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Unsolved Mysteries of the Somali Jet

- The Somali Jet (Also referred to as the Monsoon Low Level Jet, or MLLJ in short) transports a major fraction of the moisture supplying the Indian Summer Monsoon (ISM), supporting rainfall over the Indian subcontinent (Bunker, 1965; Joseph & Raman, 1966; Findlater, 1969).
- It channels the northward flow of air from the Southern to the Northern Hemisphere, turning eastward near 10°N during the summer monsoon season (Bunker, 1965; Joseph & Raman, 1966).
- The East African Highlands channel and accelerate the cross-equatorial flow, helping establish the strong, low-level Somali Jet over the Arabian Sea (Chakraborty et al., 2002, 2006, 2009).
- Variations in the jet's strength and moisture transport can affect the spatial distribution of rainfall across the Indian subcontinent (Fasullo and Webster, 2002, 2003; Jain et al., 2021).
- While the seasonal means are well-documented, the transient behavior of the low-level flow during MLLJ's lifecycle remains poorly understood.
- Despite known impacts of the El Niño Southern Oscillation and the Indian Ocean Dipole, their direct physical influence on localized energetic structures remains poorly defined.
- Current literature often treats these ocean-atmosphere phenomena as isolated drivers, leaving a significant gap in understanding the non-linear interactions during co-occurring events and their systematic effects on regional energy transport.
- Our study looks forward to quantifying how much effect the Pacific and Indian Ocean has on the Somali Jet, in particular it's variability via the ENSO and IOD Forcings.
- We further try to examine how years influenced by ENSO, IOD or their co-occurrence make affect the strength of the Somali Jet, and how Energetics affects the Somali Jet and the broader Indian Monsoon Region by examining a recent study that utilizes Kinetic Energy Generation (GKE) explained later.

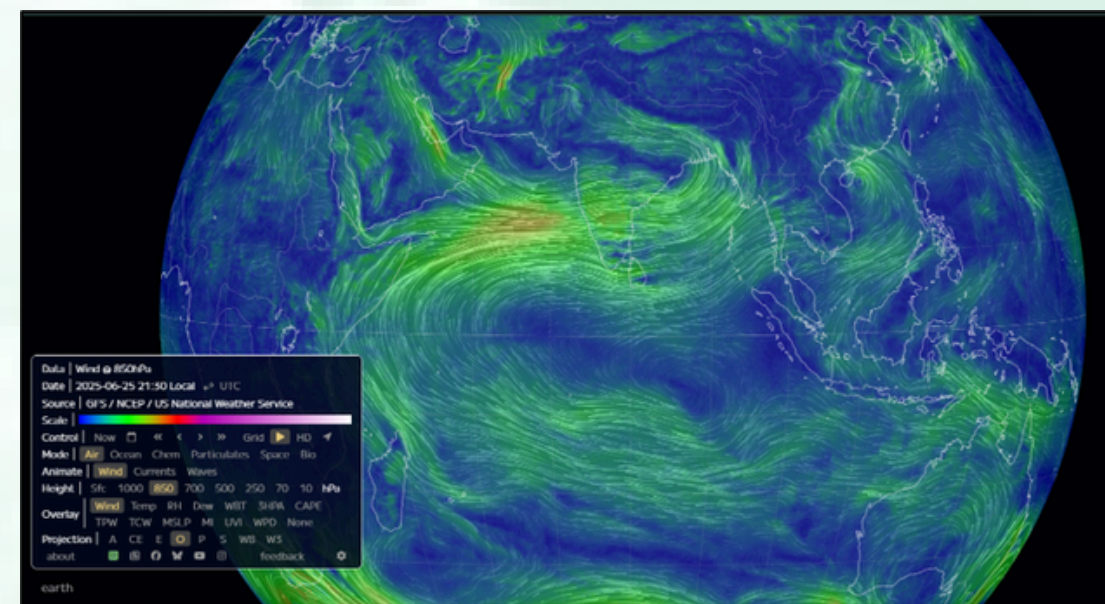


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Kinetic Energy Generation (GKE)

Inspired by the longstanding challenge of understanding the dynamics sustaining the South Asian monsoonal cross-equatorial flow and the Somali Jet, Seshadri & Dixit (2022) presents a detailed kinetic energy (KE) budget analysis using high-resolution ERA5 data. The paper addresses the gap in mechanistic understanding of KE generation in these flows.

They define the Kinetic Energy Generation (GKE) at a pressure level as:

$$G_{KE} = -\vec{\nabla}_H \phi_p \cdot \vec{U}_H$$

The terms TG12 (or TGKE12), TG3, and TGKE are defined by the following formulas, respectively:

$$TGKE12 = - \int_P^{P_0} ((R * Tv / Po) \cdot \vec{U}_a - (g * Tv / Tvo (\nabla \cdot \vec{U}_a)) \cdot \vec{U}_a) dP / g$$

$$TGKE = - \int_P^{P_0} (\nabla_h \phi_p \cdot \vec{U}_a) dP / g$$

and TG3 = TGKE - TG12, representing the residual (primarily friction). TG12 represents kinetic energy generation resulting from ageostrophic winds and surface pressure advection associated with orographic adjustments. The overbar denotes the time-average over the JJAS period.

Does Somali jet depend on ENSO & IOD?

To assess ENSO and IOD influences on Somali Jet strength, we correlated the Niño3.4 and DMI indices, respectively, with mean wind speed over the Jet core (5–15°N, 50–70°E) at 900 hPa using ERA5 reanalysis data (1940–2023).

