Antarctic Sea Ice Variability

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Sea ice keeps the Polar Regions cool and helps moderate global climate. Sea ice has a bright surface; 80 percent of the sunlight that strikes it is reflected back into space. As sea ice melts in the summer, it exposes the dark ocean surface and the ocean absorbs 90 percent of the sunlight. The oceans heat up, and temperatures in the Polar Regions rise further.

According to scientific measurements, both the thickness and extent of summer sea ice in the *Arctic* have shown a dramatic decline over the past thirty years. However, sea ice in the *Antarctic* region has not. The loss of Arctic sea ice will potentially accelerate global warming and change climate patterns.

Sea ice extent is a measure of the area of ocean where there is at least some sea ice. It forms, grows, and melts in the ocean. In contrast, icebergs and ice shelves float in the ocean but originate on land. For most of the year, sea ice is typically covered with snow. Usually, scientists define a threshold of minimum concentration to mark the ice edge; the most common cutoff is at 15 percent because it provides the most consistent agreement between satellite and ground observations.

The sea ice surrounding Antarctica has increased in extent and concentration from the late 1970s, when satellite-based measurements began, until 2015. This increase is not reproduced by climate models, and comes despite the overall warming of the global climate and the region. Although this increasing trend is modest, it is surprising given the overall warming. Indeed, climate models, which incorporate our best understanding of the processes affecting the region, generally simulate a decrease in sea ice. Moreover, sea ice in the Arctic has exhibited pronounced declines over the same period, which *is* consistent with global climate model simulations. For these reasons, the behavior of Antarctic sea ice has presented a conundrum for global climate change science.

Antarctica and the Arctic react differently to climate change partly because of geographical differences. Antarctica is a continent surrounded by water, while the Arctic is an ocean surrounded by land. Wind and ocean currents around Antarctica isolate the continent from global weather patterns, keeping it cold. In contrast, the Arctic Ocean is affected by the climate around it, making it more sensitive to climate changes.

The National Academies of Sciences, Engineering, and Medicine held a Workshop on January 11-12, 2016, in Boulder, Colorado, to bring together scientists with different sets of expertise and perspectives to further explore the mechanisms driving the evolution of recent Antarctic sea ice variability and to discuss ways to advance understanding of Antarctic sea ice and its relationship to the broader ocean-climate system.

There are many local, regional, and global processes that influence sea ice growth and melt, but it is not clear what mechanisms best explain the observed variability and the slight increase in overall Antarctic sea ice extent. Many workshop discussions emphasized the distinct regional variability of Antarctic sea ice patterns. For example, most of the increase in total sea ice extent has occurred in the western Ross Sea. The *drivers* of the increases in this region are not well understood.

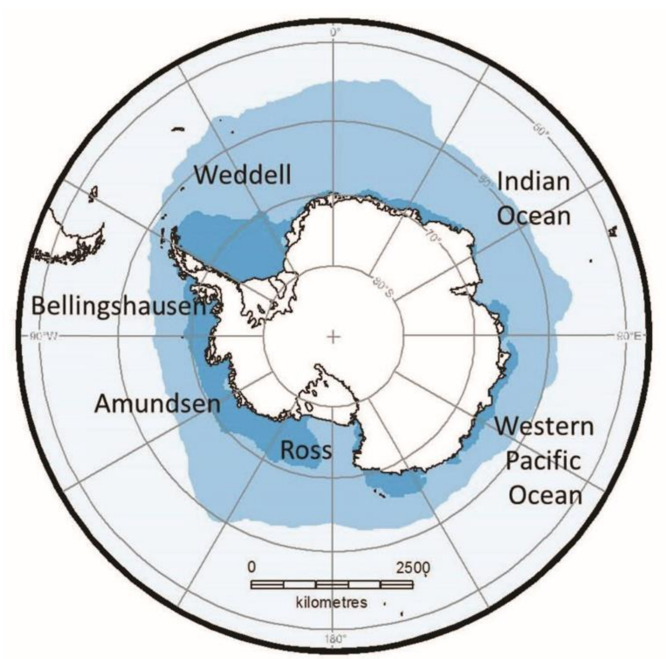

Figure 1 – Map of Antarctica and different region sectors. Light blue indicates mean winter sea ice extent; dark blue indicates mean summer sea ice extent. From presentation by Dr. Sarah Das.

