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Outline of the study project on the role of snow and ice in the water cycle on Qingzang Plateau, 1990–93

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Abstract

The general aspects of the China-Japan joint study on the water cycle on Qingzang (Tibet) Plateau, CREQ Project, done during 1990 to 1993 are described. This study focused on the role of snow and ice in the water cycle. The study mainly consisted of automatic long-term and intensive in-situ meteorlogical, hydrological and glaciological measurements in the Tanggula Mountains in the central part of the Plateau. Additional study has been made through analysis of satellite images, data collection of conventional stations and precipitation sampling on a larger spatial scale.

1. Background and aim of the study

The Asian highland where the Tibetan Plateau, Himalaya, Tian Shan, Karakoram and Pamir are located is generally cold throughout the year although they are situated in low to mid latitudes. Precipitation conditions vary, from a high 1000 to 2000 mma^{-1} in the southern part and low, less than 100 mm, in the northern part. Due to such low ground level air temperature, solid phase water such as glaciers, snow cover and permafrost exists on various spatial and temporal scales. This is primary the result of the climate, but there seems to be feedback to the climate system through various meteorological and hydrological processes, such as the negative relation between central Asian snow cover and the summer monsoon. Furthermore, the distribution of snow and ice and change in their structure will modify the runoff to the surrounding arid to semi-arid areas.

Such snow and ice does not occur independently from other climate components, but forms a part of regional land surface-atmosphere system. The land surface includes the land surface layers (soil, rocks) vegetation and water reservoirs such as glaciers, snow cover and lakes, and they show slow response. On the other hand, the atmosphere shows fast response. Such a system has an annual equilibrium state in the present global system, and will show certain variations, with feedback to the regional and global climate. In the present state of global change, investigation of the characteristics of the land surface-atmosphere system and its variation, through an efficient observation system, is strongly needed to evaluate the environmental change in this region and influence over a wider area. Such study in the Tibet Plateau Region will contribute to understanding the variation in the hydrological cycle and large scale monsoon system in this region.

The present study, which was planned under the above scientific background, will focus on the water cycle, especially the charcteristics of snow and ice and their role in this cycle and strongly related energy cycle in the land surface-atmosphere system. The spacial scale was mainly less than 100 km in the central part of the Tibet Plateau, with some wide area study ; the temporal scale was mainly daily to seasonal although for certain processes interannual variability was considered.

Past studies related to the present study have looked at atmosphere-land surface interaction. Intensive observations of surface water/heat balance, including evaporation, were made at a few sites on the Plateau in 1979 and 1982–83 (Li *et al.*, 1987 ; Chinese Academy of Science, 1984). Glacier, permafrost and runoff studies have been done on the Plateau by CAS since the 1960's (CAS, 1986). Recently, Japanese and Chinese scientists have been studying the glaciers, atmospheric processes and hydrological processes in the West Kunlun, and have done a preliminary study in the Tanggula and Nienchengtanggula Region (Zheng *et al.*, 1989 ; Yao *et al.*, 1991a ; Yao *et al.*, 1991b). A U.S. —Chinese group did a short term radiation study in the central region (Reiter *et al.*, 1987).

The four main themes of the present study are as follows :

(1) Clarify the role of the cryosphere in the seasonal variation of all components of land surface water circulation (precipitation, water storage, evaporation, runoff and others) for a unit drainage area where glaciers exist, and deduce the trend and interrelationship between them.

(2) Investigate the behavior of the atmosphere, particulary the Planetary Boundary Layer, on the Tibetan Plateau in relation to land surface-atmosphere interaction.

(3) Find the possibility and method of the usage of visible, infrared and microwave satellite data for these studies.

(4) Investigate the climate and cryosphere variation in Tibet, including the effect of recent global warming.

