Polar Meteorol. Glaciol., **15**, 141–146, 2001

Report

Arctic upper air observations on Chinese Arctic Research Expedition 1999

Han Zou, Libo Zhou, Yongxiao Jian and Wei Wang

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

Abstract: The Institute of Atmospheric Physics, Chinese Academy of Sciences, planned and operated the "Arctic Upper Air Observation 1999" program on the Chinese Arctic Research Expedition co-sponsored by 7 Chinese ministries and institutions from July 1 through September 9, 1999. The atmospheric parameters and ozone concentration were measured mainly at two locations in the Chukchi Sea. Preliminary study has been done on the diurnal variation of the atmospheric boundary layer temperature inversion and ozone variation in 7 days. The results show: Arctic boundary layer temperature inversion efficiently prevents heat and mass exchange between the atmosphere and surface; and tropospheric processes can be related to the total ozone variation.

1. Introduction: Chinese Arctic Research Expedition 1999

The Arctic climate and environment is one of the most important components in the global system (WMO/UNEP, 1990). Interactions among the air, sea and ice in the Arctic region have great influence on global climate change (WMO, 1991). Studying these interactions is a key component of the Global Atmosphere Research Project (GARP), World Climate Research Project (WCRP) and International Global Biology Project (IGBP) (PAC, 1999; IASC, 1992, 1995a, b; WMO, 1994). Studies show that climate and environment change in the Arctic is closely related to throughout the northern Hemisphere, including China. Low temperature in northeast China appears to be closely related to Arctic climate variability (PAC, 1999). Therefore, it is urgent to understand the Arctic climate and environment systems and their relation to the globe and China. As a member of International Arctic Science Committee (IASC), China has planned a research survey to the Arctic ocean for a long time (PAC, 1999; CAS, 2000).

From 1st July to 9th September, 1999, China sent its first scientific research cruise to the Arctic Ocean, with 60 scientists on board the Chinese icebreaker *Xuelong*. The expedition was supported by the Chinese Ocean Administration, Chinese Academy of Sciences and 5 other China governmental organizations (PAC, 1999). The disciplines in this research survey included atmospheric sciences, geo-sciences, oceanography, sea-ice studies and biology. The research was focused on water-ice-air interaction and its impact on global climate, water mass exchange between the Arctic Ocean and the North Pacific Ocean and its climatic effects, and the biological environment and fishery resources (PAC, 1999; CAS, 2000; Zou *et al.*, 1999).

The Institute of Atmospheric Physics, Chinese Academy of Sciences, designed and carried out "Arctic Upper-air Observation 1999" during this Arctic Ocean survey. During the expedition, more than 20 radiosondes were released to measure the atmospheric structure and vertical ozone profile in the Chukchi Sea and its neighboring regions.

2. Arctic upper air measurement

Observation of atmospheric structure and vertical ozone distribution was one of the most important projects in this expedition (PAC, 1999). The impact of the Arctic on global climate change depends on the mass and energy exchange between the surface and atmospheric boundary layer, boundary layer and troposphere, troposphere and stratosphere, and high-latitude and lower-latitude atmosphere. As one component of climate change, the structure and characteristics of the Arctic atmosphere have great influence on global climate change. Ozone is one of the greenhouse gases that modify the radiation structure of our atmosphere. A change in ozone amount and distribution can, therefore, influence climate. In addition, ozone protects the biosphere from harmful solar ultraviolet radiation. Ozone is continuously being produced and destroyed, mainly by solar ultraviolet radiation. Addition ozone is destroyed by catalytic reactions of nitrogen, hydrogen, chlorine, and bromine oxides. Studies show that the Arctic ozone loss becomes more and more obvious, with similarities to the Antarctica ozone loss, and extra UVB radiation is becoming a severe problem in the Arctic region (WMO, 1994; IASC, 1995b). Therefore, research on the Arctic atmospheric structure and ozone is essential for understanding global climate change and environment.

