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Station for the comprehensive monitoring of the atmosphere at Fonovaya Observatory, West Siberia: current status and future needs

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ABSTRACT

Here, we briefly describe the station established by IAO SB RAS at Fonovaya Observatory to carry out continuous measurements of atmospheric composition and other parameters in West Siberia. Specifications of the instrumentation installed at the station, functioning modes of individual units comprising it, collection, transferring and storage of the measurement data are presented.

Keywords: monitoring of atmospheric composition, greenhouse and trace gases, aerosols

1. INTRODUCTION

To date, it is evident that for better understanding the current and future state of the climate system, it is necessary to establish as many observation stations as possible all around the world[1] especially in areas currently sparsely covered. Taking into account possible climate feedback loops involving not only greenhouse gases (GHG) but a number of other trace gas species and atmospheric constituents, observations should be comprehensive[2]. Russia occupies a significant part of the land surface of the Northern Hemisphere, but its observational infrastructure is still weak. According to the review by M. Kulmala[1], only two Russian stations by their specifications are close to meet the modern requirements of comprehensiveness, extending in recent years the nomenclature of measured parameters: the Zotino Tall Tower Observatory (ZOTTO) and the Tiksi Hydrometeorological Observatory. The first of them is located in the western part of East Siberia, and the second one - on the shore of the Arctic Ocean. Both ones were created and upgraded under international cooperation between Russian, European and American research institutions. Fonovaya aims to be such an important observatory dedicated to atmospheric composition monitoring and climate change research.

2. GEOGRAPHICAL POSITION OF THE STATION

Taking into account the importance of the existing problem and the absence of background observation stations in West Siberia operating in continuous measurement regime, in 2009 the IAO SB RAS decided to establish its background monitoring station at the Fonovaya Observatory that is situated on the east bank of the River Ob, 60 km west of Tomsk (56°25'07" N, 84°04'27" E; Figure 1). It has a typical boreal climate (humid continental, southern taiga zone). A large area between the station and the city of Tomsk is covered mostly with coniferous trees. In the immediate vicinity of the station there is a mixed forest (birches, aspens, and Scots pines). Winds blow predominantly from the south and south-southwest.

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Figure 1. Geographical position of the station for comprehensive atmospheric monitoring at Fonovaya Observatory (indicated by arrow).

3. INSTRUMENTATION

The station has a 44 m mast that was previously used as a radio transmitter tower. During the first years, only basic meteorological quantities and concentrations of CO_2 and O_3 were measured there. Measurements of aerosol size distribution have been commenced in 2011. Recently, the instrument suite of the station has been significantly augmented and upgraded that allowed more accurate and comprehensive observations to be started. This was made possible through the international cooperation of the IAO SB RAS with LSCE and LATMOS (France), and NIES (Japan) that provided some of the new instruments and other necessary equipment.

A list of instruments at the station and their specifications are given in Table 1, and a simplified schematic diagram of the system is shown in Figure 2. All the instrumentation is housed in a small building at the base of the mast, except for outdoor sensors and special installations (e.g. automated flux chambers). Indoor air temperature is maintained at 20°C by means of an air-conditioner in summer and a heater in winter. Power supply system of the station has a powerful uninterruptible power source (UPS, battery backup + inverter) that enables to provide normal operation of the whole system, including indoor climate units, during 3 hours. If the main power supply will not be available within 3 hours, UPS starts up a diesel generator arranged 100 m east of the station.

