Historic Movement Analysis of Frozen Debris Lobes, Southern Brooks Range, Alaska

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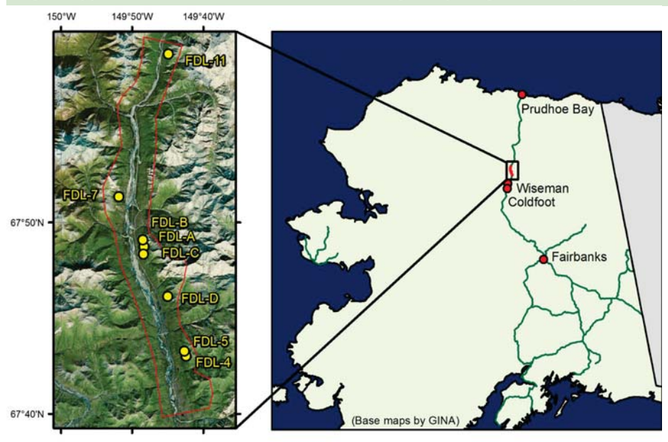
ABSTRACT

We used historic imagery analysis to characterize the movement behavior of frozen debris lobes (FDLs), which are slow-moving landslides in permafrost areas. The eight FDLs reside along the Dalton Highway, in the southern Brooks Range, Alaska. Aerial and satellite imagery, and data obtained using Light Detection And Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (IfSAR) techniques, ranging from 1955 to 2014, were acquired for the study area. Changes in FDL size and position were mapped and measured in a GIS environment and compared to recent surface surveys. All FDLs demonstrated downslope movement, with asynchronous pulses of movement occurring over the imagery timeframe. Here we present a summary and comparison of FDL long-term average movement rates from the GIS analysis, which can be used to predict future movement rates and to assess the risk FDLs may pose to important infrastructure. Based on this analysis, we predict that FDL-A (the closest FDL to the highway) will reach the current Dalton Highway alignment by 2023.



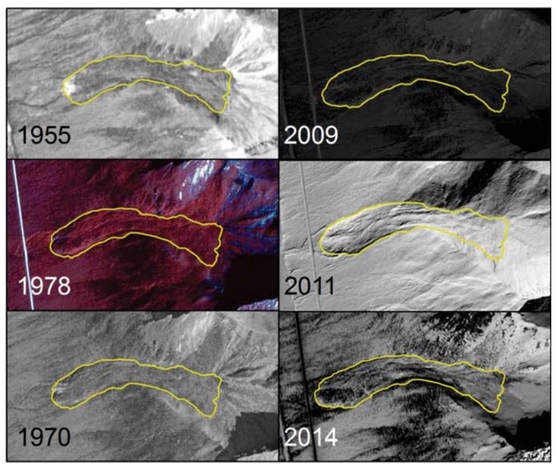
Location of study area containing eight FDLs

RESEARCH OBJECTIVES

1. Acquire historic images of FDL study area
2. Mosaic images together, orthorectify for spatial correctness
3. Analyze imagery to determine historic movement rates for FDLs, summarize trends

Photo by Todd Paris

FDL-B, FDL-A, and FDL-C (from left to right), with the Dalton Highway and the Trans Alaskan Pipeline System in foreground



