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OF
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CLIMATE
SYNOPTIC ANALYSIS OF TEMPERATURE, PRECIPITATION AND MOISTURE CONDITIONS IN THE BHUTAN HIMALAYAS

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ABSTRACT

Bhutan is located in monsoon Asia and is one of the important areas for clarifying the Indian summer monsoon. However, with regard to climate, Bhutan is the most unknown region in monsoon Asia. Therefore, the purpose of this paper is to explain the climatic situation of Bhutan on a synoptic scale.

In Bhutan, the moisture condition indicates a great regional diversity. Along the southern foothills, the annual precipitation is above 4000mm and this region is classified as Perhumid (A type) on the basis of Thornthwaite's climatic classification. On the other hand, in the lower Midland, the annual precipitation is around 600mm and according to Thornthwaite's climatic type this region is classified as Dry Subhumid (C2 type). This abrupt regional change of climate from the southern foothills to the middle reaches is expected to occur around the main ridges of the southern High Himalaya.

The seasonal change of precipitation is more obvious in the southern foothills than in the lower Midland. In the southern foothills, monthly precipitation is above 100mm from April to October and the dry period is shorter than in the western and central parts of the Himalayas.

The annual mean temperature lapse rate around Bhutan is 0.54°C/100m and the monthly mean indicates obvious seasonal change.
INTRODUCTION

Bhutan is located in the eastern part of the Himalayas bordering with Assam and Tibet. On a global scale, the climates of East Asia, India and Indochina have been clarified with an increasing number of data. However in the contact region of the three regions the climate is not clarified from the regions which surround it. For example, the onset of the rainy season is roughly clarified both in India and in East Asia, but the relationship between them is obviously shown. Because there are mountains in the areas between the two regions and it is difficult to obtain the observed data. Considering the onset of the Indian summer monsoon, it is pointed out that the region around Assam plays an important role regarding heat sources. To clarify the climate of bordering areas including Bhutan it is important to clarify the climate in South, Southeast and East Asia.

Bhutan is also important in clarifying the climate of the Himalayas and the mountain climatology. However, the climate of Bhutan has not been clarified. Papers concerning the climate of Bhutan are few. Karan (1968) reported the climate of Bhutan briefly and classified Bhutan into three climatic regions. However, he used the climatic data of a few stations and the climatic conditions were mainly concluded by vegetation type. A systematic analysis of Bhutan's climate has not been done before. Therefore, in this paper, the author intends to clarify the climate of Bhutan, including India and China.

REGIONAL AND SEASONAL CHARACTERISTICS OF PRECIPITATION

1. Data

In this paper only 18 meteorological stations in Bhutan are used and in particular, there is no station in either the eastern part of the southern foothills or in the northern High Himalaya(Fig. 1). Moreover, in the other areas, the stations are almost all located in valleys. Though the meteorological stations are not uniformly distributed, the data used in this paper are at least more than those used by Karan (1968) and it is possible to analyze the climate of Bhutan in more detail than Karan did.
Figure 1 Distribution of meteorological stations in Bhutan.
Therefore, the author intends to clarify the distribution and seasonal march of precipitation in more detail than Karan did on the basis of observed precipitation data which are mean annual and monthly data for the six years from 1975 to 1980.

2. Distribution of precipitation

In Bhutan, the annual precipitation indicates a great regional variety (Fig. 2). In the southern foothills (ex. Phuntsoling), the annual precipitation is above 4000mm. On the other hand, in the valleys of the lower Midland (ex. Thimphu), it is around 600mm. Precipitation decreases abruptly from south to north and its distribution is extremely complex. This regional difference in the distribution of precipitation is expected to be largely affected by topographic effects. On the basis of precipitation data and topographic conditions, at least four climatic regions can be recognized; the southern foothills, the southern High Himalaya, the lower Midland between the southern High Himalaya and the northern High Himalaya, and the northern High Himalaya (Fig. 2). The southern foothills include the Bhutan Sub-Himalaya and parts of the Lower Bhutan Himalaya. The southern High Himalaya include the southern part of the Bhutan High Himalaya and parts of the Lower Bhutan Himalaya. The Black Mountains are the main part of the southern High Himalaya. The lower Midland indicates the region around the cities of the middle reaches of each river. More detailed descriptions of topography in Bhutan are shown by Eguchi (1987a). In the same climatic regions, however, precipitation differs between valleys, slopes and ridges.

Karan (1968) has already pointed out the complexity of Bhutan's climate and tries to resolve this intricacy by the broad classification of climate with limits determined by altitude. He classified Bhutan into three climatic regions; the hot and humid subtropical area of Duar and the foothills, the cooler (microthermal) region of the inner Himalaya, and the tundra region of the Great Himalaya. The southern foothills and the northern High Himalaya in this paper correspond to the southern foothills and the Great Himalaya of Karan's classification, respectively. However, Karan's Inner Himalaya are separated into two regions; the southern High Himalaya and the lower Midland.

In the southern foothills, the mean annual precipitation is between
Figure 2 Mean annual precipitation in Bhutan (6 year mean: 1975-1980).

Figure 3 Mean annual precipitation around Bhutan (6 year mean: 1975-1980).
4000 and 5000mm. It is the highest in Bhutan and is about twice that of Assam in Fig. 3 (ex. Gauhati, 1705mm; Dhubri, 2169mm).

In the southern part of the southern High Himalaya, south of main ridges of the southern High Himalaya, regional variety is expected to be large. Meteorological stations are mostly located in valleys or lower parts of slopes and consequently the precipitation data in the upper parts of slopes or ridges are insufficient. On the basis of data at Dhablakha, which is the only data for the upper parts of southern slopes, precipitation is above 3000mm. On the other hand, in valleys or lower parts of slopes, precipitation is between 1000mm and 1500mm. On the basis of the data for the southern part of the southern High Himalaya, precipitation is expected to be greatest in the upper parts of southern slopes and least in the bottoms of valleys. The upper limit of precipitation in this area is expected to be 3000mm or more, but less than that of the southern foothills. On account of the complexity of topography, precipitation in this area is expected to vary greatly between 1000 and 3000mm mainly caused by the direction of slopes or altitude.

In the northern part of the southern High Himalaya, north of the main ridges of the southern High Himalaya, though the data are insufficient, precipitation is expected to be less than that of the southern part of the southern High Himalaya. Decrease in precipitation from south to north varies with the direction of main ridges and the altitude of ridges. In the eastern part of the southern High Himalaya, the altitude of ridges is the highest and the decrease of precipitation by topographic effects is expected to be remarkable.

Precipitation in the lower Midland varies from west to east. In the western part, the annual precipitation is around 600mm. On the other hand, in the central part, it is more than that of the western part. At Tongsa, it is 1280mm and almost twice more than that of Thimphu. One of the reasons why precipitation in the central part is more than that of the western part is considered to be the relationship between the monsoon flow in the lower troposphere and the topography. During the summer monsoon season, the southeasterly dominates in the lower troposphere. In the western part, west of the Mangde Chhu(River), the ridges extend from west to east as well as from south to north and the altitude of their peaks is more than 5000m. The southeast monsoon flow is disturbed by the southern High Himalaya and the moisture from Assam
cannot reach fully over the lower Midland. On the other hand, in the central part, the main ridges extend from south to north or northwest to southeast and their altitudes are lower than that of the western part. Therefore, the southeast monsoon flow penetrates into the lower Midland and brings more rainfall than in the other parts of the lower Midland. In particular, at Tongsa which is located in the southern slope of the Mangde Chhu, the valley of the Mangde Chhu, southeastward of Tongsa, runs straight from northwest to southeast and, therefore, the southeasterly flow is not disturbed unlike the other parts of the lower Midland and precipitation at Tongsa is much more than that of the other parts of the lower Midland.

In the eastern part of the lower Midland, there are two stations, Mongar and Tashigang. These two stations are located in the south compared with the other stations in the lower Midland, and their altitudes are lower than the others. The annual precipitation at Mongar is only 518mm. Although the topographic conditions in this area are not known in detail, the ridges extend from west to east south of these stations. The precipitation at the two stations are also expected to be affected by topographic effects and the moisture of the summer monsoon cannot be fully accepted. In particular, the precipitation at Mongar is the least in Bhutan. One of the reasons is considered to be that Mongar is located on a northern slope. Therefore, the precipitation data at Mongar may not represent the surrounding area and it may be less than the aerial average around Mongar.

In the northern High Himalaya (the Great Himalaya), whose lower limit is around 4000m, no meteorological data are available.

In general, precipitation along the Himalayas increases from west to east (Fig. 2). In Bhutan, because of the lack of data in the eastern part of the southern foothills, it is difficult to compare precipitation longitudinally along the southern foothills. In the middle reaches, precipitation is greater in the central part than in the western part, and at Tashigang it is greater than in the western part. On the basis of the data at Tashigang, increase in precipitation from west to east is recognized also in Bhutan. However, the precipitation at Mongar is the least of all the station and the amount of increase is not so great. The precipitation data in the lower Midland is affected by topographic effects and they do not necessarily indicate that precipitation increases from
west to east in Bhutan. This problem is very important, however, it is difficult to resolve on the basis of the data used here.

3. Seasonal change of precipitation

Bhutan is located in the monsoon region. During November through February the monthly precipitation is nearly zero at almost all stations and dry conditions dominate(Fig. 4, Fig. 5, Data 1, Data 2). Monthly precipitation increases from March and reaches its maximum in July or August. Along the southern foothills, the increase of monthly precipitation starts in April. From April to May and from May to June, precipitation increases considerably and the period from June to August is the main rainy season. On the other hand, mainly in the lower Midland, the precipitation increases gradually compared with that of the southern foothills at almost all stations.

Although the patterns of precipitation increase differ by area in Bhutan, the summer concentration of precipitation, the percentage of three months total to annual precipitation, is above 60% at almost all stations and that of the five months from May to September is above 80%. In particular, the percentage for July to annual precipitation is above 25% in central parts of the southern foothills and the southern High Himalaya. Precipitation largely decreases from September to November in Bhutan. The seasonal change from monsoon to post-monsoon in 1985 occurred on October 19 in Bhutan(Eguchi,1987b).

In accordance with the compiled map of average onset dates of the rainy season by Ramage(1971), the onset of summer monsoon in Bhutan occurs in June. However, the increase of precipitation in Bhutan occurs before June as well as in Assam. Though there are some problems that the onset of monsoon is defined by precipitation, it is evident that the onset of the rainy season is at least earlier than that of areas west of Bhutan. The relationship between the onset of the summer monsoon around Assam including Bhutan, that of the Burma summer monsoon and that of the Indian summer monsoon is an important problem and, therefore, further study is necessary.

Maximum monthly precipitation indicates regional diversity. In the southern foothills and the southern High Himalaya, it mainly occurs in July, but in the lower Midland it mainly occurs in August. The total
Figure 4: Distribution of mean monthly precipitation in Bhutan (6 year mean: 1975-1980). Unit: mm
Figure 5 Annual variation of mean monthly precipitation (6 year mean: 1975-1980). Unit: mm
amounts of precipitation in the lower Midland are much less than those in the southern foothills. In the lower Midland, precipitation falls from evening through night-time and night-time showers dominate in August and September (Nishioka, 1985). During our survey period in September 1985, precipitation at Thimphu mainly fell from evening through night-time.

Yasunari and Inoue (1978) show the difference of the features of precipitation between Shorong Himal and Khumbu Himal. Two of them are as follows; "One is that the total amounts of precipitation are 4 or 5 times larger at Shorong and Glacier EB 050 stations than at Lhajung station. Another is that at Shorong and Glacier EB 050 stations, the precipitation is concentrated during the daytime, while at Lhajung station it is concentrated during the evening through nighttime". They analyzed the causes of difference as follows; "The precipitation of a broader scale in Shorong Himal may be caused by the convective instability released by forced uplifting of the conditionally unstable air of the lower troposphere from the Indian Plain along the southern slope of this mountain range. On account of this "barrier effect" of Shorong Himal and also Hinku Himal on the moisture supply, a semi-arid climate may appear in the Khumbu region, which is located on the lee side of Shorong and Hinku Himals. However, around the rocky peaks or ridges of 5000-6000m in the Khumbu region, the relatively large amount of precipitation may be provided by the cumulus convection induced by the heating of the rocky ground by strong solar radiation".

