Arctic Sea Ice Melt Analysis

SUMMARY

Key Points

- The monthly time series of Arctic sea ice extents computed from NOAA's Sea Ice Concentration Climate Data Record (CDR) is compared with climate model sea ice extents to evaluate and characterize model simulation and projection performance.
- The climate model sea ice extents are provided by the Coupled Model Intercomparison Project (CMIP5) from the historical simulations and future projections under mid-range (RCP4.5) and high-range (RCP8.5) emissions scenarios.
- It is concluded that CMIP5 models may underestimate the rate of Arctic sea ice melting, as satellite observations suggest sea ice depletion is accelerating while models generally follow a linear trend.

Service

- Adaptation
- Coastal management
- Marine ecosystems

End users

- Local communities
- Policymakers
- Researchers

Intermediate User(s)

- Intermediate users include the climate modeling community who can use the comparisons to CDR observations to make improvements to the CMIP5 model suite

Application(s)

- Arctic sea ice melt presents both challenges and opportunities. Rapid changes to the Arctic sea ice could be catastrophic to the Arctic ecosystem with the disappearance of ice habitat. Additionally, local communities could be affected with resultant coastal erosion impacts. Alternatively, Arctic sea ice melt has impacts to the transportation and energy industries through the opening of ice-free shipping routes and easing access to oil fields. All these end users can benefit with accurate future predictions of Arctic sea ice conditions for planning and adaptation purposes.

Essential Climate Variables
—Ocean

- Sea ice

Models

- CMIP5 models are a key element in this use case: https://pcmdi.llnl.gov/mips/cmip5/
- Statistical models were also used with the CDR sea ice extent time series for future projections as described in: Peng, G., J. Matthews, and J. Yu, 2018: Sensitivity analysis of Arctic sea ice extent trends and statistical projections using satellite data. Remote Sensing, 10. http://dx.doi.org/doi:10.3390/rs10020230

References:

Peng, G., J. L. Matthews, M. Wang, R. Vose, and L. Sun, 2020: What Do Global Climate Models Tell Us about Future Arctic Sea Ice Coverage Changes? Climate, 8, 15. http://dx.doi.org/10.3390/cli8010015

Additional CMIP5 references:

WCRP Coupled Model Intercomparison Project – Phase 5: Special Issue of the CLIVAR Exchanges Newsletter, No. 56, Vol. 15, No. 2

Taylor, K.E., R.J. Stouffer, G.A. Meehl: An Overview of CMIP5 and the experiment design. Bull. Amer. Meteor. Soc., 93, 485-498, doi:10.1175/BAMS-D-11-00094.1, 2012.

Meehl, Gerald A., and Coauthors: Decadal Prediction. Bull. Amer. Meteor. Soc., 90, 1467–1486, doi:10.1175/2009BAMS2778.1, 2009.

Climate Data Records

- Sea Ice Concentration CDR https://www.ncei.noaa.gov/products/climate-data-records/sea-ice-concentration

Agencies

- The National Snow and Ice Data Center

Satellite Observations

- The Sea Ice Concentration CDR is based on the Defense Meteorological Satellite Program (DMSP) series of SSM/I and SSMIS passive microwave radiometers.

Sustainability

This analysis was carried out with the version 3 Sea Ice Concentration CDR and applicable to the CMIP5 suite of models. The current CDR version is 4 and that of climate models is CMIP6. The analysis should be repeated with the updated CDR and models.

DESCRIPTION

Arctic sea ice demonstrates seasonality by expanding and thickening in winter while retreating and thinning during summer. As a consequence of climate change and rising global temperatures, reductions in sea ice extent is occurring in all seasons but most notably during summer which impacts the annual minimum sea ice extent. 2020 marked the 2nd lowest annual minimum in the 42-year observational record at 3.74 million square kilometers. Scientists refer to the first ice-free Arctic summer year as when the annual minimum Arctic sea ice extent is less than one million square kilometers. The prospect of an ice-free Arctic in our near future due to the rapid and accelerated Arctic sea ice decline has brought about the urgent need for reliable projections of the first ice-free Arctic summer year (FIASY). Together with up-to-date observations and characterizations of Arctic ice state, they are essential to business strategic planning, climate adaptation, and risk mitigation.

