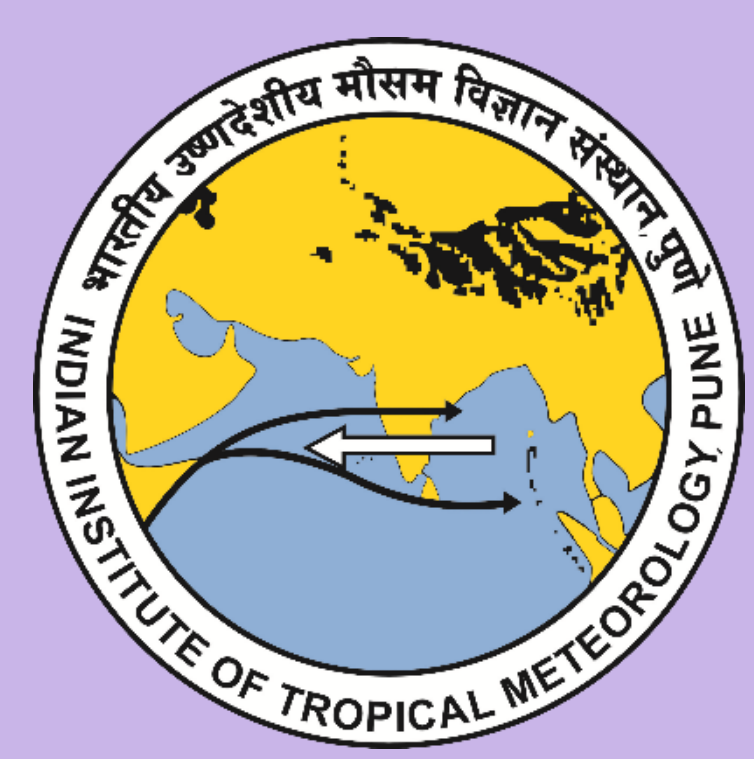




Influence of QBO Phases on Indian Summer Monsoon Intraseasonal Variability