Might the conditions of precipitation in the Nepal Himalayas shown by Yasunari and Inoue (1978), above-mentioned, to correspond to those in the Bhutan Himalayas? With regard to the topographic situation, the Bhutan Himalayas are significantly different from the Nepal Himalayas. The area of the High Himalaya is larger in the Bhutan Himalayas than in the Nepal Himalayas. In the High Himalaya of Bhutan, two ranges extend from west to east and the distance between them is larger than the distance between the Shorong-Hinku Himals and Khumbu Himal in the High Himalaya of Nepal. Though the topographic conditions are different in the Bhutan Himalayas and the Nepal Himalayas, the altitudes of peaks in the southern High Himalaya of Bhutan are over 5000m and the climatic conditions in the lower Midland, between the two ranges in the High Himalayas of Bhutan, may be similar to those of Khumbu Himal. Therefore, the difference in precipitation processes shown by Yasunari and
Inoue(1978) in the Nepal Himalaya may be one of the causes why the period of maximum monthly precipitation occurrence is different in the southern foothills and the lower Midland.

CHARACTERISTICS OF TEMPERATURE AND TEMPERATURE LAPSE RATE

The observed temperature data are available in Bhutan at only three stations. Therefore, the author intends to estimate temperature using data for regions around Bhutan. The data used here are from 16 stations in India and China(Fig. 6 and Table 1). Temperatures are estimated for the relations between temperature and altitude(Fig. 7 and Data 3). The relations between the observed temperature and estimated temperature are shown in Fig. 8 and show a good correspondence, in particular, at Paro. The only problem is the data for April at Phuntsoling. The estimated temperature is lower than the observed one. The northern part of India in April is in a period just before the rainy season and records high temperatures. The observed data at Phuntsoling is not necessarily abnormal. On the other hand, temperatures recorded at Assam are not as high as in the Gandis Plain and the precipitation around Assam is more than 100mm in April. The estimated data is not necessarily abnormal. Therefore, on the basis of the data used here, it is difficult to determine which data is wrong. It is necessary to collect more data along the southern foothills of the Himalayas.

The data for estimated temperature tend to be high compared with the observed one at higher altitudes, in particular, in winter. The estimated temperature is shown in Fig. 9. This estimated temperature is lower in winter and higher in summer in the higher altitudes compared with that of Mitsudera and Numata(1967) in Nepal.

The annual variation of estimated temperature lapse rate is shown in Fig. 10. The temperature lapse rate is large in winter and small in summer, the largest being in December (0.622C/100m) and the smallest in July (0.424C/100m). The annual temperature lapse rate is 0.544C/100m. The temperature lapse rate is, in general, considered to be around 0.6C/100m. Why is the temperature lapse rate small in summer? In summer, on account of cumulus convections in the Himalayas, the air is
Figure 6 Distribution of stations for temperature lapse rate.
Figure 7: Temperature lapse rate on the basis of annual mean temperature (10 year mean: 1971-1980).

Table 1: Temperature lapse rate around the Bhutan Himalaya.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature lapse rate</th>
<th>Regression curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.615</td>
<td>$y = -0.00615x + 18.153$</td>
</tr>
<tr>
<td>February</td>
<td>0.604</td>
<td>$y = -0.00604x + 20.281$</td>
</tr>
<tr>
<td>March</td>
<td>0.611</td>
<td>$y = -0.00611x + 24.059$</td>
</tr>
<tr>
<td>April</td>
<td>0.568</td>
<td>$y = -0.00568x + 26.160$</td>
</tr>
<tr>
<td>May</td>
<td>0.500</td>
<td>$y = -0.00500x + 27.333$</td>
</tr>
<tr>
<td>June</td>
<td>0.438</td>
<td>$y = -0.00438x + 27.823$</td>
</tr>
<tr>
<td>July</td>
<td>0.424</td>
<td>$y = -0.00424x + 28.123$</td>
</tr>
<tr>
<td>August</td>
<td>0.438</td>
<td>$y = -0.00438x + 28.109$</td>
</tr>
<tr>
<td>September</td>
<td>0.476</td>
<td>$y = -0.00476x + 27.480$</td>
</tr>
<tr>
<td>October</td>
<td>0.545</td>
<td>$y = -0.00545x + 25.711$</td>
</tr>
<tr>
<td>November</td>
<td>0.606</td>
<td>$y = -0.00606x + 22.586$</td>
</tr>
<tr>
<td>December</td>
<td>0.622</td>
<td>$y = -0.00622x + 19.057$</td>
</tr>
<tr>
<td>Annual</td>
<td>0.544</td>
<td>$y = -0.00544x + 24.951$</td>
</tr>
</tbody>
</table>
Figure 8 Comparison between observed and estimated monthly temperatures.
Figure 9 Estimated altitudinal distribution of monthly temperatures.

Figure 10 Annual variation of temperature lapse rate.
well mixed vertically. The release of latent heat by cumulus convections increases the temperature in the lower and middle troposphere. In valleys of higher altitude, clouds develop mainly during the night-time and during the daytime the solar radiation is not disturbed compared with low altitudes. These conditions are expected to make the temperature lapse rate small in summer.

The regional representative temperature is, in general, more reliable than that of precipitation. The estimated temperature shows good correspondence with the observed one also in this paper. However, in mountain regions, the distribution of temperature is thought to be also complex as is that of precipitation, in particular, that of minimum temperature. It is necessary to observe the temperature at more stations on a smaller regional scale and shorter time scale.

REGIONAL VARIETY OF MOISTURE CONDITION

Bhutan is located north of Assam, which is well known as a region with one of the highest levels of precipitation in the world. On the other hand, dry conditions exist in the bottoms of valleys of the lower Midland and have already been reported (Schweinfurth, 1957). These dry valleys in Bhutan are considered to be strange phenomenon in the moist eastern Himalayas and, in general, this phenomenon is called "Troll effect". In order to clarify the moisture conditions in these dry valleys, it is necessary to show the precipitation and evaporation. In Bhutan, precipitation is observed, but data for evaporation is not observed operationally. The climatic data using the calculation of evapo-transpiration is only temperature in Bhutan and the method of calculating evaporation using only temperature data is Thornthwaite's method (Thornthwaite, 1948). Although there are many problems in Thornthwaite's method (Thornthwaite, 1948; Kayane, 1973), the author calculates the potential evapo-transpiration using Thornthwaite's method.

Potential evapo-transpiration based on observed temperature data is shown in Data 4 and that using estimated temperature is also shown in Data 5. The summary of all stations is shown in Table 2. In the southern foothills and the southern High Himalaya facing Assam, the annual precipitation is much larger than the annual potential evapo-transpiration.
Table 2 Comparative moisture data of Bhutan.

<table>
<thead>
<tr>
<th>Station</th>
<th>Potential evap. (mm)</th>
<th>Precipitation (mm)</th>
<th>Water surplus (mm)</th>
<th>Water def. (mm)</th>
<th>Moisture index</th>
<th>Climatic type</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Observation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phuntsholing</td>
<td>1306</td>
<td>4222</td>
<td>2969</td>
<td>53</td>
<td>224.9</td>
<td>AA' ra'</td>
</tr>
<tr>
<td>Paro</td>
<td>689</td>
<td>634</td>
<td>0</td>
<td>55</td>
<td>-4.8</td>
<td>CB1' da'</td>
</tr>
<tr>
<td>Thimphu</td>
<td>621</td>
<td>597</td>
<td>6</td>
<td>30</td>
<td>-1.9</td>
<td>CB1' da'</td>
</tr>
<tr>
<td>(Estimation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sarbhang</td>
<td>1197</td>
<td>4020</td>
<td>2866</td>
<td>33</td>
<td>239.4</td>
<td>AA' ra'</td>
</tr>
<tr>
<td>Samchi</td>
<td>1186</td>
<td>4251</td>
<td>3148</td>
<td>83</td>
<td>261.2</td>
<td>AA' ra'</td>
</tr>
<tr>
<td>Pagli</td>
<td>1186</td>
<td>3916</td>
<td>2755</td>
<td>25</td>
<td>231.0</td>
<td>AA' ra'</td>
</tr>
<tr>
<td>Phuntsholing</td>
<td>1186</td>
<td>4222</td>
<td>3055</td>
<td>19</td>
<td>256.6</td>
<td>AA' ra'</td>
</tr>
<tr>
<td>Mongar</td>
<td>947</td>
<td>518</td>
<td>0</td>
<td>429</td>
<td>-27.2</td>
<td>DB3' da'</td>
</tr>
<tr>
<td>Tashigang</td>
<td>934</td>
<td>702</td>
<td>0</td>
<td>232</td>
<td>-14.9</td>
<td>CB3' da'</td>
</tr>
<tr>
<td>Wangdhu Phodrang</td>
<td>843</td>
<td>579</td>
<td>0</td>
<td>264</td>
<td>-18.8</td>
<td>CB2' da'</td>
</tr>
<tr>
<td>Shemgang</td>
<td>840</td>
<td>1489</td>
<td>649</td>
<td>0</td>
<td>77.3</td>
<td>B3B2' ra'</td>
</tr>
<tr>
<td>Chukha</td>
<td>808</td>
<td>1472</td>
<td>664</td>
<td>0</td>
<td>82.2</td>
<td>B4B2' ra'</td>
</tr>
<tr>
<td>Gongphu</td>
<td>808</td>
<td>1060</td>
<td>284</td>
<td>32</td>
<td>32.7</td>
<td>B1B2' ra'</td>
</tr>
<tr>
<td>Chirang</td>
<td>807</td>
<td>1448</td>
<td>669</td>
<td>28</td>
<td>80.8</td>
<td>B4B2' ra'</td>
</tr>
<tr>
<td>Dhabhulakha</td>
<td>796</td>
<td>3100</td>
<td>2332</td>
<td>28</td>
<td>290.9</td>
<td>AB2' ra'</td>
</tr>
<tr>
<td>Tongsa</td>
<td>694</td>
<td>1280</td>
<td>586</td>
<td>0</td>
<td>84.4</td>
<td>B4B1' ra'</td>
</tr>
<tr>
<td>Paro</td>
<td>669</td>
<td>634</td>
<td>1</td>
<td>36</td>
<td>-3.1</td>
<td>CB1' da'</td>
</tr>
<tr>
<td>Thimphu</td>
<td>657</td>
<td>597</td>
<td>0</td>
<td>60</td>
<td>-5.5</td>
<td>CB1' da'</td>
</tr>
<tr>
<td>Bhumthang</td>
<td>633</td>
<td>730</td>
<td>97</td>
<td>0</td>
<td>15.3</td>
<td>C2B1' ra'</td>
</tr>
</tbody>
</table>
and the water surplus exceeds 2000mm. Monthly precipitation is more than the monthly potential evapo-transpiration during April through October and the period of water surplus mainly continues from May to October, though a little water deficiency occurs around March.