The main method of study was field measurement, in the central part of the Plateau, the Tanggula Mountain area. Intensive meteorological, hydrological and glaciological measurements were made within this area. Additional information on areal distribution of hydrological components was obtained through analysis of satellite images, and chemical analysis including stable isotope analysis of water samples. The main time scale of concern was the seasonal and interannual variation. A detailed despcription of the background and problems to be solved is given in a booklet published in 1992 (CREQ Study Group, 1992)

This project is a cooperative study between the Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences headed by Prof. Yao Tandong, and a Japanese University group headed by Prof. Yutaka Ageta of the Institute for Hydrospheric -Atmospheric Sciences, Nagoya University (the name of the Instutite was changed from Water Research Institute in 1993). The whole project was called the CREQ (Cryosphere Research on Qingzang Plateau) Project. The previous studies made in this area in 1989 were reported in Yao *et al.* (1991a), Ageta *et al.*

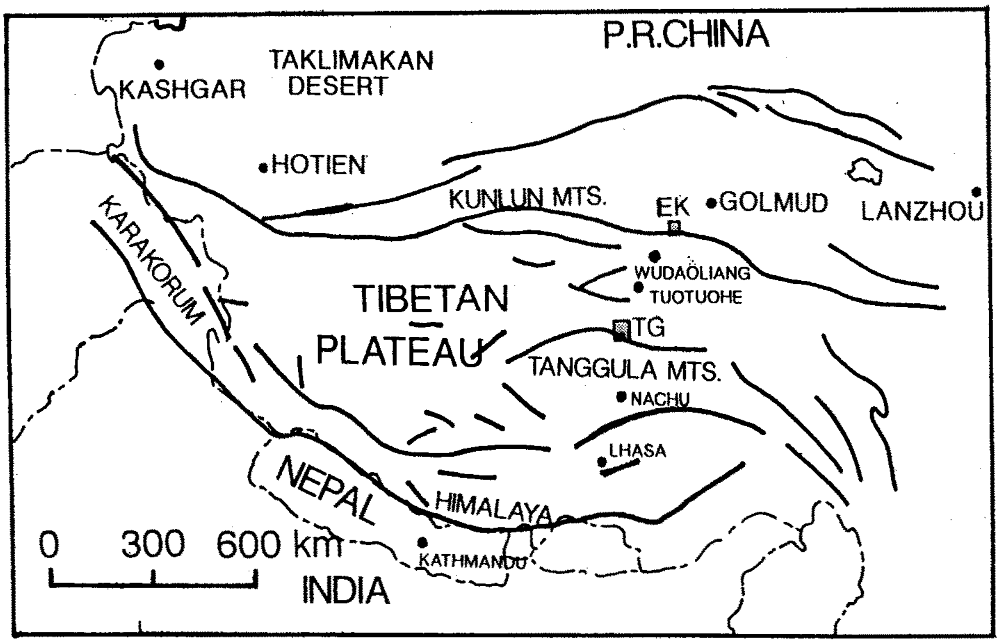

Fig. 1. Map of the study region. TG : Tanggula Mountain study area, EK : East Kunlun Mountain study area.

(1991) and Ohata *et al.* (1991), and a series of papers was presented in Yao and Ageta (1993).

This project was a contribution to the International Hydrological Programme (IHP) Phase 4 and the International Geosphere Biosphere Programme (IGBP) Core Project "Biospheric Aspects of Hydrological Cycle (BAHC)". Financial support for the Japanese side in this study came from the International Scientific Research Program of a Grant-in-Aid for Scientific Research and IGBP Scientific Research, both from the Ministry of Education, Science and Culture, Japan. As for the Chinese side, this project was supported by Natural Science Foundation of China.

2. Location of field work

The main area of study was the northern side of the Tanggula Mountain Region located in the central part of Tibetan Plateau shown in Fig. 1. This mountain range is one of the few large mountain ranges running east-west on the Plateau. The highest peak is the 6621 m peak. Three drainage areas were taken as the study unit as shown in Fig. 2. The largest drainage area, which includes other two drainages, is 4,538 km^2 ; within this drainage area, 4.5 % is glaciers. The smallest drainage is 50.5 km^2, 33 % of which is glacier area. The glaciers, rivers and lakes, and main observation points, are shown in Fig. 2. Permafrost exists in most of this drainage area, having a thickness from 20 to 130 m (Tong and Li, 1983). In addition, a glacier mass balance study was done on a glacier in the Xidatan area of East Kunlun (Shown as EK in Fig. 1).

