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EVALUATING WATER VAPOUR CHANGES IN CMIP6 SIMULATIONS

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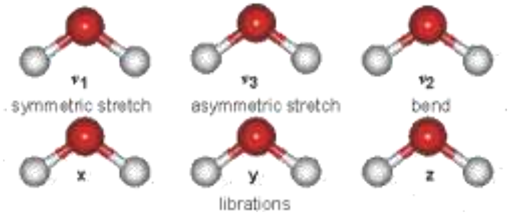
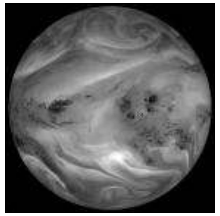
NERC SCIENCE OF THE ENVIRONMENT

INTRODUCTION





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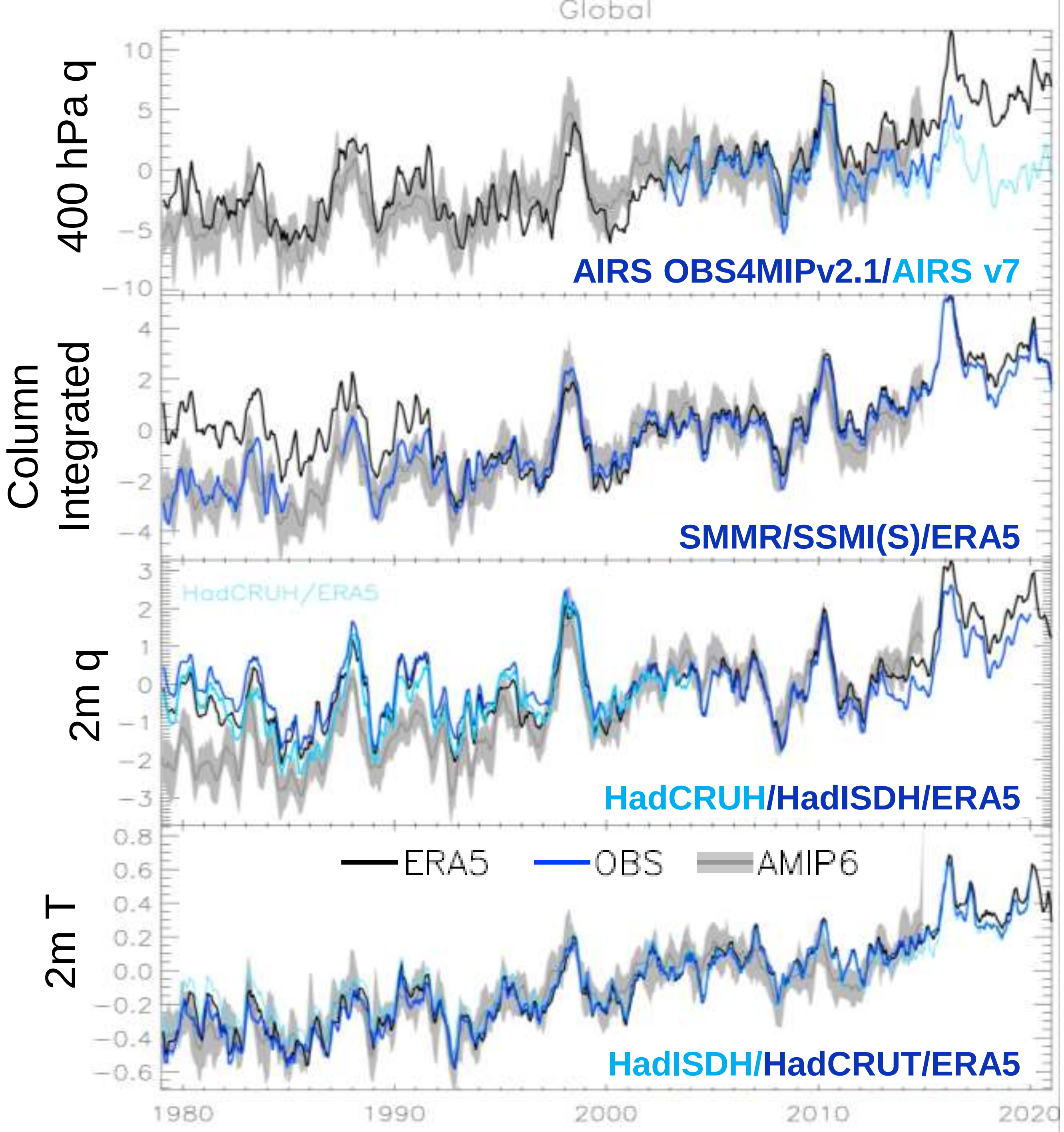
- Climate models generally accepted to represent well water vapour feedback
- …but systematic biases in mean state & moist processes e.g. John & Soden 2007 GRL
- Complex relationship between interannual & long-term response He et al. 2021 GRL
- Observing systems also struggle to capture long-term changes Schroeder et al. 2016
- How is water vapour changing over continents (e.g. Dunn et al. 2017 ESD; Byrne & O'Gorman (2018) PNAS) and throughout the atmosphere (e.g. Dessler et al. 2008 GRL)?
- Results from Met Office/Reading MOAP project

