PAPER • **OPEN ACCESS**

Gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere on the southeastern coast of Lake Baikal

To cite this article: V V Tsydypov *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **320** 012018

View the article online for updates and enhancements.



IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 58.58.213.55 on 21/09/2019 at 10:00

Gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere on the southeastern coast of Lake Baikal

V V Tsydypov[1], A S Zayakhnov[1], G S Zhamsueva[1], T S Balzhanov[1], A L Dementeva[1], A V Starikov[1] and I P Sungrapova[1]

[1] Institute of Physical Materials of Science SB RAS, Ulan-Ude, 670047, Russia

E-mail: tsydypov@inbox.ru

Abstract. Description of gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere on the southeastern coast of Lake Baikal is given. The measurements were performed at the Boyarsky stationary site (51.84° N, 106.06° E) using a 30-m meteorological mast. The results of experimental studies of the diurnal dynamics of atmospheric trace gases concentrations, meteorological and turbulent parameters of the atmosphere at different altitudes are described.

1. Introduction

The atmosphere is a complex dynamic system in which various physical and chemical processes take place. The intensity of these processes depends on the specific characteristics of the region under consideration [1]. The study of the composition of the ground-level atmosphere and its variability is an important scientific and practical task. Such investigations closely relate with the challenges of environmental and climate change. Monitoring of the parameters of atmospheric components and control of the air pollution transport are necessary for solving global environmental problems and studying climate change.

Every year the study of the regularity of local and transboundary air pollution of Lake Baikal becomes a current application value. The significance of such research is important for assessing the impact of pollution on the ecosystem of the unique natural environment of Lake Baikal. The modern approach to such research consists in the efficiency and accuracy of observations of trace gases concentrations and the dynamic characteristics of the atmosphere. This is achieved by applying highly sensitive gas-analytical and meteorological instruments using continuous and synchronous integrated observation methods.

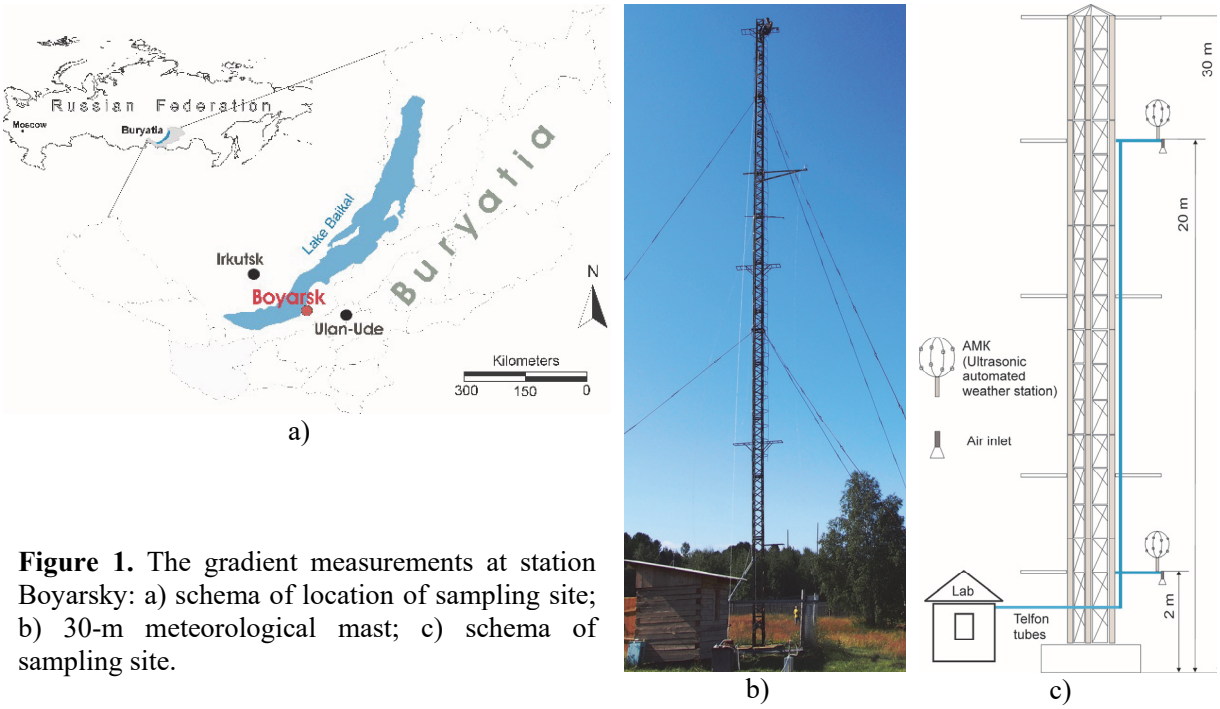
Currently, despite the increase in the number of studies on the small gas components of the atmosphere, there are still many questions related to its study. The problems of the organization of continuous synchronous measurement of atmospheric impurities for the accumulation of long-term series of observations are stand out.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

