[AV]The Evidence for a Changing Climate Recorded in Ice Sheets and Mountain Glaciers*

By
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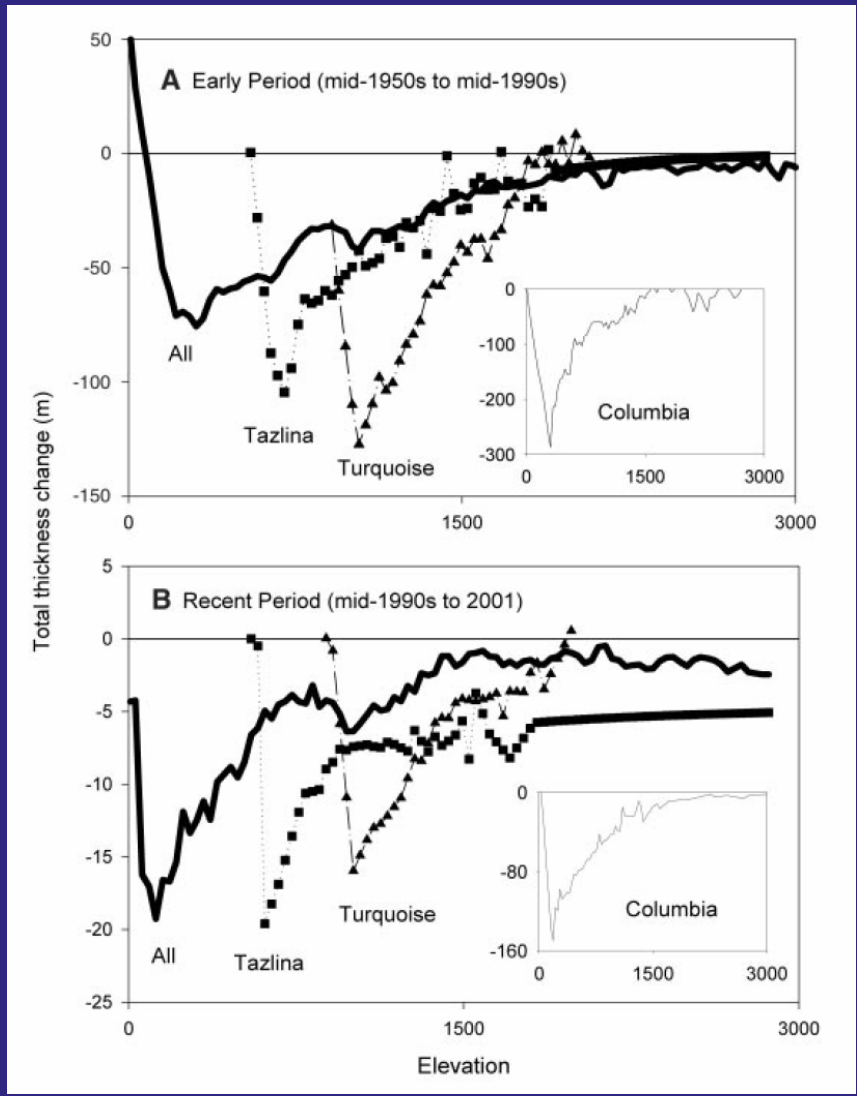
Abstract

Glaciers are sensitive to numerous aspects of climate, but their strongest relation is to summer temperatures. Through this connection, observations of glacier length can be used to reconstruct temperature history for the last few centuries, and this confirms the pattern and magnitude of 20th century warming inferred by other methods. Ice cores taken from high-altitude, low-latitude glaciers provide - via their isotopic composition - an objective measure of climate variability that suggests recent climate is anomalous. These data also reveal connections between climate and solar variability. In some places, retreat of glaciers is currently exposing organic material and sediments that were last exposed millennia ago. Current, ongoing changes of the polar ice sheets are related to increased air and ocean temperatures. These changes provide information about how polar land ice will be reduced as climate warms.

