Particularities of Formation and Transport of Arid Aerosol in Central Asia

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1. Introduction

The climate change is a global problem of humanity. During last decades anthropogenic air pollution is a main cause of the content change of the atmosphere. The situation constantly is redoubled by continuing intensive growth of the air pollution in the areas located near of emission sources and also far off territories.

At the present the square of deserts increases in East Asia, and it affects on increasing of dusty days number. The total area of deserts and desertification lands is about 1.653 million km^2 in Northern China [Wang T. & Zhu Z., 2001; Wang S., 2005]. More than 70% of the pastureland area of Mongolia is under desertification [Natsagdorj et al., 2003].

Gobi Desert covers 1/3 of Mongolia territories and is the driest area in the world. The climate of Gobi Desert is dry, cold, and more continental. Soils are poor with humus, containing a lot of gravel.

Dust storm frequently occurs in arid and semi-arid territories of Central Asia. It is known that Gobi desert is one of the major sources of dust storms occurrence in the East Asia. Asian dust storms significantly influence on air quality [Chan et al., 2005; Gillette, 1986; Lee et al, 2006; Wei & Meng, 2006]. At the intense dust storms in Gobi desert the great many of sand and dust are transferred to Eastern China, Korea and Japan. Sometimes many particles of sand and dust are raised up by strong winds and transfer all over the world [Kim & Chung, 2008]. The total dust emission from sources in East Asia is estimated is 10.4×10^6 ton yr^{-1} for PM$_{10}$, 27.6×10^6 ton yr^{-1} for PM$_{30}$ and 51.3×10^6 ton yr^{-1} for PM$_{50}$. The total dust emission from Mongolian sources is 2×10^6 ton yr^{-1} for PM$_{10}$, 2.9×10^6 ton yr^{-1} for PM$_{30}$ and 8.7×10^6 ton yr^{-1} for PM$_{50}$. It is suggested that Southern Mongolia is an important dust source region [Xuan et al., 2004].

In recent years the intense dust storms are observed not only in Central Asia but also in different parts of the world. For example, strong dust storm was observed in Australia on 23 October 2002. The dust storm was 2400 km long, up to 400 km across and 1.5-2.5 km in height. The plume area was estimated at 840,860 km^2 and was raised 3.35-4.85 million tones of sands and dust with ground [McTainsh et al., 2005].

The researches of dust storms distribution in Mexico City [Jaurequi, 1989], spatial-temporal distribution of dust storm producing by wind erosion in USA [Gillette & Hanson, 1989], sources of dust storms formation and analysis of their far transport in China [Littmann, 1991; Sun et al., 2001; Wang S. et al., 2005; Zhou, 2001], climatology of dust storms in Mongolia [Natsagdorj et al., 2003; Zhadambaa et al., 1967a, 1967b] were carried out. However the detail researches of dust storms in Gobi Desert (Mongolia) didn't carry out to present days.

The purpose of this chapter is a study of analysis of mass and number concentrations of dust aerosol, their chemical compound, meteorological and turbulent characteristics of atmosphere and the mechanism of dust storm formation in Gobi Desert.

2. Sampling and methodology

Complex researches of aerosol and small gas components, meteorological, turbulent and radiative characteristics of atmosphere of arid territories of Mongolia have been begun by Department of physical problems of Buryat science centre of SB Russian Academy of Sciences in 2005 and continue nowadays. Measurements are conducted in the summer expeditionary periods 2005-2010 at Dornogovi aimag (station Sainshand, $44^{0}54'$; $110^{0}07'$, station Zamyn-Uud, $43^{0}44'$; $111^{0}54'$) and Sukhbaatar aimag (station Baruun-Urt, $46^{0}41'$; $113^{0}17'$) [Zhamsueva et al., 2008]. Observations points are situated at the Hydrometeorological centers located on considerable removal from settlements. Round-the-clock measurements of meteorological parameters are carried out by autonomous ultrasonic meteorological complexes «AMK - 03». Autonomous ultrasonic meteorological complexes measures momentary values of three orthogonal component of wind speed, air temperature, atmosphere pressure and air humidity. Momentary values of these parameters are used for calculations of turbulent air characteristics [Azbukin et al., 2009]. Fine aerosol was selected by diffusion spectrometer DSA in size range from 1.6 to 400 nm. Sampling of aerosol particulates with a size less than or equal to 10 μm was carried out on «Whatman-41" filters by high volume sampler PM-10 of General Metal Works Inc.

3. The research of air mass transport in Central Asia

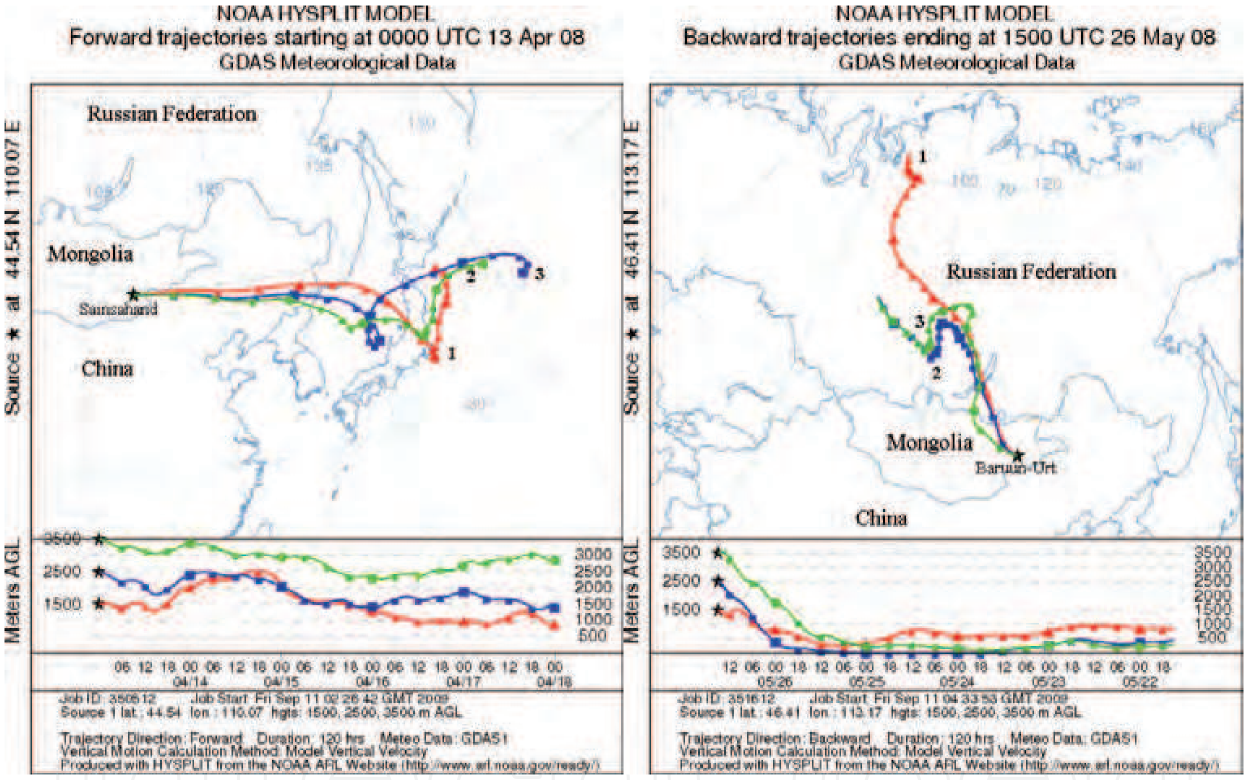
3.1 The particularities of air mass circulation in Mongolia

