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GLOBAL TO REGIONAL MANIFESTATION OF EARTH'S ENERGY IMBALANCE
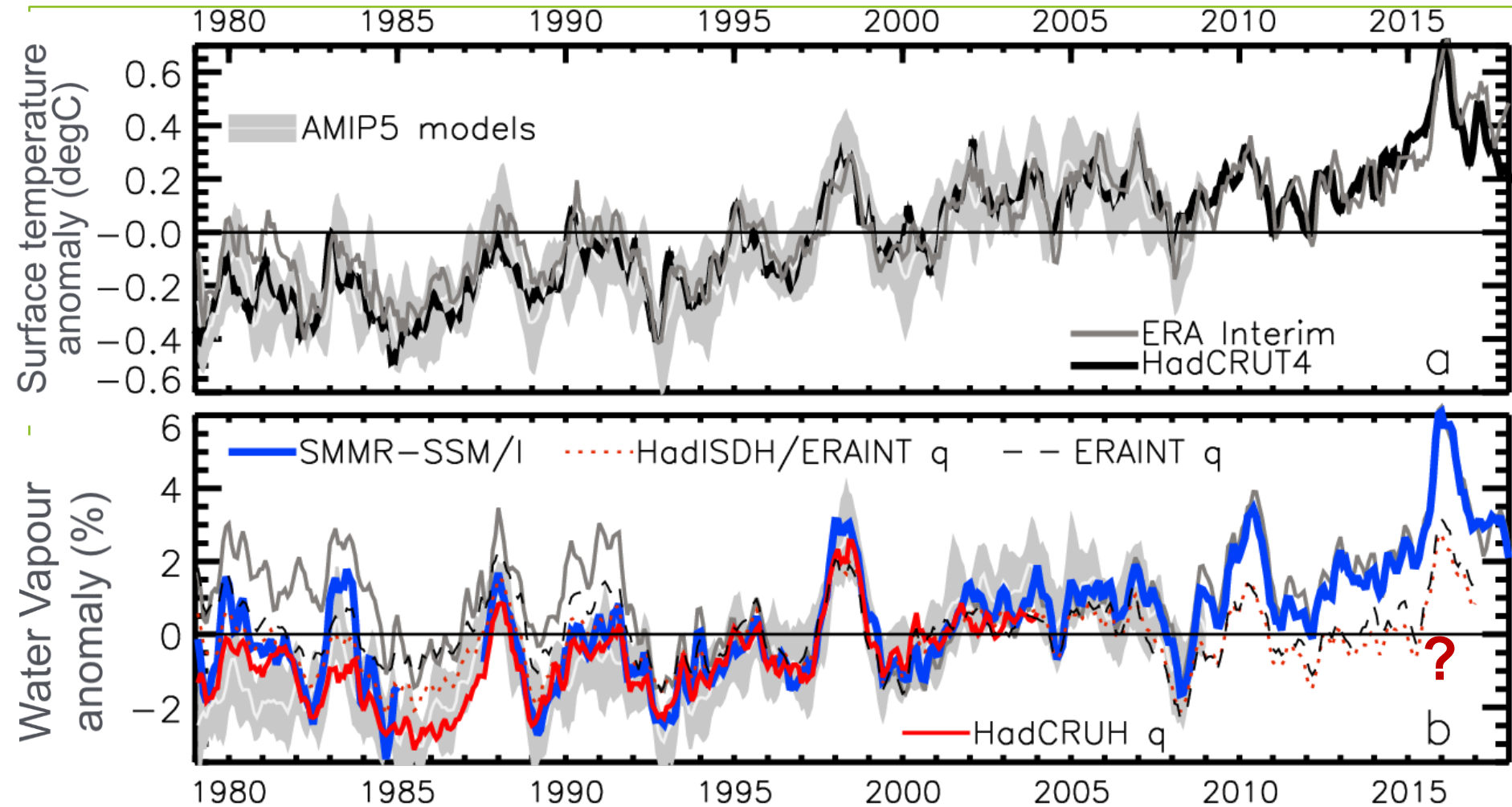
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Chunlei Liu (University of Reading); Pat Hyder, Matt Palmer, (Met Office), Chris Roberts (Met Office/ECMWF), Michael Mayer (Univ. Vienna/ECMWF)
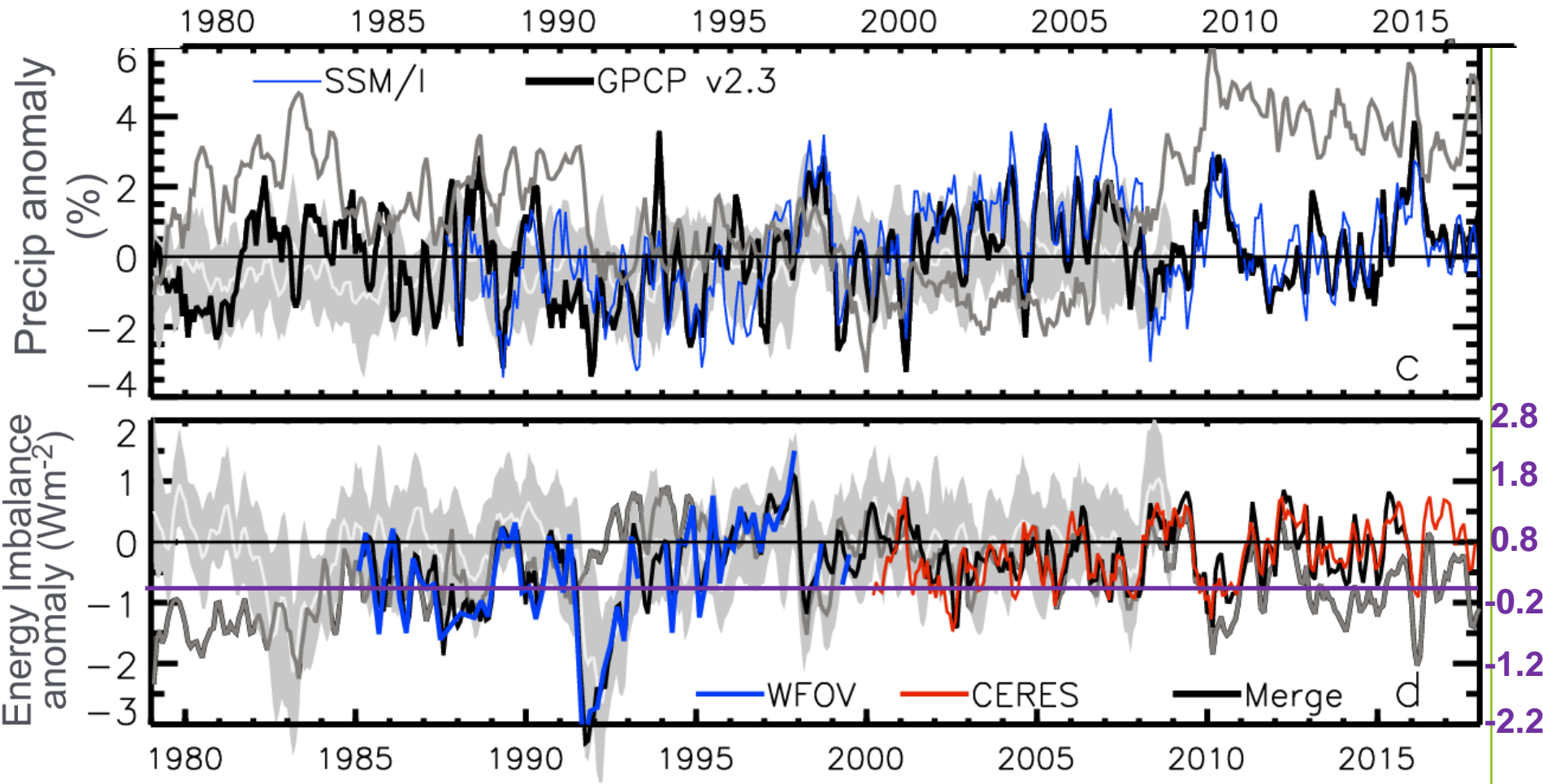
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

