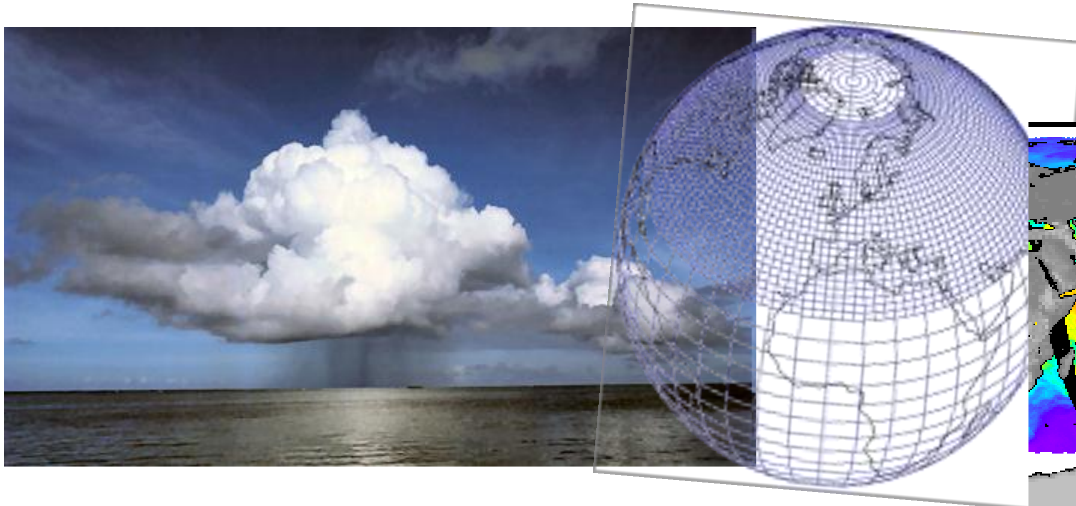

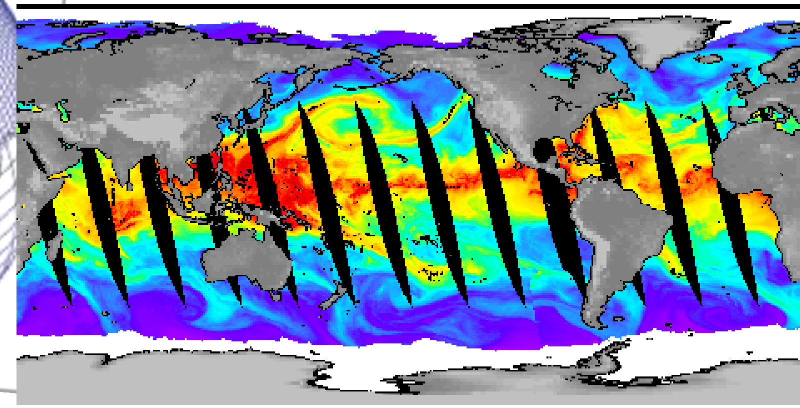

PAGODA WP3 - Observed changes in the global water cycle

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Thanks to Nicolaos Skliris, Matthias Zahn (PREPARE), David Lavers (HydEF)

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

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Introduction (WP3)

- Primary Goals
  - characterise observed changes in the water cycle on global-to-regional space scales and decadal timescales,
  - evaluate, at a process level, the consistency between observed and modelled changes.

Focus here upon satellite era

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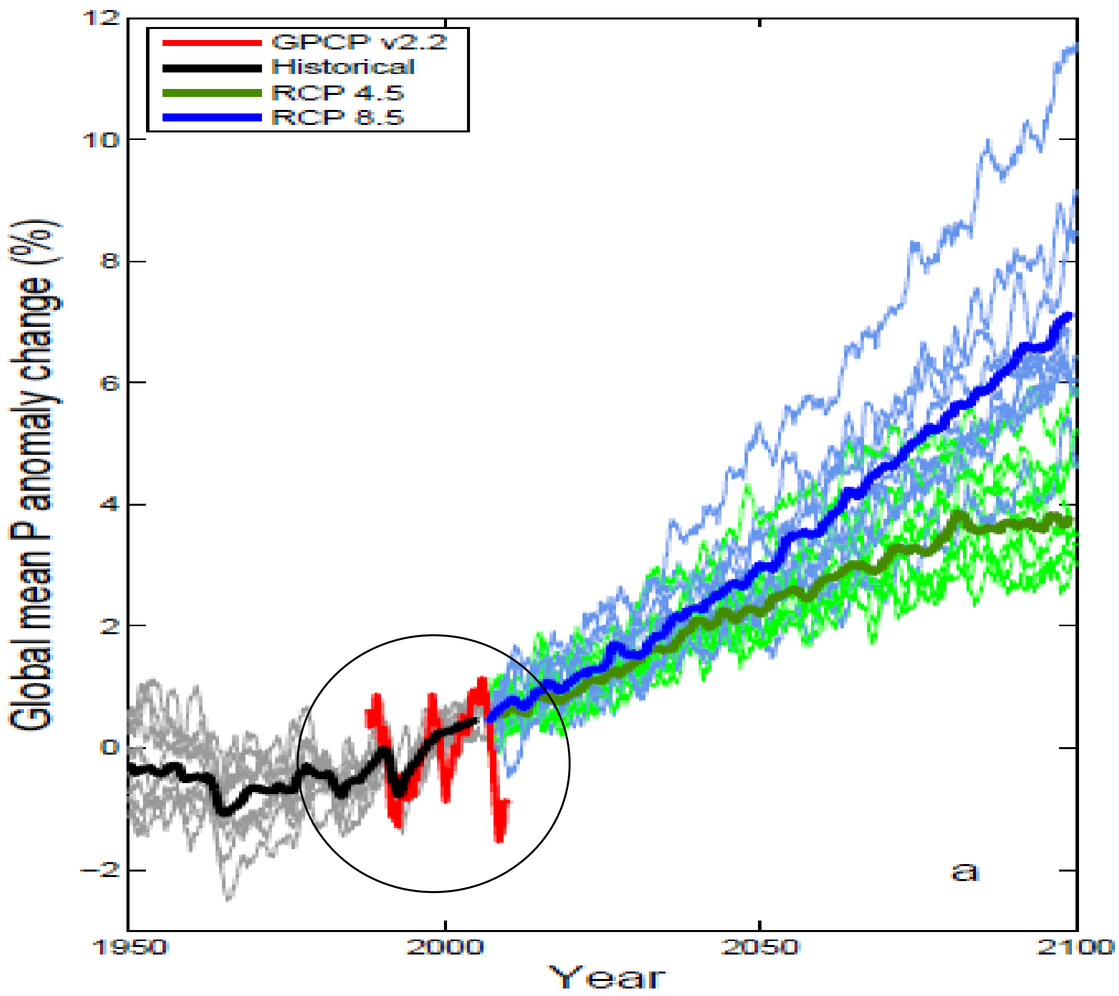
How does/will global to regional precipitation respond to climate change?



Global constraints: energy balance

- Surface T
- Radiative forcing (GHG, AA)

Regional constraints:

- Water vapour transports
- Radiative forcing:

Land vs ocean

Circulation change

- Feedbacks

Land vs ocean

Circulation change

Allan et al. (2013) Surv. Geophys. in press.

See also: Hawkins & Sutton (2010) Clim. Dyn.

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Primary Focus

- Satellite Era (blended satellite/gauge)
- Daily-monthly diagnostics, decadal changes
- Water vapour and transports, Precipitation
- Simulations: reanalyses, NWP, CMIP5

Links:

- P–E and salinity changes (WP2, WP3.2b,e)
- Processed-based detection and attribution, metrics (WP1, WP4)
- Met Office NWP drifts/HadGEM2 bias
- Land evaporation - WP3.2f (CEH);

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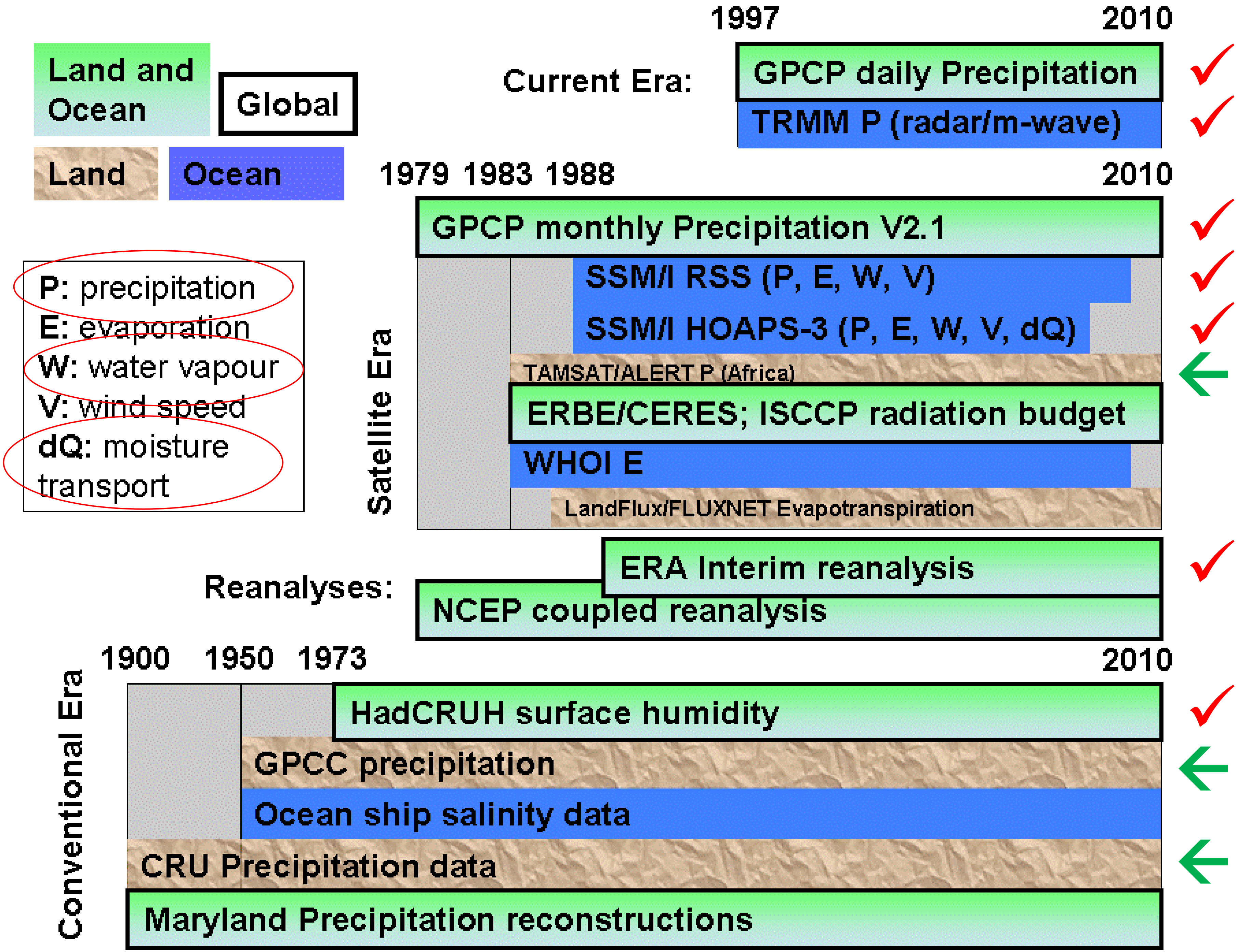

