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# In situ and satellite surface temperature records in Antarctica

Christopher A. Shuman,[1,2] Josefino C. Comiso[2]
[1]*Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20742-2465, U.S.A.*
[2]*Oceans and Ice Branch, Laboratory for Hydrospheric Processes, NASA Goddard Space Flight Center, Code 971, Greenbelt, MD 20771, U.S.A.*

ABSTRACT. Air-temperature records ($T_A$) during 1992 from five inland Antarctic automatic weather station (AWS) sites were compared with the best available infrared temperatures ($T_{IR}$) from the Advanced Very High Resolution Radiometer (AVHRR) as well as calibrated passive-microwave temperatures ($T_C$) from the Special Sensor Microwave/Imager (SSM/I). Daily and monthly average $T_A$, $T_{IR}$, and $T_C$ data indicate that each approach captures generally similar trends at each site but each approach also has limitations. AWS $T_A$ data are considered the most accurate but represent spatially restricted areas and may have long gaps due to sensor or transmission problems. AVHRR $T_{IR}$ data have daily variability similar to the $T_A$ record but have numerous small gaps due to cloud cover or observation interruptions. An offset between $T_A$ and $T_{IR}$ (>4 K) at the South Pole site was identified that may be due to the inclusion of data with large satellite scan angles necessary to cover this area. SSM/I $T_C$ data have the most continuity but exhibit calibration problems, a significantly damped daily response and do not cover all of Antarctica. Individual daily differences between $T_A$ and $T_{IR}$ as well as $T_A$ and $T_C$ can exceed 17 K, but all sites have mean daily differences of about 1 K or better, after compensating for the offset at South Pole, and standard deviations of <6 K. Monthly temperature differences are typically 5 K or better, with standard deviations generally <3 K. And finally, using the available data, the 1992 average temperature differences are <1 K.

## INTRODUCTION

Detection of climate change involves determining a multi-year baseline for a climate parameter and then detecting variations that exceed its observed range over the baseline period. Increasing temperatures, possibly linked to global climate warming, have been detected at sites on the Antarctic Peninsula (Jacka and Budd, 1991; King, 1994; Vaughan and Doake, 1996). Further inland, at specific automatic weather stations (AWSs), data on near-surface temperature ($T_A$) are beginning to define a climate baseline (Shuman and Stearns, 2001). However, these data have significant gaps and may not be representative of broader regional or continental-scale patterns. Temperature fields derived from satellite infrared (Comiso, 2000) or passive-microwave sensors can provide a much more complete characterization of spatial and temporal variations in Antarctic temperature. Currently, the only spatially detailed record of surface temperature across Antarctica is provided by Advanced Very High Resolution Radiometer (AVHRR) infrared channels ($T_{IR}$), but they must be carefully processed to remove the effects of clouds (Comiso, 2000). Passive-microwave data from the 37 GHz channel of the Special Sensor Microwave/Imager (SSM/I) are not influenced by cloud cover and can be calibrated ($T_C$) at specific AWS locations (Shuman and others, 1995) or by complex radiative transfer models (Fung and Chen, 1981; Comiso and others, 1982), but cannot yet be broadly extrapolated in space and time because of still poorly understood spatial variations in the emissivity of the surface. Time series of these satellite data, if they could be used consistently, would provide the temperature data needed to identify regional and continental-scale climate change across Antarctica. This study, using recently published temperature data, analyzes in situ and satellite temperature information, and documents the advantages and limitations of each approach. The intent of this study is to use the AWS data to gain insight into the accuracy of the surface temperatures retrieved from satellite infrared and microwave sources and establish confidence limits on these data.

*Table 1. Site data for inland Antarctic AWS temperature records*

| *AWS name* | *Location* | *Elevation* m | *Grid* | *Start* | *Stop* |
|---|---|---|---|---|---|
| Byrd | 80.01° S, 119.40° W | 1530 | 121 196 | Feb. 1980 | |
| Clean Air | 90.00° S, 120.00° W | 2835 | | Jan. 1986 | |
| Lettau | 82.52° S, 174.45° W | 55 | 155 206 | Jan. 1986 | |
| Lynn | 74.21° S, 160.41° E | 1772 | 182 239 | Jan. 1988 | Jan. 1998 |
| Siple | 75.90° S, 84.00° W | 1054 | 97 168 | Jan. 1982 | Apr. 1992 |

*Notes*: This analysis is based on available 3 hourly average data taken from the University of Wisconsin server in March 1999. The grid column contains the coordinates of the 25 km SSM/I pixel covering the AWS location. There is no SSM/I coverage at the South Pole, where AWS Clean Air is located.

