‘Internal’ Indian Monsoon variability arising from interactions between seasonal mean and Intrasesonal Oscillations

Suhas. E *and B.N.Goswami*
Indian Institute of Tropical Meteorology
Dr. Homi Bhabha Road, Pashan,Pune-
411008

Introduction

- ISO represents the dominant mode of variability in the Tropics (Waliser 2006).
- Hence it may play a significant role in modulating the seasonal mean and cause internally generated Interannual and Interdecadal variability.

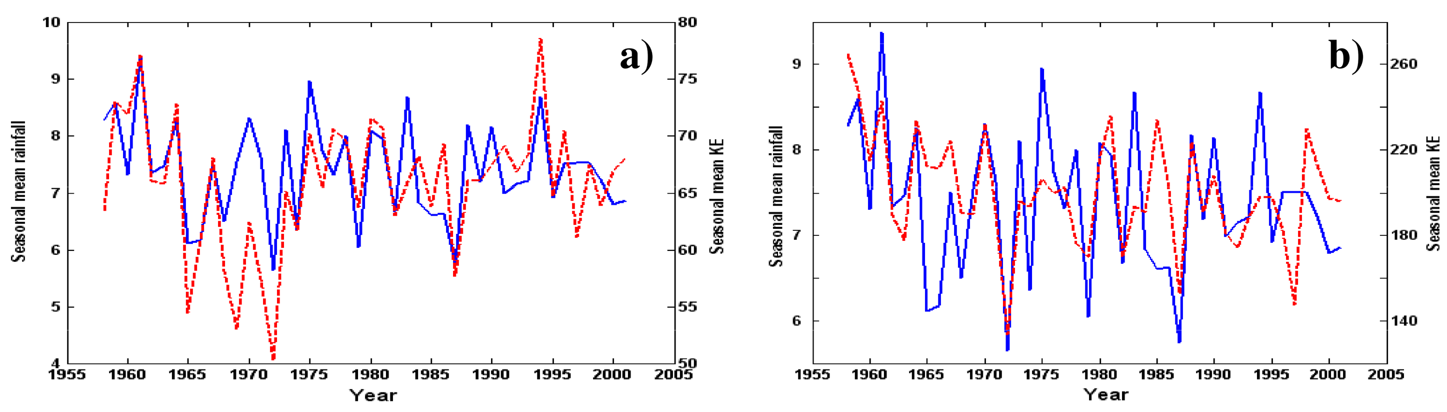
However , *the physical mechanism through which the ISOs affect the seasonal mean remains elusive*.

- ISO and seasonal mean represent two different scales. Communication between scales take place through the exchange of energy, momentum and fluxes.
- The exchange of KE between Seasonal mean and ISO scales may represent the interaction between these scales.
- A method for estimating the growth (decay) of KE of a given scale from observed data was formulated by Saltzman (1957).

The objective of this study is to bring out the physical mechanism between ISO-seaonal mean interaction and quantify the interannual and interdecadal variability of ISM arising due to this interaction.

Relationship between and seasonal mean ISM rainfall and seasonal mean KE of LLJ and TEJ

Figure-1



The IAV of seasonal mean KE of LLJ and TEJ are closely linked with the IAV of ISM seasonal mean rainfall.

Hence, the KE of LLJ and TEJ may be important parameters to study the interaction between ISO and seasonal mean time scales.

Methodology

The KE exchange between seasonal mean and ISO scales over TEJ and LLJ domains were estimated using the method originally proposed by Saltzman(1957).

Different spatial scales were separated by Fourier transforming the primitive equations of motions in spherical co-ordinate. It was simplified by Hayashi (1980) using cross spectral technique which can be used in both wavenumber and frequency domain.

The growth (decay)of KE of a given scale involves three different physical processes.

1) the transfer of KE to the scale of frequency (wavenumber) ‘n’ from couple of other frequencies (wavenumbers) ‘m’ and ‘p’.
2) the growth (decay) of KE of a given frequency (wavenumber) ’ n’ when it interacts with the time mean (zonal mean).
3) the growth (decay) of KE of a given frequency (wavenumber) from the eddy available potential energy at the same scale.

