The spatial coherence of interannual temperature variations in the Antarctic Peninsula

John C. King
British Antarctic Survey, Natural Environment Research Council, Cambridge, UK

Josefino C. Comiso
Laboratory for Hydrospheric Processes, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

Received 31 May 2002; revised 19 July 2002; accepted 15 October 2002; published 18 January 2003.

[1] The west coast of the Antarctic Peninsula is a region of extreme interannual variability in near-surface temperatures. Recently the region has also experienced more rapid warming than any other part of the Southern Hemisphere. In this paper we use a new dataset of satellite-derived surface temperatures to define the extent of the region of extreme variability more clearly than was possible using the sparse station data. The region in which satellite surface temperatures correlate strongly with west Peninsula station temperatures is largely confined to the seas just west of the Peninsula. Correlation of Peninsula surface temperatures with those over the rest of continental Antarctica is poor confirming that the west Peninsula is in a different climate regime. Our analysis suggests that only one of five existing ice cores from the region is likely to provide a proxy climate record that is representative of the west coast. *INDEX TERMS:* 3349 Meteorology and Atmospheric Dynamics: Polar meteorology; 3309 Meteorology and Atmospheric Dynamics: Climatology (1620); 3360 Meteorology and Atmospheric Dynamics: Remote sensing; 9310 Information Related to Geographic Region: Antarctica. **Citation:** King, J. C., and J. C. Comiso, The spatial coherence of interannual temperature variations in the Antarctic Peninsula, *Geophys. Res. Lett., 30*(2), 1040, doi:10.1029/2002GL015580, 2003.

1. Introduction

[2] Surface temperature records from the west coast of the Antarctic Peninsula exhibit a much higher degree of interannual and longer period variability than those from other Antarctic coastal locations [*King*, 1994]. The west coast of the Peninsula is the most rapidly warming region of the Southern Hemisphere [*Vaughan et al.*, 2001] and it is thus of considerable interest to determine whether the high degree of variability apparent at the coastal stations is a localised phenomenon or if it is characteristic of a broader area. Correlation of station temperature records suggests that temperature variations are reasonably coherent along the west coast of the Peninsula from around 62°S to around 68°S [*King*, 1994]. However, the lack of long temperature records from the interior or east coast of the Peninsula, or for the regions further south, have made it difficult to delimit the region of high variability completely.

[3] It is also important to examine recent climate variability in the Peninsula region in the context of the longer term regional climate record. One of the best potential proxies for temperature is the stable isotope record that can be obtained from ice cores. The Antarctic Peninsula is a region of relatively high snow accumulation and thus offers the possibility of obtaining climate records with quite high temporal resolution. Unfortunately, low-lying parts of the west coast of the Peninsula experience temperatures well above freezing during the summer season which cause significant snowmelt, making the interpretation of stable isotope records problematic. Most ice cores from this region have therefore been taken from the high interior of the Peninsula or the colder east coast [*Peel et al.*, 1996]. It is clearly important to determine whether the climate variations recorded in such ice cores are likely to be related to those observed on the west coast where we have long instrumental records. In this paper we use a new dataset of satellite-derived surface temperatures to define the extent of the region of extreme variability more clearly than was possible using the sparse station data and identify sites where ice core proxy records might be representative of variations on the west coast of the Peninsula.

2. Data

[4] *Comiso* [2000] describes the construction of a dataset of monthly mean surface temperatures on a 6.25 km × 6.25 km polar stereographic grid for the Antarctic region using satellite infrared radiometer data. In this study we use data for the period 1982–2000 when temperatures were obtained from the Advanced Very High Resolution Radiometer (AVHRR) carried on National Oceanographic and Atmospheric Administration (NOAA) polar-orbiting meteorological satellites. Monthly average surface brightness temperatures were calculated from the 5 km × 3 km resolution Global Area Coverage (GAC) data from this instrument after application of the cloud-clearing techniques described in *Comiso* [2000].

[5] Monthly mean surface temperatures derived from satellite observations may differ from near-surface air temperatures measured at a climatological observatory for a number of reasons. Most importantly, the satellite-derived temperature is conditionally sampled for clear-sky conditions. During the Antarctic winter, near-surface temperatures are generally lower during clear sky conditions than during cloudy conditions so the satellite-derived monthly mean temperatures may be biased cold and may not properly reflect temperature variations associated with varying cloud cover.

