REX2024
PRCI Research Exchange

Advancing Data Driven Awareness and Warning for Deep Seated Landslides

Project GHZ-2-06

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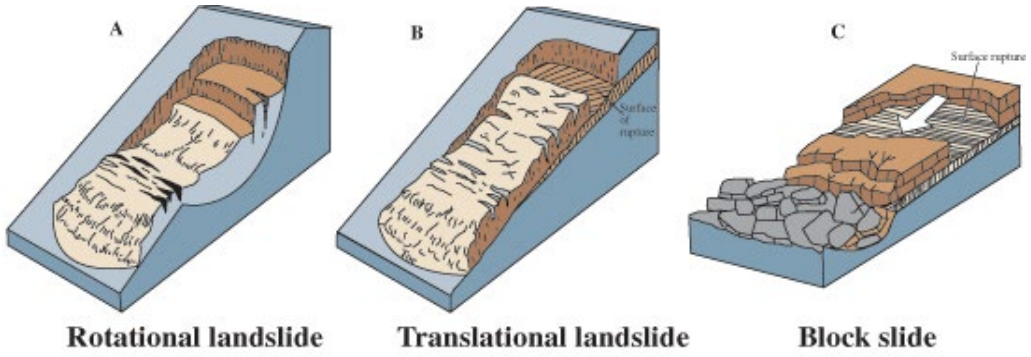
PRCI LEADING PIPELINE RESEARCH
Pipeline Research Council International

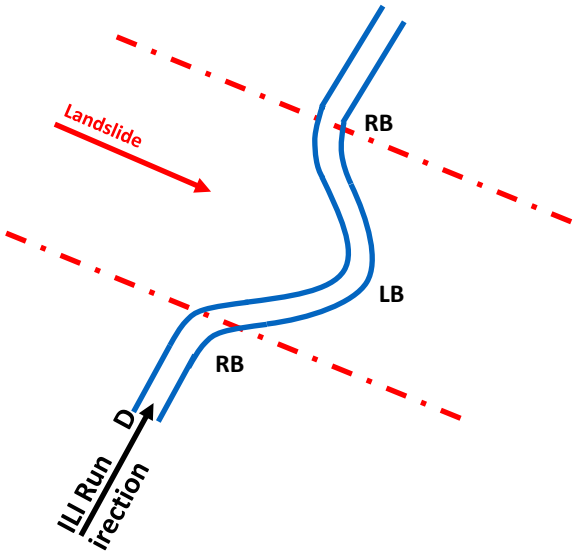
Presentation Outline

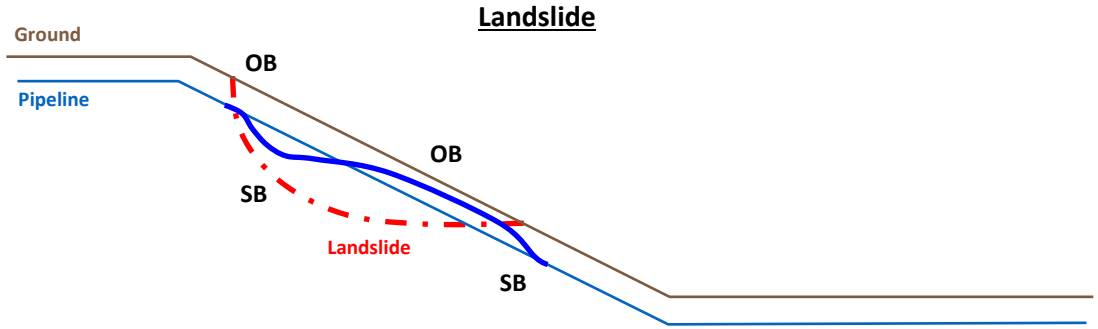
- Deep Seated Landslides and Pipelines
- Understanding hydrologic drivers.
- What does “warning” look like?
- What are we learning?
- How is this being applied in the Appalachian Plateau?
- What is on the horizon?

Deep Seated Landslides



Class	Description	Typical velocity	Proposed annual displacement criteria (m)	Proposed mean annual displacement (m)
7	Extremely rapid	>5 m/sec		
6	Very rapid	>3 m/min		
5	Rapid	>1.8 m/hr		
4+	Moderate	>13 m/month	>16	64
3	Slow	>1.6 m/yr	>1.6	6.4
2b	Very slow	>160 mm/yr	>0.16	0.64
2a	Very slow	>16 mm/yr	>0.016	0.064
1	Extremely slow	<16 mm/yr	>0.0016	0.005
0	Dormant	0 mm/yr	<0.0016	0

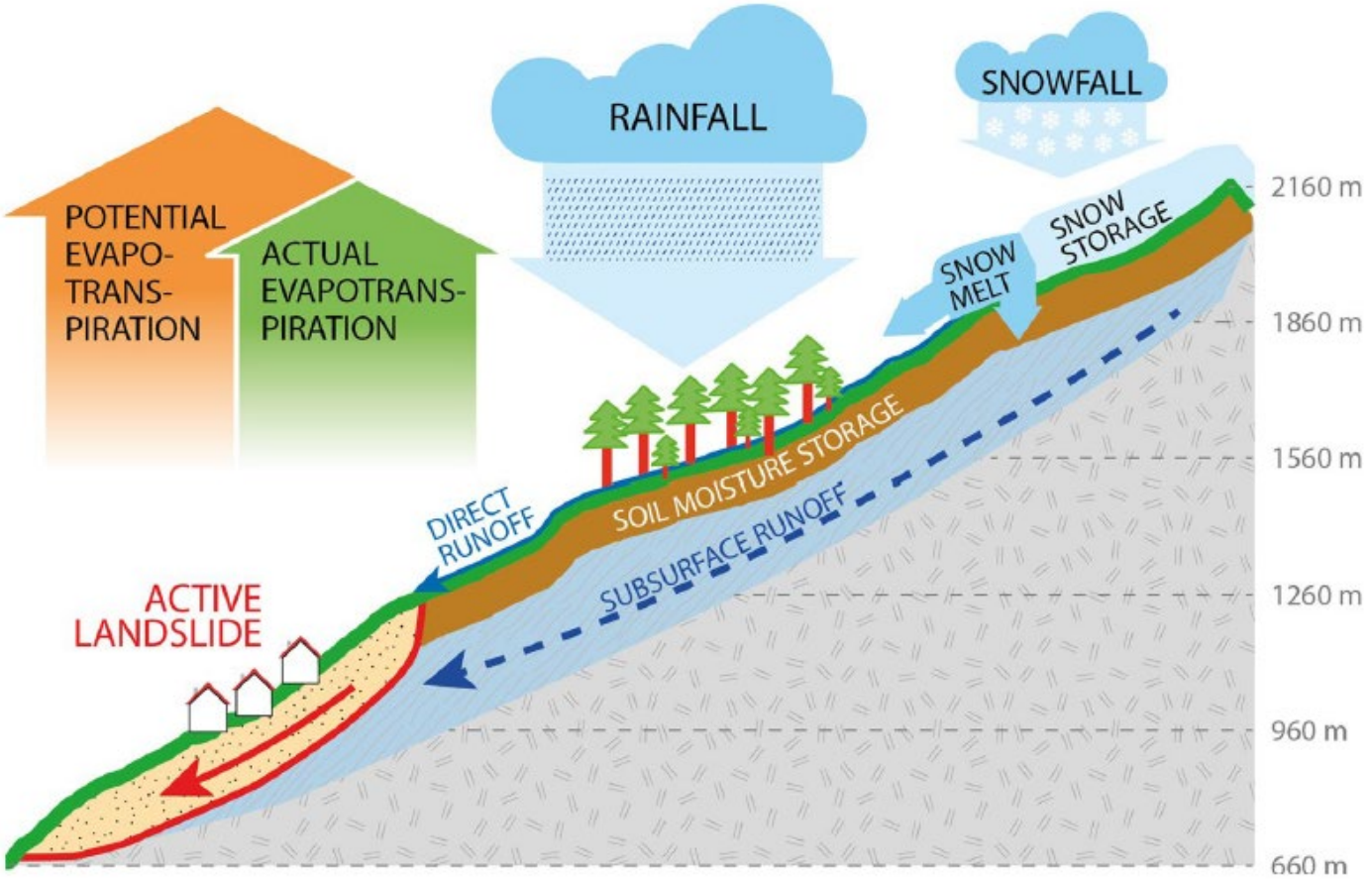




Hydrologic Drivers

For deep seated landslides, the amount of water that infiltrates and builds up pressures in the subsurface will drive activity change

