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

Patricia DeRepentigny[1], Bruno Tremblay[2], Robert Newton[3], Stephanie Pfirman[4], and Alexandra Jahn[1]

[1]University of Colorado Boulder
[2]McGill University
[3]Lamont-Doherty Earth Observatory, Columbia University
[4]Arizona State University

November 24, 2022

Abstract

Over the past decades, Arctic sea ice has declined in thickness and extent and is shifting towards a seasonal ice regime, with accelerated ice drift and an increase in the seasonal ice zone. The changing Arctic ice cover will impact the trans-border exchange of sea ice between the Exclusive Economic Zones (EEZs) of the Arctic nations, with important implications for ice-rafted contaminant transport. To investigate projected changes to transnational ice exchange, we use the Lagrangian Ice Tracking System (LITS) to follow ice floes from the location of their formation to where they ultimately melt. We apply this tool to output from two ensembles of the Community Earth System Model (CESM): the CESM Large Ensemble, which uses a high emission scenario (RCP8.5) that leads to over 4°C global warming by 2100, and the CESM Low Warming ensemble, with reduced emissions that lead to a stabilized warming of 2°C by 2060. We also use the National Snow and Ice Data Center Polar Pathfinder and Climate Data Record products to evaluate the fidelity of the CESM present-day tracking simulations. Transnational ice exchange is well represented in CESM except for ice traveling from Russia to Norway, with twice as much ice following this pathway compared to observations. Initial results suggest this might be due to a combination of internal variability and speed biases in the observational data. The CESM projects that by mid-century, transnational ice exchange will expand, with a large increase in the fraction of transnational ice originating from Russia and the Central Arctic. As the seasonal ice zone grows, ice floes accelerate and transit times decrease, eventually cutting off ice exchange between longer pathways. By the end of the 21st century, we see a large impact of the emission scenario on ice exchange: consistent ice-free summers under the high emission scenario act to reduce the total fraction of transnational ice exchange compared to mid-century. The low emission scenario on the other hand continues to see an increase in transnational ice exchange by 2100. Under both scenarios, all pathways have decreased to average transit times of less than 2 years, compared to a maximum of 6 years under present-day conditions and 3 years by mid-century, effectively bringing the Arctic nations closer together.

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

Patricia DeRepentigny[1,2], Bruno Tremblay[2,3], Robert Newton[3], Stephanie Pfirman[4] and Alexandra Jahn[1]

[1]University of Colorado Boulder, [2]McGill University, [3]Lamont-Doherty Earth Observatory, [4]Arizona State University

