In Hot Water Part 2

By John Benson

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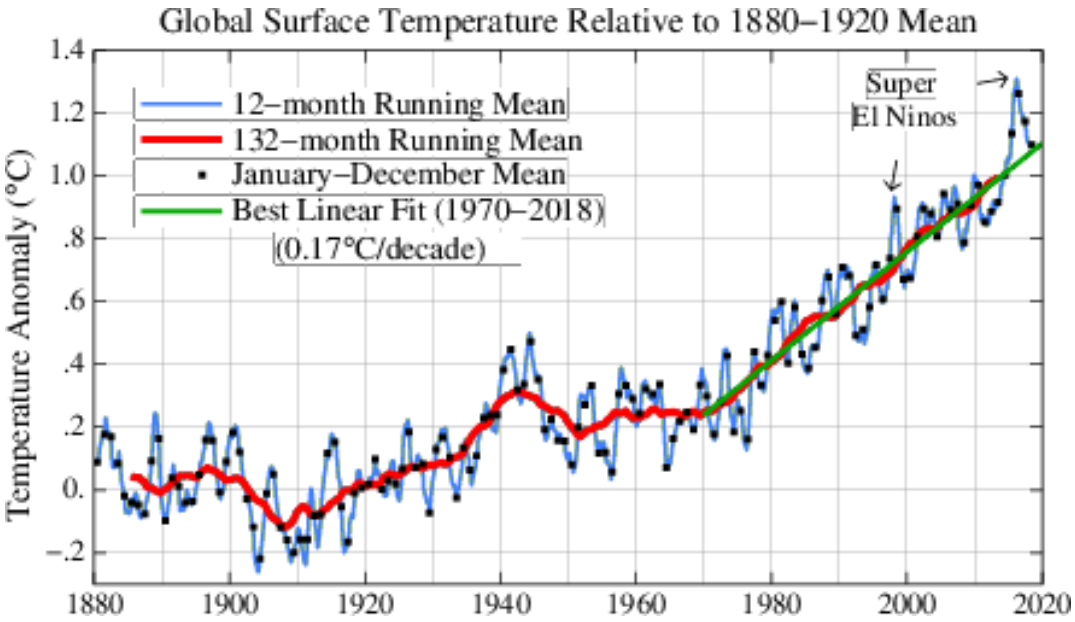
1. Introduction

This is Part 2 of this series, which explores sources of sea level rise, including the Antarctic and Greenland Ice Sheets.

Part 1 of this series explored the greenhouse effect and the warming of our oceans. Part 1 is linked below.

https://www.energycentral.com/c/ec/hot-water-part-1

However, first there is a bit of information on global surface temperature that I received between the posting of part 1, and this part. I am on Dr. James Hansen's mailing list, and receive some information from him every few weeks. On 2/6, I received a fairly lengthy email on the latest update of Global surface temperature analysis by NASA's Goddard Institute for Space Studies (GISS). This data was converted to a graph by Dr. Hansen's team, which is below.[1]



Note that the 1880-1920 period is used as a baseline is in part because it is the earliest period with substantial global coverage of instrumental measurements. Global temperature in 1880-1920 should approximate 'preindustrial' temperature.

I believe this graph clearly defines the latest story on climate change.

[1] Dr Hansen's site for this information is: http://www.columbia.edu/~mhs119/Temperature/
Goddard Institute for Space Studies (GISS) site is: https://www.giss.nasa.gov/

2. New Sources of Sea Level Rise

First to set the stage: the events described below are greatly abbreviated, to see the full scenario (and my source), go through the link to an earlier paper below, then to section 2.2.

