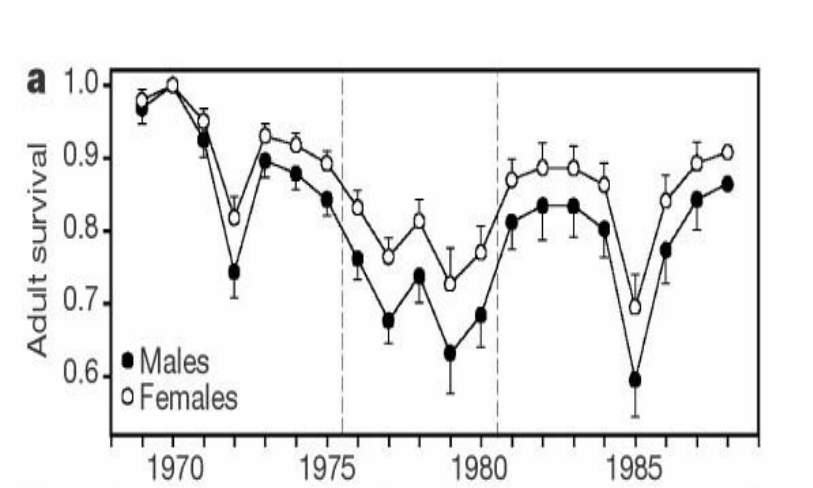
XIII. Antarctica: Penguins, Ice Shelves, and Sea-Level Rise

> ***AIT*:** Gore now turns to Antarctica, the "second canary in the coal mine." He faults the movie, *March of the Penguins*, for "thinking that the biggest challenge facing Antarctica's Emperor penguins is their icy cold habitat." According to Gore, "Scientists studying Emperor Penguins at the colony featured in the film found that their numbers have dropped by 70% since the 1960s. The likely culprit: global climate change." Global warming, he argues, weakens the ice, making it "more likely to break apart and drift out to sea, taking the penguins' eggs and chicks with it." (*AIT*, p. 178)

Comment: This is misleading at best. Gore gives the impression that Emperor penguins are in peril, their numbers falling as the world warms. He provides no reference but his source appears to be a study by Christophe Barbraud and Henri Weimerskirch, published in *Nature*.[1] Barbraud and Weimerskirch found that Antarctica's emperor penguin population "declined abruptly by 50% in the late 1970s and has stabilized since." Their data indicates that stabilization occurred around 1989. See the Figure below.



To say that the population dropped "since the 1960s" is accurate but so imprecise as to convey a false picture. There was a population decline in the 1970s but population has been stable since the late 1980s—a period of rising CO_2 concentrations and generally increasing global temperatures.

Gore attributes the population decline "since the 1960s" to ice breaking off and carrying penguin eggs and chicks out to sea. Barbraud and Weimerskirch say that "complete or extensive breeding failures in some years resulted from early break-out of the sea-ice holding up the colony," but their source is a study published in 1974. If this is an ongoing recurrent threat, as Gore suggests, why has the population been stable rather than declining over the past decade and a half?

Whereas Gore presents reduced pack ice as an unmitigated disaster for Emperor

penguins, Barbraud and Weimerskirch found a partially offsetting benefit. If there is less ice, penguins do not have to travel as far from the colony to the feeding ground. In a similar vein, Ainley et al. (2003) found that as ice shelves retreat, "extensive coastlines are available to be colonized and even re-colonized—about half the Antarctica circumference," which may be one reason most colonies of Adélie penguins are increasing.[2]

Oddly, Gore does not mention what Barbraud and Weimerskirch consider the main cause of the 1970s population decline—a reduction in the birds' food supply. They reason as follows. The penguins' diet mostly consists of krill. Krill breed under ice. Sea surface temperatures around Antarctica were anomalously high in the 1970s. Warmer seas meant less ice, hence less krill for the birds to eat. This is non-testable speculation. Nobody observed a reduction in the birds' food supply during the 1970s. Ainley et al. (2003) note that penguin diets consist not only of krill but also of fish and squid, and "the species adjusts its diet based on prey availability."

