International Scientific Journal
Environmental Science
http://environment.scientific-journal.com

SNOW COVER IN NORTHERN KAZAKHSTAN IN TERMS OF REGIONAL CLIMATE CHANGE

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Abstract: Due to regional climate changes which occur in recent years, the increased interest in research on snow cover is observed. Snow cover is one of the most important climate forming factors. The territory of Northern Kazakhstan is located in those latitudinal zone, which is characterized by long-term period of stable snow cover, up to 4-5 months without break and snow here has a great impact on climate.

In Northern Kazakhstan steady snow cover is formed in November-December, and it is formed from north to south of the explored territory. Melting of stable snow cover occurs within two months - March and April.

The analysis of the dynamics of dates of formation and melting of stable snow cover and its duration has been conducted. The calculated trends indicate a significant tendency of later periods of formation of stable snow cover and there is a slight shifting of dates of melting of stable snow cover to earlier dates.

For the duration of snow cover, the calculated trends indicate the decreasing trend in snow cover duration. Duration of snow cover is reduced due to the later formation and earlier melting of stable snow cover. The relation between the date of formation, melting of snow cover and air temperature in fall and spring has been identified.

In recent decades, a clear trend in reduction of duration of stable snow cover has been observed in terms of regional climate warming which is due to later formation and earlier melting of stable snow cover.

Keywords: steady snow cover, dates of formation and melting, duration of snow cover, air temperature, precipitation, trend, anomaly.

1 Introduction

According to natural conditions Kazakhstan is entirely located in zone with periodical snow cover duration, but different duration and specifics of its duration in particular areas.

Fluctuations of periods of snow cover duration which have impact on the albedo of underlying surface, create significant heat exchange anomalies: in early snow cover formation the underlying surface gets insufficient heat and consequently gives less warmth to atmosphere. In the spring the dates and intensity of snowmelt are very important, for which the heat from atmosphere is needed. In availability of large amount of snow by the end of winter the incoming solar energy is mainly spent for snow melting and evaporation rather than for raising soil temperature and surrounding air layers. After snowy winters the temperature of spring months, as a rule, is lower than after less snowy winters. A significant shortage of precipitation in winter is one of the reasons of increasing drought in spring and summer, because in this case heat expenditure values for evaporation from soil practically reduce to zero.

Information on distribution of snow cover is necessary to address many issues of economic activity because it supplies rivers and soil with water [1, 2].

2 Material and methods

The research area includes three regions - Akmola, Kostanai and North Kazakhstan. It covers the period from 1971 to 2008. The dates of formation and melting of stable snow cover at 34 meteorological stations have been used as initial materials.

Methods of statistical processing of meteorological data in «STATISTICA» program have been used in the work.

3 Results

Formation of snow cover is closely dependent on temperature conditions. However, snow cover itself changes heat balance of the earth surface and contributes to maintaining low freezing temperatures.

Air temperature distribution on the territory of Northern Kazakhstan has zonal character. The average annual temperature in the north of the country is positive and is 0,8-1,9 ° C.

The coldest month in Northern Kazakhstan – is January, the average temperature ranges from -16 ° C to -19 ° C. The absolute minimum air temperatures can reach minus 43-52 ° C. The coldest place in the region – is Atbasar, here the absolute minimum air temperature is equal to -57 °C. In winter months thaws are possible on the whole territory.

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Analysis of time course of average monthly air temperature and its anomalies for the cold season and winter season showed the following. We should note that time rows are presented for the period 1971-2008, when main meteorological observations network in Kazakhstan has already been formed, and fluctuations of climatic data available for analysis of temperature and methodology of their processing can be considered as insignificant (Fig. 1).

Increase of surface air temperature in cold period occurred at the rate of 0,7 °C for every 10 years. On the territory of Northern Kazakhstan several years with anomalously low temperatures of cold period can be outlined. They are 1972, 1974, 1977, 1996, 2006 and 2008, when negative anomalies in January were 1,5–3,0 °C, and sometimes more than 5,0 °C. In the recent 20 years, the temperature of the cold period was often higher than normal, calculated for 1971 and 2000. The highest temperature of the cold period in the research area was observed in 2002, when it was above the norm to 3,0–4,0 °C [3].

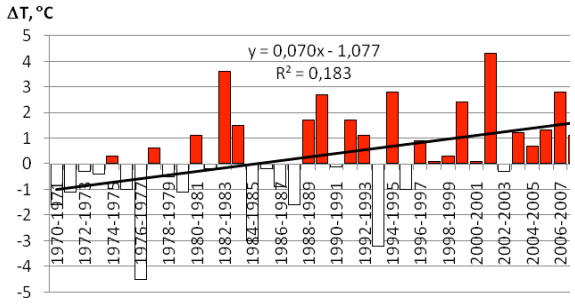

Figure 1 – Changing of air temperature anomalies (ºC) in cold period of the year, averaged on the territory of Northern Kazakhstan

Northern Kazakhstan is characterized by uneven distribution of precipitation on the territory. Here, the average annual precipitation is 300-400 mm, and precipitation in the warm period is prevailing, the amount of which is 190-290 mm (70-80% of annual amount). In the cold season during the Siberian anticyclone in the observed area, precipitation is much less, total 80-100 mm (20-30% of annual amount). Everywhere precipitation significantly vary from month to month and from year to year, so that the quantity may significantly differ from average long-term value [4-6].

