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The First Decade of the New Century: A Cooling Trend for Most of Alaska

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Abstract: During the first decade of the 21st century most of Alaska experienced a cooling shift, modifying the long-term warming trend, which has been about twice the global change up to this time. All of Alaska cooled with the exception of Northern Regions. This trend was caused by a change in sign of the Pacific Decadal Oscillation (PDO), which became dominantly negative, weakening the Aleutian Low. This weakening results in less relatively warm air being advected from the Northern Pacific. This transport is especially important in winter when the solar radiation is weak. It is during this period that the strongest cooling was observed. In addition, the cooling was especially pronounced in Western Alaska, closest to the area of the center of the Aleutian Low. The changes seen in the reanalyzed data were confirmed from surface observations, both in the decrease of the North-South atmospheric pressure gradient, as well as the decrease in the mean wind speeds for stations located in the Bering Sea area.

Keywords: Climate change, Alaska, Temperature change, PDO.

INTRODUCTION

We analyzed the temperature change of the first decade of the 21st century for Alaska, both for annual and seasonal values. For this study we used all first order meteorological stations in Alaska, which are operated by professional meteorologist of the National Weather Service (NOAA). There are 20 such stations, fairly well distributed over the different climatic zones of Alaska [1]. We limited our investigation to these stations, as all of these have similar or identical in instrumentation and operational procedures. In Fig. (**1**) the location of these stations is given.

There are many more climate stations operating in Alaska, run by different federal, state and local entities as well as by the industry and private individuals. The quality of these stations is mixed, but it should not be taken as an indication that all of these are of poor quality.

BACKGROUND

In general, the temperature has increased in Alaska since instrumental records are available. Stafford *et al*. [2] analyzed 25 Alaskan stations for the time period from 1949-1998 and found a mean annual temperature increase for all stations in the range of 1.0°-2.2°C, with the greatest warming occurring in Interior and Southeastern Alaska. Seasonally, the greatest warming occurred in winter, followed by spring. The summer warming was light and in autumn no substantial temperature change occurred.

Polyakov *et al*. [3] carried out a substantial investigation on temperature trends in the maritime Arctic, analyzing 75 stations. They found a mean temperature increase of 1.2˚C over 125 years (1875–2000). Looking at Fairbanks in Interior Alaska [4], for which a century of data are available, a total warming of 1.4°C was observed, which is about twice the global value, hence, in agreement with the so-called polar amplification. The general temperature increase was non-linear, but overlain by multi-decadal variations. 1926 was the warmest year ever recorded not only in Fairbanks, but also in Sitka (southeastern Alaska) and Barrow (northern Alaska), for which stations the data are available. The mean decadal temperatures of Fairbanks show for the 1980’s the highest value (-1.94°C) followed by the 1920’s (-2.39°C) and 1990’s (-2.59°C). Further, a sudden temperature increase in Alaska was recorded starting in 1977 [5], seemingly driven by the change in polarity of the Pacific Decadal Oscillation (PDO) Index [6], which went from dominantly negative before 1977 to dominantly positive values after that year. An update version of the temperature trend for the mean of the 20 Alaskan first order stations is presented in Fig. (**2**), showing that the temperature increase was non-linear. Besides the strong temperature increase starting in 1977, on which Hartmann and Wendler [5] reported, a cooling trend in the 2nd half of the first decade of the new century is clearly visible. At this time it cannot be decided whether this is a climatic shift during the first decade of the 21st century or if it represents decadal-interdecadal variability.

More recently Gil-Alana [7] discussed memory, seasonality and trends based on monthly mean temperatures of Alaska.

We looked at the temperature trend of the first decade of the 21st century for the 20 first order stations in Alaska and found that 19 of the 20 stations showed a cooling trend. In Fig. (**3**) we plotted the mean values of these 20 first order stations and added the line of the best linear fit. The mean cooling of the average of all stations was 1.3°C for the decade, a large value for a decade. A correlation coefficient (r) of 0.54 was calculated for this trend, confirming the trend significance at the 90% confidence level. Naturally, 11 data points is a low number, however, if we apply the deviation from the mean of monthly data, the overall trend stays similar. In Fig. (**4**) we plotted the two stations, which represent the extremes, Barrow and King Salmon. Barrow

