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The Himalayas: A Third Polar Region[1]

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Abstract The 1963 American Scientific Expedition to Everest first suggested that the Himalaya are effectively a third pole. In this article, some salient aspects of Himalaya and polar environments are dealt with and similarities between the Himalaya and the Arctic and the Antarctic are investigated. Nationally and internationally coordinated efforts aimed at monitoring the unique Himalayan environment are essential from several considerations.

INTRODUCTION

Ice on earth takes a variety of forms ranging from snow cover to continental ice sheets to mountain glaciers. The origin of these forms and their variations over short or long periods of time depends to a large extent on the details of their thermal history. Microclimates control their short term behaviour and the long term effects are observed in global (or regional) climate affecting the movement and distribution of moisture.

Massive reorganizations of the ocean-atmosphere system are the key events that link cyclic changes in the earth's orbit to the advance and retreat of ice sheets (Broker & Denton, 1990). For over three decades, evidence has mounted that the glacial cycles are ultimately driven by astronomical factors: slow cyclic changes in the eccentricity of the earth's orbit and the tilt and orientation of its axis of rotation.

As large bodies of ice exist near poles and at higher altitudes, the present article deals with the cold environments over the Himalaya, the Arctic and the Antarctic.

The Himalayan region has been considered to encompass the mountain area from the Pamir region adjoining the Karakoram-Hindukush-Zaskar ranges in the West-northwest, the Tibetan plateau at the centre bordered by the Kunlun Shan in the North and the Heng Tuan Shan in the East and by the great Himalayan range in the South.

The Chinese call it the Qinghai-Xizang Plateau (Fig. 1). In this perennially cold region, the locale of the three peaks. Everest, Lhotse and Nuptse resemble the environment of a pole and the Himalayan region resembles the Arctic and

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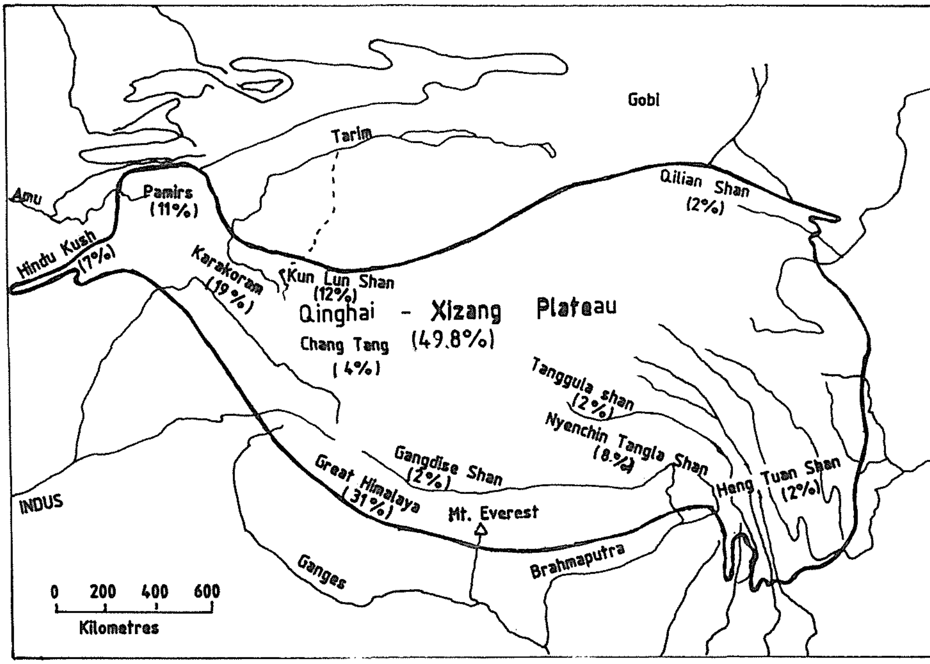

Fig. 1 Distribution of glaciers in the Himalayan Region with major mountain ranges and rivers (total glacier area: 94 554 km^2). Percentage glacier area is shown in brackets for various mountain systems (source: Lin Jigun & Xu Shying, 1984).

the Antarctic. The prolonged periods of day and night over the North and South polar regions are not existing in the Himalayan region. But the outflow of cold from the Himalayas produces a steeper temperature gradient due to their extremely high altitude and proximity to the highly energetic tropical environment. Unlike the other two poles, the Himalayan region has long supported civilizations, and yet it is one of the least explored geographical areas on earth deserving a renewed thrust from international scientific community, helping those who live in the region and its environs.