Synoptical conditions and winds in desert regions are two main factors influenced on transport of sand, dust and atmosphere impurities. It is known that in the arid and semi-arid regions of Mongolia and Northern China located near 40^{0} N the west flow of air transports great many of sand and dust particles to different parts of Earth.

For investigations of pathways of the atmospheric impurities transport in arid and semi-arid territories of Mongolia we have constructed forward and backward trajectories of air mass movement using of the reanalysis model NCEP/NCAR HYSPLIT (http://www.arl.noaa.gov/ready/hysplit4.html) [Draxler & Rolph, 2003] and archival meteorological data (archive FNL) National Oceanic and Atmospheric Administration (USA).

For construction of trajectories we set geographical coordinates of two stations of Gobi Desert (Sainshand and Baruun-Urt). Trajectories of air mass movement are calculated for 2008 with duration 120 h and step on time 6 h at heights of 1500, 2500 and 3500 m. The air mass movement of these heights mainly confirm of regional far transfer of impurities of regional and global scales. In total 283 trajectories are constructed namely 140 forward trajectories and 143 backward trajectories for all seasons of 2008. The most often repeatable types of trajectories of air transport based on their direction and length are detailed as result of average data. It is established, that east, northeast and southeast carrying out of air mass are prevailed in this region. The episode of forward trajectories of air mass movement from stations Sainshand (13 April 2008) is presented presented on Fig. 1a for illustration. Apparently from figure, air mass from Gobi Desert passed over territories of Korea, Japan and Russia.

The results of the calculation of air mass backward trajectories show the prevalence of northwest, western, southwest and southern direction of winds to Gobi Desert. Under the southern and southwestern directions the conditions for air transport from China to the area of study are formed. This is confirmed by the construction of backward trajectories by the model HYSPLIT. On Fig. 1b is shown the most typical trajectories of air mass drift to Baruun-Urt station calculated for 26 May 2008.



a) b)

Fig. 1. Forward and backward air masses trajectories during observation period at the Sainshand and Baruun-Urt stations by the model HYSPLIT: a) 13 April, b) 26 May

3.2 Study of wind regime in atmosphere of Gobi Desert

The variety of Mongolia relief leads to irregular distribution of air temperature over different locations of terrestrial surface (arid, semi-arid, steppe territories, mountain ecosystems and so on) and it promotes to development of local circulation of wind [Zhadambaa et al., 1967a, 1967b]. In this context great interest presents the study of wind regime in atmosphere of Gobi Desert.

The daily fund meteorological data for 2 years from 2004 to 2005 of meteorological stations (Sainshand and Baruun-Urt) have been analyzed for study of wind regime of Gobi Desert.

Roses of winds constructed on daily fund and experimental meteorological data show basically a northwest direction of wind. However in summer the formation of local atmospheric circulation is observed. Besides in summer the increasing of repeatability of southern (30%), northeast (26.4 %) directions of wind at Sainshand is noted in comparison with other seasons.

It proves to be true also experimental data of meteorological parameters received by means of acoustic meteorological complexes AMK-03 during scientific expeditions in June-July between 2005 and 2009, and also by using of meteorological data of CLIWARE system (http://cliware.meteo.ru/izomap).

4. Dust storm in East Gobi

4.1 Number of dusty days and trend

The analysis of daily fund meteorological data for 18 years between 1991 and 2009 has been carried out for detail research of frequency and duration of dust storms at Sainshand in East Gobi. Fig. 2 shows temporal trend of number of dusty days. It is revealed that last years number of dusty days is increased. For example, frequency of dust storms from 1991 to 2006 is increased in 3 times.

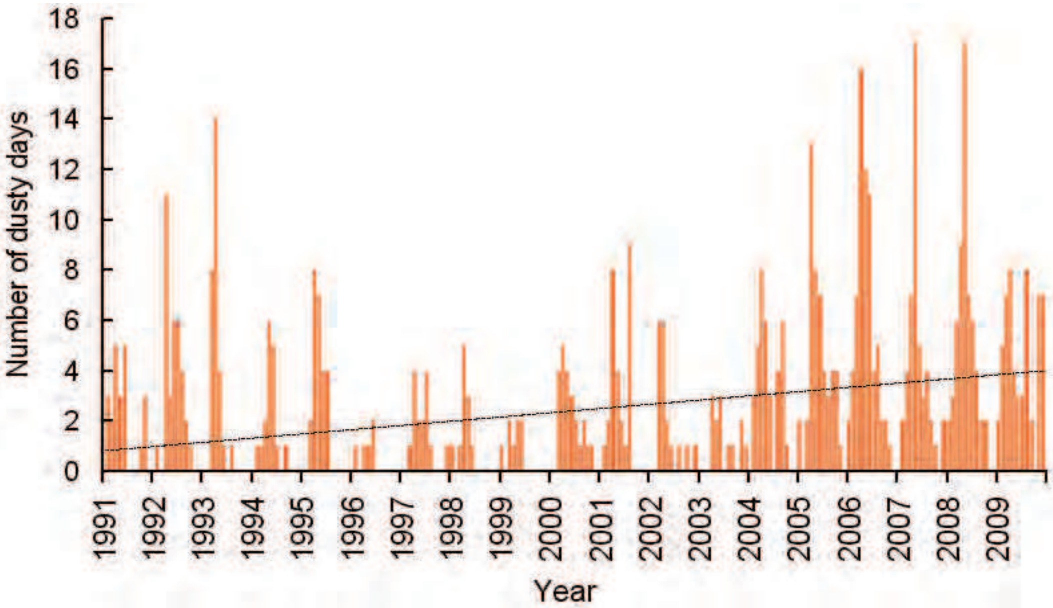


Fig. 2. Number of dusty days at Sainshand

To study the hour duration of dust storms we used daily fund data from 2003 to 2009. It is established that dust storms duration from 2003 to 2007 has increased in 40 times. The most duration of dust storms (573 hours) was observed in 2007. Analysis of number of dusty days has been allowed us to identify seasonal features. It is important to note that since 2004 dust storms began to appear in autumn and winter that it was not observed in previous years (Table 1).