Climate models provide an important tool for interpreting and extending understanding of Antarctic sea ice observations as well as exploring the potential mechanisms influencing the observed variability. Much of the research to date has focused on the notable discrepancy between observations and the models, which generally exhibit a decline in Antarctic sea ice over the last 30-50 years. If the models are improved to the point that they can reliably reproduce past sea ice conditions, then they could also be used to disentangle the roles of *internal variability* and *human-caused drivers* of changes in sea ice, as well as to project how they might change in the future.

Some participants said that there is little confidence in the models that are used for attribution of Antarctic sea ice variability. For example, many of the models have a poor representation of the mean state of the Southern Ocean, which is important to reproduce observed trends in Antarctic sea ice.

Several methods for modeling Antarctic Sea Ice were discussed. ***One method*** is with the **free-running coupled climate model**. Such a model includes components for the atmosphere, ocean, sea ice, land, and biology. It is scientists' best attempt to replicate the climate system. The model that was used in the Intergovernmental Panel Climate Change (IPCC) Assessment Reports was a coupled climate model. Simulations using coupled climate models show the internal variability of the model's climate system (e.g., El Nino Southern Oscillation (ENSO), decadal variability) in the absence of changes in radiative forcing (difference between solar energy absorbed and heat radiated). They are long term simulations of at least 1,000 years for robust sampling. Historical simulations tend to be used for model evaluation, which is the process of evaluating climate sensitivity, internal variability, and responses to external forcing. Historical runs also provide information on the range of possible outcomes. In comparing the historical runs to observations, the observations should fit within the range of simulations. However, no single simulation needs to represent the actual observed climate, because simulations have different chronologies of decadal and multidecadal variability.

Another type of model used is the **constrained coupled climate model**. It is constrained to include the observed variability *in a certain area* and finds how that impacts other areas. Simulations from these constrained models are referred to as "Pacemaker" simulations because the observed variability in a particular area sets the "pace" for the rest of the climate system. These models are particularly good for hypothesis testing and physical and mechanistic understanding. For example, to test the influence of the tropics on the Southern Ocean, a scientist could "nudge" winds or sea surface temperatures in the tropics toward observations and allow the constrained coupled model to respond (Douville et al., 2015; Kosaka and Xie, 2013; Schneider et al., 2012a).

Antarctic sea ice can also be studied with **forced-component models.** These allow scientists to test hypotheses and gain process-level understanding. For example, to explore the influence of observed wind changes on the Southern Ocean, a scientist would prescribe the observed evolution of winds to an ocean–sea ice model. However, the models would not provide information on the origin of the wind changes (Bintaja et al., 2013; Sen Gupta and England, 2006; Zhang, 2014).

Dr. Xiaojun Yuan, Lamont-Doherty Earth Observatory, discussed a **statistical forecast model** that is capable of capturing the Antarctic sea ice response to ENSO forcing. This model depicted large inter-annual variability in sea ice concentrations in the Western Hemisphere. Sea ice in the region is quite responsive to atmospheric forcing, and he showed that sea ice anomalies are predictable with a simple statistical model.

The main conclusion of the Workshop was that models that project climate conditions decades and longer into the future seem to indicate that the Antarctic sea ice *will eventually* respond to global warming and decline. Observations from late 2016 and early 2017 indeed show decreases in Antarctic sea ice extent. Nevertheless, *many participants said a better understanding of the mechanisms is critical to making **confident** statements about the future of Antarctic sea ice.*

Reference:

Antarctic Sea Ice Variability in the Southern Ocean – Climate System. Proceedings of a Workshop. Alison Macalady and Katie Thomas, Rapporteurs, Polar Research Board, The National Academies Press, 2017.