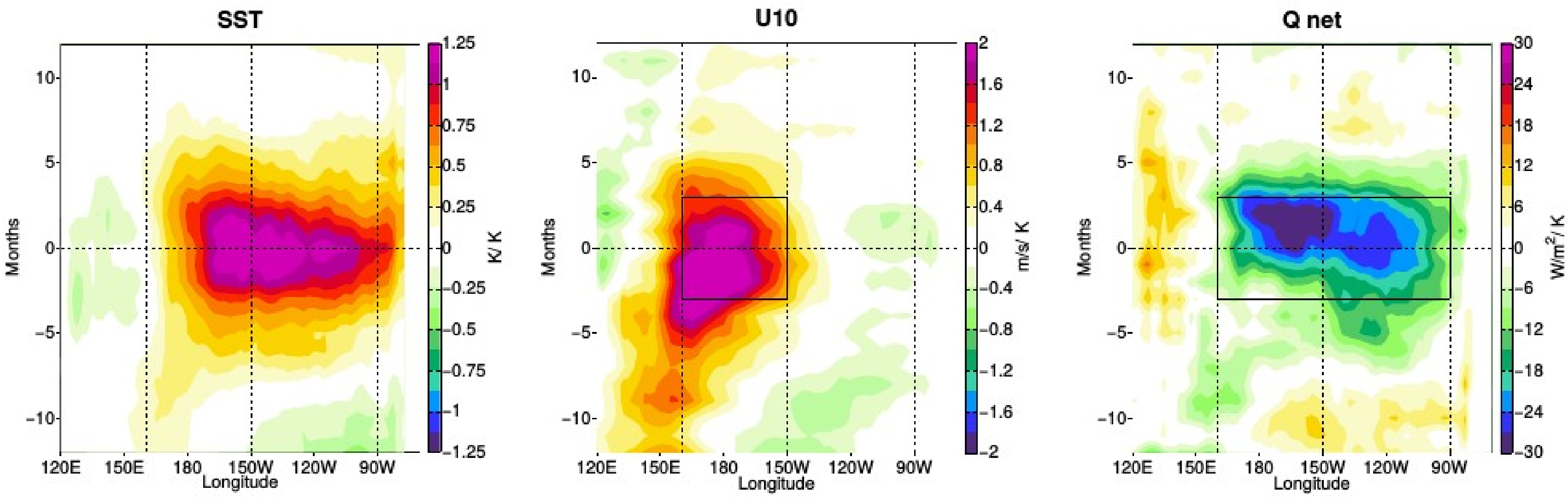
Walker Circulation controls ENSO atmospheric feedbacks in uncoupled and coupled climate model simulations



Tobias Bayr, Dietmar Dommenget and Mojib Latif

GEOMAR Kiel, Germany

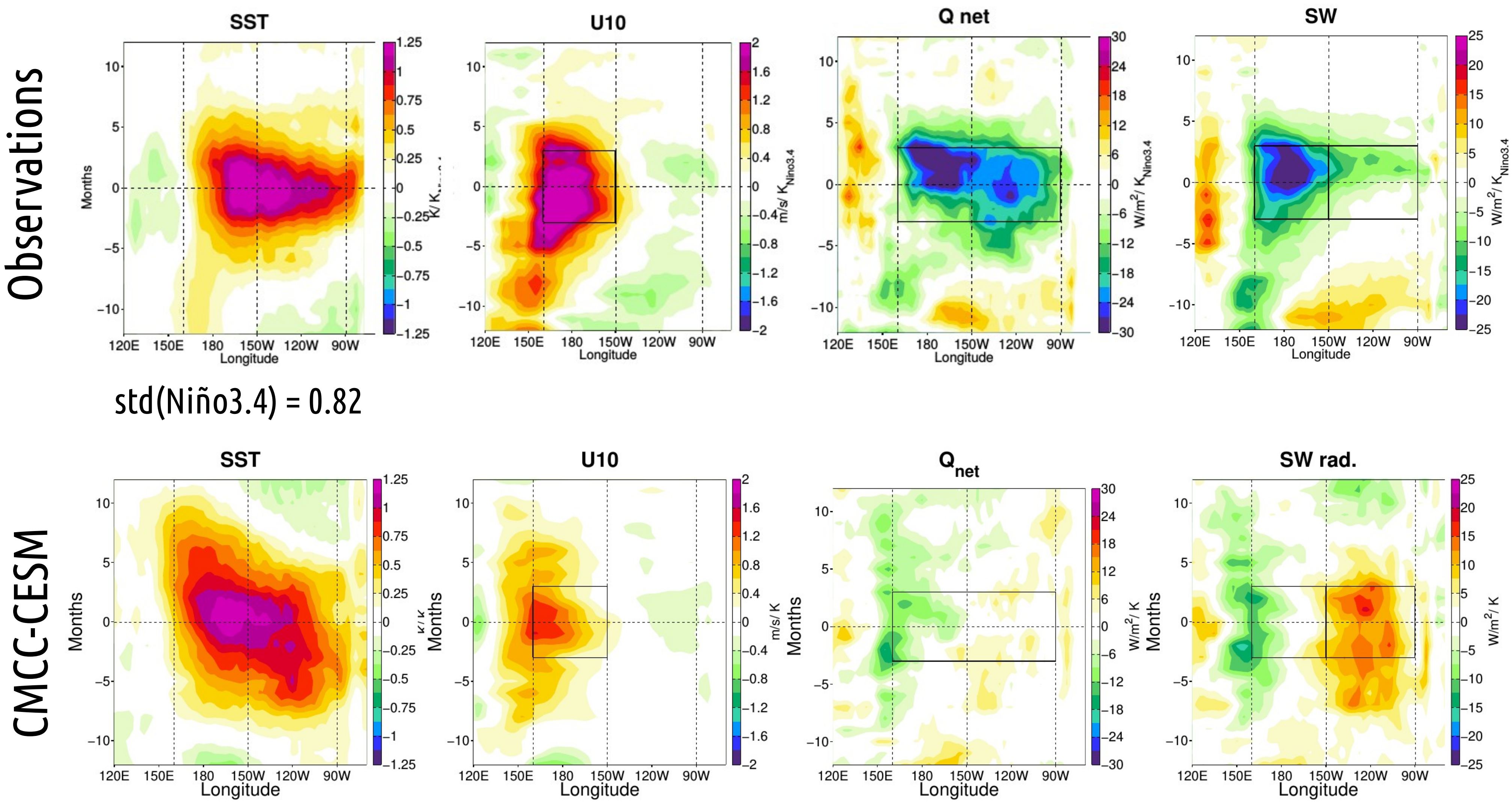
Bayr T, Dommenget D, Latif M (2020) Walker Circulation controls ENSO Atmospheric Feedbacks in Uncoupled and Coupled Climate Model Simulations. Clim Dyn. https://doi.org/10.1007/s00382-020-05152-2

