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Short-term Climate Characteristics at Ny-Ålesund over the Arctic Tundra Area

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Abstract Based on the Germany Koldwey Station's 1994-2003 conventional observation hourly data, this paper conducts a statistical analysis on the short-term climate characteristics for an arctic tundra region (Ny-Ålesund island) where our first arctic expedition station (Huanghe Station) was located. Affected by the North Atlantic warming current, this area has a humid temperate climate, and the air temperature at Ny-Ålesund rose above 0 ℃ even during deep winter season during our research period. The wind speed in this area was low and appeared most at southeast direction. We find that the temperature at Ny-Ålesund rose in the faster rate (0.68 ℃/10 a) than those at the whole Arctic area. Compared with the floating ices where our expedition conducted in the Arctic, Ny-Ålesund was warmer and more humid and had lower wind speed. Comparison of the near surface air temperature derived by NCEP/NCAR reanalysis to the conventional measurements conducted at the Koldwey site in Ny-Ålesund area shows a good agreement for winter season and a significant difference for summer season.
Key words Ny-Ålesund, Huanghe Station, Koldwey Station, Climate characteristics, NCEP/NCAR.

1 Introduction

The Arctic, which is regarded as one of Three Poles together with Antarctic and Qinghai-Xizang Plateau, is a sensitive area to global climate changes. Its particular location, underlying surface characteristics, natural environment and ecological characteristics make the Arctic a very important area in global change researches (Chen *et al.* 2003). Arctic ground surface characteristics and its atmosphere circulation have direct influences on Chinese weather and climate because China is located at the Northern Hemisphere.

Conventional meteorological observation is the foundation of meteorology researches and atmosphere sciences. Since the atmosphere is a global interactive system, the meteorological stations in the Arctic area are also important parts of the world weather monitor net. Currently the Arctic area is experiencing important changing process of the atmosphere, ocean, earth, ecology and society. Thus many countries strengthened the researches and developments about the Arctic, and organized or jointly organized many research programs. Countries with land in the Arctic Circle, such as USA, Canada had set up scientific observation stations on land or islands and organized Arctic expedition teams. Though Japan and Korea don't have land in the Arctic, the two countries also set up observation stations on the Svalbard islands in 1990 and 2001(Lu *et al.* 2004)

With the support of NSF and CAS, our scientists attended many arctic synthetical expeditions that were organized by China and other countries' official and civilian institutions from 1990s. In 1991 Chinese scientists joined the arctic expedition organized by Norway, Soviet Union and Iceland. In 1997, cooperated with Norwegian researchers, our scientists carried out observation experiments about atmosphere boundary layer's structure and turbulent flux transportation. And synthetical expedition was carried out in the Arctic Ocean and nearby ocean by "XueLong" expedition ship during Chinese First Arctic Expedition in 1999 (Chinese First Arctic Expedition Team 2000). We first used spot data to research on weather, radiation, thermal balance and boundary layer about the Arctic Ocean environment and ocean-atmosphere interactive effect (Chen *et al.* 2003; Bian *et al.* 2003; Cheng *et al.* 2000; Qu *et al.* 2001). In 2002 boundary layer observation research was carried out on Longyearbyen of Svalbard islands and in 2003 our country carried out the second arctic expedition (Zhang *et al.* 2004). Huanghe Station- the first Chinese Arctic science expedition station in Ny-Ålesund of Svalbard islands- opened a new era for Chinese arctic researches (Lu *et al.* 2004).

Ny-Ålesund's underlying surface is tundra that has distinct differences with the ocean and ice. Kang *et al.* (1998) analyzed the long-term change trend of air temperature and precipitation on Svalbard airdrome (Longyearbyen region). Up to the moment, in our country research about Ny-Ålesund's short-term climate is limited. This paper studied the short-term climate characteristics at Ny-Ålesund where Huanghe station was located using 10-year meteorological observation data of German Koldwey station and discussed the applicability of NCEP/NCAR reanalysis data at Ny-Ålesund.

