The ocean-atmosphere dialog in the MJO:
Physical processes vs systematic biases in forecast models

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S2S Prediction Task Force

MAPP
Modeling, Analysis, Predictions, and Projections

KEY MODEL DATA

- INTERNATIONAL S2S PROJEC
- SUBX
- NMME

STRATOSPHERIC POLAR VORTEX

NAO

WAVE ACTIVITY FLUX

BLOCKING

EXTRATROPICAL CYCLONES

HEAT WAVES

LAND SURFACE MEMORY

TROPICAL CYCLONES

MESOSCALE SST VARIABILITY

STORM TRACKS

ROSSBY WAVE BREAKING

ATMOSPHERIC RIVERS

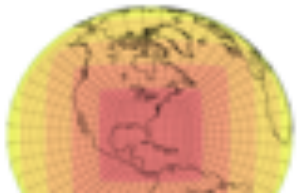
MJO CONVECTION

AIR-SEA COUPLING

MARITIME CONTINENT BARRIER

OCEANIC FEEDBACKS

ENSO



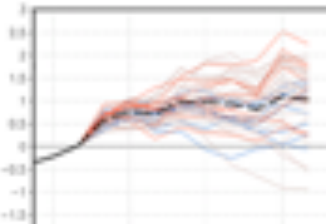
MODEL RESOLUTION

MODEL PHYSICS

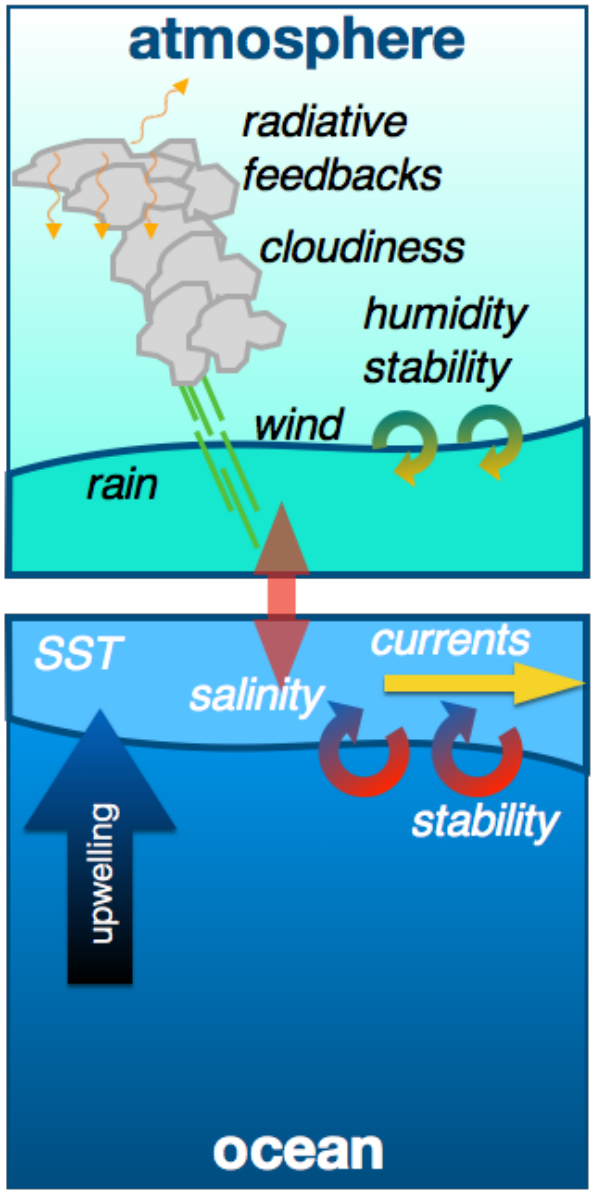
SKILL

PREDICTABILITY

VERIFICATION



ocean-atmosphere communication in the tropics



- the "dialog" involves exchanges of heat, fresh water, momentum.
- the "conversation" is jointly regulated by properties of the atmospheric and oceanic mixed layers.
- conversation can be affected by many processes (and their biases).

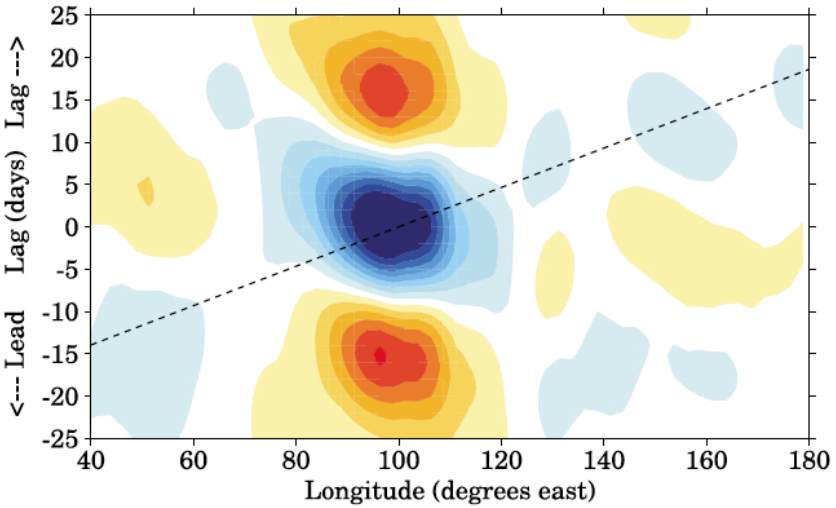
$$LH - \rho C_L |V| \left(q^*_{SST} - q_{2m} \right)$$

does the atmosphere listen to the ocean?

