PROJECTED CHANGES TO ARCTIC SEA ICE AND COMMERCIAL SHIPPING ROUTES AFTER STRATOSPHERIC AEROSOL INJECTION

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Could stratospheric aerosol injection make the Arctic less navigable in the future?

MOTIVATION

- Arctic is warming up faster than the rest of the Earth
- Arctic sea ice is disappearing quickly
- Lesser ice-cover and thinner ice means greater chances of shipping

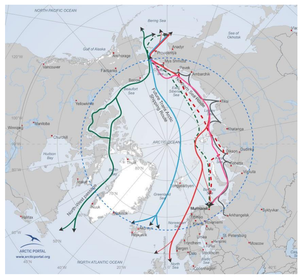


Image credit: arcticportal.org, The Arctic Gateway

- Climate intervention could possibly reduce surface temperature and climate change impacts
- Climate intervention like Stratospheric Aerosol Injection (SAI) may stabilize temperature
- Possible decreased navigability in future can affect shipping economy

ARISE-SAI-1.5

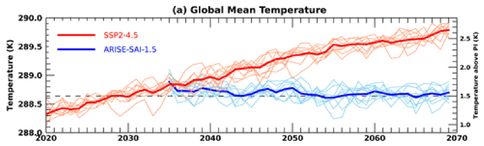


Image credit: Jadwiga H. Richter et al., 2022

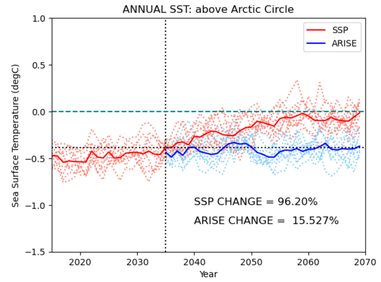
- Hypothetical climate intervention strategy run by CESM2(WACCM6) from 2035 to 2069
- Control scenario: SSP2-4.5 run from 2015-2069
- 10 ensemble members in both scenarios
- SO_2 aerosols injected into the stratosphere at 30/15°N/S, 180°E in 2035
- Aerosols reflect solar radiation
- Global mean surface temperature rise fixed at 1.5°C above pre-industrial level

METHODS

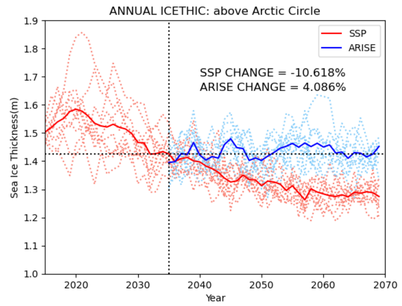
- **Consecutive Ice-Free Days**
  - Ice-free: < 15% ice-cover in a grid cell
  - Consecutive ice-free days required for ships to sail through
  - 7 consecutive ice-free days used for calculation
- **Ice-Numeral and Navigability**
  - Ice Numeral is a measure of navigability
  - Ice Numeral (IN) = f(icefraction, icethickness)
  - IN > 0 : Safely navigable
  - IN < 0 : Dangerous for navigation

ARISE-SAI-1.5 stabilizes variables relevant to shipping at 2035 levels

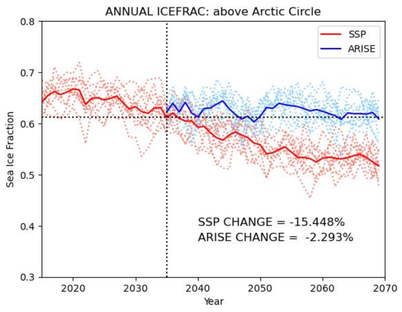
Sea-Surface Temperature increases to 0°C by 2069 in SSP2-4.5; stable in ARISE-SAI-1.5 at 2035 levels



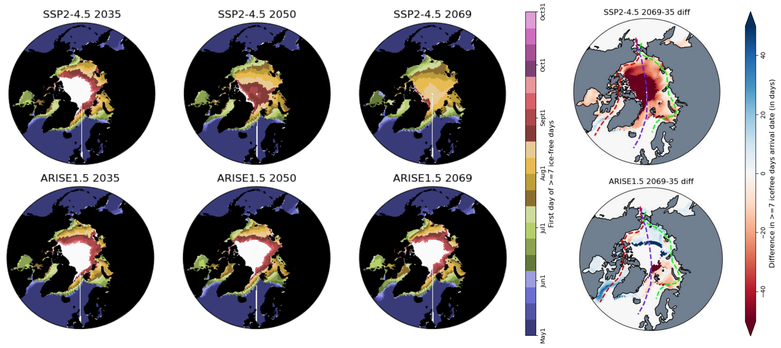
Ice-thickness decreases in SSP2-4.5; stable in ARISE-SAI-1.5 at 2035 levels