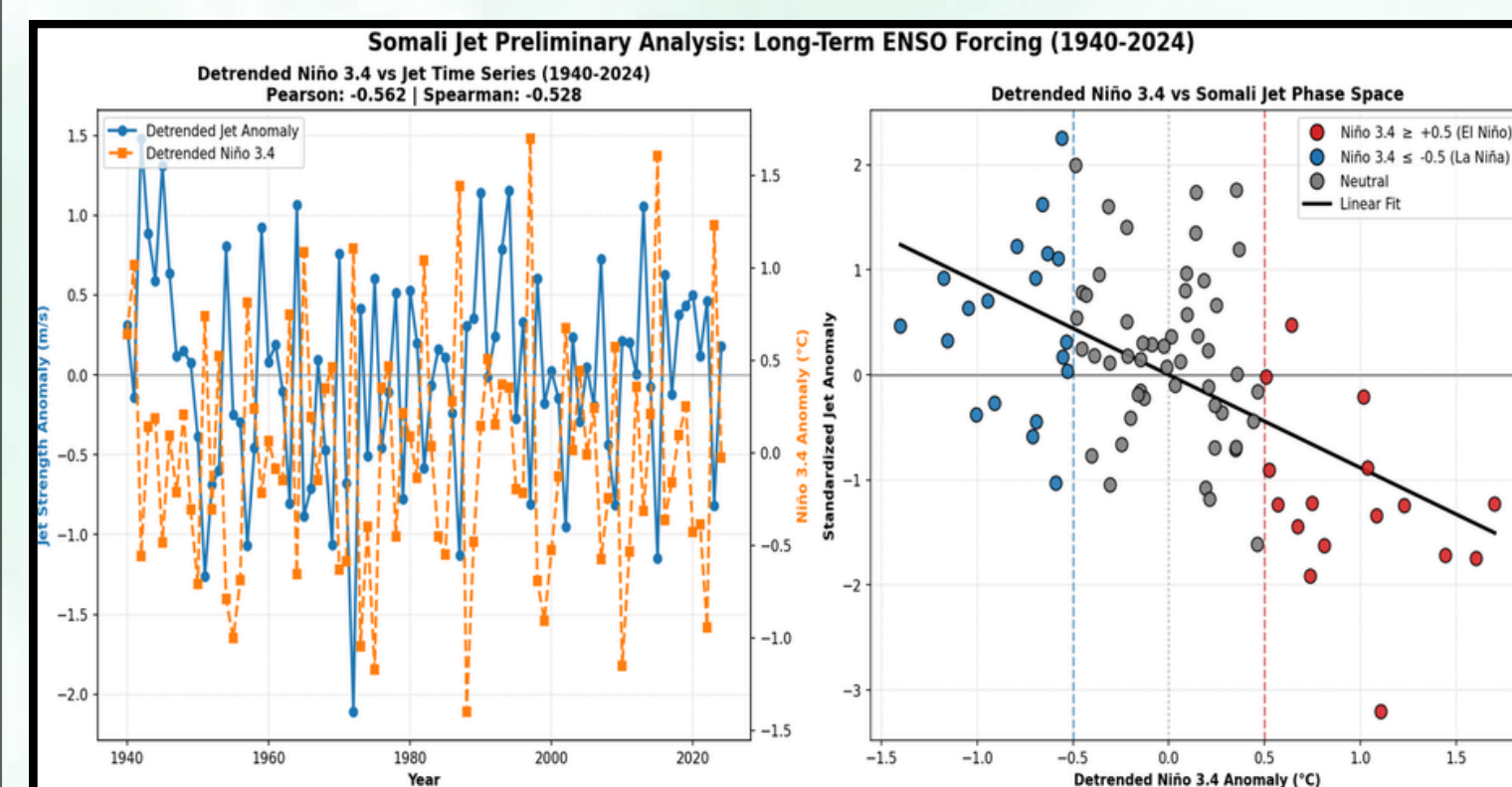


Fig. 2 (a)