In this paper, we present the description of gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere on the southeastern coast of Lake Baikal. The results of experimental studies of the diurnal dynamics of ozone, nitrogen oxides and meteorological and turbulent characteristics of the atmosphere at different altitudes, using a 30-m meteorological mast are described.

2. Instrumentation and method of measurements

The gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere at the Boyarsky stationary site (51°83'N, 106°06'E) of IPMS SB RAS were carried out using a 30-m meteorological mast and automated system for monitoring atmospheric pollution [2]. Scientific stationary is situated in 160 km from Ulan-Ude on the southeastern coast of Lake Baikal, in the village with developed transport and communication infrastructure (Figure 1a).



a) b) c)

Figure 1. The gradient measurements at station Boyarsky: a) schema of location of sampling site; b) 30-m meteorological mast; c) schema of sampling site.

The meteorological mast was installed and put into to operation in 2010 as part of the implementation of integration project No. 8 “Instrumentation and methodological support for monitoring the natural-climatic processes of Siberia”. The mast is equipped with remote platforms at heights of 2, 4, 8, 16, 20, 30 meters and a ladder for equipment installation (Figure 1b). An automated system for monitoring atmospheric pollution includes the following equipment: gas analyzers, the diffusion spectrometer of aerosols of DSA [3], acoustic meteorological complexes AMK-02B and AMK-03 [4], operating and recording block. For placement of automated system for monitoring atmospheric pollution the laboratory building is used. The laboratory building is located in the immediate vicinity of mast.

The gaseous measuring unit of the automated monitoring system for air quality consists of chemiluminescent gas analyzers for ozone (O_3) 3-02P1, nitrogen oxides (NO_x) R-310 (OPTEK, St. Petersburg), an electrochemical gas analyzer for carbon monoxide (CO) Palladii-3 (FGUP SPO Analitpribor), and a fluorescence gas analyzer (SO_2) Mod. 8850 Monitor Labs.

Measurements and recording are carried out continuously with a quantization period of 1 sec, a volume of selections up to 250,000 values followed by averaging for 1 h. Calibration and setting of the zero for the O_3 and NO_x channels is accomplished automatically by an in-built source of microflows on command of the gas analyzer Mod. 8850 Monitor Labs (SO_2) and in a manual regime by means of an in-built source of microflow (SO_2). In addition, there is episodic monitoring by means of an external calibrator Mod. 8500 Monitor Labs (SO_2, O_3, NO_2). Calibration of the Palladii-3 gas analyzer is performed regularly before measurements by means of verified gas mixtures. The measurement facilities and the main technical characteristics are provided (Table 1).

For automatic measurement and recording of instantaneous and average values of the atmosphere parameters: air temperature, velocity and direction of horizontal wind, vertical wind velocity, air relative humidity, atmospheric pressure are used an automatic acoustic meteorological unit AMK.

Table 1. Measurement facilities and their main characteristics.

