

Does the Reduction in the Southern Ocean Radiation Bias Alleviate the double-ITCZ Problem?

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Abstract

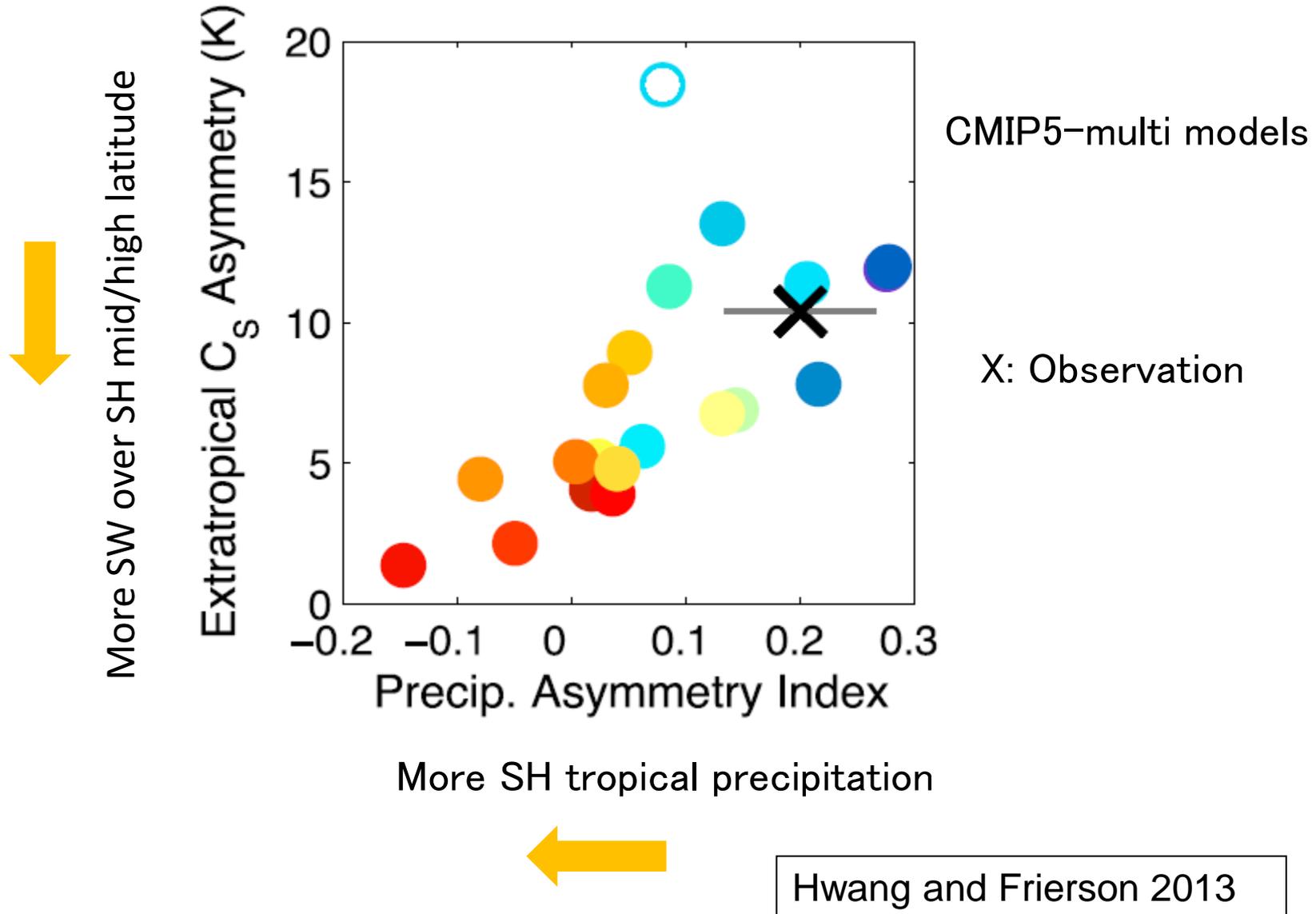
The radiation bias over the Southern Ocean was terribly bad in MRI-CGCM3 that was used for CMIP5 simulations. However, the bias is significantly reduced in MRI-ESM2 (Yukimoto et al. 2019) that is used for CMIP6 simulations by various modifications related to clouds (Kawai et al. 2019). On the other hand, the double-ITCZ problem is also alleviated in the MRI-ESM2 (Tian and Dong, 2020). Is the reduction in the Southern Ocean radiation bias the cause of alleviation of the double-ITCZ problem? Each modification that contributed to the reduction of the Southern Ocean radiation bias in the MRI-ESM2 was progressively reverted to the corresponding older treatment in order to examine their individual impacts on the ITCZ problem. Results show the double-ITCZ problem worsens almost monotonically when the excessive shortwave insolation over the Southern Ocean increases (Kawai et al. 2020, 2021).

Does the reduction in the Southern Ocean radiation bias alleviate the double-ITCZ problem?

