Evaluation of precipitation and upper-level clouds associated with large-scale circulation over the tropical Pacific Ocean in AOGCMs

Hiroki Ichikawa[1], Hirohiko Masunaga[2], and Hiroshi Kanzawa[1]

[1]Graduate School of Environmental Studies, Nagoya University
[2]Hydrospheric Atmospheric Research Center, Nagoya University

Introduction

General features of cloud and rainfall over the tropics in AOGCMs have been evaluated (e.g. Dai 2006, Su et al. 2006)

- General pattern are captured (Double ITCZ problem in some models)
- General seasonal and year-to-year variation are captured
- Sensitivity of cloud ice to SST are underestimated
- ….etc….

Evaluation is based on a global- or zonal- mean bias or regime sorted approach

The direct intercomparison of climatological mean field alone might not be necessarily informative to a suitable evaluation of physics in the models

＜ISSUE＞

Evaluating the variability of tropical precipitation and upper-level cloud associated with large-scale circulation field in the AOGCMs

・*Spatial linkage of rainfall and cloud with large-scale circulation*

＜Data＞・・・monthly data from 1984-1999

observation

GPCP (Rainfall)
ISCCP (High-level cloud amount)
NOAA OLR
ERA40 (U,V ⇒divergence at 200hPa;DIV)
Reynolds SST

Proxy of large-scale circulation

Climate Model [20century simulation]
(19 AOGCMs containing vertical cloud amount)

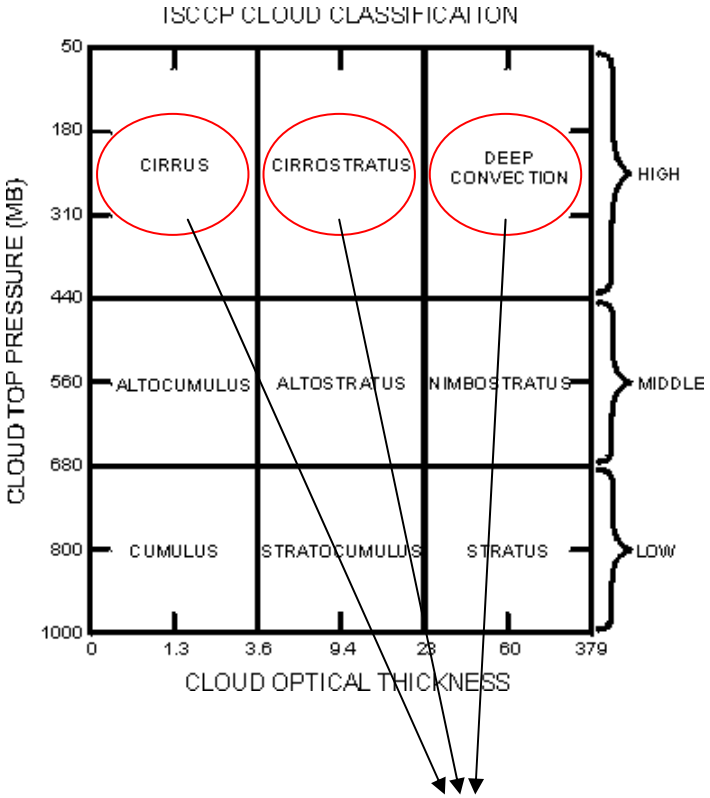
- BCCR-BCM2.0
- CCCMA-CGCM3.1(T47)
- CCCMA-CGCM3.1(T63)
- CSIRO-MK3.5
- GFDL-CM2.0
- GFDL-CM2.1
- GISS-EH
- GISS-ER
- IAP-FGOALS-g1.0
- INM-CM3.0
- INGV-ECHAM4
- IPSL-CM4
- MIROC3.2(hires)
- MIROC3.2(medres)
- MPI-ECHAM5
- MRI-CGCM2.3.2a
- NCAR-CCSM3
- NCAR-PCM1
- UKMO-HadCM3

ALL data are interpolated to the common 2.5 x 2.5 degree grid box

<Definition of High Level Cloud>

Observational data

ISCCP cloud classification
(Rossow and Schiffer 1999)



High Level Cloud (HLC), summing the three types of clouds, are mainly used for the comparison with AOGCMs output