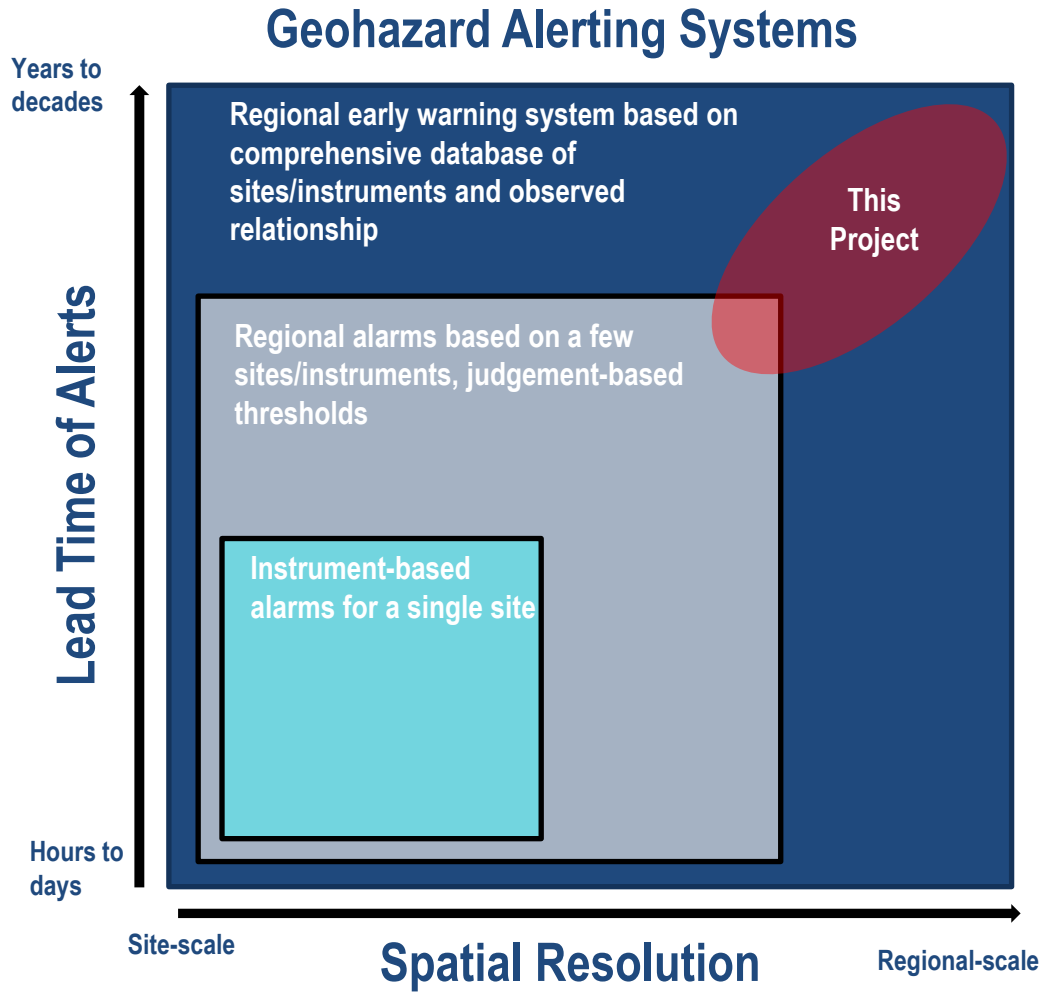
Human interactions that both change how and where water infiltrates can also lead to activity changes (water diversion, reduction of evapotranspiration)



Zieher, T., Gallotti, G., Rianna, G. *et al.* Exploring the effects of climate change on the water balance of a continuously moving deep-seated landslide. *Nat Hazards* **115**, 357–387 (2023). https://doi.org/10.1007/s11069-022-05558-7

Regional Landslide Early Warning

- Effective management involves “learning to live” with ongoing slope creep and understanding when and where accelerations may occur.
- We have access to landslide inventories across regions our clients operate in, but information about behavior is scarce– crowd sourcing data is necessary!
- The focus ongoing research is to leverage our collective access to pooled data to develop useful decision support tools for understanding landslide behavior and providing guidance to our clients on necessary action
- Need to define *meaningful and actionable* thresholds that are *data-driven*



Operational Timeframes for Warning and Awareness

Applied Earth Science Perspective		Operational Perspective
How will changing climate impact on landslide activity?	Decadal (10 to 50 years)	How does this impact on my longer term asset management approach?
Seasonal and multiyear hydroclimate trends?	Multi-Year (1 – 2 years)	Where are landslides likely to be more active and how can I plan around this?
Where to expect changes in landslide activity?	Seasonal (weeks to months)	Where should I focus monitoring resources?
Where are landslides accelerating?	Short Term (here and now)	Where do we need to deploy our resources?

Key Forecasting Components

Data

Where are the landslides, what are their characteristics, how do they behave?

Landslides

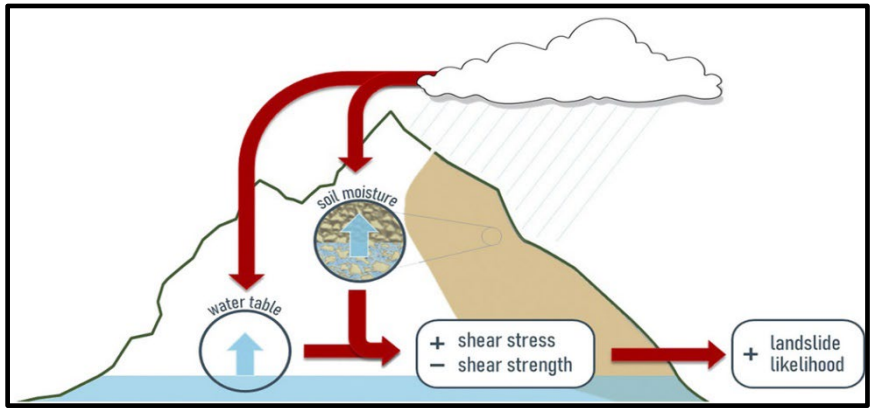
What are the hydroclimatic conditions for a given location at a given point in time?

Hydroclimate

Where are my assets? What are their condition? What is my capacity to respond?

Assets

Analytics



What is the relationship between landslide behavior and geophysical characteristics within a given region? What are the current conditions?

