Department of Meteorology

Global and regional evaluation of current changes in water vapour, precipitation and Earth's energy budget

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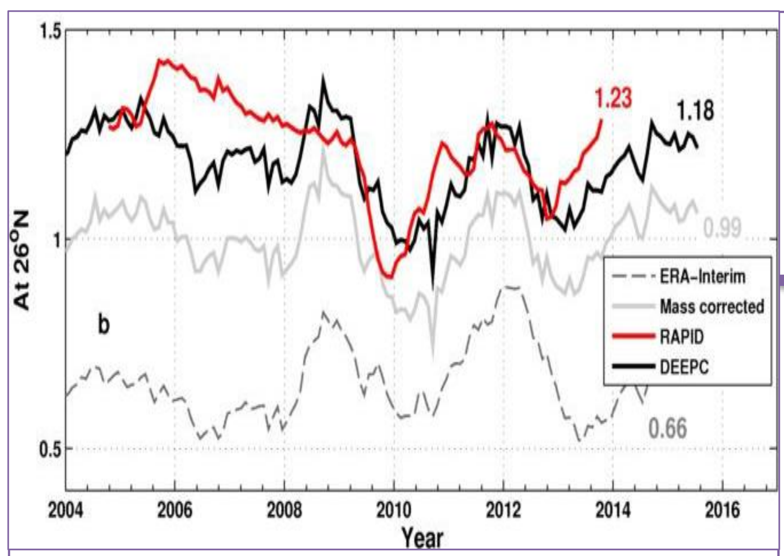
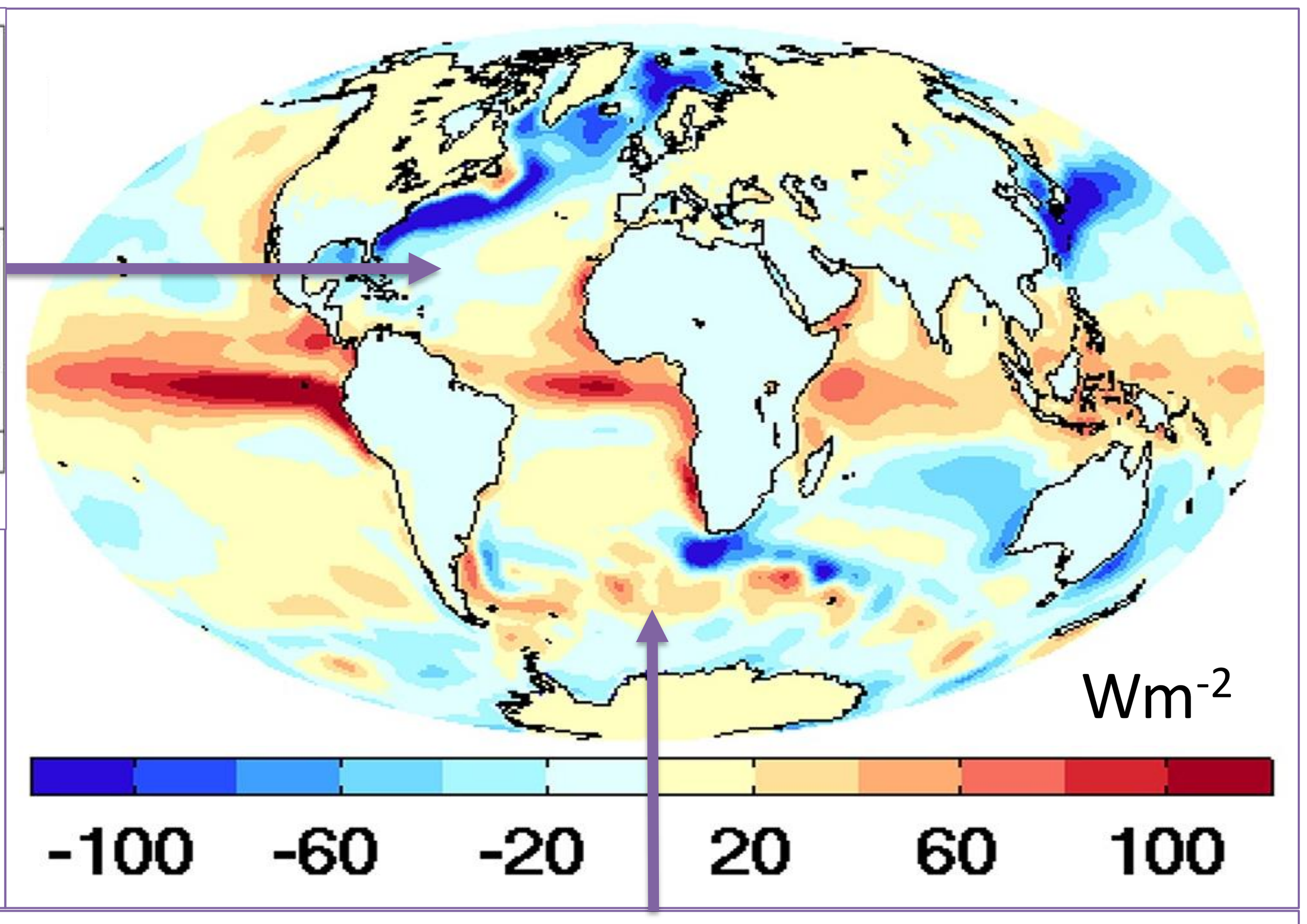
Introduction

