Analysis of Climatology of Clod Wave Variation and its Possible Mechanism over Rangpur Region in Bangladesh

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Abstract

Extreme weather events such as cold waves have disastrous effect on the health of people, especially vulnerable groups in developing countries due to ongoing global climate warming. Accordingly, this study intends to analyze the climatology of cold wave condition and its possible mechanism in Bangladesh. The minimum temperature (MinT) datasets of cold wave-affected Rangpur region for the period 1981–2021 were used for this purpose. As per the definition of cold waves provided by Bangladesh Meteorological Department (BMD), the frequencies of days with MinT in the range of 10°C have been considered and their future trends are being investigated to depict the cold wave condition in the study region. The results show that the cold wave follows a decreasing trend with a rate of decrement of -0.164/year during the study period. The lowest MinT≤15 was found in 2008-2009 while the highest MinT≤15 was observed in 1982-1983.Winter follows a decreasing trend under MaxT≤25 and MinT≤15, with a decrement rate of 0.249/year in the winter season from 1981 to 2021. Under the condition of the maximum temperature of 20°C (MaxT≤20) and a minimum temperature of 12.5°C (MinT≤12.5), the extreme winter lies on an average of 5 days in the winter season in the observation period. The maximum continuation of winter in the winter season under MaxT≤25 & MinT≤15 is 72 days, which happened in the 1984-1985. From 1981 to 2021, the standard deviation and correlation coefficient for extreme weather events in the winter season with each passing year are 11 and -0.245 in the study area. This study also found that the deviation of winter from 15th December follows a decreasing trend with a decrement of 0.0816/year. In the winter season, a center of high pressure (an anticyclone) lies over the northwestern part of India and from this high pressure a stream of cold air flows eastward that enters the country through its northeast corner by changing its course clockwise, and it initiate the cold wave situation over Bangladesh. The study reveals that the coldest region is found in the northwestern and north-northeastern parts of Bangladesh because of the geographic position of those areas and the location of the Himalayas foothills. From the large-scale synoptic condition perspectives, cold waves are shifting into Bangladesh from the north-west to northern parts.

Keywords: Cold waves, Extreme cold waves, Climatology, Trend, Season

1. Introduction

Presently climate change is a talk of the table across the world, and it is very for the sustainable development of Bangladesh. Different kinds of meteorological phenomena occur in our country that strike the normal of life, livelihoods, crop production, human health and other aspects of living bodies. Among these phenomena cold waves situations have a great impact in the various fields of living bodies that dismantle the normal flow of life irrespective of color, caste and different kinds of health hazard/disease do many harm to the human, animal health, crop, vegetable, and other fields as well. This is why the study of cold waves in different categories and their trends are very crucial for the safety of human and animal health and planning in various sectors such as agriculture, animal husbandry, livestock's, tourism sectors as well. It is explored that a few studies have been done by some authors such as Karmakar,2019; Nissan et al.,2017; Mannan et al.,2022; Hashizume et al.,2008 in the Bangladesh perspective but several studies have been accomplished in world perspective. It is shown that the underdeveloped and developing countries are most vulnerable due to climate change for its direct impact on socio-economic status in various angles (Mahmood, 2014; Elahi,2016; Mendelson,2006). Because of the geographical location of

Bangladesh, the climate becomes a unique factor to handle the overall socio-economic conditions of our country. Increasing temperatures, changing rainfall patterns, rising sea levels, and increasing frequency and intensity of extreme weather events are adversely affecting ecosystem functioning, agriculture and food security, infrastructure, water resources, and human health (Intergovernmental Panel on Climate Change (IPCC, 2014). Bangladesh was ranked 5th among 170 countries in the Global Climate Risk Index in the period 1994-2013 (Kreft et al. 2013). The duration of winter season and it's on time on set and the relevant events like fog; cold wave situation is very important for numerous purposes in different fields. Now a day's weather is considered as an important factor of everyday behavior and mood in modern life (keller et al. 2005; Persinger 1980; Watson 2000). More definitely in adulthood some emotional weather-derived disorders, such as the Seasonal Affective Disorder, have been linked to depression, anxiety and negative emotional states (Rohan and Sigmon 2003). Due to the location, northern part of Bangladesh, more especially the Rangpur division faces lots of weather-related events which have adverse effects on the agriculture industry, human health, transport system, and so on. Productivity of differents crops, vegetables and seeds influence by the length of winter season directly or indirectly. Winter is the coldest season of the year across Bangladesh specilly in the northern part, this season is characterized by falling cold temperatures, usually exacerbated by strong winds. Khatun et al. (2016) showed that annual minimum temperature increased notably over northeastern and central parts of Bangladesh, and the highest increment of minimum temperature per year of 0.3°C is found at Dhaka, Faridpur, Madaripur, Maijdi Court, Cox's Bazar, Sylhet, Srimongal, Rangpur and Bhola. Karmaker (2019) stated that though Bangladesh is a small country with huge population, its different parts have different impacts of disasters and climate change. Rangpur division in the Northern part of Bangladesh is such a kind of region having the significant impacts of thunderstorms, floods, cold waves and heat waves, drought, heat stress, riverbank erosion, scarcity of water and reduced river flows in dry season, etc.

In this study, we observe the winter season setup and withdrawal behavior and cold wave situation at Rangpur of Bangladesh using maximum and minimum temperature data during 1981-2021. Here regression analysis is used to detect the pattern of the number of days with minimum temperature (MinT≤15°C), cold wave days with minimum temperature ≤10°C (MinT ≤10°C), winter days with maximum temperature ≤25 °C (MaxT ≤ 25°C) & minimum temperature ≤15°C (MinT ≤ 15°C), extreme winter with maximum temperature ≤20°C (MaxT ≤ 20°C) & minimum temperature ≤12.5°C (MinT ≤ 12.5°C), deviation of winter from 15th December with MaxT ≤25°C & MinT ≤15°C and Length of winter season with MaxT ≤25°C & MinT≤15 °C. The atmospheric conditions are observed with the mean sea level pressure (MSLP) and surface wind which are favorable for associating winter season.

The objective of the study is to find out the trend as well as rate of extremity of maximum and minimum temperature in different types, length of winter season, variation of number of days, and deviation of winter from normal date of onset which has been defined as 15th December.

2. Data and Methodology

2.1 Study area description

Rangpur region is situated in the northern part of Bangladesh whose latitude is 24˚45′N and longitude is 89˚16′E. Its elevation is 32.6m from sea level. For some hydro-geological and socio-economic factors that include: a) its geographical location i.e very near to Himalaya b) extreme abnormality of climate that is governed by various seasons c) most of the people are engaged in agriculture which is highly as well as directly influenced by the change of normal weather behavior.

2.2 Data and quality control

To determine the winter season as well as its variation, maximum and minimum temperatures are considered primarily. But as winter is the cold feelings in society and therefore it is required to be determined by considering temperature thresholds of both maximum and minimum temperatures, which create quite strong cold feeling. As such winter has been defined by the lower value of the recorded maximum and minimum temperatures, which are equal to or below 90 percentiles. In a similar way strong winter has been defined as equal to or below 95th percentiles. To proceed further the daily maximum and minimum temperature data at Rangpur station of Bangladesh Meteorological Department (BMD) for the period of 1981-2021 are collected and considered as the representative of Rangpur Region. To examine the presence and duration of winter season maximum temperature of ≤ 25°C & minimum temperature ≤ 15°C considered jointly. Presence of strong winter defined by considering the day with maximum temperature ≤ 20°C & minimum temperature ≤ 12.5°C jointly. The cold wave days are considered when minimum temperature persists 10°C and it's lower.

The missing data of this site was less than 1% during the period from 1981 to 2021. Missing data were filled up by the average of the previous and the following day's data.

National Centre for Environmental Prediction (NCEP) reanalysis data are used for observing atmospheric conditions when winter season early setup and late setup at Rangpur. Here, mean see level pressure (MSLP) and Surface wind are conducted to validate of atmospheric condition which are associated with winter season over Bangladesh and neighborhood.

Accordingly, 15 December has been selected as the average onset date of winter at Rangpur. By following this, the years 2003 and 2017 were detected as the late onset of winter and the years of 1982 and 2014 were detected as the early onset years of winter at Rangpur region.

