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WIND CHARACTERISTICS IN WET-HUMID TROPICAL REGION OF INDIA: A CASE STUDY OF ASSAM, INDIA

Ujjal Deka Baruah and Nitashree Mili
Geography Department, Cotton University, Guwahati, Assam
https://doi.org/10.5281/zenodo.15132052
udbmail@cottonuniversity.ac.in, nitashree.mili@cottonuniversity.ac.in

ABSTRACT
We analysed the wind characteristics using both empirical (1943-2012) and reanalysis data (1948-2016) for the long term to assess the wind energy potential and anomaly in the Assam. The Weibull Probability Density Function method was applied to evaluate the pattern of wind speed. It was found that the wind in the region was non-uniform and irregular in nature. The spatial distribution of zonal and meridional wind was assessed to evaluate the variability of the wind speed. Karbi Anglong Hills acts as a wind break bifurcating the zonal wind. The anomaly in wind speed was high in the north eastern and southwestern part of the region. The scale factors indicate potentiality of the wind speed was not adequate for harnessing wind power.

Keywords- Wind, Weibull Probability Density function, NCEP/ NCAR Reanalysis data, Assam.

1. INTRODUCTION

Renewable sources are considered a bridge to the future energy demand (Dincer, 2000; Mabel et al., 2008). Wind characteristics and its potential is widely studied across the world to harness its energy (Chang et al., 2003; Ramachandra et al., 2005). India with highest annual growth in wind energy installation ranks fourth in terms of installed capacity (Mabel et al., 2008). Expected power requirement of Assam is predicted to be 2,534 MW by 2021-22, which is twice that of 2011-12 (Karmakar, 2018). So far hydropower (457 MW) is the only source of renewable energy contributing towards total installed capacity (1710 MW) as on July, 2019 in Assam (CEA, 2019). It has become an indispensable necessity to harness power from other alternate source to meet the ever-increasing demands of the state.

Even in terms of plants growth and its ecosystem services, including regulating water balance, air quality, and ground surface temperatures, winds play a vital role (Bang et al., 2010). These plant responses are directly linked with mechanical effects of wind speed and, may occur throughout the growing season of a crop (Cleugh et al., 1998). Change in growth rate – parts of the plant (e.g. changes in the root: shoot ratio) or the whole plant; change in morphology and final grain yields are the direct effects of wind speed. The dry weight of plants decreases with an increase of wind speed (Whitehead, 1962). Some of the direct and indirect effects of wind on different process includes wind erosion, plant damage, turbulent mixing of heat, transport pathways for pollens, pollutants and pathogens, etc. (Cleugh, 1998). Cirro-stratus and alto stratus clouds mostly brings rain during Monsoon period in India (Gupta et al., 2011). The travel distance of these type of rain bearing clouds depends on the nature and speed of winds. Although, anecdotal and published evidence over the last 50 years suggests that windbreaks may significantly affect precipitation, animal productivity, pasture and crop (Cleugh, 1998). Therefore, wind speed needs to be assessed for its potential as energy source (Azada et al., 2014), control of weather and climate and drivers of crop growth. Henceforth, we try to assess and evaluate the pattern of wind speed in parts of tropical humid-wet region of North East India (89°-96° 5´E & 23° -28° 30´N) with special reference to Assam, India.

2. STUDY AREA

The study area is confined within 23°-29° N and 89°-97° E bounded by lofty mountains international boundary of China, Myanmar, and Bhutan in the North-North East, and Bangladesh in the south. Assam is located in the north eastern part of India (Figure 1), where agriculture still holds the main economy of the state. More than 50% of the workforce are engaged in agricultural activities, which includes cultivators and agricultural labourers. This part of the Indian sub-continent enjoys humid wet type of tropical climate. The region receives more than 90% of their rainfall during the monsoon season (June-September) (Baruah, 2018). Annual maximum temperature is increasing at a rate of 0.11°C/ decade (ASTEC, 2011; DoEF, 2011), as well as rainfall in Brahmaputra and Barak basin has decreased significantly (Deka et al., 2012).

These anomalies in climatological parameters bears a great significance for the agricultural activities in Assam. Uncertainties in climate indices may lead to crop failures due to unprecedented rainfall causing floods (Anom, 2014a; Mandal, 2010; Mandal, 2014) and rise in temperature leading to drought like situations (Anom, 2014b; Anom, 2017; Borah et al., 2012; Pant et al., 1981; Parida et al., 2015) . Along with temperature and rainfall, wind pattern plays a vital role in growth and yield of agricultural crops.