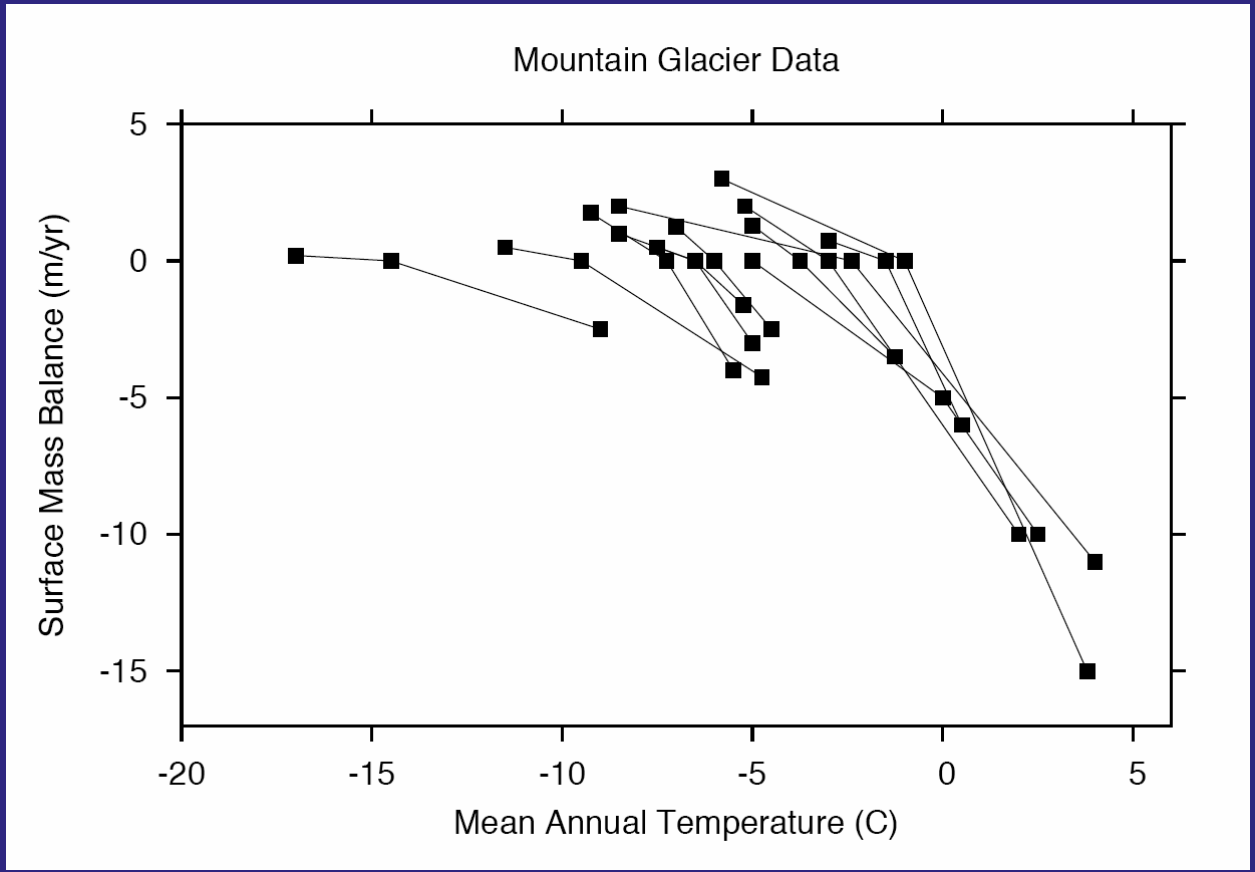

Glaciers and Recent Climate Change. Kurt M. Cuffey, U.C. Berkeley

Temperate and Sub-polar mountain glaciers: thinning and retreating

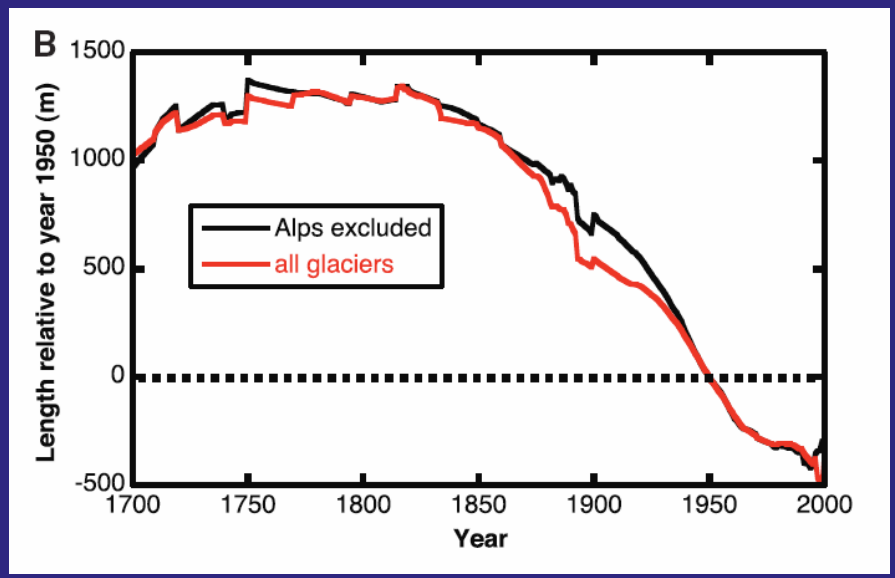


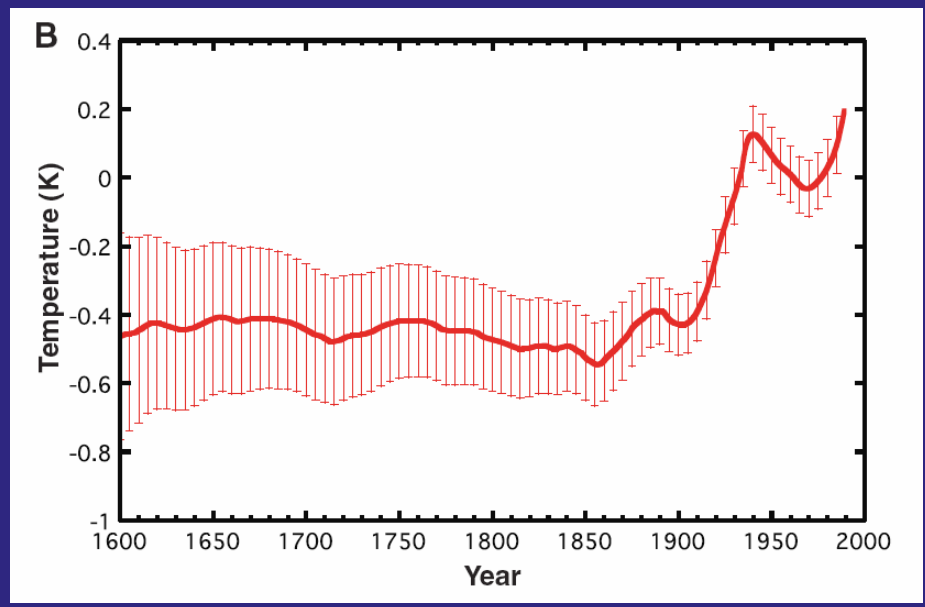