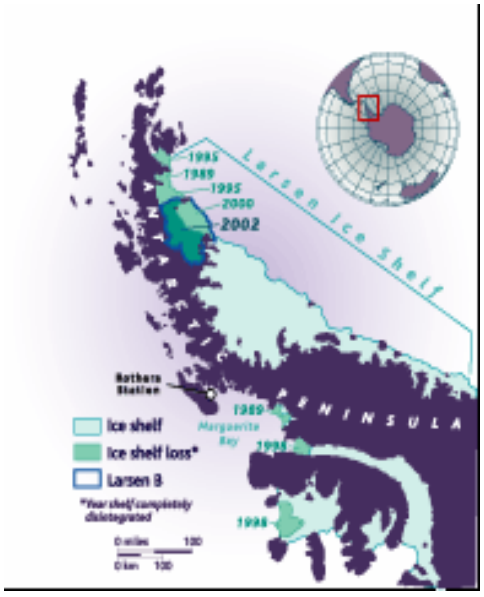
Nowhere do Barbraud and Weimerskirch state in their study that global warming caused the high SSTs assumed to have decreased the birds' food supply. Weimerskirch told *National Geographic* that he "thinks" global warming was "probably" the cause. But as *National Geographic* explains, there is no way to tell: "Whether it was the result of natural climate variability in the Antarctic circumpolar wave cycle or an anomaly related to global warming is not possible to determine because air and sea surface temperature data from many years ago are not available."[3]

What else might have reduced the Emperor penguin population in the late 1970s? According to one source, "Human disturbance may have been involved in the *c*.50% decrease in [Emperor Penguin] breeding populations in the Ross Sea sector."[4] Almost any human activity near or around a penguin colony—including tourism, use of motorized vehicles, and scientific research—"has the potential to cause mortality, reduction of reproductive success, and/or degradation of the nesting area." Patrick Michaels elaborates:

> Perhaps it's worth noting that the period of rapid decline in population coincides with the development of Antarctic "ecotourism," which means people visiting the rookeries as well as buzzing them in airplanes. Remember, the biggest thing these birds have seen in their tens of millions of years of evolutionary history is an albatross. A large airliner or a gaggle of tourists might cause quite a stir, moving them off their nests long enough to induce increased mortality. It's easy to freeze an egg at Antarctic temperatures, and we know which must come first: the egg, not the penguin![5]

A possible cause of penguin population decline in the early 1970s

> ***AIT*:** Gore presents a map showing the Antarctic Peninsula. "Each [dated, green] splotch represents an ice shelf the size of Rhode Island or larger that has broken up since [scientist John] Mercer issued his warning [in 1978]." (*AIT*, pp. 181-182) See Figure below.



Comment: "The size of Rhode Island or larger" sounds very big, hence very scary—until you recall that Rhode Island is the smallest State. Since 1978, the Antarctic Peninsula lost ice shelves totaling over 4,825 square miles.[6] That represents 1/55th the area of Texas (268,601 square miles), and falls short of the State's water area (6,687 square miles).[7] Rhode Island, at 1,214 square miles, is not even 1/220th the size of Texas. Imagine the impact on audiences had Gore said, "Each splotch represents an ice shelf 1/220th the size of Texas."

> ***AIT*:** "Scientists thought this ice shelf [Larson-B] would be stable for another century—even with global warming….They had thought the meltwater sank into the ice and refroze. Instead, as they now know, the water keeps sinking down and makes the ice mass look like Swiss cheese." (*AIT*, p. 183)

Comment: Again, some perspective is in order. The Larson-B ice shelf that broke up during January 31, 2002 to March 5, 2002 covered an area of 1,460 miles. Scientists overestimated the stability of an ice shelf 1/246th the size of the West Antarctic Ice Sheet (360,000 square miles).[8]

More importantly, research by Carol Pudsey of the British Antarctic Survey and three colleagues indicates that the breakup of the Larson-B and other Antarctic Peninsula ice shelves is not unprecedented. The Pudsey team examined the region's ice shelf history from "petrographic foraminiferal evidence" (fossils of tiny marine animals in rock sediments). Their data indicate that there was a "widespread ice shelf breakup in the mid-Holocene." This finding "suggests that the recent decay may not result entirely from anthropogenic climate perturbations." Thus, contrary to the impression Gore gives, that the Larson-B was stable until Man started to tamper with the climate, Pudsey and her colleagues note that, "the maximum ice shelf limit may date only from the Little Ice Age." Patrick Michaels comments:

> The work of Carole Pudsey and her colleagues contributes to a growing body of literature that makes clear the idea that the greatest extent of the Larsen ice shelf during the current interglacial period occurred only a few hundred years ago. The ice shelves that have recently disintegrated were likely created at about that same time, meaning that previously they did not exist. The recurring conclusion is that the recent global warming may not be unprecedented, and that a significant portion of the warming may be natural.[9]

> ***AIT*:** "Once the sea-based ice shelf was gone, the land-based ice behind it that was being held back began to shift and fall into the sea. This, too, was unexpected and carries important implications because ice—whether in the form of a mountain glacier or a land-based ice shelf in Antarctica or Greenland—raises the sea level when it melts or falls into the sea." (*AIT*, p. 184)

Comment: The break-off of floating ice shelves accelerates the flow of land-based ice behind them; however, this does not mean the larger structure is unraveling or about to do so. A recent literature review in *Science* noted that the collapse of the Larson-B ice shelf "was followed by speedup of its major tributary glaciers, by twofold to eightfold where they entered the former ice shelf," but also that the speedup was no longer observable beyond about 10 km inland, that "slight decelerations" occurred "only 1 year later," and hence that "these events may just represent fast adjustments to marginal fluctuations." The study concludes that, "The recent glacier accelerations are too young…and the observational record is too short to evaluate whether they represent short-term

fluctuations or are part of a longer term trend that might scale with future climatic warming."[10] The article estimates that the accelerated glacier flow after the Ross-B breakup "contributed about 0.07mm/year to sea-level rise"—equivalent to less than 0.3 inches in a century.

> ***AIT*:** "Many residents of low-lying Pacific Island nations have already had to evacuate their homes because of rising seas." (*AIT* p. 186)

Comment: The two-page photograph accompanying this statement is titled "High Tide in Funafuti, Tuvalu, Polynesia." The photo doesn't jibe with the text. It shows a young boy playing in the water, while his mother, unperturbed by the wave crashing a few feet from her workbench, washes clothes and tends to baby sister. Nobody is fleeing from anything in this picture.

More importantly, tide gauge records show that sea levels at Tuvalu *fell* during the latter half of the 20th century. Altimetry data from the Topex-Poseiden satellite show that Tuvalu sea levels fell even during the 1990s, touted by the IPCC as the warmest decade in a thousand years.[11] Tuvalu, at 179E longitude and 8S latitude, is smack dab in the central blue areas where sea levels fell.