Land and Ocean
Global
Land
Ocean
P: precipitation
E: evaporation
W: water vapour
V: wind speed
dQ: moisture transport
Current Era:
1997
2010
GPCP daily Precipitation
TRMM P (radar/m-wave)
Satellite Era
1979 1983 1988
2010
GPCP monthly Precipitation V2.1
SSM/I RSS (P, E, W, V)
SSM/I HOAPS-3 (P, E, W, V, dQ)
TAMSAT/ALERT P (Africa)
ERBE/CERES; ISCCP radiation budget
WHOI E
LandFlux/FLUXNET Evapotranspiration
Reanalyses:
ERA Interim reanalysis
NCEP coupled reanalysis
Conventional Era
1900 1950 1973
2010
HadCRUH surface humidity
GPCC precipitation
Ocean ship salinity data
CRU Precipitation data
Maryland Precipitation reconstructions

WP3 Objectives

1. Quantify observed changes in the water cycle on global-to-regional space scales and decadal time scales and evaluate consistency with processes anticipated by simple models and depicted by GCMs.

2. Elucidate key regional processes and feedbacks relating to energy and water fluxes, ocean salinity, ocean surface heat flux tendencies and the partitioning between land interception, evaporation and transpiration.

3. Monitor current observed changes in global water cycle variables, also employing global NWP forecasts to evaluate model drifts from analyses linking mean state errors to predicted hydrological response.

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Global changes in water vapour

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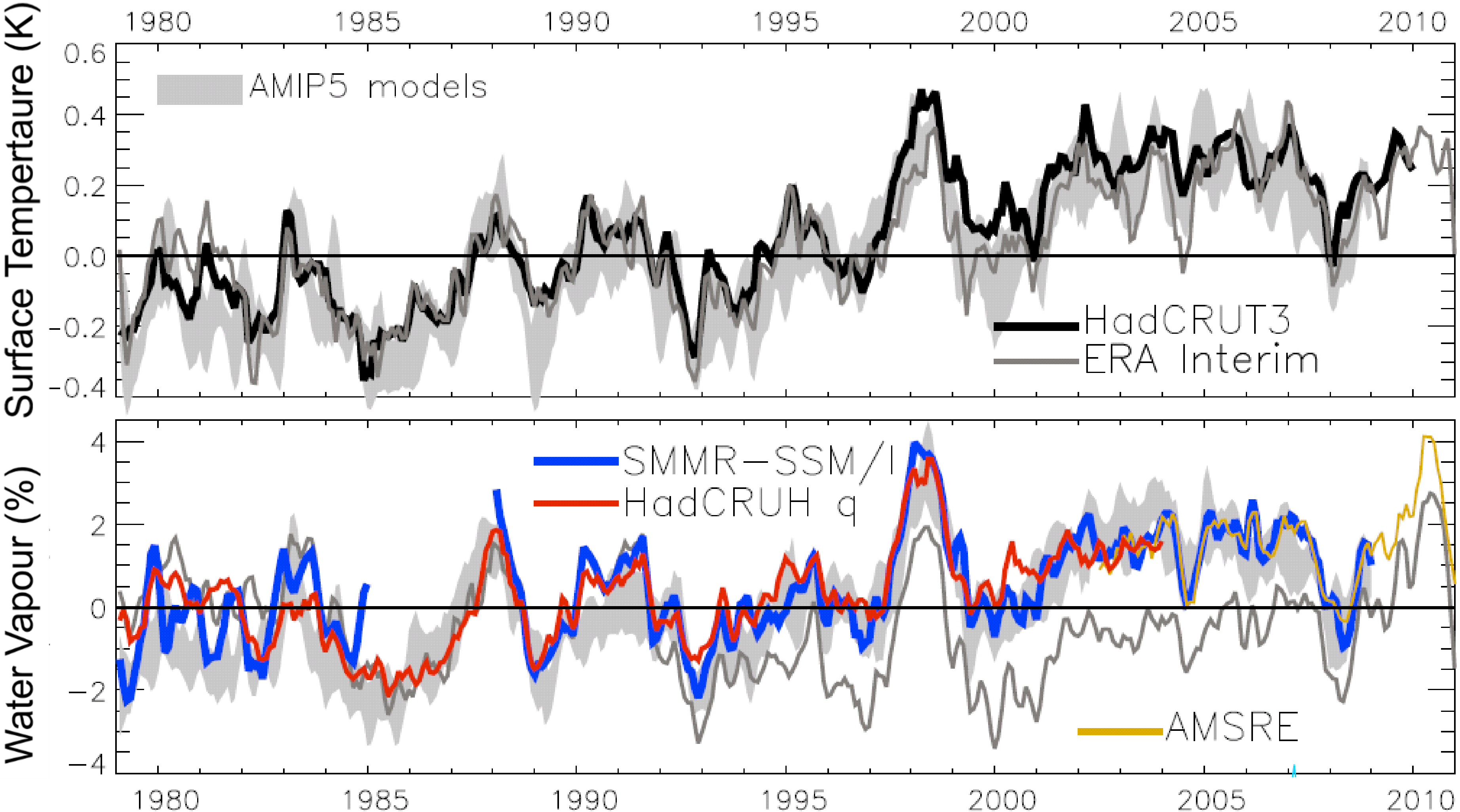

Allan et al. (2013) Surv. Geophys; see also O'Gorman et al. (2012); John et al. (2009)

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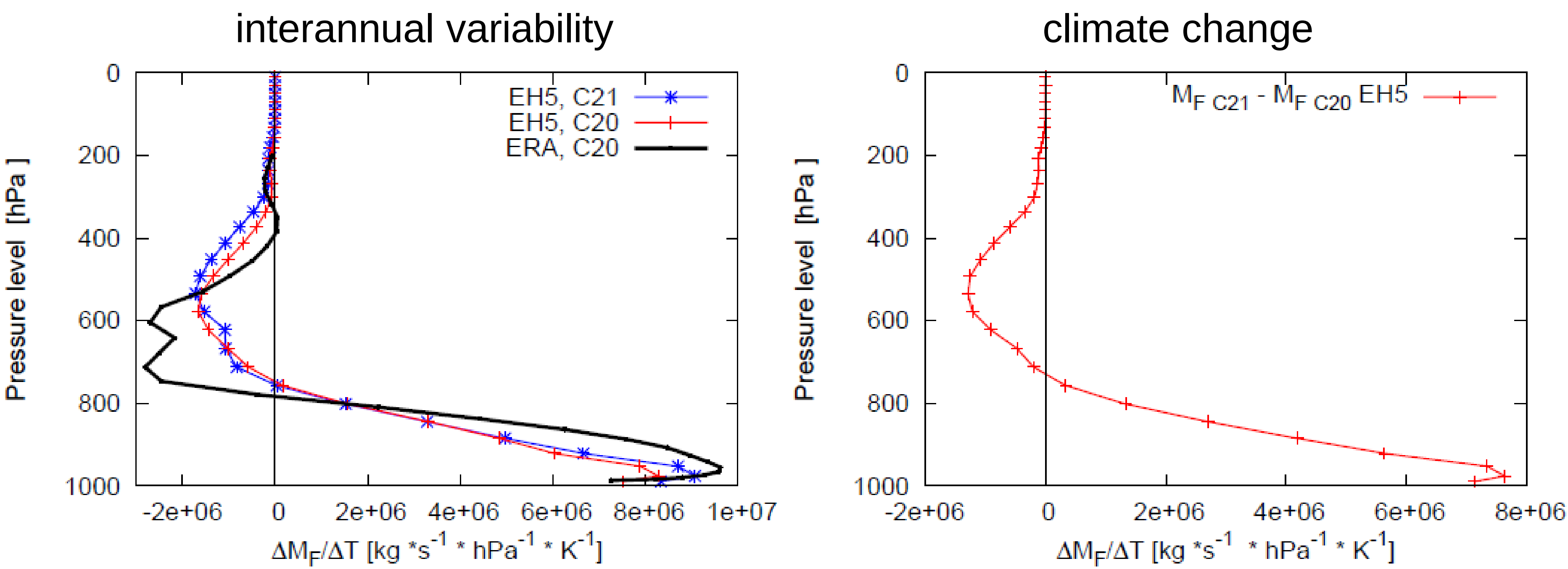
Changes in moisture transports into tropical wet region per K warming

PREPARE project



Enhanced moisture convergence at low levels with warming

Significant but smaller enhancement in mid-level outflow

Zahn and Allan (2013) J Clim, in press; Allan et al. (2013) Surv Geophys, in press

