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# Examining climate controls of recent landslides in northern British Columbia, Canada


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## Abstract


Temperature and precipitation have increased since the beginning of the instrumental record in the late 1800s in northern British Columbia, Canada. These trends may be responsible for the apparent increase in the frequency of landslides in the area. We have documented and catalogued recent landslides in northern British Columbia. We have also considered a variety of possible antecedent climate factors at intervals ranging from the day of the failure to months and years before it. We calculated long-term trends in annual, seasonal, and monthly total precipitation, mean temperature, and extreme maximum and minimum temperature from weather stations near known landslides. To examine short-term weather conditions leading up to failure, we analyzed daily and hourly weather station data for significant changes in temperature and precipitation, and we inspected digital weather imagery from satellites and radar.


## Study area

Steep mountain slopes and valley walls are the main sites of landslides in northen British Columbia, but more gentle slopes underlain by glacial sediments (till, glaciolacustrine, and glaciomarine deposits) are also failure prone.[1]

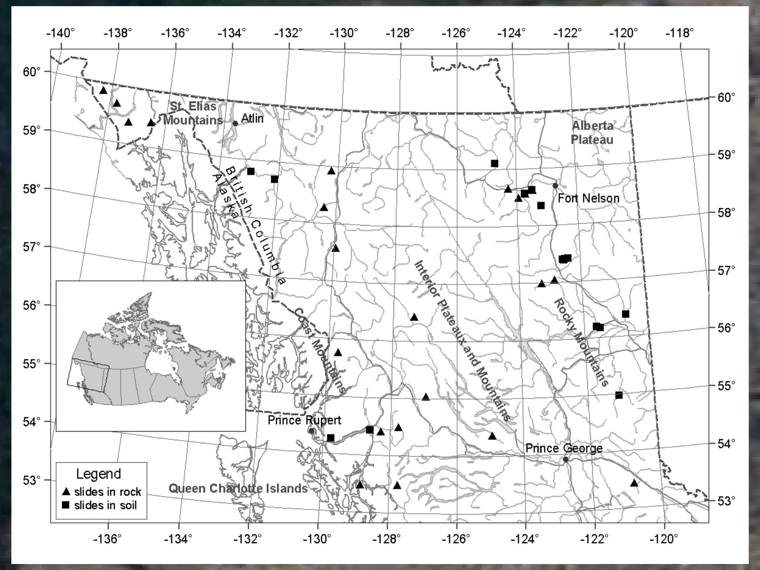

Figure 1. Large landslides in northern British Columbia, Canada. 1971-2006.

## Examples of landslides in northern BC

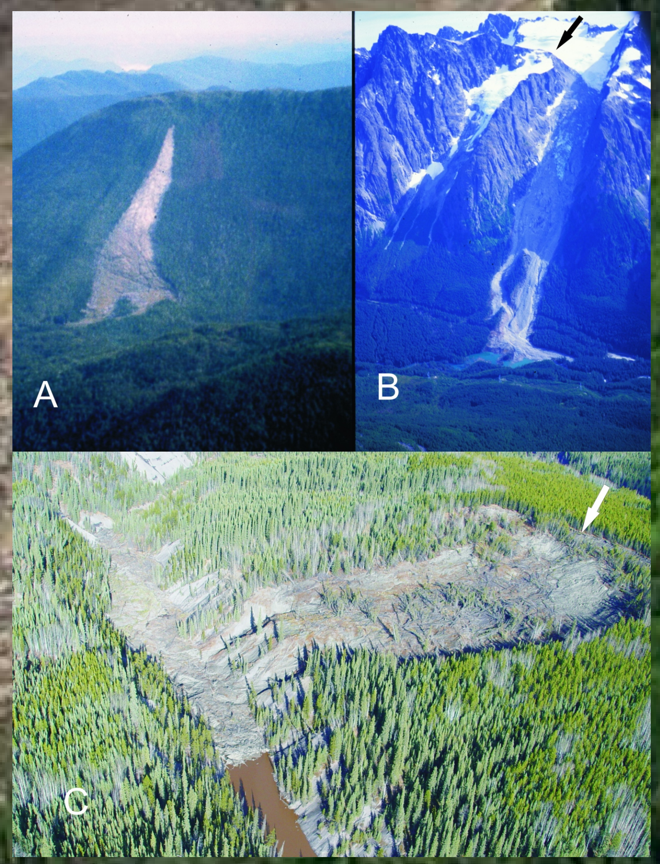


Figure 2. A rapid response landslide: A) 1996 debris avalanche on the outer coast near Chambers Creek. Delayed response landslides in rock: B) 1999 rock slide at Howson Range, the zone of detachment is arrowed; and in soil: C) mid-1990s retrogressive flowslide near Buckinghorse River in northeastern BC, the arrow points to main scarp. Thawing permafrost may have played a role in slides B) and C).[2]

## Climate controls of landslides

Greater precipitation decreases slope stability by saturating soils and increasing runoff. It also increases streamflow, which can erode the toes of potentially unstable slopes. Rising temperature can destabilize slopes at higher elevations by melting snow and glacier ice and alpine permafrost, by altering freeze-thaw activity, and by increasing rain-on-snow events. Higher temperatures can also increase frequency and intensity of convective storms. These storms produce heavy precipitation that trigger many slope failures.

