International Workshop on "Development of Atmosphere-Ocean Coupled Models towards Improvement of Long-Range Forecast", Dec. 9th, 2010, JMA, Tokyo

Coupled model Simulation by Constraining Ocean Fields with Ocean Data thorough the JMA operational ocean data assimilation system

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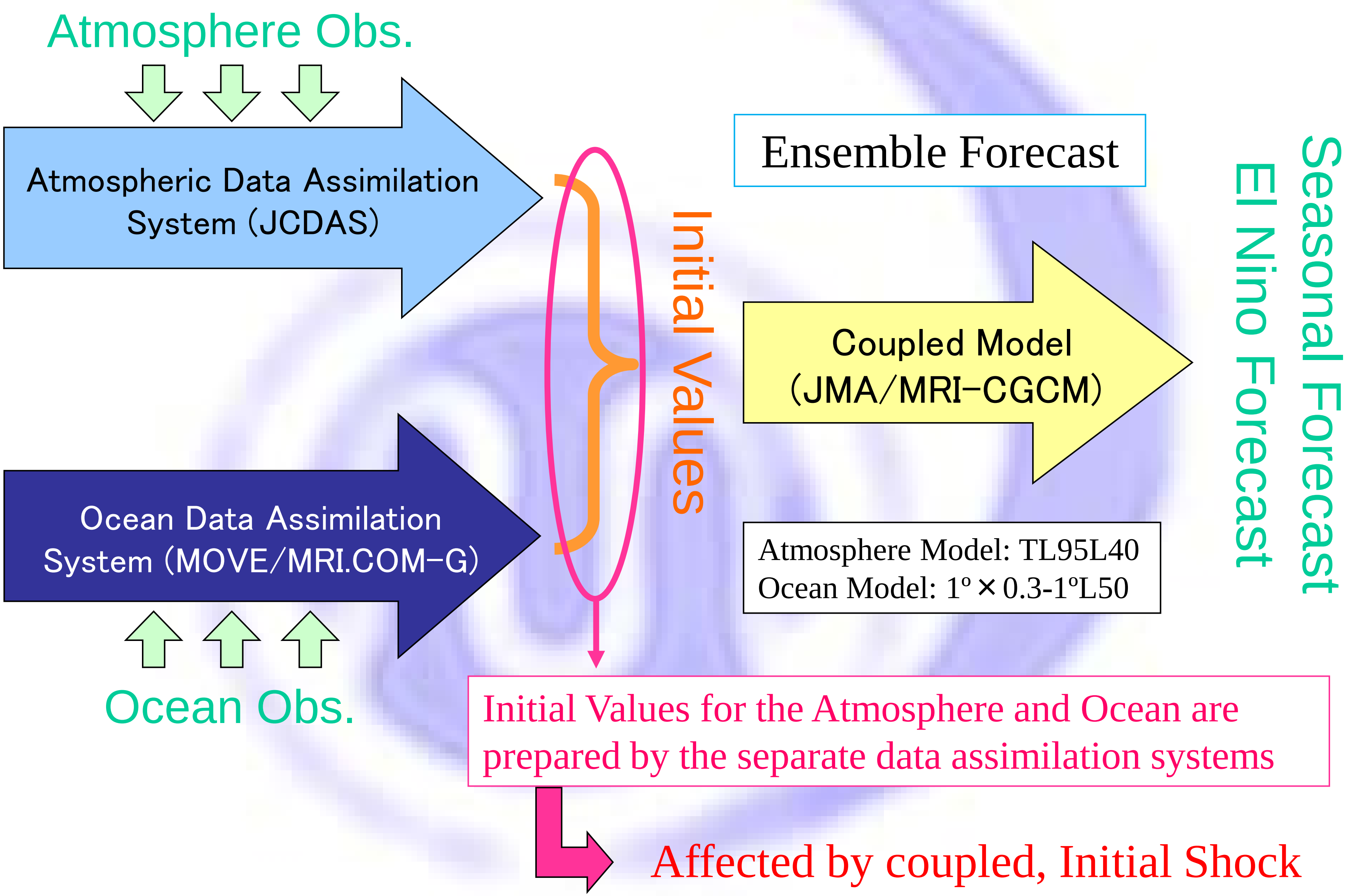
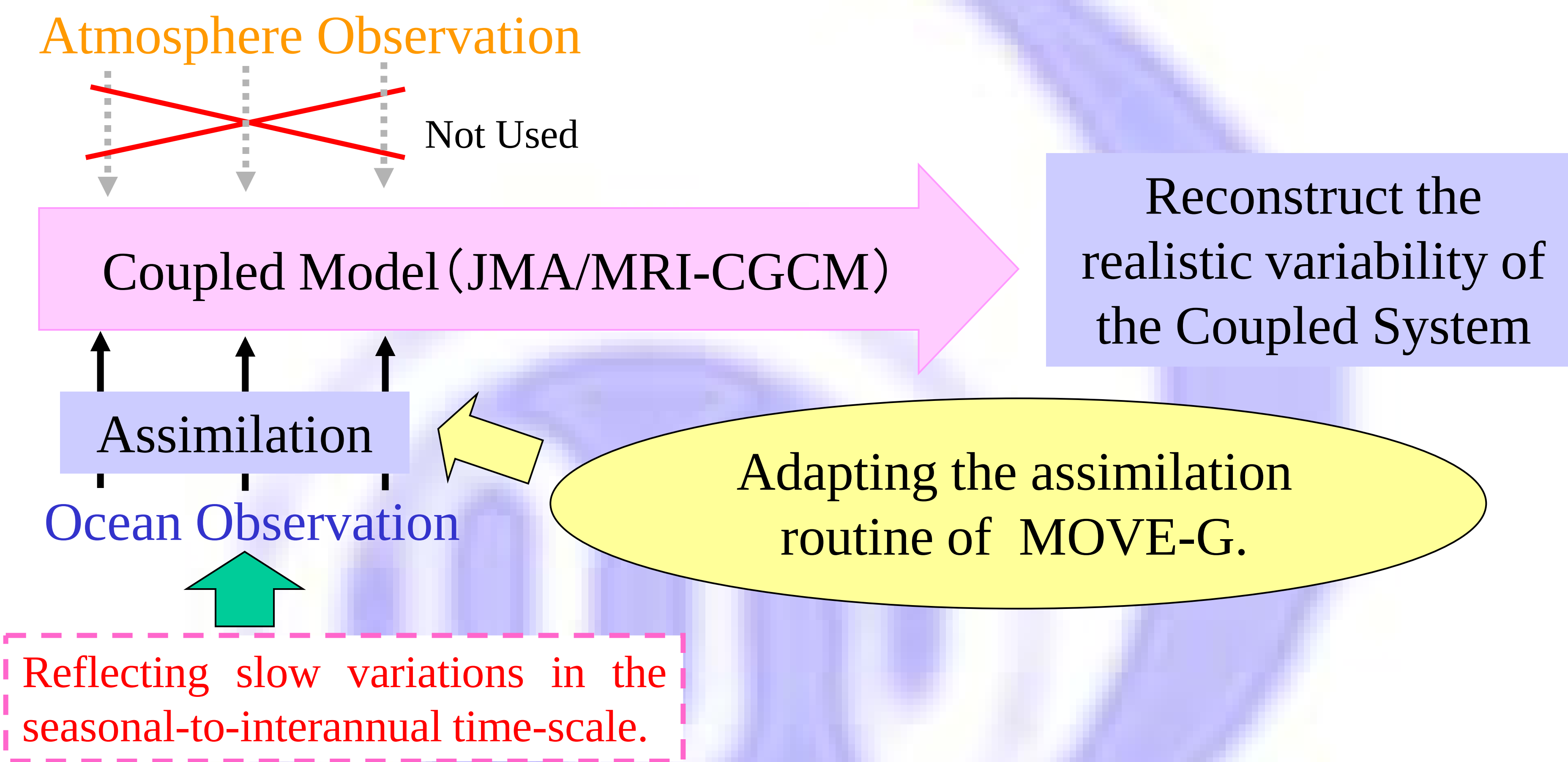
1. Introduction

★ Coupled Model Initialization in JMA Current System



★ "Quasi-Coupled" Data Assimilation System



There are no public word for the system like this.

→ We call this "Quasi-Coupled" assimilation system and here we named the system MOVE-C.

☆ Purpose of the Development

1. Reanalysis for seasonal-to-interannual variation researches.
   - reconstruct the effect of air-sea interactions
   - It does not depend on the atmospheric reanalysis and its errors.
   - To explore how good the climate variations are reconstructed with assimilating ocean data alone.

2. Initial Values and Ensemble members for Seasonal Forecast.
   - Avoid the coupled, initial shock.
   - Generating ensemble members reflecting the growth rate in the coupled system (e.g., Breeding in the assimilation system)

3. Prototype of a truly coupled data Assimilation System

☆ Outline of this Presentation

1. Introduction
2. Global Ocean Data Assimilation System in JMA (MOVE-G)
3. Evaluation of the Ocean Field in MOVE-C

   →Comparison with the free run of the coupled model and the regular ocean reanalysis by MOVE-G

4. Improvement of the Atmospheric Field in MOVE-C

   →Comparison with the coupled free run and the AMIP Run

   ･Precipitation in tropics, Tropical Cyclone Generation, Variability of the Monsoon, etc. is improved over AMIP Run

5. Effect of the Air-Sea Interaction
6. Final remarks

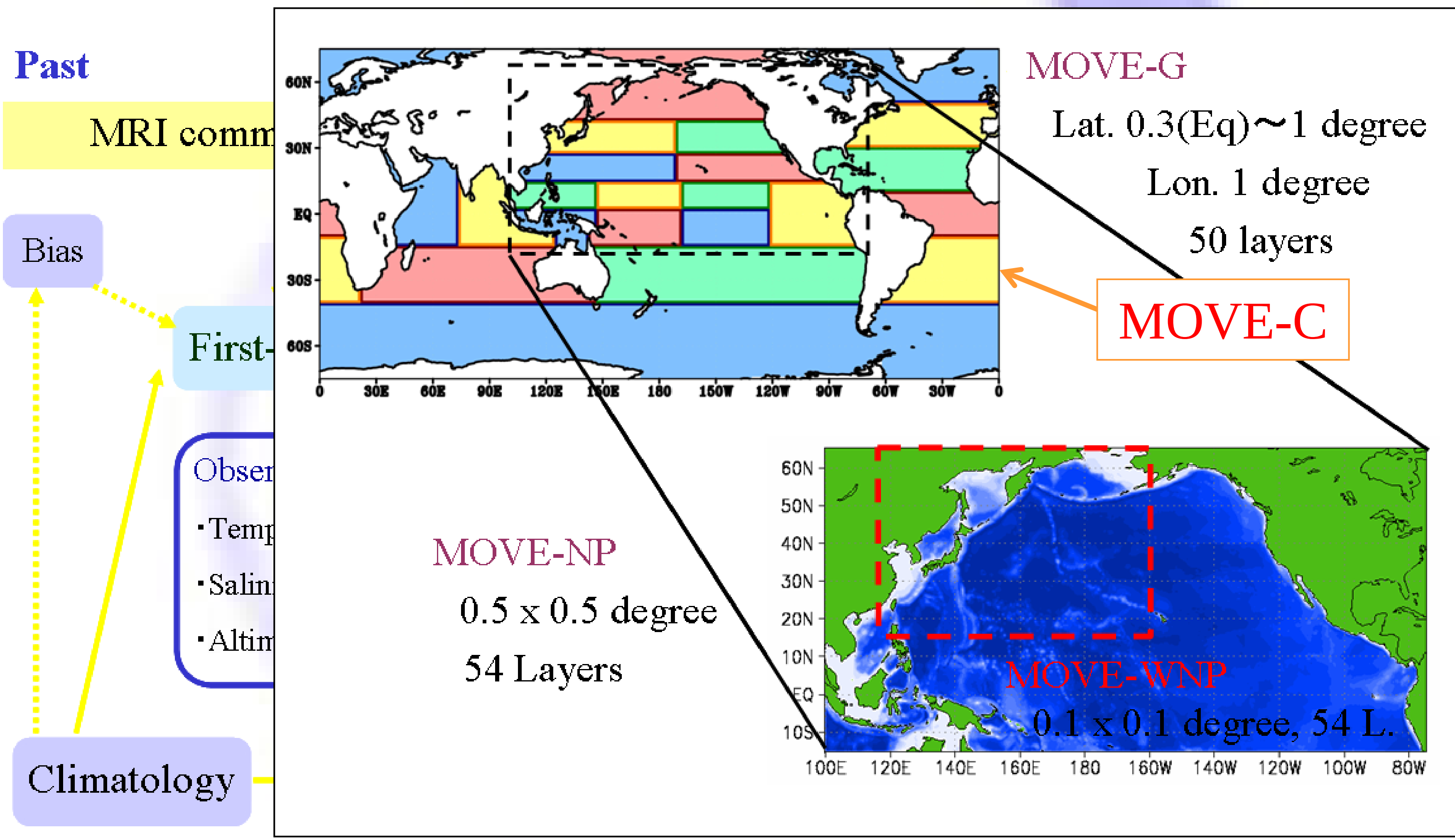
＊This presentation is based on Fujii et al. 2009, *J. Climate*, **22**,5541-5557

2. Global Ocean Data Assimilation System in JMA (MOVE-G)

★ MOVE System（MOVE/MRI.COM）

Multivariate Ocean Variational Estimation (MOVE) System

→ Ocean Data Assimilation System Developed in MRI and JMA.



