Relevance of the Four KISS Technical Foci to Glaciology

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Fig. 3.6 Global glacier inventories
Far-reaching active microwave technology - coverage does not meet needs.

Current Greenland and Antarctica bed maps posted at 5km - interpolated from sparse profiles.

Example from Dr. U. Hertzfeld
Far-reaching active microwave technology - penetration in ice >3km

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric constant</th>
<th>Conductivity (mS/m)</th>
<th>Velocity (m/ns)</th>
<th>Attenuation (dB/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
<td>0</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>Distilled water</td>
<td>80</td>
<td>0.01</td>
<td>0.033</td>
<td>0.002</td>
</tr>
<tr>
<td>Fresh water</td>
<td>80</td>
<td>0.5</td>
<td>0.033</td>
<td>0.1</td>
</tr>
<tr>
<td>Sea water</td>
<td>80</td>
<td>30,000</td>
<td>0.01</td>
<td>1,000</td>
</tr>
<tr>
<td>Dry sand</td>
<td>3-5</td>
<td>0.01</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>Saturated sand</td>
<td>20-30</td>
<td>0.1-1.0</td>
<td>0.06</td>
<td>0.03-0.3</td>
</tr>
<tr>
<td>Limestone</td>
<td>4-8</td>
<td>0.5-2</td>
<td>0.12</td>
<td>0.4-1</td>
</tr>
<tr>
<td>Shale</td>
<td>5-15</td>
<td>1-100</td>
<td>0.09</td>
<td>1-100</td>
</tr>
<tr>
<td>Silt</td>
<td>5-30</td>
<td>1-100</td>
<td>0.07</td>
<td>1-100</td>
</tr>
<tr>
<td>Clay</td>
<td>4-40</td>
<td>2-1,000</td>
<td>0.06</td>
<td>1-300</td>
</tr>
<tr>
<td>Granite</td>
<td>4-6</td>
<td>0.01-1</td>
<td>0.13</td>
<td>0.01-1</td>
</tr>
<tr>
<td>Salt (dry)</td>
<td>5-6</td>
<td>0.01-1</td>
<td>0.13</td>
<td>0.01-1</td>
</tr>
<tr>
<td>Ice</td>
<td>3-4</td>
<td>0.01</td>
<td>0.16</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table A.A: Electrical properties of geological media [after Davis et al., 1989]
Active microwave technology - ground penetration around ice margins

Holt et al. (2006) - airborne survey of Taylor Glacier. Even without penetration glaciologists use reflection strength to infer sub-ice properties.
Peters et al. (2007) - Bed penetration beneath Kamb Ice Stream (under ~1.5 km of ice) - use of phase info in addition to magnitude
Anandakrishnan et al. (2007) - sub-ice sedimentary wedge imaged with ground-based IPR (700m thick ice).
Ground-based GPR (100 MHz) penetrates to 20-30m in permafrost

Peters et al. (2007) - Bed of Kamb Ice Stream (~1.5 km of ice)
Conclusions on far-reaching active microwave technologies:

- There is still huge need for mapping out thickness, bed topography, internal accumulation layers for glaciers and ice sheets (interpolation of profiles thus far).

- Temporal variability of interest to catch ice thickness changes and because we have observed (with spatio-temporally sparse data) changes in bed properties (e.g. accumulation or drainage of water, erosion and accumulation of sediments).

- Technical challenges are huge but not hopeless and scientific/societal pay-offs are immense (glaciology, geomorphology, hydro(geo)logy, seismic hazard assessment, agriculture, land management, coastal management, military).

- Recent polar missions may provide a good place to start in terms of technology/processing (WISE, GISMO, CReSIS, UTIG, LDEO).

- Multifrequency!
InSAR and GPS Time Series

- For glaciology much of the need in the area of repeat velocity measurements will be met (?) by DESDynI, if it launches and works as planned and has high resolution/accuracy.

- High frequency repeat velocity measurements (‘seismic InSAR’) would be of interest (calving events, transient glacier response to calving events or to water drainage events).

- Improved processing approaches to integrating various displacement measurements (InSAR, GPS, feature matching) into 4D data sets.
Distributed Optical Telescope

- Use of (past and future) optical data to measure ice volume changes and displacement. Before ~1990s archival satellite and airborne data provide the only high-resolution/accuracy sources of information.

- DESDynI will help map out ice velocities starting in 2017 but there is no ice elevation mapper (just profiler) planned (ICESat 2 in 2015). Optical data will still be the only source of elevation information at scales less than dozens of km (track spacing).

- Will there be need for high-resolution glaciological data? Ice models are improving their resolution (1990s: 20–40km, 2000s: 5–10km, 2010s: down to ~1km, ultimately to ~0.1km).

- Biggest challenges have to do with getting access to data, data quality control, processing large data volumes, maximizing quality of processed products, integrating with ancillary data, etc.
Far-reaching active microwave technology
Geostationary Optical Seismometer

- Amazing idea, if over CA it may image changes in snow cover.

- Could be used as a prototype for future deployments over glaciated mountain ranges and/or Greenland/Antarctic ice margins
Summary of glaciological relevance of this KISS ‘think tank’:

1. New sensor development - ice/ground multifrequency radar mapper (high value / high risk, high cost, long term).

1. KISS proposal
2. Learn from existing data and systems
3. Adapt or develop an airborne prototype
4. Test the prototype in various environments
5. Follow-on proposals for air/spaceborne applications
Summary of glaciological relevance of this KISS ‘think tank’:

2. Advances in (optical and InSAR) data mining and processing techniques needed to cover Earth’s Cryosphere (study area of >10 mln km², high value / low risk, short tem, low cost).

KISS proposal

Data mining/qc, processing

Computing infrastructure

Follow-on proposal/s Science/Technology Center/s?
High sensitivity of ice flow to subglacial water flow may in the future offer the opportunity to actually manipulate the ice sheet mass balance (and sea-level rise) by modifying subglacial water availability.