Slab Ocean El Niño atmospheric feedbacks in Coupled Climate Models and their relationship to the Recharge Oscillator

Dogs wags tail

or

Tail wags dog

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GEOMAR

Dogs wags tail

or

Tail wags dog

Recharge Oscillator:

Ocean dynamics drive ENSO

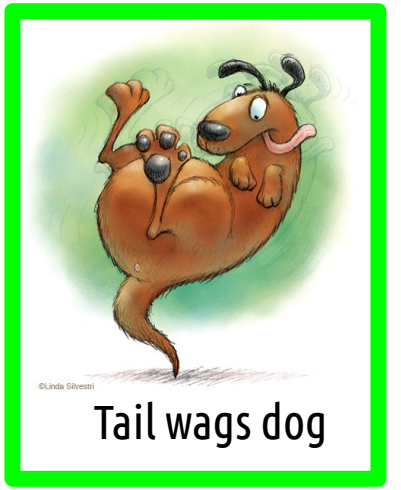
(atmosphere is slave to ocean)

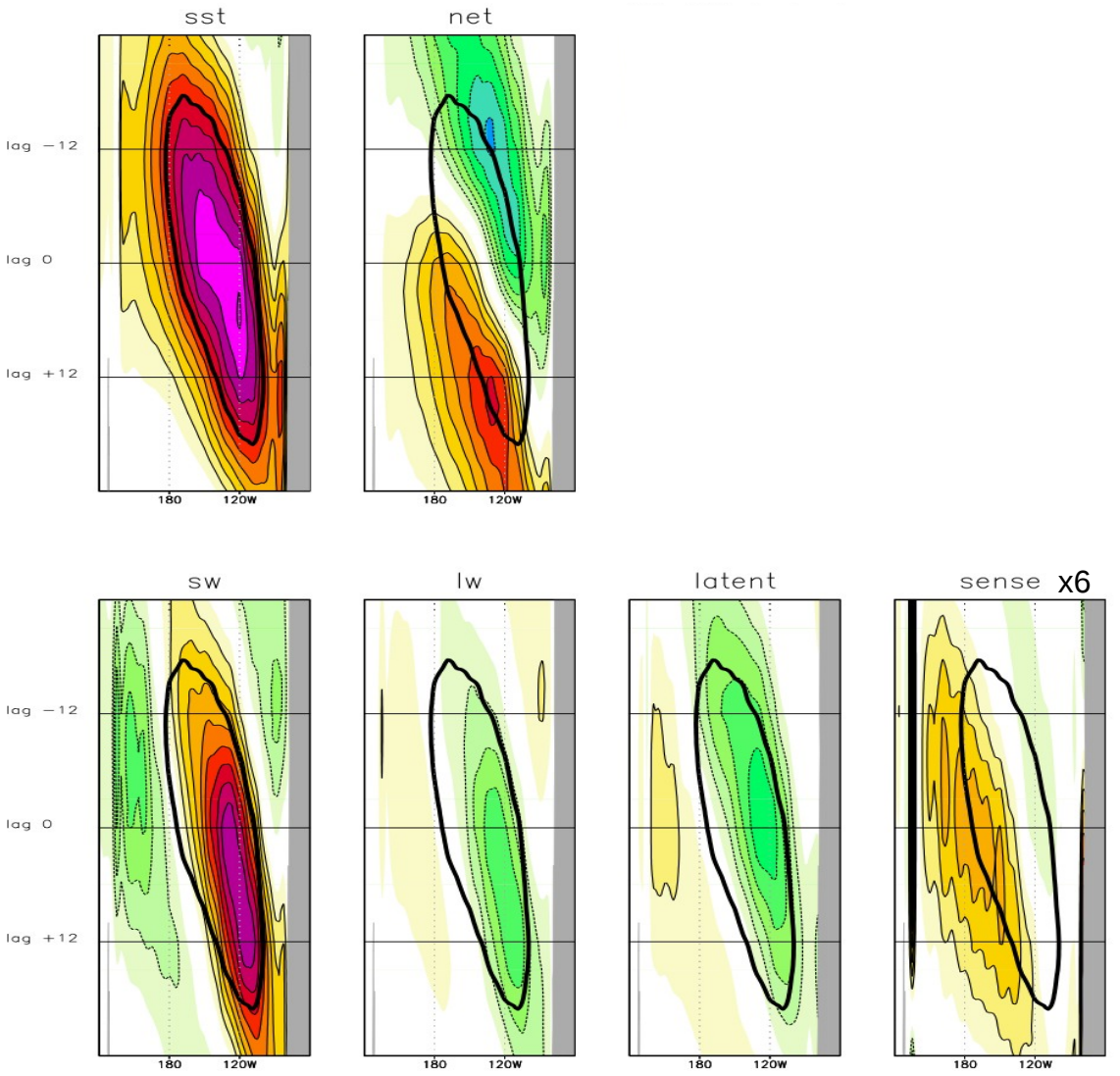
Slab Ocean El Niño:

Atmospheric feedbacks drive ENSO

(ocean is slave to atmosphere)

Motivation: Slab Ocean El Niño





Dommenget (2010)

Motivation: Slab Ocean El Niño atmospheric feedback in CMIP Models

Some CMIP3 and CMIP5 models are closer to Slab Ocean El Niño than to observed El Niño

Dommenget, Haase, Bayr and Frauen (2014)

