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The Relationship Between Intraseasonal and Interannual Variability During the Asian Summer Monsoon

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The purpose of this paper is to investigate intraseasonal (30-70 days) and higher frequency (5-30 days) variability and its relationship to interannual variability. Various modelling studies have suggested a link between intraseasonal and interannual variability of the Asian summer monsoon (Palmer 1994, Ferranti et al. 1998, and Webster et al. 1998). This relationship has been mainly based upon the similar spatial structures of the dominant EOF patterns of the monsoon circulation on intraseasonal and interannual time scales from simulations with simple models and atmospheric general circulation models. Here we investigate these relationships using 40 years of NCEP/NCAR Reanalysis. Evaluation of this extended period has the added benefit of improved statistics relative to the 17-year period analyzed by Annamalai et al. (1999). Motivation for this study is embodied in the suggestions of Charney and Shukla (1981) that boundary forcing (e.g., sea surface temperature) may predispose the monsoon system towards a dry or wet state, and the result of Palmer (1994), using the Lorenz (1963) model, that the probability of being in one regime of phase space or another is no longer equally probable in the presence of external forcing.

EOF analysis of June-September (JJAS) daily 850hPa wind (after removal of the climatological daily values) for the period 1958-97 results in the dominant spatial patterns seen in Figs. 1a-c. EOF-1 is related to the active/break cycle of convection on intraseasonal time scales over the Asian summer monsoon region. During the active phase (positive PC-1 loadings) enhanced convection is found between 5^{o}N-20^{o}N, extending from India into the western Pacific Ocean, while to the south, over the Indian Ocean, convection is suppressed (not shown). Conversely, breaks in the monsoon over the continental latitudes occur in conjunction with weakened monsoon circulation (negative PC-1 loadings). EOF-2, which also varies on intraseasonal time scales, and it has a similar spatial structure to EOF-1, being displaced relatively southward. Similarly, the active vs. break composite rainfall from PC-2 is displaced southward relative to that from PC-1, further suggesting that these two modes describe the northward propagation of the active/break cycle of Asian summer monsoon rainfall. EOF-3, which is dominated by time scales of 6-20 days, is primarily associated with a cyclonic/anticyclonic couplet over India, which corresponds to enhanced rainfall over the Arabian Sea, India and the Bay of Bengal, and below normal rainfall to the south of the subcontinent when PC-3 is positive. The anticyclonic circulation east of China is associated with below normal rainfall when PC-3 is positive. These modes extracted from the low-level flow are very robust, also being found in an analysis of NCEP/NCAR and ECMWF Reanalyses for the period 1979-95.

To investigate the influence of the boundary forcing, the probability distribution functions (PDF's) of the principal components are given in Figs. 1d-f. Shown are the PDF's for all years, and for El Niño and La Niña years (years when the JJAS averaged NINO3 SST anomalies are 0.5 and ≤ -0.5 standard deviations respectively). The ENSO boundary forcing has a systematic influence on PC-2 (Fig. 1e). During El Niño years, PC-2 is biased towards negative loadings which correspond to anticyclonic circulation and drier conditions in the vicinity of northern India, the Bay of Bengal, and southeast of China. Conversely, for this mode of variability, these regions are pre-disposed towards cyclonic conditions and are wetter during La Niña years. Significance testing indicates that the mean of the La Niña PDF is greater than the mean of the El Niño PDF with 97.5% confidence (single-sided t-test). As seen in Figs. 1d-f, the PDF's are approximately normally distributed, with the perturbation in PC-2 being manifested as shift in the mean of the distribution. This contradicts the results from simple models which suggest the boundary perturbations result in a bimodal distribution.

Of course it is the interactions of the different modes of variability that are important in determining the overall performance of the monsoon. A random bias to one of the other subseasonal modes during a given ENSO event might either exacerbate or counteract the systematic influence of EOF-2/PC-2. This, coupled with the small percentage variance explained by EOF-2/PC-2, is indicative of the complexity of the monsoon system, and the difficulty that arises in its seasonal prediction.

While the power spectra of the modes presented in Fig. 1 are dominated by subseasonal time scales (not shown), the variations are nevertheless superimposed upon interannual variations associated with the slowly varying boundary conditions due to a changing basic state, since the data employed have not been filtered (other than to remove the climatological daily values). It is the influence of the changing basic state that is responsible for the change in the mean of the PDF of PC-2. This is confirmed by an EOF analysis of the same data subsequent to application of highpass filter that isolates time scales <100 days. The filtered data do not exhibit systematic perturbations to the PDF's for El Niño versus La Niña years (not shown). Thus, it is the background state that results in the predisposition of the monsoon system towards one regime or another.

