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NOTES AND CORRESPONDENCE

Meteorological Observations in the Tanggula Region, Tibetan Plateau during 2005

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ABSTRACT

This note summarizes meteorological observations in the Tanggula region of the Tibetan Plateau in 2005. The variations of the wind velocity, air pressure, radiations, air temperature, relative humidity, precipitation and the soil moisture content at 5 cm are shown. The variations of the observed items have seasonal and diurnal characteristics.

Key words: Wind velocity, Radiations, Air temperature, Relative humidity, Precipitation

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1. INTRODUCTION

The Tibetan Plateau has a mean elevation of over 4000 m. It is the third terrace of the China continent (Zhou et al. 2000). It plays a significant role in the Asian monsoon system (Yeh and Gao 1979). There is a thermal anticyclone above the plateau (Flohn 1957; Yanai et al. 1992). Yanai et al. (1992) indicated that the Tibetan Plateau maintains a large-scale thermally driven vertical circulation which is originally separated from the planetary-scale monsoon system. It is important to understand the mechanisms of the heat and water cycles over the Plateau. The research work concerning land-atmosphere interaction has attracted the attention of geoscientists internationally.

Recently, several large research experiments were accomplished on the Tibetan Plateau. In 1979, the Chinese Qinghai-Xizang Plateau Meteorology Experiment (QXPMEX) was carried out. From 1982 to 1983, the Chinese scientists investigated heat sources on the Tibetan Plateau for the whole year and obtained long-time solar radiation data for the research work on ground surface heat balance (Ji et al. 1986). The GEWEX (Global Energy and Water Cycle Experiment) Asian Monsoon Experiment (GAME) started in 1996. In support of this international program, the Second Tibetan Plateau Experiment of Atmospheric Sciences (TIPEX) was initiated by Chinese researchers in 1998; following that, the CEOP (Coordinated Enhanced Observing Period) Asia-Australia Monsoon Project (CAMP) on the Tibetan Plateau (CAMP/Tibet) was performed from 2001 to 2005. The World Climate Research Program (WCRP) Climate and Cryosphere Project (CliC) also regarded the Tibetan Plateau as an important research region, and they put forward the land-surface processes in the permafrost region should be studied further. Those scientific experiments made rapid progress in observational studies and revealed some land surface processes about the surface energy budget, regional evaporative fraction and the seasonal variability of soil moisture distributions (Tanaka et al. 2001; Hirose et al. 2002; Ma et al. 2003; Yang et al. 2004).

Tanggula Mountain is located in the interior of the Tibetan Plateau. The underlying surface is high-altitude permafrost and the vegetation is dominated by alpine frost grassland and alpine frost meadow species. With the warming of global climate, the permafrost exhibited a tendency of degradation which influenced on the vegetation and the en-

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vironment. Over the past 30 years, the area of permafrost in Xidatan region on the Tibetan Plateau decreased about 12% due to climate warming, and the lowest elevation of permafrost receded 25 m (Wu et al. 2005). Moreover, in the last 15 years the area of alpine frost swamp meadow ecosystem in Kunlun Mountain-Tanggula Mountain region sharply decreased about 28.1% (Wang et al. 2006). Such changes influence the local microclimate on the Tibetan Plateau.

The main purpose of this paper was to investigate the characteristics of the microclimate in typical permafrost region on the Tibetan Plateau. The work was mainly about meteorological observations. Ohata et al. (1994) reported the results of meteorological observations in the Tanggula region from 1989 to 1993 under the auspices of the Cryosphere Research on Qingzang Plateau (CREQ) Project. He indicated there were only a limited number of permanent meteorological stations in this area and measured elements were too few to obtain. However, meteorological observations were important to understand and simulate land-atmosphere interaction (Su and Chu 2007; Lebedev and Kostianoy 2008; Shih 2008). The meteorological observations were necessary on the Tibetan Plateau.

2. SITE AND INSTRUMENTS

The observation site belongs to the Cryosphere Research Station on Qinghai-Xizang Plateau, Chinese Academy of Science, which is a permanent station and primarily monitors the permafrost environment. The site (91 56'E, 33 04'N, 5100 m asl) lies on a gentle slope near the Qinghai-Xizang highway in the Tanggula region comprised of continuous frozen ground region (Fig. 1). The underlying is permafrost and the vegetation is alpine frost grassland.

