Positive Feedback Accelerates Sea Level Rise

By John Benson

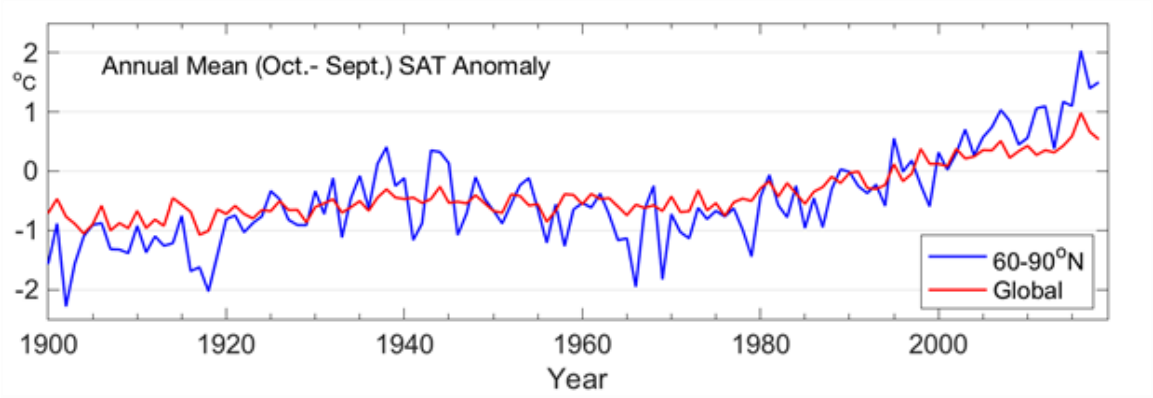
September, 2019

1. Introduction

Both this post, and my next (probably on Oct 1) are on climate change, but they are very different, so I will not post them as a two-part series.

Climate Change is sometimes called global warming. While on average, most areas in the world are warming, there are a few that are not warming significantly. Then there are the Polar Regions. These are warming much more rapidly than the rest of the world.

The surface air temperature (SAT) of the arctic (60° to 90° North) is rising twice as fast as the global air temperature (see chart below and referenced at the end of this paragraph).[1]



This causes previous simulations of how fast the Greenland ice sheet is melting to be out of date almost as soon as they are published, and not in a good way. Furthermore, Mother Nature seems to have many surprises for climatologists and many of these involve positive feedback. Let me give you a really simple example.

Most skiers like me know how beautiful fresh powder is. A major part of this beauty is its pure bright white color. It should not be surprising that this color reflects most of the sun that strikes it, just ask any of our California cool-weather skiers that have skied with very few clothes on, and received sunburns in very unusual places.

Melting snow on the other hand starts turning grey, which is much less effective at reflecting heat. So as the Greenland ice sheet's melting season over the summer becomes longer, its surface snow darkens, absorbs more sunlight, melts faster and loses more water, which creates meltwater pools on the ice sheet's surface. These pools absorb even more of the sunlight than the darkened snow, and become warmer, melting more snow, and so on. This meltwater works its way off of the ice sheet and into the

[1] J. E. Overland et al, NOAA, 2018, "Arctic Report Card: Update for 2018, Surface Air Temperature", https://arctic.noaa.gov/Report-Card/Report-Card-2018/ArtMID/7878/ArticleID/783/Surface-Air-Temperature

ocean, contributing to sea level rise. Also there is more to this scenario that we will explore later.

Climatologists can be forgiven if they don't understand all of these feedback mechanisms from the start, but it seems like the more they discover, the faster the ice melts, and the faster sea level rises.

The sections below will look at more of the new positive feedback loops that we have seen recently.

2. Not so Permafrost

The following is from the reference at the end of this paragraph, with my edits. Permafrost is soil, rock or sediment that is frozen for more than two consecutive years. In areas not overlain by ice, it exists beneath a layer of soil, rock or sediment, which freezes and thaws annually and is called the "active layer". Permafrost occurs at a mean annual temperature of 28.4 °F or colder. Active layer thickness varies with the season, but is 1 to 12 feet thick (shallow along the Arctic coast; deep in southern Siberia). The extent of permafrost varies with the climate: in the Northern Hemisphere today, 24% of the ice-free land area, equivalent to 7.34 million square miles, is more or less influenced by permafrost. Of this area slightly more than half is underlain by continuous permafrost, around 20 percent by discontinuous permafrost, and a little less than 30 percent by sporadic permafrost. Most of this area is found in Siberia, northern Canada, Alaska and Greenland.[2]

Obviously as the arctic climate warms, permafrost that has been frozen for many years to millennia is now melting. As it melts it is releasing carbon in various forms. This release includes carbon dioxide and methane to the atmosphere, as well as the release of carbon to water as methane, dissolved organic carbon, dissolved inorganic carbon, particulate inorganic carbon and particulate organic carbon. The question is how much carbon is being released.