The most repeatability of dust storms in atmosphere of Mongolia arid territories is observed in April-May at day and evening. The repeatability maximum of dust storms is marked in 15-18 hours of local time (Fig. 3).

	January	February	September	October	November	December
1991	0	3	0	1	3	0
1992	0	1	2	1	0	0
1993	0	0	0	0	0	0
1994	0	1	1	0	0	0
1995	0	0	0	0	0	0
1996	0	1	0	0	0	0
1997	0	0	0	0	0	1
1998	1	0	0	0	0	0
1999	1	0	0	0	0	0
2000	0	0	2	1	1	0
2001	0	1	0	0	0	0
2002	0	0	0	1	0	1
2003	0	0	1	0	2	1
2004	0	3	6	1	0	0
2005	2	0	4	4	1	0
2006	2	4	2	2	1	0
2007	0	2	2	1	0	2
2008	2	3	2	2	0	0
2009	2	5	2	0	7	7

Table 1. Number of dusty days in winter and autumn at Sainshand station

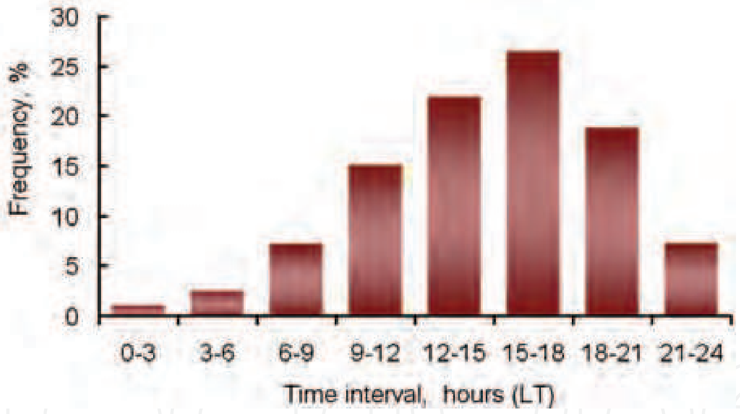


Fig. 3. The daily variation of dust storms for spring in the Gobi

4.2 Analysis of synoptical situation at severe dust storm in May 2008

The most repeatability of dust storms in arid and semi-arid territories of Central Asia is observed in spring, causing by strong winds due to passing of atmospheric fronts. For detail analysis of the episodes of strong dust storm in May 2008 in Mongolia we scrupulously considered the meteorological and weather conditions. In this time strong dust storms are mainly evidenced in East Gobi.

“Black wall” of sand and dust are accompanied by strong winds. Wind force reaches 30-40 m/s in some regions and the tones of sand and dust is transported to regions of China, Korea and Japan. The calculation of forward trajectories air mass movement using of model HYSPLIT confirms this result.

The trajectories of cyclones moving in May 2008 were investigated with help the surface and high altitude (500 hPa) meteorological maps of the Northern hemisphere (http://www.aari.nw.ru/odata/_d0010.php).

We find that the cold Arctic air masses are passed across Lake Baikal mixing with air mass of moderate latitudes in this time. Then it moved to the territories of Mongolia and China creating the significant gradients of the temperature and pressure. These meteorological and synoptical conditions were cause of intensive dust storms in arid and semi-arid territories of Mongolia and China. Therefore Lake Baikal such as huge reservoir of fresh water is a specific climatic zone which is situated on the frontier of arctic and moderate air masses. Baikal influences on pathways of air mass and dust storm occurrence in arid and semi-arid regions of Mongolia and China.

The satellite images of MODIS (http://modis.gsfc.nasa.gov) and the results of calculation of air mass backward trajectories demonstrate this fact and the episodes of severe dust storms in East Gobi on 26-27 May 2008 (Fig. 4).

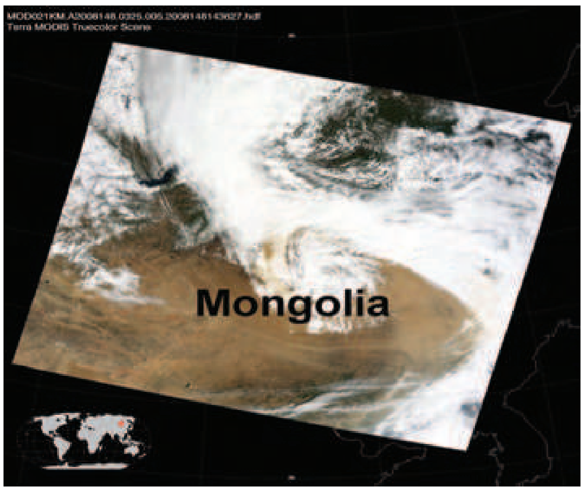


Fig. 4. Satellite picture passage of cold front in Mongolia (26 May 2008)

4.3 Behaviors of meteorological parameters during dust storm episodes

The analysis of behaviors of momentary meteorological parameters during the passage of dust storms presents a special interest for study of dust storm formation.

Usually two types of dust storms are observed such as the short-term connected with passage of atmospheric front and the long-term caused by strong winds due to elevated pressure gradients [Hoffmann et al., 2008].

Two regional dust storms were observed in the evening during complex scientific expedition in Baruun-Urt (semi-arid territory) in July, 2006. Notice, that first dust storm was accompanied by short-term precipitations, second was accompanied by a strong wind, local wind soil erosion, visibility no more than 50 m [Zhamsueva et al., 2008]. High temperature (+27^{0}C) and low relative humidity of air (20%) are registered in the beginning of dust storm. Under dust storm passage the sharp decreasing of air temperature during 15-20 minutes up to 8.8 ^{o}C (July, 10) and up to 7.9 ^{o}C (July, 11) independently of atmospheric turbidity are observed. In this time the increasing of average wind speed up to 21.5 m/s (July, 11), wind flaws are achieved up to 50 m/s and sharp increasing of relative humidity of air was noticed (Fig. 5).

