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Establishment of the GEN Automatic Weather Station (AWS) in Khumbu region, Nepal Himalayas

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Abstract

GEN-AWS was established on October 21, 1994, at Syamboche village, Solu-Khumbu district, at an altitude of 3833 m. Scientific background of the establishment, observed items, and maintenance condition are summarized. Also the meteorological data for 1994-95 are briefly shown.

1. Introduction

Under the high altitude, subtropical Asian monsoon climate, the Nepal Himalayas provide their unique meteorological and glaciological phenomena. Previous meteorological observations conducted by GEN (Glaciological Expedition in Nepal, Higuchi, 1980, 1993 ; Yamada, 1989) have successfully investigated many natural features, such as local circulation system in deep valleys, precipitation distribution along valley slopes, seasonal weather variation, and heat budget studies. (Most of these studies are reported in the Seppyo special issue Vol. 38-41, and in volumes of the Bulletin of Glacier Research). But the meteorological observations tended to be conducted in different places, such as in Khumbu Himal, Shorong Himal, Langtang Himal, Mukut Himal etc, and in different years, which has prevented the evaluation of inter-annual climatic variations at any certain region. In recent scientific issues studying the relations between glacier retreat and global warming, continuous monitoring of Himalayan climate on a decadal scale is strongly desirable. In Nepal, the Snow and Glacier Hydrology Project (SGHP) (present name 'Snow and Glacier Hydrology Unit'), with the cooperation between His Majesty's Government, Department of Hydrology and Meteorology (DHM) in Nepal and the German Agency for Technical Cooperation (GTZ), has established a network of hydro-meteorological stations since 1987 to acquire quantitative and qualitative data about hydroclimatological processes in the Himalayas for water management (Grabs and Pokhrel, 1993). In October 1994, the GEN Automatic Weather Station (AWS) was established in Syamboche village in Khumbu Himal, in part, to support the SGHP network providing regional meteorological data for DHM, and also, importantly to establish a representative and semi-permanent automated station for climatological monitoring in high altitude areas. The GEN-AWS will contribute directly to the Global Climate Observing System (GCOS) for global change at mid-latitude alpine region, and will provide data for basin scale scientific process studies of meteorology, hydrology, glaciology and engineering disaster prevention. Also, the AWS will play a key role to link all short-term observations conducted at glaciers in each local river basin, in order to integrate the local scale to basin scale structure of weather systems. This report introduces the scientific background of the establishment of GEN-AWS and its operating conditions in 1994−95.

2. Selection of the observation site

GEN-AWS was established on October 21, 1994, at Syamboche village, Solu-Khumbu district, at an altitude of 3833 m (Fig. 1). An observatory area of about 10 m×6 m was made ready in the flat pasture ground of the Livestock Development Farm (LDF), Ministry of Agriculture, and fenced to prevent yaks from coming inside (Fig. 2). Syamboche village was chosen for the GEN-AWS site because of the following reasons.