Earlier estimates of the amount of carbon released as permafrost melts were very inconsistent. A new study used an innovative approach to directly measure the carbon lost through a proxy, and the results of these measurements were much higher than prior estimates. A press release from this study is referenced at the end of this paragraph.[3]

"They used this approach to directly measure soil carbon pool changes in a five-year period, showing an annual loss of more than 5 percent of soil carbon.

"As almost a third of the Earth's surface soil carbon is trapped in the permafrost, this indicates greater ramifications not only in the present, but also as the world copes with climate change in the near future. Scientists who study the permafrost see a cycle: higher temperatures lead to more of the permafrost thawing, which leads to the release

[2] Wikipedia article on Permafrost. https://en.wikipedia.org/wiki/Permafrost

[3] César Plaza, Christina Schädel and Ted Schuur, Northern Arizona University, "NAU scientists find carbon from thawing permafrost is released into the atmosphere at higher rates than previously thought", July 2, 2019, https://news.nau.edu/schuur-carbon-permafrost-study/#.XXlcm6Ym6Ul

of soil carbon into the atmosphere, which leads to higher temperatures, which leads to permafrost thaw, and so on.

"According to the study, 5 to 15 percent of the soil carbon held in the permafrost could be released into the atmosphere by the end of the century, using the current scenario. The modelling exercise the research team used to compare agreed with the observations but suggests that the loss rate could be twofold or … higher."

3. The Drying Cycle, then the Burning Cycle

As if the release of carbon described in the prior section wasn't bad enough, that isn't the end of the story. After the permafrost melts, the soil above it continues to warm, as do the plants that live in this soil. Since these plants are acclimated to a cooler and shorter growing season, they start to die and dry out. Any spark (mainly from lightning), and, well, you know what happened in California last year, now it's the Arctic Region's turn.

"Gargantuan forest fires in Siberia, which burned for more than three months, created a cloud of soot and ash as large as the countries that make up the entire European Union. More than ten million acres of Siberian taiga forest went up in flames, the Russian military were deployed, people across the region were choked by the smoke, and the cloud spread to Alaska and beyond. Fires have also raged in the boreal forests of Greenland, Alaska and Canada." [4]

Of course these fires greatly accelerate carbon release from the vegetation and soil in the arctic region. They also accelerate the melting of the permafrost.

Those clouds of smoke carry millions of tons of particulates, which eventually come to earth, and frequently land on the Greenland Ice Sheet, or glaciers in Greenland and elsewhere. Of course all of these particulates further darken the snow, which further accelerate ice melt, resulting in faster sea level rise. Carbon particulates are also a powerful greenhouse agent, which further accelerates warming / drying / carbon release, and you know the rest of this story. It's called positive feedback.

Continuing to quote the above referenced BBC article: *"Though images of blazing infernos in the Arctic Circle might be shocking to many, they come as little surprise to Philip Higuera, a fire ecologist at the University of Montana, in the US, who has been studying blazes in the Arctic for more than 20 years.*

" 'I'm not surprised – these are all the things we have been predicting for decades," he says.'

"Higuera and his team predicted in 2016, based on sophisticated computer modeling, that fires in the boreal forests and Arctic tundra would increase by up to four times by 2100.

"A key tipping point, he says, is an average July temperature of 13.4° C over a 30-year period. Much of the Alaskan tundra has been perilously close to this threshold between 1971 and 2000, making it particularly sensitive to a warming climate. The number of

[4] Zoe Cormier, BBC, "Why the Arctic is Smoldering", Aug 27, 2019, http://www.bbc.com/future/story/20190822-why-is-the-arctic-on-fire

areas near to and exceeding this tipping point are likely to increase as the climate continues to warm in the coming decades, says Higuera.

" 'Across the circumpolar Arctic, the take-home message is that there are distinct thresholds above which you start to see the tundra burning – it's like a binary switch,' says Higuera. 'This threshold relationship is part of what makes the Arctic so sensitive: areas will stay below this threshold for years, off our radar for fire activity – and then all of a sudden with a change in temperature it will start to burn.'