Strategy:

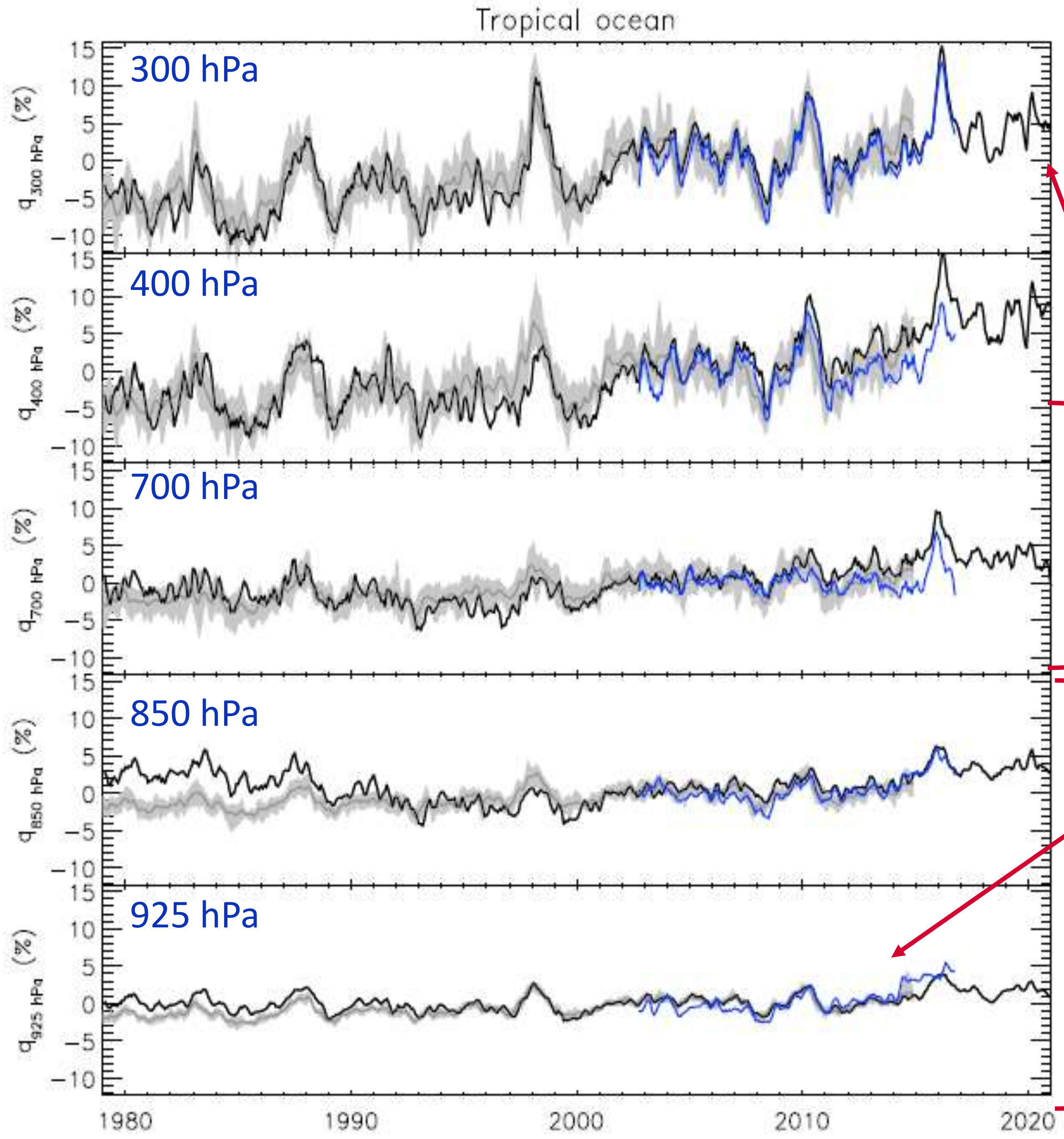
- Assess changes at largest scales (global/tropical, land/ocean), fill missing data
- Evaluate trends and sensitivity to surface temperature *(cdo and IDL to process)*
- 18 CMIP6 *amip* and *historical* experiment simulations (r1i1p1f1/2; mostly 1988-2014)
- SSM/I(S) RSSv7 F08/11/13/15/17+ERA5; AIRS OBS4MIP V2.1; HadISDH+ERA5



GLOBAL VARIABILITY

- ENSO variability captured
- Discrepancy in simulated changes in 1980s (ERA5/HadISDH and AMIP6)
  - Also for low altitude T
- Unrealistic drop in ERA5 column water vapour early 1990s:
  - e.g. Allan et al. 2020 NYAS
  - Especially tropical oceans ~850 hPa
- Divergence between AIRS/ERA5 trends in 2000s (esp. 400-700 hPa tropical oceans)