https://www.energycentral.com/c/ec/fire-and-storms-—-part-2-0

The two major ice caps on our planet (Greenland and Antarctica) have had accelerating melting over the last several decades. In the North Atlantic around Greenland this has produced a layer of freshened water on the surface. This in-turn forced the warm, salty Gulfstream below this layer, melting the footings of Greenland's glaciers. This further accelerated the melting of the Greenland Ice Cap and also diluted the Gulf Steam's saltiness. The engine that drives the Gulfstream involves this current (technically called the Atlantic meridional overturning current or AMOC) plunging into the depths south of Greenland. The Gulfstream's extreme saltiness (caused by evaporation on its journey north) is the primary driver of this plunge. So far the above sequence has slowed the AMOC circulation flow by 15% to 30%.[2]

The reduced flow of the AMOC has trapped more warm water in the southern oceans, which has accelerated the melting of the Antarctic Ice Cap. So far the glaciers in West Antarctica have melted rapidly and have calved numerous huge icebergs (which have quickly broken up, melting even faster). With this splashy show, climatologists have been mostly attentive to West Antarctica. They thought that East Antarctica was stable. They were wrong.

Currently sea level is rising by about an average rate of 3.1±0.3 mm/yr. and accelerating at 0.1 mm/yr^2 over 1993 to the present.[3] Per the prior reference (my conversions in brackets), "Ice sheets are the largest potential source of future sea-level rise and represent the largest uncertainty in projections of future sea level. Almost all land ice (appx. 99:5%) is locked in the ice sheets, with a volume in sea-level equivalent terms of [24 ft.] for Greenland and [191 ft.] for Antarctica."

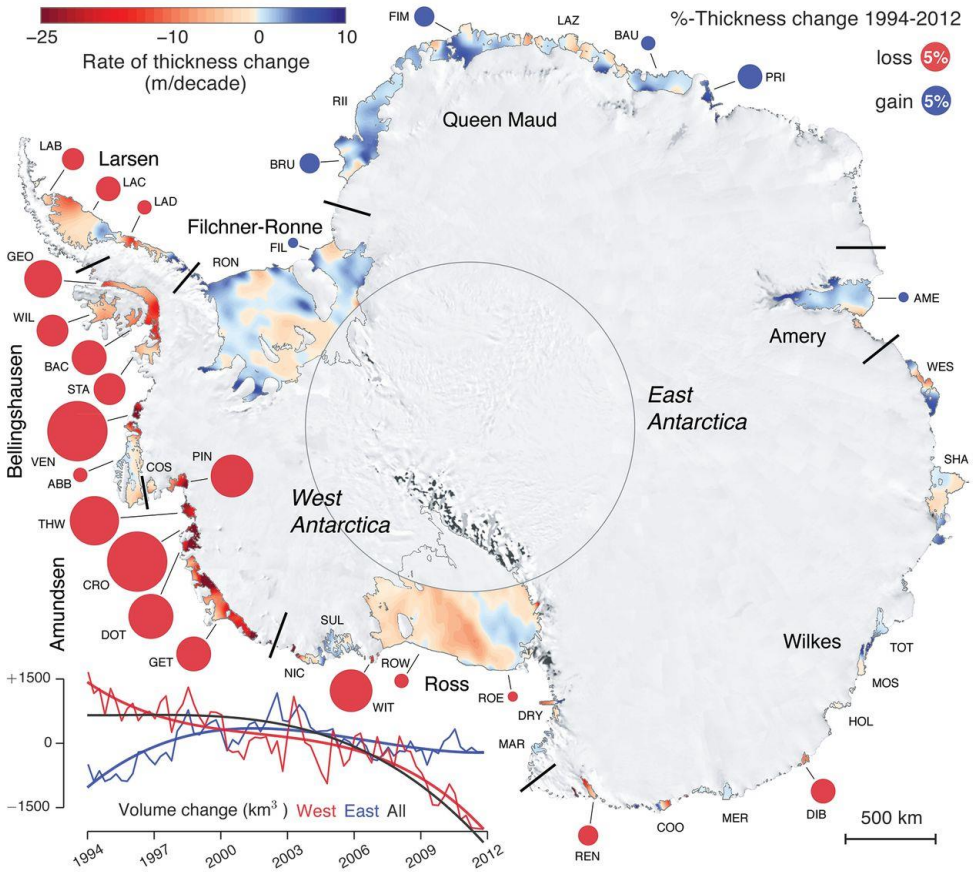
2.1. Antarctica

In this subsection we will be discussing Antarctica. The figure and table below that will be helpful in understanding this discussion.[4]

