Mechanisms of variability and predictability of the tropical coupled ocean-atmosphere system

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Abstract. A conceptual model is proposed to explain the observed aperiodicity in the short term climate fluctuations of the tropical coupled ocean–atmosphere system. This is based on the evidence presented here that the tropical coupled ocean-atmosphere system sustains a low frequency inter-annual mode and a host of higher frequency intra-seasonal unstable modes. At long wavelengths, the low frequency mode is dominant while at short wavelengths, the high frequency modes are dominant resulting in the co-existence of a long wave low frequency mode with some short wave intra-seasonal modes in the tropical coupled system. It is argued that due to its long wavelength, the low frequency mode would behave like a linear oscillator while the higher frequency short wave modes would be nonlinear. The conceptual model envisages that an interaction between the low frequency linear oscillator and the high frequency nonlinear oscillations results in the observed aperiodicity of the tropical coupled system. This is illustrated by representing the higher frequency intra-seasonal oscillations by a nonlinear low order model which is then coupled to a linear oscillator with a periodicity of four years. The physical mechanism resulting in the aperiodicity in the low frequency oscillations and implications of these results on the predictability of the coupled system are discussed.

Keywords. Aperiodicity; inter-annual variability; tropical coupled ocean-atmosphere system; predictability; convergence feedback; multiple periodic attractors; low frequency oscillator; non linear intra-seasonal modes.

1. Introduction

The short term climate in the tropics is dominated by the El Nino and Southern Oscillation (ENSO), an irregularly fluctuating inter-annual phenomenon. These fluctuations are associated with large scale climatic anomalies such as devastating droughts in western Pacific, torrential floods over eastern tropical Pacific and damaging weather patterns over other parts of the world such as north America. Therefore, ability to predict these climatic fluctuations has tremendous socio-economic impact. During the last decade or so, it has been well established that the tropical atmosphere and the ocean interact strongly in time scales longer than a season and that the ENSO is a result of such interactions between the atmosphere and the ocean (see Philander 1990 for a review).

For time scales in which the atmosphere can be considered in isolation, the predictability of the atmosphere has been studied extensively (e.g. Shukla 1985 for a review). It has been shown that there exists a limit on the predictability of the instantaneous state of the atmosphere. This limit, which happens to be between two to three weeks, depends on the internal dynamics (nonlinearity, instability etc.) and external forcing in the system. While, it may be impossible to predict the day to day
fluctuations of the weather beyond a few weeks, the averages or climatic conditions of the atmosphere may be more predictable. It has been argued (Charney and Shukla 1981; Shukla 1981) that the mean fields in the tropics may be more predictable compared to those in the extratropics as slowly varying boundary conditions (such as the SST, soil moisture, vegetation cover etc.) introduce a slowly varying component to the forcing of the tropical atmosphere. Thus, a conceptual basis for tropical climate

![Graph](image_url)

**Figure 1.** Monthly mean time series of (a) a classical index of Southern Oscillation i.e. the pressure difference between Easter Island and Darwin in mb, (b) sea surface temperature anomalies in the eastern equatorial Pacific region $T_{\text{SEP}}^{20^\circ \text{S}-20^\circ \text{N, 80 W}-180 \text{W}}$ in °C. The thick line in (a) represents a 12-month running mean and in (b) the thick line is a 15-month weighted average.