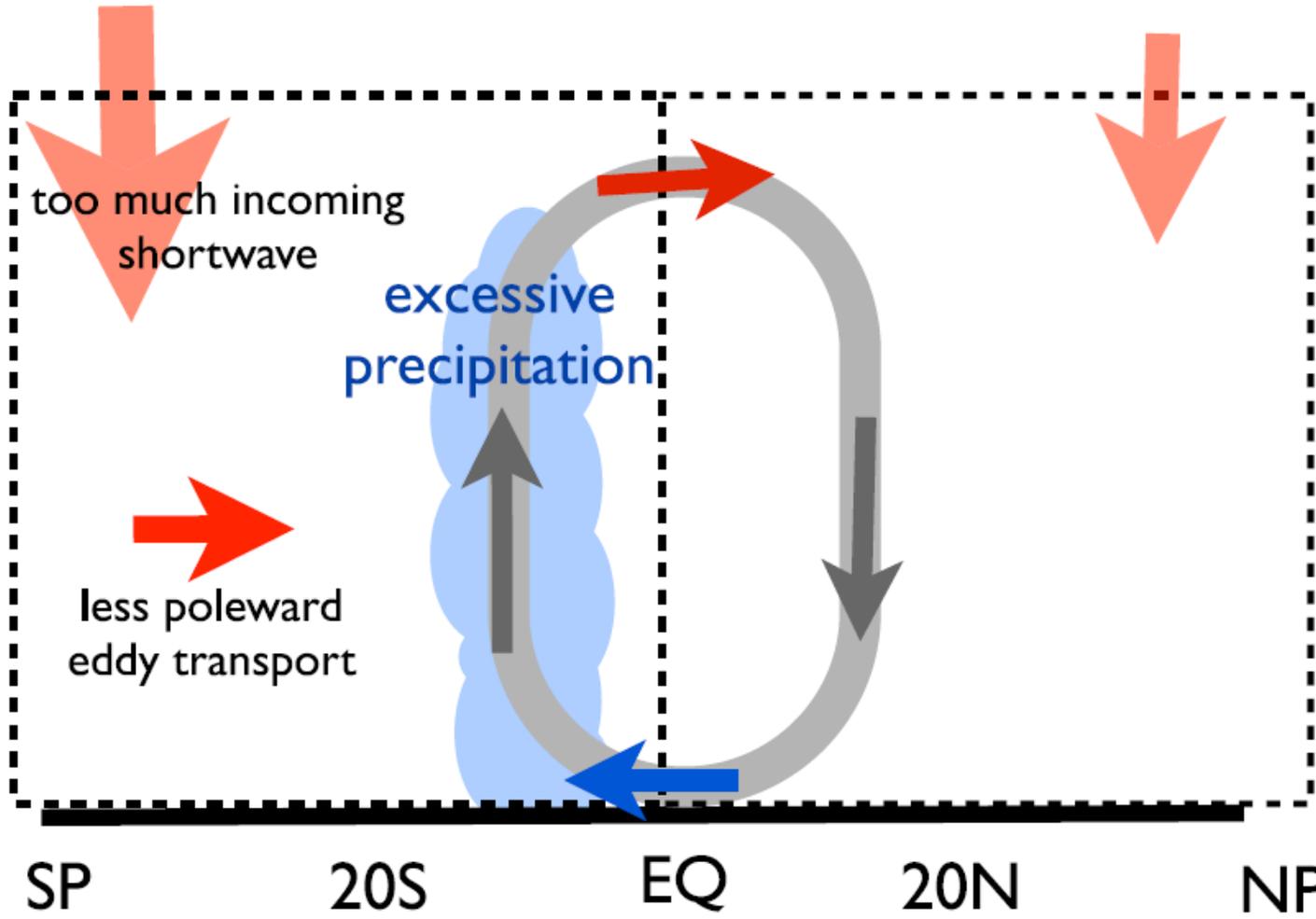
Hideaki Kawai , Tsuyoshi Koshiro, & Seiji Yukimoto
Meteorological Research Institute, JMA

Kawai, H., T. Koshiro, and S. Yukimoto, 2021: Relationship between shortwave radiation bias over the Southern Ocean and the double-intertropical convergence zone problem in MRI-ESM2. *Atmos. Sci. Let.*, **22**, e1064, <https://doi.org/10.1002/asl.1064>.

Mid/High-latitude radiation budget affects tropical precipitation?



Southern Ocean radiation bias & ITCZ based on energy transport concept



Mid/High-latitude radiation budget affects tropical precipitation?

Kang et al. (2008, 2009)

based on slab ocean models

etc.

Not so clear using A-O coupled models because the energy due to excess of SW radiation is mainly transported by the ocean?

Kay et al. (2016)

Hawcroft et al. (2017)

etc.

