

# Insights into 20<sup>th</sup>-Century Antarctic and global climate change from ITASE (and other) high-resolution ice core stable isotope records

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Clara Deser - NCAR  
Caspar Ammann - NCAR

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NSF-OPP  
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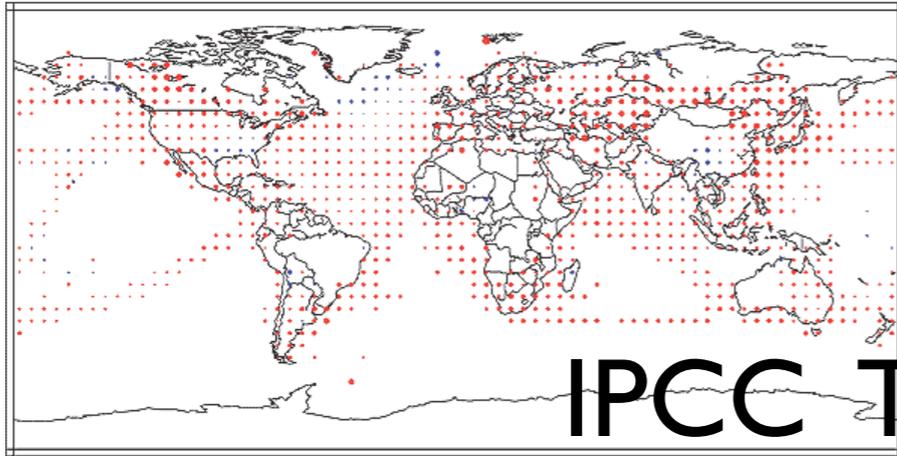
# Antarctica

Critical role in the global climate system

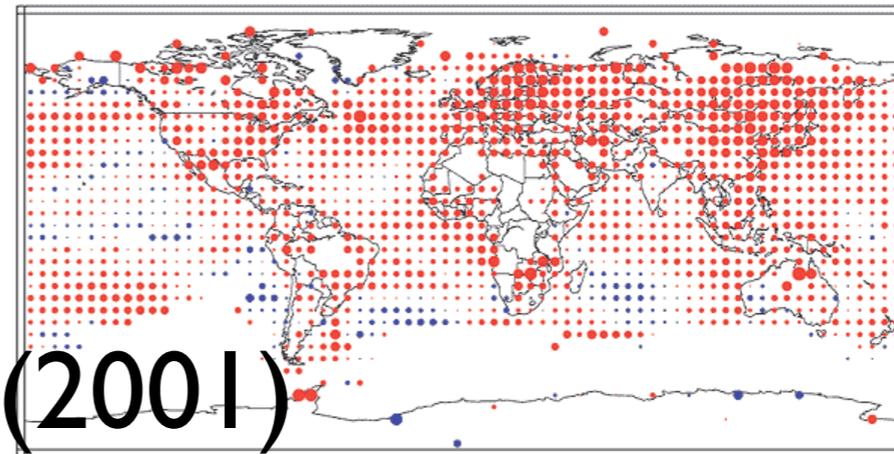
- ◆ Albedo
- ◆ Sea ice
- ◆ Sea level
- ◆ Atmospheric transport of heat & mass
- ◆ Carbon cycle

# Where's the Antarctic data?

(a) Annual temperature trends, 1901 to 2000



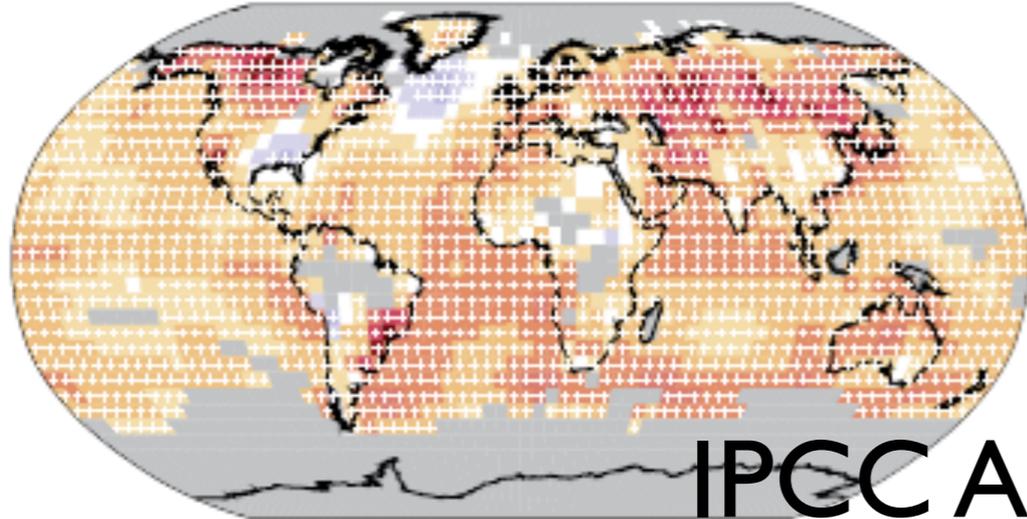
(d) Annual temperature trends, 1976 to 2000



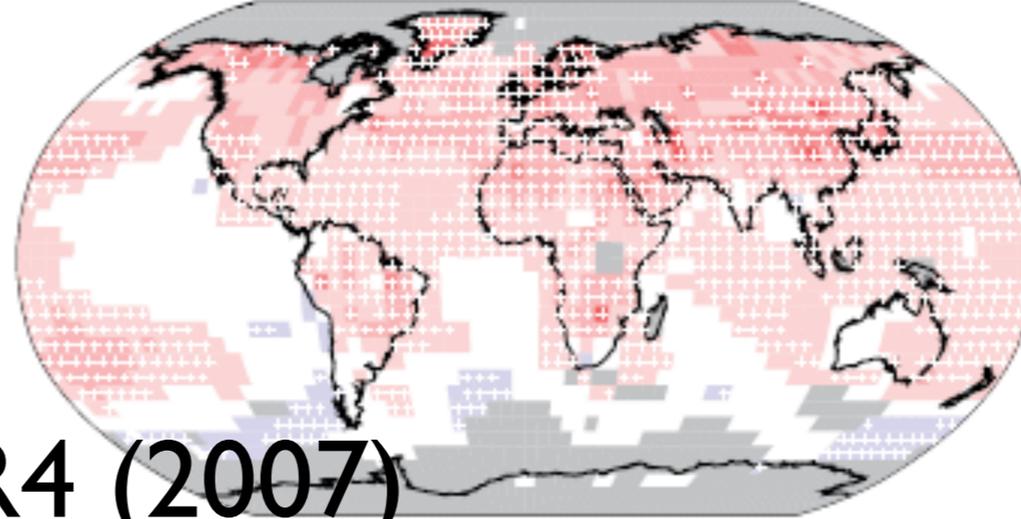
**IPCC TAR (2001)**



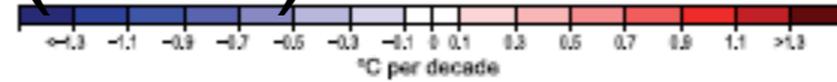
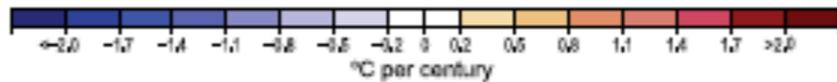
Annual Trend 1901 to 2005



Annual Trend 1979 to 2005



**IPCC AR4 (2007)**



# Filling in a data void...

Schneider, D.P., E.J. Steig, T. van Ommen, D. Dixon, P.A. Mayewski, J. Jones, and C. Bitz, 2006: Antarctic temperatures over the past two centuries from ice cores, *Geophysical Research Letters*, 33, doi:10.1029/2006GL027057.

uwnews.org | New evidence shows Antarctica has warmed in last 150 years | University of Washington News and Information

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Sept. 5, 2006 | Science  
**New evidence shows Antarctica has warmed in last 150 years**  
 Vince Stricherz [vinc@u.washington.edu](mailto:vinc@u.washington.edu)

Despite recent indications that Antarctica cooled considerably during the 1990s, new research suggests that the world's iciest continent has been getting gradually warmer for the last 150 years, a trend not identifiable in the short meteorological records and masked at the end of the 20th century by large temperature variations.

Numerous ice cores collected from five areas allowed scientists to reconstruct a temperature record that shows average Antarctic temperatures have risen about two-tenths of a degree Celsius, or about one-third of a degree Fahrenheit, in 150 years. That might not sound like much, but the overall increase includes a recorded temperature decline of nearly 1 degree in the 1990s, said David Schneider, a University of Washington postdoctoral researcher in Earth and space sciences.

"Even if you account for the cooling in the '90s, we still see that two-tenths of a degree increase from the middle of the 1800s to the end of the 20th century," said Schneider, the lead author of a paper detailing the work published Aug. 30 in [Geophysical Research Letters](#).

The main reason that Antarctica appears to have cooled during the 1990s is that a natural phenomenon called the Antarctic Oscillation, or Southern Annular Mode, was largely in its positive phase during that time. The Antarctic Oscillation is so named because atmospheric pressure in far southern latitudes randomly oscillates between positive and negative phases. During the positive phase, a vortex of wind is tightly focused on the polar region and prevents warmer air from mixing with the frigid polar air, which keeps Antarctica colder.

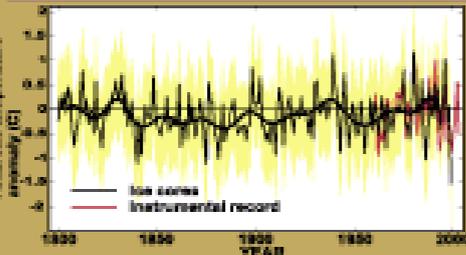
Typically the Antarctic Oscillation alternates between phases about every month. But in the 1990s the positive phase occurred much more often, Schneider said. Without the influence of the Antarctic Oscillation, he said, it is likely the Antarctic would show the same kind of warming as the rest of the Southern Hemisphere. Before 1975, Antarctica appears to have warmed at about the same rate as the rest of the hemisphere, about 0.25 degree C per century. But since 1975, while the Antarctic showed overall cooling, the Southern Hemisphere has warmed at a rate of about 1.4 degrees per century.

"The second half of the 20th century is marked by really large variability. The periods of cooling correspond with a very strong positive Antarctic Oscillation," Schneider said. "The caution is that we don't fully understand the feedbacks between overall climate warming and the Antarctic Oscillation. But having the 200-year record is what convinces us that there is a relationship between Southern Hemisphere temperature changes and Antarctic temperature changes."

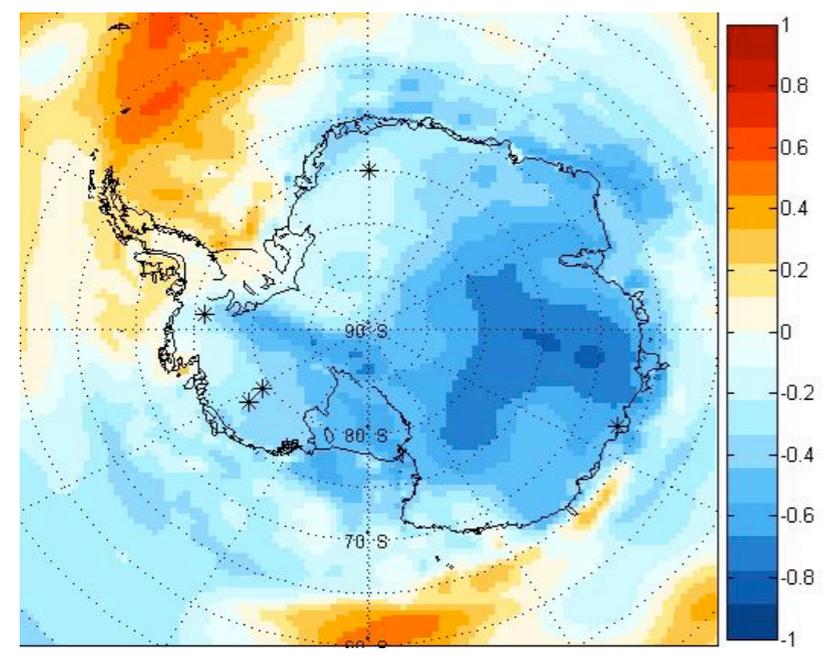
He noted that other research has suggested that ozone depletion in the Southern Hemisphere is keeping the Antarctic Oscillation in its positive phase for longer periods.