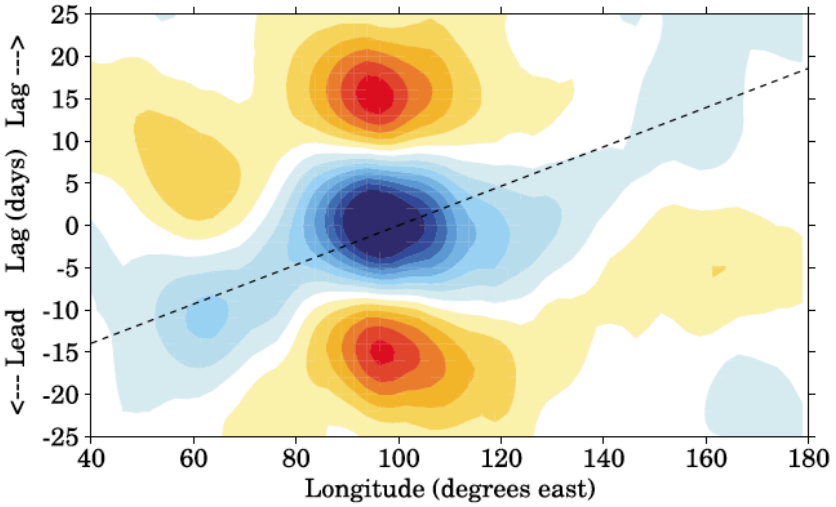
uncoupled | **coupled**

low moisture sensitivity

b. Atmosphere-only, observed SST

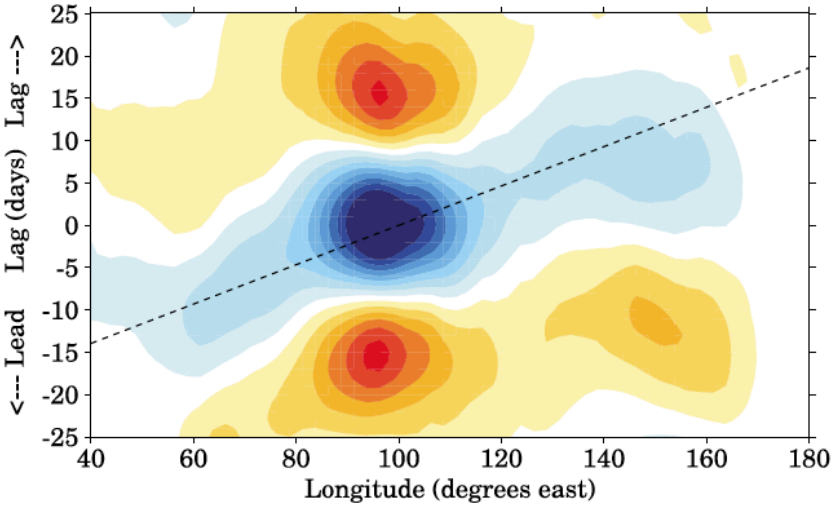


c. KPP-coupled, observed SST

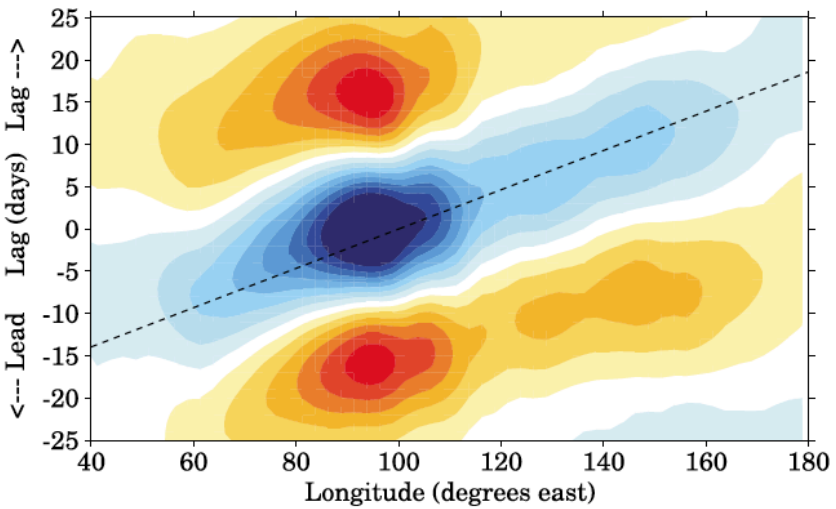


high moisture sensitivity

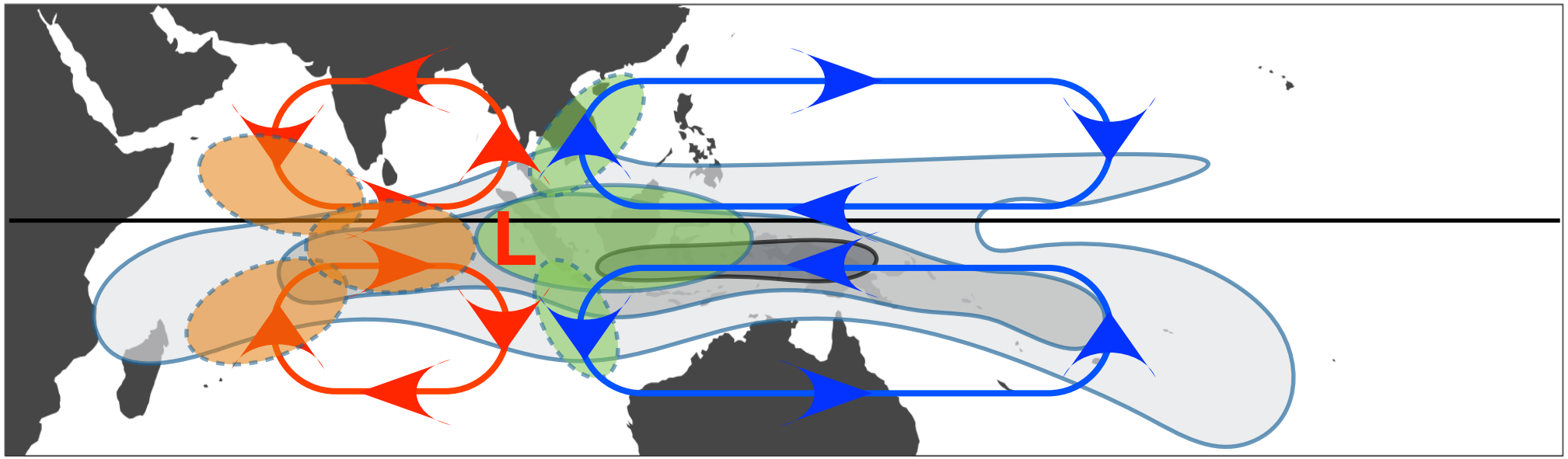
f. Atmosphere-only, high entrainment



g. KPP-coupled, high entrainment

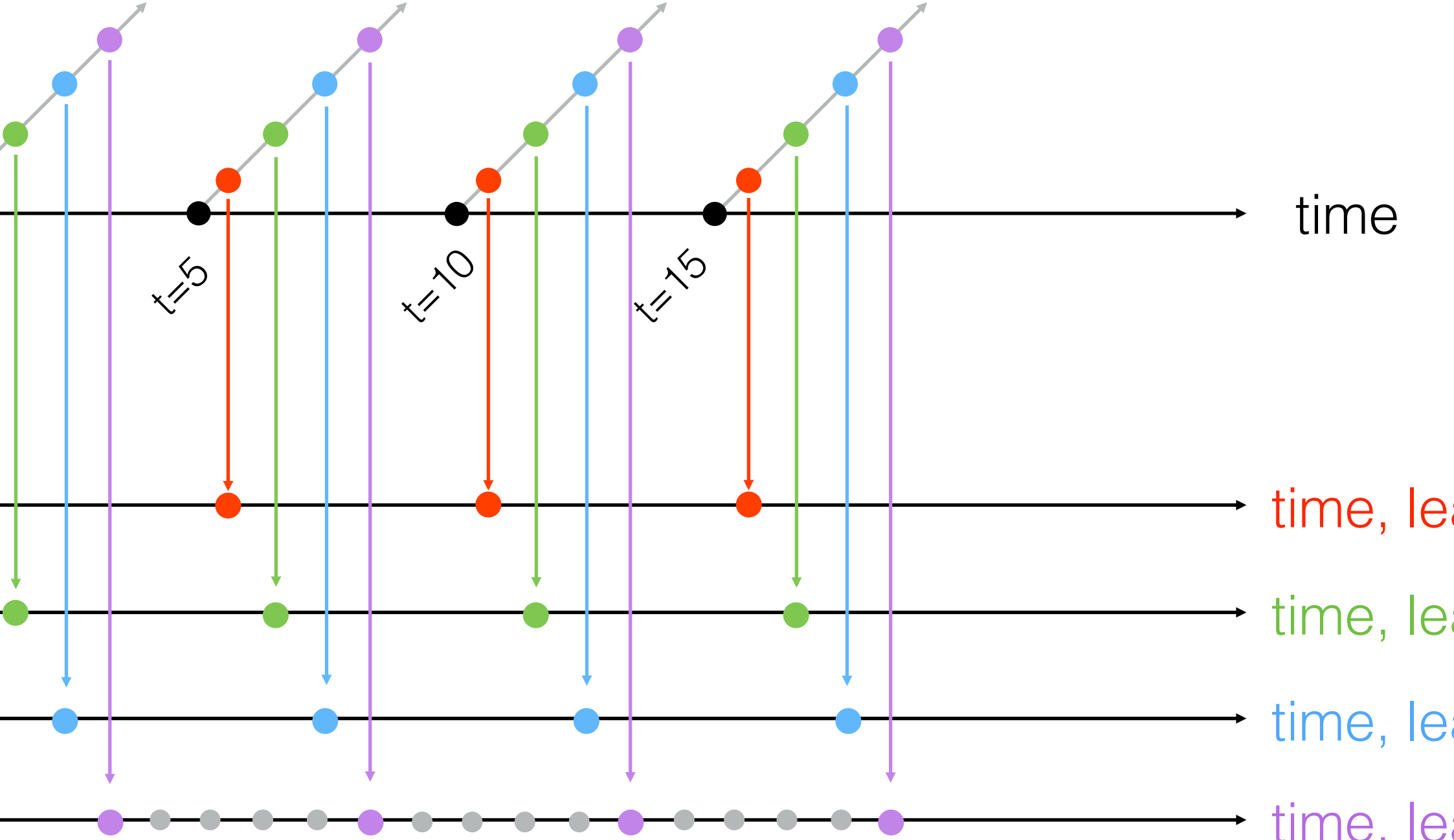


Klingaman and Woolnough (2014)



1. mean state moisture gradients.