[2] Stefan Rahmstorf, Real Climate, "What the 2018 climate assessments say about the Gulf Stream System slowdown", Jan 28, 2019, http://www.realclimate.org/index.php/archives/2019/01/what-the-2018-climate-assessments-say-about-the-gulf-stream-system-slowdown/

[3] Anny Cazenave, et al, World Climate Research Programme (WCRP), "Global sea-level budget 1993–present", 28 August 2018, https://www.earth-syst-sci-data.net/10/1551/2018/essd-10-1551-2018.pdf

[4] Fernando S. Paolo, et al, Volume loss from Antarctic ice shelves is accelerating, published in Science, 17 April 2015, Vol 348, Issue 6232, Page327, http://science.sciencemag.org/content/348/6232/327.full



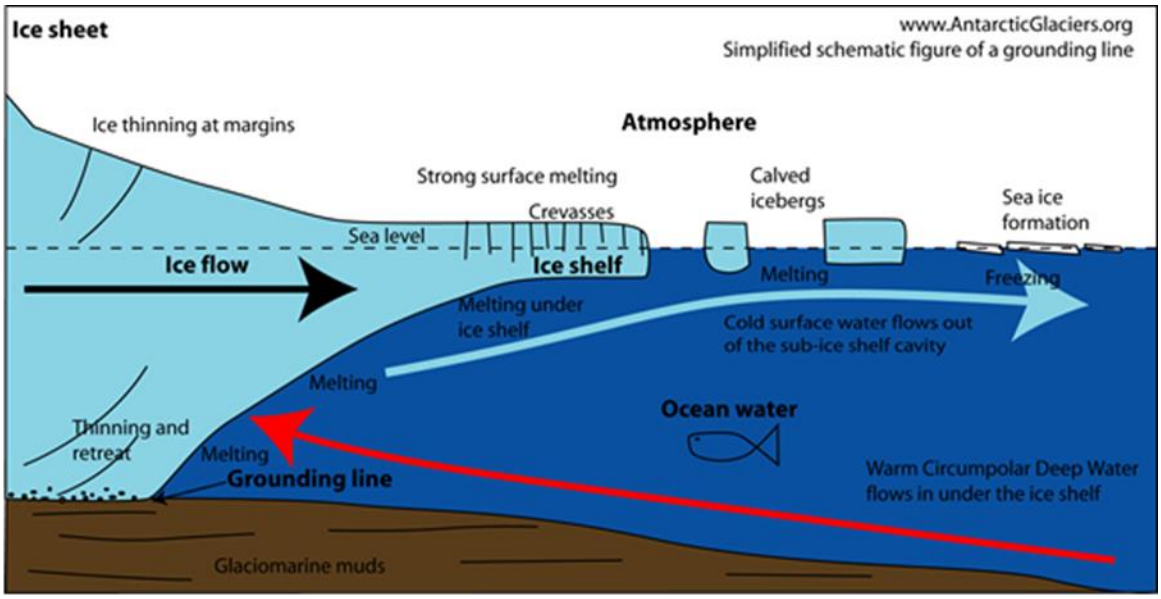
Abbrev.	Name	Abbrev.	Name
ROW	Ross – West Antarctic Ice Sheet	REN	Rennick
GET	Getz	DIB	Dibble
DOT	Dotson	HOL	Holmes
CRO	Crosson	MOS	Moscow
THW	Thwaites	TOT	Totten
PIN	Pine Island	AME	Amery
VEN	Venable	SHA	Shackleton
GEO	George VI	WES	West
LAC	Larsen C	COO	Cook

2.1.1. West Antarctica

An article from Scientific American is referenced below.[5] Unfortunately this is only in print in the February Issue of this publication, and I could not find it on the Web. I have been aware of the information in this article, however it does an excellent job of presenting this and thus I am paraphrasing some parts of this article below.