For the upper air measurement, a Väisalä ozone radiosonde system was applied with a GPS wind-finding system. The system provides a high sampling rate and accuracy, automatic sounding data processing and multiple capabilities. The differential GPS system gives wind measurement resolution of 0.1 m/s. With this ozone sounding system, vertical profiles of pressure, temperature, humidity, wind and ozone concentration were obtained up to 30000 m above sea level with 30–50 m vertical resolution.

The planned "Arctic Upper-air Observations 1999" included the following observations: 1) a cross-section along 170°W from 70°N to 80°N with 1 degree latitude steps, to study the longitudinal distribution of atmospheric structure and ozone; 2) stationary ocean and ice observations at 80°N 170°W for 7 days, to study the water-ice-air mass and energy exchanges. However, due to the severe ice condition *Xuelong* met, the planned observations were aborted.

Based on the change of navigation and observation schedule, "Arctic Upper-air Observation 1999" was modified and carried out in the following three parts:

1) In the middle of July, as the Chinese icebreaker *Xuelong* entered the Chukchi Sea, several normal and ozone radiosondes were released to collect background and calibration data over this region, with TMT (tethered meteorology tower) observation for atmospheric boundary study;

2) August 5-6, 1999, diurnal observation was completed on sea ice at 73.37°N 165.00°W, with 4 radiosondes released at 1145 (local midnight), 1704 (local early morning), 2311 (local noon), August 5, and 0430 (local afternoon), August 6, GMT;

3) August 18-25, 1999, under guidance of the Canadian RADARSAT and a helicopter, *Xuelong* found stable sea ice suitable for observation at 75°N 160°W. Thereafter 8-day ozone sonde observation was carried out at the temporal station with one ozone sonde each day.

During the Chinese Arctic Research Expedition 1999, 23 radiosondes were released.

3. Preliminary analysis of the data

3.1. Heat and mass transfer in the boundary layer inversion

In order to understand the diurnal variation of atmospheric structure, 4 balloons were released on floe located at 75°N 160°W from August 5 to 6, 1999. The floe is multi-year ice, about 1 km^2 in area with snow cover. During the observation, a warm synoptic system passed over area, with surface wind speed less than 5 m/s and cloudy sky. A strong temperature inversion was observed in the atmospheric boundary layer. From the measured temperature profile within the atmospheric boundary layer (Fig. 1), at local midnight, the highest temperature at about 17.8°C was located at about 400 m from the ground (temperature 0.7°C); in early morning, the maximum temperature at 400 m slightly lowered to 17.7°C, with surface temperature 0.5°C; at local noon, the maximum temperature center was lifted to 500 m height and cooled to 16.7°C, with surface temperature −0.4°C; and, in the afternoon, the maximum temperature center was lowered to 400 m and continuously cooled to 15.5°C, with surface temperature 1.2°C. Thus, the atmospheric boundary layer temperature inversion showed a diurnal

