

# Process Studies and Seasonal Prediction Experiment using Coupled General Circulation Model

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A coupled general circulation model (CGCM) developed under the EU-Japan collaborative framework is successfully installed on the Earth Simulator. The original coupled model known as the Scale INTeraction EXperiment (SINTEX) was initially developed in European Union. This model was modified and upgraded to the SINTEX-FRSGC CGCM (SINTEX-F1.0) by Dr. Masson and Dr. Luo of the Climate Variation Research Program in FRSGC. The new version of the ocean model has a free surface and includes the river runoff. It also includes most of the closed seas which were absent in the previous version. Several experimental model integrations were carried out to check the model performance. These model experiments helped to fix several bugs not only in the new version of the CGCM but also in the original model components. Several modifications are also carried out to improve the parallelization ratio of the CGCM. It is found that about 90 percent of the elapsed time is used by the atmospheric component alone. In a stand alone experiment, the better parallelized atmospheric component was successfully run using 80 processors. Preliminary results from a 50-yr run after all the bug fixes are analyzed and validated with observation. Baring a few model biases, the surface climatology in the CGCM in particular the sea surface temperature and surface winds has a good agreement with that of the observed climatology. The model not only produced a reasonable surface climatology but also produced several events of El Niño/Southern Oscillation in the Pacific and the Indian Ocean Dipole in the Indian Ocean. These model features are very encouraging for our future studies under the ongoing project in the Earth Simulator. We will demonstrate that the Earth Simulator has epoch-making prospects for high-resolution climate modeling and forecasting.

**Keywords:** SINTEX-F1.0 Seasonal Prediction CFES Intercomparison

## 1. Objectives

Installation of a reasonably high resolution coupled GCM on the ES. Model inter-comparison study with the CFES to understand the model biases. This will help in improving some of the parameterization schemes in the CFES. Model studies to understand physical processes in the evolution of IOD and ENSO and their interactions and teleconnections. Seasonal prediction experiments from a large number of model ensemble members.

## 2. Achievements

### Model Installation and Performance

A reasonably high resolution coupled GCM developed under EU-Japan collaboration is installed on the Earth Simulator. The coupled model known as the Scale INTeraction EXperiment (SINTEX) was initially developed by a couple of Laboratories in the European Union. The oceanic and atmospheric component of the model was modified and upgraded by Dr. Masson and Dr. Luo of the Climate

Variation Research Program in FRSGC. The new version of the ocean model has a free surface and includes the river runoff. It also includes most of the closed seas which were absent in the previous version. The upgraded AGCM uses MPI for parallel computation. This makes it possible for the new coupled model to utilize multi-nodes on the Earth Simulator. The new version of the model known as SINTEX-FRSGC CGCM (SINTEX-F1.0) was then installed on the Earth Simulator. Dr Luo's initial model experiments in the Earth Simulator helped in fixing several bugs in the atmospheric component of the coupled model. These bug fixes are appreciated by the developers and users of the ECHAM4.6. The improved atmospheric model could successfully run on 80 processors. Since the atmospheric component uses 90% of total elapsed time during model integration, we hope the experiments of using 80 processors will help the coupled model to run efficiently on the earth simulator. However, the results from this computation are found to be different from that of the previous experiments using up to 40 processors. This model bias is now under investigation. It is also realized that ECHAM4.6 code is not very efficient for higher parallelization. The new version of the atmospheric model i.e. the ECHAM5 is said to have better parallelization efficiency in the SX6 machine. We are waiting for the official release of the code that is scheduled at the end of April 2003. Similarly Dr. Masson rectified several bugs in the coupler that helped in running the coupled model on multi-processors. The effective elapsed time to run the model in the Earth Simulator is already 8 times faster compared to similar runs in the SX5 machine. Further experiments have been carried out to improve the model parallelization efficiency while using multiple nodes with the help of EU engineers.

### 3. Preliminary Research Results

After all the bug fixes the model was integrated for 50 years. The model climatology from the 50-yr run is validated against the observed climatology. Fig. 1 shows the model climatology for the sea surface temperature (SST) and the surface wind stress. The model could reproduce the eastern Pacific cold tongue and the coastal upwelling in the western Indian Ocean during summer season. However a few model biases are also apparent in the climatology. The warming in the southwestern tropical Pacific extends too far into the east. Besides, there are differences between model and observation in the SST of higher latitudes. For example, the SST in the higher latitudes of Southern Hemisphere are found to be warmer compared to the observed data. The model rainfall climatology is shown in Fig. 2. The seasonal distribution of the rainfall is quite comparable with that in the observation. Particularly, the intertropical convergence zone (ITCZ) in the Indian Ocean and the south Pacific convergence zone (SPCZ) are simulated by the coupled model. The January ITCZ in the Indian Ocean located over the southern Africa as is observed but the SPCZ extends far too eastward. Further analyses are carried out to understand the model biases.

