Department of Meteorology

University of Reading

CHANGES IN EARTH'S ENERGY & WATER CYCLES

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National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

CURRENT GLOBAL CLIMATE CHANGE

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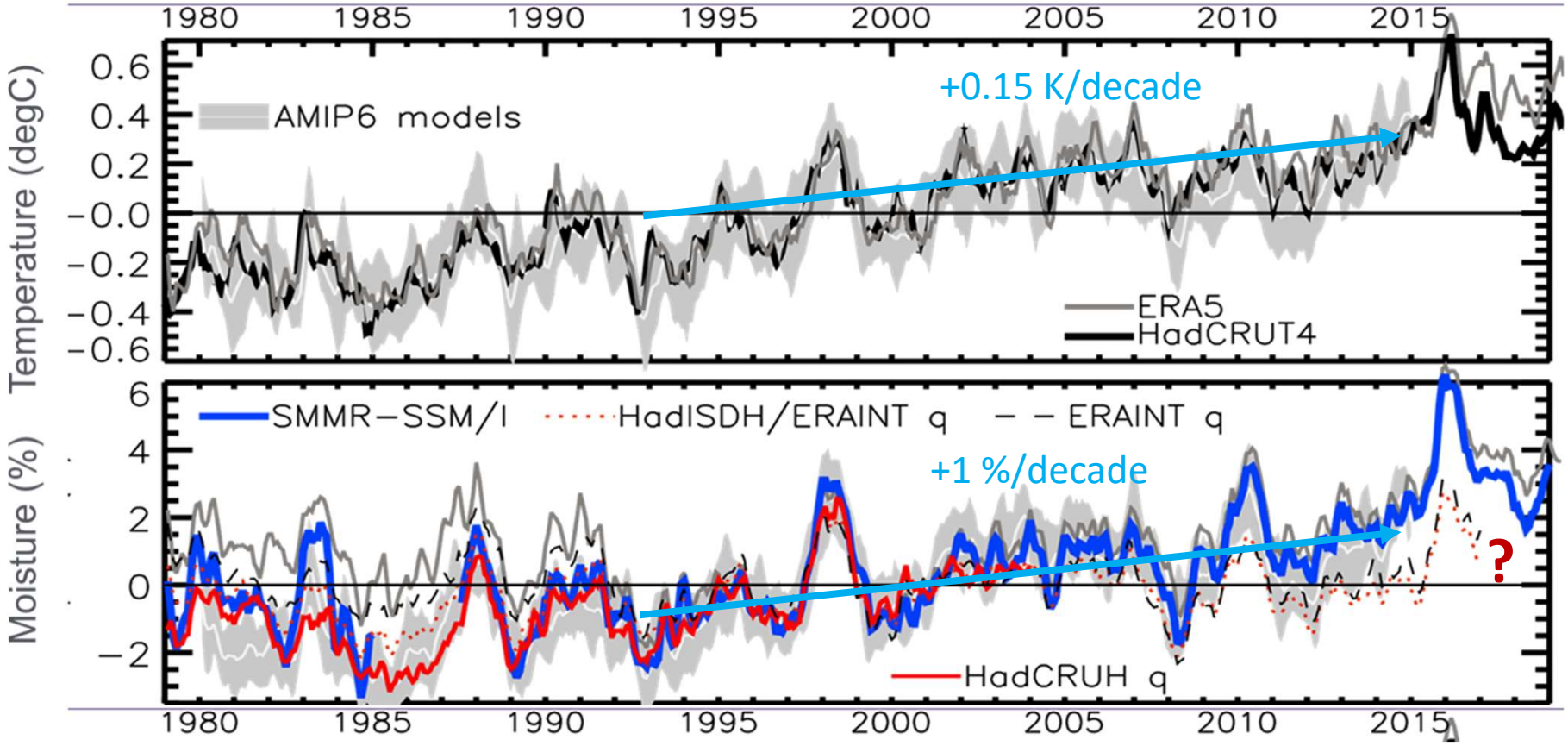

Update from Allan et al. (2014) Surv. Geophys.

Declining RH over land since ~2000 linked to land/sea warming contrast (O'Gorman & Byrne 2018 PNAS) but under-estimated by models? (Dunn et al. 2017 ESD)