Abstract

Many climate models strongly underestimate the two most important atmospheric feedbacks operating in El Niño/Southern Oscillation (ENSO), the positive (amplifying) zonal surface wind feedback and negative (damping) surface-heat flux feedback (hereafter ENSO atmospheric feedbacks, EAF), hampering realistic representation of ENSO dynamics in these models. Here we show that the atmospheric components of climate models participating in the 5th phase of the Coupled Model Intercomparison Project (CMIP5) when forced by observed sea surface temperatures (SST), already underestimate EAF on average by 23%, but less than their coupled counterparts (on average by 54%) (**slide 4**). There is a pronounced tendency of atmosphere models to simulate stronger EAF, when they exhibit a stronger mean deep convection and enhanced cloud cover over the western equatorial Pacific (WEP), indicative of a stronger rising branch of the Pacific Walker Circulation (PWC) (**slide 6-7**). Further, differences in the mean deep convection over the WEP between the coupled and uncoupled models explain a large part of the differences in EAF, with the deep convection in the coupled models strongly depending on the equatorial Pacific SST bias (**slide 8**). Experiments with a single atmosphere model support the relation between the equatorial Pacific atmospheric mean state, the SST bias and the EAF. An implemented cold SST bias in the observed SST forcing weakens deep convection and reduces cloud cover in the rising branch of the PWC, causing weaker EAF (**slide 9-11**). A warm SST bias has the opposite effect. Our results elucidate how biases in the mean state of the PWC and equatorial SST hamper a realistic simulation of the EAF (**slide 12**).

Motivation: Underestimated Atmospheric Feedbacks in CMIP5 which hamper simulated ENSO dynamics

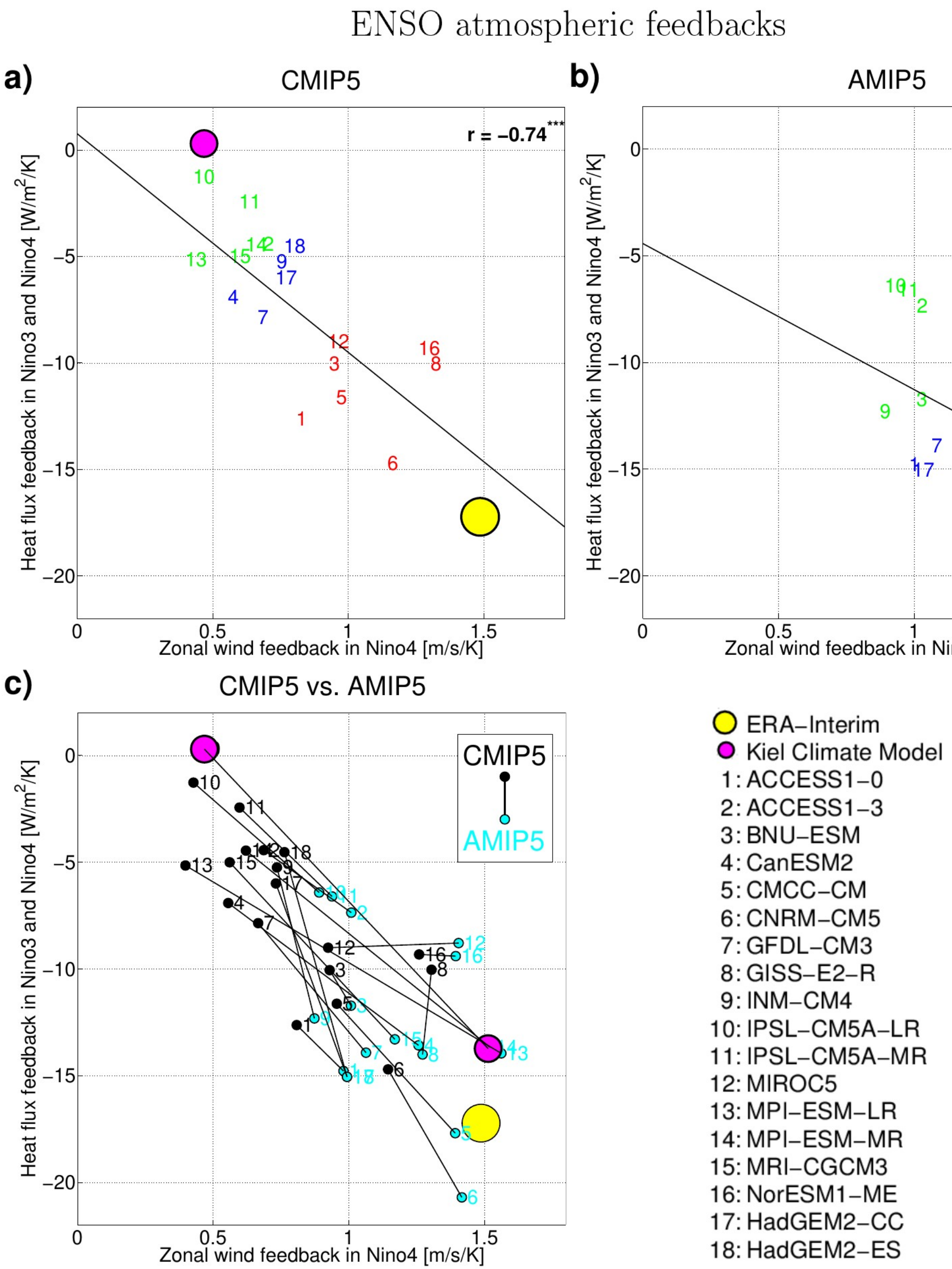
ENSO Hoevmoeller composites (normalised with Niño3.4 SST)



