Short Term Climate Variability and Prediction

Climate Variability, Predictability and Applications

On the relationship between north India summer monsoon rainfall and east equatorial Indian Ocean warming

Ramesh Kumar Yadav and Mathew Koll Roxy

Abstract

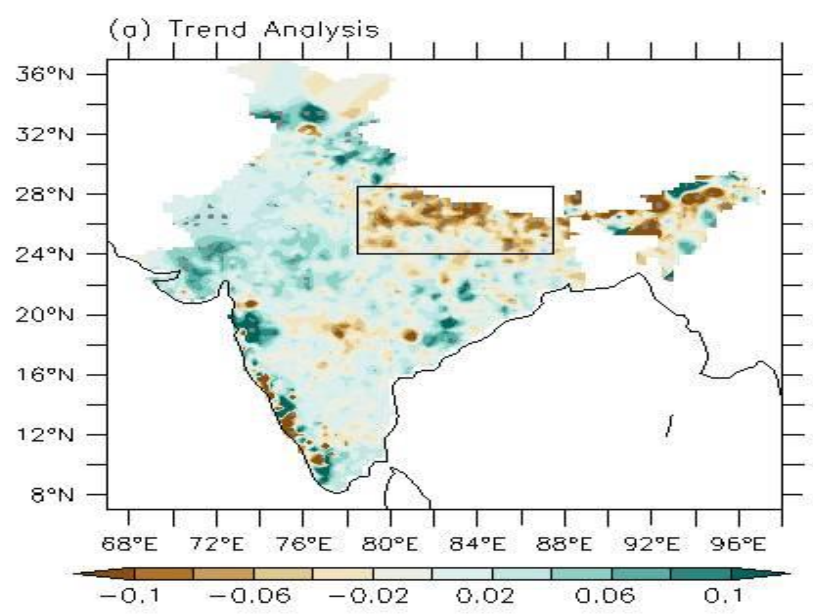
A strong north India summer-monsoon rainfall (NISR) is associated with anomalous upper troposphere ridge over northwest of India. This ridge triggers anomalous northerly winds over Tibetan Plateau and easterlies over India. The northerly at Tibetan Plateau allows frequent intrusions of high-latitude dry and cold meridional winds to interact with lower-level relatively warm and moist easterly monsoonal flow, enhancing the NISR. In recent two decades (1996-2017), the NISR has been exhibiting a decreasing trend with increased variability, much larger than the earlier period (1979-2000). A possible reason for this is due to the rise in warm sea surface temperature (SST) observed in east equatorial Indian ocean, which shows a negative correlation to NISR. The current analysis indicates that the warmer SST induce strong convection and associated northward propagating off-equatorial Rossby gyres to the west of the equatorial eastern Indian ocean, spreading the tropospheric heating towards the northeast of India, thereby elevating the geopotential height. This creates upper troposphere low pressure anomaly at the northwest of India. These factors are consistent with the suppression of the NISR, resulting in the observed decreasing trend in the recent decades. The current study, using a suite of observations, reanalysis products and numerical model sensitivity experiments, explores the changes in NISR, and its association with the warming in the equatorial Indian Ocean.

