How do Scale Interactions influence the Indian Summer Monsoon?

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Introduction

- Scale energetics is an approach to estimate the kinetic or available potential energy exchanges between two chosen scales (Dubey et al., 2018).
- The energy exchanges between seasonal mean to LPS and to ISO (30-60 day mode), during 1950-2021 JJAS months (122 days) is calculated.

Data & Methodology

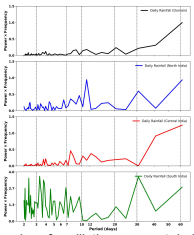
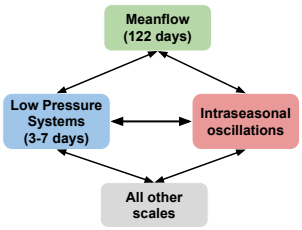


Fig. 1: Dominant modes of oscillations present during Indian Summer monsoon.



Approach

Co-spectra
Pn(u,v) = 2R (Un* Vn)

Nth fourier coefficient of u(t) and v(t)

$$K(n) = \frac{1}{2}[P_n(u,u) + P_n(v,v)]$$

The KE per unit mass for nth frequency

Horizontal gradient of seasonal mean u and v wind

$$\langle K.K_n \rangle = -[P_n(u, \frac{\partial}{\partial x}uu) + P_n(u, \frac{\partial}{\partial y}vu) + P_n(v, \frac{\partial}{\partial x}uv) + P_n(v, \frac{\partial}{\partial y}vv)$$

$$+ P_n(u, \frac{\partial}{\partial p}\omega u) + P_n(v, \frac{\partial}{\partial p}\omega v) + \frac{tan\phi}{a}P_n(u,uv) - P_n(v,uu)]$$

Horizontal gradient of seasonal mean u and v wind

Product of curvature terms and seasonal mean u and v wind

Index	Definition
Rainfall Index	Normalized rainfall by its own standard deviation.
KE Index	Normalized KE by its own standard deviation.
Niño3.4 Index	Sea Ice and Surface Temperature (SST) anomaly averaged for JJAS over the Niño 3.4 region.
PDO Index	The projections of monthly mean SST anomalies onto their first EOF vectors in the North Pacific.
MISO Index	10-90 days filtered vorticity at 850 hPa averaged over 80° N-85°N, 12°N-22°W normalized by its own standard deviation.
LPS Days	Number of LPS days in JJAS season with period of 3-7 days.

Results

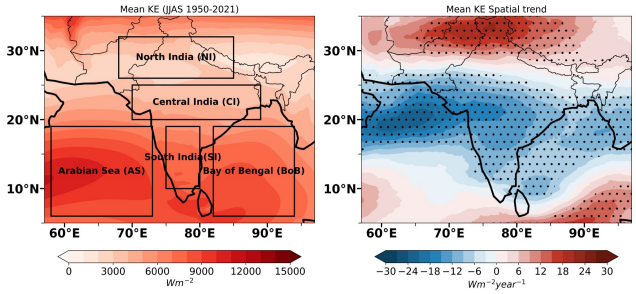


Fig. 2: spatial distributions (left) and trends (right) of vertically integrated mean KE from 1950 to 2021.

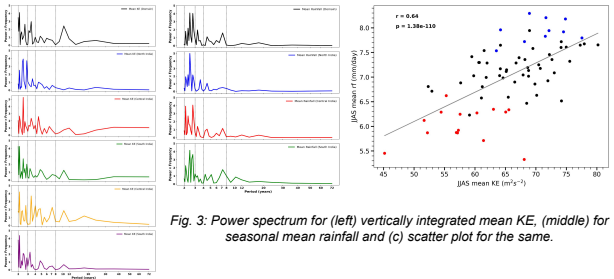


Fig. 3: Power spectrum for (left) vertically integrated mean KE, (middle) for seasonal mean rainfall and (c) scatter plot for the same.

