# Air-borne Measurements of the Surface Temperature over the Nepal Himalayas*

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**Abstract**

In the post-monsoon period, surface temperature at Ganesh and Langtang Himal areas were measured by an infrared (IR) radiometer on a Pilatus Turbo Porter aircraft. The results show the extremely high temperatures at bare and less vegetated surfaces of the Himalayan highland (over 4,000 m) due to heating by strong solar radiation, and also large temperature differences between sunlit and shaded surfaces.

## 1. Introduction

In the post-monsoon period of 1976, we made a preliminary observation of the air temperature field over Shorong, Khumbu, and Langtang Himal from the aircraft (Yasunari and Nakajima, 1978). The results of the observations suggested that the air temperature at 5,000 m and even 8,000 m height over the Himalayan ranges are affected by the thermal condition of the ground (or snow) surface. That is, relatively high air temperature over the bare ground surface, and relatively low air temperature over the broad snow and ice surface areas were observed. In this sense, the surface temperature conditions in the Himalayas should be investigated to verify the thermal effect of the Himalayas to the atmosphere.

In the post-monsoon period (October) of 1978, the present author made air-borne measurements of surface temperatures by IR radiometer over Ganesh and Langtang Himal region. The results of these measurements are reported in this paper.

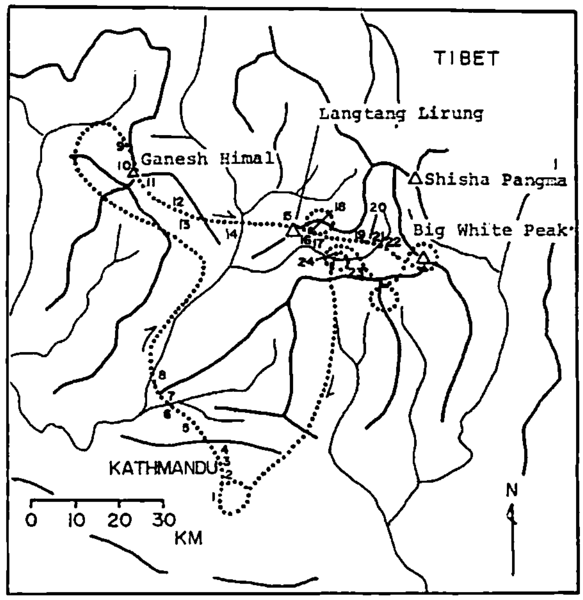


Fig. 1. Flight course over Ganesh and Langtang Himal on October 22, 1978. Point numbers in Table 1 are shown along the flight course (dotted line).

## 2. Flight course and method of measurements

The flight was made from 8:15 to 11:00 (about 3 hours) on October 22, 1978 by a Pilatus Turbo Porter aircraft. The flight course is shown in Fig. 1. This flight was combined with the measurements of atmospheric aerosol particles as well as the photographic survey of glaciers. These results are reported elsewhere in this issue (Fushimi et al., 1980, Ikegami et al., 1980).

A radiometer (Asahi, type TA-50) was installed at the floor window of the aircraft. This radiometer can measure infrared radiation in the 2–14 $\mu$m spectral band. A special 8 mm cinecamera (Digitaval-8), which can take pictures at intervals of 0.5 second, was also set by the side of the radiometer, to record surface conditions directly under the aircraft. The output of the radiometer was recorded by an electronic recorder as continuous data. The radiometric measurements were made over the surfaces of 1,000 to 7,300 m altitude level at flight altitudes from 5,600 to 7,800 m.

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* *Glaciological Expedition of Nepal, Contribution No. 73.*

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Table 1. List of points selected for this analysis.