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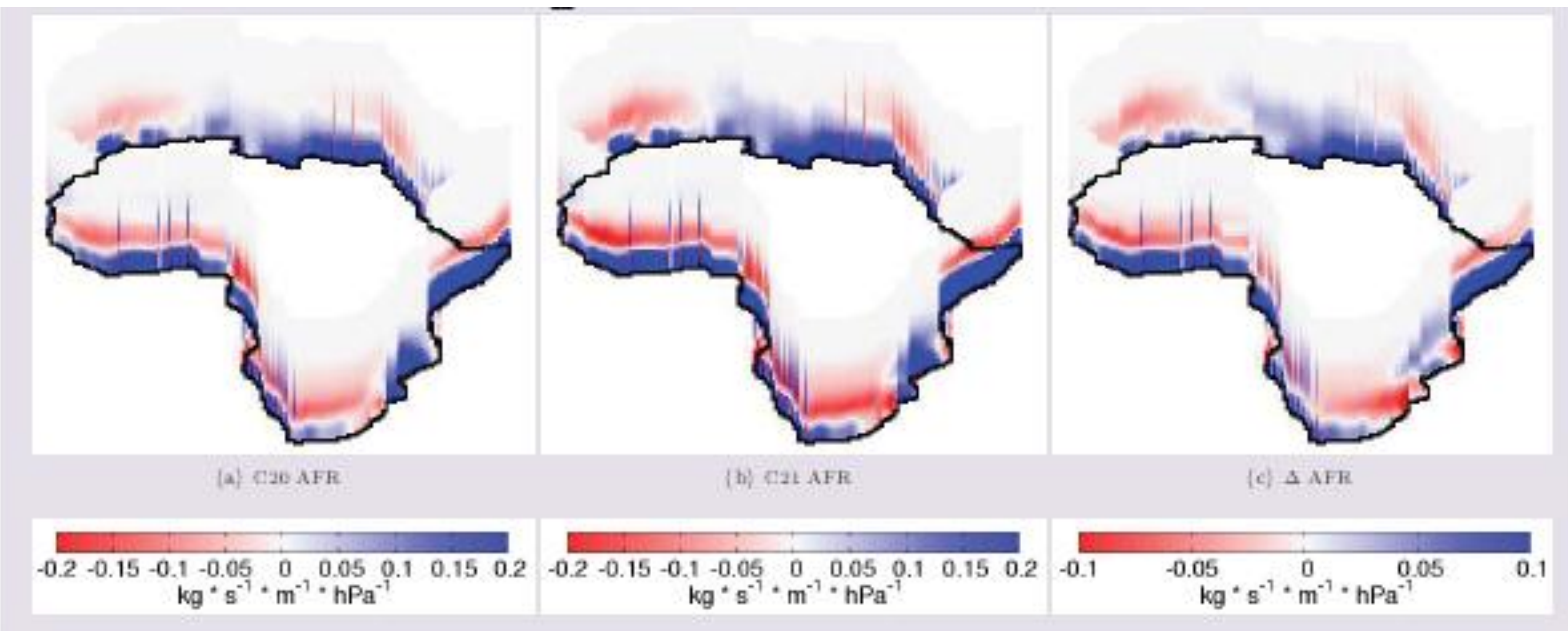
University of Reading

Moisture transports into continental regions

20C 21C 21C-20C



PREPARE project

Zahn and Allan, submitted to WRR

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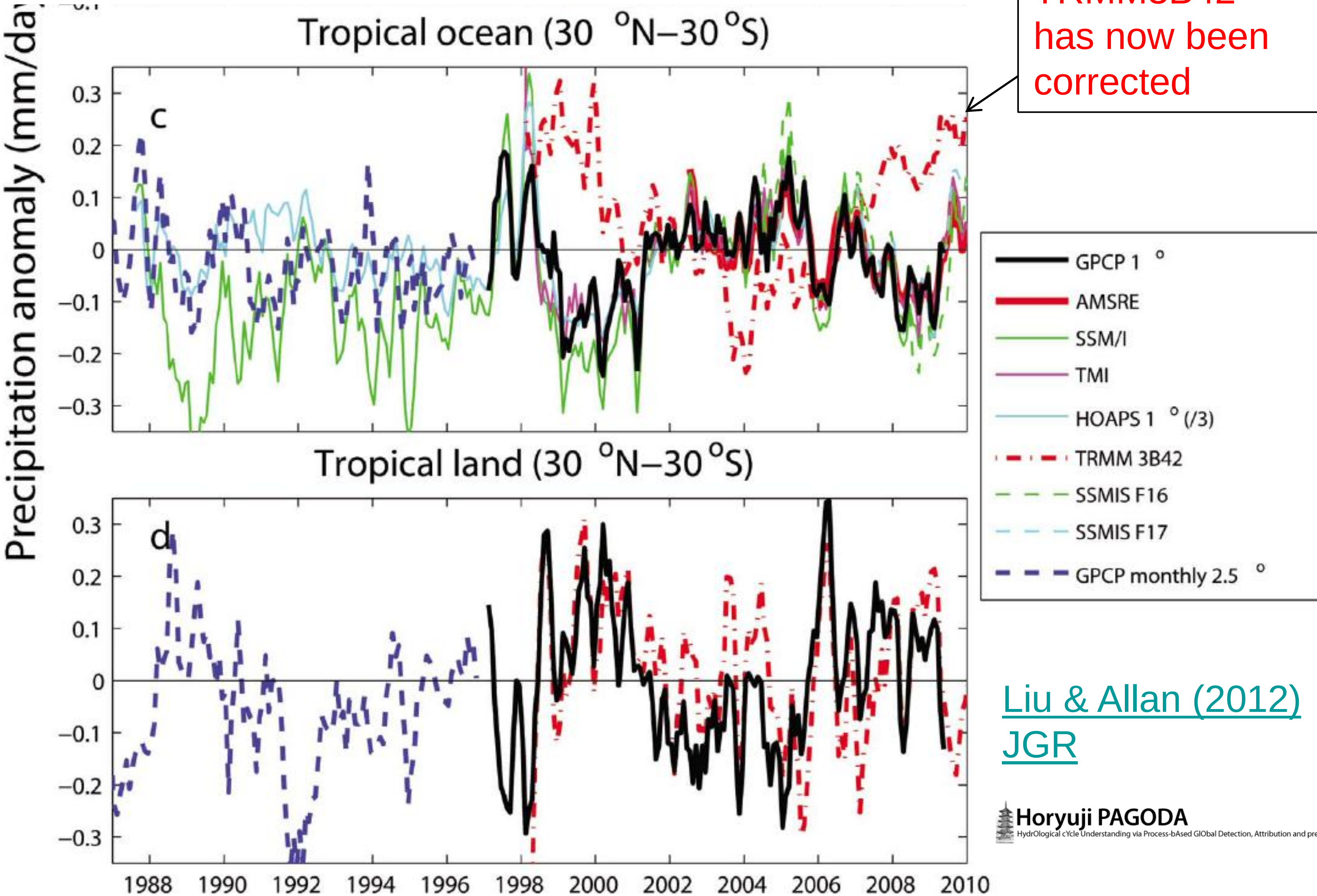
How consistent are satellite precipitation datasets?

University of Reading



TRMM3B42 has now been corrected

Liu & Allan (2012) JGR

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University of Reading

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Changing water cycle

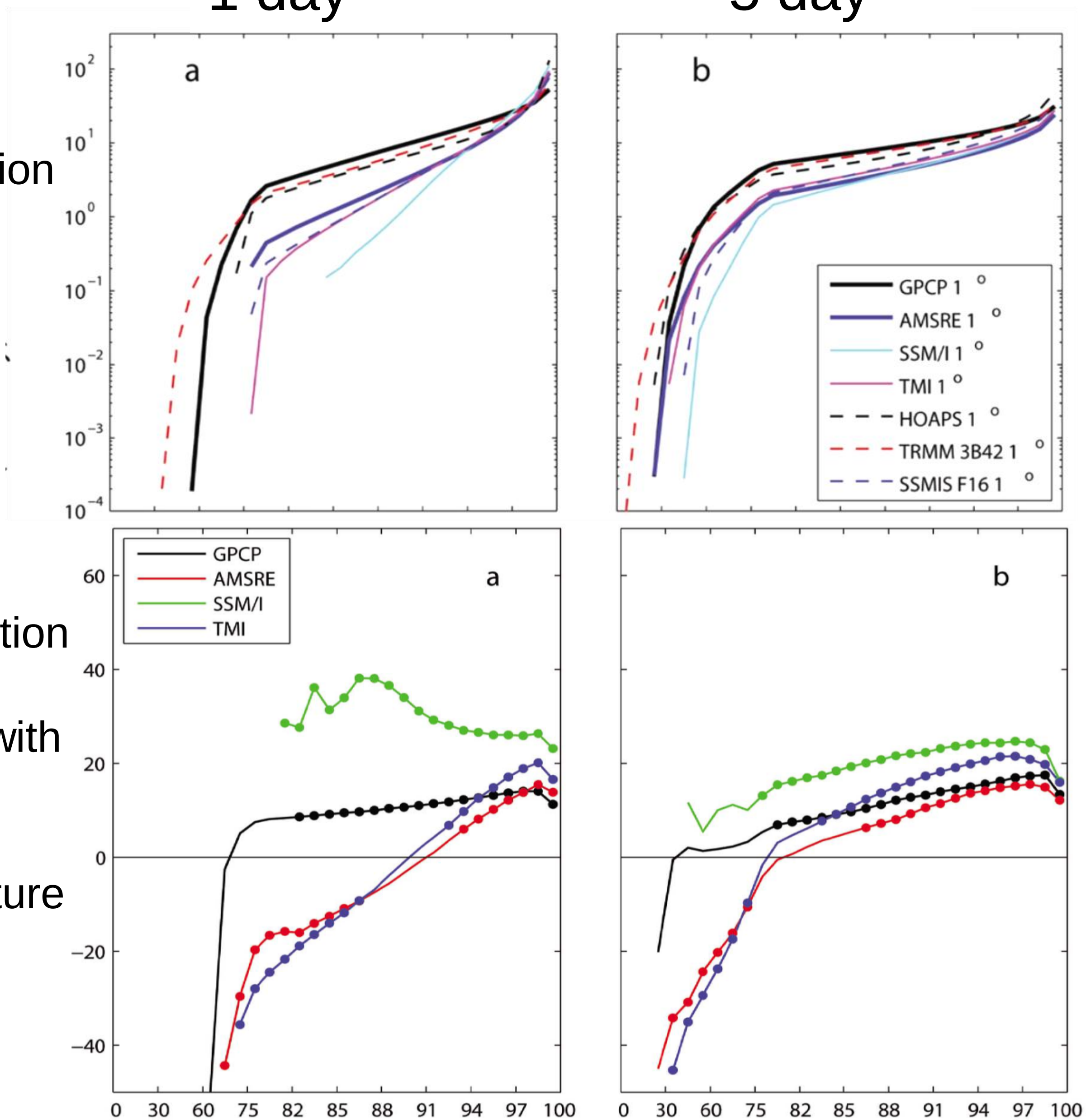
Observed P intensity & responses across datasets

(tropical oceans)

1 day

5 day

Precipitation intensity (mm/day)



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

Precipitation intensity percentile (%)

[Liu & Allan (2012) JGR](#)

