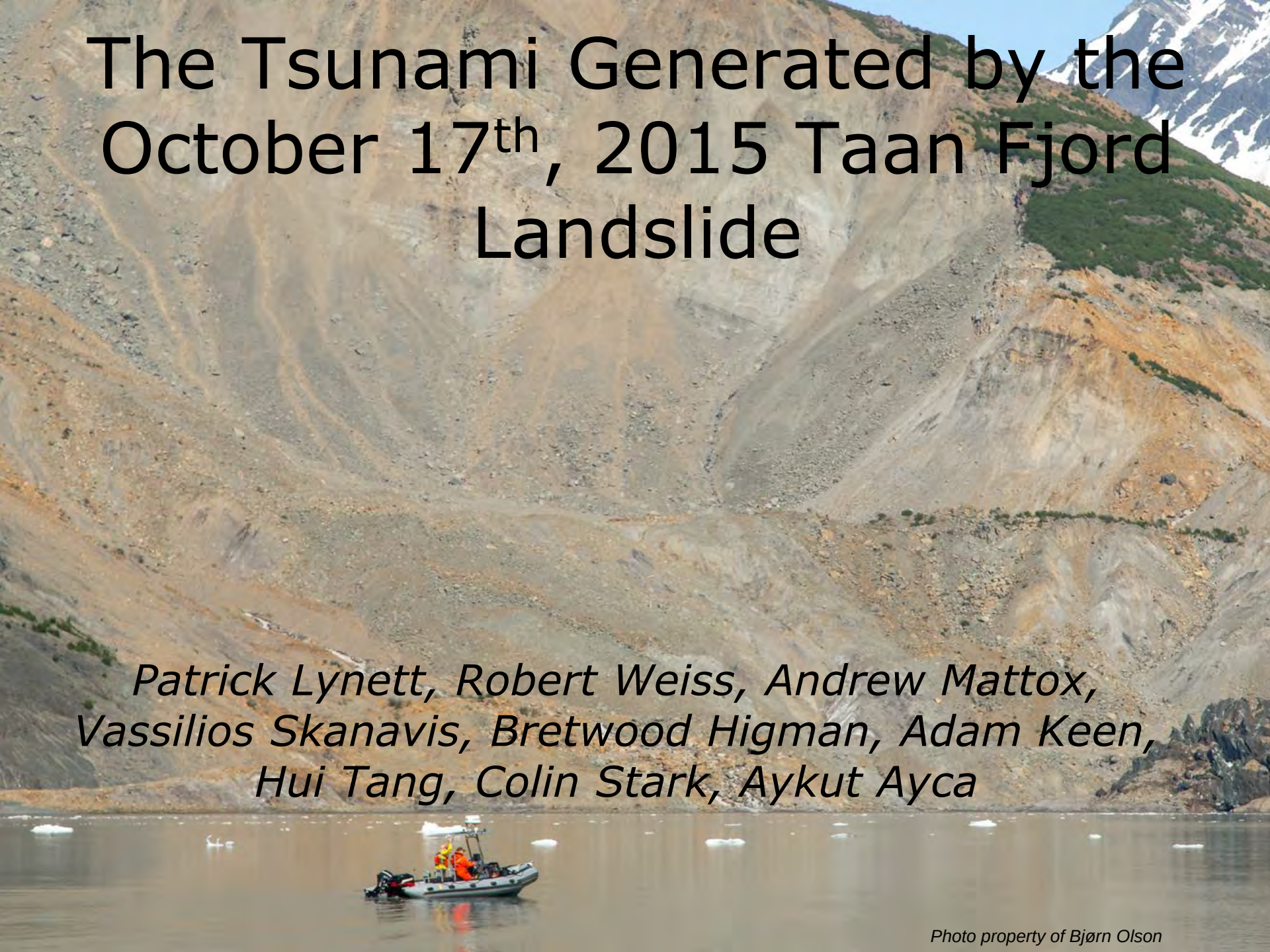
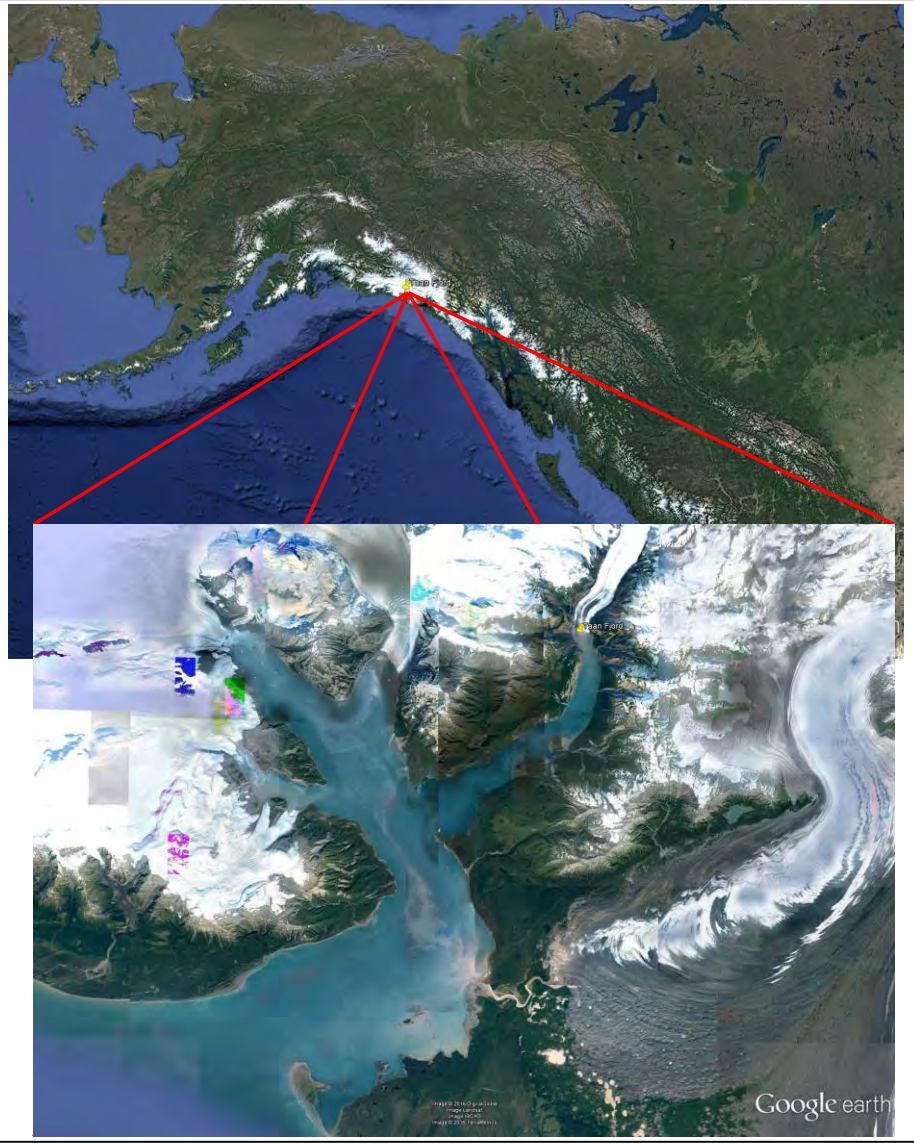
The Tsunami Generated by the October 17th, 2015 Taan Fjord Landslide

Patrick Lynett, Robert Weiss, Andrew Mattox, Vassilios Skanavis, Bretwood Higman, Adam Keen, Hui Tang, Colin Stark, Aykut Ayca



The Location – Icy Bay & Taan Fjord

- Icy Bay is a remote and un-inhabited bay in southeast Alaska
  - The nearest accessible town is Yakutat, about 120 km to the southeast
- The Bay formed over the past ~100 years by the rapid retreat of three glaciers (Guyot, Yahtse, Tyndall)
  - These three calving glaciers constantly shed ice into the bay, and hence the name Icy Bay
- Taan Fjord is a long, and narrow fjord created by the retreat of the Tyndall glacier over the past 50 years
  - The fjord is ~ 15 km in length, with depths to ~180 m
- The coastline along Taan is a mix of glacial moraines, alluvial fans, dense brush, and steep, barren slopes.