On the other hand, in the valleys of the lower Midland, except in the central part, the annual potential evapo-transpiration exceeds the annual precipitation and the water surplus is nearly 0mm. The water deficiency is great in the eastern part (Tashigang and Mongar) and at Wangdhu Phodrang, and the altitudes of these three stations are between 1000-1500m, which are less than that of the western part. In particular, at Mongar, monthly precipitation is less than monthly potential evapo-transpiration throughout the year and the conditions of water deficiency also dominate throughout the year. The annual water deficiency reaches 429mm. At Tashigang and Wangdhu Phodrang, the annual water deficiency is nearly the same amount, around 250mm, and less than that of Mongar. The monthly precipitation is less than the monthly potential evapo-transpiration except in July at Tashigang and in July and August at Wangdhu Phodrang, and the condition of water deficiency continues from November through January to June. In the eastern part (Paro and Thimphu), as the altitude is high, between 2000-2500mm, the temperature is lower than that of the eastern part and the potential evapo-transpiration is also lower than that of the eastern part. The annual water deficiency is around 50mm. The monthly precipitation exceeds the monthly potential evapo-transpiration from June to September at Paro and from July to September at Thimphu, and the water deficiency occurs in May at Paro and continues from April to June (mainly in May) at Thimphu.

In the central part of the lower Midland, the moisture conditions are different at Tongsa and at Bumthang. At Bumthang, the annual precipitation (730mm) is more than that of the eastern and western parts of the lower Midland and the water deficiency indicates 0mm. However, the water surplus and the moisture index are lower than those in the southern High Himalaya and the southern foothills. The moisture index and the climatic type at Bumthang are close to those of the eastern and western parts of the lower Midland rather than the southern High Himalaya. On the other hand, at Tongsa, the values for precipitation water surplus, water deficiency, and moisture index are very close to
those of the southern High Himalaya. The climatic type is also similar to that of the southern High Himalaya. The moisture conditions at Tongsa are considerably different from the other stations in the lower Midland and Tongsa is the wettest town in the lower Midland.

In the southern High Himalaya, the water surplus exceeds the water deficiency, and at Gomphu and Chirang the water deficiency occurs around April.

Thornthwaite's climatic classification on the basis of the moisture index together with their limits are as follows:

<table>
<thead>
<tr>
<th>Climatic Type</th>
<th>Moisture Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100 and above</td>
</tr>
<tr>
<td>B&lt;sub&gt;4&lt;/sub&gt;</td>
<td>80 to 100</td>
</tr>
<tr>
<td>B&lt;sub&gt;3&lt;/sub&gt;</td>
<td>60 to 80</td>
</tr>
<tr>
<td>B&lt;sub&gt;2&lt;/sub&gt;</td>
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On the basis of these data for moisture index, the stations in the southern foothills belong to the Perhumid climatic type (A type) and those in the southern High Himalaya to the Humid climatic types (B<sub>4</sub>-B<sub>1</sub> types). On the other hand, in the lower Midland, the Dry subhumid climatic type (C<sub>1</sub> type) and Semiarid climatic type (D type) appear. The moisture index at Mongar indicates -22.6 and this value belongs to the Semiarid climatic type. The Dry subhumid climatic type appears at three stations (Tashigang, Thimphu and Paro). With regard to the above results using Thornthwaite's climatic classification, in the valleys of the lower Midland except the central part (in particular at Tongsa), dry conditions dominate locally. Considering the distance between the southern foothills and the lower Midland (less than 100Km), abrupt changes in moisture conditions ranging from the Perhumid climatic type (A type) to the Dry subhumid climatic type (C<sub>1</sub>) or the Semiarid climatic type (D type) appear from the southern foothills to the middle reaches, except in the central part of Bhutan.
CONCLUDING REMARKS

The climate of Bhutan has not been clarified before, as already mentioned, and Bhutan is one of the most unknown areas in the world. Therefore, in this paper, the author mainly analyzes the distribution and seasonal changes of basic climatic elements (precipitation, temperature, etc.) and shows the general features of Bhutan's climate. Since climatic data are not fully available in Bhutan, the climatic factors which dominate the distribution and seasonal changes of climatic elements cannot be fully analyzed.

In Bhutan, there are many important and interesting problems left, in particular, with regard to the regional differences of climate. For example, does the onset of the summer monsoon occur at the same time throughout Bhutan? Study of the climate of Bhutan is still in its initial stages and there are many problems which should be clarified.

ACKNOWLEDGMENT

I wish to express my gratitude to Prof. H. Suzuki, Department of Geography, University of Tokyo for his guidance and encouragement. I also wish to express my thanks to the members of our survey group and Mr. K. Nishioka for his helpful advice. I also would like to thank Prof. M.M. Yoshino for kindly permitting the use of precipitation and temperature data in China, which were obtained by Prof. M.M. Yoshino through the good offices of the Institute of Geography, Academic Sinica, Beijing.

I used a HITAC M680-H computer in the Computer Center, University of Tokyo.

REFERENCES

Eguchi, T. (1987a). Topographic features in the central part of Bhutan Himalaya. (In this issue.)
Schweinfurth, U. (1957). Die horizontale und vertikale Verbreitung der
Thornthwaite, C. (1948). An approach toward a rational classification of
Yasunari, T. (1976); Seasonal weather variations in Khumbu Himal. Seppyo,
38: 74-83.
around peaks and ridges in Shorong and Khumbu Himal. Seppyo,
40: 26-32.
Data 1  Distribution of mean monthly precipitation in Bhutan
(6 year mean: 1975-1980). Unit: mm
Data 2  Annual variation of mean monthly precipitation
(6 year mean: 1975-1980).

PHUNTSOLING

PAGLI

SAMCHI

SARBHANG

Month
Data 3 Monthly mean temperature lapse rate
(10 years mean: 1971-1980).

JANUARY
\[ r = 0.9866 \]
\[ y = -0.00615x + 18.153 \]

FEBRUARY
\[ r = 0.9611 \]
\[ y = -0.00604x + 20.281 \]

APRIL
\[ r = 0.9832 \]
\[ y = -0.00558x + 26.160 \]

MAY
\[ r = 0.9788 \]
\[ y = -0.00500x + 27.333 \]

JUNE
\[ r = 0.9733 \]
\[ y = -0.00438x + 27.823 \]
Data 4 Moisture data on the basis of observed climatological data.

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SYNOPTIC- AND MESO-ANALYSIS OF CLIMATIC CONDITIONS IN BHUTAN FROM SEPTEMBER THROUGH NOVEMBER IN 1985

T. EGUCHI

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ABSTRACT

On the basis of climatic observations made during a trekking survey in 1985, the author intends to clarify the climate of Bhutan on synoptic- and meso-scales. The survey period is from September through November and this period is expected to be the transition period from the summer monsoon period to post-monsoon period.

In 1985, the seasonal change from the summer monsoon period to the post-monsoon period occurs around October 19 in Bhutan. This change occurs just after the passage of tropical cyclone from the Bay of Bengal.

The diurnal variation of temperature is more obvious during the post-monsoon period than during the summer monsoon period. The temperature lapse rates indicate diurnal variation and show a maximum in the early morning and minimum in the daytime, in particular, around noon.

The valley wind in the high altitudes is well developed during the daytime, however, the mountain wind is not well developed. In the lower Midland, though the mountain wind is observed during the early morning, it is not well developed. This mountain and valley wind system is closely connected with the diurnal variation of precipitation.
INTRODUCTION

Our trekking survey in 1985 was mainly done in the central part of Bhutan (Fig. 1) for a period of around three months, from September to November. The number of meteorological stations is around 50 in Bhutan and the observed climatic elements are mainly temperature and precipitation. There are few stations in the northern High Himalaya, and winds are observed at a few stations. Therefore, during our survey period, the author observed temperature, wind and weather. Using observed data, the author intends to clarify the climatic condition in Bhutan on a smaller scale than synoptic, which has never been analyzed before.

At first, this period is expected to be the transition period from the summer monsoon period to the post-monsoon period. In the Nepal Himalayas, Yasunari (1976) analyzed the seasonal weather variation on the basis of the observational data from Lhajung station in the Khumbu Himal and pointed out that the seasonal change from the summer monsoon period to the post-monsoon period occurs in October. During our survey period, the weather conditions changed in October. Therefore, the author analyzes the weather mainly in October in order to clarify the seasonal change from the monsoon period to the post-monsoon period in Bhutan.

Secondarily, the author analyzes temperature data in order to clarify the temperature conditions on a meso-scale mainly in the central part of Bhutan. In particular, the diurnal variation of temperature lapse rate and the relationship between the temperature lapse rates, the seasonal changes and the topographic conditions are discussed.

Finally, the author intends to clarify the wind conditions in Bhutan. The air circulations in Bhutan have not been reported using the data. In this paper, the features of local circulations and their seasonal changes are mainly shown.

SYNOPTIC ANALYSIS OF SEASONAL CHANGE FROM MONSOON TO POST MONSOON

Fig. 2 shows the maximum and minimum temperatures at Thimphu (Taba) and the weather conditions along the survey route. The bottom
Figure 1. Route map of scientific expedition in 1985.

Figure 2. Temperatures at Taba (Thimphu) and weather conditions during the survey period (from September 16 to November 16, 1985).
lines indicate the weather conditions, which show that the precipitation phenomena occur at least once a day along our survey route. Therefore, the weather was observed at different stations almost every day.

The weather condition changes around October 2 and October 19. Before October 2, from September 16 to October 1, the weather shows clear diurnal variation. As our survey route is along the bottoms of valleys, during this period, precipitation is mainly brought about during evening through night-time every day. However, after October 2, the weather does not show clear diurnal variation and fine weather dominates all day long for a few days. The minimum temperature at Taba drops on October 2 and a drop of temperature at 00z also occurs at Gauhati in India and at Pa'li in China around October 2 (Fig. 3 and Fig. 4). At Gauhati and Pa'li, the pressure reaches its maximum on October 2. Around Bhutan, temperature drop and maximum pressure occur on October 2. The fine weather on October 2 is considered to have arisen from the anticyclone extending from the west. On the 500mb weather charts, the anticyclone, centered at (30N, 60E), extends from west, and the isohypse of 5880m reaches 80E on October 1 and 90E on October 2. On the surface weather charts, though the surface anticyclone is not clearly recognized, pressure is relatively high at all stations around Bhutan (Fig. 5). On the other hand, after this fine weather, cloudy or rainy weather prevails continually from October 6 to 18. During these days, at least three tropical disturbances invade the Indian Subcontinent from the Bay of Bengal and the Arabian Sea (Fig. 6), and at least one western disturbance in the mid-latitudes passes through the Himalayas. The rainy days mainly occur around October 8 and October 17 in Bhutan and precipitation distribution is affected by these disturbances (Fig. 7). In order to clarify the relationship between rainy days in Bhutan and the disturbances above-mentioned, the author analyzes the 500mb and surface weather charts.

On October 8, a western disturbance passes around the Tibetan Plateau and the Himalayas (Fig. 8) and the tropical disturbance invades from the Arabian Sea. In Bhutan, precipitation occurs mainly on October 9 or October 10. The tropical disturbance is recognized on both surface and 500mb weather charts. This disturbance invades the Indian Subcontinent on October 8 and moves northeastward (Fig. 6 and Fig. 8). Both disturbances are expected to affect the rainy or cloudy weather around Bhutan during this period. However, as the period that the western dis-
Figure 3. Variation of climatic data at Gauhati in India from September through November in 1985.
From September through November in 1985.

Figure 4. Variation of climate data at PAII in China.
Figure 5. Surface and 500mb weather charts during October 1-3, 1985 (12GMT).
Right: Surface (ex. 2 indicates 1002mb).
Left: 500mb (ex. 582 indicates 5820 gpm.).
Figure 6. Route of tropical disturbance and cyclones.
Figure 7. Weekly precipitation around India in 1985.
Figure 8. Surface and 500mb weather charts during October 7-9, 1985 (12GMT). Signs are the same as Figure 5.
turbance passes around the Himalayas occurs at almost the same time as the period that the tropical disturbance invades the Indian Subcontinent, it is difficult to discern which disturbances largely affect the rainy or cloudy days around October 9 in Bhutan. The amount of precipitation during this period is not as great as around Bhutan and less than the precipitation in the northeastern part of India and Nepal. During this period we pass Juree-La (pass), with an altitude of around 4700m, and at that time it is rain, and not snowfall that we encounter. Therefore, these disturbances are not expected to bring about the first snowfall accumulation on the ground in the Bhutan High Himalaya.