std(Niño3.4) = 0.82

std(Niño3.4) = 1.31

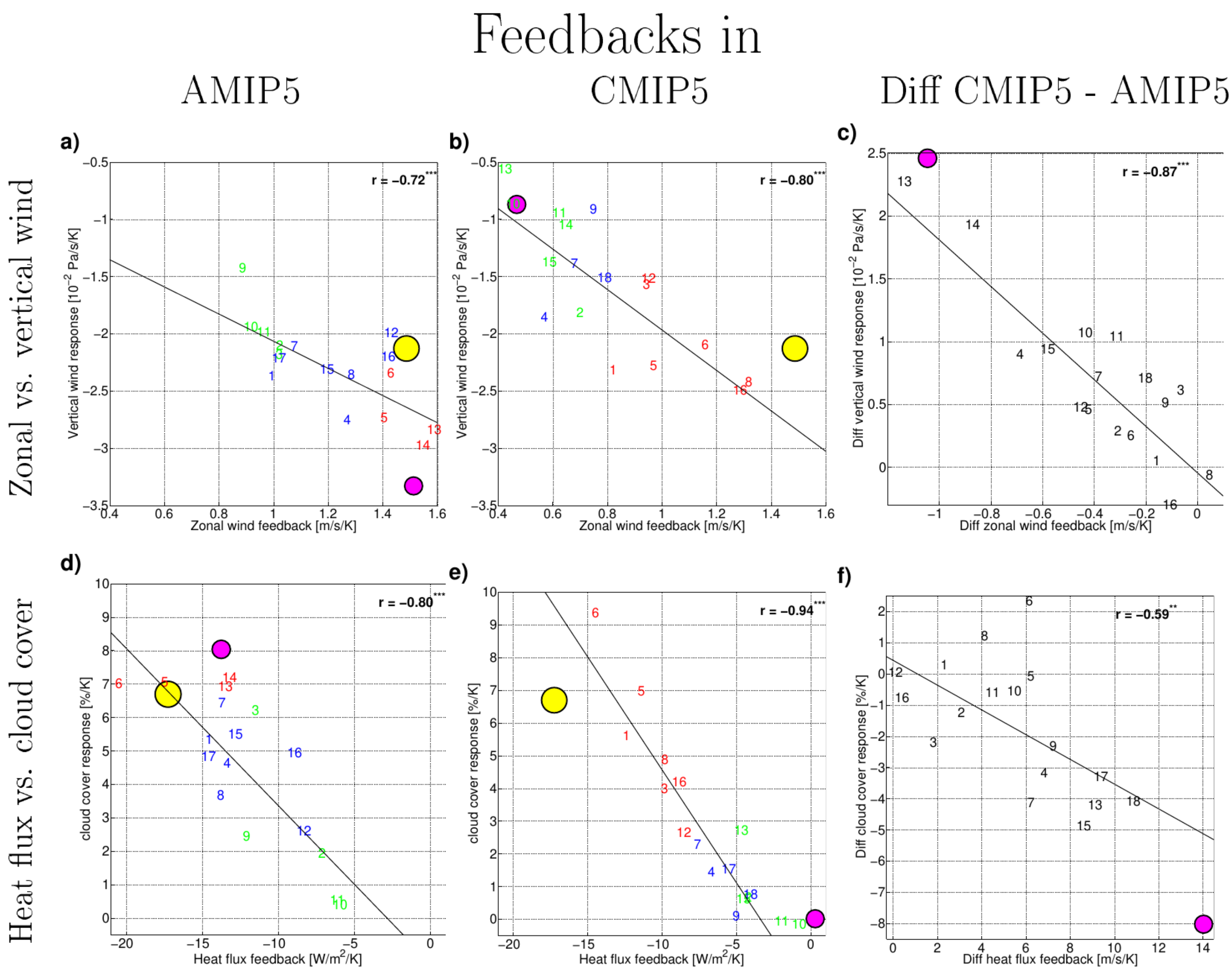
ENSO Atmospheric Feedbacks in CMIP5 and AMIP5



ENSO atmospheric feedbacks are more strongly underestimated in coupled (54% on average) than in uncoupled models (23% on average), with a similar ratio of reduction between the two feedbacks from uncoupled to coupled models.