CURRENT GLOBAL CLIMATE CHANGE

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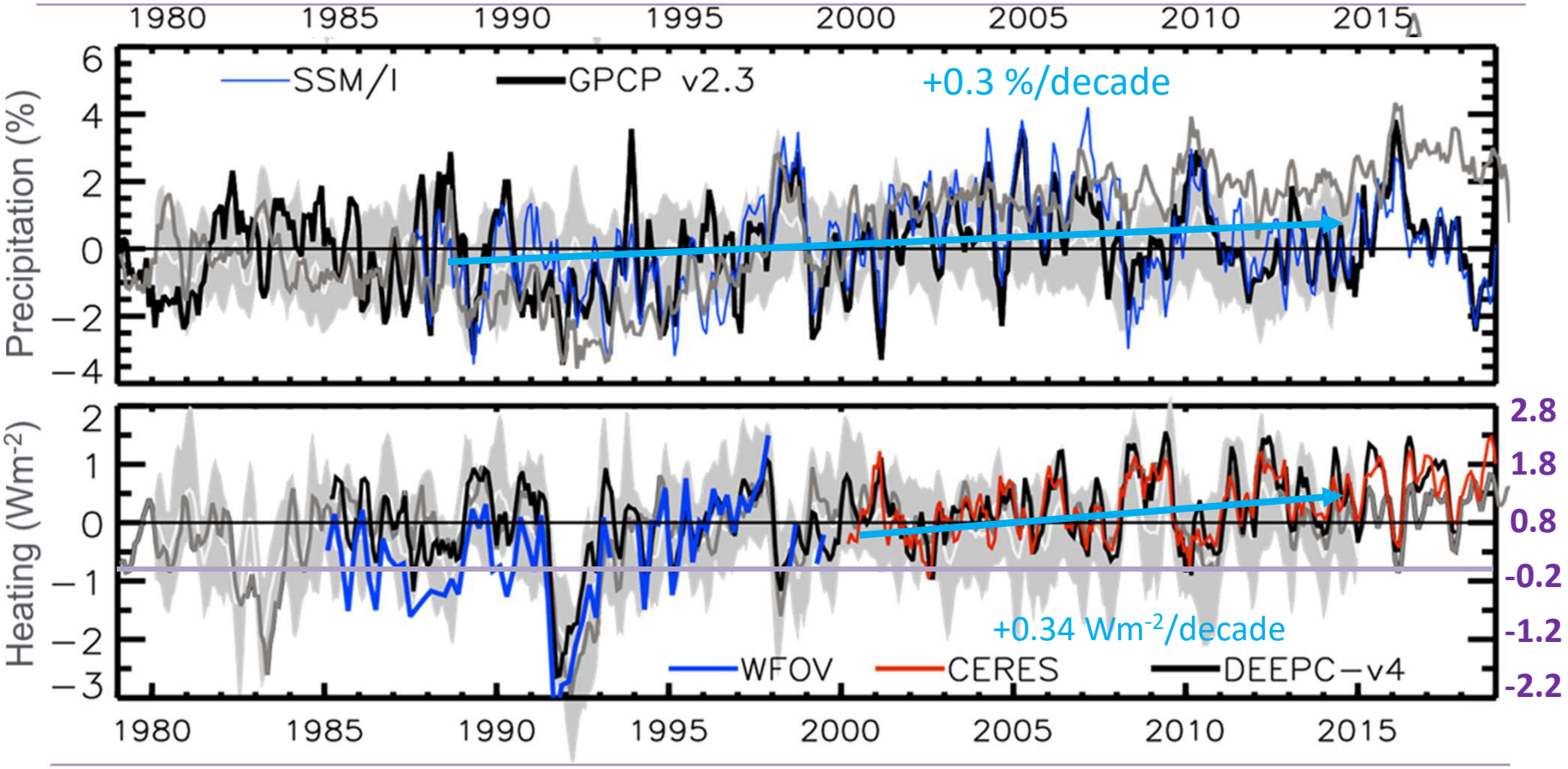
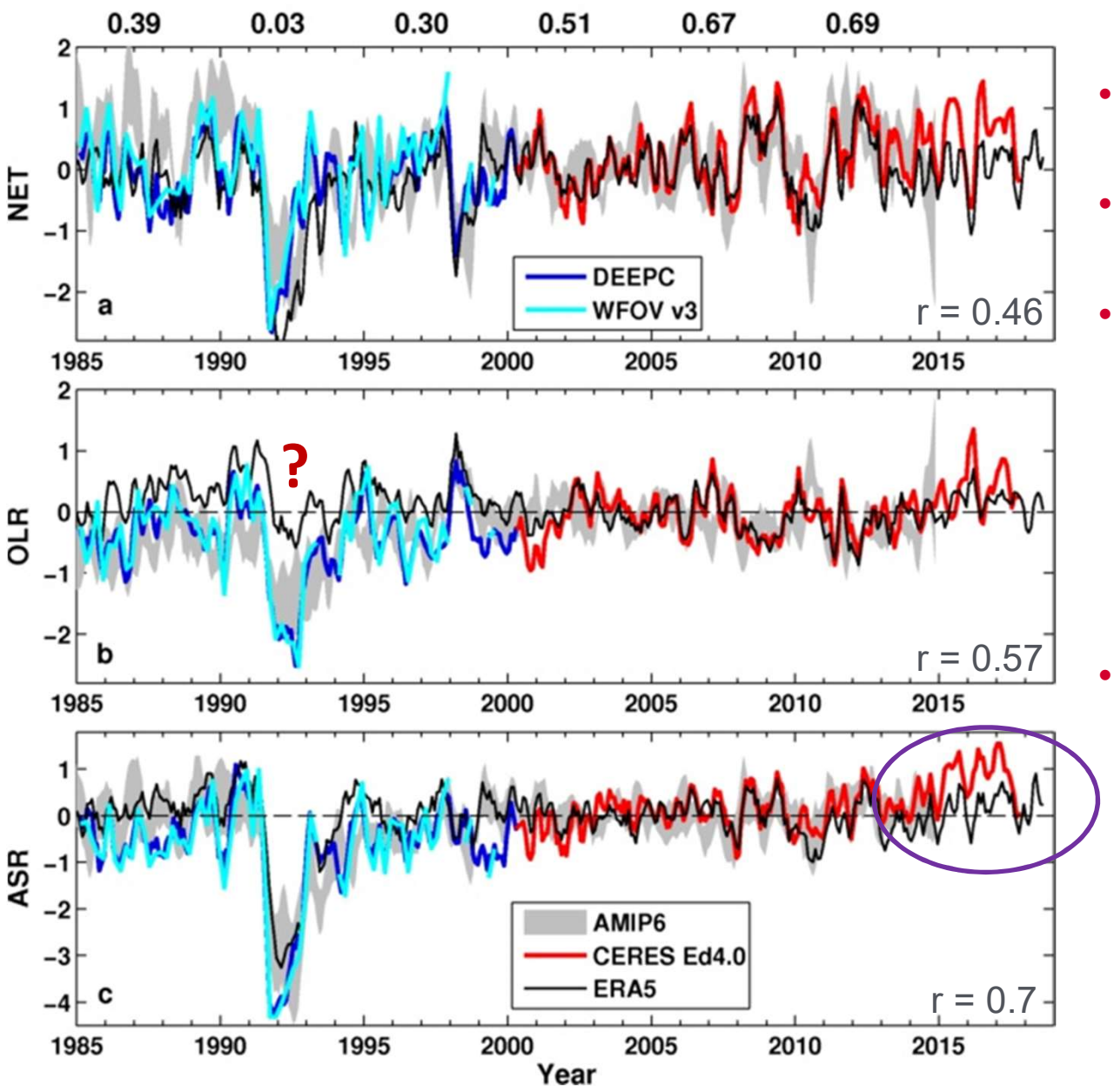


