Inter-annual and intra-seasonal variations of mountain weather in Khumbu region, Nepal Himalayas

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Automatic Weather Station (AWS) at the Syamboche village, Nepal Solu-Khumbu district, was established at an altitude of 3833m a.s.l. in October 1994 by the CREH project. An observatory exists in a flat pasture ground of the Yak farming at the middle of the deep valley running north-south direction. Such high-elevated station is quite important to monitor the climatic change and understand the hydro-meteorological processes of the Himalayan weather. Meteorological elements, such as temperature, humidity, wind, pressure, precipitation, upward and downward short-wave radiation, and soil temperature are observed with 30 minuets interval by AANDERAA AWS. The AWS observation was taken over to the GAME-AAN project since 1999, and about 5 years data have been accumulated (Ueno et al., 2001). Variation and trends of air temperature and diurnal change of the monsoon precipitation are analyzed in this study.

Shrinkage of glaciers and glacier lake outburst flood are the recent major problems in the Nepal in relation to water management and prevention of natural hazard. Shrestha et al.(1999) showed evident increase of daily maximum temperature in . the Himalayas. To investigate the variation and trends of surface air temperature at the Syangpoche AWS, 5 years record of the 2.3m level air temperature are analyzed and compared with objective analysis data, and following characteristics are found.

1) Intra-seasonal variation of daily temperature was small in the monsoon season and quite large in the winter season. Amplitude of the daily winter temperature exceeded 10 ℃ causing the year-to-year variations (Fig.1). The variation was not evident at Kathmandu, and showed better correspondence at Lhasa in the Tibet although it was smaller amplitude. Lower temperature days corresponded to the existence of snow cover determined by the albedo and surface soil temperature condition.
2) Major warming periods in winter were associated with temperature increase trough entire days with pressure increase, and decrease of downward radiation afterward (cloud development) as shown in Fig. 2. Diurnal change of the mountain-valley wind system continued through the period, with sporadic northerly wind. The warming periods showed quite good correspondence to

high pressures (pressure ridges) in the NCEP 500hPa objective analysis data.

3) 5 years comparison of the monthly AWS temperature and 500hPa NCEP temperature at a corresponding grid location showed that amplitude of the month-to-month variation is larger in winter and smaller in summer at the AWS (Fig. 4). Both data were significantly correlated in the winter season. Although linear trend of the temperature after 1975 was +0.058 ℃/y in July and +0.042 ℃/y in January, both correlations were not significant statistically. Hemispheric winter teleconnection patterns in the mid-latitudes (CPC, 1999) relating to the AWS monthly temperature variation were also not found.

These results indicates that large intra-seasonal variations in winter season were caused by the combinations of 1) cold temperature days by the valley scale cooling with snow cover under the weak wind condition, and 2) warm temperature period associated with passing synoptic scale (pressure ridge) system. To investigate the response of the local mountain weather to the global climate variability, AWS monitoring will be continued at least 10 years.

Himalayas also play an important function as orographical boundary to the Indian monsoon system that causes heavy precipitations in summer. At Syamboche, monsoon precipitation is about 750mm (year-to-year variation was less than 70mm/y) with large diurnal variations. To quantify the variation, principal component analysis was performed to the hourly precipitation data for the days with precipitation (Fig. 5). Frequent appearance of second positive patterns in the pre-monsoon season (Fac2+), corresponding to the morning increase of precipitation, was associated with increase of albedo and daily temperature below 0 ℃. Namely, this pattern was caused by the melting of snow over the tipping bucket gauge due to morning insolation. Without the snow cover days, daily precipitation amount and factor score of the first positive pattern (Fac1+), increase of precipitation from 19:00-2:00 LTM, well correlated. Second component (Fac2+, Fac2-) might be explaining the modulation of this diurnal variation. Besides, sporadic heavy precipitation was observed in the non-monsoon season affecting year-to-year change of annual precipitation amount. Daily base analysis by combining of the AWS data and TRMM satellite and GAME re-analysis data is expected to investigate the synoptic background of precipitation variability.

