The future of Arctic sea ice cover

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You may have heard that Arctic sea ice has been declining since 1979, when satellites first began to monitor the high north. But it would be perfectly fair to ask: What will Arctic sea ice look like in the future?

Scientists agree that Arctic sea ice will continue to decline over the 21st century. But by exactly how much? That is less clear. State-of-the-art climate models show a wide variation in the projected decline of Arctic sea ice area over the 21st century. For example, the current generation of climate models suggest the Arctic could be essentially ice-free as early as 2030 or as late as 2100 (Figure 1).

Why do these projections differ so much? These differences arise primarily due to how climate models respond to external factors, such as anthropogenic carbon-dioxide emissions. For instance, one of the main reasons projections differ is due to how climate models represent clouds, which have been shown to determine how fast and how much these models warm in response to rising greenhouse-gas concentrations. Climate models also predict different degrees of future Arctic warming due to differences in the amount of heat transported by the ocean.

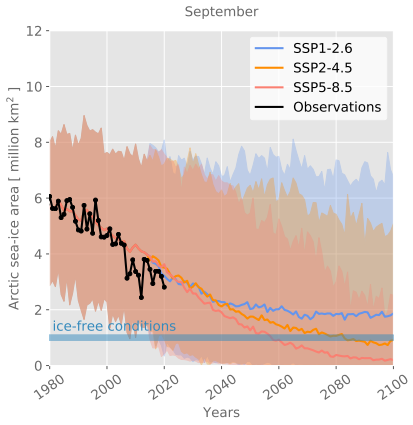

Figure 1: September Arctic sea ice area from 1980–2100 under historical (1850–2014) and SSP1-2.6 (blue), SSP2-4.5 (orange), and SSP5-8.5 (red) emissions scenarios (2015–2100). The shading indicates the full inter-model spread of each emission scenario. The solid lines denote multi-model means of 29 different climate models. The black line denotes the observed September Arctic sea-ice area.

Despite all of the intricacies of Arctic sea ice, however, one thing is clear: The decline in the areal coverage of Arctic sea ice has occurred in lock-step with Arctic warming (Figure 2). Arctic sea ice area has diminished by approximately 50% since 1979 and near-surface air temperatures in the Arctic have risen by more than 2°C, which is nearly three times as fast as the global average. In September 2020, Arctic sea ice area reached its second lowest monthly average on record and Arctic temperatures reached their second highest monthly average on record, bringing us closer to seeing an essentially ice-free Arctic in September.

In a recent study, my co-authors and I show that focusing solely on the relationship between Arctic sea ice area and Arctic temperatures can improve sea ice projections. We found that a simple model that approximates future Arctic sea ice area based on present Arctic sea ice area and the sensitivity of sea ice to Arctic temperatures is able to emulate the future evolution of Arctic sea ice as simulated by climate models. This work builds on previous research that has found linear relationships between Arctic

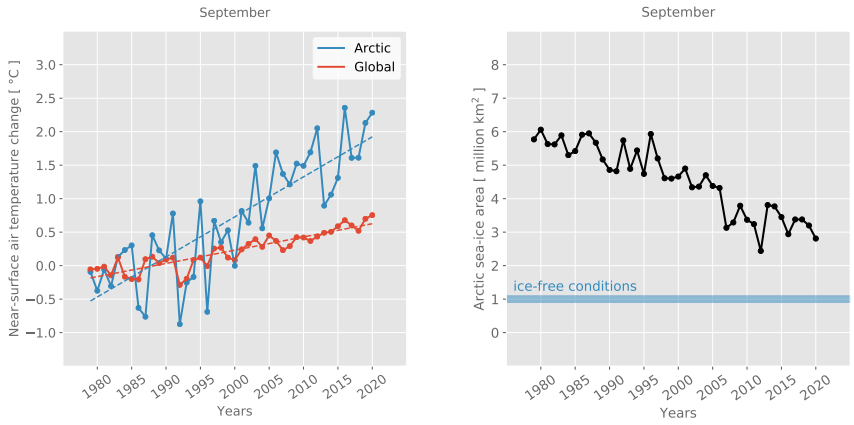

Figure 2: (left) Change in September near-surface air temperature averaged over the Arctic (blue) and the globe (red) from 1979–2020. The Arctic is defined as the average of all longitudes from 60°N to 90°N. (right) September Arctic sea ice area from 1979–2020. The sea ice data is from the NSIDC Sea Ice Index v3. The dashed lines denote least-squares regression lines.

sea ice area and human-caused carbon-dioxide emissions and global temperatures. We then used observations to constrain our simple model to improve future projections.

