# Antarctic Surface Temperature Comparison Study On Satellite Approximations and Land-Based Measurements

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## Abstract

Global warming studies have been modified to account for the apparent cooling of the Antarctic interior as reported by the AVHRR satellite measurements. A set of six Automated Geophysical Observatories (AGO) have operated on the Antarctic continent since 1993; although their primary instrumentation has focused on ionospheric and magnetospheric phenomena, they also have recorded and reported meteorological conditions (with significant gaps).

Due to the recent installation of an averaging filter to remove arbitrary data, a trend analysis has been conducted and is included in this study. It agrees with previous statements that the Antarctic interior is experiencing no major temperature deviations. However, it does suggest that satellite readings tend to be erroneous during all seasons except the Antarctic winter.

# 1 Introduction

Over the past several decades meteorological science has evolved significantly both in the observations of global weather patterns and in the ability to observe the complex changes that have manifested since as early as the turn of the previous millennium. Until recently, however, weather data could only be observed in-depth in heavily populated regions on land.

With the relatively recent use of satellites and automated weather observation stations, the amount of data we have accumulated is almost overwhelming, and has lead to a great deal of controversy over the fate of the planet and its environment. Amongst the most hotly contested controversies is the accelerated warming of the polar regions of the world, in particular Antarctica.

With the combined datasets of both ground-based observations from the manned and automated stations, as well as the continuous streams of satellite data, this paper will present some of the challenges of remote sensing and encourage further investigation.

# 2 The AGO Project

## 2.1 Mission

The Automated Geophysical Observatories (AGO) project of the National Science Foundation began in 1990 to deploy six automated observatories on the Antarctic continent for the purpose of observing geological, electromagnetic, and meteorological anomalies. In particular, the observatories are used in hopes of observing the magnetosphere and ionosphere and how they react to certain phenomena [2].

Each observatory houses meteorological instruments and send collected data via satellite to various researchers. Unfortunately, due to the excessive amount of power that is dedicated to geophysical observations, the observatories often drain the batteries faster than the thermoelectric, wind, and solar generators can produce, leading to many gaps in the data collected.

## 2.2 Instruments

Each AGO observatory is equipped with J-T Thermocouples capable of observing temperatures between -100°C and 100°C at an accuracy of 0.3°C. The data are stored in a 12-bit sequence, allowing for a range between -273°C and 227°C with increments of 0.1221°C. They are also equipped with rotary wind anemometers, wind vanes and barometers. All equipment is designed to work in extremely cold conditions, though equipment housed inside of the observatory is kept warm by heaters when there is sufficient power.

The AGO stations are designed to continuously stream the data over the Iridium satellites

| Station | Uptime | Trend (°C/year) | Standard Deviation (°C) |
|---|---|---|---|
| P1 | 1997-2008 | -0.41 | 0.38 |
| P2 | 1997-2008 | 0.06 | 0.47 |
| P3 | 1997-2008 | 0.37 | 0.42 |
| P4 | 1998-2004 | 1.59 | 0.66 |
| P5 | 1998-2005 | 0.90 | 0.42 |
| P6 | 1998-2004 | -0.23 | 0.86 |
| South Pole | 1958-2008 | -0.0078 | |
| Vostok | 1958-2008 | -0.0052 | |

Table 1: Temperature Trends in Antarctica

to a designated institute, which can then decode the information and convert it into a more usable format. The stations also use Service ARGOS (provided via CLS America) in order to transmit only the weather and maintenance data. This allows for the data to be transmitted when there is insufficient power to contact the Iridium satellites, or if the Iridium service is unavailable.

### 2.3 Accrued Data

Since 1993, the AGO project has been generating weather information for six different regions in Antarctica. However, due to the lack of proper software and resources, this information was only available in its raw format until 2004. Even though it was available in spreadsheet and graphical formats, it was discovered that the weather data contained an unusually high amount of noise, a phenomenon present on all of the AGO stations.

A noise filter was developed last year which implemented an averaging algorithm to remove as much noise as possible while preserving temperature spikes and other valid phenomena. The resulting dataset is clean and accurate, allowing for proper analysis and comparison to the observed weather from the satellites and manned stations.

Due to resource constraints, the observatories are only powered by wind and solar generators which charge a battery for long-term storage. Since solar exposure is limited to certain seasons and adequate wind cannot be guaranteed, there are many gaps in the data when there was insufficient power to operate the instruments. Also, because of the extreme conditions that the observatories face, they are prone to breaking down, and the exorbitant costs for transportation prevent timely maintenance, which can cause gaps that last for months, even years.

