Summer Season Hindcast Experiments using JMA/MRI-CGCM3

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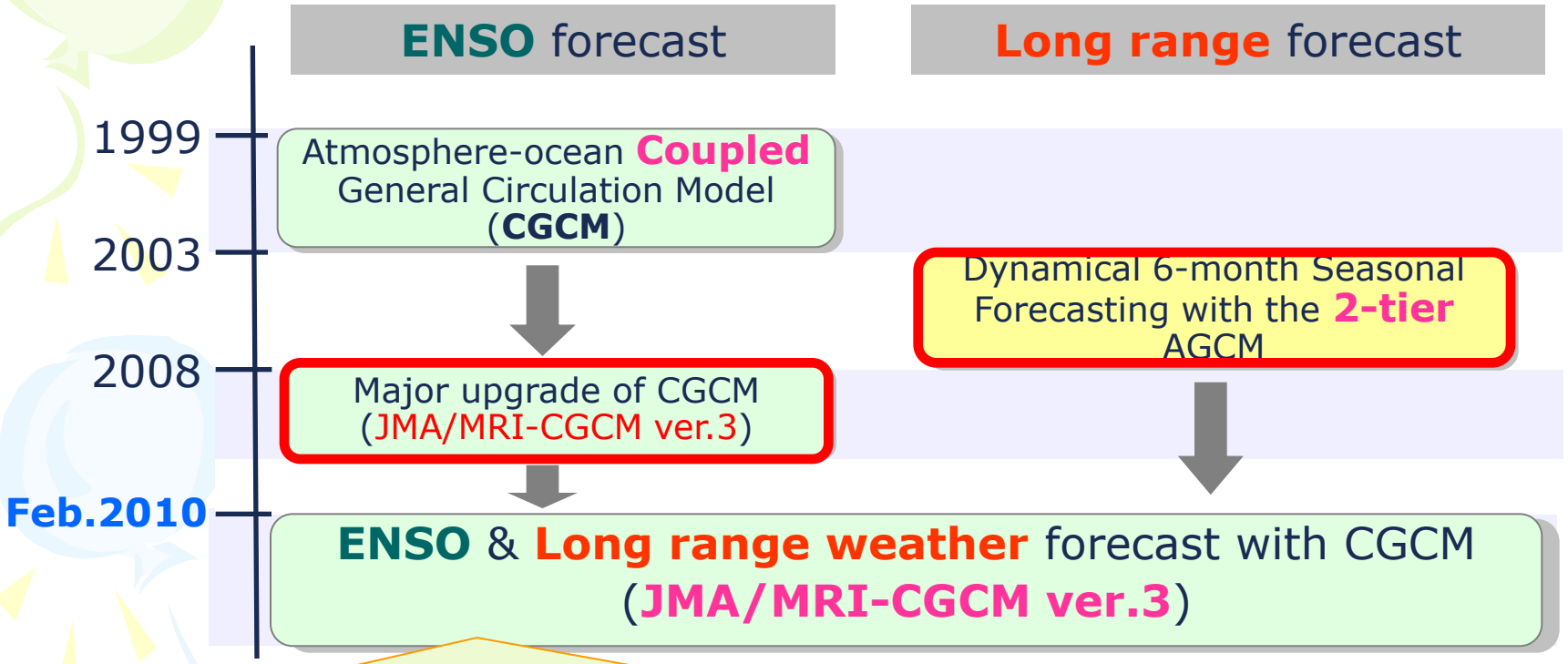
Outline

1. Introduction of Next Long Range Forecast system at JMA

2. Performance Comparison of Current and Next system

3. Summary

Next (Feb.2010~) Long Range Weather Forecast System at JMA



In 1999, JMA introduced the atmosphere-ocean copuled GCM into our ENSO forecasting service. In 2003, 2-tiered dynamical ensemble prediction system began to be used in the long range weather forecast service. In 2008, an entirely new coupled forecast system developed by JMA and Meteorological Research Institute(MRI) became an operational ENSO forecast system and we are now preparing to utilize this coupled system for long range weather forecasting services.

Model Description

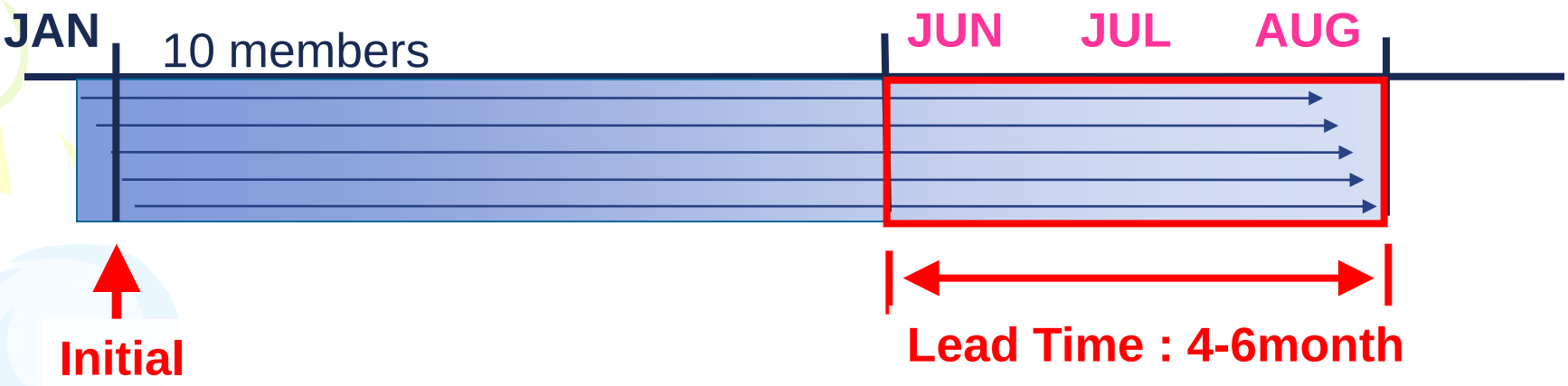
CGCM

AGCM	JMA/MRI Unified AGCM • TL95L40 (horizontal resol. ~ 180km)
OGCM	MRI.COM Ishikawa *et al*. (2005) • 75S-75N, 0-360E • horizontal resolution: lon 1.0° , lat 0.3-1.0° • vertical resolution : 50 levels (23 levels in the upper 200m)
Coupler	•flux adjustment for heat and momentum flux •coupling interval : 1 hour
Perturbation method	• Lagged Average Forecast (LAF) method (10 members)

2-tiered AGCM

AGCM	JMA/MRI Unified AGCM • TL95L40 (horizontal resol. ~ 180km)
SST	•Combination of Persisted anomaly + Predicted anomaly + Long-term trend
Perturbation method	Singular Vector (SV) method (11 members)

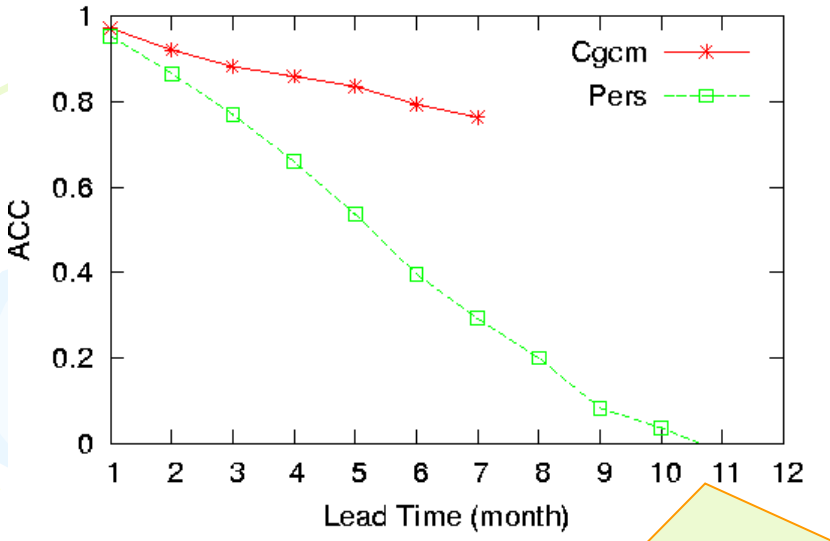
Hindcast Experiment Design



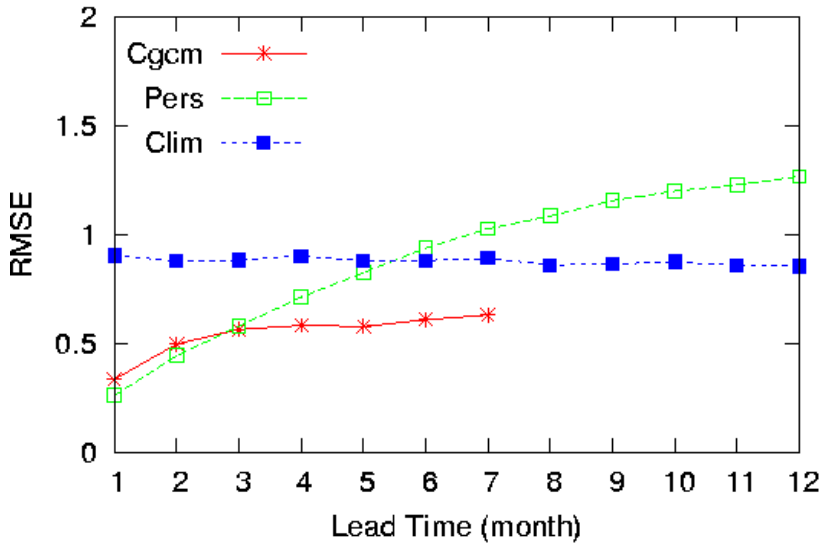
- **CGCM** hindcast experiments are started from the end of January.
- Experiments for **2-tier AGCM** are started from Feb. 10$^{th.}$
- Period of the retrospective forecast is 22 years (1984-2005).
- CO_2 concentration is updated during the retrospective forecast period in CGCM.
- Sea-ices and land surface conditions are fixed to the climatological values.