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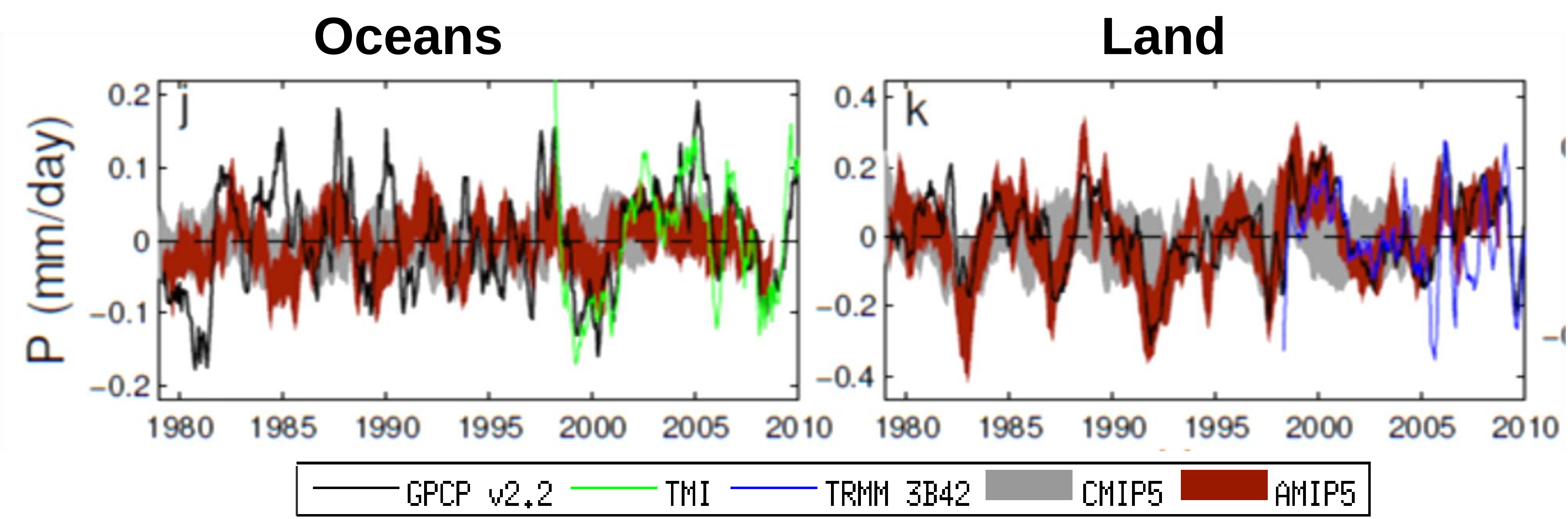
Tropical precipitation variability in satellite data and CMIP5 simulations

Note consistency between atmosphere-only AMIP model simulations over land and GPCP observations. This is not the case for the ocean, in particular before about 1996.



[Liu, Allan, Huffman (2012) GRL]

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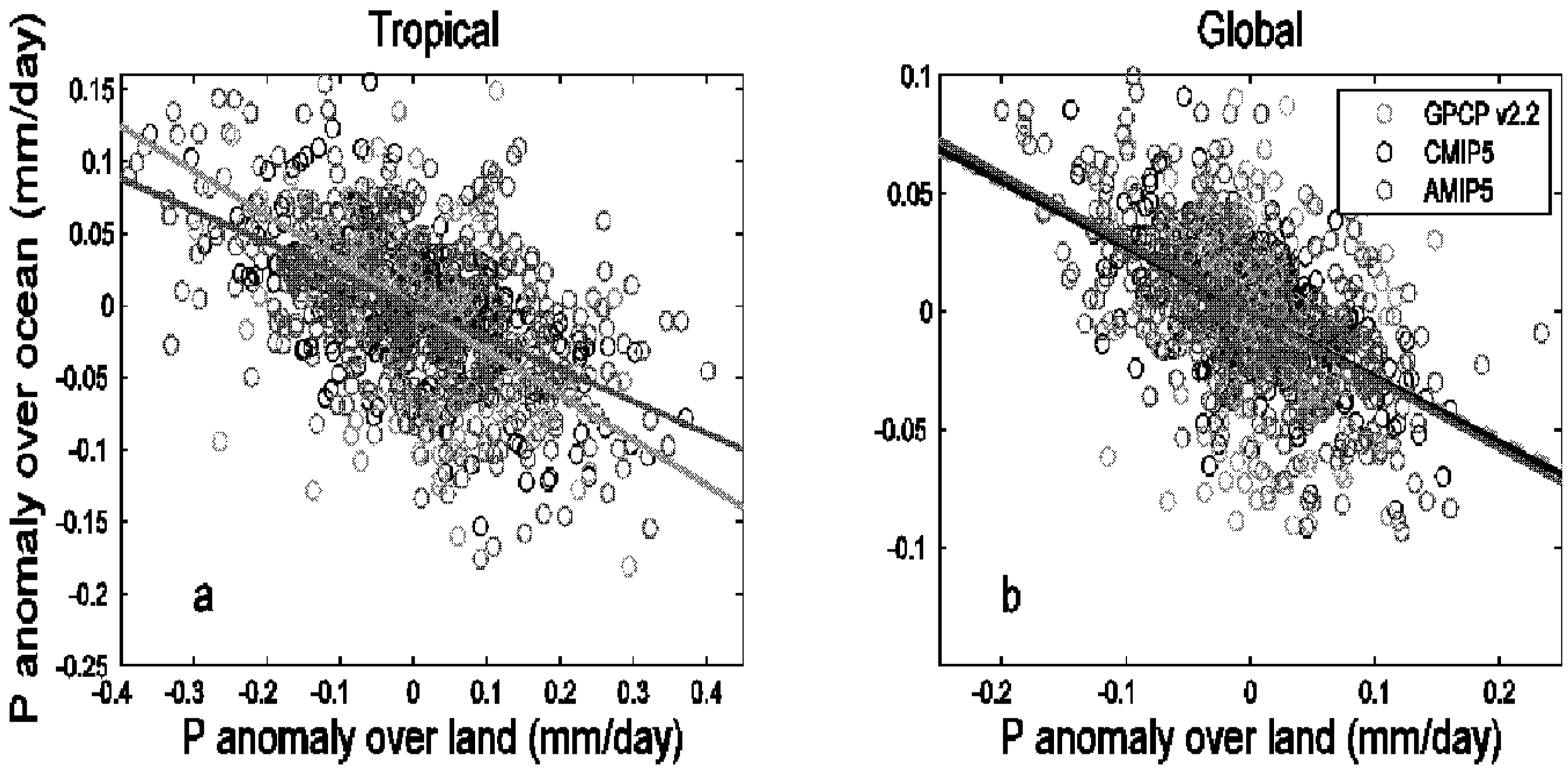
Contrasting land/ocean changes relate to ENSO



Liu et al. (2012)

See also Gu et al. (2007) J Clim

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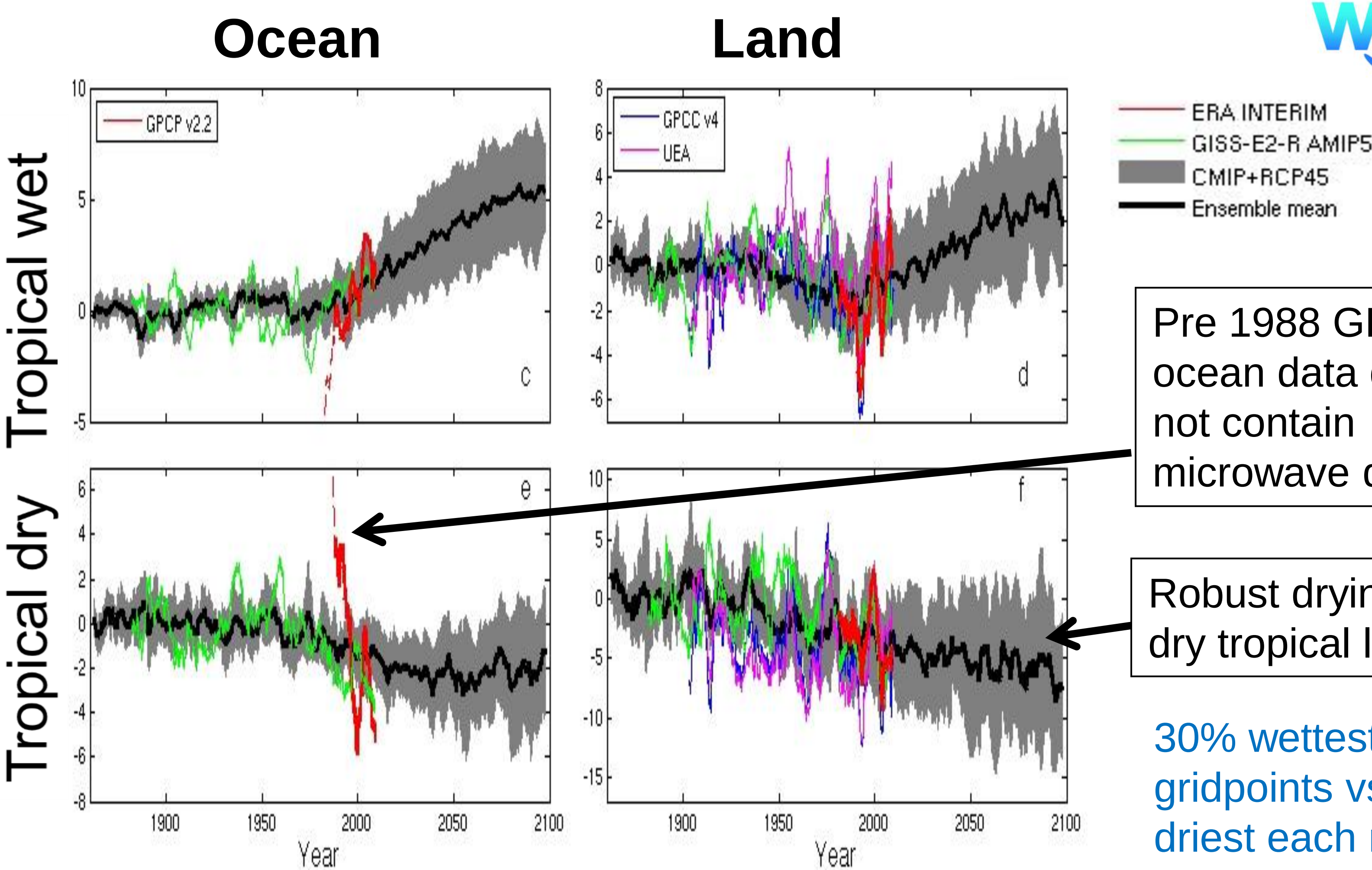
CMIP5 simulations: Wet regions get wetter, dry regions get drier



Pre 1988 GPCP ocean data does not contain microwave data

Robust drying of dry tropical land

30% wettest gridpoints vs 70% driest each month

Liu and Allan *in prep; see also* [Allan et al. (2010) ERL.]

