

Short-term Climate Variability and Prediction



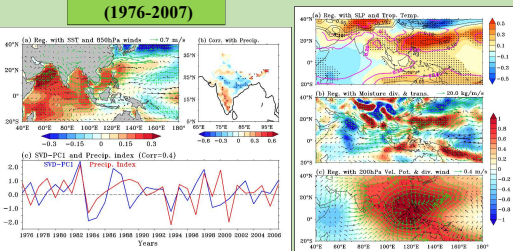
Inter-decadal modulation of the Indo-Western Pacific climate and influence on Indian summer monsoon rainfall

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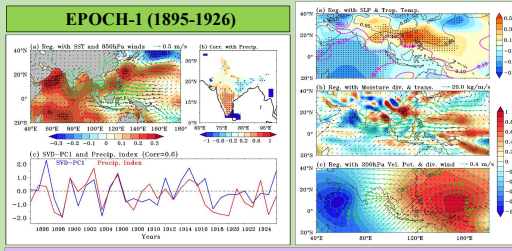
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Introduction El Niño Southern Oscillation (ENSO) is the dominant mode of interannual variability over the Pacific. Basin-wide surface warming of the Tropical Indian Ocean (TIO) and Western North Pacific (WNP) anticyclonic circulation are generally triggered by El Niño at its peak phase (Klein et al., 1999; Wang et al., 2003). The coherent evolution of TIO warming and WNP anticyclone (AC) and their co-variability (Kosaka et al., 2013) is referred as the Indo-Western Pacific Ocean Capacitor (IPOC) mode (Xie et al., 2016). This IPOC mode have strong impact on East-Asian summer rainfall and WNP monsoon (Ma et al., 2017; Xie et al., 2016). It is essential to consider the possible roles of the TIO warming and WNP circulation in predicting the South Asian summer monsoon rainfall which are the two components of IPOC mode. ENSO teleconnections to the TIO-WNP and East Asia show substantial interdecadal variations over the second half of the 20th century (Wu & Wang et al., 2002; Wang et al., 2008; Xie et al., 2010; Huang et al., 2010). This study examined these inter-decadal modulation of the IPOC mode and its influence on Indian Summer Monsoon rainfall (ISM).

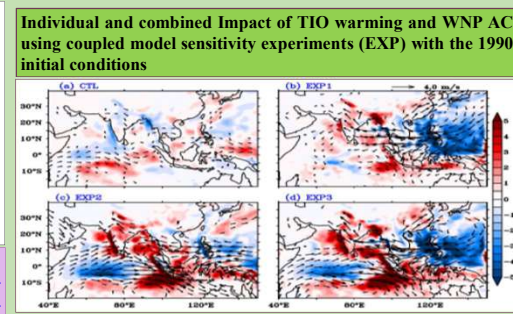
Data and Methods The Extended reconstructed sea surface temperature (ERSST), India Meteorological Department (IMD) precipitation and The National Oceanic and Atmospheric Administration 20th Century Reanalysis (NOAA-20CR) datasets are utilized for the period of 1886-2014. Singular value decomposition (SVD) is performed to extract the IPOC mode. Depending upon the 21-year sliding correlation coefficient between ISMR anomalies and SVD-PC1 for the period 1886-2014, three epochs are selected. Further, Regression, correlation and Student's T-test are used. Analysis is carried out for JJA.



- SVD mode-1 variance is 76.92%.
- IPOC mode is well developed in Epoch-3. Positive rainfall anomaly over Western Ghats and Sundarbans region and negative anomaly regions of central India.
- Tropospheric temperature and SLP shows Kelvin wave propagation from TIO to equatorial Western Pacific. Moisture convergence over Western Ghats and dry moisture transport over the central east region are noted.

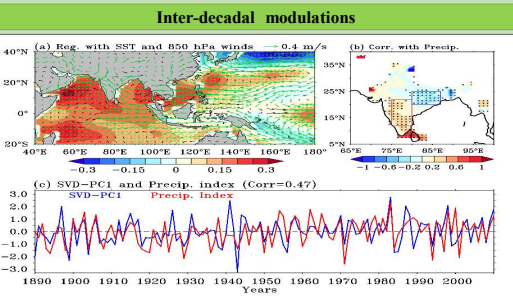


- Epoch-1: SVD mode-1 variance is 59.17%
- Dipole rainfall pattern is visible with positive rainfall anomaly over south and western Indian region whereas negative anomalies over eastern part.
- Positive SLP anomaly over WNP extending to BOB and divergent wind at 200 hPa over WNP supports AC.
- Moisture convergence over Western Ghats is noted.



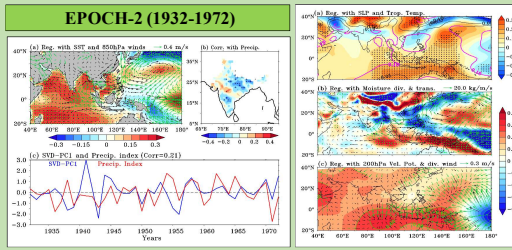
JJA precipitation and 850hPa winds for (a) CTL (JJA 1990), (b) EXP1, (c) EXP2 and (d) EXP3.