| Point No. | Time | Flight Altitude (m) | Surface Altitude (m) | Surface Condition | Sunlit (L) or Shaded (S) | Surface (Black-Body Equivalent) Temperature (°C) |
|---|---|---|---|---|---|---|
| 1 | 0858 | 5600 | 1350 | Kathmandu City | L | 31–33 |
| 2 | 0901 | 5600 | 1350 | field (suburbs of Kathmandu) | L | 26–28 |
| 3 | 0909 | 5600 | 1500–2000 | dense forest | L | 26 |
| 4 | 0910 | 5600 | 1500–2000 | " | S | 21 |
| 5 | 0912 | | 1000–1300 | forest and grass land mixed | S | 24 |
| 6 | 913 | | 1000–1300 | " | L | 34 |
| 7 | 914 | | 1200–1500 | " | S | 23–24 |
| 8 | 915 | | 1200–1500 | " | L | 29–33 |
| 9 | 948 | 7800 | 4500–5000 | bare rocky slop | L | 20–30 |
| 10 | 949 | 7800 | ≃7300 | snow and ice wall near the Peak of Ganesh Himal (7406 m) | S | −16–−17 |
| 11 | 949 | 7800 | ≃6000 | " | L | 19 |
| 12 | 951 | 7800 | ≃6900 | snow and ice wall of Lapsa Karbo V (6950) | L, S mixed | −2 |
| 13 | 951 | 7800 | ≃6900 | " | L | 12 |
| 14 | 954 | 7800 | 2300–2400 | shrubbery and grassland (near Bhote Kosi) | L | 27 |
| 15 | 956 | 7800 | 7200 | ice and snow wall of Langtang Lirung (724 6m) | S | −14 |
| 16 | 956 | 7800 | ≃6000 | " | L | 24 |
| 17 | 959 | 7800 | 4500–5000 | bare rocky slope (near Lirung Gl.) | L | 25–26 |
| 18 | 959 | 7800 | ≃4500 | debris covered glacier surface (Lirung Gl.) | L | 17–19 |
| 19 | 1000 | 7800 | 5500–6000 | snow field | L | 0 |
| 20 | 1001 | 7800 | 5000–5500 | bare rocky slope (near Shalbachum Gl.) | L | 27–28 |
| 21 | 1002 | 7800 | 5800–5900 | snowly ridge (near Morimoto Peak) | S | −12 |
| 22 | 1002 | 7800 | ≃4800 | snow and debris covered glacier surface (Langtang Gl.) | L | 2–5 |
| 23 | 1032–36 | 5600 | 3800–4200 | shrubbery and grassy slope (in Langtang valley) | S | 6–10 |
| 24 | 1032–36 | 5600 | 3800–4200 | " | L | 30–40 |

## 3. Some results of measurements and discussion

On this day, sub-Himalayan ranges (2,000–4,000 m) were mostly covered with a sea of clouds (Sc and Cu), but the data over these clouds are excluded from the present analysis. Though the temperature data were obtained as a continuous record, we selected only 24 points, where correspondences between temperature data and surface conditions are clear, for discussion. These data are indicated in **Table 1**. Point numbers in Table 1 are plotted in Fig. 1. The black-body equivalent temperature in Table 1 is lower at most places than the real surface temperature, as the emissivity at the surface is less than 1. The difference between the measured and real temperature may within several to 10°C, as the emissivity values are supposed to be more than 0.9 (Kondratyev, 1969).

From Table 1, some evident results are summarized as follows:

(1) The surface temperature of bare or less vegetated ground on the sunlit side of high altitude Himalayas (higher than 4,000 m) is very high. For example, at points 17 and 20, which are located at around 5,000 m height just below the snow line, the temperature reached 25–28°C (or evern higher, actually). These temperature values are higher (nearly 30°C) than those for the same altitude of the free atmosphere over Kathmandu observed by radiosonde at Kathmandu airport (Nepal Meteorological Service) as shown in **Fig. 2**. Temperatures on the shaded sides are, in contrast, closer to those of the free atmosphere.

(2) Large temperature differences were observed between the sunlit and shaded sides at places of almost similar surface conditions. Combinations of points 3–4, 5–6, 7–8, and 23–24 correspond to

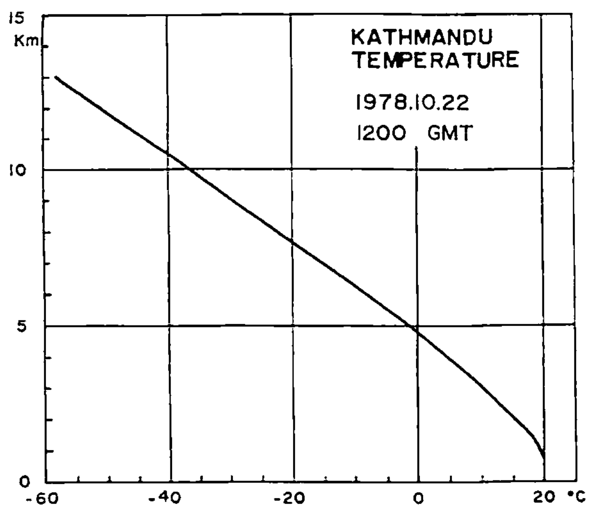


**Fig. 2.** Air temperature profile over Kathmandu at 12:00 GMT on October 22, 1978 (from the radiosonde data of Nepalese Meteorological Service).

