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Searching for Arctic Temperature Trends and Extremes from Original Station Records

Taneil Uttal

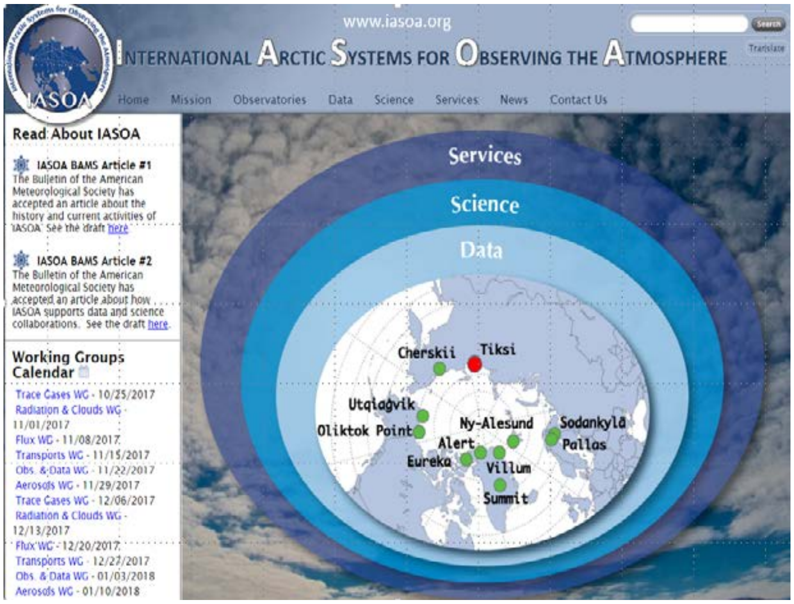
Physical Science Division, NOAA Earth Systems Research Laboratory, Boulder, Colorado

1. Introduction

Over the last decade since the International Polar Year (IPY) NOAA has led development of the International Arctic Systems for Observing the Atmosphere (IASOA) consortium (Uttal *et al.* 2016 and www.IASOA.org). The IASOA (Fig. 1) consortium has resulted in a voluntary, international partnering of Observatories operated by institutions and agencies of the 8 Arctic countries. The mission is to create networked observing practices, long-term data sets and groups of specialists to further understand and monitor the evolution and process of Arctic weather, climate and linkages to the rest of the planet. The data at the IASOA observatories is uniquely Arctic and represents a part of the planet where the diurnal cycle has significant variance over the year ranging from the extremes of 24 hours of night, 24 hours of day and long periods with mixed astronomical, nautical and civil twilight. While this sun-earth geometry is of course a well know fact for the polar regions, the resulting need for choosing averaging periods that are representative of the annual cycles of solar irradiance at Arctic sites is often overlooked, and the use of more globally representative seasonal averaging periods can obscure and distort detection of even the simple analysis of temperature trends.

2. Data

Most of the IASOA Observatories are collocated with weather stations, which have unusually long records especially for the Arctic region. In this study, the Tiksi Observatory in the Russian Arctic is highlighted by a detailed digitized historical records (referred to hereafter as AARI) starting in 1936 that was compiled by the Russian Arctic and Antarctic Research Institute from original detailed handwritten records. These are used to assess the Global Historical Climate Network Daily (GHCND) data for Tiksi that is available from NOAA/NCEI and described by Menne *et al.* (2012). In the following sections, (1) a comparison is made of the digitized historical AARI and NCEI daily temperature minimum and maximum (T_{min} and T_{max}), (2) it is shown that Arctic seasons need to be defined as "cold", "warm" and "transitional" based on temperature clustering, (3) temperature trends are analyzed based on resulting definitions of the Tiksi specific Arctic seasons and as a function of the length of the data record, and (4) a preliminary assessment is made to identify decadal changes in the occurrence of extreme temperature events in Tiksi.



Read About IASOA

IASOA BAMS Article #1
The Bulletin of the American Meteorological Society has accepted an article about the history and current activities of IASOA. See the draft here.

IASOA BAMS Article #2
The Bulletin of the American Meteorological Society has accepted an article about how IASOA supports data and science collaborations. See the draft here.