- Experiments**
- EXP1 → WNP convection is suppressed to excite AC
 - EXP2 → Strong TIO basin-wide warming is imposed
 - EXP3 → (EXP1+EXP2) Combined influence

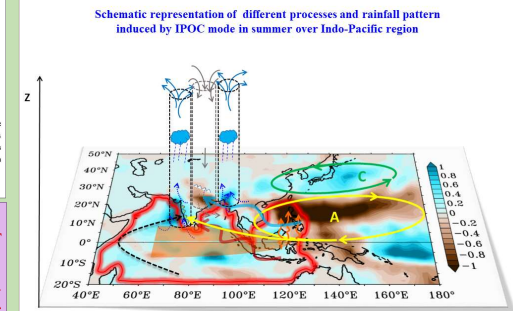


JJA SVD-PC1 regression with (a) SST (Shaded; °C) and 850 hPa wind anomalies (Vectors; m/s) (b) correlation with precipitation and (c) Precipitation index based on positive minus negative box in fig. b for the period 1886-2014

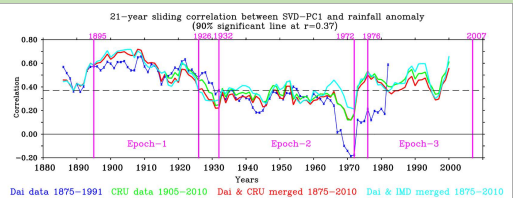
- IPOC mode extracted by SVD analysis based on TIO (20°S-20°N, 40°E-100°E) SST and WNP (0-30°N, 100-160°E) 850-hPa vorticity anomalies in JJA for 1886-2014. SVD-PC1 is the SST time series. SVD mode1 variance is 65.2%
- In response to IPOC, a southwest-northeast dipole pattern of rainfall anomalies seen over the Indian' region. Precipitation index = Positive [Red] box (75°E:80°E, 12°N:22°N) minus Negative [Blue] box (80°E:87°E, 20°N:25°N).



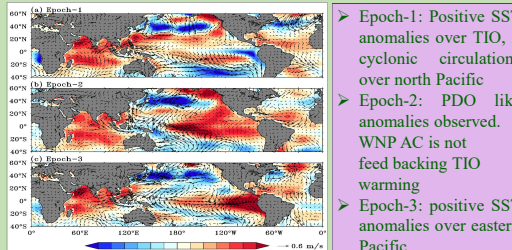
- Epoch-2: SVD mode1 variance is 52.79%
- IPOC mode is not well organised due to strong positive SST anomaly over central eastern Pacific.
- Negative rainfall anomaly over most of the Indian land region. Weakening and shifting of WNP AC to north-eastward, Moisture divergence over most of the Indian continent are evident.



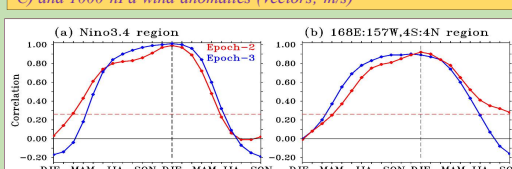
Schematic diagram of the mechanisms through which IPOC mode influences Indo-Pacific region in JJA. Shaded region with cyan (brown) colour represents positive (negative) anomalies. Area bounded by red thick closed contour indicates strong positive SST anomalies. Thick yellow (green) ellipse displays anomalous anticyclonic ('A') (cyclonic ('C')) circulation over tropical (mid-latitude) WNP region is part of PJ pattern. Extension of WNP anticyclone to Northern Indian ocean is shown by curved thick yellow arrow. Black and grey coloured dashed cylindrical figures over ISM region denote the triple pole precipitation pattern.



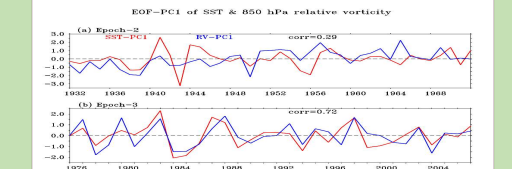
- 21-year sliding correlation coefficient between the SVD-PC1 and rainfall anomalies for 1886-2014.
- Based on this correlation, 3 epochs have been selected Epoch-1:1895-1926, Epoch-2:1932-1972, Epoch-3:1976-2007
- In Epoch 1 and Epoch 3 IPOC mode influence ISM rainfall is strong as compared to Epoch 2



Epoch-wise regression between JJA SVD-PC1 and JJA SST (Shaded; °C) and 1000-hPa wind anomalies (Vectors; m/s)



Lagged correlation of D(O)JF(1) Nino3.4 SST anomalies (°C) with seasonal SST anomalies averaged over (a) Nino3.4 region and (b) 168°E:157°W, 4°S:4°N region for both epoch-2 and epoch-3.



Normalized EOF-PC1 of SST anomalies (°C) over TIO and 850 hPa relative vorticity anomalies ($\times 10^3 \text{ s}^{-1}$) over WNP for (a) Epoch-2 and (b) Epoch-3.

Summary and Future Work

- IPOC mode induces anomalous tri-pole pattern in the precipitation anomalies over ISM region in response to the IPOC mode (recent epoch), presence of strong positive anomalies over eastern Arabian Sea-western Ghats of India and Sundarbans-Bangladesh region and negative precipitation anomalies over the monsoon trough region are noted.
- IPOC mode can exert strong impact on regional summer rainfall variability over South Asian/Indian land region via TIO warming and WNP AC and this is supported by model coupled model experiments.
- IPOC mode displays interdecadal variations during the period of 1886-2014. This is mainly because of interdecadal variations in PJ mode, which is not well developed in epoch-2, and persistent central Pacific SST warming.
- To examine the interaction between extratropical circulation, IPOC mode and Indian Summer Monsoon rainfall.
- Assessment of the current coupled models ability in representing the non-ENSO teleconnections to Indian Summer Monsoon rainfall.
- Understanding the decadal modulations of Indian Summer Monsoon rainfall and it's link with different climate modes in observations and coupled models.
- Tropical Indian Ocean Climate variability and impacts on Indian Summer Monsoon rainfall.

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