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VARIABILITY OF NAO, NORTHERN AND SOUTHERN HEMISPHERE TEMPERATURE IN RELATION TO INDIAN SUMMER MONSOON RAINFALL

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1. INTRODUCTION

North Atlantic Oscillation (NAO) is essentially the pressure difference between the Azores High (40° N, 30°W) and the Icelandic Low (63° N, 30 °W). When both features are strong, then NAO is positive and the strength of westerlies across the Atlantic basin is increased which is associated with higher European temperatures. A negative phase of NAO is associated with weaker westerly winds and lower European temperatures. Thus, the phase of NAO is directly associated with the temperature over Europe during winter season. Hurrell (1995) showed that the changes in circulation over the Atlantic have contributed much to the recent wintertime warming across Europe, the coolness over the eastern Mediterranean, and to the very cold conditions over the northwest Atlantic. He pointed out that temperature variations over North Atlantic region are related to changes in the NAO, while the changes over the North Pacific are linked to the temperature variations in tropics and involve variations in the Aleutian low with teleconnections downstream over North America. Hurrell (1996) further showed, using multivariate linear regression, that nearly all of the cooling in the northwest Atlantic and the warming across Europe and downstream over Eurasia since the mid-1970s results from the changes in the NAO. Thus, the NAO dictates climate variability from the eastern seaboard of the United States to Siberia and from the Arctic to the subtropical Atlantic. In the present paper, an attempt has been made to understand the relationship between NAO and southern hemispheric temperature.

2. DATA USED

2.1. Indian summer monsoon rainfall (ISMR) data have been taken from web address http://www.tropmet.res.in/.

2.2. North Atlantic Oscillation (NAO) data have been taken from web address http://www.cgd.ucar.edu/cas/hurrell/indices.data.

2.3. Northern hemispheric temperature (NHT), southern hemispheric temperature (SHT), southern tropical temperature (STM) and temperature over south of 30°S data have been taken from web address http://www.met-office.gov.uk/research/.

Monthly indices of above parameters are available on respective web address. ISMR indices are calculated as the percentage rainfall departure from long-term mean of rainfall during June-September. The seasonal series for NHT, SHT, STM and temperature over south of 30°S is calculated by averaging the temperatures of appropriate months in the season. The seasons consists of following months-

Winter: Previous year December, January and February
Spring: March, April and May
Summer: June, July and August
Autumn: September, October and November

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3. DISCUSSION

Hurrell (1995), Wallace (2002) and Yoo (2002) have shown the increasing trend in winter-NAO. Moreover, in recent 21-year period (1981-2001), the winter-NAO is positive for 15 years and is negative for 6 years only. In view of this increasing trend and recent positive phase of winter-NAO, its relationship with southern hemisphere temperature is studied.

3.1 NAO and Southern Hemisphere Temperature

Gutzler (1988) have shown the patterns of inter-annual variability in the Northern Hemisphere wintertime 850-hPa temperature field and Wallace (1995) have studied the dynamic contribution to hemispheric mean temperature trends. The fluctuations in NAO and northern hemispheric temperature are in phase. The probable reasoning for this direct relationship may be as: when NAO is positive then the faster westerlies minimize polar outbreaks, which create above-normal temperatures, especially in winter, which may results in above-normal temperature anomalies over northern hemisphere. In this section, we will discuss the relationship between NAO and southern hemisphere temperature.

Since NAO is strong in the winter season, the correlation between winter-NAO and seasonal temperature anomaly over south of 30°S, for 1951-2000, is computed and graphically represented in figure-1. It suggests that the relationship is direct and is statistically significant, at 5% level, in winter and spring seasons only.

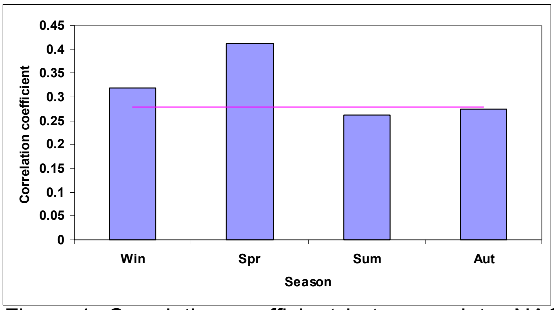


Figure-1: Correlation coefficient between winter-NAO and seasonal temperature anomaly over south of 30°S for 1951-2000

Figure-2 depicts 50-year running correlation coefficients between NAO and temperatures over southern hemisphere, southern tropical belt and south of 30°S in winter season. The relationship shows temporal and spatial variability. It reveals that the association of NAO with southern hemisphere temperature and southern tropical temperature is not statistically significant at 5% level but the association of NAO with temperature over south of 30°S is significant after 1932. It suggests that the relationship is inverse from 1901-50 to 1924-73 (though it is not significant) and becomes positive from 1924-73 onwards with statistically significant at 5% level after 1932-81.

