Department of Meteorology

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Global-scale changes in Earth's energy budget and implications for the water cycle

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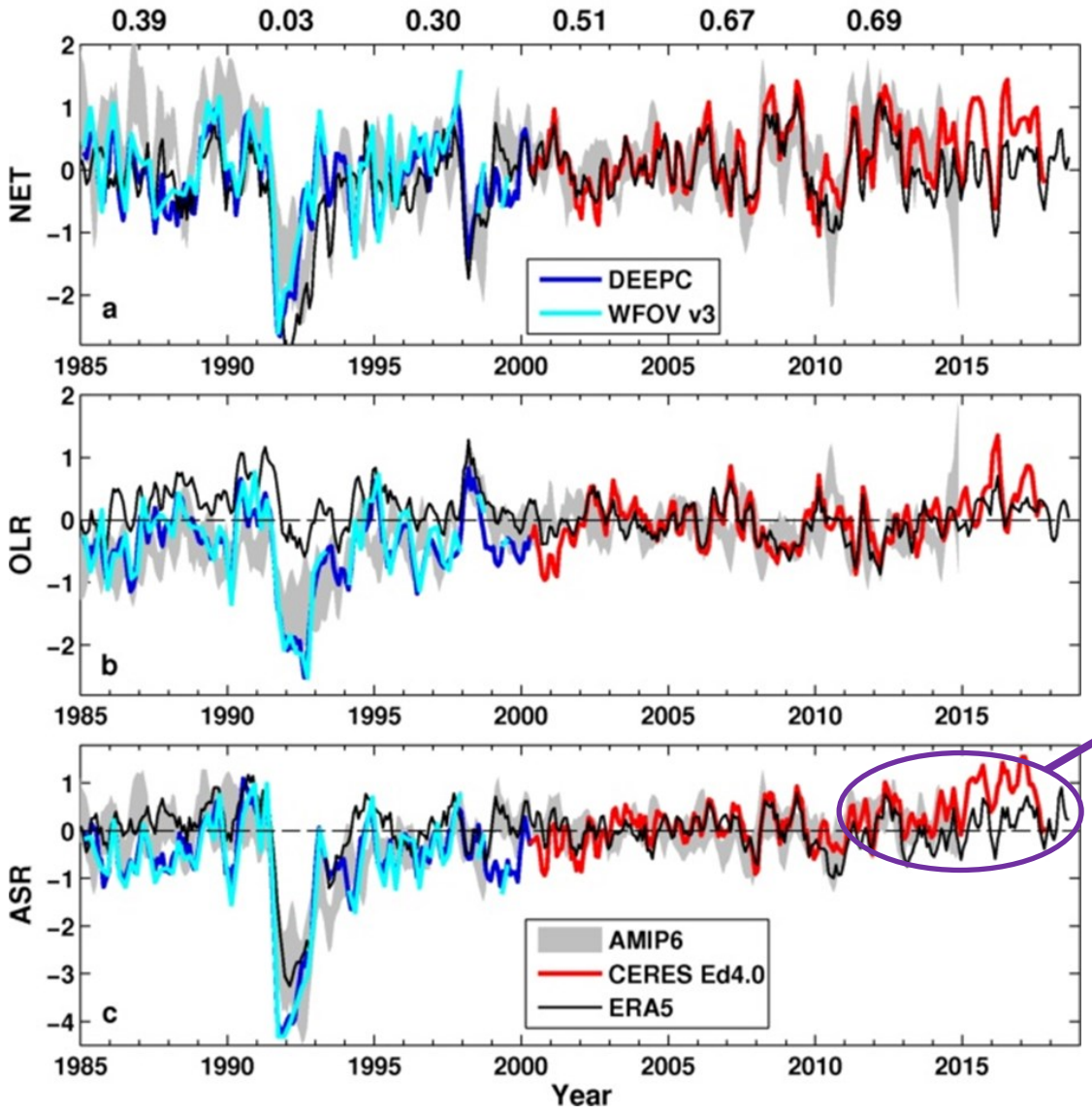
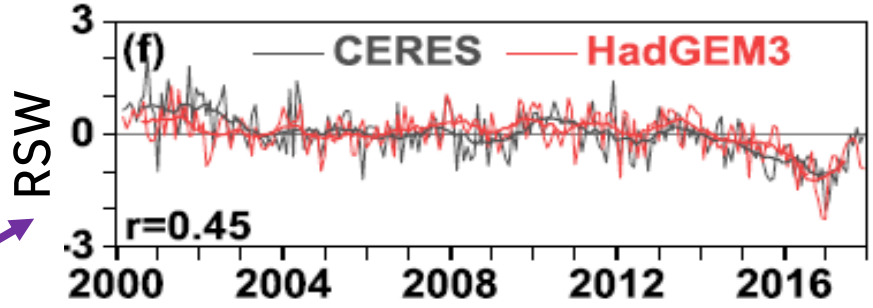
Reconstructed energy budget since 1985



