Measuring atmospheric water isotopes in Western Siberia

Konstantin Gribanov and Nikita Rokotyan

A new observation station makes continuous measurements of water isotopes for climate studies, using several remotely-operated spectrometers and meteorological instruments.

Stable water isotope concentrations can be used as tracers of the atmospheric water cycle. Differences in molecular mass of the isotopes cause them to fractionate during evaporation and condensation processes and, as such, they can record air mass history. The relative concentrations of carbon isotopes in methane (CH$_4$) and carbon dioxide (CO$_2$), i.e., $^{13}$CH$_4$, $^{12}$CH$_4$, $^{13}$CO$_2$, and $^{12}$CO$_2$, in the atmosphere provides information about the sources of these greenhouse gases and can be used to study climate change.

The atmospheric transmittance of solar radiation can be measured in the near-IR spectral region. Instruments that make such measurements with high-spectral resolution enable specific features in the spectrum, which are characteristic to different atmospheric isotopologues (chemical species that differ only in their isotopic composition), to be identified. These observations are used to calculate the total concentration of the gases in the atmospheric column.

We have been developing new methods for retrieving the ratios of hydrogen deuterium oxide (HDO) to water (H$_2$O), $^{13}$CH$_4$ to $^{12}$CH$_4$, and $^{13}$CO$_2$ to $^{12}$CO$_2$ from ground-based Fourier transform IR spectroscopy (FTIR) measurements. Ground-based FTIR measurements are made at the Ural Atmospheric Fourier Station (UAFS) simultaneously with direct wavelength-scanned cavity ring-down spectroscopy (WS-CRDS) measurements of water isotopologues, and with meteorological parameters. By combining these measurements with an atmospheric general circulation model—such as ECHAM5-wiso—the results from several different techniques can be compared.

The UAFS site for atmospheric observations is located at the Kourovka astronomical observatory (57.038°N, 59.545°E, 300m above sea level), 80km northwest of Yekaterinburg, Russia (see Figures 1 and 2). UAFS began operations in 2009 and is maintained by the Climate and Environmental Physics Laboratory (CEPL) of the Institute of Natural Sciences. The CEPL was created to work on a project entitled “Impact of climate change on water and carbon cycles of melting permafrost of Siberia” and is a separate subdivision of the Ural Federal University. It includes three actively interacting sections: the remote sensing, surface measurements and field research, and modeling groups.

UAFS is equipped with a Bruker IFS-124M high-spectral resolution FTIR spectrometer with a spectral range of 420–25000cm$^{-1}$. The spectrometer is connected to an A547N automated solar tracker, with a resolution of 0.0035cm$^{-1}$, that is mounted on the roof of the working pavilion. The tracker directs solar radiation to the spectrometer aperture via a system of gold-coated mirrors. We last upgraded the spectrometer at the beginning of 2013. The UAFS site is also equipped with a Picarro L2130-i WS-CRDS instrument and a Gill Instruments MetPak-II meteorological station. We are able to make continuous measurements of water isotopes (H$_2^{16}$O, HD$_2^{16}$O, and H$_2^{18}$O) with the WS-CRDS. We obtain continuous temperature, humidity, atmospheric pressure, and wind direction data from the
Figure 2. Panoramic view of the Kourovka astronomical observatory, taken from the roof of the UAFS pavilion.

Figure 3. The UAFS detection set up. 1: Air sampling tube for water isotope measurements. 2: Meteorological station. 3: Solar tracker dome. 4: Internet protocol camera.

The meteorological station. All the instruments are placed in one corner of the working pavilion (see Figure 3). Air sampling for the water isotope measurements occurs at a height of 7m above the ground, using a sampling tube 6m in length. The site is fully automated and allows us to operate all the instruments remotely via the internet.

We have conducted recent simulations using ECHAM5-wiso that show the UAFS site is representative of the whole of Western Siberia for climate change studies. We are planning a new observation site for water isotope (air and precipitation) measurements at Labytnangi (66.657°N, 66.418°E). At CEPL, we intend to connect studies of water and carbon cycles with climate changes in Western Siberia. We will combine model simulations with direct measurements of water isotopes in the atmosphere and precipitation from UAFS, water isotopes in soil and precipitation samples obtained during field campaigns, and data from ground-based and space-based remote sensing measurements.

The development of the observation station was partially supported by a grant from the Russian government under contract 11.G34.31.0064.

Author Information

Konstantin Gribanov and Nikita Rokotyan
Climate and Environmental Physics Laboratory, Institute of Natural Sciences
Ural Federal University
Yekaterinburg, Russia

References