Sea ice volume and age:
Sensitivity to physical parameterizations and resolution in the CICE sea ice model[1]

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As the complexity of sea ice models escalates with the inclusion of ever more detailed processes, the need for more and better sea ice measurements from the field and laboratory compounds. Sea ice models contain many more parameters than can be constrained with currently available data, confounding validation efforts and lending doubt to modeled process fidelity. Fortunately, the addition of new data types combined with a detailed comparison of fundamental processes can shed light on physical and model sensitivities to more complex processes and their controlling parameters. Sea ice age is such a data set, discriminating among the effects of parameterizations that are not easily distinguished in terms of ice area or volume alone.

CICE Version 5.0

Version 5.0 of the Los Alamos sea ice model CICE is now available[2]
http://oceans11.lanl.gov/drupal/CICE

New Physics:

- **Prognostic salinity:** fast and slow gravity drainage, flushing
- **Improved snow-ice formation** includes ocean water transfer
- **2 new melt pond parameterizations** based on ice topography
- **Biogeochemistry** in bottom "skeletal" ice layer
- **Elastic-anisotropic-plastic rheology**
- **Improved form drag parameterization:** coefficients depend on modeled roughness elements such as deformed ice, floe and melt pond edges
- **Internal layers can melt completely**

Improved infrastructure and efficiency:

- **Salinity, ice and snow enthalpy tracers**
- **Gregorian calendar with leap years**
- **Binary, netCDF or PIO restarts**
- **Read/write extended grid**
- **OpenMP threading**
- **Parallel I/O via PIO library**
- **Halo masks, new block distributions**
- **Many new diagnostics, history output**

Configuration and Forcing

CICE version 5.0, including mixed layer ocean
320 × 384 (1°) displaced-pole, global grid
Modified CORE atmospheric forcing, 1958–2009
CCSM/POP ocean model monthly climatology
AOMIP radiation

References

[1] Hunke, E. C. Sea ice volume and age: Sensitivity to physical parameterizations and resolution in the CICE sea ice model. Ocean Modelling, in review. LA-UR-14-21531

[2] Hunke, E. C., W. H. Lipscomb, A. K. Turner, N. Jeffery and S. Elliott (2013). CICE: the Los Alamos Sea Ice Model, Documentation and Software, Version 5.0. Los Alamos National Laboratory Tech. Rep. LA-CC-06-012.

[3] Courtesy of C. Fowler, J. Maslanik, and M. Tschudi, Dept. of Aerospace Engr., University of Colorado, Boulder CO.

[4] Cavalieri, D., Parkinson, C., Gloersen, P., Zwally, H. J. (1996, updated 2009). Sea ice concentrations from Nimbus-7 SMMR and DMSP SSM/I passive microwave data, 1979–2009. National Snow and Ice Data Center, Boulder, Colorado, digital media.

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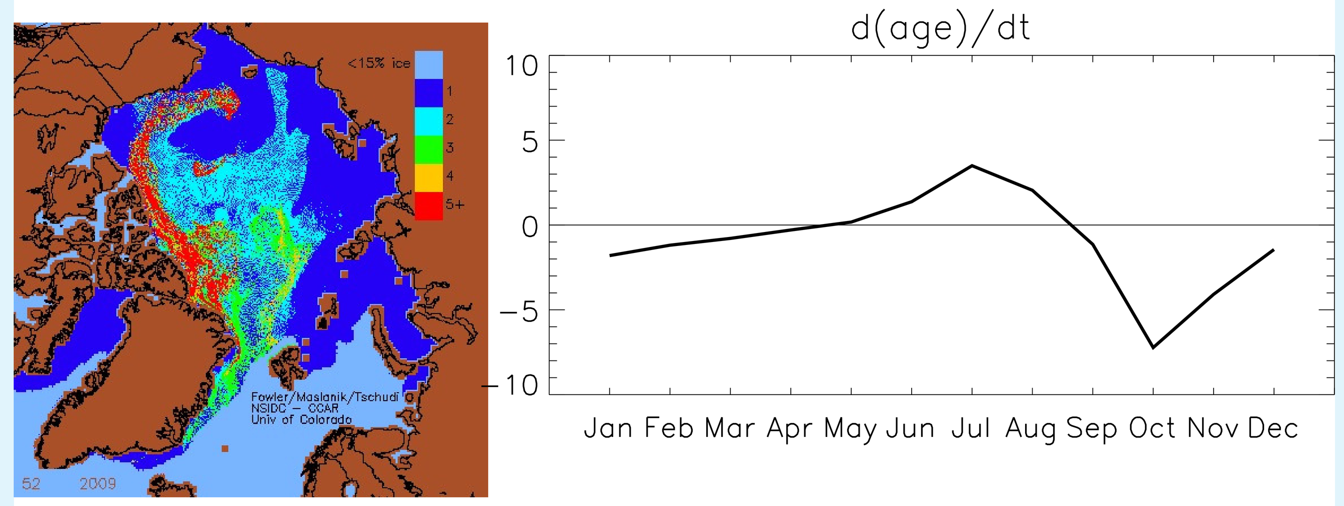
Results