Schneider began the work for his doctoral thesis and completed it as a post-doctoral researcher. Co-authors of the paper are Eric Steig, Schneider's thesis adviser, and Cecilia Bitz of the UW; Tas van Ommen of the Antarctic Climate and Ecosystems Cooperative Research Centre in Australia, Daniel Dixon and Paul Mayewski of the

**Geophysical Research Letters**  
 28 AUGUST 2006  
 Volume 33 Number 16  
 American Geophysical Union

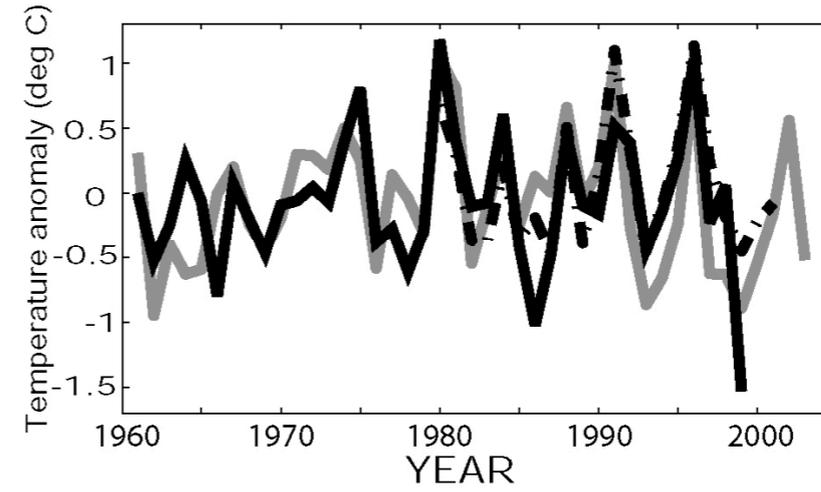
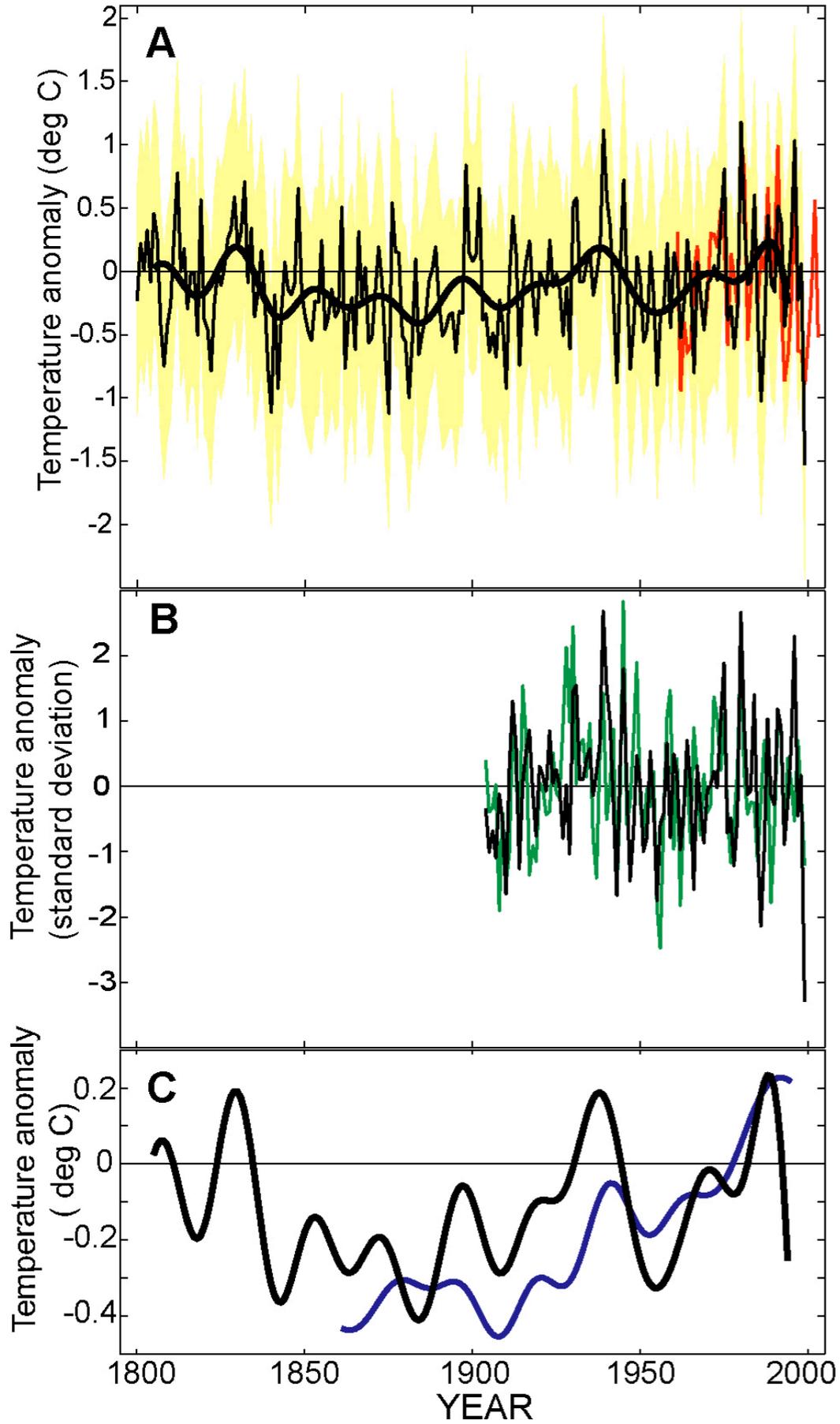



Ice core records used to extract Antarctic temperatures over the past two centuries:  
 • Equatorial ridge on Saturn's moon Iapetus: Formation through ring collapse? • Ground truths of terrestrial water storage estimates generated from satellite gravity data

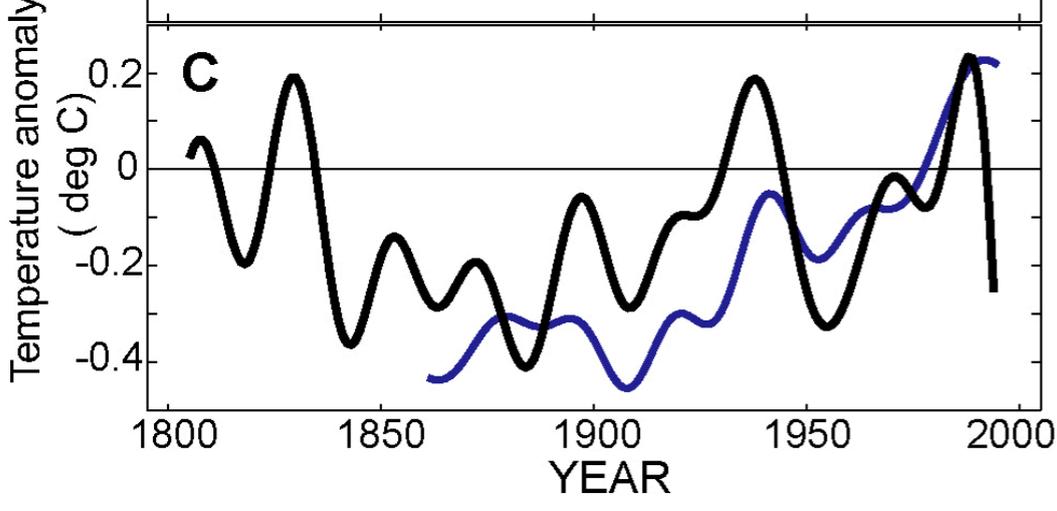
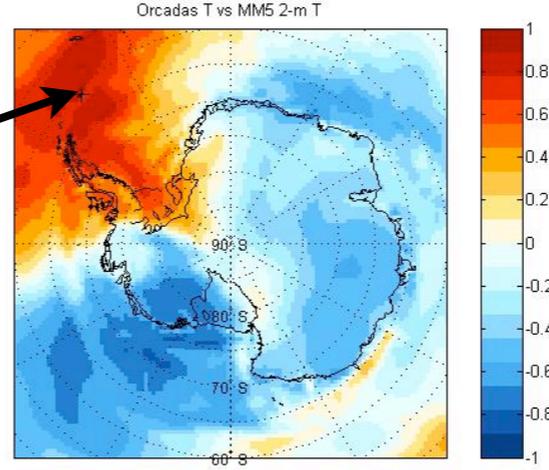
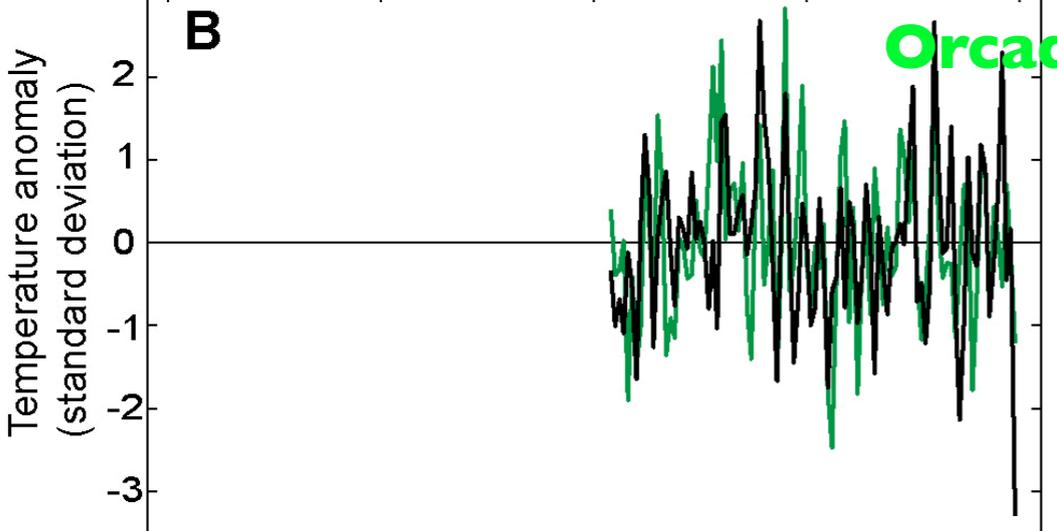
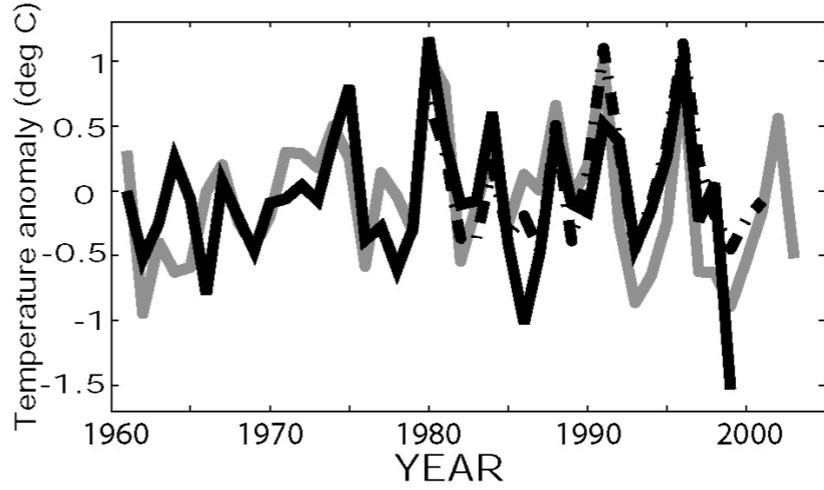
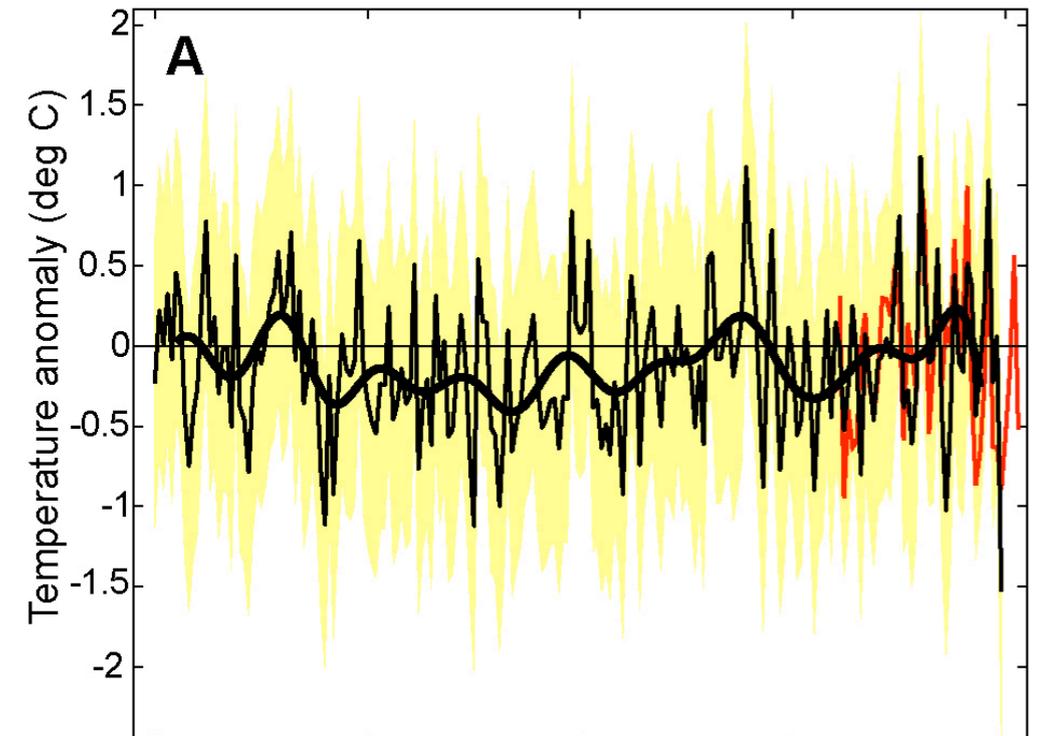


