Looking at Western Nepal's Climate

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Abstract

Working in western Nepal as a climatologist, one encounters conditions and problems very different from those in technologically advanced countries. This article discusses the working environment, the present state of climatology, some recent findings, and the prospects for future development in this area.

1. Introduction

Nepal has a reputation for remoteness. Before 1950, few foreigners, other than Indians and Tibetans, were allowed to enter the country. Nowadays numerous tourists visit Nepal, especially trekkers who may spend several weeks hiking through the country. However, working there is an experience of a different sort.

What conditions and problems does a climatologist encounter when working in Nepal? What is the present state of meteorology and climatology? What developments can be expected in the future? These questions are discussed in the present article. Climate data are not given, as they are published elsewhere (e.g., His Majesty's Government of Nepal: *Climatological Records of Nepal*). However, comments on the data's interpretation are presented.

2. Arrival in Nepal

My journey from western Canada had been an exhausting one of nearly five days, with a blizzard that paralyzed Seattle, misplaced tickets, missed flights, and sleepless nights. But finally I was flying across the Siwalik Hills, which border the plain of northern India. The Himalayan peaks were in full view through the clear winter air, and finally we descended to a landing in a wide, flat valley, to emerge into warm sunshine at Kathmandu Airport. I was just starting a six-month assignment as climatologist for a Land Resources Mapping Project, with the task of reporting on the climate, and preparing climate maps, of roughly the western third of Nepal.

Entering Kathmandu from the airport, one is likely to pass along wide, paved roads with moderately light traffic, including an inter-city trolley bus service. Near the city center is a large, open field or park, with goats and cattle grazing, soldiers drilling, and people playing cricket or football. But beyond this, entering the old part of the city is like traveling back three centuries in time. Instead of vehicle exhaust fumes, there is the smell of incense. Along the narrow streets are small shops, houses of intricately carved timber, and at nearly every corner a temple or other religious structure. Tricycle rickshaws, and the occasional foolish motorcyclist, can hardly pass through the crowds of people and cows, which wander nonchalantly amongst the fruit and vegetable vendors.

These initial impressions epitomize the present situation in Nepal. Modern technology is arriving, but conditions are not yet such that it can play as extensive a role in life as in industrialized countries, and in many respects life is still much as it was several centuries ago, especially in remote areas.

3. Climatology in Nepal

The main features of the climate of Nepal are described in various works, such as climatology texts (e.g., Rao, 1981). The climate is of the monsoon type, with a rainy season from June to September, characterized by airflow from the Bay of Bengal. During the mainly dry winter months, there are occasional brief outbreaks of precipitation accompanying decaying systems that have arrived from the region of the Mediterranean.

Climatology for Nepal as a whole has a short history. In some areas of the country, no data exist for years before 1956. Stations, which were set up in that year or shortly thereafter, were operated by the Indian Meteorological Department. In 1966 the Nepal government took over their operation and is now responsible for all of the stations. In many cases, the Indian and Nepalese equipment continued to function simultaneously for several years. Sometimes the data from the two sets of equipment agreed well, and sometimes not so well. Not all stations have operated continuously since first opening; consequently, the present supply of data is far from ideal for a climatologist's requirements, but following the establishment of more stations in recent years, this problem should eventually be remedied.

Apart from data of the Department of Meteorology and Hydrology, H. M. Government of Nepal, information on Nepal's climate is dispersed in the form of articles from sources as diverse as Japan, the United States, Germany, and France, as well as Nepal itself. Dobremez (1976) has given a fairly comprehensive summary of the general climate for the whole country. However, many of the other articles concentrate on particular aspects, such as precipitation or wind, while on certain topics such as snow, hail, and severe local storms, little detailed information is available at all.

