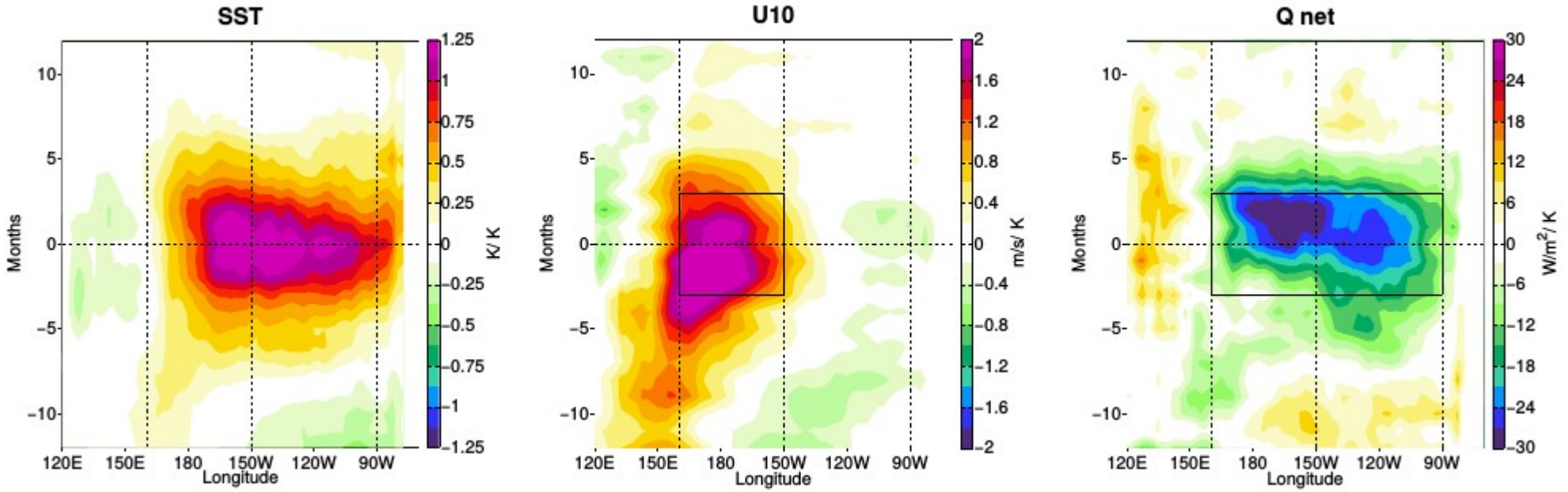
The mean state dependence of ENSO atmospheric feedbacks and ENSO dynamics in climate models



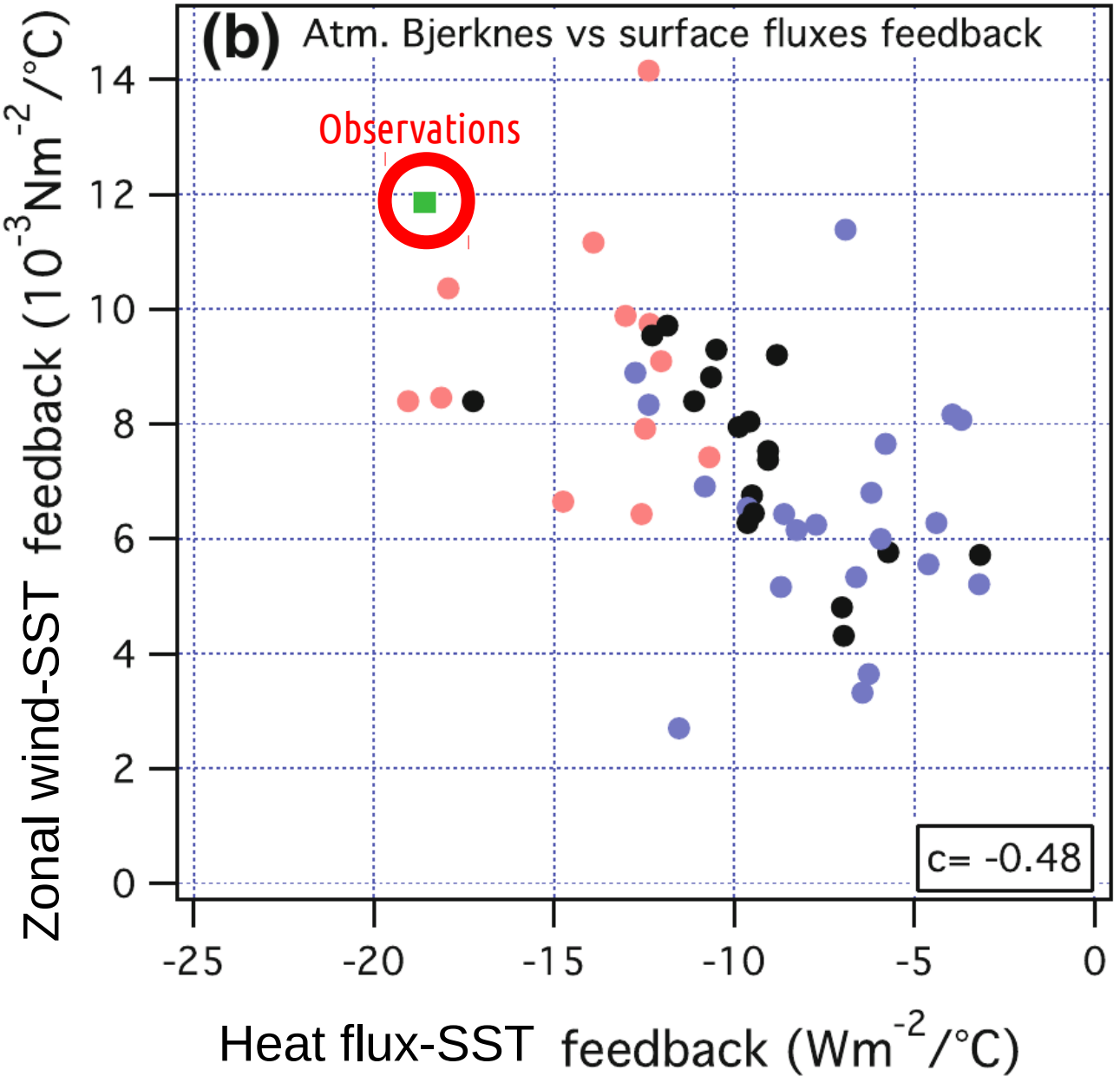
Tobias Bayr, Mojib Latif, Joke Lübbecke, Dietmar Dommenget, Christian Wengel,

Jan Harlaß and Wonsun Park

GEOMAR Kiel, Germany

GEOMAR

Motivation: Underestimated ENSO Atmospheric Feedbacks in CMIP3 and CMIP5



Most CMIP3 and CMIP5 models underestimate Wind-SST feedback and Heat flux-SST feedback

=> Compensating Error?

Red: convective in Nino3
Black: conv./sub. in Nino3
Blue: subsiding in Nino3

Bellenger et al. (2014)

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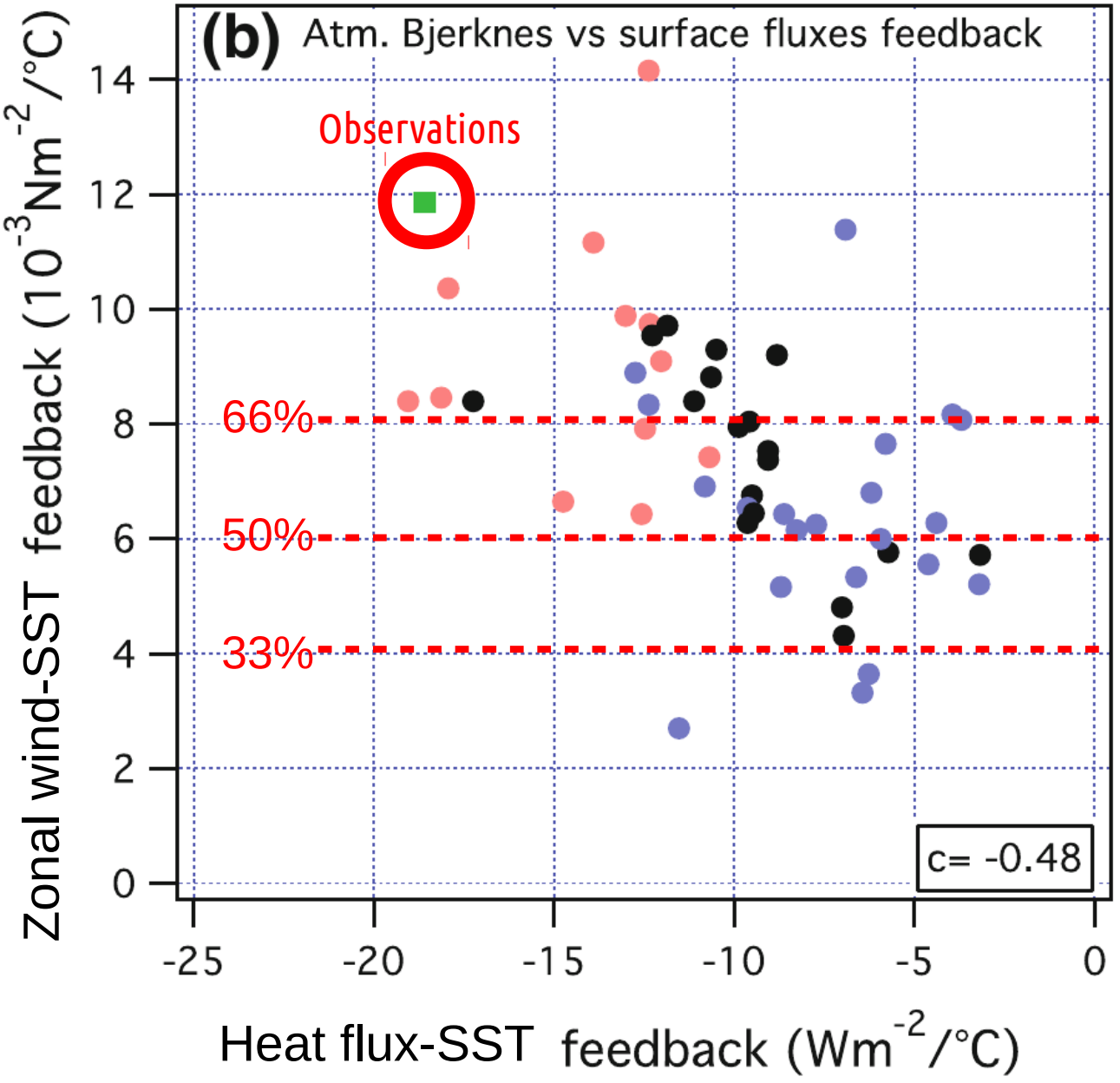