1

LIMITLESS POTENTIAL | LIMITLESS OPPORTUNITIES | LIMITLESS IMPACT

RECENT GLOBAL CLIMATE VARIABILITY

Update from Allan et al.(2014) Surv. Geophys

RECENT GLOBAL CLIMATE VARIABILITY

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Update from Allan et al.(2014) Surv. Geophys.; Allan et al. (2014) GRL

EEI RECONSTRUCTIONS

- Longer EEI record → forcing, feedback & links to water cycle
- Combine ERBS/CERES/simulations (Allan et al. 2014 GRL)
- Methods of Trenberth & Caron (2001) and others to reconstruct surface fluxes (Liu et al. (2017 JGR)
  - Mass corrections, land flux adjustment, satellite gap adjustments
  - Update with CERES EBAFv4.0 & enthalpy corrections (Mayer et al. 2018 but see Trenberth & Fasullo 2018 J. Clim),
  - Use ERBS v3 and ERA interim data for now, **poster by Chunlei Liu**


WFOV TOA NET flux anomaly (W/m^2)
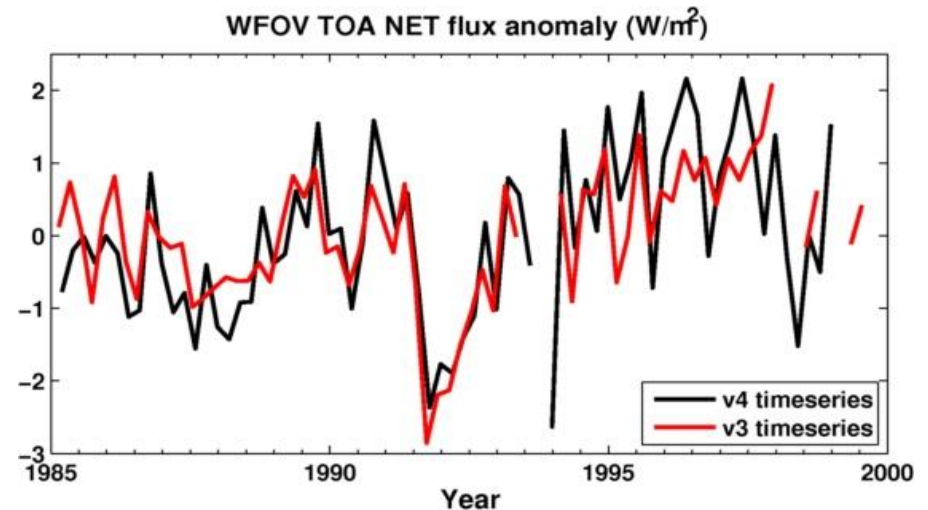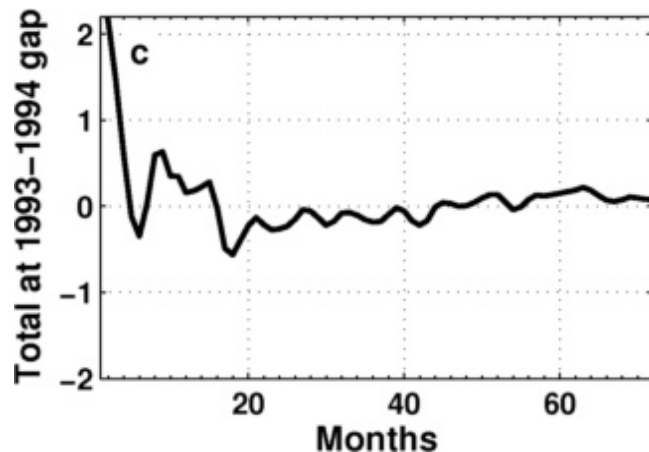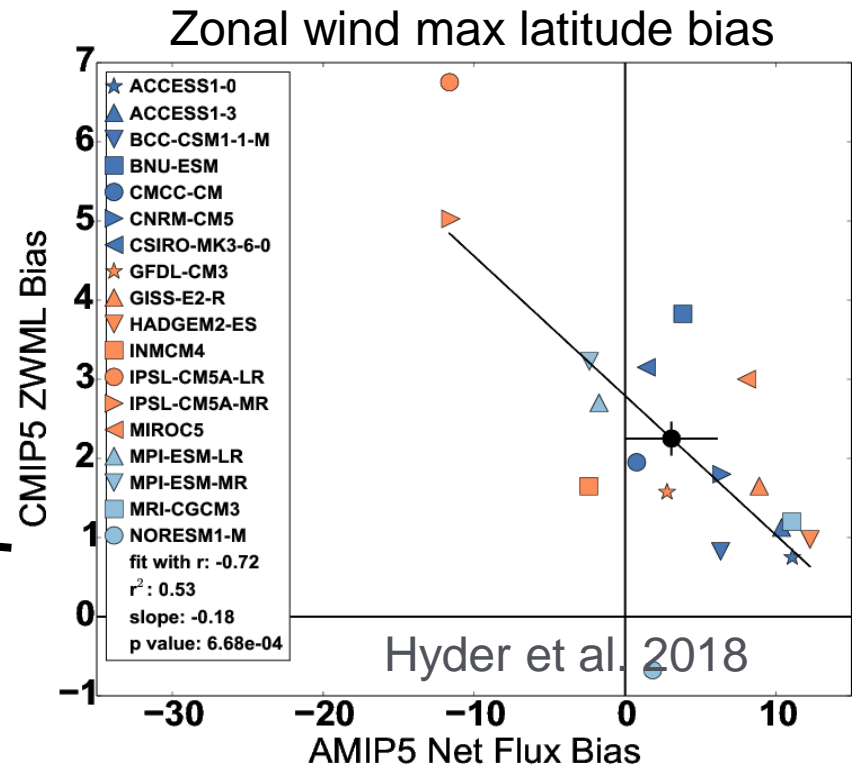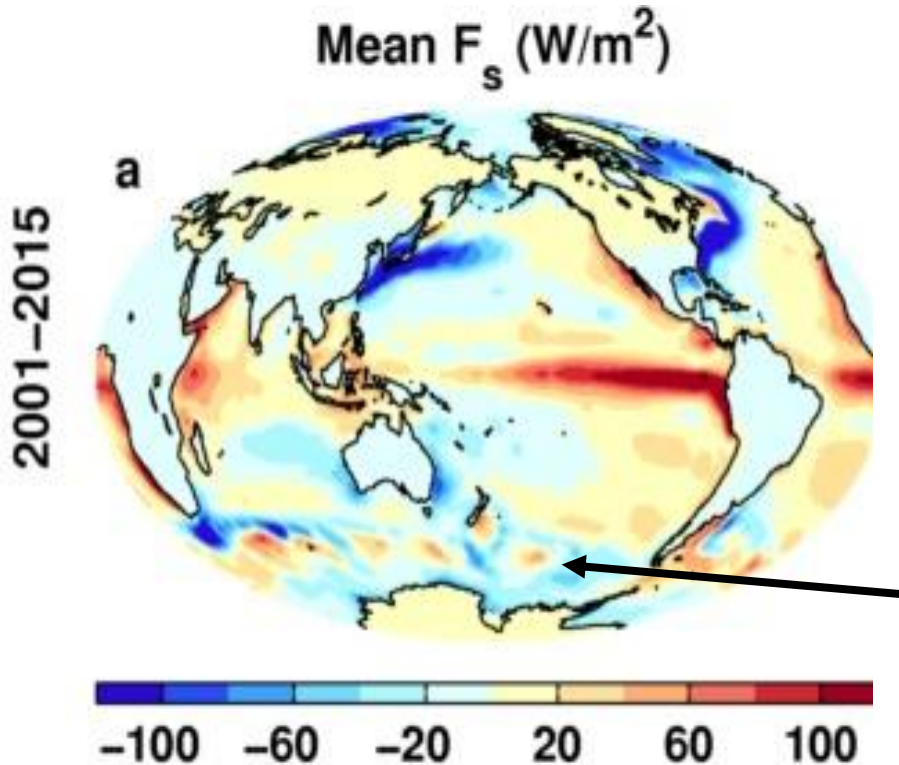
TOA downward radiation flux anomaly (W/m²)
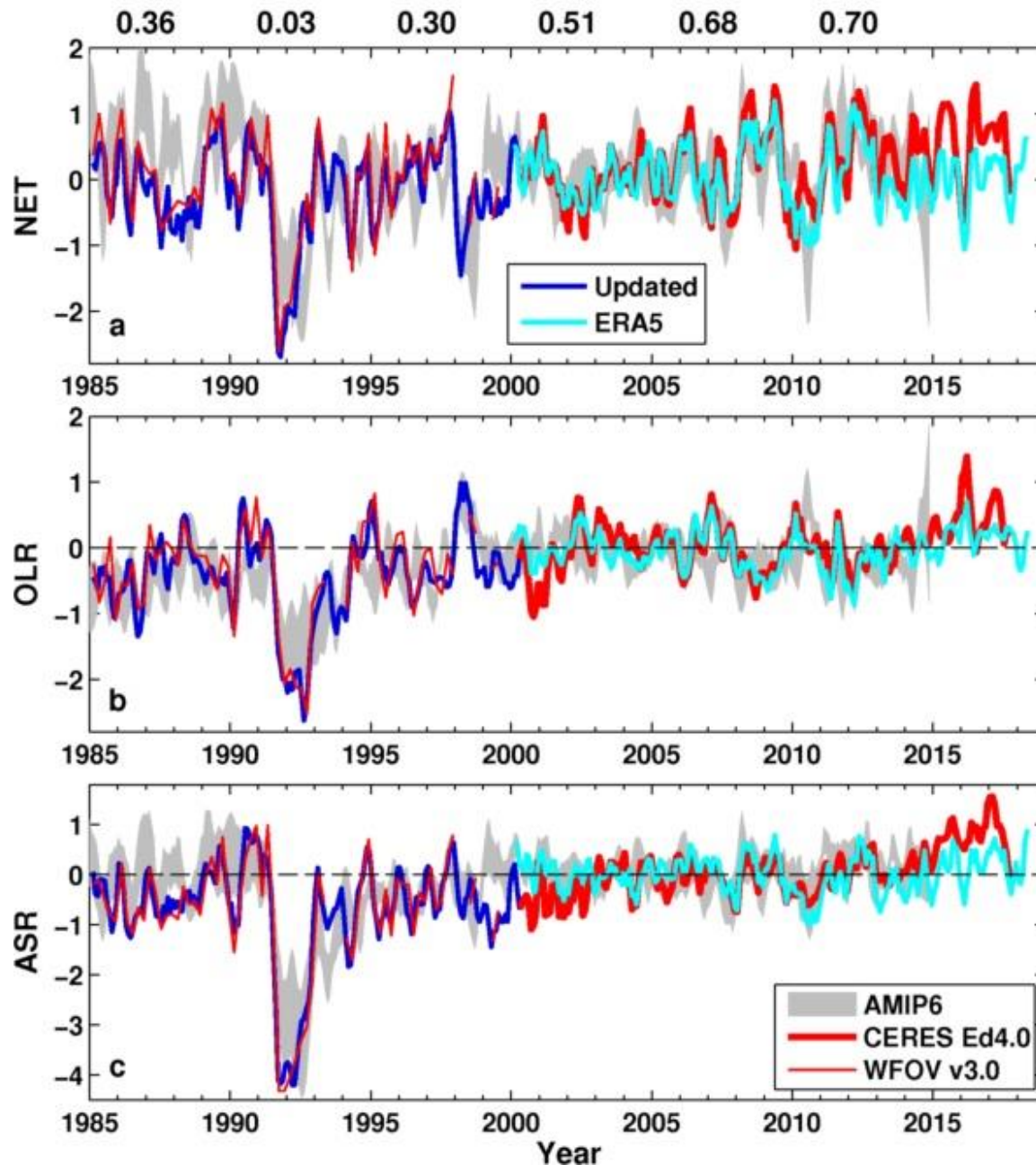
- Preliminary comparison with AMIP6 and ERA5
- Large uncertainty in pre-CERES EEI remains
- ERA5 does not capture observed ASR increase after warming slowdown (e.g. Loeb et al. 2018)
- AMIP vs reconstruction:
  - NET: r = 0.46
  - OLR: r = 0.57
  - ASR: r = 0.67
- Consistent with ocean heat content (Cheng et al. 2017 Sci. Adv.) lower than new independent estimate by Resplandy et al. (2018) Nature