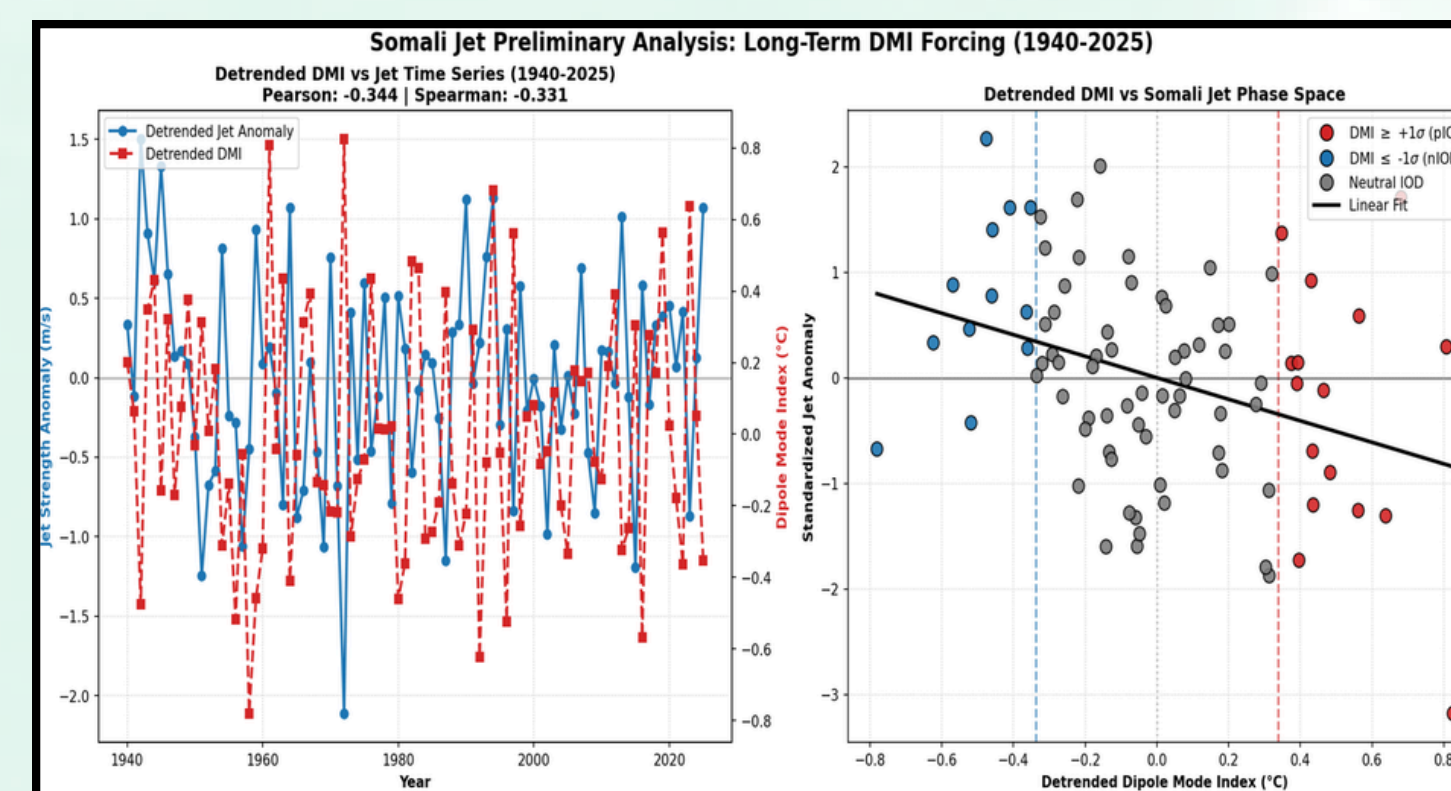


Fig. 2 (b)

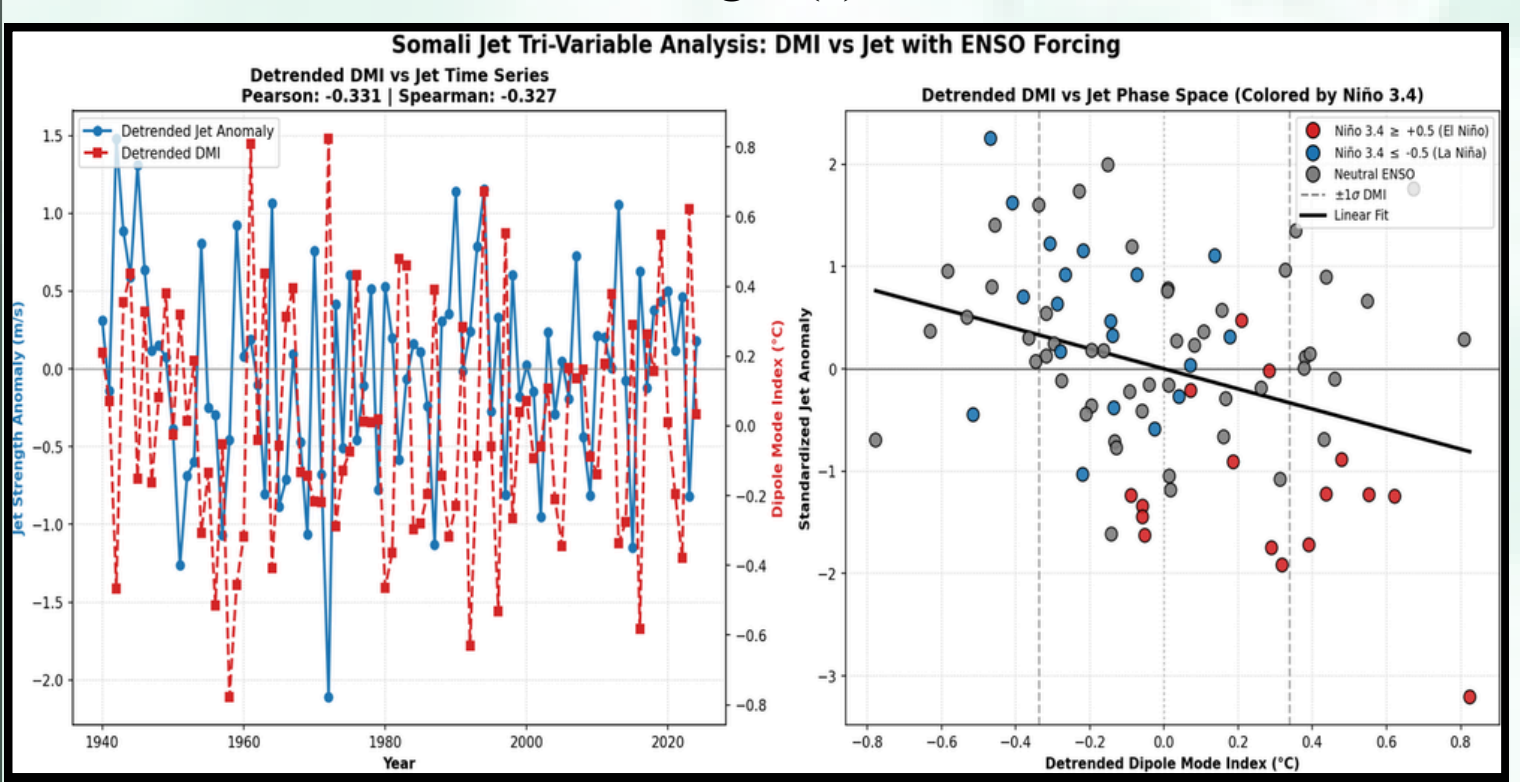


Fig. 2 (c)