Motivation: Slab Ocean El Niño atmospheric feedback in CMIP Models

Some CMIP3 and

What determines if ENSO in a coupled climate model

is more like observations,

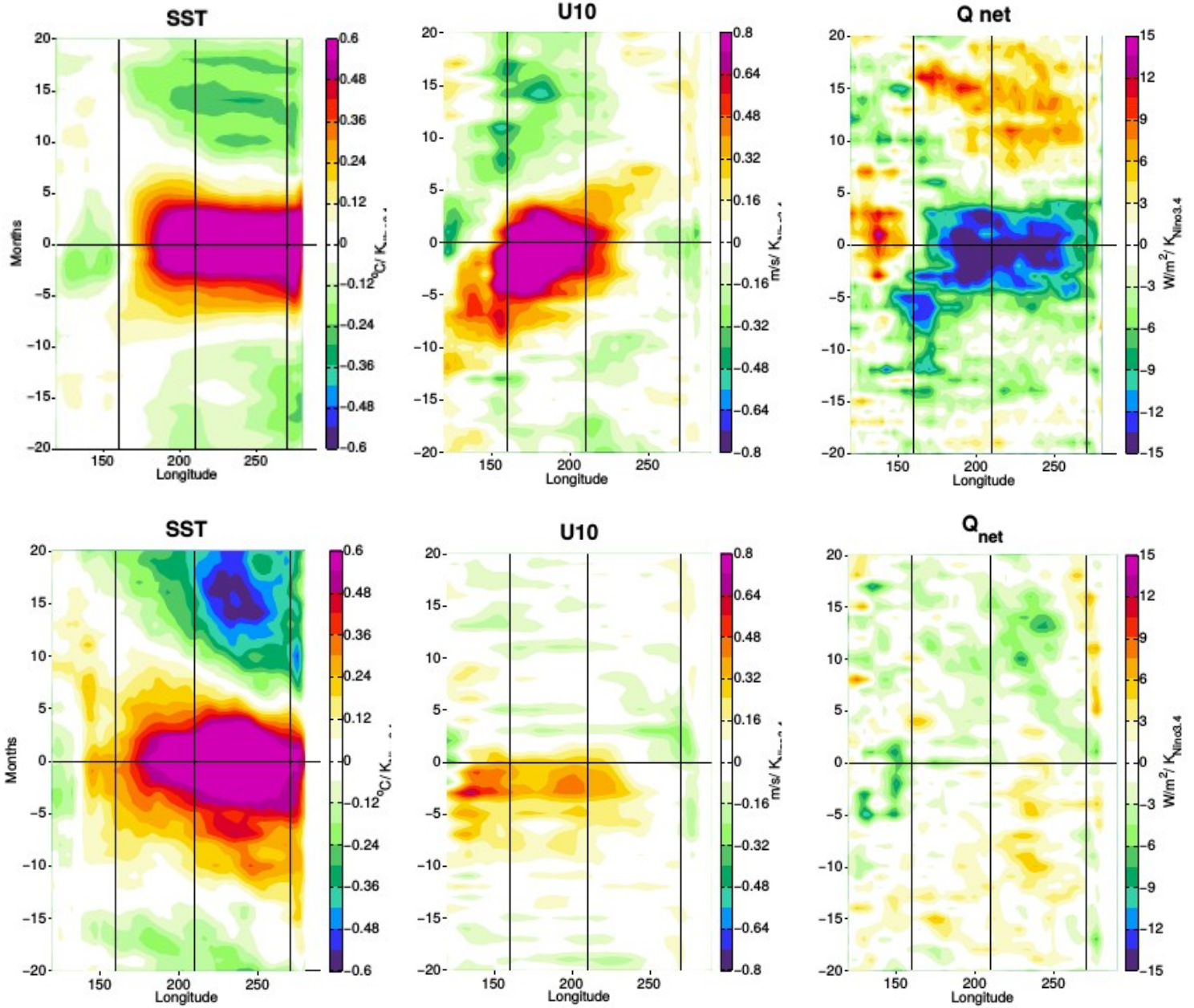
or more like the Slab Ocean El Niño?

than to

observed El Niño

Dommenget, Haase, Bayr and Frauen (2014)

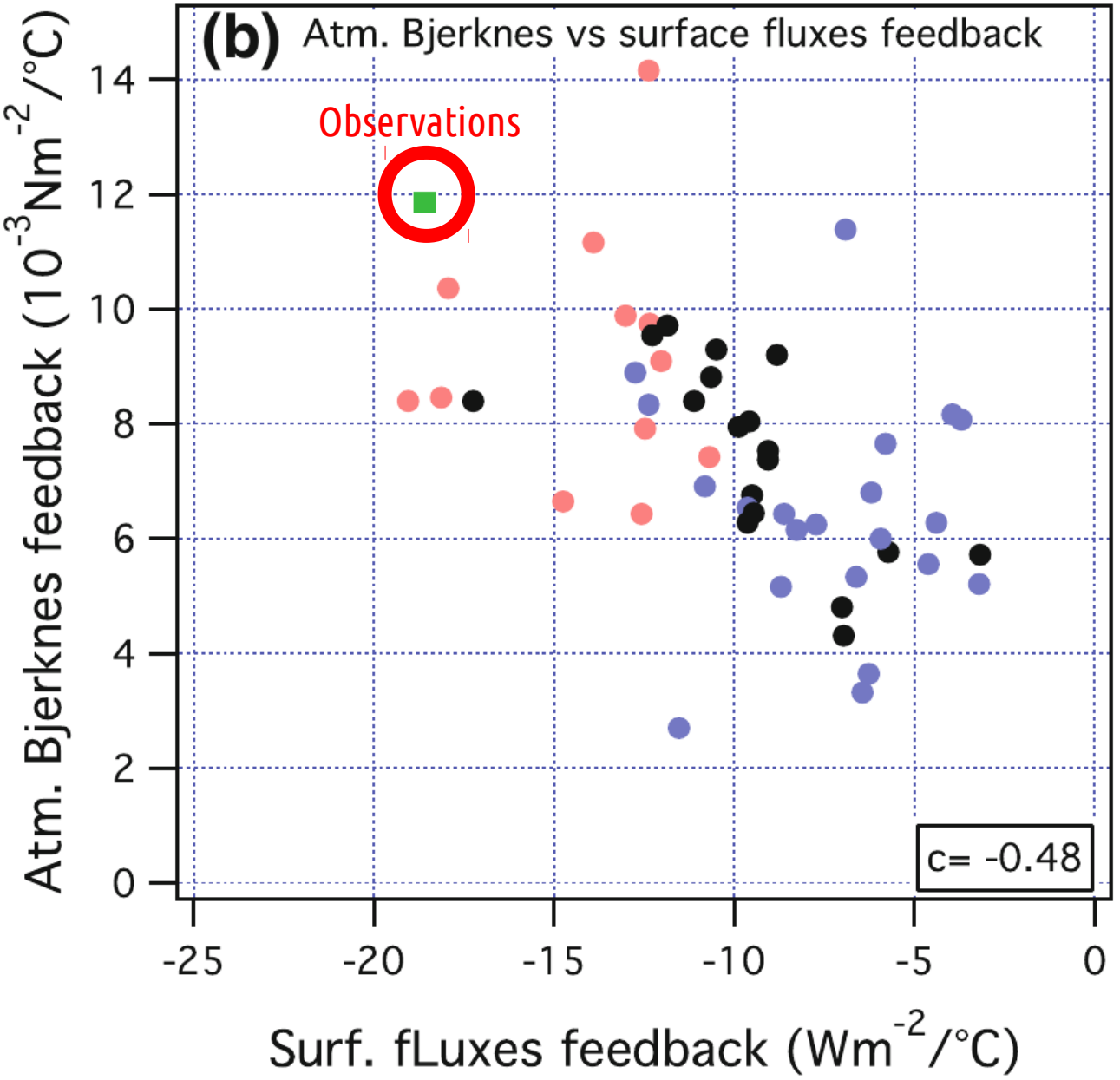
El Niño composites (normalised with Nino3.4 SST)