2.3 Linear Regression Analysis

Sir Francis Galton (1885) introduced the idea of "regression" to the research community in a study examining the relationship of fathers' and sons' heights. The same scientist in 1988 also introduced the concept of correlation, where correlation analysis is a technique to study the amount of relationship of two variables. Linear regression analysis is a parametric model and one of the most common methods to detect a pattern in data series. By fitting a linear equation to the observed data, this model establishes a relationship between two variables (dependent and independent). Next, the data is tested there to find out whether there is a relationship between the interest variables or not. If there is no relationship between two variables, the linear regression model does not prove to be a useful model. The correlation coefficient which ranges from -1 to +1 is a numerical measure of this correlation between the variables. A coefficient value ±1 for the correlation indicates a good match. A value close to zero implies that two variables have a random, non-linear relation. The linear regression model is generally described by the following equation:

$$Y = m * X + C$$

Where, Y and X are the dependent variable (no. of days of winter) and the independent variable (years), respectively, m is the line slope (day/year) and C is the intercept constant coefficient. The regression analysis is used to establish a linear regression regarding time between the observed maximum and minimum temperature result in winter seasons.

The analysis of trend for annual cold days from maximum and minimum temperature has been determined using Mann-Kendall and Sen's slope estimator for Rangpur region using statistical software R 4.0.5 during 1981-2021.The probability function of Weibull distribution is used for describing the peak and skewness of cold days of winter season at Rangpur region using Easyfit5.5. The regression analysis is used to establish a linear regression regarding time between cold wave days of winter season and correlation coefficient using excel.

2.4 Mann Kendall (MK) trend test

The non-parametric Mann-Kendall (MK) experiment (Kendall, 1975; Mann, 1945) is huge generally used for tendencies classifying in climatologic and weather data in time series analysis. Here, there are two benefits of using MK experiment. (1) It is a non-parametric test where data do not necessary to be normally distributed. (2) The trial has little sensitivity to unexpected due to inhomogeneous time series analysis (H. Tabari et al, 2011). The MK test statistic (S) is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(T_j - T_i), \qquad (1)$$

$$Sign(T_j - T_i) = \begin{cases} 1 \; if \; T_j - T_i > 0 \\ 0 \; if \; T_j - T_i = 0 \\ -1 \; if \; T_j - T_i < 0. \end{cases} \qquad (2)$$

Where, T_j and T_i are the yearly values in years j and i, j > i respectively.

If n < 10, the value of $|S|$ is shares straight to the theoretical distribution of S derived MK. The two tailed experiment is used. At definite likelihood level H_0 is rejected in favor of H_1 if the original value of S equals or exceeds a certain value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the lowest S which has the possibility less than α/2 to execute in case of no trend. A positive (negative) value of S designates an upward (downward) trend. For n ≥ 10, statistic S is almost normally distributed with the mean and variance as follows:

$$E(S) = 0. \tag{3}$$

The σ^2 for the S statistic is expressed by:

$$\sigma^2 = \frac{n(n-1)(2n+5)-\sum t_i(i)(i-1)(2i+5)}{18}. \tag{4}$$

Where t_i represents the number of ties to extent i. The synopsis term in the numerator is used only if the data series contains tied values. The standard test statistic Z_s is considered as bellows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma} \; for\; S > 0 \\ 0 \; for \; S = 0 \\ \frac{S+1}{\sigma} \; for \; S < 0. \end{cases} \tag{5}$$

The test statistic Z_s is used in a quantity of meaning of trend. In detail, this experiment statistic is used to experiment with the null hypothesis, H_0. If $|Z_s|$ is greater than $Z_{\alpha/2}$, where α denotes the special implication level (e.g., 5% with $Z_{0.025} = 1.96$) then the null hypothesis is inacceptable suggesting that the trend is important.

2.5 Sen's Slop estimator test:

Non-parametric technique (Sen, 1968) was used to assessment the degree of tendencies in the data at time series analysis. The gradient of "n" pairs of statistics can be first projected by using the below equation:

$$\beta_i = \text{Median} \left[\frac{X_j - X_k}{j-k}\right] \forall \; (k < j) \tag{6}$$

In this formula, X_j and X_k represent values statistics at time j and k, separately, and time j is after time k (k ≤ j). The median of "n" values of β_i is the Sen's slope estimator experiment. A negative β_i value signifies a declining tendency; a positive β_i value signifies an accumulative tendency over time.

If "n" is an even number, then the slope Sen's estimator is computed by using the following equation:

$$\beta_{med} = \frac{1}{2}(\beta_{[n/2]} + \beta_{[(n+2)/2]}) \tag{7}$$

If "n" is an odd number, then the slope Sen's estimator is calculated by using the below formula:

$$\beta_{med} = \beta_{[(n+1)/2]} \tag{8}$$

Finally, β_{med} is verified by a two tailed experiment at 100(1-α) % assurance level, and the true gradient of monotonic tendency can be projected by using a nonparametric experiment (Partal and Kahya, 2006).

2.6 Weibull Distribution

The probability density function (PDF) of the Weibull distribution with two parameters is given by (Weibull 1951):

$$f(x,\beta,\gamma) \propto \frac{\beta}{\gamma}\left(\frac{x}{\gamma}\right)^{\beta-1} exp\left[\left(\frac{x}{\gamma}\right)^{\beta}\right]; 0 < x < \infty, \beta > 0, \gamma > 0$$

Where β is the shape parameter of the Weibull distribution which describes the peak and skewness of the cold wave days of winter season and γ is the scale parameter which describes the cold wave days of winter season at Rangpur region during 1981-2021.

3. Results and Discussion

The winter season setup and withdrawal behavior and cold wave situation at Rangpur of Bangladesh have been computer using maximum and minimum temperature data in the different categories like the pattern of the number of days with MinT ≤ 15°C, cold wave days with MinT ≤ 10°C, winter days with MaxT ≤ 25°C & MinT ≤ 15°C or less, extreme winter with MaxT ≤ 20°C & MinT ≤ 12.5°C during 1981-2021.But the topics of the main focusing point has been made on the pre-season when the extreme heat waves occur throughout Bangladesh especially in the western and south western part.

3.1 Trend and magnitude of the frequency of MinT ≤ 15°C, MinT ≤ 10°C, MaxT ≤ 25°C & MinT ≤ 15°C and MaxT ≤ 20°C & MinT ≤ 12.5°C in winter season at Rangpur during 1981-2020

Table 1, represent the trend and magnitude of the frequency of MinT ≤ 15°C, MinT ≤ 10°C, MaxT ≤ 25°C & MinT ≤ 15°C and MaxT ≤ 20°C & MinT ≤ 12.5°C situations of maximum and minimum temperature which is obtained from the Mann-Kendall test and the slope estimator from Sen. Here the frequency of MinT ≤ 15°C follows decreasing trend which is statistically significant at 95% level of significance for both tau(τ) value of Mann-Kendall and the slope estimator from the Sen (z) these are -0.437 and -3.882. For the frequency of MinT ≤ 10°C indicates the decreasing trend which is statistically insignificant at 95% level of significance for both tau(τ) value of Mann-Kendall and the slope estimator from the Sen (z) these are -0.153 and -1.355. The frequency of MaxT ≤ 25°C & MinT ≤ 15°C shows a decreasing trend which is statistically insignificant at 95% level of significance for both tau(τ) value of Mann-Kendall and the slope estimator from the Sen (z) these are -0.148 and -1.319. And the frequency of MaxT ≤ 20°C & MinT ≤ 12.5°C indicates an increasing trend which is statistically insignificant at 95% level of significance for both tau(τ) value of Mann-Kendall and the slope estimator from the Sen (z) these are 0.158 and 1.3743.

Table 1: Mann- Kendall (τ) and Sen's Slope (z) test

	Mann-Kendall (τ)	Sen's slope(z)	Two sided (p) - value
MinT ≤ 15°C	-0.44	-3.89	0.0001
MinT ≤ 10°C	-0.15	-1.36	0.18
MaxT ≤ 25°C & MinT ≤ 15°C	-0.15	-1.32	0.19
MaxT ≤ 20°C & MinT ≤ 12.5°C	0.16	1.37	0.17

3.2 Variation of the number of days with MinT 15°C or less

The average number of days with MinT 15°C or less is found vary over the time at Rangpur during winter season. The average MinT15 is 76 days at Rangpur, its standard deviation (STD) is 8 days and its correlation coefficient (CC) with is -0.57. The lowest MinT15 is found in 2008-2009, the highest MinT15 is found in 1982-1983. There is a decreasing trend of MinT15 during 1981-2021 with the rate of -0.38 day/year (Fig.1).