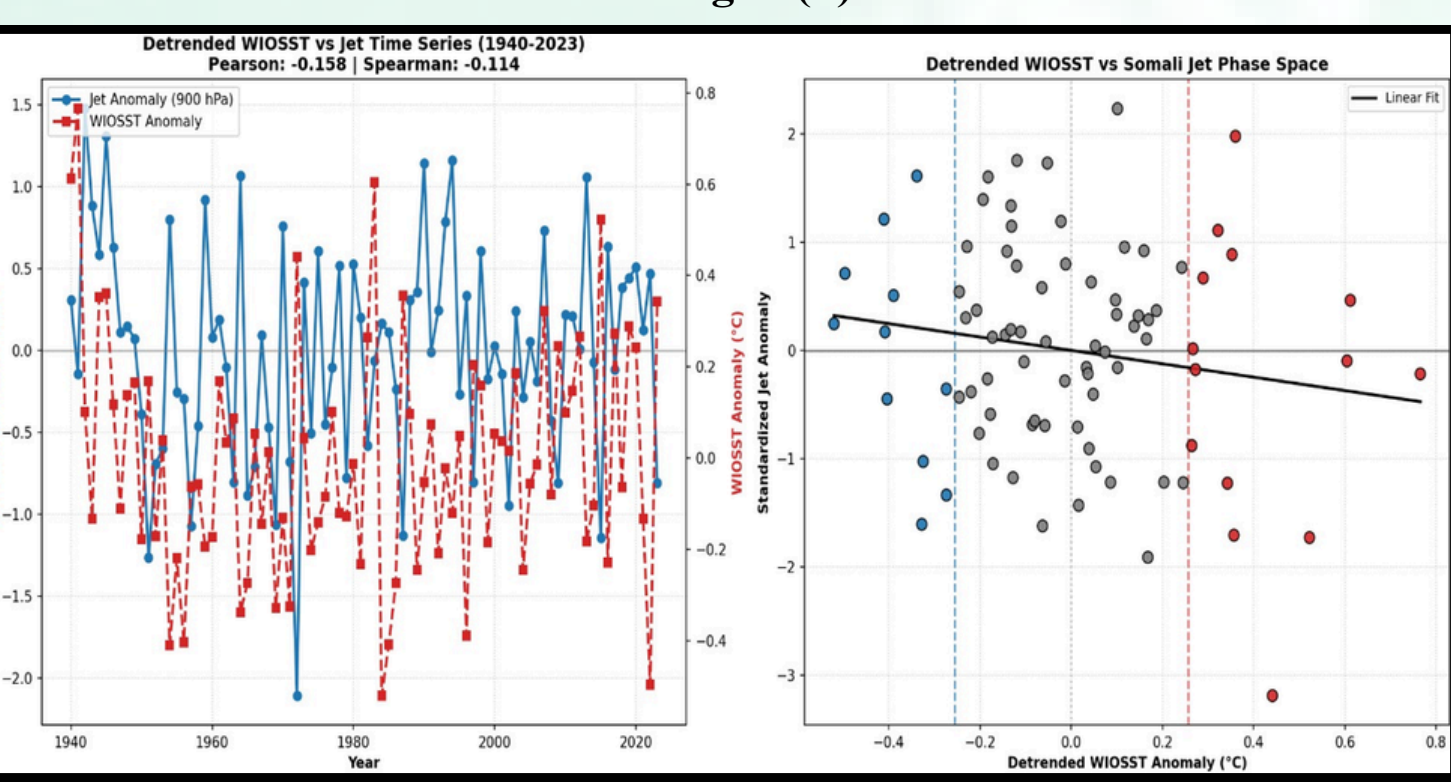


Fig. 2 (d)

