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Geophysics

Influence of Foehn Phenomena on the Processes of Atmospheric Air Pollution

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ABSTRACT. The paper presents the results of investigations of the influence of foehn phenomena on the level of pollution of atmospheric air of Kolkheti lowland (South-Western part of the Caucasus) and Akhangaran valley (Western Tien Shan). The calculations of the distribution fields of NO_x concentration in the region of Akhangaran valley are presented. It is shown that foehn events have a significant impact on the level of atmospheric air pollution in conditions of mountainous countries. *© 2008 Bull. Georg. Natl. Acad. Sci.*

Key words: *atmosphere, pollution, foehn, circulating process, hydrodynamic models*

Introduction

As far back as in 1853 and 1899 climatic peculiarities of regional character were investigated and described by the eminent scientists A.Tsimmerman and A.I.Voeikov and early in the 20th century by A.A.Kaminski and I.V.Figurovski. These peculiarities are caused by many climate-formative factors, including geographical position, orography, atmospheric processes, etc. [1-3]. Research into the influence of specific parameters on the pollution of the atmosphere on regional scale is of separate considerable scientific and practical interest. However, most interesting to us is consideration of the peculiarities of distribution of those “traditional” meteorological parameters [4, 5] which, in conditions of a constancy of quantity of emissions of harmful substances in the atmosphere, have an impact on the level of local pollution of the atmosphere and are known as «dangerous meteorological conditions».

From the stated point of view, considerable interest attaches to the investigation of such little-studied processes as influence of foehn phenomena on the level of pollution of the atmosphere.

At the same time, study of the given question in conditions of regions lying at great distances from each other is of considerable scientific and practical interest.

1. Peculiarities of the influence of foehn events on the ecological conditions of the air basin of the Kolkheti lowland

Warm winds blowing from mountains into the valley, at the reduction of relative humidity and dispersal of the lower layer clouds, constitute foehn phenomena. Foehns develop on the lee side of ridges due to the downward movement of an air stream. Thus, while crossing mountain ridges an air stream in a system of cyclones (especially at its moving near mountain ridges), the process of air suction may occur from the ground layer of the air basin of ridges [2].

It should be noted that the Kolkheti lowland, located in the south-west part of the Caucasus and Akhangaran valley of Western Tien Shan, represent classical examples of regions having all conditions for the development of foehn phenomena which are mainly determined by the peculiarities of the relief of the mountains surrounding the given regions. Thus, the orography of the given regions, bordered by mountain ridges, represents an essential climate-formative factor. In particular, massifs of the Greater and Lesser Caucasus (height: 3000-4000 and 2000 m, respectively) from West to East, up to the central part, create a range directed at inter-joining. As a result, the Kolkheti lowland has the form of a triangle, with an edge of a corner adjoining the foothills of the Likhi ridge (height within 900-2500m) and the base in the form of the coastal strip of the Black sea. Thus, the Kolkheti lowland from the West and the North, from the Black sea, and also from the East, from Likhi ridge, is open to penetration of air masses. Recurrence of these winds in the territory under discussion is, on the average 42 and 53 %, respectively. On the Kolkheti lowland, at development of east winds the indicated orographic features cause the establishment of a special circulation mode accompanied by foehn events (movement of air mass downwards from the height).

The dynamics of these processes is shown in an intensive carrying out of air masses from the lower layers of the atmosphere in the direction of the Black Sea in conditions of the establishment of East winds above the specified region, reaching speeds of 25-30 km/s. Restoration of the lost part of air stream in the 2km lower layer of the atmosphere, is obviously possible only in the presence of compensating downward movement from higher layers [6].

Besides, here local circulation of an air stream develops, caused by the difference of air temperatures between the coastal strip and sea, known as breezes.

The cited phenomena create all conditions for the shifting of atmospheric air streams in the given region to form a closed system in the atmosphere, promote the occurrence of a secondary source of pollution of the air basin of the region, as a result of circulation of local emissions of harmful substances.

Coming to such a conclusion is warranted by the consideration whose physical sense consists in the fact that in conditions of foehns the stream of warm air, during its impetuous descent from the Likhi ridge to the Black Sea, approaching the latter, weakens and, as its temperature is higher than that of the air of the coastal strip, it should mainly become directed at the upper layers of air and, at sufficient duration, may become involved in the recurring process of the mentioned phenomenon (Fig.1).

At various points of Western Georgia the number of days with foehns during a year varies in a wide range

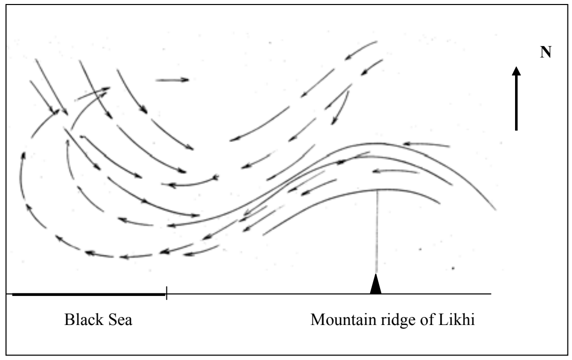

Fig. 1. The basic scheme of the circulating process at foehn events on the Kolkheti lowlands.

