

# **Antarctic Temperature and Sea Ice Trends over the Last Century**

**An Assessment of Antarctic Climate Data**

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High latitude regions of the Earth (the Arctic and Antarctic) have been considered as bellwethers in the detection of global climate change. According to IPCC (2001),

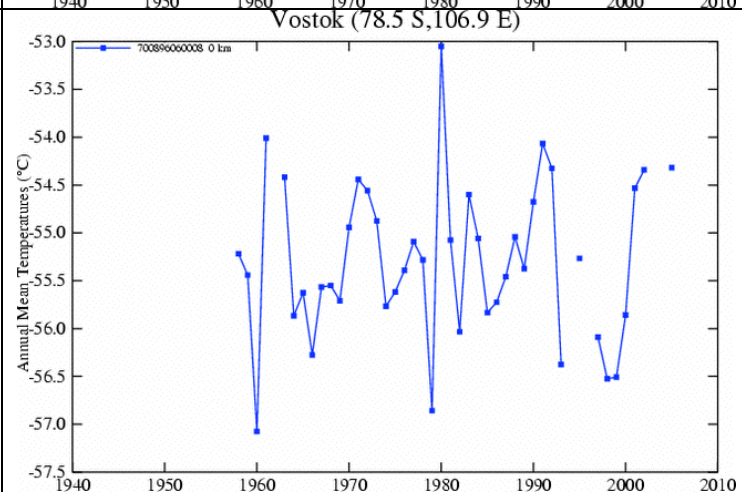
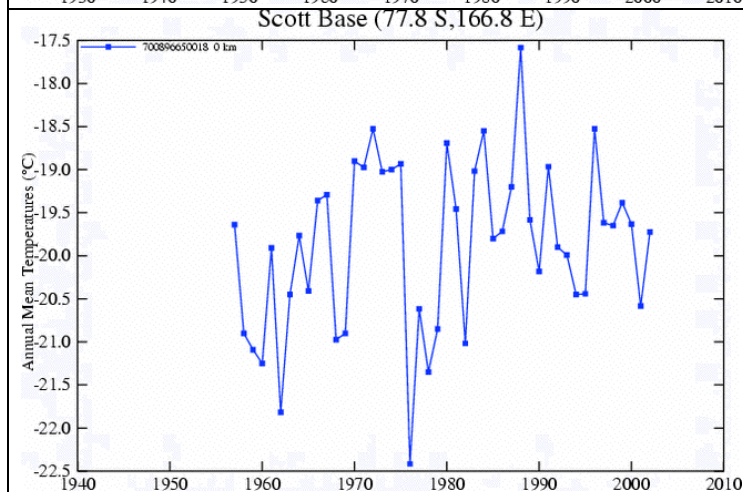
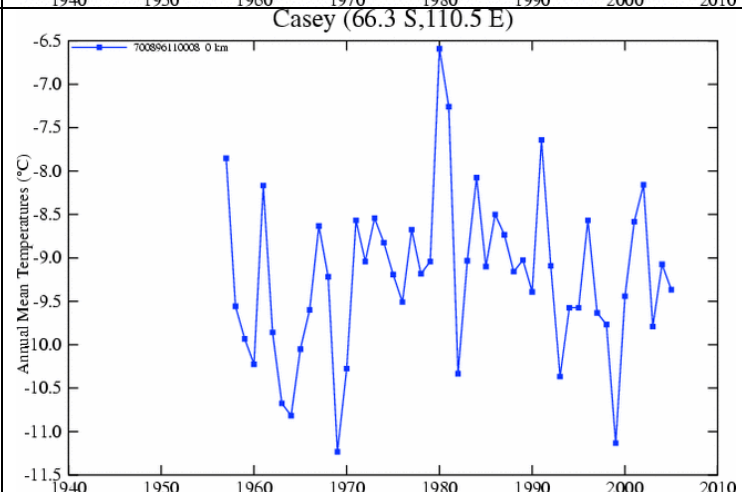
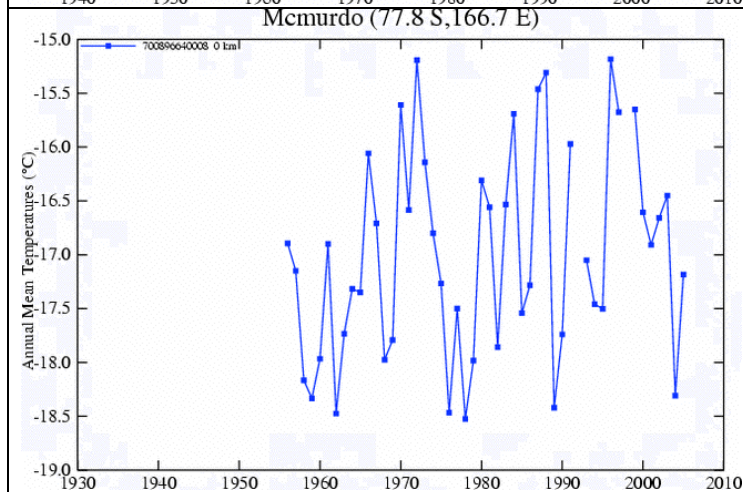
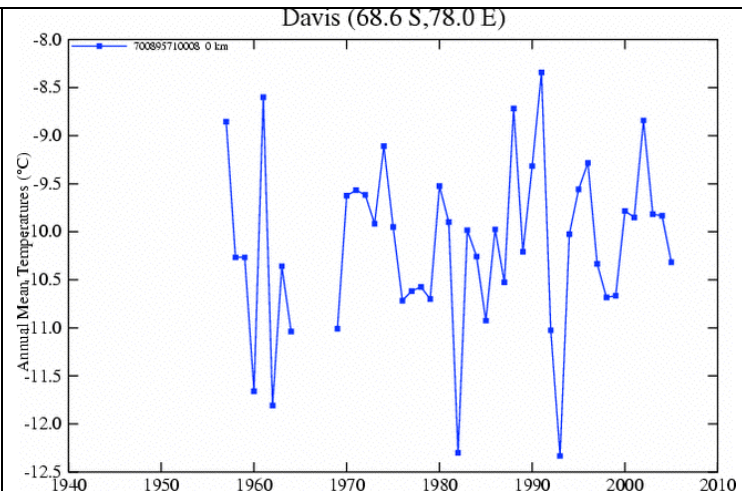
