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PREPRINT

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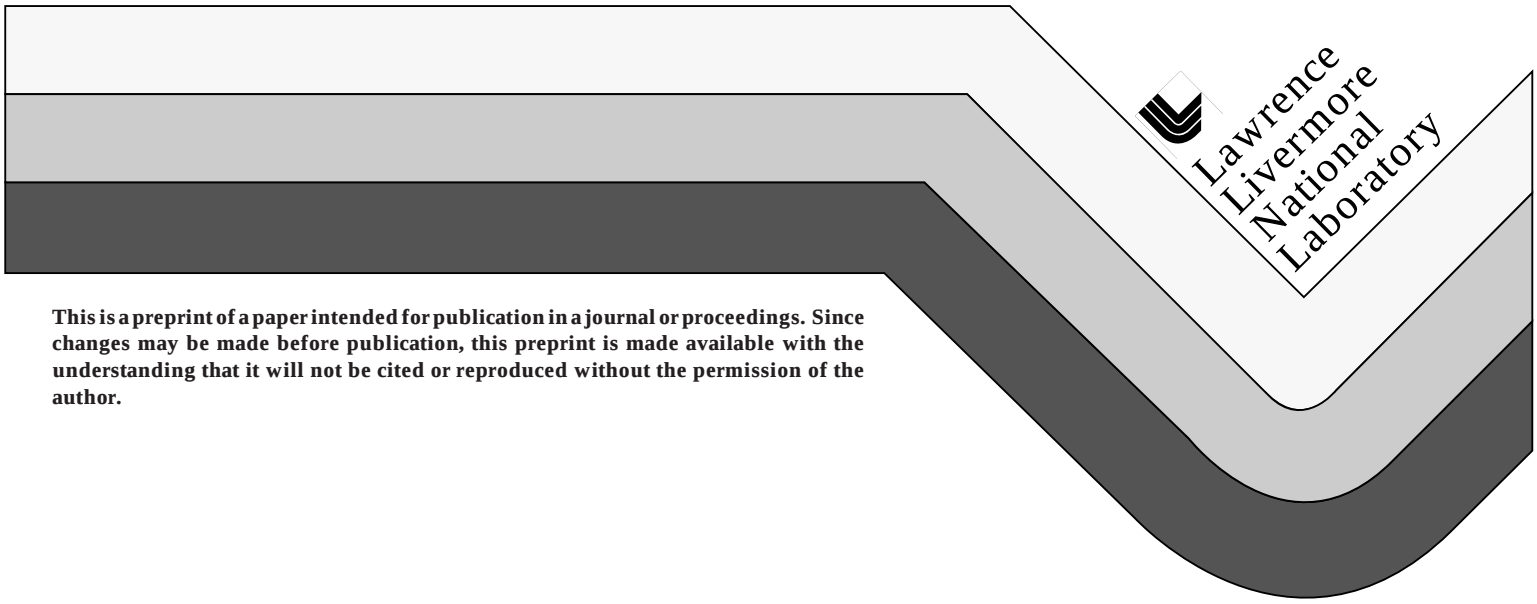

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Interannual/Decadal Variability in MJO Activity as Diagnosed in the 40-Year NCEP/NCAR Reanalysis and Simulated in an Ensemble of GISST Integrations

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The Madden-Julian Oscillation (MJO) is the dominant mode of tropical variability at intraseasonal timescales. It displays substantial interannual variability in intensity which may have important implications for the predictability of the coupled system. The reasons for this interannual variability are not understood. The interannual behaviour of the MJO has been diagnosed initially in the 40-year NCEP/NCAR Reanalysis by calculating the variance of the 20-100 day filtered zonal mean zonal wind (10^oN-10^oS averaged) in a 100-day moving window (Fig. 1a). The results suggest that prior to the mid-1970s the activity of the MJO was consistently lower than during the latter part of the record. This may be related to either inadequacies in the data coverage, particularly over the tropical Indian Ocean prior to the introduction of satellite observations, or to the real effects of a decadal timescale warming in the tropical SSTs (Fig. 1b). This interdecadal trend is captured by the dominant EOF (explaining 28% of the variance) of the monthly mean SSTs (after removal of the mean seasonal cycle), as used in the NCEP/NCAR Reanalysis for the region of the tropics where the MJO is convectively active (i.e., 60^oE-180^o E, 20^oS-20^oN). During the latter part of 1970's there was an abrupt change from a predominantly negative PC1 (i.e. colder Indian Ocean) to a positive PC1 (i.e. warmer Indian Ocean), indicative of a general warming of the tropical Indian Ocean by at least 0.5^oK over the last 40 years. However, on interannual timescales, the teleconnection patterns between MJO activity and SST show only a weak, barely significant, influence of El Niño in which the MJO is more active during the cold phase.

As well as the NCEP/NCAR Reanalysis, a 4-member ensemble of 45 year integrations with the Hadley Centre climate model (HADAM2a), forced by observed SSTs for 1949-93, has been used to investigate the relationship between MJO activity and SST. HADAM2a is known to give a reasonable simulation of the MJO, and the extended record provided by this ensemble of integrations allows a more robust investigation of the predictability of MJO activity than was possible with the 40-year NCEP/NCAR Reanalysis. The results have shown that, for the uncoupled system, with the atmosphere being driven by imposed SSTs, there is no reproducibility of the activity of the MJO from year to year. The interannual behaviour of the MJO is not controlled by the phase of El Niño and would appear to be mainly chaotic in character. However, as seen in Table 1, the model results have confirmed the low frequency, interdecadal timescale variability of MJO activity seen in the NCEP/NCAR Reanalysis. The activity of the MJO is consistently lower in all realisations prior to the mid 1970s, suggesting that the MJO may become more active as tropical SSTs become warmer. This result may have implications for the effects of global warming on the coupled atmosphere-ocean system.