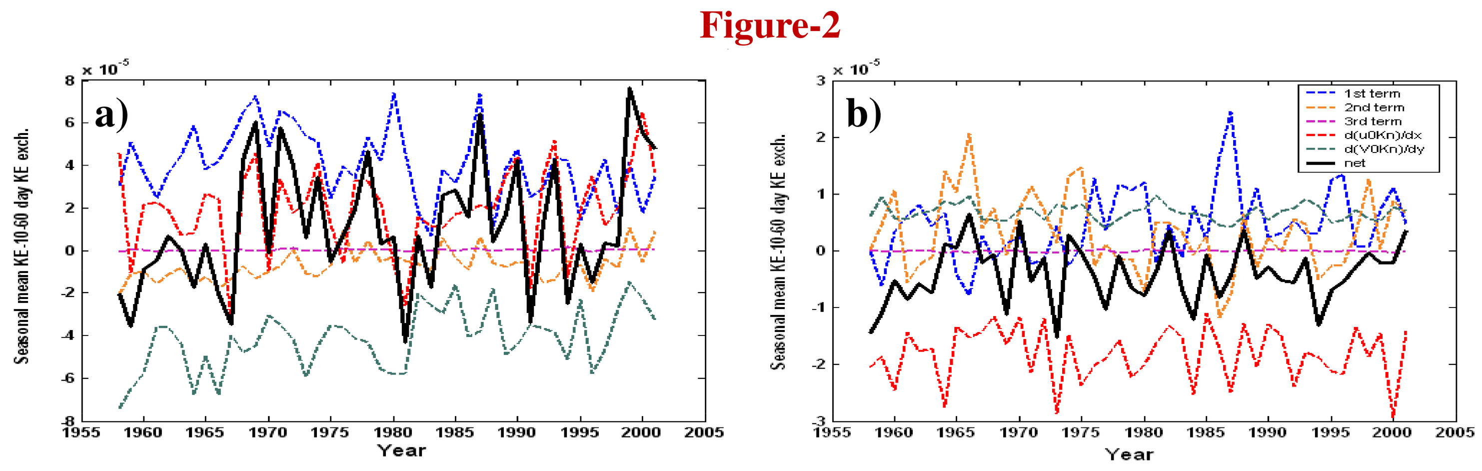
The following eqn. represents the rate of KE exchange between time mean KE and given frequency ‘n’

$$< f_0\, f_n > = -\left[\frac{\partial u_0}{\partial x} P_n(u,u) + \frac{\partial v_0}{\partial x} P_n(u,v)\right] - \left[\frac{\partial u_0}{\partial y} P_n(u,v) + \frac{\partial v_0}{\partial y} P_n(v,v)\right]$$
$$-\frac{\tan\theta}{r}\left[u_0 P_n(u,v) - v_0 P_n(u,u)\right] - \left[\frac{\partial (u_0 K_n)}{\partial x} + \frac{\partial (v_0 K_n)}{\partial y}\right]$$

Each of these component terms were computed using ERA-40 reanalysis JJAS wind data at 850 and 200 hP a and averaged over the LLJ and TEJ domains respectively. The resultant of all the averaged values gives the loss or gain of KE of frequency ‘n’ w.r.t. time mean. (which represents the zero frequency).

For each monsoon season of 122 day length, 61 frequencies are resolved. Grouping those frequencies that come under ISO scale (10-60 day periodicity, 2-12 harmonics), the sum of exchange of KE by all the frequencies with the seasonal mean is considered as the net KE exchange by the ISOs with the seasonal mean.