~Identifying the HLC in the AOGCMs ~

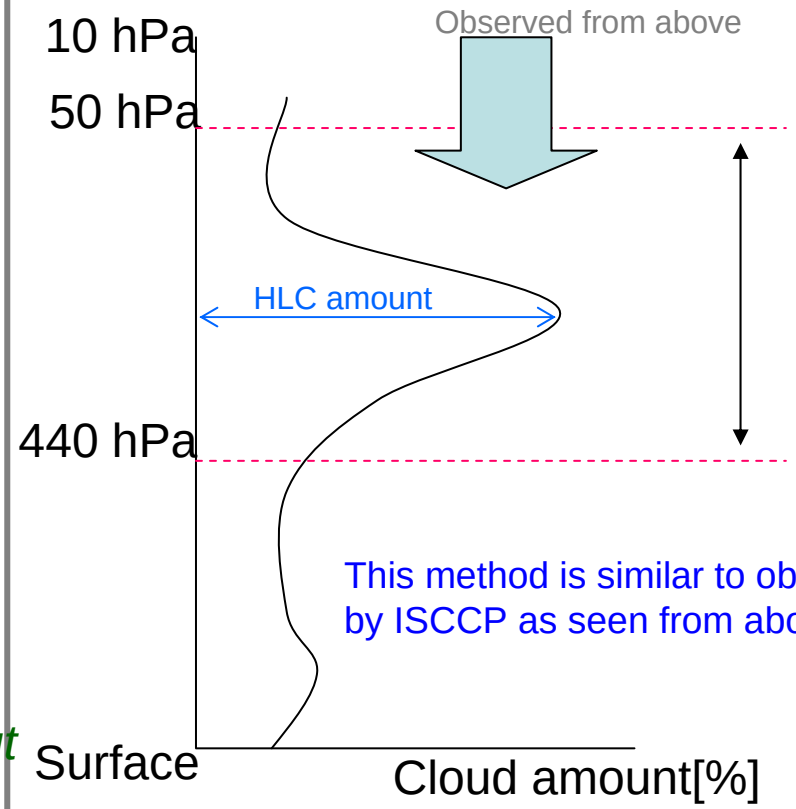
Cloud amount were calculated in each cloud layer in the models (not partitioned to cloud type)

Maximum overlap assumption (Wear 2004)

「 *Assign the largest value of all the layers with pressures between 440hPa and 50 hPa as the cloud fraction* 」

Same pressure level of HLC in ISCCP

Ex. at 1grid box



This method is similar to observation by ISCCP as seen from above (satellites)!!

<method >

Composite analysis is applied

in order to evaluate the spatial linkage of cloud/rainfall with large-scale circulation

Composite each parameter based on the DIV center

- Search the DIV center at each month from 1984-1999 (16yr X 12month = 192sample)
- Composite each parameter (Rain, HLC, OLR) based on the DIV center
- Anomaly Data from monthly climatology in each month are used for the composite

☆The DIV center is searched over the western-central Pacific ITCZ (140E-120W,2.5S-12.5N)