Allan et al. 2022 JGR



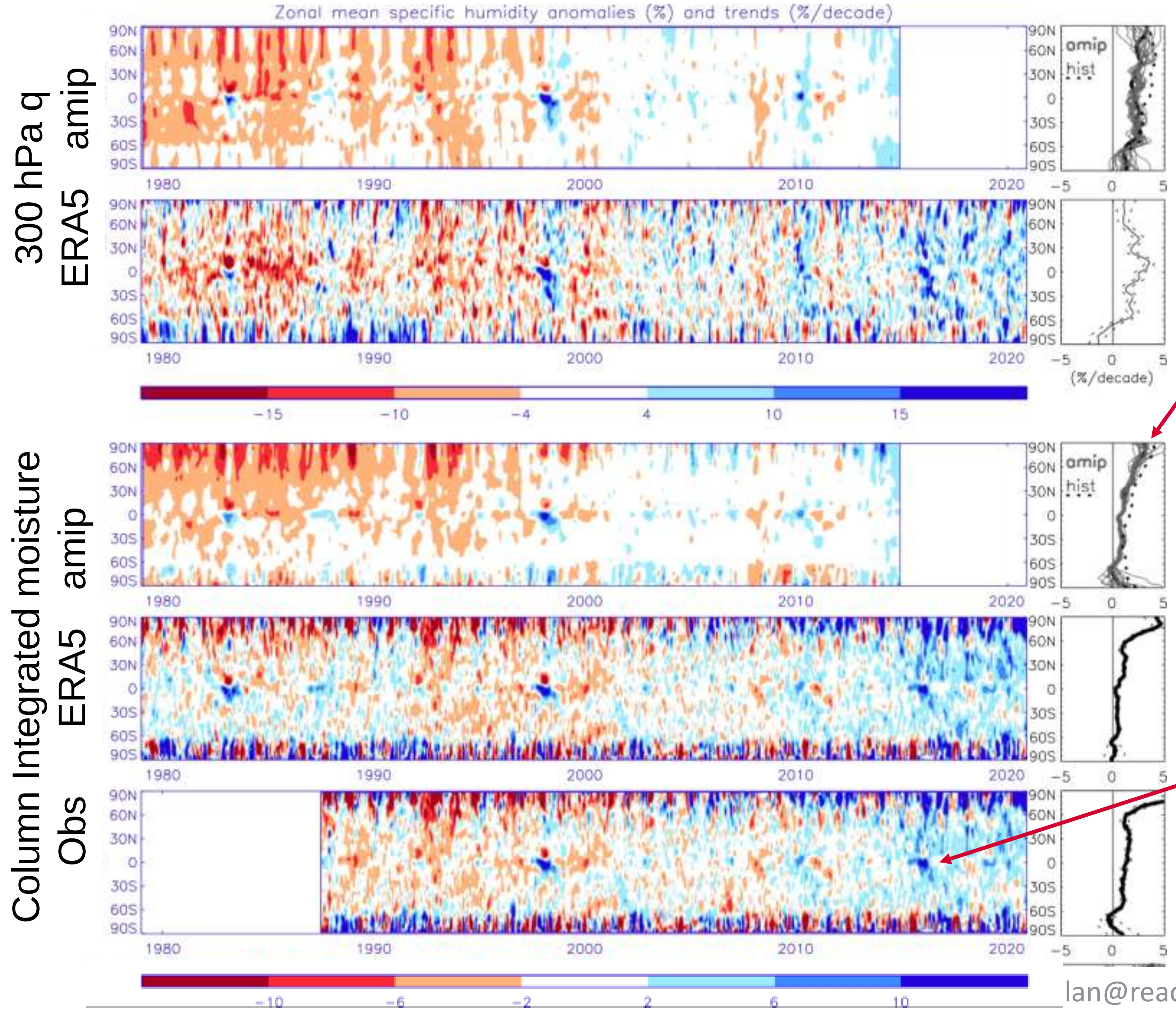
VARIABILITY WITH ALTITUDE

AIRS:

- Consistent 300 hPa variability
- Does not capture increasing trend 2008-2016 ~400-700 hPa
- Also smaller warming? (Fig. S3)
- Jump in 925 hPa q in 2014?