3.1 Gas analysis

The greenhouse gas analysis system consists of four assemblies. The first of them is a nondispersive infrared absorption (NDIR) assembly (Figure 2). It is a simplified version of an atmospheric CO_2 standard gas saving system[3] designed in NIES for the Japan-Russia Siberian Tall Tower Inland Observation Network established for the GHG monitoring in Siberia (JR-STATION). CO_2 mixing ratio is measured with a low cost NDIR gas analyzer (LI-840; LI-COR Inc., USA). Two sampling inlets are placed at 10- and 29.8-m levels of the mast. Ambient air is continuously drawn in through the Synflex 1300 tubing (6 mm OD; Eaton, USA) by diaphragm pumps (N86KN.18; KNF Neuberger, Germany). Pumps are located upstream of the LI-840 to push the air through the analyzer. Sampling air enters the pumps trough 15 micron filters (SS-4F-15; Swagelok, USA). The pressure of air exiting each pump is maintained at 150 kPa by a back pressure valve (BPV, Model 6800B; Kofloc, Japan). Before supplying the ambient air sample to the analyzer, it passes three stages of drying. The bulk of the water is removed by adiabatic expansion in a glass water trap that is periodically purged through a normally closed valve. A further stage of drying is provided by means of Nafion membrane dryer (MD-050-72F-2; Perma Pure LLC, USA). At the final stage, the sample is dried by chemical desiccant (magnesium perchlorate). The quality of drying is monitored using H_2O channel of the LI-840. In 2009, when designing the NDIR assembly, due to the lack of enough funding, we decided to use two standard gases (low and high concentrations of CO_2) for a daily calibration instead of three commonly used worldwide. The baseline drift of the analyzer is monitored hourly by means of reference gas (subworking standard[3]) that is prepared on-site by compressing previously dehumidified ambient air into third cylinder. Atmospheric samples, standard and reference gas mixtures are supplied to the analyzer through the selection manifold (assembly of stainless steel 3/2-way valves). A flow rate of the air entering the analyzer is maintained at 60 sccm using a mass flow controller (SEC-E40; Horiba Ltd., Japan). A pressure regulator valve (Model 6600A; Kofloc, Japan) is installed upstream of the SEC-E40 to avoid possible pressure differences in air supplied from different sources (ambient sample, standard and reference gas cylinders). Exhaust from the LI-840 is used to purge the Nafion dryer.

Before 2015, the mast height was 38 m. In summer 2015, it was dismantled for maintenance and re-mounted with new meteorological sensors and mounting arms, as well as additional sample inlets. When reassembling the mast, it was extended with additional sections to a full height of 44 m. We made a decision to leave sampling heights of 10 and 30 m that were used for NDIR analysis system before 2015 in order to do not interrupt long-term data set.

Table 1. List of instruments and their specifications.

System	Brand/Model	Measured parameter/units	Range	Uncertainty
Meteorology	Vaisala HMP155	Air temperature, °C Relative humidity, %	-80...+60 0...100	±0.12°C at 20°C ±1%
	Young Model 85004	Wind direction, ° Wind speed, m/s	0...360 0...70	±2° 0.1 m/s
	Young Model 61302	Barometric pressure, hPa.	150...1150	±0.3 hPa
	Kipp&Zonen CM3	Global radiation, W/m^2	0...2000	±2%
	Young Model 85004	Precipitation, mm/h	0...50	±2% (<25 mm/h)
Gas analysis	Picarro G2301-m	CO_2, ppm CH_4, ppm H_2O, ppm	0...1000 0...20 0...70000	< 0.1 ppm < 0.001 ppm < 150 ppm
	LI-COR LI-840	CO_2, ppm	0...1000	< 0.3* ppm
	OPTEC 3.02-P	O_3, μg/m^3	0...500	± 20%
	OPTEC K-100	CO, μg/m^3	0...50	± 20%
	Thermo Model 42*i*-TL	$NO/NO_2/NO_X$, μg/m^3	0...500	± 1%
	Thermo Model 43*i*-TLE	SO_2, μg/m^3	0...2000	± 1%
	Picarro G2508 (soil-atmosphere GHG exchange)	CO_2, ppm CH_4, ppm N_2O, ppm	20...5000 0.5...15 0...400	< 0.6 ppm < 0.01 ppm < 0.025 ppm
Aerosols	Diffusional particle sizer	D_p, nm (20 channels Number concentration, cm^{-3}	3...200 0...100000	– ± 10%
	GRIMM Model 1.108	D_p, μm (15 channels) Number concentration, cm^{-3}	0.3...20 0...2000	– ± 3%
	PhAN-A Nephelometer	μ (45°), km^{-1} sr^{-1} λ=0,46/0,53/0,59/0,63 μm	0.001…1	± 3%
	Thermo 5012 MAAP	BC, μg/м^3	0…180	1%
	CIMEL CE372 Lidar	β_a (808 nm), m^{-1} sr^{-1}	–	–

* when calibrated against standard gas mixtures.