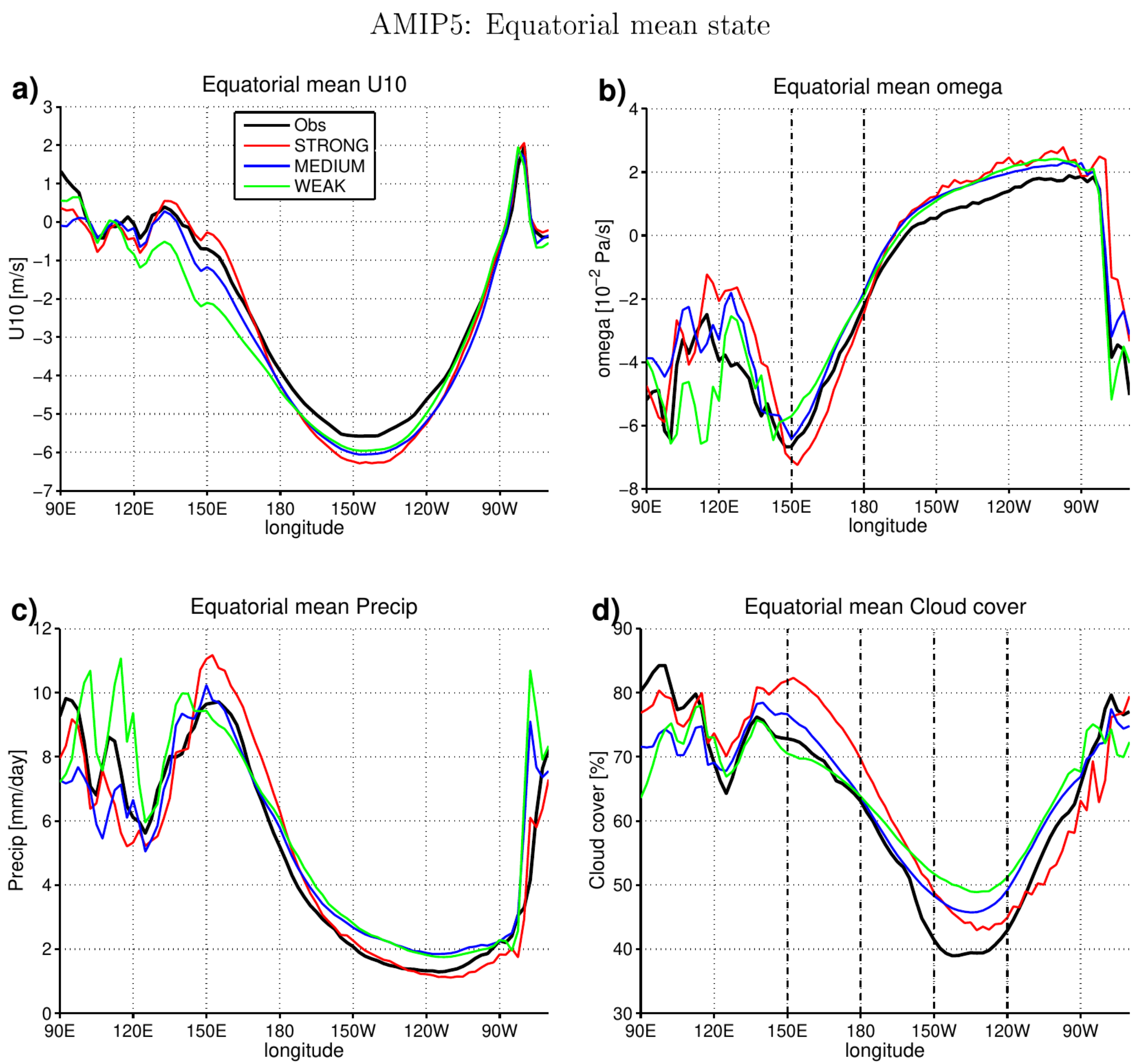
Bayr et al. (2020), Clim Dyn

Wind (heat flux) feedback strongly depends on vertical wind (cloud cover) response



Bayr et al. (2020)

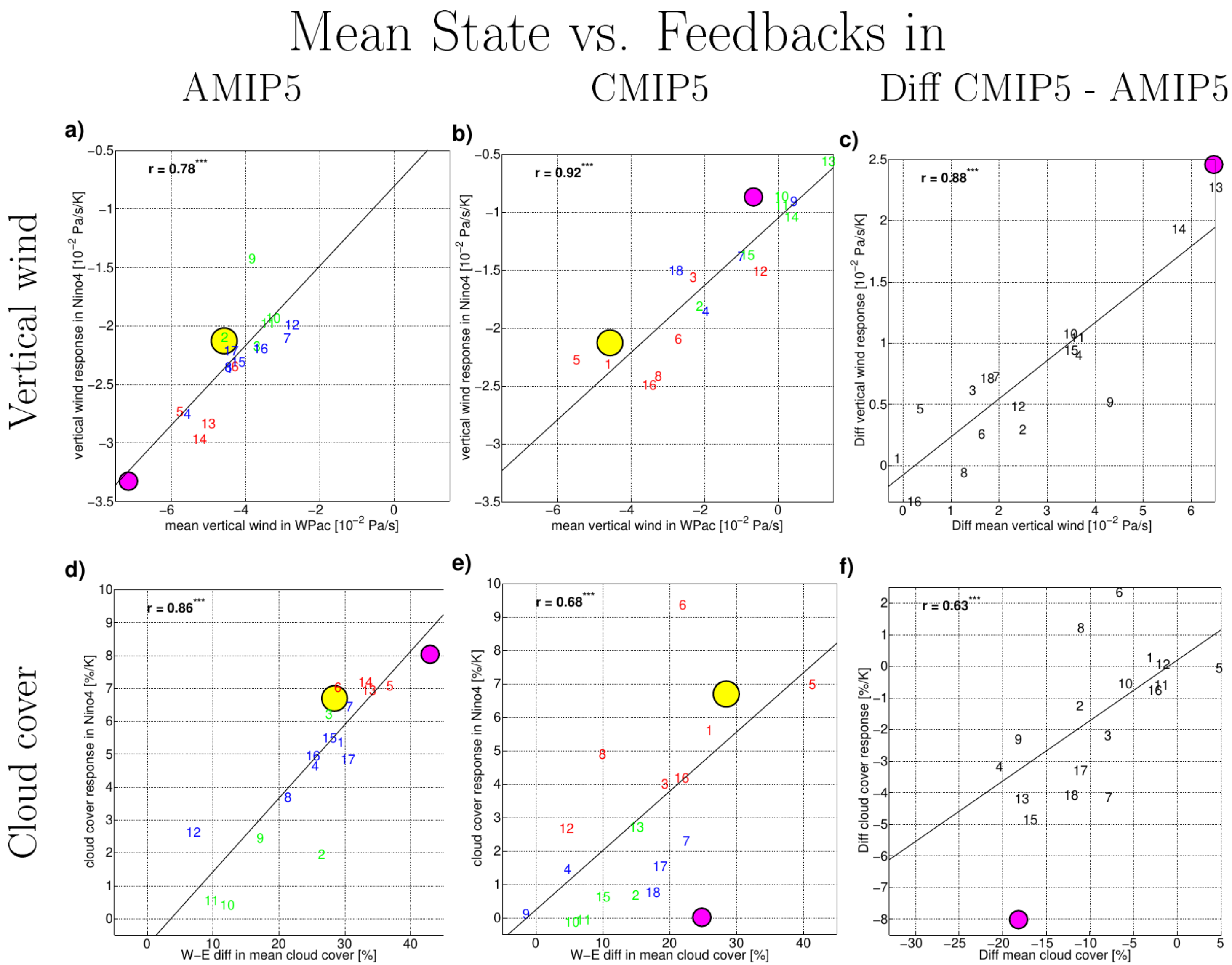
Strength of atmospheric feedbacks depends on atmospheric mean state