ERA5:

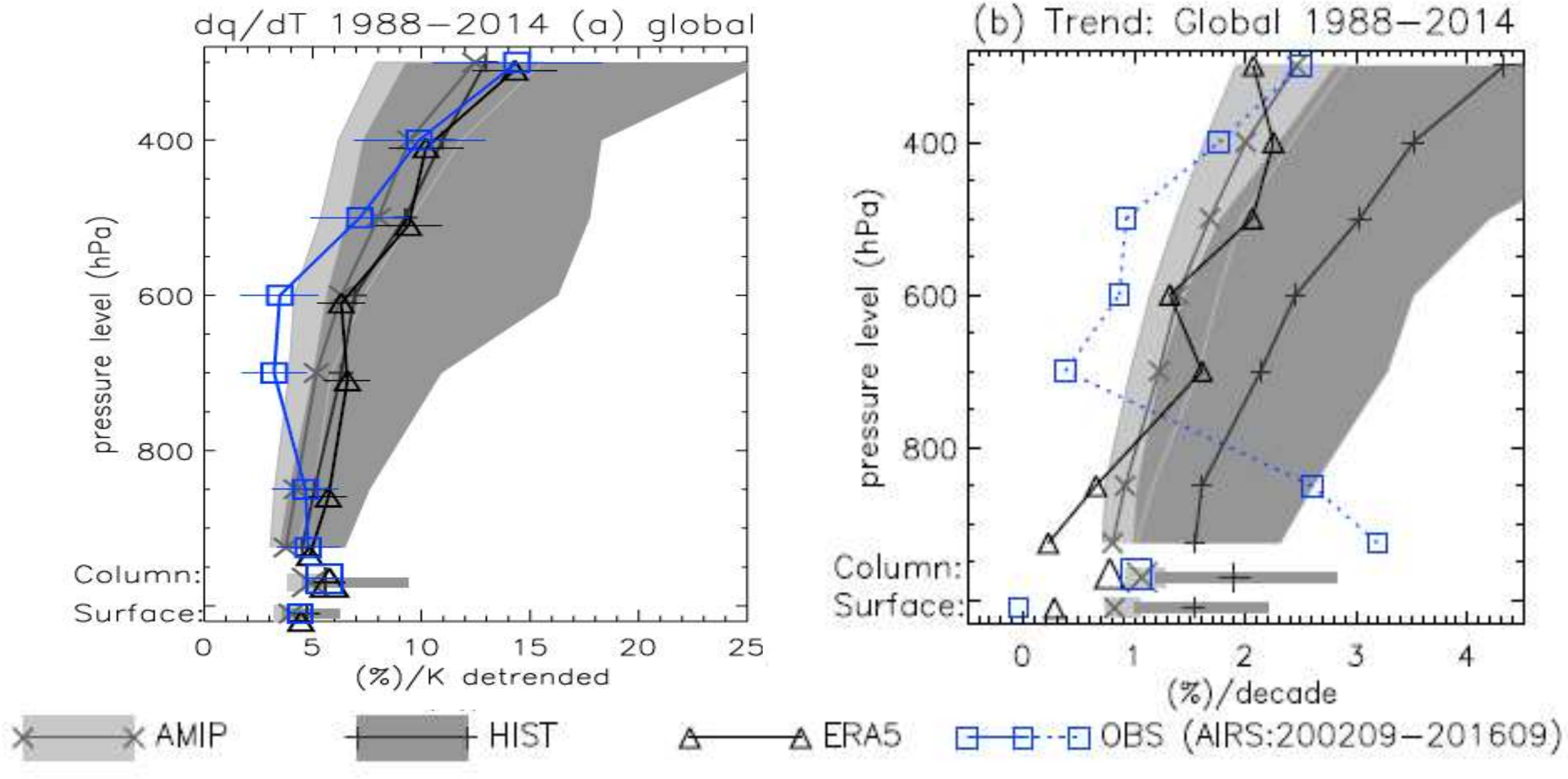
- 1980s ERA5/AMIP6 discrepancy – mostly tropical ocean low altitude



ZONAL MEAN CHANGES

- Arctic amplification of lower tropospheric moisture trends
- Positive equatorial anomalies during El Nino (e.g. 1982, 1987, 1998, 2010, 2016)

SENSITIVITY TO 1K WARMING AND TRENDS



- Clausius Clapeyron/ thermodynamic altitude-dependent effects captured
- AIRS short record; inconsistent vertical profile changes?
- Suppressed trend in amip vs **historical** CMIP6 simulations
  - SST+pattern effect?
- Near surface discrepancy
- SSMIS column integrated moisture consistent?

[Allan et al. 2022 JGR]