1) To maintain the AWS for a 10 year time scale, easy

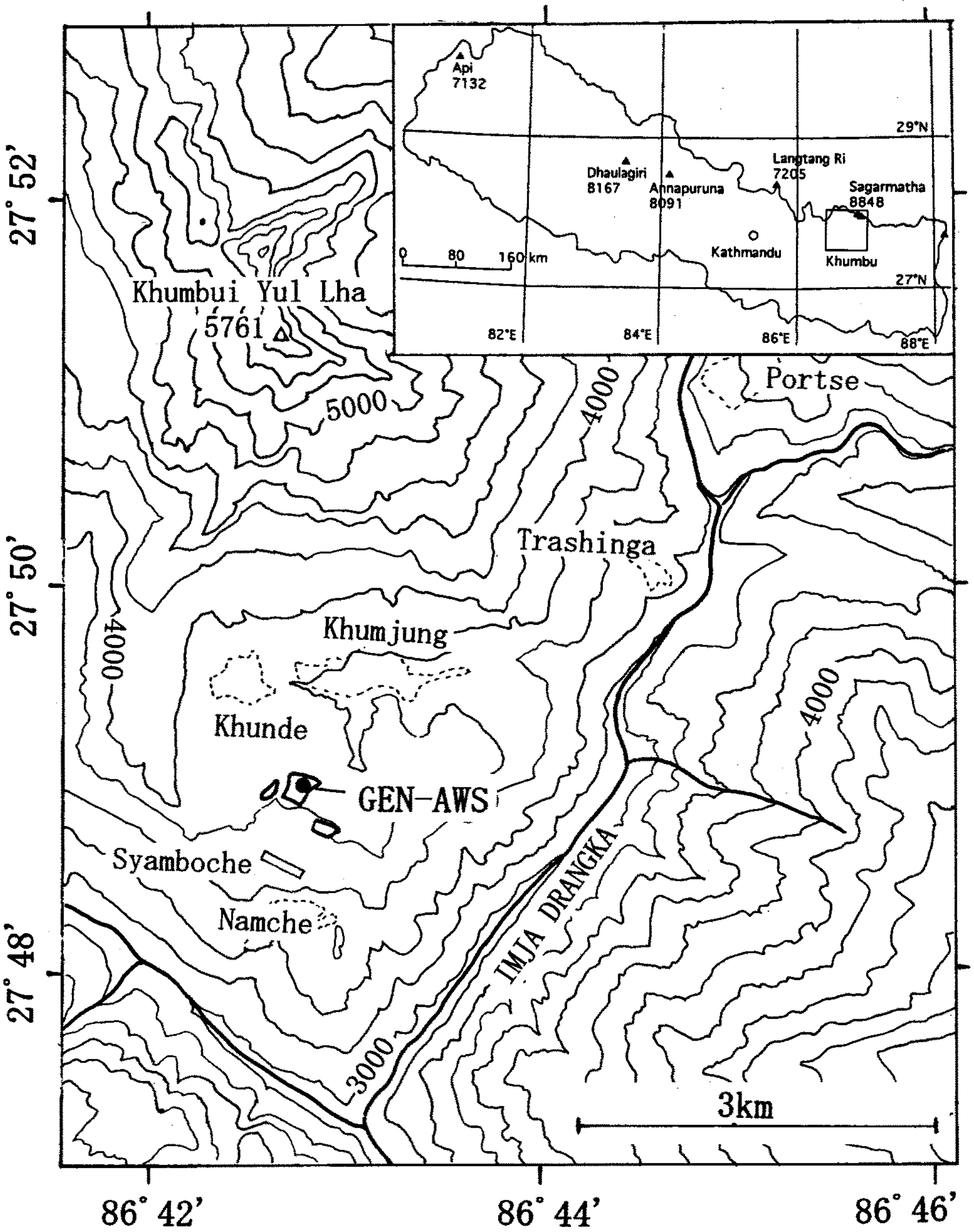

Fig. 1 Location of the GEN-AWS in Khumbu area.

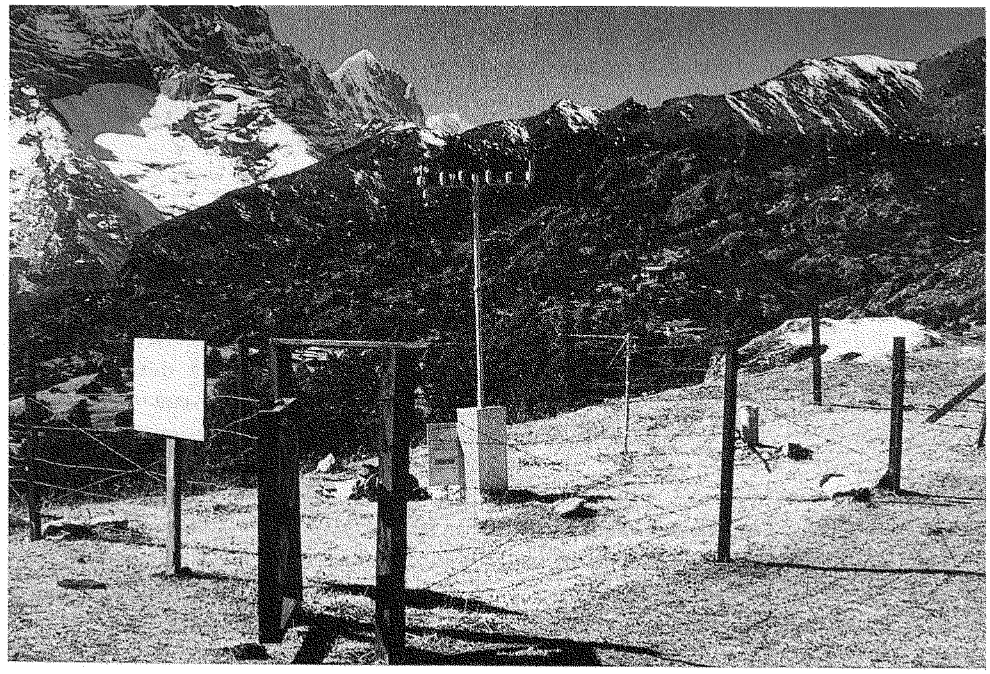

Fig. 2 Picture of the GEN-AWS. In the fenced area, Aanderaa-AWS, Net-radiation sensor, and precipitation gauge are shown from the left.

accessibility and on-demand maintenance are necessary conditions even in the severe Himalayan climate. There are frequent helicopter services between Kathmandu and Syamboche airport within 40 minutes, and the LDF is only a few hundred meters north of the airport. The farm is under government authority, and AWS can be maintained safely under the contract between DHM and LDF. Moreover, the station is located at an altitude below 4000 m, which facilitates easier acclimatization.