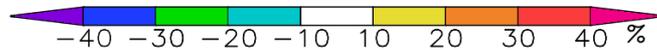
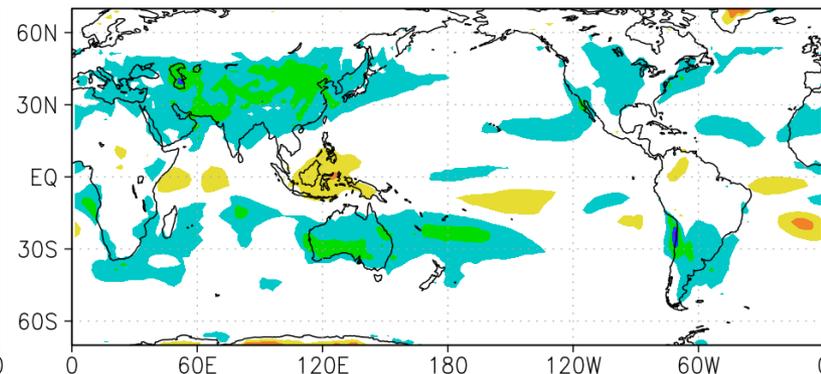
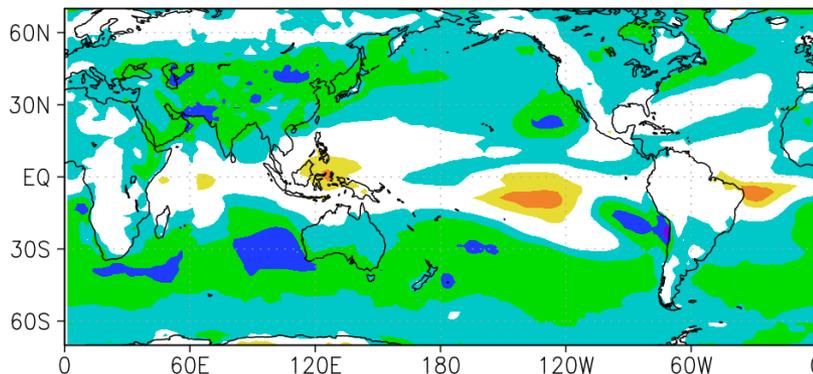
based on atmosphere-ocean coupled models

Improvement in clouds in MRI-ESM2

Old model: MRI-CGCM3

New model: MRI-ESM2

TCC bias

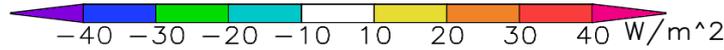
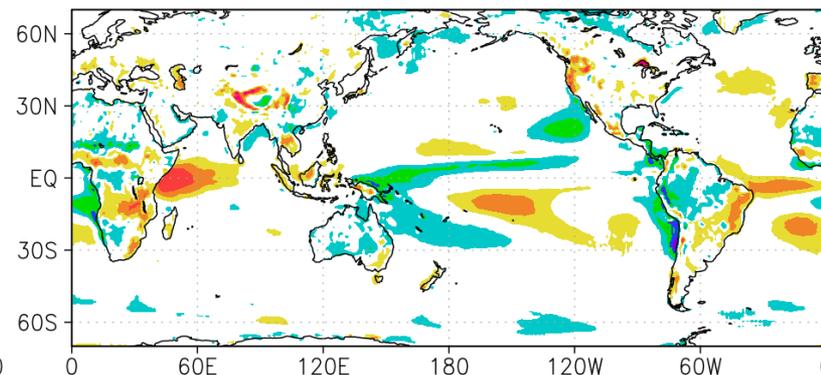
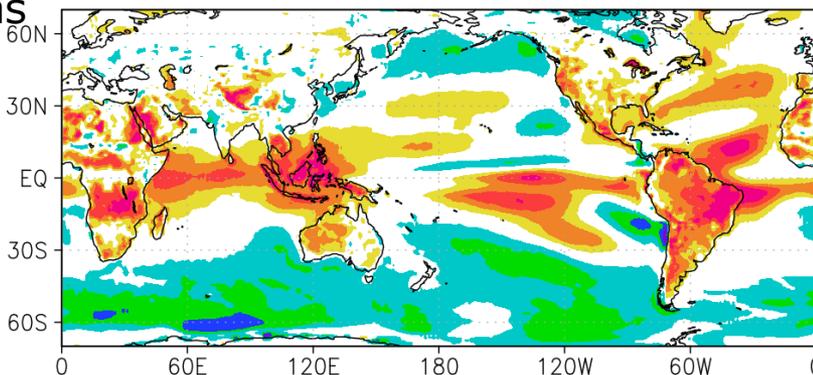


* much less over the Southern Ocean

* Improved over the SO and off Peru

obs.: ISCCP

TOA SW bias
(upward)



* Too much SW reflection over Tropics

* Much less SW reflection over the SO

* Improved over Tropics

* Improved over the SO and off Peru

Model performance

net radiation	MRI-CGCM3:	27th	among 48 CMIP5 models
	MRI-ESM2:	7th best	among 47 CMIP6 models (2m temperature 5th best)
double ITCZ	MRI-CGCM3:	Worst	among 25 CMIP5 models
	MRI-ESM2:	8th best	among 26 CMIP6 models

(Tian & Dong 2020)

Question

Is the reduction in the radiation bias the cause of alleviation of the double-ITCZ problem?