A range of satellite products used to monitor and assess current changes in global energy and water cycles and evaluate climate simulations

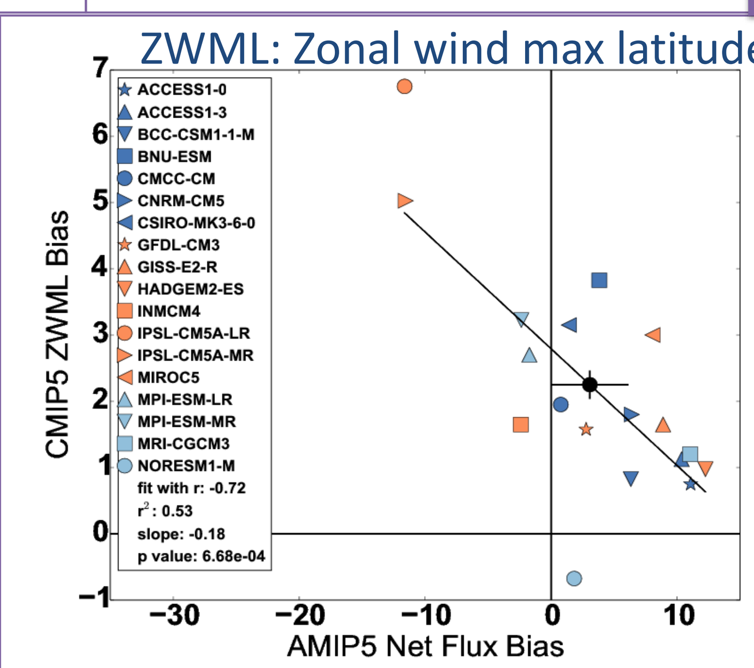
- Water vapour increases ~7%/K in satellite data and CMIP6 simulations; precipitation increases ~3%/K in satellite data, ~2%/K in CMIP6 simulations for global interannual variability
- Atmospheric moisture increasing with surface warming at a greater rate than precipitation and at a higher rate in the upper troposphere as expected from thermodynamics
- Earth's radiative energy imbalance ~0.7 Wm^{-2}, varying with ENSO & volcanic eruptions with evidence of increasing trend
- Observed Atlantic ocean heat transport captured by combined satellite/reanalysis surface energy flux product
- Southern ocean SST bias traced to cloud deficiencies and feedbacks in combined satellite/reanalysis energy fluxes

