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Dynamics of the Asian summer monsoon

Nonlinearity of intraseasonal variability via spherical PDFs

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1 Introduction

The Asian summer monsoon (ASM) exhibits wide spectrum of variability. In particular, monsoon intraseasnal variability (MISV) is highly complex. MISV undergoes periods of enhanced and reduced rainfall, known as active and break phases. Predictability of MISV is limited and the relationship with large-scale forcing is still unclear [1, 2]. A possible paradigm for MISV is that of a system with chaotic fluctuations between monsoon phases [3], and that large scale acts to increase the likelihood of one regime at the expense of the other [3, 4]. Here we investigate the hypothesis of regime-like behaviour of MISV and the role of large-scale flow in the probability of occurrence of possible nonlinear regimes. Trend variability of MISV before and after 1980 is also discussed.

2 Data & Methods

Data used:

- ECMWF reanalysis *ERA-40* [5]: daily JJAS SLP 1958 - 2001, 2.5° Gaussian grid, area: 20°S - 35°N, 50° - 150° E
- *NINO3* index [6]: seasonal JJAS mean 1958 - 2001
- Webster - Young monsoon index *(WY)* [7]: seasonal JJAS mean 1958 - 2001
- All - India rainfall index *(AIR)* [8]: JJAS mean 1958 - 2001

Methods:

- Empirical Orthogonal Functions (3 EOFs) as in [9]
- Transform Principal Components (PCs) to spherical coordinates
- Spherical Probability Density Function (PDF) [10]
- Composite analysis

3.1 Results: PDF and Preferred regimes

Spherical PDF of MISV SLP anomalies is shown in Fig. 1.

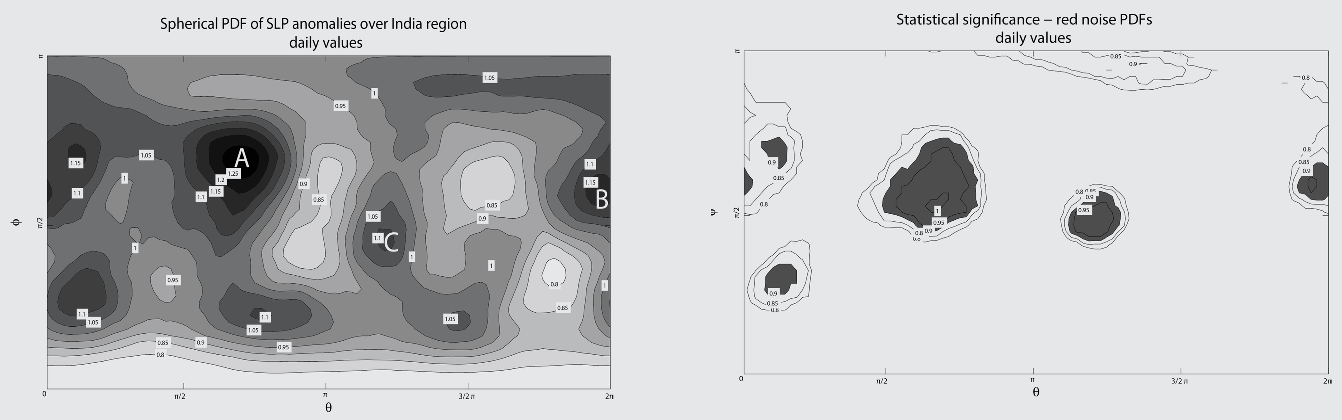
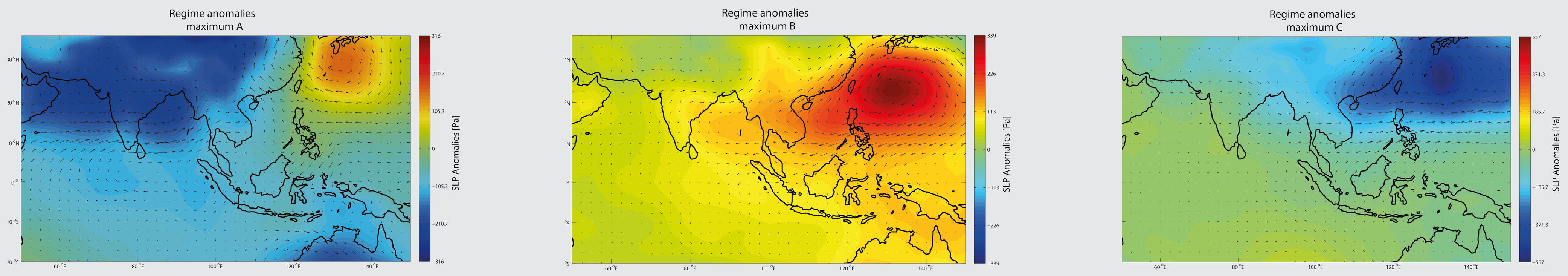


