ON THE INFLUENCE OF MOUNTAIN ELEVATIONS

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Abstract

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ON THE INFLUENCE OF MOUNTAIN ELEVATIONS

ON THE HUMIDITY OF THE ATMOSPHERE

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Large mountain elevations and, especially, large mountainous countries exert a significant influence on the structure and properties of the atmosphere above them. In particular, the humidity of the air—absolute and relative—is appreciably increased: in the atmosphere over mountains the humidity is higher than in the atmosphere over the nearest plains at the same altitude.

A similar effect was found by us over the Main Caucasus Range from data of many years of observations at meteorological stations. Special aerological soundings organized by the Transcaucasian Hydrometeorological Institute in 1957 also led to a similar conclusion.

For the Central Caucasus, i.e., the highest part of the region studied, there are data on vapor pressure over Mineralnye Vody and Tbilisi. These two points are located about 200 km apart, respectively on the northern and southern sides of the range. For comparison we selected the summer months, when the vapor pressure is greatest and its variations should be most clearly visible (see Table 1).

Table 1

Mean vapor pressure (in mb). July-August

Altitude, km	0.5	1.0	1.5	2.0	3.0	4.0	5.0
Min. Vody	14.0	12.9	11.1	9.4	6.2	3.7	2.3
Tbilisi	15.2	13.8	11.8	10.0	6.9	4.4	2.5

The air humidity is somewhat higher on the southern side of the range, where southwesterly winds prevail, arriving from the side of the most humid region of the USSR—Colchis.

If the decrease of vapor pressure with height is represented by an empirical formula of the form

$$e = e_0 \cdot 10^{-bz} = e_0 \cdot 10^{-z/H},$$

then, by the method of least squares from Table 1, we obtain for Tbilisi $b = 0.190$, $H = 5.25$, and for Mineralnye Vody $b = 0.199$, $H = 5.02$ km.

We then compared the mean vapor pressure e_i at a number of meteorological stations located in the region under consideration, both north and south of the line of the range, with the vapor pressure $\bar{e}$ at the same levels, averaged from the data for Tbilisi and Mineralnye Vody (see Table 2).

It should be noted that the data of the meteorological stations in Table 2 were obtained from observations in the near-ground layer of air at a height of 2 m above the surface of the soil of a valley or slope. From Table 2 it is evident that at all stations the vapor pressure is considerably greater than in the free atmosphere over the nearest plains or large valleys. The greatest excess of vapor pressure, Δe—up to 1.8 mb—is observed in summer at altitudes from 2 to 3 km, both north of the range (Bermamyt) and south of it (Mamison Pass and Gudaur). Higher up, Δe decreases and above 4 km approaches 0.

For a more detailed study of this effect we used the results of simultaneous radiosoundings organized in the summer of 1957 by the Transcaucasian Hydrometeorological Institute along a section crossing the Main Caucasus Range: in the city of Ordzhonikidze, at Krestovy Pass, at Mta-Sabueti, and in Tbilisi. The last three points are located 20–80 km south of the line of the range, and the first is 40 km to the north. Daytime soundings were carried out at 15 hours, on clear or partly cloudy days—13 and 15 VII and 6, 12, and 30 VIII—at altitudes up to 6 km. Table 3 gives

Table 2

Mean vapor pressure e_i in July-August and the difference $\Delta e = e_i - \bar{e}$ ($\bar{e}$ is the mean from the data for Tbilisi and Mineralnye Vody)

	z, km	e_i	Δe
Shelter of the Eleven	4,05	3,9	−0,05
Ice Base	3,70	5,2	+0,35
Kazbegi	3,67	5,3	+0,40
Terskol Peak	3,14	7,1	+0,85
Mamison Pass	2,85	8,6	+1,55
Bermamyt	2,59	9,6	+1,75
Gudaur	2,20	10,8	+1,75
Terskol Obs.	2,15	9,9	+0,70
Kobi	1,99	10,8	+1,1
Lei	1,91	11,5	+1,5
Lower Zaromag	1,73	11,8	+1,2
Mleti	1,47	12,9	+1,35