## Increasing temperature and precipitation

Trend analysis has shown most areas of northern British Columbia is experiencing wetter and warmer conditions.[3]

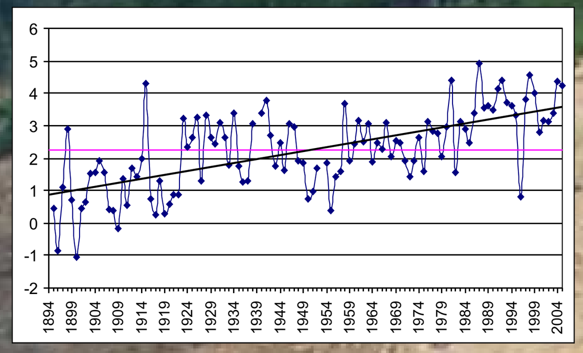

Figure 3. Fort St. James annual temperature (°C).

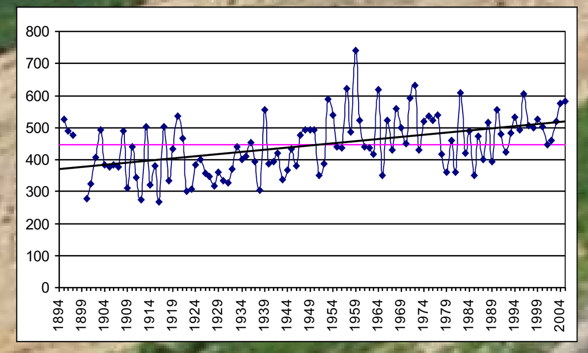

Figure 4. Fort St. James annual precipitation (mm).

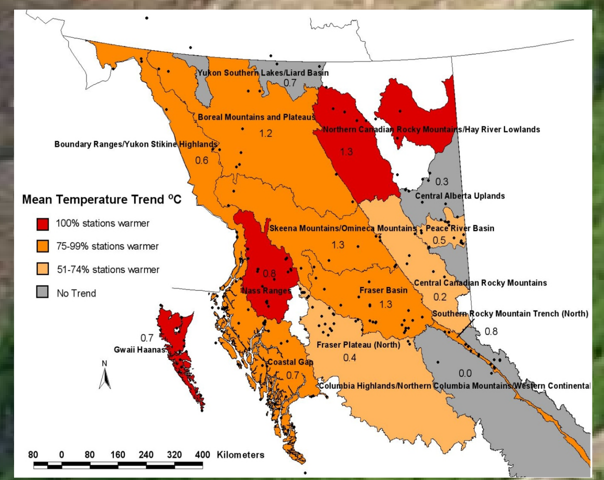


Figure 5. Regional trends in annual mean temperature. Significant trends range from +0.6°C to +1.3°C over the last century.

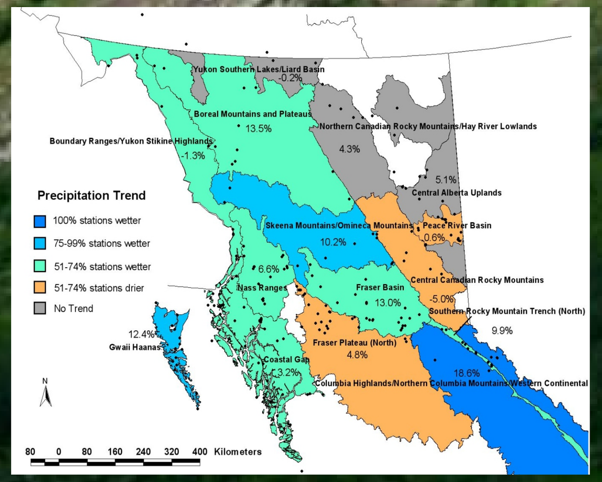


Figure 6. Regional trends in annual total precipitation. Significant trends range from +10.2% to +18.6% over the last century.

