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 EU-Japan collaborative framework to understand the climate variability and predictability. After successfully predicting the third-in-a-row positive Indian Ocean Dipole (IOD) event of 2008, SINTEX-F1 realistically predicted the 2009 El Niño event and its termination. The model has been consistent in predicting all of the recent IOD and El Niño/Southern Oscillation events to become the leading climate prediction model in the world.

In addition to the real-time predictions, the model is used in sensitivity experiments to understand climate processes. In one such study, by activating and suppressing air-sea coupling in tropical Pacific and Indian Oceans in the SINTEX-F1 prediction experiments, it is found that the extreme IOD event of 1994 played a key role in driving the El Niño Modoki of that year. It is also noted that the El Niño Modoki occurs more frequently in recent decades, coincident with a weakened atmospheric Walker circulation. Extreme IODs may also significantly enhance El Niño events and their onset forecasts as found in this sensitivity study supported by an observational study. SINTEX-F1 model simulations were also used in several process studies to understand the role of air-sea interactions in regional climate variations.

Keywords: SINTEX-F1, IOD, ENSO, Prediction, 2009

1. INTRODUCTION

Climate variability in recent years has significantly affected socio-economic conditions in many parts of the world. The variability in the Indian Ocean seems to have changed recently. In a rare occasion in the history of climate research, we witnessed three consecutive positive Indian Ocean Dipole (IOD) events back to back from 2006 to 2008. This change in the IOD behavior has caused a huge deviation in the way the Indian Ocean used to influence surrounding regions. In 2007, Australian farmers lost billions of Australian dollars in spite of a La Niña development in the Pacific since the positive IOD of 2007 destroyed the La Niña-related favorable conditions over the eastern part of Australia. The consecutive positive IOD events in 2006, 2007, and 2008 caused the serious "Big Dry" in southeastern Australia and prepared the background for the "Black Saturday" forest fires there in February 2009 (Yamagata and Behera 2009; Yamagata et al. 2009). Therefore, it has become very important to understand these decadal shifts in the IOD and El Niño/Southern Oscillation (ENSO) variations using available observation and numerical simulations.

The SINTEX-F1 coupled general circulation model (CGCM) has emerged as one of the leading CGCM in the world to provide real-time predictions of seasonal to interannual climate variations. The model has successfully predicted

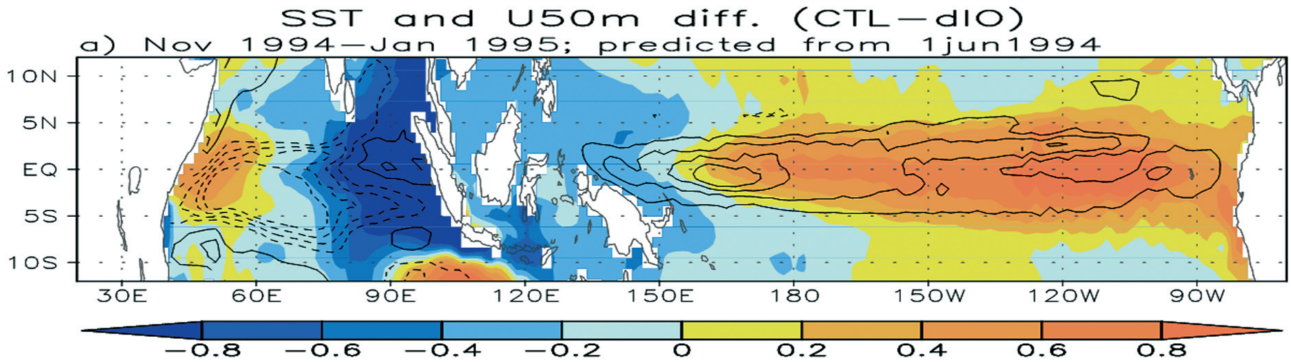

Fig. 1 Development of an El Niño Modoki event in 1994 associated with the positive IOD in the Indian Ocean from November 1994 to January 1995 period. Differences in anomalies of SST and surface zonal winds are shown in shading and contours respectively. The predictions were initiated on 1 June 1994.

all past ENSO and IOD events. In a recent study (Luo et al. 2010), 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

Real time climate forecasts for 12 to 24 lead months are continuously performed by using SINTEX-F1 CGCM and predictions are updated every month. The model has successfully predicted the evolution of the 2009 El Niño event following the La Niña conditions of 2008. In addition to the phase of the evolution, the model was able to realistically predict a moderate amplitude warm event in 2009 and its quick termination in early 2010. Because of its continuous success in the predictions of past IOD and ENSO events, the model predictions of the 2009 El Niño received a lot of attentions of news media and general public, in addition to the research community. The forecast results were 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. The high performance of the real time forecasts were applauded by Australian (The Weekly Times) and Indian (The Hindu Business Line) news papers in addition to several news papers and television channels in Japan.