☆ Analysis scheme in MOVE/MRI.COM (3DVAR)

Analysis Increment is represented by the linear combination of the EOF modes.

$$\mathbf{x}(\mathbf{y}) = \mathbf{x}_f + \mathbf{S}\sum_l w_l \mathbf{U}_l \Lambda_l \mathbf{y}_l$$

Amplitudes of EOFs

Background Constraint **Constraint for T, S observation**

$$J = \boxed{\frac{1}{2}\sum_m \sum_l \mathbf{y}_{m,l}{}^T \mathbf{B}_l^{-1} \mathbf{y}_{m,l}} + \boxed{\frac{1}{2}\left[\mathbf{Hx}(\mathbf{y}) - \mathbf{x}^0\right]^T \mathbf{R}^{-1}\left[\mathbf{Hx}(\mathbf{y}) - \mathbf{x}^0\right]}$$

$$+ \boxed{\frac{1}{2}\left[\mathbf{h}(\mathbf{x}(\mathbf{y})) - \mathbf{h}^0\right]^T \mathbf{R}_h^{-1}\left[\mathbf{h}(\mathbf{x}(\mathbf{y})) - \mathbf{h}^0\right]} + \boxed{\alpha(\mathbf{y})}$$

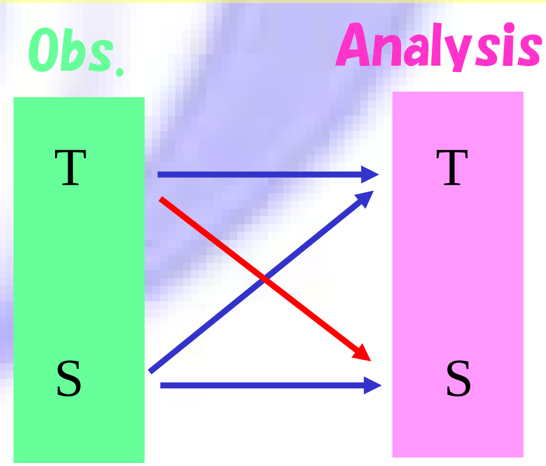
Constraint for avoiding density inversion

Constraint for SSH observation

Seek the amplitudes of EOF modes **y** minimizing the cost function *J*.

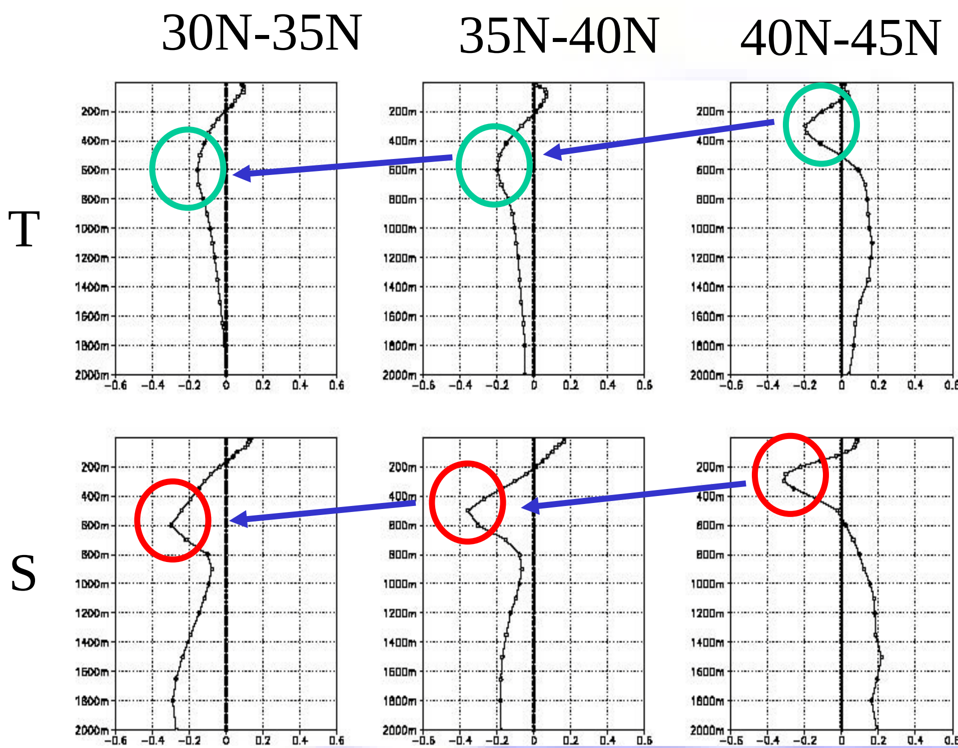
→Analysis increment of T and S will be correlated.

See. Fujii and Kamachi, JGR, 2003

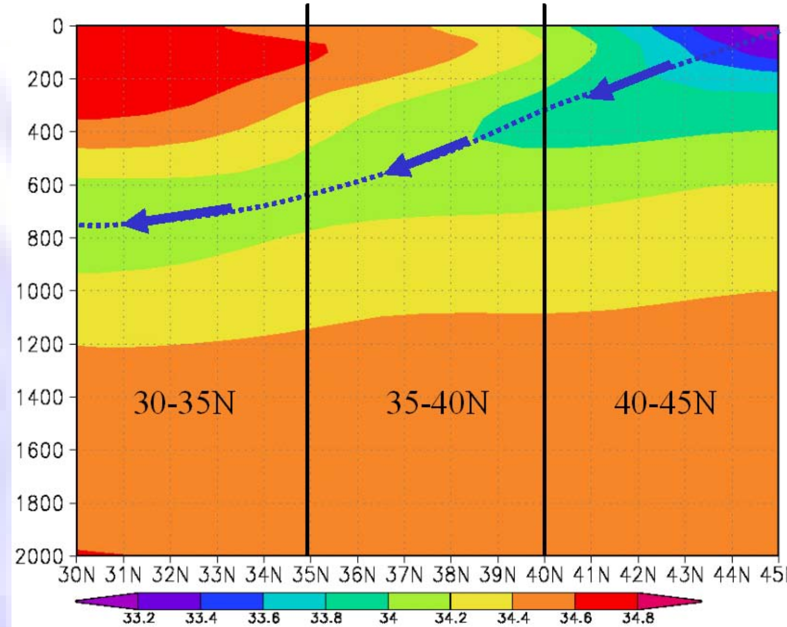


☆Example of Coupled T-S EOF modes

EOF modes representing North Pacific Intermediate Water (NPIW)



TS Climatology in the vertical section of 155E



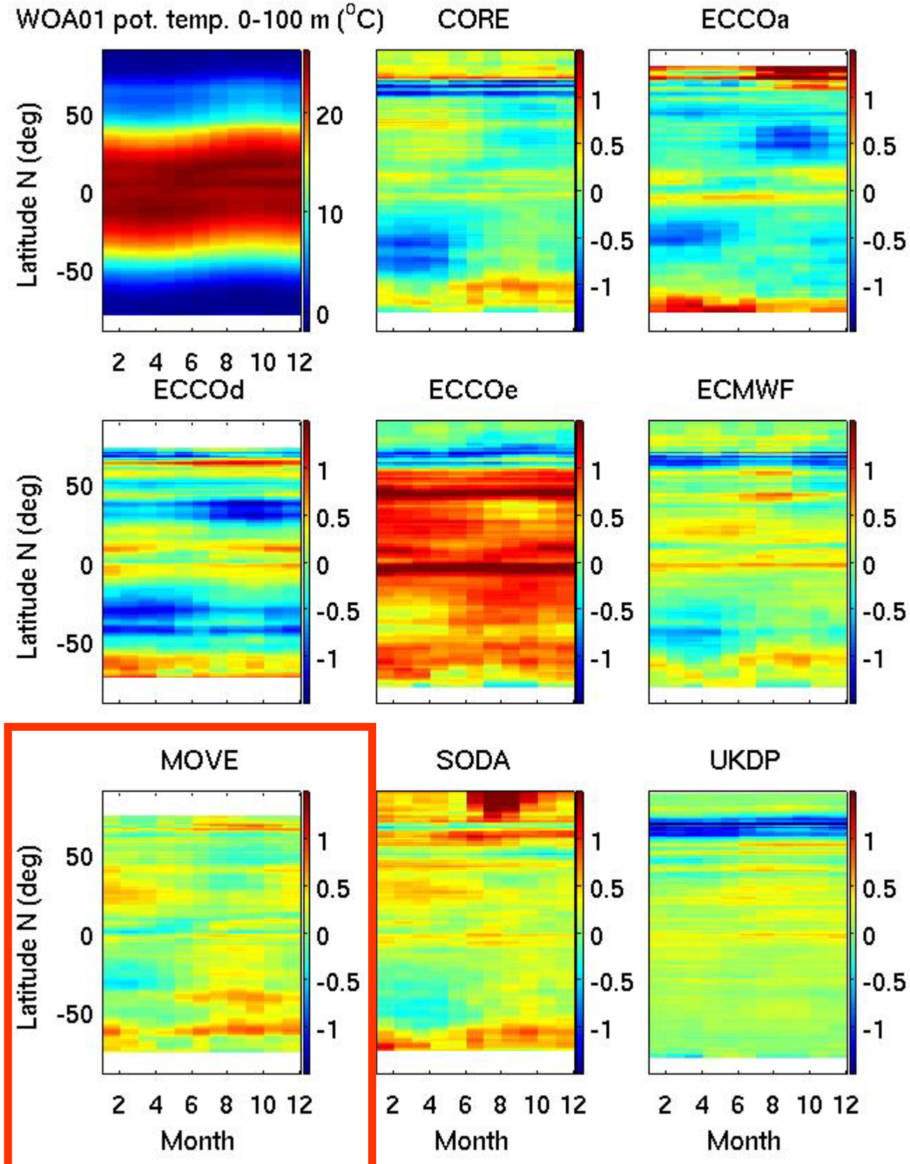
This mode represents

Low salinity water of NPIW → cold water

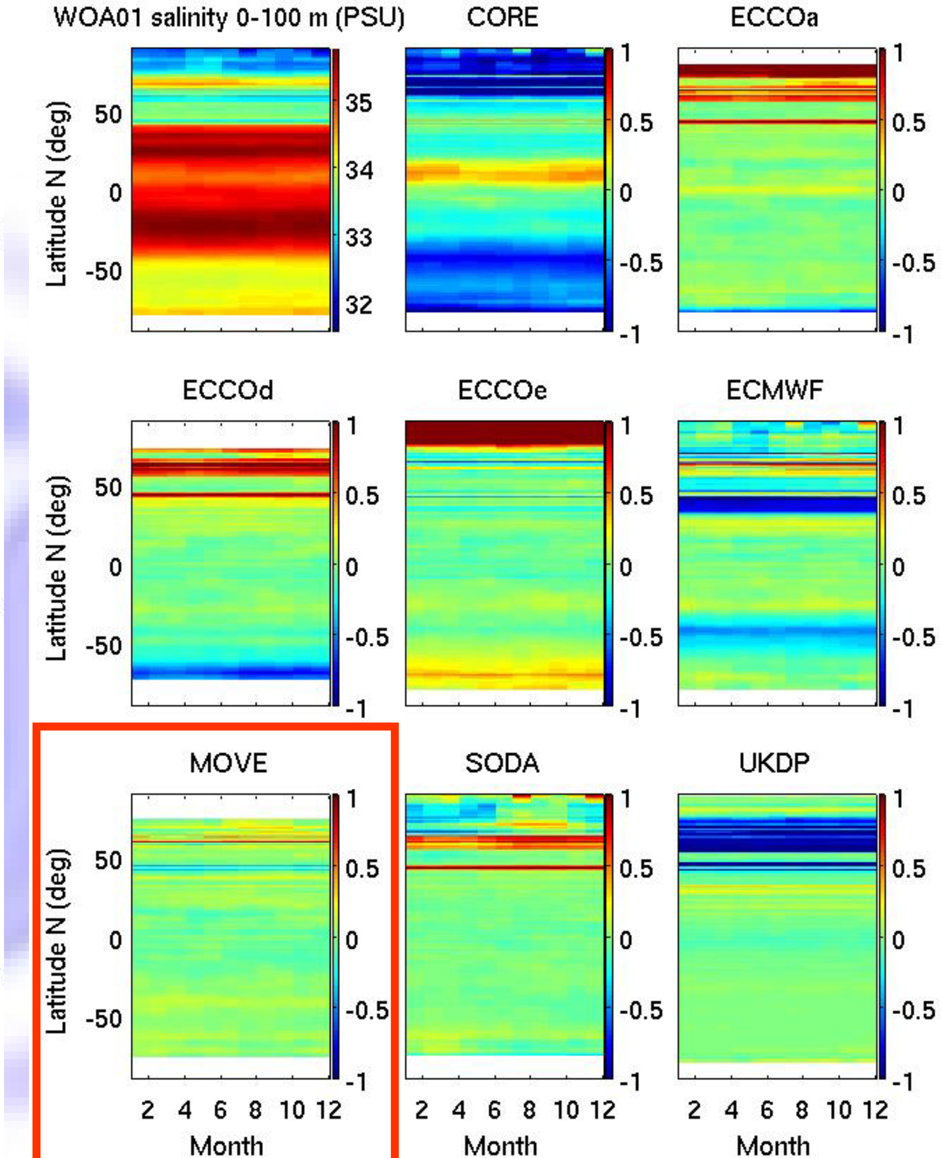
☆ Intercomparison (GODAE)

Monthly zonal Mean

0−100m mean temp.



0−100m mean Sal.



3. Evaluation of the Ocean Field in MOVE-C

☆ Simulation Run, Reanalysis, Observation

1. Reanalysis by MOVE-C

- Reanalysis from 1940 using historical ocean observation data.
- Ocean Analysis is performed once a month.

2. Regular Ocean Reanalysis by MOVE-G（MOVE-G RA07）

3. AMIP Run

The atmospheric model same as used in MOVE-C is integrated using daily COBESST data.

