Arctic Sea Ice in Two Configurations of the Community Earth System Model Version 2 (CESM2) During the 20th and 21st Centuries

Patricia DeRepentigny[1], Alexandra Jahn[1], Marika Holland[2] and Abigail Smith[1]

[1]University of Colorado Boulder, [2]National Center for Atmospheric Research

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

Motivation

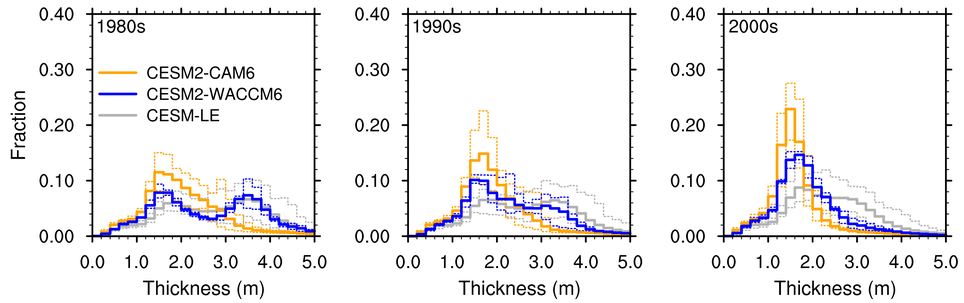
The CESM2 (*Danabasoglu et al., 2020 JAMES*) is the newest version of the CESM, and NCAR's contribution to the Coupled Model Intercomparison Project Phase 6 (CMIP6). The CESM2 was run with two different atmosphere configurations, the Community Atmosphere Model Version 6 (CAM6)* and the Whole Atmosphere Community Climate Model Version 6 (WACCM6), leading to differences in the simulated Arctic sea ice.

Here, we show analysis of the historical and future simulations of Arctic sea ice in the CESM2 (CAM6 and WACCM6) under the SSP5-8.5 scenario, compared to the CESM-LE version of the CESM (CESM1-CAM5; *Kay et al., 2015 BAMS*).

The CESM2

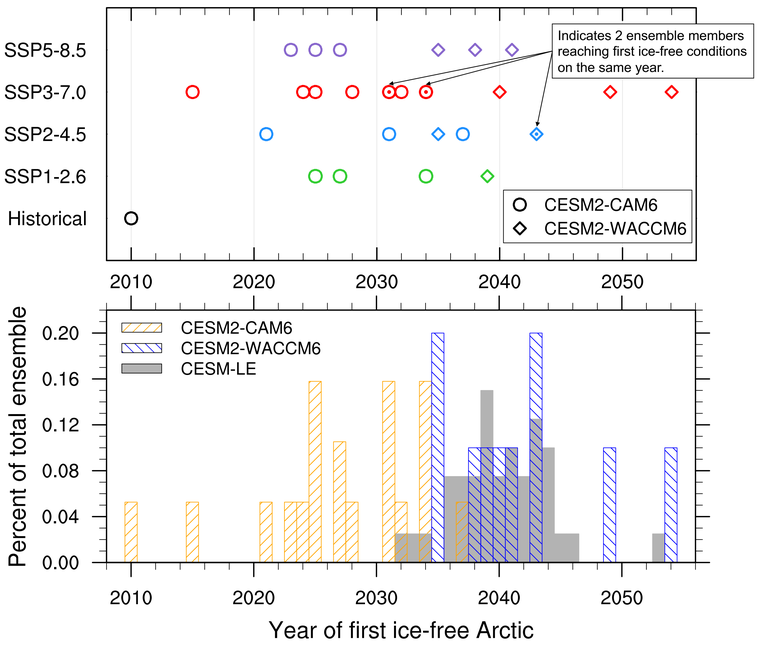
- Resolution: nominal 1° in all components
- Ocean component: POP2; Land Component: CLM5
- Sea ice component: CICE5
  - New mushy-layer thermodynamics scheme
  - Prognostic salinity and salinity-dependent freezing point
  - 8 (from 4) ice layers and 3 (from 1) snow layers
- Atmospheric component:
  - CAM6 – Standard, Historical: 11 members, SSP5-8.5: 3 members
  - WACCM6 – High-top and interactive chemistry, provides CAM6 forcing at TOA, Historical: 3 members, SSP5-8.5: 3 members

