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# The Statistical Characteristics of Hourly Values of the Height of Isotherm -6°C in the Atmosphere Above Kakheti Territory (Georgia) from April to October

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***ABSTRACT***

*The detailed statistical analysis of daily data for 04,10, 16 and 22 hours on the Tbilisi time about the height of isotherm -6°C in the atmosphere above the territory of Kakheti (Telavi) from April through October 2012-2016 is represented, information about which is necessary while planning and performing of work on the weather modification. In the work the resources of the worldwide network aerological observation http://ready.arl.noaa.gov/READYcmet.php are used, according to which data the extrapolation of the vertical distribution of meteorological elements for any location of world is possible.*

***Key Words:*** aerological sounding of atmosphere, weather modification.

## Introduction

The Kakheti region of Georgia is one of the hail-dangerous regions of world [1-3], in connection with this in the period from 1967 through 1989 here was conducted production work on the fight with the hail [1-4]. In parallel were conducted scientific studies of weather modification (regulation of the thunderstorm activity of clouds, the gain of precipitation, etc. [2,5]. In 2015 year of work on modification the weathers (first of all - fight with the hail) in this region of the Georgia were restored [6,7].

In connection with this arose the need of obtaining the operational information about the vertical distribution in free atmosphere above the territory of Kakheti of the meteorological parameters (including of the air temperature). Since in Georgia the aerological sounding of the atmosphere was conducted only up to 1991 [8-11], for obtaining this information were used the recource of service of the worldwide network of the aerological observations of http://ready.arl.noaa.gov/READYcmet.php, according to data of which the extrapolation of the vertical distribution of meteorological elements for by any point of world was possible .

In recent years with the use of these data is begun the work on the analysis of the vertical distribution of the air temperature in free atmosphere above the territory of Kakheti, the study of variations in height of zero isotherm [12-14]. Special importance have the operational and averaged data about the height of the isotherm -6°C, information about which is extremely important while planning and performing of work on the weater modification, the selection of places for the arrangement of the points of action on the clouds, the determination of the necessary quantity of anti-hail rockets into season, etc. [15-21].

The results of the statistical analysis of data for 04, 10, 16 and 22 hours on the Tbilisi time about the height of isotherm -6°C in the atmosphere above the territory of Kakheti (Telavi) from April through October 2012-2016 are represented below.

## Material and methods

For investigating the thermal regime in the free atmosphere above the territory of Kakheti as in [12-14] the resources of http://ready.arl.noaa.gov/READYcmet.php were used.

Height of isotherm (H-6°C) was determined from the formula:

$$(H\text{-}6°C)=(T1\cdot H2-T2\cdot H1)/(T1-T2)$$

where, T1 and T2 are the temperature of air at the levels H1 and H2 respectively. With this T1 must be > -6°C, and T2 <-6°C.

Work gives the statistical data about the hourly, daily and monthly average values of the height of the isotherm -6°C for the season of anti-hail works (April- October), information about which is extremely important while planning and performing of work on the weather modification. The total quantity of data composes 4280.

Analysis of data with the use of the standard statistical analysis methods is carried out [22]. The following designations will be used below: Min – minimal values, Max - maximal values, Range - variational scope, St Dev - standard deviation, $\sigma_m$ – standard error, Cv (%) - coefficient of variation, 95%(+/-) - 95% of confidence interval, height of isotherm -6°C - H(-6°C).

## Results and discussion

The results of work in tables 1-8 are represented.