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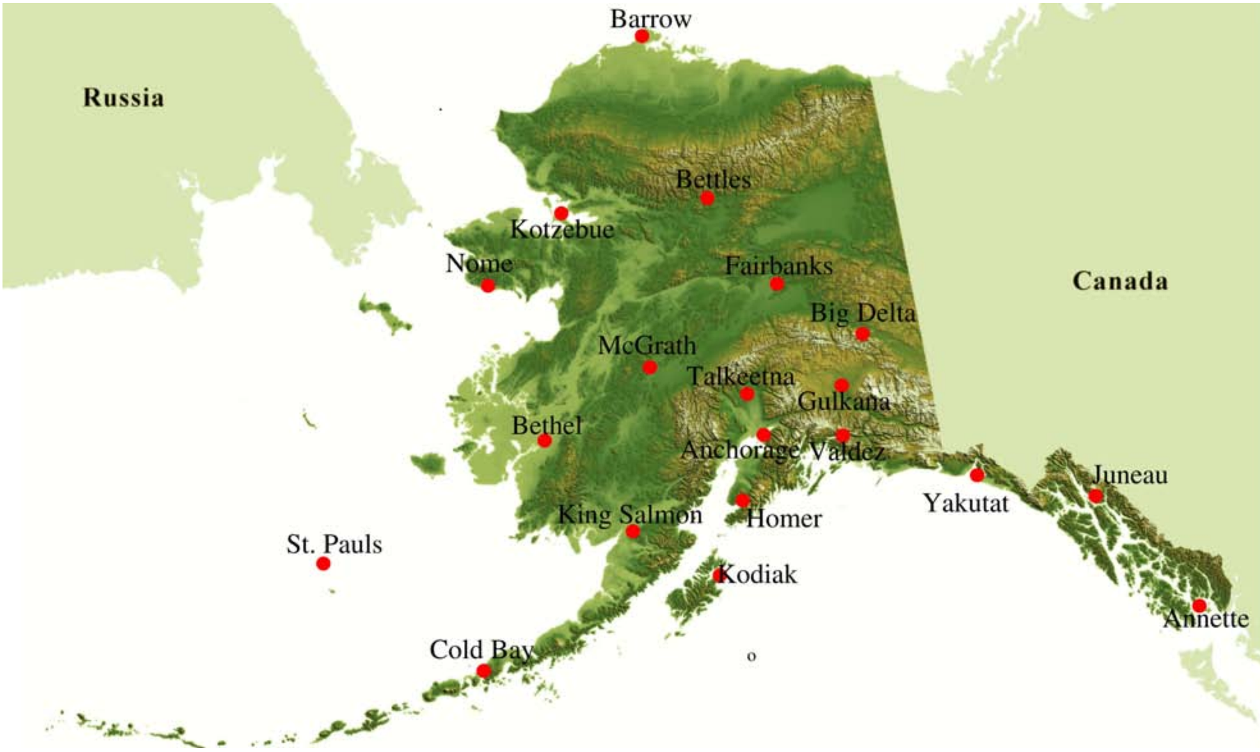

Fig. (1). Location map of 1st order meteorological stations in Alaska.

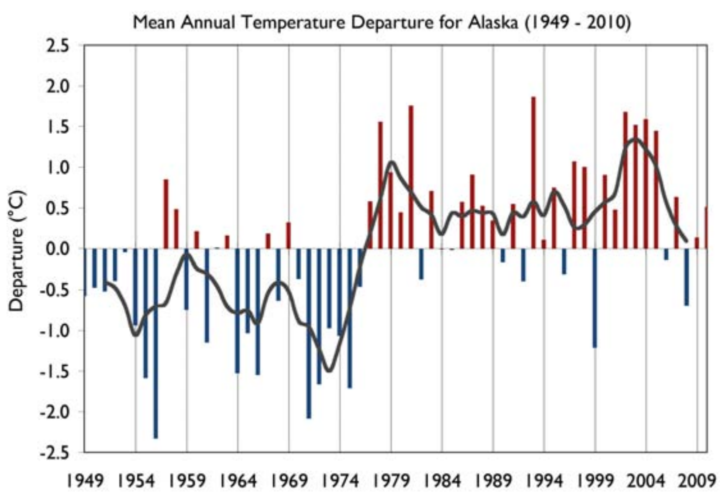

Fig. (2). Temperature deviation from the long-term mean, average of the 20 first order stations. Alaska 1949-2010.

stood out as the only station demonstrating a warming trend, which was substantial with 1.7°C for the decade. The other extreme was King Salmon, which gave a strong cooling trend for the same decade of 2.9°C. As Barrow was the only station, which showed a warming trend, we wanted to verify its values. Hence, we looked at two additional stations (non 1st order) on the coast of the Beaufort Sea (Deadhorse and Barter Island), both East of Barrow. These stations confirmed that the warming trend on the North Slope is not limited to Barrow.

