Sensitivity of sea ice age to physical parameterizations and resolution in the CICE sea ice model

Elizabeth Hunke
Ice age: So what?

- Can be deduced from satellite observations
- Related to ice physical properties (albedo, salinity, thickness)
- Might be useful for prediction of near-future ice pack
- Seasonal ice pack implies simpler logistics/shipping
- Ecosystem ramifications
Suggested proxy for ice thickness

Maslanik et al., Geophys. Res. Lett. 34, 2007
Control

thickness (m)  age (years)  obs (years)

Fowler, C., Maslanik, J., Tschudi, M. Dept. of Aerospace Engr., Univ. of Colorado, Boulder, CO.
Using Form Drag Parameterization

Fowler, C., Maslanik, J., Tschudi, M. Dept. of Aerospace Engr., Univ. of Colorado, Boulder, CO.
What changes sea ice age?

- the incessant march of time
- thermodynamics

<table>
<thead>
<tr>
<th>pack ice trend</th>
<th>grow new ice</th>
<th>melt older ice</th>
<th>melt younger ice</th>
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<tbody>
<tr>
<td>younger thinner</td>
<td>younger</td>
<td>thinner</td>
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<tr>
<td>older thicker</td>
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\[
d(\text{age})/dt
\]
What about dynamics?

\[ \frac{\partial \text{age}}{\partial t} \] due to dynamics

days per day
Using Elastic-Anisotropic-Plastic Rheology

Fowler, C., Maslanik, J., Tschudi, M. Dept. of Aerospace Engr., Univ. of Colorado, Boulder, CO.
Use $0.5 \times U_{\text{ice}}$ for advection

\[ \nabla \cdot U_{\text{ice}} \text{ is not altered explicitly} \]
Mechanical Redistribution  a.k.a. “Ridging”

Based on gravitational work necessary to build ridges

- **Participation function**
  thinnest portion of ITD participates

- **Redistribution function**
  determines ITD of ridged ice

(From Sanderson, 1988)
Ridging participation function

\[ a^* = \tilde{G} \text{ participating} \]

- \( a^* = 0.05 \)
- \( a^* = 0.1 \)
Ridging participation function

Control

\( a^* = 0.05 \)

\( a^* = 0.1 \)
Participation / redistribution negative feedback

- Ridge thin ice $\Rightarrow$ taller, narrower ridges + open water
- More open water $\Rightarrow$ more new freezing, ridging
- Thicker ice pack

- Ridge thicker ice $\Rightarrow$ wider ridges, less open water
- Less open water $\Rightarrow$ less new freezing, ridging
- Thinner ice pack
Thicknes category resolution

STD 10
WMO 6
WMO 5+
WMO 5
CNTL
Thicknes category resolution

<table>
<thead>
<tr>
<th>thickness (m)</th>
<th>age (years)</th>
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<tr>
<td>Control</td>
<td>10 categories</td>
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12 2009

12 2009
Thickness category resolution

![Graph showing thickness category resolution over a year with different categories: STD 10, WMO 6, WMO 5+, WMO 5, and CNTL. The x-axis represents the months of the year, and the y-axis represents the mean thickness in meters.]
Thickness category resolution

**thickmess (m)**

- **Control:**
  - 12 2009

- **WMO 5:**
  - 12 2009

**age (years)**

- **Control:**
  - 12 2009

- **WMO 5:**
  - 12 2009
Thicknes category resolution

thickness (m)

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age (years)

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12 2009

WMO5+

WMO 5
Thicknes category resolution

Gaussian ITD

Participation

Redistribution

area fraction

h (m)

area fraction

h (m)

$v_{eq}$ (m)

- NCAT=100
- CNTL
- STD 10
- WMO 5
- WMO 5+
Summary

Ice age may be useful for model tuning, validation.

Parameterizations:
- form drag looks very promising
- anisotropic rheology needs to be tuned
- need to constrain participation, redistribution functions

Resolution:
- need more!
- are 10 categories enough?
CICE v5 options/tests for consideration by PCWG

Physical parameterizations:
- mushy thermodynamics (prognostic salinity)
- explicit melt pond parameterizations (topo, level-ice)
- form drag
- anisotropic rheology
- other parameters?

Biogeochemistry (still in development):
- Aerosols
- Skeletal layer vs vertical BGC

Resolution:
- number of thickness categories
- vertical layers