Felsberg et al, 2021

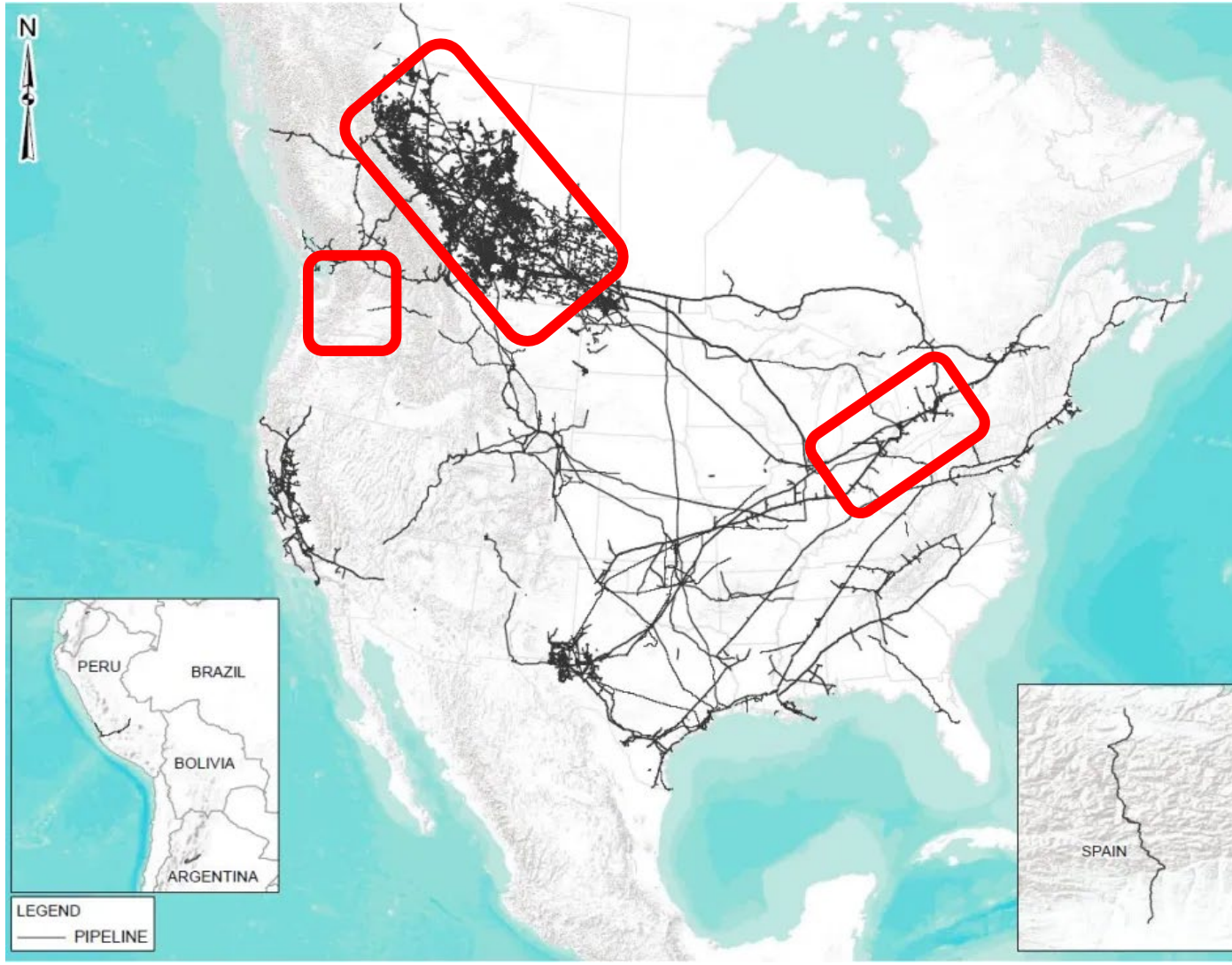
Decision Support

Given current conditions, are landslide conditions likely to change? Where will this change impact my assets? What should I do about it? When should I be taking action?

Image source: Norwegian Water and Energy Resources Directorate (NVE)