The CDR time series of annual minimum sea ice extents was coupled with multiple statistical models to estimate observed trends and extrapolate those trends to FIASY predictions. Because the rate of ice-loss appears to be increasing over time, non-linear statistical models using various subsets of data were explored. Although the projections varied significantly depending on the statistical model and range of observations used for model calibration, estimates using 1986-2015 data suggest that the Arctic could be ice-free in summer as early as 2037, plus or minus six years (Figure 1).

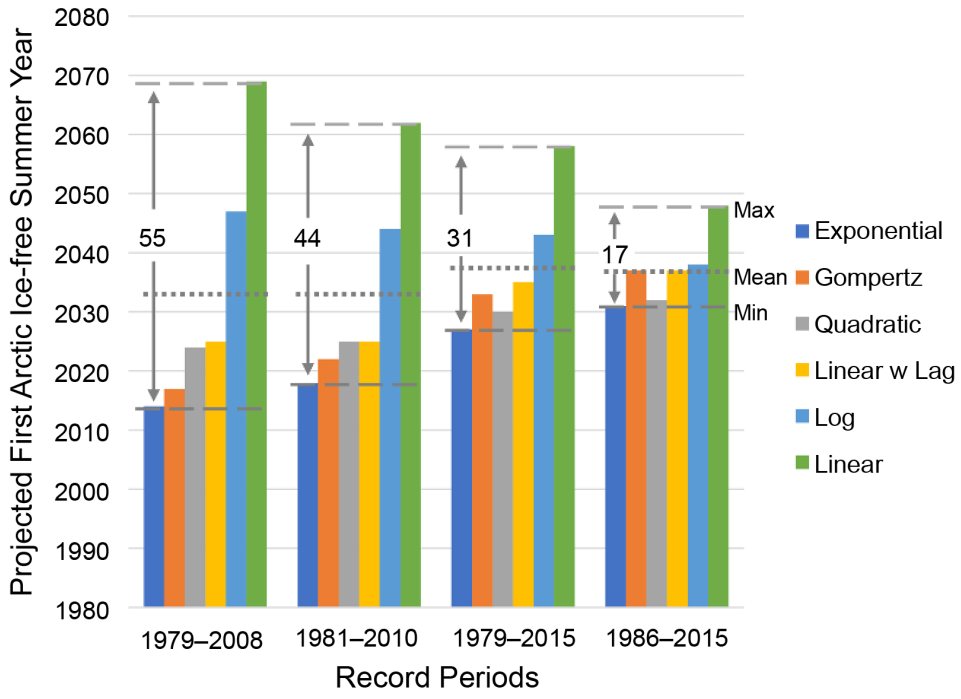


Figure 1. Projected first Arctic ice-free summer based on six models, estimated using different subsets of data. Non-linear models generally project an earlier ice-free Arctic. Using data from the last 30 years (1986–2015, fourth set of bars) produces the best agreement between models. Averaging those models produces a projected ice-free summer in 2037. Source: Peng et al. 2018.

In this use case application, the monthly Arctic sea ice extents from 12 global climate models from the Coupled Model Intercomparison Project (CMIP5) suite are utilized to obtain projected FIASYs and their dependency on different emission scenarios, as well as to examine the nature of the ice retreat projections. Figure 2 shows the spread of simulated model sea ice extents overlaid with the CDR observations for the historical, RCP4.5 (medium emissions), and RCP8.5 (high emissions) scenarios. The average value of model-projected FIASYs is 2054/2042, with a spread of 74/42 years for the medium/high emission scenarios, respectively. The earliest FIASY is projected to occur in year 2023, which may not be realistic, for both scenarios. As shown in Figure 3, the sensitivity of individual climate models to scenarios in projecting FIASYs is very model-dependent.

