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
In 1999, JMA introduced the atmosphere-ocean coupled 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

<table>
<thead>
<tr>
<th>AGCM</th>
<th>JMA/MRI Unified AGCM</th>
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<tbody>
<tr>
<td></td>
<td>• T₉₅L₄₀ (horizontal resol. ~ 180km)</td>
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<tr>
<th>OGCM</th>
<th>MRI.COM</th>
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<tbody>
<tr>
<td></td>
<td>Ishikawa et al. (2005)</td>
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<tr>
<td></td>
<td>• 75S-75N, 0-360E</td>
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<td></td>
<td>• horizontal resolution: lon 1.0°, lat 0.3-1.0°</td>
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<td>• vertical resolution: 50 levels (23 levels in the upper 200m)</td>
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<tr>
<th>Coupler</th>
<th>flux adjustment for heat and momentum flux</th>
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<td>• coupling interval : 1 hour</td>
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| Perturbation method       | Lagged Average Forecast (LAF) method (10 members) |

## 2-tiered AGCM

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| SST                       | Combination of Persisted anomaly + Predicted anomaly + Long-term trend |

| Perturbation method       | Singular Vector (SV) method (11 members) |
CGCM hindcast experiments are started from the end of January.
Experiments for 2-tier AGCM are started from Feb. 10th.
Period of the retrospective forecast is 22 years (1984-2005).
CO₂ 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)

- 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.

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

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
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.
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)

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)

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.

Xie et al. (2009) Fig. 12
A: Precipitation forecast skill

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

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 observed 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)

ACC > 0.43 is statistically significant at 5% level.

2-tier AGCM (ACC)

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.
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.

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

Xie et al. (2009)
Forecast skill of Tropospheric temperature

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.

(Xie et al. 2009)
**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

Blue contours: negative  Red contours: positive  Shades: Regression coefficients are significant at study 5% level.
Forecast for 1998 summer

Analysis

CGCM

2-tier AGCM
Forecast Skill of Precipitation (JJA, 4 months lead)

- 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
Why CGCMs can predict precipitation better than AGCMs?

(a) Observation
(b) JMA/MRI-CGCM
(c) Two-tier AGCM

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.

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

**JMA/MRI-CGCM**

ACC = 0.64

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

**Two-tier AGCM**

ACC = 0.47

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)

JMA/MRI-CGCM

ACC=0.58

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

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)

- 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.

ROC Area (tropics) : 0.65

ROC Area (tropics) : 0.59

cf. Graham et al. (2005)