The observations rely mainly on a 10-m-high meteorological tower. The instruments and measurement heights are presented in Table 1. Power is supplied by the solar panels. The data was acquired by the CR23X data collector. Its frequency was 30 seconds; however, the air pressure was obtained by the LI7500 sensor of the open path eddy covariance system at a frequency of 10 Hz. The data collector of the eddy covariance system was CR5000. The power was supplied by the solar panels as well. The observation periods were throughout 2005 and the recorded time was Beijing time.

3. ANNUAL VARIATIONS OF METEOROLOGICAL ELEMENTS IN 2005

3.1 Air Pressure and Wind Velocity

The variation trend of the air pressure was similar to the result of station D105 (90 04'E, 33 00'N, 4990 m asl) which is near the observation site (Ohata et al. 1994; Zhang et al. 1994). The air pressure was high in the summer and low in the winter (Fig. 2a). It was consistent with the variations of the air temperature. On average, the air pressure was 542 hPa in the spring, 544 hPa in the summer, 545 hPa in the autumn, and 538 hPa in the winter. The mean air pressure for the year was 542 hPa which was lower than station D105 11 hPa perhaps owing to the difference of the site/station altitude (Zhang et al. 1994).

Wind velocity was high in the winter but low in the summer (Fig. 2b). The mean annual wind velocity at 10 m height was 4.9 m s^{-1}. The maximum wind velocity occurred in February and the minimum velocity occurred in August. The maximum wind velocity was 22.4 m s^{-1} throughout the year. The monthly wind velocity is shown in Table 2. The variations in wind velocity was also similar to station D105 (Ohata et al. 1994).

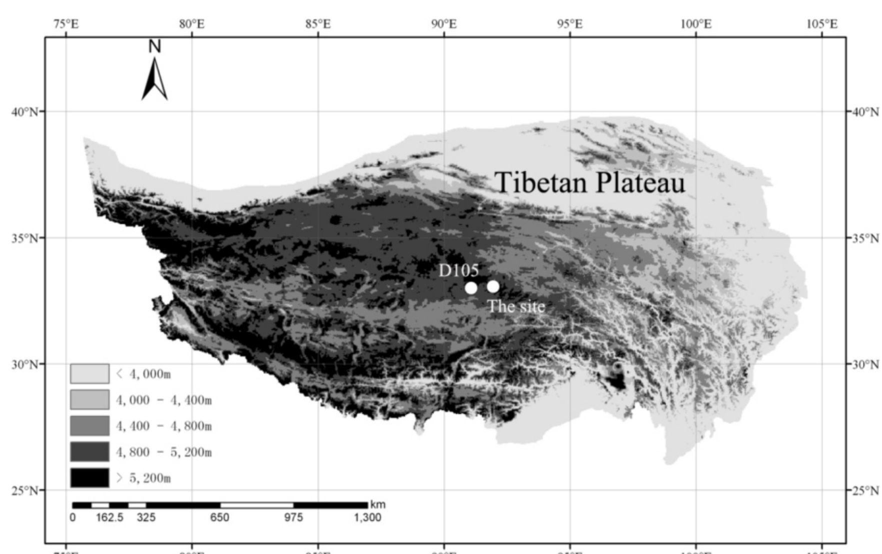

Fig. 1. Location of the observation site.

Table 1. List of the meteorological measurements.

Observation item	Instrument	Accuracy	Height	Frequency
Air pressure	LI-7500	±1.5%	3 m	10 Hz
Wind velocity	05103_L Wind Monitor	±0.3 m s^{-1}	10 m	30 seconds
Air temperature	HMP45C temperature/RH Probe	±0.5°C	2 m	30 seconds
Relative humidity	HMP45C temperature/RH Probe	±0.04%RH/°C	2 m	30 seconds
Precipitation	T-200B Precipitation Gauge	0.1 mm	5 meters away	30 seconds
SMC	CS616 Water Content Reflectometers	±2.5%	5 cm	30 seconds
Snow depth	SR50 Sonic Ranging Sensor	1 cm	2 m	30 seconds
USR	CM3 Pyranometer	10%	2 m	30 seconds
ULR	CG3 Pyranometer	10%	2 m	30 seconds
DSR	CM3 Pyranometer	10%	2 m	30 seconds
DLR	CG3 Pyranometer	10%	2 m	30 seconds
PAR	Li190SB Quantum Sensor	±5%	2 m	30 seconds

Notation of meteorological elements: SMC: Soil moisture content; USR: Upward short wave radiation; ULR: Upward long wave radiation; DSR: Downward short wave radiation; DLR: Downward long wave radiation; PAR: Photosynthetically active radiation.