Arendt et al. 2002

On glaciers in “warm” conditions, the surface mass balance decreases by 1 to 2 m/yr per C of warming.



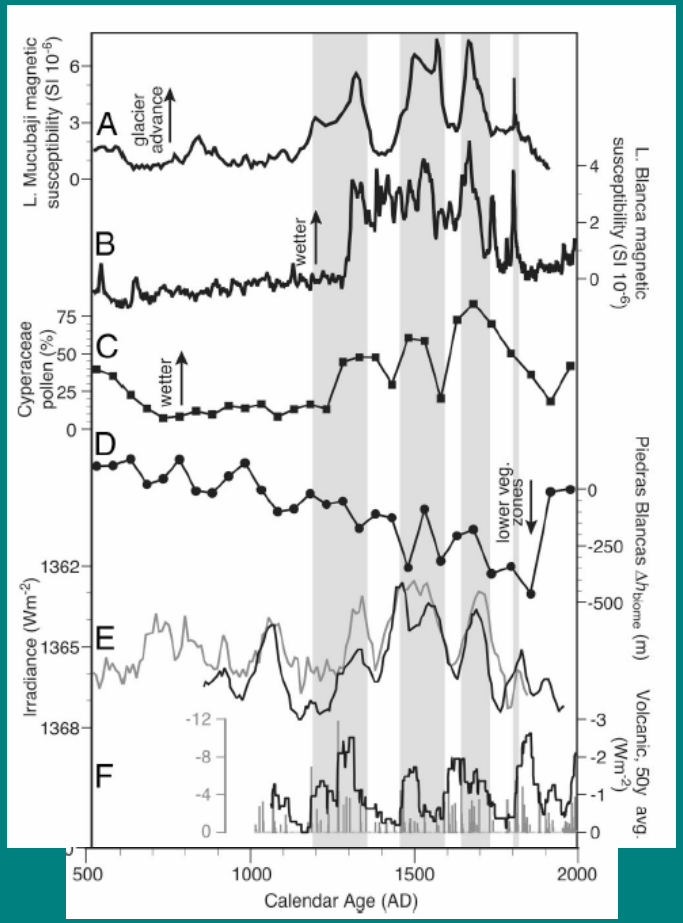
Implications of observed glacier retreat (Oerlemans, 2005)