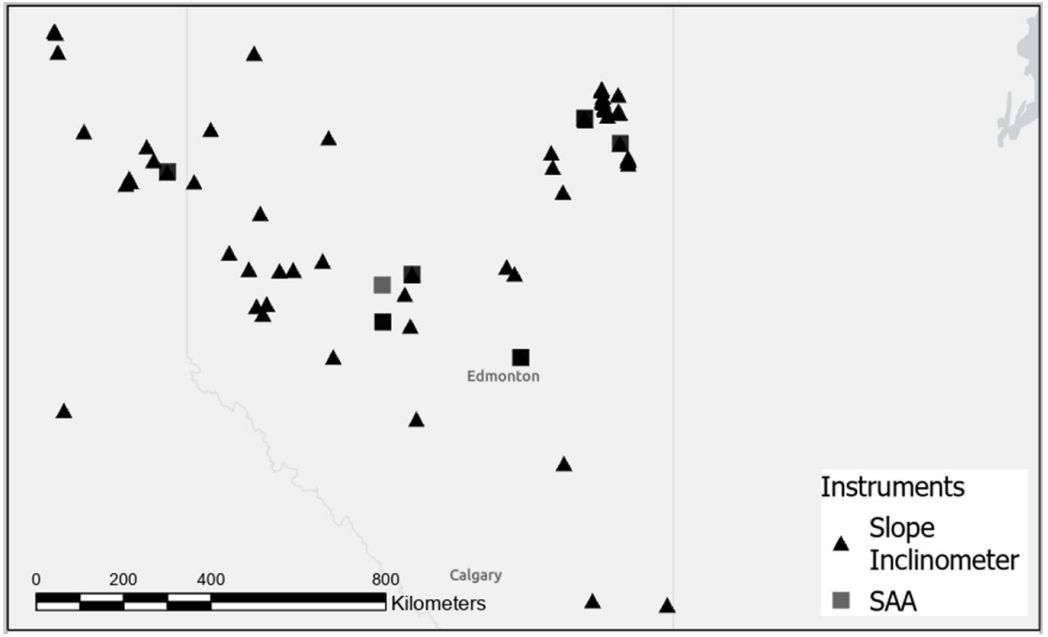
What Are We Learning

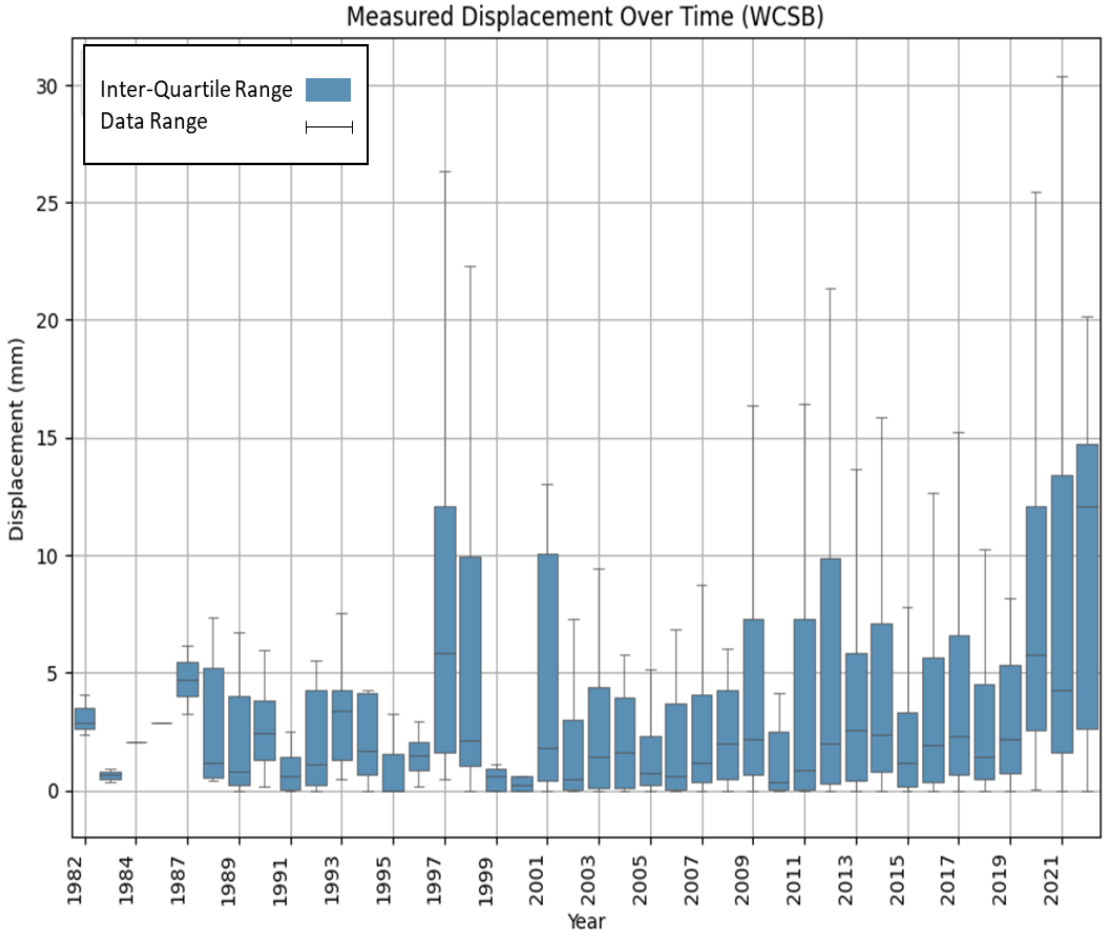
- **Three large regional projects being undertaken across North America:**
  - Western Canada Sedimentary Basin
  - Washington State
  - Appalachia Plateau



Western Canada Sedimentary Basin

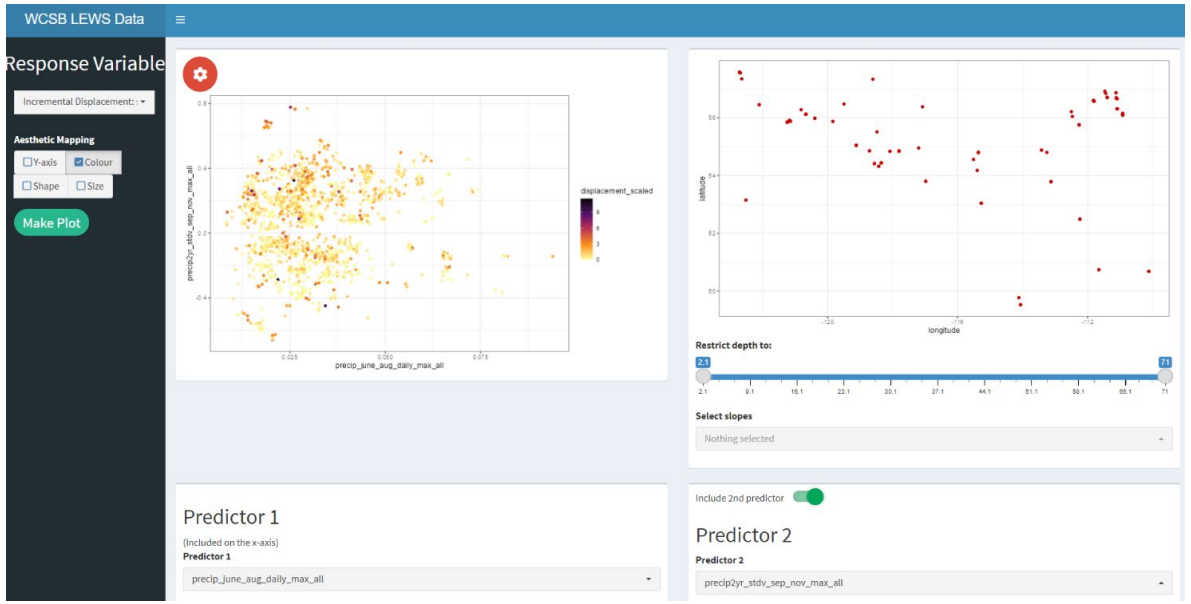
- Point source time-series data obtained from 6 pipeline operators and 1 electrical utility
- 500 slope inclinometers and over 50 shape accelerometer arrays

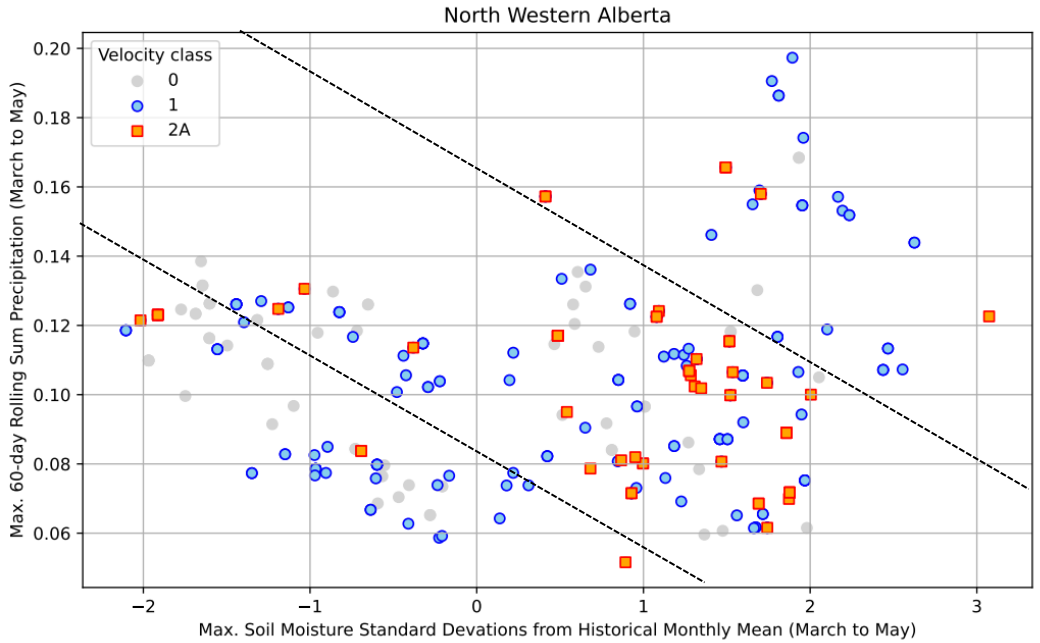




Western Canada Sedimentary Basin

- Displacement data integrated with hydroclimatic data in a data cube
- Analyses of data trends being undertaken in early 2024

