Is there regime behaviour in monsoon convection in the late 20th century?

A G Turner & A Hannachi

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
Walker INSTITUTE
University of Reading

Introduction

Large-scale drivers of the seasonal mean Asian summer monsoon are relatively well understood through low frequency variations in lower boundary forcing (*e.g.*, ENSO, IOD).

Relationships between modes of intraseasonal variability (ISV; "active" and "break" events) and the overall seasonal mean are unclear, however.

Palmer (1994) envisaged a chaotic Lorenz model in which the probability of lying in the active or break regimes is influenced by the large-scale forcing.

Sperber *et al.* (2000) showed that in general, anomalous monsoons were not associated with changes in weather regimes, although a small subset of ISV modes could be perturbed.

Other authors such as Krishnamurthy and Shukla (2000) suggest that seasonal mean rainfall is the sum of a large-scale forced component and the (inherently unpredictable) statistics of ISV behaviour through the season.

In this study we use mixture model techniques to examine the existence of regimes of monsoon convection and their interaction with the large-scale.

Methodology

A daily index of monsoon convection over South and Southeast Asia is generated by projecting the daily OLR timeseries from ERA-40 reanalysis over the monsoon domain onto the leading mode of monthly convection (Fig 1a). This mode explains 24% variance and illustrates the dominance of convection over the South Asian and Western North Pacific (WNP) monsoon regions.

The overall distribution function of the daily index (Fig 1b) has significant negative skewness (-0.3) suggesting bimodality and supporting regime behaviour.

Mixture models are constructed using Gaussian components (see Hannachi & Turner, 2008; Woollings *et al.*, 2010 for details). These are shown to support only two significant regimes (Fig1b-d).

When subsets of the same daily OLR index are generated from a circulation index over the western north Pacific (Wang & Fan, 1999; Wang *et al.*, 2001), the decomposition appears qualitatively similar (not shown).