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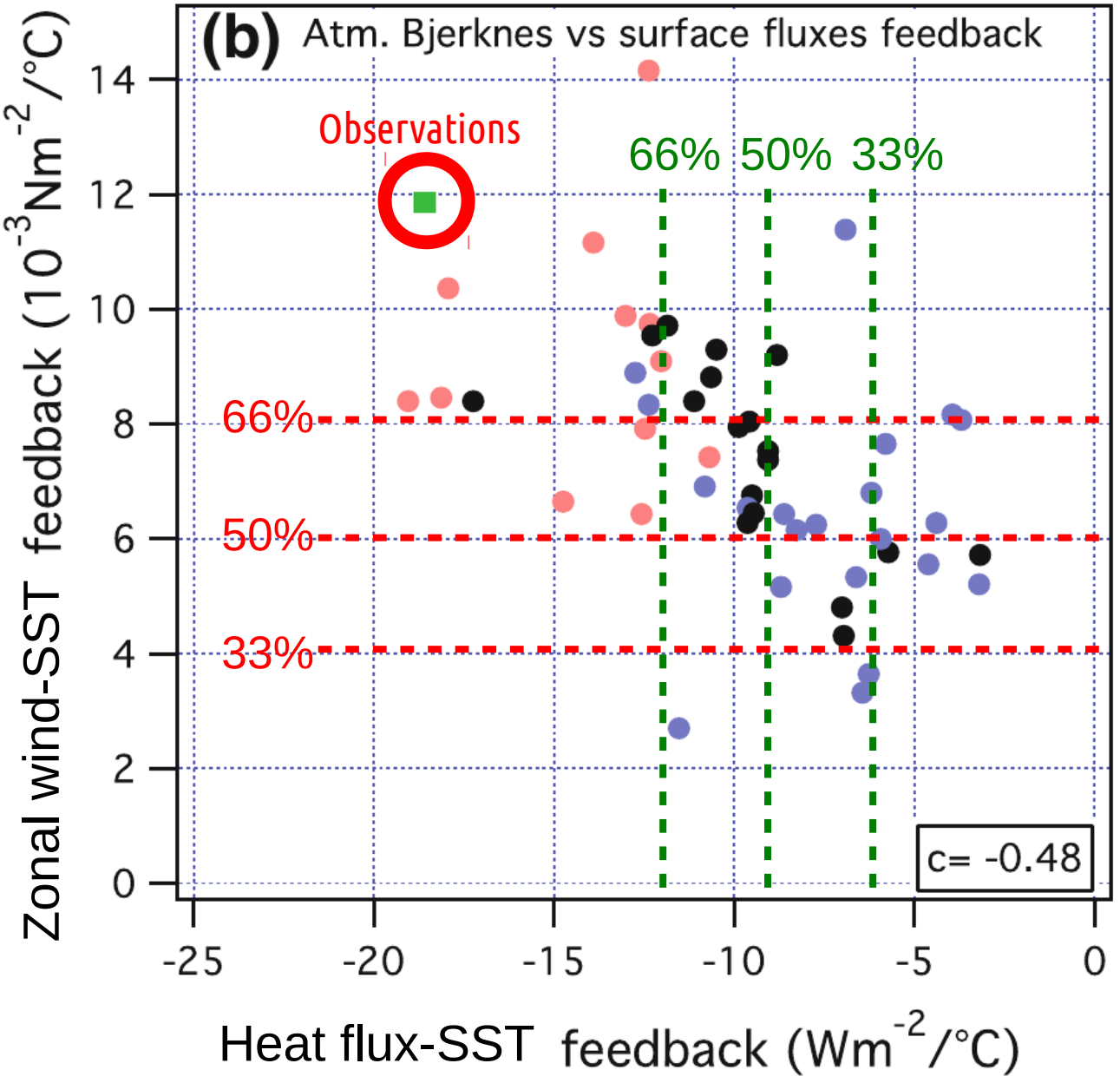

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=> Compensating Error?

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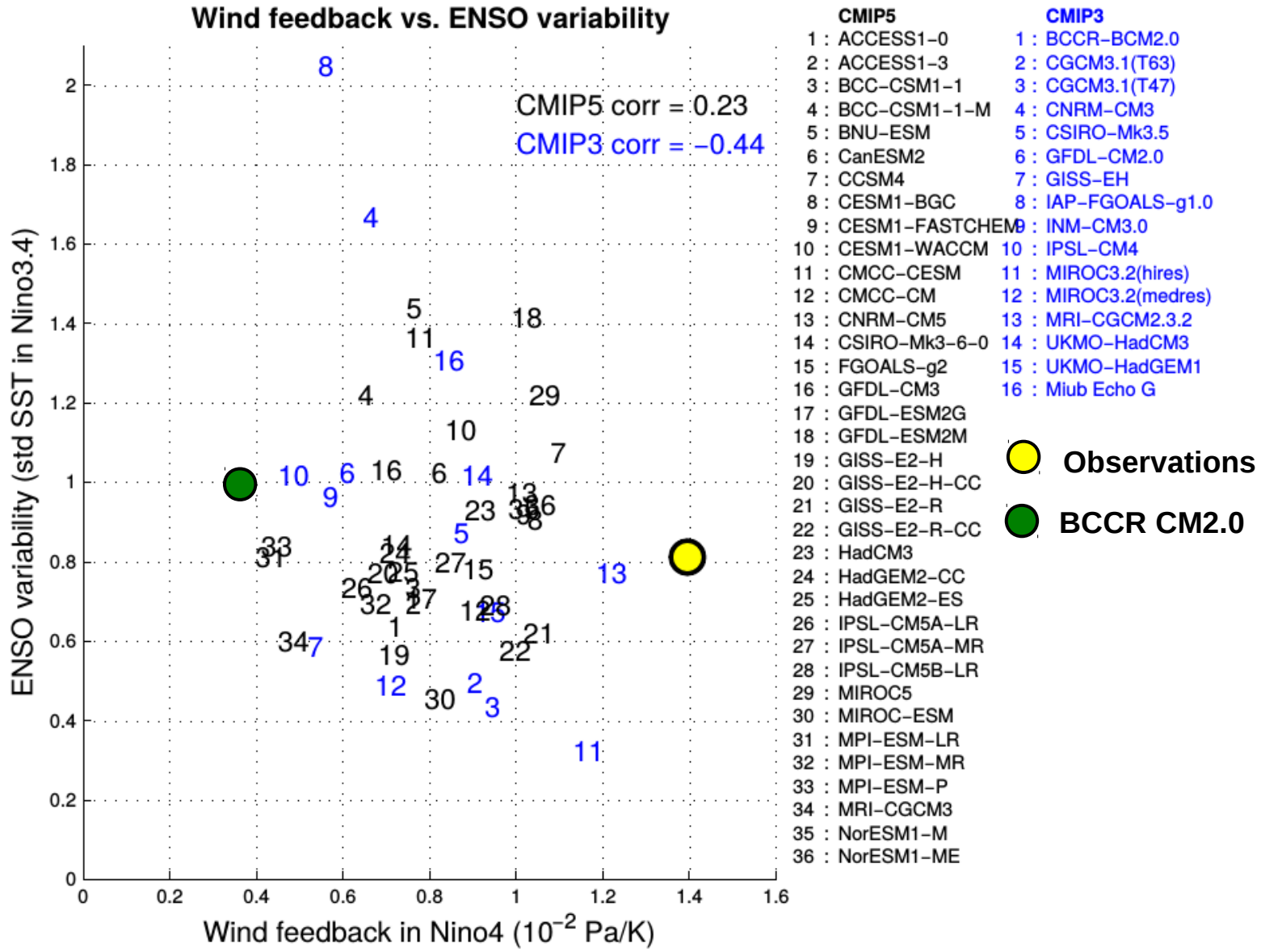
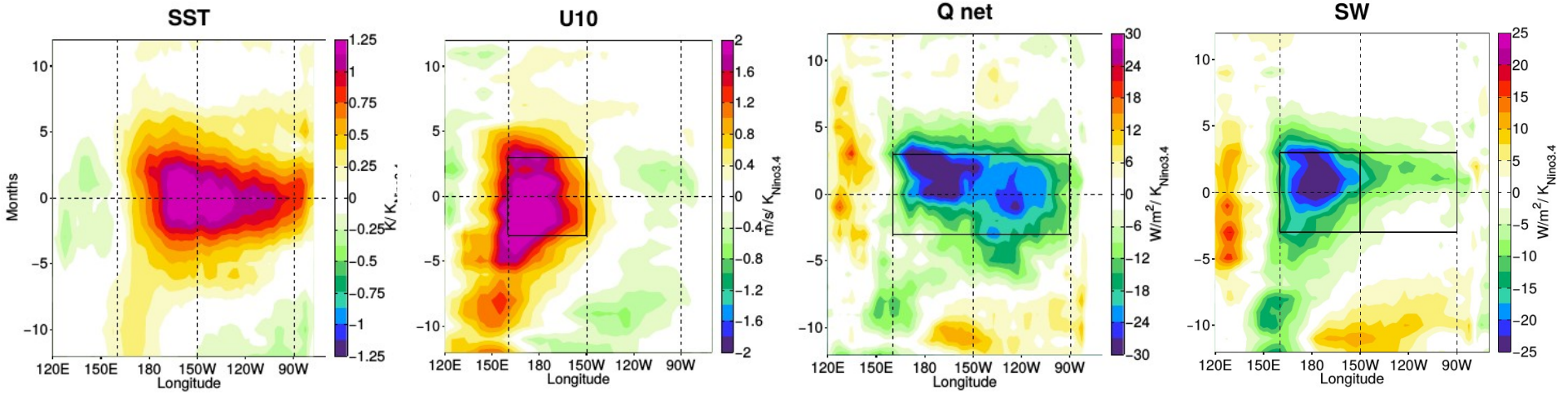
Bellenger et al. (2014)

Motivation: How can models have a realistic ENSO amplitude with strongly underestimated wind feedbacks ?



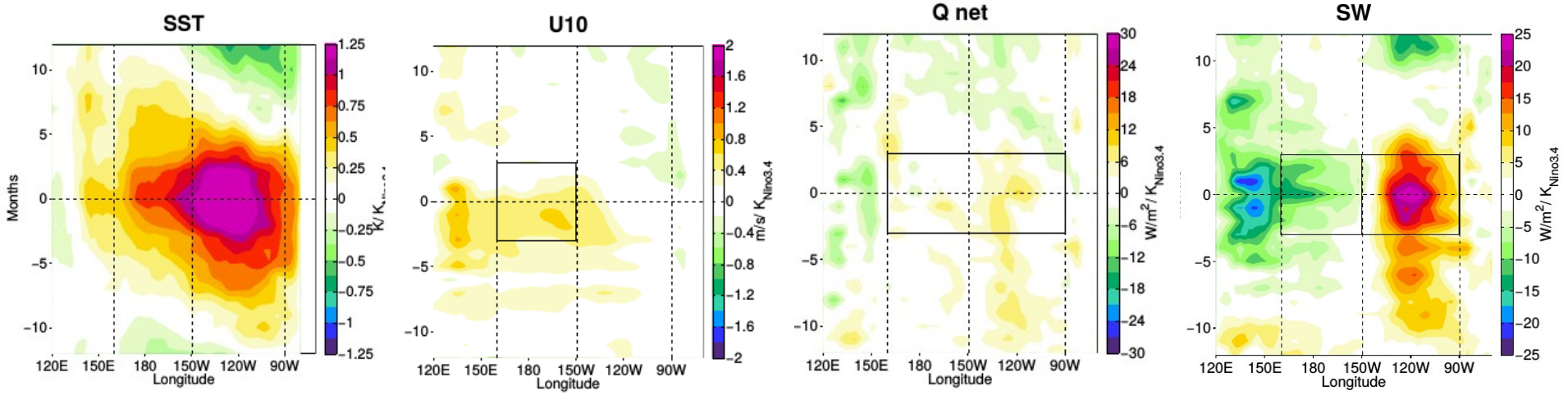
ENSO Hoevmoeller composites
(normalised with Niño3.4 SST)