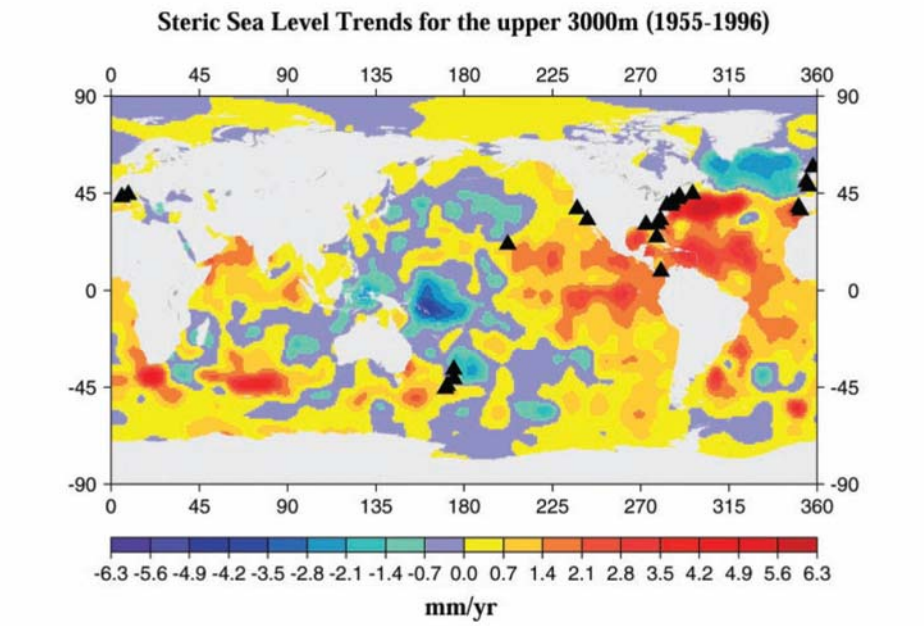
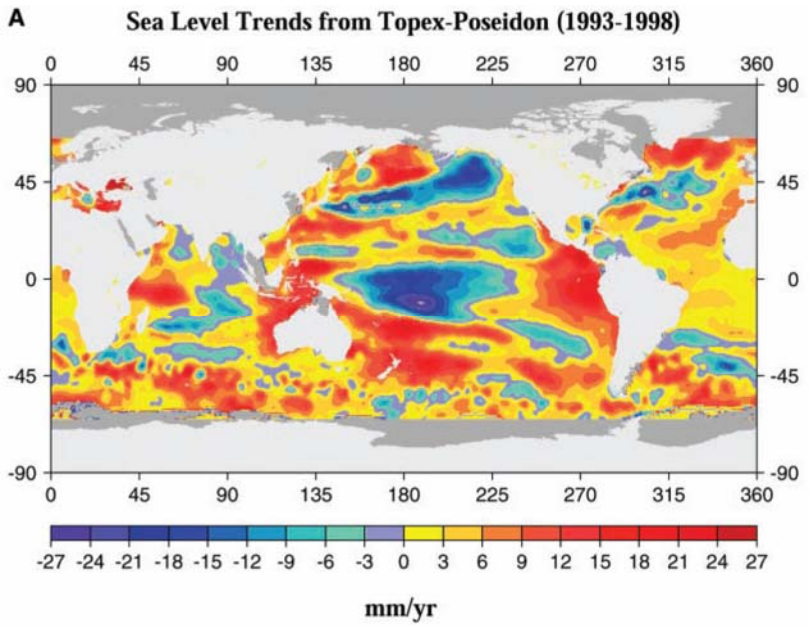


Fig. 4. Map of the geographical distribution of thermosteric sea level trends for 1955–96 computed with temperature data from (3) down to 3000-m depths. Black triangles show the locations of the 25 tide gauges.



Source: Cabanes et al. (2001).

> ***AIT*:** "The Thames River, which flows through London, is a tidal river. In recent decades, higher sea levels began to cause more damage during storm surges, so a quarter of a century ago, the city built these barricades that can be closed for protection." Gore presents a graph showing that annual closures of the Thames barriers increased in recent years. (*AIT*, pp. 188-189)

Comment: Recent increases in the annual number of Thames barrier closings are not evidence of increased flood risk due to global warming-induced sea-level rise.

To begin with, in recent years authorities have closed the barriers to keep water in the Thames as well as keep tidal surges out. As the U.K. Department of Environment, Food, and Rural Affairs explains:

> Because the Thames River Barrier is now subject to different operating rules, it may be less useful as an indicator [of flood defence]. The barrier is now closed to retain water in the Thames River as well as to lessen the risk of flooding. (It was closed on 9 successive tides at the start of 2003.) Thus, the number of closures has increased greatly in recent years. This indicator would only be useful if it were possible to distinguish the number of closures made specifically to lessen flood risk.[12]

Second, quite apart from any global change in sea levels, London is sinking. As the UK Environment Agency explains:

> Tide levels are steadily increasing owing to a combination of factors. These include higher mean sea levels, greater storminess, increasing tide amplitude, the tilting of the British Isles (with the south eastern corner

> tipping downwards) and the settlement of London on its bed of clay. As a result tide levels are rising in the Thames Estuary, relative to the land, by about 60cm per century. Surge tides are a particular threat and occur under certain meteorological conditions.[13]

To put this in perspective, according to the IPCC, "the rate of average global sea level rise in the 20th century is in the range of 1.0 to 2.0 mm/year."[14] That means 1-2 centimeters per decade or 10-20 centimeters per century. So relative to the land, the London tide is rising anywhere from three to six times faster than global sea-level rise.

