Study on the Real-time Ensemble Seasonal Prediction System and Its Application

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The APL/JAMSTEC seasonal prediction system was built on the basis of the Scale Interaction Experiment-Frontier (SINTEX-F1) fully coupled global ocean–atmosphere GCM, which has been developed under the EU-Japan collaborative framework on the Earth Simulator. The SINTEX-F1 seasonal prediction system has so far demonstrated high performance of predicting the occurrences of El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole Mode (IOD) events in the tropics and subtropical dipole events in southern Indian and Atlantic Oceans.

Using the SINTEX-F1 prediction outputs, we found seasonal predictability of subtropical dipoles in southern Indian and Atlantic Oceans. Because of good performances of the SINTEX-F1 prediction on the subtropical dipoles, ENSO, and IOD, the prediction skill of the southern African summer precipitation is also high in the SINTEX-F1 system. In addition to those basin-scale climate variations, the predictability of the regional climate mode off the west coast of Australia, the Ningaloo Niño/Niña, is found two seasons ahead by the SINTEX-F1 seasonal prediction system.

We also explored possibility of a climate-based global yield prediction, and found that it is significantly skillful in predicting rich or poor harvest in the world.

Keywords: SINTEX-F1 seasonal prediction system, Subtropical Dipole Modes, the Ningaloo Niño/Niña, climate-based yield prediction

1. Introduction

The APL/JAMSTEC seasonal prediction system on the basis of the Scale Interaction Experiment-Frontier (SINTEX-F1) fully coupled global ocean–atmosphere GCM has been developed under the EU-Japan collaborative framework using the Earth Simulator. The SINTEX-F1 has emerged as the leading CGCM in the world to provide reliable real-time predictions of seasonal to interannual climate variations. The experimental seasonal predictions based on the CGCM are produced regularly, and the real-time outlook is published every month on our website since 2006 (http://www.jamstec.go.jp/frcgc/research/d1/iod/e/seasonal/outlook.html). In this fiscal year, the process studies and model development with the SINTEX-F2 GCM were initiated on another project (Project representative: Yukio Masumoto, RIGC/JAMSTEC). Therefore, we focused on investigating recent tropical climate variations and their prediction skills, and their experimental societal application in this project.

In the following sections, we introduce several important results obtained from our research activities in the fiscal year of 2013. In Section 2, we show recent important discoveries of seasonal predictability of subtropical dipoles and the new regional climate phenomenon off the west coast of Australia, the Ningaloo Niño/Niña. In Section 3, possibility of a climate-based prediction of global yield with the SINTEX-F1 seasonal prediction is discussed.

2. Discovery of seasonal predictability

2.1 Predictability of the Subtropical Dipole Modes

Seasonal predictability of the subtropical dipole modes is explored (Yuan et al. 2014a [1]) using the SINTEX-F1 coupled model (Fig. 1). Despite the known difficulty in predicting subtropical climate due to large internal variability of the atmosphere and weak ocean–atmosphere coupling, it is shown for the first time that the coupled model can successfully predict the South Atlantic Subtropical Dipole (SASD) 1 season ahead, and the prediction skill is better than the persistence in all the 1–12 month lead time in the hindcast experiments. The prediction skill is lower for the Indian Ocean Subtropical Dipole (IOSD), and only slightly better than the persistence till

6-month lead because of the low predictability of the sea surface temperature anomaly in its southwestern pole. However, for some strong IOSD events in the last three decades, the model can predict them 1 season ahead. The co-occurrence of the negative SASD and IOSD in 1997/98 austral summer can be predicted 5 months ahead. This is because the negative sea level pressure anomalies over the South Atlantic and the southern Indian Ocean in September–October (November– December) that trigger the occurrence of the negative SASD and IOSD are related to the well-predicted tropical IOD (ENSO).

