8 A.2

ROLE OF STOCHASTIC FORCING IN ENSO VARIABILITY IN A COUPLED GCM

Atul Kapur *, Chidong Zhang
University of Miami, Miami, Florida

Javier Zavala Garay
Rutgers University, New Brunswick, New Jersey

1. INTRODUCTION

Evidence has mounted that El Niño – Southern Oscillation (ENSO) is driven by rapidly varying atmospheric components acting as stochastic forcing (SF). Observations suggest that Madden Julian oscillation (MJO) – a dominant eastward propagating mode in the tropics – can be a key ingredient of SF due to its ability to force downwelling ocean Kelvin waves which are hypothesized to trigger an El Niño.

The role of SF in ENSO simulated by coupled general circulation models (CGCMs) is, however, uncertain. This study attempts to answer the following questions:

- To what extent is the ENSO in a given CGCM driven by SF?
- What is the underlying dynamical regime (damped or unstable) of the coupled system over which SF acts?
- What are the relative contributions from MJO and non-MJO components of SF to ENSO?

All these questions are important for point of view of ENSO predictability.

2. CGCM AND DATA

We illustrate our procedure with a 163-year run of the Bureau of Meteorology Research Center (BMRC) Coupled General Circulation Model (CGCM). The atmospheric component of the CGCM is the BMRC "unified" model, and the ocean component is the Geophysical Fluid Dynamics Laboratory (GFDL) modular ocean model (MOM, global). The CGCM has been documented in literature to have very realistic ENSO (Wu et al., 2002) and intraseasonal variability (Zhang et al., 2006).

We use NCEP-2 Reanalysis as a validating dataset, and for CZZ model evaluation.

3. CANE ZEBIAK ZAVALA-GARAY MODEL

The intermediate coupled model used is the Cane and Zebiak (1987) model with few modifications. Most dynamical features are same as standard CZ model. The thermocline displacements affect the SST anomalies, which are also affected by forcing by anomalous wind stress anomalies. The atmosphere in the model is Gill-type. The ocean domain represents the tropical Pacific with, and the grid size used is 5.625° in zonal direction and 2° in meridional direction.

The main modification over the standard CZ model is that the chaos has been switched off. This implies that ENSO oscillates periodically in the absence of SF. This modification was achieved by turning off the near-annual mode identified by Mantua and Battisti (1995).

Another modification is that the model is capable of admitting daily values of stochastic forcing as opposed to the standard CZ model which allows a minimum timestep in forcing of 10 days. This modification is important because decorrelation time of tropical weather is ~ 3-8 days.

4. PROCEDURE

The procedure designed to investigate the role of SF is illustrated in Figure 1. The stochastic components from BMRC CGCM are extracted and validated against those derived from NCEP-2 reanalysis. An intermediate coupled ocean-atmosphere model (ICM) of tropical Pacific is then forced with:

(a) NCEP-2 stochastic components – to evaluate the performance of ICM, and then with
(b) BMRC CGCM stochastic components – to estimate their role by comparing simulated ENSO to the CGCM ENSO, while acknowledging benchmarks set in (a).

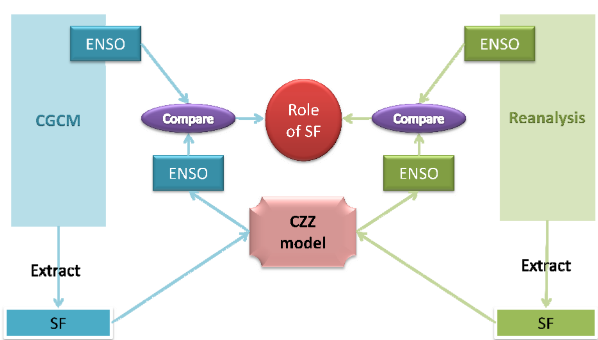

Figure 1. Schematic of procedure adopted to investigate the role of stochastic forcing (SF) in BMRC CGCM.