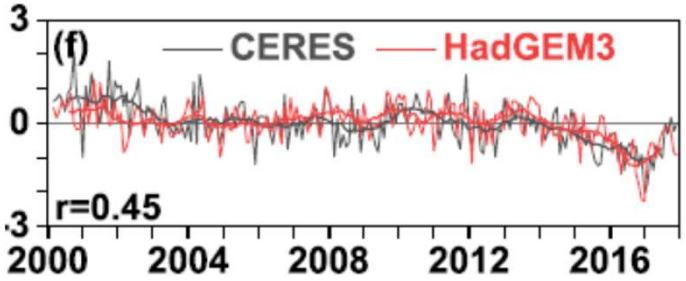
Update from Allan et al. (2014) Surv. Geophys.; Allan et al. (2014) GRL

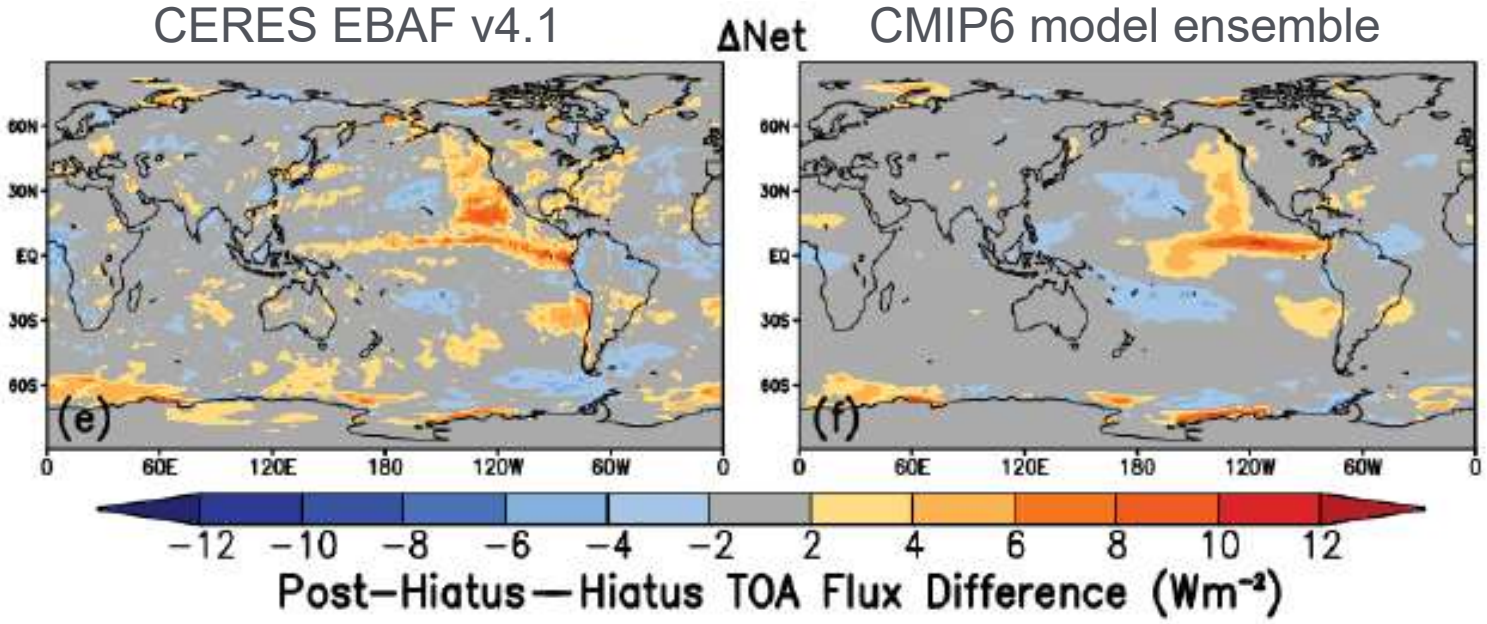
CURRENT ENERGY BUDGET CHANGES



- Preliminary comparison with AMIP6 and ERA5
- Large uncertainty in pre-CERES EEI remains
- Consistent with ocean heat content changes (Cheng et al. 2017 Sci. Adv.), lower than Resplandy et al. (2019) Sci. Rep. which now has larger range following correction (0.3-1.3 Wm^{-2})
- ERA5 does not capture observed ASR increase after warming slowdown (e.g. Loeb et al. 2018)
  - ↑Heating 2015/16
  - Cloud plus aerosol?

