MEASUREMENT OF WATER VAPOR CONTENT IN THE POLAR STRATOSPHERE: SYOWA STATION (69°00'S, 39°35'E), SPRING 1983

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Abstract: Water vapor content was measured by a balloon-borne hygrometer (Lyman-alpha/OH fluorescence type) at Syowa Station (69°00'S, 39°35'E), Antarctica on October 27, 1983. The result showed a very dry air of about 1 ppmv just above the tropopause. This may be a consequence of the active "freeze-out" of water from the Antarctic stratosphere because of its coldness in winter.

1. Introduction

It is well documented that the stratospheric water vapor plays an important role in various aeronomical processes; OH radical production through the destruction of water vapor by $O(^1D)$ reaction, the formation of water cluster ion, the radiative energy transfer in the lower stratosphere, the condensation onto particulate matter, and so on.

However, as has been described by many investigators (*e.g.*, HARRIES, 1976; KLEY *et al.*, 1979), the water vapor concentration of the stratosphere and its temporal changes especially in the polar region, have been less clear.

From the viewpoint of the global budget of stratospheric water vapor, it has been speculated that polar stratosphere works an as active sink, STANFORD (1973, 1977) presented a model suggesting that the freeze-out of water vapor caused by a severe coldness in the polar winter stratosphere (about $-80°C$ or colder) is an effective loss mechanism for the global balance of stratospheric water vapor. The knowledge of the water vapor concentration in the polar stratosphere is essential to clarify this mechanism. Therefore, the observation presented here, even though it is preliminary, should be useful.

The water vapor concentration from the ground to a height of about 15 km was measured on 27 October 1983 at Syowa Station (69°00'S, 39°35'E), Antarctica by the balloon-borne hygrometer (Lyman-alpha/OH fluorescence type). The result showed that there was a very dry region having about 1 ppmv (part per million by volume; 1 ppm$=10^{-6}$) mixing ratio above the tropopause.

2. Instrument

Recently BERTAUX and DELANNOY (1978), and KLEY *et al.* (1979) developed a new type of instrument for *in situ* measurement of water vapor content, which used

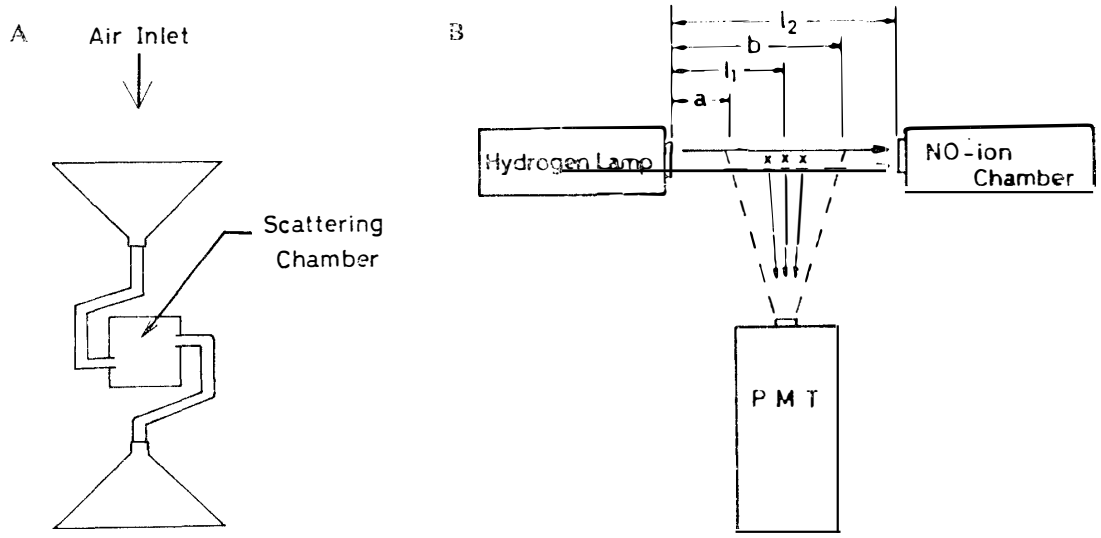

Fig. 1. Schema of the principle of measurement. The air flow system of the hygrometer (A), and the scattering chamber (B). The absorption of the hydrogem emission by water vapor is monitored by an NO ionization chamber and the fluorescence from the excited OH is detected by the photomultiplier tube (PMT).

the ultraviolet fluorescence from excited OH radicals when they were produced through the photodissociation of water vapor by the hydrogen Lyman-alpha lamp.