In Fig. (**5**) an isoplete presentation of the decadal temperature changes is presented. The only warming trend for the decade was observed in Northern Alaska. The 0°C isobar parallels roughly the Brooks Range. All the rest of Alaska experienced cooling, which was especially pronounced in western Alaska. The warming trend found in the Beaufort Sea coastal stations of northern Alaska is in opposition to the cooling trend of the coastal and island stations of the Bering Sea.

When looking at the observed cooling trend for the mean of Alaska by season, winter contributed the majority with 77%, followed by spring, which contributed 17%. The temperature in summer and autumn cooled only very slightly, with statistically non-significant values.

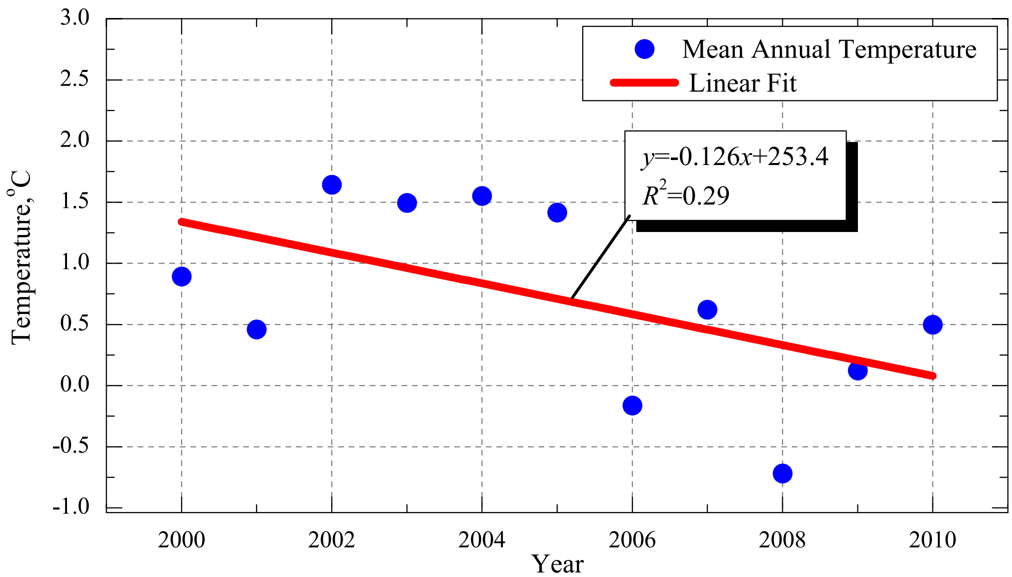

Fig. (3). Annual temperature trend for the first decade of the 21st century for the mean of all first order stations in Alaska.