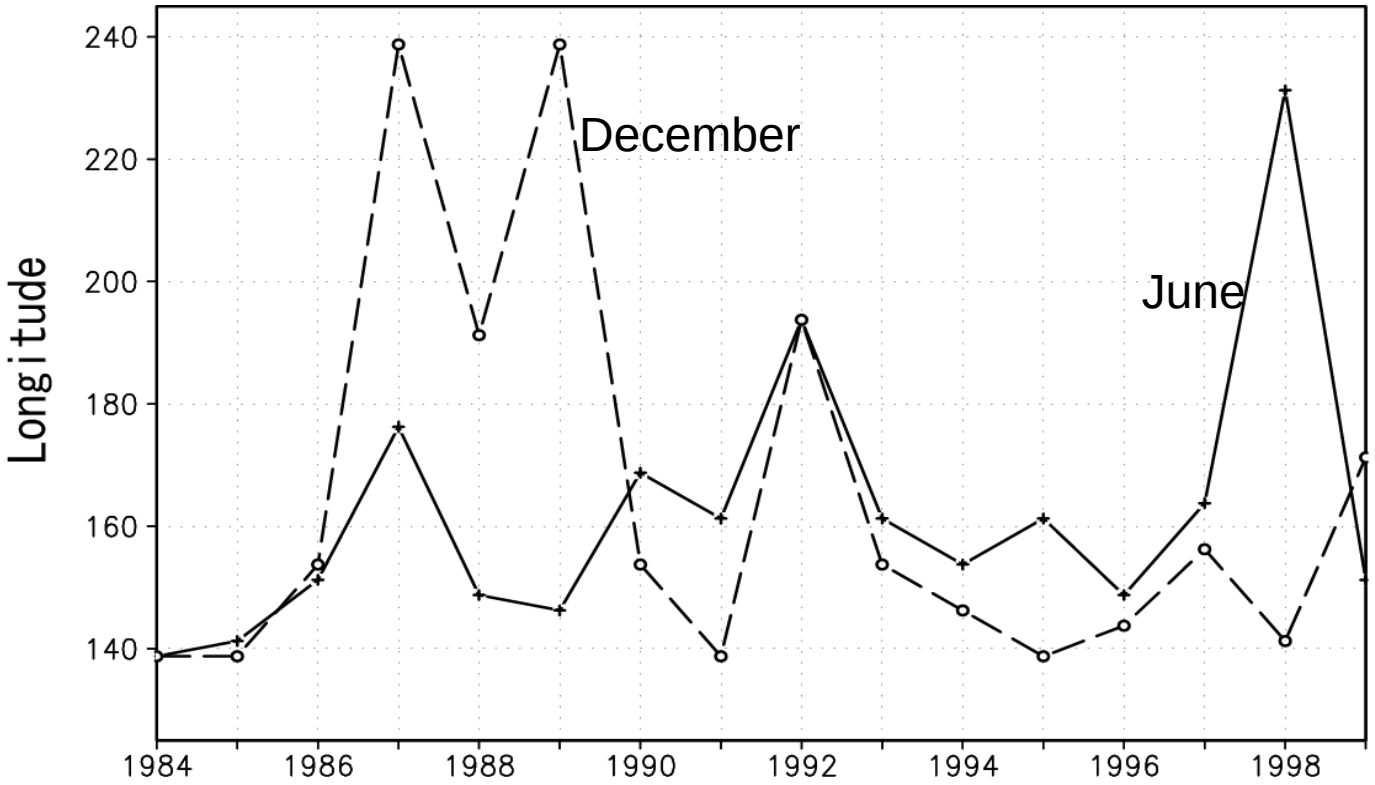
Most models well simulate the ITCZ over the western-central Pacific in climatology.
Simulated ITCZ over other regions (i.e. the eastern Pacific) tend to be faint in some model.

<Results>

Observation

IAV of detected longitude of the DIV center over the western-central Pacific

[Example in June (solid line) and December (broken line)]



- The DIV centers tend to wander across the tropical Pacific mostly in response to ENSO (e.g.1987, 1992, and 1998).
- The DIV center flexibly identifies the horizontal longitude of the ascending branch of the Walker circulation, which varies with year

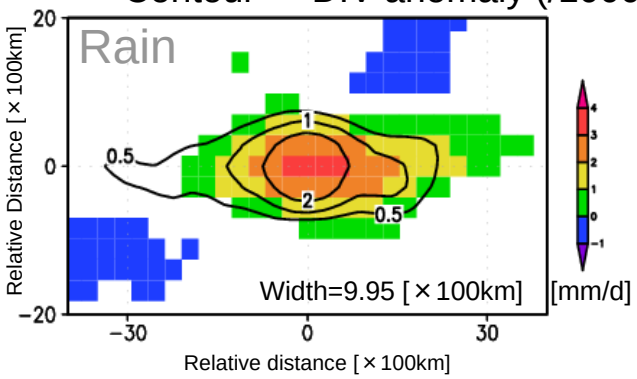
Each parameter is composited around the DIV centers

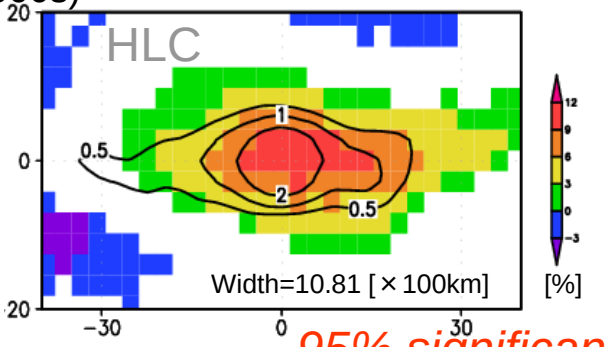
[The DIV centers are searched in all months for all 16 year (1984-1999)]