The intensity of fluorescence enables us to infer the density of water vapor, the parent molecules as described by KLEY and STONE (1978) and BERTAUX and DELANNOY (1978).

A schematic view of the instrument is shown in Fig. 1. The air flow system of this instrument also is shown in the same figure. In order to prevent the light from outside, the air inlet pipes were bent and their inside walls were painted black. The scattering chamber was an aluminium box whose wall was also painted black. The chamber, NO cell, and air inlet pipes were warmed by ohmic heating during the flight measurement.

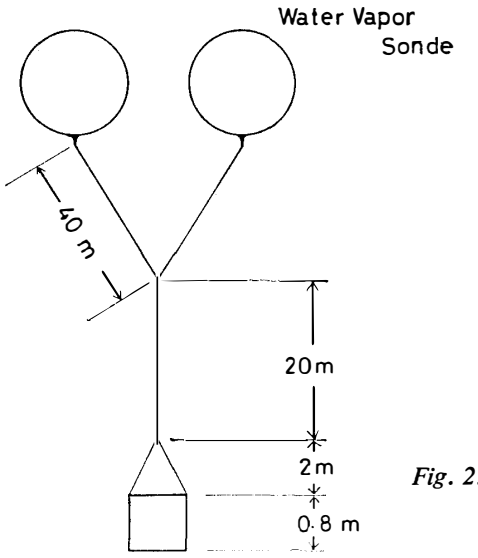

Fig. 2. Balloon train. Twin rubber balloons (the weight of each is 3 kg) were used to avoid the contamination due to the outgas from balloon fabric.

A series of calibrations were performed using dry air (IWASAKA *et al.*, 1981) and/or in cold room (0°C, −20°C and −40°C at standard atmospheric pressure). Just before the balloon flight, we made calibration of the instrument once more by comparing it with the carbon type hygrometer which was used for the routine radiosonde measurements, even though the range of calibration was limited because of an insufficient sensitivity of the carbon type hygrometer under the very dry atmospheric condition. The instrument was isolated in dry condition (relative humidity was lower than about 10% at about 15°C) after the calibration and some water vapor was outgassed from the chamber and the pipes of the instrument.

The balloon train used here is illustrated in Fig. 2. We chose small rubber balloons in order to prevent the contamination due to the outgassing of water vapor from the balloon fabric.