Data and Methodology

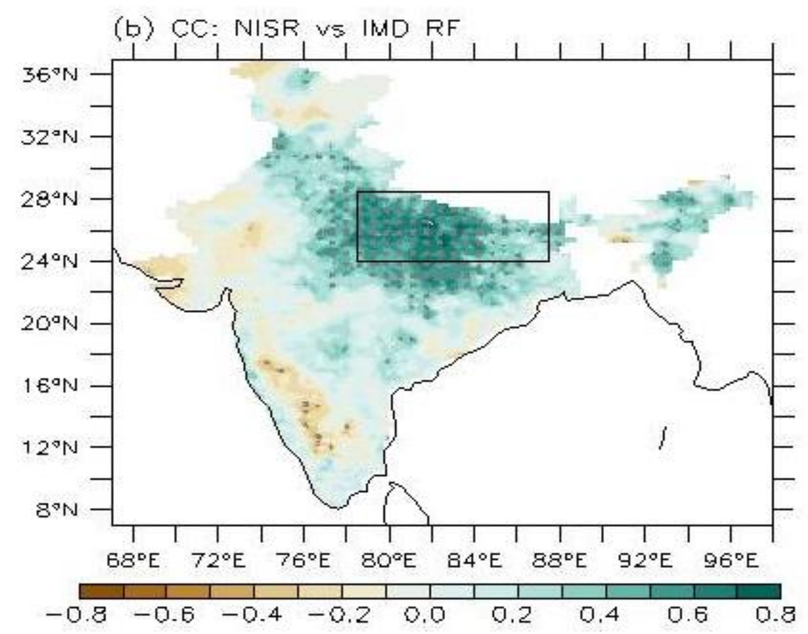
- ERA-Interim dataset available at a 0.75° and IMD gridded rainfall data at a 0.25° spatial resolution used for the period 1979-2017.
- The time-series has been prepared by averaging the gridded rainfall over the box (78.5° E–87.5° E, 24° N–28.5° N; NISR).
- For the climate model sensitivity experiments, the Climate Forecast System version 2 (CFSv2) is used.
- CFSv2 is time integrated over a period of 40 years, and utilized as the reference run ($CFSv2_{CTL}$).
- Ensembles (10 members) of short integrations for the summer monsoon season during June-September were performed by adding temperature anomalies to the SSTs passed over the equatorial Indian Ocean, to the atmosphere ($CFSv2_{EQIO}$).
- The difference between $CFSv2_{EQIO}$ and $CFSv2_{CTL}$ is taken as the model response to the summer warming over the equatorial Indian Ocean.

Results

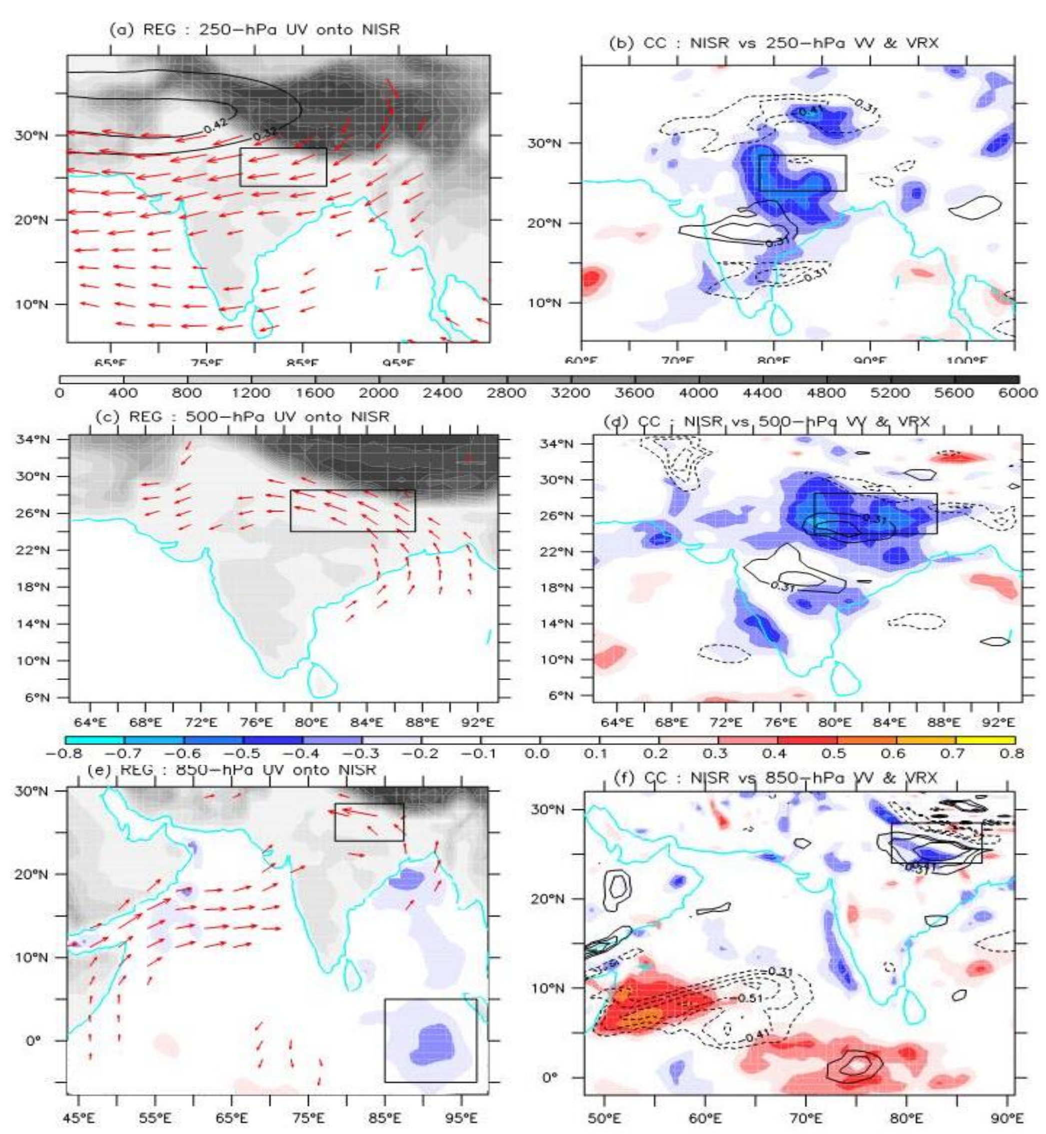
- The analysis shows that the NISR manifest as the combined contribution of the interaction between the lower-level moisture laden monsoonal flow and the upper-tropospheric dry and cold meridional winds.
- The NISR time series depicts decreasing trend of -0.03865 mm/day, significant at 98% confidence level.
- The decreasing trend is more accelerated in last two decades 1996-2017 (-0.0443 mm/day) than the earlier period (-0.02485 mm/day).
- The significant negative correlation is observed over the eastern equatorial Indian Ocean.
- The EEIOSST are always more than 28.94°C in the study period and depict warming trend of 0.0165°C/month, significant at 99.9% level.
- To confirm the monsoon response to EEIO, coupled model experiments have been conducted with SST anomalies imposed over EEIO.
- A Kelvin wave response is there to the east of EEIO and a Rossby wave pattern to the west.
- The warm EEIO generates off equatorial Rossby gyres to the west of convection leading to the warming of the troposphere and elevating GPH.