Measuring instrument	Measurement	Measurement range	Error, %	Notes
R-310	NO_2	0÷1 mg/m^3	± 25	2 level
R-310	NO	0÷1 mg/m^3	± 25	2 level
3.02P1	O_3	0÷0.5 mg/m^3	± 15	2 level
"Palladii-3"	CO	0÷50 mg/m^3	± 10	1 level
"Mod. 8850 Monitor labs"	SO_2	0÷0.5 mg/m^3	± 10	1 level
S310A	SO_2	0÷2 mg/m^3	± 25	1 level
DSA	Aerosol concentration	< $5\cdot10^5$ cm^{-3}	± 10	1 level
	Particle diameter	3-200 nm	± 10	1 level
AMK Meteorological Station	Air temperature	-50…+50 ºC	± 0.5	2 level
	Horizontal wind speed	0÷40 m/sec	± 0.5	2 level
	Horizontal wind direction	0÷360 deg	± 4	2 level
	Vertical wind speed	0÷15 m/sec	± 0.25	2 level
	Relative humidity	5÷100 %	± 6	2 level
	Atmospheric pressure	$74.7\cdot10^3$÷$106.6\cdot10^3$ Pa	± 33.3	2 level

This unit supplies to the computer instantaneous values of air temperature and wind velocity (for three orthogonal directions) that are additionally subjected to mathematical processing followed by estimation of up to 60 statistical and turbulence parameters of the atmosphere. A distinguishing feature of the meteorological unit is use of an ultrasonic method for measuring the main meteorological parameters (wind velocity and direction, air temperature, humidity) that provides high accuracy and low inertia of measurements, and compactness of the measuring system.

Air samples were taken at two altitudes, 2 and 20 m above ground level. On the remote platforms of mast the air inlets which prevent of precipitations influence were installed. The air inlets connect with gas analyzers by teflon tubes. Position of the air inlets on two altitudes allows to determine not only the atmospheric trace gases concentrations, but also their flows by the gradient method.

Analog signals from the outputs of the gas analyzers enter the input of the ADC analog commutator

whose operating control is accomplished by a computer command program. The data obtained from the ADC output are transferred to the operational memory device of the computer where they are stored until the end of a session of measurements. At the end of a session data and the results of their preliminary processing are written to the hard disk of the computer in standardized form. The output file of the program is a test file and contains the data, time and results of measurements of the gas concentrations. Information on the results of a periodic internal calibration of the instrument may also be input into the file.

3. Results and Discussion

Figure 2 shows the diurnal variations in hourly average values of ozone concentration at altitudes of 2 and 20 m over the period of summertime experiments in 2015–2016. The diurnal ozone variations differ between near-surface (2 m) and near-ground (20 m) layers, where the effect of the underlying surface is markedly weaker. The ozone concentrations at different altitudes become equal in daytime, as the temperature rises and turbulent processes intensify in the near-ground atmospheric layer.

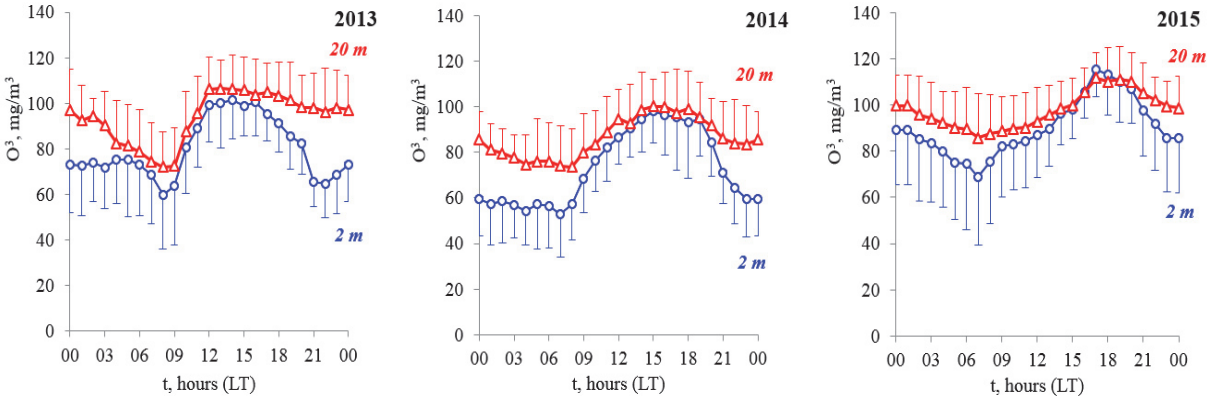


Figure 2. Diurnal behavior of the hourly average concentrations of ozone at the Boyarsky stationary site at altitudes of 2 and 20 m and their standard deviations: (a) August 1–15, 2013; (b) July 28–August 13, 2014; (c) August 1–17, 2015.