The instrumentally measured warming is obviously not due to "urban heat islands" or similar artefacts

Glacier Advance/Retreat at Low Latitudes: The Equatorial Andes



Polissar et al. 2006

1. Some variations likely due to changes of the solar irradiance

2. Some good evidence that recent retreat is anomalous for the entire last half of the Holocene

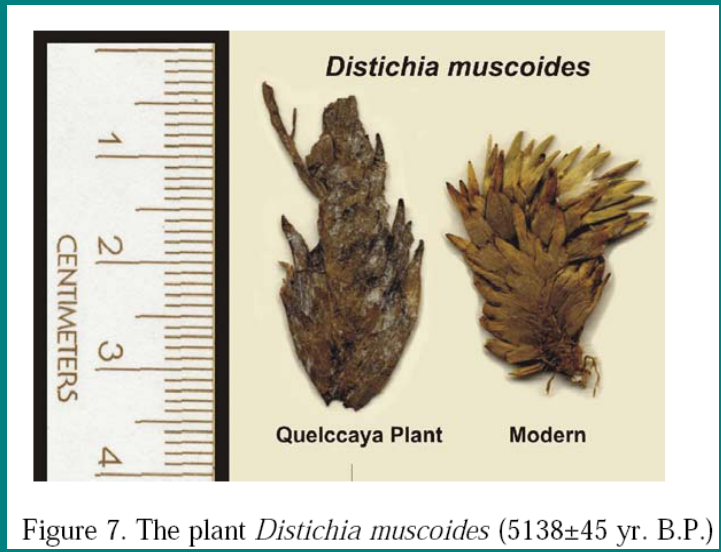
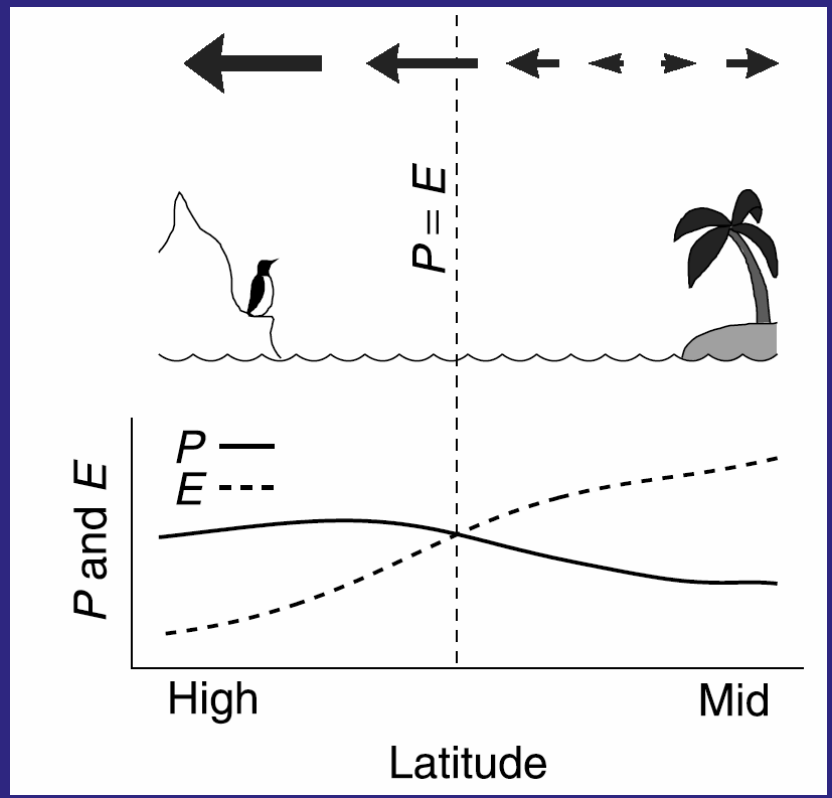