2. MJO-like circulation anomalies.


time
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t=15
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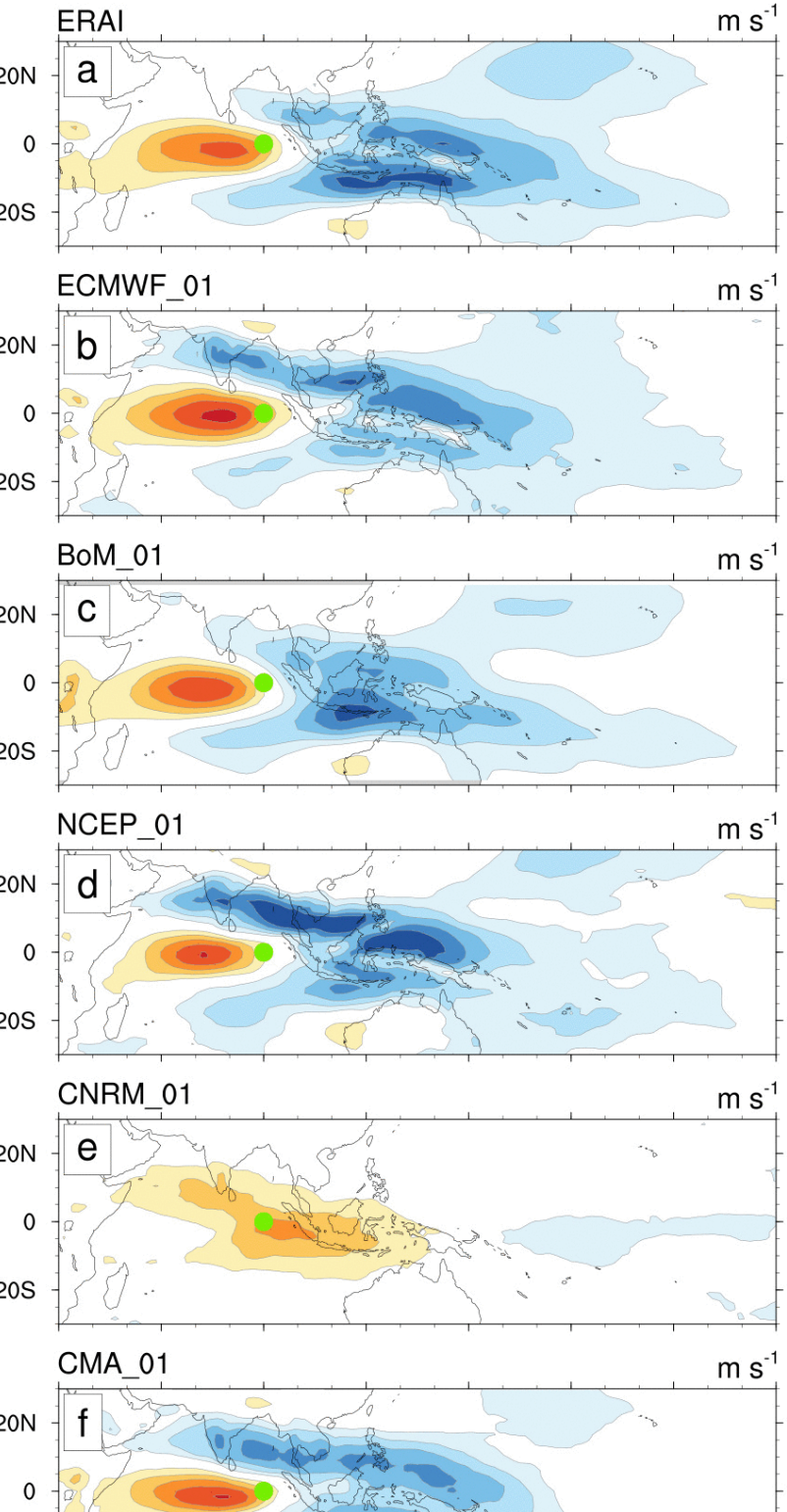
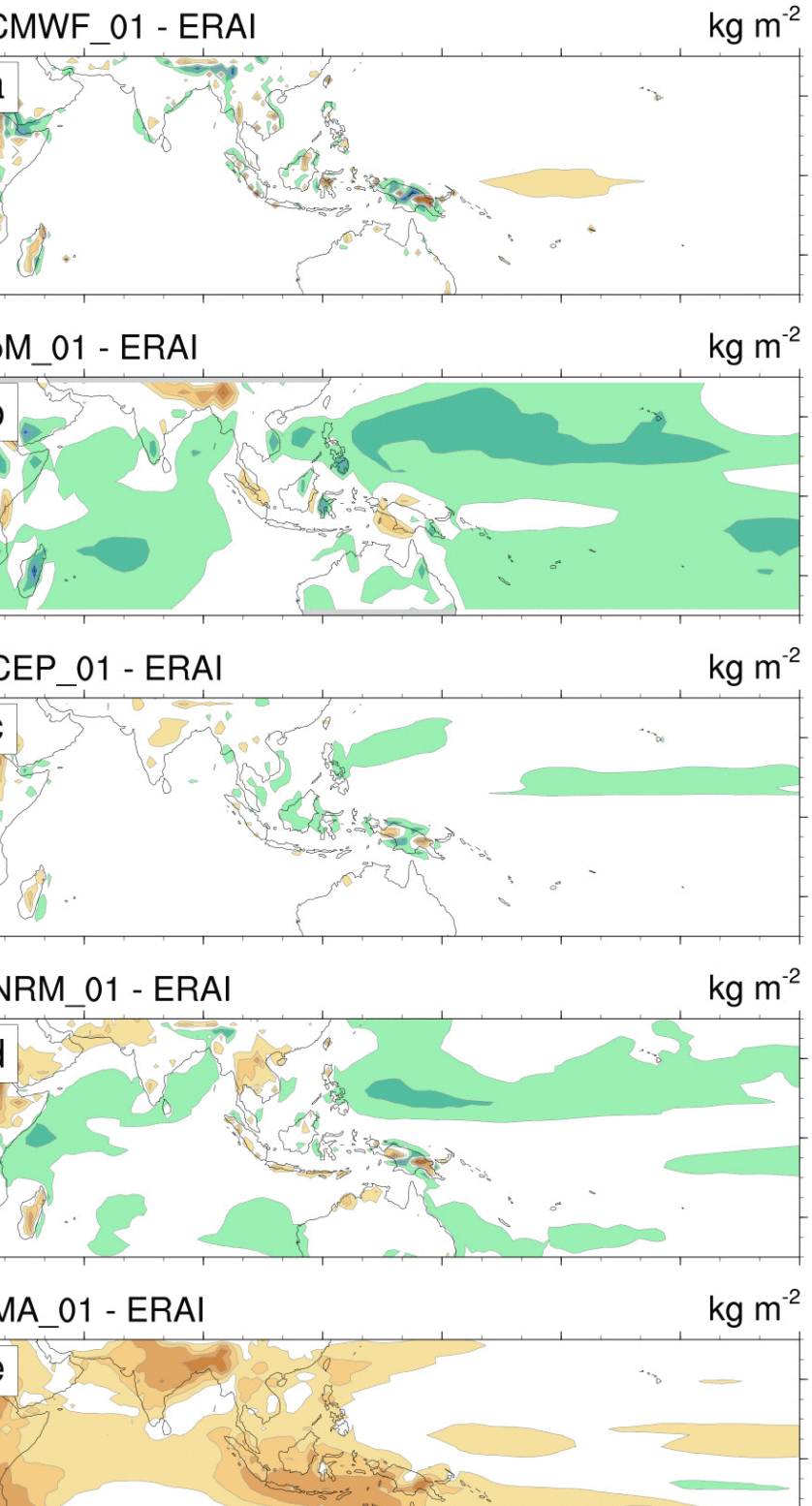