5

INTERPRETING VARIABILITY & BIAS USING OCEAN MIXED LAYER ENERGY BALANCE
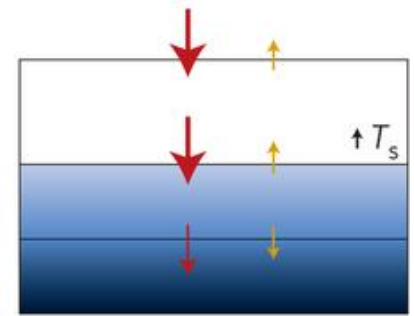
- Interpreting warming slowdown: upper ocean mixed layer heat budget (e.g. Hedemann et al. 2017; Roberts et al. 2017 JGR)
- Combine with surface radiation estimates (Kato et al., 2018 J. Clim) to investigate Southern Ocean biases (Hyder et al. 2018 Nature Comms)

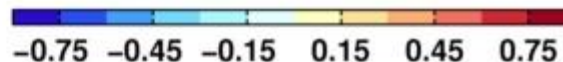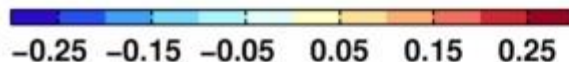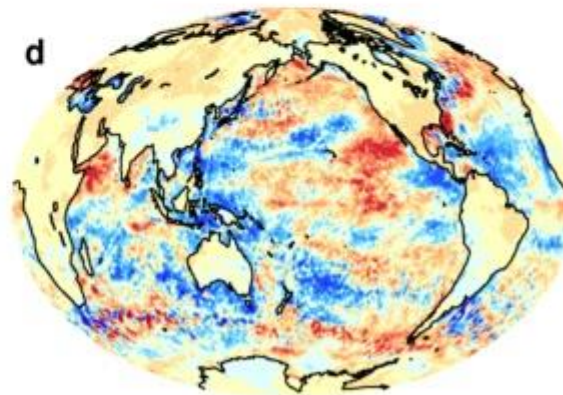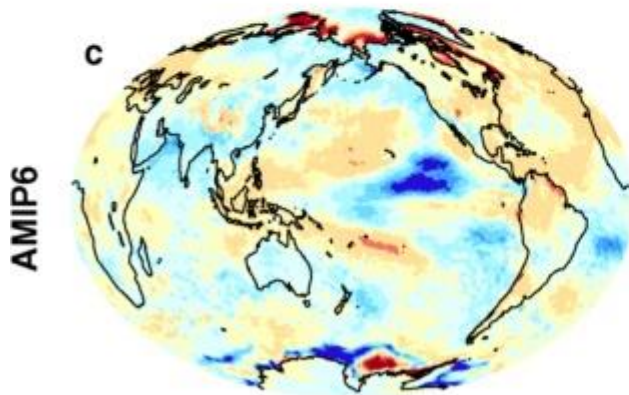Mean F_s (W/m^2)