2) The observatory must be representative to monitor both alpine local weather condition and monsoonal large scale climate. Syamboche is located in the center of Khumbu Himal, Rolwaling Himal and Solu Khumbu, and the site exists on a barren hilly slope pushing out to the Dudh Kosi valley. The site locates in the middle of slope in the deep valley facing south, where the Imja and Nangpo rivers join to make the Dudh Kosi river.

3) Many scientific observations have been conducted in the Khumbu region since the 1970s, and limited meteorological observations have been conducted at Syamboche Airport. Decadal scale data comparison can be expected there. Syamboche village is therefore familiar and convenient for Japanese expedition members who maintain the AWS.

4) The nearest SGHP station of Dingboche village (4355 m a.s.l.) locates about 15 km north-east of Syamboche, where rather dry climate prevailed in the bottom of the valley in interior Himalaya (Yasunari and Inoue, 1978, Grabs and Pokhrel, 1993). Continuous data comparison between the two stations will clarify the altitudinal difference of meteorological variables along the Imja valley river, which can be used to understand basin scale meteorological processes and estimate physical parameters on the altitude.

3. Establishment, data collection, and maintenance

Obsevatory for the AWS was established on October 21, and data collection and maintenance of AWS were done on April 11, October 7, and December 3–4, 1995. The AWS has been safely maintained with no physical damage in the observatory. The radiation dome and rain gauge were cleaned at each visit, and all the instruments were checked.

The following operations were conducted.

a) 1994 October

Two main parts of the AWS were installed on October 21, to start measuring of basic meteorological elements. One part is the Aanderaa-AWS, observing temperature, pressure, relative humidity, wind direction/speed, upward and downward short wave radiation, downward all wave radiation, at a height of 3.1 m, and soil temperature at depth of 15 cm and 0.5 cm, respectively. All the sensors were well calibrated in Japan. The data were recorded at every half hour in the local time (LTM) to evaluate accurate diurnal variation, and stored in a Data Storage Unit (DSU). Measurements were drived by lithium battery. The second part is the tipping bucket type raingauge with a KADECU data storage unit (Kona System Co.), with a 0.5 mm capacity measures the rain and the data are stored at 1 hour interval. Correction of precipitation due to the wind induced undercatch for solid precipitation can be done using wind speed and temperature data.

b) 1995 April

REBS net radiation sensor was installed on April 11 with a KADECU data storage unit. The sensor is of maintenance-free type with no electric ventilation, set at 1.5 m in height at the west corner of the site. Air in the radiation dome can be kept dry by artificial ventilation through a desiccant hold in the arm. Output value is in mV with different calibrate coefficients for positive and negative values, respectively. KADECU saves the instantaneous value at 10 minutes interval. Radiation is the most important element for surface heating to drive the local circulation in the valley, and for glacier melting which affect river runoff. GEN-AWS tries to evaluate individual radiation components, such as upward and downward shortwave radiation, net radiation, and evaluate upward longwave radiation by surface soil temperature and downward longwave radiation by the all wave radiation minus shortwave radiation, respectively.

c) 1995 October

Data collection and maintenance were conducted on October 7.

d) 1995 December

Snow depth meter with a supersonic sensor was installed on December 3, together with 12V battery, to evaluate winter precipitation. Output value is in mV, and Data-mark memory unit (Hakusan Kogyo Co.) saves the instantaneous value at 2 hour interval. The observation was only conducted in the winter season. Aanderaa and KADECU data were collected on December 4.

Table 1 lists the instruments. The components of the measurement are sufficient not only to observe the basic elements of weather but also to evaluate surface heat flux by simple bulk method and monitor the variation of land surface condition due to snowcover, freezing, or vegetation effect.

Up to the present time, data were missed for several periods due to battery trouble. Aanderaa AWS data was missed after March 10 to April 11 in 1995 due to the abnormal battery consumption. Wind speed data showed sporadic abnormal large values since December as spikes in the time sequence, was a symptom for wind sensor trouble. Lithium battery was consumed abnormarly by the wind speed sensor trouble. The sensor was changed to a new one on May, 1995. Aanderaa and REBS data were found to be missing on October, 1997, due to the low battery in the DSU and KADECU data memory. It is very regrettable that we could not get meteorological data in the monsoon season of 1995, except for the precipi-

Table 1. List of components for GEN-AWS

Channel	Element	Sensors	Catalogue accuracy	Manufacturer
2	Wind speed	3-cup anemometer	2%	Aanderaa Co. (2740)
4	Wind direction	Potentiometer type	5°	same (3150)
5	Relative humidity	Hygrophiber	3%	same (2820)
6	Downward shortwave radiation	Temperature difference type (0.3-2.5μm)	2mW/cm^2	same (2770)
7	Pressure	Silicon chip	0.2hPa	same (2810)
8	Soil temperature (15cm)	Platinum resistor		
9	Air temperature	Platinum resister	0.1°C	same (2775)
10	Downward all wave radiation	Temperature difference type (0.3-60μm)	3%	same (2811)
11	Upward shortwave radiation	Temperature difference type	2mW/cm^2	same (2770)
12	Soil temperature (0.5cm)	Platinum resister		
*	Rain gauge	Tipping bucket type	0.5mm	
*	Net radiation	Temperature difference (0.25-60μm)		REBS (Q*7)
*	Snow depth	Supersonic	1mm	Keyence Co. (UD-320)

tation.