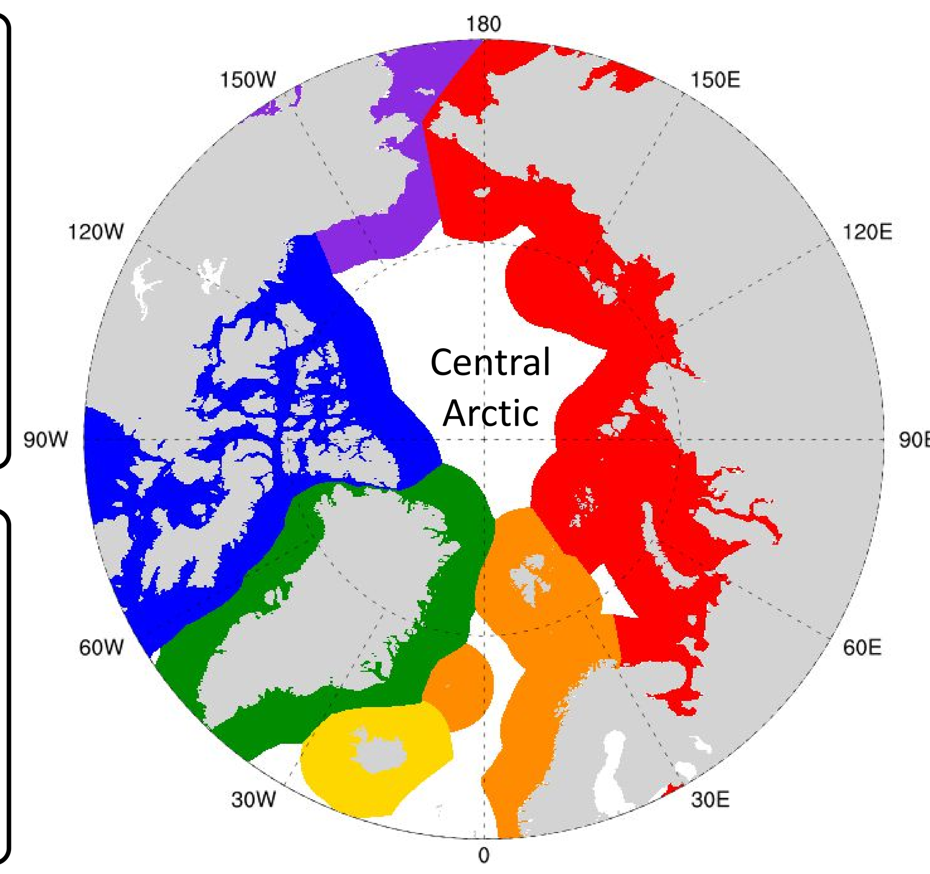
Contact: **patricia.derepentigny@colorado.edu**

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.