## 3 Analysis of AGO Data

The P1 AGO station observed a downward temperature trend over the last nine years with the smallest standard deviation between the six observatories. This is not unexpected, as it

is fairly close to the South Pole station and within the cooling zone that was observed by satellite. P2 and P3 both have observed warming trends and are supposedly well within the cooling zone, contradicting the satellite observations [3], but it should be noted that their periods of operation have been only for around a decade and sporadic, especially during the Antarctic winter.

Stations P4, P5, and P6 operated up until 2005 when mechanical failures and lack of sufficient funds brought them offline indefinitely. During their periods of operation, P4 and P5 recorded high warming trends, although this is most likely due to them being online during different seasons over the years that they were functional. P6 recorded a decrease in temperature, but has the highest standard deviation and cannot be considered to be reliable at this point in time.

All of the AGO stations predominantly observed temperatures between the range of 20°C and 60°C, with a record low of 79°C in 1999 at P1 and a record high of 9°C in 2002 at P6. The most complete year in terms of data collected at the stations was 1999 with five out of six stations operational throughout most of the year except the Antarctic winter. 2003 had the least amount of data collected, with P2 and P3 operating except in the Antarctic winter and P6 operating sporadically during the Antarctic fall, completely offline in the winter, and back online in the summer. Vostok and South Pole station are from the British Antarctic Survey READER [7].

# 4 Satellite Observation

## 4.1 AVHRR Project

In October of 1978 the Advanced Very High Resolution Radiometer satellites were launched into orbit to analyze the thermal emissions of the Earth and analyze the properties of the clouds [4]. The instruments pass over both poles of the planet twice a day and are designed to approximate surface temperature based on its internal calibrations and algorithms. This data has been utilized in numerous studies of the Arctic and Antarctic, allowing considerable study in the climate changes at the respective regions.

The satellites have undergone several revisions in calibration and algorithms to compensate for anomalous factors, but the reliability and accuracy of the data has been debated. With the AGO data now available, it is possible to determine the satellite's accuracy in predicting surface temperatures in the Antarctic.

## 4.2 AVHRR Instrumentation

The AVHRR satellites currently in use as of the time this paper was written use wide spectral radiometers at multiple wavelengths. For measuring surface temperatures, the wavelength 0.58 to 0.68 micrometers is used with a field-of-view of approximately 0.3 milliradians and a resolution of 1.09 kilometers [6]. The satellites are designed to automatically

calibrate the sensors continuously throughout operation, as well as use special algorithms to further increase the accuracy of the data.

### 4.3 Observed Trends

Satellite observations have recorded a cooling trend at the Antarctic pole at approximately -0.2°C per year [1] and outerlying regions with minimal to no temperature change. The coastal regions and the ice shelves are the only parts of Antarctica that have observed a warming trend. This deviates from the common assumption that the polar regions are increasing in temperature due to global warming and agrees with previous findings [5].

## 5 Data Comparison

### 5.1 Consistency

Since 1999 was the only year where five observatories were operational for the majority of the year, it has been selected to determine how consistent the satellite data is with the actual surface temperatures observed. Due to the resolution of the satellites and the locations of the observatories, exact matches between the readings gathered from the satellite and the AGO stations was not possible. Instead the satellite samples closest to each AGO station were used in this comparison.

Another problem with comparing the datasets is the time of observation. The satellites sample the data at precisely 0200 hours and 1400 hours. The AGO stations sample data at any time possible and transmit it whenever a medium can establish a connection. This is necessary, as the stations are not guaranteed to be operational at any given time, nor are they guaranteed to connect to a satellite at any given time. The closest time sample was selected in the comparison.

The satellites and ground stations match most closely to each other during the Antarctic winter, most likely due to a lack of cloud coverage and solar activity. During all other seasons the satellite is often off in its readings by up to 20°C (see Figure 3). The variance differed depending on location and pass, as the 0200-hour samples tended to underestimate the temperature (see Figure 1) and the 1400-hour samples tended to overestimate (see Figure 2).

### 5.2 Possible Issues

The AGO stations P1, P2, and P3, in their current configuration, primarily sample temperatures near the Antarctic pole (see Figure 4). These stations experienced the highest amount of uptime and can compensate for satellite irregularities with their readings, as the satellites tend to get the most erroneous data when the AGO stations are operating.