1. Sea Ice Age

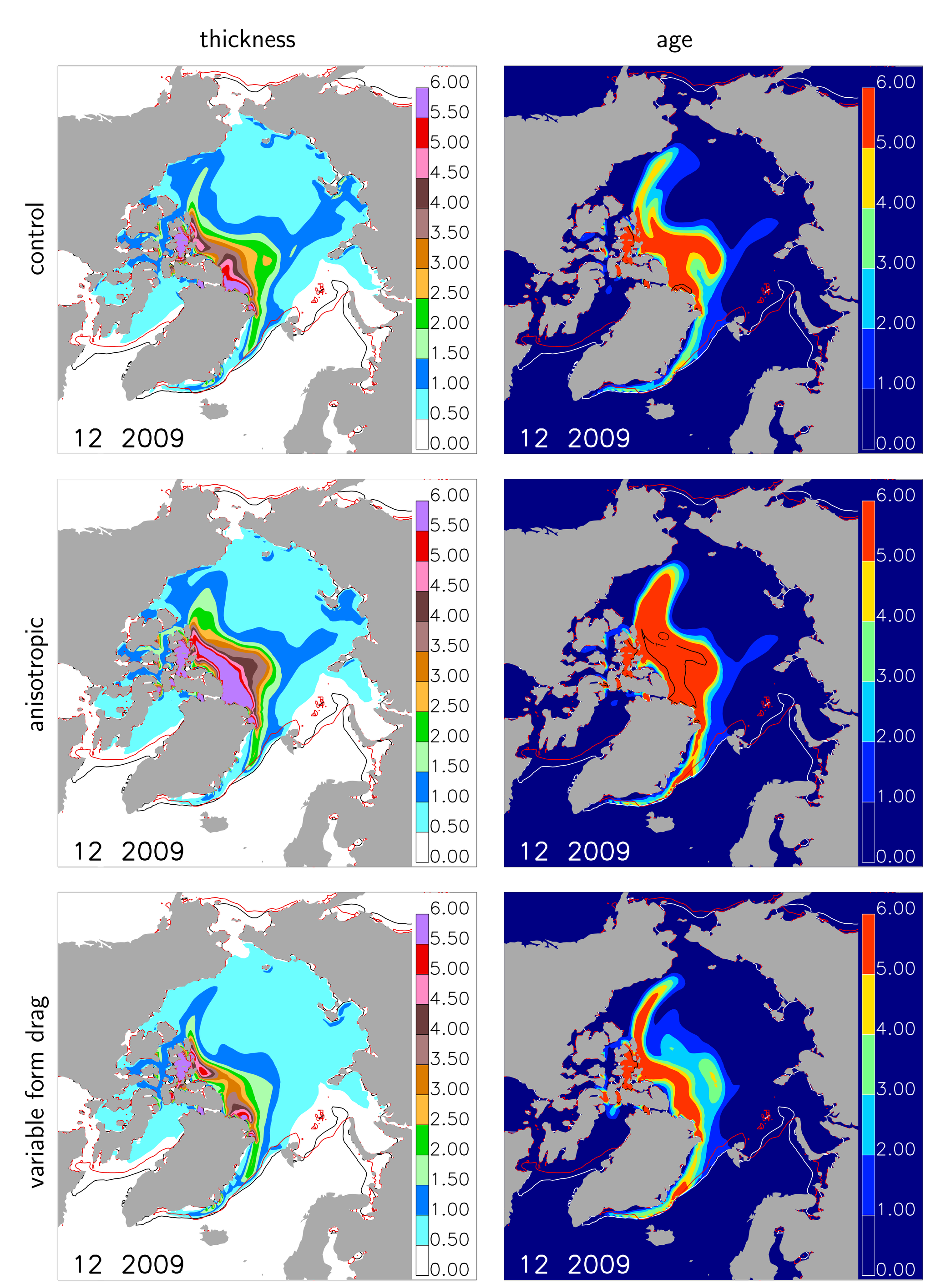
- Sea ice ages chronologically by Δt for every Δt of time that passes.
- Thermodynamics processes can cause the pack ice to become younger on average, as new ice freezes or as older ice melts.
- Melting of younger ice causes the ice pack to become older.
- Dynamic sea ice processes such as transport and deformation do not change the total age or volume of the ice pack, but they affect spatial patterns of age and volume.