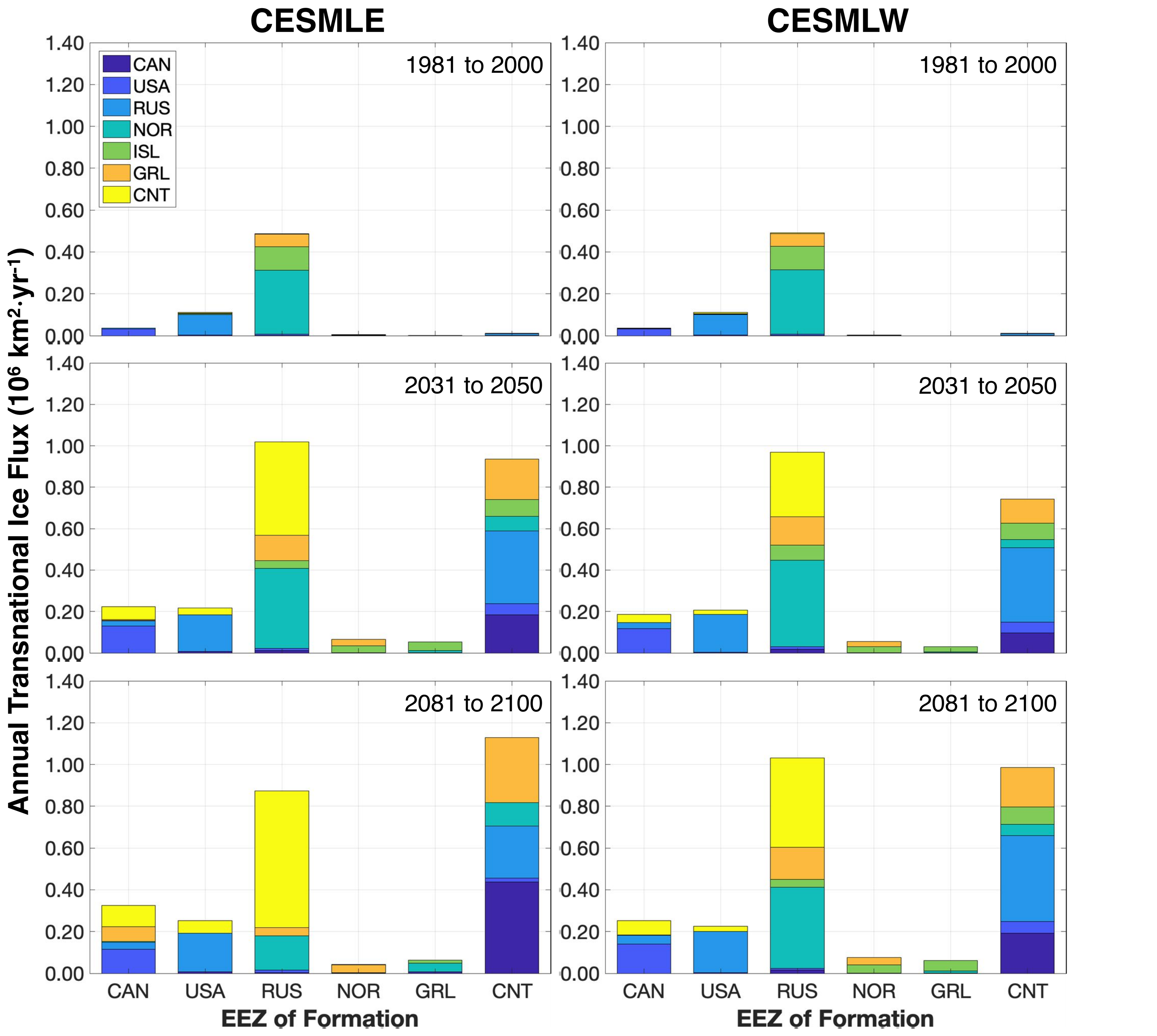


Methodology

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.

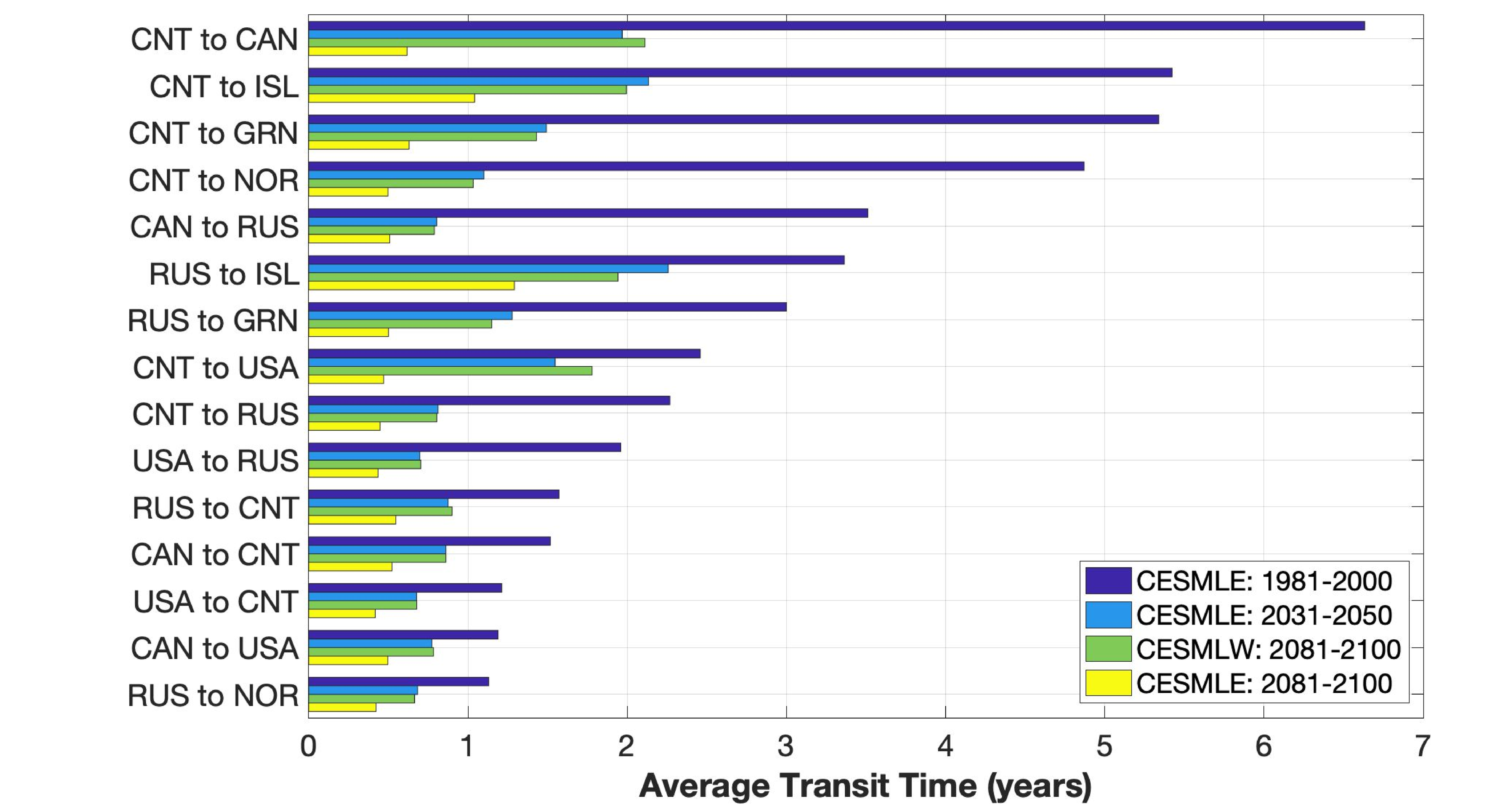
We use the Community Earth System Model Large Ensemble (CESMLE; *Kay et al., 2015*) from 1920 to 2100 (40 members) as well as the CESM ensemble simulations following the 2℃ target Low Warming scenario (CESMLW; *Sanderson et al., 2017*) from 2006 to 2100 (11 members). CESMLE uses the business-as-usual scenario (RCP8.5) and reaches consistent summer ice-free conditions with a global mean warming of over 4℃ 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℃ above pre-industrial levels.