Owing to the overall good performances of the SINTEX-F1 model in predicting the SASD, some strong IOSD, and ENSO, the prediction skill of the southern African summer precipitation is high in the SINTEX-F1 model (Yuan et al. 2014b [2]). The precipitation anomalies over southern Africa (16°– 33°E, 22°–35°S) in December-February are the most predictable from the October 1st initialization (Fig. 2). This study presents promising results for seasonal prediction of precipitation anomaly in the extra-tropics, where seasonal prediction has been considered a difficult task.

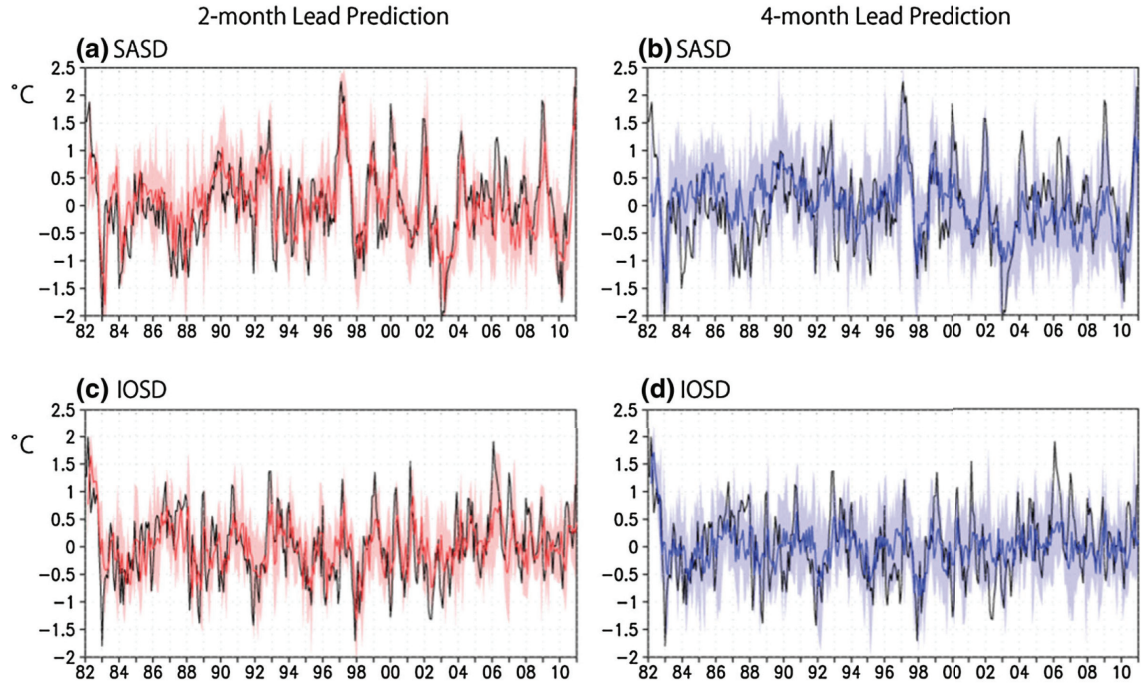

Fig. 1 Time series of (a,b) the SASD and (c,b) IOSD indices obtained from the observational data (black lines) and ensemble-mean predictions at (left panels, red lines) 2-month and (right panels, blue lines) 4-month leads. Red (blue) shading denotes the ensemble spread of 2 (4)-month lead predictions. No smoothing has been applied to all the monthly time series. (Fig. 15 in Yuan et al. 2014a)

