Using Satellites to Measure Temperature Trends on the Greenland Ice Sheet

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Introduction

According to the National Snow and Ice Data Center the Greenland Ice Sheet is about 1.7 million square kilometers in size, covering most of Greenland. Both the Greenland Ice Sheet and the Antarctic ice sheet combined contain 99% of Earth's freshwater. Between 1979 and 2006 the summer melt on the Greenland ice sheet increased by 30%. The loss of the ice sheet has continued to increase in the following years.

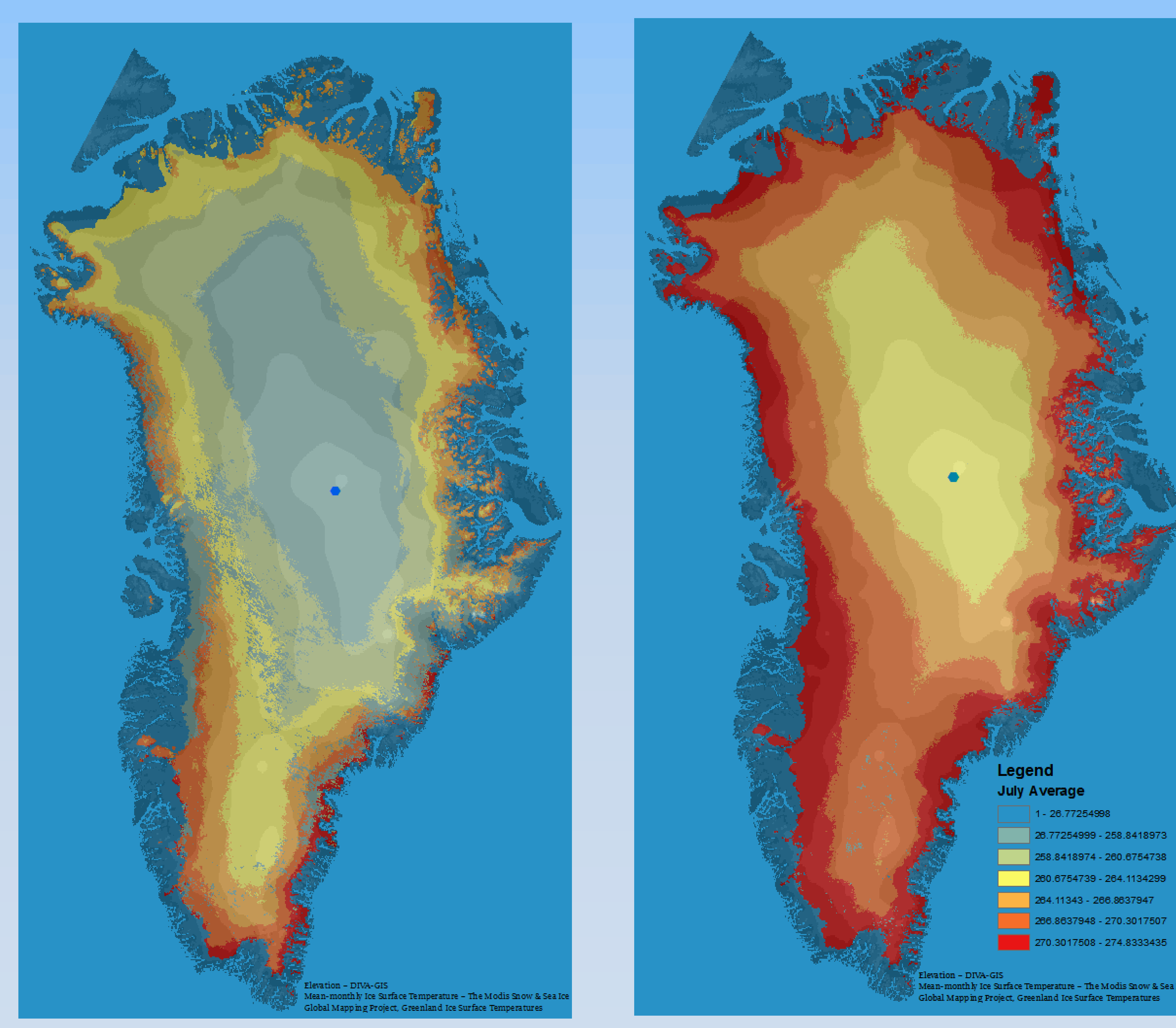
Monitoring Greenland's surface temperature is becoming increasingly important due to the changes in atmospheric and oceanic temperatures. Both MODIS (Moderate Resolution Imaging Spectroradiometer) Land surface temperature and AIRS (Atmospheric Infrared Sounder) aboard the NASA Aqua satellite have been taking infrared observations since September 2002. This paper will assess the temperature trends in the reanalysis of weather observations.