Observations



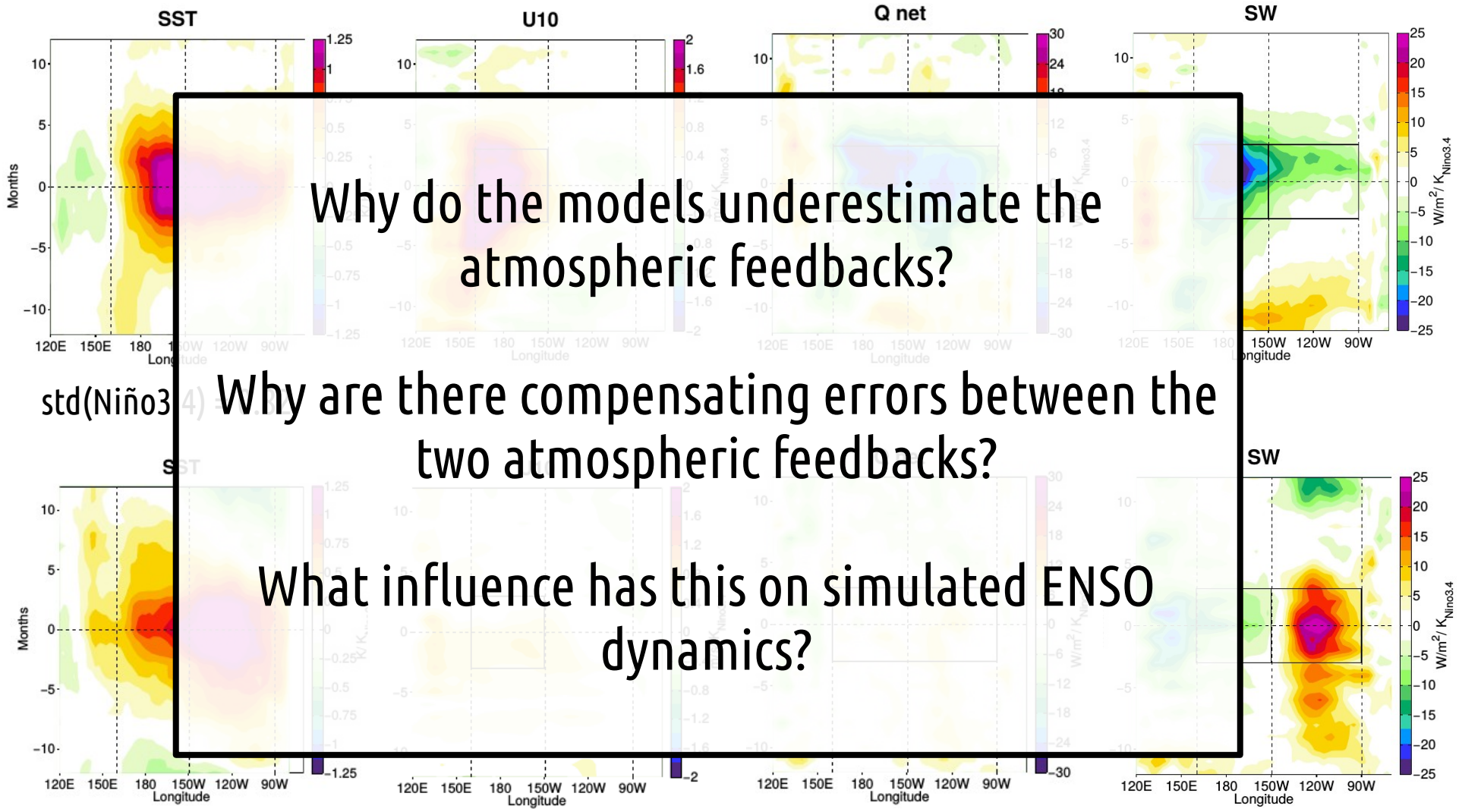
std(Niño3.4) = 0.82

BCCR BCM2.0



std(Niño3.4) = 0.98

ENSO Hoevmoeller composites
(normalised with Niño3.4 SST)



Why do the models underestimate the atmospheric feedbacks?

Why are there compensating errors between the two atmospheric feedbacks?

What influence has this on simulated ENSO dynamics?

Data of Obs, CMIP5 and KCM

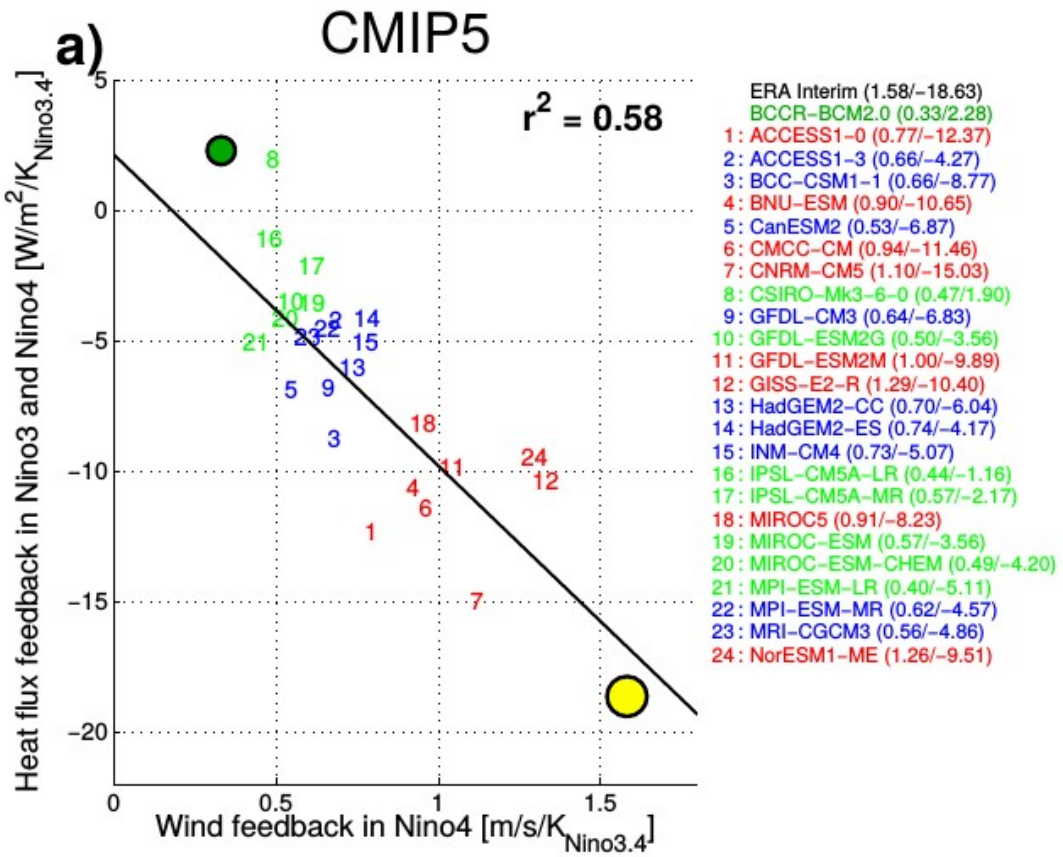
- Observations and reanalysis data:
  HadISST, ERA40, ERA Interim and SODA reanalysis

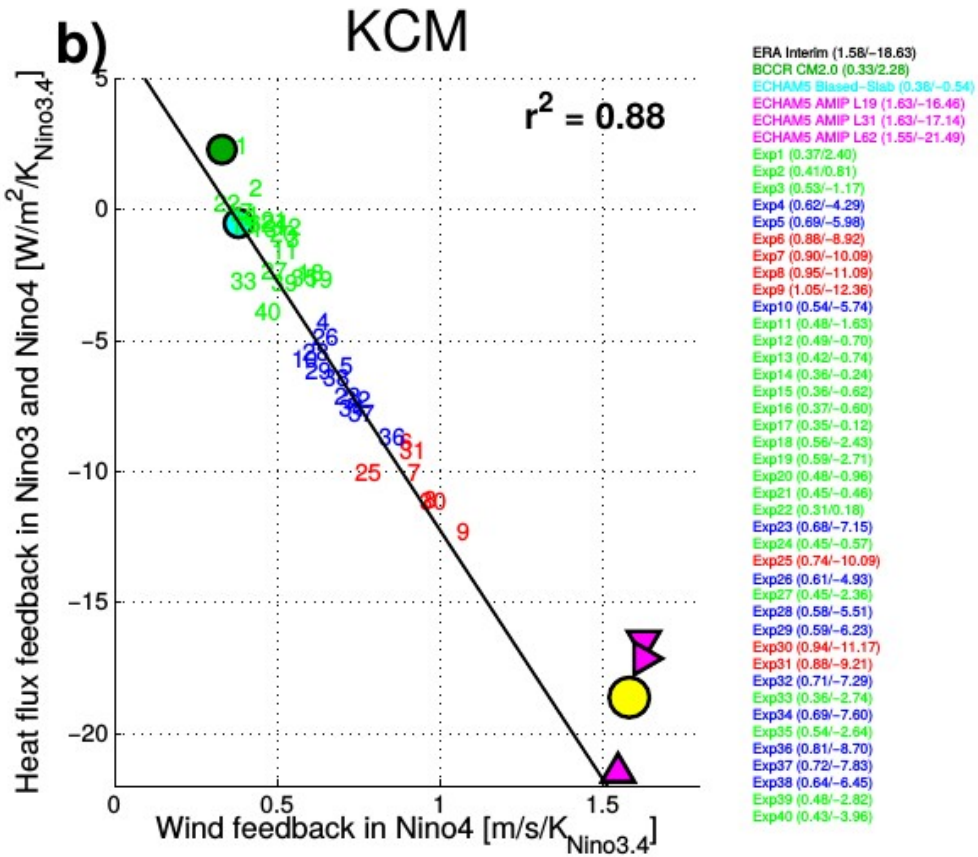
- Multimodel ensemble of 24 models of CMIP5 data base,
  historical simulations (1900-1999)

- Perturbed physics ensemble of the Kiel Climate Model (KCM) 1.4.0 with
  - ECHAM5 with T42 (2.8°x2.8°)
  - Nemo Orca2 (~2°x2°)
  - 40 different sets of convection parameters (= tuning parameters)
    based on Mauritsen et al. (2012) => 40 different mean states