Observations

BCCR BCM2.0

ENSO in CMIP3 and CMIP5



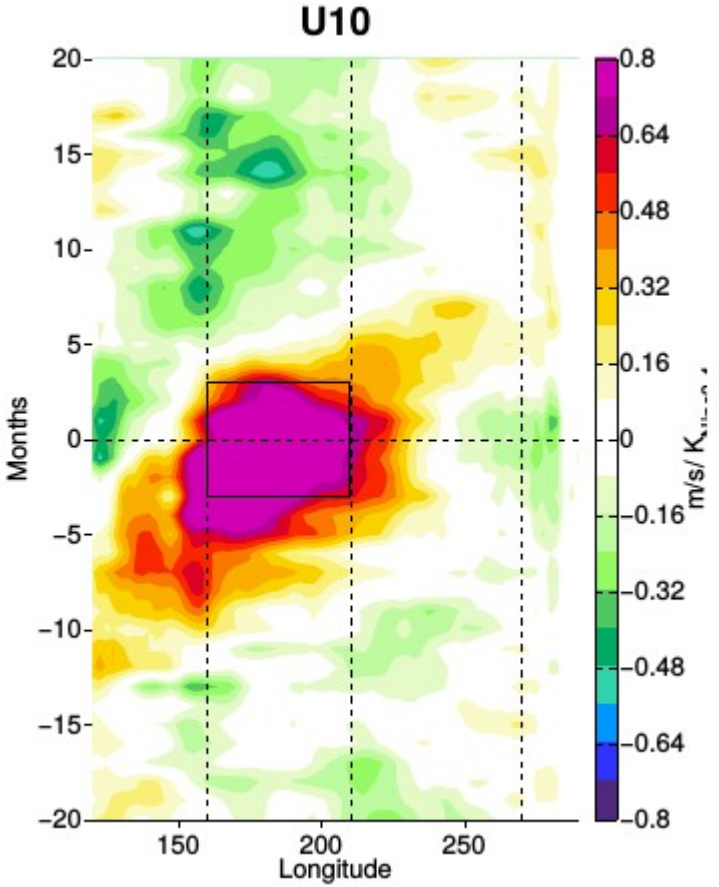
Most CMIP3 and CMIP5 models underestimate Wind-SST and Shortwave-SST feedback

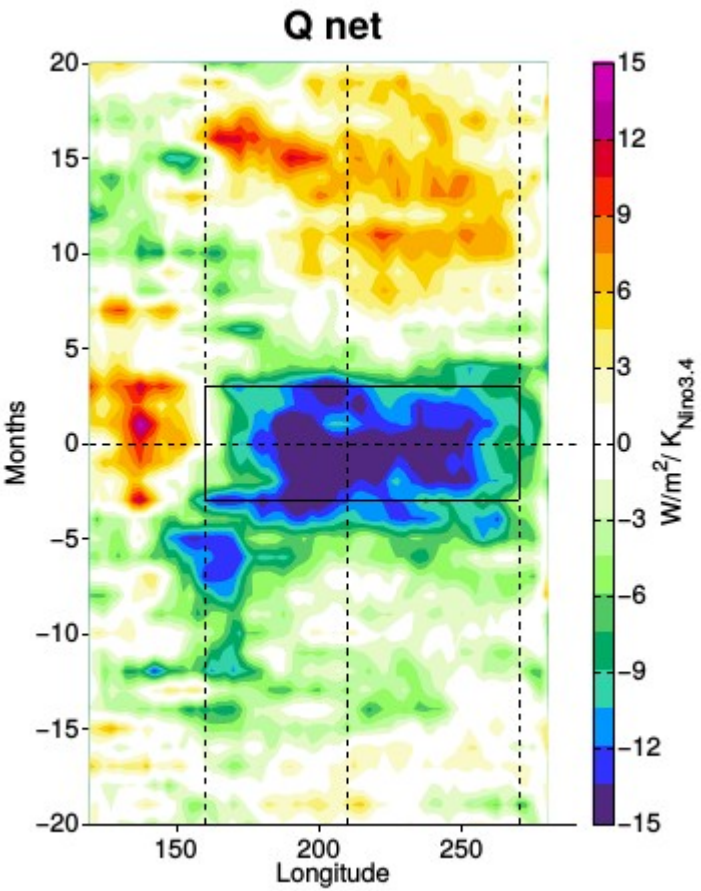
=> Error compensation

Bellenger et al. (2014)