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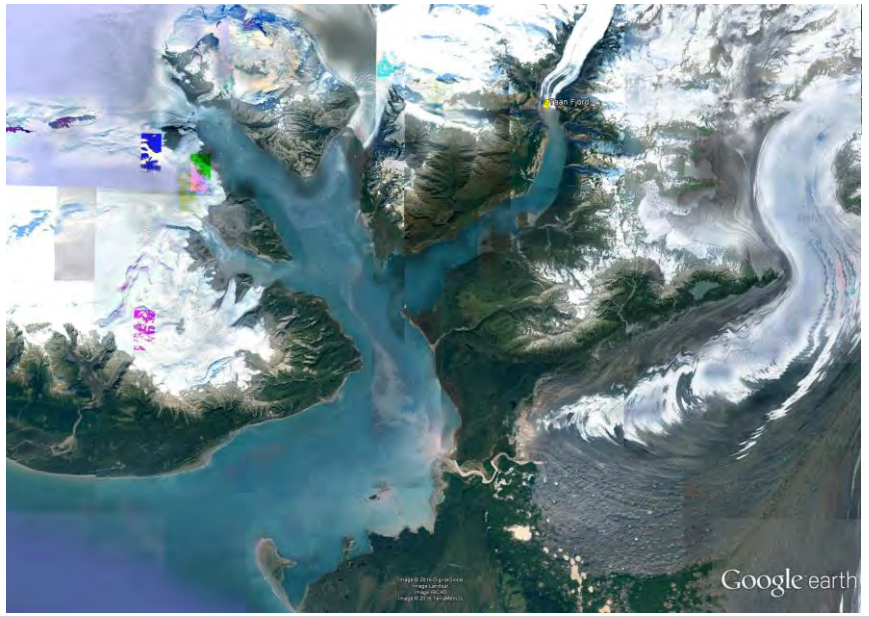

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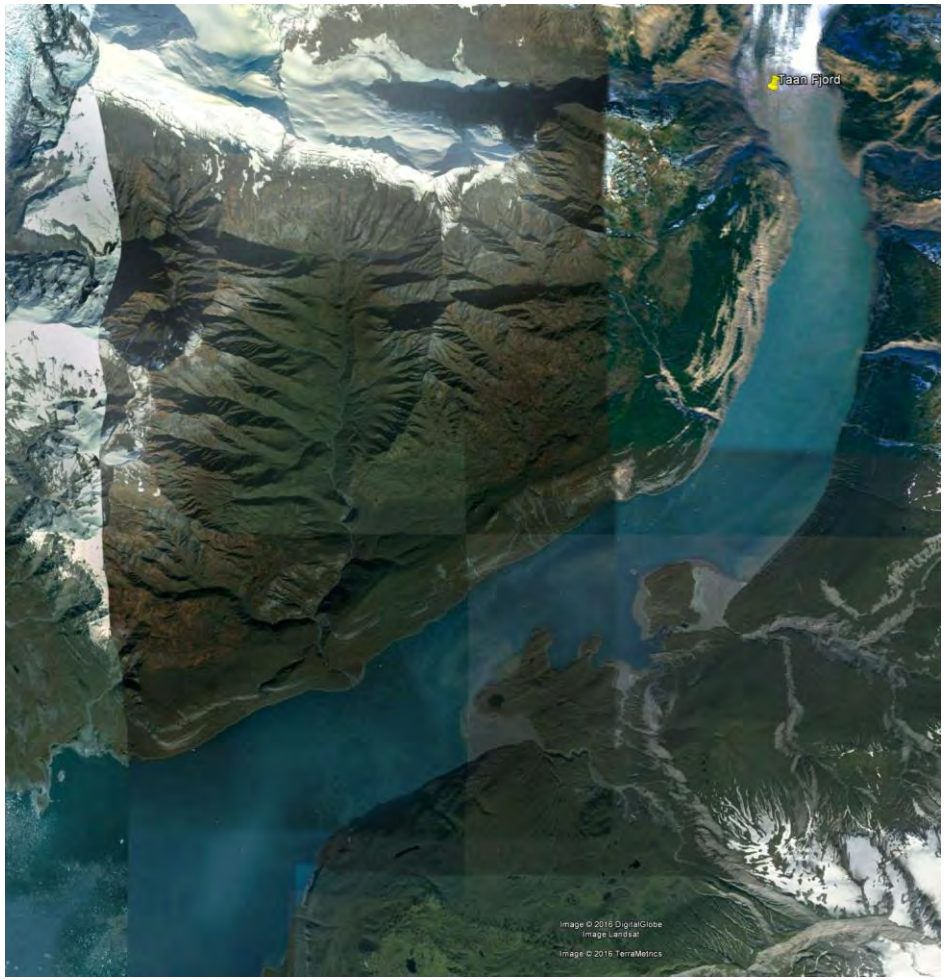
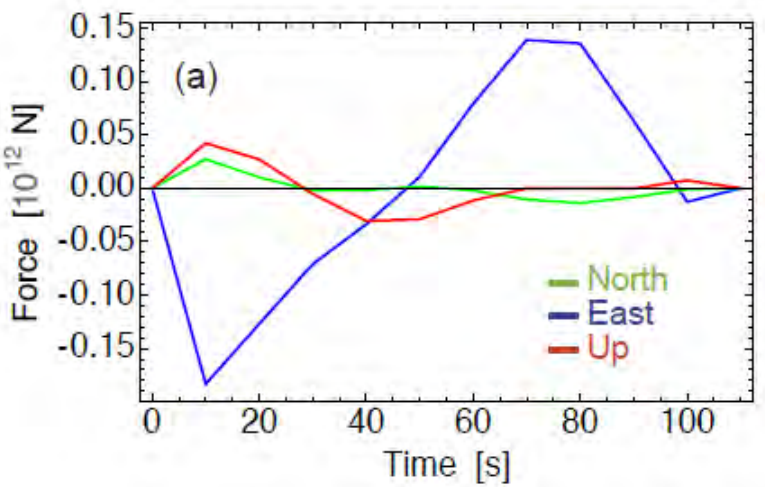


Initial Detection of Slide

- Slide occurred at 8:19 p.m. on Oct. 17, 2015
- The slide was initially detected by Göran Ekström and Colin Stark at Lamont-Doherty using a long-period seismic detection method
- Initial estimates of slide:
  - Mass of ~150 Mt
  - Volume ~55 million m^3
  - Peak speed of 20-30 m/s
  - Duration ~100 seconds
  - ~90% of volume entered fjord
- A small wave signal was detected at the Yakutat tide gage
  - Period of ~40 minutes
  - Crest-to-trough height of ~15 cm
  - 140 km away from slide
- Satellite imagery in the following days indicated signficiant areas of new scour, at elevations greater than 100 m