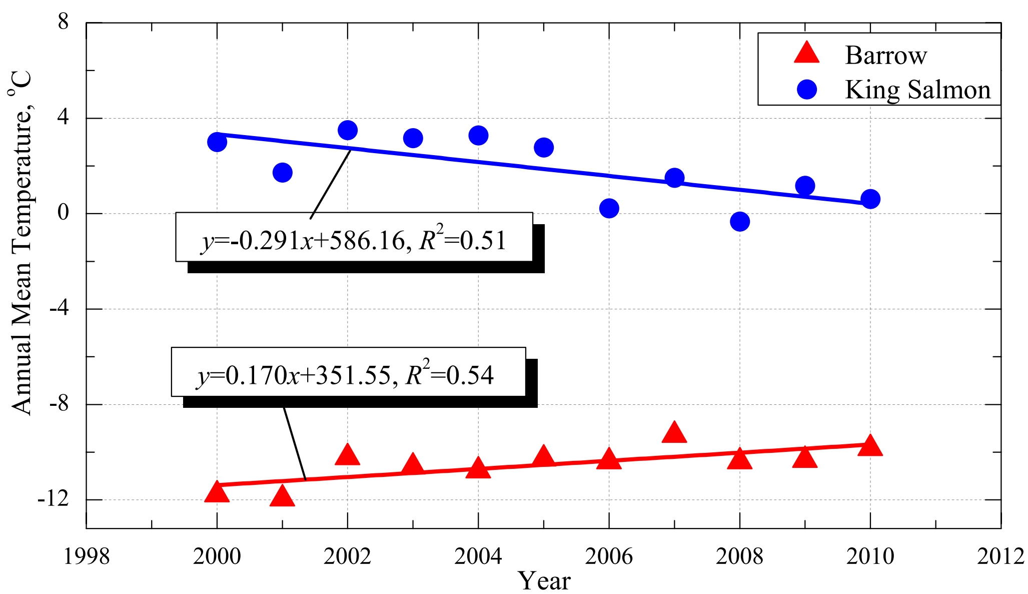

Fig. (4). Mean annual temperatures for the first decade of the 21st century for Barrow and King Salmon as well as the trend line of the best linear fit.

CO_2, which increases semi-exponential [8], cannot be the source the observed cooling, as the opposite effect would be expected. However, there are a great number of circulation indices, and Mantua *et al.* [6] were the first to show the strong influence of the phase of the Pacific Decadal Oscillation (PDO) on the climate of Alaska by examining the relationship between climate variability and salmon production in Alaska and the U.S. Pacific Northwest. Monthly anomalies in the sea surface temperature (SST) field of the North Pacific, poleward of 20°N, constitute the basis of the PDO index.

Other studies with emphasis on Alaska were carried out by Papineau [9] and Hartmann and Wendler [5]. The latter studies showed clearly, that in 1976/77, when the PDO value changed from dominantly negative to dominantly positive values, a sudden temperature increase across Alaska was observed. Hence, it became naturally to review the PDO values for the first decade of the 21st century, and indeed, the values have trended negative once more. In Fig. (**6**) we plotted the mean of temperature deviations of all Alaskan 1st order stations against the PDO values and indeed, a good correlation coefficient of r=0.76 was found, which is significant at the 99% confidence level. This result in a variance of 0.58 or differently expressed, 58% of the observed cooling can be attributed to the change in circulation as expressed in the PDO value.

Other indices, which correlated well with the mean annual temperature deviations of Alaska, are given in Table **1**. While the PDO gave the highest correlation, it was followed by the East Pacific - North Pacific (EP-NP) pattern. The positive phase of this pattern, which correlated well with the Alaskan temperatures, features positive height anomalies located over Alaska/ Western Canada, and negative anomalies over the central North Pacific and eastern North