Experiments

Each modification that contributed to the reduction of the Southern Ocean radiation bias in the MRI-ESM2 (not expected to improve convections directly) was progressively reverted to the corresponding older treatment. (using atmosphere ocean coupled configuration for 1984-2014)

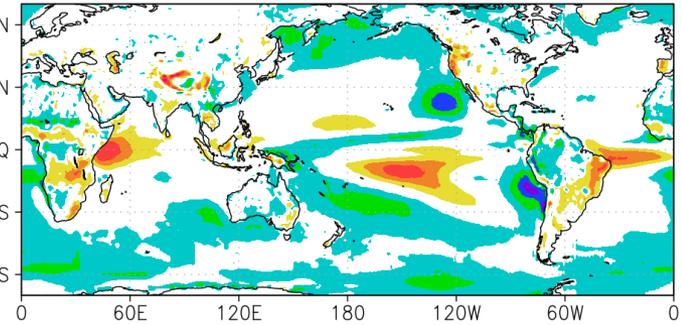
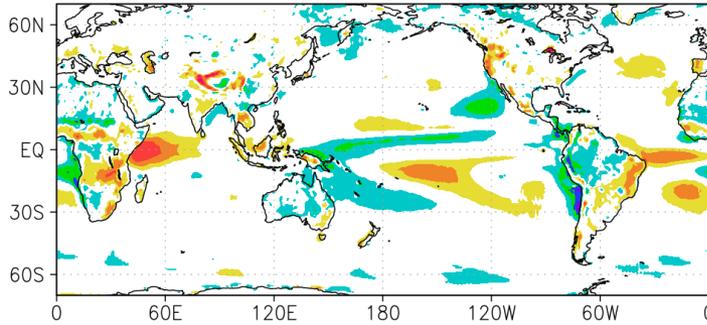
	CNTL	EXP1	EXP2	EXP3	EXP4
stratocumulus scheme	new	old	old	old	old
shallow convection conditional turning off	yes	yes	no	no	no
WBF effect	new	new	new	old	old
fine sea aerosols	yes	yes	yes	yes	no

Impact on Radiation Budget

ToA SW radiation bias (upward)

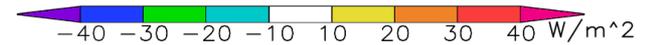
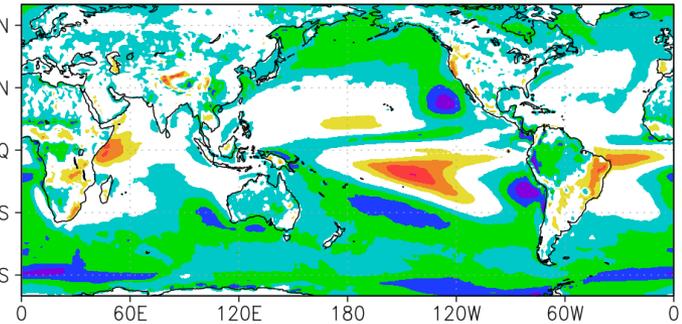
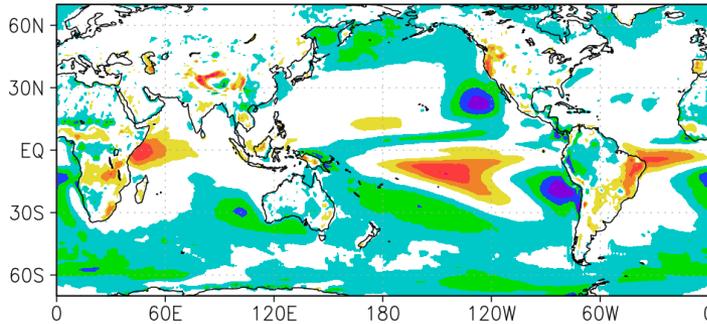
CNTL