Fig. 1: The left side shows spherical PDF of daily values of MISV SLP anomalies in a reduced phase space. Each data point was divided by the constant probability density of a Gaussian. The letters A - E indicate five maxima in the PDF. The right shows a regions with significantly increased probability compared to a Gaussian.

Three robust and significant maxima (modes) are obtained (A, B and C). They are shown in Fig. 2. Maxima B and C have opposite patterns with centre of variability over East China sea. Mode B has also strenghtened Westerlies which weaken the Somali Jet (contributing to the break event), while mode C has Easterlies which do not affect the Somali Jet. Mode A has twin centres - one over East China sea and second one over Himalayas. Overall result would be that patterns A and C are associated with an active monsoon phase, while pattern B is associated with break monsoon phase.



A - active monsoon phase B - break monsoon phase C - China sea active phase

Fig. 2: Composites of SLP & 850 hPa wind anomalies associated with the PDF modes.

3.2 Results: Large scale forcing and Trend analysis

To determine the relationship with large scale, the PCs were stratified according to large amplitudes of *AIR*, *NINO3* and *WY* indices. The associated PDFs are shown in Fig. 3 and the patterns are shown in Fig. 4. As expected, *AIR+* regime is associated with the active phase, while *AIR-* is associated with the break phase. During El Niño (*NINO+* regime) the break phase is more likely to occur, while during La Niña (*NINO-*) the active phases are more likely. Finally, there exist a relationship between seasonal mean (*WY* index) and its intraseasonal behavior: *WY-* leads to the break phase, while *WY+* leads to the active phase.

For the trend variability, we applied the same method to the 1958 - 1979 and 1980 - 2001 periods. Two modes are obtained in each period. The composite analysis suggests, that the break phases after 1980 were stronger and the active phases were weaker as can be seen in Fig. 5. Also, the PDFs suggest that after 1980 the active phases were less probable.