4. Brief description of winter data for 1994–95

Precipitation for all the period is shown in Fig. 3. Total amount of non-monsoonal precipitation from 1994/10/21 to 1995/5/31 was 140.5 mm, and monsoonal precipitation from 1995/6/1 to 9/30 was 739 mm. Non-monsoonal precipitation may be underestimated largely due to undercatch of solid precipitation and freezing of tipping bucket. Intermittent precipitation was observed in a period from June 3 to October 1 indicating active monsoon period in the Himalayas, where the maximum record of daily precipitation was 27.5 mm/d on August 30. Sporadic heavy precipitation was observed in November which will be described in details in the next section. Diurnal change of the total hourly precipitation during the active monsoon period is shown in the upper left corner of Fig. 3. Obvious trend of increasing precipitation existed in the evening to night. It is notable that the maximum amount was recorded at the midnight. In contrast, precipitation was smaller from 4:00 to 14:00 LTM, especially from 8:00 to 12:00. The abrupt diurnal variation is caused by mountain-valley circulation prevailing in Khumbu Himalaya, and such evening to nocturnal precipitation is the representative characteristic at the bottom or center of the deep valley.

Time sequence of the Aanderaa-AWS data are shown in Fig. 4, and the monthly average and standard deviation are shown in Table 2. Time sequence of the air temperature shows large diurnal variation ranging 5°C and monthly scale variation ranging 5–10°C. Lowest temperature record was −13.7°C on January 18. Ground temperature at 0.5 cm showed large diurnal variation with its range of 15–20°C until January 7, then the amplitude became very small and temperature only indicates lower that 0°C which continued until March 2. At the same moment, upward shortwave radiation in the noon suddenly increased from 100–150 W/m^2 to 550–600 W/m^2 between January 8 and 9. This is an evidence that snowcover existed since January 9 until the end of

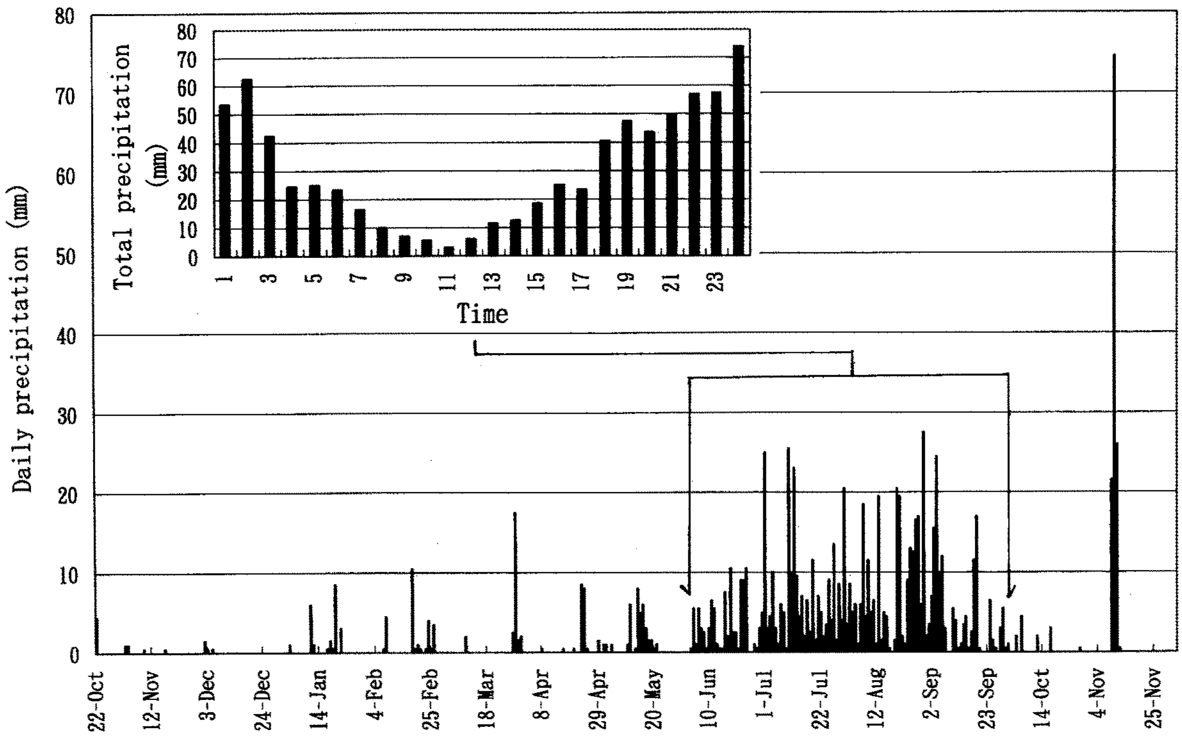

Fig. 3 Daily precipitation change in 1994–95.
Upper figure shows diurnal variation of hourly precipitation accumulated from June 3 to October 1, 1995.