Figure 7. The plant *Distichia muscoides* (5138±45 yr. B.P.)

Thompson et al. 2006 PNAS

Also: melt-elimination of seasonal isotopic signal at Quelccaya (Thompson et al. 2003)

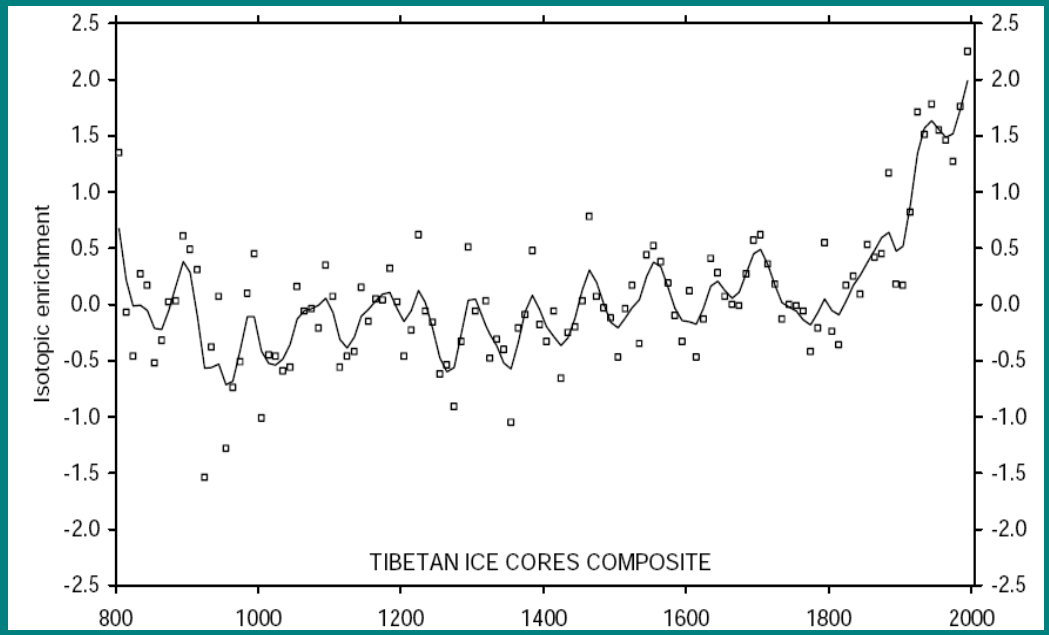
Isotopic distillation accompanies vapour transport to cold regions: whether high latitude or altitude. Depends on major climate variables: the temperature distribution, and strength of evaporative recharge.

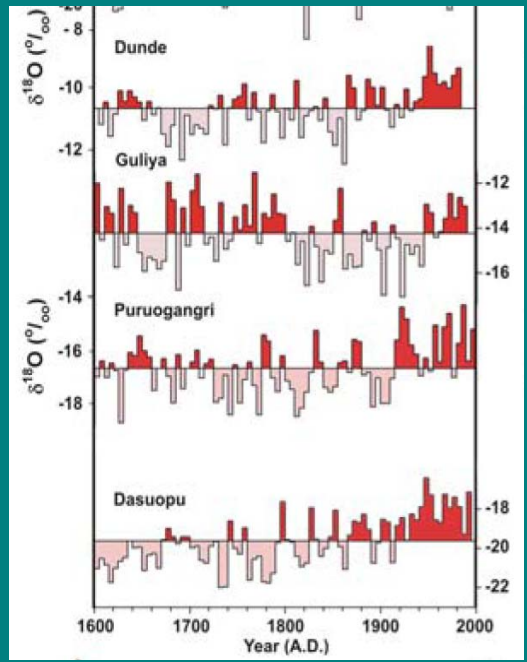


See, e.g. Kavanaugh and Cuffey, 2003.