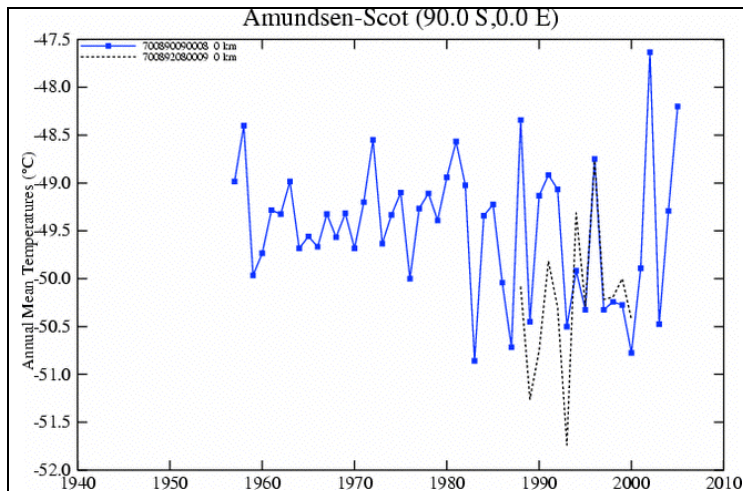
“Climate change in polar regions is expected to be among the largest and most rapid of any region on the Earth, and will cause major physical, ecological, sociological, and economic impacts, especially in the Arctic, Antarctic Peninsula, and Southern Ocean. Polar regions contain important drivers of climate change. Once triggered, they may continue for centuries, long after greenhouse gas concentrations are stabilized, and cause irreversible impacts on ice sheets, global ocean circulation, and sea-level rise.”