AMIP5 models are divided into three sub-ensembles with STRONG, MEDIUM and WEAK atmospheric feedbacks

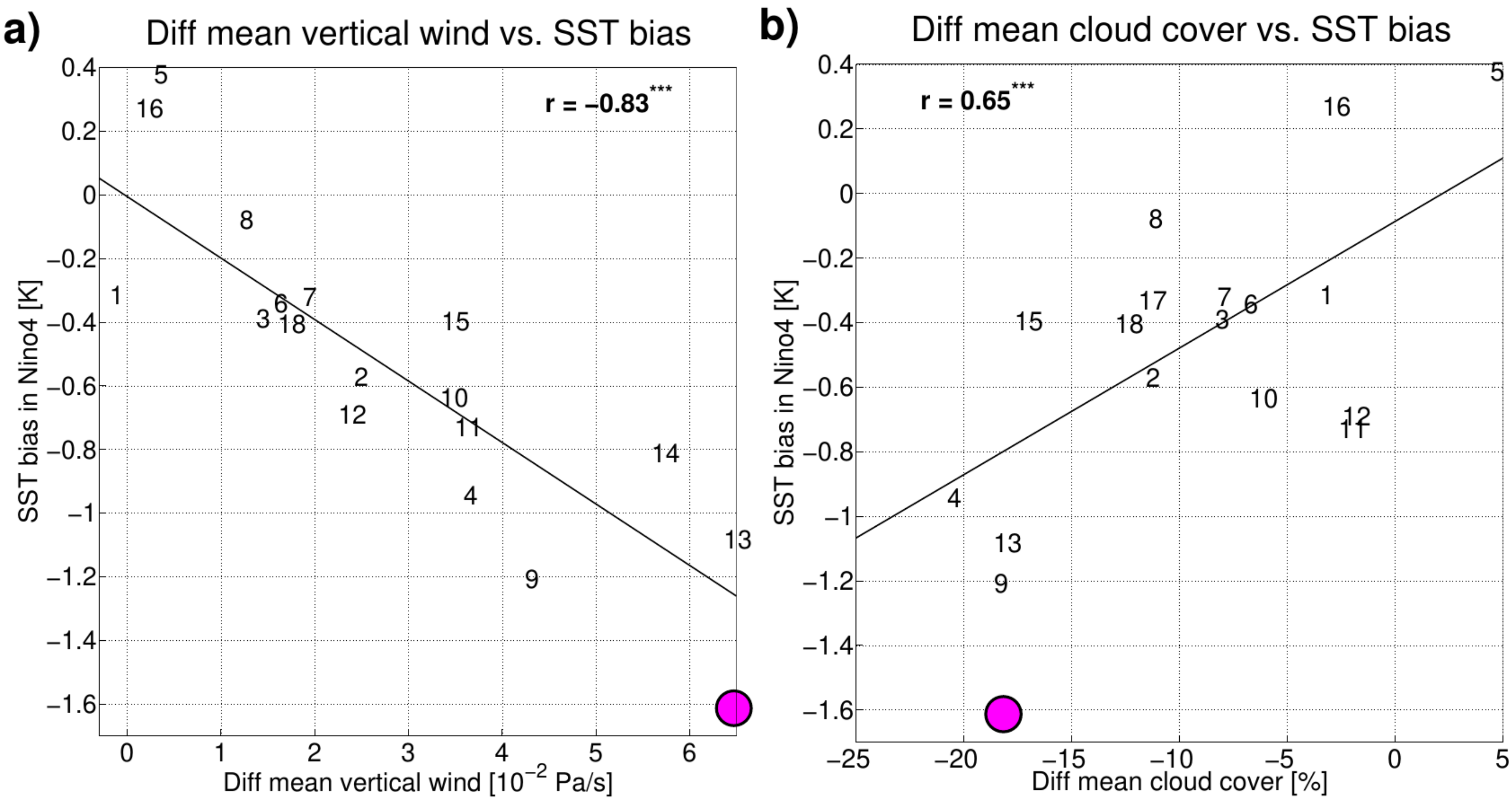
Bayr et al. (2020)

Vertical wind (cloud cover) response depends on mean vertical wind (cloud cover)