Ice cores used in stack, regressed upon temperature

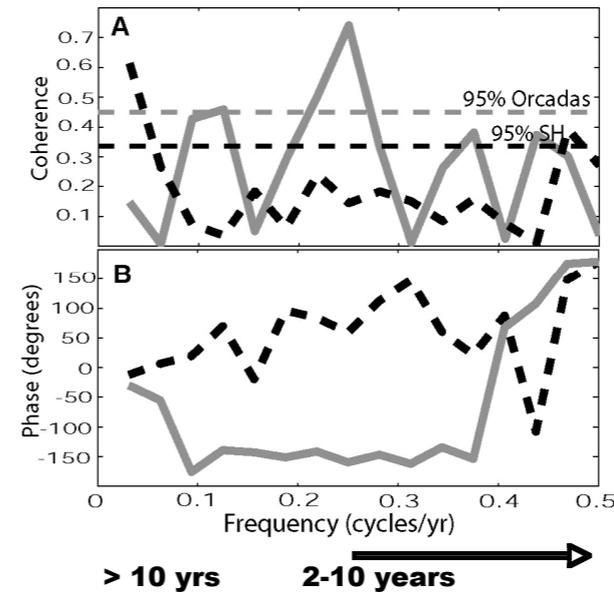
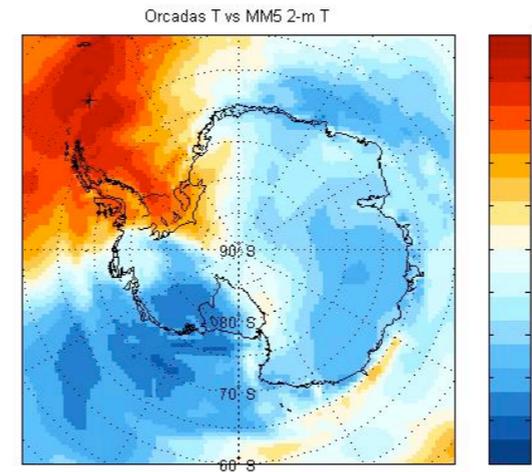
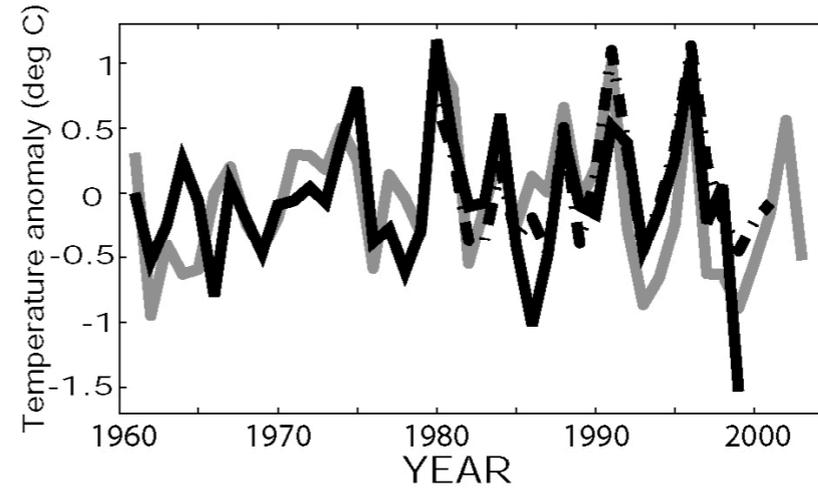
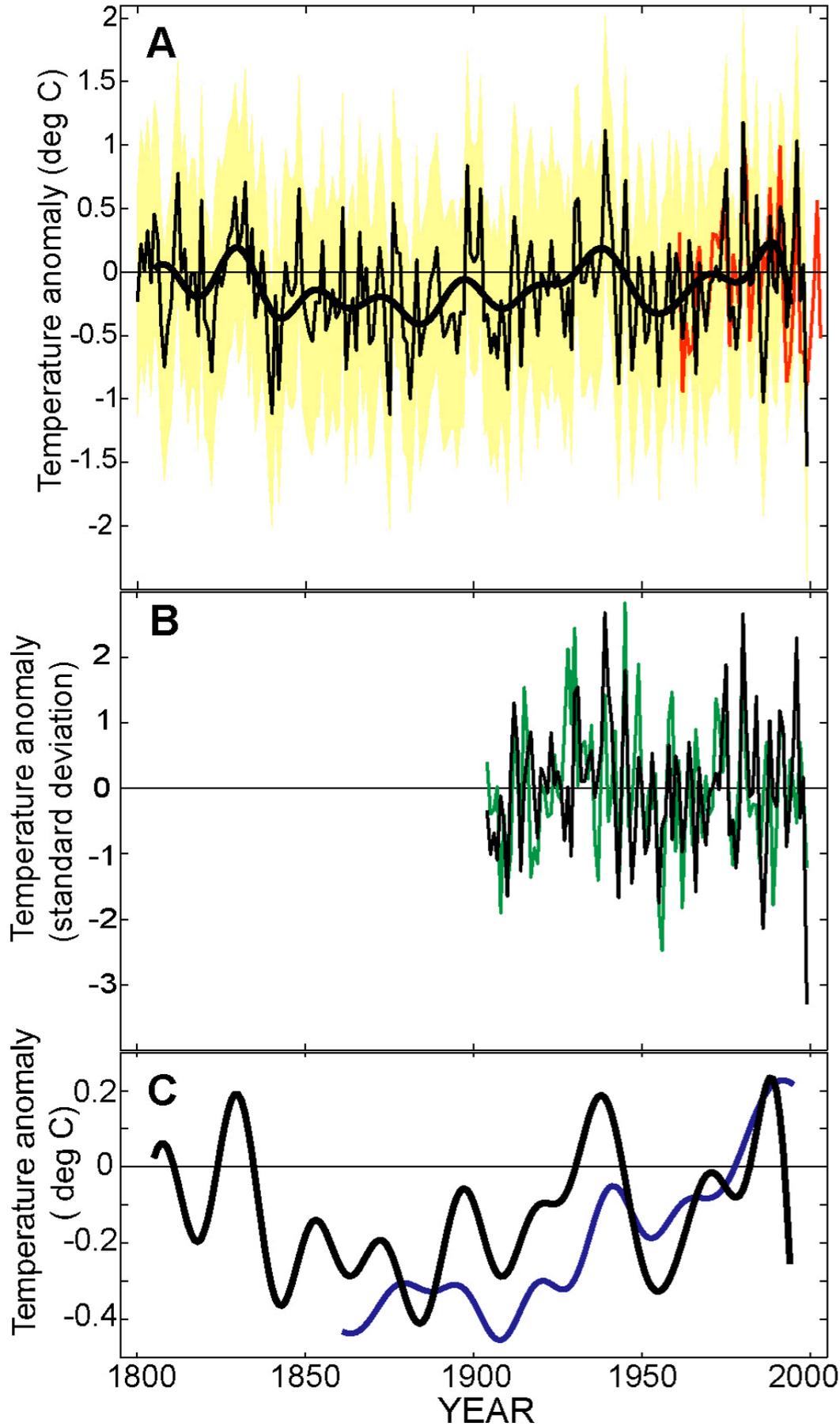
# Calibrated annual temperature reconstruction.