[7]. Thus, effects of foehn events with removal from the Likhi ridge decrease and near Pitsunda they have a noticeably weakened character. For example, in Gagra they total on the average 23, and to the West, in the area of Pitsunda - 8 days. Their maximal number is observed in the winter, and minimal - during the summer. The velocities of foehn winds total on the average 10 m/s. However, in individual cases they can exceed velocities of 15-20m/s. At the same time, increase of air temperature varies within the limits of 2-9ºC, and in some cases it can surpass 15ºC.

2. Assessment of the pollution of the atmosphere of Akhangaran valley in the period of foehn with the help of hydrodynamic models

The present study considers the feasibility of applying the three-dimensional hydrodynamic model and, on its basis, the calculation of fields of dispersion of polluting substances (PS) is made for Akhangaran, one of the valleys of Western Tien Shan. The valley is chosen not casually as an object of research. First, in terms of morphometrical and meteorological parameters this valley is a typical valley not only of Western Tien Shan but also of other mountain systems of the world. Secondly, it is investigated sufficiently in respect of circulation for all seasons of the year. Thirdly, numerous large enterprises of non-ferrous metallurgy, chemical, building and fuel and energy complexes of industry are concentrated here. As to the volume of emissions of polluting substances, the valley occupies a leading place among the regions of Uzbekistan (Table [8]).

In the cold half-year foehn winds set in in the valleys of Western Tien Shan. The structure of these winds in Akhangaran valley was studied by S.G.Chanysheva [9]. She notes that in this period in the valley there are observed well expressed flowing winds and exhaustion

Table

The polluting substances released into the atmosphere, in the Republic of Uzbekistan (10^3 tons per year)

City/town	1995	1996	1997	1998	1999
Tashkent	16.0	15.3	13.3	11.8	12.7
Andijan	1.0	9.6	8.7	7.7	6.2
Navai	48.3	43.7	42.2	42.6	28.2
Samarkand	7.8	7.1	8.1	8.3	8.2
Almalyk	106.6	105.4	105.9	103.6	100.0
Angren	91.6	111.2	111.8	101.0	112.6
Bekabad	9.1	7.7	6.8	7.4	7.3
Chirchiq	7.5	6.7	6.3	6.5	5.6
Kokand	3.9	4.3	5.4	5.3	2.9
Fergana	70.7	72.5	67.8	55.0	49.4
Margelan	0.5	0.4	0.3	0.3	0.1
Nukus	2.6	2.9	3.0	3.7	3.4
Urgench	6.0	3.4	10.2	13.1	1.3
Bukhara	7.1	14.6	9.2	8.0	3.1
Djizzak	3.2	2.3	6.5	3.7	3.3
Qarshi	129.0	85.0	75.9	65.4	2.7
Namangan	5.7	6.7	6.5	6.7	4.3
Termez	2.1	2.0	1.9	1.4	0.5
Gulistan	1.6	1.6	1.4	1.4	1.0

winds. The vertical structure of foehn winds of a North-East direction was studied using the materials of an aerologic expedition to Turk and Ablik in the cold half-year of 1960-1961. The total duration of the expedition was 5 months. The results of the expedition showed that the duration of one case of a foehn wind amounts to 2-2.5 days. The total duration of foehn wind per winter half-year is about one month.

The magnitude of foehn velocity depends on the width of a valley. Thus, the flow, in the upper, narrow part of a valley is expressed better than in the central, wide part. The vertical thickness of a foehn flow set in is of the order of 1000 m. At especially drastic processes, when the velocity of a North-East wind reaches the characteristic maximal value, the upper border of a North-East wind can lie at a level of 2000 m. S.G.Chanysheva allocates 3 types of distribution of wind velocity with height:

1. Reduction of speed with height, which is characteristic of the beginning and end of a foehn period;
2. Increase of velocity up to a certain height, with a subsequent easing down to the upper border of a north-east wind is observed at any time of foehn development period.
3. The presence of two maxima of velocity, which is characteristic of the height of a foehn process.

At the maximal development of foehn the magnitude of wind velocity in a flow can reach a large value. The author notes that above Turk the velocity about and above 30 m/s at a level of 500-600m was repeatedly registered.

Assessment of the pollution level of the atmosphere in the period of fohen winds is of considerable interest, as the total duration of these winds is rather long. In one case the duration of a foehn wind totalled 5 days.

For this case the fields of distribution of polluting substances were calculated.

We applied the hydrodynamical model, which was used earlier for calculations of the fields of distribution of PS under conditions of mountain-valley circulation [8].

According to the data of calculation the fields of distribution of concentration in terms of extreme allowable concentrations (EAC) were obtained for 13 kinds of PS, ejected into the atmosphere of a valley. These are nitrogen oxides, sulphurous anhydride, carbon monoxide, ashes, inorganic dust, cement dust, clinker dust, hydrogen fluoride, sulfuric acid, arsenic, lead, copper and zinc compounds.