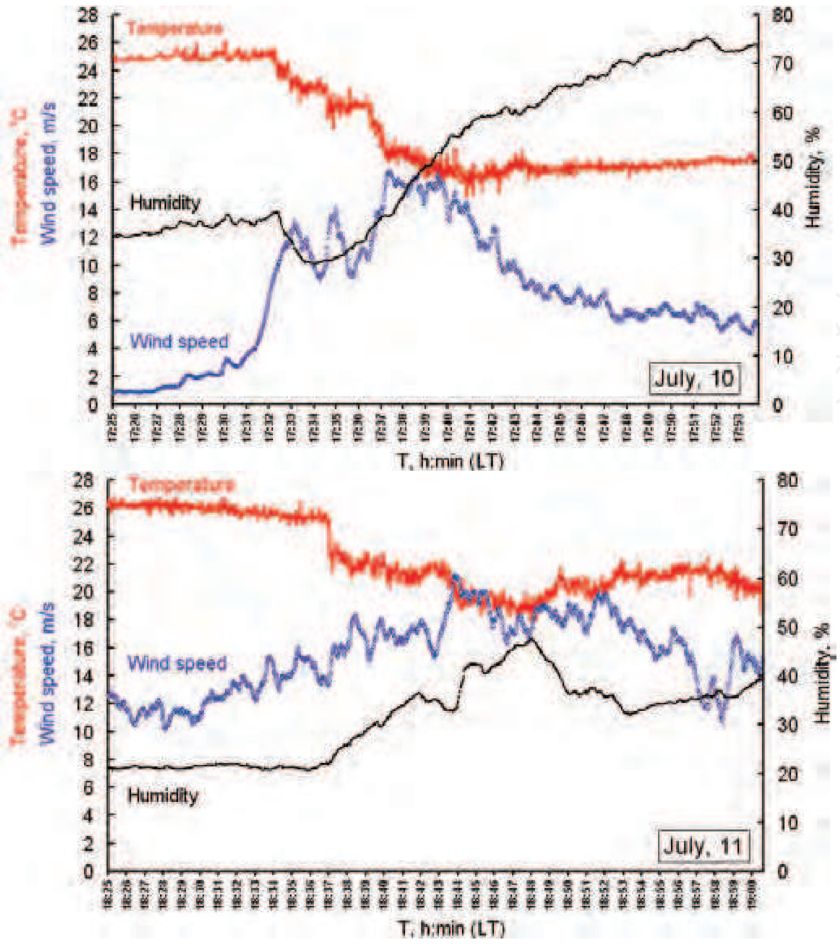


Fig. 5. Temporal variations of wind speed, temperature, humidity in atmosphere of Baruun-Urt during dust storm (10, 11 July 2006)

Under the weakening of dust storm the temperature of air stayed without change. After local dust storm we observed the decreasing of temperature and wind speed and increasing of relative humidity due to cold atmosphere front passage.

4.4 Turbulent characteristics of Gobi Desert atmosphere

The research of turbulent characteristics of atmosphere during dust storm is a great importance.

The turbulence promotes to heat and moisture exchange in the atmosphere of the Earth. Turbulence is caused by topographical heterogeneity and non-uniform heating of the Earth surface. The increasing of atmospheric turbulence conduces to the far transport of dust aerosol [Tverskoi, 1951; Bezuglaya & Berlyand, 1983].

According [Park et al., 2010; Bezuglaya & Berlyand, 1983] the dust storms usually occur under certain critical values of wind speed depending on terrain features and soil properties, which are irregular for different regions.

To get a complete picture of the atmospheric dynamics we analyzed around-the-clock daily measurements of turbulent characteristics obtained using of autonomous ultrasonic meteorological complex AMK-03 in Gobi Desert from 2005 to 2009 in summer. The turbulent characteristics of atmosphere are calculated based on the theory of Monin-Obukhov [Monin & Yaglom, (1965); Obukhov, (1988)]:

$$H = c_p \rho < T^{/} \cdot w^{/} > \tag{1}$$

$$K_h = v * T * / (\partial \theta / \partial z) \tag{2}$$

By results of the analysis it is revealed that in days without dust storms average vertical turbulent heat flux (H) in the surface layer in the day is H = 50 W/m^2. The maximal average daily value of the turbulent exchange coefficient (kh) is kh = 0.8 m^2/s. Turbulence data analysis during dust storms showed that the vertical heat flux was directed downward from atmosphere to surface due to a sharp temperature fall. Maximum H value was -281 W/m^2 and kh = 2.7 m^2/s during the passage of dust storms. After passing of dust storm the vertical heat flux varies from -7.3 to 6.0 W/m^2, and the coefficient of turbulent exchange equals 0.7 m^2/s (Fig. 6).

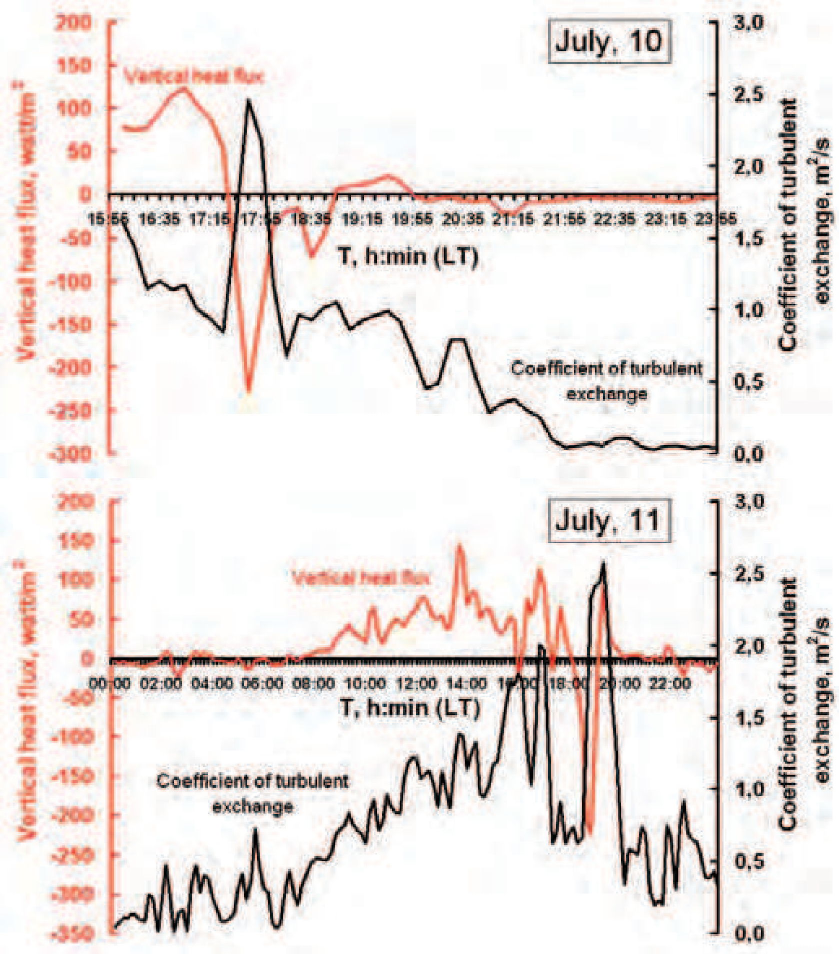


Fig. 6. Temporal variations of vertical heat flux, coefficient of turbulent exchange in atmosphere of Baruun-Urt during dust storm (10, 11 July 2006)

