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EVALUATING WATER VAPOUR CHANGES IN CMIP6 SIMULATIONS

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NERC SCIENCE OF THE ENVIRONMENT

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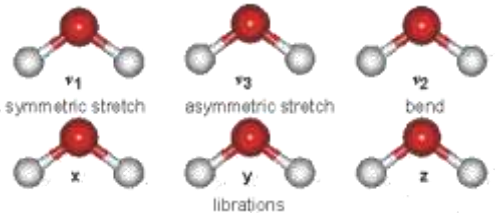
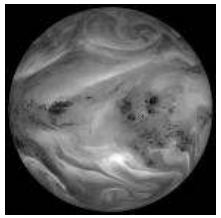
INTRODUCTION





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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)?
- Preliminary results - contribution to NCEO/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

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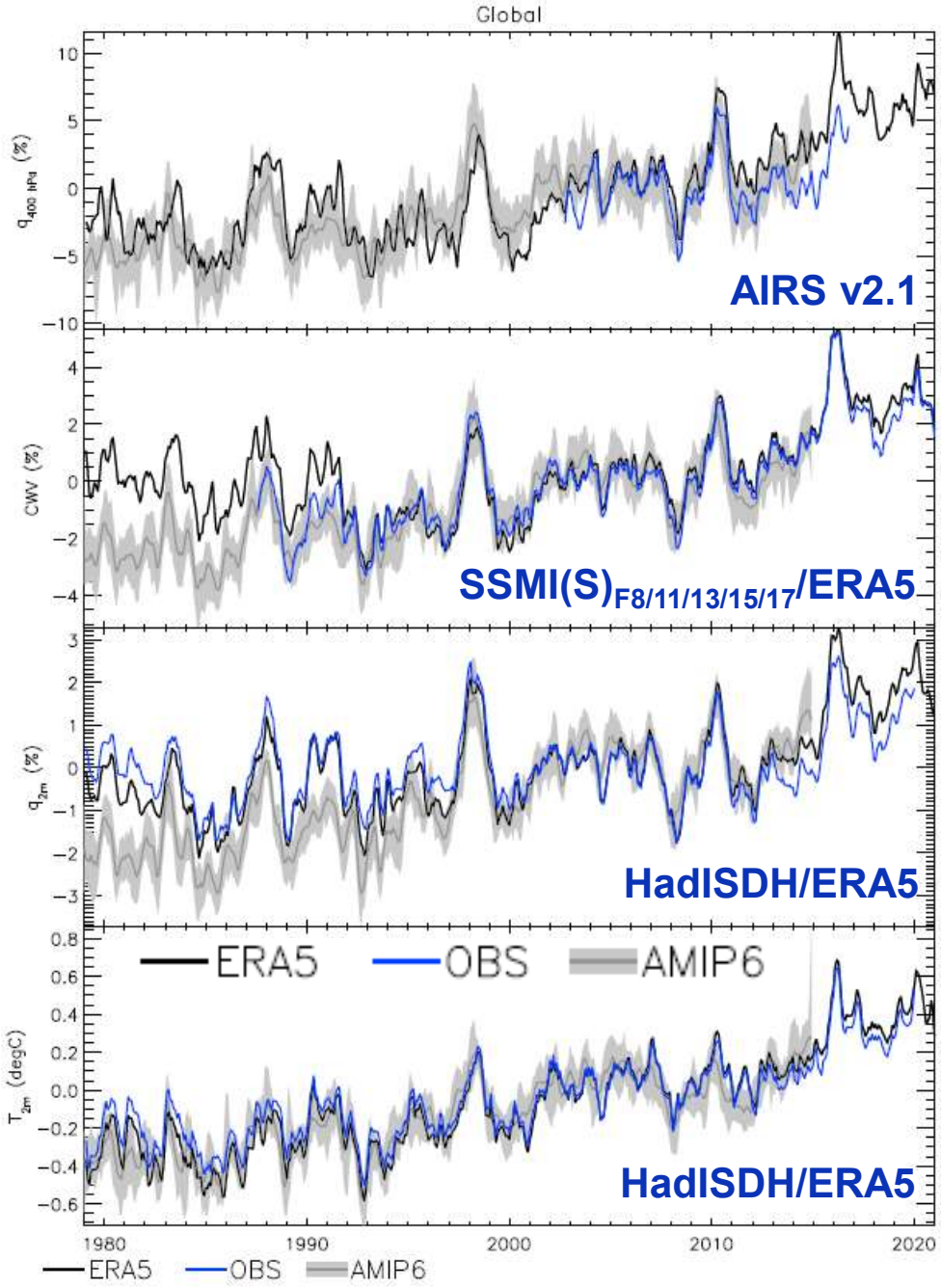
400 hPa q