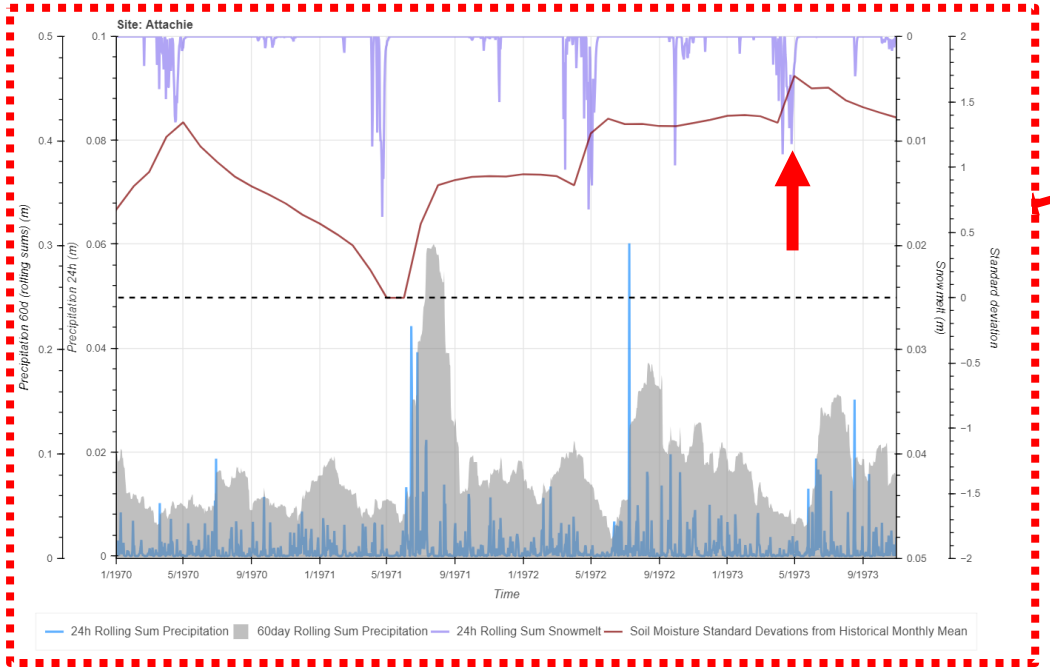


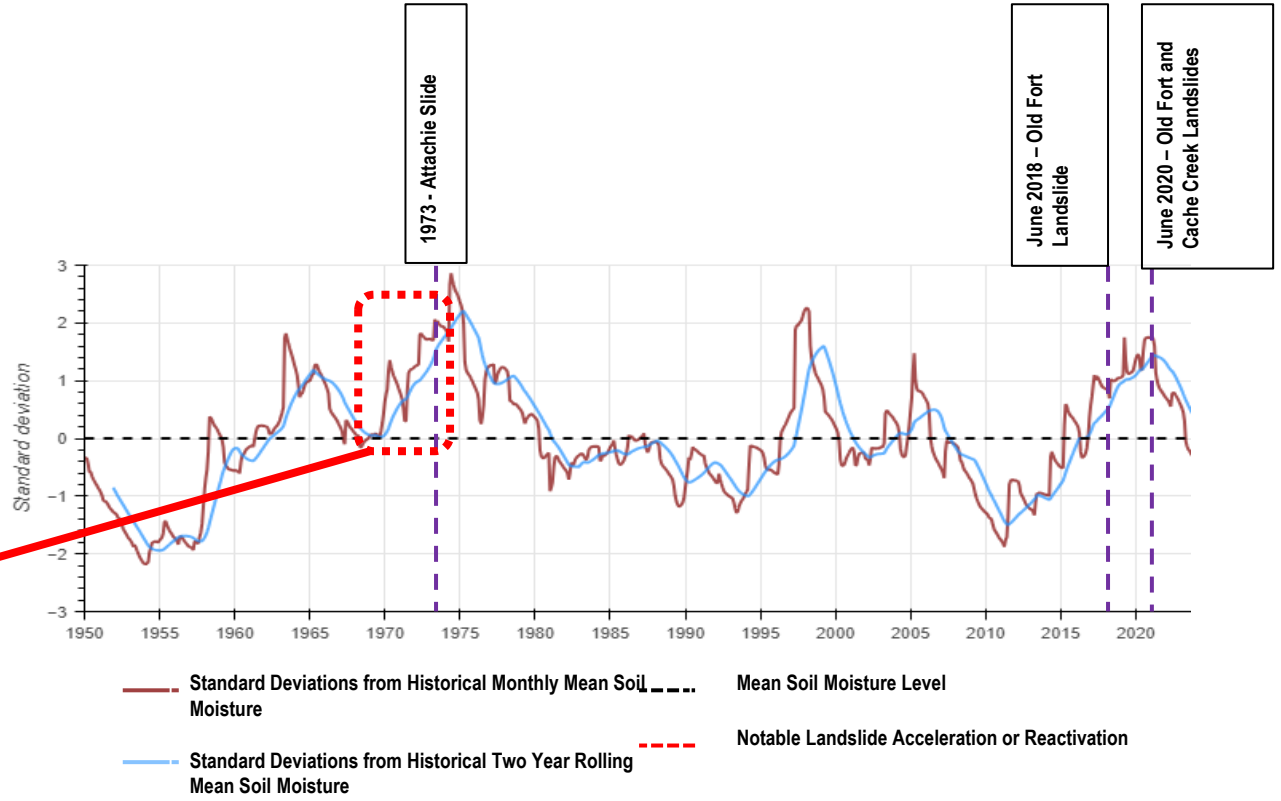


- Starting to look at regional relations between sliding depth, activity level and inputs of precipitation and soil moisture

Western Canada Sedimentary Basin

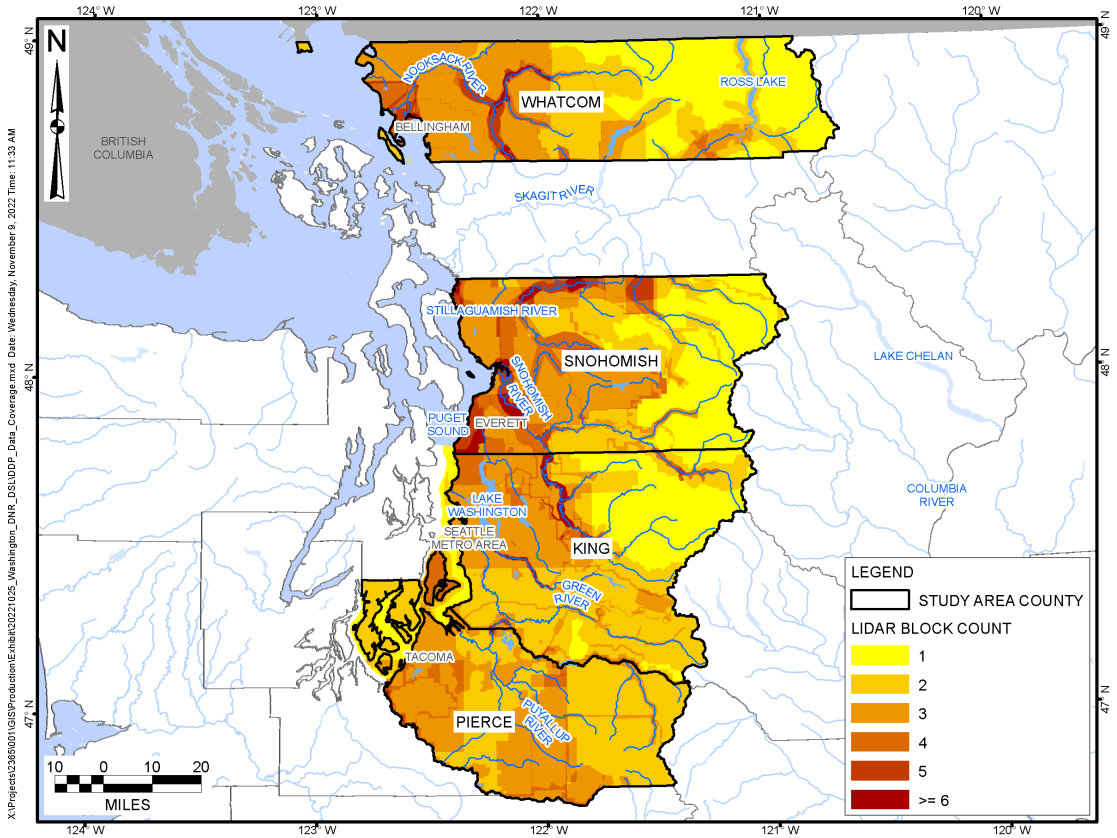
- **Accessibility of big hydroclimatic data sets are allowing for new insights on historic landslides.**

