Climate variability sensitivity to the parameterization of surface fluxes in CESM2

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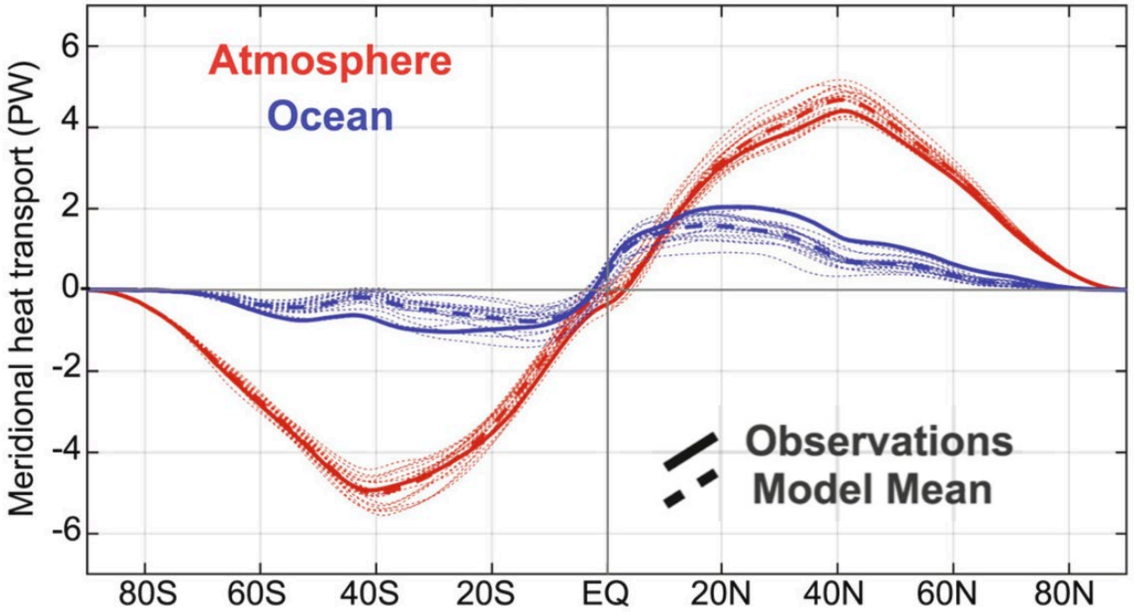
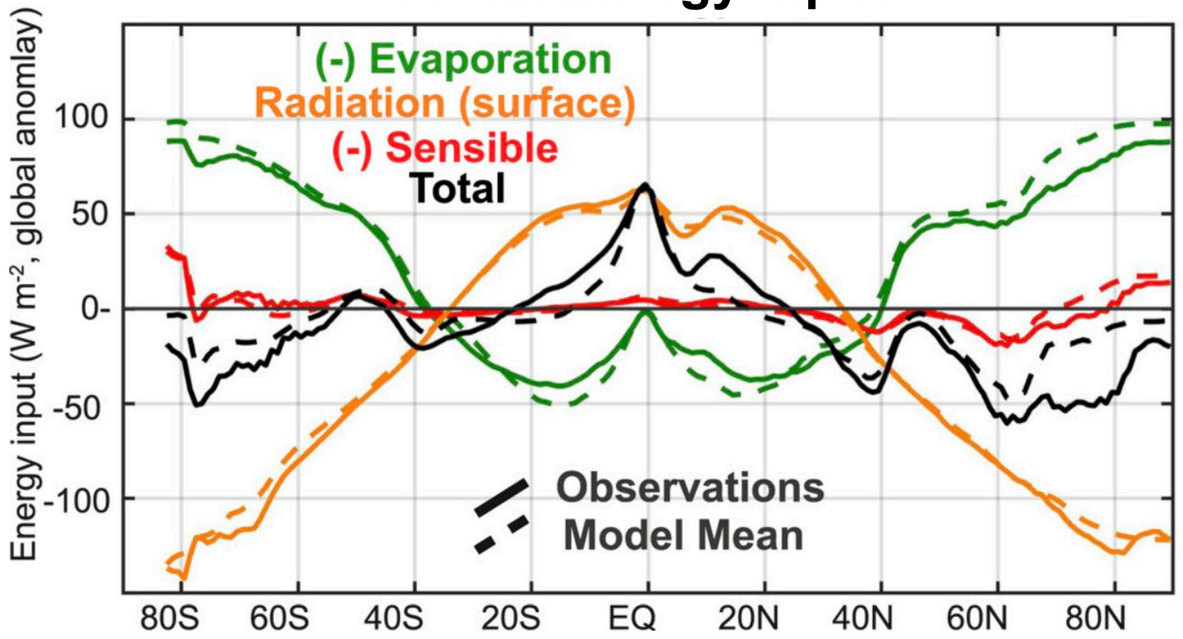
global heat transport and energy input

