Process Studies and Seasonal Prediction Experiment using Coupled General Circulation Model

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The SINTEX-Frontier coupled ocean-atmosphere GCM is developed under the EU-Japan collaborative framework to study the variability in global climate and its predictability. The SINTEX-F model is used to produce real-time seasonal climate forecasts in addition to long-term simulations and sensitivity experiments used in climate variation studies. SINTEX-F has successfully predicted recent Indian Ocean Dipole (IOD), El Niño-Southern Oscillation (ENSO) and ENSO Modoki events. The most recent one is the prediction of the return of a La Niña condition in the later half of 2011 after a slight warming in the eastern Pacific in the middle of the year. The model is consistent in its predictions of IOD and ENSO events to maintain its leading position for the seasonal climate predictions in the world. In addition to the tropical Indian and Pacific Ocean conditions, the model has shown excellent skills in the prediction of subtropical Indian and Atlantic Ocean dipoles. Based on the retrospective forecasts, it is demonstrated in a recent study that the subtropical Indian Ocean dipole and the southern subtropical Atlantic Ocean dipole are predictable at least a couple of seasons ahead with good accuracy.

In addition to the real-time predictions, the model is used in sensitivity experiments to understand climate processes. In one such study, using the long simulation results, it is corroborated that the ocean mixed-layer plays an important role in the formation of subtropical dipoles. The high-resolution version of the model known as the SINTEX-F2 is able to simulate the frequency and the genesis bands of tropical cyclones accurately in the global oceans.

Keywords: SINTEX-F, El Niño Modoki, La Niña, Prediction, 2011

1. INTRODUCTION

The SINTEX-F1 coupled general circulation model (CGCM) has emerged as the leading CGCM in the world to provide real-time predictions of seasonal to interannual climate variations. The model has successfully predicted all past El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events. In a recent study, it is also shown that the model is capable of predicting the ENSO Modoki, 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 climate variations in the tropical regions, the model results are useful in understanding the slow processes in higher latitudes. The high-resolution version of the model, the SINTEX-F2, is under development and the model results are expected to help in understanding of finer scale climate processes.

2. CLIMATE PREDICTIONS

The real time climate forecasts for 12-24 lead months are continuously performed and updated every month. Unlike the model predictions from several other climate centers, which predicted a return of El Niño in 2011, JAMSTEC's SINTEX-F1 model has correctly predicted the return of the La Niña (Fig. 1) after a brief period of La Niña Modoki condition in which the eastern Pacific became warmer than normal around the middle of 2011. The model has been consistent in predicting all of the recent IOD and ENSO events to become the leading prediction model in the world. Because of this, the 2011 La Niña predictions by SINTEX-F were widely reported in various newspapers in Japan, Australia, 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 through the JAMSTEC website. Some of the Australian farmers have developed best agricultural practices for their regions based on SINTEX-F1 predictions.

The seasonal to interannual predictability of subtropical dipoles in southern Indian (IOSD) and Atlantic (AOSD) Oceans are found to be very promising in the SINTEX-F1 retrospective forecasts. From a recent study (Yuan et al. 2011[14]), it is found that the subtropical dipoles in those two basins can be predicted at least a couple of seasons ahead with very high reliability. The overall prediction skills of the IOSD are found to be higher than that of the SASD and a prediction barrier is found in austral autumn for both IOSD and the SASD. Also the predictability of SST anomalies in the northeastern pole of the IOSD is higher than the southwestern pole, whereas no large difference is found in that for the two poles of the SASD. Some of the other studies evaluated the model predictability for ENSO, monsoon, intraseasonal oscillations and interactions among those climate modes (An et al. 2011[1]; Hsu et al. 2011[2]; Jeong et al. 2011[3]; Joseph et al. 2011[4]; Kulkarni et al. 2011[5]; Li et al. 2011[6]; Lin et al. 2011[7]; Luo 2011[8]; Luo et al. 2011[9]; Masson et al. 2011[10]; Terray et al. 2011[13]).