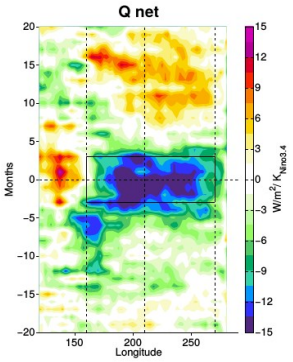
Slab vs. Recharge

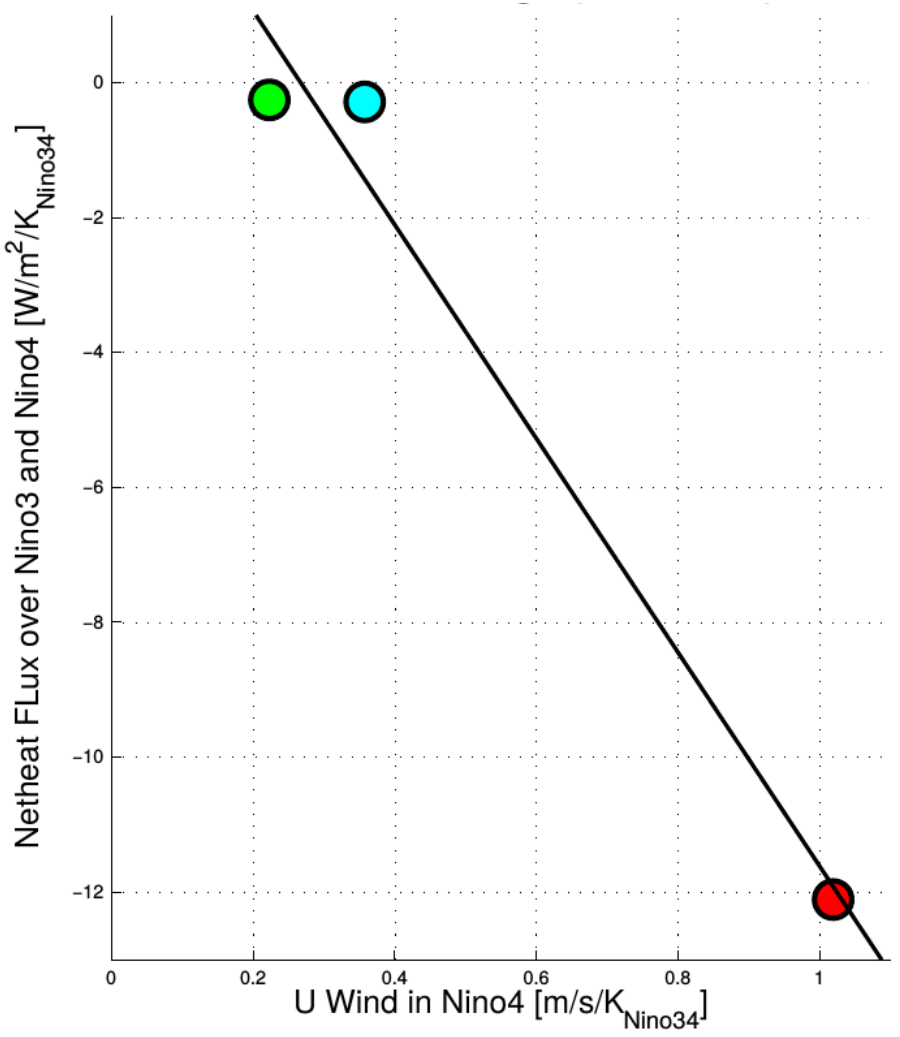
Observations





Slab vs. Recharge



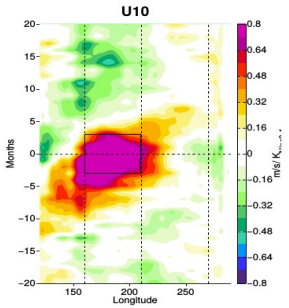


Model

Obs (1.02/−12.11)

BCCR-BCM2.0 (0.22/−0.25)

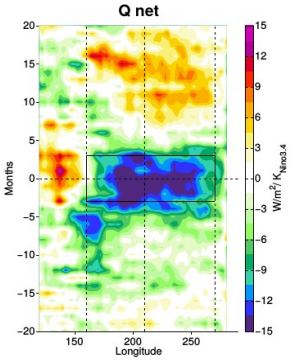
ECHAM5 Slab (0.36/−0.29)

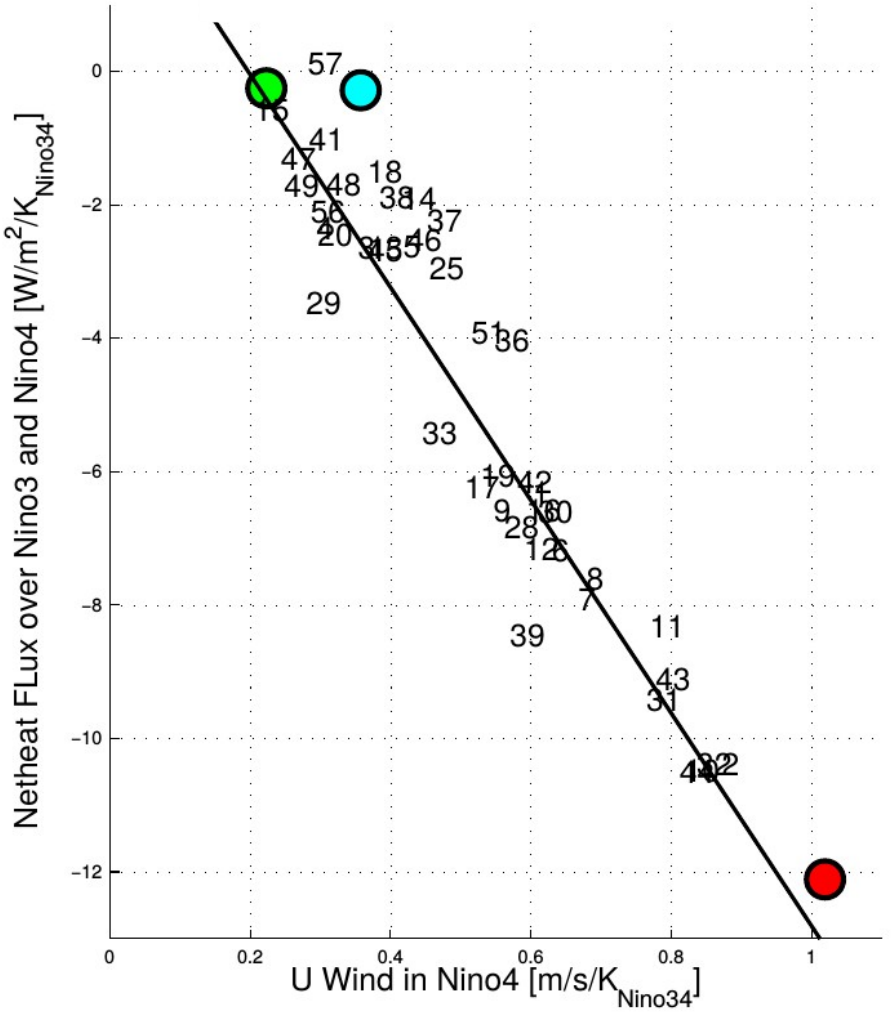


Experiments from Christian Wengel (GEOMAR)

- Kiel Climate Model 1.4.0 with
  - ECHAM5.3 with T42 (2.8°x2.8°)
    3 vertical resolutions (L19, L31, L62)
  - Nemo Orca2 (~2°x2°)
- KCM with 43 different convection parameters based on Mauritsen et al. 2012 => different mean states

Slab vs. Recharge (R^2 = 0.91)