- ERBS-WFOV + CERES
- ERA5 horizontal energy transports
- Surface total flux estimate

data: doi.org/10.17864/1947.111

Allan et al. 2014 GRL; Liu et al. 2020 Clim. Dyn.



- Increased reflected SW linked to Pacific cloud feedbacks (Loeb et al. 2020 GRL) – captured by CMIP6 simulations (above) but not ERA5 (left)
- Kramer et al. 2021 GRL combine CERES with feedback estimates to show increased radiative forcing 0.53±0.11 W/m^2 from 2003-2018

Planetary heating since the 1980s from multiple independent datasets

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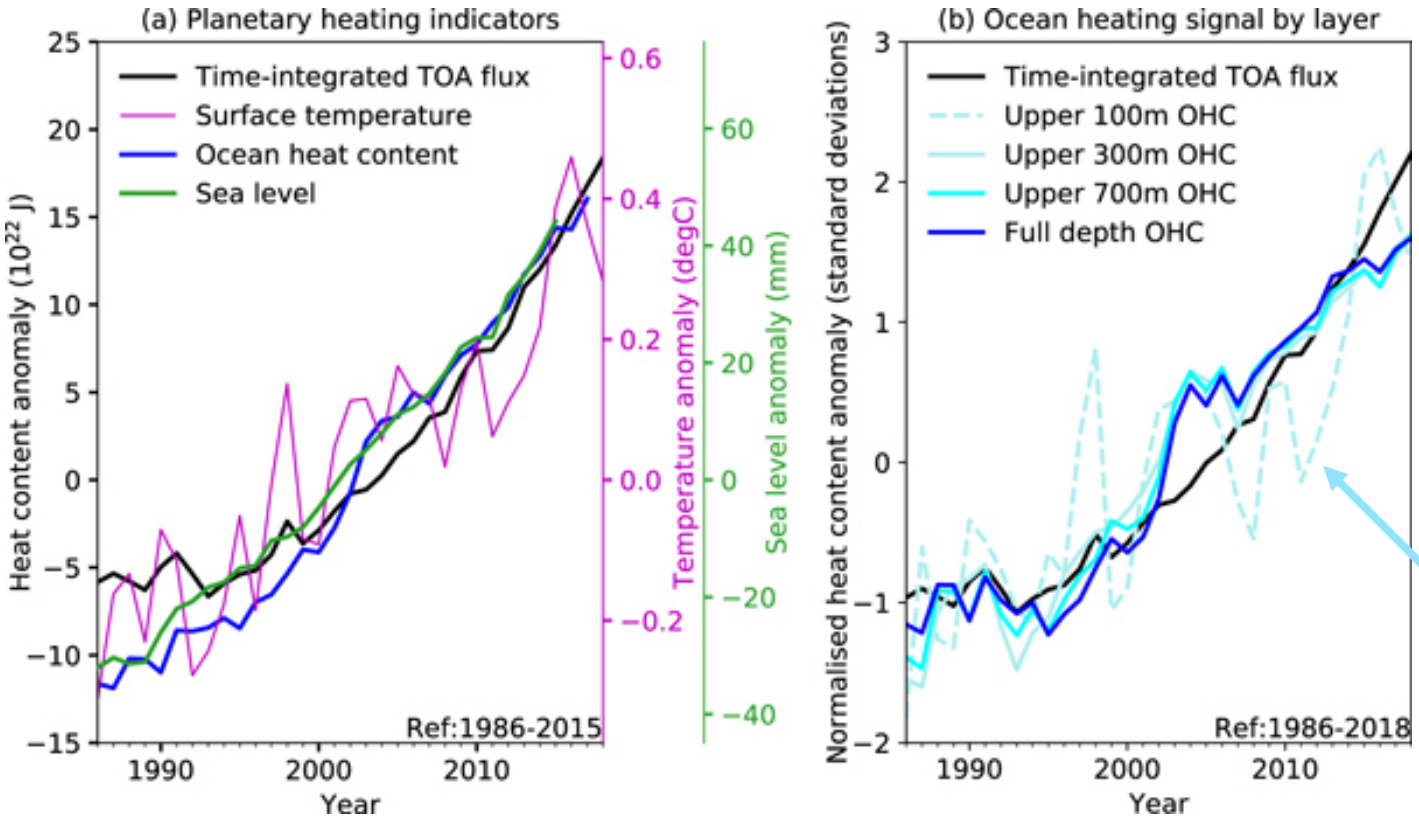

Allison et al. (2020) ERC doi:10.1088/2515-7620/abbb39

See also Cheng et al. 2017 Sci. Adv.