Table 1

Statistical characteristics of values of H(-6°C) above the territory of Kakheti in April- October 2012-2016 (meter)

| Parameter | April | May | Jun | July | August | September | October |
|---|---|---|---|---|---|---|---|
| Mean | 3602 | 4285 | 4896 | 5393 | 5355 | 4686 | 3978 |
| Min | 1648 | 1854 | 3679 | 4095 | 3381 | 1572 | 1666 |
| Max | 4775 | 5737 | 5843 | 6363 | 6149 | 5778 | 5262 |
| Range | 3127 | 3883 | 2163 | 2268 | 2769 | 4205 | 3597 |
| St Dev | 589 | 483 | 380 | 360 | 428 | 650 | 632 |
| $\sigma_m$ | 24 | 19 | 16 | 14 | 17 | 27 | 25 |
| Cv (%) | 16 | 11 | 8 | 7 | 8 | 14 | 16 |
| Count | 600 | 620 | 600 | 620 | 620 | 600 | 620 |
| 95%(+/-) | 47 | 38 | 30 | 28 | 34 | 52 | 50 |

As follows from Table 1, the average values of H (-6 ° C) vary from 3602 m (range: 1648 - 4775 m) in April to 5393 m (range: 4095 - 6363 m) in July.

Table 2

Repetition of the heights of isotherm -6°C above the territory of Kakheti in April- October 2012-2016 according to the data for 04, 10, 16 and 22 hours on the Tbilisi time (km)

| Month | >1.4-1.8 | >1.8-2.2 | >2.2-2.6 | >2.6-3.0 | >3.0-3.4 | >3.4-3.8 | >3.8-4.2 | >4.2-4.6 | >4.6-5.0 | >5.0-5.4 | >5.4-5.8 | >5.8-6.2 | >6.2-6.6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 0.7 | 1.2 | 4.8 | 10.0 | 14.8 | 25.2 | 29.8 | 11.5 | 2.0 | | | | |
| 5 | | 0.5 | 0.6 | 0.6 | 2.4 | 5.8 | 26.3 | 42.7 | 17.7 | 1.5 | 1.8 | | |
| 6 | | | | | | 0.5 | 2.5 | 22.3 | 31.5 | 34.7 | 8.3 | 0.2 | |
| 4 | | | | | | | 0.6 | 1.6 | 7.7 | 44.0 | 32.6 | 12.7 | 0.6 |
| 8 | | | | | | 1.5 | 1.9 | 2.1 | 8.5 | 31.5 | 45.5 | 9.0 | |
| 9 | 0.8 | 0.7 | 0.2 | 0.3 | 1.7 | 5.2 | 9.5 | 14.2 | 33.5 | 26.8 | 7.2 | | |
| 10 | 0.3 | 1.0 | 0.6 | 4.5 | 11.3 | 20.5 | 21.8 | 23.9 | 13.7 | 2.4 | | | |

Table 2 presents data on the repeatability of the height of isotherm -6 °C for individual months of the anti-hail season. As follows from this table, the highest repeatability of values of H (-6 °C) falls on the following altitude ranges: April: > 3.8-4.2 km (29.8% of cases), May: > 4.2-4.6 km (42.7% of cases), June: > 4.6-5.0 km (31.5% of cases), July: > 5.0-5.4 km (44.0% of cases), in August: > 5.4-5.8 km (45.5% of cases), September: > 4.6-5.0 km (33.5% of cases), October: > 4.2-4.6 km (23.9% of cases).

Tables 3 - 6 show the results of a statistical analysis of the characteristics of height of isotherm -6 ° C in separate observation periods (04, 10, 16 and 22 hours in Tbilisi time) for individual months from April to October.

Table 3

Statistical characteristics of values of H(-6°C) above territory of Kakheti in April- May within the various periods of observations (meter)