4. Field work

Arrays of numbers taken from a book do not necessarily give a true impression of the climate of a place. Ideally, anyone who is to report on the climate of a region should live, and observe the weather, in that region for at least one year, and preferably much longer. Failing this, he should supplement the basic data with descriptive material, preferably first-hand information from people who live there. In this instance, I took the opportunity to visit several climate stations in the study area and interview the observers. Transport facilities in Nepal would be considered undeveloped by North American standards, and essentially there were only two ways to visit the stations: on foot, which would have taken several months, and by helicopter.

Since the project was already operating a helicopter in that area, this method was used. However, the helicopter is not in every way the best means of travel on such an assignment. One's visits are far too brief and sudden, and one hears stories about unwarranted disruptions caused by the arrival of a helicopter in an environment that was not prepared for it.

The study area comprised roughly the western third of the kingdom (Fig. 1). Topographically, it consists of a strip of lowland along the Indian border (the Terai), and successively higher ranges of hills, aligned approximately WNW-ESE, which culminate in some major Himalayan peaks south of the border with Tibet.

While the project headquarters was in Kathmandu, the base of field operations was the town of Nepalganj, in the Terai, where temperatures are warm in winter, but become oppressively hot by late spring. The helicopter operation schedule had to accommodate the needs of geologists, soil specialists, foresters, etc., as well as the climatologist. It also depended on the serviceability of the machine and the weather. In February–March, the latter was favorable most of the time, though there was one morning when we woke up to the sound of thunder rolling continuously, without a moment's break, for at least half an hour. Within two or three weeks, it proved possible to visit 11 stations.

An unexpected visit by a helicopter is a major event for a remote village. On a typical occasion, it would be necessary to find the weather station (which no one on board had ever seen or visited before), find a landing place for the helicopter nearby, land, disembark, find the weather observer (to whom this visit was a complete surprise), interview him or her, usually through an interpreter and often in the midst of 30 or 40 curious boys from the village, make notes on the interview, visit the station site and make notes on it, return to the heli-