ENSO forecast skill of JMA/MRI-CGCM3

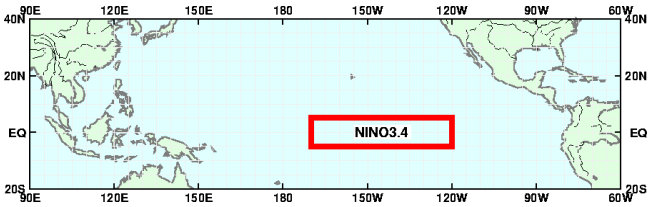
(a) Anomaly Correlation (ACC)



(b)Root Mean Square Error (Deg.C.) (RMSE)

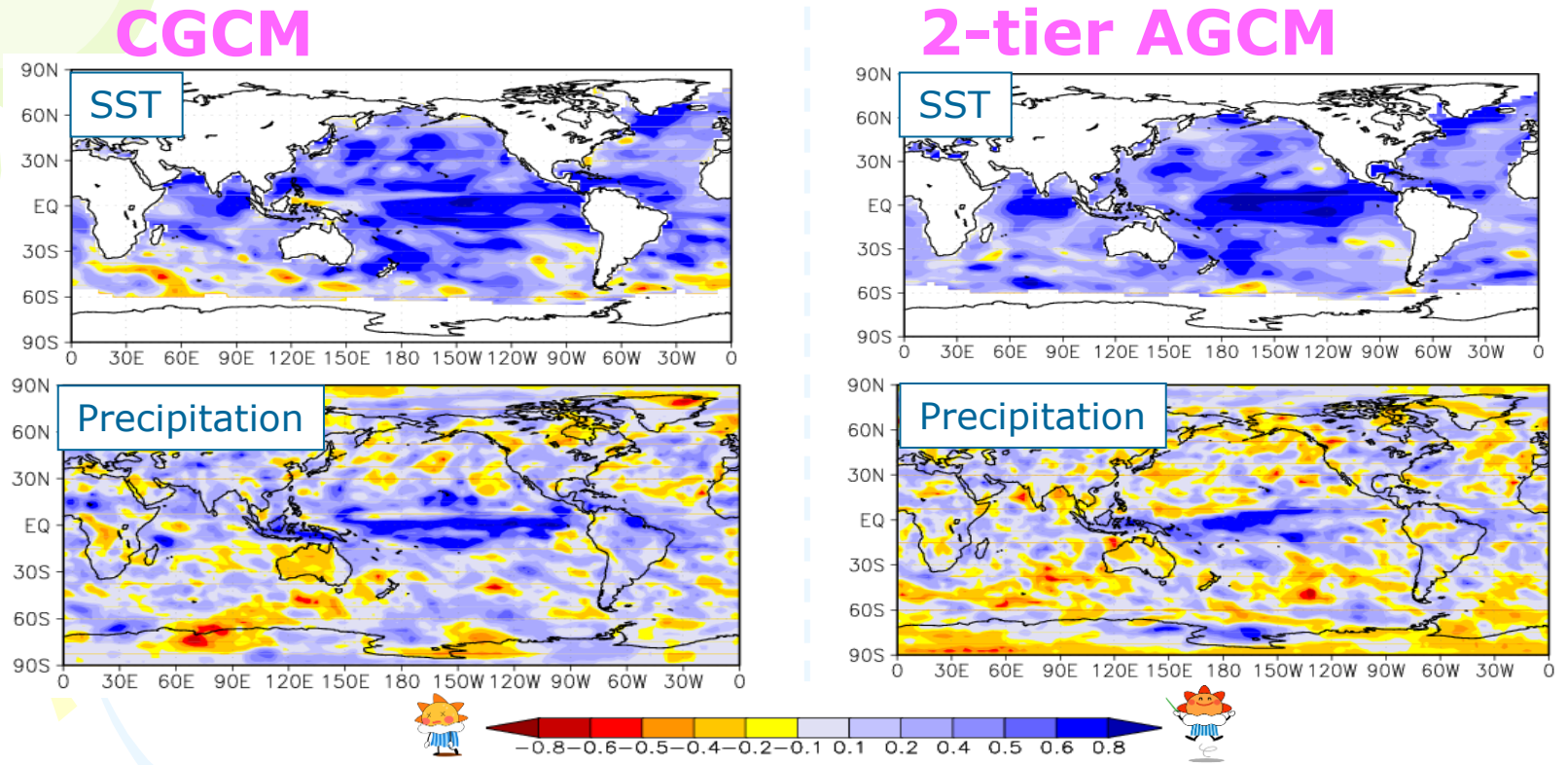


•ACC coefficients with CGCM are higher than 0.8 within 5-6 month lead time and higher than that with persistence forecast not only for long but also for short lead times.



a) Anomaly correlation coefficients and b) RMSE of NINO3.4 index during 1984-2005 with respect to lead time after removing the mean bias. Red lines for JMA/MRI-CGCM, green lines for persistence forecast and a blue line for standard deviation of NINO3.4

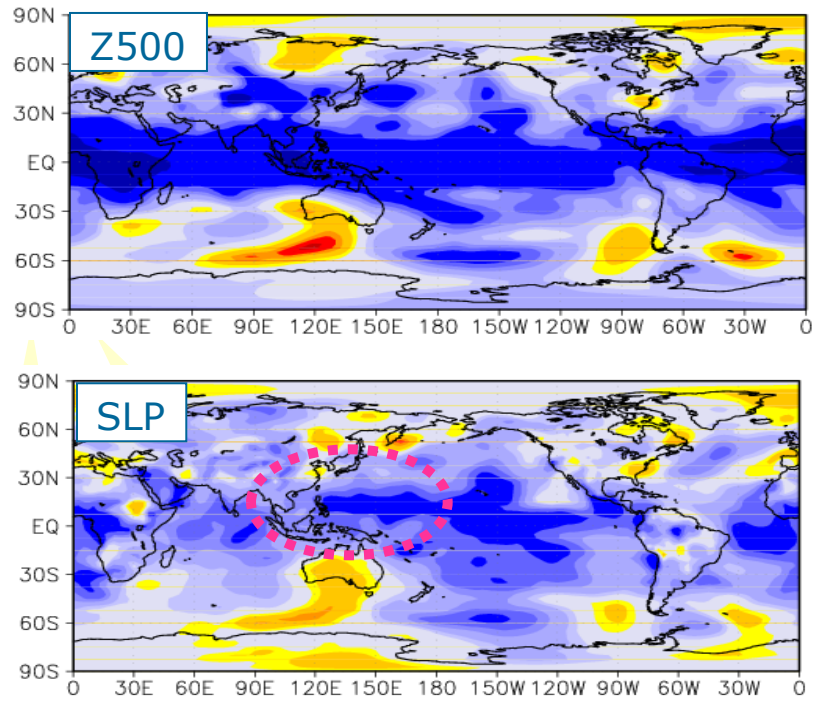
Comparison : CGCM vs. 2-tiered AGCM
(Anomaly Correlation Map, 4-6 months lead JJA)



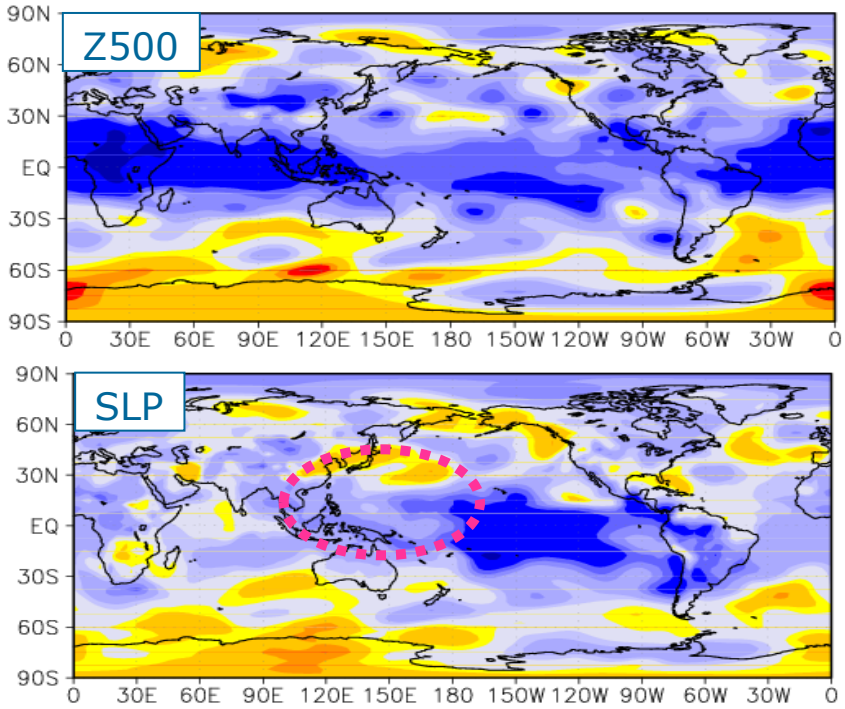
Figures above show correlation coefficients (ACC) between analyzed anomalies and ensemble mean anomalies of SST (upper figures) and precipitation (lower figures) at each grid box. Verification period is 1984-2005 (22yr) and verification datasets used here are COBE-SST for SST, and GPCP for precipitation. ACCs are positive in the areas colored blue.

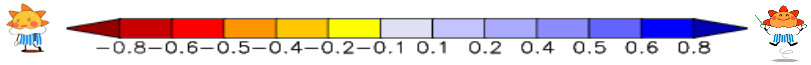
SST anomalies and precipitation anomalies are well predicted in CGCM in the areas from around Indian Ocean to Western North Pacific
> Forecast capability of Asian summer monsoon circulation is improved.

CGCM



2-tiered AGCM





Figures above show correlation coefficients (ACC) between analyzed anomalies and ensemble mean anomalies of Z500 (upper figures) and SLP (lower figures) at each grid box.
Verification period is 1984-2005 (22yr) and verification dataset used here is JRA-25. ACCs are positive in the areas colored blue.

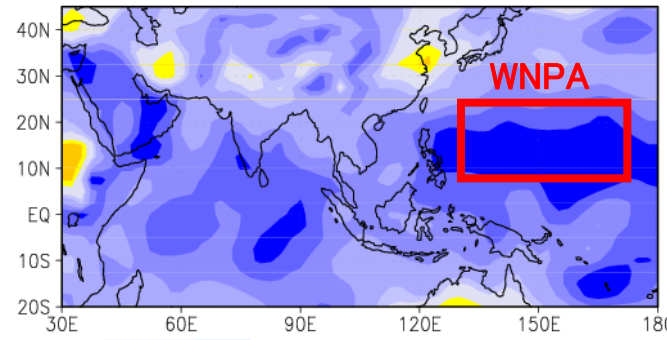
- As for Z500, high ACC area spreads east and west not only in the tropics but also in the mid-latitudes.
- As for SLP, CGCM has a higher potential than 2-tiered AGCM to forecast the variability of the Western North Pacific High

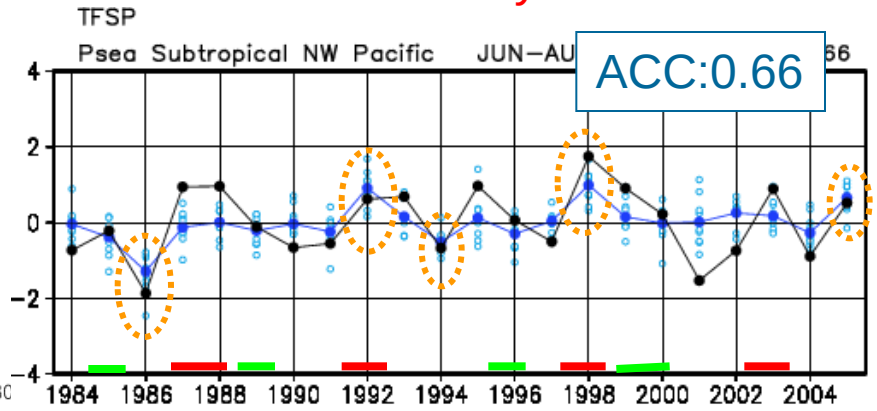
What brings these improvements to CGCM?