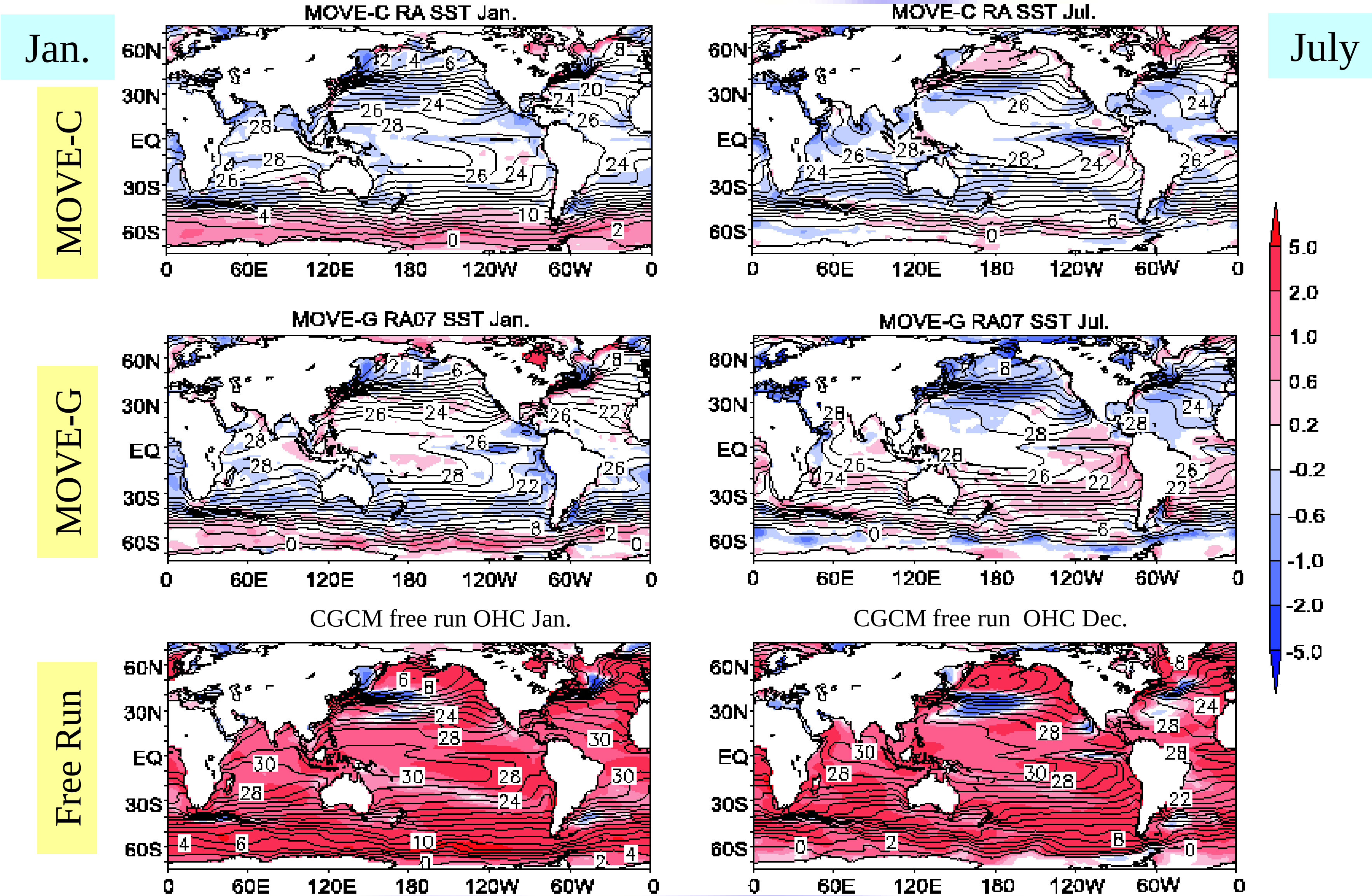
4. Free Run of the coupled model used in MOVE-C

5. Regular Atmospheric Reanalysis (JRA-25, etc.)

6. Observation Data （COBESST, CMAP)

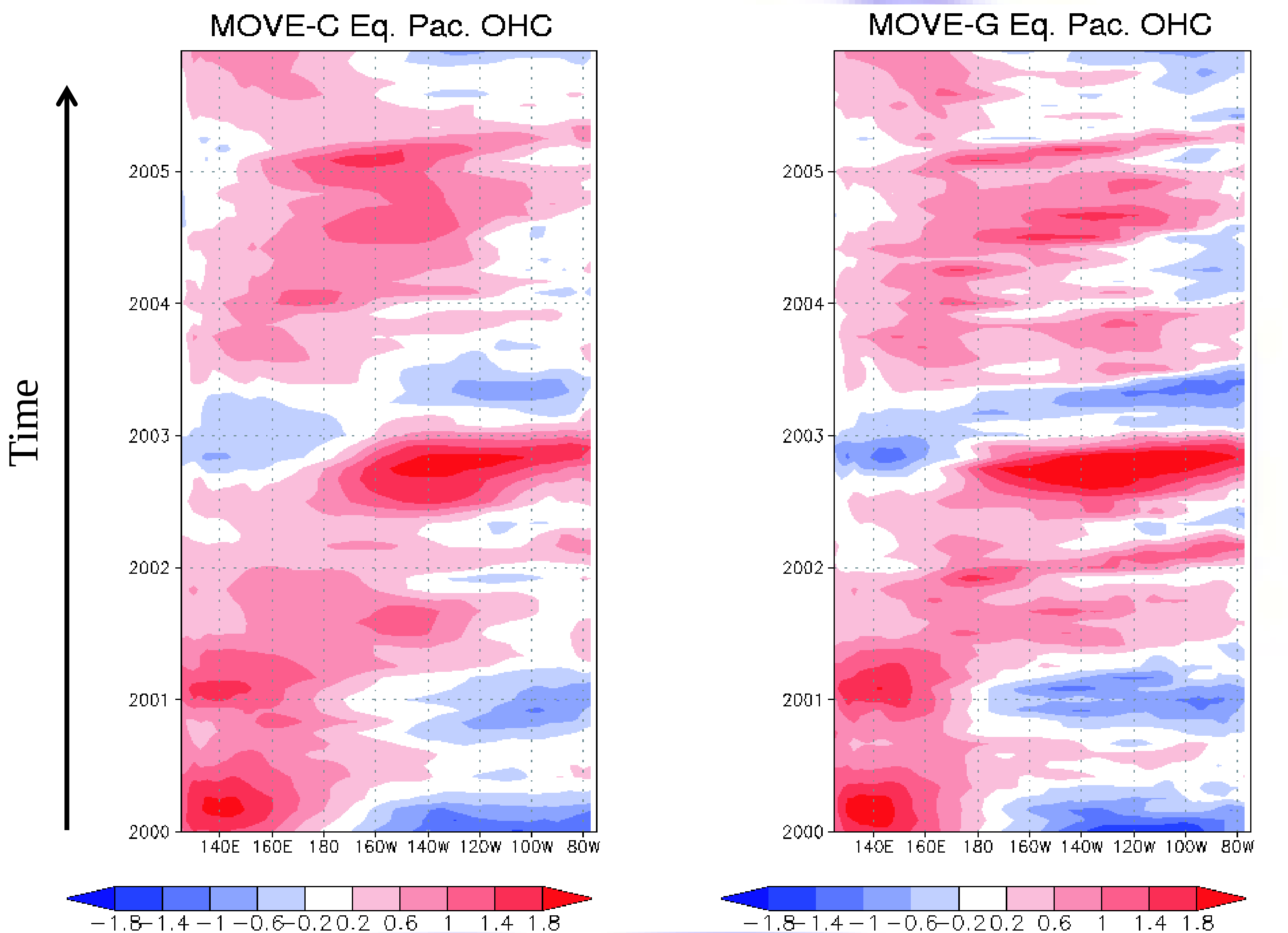
∗ Analysis is performed for the period of JRA25 (1979-2004).

★SST Climatology (MOVE-C .vs. MOVE-G）



The shading shows the deviation from COBE-SST (Observation）

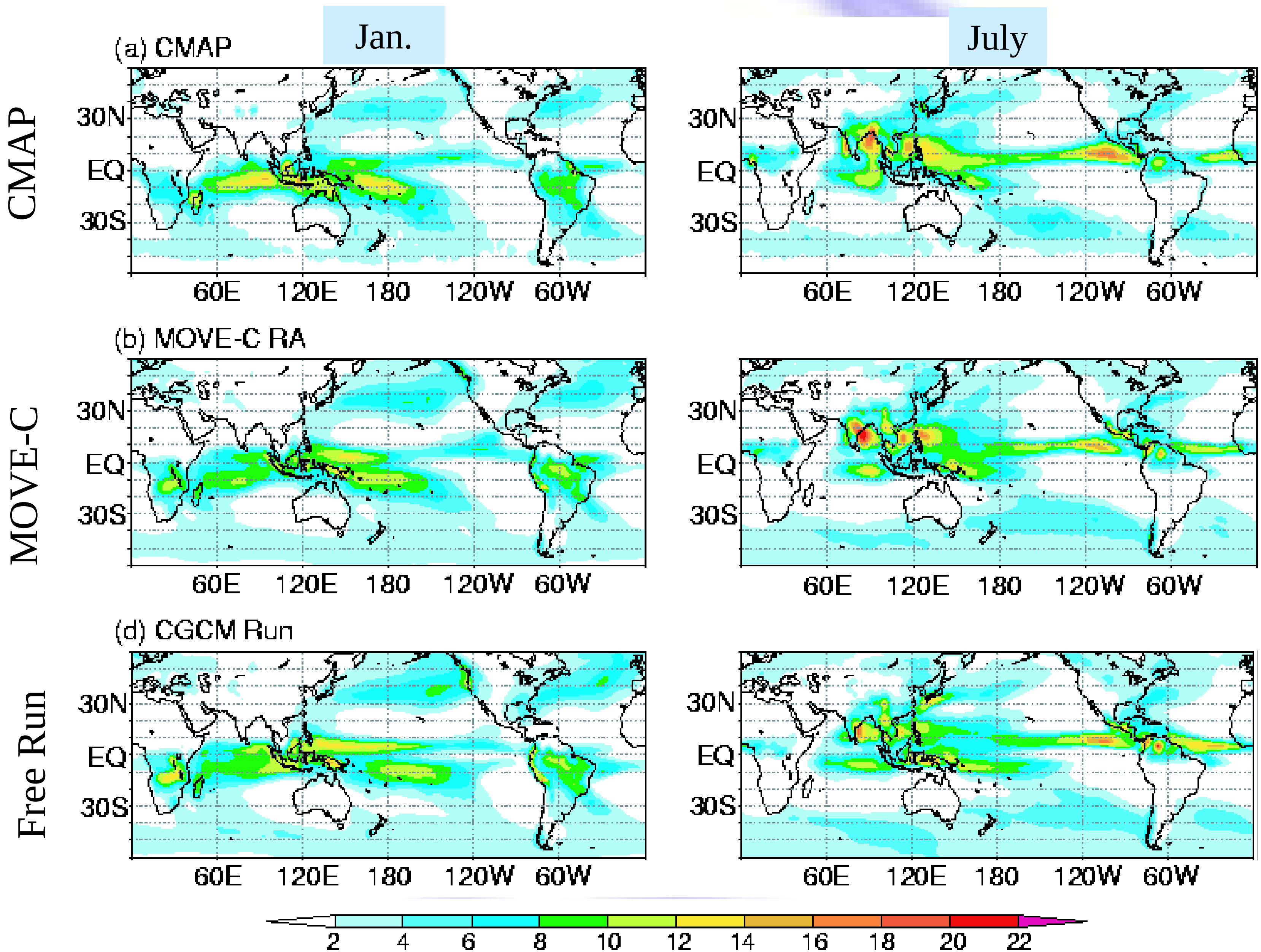
☆ Variation of the OHC on the equatorial Pacific



