Estimating Firn Emissivity, from 1994 to1998, at the Ski Hi Automatic Weather Station on the West Antarctic Ice Sheet Using Passive Microwave Data

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ABSTRACT

Firn is the compacted snow layer that has remained at or near the surface of an ice sheet for longer than one season but has not yet compressed into glacial ice. Knowledge of firn surface temperature trends across the Antarctic Ice Sheet is useful for documenting and quantifying change and for providing a temporal and spatial context for Antarctic research performed during the upcoming International Polar Year (IPY). The spatial and temporal variability of firn emissivity and the factors that control it are not currently well known although satellite passive microwave radiometer data has been proven to be useful to obtain reasonable surface temperature trend estimates across limited temporal and spatial gaps in AWS coverage. Over the last decade, techniques using passive microwave data have been pioneered by a number of investigators; including Jezek et al., (1993) and. Shuman et al., (1995).

In collaboration with Dr. Christopher Shuman, at NASA Goddard Space Flight Center's Cryospheric Sciences Branch, the 2005-2006 Polar Science Research Team is comparing archived surface temperature data from an Automatic Weather Station (AWS) on the West Antarctic Ice Sheet with brightness temperature data collected by the Special Sensor Microwave Imager (SSM/I) aboard the Defense Meteorology Satellite Program (DMSP) polar orbiting meteorology satellite series. The ratio of passive microwave brightness temperature and AWS in-situ near surface temperature provides the firn emissivity estimate necessary to extrapolate surface temperature trends across temporal and spatial gaps in AWS coverage. This relationship is generally known as the 'Rayleigh-Jeans Approximation' (Hall and Martinec 1985)

As 'ground truth' data for our study, AWS temperatures at 3 hourly intervals for the "Ski Hi" AWS site (75º South Latitude, 71 º West Longitude) in West Antarctica were obtained via internet file transfer from the AWS Project data archive at the Space Science and Engineering Center (SSEC) at the University of Wisconsin in Madison.

The passive microwave time series of daily DMSP SSM/I brightness temperatures, geographically and temporally overlapping the Ski Hi site were obtained via Internet ftp file transfer from the National Snow and Ice Data Center (NSIDC) at the University of Colorado in Boulder. These 25x25 km remote sensing data were tabulated in a Microsoft EXCEL spread sheet to derive daily average surface temperatures at Ski Hi AWS location. The daily ratio of the SSM/I brightness temperature to the AWS surface temperature provided an emissivity trend from which to extrapolate surface temperatures The Ski Hi AWS operated from late February 1994 until late November 1998. The team will develop mathematical/statistical techniques to robustly estimate the surface emissivity trend over this time period, and use it to obtain estimates of surface temperature during data gaps in the AWS archive longer than one day. This work is the first step to deriving a surface temperature trend across the Antarctic ice sheet from 1987 through the present. Additional efforts may include assessing the previous passive microwave sensor (SMMR) that operated from 1978 to 1987 and also temperature retrievals from IR sensors such as AVHRR and MODIS.

I. INTRODUCTION

Research activities planned for the upcoming International Polar Year (IPY) has revealed a lack of basic historical data on Surface Temperatures across most of the Antarctic Ice Sheet. In collaboration with Dr. Christopher Shuman of NASA Goddard Space Flight Center, the team examined archived records of Ski-Hi Automatic Weather Station (AWS) and Special Sensor Microwave/Imager (SSM/I) data to determine surface temperatures over the southern continent. The better part of this work will involve elimination of cloud contaminated data and compilation of the highest possible spatial and temporal resolution record of the surface temperature which can be compared to data to be collected during IPY.

The team will also attempt to create a database of the average Antarctic surface temperature over time to reveal seasonal and long-term changes of the South Polar climate.

II. BACKGROUND INFORMATION

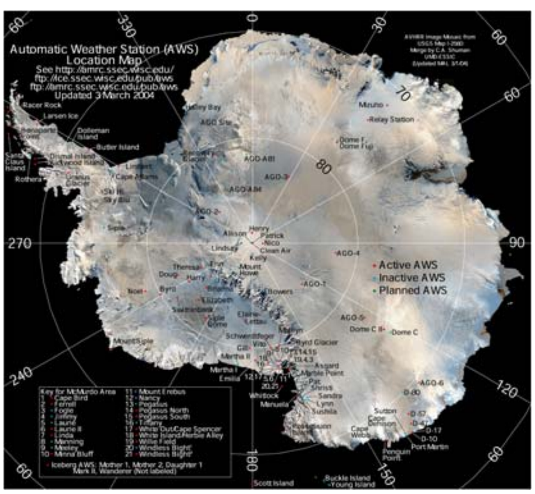
Scientists have used synoptic passive microwave sensors, such as the Special Sensor Microwave/Imager (SSM/I) and infrared sensors, such as the Advanced Very High Resolution Radiometer (AVHRR), to estimate surface temperature across the Polar Regions. Emissivity estimates have been made by combining these two types of sensors. The ability of these satellites to monitor remote locations is well established; over the polar ice sheets, satellites are rapidly becoming a primary research tool. However, a number of factors have so far effectively limited the accuracy of temperature estimates using satellite observations in the Polar Regions.

