What you should know about Arctic sea ice

Arctic sea ice is diminishing rapidly. Sea ice (frozen sea water) persists across much of the Arctic Ocean all year. It expands throughout fall and winter to partially cover much of the Arctic's peripheral seas as well, including the Bering Sea. The minimum sea ice extent at the end of summer, which is an important indicator of the overall state of sea ice, has steadily decreased at the rate of 13% per decade since the satellite record began in 1979 (see Figure 1). Half of summer ice extent has been lost in only 40 years. Over this same time period, the volume of sea ice has declined by approximately 70% owing to both the loss of thick, multi-year ice (ice that has survived at least one summer) and overall thinning. The Arctic Ocean could be virtually ice free (< 1 million sq km) in summer as soon as the late 2030s.

The loss of sea ice is an effect of global atmospheric warming driven by greenhouse gas (GHG) emissions. In the Arctic, warming is amplified by several reinforcing feedbacks. For example, loss of ice means more open water. Open water absorbs more sunlight than reflective ice, leading to more warming and further reductions in ice. This is known as the ice-albedo feedback.

Arctic sea ice loss has local, regional, and global impacts.

Coastal Arctic communities: Loss of sea ice is altering hunting and fishing opportunities and exposing shorelines and coastal infrastructure to increased damage from fall storms.

Marine ecosystems: The timing and extent of sea ice cover directly and indirectly influence the abundance and seasonal behavior of many species. As sea ice recedes, some sub-Arctic species may shift their ranges northward into the Arctic, while some Arctic species may be displaced by these new migrants through competition or predation. These shifts are already being observed.

Mid-latitude weather: A growing body of research suggests that differential warming between the Arctic and lower latitudes will increase the persistence of weather patterns, leading to more frequent extreme weather events in the United States and elsewhere in the northern hemisphere.

Marine access: Access to Arctic waters is expanding, driving increased interest in Arctic shipping and tourism. Shipping is significantly influenced by a host of factors, however, such as commodity prices, insurance rates, and environmental variability.

Industrialization: Offshore oil and gas reserves will become more accessible as sea ice declines, yet industrial operations in the Arctic will continue to face challenges of operating in remote, harsh, and logistically constrained environments.

Environmental stewardship: Our current understanding and ability to monitor cumulative impacts and respond to disasters may not keep pace with the rate of increased human activity in the Arctic marine environment.

International relations: Several agreements and forums (e.g., Arctic Council, U.N. Convention on the Law of the Sea, Polar Code, Central Arctic Ocean Fisheries Agreement, etc.) provide an important foundation for international cooperation and oversight. More work may be needed to establish effective governance with further increases in marine use, resource development, and tourism in Arctic waters.