# SAM-related variability evident for past 100 years

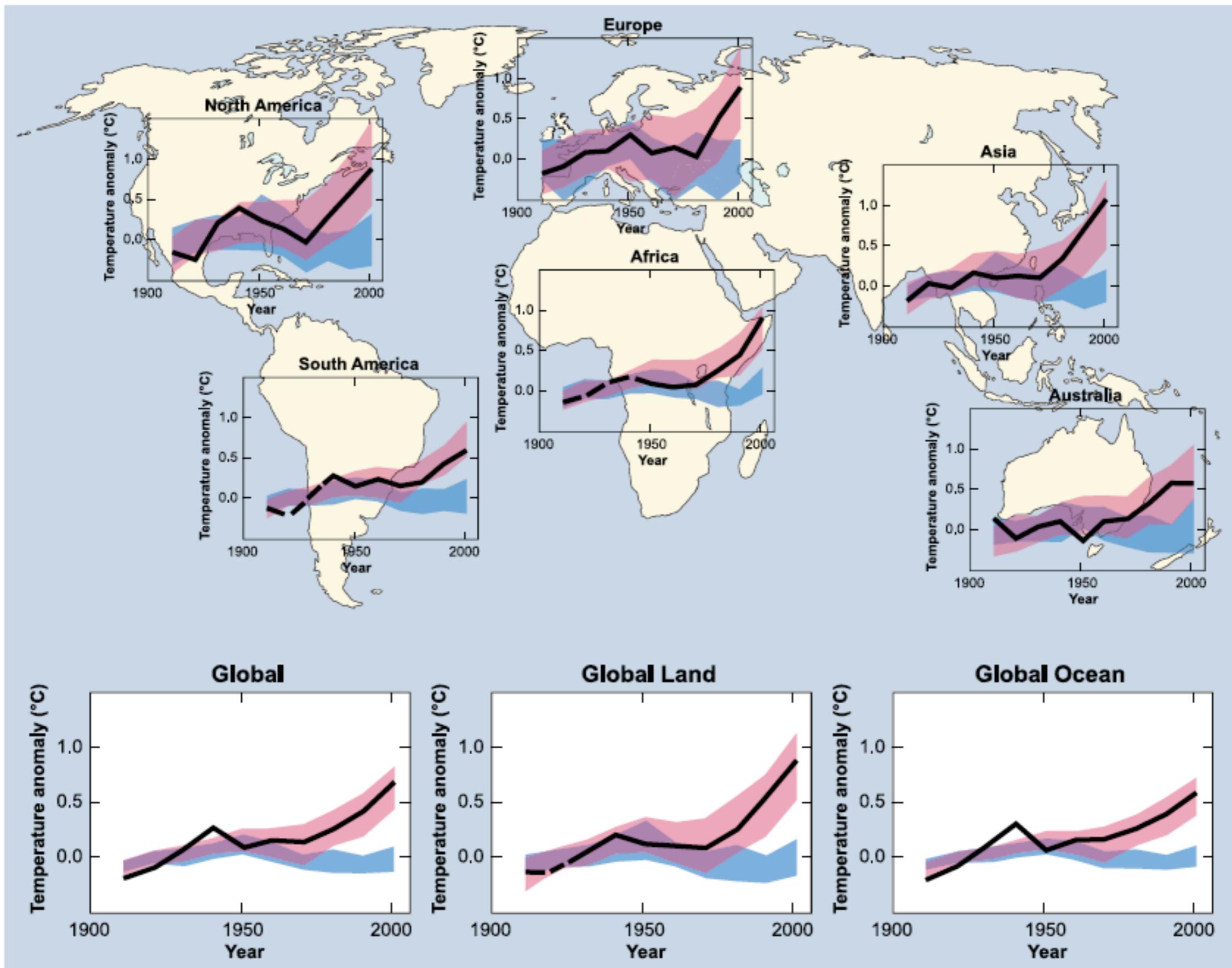


# Though not all variance is explained by SAM



Coherence of reconstruction with **Orcadas & SH mean**

# GLOBAL AND CONTINENTAL TEMPERATURE CHANGE



models using only natural forcings

models using both natural and anthropogenic forcings

observations

# Comparing reconstructed & instrumental temperature records with IPCC model simulations

Climate Models Overheat Antarctica, New Study Finds - News Release

8/27/08 3:38 PM



## Climate Models Overheat Antarctica, New Study Finds

May 07, 2008

BOULDER— Computer analyses of global climate have consistently overstated warming in Antarctica, concludes new research by scientists at the National Center for Atmospheric Research (NCAR) and Ohio State University. The study can help scientists improve computer models and determine if Earth's southernmost continent will warm significantly this century, a major research question because of Antarctica's potential impact on global sea-level rise.



Andrew Monaghan. (Photo by Carlye Calvin, ©UCAR.)  
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"We can now compare computer simulations with observations of actual climate trends in Antarctica," says NCAR scientist Andrew Monaghan, the lead author of the study. "This is showing us that, over the past century, most of Antarctica has not undergone the fairly dramatic warming that has affected the rest of the globe. The challenges of studying climate in this remote environment make it difficult to say what the future holds for Antarctica's climate."

The study marks the first time that scientists have been able to compare records of the past 50 to 100 years of Antarctic climate with simulations run on computer models. Researchers have used atmospheric observations to confirm that computer models are accurately simulating climate for the other six continents. The models, which are mathematical representations of Earth's climate system, are a primary method for scientists to project future climate.

Antarctica's climate is of worldwide interest, in part because of the enormous water locked up in its ice sheets. If those vast ice sheets were to begin to melt, sea level could rise across the globe and inundate low-lying coastal areas. Yet, whereas climate models accurately simulate the last century of warming for the rest of the world, they have unique challenges simulating Antarctic climate because of limited information about the continent's harsh weather patterns.

The study was published on April 5 in *Geophysical Research Letters*. It was funded by the National Science Foundation, NCAR's primary sponsor, and the Department of Energy.

The authors compared recently constructed temperature data sets from Antarctica, based on data from ice

<http://www.ucar.edu/news/releases/2008/antarctica.jsp>

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**(this story is ranked 5th in google search for "Antarctic climate")**

Monaghan AJ, Bromwich DH and Schneider DP, 2008: Twentieth-century Antarctic air temperature and snowfall simulations by IPCC Climate models. *Geophysical Research Letters*, 35, L07502, doi: 10.1029/2007GL032630.

Overheating Antarctica : article : Nature Reports Climate Change

8/27/08 3:31 PM



## Research Highlights

*Nature Reports Climate Change*  
Published online: 29 May 2008 | doi:10.1038/climate.2008.51

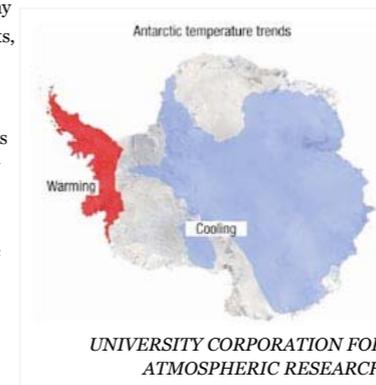
## Overheating Antarctica

Alicia Newton

*Geophys. Res. Lett.* 35. L07502 (2008)

Computer models of climate change have overstated Antarctic warming, say scientists. The large volumes of water locked up in the Antarctic's ice sheets, which could raise sea level if melted, have created intense interest in how much the region is likely to warm.

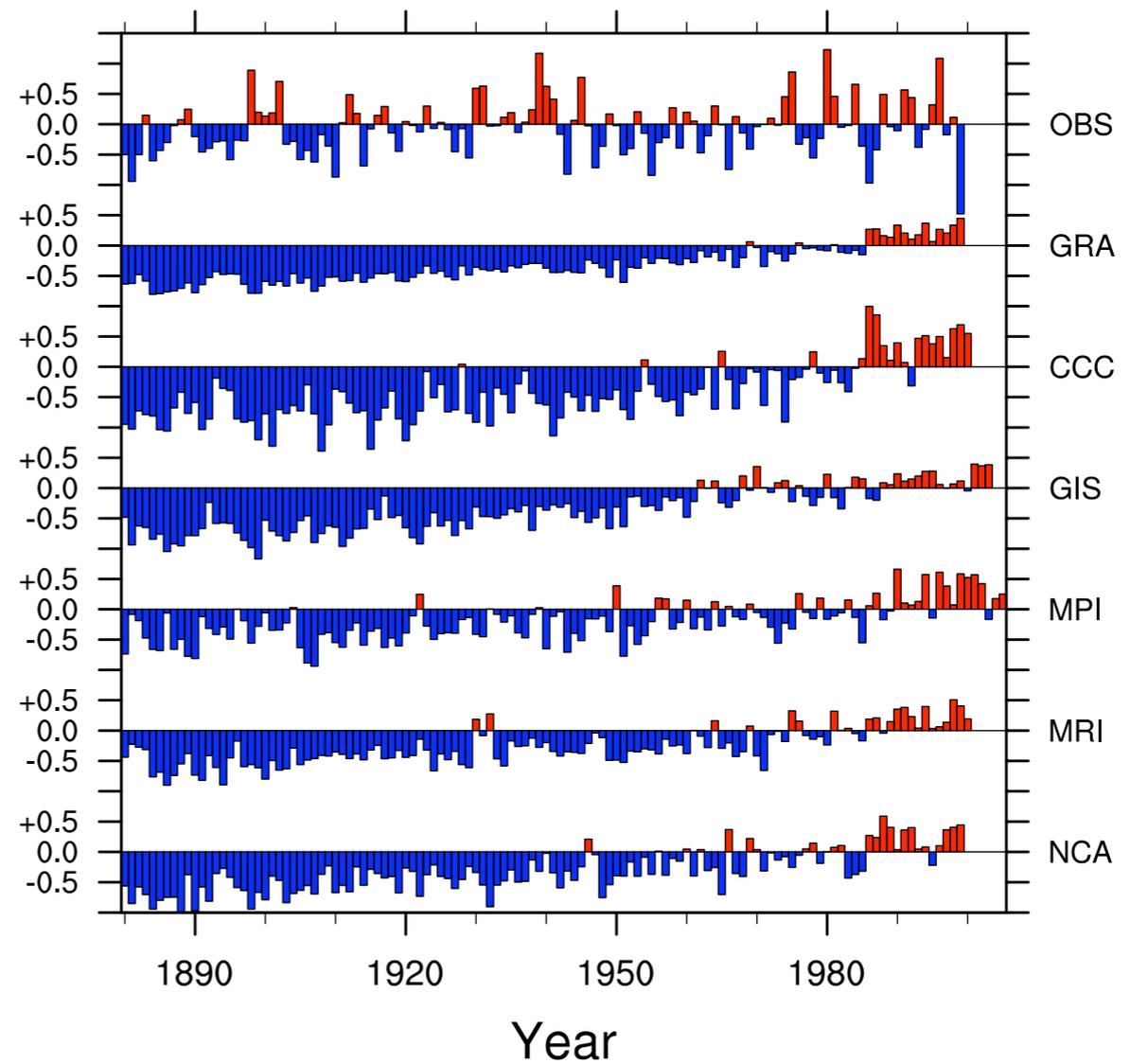
Traditionally, this has been estimated mainly from models, as observations on the ground are sparse. But Andrew Monaghan at Ohio State University and colleagues have now compiled temperature and snowfall data across Antarctica and compared them to model simulations. Monaghan's team found that whereas the models estimated about a 0.75 °C temperature rise over the last century, temperatures actually rose by only 0.2 °C over the continent. One exception is the Antarctic peninsula, which has warmed by several degrees. The models did a good job of representing changes in snowfall, which increased in the later part of the twentieth century and decreased in the past decade.



The discrepancy in temperature change may result from the models overestimating the amount of water vapour in the Antarctic atmosphere. Interestingly, when temperatures are colder over Antarctica, there is less snowfall to replenish the ice sheet, which could potentially increase sea level rise, although other factors also affect the overall amount of ice on the continent.

