Climate change response of Vatnajökull, Hofsjökull and Langjökull ice caps, Iceland

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Objectives and methods

• Simulate glacier response to future climate change scenario:
  - Applying coupled dynamic ice flow and mass balance models
  - Volume, area and runoff change

• Dynamic ice flow model:
  - Vertical integrated, finite difference with shallow ice approximation
  - Neglects bed-isostatic adjustments, surges and seasonal sliding

• Degree-day mass balance model:
  - Uses temperature and precipitation observations from outside the glaciers
  - Calibrated to fit 10-17 years of mass balance observations
  - Evaluated with full energy balance observations on Vatnajökull and Langjökull
Study area and observations sites

Characteristics of the Langjökull, Hofsjökull and Vatnajökull ice caps.

<table>
<thead>
<tr>
<th>Ice cap</th>
<th>Area (km²)</th>
<th>Volume (km³)</th>
<th>Maximum ice thickness (m)</th>
<th>Range in elevation (m a.s.l.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langjökull</td>
<td>920</td>
<td>190</td>
<td>580</td>
<td>400-1450</td>
</tr>
<tr>
<td>Hofsjökull</td>
<td>890</td>
<td>200</td>
<td>760</td>
<td>600-1800</td>
</tr>
<tr>
<td>Southern Vatnajökull</td>
<td>3700</td>
<td>1280</td>
<td>900</td>
<td>0-2100</td>
</tr>
</tbody>
</table>
Surface- and bedrock topography

- Constructed from GPS and radio echo surveys undertaken 1980-2000
Mass balance models

Calibration

• Calibrated to the mass balance observations
• The model explains on Langjökull, Hofsjökull and southern Vatnajökull:
  - 86%, 95% and 92% of the variance in the summer balance
  - 39%, 80% and 92% of the variance in the winter balance
  - 92%, 96% and 95% of the variance in the annual balance
• Some of the deviations are related to snow drift
Model spin-up with zero mass balance input

- **Coupled ice flow and mass balance models:**
  - Few hundred years spin-up with zero mass balance input $\leftrightarrow$ average climate condition of 1981-2000
  - Deriving a stable ice cap geometry
  - Initial reference climate: average climate condition of 1981-2000 and 1990 the initial year of model runs
CE climate change scenario for the Icelandic highland

- **Temperature changes:**
  - 0.2 °C to 0.3 °C per decade during the summer
  - 0.1 °C to 0.4 °C per decade during the winter

- **Precipitation changes:**
  - ~0% during the summer
  - 0% to 1.6% during the winter
CE climate change scenario for the Icelandic highland

Annual mean temperature at Hveravellir

- Observed 1961–2006
- Predicted 2006–2200

- 0.18 °C/decade
- 0.25 °C/decade

Annual mean precipitation at Hveravellir

- 3.4 mm/decade
Predicted response to the CE climate change scenario

Year

1990 2040 2090 2190

L 65% 15% 0%
H 75% 40% 5%
V 75% 40% 1%
Predicted response to the CE climate change scenario

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</table>

- The volumes and areas are normalized to the present day values
- The specific runoff is from the present day glacier covered area
Year: 1990
Year: 2090
Year: 2140
Year: 2190
Conclusion

• **Response to the CE climate change scenario:**
  - Langjökull disappears within 150 years from now
  - The more elevated Hofsjökull and Vatnajökull almost vanish within 200 years from now
  - Only small glaciers survive on the highest peaks of Iceland after 200 years
  - Runoff increases as the climate get warmer, but peaks after 40-60 years due to the reduced areas of the glaciers
  - Specific runoff changes up to: 2.7 m/yr (Langjökull), 1.5 m/yr (Hofsjökull), 2.3 m/yr (southern Vatnajökull)
  - Highest runoff change is obtained for Langjökull and lowest for Hofsjökull as expected from their elevation range