Heating:

- 1985-1999:

0.10 ± 0.61 W m^{-2}

- 2000–2016

0.62 ± 0.1 W m^{-2}

Liu et al. 2020 Clim. Dyn

Surface temperature determined by upper mixed layer ocean heat

e.g. Allan (2018) Nature Clim.

Interhemispheric energy accumulation

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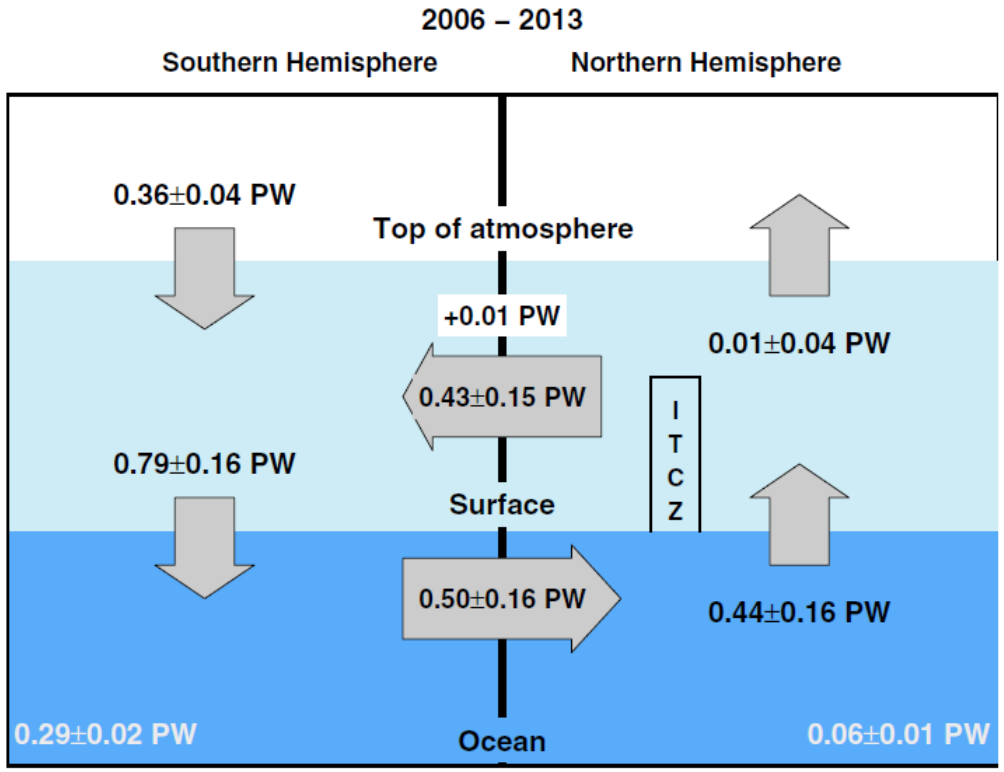
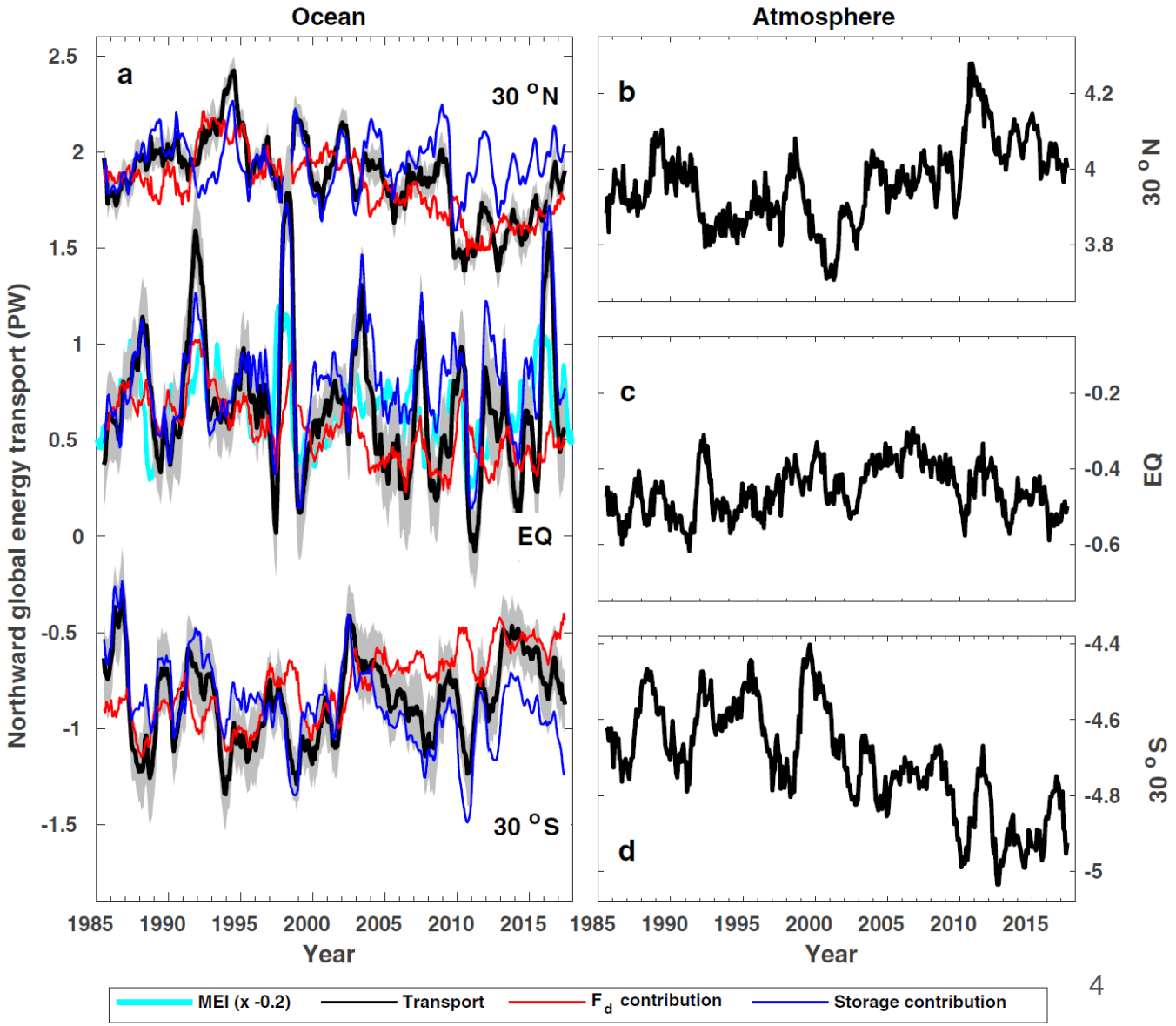
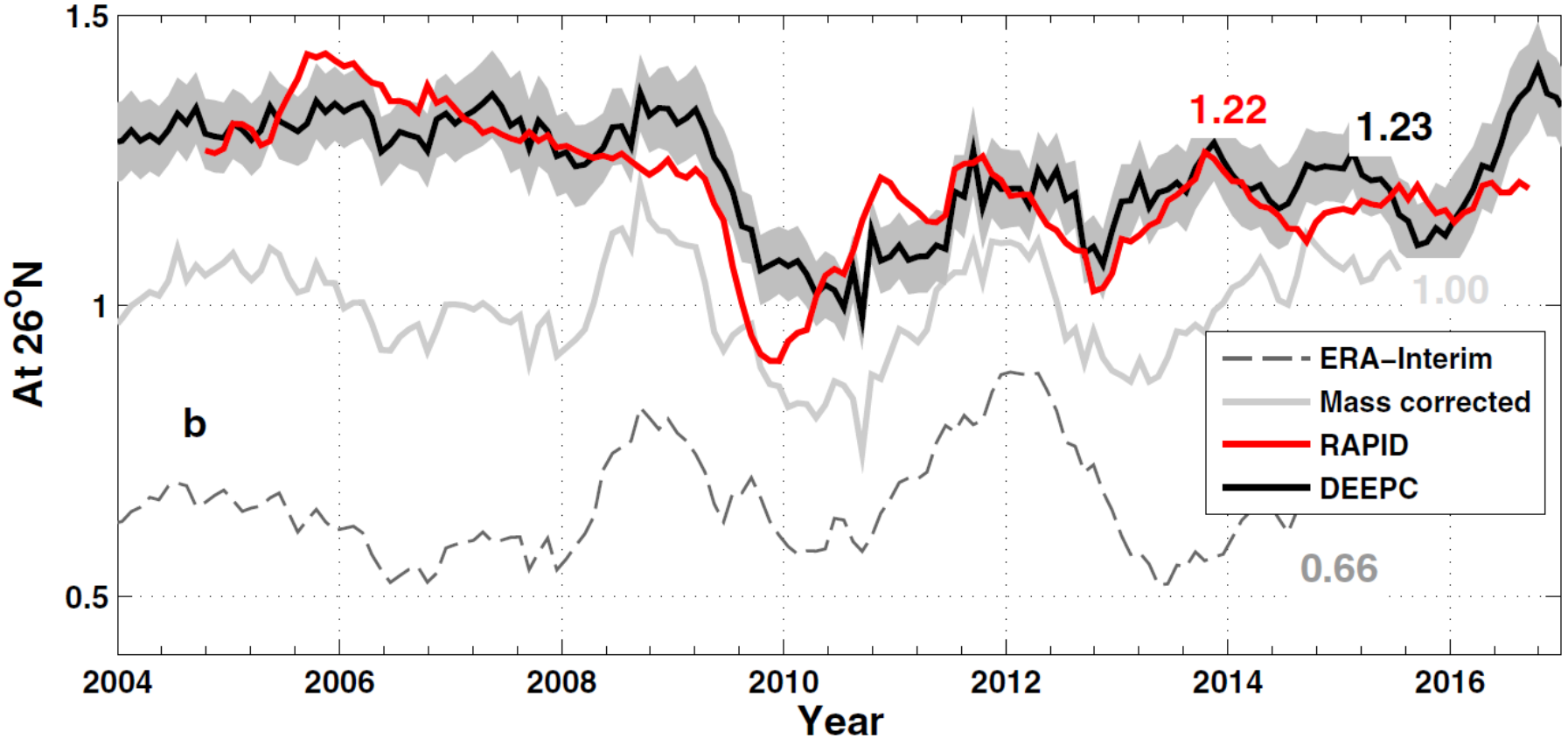
- Heat accumulates in S hemisphere
- Inferred atmospheric and oceanic transports Liu et al. 2020 Clim. Dyn.