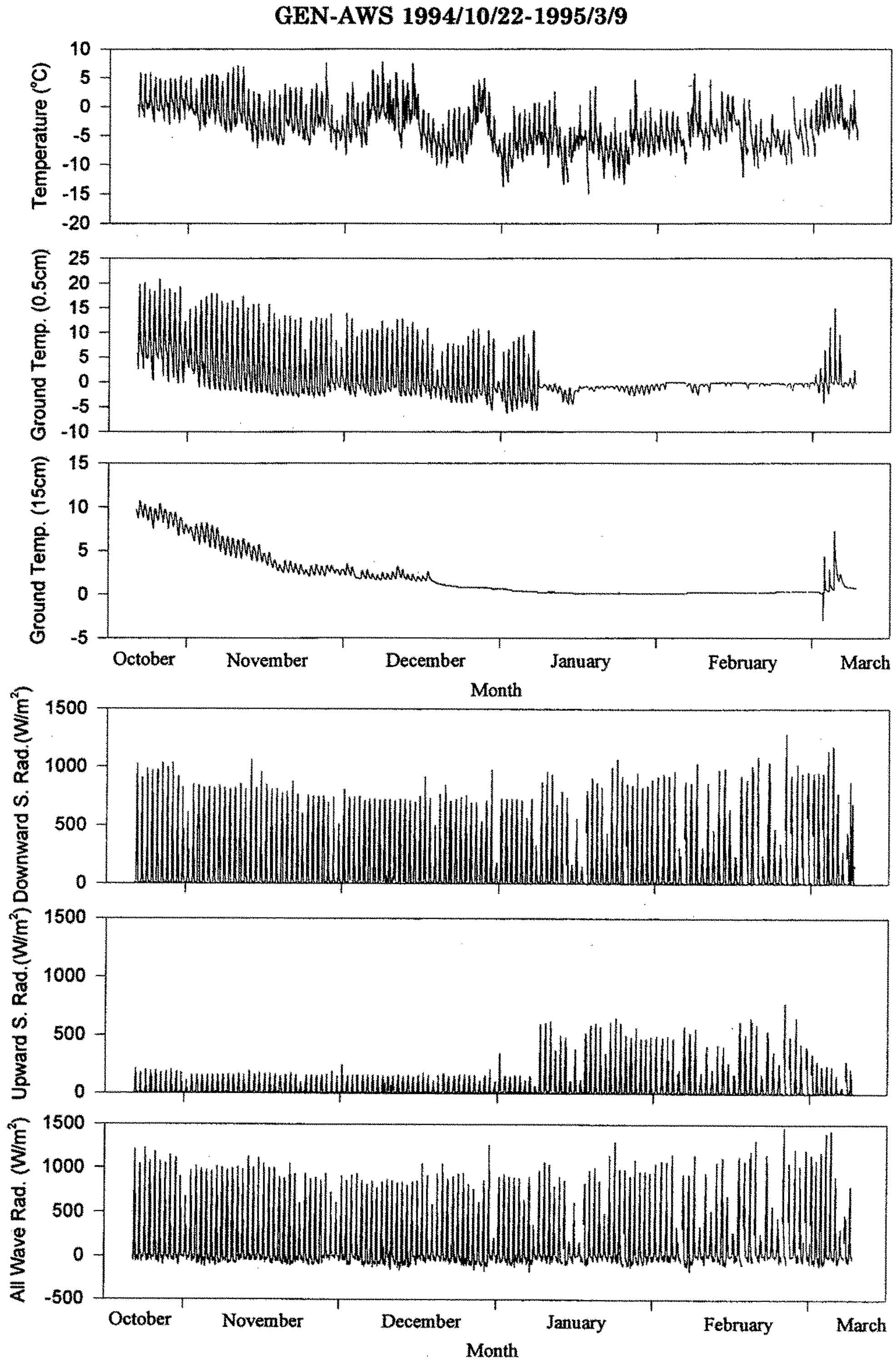

Fig. 4 Time sequences of meteorological elements observed with Aanderaa-AWS with 30 minutes interval, from Oct. 22, 1994 to March 3, 1995.