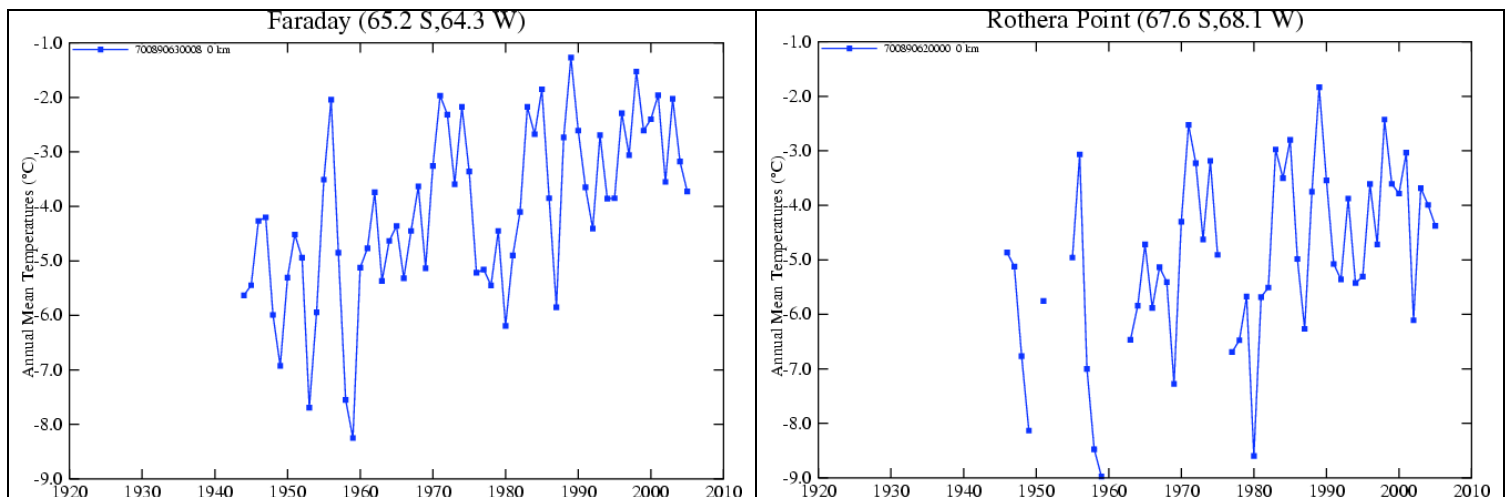
Climate models (GCMs) suggest that polar regions should warm more quickly than temperate or tropical regions because the cold temperatures cause the air to be very dry. The low amounts of water vapor, the most important greenhouse gas, causes the relative effects of other gases, notably carbon dioxide (CO<sub>2</sub>), to be greater. Thus climate change caused by an increase in the latter should be most evident in the polar regions.

This paper considers climate trends in Antarctica. In the sections below we examine the results of studies by various researchers who have analyzed Antarctic temperatures and sea ice. We also present temperature data from long-term Antarctic stations.

### **Antarctic Temperature Trends – Station Data**

We begin by examining measured data from surface temperature stations. Below are annual average temperatures from six long-term stations in Antarctica, obtained from the NASA GISS climate page. Amundson-Scott is at the South Pole, McMurdo, Scott Base and Vostok are high-latitude stations, Davis and Casey are in East Antarctica, and Faraday and Rothera Point are in the Antarctic Peninsula.





## Antarctic Temperature Trends – Journal Article Summaries

Numerous journal articles have reported on studies of temperature trends in Antarctica, with a remarkably consistent conclusion.