The general annual climate of this area is shown in Fig. 3 using the data from Nachu (4507 m a.s.l.) 200 km south of Base Camp. This area is under the influence of the summer Asian monsoon from May to September, as can be seen from the precipitation data. At Nachu, the annual mean air temperature is $-1.9\ ^\circ$C, and total precipitation is 400 mm. The annual mean air temperature at the average altitude of the Tanggula study area, approx. 5000 m, is -4.9 °C, which is in a temperature range that allows the existence of permafrost.

3. Research members and field work period

Research work including the field study and analysis, from 1990 to 1993 was done by the following members. The specialized study fields of the members and time of the field work are written in parentheses. Notations are as follows : 90 to 93 corresponds to 1990 to 1993 ; A : Autumn, S : Spring ; 93−1 to 93−3 stands for 1st to 3rd period in the Intensive Observation Period from May to September in 1993. The family names are written in capital letters.

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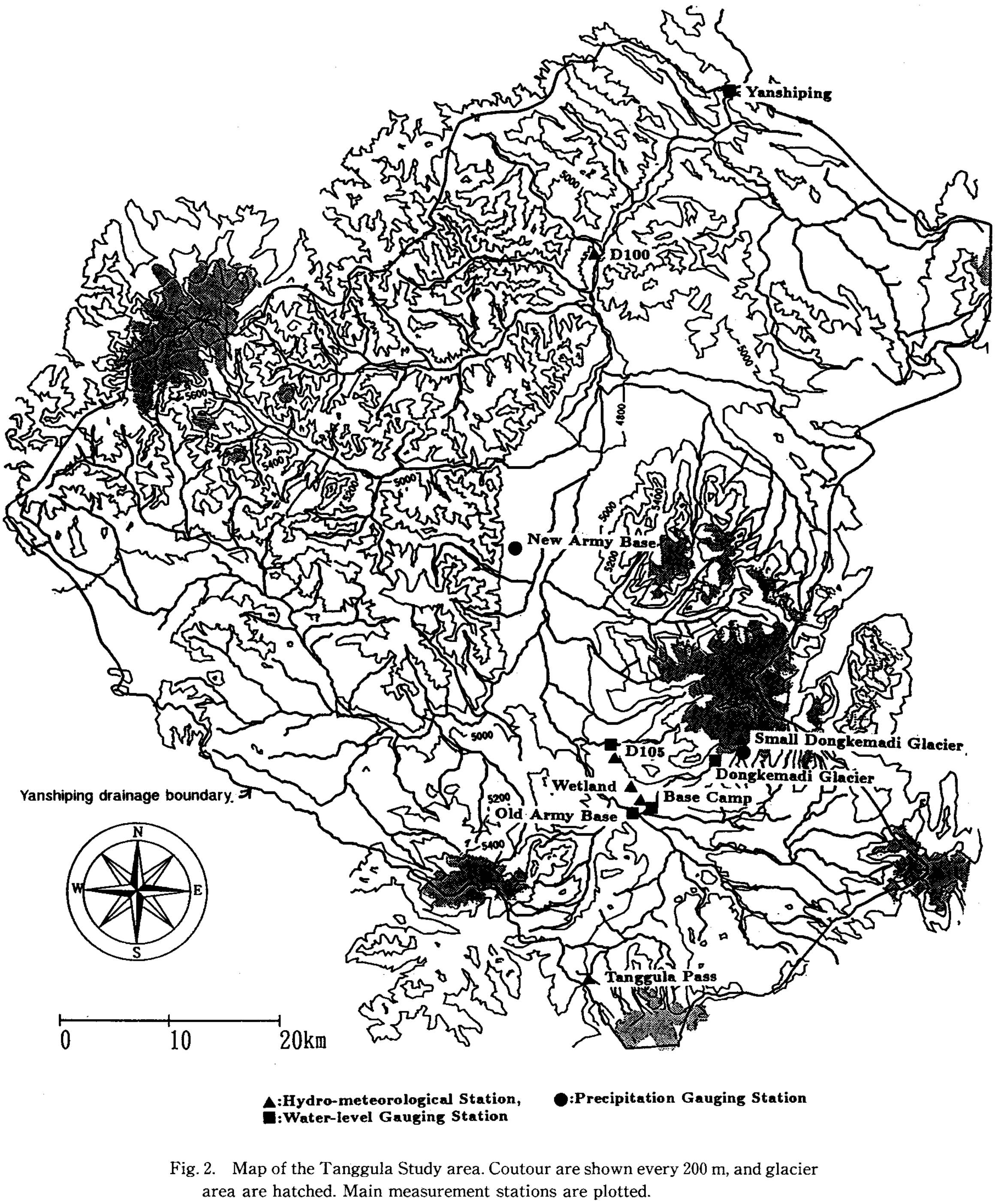