2001–2015

Zonal wind max latitude bias

ACCESS1-0
ACCESS1-3
BCC-CSM1-1-M
BNU-ESM
CMCC-CM
CNRM-CM5
CSIRO-MK3-6-0
GFDL-CM3
GISS-E2-R
HADGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
MIROC5
MPI-ESM-LR
MPI-ESM-MR
MRI-CGCM3
NORESM1-M
fit with r: -0.72
r^2: 0.53
slope: -0.18
p value: 6.68e-04

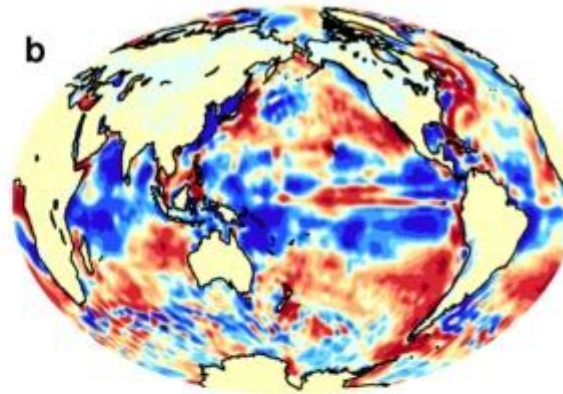CMIP5 ZWML Bias

AMIP5 Net Flux Bias
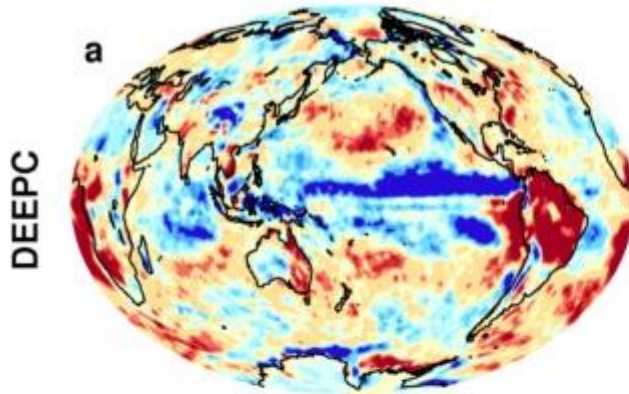
Hyder et al. 2018
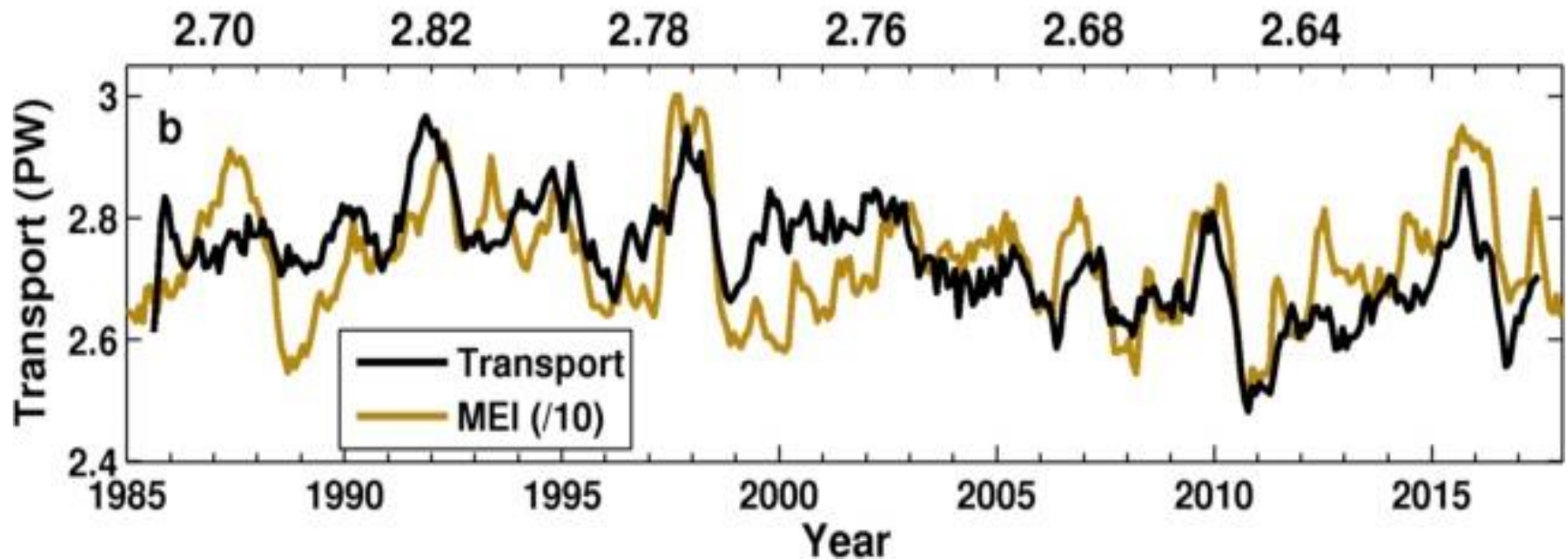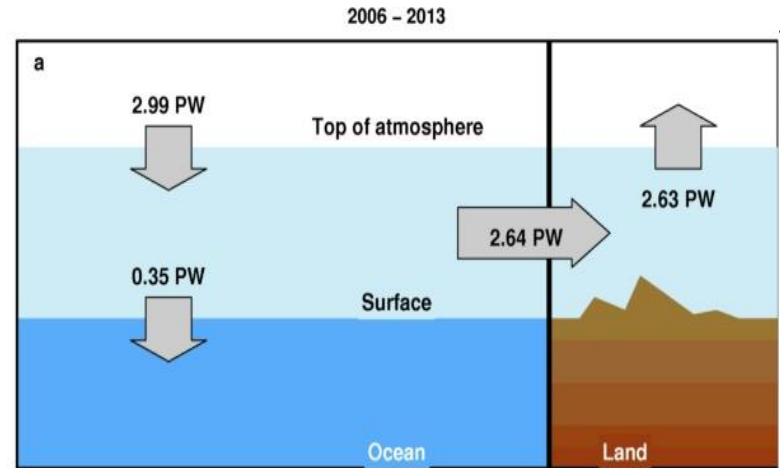
TRENDS IN NET FLUXES 1985-2014