Model
Obs (1.02/−12.11)
BCCR−BCM2.0 (0.22/−0.25)
ECHAM5 Slab (0.36/−0.29)
CW01 (0.60/−6.32)
CW02 (0.87/−10.39)
CW03 (0.35/−2.64)
CW04 (0.29/−2.37)
CW05 (0.42/−2.63)
CW06 (0.63/−7.18)
CW07 (0.67/−7.92)
CW08 (0.68/−7.62)
CW09 (0.55/−6.58)
CW10 (0.82/−10.50)
CW11 (0.77/−8.32)
CW12 (0.59/−7.17)
CW13 (0.37/−2.64)
CW14 (0.42/−1.91)
CW15 (0.21/−0.58)
CW16 (0.59/−6.59)
CW17 (0.51/−6.24)
CW18 (0.37/−1.50)
CW19 (0.53/−6.06)
CW20 (0.30/−2.46)
CW25 (0.46/−2.96)
CW28 (0.56/−6.84)
CW29 (0.28/−3.49)
CW30 (0.61/−6.60)
CW31 (0.76/−9.43)
CW32 (0.84/−10.38)
CW33 (0.45/−5.43)
CW36 (0.55/−4.05)
CW37 (0.45/−2.26)
CW38 (0.38/−1.90)
CW39 (0.57/−8.47)
CW41 (0.28/−1.03)
CW42 (0.58/−6.16)
CW43 (0.78/−9.11)
CW44 (0.81/−10.52)
CW45 (0.37/−2.69)
CW46 (0.42/−2.54)
CW47 (0.24/−1.31)
CW48 (0.31/−1.70)
CW49 (0.25/−1.73)
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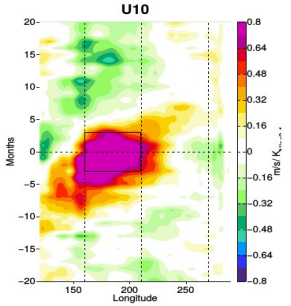
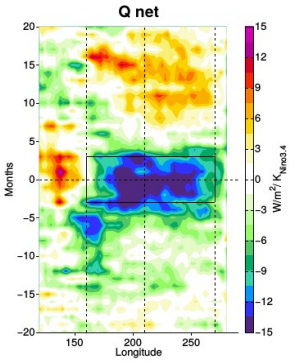
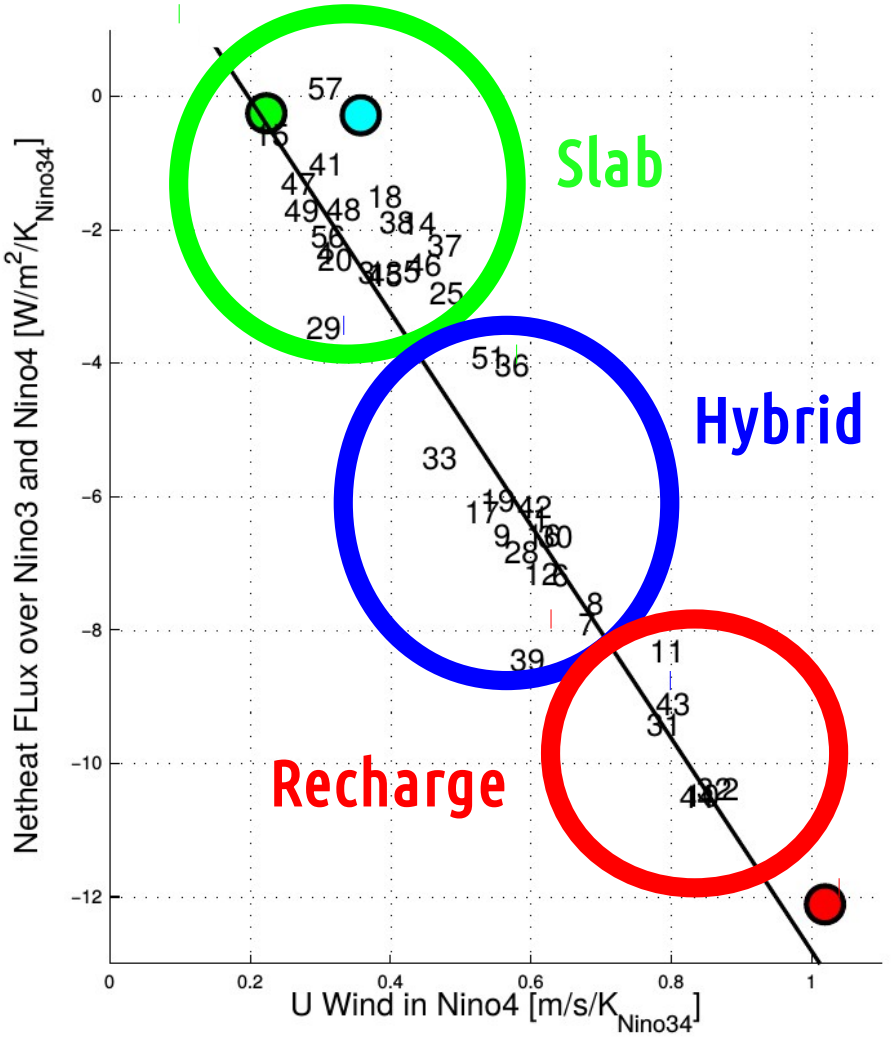
CW56 (0.29/−2.11)
CW57 (0.28/0.11)



Slab vs. Recharge (R^2 = 0.91)





