

THE ROLE OF GREENLAND IN SEA LEVEL RISE  
*A Summary of the Current Literature*

by  
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*The Greenland ice sheet would appear to have experienced no net loss of mass over the last decade for which data are available. Quite to the contrary, in fact, it was likely host to a net accumulation of ice, which Zwally et al. found to be producing a  $0.03 \pm 0.01$  mm/year decline in sea-level.*

In the 24 March 2006 issue of *Science*, a number of commentaries heralded accelerating discharges of glacial ice from Greenland and Antarctica, while dispensing dire warnings of an imminent large, rapid and accelerating sea-level rise (Bindschadler, 2006; Joughin, 2006; Kerr, 2006; Kennedy and Hanson, 2006). This distressing news was based largely on three reports published in the same issue (Ekstrom *et al.*, 2006; Otto-Bliesner *et al.*, 2006; Overpeck *et al.*, 2006), wherein the unnerving phenomena were attributed to anthropogenic-induced global warming, which is widely claimed to be due primarily to increases in the air's CO<sub>2</sub> content that are believed to be driven by the burning of ever increasing quantities of fossil fuels such as coal, gas and oil. But does all of this make any sense?

Consider the report of Ekstrom *et al.*, who studied "glacial earthquakes" caused by sudden sliding motions of glaciers on Greenland. Over the period Jan 1993 to Oct 2005, they determined that (1) *all* of the best-recorded quakes were associated with major outlet glaciers on the east and west coasts of Greenland between approximately 65 and 76°N latitude, (2) "a clear increase in the number of events is seen starting in 2002," and (3) "to date in 2005, twice as many events have been detected as in any year before 2002."

With respect to the *reason* for the recent increase in glacial activity on Greenland, Clayton Sandell of ABC News (23 March 2006) quoted Ekstrom as saying "I think it is very hard not to associate this with global warming," which sentiment appears to be shared by almost all of the authors of the seven *Science* articles. Unwilling to join in that conclusion, however, was Joughin, who in the very same issue presented histories of summer temperature at four coastal Greenland

stations located within the same latitude range as the sites of the glacial earthquakes, which histories suggest that it was warmer in this region back in the 1930s than it was over the period of Ekstrom *et al.*'s analysis.

Based on these data, Joughin concluded that the recent warming in Greenland "is too short to determine whether it is an anthropogenic effect or natural variability," a position that is supported - and in some cases even more rigorously - by numerous scientists who have researched the issue, as noted in the following brief synopses of some of their studies.

Hanna and Cappelen (2003) determined the air temperature history of coastal southern Greenland from 1958-2001, based on data from eight Danish Meteorological Institute stations in coastal and near-coastal southern Greenland, as well as the concomitant sea surface temperature (SST) history of the Labrador Sea off southwest Greenland, based on three previously published and subsequently extended SST data sets (Parker *et al.*, 1995; Rayner *et al.*, 1996; Kalnay *et al.*, 1996). Their analyses revealed that the coastal temperature data showed a cooling of 1.29°C over the period of study, while two of the three SST databases also depicted cooling: by 0.44°C in one case and by 0.80°C in the other. In addition, it was determined that the cooling was "significantly inversely



correlated with an increased phase of the North Atlantic Oscillation over the past few decades."

In an even broader study based on mean monthly temperatures of 37 Arctic and 7 sub-Arctic stations, as well as temperature anomalies of 30 grid-boxes from the updated data set of Jones, Przybylak (2000) found that (1) "in the Arctic, the highest temperatures since the beginning of instrumental observation occurred clearly in the 1930s," (2) "even in the 1950s the temperature was higher than in the last 10 years," (3) "since the mid-1970s, the annual temperature shows no clear trend," and (4) "the level of temperature in Greenland in the last 10-20 years is similar to that observed in the 19th century." These findings led him to conclude that the meteorological record "shows that the observed variations in air temperature in the real Arctic are in many aspects not consistent with the projected climatic changes computed by climatic models for the enhanced greenhouse effect," because, in his words, "the temperature predictions produced by numerical climate models significantly differ from those actually observed."