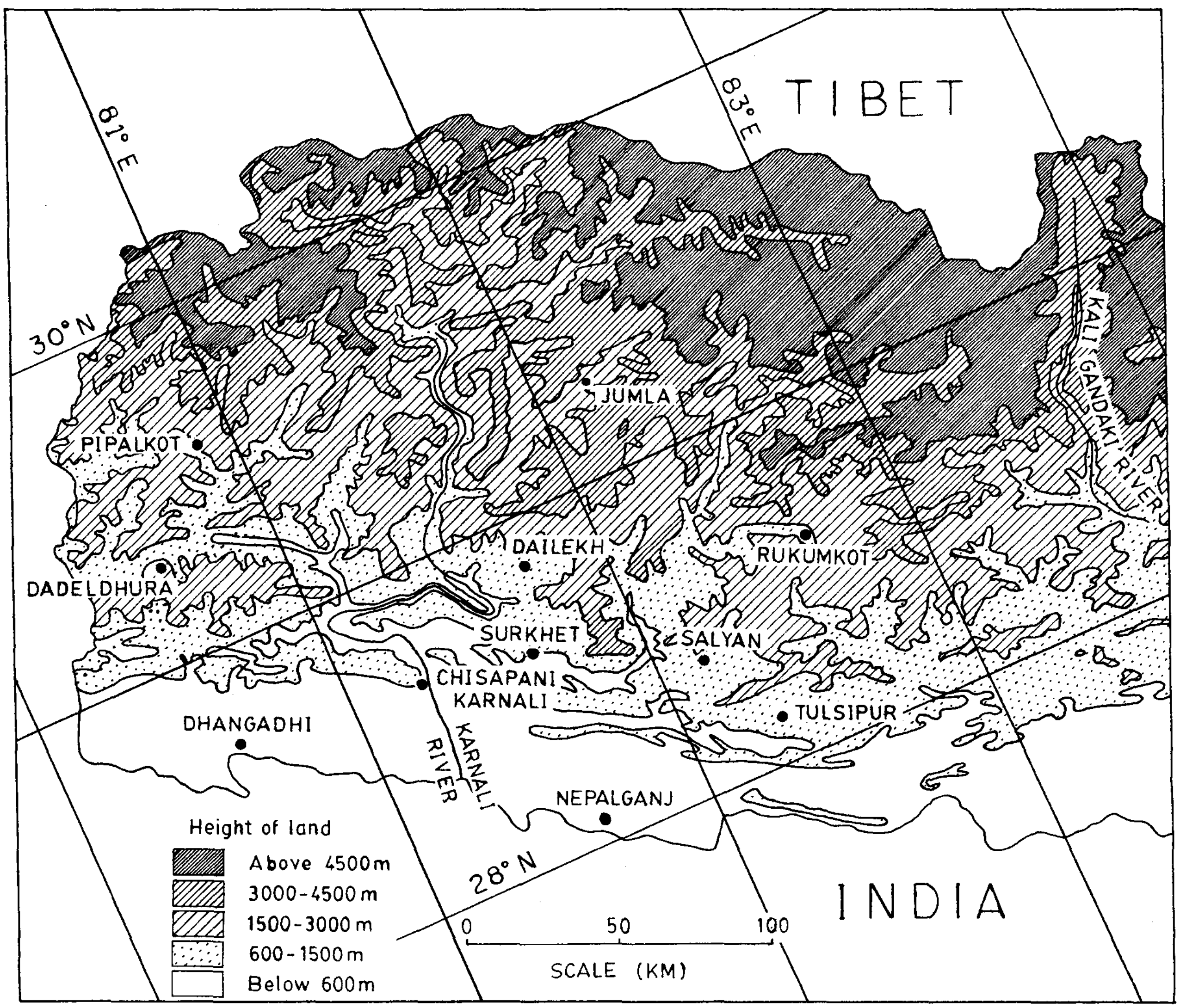

FIG. 1. Map of far western region of Nepal, showing selected climate and precipitation stations.

copter, and sometimes complete all this within half or one hour. Nevertheless, much interesting information was obtained in this way, to form a qualitative supplement to the data summaries.

Landing the helicopter was not always easy, especially at hilltop villages where every flat space seemed to be occupied by buildings, trees, or volleyball nets. At Dailekh, the machine just fitted within the massive stone walls of an ancient fort. The hilltop towns were a pleasant contrast to Nepalganj, clean and quiet but apparently reasonably prosperous, such as Salyan with its solid stone or brick houses painted reddish-brown, with black woodwork and slate roofs, flagstones paving the street (used by pedestrians only), and a piped water supply, but not yet any electricity or road.

Interviews with the observers provided the opportunity to investigate climate features that are not adequately covered by previous reports. Some such topics will be discussed in the following sections.

5. Hail

Hail proved to be generally quite widespread across the area, but also localized both with respect to individual storms and the susceptibility of individual places. It is most prevalent in the region of the lower hills, and there, too, the largest hailstones occur. Most hail falls outside the June–September period of monsoon rains. In the Terai and at the northern station of Jumla (altitude 2300 m), 1 cm diameter is a typical size for hailstones, but in the intervening areas larger sizes are likely to occur, and various places have reported occasional falls with sizes of 5–6 cm diameter, large enough to harm birds, small animals, and crops and to damage roofs.

6. Severe Windstorms

Tulsipur is located in the wide Dang valley, which is separated from the Terai by a range of hills. Ganesh Nirala, the observer there, gave the following information on a severe windstorm that appeared to have many of the features of a tornado. It is based on the memory of witnesses of an event that had taken place 12 years before.

The storm occurred at about 2:30–3:00 p.m. on the 30th day of Poush, 2024 in the Nepalese calendar (equivalent to February 1968) and lasted about one and a half hours. It traveled about half a mile (0.8 km) and moved at high speed towards the east. It was about 120 m in diameter and looked like a pillar of dust and rain. The sky was clear, without noticeable wind, before and after the storm; there was no rain with it, though hail occurred in the subsequent two days.