Model
Obs (1.02/−12.11)
BCCR−BCM2.0 (0.22/−0.25)
ECHAM5 Slab (0.36/−0.29)
CW01 (0.60/−6.32)
CW02 (0.87/−10.39)
CW03 (0.35/−2.64)
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CW16 (0.59/−6.59)
CW17 (0.51/−6.24)
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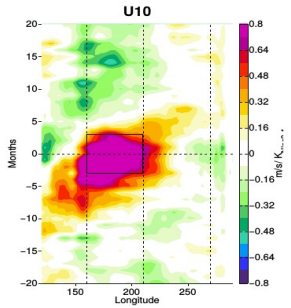
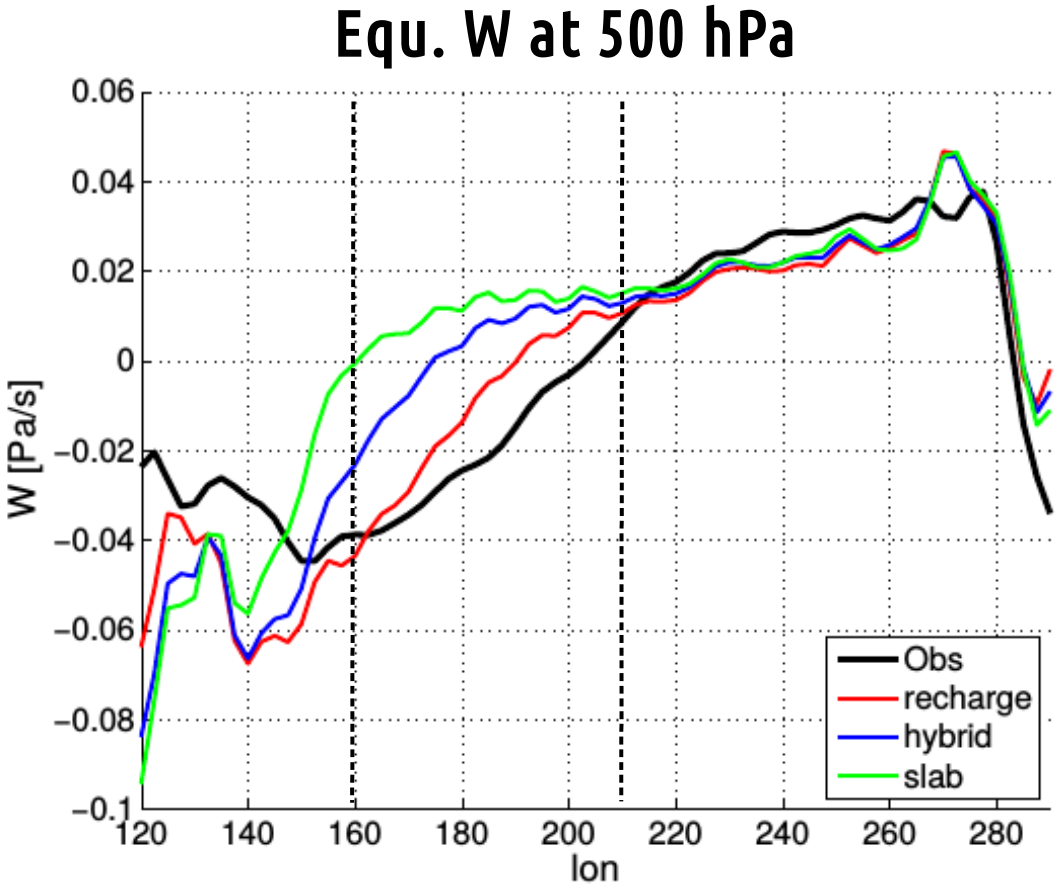
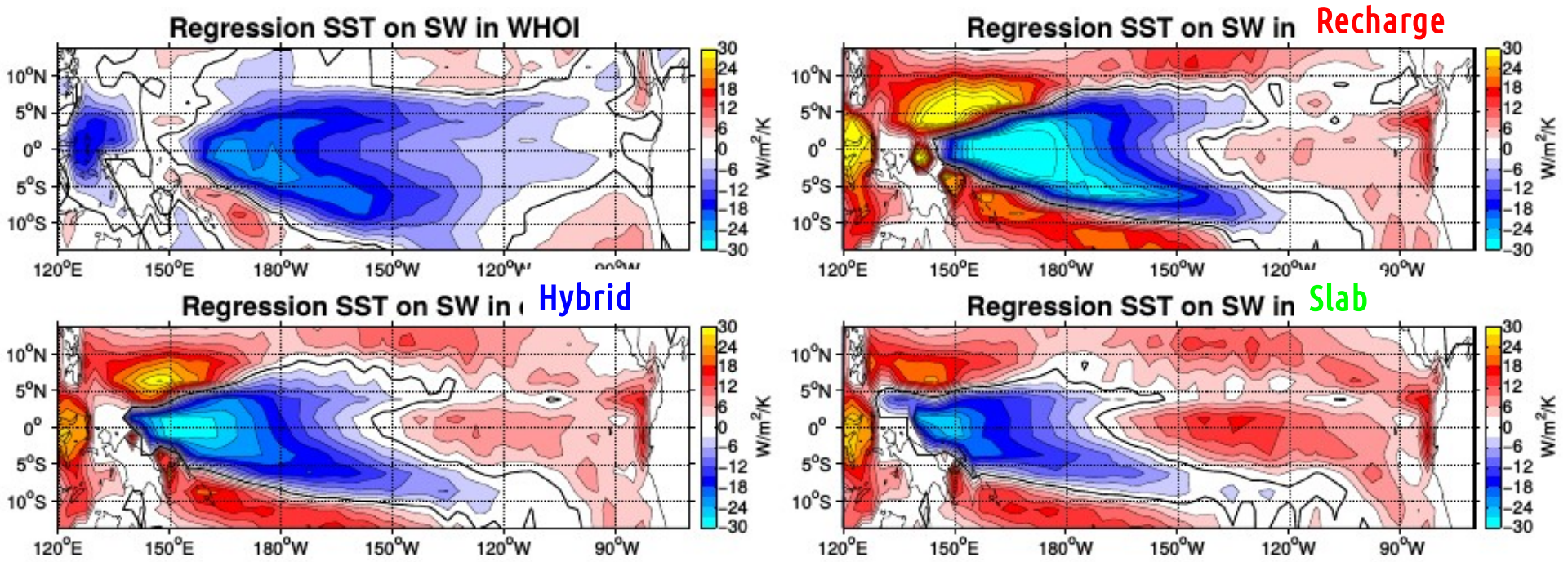


Mean state of Observations, Recharge, Hybrid and Slab ensemble



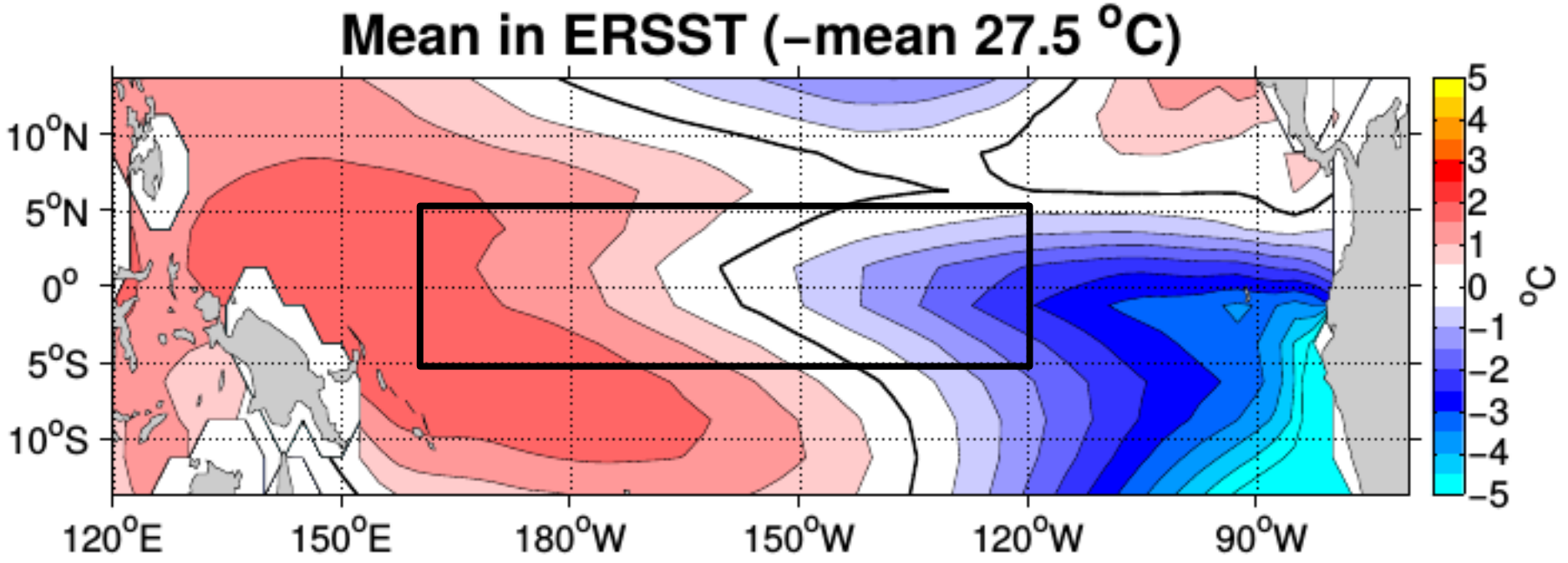
Descending air at 500 hPa level in Nino4 makes convection insensitive to SST changes => Bjerknes Feedback does not work proper in Slab

