The September 2007 Arctic sea ice minimum: A CICE simulation

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A 50-year simulation using the Los Alamos Sea Ice Model, CICE, captures decadal variation in Arctic sea ice thickness for the period 1958–2007, including the thinning trend of recent decades. The sea ice minimum in September 2007 is well represented in this stand-alone CICE simulation, in spite of the fact that only 3 atmospheric forcing fields vary interannually in the model simulation — all other atmospheric fields and oceanic forcing data are monthly-mean climatologies. These results confirm prior conclusions that an anomalous pressure pattern, ice-ocean albedo feedback effects on sea surface temperature, and the long-term sea ice thinning trend are primarily responsible for the extreme sea ice minimum of 2007.

Methodology

2. Tune CICE mean thickness to observations as closely as possible without degrading the ice concentration [2]
   • Choose tuning parameters based on DOE adjoint sensitivity study [5]
   • Set visible and near IR albedos, ice conductivity, and ocean heat flux (u*,max) parameters to best estimates based on measurements
   • Adjust ridging parameter μrdg
3. Extend simulation through 2007 for validation, evaluation

CICE Model Configuration

• UNCOUPLED
• G:120, 384, 1° (g1v1) displaced-pole grid
• thermodynamic ocean mixed layer
• CORE, AOMIP atmospheric forcing fields [3]


• air temperature
• wind components
• specific humidity

Annual Climatologies:

• precipitation
• cloud fraction
• CCSM3/POP (b4.0.09) sfc currents, slope, salinity, deep ocean heat flux

Computed/Feedbacks:

• air temperature (if u > 0.1 then Td ≤ 0.1°C)
• turbulent fluxes
• downwelling LW, SW
• sea surface temperature
• albedo

Simulation

Tuning Target: Monthly mean Arctic sea ice draft from the model (ø) compared with submarine-based upward looking sonar measurements (+) [7].

mean draft = 3.059±0.85 m
observed = 3.095±0.83 m
corr. coefficient = 0.83

In [2], we demonstrate that the pattern of ice thickness, ridged ice area, and ridging activity is similar to submarine and satellite observations through 2006. The extension through 2007 validates this model configuration.

September 2007
Sea ice thickness, extent


A number of researchers have investigated various aspects of this event.

Schweiger et al. [8]: Unusually sunny skies? No. Our simulation, which employs climatological cloud fraction, concurs.

Zhang et al. [9]: 30% of the ice loss was due to export through Fram Strait; the remaining 70% melted, associated with an increase in upwelling shortwave flux—surface albedo—as a significant driver. Our simulation used 2007 winds; radiation was computed using climatological cloud fraction along with 2007 temperature and humidity. Our thermodynamic ocean mixed layer parameterization includes albedo feedback effects.

Lindsay et al. [6]: the long-term thinning trend was a necessary preconditioning of the Arctic ice pack for the 2007 event, which would not have occurred had the ice been as thick as it was in the mid-1980s. Our simulation captures this thinning trend as well.

Kauker et al. [4]: ice-ocean adjoint model produced the critical parameters: initial ice thickness (preconditioning), wind stress in May and June, and September 2m air temperature—warmed via the ice-ocean albedo feedback.

There have been many more studies of other possible forcing mechanisms for the September 2007 event, but the 4 studies above explain the ability of our uncoupled CICE simulation to capture the first-order effects.


Conclusions

• Long-term ice thinning made the pack more susceptible to loss.
• Sea level pressure anomaly (wind) was a contributing factor.
• Ice-ocean albedo feedback was critical for the magnitude of the 2007 ice loss.
• Despite the climatological forcing, this CICE model configuration includes the essential elements for simulating long-term thinning and retreat of the summer ice pack.

References