In a study that utilized satellite imagery of the Odden ice tongue (a winter ice cover that occurs in the Greenland Sea with a length of about 1300 km and an aerial coverage of as much as 330,000 square kilometers) plus surface air temperature data from adjacent Jan Mayen Island, Comiso *et al.* (2001) determined that the ice phenomenon was "a relatively smaller feature several decades ago," due to the warmer temperatures that were prevalent at that time. In fact, they report that observational evidence from Jan Mayen Island indicates that temperatures there actually cooled at a rate of  $0.15 \pm 0.03^{\circ}\text{C}$  per decade throughout the prior 75 years.

More recently, in a study of three coastal stations in southern and central Greenland that possess almost uninterrupted temperature records between 1950 and 2000, Chylek *et al.* (2004) discovered that "summer temperatures, which are most relevant to Greenland ice sheet melting rates, do not show any persistent increase during the last fifty years." In fact, working with the two stations with the longest records (both over a century in length), they determined that coastal Greenland's peak temperatures occurred between 1930 and 1940, and that the subsequent decrease in temperature was so substantial and sustained that then-current coastal temperatures were "about  $1^{\circ}\text{C}$  below their 1940 values." Furthermore, they note that "at the summit of the Greenland ice sheet the summer average temperature has decreased at the rate of  $2.2^{\circ}\text{C}$  per decade since the beginning of the measurements in 1987."



At the *start* of the 20th century, however, Greenland *was* warming, as it emerged, along with the rest of the world, from the depths of the Little Ice Age. What is more, between 1920 and 1930, when the atmosphere's CO<sub>2</sub> concentration rose by a mere 3 to 4 ppm, there was a *phenomenal* warming at all five coastal locations for which contemporary temperature records are available. In fact, in the words of Chylek *et al.*, "average annual temperature rose between 2 and  $4^{\circ}\text{C}$  [and by as much as  $6^{\circ}\text{C}$  in the winter] in less than ten years." And this warming, as they note, "is also seen in the  $^{18}\text{O}/^{16}\text{O}$  record of the Summit ice core (Steig *et al.*, 1994; Stuiver *et al.*, 1995; White *et al.*, 1997)."

In commenting on this dramatic temperature rise, which they call the *great Greenland warming of the 1920s*, Chylek *et al.* conclude that "since there was no significant increase in the atmospheric greenhouse gas concentration during that time, the Greenland warming of the 1920s demonstrates that a large and rapid

temperature increase can occur over Greenland, and perhaps in other regions of the Arctic, due to internal climate variability such as the NAM/NAO [Northern Annular Mode/North Atlantic Oscillation], without a significant anthropogenic influence."

In light of these several real-world observations, it is clear that the recent upswing in glacial activity on Greenland likely has had nothing to do with anthropogenic-induced global warming, as temperatures there have yet to rise either as *fast* or as *high* as they did during the great warming of the 1920s, which was clearly a *natural* phenomenon. It is also important to recognize the fact that



coastal glacial discharge represents only *half* of the equation relating to sea level change, the other half being inland ice accumulation derived from precipitation; and when the mass balance of the *entire* Greenland ice sheet was recently assessed via satellite radar altimetry, quite a different result was obtained than that suggested by the seven *Science* papers of 24 March.

[Zwally et al. \(2005\)](#), for example, found that although "the Greenland ice sheet is thinning at the margins," it is "growing inland with a small overall mass gain." In fact, for the 11-year period 1992-2003, [Johannessen et al. \(2005\)](#) found that "below 1500 meters, the elevation-change rate is [a negative]  $2.0 \pm 0.9$  cm/year, in qualitative agreement with reported thinning in the ice-sheet margins," but that "an increase of  $6.4 \pm 0.2$  cm/year is found in the vast interior areas above 1500 meters." Spatially averaged over the bulk of the ice sheet, the net result, according to the latter researchers, was a mean increase of  $5.4 \pm 0.2$  cm/year, "or ~60 cm over 11 years, or ~54 cm when corrected for isostatic uplift." Consequently, the Greenland ice sheet would appear to have experienced no net loss of mass over the last decade for which data are available. Quite to the contrary, in fact, it was likely host to a net *accumulation* of ice, which Zwally et al. found to be producing a  $0.03 \pm 0.01$  mm/year *decline* in sea-level.