The cyclone picked up about 20 muris of rice that was heaped up in a field, and uprooted bamboo trees, while the subsequent hail damaged about 400 muris of mustard crop. (A muri is a measure of mass, about 85 kilograms. It also appears to be used as a measure of area.)

A similar event had occurred in the month of Ashad, 2016 (about July 1959). At that time, a lady was carrying some plates on her head. The wind picked up the plates and destroyed them, and the lady died from injuries after 10 days.

7. Wind

Quantitative data on wind in western Nepal are very sparse. A few stations measure the daily run of wind, while within the past decade three stations (Jumla, Surkhet, and Dadeldhura) have started to supply synoptic-type observations. In such complicated topography, the wind field is of course very variable. The best that can be achieved in a brief summary is to say that wind speeds tend to be greatest in the afternoon, when they blow from a westerly direction, and that the strongest winds tend to occur in the spring, before the monsoon.

One most noteworthy feature is the regular strong wind that blows in the major valleys, such as those of the Karnali and Kali Gandaki rivers. Most observers report that it blows strongly up the valleys during the day. Sometimes it changes to a weak down-valley flow in the night and early morning. This behavior suggests that it is basically a mountain-valley wind system governed by diurnal variations in temperature. However, Flohn (1968) mentions that it sometimes blows in an upstream direction at all hours of the day. He suggests that the diurnal mountain-valley circulation is combined with a seasonal circulation, in which the effect of daytime insolation is effectively continued at night by the release of latent heat from large convective storms in Tibet. Evidently the winds are strong and persistent enough to deform trees in the valleys. In one U-shaped valley, Ohata and Higuchi (1978) found wind-deformed trees not only on the valley floor but as much as 300–400 m higher on the slopes. The nature of the deformation indicated winds blowing generally up the valley, though the trees on the slope indicated an up-slope component as well.

Many people have remarked that the centers of these valleys are much drier than their slopes. Troll (1959) has reported a similar phenomenon in the Peruvian Andes. A clear band in an otherwise cloudy sky often occurs above the center of the valley, indicating subsiding air over the valley, which would result in a low relative humidity there and encourage the evaporation of falling rain. What is the cause of this subsidence? Is it a counterflow to currents ascending the sides of the valley, as would be consistent with the computer model of Thyer (1966)? Could the strong wind within the valley cause a Bernoulli effect (a decrease in pressure proportional to the square of the speed of flow) which disturbs the hydrostatic balance? Or are these two possibilities merely different aspects of a more general mechanism?

8. Rainfall

Preparation of a map depicting rainfall in the study area proves to be more troublesome than preparing one for temperature, for example. The fact that there are far more stations reporting precipitation (over sixty) than temperature, or any other element, does not facilitate the drawing of isohyets because large, apparently erratic fluctuations in values

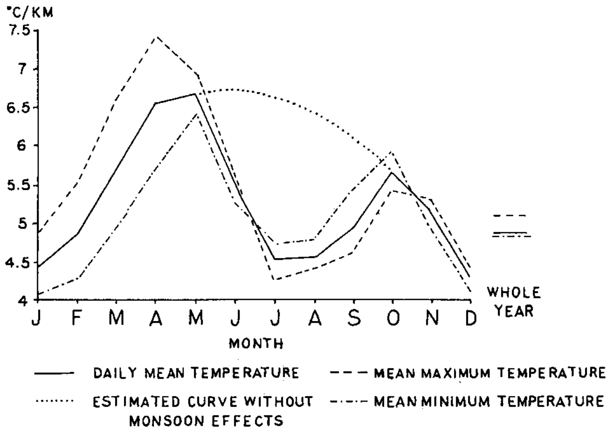

FIG. 2. Vertical gradients of surface temperatures in western Nepal for each month and the whole year.

occur. For instance, Rukumkot consistently reports precipitation about twice as great as any other station in its vicinity, for no obvious geographic reason. Assuming no systematic observation error, this anomaly creates a problem in drawing isohyets and interpolating values between stations. If there were not a station at Rukumkot, this problem would not exist. On the other hand, similar anomalies may exist elsewhere, but if so, they are unknown because of lack of stations.