# How do 20-th Century simulations compare with “observations?”

Annual Antarctic Near-Surface Temperature



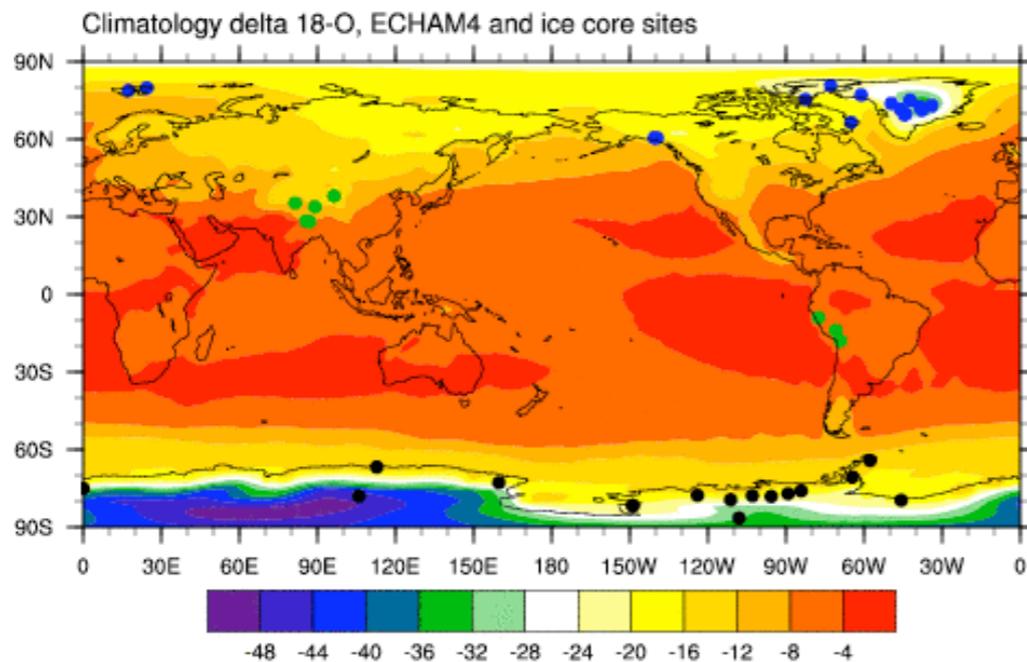
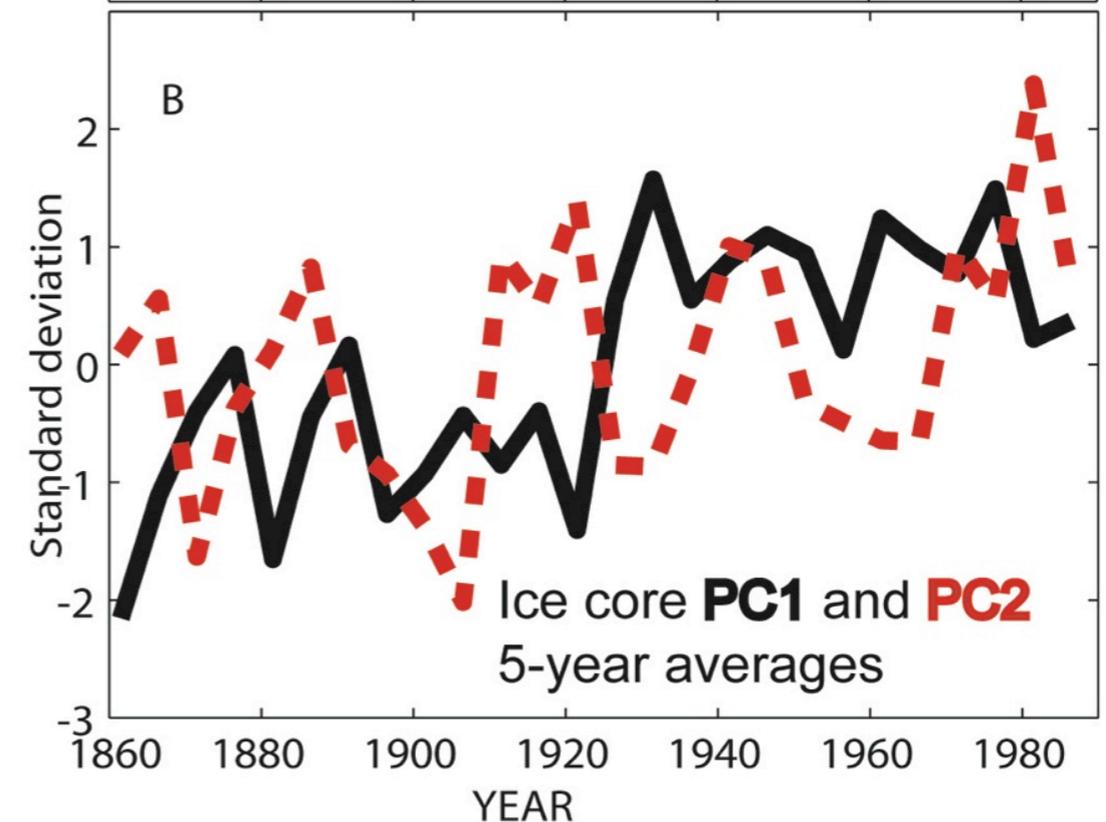
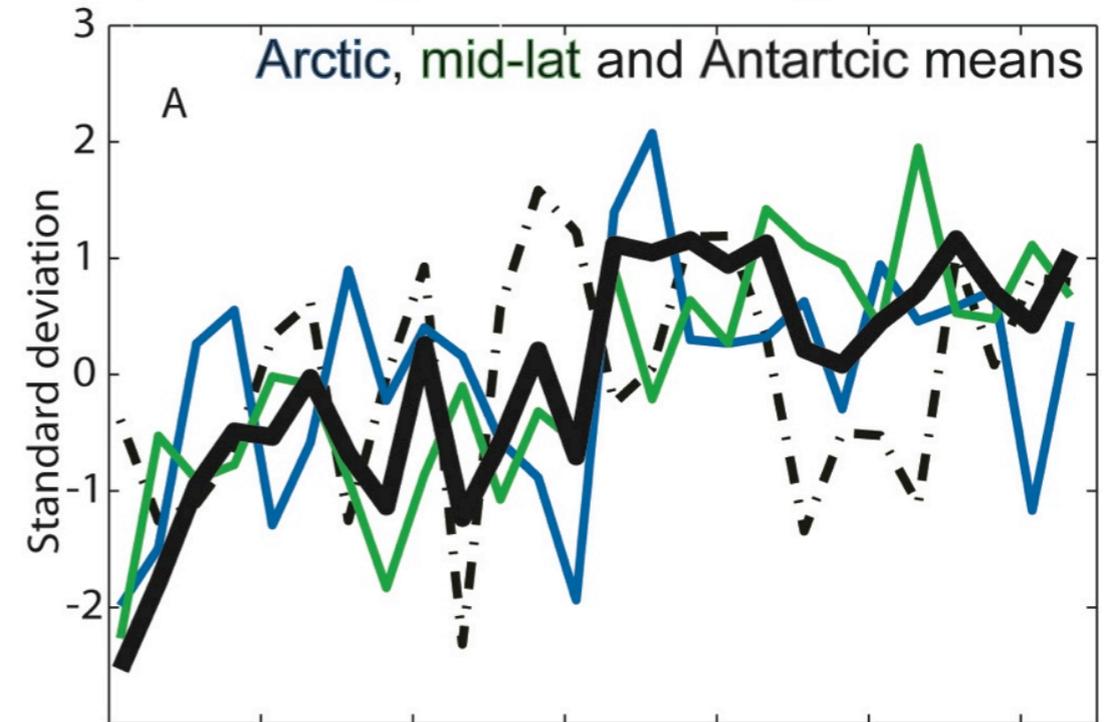
**Table 2.** Antarctic NSAT and Snowfall Trends and Confidence Intervals ( $p < 0.05$ ) for Observations and GCMs for Various Periods and Seasons<sup>a</sup>

Variable	Units	Period	Season	Schneider	Monaghan	GCM 'GRA'	Min GCM	Max GCM
Temperature Trend	K century <sup>-1</sup>	1880–1999	Annual	0.20 ± 0.32	±	0.75 <sup>b</sup> ± 0.07 <sup>b</sup>	0.52 <sup>b</sup> (MPI)	0.97 <sup>b</sup> (CCC)
Temperature Trend	K century <sup>-1</sup>	1960–1999	Annual	0.13 ± 1.95	0.06 ± 2.03	1.44 <sup>b</sup> ± 0.34 <sup>b</sup>	0.68 <sup>b</sup> (GIS)	2.45 <sup>b</sup> (CCC)
Temperature Trend	K century <sup>-1</sup>	1960–1999	DJF	±	1.09 ± 3.06	1.11 ± 0.37	0.06 (GIS)	2.51 (CCC)
Temperature Trend	K century <sup>-1</sup>	1960–1999	MAM	±	-0.61 ± 3.95	1.48 <sup>b</sup> ± 0.57 <sup>b</sup>	0.77 (GIS)	2.80 <sup>b</sup> (CCC)
Temperature Trend	K century <sup>-1</sup>	1960–1999	JJA	±	1.56 ± 4.32	1.88 <sup>b</sup> ± 0.67 <sup>b</sup>	1.06 (GIS)	2.73 <sup>b</sup> (CCC)
Temperature Trend	K century <sup>-1</sup>	1960–1999	SON	±	0.96 ± 2.92	1.28 <sup>b</sup> ± 0.59 <sup>b</sup>	0.71 (GIS)	1.78 <sup>b</sup> (CCC)
Snowfall Trend	mm century <sup>-1</sup>	1955–1999	Annual	±	32 <sup>b</sup> ± 31 <sup>b</sup>	17 <sup>b</sup> ± 4 <sup>b</sup>	5 (GIS)	26 <sup>b</sup> (CCC)
S/T Sensitivity	% K <sup>-1</sup>	Varies <sup>c</sup>	Annual	±	4.9 ± 4.9	5.5 ± 0.8	2.4 (MRI)	7.1 (MPI)

# What is the global connectivity of Antarctic ice cores?

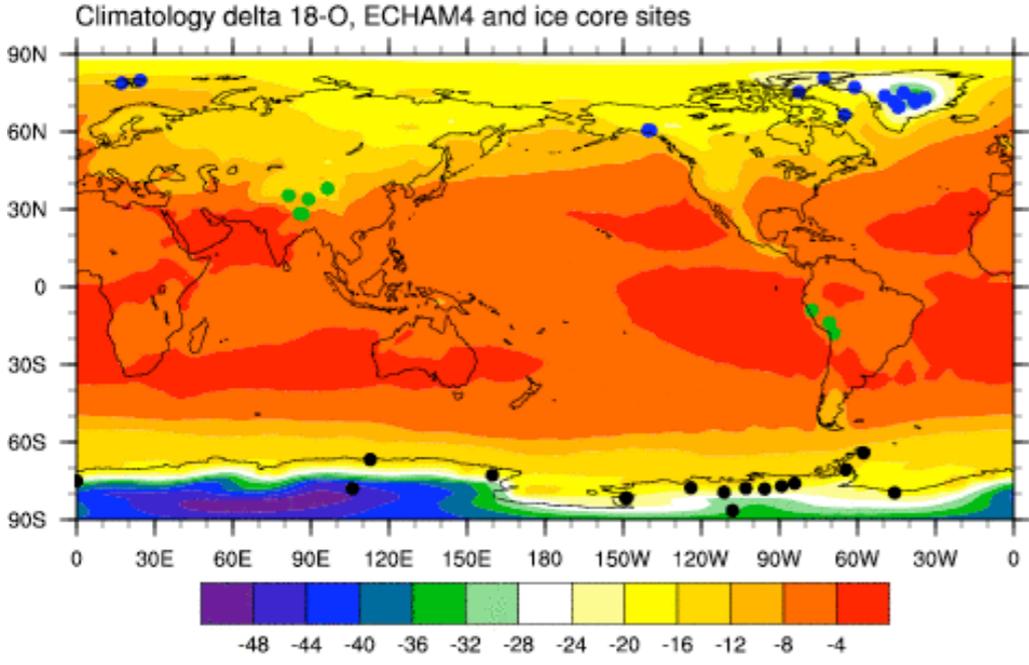
Schneider, D.P., and D.C. Noone, 2007:  
Spatial covariance of water isotope records in a global network of ice cores spanning twentieth-century climate change, *Journal of Geophysical Research*, 112, D18105, doi: 10.1029/2007JD008652.