HIMALAYA

Himalaya, the abode of eternal snow forms a unique environment: the highest mountain environment on earth where snow and icy environmental conditions rival those existing at polar regions (Bahadur, 1972, 1992). Also called the Roof of the World the region extends through eight countries: Russia, The Peoples Republic of China, India, Bhutan, Myanmar, Nepal, Pakistan and Afghanistan. The conditions on gale-whipped Himalayan summits covered by perennial snow and ice above 5000 m altitude resemble the environment in Arctic and Antarctic polar regions. The Leader of the 1963 American Scientific Expedition to Everest Norman Dyhrenfurth called it a third pole (Miller, 1964). The triumvirate of peaks Everest (8903 m), Lhotse (8501 m) and Nuptse (7879 m) and the upper Khumbu glaciers (4600 m to 8200 m) have been called in a meteorological sense, the "Mother Goddess of the Winds" (The Tibetan name of Mt. Everest is Chomolongma – the goddess mother of the world). The extremely high altitude of Himalaya probably provides a unique glacial climate on earth and there is need to study the primary atmospheric processes operating here which affect regional and global weather.

Climate of the Himalaya

The Himalaya are characterized by cold arid to wet tropical conditions seasonal alterations of dry and moist conditions in wide range of altitudes. The climate of the Himalaya may be said to consist of four broad and contrasting regions (Mani, 1981):

- the rain forest of the East, ranging in altitude to 2000 m;
- the wet alpine zone above the tree-line rising to 6000 m or more;
- transitional semi-wet region in the central portion of the mountains;
- an arid region in the Hindu Kush far to the West.

The four parallel ranges which constitute the Himalaya and the Sub, Lower, Higher and Tibetan Himalayan Ranges have their own physiographic features, geological history and climate. The following aspects are noteworthy:

(a) The temperature differences are striking when we compare the temperatures at stations at the same altitude. Summers are warmer and winters are colder in the West, while the annual range of temperature is comparatively small in the East.

(b) The Eastern Himalaya has a prolonged monsoon season from June to October, with very little rain from Western disturbances in winter. On the other hand, the Western Himalaya has a short monsoon from July to August and fairly long wet season from November to April.

(c) Pre-monsoon summer season (March to May) thunder-storms occur frequently in the Eastern Himalaya and precipitation is heavy, increasing from March to May with the advance of the hot season. On the other hand, the pre-monsoon season is quite dry over the Western Himalaya except for very occasional thunderstorms. The arrival of monsoon in the West is quite sudden, with an abrupt change in cloudiness, temperature, humidity, wind and rainfall. In the East, the transition is gradual and restricted mainly to an increase in cloud, fog and rain, with little change in humidity and temperature.

(d) During winter the snow accumulates around the Himalayan high peaks and the snow-line comes down to about 1500 m in the Western Himalaya, whereas it is at 3000 m or above in the Eastern Himalaya.

(e) The wind pattern in the Himalaya is extremely complicated. The general direction of the wind over the Himalaya in winter is from Northeast to Northwest. Over the mountainous terrain the actual wind may show considerable deviations due to local influences. At higher levels, the winds are westerly, averaging ~ 120 km h^{-1} reaching 160 km h^{-1} or more. At low levels, the wind speeds are about 50 to 60 km h^{-1}.

(f) The precipitation pattern is equally complex. In general, there is very heavy and prolonged precipitation in the Eastern region, rapidly decreasing in both intensity and duration as the monsoon advances westward. Summer monsoon currents passing over the Eastern Himalaya reach heights of 6000 m.