Working Groups Calendar

Trace Gases WG - 10/25/2017
Radiation & Clouds WG - 11/01/2017
Flux WG - 11/08/2017
Transports WG - 11/15/2017
Obs. & Data WG - 11/22/2017
Aerosols WG - 11/29/2017
Trace Gases WG - 12/06/2017
Radiation & Clouds WG - 12/13/2017
Flux WG - 12/20/2017
Transports WG - 12/27/2017
Obs. & Data WG - 01/03/2018
Aerosols WG - 01/10/2018

Fig. 1 Screenshot of the Home Page of the International Arctic Systems for Observing the Atmosphere (IASOA) web site (www.iasoa.org). The Tiksi Station in the Russian Arctic is highlighted as the focus of this surface temperature study.

Correspondence to: Taneil Uttal, Physical Science Division, NOAA Earth Systems Research Laboratory, Boulder, Colorado 80305; E-mail: taneil.uttal@noaa.gov

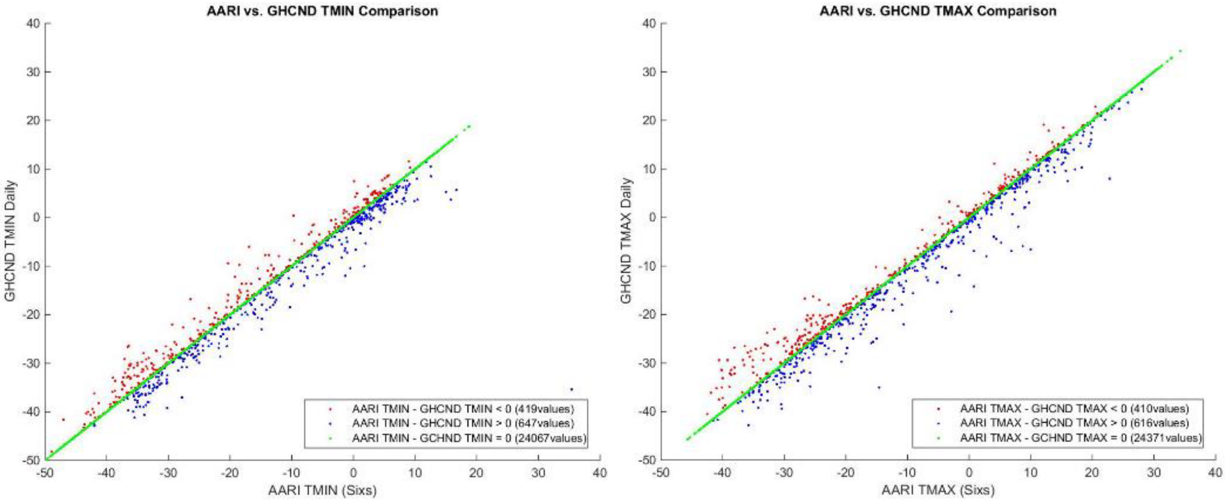


Fig. 2 Comparisons of AARI and GHCND for T_{min} (left) and T_{max} (right) over the period 1936-2014.

