Subglacial flood event observed using \textit{in situ} GPS data, CryoSat-2 altimetry, and MODIS image differencing on the Whillans Ice Plain

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Whillans Ice Plain Overview

Whillans Ice Stream
Mercer Ice Stream
Ross Ice Shelf

ICESat Anomaly (m)

GPS Station
Seismic Station
Water Flow Path
MOA GL
InSAR F Point
InSAR H Point

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Whillans Ice Plain subglacial flood events
Whillans Ice Plain instrumentation

![Map of Whillans Ice Plain with various markers and lines indicating GPS stations, seismic stations, water flow paths, MOA GL, InSAR F Point, and InSAR H Point.]

**ICESat Anomaly (m)**

- **GPS Station**
- **Seismic Station**
- **Water Flow Path**
- **MOA GL**
- **InSAR F Point**
- **InSAR H Point**

**Whillans Ice Plain subglacial flood events**

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(Fricker and Scambos, 2009)

Precise, but **spatially** and **temporally** discontinuous
Disconnect between ICESat time-series and GPS observations.

*Advection upslope? Change in hydropotential regime?*

*Ready to burst?!
CryoSat-2: 2010–present

Radar altimeter, 92° inclination, 369-day orbit, 30-day sub cycle

Modes:
- LRM: conventional pulse-limited radar ($\sim$ kms x kms)
- SAR: traditional synthetic aperture radar ($\sim$ 300m x kms)
- SARin: short-baseline interferometer ($\sim$ 300m x 300m)
Comparing satellites...
Comparing satellites...

1 year of wandering ground tracks

ICESat (2003–2009)
GPS (2008–present)
CryoSat–2 (Jan. 2012)
CryoSat–2 (All 2012)
Spatial and temporal monitoring of $dh/dt$

CryoSat-2, July/Aug 2012

CryoSat-2, Jan/Feb 2013

CS2 on SLM
CS2 off SLM
Difference

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Whillans Ice Plain subglacial flood events
Spatial Validation: MODIS image differencing

Early 2013-Mid 2012 CryoSat-2

Early 2013-Late 2011 MODIS Image Differencing
Temporal Validation: GPS surface elevation

CryoSat-2 DEM elevation at GPS location

~1m offset combination of known processing issue and volume scattering

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Subglacial Lake Mercer: 10+ years of history

GPS scaled to lake average $dh$

WIP GPS tie together cryo-focused satellite-borne datasets
Where does the water go??

SLM

relative elevation (m)

year

- SLM

-540000 -520000 -500000 -480000

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Whillans Ice Plain subglacial flood events
Where does the water go??

SLM

Lake 7

relative elevation (m)

year

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Whillans Ice Plain subglacial flood events
Where does the water go??

- **SLM**
  - Relative elevation (m) vs. year
  - Peaks around 2011, with a subsequent drop in 2012 and 2013.

- **Lake 7**
  - Similar trend to SLM with a peak around 2010 and a significant drop in 2011.

- **LA08**
  - Fluctuations with a notable increase around 2011, followed by a dip in 2012, and another rise in 2013.

Images show multi-year data analysis focusing on subglacial lake activity.
Ice Stream Velocity

Whillans Ice Plain subglacial flood events
Ice Stream Velocity

**Whillans Ice Stream**

- LA06
- LA04
- SLW
- *lq data*

- Velocity (m/yr)
- Year

**Mercer Ice Stream**

- Lake 7
- LA08
- SLM
- *lq data*

- Velocity (m/yr)
- Year

Whillans Ice Plain subglacial flood events
Whillans Ice Stream Velocity

Mercer Ice Stream Velocity

Whillans Ice Plain subglacial flood events
More overlap between GPS and satellite missions than at SLM
Subglacial Lake Whillans

Corrected for: on lake/off lake bias, penetration (ad hoc), antenna height, and scaled to full lake elevation change.

GPS: 15.0±0.001 cm yr$^{-1}$
CryoSat–2: 15.9±8.4 cm yr$^{-1}$

can recover small $dh/dt$ signals.
More lake action...
Conclusions

- Independent, coincident measurements of a subglacial lake discharge event with high spatial and temporal resolution
- SLM discharge corresponds to a measurable increase in ice velocity
- CryoSat-2 is quite adept at measuring dynamic $dh/dt$
- We need high quality datasets between major satellite missions
Thank You!

- NSF-OPP, NASA, SIO, UCSD
- KBA, NYANG, UNAVCO
- WISSARD 2011/2012, 2012/2013 field teams
- POLENET
CryoSat-2 Validation: salar de Uyuni

Cryosat SARin elevations over salar de Uyuni, Bolivia

Uyuni DEM minus Cryosat SARin Elevations

Cryosat SARin minus Uyuni DEM - Track Statistics

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Whillans Ice Plain subglacial flood events