Top of atmosphere
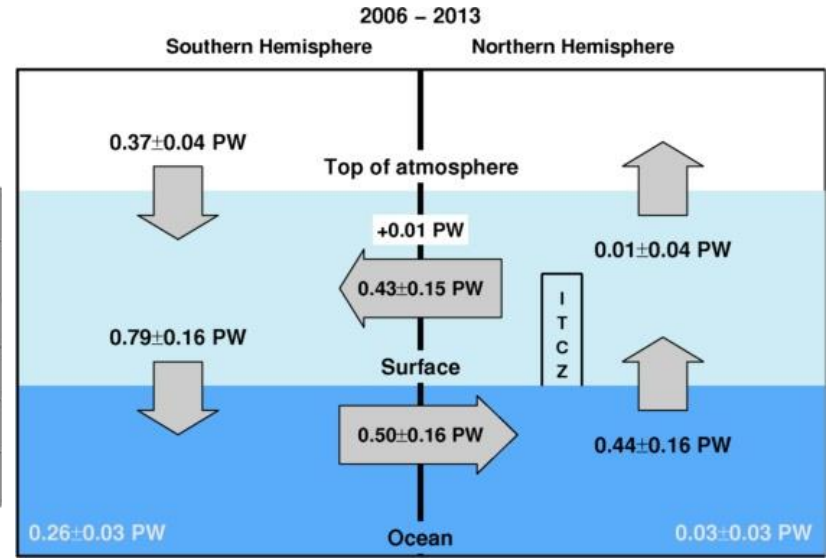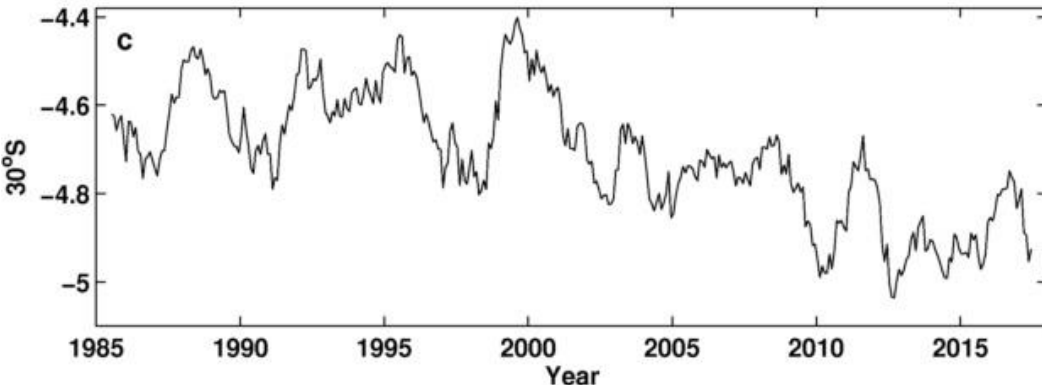F_T (W/m^2/yr)

Surface
F_s (W/m^2/yr)