Short Wave feedback in Observations, Recharge, Hybrid and Slab ensemble



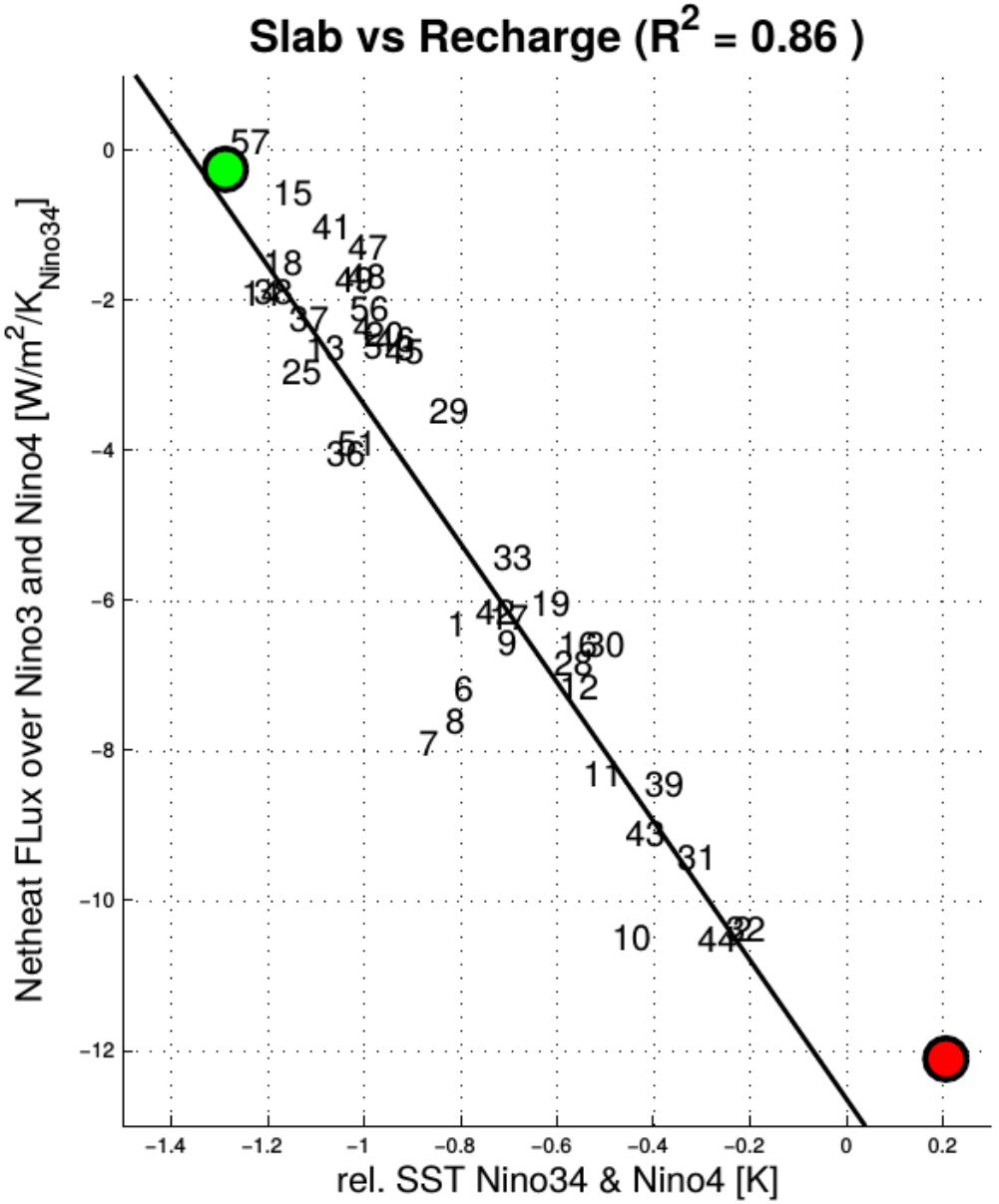
Model has unrealistic positive SW feedback in Nino3 region, that becomes stronger as more it is Slab Ocean El Niño like

Relative SST in Observations (relative to tropical Pacific mean)