5. Mass concentration of dust aerosol PM10 and PM2.5 in Gobi Desert

In recent decades the problem of global and regional changes of environment and climate are actual due to increasing of air pollution by aerosol or particulate matter (PM). The aerosol changes the radiative balance in the earth-atmosphere system and, consequently, in weather and climate change. Also a harmful effect of particulate matter on human health is noted. The epidemiological studies reveal that under increase $PM_{2.5}$ (particles with an aerodynamic diameter of 2.5 μm or less) and PM_{10} (particles with an aerodynamic diameter of 10 μm or less) concentrations the morbidity, hospitalization and premature mortality of peoples are increased due to particle penetrate into the lower respiratory tract [WHO, 2006, 2007]. Particularly the most attention is devoted to study of $PM_{2.5}$ fine aerosols due to their relatively long lifetime in atmosphere and therefore far transfer. Consequently, the air pollution by suspended particles is not only local but also global problem. Monitoring measurement of mass concentration of PM_{10} and $PM_{2.5}$ at Sainshand station are conducted from 2008 within the framework of the program KOSA Monitor on development of network of dust and sand storms in Central Asia. Samples are collected using high volume samplers Partisol FRM Model 2000 Air Sampler (Japan).

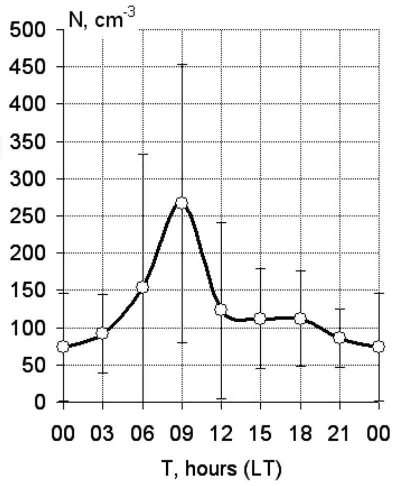
We analyzed daily fund data of 2008 to reveal of daily and annual changes the aerosol mass concentration of PM_{10} and $PM_{2.5}$ at Sainshand and Zamyn – Uud. It is revealed the mean annual course of mass concentration of PM_{10} and $PM_{2.5}$ fine aerosols at Sainshand and Zamyn -Uud. Average annual concentrations of aerosol don't exceed 30 μg/m^3 of PM_{10} and 8 μg/m^3 of $PM_{2.5}$. The elevated monthly average PM_{10} and $PM_{2.5}$ concentrations are observed in spring and winter but minimum is autumn. The maximal average concentrations 30 μg/m^3 of PM_{10} and 20 μg/m^3 of $PM_{2.5}$ are marked in May 2008. Concentrations of these fractions are minimum value in autumn and up to 5 and 3 μg/m^3, according. Under the stable weather the daily average concentrations of 5 – 8 μg/m^3 of PM_{10} and 3 – 5 μg/m^3 of $PM_{2.5}$ are observed usually. But at dust storms the highest hourly concentrations exceed 1400 μg /m^3 (PM_{10}) and 380 μg /m^3 ($PM_{2.5}$). Average annual concentrations of aerosol at Zamyn-Uud located on the border of Mongolia and China considerably exceeds values at Sainshand and is 83 μg/m^3 of PM_{10} and 55 μg/m^3 of $PM_{2.5}$. The maximal average concentrations 100 μg/m^3 of PM_{10} and 59 μg/m^3 of $PM_{2.5}$ are marked in May 2008. Concentrations of these fractions are minimal in July and up to 11 μg/m^3 (PM_{10}) and 13 μg/m^3 ($PM_{2.5}$) in September. The daily average concentrations are varied range 18 - 20 μg /m^3 (PM_{10}) and 16 - 18 μg /m^3 ($PM_{2.5}$) under week wind. Maximum values of 1230 μg /m^3 (PM_{10}) and above, the 700 μg/m^3 ($PM_{2.5}$) and above under dust storms are observed. Data of mass concentration of PM_{10} at Sainshand and Zamyn - Uud good agree with data Erdene station (44^0 27′N, 111^0 05′E). The Erdene station is located in the about 90 km southeast from the station Sainshand and 100 km northwest from the station Zamyn - Uud. According to [Park et al., 2010] 10-day averaged daily maximum concentration of PM_{10} is 140 μg/m^3 in early May 2009.

6. Experimental studies of fine and chemical composition of arid aerosol in the atmosphere of the Gobi Desert

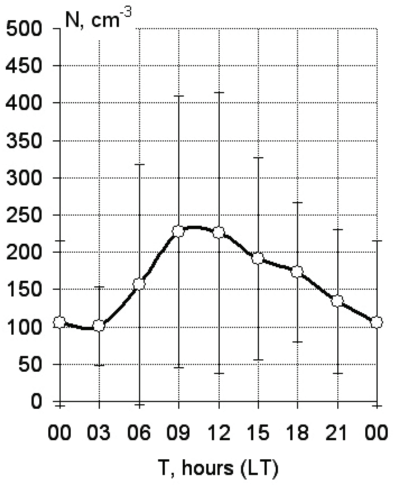
6.1 Study of fine arid aerosol

Studies of the daily dynamics of fine arid aerosol were carried out using the diffusion spectrometer DSA range in size from 1.6 to 400 nm at the Sainshand station (Gobi Desert, Mongolia) in August 2009.

The presence of night minima in the diurnal variation of total number concentration of fine aerosol is founded (Fig. 7). In addition, unlike the diurnal cycle of fine aerosol concentrations with peaks during the daytime in other regions, the maximum of the nuclei mode particles (d <0.01 μm) in the daily dynamics is often observed in the morning due to the rise of the particles of fine fraction due to more rapid heating of the earth's surface in arid territories and intensification of the turbulent processes in these hours [Ayurzhanaev et al., 2009].



a)



b)

Fig. 7. Daily variations of the total number concentration of aerosol (August 2009, Sainshand station, Mongolia): a) nuclei mode; b) the Aitken mode

Reduction of number concentration of nuclei mode particles during the daily hours apparently associate with increased of particle coagulation of this fraction and their transition to the range of Aitken particles fraction (0.01 <d <0.08 μm). The diurnal variations of Aitken particle concentration is confirmed by this conclusion (Fig. 7 b).