3. PROCESS STUDIES

Interannual variations of subtropical dipole modes are also investigated using SINTEX-F1 results (Morioka et al. 2011[11]). The positive (negative) SST anomaly pole starts to grow in austral spring and reaches its peak in February. From the analysis it is found that the suppressed (enhanced) latent heat flux loss associated with the variations in the subtropical high causes a thinner (thicker) than normal mixed-layer thickness,

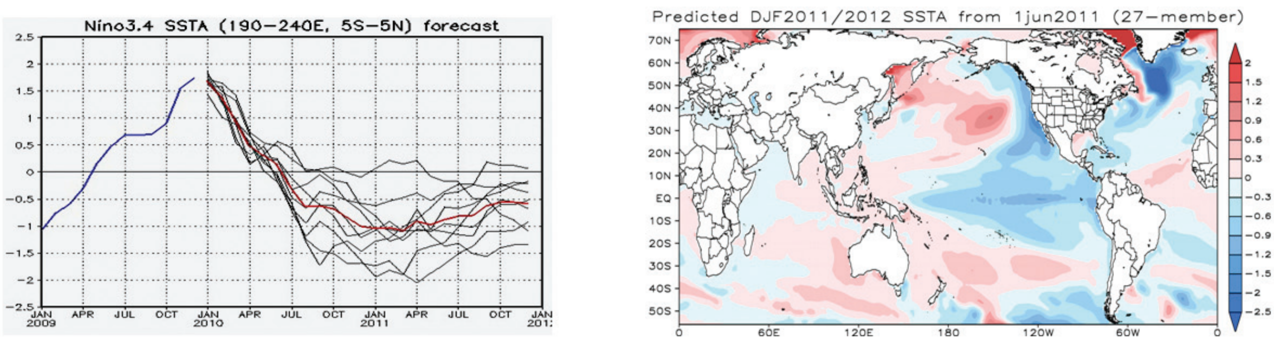

Fig. 1 SINTEX-F real-time prediction of the return of the La Niña state in winter of 2011 from 1 June 2011 initial conditions.

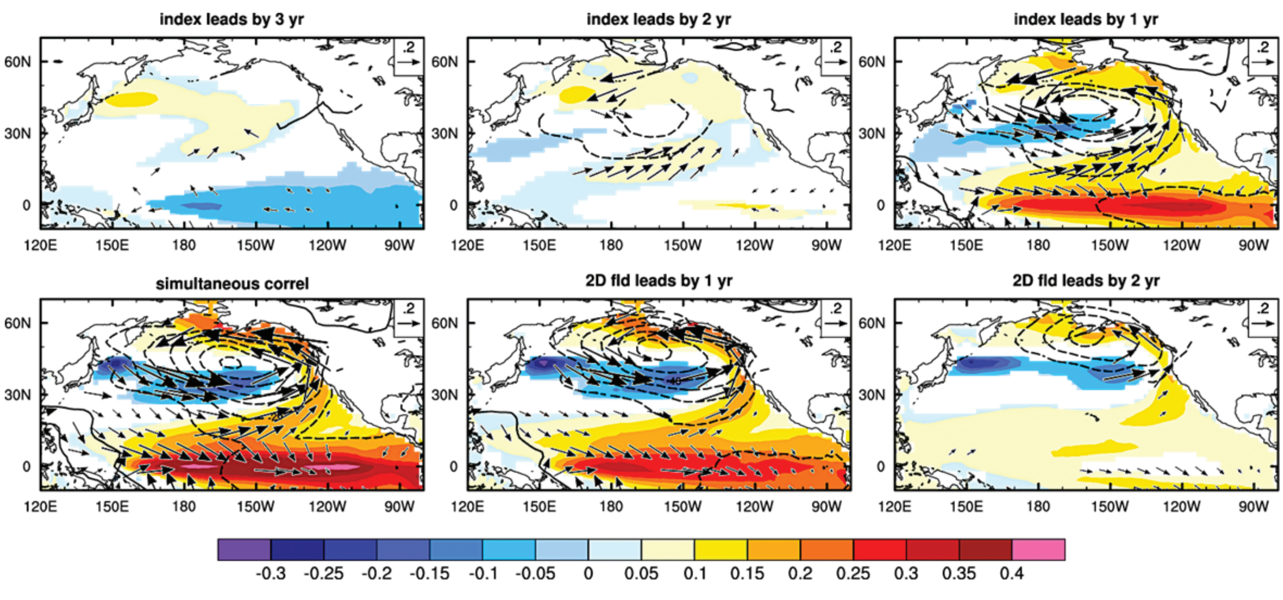

Fig. 2 Regression of SST (shading) and surface wind stress on normalized Nino-3 index at different lead and lag times as indicated in the titles of each plot.

which, in turn, enhances (reduces) the warming of the mixed layer by the seasonal shortwave radiation in austral late spring. The positive (negative) pole gradually decays in austral fall, because the mixed-layer cooling by the entrainment is enhanced (reduced) mostly owing to the larger (smaller) temperature difference between the mixed layer and the entrained water. The increased (decreased) latent heat loss due to the warmer (colder) SST also contributes to the decay of the positive (negative) pole.