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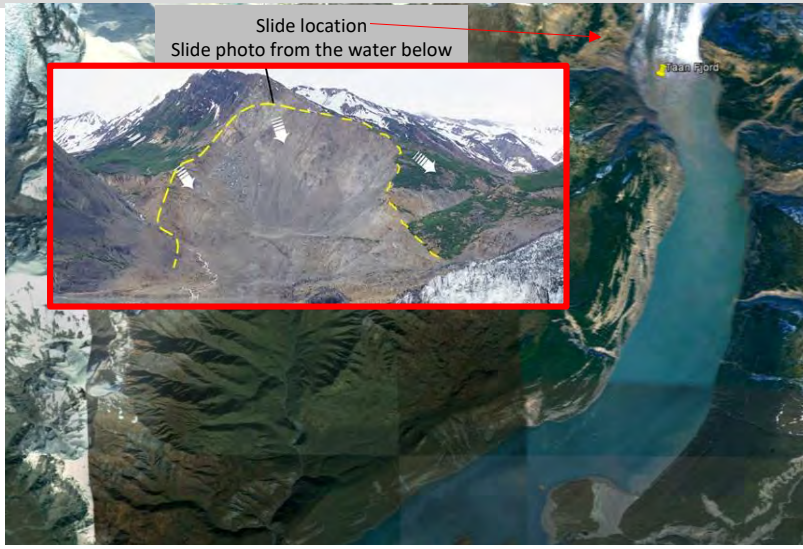

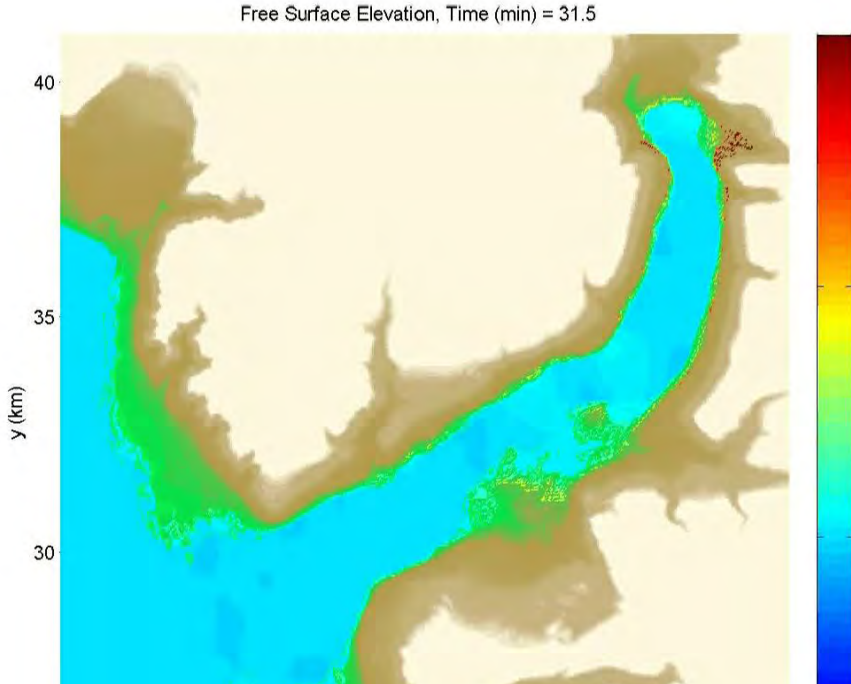

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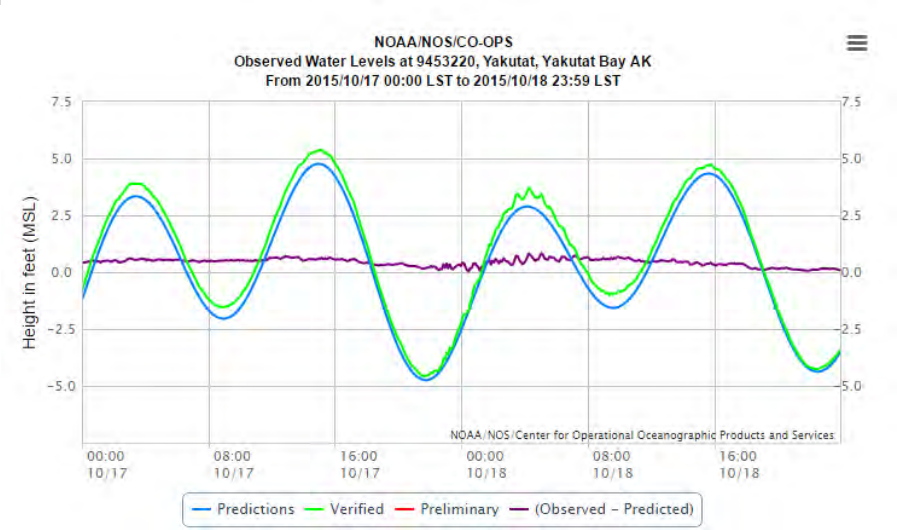

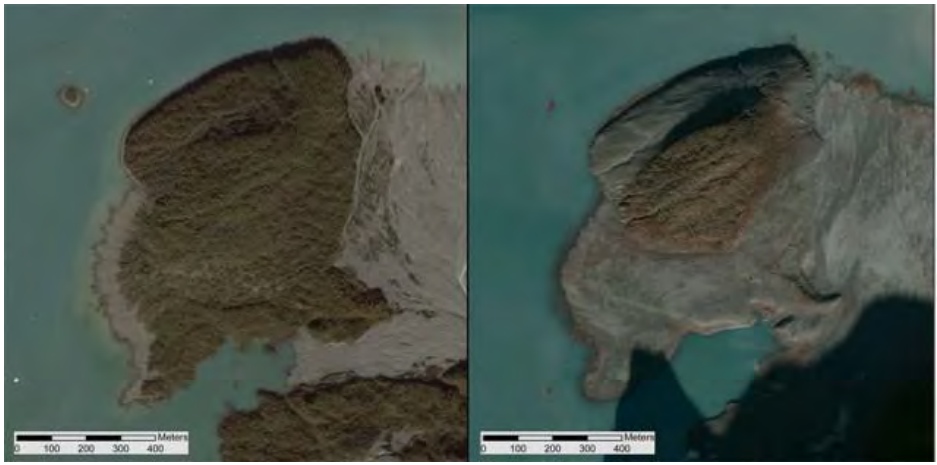

The Field Surveys & Team

- First tsunami survey in April
  - Small team with the goal of measuring "low" runup markers, before spring and summer vegetation
  - Assess challenges of working in the area
- Second tsunami survey in June
  - Purpose was to perform a complete tsunami field survey throughout Taan Fjord and Icy Bay
  - Part of a larger multi-disciplinary team
- Third tsunami survey in August
  - Short survey to get the few remaining areas missed by other surveys
- Other groups not focusing on tsunami impacts
  - Bathy changes (survey in July)
  - Glacier changes

- Patrick Lynett (USC)
- Adam Keen (USC)
- Vassilios Skanavis (USC)
- Robert Weiss (Virginia Tech)
- Hui Tang (Virginia Tech)
- Bretwood Higman (Ground Truth Trekking)
- Andrew Mattox (Ground Truth Trekking)
- Bjørn Olson (Ground Truth Trekking)
- Breanyn MacInnes (CWU)
- Colin Bloom (CWU)
- Marten Geertsema (UNBC)
- Anja Dufresne (RWTH Aachen University)
- Peter Haeussler (USGS)
- Bruce Richmond (USGS)
- Colin Stark (Columbia)
- Dan H. Shugar (University of Washington Tacoma)
- Sean Gulick (UTexas)
- Mike Willis (Cornell)
- Michele Koppes (UBC)
- Christopher Larsen (University of Alaska Fairbanks)
- Michael West (University of Alaska Fairbanks)
- Michael Loso (Wrangell-St. Elias National Park)