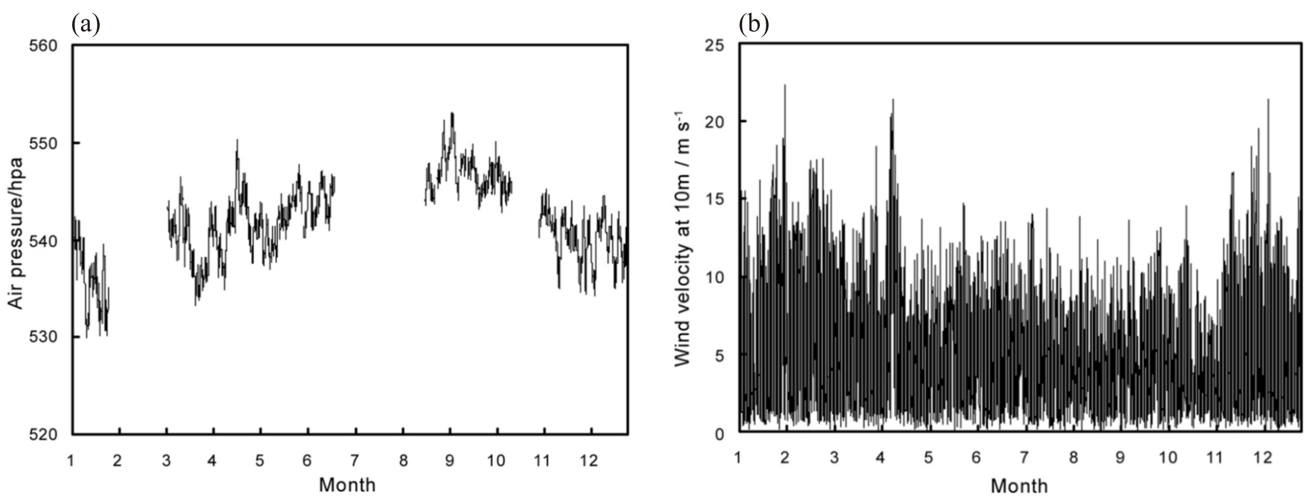

Fig. 2. Variations of the air pressure (a), the wind velocity at 10 m (b) in 2005.

Table 2. Monthly mean values of the wind velocity at 10 m in 2005.

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
WV [m s^{-1}]	6.0	6.3	5.4	5.6	4.6	4.7	4.4	3.8	4.1	4.3	4.4	4.9	4.9

3.2 Air Temperature, Relative Humidity and Specific Humidity

The air temperature in this region was low due to its high altitude. It was negative in winter or spring and positive from June to September (Fig. 3a). August was the hottest month and January was the coldest (Table 3). The maximum air temperature value was 15.3 C and the minimum was -27.5 C over the year. The annual air temperature range was large and about 20.5 C, and similar to the results