Atmospheric & Ocean Heat Transport



Ocean Energy Input

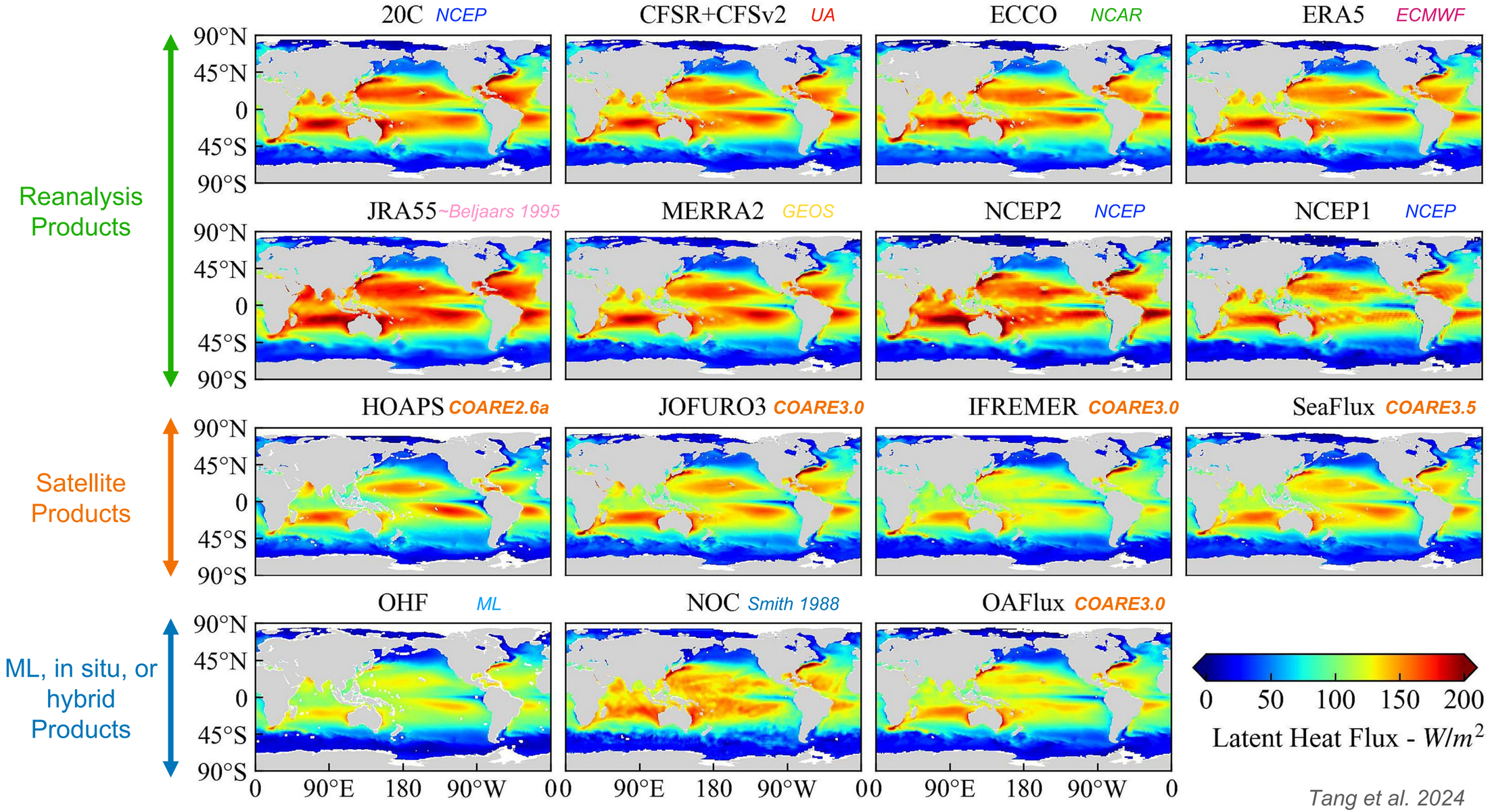


Donahoe et al. 2024

- models consistently underestimate ocean transport, overestimate atmospheric transport
- this is true for CMIP3, CMIP5, and CMIP6

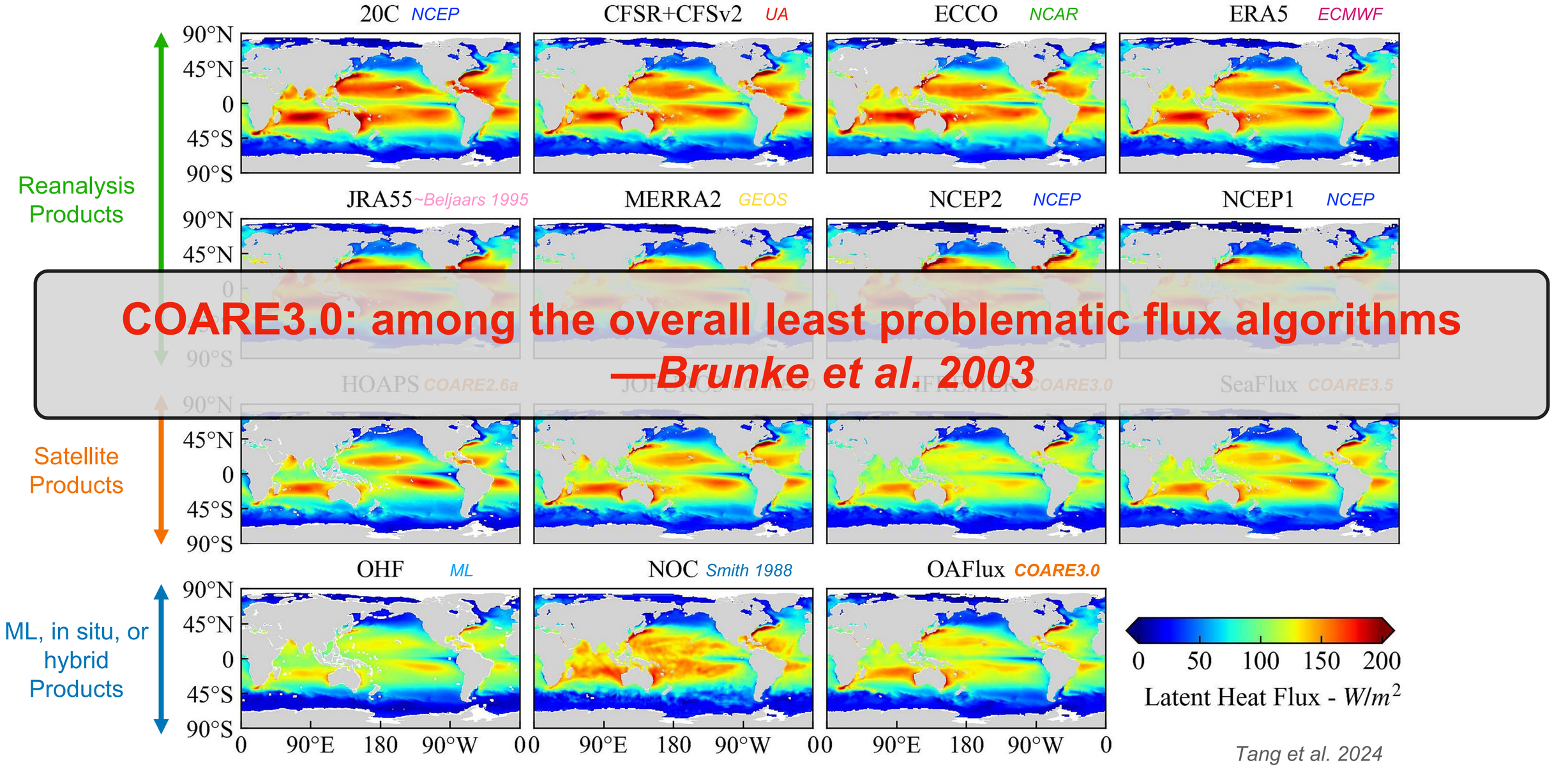
- **too-strong evaporation in tropics drives the ocean heat transport bias**
- potential sources of evaporation biases
  - too strong winds
  - too warm SST
  - too dry MBL
  - erroneous surface flux parameterization