OHC: Ocean Heat Content

4. Improvement of the Atmospheric Field in MOVE-C

★ Monthly Climatology of Precipitation

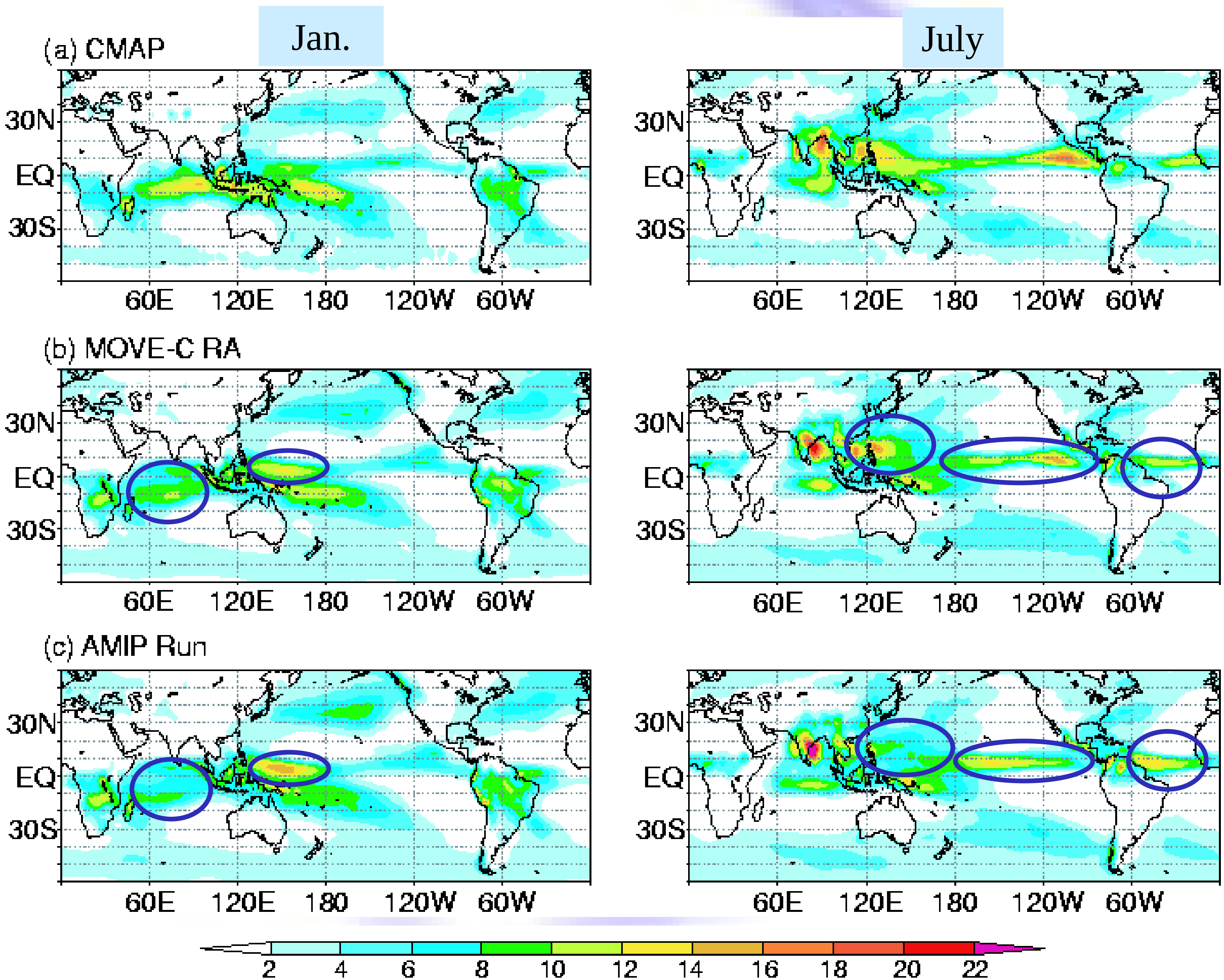


★ Monthly Climatology of Precipitation

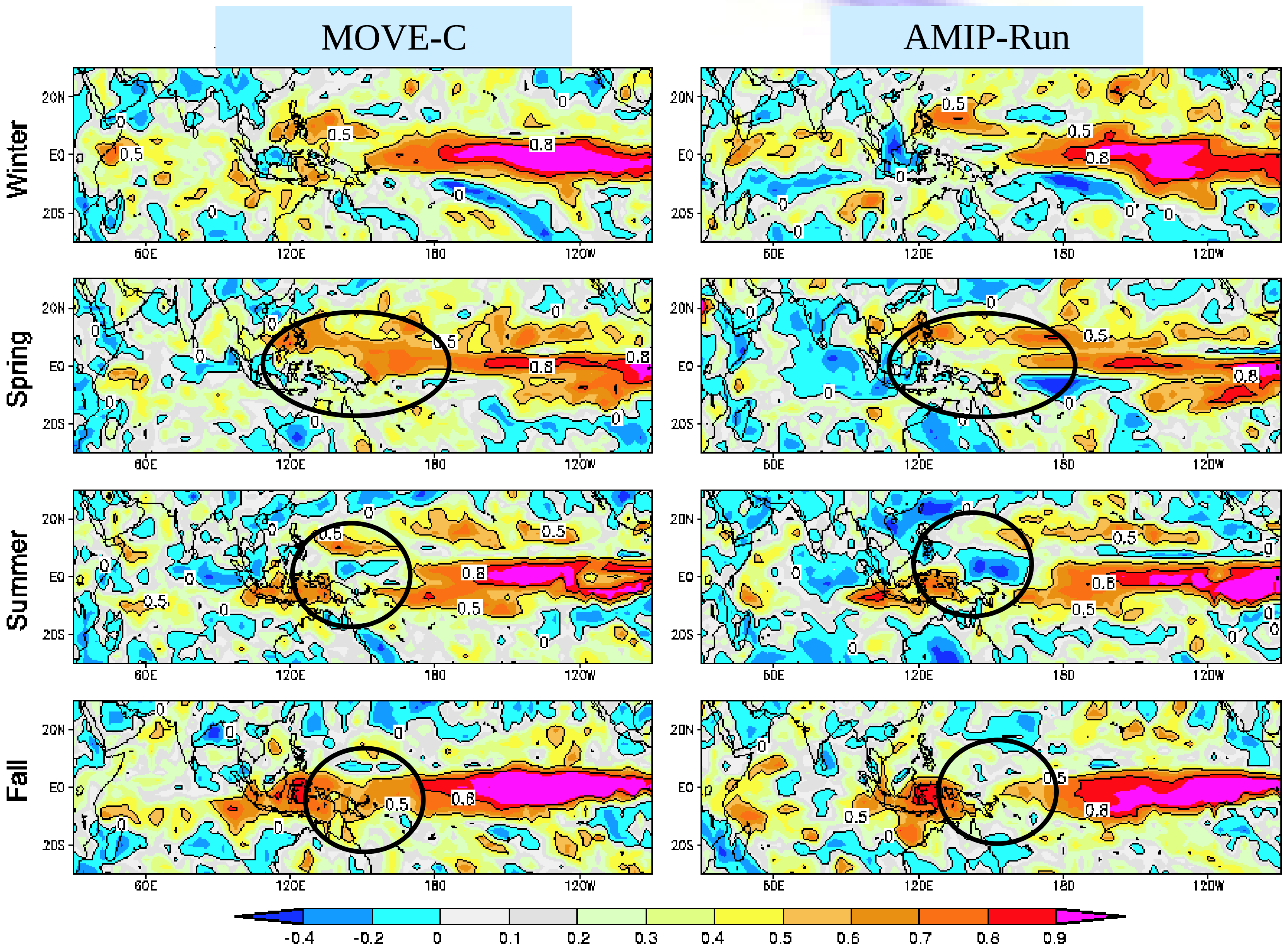
CMAP

MOVE-C

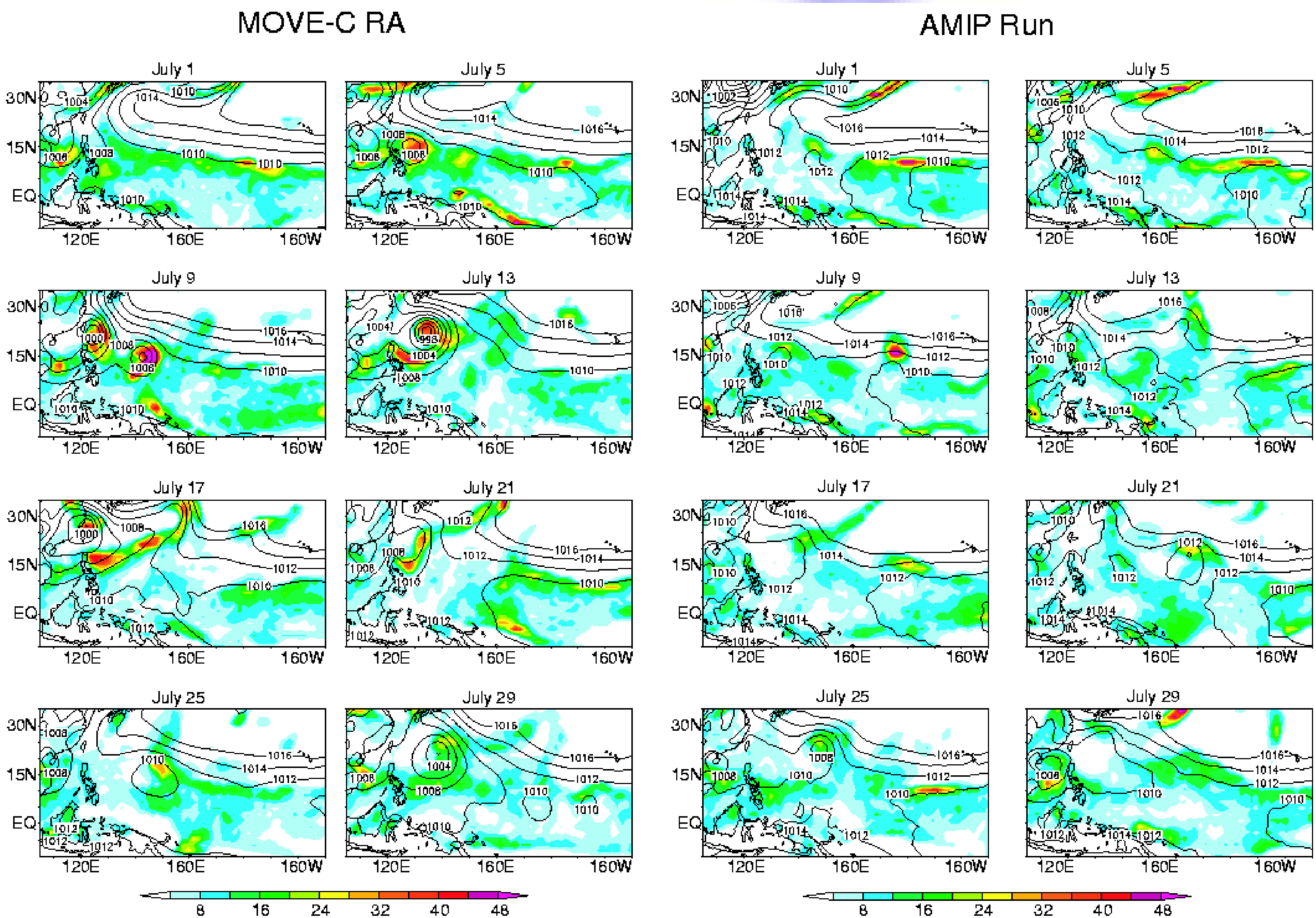
AMIP



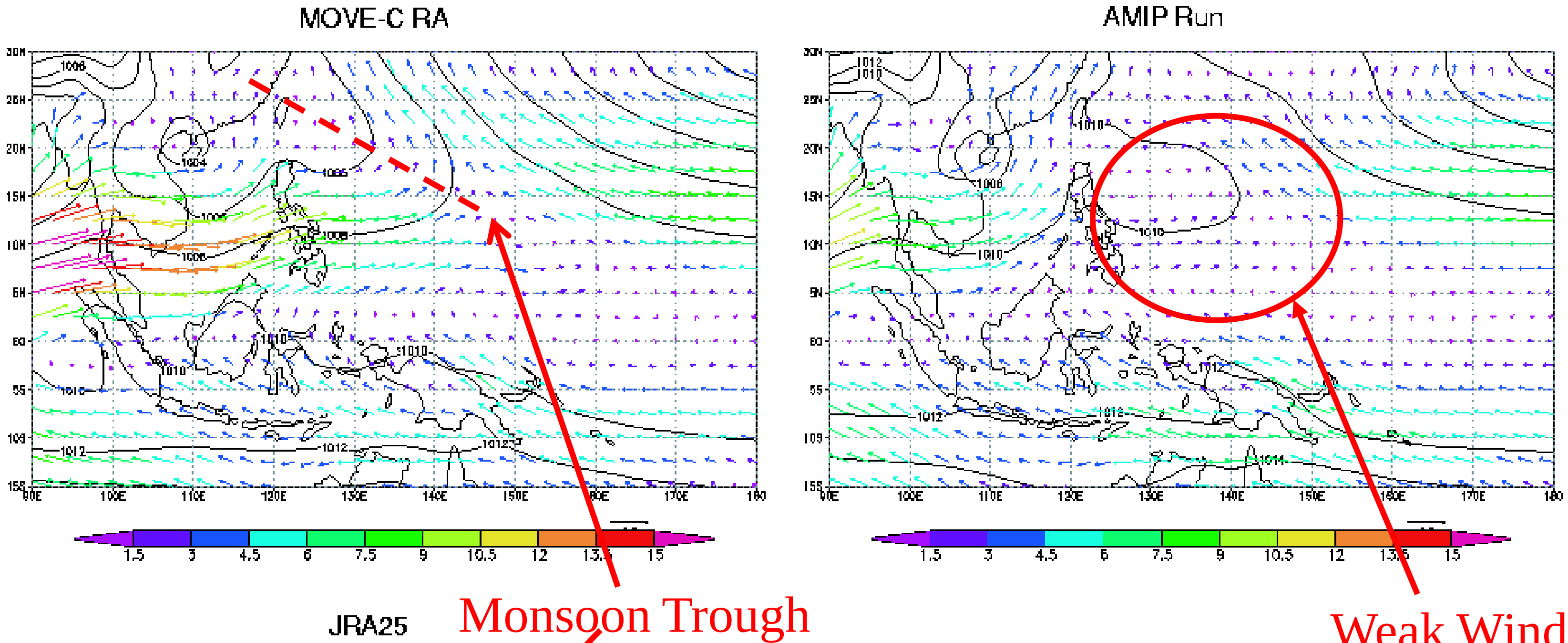
★ ACC score for the monthly average precipitation

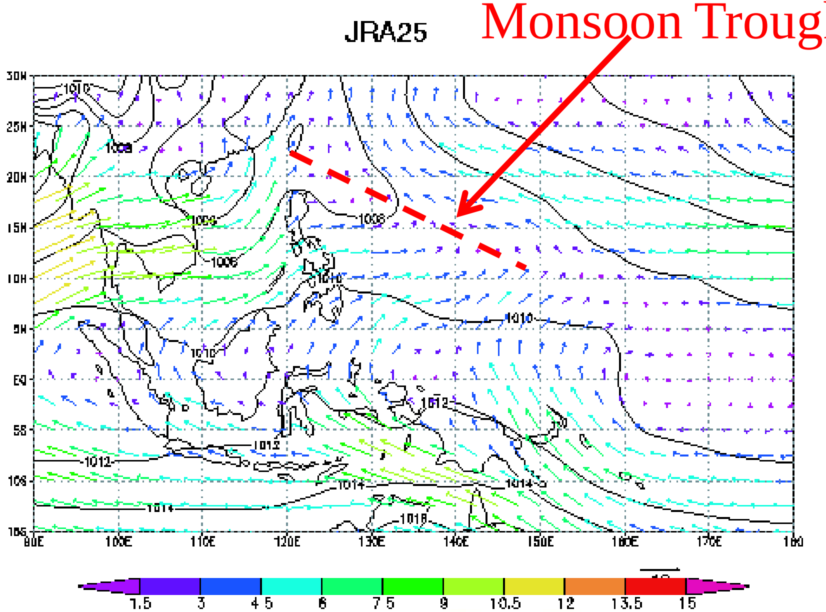


★ Difference of SLP and Precipitation (July 1997)



★ SLP and 850hPa Wind (Jun.-Aug., 1997)



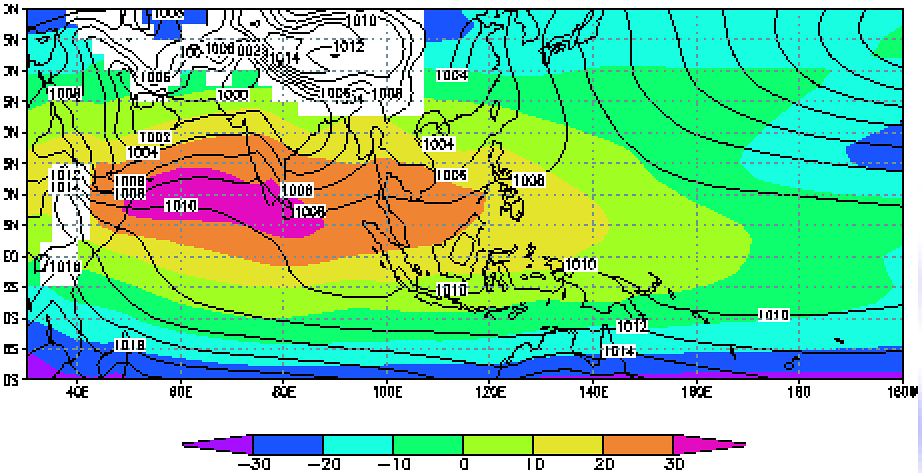


Isobars are gathered and cyclonic winds are developed around the monsoon trough in MOVE-C and JRA25.

