Teleconnection of Siberian High with wintertime temperature variability in Sri Lanka

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Abstract: *This study examines the impact of the Siberian High on wintertime temperature variability in Sri Lanka. The study uses area-weighted pressure and area-weighted latitudinal and longitudinal displacements to show that the meridional movement of the Siberian High pressure has a significant correlation with wintertime temperature. The study finds that the latitudinal index of the Siberian High explains 31% of the variability in regional wintertime temperature, while El Nino Southern Oscillation (ENSO) explains only 12%. A linear model is constructed using the pressure index of the Siberian High, which explains the variability of wintertime temperature over the region. Composite maps are plotted using NCEP/NCAR Reanalysis, and physical justifications are given to support the statistical findings. The study concludes that including the Siberian High pressure with ENSO increases the explanation of variability of wintertime temperature in the region under consideration.*

Keywords*:Wintertime temperature, Center of Action, Siberian High*

1. Introduction

El Niño Southern Oscillation (ENSO) is a natural climate phenomenon that affects weather patterns worldwide. It is characterized by a warming of the surface waters in the eastern and central equatorial Pacific Ocean, which can lead to significant changes in global weather patterns. The effects of ENSO on Sri Lanka's climate have been the subject of much research, with a particular focus on the impact of ENSO on temperature.

Sri Lanka, located in the Indian Ocean, is a small island nation with a tropical climate. Its climate is influenced by the monsoon winds, which bring heavy rainfall to the country in two distinct periods: the northeast monsoon (December to February) and the southwest monsoon (May to September). The temperature in Sri Lanka is influenced by a range of factors, including topography, ocean currents, and atmospheric circulation patterns.

ENSO has been found to have a significant impact on Sri Lanka's climate, particularly on its temperature. During El Niño events, Sri Lanka experiences above-average temperatures, while La Niña events result in cooler temperatures.

Several studies have investigated the relationship between ENSO and Sri Lanka's temperature. One study found that during El Niño years, the temperature in Sri Lanka increases by an average of 0.6-1.0°C, while during La Niña years, the temperature decreases by an average of 0.3-0.6°C. This temperature variability has been found to be particularly pronounced during the winter season

(December to February), with El Niño events leading to higher temperatures and La Niña events leading to lower temperatures.

The impact of ENSO on Sri Lanka's temperature has important implications for the country's economy, particularly its agriculture sector. Sri Lanka's agriculture is heavily dependent on rainfall, and changes in temperature can significantly impact crop yields. During El Niño events, Sri Lanka experiences reduced rainfall, which can lead to drought conditions and reduced crop yields. Conversely, during La Niña events, Sri Lanka experiences increased rainfall, which can lead to flooding and crop damage.

In addition to its impact on temperature, ENSO also affects other aspects of Sri Lanka's climate, including rainfall patterns, wind patterns, and ocean currents. Understanding the relationship between ENSO and Sri Lanka's climate is therefore essential for developing effective climate adaptation strategies in the country.

In conclusion, ENSO has a significant impact on Sri Lanka's temperature, with El Niño events leading to higher temperatures and La Niña events leading to lower temperatures. This temperature variability has important implications for Sri Lanka's economy, particularly its agriculture sector. Further research is needed to fully understand the relationship between ENSO and Sri Lanka's climate and to develop effective climate adaptation strategies for the country.

The North Atlantic Oscillation (NAO) is a large-scale atmospheric circulation pattern that describes the pressure differences between the Icelandic Low and the Azores High. It can have a significant impact on the winter climate of Asia by influencing the strength and position of the westerly winds over the region.

During a positive phase of NAO, the westerly winds over Asia become stronger and shift northward, leading to warmer and wetter conditions in northern and central parts of the region, including northern China, Mongolia, and Siberia. Conversely, a negative phase of NAO is associated with weaker and southward-shifted westerly winds, resulting in colder and drier conditions in those areas.

The NAO can also influence the intensity and frequency of extratropical cyclones and the associated precipitation patterns over Asia, particularly in the eastern part of the continent. In addition, the NAO can influence the distribution of sea ice in the Arctic Ocean, which in turn can impact the atmospheric circulation and the climate of the Northern Hemisphere.