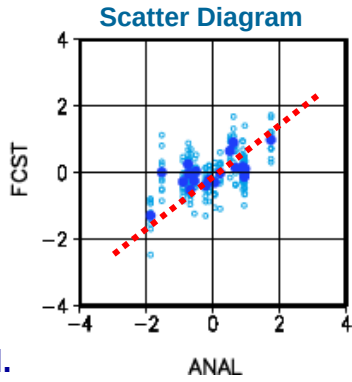
SLP forecast skill around WNPM area

WNPA: WN Pacific Anticyclone（130-170E, 10-25N)

CGCM (ACC)

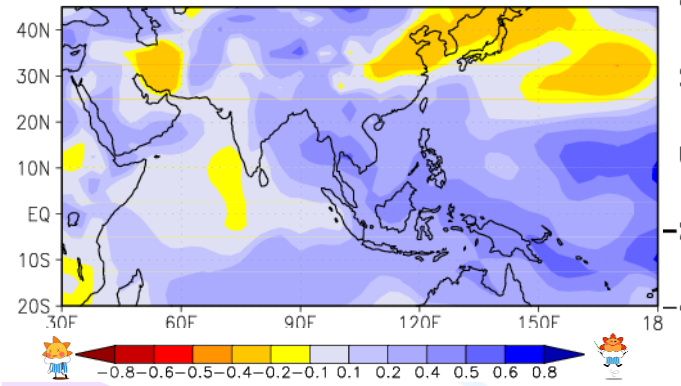


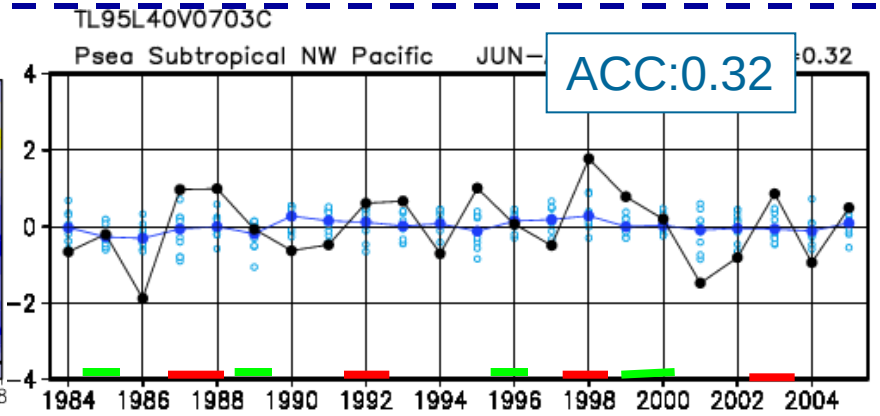


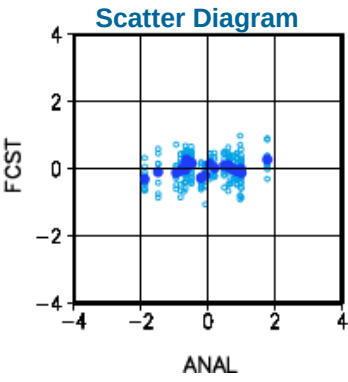


ACC > 0.43 is statistically significant at 5% level.

2 tiered AGCM (ACC)

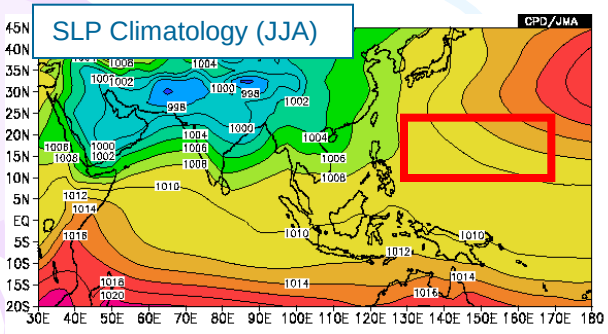






JJA following El Nino

JJA following La Nina

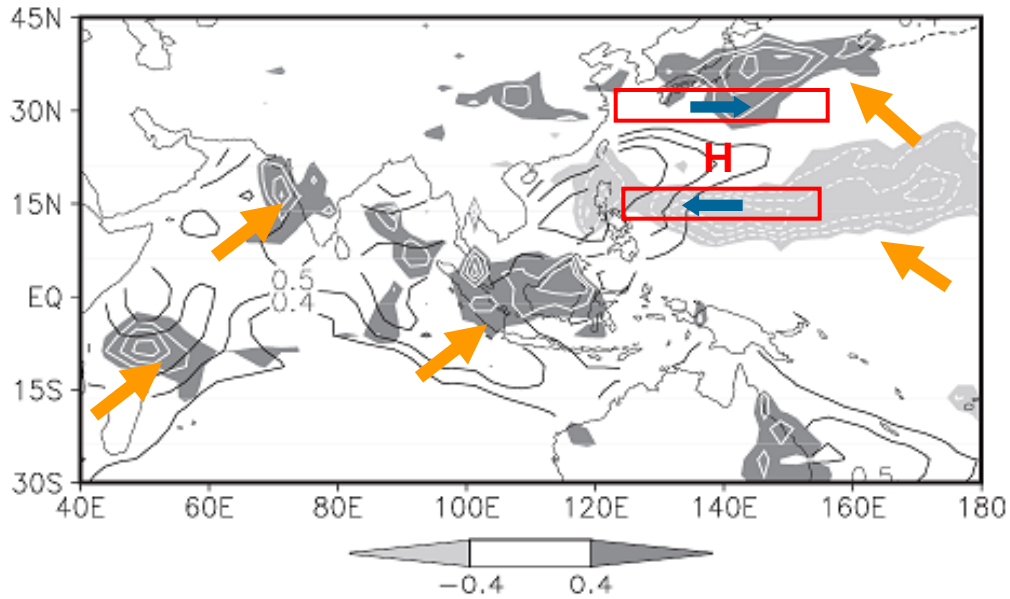


In the scatter diagram for CGCM, distribution of dots spreads along the diagonal line, which indicates an interannual variation of the WNPA is possibly able to be well reproduced by including the air-sea coupling process.

Why is summertime SLP forecast skill improved in Western North Pacific?

Correlation coefficients between Western North Pacific Anti-cyclone and precipitation(shades), SST(contour)

WNPA: U850[(27.5-32.5N)-(10-15N),120-150E]



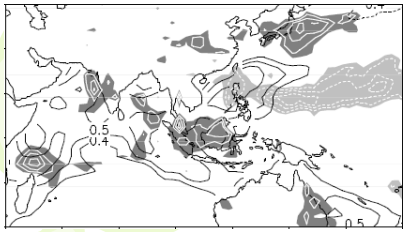
Xie et al.(2009) Fig. 12

Summertime western north pacific high covariates with

A：negative precipitation anomalies around the east of the Philippines, and positive precipitation anomalies from Maritime Continent to the Indian Ocean (positive)

B : positive SST anomalies around the South China Sea and the Indian Ocean

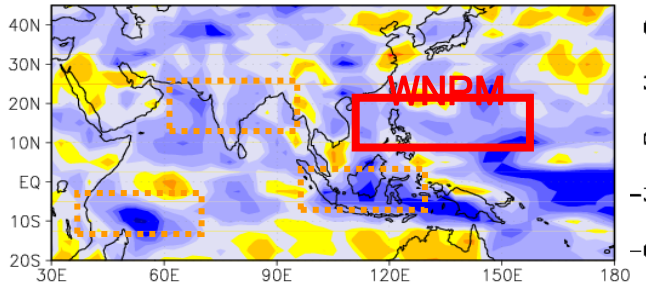
The picture above shows precipitation (gray shade and white contours) and SST (black contours) correlation coefficients during JJA with a Western North Pacific Anticyclone index. The areas colored dark-gray (light-gray) are positively (negatively) correlated with WNPA.

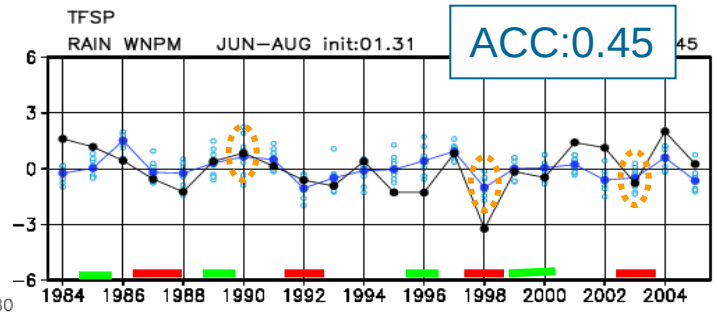


A:Precipitation forecast skill

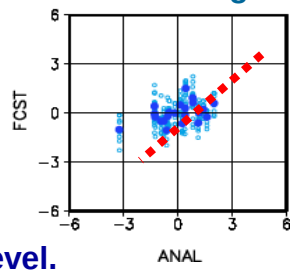
WNPM: Western North Pacific Monsoon
(110-160E, 10-20N)

CGCM（ACC）



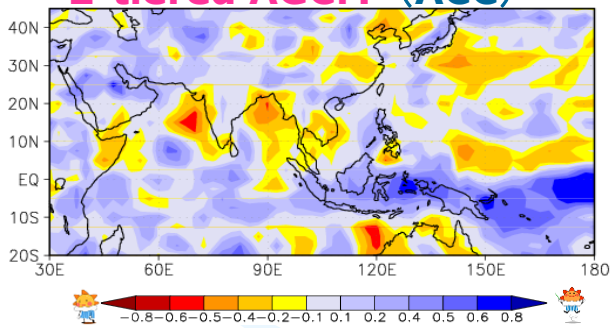


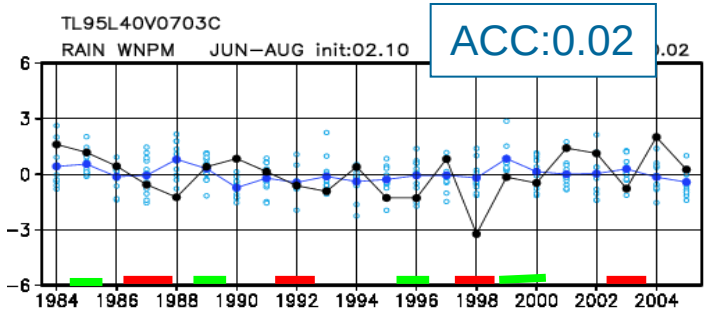
Scatter Diagram

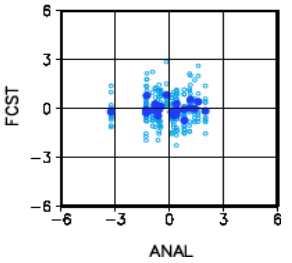


ACC > 0.43 is statistically significant at 5% level.