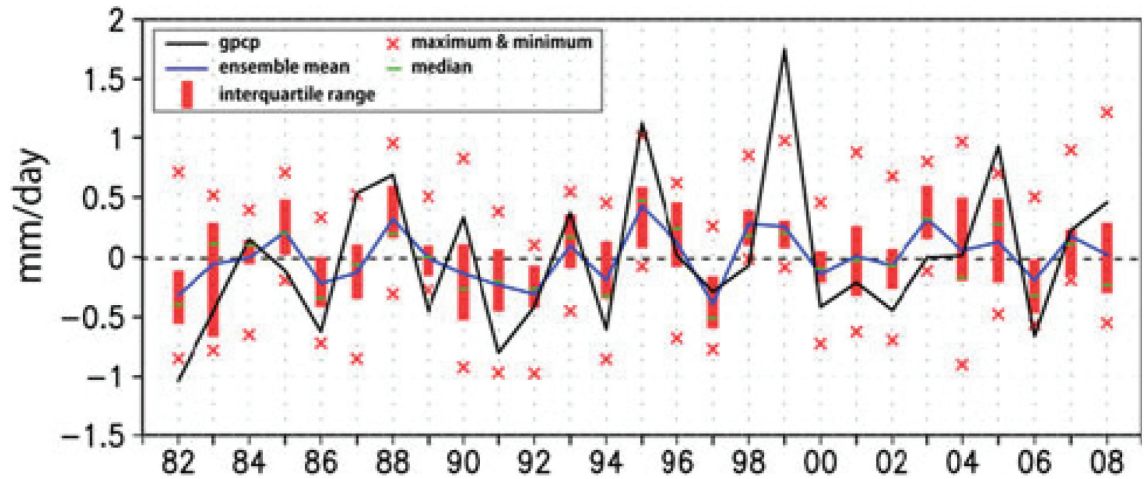

Fig. 2 Time series of the southern African precipitation indices in DJF. Years in the x-axis represent the 3-month-mean period from December of that year till the following February. Black (blue) solid line represents the index derived from GPCP (ensemble-mean predictions initialized on October 1st). Also shown are the box-and- whisker plots for the nine ensemble members at each year; the red boxes represent the interquartile ranges of the middle 56% ensemble members (five out of nine members). Green horizontal bars within the red boxes indicate precipitation anomalies of the median member, and red cross symbols show the maximum and minimum precipitation anomalies from the nine members (Fig. 2 in Yuan et al. 2014b)

2.2 Predictability of the Ningaloo Niño/Niña

The Ningaloo Niño is newly identified as a regional climate phenomenon, which is characterized as warmer-than-normal SST anomalies off the west coast of Australia. In particular, we experienced an unprecedented Ningaloo Niño in 2011. The SST anomalies in Feb.-Mar. 2011 reached about 3ºC off the west coast of Australia, which is above four times of the standard deviation of its interannual variation in recent 30 years. Using the SINTEX-F1 CGCM, we have examined its prediction skill of the Ningaloo Niño/Niña (Doi et al. 2013).

It has turned out that the model is skillful in predicting the Ningaloo Niño (anomaly correlation coefficient (ACC) > 0.6 and normalized root mean square error (RMSE) > 1) up to 5-month ahead when initialized on the first day of each month form May to November. In particular, the Ningaloo Niño is predicted very well when the model is initialized in austral winter-spring. Also, we have focused on the prediction of the unprecedented extreme warm event of the 2011 Ningaloo Niño. The SINTEX-F1 prediction initialized on June 1st, 2010 successfully predicted this extreme warm event in February 2011, i.e. 9 months in advance (Fig. 3). The potential source of this predictability is due to high prediction skill of La Niña. The model reasonably predicted the rapid development of the La Niña condition and the easterly wind anomalies over the equatorial western Pacific in December 2010. It also predicated successfully warm SST anomalies off the west coast of Australia with northerly wind anomalies, the intensification of the Leeuwin Current, and the coastal downwelling in February 2011.

