B-4.3.3 Water Circulation Study by the ^{18}O Measurement in Precipitating Water

Contact Person Gen Inoue
Principal Research Scientist
Atmospheric Division and Global Environment Division,
National Institute for Environmental Studies, Environment Agency Japan
16-2 Onogawa, Tsukuba, Ibarakei 305, JAPAN
Phone +81-298-50-2402, Fax +81-298-50-2468
e-mail inouegen@nies.go.jp

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Abstract

The terrestrial water cycle study plays an important role in the climate reteach not only it is the energy transportation process but also the influence to the vegetation. The stable isotope of water, $H_2{}^{18}O$, is one of the key elements to understand the water cycle processes. It is influenced by the evaporation/condensation and the transportation.

In this program, the precipitation sampling network was formed over European Russia and Siberia, 13 stations, as a two years project from 1996-1997. The samples are being collected but the analysis is not made by this time.

For the in situ measurement of water vapor, surface or underground water, and the water in trees, a new method was searched; Laser photo-acoustic determination of $H_2{}^{18}O/H_2{}^{16}O$ ratio was examined.

Key Words Hydrology, Water cycle, Greenhouse gases, Siberia

1.Introduction

Siberia, especially East Siberia, is the most continental area in the world, and the precipitation in Siberia is as low as 200 mm yr-1, which is the level of desertification. However, the vegetation in Siberia is thick and most of it is covered by conifers trees, Taiga. This is because the flow out of precipitation is small as the permafrost prevents the infiltration. The water evaporated from Atlantic Ocean repeats the precipitation and the evaporation during the transportation to the east, during which the isotope separation is repeated. As the result, the heavy water is removed and the light water is enriched in East Siberia. In East Siberia, the air containing Pacific Ocean vapor is removed passing through the high mountains, and the precipitation is small in inland. In addition, the average air temperature is low and $\delta^{18}O$ is small in Siberia.

2. Water sampling network over Russia

The water sampling network has been established in 1995, and the water sampling has been started from 1996 as a two years program. The network is consist of the selected aerological observatories organized by Central Aerological Observatory. The location of them are shown in Fig.1, together with the data of IAEA, November 1975, where the data over Northern Eurasia is lacking. The samples collected are now stored in Moscow and it will be analyzed in Japan in 1998 after the sampling program is completed.

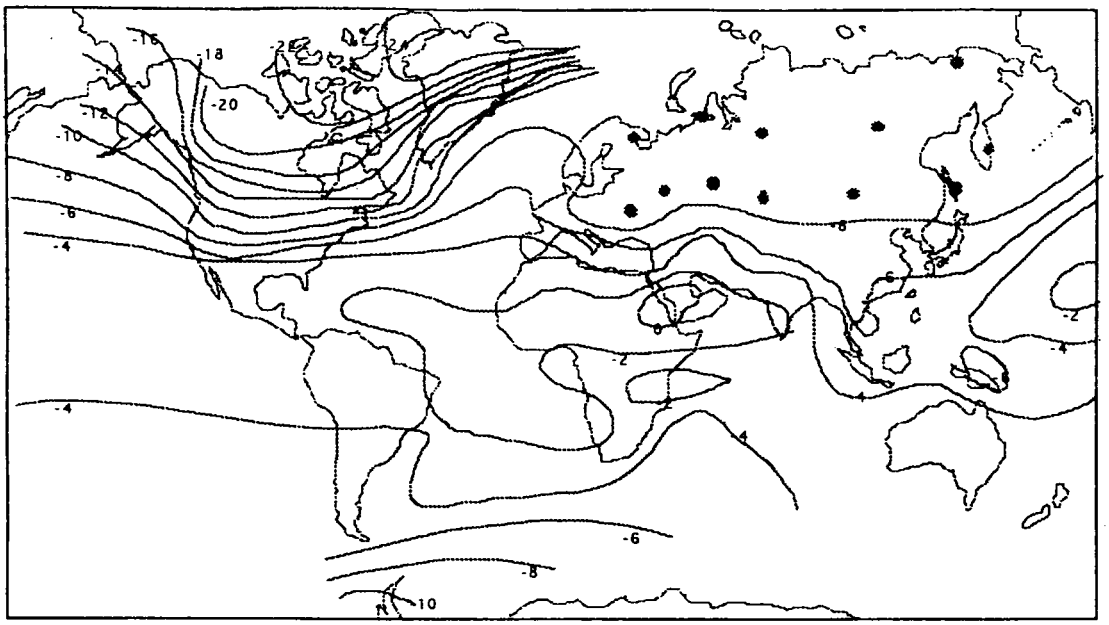

Fig.1. The counter map of δ H2^{18}O and the location of precipitation sampling network.

