A coupled iceflow and mass balance models of Langjökull ice cap, W-Iceland

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Objective and methods

• Use coupled dynamic iceflow and mass balance models of Langjökull ice cap:
  – simulate response to possible future climate changes.

• Dynamic iceflow model:
  – flow parameters the same as for Hofsjökull and Vatnajökull ice caps.

• Degree-day mass balance model:
  – uses precipitation and temperature from outside the glacier.
  – calibrated to 8 years of mass balance observations.

• Long term energy balance observations on the glacier:
  – used to evaluate empirical degree-day models of melting.
Study area and observations sites
Degree-day melting models (DDM)

Comparison to the observed energy balance

- The melting rates are better described with DDM using temperature observations outside than on the glacier:
  - temperatures in the low-albedo surroundings of the glacier signifies solar radiation better than the damped temperature signals over a melting ice.

- A degree day scaling factor ($ddf$) is not time independent:
  - e.g. does not account for changes in the solar zenith angle.

- The $ddf$ is, however, fairly constant (in time and space) when using temperature from outside the glacier and a constant lapse rate:
  - varies mainly with the surface conditions (snow or ice).

- Success in general:
  - short term variations in melting are often reflected in the temperature.
  - surface conditions (albedo) are partly reflected in the scaling factor.

- Failure in predictions often observed:
  - e.g. when the melting is highly influenced by turbulent heat fluxes driven more by wind speeds than temperatures.
Degree-day melting model (DDM)

Daily correlation

\[ \hat{a}_s = ddf_2 \cdot (T_S + \gamma (h_s - h_G))^+ \]

DDM$_2$:

1060 m a.s.l.  \( r = 0.87 \)

490 m a.s.l.  \( r = 0.86 \)

2001  2002  2003
Mass balance model

Calibration

- Calibrated to mass balance observations since 1997.
- The model explains:
  - 86% of the variance in the summer balance.
  - 39% of the variance in the winter balance.
  - 92% of the variance in the annual balance.
- Some of the deviations are related to snow drift.
Mass balance model

Iceflow- and mass balance models


Initial surface when simulating the response to climate changes.
Climate scenario

- Based on CWE climate change scenario near Iceland, 1990-2050.
- Temperature changes approximated by:
  - sinusoidal annual variation.
  - continuous linear warming: maximum of +0.3 °C per decade (winter) and a minimum of 0.15 °C per decade (summer).
- Precipitation changes:
  - monthly fluctuations appear without a clear climate change signal.
  - simplified to 5% per 1 °C warming, independent of the season.
Iceflow- and mass balance models

Response to the CWE climate change scenario

CWE (dP/dT = 5%/°C)

Initial surface 1990

2100

2150

[Graphs showing volume and specific runoff change over time for CWE (dP/dT = 0%/°C) and CWE (dP/dT = 5%/°C).]
Concluding remarks

- The mass balance model describes most of the variance in the observed annual mass balance.

- However, the mass balance model:
  - overestimates the accumulation on the SA-part of the glacier where no stake observations are available for calibration.
  - does not account for a snow drift - slightly to high accumulation at the highest exposed ridges and some outlets disappears when using zero mass balance input.

- Possible improvements:
  - add more mass balance stakes at the SA-part and the unmeasured outlets.
  - derive a more distributed accumulation model, accounting for snow drift.
  - use temperature index melting model accounting for the changes in the solar zenith angle (e.g. Regine Hock).
  - use melting model related to the energy balance.