The Field Surveys & Team

The Field Surveys

- Conditions were challenging, especially during the April survey
- Access to Icy Bay was by boat (primarily), prop plane, and helicopter
- Travel throughout the fjord was by boat, skiff, and packraft
- Survey measurements were taken by
  - Rangefinder for elevations less than 10m and short inundation distances
  - A combination of RTK GPS, TotalStation, and Rangefinder
  - For the RTK, Base Station was set up at camp, and a series of survey monuments were created through the fjord
- Survey was difficult in many locations, due to terrain and runup elevations

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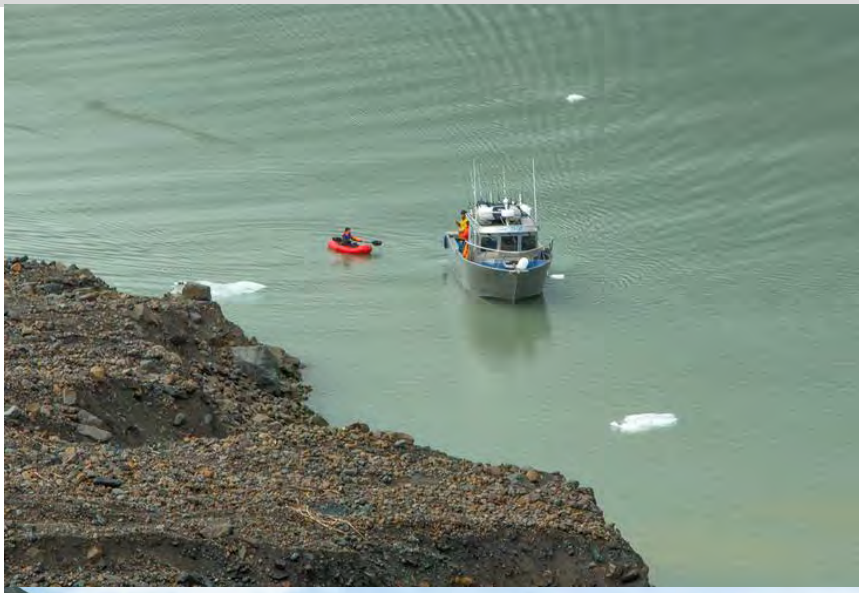

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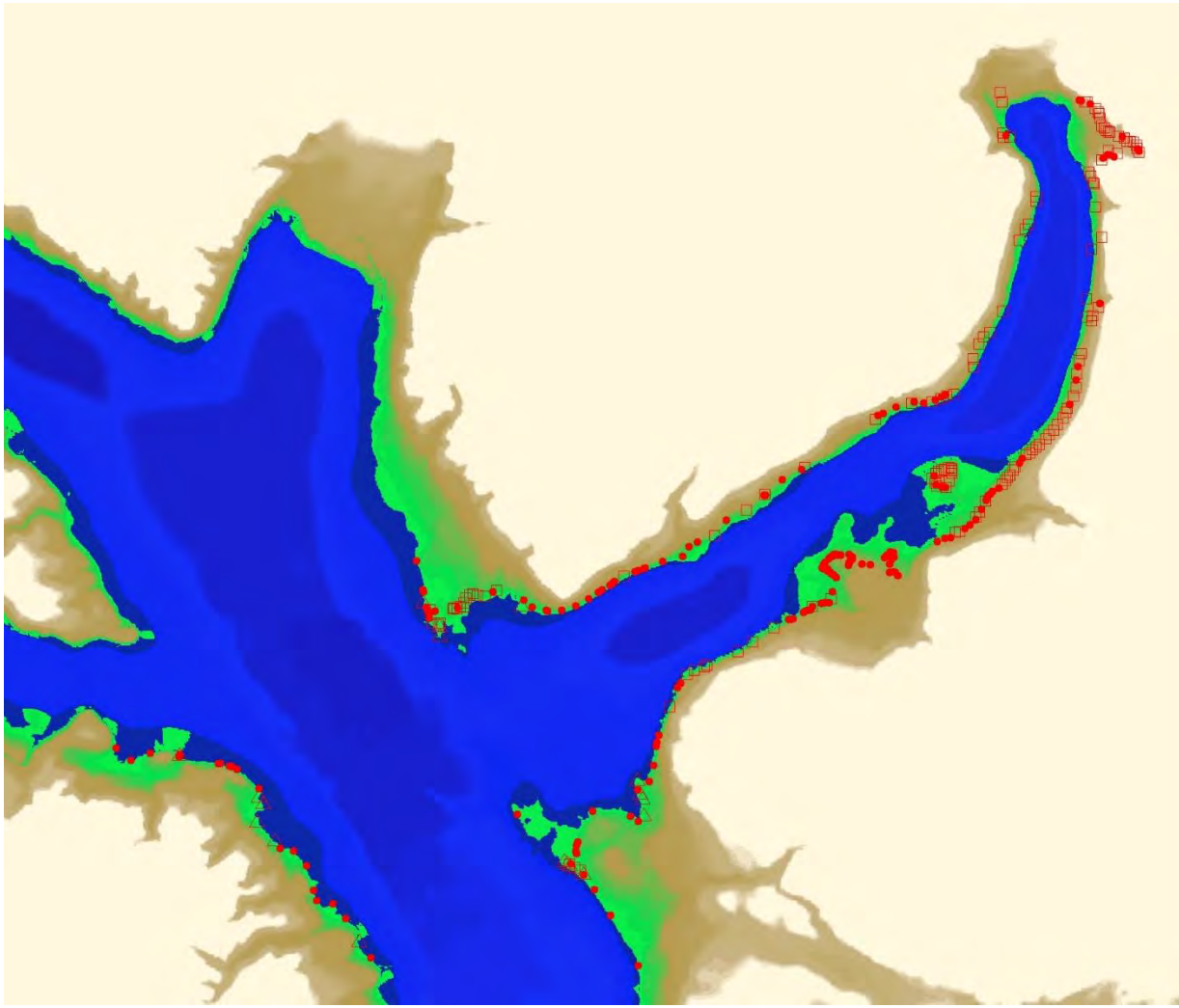
Tsunami Runup Results

- Complete coverage of tsunami impacted areas throughout Icy Bay
  - Tsunami occurred near low tide; tide range is ~3.5 m
  - Inside fjord, minimum detectable runup was 3-4 meters
  - Outside fjord, 4-5 meters
- The peak runup, immediately opposite of the slide is near 190 m
- There is a strong and complex interaction between the tsunami and the moraines in the middle fjord
- Measurable runup attenuates quickly outside of Taan Fjord