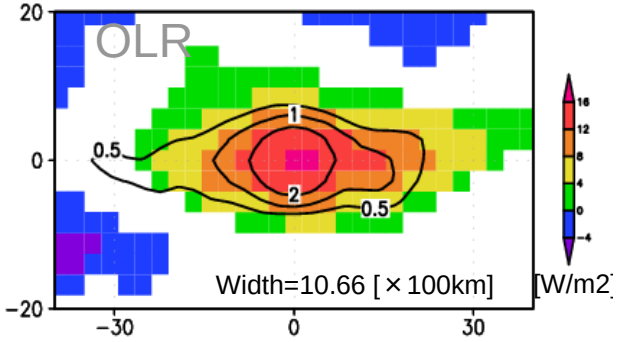
<result of composite>

Observation

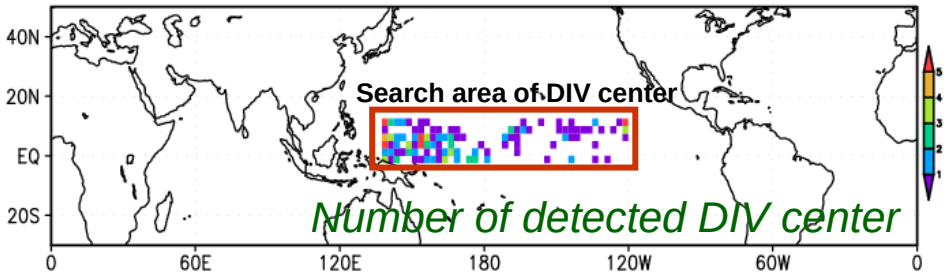
Contour・・・DIV anomaly (/1000000s)



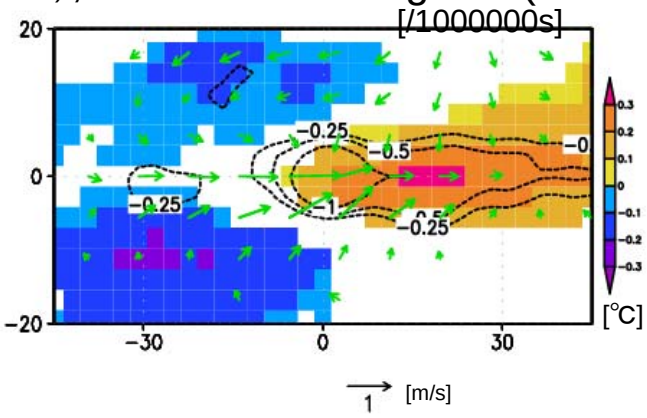




95% significance



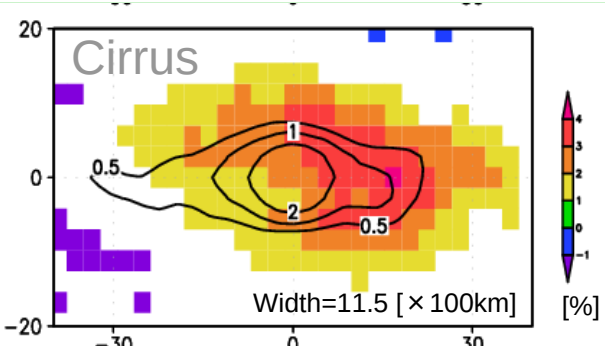
SST(shade) , wind and convergence(1000hPa)



- DIV anomaly become maximum at DIV center
- SST is high (low) at east (west) of DIV center
- each parameter spread eastward (related to SST)
- Width　Rain＜＜OLR＜HLC

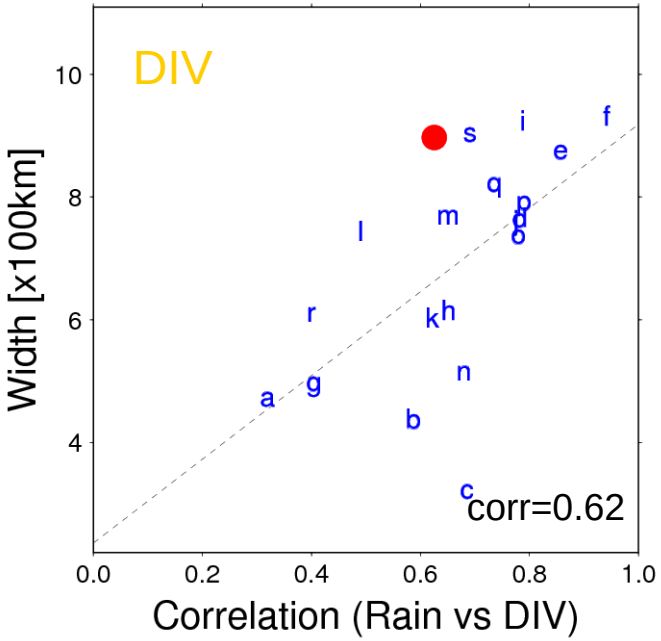
Difference of width between HLC and rainfall is due to cirrus!!