[5] Richard B. Alley, "Scientific American, "Is Antarctica Collapsing?" February, 2019.

Climatologists have been really worried about Thwaites Glacier in West Antarctica. It is retreating rapidly, as are other glaciers in West Antarctica, but that's not why they are worried. In order to understand their concern you need to understand how many ocean-facing glaciers retreat. See the figure below. Warm deep ocean water melts the glacier from below, but leaves tongue of ice (the ice shelf) protruding into the sea. The glacier is frequently anchored on a grounding line, which is an outcrop from the sea-floor. The grounding line can be destabilized by several things: (1) continued melting at the base of the glacier until it passes the grounding line, (2) meltwater penetrating to the base of the glacier through crevasses and moulins fed by supraglacial meltwater lakes and starting to melt it from below, and/or (3) both of the above effects pushing water under the base of the glacier until buoyancy lifts it off of the grounding line.



What happens next depends on the surface under the glacier. If this slopes upward as it goes further inland, the grounding line will eventually reestablish itself. However, if the grounding line reached a precipice where there is a depression further inland, the sea water will rush into this depression, accelerate the melting of the glacier's underside, and prevent the reestablishment of the grounding line.

In the case of the Thwaites Glacier, behind the current grounding line is a very large trench (Bentley Subglacial Trench) that plunges to a mile and a half below sea level. This trench leads to a large basin behind it. If this trench and the basin were flooded by warm ocean water, the glacier and a large section of the West Antarctic Ice Sheet would start to break up. The timing of the resulting sea level rise is uncertain (think a few decades to a century). When it does happen, it could potentially raise the sea level by 11 feet.

2.1.2. East Antarctica

A recent article released by NASA strongly indicates that East Antarctica is starting to contribute to sea-level rise. The following is an excerpt from this article (with my edits).[6]

If the ice cover over East Antarctica were to melt, it would reshape coastlines around the world through rising sea levels. But scientists have long considered the eastern half of the continent to be more stable than West Antarctica. Now new maps of ice velocity and elevation show that a group of glaciers spanning one-eighth of the East Antarctic coast have been losing some ice over the past decade.

Glaciologists have warned in recent years that Totten Glacier—the fastest moving ice in East Antarctica—appears to be retreating due to warming ocean waters. Totten contains enough ice to raise sea level by at least 3 meters. Researchers have now found that four glaciers to the west of Totten, plus a handful of smaller glaciers farther east, are also losing ice.

"Totten is the biggest glacier in East Antarctica, so it attracts most of the research focus," said Catherine Walker, a glaciologist at NASA's Goddard Space Flight Center. "But it turns out that other nearby glaciers are responding in a similar way to Totten."

Walker and colleagues found that the surface height of four glaciers west of Totten, in an area facing Vincennes Bay, has dropped by an average of nearly three meters since 2008. (There had been no measured change in elevation for these glaciers before then.) To the east of Totten, the surfaces of some glaciers along the Wilkes Land coast have dropped by 0.25 meters per year since 2009, about double their previous rate.

Such levels of ice loss are small when compared to those of glaciers in West Antarctica. But still they speak of nascent and widespread change in East Antarctica.

"This change doesn't seem random; it looks systematic," said Alex Gardner, a glaciologist with NASA's Jet Propulsion Laboratory. "And the systematic nature hints at underlying ocean influences that have been incredibly strong in West Antarctica. Now we might be finding clear links of the ocean starting to influence East Antarctica."