Diurnal variation of Aitken particle concentrations is similar to the behavior of the total concentration of fine faction. Number concentration maximum of particles of this fraction is often observed during daily hours, which may be the result of the increased coagulation of nuclei mode particles and the equalization of the generation and destruction rates of this aerosol fraction in this period [Ayurzhanaev et al., 2009; Zhamsueva et al., 2009]. Figure 8 shows a comparison of diurnal variations of soil and air temperatures during the experiments.

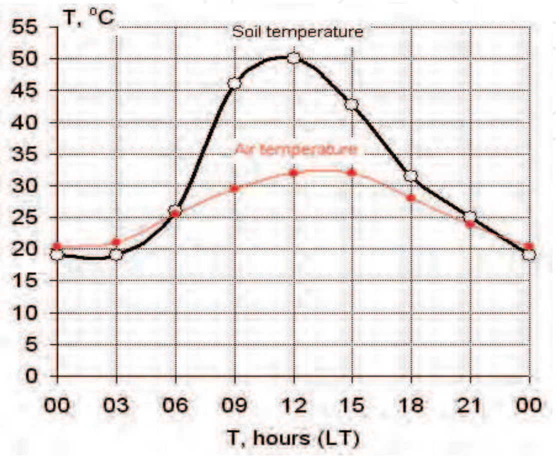


Fig. 8. Daily variations of soil and air temperatures (11 August 2009, Sainshand station, Mongolia).

It is revealed that the number concentration of particles of nuclei mode and Aitken mode differ depend on meteorological and weather conditions of the experiment. Figure 6 shows diurnal variation of the fine particles distribution for days with different weather conditions: under clear weather, with weak winds (10 and 12 August) and in cloudy weather, with gusty winds (13 and 14 August). As can be seen from the figure, the Aitken mode in the distribution of size spectrum particle presents for all days and is a major fraction the fine aerosol.

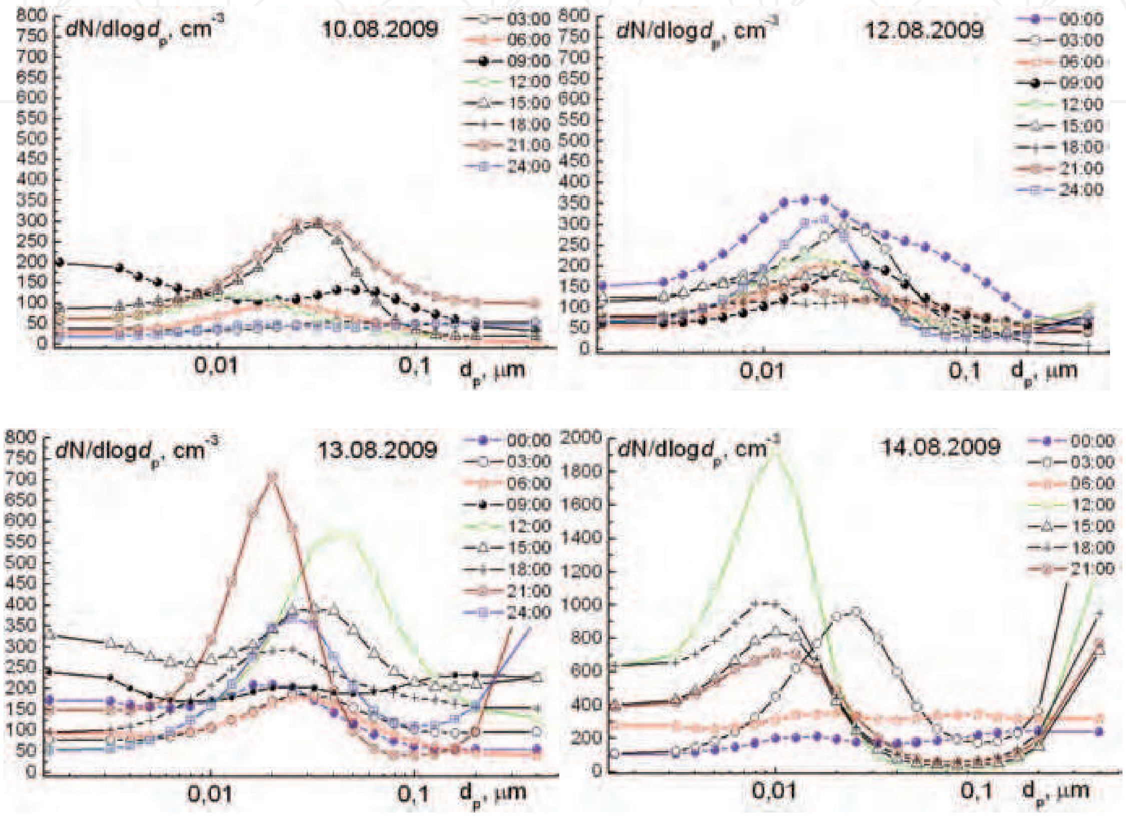


Fig. 9. Diurnal variation of size distribution of the fine aerosol (August 2009, Sainshand station, Mongolia).

6.2 The research of chemical composition of aerosol

The data of the chemical composition of aerosol are important source of information about the processes of transport, distribution and transformation of atmospheric pollutants. As the tracer component composition of atmospheric aerosol is generally conserved during the transport, the chemical composition of aerosol and its microstructure contain the important information about sources and ways of long-range transport of aerosol, including trace gases. Sampling of aerosol particulates with an size less than or equal to 10 µm was carried out on «Whatman-41" filters by high volume sampler PM-10 of General Metal Works Inc. with the volumetric rate of 0.4-1.7 m^3/min and accuracy of ± 0.03 m^3/min in the temperature range 0 ° C - 45 ° C.

The analysis of ionic composition of aerosols was carried out by liquid chromatography Milichrom A-02 on anions and atomic absorption method AAS-30 on cations in the Limnological Institute of SB RAS. The dates of sampling and their duration are presented in Table 2.

Sample number	Date	Time	
		Sampling start	Sampling end
30	11.08.09 – 12.08.09	09:34	08:20
31	12.08.09 – 13.08.09	09:13	08:52
32	13.08.09 – 14.08.09	09:56	07:00
33	15.08.09 – 16.08.09	20:05	17:45
34	16.08.09 – 17.08.09	19:24	16:28
35	17.08.09 – 18.08.09	17:05	15:40
36	18.08.09 – 19.08.09	16:51	16:13

Table 2. Periods of aerosol sampling

Figure 10 shows the results of the analysis of ionic composition of aerosols in the atmosphere of the arid area of Mongolia (Sainshand, August 2009).