Doran, et al (2002) conducted a study of temperatures and ecosystem response in Antarctica's dry valleys. They begin by stating that

“The average air temperature at the Earth's surface has increased by  $0.06^{\circ}\text{C}$  per decade during the 20<sup>th</sup> century,” according to the IPCC, “and by  $0.19^{\circ}\text{C}$  per decade from 1979 to 1998.”

In fact, “Climate models generally predict amplified warming in polar regions,” which would suggest that Antarctic temperatures should have warmed more than this in response to increases in greenhouse gases.

However, “Although previous reports suggest slight recent continental warming,” they declare that “our spatial analysis of Antarctic meteorological data” demonstrated “a net cooling over the entire Antarctic continent between 1966 and 2000, particularly during summer and autumn,” when ice melt would be most likely to occur. A study of temperatures and ecosystem response in the McMurdo Dry Valleys indicated a cooling of  $0.7^{\circ}\text{C}$  per decade between 1986 and 2000.

Antarctic ecosystems show clear evidence of cooling, suggesting that the temperature measurements reported by Doran et al are occurring widely. Among those effects are

“decreased primary productivity of lakes (6-9% per year) and declining numbers of soil invertebrates (more than 10% per year)”

The authors conclude by saying, “Continental Antarctic cooling, especially the seasonality of cooling, poses challenges to models of climate and ecosystem change.”

Turner, et al (2005) analyzed 19 long-term stations reporting temperature, sea level pressure, and wind speed over the Antarctic continent. They noticed a warming of the Antarctic Peninsula (as have others), but suggested that since the Peninsula is where the strongest influence of the El Niño-Southern Oscillation (ENSO) is felt, tropical forcing may be the cause of at least some of the warming.

Turner et al also noticed a change in the trend in temperatures between the 1961-1990 period and 1971-2000. A comparison of the two averaging periods showed that “the warming trend was greater (or the cooling trend less) during the 1961-1990 period compared to 1971-2000.

There are relatively few inland stations in Antarctica. The Vostok base shows slight cooling from 1979-1998, while the Amundsen-Scott station shows a cooling in all seasons, with a decrease of 0.17°C per decade.

Thompson and Solomon (2002) analyzed recent climate change in the Antarctic and other high southern latitudes. They concluded that “Climate variability in the high-latitude Southern Hemisphere (SH) is dominated by the SH annular mode, a large-scale pattern of variability characterized by fluctuations in the strength of the circumpolar vortex.” Trends in the SH circulation have been dominated recently by “the high-index polarity of this pattern, with stronger westerly flow encircling the polar cap... the largest and most significant tropospheric trends can be traced to recent trends in the lower stratospheric polar vortex, which are due largely to photochemical ozone losses.”

Finally, “During the summer-fall season, the trend toward stronger circumpolar flow has contributed substantially to the observed warming over the Antarctic Peninsula and Patagonia and to the cooling over eastern Antarctica and the Antarctic plateau.”

Comiso (2000) reported predominately positive temperature trends along the Antarctic Peninsula. Other parts of the continent have cooled, however. Furthermore, the trend depends in large part on the length of record analyzed. A 45-year trend from station data showed a warming trend of about .12°C per decade, but over the most recent 20 year period there was cooling in both the station data and from satellite observations. Of the 22 long-term stations on the continent, 13 showed temperature decreases and only 9 showed increases. Comiso was puzzled about the cooling trend because “during the same time

period a general warming is being observed globally.” This corresponds to an increase in the sea ice extent around the continent – not a decrease, as would be expected if a general warming were to occur.