2-tiered AGCM （ACC）





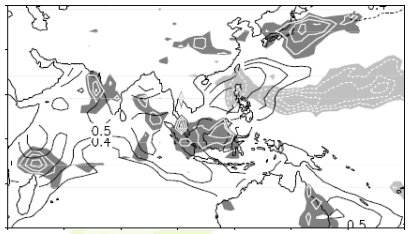


JJA succeeding El Nino

JJA succeeding La Nina

Precipitation forecast skills around the area related to the Western North Pacific High are remarkably improved in CGCM. 1990, 1998, 2003

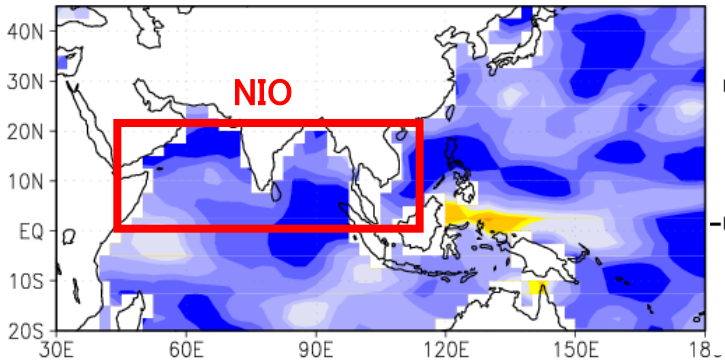
Left figures show correlation coefficients (ACC) between analyzed anomalies and ensemble mean forecasted anomalies of precipitation (left figures) at each grid box. Center figures show oveserved precipitation anomaly time series averaged over the WNPM area with black line, blue line for predicted time series.

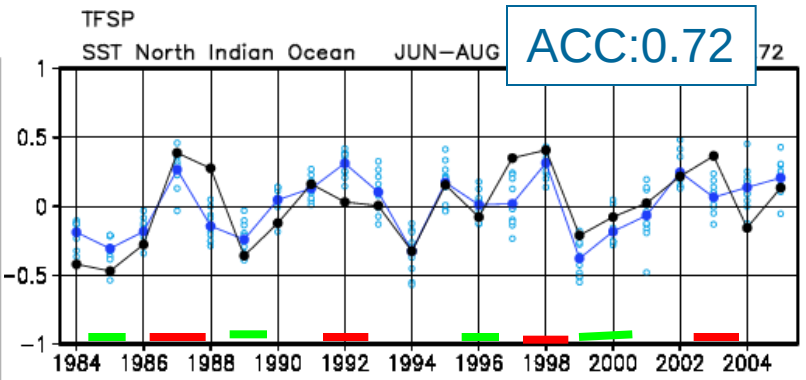


B:SST forecast skill

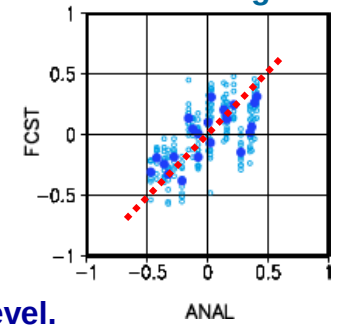
NIO: North Indian Ocean 40-110E, 0-20N

CGCM（ACC）



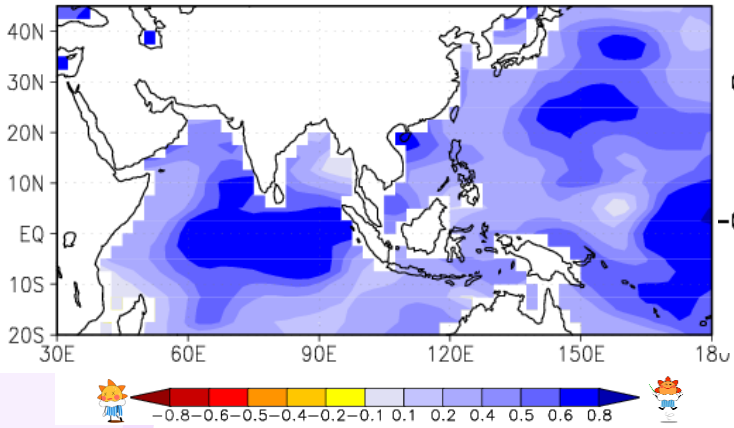


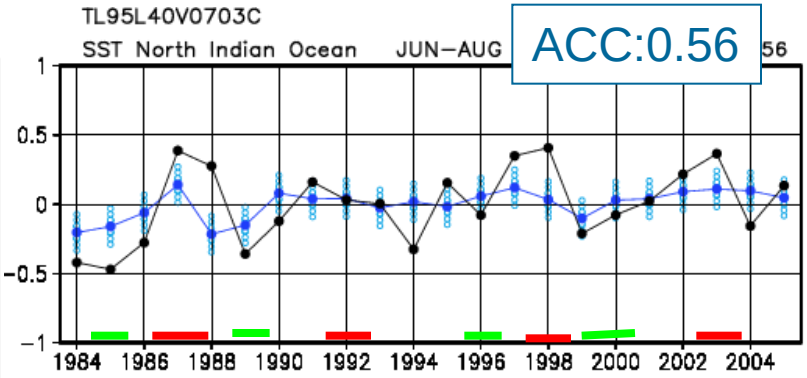
Scatter Diagram

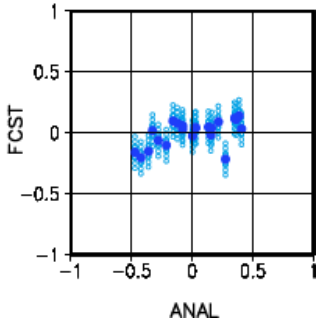


ACC > 0.43 is statistically significant at 5% level.

2-tier AGCM（ACC）





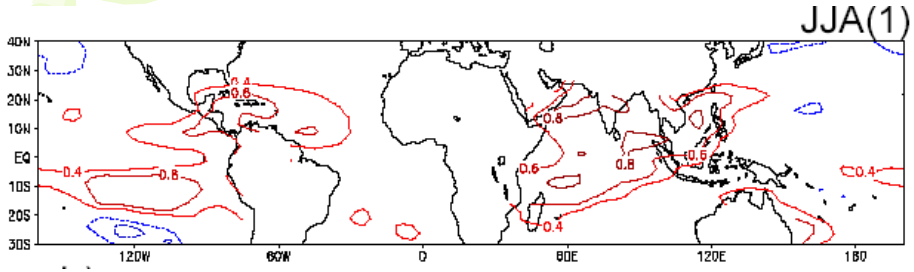


JJA succeeding El Nino **JJA suceeding La Nina**

In the scatter diagram for CGCM, distribution of dots spreads along the diagonal line -> CGCM forecasts well year-to-year variations of the Indian Ocean SST.

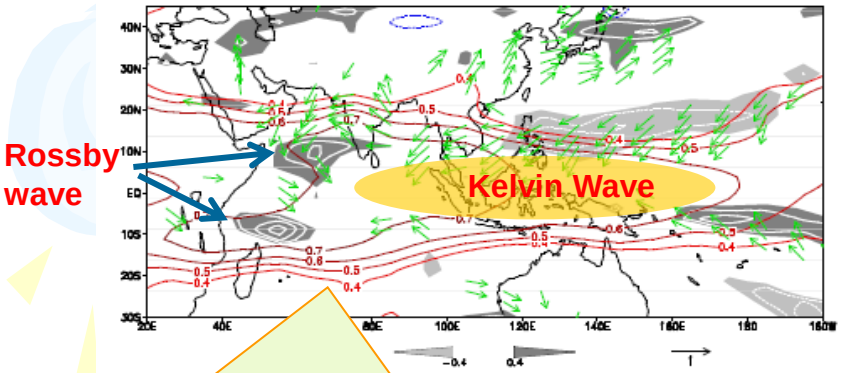
Why can CGCM predict summertime Indian Ocean SSTs and the Western North Pacific SLPs better than AGCM?

Xie et al.(2009)

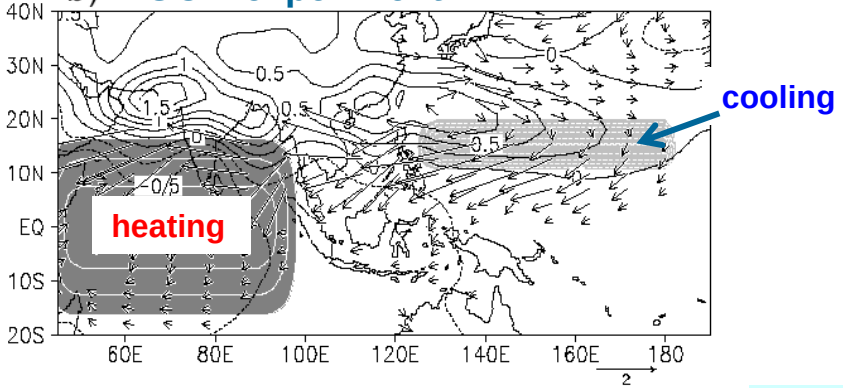


Correlation coefficients between winter NINO3.4 SST and succeeding summer SST (left figure, contours)

Observation



b) AGCM experiment



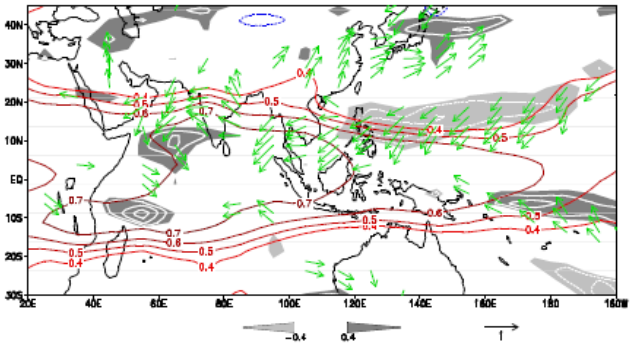
Matsuno-Gill type response

Correlation coefficients between winter NINO3.4 SST and succeeding summer tropospheric temperature (contours), precipitation (shades) and surface wind (vectors)

As a response to the basin-wide warming of Indian Ocean SST, the Matsuno-Gill type atmospheric response is invoked, and Kelvin waves emanating from the Indian Ocean to the Maritime Continent, in turn, induces low-level divergent wind, and low-level wind divergence suppresses the convective activities in WNP through the Ekman pumping mechanism and this suppressed convection create low-level anti-cyclonic response.