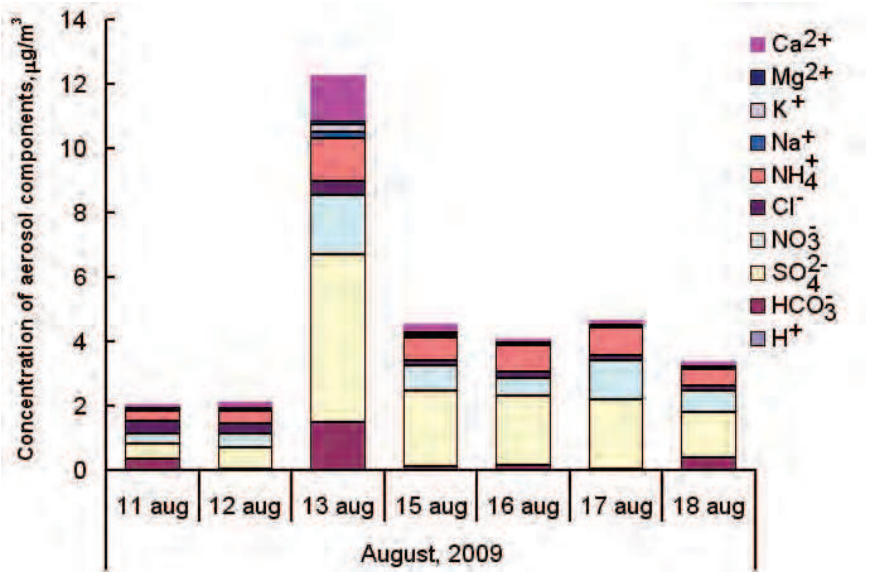


Fig. 10. The chemical composition of aerosols in the atmosphere of Gobi Desert (August 2009)

Apparently from Fig. 7 the anions SO_4^{2-}, NO_3^- and cations NH_4^+ are major components of aerosols in the atmosphere. These anions and cations are the most typical components of industrial emissions. Also the anions HCO_3^+, the cations Ca, Mg, K are contained in significant amount. Samples pH is basically slightly acidic due to the predominance strong anions SO_4^{2-}, NO_3^- in aerosol.

The proportion of these ions is high and is range 15-18%-eq. for nitrate-ions and is range 31-73% eq for sulphate-ions. Also content of chloride is heightened (7-34% eq) (Fig. 11).

Observation site was located in a relatively clean area at a distance of 6-7 km from the Sainshand and 500 km or more from the nearest major industrial centers of China and Mongolia. Influence of local anthropogenic emission sources is minimal in the summer.

Possible mechanism of transport of anthropogenic contaminants to the region of study could be a long-range atmospheric pollutants transfer. The results of calculations of the trajectories of air masses by reanalysis trajectory model HYSPLIT is confirmed this fact (Fig. 12 a, b).

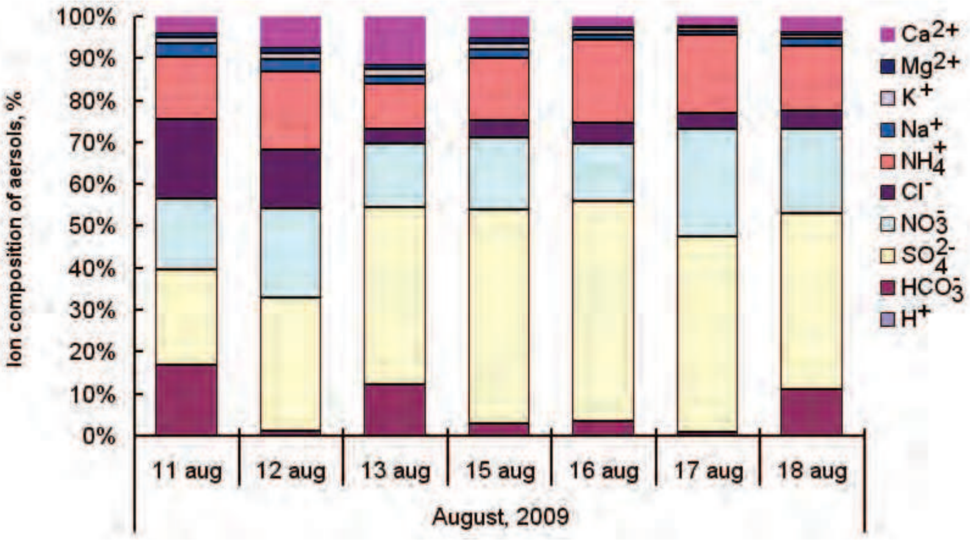
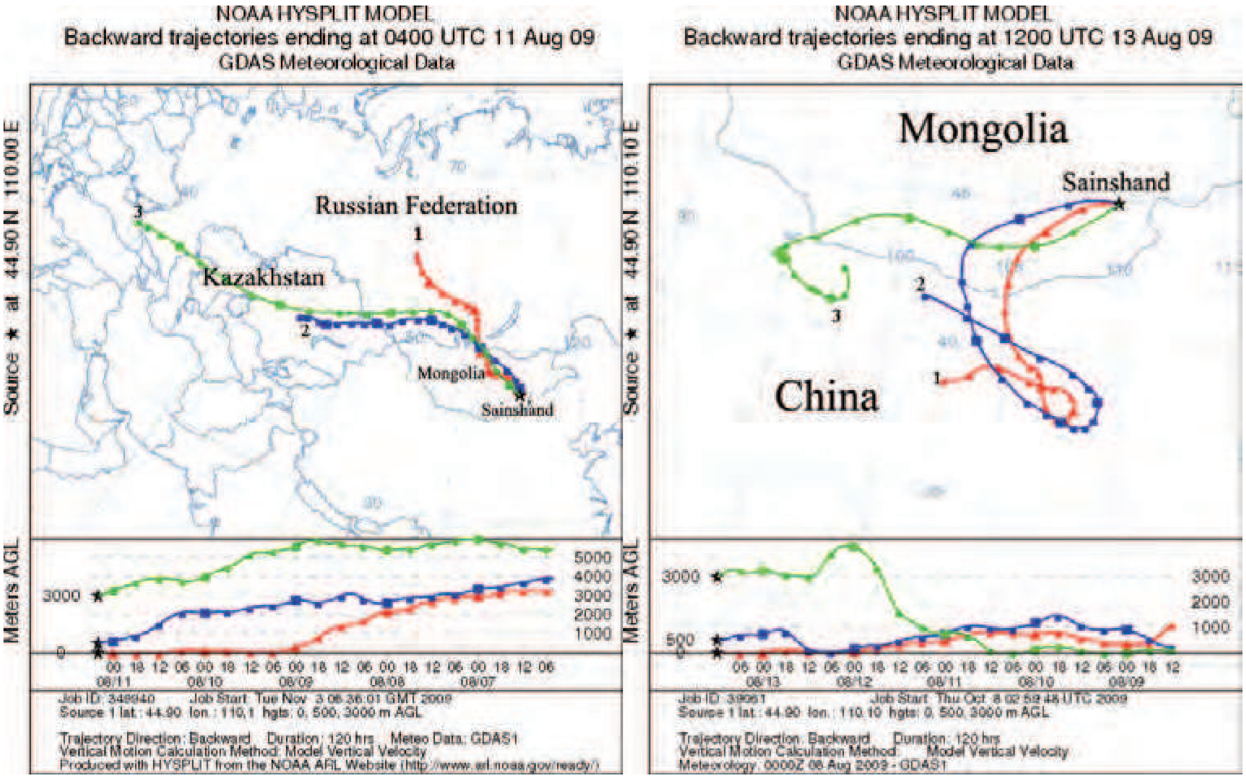