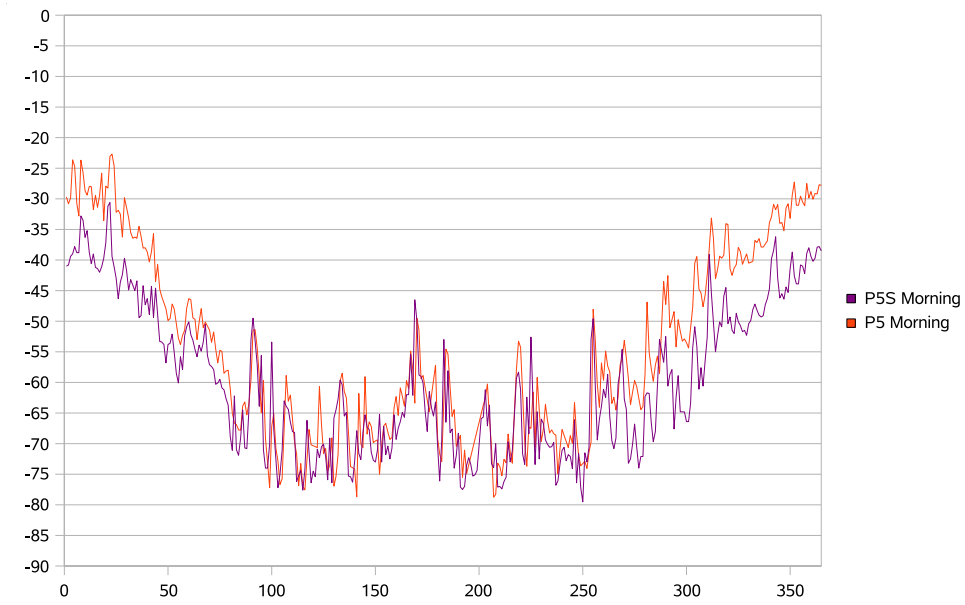


Figure 1: Satellite v. Ground Observations at 0200 Hours

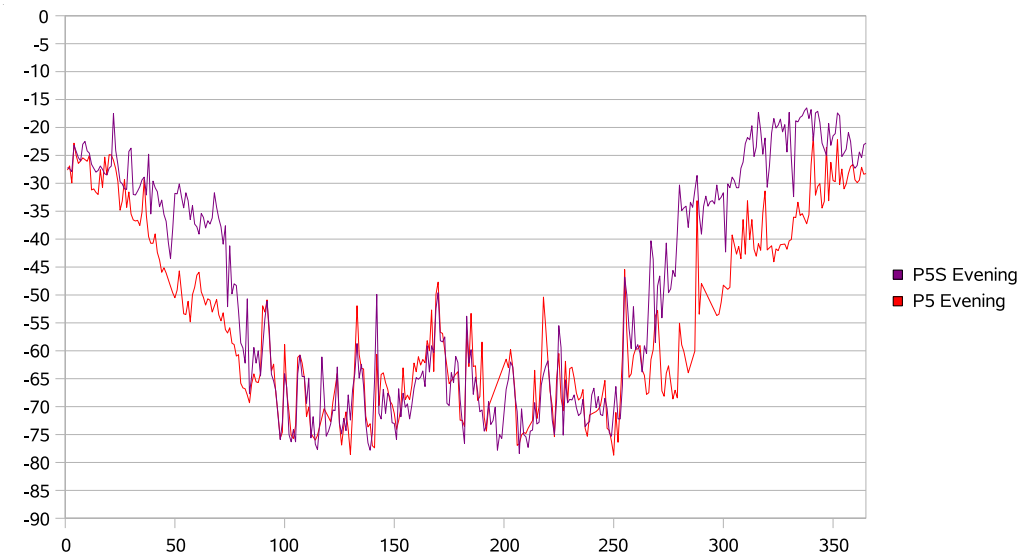


Figure 2: Satellite v. Ground Observations at 1400 Hours

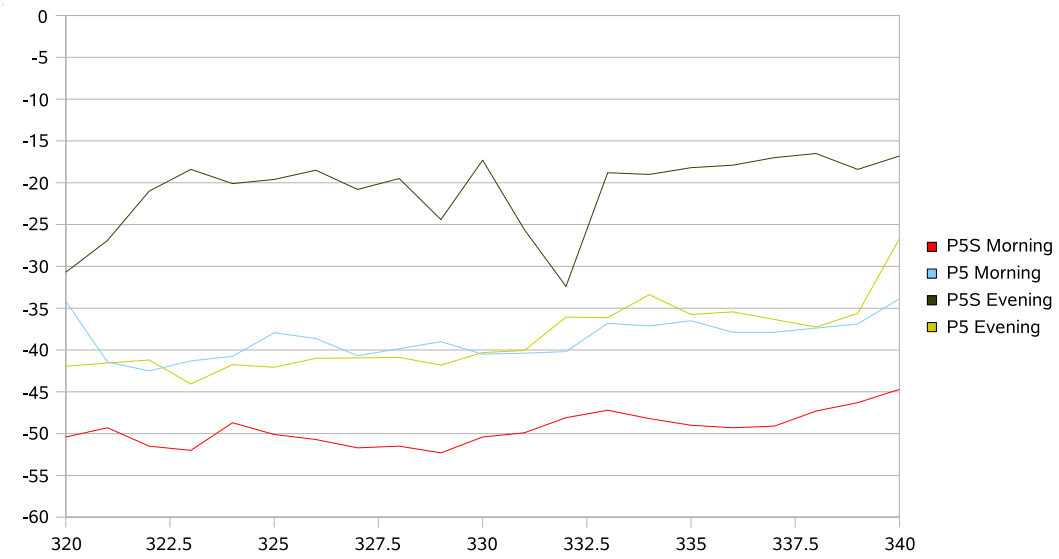


Figure 3: Extreme Variances Between Satellite and Ground

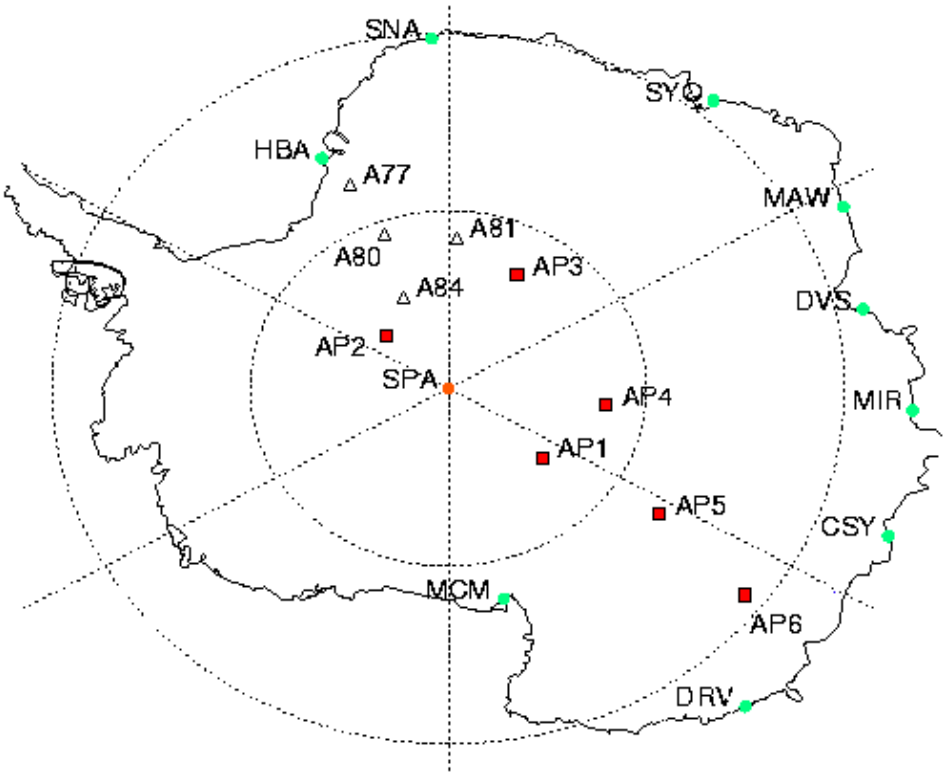


Figure 4: Locations of the AGO Stations

P5 and P6 are closer to the major coastline opposite of the Ross and Ronne ice shelves and have either broken down or functioned sporadically, making it extremely difficult to determine long-term trends. Without at least one of the two stations operating on any given year during the Antarctic fall, spring, and summer, determination of coastline accuracy for the AVHRR satellites is difficult to evaluate.

For all stations two major issues have been ongoing with no established resolution. The first of these being that the stations are highly prone to breaking down due to the extreme conditions and need to be serviced in order to accumulate an adequate amount of data for true analysis. The second issue is the lack of adequate power generation during the Antarctic winter; while the AVHRR satellites appear to be measuring temperatures acceptably well during that season, true confirmation would require all stations to be operational throughout one entire year.

It may also be prudent in the interests of confirming satellite observations to place stripped-down AGO units near or along the Ross and Ronne ice shelves to monitor the weather conditions in these crucial areas. Assuming that said units would only be equipped with meteorological instruments and the necessary power generators and transmitters, they should remain operational throughout most of the year barring physical breakdown.

# 6 Conclusion

The AGO stations have currently observed no major temperature trends in the interior of the Antarctic, although due to significant periods of downtime it is difficult to confirm these findings alone. The P1 station has observed a cooling trend, corresponding with prior findings, and has the smallest standard deviation. All other stations noticed a warming trend, but this could easily be caused by the inconsistent data and cannot be considered a contradiction of previous findings without supplemental data.

It was confirmed by the AGO stations that the satellite observations of the Antarctic continent were fairly accurate during the Antarctic winter, when there was a minimal amount of sunlight and cloud coverage to obfuscate the readings. There were significant errors in the satellite data during all other seasons, however, which may need to be addressed.

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