- ER wave westerlies decay rapidly
- KW wave easterlies persist
- CNRM seems to have initialization shock

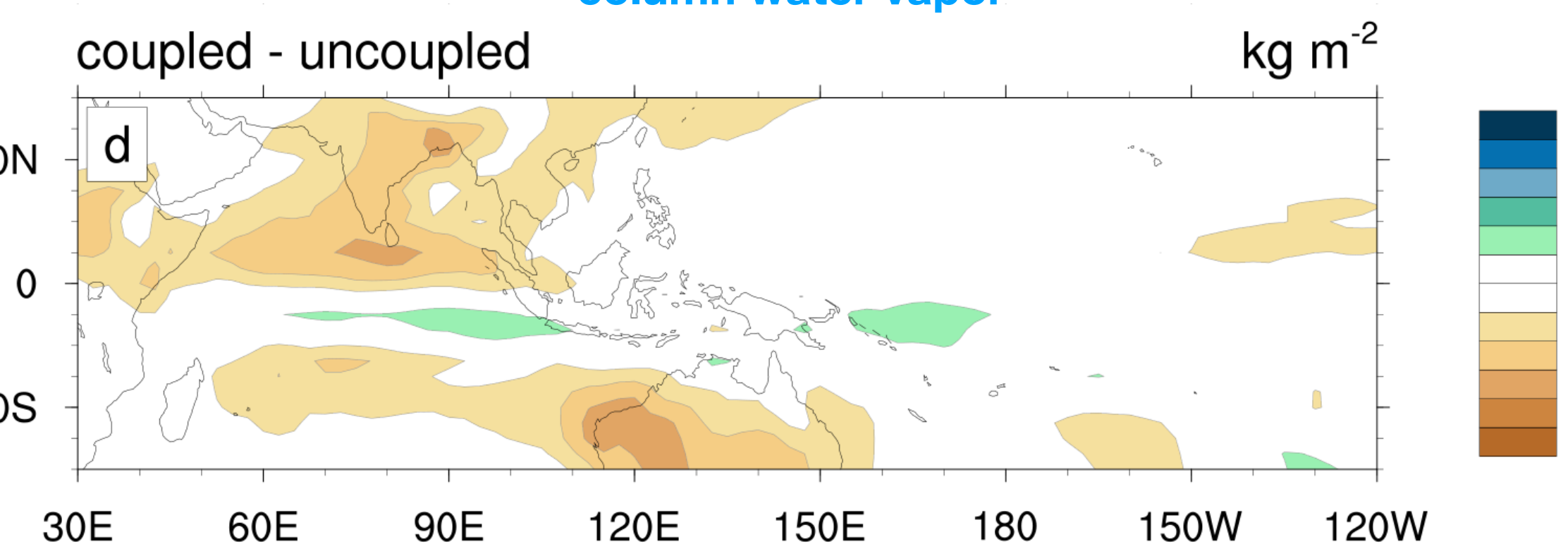


- moisture biases develop rapidly:
  - drying on Equator
  - moistening away from Equator
  - some of both

- “flattening” of meridional moisture gradients with lead time

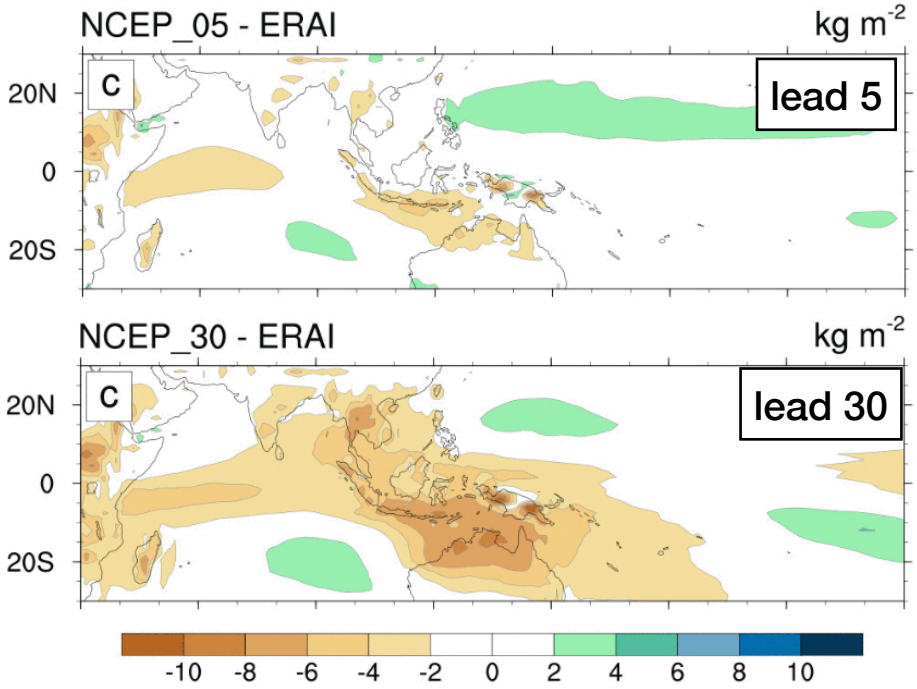
what causes this?

column water vapor



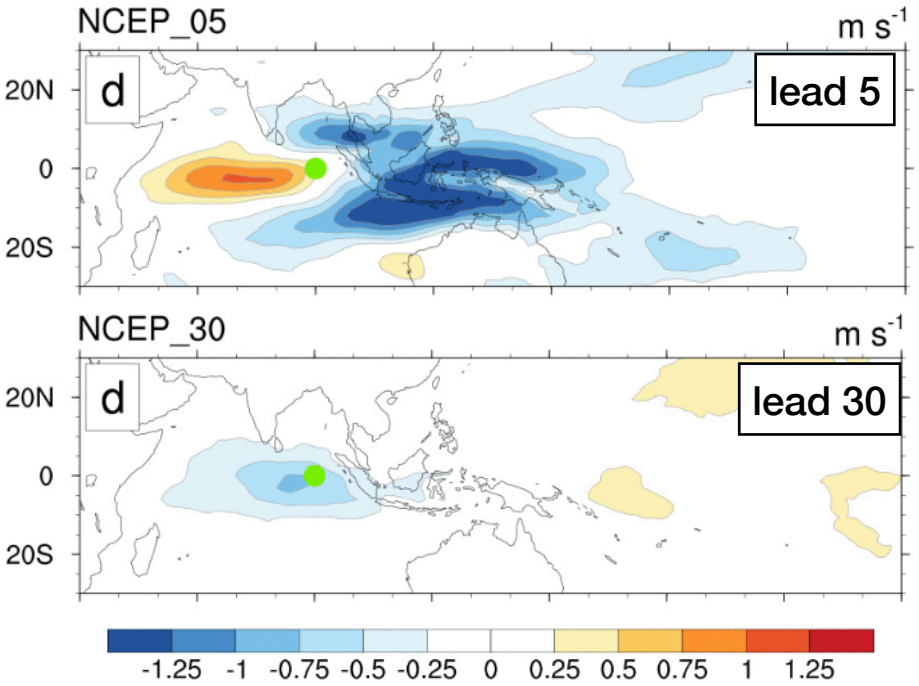
- more favorable moisture gradients in coupled than uncoupled models.
- not attributable to change in the MJO itself.