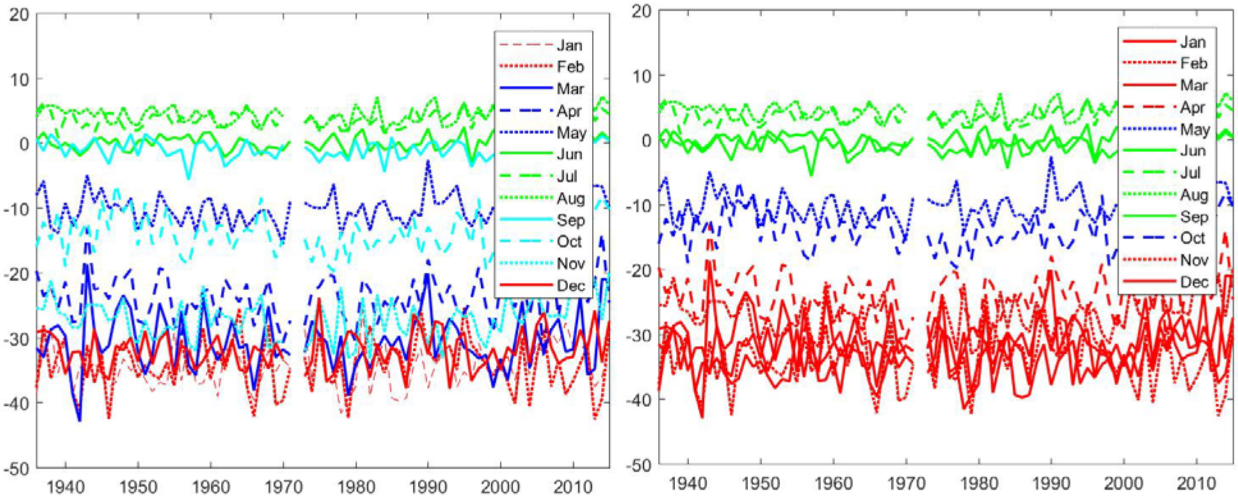


Fig. 3 AARI and GHCND for T_{min} (left) and T_{max} (right) over the period 1936-2014. Months are color coded green (JJA (left) and JJAS (right), red (DJF (left) and NDJFMA (right)), blue (MAM (left) and M (right)) and turquoise (SON (left) and O (right)).

3. Comparison of the historical and NCEI daily temperature minima and maxima (T_{min} and T_{max}) at the Tiksi Station

Temperature records in Tiksi started in 1934 with reported measurements at 00Z, 06Z, 12Z, 18Z and 21Z. Additional reported measurements were added at 03Z, 09Z, and 15Z from 1965. Daily minima and maxima temperatures were separately recorded throughout the measurement period with six's thermometers that are designed to record highest/lowest temperature until reset (after each 24 hour reporting period). Figure 2 shows comparison of AARI and GHCND for daily T_{min} and T_{max}.

Despite the apparent visual scatter, daily values are identical (TAARI – TGHCND = 0) for 95.76% and 95.96% of the time for T_{min} and T_{max} respectively. Preliminary analysis suggests that the small percentage of time (~ 4%), when sometimes large discrepancies occurred, is when the GHCND data set substituted a minimum and maximum temperature value from 3 hourly measurements; these have been shown to have exceedingly poor correspondence with actual daily minimum and maximum temperatures. Based on these results it was determined that the GHCND data are reliable for determining multi-decadal temperature trends and extremes and are used in the following sections.

4. Arctic seasonality

Figure 3 shows monthly average temperatures at Tiksi from 1936 to 2014 from GHCND data illustrating how monthly temperatures at this high latitude (71.596°N) site naturally cluster into a warm season, a cold season and 2 shorter transition seasons. Based on this clustering the Tiksi seasons are partitioned as 'warm' defined as June-July-August-September (JJAS), 'cold' defined as November-December-January-February-March-April (NDJFMA), 'cold-to-warm' transition as May (M) and 'warm-to-cold' transition as October (O).

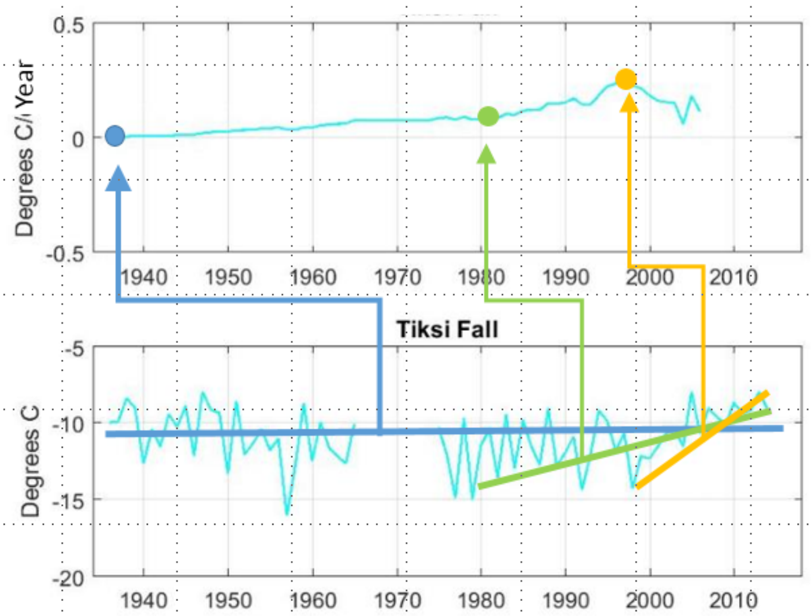


Fig. 4 Illustration of how trends 'accumulate' as the start time over which the trend is calculated varies. Note: Trend calculation stops 10 years before end of record which in this example is 2004-2014.