<References>

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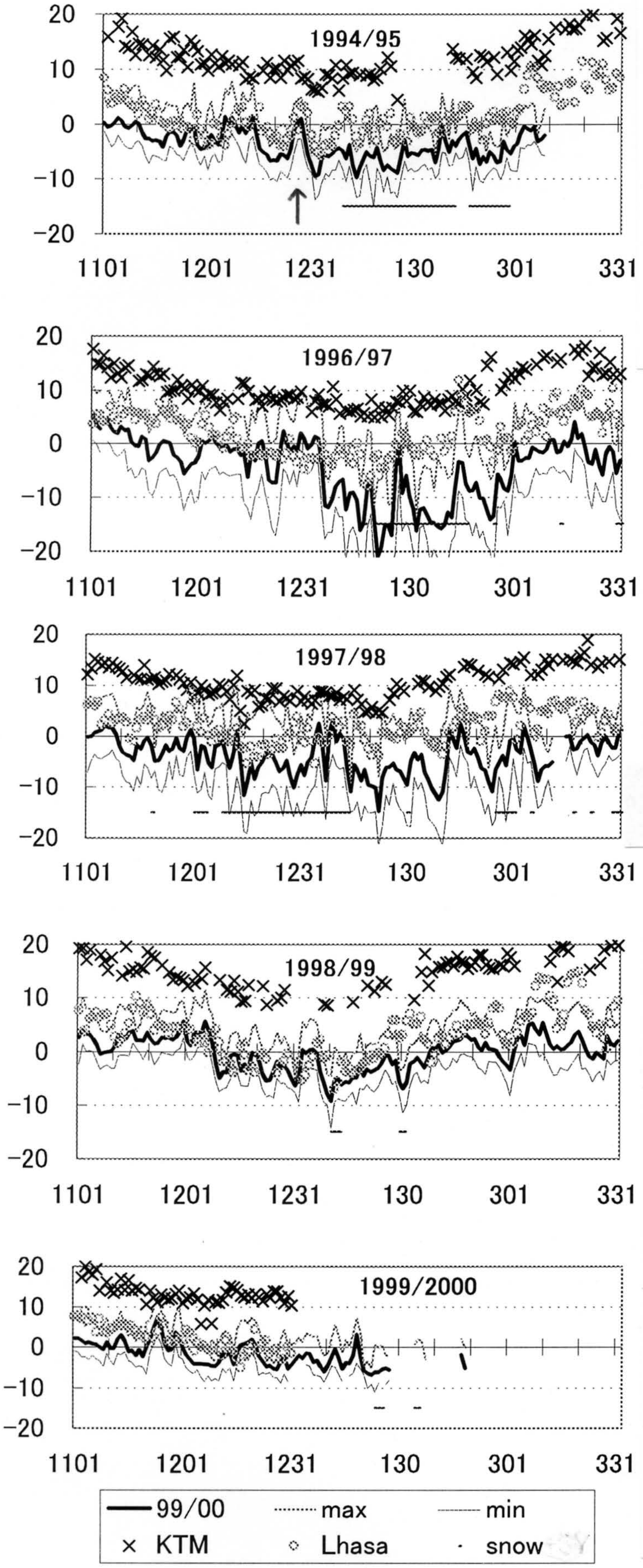

Fig. 1 5 years record of winter daily, minimum and maximum temperature at AWS, with daily temperature at Kathmandu and Lhasa. Under bars correspond to days with snow cover at AWS.