In an attempt to downplay the significance of these inconvenient findings, Kerr quoted Zwally as saying he believes that "right now" the Greenland ice sheet is experiencing a net loss of mass. Why? Kerr says Zwally's belief is "based on his gut feeling about the most recent radar and laser observations." Fair enough. But *gut feelings* are a poor substitute for comprehensive real-world measurements; and even if the things that Zwally's intestines were telling him are ultimately found to be correct, their confirmation would only demonstrate just how rapidly

the Greenland environment can change. Also, we would have to wait and see how long the mass losses prevailed in order to assess their significance within the context of the CO<sub>2</sub>-induced global warming debate. For the present and immediate future, therefore, we have no choice but to stick with what existent data and analyses suggest, i.e., that *cumulatively since the early 1990s* and *conservatively* (since the balance is likely still positive), there has been no net loss of mass from the Greenland ice sheet.

Nevertheless, to hear Al Gore and his acolytes talk nowadays, one would think the Greenland Ice Sheet is teetering on the verge of extinction, melting rapidly and all but "slip-sliding away" into the ocean, where its unleashed water will raise global sea levels to heights that will radically alter continental coastlines and submerge major cities. The recent study of [Eldrett \*et al.\* \(2007\)](#), however, provides further new evidence that Mr. Gore's view of the matter is poles away from the truth.

The five researchers from the School of Ocean and Earth Science of the National Oceanography Centre of the University of Southampton in the UK report they "have generated a new stratigraphy for three key Deep Sea Drilling Project/Ocean Drilling Program sites by calibrating dinocyst events to the geomagnetic polarity timescale." In doing so, they say their detailed core observations revealed evidence for



"extensive ice-rafted debris, including macroscopic dropstones, in late Eocene to early Oligocene sediments from the Norwegian-Greenland Sea that were deposited between about 38 and 30 million years ago." They further report that their data "indicate sediment rafting by glacial ice, rather than sea ice, and point to East Greenland as the likely source," and they conclude that their data thus suggest "the existence of (at least) isolated glaciers on Greenland about 20 million years earlier than previously documented."

What is particularly interesting about this finding, as Eldrett *et al.* describe it, is that it indicates the presence of glacial ice on Greenland "at a time when temperatures and atmospheric carbon dioxide concentrations were substantially higher." How much higher? According to graphs the researchers present, ocean bottom-water temperatures were 5-8°C warmer, while atmospheric CO<sub>2</sub> concentrations were as much as *four times greater than they are today*.



The problem these observations provide for Mr. Gore, to quote Eldrett *et al.*, is that "palaeoclimate model experiments generate substantial ice sheets in the Northern Hemisphere for the Eocene only in runs where carbon dioxide levels are lower (approaching the pre-anthropogenic level) than suggested by proxy records," which records indicate atmospheric CO<sub>2</sub> concentrations fully *two to seven times greater than the pre-anthropogenic level* during the time of the newly-detected ice sheets.

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"Regardless," as the researchers say, their data "provide the first stratigraphically extensive evidence for the existence of continental ice in the Northern Hemisphere during the Palaeogene," which "is about 20 million years earlier than previously documented, at a time when global deep water temperatures and, by extension, surface water temperatures at high latitude, were much warmer."

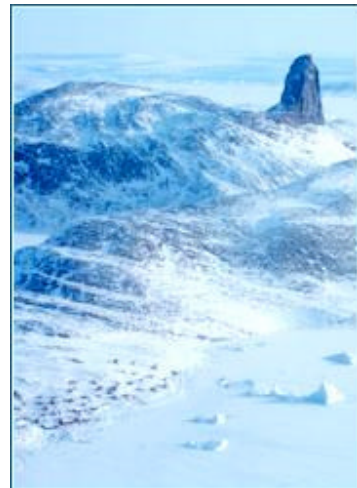


Therefore - and also "by extension" - there is great reason to not only *doubt*, but to *reject out-of-hand*, Mr. Gore's scare stories of sea levels rapidly rising tens of feet in response to his predicted rapid demise of the Greenland Ice Sheet, which he sees as occurring in response to a warming of the planet that may be pushing it perilously close to a high-temperature "tipping point," for we now have evidence of a *much* warmer period of time that *failed* to bring about such a catastrophic consequence.