The implications of these results for the predictability of the tropical ocean-atmosphere system are important since intraseasonal activity in the atmosphere, associated with MJO's and westerly wind bursts, can have a substantial impact on the Pacific Ocean. As the events in 1997 indicate, MJO activity may have a significant impact on the magnitude and growth rate of El Niño events. In turn the decadal changes in MJO activity suggest that if tropical SSTs continue to warm, the activity of the MJO may tend to increase which then might have implications for the future behaviour of El Niño. This work is presented in full by Slingo et al. (1999, Quart. J. Roy. Meteorol. Soc., in press).

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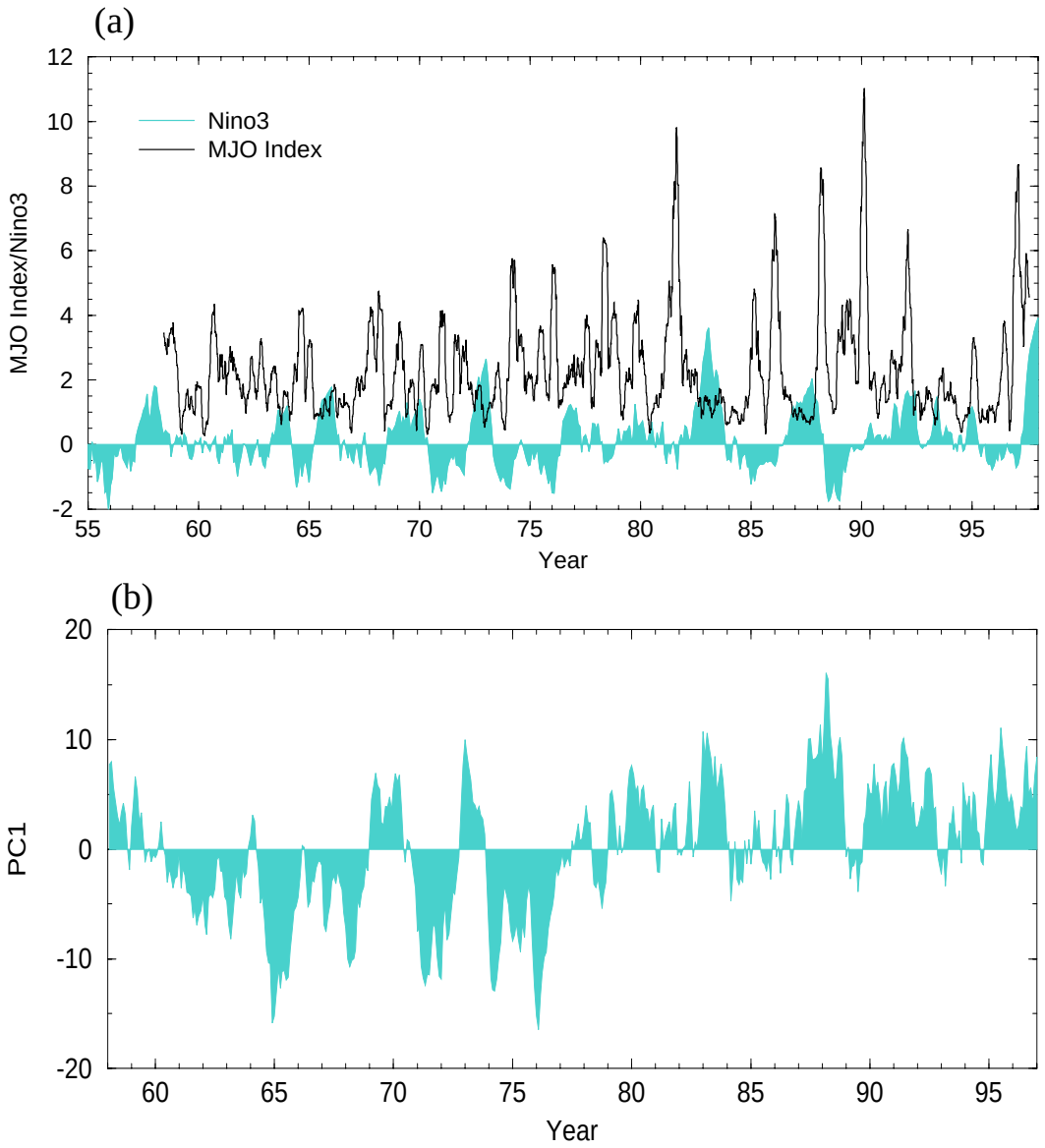

Fig. 1 (a) The MJO index from the NCEP/NCAR reanalysis (solid line) is compared with NINO3 SST variability (filled time series); (b) first principal component of seasonally detrended SST for the region 60^{o}E-180^{o}E, 20^{o}S-20^{o}N. The first mode explains 28% of the total SST variability, indicating a warming of the tropical Indian Ocean of at least 0.5^{o}K over the last 40 years.

Table 1: Mean MJO index for all months, for the years shown. Values in parentheses are for the period of overlap between the NCEP/NCAR Reanalysis and the model integrations.

Realisation	1	2	3	4	NCEP
1950(59)-92	1.80 (1.85)	1.95 (1.98)	1.91 (2.02)	1.80 (1.75)	(2.30)
1950(59)-76	1.68 (1.73)	1.81 (1.79)	1.65 (1.74)	1.67 (1.51)	(2.05)
1977-92	2.00	2.19	2.34	2.02	2.60