global latent heat flux estimates



Tang et al. 2024

global latent heat flux estimates



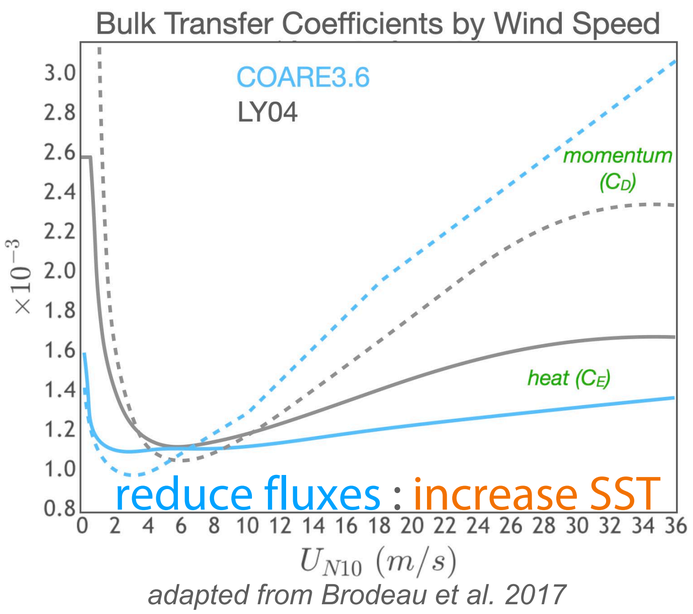
COARE3.0: among the overall least problematic flux algorithms

—Brunke et al. 2003

Tang et al. 2024

surface flux parameterization in CESM2: what can be improved?