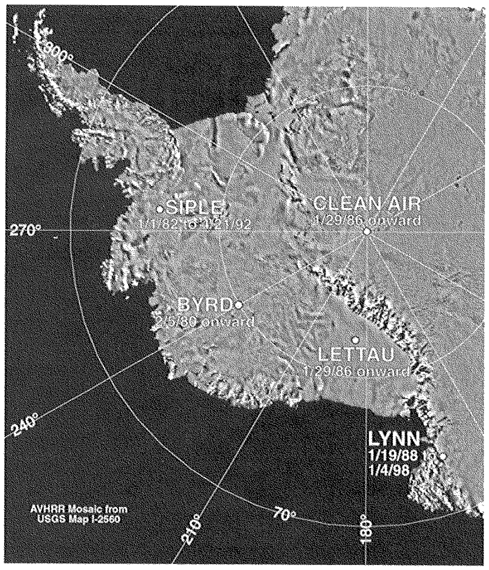


*Fig. 1. The locations and dates of operation of the five inland Antarctic AWSs used in this study. Dates are mm/dd/yy.*

This project used three types of temperature data from 1992 that were spatially and temporally co-registered:

(1) daily-average $T_A$ records from five AWSs in Antarctica operated by the University of Wisconsin (see Fig. 1; Table 1);

(2) daily-average AVHRR $T_{IR}$ data compiled and processed as described in Comiso (2000); and

(3) daily-average $T_C$ data derived from the SSM/I datasets compiled by the U.S. National Snow and Ice Data Center (NSIDC) and calibrated as described in Shuman and Stearns (2001).

The three measurements are not exactly for the same physical parameter since the AWS measures near-surface air temperature (~2 m), the infrared sensor measures skin-depth temperature, and the passive-microwave sensor measures the average temperature of the upper surface layer. This comparative analysis will help establish how the three datasets can be used in conjunction to study the variations of an important climate parameter through time.

## CONCLUSIONS

The significance of this study is that it enabled an improved understanding of three currently available Antarctic surface temperature datasets. At present, the thermal infrared data provide the only spatially detailed temperature distributions in Antarctica, but contain data gaps due to intermittent cloud cover. The passive-microwave data have the potential to provide spatially detailed, continuous and gap-free temperature distributions. However, more research is needed to correctly calibrate these data for regional changes in the radiative characteristics of the snow cover. The AWS data are the most accurate, but are the most difficult to use for large-scale scientific research because of their limited spatial coverage and gaps in the temporal series due to occasional instrument malfunction. The AWS data, however, provide the means to determine the value and the significance of both the infrared and the passive-microwave datasets.

These different near-surface temperature datasets are quite complementary and should enable the development of improved temperature baselines for sites in Antarctica. Although $T_A$ data may be discontinuous, $T_{IR}$ data can accurately fill most gaps at specific sites. Any gaps due to cloud cover in the $T_{IR}$ record can then be filled with extrapolated $T_C$ values, and these values also provide a reliability check on the spatially more extensive $T_{IR}$ data. Processing requirements are significant, especially for $T_{IR}$, however, and detecting and removing cloud impacts and accurately calibrating these data remains a challenge. Overall, this study has demonstrated that the satellite data compare quite well in most cases, assuming that these AWS $T_A$ data reliably represent these locations. The limited comparisons presented here certainly justify continued efforts with additional years of data at these and other sites across the Antarctic continent. Although individual day differences between in situ and satellite temperatures can be quite large, the average errors are relatively small and appear well constrained. For the thermal infrared dataset, the standard products are the monthly averages that appear to provide a realistic representation of temperature distributions around the continent. Some of the discrepancies between the methods studied here are probably due to the differing spatial and temporal resolutions of the three different methods. We also have assumed that the AWS hardware for measuring temperature is always in perfect condition, which is not guaranteed in such an adverse environment, and there may be some instances when the AWS actually provides erroneous results despite quality-control procedures. For optimal accuracy, especially at high temporal resolution, a combination of the three methods may be necessary to determine an accurate climate baseline and then evaluate potential changes that may come in the years ahead.

*Table 4. Difference statistics for all 1992 $T_{IR}$ and $T_C$ daily mean temperatures*

| | *Byrd* | *Clean Air* | *Lettau* | *Lynn* | *Siple* |
|---|---|---|---|---|---|
| Days | 323 | 305 | 313 | 342 | 328 |
| $T_{IR}$ | 245.66 | 226.38 | 246.97 | 238.85 | 248.12 |
| $T_C$ | 247.02 | | 246.64 | 237.64 | 247.61 |
| $T_{IR} - T_C$ | −1.36 | | 0.33 | 1.21 | 0.52 |

*Notes:* This analysis is based on all days where there was both an AVHRR infrared temperature ($T_{IR}$) and a calibrated SSM/I temperature ($T_C$). There are no $T_C$ data for AWS Clean Air due to the hole in SSM/I coverage at the South Pole.