Future Sea-Ice Decline Predicted to Bring the Arctic Nations Closer Together

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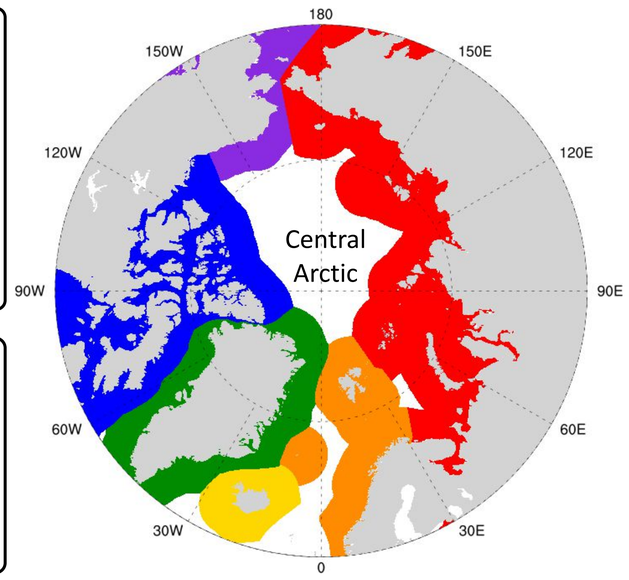
Motivation

Sea ice can raft various material from where it originally forms to where it melts: aerosol deposits, aeolian dust, sediments, biological communities growing under the ice, freshwater and pollutants such as mercury and lead. We investigate how ice transport from one EEZ to another change as the Arctic ice cover continues to decline over the 21st century, which can inform policymakers about the potential for ice-rafted pollutant transport.

Exclusive Economic Zones

An exclusive economic zone (EEZ) is a sea zone prescribed by the United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources, including energy production. It extends 200 nautical miles from the coastline.