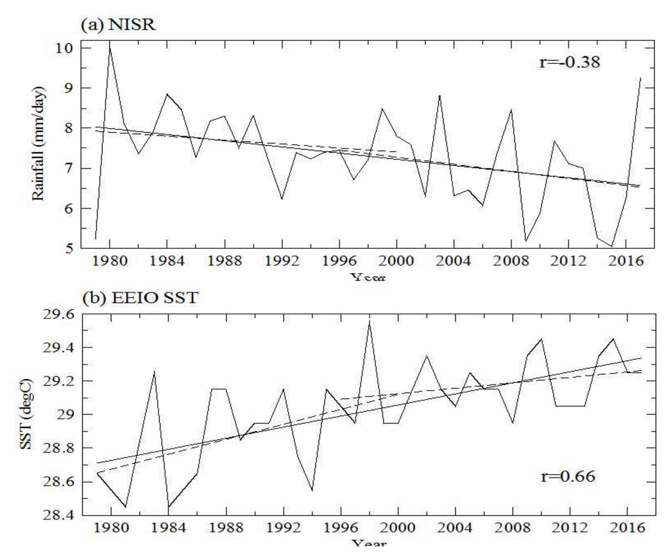
JJAS seasonal trend analysis for India rainfall. Areas of 95% significance level are shaded by grey dots.