If one constructs a map of annual rainfall using a high degree of smoothing and ignoring isolated anomalous values, the isohyet pattern shows, on the whole, bands of alternately higher and lower values, parallel to the mountain ranges, as one proceeds from the Terai towards the Chinese border.

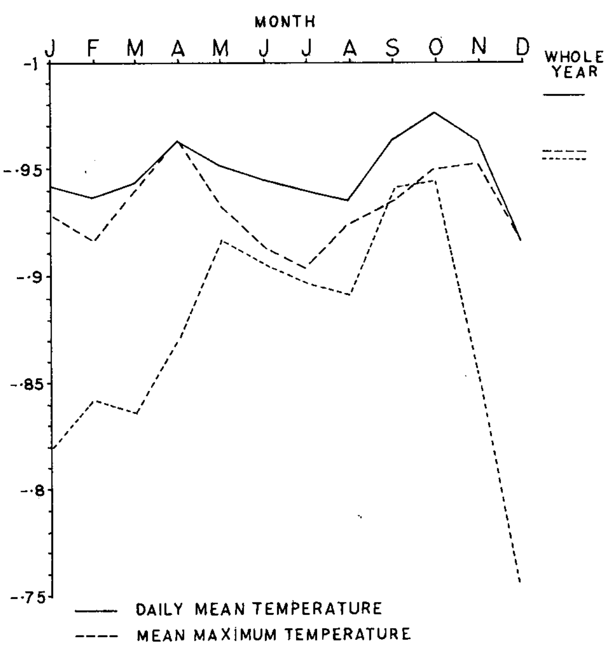

FIG. 3. Coefficients of correlation between daily mean, mean maximum, and mean minimum temperature and altitude.

9. Temperature

Surface temperature usually shows less unpredictable variability with location than precipitation does; however, its value depends not only on geographical location but also on altitude. Therefore, for map preparation, it was necessary to determine a relation between temperature and altitude for the study area. Dobremez (1976) found a good correlation between altitude and mean temperatures for the whole of Nepal. For the present project, however, it was necessary to estimate typical maximum and minimum temperatures for all seasons of the year.

As a first step towards this end, regression formulas and correlation coefficients relating altitude to daily mean temperature, mean maximum temperature, and mean minimum temperature were determined for each month of the year, plus the whole year, for 15 stations. The slopes of the regression lines gave the mean vertical temperature gradients, whose values are plotted graphically in Fig. 2. These gradients showed a minimum in winter, increasing towards spring, when one expects greater convective activity. In the summer months the gradients showed a second minimum, corresponding to the monsoon season, when surface temperatures have decreased, and moist adiabatic processes are at work. Indeed, if one ignores the summer values and instead extrapolates the curve for the dry months, one obtains a curve that is similar to a sine wave with a period of one year (see Fig. 2).

The coefficients of correlation are displayed in Fig. 3. It is evident from this graph that the daily mean temperature is much more highly correlated with altitude than either the maximum or minimum temperature, probably because the latter two are affected in different ways by factors other than altitude. This is particularly the case for minimum temperatures in winter and early spring. In this season, skies are clear, and at night cooling by radiation is intense, leading to stable stratification and facilitating the development of microclimates that are largely independent of free atmospheric conditions, especially in valleys and flat areas.

Thus it appears that in order to estimate the dependence of temperature on altitude, it is best to work with the daily mean temperature. Formulas relating this temperature to altitude for each month of the year are given in Table 1.

As a next step towards estimating mean maximum and minimum temperatures for a given station, the deviations of the actual mean maximum/minimum temperatures from the calculated daily mean temperatures were plotted for eight stations. Examples of the resulting graphs are shown in Fig. 4. Two features stand out clearly. First, the deviations from the calculated daily mean are noticeably smaller during the

TABLE 1. Regression formulas giving daily mean temperature T in degrees Celsius as a function of altitude z in meters.