Forecast skill of Tropospheric temperature

(Xie et al. 2009)



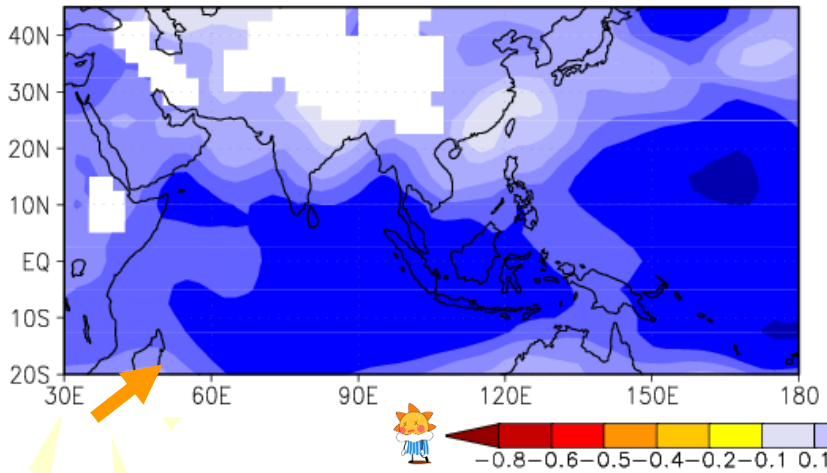
CGCM's can predict a steady Kelvin-wave response emanating from the Indian Ocean to the Maritime Continent.

The bottom line is ….

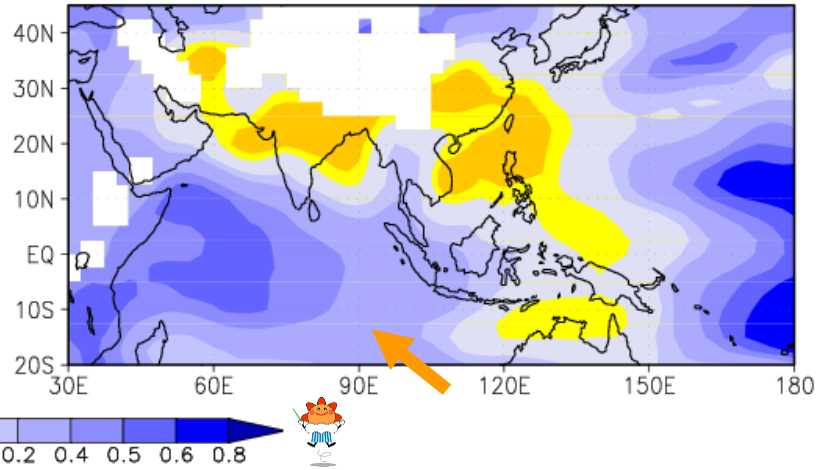
Improvement of SLP forecast skill in WNP would be brought by delayed ENSO effects.

The CGCM can predict the delayed atmospheric and oceanic responses to ENSO, which cannot be predicted by current 2-tiered forecast system.

CGCM (ACC)



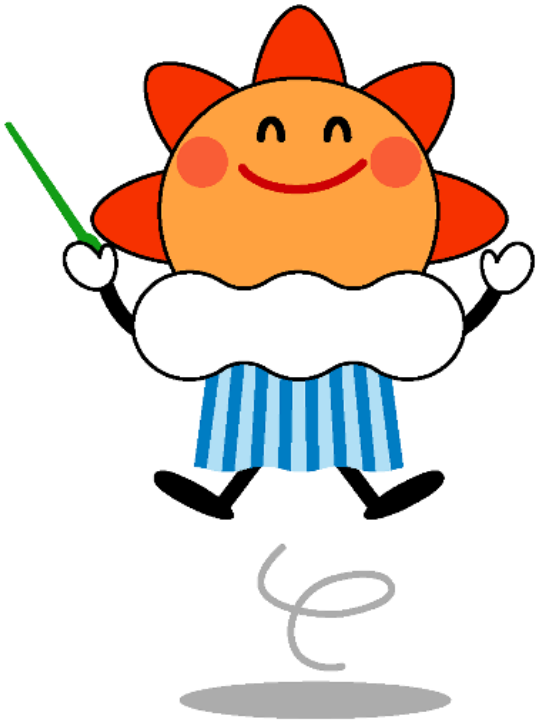
2-tiered AGCM (ACC)



Summary

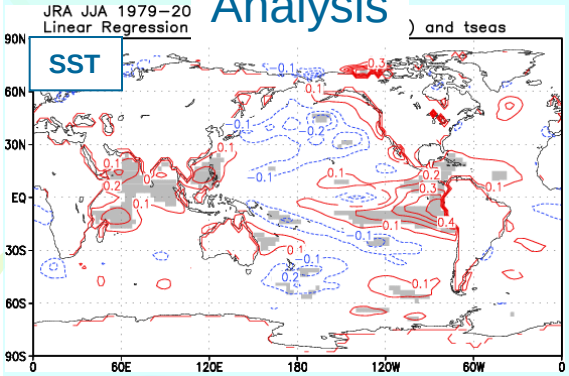
- JMA/MRI-CGCM shows far better forecast skill of the Indian Ocean SSTs and western north Pacific SLPs compared with the current 2-tiered system.
- It seems that these improvements would probably be brought by the atmosphere-ocean covariant mechanism related to ENSO indicated in Xie et al.(2009).
- We will offer verification results of hindcasts in addition to the forecast maps and GPVs of the CGCM after Feb.2010 at Tokyo Climate Center website.

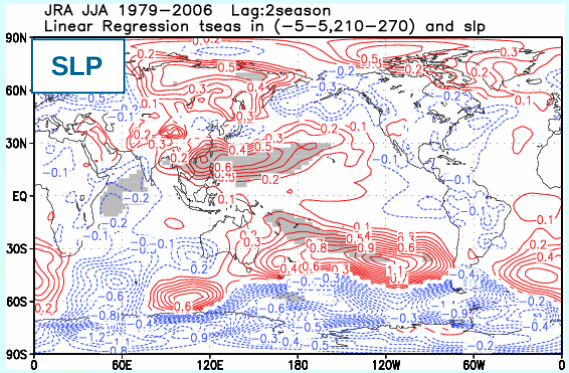
Thank you for your attention!

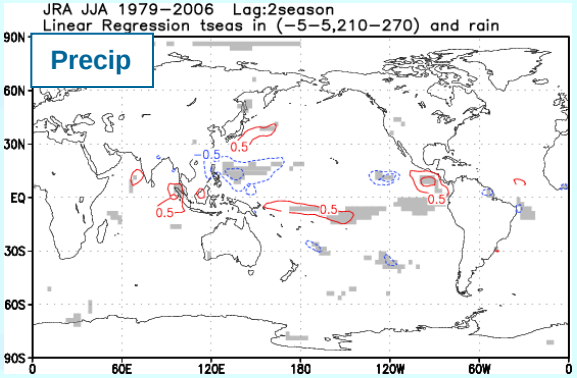


6-month lagged regression coefficients between winter NINO3.4 and succeeding summer SST, SLP and Precipitation

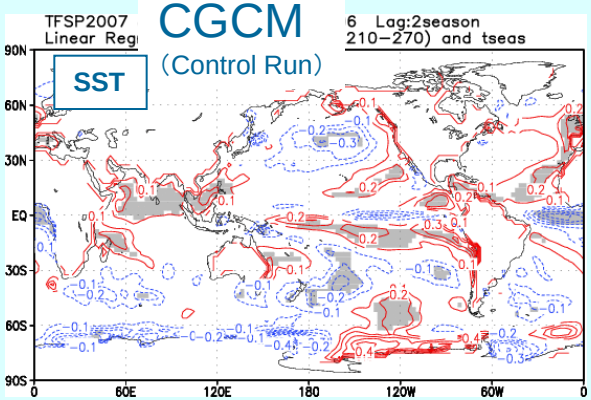
Analysis

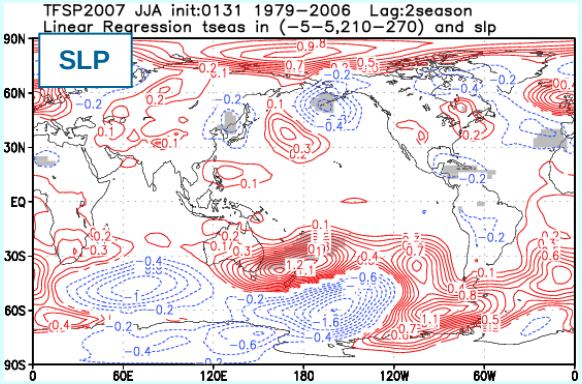


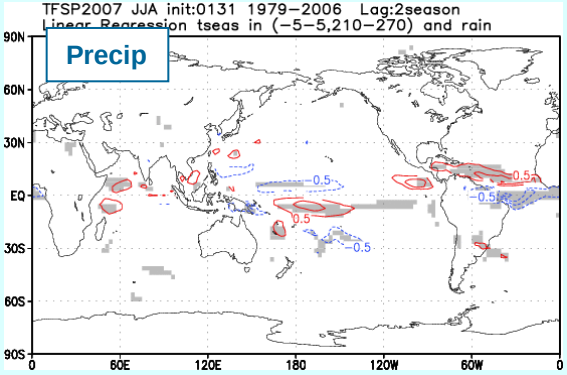




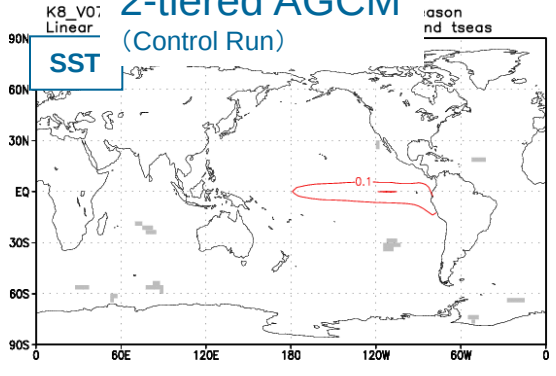
CGCM (Control Run)