3. Prediction of seasonal climate-induced variations in global food production

We present a global assessment of the reliability of crop failure hindcasts for major crops at two lead times derived by linking ensemble seasonal climatic prediction with statistical crop models (Iizumi et al. 2013 [4]). We found that moderate-to-marked yield loss over a substantial percentage (26–33%) of the harvested area of these crops is reliably predictable if climatic predictions are near perfect. However, only rice and wheat production are reliably predictable three months before the harvest using within-season hindcasts (Fig. 4). The reliabilities

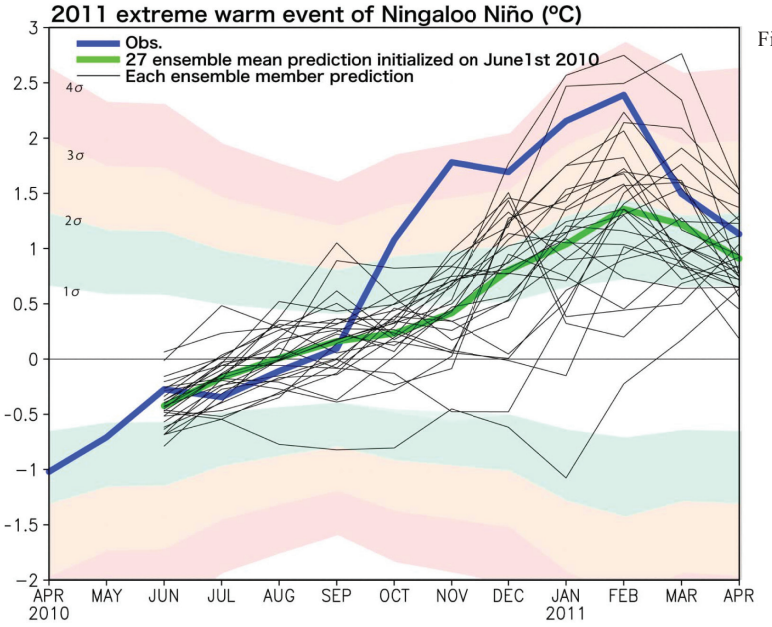

Fig. 3 Monthly time series of the Ningaloo Niño Index (NNI) for observational data of NOAA OISSTv2 (blue) and SINTEX-F1 27 ensemble member prediction initialized on June 1st, 2010 in ºC (ensemble member mean: green; each member: thin black). One, twice, three-, and four-times of the standard deviation of the observed NNI in 1983–2006 (σ) are also shown by shaded (Fig. 3 in Doi et al. 2013 [3]).

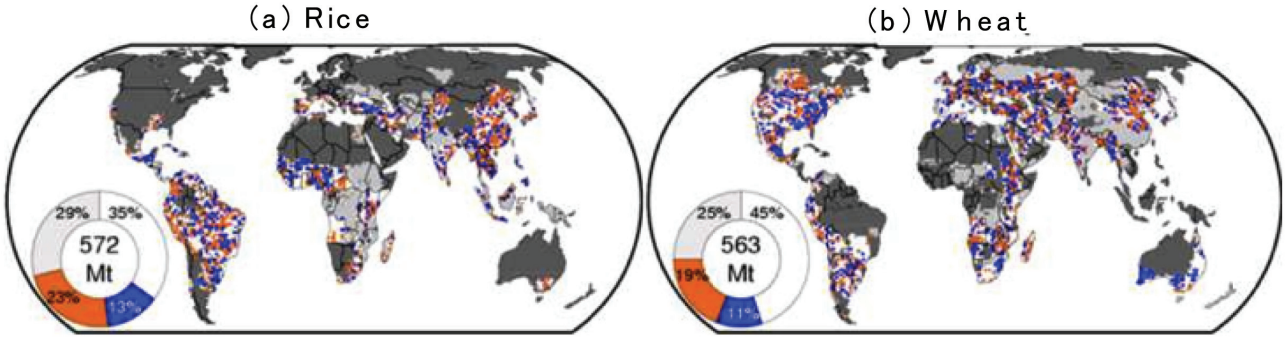

Fig. 4 3-month lead climate-based prediction of the year-to-year variations in the yields of rice (left) and wheat (right). A region where the model is skillful is shown by orange. Blue shows a region where the model fails to predict the yield variation owing to failure of seasonal climate prediction. White shows a region where the observed climate information (temperature and soil moisture) is not significantly correlated with the yield variation. Grey indicates a region where historical yield data is not available. The dark grey area indicates non-cropland.

of estimates varied substantially by crop: Rice and wheat yields were the most predictable, followed by soybean and maize. The reasons for variation in the reliability of the estimates included the differences in crop sensitivity to the climate and the technology used by the crop-producing regions. Our findings reveal that the use of our system to predict crop failures will be useful for monitoring global food production and will encourage the adaptation of food systems to climatic extremes.