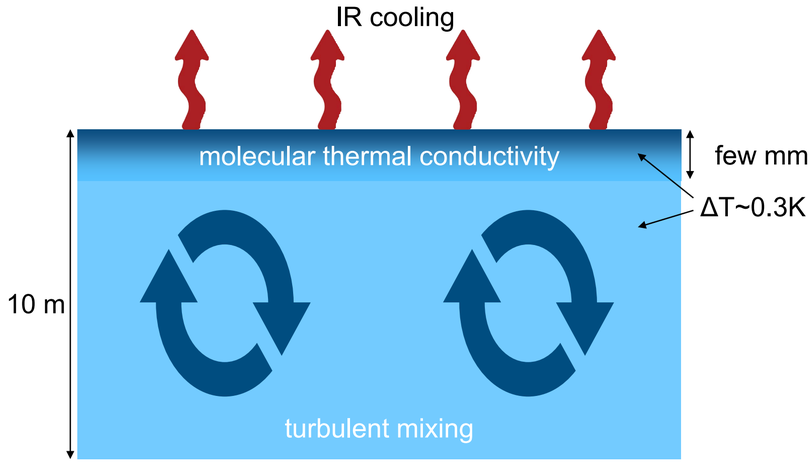
bulk transfer coefficients



reduce fluxes : increase SST

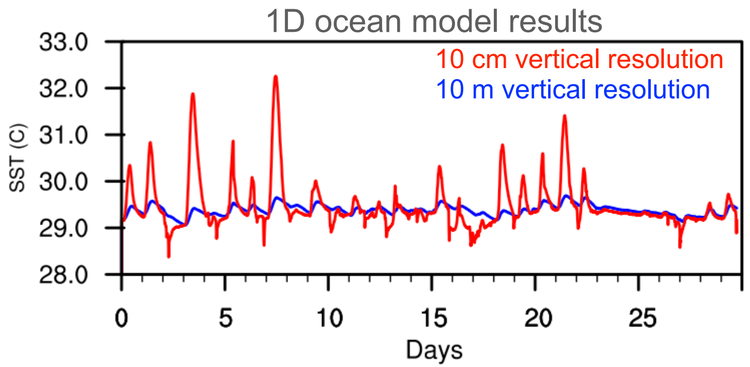
adapted from Brodeau et al. 2017

ocean cool skin effects

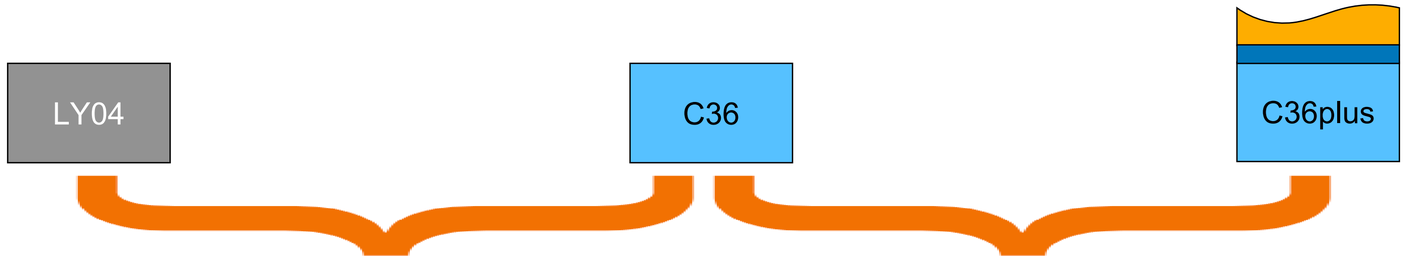


reduce fluxes : increase SST

diurnal warm layer effects



increase fluxes : decrease SST

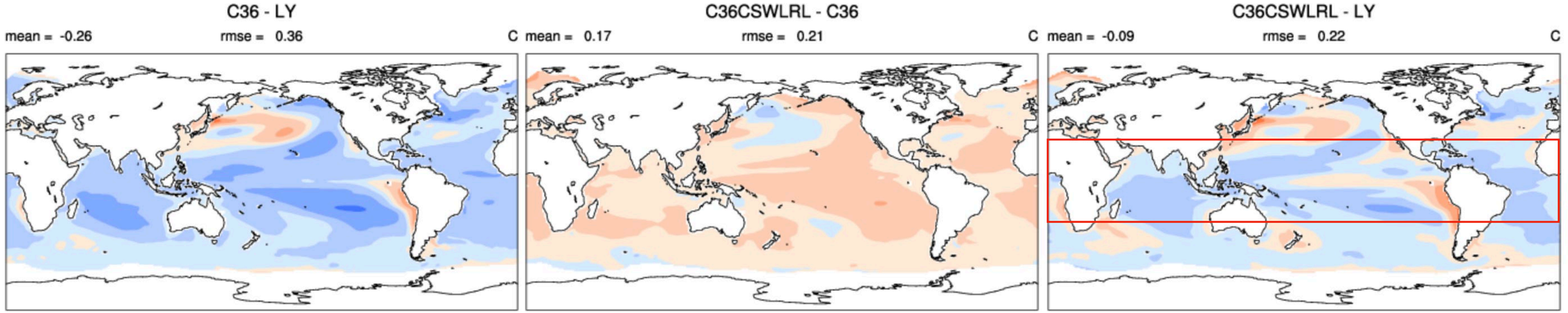


coefficient effect + *cool skin & diurnal warm layer effects* = *total effect*

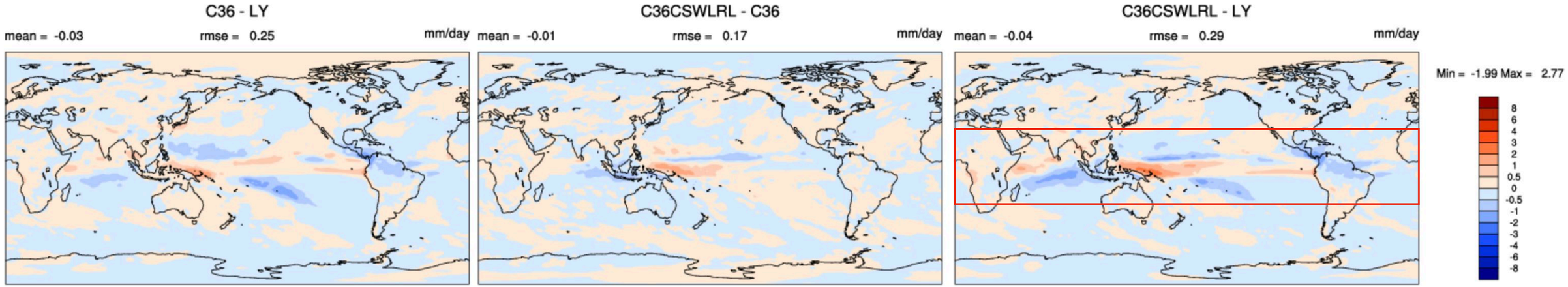
CESM2: mean state changes

coefficient effect | *CS+DWL effects* | *total effect*

SST

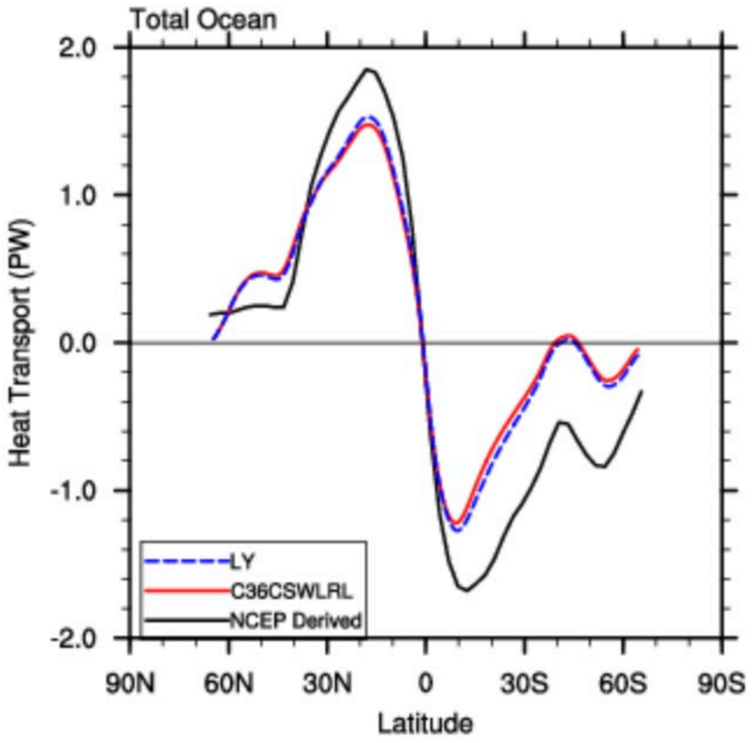


