CHAPTER III

WIND IN THE BRAHMAPUTRA VALLEY

It has been already mentioned that the Brahmaputra Valley is almost surrounded by high mountain barriers which may affect the wind flow pattern, specially at the lower levels. So, the study of the characteristics of wind in the valley at the surface level (about 10 metres above ground) is very important. It will be helpful in understanding the spatial distributions of rainfall, mainly storm precipitation, temperature, humidity, etc. and in the estimation of extractable wind power of the region. Here, some characteristics of wind, such as - seasonal and areal variations of the direction and speed of the prevailing wind as well as the extractable power from wind in the Brahmaputra Valley are discussed.

Data

Necessary wind data is collected from the Indian Meteorological Department, Pune. The meteorological stations used are Dhubri, Goalpara, Gauhati, Tangla, Tezpur, Gohpur, Majbat, Chaparmukh, Lumding, Sibsagar, Golaghat, Dibrugarh, Digboi, North Lakhimpur, Pasighat, Haflong, Imphal, Silchar, Agartala,
Results and discussion

Prevailing wind direction

The prevailing direction of wind in the Brahmaputra Valley, specially at the lower levels (surface to about 1.5 Km a.s.l.) is highly affected by the topography of the region. Comparing the pressure distribution, Mukherjee and Ghosh (1965) showed that the direction of wind flow in the valley is not consistent with the mean sea-level pressure distribution at the lower levels. The study of Rao and Ramamurti (1968) indicates that only the surface wind flow is consistent with the mean sea-level pressure distribution throughout the year and along the downslope of the valley. But above the surface layers, the direction of wind gradually changes and even becomes opposite to that of the surface layers (Ramakrishnan et al., 1958; Krishnan et al., 1961; Rao and Ramamurti, 1968). Considering the months of January, April, July and October as the representatives of north-east monsoon, pre-monsoon, south-west monsoon and winter seasons respectively, wind direction over India and its neighbourhood which includes the Brahmaputra Valley also, are shown in Figures 2.1 to 2.4 for different levels. Figures 2.1 and 2.2 show that the wind direction over the valley is westerly above about 3 Km a.s.l. (above sea level) in January and south-westerly and then westerly above
Fig. 2.1 Upper wind flow pattern over India and its neighbourhood in January (after Rao and Ramamurti, 1968).
Fig. 2.2 Upper wind flow pattern over India and its neighbourhood in April (after Rao and Ramamurti, 1968).
Fig. 2.3 Upper wind flow pattern over India and its neighbourhood in July (after Rao and Ramamurti, 1968).
Fig. 2.4 Upper wind flow pattern over India and its neighbourhood in October (after Rao and Ramamurti, 1968).
1 Km a.s.l. in April. In July, the prevailing direction of wind in the valley is southerly at the levels 900 mb (about 1 Km a.s.l.) to 700 mb (about 3 Km a.s.l.). At 500 mb (about 6 Km a.s.l.) level wind is westerly and aloft it is easterly. During winter (October) wind at 850 mb (about 1.5 Km a.s.l.) and 700 mb levels blows along the upslope of the valley. At 500 mb and aloft westerly prevails.

The mean sea-level pressure distribution in the valley and its neighbourhood along with the surface wind direction are shown in Figures 2.5 to 2.8 for the months of January, April, July and October respectively. These figures show that in the valley region as a whole, wind flow pattern is consistent with the mean sea-level pressure distribution. Throughout the year, the low pressure area (L) is located towards the south-west of the valley and wind blows along the downslope of the valley towards the low pressure area. Thus the cold air is drained out through the valley. This cold and downslope wind is nothing but the katabatic wind which blows from the Eastern Himalaya and the Tibetan plateau.