Figure-2



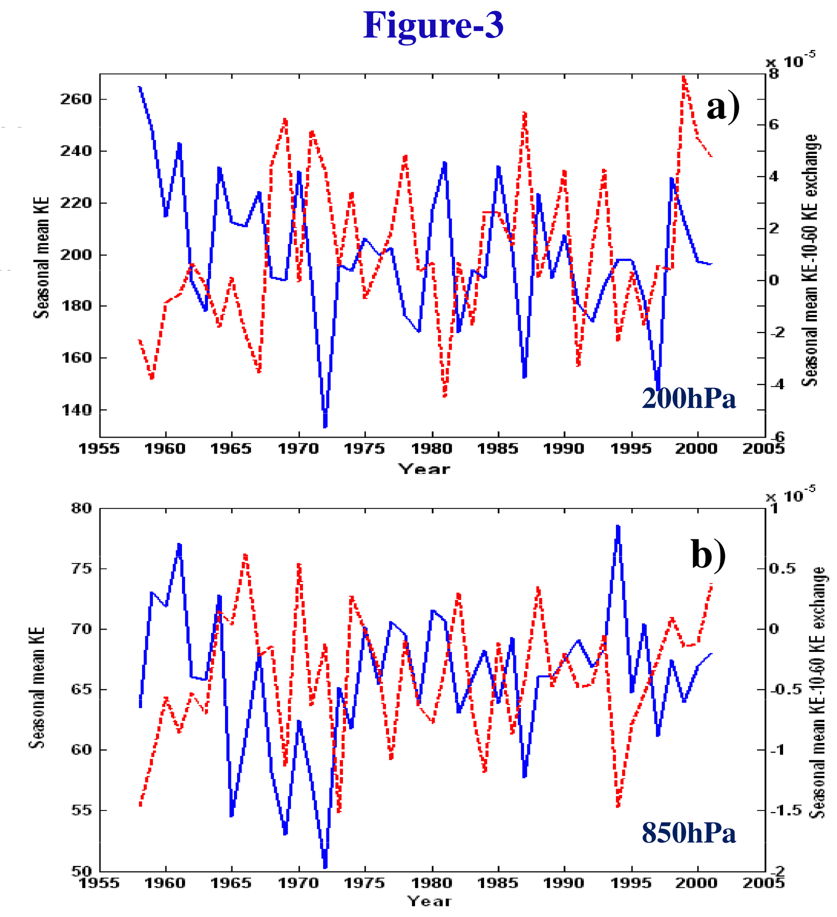
Different components of rate of kinetic energy exchange between seasonal mean KE per unit mass and 10-60 day KE per unit mass. a) at 200 hPa over the region 0°-15°N,50°E-80°E b) at 850 hPa over the region 0°-20°N,50°E-70°E.

KE exchange positive means that ISO gains energy from seasonal mean ………….