Warming Pattern Effect

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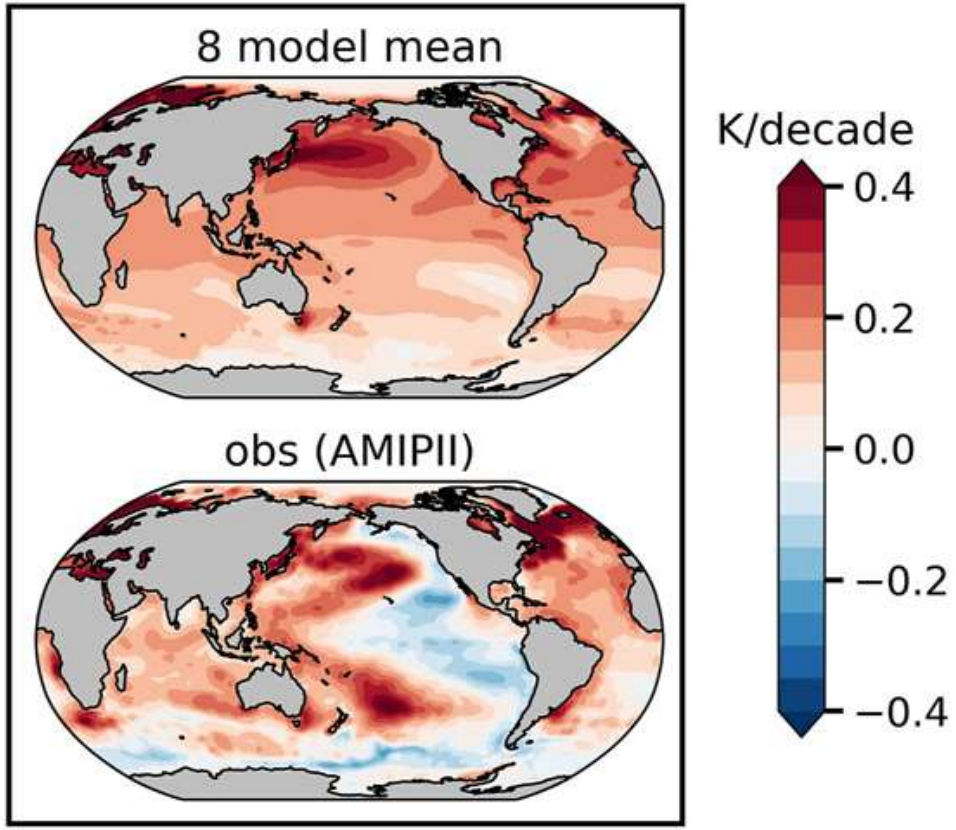