The surface wind flow pattern is not consistent with the mean sea-level pressure distribution at Lumding for the months of January, April and October, and at Haflong throughout the year. Lumding is surrounded by hills on three sides. So surface wind direction may be partly modified by the hills. Haflong is not a valley station. It is located on the southern slope of the southern hill barrier of the valley. Because of its separation from the valley and height from the sea level, wind direction at this station
Fig. 2.5 Mean sea level pressure (mb) distribution and surface wind direction in the Brahmaputra Valley and its neighbourhood in January.
Figure 2.6: Mean sea level pressure (mb) distribution and surface wind direction in the Brahmaputra Valley and its neighbourhood in April.
Fig. 2.7 Mean sea level pressure (mb) distribution and surface wind direction in the Brahmaputra Valley and its neighbourhood in July.
Fig. 2.8 Mean sea level pressure (mb) distribution and surface wind direction in the Brahmaputra Valley and its neighbourhood in October.
may not be similar to the valley stations.

For the period, 1957 to 1965, the average picture of wind in an eight-point compass at twelve stations widely distributed in the Brahmaputra Valley is shown in Figure 2.9. The circles drawn by taking each station at the centre represent the percentage number of calm days. The arrows indicate the direction of wind flow and their lengths represent the percentage number of days with wind in the respective direction.

It is observed that the prevailing wind of the valley almost follows the course of the river Brahmaputra. At all the stations except Tangla, Lunding and Haflong, the prevailing wind is either easterly or north-easterly. Only at Lunding and Tangla the prevailing direction of wind is from south-east to north-west. At Haflong where orographic influences on wind flow is almost negligible due to its elevation, the prevailing wind is south-westerly. The other components of wind except southerly is negligible. The hill stations - Tura, Shillong, and Charra-punje (not shown in figure) also show almost similar wind flow pattern. Thus a difference in the prevailing wind direction is observed between the valley stations and the hill stations.

From the above discussions it seems that the wind flow pattern in the valley is greatly affected by the surrounding topography of the valley. Specially, the southern hill boundary of the valley has an important role on the wind flow pattern.
Fig. 2.9 Average picture of wind direction at 12 stations located in the Brahmaputra Valley, for the period 1957-1965. The lengths of the arrows represent the percentage number of days with wind in the respective directions (1 cm = 30%).
and hence on the areal distribution of rainfall in the valley. For this investigation airflow patterns at different heights above mean sea level are studied. The airflow patterns for the typical premonsoon and monsoon months May and July respectively, at the levels of heights 0.3 km, 0.9 km and 1.35 km above sea level (a.s.l.) are shown in Figures 2.10 to 2.15. The upper air data is available only for the stations Agartala, Gauhati, Tezpur, Dibrugarh and Imphal of north-east India. These data along with the reports of Indian Meteorological Department have been used to prepare the airflow patterns. The height contours indicated in the maps also show the various mountain gaps, specially in the southern boundary of the valley at different heights.

It is observed that during the months of May and July, the prevailing wind at the lower levels (below 3 km a.s.l.), except at the surface layer, have a tendency to be both downslope and upslope along the valley. The downslope wind is nothing but the existing katabatic wind that blows from the Tibetan plateau and the Eastern Himalaya during winter on a seasonal scale. This downslope or katabatic wind prevails upto about 0.9 km a.s.l. during May and upto about 0.6 km a.s.l. during July. As this katabatic wind fails to bring moisture into the valley, its effect on the areal distribution of rainfall in the valley is negligible. So, in drawing the airflow patterns the existence of the katabatic wind is neglected except for the month of May at the level of 0.3 km. a.s.l., since in this month only the katabatic wind is significant at
Fig. 2.10 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 0.3 km a.s.l. for the month of May. (An overlay in the pocket is also enclosed.)
Fig. 2.11 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 0.9 km a.s.l. for the month of May. (An overlay in the pocket is also enclosed.)
Fig. 2.12 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 1.35 m a.s.l. for the month of May. (An overlay in the pocket is also enclosed.)
Fig. 2.13 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 0.3 km a.s.l for the month of July. (An overlay in the pocket is also enclosed)
Fig. 2.14 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 0.9 km a.s.l. for the month of July. (An overlay in the pocket is also enclosed.)
Fig. 2.15 Airflow pattern over the Brahmaputra Valley and its neighbourhood at the level of 1.35 km a.s.l for the month of July. (An overlay in the pocket is also enclosed)
that level. The airflow patterns (Figures 2.10 to 2.15) show the regions of convergence and divergence due to mountain barriers which are discussed in Chapter IV along with the areal distribution of rainfall in the valley.