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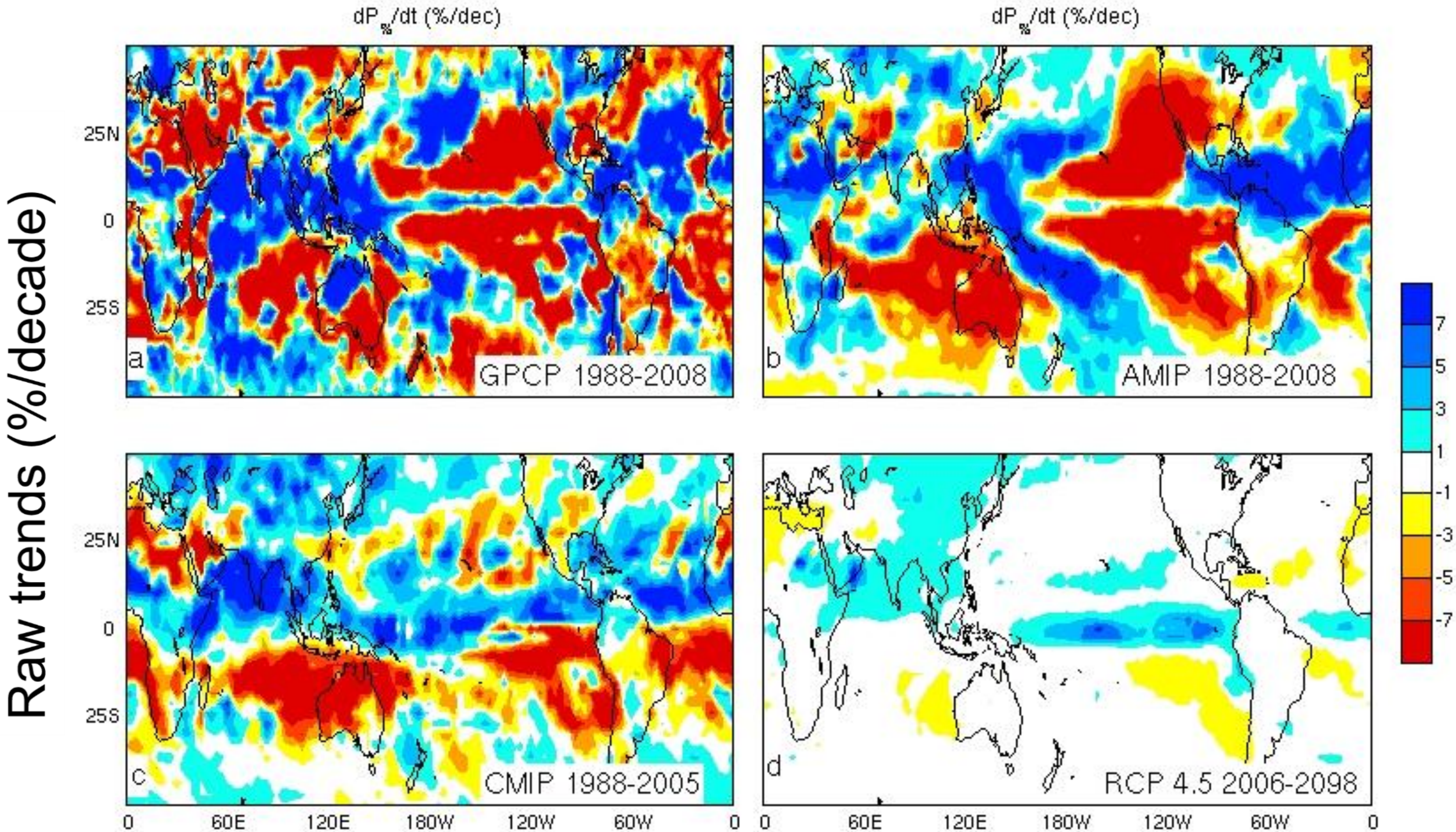
Spatial signatures of Precipitation trends



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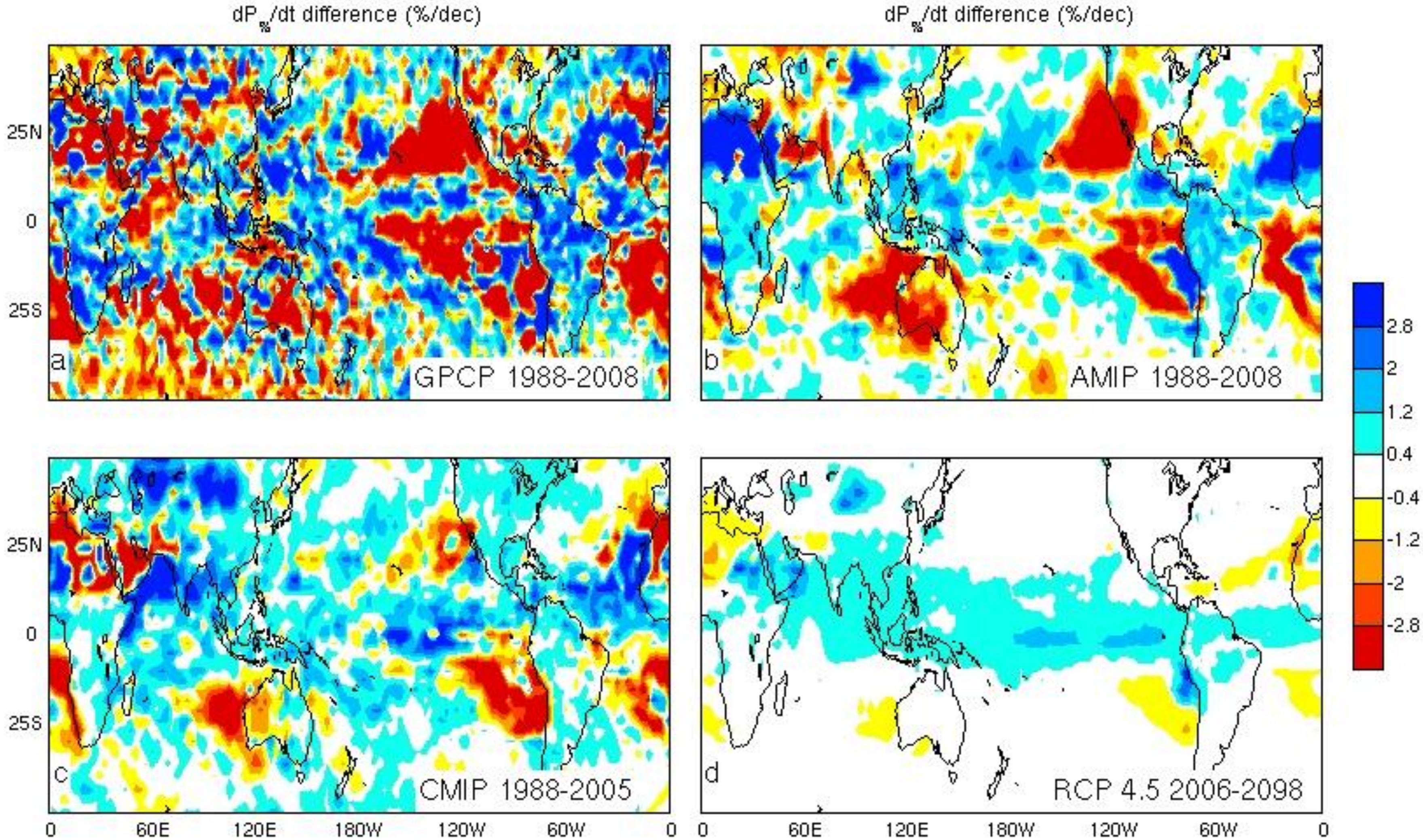
HydrOlogical cYcle Understanding via Process-bAsed GlObal Detection, Attribution and prediction

Chuunlei Liu, work in prep

Spatial signatures of Precipitation trends

Residual "thermodynamic" trends (%/decaded)



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

Chuunlei Liu, work in prep

Use of NWP simulations

- *"Employ global NWP forecasts to evaluate model drifts from analyses linking mean state errors to predicted hydrological response"*
- Looking at model drifts at the model time-step provides an opportunity for investigating process level responses