Whole Year:	$T = 25.5–0.00516z$		
January	$T = 16.4–0.00443z$	July	$T = 29.3–0.00452z$
February	$T = 18.7–0.00482z$	August	$T = 29.1–0.00455z$
March	$T = 24.0–0.00572z$	September	$T = 28.7–0.00494z$
April	$T = 29.5–0.00654z$	October	$T = 26.7–0.00566z$
May	$T = 32.4–0.00668z$	November	$T = 21.8–0.00513z$
June	$T = 31.5–0.00549z$	December	$T = 17.3–0.00430z$

cloudy monsoon season than at other times of the year. Second, the deviations of the minimum temperature during winter and spring are about twice as great at valley and plain stations (Fig. 4b) as at hilltop stations (Fig. 4a), again demonstrating how valley and plain stations tend to have their own microclimates at night, while ridge stations remain exposed to the effects of the free atmosphere.

Chisapani Karnali was an exception. The annual amplitude for the deviation of minimum temperature was only about half as great as for Jumla and Surkhet, possibly because the station is situated in a gorge through the Siwalik Hills, a location where calms may be rare.

To estimate the mean maximum and minimum temperatures, one can make a first estimate of the daily mean from Table 1, and apply adjustments using typical values from Fig. 4. If the daily mean temperature is assumed to be the mean of the maximum and minimum, its value could be different from the value estimated by Table 1 for an individual station.

