

Change of climate conditions in the forest area of South Yakutia

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Abstract. A statistical analysis of meteorological parameters which influence the intensity of exogenous processes in the forest area of South Yakutia has been performed. The indicated increase in mean annual air and soil temperature rates occurred non-uniformly. Annual precipitation increase was due to precipitation rates in cold or transitional seasons; increase in snow cover depth and decrease in diurnal air temperature range was observed in cold season.

1. Introduction

The negative effects of climate change are considered one of the global problems that mankind is facing today. Planning of effective measures on climate change effect mitigation is of great significance, in particular, ensuring accident-free running of gas transmission lines. It is impossible to consider the climate change influence on intensity of exogenous processes without objective estimate of long-term changes in meteorological parameters, which, in its turn, is the relevance of the research.

The results of the statistical analysis of meteorological parameters for the construction area of the transmission line “Power of Siberia” in the pipeline section Chayanda-Lensk are presented. The research objective is to reveal trends in climate condition change which affect the intensity of exogenous processes in the area under complex natural conditions.

2. Study area characteristics

The study area is characterized by warm summers and severe winters with relatively little snow. The transitional seasons are not long. The spring coming is characterized by great diurnal temperature variations. The maximum temperature range (24°C - 27°C) is registered in March and April. The annual precipitation is 347–454 mm, most precipitation (70–75 %) falling during the warm period. Insignificant snow cover and extremely low temperatures (- 60°C) contribute to permafrost extension. Exogenous processes, freeze-thaw action and karst processes present the most unfavorable conditions for gas line construction. As described in [1], the territory refers to the sporadic permafrost zone. The permafrost occurrences account for 40-80 %.

According to a number of researchers [2-9], the climate conditions of permafrost zones are becoming less favorable; however, in general permafrost thickness does not change. As reported in [4,5], significant changes of meteorological characteristics that affect permafrost conditions took place in Siberia. Therefore, the most serious consequences of climate change can be observed in Siberia.

According to [8], the increase in snow cover and temperature changes resulted in displacement of permafrost borderline at distance up to few tens of kilometers to the north. As noted in [5], in Cisbaikalia and Trans Baikal regions, isotherm specific for the southern border of insular permafrost was displaced up to 500±50 km to the north at the depth of 320 cm in 1976 – 2006. The analysis of



temperature trends in Siberia [10] revealed the areas of warming where temperature exceeded $0.5^{\circ}\text{C}/10$ years, i.e. one order of magnitude higher than in the Northern hemisphere. A major cause of warming is the change in atmospheric circulation [10].

3. Materials and methods

The source of information for the current research is data obtained in meteorological stations Lensk and Vitim. They included measurements of surface air temperature, amount of precipitation, and snow cover depth in 1960-2014. In addition, the following information was also considered: the data on soil temperature (320 cm) obtained in meteorological stations Lensk in 1988-2011 and Vitim in 1963-2011[11]; amount of rain, mixed, and solid precipitation in 1960-2010. The accuracy correction of measurement equipment was also made.

The selected series were checked for uniformity, precisely, for the presence of climatological and statistical heterogeneities. As is known, one of the main reasons for climatological heterogeneity is microclimate change as a result of station transfer to different local conditions or change in the station surrounding environment. This may affect meteorological parameter values and can be referred to as climate change improperly.

The investigation procedure started with verification of the null hypothesis about series of homogeneities, randomness, and presence of the observed trend. The homogeneities was checked by means of Student tests, Abbe test, and F-test, while statistical independence and trend presence were verified by Pitman test and the inversion criterion [12]. The conclusions about series fluctuation or nonrandom change were made at 0.05 significance level provided that calculated statistics in the module was above the corresponding threshold or was outside the variable type range. Abbe test, which is used by climatologists to study precipitation and temperature series, implies the condition (1) to be met in case of non-uniform series:

$$1 - \frac{1}{\sqrt{n-1}} \leq \frac{2A}{B} \leq 1 + \frac{1}{\sqrt{n-1}} \quad (1)$$

$$\text{where: } A = a_1'^2 + a_2'^2 + \dots + a_n'^2 - \frac{1}{2} (a_1' + a_n')^2 \quad (2)$$

$$B = (a_1' - a_2')^2 + (a_2' - a_3')^2 + \dots + (a_{n-1}' - a_n')^2 \quad (3)$$

Where a_i' – sample deviation from the sample mean, n – number of samples. This condition being violated, the hypothesis of series uniformity is rejected.

3. Results and discussion

Based on the conducted analysis, statistical heterogeneity of more than one-third of air, soil temperature, and precipitation series has been detected.