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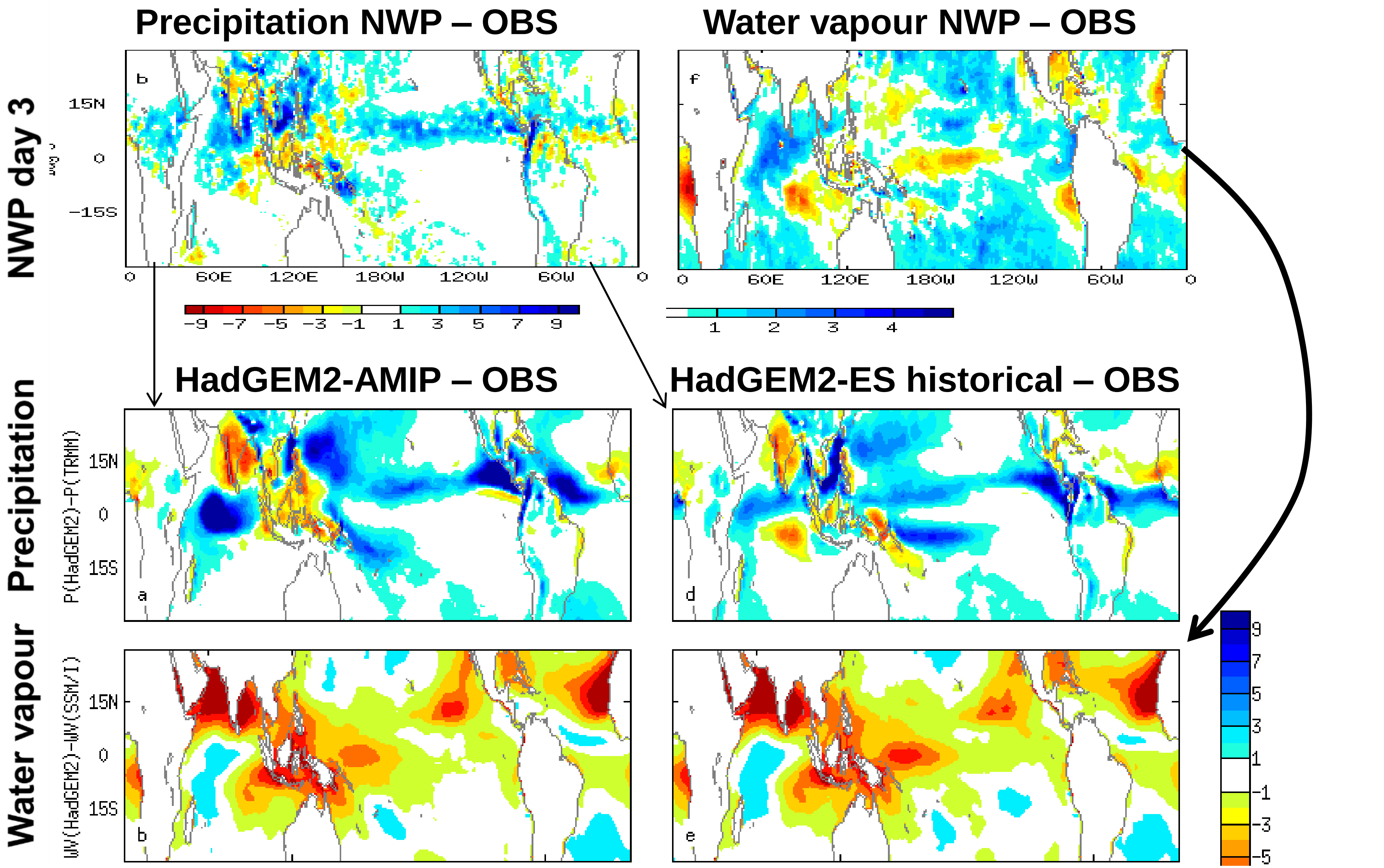
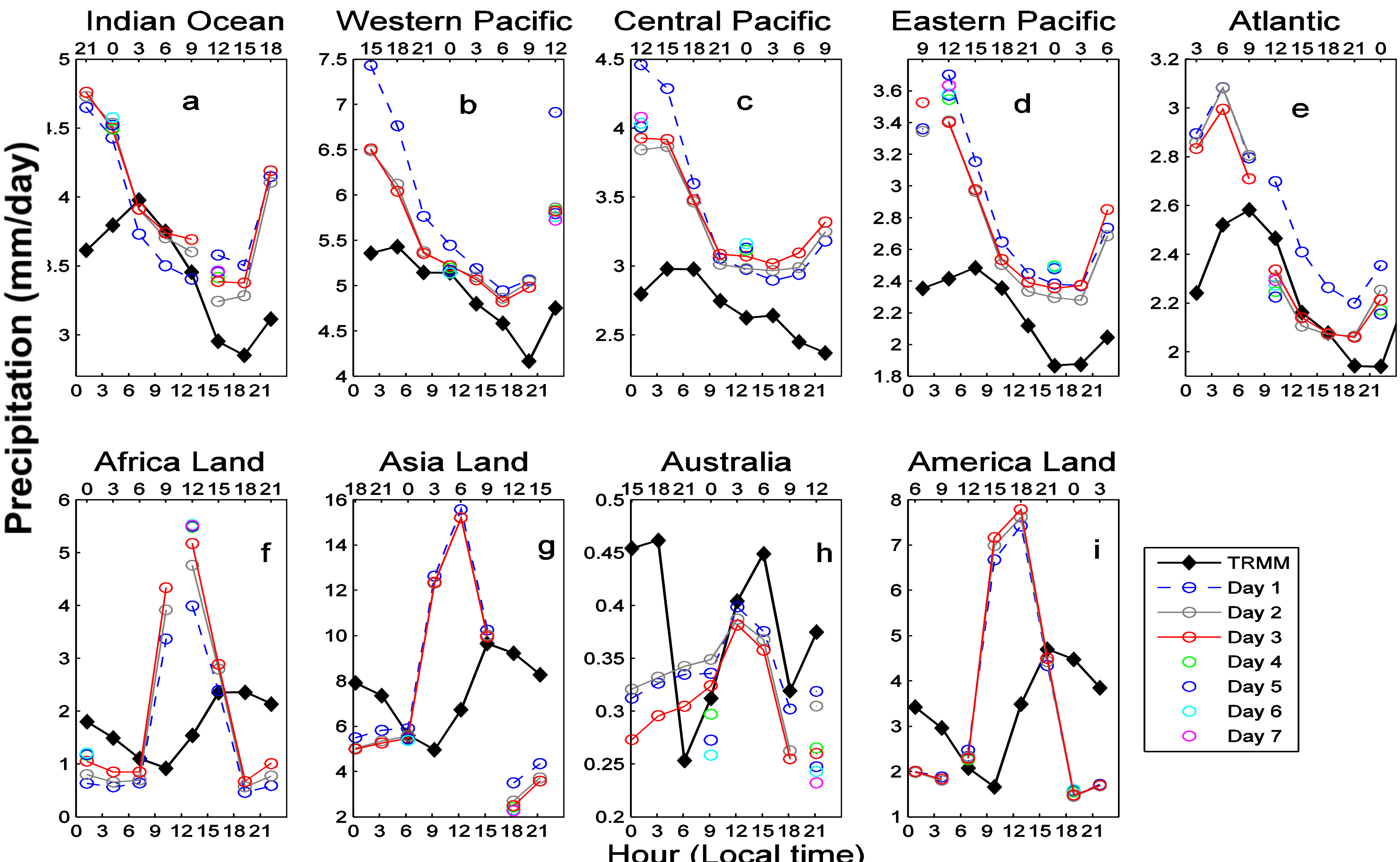
Systematic biases in water vapour and precipitation in NWP and climate models

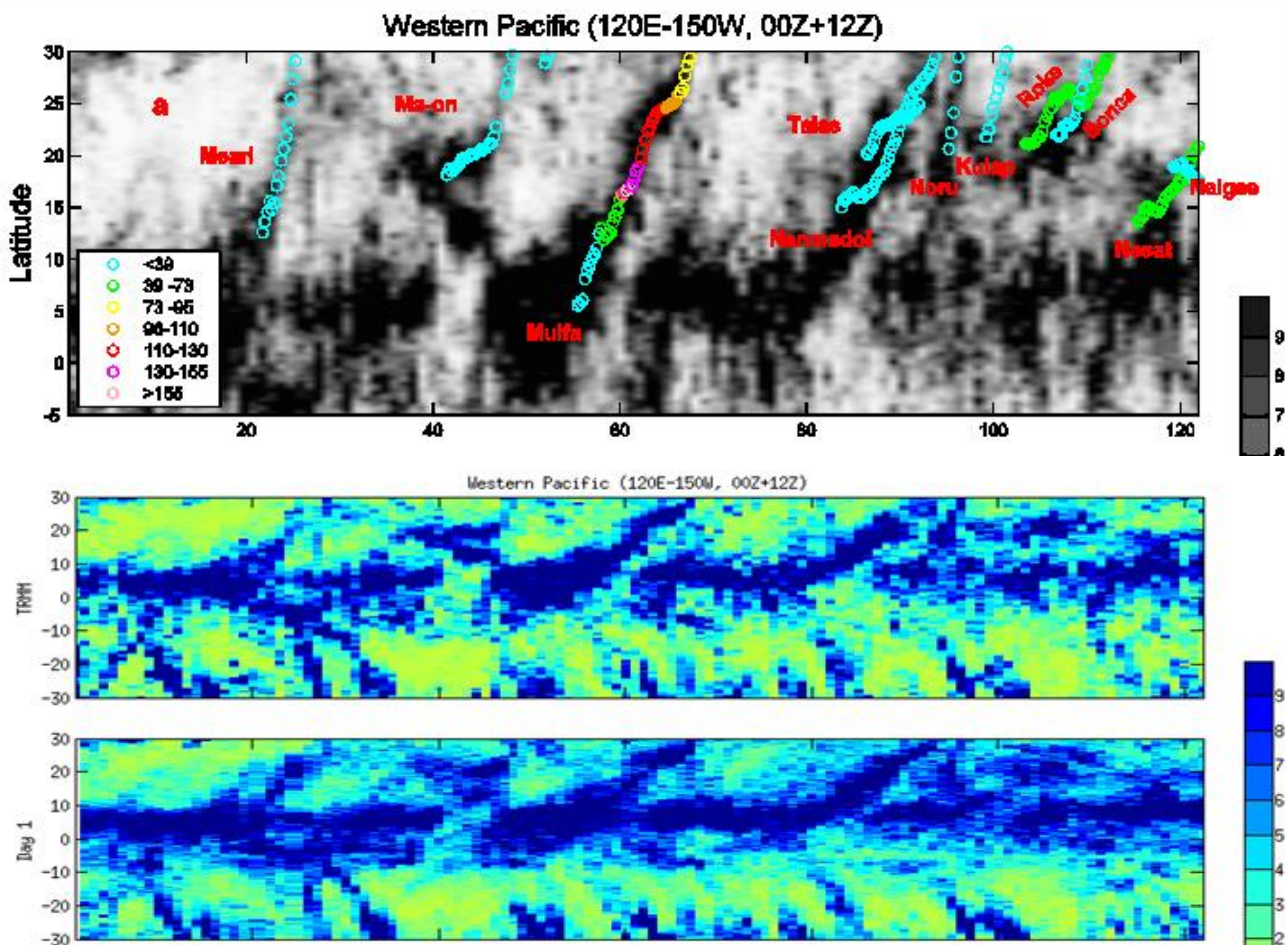


Diurnal Cycle in Precipitation:

UK Met Office NWP vs TRMM data



Propagation of precipitation anomaly



Western Pacific zonal mean Precipitation (mm/day): TRMM simulation

Days since 1 Jun: 40 60 80 100 120

Evaluating climate model simulations of precipitation extremes

University of Reading

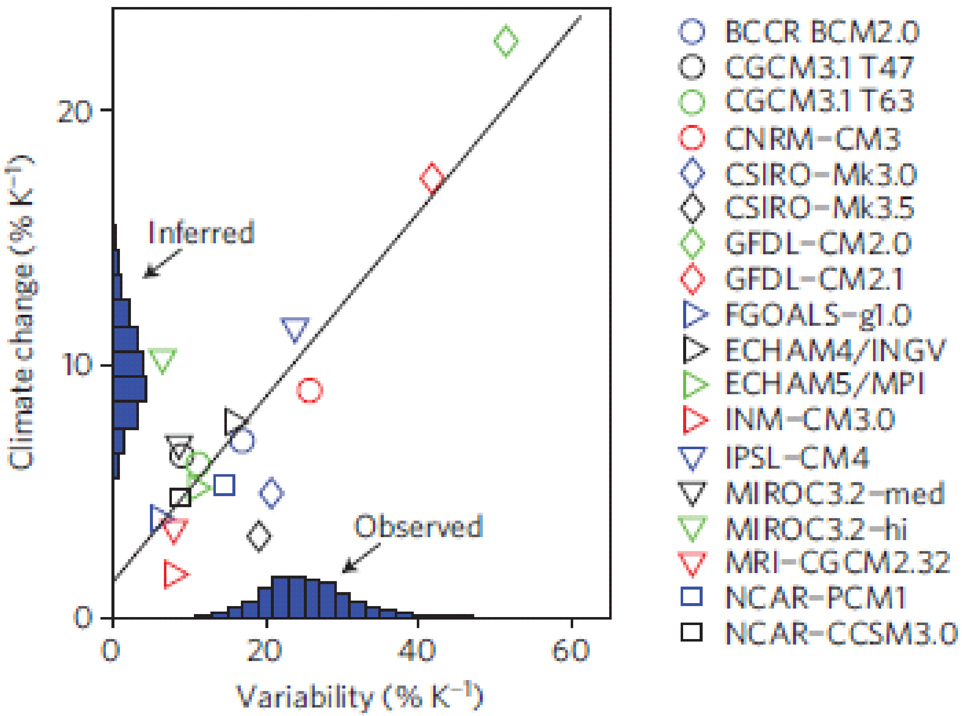


Figure 2 | Sensitivities (% K^{-1}) of the 99.9th percentile of precipitation for variability versus climate change in the CMIP3 simulations. The solid

Can observations be used to constrain the projected responses in extreme precipitation?