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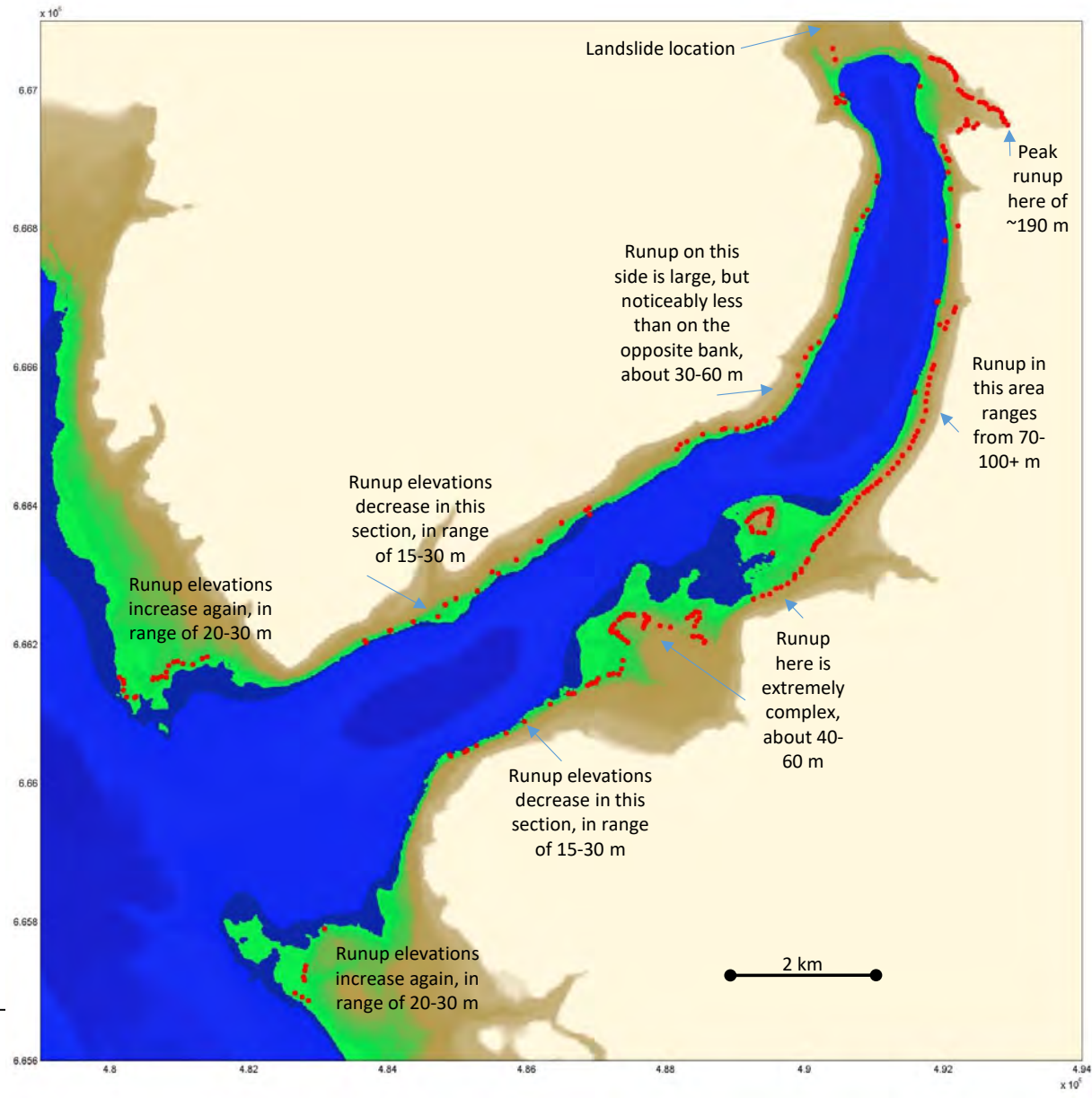