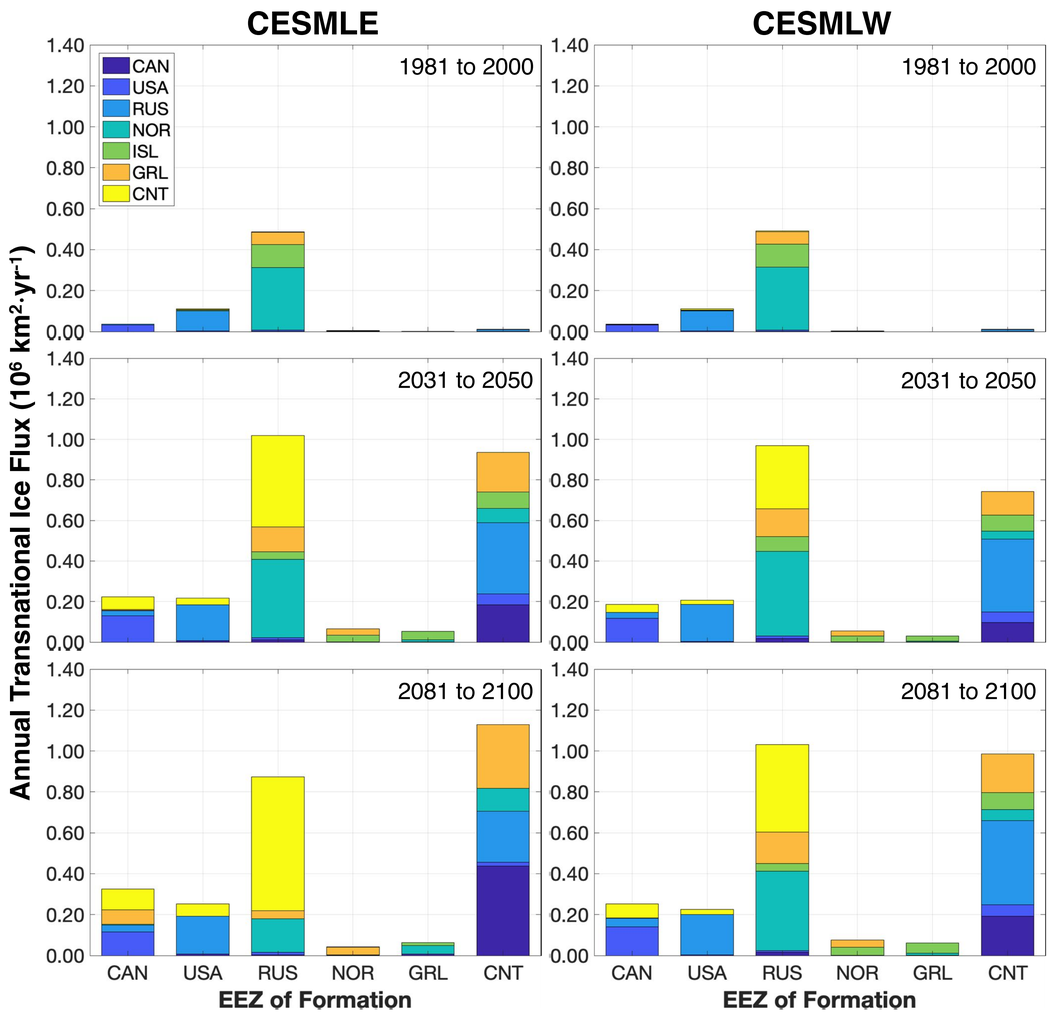


Methodology

We developed a Lagrangian Ice Tracking System (LITS; *Newton et al., 2017*) to track ice floes from the location where they form to where they ultimately melt. This is done using sea-ice velocity and concentration from climate model output with a monthly time resolution.

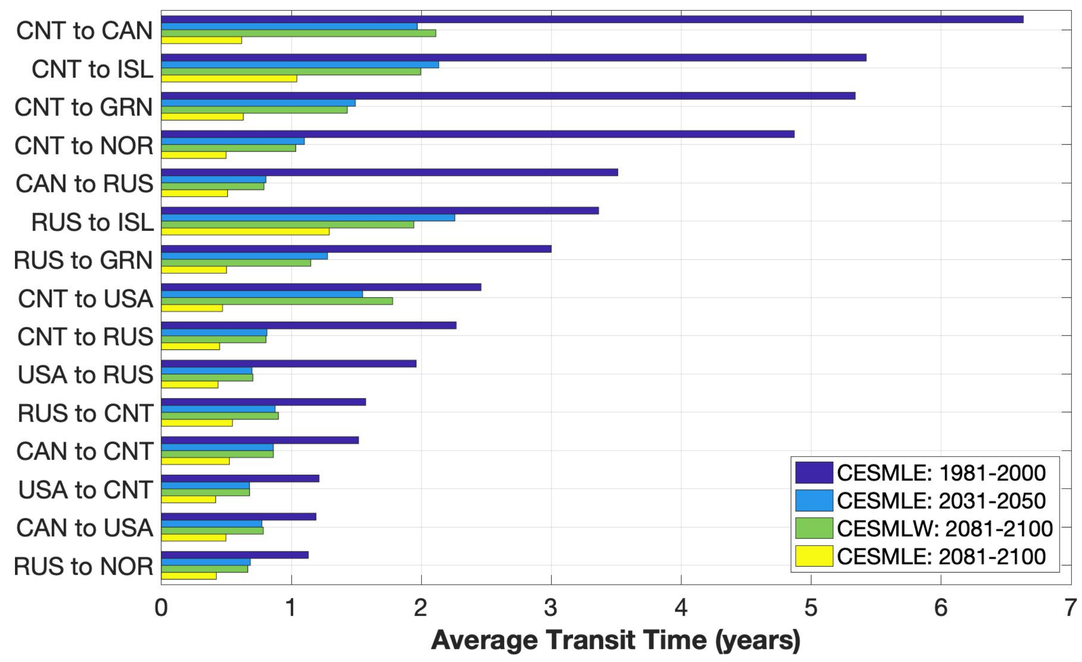
We use the Community Earth System Model Large Ensemble (CESMLE; *Kay et al., 2015*) from 1920 to 2100 (40 members) as well as the CESM ensemble simulations following the 2°C target Low Warming scenario (CESMLW; *Sanderson et al., 2017*) from 2006 to 2100 (11 members). CESMLE uses the business-as-usual scenario (RCP8.5) and reaches consistent summer ice-free conditions with a global mean warming of over 4°C by the end of the 21st century (*Jahn, 2018*). CESMLW follows an emission scenario designed so that the multi-year global mean temperatures never exceed 2°C above pre-industrial levels.