CLOUD FEEDBACKS



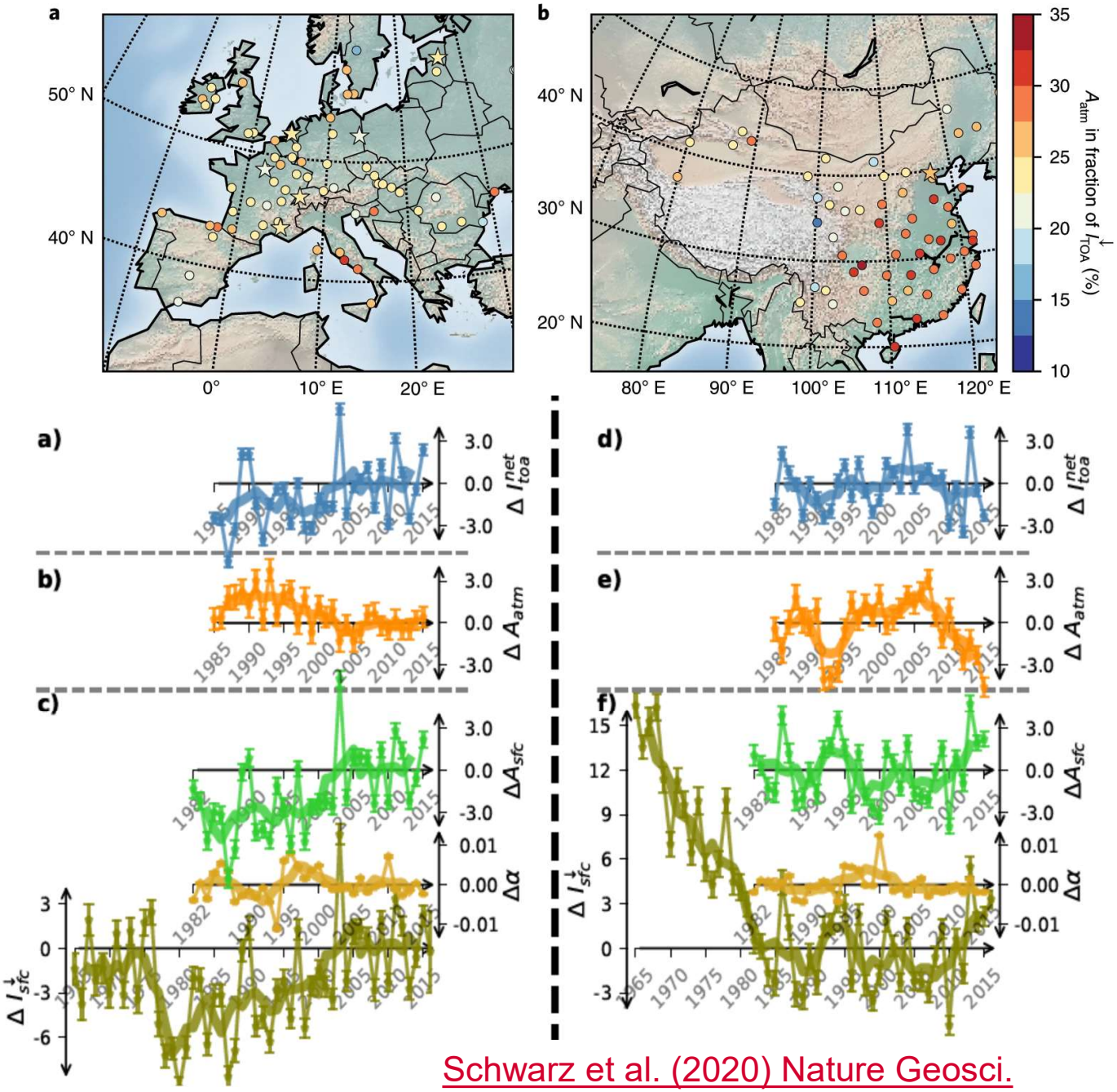


July 2014–June 2017 minus July 2000–June 2014

- Use 2015/16 El Nino as laboratory to test cloud feedbacks (Loeb et al. 2020 GRL)
  - CMIP6 AMIP simulations generally able to capture net flux responses
  - Depends on model ability to represent SW radiation changes in low cloud regions
- Cloud errors and wind-feedbacks also determine systematic model biases in Southern Ocean (Hyder et al. 2018 Nature Comms) and globally (Hyder et al. in prep)