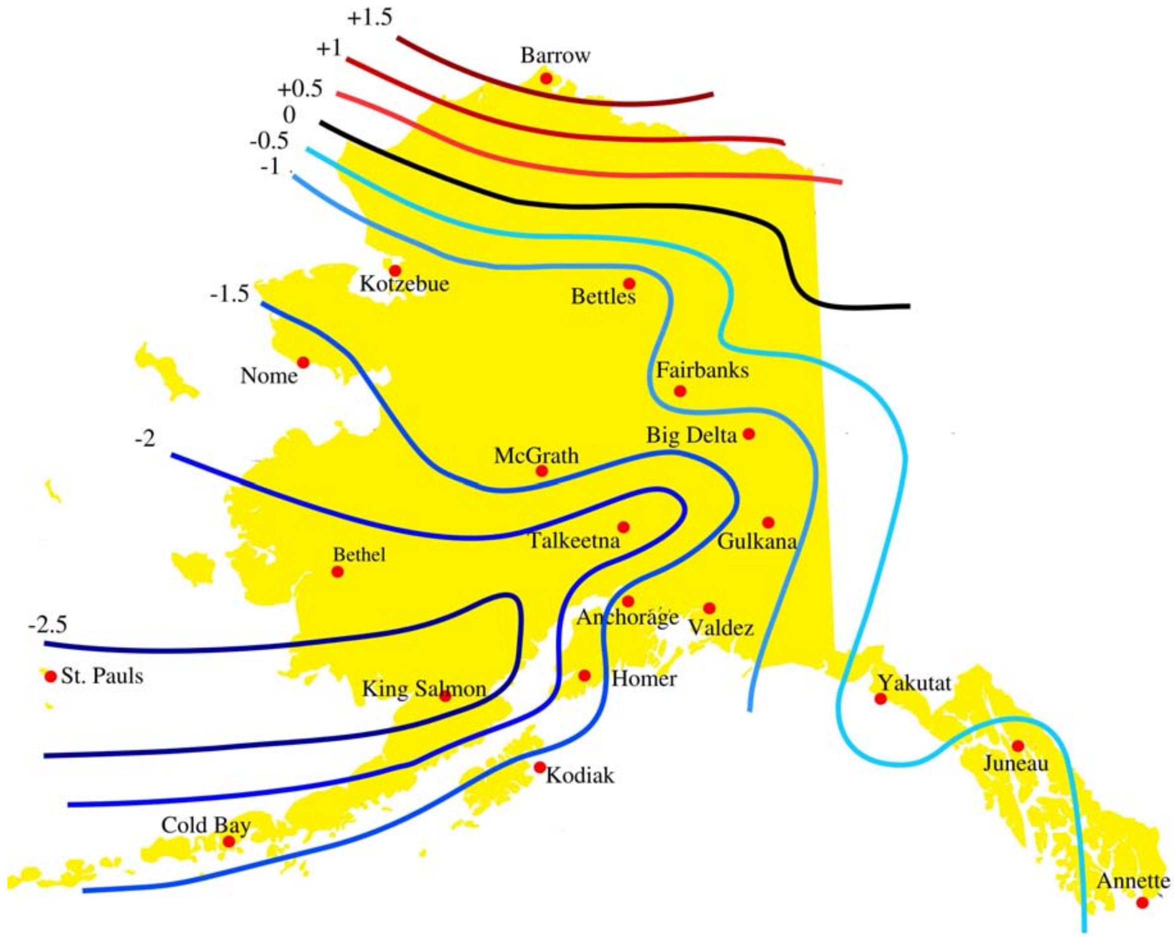

Fig. (5). Isoplete presentation of the observed temperature change for the first decade of the 21st century based on all first order meteorological stations in Alaska.

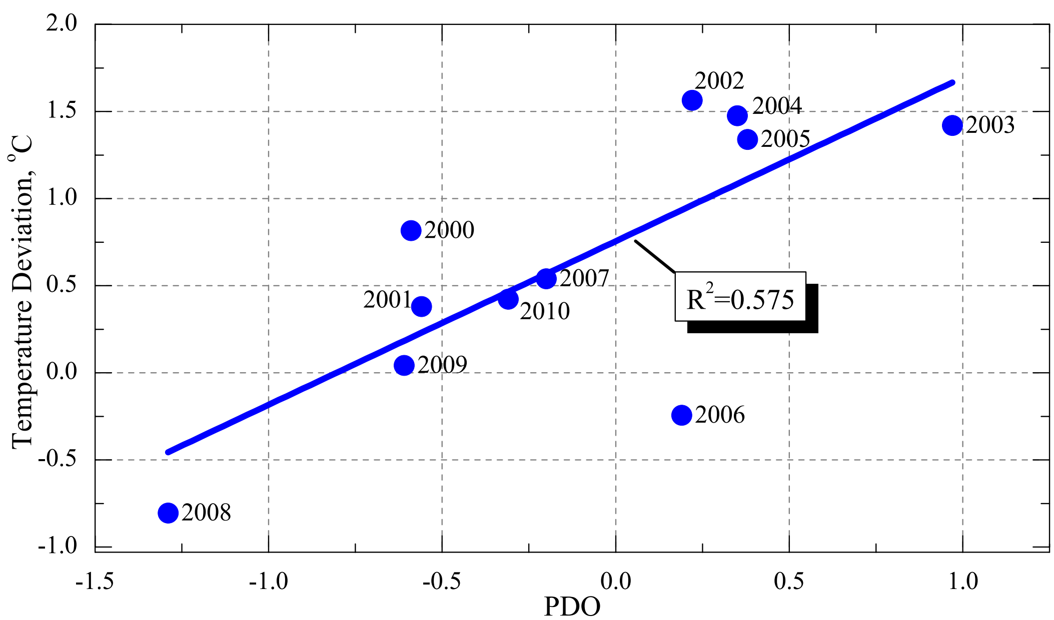

Fig. (6). Averaged mean annual temperature deviation from the norm against the Pacific Decadal Oscillation values for the first decade of the 21st century.

America [10]. The other two relatively high correlation coefficients were found with the Southern Oscillation Index (SOI), which depends on the atmospheric pressure differences between Darvin and Tahiti, and the El Nino (NIN 04), based on Pacific Ocean surface temperature. All 4 of these indices are related.