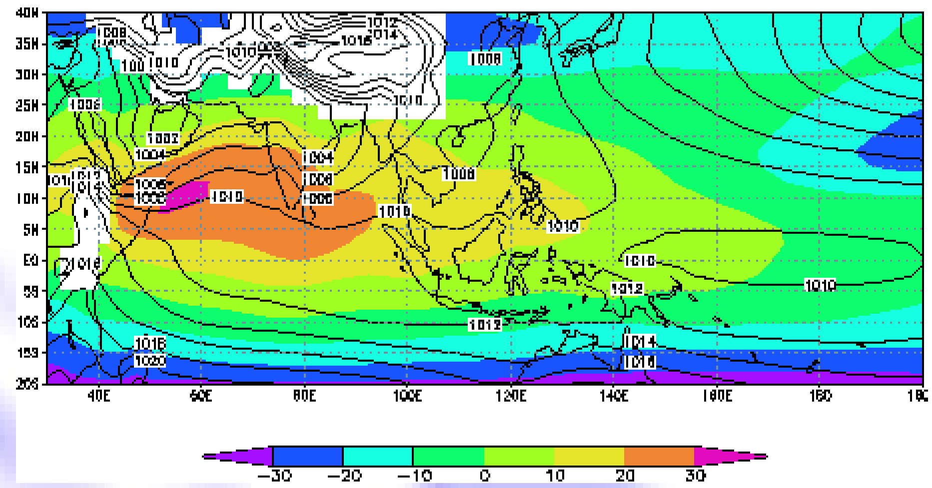
But isobars are sparse, and the winds are weak particularly south of the monsoon trough in AMIP Run.

★SLP, Vertical sheer of zonal winds (Jun.-Aug. Clim.)

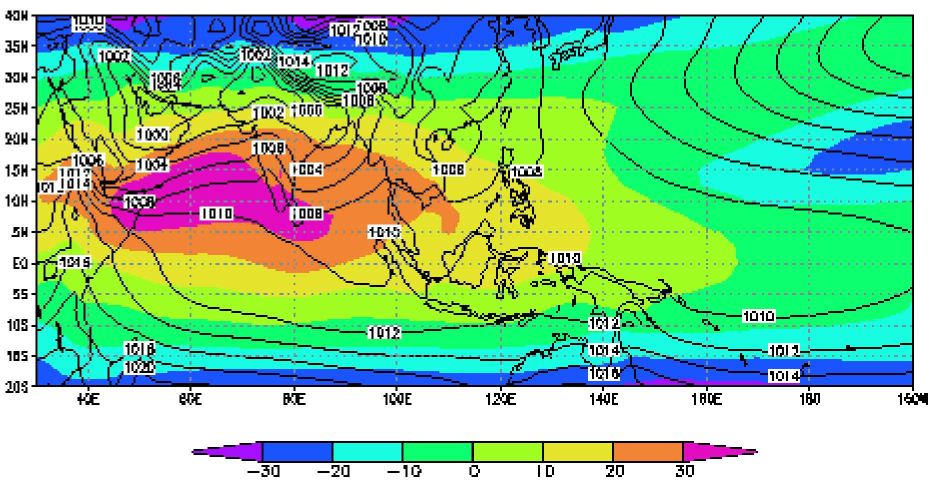
MOVE-C RA



AMIP Run



JRA25



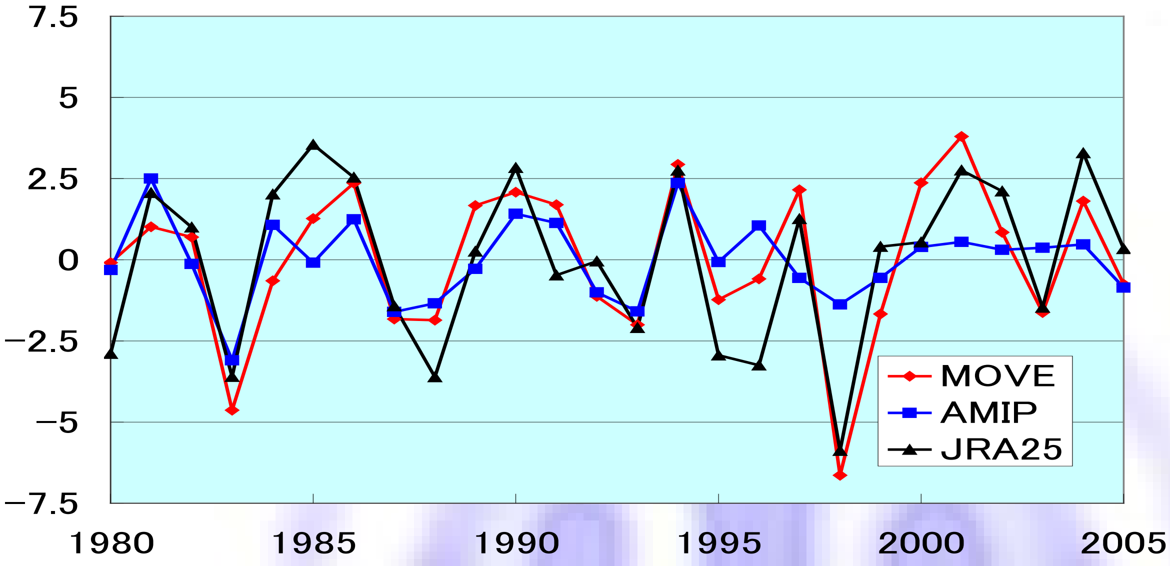
Isobars shows the monsoon trough is not developed in AMIP compared with MOVE-C and JRA25.

The small sheer in AMIP imply the weak walker circulation, which is improved in MOVE-C.

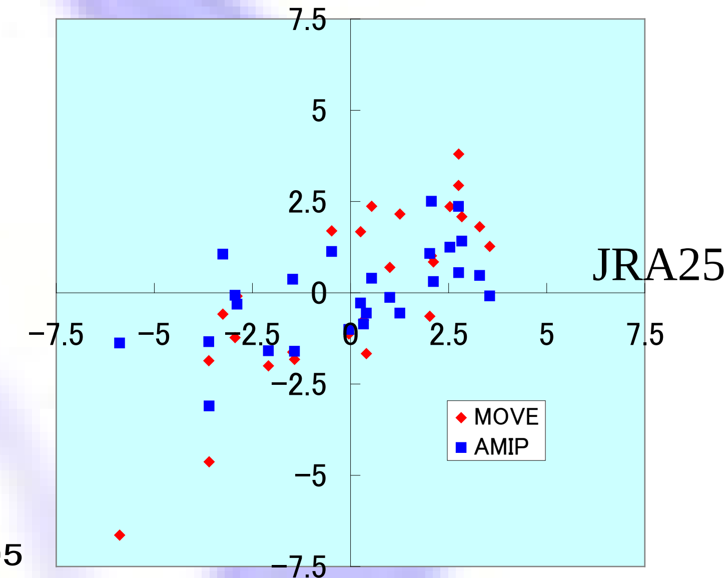
Vertical Sheer of zonal Winds : U(850hPa)-U(200hPa)

★Reproducibility of the Asian Monsoon（Jun.-Aug.）

Time Series of DU2 Index



MOVE or AMIP

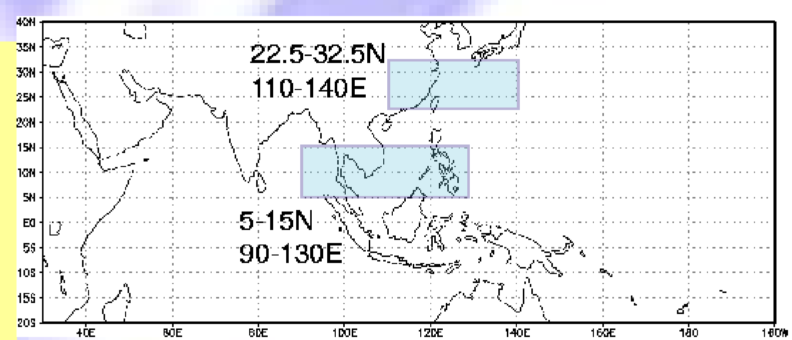


Correlation Coefficients： MOVE 0.81 AMIP 0.60

DU2 Index (Wang and Fan, 1999) represents the strength of the summer monsoon trough.

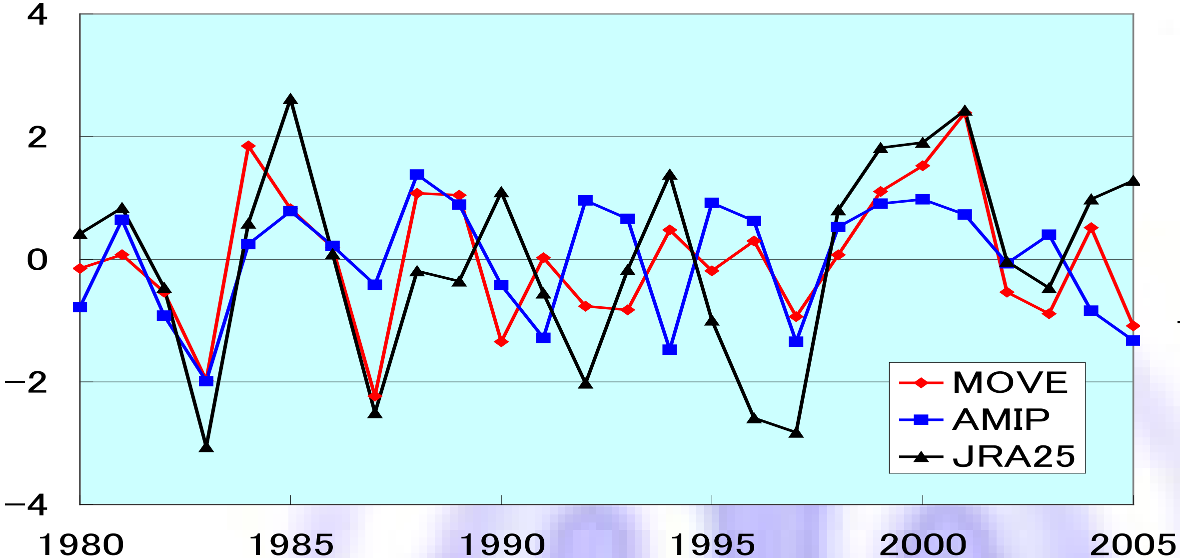
U850hPa(5-15N, 90-130E) －

U850hpa(22.5-32.5N, 110-140E).

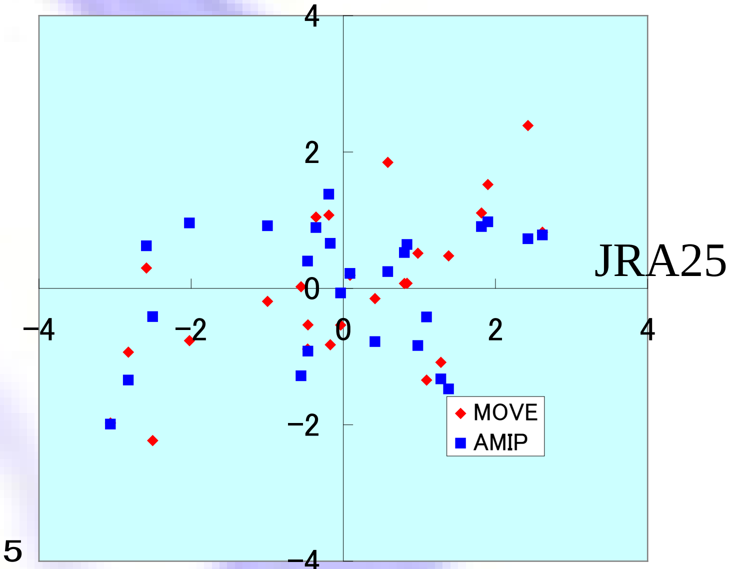


★Reproducibility of the Walker Circulation (Jun.-Aug.)