Third, risk perceptions influence barrier closure decisions. The initial stimulus to build the barrier system was a flood in 1953 that killed 300 people. "Today," a CBS News feature comments, "such a flood would be far more deadly. One and a quarter-million people now live on the Thames river flood plain. Thanks to a booming economy, more are moving in each month."[15] The more people and property at risk, the more risk-averse decision makers are likely to be.

Given the confounding variables—barrier closings for purposes other than flood control, the sinking of London, the post-glacial tilt of the British Isles, the high priority UK authorities place on avoiding the next killer flood, to say nothing of the natural variability of North-Sea weather—it is impossible to discern a global climate signal in the number of annual Thames barrier closings.

Although the Thames barriers were completed in 1982 and was first used in 1983, Gore's graph of annual barrier closings (page 189) goes back to 1930. Perhaps the graph's pre-1980s portion illustrates the operation of earlier flood control devices—in which case, it is comparing apples to oranges. By so doing, the graph gives the impression that storm surges on the Thames became a serious threat only recently, in the era of greenhouse warming. Not so. Consider this snippet from the UK Government's Environment Agency:

> **"There was last night the greatest tide that was ever remembered in England to have been in this River all Whitehall having been drowned."** Thus wrote Samuel Pepys in his diary on 7th December 1663. Even in Pepys' day the menace of flooding on the Thames had a long established history. In 1236 the river was reported as overflowing "and in the great Palace of Westminster men did row with wherries in the midst of the hall." (John Stow, The Chronicles of England) The last time that central London flooded was in 1928 when 14 people drowned. In 1953 there was disastrous flooding on the East Coast and the Thames Estuary with a toll of over 300 lives. If this flood had reached central London's highly populated low lying areas the result could have been horrifying beyond measure.[16]

***AIT*:** "Further sea level rise could be many times larger and more rapid depending on what happens in Antarctica and Greenland—and on choices we make or do not

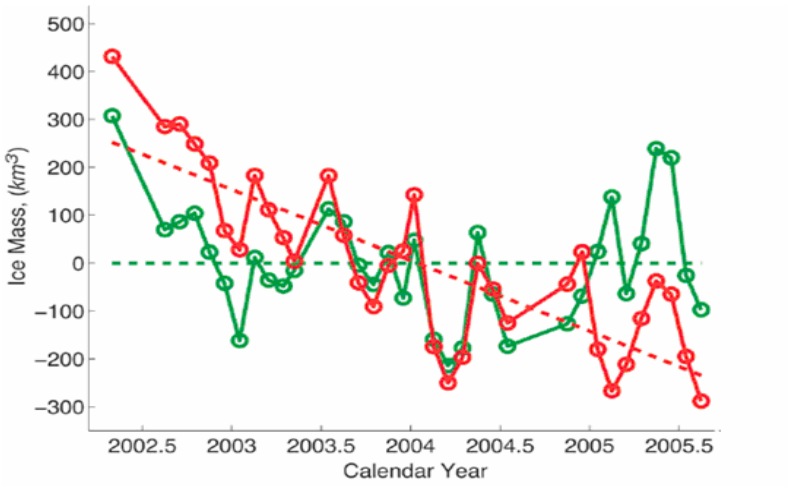
> make—now concerning global warming." (*AIT*, p. 189)

Comment: Almost anything is possible, but how much sea level rise may we reasonably infer from 20th century data? A recent study by Church and White (2006), using TOPEX-Poseidon and Jason-1 satellite altimeters as well as tide gauge data, found a global mean sea level rise of 195 mm (~7.6 inch) from January 1870 to December 2004, a 20th century sea-level rise rate of 1.7 ± 0.3 mm/year, and "a significant acceleration of sea-level rise [during the 135-year period] of 0.013 ± 0.006 mm/year."[17] The researchers estimate that if this acceleration persists through the 21st century, "sea level in 2100 would be 310 ± 30 mm higher than in 1990"—about 12 inches higher. A foot of sea-level rise is not trivial, but neither is it alarming. The U.S. East Coast experienced some of the world's most rapid sea level rise during the last half of the 20th century.[18] Yet development and property values exploded.