| Month | April | | | | | May | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hour | 04 | 10 | 16 | 22 | 04-22 | 04 | 10 | 16 | 22 | 04-22 |
| Mean | 3550 | 3546 | 3662 | 3650 | 3602 | 4250 | 4260 | 4297 | 4333 | 4285 |
| Min | 1648 | 1691 | 2253 | 1886 | 1999 | 2395 | 2817 | 1854 | 2625 | 2548 |
| Max | 4742 | 4753 | 4768 | 4775 | 4690 | 5665 | 5670 | 5695 | 5737 | 5674 |
| Range | 3094 | 3062 | 2515 | 2889 | 2691 | 3270 | 2854 | 3842 | 3111 | 3125 |
| St Dev | 607 | 630 | 561 | 551 | 569 | 509 | 448 | 524 | 446 | 445 |
| $\sigma_m$ | 50 | 52 | 46 | 45 | 47 | 41 | 36 | 42 | 36 | 36 |
| Cv (%) | 17 | 18 | 15 | 15 | 16 | 12 | 11 | 12 | 10 | 10 |
| Count | 150 | 150 | 150 | 150 | 150 | 155 | 155 | 155 | 155 | 155 |
| 95%(+/-) | 97 | 101 | 90 | 89 | 91 | 80 | 71 | 83 | 70 | 70 |

In April (Table 3), the average value of the height of isotherm -6 °C varies from 3546 m to 10 h. up to 3662 m at 16 h., the minimum value of values of H (-6 °C) varies from 1648 m to 04 h. up to 2253 m at 16 h., the maximum - from 4,742 m at 04 h. up to 4775 m at 22 h.

In May (Table 3), the average value of the height of isotherm -6 °C varies from 4250 m to 04 h. up to 4333 m at 22 h., the minimum value of H (-6 °C) varies from 1854 m at 16 h. up to 2817 m at 10 h., the maximum - from 5665 m at 04 h. up to 5737 m at 22 h.

Table 4

Statistical characteristics of values of H(-6°C) above territory of Kakheti in June - July within the various periods of observations (meter)

| Month | June | | | | | July | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hour | 04 | 10 | 16 | 22 | 04-22 | 04 | 10 | 16 | 22 | 04-22 |
| Mean | 4841 | 4858 | 4945 | 4941 | 4896 | 5347 | 5350 | 5442 | 5434 | 5393 |
| Min | 3679 | 3697 | 3990 | 4121 | 3967 | 4160 | 4095 | 4212 | 4128 | 4188 |
| Max | 5689 | 5732 | 5843 | 5778 | 5737 | 6306 | 6335 | 6363 | 6258 | 6291 |
| Range | 2009 | 2035 | 1852 | 1658 | 1770 | 2146 | 2240 | 2151 | 2129 | 2103 |
| St Dev | 379 | 380 | 372 | 383 | 365 | 356 | 364 | 361 | 350 | 342 |
| $\sigma_m$ | 31 | 31 | 31 | 31 | 30 | 29 | 29 | 29 | 28 | 28 |
| Cv (%) | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 6 |
| Count | 150 | 150 | 150 | 150 | 150 | 155 | 155 | 155 | 155 | 155 |
| 95%(+/-) | 61 | 61 | 60 | 61 | 59 | 56 | 58 | 57 | 55 | 54 |

In June (Table 4), the average value of the height of isotherm -6°C varies from 4841 m at 04 h. up to 4945 m at 16 h., the minimum value of H (-6°C) varies from 3679 m at 04 h. up to 4121 m at 22 h., the maximum - from 5689 m to 04 h. to 5843 m at 16 h.

In July (Table 4), the average value of the height of isotherm -6°C varies from 5347 m to 04 h. up to 5442 m at 16 h., the minimum value of H (-6°C) varies from 4095 m at 10 h. up to 4212 m at 16 h., the maximum - from 6258 m at 22 h. up to 6363 m at 16 h.

Table 5

Statistical characteristics of values of H(-6°C) above territory of Kakheti in August - September within the various periods of observations (meter)