In another study, it is found that the low-frequency variations in the Kuroshio Extension region off Japan are modulated by the teleconnection arising from the decadal variations in ENSO (Fig. 2). The two phases of ENSO variability give rise to different patterns of the teleconnection in the midlatitude regions of northern Pacific. This in turn induces decadal variations in the Kuroshio Extension region.

4. SINTEX-F2 DEVELOPMENT

The simulation results from the high-resolution version of the SINTEX-F2 (63×63km atmosphere coupled to 25×25km ocean) are examined in terms of the reproducibility of the northern hemisphere tropical cyclone (TC) activity as well as the associated large-scale environmental conditions (Sasaki et al. 2011[12]). The high-resolution SINTEX-F2 successfully simulates the realistic TC structure, TC-induced ocean response, and TC genesis frequency. Compared to the results of the original medium-resolution model, with atmospheric resolution of 125×125km, the global TC genesis frequency and TC intensities simulated by the SINTEX-F2 are much closer to that of the observed (Fig. 3). It is also found that the high-resolution SINTEX-F2 reasonably reproduces the environmental conditions favorable for the TC genesis; warm sea surface temperature, low-level cyclonic circulation, weak vertical wind shear, and high relative humidity in the mid-troposphere.

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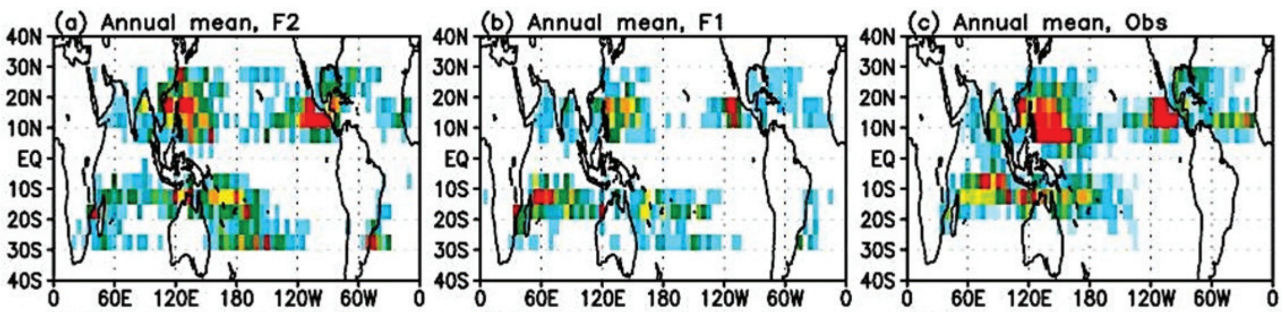

Fig. 3 SINTEX-F simulated tropical cyclone genesis regions in the tropical oceans for a) SINTEX-F2 model simulation, b) SINTEX-F1 simulation and c) observations.

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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、これを用いた気候変動予測研究を行っている。その第一版である 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、近年発生したインド洋ダイポールモードやエルニーニョ現象のほとんどを現実的に予測している。2011 年には、年初のラニーニャ現象が夏季に一度弱まった後、再びその勢力を盛り返したことについて、発生の 1 年前から SINTEX-F1 での予測に成功した。さらに、インド洋および大西洋の亜熱帯域に発達する亜熱帯ダイポールモード現象について、それらの予測が半年程度前から可能であることを初めて示した。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。

さらに、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、SINTEX-F1 による長期積分結果の解析から、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発達に海洋混合層厚の変化が重要な役割を果たしていることを明らかにした。また、SINTEX-F1 を高度化した SINTEX-F2 の精度評価を継続して行い、SINTEX-F2 の結果では、エルニーニョやインド洋ダイポールモード現象などに加えて熱帯低気圧の発生頻度などが向上し、季節内変動も現実的に取り入れた季節予測の精度向上の可能性が示された。

キーワード: SINTEX-F, エルニーニョもどき, 予測, 2011 年ラニーニャ現象