Other evidence that contradicts climate-alarmist contentions of the impending demise of the

Greenland Ice Sheet has been around for several years. [Cuffey and Marshall \(2000\)](#), for example, reevaluated previous estimates of the Greenland Ice Sheet's contribution to sea level rise during the last interglacial (a rise of one to two meters), based on a recalibration of oxygen-isotope-derived temperatures from central Greenland ice cores. The results of their analysis suggested that the Greenland Ice Sheet was much smaller during the last interglacial than had previously been thought, with melting of the ice sheet contributing somewhere between four and five and a half meters to sea level rise. Although these results suggest that wastage of the Greenland Ice Sheet could potentially raise sea levels considerably more than had previously been believed, Hvidberg (2000) put a positive spin on the subject by stating that "high sea levels during the last interglacial should not be interpreted as evidence for extensive melting of the West Antarctic Ice Sheet, and so challenges the hypothesis that the West Antarctic is particularly sensitive to climate change," which is *good* news, as West Antarctica presents a much greater threat to global sea level rise than does Greenland. Also, whereas the possibility exists that sea levels in the present interglacial could yet rise to the heights of those of the last interglacial as a result of a major shrinking of the Greenland Ice Sheet, Cuffey and Marshall estimate that the ice sheet's widespread melting during the prior interglacial took place over the course of a few *millennia*, as opposed to the *decades* that could be counted on one's hands and toes that are suggested by Al Gore's scaremongering.

Continuing, [Krabill et al. \(2000\)](#) used data obtained from aircraft laser-altimeter surveys over northern Greenland in 1994 and 1999, together with previously reported data from southern Greenland, to evaluate the mass balance of the Greenland Ice Sheet. Above an elevation of 2000 meters they found areas of both thinning and thickening; and these phenomena nearly balanced each other, so that in the south there was a net thinning of  $11 \pm 7$  mm/year, while in the north there was a net thickening of  $14 \pm 7$  mm/year. Altogether, the entire region exhibited a net thickening of  $5 \pm 5$  mm/year; but in correcting for bedrock uplift, which averaged 4 mm/year in the south and 5 mm/year in the north, the average thickening rate decreased to *practically nothing*. In fact, the word used by Krabill *et al.* to describe the net balance was "zero."



At lower elevations, thinning was found to predominate along approximately 70% of the coast. Here, however, flight lines were few and far between, so few and far between, in fact, that the researchers said that "in order to extend our

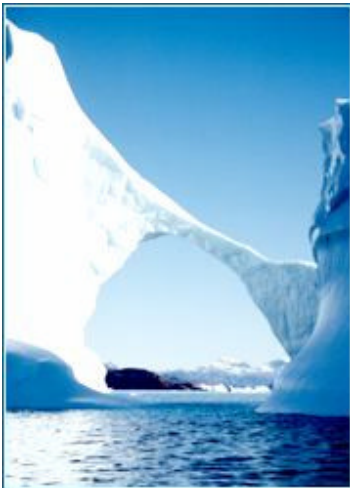


estimates to the edge of the ice sheet in areas not bounded by our surveys, we *calculated* [our italics] a *hypothetical* [our italics] thinning rate on the basis of the coastal positive degree day anomalies." Then, they *interpolated* between this calculated coastal thinning rate and the nearest observed elevation changes to obtain their final answer: a total net reduction in ice volume of 51 km<sup>3</sup>/year.

Unfortunately, it is hard to know what *estimates* derived from *interpolations* based on *calculations* of a *hypothetical* thinning rate mean. Hence, we question their significance; and, in fact, the commentary of the researchers themselves tends to do the same. They note, for example, that they do not have a "satisfactory explanation" for the "widespread thinning at elevations below 2000 m," which suggests, to us at least, that the reason this phenomenon is unexplainable is that it may not be real. Furthermore, they note that even if the thinning was real, it could not be due to global or regional warming; for they report that Greenland temperature records indicate "the 1980s and early 1990s were about half a degree cooler than the 96-year mean."