Column Integrated

2m q

2m T



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VARIABILITY SINCE 1979

- 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)

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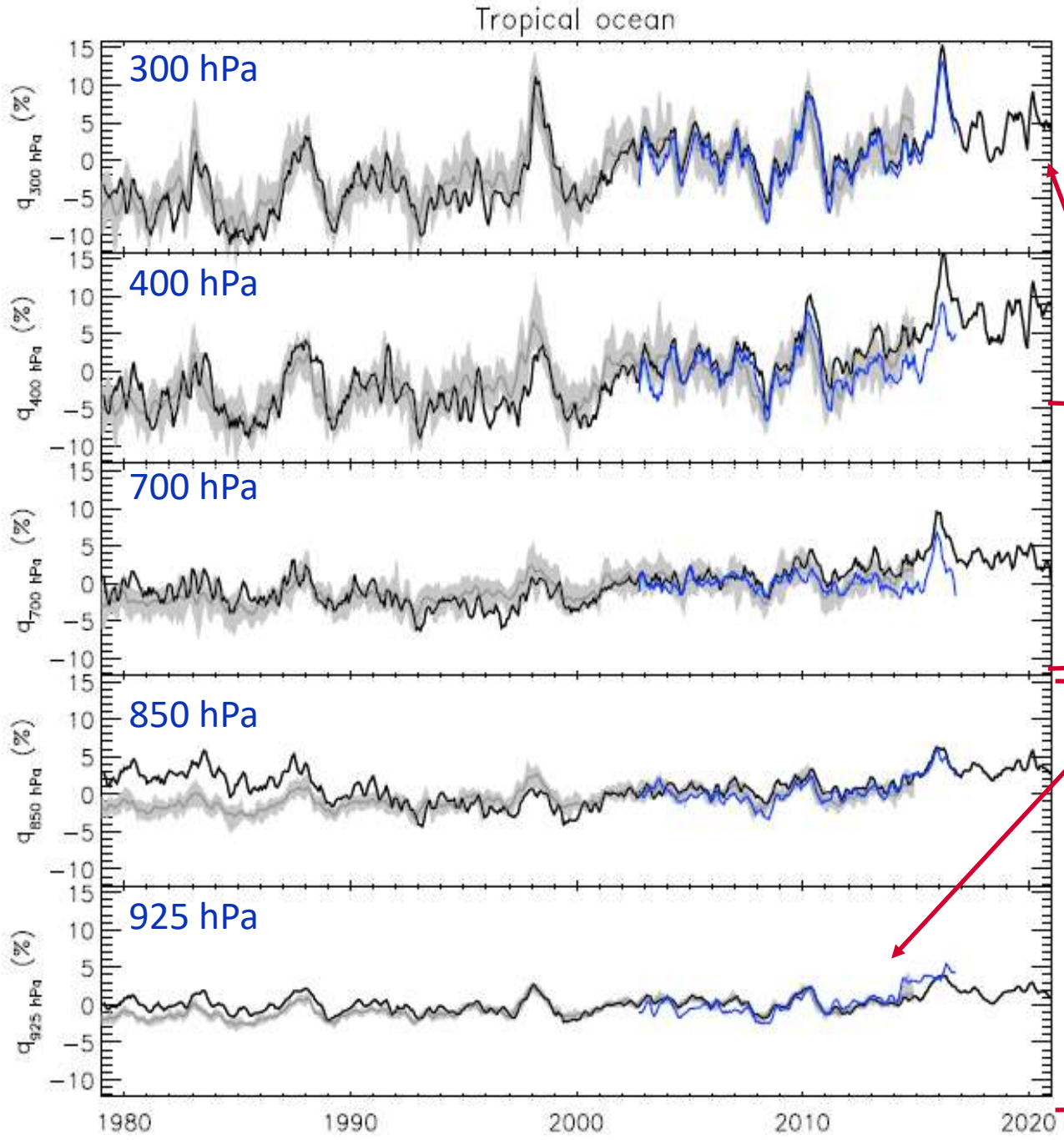