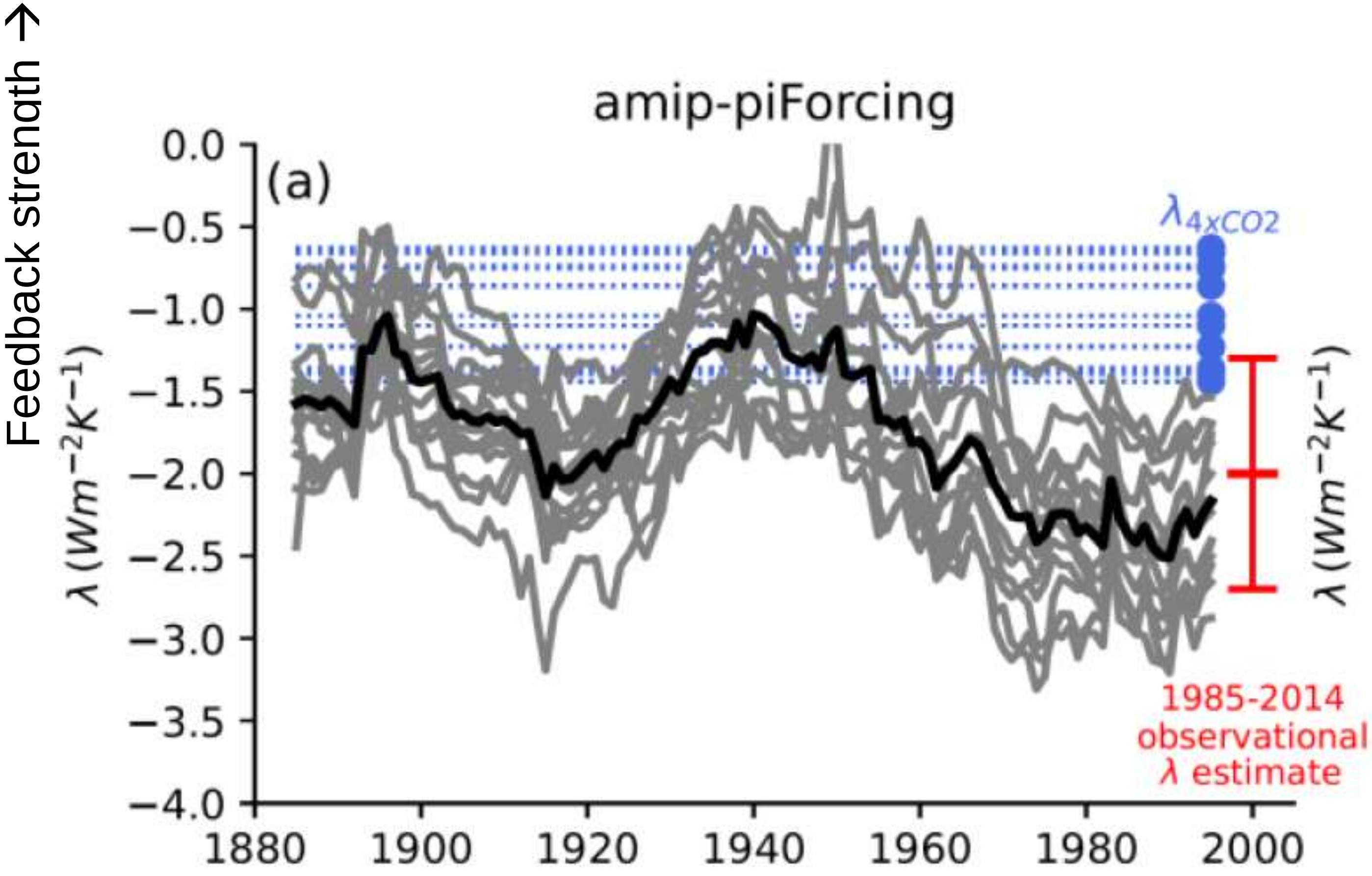
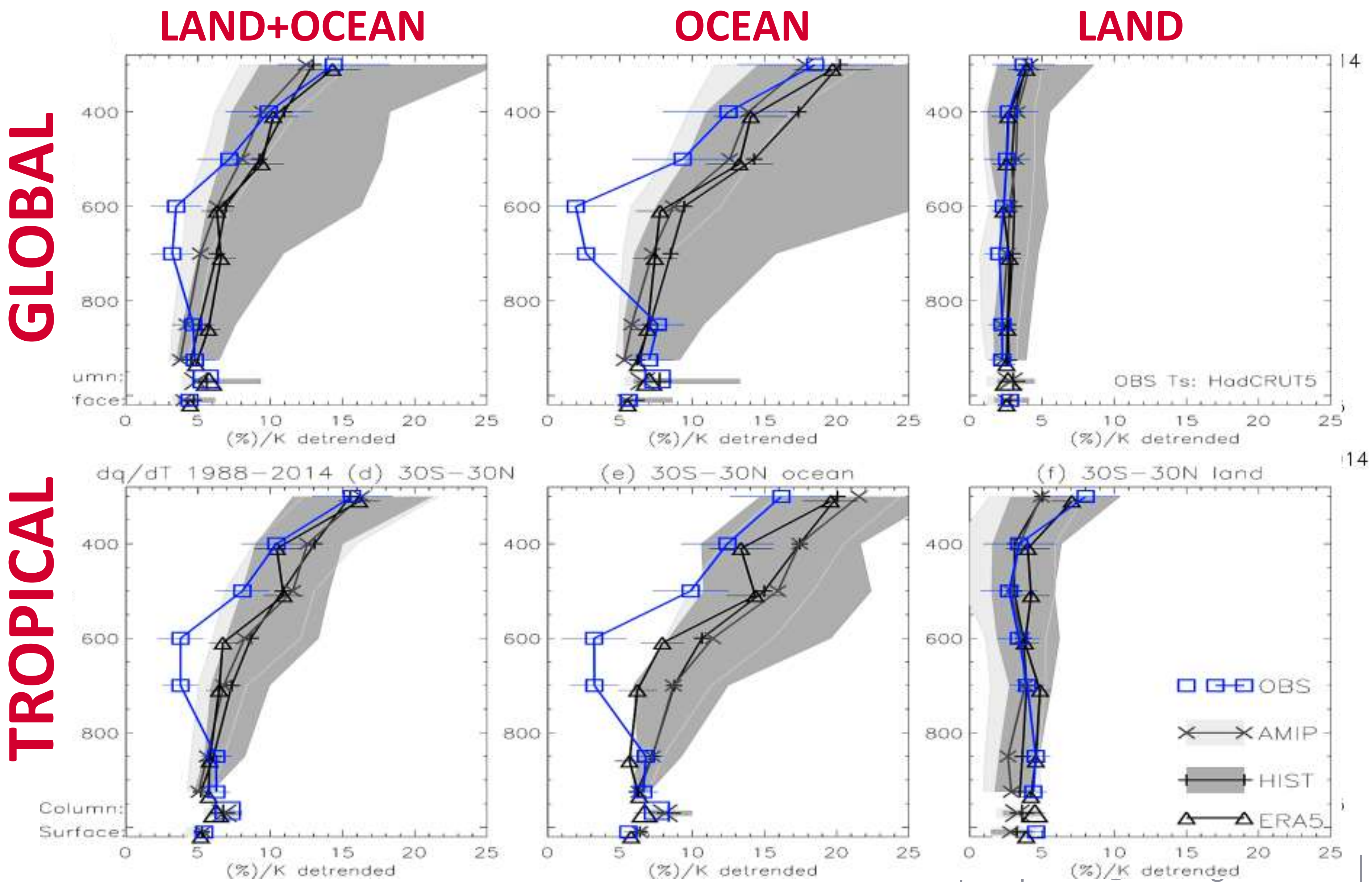




