Estimate of the ratio of the ozone formation rate in the atmospheric boundary layer

Antokhin P.N., Antokhina O.Yu., Belan B.D.

V.E. Zuev Institute of Atmospheric Optics SB RAS
634021, Russia, Tomsk , Academician Zuev square 1
apn@iao.ru

Abstract. In this paper estimates of the ratio of the ozone formation rate in the atmospheric boundary layer to its income from the free troposphere are presented. Estimates are based on the data derived from in situ airborne measurements carried out over the background region of West Siberia. As a result, it was found that the rate of ozone inflow into the atmospheric boundary layer (ABL) from upper layers is of about 20% of its formation rate within the boundary layer. Vertical profiles of ozone fluxes in the ABL have been calculated by means of *k*-theory methods using the model proposed by Troen and Mahrt. Results of calculations showed that the noon-time ozone maximum in the ABL is determined by the photochemical production from ozone precursors.

Key words: *airborne sounding, ozone flux, vertical distribution of ozone, the rate of ozone formation.*

Area of study

Since July 2010 , the complex began to be used in the measurements of the vertical distribution of ozone and carbon dioxide in the ABL. District of experiments is far from the village Berezorechka Tomsk region , and satisfies all the conditions imposed on the background studies of the atmosphere. Profile measurements are taken over the post of monitoring greenhouse gas emissions Russian-Japanese project TOWERS. The post is equipped with research equipment mast , located within a large forest at a distance of 60 km from the city of Tomsk (coordinates : 56 ° 08 'N and 84 ° 20 ' E) . This combination is possible to obtain profiles of ozone from the surface to an altitude of 3,000 m, in the summer and in the winter of 2000 m .