(g) The radiation balance over the Himalaya is controlled by the distribution of snow and ice. Long wave radiation losses are relatively high because the atmosphere is relatively dry. Cooling of about 20°C can occur in 12 hours in a layer 500 m thick, and such large diurnal ranges of temperature, of (20-25°C) have been reported by field expeditions. Radiation measured near Everest or direct solar radiation are of the order of 1.6 calories cm^{-2} min^{-1}.

(h) There is also great contrast between the ground and air temperature above it. Diurnal changes of surface temperature are very considerable, and mountain slopes which are turned away from the snow are extremely cold at all times at high altitudes.

(i) Over the Western and Northern parts of the Himalaya, which receive little rain in the monsoon months, the skies are generally clear but the visibility is poor due to dust haze which may extend up to 6 km or more. Even at 6 km atmospheric turbidity is known to be higher than over mountains half the height of Himalayas in Europe & America. The dust over the Himalaya extends to heights of 10 km or more.

Snow cover vis-à-vis monsoonal activity

Some noteworthy aspects of snow cover interacting with weather and climate are as follows:

- High reflectivity, high transmissivity, low vapour pressure and low conductivity makes snow an important element of the climatic system. Snow formation and dissipation closely depend on the amount and angular distribution of incoming radiation.
- Snow cover variations are important for diagnosis and forecasting on monthly, seasonal and inter-annual time scales. The variable extent of snow cover effects advancing polar air masses and introduces variable horizontal temperature gradients which in turn may influence cyclogenesis and may reinforce blocking, thereby modifying weather and climatic patterns both on local and continental scales.

Accurate snow and ice information is needed to provide boundary conditions for atmospheric GCMs, utilize forecast models and to validate forecast and climate models.

The seasonal snow cover is a network of snow crystals randomly arranged. It is inter-communicable through the voids and keeps changing its texture and physical properties almost continuously under various metamorphic processes caused by temperature gradient and differences of saturation vapour pressure. Albedo of snow surface keeps changing with the age of snow and also with the variation in free water content of the snowpack.

The snow cover effects atmospheric processes altering climatic elements such as temperature, humidity and wind due to:

(a) Change in the energy regime due to large albedo and net radiative deficit; the amount of heat retained in air is affected.
(b) Change in wind dispersion potential.
(c) Formation of air mass and pressure system.

Northern hemispheric weekly snow cover charts and global monitoring of the Himalayan snow cover data carried out by NOAA show that the snow cover is minimum in August and maximum in February. The maximum cover is about 40 times the permanent snow/ice cover in August. The study showed that the snow pack covered an area of 0.8×10^6 km^2 in August to 29.9×10^6 km^2 in February, (Upadhyay *et al.*, 1986).

In general, it is known that extensive and prolonged snow cover has significant influence on the earth's climate system, primarily through positive feedback processes caused by high snow albedo (varying from 95% for fresh dry snow to less than 40% for ripe snowpack). These feedback processes operate on monthly, seasonal and long-term scales thereby providing clues for long-range weather prediction. On smaller scales the same feedback may prolong a cold spell or contribute to the continued steering of the winter storms South of the extensive snow cover region yielding quasi-stationary atmospheric circulation patterns (Thapliyal, 1986).

Early modelling studies through the energy balance by Budyko (1969) and Sellers (1969) have emphasized the importance of ice albedo feedback in increasing sensitivity of earth's climate. Model studies by Koerner (1980) and Oerlemans & Varnekar (1981) have suggested that the propagation of snow cover in annual periods is very important to the feedback process such that the disappearance of anomalous warm summers may be an integral part of the glaciation process. GCM model experiments (Williams *et al.*, 1974; Williams, 1975; Gates, 1976; Manabe & Hahn, 1977; Upadhyay & Kaur, 1985) have studied the sensitivity of tropical climate to the extension of ice-sheet boundaries. In spite of the limitations of GCMs e.g. small signal to noise ratio, it is possible to speculate that some of the anomalies of the present climate may be caused by feedback mechanisms of the increased continental albedo of snow/ice cover due to altered boundary conditions. Thus a sense of the physical significance of the role of snow cover in the positive feedback on the climate system is gaining momentum.