degraded CWV



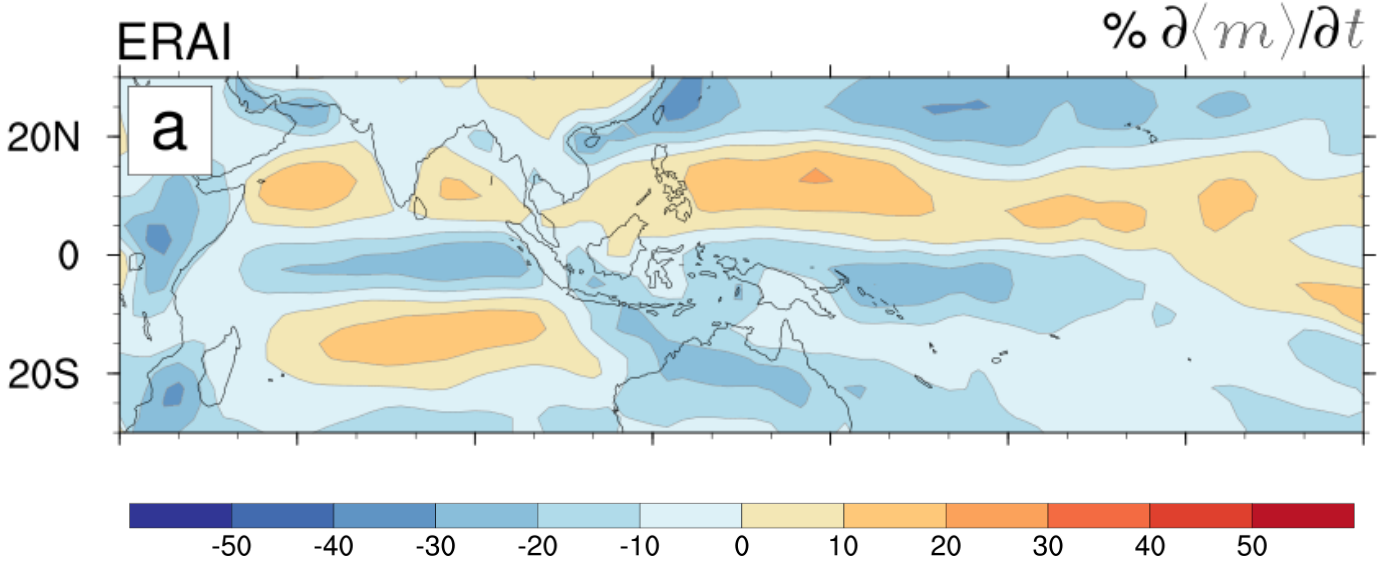
- "flattened" meridional moisture distribution.
- resembles the transition from strongly to weakly coupled state.
- other processes could also

degraded wind anomalies



- degraded wind patterns, especially ER wave westerlies.
- reduced ER wave westerlies may be more directly related to reduced surface flux feedbacks.

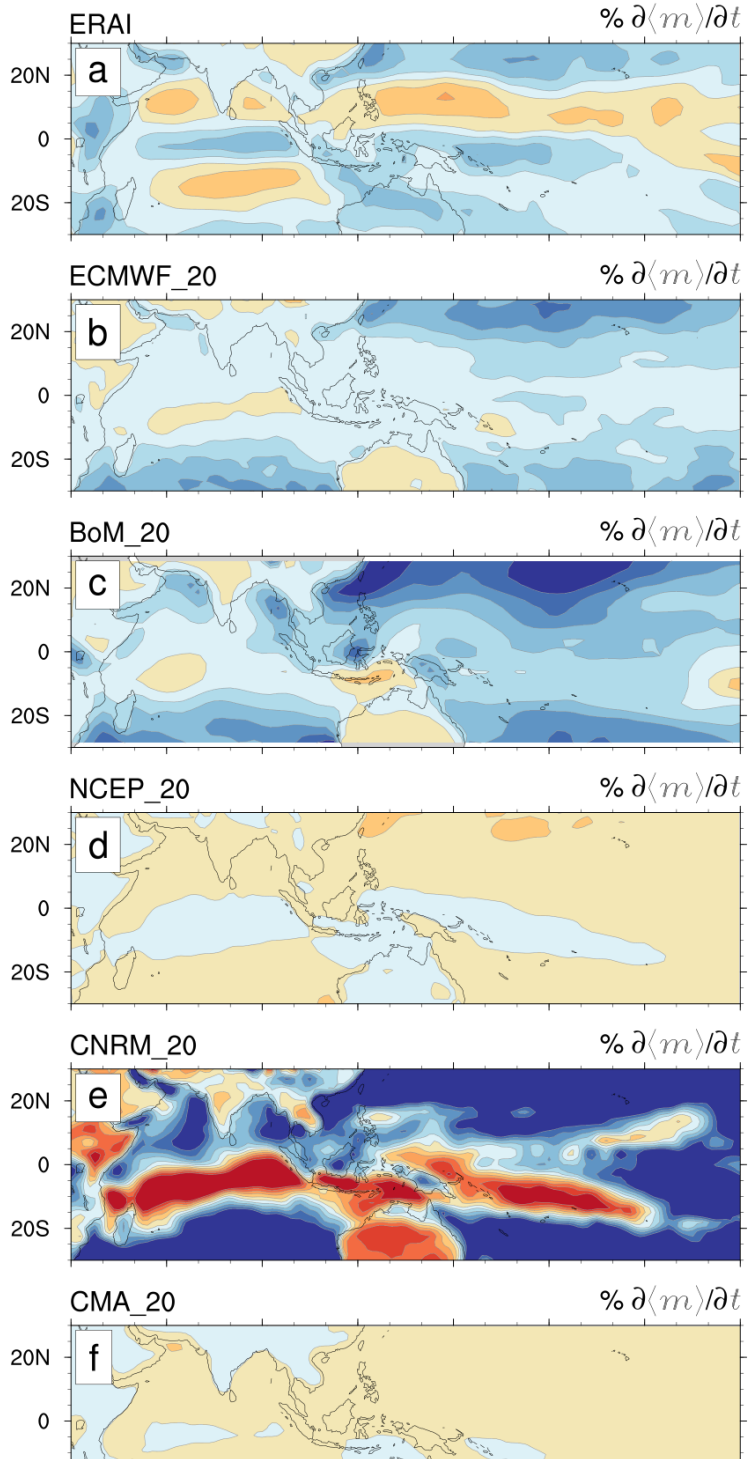
LH projection onto $\partial\langle m \rangle/\partial t$, Nov-Apr



- LH fluxes contribute positively to moisture tendencies at ER wave latitudes.

(DeMott et al. 2016)

LH projection onto $\partial\langle m\rangle/\partial t$, Nov-Apr



too weak

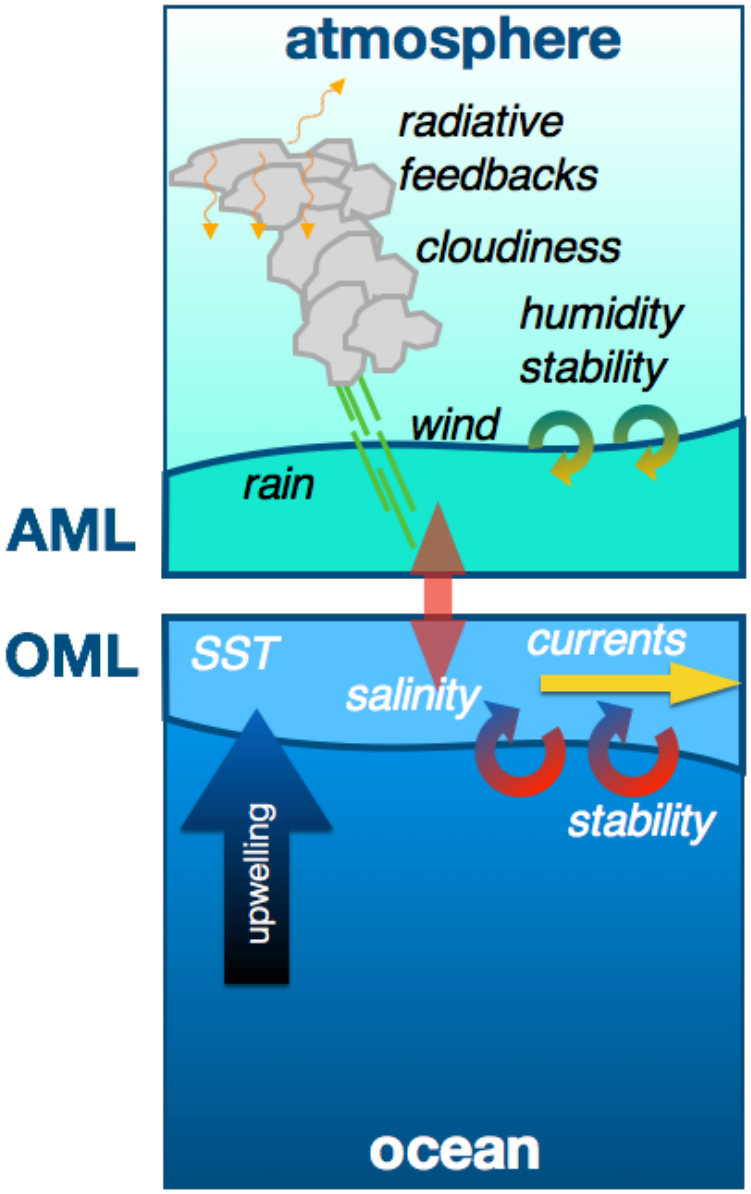
too weak

too weak

too strong

too weak

how can we understan
these differences?