The positive trend in mean annual air and soil temperature has been stated. It is worth noting that rise in mean annual air temperature did not occur linearly. During the first half of the study period till 1986-1990 the temperature increased by 0.03°C per year in Lensk and by 0.04°C per year in Vitim. In the later period the rate of increase falls down to 0.02°C per year in Vitim, and no temperature increase is observed in Lensk. Statistically significant increase in average monthly temperature can be observed in transitional period (May-June), being manifested non-uniformly in the considered stations. In Lensk, average monthly air temperature rises approximately by 0.04°C per year in April, May and June, whereas in the meteorological station Vitim (Figure 1) it increases by 0.05 - 0.07°C per year from March to June (Table 1).

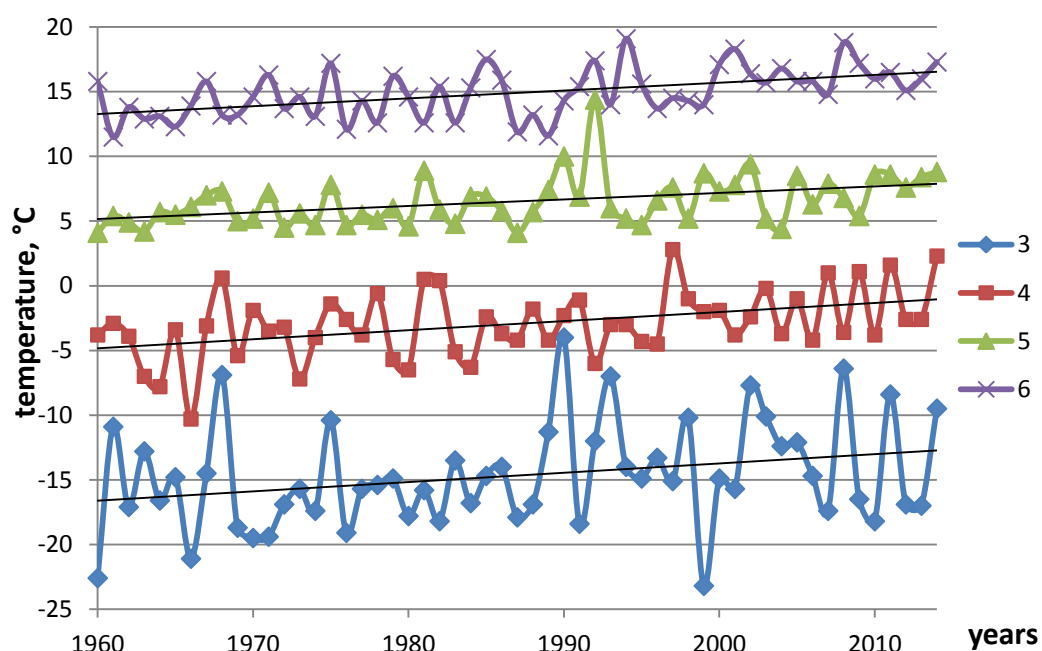


Figure 1. Long-term changes in average monthly air temperature in March (3), April (4), May (5) and June (6). Vitim, 1960-2014.

The statistically significant trend in annual temperature variation was not revealed. Based on the analysis of long-term maximum diurnal temperature range, it has been stated that maximum diurnal temperature variation increases only in May (0.09°C per year) in the meteorological station Lensk, while no trends have been distinguished throughout the remaining period (Table 1). In Vitim the decrease in maximum diurnal temperature range is registered in the cold season from October to April (by $0.05\text{-}0.1^{\circ}\text{C}$ per year) and in July (0.05°C per year).

Table 1. Variations in air temperature (t_{air}), maximum diurnal air temperature range (Δt_{max}) and precipitation amount (ΔX).

Month	$t_{\text{air}}, ^{\circ}\text{C}/\text{year}$		$\Delta X, \text{mm}/\text{decade}$		$\Delta t_{\text{max}}, ^{\circ}\text{C}/\text{year}$	
	Lensk	Vitim	Lensk	Vitim	Lensk	Vitim
I	—	—	—	—	—	-0.09
II	—	—	1.5	2.7	—	-0.06
III	—	0.06	1.0	—	—	-0.05
IV	0.05	0.07	—	—	—	-0.1
V	0.04	0.05	—	—	+0.09	—
VI	0.04	0.06	—	—	—	—
VII	—	—	3.8	3.1	—	-0.05
VIII	—	—	—	—	—	—
IX	—	—	4.1	4.1	—	—
X	—	—	—	4.8	—	-0.07
XI	—	—	1.6	2.1	—	-0.05
XII	—	—	—	—	—	-0.09
year	0.02	0.03	16	19		

