Update: Ocean/Ice shelf interactions

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Weddell Sea
Antarctica
Status of ACME ocean / ice shelf simulations

- Static ice shelves functioning in MPAS-Ocean since May 2016
- Simulations underway:
  - G-Case (active ocean/sea ice, CORE-II forced data atmosphere)
  - B-Case (active ocean, sea ice, atmosphere, land)
  - Low resolution and medium resolution (EC60o30 and RRS30to10 ocean)
- Runs from ACME master
- MPAS-Ocean not yet capable of running with dynamic ice shelves. We still need wetting/drying of ocean columns, moving grounding lines, steeply tilted layers.
- Highlight: CORI-KNL early access 10 year simulation at mid-resolution
- Highlight: ALCC proposal granted 87 million CPU hours
Highlight: Cori-KNL simulation, 10 year, medium resolution

- CORI-KNL early access, Dec 2016
- Led by Noel Keen at LBL
- G-Case CORE-forced medium resolution (RRS30to10).
- 10 year simulation
- 301 nodes: 150 ICE/CPL, 150 OCN, 1 for others. Get 1.8 to 2 SYPD

Figure 1: A view of sub-ice shelf statistics after ten years of the Cori-KNL simulation: (a) Column-integrated speed [m²/s] shows ocean currents that extend from the open ocean to below the ice shelf. The black arrows indicate the edge of the Filchner-Ronne ice shelf. (b) Rate of ice melt from the bottom of the ice shelf into the ocean, in meters of water per year.
Highlight: 2017 ALCC on Ice-Shelf/Ocean Interactions

- Title: Understanding the Role of Ice shelf-Ocean Interactions in a Changing Global Climate
- Mark Petersen (PI), with Stephen Price, Todd Ringler, Jones Philip, Luke Van Roekel, Jeremy Fyke, Xylar Asay-Davis, Phillip Wolfram

- Purpose:
  - Compare to observations
  - Tune and adjust model and initial conditions
  - Altered Southern Ocean wind experiment
  - Advanced analysis, including Lagrangian Particles

- July 2017 to June 2018

<table>
<thead>
<tr>
<th>System</th>
<th>Hours</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cori-I/Edison</td>
<td>35M</td>
<td>NERSC</td>
</tr>
<tr>
<td>Cori-II KNL</td>
<td>25M</td>
<td>NERSC</td>
</tr>
<tr>
<td>Theta</td>
<td>25M</td>
<td>Argonne</td>
</tr>
<tr>
<td>Titan</td>
<td>2M</td>
<td>Oak Ridge</td>
</tr>
</tbody>
</table>
Current simulations: G-case, low rez, on edison

- Model ocean below ice shelf is too warm, producing higher melt rates.

Model:

Observations: (SOSE)

Model - observations
Comparing Melt Rates to Observations

Filchner-Ronne Ice Shelf
- Observations
- ACME yr 2
- ACME yr 8
- Melt rate, m/yr

Ross Ice Shelf
- Observations
- ACME yr 2
- ACME yr 8
- Melt rate, m/yr

Filchner-Ronne Ice Shelf observations after Moholdt et al. (GRL, 119, 2014)

Work with Xylar Asay-Davis, Stephen Price, Jeremy Fyke
Current simulations: G-case, low rez, on edison

- Cross-section tool, created by Jeremy Fyke

  - Analysis:
    - ec60to30-based B-compset with ice shelves
    - Year 10 against SOSE 2005-2010 climatological annual average
An experiment with perturbed winds

1. Winds move south
2. Westward currents weaken
3. Isotherms lift along coast (Antarctic slope front flattens)
4. Warmer water increases ice shelf melt rates.
Control: Historical winds

Work with Xylar Asay-Davis, Stephen Price, Jeremy Fyke, Noel Keen
Experiment: Perturbed winds

Work with Xylar Asay-Davis, Stephen Price, Jeremy Fyke, Noel Keen
Melt rates below ice shelf (perturbed minus control)

Blue: melt rates are higher in the perturbed experiment, which is what we expect to see because more warm water is on the shelf.

Work with Xylar Asay-Davis, Stephen Price, Jeremy Fyke, Noel Keen
Proof of concept: ACME Arctic Enhanced Mesh

Ocean and sea ice grid

High resolution Arctic
6 km cells

Mid-resolution N. Atlantic,
10-20 km cells

Low resolution Pacific and southern hemisphere
30 to 60 km cells

Mesh generated by Darren Engwarda, MIT
Month: 0.0

MPAS-Ocean
Los Alamos National Laboratory
Arctic-Enhanced Mesh: 6 km cells
Highlight: Publications by Xylar Asay-Davis


Plan for coming year: ocean / ice shelf simulations

- Planning simulations for 87M cpu-hours, on four machines.
- Address biases at low resolution first (EC60to30). Why are melt rates too high?
- Create a Southern Ocean enhanced mesh
- Topics for publications:
  - Characterization and methods of MPAS-Ocean ice shelf cavities
  - How does the addition of ice shelf cavities effect the global circulation, in particular the Southern Ocean?
  - Perturbed wind experiment
Highlight: 2017 ALCC on Ice-Shelf/Ocean Interactions

Table 1: Resolutions of MPAS-Ocean and MPAS-Sea Ice. All have 100 vertical levels. The abbreviations correspond to the global mesh density function: gridcell size in RRS domains scale with the Rossby Radius of deformation in latitude; SO is enhanced Southern Ocean; EC is low resolution and requires an Eddy Closure parameterization.