Acknowledgement

We appreciate the support extended by the Earth Simulator in achieving our project goals. Also, we are grateful to Dr. Jing-Jia Luo. Dr. Sebastian Masson and our European colleagues of INGV/CMCC and L'OCEAN for their contribution to developing the prototype of the prediction model.

References

[1] Yuan, C., T. Tozuka, J. J. Luo, and T. Yamagata, 2014a: Predictability of the subtropical dipole modes in a coupled ocean–atmosphere model. *Clim Dyn*. DOI:10.1007/s00382-013-1704-1.

[2] Yuan, C., T. Tozuka, W. A. Landman, and T. Yamagata, 2014b: Dynamical seasonal prediction of Southern African summer precipitation. *Clim. Dyn*. DOI:10.1007/s00382-013-1923-5.

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リアルタイム－アンサンブル短期気候変動予測とその応用可能性について

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数ヶ月から数年スケールで発生する気候変動の理解ならびにその予測可能性研究のため、SINTEX-F1 大気海洋結合大循環モデルを日欧研究協力に基づき開発および改良してきた。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（IOD）やエルニーニョ・南方振動（ENSO）現象のほとんどを現実的に予測している。本課題では、そのリアルタイムの季節・経年変動予測実験の計算と、その予測情報の社会応用可能性を研究する。SINTEX-F2 の開発やそれを使った気候変動プロセス研究を実施した課題（課題責任者：JAMSTEC/RIGC 升本　順夫）と本課題は相補的な関係にある。

SINTEX-F1 季節変動予測システムの結果を解析し、インド洋亜熱帯ダイポールモード現象と南大西洋亜熱帯ダイポールモード現象に予測可能性があることを世界で初めて示した。更に、SINTEX-F1 予測システムでは亜熱帯ダイポール、ENSO, IOD の予測精度が高いために、アフリカ南部の 12-2 月の降水量変動を 10 月初旬から予測できることも示した。これらの研究により、亜熱帯域の気候予測研究について新たな扉が開かれたと言える。また、オーストラリア西岸で発生する新しい地域気候変動現象「ニンガルー・ニーニョ」の発生についても、約半年前から予測可能であることを初めて示した。

気候変動予測情報の社会応用研究としては、本プログラムと農業環境技術研究所の共同研究チームによって、３か月先の短期気候予測による穀物の世界的豊凶予測の手法開発を行った。気温と土壌水分量の季節予測データを用いることで、コムギとコメの豊凶を世界の栽培面積の約２割について、収穫３か月前に予測できることを示した。

キーワード：SINTEX-F1 季節予測システム , 亜熱帯ダイポールモード , ニンガルーニーニョ / ニーニャ ,
気候ベースの豊凶予測システム

Published news articles：

＜成果＞（1）関係：
取材・制作協力
H25.5.21 取材 H25.5.28 掲載 H25.6. 9 掲載
日本経済新聞
（5/28 掲載）今年の梅雨や夏の予測について「米国の竜巻、背景に温暖化？　極端気象、日本でも」
（6/9 掲載）「ラニーニャ多発、なぜ」

取材・制作協力
H25.6.13
ET NOW（インドムンバイのテレビ局　※日本・トムソンロイターで収録）
インドの季節予測と農業への影響など

取材・制作協力
H25.7.18
夕刊フジ
今年の猛暑・異常気象の原因について（メールで回答）

取材・制作協力
H25.7.25
テレビ朝日
池上彰の学べるニュース　インド洋ダイポールモード現象について（メールで回答）

取材・制作協力
H25.7.29
報道ステーション
山口・島根豪雨の原因について（取材対応ができなかったため資料にまとめて回答）

取材・制作協力
H25.7.29 電話取材 H25.8.7 収録
テレビ朝日スーパー J チャンネル
今年の異常気象の原因について（7/29 電話で事前取材、8/7 収録）