Since the sparse stations in the Arctic area add difficulties to the acquisition of continuous data current available observation data can't satisfy actual research needs. NCEP/NCAR reanalysis data is the cooperative result of U. S National Centre of Environmental Forecast (NCEP) and National Centre of Atmosphere Research and uses Climate Data Assimilation System (CDAS) of U. S National Meteorology Centre (NMC). NCEP data is long-term, well continuous and has broad data sources, so as an alternative data source we can carry out primary researches on the Arctic based on it. But first and foremost the validation about its effectiveness in the Arctic region is necessary. The purpose of this paper was to find out possible deficiencies of the NCEP data in the Arctic and give comments on the using of NCEP data instead of observation data at Ny-Ålesund through comparisons between the observation data of Koldwey station and NCEP grid data adjacent to Koldwey station.

Research in this paper is great scientific significance not only for better understanding of the Arctic, but also for offering background information to carry out multi-subjects synthesis research at Ny-Ålesund, and it is also essential for further study on the boundary physical process about tundra-sea-ice-air interaction in the Arctic region.

2 Background of the station and data

The Svalbard islands are the research centre in the Arctic area and Ny-Ålesund is called the Arctic Science City. Koldwey station (78°56′ N, 11°57′ E, and the height above sea level is 11 m) was built by German Alfred-Wegener-Institute (AWI) on August 1991 and developed many observation subjects such as conventional surface observation, wire remote sensing of surface layer and balloon radiosounding. The distance from Koldwey station to Huanghe station is less than 200 m.

Observation data used in this paper is hourly mean and includes sea level pressure, air temperature on 2 m, relative humidity on 2 m and wind on 10 m. Time length is from 1994 to 2003. the data uses Greenwich Mean Time (GMT) that is behind local time by 0. 8 hour. Real-time data can be downloaded through the Internet at http://www. awi-bremerhaven. de/MET/Ny—Ålesund/wettertab. html.

NCEP reanalysis data is obtained four times per day (00, 06, 12, 18 GMT). Model exporting products can be divided into four kinds according to the influencing degree of observation data and models (Su *et al.* 1999). Data in this paper is daily from U. S Climate Diagnose Centre (CDC) and includes air temperature on 2m, surface air pressure, special humidity on 2m and wind on 10m from 1994 to 2003. The storage format is Gauss grid (192 * 94 grid). Data can be downloaded from ftp://ftp. cdc. noaa. gov/datasets/ncep. reanalysis. dailyavgs/surface– gauss/.

3 Climate Characteristics

Fig. 1 showed annual cycles of average monthly air temperature, air pressure, special humidity, and wind speed. Real line was mean value, while dashed line was hourly extremum. Special humidity (g kg^{-1}) was computed by air temperature (℃), relative humidity (%) and sea level pressure (hPa) (Humidity calculate table 1980). Saturation vapour pressure adopted water surface when above −15 ℃ or ice surface when below −40 ℃ or a weighting factor when air temperature was between −15 ℃ and −40 ℃ (Ding 1989).

Wang BZ (1991) offered more accurate computing method about solar declination that adopted 1985 as standard year and considered the errors according to the geography longitude and observation time at different sites. Computation adopted solar declination at 12 PM and did not consider the atmosphere refraction rate. Results showed that polar daytime was about 128 days (April 19-Augest 24) and polar night was about 120 days (October 23- February 19 in next year).

3. 1 Temperature, pressure and humidity

Annual mean air temperature was -5. 1℃ together with a clear annual change curves, and also had the distinct characteristics of short summer and long and gently winter (Schwerdtfeger 1984). We defined July-August as summer and December-March as winter according to air temperature's annual change. In summer, Ny-Ålesund's mean temperature was 5.1 ℃ and 17.0 ℃ higher than in winter. Spring and autumn were interim period and monthly change of air temperature was over 3 ℃. Mean temperature in polar daytime was 0.9 ℃, while that in polar night was −10.4 ℃. The highest hourly mean temperature (17.1 ℃) appeared in September, while the lowest hourly mean temperature (−32.8 ℃) appeared in February. Even in the warmest month (July) air temperature might drop to below 0 ℃, while in the coldest season temperature might raise to above 0 ℃.