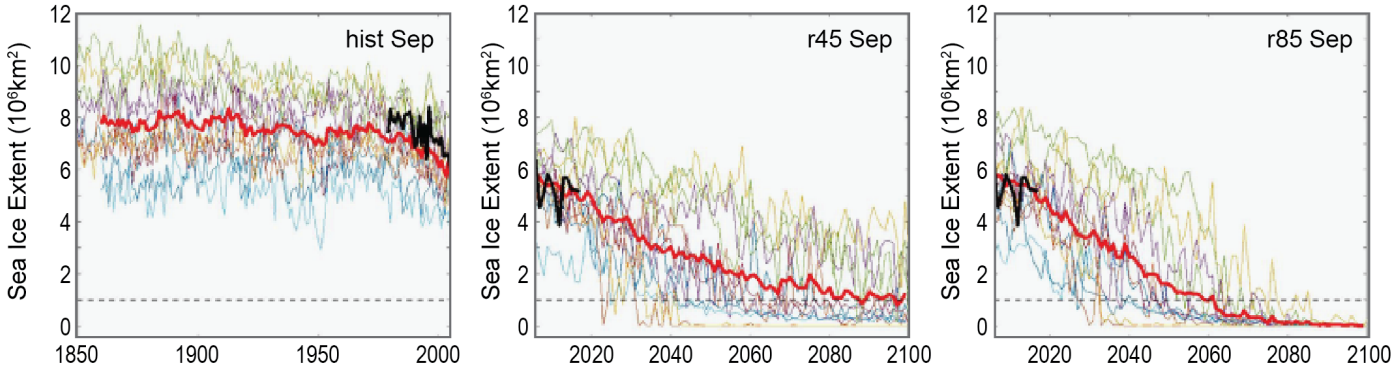


Figure 2. Time series of model sea ice extent (SIE) in September for historical simulations (hist, left panels), RCP4.5 projections (r45, middle panels), and RCP8.5 projections (r85, right panels). The thick red and black solid lines are ensemble means of all model runs and the observations, respectively. The black dashed lines denote the ice-free Arctic threshold of $1x10^6$ km^2. Source: Peng et al. 2020.