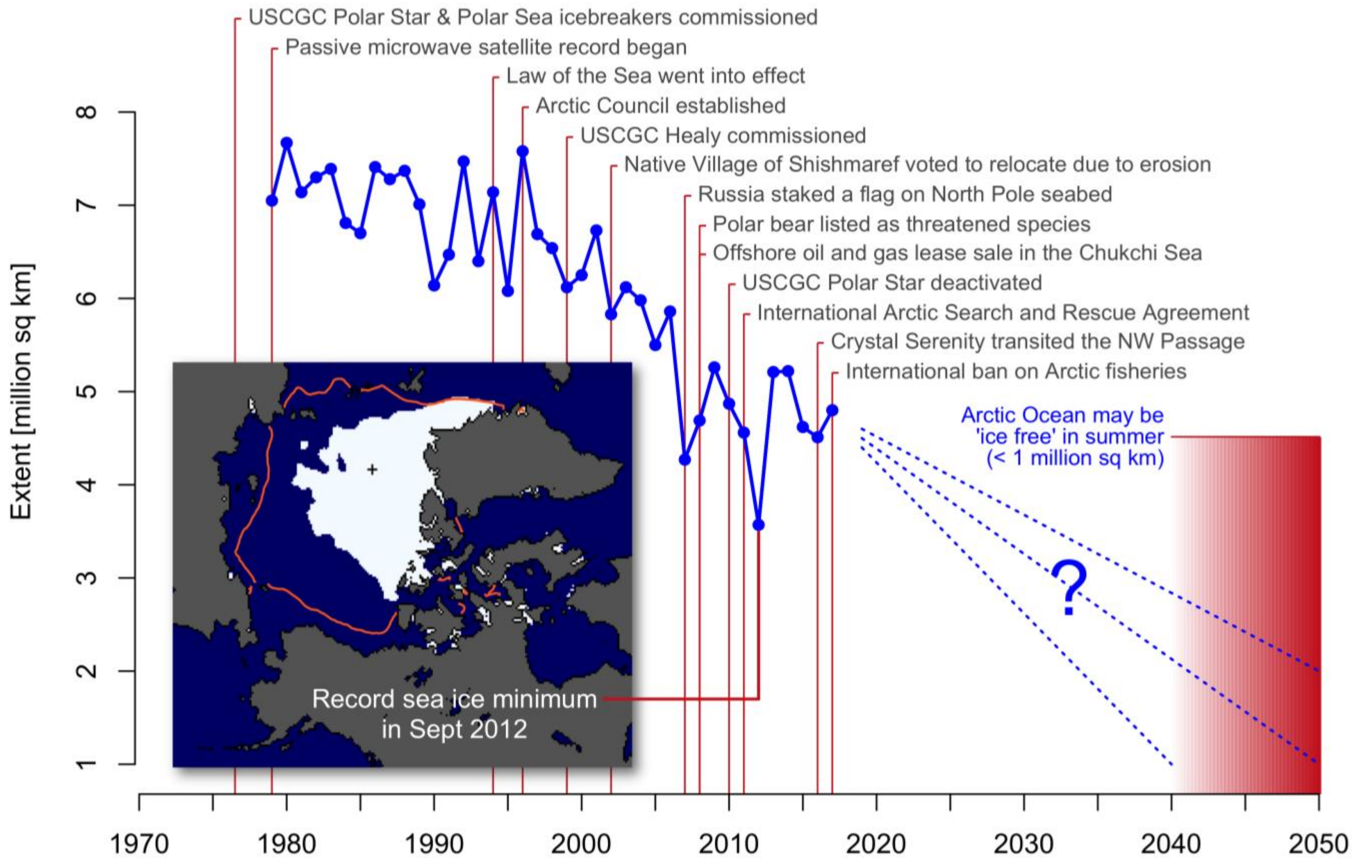

Figure 1. Arctic summer sea ice extent (1979-2017), annotated with significant events related to impacts, monitoring, governance, and stakeholder activities.

The research community is addressing various interrelated topics concerning potential implications of plausible future sea-ice conditions. The overarching goal is to inform adaptive responses by various stakeholders: governments, industries, coastal communities, conservationists, and others affected directly and indirectly by declining sea ice. To do this, scientists must engage with decision-makers to better focus research toward addressing societally relevant questions. For example, what are the major thresholds in sea ice conditions that could represent potential "game-changers" for particular stakeholders, such as the shipping industry? To what extent is a lack of knowledge or information about specific sea ice conditions a hindrance to planning and response across various domains? What kinds of data products and communication will best promote informed and adaptive responses?

In many cases, information from different domains must be synthesized to understand the implications of ice loss. For example, continued research across disciplines is needed to further understand what promotes or limits Arctic marine primary production, and thus influences the larger Arctic food web, including subsistence species such as the bowhead whale. To track relationships across components of the climate system, science is gathering quantitative information on the role of sea-ice loss in accelerating both melt of the Greenland ice sheet melt (augmenting global sea-level rise) and the thaw of permafrost (accelerating releases of carbon into the atmosphere). This synthetic approach is providing further evidence linking rapid Arctic warming to shifting large-scale atmospheric patterns, which influence global weather.

Improved predictions of Arctic sea ice conditions have inherent limitations.

- The predictability of sea ice conditions varies across the different timeframes of interest—weekly, seasonal, inter-annual, or decadal. Most predictions of sea ice conditions use dynamical computer models that simulate the physical interactions among the ocean, atmosphere, land, and sea ice. The chaotic nature of the system creates inherent limits to predictability.
- Predictability may increase with more accurate information about ice thickness, model refinement, and comparisons to identify the most realistic models as key sea-ice processes change, such as a more mobile thin ice cover and changing melt/freeze patterns.
- A warming atmosphere and ocean caused by increasing GHGs drive long-term sea ice loss, which provides predictability decades into the future. However, uncertainties in future GHG emissions and random natural fluctuations limit predictability. Therefore, there is an irreducible uncertainty of about two decades on the timing of the first ice-free summer.

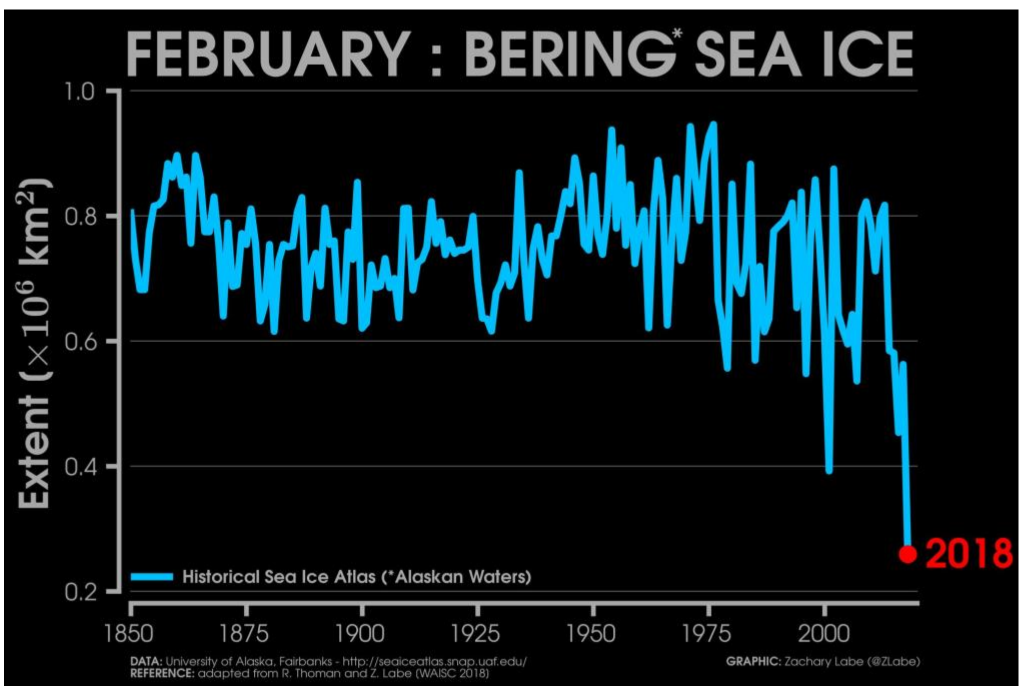

Figure 2. February sea ice extent (1850-2018) in the Bering Sea. Not only is Arctic summer sea ice rapidly diminishing; winter sea ice coverage is also changing. The Bering Sea experienced exceptionally low ice cover during winter 2018. This winter's vast stretches of open water permitted stormy conditions to damage village infrastructure across several coastal communities.