Pattern of observed warming (1979-2014) is unexpected!
Dong et al. (2021) GRL

Observed pattern of global warming has weakened climate feedbacks relative to coupled models
(Andrews et al. 2022 JGR)

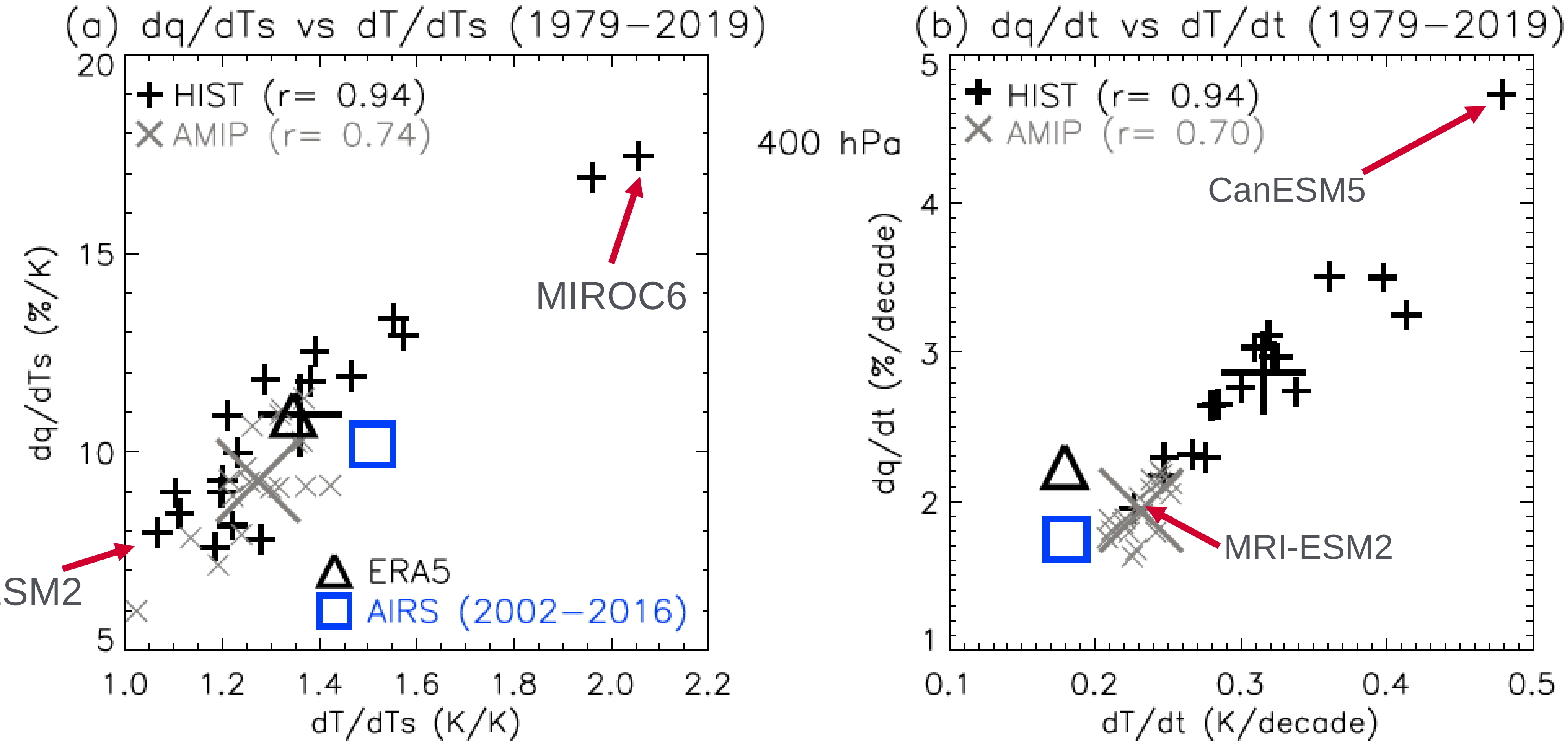
dq/dTs sensitivity 1988-2014



- Consistent amip/hist
- Smaller land response expected
  - warmer/drier Trenberth & Shea 2005 GRL
  - Ocean moisture source e.g. Byrne & O'Gorman (2018) PNAS
- Suppressed AIRS 600-700 hPa ocean response
- ERA5/HadISDH: small (extra-tropical?) ocean response? *Willett et al. 2020 ESD*

MOISTURE COUPLING WITH TEMPERATURE

- Models with stronger warming simulate larger moisture changes as expected
- Most *historical* simulations warm more than has been observed