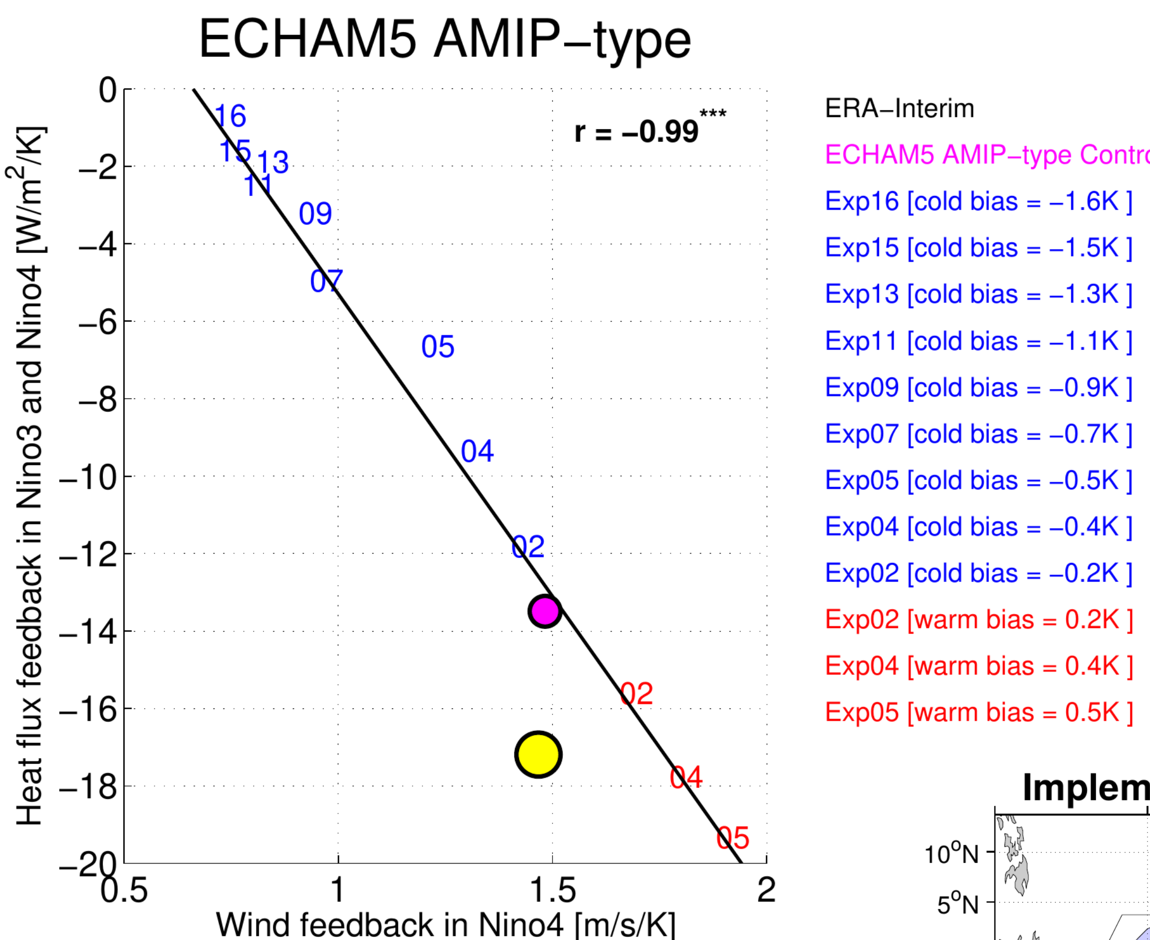
Bayr et al. (2020)

Equatorial SST bias explains difference between uncoupled and coupled experiments



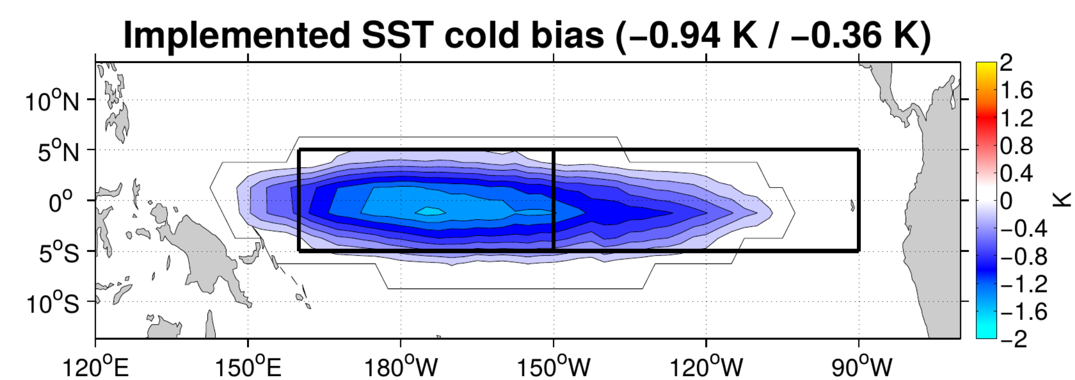
Bayr et al. (2020)

Uncoupled sensitivity experiments with implemented cold/warm bias to support the CMIP5 and AMIP5 results