EXP1

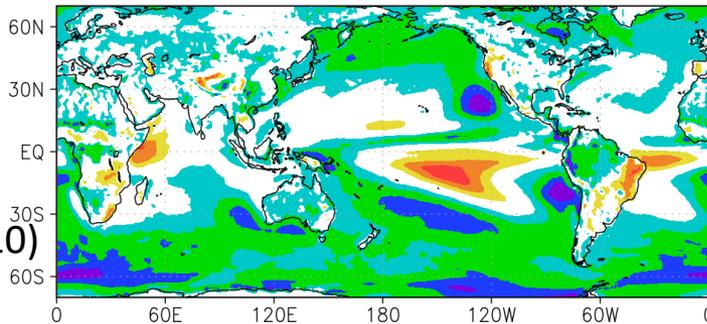


EXP2

EXP3



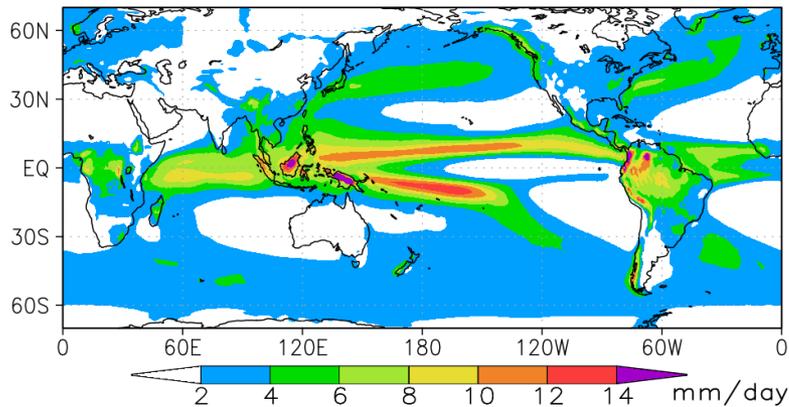
EXP4



Radiation bias is larger, especially over the SO, when EXPs are closer to the old model.

Obs.
CERES (2001-2010)

CNTL

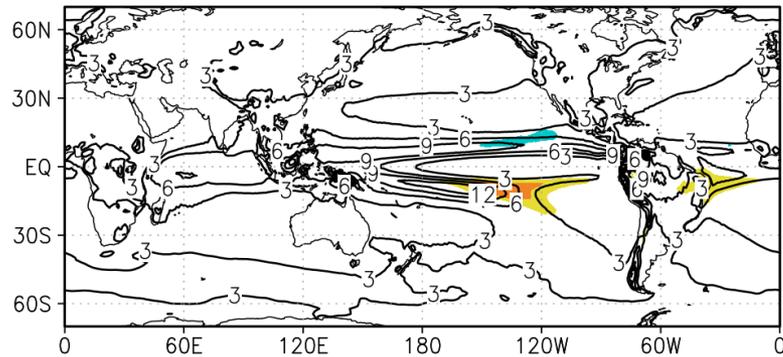


Impact on Precipitation

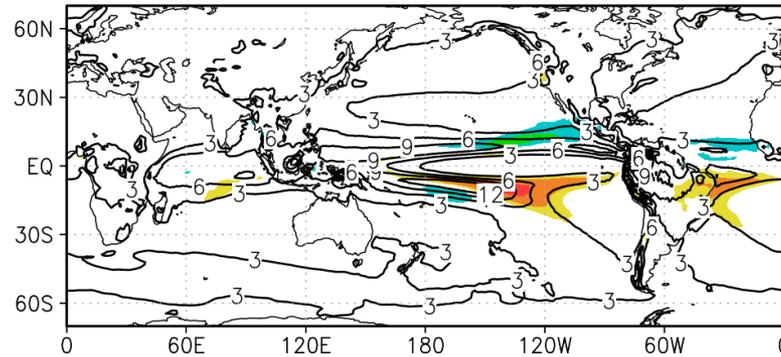
SH tropical precip. increases (deteriorates),
when EXPs are closer to the old model.
More distinct double ITCZ

Contour: Climatology
Shade: Diff from CNTL

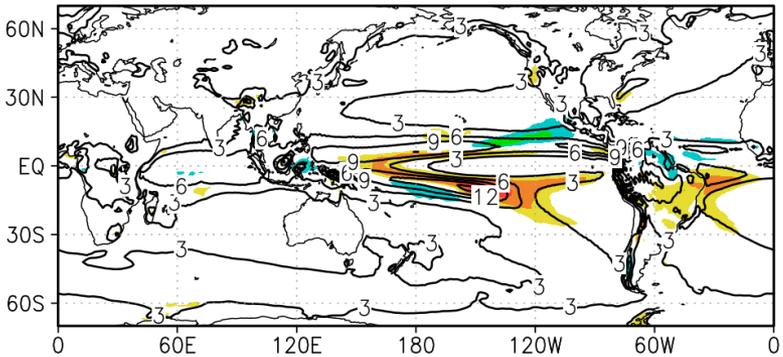
EXP1 - CNTL



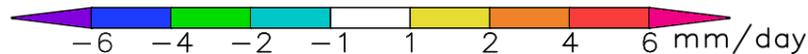
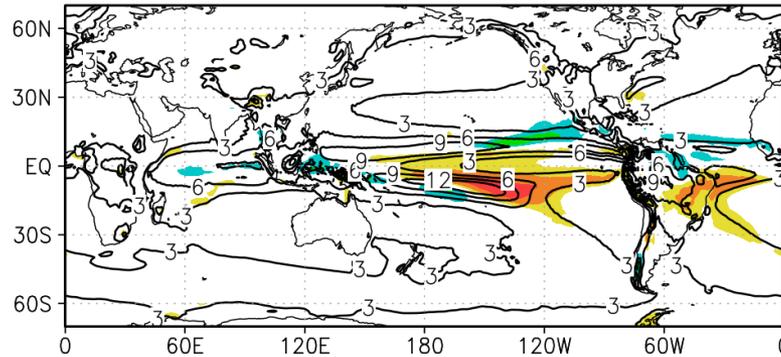
EXP2 - CNTL