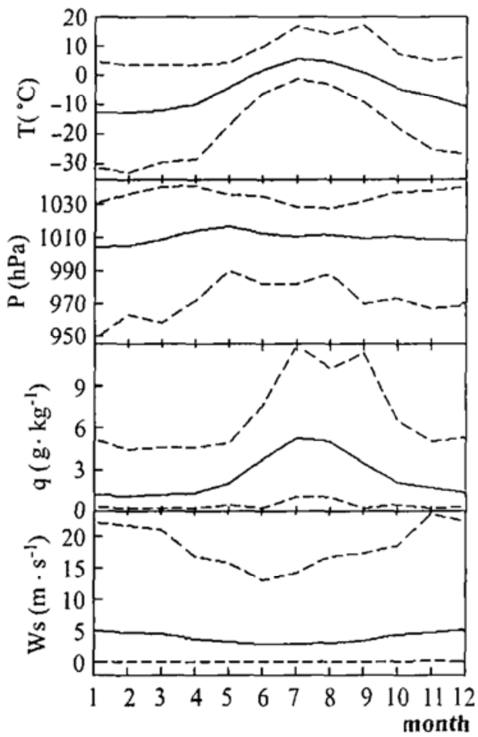

Fig. 1 Annual cycle of average monthly air temperature, air pressure, special humidity and windspeed obtained by the direct measurements.

Annual mean sea level pressure was 1009.8 hPa and its change range was about 20hPa. In January and May mean pressure got the extremum, and corresponding weather systems were polar cold high and cyclone. Hourly extremum appeared in April (1041.1 hPa) and January (947.3 hPa).

Annual mean special humidity was 2.5 g • kg^{-1}, while Mean special humidity was 5.2g • kg^{-1} in summer. During 6-9 month special humidity was obviously higher than other period. The highest special humidity (12.1 g • kg^{-1}) appeared in July.

3.2 Wind

Annual mean windspeed was 3.9 m • s^{-1} and had no clear change among months. Strong wind days (> Beaufort Scale 6, 12.68 m • s^{-1}) were 35 days that occupied 9.6% of whole year, while strong wind days in summer were only 3.2 days. Hourly windspeed above 17 m • s^{-1} was only occupied with frequency of 0.4%. In a word, windspeed at Ny-Ålesund was small and times when windspeed exceeding 20 m

• s^{-1} were only during winter year. The possible reason was that the cold air and frontal cyclone that had great influences on the expedition in the field.

Fig. 2 showed frequencies distribution of monthly wind directions (36 directions). Star real line was frequencies of June. Southeast direction especially 130° direction dominated at Ny-Ålesund and was consistence with polar east-wind. Because of influences of geotropic deflection force and sea surface, wind direction rotated south. Northwest wind began to increase in May, and wind direction had a break from prevail southeast (near 130°) direction to southeast (120°), northwest (300°) and southwest (240°) direction. Then north wind changed into south wind in July.

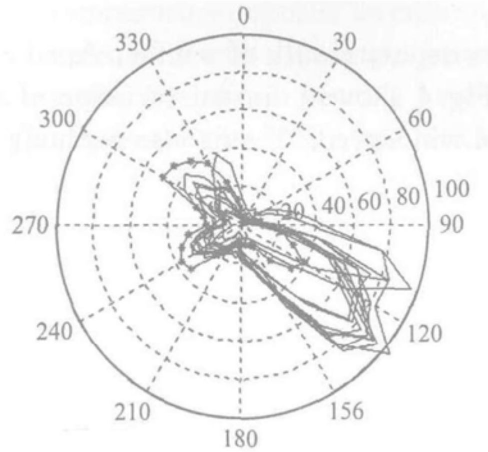

Fig. 2 Frequencies of the wind direction for months.

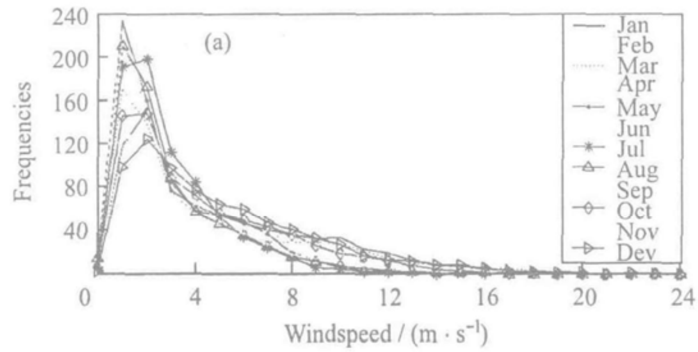

Fig. 3a Distribution of the wind speed for months.