Figure 3 shows in more detail the results of synchronous measurements of ozone, nitrogen dioxide, air temperature and wind direction at altitudes of 2 and 20 m on summer expedition period 2017. In the evening and night hours, a change of wind direction (Figure 3c) in conditions of a breeze, leading to a change in air masses, has a noticeable effect on the ozone content. At the same time, the average daily concentration of ozone in the upper layer is 10–15 μg/m^3 higher than near the surface of the Earth.

The formation of temperature inversions in ground level of atmosphere renders a significant impact on the ozone content in the evening and night hours. In this period, the most appreciable differences in the distribution of ozone in height are observed. Figure 4 shows in more detail the results of synchronous measurements of ozone as a function of temperature gradient, wind direction, turbulent diffusion coefficient, air temperature at different altitudes on July 31–August 8, 2017, as most typical conditions of breeze formation. Maximum ozone temperatures are observed during periods of maximum temperature at 2 different levels. At 18 h the surface temperature usually begins to fall immediately after reaching maximum values, while at a level of 20 m it remains high for a long time.

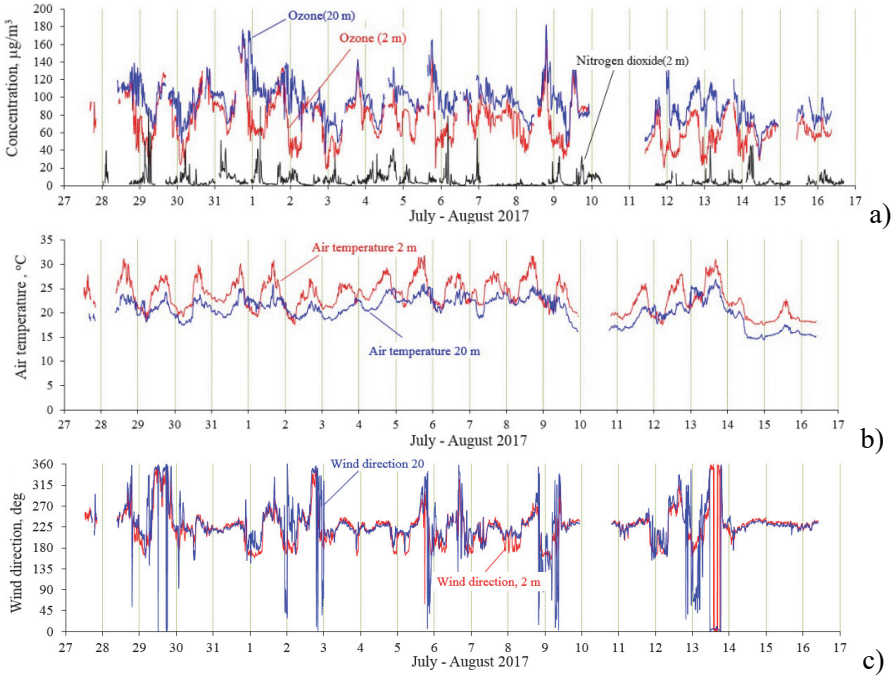


Figure 3. The temporary variability of ozone and nitrogen dioxide (a), air temperature (b) and wind direction (c) at altitudes of 2 and 20 m.

During evening hours at altitudes of 2 m ozone concentration decreases to a minimum with a decrease in temperature and turbulent activity. At an altitude of 20 m in the evening hours, the ozone concentration decreases with a decrease in turbulent activity, but then it grows due to the formation of inversion in the lower layers of an atmosphere. Inversion layer makes it difficult to mix air in the layer up to 20 m.