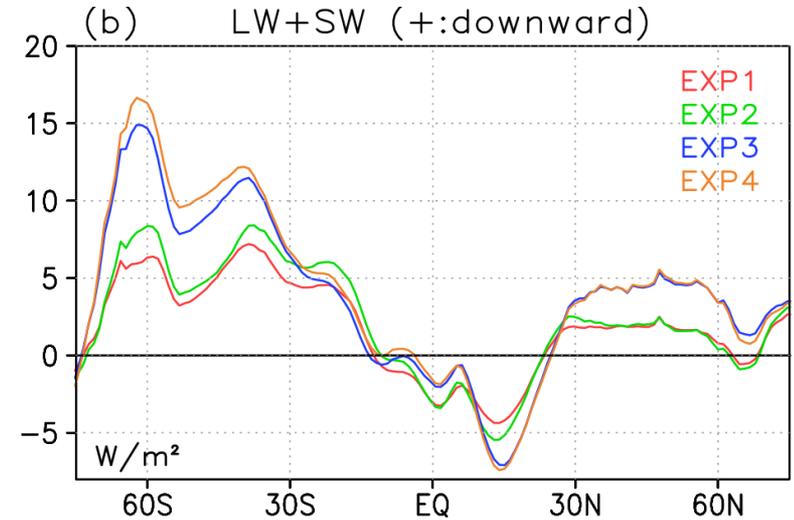
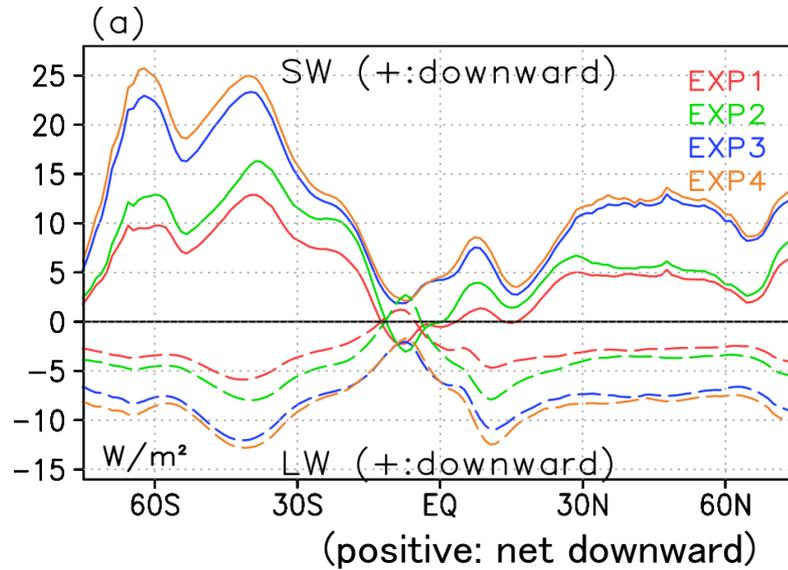
EXP3 - CNTL



EXP4 - CNTL

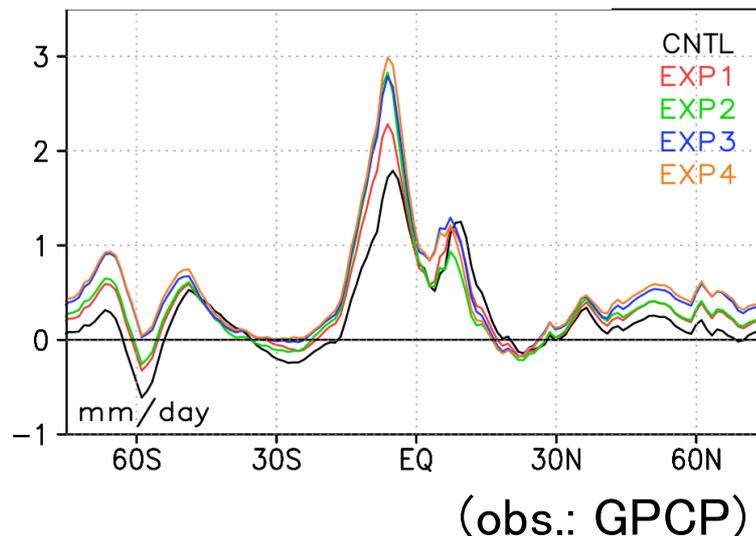


Impact on ToA radiation budget (difference from CNTL)