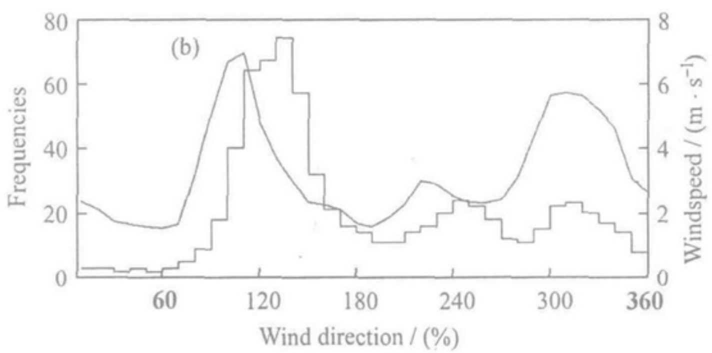

Fig. 3b Frequencies of wind direction and distributions of windspeed.

For better study of the distribution of wind directions and windspeed, fig. 3a showed distribution of monthly windspeed at Koldwey station and we found that windspeed of 1-2 m • s^{-1} occupied dominance in every month. Fig. 3b displayed frequencies of wind directions and distribution of wind speed. The most significant frequency of wind direction appeared at 130° direction, and the biggest windspeed (7 m • s^{-1}) appeared at 110° direction.

4 Diurnal variation

We defined January as deputy month of winter, April as spring, July as summer and October as autumn. Fig. 4 showed diurnal variation of air temperature, air pressure, special humidity and windspeed. Y-axis was anomaly of elements while X-axis was local time.

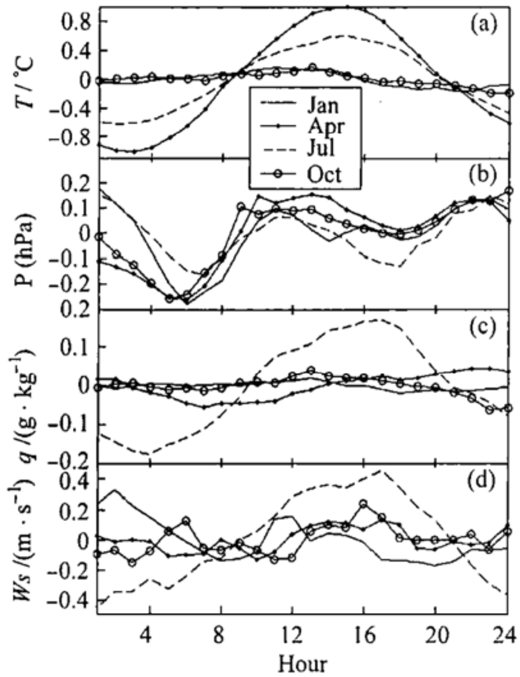

Fig. 4 Diurnal variation of air temperature, air pressure, special humidity and wind speed in January, April, July and October during the observation period.

In April and July of the summer year the diurnal change of air temperature was significant with the maximum appeared at 15 P. M. and the minimum appeared at 2 A. M. In July daily change range of temperature was 2 ℃, but that in the winter year (January and October) was even less than 0. 1 ℃. In winter year daily maximum appeared at 13 P. M. while the minimum appeared at 22-23 P. M.

Sea level pressure had a very small change range (no more than 0. 5 hPa) a day. Change curve of each season had the same "W" -shape half-day change characteristic.

Significant diurnal change appeared in July with 0. 4 g • kg^{-1} change ranges. In April the least special humidity appeared at 7 A. M. , then aerial humidity was increasing slowly till 23 P. M.. Except July, other months had no significant diurnal variation.

The windspeed diurnal variation of the spring and autumn had no significant fluctuation. In January windspeed in the night was bigger than in daytime with the maximum appeared at 2 A. M. In July, windspeed was increasing from 0 A. M. until 17 P. M.. Change range of July was the biggest value(only 1 m • s^{-1}).

5 Comparison with the climate at the floating ices

During the Chinese first Arctic expedition, we set up union ice station (75°N, 160°W) at floating ice in the Arctic Ocean. The correlative observation subjects were surface air pressure and air temperature, special humidity, wind at height of 0. 5 m, 4 m, and 8 m. The Chinese second Arctic expedition team obtained surface air pressure and air temperature, special humidity, wind at height of 0. 5 m, 4 m, 6 m at floating ice (149°W, 78°N). Since they had the close latitudes with Koldwey station, to find out the climate differences of different underlying surface we compared 136 hourly samples from 19 P. M. August 19 to 10 A. M. August 24 in 1999 and 291 samples from 14 P. M. August 23 to 16 P. M. September 4 in 2003 against observation data at Koldwey station of the same period. All data had been translated into Greenwich Mean Time from local time and was averaged by hour.