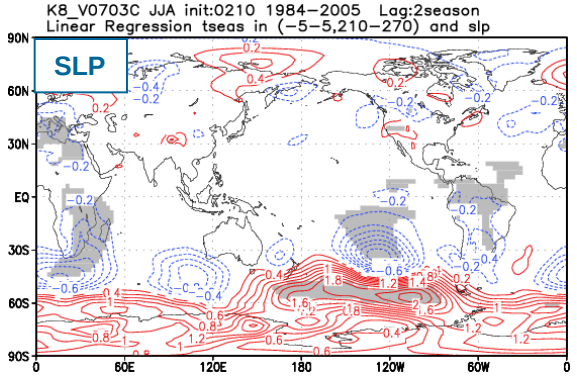


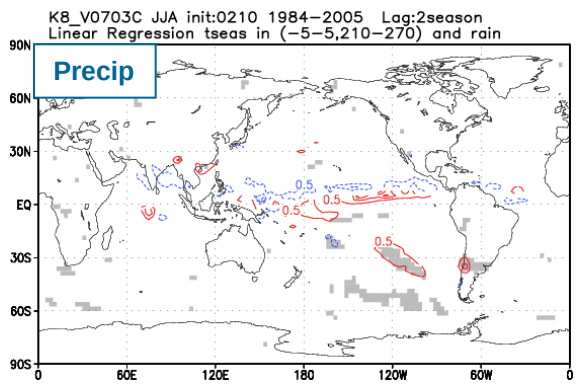




2-tiered AGCM (Control Run)

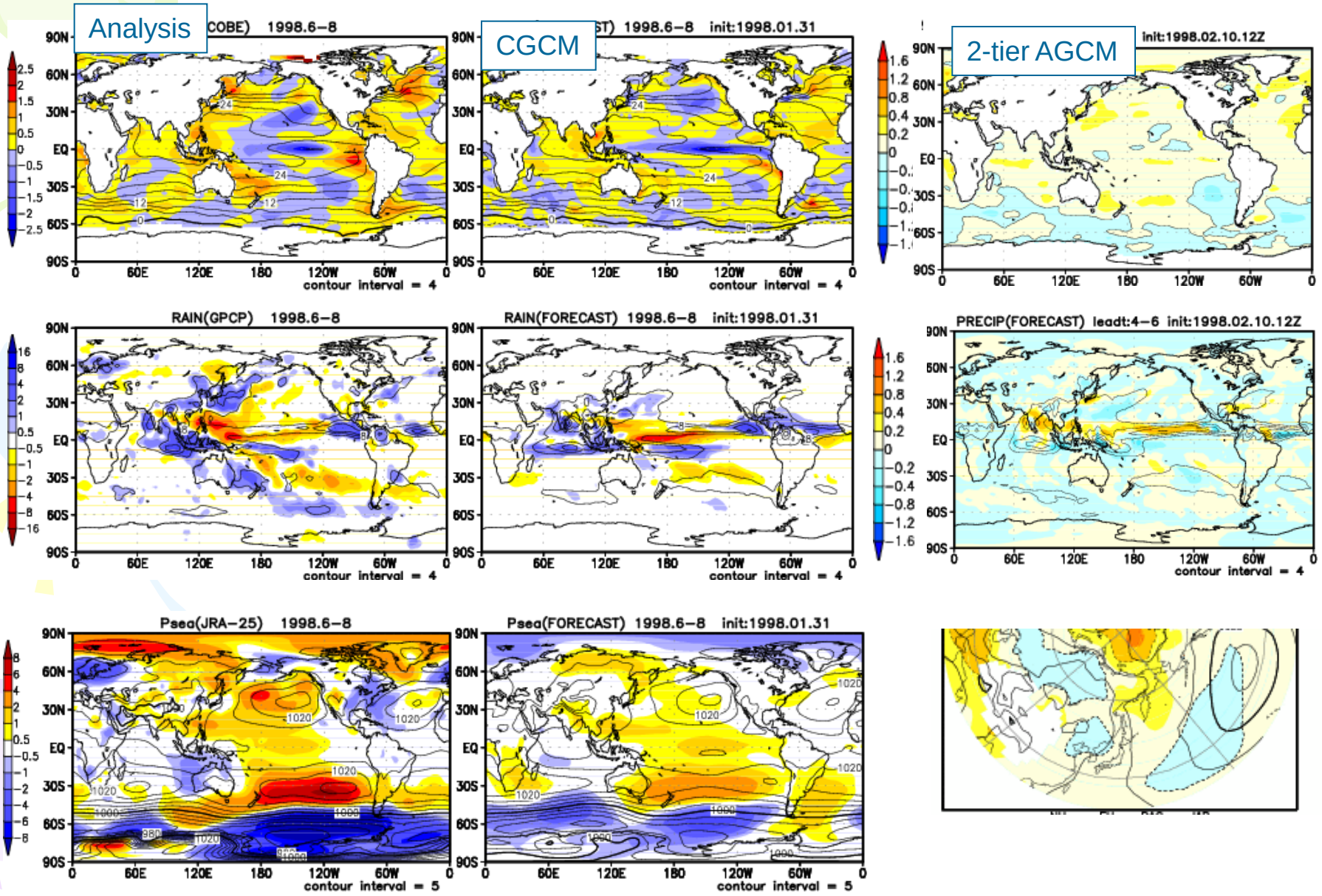






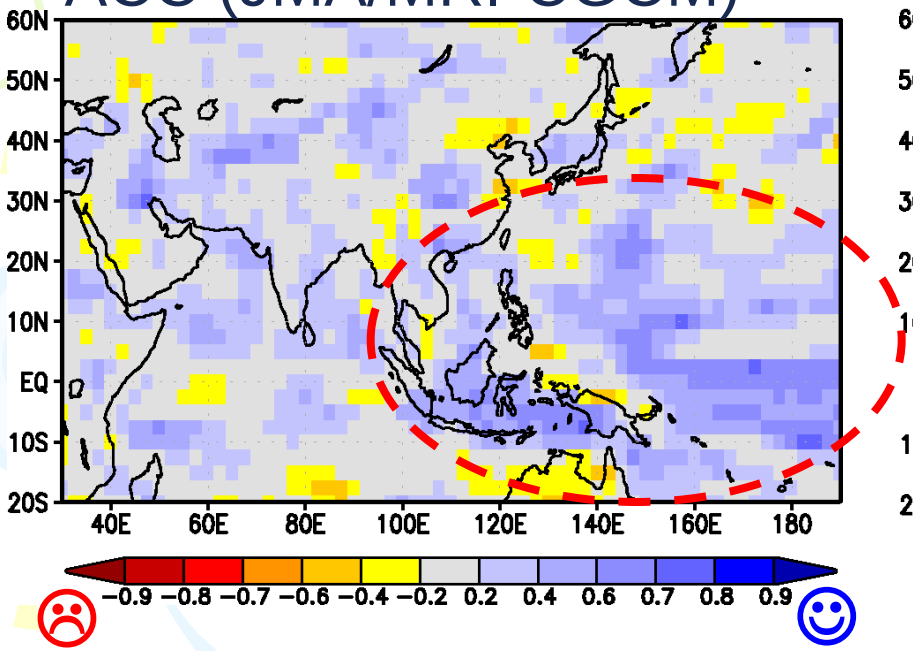
Blue contours : negative **Red contours : positive** **Shades : Regression coefficients are significant at stud5% level**

Forecast for 1998 summer

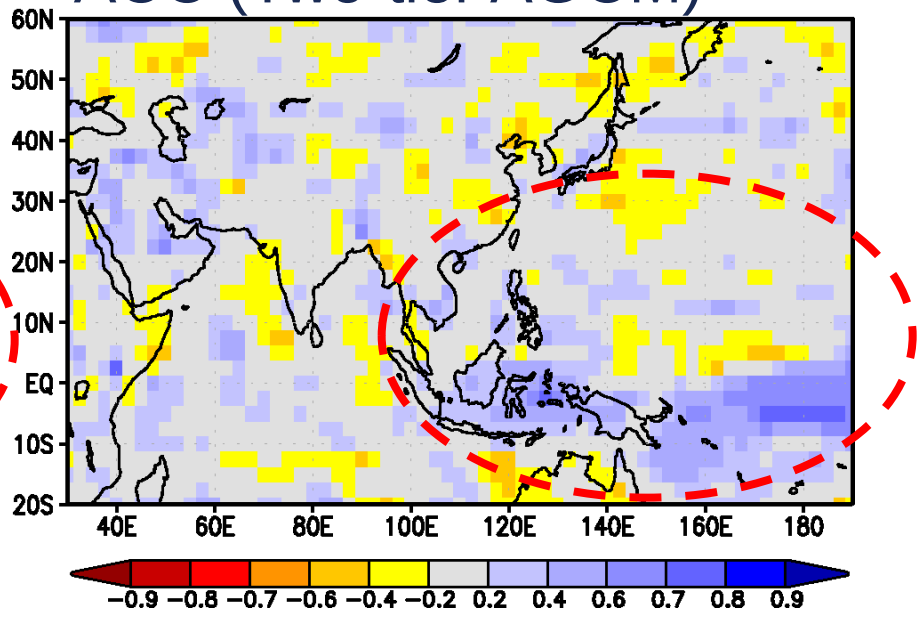


Forecast Skill of Precipitation (JJA, 4 months lead)

ACC (JMA/MRI-CGCM)



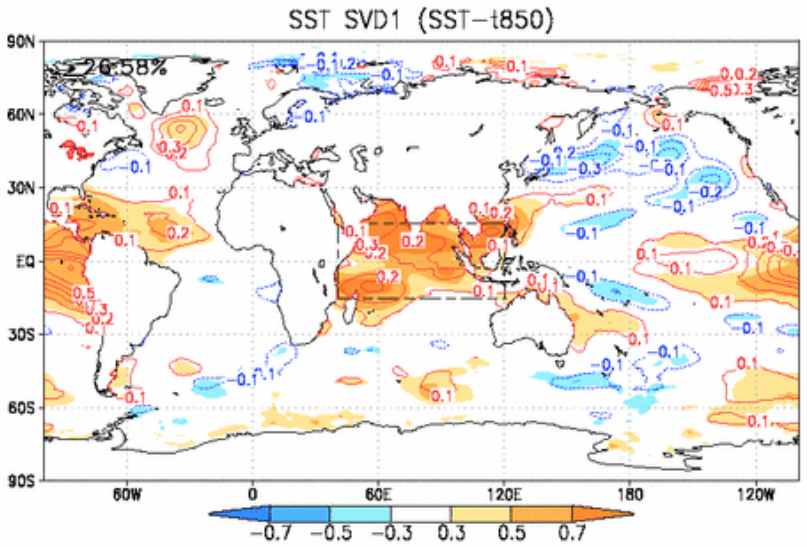
ACC (Two-tier AGCM)