Increase in Transnational Ice Exchange



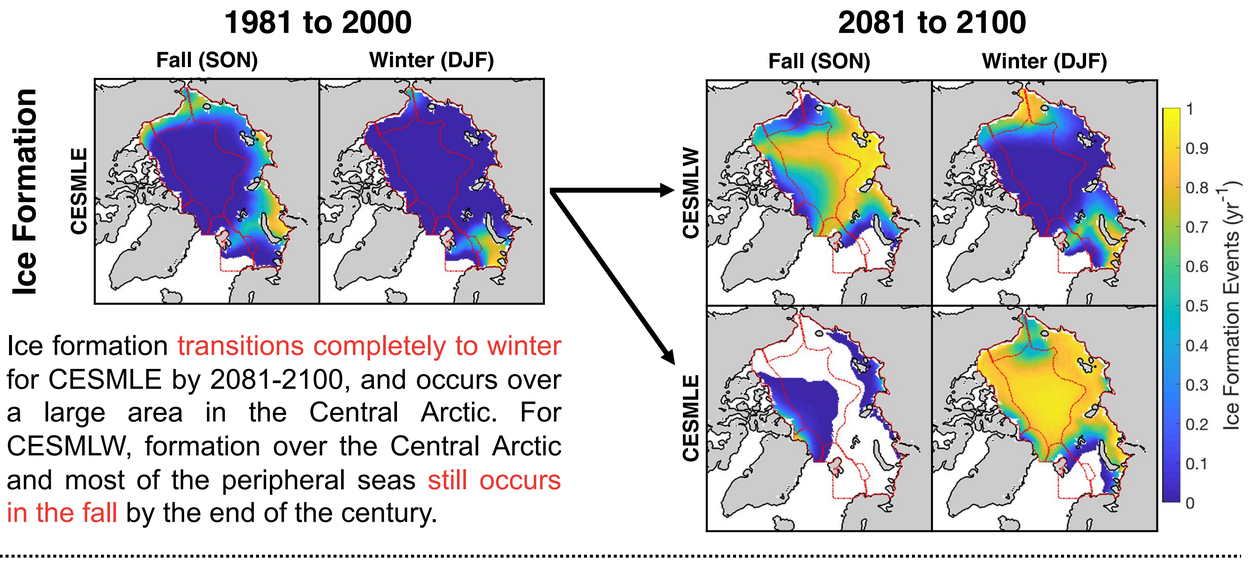
Increase in transnational ice exchange by 2031-2050, with the Central Arctic becoming more involved both as a region of formation and melt (larger seasonal ice zone). By 2081-2100, the fraction of transnational ice exchange reduces for CESMLE but continues to increase for CESMLW.

Decrease in Average Transit Time

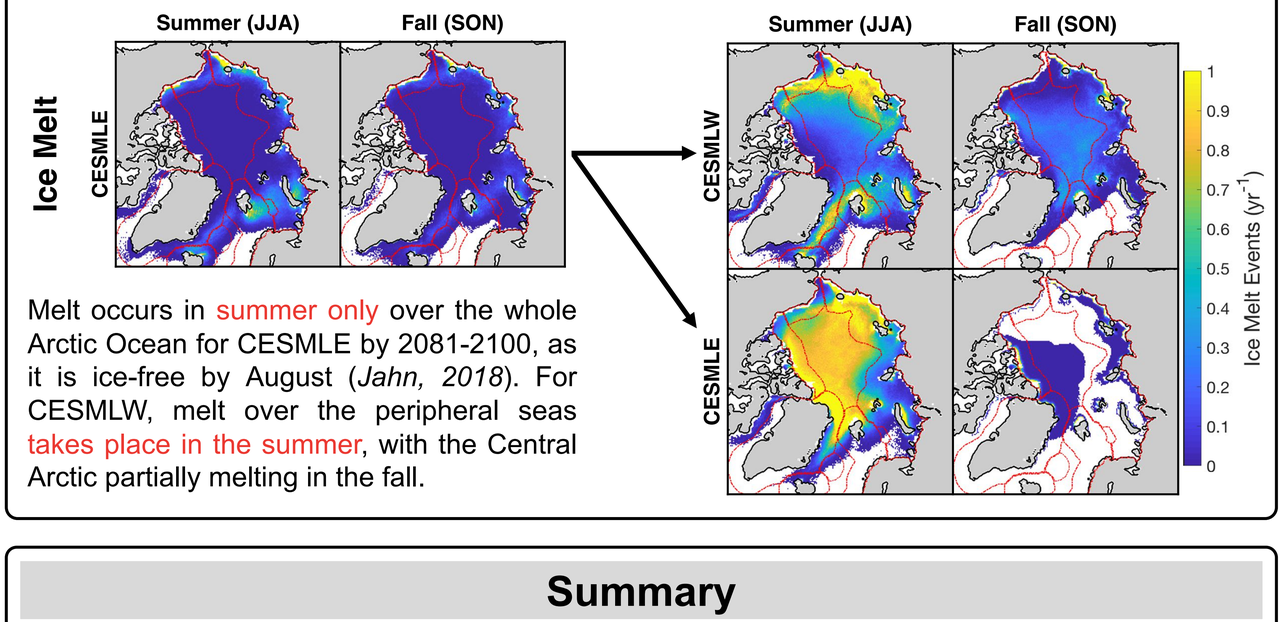


Reduction in transit time to under two years for most exchange pathways by the middle of the 21st century for both scenarios, and a continued decrease to under one year by the end of the century for CESMLE, while CESMLW stays at mid-century transit times.

