The Importance of High-Frequency Sea-Surface Temperature Variability in the Intraseasonal Oscillation of the Indian Summer Monsoon

1. Introduction

Objective: To determine the influence of high-frequency, observed sea-surface temperatures (SSTs) on the intraseasonal variability of Indian summer monsoon rainfall.

While the Indian summer monsoon exhibits substantial interannual variations, its intraseasonal variability of greater magnitude and hence of critical importance for predictability of monsoon rainfall. This intraseasonal variability comprises a 30–50 day northward-propagating oscillation (NPISO) between “active” and “break” events of enhanced and reduced precipitation over the Indian subcontinent. Convecton in the eastern equatorial Indian Ocean is almost in quadrature with convection over central India (see Klingaman et al. 2007 for a review of salient NPISO features).

Several recent studies have used general circulation models (GCMs) to suggest that while the NPISO is an intrinsically atmospheric mode, atmosphere-ocean coupled processes help to determine its propagation speed and intensity (e.g., Fu et al. 2003; Fu and Wang 2004; Rajendran et al. 2006). These studies found coupled GCMs (CGCMs) to have better representations of the NPISO than atmosphere-only models (AGCMs), due to the former’s ability to reproduce the observed near-quadrature phase relationship between convection and SSTs. Lacking atmosphere-ocean feedbacks, AGCMs too readily initiate (suppress) convection over the warmest (coolest) SSTs. Such studies have forced their AGCMs with SSTs from either a CGCM integration or the NCEP (Reynolds) satellite product, both of which substantially underestimate intraseasonal SST variability in the Indian Ocean.

2. Experiment Design

Objective: To force high-resolution HadAM3 runs with a high-frequency dataset of observed SSTs from the National Center for Ocean Forecasting and the U.K. Met Office.

It is crucial to evaluate the performance of an AGCM forced by observed, high-resolution and high-frequency SSTs. The GODAE High Resolution Sea-Surface Temperature (GHRSST) dataset contains daily-mean SSTs at a resolution of 0.05°; it has far greater intraseasonal variability in the Indian Ocean than either CGCMs or the Reynolds analyses, due to assimilation of satellite-based microwave imager data (Figure 1).

We conducted two ensembles of 30 simulations of HadAM3 at high spatial resolution (1.25°x0.83°). The “Daily” ensemble updates global SSTs each day from GHRSST data, while the “Monthly” ensemble is forced by the monthly means of GHRSST data.

3. Results: Wavelet Analysis

The ensemble-mean wavelet transforms for rainfall in the Bay of Bengal demonstrate that including realistic submonthly SST variability has increased the power in rainfall on intraseasonal timescales in the Daily ensemble (Figure 2). Wavelets of the forcing SSTs in this region suggest that the greatest power in intraseasonal rainfall occurs when significant power exists in the SSTs on similar timescales.

4. Results: Quantifying Intraseasonal Power

The “intraseasonal-power metric” measures the combination of the frequency and intensity of statistically significant (10% level) intraseasonal power in rainfall. When this metric is computed for each ensemble member, a PDF can be constructed for each ensemble (Figure 3). The intraseasonal power in the Daily ensemble strongly resembles the power in the high-resolution (1°x1°) GPCP observations, while the Monthly ensemble is far too weak overall.

5. Results: Individual NPISO Events

Using the intraseasonal-power metric, we can directly compare members from each ensemble with similar variability in rainfall on NPISO timescales. It is not obvious that members with similar values of intraseasonal power should display similar levels of coherence or organization in northward-propagating events. Indeed, members from the Daily ensemble show more-frequent and more-coherent NPISO-like events than counterpart members in the Monthly ensemble with similar amounts of intraseasonal power in rainfall (Figure 4).

6. Summary, Conclusions, Future Work

We have conducted two large ensembles of HadAM3 simulations at high spatial resolution. The sole difference between these ensembles is the SST forcing: the “Daily” ensemble is forced by GHRSST SSTs every day, while the “Monthly” ensemble is forced by the monthly means of the GHRSST dataset.

Our ensembles have demonstrated the importance of submonthly SST variability in not only the strength of the monsoon intraseasonal oscillation (Figures 2 and 3), but also the frequency of intraseasonal convective events, their organization, and their propagation from the equator northwards (Figure 4). This suggests the need for coupled-model studies in which the vertical resolution of the upper ocean has been refined; currently high-frequency SST variability is too weak due to high thermal inertia from coarse vertical resolution.

We plan to conduct further simulations of NPISO-like variability with a version of HadAM3 coupled to a simple mixed-layer ocean model with fine vertical resolution near the surface.

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References