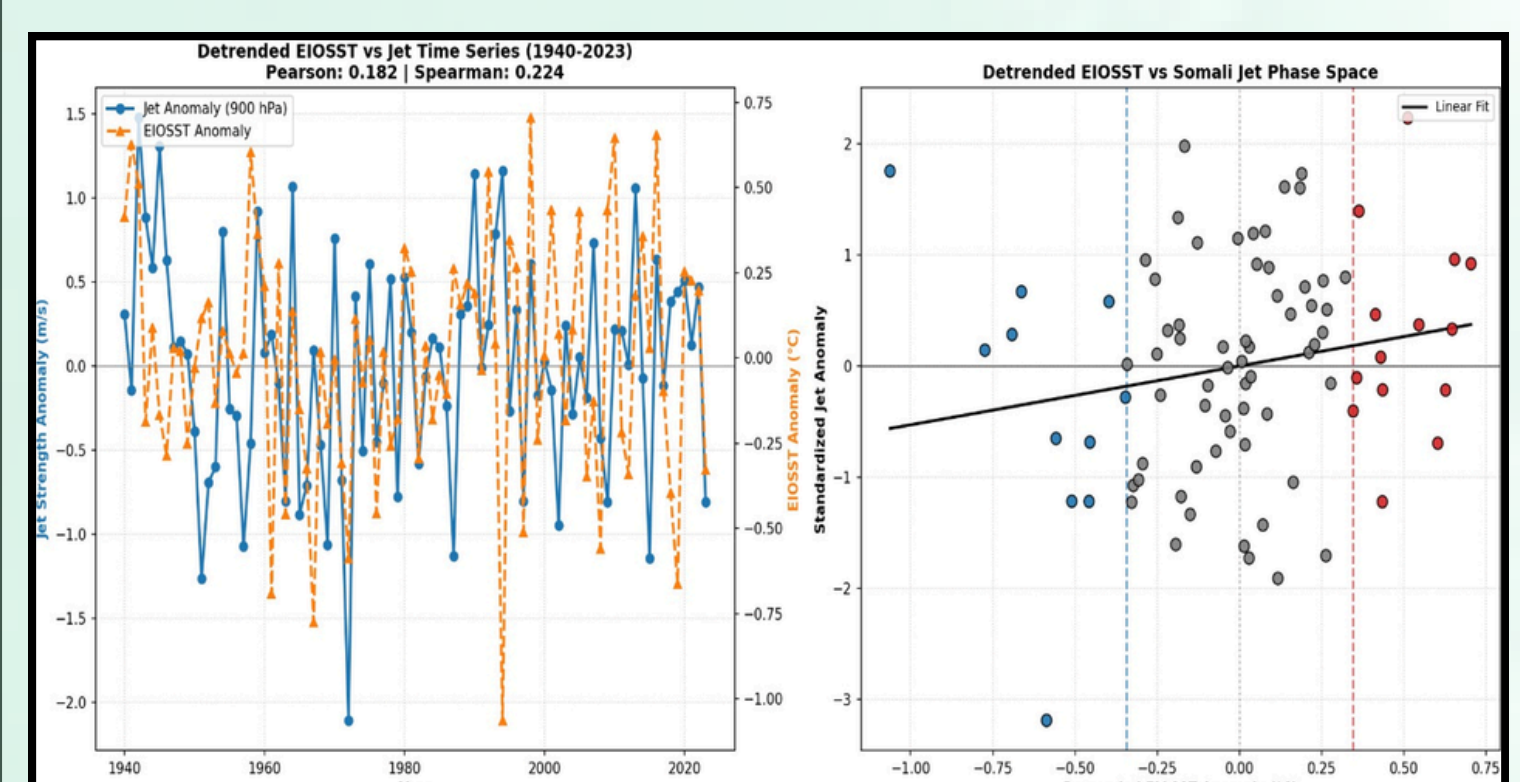


Fig. 2 (e)

Figures 2(a) and 2(b) show the respective relationships, while Fig. 2(c), with points coloured by Niño3.4 values, indicates that the IOD-Jet relationship is considerably independent of ENSO. Figures 2(d) and 2(e) examine western and eastern Indian Ocean SSTs separately, suggesting that their combined variability, captured by the DMI, is more closely associated with Jet strength than either SST alone. These results highlight the importance of considering basin-wide SST gradients when investigating oceanic controls on Somali Jet variability.

Classification of ENSO IOD and Coupled Years

Following and extending Meyers et al. (2007), we classified 1940–2023 into seven climate modes using an EOF-based approach. The classifications were evaluated against expected SST and rainfall patterns using COBE-SST3 and IMD 0.25° × 0.25° rainfall data, respectively. Figures 3(a) and 3(b) assess the consistency of the classified climate modes with their expected SST and rainfall signatures. COBE-SST3 data (Fig. 3a) reveal the associated SST patterns, while IMD rainfall data (Fig. 3b) verify the corresponding precipitation patterns, providing a robust verification of the classifications.