Fig. 11. Contents of the main components in aerosols in the atmosphere of Gobi Desert in August 2009



a) b)

Fig. 12. Backwards air masses trajectories during observation period at the Sainshand in August 2009 on the model HYSPLIT: a) 11August, b) 13 August

The total content of ions at Sainshand are less than 2 $\mu g/m^3$ under the western and north-western direction of air masses movement from the Eastern Siberia, Kazakhstan and clear stable weather 11-13 August 2009 (Fig. 12). The sulphate-ion (0.46-0.67 $\mu g/m^3$), nitrate-ion (0.34-0.45 $\mu g/m^3$), ammonium-ion (0.30-0.40 $\mu g/m^3$), chloride-ion (0.29-0.39 $\mu g/m^3$) are predominant ions in aerosols in this time. The total ion content is increased up to 12.3 $\mu g/m^3$

with the passage of cold atmospheric front and the change of synoptic situation from 13 August 2009. The content of main aerosol components is increased, for example, calcium ions up to 1.4 μg/m^3, nitrate-ion up to 1.8 μg/m^3, sulphate-ion up to 5.2 μg/m^3, hydrocarbonate-ion content up to 1.5 μg/m^3. Calculations of air masses movement by model HYSPLIT indicate the transport of atmospheric pollutants from the industrial regions of China during this period. Under the development of local circulation processes from 15 August to 18 August 2009 the concentration of suspended particles is decreased to 3.4-4.6 μg/m^3. In these days we observed the high proportion of some ions such as sulphate-ions (73%-eq.), nitrate-ions (28%-eq.) and ammonium ions (80%-eq.) (Fig. 11). These ions are typical components of industrial emissions. The obtained data testify to strong influence of anthropogenic sources on the air composition of arid areas of Eastern Gobi due to long-range transport.

7. Conclusion

In this chapter the investigations of pathways and basic directions of the atmospheric impurities transport in arid and semi-arid territories of Mongolia using of the reanalysis model NCEP/NCAR HYSPLIT (http://www.arl.noaa.gov/ready/hysplit4.html) and archival meteorological data (archive FNL) are conducted. It is established that east, northeast and southeast carrying out of air mass prevail in this region.

As a whole the wind regime within a year in Gobi Desert repeats a direction of the general northwest, characteristic for free atmosphere. During the summer the influence of local circulation is significant. It is revealed that the duration and number of dusty days increase in Gobi Desert. The repeatability of dust storms from 1991 to 2006 has increased in 3 times. It is established that dust storms duration from 2003 to 2007 has increased in 40 times. It is noted that dust storms observe in autumn and winter since 2004 that it was not marked in previous years. The most repeatability of dust storms in atmosphere of arid territories of Mongolia is observed in April-May in day and evening with the maximum concentration of fine aerosols exceeding 1400 μg/m^3 (PM_{10}) and 380 μg/m^3 ($PM_{2.5}$) at Sainshand and 1230 μg/m^3 (PM_{10}) and 700 μg/m^3 ($PM_{2.5}$) at Zamyn-Uud station. Under the days with stable, settled weather the mass mean concentration of aerosols PM_{10} and $PM_{2.5}$ changes 5-8 μg/m^3 (PM_{10}) and 3-5 μg/m^3 ($PM_{2.5}$) at Sainshand. In similar conditions daily mean concentration at Zamyn-Uud change within 18-20 μg/m^3 (PM_{10}) and 16-18 μg/m^3 ($PM_{2.5}$).

For research of dust storm formation in the Central Asia in May, 2008 we analyzed the surface and high altitude (500 hPa) meteorological maps (http://www.aari.nw.ru/odata/_d0010.php) of Northern hemisphere for 2008. It is established that Lake Baikal is the special climatic area which lies on frontier of Arctic and moderate air mass and influences on trajectories of air mass moving in arid and semi-arid areas of Mongolia and China. In this time the cold Arctic air masses passed across Lake Baikal mixing with air mass of moderate latitudes. Then they moved to the territories of Mongolia and China creating the significant gradients of the temperature and pressure. These meteorological and synoptical conditions were cause to intensive dust storms in arid and semi-arid territories of Mongolia and China.

The chemical composition of aerosol, number concentration and size distribution of submicron fraction of aerosol are analyzed. It is established that the SO_4^{2+}, NO_3^- and NH_4^+ are major components of aerosol particles in atmosphere of Sainshand. These anions and cations are the most typical components of industrial emissions. Also the anions HCO_3^+, the

cations Ca, Mg, K are contained in significant amount. The revealed high ion concentration SO_4^{2+}, NO_3^- and NH_4^+ in aerosol at station Sainshand located far from industrial centers and results of modeling by HYSPLIT confirms the strong influence of anthropogenic sources of China on the air composition of arid areas of Eastern Gobi due to long-range transport.
The investigation of fine aerosol content revealed that the Aitken mode in the distribution of size spectrum particle is a major fraction and depends on meteorological and weather conditions.

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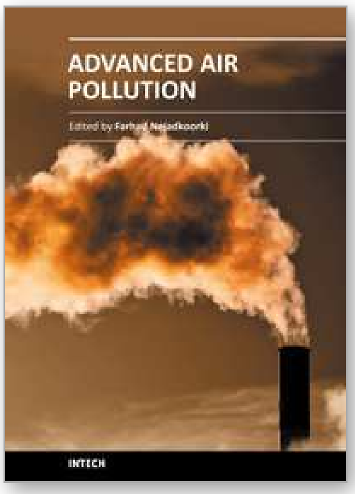

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