Currently, according to [4], the lower values in the positive mean annual soil temperature trend compared to air temperature trends are characteristic for the entire cryolithzone of Russia. This tendency persists in Vitim. It has been found that over the study period (1963-2011) mean annual soil temperature at the depth of 320 cm rises by 0.02°C per year, positive trends being revealed over the January-September period. In Lensk over the available study period in 1987-2011 the increase by 0.05°C per year, and soil temperature rise in October-June were detected. However, in Lensk testing did not reveal any statistically valid positive air temperature trend over this period. This peculiarity can result from local anthropogenic changes in the area which surrounds the station, i.e. climatological heterogeneity; subsequently, data on soil temperatures in Lensk can be insignificant for estimating climate change and impact on permafrost condition. The experience has shown that such facts must be considered. For instance, it was determined that temperature increase and permafrost melting, for example in Yakutsk region, are directly caused by natural and anthropogenic damages of the underlying surface, hydraulic and thermal balance [6]. Therefore, temperature increase and permafrost melting do not correlate with climate change [8].

It is well known that precipitation affects soil moistening in warm months and snow cover depth in the cold season, which, in their turn, determine to a greater extent intensity of hot and cold wave penetration into soil depth. According to [2] increase in soil temperature in the study area is more dependent on the increase in snow cover depth rather than the increase in air temperature.

In the area under the study monthly total precipitation increases mainly in the cold season in February, March, November in Lensk; in February, October and November in Vitim; and in July and September in all the stations (table 1). The highest values (up to 4 mm/decade) are registered in September, November. The positive trend in annual total precipitation has been distinguished, precipitation amount increases by 16-19 mm per decade. In Lensk the increase in both annual and monthly total precipitation is greater than in Vitim. Moreover, in the second half of the considered period May total precipitation exceeds three times long-term mean values which are typical for June in Lensk (Figure 2)

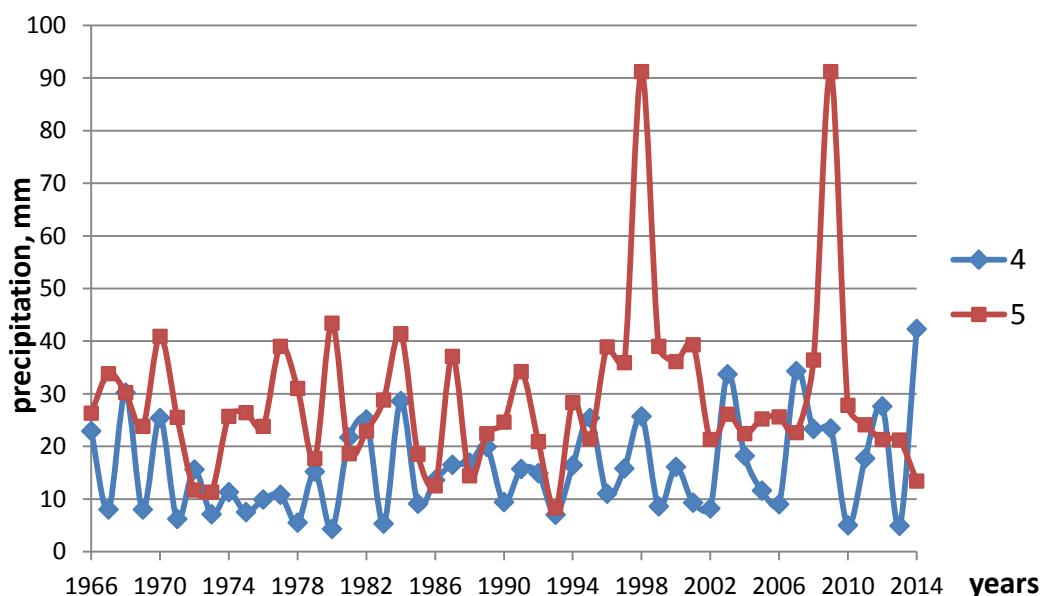


Figure 2. Time variations in monthly precipitation in April (4) and May (5), based on data obtained in the meteorological station Lensk, 1966-2014.

Based on the analysis of long-term variations in monthly total rain, mixed and solid precipitation, it has been detected that the revealed decrease in solid precipitation and increase in mixed precipitation in the transitional periods are due to rise in air temperature. Mixed precipitation amount increases in

April, May, September in Lensk, and in April, October, November in Vitim. Besides, there is a positive trend in rain precipitation in September and October in Vitim. After the period of mid 80-s no solid and mixed precipitation in summer months is observed or it decreases in amounts, whereas at the beginning of the study period solid precipitation amount could be of up to 6.1 mm (Vitim; June, 1967) and mixed precipitation could be as high as 9.1 mm (Lensk; June, 1983) a day.

In the analysis of snow cover depth, a positive trend in snow cover changes in January-March was detected in both stations, while in Lensk this trend occurred in April. It should be noted that the most intensive rise was before mid 80-s, after that it slowed down.