2.Photo-acoustic measurement of $H_2{}^{18}O/H_2{}^{16}O$ ratio measurement

The $H_2{}^{18}O/H_2{}^{16}O$ ratio of precipitation is dependent on both the ratio in water vapor and the condensation temperature, and it is difficult to separate. But the sampling of necessary amount of water vapor for the CO2 conversion followed by isotope mass spectrometer analysis is not easy. So, it is desirable to develop a method to measure the isotope ratio in gas phase and hopefully in situ.

Several method including RI absorption measurements have been evaluated, and we chosen the photo-acoustic method with top priority. The reasons are as follows: (1) the laser necessary is a pulsed dye laser in the range of 700-800nm, which is easily obtained by YAG-Ti-Sapphire laser system. (2) spectroscopic separation is large between oxygen isotope as it is an over-tone absorption of Δv=4, (3) the amount of sample can be small as no long absorption cell nor pretreatment is necessary.

The principle of operation is as follows. The water vapor in the air is irradiated by 719-731 nm laser pulses. Water vapor is vibrationally excited to v=4 level by overtone absorption, where the absorption wavelengths between $H_2{}^{18}O$ and $H_2{}^{16}O$ are different

because of molecular weight difference. Water vapor vibrationally excited relaxes both by infrared emission and by the collision with environment molecules, nitrogen and oxygen mainly. At higher pressure, the latter process is dominant, and the energy transferred to the other molecule is converted to the translational energy. The increase of translational energy is observed as an acoustic wave at the beginning and the temperature in later. The acoustic signal is detected by a microphone efficiently, and the signal is processed by some electronics. The block diagram of experimental setup is shown in Fig.2.

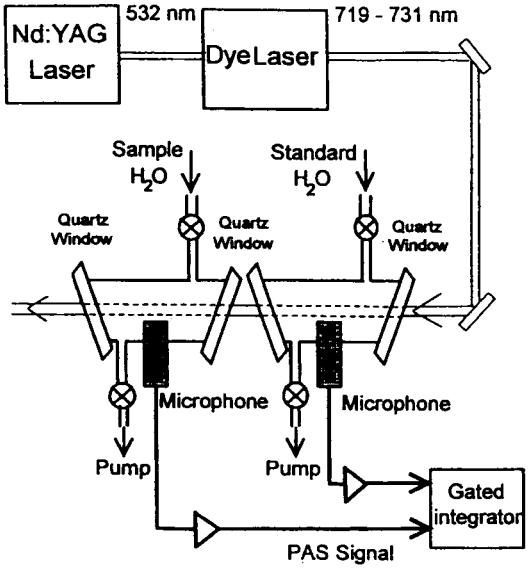

Fig.2. Experimental setup of photo-acoustic measurement.

Typical acoustic signal is shown in Fig.3, where the signal appears at the delay of 50 - 400 μs after laser shot is from the water vapor, and the following strong signal about 450 μs is due to the photo-acoustic signal from the cell windows. This strong signal appears in later stage and it can be distinguished from the signal quite well. The duration of this noise is long but it disappears completely before the next laser shot, 100ms.

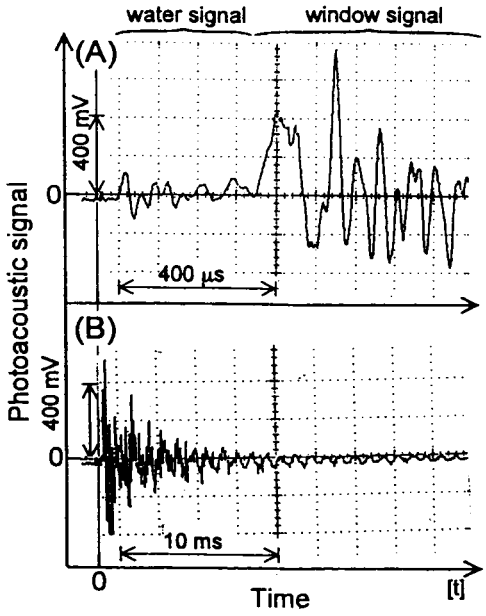

Fig.3. Photo-acoustic signal produced by water vapor and cell windows. The first 350 μs is due to water vapor and the later signal is from windows (A). The strong signal from windows decays gradually (B)