Increase in Transnational Ice Exchange



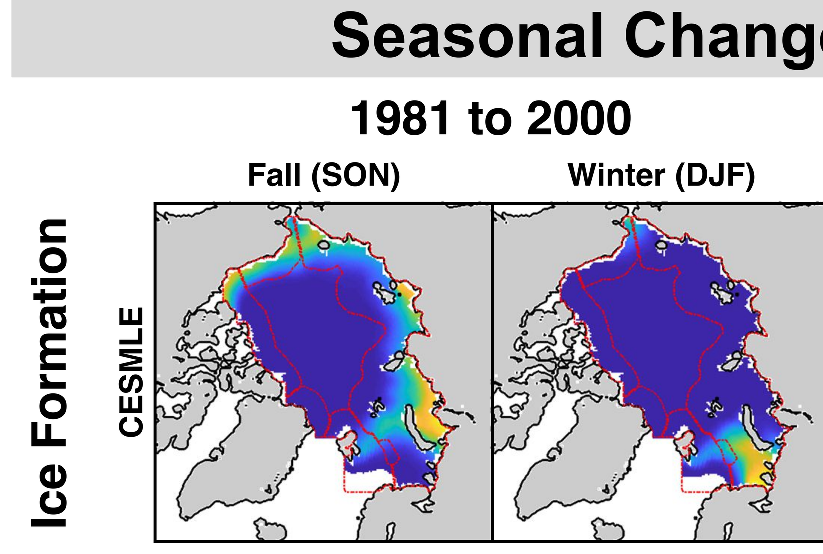
Increase in transnational ice exchange by 2031-2050, with the Central Arctic becoming more involved both as a region of formation and melt (larger seasonal ice zone). By 2081-2100, the fraction of transnational ice exchange reduces for CESMLE but continues to increase for CESMLW.