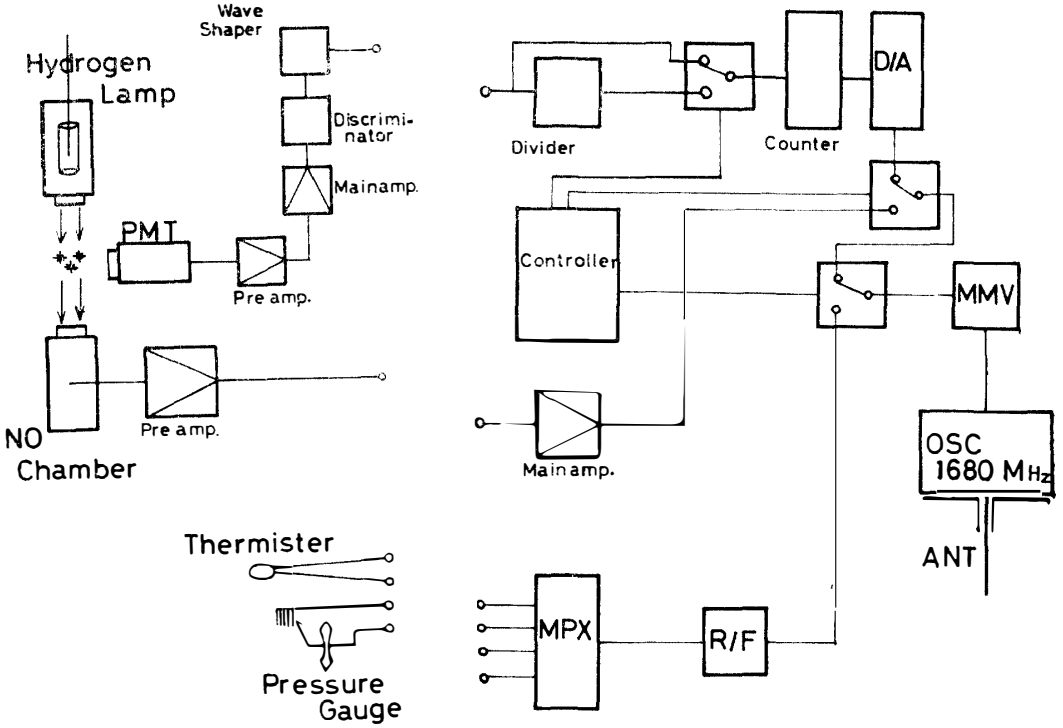

Fig. 3. Block diagram of the electronics.

A schematic diagram of the electronics is illustrated in Fig. 3. The OH fluorescence and the Lyman-alpha emission intensities were simultaneously observed. Additionally the fluorescence intensity was measured in two sensitivity ranges to enlarge the dynamic range of the sensor; high level and low level. The low level counter degrades the fluorescence intensity to one tenth.

3. Balloon-borne Measurement

The measurement was made in spring (October 27, 1983) at Syowa Station. The balloon reached an altitude of 15 km at 1120 LT. The mixing ratio of water vapor and the atmospheric temperature measured are illustrated in Figs. 4 and 5, respectively.

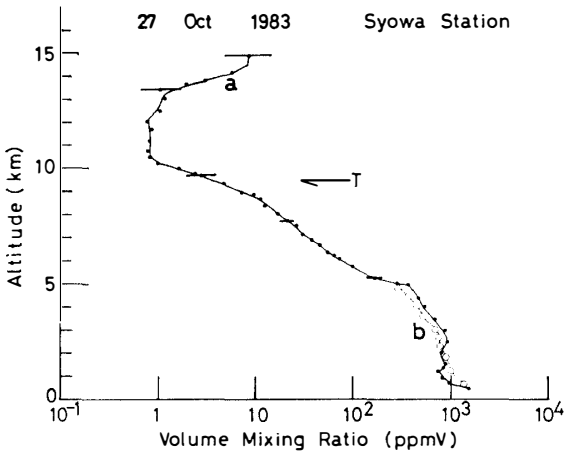

Fig. 4. Water vapor concentration measured on 27 October 1983 at the Syowa Station (69°00'S, 39°35'E). Curve a is the result from the Lyman-alpha/OH fluorescence type, and curve b from the carbon type. "T" shows the tropopause height.

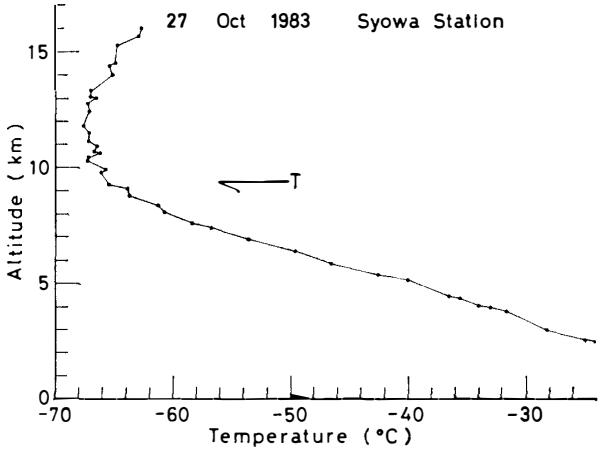

Fig. 5. Temperature distribution on 27 October 1983 at Syowa Station. "T" shows the tropopause height.

The error bars in Fig. 4 are the measured dispersion due to the fluctuation of the photon number measured by a photoncounter. The open circles are the water vapor mixing ratio measured by a carbon type hygrometer three hours after the balloon measurement. Though the absolute values do not perfectly coinside with each other, the difference is very small. Such a difference may have been possibly because of the time lag between two measurements.

A very dry region (about 1 ppmv) is evident above the tropopause.

4. Discussion and Conclusion

STANFORD (1973) speculated that the Antarctic winter stratosphere provided a frost-trap sink for the stratospheric water vapor, on the basis of the analysis of the radiosonde data measured at Amundsen-Scott (South Pole).