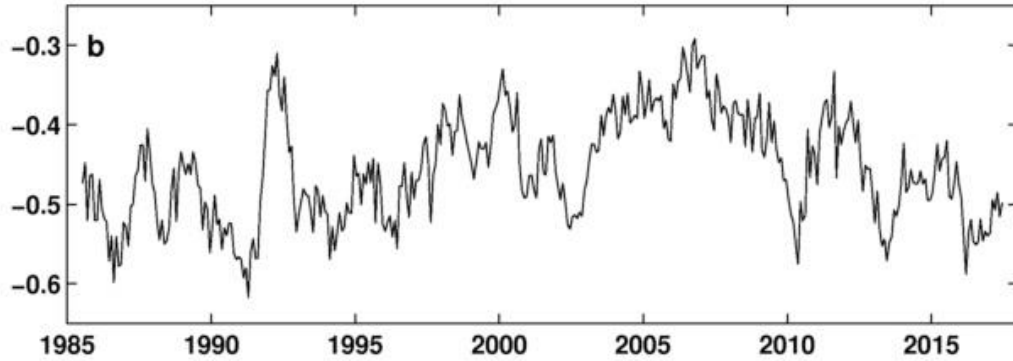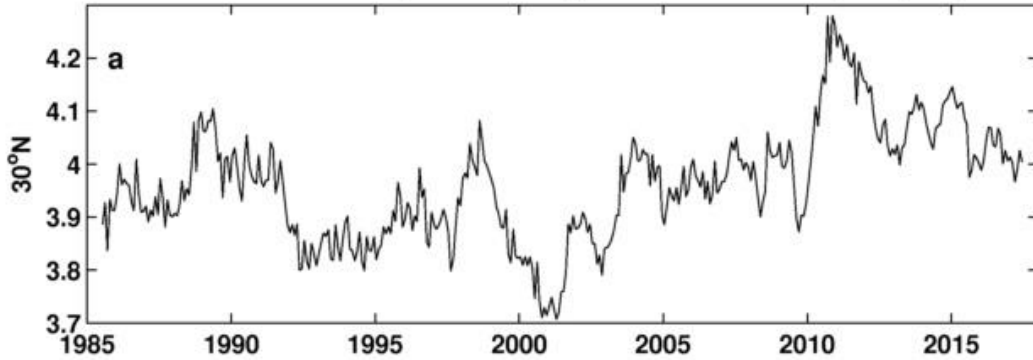- Contrasting changes in AMIP & observed surface fluxes into warming slowdown (Liu et al., 2015 JGR)

← Also for prelim AMIP6

- Cloud feedbacks in E Pacific identified as important (Zhou et al., 2016 Nature Geosci)

- Surface evaporation increases contribute at surface (Liu & Allan, 2018 J. Clim; Hu et al. 2018 Clim. Dyn.)

7

LAND/OCEAN ENERGY TRANSPORT ESTIMATE

ESTIMATED VARIABILITY IN ENERGY TRANSPORTS
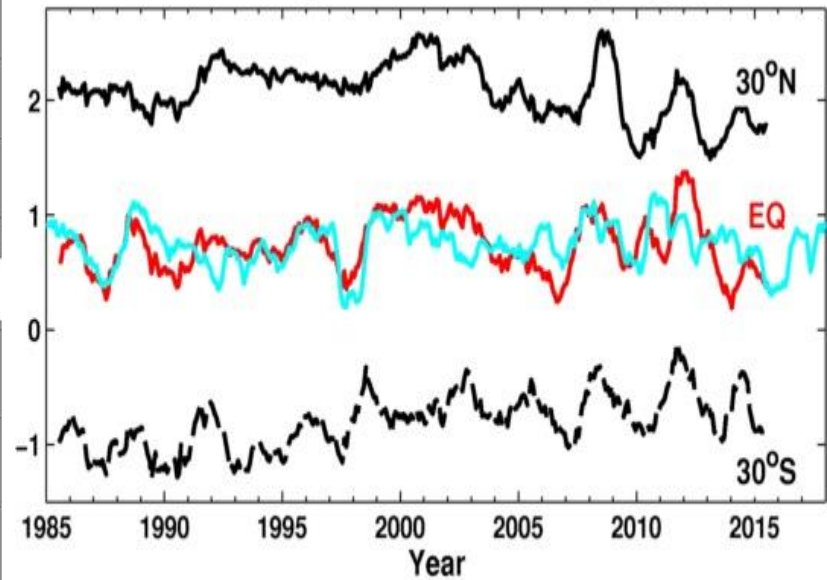
OCEAN HEAT TRANSPORT 26ºN

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Northward ocean heat transport across 26ºN (PW)