The second GHG analysis suite is a cavity ring-down spectrometer (CRDS) assembly. A Picarro G2301-m CRDS $CO_2/CH_4/H_2O$ analyzer was integrated into the instrument suite of the station in 2016. Sample inlets of the CRDS assembly were mounted at 10- and 44-m heights. One more sampling line with an inlet positioned at 44 m was reserved for flask sampling. The ambient air is continuously drawn in through two Synflex 1300 tubing (1/4 in. OD; Eaton, USA) by the pumps of same type as used in the NDIR assembly. Ambient air enters the pumps trough 15 micron filters (SS-4F-15; Swagelok, USA). The output pressure of the pumps is set at 150 kPa using back pressure valve (Model 6800B; Kofloc, Japan). The compressed air is dried by an adiabatic expansion in a glass water traps. In total, five standard gas mixtures bracketing ambient concentrations are used for the CRDS system (Figure 2) traceable to the WMO primary scale. Ambient air samples, calibration and target gases are selected with a Valco SD 10-position valve (VICI Valco Instruments Co. Inc., USA). A flow rate of 100 sccm is set using a mass flow controller (SEC-E40; Horiba Ltd., Japan). We added poppet check valve (SS-4C-1/3, Swagelok, USA) upstream of the Valco one to avoid pressure drops when purging the water traps that may lead to the Picarro analyzer failure. A pressure regulator valve (M008-R21; Camozzi, Italy) is set upstream of the SEC-E40 to maintain constant pressure of the air entering the analyzer.