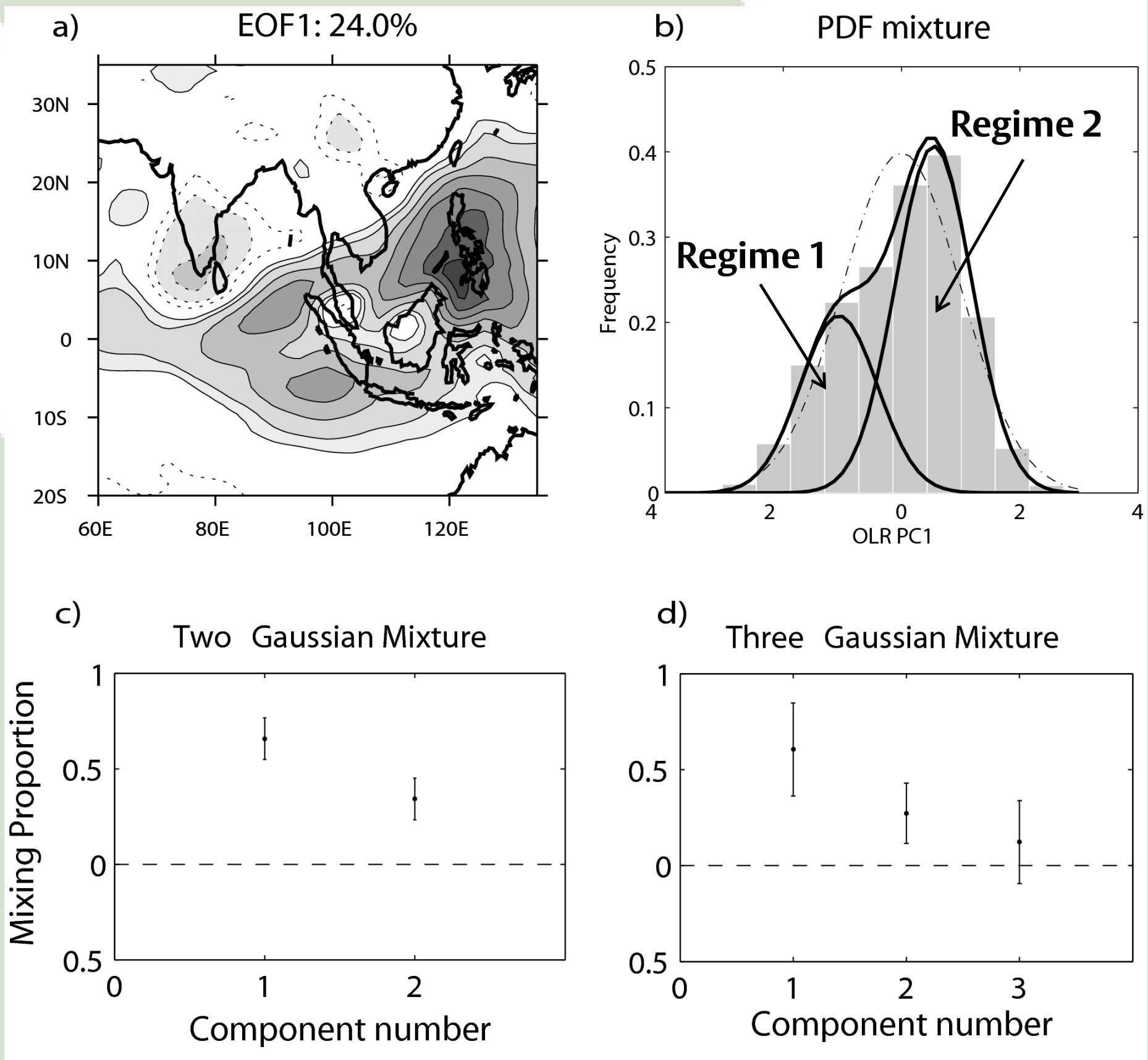

Fig 1a: EOF1 in monthly OLR during JJAS 1958–2001 of ERA-40 data, explaining 24% of variance.
Fig 1b: PDFs of the daily OLR index (upper curve) and its decomposition into a 2-component Gaussian mixture (lower curves). A normal fit is also shown.
Fig 1c-d: Mixing proportions of 2- and 3-component Gaussian mixtures indicate that only two regimes are supported at 1% significance.

Trends in the observed record

Possible trends in the observed record are examined by recalculating the mixture model during early (1958–1975, prior to the late 1970s climate shift) and later parts of the timeseries (1979–2001). Composite fields are generated for each regime from the mixing weights, for the whole period and each subset.

Regime 1 (Fig 2a, top) shows reduced convection and anticyclonic anomalies over the western north Pacific, with decreased OLR over southern India. This is reversed in regime 2 (Fig 2a, bottom), which also shows southward deviation of the Somali Jet over southern peninsular India. In simple terms these regimes can be associated with active and break conditions over India respectively.

Since the late 1970s regime 1 becomes less frequent while regime 2 becomes more populated (Fig 3). The change in weighted composites (Fig 2b) underlines the general weakening of regime 2 at a broad scale, while regime 1 suggests more intense active periods over India.