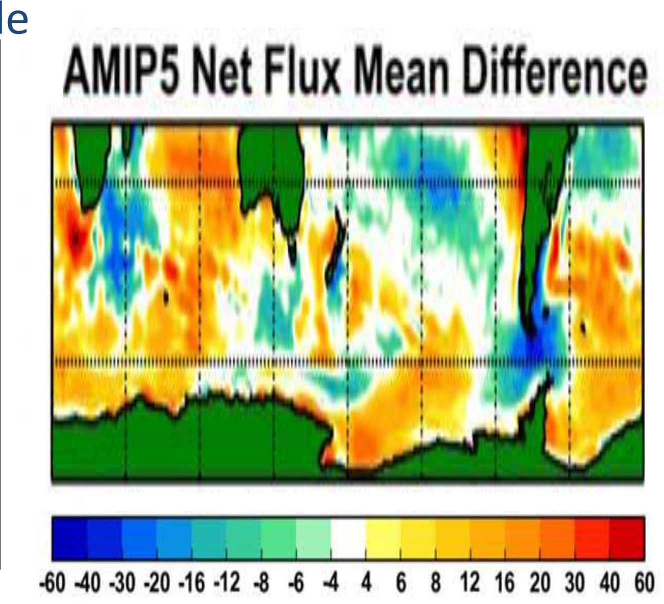




3. Atlantic heat transport

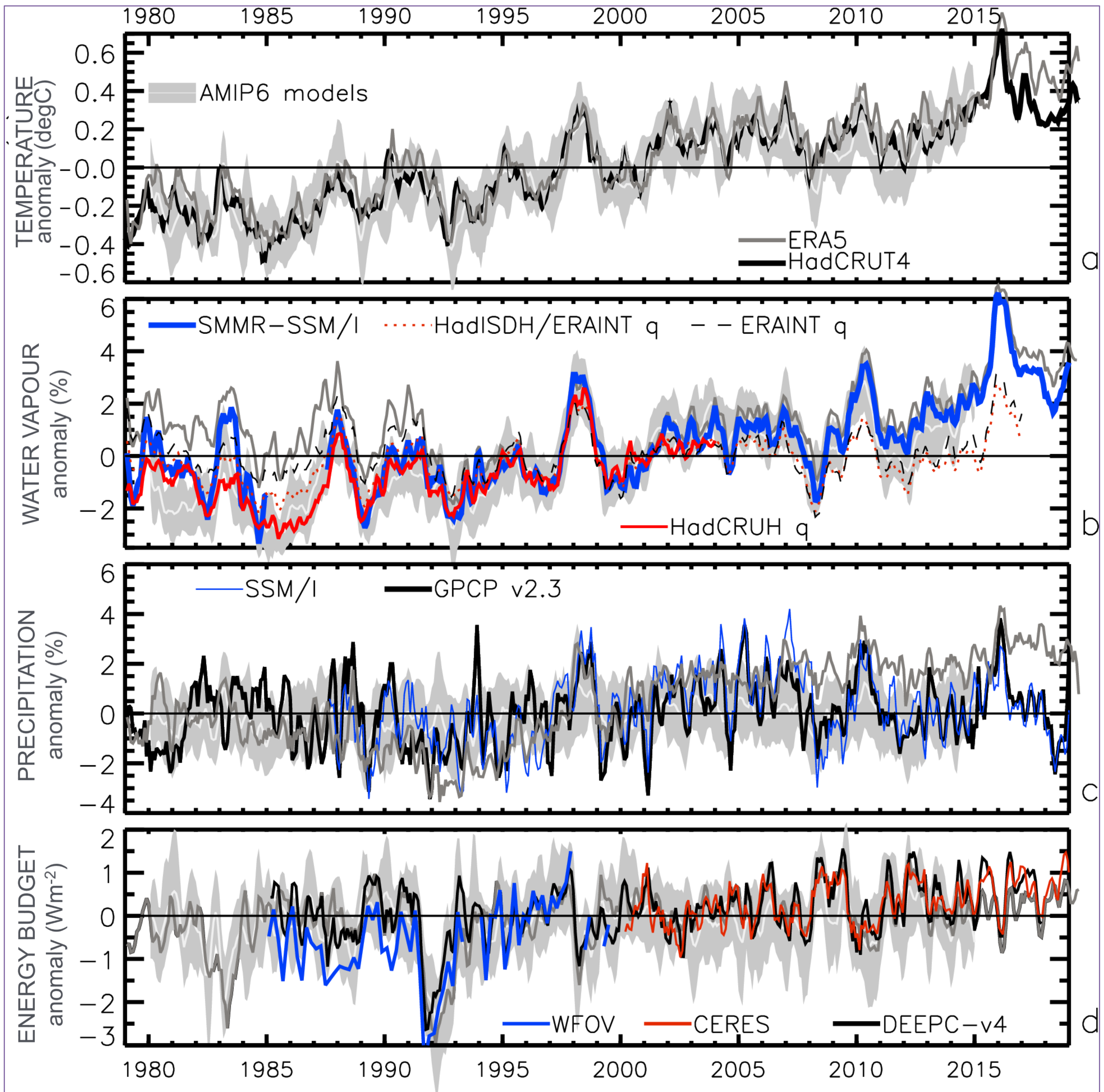
Satellite/reanalysis surface energy flux product (Liu et al. 2017; right) indicates N Atlantic heat transport of 1.2 PW (above)