After discussing some other factors that could possibly be involved, Krabill *et al.* state they are left with changes in ice dynamics as the most likely cause of the hypothetical ice sheet thinning. But they admit in their final sentence that "we have no evidence for such changes, and we cannot explain why they should apply to many glaciers in different parts of Greenland." Hence, it would seem that the logical thing to do is admit that this study resolves almost nothing about the mass balance of the coastal regions of the Greenland Ice Sheet, and that it

resolves *absolutely* nothing about the subject of global warming and its effect or non-effect upon this hypothetical phenomenon.



In a preliminary step required to better understand the relationship of glacier dynamics to climate change in West Greenland, [Taurisano \*et al.\* \(2004\)](#) described the temperature trends of the Nuuk fjord area during the last century. This analysis of all pertinent regional data led them to conclude that "at all stations in the Nuuk fjord, both the annual mean and the average temperature of the three summer months (June, July and August) exhibit a pattern in agreement with the

trends observed at other stations in south and west Greenland (Humlum 1999; Hanna and Cappelen, 2003)." As they describe it, the temperature data "show that a warming trend occurred in the Nuuk fjord during the first 50 years of the

1900s, followed by a cooling over the second part of the century, when the average annual temperatures decreased by approximately 1.5°C." Coincident with this cooling trend there was also what they describe as "a remarkable increase in the number of snowfall days (+59 days)." What is more, they report that "not only did the cooling affect the winter months, as suggested by Hanna and Cappelen (2002), but also the summer mean," noting that "the summer cooling is rather important information for glaciological studies, due to the ablation-temperature relations." Last of all, they report there was no significant trend in annual precipitation.

*Hence, we can be thankful that whatever the rest of the Northern Hemisphere may be doing, the part that holds the lion's share of the hemisphere's ice has been cooling for the past half-century, and at a very significant rate, making it ever more unlikely that its horde of frozen water will be released to the world's oceans to raise havoc with global sea level any time soon.*

In their concluding discussion, Taurisano *et al.* remark that the temperature data they studied "reveal a pattern which is common to most other stations in Greenland." Hence, we can be thankful that whatever the rest of the Northern Hemisphere may be doing, *the part that holds the lion's share of the hemisphere's ice has been cooling for the past half-century*, and at a very significant rate, making it ever more unlikely that its horde of frozen water will be released to the world's oceans to raise havoc with global sea level any time soon. In addition, because the annual number of snowfall days over much of Greenland has increased so dramatically over the same time period, it is possible that enhanced accumulation of snow on its huge ice sheet may be compensating for the melting of many of the world's mountain glaciers and keeping global sea level in check for this reason too. Last of all, Greenland's temperature trend of the past half-century has been just the *opposite* - and strikingly so - of that which is claimed for the Northern Hemisphere and the world by the IPCC and its climate-alarmist friends. Furthermore, as Greenland contributes significantly to the land area of the Arctic, it presents these folks with a *double* problem, as they have historically claimed that high northern latitudes should be the first to exhibit convincing evidence of CO<sub>2</sub>-induced global warming.

In a study with a negative take on the issue, [Rignot and Kanagaratnam \(2005\)](#) used satellite radar interferometry observations of Greenland to detect what they

described as "widespread glacier acceleration." Calculating that this phenomenon had led to a doubling of the ice sheet mass deficit in the last decade and, therefore, a comparable increase in Greenland's contribution to rising sea levels, they went on to claim that "as more glaciers accelerate ... the contribution of Greenland to sea-level rise will continue to increase."