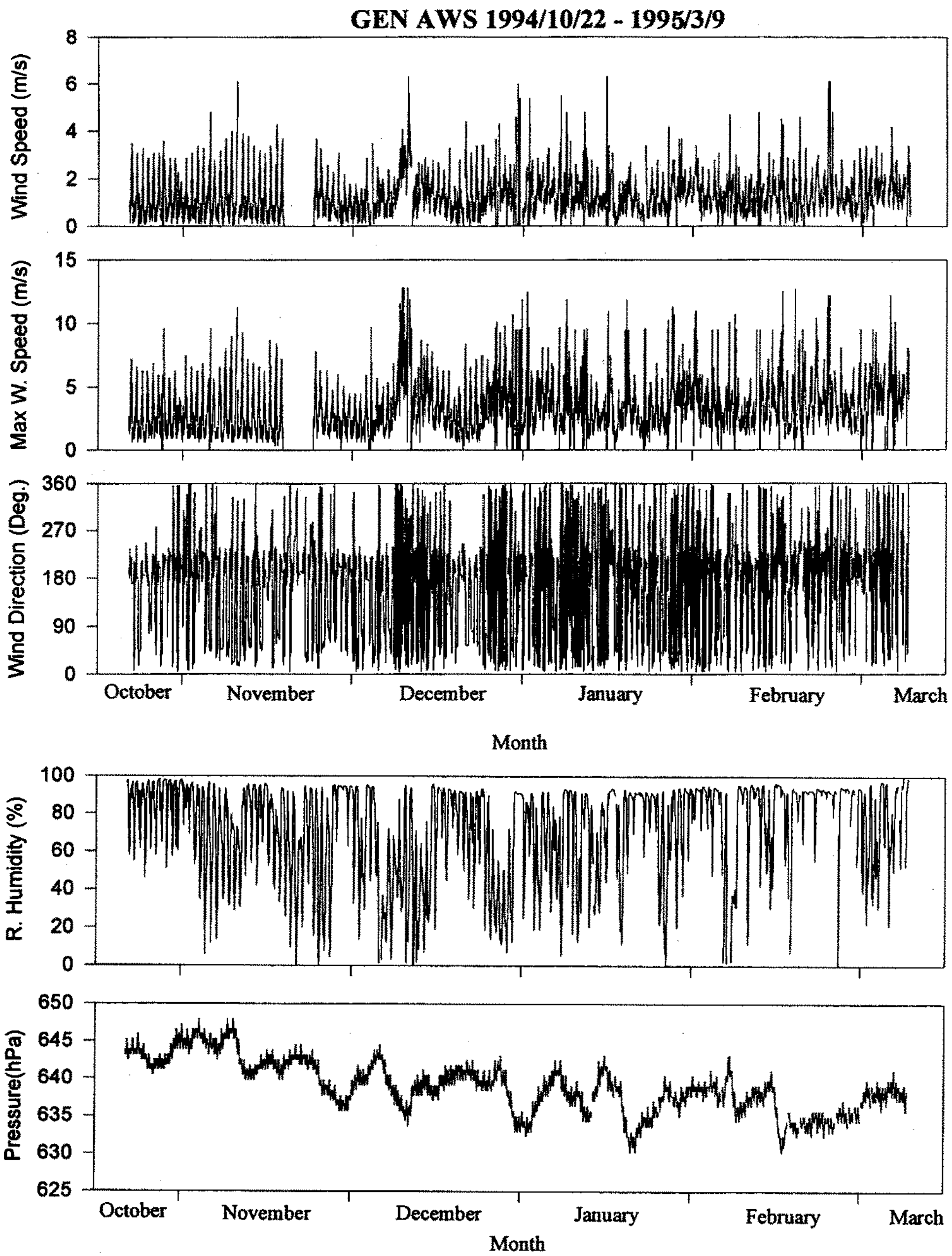
GEN AWS 1994/10/22 - 1995/3/9
Wind Speed (m/s)
Max W. Speed (m/s)
Wind Direction (Deg.)
R. Humidity (%)
Pressure(hPa)
October
November
December
January
February
March
Month

Table 2. Average (AVG) and standard deviation (STD) of meteorological deta for 1994/10/12-1995/3/9 in Syangpoche
Abbreviation : Air temp. at 3.1m (AT3.1), Soil temperature at 0.5cm (ST0.5), Soil temperature at 15cm (ST0.5), Relative humidity (RH), Wind speed (WS), Air pressure (AP), Downward short wave radiation (DS), Upward Short wave radiation (US)

Elements		AT3.1	ST.0.5	ST15	RH	WS	WD	AP	DS	US
1995	Unit	℃	℃	℃	%	m/s	Deg.	hPa	W/m^2	W/m^2
Oct.	AVG	0.9	7.9	8.9	85.3	1.1	161.6	643.1	188.1	32.9
	STD	2.1	5.1	0.9	13.4	0.9	113.2	1.3	301.3	56.8
Nov.	AVD	-1.6	3.0	4.4	70.9	1.0	155.3	642.3	194.6	33.8
	STD	3.1	5.5	1.7	24.0	1.0	90.0	2.8	284.8	51.4
Dec.	AVG	-2.9	0.7	1.6	60.5	1.3	147.4	639.3	188.2	34.6
	STD	3.7	4.3	0.7	27.6	0.9	87.0	2.1	260.0	50.2
Jan.	AVG	-6.4	-1.3	0.2	70.8	1.3	145.5	637.0	161.5	76.5
	STD	3.0	2.3	0.1	23.5	0.8	140.1	2.7	247.7	133.9
Feb.	AVG	-4.6	-0.4	0.2	83.0	1.3	112.9	636.4	166.5	81.6
	STD	2.6	0.4	0.1	19.1	0.9	275.4	2.5	265.7	140.7