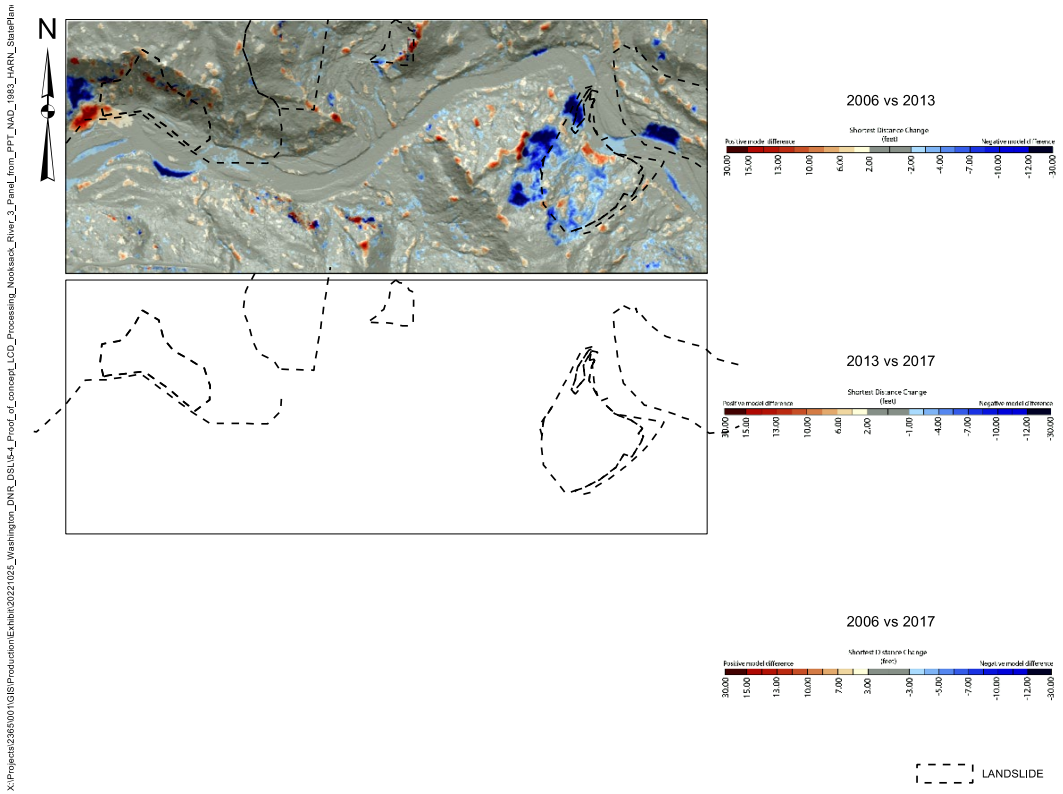




Washington State

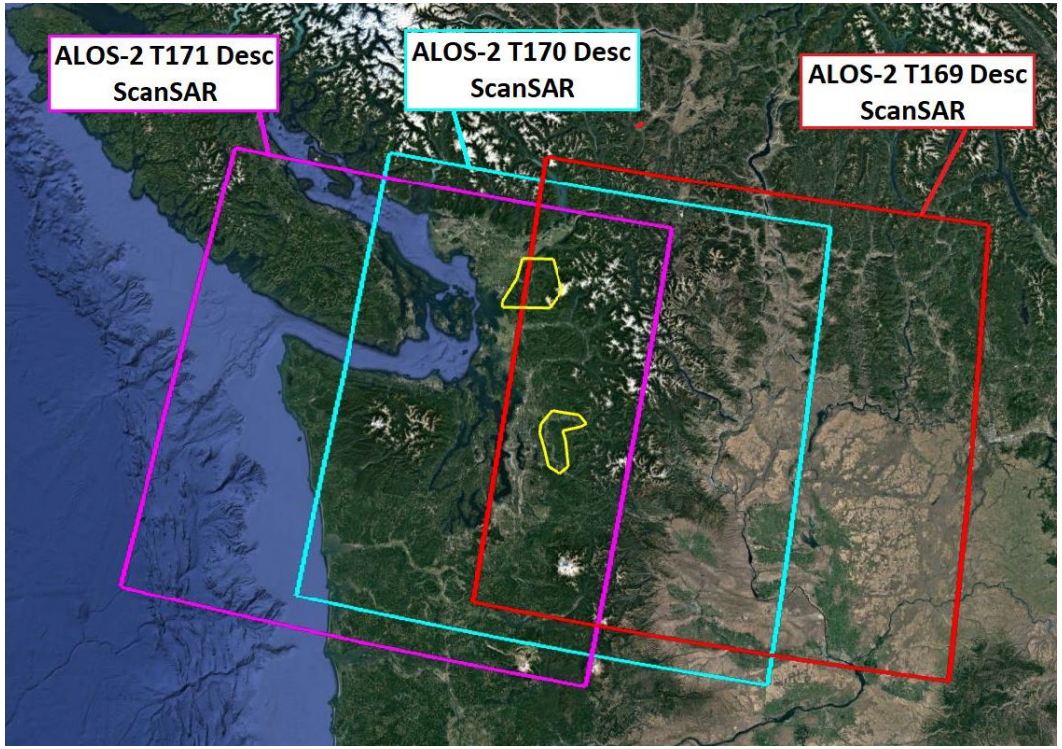
Have designed a project pilot based on obtaining displacement data from multiple epochs of Lidar and InSAR for Dept. Of Natural Resources