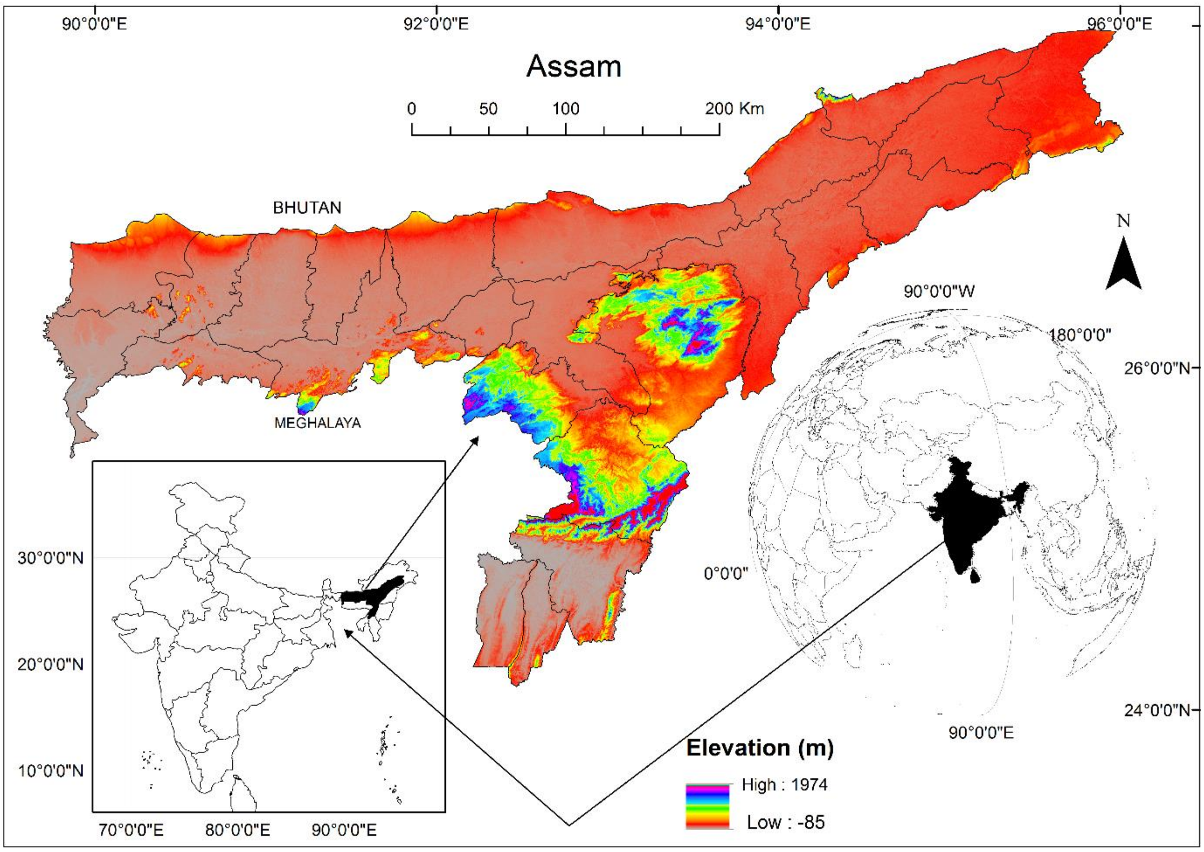

Figure 1 Location of the study area

3. DATABASE AND METHODOLOGY

The wind data were collected from the four airport of Assam viz. Dibrugarh, Guwahati, Tezpur, and North Lakhimpur for the period 1943-2012. There were 48 number of observation in time series with 16 years missing data. We also used NCEP/ NCAR Reanalysis wind data for the period 1948-2016 (http://www.esrl.noaa.gov/psd/) provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA during 1948-2016 to compare the statistics with the ground station data.

In order to assess the strength distribution and energy of wind, the Weibull distribution is used (Nage, 2016; Yürüşen et al., 2016). The Weibull was identified as the best 2-parameter distribution and performs better than some 3-parameter distributions (Ouarda et al., 2015). The Weibull 2-parameter is by far the most widely used distribution to characterize wind speed (Ouarda et al., 2015) and is given by:

$$f(v) = \frac{k}{\lambda} \left(\frac{v}{\lambda}\right)^{k-1} \exp\left(-\left(\frac{v}{\lambda}\right)^{k}\right)$$

λ is the Weibull scaling factor in m / s, a measure of the wind velocity characterizing the time series. λ is proportional to the average wind speed. k is the Weibull form or shape factor is equal to the slope of the regressed line in a probability plot. It specifies the form of the distribution and assumes a value between 1 and 3. A small k-value (k<1) indicates very variable winds with failure rate decrease over time; whereas variable winds with larger k-value (k>1) indicates increase in rate of failure over time or power is more likely to fail as time goes on; k=1 indicate constant winds with constant failure rate over time. The value of k remains closer to 2, which means that the wind wave is regular and uniform in nature. It varies 1 to 4 according to the nature of wind wave (Azada et al., 2014). To test the significance, if p-value is less than (or equal to) α null hypothesis (H_o) is rejected, in favour of the alternative hypothesis (H_1). Weibull and Rayleigh Probability Density Function (pdf) are most widely used to analyse wind speed data. Wind speed was also assessed both in terms of zonal or x-coordinate (u) and meridional or y-coordinate (v) components. Scalar averaged wind is ‘standard’ arithmetic mean of wind speed while vector averaged winds are averaged wind direction and can be used to compute a type of average wind speed which is different from scalar averaged wind speed (Grange, 2014). Anomaly in wind speed were analysed in Assam with 1981-2010 as base period using airports empirical data.