## Frequency of landslides

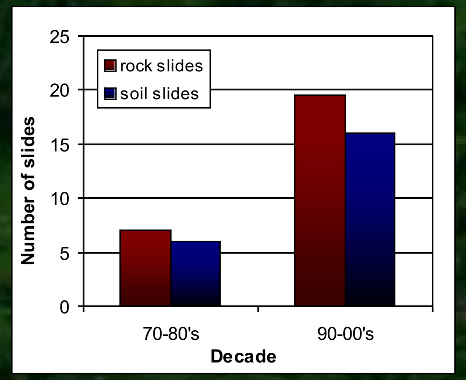


Figure 7. Known landslides, 1971-2006. Observations indicate the frequency of large landslides (>0.5 $Mm^3$) have increased in the last two decades. The majority of most recent landslides have initiated in rock. The current decade has been adjusted.[2]

## Associating climate trends and landslides

### a. Long-term precipitation and temperature trends

Cumulative deviation from the mean graphs for the nearest weather station to a landslide provide a visual representation of antecedent climate conditions.

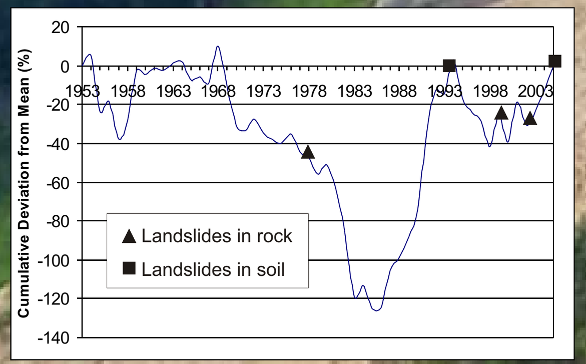


Figure 8. Percent deviation in annual precipitation associated with five large failures. Most notably, the 1993 slide occurred after ten years of above-average precipitation

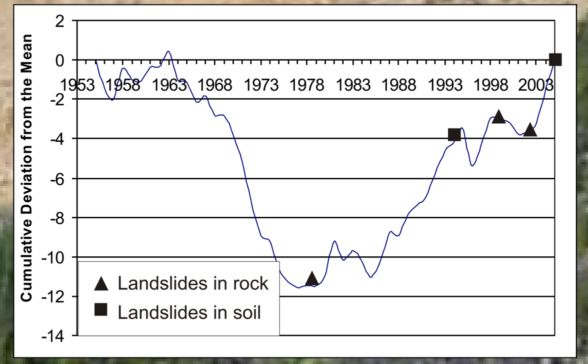


Figure 9. Deviation in mean annual temperature associated with five large failures. Four occurred in an increasing temperature trend, which started in 1978.

### b. Short-term precipitation and temperature trends

Examining weather station data for extreme events as well as above- or below- average annual, seasonal, monthly, and daily weather conditions leading up to the time of failure, provides information on climate conditions during the failure period.

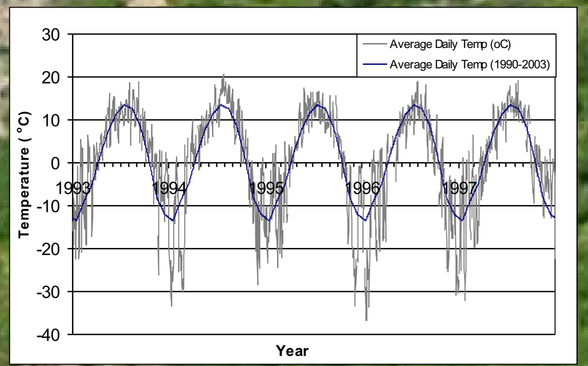


Figure 10. Daily temperature graph representing conditions for eight flowslides that occurred in the mid 1990s. Variable winter temperatures fluctuating well below average (below zero) to well above average (above zero) over short periods, can cause instability through freeze-thaw processes.

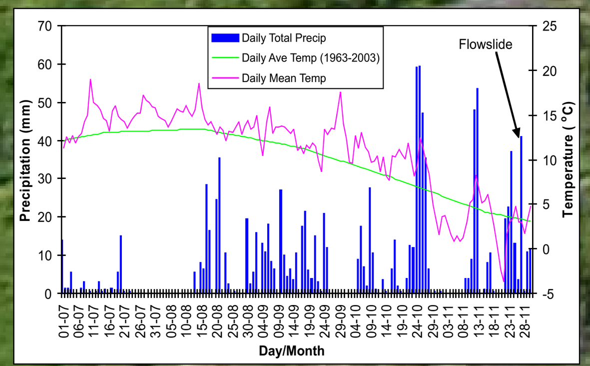


Figure 11. Daily temperature and precipitation data leading up to a known landslide. This graph shows 40 mm of precipitation on the day of the failure and 137 mm during the ten days prior. Daily temperatures below freezing before the slide and above freezing after, indicate this landslide may have been associated with a rain-on-snow event.