Table 1. Averaged Mean Annual Temperature Deviation from the Norm Against the Different Circulation Indices for the First Decade of the 21st Century

Index	Abbreviation	Correlation Coefficient (r)
Pacific Decadal Oscillation	PDO	0.76
East Pacific/N.P. Pattern	EP/NP	0.73
Southern Oscillation Index	SOI	-0.66
El Nino	NIN 04	0.63
El Nino	Nino 3.4	0.50

Solar activity can have a strong influence on the climate [11, 12]. It is well known, that the Little Ice Age coincided with the Maunder Minimum (about 1645 - 1715), a time period of low solar activity, which can be expressed in the sunspot number. Hence, we plotted the sun spot number against the mean deviation of the averaged temperature of Alaska (Fig. **7**). The correlation (r=0.53) was not as strong as with the PDO, resulting in a variance of 28%. We tested further, if PDO and sun spot number were related, and found that this is not the case, as the variance between the two parameters was less than 2%. Hence, it is not surprising, that the multiple regression of the combination of circulation changes as expressed in the PDO and the solar activity as expressed in the sun spot number resulted in a coefficient (r^2) of 0.73.

Variability of the Aleutian Low and its relation to high-latitude circulation was studied by Overland *et al*. [13]. Positive PDO numbers are caused by high SST temperatures in the Northern Pacific, resulting in a strong Aleutian Low. However, the trend of the PDO was going into negative numbers during the first decade of the 21st century. This should result in a weakening of this semi-permanent cyclone in the Aleutians, and indeed this was observed when comparing the first half of the period with the second half of the observation period. In Fig. (**8**) the change of the winter values of the reanalyzed NCEP/NCAR 1000 hPa data for Alaska is presented. As pointed out above, winter gave the strongest cooling, as at this time solar radiation is weak, and advection plays the major role. Surface observations confirmed the reanalyzed data set. Cold Bay, located at the western extreme of the Alaskan Peninsular (see Fig. **1**), recorded an increase of atmospheric surface pressure during the study period and the N-S pressure gradient between Cold Bay and Nome decreased. In addition, the stations of the Bering Sea: St. Paul Island, Nome and Kotzebue - all reported a decreasing wind speed, a result to be expected with a weakening Aleutian Low. All of the above observations cause a smaller amount of relatively warm air from the Northern Pacific being advected into the Bering Sea and Alaska; hence the observed cooling [13]. However, Barrow, north of the Brooks Range, is not substantially affected by the decrease in advection, and here the general warming observed for the Arctic Ocean is dominant.

In summary, the long term observed warming of Alaska of about twice the global value, as expected by the increasing CO_2 and other trace gases, is sometimes temporarily modified or even reversed by natural decadal variations. This is not the first observed occurrence that can be found in the historical record of Alaska [14], as the 1920's were warm, and starting in the mid-1940's a cold period occurred lasting some 3 decades, after which it become warm again.

ACKNOWLEDGEMENT

We are thankful for financial support given by Dr. Roger Smith, Director, Geophysical Institute and Dr. Mark Myers, Vice Chancellor of Research, University of Alaska, Fairbanks.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