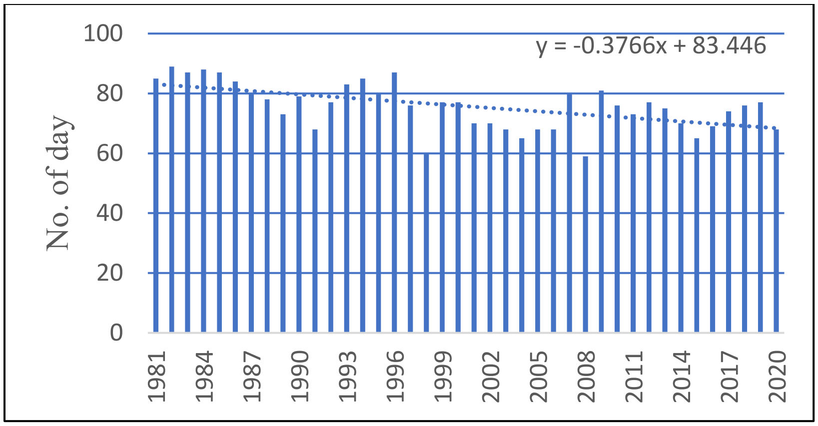


Fig.1: Number of days with MinT 15°C or less at Rangpur during 1981-2021

3.3 Variation of cold wave days with MinT 10°C or less

In winter season the average number of days with MinT 10°C or less is 16 at Rangpur of Bangladesh from 1981-2021. Fig. 2 depicts variation of MinT10 days during 1982-1983. Its average value is 33 and lowest magnitude of 1 is found in 2008-2009. The CC and STDs are -0.231 and 8. MinT10 follows a decreasing trend with the rate of -0.164 day/year during the observed period.

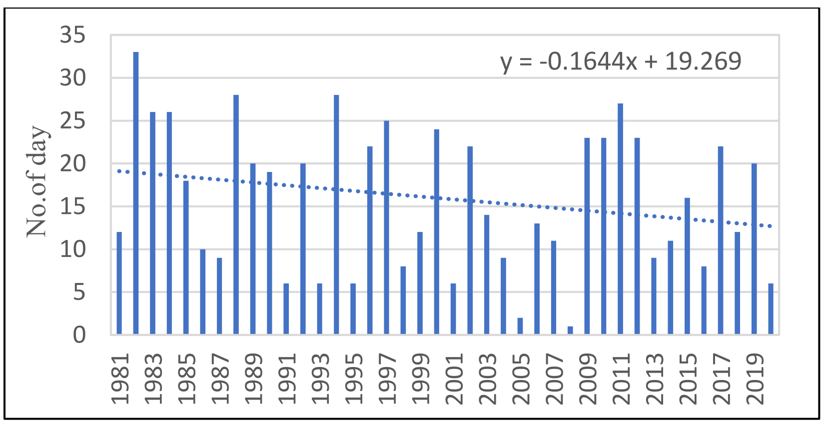


Fig.2: Number of cold wave days with MinT 10°C or less at Rangpur during 1981-2021

3.4 Variation of winter season with MaxT≤25°C & MinT≤15°Cat Rangpur during 1981-2021

With the condition of the MaxT ≤ 25°C & MinT ≤ 25°C, the average no. of day observed during 1981-2021 at Rangpur is 1981-2021. Accordingly, the highest MaxT ≤ 25°C & MinT ≤ 25°C of 62 days is found in1982-1983 and the no. of MaxT ≤ 25°C & MinT ≤ 25°C of 20 day is in winter season in 2016-2017 (Fig. 3). Under same condition the no. of MaxT ≤ 25°C & MinT ≤ 25°C in winter at Rangpur follows a decreasing trend with the rate of 0.249 day/year. The STD and CC of it are 11 and -0.2645 respectively.

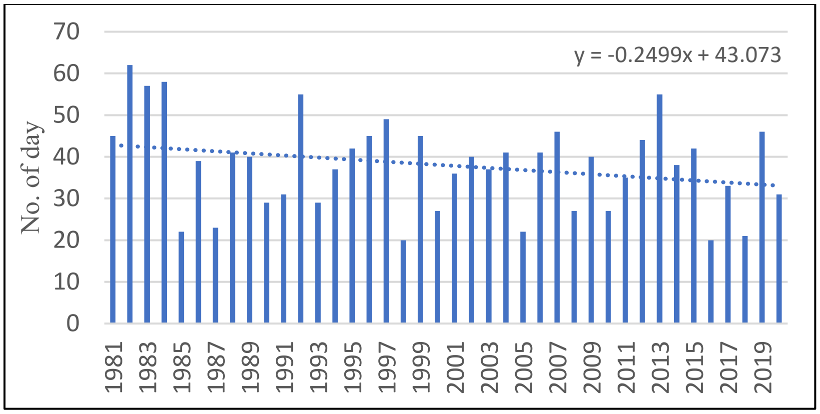


Fig.3: Number of winter days with of MaxT≤ 25°C & MinT≤ 25°C at Rangpur during 1981-2021

3.5 Variation of extreme winter with MaxT≤20°C & MinT ≤12.5°C at Rangpur during 1981-2021

Under the condition of the MaxT≤ 20°C & MinT≤12.5°C, the extreme winter lies on an average 5 days in winter season at Rangpur during 1981-2021. In Fig.4 it is shown that the highest extreme winter is 18 days in 2002-2003 at Rangpur and there is no extreme winter in 1981, 1982, 1987-1988, 2001-2002, 2007-2008 and 2017-2018. The standard deviation and correlation coefficient for extreme winter in winter season with year is 11 and 0.2333 at Rangpur from 1981-2021. Extreme winter follows increasing trend with the rate of 0.085/year.

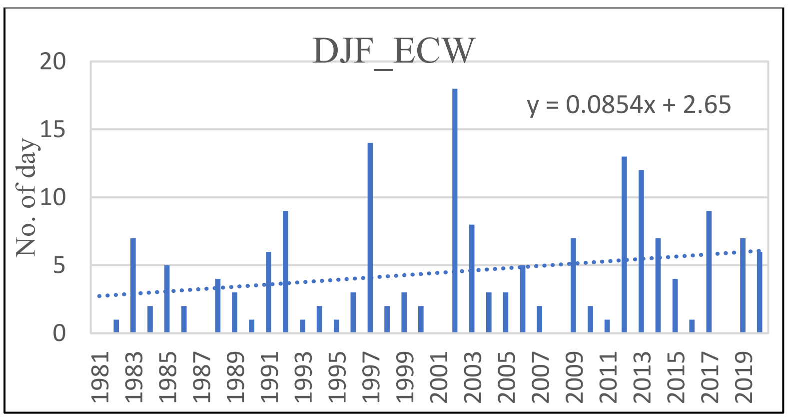


Fig.4: Number of winter days with MaxT≤20°C and MinT≤12.5 °C at Rangpur during 1981-2021

3.6 Length of winter season with MaxT≤25 & MinT≤15 at Rangpur during 1981-2021

Average length of winter in winter season is 53 days per year and the maximum continuation of winter in winter season under maxT25 & MinT15 is 72days which happened in 1984-1985 season from 1981-2021 at Rangpur. According to MaxT25 & MinT15 the length of winter in winter season follows decreasing trend with the rate of -0.082/year. The correlation coefficient of winter in winter season with year is -0.089 and its standard deviation is 11 at Rangpur from 1981-2021.