The time span of the study is from January 2003 to July of 2014 with emphasis on both January and July surface temperatures. ERA Interim data was compiled for the first of each month. MODIS Snow and Sea Ice Data came in monthly collections with daily readings and then monthly means.

MODIS Sea and Ice Surface Temperatures

MOD/MYD29 was used to produce the IST products. "The image gallery below shows the mean-monthly ice surface temperature (IST) of the Greenland Ice Sheet (left image), and the number of days of data available that month for each grid cell (right image). The dataset has been updated recently to provide ISTs and melt maps at 1.5-km resolution. Some additional manual cloud screening has also been done, beyond the cloud screening that was done in the previous dataset which was provided at 6.25-km resolution and is described in Hall et al. (2012 and 2013)." [2]

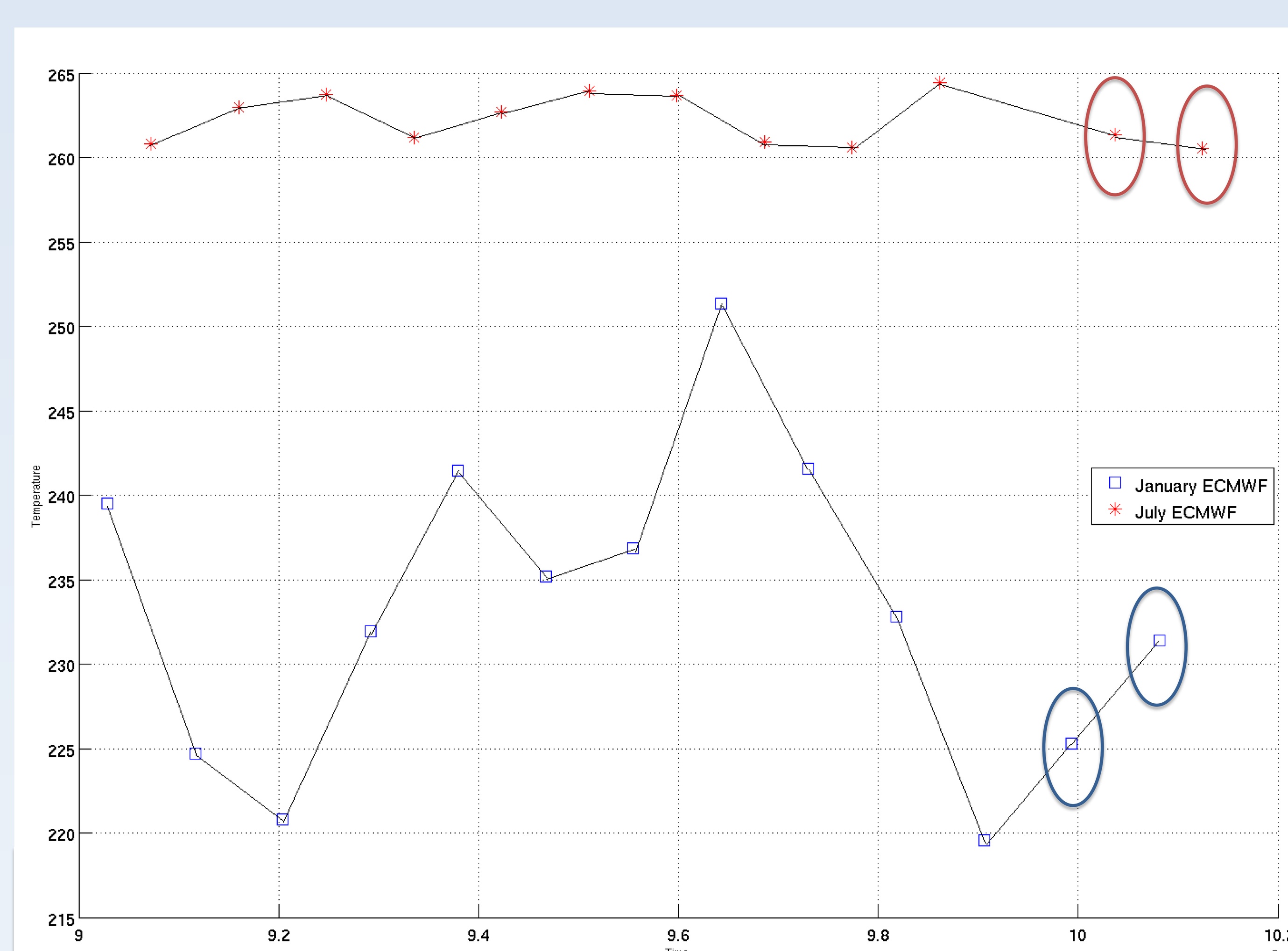
Each GeoTiff file was imported into ArcGIS and then mapped using classified temperature values. January and July files were separately compiled and averaged using an equal weight system. The weighted collections were classified using the same temperature scales as the mean-monthly ice surface temperature map.