There is a phenomenon, namely, western disturbances that have a significant impact on the winter climate of Asia. These extratropical storms, originating from the Mediterranean region, bring moisture and precipitation to the Indian subcontinent, Central Asia, and parts of China. In India, Western disturbances bring rain and snowfall to the northwestern region, including Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Punjab. They also bring rainfall to the central and eastern parts of India.

In addition to precipitation, western disturbances also affect temperature patterns in the region. During their passage, they bring cold air masses from Central Asia, leading to a decrease in temperatures in the region. This can result in frost and even snowfall in some areas.

Western disturbances also have an impact on the atmospheric circulation patterns over the region. They interact with the subtropical westerly jet stream and can cause disturbances in the flow of air masses, leading to changes in weather patterns. This can result in anomalies such as prolonged cold spells or dry spells in the region.

The impact of western disturbances on the winter climate of Asia is crucial, as it affects the water balance, agriculture, and energy demand of the region. Proper monitoring and forecasting of Western disturbances can help in the efficient management of water resources, agriculture, and energy demand during the winter season.

Using the "centers of action" approach established by Rossby et al. (1939), this study aims to investigate the new parameters responsible for the variability of wintertime (December-January-February; DJF) temperature in the northern region of South Asia. The "centers of action" (COA) approach involves examining specific areas of the Northern Hemisphere that have a significant impact on seasonal weather patterns, including the Icelandic and Aleutian Lows, the Azores High, the Hawaiian High, and the Siberian High.

Previous research by Cohen (2001) has identified three semi-permanent COAs in the Northern Hemisphere during the middle to high latitude winter season, with two of them situated in the major ocean basins (i.e., the Icelandic and Aleutian lows) and the third located in Asia (i.e., the Siberian High). Rossby et al. (1939) also observed that changes in the intensity and position of a COA can affect regional circulation, as noted by Iqbal, Riaz, and Ghauri (2012).

The Siberian High (SH) is a semi-permanent and quasi-stationary atmospheric COA that is dominant during the boreal winter season. According to Lydolf (1977), it is associated with the coldest and densest air masses found in the Northern Hemisphere. The SH usually emerges in October as a result of intense and prolonged radiative cooling in the lower troposphere above the snow-covered surface of Asia. It remains in place until the end of April, as observed by Panagiotopoulos et al. (2005).

The SH is a high-pressure system that forms over Siberia during the winter months, and it can have a significant impact on the winter climate in surrounding regions. This high-pressure system is characterized by cold, dry air that flows southward towards East Asia and the Pacific Ocean, and it can lead to the development of cold, dry winters in these regions.

The Siberian High has several impacts on winter climate:

1. Temperature: The Siberian High brings cold air masses into the surrounding regions, which can cause temperatures to drop significantly. During periods when the Siberian High is particularly strong, temperatures can drop to extremely low levels, leading to severe winter conditions.
2. Precipitation: The cold, dry air associated with the Siberian High inhibits the formation of precipitation, resulting in dry winter conditions in the surrounding regions. This can be

particularly noticeable in areas that typically receive a significant amount of winter precipitation.

3. Wind: The Siberian High can also cause strong winds to develop, particularly in regions that are located on the periphery of the high-pressure system. These winds can cause further cooling and exacerbate the effects of the cold temperatures.
4. Snow cover: The Siberian High can also lead to the development of extensive snow cover in the surrounding regions. This can be due to the cold temperatures and the lack of precipitation, which can result in snowfall accumulating and persisting on the ground for long periods of time.

Overall, the Siberian High has a significant impact on the winter climate in surrounding regions, and it is an important factor to consider when studying and forecasting winter weather patterns.

Despite the fact that the Siberian High is the primary atmospheric circulation system in the lower troposphere that governs a significant portion of continental Asia, it has received comparatively little scrutiny (Gong & Ho 2002). Consequently, an effort was made to investigate the potential influence of the Siberian High on winter temperatures in Sri Lanka.

2. Data and Methodology

Monthly mean minimum temperature data has been obtained from Climate Research Unit (CRU) of University of East Anglia, United Kingdom. It is high resolution data of 0.5^o latitude x 0.5^o longitude. Monthly gridded mean sea level pressure (SLP) has been obtained from National Center for Environmental Prediction (NCEP), USA used to calculate objective COA indices for monthly averaged pressure, zonal and meridional position of Icelandic low, Azores High, the Siberian High and etc. The North Atlantic Oscillation (NAO), Atlantic Oscillation (AO) and Southern Oscillation Index (SOI) have also been obtained from Climate Prediction Center (CPC), NCEP, USA.