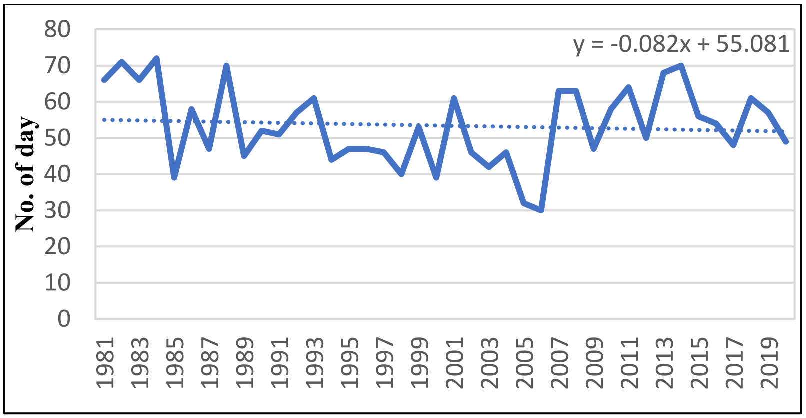


Fig.5: Number of days with MaxT≤25°C & MinT≤15 °C in winter Season at Rangpur during 1981-2021

3.7 Deviation of winter from 15th December with MaxT≤25°C & MinT≤15°C at Rangpur during 1981-2021

In Fig.6 it is noticed that winter with maximum temperature≤25°C and minimum temperature≤15 °C has come before 14 days in 1982-1983 and it started to delay 14 day in 1995-1996 and 2003-2004 on 15th December at Rangpur during 1981-2021. It is also observed that as a whole deviation of winter from 15th December follows decreasing trend with decrement is 0.0816/year.

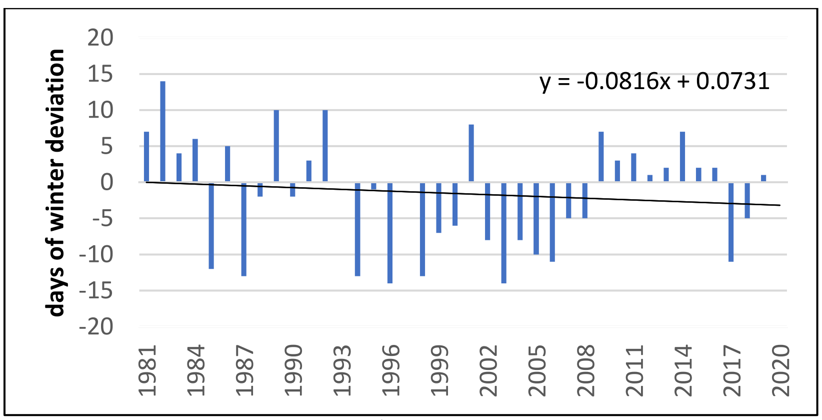


Fig.6: Deviation of winter from 15th December at Rangpur during 1981-2021

3.8 Probability Density Function of Weibull Distribution for MinT≤15°C, MinT≤10°C, MaxT≤25°C & MinT≤15°C and MaxT≤20°C & MinT ≤12.5°C at Rangpur during 1981-2021

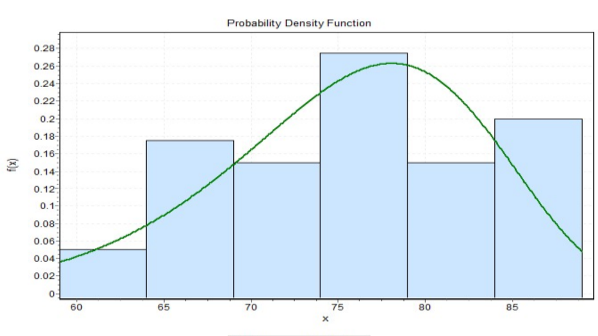


Fig.7(a): PDF of Weibull Distribution of MinT≤ 15°C

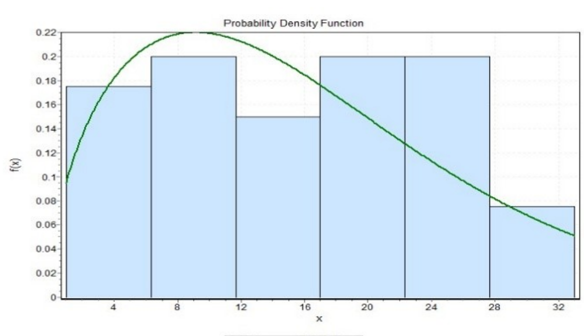


Fig.7(b): PDF of Weibull Distribution of MinT≤ 10°C

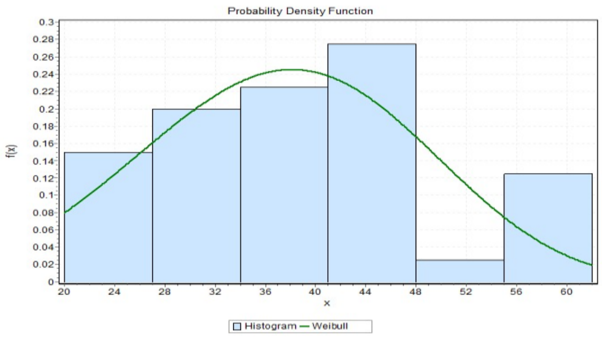


Fig.7(c): PDF of Weibull Distribution of MaxT$\leq 25°C$ and MinT $\leq 15°C$

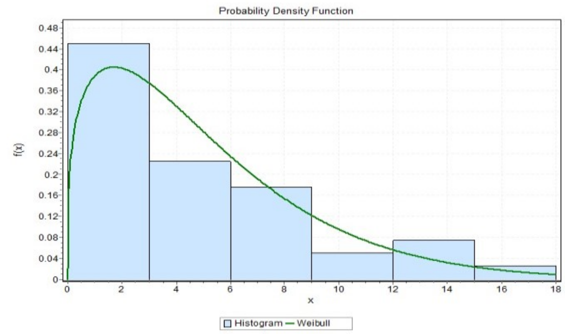


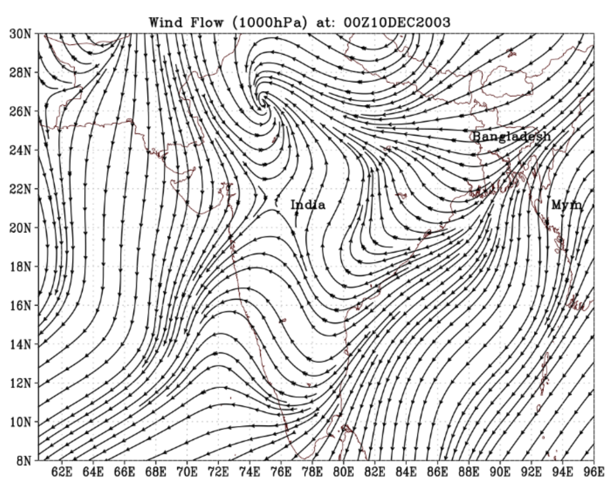
Fig.7(d): PDF of Weibull Distribution of MaxT$\leq 20°C$ and MinT $\leq 12.5°C$

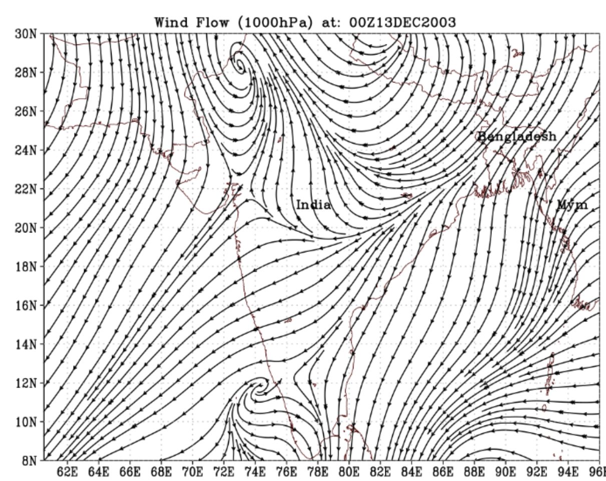
Fig.7 (a), 7(b), 7(c) and 7(d) shows the fitted PDF of Weibull distribution with β = 11.208 & γ = 78.736 for MinT $\leq 15°C$, β = 1.5314 & γ = 18.191 for MinT$\leq 10°C$, β = 3.7857 & γ = 41.339 for MaxT$\leq 25°C$ & MinT $\leq 15°C$ and β = 1.2861 & γ = 5.4651for MaxT$\leq 20°C$ & MinT $\leq 12.5°C$ compared to the histogram of cold days using maximum and minimum temperature of winter season at Rangpur region during 1981-2021. The Weibull curve is used to obtain shape and scale factors using cold days.