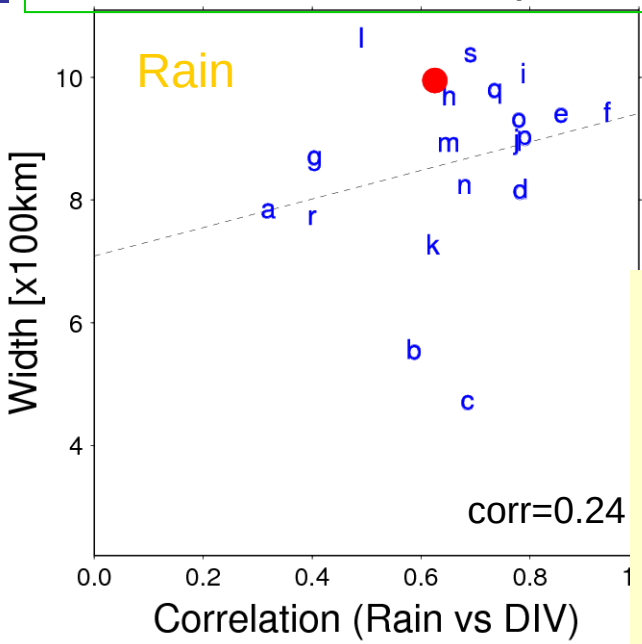
Cirrus is a lot east of DIV center, and width is the largest
(Distribution of DC(10.0), CS(10.4) is similar to rainfall.)



Inter-model comparison of 'width' over the western-central Pacific

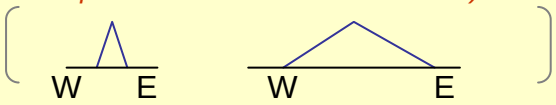
X-axis; temporal correlation of Rain and DIV at DIV center in 12mo×16yr=192 samples
Rain ⇔ column integrated diabatic heating
⇒ correlation = **relationship of latent heating and large-scale circulation**



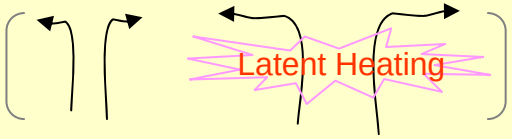


● ・・・ observation
a～s・・・ models

In the models
・Width tends to be underestimated
(→each param concentrate on DIV center)

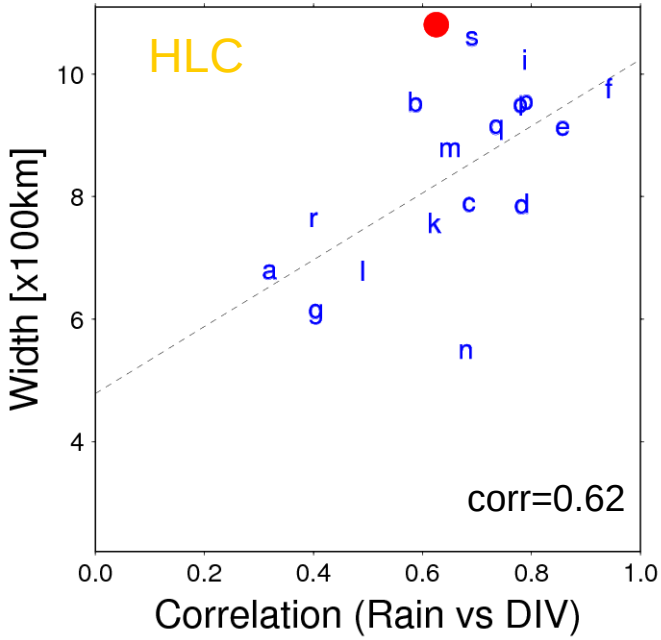


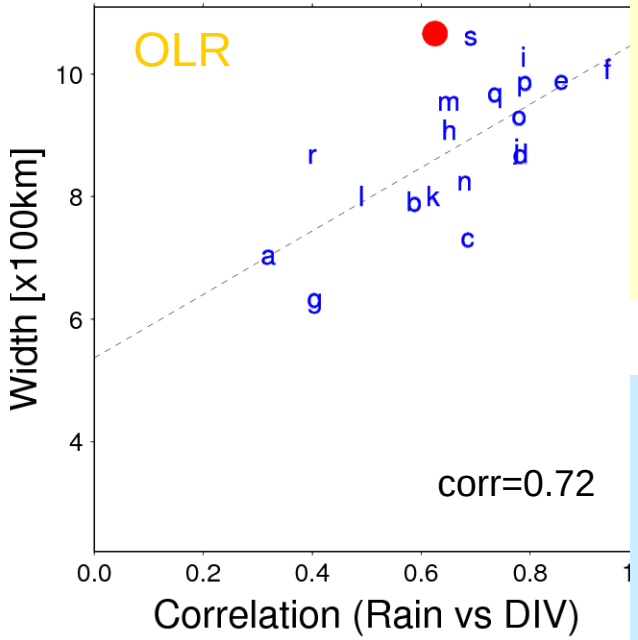
・Width increase as the correlation in X-axis increase (DIV, HLC, OLR)
(DIV spread more and more if latent heating strongly coupled with circulation)



(Width cannot spread as *obs.* until Rain-DIV coupling becomes strong!!)