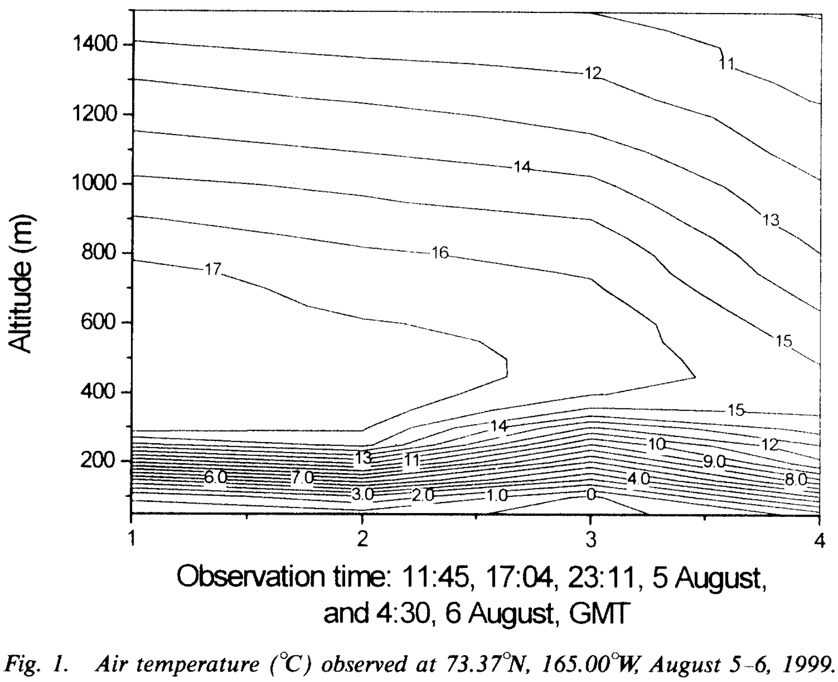

Fig. 1. Air temperature (°C) observed at 73.37°N, 165.00°W, August 5-6, 1999.

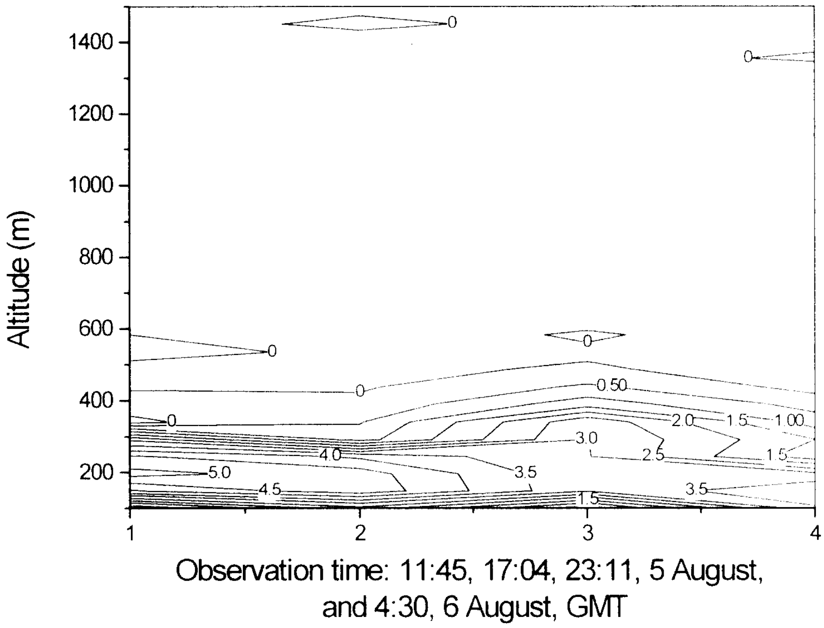

Fig. 2. Temperature (°C/50 m) at 73.37°N, 165.00°W, August 5–6, 1999.