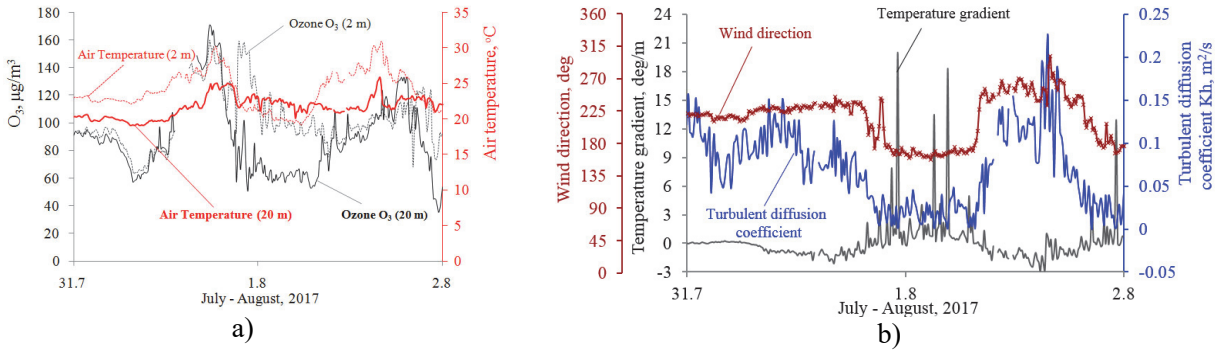


Figure 4. Diurnal variation of ozone and air temperature (a) at altitudes of 2 and 20 m; wind direction, turbulent diffusion coefficient, temperature gradient at altitudes of 2 m (b).

4. Conclusion

Using a 30-m meteorological mast and automated system for monitoring atmospheric pollution the gradient measurements of atmospheric trace gases concentrations and dynamic characteristics of atmosphere were carried out. By results of analysis of gradient measurements, the differences of diurnal

variation of ozone concentration near-surface (2 m) and near-ground (20 m) layers are revealed. At the heights remote from the Earth the diurnal variation of ozone is smoother than that of the Earth's surface.

The distribution of ozone concentration was analyzed depending on changes of meteorological parameters of the atmosphere, as well as under various synoptic conditions. The significant influence of temperature inversions, turbulent characteristics on the conditions of transformation, transfer and destruction of ozone, especially at near-surface Earth is shown.

Acknowledgments
The research was carried out within the state assignment № 0336-2019-0007 and by the Russian Foundation for Basic Research № 18-45-030032 r_a, wherein the investigation concerning of processing and analysis of experimental data was partly supported by RFBR № 18-35-00143 mol_a.

References

[1] Marchuk G I and Aloyan A E 2009 Dynamics and kinetics of gaseous pollutants and aerosols in the atmosphere and their significance for the biosphere *Biosphere* **1** 45-57
[2] Zayakhanov A S, Zhamsueva G S, Tsydypov V V and Ayurzhanaev A A 2008 Automated system for monitoring atmospheric pollution *Measurement Techniques* **51** 1342-6
[3] Ankilov A, Baklanov A, Colhoun M, Enderle K, Gras J, Julanov Yu, Kaller D, Lindner A, Lushnikov A A, Mavliev R et al. 2002 Intercomparison of number concentration measurements by various aerosol particle counters *Atmospheric Research* **62** 177-207
[4] Azbukin A A, Bogushevich A Yu, Il'icheskii V S, Korol'kov V A, Tikhomirov A A and Sheveleva V D 2006 Automated ultrasonic meteorological complex AMK-03 *Meteorology and hydrology* **11** 89-97
[5] Zayakhanov A S, Zhamsueva G S, Tsydypov V V, Balzhanova T S, Balin Yu S, Penner I E, Kokhanenko G P and Nasonov S V 2019 Specific features of transport and transformation ofatmospheric aerosol and gas admixtures in the coastal zone of lake Baikal *Atmospheric and Oceanic Optics* **32** 158-64