Process Studies and Seasonal Prediction Experiment using Coupled General Circulation Model

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The SINTEX-Frontier ocean-atmosphere coupled GCM is developed under the EU-Japan collaborative framework to study the global climate variability together with its predictability. The SINTEX-F model has been used in the real-time predictions of seasonal to interannual climate variations. In addition, the model simulation and sensitivity experiment results are used in climate process studies. After successfully predicting the previous IOD and El Niño events, SINTEX-F1 has realistically predicted the La Niña of 2010 from the middle of 2009. The model is consistent in its predictions of IOD and ENSO events to maintain its leading position in the world. Besides the tropical Indian and Pacific Ocean conditions, the model could predict the teleconnections to many parts of the world. For example, the model has correctly predicted higher than normal rainfall for Australia and South Africa. Both countries suffered from severe floods during austral summer of 2010-11.

The model simulation and sensitivity experiment results were used in several studies to understand the mechanism of several climate processes. Air-sea interactions in the tropical Indian Ocean are seen to influence the intra-seasonal variations in the tropical Indian Ocean. Subtropical dipole modes of the Indian and Atlantic Oceans are well simulated by the SINTEX-F model. The model results revealed close relationship between the ocean mixed-layer and the atmosphere in the initiation of the subtropical dipole modes. The model results also revealed shift in the breeding grounds of the tropical cyclones.

Keywords: SINTEX-F, IOD, ENSO, Prediction, 2010 La Niña event

1. INTRODUCTION

The SINTEX-F1 coupled general circulation model (CGCM) has emerged as a leading CGCM in the world for the real-time predictions of seasonal to interannual climate variations. The model has successfully predicted all past ENSO and IOD events in addition to the ENSO Modoki (Luo et al. 2010), which is recently identified as one of the leading modes of variability in the tropical Pacific. In addition to the good predictions at long lead times, the realistic simulation results of SINTEX-F1 are helpful in understanding the processes associated with climate phenomena. Besides the predictions of seasonal climate variations in the tropical regions, the model is successfully used in the understanding of teleconnetion and other climate processes in higher latitudes.

The sparse observations in space and time over most parts of the world oceans limit the scope of any scientific analysis in fine-scale climate processes. The realistic simulations of the SINTEX-F have helped us to overcome these limitations. A high-resolution version of the model, called as the SINTEX-F2, is under development for resolving the fine-scale climate processes. After fine-tuning and initial validation processes, this new model will be used in the process and predictability studies. The initial results from the preliminary version of the model have shown promises in resolving tropical cyclone and other fine-scale processes.

2. CLIMATE PREDICTIONS

The real time climate forecasts for 12-24 lead months are continuously performed and updated every month. After successfully predicting the 2009 El Niño event, the SINTEX-F has predicted a strong La Niña event in 2010. Toward the end of summer 2009, the model initiated from August conditions (Fig. 1), which is a several months before the peak phase of the 2009 El Niño event, correctly predicted the quick turn-around of the ENSO event as was actually observed later in early 2010. The model not only predicted the phase change but also the intensity of the La Niña accurately. Those predictions were much better compared with other existing real time forecast systems. Because of this, the 2010 La Niña predictions by SINTEX-F were widely reported in various newspapers and media reports in Japan, Australia, South Africa, India and several other Southeast Asian countries. In addition, the forecast results are distributed to many research scientists and operational forecast centers (e.g. IRI, APCC, CLIVAR, IIT) and made available to general public on the JAMSTEC website.

The role of global surface temperature rise on the seasonal-to-interannual climate predictability is investigated using SINTEX-F coupled GCM (Luo et al. 2011). Based on the experiment in which only observed sea surface temperature (SST) is assimilated for coupled model initialization, it is found that the historical rise in SST plays a key role in driving the intensified terrestrial warming over the globe. The SST trend, while is negligible for short-lead predictions, has shown substantial impact on the climate predictability at long-lead times (>1 year) particularly in the extratropics. It is also found that the global surface air temperature and precipitation could be predicted beyond 2 years in advance with anomaly correlation skill of above ~0.6 with a perfect warming trend and/or a perfect model.