OBSERVED CHANGES IN SHORTWAVE ABSORPTION

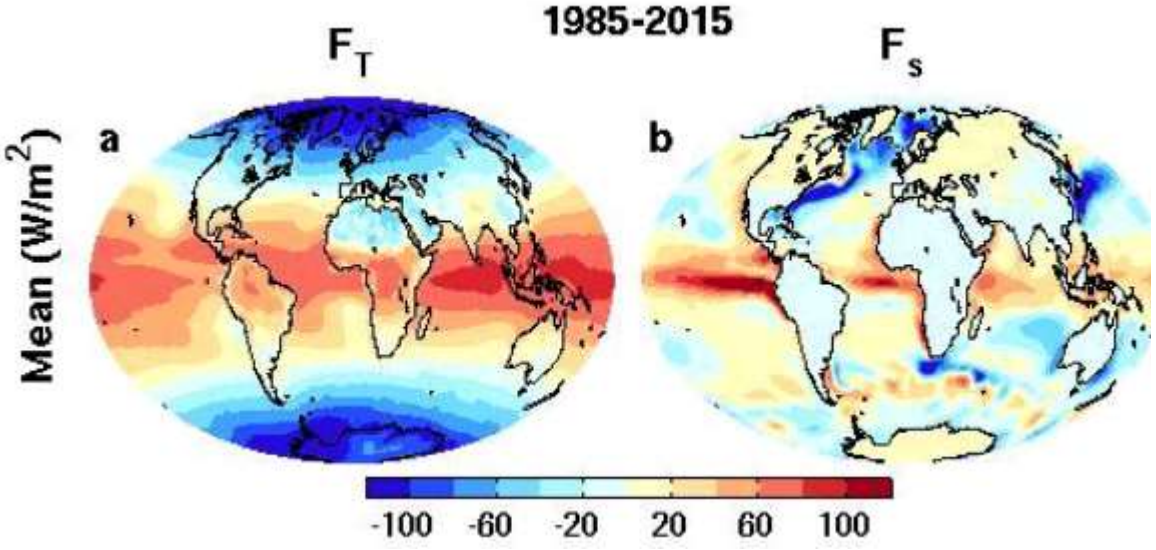
- Combine TOA & surface obs
- Surface dimming then brightening after air pollution control
- Atmospheric absorption more important than previously thought
- Implications for water cycle e.g. Wilcox et al. (2020) ACPD

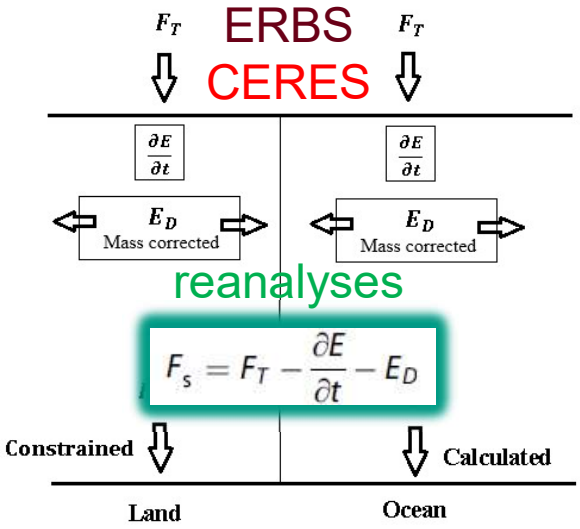


Schwarz et al. (2020) Nature Geosci.

GLOBAL SURFACE FLUX ESTIMATES

top of atmosphere surface



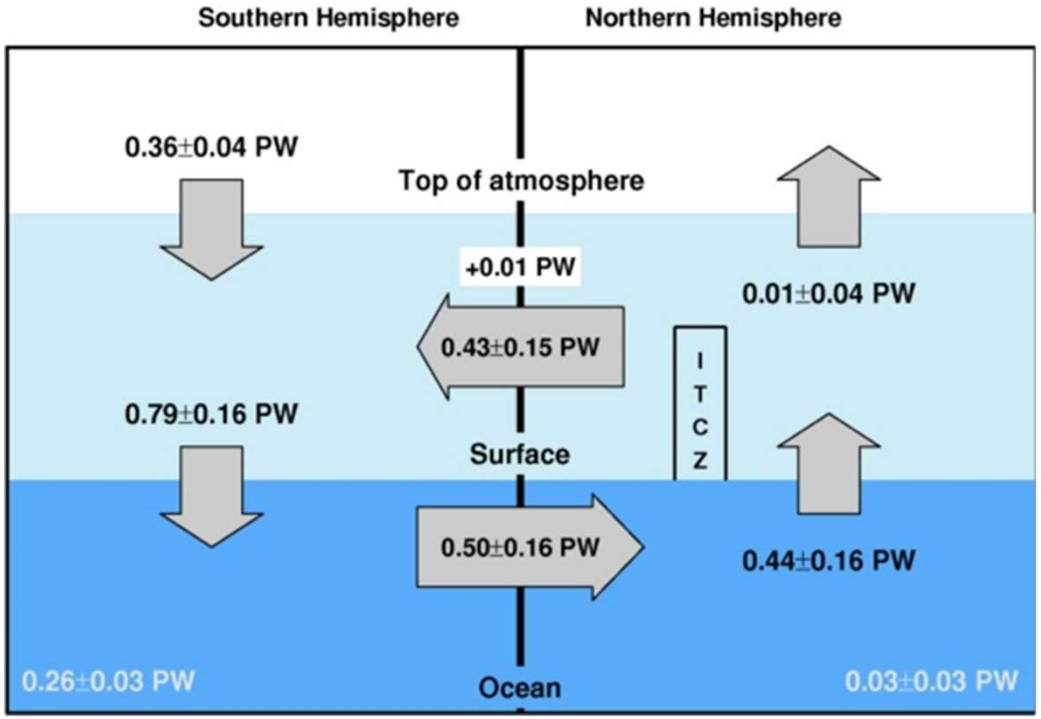


Liu et al. (2017) JGR Data: http://dx.doi.org/10.17864/1947.111

- Evaluation of models, reanalyses, satellite products e.g. Williams et al. (2018) *JAMES*; Wittenberg et al. (2018) *JAMES* ; Roberts et al. (2018) *GMD*; Sus et al. (2018) *AMT*, etc
- Southern Ocean biases: Hyder et al. (2018) *Nature Comms*
- Volcanic radiative responses: Schmidt et al. (2018) JGR
- North Atlantic Heat transports: Brydon et al. (2020) J. Clim
- Aerosol effects on energy budget: Schwarz et al. 2020 Nature Geosci.

