Sensitivity of the spherical granular sea-ice model to the ice strength and the angle of friction

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Model description
  UVic Model
  Parameters of the granular sea-ice model

Parameter effect on ...
  Sea-ice thickness
  Sea-ice speed
  THC strength

Summary
UVic Earth System Climate Model version 2.6

3-D ocean model (MOM 2.2) (3.6° E-W and 1.8° N-S, 19 unequally spaced layers)

energy-moisture balance model for the atmosphere with heat and moisture transport as diffusion

moisture advection is also included

simple zero layer thermodynamics with two categories (sea ice, open water)

NOW: sea-ice model with elastic-viscous-plastic rheology or granular rheology
The different parameters of the granular sea-ice model

\[ q = p \sin \phi \]

- \( P_{\text{max}} = P^* h \exp[-C(1 - A)] \)
  - with \( h \) the ice thickness, \( C \) a constant and \( A \) the ice concentration
- \( \phi \) the angle of friction

- We can change two other variables:
  - \( \delta \) angle of dilatancy
  - \( \eta_{\text{max}} \) maximum coefficient of friction
Parameters Settings

- UVic Model run with a CO$_2$ concentration of 365 ppm
- started from a restart with a sea-ice cover and existing THC
- mean monthly wind stress forcing
- $\delta = 0^\circ$
- $\eta_{\text{max}} = 1 \times 10^{15} \cos^2(\phi_{\text{lat}}) \text{ g/s}$

<table>
<thead>
<tr>
<th>$P^*$ in [dynes/cm$^2$]</th>
<th>$\phi = 30^\circ$</th>
<th>$\phi = 45^\circ$</th>
<th>$\phi = 60^\circ$</th>
<th>$\phi = 75^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3 \times 10^5$</td>
<td>X</td>
<td>X</td>
<td>(X)</td>
<td>(X)</td>
</tr>
<tr>
<td>$3 \times 10^6$</td>
<td>X</td>
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<tr>
<td>$3 \times 10^7$</td>
<td>(X)</td>
<td>(X)</td>
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</tr>
</tbody>
</table>

Nomenclature during the presentation:

- $P^* = 3 \times 10^5 \rightarrow P5 , \phi = 30^\circ \rightarrow \phi 30$
- $P^* = 3 \times 10^6 \rightarrow P6 , \phi = 45^\circ \rightarrow \phi 45$
- $P^* = 3 \times 10^7 \rightarrow P7 , \phi = 60^\circ \rightarrow \phi 60$
Sea-ice thickness

Seasonal ice thickness after 80 years of integration

EVP

P5 and $\phi 30$
Sea-ice thickness differences as a function of $P^*$

Snapshot of the 14th of March after 80 years of integration

P5-P6 at $\phi 30$

P5-P6 at $\phi 45$
Sea-ice thickness differences as a function of $\phi$

Snapshot of the 14th of March after 80 years of integration

$\phi_{30} - \phi_{45}$ with P5

$\phi_{30} - \phi_{45}$ with P6
Sea-ice speed

Snapshot of the 14th of March after 80 years of integration

EVP

P5 and φ30
THC strength with changing parameters

Max. THC strength as a function of $P^*$

Max. THC strength as a function of $\phi$

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$P^* = 3 \times 10^5$ dynes/cm$^2$

$\phi = 30^\circ$

$\phi = 45^\circ$

$\phi = 60^\circ$

EVP
Summary

- Converted the granular sea-ice model to spherical coordinates
- Maximum sea-ice thickness of the granular model is larger than with the evp, but overall thickness is lower
- Changes in sea-ice thickness as a function of $P^*$ larger than the ones in function of $\phi$
- With increasing $P^*$ → thicker ice north of Greenland, thinner ice at Fram Strait
- With increasing $\phi$ the thickness is not changing much
- The sea-ice speeds in the Arctic Basin are larger for the granular rheology than for the evp rheology
- With increasing $P^*$, the maximum overturning strength is decreasing
- With increasing $\phi$, the maximum overturning strength is increasing