Table 1. Comparison of the air temperature, relative humidity, wind speed and air pressure collected at the Ny-Ålesund against those collected at the Arctic foating ice surface during the same period

	Elements	Temperature (℃)			Relative humidity (%)			Windspeed (m • s^{-1})			Pressure (hPa)
Floating ice 1999	Height	0. 5 m	4 m	8 m	0. 5 m	4 m	8 m	0. 5 m	4 m	8 m	Sea Level
	Mean	−2. 0	−2. 1	−2. 1	90. 0	92. 0	94. 1	4. 6	5. 6	6. 2	1020. 3
Ny-Ålesund	Height	2 m			2 m			10 m			Sea Level
	1999	3. 4			85. 5			3. 2			1005. 8
Floating ice 2003	Height	0. 5 m	3 m	6 m	0. 5 m	3 m	6 m	0. 5 m	3 m	6 m	Sea Level
	Mean	−1. 9	−1. 7	−1. 6	92. 4	95. 7	95. 7	4. 0	4. 9	5. 3	1010. 3
Ny-Ålesund	Height	2 m			2 m			10 m			Sea Level
	2003	3. 3			80. 8			3. 5			1012. 2

Table 1 showed detailed differences of climate the elements between in Ny-Ålesund and at the floating ices. The wind direction was about 160° for both Ny-Ålesund and at floating ices. To sum up, Ny-Ålesund had higher air temperature, more humid air, and smaller windspeed. So Ny-Ålesund was an adaptive place for our Huanghe station.

6 Change trends

Fig. 5 showed monthly mean standard anomaly of elements. Thin real line was monthly mean standard anomalies, while thick real line was 12-month moving average change and dashed line was linear regression line with regression equation under regression line. Temperature, special humidity and windspeed passed significance test with 0. 001 degree of confidence.

Results of regression analysis showed monthly mean temperature had an increasing trend with a rate of 0.68 ℃/10 a. The increasing rate of temperature at Ny-Ålesund was far faster than that in the whole Arctic (0.08 ℃/10 a) (Przybylak 2003). IPCC (2001) report pointed out that the fastest increasing temperature region was located mid-high latitude of the Northern Hemisphere land during the latest heating period (1976-1999). Ny-Ålesund located at north of Norway Land with the influences of North Atlantic Current and suffered from the effects of the positive phase of North Atlantic Oscillation, so its temperature had a large increasing rate. This was consistent with IPCC report. During 1957-1993 in Antarctic area the heating rate of Ross Bay and Antarctic Peninsula was about 0.3 ℃/10 a. The largest rate (0.72 ℃/10 a) appeared at Rothera station (Lu *et al.* 1997) and even larger than that of Ny-Ålesund.

Special humidity showed an obvious uptrend with a rate of 0.79 $g \cdot kg^{-1}/10$ a. And monthly mean windspeed was descending with a rate of 0.26 $m \cdot s^{-1}/10$ a. But the increasing rate of sea level pressure couldn't passed significance test with degree of confidence being 0.005.

Table 2 listed temperature status in 1961-1993 (Umbreit 1997) and strong wind days in 1975-1996 (Hisdal 1998) at Ny-Ålesund. Data was hourly instantaneous value while Data in 1994-2003 was hourly mean value. The mean temperature during 1961-1993 was 1.3 ℃ lower than that during 1994-2003 and the increasing rate of temperature was consistent with previous analysis results. Hourly mean temperature in January and December of 1994-2003 was even higher than instantaneous value of 1961-1993. Annual mean strong wind days of 1994-2003 were 35 days (occupied 9.6% of whole year) and more than statistical days of 1975-1996. Strong wind days had little differences in summer year during latest 30 years, but increased fast in winter year during latest 10 years.