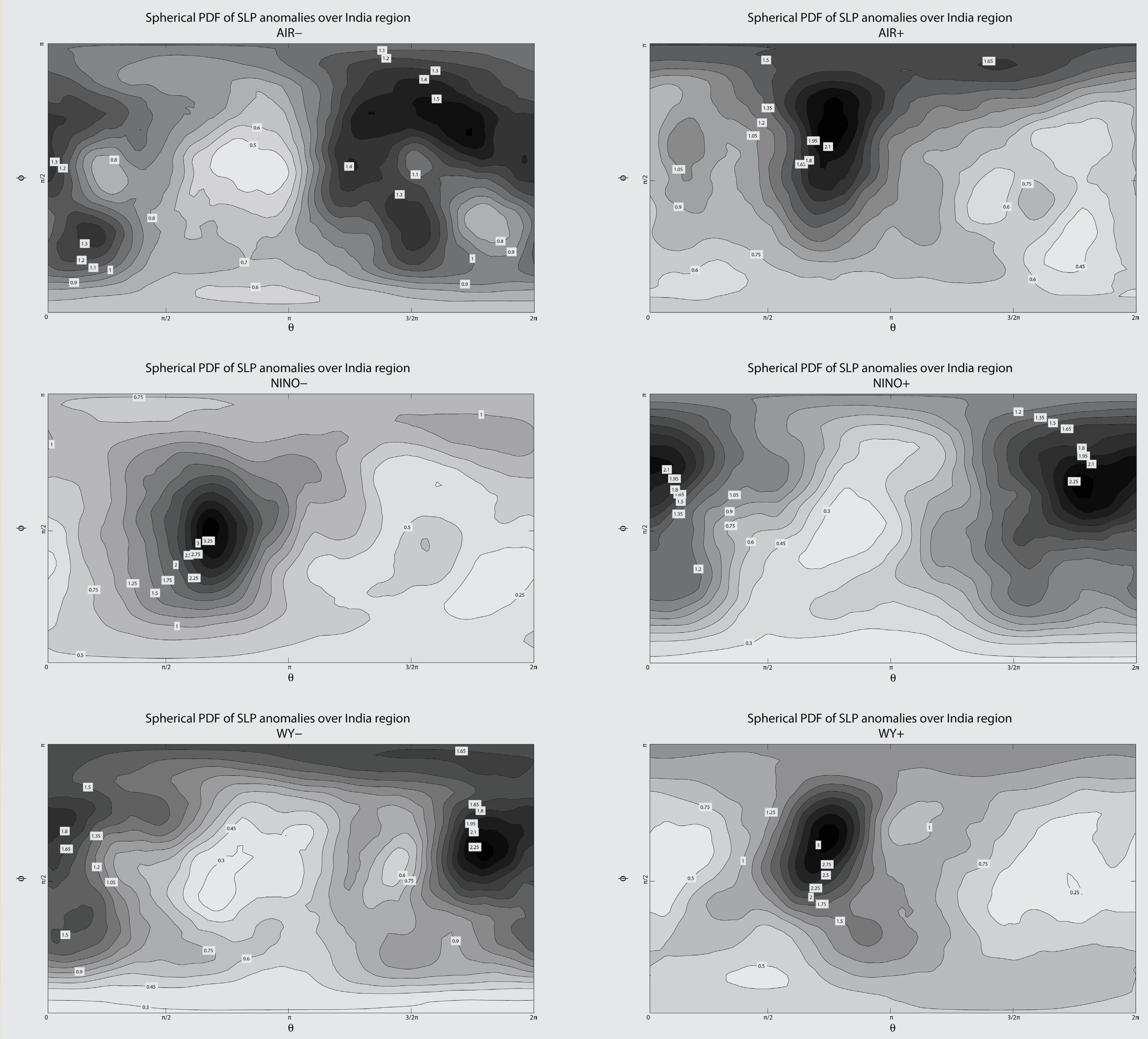


Fig. 3: Spherical PDF of stratified daily values according to different large scale forced regimes. On the left side are - regimes, on the right side are + regimes. First row is *AIR*, second row is *NINO* and last row is *WY*.