(left) Satellite derived estimate of sea ice age (years) for week 52 of 2009[3]. (right) Derivative of sea ice age with respect to time (days per day), averaged for 1990–2009 over Arctic grid cells with ice area greater than 50%, from the control run. Chronological aging is not included in the derivative. During the cold months of the year, the ice pack tends to grow younger (in the absence of chronological aging), while in the warm months it ages markedly.

2. Spatial Effects

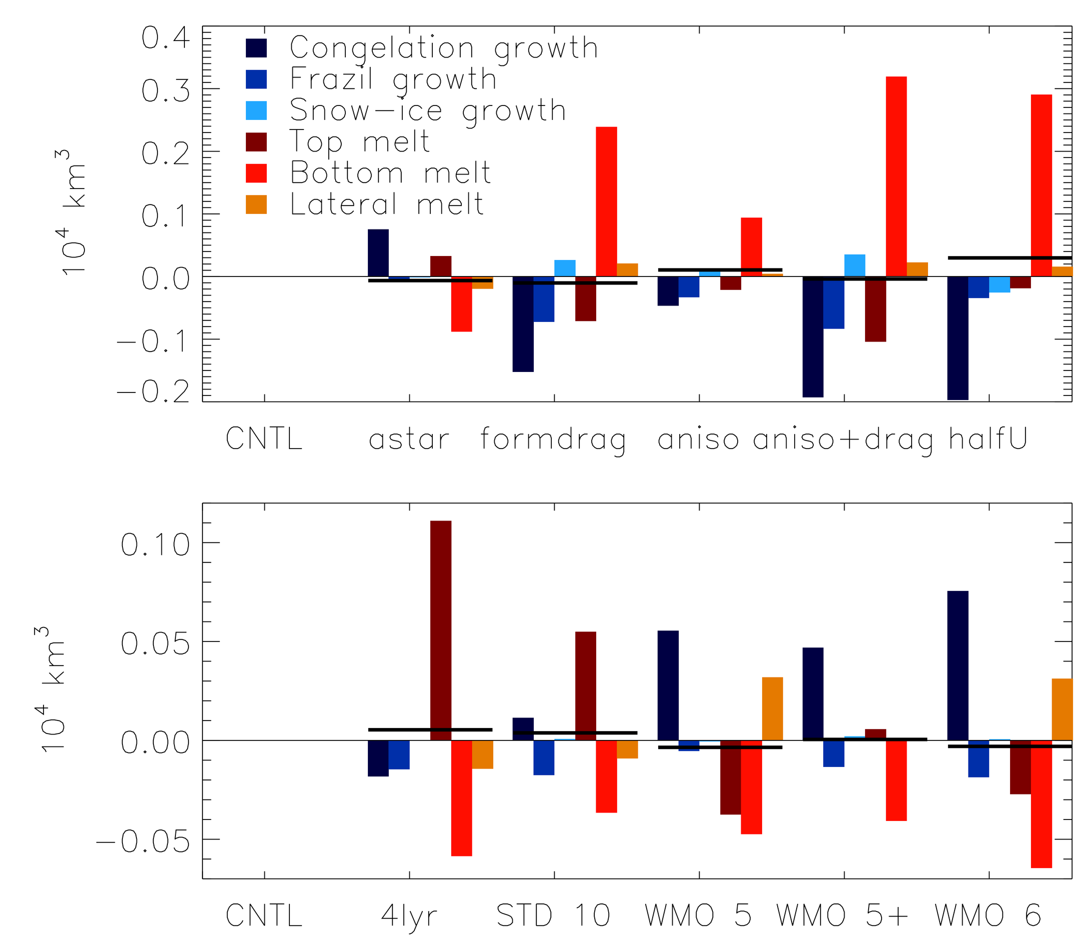
- By increasing shear stress between floes, the anisotropic rheology slows the ice motion, producing a thicker, older ice pack.
- Variable drag coefficients lead to thinner ice and more realistic age.