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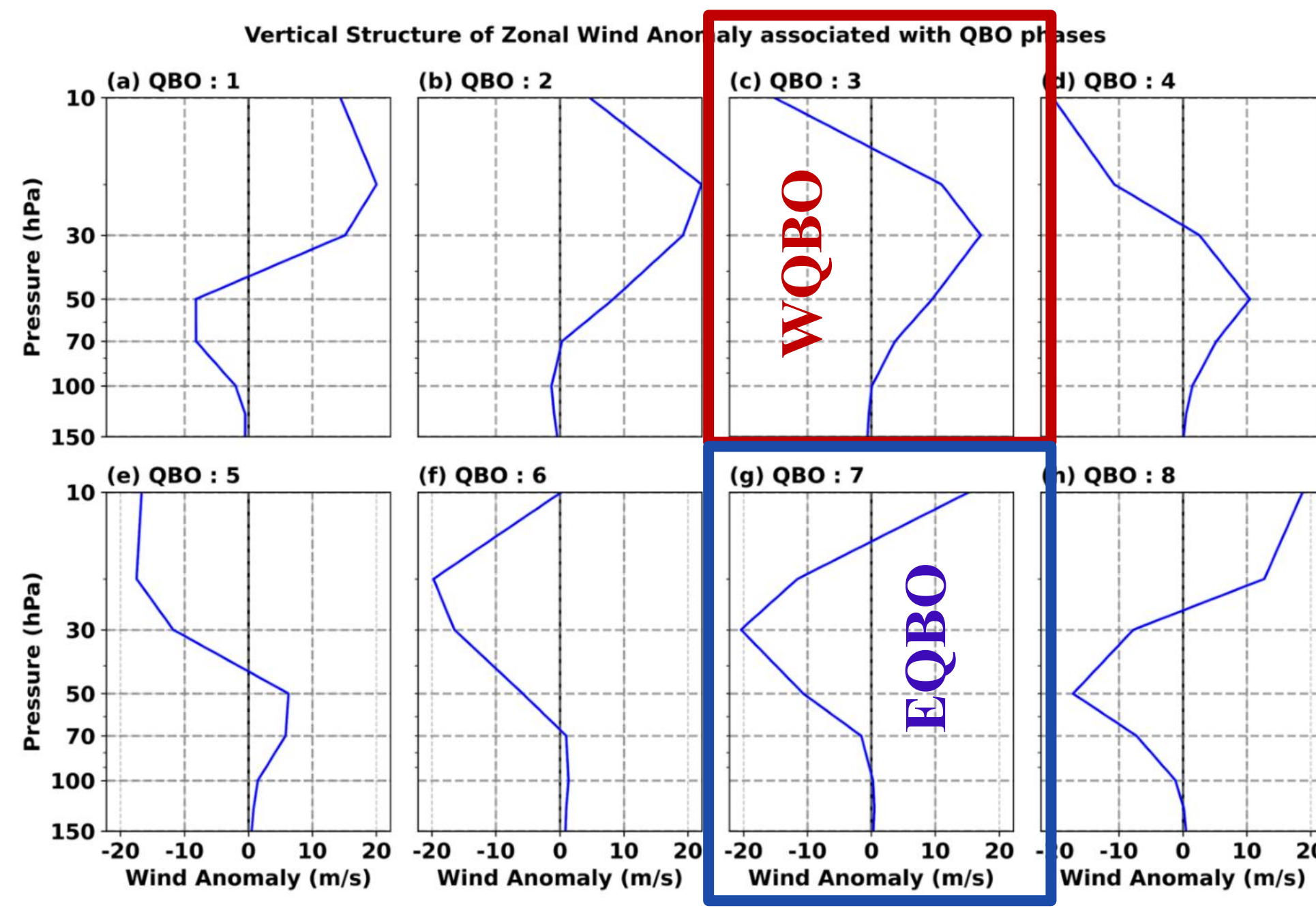
Abstract