Fig. 2. Map of the Tanggula Study area. Coutour are shown every 200 m, and glacier area are hatched. Main measurement stations are plotted.

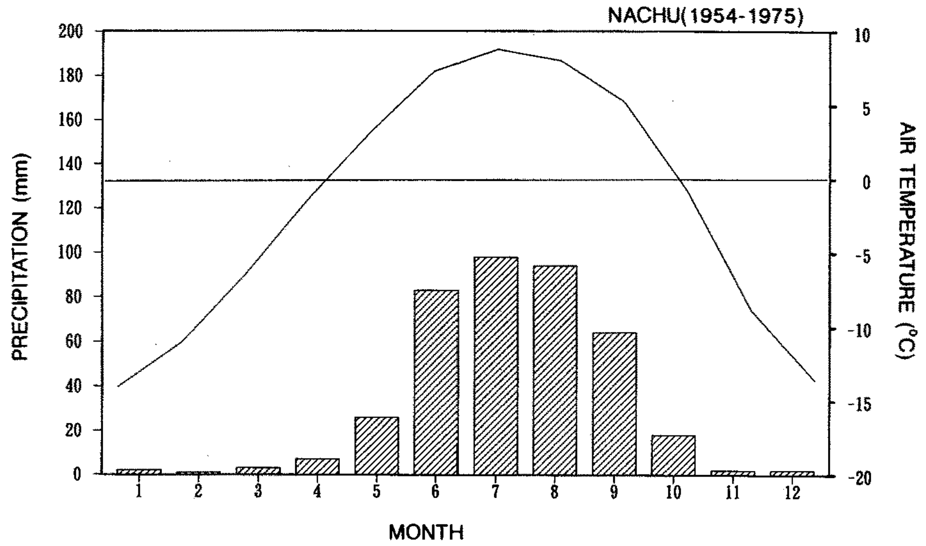

Fig. 3. Climatological value of monthly air temperature and precipitation at Nachu (After CAS, 1984).

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All members are from Lanzhou Institute of Glaciology and Geocryology, CAS.
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Senior Engineer
ZHANG Yinsheng (Meteorology)
Assistant Professor
KANG Xincheng (Meteorology)
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TIAN Lide (Glaciology)
Post Graduate Student
KANG Shichang (Climatology)
Post Graduate Student
XIAO Cunde (Glaciology)
Post Graoduate Student
HOV Shugui (Glaciology)
Post Graduate Student

4. Research work

The methods used for the present study can be classified into three categories, long term monitoring, intensive process study and sampling. Other parts of the study were satellite image analysis and analysis of the meteorological and hydrological data of permanent stations.

4.1. Long term monitoring

Since the 1989 intensive observations, measurements of the meteorological conditions, including meteorological elements and ground temperature, glacier conditions and runoff has been made in the study area using automatic measurement systems, the time duration depending on the elements. Table 1 shows the sites and measured elements. The sites have been changed slightly due to maintenance conditions. The numbers of elements and sites were increased gradually in autumn 1991 and spring 1992. The numbers of measurement sites and measured elements were increased considerably in autumn 1992 as preparation for the intensive observations in 1993. Most of the instruments are still functioning in March 1994, and will be recovered in May 1994. These long

Table 1. List of types and periods of observations made during 1989 to 1993. The number in parentheses below each site are the altitudes.