With respect to these contentions, we have no problem with what the two researchers have *observed* with respect to Greenland's glaciers; but we feel compelled to note that what they have *calculated* with respect to the mass balance of Greenland's Ice Sheet and what they say it implies about sea level are diametrically opposed to the story told by other more inclusive real-world data. One reason for this discrepancy is that instead of relying on *measurements* for this evaluation, Rignot and Kanagaratnam relied on the *calculations* of Hanna *et al.* (2005), who used *meteorological models* "to retrieve annual accumulation, runoff, and surface mass balance." When actual *measurements* of the ice sheet via satellite radar altimetry are employed, for example, a decidedly different perspective is obtained, as indicated by the work of Zwally *et al.* (2005) and Johannessen *et al.* (2005), which we cited earlier in this Summary. Consequently, and in direct contradiction of the claim of Rignot and Kanagaratnam, Greenland would appear to have experienced no ice sheet mass deficit in the last decade. Quite to the contrary, in fact, it has likely been host to a net *accumulation* of ice, which Zwally *et al.* estimate to be contributing a negative  $0.03 \pm 0.01$  mm/year to sea-level change. As a result, the net accumulation of ice on Greenland over the past decade or more may well have been ever so slightly *lowering* global sea level.

Yet in spite of all the real-world evidence that supports this positive perspective, climate alarmists such as Al Gore continue to claim that *if Greenland melted or broke up and slipped into the sea .. sea levels worldwide would increase by between 18 and 20 feet* (Gore, 2006). Quoting politicians like the UK's Sir David King, who says "the maps of the world will have to be redrawn," Gore conveys the impression that the occurrence of this hypothetical scenario is something we could expect to witness in the very near future. And to make this point even more poignant, Gore illustrates in his *An Inconvenient Truth* book what would likely happen to Florida, San Francisco Bay, the Netherlands, Beijing, Shanghai, Calcutta, Bangladesh and Manhattan if this were to occur, suggesting that we should begin combating now what he implies is a *serious threat* commensurate with other major present-day concerns.



The perspective provided by real-world science, however, is something far different, as the materials we have reviewed above clearly demonstrate, and as the findings of yet another analysis of the subject indicate as well.

In the 16 March 2007 issue of *Science*, which highlights the current status of polar-region science at the start of the International Polar Year, [Shepherd and Wingham \(2007\)](#) review what is known about sea-level contributions arising from wastage of the Antarctic and Greenland Ice Sheets, concentrating on the results of 14 satellite-based estimates of the imbalances of the polar ice sheets that have been derived since 1998. These studies have been of three major types - standard mass budget analyses, altimetry measurements of ice-sheet volume changes, and measurements of the ice sheets' changing gravitational attraction - and they have yielded a diversity of values, ranging from a sea-level-rise-equivalent of 1.0 mm/year to a sea-level-fall-equivalent of 0.15 mm/year.

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Of these three approaches, the results of the latter technique, according to Shepherd and Wingham, "are more negative than those provided by mass budget or altimetry." Why? Because, in their words, the gravity-based technique "is new, and [1] a consensus about the measurement errors has yet to emerge, [2] the correction for postglacial rebound is uncertain, [3] contamination from ocean and atmosphere mass changes is possible, and [4] the results depend on the method used to reduce the data." In addition, they say that (5) the Gravity Recovery and Climate Experiment (GRACE) record is only three years long, and that (6) it is thus particularly sensitive to short-term fluctuations in ice sheet behavior that may not be indicative of what is occurring over a much longer timeframe. Even including these likely-inflated results, however, the two researchers conclude that the current "best estimate" of the contribution of polar ice wastage (from both Greenland *and* Antarctica) to global sea level change is a rise of 0.35 millimeters per year, which over a *century* amounts to only 35

millimeters *or* - to better compare it to the 20-foot rise described by Gore - *a little less than an inch and a half*.

Yet even this unimpressive sea level increase may be way too large, for although two of Greenland's largest outlet glaciers doubled their rates of mass loss in less than a year in 2004 - causing climate alarmists to claim the Greenland Ice Sheet was responding much more rapidly to global warming than anyone had ever expected - Howat *et al.* (2007) report that the two glaciers' rates of mass loss "decreased in 2006 to near the previous rates." And these observations, in their words, "suggest that special care must be taken in how mass-balance estimates are evaluated, particularly when extrapolating into the future, because short-term spikes could yield erroneous long-term trends."



In light of these many observations, we feel it should be obvious to all reasonable people that former U.S. Vice President Gore has implied much more than is scientifically justified about the future behavior of the Greenland Ice Sheet and its impact on global sea level. In fact, he has implied *vastly* more than is justified.





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