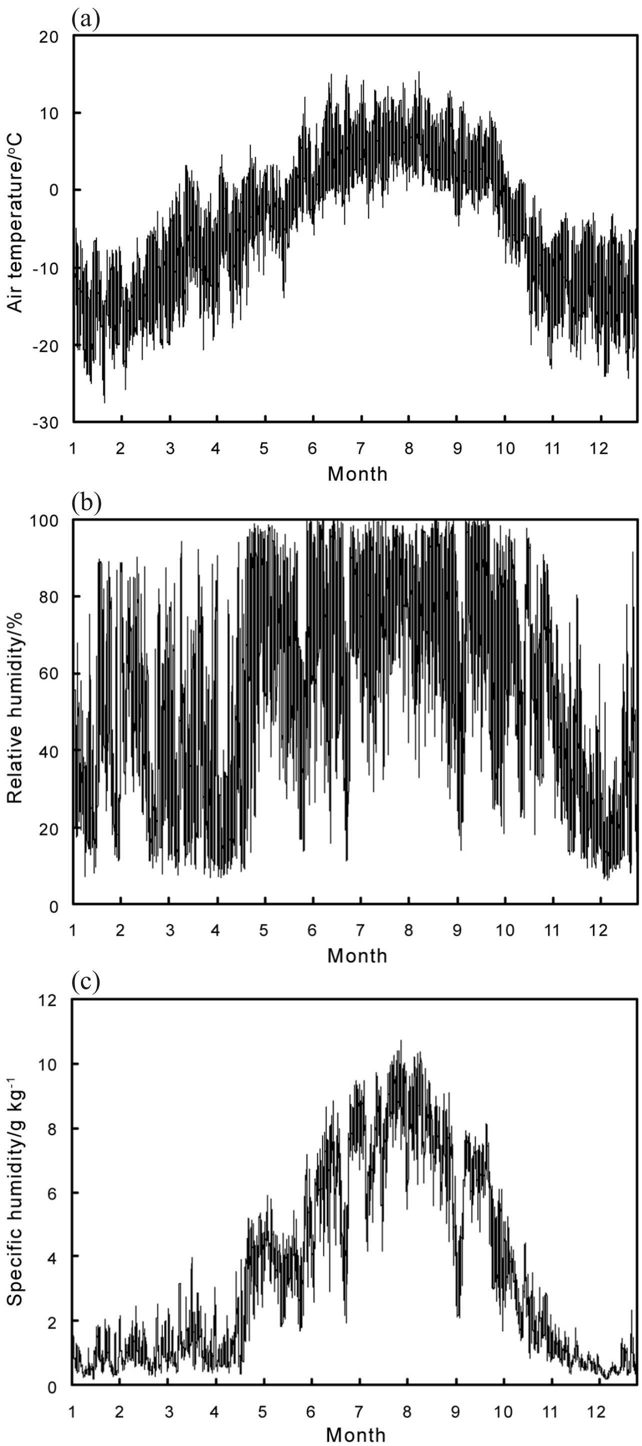

Fig. 3. Variations of the air temperature (a), relative humidity (b) and specific humidity (c) at 2 m in 2005.

at station D105. One of the reasons may be the deep isolation and low density of air due to the high altitude (Ohata et al. 1994).

The mean air relative humidity was 55.9% in 2005. It had large seasonal characteristics which were high in the summer and low in the winter (Fig. 3b). This may be attributed to the effects of the monsoon and the thawing of the active layer. Precipitation was concentrated in the summer because of the monsoon, and it brought much water vapor to the air. Moreover in the summer, the active layer thawed and led to an increase of the surface moisture which could help to enhance the evapotranspiration and bring much water vapor to the air.

The specific humidity is the mass ratio of the water vapor to the air. It was obtained by Eq. (1):

$$q = \frac{\varepsilon e}{p - 0.378 \times e} \tag{1}$$

where q is specific humidity and the unit is g g^{-1} or g kg^{-1}; p is air pressure, and the annual average value 542 hPa was used here; e is water vapor pressure and ε is the constant of 0.622 (Sheng et al. 2003).

The variations of the specific humidity were greater and had more clearer seasonal characteristics (Fig. 3c). The annual average specific humidity was 3.41 g kg^{-1}. August was the wettest month and December was the driest (Table 3).

3.3 Radiation

The radiation fluxes were listed in Table 4 including downward-short-wave radiation, upward-short-wave radiation, downward-long-wave radiation, upward-long-wave radiation, net radiation and photo-synthetically active radiation (PAR). Except for the upward-short-wave radiation, the radiation types tended to increase in summer and decrease in winter. The upward-short-wave radiation was affected strongly by the conditions of the underlying surface, such as the growth of vegetation, frozen or thawed ground surface and snow cover. The snow data indicated that the ground surface was covered by snow during January, May, October, and November in 2005. The upward-short-wave radiation became correspondingly large and affected the

Table 3. Monthly mean values of air temperature (°C) and specific humidity (g kg^{-1}) at 2 m and their ranges in 2005.

Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ave.**
Air temperature	-14.9	-13.8	-8.5	-5.7	-2.0	3.0	5.1	5.6	2.9	-5.1	-12.2	-13.7	-4.9
Monthly air temperature range	13.1	12.0	15.2	14.1	10.6	11.6	10.5	9.9	10.8	11.3	13.8	14.9	
Specific humidity	0.77	0.97	1.22	1.82	3.79	5.91	7.81	8.05	6.00	2.93	1.06	0.55	3.41

albedo results. The albedo was low in summer but high in winter (Fig. 4). There were several reasons: the vegetation was present in the summer which increased the surface roughness and decreased the albedo. The precipitation concentrated in summer because of the monsoon, moreover the active layer was thawed, and then the surface moisture became high which led to the decrease of the albedo. However, the active layer was frozen and little vegetation was present in the winter so that the albedo during that time was higher. If there was snow on the ground, the albedo would increase much higher (Fig. 4). The similar results were obtained at other sites on the Tibetan Plateau, such as Amdo. (Li and Hu 2006, 2009). In statistic, the mean albedo in this region was 0.31.

Table 4. Total monthly radiation in 2005.

Month	Downward short wave [MJ m^{-2}]	Upward short wave [MJ m^{-2}]	Downward long wave [MJ m^{-2}]	Upward long wave [MJ m^{-2}]	Net Radiation [MJ m^{-2}]	PAR [mol S m^{-2}]	Average albedo
Jan.	387.2	210.8	465.8	646.8	-4.6	819.4	0.54
Feb.	357.8	164.7	452.7	617.4	28.4	848.5	0.46
Mar.	450.1	153.1	536.3	775.6	57.7	1144.6	0.34
Apr.	449.4	161.5	581.7	797.8	71.7	1197.0	0.36
May	619.2	229.1	634.3	855.3	169.1	1496.4	0.37
Jun.	703.3	152.2	697.9	912.5	336.6	1401.8	0.22
Jul.	646.2	115.0	782.9	944.4	369.6	1239.3	0.18
Aug.	634.9	106.9	786.4	951.5	362.9	1210.6	0.17
Sep.	624.8	122.4	671.9	882.6	291.7	1149.6	0.20
Oct.	636.6	207.2	543.1	808.8	163.6	1162.7	0.33
Nov.	519.3	160.1	408.4	688.0	79.6	912.1	0.31
Dec.	467.0	118.5	376.0	675.3	49.2	799.8	0.25
Ave.	541.3	158.4	578.1	796.3	164.6	1115.2	0.31

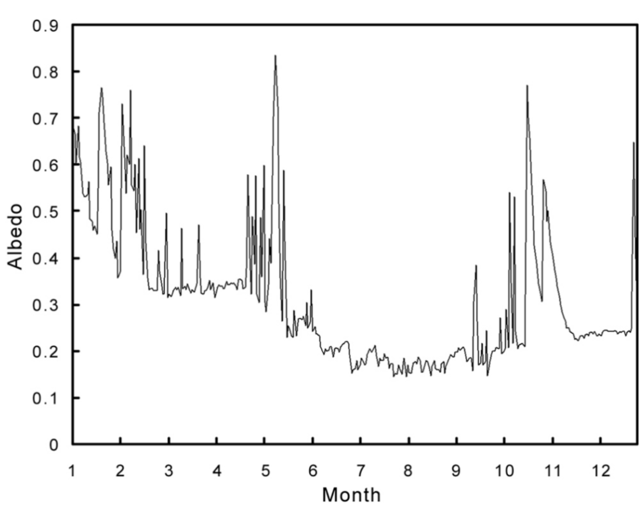

Fig. 4. Variations of the albedo in 2005.

3.4 Precipitation and Soil Moisture Content at 5 cm

Precipitation in this region mainly fell in the summer because of the monsoon (Fig. 5a). And July had the largest monthly rainfall. The largest daily rainfall was 20.1 mm d^{-1} which appeared in August. The total precipitation was 538.2 mm y^{-1} in 2005 (Table 5). Of course, there were some unavoidable disturbances during the measurements of the precipitation in winter time, such as blowing wind.