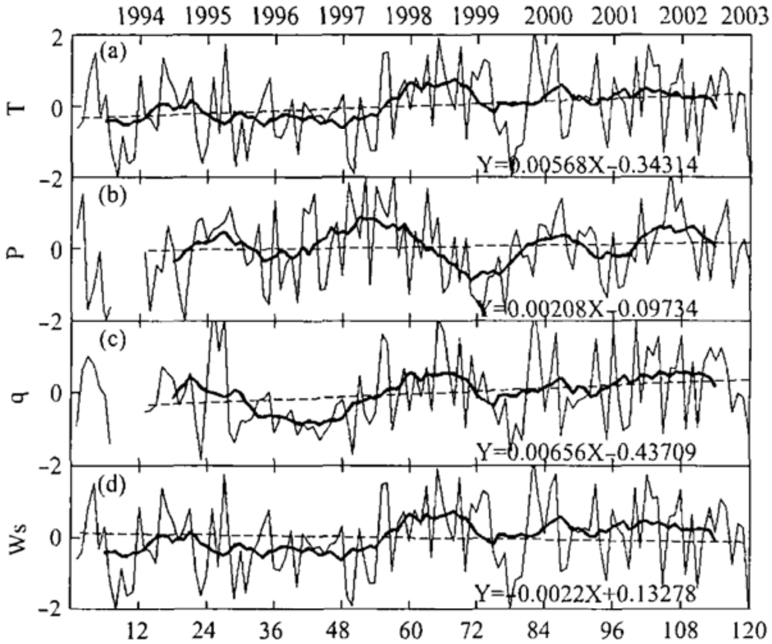

Fig. 5 Monthly temperature, pressure, special humidity and wind speed standard variation.

Table 2. Temperature status (℃) and strong wind (>6B) days at the Ny-Ålesund site

Factors	Mon	1	2	3	4	5	6	7	8	9	10	11	12	Year
1961-1993														
T (℃)	Mean	−14.1	−15.2	−14.6	−11.3	−4.2	1.4	4.7	3.9	−0.1	−5.6	−9.6	−12.6	−6.4
	Max	3.7	4.7	5.0	5.5	8.0	11.2	17.0	13.6	12.3	7.5	7.4	5.5	17.0
	Min	−36.6	−41.1	−42.2	−34.0	−19.1	−8.5	−0.5	−5.5	−15.0	−20.6	−26.6	−34.3	−42.2
1975-1996														
Strong wind	Days	3.5	2.9	3.1	2.2	1.1	0.6	0.3	0.6	1.0	2.3	2.7	2.8	23.1
1994-2003														
T (℃)	Mean	−12.8	−12.8	−12.1	−9.8	−4.1	2.0	5.5	4.7	0.7	−4.6	−7.3	−10.8	−5.1
	Max	4.5	3.6	3.5	3.6	4.1	9.9	16.8	14.0	17.1	7.5	4.9	6.3	17.1
	Min	−31.1	−32.8	−29.4	−28.3	−16.8	−6.1	−1.2	−3.3	−9.1	−17.8	−25.3	−26.7	−32.8
Strong wind	Days	5.9	4.3	5.6	2.9	0.7	0.1	0.4	0.5	1.5	3.3	4.4	5.4	35.0

7 Comparison with NCEP data

The data for the Gauss grid close to Koldwey station (13.125°E, 79.0435°N) was picked up during 1994-2003 and compared with the observation data in the same period. The elements included air temperature on 2m, surface air pressure, special humidity on 2 m and wind on 10 m. These were mean values of forecast products of global spectral model (T62L28) and had better effect than reanalysis data which only used assimilation analysis (Kalnay *et al* 1996; Kistler *et al* 2001).

Because the grid location adopted by NCEP data was not completely consistent with Koldwey station and NCEP data's resources were multiplex, some differences with the observation data were understandable. But the latitudes of the two kinds of data were very close, so the comparison was reasonable for understanding of the applicability of NCEP data in the Arctic area.

Fig. 6 displayed scattered distribution of daily NCEP data and observation values. X-axis was NCEP data while Y-axis for observation data. Relative coefficient was labeled at bottom. Fig. 7 figured 10-year daily mean curve. Dashed line was NCEP data while real line for observation data. Analysis results indicated:

1) In general, NCEP data could figure main change trend of each element.

2) The height above sea level at Koldwey station was only 11 m, so sea level pressure could be regarded as surface air pressure. Relativity of surface air pressure of NCEP data and sea level pressure of observation data was high, but the value of surface air pressure was 20 hPa lower than that of observation data. This was equal to 150 m height difference. The possible reason was differences between surface parameter (terrain height) of NCEP T62 model and the height above sea level at the actual station.

3) Peak values of air temperature and special humidity couldn't be simulated well and NCEP data's windspeed was less than actual data.

