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Atmospheric Response to the ENSO in a Quasi-coupled Data Assimilation System

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1. Introduction

We develop "quasi coupled data assimilation system", i.e., a data assimilation system in which ocean observation data is assimilated to a coupled model (atmospheric observation data is not applied). The system is called MOVE-C here. We conduct a reanalysis experiment using this system and examine what is improved compared to the AMIP Run, a simulation run of the atmosphere model adopted in MOVE-C using the observed daily SST (COBE-SST) as the ocean boundary condition. Then, we found that the precipitation field around the equator in the MOVE-C reanalysis is improved over the AMIP Run (Fujii et al. 2009). In this poster, we introduce the improvement of the atmospheric response to the ENSO in the MOVE-C Reanalysis.

2. MOVE-C System Configuration

Coupled Model : JMA/MRI-CGCM
(Used for the seasonal and ENSO forecast in JMA.)

- Atmosphere Model : JMA's Global Model
  TL95L40 (Horizontal resolution: about 180km)
- Ocean Model : MRI Community Ocean Model
  (MRI.COM ; Tsujino et al., 2011)
  Global model within 75°S-75°N
  Resolution: 1°(lon.)x0.3°(lat.) within 6°S-6°N
  1°(lon.)x1°(lat.) poleward of 15°N and 15°S
  50 vertical levels (23 levels in the upper 200m)

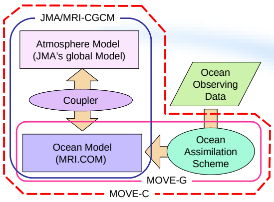


Fig. 1. Outline of MOVE-C.

Ocean Data Assimilation scheme : Multivariate 3DVAR scheme with vertical coupled T-S EOF modes. (Fujii and Kamachi, 2003)

- Analysis is implemented once a month.
- Incremental Analysis Updates (IAU) technique is used for the insertion of the analysis to the model.
- Observation data → In situ temperature and salinity measurement (ship, buoy, ARGO float)
  → altimetry data (TOPEX/Poseidon, Jason-1, ERS-1/2, ENVISAT)
  → COBE-SST (Ishii et al. 2005)
- On-line bias correction scheme is applied.
- This scheme is based on MOVE-G, that is, the global ocean data assimilation system currently used for the seasonal and ENSO forecast in JMA (Usui et al. 2006).

3. Experiment

- **MOVE-C Reanalysis** → 5-member ensemble (1979-2008)
- **AMIP Run** → 5-member ensemble (1979-2008) with daily COBE-SST.
- **CGCM free fun** → (1-member) simulation data for 60 years are adopted.

4. Reconstruction of the negative feedback between SST and precipitation

Fig. 2. Schematic figure of the negative feedback between SST and precipitation.

This feedback avoids the continuous (overestimated) precipitation over the high SST regions. It cannot be represented in the AMIP Run since the SST (that is prescribed) is not affected by precipitation. This defect is overcome in the MOVE-C Reanalysis.

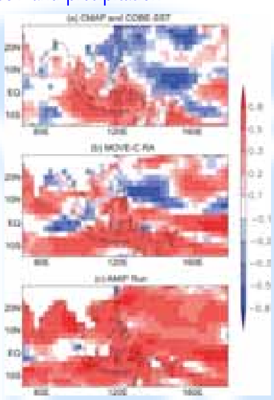


Fig. 3. Maps of the correlation coefficients between SST and precipitation in summer for (a) observation-based analysis (CMAP & COBE-SST), (b) MOVE-C Reanalysis, (c) AMIP Run.

The correlation is positive almost everywhere in the AMIP Run because the coupling between SST and precipitation is too strong. The negative feedback moderates the coupling in the MOVE-C reanalysis.

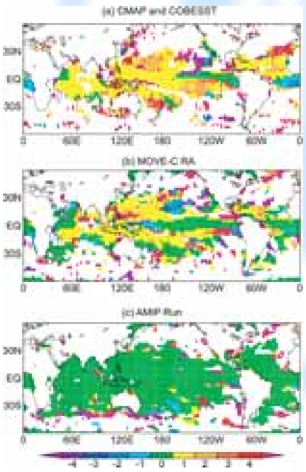


Fig. 4. Maps of time lag (month) which maximizes the correlation coefficients between monthly SST and precipitation (positive values denote precipitation lags SST). (a) CMAP & COBE-SST. (b) MOVE-C Reanalysis. (c) AMIP Run.

In the real world, the precipitation change lags about a month. However, SST and precipitation are correlated with no lag in the AMIP Run because the negative feedback does not work. This problem is suppressed in the MOVE-C reanalysis.

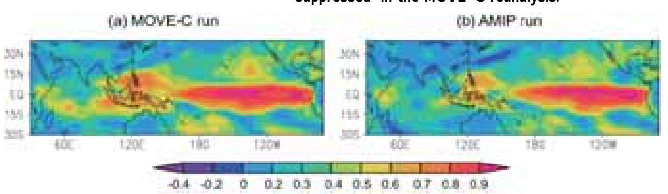


Fig. 5. Anomaly Correlation Coefficients (ACC) maps for the Outgoing Longwave Radiation (OLR) between the observation-based analysis (NOAA-OLR) and (a) MOVE-C reanalysis, (b) AMIP Run.

The variability of precipitation in MOVE-C reanalysis is improved around the western tropical Pacific, Philippine Sea, maritime continent, and Indian Ocean.