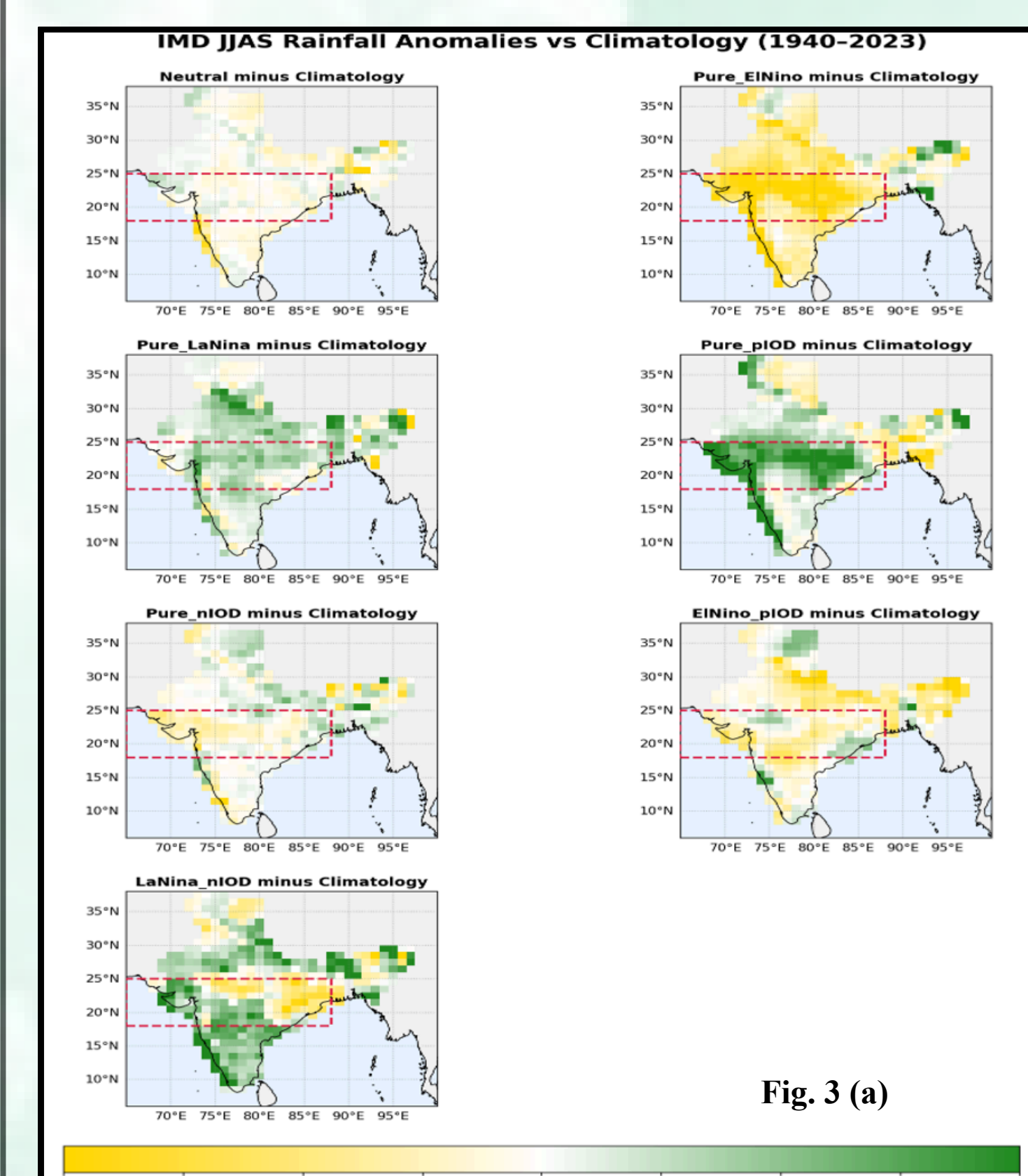


Fig. 3 (a)