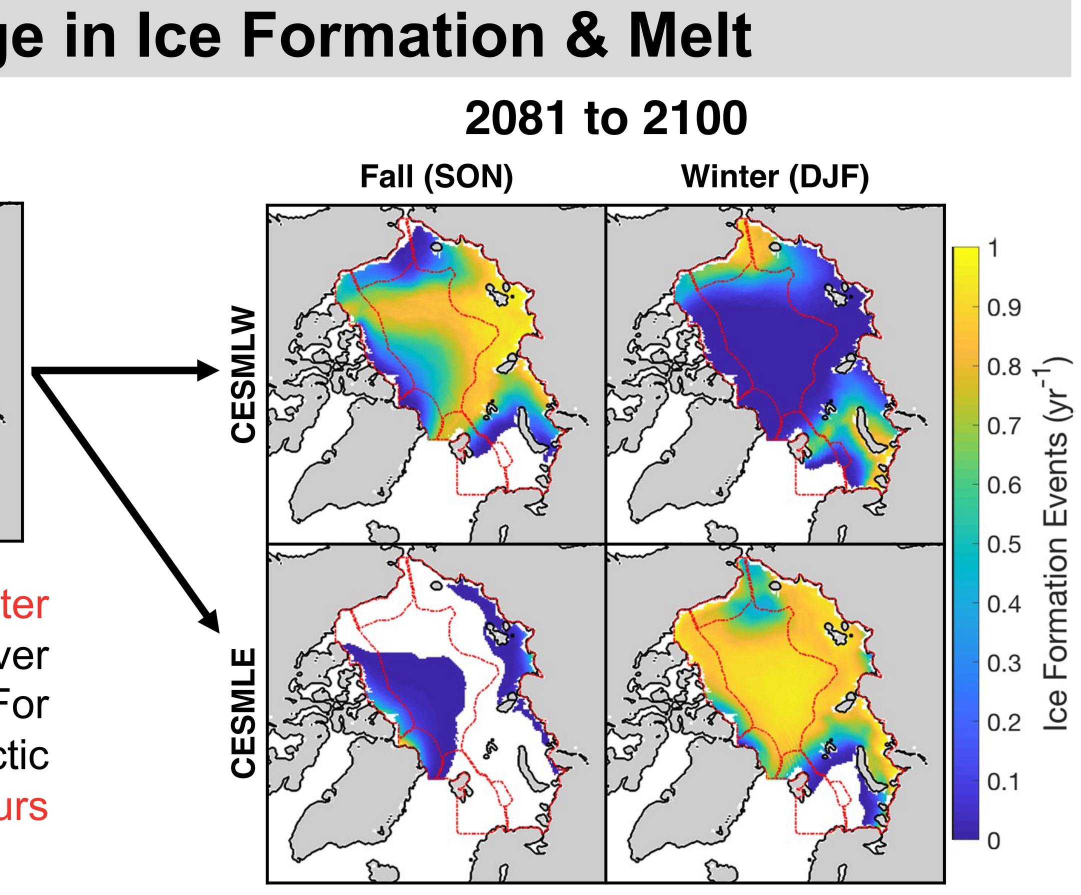
Decrease in Average Transit Time



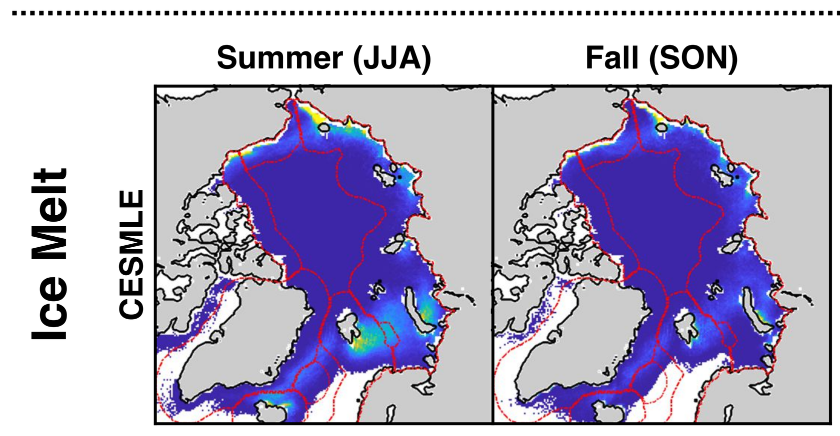
Reduction in transit time to under two years for most exchange pathways by the middle of the 21st century for both scenarios, and a continued decrease to under one year by the end of the century for CESMLE, while CESMLW stays at mid-century transit times.