2.2. Greenland

Since this subsection will cover Greenland, I thought it would be good to start with a map similar to the above map of Antarctica. The Map below shows the currents (warm – red to yellow, cold -- blue), ocean temperatures (°C, in square boxes) Glacier abbreviations follow it.[7]

Another important element in the paper referenced below is the North Atlantic Oscillation (NAO). The description below is from the referenced site.[8]

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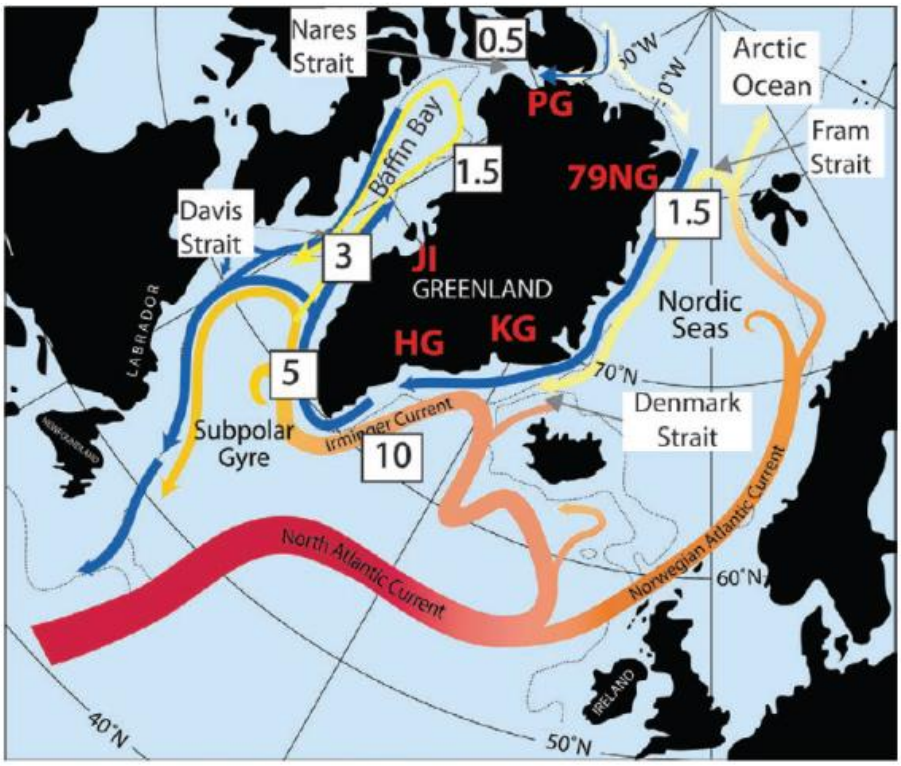
[6] Maria-José Viñas, NASA's Earth Science News Team, " More Glaciers in East Antarctica Are Waking Up", December 10, 2018, https://www.nasa.gov/feature/goddard/2018/more-glaciers-in-antarctica-are-waking-up

[7] Straneo, Fiammetta, et al. "Challenges to Understanding the Dynamic Response of Greenland's Marine Terminating Glaciers to Oceanic and Atmospheric Forcing." American Meteorological Society, https://dspace.mit.edu/openaccess-disseminate/1721.1/87785

[8] NOAA Climate Prediction Center, " North Atlantic Oscillation", http://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml

The NAO consists of a north-south dipole of anomalies, with one center located over Greenland and the other center of opposite sign spanning the central latitudes of the North Atlantic... The positive phase of the NAO reflects below-normal heights and pressure across the high latitudes of the North Atlantic and above-normal heights and pressure over the central North Atlantic, the eastern United States and western Europe. The negative phase reflects an opposite pattern of height and pressure anomalies over these regions…



Glacier Abbreviations:

PG -- Petermann Glacier – This is the most northern of the major glaciers.

JI -- Jakobshavn Isbræ (several other important glaciers, including Kangilernata Sermia, Store Gletscher, and Rink Isbræ are near Jakobshavn Isbræ).

HG -- Helheim Glacier

KG -- Kangerdlugssuaq Glaciers

79NG – Nioghalvfjerdsbrae, a.k.a. 79 North Glacier (Zachariae and Storestrommen are just south of Nioghalvfjerdsbrae).