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VARIABILITY WITH ALTITUDE

AIRS:

- Consistent 300 hPa variability
- Does not capture increasing trend 2008-2016 ~400-700 hPa (↓RH)
- Jump in 925 hPa q in 2014?

ERA5:

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

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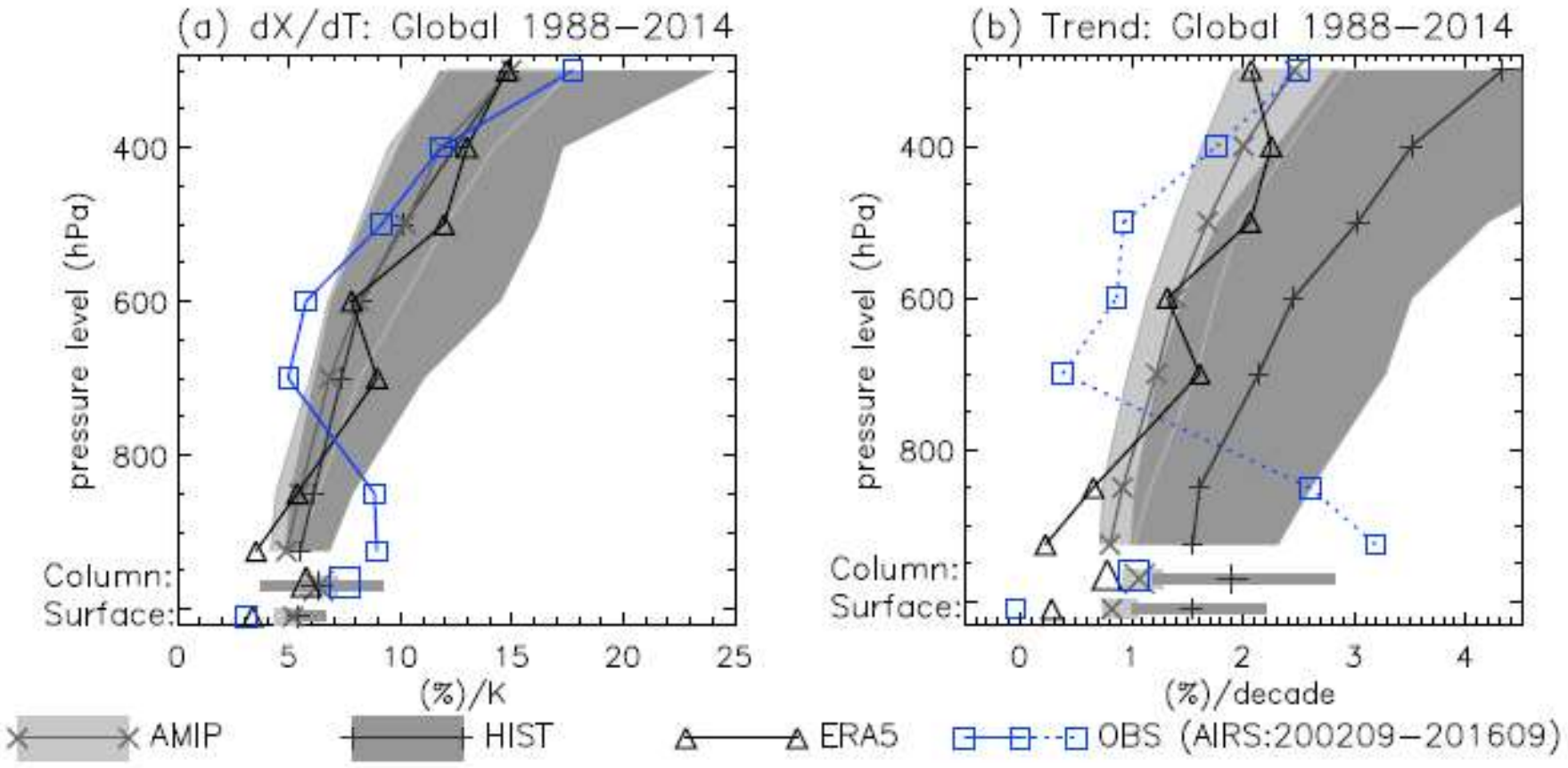
SENSITIVITY TO 1K WARMING AND TRENDS