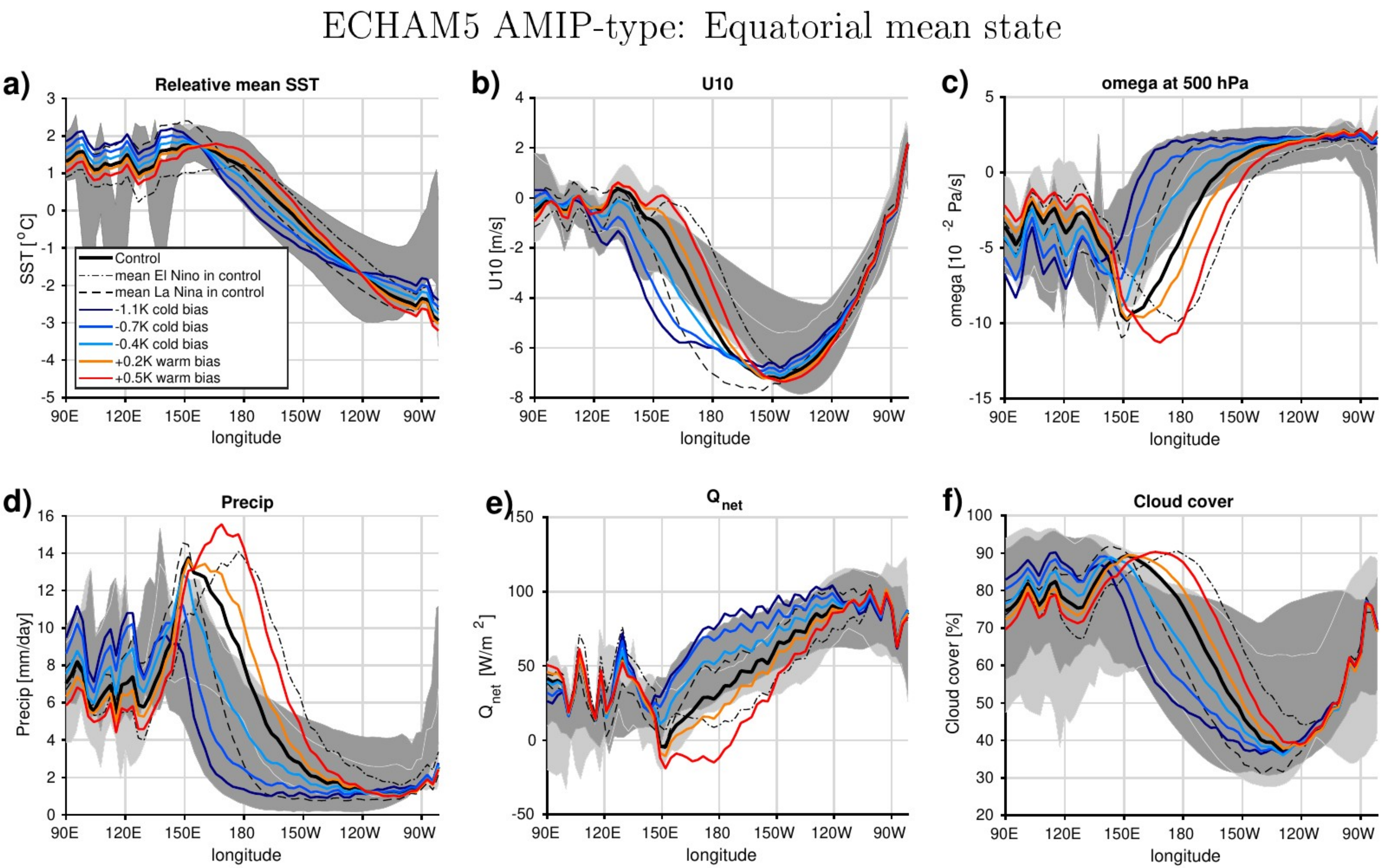
Sensitivity experiments are forced by observed SST with implemented SST bias

=> Both atmospheric feedbacks strongly depend on the mean equatorial SST



Bayr et al. (2020)

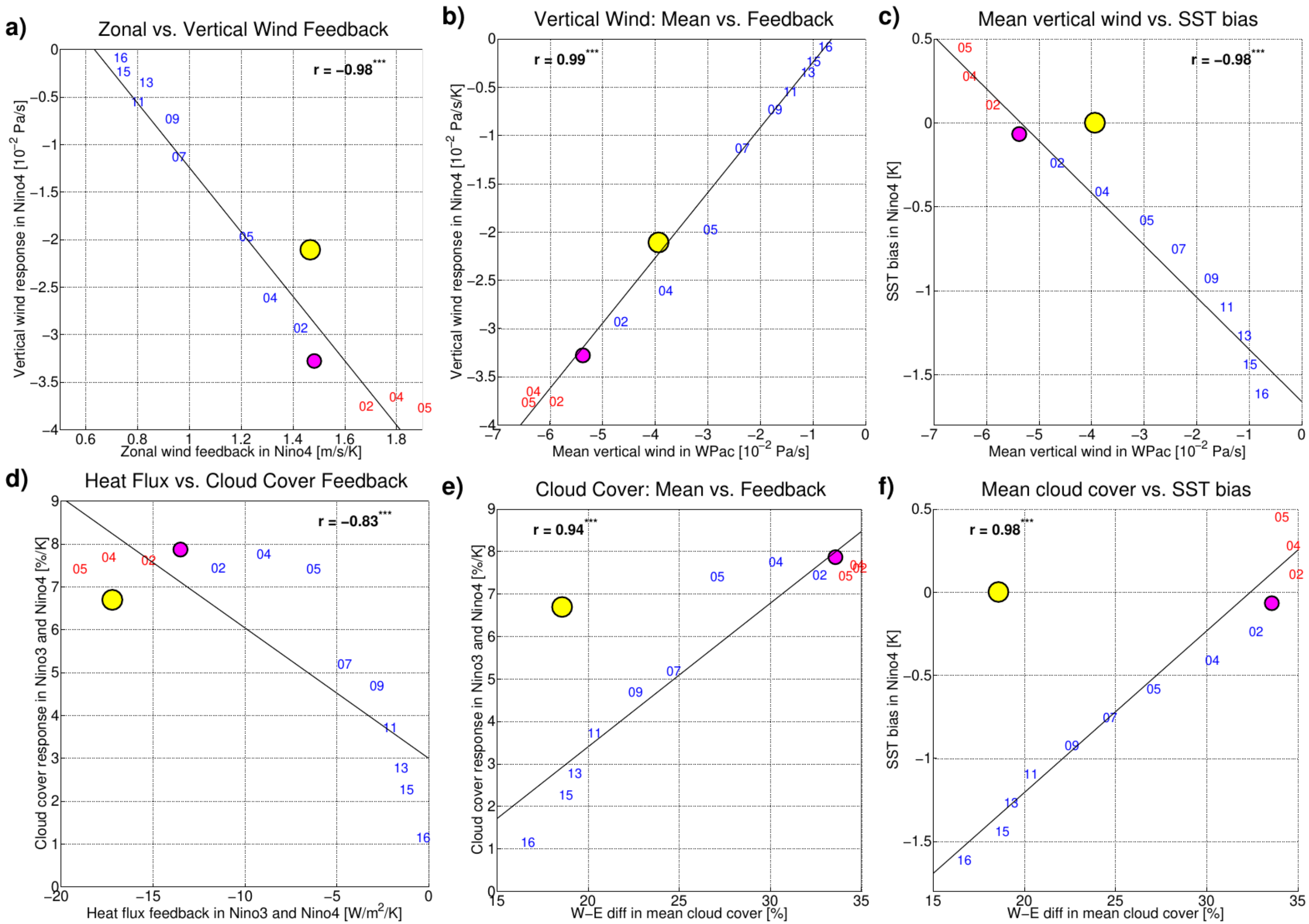
Cold/warm bias alters the atmospheric mean state