HEMISPHERIC ASYMMETRY IN EARTH'S ENERGY BUDGET

- Mean position of the tropical rainy belt in northern hemisphere determined by northward energy transport by ocean e.g. Frierson et al. (2013) Nature Geosci

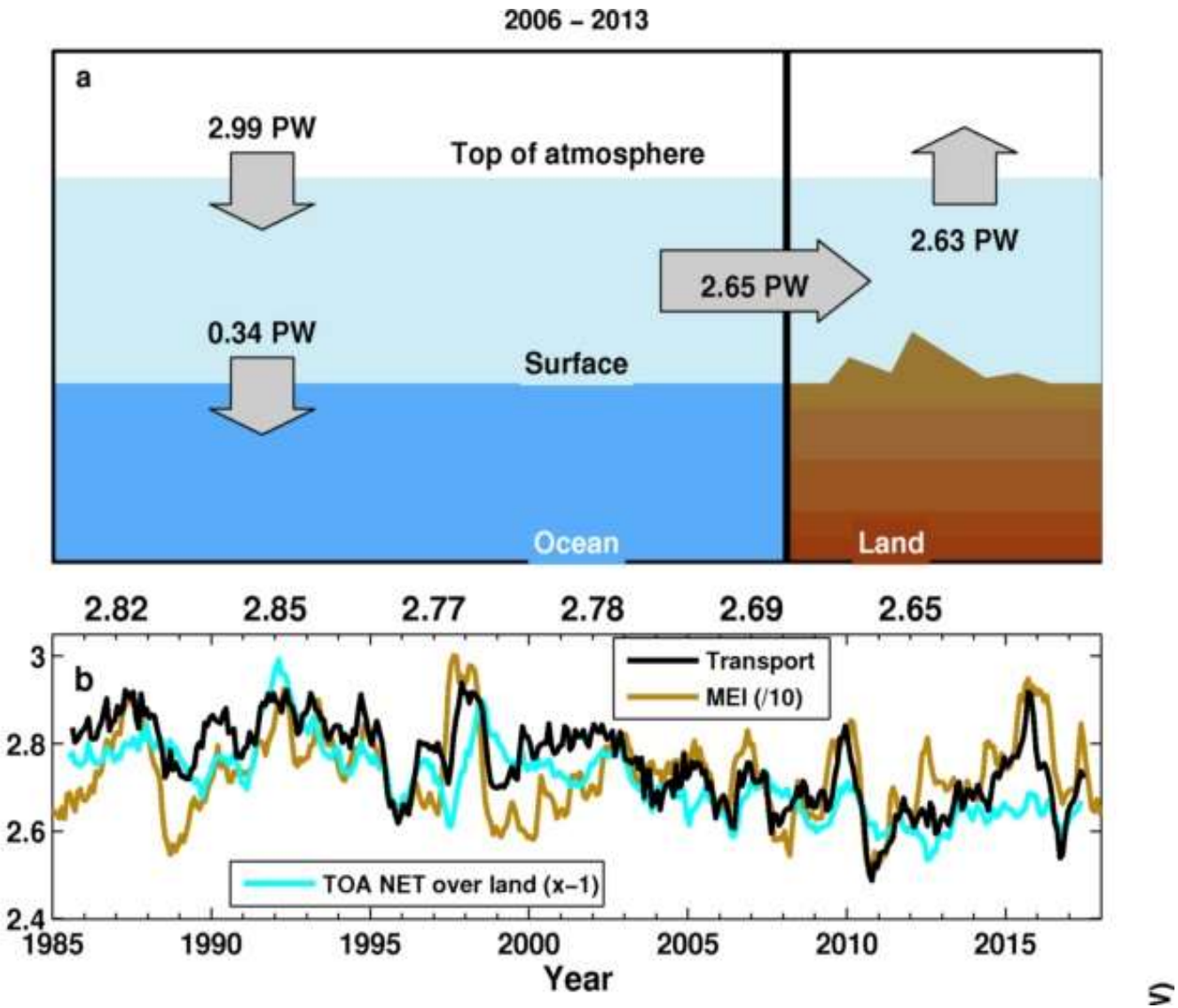


Liu et al. in prep

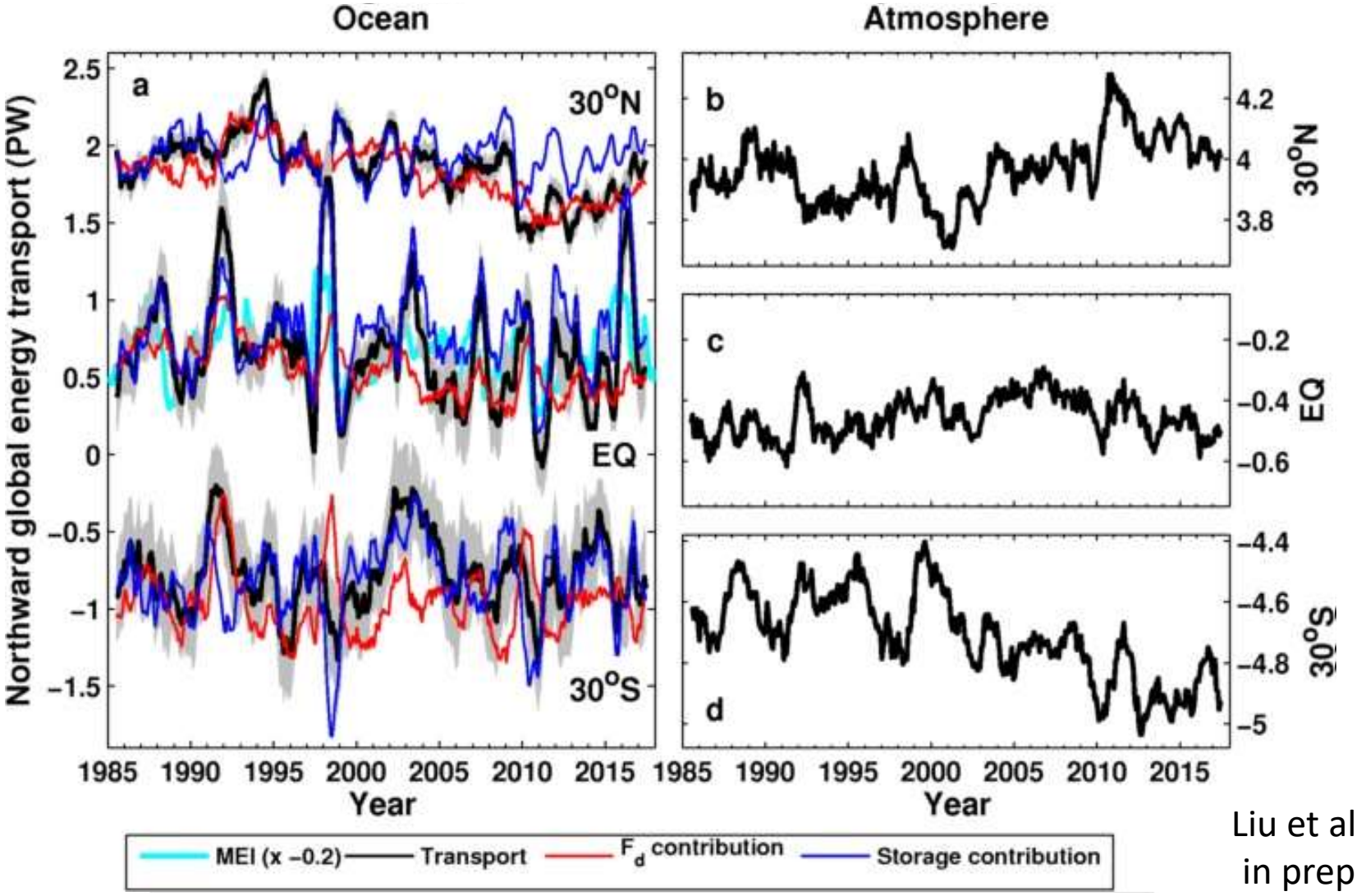
Important to quantify hemispheric energy budget:

← Inferred 2006-2013 cross equatorial energy flux (updated from Liu et al. 2017 & Loeb et al. (2015) Clim. Dyn using ocean heating from Roemmich et al. (2015) Nature Clim, Desbruyeres et al. (2016) GRL or ORAS4 reanalysis)