[6] *Comiso* [2000] compared temperatures from this dataset with monthly mean surface air temperatures from

0094-8276/03/2002GL015580$05.00

Table 1. Correlation Coefficients, r, Mean Differences and Standard Deviation of the Differences Between Monthly Mean Air Temperatures, T_A, at Faraday and Satellite-Derived Surface Temperatures, T_S, at a Neighbouring Grid Point

Months	Cloud Amount	r	$T_S - T_A$(K)	σ (T_S-T_A) (K)
All	All	0.57	−4.71	3.33
JJA	All	0.72	−4.41	3.28
DJF	All	0.29	−3.55	1.90
All	≤3/8	0.57	−2.28	3.20
JJA	≤3/8	0.76	−0.77	3.00
DJF	≤3/8	0.22	−3.04	2.01

T_A has been calculated for all faraday synoptic observations during 1982–2000 and also just for those observations for which the reported total cloud amount was 3/8 or less. Long-term monthly means were subtracted from both the satellite and air temperature time series before calculating correlation coefficients.

a number of Antarctic stations. He concluded that the satellite-derived surface temperatures represent seasonal and interannual fluctuations well and that biases in monthly mean temperatures due to conditionally sampling clear-sky conditions are on average less than 0.5°C. The west coast of the Antarctic Peninsula is affected by cyclones moving across the Bellingshausen Sea and thus has a very cloudy climate. At the coastal station Faraday (65.25°S, 64.26°W), only 19% of three-hourly synoptic observations during the winter months (July–August) recorded 2/8 or less total cloud cover during 1982–1997, while 66% recorded 7/8 or greater. During summer (December–February), even cloudier conditions prevailed and the corresponding figures are 10% and 84% respectively. The satellite record will thus be a highly conditionally sampled record of surface temperatures in this region. However, it does appear to represent interannual variations quite accurately. Table 1 summarises the results of a comparison of Faraday monthly mean air temperatures with satellite surface temperatures from a neighbouring grid point. The correlation is reasonable during the winter months although, as expected, the satellite temperatures are biased cold. The correlation becomes poor during the summer, when interannual temperature variations are much smaller [*King*, 1994]. If the comparison is repeated using monthly mean Faraday temperatures computed only from observations when the cloud cover was 3/8 or less, the cold bias is reduced and the correlation coefficient for the winter months is slightly improved.

[7] Few data are available for checking the reliability of satellite temperatures over the high interior of the Antarctic Peninsula. Table 2 summarises the results of a comparison of satellite temperatures with those from an automatic weather station (AWS) at Siple station (75.92°S, 83.92°W, 1054 masl). AWS data are available for 1982–84 and 1988–91 [*Stearns et al.*, 1993]. The correlation of satellite and AWS temperatures is high throughout the year. In summary, we conclude that the satellite surface temperature dataset provides a reasonable representation of interannual variations in winter temperature on the west coast of the Peninsula and a good representation of temperature variations in all seasons in the interior of the Peninsula. In what follows, we restrict our attention to the winter season, when interannual temperature variations on the west coast are at their largest.

Table 2. Correlation Coefficients, r, Mean Differences and Standard Deviation of the Differences Between Monthly Mean Air Temperatures, T_A, at the Siple AWS and Satellite-Derived Surface Temperatures, T_S, at a Neighbouring Grid Point

Months	r	$T_S - T_A$(K)	σ (T_S-T_A) (K)
All	0.97	−0.49	2.00
JJA	0.90	0.37	1.63
DJF	0.82	−0.95	1.71

AWS observations are available for 1982–84 and 1988–91.

5. Discussion

[13] Analysis of a new, satellite-derived surface temperature dataset has shown that the coherent region of high interannual temperature variability is largely confined to the west coast of the Peninsula, with a southward extension through Alexander Island into southern Palmer Land and a northward extension through the South Shetland Islands. Temperatures on the eastern side of the Peninsula were found to correlate rather poorly with those on the west. This confirms that the two sides of the Peninsula are in very different climatic regimes [*Martin and Peel*, 1978]. The west coast is under the influence of relatively warm airmasses associated with synoptic-scale systems moving across the Bellingshausen Sea. The high and steep orography of the Peninsula provides an effective barrier to these airmasses, leaving climate of the east coast under the influence of cold airmasses of continental origin. On a broader scale, our results highlight the lack of correlation between temperature variations in the Peninsula with those over the rest of continental Antarctica [*Raper et al.*, 1984] for the first time in good spatial detail.

[14] Our results suggest that most ice cores obtained from the Peninsula so far will not provide records that are representative of the west coast. The exception is the record from Gomez. We hypothesise that this region - the western slopes of the southern part of Palmer Land - is influenced by the same air masses that determine the climate at stations on the west coast of the Peninsula. This hypothesis needs to be tested using high-resolution regional atmospheric models. Given the importance of producing a long proxy climate record for the west coast, obtaining further ice cores from this region should be a high priority.

[15] While the results of our study may usefully identify areas where ice core records will not be representative of Peninsula west coast conditions, a high correlation at a location on Figure 2 does not imply the inverse. The stable isotope record in an ice core is related to the surface temperature at the core site through a complex transfer function that is dependent on the local and regional meteorology and the source region for the moisture that formed the precipitation. The present study thus only offers a starting point for choosing representative ice core sites. A further limitation of the study is that it is only based on 19 years of data. It is possible that the spatial coherence of interdecadal and longer timescale temperature variations is larger than that of the predominantly interannual fluctuations studied here. In an attempt to address this question, we recreated Figure 1 after first smoothing the winter mean temperature timeseries at each point in the dataset using a 5-point binomial filter. The correlation pattern that emerges (not shown) is reassuringly similar to that seen in Figure 1. In particular, there is very little increase in the area of the region of highest correlation ($r \geq 0.75$), suggesting that our findings may hold for longer timescales.