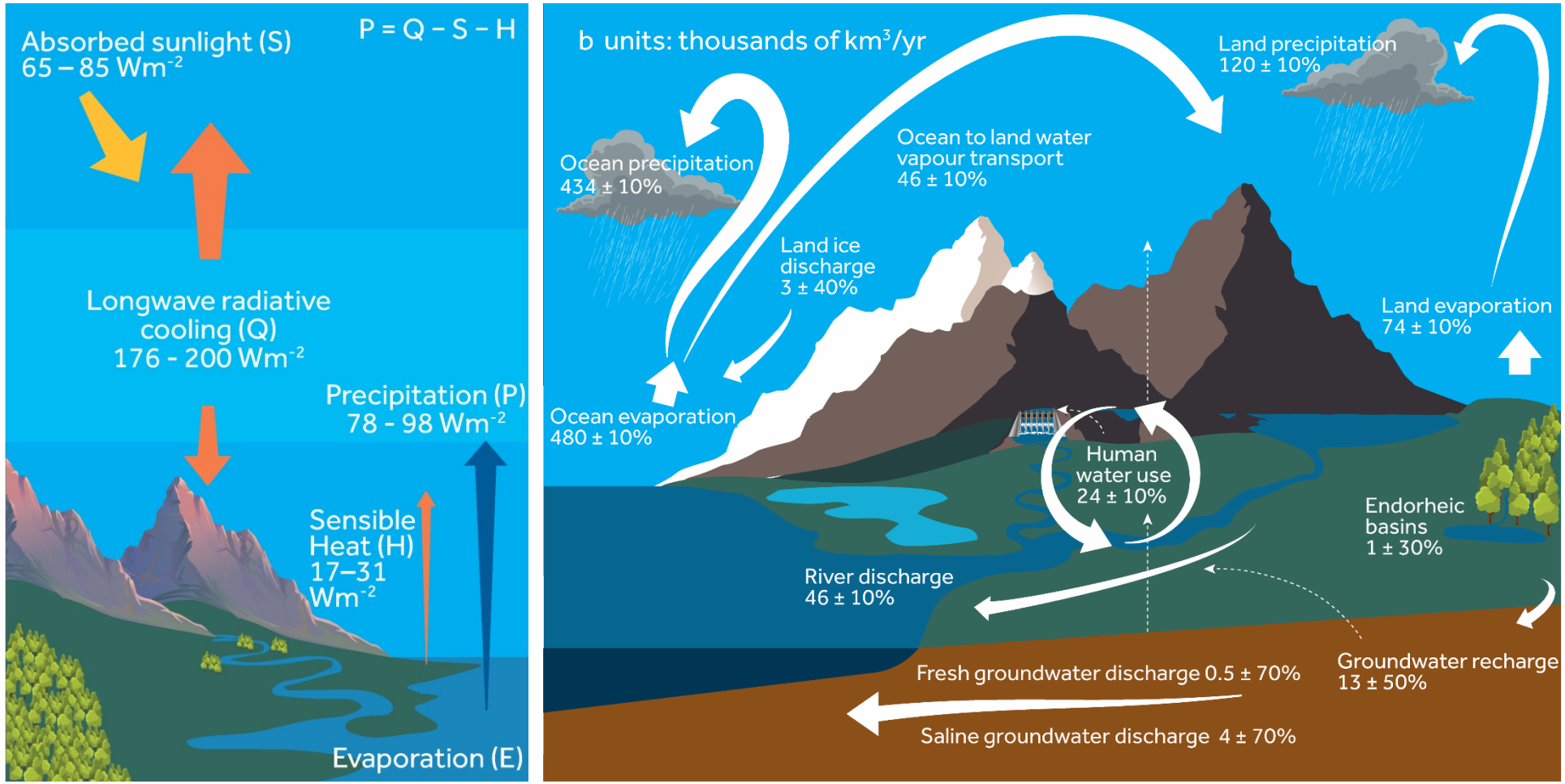
Inferred Ocean energy transports@26N



Liu et al. 2020 Clim. Dyn. after Trenberth & Fasullo, 2017 GRL