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

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dq/dTs sensitivity

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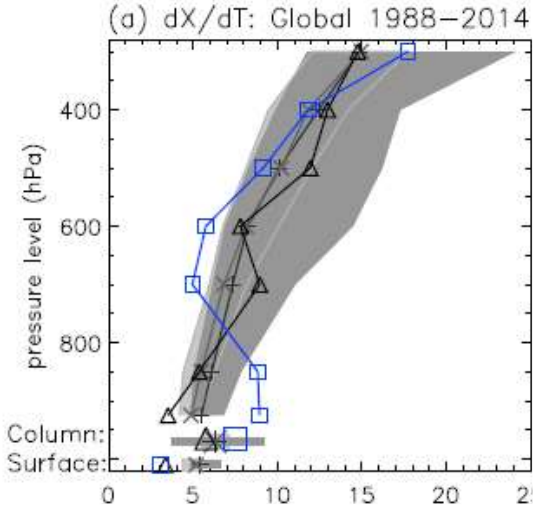
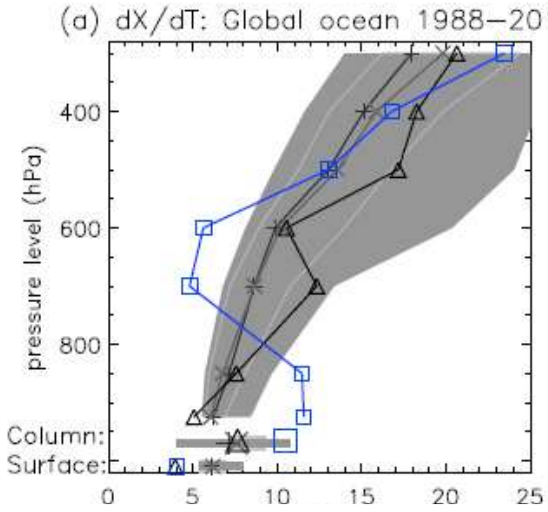
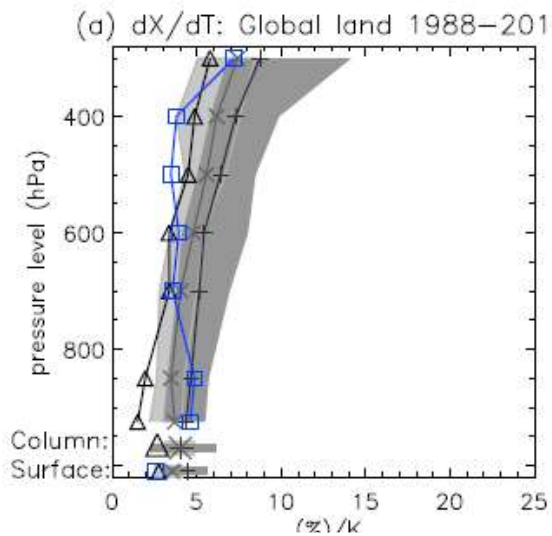
LAND+OCEAN | **OCEAN** | **LAND**

