Snow, Ice and Temperature Trends in the Arctic and Antarctic[1]

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1. Introduction

The term "cryosphere" refers to the frozen water regions on the Earth: e.g., glaciers, snow-covered regions, sea ice and permafrost regions. Glaciologists define an "ice age" for the Earth as periods where permanent ice sheets are present in both hemispheres. Therefore, technically, since there are permanent ice sheets in Greenland and Antarctica, we are currently in an ice age. However, fortunately, we are in an "interglacial" period of this ice age – much milder than the glacial period that ended 10-15,000 years ago.

Many people rely on the UN's Intergovernmental Panel on Climate Change (IPCC)'s Assessment Reports for evaluating trends in the cryosphere. These IPCC reports tend to describe quite accurately all those trends related to the cryosphere that imply "the ice is melting dramatically" (IPCC, 2014; 2019). However, they tend to downplay or overlook those trends which contradict this narrative. If we are interested in studying climate change, it is important to consider all the relevant trends – not simply the ones that agree with our chosen narrative. Therefore, in this talk (and accompanying abstract), I will briefly summarize the current scientific understanding of what we know about cryosphere trends and highlight some of the key observations that have been overlooked or downplayed by recent IPCC reports.

In the talk, I summarize the key trends associated with each aspect of the cryosphere (glaciers, ice sheets/ice shelves, sea ice, permafrost, and snow cover) and compare these trends to those described by the IPCC reports and the "hindcasted" trends that the global climate models (GCMs) used for the IPCC reports argue should have occurred. There, I demonstrate that the GCM hindcasts fail to replicate many of the observed trends, and that the IPCC reports are remarkably selective in which trends they report on. However, for brevity, in this extended abstract, I will mostly focus on the trends themselves.

2. Arctic sea-ice

Observations show that Arctic sea-ice has declined since satellite records began in 1978. But this long-term decline is more chaotic and intermittent than continual year-on-year decline the GCM hindcasts expect should have occurred. Also, in Connolly et al. (2017), we showed that 1978 coincidentally marked the end of roughly three decades of Arctic cooling (and increasing sea ice extent) since the 1940s. In Connolly et al. (2017), we compiled multiple pre-satellite era estimates of Arctic sea-ice extent from a range of different sources, e.g., ship measurements and aerial reconnaissance. However, because each source only covered a relatively short time period and was regional in nature, they were not always directly comparable with each other. Therefore, we used the corresponding regional surface air temperature trends to recalibrate each sea-ice estimate into a common format.

[1] The talk can be seen here: https://www.youtube.com/watch?v=YJbnBFsEDYw (Recorded by Yngvar Engebretsen)

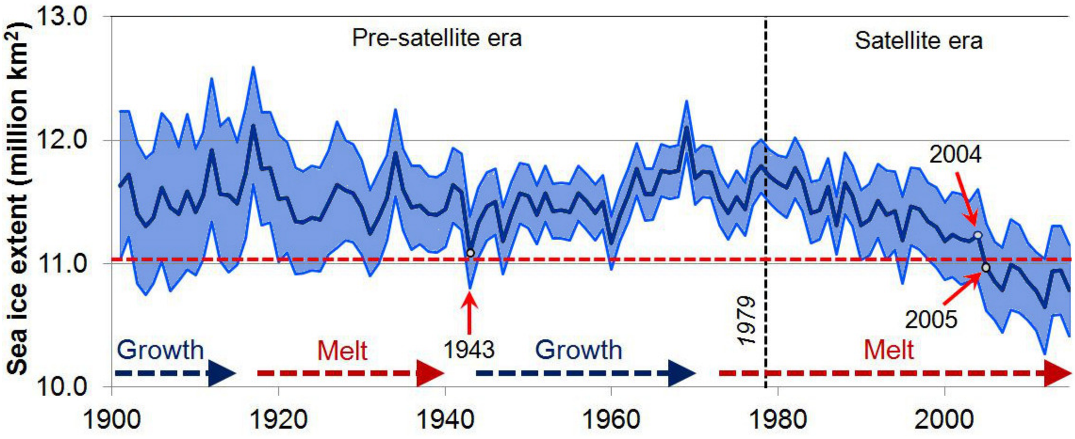

Figure 1. Annual trends of Arctic sea-ice (Connolly, Connolly and Soon 2017). The shaded area shows the uncertainty.

These recalibrated estimates could then be directly composited together to generate continuous time series from 1901-2016. In Figure 1, this recalibration of the amount of Arctic sea-ice back to the year 1901 is shown. We see a general growth in ice until 1920s, a decline 1920-1940s, growth 1940s-1970s, and then decline.

Stein et al. (2017) have used sediment core samples to estimate periods of permanent ice, seasonal ice, and ice-free areas for four different Arctic regions far back in time. According to these estimates, all four of the investigated areas (Chukchi, East Siberian and Laptev Seas and the Fram Strait) were "mostly ice-free" 6000 B.C. In the Bronze age, the cores imply there was "seasonal ice" in the Fram Strait and Laptev Sea while Chukchi and East Siberian Seas were "mostly ice-free". At present, only the Fram Strait is "mostly ice-free".