OCEAN AND LAND ENERGY BUDGET

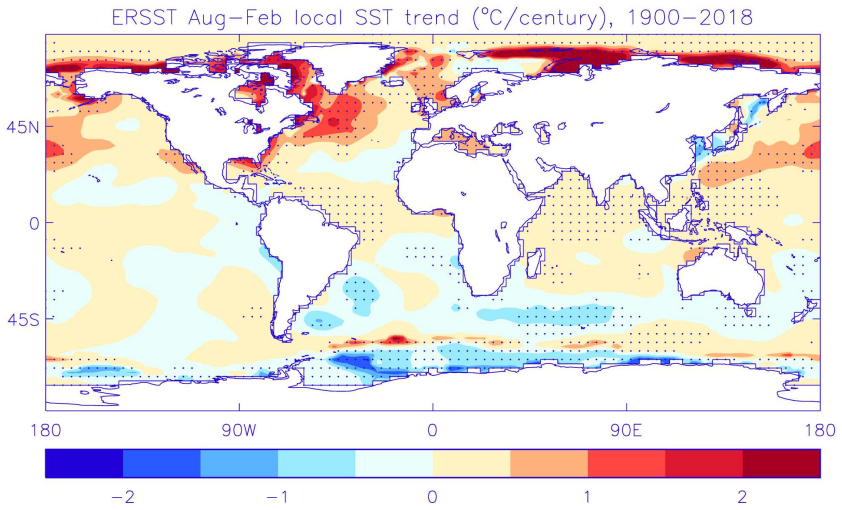


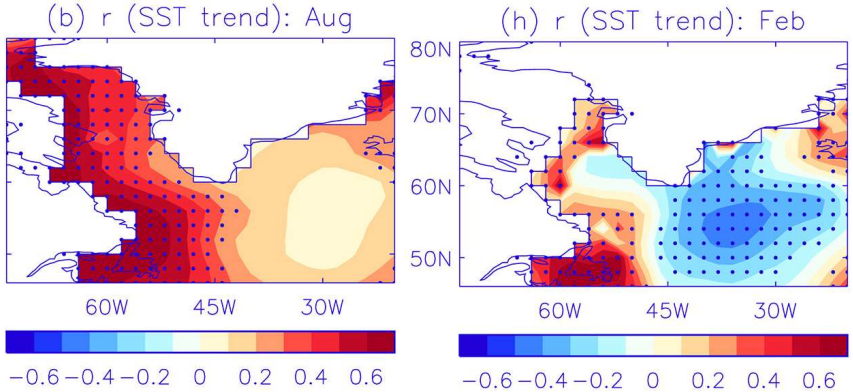
COMPUTED GLOBAL MERIDIONAL ENERGY TRANSPORTS (30°N, EQUATOR, 30°S)



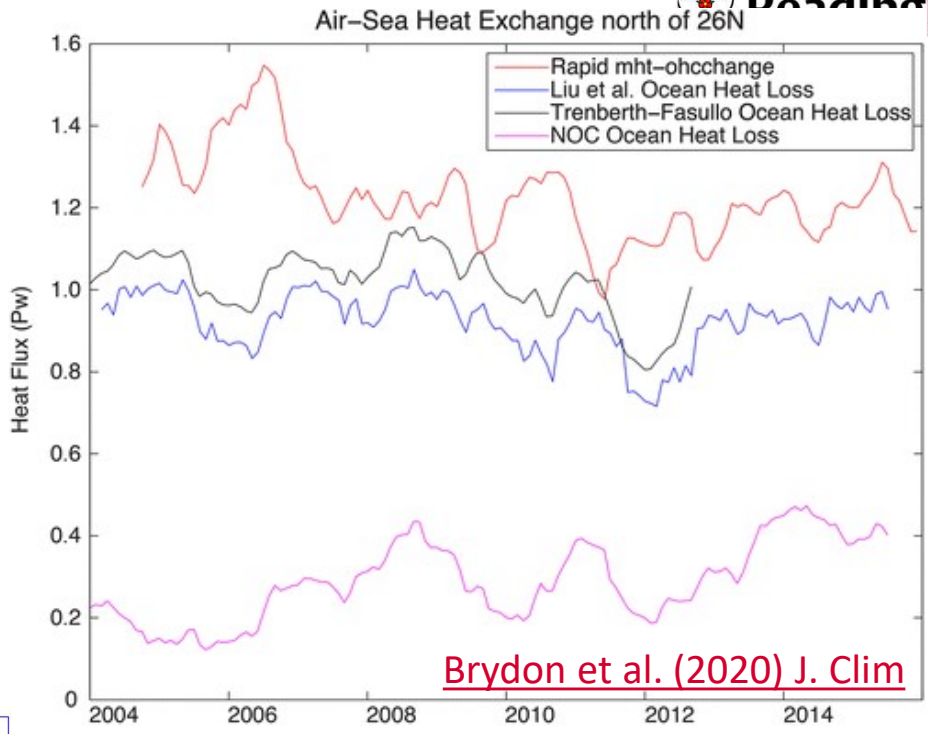
Liu et al. in prep

ATLANTIC HEAT TRANSPORT AND THE COLD BLOB

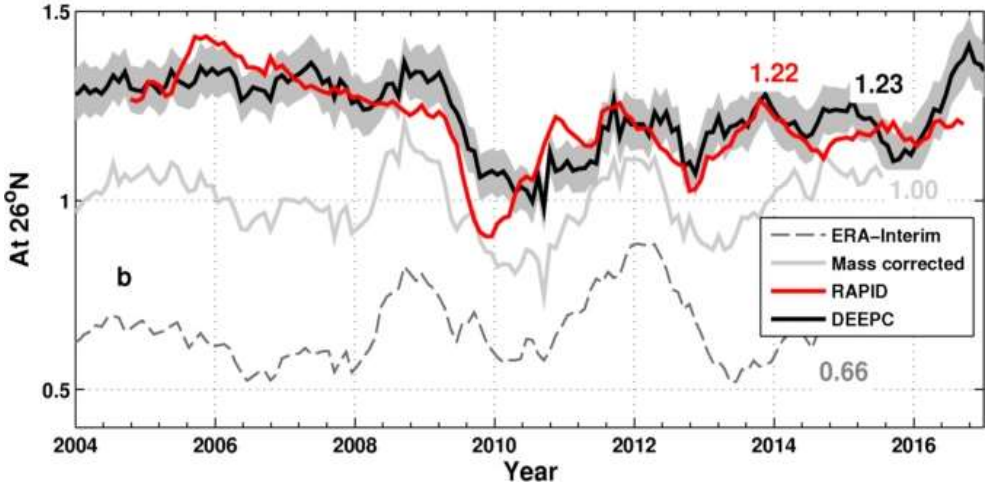




Allan & son Ltd (2019) JGR



Brydon et al. (2020) J. Clim



SUMMARY

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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)
- 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 ; Loeb et al. 2020 GRL
- 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?
- What are the mechanisms that determine N Atlantic variability and links with Pacific and ocean heat uptake? How are inter-hemispheric, land/ocean and low to high latitude heat transports changing?
- What is the aerosol impact on atmospheric absorption and hydrological cycle?