4. Algae – Enter the Dark Zone

Algae is a huge diverse family of plant-like organisms. Like plants they use photosynthesis to produce their substance from carbon dioxide and sunlight, and land-plants probably evolved from Algae, because many algae closely resemble these plants. However algae primarily live in water. We are concerned with a particular type of algae that is described below. For more general information on algae, I would recommend the Wikipedia article on algae.

The above described deposition of particulates on the Greenland ice sheet creates substantial darkening of the snow, but that isn't the end of the process. Darkened snow may appear unattractive to you and I, but to a particular algae (see below) it looks like a smorgasbord. The reference at the end of this paragraph identified that the primary algae were of the order *"… Zygnematales, comprising Ancylonema nordenskiöldii Berggren 1871, Mesotaenium berggrenii Lagerheim 1892 and Cylindrocystis brebissonii f. cryophila Kol 1942. Ice algae produce a brown vascular pigment with a tannin structure identified as purpurogallin carboxylic acid-6-O-b-D-glucopyranoside as a means of protecting their photosystematic apparatus from photoinhibition. Together with airborne-delivered impurities such as mineral dust, black carbon and bacteria, this algal-derived pigment causes a darkening of the ice surface, which in turn decreases albedo and increases melt rates."* [5]

By the way, I believe the organization that sponsored the above referenced paper was a UK organization called Black and Bloom (at least that is how I found it). This is linked below.

https://blackandbloom.org/

Also, Greenlanders call the area of bare ice with particularly low albedo (maximum darkening) that appears across the west and southwest sectors of their ice sheet each summer the "dark zone", and the dark zone is expanding every year.

5. Tundra be Dammed, The Beavers' Revenge

A few years ago no one would have believed that a large furry rodent with a flat tail would be a primary agent of climate change, but here we are. This is a complicated story that we will tell in the subsections below.

[5] Stefanie Lutz1, Jenine McCutcheon, James B. McQuaid, Liane G. Benning, Microbial Genomics, Volume 4, Issue 3, First Published: 16 March 2018, "The diversity of ice algal communities on the Greenland Ice Sheet as revealed by oligotyping, https://www.microbiologyresearch.org/content/journal/mgen/10.1099/mgen.0.000159

5.1. Tundra to Forest Ecosystems

I'm sure there are far more than three ecosystems as described below, but most seem to share the three layers described below. These are from the source referenced here.[6]

The lowest tundra plants which can thrive in a minimum depth active layer (seasonally thawed soil) is mostly composed of lichen and mosses. As the depth of the active layer increases, the lowest plants will be joined by a few woody shrubs, mainly dwarf willows, alders and heathers, to form bushlands. As the thawed soils become deeper still, alders will start to increase their height, and be joined by spruce and fir trees to form the boreal forests.

5.2. The Beavers Role

Once the boreal forest forms, beavers will be right there. There are streams in all of the above ecosystem, and in the forest the beavers dam these streams to create beaver ponds. The beaver ponds locally increase the depth of the active layer and the length of the growing season by attenuating freezing and creating a region of high-moisture soil around the pond.

A recent article reference here[7] summarized a paper by Ken Tape, professor at the University of Alaska Fairbanks (and others). Dr. Tape's team used satellite data to map the formation and disappearance of beaver ponds in a 7,000 square mile area of the northwest Arctic over a 15-year period ending in 2014. Satellite imaging can see beaver ponds, and this data showed that beavers are increasingly moving out from the boreal forests into the bushland (see photo and caption below). The bushes described in the prior subsection are a prime beaver food. In addition to providing a winter habitat for the beavers, the ponds also accelerate the melting of permafrost, increasing soil depth (year round) and this accelerates the advance of boreal forest. This in turn accelerates the release of greenhouse gases (from the melting permafrost), which increases the temperature, and makes an increasing number of beavers very happy.