Gore's remark that sea level rise could be "many times larger and more rapid depending…on the choices we make or do not make—now concerning global warming," is just plain wrong. The most aggressive choice America could make "now" would be to join the European Union in implementing the Kyoto Protocol. But according to Tom Wigley of the National Center for Atmospheric Research, Kyoto would avert only 1 cm of sea-level rise by 2050 and 2.5 cm by 2100. That's because Kyoto would avert only 0.07°C of warming by 2050 and 0.15°C by 2100.[19] The energy policy choices we make or do not make "now" cannot materially affect the rate of sea-level rise in the 21st century.

> ***AIT*:** "The East Antarctic ice shelf is the largest ice mass on the planet and had been thought to be still increasing in size. However, two new studies in 2006 showed overall volumes of ice in Antarctica appear to be declining, and that 85 percent of the glaciers there appear to be accelerating their flow toward the sea." (*AIT*, p. 190)

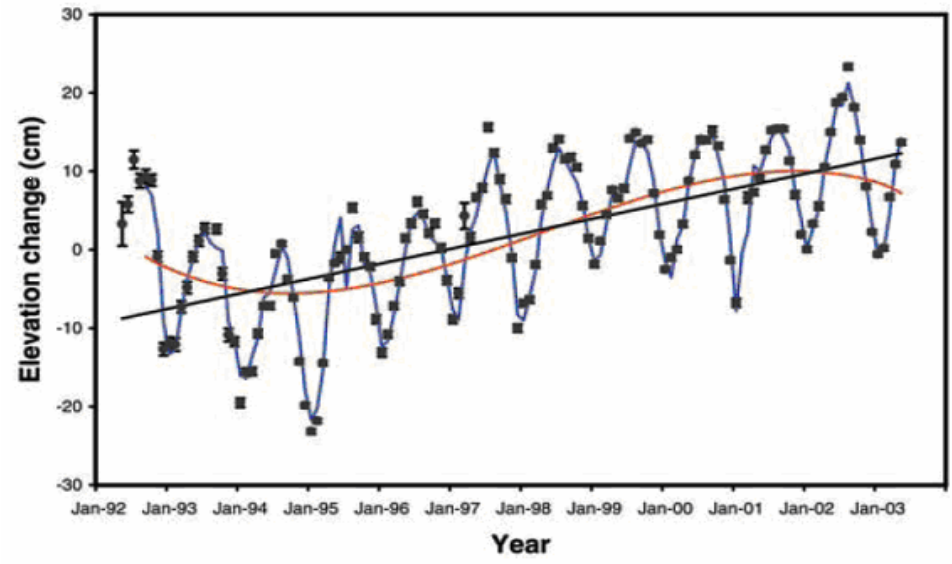
Comment: Of the two studies to which Gore alludes, I can identify only one. Isabella Velicogna and John Wahr of the University of Colorado used satellite measurements of gravity fluctuations to infer ice-mass changes in Antarctica.[20] Gore gives the impression that all of Antarctica, including the East Antarctic Ice Sheet (EAIS), is losing ice mass. In fact, almost all the ice loss observed by Velicogna and Wahr comes from the smaller West Antarctic ice sheet (WAIS).[21]



Source: Velicogna and Wahr (2006). The ice mass variations over the West Antarctic Ice Sheet (red) and the East Antarctic Ice Sheet (green).

A few months earlier, *Science* published a study by Davis et al. (2005), who examined Antarctic ice mass balance changes over a somewhat longer period, from May 1992 to May 2003.[22] The Davis team also found that the WAIS was losing mass. However, the larger EAIS was gaining mass (from snow accumulation) at a faster rate, yielding a net increase in Antarctic ice. The overall effect was to *reduce* sea-level rise by 0.09 mm/year.

As Patrick Michaels points out, Velicogna and Wahr begin their analysis at the peak of ice mass accumulation in Davis et al.'s longer record. See the Figure below.



Source: Davis et al. (2005). The ice mass changes (in terms of elevations change) observed over the East Antarctic Ice Sheet from May 1992-May 2003.

"Notice," says Michaels, "that in mid-2002 (the start of the Velicogna and Wahr analysis) ice mass was at the highest level in the record. This means that the apparent decline in the record of Velicogna and Wahr may simply be the short-term correction to an anomalously high mass gain during a period of long-term mass growth." He then adds:

"But who is to know for sure? It is impossible to tell anything about a trend in a system as vast as Antarctica with less than three years worth of data."