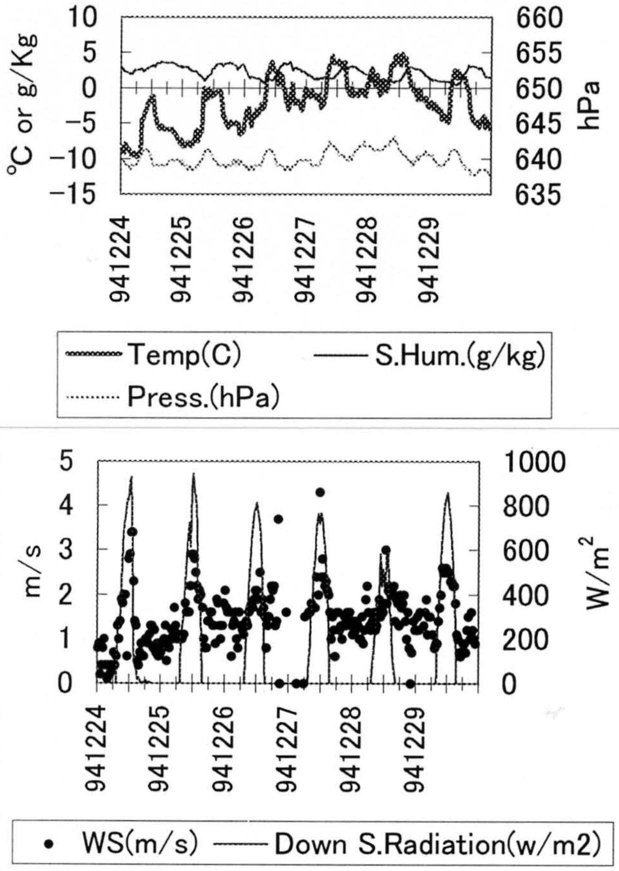

Fig. 2 Example of warm period in 1994 winter marked as ↑ in Fig. 1.

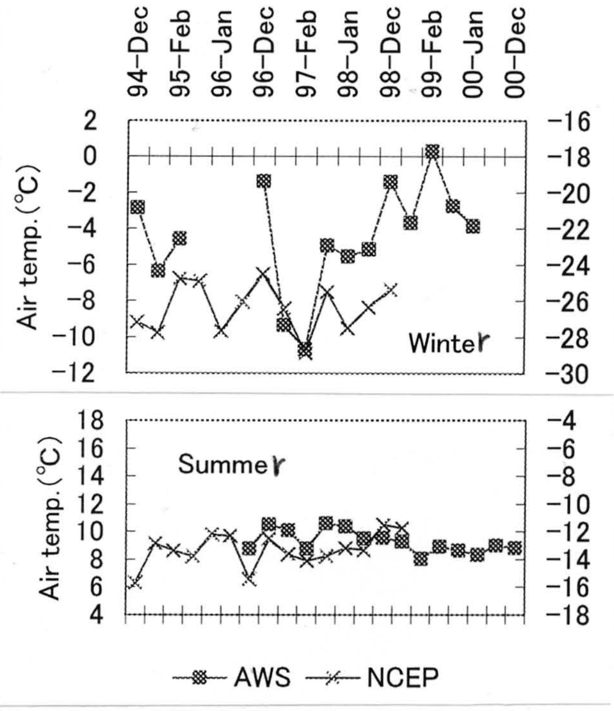

Fig. 3 Comparison of monthly temperature between AWS and NCEP 500hPa grid.