Time Series of W-Y Index



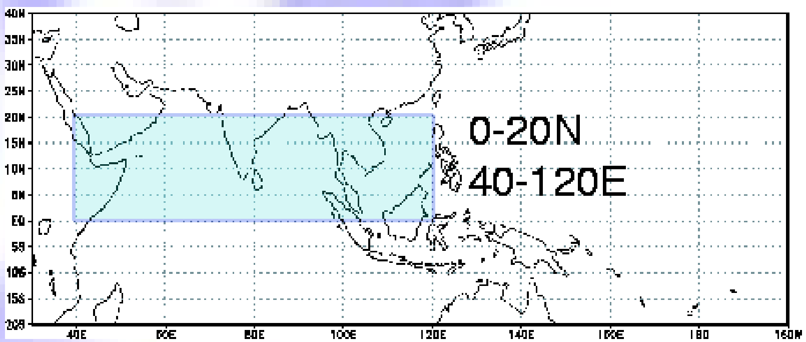
MOVE or AMIP



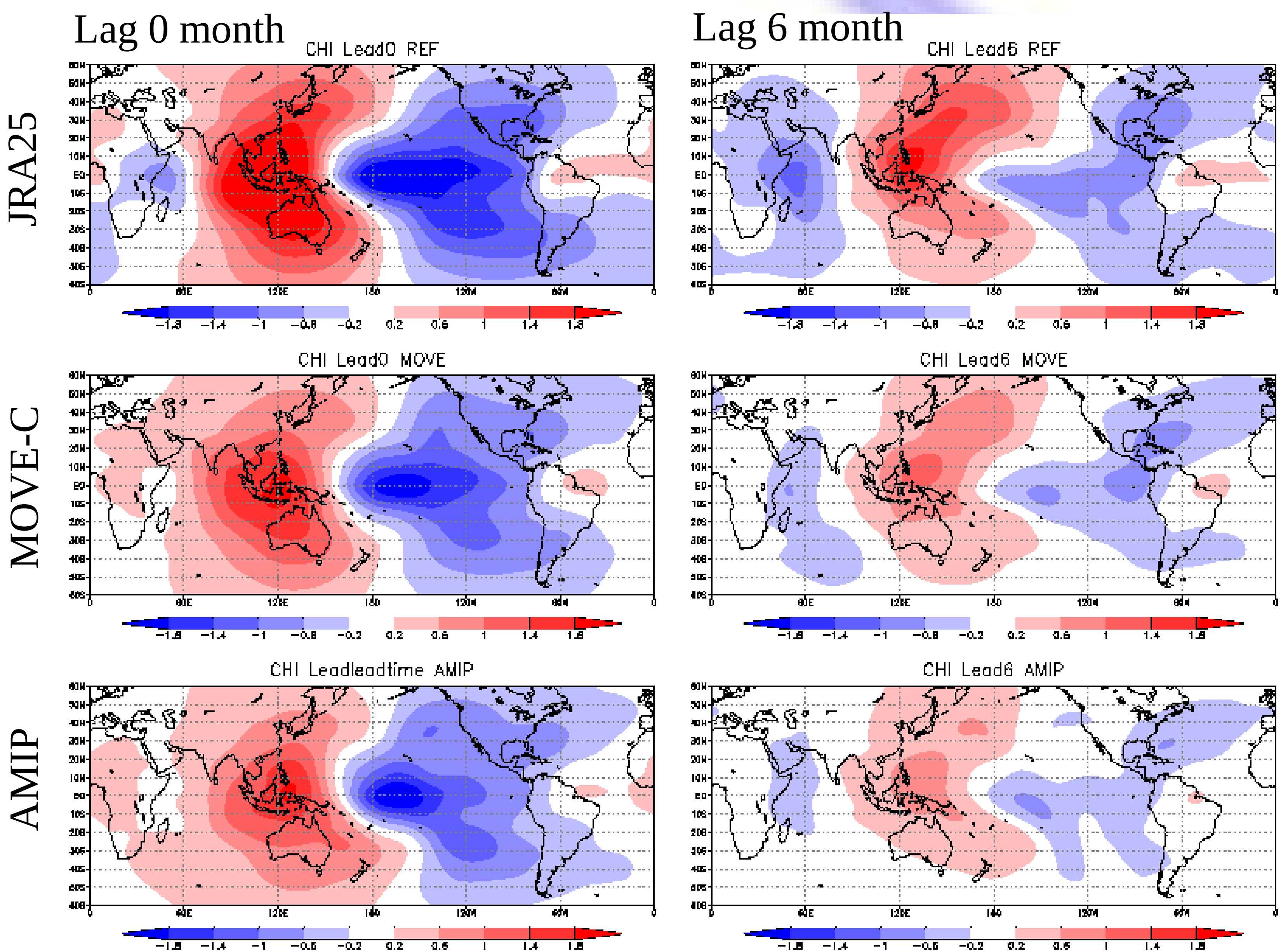
Correlation Coefficients： MOVE 0.62 AMIP 0.26

W-Y Index (Webster and Yang, 1992) represents the strength of the Walker Circulation in summer.

Average anomaly of U850hPa - U200hPa in 0-20N, 40-120E in the summer period.

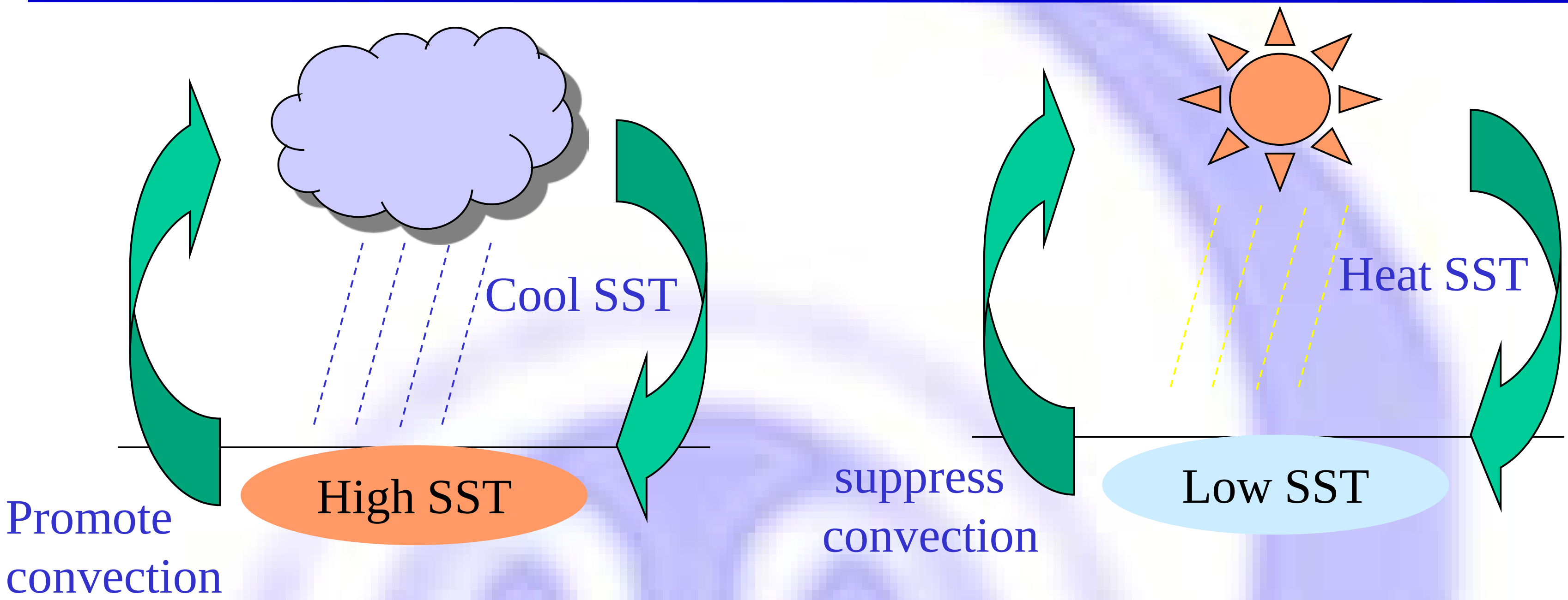


★ Regression of 200hPa V potential to NINO3 Index



5. Effect of the Air-Sea Interaction

☆ Negative Feedback between SST and Precipitation



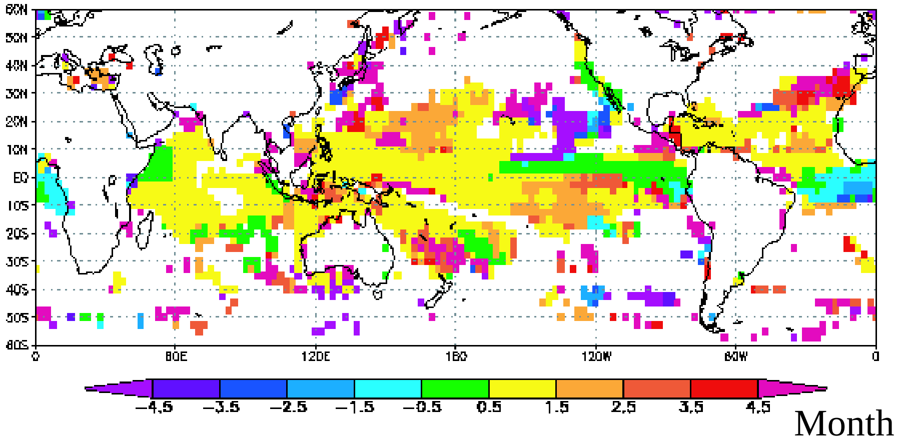
・This negative feedback has a role of adjusting the precipitation (avoiding the continuous rainfall over high SST regions).

・Because of the negative feedback, the variation of precipitation lagged SST about a month.

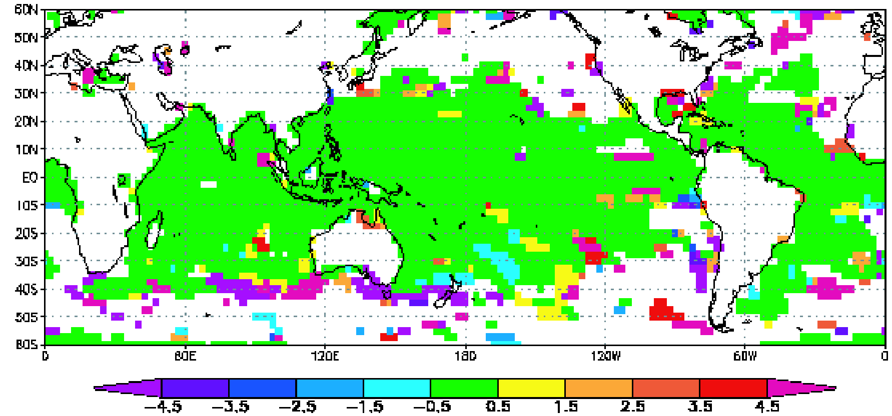
・This negative feedback does not work in non-coupled atmosphere models (and in the AMIP Run) !!

☆ Time Lag of the precipitation behind SST

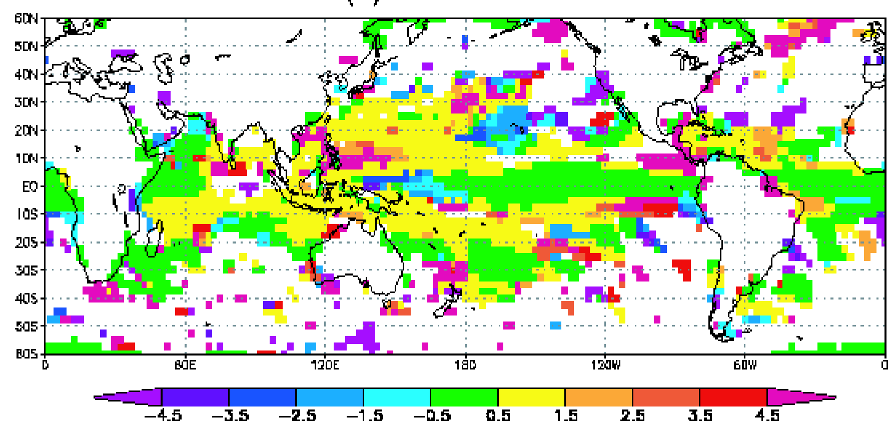
(c) CMAP and COBESST



(a) AMIP Run



(b) MOVE-C RA



Yellow: One month Time Lag

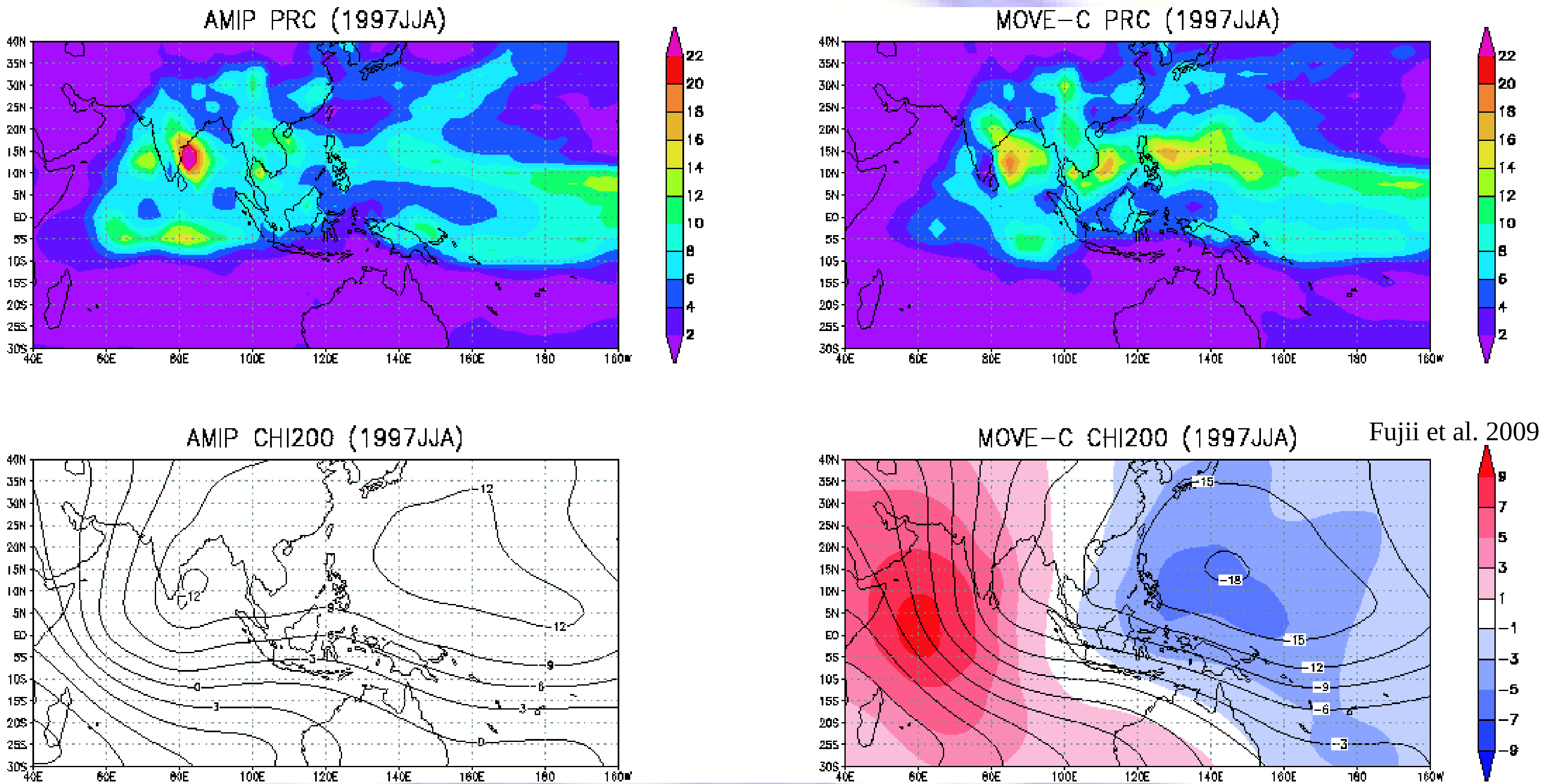
Green: No time Lag

Significance > 99%

MOVE-C: Assimilation interval of IAU → Monthly.