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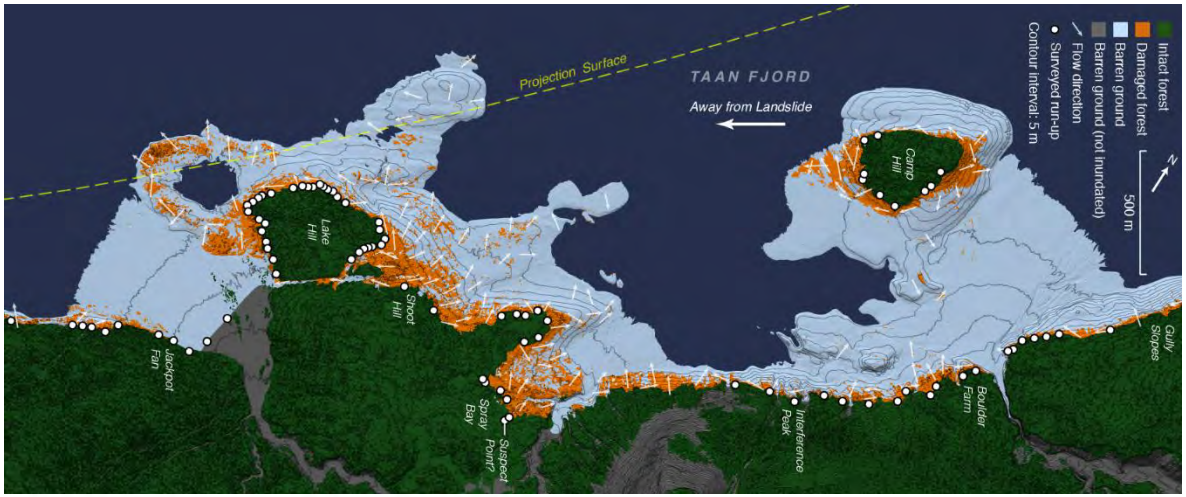
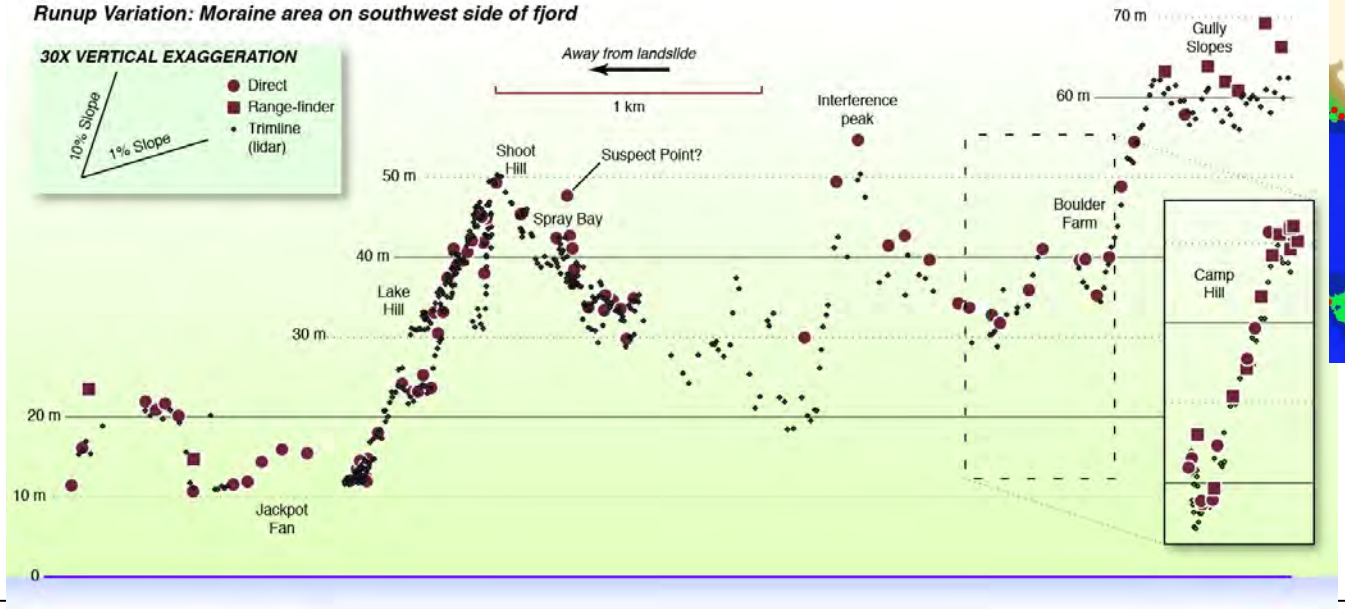
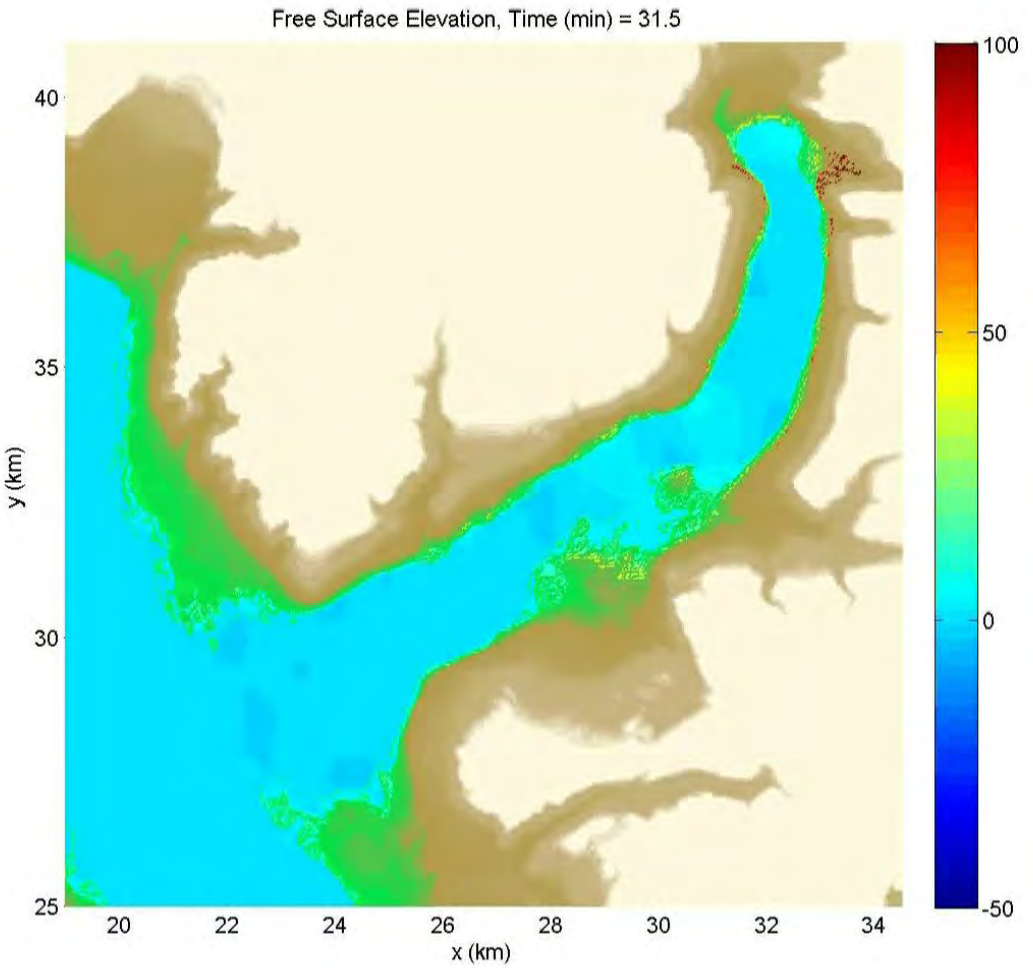
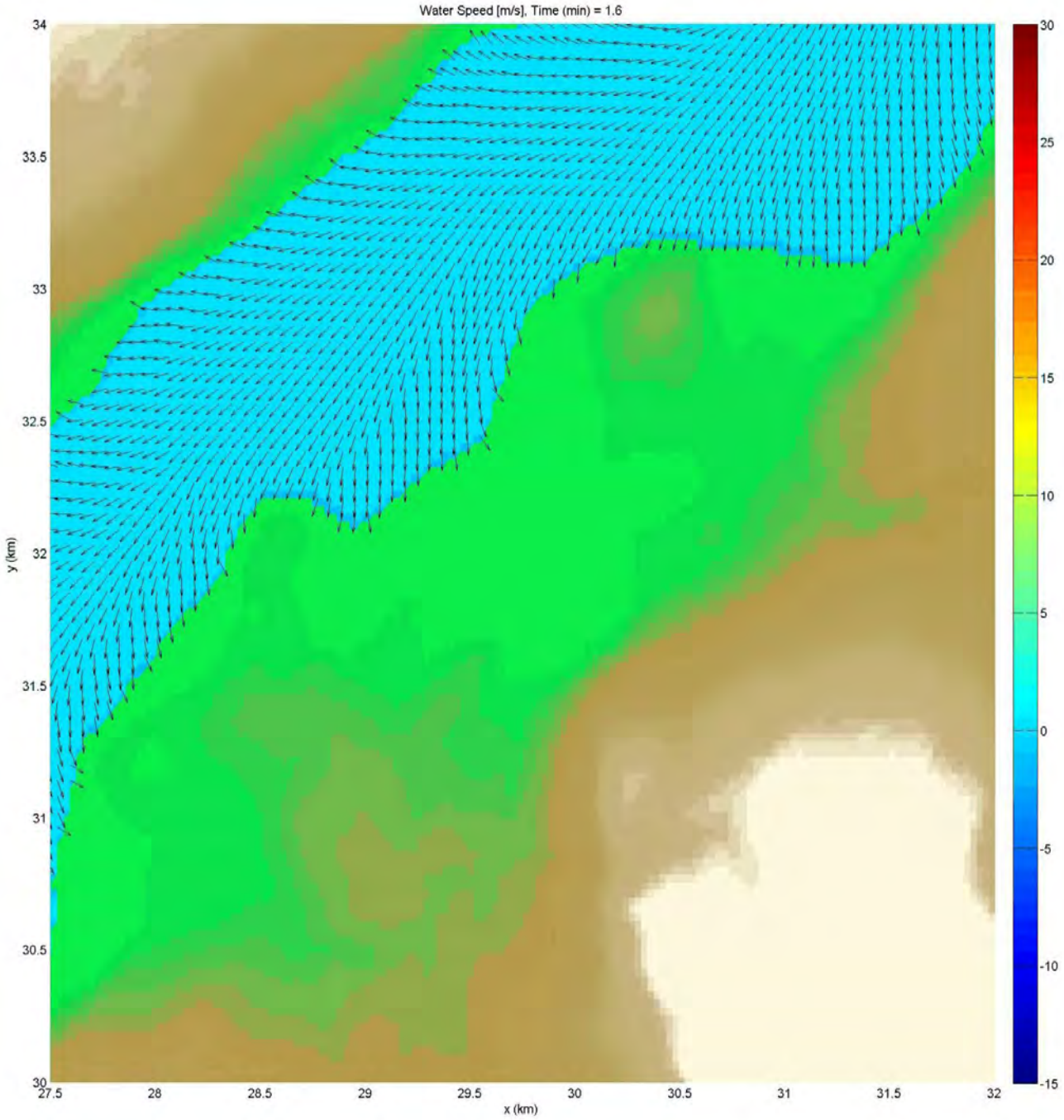




Simulations of the Slide and Tsunami

- Based on the slide constraints from the seismic inversion, use the 3D model iSALE to constrain the initial waves
- Use the iSALE output to develop the initial condition for a 2D (horizontal) model
- Matches the observed runup well (we have good topography!)
- Simulation shows that the fundamental resonant period of Taan Fjord is ~40 minutes
- This is the source of the 40 minute signal in Yakutat, 140 km away
  - From a two-minute duration impulsive event!