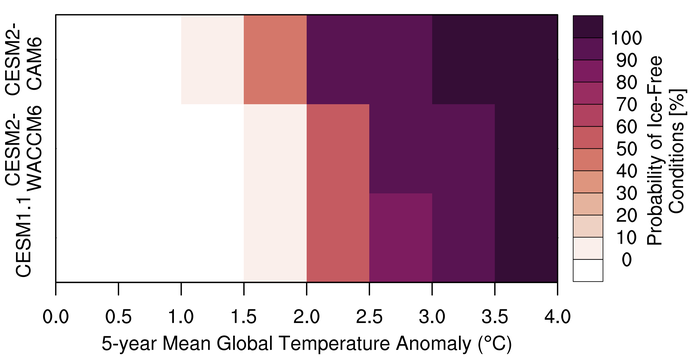
Result #1: Differences in Historical Simulations



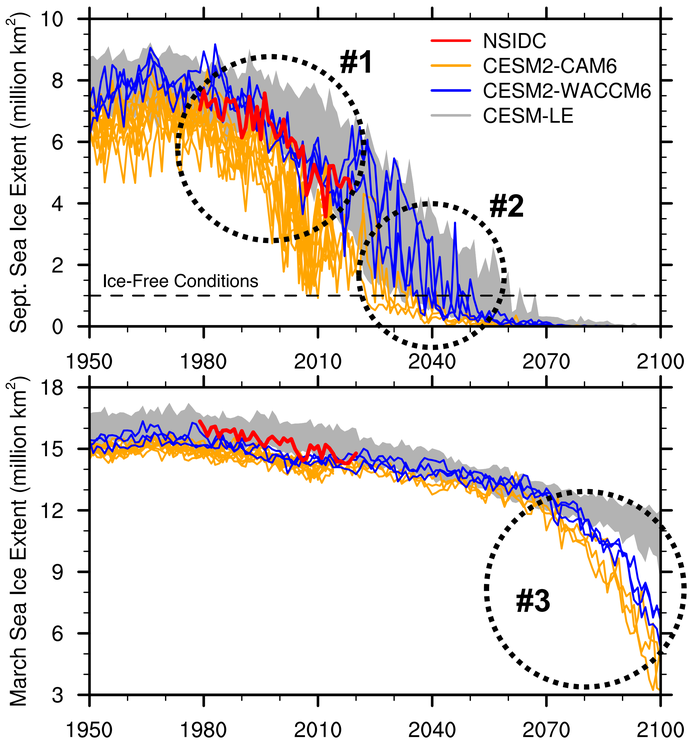
Over the historical period, the CESM2-CAM6 winter ice thickness distribution is skewed thin, with an insufficient amount of ice thicker than 3 m. This leads to a lower summer ice extent compared to the CESM2-WACCM6, the CESM-LE and observations.