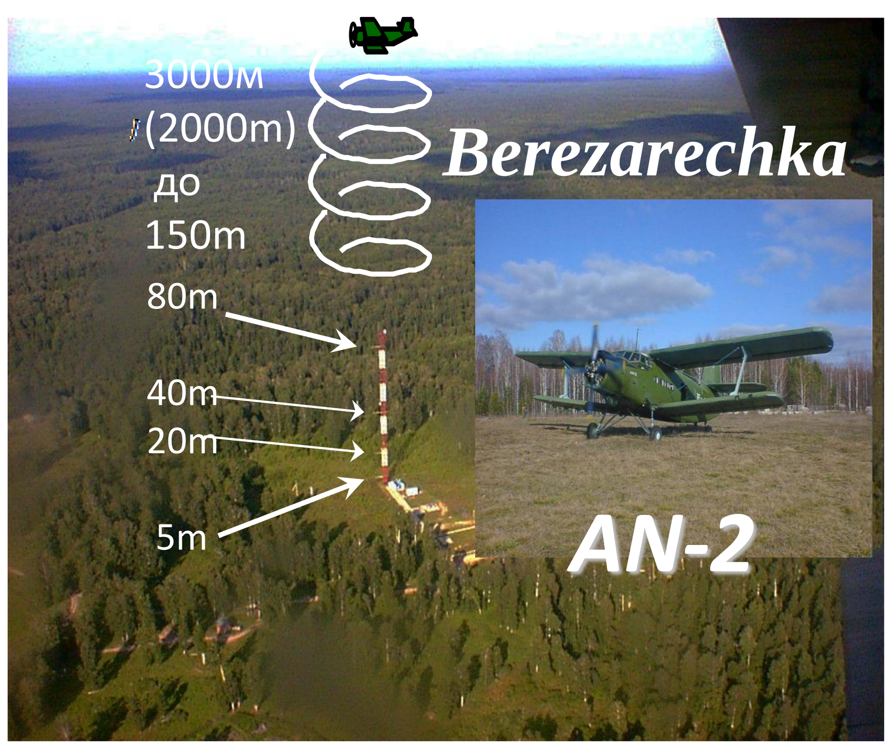

Fig.1 Area of research

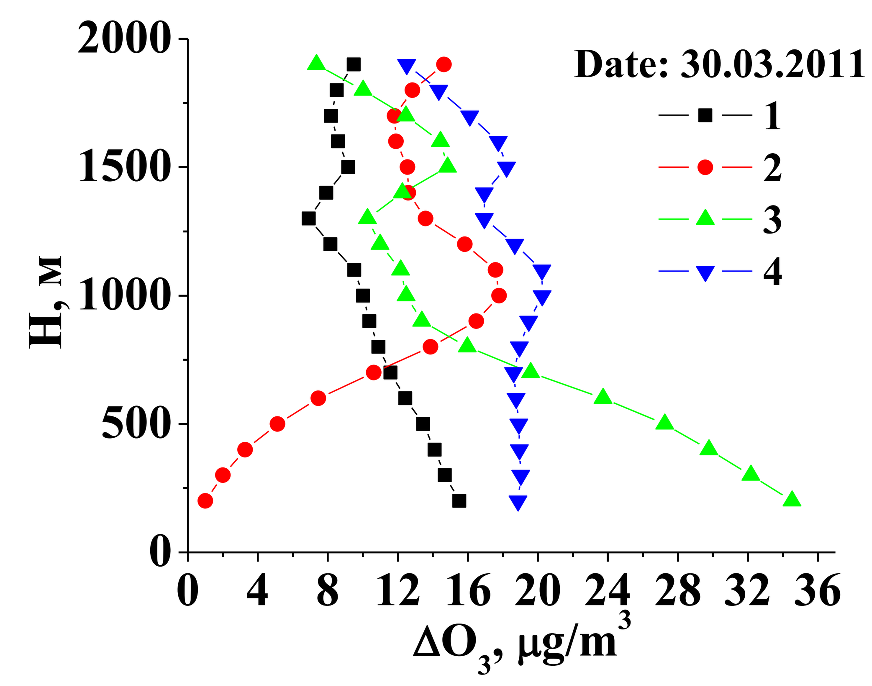

Fig. 2. Profiles of the difference in the concentration of ozone (ΔO_3) obtained during the day
1 - between the morning and afternoon;
2 - after the morning and afternoon, and evening - midday 3 and 4 - afternoon and evening flights.

Results

The main objective of our research was to determine the causes of the diurnal variation of the vertical distribution of ozone in the atmospheric boundary layer, discovered as a result of aircraft measurements. For this purpose, we calculated the difference of concentration profiles obtained during a daily cycle measurements. The resulting difference shown in Figure 1. It is seen that in the period from the morning until noon ozone concentration increases around the boundary layer. The largest increase (almost twice) recorded in the surface that favors the admission here ozone-forming compounds with the underlying surface and the subsequent photochemical ozone generation. In the afternoon peak ozone generation rate was observed already at the upper limit of the boundary layer, where with the help of turbulent exchange also began to receive gas precursor. In turn, the difference between the profiles obtained between the Afternoon and evening departures, shows that in the future for the turbulent exchange Thu ozone concentration is aligned throughout the entire thickness of the boundary layer. The difference between the afternoon and evening profiles maximum in the lower layers, which clearly indicates the predominant here at this time the mechanism of ozone flow to the underlying surface. The second important finding is the transfer of the overlying layers. These profiles showed no difference significant daily dynamics in the layer above the boundary that probably favors, in order that the transport of ozone from the upper layer does not have a significant effect on his daily course in the boundary layer.

Conclusion. *In work on the basis of aircraft sounding shows that the main source of ozone in the boundary layer of the atmosphere is its photochemical generation of gas precursors. A transfer from the free troposphere is on average 20% of the photochemical ozone generation.*

Instruments

The purpose of this paper is to develop a hardware system for the experimental study of the daily dynamics of the vertical distribution of ozone in the atmospheric boundary layer .

Table 1. Devices have been installed on board airplane

Sensors	Range	Accuracy	Response time
O_3 (TEI Model 49)	0 – 200 ppb^{-1}	1 ppb^{-1}	5 s
O_3 (OPTEC 3.02P)	1 – 500 ug/m^3	13%	1s
CO_2 (Licor LI-800)	0 – 2000 ppb^{-1}	1 ppm^{-1}	1s
Temterature (Vaisala)	–60…+80	0,2 ^{0}C	15 s
Humidity (Vaisala)	0 – 100%	1,7%	15 s
Pressure Sensor MPX4115AP (Motorola)	15 – 115kPa	1,5%	0,001 s
Differential pressure sensor MPX5010DP (Motorola)	0-10 kPa	5%	0,001 s

Based on the profiles obtained during all aircraft measurements designed to study the diurnal variation were assessed value of the rate of arrival of ozone from the upper layers of the atmosphere and its generation in the boundary layer in the following manner. First, the difference between the calculated ozone profiles obtained during the daytime and early morning departures, the difference was divided by the time between departure, the rate obtained showed the amount of photochemical ozone generation. The same procedure is done with the day and evening profiles obtained at this stage of the rate reflected the magnitude of flow of ozone. For the speed of generation during the day, resulting profiles were formed. Then the procedure is carried out separately for integration of the boundary layer and the free troposphere, the values obtained were divided by the value of the thickness of the layer of integration, to obtain the values in the column thickness of 1 m. The rate of generation of ozone produced by airborne data were compared with the rates calculated according to TOR-stations for days of flights, calculation was carried out similarly to the method described above, except for the procedure of integration and normalization of the thickness of the layer. The calculation results are summarized in Table 2.