rain



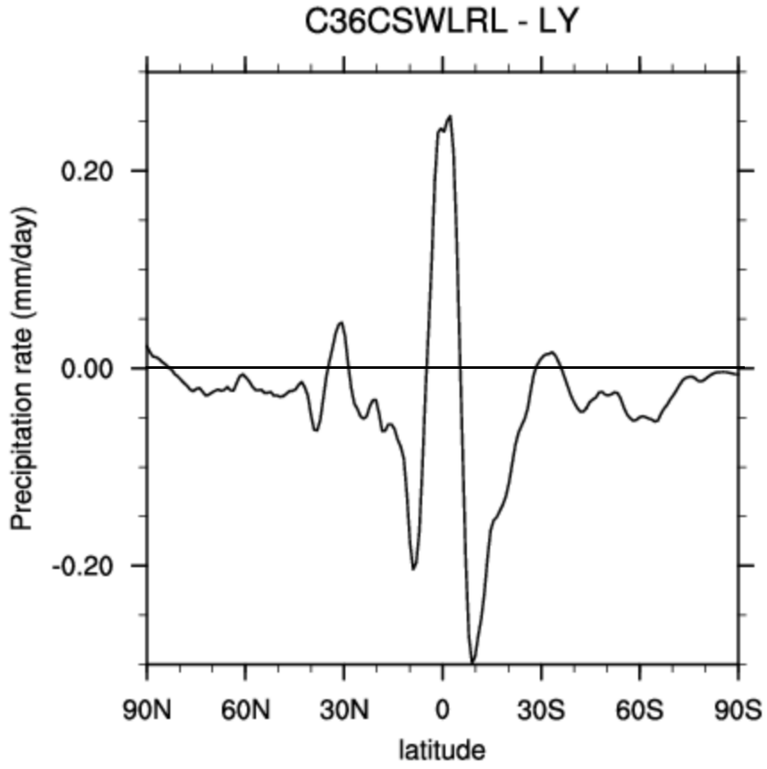
CESM2: mean state changes

OHT



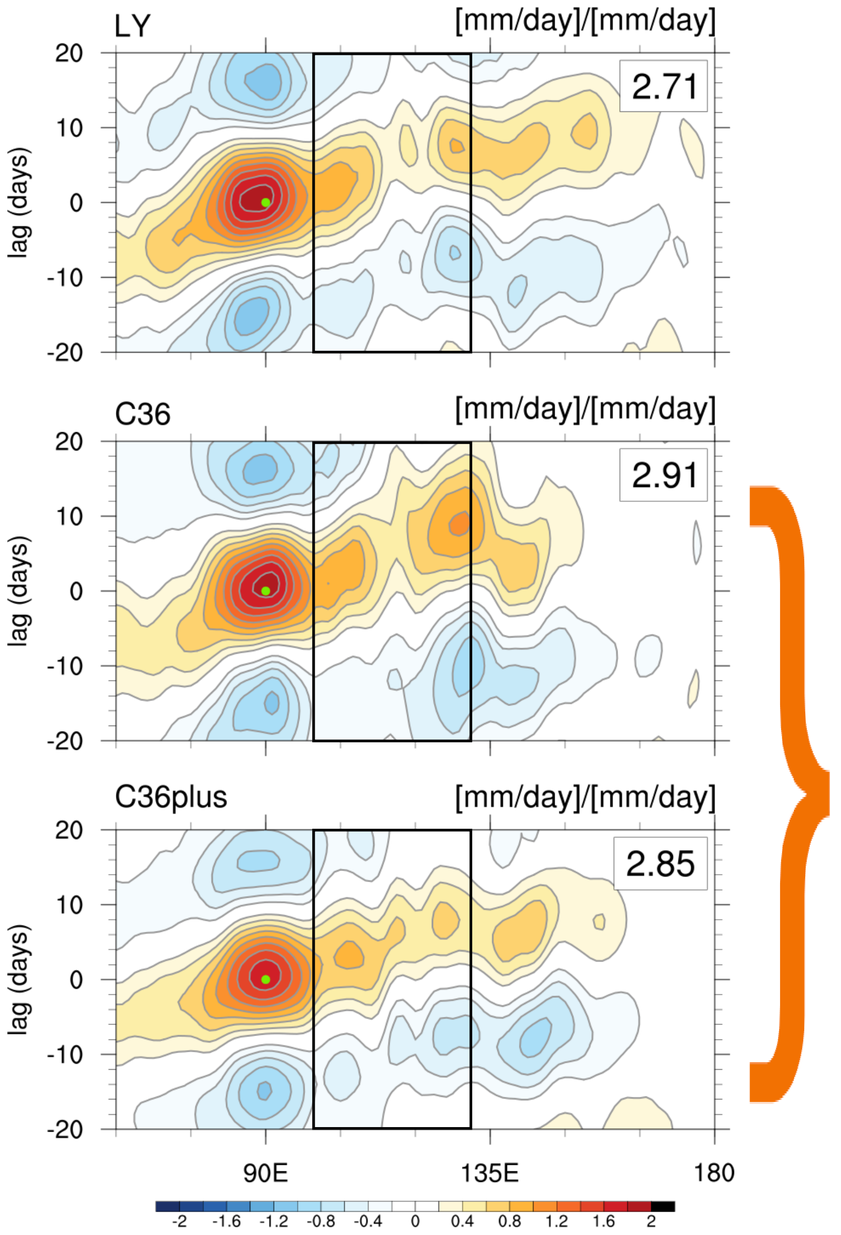
- slightly less OHT with C36plus

rainfall: total effect



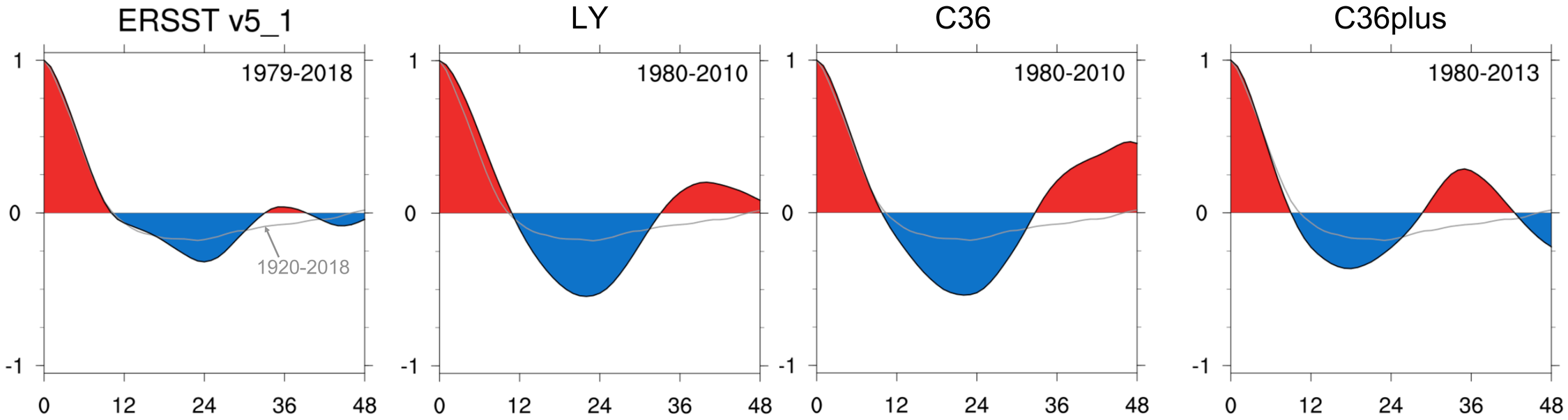
- stronger Hadley circulation with C36plus

CESM2: tropical variability and the MJO



- greater amplitude MJO
- improved propagation across Maritime Continent

CESM2: ENSO changes



- too periodic ❌
- weak asymmetry ❌

- too periodic ↑ ❌
- weak asymmetry ❌

- too periodic ↓ ❌
- improved asymmetry ✅

COARE fluxes in CEMS2: summary

feature	effect of COARE fluxes
mean state	modest changes: enhanced Hadley circulation
