The Greenland Firn Aquifer: Discovering englacial water storage and motion

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February 2, 2015
2011 Aquifer Observed and Modeled

- First discovered 2011
- ACT11-A2 core 1559 m
- Modeled Area: 70 ± 10 x 10³ km²
- Water persists through the winter
- Mapped with OIB radar
Firn aquifer mapped for three OIB campaigns (2011-2013)

Total area: ~28,000 km²

Miège et al., Submitted
Firn aquifer related to high accumulation regions

Firn aquifer found in:
- High accumulation areas
- Sufficient melt rates

Accumulation map
(Burgess et al., 2010)

Melt days for May-Aug 2007 from SSM/I
(Van Angelen et al., 2012)
Accumulation Radar on board of NASA Operation IceBridge P-3

**Accumulation radar:** Freq. 600 - 900 MHz - 65 cm vertical resolution (Rodriguez-Morales et al., 2013)

Example of airborne data over the ACT-11 traverse: (Forster et al., 2014)

Recent accumulation rates

Firn aquifer

Clément Miège
Geography Dept.
Fieldwork in April 2013

Side winder mechanical drill (for cold firn)

Electrothermal drill (for wet firn & 0°C ice)

Drills provided by IDDO
Aquifer Borehole Video

Stable water table at 12.2 m ± 0.1, water filled bore hole
Drilling into the firn aquifer

Snapshots from borehole camera taken at PFA field work site (April 2013)

Air entrapped in the firn is released
Water Percolating/Sloshing in Core
Density Comparison

Water table is 24.7 m thick

Koenig et al, 2014
Hörhold et al. 2011; Herron and Langway, 1980
Estimating Volume

Assumptions:
• Porosity determined by closest seasonal dry firn core (ACT11B)
• Area of Aquifer: $70 \pm 10 \times 10^3 \text{ km}^2$
• Density of water: $134 \text{ kg/m}^3$
• Bottom constant: 37 m
• Thickness: 2-σ range of 0 to 28 m, mean 14 m

Firn Aquifer Volume:
$980 \pm 140 \text{ km}^3$

Stored Water:
$140 \pm 20 \text{ Gt}$ or $\sim 0.4 \text{ mm of SLR}$

Forster et al., 2014
Koenig et al., 2014
1-D temperature study: Progressive Summer warming

Slow progress of the wetting front from the surface

Dates:
Surface melt onset: June 12
Firn column at 0°C: July 31
Surface < 0°C: Aug 14
Temperature evolution between April 2013 – April 2014

*Note that the sensor depth is valid for April 2013 and the new snowfall added during the winter are not taken into account here.
Influence of the ice-sheet surface undulations

Water table follows the topography in an unconfined system

Average slope: 0.6°
Firn aquifer connection with crevasses

Crevasses observed
- High-res images
- Radar profiles

Marks the end of the aquifer.

Drainage of water is suspected but further investigation is needed to quantify runoff volume and fate of the liquid water

Clément Miège
Geography Dept.
Evolution of the firn aquifer for the upper part of Helheim Gl.

Partial Drainage?
Storage Capacity

Site measured is filled to 50% capacity
Aquifer regions can store 8.9 % more mass than refreezing

Koenig et al., 2014
Harper et al. 2012
Firn aquifer in the vicinity of Helheim Glacier

Field work location for April – May 2015
Aquifer estimated at ~140 Gt of water, ~0.4 mm of SLR

Two end member hypothesis for Aquifer discharge need further investigation:
1) Stored water connected to a well established englacial hydrologic system (seasonally discharging).
2) Stored water fills over long time scales and then drains catastrophically.

Likely both contribute and more work /measurements are needed to further constrain this new glacier facies

Acknowledgements:
Susan Zager and the PFS team and J. Kayne and the IDDO team for drilling support.
NSF grant #1311655 and the NASA Cryospheric Sciences, NIP and ESS programs.