・Performance of Rain is better



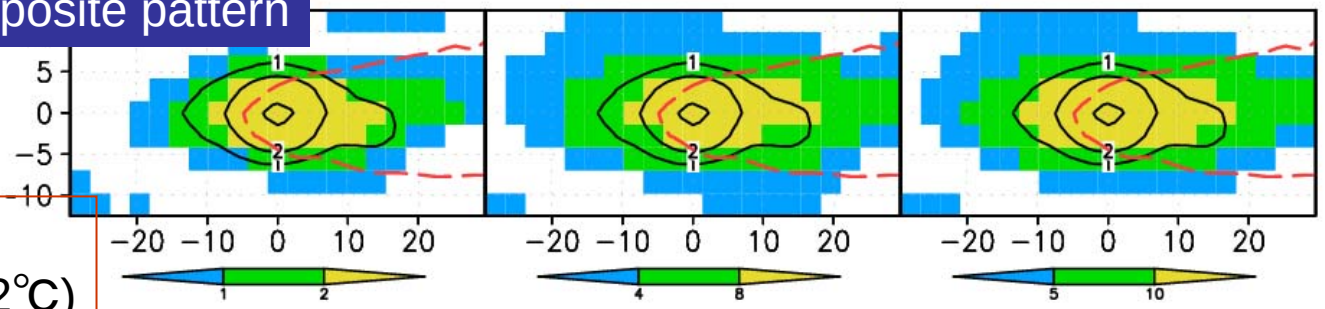


Width of HLC・OLR is similar to or less than that of Rain
(Width of HLC is larger than rain due to cirrus in the Obs.)
↓ ↓
Representation of upper-level cloud including cirrus is difficult in the GCM

Example of composite pattern

Obs.

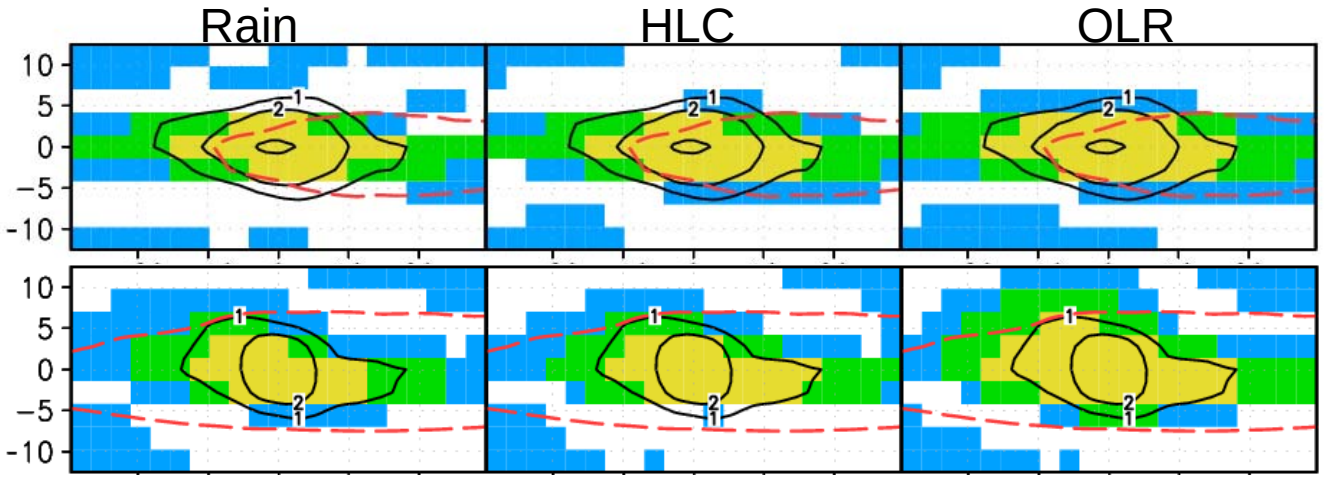
Black・・DIV
Red・・SST (0.2℃)



