INFLUENCE OF DECADAL VARIABILITY OF OCEANS ON SOUTH ASIAN MONSOON

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Introduction

➢The South Asian Monsoon is known exhibit high negative correlation with the Pacific Ocean sea surface temperature (SST) (ENSO-monsoon relation).

➢However, not all El Niño (La Niña) years are associated with drought (flood) conditions over India.

➢It is not clearly understood what causes the failure of ENSO-monsoon relation during these unusual years or what causes the enhanced negative ENSO-monsoon relation during certain other years.

➢The motivation for this study is the need to understand the failure of ENSO-monsoon Relation.

➢This study investigates the possible role of decadal modes associated with global oceans in either enhancing or decreasing the conventional ENSO-monsoon relationship.

Decadal Modes in Indian Monsoon Rainfall

Multi-channel singular spectrum analysis (MSSA) on JJAS seasonal anomaly of rainfall over India yields,

1) **Atlantic Multidecadal Oscillation (AMO)** – period of 51 years (Fig 1) – related to SST anomalies of same sign over the entire North Atlantic (Fig 2A).

2) **Pacific Decadal Oscillation (PDO)** – period of 21 years (Fig 1) – related to negative SST anomalies over the central North Pacific and positive SST anomalies in the west coast of North America (Fig 2B).

3) **Atlantic Tripole mode** – period of 13 years (Fig 1) – related to positive SST anomalies at 50^{0}N and 10^{0}N and negative SST anomalies at 40^{0}N (Fig 2C).

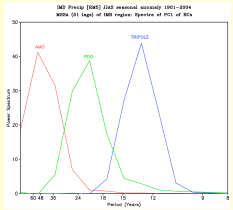

Fig.1*: Power Spectrum of PC1 of decadal modes obtained by MSSA analysis on JJAS seasonal anomaly of precipitation at lag of 51 years.*

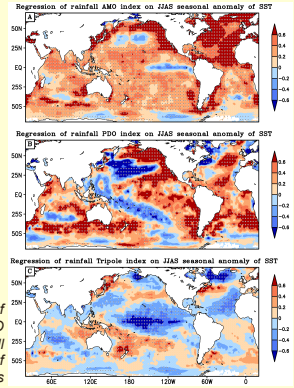

Fig.2*: Regression of JJAS seasonal anomaly of SST on (A) Rainfall AMO index (B) Rainfall PDO index (C) Rainfall Tripole index. The rainfall indices are obtained by selected area average of corresponding MSSA RC modes. Dotted regions indicate 95% confidence level.*

Influence of PDO

➢SST PDO shows significant negative correlation with IMR (Fig. 3, Figs.4C, 4D), similar to ENSO-IMR relation (Fig 3).

➢Warm (cold) PDO and El Niño (La Niña) act together and cause enhanced drought (flood) over India as seen in Fig. 4E (Fig. 4H).

➢Cold (warm) PDO and El Niño (La Niña) have counteracting effect resulting in mixed signature of flood and drought over India as seen in Fig. 4F (Fig. 4G).

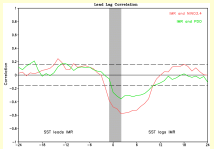

Fig.3: *Lead lag correlation between monthly SST anomaly NINO3.4 index and JJAS seasonal anomaly IMR index (red) and between monthly SST anomaly PDO index and JJAS seasonal anomaly IMR index (green). Dashed line indicates 95% confidence level.*

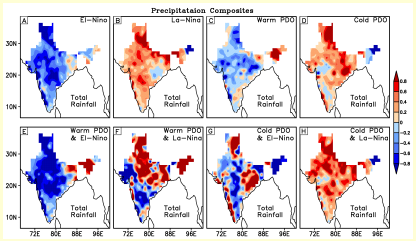

Fig.4: *Composites of Precipitation for (A) El Niño (B) La Niña (C) Warm PDO (D) Cold PDO (E) Warm PDO & El Niño (F) Warm PDO & La Niña (G) Cold PDO & El Niño (H) Cold PDO & La Niña. The criteria for ENSO and PDO composites is based on standardized JJAS seasonal anomaly NINO3.4 and PDO indices respectively.*

Mechanism

➢The cyclonic circulation (Fig. 5A) associated with the warm PDO enhances the westerlies along the equator (Fig. 5E).