ENSO	positive effects: improved asymmetry negative effects: greater periodicity
MJO	improved amplitude improved E/W power ratio reduced MC propagation barrier

- bulk transfer coefficients alone can have negative impacts on variability compared to LY
- **inclusion of cool skin and diurnal warm layer approximations yield greatest improvements!**

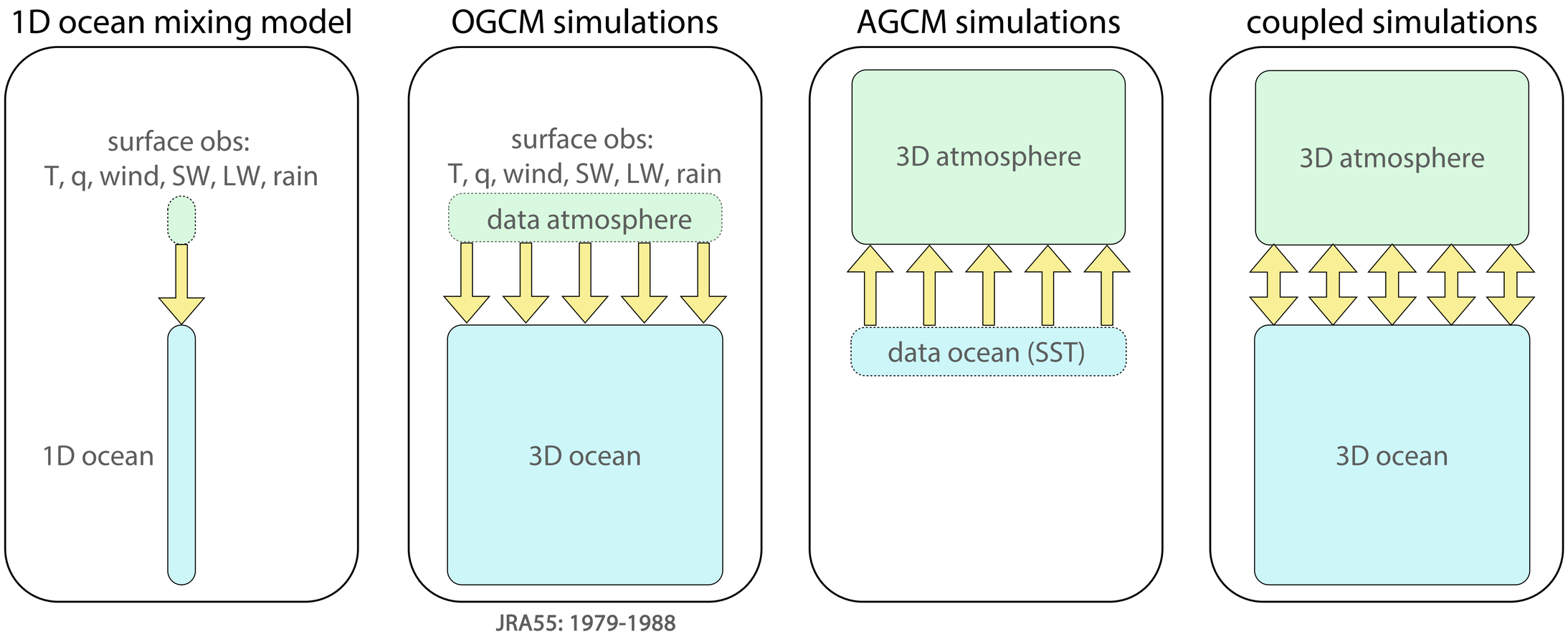
CESM3: thinking ahead

- **MOM6 ocean**:
  - near-surface vertical resolution increases from 10 m to 2.5 m
  - diurnal warm layers and (perhaps) rain layers can be directly simulated
  - cool skin effect must still be parameterized