5. Tiksi accumulating temperature trends

In Fig. 5 accumulating trends and monthly averages are shown for both JJA-DJF and JJAS- NDJFMA seasons. Accumulating trends (°C/year) are a function of the length of the record over which the trend is calculated. Figure 4 illustrates how accumulating trends are calculated; the trend °C/decade for a start time of 1940 to 2014 (blue line in lower figure) is near 0°C/year. The trend in °C/decade for a start time of 1980 to 2014 is 0.125°C/decade, the trend for a start time of 1998 to 2014 is 0.27 0°C/year. Therefore the top panels in Fig. 5 shows the how the trend changes as data is utilized from further and further back in the record; this is an alternative to straight line regressions through different sections of a time-series which is a more standard practice. Figure 5 indicates that the rate of warming is small when calculated from the beginning of the record; this is largely due to the fact the 1940s were a decade of notable Arctic warming, a phenomena that is still poorly understood (Yamanouchi 2011). It is also noted that for the Arctic cold season, the sign as well as the magnitude of the trend can change depending on whether or not DJF or ONDMFM is used to subset the data. This is especially true for trends calculated with start dates in the 1970s and later. For the Arctic warm season JJA/JJAS, it is not unexpected that there are

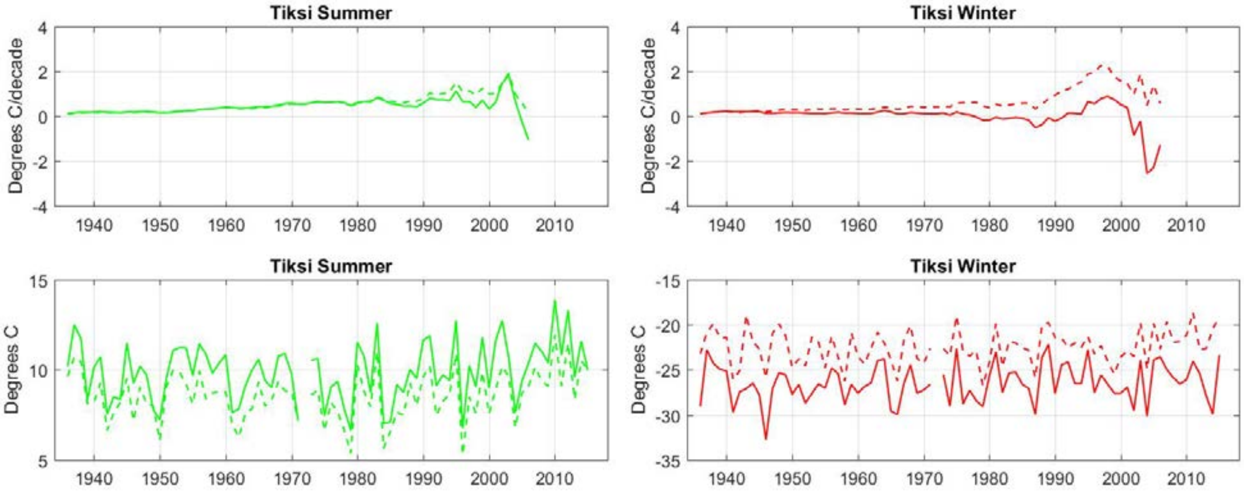


Fig. 5 The accumulating trend (top panels) and the monthly mean temperatures (bottom panels) for Tiksi summer/warm season (left) and Tiksi winter/cold season (right). Solid lines are for summer (JJA) and winter (NDJ) periods and dashed lines are for warm (JJAS) and cold (ONDJFM) periods.

only small changes in the trends as the Arctic is a state of melt that stabilizes surface air temperature.

6. Tiksi extreme temperature events

The occurrence of temperature events exceeding the 95th and 99th percentiles was assessed. For the 95th percentile events and between the 1960s and the 2000s (last full decade) there was a fairly monotonic increase from 65 to 98 events/decade. However, it should be noted that in the 1940s and 1950s there were 115 and 90 extreme warm events respectively at the Tiksi station.

7. Conclusions

This article calls attention to the long-term detailed Arctic station data that is available through IASOA which is useful for model assessment and improvement, especially for the recent decades when the station meteorological data is accompanied with intensive measurements of process variables such as surface energy budget terms and clouds. It is also demonstrated that trend analysis should be based on periods defined by the latitude dependent seasonal forcing of the sun; otherwise true trends can be obscured and or misinterpreted. Finally, it is concluded that Arctic change must be assessed in the context of longer time records covering mid-century warming to fully understand the current processes and significance of what is currently considered to be the “new Arctic” system.

References

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