Water Speed [m/s], Time (min) = 1.6
34
33.5
33
32.5
32
31.5
31
30.5
30
y (km)
27.5
28
28.5
29
29.5
30
30.5
31
31.5
32
x (km)
30
25
20
15
10
5
0
-5
-10
-15

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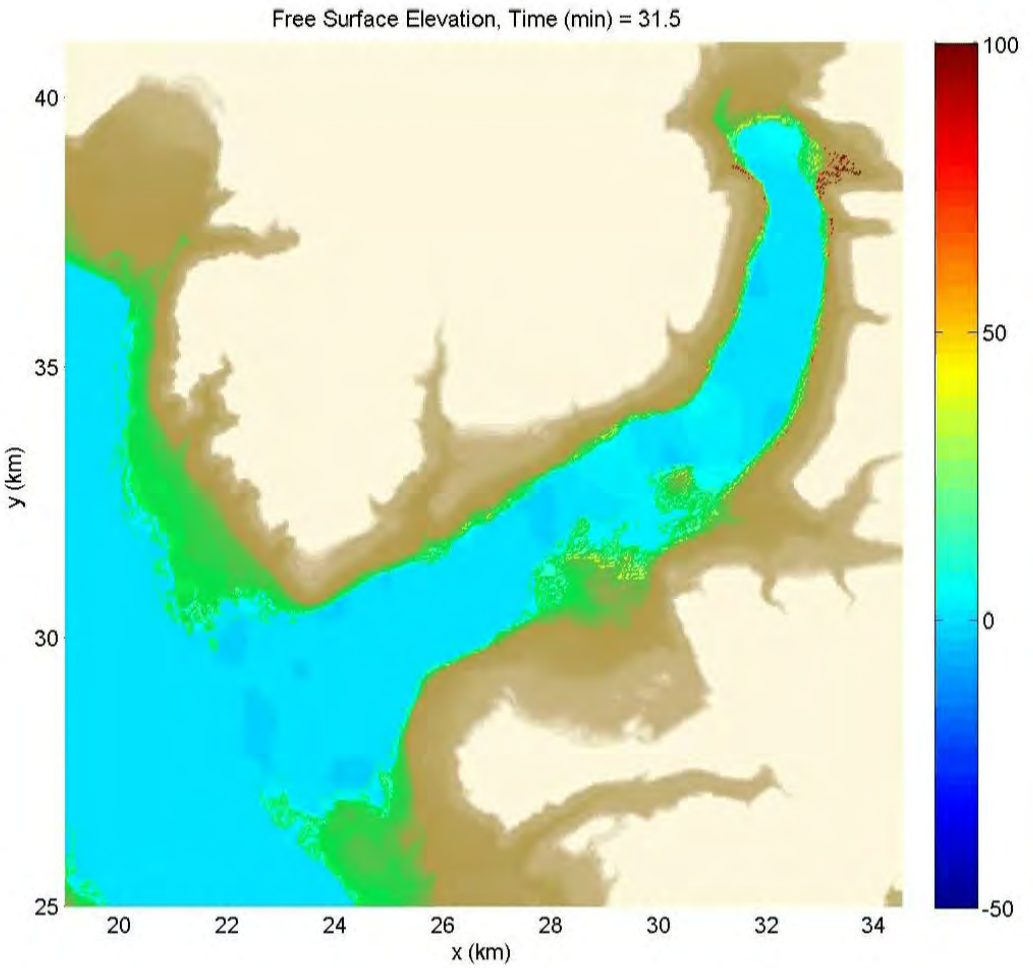
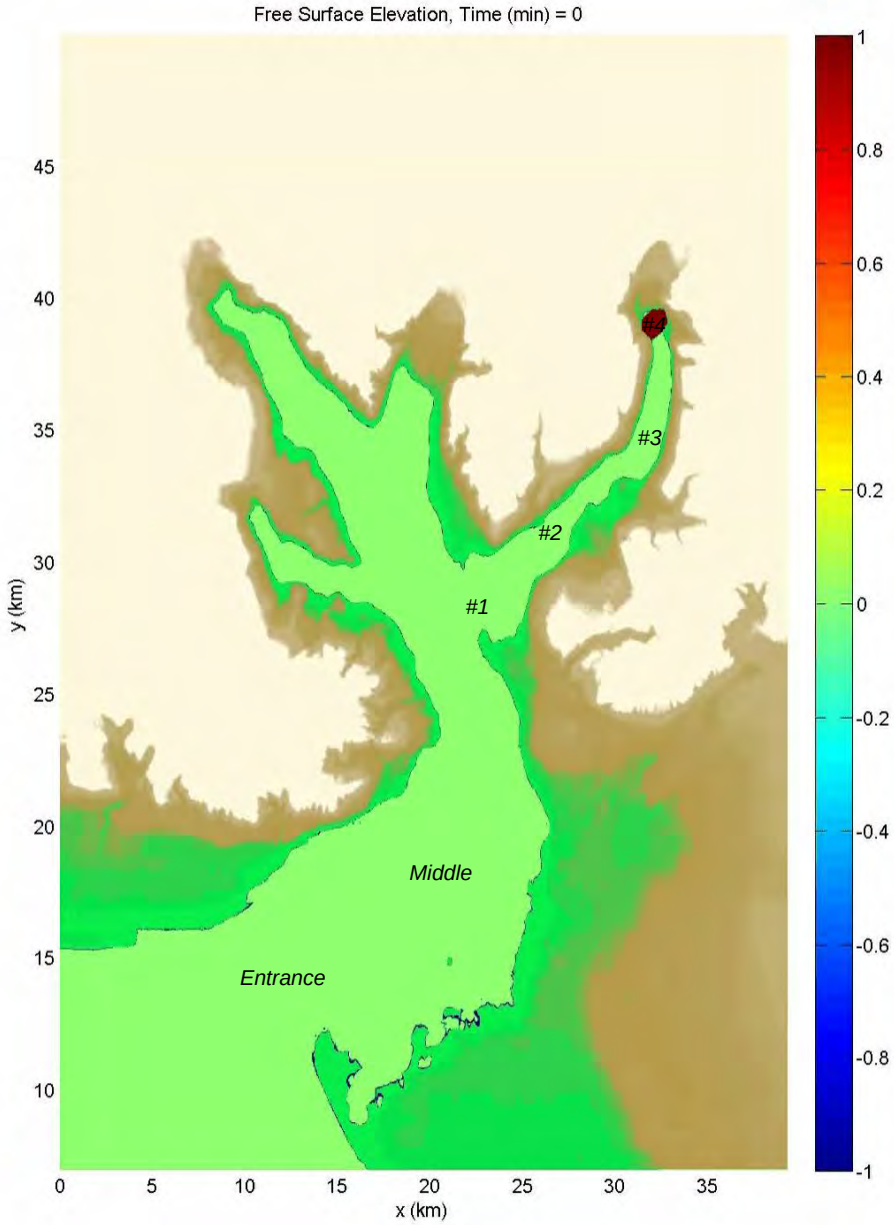
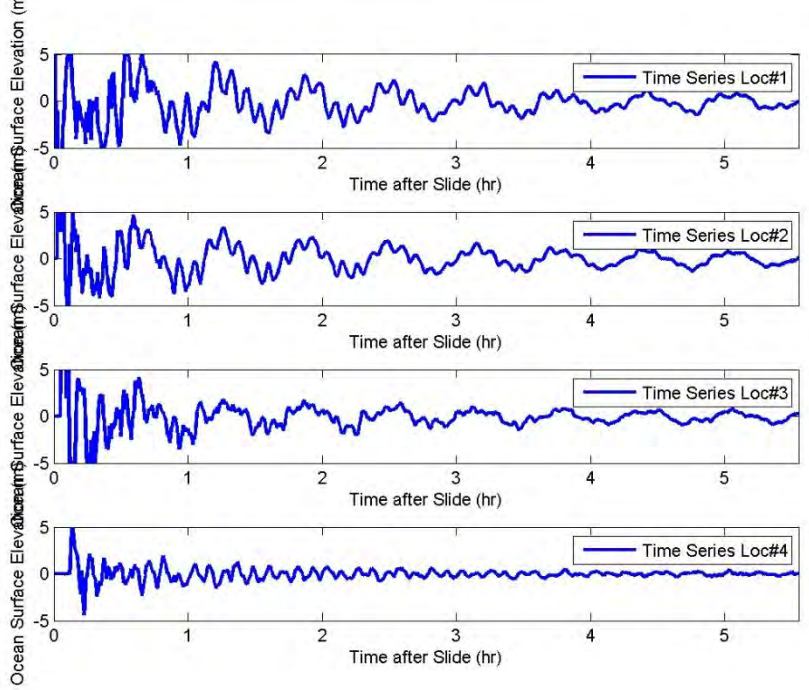
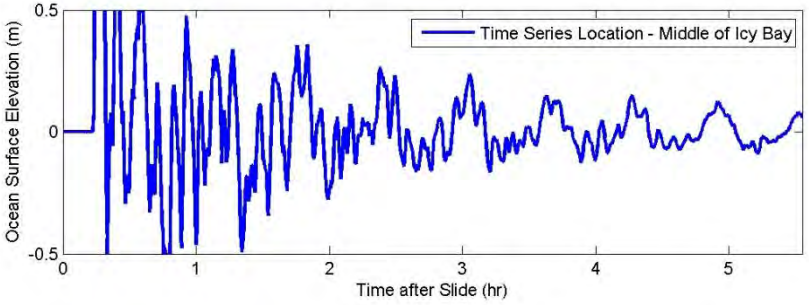
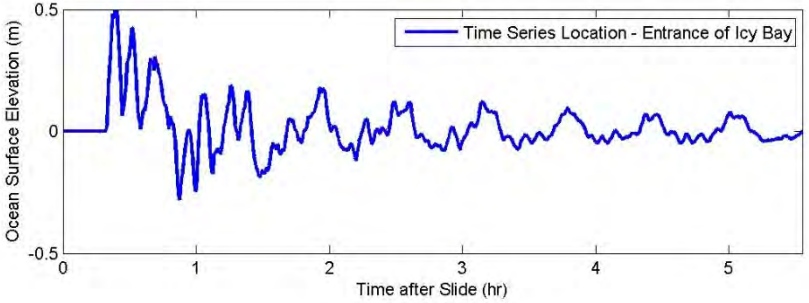