The changes of the soil moisture content mainly depended on the freezing or thawing process of the active layer and the precipitation. The active layer was thawed during May - October so that the soil moisture content increased in this period (Zhao et al. 2000). Precipitation was important to the variations of the soil moisture content. The extreme-value points of the soil moisture content corresponded to the rainfall events respectively (Fig. 5b). The summer concen-

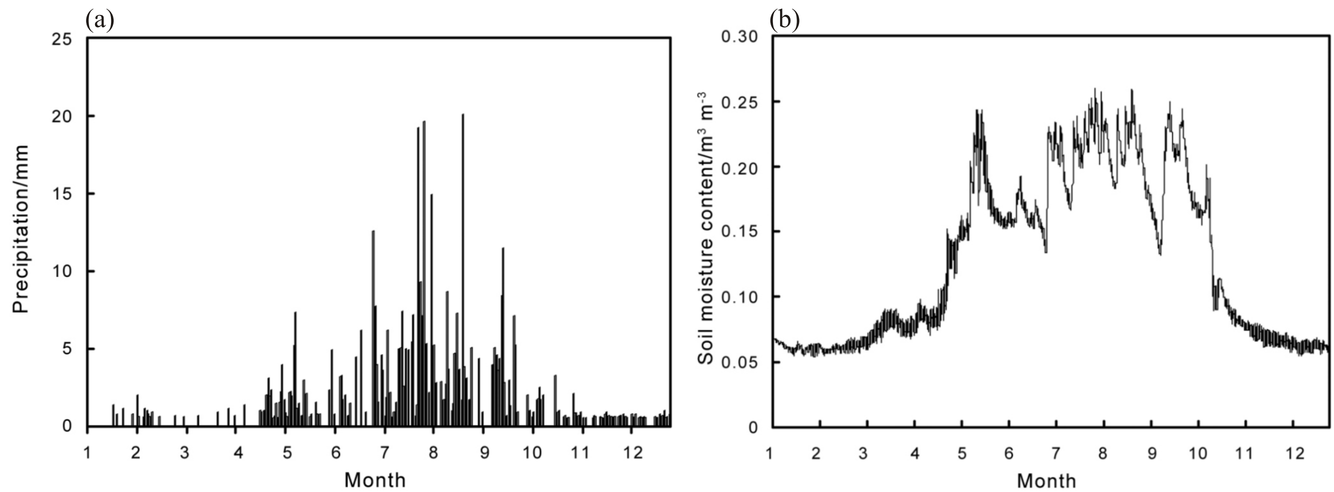

Fig. 5. Variations of the precipitation (a) and soil moisture content at 5 cm (b) in 2005.

Table 5. Total monthly precipitation for 2005.

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Precipitation [mm]	10.5	22.4	8.9	21.6	46.6	55.4	129.3	105.6	72.5	26.8	20.2	18.4
Total [mm]						538.2						

tration of the precipitation influenced the soil moisture content greatly as well.

3.5 The Diurnal Variations

September 7th of 2005 was a typical clear day in this region. It was selected to show the diurnal characteristics of the meteorological elements (Fig. 6).

It was showed that the air pressure was high during the day time but low at night and its variation range was about 1 hPa. The wind velocity was low in the morning but high in the afternoon correspondingly with the air temperature, because the variations of the air temperature could influence the turbulence activity. The specific humidity was high in the morning but low in the afternoon. It was influenced by the variations of the wind velocity. The variations of the wind velocity, air temperature and specific humidity were close. The albedo took on the variations like a “U” shape because of the influence of the solar altitute. The variations in soil moisture content were the same as air temperature.

4. CONCLUSION

This paper made a note about the meteorological observations in the Tanggula region on the Tibetan Plateau in 2005 wherein:

1. The mean annual wind velocity was 4.9 m s^{-1} and the mean air pressure was 542 hPa. Air temperature in the region was low. The maximum air temperature was 15.3 C and the minimum was -27.5 C. The mean relative humidity was 55.9%. The mean specific humidity was 3.41 g kg^{-1}. The mean albedo was 0.31. Precipitation in this region was concentrated in the summer because of the monsoon. The total precipitation was 538.2 mm y^{-1} in 2005.
2. The air pressure was high during the day time and low at night. Variations of the wind velocity, air temperature and soil moisture content were similar, low in the morning and high in the afternoon. The specific humidity was high in the morning and low in the afternoon. The variations of albedo were “U” shaped because of the solar height angle.
3. Long duration meteorological observation on the Tibetan Plateau is necessary for atmosphere and geographic research. The continuous observation results are important for further study and should be continued in which more observation points should be set up on this Plateau.

