Research Development of 4-Dimensional Data Assimilation System Using a Coupled Climate Model and Construction of Reanalysis Datasets for Initialization

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We have developed the 4-dimensional data assimilation system using a coupled climate model. We use the CFES (The Coupled model for the Earth Simulator) as a coupled model platform. We added many modifications and tunings to the CFES to improve its physical performance. The climate and its variability reproduced by the CFES are reasonable and very good. We have developed the adjoint code for the atmospheric dynamic component. The system successfully assimilates real observational data and improves the model climate. We have also constructed the oceanic assimilation system and used to produce global ocean state during 1996–2002. We have combined all these components and started the coupled data assimilation.

Keywords: Data Assimilation, Coupled Model, Climate Variability, 4D-VAR, El Niño

1. Introductio

Our research goal is to provide integrated climatological reanalysis datasets to science community. For this purpose, we are constructing the 4-dimensional variational data assimilation system (4D-VAR) on the coupled atmosphere-ocean-sea ice model. This year, we (1) improved the coupled model, (2) completed the assimilation system of each model components, and (3) started experiments by the coupled data assimilation.

2. CFES as a platform for coupled assimilation system

We use the Coupled Atmosphere-Ocean-Sea Ice model for the Earth Simulator (CFES) as a platform for coupled assimilation system. The atmospheric component (AFES) is based on the CCSR/NIES model. The ocean plus the ice component (OIFES) is from the GFDL/MOM3 and the IARC Ice model. We also integrated the land parameterization scheme MATSIRO (Minimal Advanced Treatments of Surface Interaction and Runoff) into the CFES instead of the current one layer model so called "bucket model".

We added many modifications and tunings to the CFES to improve its physical performance. One example of such tunings is shown in Fig 1. It is well known that in many coupled models the precipitation over the tropical Pacific Ocean is too symmetric about the equator (so called "Double ITCZ") as is shown in Fig 1 (a). Our tuning to the cloud parameters, however, lessened the Double ITCZ structure (Fig 1 (b)).

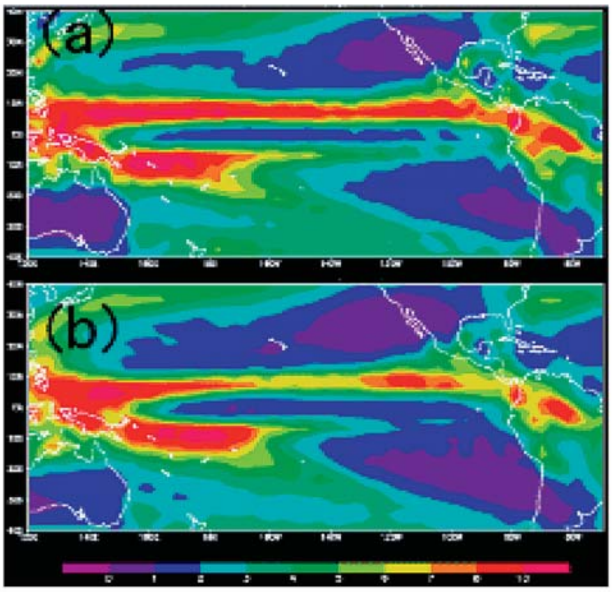

Fig. 1 Precipitation over tropical Pacific Ocean from the CFES. (a) Before tuning. (b) After Tuning.

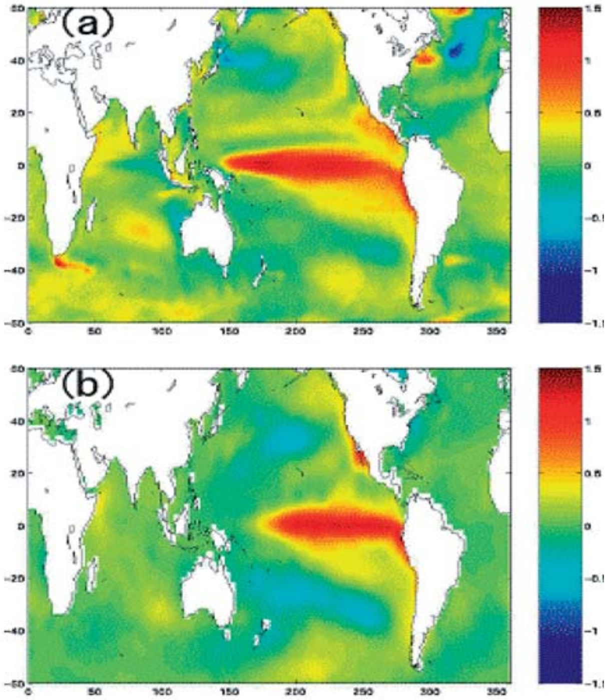

Fig. 2 Liner regression of SSTs at each grid box against Nino 3.4 SST anomalies. (a) From CFES. (b) From the observation (ERSST).

After tunings, the CFES reproduces important climatological phenomena reasonably well. This is the good base for further perfection of the datasets by the assimilation system. Figure 2 confirms that the interannual variation pattern of the sea surface temperature (SST) of the CFES is close to the one of observation.