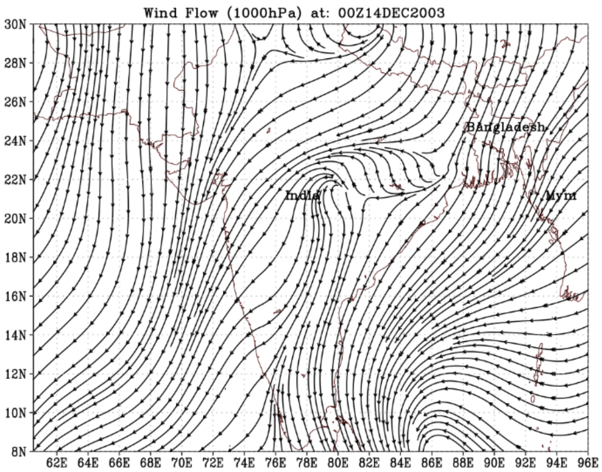
3.9 Mechanism of cold wave

3.9.1 Wind flows at 1000hPa in 2003 and 2017

The years of 2003 and 2017 were the recent late onset years of winter at Rangpur as defined in Fig.6. Analysis reveals that an anti-cyclonic circulation originated over east-central part of India at 1000 hPa level, very close to surface level on 1000 hPa, which was persisting afterwards. A seasonal low was persisting over South Bay. Due to these two weather systems, there were North/Northwesterly dry air flow at surface level was originated over northwestern Bangladesh on 29 December 2003, which was also continuing afterwards over the same region. The situation helped to onset of Winter Season over Rangpur region. Similar situation started to occur on 26 December 2017 and accordingly winter was onset over Rangpur region (Fig.8).



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Bangladesh
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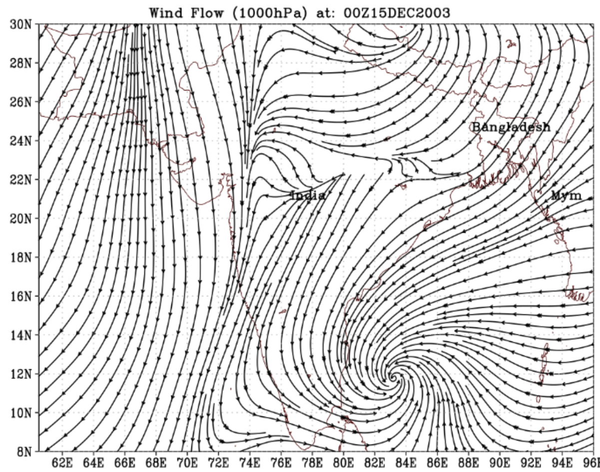
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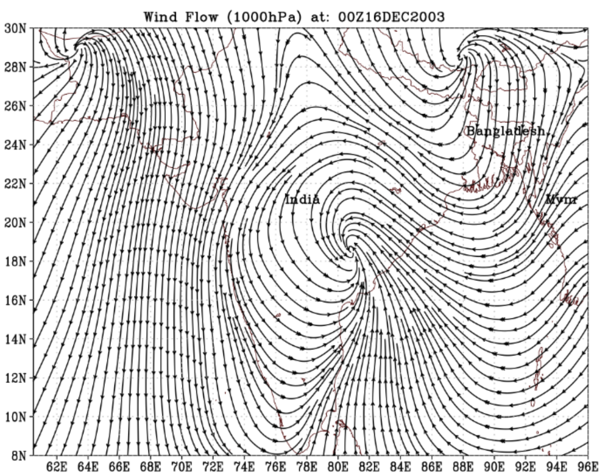
Bangladesh
India
Mym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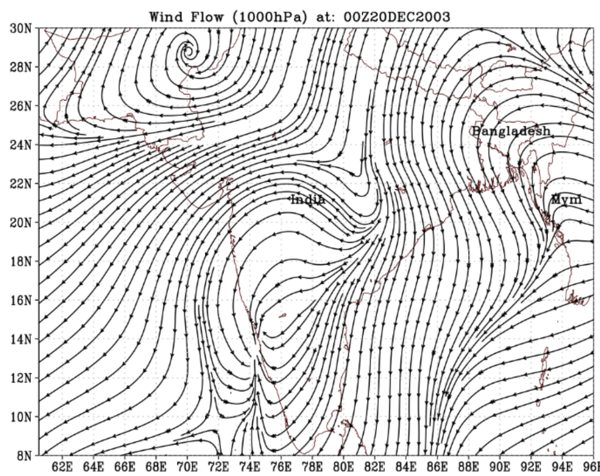
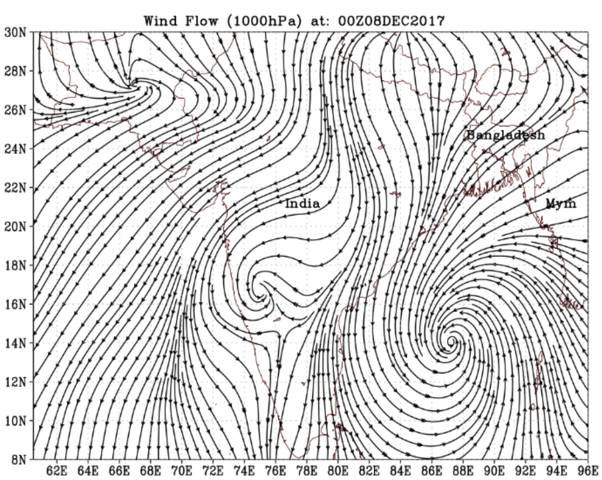
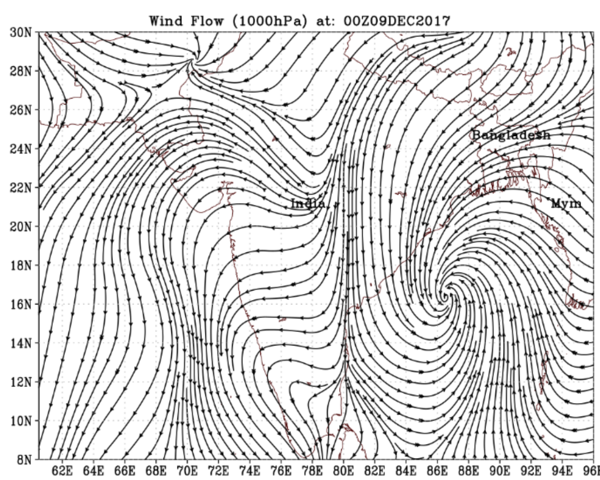

Wind Flow (1000hPa) at: 00Z20DEC2003
Bangladesh
India
Mym


Wind Flow (1000hPa) at: 00Z08DEC2017
Bangladesh
India
Mym


Wind Flow (1000hPa) at: 00Z09DEC2017
Bangladesh
India
Mym

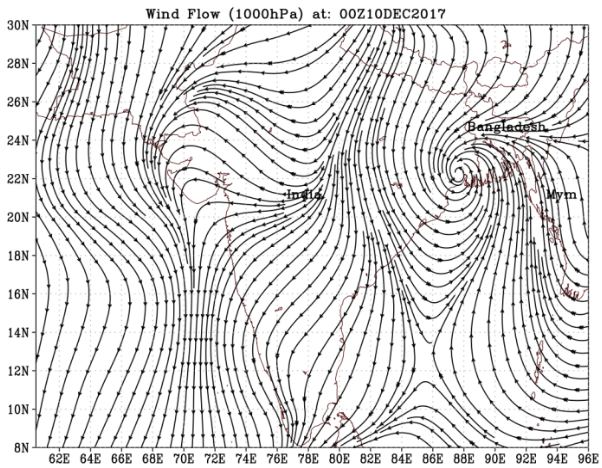
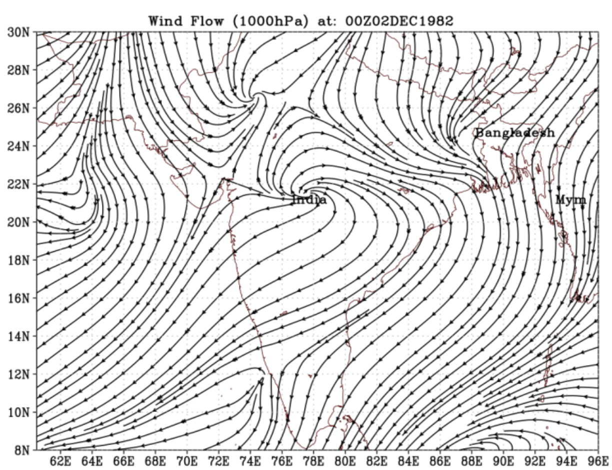


Fig.8: Wind flows at 1000hPa level in 2003 and 2017

3.9.2 Wind analysis at Rangpur 1000hPa in 1982 and 2014

As per the methodology, the years of 1982 and 2014 were the early onset winter seasons over Rangur Region. In 1982, the presence of anti-cyclonic flow detected first over Northwestern part of India on 2nd December, accordingly there were north/northeasterly flow started in the northern part of Bangladesh and afterwards and a cyclonic flow appeared over eastern part of India centered over Odisha. Due to this situation, winter season onset earlier in 1982 season, which was 12 days ahead. In 2014, an anticyclonic flow appeared first over northwestern/western part of India in the beginning of December, when a seasonal low persisted over South Bay. Due to these favorable conditions, winter season started over northwestern part of Bangladesh well ahead of average normal date, i.e., on 08 December 2014.