Large width

Model A1

Model A2



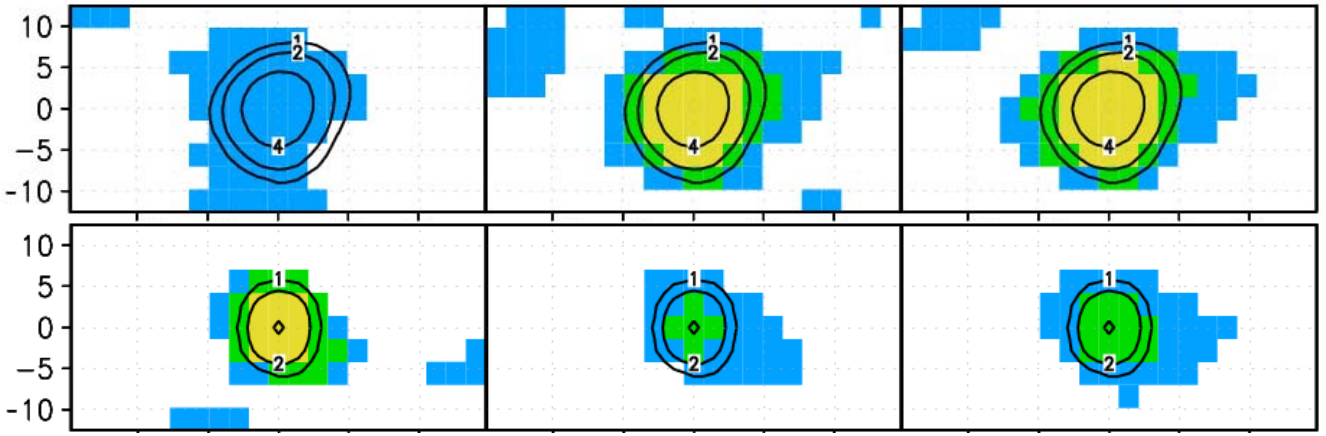
95% significance

These models well simulate the SST pattern also !!

Small width

Model B1

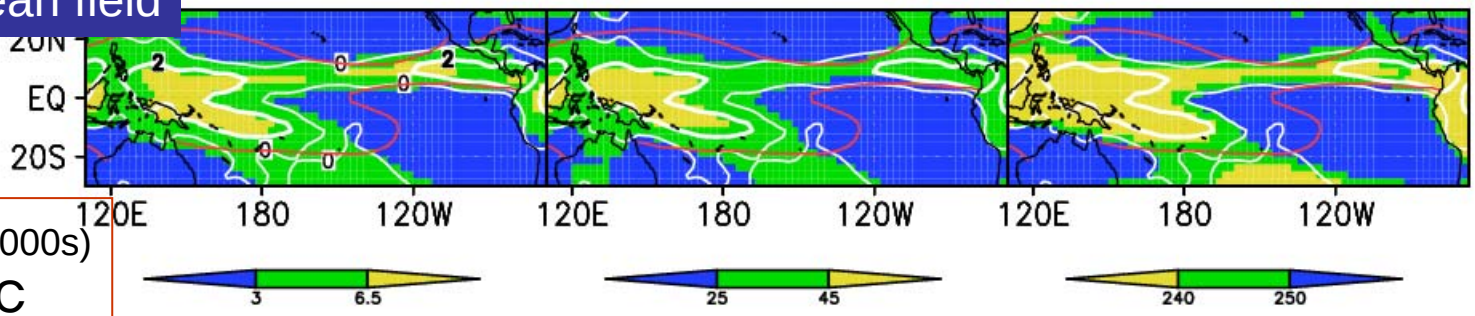
Model B2



Positive SST anomalies is not seen !!

Climatological mean field

Obs.