Multi model ensemble of CMIP5 and perturbed physics ensemble of KCM

Zonal wind vs. net heat flux feedback in





BCCR CM2.0 **Reanalysis**

Bayr et al. (2017), Clim Dyn

Multi model ensemble of CMIP5 and perturbed physics ensemble of KCM

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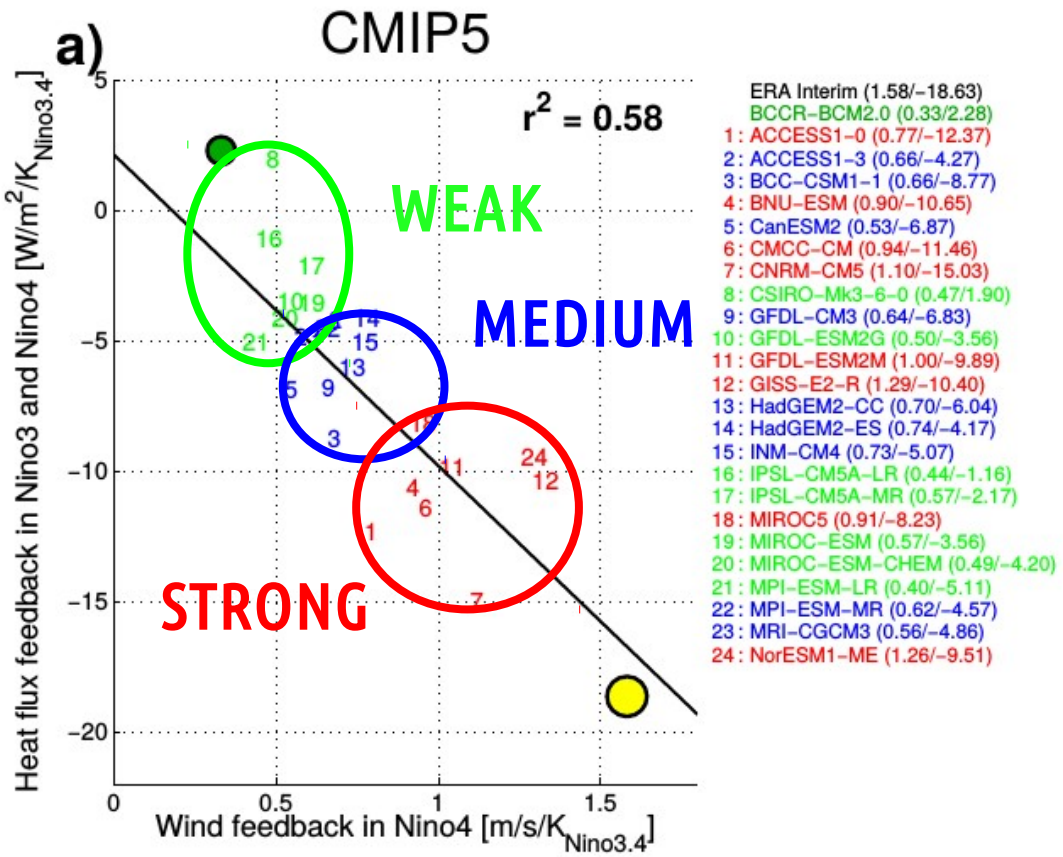
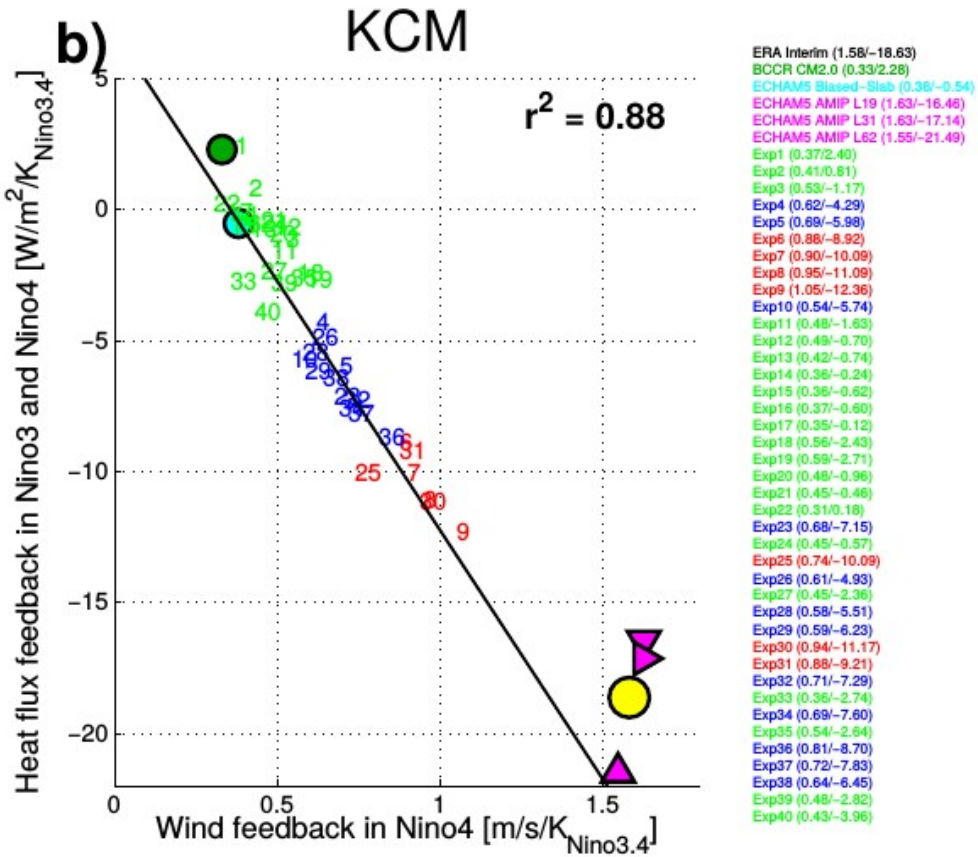
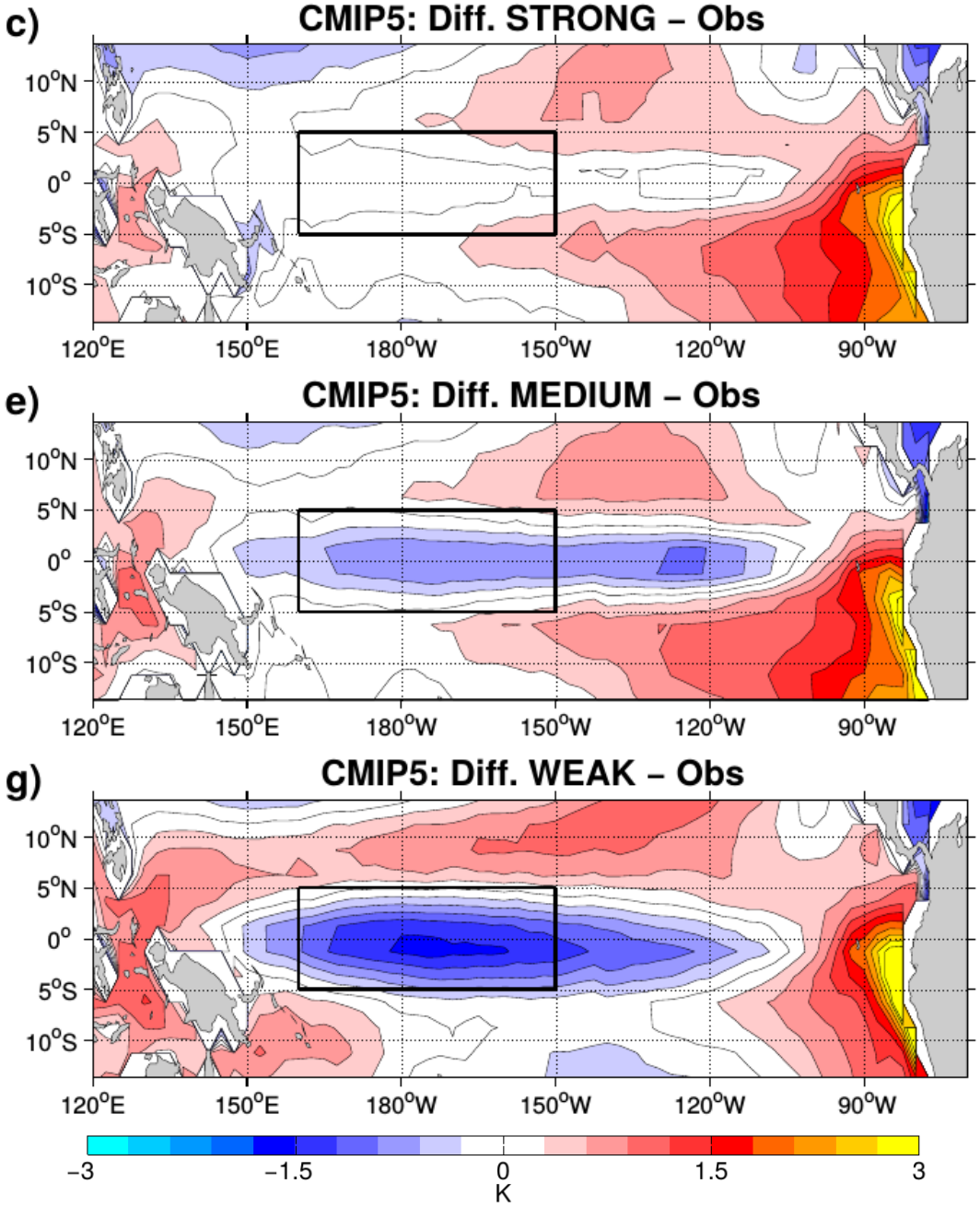