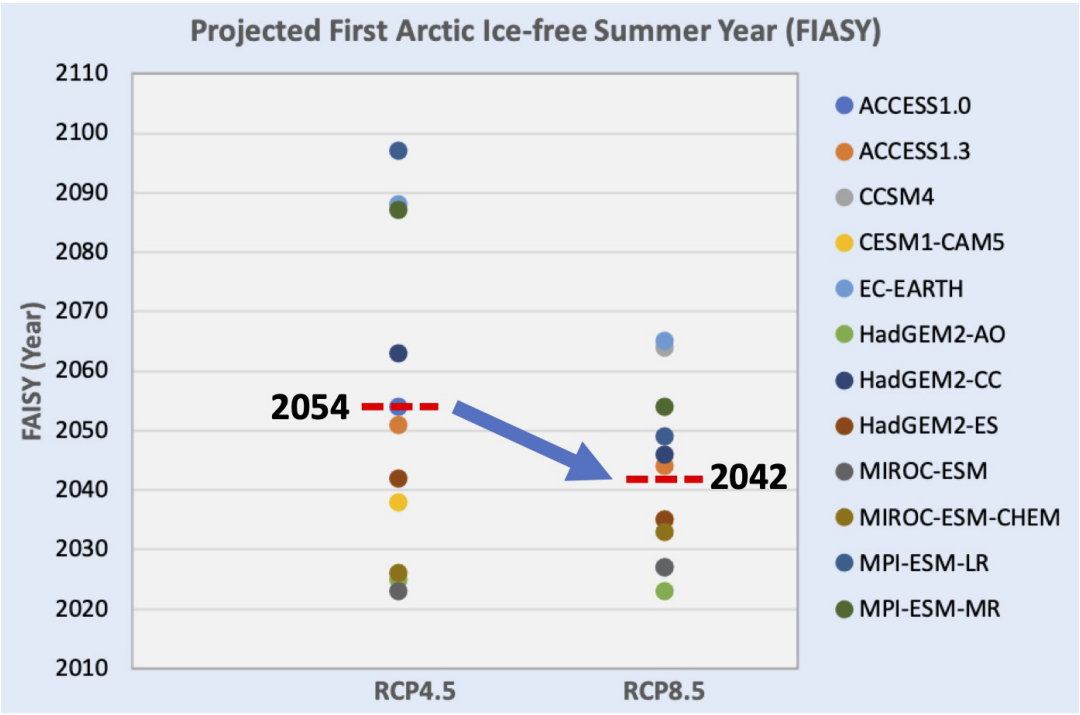
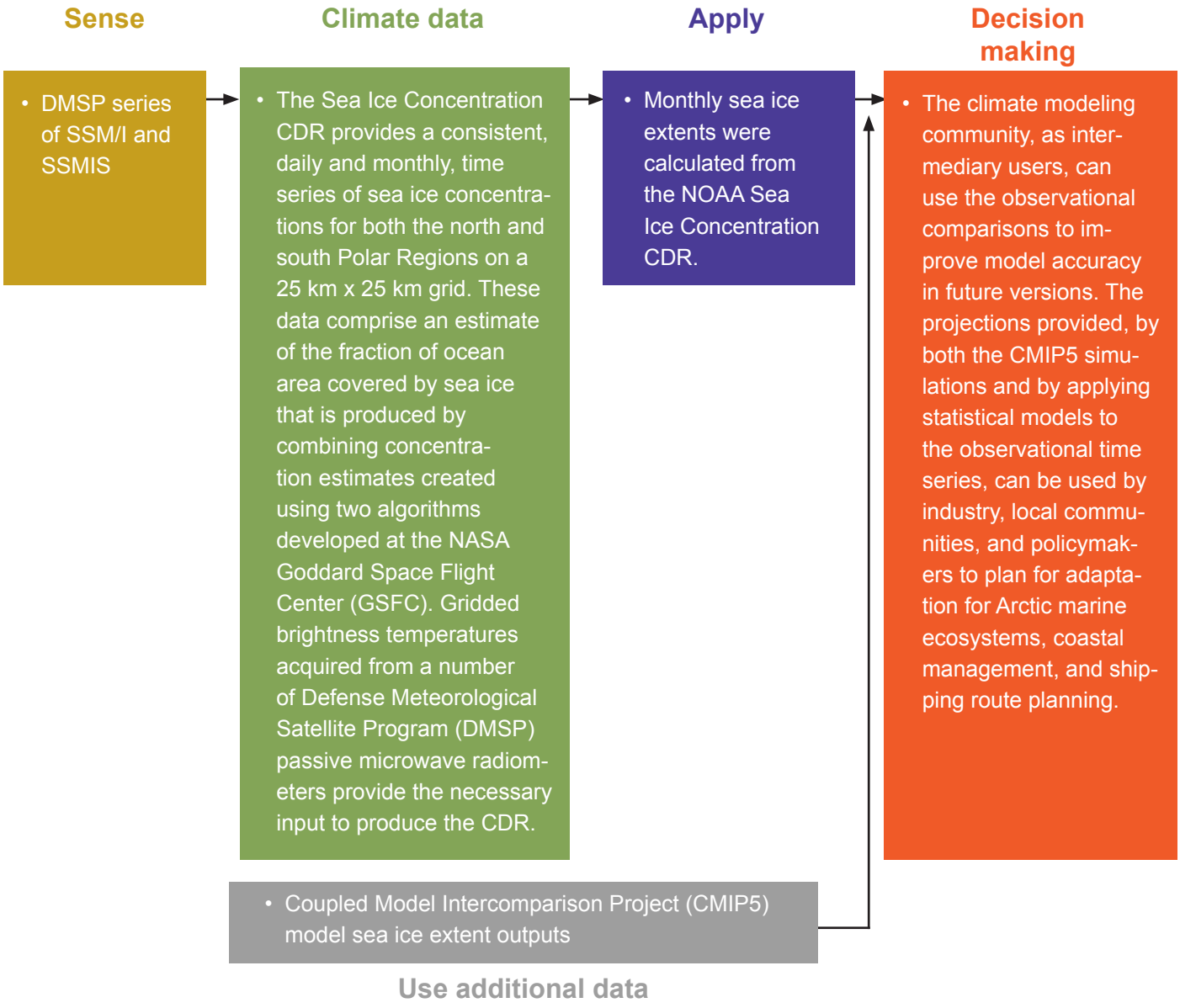


Figure 3. Projected first ice-free Arctic summer year (FIASY) with the RCP4.5 and RCP8.5 scenarios for 12 CMIP5 models. Source: Peng et al. 2020.

The nature of model-projected Arctic sea ice coverage changes is shown to be primarily linear while CDR observations suggest sea ice depletion is accelerating. Thus, CMIP5 model projections may underestimate the rate of Arctic sea ice melting. FIASY values predicted by six commonly used statistical models that were curve-fitted with the first 30 years of CMIP5 climate projections (2006– 2035), on other hand, show a preferred range of 2030–2040, with a distinct peak at 2034 for both scenarios, which is more comparable with the projected FIASY from the CDR time series. This use case suggests that the first ice-free Arctic summer year is projected to take place within our lifetime (in less than 20 years), and that this date is overestimated by many of the CMIP5 model simulations.

INFORMATION FLOW



https://climatemonitoring.info/use-cases/