A Model for Earth's Surface Mass Transport: Integrating Polar Ice Sheets & Global Geodetic Observations

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February 9, 2016
Ice sheets: Need for high-resolution observation & modeling.

Rignot et al., 2011
Relative sea level: For a self-gravitating, rotating Earth.

\[
\Delta S(\theta, \lambda, t) = -\frac{m_i(t)}{\rho_o A_o} + \frac{1}{g} \Phi(\theta, \lambda, t) + \frac{1}{g} \Lambda(\theta, \lambda, t) + C(t)
\]

\[ \Delta S(\theta, \lambda, t) = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} \Delta S_{lm}(t) Y_{lm}(\theta, \lambda) \]

<table>
<thead>
<tr>
<th>Resolution $R$</th>
<th># nodes $4\pi a^2/R^2$</th>
<th>Max degree $\pi a/R$</th>
<th># coefficients $(\pi a/R + 1)^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 km</td>
<td>51,000</td>
<td>200</td>
<td>40,400</td>
</tr>
<tr>
<td>2 km</td>
<td>127,516,000</td>
<td>10,000</td>
<td>100,020,000</td>
</tr>
</tbody>
</table>

Great-circle distance from load (degrees)
A mesh-based approach.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Max degree</th>
<th># nodes</th>
<th># coefficients</th>
<th>OS X 10.9.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>~2 km</td>
<td>10,000</td>
<td>Variable (16,553)</td>
<td>–</td>
<td>~5 mins</td>
</tr>
<tr>
<td>100 km</td>
<td>200</td>
<td>49,152</td>
<td>40,401</td>
<td>~30 mins</td>
</tr>
<tr>
<td>50 km</td>
<td>400</td>
<td>196,608</td>
<td>160,801</td>
<td>~6 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;127 M</td>
<td>&gt;100 M</td>
<td></td>
</tr>
</tbody>
</table>
GRACE CSR Release-05 Level-2 GSM monthly gravity fields.
Implications for ice sheet modeling

Pine Island Glacier

Adhikari et al., 2014

Bindschadler et al., 2013

RCP 8.5+
Implications for space geodesy

GIA
9.4 cm/yr

Observed
16.7 cm/yr

Climate driven
17.1 cm/yr

Greenland
11.1 ± 0.7 cm/yr

Antarctica
6.9 ± 0.6 cm/yr

AIS + GrIS
13.1 ± 0.9 cm/yr
Summary

- Our global-scale computational tool, developed within the JPL’s **Ice Sheet System Model (ISSM)**, allows for solving km-scale ice mechanics and global geodetic observables simultaneously.

- Geodetic observables can be utilized to constrain ice sheet models.

- Possibility of simulating both the polar ice sheets simultaneously.

- Paper in revision for *Geoscientific Model Development*. 
Discrete methods:
Works of Clark, Peltier, & others.

Tushinghem & Peltier, 1991