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4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics on Wind Speed

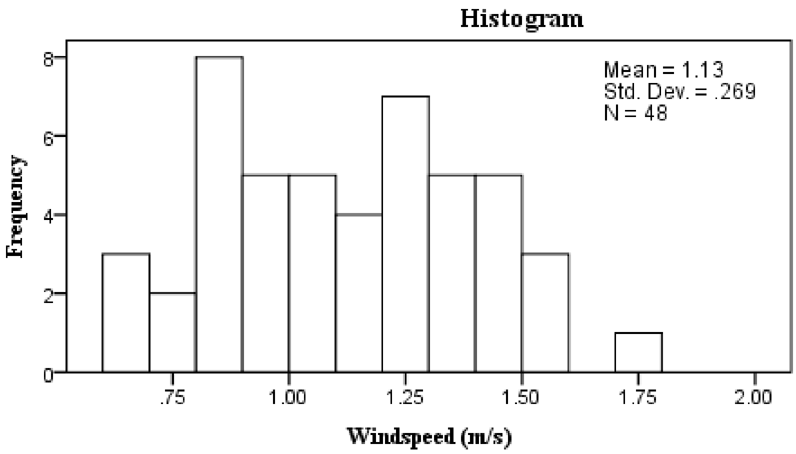
The average annual wind speed was observed to be 1.13 m/s. 50% of wind blowed at a speed below 1.10 m/s during 1943-2012. The maximum average of 1.85 m/s and a minimum of 0.67 m/s wind speed was observed during 1943-2012. The average monthly wind speed was at a maximum during April (1.85 m/s) and at a minimum during December (0.59 m/s). The shape of the data is highly symmetrical (skewness=0.19) as and mesokurtic (excess kurtosis= -0.17) indicating normal distribution (Table 1).

Table 1 Descriptive statistics on wind speed of Assam during 1943-2012 (m/s)

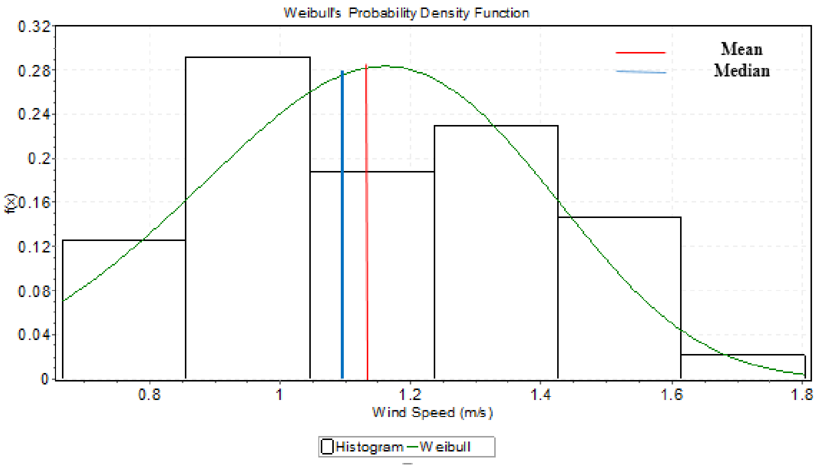
Mean	1.13	Std. Error of Kurtosis	.674
Standard Error	0.04	Skewness	0.19
Median	1.10	Std. Error of Skewness	.343
Standard Deviation	0.27	Range	1.13
Sample Variance	0.07	Minimum	0.67
Excess Kurtosis	-0.71	Maximum	1.85

4.2 Wind speed distribution and trend

The histogram and the two parameter (γ=0) Weibull distribution curve indicates that half of the time, wind blows at speeds, less than 1.10 m/s. The shape of the curve is determined by shape factor of 4.845. The shape factor (k=4.845) indicates that the wind is irregular and non-uniform with the rate of failure likely to increase over time. The distribution is almost symmetrical but a little right skewed (positive skewed). The scale factor (λ) of 1.21(m/s) indicates the potentiality of wind of the region. Therefore, the maximum probability of occurrence of wind speed is always less than 1.1m/s concentrated on the left of the mean in the Weibull probability density function (Figure 2b). Weibull distribution may vary, both in shape and scale factor, in different location depending on the climatic conditions, local topography and land surfaces configuration.



(a)



(b)

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Figure 2 (a) Histogram of wind speed (m/s) during 1943-2012 in Assam; (b) Weibull's Probability Density Function results in a shape factor (k) =4.845 & scaling factor (λ) =1.2174

The various methods of significance revealed that it failed to reject the null hypothesis, since the p-value was greater than α, not in favour of alternate (Table 2). This indicates there was no significant trend in wind speed during 1942-2012. The annual average wind speed was decreasing at a rate of 0.124/ year, although it is not statistically significant.