On October 12, the tropical cyclone invades the Indian Subcontinent and runs through westward of Bhutan (Fig. 9). Although the cyclone may bring much precipitation or snowfall in the western part of the Himalaya, it is considered that the cyclone does not largely affect the weather in Bhutan, because its route is about 10 degrees west of Bhutan and the pressure around Bhutan does not show the clear minimum value as the cyclone follows.

Around October 17, the cyclone passes around Bhutan (Fig. 10). This cyclone originates in the Bay of Bengal and reaches West Bengal on October 17. This cyclone is evidently recognized on the 500mb charts from October 14 and recorded 5670 gpm at 12z on October 15. On the basis of the observations made between Bumthang and Mongar in Bhutan (Fig. 1), the rainy or cloudy weather continues from the afternoon of October 15 to the morning of October 18. In this region, the cyclone produces rainfall without the diurnal variation. On the other hand, in the regions with altitudes of at least more than 5000m in the northern Bhutan High Himalaya, this is the first snowfall accumulation on the ground. Just after the passage of this cyclone, fine weather dominates and this is a drop in temperature at many stations in and around Bhutan and pressure rises at Pa'li and Gauhati (Fig. 2, Fig. 3, Fig. 4). In particular, the pressure at Gauhati, located in Assam south of the Himalayas, rises remarkably. The upper air data at Calcutta shows the continuous westerly at all strata from October 19 and its speed is greater than before (Fig. 11). The value of dew point depression indicates more than 15C at 12Z on October 19 at 850mb and 700mb.

On the basis of the observation made in Nepal in 1973 and 1974, Yasunari (1976) points out that the monsoon weather pattern ended
Figure 9. Surface and 500mb weather charts during October 10-12, 1985 (12GMT). Signs are the same as Figure 5.
Figure 10. Surface and 500mb weather charts during October 16-18, 1985 (12GMT). Signs are the same as Figure 5.
Figure 11. Variation of upper winds at Calcutta (October 1-25, 1985). Isoline indicates dew-point depression ($^\circ$C).
abruptly with the first arrival of a westerly disturbance, associated with
the Sub Tropical Jet Stream, which brought about the first snowfall ac-
cumulation on the ground and just after these days of snowfall the
weather changes entirely to the post-monsoon type. In 1985, the first
snowfall accumulation on the ground in Bhutan occurs just after the pas-
sage of the tropical cyclone.

On the basis of the above climatic conditions in and around
Bhutan, the seasonal changes from the summer monsoon period to the
post-monsoon period around Bhutan are considered to occur around Oc-
tober 19, 1985 and this change occurs just after the passage of the
tropical cyclone from the Bay of Bengal. Further study is necessary as to
whether the seasonal change from the summer monsoon to the post-
monsoon period in 1985 applies to other years and whether the period of
this change is same in the Himalayas or different between the western
part and the eastern part.

### DIURNAL VARIATION OF TEMPERATURE
#### IN THE CENTRAL PART OF BHUTAN

In this section, the author mainly discusses the diurnal variation of
temperature as observed in data taken during our survey period. Tempera-
tures are observed every three hours along our survey route between
150m and 5300m, though temperatures are observed at different stations.
The minimum temperature is -5°C observed at 00Z on October 3 at
Tsoreim(5200m). The maximum temperature is 27°C observed at 06Z on
October 27 at Manas(140m). The temperature largely varies in accordance
with the topographic and weather conditions, and the seasonal variation is
expected to be large (Fig. 2). As the data of temperature are observed
at different stations and temperature data for three or six hour periods
are not available in Bhutan, temperature data are reconstructed from the
data for Gauhati in India, i.e. the differences between the observed data
and those at Gauhati.

Figs. 12 a-d show the scatter diagrams for temperature differences
by altitude taken every six hours (00Z, 06Z, 12Z, 18Z). 00Z, 06Z, 12Z,
and 18Z indicate 06, 12, 18, and 24 Standard Time in Bhutan(BST),
respectively. The temperature lapse rate on the basis of the data of
Figure 12. Scatter diagram of temperature difference between Gauhati and observation points of Bhutan. (A) 00GMT (B) 06GMT (C) 12GMT (D) 18GMT
temperature differences is larger at 00Z (0.586°C/100m) and smaller at 06Z (0.463°C/100m). The temperature lapse rate is expected to be larger during the period between mid-night and early morning and smaller around noon, and in fact does show the clear diurnal variation. The mean temperature lapse rate of four times indicates 0.523°C/100m. This value is nearly equal to the monthly mean temperature lapse rate in October by Eguchi (1987).

However, the difference between the observed and estimated temperature data is larger than those of mean monthly data (Fig. 13). The mean difference between the observed and estimated temperatures is 1.69°C at 00z (51 days) and 1.87°C at 06z (40 days), and this mean difference is larger at 06Z than at 00Z. The data at both times are largely affected by weather conditions. At 00Z, the estimated temperatures are generally lower than the observed temperatures, in particular, in the higher altitudes or during the summer monsoon season. On the other hand, during a few days after the retreat of the summer monsoon (October 19-22), the estimated temperatures are higher than the observed temperatures. After the passage of the cyclone, as already mentioned in section 2, a drop in temperature occurs on October 19 in the Bhutan High Himalaya. However, in Assam it occurs on October 24 on the basis of the data at Gauhati. Therefore, the differences are large during this period. At 12Z, though the obvious seasonal features are not recognized, the temperature is largely affected by the weather conditions rather than the data at 00Z. The estimated temperatures are larger than the observed temperatures for the cloudy or rainy days and the reverse differences occur in the fine days. The percentage of estimated temperatures which differ from the observed temperatures by less than 2°C is around 70% at 00z and 06Z.

The diurnal temperature difference between the data at 00Z and 06Z is observed for 19 days at the same stations. The largest temperature difference is recorded on November 16 at Thimphu and its value is 14.2°C. In the higher altitudes above 3000m, the difference is lower than expected. In the fine days, for example on October 3, the difference reaches 12.5°C, however, on the other days the differences are around 5°C. In particular, on September 28, its value is only 1.4°C at 4920m. The estimated diurnal differences on the basis of the estimated temperatures are shown in Fig. 14. As the estimated temperatures include the above-
Figure 13. Difference between observed and estimated temperatures.  
(A) 00GMT  (B) 06GMT  
(upper) Altitude of observation point.  
(lower) Temperature difference (estimated minus observed).
Figure 14. Diurnal Difference of temperature.

(upper) Estimated diurnal difference of temperature by altitude.
(middle) Diurnal difference of observed and estimated temperatures.
(Lower) Altitude of observation points.
mentioned problems, the relationship between the estimated and observed temperatures is not necessarily a good one.

The data for diurnal variation of temperatures shown in Figs. 15-20 were mainly recorded in the higher altitudes. The temperature varies with the weather conditions. In Figs. 15-20, the maximum temperature occurs between 9 and 12 BST., because the weather worsens in the afternoon. The temperatures in Figs. 15-19 are observed before the retreat of the monsoon, i.e. during the summer monsoon season. On the other hand, in Fig. 20, at Kurthang the daily maximum temperature is recorded around 15 BST. Since these data for Kurthang are recorded after the retreat of the summer monsoon, the weather is fine all day long. The temperature drops considerably just after sunset and does not vary significantly during the night-time. The temperature reaches its daily minimum at around 06 BST. in the early morning, and just after sunrise the temperature increased greatly, in particular, on fine days.

LOCAL CIRCULATION IN THE BHUTAN HIMALAYAS

The wind data for the same stations are shown in Figs. 15-20. At stations in the northern Bhutan High Himalaya(Figs. 16-19), the valley wind is dominant. The valley wind is mainly dominant from 09 BST. to 18 BST., while, during the night-time through the early morning, calm condition are dominant. The mountain wind is not necessarily observed. On the other hand, in the lower Midland of the Bhutan High Himalaya, the mountain and valley wind system is recognized. In particular, at Kurthang, the mountain and valley wind system is obviously observed, though the wind speeds are not so great.

Inoue(1976) described the mountain and valley wind system in Nepal and found that, during the summer monsoon season, the valley wind is dominant and the mountain wind is not well developed. In Bhutan, the same features are recognized at least during the summer monsoon season in the higher altitudes( the northern Bhutan High Himalaya). However, in the lower Midland, the mountain and valley wind system is recognized during the summer monsoon season, though the amount of available data is limited. Further studies are necessary regarding the problems of regional difference in local wind systems.
Figure 15. Climatic elements observed at Dochu-La (3120m).
Figure 16. Climatic elements observed at Nikkachu (2580m).
Signs are the same as Fig. 14.
Figure 17. Climatic elements observed at Morathang (3580m). Signs are the same as Fig. 14.
Figure 18. Climatic elements observed at Tsongtsothang (4340m). Signs are the same as Fig. 14.
Figure 19. Climatic elements observed at Jichidagmo (4920m). Signs are the same as Fig. 14.
Figure 20. Climatic elements observed at Kurthang (1300m).
Signs are the same as Fig. 14.
CONCLUDING REMARKS

The following results are obtained on the basis of data observed in 1985;

1). Around Bhutan, the seasonal change from the summer monsoon period to the post-monsoon period in 1985 occurs on October 19 just after the passage of the tropical cyclone.
2). The temperature lapse rate indicates obvious diurnal variation and the diurnal difference of temperature indicates seasonal and regional differences.
3). Local circulations in Bhutan are also expected to indicate seasonal and regional differences.

The results, above-mentioned, are closely connected with one another. In particular, during the monsoon period, the clarification of relationships between climatic elements is an important and interesting problem.

The survey period in 1985 is from September to November and is also from the latter part of the summer monsoon period to the post-monsoon period. Although this period includes the latter part of the monsoon period, it does not include the main period of the summer monsoon season. Therefore, the remaining important and interesting problems concerning the monsoon in Bhutan are as follows;

1). When does the onset of the summer monsoon season occur in Bhutan?
2). What is the relationship between Bhutan, India and Burma regarding the onset of the summer monsoon?
3). Do the local circulations change in accordance with the onset of the summer monsoon?
4). Do the climatic conditions change in Bhutan in accordance with the intra-seasonal variation during the summer monsoon season?

These problems are important not only for Bhutan but for South Asia in general. In particular, further study is considered necessary to clarify seasonal and regional differences in the relationship between the upper winds and local circulations and the other climatic elements. These studies are necessary in order to clarify the regional differences in
vegetation and soil.

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I used a HITAC M680-H computer in the Computer Center, University of Tokyo.

REFERENCES

Eguchi, T (1987). Synoptic analysis of temperature, precipitation and moisture conditions in the Bhutan Himalayas. (In this issue.)
PART IV

MISCELLANEOUS
LIST OF PLANTS COLLECTED IN BHUTAN, BY K. TSUCHIDA, 1985

About 1,000 plant specimens were collected along the survey routes by the author. These plants were checked to identify by the author and others in Japan. Only plants identified were described in this list. The identification of plants of Bhutan is difficult because there are few specimens in Japan and the floristic study does not still advanced. These are provisional identification. Some specimens were identified by specialists as follows: Saxifragaceae and Crassulaceae by Dr. H. Ohba, University Museum, University of Tokyo, Scrophulariaceae and Acanthaceae by Dr. T. Yamazaki, Koishikawa Botanical Garden, and Kobresia spp. by Dr. R.K. Rajibhandari, Department of Medicinal Plants, His Majesty's Government of Nepal. The author wishes to thank them and Mr. N. Shirai who helped the identification of plants.