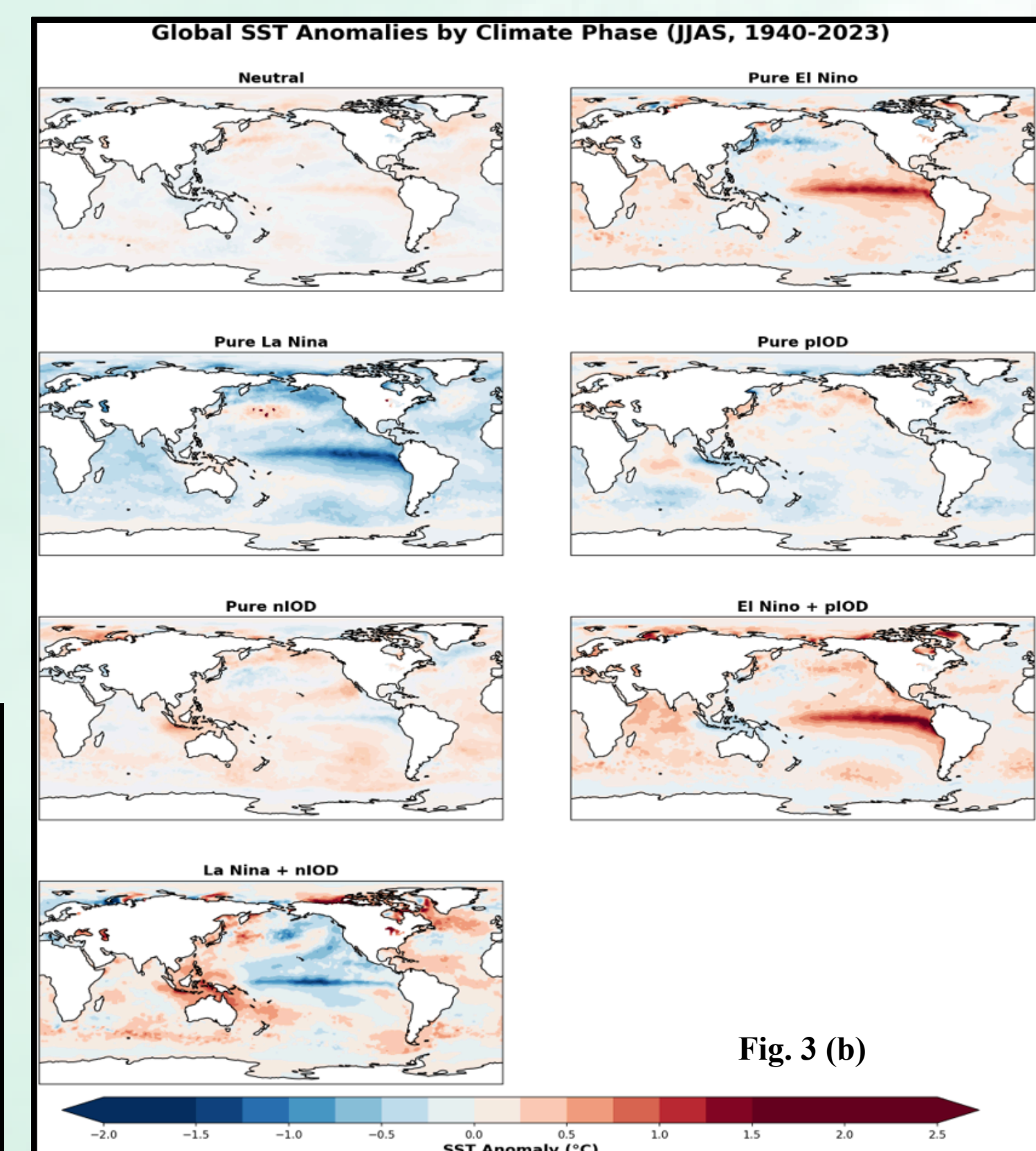


Fig. 3 (b)

IMD JJAS RAINFALL: PERCENTAGE DIFFERENCE VS CLIMATOLOGY (1940-2023)	
Phase: [Pure_ElNiño]	
• All-India Rainfall:	decreased by 11.83%
• Central India Rainfall:	decreased by 17.45%
Phase: [Pure_LaNiña]	
• All-India Rainfall:	increased by 5.33%
• Central India Rainfall:	increased by 5.38%
Phase: [Pure_pIOD]	
• All-India Rainfall:	increased by 7.78%
• Central India Rainfall:	increased by 15.75%
Phase: [Pure_nIOD]	
• All-India Rainfall:	decreased by 0.01%
• Central India Rainfall:	decreased by 2.17%
Phase: [ElNiño_pIOD]	
• All-India Rainfall:	decreased by 4.77%
• Central India Rainfall:	decreased by 3.24%
Phase: [LaNiña_nIOD]	
• All-India Rainfall:	increased by 7.35%
• Central India Rainfall:	increased by 0.08%

Somali Jet Kinetic Energy Variability as per ENSO-IOD Years

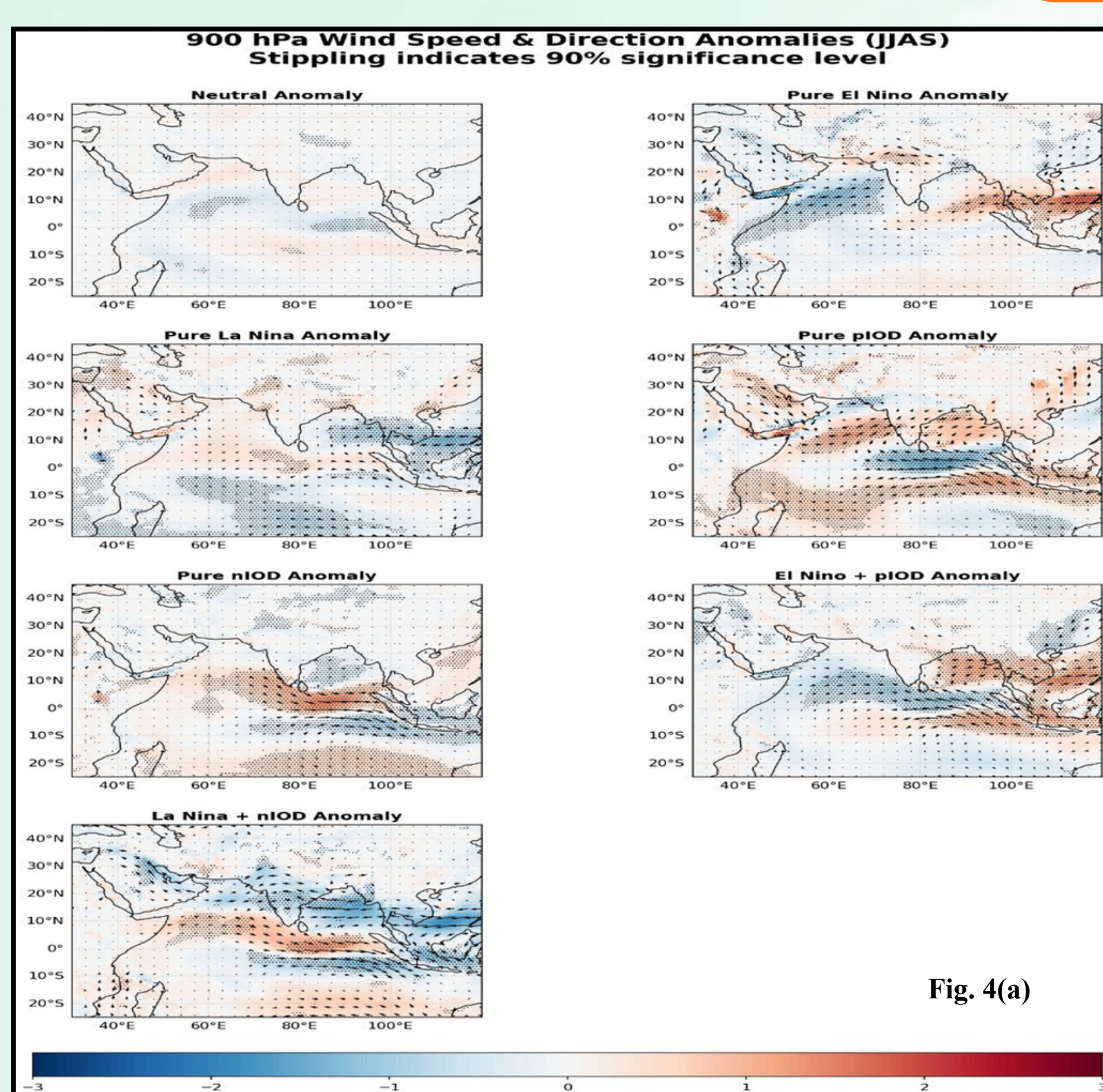


Fig. 4(a)