- **COARE3.x flux algorithm**:
  - is among the “least problematic” algorithms when compared to direct covariance flux measurements
  - getting the flux “right” improves some aspects of variability with minimal changes to the mean state

extra slides

understanding flux algorithm effects: a model hierarchy approach



JRA55: 1979-1988

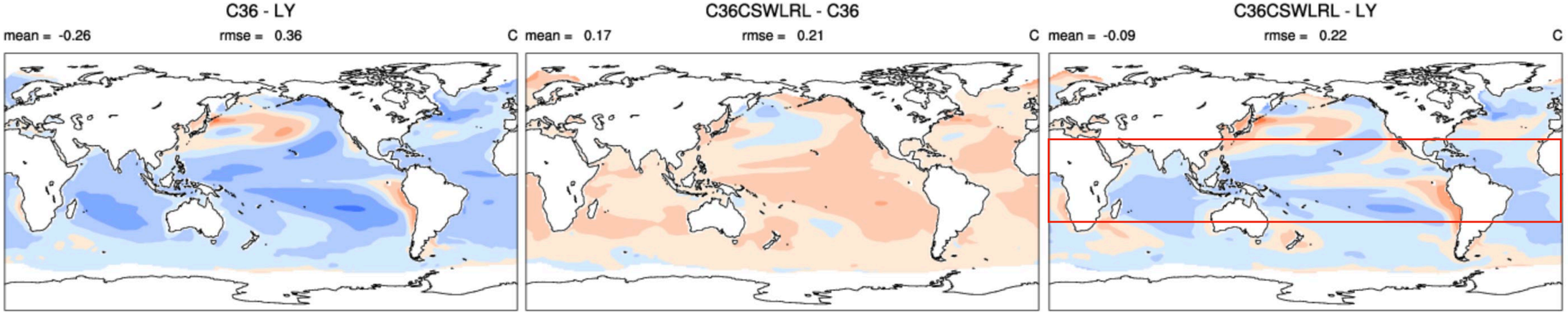
CESM2: mean state changes

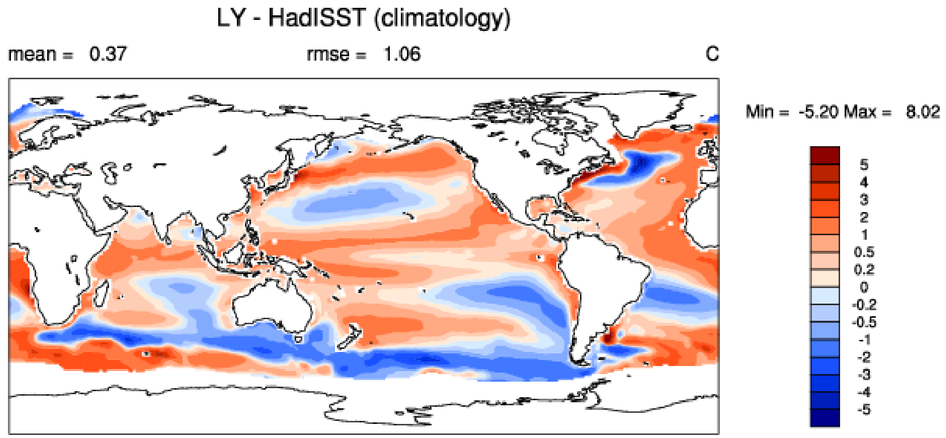
coefficient effect

CS+DWL effects

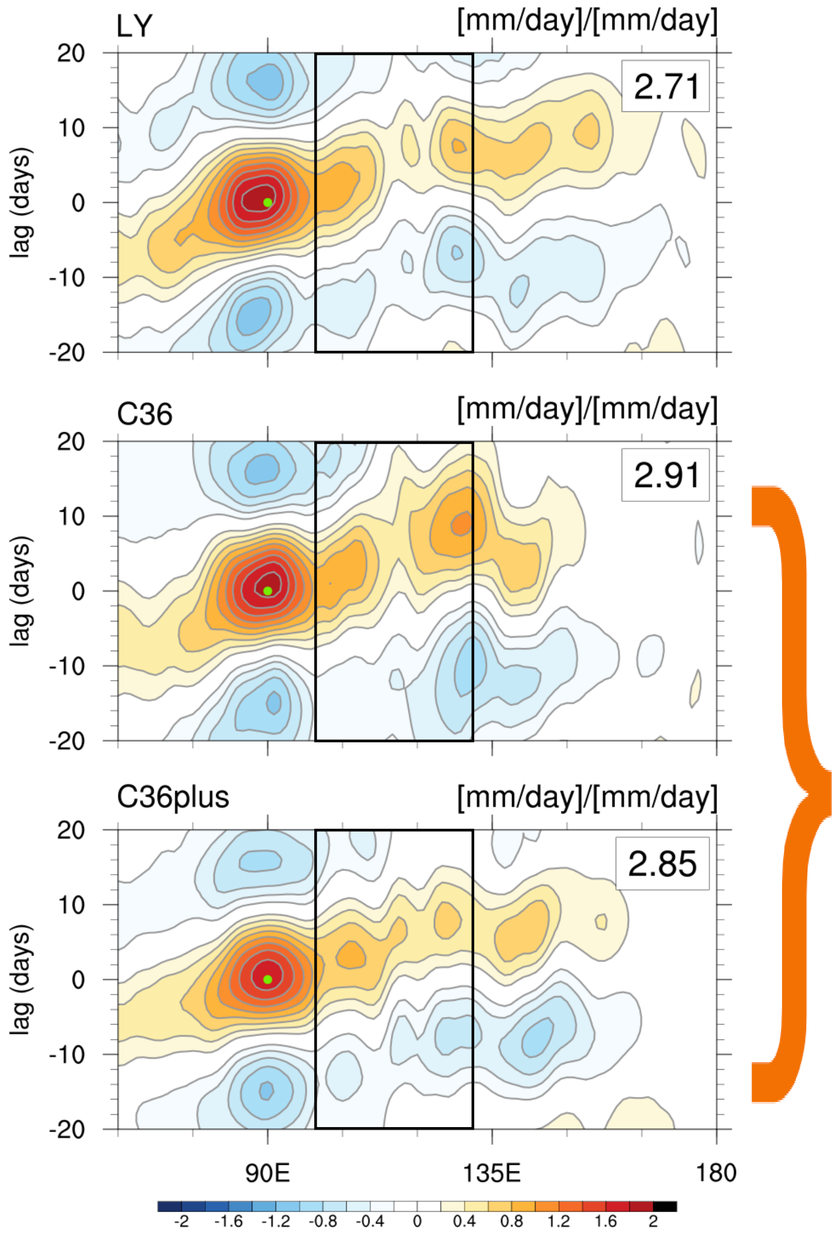