➡ It does not destroy the negative feedback.

★ Precipitation and 200hPa V Potential (Jun-Aug 97)



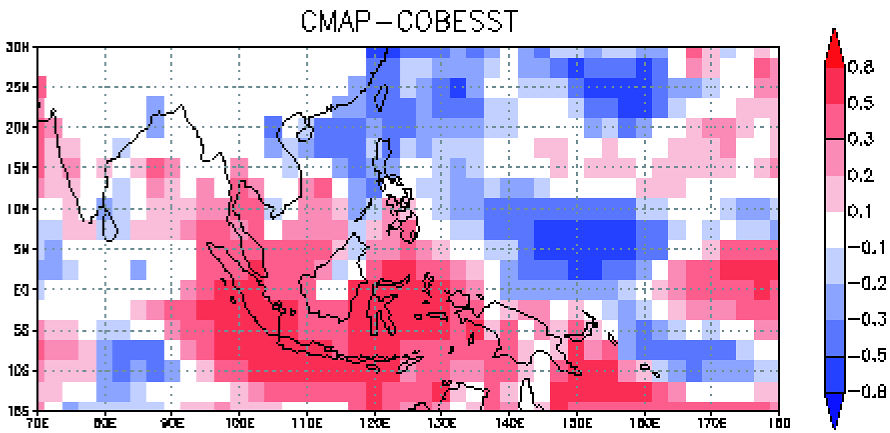
Fujii et al. 2009

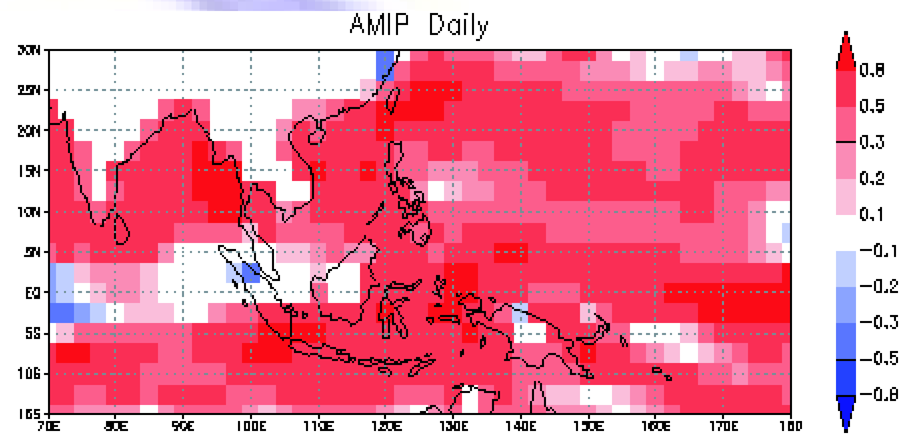
<u>Color: Difference (MOVE-C – AMIP)</u>

AMIP: Overestimate of PRC at E India → Suppress the divergence over the Pacific.

MOVE: Overestimate is removed → The Walker Circulation is improved.

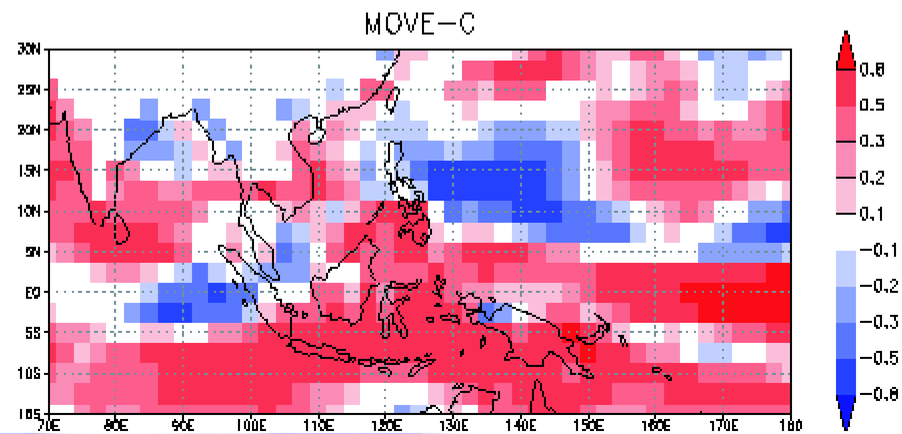
★Correlation between SST and PRC in Jun-Aug





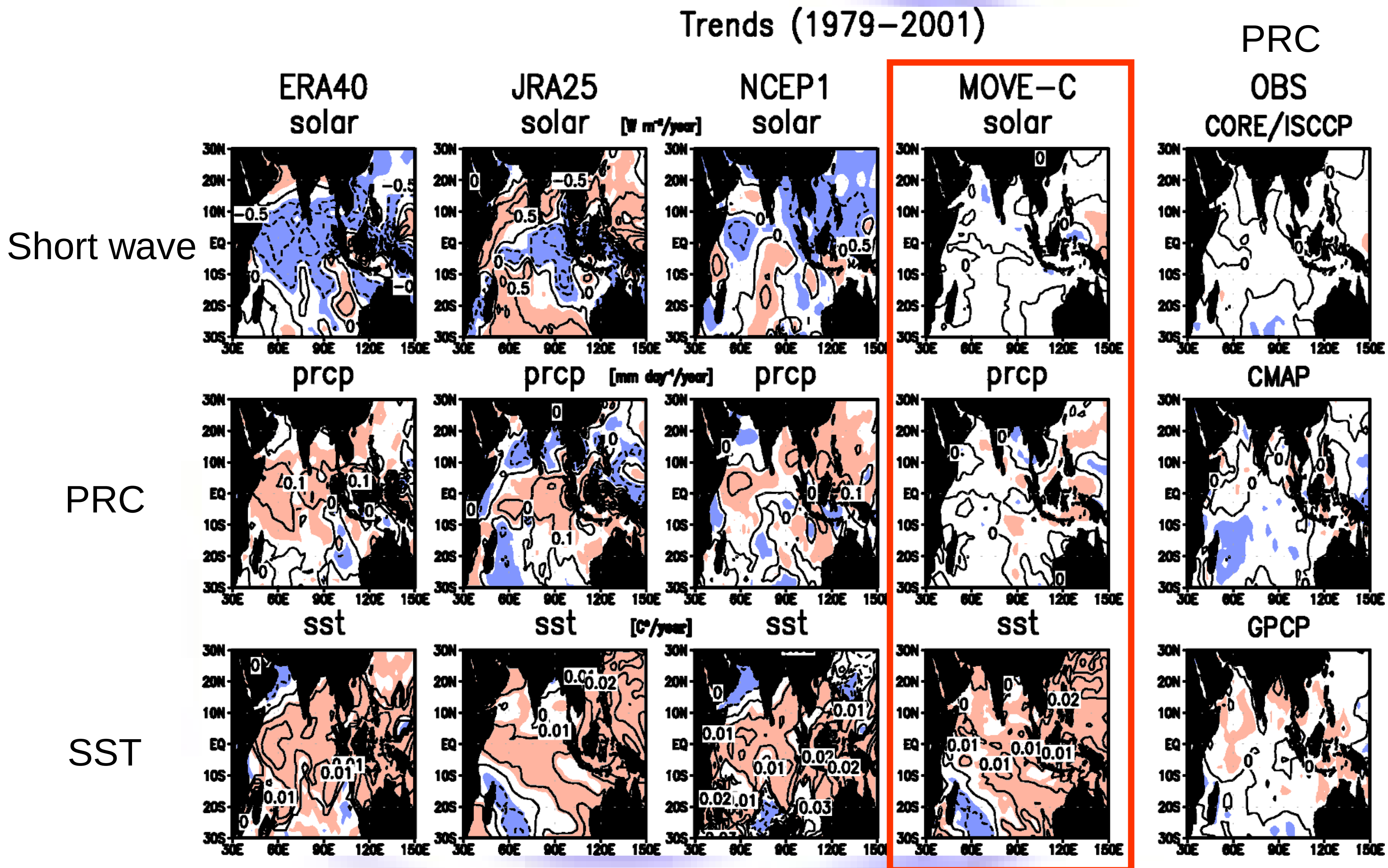
AMIP Run: Variation of PRC is controlled by SST.

CMAP-COBESST: The negative feedback mitigates the coupling. The atmosphere rather controls the SST variation.



MOVE-C: The negative correlation on the Philippine Sea is recovered, and the positive correlation in the Indian Ocean is reduced because of the existence of the negative feedback.

☆Trends in the Indian Ocean



The spurious trends in PRC is removed in MOVE-C.

→ Better than regular atmospheric reanalyses!!

6. Final Remarks

☆ Final Remarks

・We developed the quasi-coupled data assimilation system where ocean observation data is assimilated into the coupled model, JMA/MRI-CGCM.

・Reconstruction of the negative feedback between SST and PRC in the system improves the atmospheric fields (precipitation, monsoon trough, Walker Circulation, TC generation) over AMIP Run.

・The system removes the spurious increasing trend of precipitation over the Indian seen in the regular atmospheric reanalyses.

⇒ Showing the potential of the truly coupled data assimilation system

・Improvement of the seasonal forecast skill in JMA by the system update is probably caused by the similar mechanism (the negative feedback between SST and precipitation).

Thank you

☆ Final Remarks

・Atmospheric Data Assimilation System without coupling

Absence of the negative feedback between SST and precipitation.

→Degrade the reproducibility in the tropics.

（Tropical Cyclone, Monsoon, Walker Circulation, etc.)

If the model is nudged to the observation strongly, errors will appear where no observation exists (e.g., air-sea flux).

・Ocean Data Assimilation System

The wind stress and the pressure gradient produced by the observed sloping thermocline is not balanced.

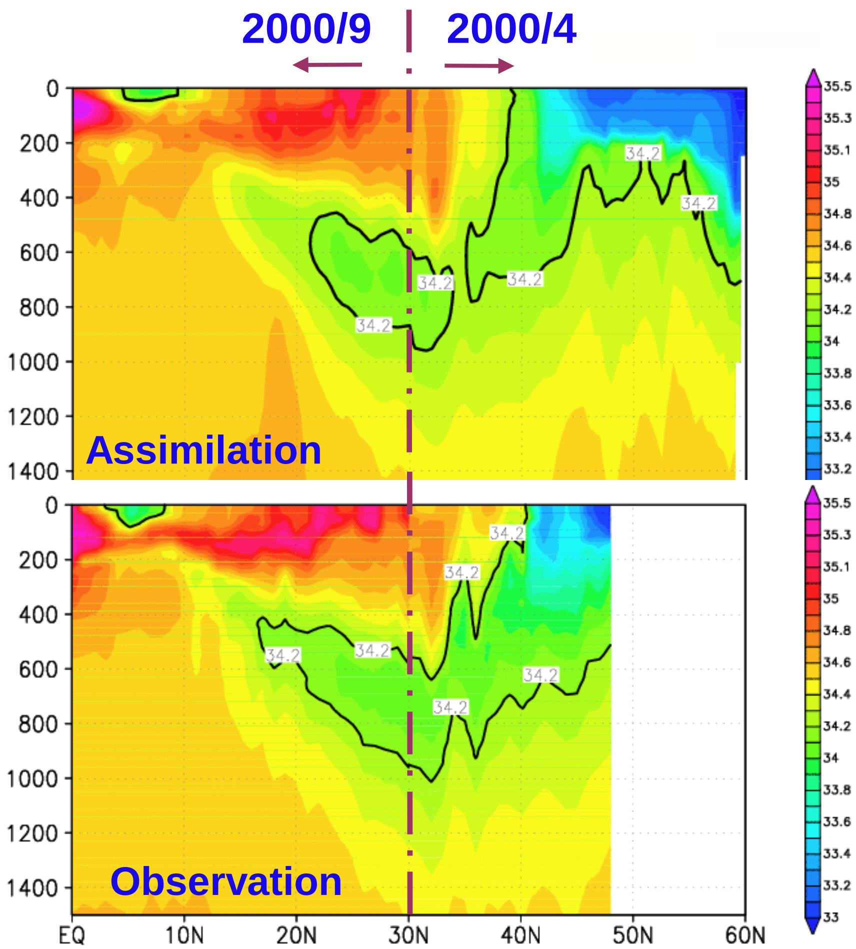
→If the model TS fields are nudged to obs. strongly, the spurious vertical circulation occurs. → Correction of wind stress

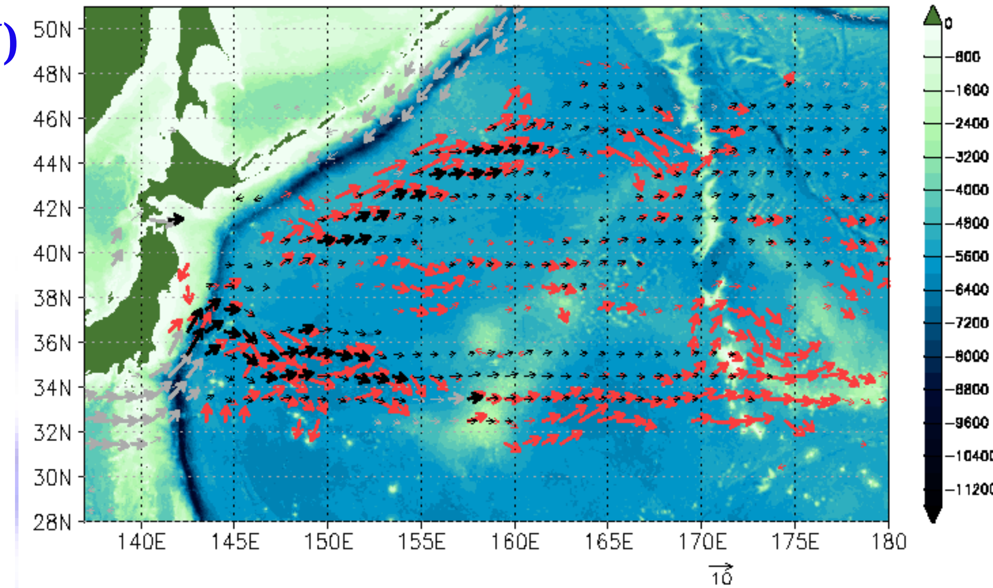
・Coupled Data Assimilation System is required for resolving the problems above. → Mitigating shocks and improving the score.