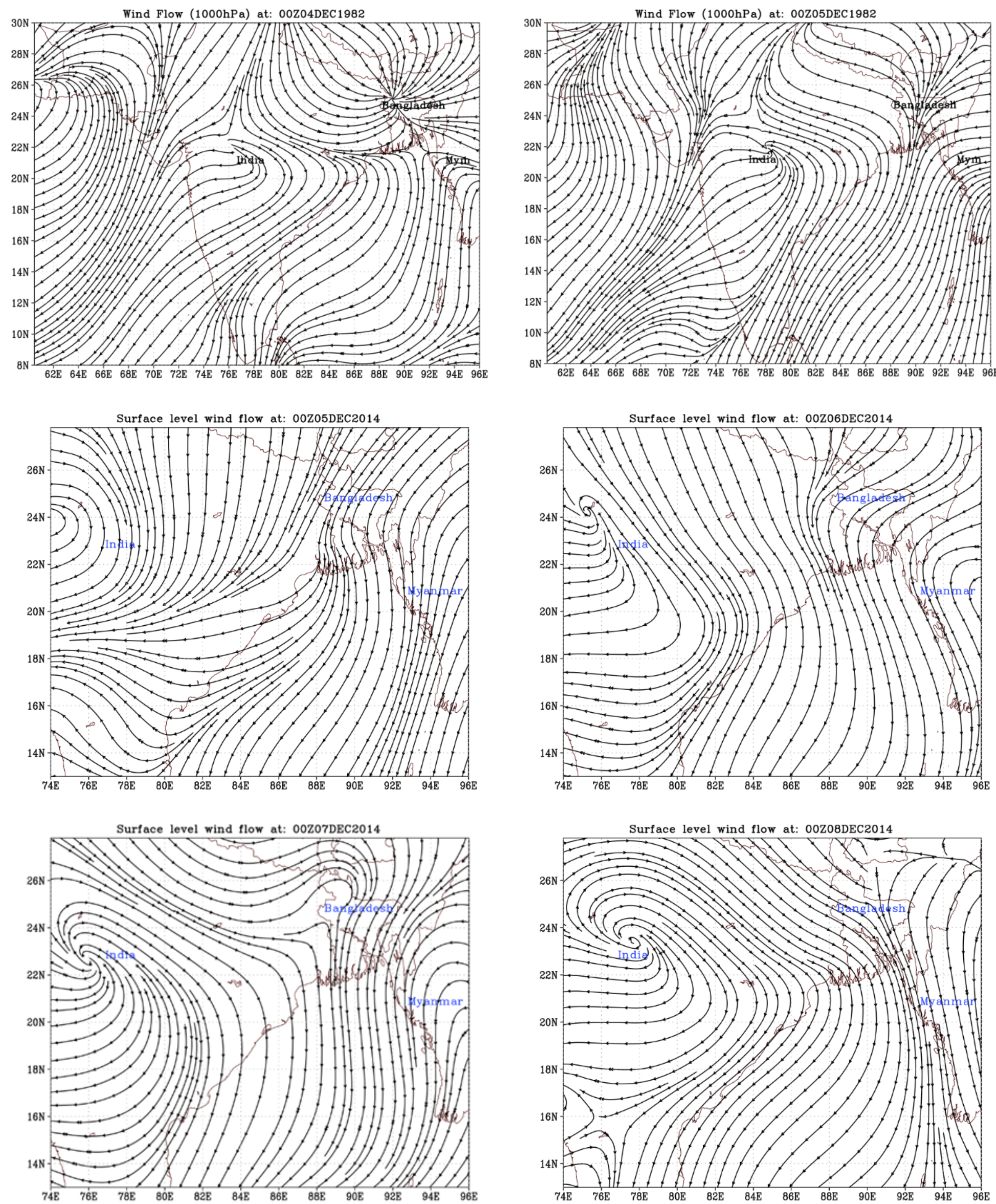
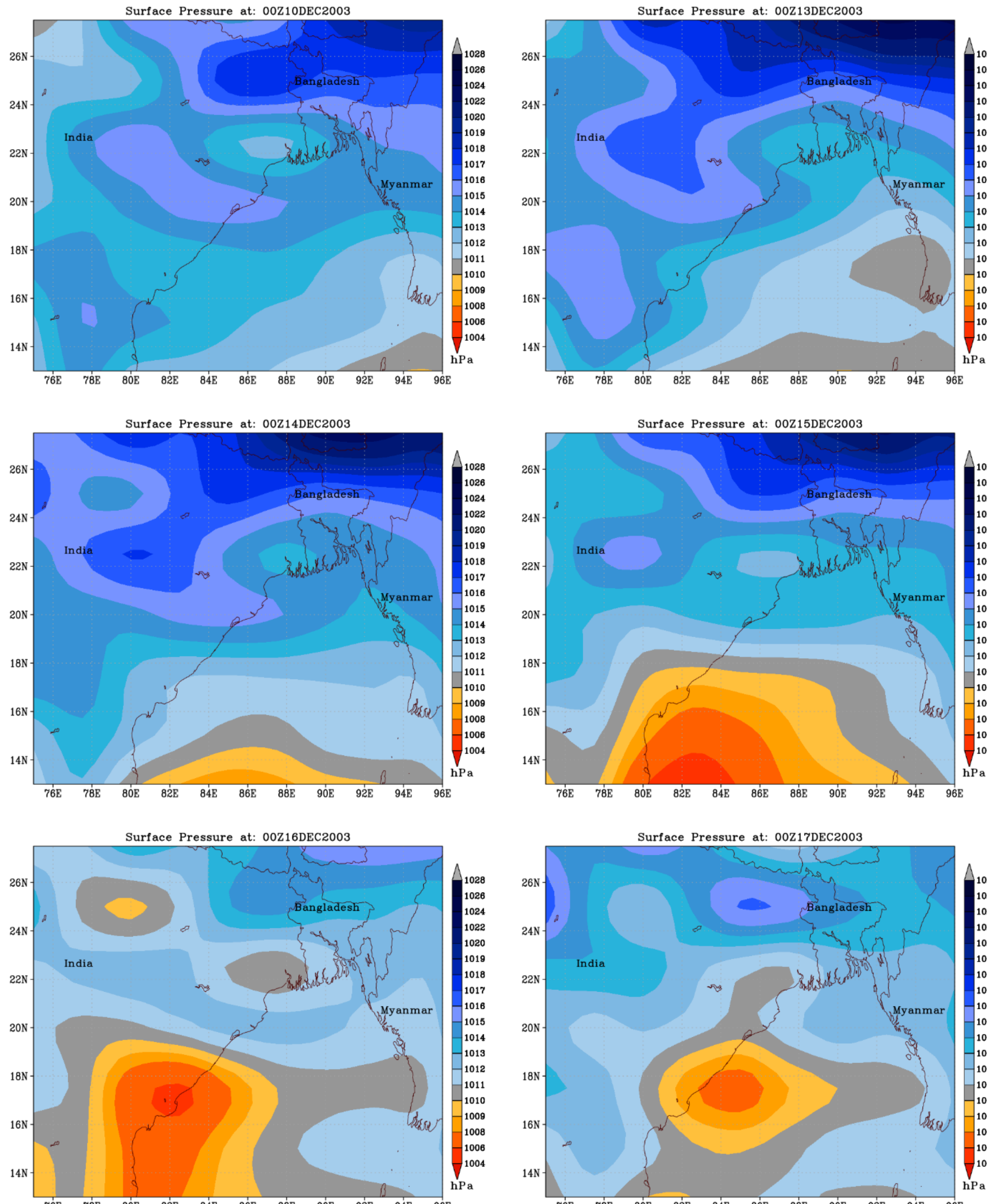


Fig.9: Wind flows at 1000hPa level in 1982 and 2014

3.9.3 Mean sea level pressure analysis for setup of winter lately at Rangpur 1000hpa at 2003 and 2017

In 2003 a low pressure area formed over west central Bay and the adjoining area on 13th December which extended up to Bangladesh. Due to these two weather systems, there were North/Northwesterly dry air flow at surface level was originated over northwestern Bangladesh on 29 December 2003. In 2017 a low pressure area formed Northwest Bay of Bengal and adjoining area which extend up to head Bay. Due to this in 2017 winter season has been delayed starting on 26 December 2017.