BCCR CM2.0 **Reanalysis**

Bayr et al. (2017), Clim Dyn

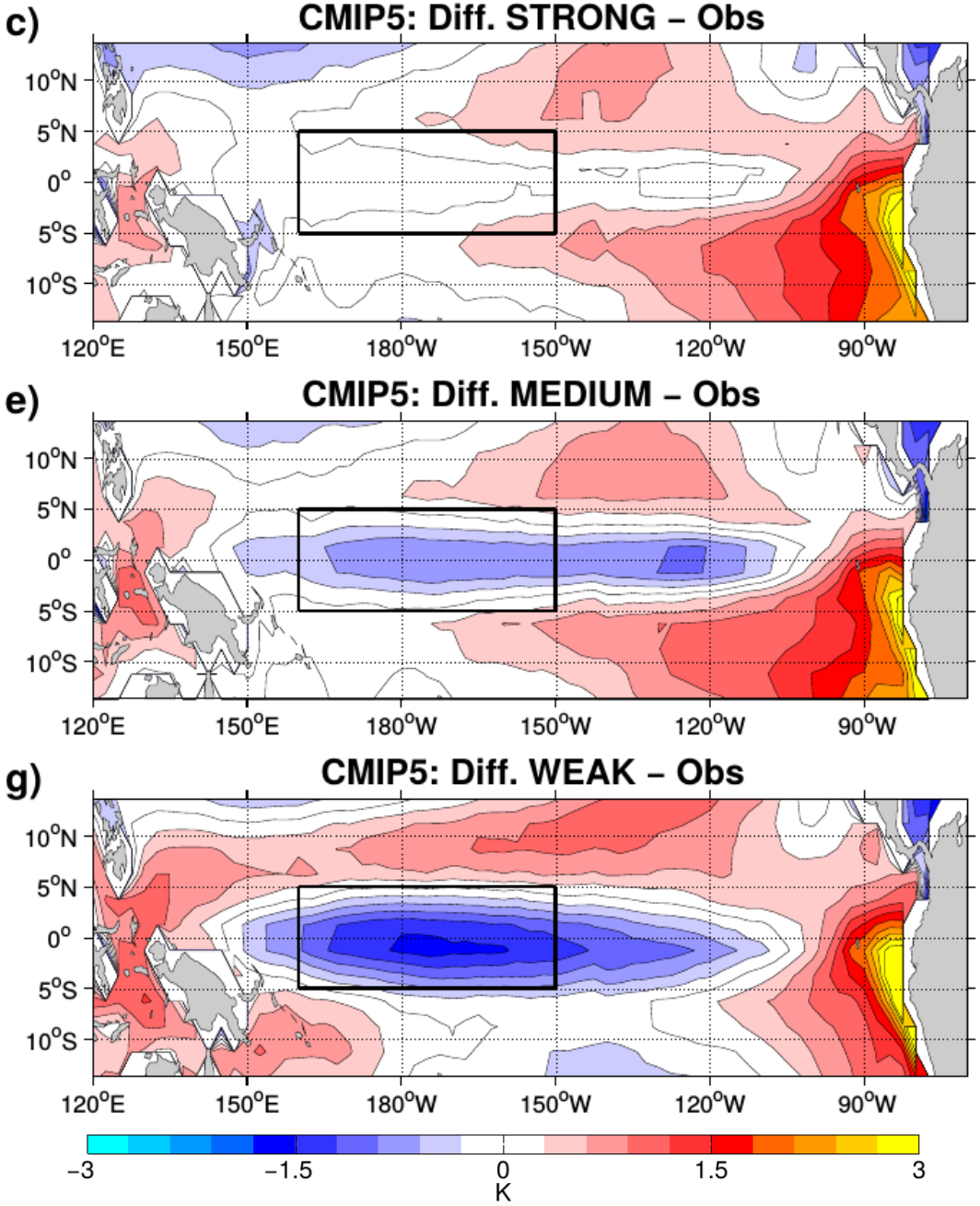
SST bias of STRONG, MEDIUM and WEAK



SST bias in the Nino4 region controls ENSO atmospheric feedbacks

Bayr et al. (2017), Clim Dyn

SST bias of STRONG, MEDIUM and WEAK



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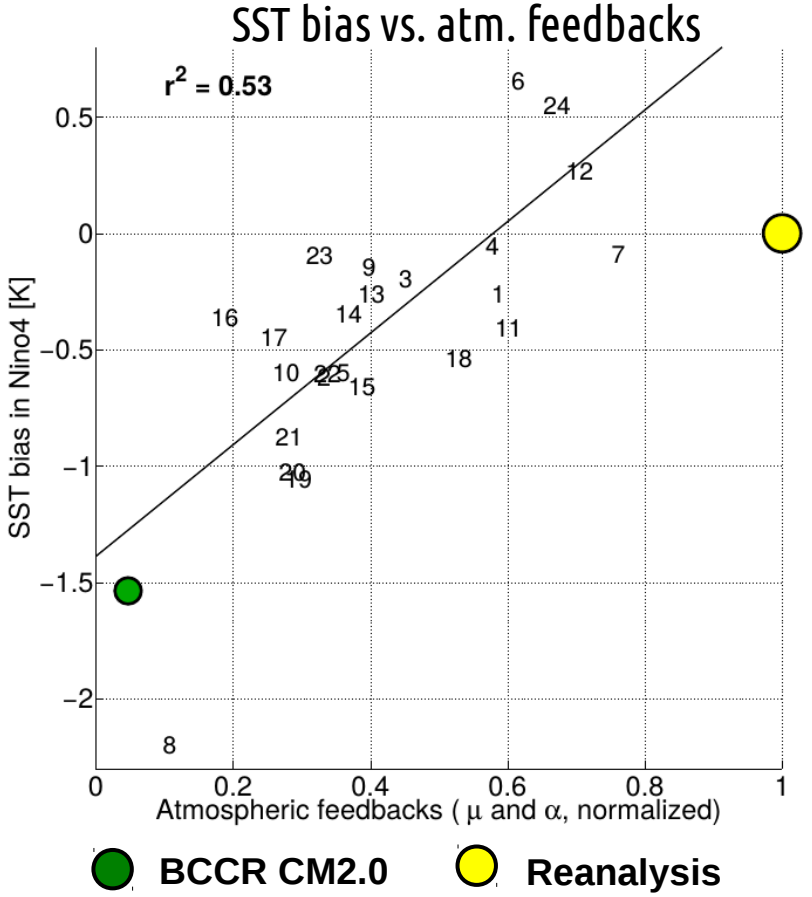
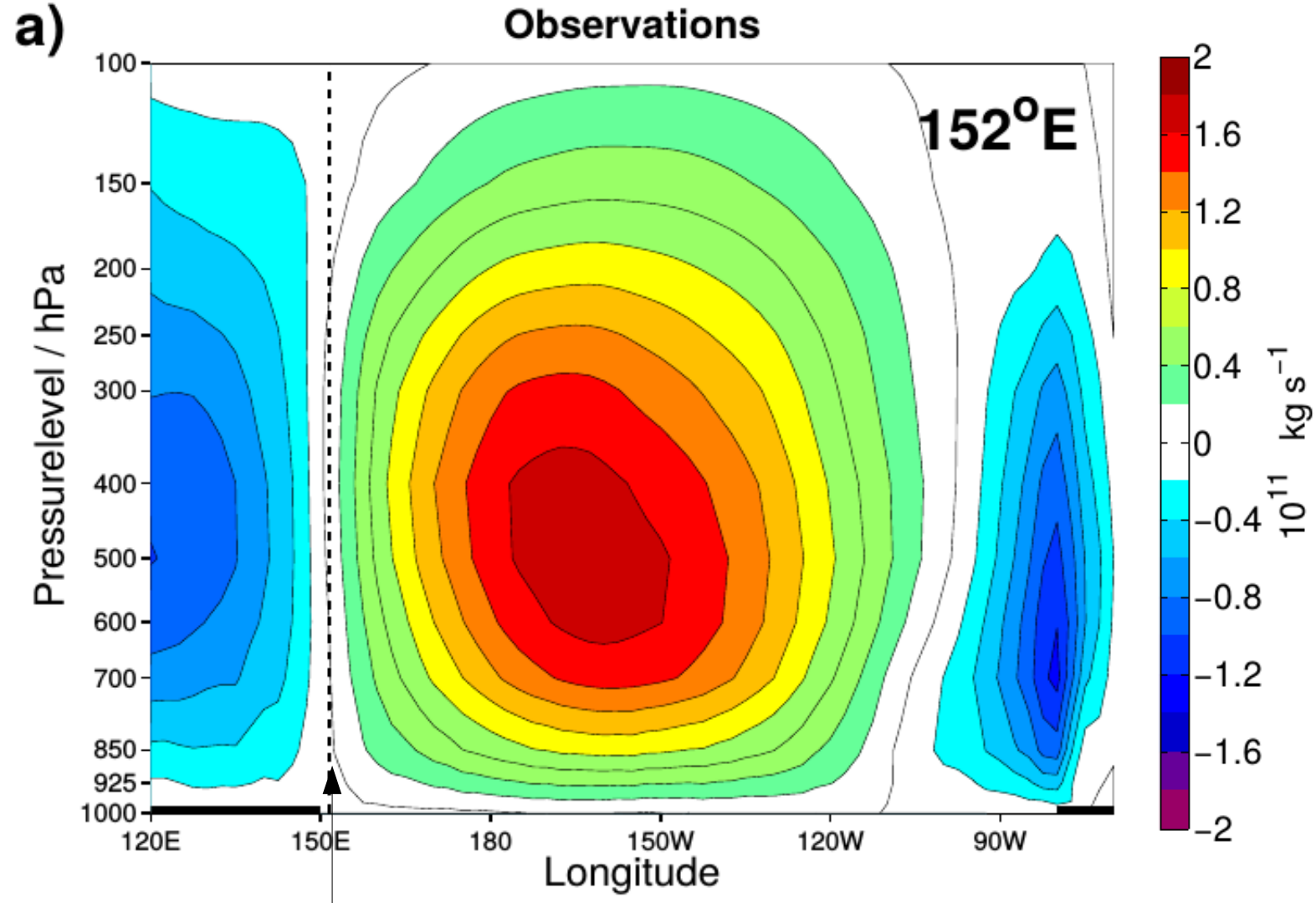