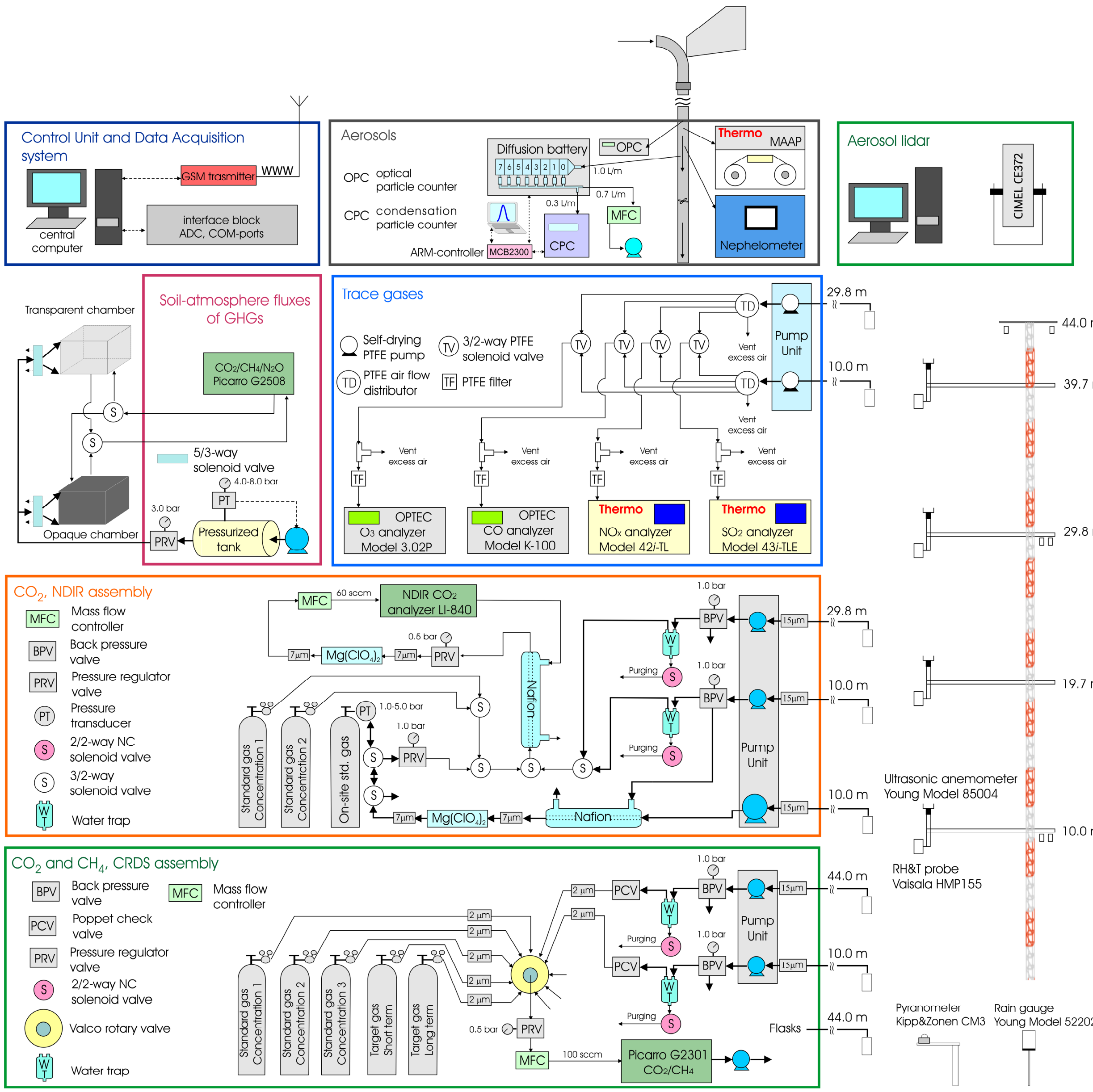

Figure 2. Schematic diagram of the system for comprehensive atmospheric monitoring at the Fononovaya Observatory.

The third gas analysis system was developed to measure concentration of the following trace gases: CO, O_3, $NO/NO_2/NO_X$, and SO_2. Due to the most of them are reactive, the intake air is drawn in through the sample inlets and sampling lines (1.0 cm ID) made of polytetrafluoroethylene (PTFE) by PTFE diphragm pumps with integrated self-drying system (LABOPORT® SD N 820.3 FT.40.18; KNF Neuberger, Germany). The inlets are mounted at 10- and 29.8-m levels of the mast. Each pump provides a flow rate of 20 slm. Air exiting the pumps enters the PTFE air distributors and then to a PTFE solenoid valve manifold. One of the outlets of air distributors is used to vent the excess air. The air from manifold enters the analyzers through the Teflon filters to protect them from particulates. The air from manifold is introduced into the analyzers through the Teflon filters to protect them from particulates. An atmospheric bypass plumbing arrangement is installed immediately before the filters to deliver sample air to the analyzers at atmospheric pressure. The 3.02-P chemiluminescence O_3 analyzer (OPTEC JSC, Russia) has an internal calibrator. The K-100 electrochemical CO analyzer corrects its baseline by routing periodically the air sample through a heated catalytic CO scrubber. The Model 42i-TL chemiluminescence $NO\text{-}NO_2\text{-}NO_X$ Analyzer (Thermo Fisher Scientific Inc., USA) and the Model 43i-TLE pulsed fluorescence SO_2 Analyzer (Thermo Fisher Scientific Inc., USA) are periodically calibrated using zero air generator and a source of span gas.

Measurements of GHG fluxes between the soil and the atmosphere during the growing season are performed with an installation consisted of the Picarro G2508 CRDS $N_2O/CH_4/CO_2/NH_3/H_2O$ analyzer and two automated static chambers designed in IAO SB RAS. The G2508 analyzer operates in a recirculation mode using the Picarro A0702 closed-loop sampling vacuum pump. An opaque chamber (OCh) is used for measurements of the ecosystem respiration (R_{eco}), and a transparent one (TCh) for net ecosystem exchange (NEE) that enables a gross primary production (GPP) to be derived. Both chambers have a volume of 0.324 m^3. They are placed on the meadow in vicinity of the station. The chambers are opening and closing automatically through the pneumatic control system in accordance with the following schedule: 5 minutes - the TCh is closed, and the OCh is open; the next 8 minutes - the TCh is open, and the OCh is closed; and then both chambers are open during 7 minutes to normalize conditions of a natural state of the ecosystem, and so on (a total 3 cycles per hour).

3.2 Aerosols

A transport system of the ambient aerosol sample consists of an air plumbing (10 cm ID). The outdoor part of it comprises an elbow that is joined with the main air duct via bearing and has a tail fin enabling the inlet plane always to be facing the wind (Figure 2). The system has an internal fan that aspirates ambient air with a flow rate of 100 m3/h in order to convey the aerosol sample under low wind speed and calm air conditions with minimal particle losses. Sample transport to the individual aerosol instruments is performed by metal tubing which inlets are located coaxially the main air flow inside the plumbing.