---

* *Corresponding author address:* Atul Kapur, University of Miami, Rosenstiel School (MPO), 4600 Rickenbacker Causeway, Miami, FL 33149-1098; email: akapur@rsmas.miami.edu

5. STOCHASTIC FORCING

The stochastic components from BMRC CGCM are extracted and validated against those derived from NCEP-2 reanalysis. A linear statistical model of surface zonal wind ($\mathbf{U}$) anomalies predicted by the SST anomalies ($\mathbf{S}$) is constructed using singular vector decomposition (SVD) technique. The residual ($\mathbf{F}$) is treated as SF, i.e.

$$\mathbf{U} = \mathbf{AS} + \mathbf{F}$$

where $\mathbf{A}$ is a matrix of regression coefficients. The caveat in using this technique is that the atmospheric variability related to SST anomalies in non-linear or non-contemporaneous manner may still be a part of SF.

The MJO is extracted from the SF using Hilbert EOF technique, which recognizes it as a dominant eastward propagating mode. The time-space spectra of various components of anomalous surface wind are shown in Figure 2.

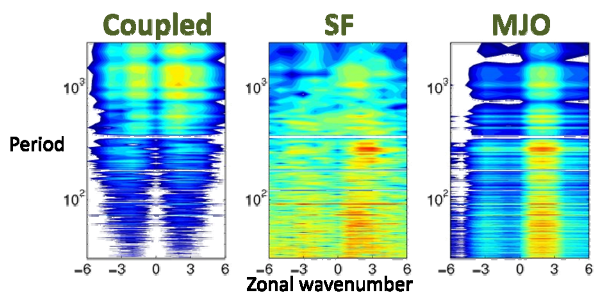

Figure 2. Time-space spectra (variance preserving) for coupled, SF, and MJO components of u_{10} anomalies from the BMRC CGCM. Positive wavenumbers represent eastward propagation and vice versa.

6. RESULTS

The CZZ model is forced first with NCEP-2 stochastic components and then with BMRC CGCM stochastic components.

6.1. Simulations using NCEP-2 SF

First EOF principal component (PC_1) is computed from the SST anomalies obtained from the CZZ model simulations forced with SF. Various ENSO characteristics are statistically characterized from the PC_1 and compared with those from NCEP-2 reanalysis and BMRC CGCM ENSO.

The CZZ model performs satisfactorily as it produces desired shape of PC_1 spectrum when forced with reanalysis SF (Figure 3).

The model also produces the desired seasonality, at least for warm events (Figure 4).

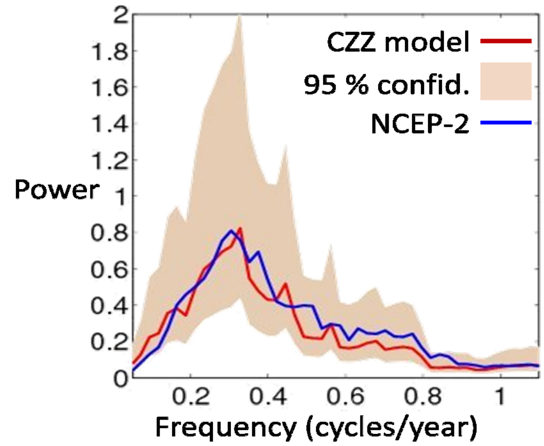

Figure 3. Variance-preserving power-spectrum of PC_1 (red curves) obtained from CZZ model forced with SF derived from NCEP-2 reanalysis. The model is tuned in weakly stable regime. Shaded region is the 95 % confidence interval. Also superimposed (blue curves) is the PC_1 spectrum from NCEP-2 reanalysis. X-axis is frequencies in cycles per year, y-axis is power times frequency.

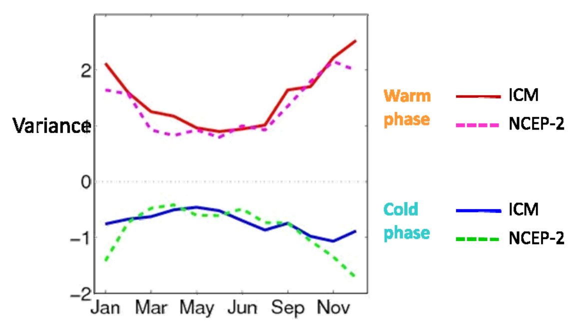

Figure 4. Seasonal variance of warm (red) and cold (blue; shown as negative) phases derived from PC_1 of SST anomalies obtained from CZZ model forced with NCEP-2 SF. The CZZ model is tuned in a weakly stable regime. Also superimposed are the warm (dashed magenta) and cold (dashed green) seasonal variance derived from NCEP-2.