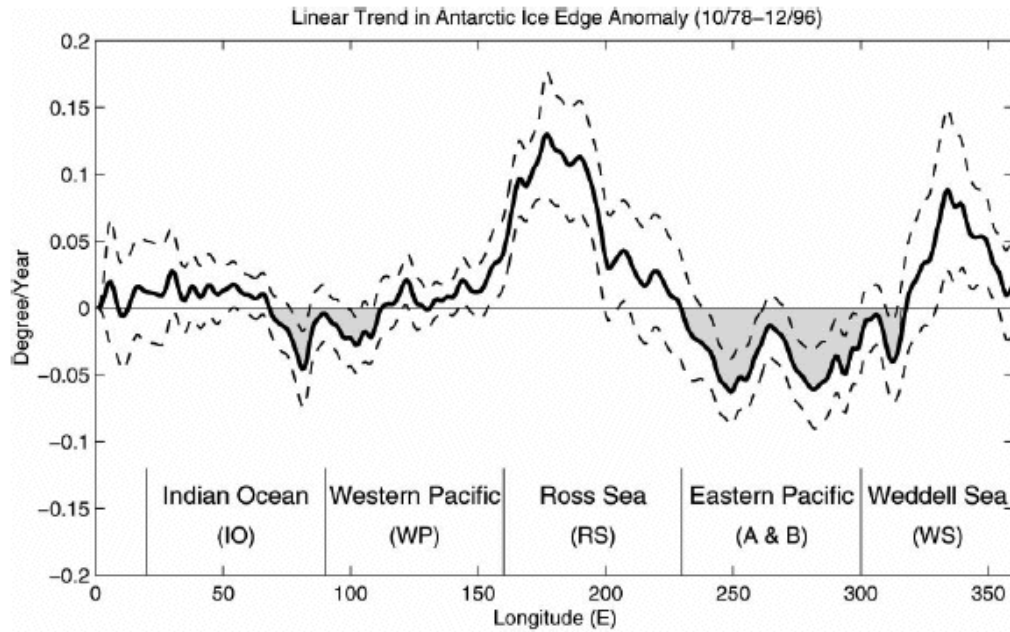
Bertler, et al (2004) studied isotope records from snow samples in the McMurdo Dry Valleys and concluded that warming in areas such as the Antarctic Peninsula and cooling of the terrestrial Ross Sea region are linked to ENSO changes, not to greenhouse gas effects.

Conclusion: Whereas climate models suggest that temperatures in Antarctica should have been warming in recent decades in response to increases in greenhouse gases, measurements show otherwise. Although some regions do show increases, the majority of the continent shows no significant trend or an actual decrease. There is evidence that atmospheric and ocean circulation patterns have much stronger impacts on Antarctic climate than do greenhouse gas increases.

### **Antarctic Sea Ice Trends**

Cavalieri, et al (2004) extended the analysis of Arctic and Antarctic sea ice variability from two to three decades (1973–2002) by bridging the gap between the Nimbus 7 data and the earlier Nimbus 5 satellite data record. While Arctic sea ice extent decreased by  $0.36 \pm 0.05$  million sq. km. per decade from 1979 through 2002, the Antarctic sea ice extent decreased dramatically over the period 1973–1977, then gradually increased. Over the period 1979–2002, Antarctic sea ice extent has increased by  $0.11 \pm 0.05$  million sq. km. per decade.

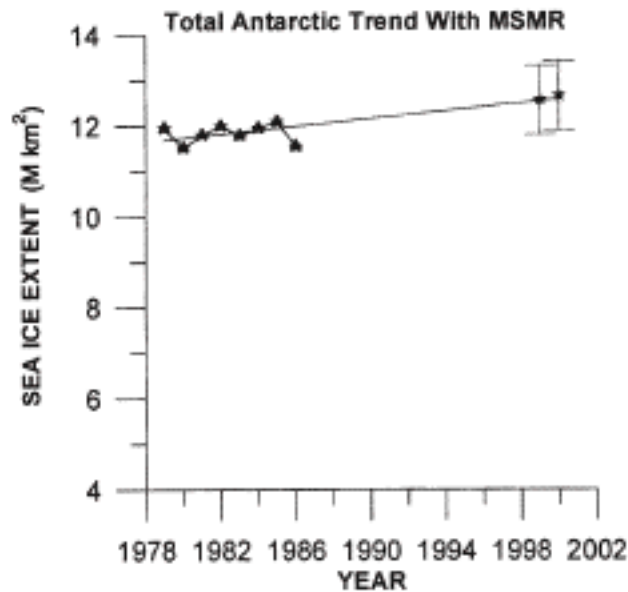
Yuan and Martinson (2000) stated that the Antarctic Sea Ice Edge (SIE) index responds largely to ENSO and Pacific Ocean precipitation patterns. They reported that there was geographical variation in SIE trends, but that the overall monthly anomalies, averaged around the entire Antarctic continent showed a net increasing trend of  $0.011 \pm .043$  degrees per year over the period 1978–1996. Their figure showing the longitudinal trends in SIE appears below.