The obtained results, compared to forecasts for climate change in the territory of Russia in the XXI century [7, 13], indicated that rate of air temperature rise decreased relative to the expected rate in 2010-2015 [13]. It was confirmed that temperature rises to higher rates in cold seasons than in warm months. The further increase in the average precipitation is due to precipitation amount increase in the cold period [8, 13].

The detected precipitation increase in the cold season will lead to soil temperature rise and intensify permafrost degradation. The intensity of seasonal heaving can be influenced due to decrease in diurnal air temperature range in cold season and the distinguished increase in precipitation in July and September. This trend can intensify mollisoiil moistening with water accumulated in summer months. July precipitation increase may intensify landslide and solifluction processes.

4. Conclusion

The conducted research has indicated decrease in mean annual air temperature rates since mid 90-s. Average monthly temperature rises in transitional season (March-June) and this occurs non-uniformly in the considered meteorological stations. Diurnal air temperature range decreases mainly in cold season in Vitim; whereas in Lensk no distinctive changes can be traced.

Mean annual soil temperature increases at the depth of 320 cm both in Vitim and Lensk. Climatological heterogeneity is supposed to be present in data series obtained in Lensk, which is probably due to local anthropogenic changes affecting the station environment. Consequently, data on soil temperature in Lensk can be of no significance for climate change estimates.

In the study area the positive trend in annual total precipitation has been detected. Monthly total precipitation increases mainly in the cold season and in July. The highest values are observed in September, November. In Lensk, the increase in monthly total precipitation dispersion is distinguished in the spring months. Solid precipitation decreases, while mixed precipitation increases in transitional seasons, which is due to air temperature increase.

The positive trend in snow cover depth occurs in January and in April-March. It should be mentioned that rates slow down in the second half of the considered period.

Thus, the conducted analysis of long-term changes in meteorological parameters revealed non-linear climate changes, their non-uniform intensity and orientation observed in data of relatively closely-located meteorological stations. In studying climate change the emphasis should be made on the reliability verification of datasets.

References

- [1] Strokova L A, Dutova E M, Ermolaeva A V, Alimova A N and Strelnikova A B 2015 Karst hazard assessment in the design of the main gas pipeline (South Yakutia) *IOP Conf. Ser.: Earth Environ. Sci.* **27** 12032
- [2] *Metody otsenki posledstviy izmeneniya klimata dlya fizicheskikh i biologicheskikh sistem [kollektivnaya monografiya]* ed S M Semenov 2012 (M. Rosgidromet)
- [3] Pavlov A V and Malkova G V 2009 Melkomasshtabnoe kartografirovaniye trendov sovremennykh izmeneniy temperatury gruntov na severe Rossii, Kriosfera Zemli t. XIII 4 32-39
- [4] Sherstyukov A B 2007 Temperatura pochvogruntov Rossii na glubinakh do 320 cm v usloviyakh izmenyayushchegosya klimata *Trudy VNIIGMI-MTsD* **173** 72-88

- [5] Sherstyukov A B 2009 *Izmeneniya klimata i ikh posledstviya v zone mnogoletney merzloty Rossii* Obninsk: GU «VNIIGMI-MTsD»
- [6] Fedorov A N and Konstantinov P Y 2008 Recent changes in ground temperature and the effect on permafrost landscapes in Central Yakutia *Proceedings of the 9th International Conference on Permafrost, D. L. Kane and K. M. Hinkel (eds)* (June 29-July 3) Fairbanks, Alaska, Institute of Northern Engineering, University of Alaska Fairbanks **1** 433-438
- [7] Groisman P Ya, Blyakharchuk T A, Chernokulsky A V et al 2012 Chapter 3 Climate changes in Siberia. *In: Regional environmental changes in Siberia and their global consequences, Springer environmental science and engineering* (Springer, Dordrecht) 57–109
- [8] Romanovsky V E, Drozdov D S, Oberman N G, Malkova G V and et al. 2010 Thermal state of permafrost in Russia *Permafr. Periglac. Process.*, 21, 136-155, doi: 10.1002/ppp.683.
- [9] Shiklomanov N I 2005 From exploration to systematic investigation: Development of geocryology in 19th- and Early–20th-Century Russia *Physical Geography* **4** 249–263
- [10] Gorbatenko V P, Ippolitov I I, Podnebesnykh N V 2007 Atmospheric Circulation Over Western Siberia In 1976-2004 *Russian Meteorology and Hydrology* **32** (5) 301-306
- [11] FGBU VNIIGMI-MTsD [Elektronnyy resurs] URL: <http://meteo.ru/data>
- [12] Bendat Dzh and Pirsol A 1989 *Prikladnoy analiz sluchaynykh dannyykh*. Per. s angl (M.:Mir) p 540
- [13] *Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) 2005 Strategic Prediction for the Period of up to 2010-2015 of Climate Change Expected in Russia and Its Impact on Sectors of the Russian National Economy Moscow*