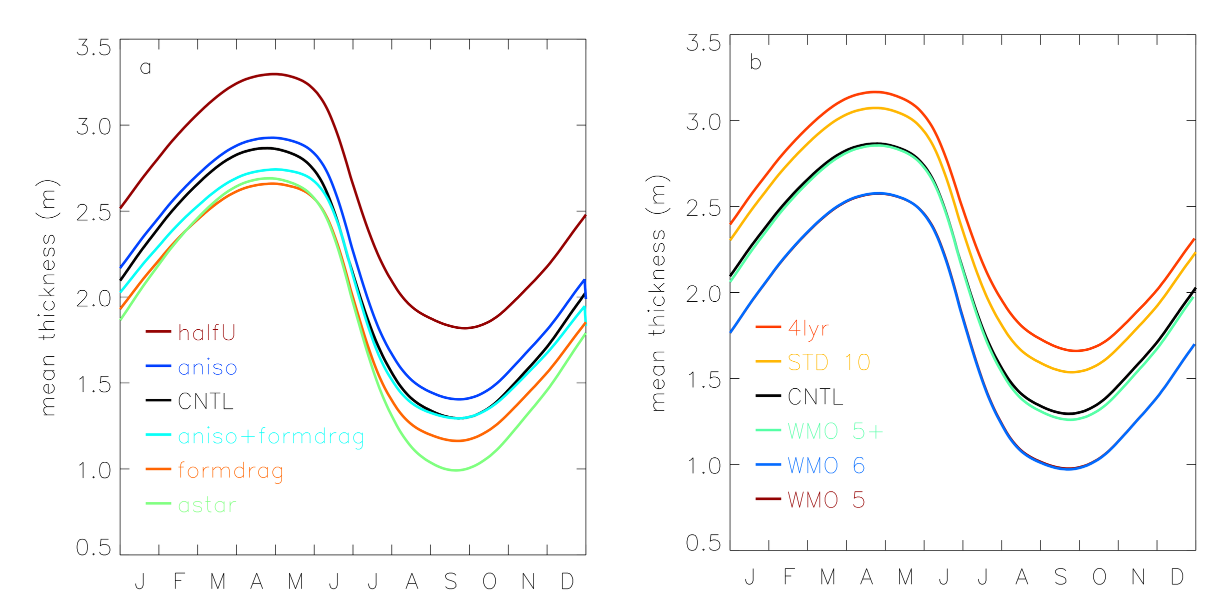
Sea ice model thickness (left, m) and age (right, years) for the control, anisotropic and variable form drag simulations. 15% ice concentration contours: (black, white) model and (red) passive microwave satellite data[4]. Black age contours encompass ice older than 10 years.

3. Resolution and Feedback

- Resolution of thicker ice types is crucial for proper modeling of sea ice volume, because the volume of ice in thinner categories is small; ice in thicker categories determines the total ice volume.
- 5 ice thickness categories are not enough to accurately represent observed thickness data, nor to properly model mechanical sea ice processes that control ice volume and age.
- A feedback process: If less open water is produced mechanically through ice deformational processes (e.g. ridging), the simulated ice thins relative to runs with more mechanically produced open water. When thicker ice deforms, the resulting ridges cover a larger area than when thinner ice ridges, decreasing frazil ice growth while increasing bottom melting.
- Thermodynamic processes can have opposing effects on ice age and volume; e.g. new ice growth increases pack ice volume while decreasing age.



Mean annual incremental differences from the control run for volume of ice gained or lost through thermodynamic processes (1990–2009) and resolution tests (1958–2009, see below). Positive melt terms indicate increased ice volume due to decreased melting, relative to CNTL. Horizontal black lines represent the net change in volume from the control run for all processes. Thicker ice ridges in 'astar', while transport velocities are halved in 'halfU'. The '4lyr' test uses 4 ice layers instead of 7.



Mean annual cycle of sea ice thickness (m) for the control run and (a) 5 physical parameterization tests and (b) 5 resolution tests for 1990–2009. Category boundaries for the resolution tests are shown below.