Free Surface Elevation, Time (min) = 0
#1
#2
#3
#4
Middle
Entrance
y (km)
x (km)
0
5
10
15
20
25
30
35
10
15
20
25
30
35
40
45
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


Time Series Loc#1
Time Series Loc#2
Time Series Loc#3
Time Series Loc#4
Ocean Surface Elevation (m)
Time after Slide (hr)
5
0
-5
0
1
2
3
4
5


Time Series Location - Middle of Icy Bay
Ocean Surface Elevation (m)
Time after Slide (hr)
0.5
0
-0.5
0
1
2
3
4
5


Time Series Location - Entrance of Icy Bay
Ocean Surface Elevation (m)
Time after Slide (hr)
0.5
0
-0.5
0
1
2
3
4
5

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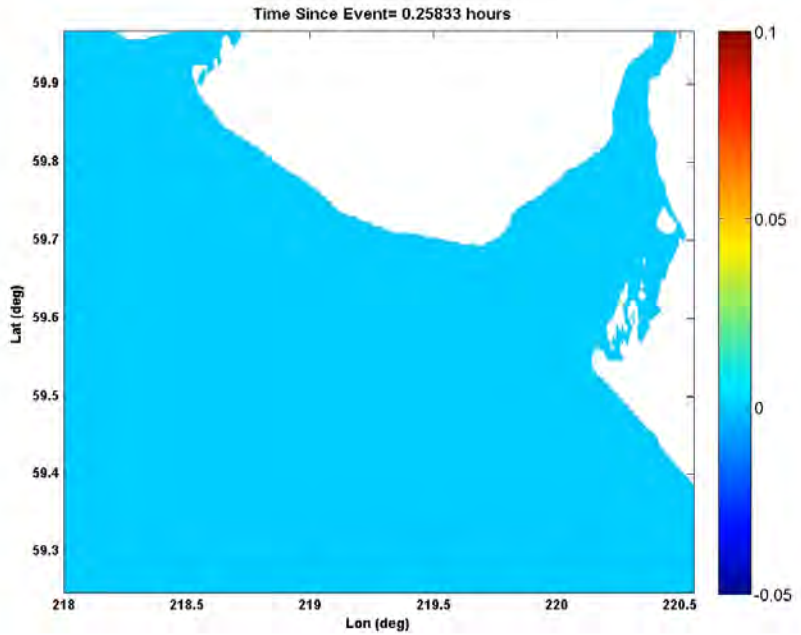

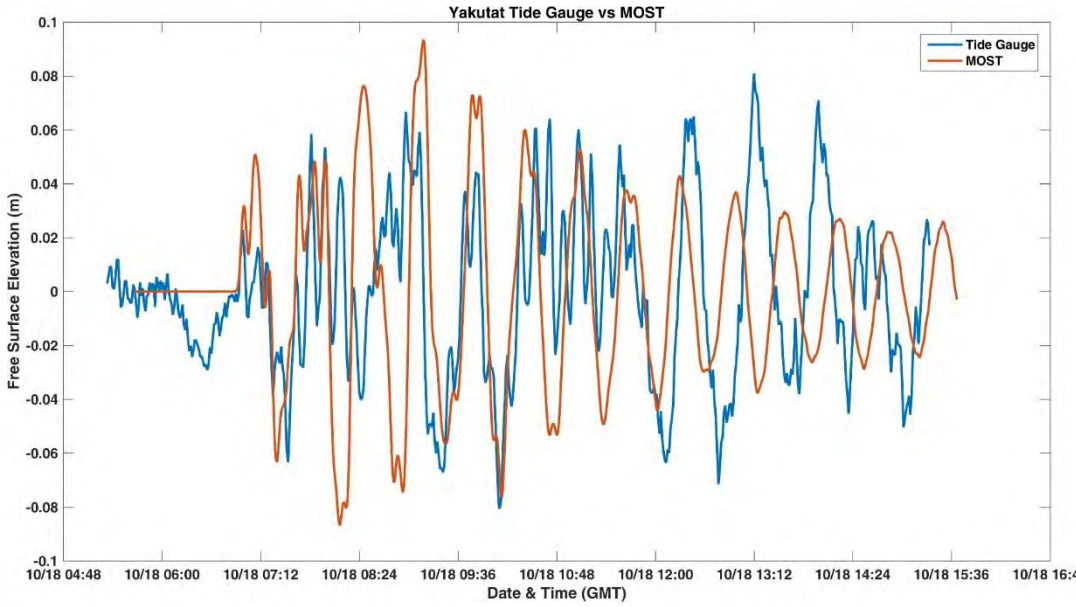

Conclusions

- Unique and large event!
- The tsunami survey data, when combined with the seismic information, tsunami deposit information, measured bathy (post) and topo (pre and post), should allow for highly constrained reconstructions of the source dynamics
- Opportunities to better understand transport across many scales
- Implications for landslide and tsunami hazard in areas with rapidly retreating glaciers
- Data available early 2017