Bayr et al. (2017), Clim Dyn

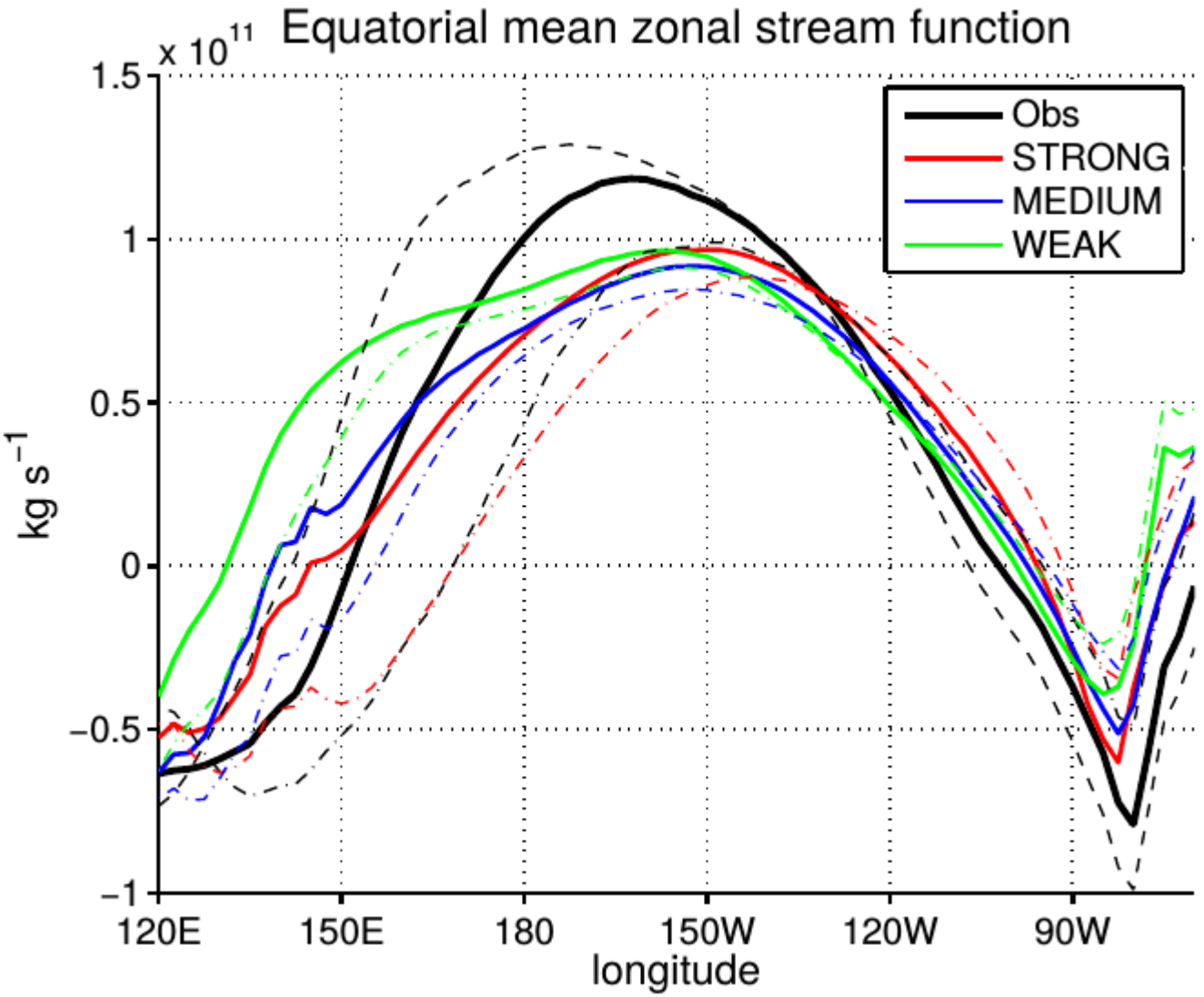
Walker Circulation & feedback strength



Rising branch of the Walker Circulation
= region of strongest convection

Bayr et al. (2017), Clim Dyn

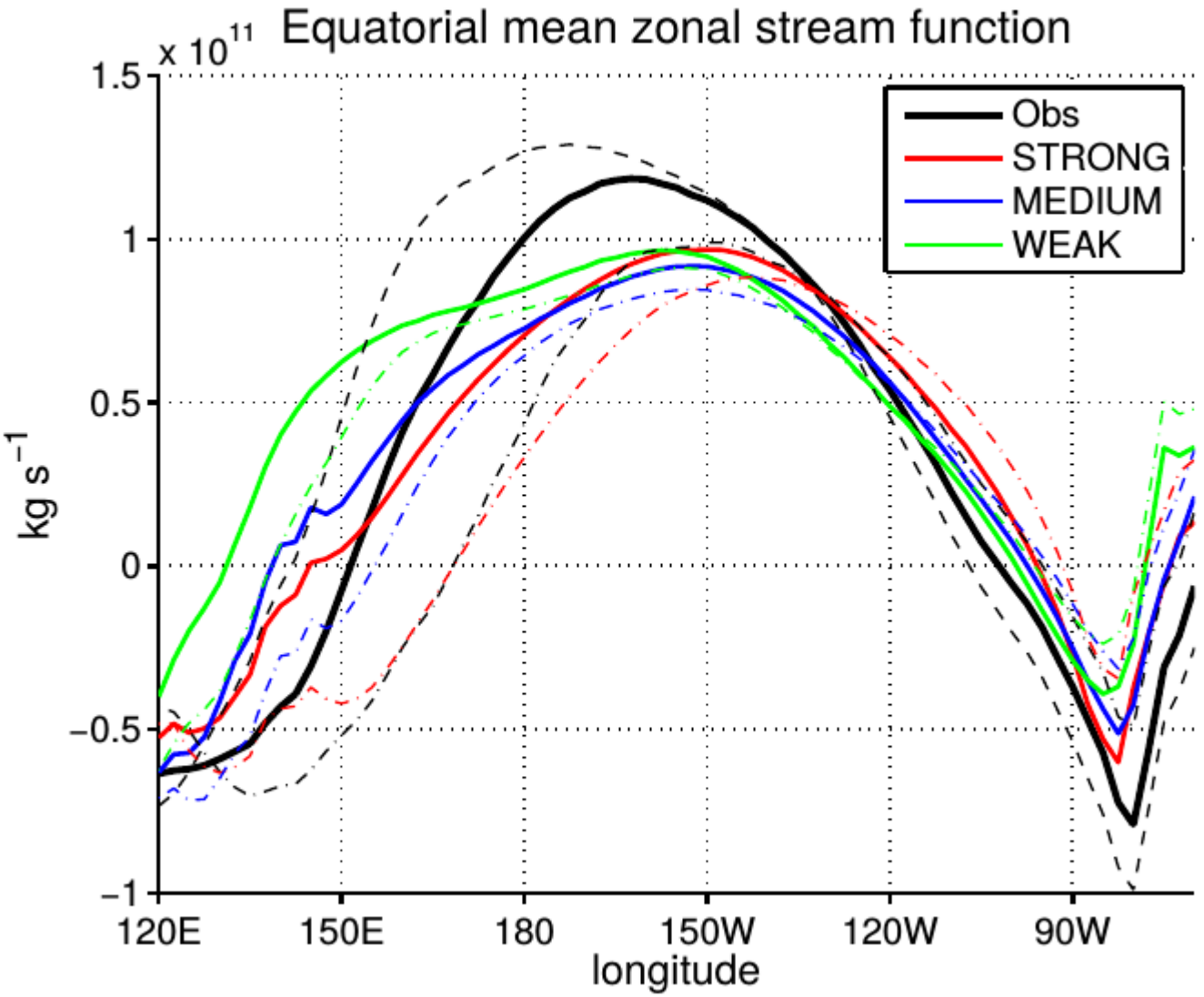
Walker Circulation & feedback strength

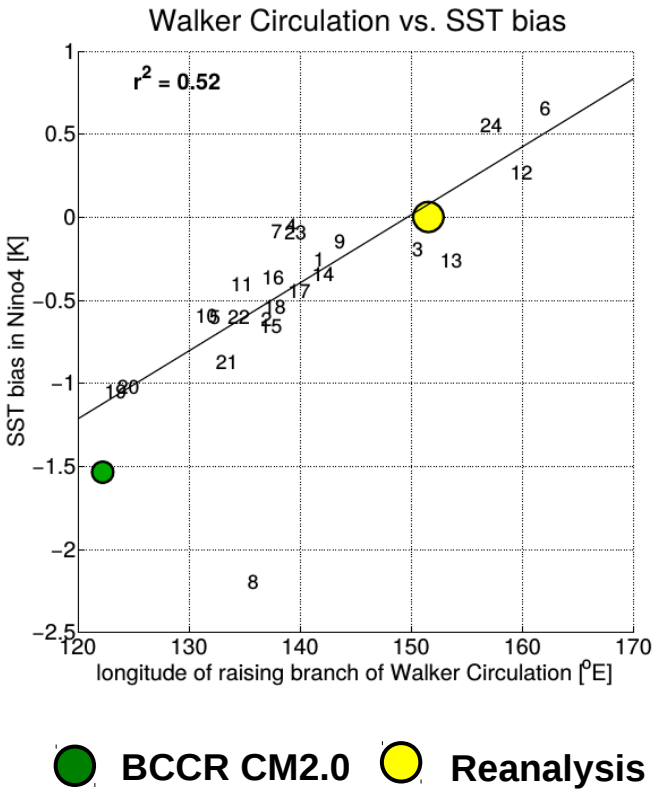


In WEAK the rising branch of the Walker Circulation is too far in the west

Bayr et al. (2017), Clim Dyn

Walker Circulation & feedback strength





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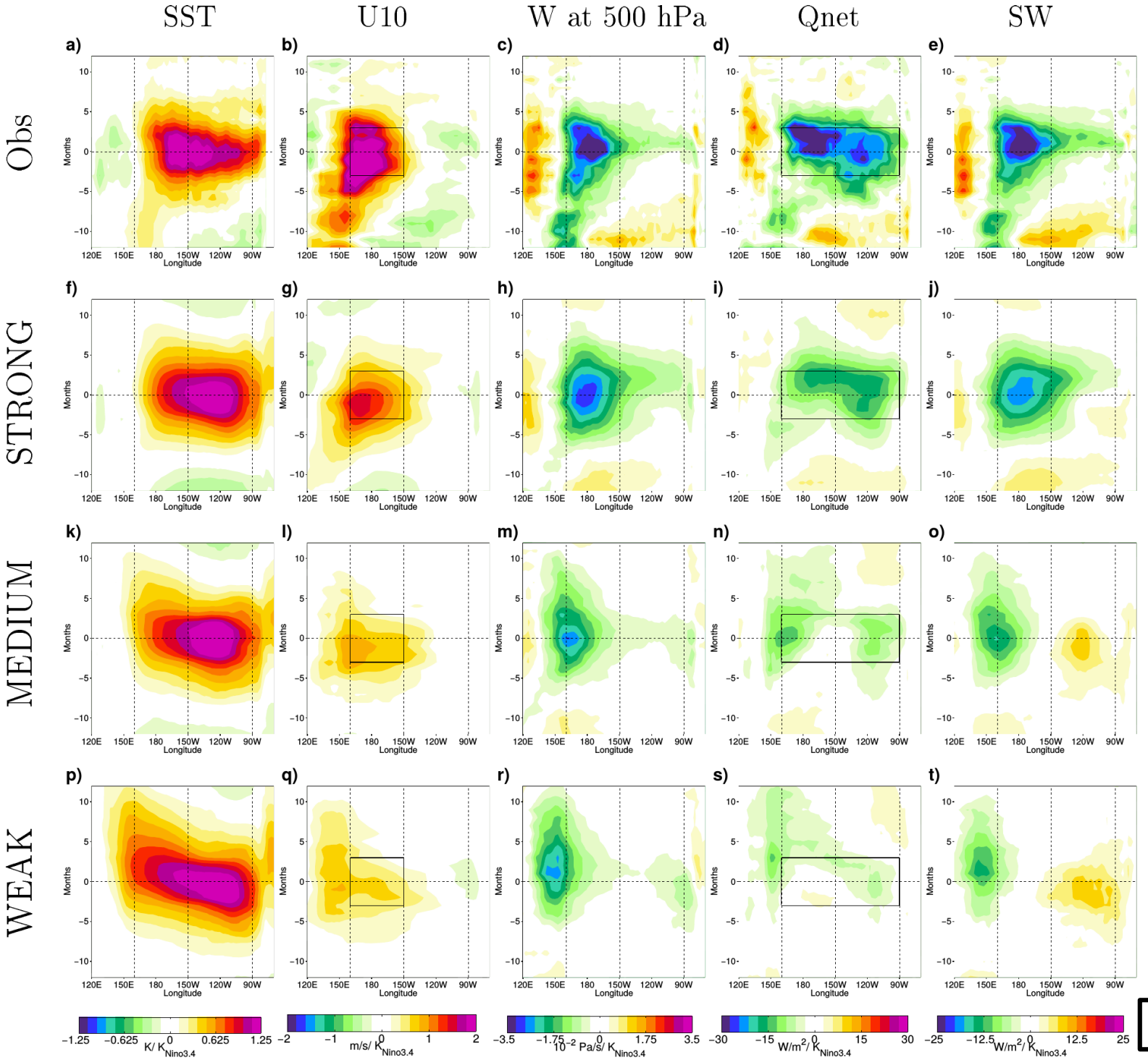
Bayr et al. (2017), Clim Dyn

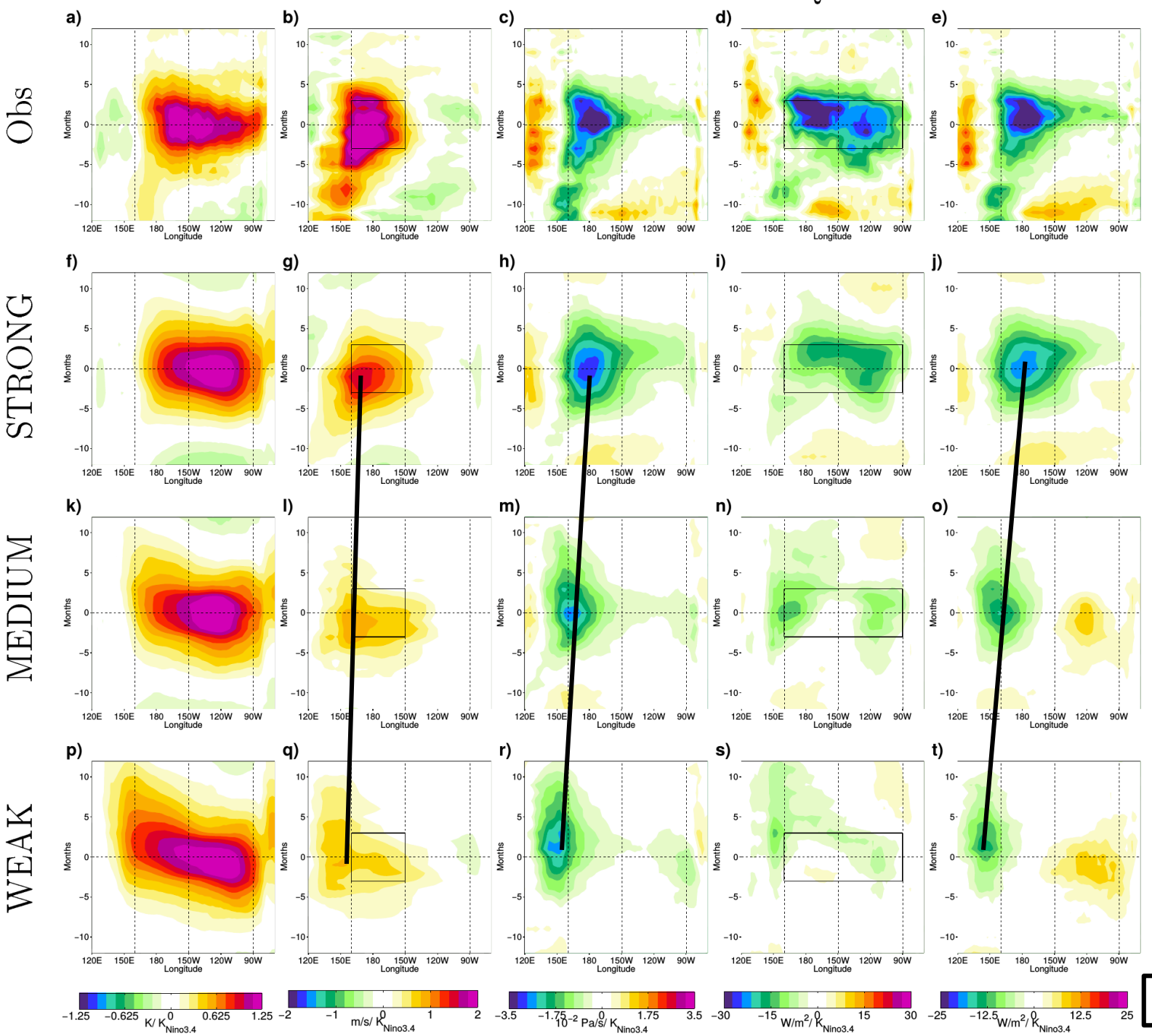
ENSO Composites in Obs and CMIP5



Convective response shifts to the west from STRONG to WEAK

Bayr et al. (2017), Clim Dyn

ENSO Composites in Obs and CMIP5



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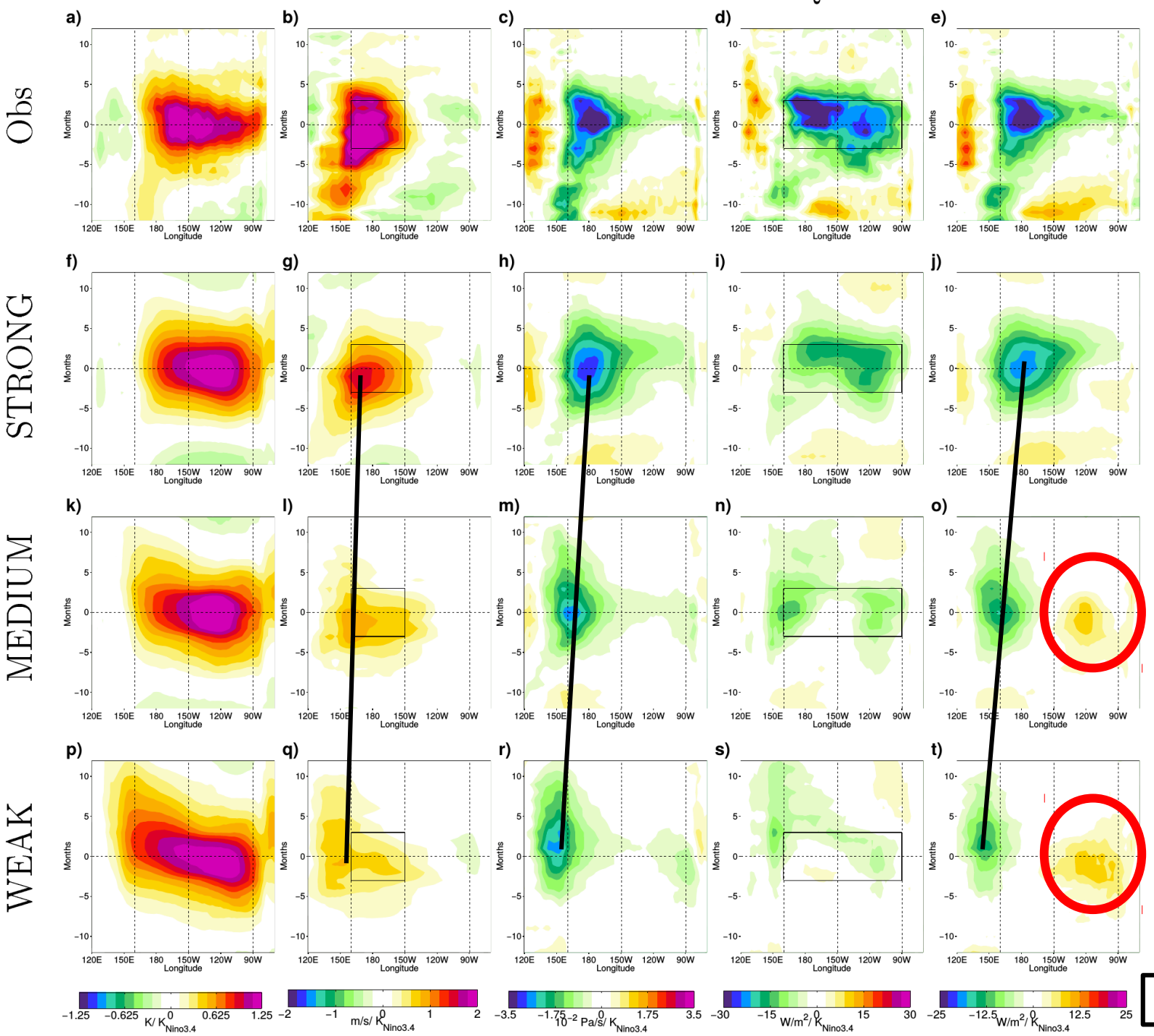
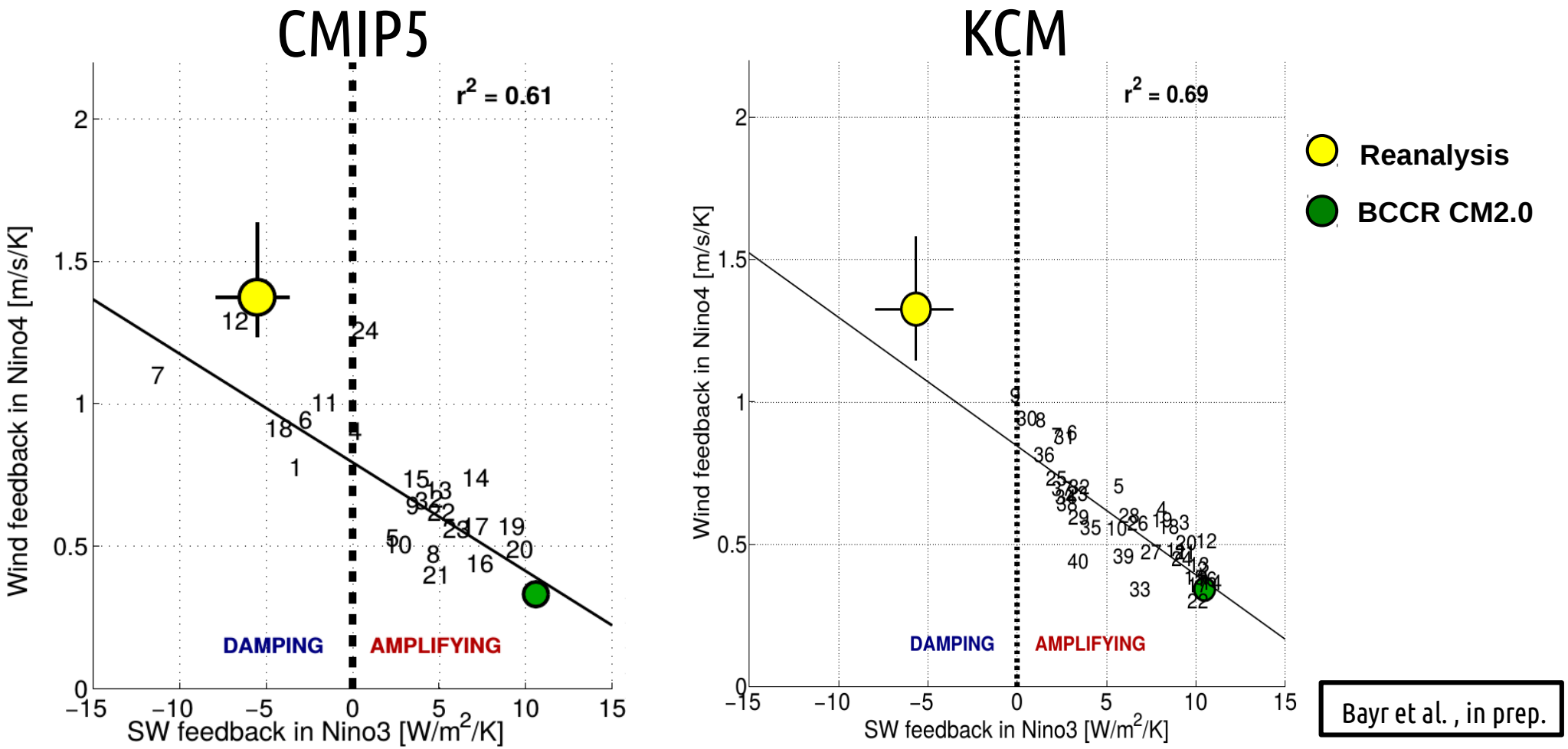