In the list, the scientific name of plants is followed by locality from where the plants were collected, altitude of the locality and date of collection. The species, genera and families under Gymnospermae, Monocotyledons and Dicotyledons are arranged in alphabetic manner.
[GYMNOSPERMAE]

EPHEDRACEAE
Ephedra gerardiana Wall. var. sikkimensis Stapf
   Jichudagmo, 4,920m (Sep.29); near Dangjoy, 4,600m (Oct.2);
   near Duersachu, 3,500m (Oct.6)

PINACEAE
Abies densa W. Griff.ex Parker
   near Tsongtsothang, 3,750m (Sep.24)
Picea spinulosa Henry
   Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19);
   Nikkachu, 2,580m (Sep.19); near Duersachu, 3,500m (Oct.6)
Tsuga dumosa (D.Don) Eichler
   Thimphu - Dochu-la, 2,500m (Sep.16)

CUPRESSACEAE
Juniperus wallichiana Hook.f. & Thomas.
   Umatatso, 4,300m (Sep.22)
Juniperus recurva Buch.-Ham.,e D.Don
   Morathang, 3,580m (Sep.21); near Tsongtsothang, 3,750m
   (Sep.24); Saga-la, 4,920m, (Oct.5); Kurbang, 3,520m
   (Oct.11); Gorsuem, 3,120m (Oct.11)
Juniperus squamata Buch.-Ham. ex D.Don
   Umatatso, 4,300m (Sep.22)

[ANGIOSPERMAE]

(MONOCOTYLEDONES)

AMARYLLIDACEAE
Allium wallichii Kunth
   Dochu-la, 3,120m (Sep.17)

HYPOXIDACEAE
Hypoxis aurea Lour.
   Wangdiphodrang, 1,180m - Nikkachu, 2,530m (Sep.19)

-282-
LILIACEAE
Polygonatum curvistylum Hua
   near Duersachu, 3,500m (Oct.6)
Streptopus simplex D.Don
   Kurbang, 3,520m (Oct.11)

COMMELINACEAE
Commelina benghalensis L.
   Lingmethang, 720m (Oct.17)
Commelina paludosa Blume
   Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18);
   Bumthang - Kurichu, 2,100m (Oct.16)
Cyanotis vaga (Lour.)J.A. & J.H. Schultes
   Dochu-la 3,050m (Sep.17)
Murdannia spirata (L.) Bruckner
   Kurtang, 1,300m (Nov.15)

CYPERACEAE
Carex nubigena D.Don
   Thimphu - Dochu-la, 2,500m (Sep.16); near Tsongtsothang,
   3,750m (Sep.24); Bumthang, 2,580m (Oct.14); Bumthang -
   Kurichu, 2,350m (Oct.16); Thimphu, 2,370m (Oct.26)
Kobresia duthiei C.B. Clarke
   Umatatso, 4,300m (Sep.23); Yango - Rinchenze-la, 4,700m (Sep.27)

GRAMINEAE
Agrostis inaequiglumis Griseb.
   Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22);
   near Tsongtsothang, 3,750m (Sep.24); Juree, 4,280m (Oct.10)
Agrostis myriantha Hook.f.
   Dochu-la, 3,120m (Sep.17); Lobisa, 1,380m - Nikkachu, 2,580m
   (Sep.18); Kurbang, 3,520m (Oct.11)
Agrostis nervosa Nees ex Trin.
   Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Nikkachu,
   2,580m - Morathang, 3,580m (Sep.20); Morathang, 3,580m
Agrostis pilosula Trin.
Thimphu - Dochu-la, 2,900m (Sep.16); Morathang, 3,580m (Sep.21); Umatastso, 4,300m (Sep.22); near Tsongtsothang, 3,750m (Oct.6); Duersachu, 3,500m (Oct.15); Kurbang, 3,520m (Oct.11)

Andropogon munroi C.B.Clarke
Thimphu - Dochu-la, 2,900m (Sep.16); near Bumthang, 3,000m (Oct.11); Paro, 2,200m - Taxan, 3,000m (Nov.7); Tongsa, 2,200m (Nov.13)

Anthoxanthum sikkimense (Maxim.) Ohwi
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); near Duersachu, 3,500m (Oct.6); Duersachu, 3,500m (Oct.6); Gorsuem, 3,120m (Oct.11)

Apluda mutica L.
Kurichu, 560m (Oct.16)

Arthraxon lancifolius (Trin.) Hochst.
Thimphu, 2,370m (Oct.26)

Arthraxon micans (Nees) Hochst.
Bumthang - Kurichu, 720m (Oct.16)

Arthraxon sikkimensis Bor
Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Pele-la, 3,380m (Nov.14)

Arundinella hookeri Munro ex Keng
Thimphu - Dochu-la, 2,900m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Gorsuem, 3,120m (Oct.11); Paro, 2,200m - Taxan, 3,000m (Nov.7)

Arundinella nepalensios Trin.
Lingmethang, 720m (Oct.17)

Arundo donax L.
Chimilakang, 1,200m (Nov.15)

Bothriochloa intermedia (R.Br.) A.Camus
Bumthang - Kurichu, 720m (Oct.16); Monger, 1,680m (Oct.17); Thimphu, 2,370m (Oct.26); Chimilakang, 1,200m (Nov.15)

Bromus staintonii Melderis
Morathang, 3,580m (Sep.21); Gorsuem, 3,120m (Oct.11);
Duersachu, 3,500m (Oct.15)

Chloris virgata Swartz
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18)

Chrysopogon aciculatus (Retz.) Trin.
Lingmethang, 720m (Oct.17); Bumthang - Kurichu, 720m (Oct.16)

Cymbopogon flexuosus (Nees ex Steudel) W.Watson
Thimphu - Dochu-la, 2,400m (Sep.16)

Cynodon dactylon (l.) Pers.
Bumthang, 2,470m (Oct.21)

Deyeuxia pulchella (Griseb.) Hook.f.
Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22); near Tsongtsothang, 3,750m (Sep.24); Yango, 4,840m (Sep.27); Jichudagmo, 4,920m (Sep.29); Juree, 4,280m (Oct.10); Gorsuem, 3,120m (Oct.11); near Bumthang, 3,000m (Oct.11); Duersachu, 3,500m (Oct.15)

Deyeuxia scabrescens (Griseb.) Munro ex Duthie near Duersachu, 3,500m (Oct.6); Kurbang, 3,520m (Oct.11)

Digitaria cruciata (Nees ex Steudel) A.Camus
Dochu-la, 3,050m (Sep.17); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Bumthang - Kurichu, 1,970m (Oct.16); Bumthang - Kurichu, 2,350m (Oct.16)

Digitaria setigera Roth apud Roemer & Schultes
Bumthang, 2,580m (Oct.14); Wamay, 1,030m (Nov.12)

Digitaria stricta Roth ex Roemer&Schultes
Bumthang - Kurichu, 720m (Oct.16); Thimphu, 2,370m (Oct.26)

Digitaria violascens Link
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Sengor, 3,000m (Oct.15); Shemgang, 1,820m (Nov.11)

Echinochloa colona (L.) Link
Lingmethang, 720m (Oct.17); Kurtang, 1,300m (Nov.15)

Eleusine indica (L.)Gaerth.
Kurichu, 560m (Oct.16); Bumtang - Kurichu, 930m (Oct.16); Monger, 1,680m (Oct.17); Lingmethang, 720m (Oct.17); Monger, 1,680m - Sengor, 2,900m (Oct.20); Bumthang, 2,470m (Oct.21); Phuntsoling, 350m (Nov.1); Wamay, 1,030m (Nov.12); Kurtang, 1,300m (Nov.15); Chimilakang, 1,200m
Elymus sikkimensis (Melderis) Melderis
Thimphu - Dochu-la, 2,500m (Sep.16); Gorsuem, 3,120m (Oct.11); Sengor, 3,000m (Oct.15)

Elytraphorus spicatus (Willd.) A.Camus
Kurtang, 1,300m (Nov.15);

Eragrostis nigra Nees ex Steudel
Thimphu - Dochu-la, 2,400m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Gorsuem, 3,120m (Oct.11); near Bumthang, 3,000m (Oct.11); Bumthang, 2,580m (Oct.14);

Eragrostis unioloides (Retz) Nees ex Steudel
Phuntsoling, 350m (Nov.1)

Erianthus rufipilus (Steudel) Griseb.
Thimphu - Dochu-la, 2,400m (Sep.16); Dochu-la, 2,600m (Nov.16)

Festuca ovina L.
near Dangjoy, 4,600m (Oct.2)

Festuca undata Stapf
Gorsuem, 3,120m (Oct.11)

Gryceria tonglensis C.B. Clarke
Morathang, 3,580m (Sep.21); near Tsongtsothang, 3,750m (Sep.24); Juree, 4,280m (Oct.10); Kurbang, 3,520m (Oct.11)

Helictotrichon parviflorum (Hook.f.) Bor
Thimphu - Dochu-la, 2,900m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Morathang, 3,580m (Sep.21); near Duersachu, 3,500m (Oct.6); Gorsuem, 3,120m (Oct.11); near Bumthang, 3,000m (Oct.11); Thimphu, 2,370m (Nov.4);

Heteropogon contortus (L.) Beauvois ex Roemer & Schultes
Lingmethang, 720m (Oct.17); Chimilakang, 1,200m (Nov.15);

Ischaemum rugosum Salisb
Kurtang, 1,300m (Nov.15)
Miscanthus nepalensis (Trin.) Hackel
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Bumthang - Kurichu, 1,970m (Oct.16); Bumthang - Kurichu, 2,100m (Oct.16); Dochu-la, 2,900m (Nov.16)

Miscanthus nudipes (Griseb) Hackel
Gorsuem, 3,120m (Oct.11); near Bumthang, 3,000m (Oct.11); Thimphu, 2,370m (Oct.26); Thimphu, 2,370m (Nov.4)

Oplismenus burmannii (Retz.) Beauvois
Kurichu, 560m (Oct.16); Bumthang - Kurichu, 720m (Oct.16);

Oprismenus compositus (L.) Beauvois
Wamay, 1,030m (Nov.12)

Panicum trypheron Schultes
Bumthang - Kurichu, 720m (Oct.16)

Paspalidium flavidum (Retz.) A.Camus
Bumthang - Kurichu, 930m (Oct.16); Lingmethang, 720m (Oct.17)

Paspalum scrobiculatum L.
Bumthang - Kurichu, 720m (Oct.16); Lingmethang, 720m (Oct.17); Monger, 1,680m - Senger, 2,900m (Oct.20);
Phuntsoling, 350m (Nov.1)

Polypogon fugax Nees ex Steudel
Phuntsoling - Thimphu, 2,150m (Nov.1)

Saccharum spontaneum L.
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Kurthang, 1,300m (Nov.15)

Sacciolepis indica (L.) Chase
Bumthang - Kurichu, 720m (Oct.16); Monger, 1,680m - Senger, 2,900m (Oct.20)

Setaria glauca (L.) Beauvois
Thimphu - Dochu-la, 2,400m (Sep.16)

Sporobolus diander (Retz.) Beauvois
Monger, 1,680m (Oct.17); Bumthang - Kurichu, 720m (Oct.16);
Phuntsoling, 350m (Nov.1); Chimilakang, 1,200m (Nov.15)

Sporobolus fertilis (Steudel) W.D.Clayton
Thimphu - Dochu-la, 2,400m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Monger, 1,680m (Oct.17);
Phuntsoling - Thimphu, 2,150m (Nov.1); Shemgang, 1,820m
Tripogon trifidus Munro ex Stapf
- Bumthang, 2,580m (Oct.14); Paro, 2,200m - Taxan, 3,000m (Nov.7); Thimphu, 2,370m (Nov.8)

Trisetum spicatum (L.) K. Richter
- Morathang, 3,580m (Sep.21); Yango, 4,840m (Sep.27); near Dangjoy, 4,600m (Oct.2); Juree, 4,200m (Oct.10)

(RANUNCULACESE)

Clematis napalensis DC.
- Umatatso, 4,300m (Sep.22)

Delphinium caeruleum Jacquem. ex Cambess.
- Umatatso, 4,300m (Sep.22); Saga-la, 4,920m (Oct.5)