| Month | August | | | | | September | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hour | 04 | 10 | 16 | 22 | 04-22 | 04 | 10 | 16 | 22 | 04-22 |
| Mean | 5323 | 5322 | 5383 | 5391 | 5355 | 4664 | 4665 | 4711 | 4703 | 4686 |
| Min | 3543 | 3381 | 3496 | 3555 | 3494 | 1675 | 1572 | 1751 | 1761 | 1690 |
| Max | 6064 | 6124 | 6149 | 6047 | 6073 | 5662 | 5778 | 5670 | 5636 | 5679 |
| Range | 2521 | 2743 | 2654 | 2491 | 2579 | 3988 | 4205 | 3919 | 3875 | 3989 |
| St Dev | 409 | 430 | 447 | 424 | 417 | 652 | 659 | 645 | 649 | 643 |
| $\sigma_m$ | 33 | 35 | 36 | 34 | 34 | 53 | 54 | 53 | 53 | 53 |
| Cv (%) | 8 | 8 | 8 | 8 | 8 | 14 | 14 | 14 | 14 | 14 |
| Count | 155 | 155 | 155 | 155 | 155 | 150 | 150 | 150 | 150 | 150 |
| 95%(+/-) | 65 | 68 | 71 | 67 | 66 | 105 | 106 | 104 | 104 | 103 |

In August (Table 5), the average value of the height of isotherm -6°C varies from 5322 m to 10 h. up to 5391 m at 22 h., the minimum value of H (-6°C) varies from 3381 m at 10 h. up to 3555 m at 22 h., the maximum - from 6047 m to 22 h. up to 6149 m at 16 h.

In September (Table 5), the average value of the height of isotherm -6°C varies from 4664 m at 04 h. up to 4711 m at 16 h., the minimum value of H (-6°C) varies from 1572 m to 10 h. up to 1761 m at 22 h., the maximum - from 5636 m to 22 h. up to 5778 m at 10 h.

Table 6

Statistical characteristics of values of H(-6°C) above territory of Kakheti in October within the various periods of observations (meter)

| Month | October | | | | |
|---|---|---|---|---|---|
| Hour | 04 | 10 | 16 | 22 | 04-22 |
| Mean | 3969 | 3949 | 4013 | 3981 | 3978 |
| Min | 1666 | 1687 | 1831 | 1877 | 1778 |
| Max | 5199 | 5249 | 5262 | 5252 | 5241 |
| Range | 3533 | 3562 | 3431 | 3375 | 3462 |
| St Dev | 613 | 659 | 629 | 628 | 613 |
| $\sigma_m$ | 49 | 53 | 51 | 51 | 49 |
| Cv (%) | 15 | 17 | 16 | 16 | 15 |
| 95%(+/-) | 97 | 104 | 99 | 99 | 97 |

In October (Table 6), the average value of the height of isotherm -6°C varies from 3494 m at 10 h. up to 4013 m at 16 h., the minimum value of H (-6°C) varies from 1666 m to 04 h. up to 1877 m at 22 h., the maximum - from 5199 m at 04 h. up to 5262 m at 16 h.

Table 7

Statistical characteristics of the daily amplitude of values of H(-6℃) above the territory of Kakheti in April-October 2012-2016 according to the data for 04, 10, 16 and 22 hours on the Tbilisi time (meter)

| Параметр | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| Mean | 312 | 275 | 215 | 235 | 192 | 226 | 318 |
| Min | 58 | 28 | 22 | 38 | 23 | 48 | 35 |
| Max | 1424 | 2539 | 1293 | 1019 | 1264 | 996 | 1324 |
| Range | 1366 | 2511 | 1271 | 981 | 1241 | 948 | 1288 |
| St Dev | 247 | 355 | 169 | 166 | 167 | 162 | 243 |
| $\sigma_m$ | 20 | 29 | 14 | 13 | 13 | 13 | 20 |
| Cv (%) | 79 | 129 | 79 | 71 | 87 | 72 | 76 |
| Count | 150 | 155 | 150 | 155 | 155 | 150 | 155 |
| 95%(+/-) | 40 | 56 | 27 | 26 | 26 | 26 | 38 |

As follows from Table 7, the average value of the daily amplitude of the values of H (-6°C) is: in April - 312 m (range: 58 - 1424 m), in May - 275 m (range: 28-2539 m), in June - 215 m (range: 22 - 1293 m), in July 235 m (range: 38 - 1019 m), in August - 192 m (range: 23 - 1264 m), in September - 226 m (range: 48 - 996 m), in October - 318 m (range: 35 - 1324 m).