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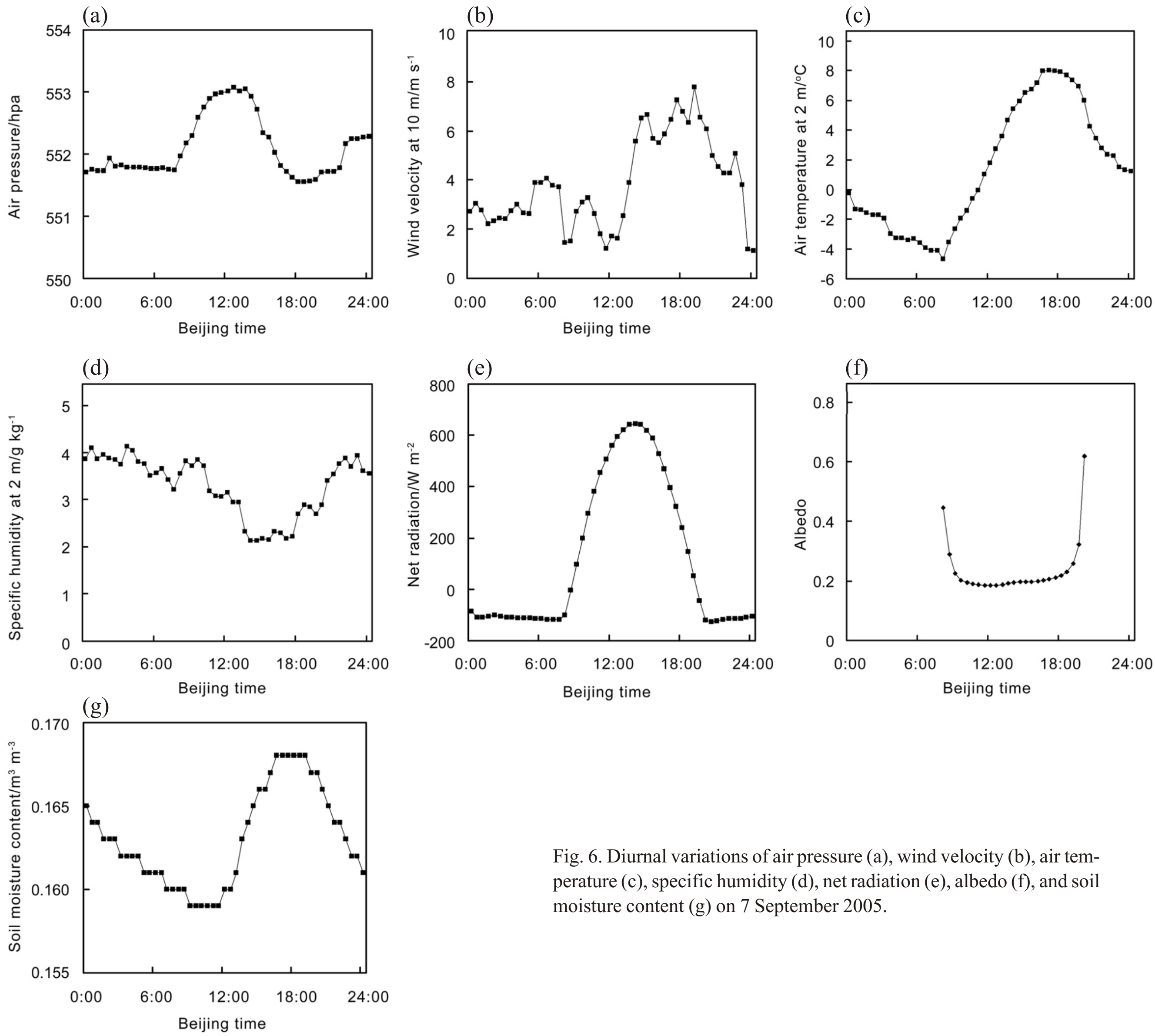

Fig. 6. Diurnal variations of air pressure (a), wind velocity (b), air temperature (c), specific humidity (d), net radiation (e), albedo (f), and soil moisture content (g) on 7 September 2005.

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