Delphinium nepalense Kitam. & Tamura
- Morathang, 3,580m (Sep.21)

Delphinium stapeliosum Bruhl ex Huth
- Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19);
  Lobisa, 1,380m - Nikkachu, 2,580m (Sep.19)

Ranunculus brotherusii Freyn
- Jichudagmo, 4,920m (Sep.29); near Dangjoy, 4,600m (Oct.2)

Ranunculus laetus Wall. ex D.Don
- Shemgang, 1,820m (Nov.11)

Thalictrum chelidonii DC.
- Dochula, 3,120m (Sep.17)

Thalictrum rostellatum Hook.f. & Thoms
- Dochula, 3,050m (Sep.17)

(BERBERIDACEAE)

Berberis umbellata Wall.
- Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22);
  Donshingang, 3,480m (Oct.6); near Duersachu, 3,500m (Oct.6); Juree, 4,280m (Oct.10);
  Kurbang, 3,520m (Oct.11);
  Sheltang, 3,450m (Oct.15)
PAPAVERACEAE
Corydalis longipes DC.
   Dochula, 3,050m (Sep.17); Morathang, 3,580m (Sep.21)

CRUCIFERAE
Barbarea intermedia Boreau
   Morathang, 3,580m (Sep.21)
Capsella bursa-pastoris (L.) Medikus
   Bumthang, 2,580m (Oct.14)
Thlaspi arvense L.
   Bumthang, 2,580m (Oct.14)

VIOLACEAE
Viola biflora L.
   Dochula, 3,120m (Sep.17)

POLYGALACEAE
Polygala linariifolia Willd
   Kurtang, 1,300m (Nov.15)

CARYOPHYLLACEAE
Arenaria glanduligera Edgew. ex Edgew.& Hook.f.
   Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22);
   Thimphu, 2,730m (Oct.26)
Arenaria orbiculata Royle ex Edgew.& Hook.f.
   Saga-la, 4,920m (Oct.5)
Cerastium glomeratum Thuill.
   Morathang, 3,580m (Sep.21)
Sagina japonica (Swartz) Ohwi
   Thimphu, 2,370m (Oct.26); Chimilaking, 1,200m (Nov.15)
Silene gonosperma (Rupr.) Bocquet
   near Dangjoy, 4,600m (Oct.2)
Stellaria media (L.) Vill.
   below Juree-la, 3,900m (Oct.10); Phuntsoling - Thimphu,
   1,200m (Nov.1); Shemgang, 1,820m (Nov.11); Wamay, 1,030m
   (Nov.12)
Stellaria sikkimensis Hook.f. ex Edgew.& Hook.f.
Stellaria vestita Kurz

Dochu-la, 3,120m (Sep.17); Morathang, 3,580m (Sep.21);
Bumthang, 2,580m (Oct.14); Thimphu, 2,370m (Oct.26);
Thimphu, 2,370m (Nov.4)

TAMARICACEAE
Myricaria rosea W.W.Sm.
Morathang, 3,580m (Sep.21)

HYPERICACEAE
Hypericum elodeoides Choisy
Dochu-la, 3,050m (Sep.17); Dochu-la, 3,120m (Sep.17); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Nikkachu, 2,580m (Sep.19); Tongsa, 2,200m (Nov.13)

MALVACEAE
Urena lobata L.
Lingmethang, 720m (Oct.17)

TILIACEAE
Triumfetta rhomboides Jacq.
Lingmethang, 720m (Oct.17)

GERANIACEAE
Geranium donianum Sweet
Morathang, 3,580m (Sep.21); near Duersachu, 3,500m (Oct.6)
Geranium lambertii Sweet
Morathang, 3,580m (Sep.21)
Geranium nepalense Sweet
Dochu-la, 3,120m (Sep.17); Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18); Nikkachu, 2,580m (Sep.19); Bumthang, 2,580m (Oct.14); Shemgang, 1,820m (Nov.11)
Geranium procurrens P.F.Yeo
Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16); Dochu-la, 3,050m (Sep.17); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19)
OXALIDACEAE
Oxalis corniculata L.
Chimilakang, 1,200m (Nov.15)

RUTACEAE
Boenninghausenia albiflora (Hook.) Reichenb. ex Meissn.
Thimphu, 2,370m (Nov.8)

ACERACEAE
Acer pectinatum Wall. ex Pax
Saga-la, 4,920m (Oct.5); Donshigang, 3,480m (Oct.6)

LEGUMINOSAE
Acacia pennata (L.) Willd.
Bumthang - Kurichu, 2,400m (Sep.16); Lingmethang, 720m (Oct.17)
Astragalus donianus DC.
Morathang, 3,580m (Sep.21)
Astragalus emodi Steud.
Duersachu, 3,500m (Oct.15)
Cassia mimosoides L.
Thimphu - Dochu-la, 2,400m (Sep.16); Thimphu, 2,370m (Oct.25); Thimphu, 2,370m (Nov.4)
Cassia occidentalis L.
Kurichu, 560m (Oct.16)
Cassia tara L.
Kurthang, 1,300m (Nov.15)
Crotalaria cytisoides Roxb. ex DC.
Shemgang, 1,820m (Nov.11)
Desmodium heterocarpon (L.) DC.
Phuntsoling, 350m (Nov.1)
Desmodium microphyllum (Thunb.) DC.
Tongsa, 2,200m (Nov.13)
Desmodium multiflorum DC.
Thimphu - Dochu-la, 2,400m (Sep.16); Mongar, 1,680m (Oct.17); Tongsa, 2,200m (Nov.13)
Lespedeza gerardiana Grah.
Thimphu - Dochu-la, 2,400m (Sep.16)

Lespedeza cuneata (Dum.-Cours.) G.Don
Tongsa, 2,200m (Nov.13); Kurthang, 1,300m (Nov.15);
Chimilakang, 1,200m (Nov.15)

Parochetus communis Buch.-Ham. ex D.Don
Dochu-la, 3,120m (Sep.17); Morathang, 3,580m (Sep.21)

Piptanthus nepalensis (Hook.) D.Don
Sengor, 2,900m (Oct.20)

Smithia ciliata Royle
Thimphu, 2,370m (Oct.26)

Vicia angustifolia L.
Thimphu, 2,370m (Oct.26)

Vigna umbellata (Thunb.) Owhi & Ohashi
Thimphu, 2,370m (Oct.25)

Zornia gibbosa Spanoghe
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Chimilakang,
1,200m (Nov.15)

ROSACEAE

Agrimonia pilosa Ledeb. var. nepalensis (D.Don) Nakai
Thimphu - Dochu-la, 2,900m (Sep.16); Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18)

Duchesnea indica (Andr.) Focke
Dochu-la, 3,050m (Sep.17)

Potentilla ambiguа Cambess.
Morathang, 3,580m (Sep.21)

Potentilla fructicosa L.
Jichudagmo, 4,920m (Sep.29)

Potentilla fulgens Wall. ex Hook.
Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16); Dochu-la, 3,120m (Sep.17)

Potentilla griffithii Hook. f.
Thimphu - Dochu-la, 2,900m (Sep.16); Dochu-la, 3,050m (Sep.17); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Bumthang, 2,580m (Oct.14)

Potentilla microphylla D. Don
Umatatso, 4,300m (Sep.22)
Potentilla saundersiana Royle
near Dangjoy, 4,600m (Oct.2)

Prunus rufa Hook. f.
near Tsongtsotang, 3,750m (Sep.24)

Rosa sericea Lindl.
Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18);
Nikkachu, 2,580m (Sep.19); Donshigang, 3,480m (Oct.6)

Rubus ellipticus Smith
Dochu-la, 2,120m (Sep.17); Monger, 1,680m (Oct.17);
Shemgang, 1,820m (Nov.11)

Rubus pedunculosus auct non D.Don
Donshingang, 3,480m (Oct.6)

Sanguisorba diandra (Hook.f.) Nordborg
Duersachu, 3,500m (Oct.15)

Sorbus microphylla Wenzig
Umatatso, 4,300m (Sep.22)

Spiraea arctica Hook.f
Umatatso, 4,300m (Sep.22)

Spiraea micrantha Hook.f
Duersachu, 3,500m (Oct.15)

SAXIFRAGACEAE
Chrysosplenium forrestii Diels
Umatatso, 4,300m (Sep.22)

Saxifraga montanella H.Smith
Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22)

Saxifraga moorecroftiana (Seringe) Wall. ex Sternb.
Morathang, 3,580m (Sep.21)

Saxifraga sphaeradenia H.Smith
Morathang, 3,580m (Sep.21)

HYDRANGEACEAE
Hydrangea aspera Buch. - Ham. ex D.Don
Donshigang, 3,480m (Oct.6)

CRASSULACEAE
Rhodiola crenulata (Hook.f. & Thom.s.) H.Ohba
Yango, 4,840m (Sep.27)
Rhodiola wallichiana (Hook.) Fu
Saga-la, 4,920m (Oct.5)

DROSERACEAE
Drosera peltata Smith
near Duersachu, 3,500m (Oct.15)

CALLITRICHACEAE
Callitriche stagnalis Scopoli
Sengor, 3,000m (Oct.15)

MELASTOMATACEAE
Osbeckia sikkimensis Craib
Thimphu, 2,370m (Nov.4); Shemgang, 1,820m (Nov.11)

ONAGRACEAE
Epilobium wallichianum Hausskn.
Dochu-la, 3,120m (Sep.17); Morathang, 3,580m (Sep.21);
Donshigang, 3,480m (Oct.6)

UMBELLIFERA
Bupleurum candollii Wall. ex DC.
near Duersachu, 3,500m (Oct.6)
Cortia depressa (D.Don) C.Norman
Umatatso, 4,300m (Sep.22)
Cortiella hookeri (C.B.Clarke) C.Norman
Saga-la, 4,920m (Oct.5)
Selinum candollii DC.
near Duersachu, 3,500m (Oct.6)

CAPRIFOLIACEAE
Leycesteria gracilis (Kurz) Airy Shaw
Bumthang - Kurichu, 2,000m (Oct.16)
Lonicera myrtillus Hook.f. & Thoms.
near Dangjoy, 4,600m (Oct.2)
SAMBUCACEAE
Sambucus adnata Wall.
Dochu-la, 3,120m (Sep.17)
Viburnum coriaceum Blume
Tongsa, 2,200m (Nov.13)

RUBIACEAE
Borreria alata (Aubl.) DC.
Phuntsoling, 350m (Nov.1)
Coffea benghalensis Heyne ex Roem. & Schult.
Phuntsoling, 350m - Thimphu, 2,370m (Nov.2)
Galium asperifolium Wall.
Dochu-la, 3,050m (Sep.17); Lobisa, 1,380m - Wangdi-
phodrang, 1,180m (Sep.18); Donshigang, 3,480m (Oct.6);
near Gorsuem, 3,200m (Oct.11); Gorsuem, 3,120m (Oct.11);
Tongsa, 2,200m (Nov.13)
Leptodermis kumaonensis Parker
Thimphu, 2,370m (Oct.26)
Rubia wallichiana Decne.
Monger, 1,680m (Oct.17)

DIPSACACEAE
Dipsacus inermis wall. var. mitis (D. Don) Y. Nasir
Dochu-la, 3,120m (Sep.17)

COMPOSITAE
Adenostemma lavenia (L.) Kuntze
Bumthang - Kurichu, 2,000m (Oct.16)
Ageratum conyzoides L.
Lingmethang, 720m (Oct.17); Kurichu, 560m (Oct.16)
Ainsliaea aptera DC.
Dochu-la, 3,050m (Sep.17)
Anaphalis busua (Buch.-Ham. ex D. Don) DC.
Thimphu - Dochu-la, 2,400m (Sep.16); Thimphu, 2,370m -
Dochu-la, 3,120m (Sep.16); Dochu-la, 3,050m (Sep.17)
Anaphalis margaritacea (L.) Benth.
Thimphu - Dochu-la, 2,900m (Sep.16); Lobisa, 1,380m - Wang-
diphodrang, 1,180m (Sep.18); Duersachu, 3,500m (Oct.15); Shemgang, 1,820m (Nov.11)