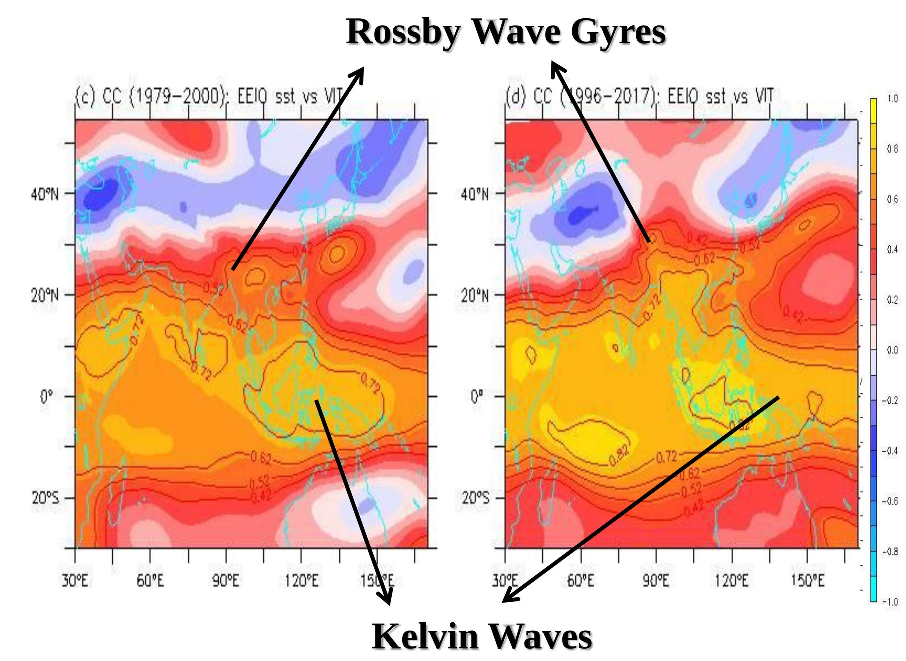
Simultaneous correlation coefficients between NISR and IMD RF. Areas of 95% significance level are shaded by grey dots.



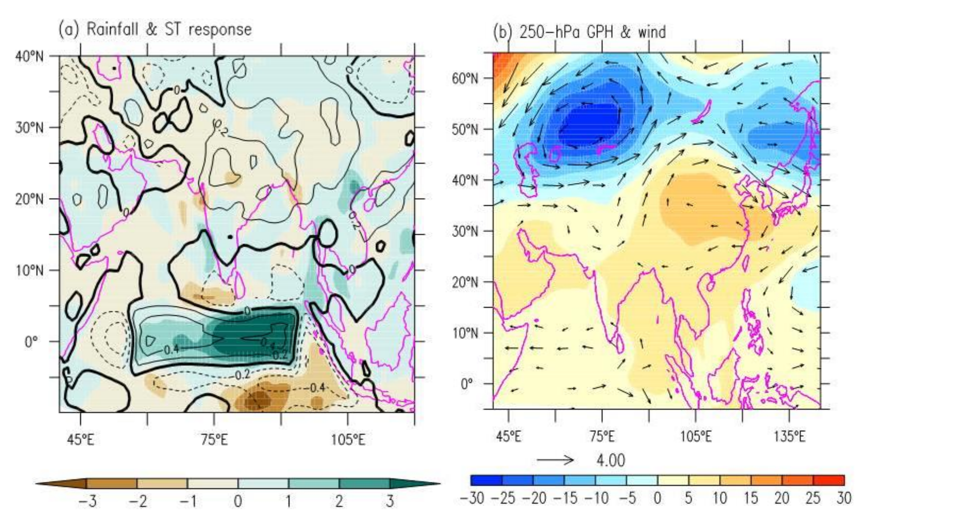
Regression of (a) 250-, (c) 500- and (e) 850-hPa wind onto NISR. The grey shading is the altitude. Correlation coefficients of NISR with (a) 250-hPa GPH (contours), (e) SST (color shade), (b) 250-, (d) 500- and (f) 850-hPa vertical velocity (color shade) and vorticity (black contours).



Time-series of (a) NISR (mm/day), (b) EEIOSST. The straight black line in a and b represents the trend line for the entire period and the straight dashed line represents the trend line for the respective epochs



Contiguous correlation coefficients of EEIOSST with vertically integrated temperature from 650 and 175-hPa for (c) period 1 and (d) period 2



Model experiment (a) surface temperature (°C, black contours), rainfall (mm/day, color shade), and, (b) 250-hPa wind (m/s, black arrows) and GPH (m, color shade) response.

Conclusions

- NISR manifest as the combined contribution of the interaction between the lower-level moisture laden monsoonal flow and the upper-tropospheric dry and cold meridional winds.
- The warm SST over the equatorial Indian Ocean, decrease in northerly over the Tibetan Plateau, and decreased rainfall in the later period over NISR.
- The warming of the eastern equatorial Indian Ocean generates off equatorial Rossby gyres to the west.
- The elevated GPH has separated two low pressure anomalies over northwest of Indian and east Asia, associated with anomalous southerly wind over the Tibetan Plateau.
- This southerly wind hinders the interaction of upper-troposphere dry winds from mid-latitude winds to the lower-level monsoonal wind, thereby reducing the NISR.