Dark(light) grey shading: spread in CMIP5(AMIP5)

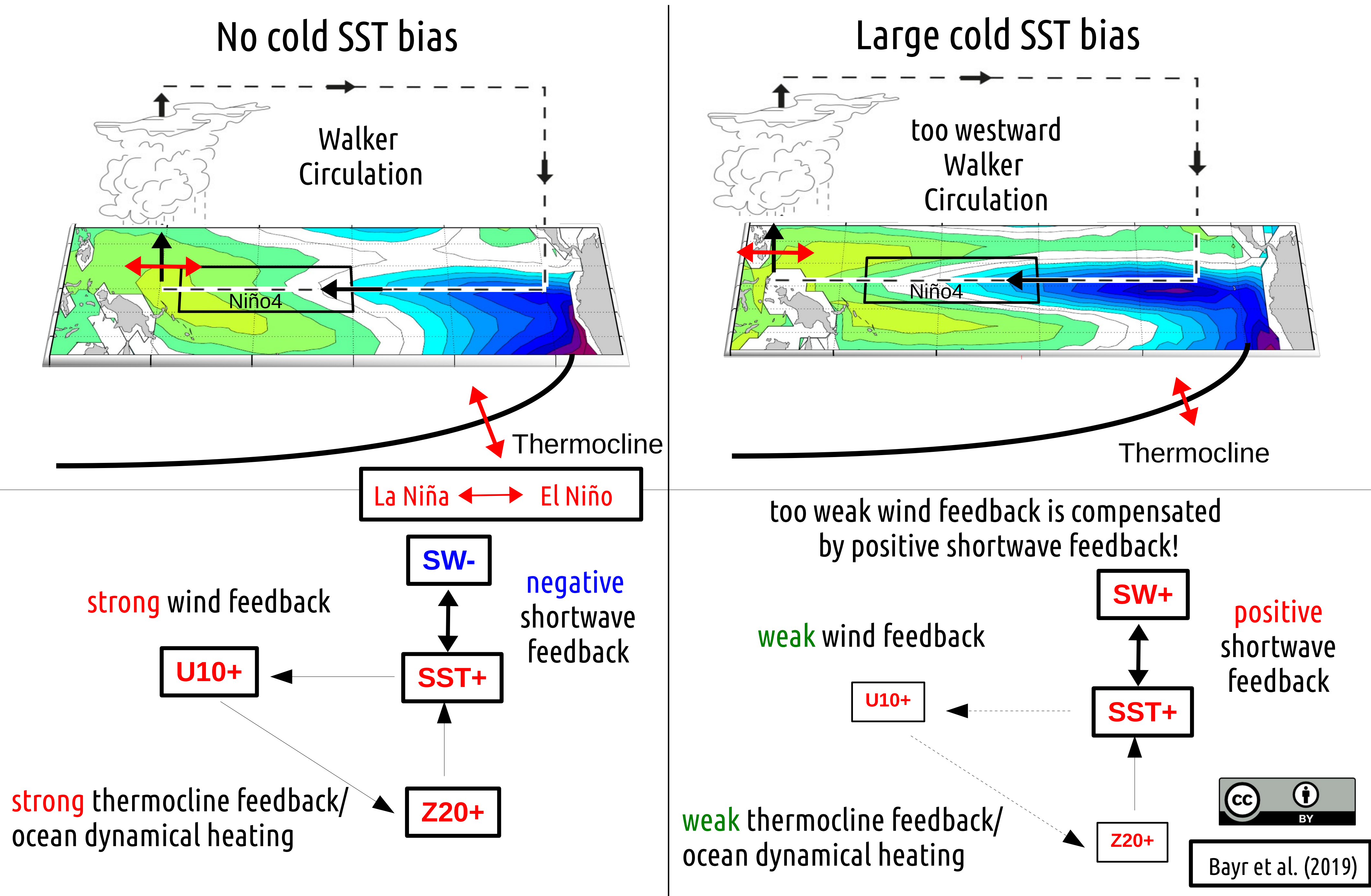
Bayr et al. (2020)

SST bias determines ENSO atmospheric feedback strength



Bayr et al. (2020)

Summary: Biased ENSO atmospheric feedbacks



Thank you for your attention!

Contact: Tobias Bayr (tbayr@geomar.de)

Further References:

- Bayr T, Latif M, Dommenget D, et al (2018) Mean-state dependence of ENSO atmospheric feedbacks in climate models. Clim Dyn 50:3171–3194. https://doi.org/10.1007/s00382-017-3799-2

- Bayr, T., C. Wengel, M. Latif, D. Dommenget, J. Lübbecke, and W. Park, 2019: Error compensation of ENSO atmospheric feedbacks in climate models and its influence on simulated ENSO dynamics. Clim. Dyn., https://doi.org/10.1007/s00382-018-4575-7

GEOMAR