This study evaluates the concurrent relationship between Quasi-Biennial Oscillation (QBO) phases and the Indian Summer Monsoon (ISM) on a subseasonal scale. The QBO is identified by the Empirical Orthogonal Function (EOF) analysis of equatorial zonal wind bounded by 10°S-10°N over 100-10 hPa. The QBO affects the tropical troposphere and influences the ISM through upper-level wind circulation, particularly the tropical easterly jet (TEJ). The easterly phase of QBO (EQBO) is associated with strong easterlies (westerlies) at 200 hPa (850 hPa), which enhances vertical zonal wind shear, strengthens the TEJ, and increases upper-level divergence and lower-level convection, creating favorable conditions for a strong ISM. On the contrary, the westerly phase of QBO (WQBO) exhibits opposite features, signifying weak monsoon conditions. On the intraseasonal scale, active spells are more persistent and spatially extended during EQBO, while break spells are shorter and weaker. The robustness of these relationships is confirmed by considering El Niño-Southern Oscillation (ENSO) neutral cases. The QBO-ISM subseasonal relationship is analyzed in two S2S models (ECMWF and IITM-ERPv2), and it is observed that prediction skill and predictability are higher during WQBO than during EQBO.

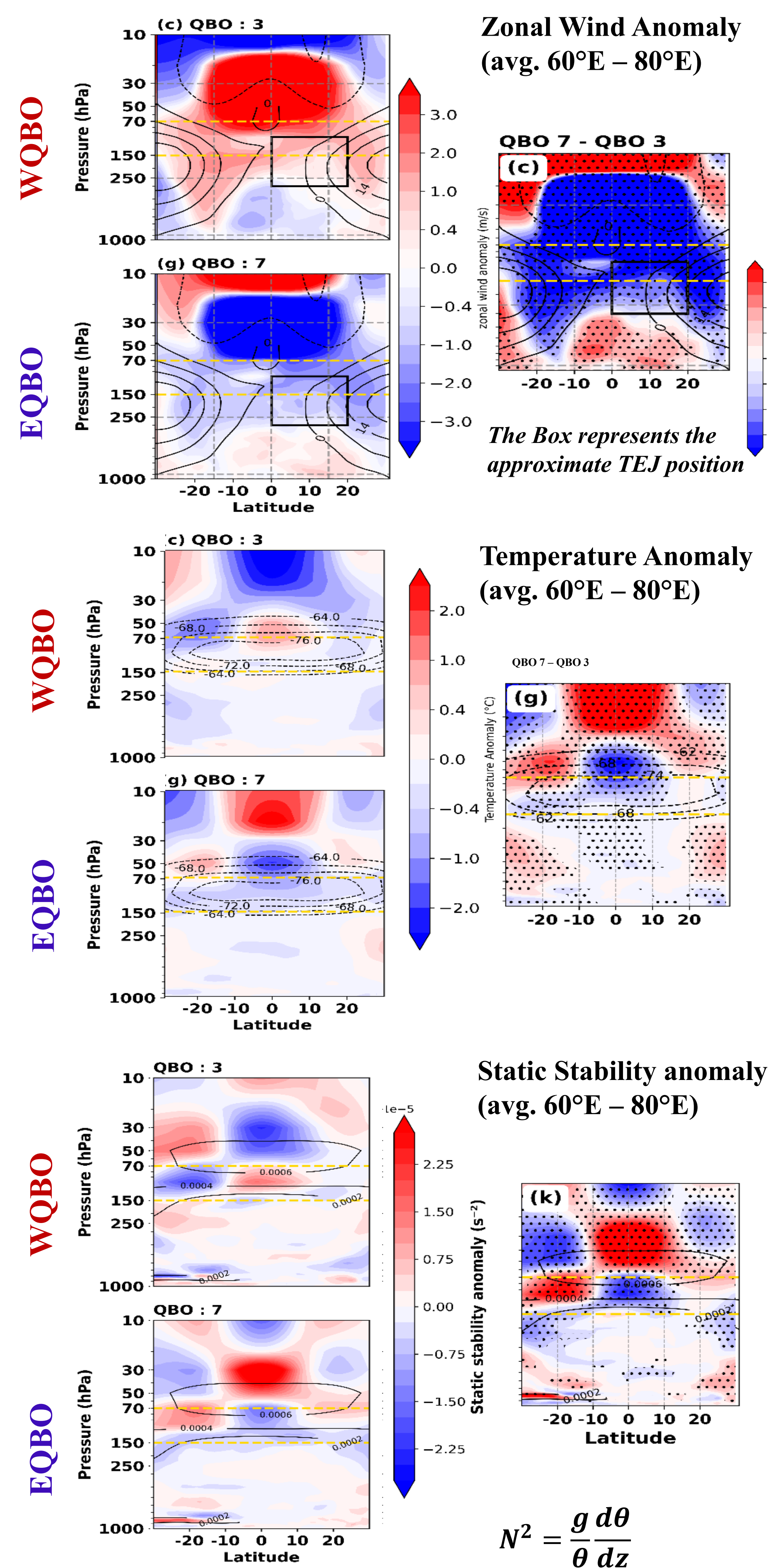
Methods

Data: Wind, temperature from ERA5 reanalysis, rainfall observations from IMD, MISO Index, NOAA OLR

Methodology: In this study, the QBO indices are generated from zonal wind between 10°S- 10°N in the lower stratosphere (100 hPa – 10 hPa) using the EOF (John M. Wallace, 1993) and threshold-defined (Yoo & Son, 2016) methods. In the threshold method, the three-monthly moving mean anomaly is calculated by subtracting the monthly climatology at 50 hPa. The values greater(or less) than half of its standard deviation are called WQBO(EQBO) at particular levels. While the EOF-based method is identified as more suitable because it uses all levels to define phases. The Active/Break spells are identified by the criteria explained by Rajeevan et al. (2010).