Box: measure of the equatorial cold bias

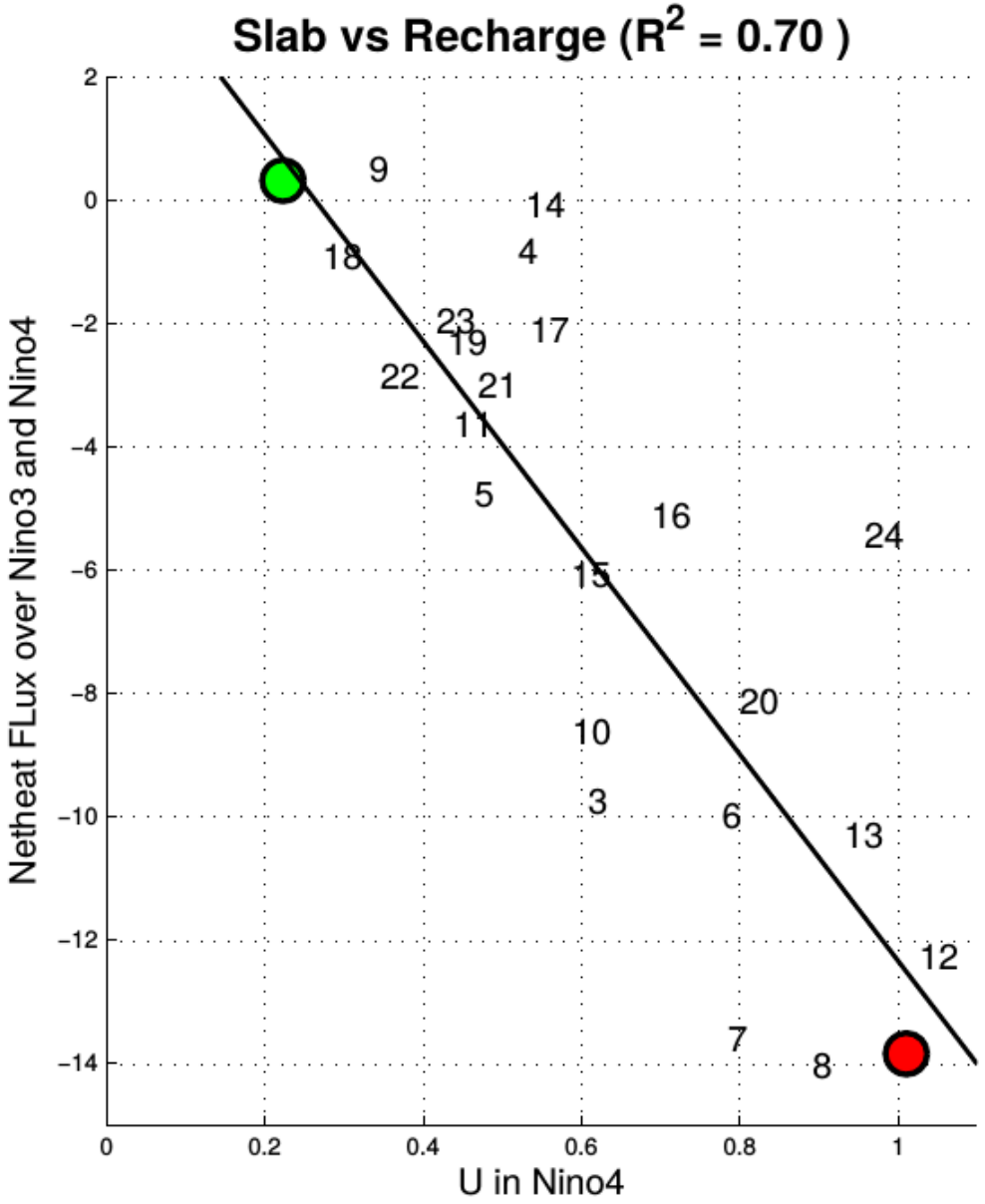
Relative SST of Nino3.4 & Nino4



Model
Obs (0.21/−12.11)
BCCR−BCM2.0 (−1.29/−0.25)
CW01 (−0.83/−6.32)
CW02 (−0.24/−10.39)
CW03 (−0.93/−2.64)
CW04 (−1.02/−2.37)
CW05 (−1.00/−2.63)
CW06 (−0.81/−7.18)
CW07 (−0.89/−7.92)
CW08 (−0.83/−7.62)
CW09 (−0.72/−6.58)
CW10 (−0.49/−10.50)
CW11 (−0.55/−8.32)
CW12 (−0.60/−7.17)
CW13 (−1.12/−2.64)
CW14 (−1.25/−1.91)
CW15 (−1.19/−0.58)
CW16 (−0.60/−6.59)
CW17 (−0.74/−6.24)
CW18 (−1.21/−1.50)
CW19 (−0.65/−6.06)
CW20 (−1.00/−2.46)
CW25 (−1.17/−2.96)
CW28 (−0.61/−6.84)
CW29 (−0.86/−3.49)
CW30 (−0.54/−6.60)
CW31 (−0.35/−9.43)
CW32 (−0.25/−10.38)
CW33 (−0.73/−5.43)
CW36 (−1.08/−4.05)
CW37 (−1.15/−2.26)
CW38 (−1.23/−1.90)
CW39 (−0.42/−8.47)
CW41 (−1.11/−1.03)
CW42 (−0.77/−6.16)
CW43 (−0.46/−9.11)
CW44 (−0.31/−10.52)
CW45 (−0.96/−2.69)
CW46 (−0.98/−2.54)
CW47 (−1.03/−1.31)
CW48 (−1.04/−1.70)
CW49 (−1.06/−1.73)
CW51 (−1.06/−3.92)
CW56 (−1.03/−2.11)
CW57 (−1.28/0.11)

Stronger equatorial cold bias
=> more Slab Ocean El Niño like

Slab vs. Recharge in CMIP5



Model

1 : Obs (1.010/−13.84)
2 : BCCR−BCM2.0 (0.223/0.31)
3 : ACCESS1−0 (0.609/−9.76)
4 : ACCESS1−3 (0.520/−0.84)
5 : BCC−CSM1−1 (0.465/−4.78)
6 : BNU−ESM (0.778/−9.99)
7 : CMCC−CM (0.785/−13.62)
8 : CNRM−CM5 (0.892/−14.05)
9 : CSIRO−Mk3−6−0 (0.332/0.49)
10 : GFDL−CM3 (0.588/−8.65)
11 : GFDL−ESM2G (0.438/−3.65)
12 : GFDL−ESM2M (1.026/−12.28)
13 : GISS−E2−R (0.932/−10.31)
14 : HadGEM2−AO (0.530/−0.10)
15 : HadGEM2−CC (0.587/−6.08)
16 : HadGEM2−ES (0.689/−5.14)
17 : INM−CM4 (0.535/−2.13)
18 : IPSL−CM5A−LR (0.273/−0.94)
19 : IPSL−CM5A−MR (0.431/−2.33)
20 : MIROC5 (0.800/−8.14)
21 : MIROC−ESM (0.469/−3.01)
22 : MIROC−ESM−CHEM (0.346/−2.88)
23 : MRI−CGCM3 (0.417/−1.98)
24 : NorESM1−ME (0.958/−5.45)

CMIP5 models show same relationship, but with a weaker linear relation

Take home massage

Dogs wags tail

Tail wags dog

Recharge Oscillator

explains observed ENSO

but is partly absent in CGCMs

Slab Ocean El Niño:

model artifact due to

equatorial cold bias,

is partly present in CGCMs

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Conclusion

- KCM can be tuned to be close Recharge Oscillator and to Slab Ocean El Niño and to be somewhere in between (Hybrid)
- Same relationship can be found in CMIP models
- Equatorial cold bias determines type of El Niño in KCM
- Equatorial cold bias causes descending in Nino4 region
  => descending makes convection insensitive to SST changes
  => damps Recharge Oscillator dynamics
  => enhances Slab Ocean El Niño due to positive SW feedback

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