In the research area the precipitations of the cold period are unevenly distributed (varying from 60-70 mm in the northern to 80-90 mm in the southern regions). If we look at the ratio of precipitations quantity in November-December and January-February, everywhere most of it fall in the first half of the cold period, and therefore snow cover is formed mainly due to these precipitations.

Snow accumulation depends both on quantity of precipitations and their nature and frequency. In most parts of northern Kazakhstan in winter months precipitations fall almost daily up to 28-30 days per month, the average daily quantity of precipitations in rare cases is up to 2 mm, average maximum daily precipitation is 3-7 mm.

During the cold period the biggest number of days with precipitation occur at the beginning of winter due to the development of active cyclonic activity. The number of days with precipitation ranges from 95 to 110 days.

In this paper the temporal course of precipitations has been analyzed and direction and pace of their change during specific periods of time have been determined. The coefficients of linear trends, expressed in millimeters for 10 years (Fig. 2).

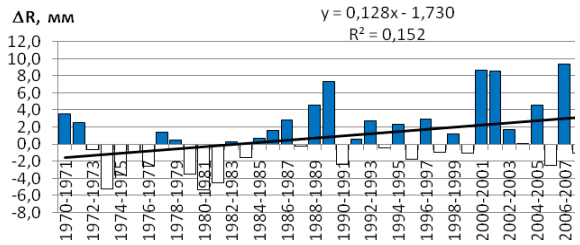

Figure 2 – Changing of precipitation anomalies (мм) in cold period of the year, averaged on the territory of Northern Kazakhstan

Analysis of linear trend in temporal course of anomalies of annual precipitation amounts and cold period precipitation quantities showed slightly expressed that trends. On the explored territory during the period 1971-2008 there is a weak positive trend of increase of precipitations to 1,9-2,9 mm /10 years.

Steady snow cover is formed in the northern Kazakhstan in November-December. In North Kazakhstan and Akmola regions, it is formed from 5 to 12 November, in Kostanai region it is formed 8-10 days later (14-21 November).

In some years, there is a considerable deviations in duration of stable snow cover compared to the average long-term periods. The earliest formation of stable snow cover in the north of the country was observed on 3-9 October, and the latest – on 18-24 December. The amplitude of dates of formation of stable snow cover in the research area is about 70 days, and average square deviations vary from 10 to 15 days.

Melting of stable snow cover occurs within two months - March and April. Earliest melting of stable snow cover in the north of the country was observed during February 20 - March 5, the latest - April 25-28. Almost on the entire territory of Northern Kazakhstan steady snow cover melts from 1 to 10 April. The average value of square deviations of dates of melting of stable snow cover is 7-12 days.

The amplitude of oscillations of dates does not exceed 60 days. This is due to many reasons: the intensity of spring influx of solar radiation, advection of warm air masses, forested areas, the amount of snow stock, etc. Usually early melting of snow cover occurs in winters with little snow, and later - in snowy winters.

The average duration of snow cover is 145 days, ranging from the north (Petropavlovsk, Bulayevo) to the south (Torgai) from 150 to 116 days. The minimal number of days with snow in the research area is 77 days, maximal - 187 days (Uritzky).

For the explored parameters of snow cover the trends (Fig. 1) have been calculated, which indicate a trend of later formation and earlier melting of stable snow cover and reduction of its duration [7].

Figure 3 shows spatial and temporal variability of dates of snow cover duration in the period 1971-2008 for the research area. The calculated trends indicate a significant trend of later periods of duration of stable snow cover (0,20-0,28 day / year).

The process of spring snowmelt and destruction of stable snow cover starts from the third decade of March and finally ends in the northern areas in late April. Every year the spring snow melting dates of stable snow cover begin may deviate from average long-term values almost in the same ranges as the dates of snow cover formation. Figure 4 shows the dynamics of dates of snow cover melting.