Antarctic Sea Ice Edge index (SIE) trend, 1978-1996, from Yuan and Morrison (2000).

Zwally, et al (2002) used “a systematically calibrated and analyzed data set for 20.2 years (1979–1998).” They report that the total Antarctic sea ice extent increased by  $11,180 \pm 4190$  sq. km per year. Regionally, the trends in extent are positive in the Weddell Sea, Pacific Ocean, and Ross sectors, slightly negative in the Indian Ocean, and strongly negative in the Bellingshausen-Amundsen Seas sector. For the entire ice pack, ice increases occur in all seasons, with the largest increase during fall. The authors conclude: “The observed increase in Antarctic sea ice cover is counter to the observed decreases in the Arctic. It is also qualitatively consistent with the counterintuitive prediction of a global atmospheric-ocean model of increasing sea ice around Antarctica with climate warming due to the stabilizing effects of increased snowfall on the Southern Ocean.”

Vyas, et al (2003) used data from several satellite platforms (Nimbus-7, DMSP and OCEANSAT-1) to estimate trends in sea ice around Antarctica. They found decreasing sea ice in the Weddell Sea, increases in the Ross Sea, and insignificant changes elsewhere. For the continent as a whole there has been an increase in sea ice, a “weak but consistent increasing trend of approximately 43,000 sq. km. per year.” The figure below (Figure 4c from the Vyas, et al article) shows the total sea ice extent trend.