February in Syangpoche village. Consequently, daily maximum downward shortwave radiation was about 700−800 W/m^2 through the period, but the average surface albedo changed from 15−20% to 40−60% after the ground was covered with snow. Soil temperature at 15cm showed its diurnal amplitude of 2−3℃ until December 17, then it changed to stay in a constant range with few diurnal variation. Several days before this event, the air temperature fell below 0℃.

Wind speed data contained abnormal large value. If the data more than 7 m/s are treated as errors, averaged wind speed for 30 minutes was less than 4 m/s and maximum wind speed was less than 10 m/s even in winter season. Wind direction changes from 0 to 180 degrees, which corresponds to the direction from north to south via the east. Most of the wind direction stayed within 0−200 degrees, which indicates that wind came from north to south-southwest via the east. The wind tended to flow from south in the daytime, and changed from north-northwest around midnight. The wind prevailed along the direction of Imja valley, and hilly mountain near the AWS site prevent the wind from northeast as shown in the Fig. 1.

Time sequence of relative humidity stayed mostly over 60%. The upper limit around 97% of the sensor measurment should be considered to be 100%. Sporadic dry periods for several weeks were observed in December which corresponded to the periods for warm air temperature. Pressure data tend to decrease as season progresses. On the time sequence, diurnal variation ranging of several hPa and monthly scale variation ranging 5−10 hPa existed. Latter time scale variation corresponded to the monthly scale temperature change, i.e., temperature decreased as the pressure decreased.

5. Heavy precipitation event on November 9, 1995

Sporadic heavy precipitation occured on November 9−10 by the cyclone migrating from the Bay of Bengal and caused many disasters in the Himalayas. An avalanche at Pangka village, about 10 km north of Syamboche, swallowed many foreign trekkers (Yamada et al., 1996). To investigate the meteorological condition there, Aanderaa-AWS and precipitation data were optionally collected on December 4. Figure 5 shows the time sequence of the meteorological elements, such as temperature, 0.5 cm soil temperature, downward and upward short wave radiation, wind velocity and wind direction, from October 6 to December 4. Since November 9, diurnal variation of the soil temperature disappeared and upward shortwave radiation suddenly increased, indicating that it was snowy in Syangpoche and snowcover remained until November 14−15 in the observatory. Temperature data also stayed below 2℃ without the diurnal variation. Two explanations would be made for this low temperature : one is that radiation screen trapped snow to keep low temperature inside the sensor, and the other is that snow covered the surface in the valley to prevent local circulation and suppress heating of the valley atmosphere. Unfortunately, accurate wind speed and direction was not measured at 30 minutes interval due to freezing and accumulation of snow at sensors. But generally, the wind direction data indicated that sporadic northerly wind prevailed during the week. Total precipitation for November 9−11