An east-west discontinuity of wind flow is observed near Dibrugarh at 0.9 km a.s.l. in the month of May (Figure 2.11) and at 0.3 km a.s.l. in July (Figure 2.13). This discontinuity of wind might be the result of superposition of dominant katabatic wind with the general wind flow pattern.

Wind speed

The mean monthly wind speed and their annual averages at all the stations located in the valley are shown in Figure 2.16. The mean annual wind speed over the valley as a whole is 4.11 km/hr, having the range from 2.4 km/hr (at Dibrugarh) to 8.4 km/hr (at Haflong). Among the stations in the plain, mean wind speed is observed to be the highest at Dhubri (5.9 km/hr).

The monthwise variation of wind speed shows that at majority of the stations maximum wind speed is observed in the month of April. At the hill station Haflong, and at Tanga the maximum is observed in the month of May. Only at North Lakhimpur and Chaparmukh, the maximum is shifted to June and July respectively. The minimum of the mean wind speed at all the stations except Goalpara and Tezpur is observed in either
Fig. 2.16 Mean monthly wind speed at some stations located in the Brahmaputra Valley. The inset represents the average picture of the variation pattern of mean monthly wind speed for all the stations except Haflong.
November or December. It is shifted to January at Goalpara and to October at Tezpur.

The average variation pattern of the mean monthly wind speed of all the stations except Haflong (inset of Figure 2.16) shows that the variation of mean wind speed is approximately linear from December to April where it obtains the maximum value and then decreases almost linearly to November. Thus the variation pattern is approximately conical in shape. The highest value of wind speed in the month of April is the effect of pressure gradient. The normal pressure gradient from lower end (Dhubri) to the upper end (Dibrugarh) of the valley is found to be maximum (0.28 mb/100 km) in this month. During this month wind is also observed to be almost unidirectional (79 % of the days with wind) and blows along the downslope of the valley.

**Wind power**

Converting the kinetic energy of wind into electrical energy, wind may be used as a source of energy or power. The kinetic energy of a stream of wind having crossectional area A and speed v with the density of air p, may be represented by,

\[ \text{Kinetic energy} = \frac{1}{2} p A v^2 \]  

(1.1)

Theoretically, Betz (1919) showed that the maximum fraction of this kinetic energy that can be extracted is about 0.593.
Hence, theoretical maximum power output,

\[ P_t = \frac{0.593}{2} \text{ p A } v^3 \]  

\[ = 0.2965 \text{ p A } v^3 \]  

Again, about one-third of this theoretical power output \( P_t \) is lost in the process of energy conversion depending on the type of wind turbine or aerogenerator (Hewson, 1977). Thus, the maximum power, \( P \) that can be extracted from wind is given by,

\[ P = \left(\frac{2}{3}\right) \times 0.2965 \text{ p A } v^3 \]

\[ = 0.1977 \text{ p A } v^3 \]  

In the equation (1.3), \( P \) gives the instantaneous value of the maximum extractable wind power, as \( v \) represents the instantaneous wind speed. But, generally, to estimate the monthly/annual wind power, mean values of wind speed are used. So, the monthly/annual wind power estimated by equation (1.3) will be less than that of the actual value, since wind power is proportional to the cube of wind speed. Hence, when \( v \) represents the mean wind speed, the power estimated should be multiplied by a factor, called the energy pattern factor (Shrinivasa et al., 1979). This energy pattern factor depends on the temporal variation, specially diurnal and
seasonal variations of wind speed. In the study of wind power in India, some workers took the value of this factor (annual) as 5.5 (Jagadeesh et al., 1981, 1982; Shrinivasa et al., 1978). As the evaluation of this energy pattern factor for the Brahmaputra Valley is still lacking, the same value of the energy pattern factor (5.5) is used here also. Thus, the maximum extractable wind power will be,

\[ P = 5.5 \times 0.1977 \, p \, A \, v^3 \]

\[ = 1.0874 \, p \, A \, v^3 \]  

(1.4)