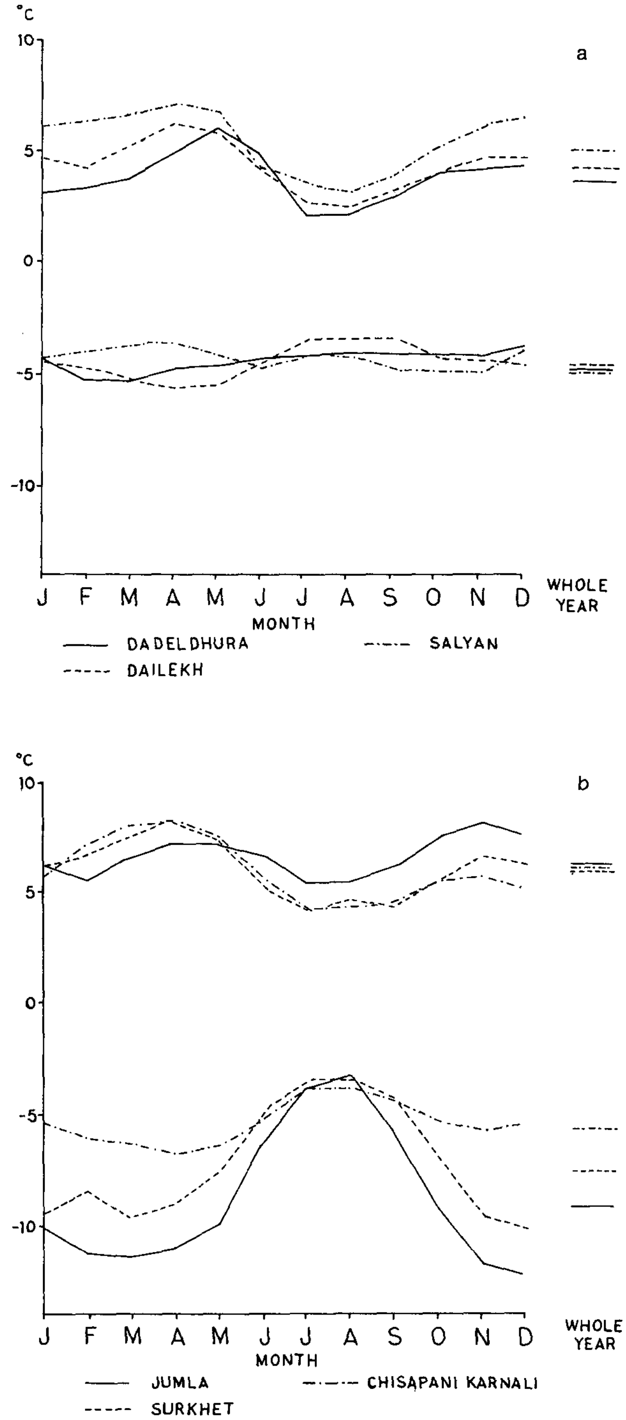

FIG. 4. Deviations of mean maximum temperatures (upper curves) and mean minimum temperatures (lower curves) from mean temperatures calculated from Table 1. (a) Hilltop stations. (b) Valley and plain stations.

10. Climatic change

A question that arises in connection with long-term planning is whether any trends exist which suggest a gradual climatic change. In general, records for western Nepal are far too short to give such an indication with any acceptable degree of reliability. Application of Wilcoxon's Sum of Ranks Test to precipitation data of 15 stations for the periods 1956–1962 and 1972–1977 showed no significant change between these two periods, apart from one (Pipalkot), which showed a decrease significant at the 5% level. The observer at Dadeldhura, Mr. Chopara, mentioned that around 1960 there were often winter snowfalls of depth 45 cm, but in recent years typical depths have been 8–10 cm. This change suggests a decrease in winter precipitation, or a rise in temperature, over the last 20 years.

11. The future

What developments in climatology in western Nepal can be expected in future years? In the area studied, there are now over 60 rain gauges, about a dozen stations that measure temperature and humidity, and three or four locations with evaporation pans, sunshine recorders, and anemometers. Occasionally in Nepal one sees what appears to be a cup anemometer on the roof of a building. Closer inspection shows that its purpose is not to measure wind speed but to turn a prayer wheel—a curious cooperation between science and religion!

Only time can remedy the present short observation history of most stations. As for extension and improvement of the present network, one must take care in applying methods that may currently be used in technologically advanced countries. To give an example, there is at present very little knowledge of rainfall intensity. Various projects have installed recording rain gauges in several locations, but very few of them are working because of lack of knowledge, equipment, or parts for repairs. Even a broken thermometer takes months to replace because of communication problems. Expensive remote-sensing devices cannot be a solution in a situation where the national meteorological service has had to cancel subscriptions to foreign journals because of their high cost.

Even satellite data that have been collected by another country do not provide convenient raw material for someone working in Nepal when they are stored on the other side of the world, and/or require a computer for retrieval and analysis.

Even in these times of advanced technology, there are still instances where a machine is not a viable substitute for a human being. Weather observing in certain remote areas may be one of them, especially when new data should be obtained without delay, but the support system for high technology does not yet exist. Much can still be done with very basic equipment. Rather than operate a complicated automatic rain gauge, an observer could make a note to the effect that, for example, 80% of the day's rainfall occurred within two hours, in order to estimate the maximum rainfall rate. Rather than install an expensive anemometer and vane, an observer could estimate wind direction by a flag and speed by Beaufort force, and make notes of the times of major wind changes. The resulting error would probably not be greater than that resulting from bad instrument exposure, or moving the instrument a few hundred meters in complex terrain. A dense network of cheap, homemade rain gauges would help to locate places with unusually high or low precipitation, even though their absolute accuracy might be low. If immediate results are desired, it should be easier to train an observer to estimate cloud amount and type and wind speed than to train an electronics technician.

Even though such observations might not be of a high enough standard for official climate summaries, they could significantly help to fill in gaps in our knowledge of climate in remote areas. The main problem would be to find enthusiastic, diligent, and dependable observers. Making the weather observations part of the school curriculum might be a good approach to its solution.

12. Conclusion

With the assignment finished, departure from Nepal was like entering a different world. Lack of modern technology has its drawbacks, such as low levels of hygiene, sanitation, and medical services, and inadequate supplies of energy. But with the absence of television, supermarkets, and stock exchanges, and little motor traffic, there is also a tranquillity that is hard to find nowadays.

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