Table 8

Repetition of the daily amplitude of values of H(-6℃) above the territory of Kakheti in April- October 2012-2016 according to the data for 04, 10, 16 and 22 hours on the Tbilisi time

| Meter | 0-100 | >100-200 | >200-300 | >300-400 | >400-500 | >500-600 | >600-700 |
|---|---|---|---|---|---|---|---|
| H(-6 ℃), % | 18.0 | 36.0 | 19.1 | 11.9 | 4.9 | 3.9 | 2.1 |
| Meter | >700-800 | >800-900 | >900-1000 | >1000-1200 | >1200-1500 | >1500-2000 | >2000-2500 |
| H(-6 ℃), % | 1.4 | 0.56 | 0.75 | 0.47 | 0.65 | 0.19 | 0.19 |

Table 8 presents data on the frequency of the daily amplitude of the height of isotherm -6°C above the territory of Kakheti in April-October, according to all observational data. From this table it follows that the greatest repeatability of the daily amplitude of the height of the isotherm -6°C falls within the range >100-200 m (36.0% of cases). On a range of 0-400 m there are 85.0% of cases of observation. On a range > 1500-2500 m - 0.38% of cases of observations. Significant fluctuations in the daily amplitude of the height of the isotherm -6°C during the intrusion of atmospheric fronts are usually observed.

## Conclusion

With the operational work on averting of hail damages it is expedient to use at least six hours observational data of the vertical distribution of the temperature of air in the troposphere in order not to miss the sharp of the oscillation of values of H(-6°C).

During the statistical processing of the large massif of the data about the values of H(-6°C) for the purpose of the establishment of general laws governing their intra-annual changeability, average monthly profiles of the temperature of air, etc. is sufficiently the presence of given in two periods observations (for example, into 04 and 16 hours).

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# ატმოსფეროში -6°C იზოთერმის სიმაღლის საათობრივი მნიშვნელობების სტატისტიკური ანალიზი კახეთის ტერიტორიაზე (საქართველო) აპრილიდან ოქტომბრის ჩათვლით

ხ.თავიდაშვილი

## რეზიუმე

ნაშრომში წარმოდგენილია, კახეთის ტერიტორიაზე (თელავი), ატმოსფეროში -6°C-იანი იზოთერმის სიმაღლის ყოველდღიური დეტალური სტატისტიკური ანალიზი, დაკვირვებათა 4 ვადისათვის (04, 10, 16 და 22 სთ, თბილისის დროით), აპრილიდან ოქტომბრის ჩათვლით, 2012-2016 წწ. მოცემული ინფორმაცია აუცილებელია ამინდის მოდიფიკაციისთვის საჭირო სამუშაოების დასაგეგმად. 2012-2016 წლების მონაცემები გამოყენებულია მსოფლიო აეროლოგიური ცენტრის ბაზიდან https://ready.arl.noaa.gov/READYcmet.php, არსებული ცენტრის მონაცემებით შესაძლებელია მეტეოროლოგიური ელემენტების ვერტიკალური განაწილების ექსტრაპოლაცია მსოფლიოს ყველა წერტილისთვის.

# Статистические характеристики часовых значений высоты изотермы -6 ° С в атмосфере над территорией Кахетии (Грузия) с апреля по октябрь месяцы

**Х. З. Тавидашвили**

## Резюме

Представлен детальный статистический анализ ежедневных данных за 04, 10, 16 и 22 час. по Тбилисскому времени о высоте изотермы -6°С в атмосфере над территорией Кахетии (Телави) с апреля по октябрь месяцы 2012-2016 гг., информация о которой необходима при планировании и проведении работ по модификации погоды. В работе использованы ресурсы мировой сети аэрологических наблюдений http://ready.arl.noaa.gov/READYcmet.php, по данным которой возможна экстраполяция вертикального распределения метеорологических элементов для любой точкой Мира.