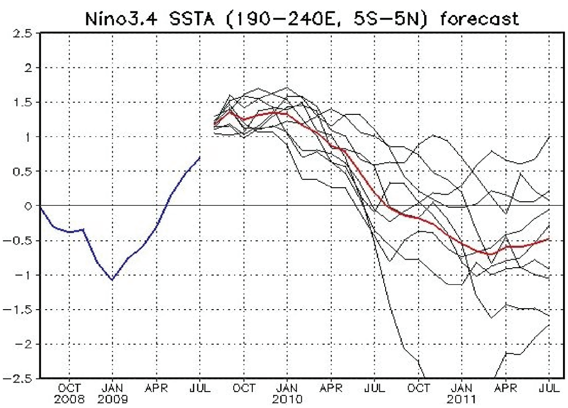

Fig. 1 SINTEX-F prediction of El Niño transition to La Niña condition in 2010 from the initial conditions of August 2010. Blue line represents observed Niño3.4 index until the time of prediction and red line represents the ensemble mean prediction based on SINTEX-F1 individual predictions (black lines).

3. PROCESS STUDIES

Model biases are investigated with an intercomparison of SINTEX-F with CFES (CGCM for the Earth Simulator) model under the collaboration with scientists in the Earth Simulator Center. Interannual variability in the tropical and South Atlantic is found to be resolved better in the CFES coupled GCM as compared to SINTEX-F. Based on the CFES results and observations, it was found that the local along-shore wind anomalies play a vital role in the generation of Benguela Niños (Richter et al. 2010). These wind anomalies are also linked to large-scale fluctuations of the subtropical anticyclone.

SINTEX-F model simulated results are also used in the process studies of subtropical dipole modes of the southern Atlantic and Indian Oceans. The EOF analysis of model SST anomalies showed clear patterns of subtropical dipole modes in both basins in agreement with the observed anomalies (Fig. 2). Further analyses are being conducted to understand the physical and dynamical processes associated with the initiation and termination mechanisms of the subtropical dipole modes (Morioka et al. 2011; personal communications).

In another such studies the decadal variations of the subtropical northern Pacific Ocean is investigated using the long

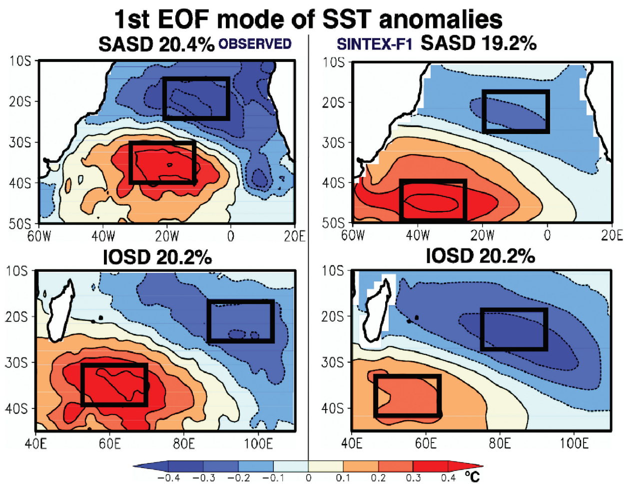

Fig. 2 Observed (left panels) and SINTEX-F simulated (right panels) subtropical dipole modes of south Atlantic and Indian Oceans.

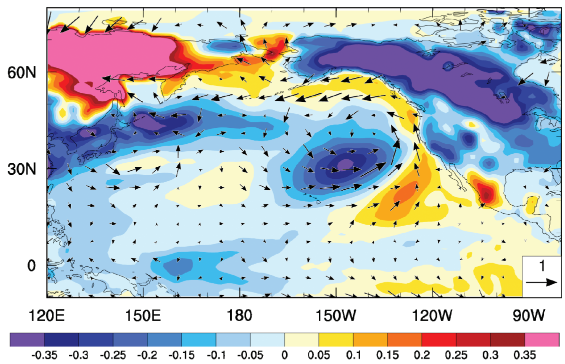

Fig. 3 Difference between yr190-250 (high Nino3 variability) and yr270-330 (low Nino3 variability) of surface temperature (shading) and wind from SINTEX-F simulations.