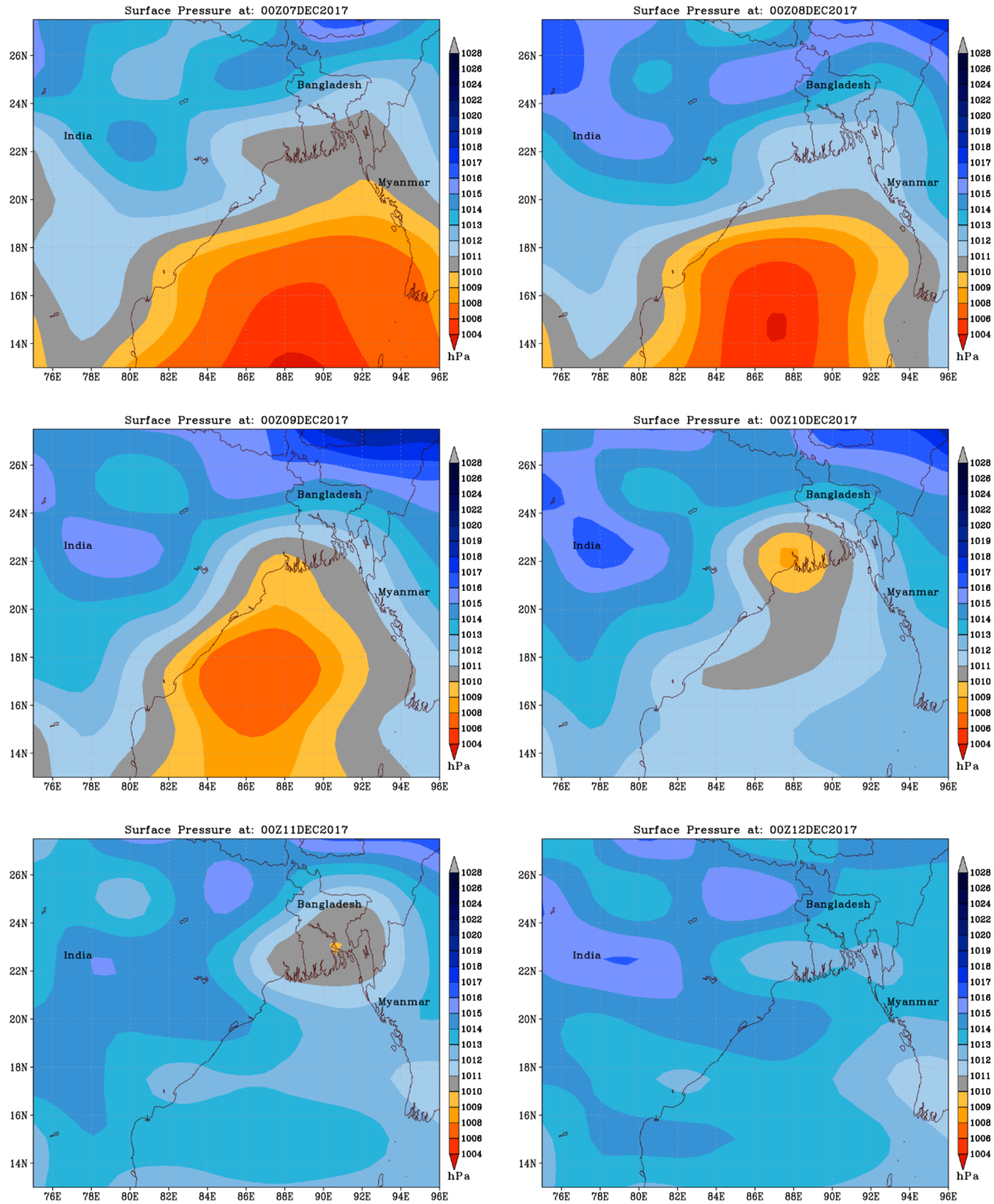
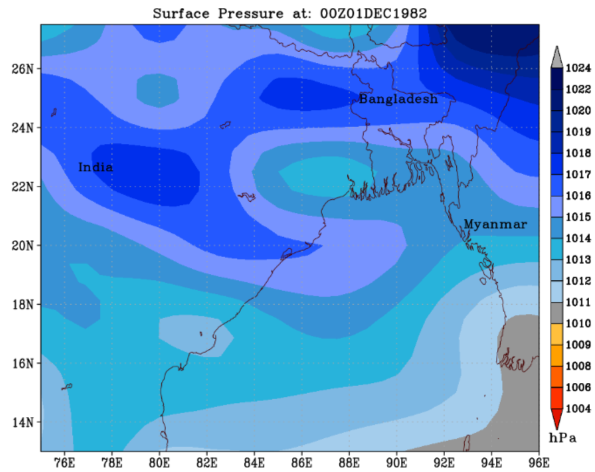
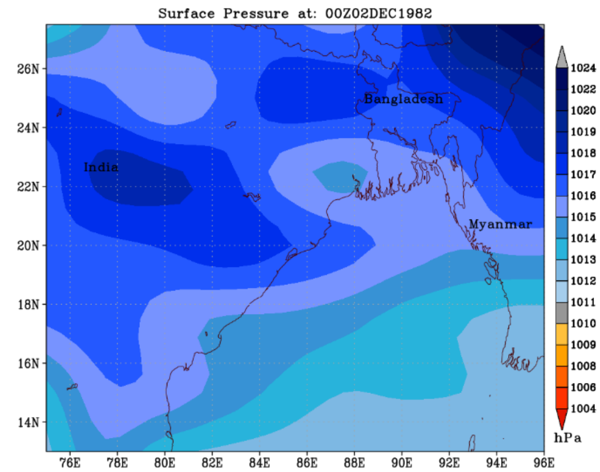


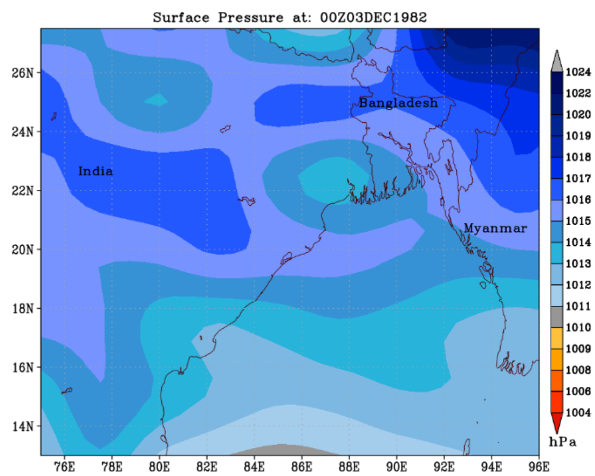
Fig.10: Mean sea level pressure at 0000UTC in 2003 and 2017

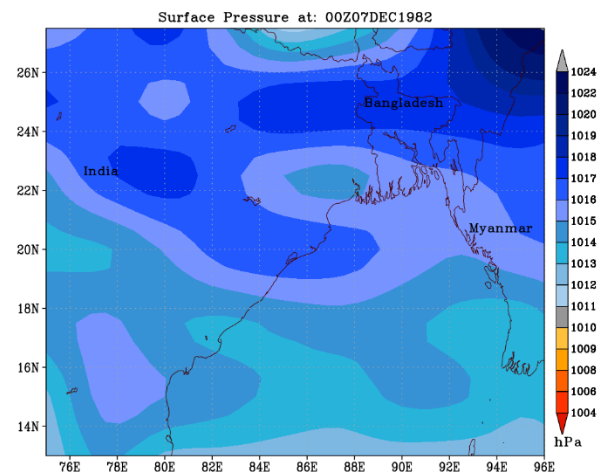
3.9.4: Mean sea level pressure analysis for winter set earlier at Rangpur in1982 and 2014