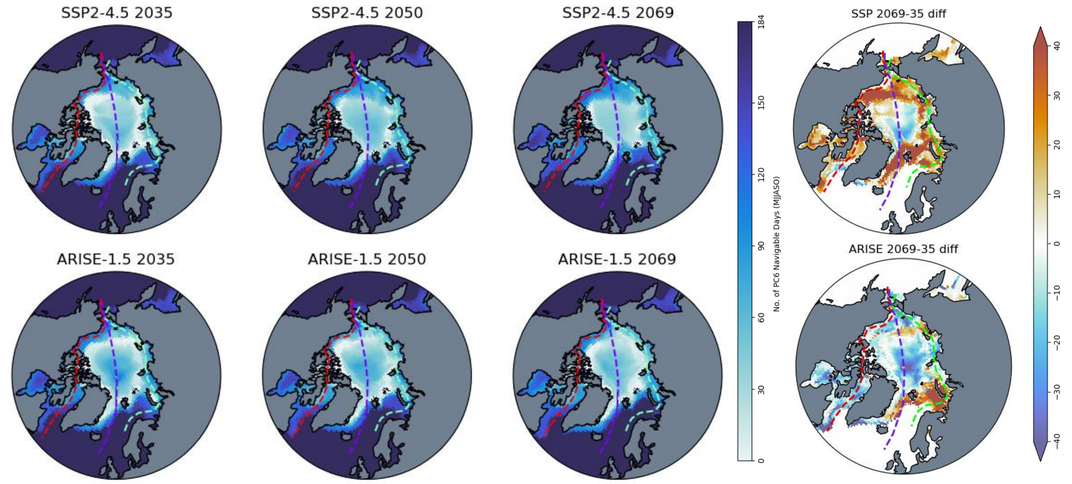
Ice-fraction decreases in SSP2-4.5; stable in ARISE-SAI-1.5 at 2035 levels



Ice-free days arrive earlier over the years in SSP2-4.5; stable in ARISE-SAI-1.5

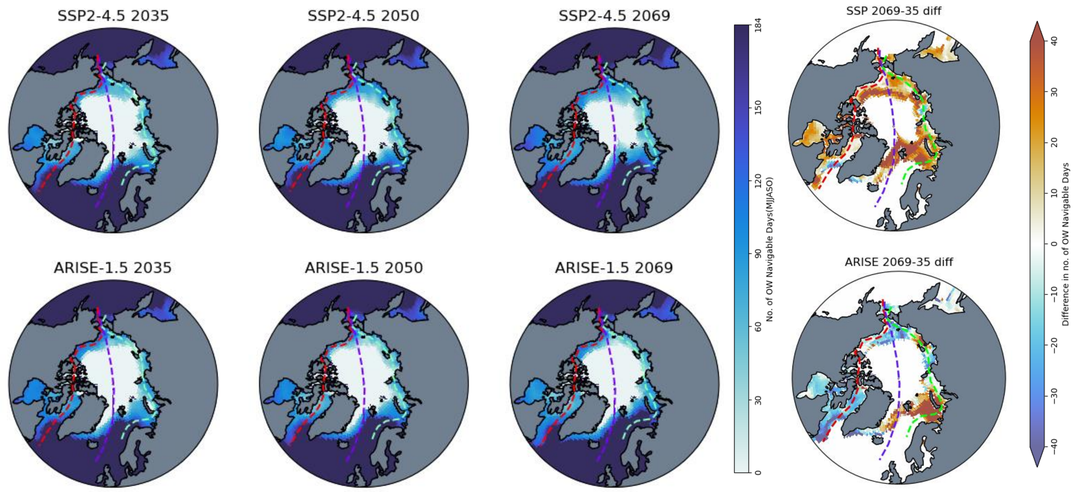


Central Arctic is **navigable for Polar Class ships** (PC6) as early as 2035 in SSP2-4.5 and ARISE-SAI-1.5



SSP2-4.5 navigability increases in Northern Sea Route, Northwest Passage;
ARISE-SAI-1.5 navigability decreases in Northwest Passage, Transpolar Route

Central Arctic is **not navigable for Open Water vessels** (OW) until 2069 in SSP2-4.5 and ARISE-SAI-1.5



SSP2-4.5 navigability increases in Northern Sea Route, Northwest Passage; ARISE-SAI-1.5 navigability decreases in Northwest Passage

CONCLUSIONS

- **Ice-fraction** and **ice-thickness** decrease in SSP; stable in ARISE (2035)
- Ice-covered regions in 2035 are ice-free in Aug 2069 in SSP
- Up to 113 **more navigable days** in SSP; 119 in ARISE 2069
  58 **less navigable days** in SSP; 82 in ARISE in 2069
- **Transpolar Route** PC6 navigable in 2035; not for OW
- **NWP + NSR** navigability increases in SSP; decreases in ARISE
  - Navigable dates need to be consecutive to allow shipping
- **SSP2-4.5: shipping easier** due to reduced ice-cover
- **ARISE-SAI-1.5:** shipping conditions mostly stable around 2035 conditions
  - Later **navigability decreases as ice recovers**
- **Shipping is easier in SSP2-4.5 than ARISE-SAI-1.5**

ACKNOWLEDGEMENTS
This work has been supported by the National Science Foundation Research Experiences for Undergraduates Site in Earth System Science at Colorado State University under the cooperative agreement No. AGS-1950172.

• Jadwiga H. Richter et al., 2022, Assessing Responses and Impacts of Solar climate intervention on the Earth system with stratospheric aerosol injection (ARISE-SAI): protocol and initial results from the first simulations • Laurence C. Smith and Scott R. Stephenson, 2013, New Trans-Arctic shipping routes navigable by midcentury.