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                      o      : Manned observations
                  ---------- : Meteorological obs. (Auto and manual)
                  * * * *    : Glacier meas.       (Auto and manual)
                  + + + +    : Runoff meas.        (Auto)
                      >      : Continued

Site/Year         1989        1990        1991        1992        1993
  Month           1. . . . .7. . . . .1. . . . .7. . . . .1. . . . .7. . . . .1. . . . .7. . . . .1. . . . .7. . . . .
  Manned obs         oo o        o    o       o    o       o    o        ooooo
                                                                          IOP
 [TANGGULA]
D105                 ---------------             ---------------------------------->
  (5020m)
D104                                      -----
  (4900m)
Xiao Dongkemadi                                  ---------------------------------->
  Glacier            * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * >
  (5380-5920m)
Da Dongkemadi                                                    *    *       * * * *
  Glacier
  (5280-6100m)
Tanggula Pass (TS)                                                    --------------
  (5206m)
Wetland (WL)                                                          -------------->
  (5100m)
D100                                                                  -------------->
  (4800m)
Base Camp (BC)                                                              --------
  (5060m)                                                             + + + + + + +>

Yanshiping
  (4800m)                                                             + + + + + + +>
D106 (Old Army Base)
  (5030m)                                                             + + + + + + +>
 [EAST KUNLUN]
D66                                  ----------
  (≈4500m)
Meikuang            *    *     *    *     *     *     *    *       *   *   *
  Glacier
  (4790-5520m)
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-term measurements will be analyzed to clarify the mean meteorological conditions and year to year variability of surface heat-water fluxes, ground surface conditions and runoff.

Besides these measurements, glacier mass balance studies on selected glaciers have been continously carried out on the Meikuang Glacier in Xidatan on the north slope of the East Kunlun Mountains and Xiao Dongkemadi Glacier on the northern side of the main range of the Tanggula Mountains from 1989 to 1993.

During the period from 1989 to 1993, the automatic instruments were maintained and glacier measurements were made approximately every six months by Japanese and/or Chinese scientists as shown in Section 3.

4.2. Intensive observations in 1993

Manned intensive observations (IOP) were made in the summer of 1993. Measurements in the Tanggula area by Japanese members lasted from May 14 to September 23, 1993. The whole period was divided into three parts, as mentioned in section 3 ; members were changed in order to maintain continuous measurements under the severe conditions of high altitude.

The following observations were added during the IOP, as only a limited number of hydrological components can be measured with automatic instruments,

4.2.1. Meteorology and climatology

In order to evaluate the areal meteorological, surface conditions and surface heat/water fluxes, Aanderaa automatic measurement systems were set up at five sites (D100, D105, WL, TS, GL shown in Fig. 2) in an altitude range from 4800 to 5600 m a.s.l. from October 1992 to September 1993 including the IOP. Other observations made during the IOP were the following:

(a) General meteorological conditions at BC (Base Camp)

Eye and instrumental measuremets of general meteorological elements, heat balance measurements, snow cover measurements and precipitation sampling were made every three hours. These observations were done to obtain data which can not be measured by automatic instruments.

(b) Aerological observations with sonde system.

152 measurements of upper wind, air temperature and humidity were made to clarify the characteristics of the daily variation of atmospheric boundary-layer and seasonal variation of the troposphere.

(c) Aerial distribution of precipitation

Several precipitation stations were set up in the study area in order to obtain areal precipitation gauges, in addition to the automatic measuring stations.

4.2.2. Hydrology

(a) Evaporation, soil moisture, soil temperature and permafrost table measurements at various sites.

These were made to investigate the evaporation and moisture characteristics and the water storage in the surface ground layers under permafrost conditions.

(b) Vegetation types and biomass observations.

These were made to identify the type and amount of surface vegetation, and evaluate the evapotranspiration and radiative characteristics of the ground surface.

(c) Runoff.