O'Gorman (2012) Nature Geosciences

See also Allan and Soden (2008) *Science*

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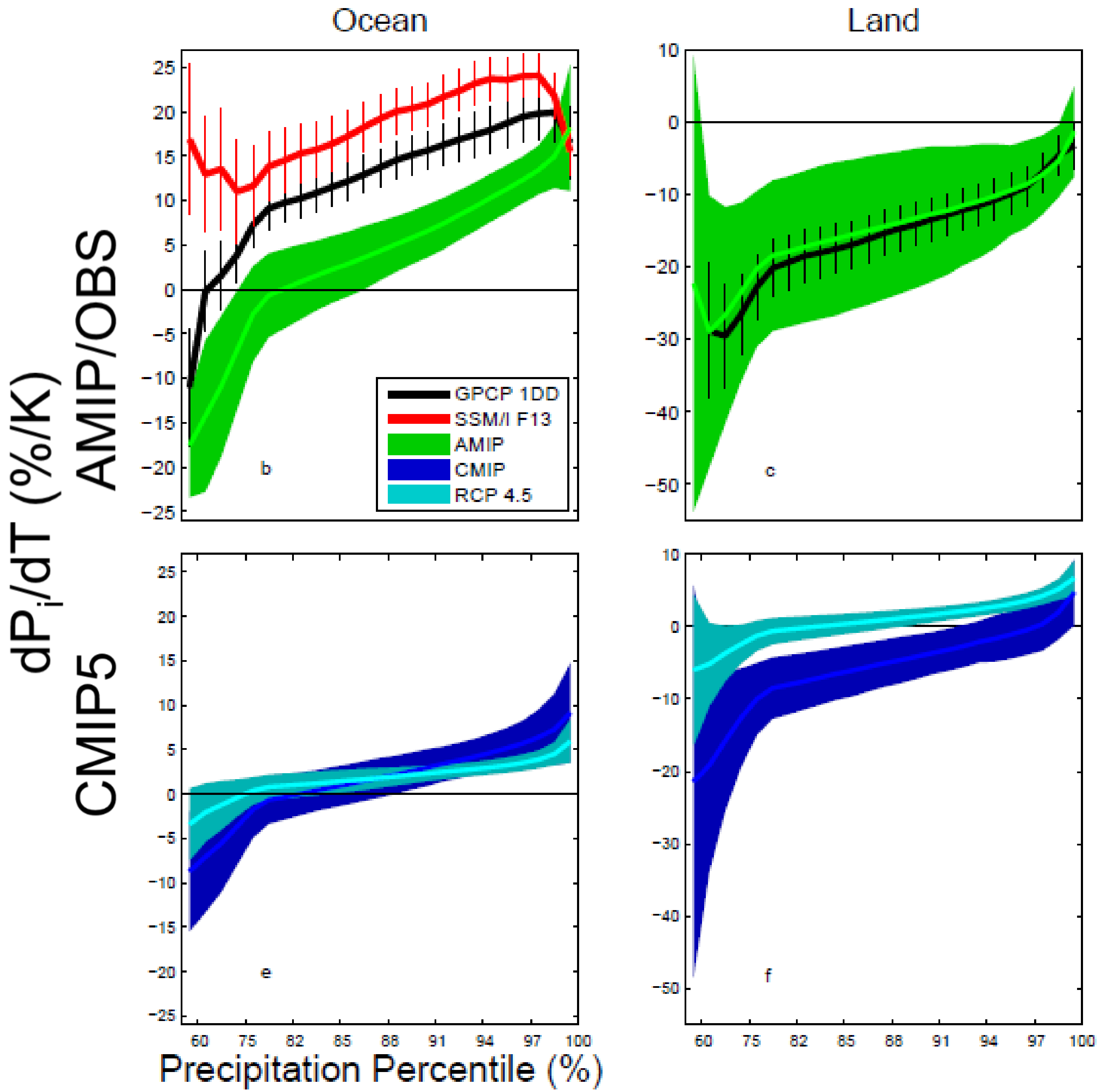
Response of 5-day Precip intensity distribution to warming: CMIP5 and observations



Allan et al. (2013) Surv. Geophys, in press

Floating Tasks in WP3

- Calculate energy and water budgets
- P-E fields and links to salinity (ongoing collaboration with WP2)
- heat flux feedbacks in the tropical central Pacific
- fingerprints of terrestrial evaporation in observations and models (CEH)
- Update the CRUTS3.0 precipitation dataset (UEA)

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Links to PAGODA WPs and other projects

- P-E collaboration with WP2
- Metrics (WP1, 4, 5)
- Datasets and NWP (Met Office partners)

- Links to other CWC projects

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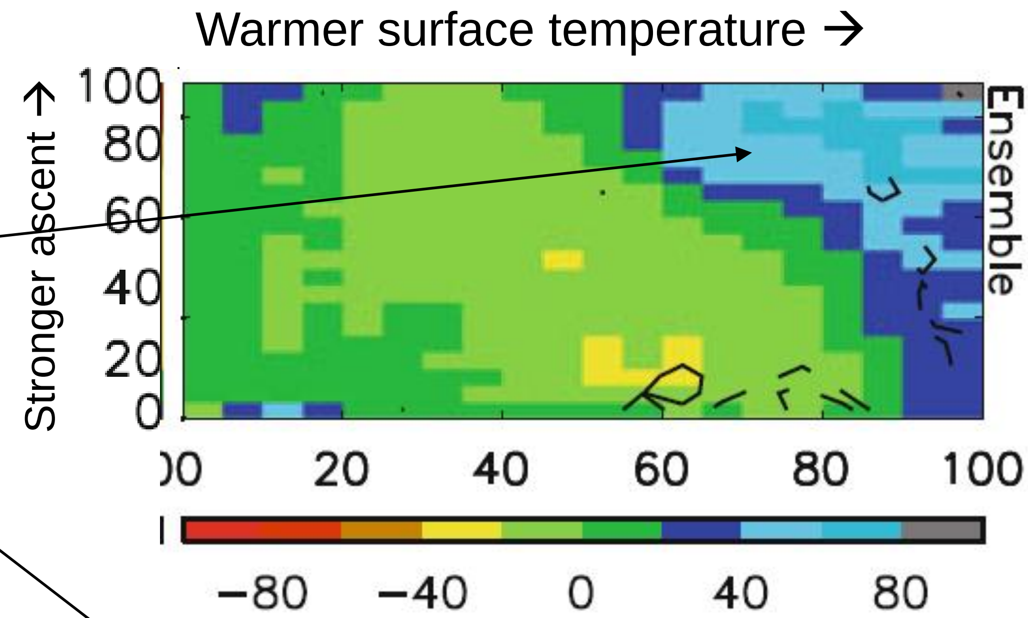
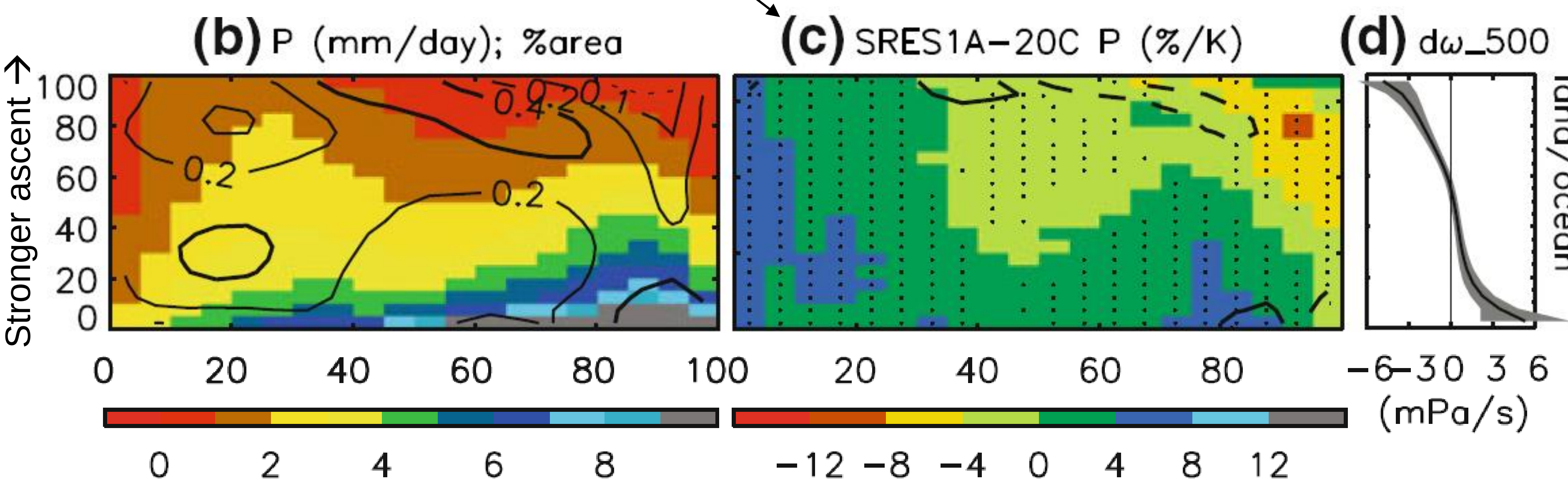
Fingerprints: precipitation bias and response by dynamical regime

- Model biases in warm, dry regime
- Strong wet/dry fingerprint in model projections (below)

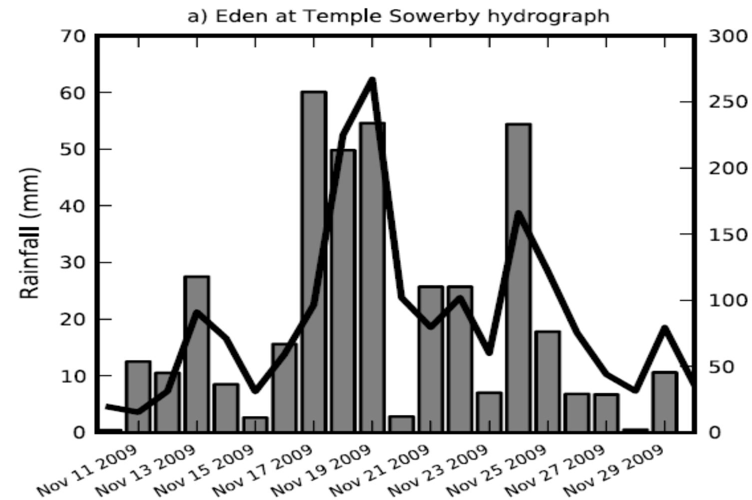
Allan (2012) Clim. Dyn.