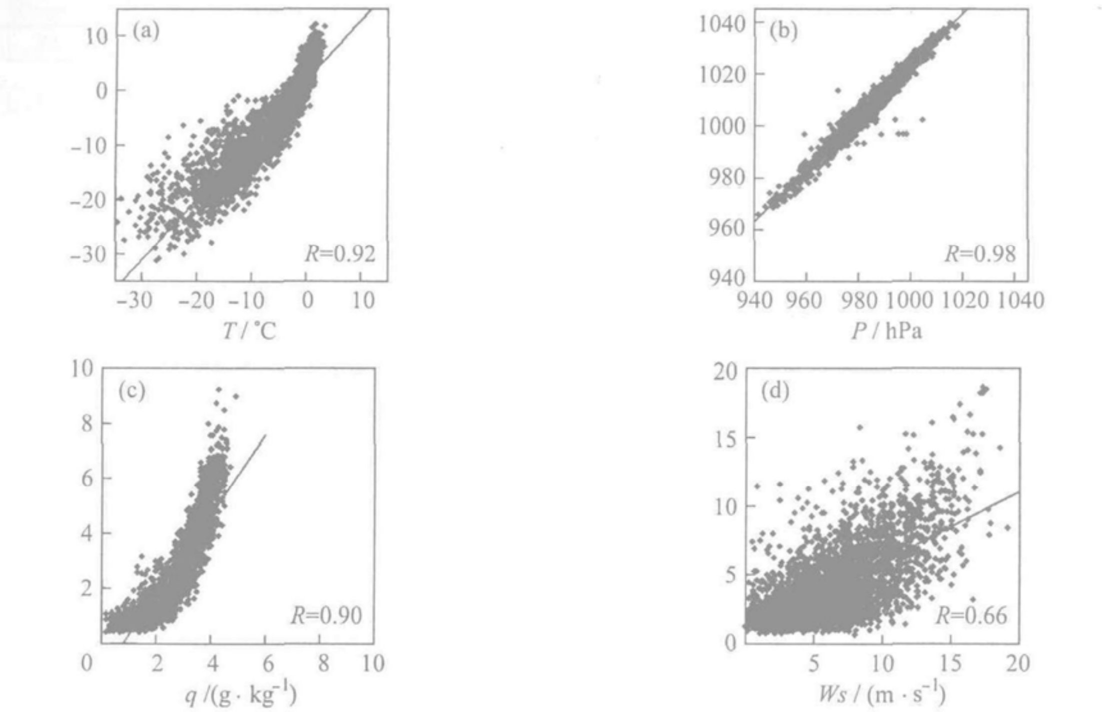

Fig. 6 Correlation of the daily air temperature, air pressure, special humidity and wind speed from NCEP reanalysis and the observation at the Koldwey site.