this category. Actually, these combinations correspond to the north and south faces of mountains. The difference of temperature seems to be larger at higher altitude. For example, in the sub-Himalayan mountains (1,000–2,000 m) to the north of Kathmandu Valley (points 3–4, 5–6, and 7–8), the differences is 5–6°C or at most 10°C, but at Langtang Valley (points 23–24, at the altitude of 3,800–4,200 m) it reaches 20–30°C. This feature may be due partly to the differences of insolation angles against the slopes, but also to the differences of intensities of solar radiation on the ground surface. Large difference of surface temperature also occurred at the sunlit and shaded snow and ice slopes around peaks of Ganesh Himal (points 10–11) and Langtang Lirung (points 15–16). In these cases, the temperature of the sunlit side was extremely high, if we condiser the altitude (about 6,000 m) of the snow (or ice) surface. As mentioned above, the radiometer detects radiation of a rather wide spectral band (2–14 $\mu$m) including the near-IR band. Therefore, the abnormally high temperature values may be attributed to the additional insolation of reflected solar radiation from the high-albedo snow (or ice) surface, occurring on a suitable slope angles.

(3) The surface temperature of the sunlit snow field (point 19) was 0°C, which may show that the snow at the surface was melting at this time of the day (10:00 a.m.).

(4) The temperature of the debris-covered surface of Lirung glacier (point 18) is 7–8°C lower than those of bared rocky slopes (point 17) on both sides of the glacier, as clearly shown in **Fig. 3.** This fact may be attributed to the cooling effect of the ice body under the debris, as well as the relatively high albedo of the debris compared to that of a bare (or less vegetated) rocky slope. Similar results are obtained for the debris-covered glacier in Ganesh Himal (data not shown).

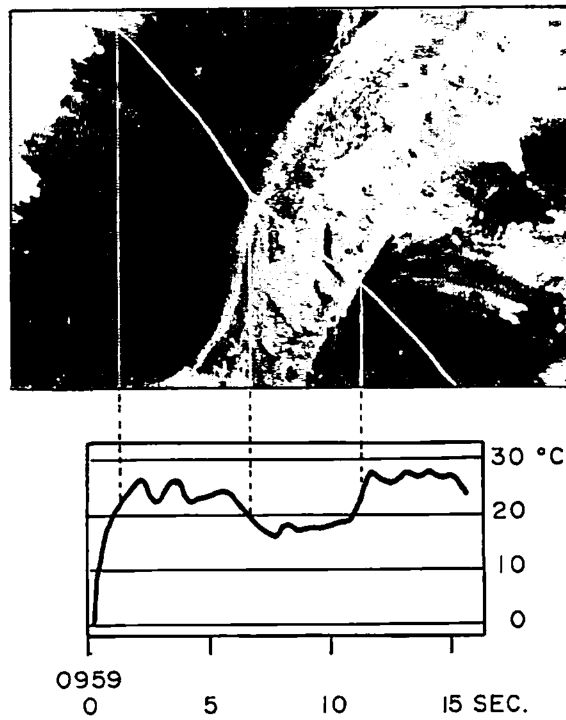


**Fig. 3.** Flight course (thick white line) over the debris-covered area of Lirung glacier (upper), and the surface temperature variation along the flight course (lower). Temperature values corresponding to some surface places are indicated with thin white and dotted lines.

The results mentioned above suggest that Himalayan highlands warm the atmosphere by absorbing strong solar radiation even in the morning of the post-monsoon period, though the snow (or ice) covered and shaded areas may reduce this effect to some extent.


**Acknowledgements**

The author would like to express his hearty gratitude to Captain E.J. Wick of R.N.A.C. for assisting with our flight observations.


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