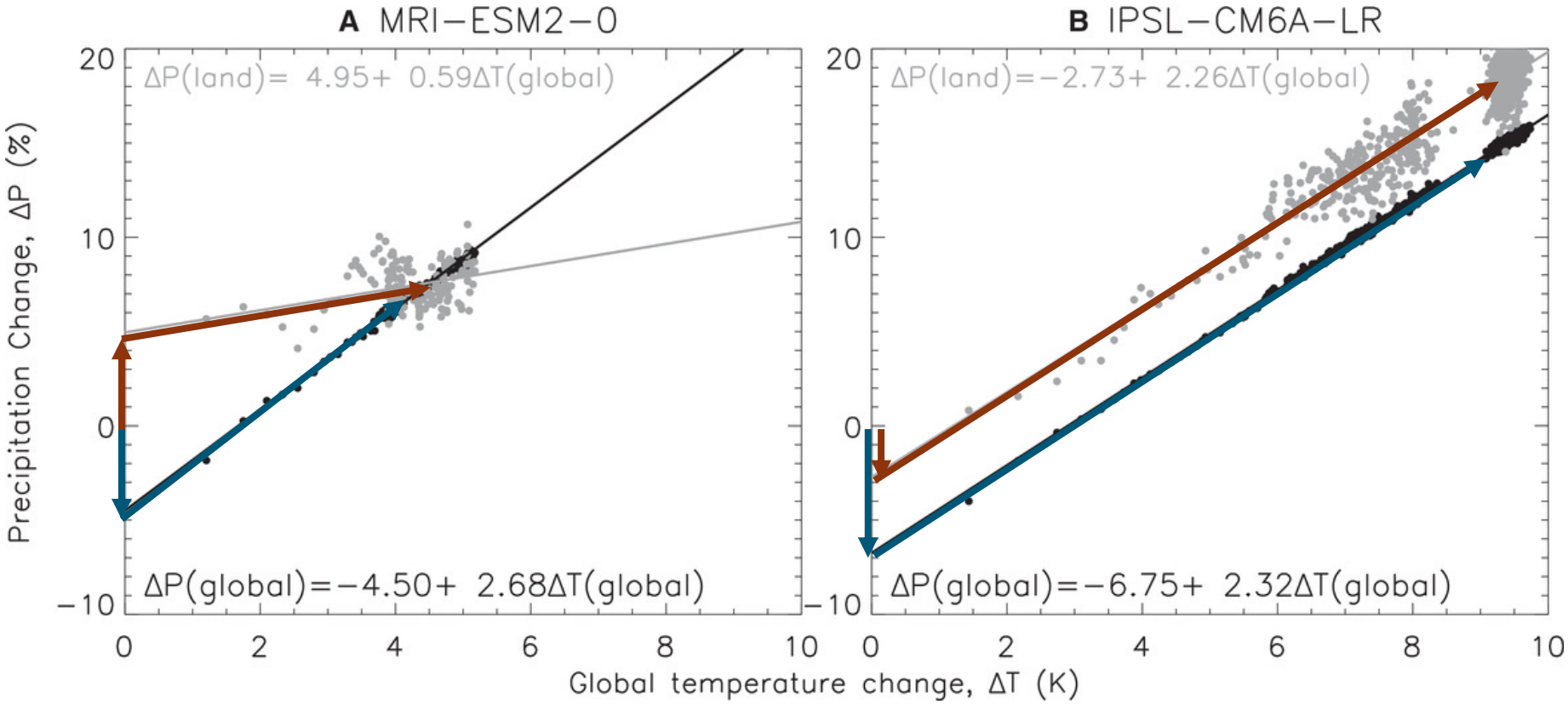
Current Atlantic Meridional Overturning Circulation weakest in last millennium (Caesar et al. 2021 Nature Geosci.)