Three basic runoff measurement points (BC, D106 D106 (Old army base), Yanshiping) were functioning from 1992. Additional points were set up at the glacier terminus and a site near D105 in order to compare the runoff characteristics of glaciated and non-glaciated basins.

(d) Intensive short-term measurements of heat balance at sites WL, D105 and Xiao Dongkemadi Glacier.

These were done to investigate the diurnal variation of surface heat/water fluxes under different surface conditions.

4.2.3. Glaciology

(a) Glacier mass balance measurements.

Variations in the mass storage of the glacier were observed through this work. Every 10−15 days measurements were made on Xiao Dongkemadi Glacier, based on 28 stakes. On Da Dongkemadi Glacier, 9 stakes were set up along the east main flow line, and measured on May 26 and September 19. Ice temperatures and superimposed ice were also measured at several points on Xiao Dongkemadi Glacier. On Meikuang Glacier in East Kunlun, mass balance measurements were made on May 13, July 6 and September 25 based on 18 stakes.

(b) Impurities on glacier surface and surface albedo.

Biological and aeolian impurities on glaciers were studied in order to clarify the radiative charcteristics and effects on albedo at the snow surface.

4.2.4. Satellite ground truth

Ground truth measurements for various satellites (EERS, MOS1, LANDSAT) were carried out. This was a basic study in order to develop a method for retrieving areal hydrological and ground surface information from the satellites. Surface conditions such as ground moisture, vegetation and snow cover were measured on the dates of satellite passes in this area along the Qingzang Highway.

4.3. Water sample and data collection

4.3.1. Precipitation sampling

This was done to study the temporal and spatial features of oxygen isotope and chemical elements, to reveal the variation of the northern boundary of the monsoon. Precipitation, runoff and snow samples were collected in the intensive study area, and precipitation samples at conventional meteorological stations (Lhasa, Dangxiong, Nachu, Amdo, BC, Tuotuohe, Wudaoliang) at various locations along the Qingzang Highway. The quality of samples differs among the stations. More than 400 samples were collected at the Tanggula Base Camp in 1993, and only few were collected at Dangxiong.

Additional precipitation sampling was done at four sites in Nepal (Kathmandu, Ilam Tea Estate, Doti and Langtang) on the southern side of the Great Himalaya Range, to study the effect of the Himalaya Range on vapor transportation in the atmosphere.

4.3.2. Snow cover sampling

The major purpose of this was to monitor the changes of stable isotopes and chemical elements in snow cover with time. Snow samples were collected just after snowfall and afterward regularly until snow cover melted away.

4.3.3. Glacier discharge sampling

River water samples were collected three times a day during the summer at BC, for stable isotope analysis and conductivity measurements.

5. Logistics

Visits to the study area from 1990 to 1993 were made approximately every half year by 1 to 3 Japanese members and several Chinese members. Unsually, 1 to 2 jeeps were used, and in case there was much equipment (1992 Spring and 1992 Autumn), one truck was used for transportation. During the IOP in 1993, two jeeps and two trucks were necessary.

The total amount of scientific and logistic equipment which was transported from Japan ranged from 50 to 500 kg from 1990 to 1992, and was 1,900 kg for the IOP in 1993.

There were the following problems in the systematic measurements and operations during the monitoring period and IOP.

(1) Damage to the instruments by domestic animals ; water inflow to the containers of instruments in case of abrupt rise of the water table.

(2) Thunder, which is quite common in summer, damaged several automatic instruments and influenced operation.

(3) Inaccessibility to the glaciers from the main Highway by vehicles due to softening of the ground surface by melt water. The last possible date was the beginning of June ; from the middle of September, access again became possible.

Several members suffered from slight high-altitude sickness. Simple medical treament was available at Tanggula Army Station, one hour by jeep from the BC. A hospital was available only at Golmud, north of the East Kunlun Mountains, more than 10 hours ride along the Qingzang Highway from BC.

6. Concluding remarks

Details of the observations and preliminary results in this project are presented elsewhere in this issue. The results of future analysis will be published in the near future.

Acknowledgments

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