Table 2. Ozone formation rate

Date of fly	30.03.2011	30.06.2011	16.09.2011	14.12.2011	29.03.2012	24.08.2012	03.02.2013	03.04.2013	08.08.2013	20.10.2013
The average rate of formation of the boundary layer ($\mu g\ m^{-3} h^{-1}$)	5.1	3.5	6.4	5.5	5.4	2.8	4.2	3.3	9.9	4.7
The average rate of formation of the surface layer ($\mu g\ m^{-3} h^{-1}$)	2.2	6.0	6.8	1.1	4.5	4.4	4.1	5.6	5.5	3.9
The average rate of arrival of the free troposphere ($\mu g\ m^{-3} h^{-1}$)	2.1	0.5	1.6	0.7	1.5	0.6	0.9	0.7	0.9	1.6
The difference between the rate of formation of ozone in the boundary layer and flow from the free troposphere ($\mu g\ m^{-3} h^{-1}$)	2.9	3	4.8	4.8	3.9	2.2	3.3	2.6	9	3.1
The ratio of the flow of ozone from the free troposphere to the rate of formation of the boundary layer(%)	41	14	25	12	27	20	20	21	10	34

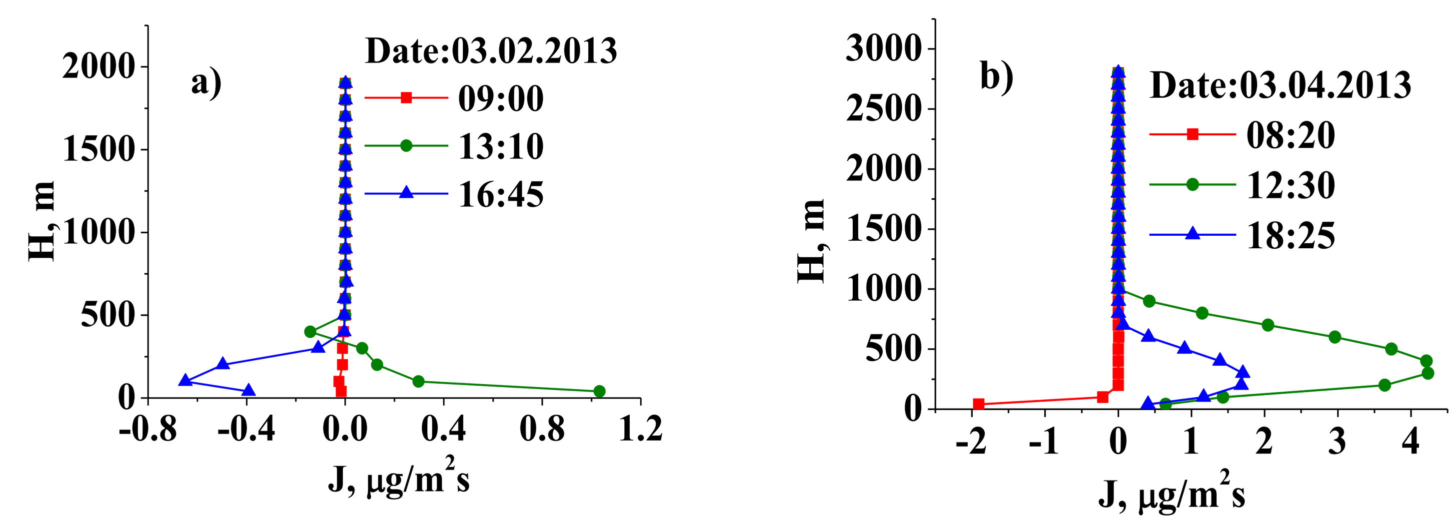

Fig. 3. The vertical distribution of ozone flux (J) received 03.02.2013, the (a) and of 4.3.2013 (b). Plus flows indicates that the flow is directed upwards

The work was supported by the Ministry of Education of the state contract No14.613.21.0013, identification number RFMEFI61314X0013.