The pressure index I_p of a High pressure system is defined as an area-weighted pressure departure from a threshold value over the domain (I, J):

$$I_{p,\Delta t} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\cos\phi_{ij}\delta_{ij,\Delta t}}{\sum_{i=1}^{I}\sum_{j=1}^{J}\cos\phi_{ij}\delta_{ij,\Delta t}} \tag{1}$$

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Similarly, the latitudinal index is defined as:

$$I_{\phi,\Delta t} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\phi_{ij}\cos\phi_{ij}\delta_{ij,\Delta t}}{\sum_{i=1}^{I}\sum_{j=1}^{J}\left(P_{ij,\Delta t} - P_t\right)\cos\phi_{ij}\delta_{ij,\Delta t}} \quad (2)$$

And the longitudinal index is defined in analogous manner.

In equations 1 and 2, P_{ij} is the gridded SLP over the grid point (i,j) averaged over a time interval Δt. P_t is the threshold SLP value obtained by examining the geographical ranges in NCEP Reanalysis data over the period 1948 to 2006. $\emptyset_{ij}$ (λ_{ij}) is the latitude (longitude) of the grid point (i,j). In order to ensure the difference is due to high pressure we test the factor $(P_{ij} - P_t)$. If the factor is positive we take $\delta = 1$ and $\delta = 0$ if it is negative. The intensity is thus a measure of the anomaly of the atmospheric mass (pressure) over the section (I,J). The domain of the Siberian High is chosen as 25-75^{o}N and 50-170^{o}E.

Regression analysis has been employed to investigate the possible relationship of wintertime temperature of Sri Lanka with Siberian High. The wintertime temperature (December-January-February; DJF) has been computed. Correlations between wintertime temperature and all COA indices have been calculated. The purpose is to identify regions where a significant amount of variation can be possibly explained by further study. The indices with large contributions that could be significant have been identified. Correlations among the indices are then calculated to identify the significant independent COA indices. Next, multiple linear regression have been applied between the regional DJF temperature and the identified significant independent indices only. The variance associated with each index designates the relative importance of the index in modulating the regional variability. Also, the total variance gives confidence in relating and explaining these inter annual variations.

3. Results and Discussion:

Correlation maps have been plotted between the regional wintertime temperature and SBPS, SBLT and SOI for the period 1952 to 2002 for the correlations significant at 5% level. Positive correlations are marked with plus red signs and negative correlations are marked with blue circles. Table 1 depicts the correlations between the wintertime temperature and different teleconnection indices. In view of figures the average wintertime (DJF) temperature for sub region 79-82oE, 6-10oN have been calculated for Sri Fig 2 Correlation between wintertime temperature and Siberian High Latitude (SBLT) at 5% significance level. Negative correlations are marked with blue circles. It is to be noted that pressure index and latitudinal index of Siberian High is more significant than other parameters. Although SOI also have contribution in explaining variability of the regional wintertime temperature but SH has more contribution over the regional wintertime temperature.

Next we have interpreted the significant independent indices and constructed a linear model of wintertime temperature over Sri Lanka using pressure index of Siberian High and Southern Oscillation index (Eq. 3). A linear regression model has been constructed which explains 25% variability of regional DJF temperature. The regression equation is:

DJF temperature = 348.290 – 0.27 (SBPS) – 0.206 (SOI)

4. Physical Justifications Of Teleconnection Mechanism Of Siberian High With Wintertime Temperature

Various composite maps have been plotted using NCEP/NCAR Reanalysis data to examine the possible relationship of SH with wintertime temperature. By constructing these composite maps in this section, evidence will be given that mathematically determined relationships are consistent with the regional atmospheric circulations. We examine air temperature composite anomalies during the winter season from monthly NCEP-NCAR reanalysis data. To produce these composite anomalies, we determine the pressure values of Siberian High when they were extremely high or extremely low. The high years correspond to the years when SH pressure was the highest from 1952-2002 and the low years correspond to the years when SH pressure was the lowest from 1952-2002. Figure 4 (a, b and c) shows the difference between high and low years of air temperature composite anomalies at 500 millibars (mb). In years when pressure values of Siberian High were high the air temperature was low and in the years when pressure values of Siberian High were low the air temperature was high.