Examples of historic imagery of FDL-A

Toe of FDL-A in April 2016, from Dalton Highway

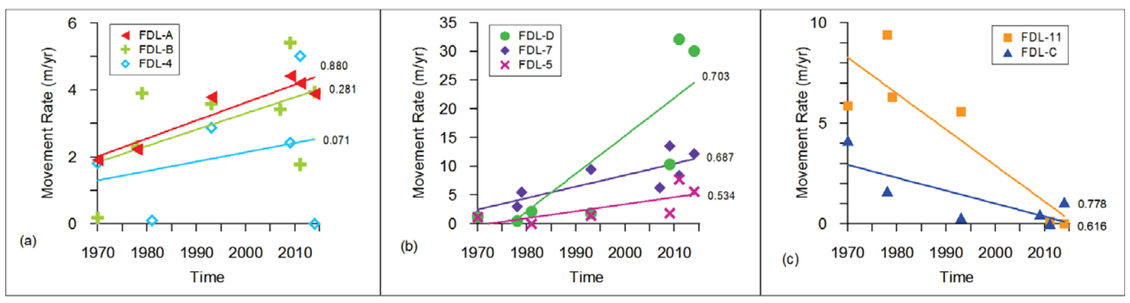
METHODS

Data Preparation

- Variety of sources used for aerial and satellite imagery: U.S. Geological Survey, Alaska High-Altitude Photography, Quantum Spatial, DigitalGlobe WorldView, and Ikonos
- Geographic Information Network of Alaska (GINA) produced orthorectified mosaics for each data set
- Light Detection And Ranging (LiDAR) data and Interferometric Synthetic Aperture Radar (IfSAR) data were obtained and used to define extent of each FDL and catchment area
- Outlined change in extent of FDL for each year
- Some imagery only available for part of study area, creating gaps in time for FDLs without coverage

Measurement

- Longitudinal profile line created for each FDL, as FDLs move downslope with minor lateral spreading
- Progression of toe of lobe measured for each data set
- Distance between each toe position divided by the time interval between data sets



Average movement rates versus time, with Y-axis scales adjusted for each group

SIGNIFICANCE

- The Dalton Highway is Alaska's most economically important route, only overland connection to North Slope energy resource industries
- FDL speed and proximity to infra-structure confirms their geohazard potential

Leaning trees, cracked ground, and thaw slumps on FDL-D

RESULTS

FDLs in study area can be divided into two general groups

- increasing movement rates: FDL-A, -B, -D, -4, -5, and -7
- decreasing movement rates: FDL-C and -11

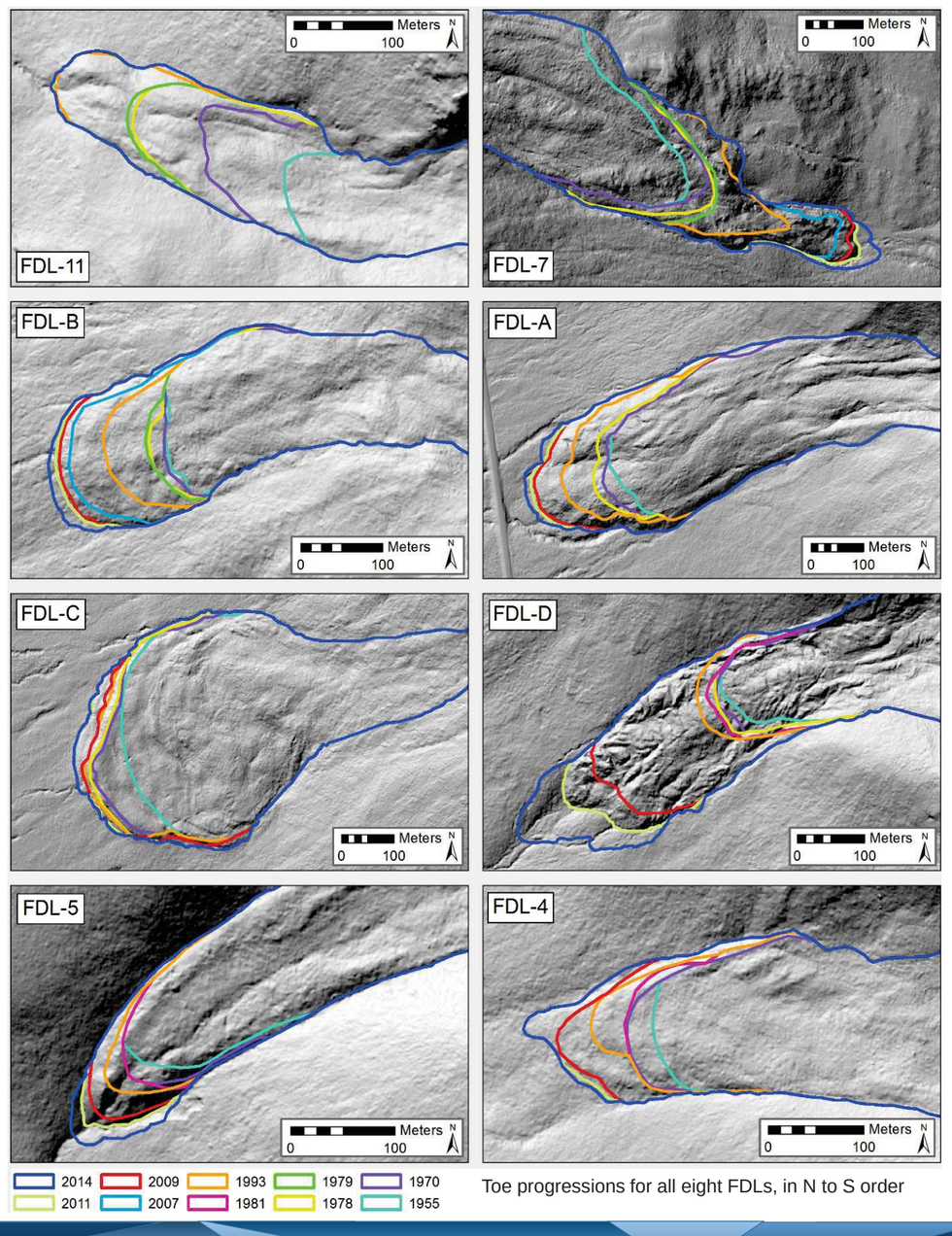
FDLs have varied behavior, some show pulses of accelerated movement. For example:

- FDL-D moved at 1.2 m yr^{-1} in 1970, reaching a peak average rate of 32.1 m yr^{-1} in 2011, and slowing to 30.1 m yr^{-1} in 2014
- FDL-11 experienced peak movement rate in 1978 at 9.4 m yr^{-1}, but rate has been decreasing since, ending with no significant change in toe position from 2011 to 2014.
- FDL-A moved at 1.9 m yr^{-1} in 1970, reaching an average rate of 3.9 m yr^{-1} in 2014

Measured movement rates for each FDL, by dataset interval

Movement rate (m yr^{-1})	FDL-11	FDL-7	FDL-B	FDL-A	FDL-C	FDL-D	FDL-5	FDL-4
1955 - 1970	5.85	1.58	0.19	1.92	4.15	1.17	1.18	1.82
1970 - 1978	9.41	3.01	2.31	2.22	1.63	0.47		
1978 - 1979	6.31	5.45	3.90					
1979 - 1981						2.10	0	0.09
1981 - 1993	5.60	9.52	3.60	3.79	0.32	1.88	1.47	2.88
1993 - 2007		6.27	3.43					
2007 - 2009		13.56	5.42	4.42	0.48	10.34	1.78	2.42
2009 - 2011	0.12	8.42	1.77	4.21	0	32.14	7.73	5.03
2011 - 2014	0	12.19	3.93	3.89	1.09	30.13	5.58	0

- Remote sensing method is inexpensive, requires few resources
- Able to analyze change over largest time scale to date
- Project long term averages to predict future movement rates



Toe progressions for all eight FDLs, in N to S order

CONCLUSION

Historic imagery analysis can be used as an effective remote sensing tool to characterize FDL movement behavior on a decadal scale. The analysis indicates asynchronous movement of these features, despite their close proximity to each other. A limitation to this research is the lack of suitable aerial imagery for this area. A significant amount of available imagery was unusable because of cloud cover, shadowing, skewed image geometry, and/or wash out. Additional imagery sets over the time period would increase the temporal resolution and improve the accuracy of the long-term trends.

Despite this limitation, this analysis of movement gives us a greater understanding of these geohazards. Most notable is the movement of FDL-A, as the historic rates fit a linear trend with an R^2 of 0.88, providing confidence in projected movement rates. The Alaska Department of Transportation and Public Facilities plans to reroute the highway to avoid the approaching FDL-A (Currey, pers. comm., Aug. 2015). While this will place more distance between the Dalton Highway and the approaching FDL-A, a long-term solution is still needed.

For more information on FDL research: fdlalaska.org

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REFERENCES

Daanen RP, Grosse G, Darrow MM, Hamilton TD, Jones BM. 2012. Rapid movement of frozen debris-lobes: implications for permafrost degradation and slope instability in the south-central Brooks Range, Alaska. Natural Hazards and Earth Systems Sciences 12: 1521-1537.

Darrow MM, Simpson JM, Daanen RP, Hubbard T. 2015. Characterizing a frozen debris lobe, Dalton Highway, Alaska. Cold Regions Engineering 2015: 57-67.

Hubbard TD, Koehler RD, Combellick RA. 2011. Lidar Data Sets of Alaska: High Resolution Lidar Data for Alaska Infrastructure Corridors. Alaska Division of Geological and Geophysical Surveys: Raw Data File 2011-3, 291 p.

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