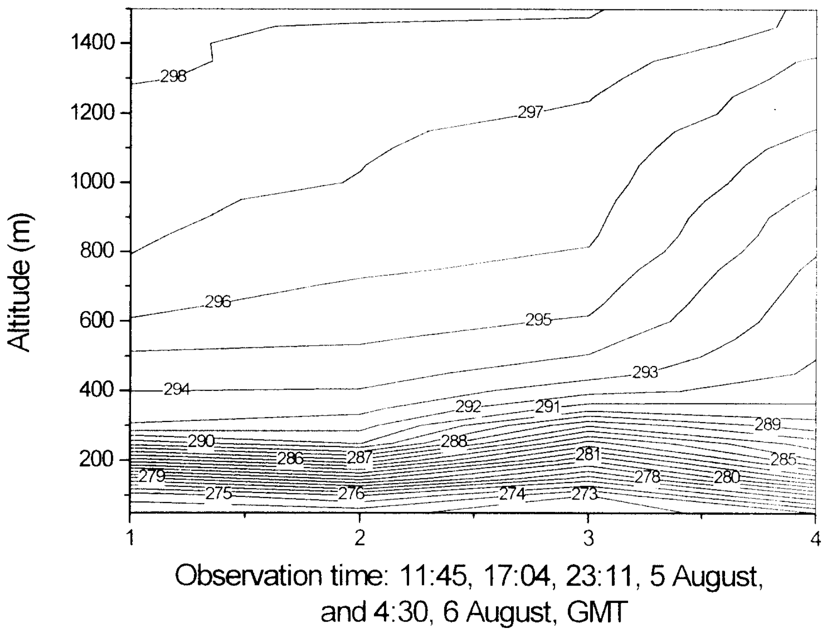

Fig. 3. Potential temperature (K) at 73.37°N, 165.00°W, August 5–6, 1999.

variation with maximum strength 4.3°C/100 m within 400 m above the surface from local midnight to early morning, weakening to 3.4°C/100 m at local noon, and strengthening to 3.6°C/100 m in late afternoon.

Further study based on isentropic surface and temperature gradient shows that the atmosphere within 400 m from the surface transferred sensible heat to the ground from local midnight to early morning, and the downward heat transfer layer expanded to 450 m as the temperature inversion weakened at noon (Fig. 2). At the same time, the temperature inversion strongly prevented upward mass transfer from the ground. The fast mass transfer layer was supressed within 200 m above the ground from local midnight to early morning, and expanded to 300 m thickness as the temperature inversion weakened at local noon (Fig. 3). Focusing on the mass surface at 600 m height from the surface at local midnight, its height increased to 700 m in early morning, reached 800 m as the inversion weakened at local noon, and kept increasing in the local afternoon until 1300 m in later afternoon. Therefore, the Arctic boundary layer temperature inversion strongly suppressed sensible heat and mass exchange between the atmosphere and the surface.

3.2. Total ozone variation with ozone in the troposphere

The upper-layer atmospheric structure and ozone data were obtained on a multi-year floe (1 km long from west to east, and 0.3 km from south to north) at 75°N 160°W from August 18 to 24, 1999 (Fig. 4). Due to strong wind gusts, the observation was interrupted on August 22, 1999, and therefore interpolation is applied for this day. In addition, the vertical observation range was not high enough to study all of the stratospheric ozone, thus the analysis is applied only from 0 to 25 km height.

The observed vertical ozone distribution is bimodal, with the highest concentration 12–14 mPa located within 20–22 km from the ground and second highest 4–8 mPa located 10–12.5 km from the ground. During the observation, total ozone (TOMS) over this region experienced a decreasing and increasing variation, beginning with total ozone 292 DU on August 18, 1999, decreasing to a minimum on 21, and ending with 274 DU on 24 (Table 1). Following the total ozone variation, the tropopause height experienced negative variation with low, high and low positions (Table 1), however, the