Anapharis triplinervis (Sims) C.B.Clarke
Lobisa, 1,380m - Wang di Phodrang, 1,180m (Sep.18); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Nikkachu, 2,580m (Sep.19); Morathang, 3,580m (Sep.21); Umatatso, 4,300m (Sep.22); Saga-la, 4,920m (Oct.5)

Artemisia dubia Wall. ex Besser
Thimphu - Dochu-la, 2,400m (Sep.16); Dochu-la, 3,050m, (Sep.17)

Artemisia indica Willd.
Thimphu - Dochu-la, 2,400m (Sep.16); Dochula, 3,120m, (Sep.17); Lobisa, 1,380m - Wangdiphodrang, 1,180m, (Sep.18); Duersachu, 3,500m (Oct.15); Gorsuem, 3,120m (Oct.11); Bumthang - Kurichu, 720m (Oct.16); Chimilakang, 1,200m (Nov.15)

Bidens pilosa L.
Lingmethang, 720m (Oct.17); Bumthang - Kurichu, 2,000m (Oct.16); Shemgang, 1,820m (Nov.11)

Bidens tripartita L.
Thimphu, 2,370m (Oct.26)

Cacalia pentaloba Hand. Mazz
Kurbang, 3,520m (Oct.11)

Carpesium nepalense Less.
Dochu-la, 3,120m (Sep.17)

Cicerbita macrorhiza (Royle) Beauv.
Morathang, 3,580m (Sep.21)

Cirsium falconeri (Hook.f.) Petrak
Morathang, 3,580m (Sep.21)

Cirsium tribeticum Kitam.
Nikkachu, 2,580m (Sep.19)

Crisium verutum (D.Don) Spreng.
Dochu-la, 3,120m (Sep.17); Bumthang - Kurichu, 2,350m, (Oct.16)

Conyza stricta Willd.
Thimphu - Dochu-la, 2,400m (Sep.16); Thimphu, 2,370m (Oct.26); Thimphu, 2,370m (Nov.4)
Dubyaea hispida DC.
   Dochu-la, 3,120m (Sep.17); Gorsuem, 3,120m (Oct.11)

Elephantopus scaber L.
   Phuntsoling, 350m (Nov.1)

Emilia sonchifolia (L.) DC.
   Chimilakang, 1,200m (Nov.15)

Erigeron bellidioides (Buch. - Ham. ex D.Don) Benth. ex C.B. Clarke
   Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Morathang, 3,580m (Sep.21)

Eupatorium adenophorum Spreng.
   Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Phuntsoling, 350m - Thimphu, 2,370m (Nov.1)

Eupatorium odoratum L.
   Lingmethang, 720m (Oct.17)

Galinsoga parviflora Cav.
   Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18); Bumthang, 2,580m (Oct.14); Lingmethang, 720m (Oct.17); Thimphu, 2,370m (Oct.26)

Gnaphalium affine D.Don
   Thimphu, 2,370m (Oct.26); Shemgang, 1,820m (Nov.11)

Gnaphalium hypoleucum DC.
   Thimphu, - Dochu-la, (Sep.16); Umatatso, 4,300m (Sep.22)

Inula cappa (Buch.-Ham. ex D.Don) DC.
   Sheltang, 3,450m (Oct.15); Lingmethang, 720m (Oct.17)

Inula hookeri C.B. Clarke.
   Nikkachu, 2,580m - Morathang, 3,580m (Sep.20)

Leibnitzia nepalensis (Kunze) Kitam.
   near Duersachu, 3,500m (Oct.6)

Myriactis nepalensis Less.
   Thimphu - Dochu-la, 2,900m (Sep.16); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Dochu-la, 3,120m (Sep.17)

Saussurea auriculata (DC.) Sch.
   Dochu-la, 3,050m (Sep.17)

Saussurea gossypiphora D.Don
Morathang, 3,580m (Sep.21)
Saussurea obvallata (DC.) Edgew.
Duersachu, 3,500m (Oct.15)
Saussurea pachyneura Franch.
Umatatso, 4,300m (Sep.22)
Saussurea tridactyla Sch. Bip. ex Hook. f.
Morathang, 3,580m (Sep.21)
Senecio chrysanthemoides DC.
Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16); Dochu-la, 3,050m
Siegesbeckia orientalis L.
Thimphu - Dochu-la, 2,400m (Sep.16); Bumthang, 2,580m (Oct.14)
Spilanthes iabadicensis A.H.Moore
Shemgang, 1,820m (Nov.11); Wamay, 1,030m (Nov.12)
Synedrella nodiflora Gaertn.
Phuntsoling, 350m (Nov.1)
Tanacetum gossypinum Hook.f.&Thoms. ex C.B.Clarke
Yango, 4,840m (Sep.27)
Tridax procumbens L.
Lingmethang, 720m (Oct.17); Phuntsoling, 350m (Nov.1)

CAMPANURACEAE
Campanula pallida Wall.
Thimphu, - Dochu-la, 2,900m (Sep.16); Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Morathang, 3,580m (Sep.21); Tongsa, 2,200m (Nov.13)
Cyananthus inflaus Hook.f.&Thoms.
Dochu-la, 3,050m (Sep.17); Dochu-la, 3,120m, (Sep.17)
Cyananthus lobatula Wall. ex Benth.
near Kurbang, 3,850m (Oct.11)
Lobelia erectiuscula Hara
Dochu-la, 3,120m (Sep.17)
Lobelia pyramidalis Wall.
Bumthang – Kurichu, 1,800m(oct.16)

ERICACEAE
Cassiope fastigiata (Wall.) D.Don
    Umatatso, 4,300m (Sep.22); Yango, 4,840m (Sep.27)

Gaultheria nummularioides D.Don
    Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19)

Gaultheria trichophylla Royle
    Morathang, 3,580m (Sep.21)

Rhododendron anthopogon D.Don
    Yango, 4,840m (Sep.27)

Rhododendron campanulatum D.Don var. wallichii Hook. f.
    Umatatso, 4,300m (Sep.22); Juree, 4,280m (Oct.10)

Rhododendron lepidotum Wall. ex G.Don
    near Duersachu, 3,500m (Oct.6); Gorsuem, 3,120m (Oct.11);
    Duersachu, 3,500m (Oct.15)

Rhododendron nivale Hook.f.
    Yango, 4,840m (Sep.27); Jichudagmo, 4,920m (Sep.29)

Rhododendron setosum D.Don
    Umatatso, 4,300m (Sep.22)

Rhododendron thomsonii Hook.f.
    Nikkachu, 2,580m - Morathang, 3,580m (Sep.20)

PRIMULACEAE

Primula capitata Hook.f.
    Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16)

Primula primulina (Spreng.) Hara
    Umatatso, 4,300m (Sep.22)

MYRSINACEAE

Maesa rugosa C.B.Clarke
    Bumthang - Kurichu, 2,100m (Oct.16)

GENTIACEAE

Gentiana algida Pall.
    Umatatso, 4,300m (Sep.22); near Dangjoy, 4,600m (Oct.2)

Gentiana lacerulata H. Sm.
    Umatatso, 4,300m (Sep.22)

Halenia ellipitica D.Don
    Thimphu - Dochu-la, 2,900m (Sep.16)
Lomatogonium micranthum H.Sm.
   Tongsa, 2,200m (Nov.13)
Swertia kingii Hook.f.
   Morathang, 3,580m (Sep.21)
Swertia nervosa (G.Don) C.B. Clarke
   Thimphu - Dochula, 2,400m (Sep.16)

**SCROPHULARIACEAE**
Euphrasia schlagintweitii Wettst.
   Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19);
   Morathang, 3,580m (Sep.21); Tongsa, 2,200m (Nov.13)
Hemiphragma heterophyllum Wall.
   Thimphu - Dochula, 2,900m (Sep.16); Dochula, 3,050m
   (Sep.17); Dochula, 3,120m (Sep.17); Wangdiphodrang,
   1180m - Nikkachu, 2,580m (Sep.19); Gorsuem, 3,120m (Oct.11)
Mazus deravayi Bonati
   Thimphu - Dochula, 2,500m (Sep.16)
Pedicularis longiflora Rudolph
   Morathang, 3,580m (Sep.21)
Pedicularis megalantha D.Don
   Dochula, 3,120m (Sep.17)
Pedicularis pennelliana Tsoong
   Nikkachu, 2,580m - Morathang, 3,580m (Sep.20)
Pedicularis siphonantha D.Don
   Umatatso, 4,300m (Sep.22)
Veronica umbelliformis Pennell
   Umatatso, 4,300m (Sep.22)

**ACANTHACEAE**
Barleria cristata L.
   Lingmethang, 720m (Oct.17)
Dicliptera bupleuroides Nees
   Phuntsoling, 350m (Nov.1)
Rungia parviflora (Retz.) Nees
   Phuntsoling, 350m (Nov.1)

**VERBENACEAE**
Verbena officinalis L.
Monger, 1,680m (Oct.17); Thimphu, 2,370m (Oct.25)

LABIATAE
Clinopodium umbrosum (M.Bieb.) C.Koch
Lobisa, 1,380m - Wangdiphodrang, 1,180m (Sep.18); Dochu-la, 3,120m (Sep.17); Morathang, 3,580m (Sep.21)
Elsholtzia strobilifera (Benth.) Benth.
Morathang, 3,580m (Sep.21)
Eriophyton wallichii Benth.
Yango, 4,840m (Sep.27)
Lamium amplexicaule L.
Wamay, 1,030m (Nov.12)
Leucas cephalotes (Roth) Spreng.
Lingmethang, 720m (Oct.17)
Nepeta lamiopsis Benth. ex Hook.f.
Morathang, 3,580m (Sep.21)
Origanum vulgare L.
Lobisa, 1,380m - Nikkachu, 2,580m (Sep.18); Wangdiphodrang, 1,180m - Nikkachu, 2,580m (Sep.19); Tongsa, 2,200m (Nov.13)
Prunella vulgaris L.
Thimphu, 2,370m - Dochu-la, 3,120m (Sep.16); Dochu-la, 3,050m (Sep.17); Morathang, 3,580m (Sep.21); Donshigang, 3,480m (Oct.6)
Rabdosia coesta (Buch.-Ham. ex D.Don) Hara
Bumthang - Kurichu, 1,900m (Oct.16)
Salvia campanulata Wall. ex Benth.
Dochu-la, 3,120 (Sep.17)

PLANTAGINACEAE
Plantago erosa Wall.
Dochu-la, 3,050m (Sep.17); Morathang, 3,580m (Sep.21)

AMARANTHACEAE
Achyranthes bidentata Blume
Shemgang, 1,820m (Nov.11)
Alternanthera sessilis (L.) DC.  
Lingmethang, 720m (Oct.17)  

Amaranthus caudatus L.  
Thimphu - Dochu-la, 2,500m (Sep.16); Thimphu, 2,370m (Oct.26)  

Amaranthus viridis L.  
Monger, 1,680m (Oct.17); Lingmethang, 720m (Oct.17); Thimphu, 2,370m (Oct.26); Wamay, 1,030m (Nov.12)  

Cyathula prostrata (L.) Blume  
Phuntsoling, 350m (Nov.1)  

CHENOPODIACEAE  
Chenopodium album L.  
Bumthang, 2,580m (Oct.14); Lingmethang, 720m (Oct.17)  

POLYGONACEAE  
Aconogonum molle (D.Don) Hara  
Dochu-la, 3,120m (Sep.17); Morathang, 3,580m (Sep.21); near Gorsuem, 3,200m (Oct.11); Gorsuem, 3,120m (Oct.11); Shemgang, 1,820m (Nov.11)  

Bistorta macrophylla (D.Don) Sojak  
near Rinchenze-la, 4,800m (Sep.27)  