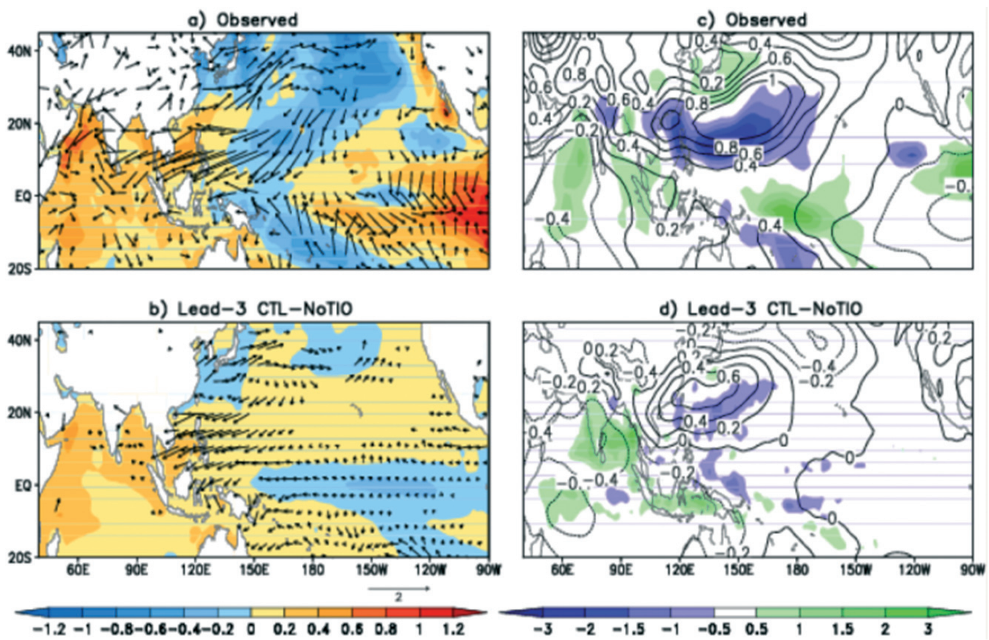

Fig. 2 Anomalies of a) observed SST and surface wind, and c) observed precipitation (shaded) and sea level pressure (contour) during June-August 1998. b–d) As in (a, b), but for the difference of model anomalies between control and no-Indian Ocean integrations at 3-month lead.

The model predictions were further tested by activating and/or suppressing air-sea coupling in tropical Pacific and Indian Oceans (Luo et al. 2010) to understand their individual and combined roles in ENSO and IOD developments. It is found that the extreme IOD event of 1994 played a key role in driving the El Niño Modoki event in that year (Fig. 1), which is in contrast to the traditional point of view, which suggests that El Niño dominates the Indo-Pacific climate variations. Luo et al. (2010) also noted that El Niño Modoki is more frequently observed in recent decades, coincident with a weakened atmospheric Walker circulation. Extreme IODs may also significantly enhance El Niño events and their onset forecasts as found in their analysis and that of Izumo et al. (2010), which was mainly based on observational data analysis.

3. PROCESS STUDIES

The simulation results of SINTEX-F1 CGCM were used in several process studies. Chowdary et al. (2009) found that the SINTEX-F1 retrospective forecasts capture major modes of atmospheric variability over the Northwest Pacific during June-August including a rise in sea level pressure, an anomalous anticyclone at the surface, a reduction in subtropical rainfall, besides increased rainfall over the northeast and East Asia. In the sensitivity experiment, when the sea surface temperature in the tropical Indian Ocean is fixed to monthly climatology, the Northwest Pacific anticyclone during June-August weakened considerably and condensed its westward extension (Fig. 2). Without an interactive tropical Indian Ocean, the anomaly correlation for anticyclone prediction dropped significantly. Several other studies have reported high performance of the SINTEX-F in the predictions of the intraseasonal variations including the monsoon intraseasonal oscillations (Wang et al. 2009; Lee et al. 2009, Ajayamohan et al. 2009). Further, these intraseasonal variations are shown to have interactions with climate modes such as IOD and ENSO (Rao et al. 2009; Kug et al. 2009; Lin et al. 2009).