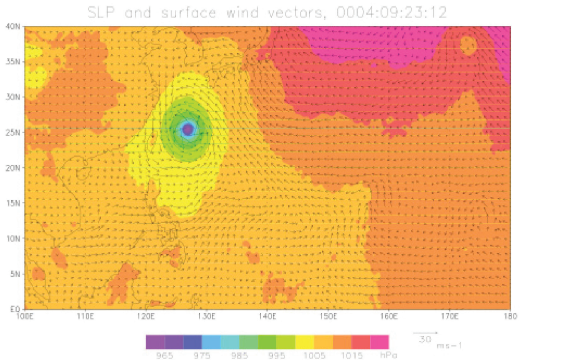

Fig. 4 Tropical cyclone simulated by a high-resolution SINTEX-F2 model with a horizontal atmospheric resolution of about 40km and ocean resolution of about 25km.

time series data obtained from the SINTEX-F simulation results. The model-simulated results were analyzed to understand the variations associated with active and inactive phases of ENSO variability on decadal time scales (Fig. 3). It is found that the ENSO variability and its decadal-scale modulation have important influences on the North Pacific SST. Those influences appear to be mediated through changes in teleconnection patterns involving the Aleutian low (Richter et al. 2011; personal communication).

Using the SINTEX-F results other studies have investigated the impact of air-sea interactions on the intra-seasonal oscillations (Lin et al. 2010), shift in the tropical cyclones owing to global warming (Li et al. 2010) and the effect of the Maritime Continent on the boreal summer intraseasonal oscillation (Zhu et al. 2010).

4. MODEL DEVELOPMENT

SINTX-F1 model was optimized to improve its computational performance and usage of CPU time on ES2. The tested version suggests a marginal improvement. However, differences in model results are noticed when results of ES2 were compared with that of ES1 from the same sets of experiments. Possible causes of these errors are being investigated. Tropical cyclones simulated by another high-resolution version of SINTEX-F (Fig. 4) are now analyzed to recognize the air-sea interactions associated with the genesis of those model-simulated cyclones. In the process of development, when ocean model resolution is increased to a quarter degree (ORCA025), it is found that model biases related to the equatorial Pacific cold tongue and northern Atlantic are reduced besides better simulations of El Niño and IOD events. Several sensitivity experiments were also carried out to understand the role of vertical mixing parameterization in the behavior of the simulated cold tongue SST.

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大気海洋結合モデルを用いたプロセス研究と季節予測実験

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気候変動ならびにその予測可能性研究のための日欧研究協力に基づき、SINTEX-Frontier 大気海洋結合大循環モデルの開発および改良を推進している。その第一版の SINTEX-F1 は、リアルタイムの季節・経年変動予測実験に長く用いられており、近年発生した IOD やエルニーニョのほとんどを現実的に予測している。特に、2010 年の夏期から発達したラニーニャ現象については、エルニーニョ現象からの移行時期や振幅も含めて、発生の 1 年前から予測することに成功しており、オーストラリアや南アフリカでの多雨傾向を的確に予測していた。これらの成果は国内外のメディア等で取り上げられると同時に、世界の気候変動予測研究を先導するモデルとして SINTEX-F の地位を確立する礎となっている。

また、SINTEX-F1 モデルは気候変動のメカニズムを解明するための感度実験などにも利用されている。特に今年度は、インド洋熱帯域での大気海洋相互作用がその海域での季節内変動に及ぼす影響や、インド洋および大西洋の亜熱帯ダイポールモード現象の再現性と南アフリカ域の気候変動に与える影響等の研究を進めた。その結果、亜熱帯ダイポールモード現象の発生には、海洋の表層混合層と大気との相互作用が重要であることや、気候変化に伴い太平洋域での熱帯低気圧の発生領域がこれまでよりも東へ移動することを示した。

キーワード : SINTEX-F, IOD, ENSO, 予測 , 2010 年ラニーニャ現象