QBO modulation over Indian region



$$N^2 = \frac{g}{\theta} \frac{d\theta}{dz}$$

Conclusion

EQBO favors: Strong Monsoon Seasonal Signals

- Strong Tej Core Strength
- Cooler UTLS & Static Instability at 150 hPa
- Strong monsoon vertical shear
- Strong N-S TT

ISM subseasonal features

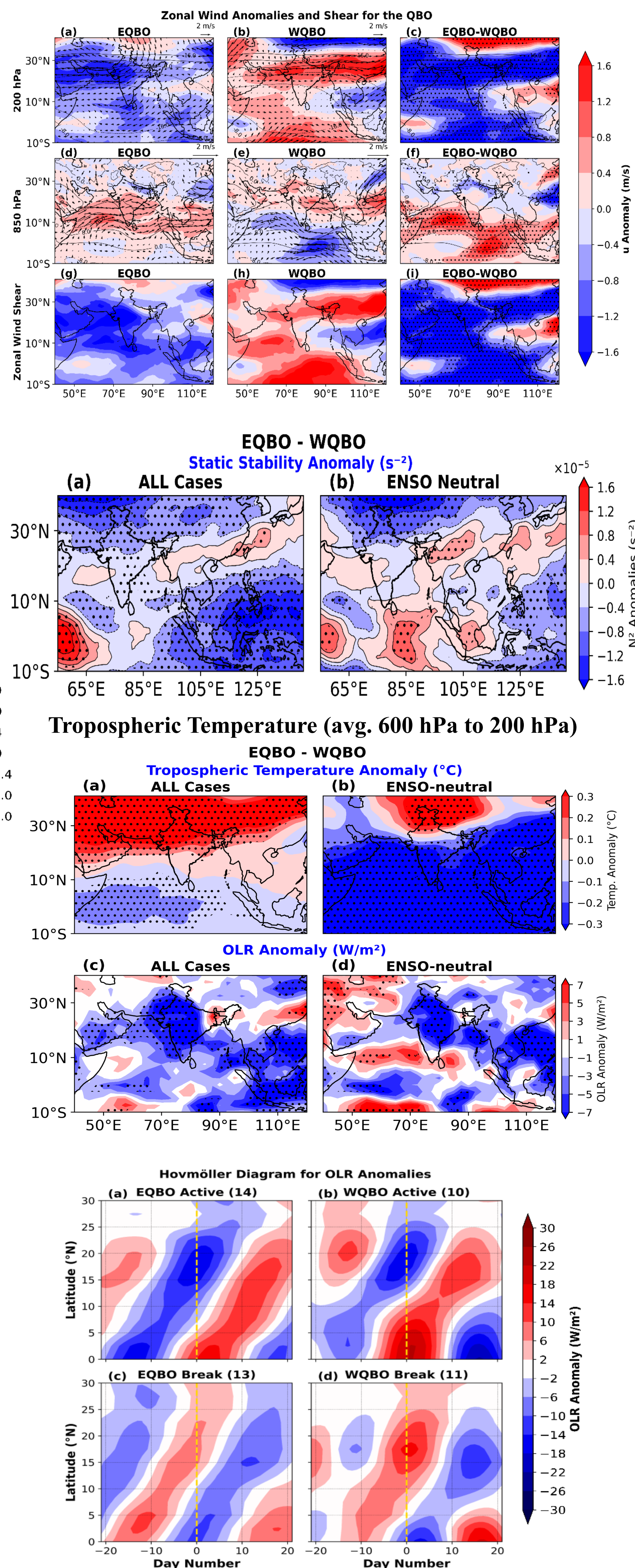
- Well-propagating longer Actives
- Low break duration
- Strong (Weak) MISO-3 (MISO-7)

The opposite is true for the WQBO phase

Impact of QBO on subseasonal features

- Both models show better representation of TEJ in **WQBO** than **EQBO** (figure here shows only the difference)
- MISO has better prediction skill and predictability in **WQBO** than **EQBO**