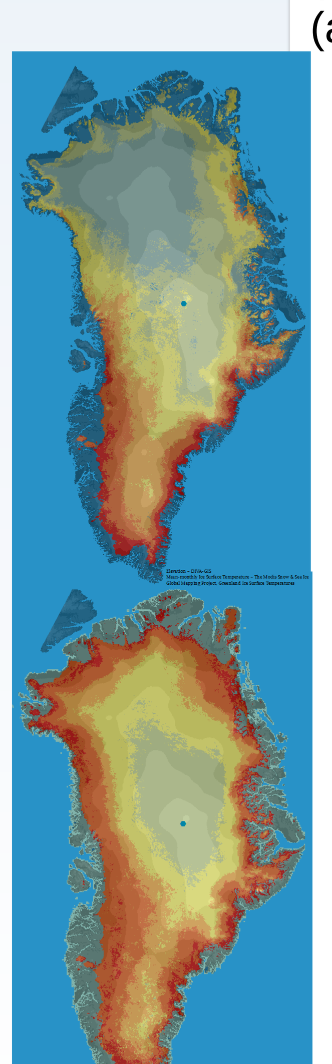
January average surface temperature between 2003 to 2014 (left) and July average surface temperature between 2003 to 2014 (right)

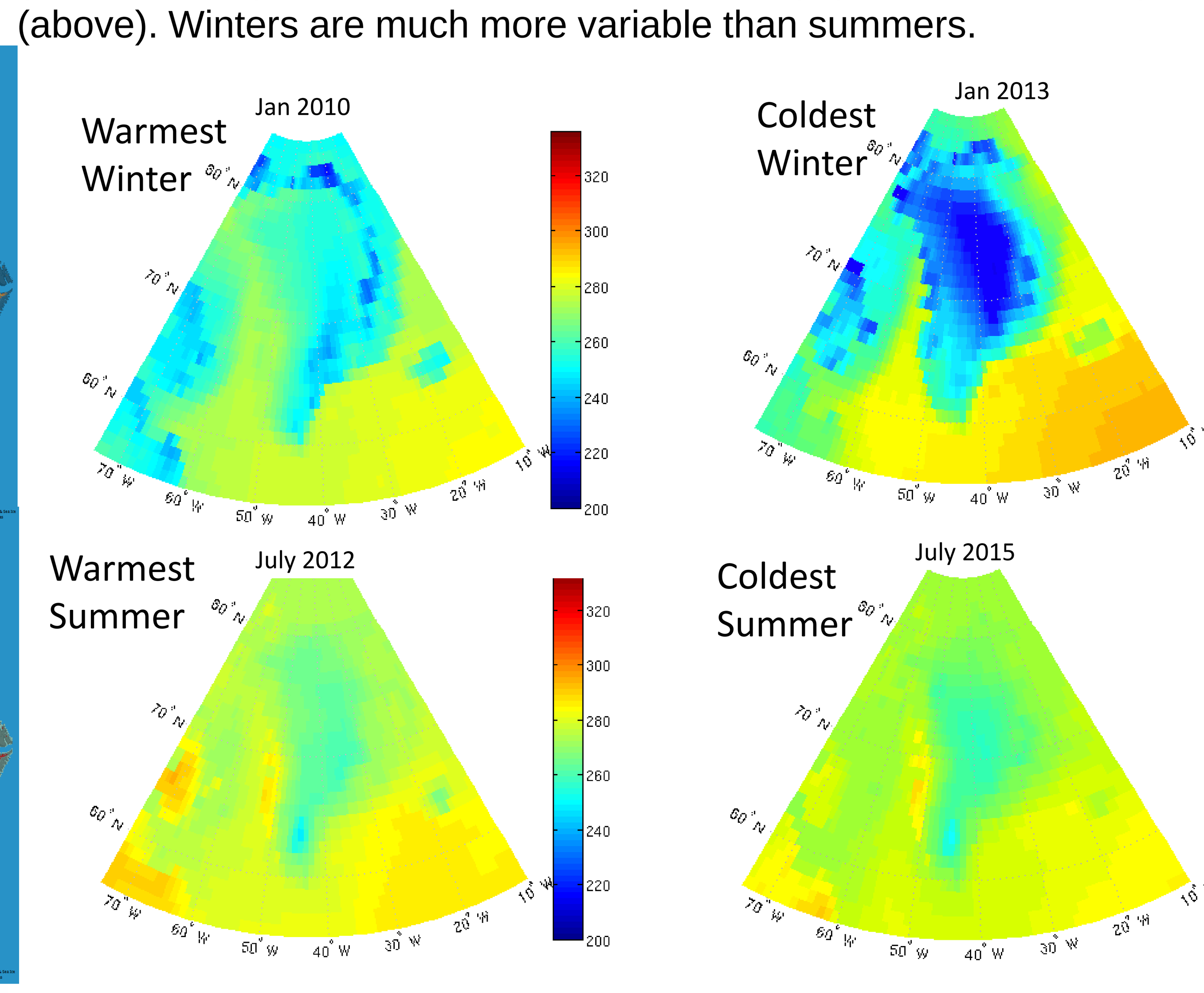
ECMWF – ERA Interim

The European Center for Medium Ranged Weather Forecasting has a data set of compiled temperature collections spanning from the late 1970s to present. One of the products produced is the Interim ECWMF Reanalysis, which is what was used for this project. "The data assimilation system used to produce ERA-Interim is based on a 2006 release of the IFS (Cy31r2). The system includes a 4-dimensional variational analysis (4D-Var) with a 12-hour analysis window. The spatial resolution of the data set is approximately 80 km (T255 spectral) on 60 vertical levels from the surface up to 0.1 hPa."[1]



ERA – Interim land surface temperature (Kelvin) for January and July (2003 to 2015) at the Greenland Summit Camp (72.58°N,38.46°W) (above). Winters are much more variable than summers.