Results

a) IAV of seasonal mean KE and exchange between seasonal mean and ISO

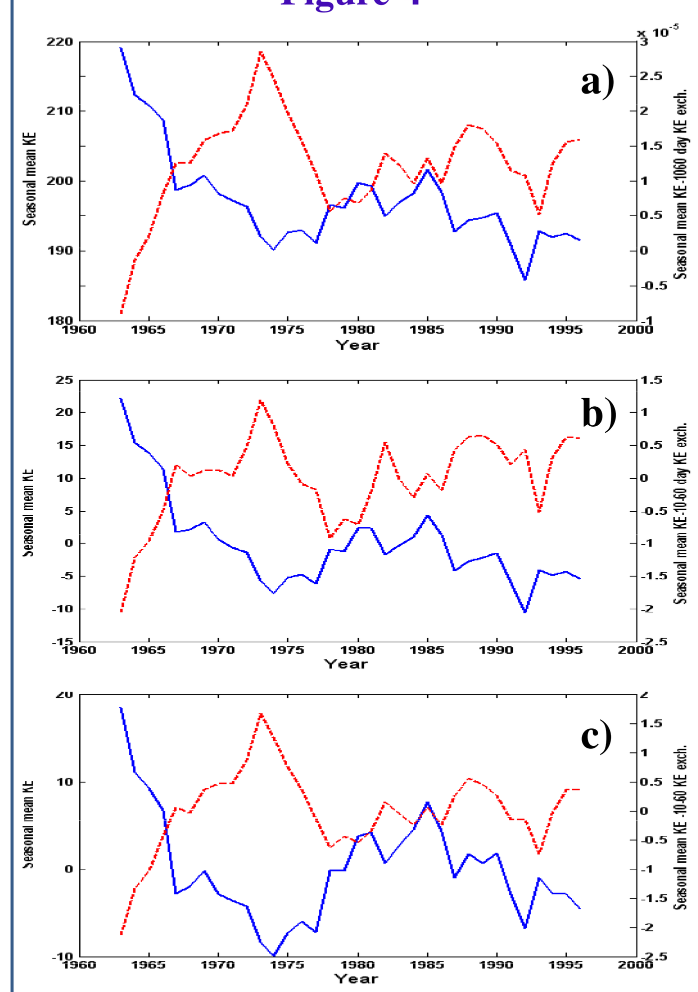
Figure-3



- Both upper level and lower level seasonal mean KE show significant phase relationship with the KE exchange between IS and seasonal mean.
- It verifies that the energy exchange process are not random and is strong enough to modify the amplitude of seasonal mean KE and cause ‘internal’ IAV of the seasonal mean KE.
- Most of the local maxima and minima of seasonal mean KE ca be explained in terms of the exchange of KE between seasonal mean and ISO.
- When seasonal mean KE exhibits a maxima, ISOs supply relati more energy to the seasonal mean.
- The decreasing trend of upper level seasonal mean KE may be attributed to the increasing flow of energy from seasonal mean to ISOs scale.

b) IDV of seasonal mean KE and exchange between seasonal mean and ISO

Figure-4



Correlation Coefficient	Interannual timescales		Interdecadal timescales	
	850 hPa	200 hPa	850 hPa	200 hPa
Seasonal mean KE and exchange	-0.28	-0.425	-0.65	-0.76
Seasonal mean KE and Nino3.4	-0.33	-0.53	0.32	0.49
Exchange and Nino3.4	-0.01	0.03	0.04	-0.6
Seasonal mean KE and PDO	****	****	0.46	0.36
Exchange and PDO	****	****	-0.47	-0.4
ENSO removed Seasonal mean KE and exchange	-0.31	-0.48	-0.65	-0.71
Partial corr.coeff. between seasonal mean KE and exchange excluding the influence of Nino3.4	-0.33	-0.483	-0.70	-0.67
Partial corr.coeff. between seasonal mean KE and exchange excluding the influence of PDO	****	****	-0.55	-0.72

- Interdecadal variability was brought out by applying 11 year running mean on both seasonal mean KE and the energy exchange.

Figure 4a) shows the relationship between seasonal mean KE and KE exchange between ISO and seasonal mean.
Figure 4b) shows the relationship between seasonal mean KE and KE exchange between ISO and seasonal mean after removing the ENSO signal from both the time series by linear regression.
Figure 4c) shows the relationship between seasonal mean KE and KE exchange between ISO and seasonal mean after removing the PDO signal from both the time series by linear regression.

- *On interdecadal time scale the seasonal mean KE exhibits a strong relation with the exchange processes*. (**See Table**)
- *However, the relationship seems to be independent of known external forcings such as ENSO, PDO ……….*

Conclusions

✓ **We have introduced a conceptual frame work for quantifying the role of ISO in causing the interannual and interdecadal variability of seasonal mean ISM.**

✓ **The internal IAV of ISM could independently account for approximately 20% of the ISM seasonal mean variability.**

✓ **The internal process could independently explain about 50% of the ISM seasonal mean on interdecadal time scale.**

✓ **On the contrary to many modeling studies, we present an alternative view regarding the weakening of monsoon circulation in a warming environment**.

References

1) **Waliser D E** (2006): Intraseasonal Variability, The Asian Monsoon (chapter-5), Springer Praxis, Chicherster, 203-257.
2) **Saltzman, B.**, 1957: Equations governing the energetics of the larger scales of atmospheric turbulence in the domain of wave number. *J. Atmos. Sci.*, 14, 513–523.
3) **Hayashi Y**, (1980) Estimation of Nonlinear Energy Transfer Spectra by the Cross-Spectral Method. J. Atmos. Sci., 37, 299–307.

Acknowledgements

Suhas E thank CSIR, India for a research fellowship . **BNG** and I.I.T.M are fully supported by Ministry of Earth Sciences, Govt. India, New Delhi.

Email IDs of authors : suhas@tropmet.res.in : goswami@tropmet.res.in,
Phone : +91 020 25893924