Convective response shifts to the west from STRONG to WEAK

Bayr et al. (2017), Clim Dyn

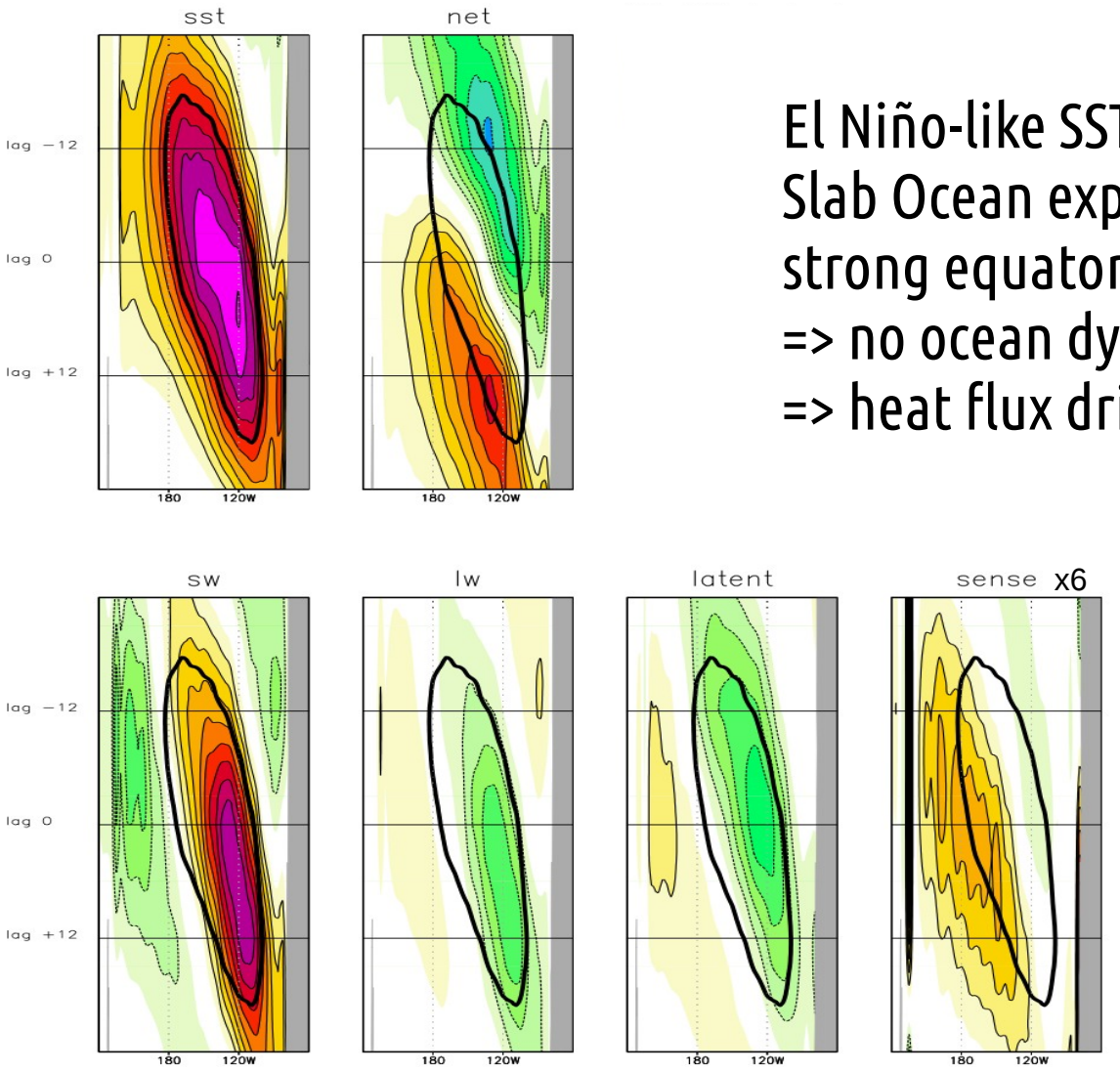
Wind-driven or short wave-driven ocean-atmosphere coupling?



gradual shift in ENSO dynamics!

=> a continuum of possible ENSO dynamics exists in the climate models!

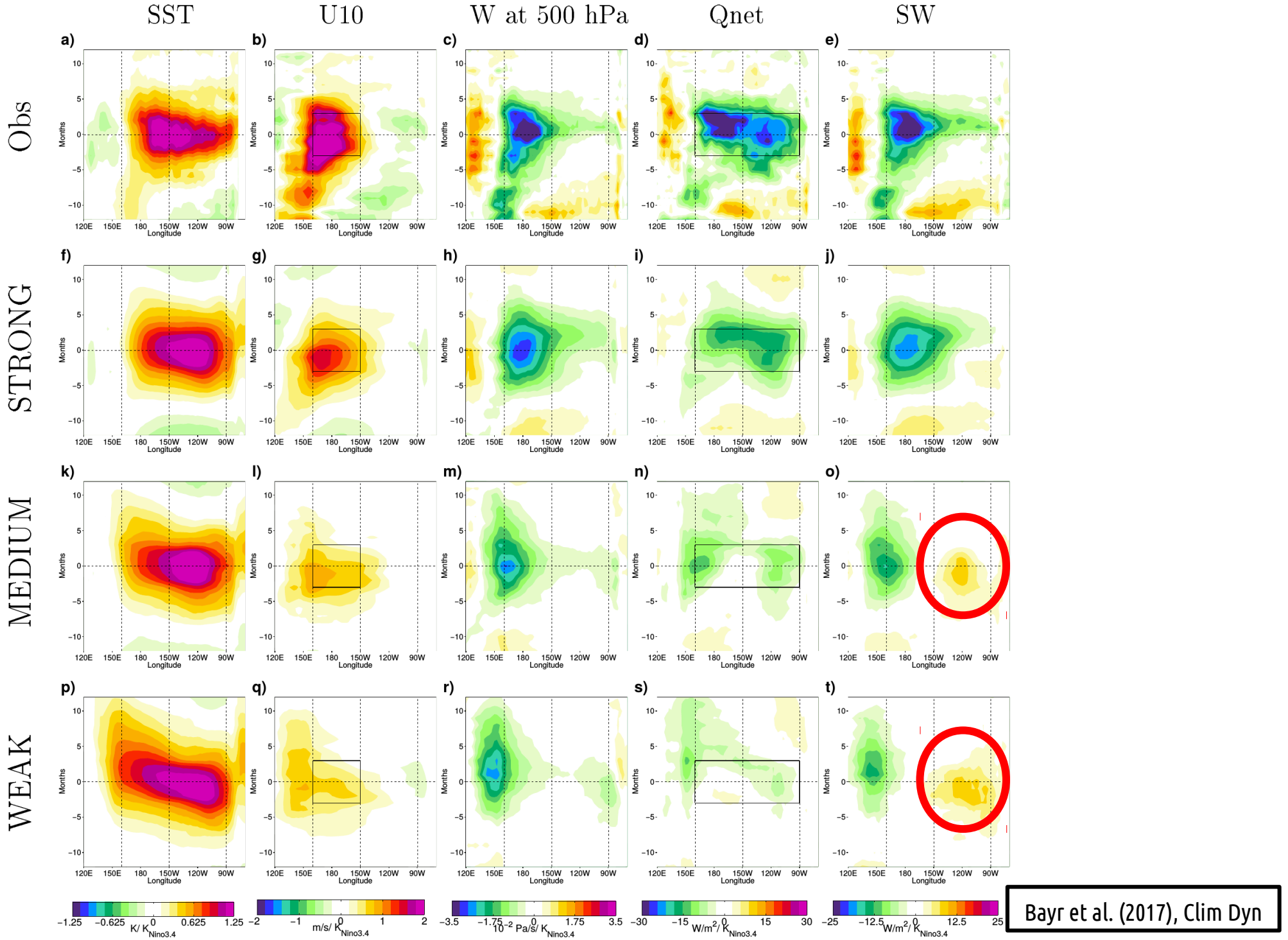
Heat Flux El Niño (or Slab Ocean El Niño)



El Niño-like SST variability in a Slab Ocean experiment with strong equatorial cold SST bias
=> no ocean dynamics
=> heat flux driven

Dommenget (2010)