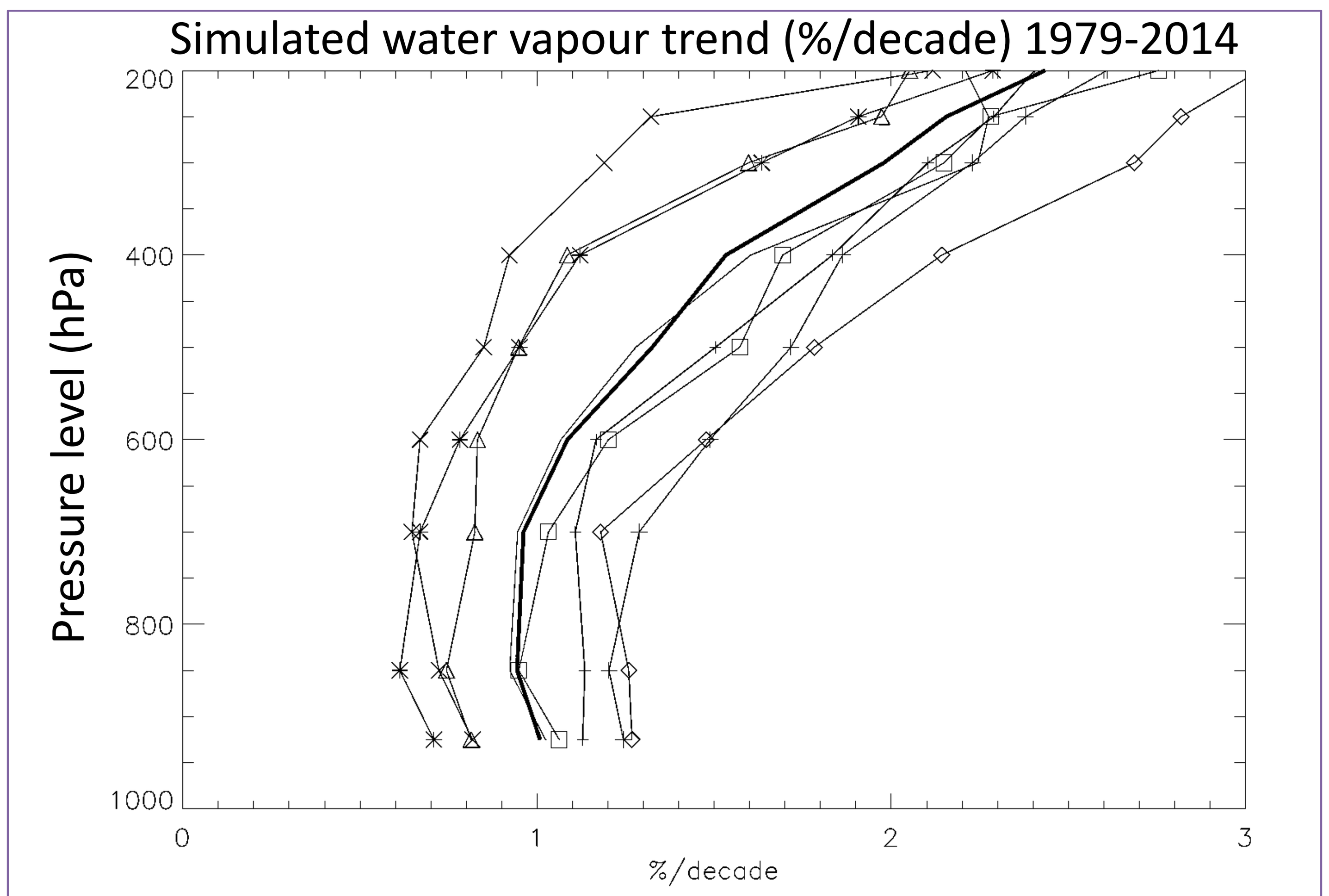
4. Southern ocean climate model biases

Comparing AMIP/CMIP simulations with satellite/reanalysis derived surface energy fluxes allows climate model biases to be traced back to the atmosphere component involving clouds and ocean/wind feedbacks (Hyder et al. 2018, above).