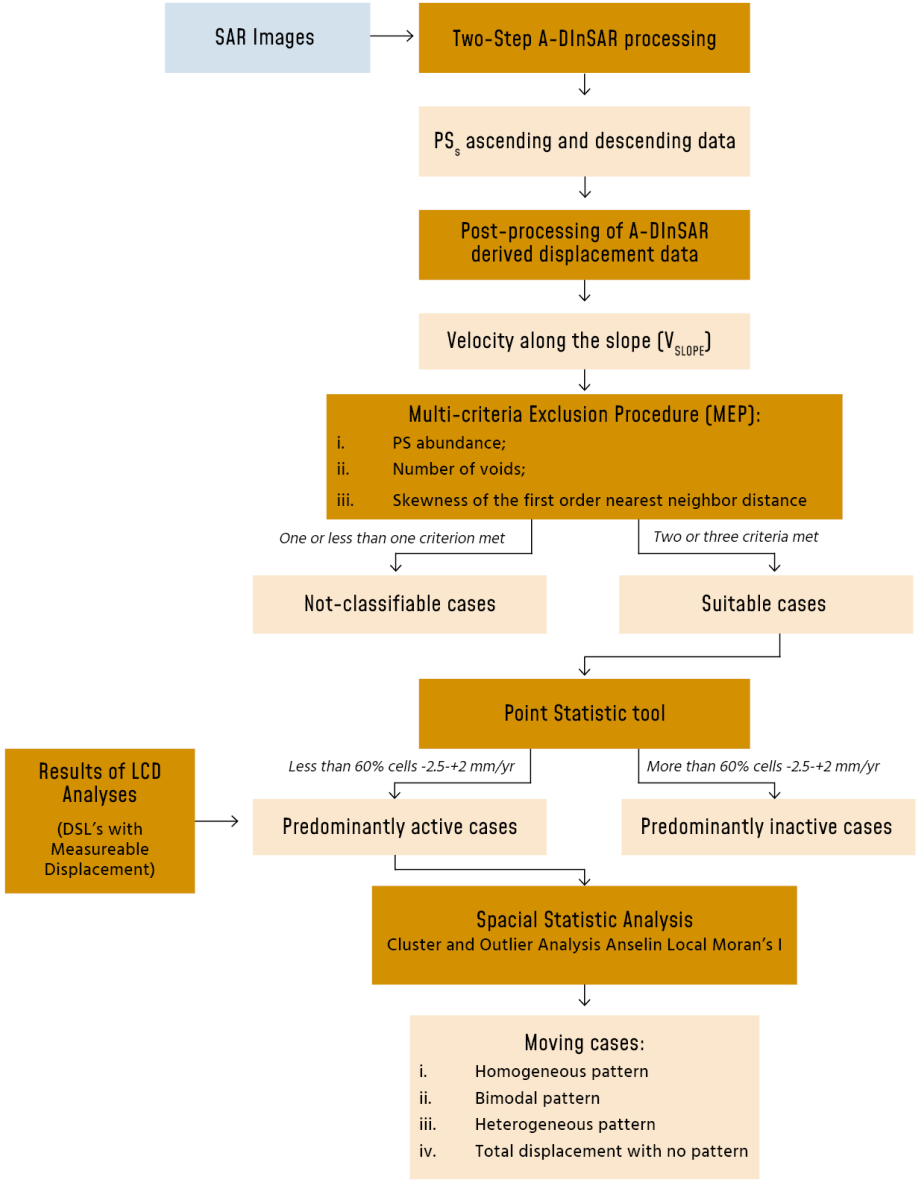




Washington State

- **Over 20 years of archived L-Band SAR coverage will be utilized to derive displacement data for landslides across the study area (with LCD data).**





Focus on Appalachian Plateau (GHZ-2-06)

- Project funded initially for two years: July 2023 to June 2025.
- Project Sponsor: Justin Taylor – TC Energy
- Funded through PRCI contributions from 10 members.
- Focus on building a regional pilot that could be applied across other regions.
- Initial focus on building awareness and warning for deep seated landslides in the Appalachia Region.