Table 2 Significance test at various level for 48 wind speed obervation

Weibull Probability Density Function					
Kolmogorov-Smirnov					
Statistic P-Value	0.09455 0.74858				
□	0.2	0.1	0.05	0.02	0.01
Critical Value	0.1513	0.17302	0.19221	0.21493	0.23059
Reject?	No	No	No	No	No
Chi-Squared					
Deg. of freedom Statistic P-Value	48 1.7394 0.78355				
□	0.2	0.1	0.05	0.02	0.01
Critical Value	5.9886	7.7794	9.4877	11.668	13.277
Reject?	No	No	No	No	No

4.3 Mean wind speed spatial distribution

The spatial distribution of mean wind speed (indicates high wind speed in the north western (3-3.6 m/sec) and south western part of the region (2.7-2.85 m/sec) at 1000 mb during 1948-2016. The presence of Karbi Anglong hills acts as windbreak and bifurcates the easterly wind. The wind speed decreases from northern to southern part of Assam (Figure 3).

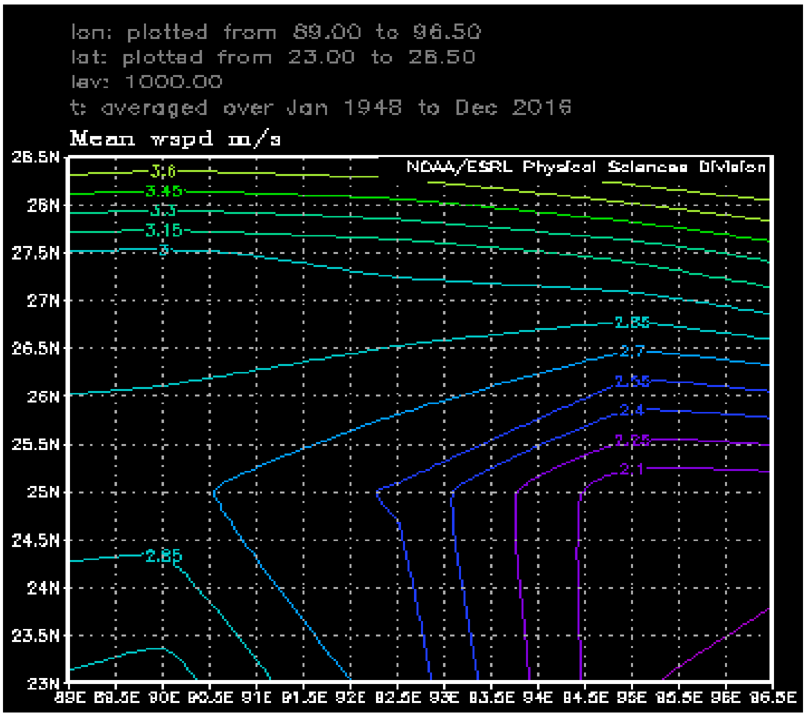

Figure 3 General pattern of wind speed for the region (23.00-28.50 N & 89-96.50 E) at 1000mb, 1948-2016