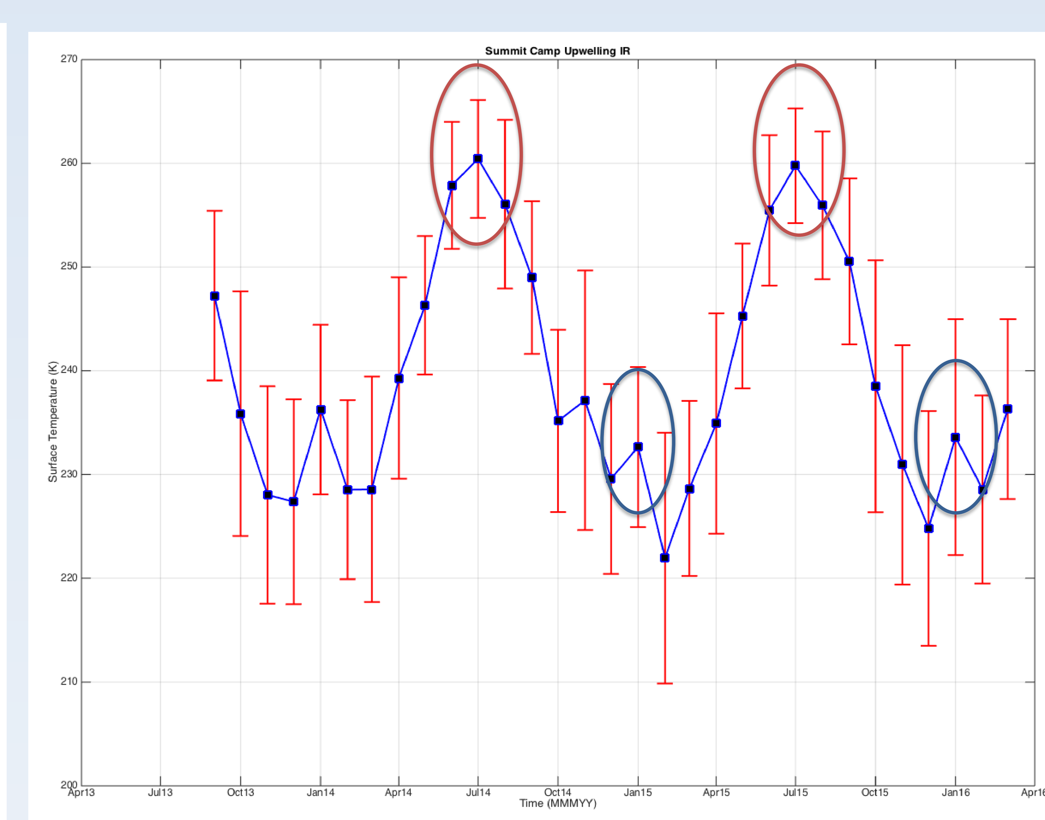




Greenland Summit Camp

"Summit Station began its life at the summit of the Greenland Ice Sheet (72°N, 38°W, 3200 m.a.s.l.), as "Summit camp", the base camp for the drilling of the GISP2 ice core in 1989. Since then, the station has hosted both summer campaign science, and, since 1997, year-round monitoring observations of cryospheric processes, both chemical and physical." - www.geosummit.org

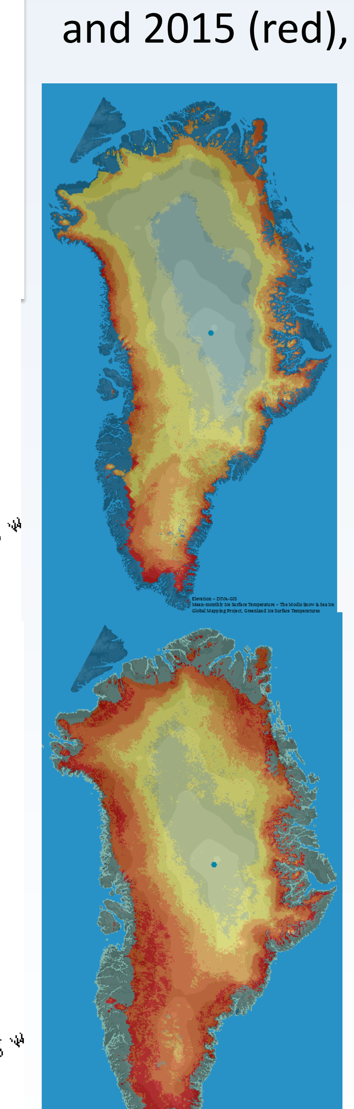
Image credit: http://nsidc.org/greenland-today/ Greenland reference map



NOAA Summit Camp Tower observations of upwelling IR flux converted to skin temperature. Error bars are the standard deviation of temperatures over each month. The colored ovals indicate corresponding temperatures for July 2014 and 2015 (red), and January (blue).

Conclusions

- Both the ECMWF ERA Interim data and the MODIS data show that there is higher temperature variability in the winter months compared to the summer months. The standard deviation of the January ERA Interim data was 9.2K, whereas July had a standard deviation of 1.5K.
- Within this 13 year dataset, the summer months show no trend within the inter-annual variability. The lower variability makes trend detection in summer possible with the shorter record.
- The higher variability in winter requires a longer record to detect a trend. There is a 33K difference between 2010 and 2013!



Sources: National Snow and Ice Data Center Quick Facts, MODIS Snow and Sea Ice Global Mapping Project, Elevation – DIVA-GIS, Mean-monthly Ice Surface Temperature – The Modis Snow & Sea Ice Global Mapping Project[2], Greenland Ice Surface Temperatures, European Centre for Medium-Range Weather Forecasts[1], NASA, SSEC and CIMSS.

Reference:
Hall, D. K., Comiso, J. C., DiGirolamo, N. E., Shuman, C. A., Key, J. R., & Koenig, L. S. (2012). A satellite-derived climate-quality data record of the clear-sky surface temperature of the Greenland ice sheet. *Journal of Climate*, 25(14), 4785-4798.