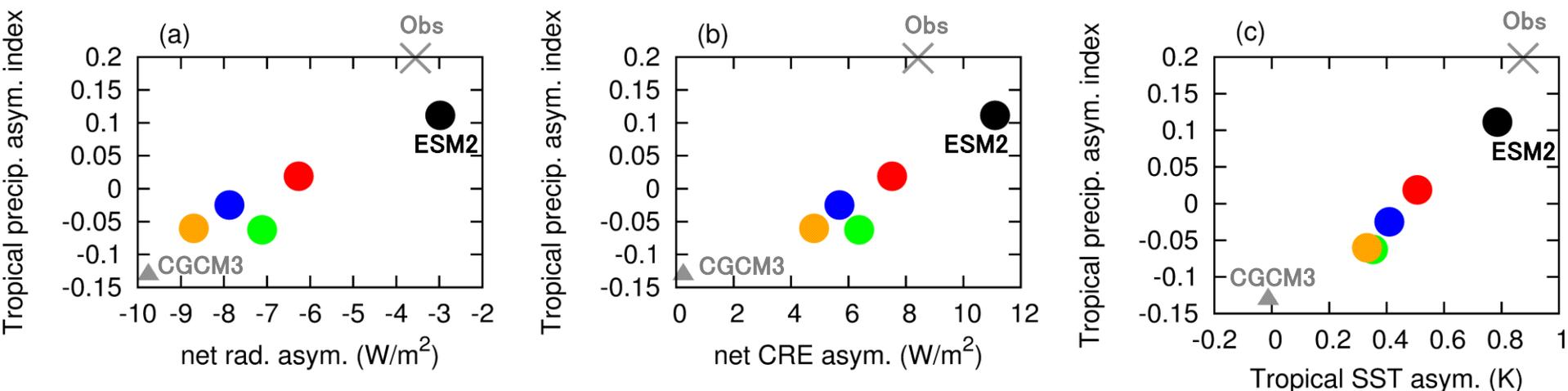
Radiation bias increases over the SO when EXPs are closer to MRI-CGCM3 (old model)

Precipitation bias



Precipitation increases (deteriorates) in the Southern Tropics when EXPs are closer to MRI-CGCM3 (old model)

Radiation bias over the Southern Ocean and the ITCZ in MRI-ESM2



- Tropical precipitation asymmetry index
(Hwang and Frierson 2013)
- Asymmetry of extratropical radiative flux (or CRE)
(Hwang and Frierson 2013)
- Tropical SST asymmetry
(Hawcroft et al. 2018)

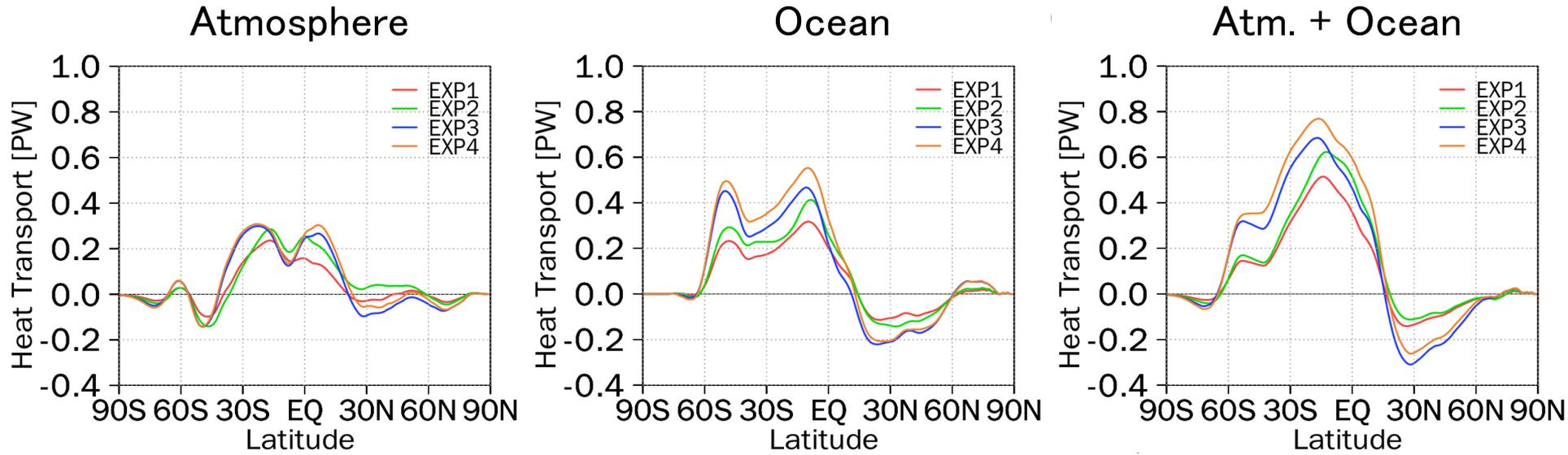
- CNTL (ESM2)
- EXP1
- EXP2
- EXP3
- EXP4
- × Obs.
- ▲ CGCM3

Clear relationship!