1. AML/OML budget studies.

2. model experiments

hypothesis	mechanism denial experiment
H1: atmospheric precursors dominate ocean feedbacks	uncoupled simulations with 1) persisted backgrounded and 2) prescribed climatological SSTs
2: diurnal warm layers help promote MJO propagation	replace time step SST with 24-hour averag SST for sensible heat flux
H3: horizontal SST gradients promote suppressed phase convergence, convection	replace grid-point SST with area-average SST for sensible heat flux
H4: upper ocean heat content helps maintain MJO convection	replace grid-point SST with 61-day mean SST for latent heat flux

- coupled feedbacks within the MJO are like a conversation between ocean and atmosphere.

- in models, these conversations may:
  - be artificial
  - reflect biases
  - lead to misunderstandings

- coupled feedbacks in forecast models may affect:
  - background moisture distribution and gradients
  - circulation anomalies

- circulation anomaly degradation may be tied to surface flux feedbacks to the ER wave.

- moisture distribution feedbacks are harder to understand, but are not simply a result of MJO changes.

- mixed layer budgets studies and model experiments will help us understand both.

extra slides

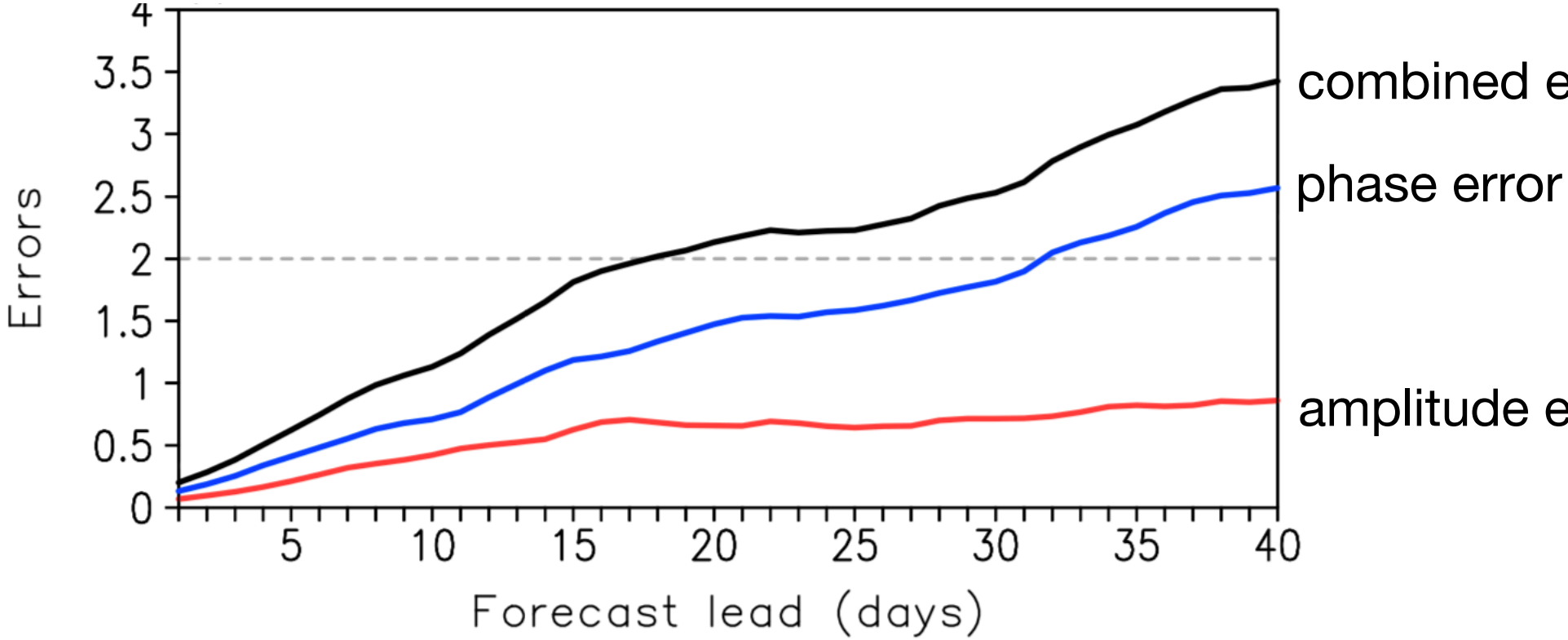
nterannual SST perturbation (ENSO) regulate mean state moisture ar
MJO propagation (e.g., Polh & Matthews 2007; DeMott et al. 2018).

he upper ocean stores and releases energy throughout the MJO life
ycle (links to MSE budget)
- intraseasonal timescales
- diurnal timescales

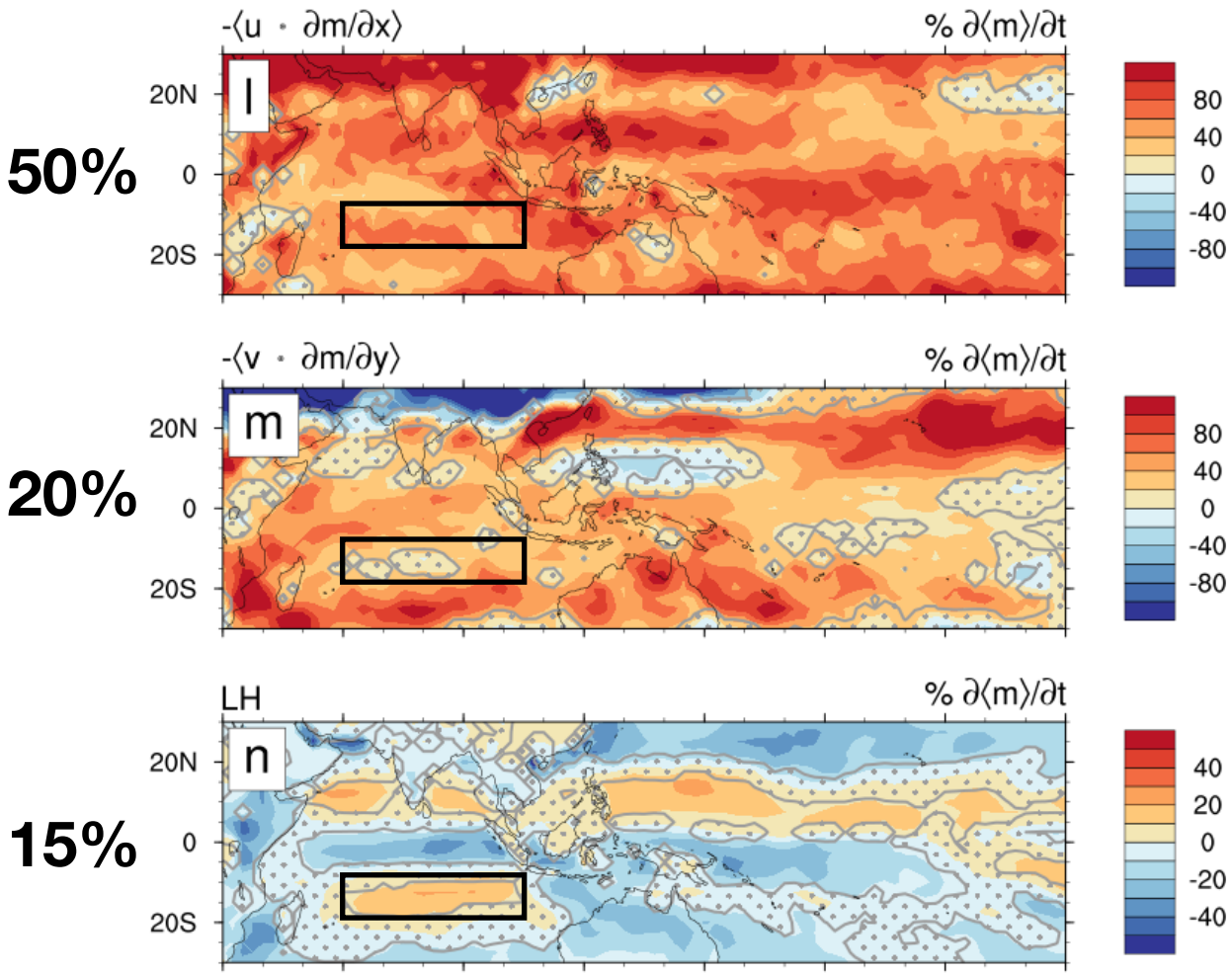
pper ocean surface currents can alter the SST response to net surfa
nergy inputs.
- advection and mixing
- generation of SST gradients