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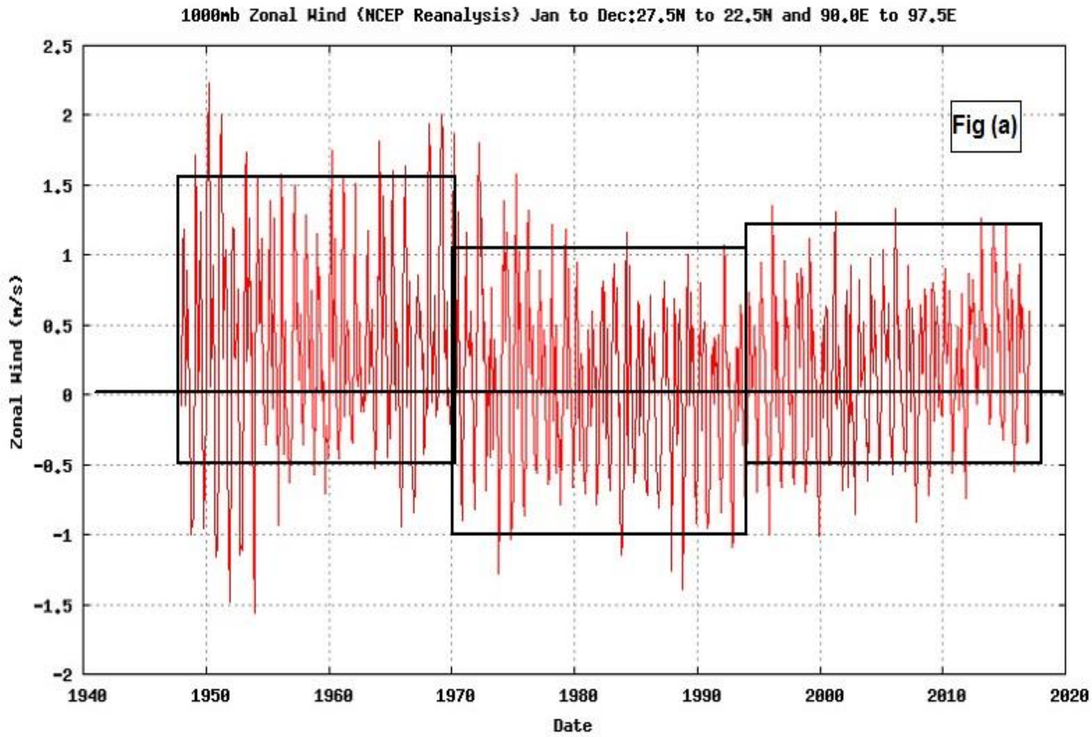
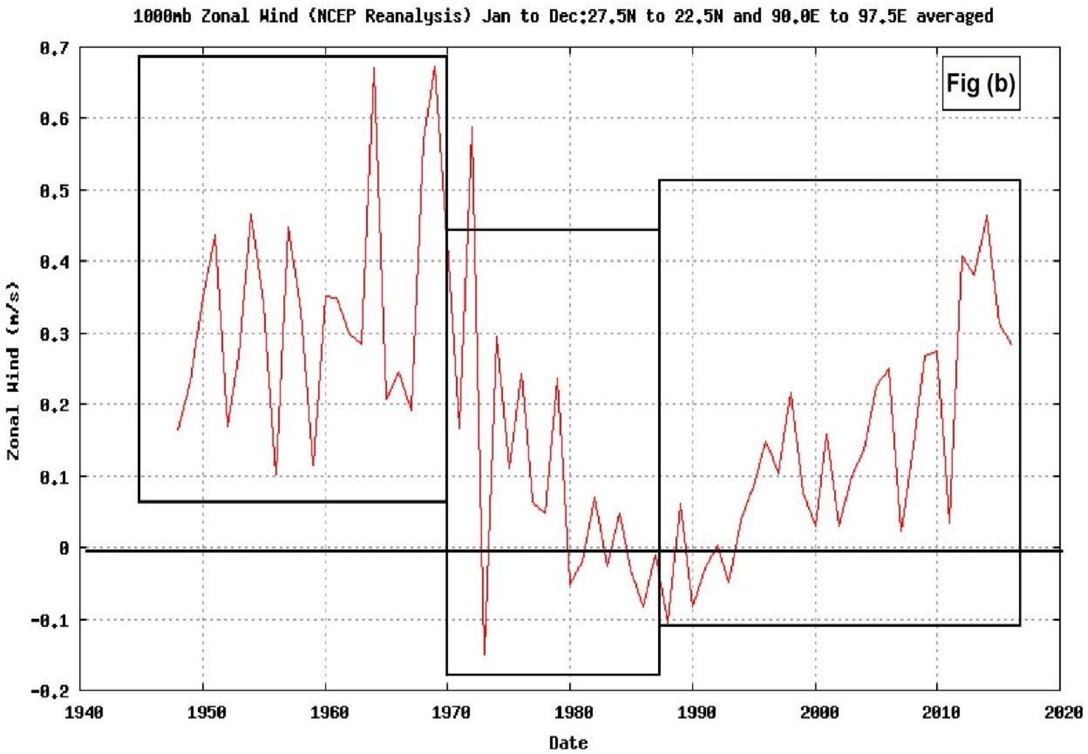
4.3.1 Zonal Wind Pattern

Zonal winds are positive was wind blows in the west-east direction and negative if it blows in east-west direction. Zonal wind speed ranged between -1.5 to 2 (m/s) and a decreasing trend of wind speed in east-west direction was observed during mid-1970’s to mid-1990’s. There was a shift in the direction of wind leading to a weakening of the E-W winds and strengthening of (W-E) winds during mid-1970 to mid-1990. The wind tended to blow in a W-E (westerly) direction from the mid-1990 onwards and the magnitude of wind speed decreased as compared to the pre-1970’s (Figure 4a and 4b). The anomaly of wind speed (-0.12 to 0.32 m/s) and increased towards north western part of the region and its neighbouring states as observed based on NCEP/NCAR data during 1948-2016 (Figure 4d). The negative anomaly was observed post mid-1990 and increasing thereafter (Figure 4e). Maximum wind speed of 1.25 m/s and minimum of 0.5 (m/s) (Figure 4f) was observed using NCEP/ NCAR Reanlysis data during 1948-2016, which closely approximates the values derived from four ground stations data from Assam (maximum 1.8 m/s and a minimum 0.67 m/s) during 1943-2012.