Now, if \( v \) is in kilometre per hour, assuming \( p = 0.001165 \) gm/cc at normal temperature and pressure, the wind power per square metre cross-sectional area perpendicular to the direction of the wind \((A = 1 \text{ sq. metre})\) will be obtained as,

\[ P = 97.744 \, v^3 \, \text{watt hour/metre}^2 \]  

(1.5)

Maximum extractable wind power calculated for various stations by using equation (1.5) are presented in Table I. It is observed that wind power in the valley varies significantly from place to place. Among all the stations considered wind power is found to be minimum at Dibrugarh \((10.42 \times 10^3 \, \text{Kwh/metre}^2 \, \text{annually})\) and maximum at Haflong \((514.60 \times 10^3 \, \text{Kwh/metre}^2 \, \text{annually})\). Among the plains stations, extractable wind power is found to be maximum at Dhubri \((175.85 \times 10^3 \, \text{Kwh/metre}^2)\).

The areal distribution of the maximum extractable wind
Table I: Annual output of extractable wind power observed at various stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Wind power (annual output) in $10^3$ Kwh/metre$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dhubri</td>
<td>175.85</td>
</tr>
<tr>
<td>2. Goalpara</td>
<td>25.21</td>
</tr>
<tr>
<td>3. Guwahati</td>
<td>28.06</td>
</tr>
<tr>
<td>4. Tangla</td>
<td>11.46</td>
</tr>
<tr>
<td>5. Tezpur</td>
<td>25.51</td>
</tr>
<tr>
<td>6. Haibat</td>
<td>58.41</td>
</tr>
<tr>
<td>7. Gohpur</td>
<td>50.21</td>
</tr>
<tr>
<td>8. Chaparmukh</td>
<td>64.76</td>
</tr>
<tr>
<td>9. Sibsagar</td>
<td>72.94</td>
</tr>
<tr>
<td>10. North Lakhimpur</td>
<td>77.82</td>
</tr>
<tr>
<td>11. Dibrugarh</td>
<td>10.42</td>
</tr>
<tr>
<td>12. Digboi</td>
<td>50.48</td>
</tr>
<tr>
<td>13. Haflong</td>
<td>514.60</td>
</tr>
</tbody>
</table>
power (not shown in figure) indicates that generally, extractable wind power increases outwards from the both banks of the river Brahmaputra. Wind power seems to be less along the river banks except at Dhubri. As the seasonal variation pattern of mean wind speed (Figure 2.16) shows April maximum and December minimum, the seasonal variation of maximum extractable wind power (not shown in figure) will also show April maximum and December minimum (since $P \propto v^3$).

Conclusion

Analysis of the prevailing direction of surface wind (about 10 metres above ground level) at different locations in the valley with the mean sea-level pressure distribution shows that throughout the valley except at Lumding and Haflong, the surface wind is consistent with the pressure distribution. The anomalies observed at Lumding and Haflong are due to the physiography of the region. Throughout the year, the surface wind almost follow the course of the river Brahmaputra and prevails along the downslope of the valley. At the higher levels, the direction of wind changes in all the seasons of the year. The downslope wind at the lower levels is the dominant katabatic wind from the Tibetan plateau and the Eastern Himalaya. During pre-monsoon and monsoon months the wind in the valley at the lower levels have two dominant directions, either along the downslope or along the upslope of the valley. The airflow patterns at 0.9 km a.s.l. in May and at 0.3 km.
a.s.l. in July shows an east-west discontinuity of wind in the upper part of the valley (near Dibrugarh). This anomaly in wind flow is due to the superposition of the dominant katabatic wind with the general flow pattern.

Mean annual wind speed over the valley as a whole seems to be 4.11 km/hr. Wind speed increases linearly from a minimum in the month of December to a maximum in April and then it decreases almost linearly to November. In the month of April, the gradient of mean sea level pressure is found to be maximum and the surface wind flow is almost unidirectional. As a result wind speed becomes maximum in this month.

Maximum extractable wind power in the valley varies significantly from place to place. Generally, along the both banks of the river, wind power seems to be less. It seems to increase towards the outer ramparts from both banks of the river. On the average, the valley shows an annual output of wind power of about $89.67 \times 10^3$ Kwh/metre$^2$. 