Simple averages and leading PCs of ice cores

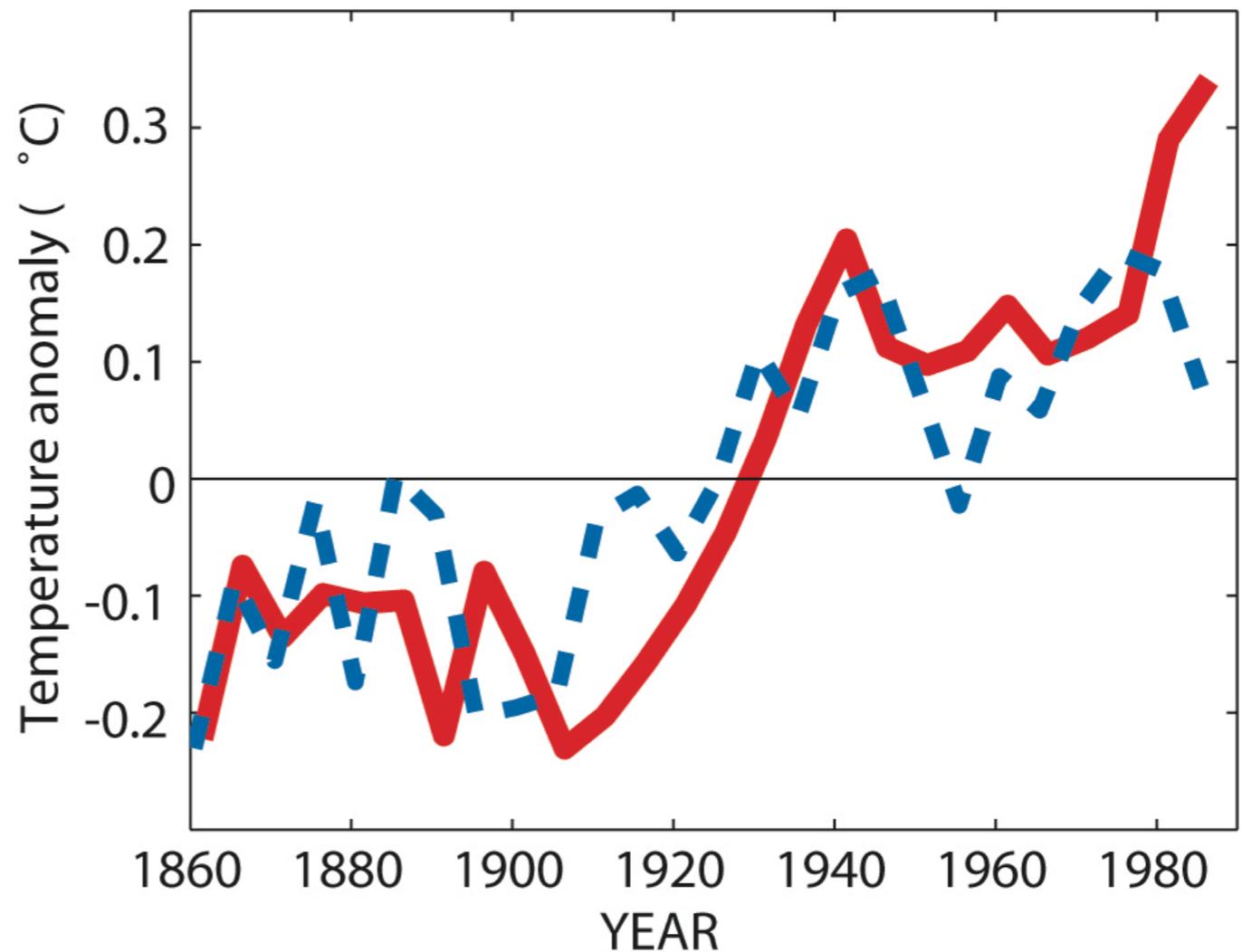


ice core locations & modeled d18O

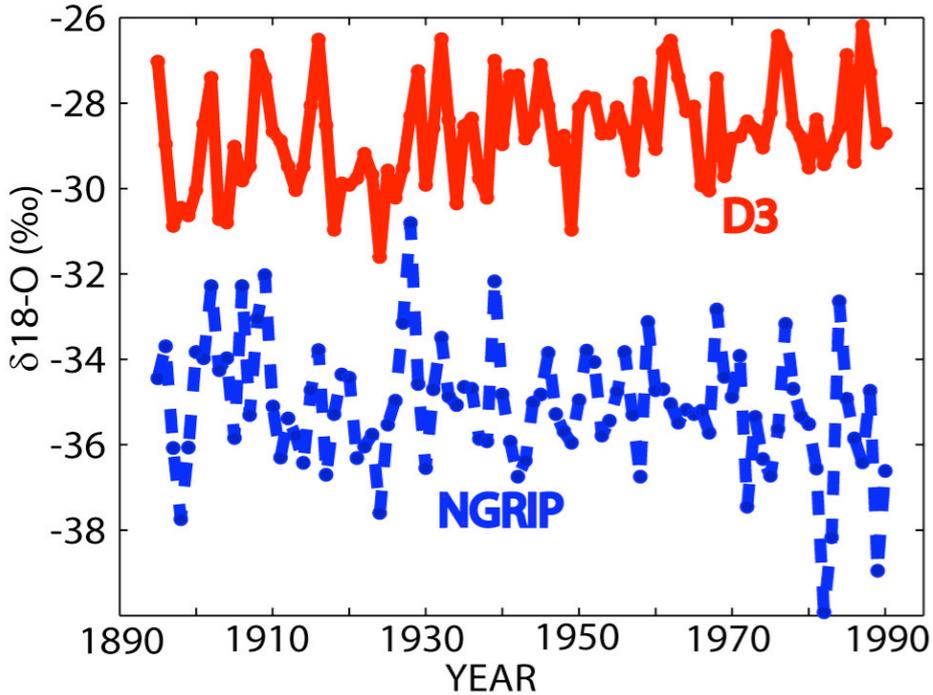
# We are moving towards a global data base of ice core records...



## Global temperature & ice cores



## Ice cores from Greenland



...regional and global-scale signals are evident, but many coverage gaps exist.

(Schneider and Noone, 2007)

# An exceptional mid-century El Niño recorded in West Antarctic ice

Schneider D.P., and E.J. Steig, 2008: Ice cores record significant 1940s Antarctic warmth related to tropical climate variability, *Proceedings of the National Academy of Sciences*, 105, 12154-12158.

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## Antarctic Climate: Short-Term Spikes, Long-Term Warming Linked to Tropical Pacific

August 12, 2008

BOULDER—Dramatic year-to-year temperature swings and a century-long warming trend across West Antarctica are linked to conditions in the tropical Pacific Ocean, according to a new analysis of ice cores conducted by scientists at the National Center for Atmospheric Research (NCAR) and the University of Washington (UW). The findings show the connection of the world's coldest continent to global warming, as well as to periodic events such as El Niño.



"As the tropics warm, so too will West Antarctica," says NCAR's David Schneider, who conducted the research with UW's Eric Steig. "These ice cores reveal that West Antarctica's climate is influenced by atmospheric and oceanic changes thousands of miles to the north."

The research appears this week in the online Early Edition of Proceedings of the National Academy of Sciences. The work was supported by the National Science Foundation, NCAR's sponsor.

Scientists are keenly interested in whether warming will destabilize the West Antarctic ice sheet over a period of decades or centuries. The ice sheet covers an area the size of Mexico, averages about 6,500 feet deep, and, if melted, would raise global sea levels by about 8 to 16 feet (2.5-5 meters).

Antarctica's climate is difficult to study, partly because there are few observations of this vast and remote region and partly because the cold, dry atmosphere is unlike that of the other six continents. Scientists previously determined that Antarctica overall probably warmed by about 0.4 degrees Fahrenheit (0.2 degrees Celsius) in the last century. But it has not been apparent until now that low-lying West Antarctica is more responsive to global warming trends than East Antarctica, where wind patterns have largely kept out comparatively warm air.

Schneider and Steig estimate that West Antarctica warmed about 1.6 degrees F (0.9 degrees C) over the 20th century. That is slightly more than the global average of about 1.3 degrees F (0.7 degrees C). Because of the large swings in annual temperature during the 1930s and 1940s, there is a considerable margin of uncertainty in the century-long estimate, says Schneider. He notes that there is increased confidence that warming has occurred since 1950, averaging about 0.8 degree F (0.4 degrees C) per decade.

The new set of cores analyzed by Schneider and Steig comes from a relatively snowy part of the continent.

When a strong El Niño develops across the tropical Pacific, it can influence weather and climate as far away as the southern polar region. This occurs via a "wave train" of areas with unusually high or low pressure in the upper atmosphere (H's and L's) that leads to warmer-than-normal temperatures in West Antarctica. Bright reds near the equator show the unusually warm sea-surface temperatures (SSTs) associated with an El Niño during 1940-41. There are no SST data for that period for the portions of the Southern Ocean shown here. Analysis of ice cores drilled in West Antarctica (red dots) reveals that air temperatures there warmed by as much as 10° Fahrenheit as this three-year-long El Niño unfolded, then dropped by as much as 13° F afterward. [ENLARGE] (Image by Steve Deyo, ©UCAR.) News media terms of use\*

This provides enough detail for scientists to infer year-to-year temperature changes. The data show that the Antarctic climate is highly responsive to changes in the Pacific. For example, during a major El Niño event from 1939 to 1942, temperatures in West Antarctica rose by about 6 to 10 degrees F (3-6 degrees C), and then dropped by an estimated 9 to 13 degrees F (5-7 degrees C) over the next two years. El Niño is a periodic shift in air pressure accompanied by oceanic warming in the tropical Pacific.

Although the heart of El Niño's oceanic warming is in the tropical Pacific, it often fosters a circulation pattern that pushes relatively mild, moist air toward West Antarctica, where it can temporarily displace much colder air. As a result, West Antarctica has one of the world's most variable climates.

"These results help put Antarctica's recent climate trends into a global context," says Schneider.

Steig adds that while the influence of tropical climate on West Antarctica climate was not unknown, "these results are the first to demonstrate that we can unambiguously detect that influence in ice core records."

(ranked 7th in google search for "Antarctic climate")

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Antarctic Climate Affected by Humans and Nature Alike : Planetsave

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Written by **Joshua S Hill**

Published on August 17th, 2008

in **Climate Science & Research**

3 Comments

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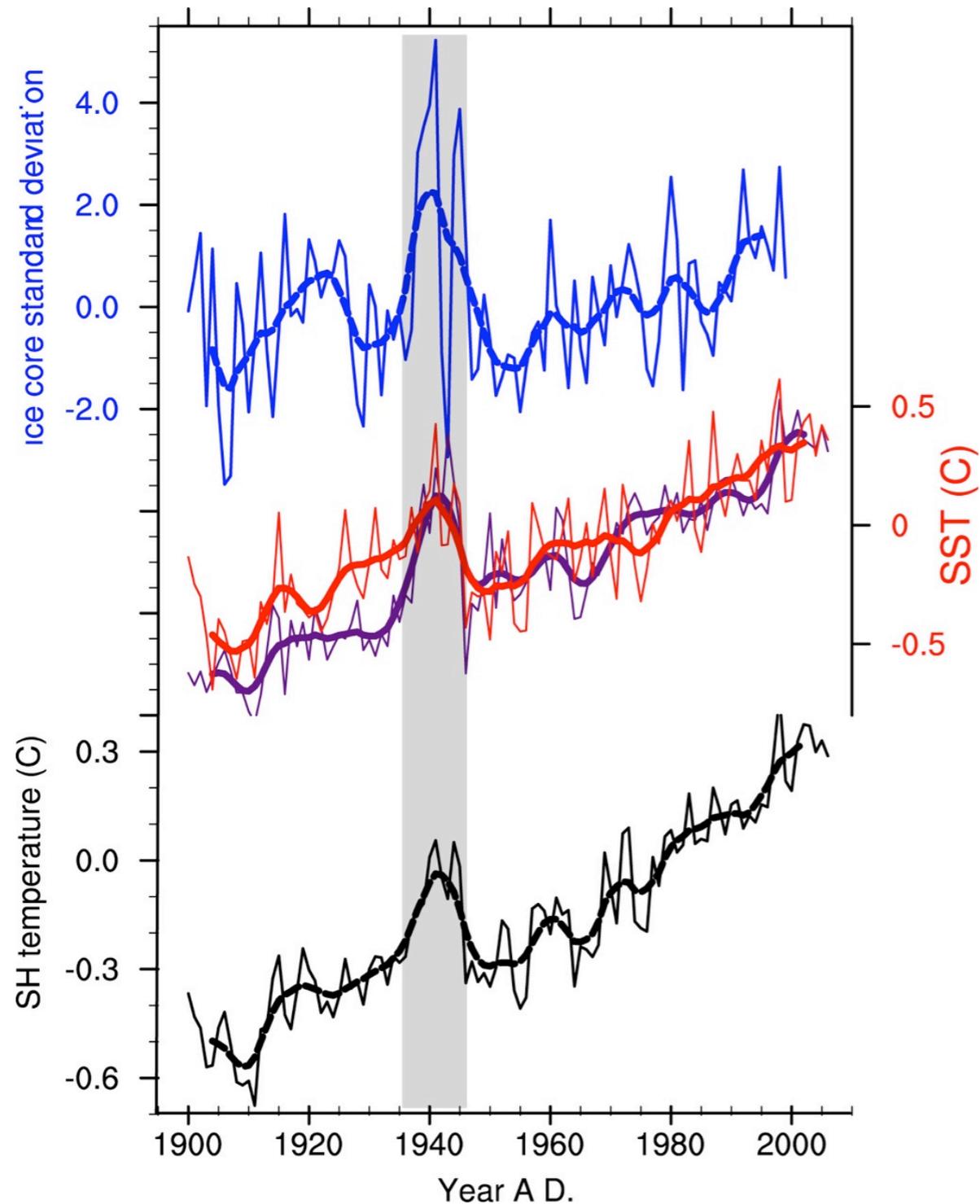


<http://planetsave.com/files/2008/08/elnino.jpg> While much of the world is focused on the Arctic during this Northern Hemisphere's summer, my own polar region is once again in the scientific news. Apparently, dramatic year-to-year temperature swings, as well as a century-long warming trend across West Antarctica, are not solely the fault of humans. Granted, we haven't helped matters.