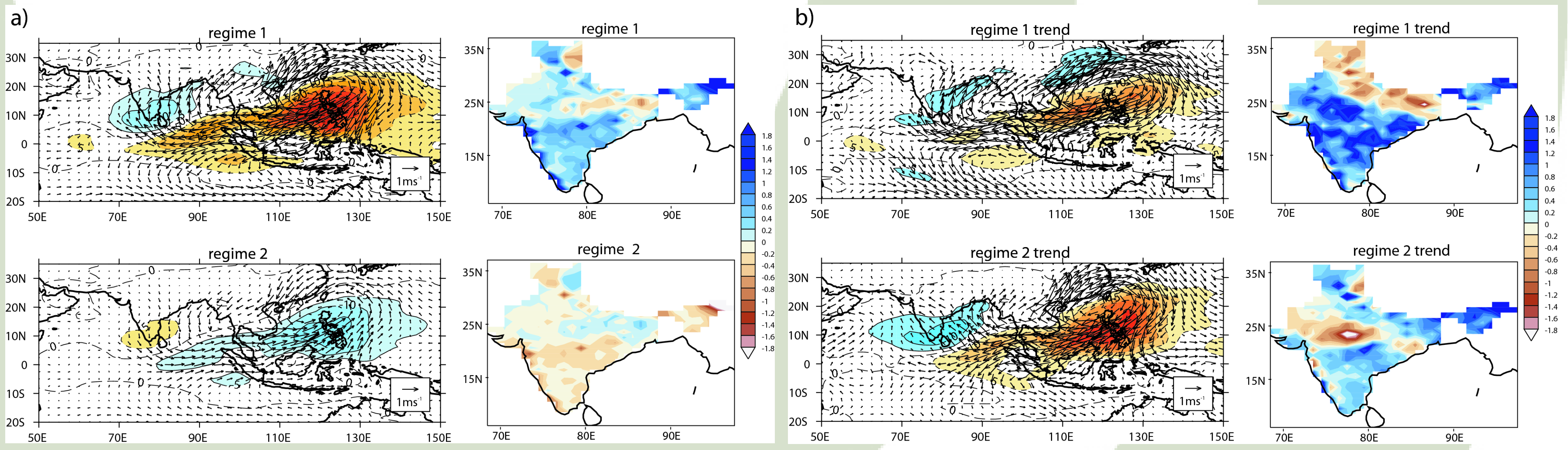

Fig 2a: Weighted composites of 850hPa wind, OLR (source: ERA-40) and Indian precipitation (source: IMD 1°-gridded product) anomalies during the first and second regimes of the 1958–2001 period.
Fig2b: Trends in regime composites from the early (1958–1975) to later (1979–2001) periods.
In both cases, positive (negative) OLR anomalies are red (blue).

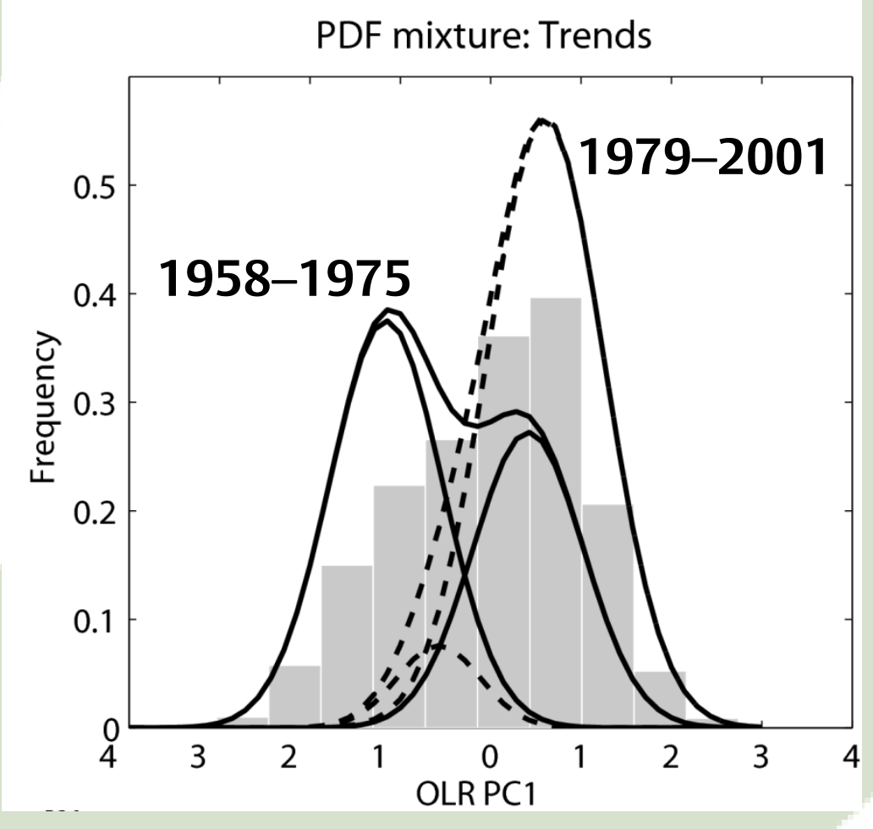

Fig 3: Comparison of Gaussian mixtures during the early (solid) and later (dashed) parts of the 1958-2001 reanalysis period.

Relationship with the large scale

To determine if large-scale conditions can aid predictability of regimes of intraseasonal convection, we stratify the timeseries according to the dynamical monsoon index (DMI, Webster & Yang 1992).

Fig 4 shows the dramatic impact of the large scale monsoon behaviour. Under DMI+ conditions, both regimes are approximately equally likely, whereas under DMI- conditions, the second regime (representing break events over India) becomes much more frequent.