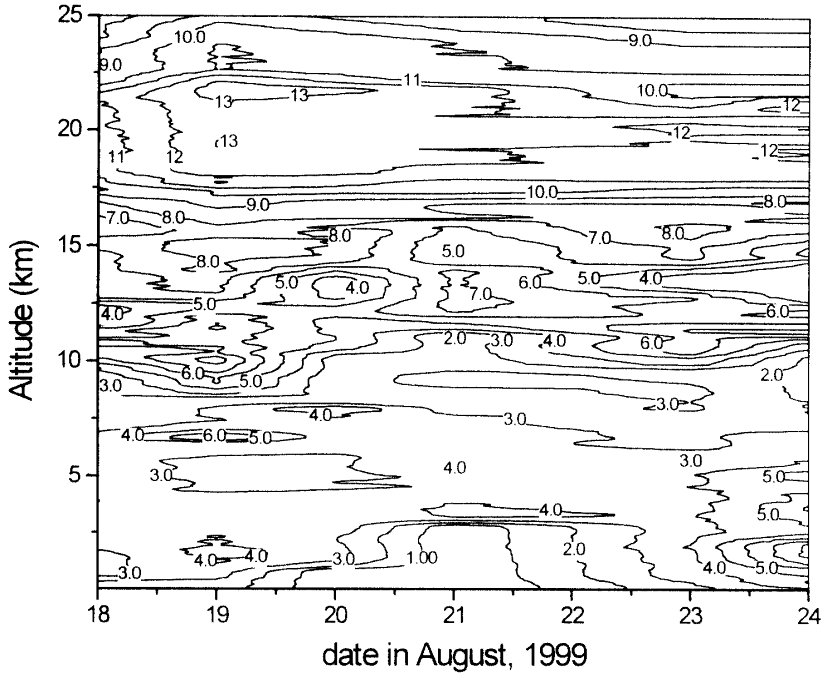

Fig. 4. Ozone concetration (mPa) observed at 75°N, 160°W, August 18–24, 1999.

Table 1. Variation of ozone concentration in the troposphere, lower stratosphere and total atmosphere, at 75°N, 160°W, August 18–24, 1999.

Date in August 1999	18	19	20	21	22	23	24
TOMS ozone (DU)	292	291	273	249	259	264	274
0–25 km ozone (DU)	178	219	188	179	183	186	188
0–13 km ozone (DU)	53	66	46	43	50	57	61
13–25 km ozone (DU)	126	154	142	136	133	129	127
Tropopause height (km)	9.90	10.95	10.10	11.1	10.90	10.10	10.85

ozone concentration in the first maximum ozone peak did not vary with the same trend. If integration is made for the ozone concentration in 0–25, 0–13 and 13–25 km altitude ranges (Table 1), one can easily recognize that the total ozone varies with close relation to the ozone concentration in the low atmosphere including troposphere but not the ozone concentration in the lower stratosphere. This implies that the synoptic advection process in the troposphere was the main cause of total ozone variation during this Arctic ozone observation.

Acknowledgments

The authors are obliged to the Nature Science Foundation of China (49775276), Chinese Academy of Sciences (KZ951-A-205-05) and Chinese Polar Administration. The authors are very grateful to Prof. Dengyi Gao for his discussion and suggestions for our program. The authors are very thankful to the ozone processing team at Goddard Flight Center, NASA, for their TOMS data support.

References

CAS (Chinese Academy of Sciences) (2000): Scientific report 2000. Beijing, Scientific press.

IASC (1992): Scientific plan for a regional research program in the Arctic on global change. Proceedings of a Workshop at Reykjavik, Iceland, 22–25 April, 1992.

IASC (1995a): Executive summary from ICARP - International conference for Arctic research planning. IASC, U.S.A. 1995.

IASC (1995b): Effects of increasing ultraviolet radiation in the Arctic. An Interdisciplinary Report on the State of Knowledge and Research Needed, Washington, D.C., U.S.A.

PAC (Polar Administration of China) (1999): Project plan of first Chinese Arctic Expedition. Beijing, National Marian Bureau.

WMO (1985): Atmosphere ozone 1985. Assessment of Our Understanding of Process Controlling Its Distribution and Change, Global Ozone Research and Monitoring Project, Rep. 16, Geneva.

WMO (1991): Scientific concept of the Arctic climate system study (ACSYS). Report of the JSC study group on ACSYS, Bremerhaven, Germany, 10–20 June 1991 and London, U.K., 18–19 November 1991.

WMO (1994): Scientific assessment of ozone depletion: 1994. Global Ozone Research and Monitoring Project, Rep. 37, Geneva.

WMO/UNEP (1990): Climate change. The IPCC Scientific Assessment. Cambridge University Press.

Zou, H., Wang, W. and Zhou, L. (1999): Project Summary of Arctic Upper-air Observation 1999. Beijing, Institute of Atmospheric Physics, Chinese Academy of Sciences.

(Received February 5, 2001; Revised manuscript accepted August 24, 2001)