1. Monitoring global temperature, water vapour, precipitation & energy budget

Global mean de-seasonalised anomalies of (a) surface temperature, (b) atmospheric water vapour (column integrated, W and surface specific humidity, q), (c) precipitation and (d) net downward top of atmosphere radiative energy imbalance for a range of surface/satellite-based products & CMIP6 atmosphere-only amip simulations; updated from Allan et al. (2014a,b)

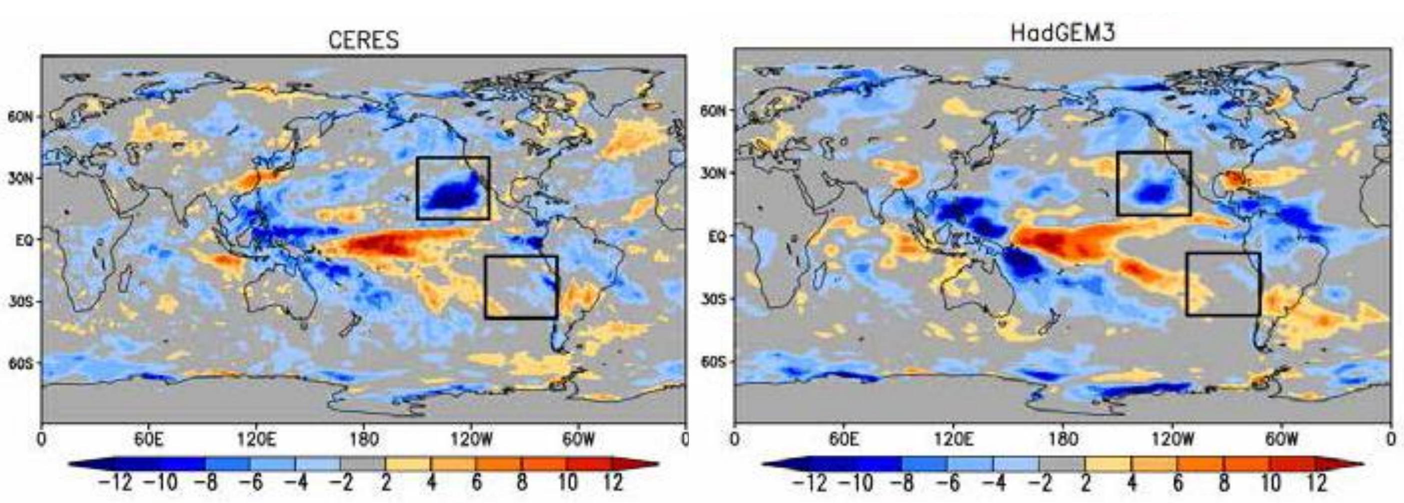


5. Water vapour trends in CMIP6 amip simulations

Basic thermodynamics causes water vapour to increase with warming; this drives a strongly amplifying climate feedback. CMIP6 amip simulations demonstrate the moistening trend (above) which is larger at higher altitudes due to non-linearities in the Clausius Clapeyron equation. Simulations are being evaluated using satellite data (AIRS, SSM/I).

2. Cloud feedbacks and climate variability

Changes in cloud and radiation during and after the recent global warming slowdown period are used to evaluate cloud feedback processes in CMIP6 simulations (below). Positive (amplifying) cloud feedbacks are identified for the eastern Pacific strato-cumulus regimes. Observed reductions in reflected sunlight in north east Pacific (~4 Wm^{-2}; CERES) are broadly captured by AMIP6 simulations (0-5 Wm^{-2}) →



References

Allan et al. (2014a) Physically consistent responses of the global atmospheric hydrological cycle in models and observations, *Surv. Geophys.*, **35,** 533-552, doi:10.1007/s10712-012-9213-z; **Allan at al. (2014b)** Changes in global net radiative imbalance 1985-2012,GRL, 41, 5588-5597, doi:10.1002/2014GL060962; **Hyder et al. (2018)** Critical Southern Ocean climate model biases traced to atmospheric model cloud errors, Nature Comm. 9, 3625, doi:10.1038/s41467-018-05634-2; **Liu et al. (2017)** Evaluation of satellite and reanalysis-based global net surface energy flux and uncertainty estimates, *J. Geophys. Res.*, **122,** 6250-6272, doi: 10.1002/2017JD026616

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