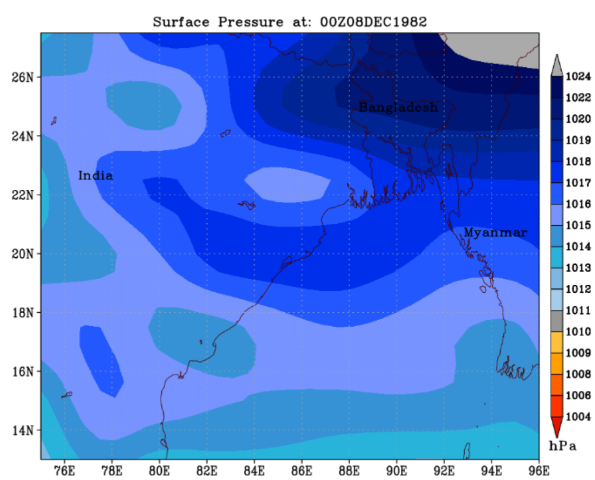
In 1982, a high-pressure region traced out first over Northwestern part of India on 2nd December, as a result there were north/northeasterly flow started in the northern part of Bangladesh. Due to this situation, winter season onset earlier in 1982 season, which was 12 days ahead. In 2014, a high-pressure area appeared first over northwestern/western part of India in the beginning of December, when a seasonal low persisted over South Bay. Favorable conditions persist over the northern part of Bangladesh for the earlier onset of winter during the first quadrant of December i.e on 2nd December in 1982 and on 8th December in 2014 respectively.

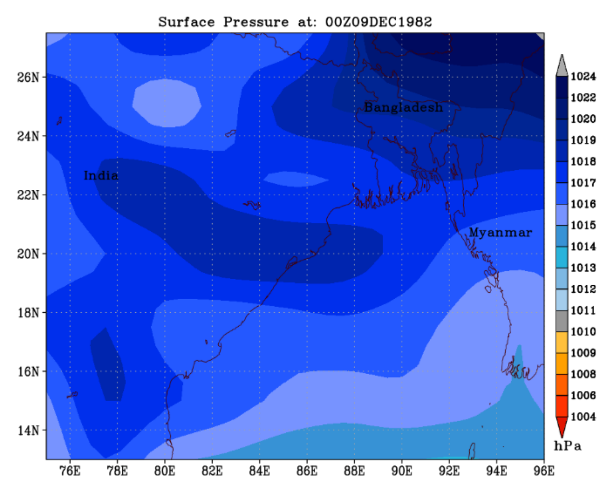












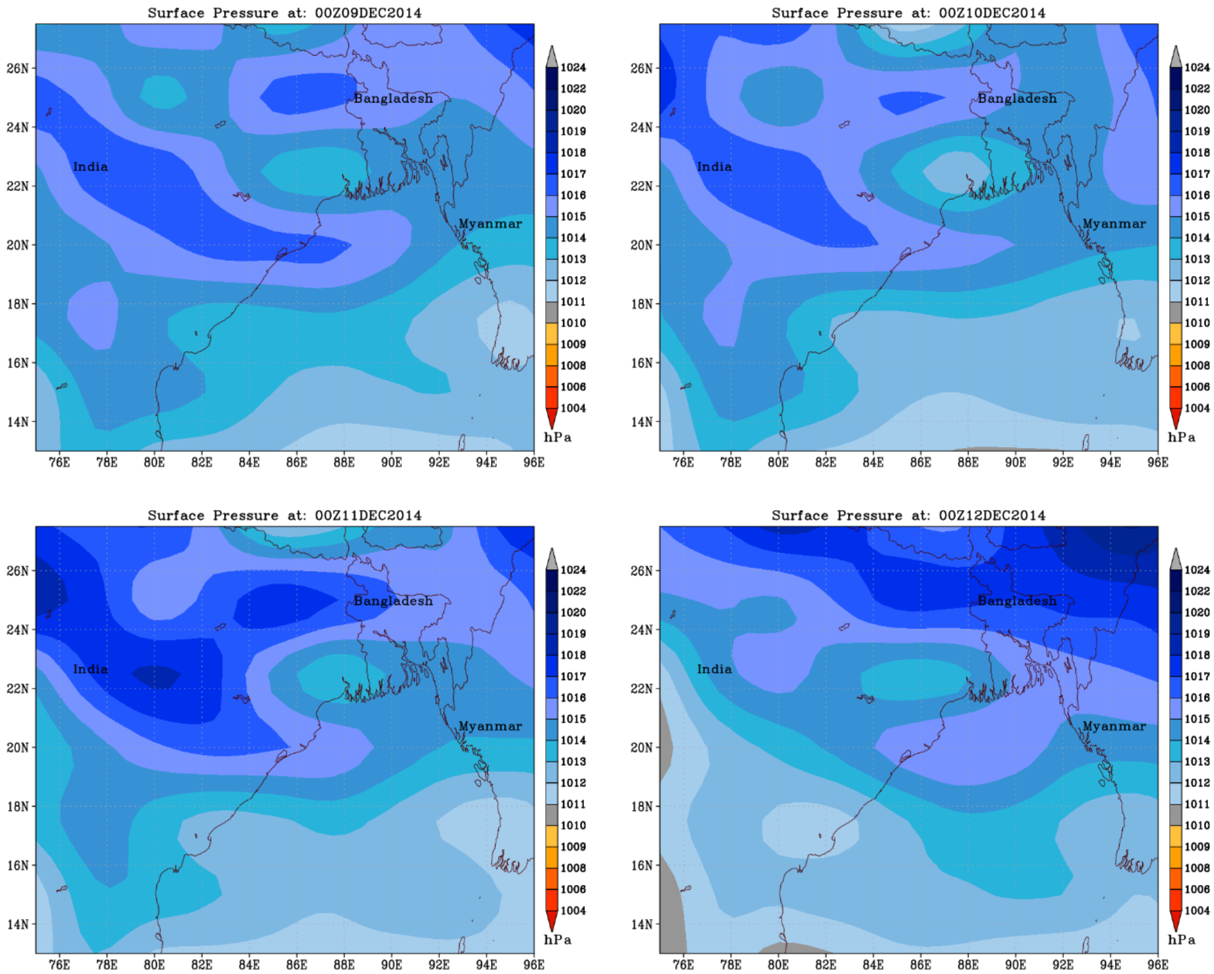


Fig.11: Mean sea level pressure at 0000UTC in 1982 and 2014

4. Discussion

A low pressure system persist over Northwest Bay & adjoining area that's why winter season start to delay in Bangladesh. On the other hand, an anti-cyclonic circulation persist over Northeastern part of India and the same time a low pressure system persist in South Bay that's why winter season startup earlier in Bangladesh. In this study, it is found that Cold wave days for MinT≤15°C, MinT≤15°C and MaxT≤25 & MinT≤20°C are decreasing trend but cold wave days for MaxT≤20°C & MinT≤12.5°C is increasing trend.

The future research plan is to find out why cold wave days for MaxT≤20°C & MinT≤12.5°C is increasing and MinT≤15°C, MinT≤15°C and MaxT≤25 & MinT≤20°C are decreasing.

5. Conclusion

The objective of this study is to evaluate the variability of cold wave situation and the onset of winter monsoon over Rangpur division during the session 1981 to 2021 taking data of Rangpur weather station from climate division of Bangladesh Meteorological Department. It is found that this region has a decreasing trend of minimum temperature 15°C or less during 1981-2021 with the rate of -0.38/year. The research explores that the number of cold wave days is in an augmented level over this region. It is found that deviation of winter from 15th December with maximum temperature≤25°C and minimum temperature≤15 °C in winter season during 1981-2021 follows a decreasing trend of 0.0816/year The study reveal that the average number of days in winter season is 53 in every year and it is following a decreasing rate of -0.082/year. The standard deviation and correlation coefficient shows that the extreme winter has an increasing trend with the rate of 0.085/year, and it is to be assumed easily that these cause a great uneasy condition for the inhabitants of the Rangpur division. Sudden decrease of temperature upto an enduring limit results in a severe health related hazard to most of the peoples especially the old aged, child and women portion.

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