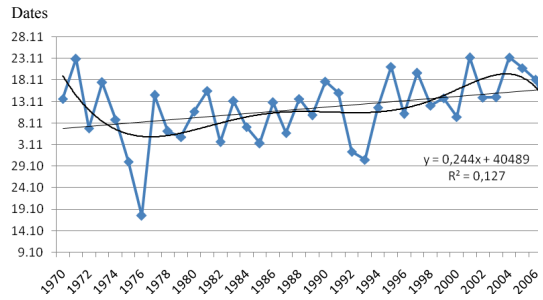

Figure 3 – Dynamics of stable snow cover formation for the territory of Northern Kazakhstan

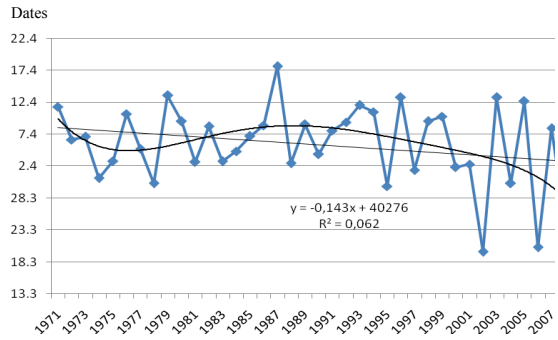

Figure 4 – Dynamics of stable snow cover melting for the territory of Northern Kazakhstan

Trend -3.8 days/10 years has been calculated for the duration of snow cover, which indicates the tendency of reduction of the duration of snow cover.

Formation and destruction of snow cover is closely dependent on temperature conditions. Changing of dates of formation and melting of snow cover is associated with regional warming.

Late formation of snow cover and early destruction is determined by abnormally warm autumn and spring. In contrast, the early formation and later melting are caused by abnormally cold autumn and spring. Early formation of stable snow cover is observed when average monthly air temperature in October and November is below long-term average temperatures to 2-5^{0}C. Later periods of snow cover formation are observed in warm autumn, when there are positive temperature anomalies (3-5^0 C above normal). Early melting of snow cover is in the spring when positive anomalies of air temperature in March range from 3 to 5, sometimes 7^{0}C. Late snow cover melting is observed at negative temperature anomalies minus 2 - minus 5^{0}C in March and April. Usually late melting of stable snow cover occurs in snowy winters, and early - in winters with little snow.

The correlation coefficient between the date of snow cover staying and air temperature in October and November was 0.54, and between the date of snow cover melting and air temperature in March-April the correlation coefficient was 0.55. The correlation coefficient between the date of stable snow cover staying and air temperature separately for October was 0.40 and for November 0.58. The correlation coefficient between the date of snow cover melting and air temperature in March is -0.78. Consequently, there is a significant correlation between changes of air temperature of the cold period and periods of formation and melting of stable snow cover.

Significant correlation dependence in the research area between the number of days with snow cover, air temperatures and precipitation quantity, averaged during cold period, has not been found. However, in most extreme cases short duration of snow cover is observed at positive temperature anomalies of the cold period, and long – in negative air temperature anomalies

6 Conclusion

The following conclusions were done during the research:

1. In most parts of Northern Kazakhstan snow cover is formed by mid-November. In some years, there are deviations from normal mode, when the formation of stable snow cover in the northern areas lasts until the end of November and beginning of December, in the south - until mid-December, and vice versa, when stable snow cover is formed 10-20 days earlier than usual period. During winter months in the Northern Kazakhstan the intensive thaws, completely destroying the snow cover, are almost not observed. Almost on the entire territory of Northern Kazakhstan steady snow cover is melting from 1 to 10 April.

2. Spatio-temporal variability of dates of snow cover formation and melting in the period 1971-2008 on the territory of Kazakhstan has been explored. The calculated trends indicate a significant trend of later periods of stable snow cover formation (0,20-0,28 day/year); weak trend of shift of periods of stable snow cover melting to earlier dates (0,10-0,17 day/year).

3. The duration of snow cover varies widely and significantly depends on its capacity, intensity of radiation-advective factors and topography specifics. The average duration of snow cover is 145 days, ranging from north to south from 162 to 115 days.

Reduction of duration of snow cover is observed since the mid 90-ies of XX century, which is especially significant in the last decade, the linear trend coefficient is -3.8 days / 10 years.

4. Formation of snow cover is closely dependent on temperature conditions. Changing of the dates of formation and melting of snow cover is associated with regional warming. Over the past decades, the stable trend toward increasing the temperature in October at rate of 0.7^0 C/ 10 years has been observed. In November, air temperatures vary around average long-term values. In spring, in March, and in late winter, in February, a warming trend has been observed (0,9 ^{0}C/10 years and 0,2 ^{0}C/10 years, respectively), in April a steady trend to cooling has been observed (-1,4 ^{0}C/10 years). The shift of dates of spring melting of snow cover to earlier dates is much slower than shift of dates of its formation.

5. The correlation coefficient between the date of snow cover formation and air temperature in October and November was 0.54, and correlation coefficient between the date of snow cover melting and air temperature in March-April was -0.55.

It is hard to overestimate the value of snow cover to ensure sustainability of the environment and agriculture in grain growing areas of Northern Kazakhstan.

Data on the duration of snow cover, melting periods, largely determine the start and end of field works in agriculture, and as a result, crop yield forecast. In this regard, the research on snow cover is of great scientific and practical interest

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