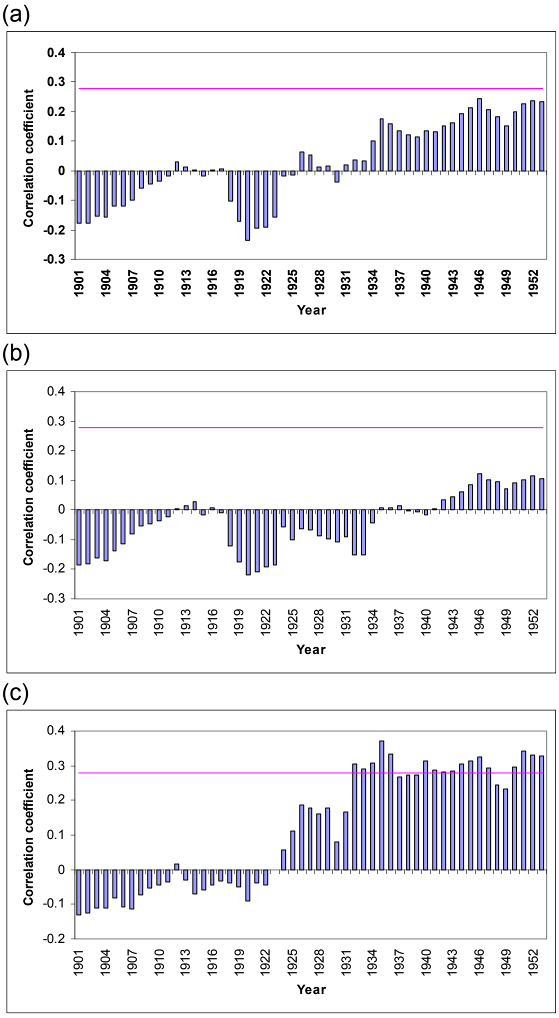


Figure-2: 50-year running correlation coefficients of NAO with (a) Southern hemisphere temperature, (b) Southern tropical temperature and (c) temperature over south of 30°S in Winter season.

3.2 Northern hemisphere temperature, Indian summer monsoon rainfall and temperature over south of 30°S.

Indian summer monsoon rainfall (ISMR) is thermally driven large-scale phenomenon. Many earlier studies have shown the effect of temperature field on monsoon circulation over India. Verma (1985) have shown direct association between Northern hemisphere surface air temperature anomaly during January-February and Indian summer monsoon rainfall. However, in recent decades this relationship seems to lose its statistical significance. In view of this, the inter-relationship of ISMR, northern hemispheric temperature (January-February) and temperature anomaly over south of 30°S is studied in this section.

The positive relationship between Northern hemispheric temperature anomaly in winter ((January+February)/2) season and Indian summer monsoon rainfall, for different 50 years, is depicted in the figure-3. It suggests the stable relationship but this relationship is statistically significant, at 5% level, for 1923-94 only (1923-72 to 1945-94). After 1945-94, the association seems to be statistically insignificant.

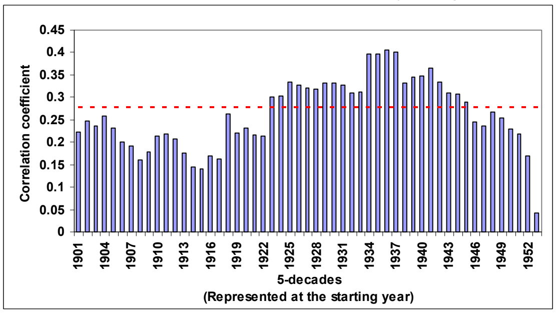
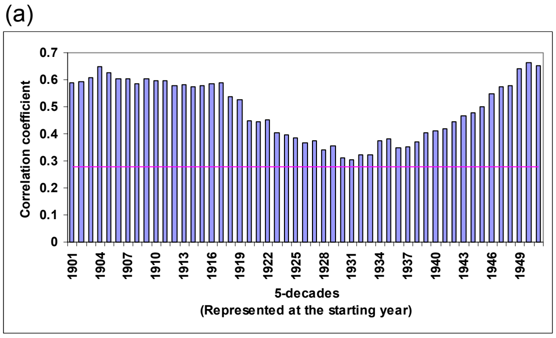


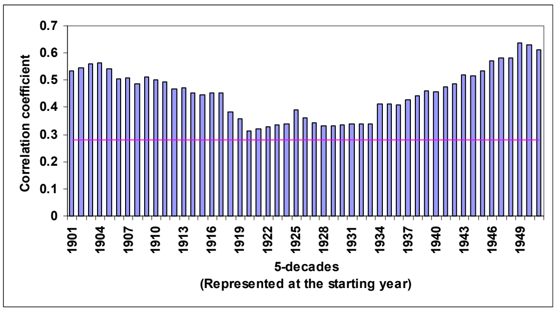
Figure-3: 50-year running correlation coefficients between Northern hemisphere temperature in winter season ((January+February)/2.0) and Indian summer monsoon rainfall.