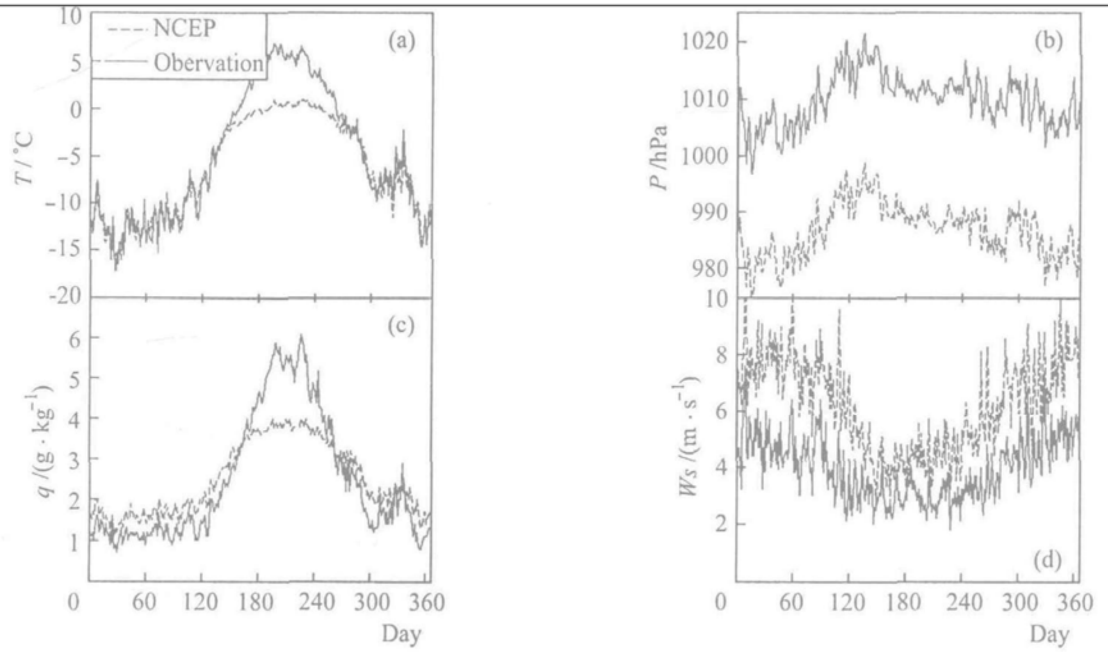

Fig. 7 Annual cycle of daily average of air temperature, air pressure, special humidity and windspeed

For Qinghai-Xizang Plateau area comparison of NCEP reanalysis data with observation data also got similar results (Wei and Li 2003). We analyzed relativity of monthly NCEP data and actual values in 1994-2003 and figured the change (fig. 8). Relative coefficient felled lowest values in summer. We concluded that NCEP model's simulation accuracy for peak & trough was worse. It perhaps was because that in summer air temperature at Ny-Ålesund was faster increasing than other places with the same latitude and NCEP model didn't consider the climate differences. Relative coefficient of special humidity fell to trough in November. And annual change of air temperature and special humidity appeared second peak in deep winter (November). NCEP model could simulate the change of air temperature but couldn't do so for special humidity.

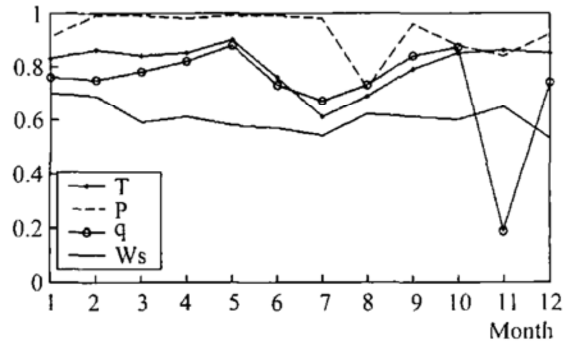

Fig. 8 Correlation coefficient series between NCEP reanalysis data and Koldwey observation data of monthly air temperature, air pressure, special humidity and windspeed

8 Conclusions

So climate characteristics of Ny-Ålesund listed as follows:

1) At Ny-Ålesund, the polar daytime and polar night days were four months long. Affected by the North Atlantic warming current, this area is one of the warmest areas in the Arctic region with the same latitude. Its obvious characteristic was short summer and long & gently winter. Ny-Ålesund had a humid temperate climate, and annual change of air temperature, air pressure and humidity had a break in November. The phenomena also existed during previous period (1961-1993). Wind direction at Ny-Ålesund was mainly southeast. Windspeed was low and strong wind days were of low frequency.

2) Comparison between our observation data on floating ices in the Arctic Ocean and the ground observation data at Koldwey Station during the same period showed that there were significant climate differences between tundra and snow-ice underlying surface. Ny-Ålesund had relatively better climate condition than the floating ice region at the same latitude (5-6 ℃ higher in air temperature, more humid air, lower windspeed).

3) Regression analysis indicated that the air temperature and special humidity had up trend and windspeed had down trend. Air pressure had no distinct change trend. Monthly mean air temperature at Ny-Ålesund was rising with the larger rate (0.68 ℃/10a) than those in other places of the whole Arctic area.

4) Compared with Koldwey Station observation data, NCEP/NCAR reanalysis data roughly showed the general characteristics of surface factors. For air temperature and specific humidity the annual change curves of NCEP data and observation data were basically consistent in the winter while were more divergent in the summer. Relativity for the surface air pressure was high, but the value of surface air pressure was far lower than that of observation data. The possible reason was the differences between surface parameter (terrain height) of NCEP T62 model and the height above sea level at the actual station. So due to not considering about local underlying surface and climate differences especially in the polar area, the use of NCEP data should

be paid more attention in practice. Some parameters need to be improved in the reanalysis model in the future. And this paper only compared single station data so that the work would be more complete with other station's observation data.

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