6.2. Simulations using BMRC CGCM SF

In case of BMRC CGCM, several spectral peaks are reproduced at desired frequencies by the CZZ model forced by its SF (Figure 5). As these peaks are not observed when the model is forced with NCEP-2 SF, their source must lie in the BMRC CGCM SF.

Figure 6 shows that SF from the CGCM is unable to reproduce the seasonal changes in variance.

The correlation of simulated PC_1 with observed is largest when then model is tuned in stable regime. Further, PC_1 obtained from MJO forcing is much realistic than non-MJO. As these comparisons also hold in case of NCEP-2, it suggests that the role of SF in the BMRC CGCM is similar to that in reality.

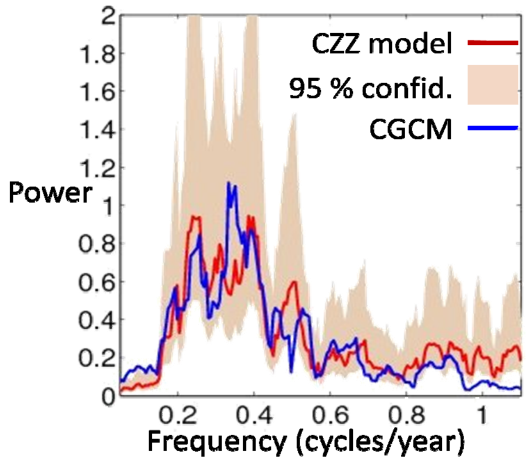

Figure 5. Same as Figure 3 except for BMRC CGCM.

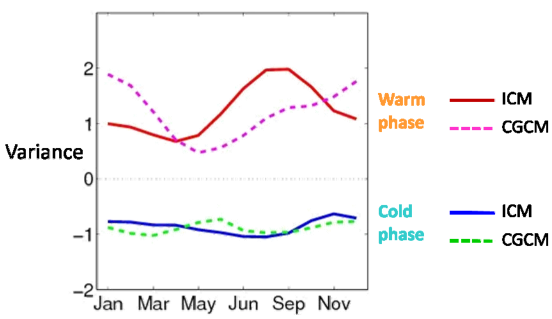

Figure 6. Same as Figure 4 except for BMRC CGCM.

7. CONCLUSIONS

The SF in the BMRC CGCM plays an important role in at least strong El Niño events in a similar way as in the reanalysis. However, the seasonality of ENSO in the BMRC CGCM may not be governed by stochastic components.

The contribution of MJO component of SF in producing desired ENSO statistics appears to be larger than non-MJO. The dynamical regime of the coupled ocean-atmosphere system appears to be weakly stable. The ocean-atmosphere coupling strength in the BMRC CGCM appears to be realistic.

REFERENCES

Mantua, N.J., and D.S. Battisti, 1995: Aperiodic variability in the Zebiak–Cane coupled ocean–atmosphere model: Air–sea interactions in the western equatorial Pacific. *J. Climate*, 8, 2897–2927.

Wu, D.H., D. L. Anderson, and M. K. Davey, 1993: ENSO variability and external impacts. *J. Climate,* 6, 1703–1717.

Zebiak, S.E., and M.A. Cane, 1987: A model El Niño–Southern Oscillation. *Mon. Wea. Rev.*, 115, 2262–2278.

Zhang, C., M. Dong, S. Gualdi, H.H. Hendon, E.D. Maloney, A. Marshall, K.R. Sperber, and W. Wang, 2006: Simulations of the Madden-Julian Oscillation in Four Pairs of Coupled and Uncoupled Global Models. *Clim. Dyn.*, 27, 573–592.

Zhong, A., O. Alves, A. Schiller, F. Tseitkin, and N. Smith, 2004: Results from a preliminary version of ACOM2/BAM coupled seasonal forecast model, *BMRC Research Rep.*, 95, 35pp.