取材・制作協力
H25.7.30
日刊ゲンダイ
今年の異常気象の原因について

取材・制作協力
H25.8.4
TBS サンデーモーニング
今年の異常気象の原因について（ニュース 23 クロスの映像を使用）

取材・制作協力
H25.8.6
テレビ朝日モーニングバード
異常気象のメカニズムについて

取材・制作協力
H25.8.14
読売新聞
猛暑の原因

取材・制作協力
H25.9.10
週刊プレイボーイ
今年の猛暑について

取材・制作協力
H25.10.22
NHK
10 月に台風が多いことについて（電話取材）

取材・制作協力
H25.11.7 事前打合せ H25.11.23 収録
BS ジャパン「咲くシーズ」出演（生島ヒロシとの対談）
12/21 放映予定

ラジオ NIKKEI 第 2 番組「Groovin’ × Groovin’」
「海洋システムから読み解く気候変動」についてトーク
12/19 収録予定

＜成果＞（3）関係：
•JAMSTEC プレスリリース“ニンガルー・ニーニョ現象の予測可能性を世界で初めて発見”
文部科学省記者クラブ
http://www.jamstec.go.jp/j/about/press_release/20131008_3/

•JAMSTEC 海と地球のフォトグラフィー　今週の一枚
http://www.jamstec.go.jp/j/hot_pictures/?334

• マイナビニュース“ニンガルー・ニーニョ現象の予測可能性を発見”
http://news.mynavi.jp/news/2013/10/10/199/

• 日刊工業新聞“海洋機構、ニンガルー・ニーニュ現象の予測可能性を発見”
http://www.nikkan.co.jp/news/nkx0720131009eaai.html

• 官庁通信　“ニンガルー・ニーニョ予測可能性　JAMSTEC 研究員が世界で初発見”
http://kancho5751.blog.fc2.com/blog-entry-511.html

• 科学新聞（2013, 10/18 号）“ニンガルーニーニョ現象　高精度予測手法を発見”

• 共同通信“ニンガルー・ニーニョ現象の予測可能性を発見”

• 時事通信“ニンガルー・ニーニョ現象の予測可能性を発見”

＜成果＞（4）関係：
• 農業環境技術研究所 プレスリリース
“世界のコムギとコメの不作を収穫 3 か月前に予測する手法の開発―季節予測による穀物の世界的豊凶予測―”
http://www.niaes.affrc.go.jp/techdoc/press/130719/press130719.html

• マイナビニュース
NIAES など、穀物の世界的「豊凶予測」を 3 カ月前に行う手法を開発
http://news.mynavi.jp/news/2013/07/23/105/

• 毎日新聞（2013,7.22 号）
“＜農業環境技術研＞3 カ月前にコメの豊凶を予測　手法を開発”

新聞記事など
NASA. Climate forecasts shown to warn of crop failures.
http://climate.nasa.gov/news/954, July 22, 2013.

University of Leeds. Climate forecasts shown to warn of crop failures.
http://www.leeds.ac.uk/news/article/3422/, July 23, 2013

SciDev. Computer model gives early warning of crop failure.
http://www.scidev.net/global/data/news/computer-model-gives-early-warning-of-crop-failure.html,
July 24, 2013.

Nature Climate Change. Highlights: Forecasting failure.
http://www.natureasia.com/en/research/highlight/8567, July 22, 2013.

Nature Japan. 日本の研究論文：季節的な気候による食糧生産の変動を、世界規模で予測する手法を開発 .
http://www.natureasia.com/ja-jp/nclimate/papers-from-japan/article/48675.

* この他に、毎日新聞、食品産業新聞、農業協同組合新聞、日本農業新聞で報道された。また、時事通信より取材があった。