In another study of the tropical Atlantic, it is found that SINTEX-F1 produces a realistic pattern of precipitation variability there. Model simulations have reproduced the two rainfall maxima along the African coast and over the Gulf of Guinea (Fig. 3) realistically. However, the model simulated rainfall variability was found to be somewhat stronger than the observation. The model simulations also showed decent variability in SST off the Namibian/Angolan coast but almost no variability in equatorial cold tongue region.

4. SINTEX-F2 DEVELOPMENT

The real-time forecasts and model simulation studies were affected to some extent by the change in the computational environment following the installation of ES2 in place of ES1. Both SINTEX-F1 and SINTEX-F2 are being optimized to achieve higher level of computational performances on ES2. In the process of development, when ocean model resolution is increased to a quarter degree (ORCA025), it is found that 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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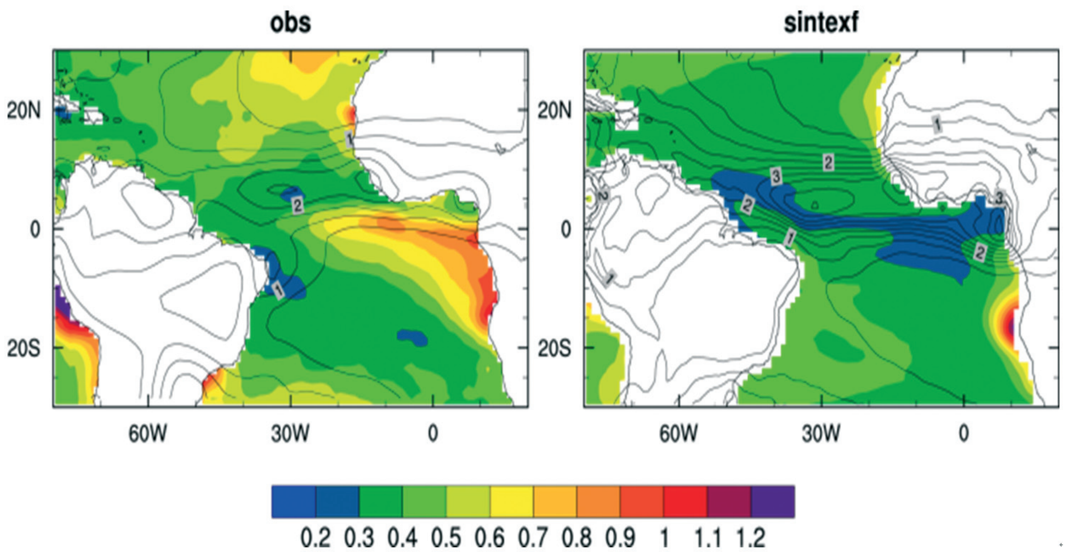

Fig. 3 Standard deviations of SST and precipitation from observations (left) and SINTEX-F simulations (right).

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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を推進している。その第一版の SINTEX-F1 は、３年連続で発生したインド洋ダイポールモード現象（IOD）の３年目に当たる 2008 年の IOD の予測に成功したばかりでなく、2009 年に発生したエルニーニョ現象とその終息についても現実的に予測している。このモデルは、近年発生した全ての IOD およびエルニーニョ／南方振動現象の予測で一定の成功を収めており、世界の気候変動予測研究を先導するモデルとしての地位を確立している。

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。熱帯太平洋あるいはインド洋での経年的な大気海洋結合過程を取り入れた場合と取り入れなかった場合の感度実験から、1994 年に発生した非常に強い IOD が太平洋でのエルニーニョもどきの発生に対して重要な役割を果たしていることが示されると共に、インド洋での IOD が太平洋のエルニーニョ現象の発生とその後の発展に対しても寄与していることが明らかとなった。さらに、近年のウォーカー循環の弱化と関連して、エルニーニョもどきの発生が多発する傾向があることも分かった。

キーワード : SINTEX-F1, IOD, ENSO, 予測 , 2009