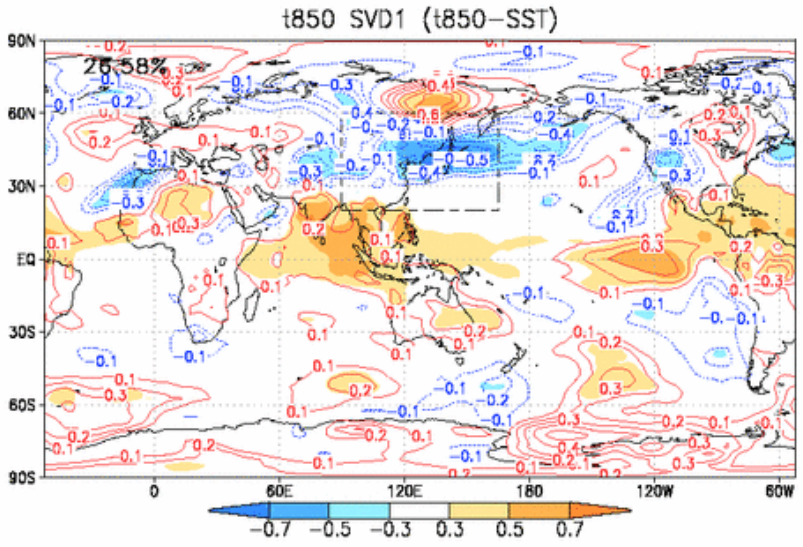


- 10-member ensemble forecast started from around the end of January.
- Period of the retrospective forecast is 22 years (1984-2005).
- JJA mean precipitation is verified with CMAP analysis.

The JMA/MRI-CGCM shows better skill than JMA's two-tier operational model.

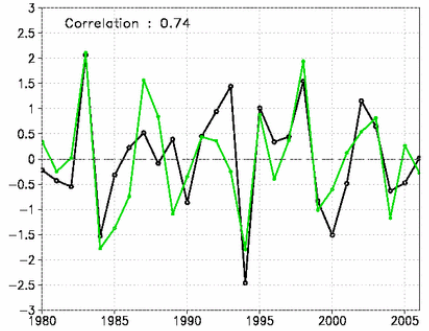
Singular Value Decomposition analysis between the Indian Ocean SSTs and 850hPa temperatures in the East Asia (JJA)





Interannual linear trend components are removed before SVD analysis

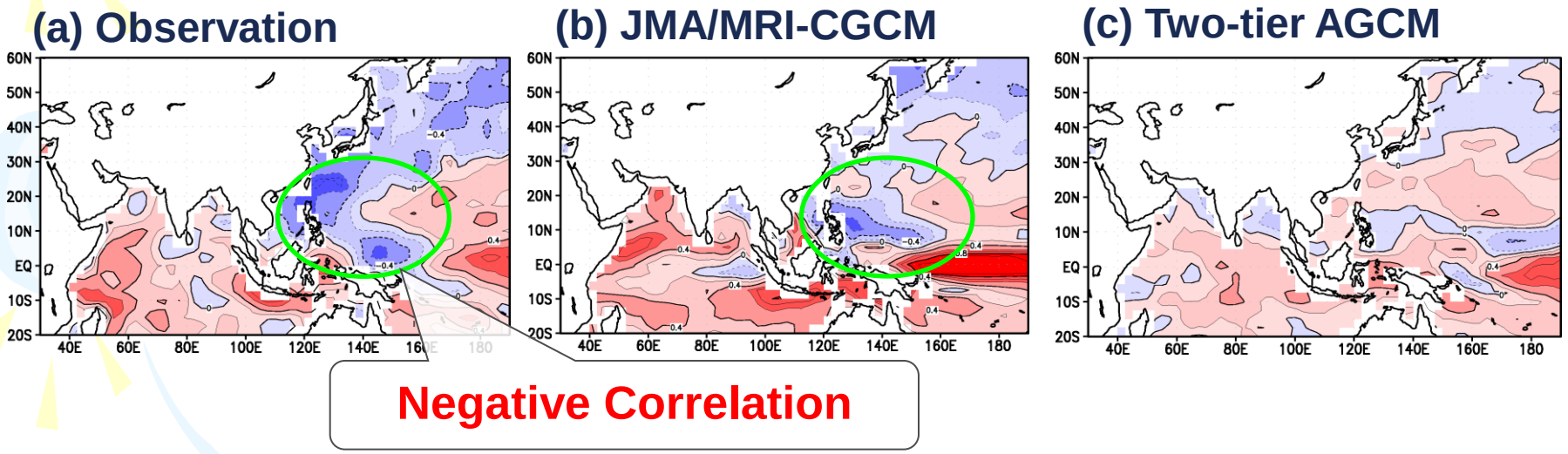
Upper Left : SST SVD1
Upper Right : T850 SVD1
Bottom Right : SVD1 time series
(green : SST, black : T850)



High Indian Ocean SST & Low temperature in the East Asia

SST-Precipitation Relationship in WTP in Boreal Summer

- Why CGCMs can predict precipitation better than AGCMs ?

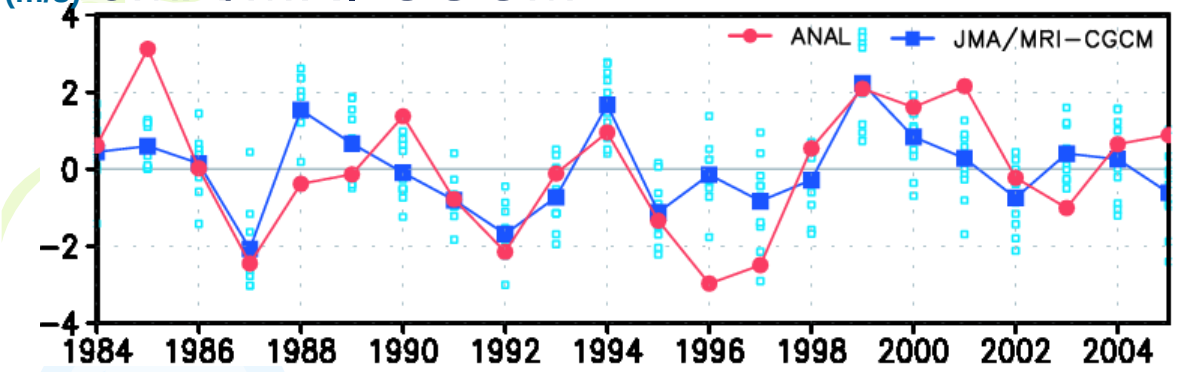


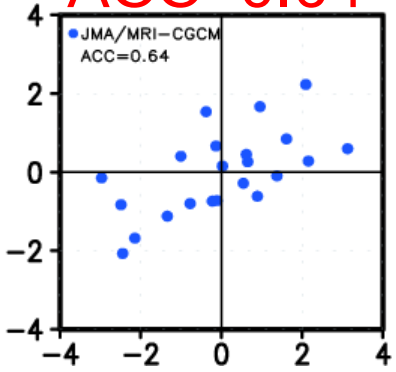
Temporal correlation coefficients between JJA mean precipitation and JJA mean SST from (a) CMAP and COBE-SST analysis, (b)JMA/MRI-CGCM, (c)JMA two-tier operational model.

eg. Wang *et al*. 2004, Wang *et al*. 2005,
Kitoh and Arakawa 1999, Kobayashi *et al*. 2005

Forecast Skill of Webster-Yang Index (JJA, 4-6months lead)