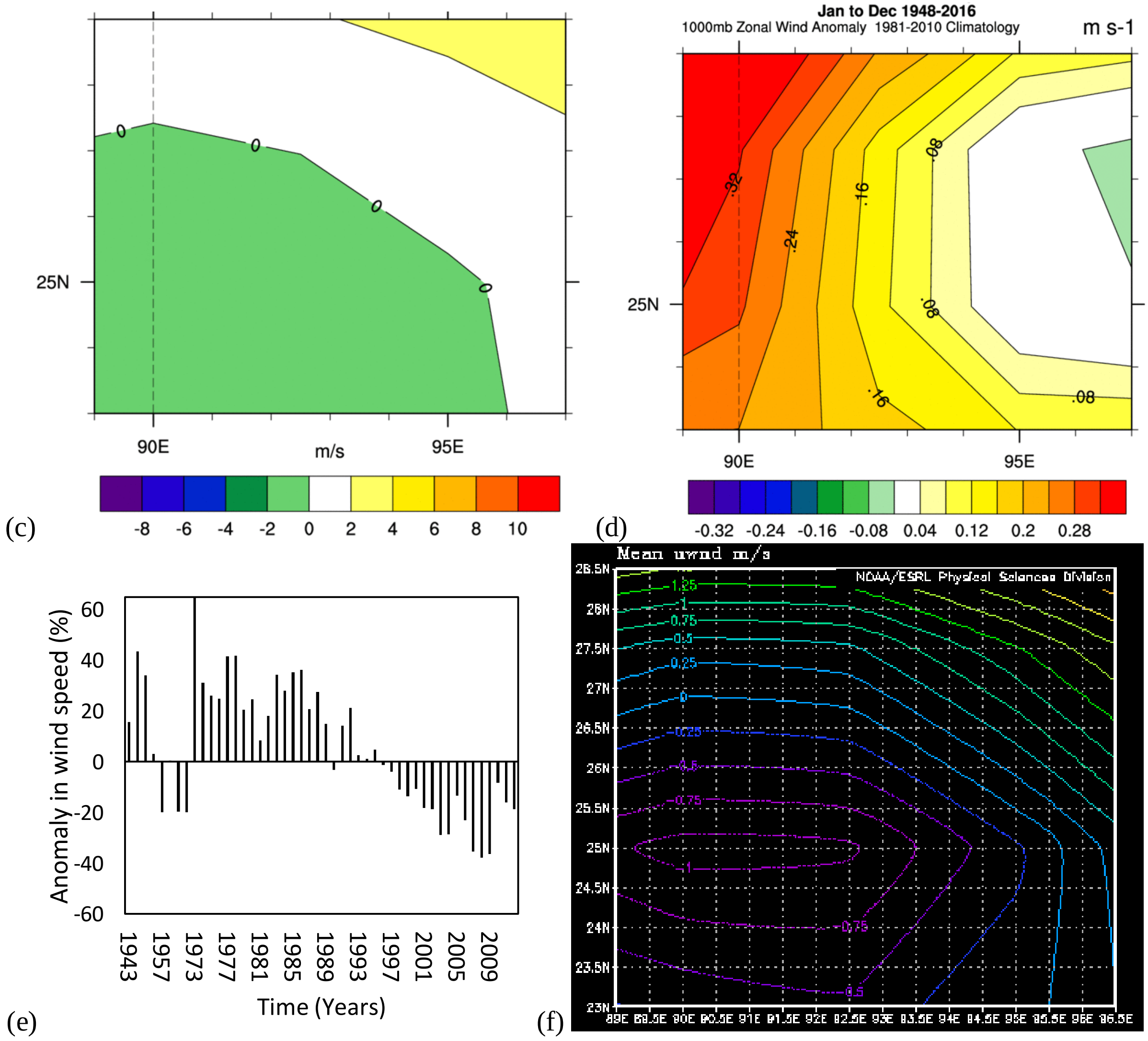


Figure 4 (a) & (b) Daily mean and annual mean zonal wind speed (m/s) resp. during 1948-2016 at 1000mb using NCEP/NCAR reanalysis data; (c) Long term mean/normal wind speed with 1981-2010 as the base period; (d) Mean zonal wind anomaly for the period Jan-Dec, 1948-2016 between 23°-28°50′N and 89°-96°59′E at 1000mb using NCEP/NCAR Reanalysis data; (e) Anomaly in zonal wind speed (%) over Assam during 1943-2012; (f) Mean U-wind (m/s) at 1000mb using NCEP/NCAR Reanalysis data during 1948-2016

Mean zonal wind speed seasonal characteristics in the troposphere was observed for DJF, MAM, JJA, and SON for long term mean base period 1981-2010 (Figure 5). Wind speed is maximum during spring season (MAM) with an average zonal speed of 1.57 (m/s) and minimum during autumn (SON) 0.76 (m/s).

Table 3 Zonal mean wind speed (m/s) based on ground station data and NCEP/NCAR reanalysis data, 1943-2012

Zonal Wind Speed (m/s)			
DJF	MAM	JJA	SON
0.84	1.57	1.16	0.76

During summer (JJA) and autumn (SON), gentle and regular flow of air is observed (Figure11) through-out the region. The direction of wind during summer is observed to be westerly and easterly in the region, while wind during autumn are generally easterly. The zonal wind speed during winter (JJA) and spring (MAM) are 0.84 and 1.57 m/s respectively during 1943-2012. The flow of wind is very complex during winter and spring as evident from the figures (Figure 5) in the region. High speed winds during spring season brings in pre-monsoon rainfall along with them. The winds in north-eastern part of the region are predominantly easterly winds with moderate to high speeds (0.25-3.25 m/s) during spring. Other parts of the region witnessed westerly winds during spring. Similar patterns were observed during winter as well. Thus, both easterly and westerly winds prevailed in the region during both winter and spring.