Under a high-emissions scenario, we show that it is 'likely' (>66% probability) the Arctic will be ice-free sometime between 2036-2056 in September, which is 10–20 years earlier than climate models suggest (Figure 3). Under a medium-emissions scenario we find a similar picture, with the Arctic projected to be free of sea ice in September sometime between 2042-2062 — close to 15 years sooner than climate models suggest. Importantly, however, we show that under a low-emissions scenario, the Arctic will likely not experience ice-free conditions that persist from July to October. This suggests reducing human-caused carbon-dioxide emissions will reduce the likelihood of seeing ice-free Arctic summers.

Indeed, these refined estimates of future Arctic sea ice loss are not good news for polar bears or walruses, which have been steadily declining in the Beaufort Sea already. Because polar bears depend on sea ice for hunting seals, as the sea ice recedes farther north there is less space for hunting. Still, we have an opportunity to reduce future warming in the Arctic by systematically reducing our greenhouse-gas emissions. Doing so will decrease the probability of seeing ice-free conditions in Arctic in September and decrease the duration of ice-free Arctic summers, both of which will help to preserve polar bear habitats.

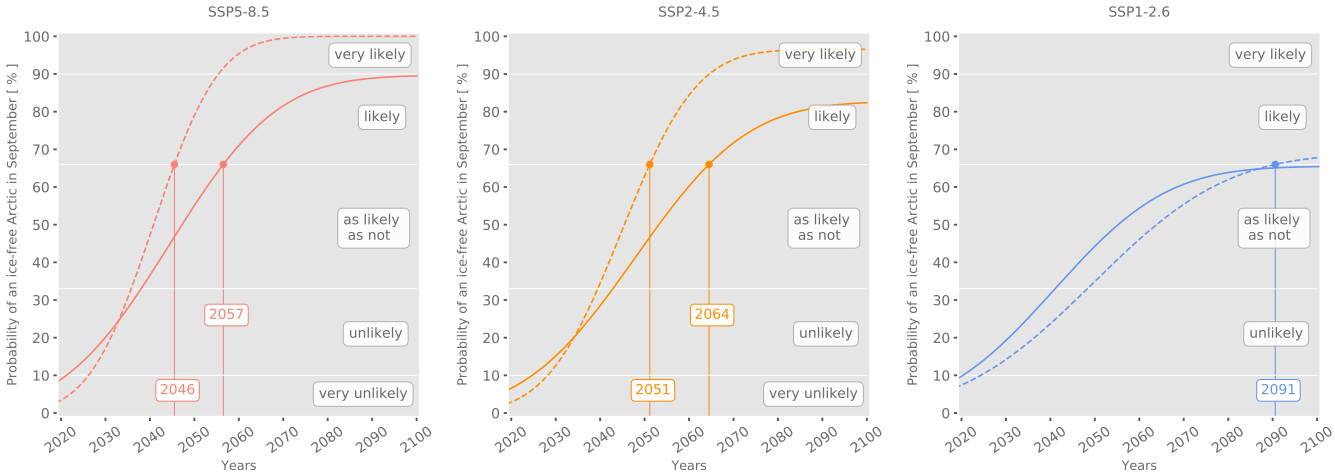

Figure 3: Probability of seeing an ice-free Arctic in September over the 21st century for (left) SSP5-8.5, (middle) SSP2-4.5, (right) SSP1-2.6 emissions scenarios. Ice-free conditions are defined as the first year when each model crosses the 1 million km^2 threshold. The solid line denotes the raw model output and the dashed line denotes our constrained estimates.

Dave Bonan is a graduate student in the Environmental Science and Engineering program at the California Institute of Technology. Follow him on Twitter at @Dave_Bonan and learn more about his work via his website.