A diffusional particle sizer (DPS) is used to measure size distribution of particles below 200 nm. The DPS consists of a diffusion battery (8-channel synthetic screen DB, designed at the Institute of Chemical Kinetics and Combustion SB RAS, Russia) and the Model 5.403 condensation particle counter (CPC; Grimm Aerosol Technik GmbH, Germany). Aerosol particles in the size range from 0.3 μm to 20 μm are measured with the Model 1.108 optical particle counter (OPC; Grimm Aerosol Technik GmbH, Germany). The observations of the black carbon (BC) content of the aerosols are undertaken by means of the Model 5012 multi angle absorption photometer (MAAP; Thermo Fisher Scientific Inc., USA).

The PhAN-A photoelectric aerosol nephelometer (Zagorsk Optical-Mechanical Plant, Russia) modified and improved at IAO SB RAS is used for in situ observations of the aerosol scattering coefficient. In 2015, the CIMEL CE372 eye-safe aerosol lidar was installed at Fonovaya Observatory that enables to derive such important atmospheric parameters like vertical aerosol and cloud distributions, as well as boundary layer heights.

3.3 Meteorology

As was mentioned above, the mast was re-equipped with new meteorological sensors that are compliant the World Meteorological (WMO) recommendations. Before that, we used meteorological sensors manufactured in Russia. When choosing the new wind, relative humidity (RH) and temperature sensors, the preference was given to the following ones that have the RS485 interface in order to reduce the measurement uncertainty: the Model 85004 ultrasonic anemometer (R. M. Young Company, USA) and the Humicap® HMP155 RH and temperature probe (Vaisala Oyj, Finland), respectively. Every pair of sensors was positioned on a mounting arm at heights of 10, 19.7, 29.8, and 39.7 m to enable gradient-method of flux estimation. Precipitation and atmospheric pressure are measured by using the Model 52202 tipping bucket rain gauge and the Model 61302 barometric pressure sensor (R. M. Young Company, USA), respectively.

Observations of the global solar radiation are carried out with the CM3 pyranometer (Kipp&Zonen B.V., The Netherlands).

3.4 Data acquisition and transferring

We use an onsite desktop PC for operating the whole system, data storage, and remote access via cellular modem. Data from the Picarro and from the Thermo Fisher Scientific analyzers are retrieved via a TCP/IP interface through an Ethernet connection. The data from the OPTEC and LI-COR analyzers, rain gauge, pyranometer, and a bulk of engineering data are recorded via an analog-to-digital converter (NI USB-6211; National Instruments, USA), digital outputs of which are also used to operate soil flux chambers. All the aerosol instruments are operated by means of their own PC laptops connected to the local network. The UPort 1450I (Moxa Inc.,) USB-to-serial converters are used to retrieve the data from the R.M. Young Model 85004 and from Vaisala HMP155 meteorological sensors. All the obtained data are stored in a local MySQL database managed in HeidiSQL and every hour are transmitted to a remote MySQL server located at IAO SB RAS. The near-real-time data are displayed in a graphical form on the web page of the IAO SB RAS (http://lop.iao.ru/EN/).

4. CONCLUSIONS

Despite of the progress reached in establishing continuous and comprehensive observations at the Fonovaya Observatory, the station instrument suite still needs to be augmented to study a variety of climate change feedback mechanisms. In the future, we plan to equip it with a full set of commercially available solar radiation sensors. Measurements of biogenic volatile organic compounds (BVOC) are also highly needed to investigate new particle formation of secondary organic aerosols, as well as aerosol-cloud-climate and geosphere-biosphere interactions.

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REFERENCES

[1] Kulmala, M., "Build a global Earth observatory," Nature 553(7686), 21-23 (2018).

[2] Kulmala, M., Nieminen, T., Nikandrova, A., Lehtipalo, K., Manninen, H. E., Kajos, M. K., Kolari, P., Lauri, A., Petäjä, T., Krejci, R., Hansson, H.-C., Swietlicki, E., Lindroth, A., Christensen, T. R., Arneth, A., Hari, P., Bäck, J., Vesala, T. & Kerminen, V.-M., "CO_2-induced terrestrial climate feedback mechanism: From carbon sink to aerosol source and back," Boreal Env. Res. 19 (suppl. B) 122-131 (2014).

[3] Watai, T., Machida, T., Shimoyama, K., Krasnov, O., Yamamoto, M., and Inoue, G., "Development of an Atmospheric Carbon Dioxide Standard Gas Saving System and Its Application to a Measurement at a Site in the West Siberian Forest," J. Atmos. Oceanic Technol. 27 (5) 843-855 (2010).