total effect

SST





CESM2: tropical variability and the MJO

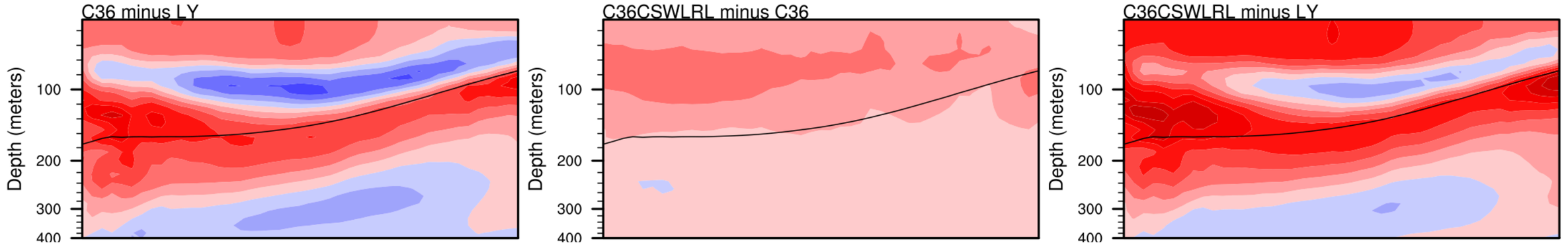


source	E/W power ratio
TRMM	2.30
LY	2.22
C36	1.88
C36plus	2.04

- greater amplitude MJO
- improved propagation across Maritime Continent

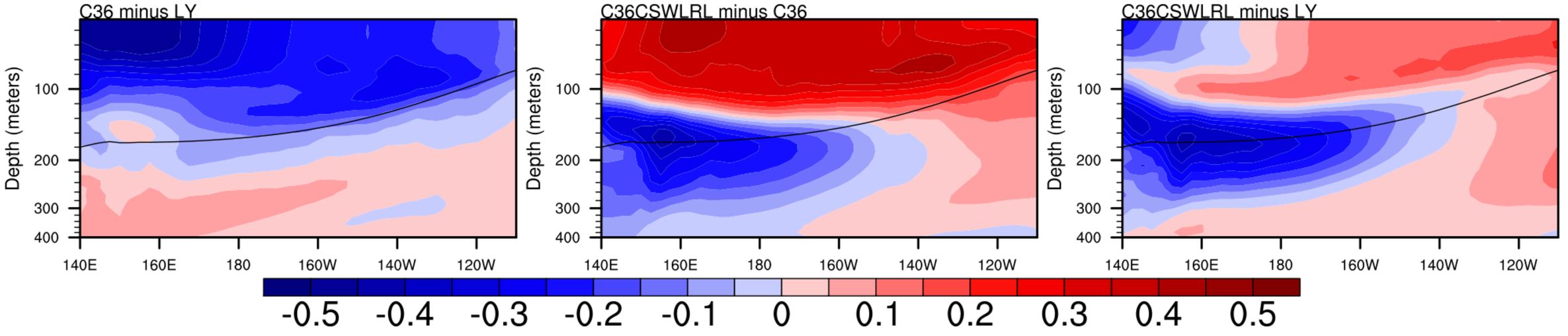
CESM2 Ocean Potential Temperature Difference

OGCM



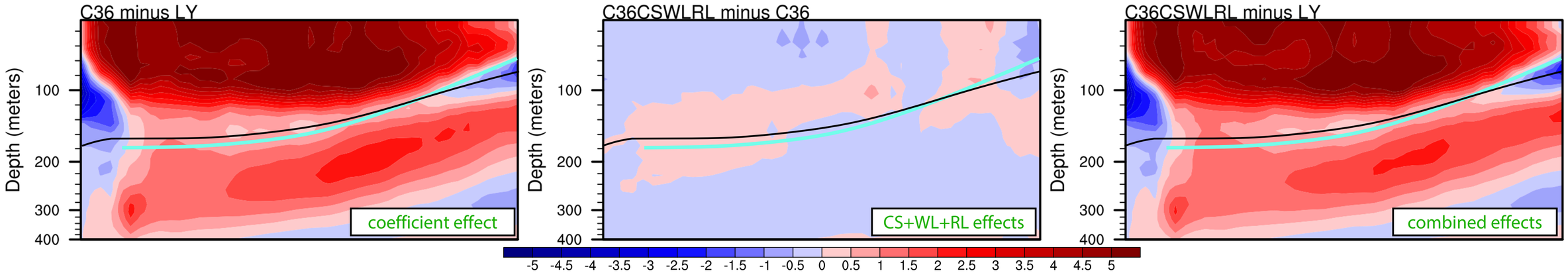
CESM2 Ocean Potential Temperature Difference

CGCM



CESM2 Ocean Velocity in grid-x direction Difference

OGCM



CGCM