Allan et al. 2022 JGR

RELATIVE HUMIDITY SENSITIVITY

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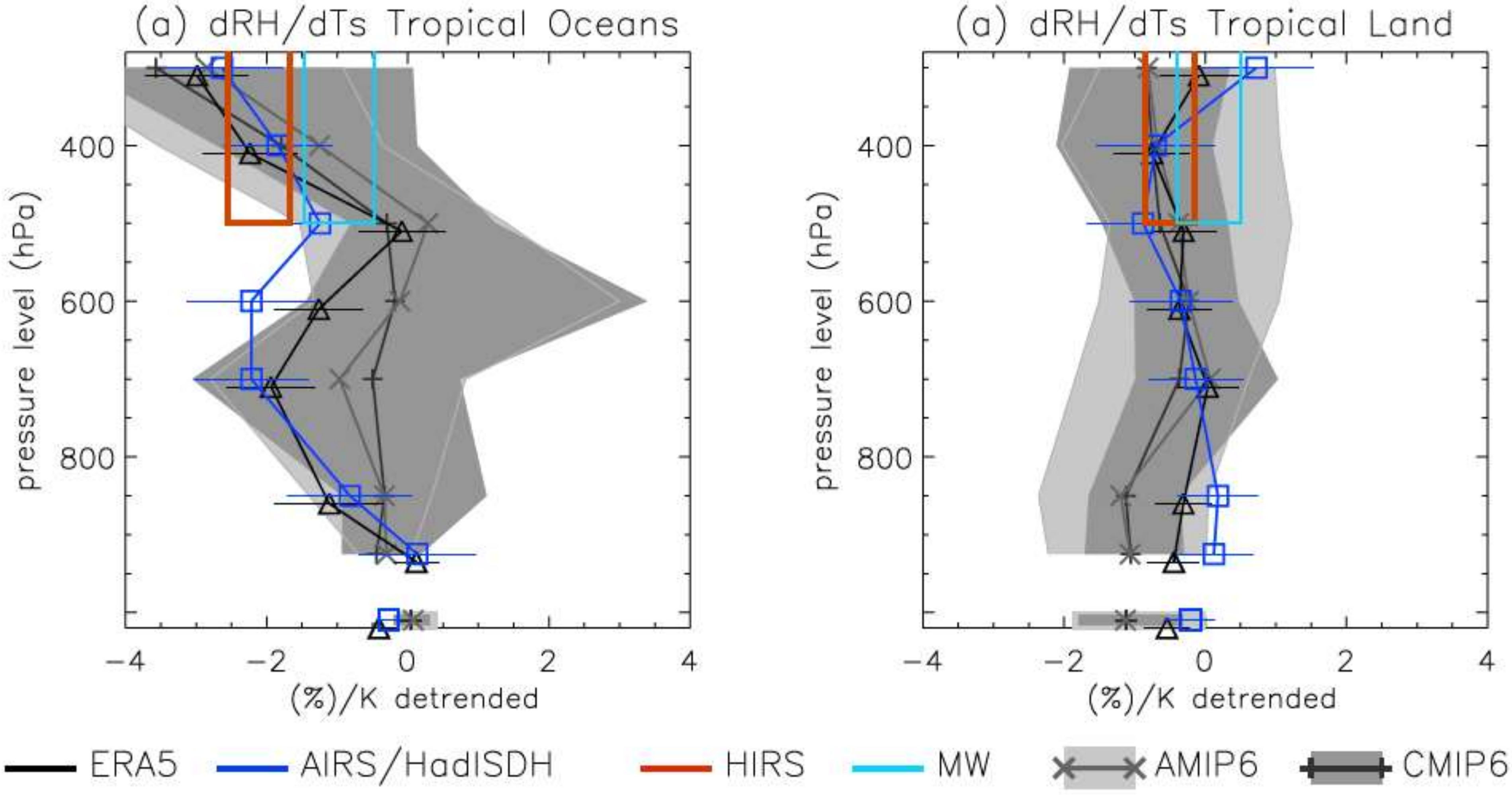

Small changes in relative humidity (RH)

Slight decrease in upper tropospheric humidity in warmer (El Niño) years (radiator fins?)

More from Thea's PhD project!

CONCLUSIONS

- Moisture-temperature coupling broadly consistent in CMIP6 models/observations
  - Altitude/latitude dependent effects of Clausius Clapeyron equation/thermodynamics
- Suppressed water vapour trends in amip vs historical (SST pattern effect?)
  - Implications for projections; Allan et al. 2020 NYAS; **Douville et al. (2022) Comm.Earth Env.**
- Limitations of observing system
  - Unrealistic decreases in 1980s-1990s in ERA5 (mainly low level, tropical ocean)
  - Discrepancy in low altitude moisture changes (observations/reanalyses vs CMIP6, especially tropical ocean) – see *Willett et al. 2020 ESD*
  - Altitude dependent artifacts in AIRS specific humidity data?
- Next: Thea's UTH project (e.g. John et al. 2019 BAMS)

histroical global prw *prizes so far!*

- Wettest model – BCC-ESM1, GISS-E: 27 kgm^{-2}; Driest - CNRM-CM6-1: 23 kgm^{-2}
- Most sensitive – MIROC6: 9%/K; Least sensitive – UKESM1, BCC-CSM2: 4.6 %/K