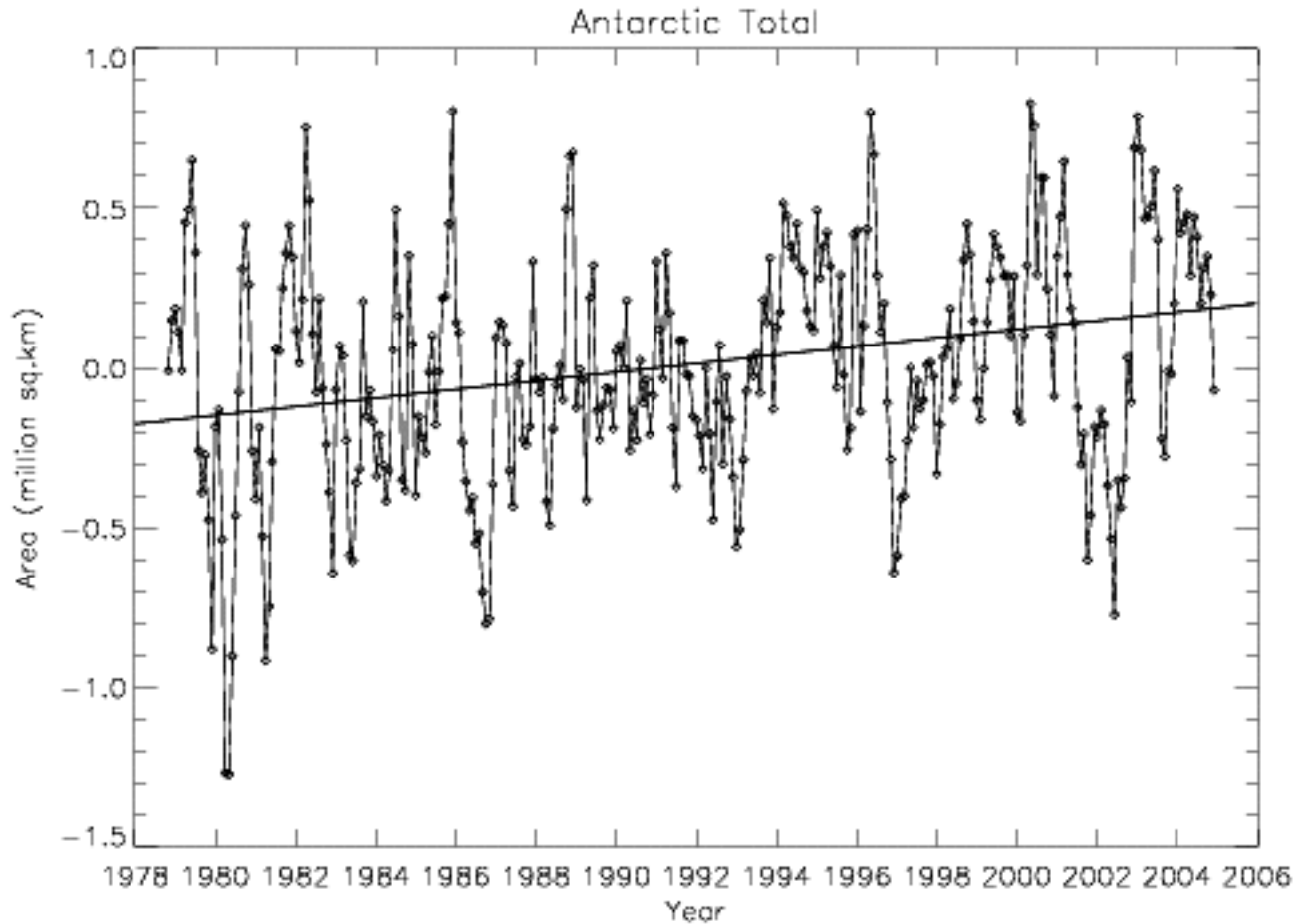
Sea Ice for the entire Antarctic (Figure 4c from Vyas, et al, 2003)

Vyas et al conclude that their estimates may actually understate the increase in sea ice: “the increasing trend in the sea ice extent over the Antarctic region may be slowly accelerating in time, particularly over the last decade. In fact, it is interesting to note that most of the SSM/I derived sea ice extents estimates during the middle of the last decade have been on the higher side of the long-term trend.” Antarctic climate and sea ice trends, in fact, are “paradoxical in the global warming scenario resulting from increasing greenhouse gases in the atmosphere,” which suggest that polar regions should be warming (and melting) in response to greenhouse gas enhancement.

Liu, et al (2004) report that total Antarctic sea ice (the area covered by at least 15% ice concentration) has increased significantly since 1979, by about 13,295 sq. km. per year. Regionally, there has been a large increase in the central Pacific sector and a smaller decrease in the Weddell Sea. Although ENSO and the Antarctic Oscillation appear to influence sea ice trends, they cannot explain them. There may be “less understood large-scale processes at work” influencing sea ice.

The National Snow and Ice Data Center (NSIDC, 2006) publishes updated values of historical sea ice extent around Antarctica, using data from SMMR and SSM/I satellite platforms. Below is their chart of sea ice extent anomalies since 1978. While there has been considerable variation from year to year, the overall linear trend shows an increase of about 400,000 sq. km. in sea ice over the period of record.





Antarctic Sea Ice Area Anomalies, 1978-2005, from NSIDC (2006)

Conclusion: The data clearly show that Antarctica as a whole is seeing increases in sea ice extent in recent decades, in spite of what climate models suggest should be occurring: steady warming. There are regional differences, with Weddell Sea ice extent decreasing and Ross Sea ice increasing, but overall the pattern is clear: there is more ice, not less, surrounding Antarctica.

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