3. Snow cover

The IPCC reports only mention the Northern Hemisphere spring snow cover, which has been declining from 1967 – the start of the satellite records. They did not mention that the autumn and winter snow cover have generally increased over the period of this satellite record. Nor did they highlight the fact that the GCM hindcasts have predicted that snow cover should have been continually decreasing for all four seasons (Connolly et al. 2019).

4. Arctic temperature trends

As part of our analysis for Connolly et al. (2017), we also estimated Arctic temperature variations. This estimate was an update of a similar analysis we described in Soon et al. (2015). The estimate is shown in Figure 2. It can be seen that Arctic temperatures have gone through multiple multi-decadal periods of warming and cooling: an Arctic warming 1900s-1940s, an Arctic cooling 1940s to 1970s, and then another period of Arctic warming (1980s to present).

The warming before 1940 is very unlikely to be related to increasing greenhouse gases, since atmospheric concentrations of CO_2 and other greenhouse gases were still relatively close to pre-industrial concentrations according to the estimates favored by the IPCC. Therefore, current GCMs are unable to explain it satisfactorily, since the current GCMs assume that greenhouse gases are the main climatic driver. However, given that this early 20th century Arctic warming is qualitatively quite similar to the current Arctic warming, it is plausible that whatever caused it might also be involved in the current warming. With that in mind, in Soon et al. (2015), we showed that if you used a different estimate of solar activity than the ones considered by the

GCM hindcasts submitted to the IPCC reports, you can explain much of the early and current Arctic warming as well as the cooling from the 1940s-1970s in terms of changes in solar activity.

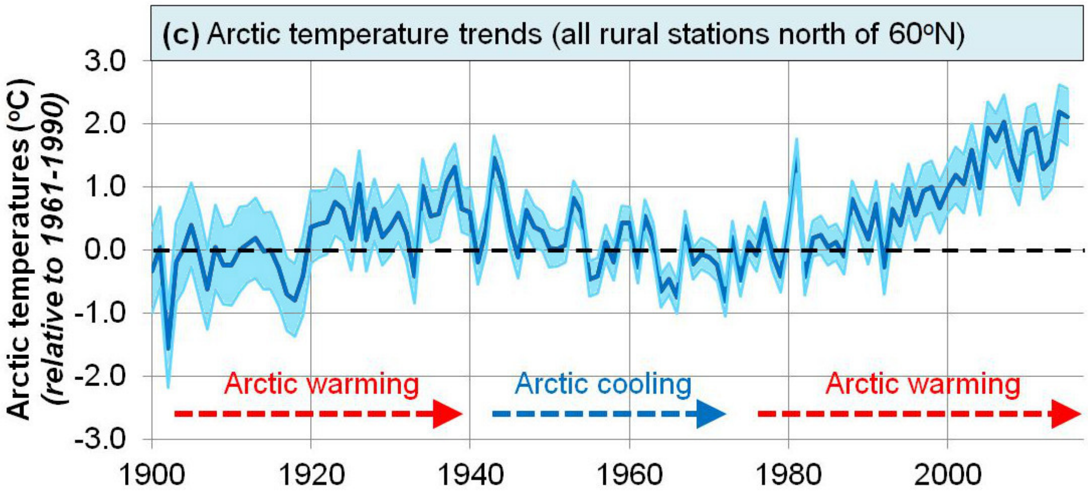

Figure 2. Arctic temperature trends (Connolly and Connolly 2015).

5. Antarctic

During the satellite era, the Antarctic sea -ice has mostly been increasing, not decreasing as expected by the GCM hindcasts.

In terms of Antarctic temperatures, the available temperature records are very limited before 1957/58, i.e., the International Geophysical Year) and are still quite limited post-1958. Nonetheless, Steig et al. (2009) applied statistical interpolation techniques to this limited data and calculated a general warming for the entire continent since 1957. However, O'Donnell et al. (2011) later reanalyzed Steig et al. (2009)'s data and discovered that their interpolation techniques had inadvertently blended conflicting trends for different regions of the continent. O'Donnell et al. (2011)'s analysis revealed that while the West Antarctic Peninsula has warmed considerably since 1957, large sections of the much bigger East Antarctica have generally cooled.

6. Summary

- The UN IPCC is great at identifying any "warming trends", but they seem to have a blind spot for anything else
- Current Global Climate Models blame almost all their "melting ice" on human-caused greenhouse gas emissions
- But, the Global Climate Models are doing an awful job of "hindcasting" the observed cryosphere trend
- The Arctic seems to alternate between multidecadal periods of warming and cooling
- Recent Antarctic trends have been the opposite to Arctic, but:
    - Some localized warming (the West Antarctic Peninsula)
    - Data is very limited before 1957
- For the future: Plan for warming **<u>or</u>** cooling

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