Seasonal Change in Ice Formation & Melt

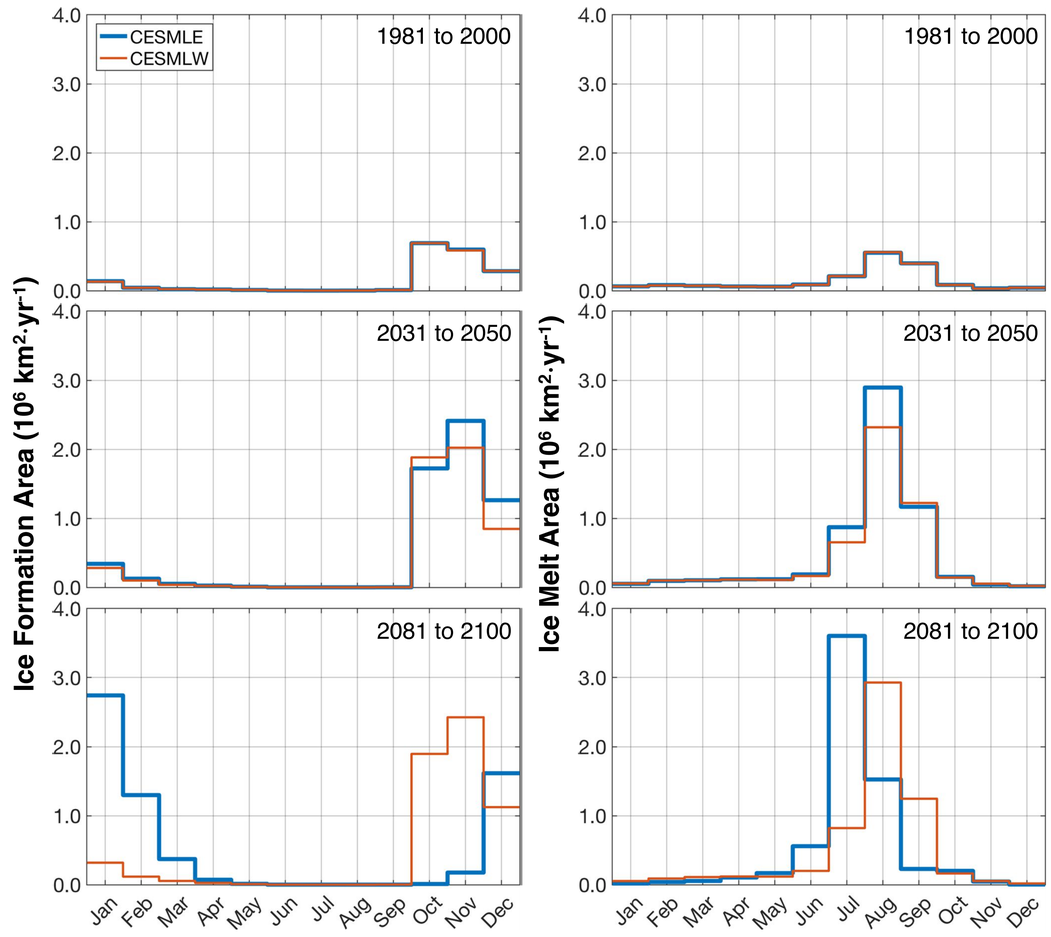


Ice formation transitions completely to winter for CESMLE by 2081-2100, and occurs over a large area in the Central Arctic. For CESMLW, formation over the Central Arctic and most of the peripheral seas still occurs in the fall by the end of the century.



Melt occurs in summer only over the whole Arctic Ocean for CESMLE by 2081-2100, as it is ice-free by August (*Jahn, 2018*). For CESMLW, melt over the peripheral seas takes place in the summer, with the Central Arctic partially melting in the fall.

Longer Melt Season Length



By 2081-2100, formation occurs later in the year, with the maximum in January for CESMLE and November for CESMLW. Melt peaks in July by 2081-2100 for CESMLE and in August for CESMLW.

Summary

- Sea-ice retreat leads to growing transnational ice exchange due to a larger seasonal ice zone.
- By mid-century, Russia and the Central Arctic increasingly dominate transnational ice exchange.
- Long distance ice transport pathways disappear by the end of the 21st century.
- By the end of the century, consistent ice-free summers in CESMLE act to reduce the fraction of transnational ice exchange, whereas CESMLW continues to see an increase.

Jahn, (2018). Reduced probability of ice-free summers for 1.5°C compared to 2°C warming. *Nature Climate Change*.
Kay et al., (2015). The Community Earth System Model (CESM) large ensemble project. *Bulletin of the American Meteorological Society.*
Newton et al., (2017). Increasing transnational sea-ice exchange in a changing Arctic Ocean. *Earth's Future.*
Sanderson et al., (2017). Community climate simulations to assess avoided impacts in 1.5 and 2°C futures. *Earth System Dynamics.*

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