In order to understand the association between northern and southern hemispheric temperature, 50-year running correlation coefficients between NHT in January-February and temperature over different regions of southern hemisphere in winter season are computed. Figure-4 depicts the same and reveals that the direct association of NHT in January-February with southern hemispheric temperature and southern tropical temperature is statistically significant at 5% level for all 50-year periods whereas the association of NHT in January-February with temperature over south of 30°S is significant for 50-year periods except from 1925-74 to 1943-92.

(a)



(b)



(c)

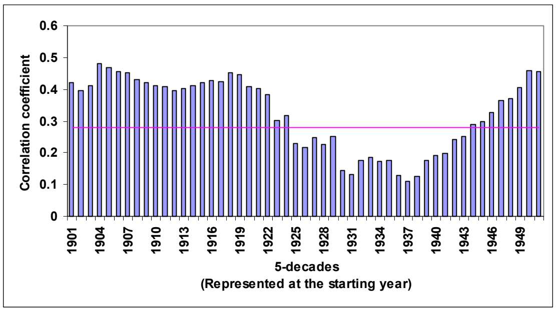


Figure-4: 50-year running correlation coefficients of northern hemispheric temperature in January-February with (a) Southern hemisphere temperature, (b) Southern tropical temperature and (c) temperature over south of 30°S in Winter season.

In order to understand the effect of temperature anomaly over south of 30°S, 50-year running correlation coefficients between Indian summer monsoon rainfall and temperature over south of 30°S in winter season are computed. Figure-5 is the graphical representation of the same. It suggests that the relationship between ISMR and temperature over south of 30°S is direct for 50-year periods from 1901-50 to 1929-78 and becomes negative from 1930-79 onwards.

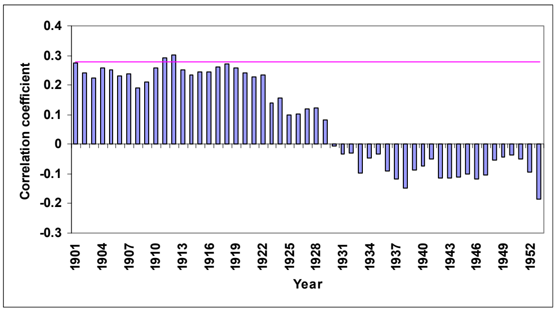


Figure-5: 50-year running correlation coefficients between Indian summer monsoon rainfall and temperature over south of 30°S in winter season.

Thus, wintertime temperature over south of 30°S is showing significant positive relationship with winter-NAO but insignificant inverse relationship with ISMR in recent decades. Moreover, the northern hemisphere temperature in January-February is also showing temporal and spatial variability in the relationship with southern hemisphere temperature anomaly. This temporal and spatial variability in the relationship of southern hemisphere temperature anomaly with NAO and northern hemispheric temperature during winter season may have resulted in insignificant association between NHT in January-February and ISMR in recent decades.

4. CONCLUSIONS

Following conclusions can be drawn from this study,

4.1. The relationship between NAO and southern hemisphere temperature shows temporal and spatial variation. Winter-NAO is directly associated with seasonal temperature over south of 30°S, but the relationship is statistically significant at 5% level for winter and spring seasons only. In recent decades (after 1932-81) relationship between NAO and temperature over south of 30°S, during winter season, is statistically significant and is stable one.

4.2. The temperature over south of 30°S in winter season is showing temporal variation in the relationship with northern hemispheric temperature in January-February and Indian summer monsoon rainfall. The relationship between ISMR and temperature over south of 30°S is direct for 50-year periods from 1901-50 to 1929-78 and becomes negative from 1930-79 onwards.

4.3. This temporal variation in the relationship of the temperature over south of 30°S in winter season with northern hemispheric temperature in January-February, Indian summer monsoon rainfall and NAO may have resulted in insignificant association of Indian summer monsoon rainfall with northern hemispheric temperature in January-February and good association between Indian summer monsoon rainfall and NAO related parameters.

5. REFERENCES

Hurrell, J.W., 1995: Decadal trends in the North Atlantic Oscillation regional temperatures and precipitation, *Science*, **269**, 676-679.

Hurrell, J.W., 1996: Influence of variations in extratropical wintertime teleconnections on Northern Hemisphere temperature, *GRL*, **23**, 665–668.

Wallace, J.M. and D. W.J. Thompson, 2002: Annular modes and climate prediction, *Physics Today*, **55(2)**, 28-33.

Yoo, JC, and P. D'Odorico, 2002: Trends and fluctuations in the dates of ice break-up of European lakes and rivers, *J. Hydrol*., **268(1-4)**, 100-112.

Gutzler, D.S., Rosen, R.D. and Salstein, D.A., 1988: Patterns of interannual variability in the Northern Hemisphere wintertime 850 mb temperature field, *J. Climate*, **1**, 949-964.

Wallace, J.M., Zhang, Y. and Renwick, J.A., 1995: Dynamic contribution to hemispheric mean temperature trends, *Science*, **270**, 780-783.

R.K.Verma, K, Subramanium and S.S.Dugam, 1985: Inter- annual and long term variability of summer monsoon and its possible link with Northern

Hemispheric surface air temp. *Proceeding of Indian Academy of Sciences (EPS)*, 94, 30, 187-196.

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