Legend:
- ERA–Interim
- Mass corrected
- RAPID
- Updated (ORAS4 700)
- Updated (ORAS5 700)
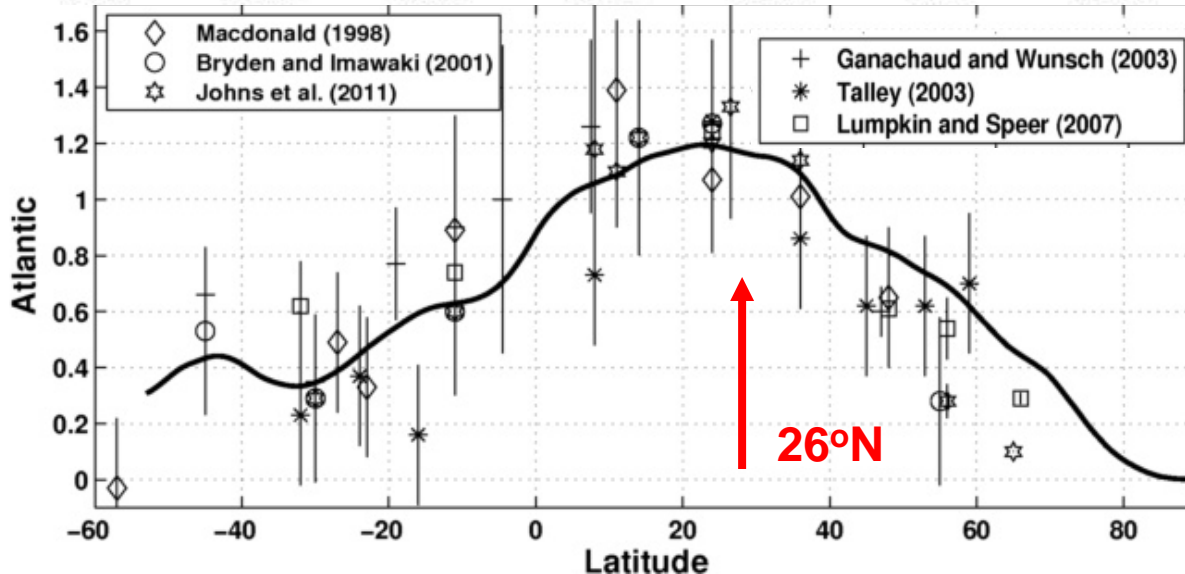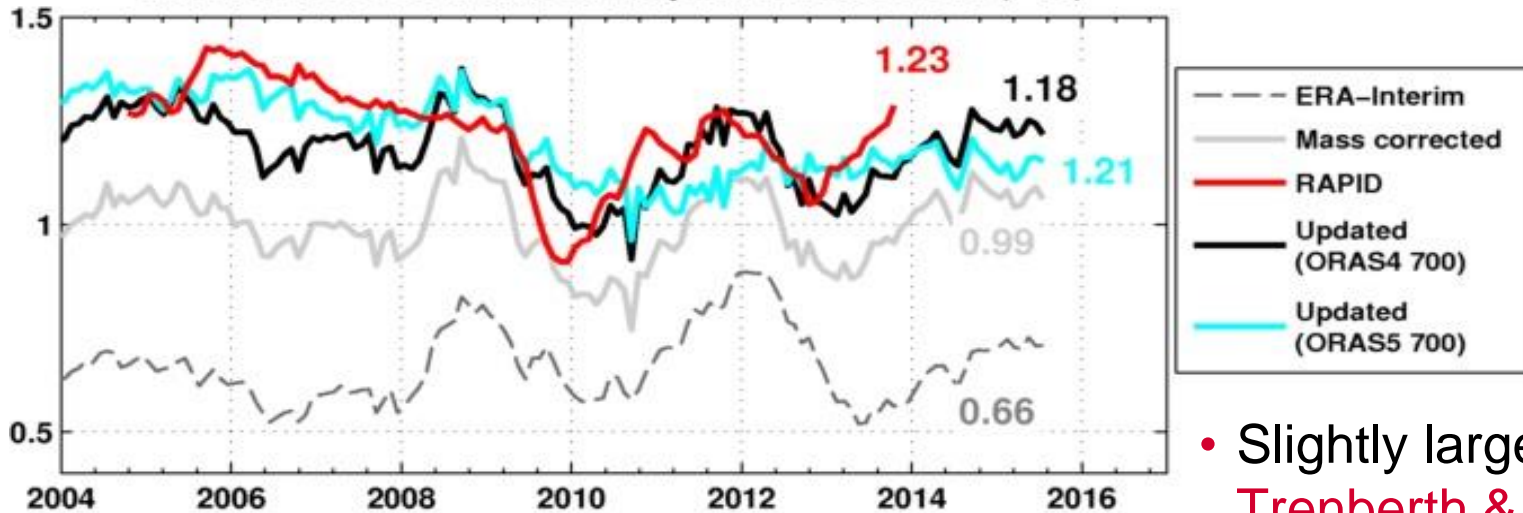
- Slightly larger than Trenberth & Fasullo (2017) GRL (~1 PW)

- Agreement with magnitude of RAPID observations

- Variability: some agreement, ORAS5 worse than ORAS4?

SUMMARY & QUESTIONS

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- Multi-decadal estimates of Earth's energy imbalance/sea level *broadly* consistent (e.g. Cheng et al. 2017 Sci. Adv.; Allan et al. 2014 GRL; Nerem et al. (2018) PNAS)

- Advances in observing energy transports (Trenberth & Fasullo, 2017 GRL)

- Upper ocean mixed layer energy budget links EEI & surface warming rate (Roberts et al. 2015 JGR; Hedemann et al. 2017 Nature Clim.; Xie & Kosaka 201 CCCR)

- What explains discrepancy in AMIP vs observed surface flux change?

- Distinct feedbacks on internal variability & forced change e.g. Brown et al. 2016; Xie et al. 2015 ; England et al. (2014)

- Do climate models underestimate low cloud amplifying feedbacks, internal variability &climate sensitivity? Marvel et al. 2018; Silvers et al. 2017 ; Yuan et al. 2018

- Spatial patterns of warming crucial for feedbacks & climate sensitivity e.g. He & Soden (2016); Richardson et al. (2016); Ceppi & Gregory (2017); Andrews & Webb (2017)

- Can radiative forcing spatial pattern drive temperature change?

- Are there missing dynamical feedbacks on warming?

- How does rebound from volcanic eruptions (e.g. Pinatubo) influence the climate system; is this represented by models?)

- Can fast water cycle/energy budget adjustments to forcings be observed?

- Combine energy/water(&salinity?/carbon?) budget constraints (Keith Haines)