ceanic shallow water wave modes (KW, ER)

The prediction errors increase with time



ERAI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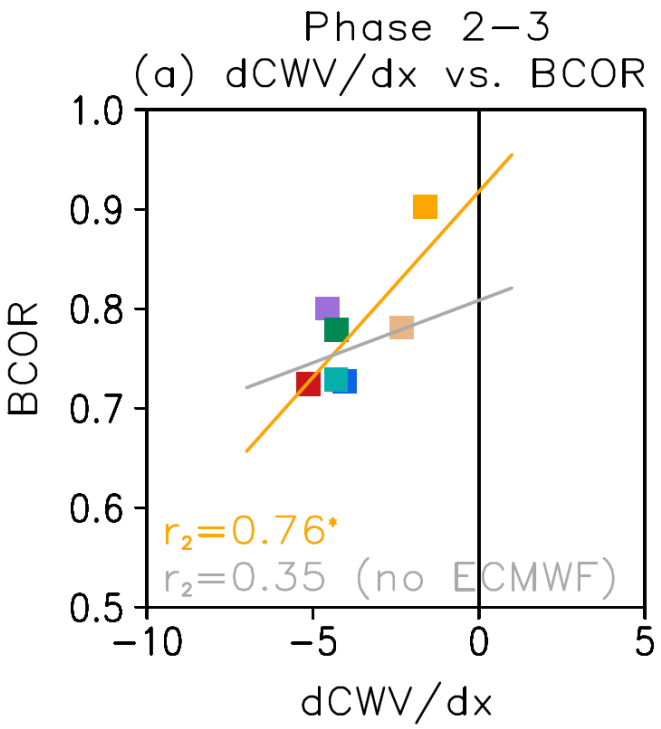
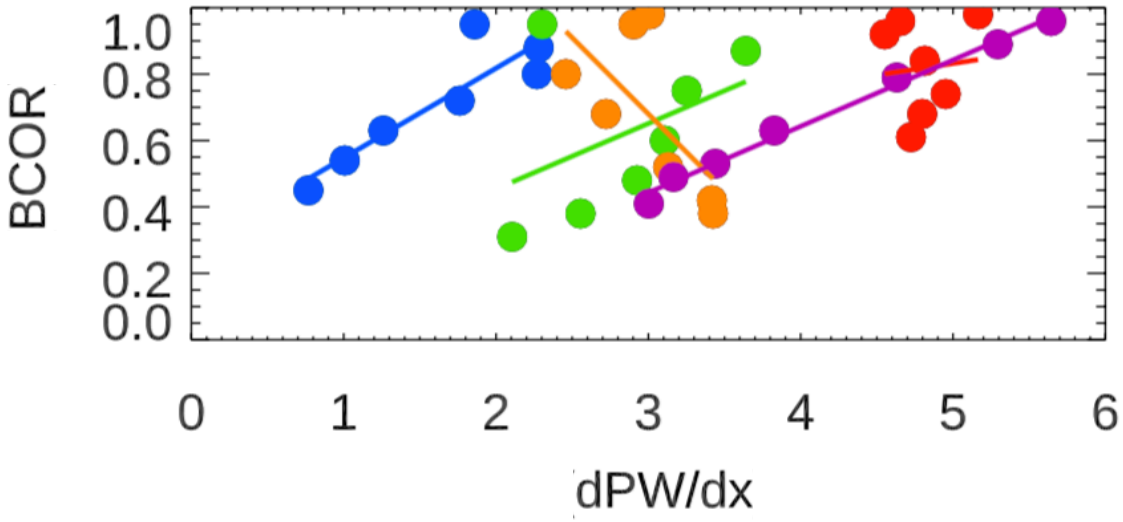
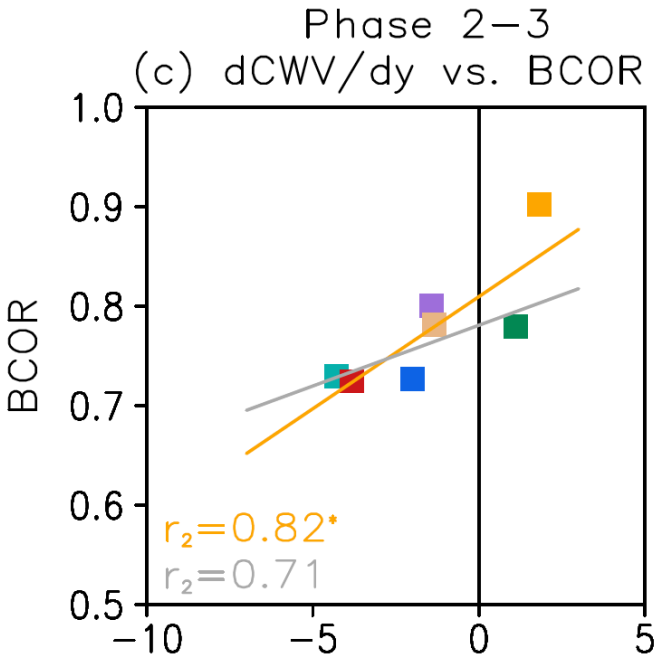
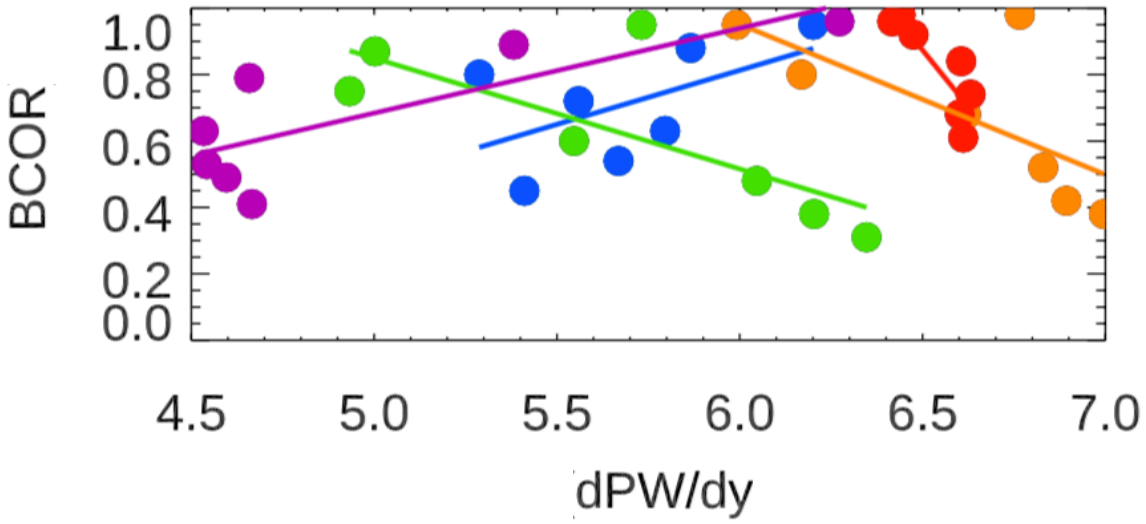
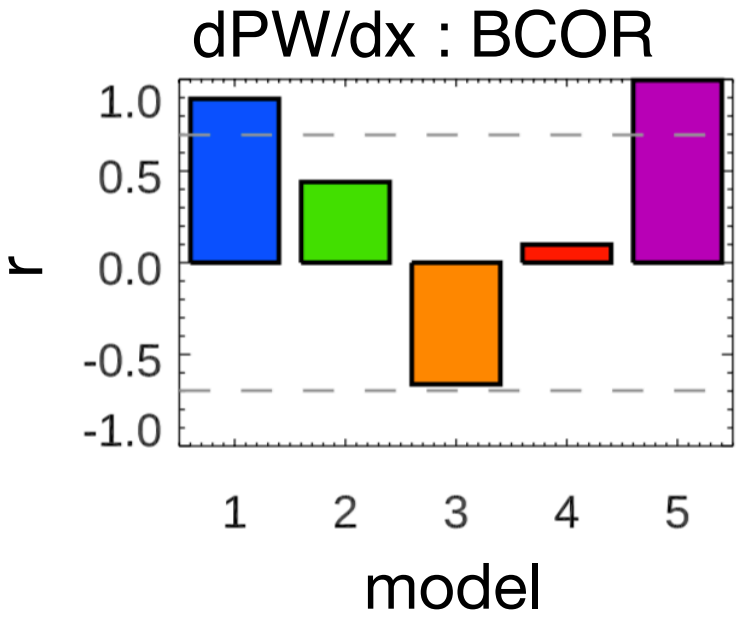
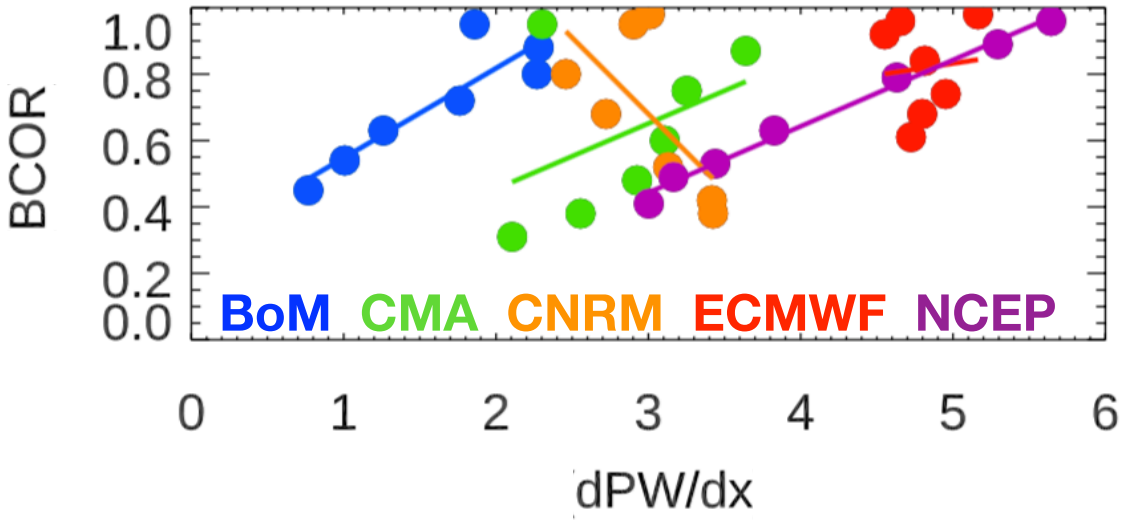