Low-Latitude Isotope Records: Tibet

Thompson et al. 2006 PNAS





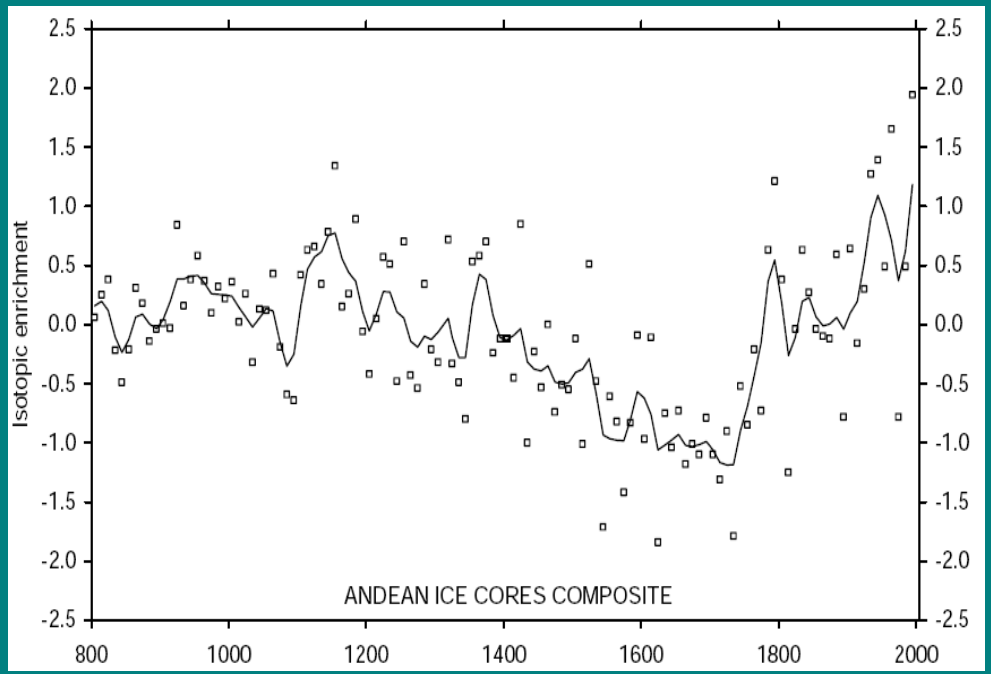
continental

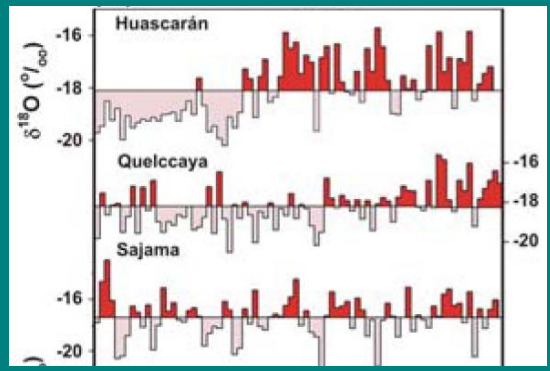
monsoonal

1. Solar variability (almost certainly!) at 80-year period
2. Solar effect from 1500-1800, evident in Andean retreat, is subtle
3. Recent climate change is anomalous

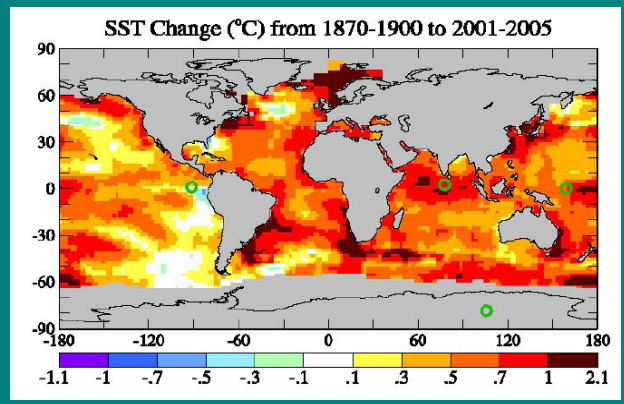
Low-Latitude Isotope Records: Andes

Thompson et al. 2006 PNAS





1. Recent climate is anomalous
2. Major pre-anthropogenic change: (solar? Seems plausible)
3. Recent isotopic enrichment (1850 - 2000) related to sea surface warming?