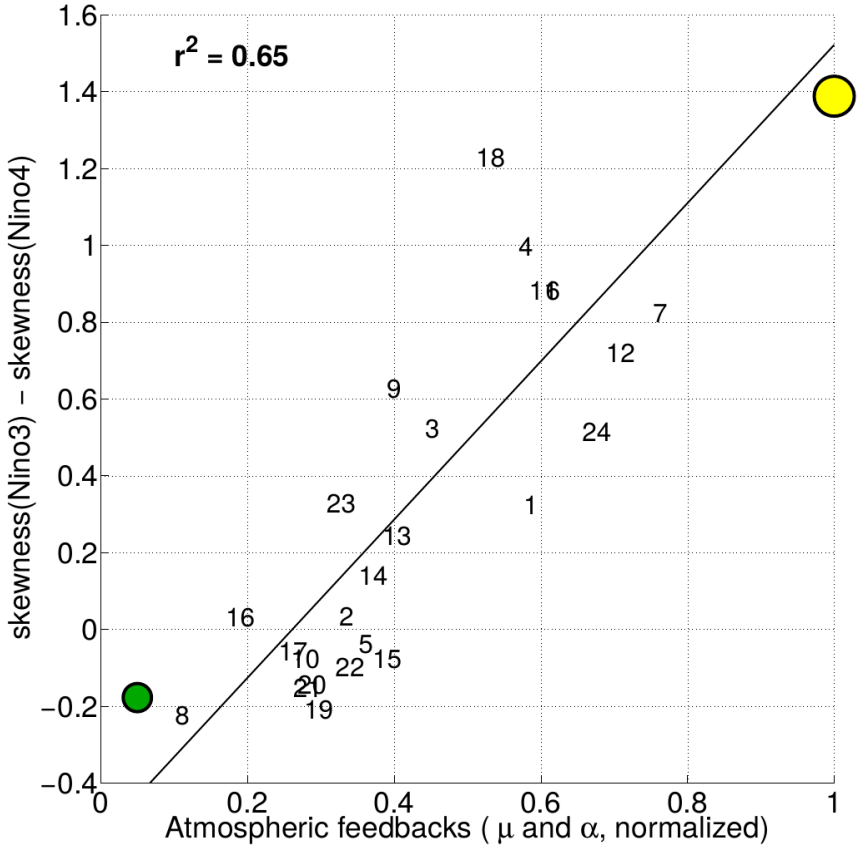
ENSO Composites in Obs and CMIP5



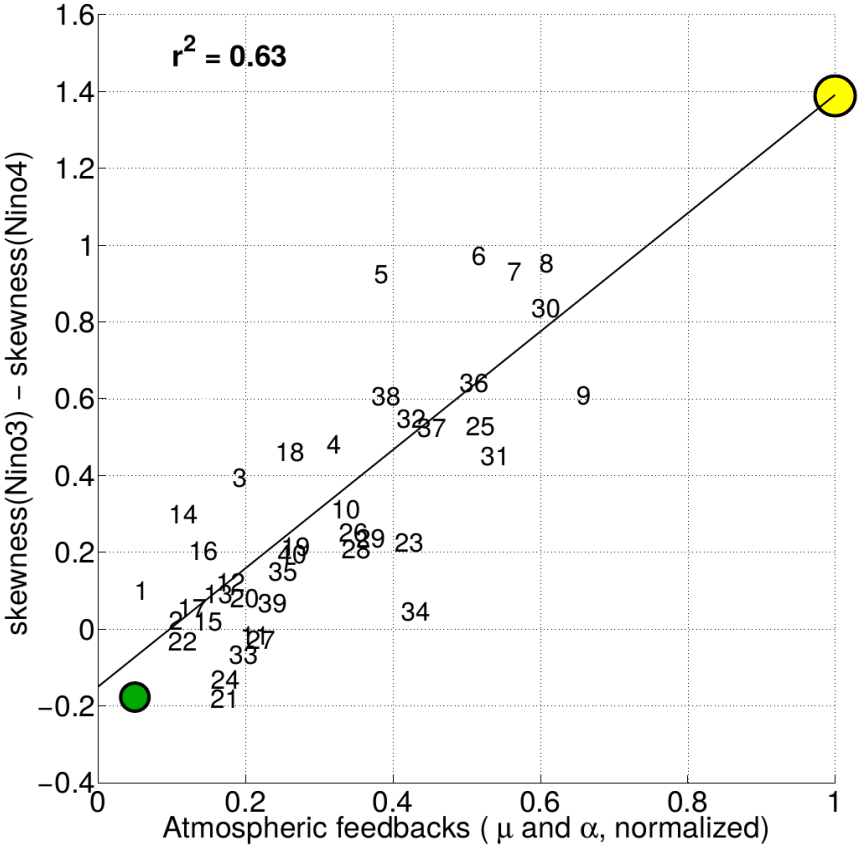
Bayr et al. (2017), Clim Dyn

Influence of atmospheric feedbacks on ENSO asymmetry

CMIP5



KCM



Stronger atm. feedbacks lead to a more realistic ENSO asymmetry!

Bayr et al. (2017), Clim Dyn

Summary

Why do the models underestimate the atmospheric feedbacks?

The cold SST bias shifts the rising branch of the Walker Circulation to the west

Why are there compensating errors between the two atmospheric feedbacks?

The wind and the short-wave feedback both depend on the position of the rising branch of the Walker Circulation

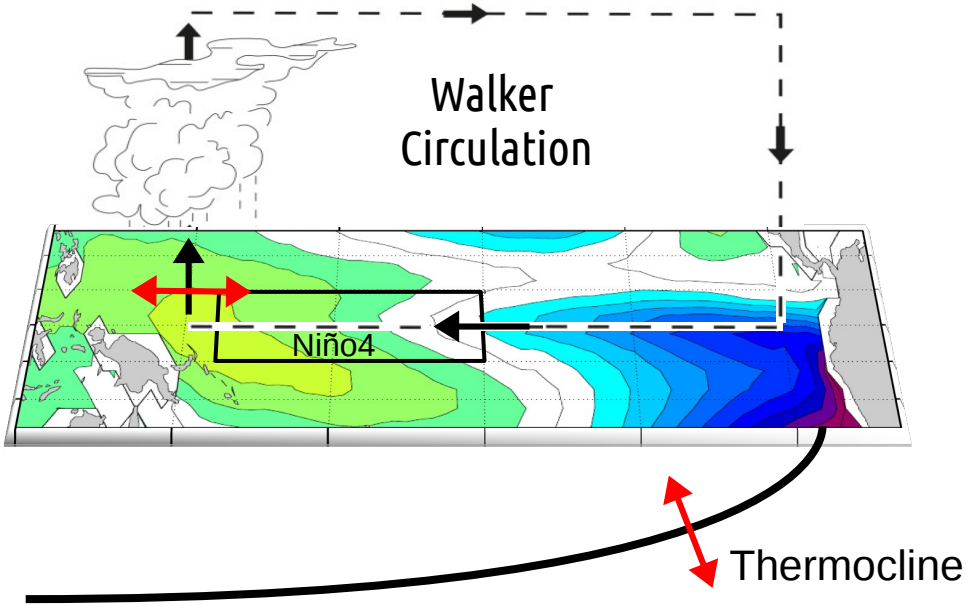
What influence has this on simulated ENSO dynamics?

This shifts ENSO dynamics from a wind-driven mode into a partly short-wave-driven mode => the models do the right thing for the wrong reasons!

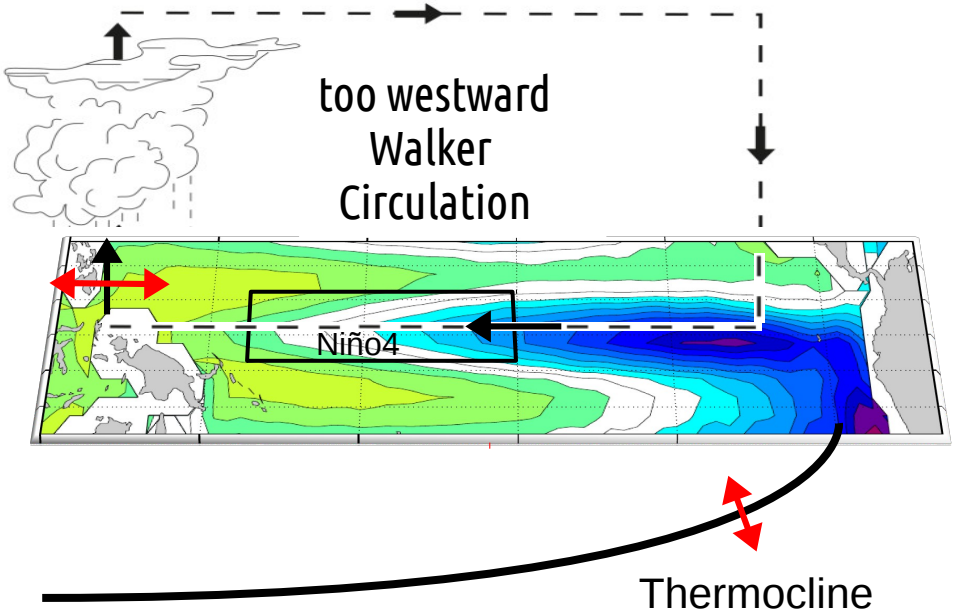
La Niña ⟷ El Niño

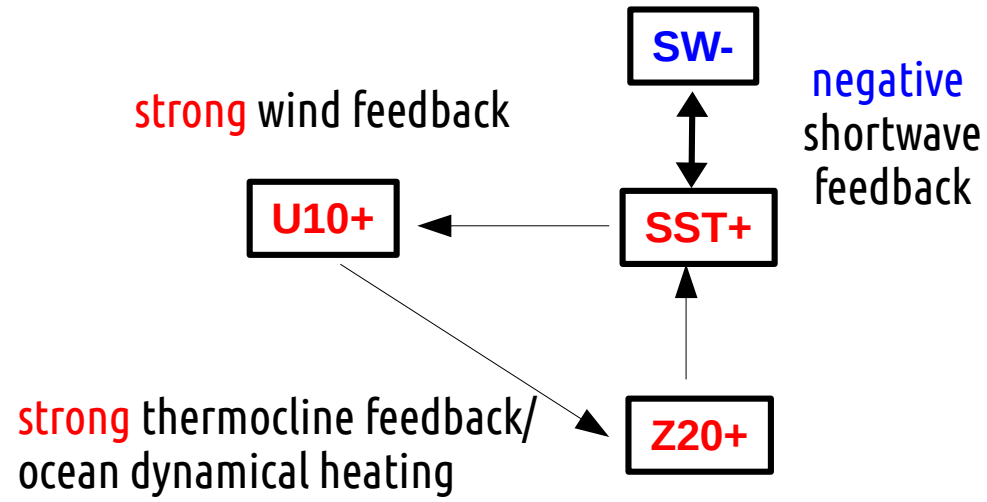
Thank you for your attention!

No cold SST bias

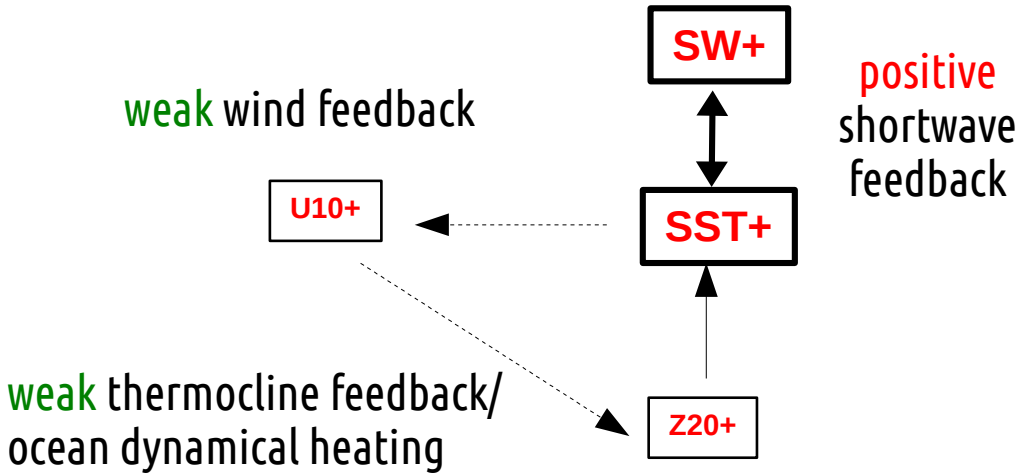


Large cold SST bias





too weak wind feedback is compensated
by positive shortwave feedback!



References

Bayr, T., M. Latif, D. Dommenget, C. Wengel, J. Harlaß, and W. Park, 2017: Mean-State Dependence of ENSO Atmospheric Feedbacks in Climate Models. *Clim. Dyn.*, doi:10.1007/s00382-017-3799-2.

Bellenger, H., E. Guilyardi, J. Leloup, M. Lengaigne, and J. Vialard, 2014: ENSO representation in climate models: From CMIP3 to CMIP5. *Clim. Dyn.*, **42**, 1999–2018, doi:10.1007/s00382-013-1783-z.

Dommenget, D., 2010: The slab ocean El Niño. *Geophys. Res. Lett.*, **37**, L20701, doi:10.1029/2010GL044888.