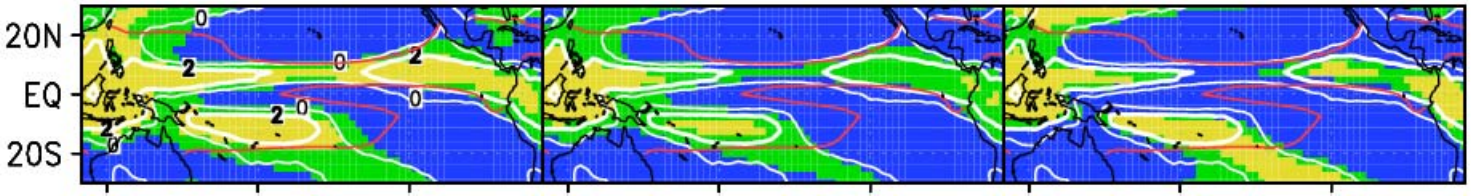


White・・DIV (/1000000s)
Red・・SST at 27℃

Large width

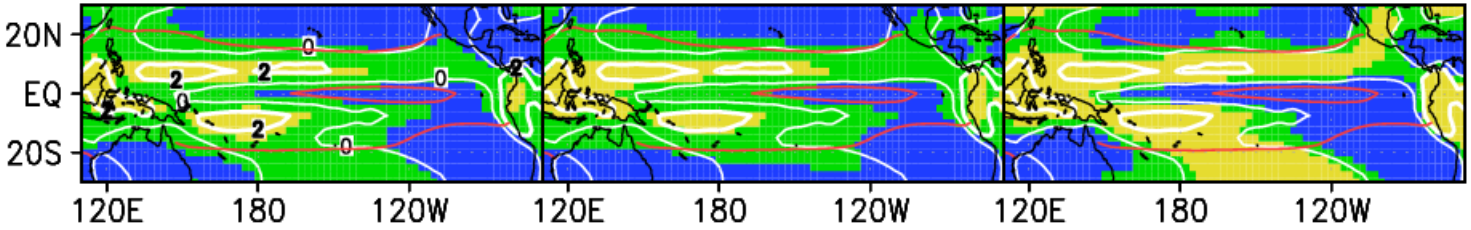
Rain HLC OLR

Model A1



Band-like structure of strong portion of DIV and related cloud/rainfall are seen over ITCZ

Model A2

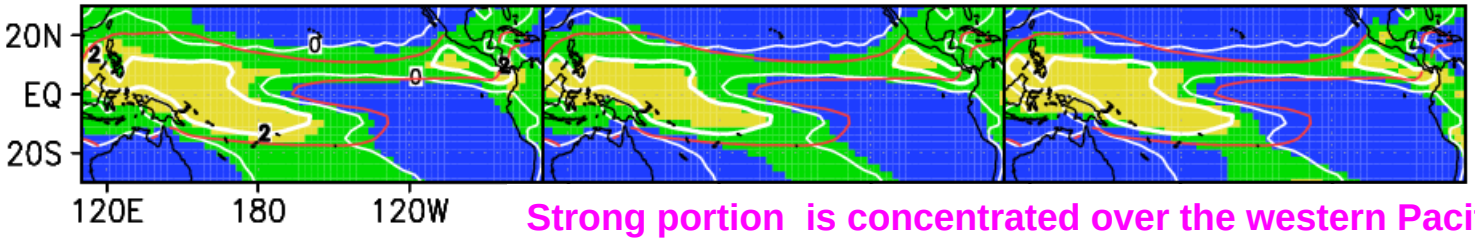


Small width

Model B1

DIV and SST patterns are different from the obs.

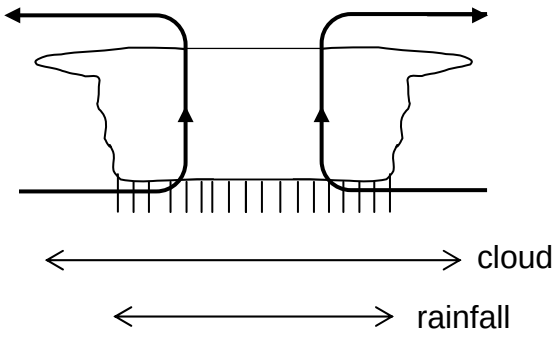
Model B2



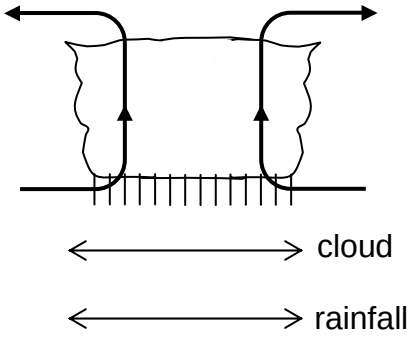
Strong portion is concentrated over the western Pacific

Conclusion

Observation



AOGCMs



・Width of DIV, Rainfall, HLC, around OLR around the DIV center is underestimated in the models →systematic model bias

・A model with a tighter coupling of the large-scale circulation field with the cumulus latent heating tends to have a wider spread of HLC and OLR around the DIV center.
・A model better reproducing the observed spread tends to have stronger coupling of the large-scale circulation field with the cumulus latent heating than the observation.

・In the observation, the width of HLC > Rainfall owning to the spread of cirrus.
but, in the models, the width of HLC ≒Rainfall
→The representation of cirrus clouds would be not well captured in the models