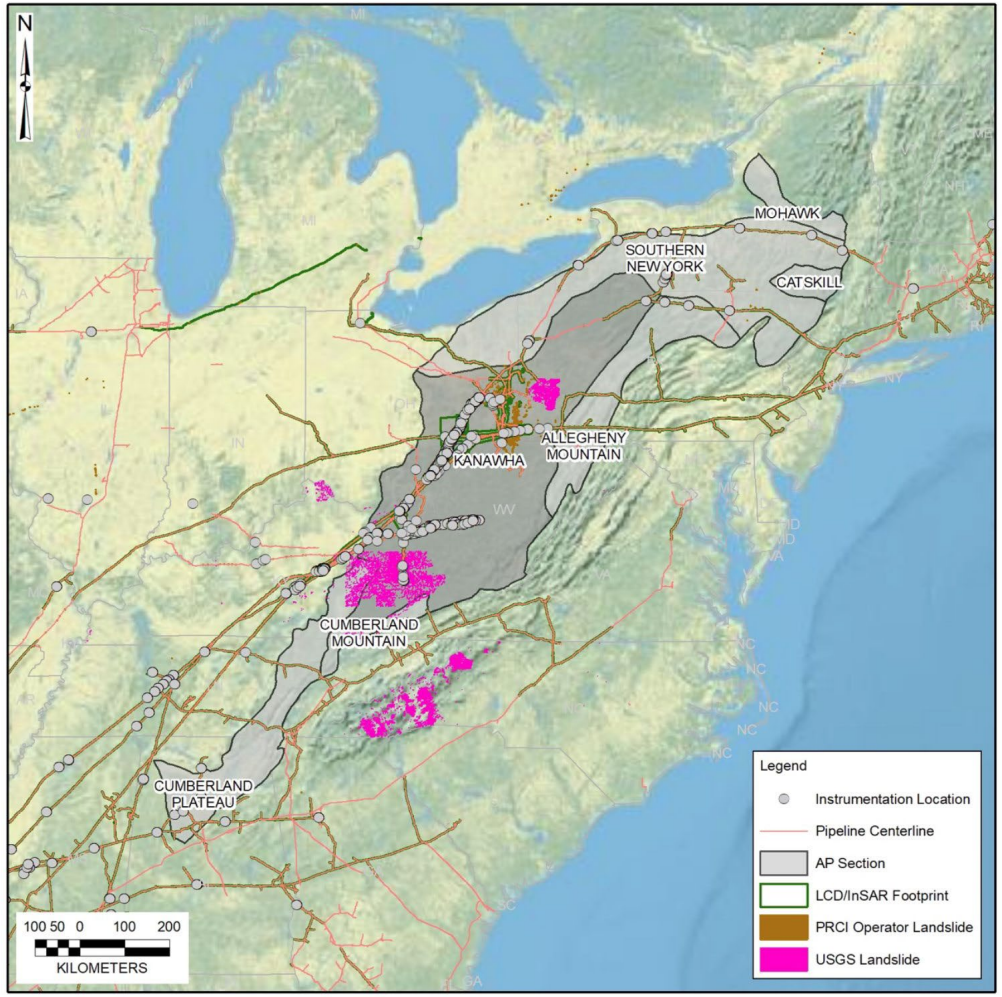
Project Focus

Year 1

- Study Area Selection
- Data Collection
- Access to Data for Project Team

Year 2

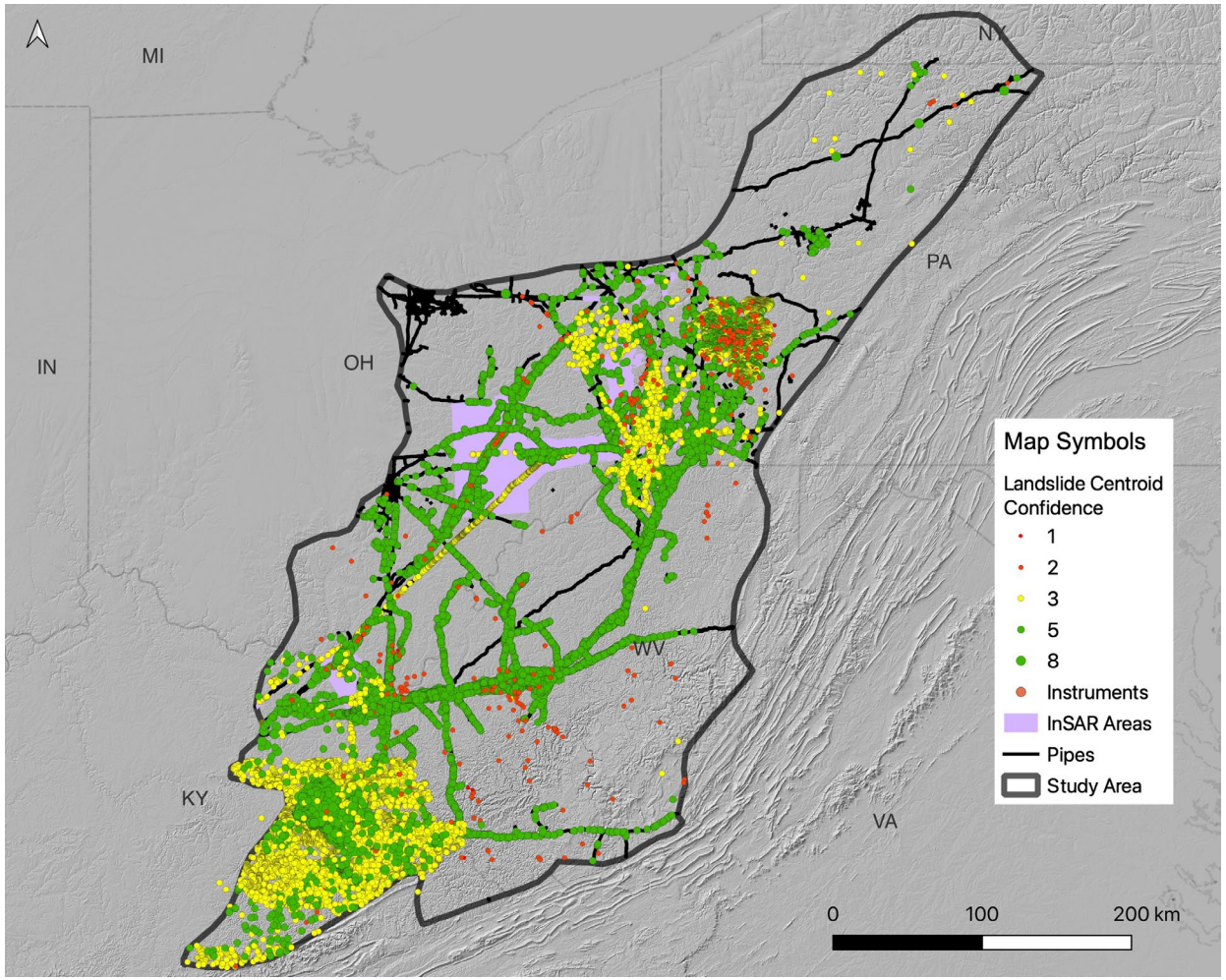
- Define landslide Classes in relation to geological and topographic controls
- Assign activity states to landslides within landslide Classes.
- Establish spatial relations in relation to landslide activity.



Crowdsourced Data Integration

To date have collected:

- Over 11,500 mapped landslide locations (points or polygons)
- 30,000 surface monitoring points
- *** subsurface monitoring points
- *** km of lidar coverage
- ** km of lidar change detection
- ** km of InSAR coverage



Landslide Classification

Landslides will be classified based on variables such as:

- **Geology**
- **Topography**
- **Aspect**
- **Curvature**
- **Slope angle**

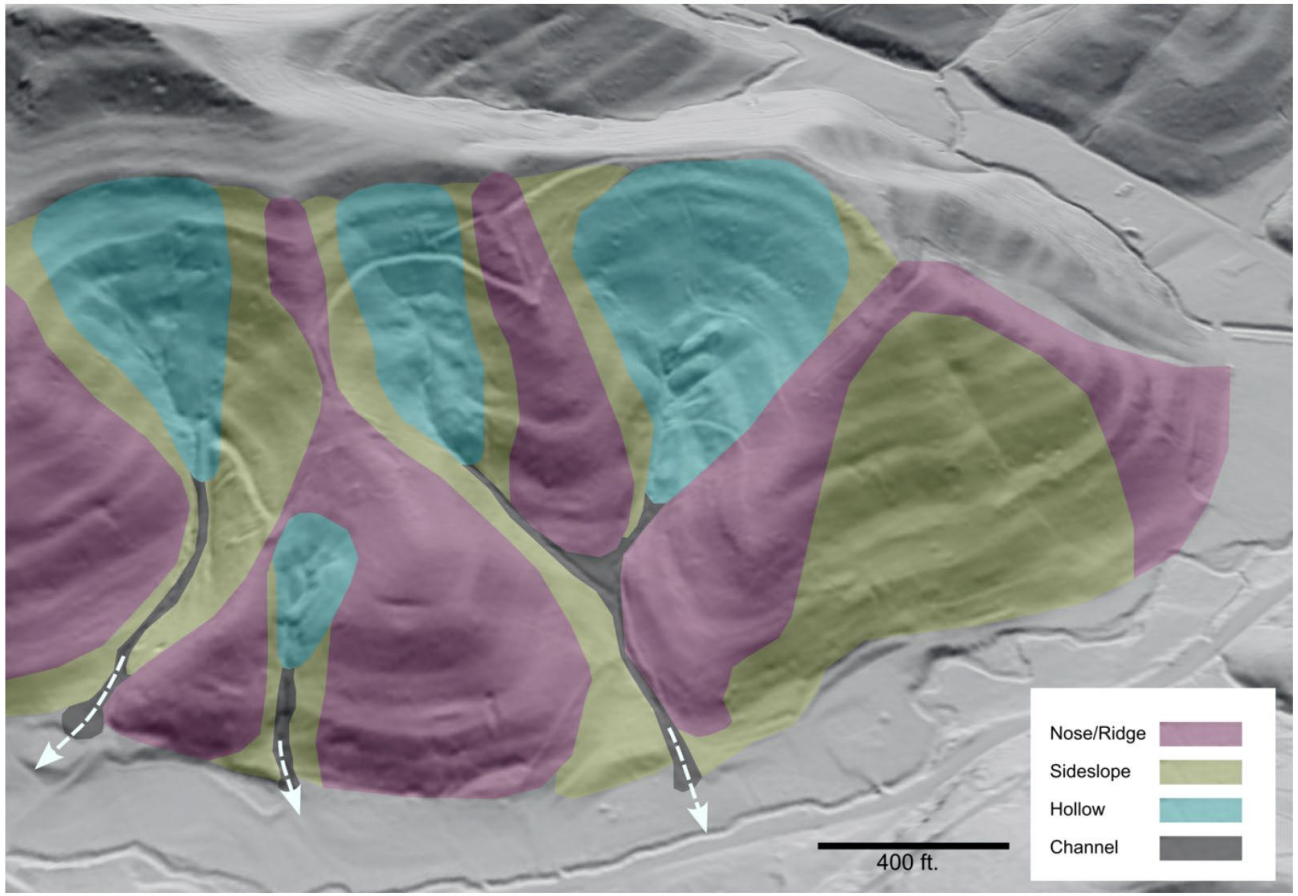


Figure 2-2 Type-example of upland slope areas in the Appalachian Plateau shown on lidar imagery (USGS, 2023). White arrows indicate channel flow direction.

Appalachia Project: Next Steps

- Project is benefiting from advances and learnings from other regional projects and (monthly) advances in the state-of-the-art.
- By the end of Year 2 the desired end state is to have a spatial understanding as to the geological and topographic controls on DSLs and to understand spatial variability in activity levels. (Why and Where).
- By the end of 2025, the availability of NiSAR and additional operator displacement data would support better linkages between displacement and hydroclimatic variables to move towards awareness and the generation of regional thresholds and alert tools.

thank you

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