Passive Microwave brightness temperature in dry firn, the compacted snow layer that has remained at or near the surface of an ice sheet for longer than one season, is primarily controlled by the physical temperature of the firn and the radioactive scattering from the ice grains.

The National Science Foundation’s Office of Polar Programs funds the placement of automatic weather station (AWS) units in remote areas in Antarctica in support of meteorological research, applications and operations. The basic AWS units measure air temperature, wind speed and direction at a nominal height of 3 meters above the surface. Air pressure is measured at the height of the electronics' enclosure. Some units measure relative humidity at 3 meters above the surface and the air temperature difference between .5 and 3 meters above the surface at the time of installation. The data are collected by the ARGOS Data Collection System (DCS) on board the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites.

The AWS units are located in arrays for specific proposals and at other sites for operational purposes. Any one AWS may support several experiments and all support operational meteorological services - especially support for weather forecasts for aircraft flights.

The Ski Hi AWS has been collecting data from February 1994 - November 1998, when it was then replaced by Sky Blue. The Sky Blue AWS was placed approximately 0.5 miles from where the Ski Hi AWS was located.



Special Sensor Microwave/ Imager (SSM/I) data has been provided by Dr. Christopher Shuman.

The Special Sensor Microwave Imager (SSM/I) is a passive microwave radiometer flown aboard Defense Meteorological Satellite Program (DMSP) satellites The SSM/I rotates continuously about an axis parallel to the local spacecraft vertical and measures the upwelling scene brightness temperatures. The absolute brightness temperature of the scene incident upon the antenna is received and spatially filtered by the antenna to produce an effective input signal or antenna temperature at the input of the feedhorn antenna. The (SSM/I) temperatures coupled with the AWS data can be used to determine the emissivity of an area.

III. METHODOLOGY

We examined microwave brightness, near-surface snow, and atmospheric temperatures. This data was collected and graphed to view the temperature change of Antarctica from February 1994 to December 1994. T

IV. RESULTS

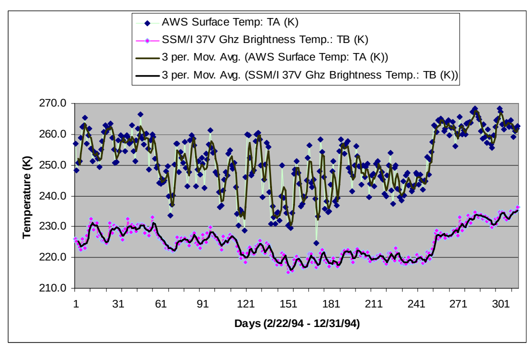


Figure 3.1 AWS Temperature vs. SSMI/ Temperature

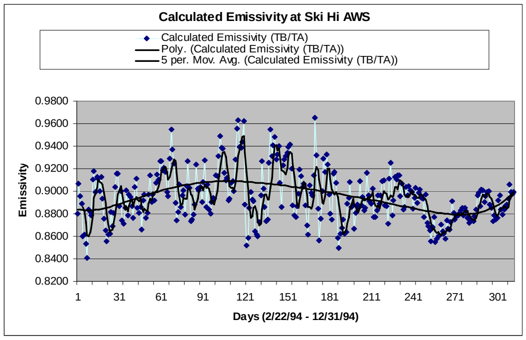


Figure 3.2 Emissivity Graph

V. CONCLUSIONS

With this data the researchers determined the relationship between the amount of radiation emitted from the snow and the actual temperature measured at a few sites where automatic weather stations have been placed. The emissivity of the snow is the parameter that relates measured surface temperatures to emitted radiation brightness of the surface ice.

The graphs show calculations of emissivity for the Ski Hi AWS site. Snow emissivity values over 30 years near Ski Hi allowing surface temperatures miles away from the Ski Hi AWS to be determined for the first time.

VI. FUTURE WORK

There has been data collected from the Ski Hi AWS from February 22, 1994-1998. Ski Hi AWS was replaced by the Ski Blue AWS about 0.5 miles from the original Ski Hi site. The researchers calculated the emissivity of the Antarctica region from February 22, 1994 to December 31, 1994.

The remaining data can now be used to determine emissivity trends at this locale from January 1, 1995 to June 30, 2001.

Emissivity trends can be used to extrapolate the surface or brightness temperatures at the AWS site, and in surrounding regions, between the wide spatial gaps in AWS coverage or any temporal gaps in the coverage provided by either data set. Performing the same analysis for every AWS site on the Antarctic continent will ultimately provide a complete history of surface temperature over the entire continent since 1978. The result will be a 28 year record for the entire continent with values associated with spatial coverage in a grid of 25 km square cells from which an animation can be created to view surface temperature trends which can be compared to data collected in the future, particularly during the upcoming IPY.

To create an animation showing the Surface temperature of the Antarctic continent the researcher would have obtain each measurement in increments of 25km pixel by 25km pixel of Antarctica. Knowing that the approximate size of Antarctica is 14,000,000 sq. km the researcher would have to divide 14,000,000 sq. km by 625 sq. km giving an overall total measurement of 22400 sq. km pixels. By doing so each frame will be put together to create the overall animation of the surface temperature.

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