Table 3

Mean vapor pressure e_i for 5 days in July–August 1957. Parallel radiosoundings

z, km	Ordzhonikidze	Krestovy Pass	Mta-Sabueti	Tbilisi
0,5	14,6	–	–	13,4
1,0	12,4	–	–	10,7
1,5	9,4	–	13,0	9,6
2,0	7,8	–	10,0	8,0
2,4	7,1	10,4	7,1	7,0
3,0	6,0	7,6	5,9	5,5
4,0	3,2	4,2	3,4	3,7
5,0	1,95	1,82	1,92	2,12
6,0	1,20	0,81	1,18	1,24

the vapor pressure averaged over these days. From this table it is evident that, at the same altitude, e_i is considerably greater over Krestovy Pass than over the foothill stations. If one compares the values of e over Krestovy Pass with the mean for Tbilisi and Ordzhonikidze, then the excess Δe reaches 3,3 mb at the pass level of 2,4 km, 1,8 mb at an altitude of 3 km, and 0,8 mb at an altitude of 4 km. At about 4,8 km it becomes 0. Thus, the phenomenon previously found by us from many years of data from meteorological stations is confirmed.

An increase of the vapor pressure Δe over the mountains is equivalent to an elevation of the surfaces of equal vapor pressure over them in comparison with the plain. From the data of Table 3 it can be calculated that the surface $e = 10$ mb is raised over the Caucasus by approximately $\Delta z = 1,2$ km, the surface $e = 6$ mb by $\Delta z = 0,7$ km, and the surface $e = 4$ mb by $\Delta z = 0,3$ km. The decrease of Δz with height is, in essence, an increase of the vertical gradient of vapor pressure over the mountains. This indicates enhanced evaporation from the Earth’ s surface (slopes or valleys) in a mountainous region.

There is no doubt that the increased humidity of the air in the mountains is caused by enhanced evaporation in forests, from meadows, snowfields, and glaciers. This is promoted both by intensified turbulent mixing and by the somewhat higher temperature of the atmosphere over the mountains. An increase of humidity has already been described by a number of authors: by de Quervain over the Alps; by E. S. Selezneva over the Lesser Caucasus ([1]), by L. I. Bordovskaya over the Central Caucasus, by V. A. Dzhordzhio and M. A. Petrosyants ([3]) over Tibet. Recently S. Hastenrath ([4]) studied the increase of humidity over the mountains of Central America, where it is also associated with a rise of the vertical limits of forest vegetation in the interior parts of the mountainous region in comparison with the outer parts (with its margins).

It could be supposed that the greater humidity in the mountains is also promoted by the upward ascent along windward slopes of moister air from the lowlands of humid Western Transcaucasia. But in this case, over the leeward–

···the northern slopes of the North Caucasus, a background decrease in humidity should have been observed, extending down to the lowest levels. However, there is no such decrease (see Tables 1, 2), and, consequently, the ordered flow of air around the ridge does not determine the described increase in humidity. The latter is most likely connected with local evaporation and, for this reason, extends only to comparatively small heights (4–5 km).

A consequence of the increase in humidity is a lowering of the condensation level and an increase in the amount of precipitation of all kinds. The increase in atmospheric humidity leads to enhanced absorption of the long-wave radiation of the Sun and the Earth. This circumstance helps to explain the above-mentioned increase in air temperature over the mountains. If the latter were caused by the release of latent heat of condensation in clouds over the mountains, then it could not manifest itself in approximately the same way both over arid Tibet and over very humid Central America.

It would be desirable to study the effect of increased humidity also in other climatic regions of our country.

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CITED LITERATURE

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Note: Figure translations are in progress. See original paper for figures.