Out-of Scale Interactions

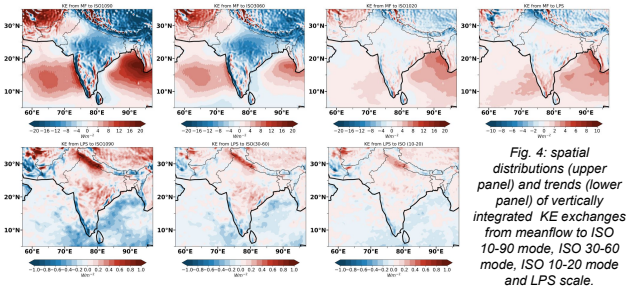


Fig. 4: spatial distributions (upper panel) and trends (lower panel) of vertically integrated KE exchanges from meanflow to ISO 10-90 mode, ISO 30-60 mode, ISO 10-20 mode and LPS scale.

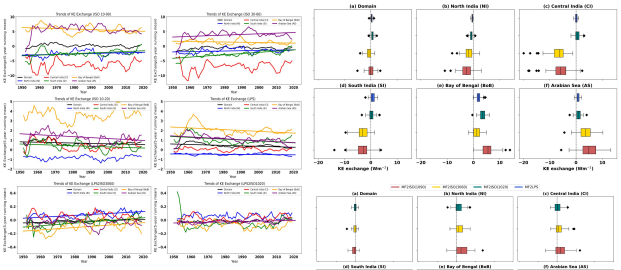


Fig. 5: Trends of vertically integrated KE exchanges from meanflow to ISO 10-90 mode, meanflow to ISO 30-60 mode, meanflow to ISO 10-20 mode, meanflow to LPS scale and ISO to LPS.

Fig. 6: Energy diagrams for all nonlinear KE interactions.

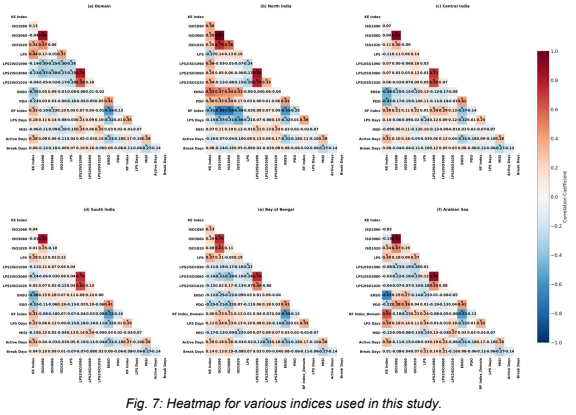


Fig. 7: Heatmap for various indices used in this study.

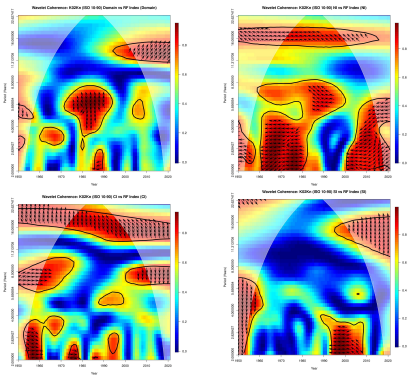


Fig. 8: Wavelet coherence for K02Kn (ISO1090) and RF Indices.

Discussions & Conclusions

- The spatial distributions of the scale interactions occur in locations that significantly influence the corresponding frequencies, highlighting the significance of scale interactions in the Indian summer monsoon.
- The KE in the Arabian Sea explains the 40% of rainfall in the Indian subcontinent.
- KE exchange from meanflow to LPS significantly increases with the increase of mean KE.
- the ISO 30-60 day mode regulates the monsoon meanflow in central India. In contrast, meanflow regulates all other higher frequency modes over the Northern Indian Ocean.
- The MF-ISO (30–60 day mode) interaction is more dominant in the Arabian Sea (AS), while the ISO (10–20 day mode) and LPS interact more with the meanflow in the Bay of Bengal (BoB).

Future Scope

- Incorporating these KE exchanges into predictive frameworks could bridge the predictability gaps identified in sub-seasonal to seasonal (S2S) models.
- Specifically, the patterns of the out-of-scale KE interactions may serve as reliable precursors which could potentially enhance the prediction of ISV-linked rainfall anomalies.

References

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