Two other recent studies also indicate a positive mass balance in Antarctica. Chen et al. (2006) found that, during April 2002 to November 2005, ice mass gains in the EAIS exceed ice mass losses in the WAIS, creating a small positive net gain.[23] Similarly, Wingham et al. (2006) found that, during 1992-2003, mass gains from accumulating snow on the Antarctic Peninsula and within East Antarctica exceeded ice mass loss in West Antarctica.[24]

> ***AIT*:** "Second, air temperatures higher above the ice warmed more rapidly than air temperatures anywhere else on earth. This finding was actually a surprise, and scientists have not yet been able to explain why it is occurring." (*AIT*, p. 190)

Gore refers to a study by John Turner and colleagues of the British Antarctic Survey. The Turner team analyzed weather balloon data over the past 30 years and found a 0.5°C to 0.7°C per decade wintertime warming trend in the mid-troposphere above Antarctica. That is a warming rate about three times faster than the global average.

Lest anyone start to panic, several points should be kept in mind. First, NASA satellites that also measure troposphere temperatures show a 0.12°C per decade Antarctic *cooling trend* since November 1978.[25] Second, as Gore indicates, the Turner group could not reproduce the observed warming pattern using climate models, leading the researchers to state that they "are unable to attribute these changes to increasing greenhouse gas levels at this time." Third, the 0.5-0.7°C per decade warming observed by Turner et al. is occurring in the middle atmosphere (at 600 hPa), not at the surface, where the ice is. The Turner team reports an Antarctic surface-warming trend of 0.15°C per decade from 1971 to 2003—roughly the global average. Fourth, some records indicate that large areas of the Antarctic surface actually cooled in recent decades.[26]

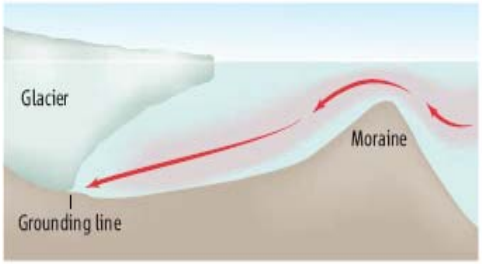
> ***AIT*:** "East Antarctica is still considered far more stable over long periods of time than the West Antarctic ice shelf, which is propped up against the tops of islands. This peculiar geology is important for two reasons: first, its weight is resting on land and therefore its mass has not displaced seawater as floating ice would. So if it melted or slipped off its moorings into the sea, it would raise sea levels worldwide by 20 feet. Second, the ocean flows underneath large sections of this ice shelf, and as the ocean has warmed, scientists have documented significant and alarming structural changes on the underside of the ice shelf." (*AIT*, p. 190)

Comment: Gore provides no information allowing the reader to assess whether the "structural changes on the underside of the ice sheet" are "significant" or "alarming." He probably refers to research by NASA's Robert Bindschadler showing that water from the intermediate depths—the warmest water in polar oceans—is melting the submarine base of the glaciers, accelerating their flow towards the sea.[27]

Bindschadler is careful to point out "the absence of any indication of increasing sea

surface temperature" in the polar oceans, and he notes that "warmth in the ocean arriving from lower latitudes would raise the temperature of this [comparatively warm] intermediate water a fraction of a degree, hardly enough to initiate a sudden glacier acceleration." So why are glaciers accelerating?

According to Bindschadler, once the intermediate layer penetrates the moraine, or sill (the barrier-like accumulation of boulders, gravel, and other debris deposited by the glacier as it retreats from its maximum extent), the water reaches the "grounding line," the boundary of the ice sheet's base on the sea floor. See the Figure below.