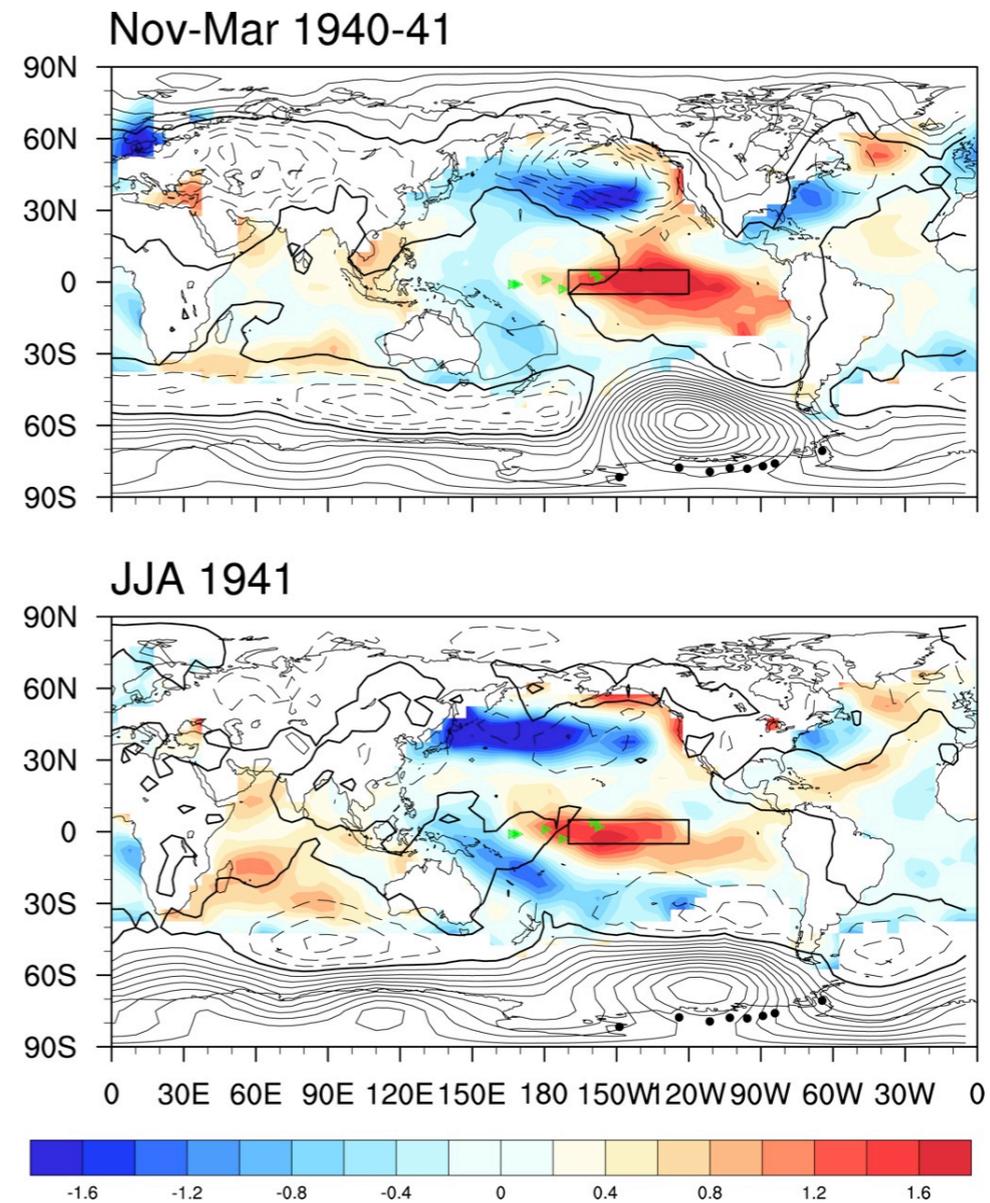
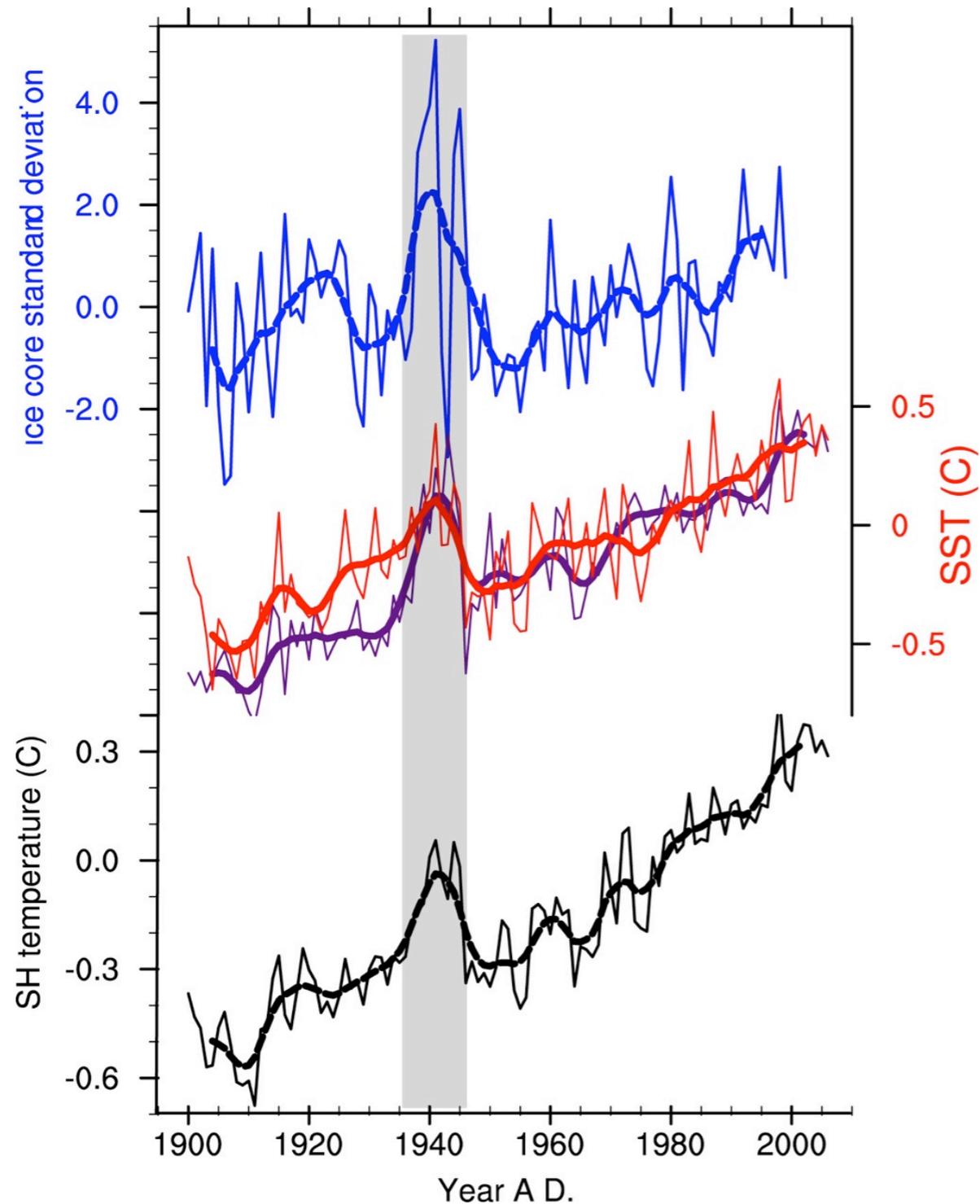
And while our getting let off the hook a little is and of itself intriguing, the source for West Antarctica's mysterious temperature swings makes its home in the tropical Pacific Ocean.

"As the tropics warm, so too will West Antarctica," said the National Center for Atmospheric Research's (NCAR) David Schneider, who conducted the research with the University of Washington's (UW) Eric Steig. "These ice

# Elucidating the connection of the tropics with Antarctic climate: A key role for tropical SST?



# Elucidating the connection of the tropics with Antarctic climate: A key role for tropical SST?



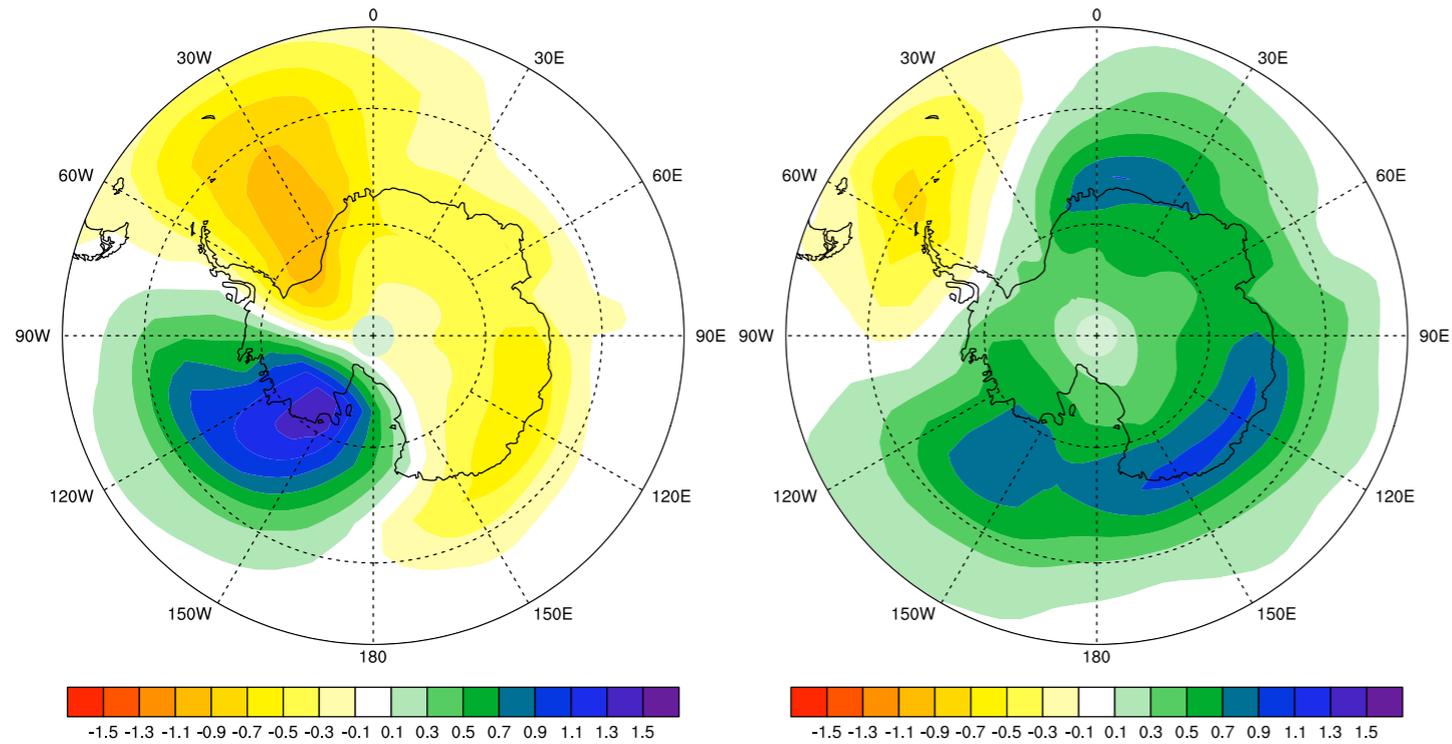
SST & SLP anomalies during the 1939-42 El Niño