Influence of QBO on ISM



Impact of QBO on MISO in S2S models

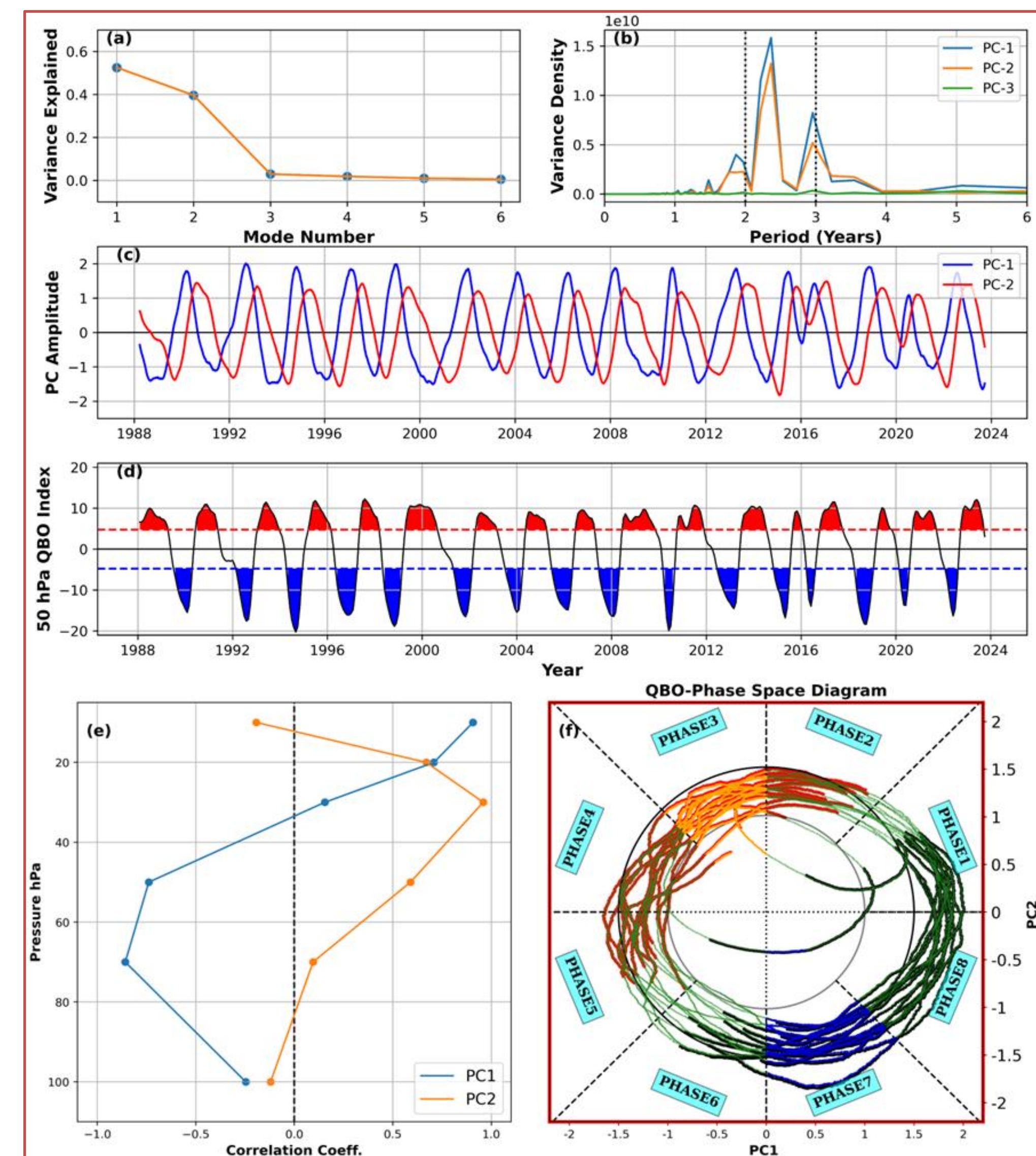
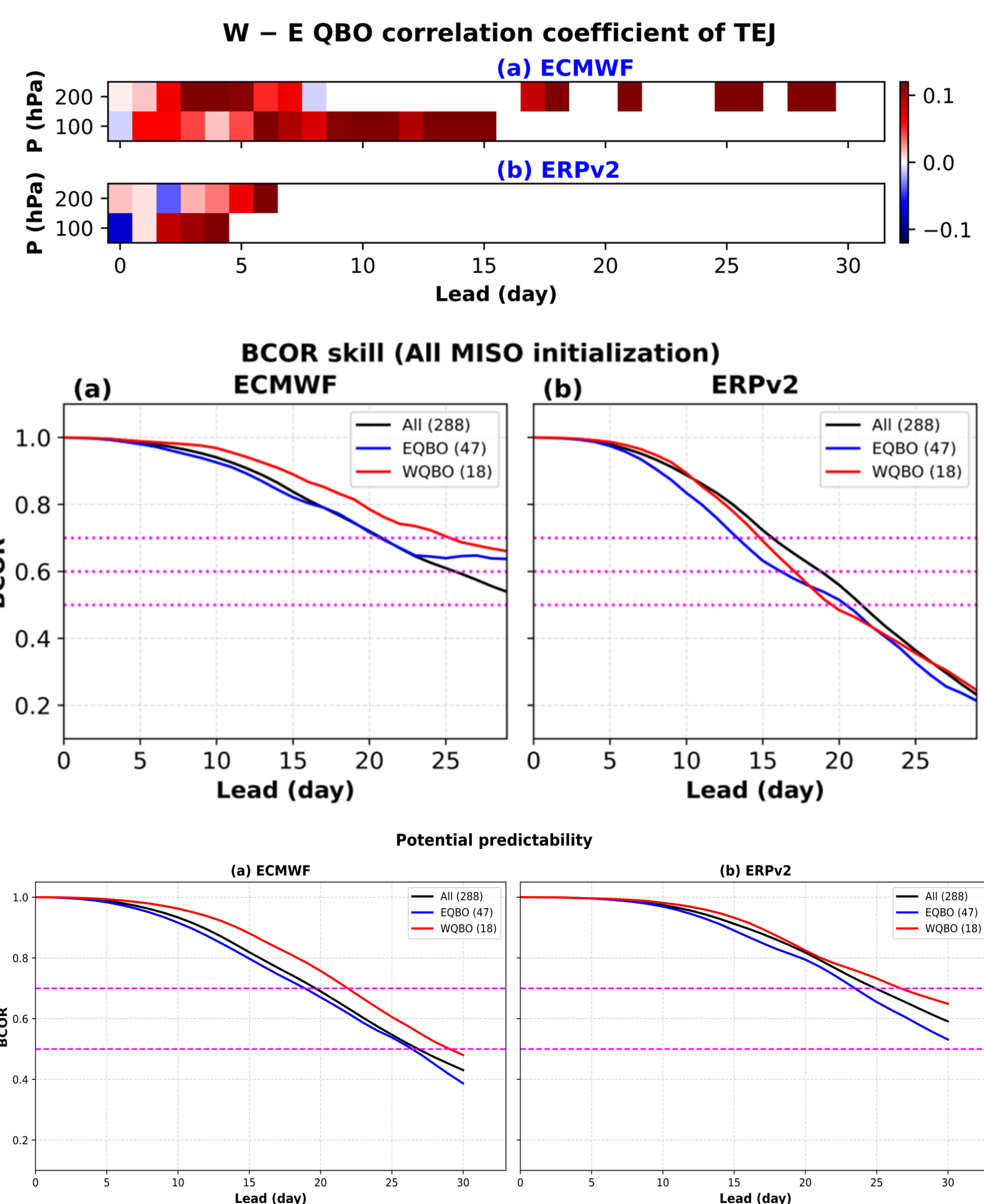


Fig. (a) Variance (b) Power Spectrum (c) Amplitudes of PC1 and PC2. (d) The QBO Index defined at 50 hPa (e) The correlation coefficient (f) The phase-space diagram of the QBO.

References

- Waje, Shubham, et al. "Role of Quasi-Biennial Oscillation in modulating subseasonal to seasonal variability of Indian Summer Monsoon." *Climate Dynamics* 63.6 (2025): 248.