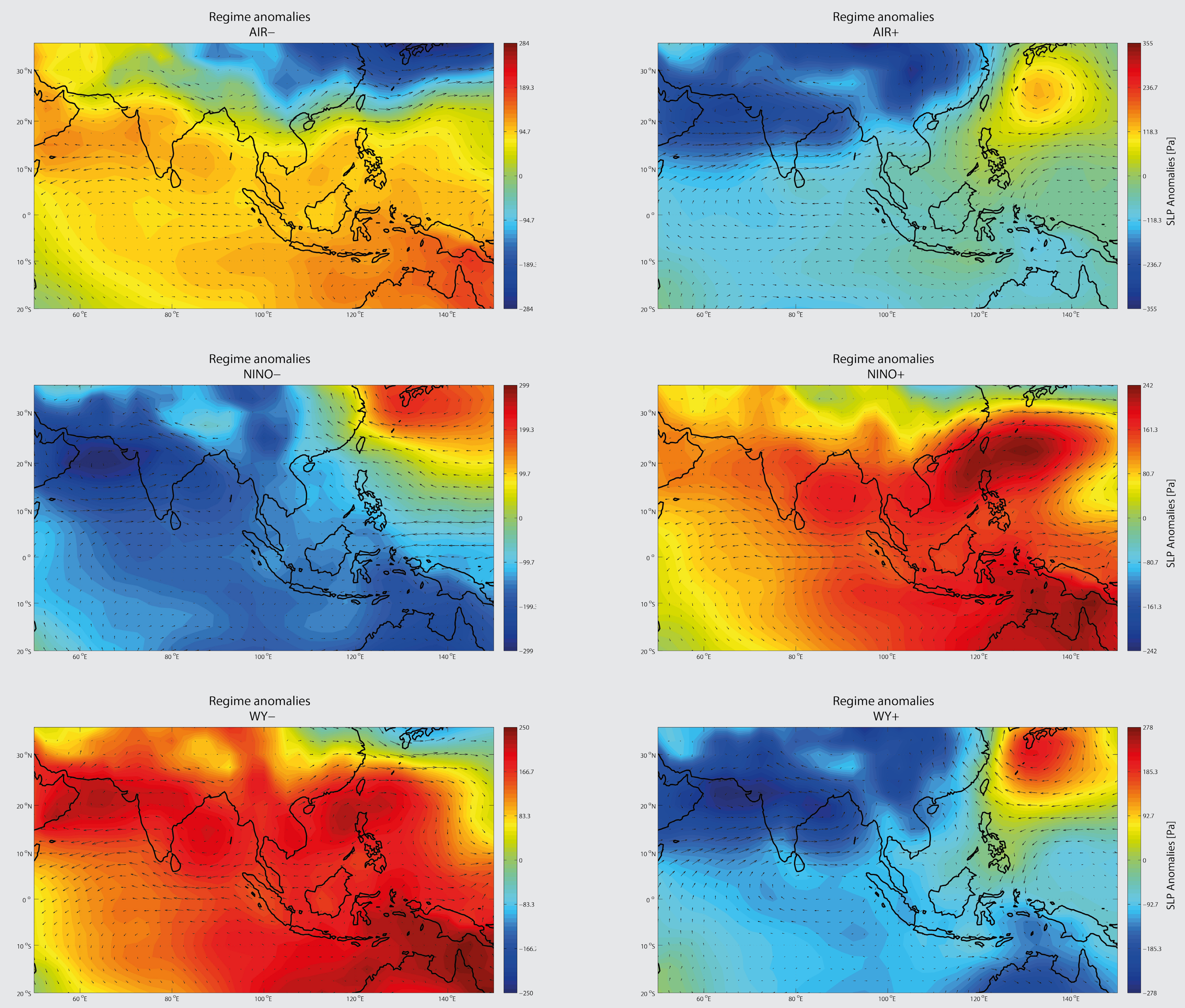


Fig. 4: Regime anomalies corresponding to different large scale forced regimes. On the left side are - regimes, on the right side are + regime. First row is *AIR*, second row is *NINO* and last row is *WY*. Shown are SLP anomalies with 850hPa wind anomalies.