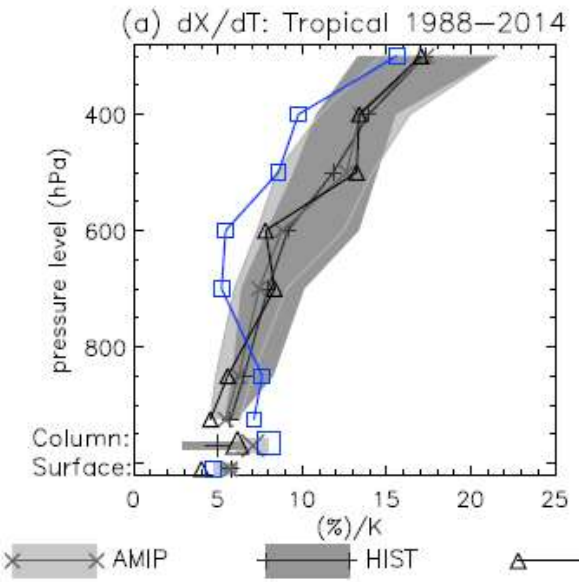
GLOBAL

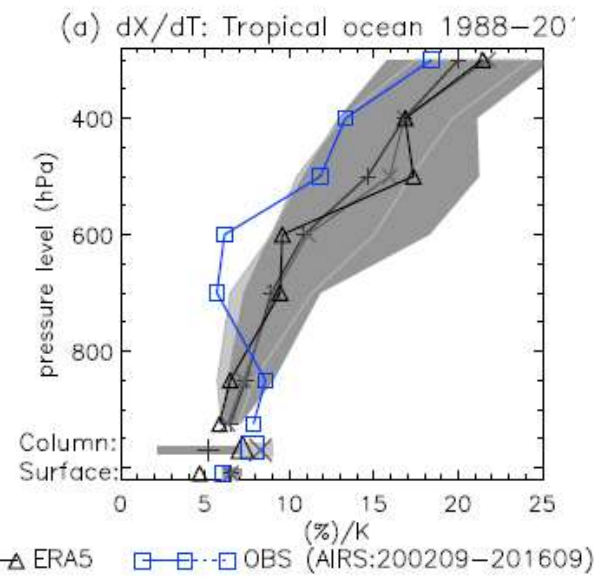


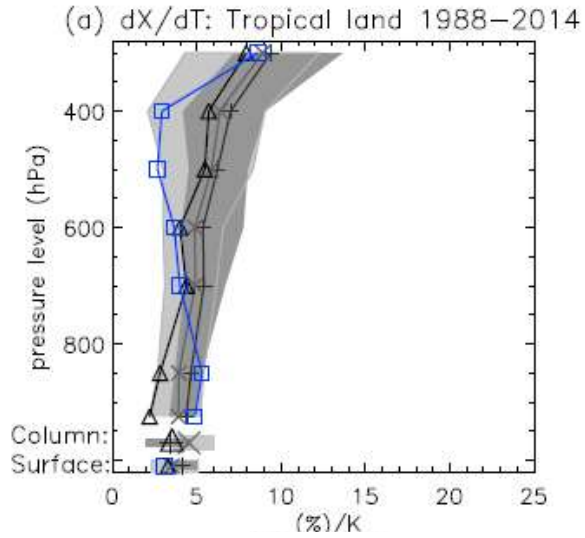




TROPICAL







- 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*

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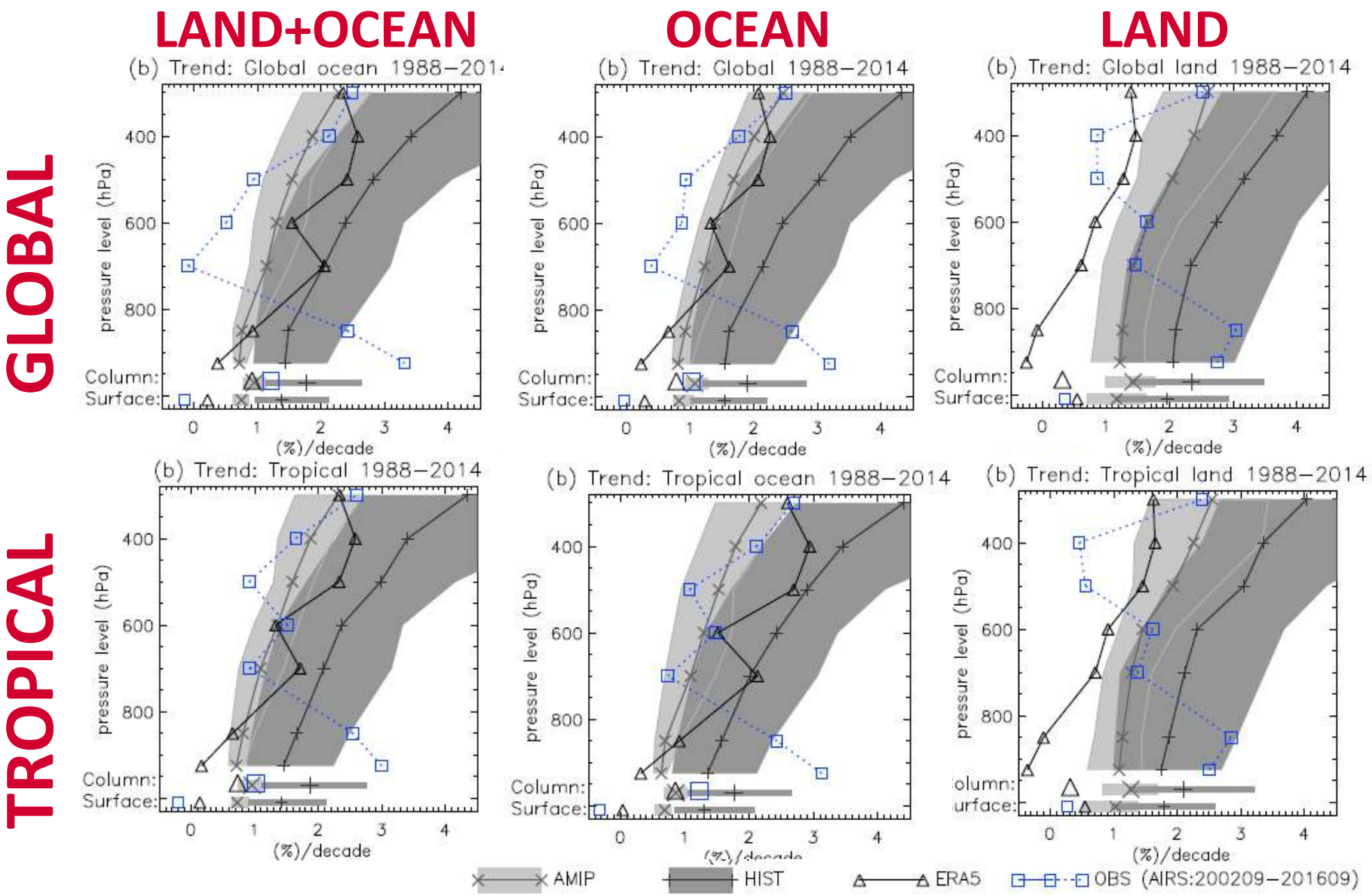
dq/dt: trend



- ~1%/decade column trends in SSMI(S), ERA5, amip
- **historical** simulations warm & moisten more
- Small ERA5 tropical tropospheric trends (pre 2000)
- Small ERA5/HadISDH tropical ocean surface trends

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PRELIMINARY CONCLUSIONS

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- Water vapour changes broadly captured by CMIP6 models and observing systems
  - Altitude/latitude dependent effects of Clausius Clapeyron equation/thermodynamics
- Suppressed water vapour trends in amip vs historical (SST pattern effect?)
  - Implications for projections/water cycle; Allan et al. 2020 NYAS; Watters et al. 2021 JClim
- 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: microwave UTH (e.g. John et al. 2019 BAMS); $\Delta T(p)$, $\Delta RH(p)$; unfilled; detrend; …

***amip global prw** prizes so far!*

- Wettest model - MIROC6: 26.6 kgm^{-2}; Driest models - GFDL-ESM4&CNRM-CM6-1: 24 kgm^{-2}
- Most sensitive - GFDL-ESM4: 7%/K; Least sensitive - INM-CM5-0: 5.5 %/K

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