The paper referenced below is important mainly because of its conclusion, but it is long, and marginally readable.[9] NASA's GRACE satellites provide measurement of gravity changes in Earth's land-masses.[10] For those land-masses that have ice sheets (read: Greenland and Antarctica), the changes in the measured gravity equates to changes in

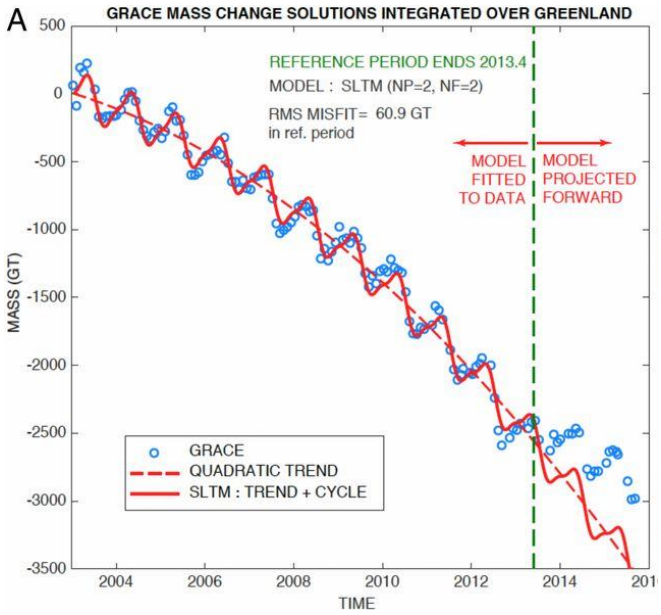
[9] Proceedings of the National Academy of Sciences of the USA, Michael Bevis et al, " Accelerating changes in ice mass within Greenland, and the ice sheet's sensitivity to atmospheric forcing", January 22, 2019, https://www.pnas.org/content/early/2019/01/14/1806562116

[10] NASA GRACE Mission Overview, https://www.nasa.gov/mission_pages/Grace/overview/index.html

the mass of the ice-sheets (ice-loss or -gain). This was the data that was used by the referenced paper to understand how climate is affecting the ice-loss from the Greenland Ice Sheet, and thus how this might play out in the future.

As a verification for the GRACE data, the team used Greenland GPS Network (GNET), which senses mass changes by measuring the solid earth's elastic response to changing surface loads (changes in ice mass).

By using data from GRACE, the authors of the PNAS paper noted that from 2003 through 2012 the data showed an annual winter/summer cycle of ice gain and loss, with a multiyear pattern of ice loss (see the graph below). "*The Greenland Ice Sheet (GrIS) and its outlying ice caps were losing mass at a rate of about −102 Gt/y (Gigatons/year) in early 2003, but 10 years later this rate had increased nearly fourfold to about −393 Gt/y.*"



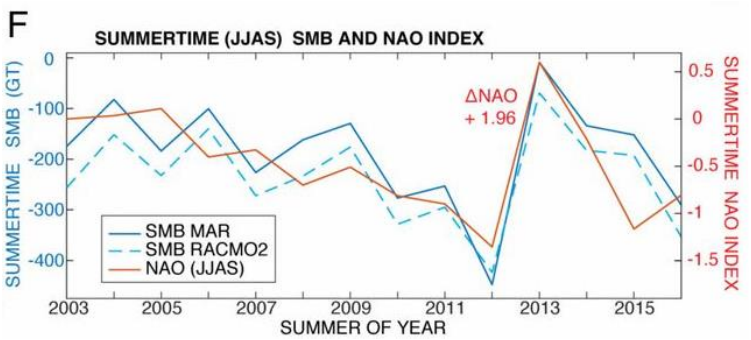
However in 3013, there was a "Pause" in the long-term trend.