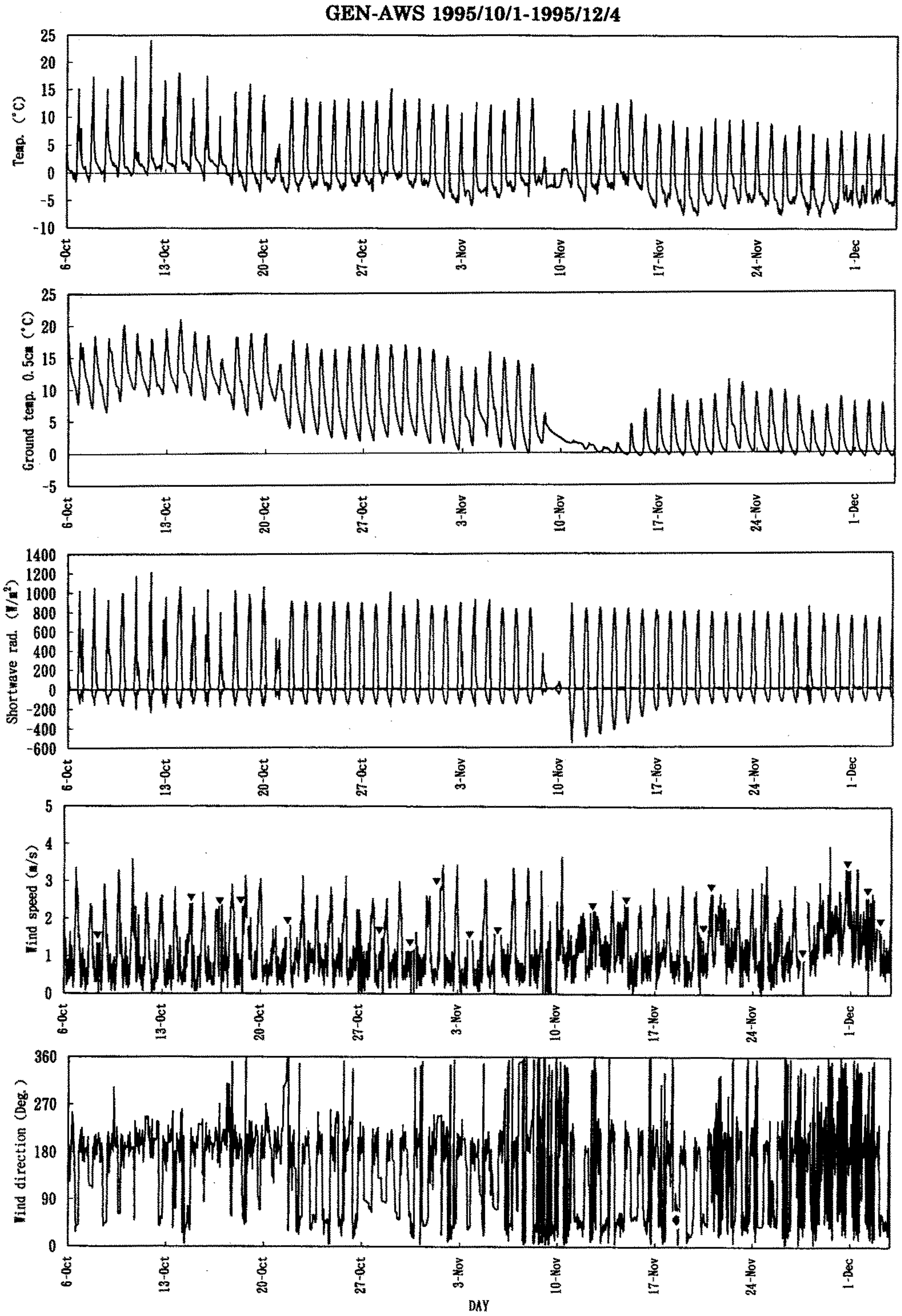

Fig. 5 Same as Fig. 4, but from October 6 to December 3, 1995.
Downward and upward shortwave radiation are indicated in the same figure, as positive and negative value, respectively.
Triangles for the wind speed indicate the lack of data.

was measured as 122.5 mm, without correction of wind induced undercatch. Precipitation was intermittently counted even in the night through Sep. 9 to 10, thus precipitation was provided not only as snow but also with rain or sleet. Then, it was melted on the orifice of the gauge in the daytime to be counted enough for daily amount by the tipping bucket. As shown in Fig. 3, daily precipitation exceeded 70 mm/d on November 10, which was an abnormal record through the year in the Syangpoche village.

This is a good case that the AWS provided accurate time stamps and meteorological values for natural disaster in Himalaya. In the future, if the data can be measured by on-line system linked with satellite imagery in Kathmandu, we might be able to use the AWS data to alert the local people for disaster prevention.

6. Sensor calibration and data management plans

Temperature, and radiation data are planned to be compared with standard instruments by manual observation once a year at Syamboche to correct the annual scale data trend due to physical deterioration of the sensors. Pressure and humidity sensors must be changed to spare parts once in several years, and removed sensors must be calibrated at Aanderaa Co. Also the sensor will be changed if a serious lack or abrupt change is found in the data sequence. All the measured digital data are stored in the data unit for half a year and are collected directly to the floppy diskette through a note-type personal computer at the observatory, or DSU is changed and carried back to DHM. This systematic data management prevents data errors by manual transcribing, and provides easy and rapid data analysis and distribution. Establishment of data management system, including technical training for AWS maintenance and data acquisition, are planned in 1996.

Most of the data trouble in 1995 was due to the abnormal consumption of the backup battery. To prevent the missing of data in DSU, installation of solar panel are urgently required. Also, spare parts of sensors must be ready for the coming deterioration to keep data in standard accuracy.

7. Concluding remarks

The first year was a set-up phase for GEN-AWS, when the observatory was arranged and main sensors were installed. In the next step, we need to establish systematic maintenance, data management and distribution system under the international cooperative studies. To keep the climate station for decadal scale, this step will be the most important phase.

An international meteorological project, GEWEX Asian Monsoon Experiment (GAME), is now proposed as a part of WMO (World Meteorological Organization) GEWEX project. Asian AWS Network (AAN) is one of the branch projects in the GAME, to establish AWS network in Asian monsoon region. AAN plans to measure surface heat flux and monitor the weather in different land surface condition and climate areas. GEN-AWS is one of the candidates to compose the AAN in the representative mountainous areas of the Himalayas, in Nepal.

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