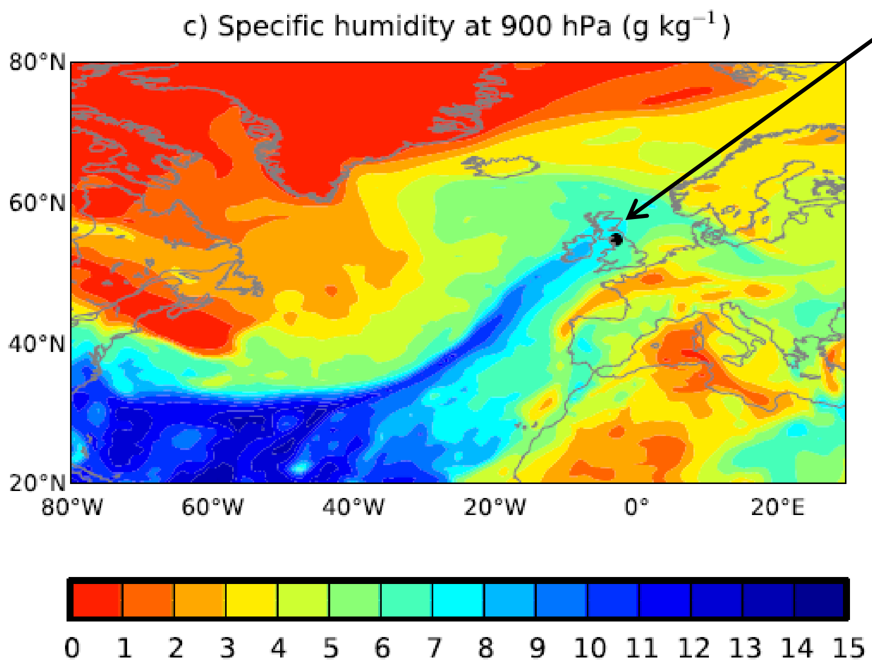


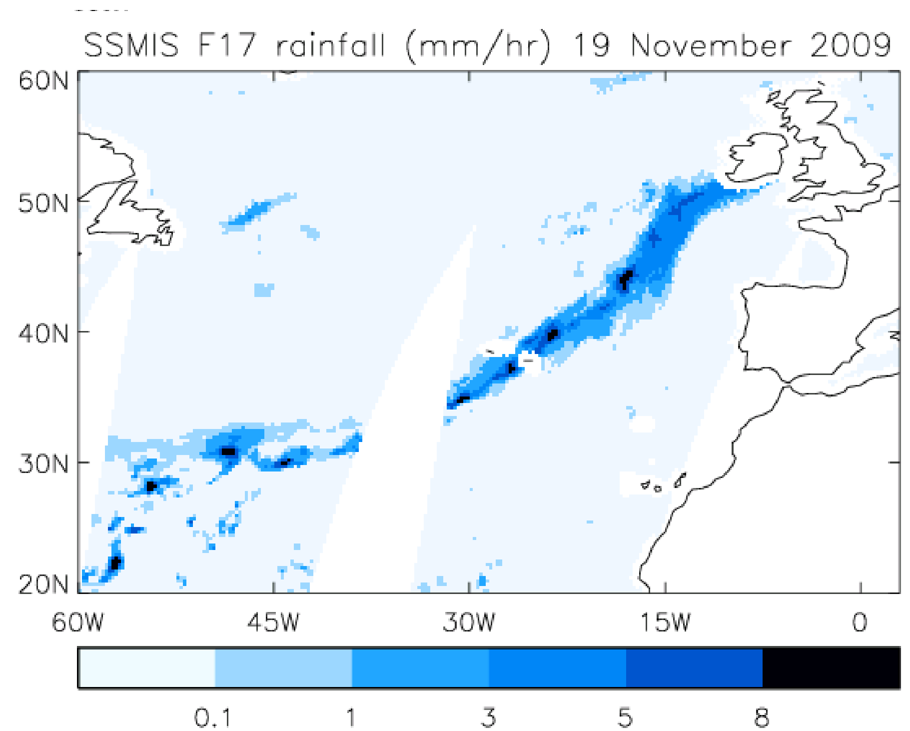


Applications: Linking flooding to moisture transports (HydEF)

HydEF project: Importance of large-scale atmospheric precursors for flooding e.g. 2009 Cumbria floods





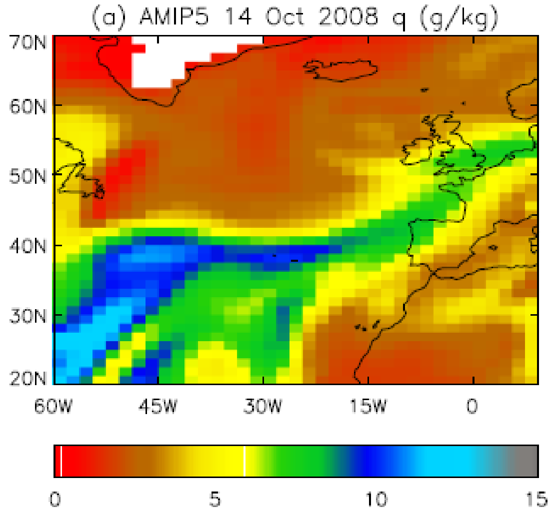


Lavers et al. (2011) Geophys. Res. Lett.

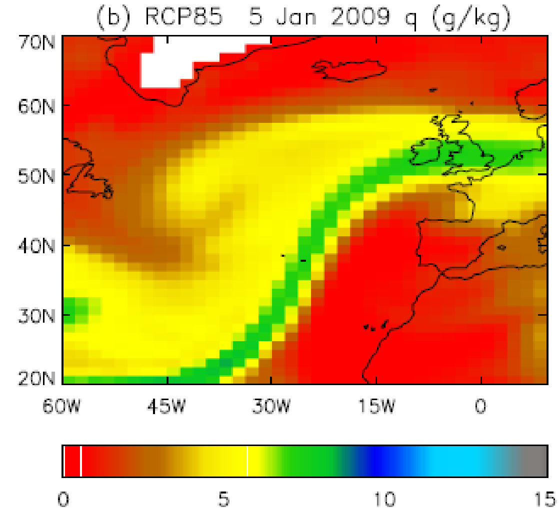
Identifying “Atmospheric Rivers” simulated by climate models

University of Reading

AMIP



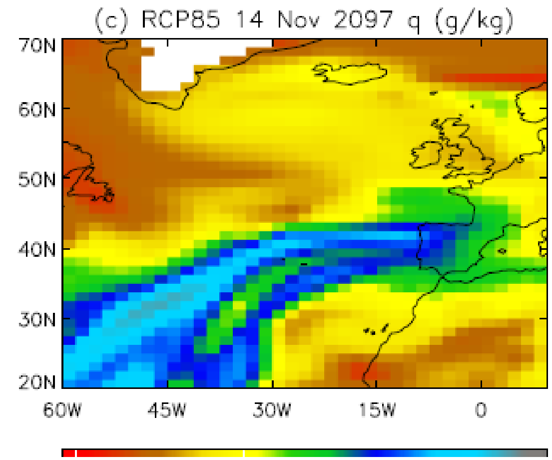
CMIP



← Coarse-scale climate models able to capture flood-generating mid-latitude systems

- Will thermodynamics dominate over changes in dynamics under climate change? →

…work in progress (HydEF)



Allan et al. (2013) Surv. Geophys, in press

Science outcomes

University of Reading

- Evaluation of blended observations (precip, water vapour)
  - Liu & Allan (2012) JGR [LINK to Met Office partners]
- Quantification of trends/hydrological sensitivity at global to largest regional scales (including extremes)
  - Liu & Allan (2012) JGR; Liu et al. (2012) GRL; Allan et al. (2013) Surv Geophys in press [LINK to WP2]
- Process-based metrics (tropical wet/dry-land/ocean, dP/dT, dMF/dT) [LINK to WP4/5]
  - Allan (2012) Clim. Dyn.; Allan et al. (2013) Surv. Geophys in press; Lavers et al. (2011) GRL; Zahn and Allan (2013) WRR in prep
- Linking NWP forecast drift with climate model bias
  - Liu et al. in prep [LINK to Met Office partners]
- Links to other NERC projects (HydEF, PREPARE)

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Science outcomes

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- Robust increases in water vapour & transports with warming (~7%/K) [O'Gorman et al. 2012; Allan et al. 2013; Zahn & Allan 2013]
- Erroneous P variability in reanalyses and some satellite datasets over the ocean [Liu & Allan 2012]
- AMIP simulations can reproduce observed land P variability (relating to ENSO) [Liu et al. 2012; Allan et al. 2013]
- Little agreement between AMIP and satellite data over ocean before 1996 [Liu et al. 2012]
- Interannual P sensitivity to Ts may provide a constraint upon future projections [Liu & Allan 2012; see O'Gorman 2012]
- Tropics: wet get wetter, dry get drier (when dynamically define regimes) [Allan 2012; Liu et al. 2012; Liu in prep]
- Systematic water vapour and precipitation biases in climate models linked to NWP model drift [Liu in prep]

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PAGODA WP3 Outputs

- R. P. Allan, C. Liu, M. Zahn, D. A. Lavers, E. Koukouvagias and A. Bodas-Salcedo (2013) Physically consistent responses of the global atmospheric hydrological cycle in models and observations, Surv. Geophys., doi:10.1007/s10712-012-9213-z . **PDF**
- Allan, R.P., (2012) Regime dependent changes in global precipitation, Climate Dynamics 39, 827-840 10.1007/s00382-011-1134-x **Online**
- Liu, C., R. P. Allan, and G. J. Huffman (2012) Co-variation of temperature and precipitation in CMIP5 models and satellite observations, Geophys. Res. Lett., 39, L13803, doi:10.1029/2012GL052093 **Online**
- Liu, C.-L. and R. P. Allan, (2012) Multi-satellite observed responses of precipitation and its extremes to interannual climate variability, J. Geophys. Res. 117, D03101, doi:10.1029/2011JD016568 **Online**
- O'Gorman, P. A., R. P. Allan, M. P. Byrne and M. Previdi (2012) Energetic constraints on precipitation under climate change, Surv. Geophys., 33, 585-608, doi: 10.1007/s10712-011-9159-6 **PDF**
- R. P. Allan (2012) The role of water vapour in Earth's energy flows, Surv. Geophys., 33, 557-564, doi: 10.1007/s10712-011-9157-8. **PDF**

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