Hansen et al. 2006

Recent Collapse of Ice Shelves on Antarctic Peninsula

The Peninsula is the one part of Antarctica that has warmed a lot in the last fifty years. The effects on ice have been major.

(1) Due to warming causing surface melt, assisting fracturing

(2) "Southward" progression of ice shelf collapses:
Wordie (1980s)
Gustav Channel (1980s)
Larsen A (1995)
Larsen B (2002)

(3) Persistence of Larsen B shelf through Holocene until about AD 2000.

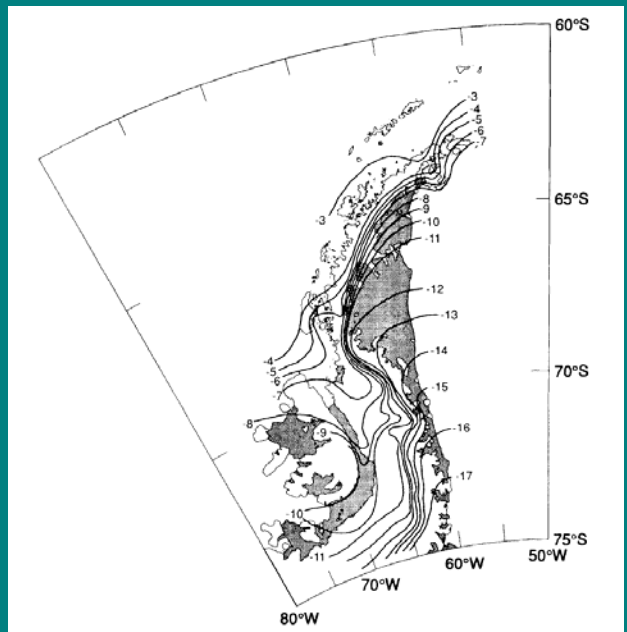


FIG. 1 Map of pre-1981 mean annual air temperatures in °C. Derived from temperatures 10 m below the ice surface, normalized to sea-level by Reynolds[16]. Ice shelves (shaded) are indicated at their mid-1970s extent.