5. Improvement of the atmospheric response to the ENSO

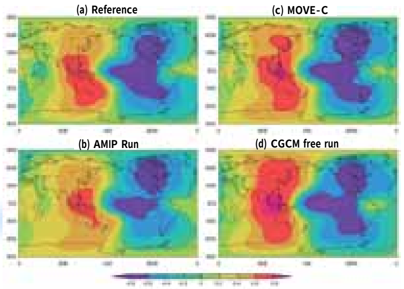


Fig. 6. Maps of the simultaneous correlation coefficient of the anomaly of Velocity Potential at 200hPa (VP200) from its monthly climatology with the NINO3 index in (a) atmospheric reanalysis (JRA-25), (b) AMIP run, (c) MOVE-C reanalysis, (d) CGCM free run. The correlation coefficients averaged for ensemble members are adopted for the MOVE-C and AMIP runs.

The response to the ENSO is underestimated because of the lack of the negative feedback in the AMIP Run. Precipitation (a drought) tends to decrease (increase) SST in the real world. However, precipitation is likely to be underestimated (overestimated) if the decreased (increased) SST is given as the oceanic boundary condition in the AMIP run. Thus, the atmospheric response is underestimated. This problem is improved in the MOVE-C reanalysis.

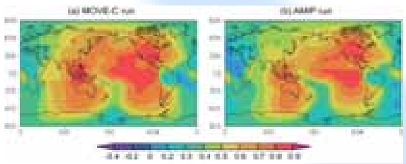


Fig. 7. Maps of ACC for VP200 between JRA-25 and (a) MOVE-C reanalysis, (b) AMIP Run.

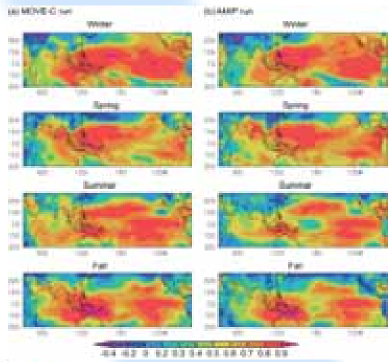


Fig. 8. ACC maps of ensemble mean Sea Level Pressure (SLP) with the reference data in (a) MOVE-C reanalysis, (b) AMIP Run for boreal winter, spring, summer, and fall. ACCs are calculated from the seasonal anomalies (deviation of the seasonal mean from the seasonal climatology).

The ACCs are generally increased in the Indian Ocean and central tropical Pacific in the MOVE-C reanalysis. The ACCs over the Philippine Sea exceed 0.8 and are much higher than those in the AMIP run in summer.

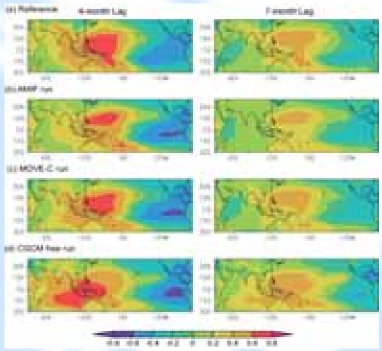
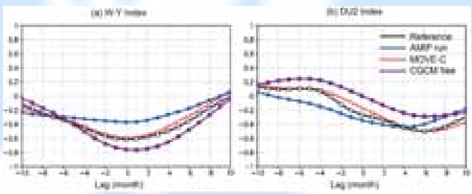
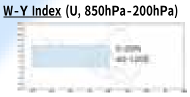


Fig. 9. Maps of the 3-month and 7-month lagged correlation coefficients of the anomaly of SLP from its monthly climatology with the NINO3 index in (a) JRA25, (b) AMIP run, (c) MOVE-C reanalysis, (d) CGCM Free run.

In the AMIP run, the correlation is underestimated in the Philippine Sea and eastern Indian Ocean. In particular, the negative correlation between SST and precipitation is missed in the Philippine sea in the AMIP Run (Fig. 3). The spuriously strong coupling between SST and precipitation degrades the response of the Philippine high to the ENSO. This defects is improved in MOVE-C reanalysis.



W-Y Index (U, 850hPa-200hPa)



DU2 Index (U 850hP)

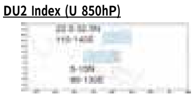


Fig. 10. Plots of the correlation coefficients of (a) W-Y index, (b) DU2 index, with the NINO3 index against the lag (month) of the W-Y or DU2 indices for reference data (black), AMIP run (Blue), MOVE-C run (Red), and CGCM Free run (purple). The correlation coefficients averaged for ensemble members are adopted for the MOVE-C and AMIP runs.

6. Conclusion

MOVE-C improves responses of the atmospheric circulation, including the Walker Circulation and the circulation associated with the monsoon trough, over the AMIP run, resulting in the better SLP and upper-tropospheric velocity potential field. This improvement stems from the recovering of the negative feedback between SST and precipitation in MOVE-C. The feedback adjusts the response of precipitation on the oceanic SST fields in the adequate level. Calculating the coupled air-sea process explicitly through a CGCM (which is not possible with an AGCM alone), thus, mitigates the inconsistency between the ocean and atmosphere, and improve the representation of the climate variability, including the ENSO response of the atmosphere. This result demonstrates a benefit of assimilating observation data directly into a CGCM in a coupled data assimilation system.

7. References

Fujii et al. 2009: *J. Climate*, **22**(20), 5541-5557.
Fujii et al. 2011: In *Climate Variability* (ISBN:979-953-307-236-3), INTECH, Croatia (in press).