How will the water cycle change?



Allan et al. (2020) NYAS; see also Abbott et al. (2019) Nature Geosci.

Fast & slow global precipitation responses to 4xCO_2



Allan et al. (2020) NYAS

Global: rapid decline, consistent slow increase with warming (2-3%/°C)
Land: model-dependent rapid response & suppressed increase with warming e.g. **Samset et al. (2018) Clim. Atmos. Sci.**:

Global precipitation & imbalance changes

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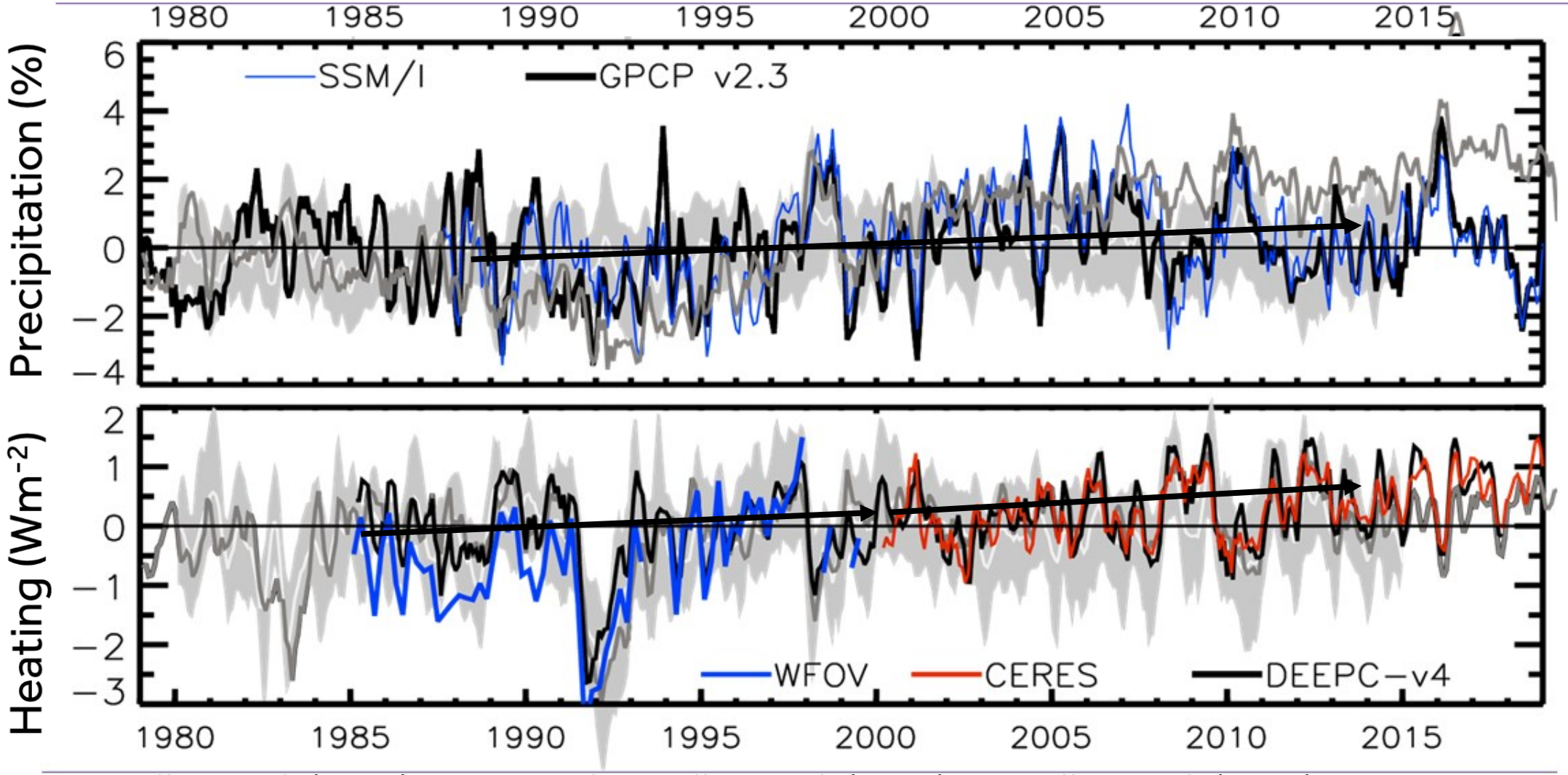