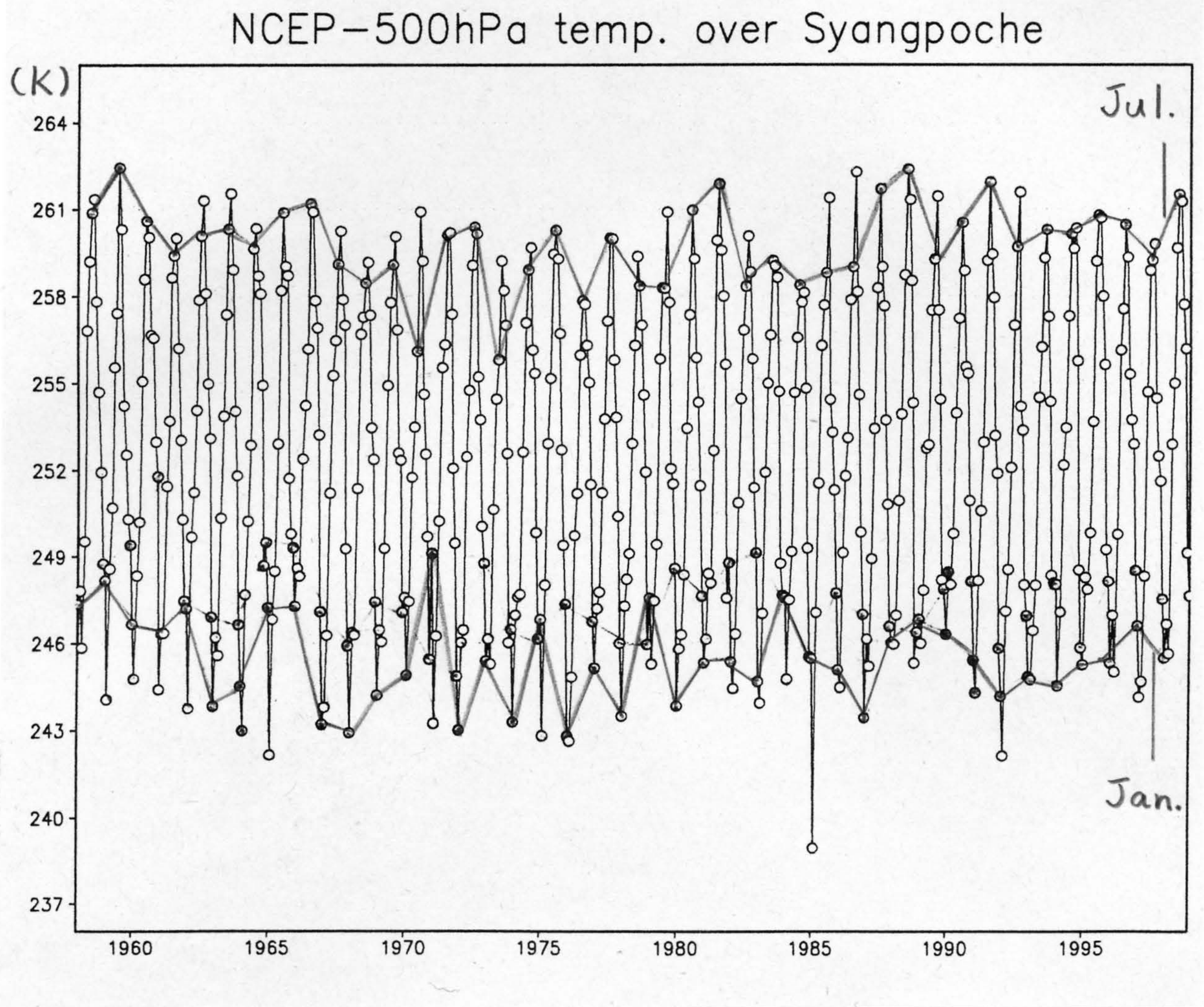

Fig. 4 Time sequence of the monthly temperature for 1958-98 at NCEP 500hPa 27.5N,87.5E grid.

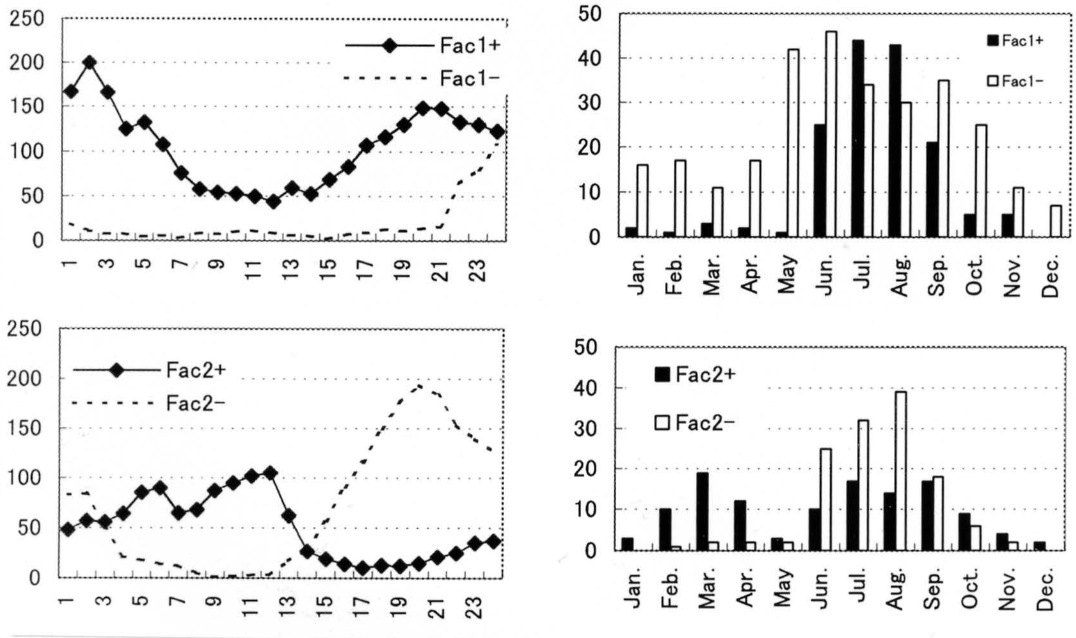

Fig. 5 First and second principal component patterns of hourly precipitation as a function of local time, composed in positive and negative scores (left), and seasonal changes of frequency appearance for each pattern (right).