<table>
<thead>
<tr>
<th>resolution</th>
<th>maximum gridcell, km</th>
<th>minimum gridcell, km</th>
<th>horizontal gridcells (\times10^6)</th>
<th>file size for one sim. month, GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>high: RRS18to6</td>
<td>18</td>
<td>6</td>
<td>3.7</td>
<td>106</td>
</tr>
<tr>
<td>medium: RRS30to10</td>
<td>30</td>
<td>10</td>
<td>1.4</td>
<td>40</td>
</tr>
<tr>
<td>enhanced: SO60to10</td>
<td>60</td>
<td>10</td>
<td>0.47</td>
<td>14</td>
</tr>
<tr>
<td>low: EC60to30</td>
<td>60</td>
<td>30</td>
<td>0.23</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 2: Proposed number of simulated years for three simulations. The latter two include ice shelf (IS) cavities. “By ACME” denotes simulations that will be carried out by the core ACME effort, and are not included in this proposal’s allocation.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>high resolution</th>
<th>medium resolution</th>
<th>enhanced Southern Ocean</th>
<th>low resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard: no IS cavities</td>
<td>by ACME</td>
<td>200</td>
<td>650</td>
<td>by ACME</td>
</tr>
<tr>
<td>Control: with IS cavities</td>
<td>125</td>
<td>200</td>
<td>650</td>
<td>1000</td>
</tr>
<tr>
<td>Perturbation: IS cavities, altered winds</td>
<td>125</td>
<td>200</td>
<td>650</td>
<td>1000</td>
</tr>
<tr>
<td>total</td>
<td>250</td>
<td>600</td>
<td>1950</td>
<td>2000</td>
</tr>
</tbody>
</table>
### Table 3: Measured ACME performance, using active ocean/sea ice and data atmosphere.

<table>
<thead>
<tr>
<th>resolution</th>
<th>platform</th>
<th>cores</th>
<th>SYPD</th>
<th>million CPU–hrs per simulated century</th>
</tr>
</thead>
<tbody>
<tr>
<td>high: RRS18to6</td>
<td>Edison</td>
<td>1,200</td>
<td>0.2</td>
<td>14.1</td>
</tr>
<tr>
<td>high: RRS18to6</td>
<td>Cori KNL</td>
<td>26,000</td>
<td>1.2</td>
<td>52.0</td>
</tr>
<tr>
<td>high: RRS18to6</td>
<td>Titan</td>
<td>8,192</td>
<td>1.2</td>
<td>31.8</td>
</tr>
<tr>
<td>medium: RRS30to10</td>
<td>Edison</td>
<td>12,000</td>
<td>7.3</td>
<td>4.0</td>
</tr>
<tr>
<td>medium: RRS30to10</td>
<td>Cori KNL</td>
<td>17,000</td>
<td>2.5</td>
<td>16.3</td>
</tr>
<tr>
<td>low: EC60to30</td>
<td>Edison</td>
<td>6,500</td>
<td>22.0</td>
<td>0.7</td>
</tr>
<tr>
<td>low: EC60to30</td>
<td>Cori Haswell</td>
<td>3,000</td>
<td>7.5</td>
<td>1.0</td>
</tr>
<tr>
<td>low: EC60to30</td>
<td>Cori KNL</td>
<td>3,800</td>
<td>3.1</td>
<td>2.9</td>
</tr>
</tbody>
</table>

### Table 4: Computing requirements of simulations in million CPU-hrs, based on measured performance and the partitioning amongst platforms described in the text. Compare to plan for simulated years in Table 2.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>high resolution</th>
<th>medium resolution</th>
<th>enhanced Southern Ocean</th>
<th>low resolution</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard: no IS cavities</td>
<td>by ACME</td>
<td>13</td>
<td>11</td>
<td>by ACME</td>
<td>24</td>
</tr>
<tr>
<td>Control: with IS cavities</td>
<td>28</td>
<td>13</td>
<td>11</td>
<td>12</td>
<td>63</td>
</tr>
<tr>
<td>Perturbation: IS cavities, altered winds</td>
<td>28</td>
<td>13</td>
<td>11</td>
<td>12</td>
<td>63</td>
</tr>
<tr>
<td>total</td>
<td>56</td>
<td>39</td>
<td>32</td>
<td>23</td>
<td>150</td>
</tr>
</tbody>
</table>

### Table 5: Allocation request

<table>
<thead>
<tr>
<th>platform</th>
<th>million CPU–hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edison &amp; Cori Haswell</td>
<td>60</td>
</tr>
<tr>
<td>Cori KNL</td>
<td>40</td>
</tr>
<tr>
<td>theta</td>
<td>40</td>
</tr>
<tr>
<td>titan</td>
<td>10</td>
</tr>
<tr>
<td>total</td>
<td>150</td>
</tr>
</tbody>
</table>