Phase 2–3
(a) dCWV/dx vs. BCOR
BCOR
dCWV/dx
r₂=0.76*
r₂=0.35 (no ECMWF)

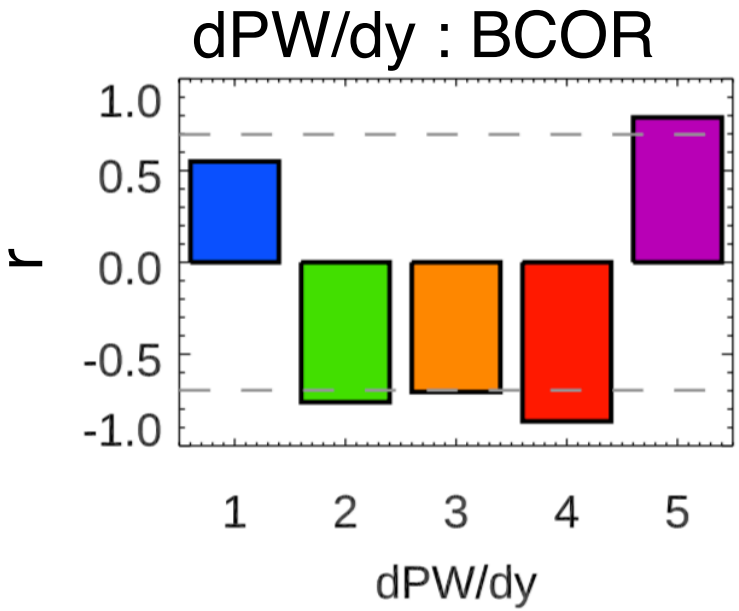

BCOR
dPW/dx


Phase 2–3
(c) dCWV/dy vs. BCOR
BCOR
r₂=0.82*
r₂=0.71


BCOR
dPW/dy


dPW/dx : BCOR
r
1.0
0.5
0.0
-0.5
-1.0
1
2
3
4
5
model


BCOR
1.0
0.8
0.6
0.4
0.2
0.0
BoM
CMA
CNRM
ECMWF
NCEP
0
1
2
3
4
5
6
dPW/dx


dPW/dy : BCOR
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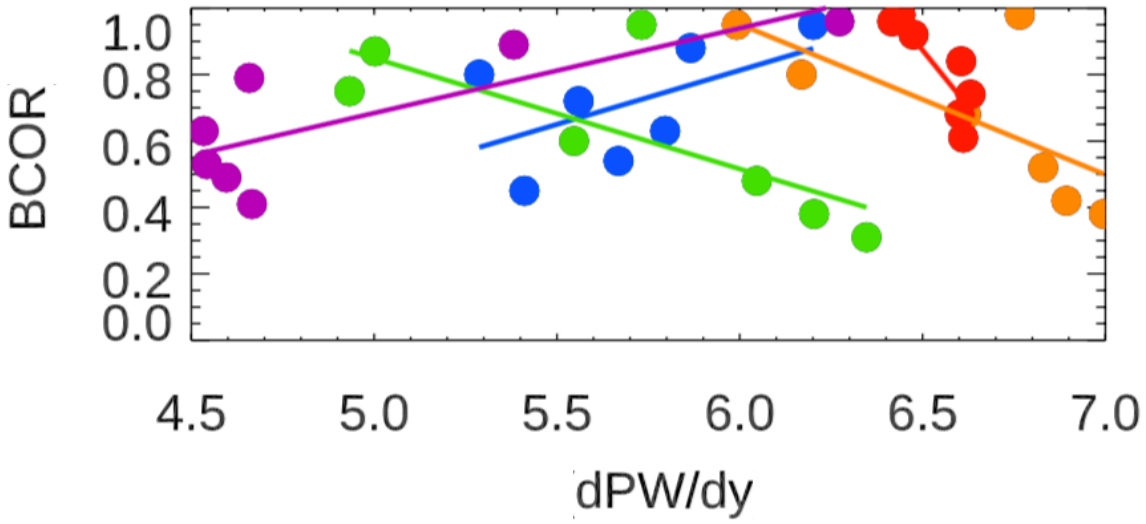
dPW/dy


BCOR
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dPW/dy