☆ Reproducibility of MOVE-G

North Pacific Intermediate Water (NPIW)

Salinity Minimum（165E, 2000/4and9）





Currents in the mid-depth layer in the North Pacific（Climatology）

Red：Calculated from floats

Black, Gray：MOVE-G

(Gray denotes the absence of the floats data.）

★ ACC for PRC, SLP, 200hPa zonal Winds

REF: CMAP, JRA25

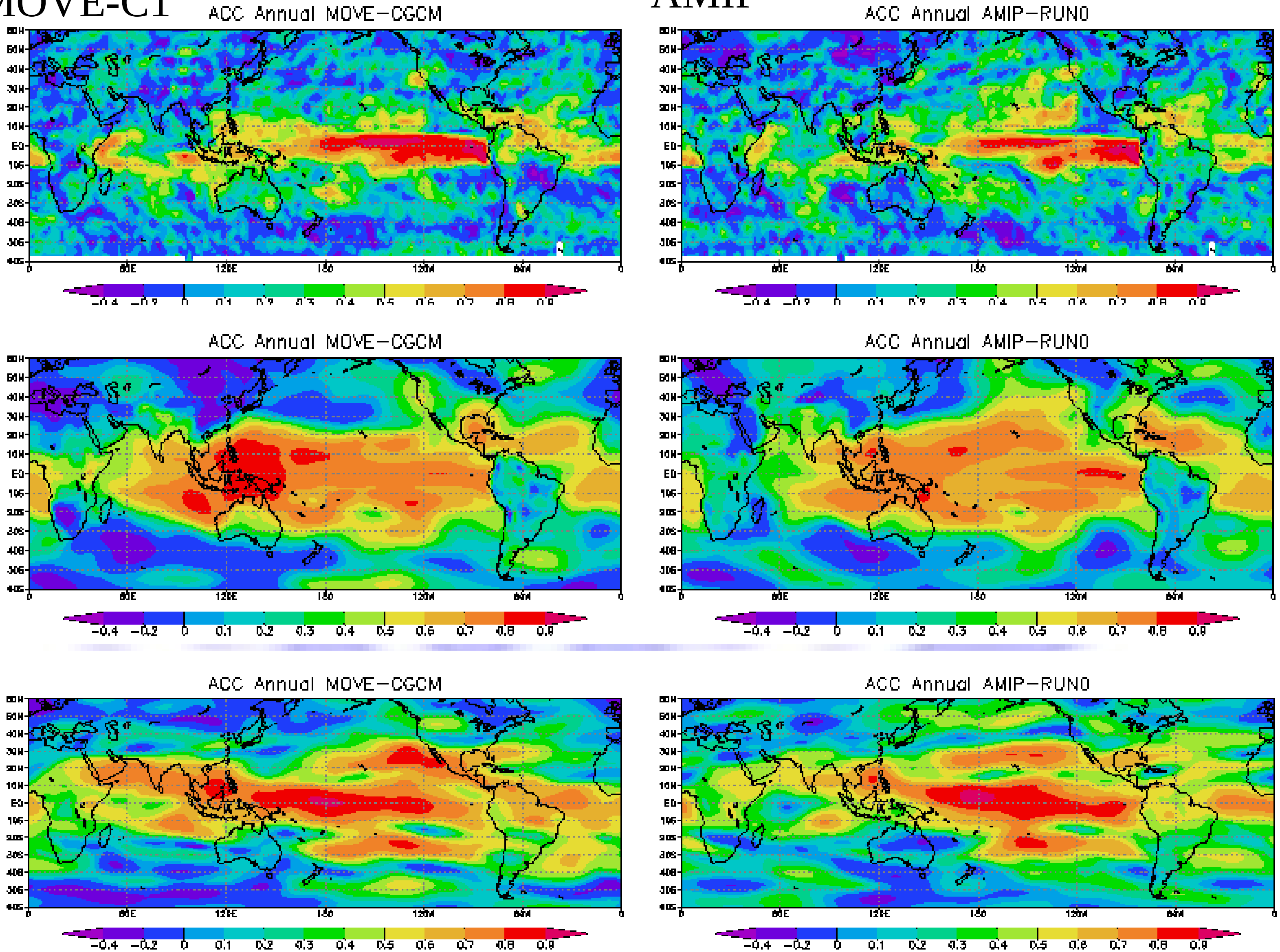
MOVE-C1

AMIP

PRC

SLP

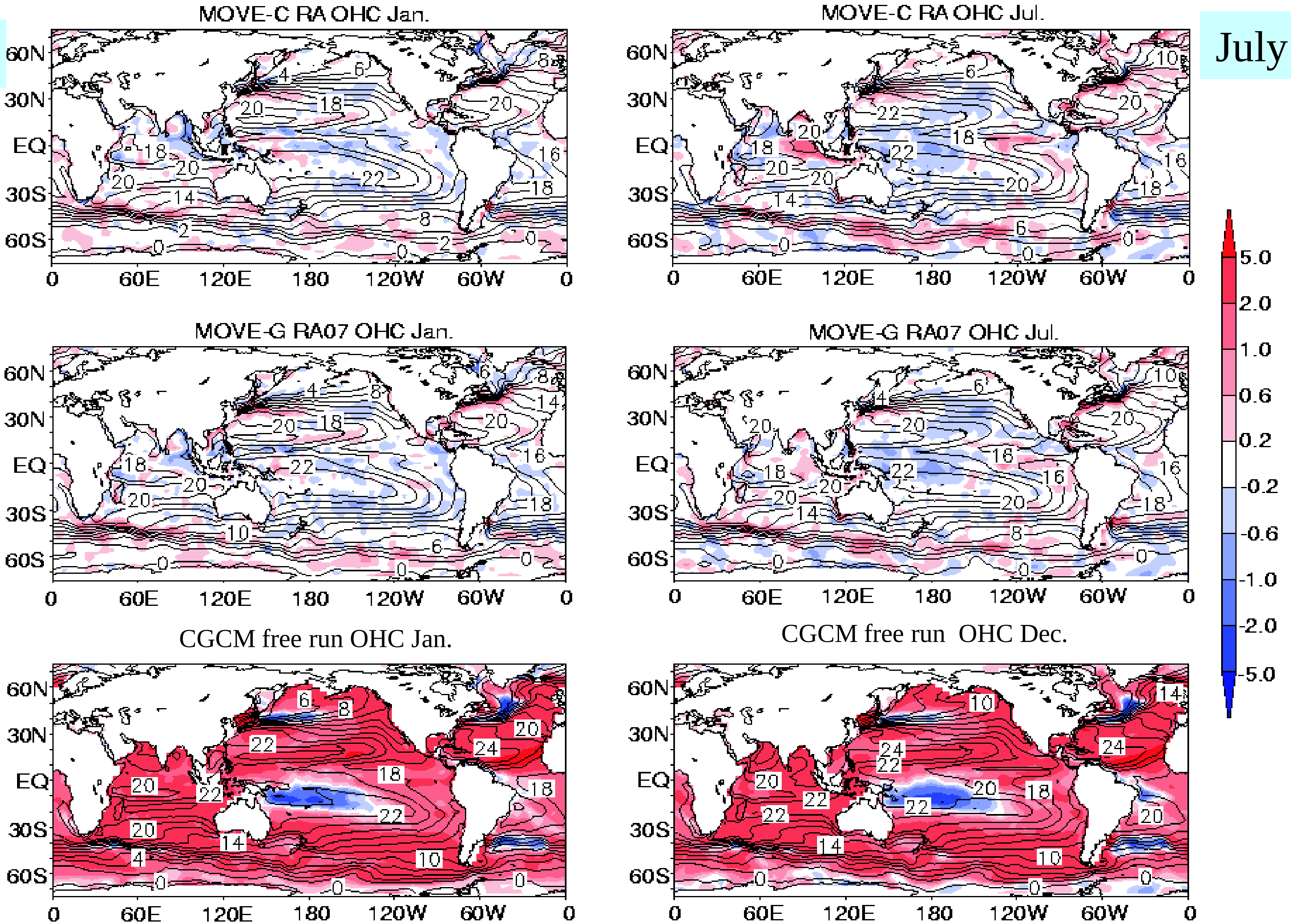
200hPa
Zonal Winds



★Comparison of 0-300m Temp. (OHC)

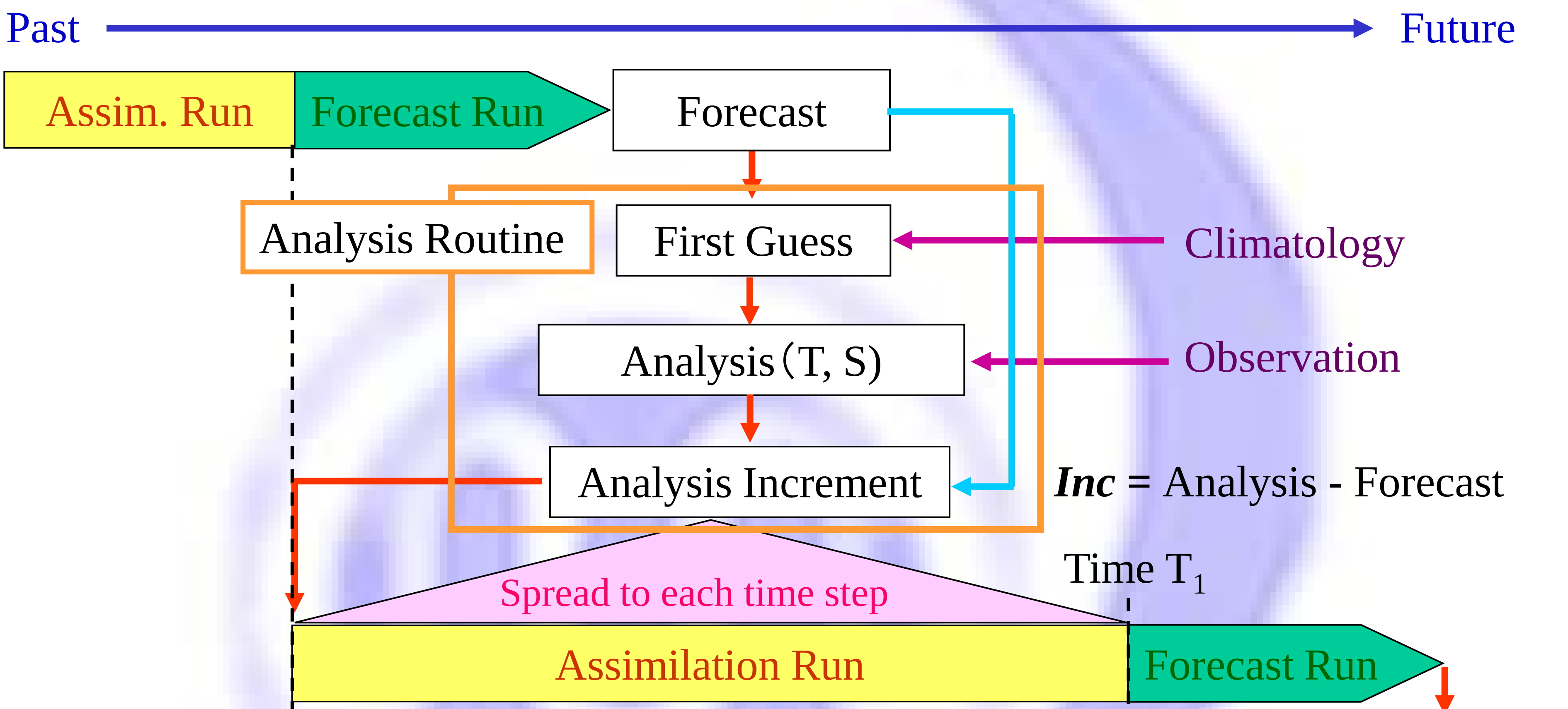
Jan.

July



Shading shows the deviation from WOA05.

☆ Incremental Analysis Updates (IAU)



$$\frac{d\mathbf{x}}{dt} = M(\mathbf{x}) + \frac{I_{nc}}{N_{step}}$$

＊Analysis fields are calculated for T and S alone.
Current fields are adjusted through the assimilation.