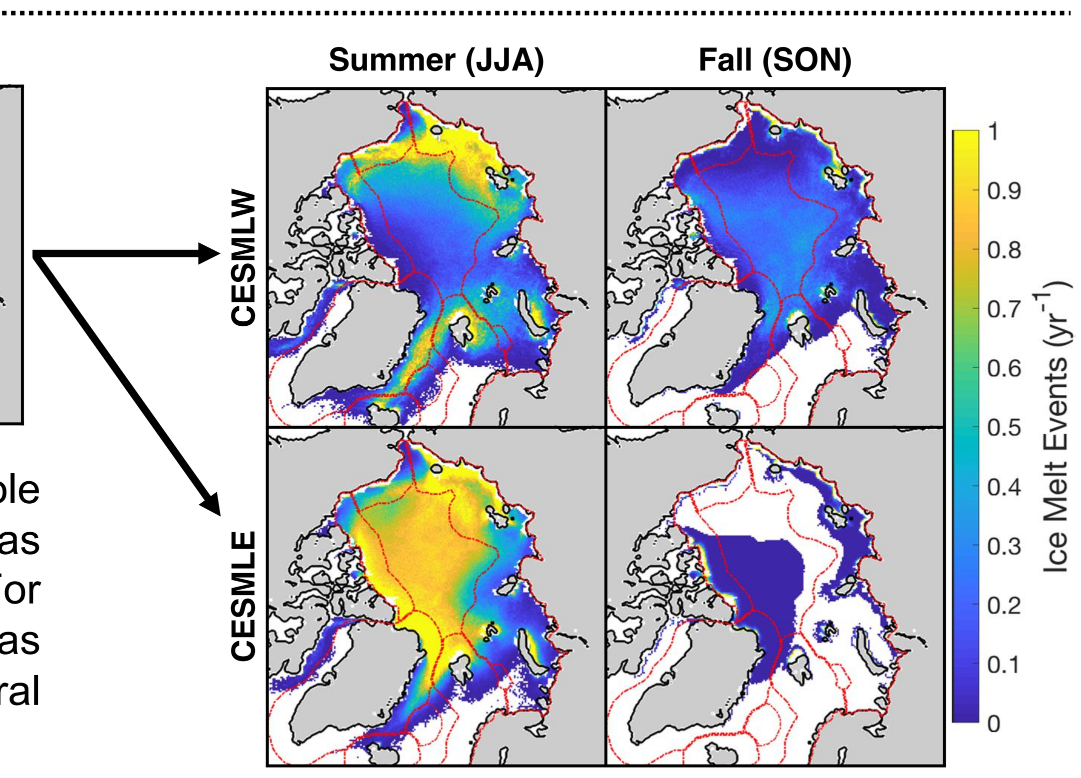
Seasonal Change in Ice Formation & Melt





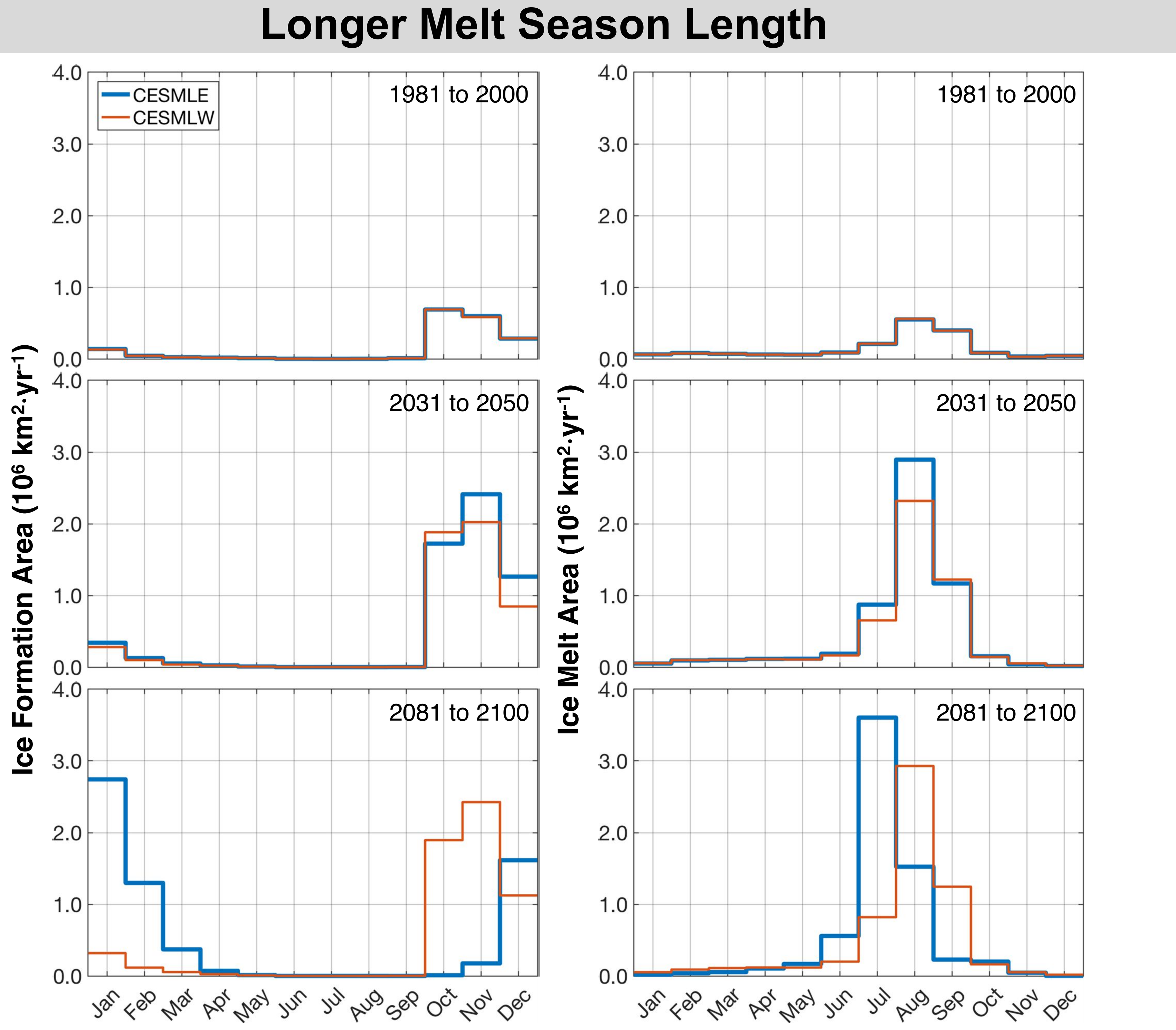
Ice formation transitions completely to winter for CESMLE by 2081-2100, and occurs over a large area in the Central Arctic. For CESMLW, formation over the Central Arctic and most of the peripheral seas still occurs in the fall by the end of the century.





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℃ compared to 2℃ 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℃ futures. *Earth System Dynamics*.

We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC), the Fonds de recherche – Nature et technologies (FRQNT) and the Canadian Meteorological and Oceanographic Society (CMOS).