➢This, in turn, strengthens the ascending and descending branches of the Walker and Hadley cells associated with El Niño leading to enhanced drought over India (Fig. 5F).

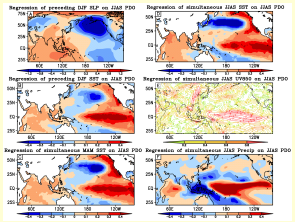

Fig 5: *Regression of JJAS seasonal anomaly of PDO index on (A) Preceding DJF SLP (B) Preceding DJF SST (C) Simultaneous MAM SST (D) Simultaneous JJAS SST (E) Simultaneous JJAS U & V winds at 850hPa and (F) Simultaneous JJAS Precipitation.*

Influence of AMO and Atlantic Tripole

➢The total SST AMO index (area average over North Atlantic) indicates weak relation with the monsoon rainfall (Fig. 6) because it includes all the Atlantic modes.

➢When the SST modes are decomposed from total SST using MSSA on monthly SST over North Atlantic (Fig. 7) and correlated with corresponding MSSA rainfall modes, they exhibit strong relations with the monsoon rainfall (Fig. 6).

➢AMO modes (SST and rainfall) exhibit high positive correlation (Fig. 5). Warm (cold) AMO is associated with flood (drought) condition over India (Figs. 7A, 7B).

➢Warm (cold) AMO and La Niña (El Niño) enhance positive (negative) rainfall anomalies over India, as seen in Fig. 7F (Fig. 7G).

➢Tripole modes (SST and rainfall) exhibit high negative correlation (Fig. 5). Warm (cold) Tripole is associated with drought (flood) condition over India (Figs. 7C, 7D).

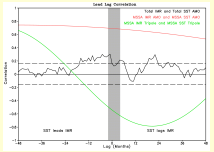

Fig 5: *Lead lag correlation between total monthly SST anomaly AMO, MSSA SST AMO and MSSA SST Tripole with total JJAS seasonal anomaly IMR (black), MSSA IMR AMO (red) and MSSA IMR Tripole (green) indices respectively. Dashed line indicates 95% confidence level.*

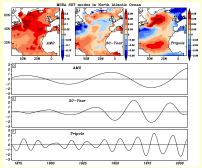

Fig 6: *EOF1 and PC1 of (A), (E) AMO mode (B), (F) 30-year mode (C), (G) Tripole mode (period > 10 years) (D), (H) Tripole mode (period < 10 years) from MSSA analysis over North Atlantic.*

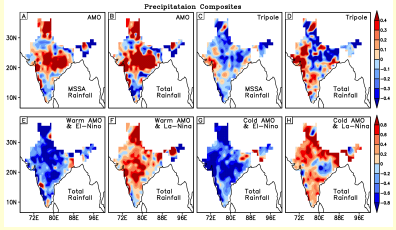

Fig 7: *Composites of Precipitation for (A),(B) Warm AMO-Cold AMO (C), (D) Warm Tripole-Cold Tripole (E) Warm AMO & El-Niño (F) Warm AMO & La Niña (G) Cold AMO & El Niño (H) Cold AMO & La Niña. The criteria for AMO and Tripole composites is based on standardized area averaged indices of JJAS seasonal anomaly MSSA modes.*

Conclusions

➢Indian monsoon rainfall exhibits three decadal modes. One of them is associated with North Pacific (PDO) and other two with North Atlantic (AMO and Tripole).

➢PDO exhibits significant negative correlation with Indian monsoon rainfall similar to that of ENSO.

➢When ENSO and PDO are in (out of) phase, they complement (counteract) each other to enhance (decrease) the conventional ENSO-monsoon relationship.

➢AMO has positive relation and Atlantic Tripole has negative relation with rainfall over India.

➢Warm (cold) AMO enhances La Niña (El Niño) influence on Indian monsoon.