The SINTEX-F1 coupled model simulations results are also analyzed to understand the model efficiency in capturing the interannual variability. One of the challenging features for the coupled models is to capture the ubiquitous Yoshida-Wyrski jet in the Indian Ocean. It is found that the SINTEX-F1 coupled model is able to simulate realistic seasonal variability of the Yoshida-Wyrski jet. However, the maximum amplitude of the model jet occurs one month later (June for the spring jet and December for the fall jet) as compared to the reported strengthening of the jet based on

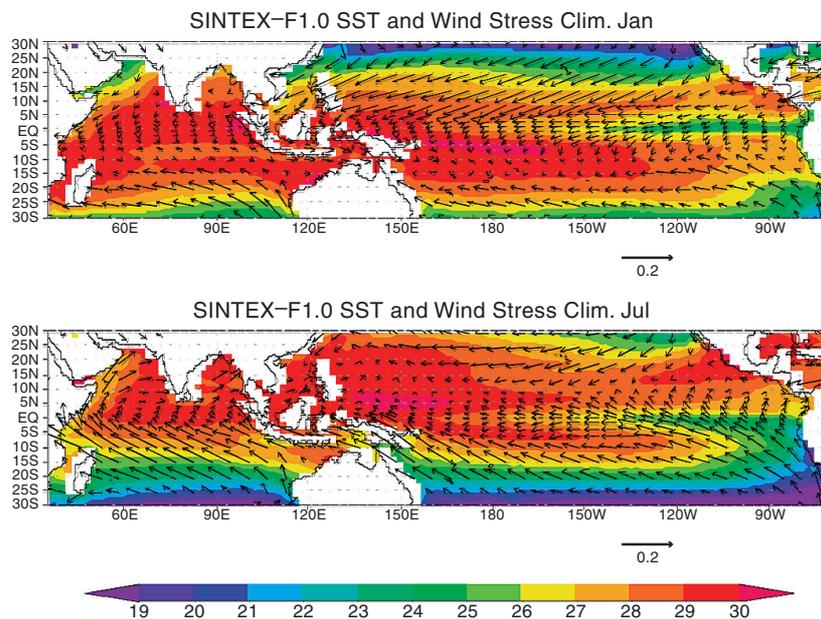


Fig. 1 50-yr model climatology of SST and surface wind stress in the tropical Indo-Pacific sector for January (upper panel) and July (lower panel).

observations. Fig. 3 illustrates the strong intraseasonal to interannual variability of the fall jet in our simulation in agreement with observation from TRITON buoys (Masumoto et al. 2003, personal communications). Most of the years the jet amplitude exceed 1 m/s but jet of years 2, 13 and 17 are very weak. Some years (18 for example) present one unique and strong jet but most of years show 2 or 3 fall jets that are sometimes difficult to be described as jets

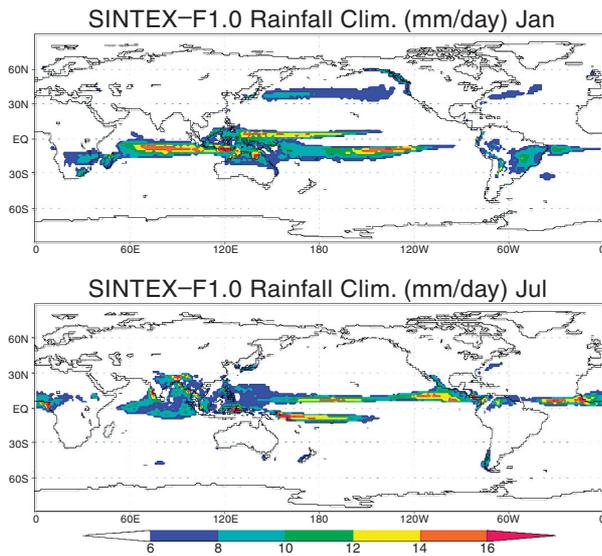


Fig. 2 50-yr model rainfall climatology for January (upper panel) and July (lower panel).

(see years 20 or 21 for example). In addition this figure illustrates some interactions between salinity and equatorial dynamics. In agreement with recent works of Masson et al. [2003, JGR]; when the jet reaches the eastern part of the equatorial basin, it creates a strong salinity front and stratification that increases drastically the zonal pressure gradient and favors a surface current reversal against the wind forcing. This can be clearly seen for years 3, 8, 9, 12, 15, 19.