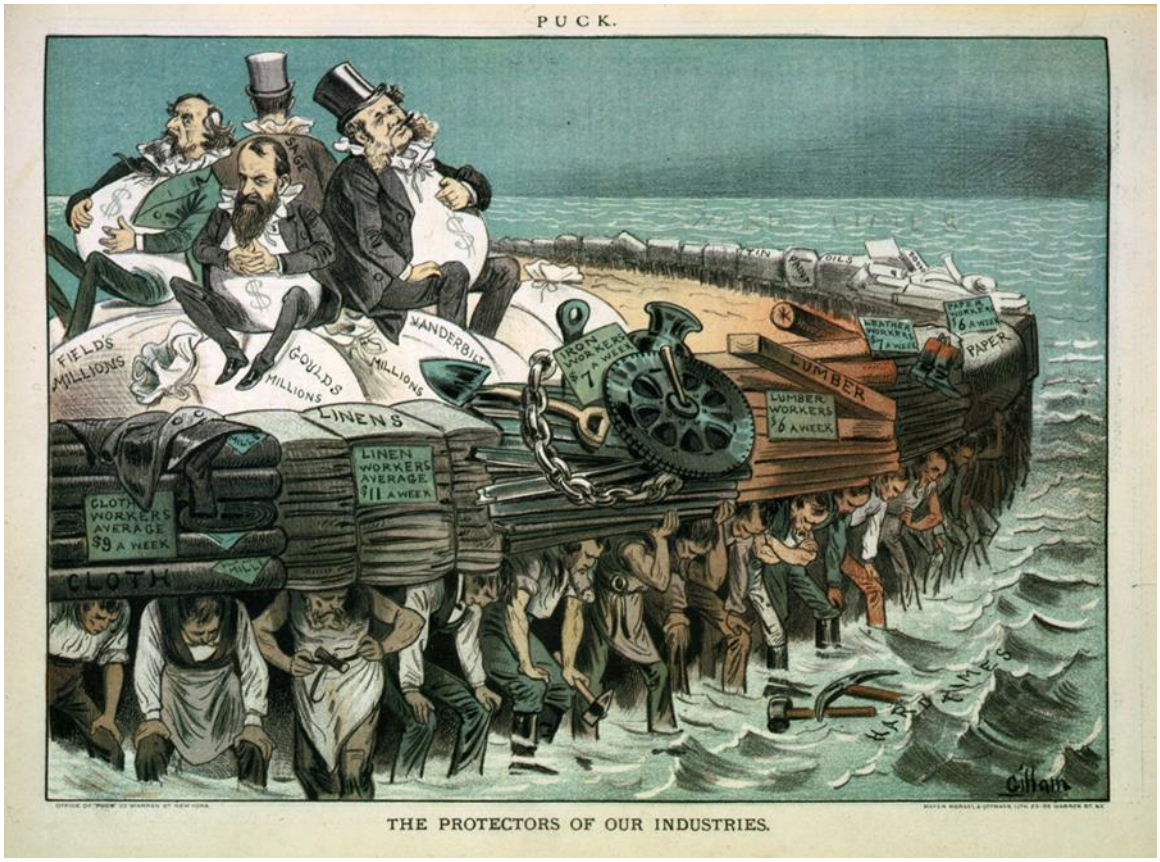
A beaver dam, spotted in 2015 in Ivvavik National Park in Canada's Yukon Territory, near the Alaskan border. (JAY FRANDSEN/NYT)

[6] Lizzie Brooks, Sciencing, "Tundra Trees", April 24, 2017, https://sciencing.com/tundra-trees-7423473.html

[7] By Kendra Pierre-Louis, New York Times, Article was downloaded from the Seattle Times, " Beavers emerge as agents of Arctic destruction ", Originally published Dec 22, 2017, https://www.seattletimes.com/nation-world/beavers-emerge-as-agents-of-arctic-destruction/

5.3. The Beavers Revenge

If one could say when we first started down the road to climate change, it would probably be in the late 19th century when industrialization rapidly started expanding. The primary leaders in this push were what are often referred to as the robber barons (industrialists). If there is one symbol of these gentlemen (only one lady that I'm aware of: Marjorie Merriweather Post), it is the top hat (see the Puck editorial cartoon below)[8].



The top hat was invented by English milliner John Hetherington and popularized by English dandy, George “Beau” Brummel. However, it was embraced by the U.S. robber barons. The outer fabric of high-quality top hats is silk, but the primary structural fabric was felt, and not just any felt, but (you guessed it) beaver felt.

So in a few decades when the robber barons' successors look out from their Wall Street offices, and note their "Street" has been replaced with a river (ditto the London central business district), the beavers will be quietly chortling, perhaps with an occasional tail slap, as they continue to build their dams: Busy beavers and positive feedback.

[8] Wikipedia article on "Robber baron (industrialist)" https://en.wikipedia.org/wiki/Robber_baron_(industrialist) . This article also contains a list of robber barons that does not include Ms. Post, probably because, although very successful (she built General Foods), she was also highly respected. A bio linked here http://www.paulbowles.org/marjoriemerriweatherpost.html