5. Conclusion

In this study, the "centers of action" approach is utilized to demonstrate the dominant influence of the Siberian High on the variability of wintertime (DJF) temperature in Sri Lanka. The researchers analyze NCEP-NCAR reanalysis composites with Siberian High pressure, revealing that Siberian air penetrates the region, as indicated in Figure 3. The calculations performed indicate that the contribution of the Siberian High on the regional wintertime temperature is greater than that of NAO and SOI.

Furthermore, the study finds that the Indian Ocean High pressure index provides a more substantial explanation of the variability of seasonal temperature in the mentioned region compared to NAO and ENSO. The researchers conclude that including the Siberian High pressure (with ENSO) increases the explanation of the variability of wintertime temperature in the region under examination.

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Table 1 Correlation of wintertime (DJF) temperature with various teleconnection indices at 5% significant level for the region 79-82^{o}E, 6-10^{o}N. Significant correlations are marked bold.

Parameters	**Pearson's Correlation Coefficients**
Siberian High Pressure (SBPS)	**-0.43**
Siberian High Latitude (SBLT)	**-0.56**
Siberian High Longitude (SBLN)	-0.05
Southern Oscillation Index (SOI)	**-0.35**
Arctic Oscillation (AO)	0.21
Indian Ocean High Longitude (IOLN)	-0.24
Indian Ocean High Latitude (IOLT)	-0.08
Indian Ocean High Pressure (IOPS)	**0.37**
North Atlantic Oscillation (NAO)	0.20
Nino 3.4	**0.35**
SBPS & SOI	**0.50**

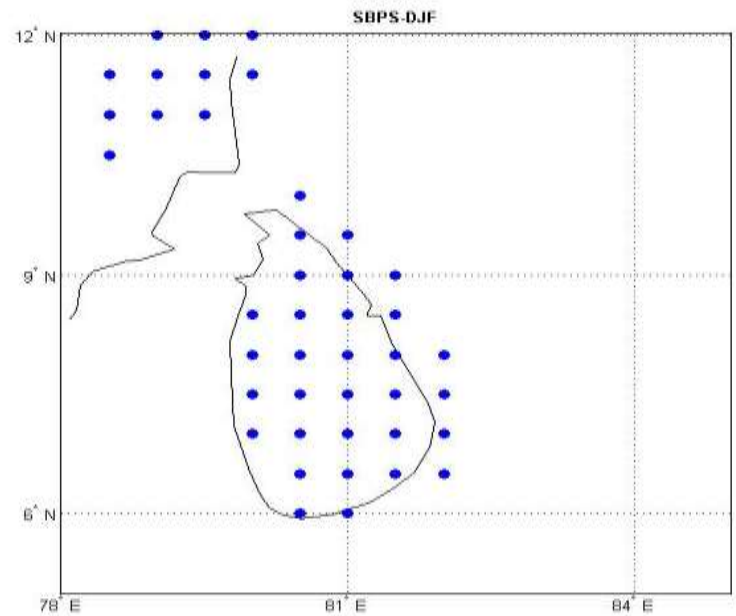

Fig. 1. Correlation between wintertime temperature and Siberian High Pressure (SBPS) at 5% significance level. Negative correlations are marked with blue circles.

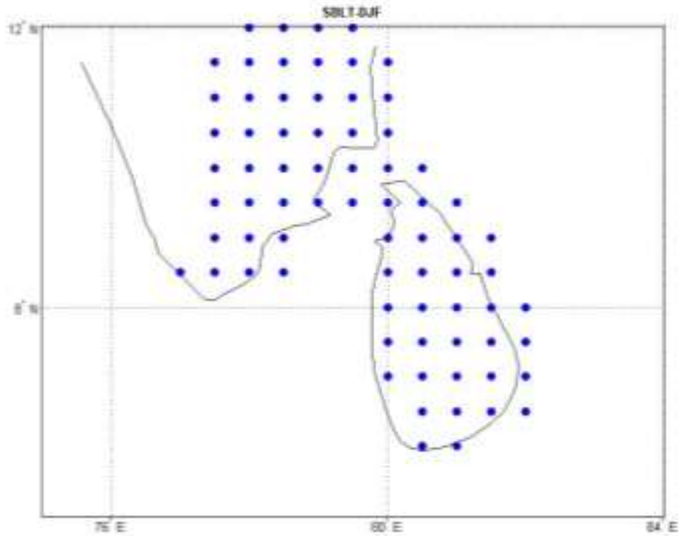

Fig. 2. Correlation between wintertime temperature and Siberian High Latitude (SBLT) at 5% significance level. Negative correlations are marked with blue circles.