The snow cover tends to create a net radiative deficit in the atmosphere which may weaken the intensity or delay the formation of seasonal heat low over Northwest India. Thus excessive accumulation of snow over Central Asia seems to have an inverse relation to the strength of Southwest monsoon particularly over Northern India as suggested by Walker (1941) who established a correlation coefficient of −0.31 between snow accumulation at the end of May on the Western Himalayas and subsequent rainfall over Northwest India. His inference was based on qualitative observations of snow cover recorded from 1876 to 1940. This study was extended by Upadhyay & Kaur (1985) by analysing winter snowfall over the Western Himalayas and monsoon rainfall over the plains of Northwest India up to 1970, arriving at a correlation coefficient of −0.41.

Studies on snow covered areas will provide vital inputs for short and long-term monsoon predictability making use of deterministic mathematical models.

POLAR ENVIRONMENTS

In Polar regions, winter is long, cold and dark. The sun does not rise above the horizon for long periods. The darkness is far from absolute, however; twilight exists so long as the sun is not more than 6° below the horizon. There are several reasons which help to explain these cold regions (Sugden, 1982):

- polar regions receive less solar radiation because of the low angle of the sun in relation to ground surface. On an average, the poles receive about 40% less radiation than the equator;
- the regions reflect more solar radiation received than elsewhere in the world;
- the clarity of the atmosphere (as the cold air holds some 10 times less moisture than in temperate latitudes) and is notably free of solid particles.

On a world scale, the polar regions are heat sinks and in order for the world atmosphere to maintain itself in equilibrium there must be a net poleward shift of heat. It is the manner in which this movement of heat takes place that determines the particular climate of any area in the polar regions.

In spite of the popular image of the uniformity of the polar climate consisting of perpetual blizzard, there are dramatic contrasts between North and South and between different parts of the polar zones. Many of these contrasts can be attributed to the effect of macro-scale topography of the earth's surface and in particular the distribution of land, sea and mountains.

The temperature difference between the poles and the equator causes air over the poles to be denser which effects the lines of equal density in the atmosphere, forming a bowl over the poles (high at the perimeter and low at the centre). As the air flows down the gradient towards the poles, it is diverted by the rotation of the Earth so that it flows roughly parallel to the contours, forming an anticlockwise vortex over the North Pole and a clockwise vortex over the South Pole.

One of the characteristics of the polar climate is the presence of a temperature inversion above snow or ice surfaces which results from strong radiational cooling. The inversion may be only 10-100 m thick and yet represents a temperature difference of 30°C. Its development is commonly associated with calm anticyclonic conditions in winter, and it is only disturbed by strong winds, cloud cover, or precipitation associated with cyclones.

Air circulation reinforces the basic contrast between the Arctic and the Antarctic. Whereas meridional circulation is discouraged by the symmetry of the Antarctic, Arctic topography favours a northward movement of warm air, especially in winter over the Atlantic sector. This helps to make the Antarctic colder than the Arctic. It also helps to explain the sharp longitudinal temperature gradients in the Arctic, a pattern which is unimportant in the Antarctic, except locally in the vicinity of the Antarctic Peninsula.

Precipitation in the polar region is light and indeed most of the zone is arid. The seasonal contrast in precipitation maximum between North and South is also related to distribution of land and sea. Cyclones tend to move into Antarctica and cross the lower part of the continent in winter when the westerly circulation is intensified and deep cyclones form. In the Arctic in winter an enhanced westerly circulation is interrupted by strong pressure differences between land and sea. In summer the cyclones penetrate the continental interiors, bringing summer rainfall maxima.

The polar climates result from the operation of two sets of processes. On the global scale, basic geometric considerations imply a cooler climate at the poles than elsewhere and a westerly circumpolar air circulation. The interaction between these features and the distribution of land, sea and high topography introduces a second set of processes which determine the climate at any point within the polar region.