(Schneider and Steig, 2008)

# Not all bad news for models

EOFs 1-2 of SH TREFHT JJA CSM1.4

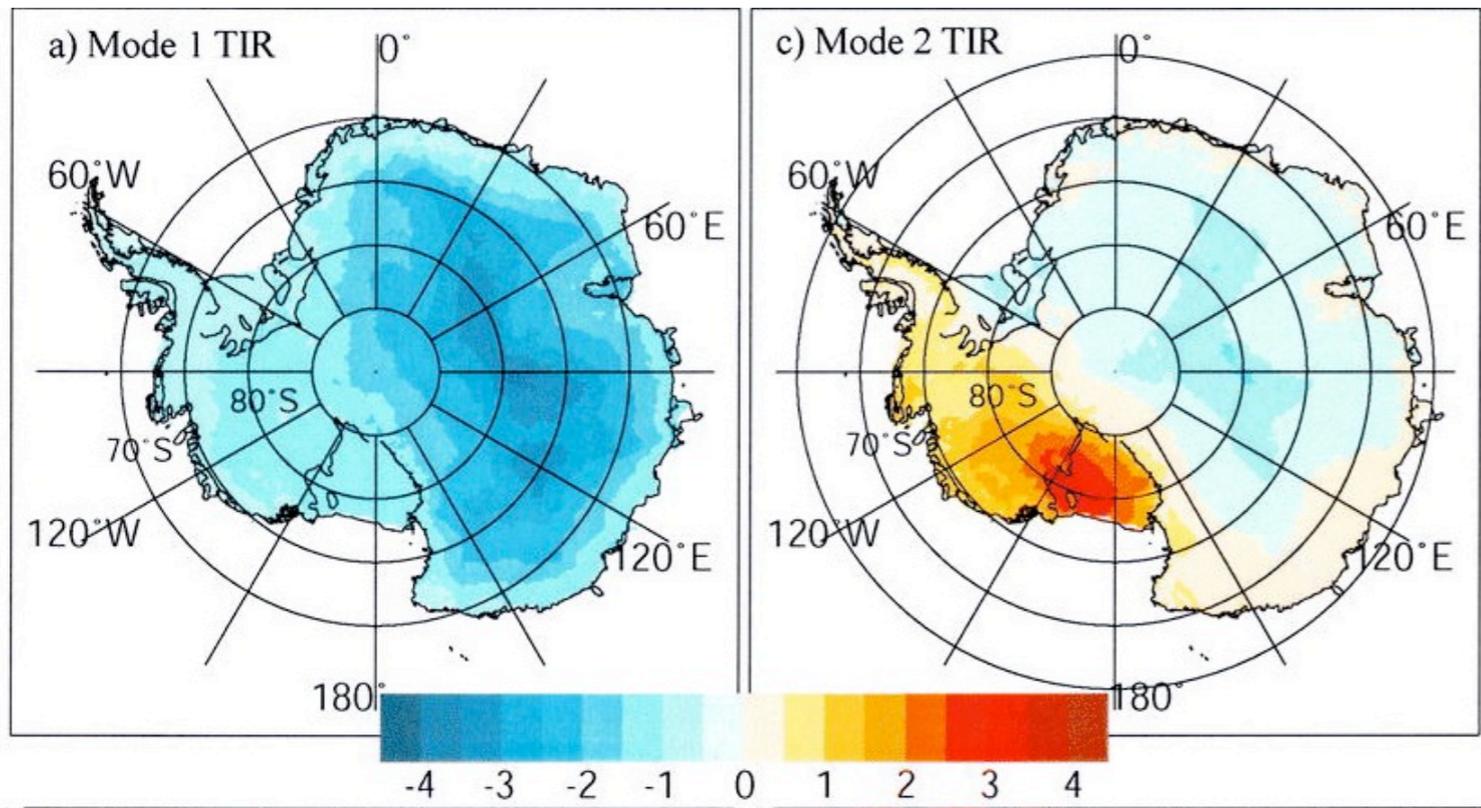
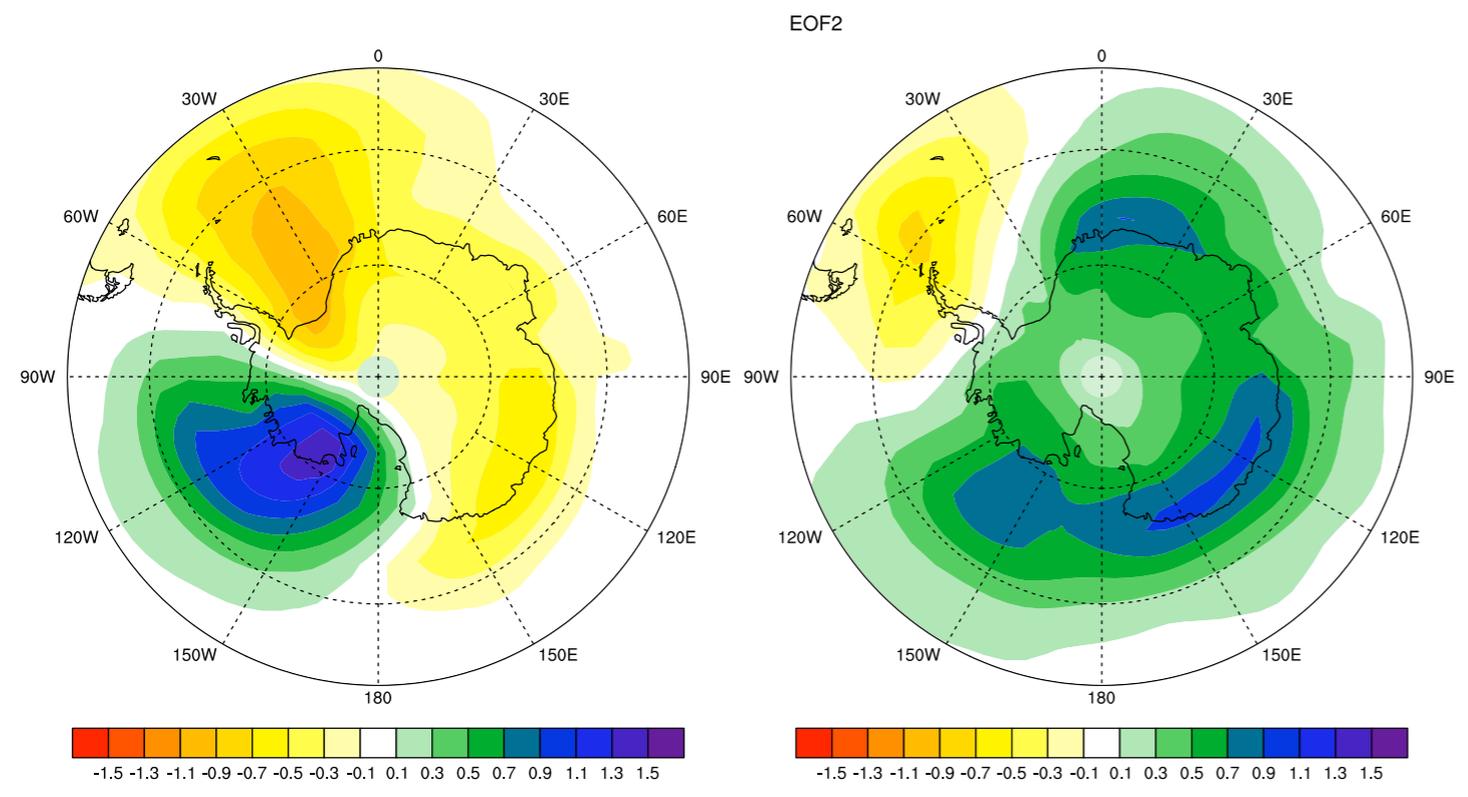
EOF2



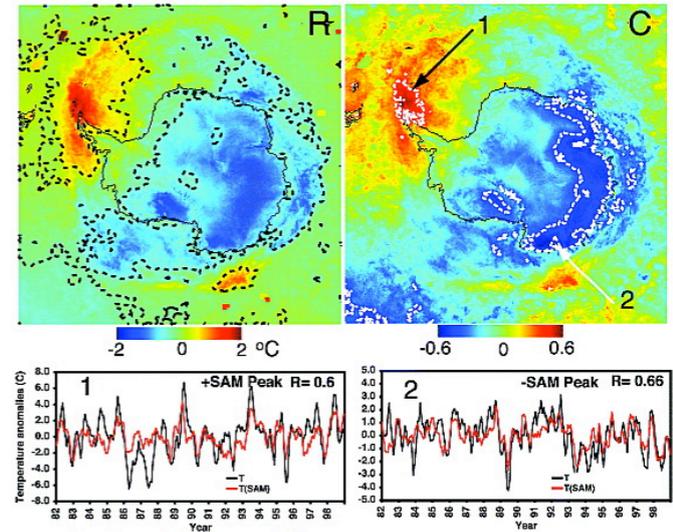
EOFs 1&2 in a 1150-year simulation using the Climate System Model version 1.4 (simulations by Caspar Ammann et al)

# Modeled & observed spatial patterns in near-surface temperature

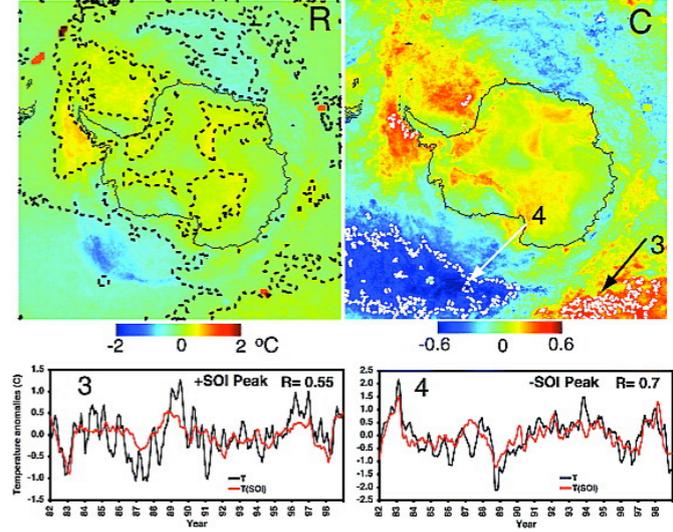
EOFs 1-2 of SH TREFHT JJA CSM1.4



(a) Surface Temp vs SAM



(b) Surface Temp vs SOI



surface temps vs SAM and SOI (Kwok and Comiso, 2003)

EOFs 1&2 of satellite-derived temps (Schneider et al., 2004)

# Summary

- Antarctic climate is poorly observed
- ITASE ice cores fill in a huge data gap
- Climate reconstructions based on ice cores enable comparisons with climate model simulations
- *Coupled* climate models have trouble reproducing the observed trends in Antarctic temperatures
- SST trends, El Ninos, are strongly linked to Antarctic climate, and are evident in the ice cores
- *Atmospheric* models forced by observed SSTs do a reasonably decent job of reproducing observed changes
- SST appears to play a stronger role in driving Antarctic trends than does ozone depletion
- West Antarctic warming over the past 100 years is greater than East Antarctic warming/cooling