Bistorta vaccifolia (Wall. ex Meisn.) Greene  
Umatatso, 4,300m (Sep.22)  

Bistorta vivipara (L.) Spach  
Umatatso, 4,300m (Sep.22)  

Persicaria hydropiper (L.) Spach  
Bumthang, 2,580m (Oct.14)  

Persicaria nepalensis (Meisn.) H.Gross  
Thimphu - Dochu-la, 2,500m (Sep.16); Nikkachu, 2,580m (Sep.19); Morathang, 3,580m (Sep.21)  

Persicaria pubescens (Blume) Hara var. acuminata (Franch. & Sav.)  
Hara  
Bumthang - Kurichu, 1,800m (Oct.16)  

Persicaria runcinata (Buch.-Ham. ex D.Don) H.Gross  
Dochu-la, 3,120m (Sep.17); near Tsongsothang, 3,750m (Sep.24); Bumthang, 2,580m (Oct.14); Monger, 1,680m
Persicaria tenella (Blume) Hara
Kurthang, 1,300m (Nov.15)
Rumex nepalensis Spreng.
Dochu-la 3,120m (Sep.17)

ELAEAGNACEAE
Elaeagnus parvifolia Wall. ex Royle
Nikkachu, 2,580m (Sep.19); Thimphu, 2,370m (Nov.4);
Thimphu, 2,370m (Nov.8)

EUPHORBIACEAE
Euphorbia hirta L.
Kurichu, 560m (Oct.16)
Phyllanthus virgatus G.Forst.
Lingmethang, 720m (Oct.17)

URTICACEAE
Debregeasia longifolia (Burm.f.) Wedd.
Bumthang - Kurichu, 1,800m (Oct.16)

BETULACEAE
Betula utilis D.Don
near Gorsuem, 3,200m (Oct.11)
ITINERARY

Date: September-November 1985
Region: Bhutan (mainly in the central part)
Route: Narita-*-Calcutta-*-Paro=Thimphu=Wangdu Phodrang=Nikkachu-
       Gophu La-Bumthang=Mongar=Manas-Shemgang=
       Tongsa=Nikkachu=Pele La=Wangdu Phodrang= Punakha=
       Dochu La=Thimphu=Phuntsoling-*-Calcutta-*-Narita
Members: Masahiko Ohsawa Chiba University
         Makoto Numata Shukutoku University
         Katsuyoshi Tsuchida Shinshu University
         Masanori Okazaki Tokyo University of Agricultur
         and Technology
         Takashi Eguchi University of Tokyo
Contents: Route, weather and some remarks
  1). Route
         Station name(altitude;time of departure,
         passing and arrival).
         ( -*- by air, = by car, - on foot)
  2). Weather(W)
         F-F-C-R-S indicates the weather conditions
         around 6, 9, 12, 15, 18 Bhutan Standard Time
         respectively.
         ( F-fine, C-cloudy, R-rain, S-snow )
Figure 1. Survey route map of Bhutan.
Figure 2. Survey route in the central part of Bhutan.
Figure 3. Vertical route section of the survey in 1985.
September 1985

4: Eguchi leaving the Narita Air Port (Japan) for Calcutta.
11: Ohsawa, Numata, Tsuchida and Okazaki leaving the Narita Air Port for Calcutta.

[Ohsawa, Numata, Tsuchida, Okazaki, Eguchi]

13: Calcutta-*-Paro (2360m)=Thimphu (2370m)
14: Thimphu
15: Thimphu
   (W) Heavy rain in the late afternoon through nighttime.
16: Thimphu (2370m)=Dochu La (3120m)
   (W) R-F-F-C-F. Heavy rain (nighttime).
   Land slide between Dochu La and Lobisa.
17: Dochu La=Lobisa (1380m)
   (W) F-C-C-R-F. Heavy rain (14:00-15:00).
18: Lobisa=Wangdi Phodrang (1360m)=Pele La (3380m)=Nikkachu (2580m)
   (W) C-F-R-C-C. Rain around Pele La.
19: Nikkachu
   (W) C-F-R-C-C.

[Numata]

20: Nikkachu=Thimphu
21: Thimphu (survey around Thimphu)
22: Thimphu
23: Thimphu=Paro
24: Paro-*-Calcutta-*-Narita
25: arrived at the Narita Air Port.

[Ohsawa, Tsuchida, Okazaki, Eguchi]

20: Nikkachu (8:50)-Morathang (3580m; 19:00)
   (W) F-C-R-R-R. Rain (13:00-19:00, nighttime)
21: Morathang
   (W) F-F-F-R-R. Rain (13:00- )
   Heavy Rain (17:15- )

- 309 -
22: Morathang(8:15)-Umatatso(4300m;16:00)
    (W) C-C-C-C-C. Rain(7:00-8:00,13:00-17:30)
23: Umatatso(10:30)-Tampey La(4620m;12:30)-Tampeytso(4300m;14:30)
    (W) F-C-C-C-R. Rain(16:00-19:00)
24: Tampeytso(8:30)-Tsongtsotang(4340m;16:40)
    (W) C-C-C-R-R. Rain(12:15-19:00).
25: Tsongtsotang
    (W) C-C-C-R-R. Rain(14:00-).
26: Tsongtsotang(11:20)-Yang(4840m;17:00)
    (W) C-R-C-R-R. Rain(8:50-10:50,14:00-). Graupel during nighttime.
27: Yang(8:50)-Rinchenze La(5240m;15:00)-Jichudagmo(4920m;17:00)
    (W) F-F-F-F-S. Snow(17:20-).
28: Jichudagmo
    (W) C-C-S-F-F. Snow(12:00-13:00).
29: Jichudagmo
    (W) F-F-C-S-C. Snow(13:30-17:00).
30: Jichudagmo(8:15)-Tsochena(4880m;13:50)
    (W) F-F-C-C-S. Snow(17:30-).

October 1985
1: Tsochena(8:30)-Jyaze La(5100m;10:45)-
    Dangjoy(4650m;13:00)
    (W) F-F-C-S-S. Snow(14:00-).
2: Dangjoy(9:35)-Tsoreim(5200m;15:00)
    (W) F-F-F-F-F. No rain and snow.
3: Tsoreim(8:45)-Gophu La(5300m;10:30)-Gechewoma(4600m;17:15)
    (W) F-F-F-F-F. No rain and snow.
4: Gechewoma(8:30)-Yak Camp(4660m;15:30)
    (W) F-F-F-F-C. Rain(18:30-).
5: Yak Camp(8:45)-Saga La(4920m;10:20)-Donshigang(3480m;17:15)
    (W) F-F-F-C-C. Graupel around 14:00.
    Rain around 17:00.
6: Donshigang(10:00)-Duersachu(3400m;12:00)
    (W) F-F-F-C-C. Rain during nighttime.
7: Duersachu
    (W) C-C-C-C-C. Rain in the early morning.
8: Duersachu
    (W) C-C-C-R-R.
9: Duersachu(9:30)-Juree(4280m;16:15)  
(W) C-R-R-R-R.

10: Juree(9:30)-Juree La(4700m;11:45)-Kurbang(3520m;17:30)  
(W) R-C-C-R-C. Heavy rain(12:50-15:00).

11: Kurbang(12:20)-Gorsuem(3120m;15:00)  
(W) F-C-C-F-F. No rain.

12: Gorsuem(8:00)-Bumthang(2580m;17:40)  
(W) C-C-C-F-F. Rain around 12:00.

13: Bumthang  
(W) F-F-F-F-F. No rain.

14: Bumthang  
(W) F-F-F-F-F. No rain.

15: Bumthang=ThurumsengLa(3780m)=Sengor(3000m)  
(W) F-F-F-C-C. Heavy rain during nighttime.

16: Sengor=Mongar(1680m)  
(W) R-R-R-R-R.

17: Mongar  
(W) R-R-R-R-R.

18: Mongar=Lingmethang(720m)  
(W) R-R-C-F-F. Rain( -11:00).

19: Lingmethang  
(W) F-F-F-F-F. No rain.

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[Tsuchida]

20: Lingmethang=Bumthang

21: Bumthang=Thimphu

22: Thimphu(survey around Thimphu until November 9)  
(November 10): Thimphu=Tongsa  
(November 11): Tongsa=Shemgang

--------------------------------------------------------------------------------

[Ohsawa,Okazaki,Eguchi]

20: Lingmethang(7:50)-Eruthang La(1950m;16:00)-Rindergang(1300m;17:30)  
(W) F-F-F-F-F. No rain.

21: Rindergang  
(W) F-C-F-F-C. No rain.
22: Rindergang(7:00)-Shele La(2500m;11:30)-Doh La(2400m;15:15)-Silambri(1820m;17:00)
(W) C-F-F-F-F. No rain.
23: Silambri(8:20)-Nagor(1550m;17:00)
(W) F-F-F-F-F. No rain.
24: Dali(1500m;14:30)-Umshalbi(670m;18:00)
(W) F-F-F-F-F. No rain.
25: Umshalbi(8:15)-Dogar(1110m;11:30)
(W) F-F-F-C-C. Rain(15:30-17:00).
26: Dogar(7:40)-Derthang La(1300m;9:40)-Nganla(1280m;14:00)
(W) C-F-C-C-F. Rain(16:00-17:30).
27: Nganla(8:10)-Pangbang(200m;18:00)
(W) C-C-C-F-F. No rain.
28: Pangbang
(W) F-F-F-F-F. No rain.
29: Pangbang(8:30)-Manas(140m;15:30)
(W) F-F-F-F-F. No rain.
30: Manas
(W) F-F-F-F-F. No rain.
31: Manas(8:15)-Pangbang(15:00)
(W) F-F-F-F-F. No rain.

November 1985

1: Pangbang(8:20)-Changang(210m;16:30)
(W) F-F-F-C-C. Rain(14:00-14:30).
2: Changang(8:00)-Pangthang(240m;17:00)
(W) F-F-F-F-F. No rain.
3: Pangthang
(W) F-F-F-F-F. No rain.
4: Pangthang(7:45)-Gomphu(1480m;18:00)
(W) F-F-F-C-C. No rain.
5: Gomphu(8:00)-Dummong Tsachu(320m;12:00)
(W) C-C-F-F-C. Rain(11:00-11:30,Nighttime).
6: Dummong Tsachu(8:00)-Tshaidang(1400m;18:00)
(W) C-R-F-C-C. Rain(7:00-9:00).
7: Tshaidang(8:00)-Buri(1720m;17:00)
(W) F-F-F-C-R. Heavy rain(16:30- ).

-312-
8: Buri
   (W) C-C-C-C-C. Rain(7:30-8:00,19:00-19:40,Nighttime)
9: Buri(7:45)-Taley(1740m;14:00)
   (W) C-C-F-C-C. No rain.
10: Taley(9:00)-Dakphey(1320m;13:00)
    (W) F-C-F-C-F. No rain.
11: Dakphey=Shemgang(1820m)
    (W) F-F-F-F-F. No rain.

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[Ohsawa,Tsuchida,Okazaki,Eguchi]
12: Shemgang=Tongsa(2200m)
    (W) F-F-F-F-F. No rain.
13: Tongsa
    (W) F-F-F-F-F. No rain.
14: Tongsa=Pele La=Kurthang(1300m)
    (W) F-F-F-F-F. No rain.
15: Kurthang
    (W) F-F-F-F-F. No rain.
16: Kurthang=Dochu La=Thimphu
    (W) F-F-F-F-F. No rain.
17: Thimphu
18: Thimphu
19: Thimphu
20: Thimphu
21: Thimphu=Phuntsoling

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26: Ohsawa,Tsuchida and Okazaki leaving Calcutta for Japan.
27: Ohsawa, Tsuchida and Okazaki arrived
    at the Narita Air Port.
29: Eguchi leaving Calcutta for Japan.
30: Eguchi arrived at the Narita Air Port.

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