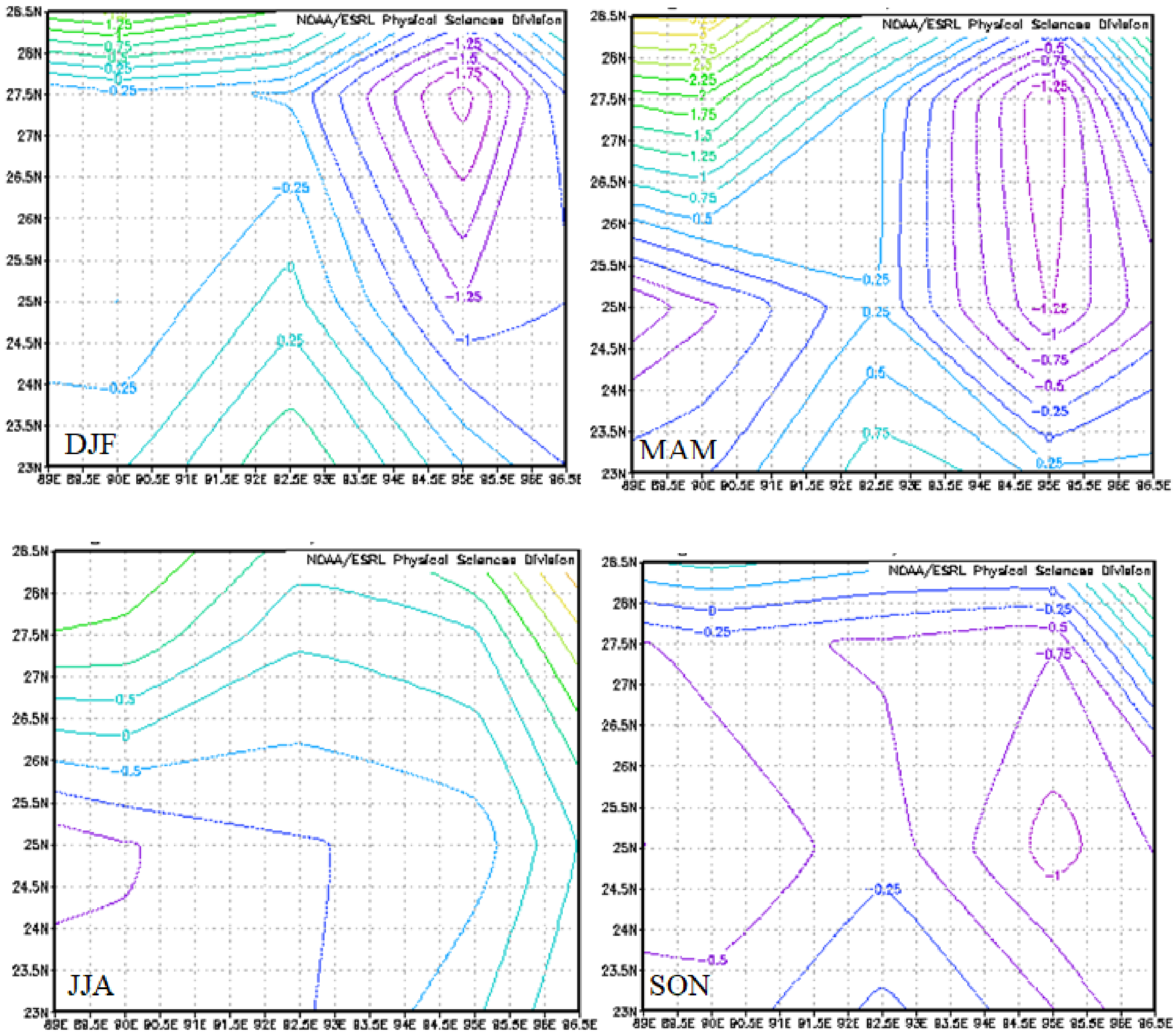


Figure 5 Mean zonal wind speed ,U-Winds (m/s), for the four seasons: December-February, March-May, June-August, and September-November, based on long term mean,1981-2010; region 23-28.5 N and 89-96.50 E (positive and negative value indicates westerly and easterly wind components)

4.3.2 Meridional Wind Pattern

Meridional wind speed decreased from north to south (0.3-2.4 m/s) during 1948-2016 at 1000mb (Figure 6a). This may be due to the presence of lofty Eastern Himalayas, which presents a high downslope towards the Brahmaputra plains. The meridional wind speed during the summer season was higher than during the other seasons, perhaps due to the increased heating during this season. Wind blew mostly from a north-east direction except during summer, when it blowed in a south-north direction. The flow pattern of meridional winds in the region was not uniform during spring and summer seasons and speeds varied according to their local geographical settings. The anomaly in meridional wind was higher in central part in comparison to the other parts of the study area (Figure 6b).