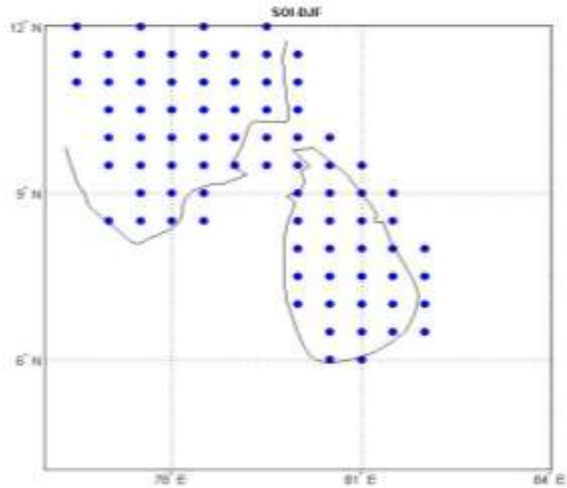

Fig 3 Correlation between wintertime temperature and SOI at 5% significance level. Negative correlations are marked with blue circles.

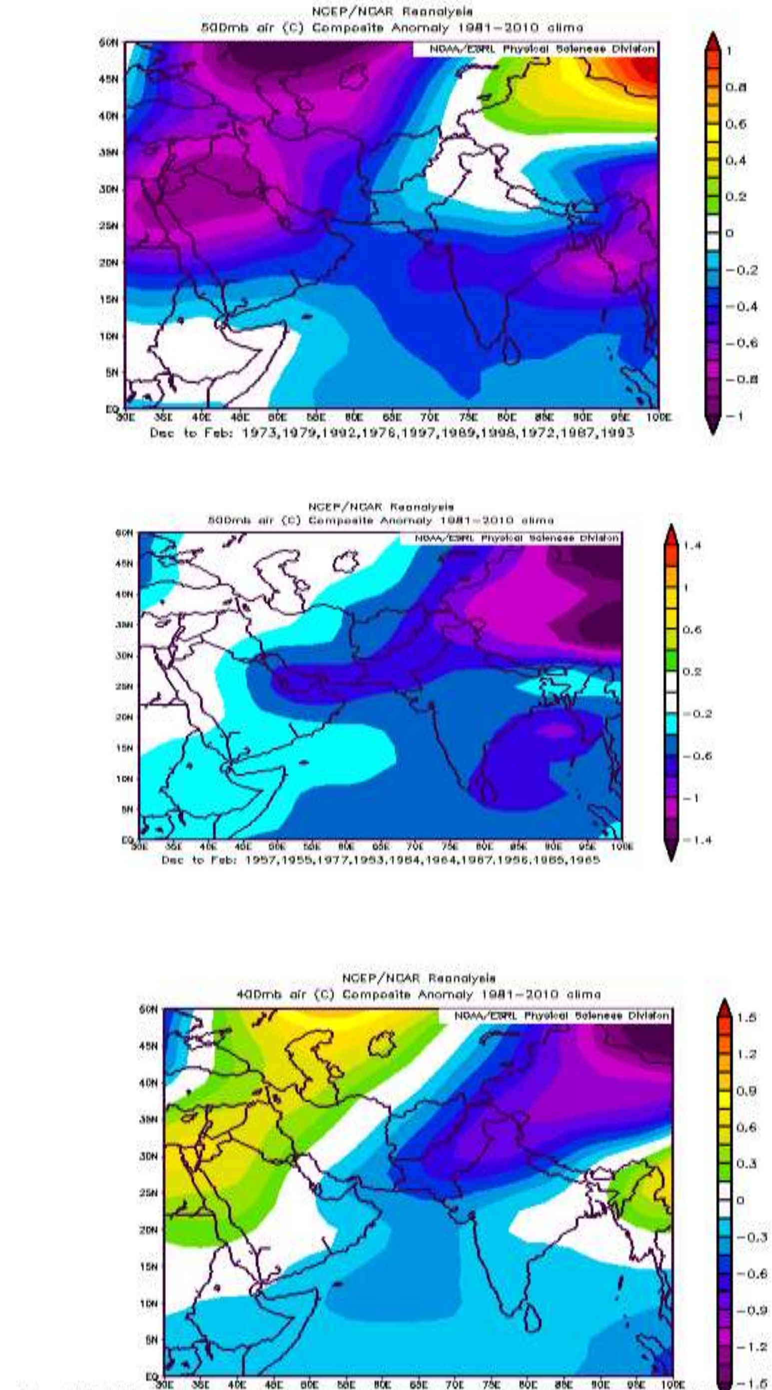

Fig. 4. Composite anomaly for surface air tempetaure (°C) at 500-mb for the years a) when pressure values of Siberian High were