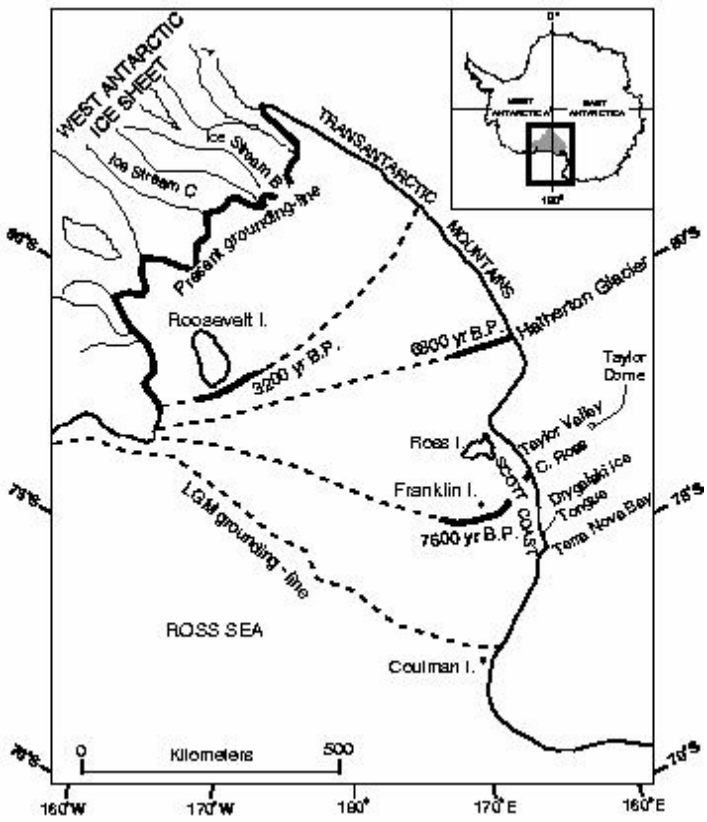
Oceanic low blows. Schematic representing warm intermediate-depth water breaching a submarine sill and sinking in a water cavity beneath the ice shelf to access the grounding line of an outlet glacier.

Source: Bindschadler (2006)

"Increased pressure at these greater depths lowers the melting point of this ice, increasing the melting efficiency of the warmer water. Rapid melting results." This explanation suggests a process that would occur with or without global warming. It also suggests a process that cannot be stopped. And that is what Bindschadler concludes:

> Retreating glaciers lengthen the distance warmer water must travel from any sill to the grounding line, and eventually tidewater glaciers retreat to beds above sea level. This might limit the retreat in Greenland but will save neither West Antarctica, nor the equally large subglacial basin in East Antarctica where submarine beds extend to the center of the ice sheet.

Conway et al. (1999), in a study mapping the retreat of the Ross Ice Shelf grounding line since the last glacial maximum (see Figure below), found that "most recession occurred in the middle to late Holocene in the absence of substantial sea level or climate forcing."[28]



Holocene grounding-line recession in the Ross Sea Embayment. Adapted from Conway et al. (1999).

Conway et al. conclude that the current grounding line retreat is likely natural and will continue even in the absence of greenhouse forcing:

> We suggest that modern grounding-line retreat is part of ongoing recession that has been under way since the early to mid-Holocene time. It is not a consequence of anthropogenic warming or recent sea level rise. In other words, the future of the WAIS may have been predetermined when grounding-line retreat was triggered in early Holocene time. Continued recession and perhaps even complete disintegration of the WAIS within the present interglacial period could well be inevitable.

When might the "inevitable" occur? Conway et al. state that "if the grounding line continues to pull back at the present [i.e. 1990s] rate, complete deglaciation will take about 7,000 years." Of course, such estimates are uncertain, because ice sheets are dynamic systems that can change in unpredictable ways and global warming might measurably accelerate the ongoing recession of the WAIS.

Nonetheless, the "significant and alarming structural changes" to which Gore alludes have likely been going on for millennia, with no help from man-made global warming.

Gore cites no specific evidence to justify fears of an impending collapse of the WAIS, or large portions of it, within the next several centuries.

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[26] See, for example, Doran, P.T., J.C. Priscu, W.B. Lyons, J.E. Walsh, A.G. Fountain, D.M. McKnight, D.L. Moorhead, R.A. Virginia, D.H. Wall, G.D. Clow, C.H. Fritsen, C.P. McKay, and A.N. Parsons. 2002. Antarctic climate cooling and terrestrial ecosystem response. *Nature* 415: 517-520.
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