Another interesting Indian Ocean phenomenon called the Indian Ocean Dipole (IOD) mode has generated a lot of interest in the modeling community. Since it is an ocean-atmosphere coupled mode, it is natural to verify its evolution in the SINTEX-F1.0 simulations. We found several IOD events in the 50-yr simulation. Fig. 4 shows the evolution of SST and wind stress anomalies during some of the IOD events. The top panel shows the evolution of a positive IOD event that co-occurred with an El Niño event in the Pacific. The model SST and wind stress anomalies during the event are very similar to that in the observed anomalies of 1997. The middle panel in the figure shows the evolution of the positive IOD event during a La Niña event in the Pacific. These inter-basin events in the model compare to the 1967 events in the observed data. Finally, the lower panel shows the evolution a positive IOD event in the Indian Ocean in the absence of an ENSO event in the Pacific. Since the Walker circulation associated with these three example

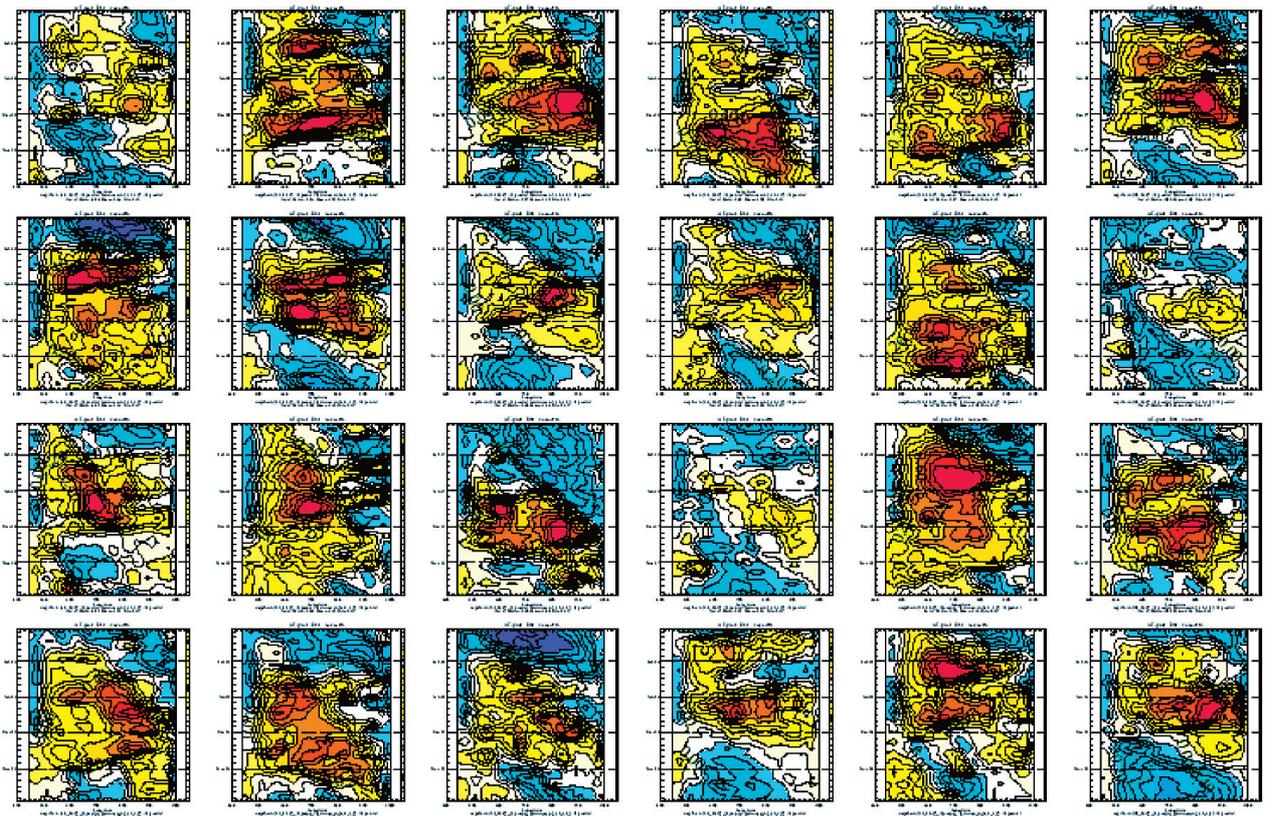


Fig. 3 Model Yoshida-Wyrtki of the surface zonal current along the Equator ( $1^{\circ}\text{S}-1^{\circ}\text{N}$ ) in the Indian Ocean from September to February for 24 different years. Contour Interval=1m/s. Eastward current in yellow, orange, red.