3. Assimilation of the atmospheric component

We have developed an adjoint code for the atmospheric component with the use of an automatic differentiation tool TAF. Figure 3 shows the assimilation results of the atmospheric model to the SSM/I observed wind speed. The difference of the observed 10 m wind speed between the simulation and the observation (Figure 3(a)) decreased well after the assimilation to the 1-month averaged data (Figure 3(b)). This figure demonstrates that the assimilation to the climatological (beyond weather) data is possible by our system.

4. Assimilation of the oceanic component

We have constructed the oceanic component of the assimilation system. Using this system, a data assimilation experiment is performed to define a global ocean state during 1996–2002. The assimilated elements in this experiment are water temperature, salinity data, and sea surface height anomaly data. The ARGO float data, which can provide higher quality subsurface information covering the entire ocean, is also used for recent years. Horizontal resolution of the ocean model is 1 degree in both latitude and longitude, with 36 vertical levels. This model is better able to reproduce ocean circulation and is expected to form a platform

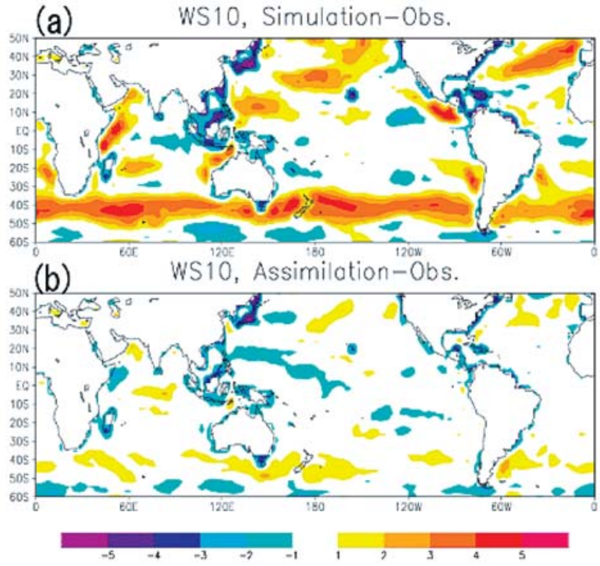

Fig. 3 The difference of the 10 m wind speed. (a) Between the simulation and the observation. (b) Between the assimilation and the observation.

suitable for the use of the 4D-VAR adjoint model. The obtained reanalysis dataset shows good consistency with previous knowledge of important climate events. For example, the root mean square difference value between the observed time-evolution of Niňo3 SST and the assimilated one is 0.69 K during 1996–1998, while for the simulated case the difference is 1.60 K (Fig. 4). This much improved reproduction of the evolution of Niňo3 SST gives us confidence in the validity of our dataset as representing the climate variability in this region. Further, our dataset exhibits realistic subsurface water mass distribution and enables us to clarify the water mass formation and movement processes. The North Pacific Intermediate Water, which is characterized by a subsurface salinity minimum, is also successfully reproduced. This good correspondence is the result of both realistic subsurface flow patterns and surface processes in our reanalysis data. These results illustrate that the ocean state derived from our data assimilation has greater information content and that the forecast potential for climate variability is greater than that due either to the models or the data alone.

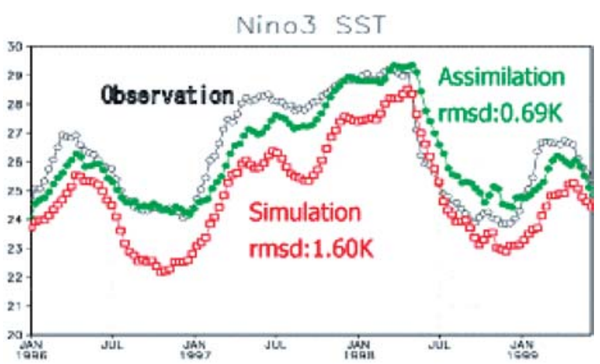

Fig. 4 Time change of the NINO3 SST. Result from observation (black), simulation (red), and assimilation (green).

In addition, we have investigated the impacts of the subsurface observational data (ARGO) to reveal that they are striking particularly in the North Atlantic region (and the Bering Sea) in this assimilation experiment (Fig. 5). This result is reasonable and implies that the ARGO buoy is promising tool.

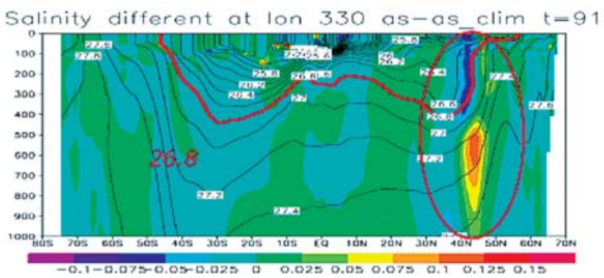

Fig. 5 Impact of interannual subsurface observations (vertical section 30W). Color shade denotes salinity difference between the results of assimilation experiment with and without subsuraface data

5. Coupled Assimilation

We have started the experiments of the assimilation on the coupled model. Our preliminary result shows that the cost function to the observational data successfully decreases by controlling the bulk coefficient for the air-sea fluxes.

6. Concluding remarks

We have developed each component of a coupled data assimilation system. We use the Coupled model for the Earth Simulator as the coupled data assimilation platform. After improvements and tunings, the CFES reproduces the global climate and its variability very well. We have developed the assimilation systems of an atmospheric and an oceanic component. Both components show capability of improving simulation results by assimilating observational data. We have combined all these components and started the coupled data assimilation.

Acknowledgments

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