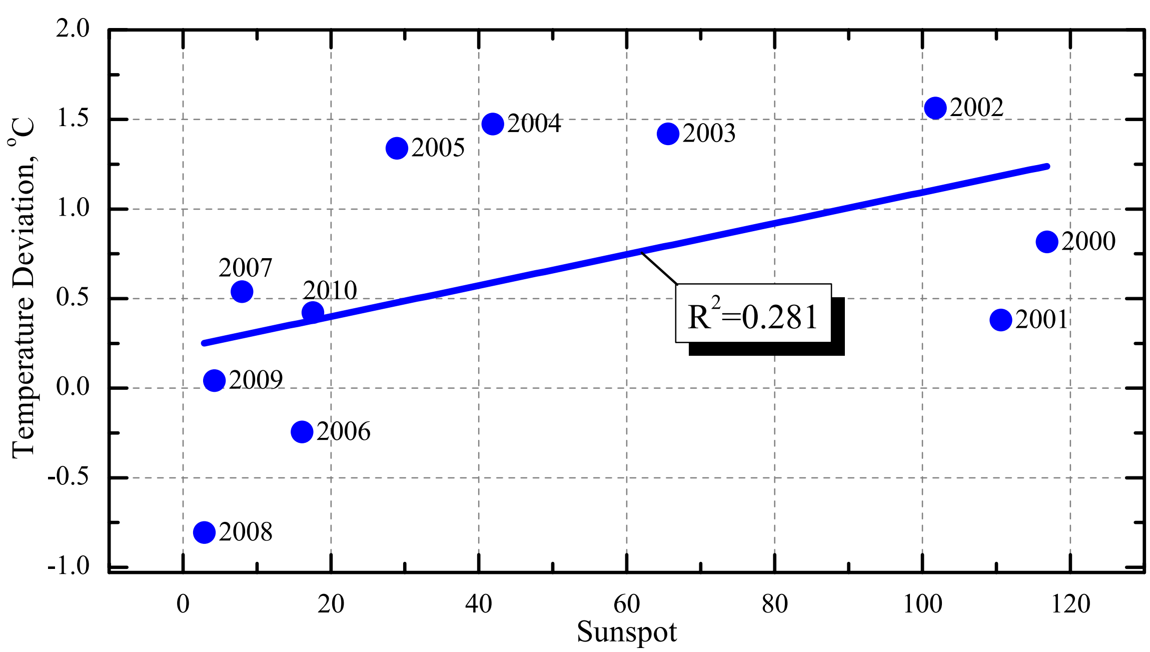

Fig. (7). Averaged mean annual temperature deviation from the norm against the sun spot number for the first decade of the 21st century.

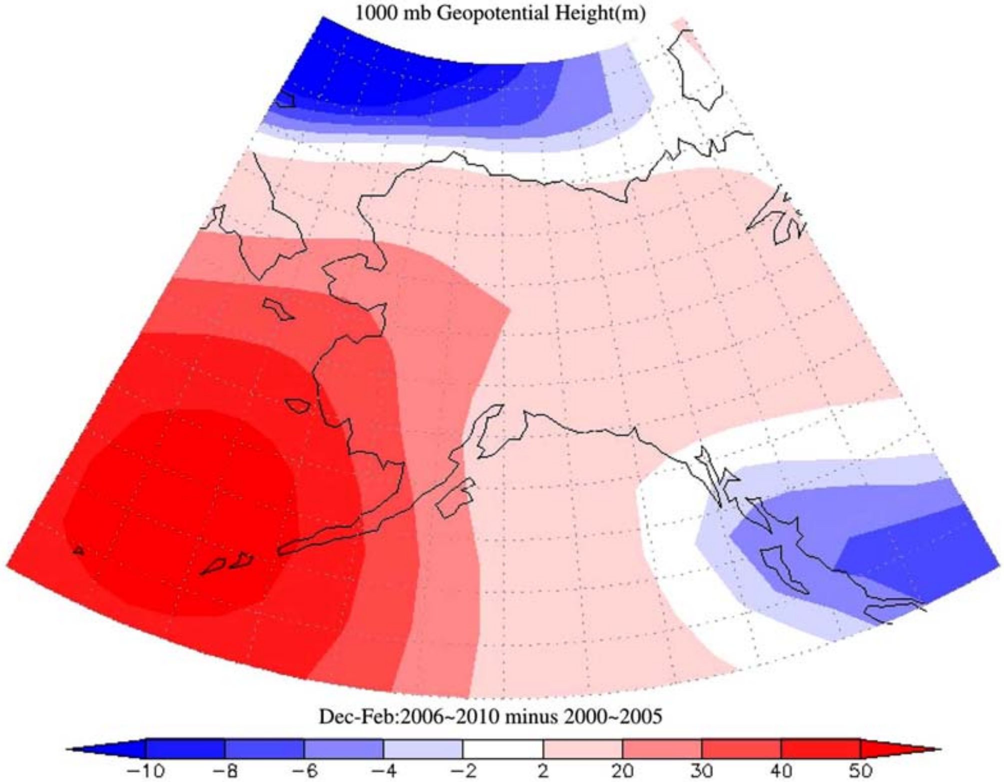

Fig. (8). Change in the geopotential height (1000 mb) in winter during the first decade of the 21 century - (2000 to 2005) minus (2006 to 2010) – for Alaska as obtained from the NCEP/NCAR reanalyzed data set.

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Received: May 15, 2012 Revised: June 16, 2012 Accepted: June 17, 2012