Larger SH radiation bias → worse ITCZ

Impact on Energy Transport

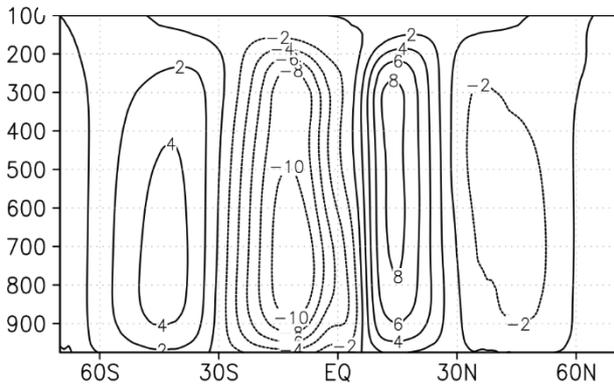
difference from CNTL



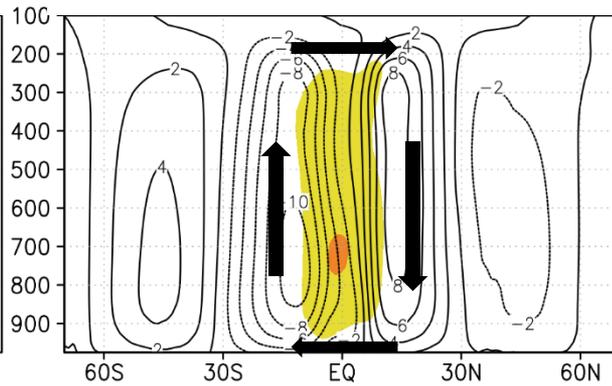
(Northward: positive)

- Northward energy transport increases for EXPs with larger insolation bias over SH.
- Energy transport increase due to the ocean is 2 times that due to the atmosphere.
- But the energy transport due to the atmosphere still increases too.
→ This part corresponds to the deterioration of double ITCZ.

CNTL

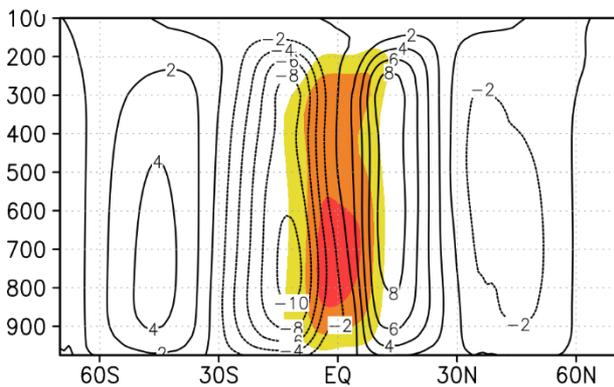


EXP1

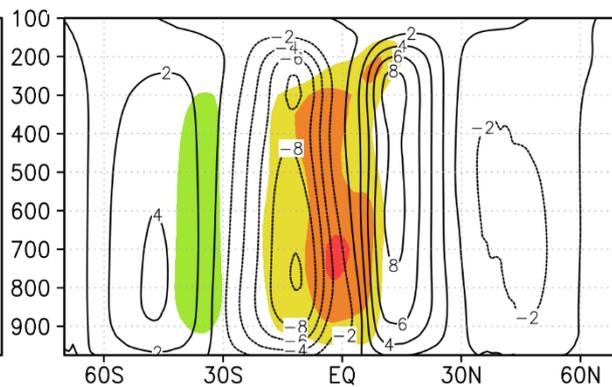


Impact on mass stream function

EXP2

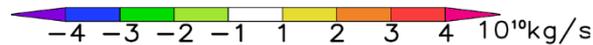
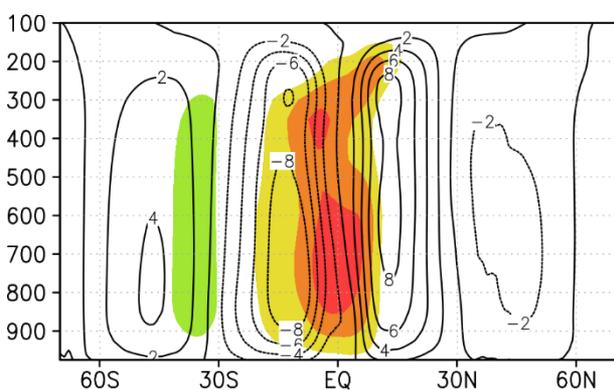


EXP3



Contour: Climatology
Shade: Diff from CNTL

EXP4



Upward anomaly south of eq. and downward anomaly north of eq. strengthen when EXPs are closer to MRI-CGCM3 (old model) (consistent with Hwang and Frierson 2013)

- ❑ The representations of clouds in climate model MRI-ESM2 (for CMIP6) are significantly improved, especially over the Southern Ocean.
- ❑ Impact on ITCZ is investigated by intentionally increasing the radiation bias by making the cloud representation closer to the old model version (using an A-O coupled model.)
- ❑ We could confirm that the alleviation of double ITCZ problem in MRI-ESM2 can be mostly attributed to the reduction in the (SW) radiation bias.
- ❑ It is interesting that the double-ITCZ problem was substantially alleviated by the model modifications which are to reduce the SO radiation biases, although we did not try to reduce the tropical precipitation bias intentionally.

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