1988-2014:
+0.3 ± 0.2%
/decade

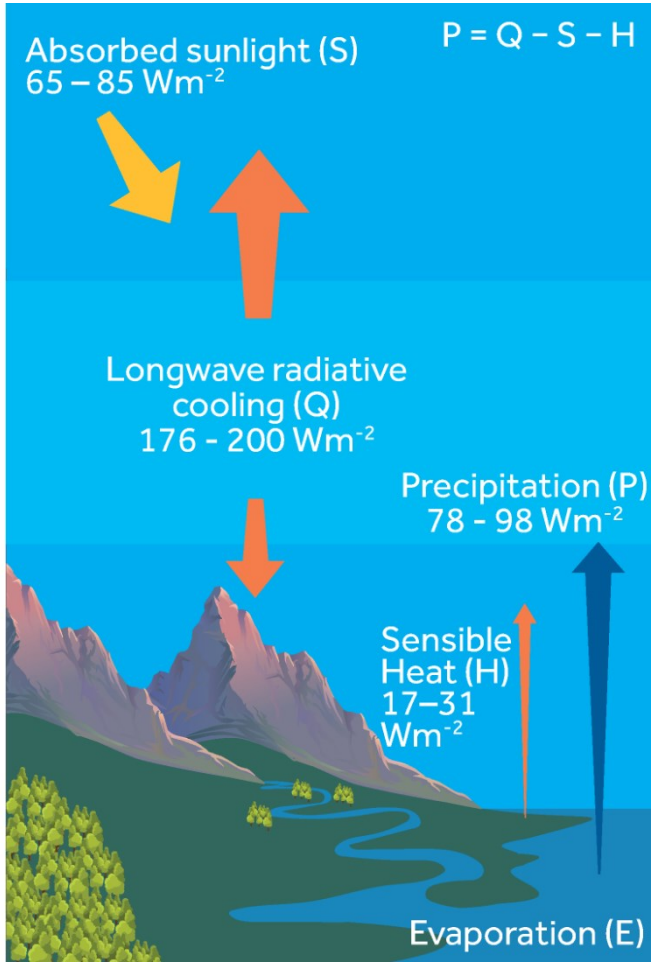
1985-2000:
0.22 ± 0.14
Wm^{-2} /decade

2001-2014:
+0.34 ± 0.15
Wm^{-2} /decade

Allan et al. (2014) Surv. Geophys.; Allan et al. (2014) GRL; Allan et al. (2020) NYAS

Conclusions

- Multi-decadal estimates of Earth's energy imbalance/ sea level *broadly* consistent e.g. Cheng et al. 2017 Sci. Adv.; Nerem et al. 2018 PNAS; Allison et al. 2020 ERL
- Inferred changes in atmosphere/ocean heat transports by combining satellite/reanalysis energy budget data e.g. Trenberth & Fasullo, 2017 GRL; Liu et al. 2020 Clim. Dyn
- Can models represent internal variability & climate sensitivity? e.g. Loeb et al. 2020 GRL; Marvel et al. 2018; Yuan et al. 2018; Silvers et al. 2017; Ceppi & Gregory 2017; Andrews & Webb 2017; He & Soden 2016; Richardson et al. 2016
- Observational insight on fast/slow coupling between the energy and water cycles? Joint energy/water cycle approaches e.g. Rodell et al. 2015 J.Clim; Thomas et al. 2019 J. Clim; Allan et al. (2020) NYAS



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