highest b) pressure values of Siberian High were lowest c) pressure values of Siberian High were highest minus the years when pressure values of Siberian High were lowest

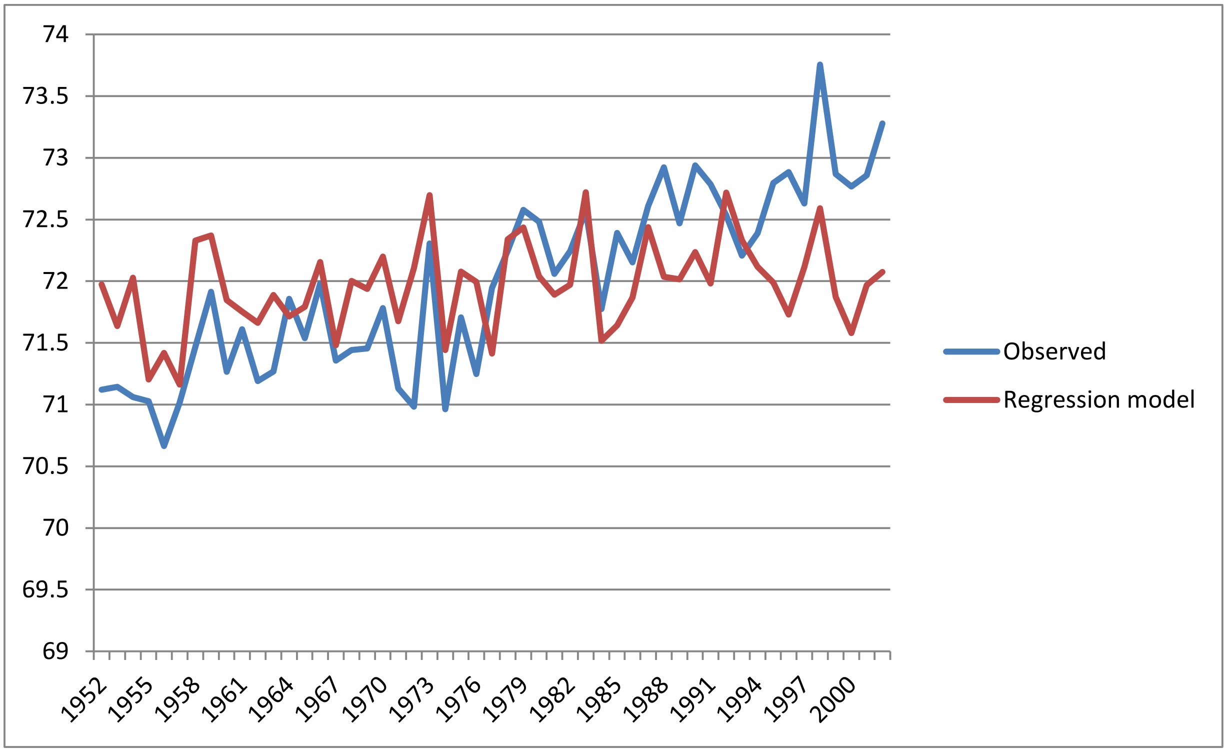

Fig 5 Comparison between wintertime (DJF) temperature and regression model at 5% significance level. R-square for the model is 0.25