"*Van Angelen et al.*[11] *noted that the accelerating ice loss observed by GRACE through year 2012 correlated with an increasingly negative summertime North Atlantic Oscillation (NAO) index during six successive summers (Fig. F). The negative phase of the summertime NAO index increases the prevalence of high pressure, clear-sky conditions, enhancing surface absorption of solar radiation and decreasing snowfall, and it causes the advection (transport of a substance or conserved property by a fluid due to the fluid's bulk motion) of warm air from southern latitudes into west Greenland. These changes promote higher air temperatures, a longer ablation season and enhanced melt and runoff. Van Angelen et al. concluded that if the summertime NAO switched back to positive values after 2012, then surface mass balance (SMB) might partially recover. Indeed, not only did the June to August and June to September NAO indices turn*

[11] Van Angelen J, et al., (2014) Contemporary (1960–2012) evolution of the climate and surface mass balance of the Greenland ice sheet. Surv Geophys 35:1155–1174. https://scholar.google.com/scholar_lookup?author=J+Van+Angelen&title=Contemporary+%281960%E2%80%932012%29+evolution+of+the+climate+and+surface+mass+balance+of+the+Greenland+ice+sheet&publication_year=2014&journal=Surv+Geophys&volume=35&pages=1155-1174

positive in 2013, but the change in each of these summertime NAO indices from 2012 to 2013 was the single biggest inter-annual change recorded since 1950 (see figure F below). Furthermore, when the summertime NAO index again turned strongly negative in 2015, significant ice loss was reestablished and the Pause had ended."

Note that in the figure below SMB is surface mass balance, that is, the gain or loss of mass at the surface of the ice sheet.



So the smoking gun on the pattern between 2003 and 2016 is the North Atlantic Oscillation. But what does that say about future ice mass loss (with attendant sea level rise) from the Greenland Ice Sheet?

*"The decadal acceleration in mass loss in southwest Greenland arose due to the combination of sustained global warming and positive fluctuations in temperature and insolation driven by the NAO… Since 2000, the NAO has worked in concert with global warming to trigger major increases in summertime runoff. Before 2000, the air was too cool for the NAO to do the same. In a decade or two, global warming will be able to drive 2012 levels of runoff with little or no assistance from the NAO. In the shorter term, we can infer that the next time NAO turns strongly negative, SMB will trend strongly negative …, just as future warming of the shallow ocean is expected to have its largest impact, via DMB (*Discharge Mass Balance, primarily iceberg calving*), in southeast and northwest Greenland. Because ice sheet topography equips southwest Greenland with greater sensitivity to atmospheric forcing, we infer that within two decades this part of the Greenland Ice Sheet will become a major contributor to sea level rise. There is also the suggestion that enhanced summertime melting may induce more sustained increases in discharge rates."*

3. Conclusion

How much is sea level likely to rise in the next few decades? I just read a recent document from the State of California (and it boldly projects what our current federal administration doesn't even want to think about (below).[12]

Sea-level rise is virtually certain to increase beyond the 6 inches that much of California experienced in the past century, but there are important questions involving how fast and how extreme the rates of sea-level rise will be. The Fourth Assessment's projections underscore the dependence of sea levels upon greenhouse gas emissions and the associated melt and ice-loss from Greenland and Antarctica. If emissions continue at current rates, Fourth Assessment model results indicate that total sea-level rise by 2100

[12] California's Fourth Climate Change Assessment, 2019,Key Findings Brochure, http://www.climateassessment.ca.gov/

is expected to be 54 inches, almost twice the rise that would occur if greenhouse gas emissions are lowered to reduce risk.

Final author's note: In order to simplify this assessment, it reduced the RCP used by many other reports (see prior paper through the link below, section 2.3) into just two measures of success: “if (greenhouse gas) emissions continue at current rates” (RCP8.5) and "if (greenhouse gas) emissions are reduced at a moderate rate" (RCP4.5). In the above paragraph read "… lowered to reduce risk." as RCP4.5.

https://www.energycentral.com/c/pip/climate-change-impacts-energy-systems-part-1-te-future