Result #2: Ice-Free Conditions





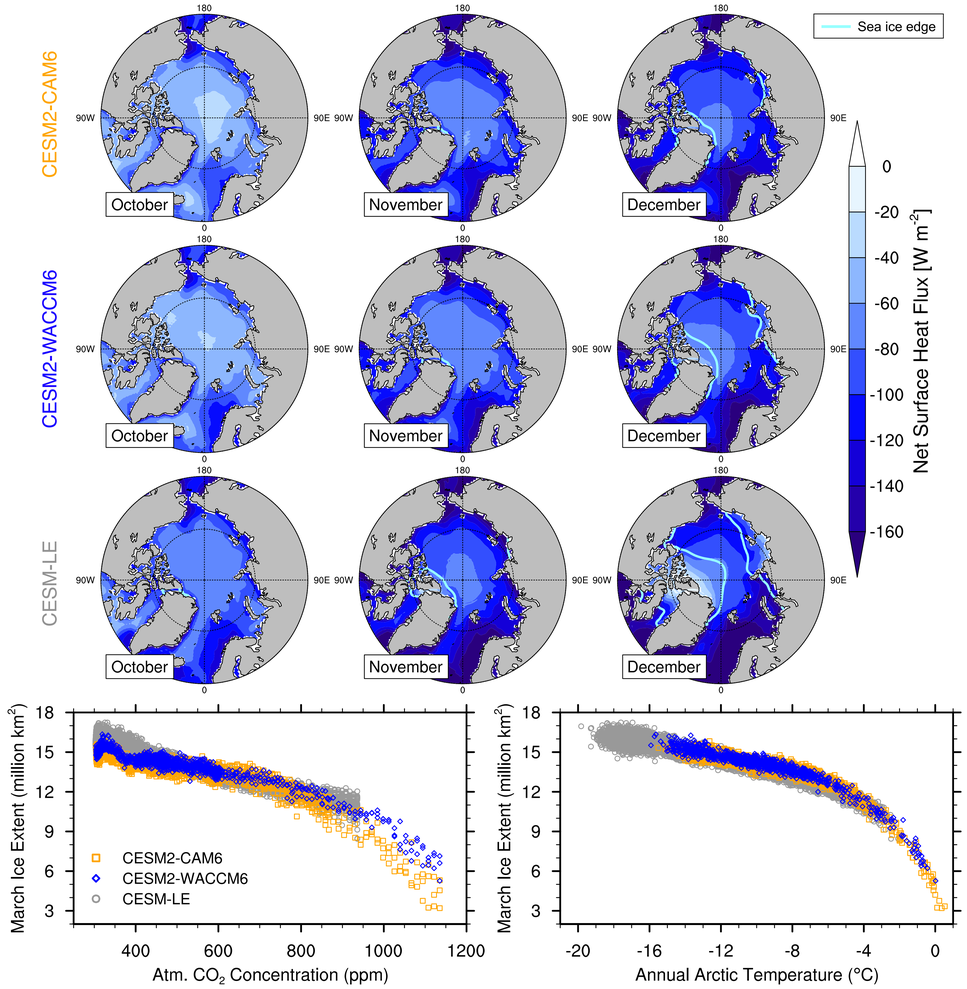
In both CAM6 and WACCM6, the timing of first ice-free conditions is insensitive to the choice of future emissions scenario, with a similar range of internal variability on the year of first ice-free conditions as the CESM-LE. If global warming stays below 1.5ºC, the probability of an ice-free summer remains low, consistent with the CESM-LE.



Summary

- The CESM2 shows lower ice extent compared to the CESM-LE, particularly in winter and spring. In September, the CESM-WACCM6 is comparable to the CESM-LE and observations.
- The CESM2-CAM6 is consistently lower in its sea ice extent and thickness than the CESM2-WACCM6 configuration.
- The CESM2 shows no scenario dependence on the timing of first ice-free conditions, but a similar response to global warming and range of internal variability on the year of first ice-free Arctic as CESM-LE.
- By 2100, both CAM6 and WACCM6 exhibit an accelerated decline in winter ice extent, leading to ice-free conditions for up to 8 months.
- Differences in climate sensitivity and higher levels of atmospheric CO_2 by 2100 in the CESM2 compared to the CESM-LE could explain why this winter ice loss was not previously simulated by the CESM.
- A paper including the results shown here is currently under review in JGR-Oceans (CESM2 special issue) with the same title as this poster.

Result #3: Accelerated Decline in Winter Ice Extent



The CESM2 simulates less ocean heat loss during the fall months compared to the CESM-LE, delaying the formation of sea ice. Our results suggest that warmer annual Arctic temperatures by 2100 in the CESM2 (caused by higher atmospheric CO_2 concentration and a higher climate sensitivity) compared to the CESM-LE reduces the temperature gradient between the ocean and the atmosphere.

*A bug was recently found in the forcing of the CESM2-CAM6 future simulations, but the impact in the Arctic is small. The simulations are currently being rerun and the paper under review including the results shown here will show the corrected simulations.

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