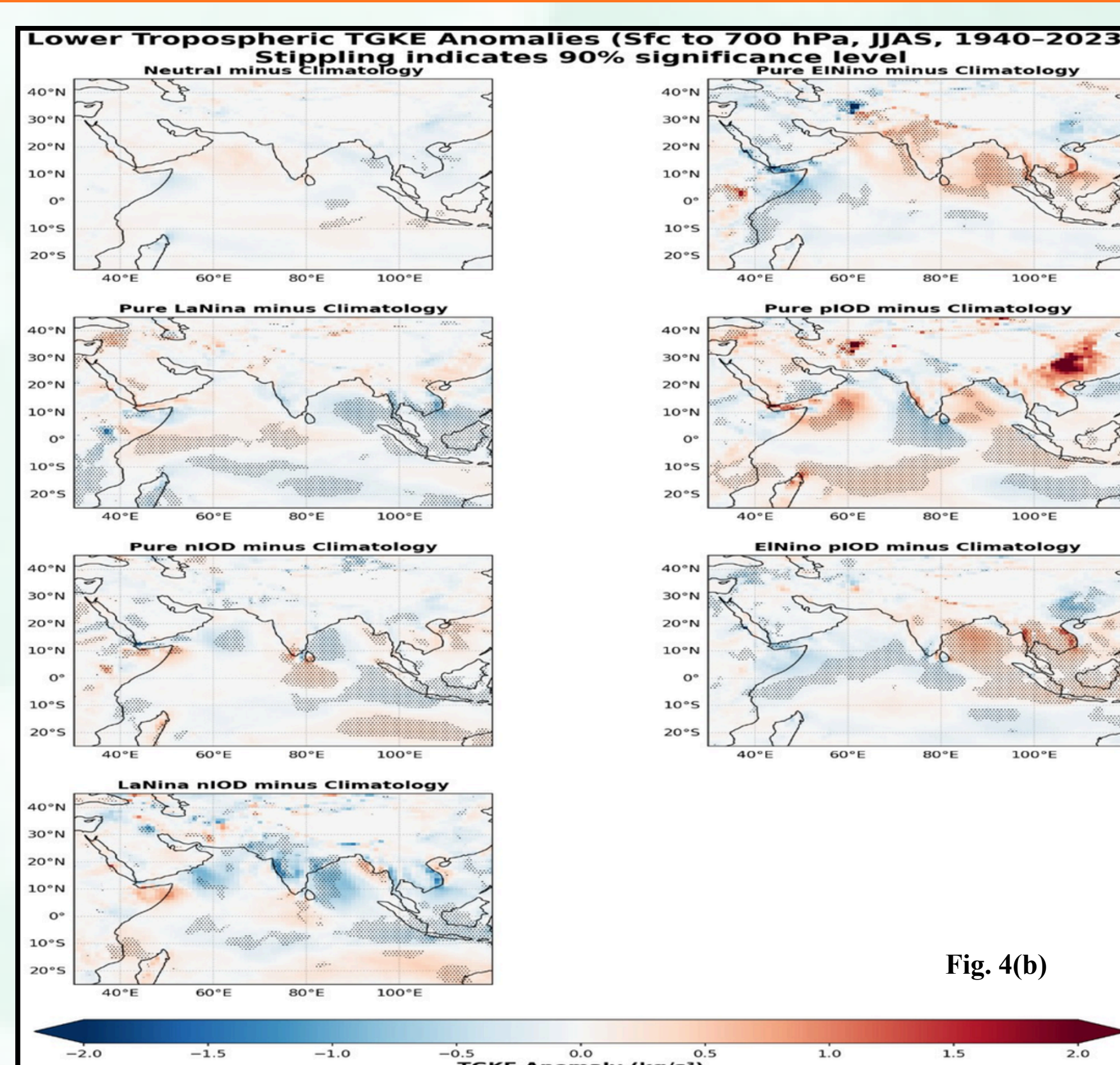


Fig. 4(b)

Fig. 4(a) represents the anomalies of wind direction and mean wind speed which are akin to Kinetic Energy between the 7 climate modes and 84 years climatology at 900 hPa. Fig. 4(b) represents the TGKE anomalies over the same region and the 7 climate modes from the 84 years of climatology from 1940-2023.

Conclusions:

- The Somali Jet influences the Indian Summer Monsoon, and this study further highlights the role of Total Generation of Kinetic Energy (TGKE) in monsoon dynamics.
- The Somali Jet exhibits distinct, localized energetic behaviours across multiple climate modes.
- ENSO and IOD are observed to influence Somali Jet strength, whereas western and eastern Indian Ocean SSTs individually show little to no influence; their relative SST contrast, represented by the DMI, exhibits a considerably stronger association.
- The 1940–2023 period was classified into seven climate modes, with the classifications verified against COBE-SST3 SST patterns and IMD rainfall data.
- Kinetic energy generation varies substantially across the seven climate modes, highlighting phase-dependent energetic responses.
- The TGKE provides a viable perspective for understanding how wind speed, kinetic energy through it's generation varies across climate phases and influences Indian Summer Monsoon variability.

References