As an example we shall consider a field of distribution of NOx concentration. During the whole process of foehn wind the magnitude of concentration remains within the limits of norm. However, depending on the vertical distribution of horizontal and vertical components of the velocity of a wind the scope of the field of pollution essentially varies in time. At the beginning of the process of foehn wind the horizontal field of distribution has a wide area, but owing to the large value of the wind velocity (10 m on the axis of the jet), the maximal value of concentration does not exceed 0.2 EAC. The analysis of the vertical field of distribution shows that the substance is distributed basically in the horizontal direction).

This is explained by the fact that at the bottom of the jet ascending flows and from above, descending flows are observed.

In daytime gradual diminishment of the wind velocity is observable, which is reflected in the field of distribution of the substance. The area of distribution somewhat decreases; however, the value of maximal concentration rises, totaling 0.5 EAC.

By evening the wind velocity weakens further. The area of distribution of the substance appreciably increases in the upper layers of the area, and it sharply reduces in the lower. The maximal value of NOx concentration is observed at the height of 330-350 m, amounting to 1 EAC.

This is accounted for by the fact that at weak horizontal component of velocity vertical currents are observed, which have a positive mark up to the height 120-150 m, then they gradually change their direction and have a negative mark above 330 m.

In night time hours the wind velocity begins to increase, reaching its maximal value by morning. Therefore, the field of distribution of the substance again has a wide area with a small value of maximal concentration, equaling 0.2 EAC. In this case the situation observed at the beginning of the process repeats almost fully.

In day time reduction of the area of propagation of substance with a simultaneous increase of the maximal value of concentration near the source of emission (Nurabad TPS) is observed. However, at lower levels the field of distribution of substance changes insignificantly.

If we analyze the case of the field of distribution in evening hours, which was observed on the second day of the process, it will be seen that the maximal accumulation of substance occurred at this time. The velocity of wind with height increased almost linearly, and the vertical currents had a positive sign. Owing to the weakness of wind velocity the area of distribution of substances is insignificant; however, the maximal value of concentration increases up to 1EAK. As shown by the vertical section of field distribution, in this case transfer of substances occurs in the vertical direction.

Within the next two days the field of distribution of NOx had an approximately identical appearance in the character of scope of the area of pollution and value of maximal concentration**.** This is explained by the fact that during this period the foehn process had reached its maximal development, and the wind velocity practically changed in small limits.

By the end of the process the wind velocity decreases, totalling the value of 2-3 m/s. As the velocity of the wind is not large, according to it, the area of distribution of substance decreases. However, at the same time the value of the maximal concentration rises, reaching its maximal value near the sources of emission.

The comparison of the results of calculation of the present study with the results of calculations for the warm half of the year at the establishment of mountain-valley circulation (MVC) allows us to make the following conclusion.

At foehn winds the distribution fields of concentration of polluting substances have an approximately identical appearance. This means that, as well as in the case of MVC, the establishment of foehn winds does not promote full carrying out of polluting substances from a valley.

Conclusion

Thus, it is necessary to conclude that foehn processes exert appreciable influence on the level of the pollution of the atmosphere.

Their consideration in investigations of atmospheric pollution in conditions of mountainous countries will allow to raise significantly the accuracy of regional ecological assessments of the natural environment.

As a result of the above peculiarities the given meteorological phenomenon should be raised to the rank of regional «dangerous meteorological conditions», promoting the intensification of pollution of atmospheric air.

გეოფიზიკა

ფიონური მოვლენების გავლენა ატმოსფეროს დაბინძურების პროცესებზე

გ. გუნია*, ზ. ცქვიტინიძე*, ბ. ხოლმაჯანოვი**, ზ. ფათხულაევა**

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(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

ნაშრომში, კოლხეთის დაბლობისა და ახანგარანის ხეობის (დასავლეთ ტიან-შანი) მაგალითებზე, მოყვანილია ატმოსფერული ჰაერის დაბინძურების დონეზე ფიონური მოვლენების ზემოქმედების კვლევის შედეგები.

მოცემულია ახანგარანის ხეობის რაიონში NO_x-ის კონცენტრაციების ველის განაწილების გაანგარიშებები.

ნაჩვენებია, რომ ფიონური პროცესები მნიშვნელოვან ზემოქმედებას ახდენენ ატმოსფეროს დაბინძურების დონეზე მთიანი ქვეყნების პირობებში. მათი გათვალისწინება ატმოსფეროს რეგიონალური დაბინძურების კვლევებისას მნიშვნელოვნად აამაღლებს ბუნებრივი გარემოს მდგომარეობის ეკოლოგიური შეფასების სიზუსტეს.

გაკეთებულია დასკვნა იმის თაობაზე, რომ აღნიშნული მეტეოროლოგიური მოვლენა უნდა იყოს აყვანილი რეგიონალური "საშიში მეტეოროლოგიური პირობების" რანგში, რომლებიც ხელს უწყობენ ატმოსფეროს დაბინძურების გაძლიერებას.

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