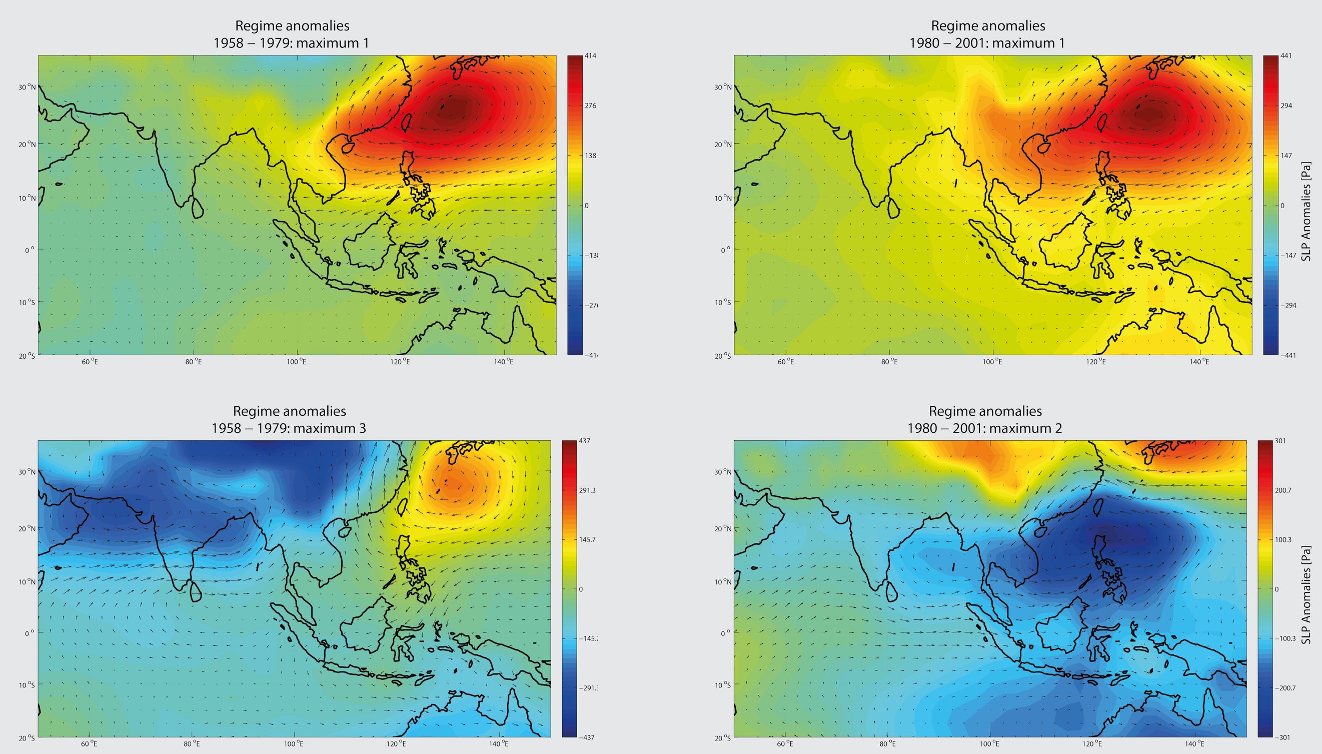


Fig. 5: Regime anomalies corresponding to two maxima in the PDF for two periods. On the left are plots of the first period 1958 - 1979, on the right are plots of the second period 1980 - 2001. Shown are SLP anomalies with 850hPa wind anomalies.

4 Summary & Conclusions

In the PDF for the whole period, three robust and significant maxima were found and associated modes can be seen in Fig. 2. The issues of trend was investigated by dividing the data set into two periods and the same analysis was used to obtained two robust maxima, which are a bit different each period (Fig. 3). Trend analysis suggests that the break events are stronger and the active events are weaker after 1980. Finally, the relationship with the large scale was investigated and the most probable modes in each regime can be seen in Fig. 4, where *AIR+*, *NINO-* and *WY+* regimes lead to the active event and *AIR-*, *NINO+* and *WY-* regimes lead to the break event. This results correspond with Palmer's conceptual ideas [3, 11] that the regime could change the frequency under forcing changes in a chaotic system and that the large scale effects probability of occurence of the intraseasonal monsoon phases.

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