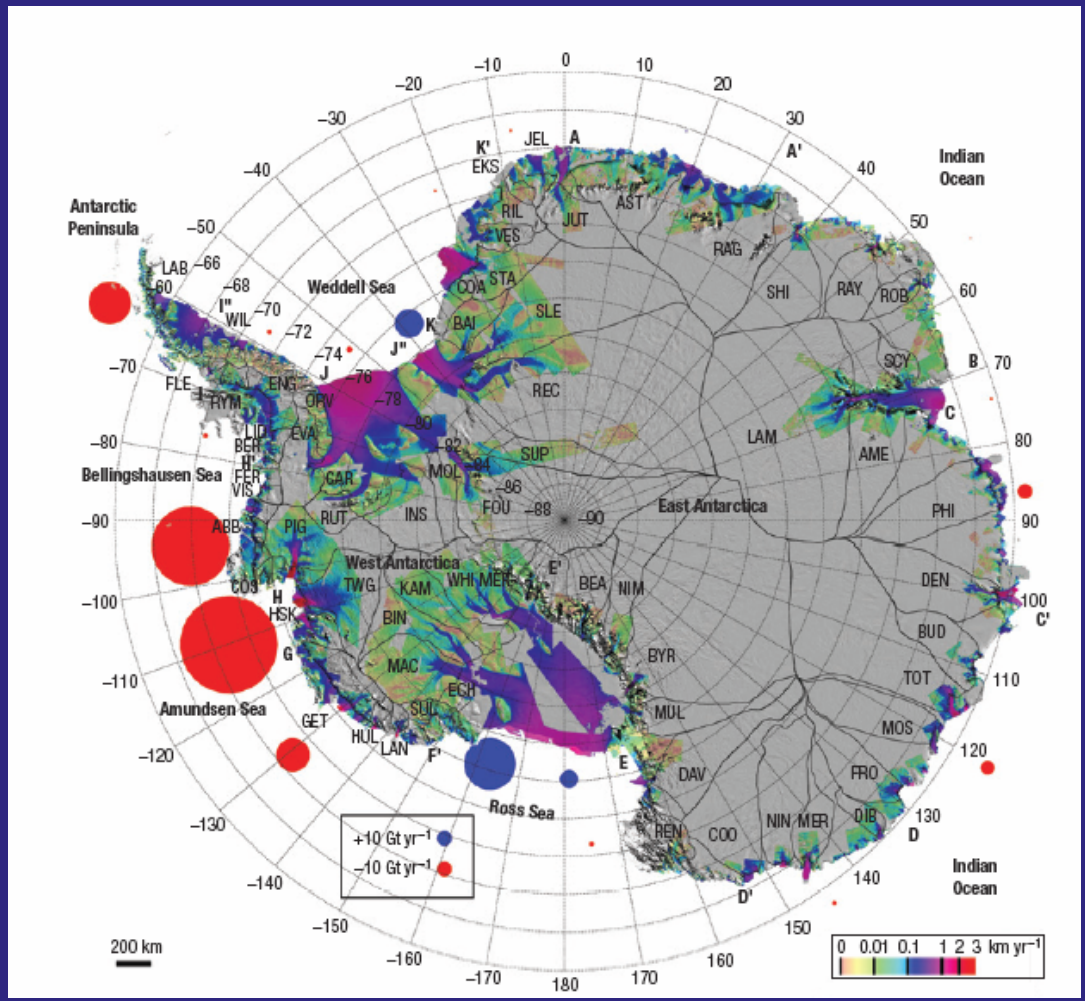
NATURE · VOL 379 · 25 JANUARY 1996

Image from NASA - EOS

J.H. Mercer (1978, Nature 271, p. 325): "One of the warning signs that a dangerous warming trend is under way in Antarctica will be the breakup of ice shelves on both coasts of the Antarctic Peninsula, starting with the northernmost and extending gradually southward."

Domack et al. 2005; Vaughan and Doake 1996; Scambos et al. 2004; Rack and Rott, 2004

Currently, both Antarctic and Greenland are losing mass. Here is Antarctica. Changes are apparently mostly due to ocean warming (Shepard et al 2004) and, in the Peninsula, increased surface melt (warming air).



Rignot et al. 2008

CONCLUSIONS:

1. Glacier retreat has, for many years, shown that global warming is not an artefact of urban heat islands and related effects.

2. Glacier retreat confirms the general pattern of warming established by the instrumental measurements

3. The recent tropical climate is anomalous

4. The solar forcing of climate imprints some glaciologic records; it is not a consistent signal compared to the recent warming

5. Warming on the Antarctic Peninsula has caused major glaciologic changes

6. Warming of air and ocean waters is currently causing the Antarctic and Greenland Ice Sheets to lose mass: Models of this process are inadequate.

7. Concerns about anthropogenic warming, and its possible effects on the cryosphere, were articulated clearly in the 1970s.

Acknowledgments: Please See the Reference List on the next page.

Slide References:

Slide 1: photograph of Ruth Glacier, Alaska Range. Photo by K. Cuffey.
Slide 2: Arendt, A.A., K.A. Echelmeyer, et al. 2002. Science 297, p. 382
Slide 3: data for twelve glaciers compiled from various sources by K. Cuffey. (most from the World Glacier Monitoring Service's Mass Balance Bulletins).
Slide 4: Oerlemans, J. 2005. Science 308, p. 675.
Slide 5: Polissar, P.J., M.A. Abbott, et al. 2006. PNAS 103, p. 8937;
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Slide 6: Kavanaugh, J.L. and K.M. Cuffey. 2003. Global Biogeochemical Cycles, 17, p. 1017
Slide 7: Thompson, L.G., E. Mosley-Thompson, et al. 2006. PNAS 103, p. 10536
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Slide 10: E. Rignot, J.L. Bamber, et al. 2008. Nature Geoscience, doi:10.1038/ngeo102;
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