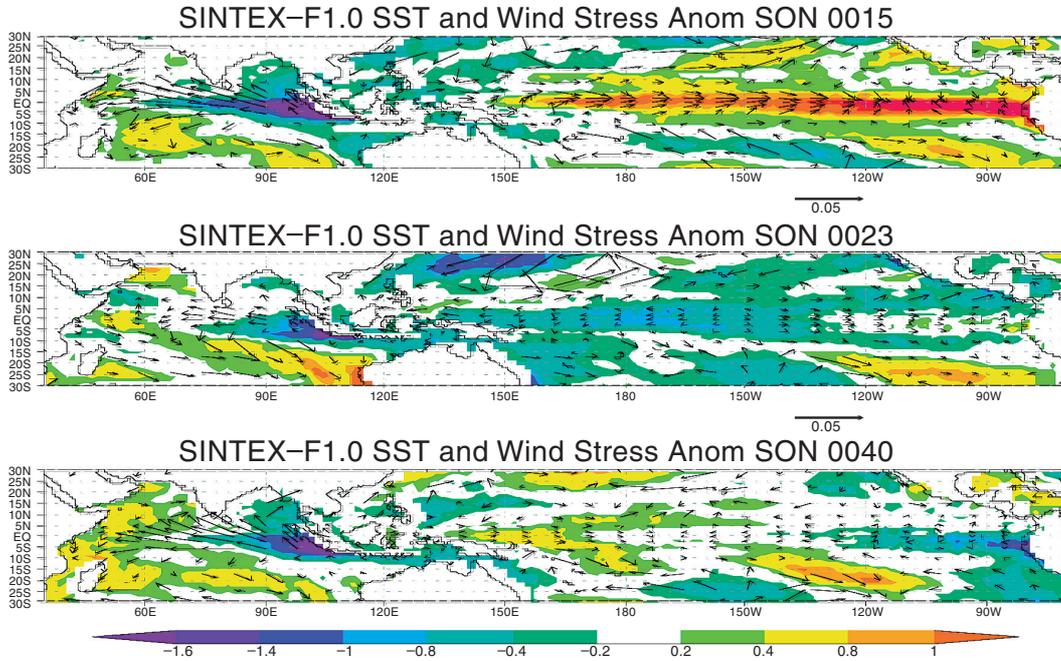


Fig. 4 Anomalies of SST and wind stress during September-November of model simulated IOD events.

events will be different, therefore it contrasts the arguments that the ENSO event in the Pacific causes the IOD. In fact the coupled model results favor the independent mechanism for the IOD as showed in Yamagata et al. [2002, CLIVAR EXCHANGES] from the observed data. The model results are very encouraging in this regards and will be very helpful to resolve the issue of the IOD and ENSO interaction.

#### 4. Work for the FY2003

The model integrations will continue for several hundreds

of years, since the preliminary results from the model are very encouraging. The model parallelization ratio will be increased further to effectively use many more nodes in the Earth Simulator. In addition to the technical achievements, the enhanced computational skill will enable us to carry out many more model experiments in record time. One of the major goals of the project is to start a seasonal prediction experiment with at least 50-member ensemble run. We appreciate the continued support from the Earth Simulator in achieving our project goals.

## 海洋結合モデルによるプロセス研究と季節予報実験

利用責任者

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地球フロンティアの気候変動予測領域とEUの研究者との研究協力のもとで開発した大気海洋結合大循環モデル(CGCM)を地球シミュレータで走らせることに成功した。この結合モデルの原型となったものは、SINTEX (Scale Interaction Experiment) モデルとして知られており、もともとEUにおいて開発されたものであるが、日本側でルオ研究員やマッソン研究員がこれを修正、改良し、地球フロンティアとの合同モデル、SINTEX-FRSGC CGCM (SINTEX-F1.0)としたものである。

新しいバージョンの海洋モデルは、自由表面モデルで、かつ、河川流量もあらわに表現している。また、以前のバージョンではほとんど無視されていた世界の内海のほとんどすべてを含んでいる。モデルの実効性能を調べるために数例の数値積分を実行した。これらのモデル実験により、CGCM の新バージョンのみならず、オリジナルのモデルについても、いくつかのバグを修正することが出来た。また、CGCM のパラメタリゼーションを改良するための修正も施された。

この大気海洋モデルの数値実験では、大気部分の計算が約90%を占める。そこで大気モデルのみの実験で、その並列化に改良を加え、80個のプロセッサを使用する数値実験に成功した。

大気海洋結合モデルにおいても、全てのバグを修正した後、予備的な50年積分実験を行い、その結果の解析と実際の観測との比較を行った。いろいろなモデルバイアスが存在するが、CGCM の地表付近の気候平均値、とくに海面水温や地表の風の平均値は、観測の気候平均値と良い一致を示した。このモデルは、こうした地表付近の気候平均値を良く再現するだけでなく、太平洋におけるエルニーニョ/南方振動や、インド洋におけるダイポール現象をも再現している。

このように、地球シミュレータを利用することにより、地球フロンティアのモデル研究が更に推進され、また、より高解像度の気候モデルやそれを用いる気候予報研究において、画期的な研究が展開することが期待される。

キーワード: SINTEX-F1.0 季節予報、CFES 相互比較