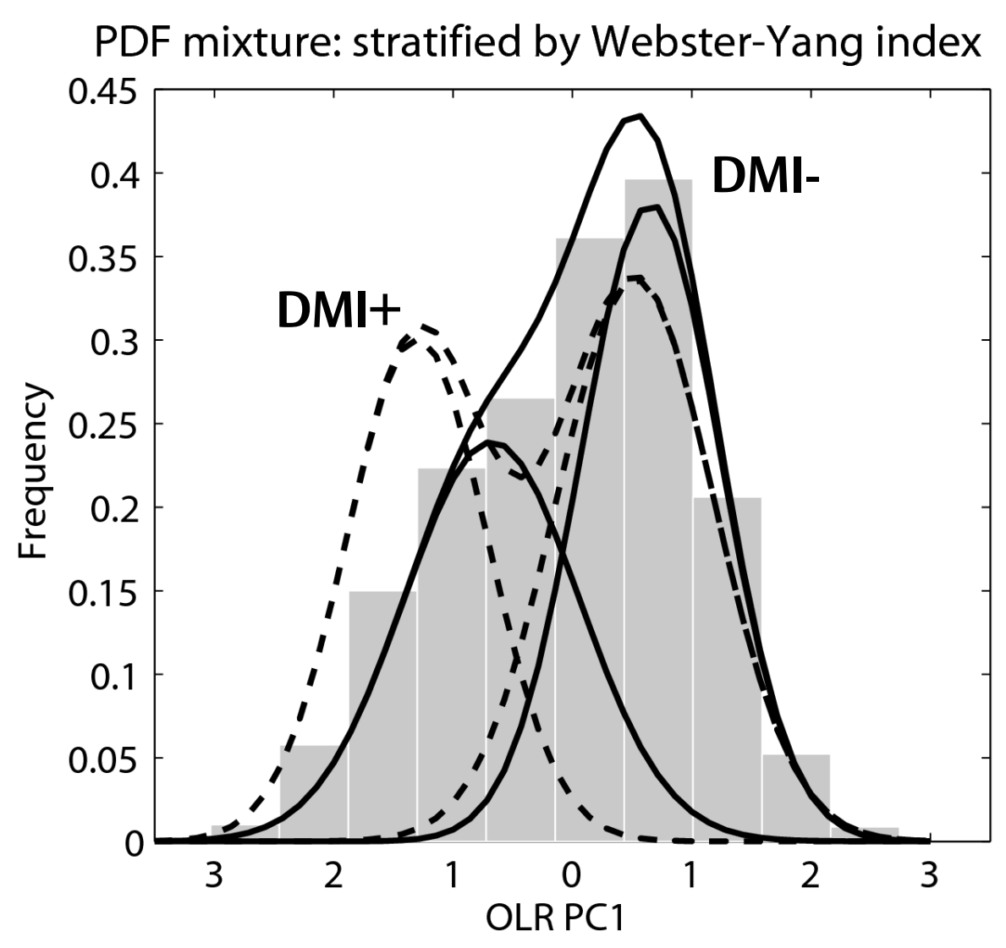

Fig 4: Perturbations to the whole period Gaussian mixture in Fig 1 based on the large-scale dynamical monsoon index during strong (DMI+, dashed) and weak (DMI-, solid) monsoon summers.

Conclusions and further work

- **This work suggests that Gaussian mixture models may be used to explore active and break regimes of convection in monsoon intraseasonal variability.**
- **Trends in regime behaviour are identified in the recent observed record using ERA-40 reanalysis data.**
- **We show evidence for perturbation to the Gaussian mixtures by the large scale, suggesting an inherent relationship between intraseasonal and interannual scales as hypothesized by Palmer (1994) and Sperber *et al.* (2000).**
- **This technique will be used with a more refined monsoon index to examine predictability issues and identify regime behaviour in centennial scale coupled model integrations.**

References Turner, AG & A Hannachi (2010, this work) *GRL* **submitted**. || Hannachi, A & AG Turner (2008) *QJRMS* **134**: 469—480. || Krishnamurthy, V & J Shukla (2000) *J. Clim*. **13**: 4366—4377. || Palmer, T (1994) *Proc. Indian Natn. Acad. Sci*. **60**: 57—66. || Sperber, KR & H Annamalai (2008) *Clim. Dyn*. **31**: 345—372. || Sperber, KR, JM Slingo & H Annamalai (2000) *QJRMS***126**: 2545—2574. || Webster, PJ & S Yang (1992) *QJRMS* **118**: 877—926. || Wang, B & Z Fan (1999) *BAMS* **80**: 629–638. || Wang, B, R Wu & K-M Lau (2001) *J. Clim*. **14**: 4073–4090. || Woollings, T, A Hannachi, B Hoskins & A Turner (2010) *J. Clim*. **23**: 1291—1307.

E: a.g.turner@reading.ac.uk
T: +44 118 378 6517
F: +44 118 378 8905

Department of Meteorology
University of Reading
Reading RG6 6BB, UK