A more comprehensive manuscript describing this work is in preparation.

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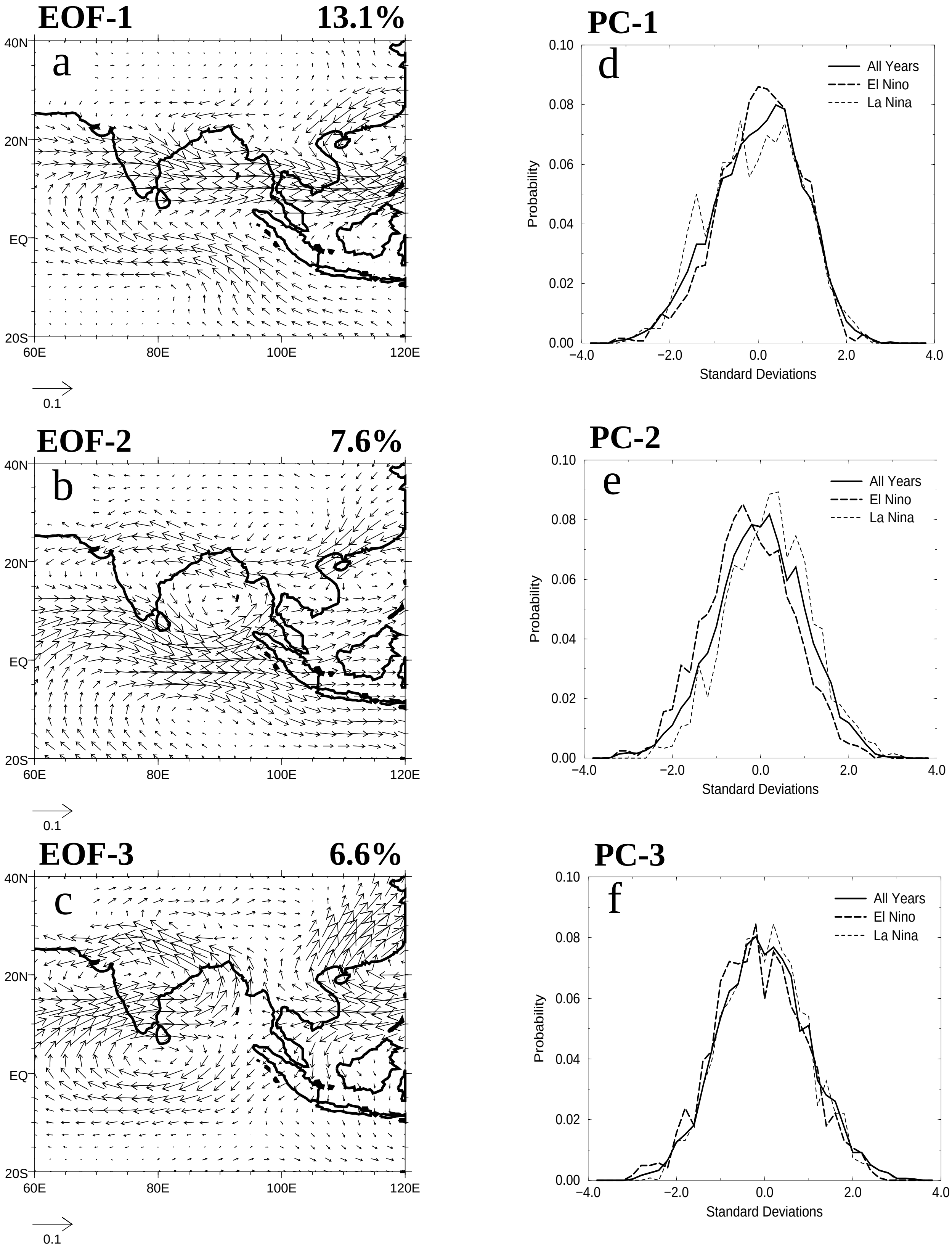

Figure 1. (a-c) are the first three EOF's of June-September daily 850hPa winds for 1958-97 from NCEP/NCAR Reanalysis. (d-f) are the probability distribution functions (PDF's) of the principal components for each EOF. Also included are the PDF's for El Niño and La Niña years.