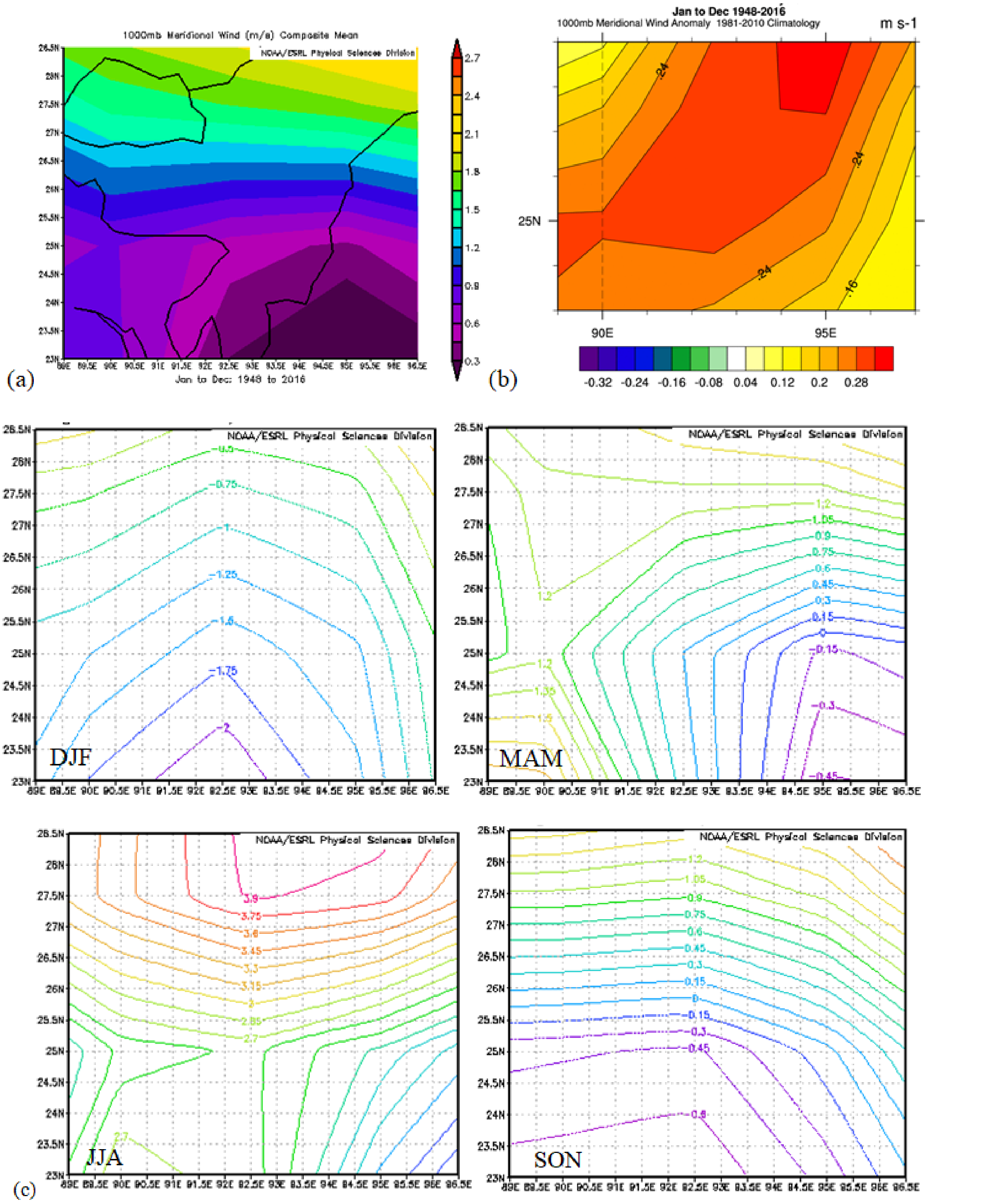


Figure 6 (a) Mean V-wind (m/s) at 1000mb using NCEP/NCAR Reanalysis data during 1948-2016 (b) Meridional Wind anomaly, 1948-2016; (c) Mean zonal wind speed ,V-Wind (meridional) (m/s); for the four seasons: December-February, March-May, June-August, and September-November, based on long term mean,1981-2010; region 23-28.5 N and 89-96.50 E

6. CONCLUSION

The study area is characterised by lack of research emphasizing on assessment of wind speed and distribution pattern. This study followed an empirical approach to study the potential wind energy and distribution pattern in Assam. Wind pattern in this part of Assam was found to be non-uniform and irregular. The Weibull scale factor (λ) of 1.21(m/s) indicates the low potentiality of wind in the region, which was not enough for generation of wind power. The easterly winds are generally high during spring season than any other season. Meridional winds are responsible for the bringing the rain bearing clouds during monsoon season. The winds flowing downslope of Eastern Himalayas and enters the Brahmaputra valley. This results into high wind speed anomaly in the northwestern part of the region. Therefore, hydropower may be an alternative to wind energy as renewable resource because of abundance water availability from different sources.

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