Oceanic circulation is probably responsible for the major contrast between arctic and antarctic marine ecosystems, their productivity and biomass. The adage "polar bears in the North, penguins in the South" is a fair summary of much that is significant in polar biogeography.

The available records of Arctic climate, including instrumental data, visual observations and various sources of long-term proxy data demonstrate that climatic variability in the Arctic is very much greater on time scales of decade or longer than is the case for year to year variations, which differ little from inter-annual variations recorded at low latitude.

INTERCOMPARISON OF THE HIMALAYA, THE ARCTIC AND THE ANTARCTIC

The three major cold environments under discussion are the Arctic, the Antarctic and the Himalaya. The Arctic is an ocean basin almost completely surrounded by continents. It is sometimes referred to as a Mediterranean in the continental hemisphere of the world. The Antarctic is a continent surrounded by ocean and is known as a remote outpost in the ocean hemisphere of the

Table 1 Comparison of three great cold environments.

Features	The Himalaya	The Arctic	The Antarctic
Glacier area (10^3 km^2)	~95	134	50
Volume (10^3 km^3)	~1000	30	10
Mean elevation (m)	~6000	>100 m	~2400
Highest elevation (m)	8848	3700	5140
Mean depth of ice (m)	~500	~1000	~2000
Velocity of ice flow (m a^{-1})	>>10	>1-<1000	>1 - <1000
Mean winter temp. (°C)	-36 to -1 (W to E)	-40	-60
Mean summer temp. (°C)	41 to 23 (W to E)	5	-20
Lowest temp. recorded (°C)	-47	<50	-89.2
Mean wind speed (km h^{-1})	~100	<100	~100
Mean precipation (mm)	~500	25	189
Meltwater (km^3)	3000-5000	~1400	~2300

world. Some have called the Arctic a hollow and the Antarctic a hump. The Himalaya is the highest but the youngest mountain belt (20 to 60 million years B.P.) of the earth running in arcuate shape for about 2500 km. It has more than 90 peaks above 6000 m and contains about 50% of all glaciers outside of the polar environments. Table 1 gives a quick comparison of three great cold regions affecting climate on earth and its environment.

INTEGRATED R&D FOR THE HIMALAYAN REGION

As the Himalayan region contains more than 5000 glaciers, it is like an open cold laboratory which generates a variety of climates for scientific research. In the Himalayan region, the study of the land-atmospheric interactions in greater detail will contribute to our understanding of climate dynamics. Determination of the energy and water balance of high altitude lakes, and forecasting of meltwater contributions from snow and ice to streamflow, measurements of rates of erosion and siltation, evaluation of rate of uplift and associated seismicity, characterization of floral and faunal distribution and their ecological significance through extensive and intensive observations in the rarefied environment are of great significance for development of the region. We have also to understand various atmospheric processes operating at different temporal scales which influence monsoonal circulation. Integration of all these scientific efforts will help us to evolve an appropriate set of technologies for regeneration of the high altitude Himalayan environment which is presently under great stress of decay and degeneration. This is possible if research groups covering different scientific disciplines are established and nurtured in all institutions of higher learning and government organizations supported by High Level

National Coordination Committees of various countries. A High Level Standing Agency could be charged to overview the research work of multidisciplinary groups and provide adequate resource support and guidelines along with a suitable forum to monitor the physical, chemical and biological interactions of this great asset of nature. This becomes of greater importance in view of the threat of global warming on the world's climate.

Since this work involves monitoring of a very extensive environment, a large number of instruments are required for surface measurements and telemetry of data with added thrust to remote sensing technology. The manning and maintenance of these observations requires extensive financial support which appears to be beyond the means of the poor countries of this region. International financial inputs are therefore needed for procurement of instruments and sustaining the R&D thrust for monitoring the unique environment and establishing a proper data base for the region on the lines of other world data centres for the cold regions. A comparison of data from the cold regions will help in evolving appropriate eco-friendly strategies for development of the Himalayan environment.

It is suggested that the countries of the region must cooperate to strengthen hydrometeorological data networks by conducting a Himalayan Experiment similar to the ALPEX – the Alpine Experiment.

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