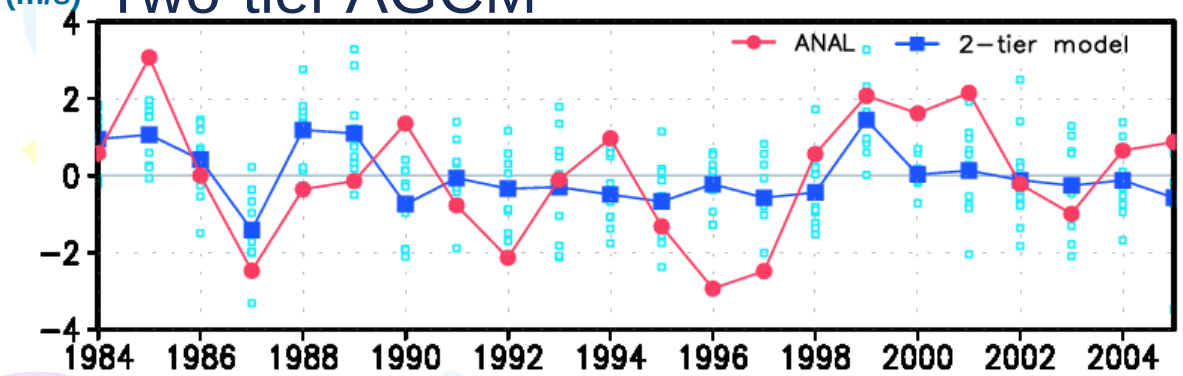
JMA/MRI-CGCM

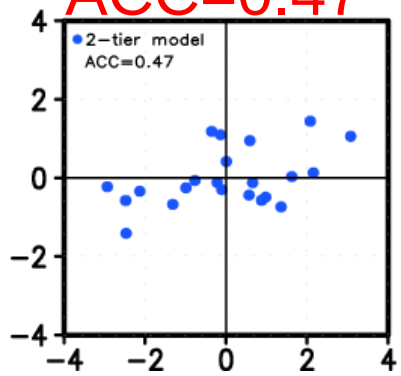




10-member ensemble
Init: the end of Jan.
Period:1984-2005
Ref. : JRA-25
JJA mean

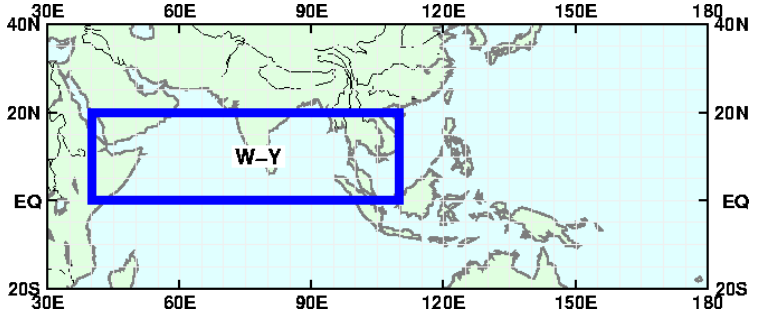
Two-tier AGCM





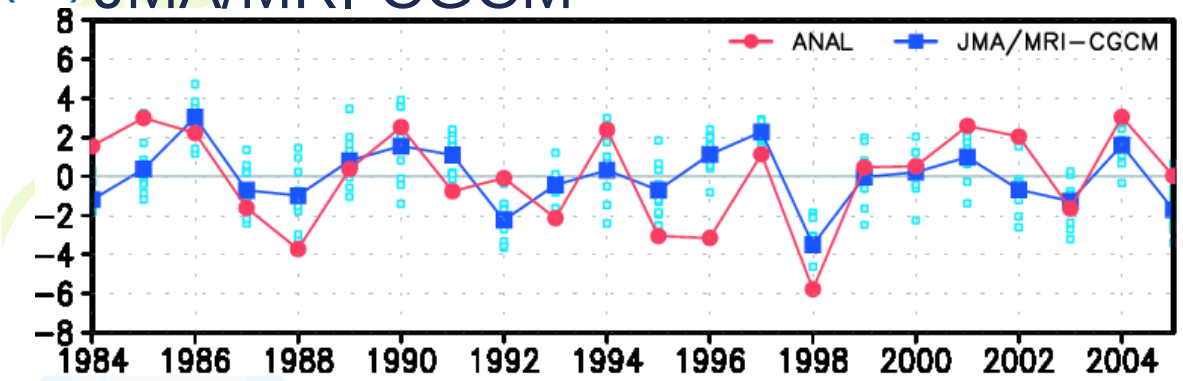
Webster-Yang index:
U850(EQ-20N, 40-110E) –
U200(EQ-20N, 40-110E)

Webster and Yang (1992)

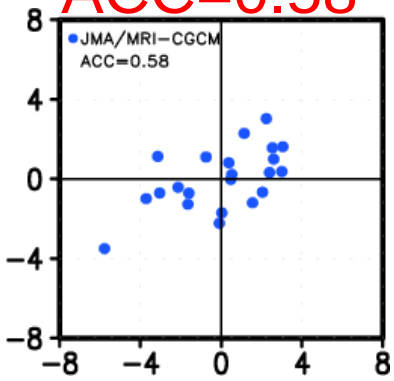


Forecast Skill of East Asian Summer Monsoon (JJA, 4-6 months lead)

(m/s) JMA/MRI-CGCM

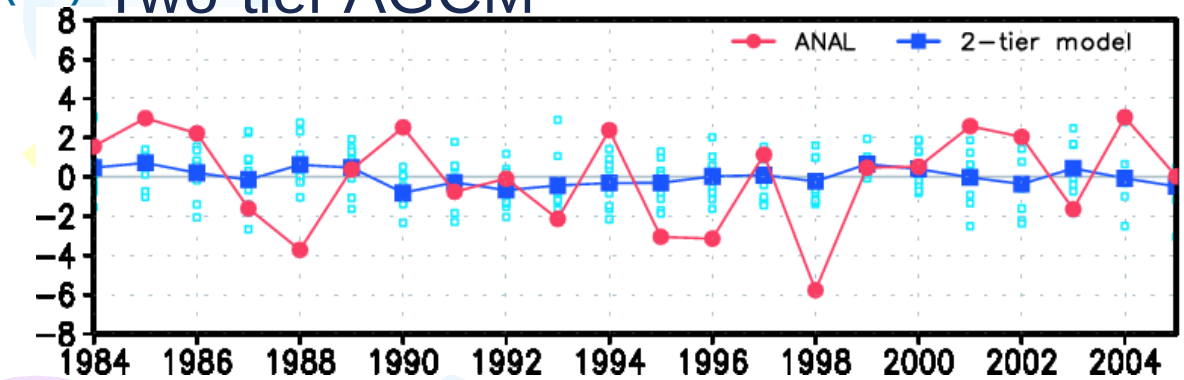


ACC=0.58

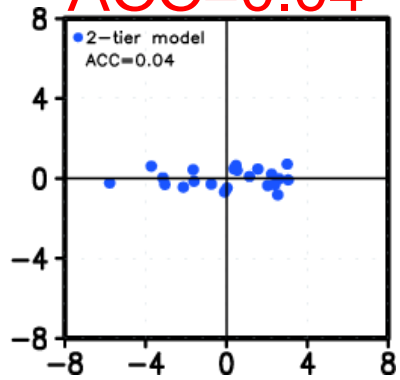


10-member ensemble
Init: the end of Jan.
Period:1984-2005
Ref. : JRA-25
JJA mean

(m/s) Two-tier AGCM



ACC=0.04

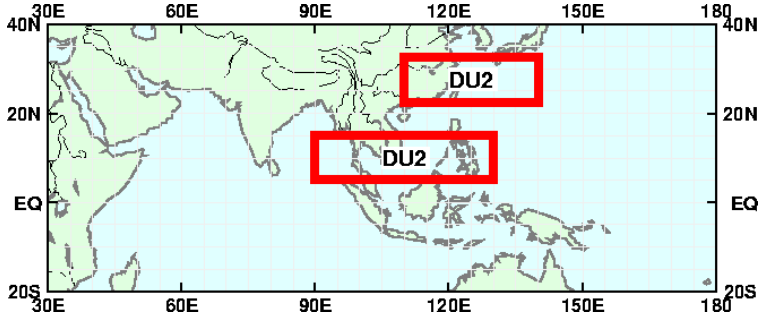


cf. Kug *et al.* (2007)

DU2 index:

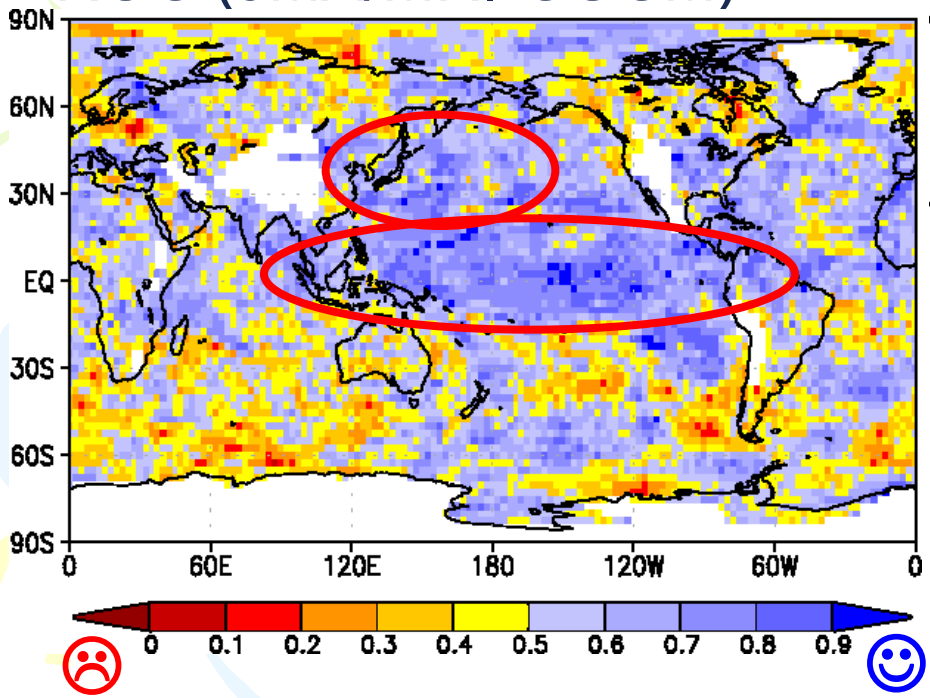
U850(5-15N, 90-130E) -
U850(22.5-32.5N, 110-140E)

Wang and Fan (1999)



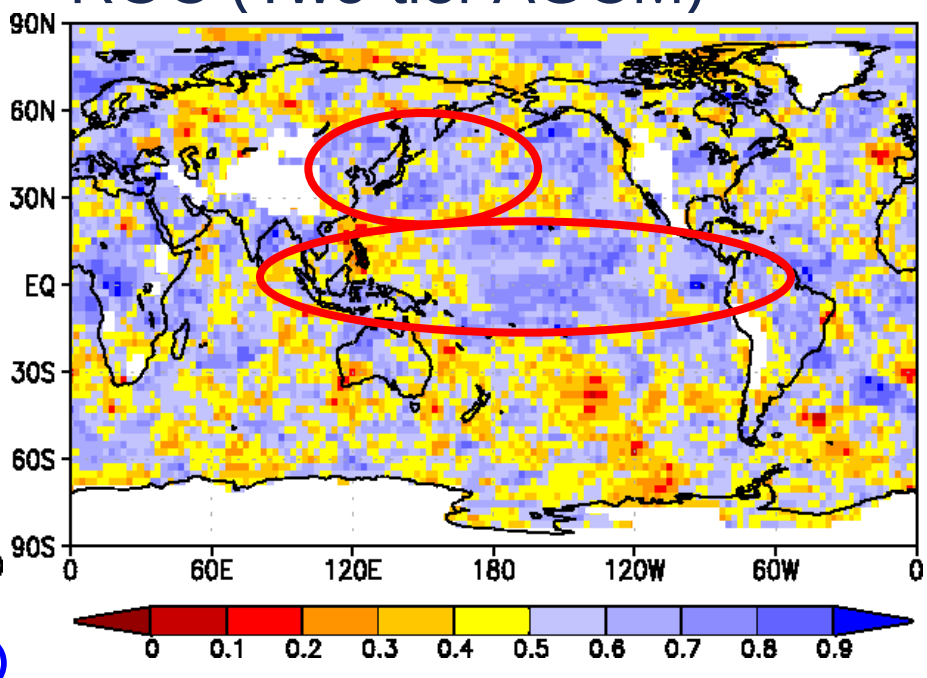
ROC Score of 850 hPa Temperature (upper tercile, JJA, 4 months lead)

ROC (JMA/MRI-CGCM)



ROC Area (tropics) : 0.65

ROC (Two-tier AGCM)



ROC Area (tropics) : 0.59

- 10-member ensemble forecast started from around the end of January.
- Period of the retrospective forecast is 22 years (1984-2005).
- JJA mean temperature at 850 hPa is verified with JRA-25.

cf. Graham *et al.* (2005)