O'Gorman et al. (2012) submitted; see also John et al. (2009) GRL

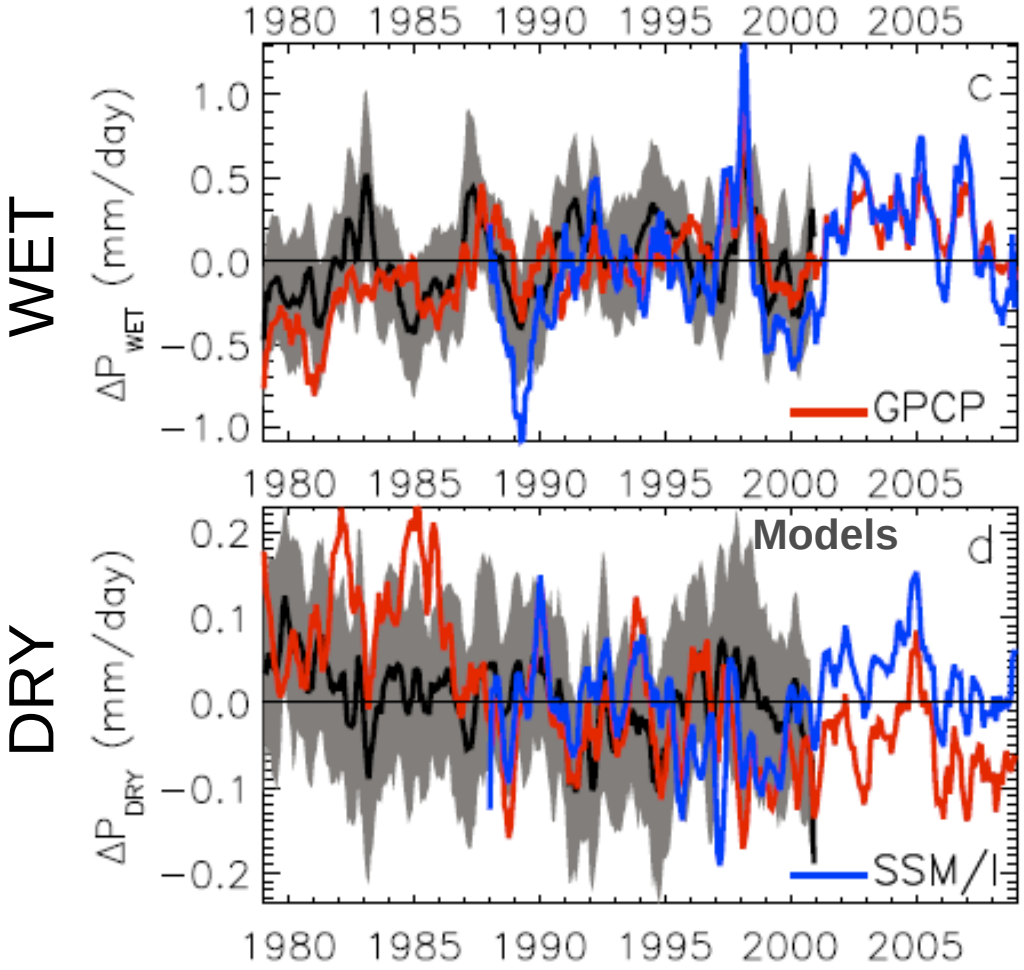
Contrasting precipitation response in wet and dry regions of the tropical circulation



Sensitivity to reanalysis dataset used to define wet/dry regions

Updated from Allan *et al.* (2010) Environ. Res. Lett.

Current trends in wet/dry regions of tropical oceans



Allan et al. (2010) Environ. Res. Lett.

- Wet/dry trends remain
  - 1979-1987 GPCP record may be suspect for dry region
  - SSM/I dry region record: inhomogeneity 2000/01?
- GPCP trends 1988-2008
  - Wet: 1.8%/decade
  - Dry: -2.6%/decade
  - Upper range of model trend magnitudes