Satellite measurements (MCCORMICK *et al.*, 1985) and lidar measurements (IWASAKA, 1985) showed a highly concentrated particle layer in the winter Antarctic stratosphere, suggesting the winter development of the particulate layer due to the formation of ice crystals.

It should be noticed that the water vapor concentration presented here was measured after the cold winter. One possible interpretation of the very dry stratosphere is that the active "freeze-out of stratospheric water vapor in winter" as suggested in the observations by IWASAKA (1985) and MCCORMICK *et al.* (1985) leads to the low humidity in spring.

In Fig. 6, we compared the measurements made in the polar region. Unfortunately, temperature distributions were not obtained during the measurement of water vapor content. Therefore, we cannot discuss the comparison between the

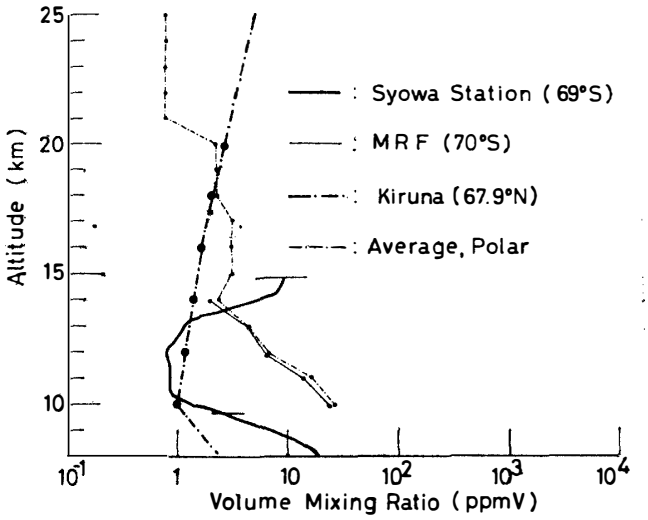

Fig. 6. Water vapor concentrations measured in the polar region. The result by the British Meteorological Research Flight (MRF) and the average value in the polar region are referred to HARRIES *(1976). The measurement at Kiruna is referred to O'*BRIEN *and* EVANS *(1981).*

present values and others. However, all the measurements show the presence of a very dry air of about 1 ppmv in the lower stratosphere.

The present measurement shows an increase of mixing ratio with altitude above 12 km. SISSENWINE *et al.* (1968) measured a systematic and noticeable increase with altitude at a rate of 4 ppmv/km from 16 km to 25 km. The increase measured here does not seem to extend to the upper region since the increasing rate becomes very low near 15 km. No information is available directly from this flight to decide whether this small increase is due to the contamination arising from water in the wake of a rising balloon or due to a poor exchange of air in the scattering chamber. Considering the flight conditions, however, this increase probably is not due to the contamination but due to a nonuniformity of water vapor content above the tropopause, which has been frequently found also in other investigators measurements (*e.g.*, KLEY *et al.*, 1979).

The temperature measured simultaneously on 27 October 1983 was not so low as to produce a very dry atmosphere, which must have been cooled below −87°C. This is possibly because the time scales of changes in water vapor content and in atmospheric temperature are not in the same range. The atmospheric temperature is strongly affected by solar radiation and dynamical air motion but the water vapor content in this season may be due to dynamical transport only. The possible interpretation is that this air mass had gone through a region where the temperature decreased to lower than −87°C. Now we cannot define the position of this region, whether it is the polar stratosphere or the tropopause over the tropics, owing to the lack of necessary information to estimate a trajectory of the air mass. As described before it should be noticed that the polar stratospheric temperature frequently decreased to −80°C or colder.

The water measurements especially in the polar region are so limited that it is hard to depict the distribution of Antarctic stratospheric water vapor in detail. As pointed out by many investigators (*e.g.*, HARRIES, 1976; ELLSAESSER *et al.*, 1980), it should be necessary to accumulate more observational data to construct clear models

concerning the stratospheric vapor cycle and the effect of the winter polar stratosphere on the global balance of water vapor.

Acknowledgments

The authors would like to thank the wintering members of the 24th Japanese Antarctic Research Expedition (leader Prof. S. MAE of Hokkaido University) for their assistance during the balloon measurement.

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(Received April 30, 1985; Revised manuscript received September 26, 1985)