The signal intensity is proportional to the laser power suggesting no saturation, and the normalization to a constant laser power is possible. In fig.4, a typical spectra in 720.9-721.1 nm range for normal water and ^{18}O enriched water. where the upper trace is the spectrum of normal water expanded by 60 times in signal scale. The position and the strength of the peaks agree to the HITRAN data base values.

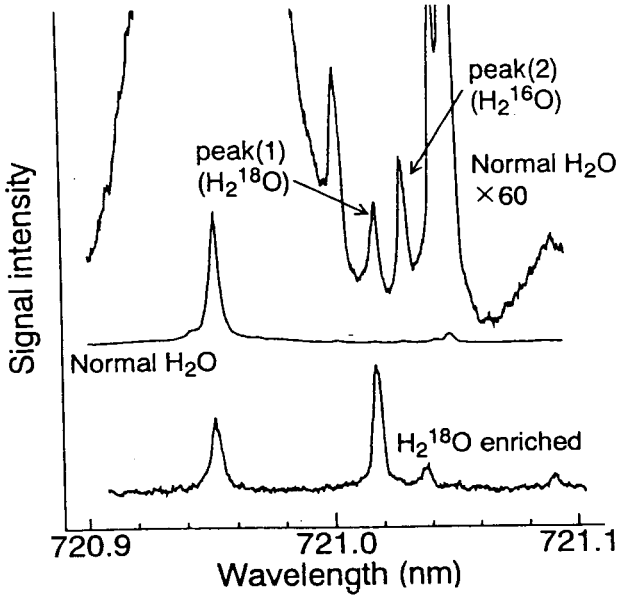

Fig.4. Spectra of normal water (middle) and ^{18}O enriched water (bottom) in the range of 720.9-721.1 nm. The upper trace is the expanded spectrum of normal water, where small peaks of $H_2{}^{18}O$ is clearly observed separately. Total pressure is 0.1 atmosphere.

However, the spectra obtained at higher total pressure is broad, Fig.5, and the overlapping with strong absorption lines diminished the separation.

The value of δ H2^{18}O obtained for a water sample the $\delta\,^{18}O$ value of which is determined by isotope MS. The flue of laser method is -24.1 $\pm$25.4 ‰ for the reliable value of -28‰; the agreement was satisfactory as the experimental stage.

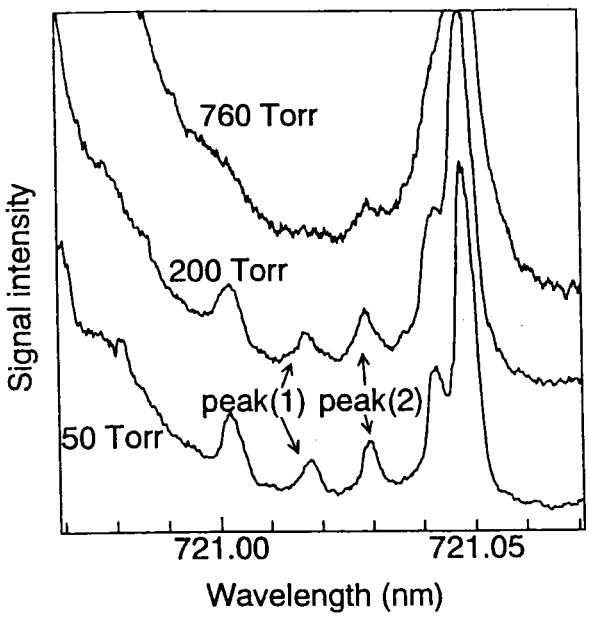

Fig.5. Pressure dependence of photo-acoustic spectra of normal water vapor. The total pressures are 760, 200 and 50 Torr from the top to bottom, respectively. The water vapor partial pressure was 15 Torr, and the buffer gas is air.

3. Conclusion

Precipitation water sampling network is under operation for the analysis of $\delta\,^{18}O$.

Laser photo-acoustic measurement of $\delta\,^{18}O$ was examined with moderate success.