Ocean interactions with ice-shelves/sheets

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Ice drilling workshop
Oceans could be a “blowtorch” at underside of ice shelves.
Ice shelves provide backstress to grounded ice.
Grounding lines are where the melt occurs.
Further analysis is required to remove biases from the apparent rates (Fig. 1) introduced by a limited range of spherical harmonics, Gaussian smoothing, and other processing steps, and to obtain a separate estimate for ice loss. We focus efforts on several geographical regions with relatively large apparent rates. These include areas with negative rates (northern AP, coastal ASE) and positive rates (Southern Ronne Ice Shelf, and Enderby Land, East Antarctica). The mass increase extending into the Ronne Ice Shelf region, is possibly from either PGR effect (Peltier, 2004; Ivins and James, 2005), residual error in GRACE data, leakage from land signal, or some combination of the three. Smaller negative rates are found along the coast near the Stancomb–Wills (STA) and Jutulstraumen (JUT) glaciers in Queen Maud Land in East Antarctica.

To remove PGR effects, we adopt the IJ05 model (Ivins and James, 2005) shown in Fig. 1b in the same units of equivalent water layer change per year. The model was represented in SH, and filtered with P4M6 and 300 km Gaussian smoothing. The Fig. 1b color scale differs by a factor of 2 from Fig. 1a. The IJ05 model predicts that most PGR is to be found in West Antarctica, with quite small effects in the AP, although uncertainty of PGR models over West Antarctic is expected to be quite large, due to limited data available to constrain the models (Velicogna and Wahr, 2006).

An estimated ice mass rate map (Fig. 2a) is Fig. 1a minus the PGR model (Fig. 1b). AP and ASE rates change little from Fig. 1a. A negative rate has been anticipated for the AP, but earlier GRACE data were not able to resolve it. The region with negative rate near STA/JUT (Point E) has larger magnitude, and has moved towards land. The Enderby Land rate is relatively unchanged by removal of PGR because IJ05 predicts a low PGR rate in this region. Negative rates in the ASE and positive rates in Enderby Land are similar to those found using earlier GRACE data (e.g., Chen et al., 2006a; Ramillien et al., 2006).

2.4. Corrected mass rates for selected regions

We examine mass rates in the ASE coastal, northern AP, and STA/JUT regions, correcting apparent rates in Fig. 2b for biases due to filtering and limited spatial resolution. We employ a forward modeling technique developed in earlier studies (Chen et al., 2006a,b,c). Estimates are obtained by assuming that geographical locations of mass change are confined to land. This assumption leads to mass rate models with spatial resolution somewhat better than the fundamental resolution.
Fig. 2. (A) GRACE long-term mass rates over Greenland and surrounding regions during the period April 2002 to November 2005, determined from mass change time series on a 1° grid. (B) Simulated long-term mass rates over Greenland and surrounding regions from the experiment as described in SOM text and fig. S1.
Speedup of Grounded Ice

de Angelis and Skvarca, 2003
Ice Shelf observations

- Physical oceanographic measurements (temperature, salinity, heat flux).
- Basal melt and freeze-on.
- Biota.
- Ice sheet advance/retreat history.
Ice Shelf projects

- LARISSA (Larsen Ice Shelf)
- PIG (Pine Island Glacier)
- WISSARD (Whillans Ice Stream)
- Petermann Glacier
- NE Greenland Ice Stream
- ... Andrill
Grounding Line Processes affect Stability

- Colors represent reflection strength.
- Ice thickness \( \sim 600 \text{ m} \) based on \( 168 \text{ m} \cdot \mu \text{s}^{-1} \).
- Basal crevasses prominent to left (floating).
- Sub-base reflection: “Till Wedge”
Consequences of Subglacial Till Deposition

- With a subglacial wedge, grounding line retreat interrupted.
- Grounding line stable for millenium.
- Submarine deposition would not stabilize grounding line.

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Ice-Ocean Interactions
Consequences of Subglacial Till Deposition

With a subglacial wedge, grounding line retreat interrupted. Grounding line stable for millenium. Submarine deposition would not stabilize grounding line.
Grounding Line projects

- WISSARD (Whillans Ice Stream)
- Thwaites Glacier (Cresis)
- Byrd Glacier
- PIG, Helheim,
- NE Greenland Ice Stream
Required measurements

- Physical properties (water, sediment, temperature)
- Dynamics of basal environment.
- Microbiology.
Ice Drilling Needs

- Access to underside of ice shelf (~1000 m thick) for physical oceanography.
  - Commercial instruments are ~25 cm diameter.
  - AUV/ROV (Autonomous, Remotely-operated vehicles are larger (up to 1 m diameter).
  - Hole needs to stay open for deployment (ROV/AUV: ... and retrieval).
  - Ice shelves are crevassed, but safe areas are helo accessible.

- Accesss to grounding zone for sedimentation data.
- Lightweight (twin-otter/helo), rapid (days), hot water drill.
- Data cables remain in frozen hole.
Ice drilling needs for geophysics

- Shallow access holes ($\sim 30–100$ m) for shotholes.
- Deep access holes (full ice depth) for basal heat flux.
- Access holes for instrumentation (strain, EM, acoustics, seismics, etc.)