### c. Weather satellite and radar imagery

Examining climate controls of landslides with weather station data can be limited by data collection errors, missing data, and distant or unrepresentative locations. It is improved by supplementing with satellite and radar imagery. In our analysis, many landslides occurred during convective or large cyclonic storms found with the imagery, but not with the station data.


Figure 12. Weather satellite image of convective thunderstoms associated with a rock avalanche. The storm was likely accompanied by heavy precipitation, but was not recorded at the nearest weather station (McBride).

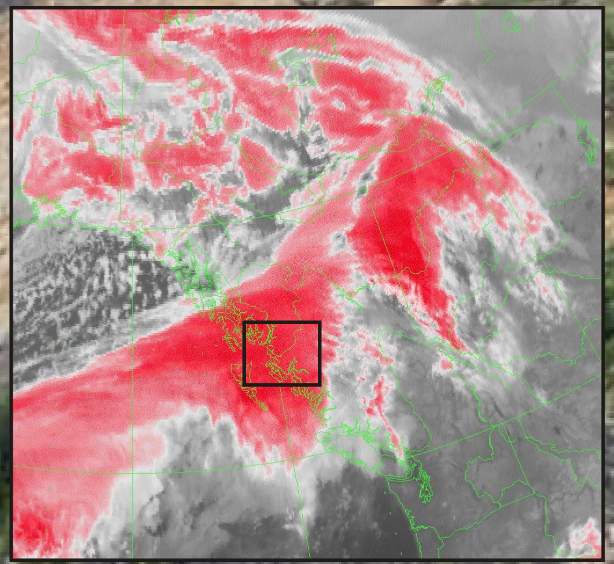

Figure 13. An intense and large cyclonic storm was likely responsible for triggering approximately 20 debris slides on the north-central coast of British Columbia (boxed area). Weather station data within the area was missing.

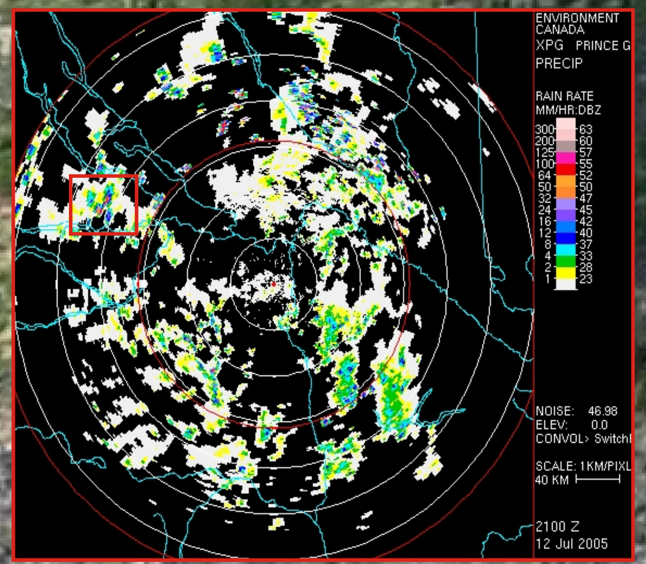


Figure 14. Radar imagery showing convective thunderstorms associated with a rockslide (boxed area). Precipitation intensity amounts were up to 64 mm/hr in the landslide area.

## Summary

Climate controls of landslides in northern British Columbia were examined by long- and short-term analysis of weather station data. This was supplemented with satellite and radar imagery for conditions at the exact failure site. Landslides frequency may have increased from warmer and wetter conditions found in the instrumental record.

The changes in climate that we have documented may be preconditioning marginally safe slopes for failure. Short intense convective storms or large regional cyclonic storms may be the triggers of such failures. Large landslides in bedrock occurred during years or long periods of above-average temperature. Landslides in unconsolidated sediments occurred during years or long periods of above-average precipitation.

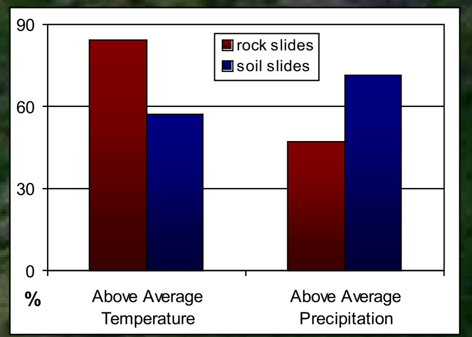


Figure 15. Percent of landslides that occurred during above- average annual temperature or precipitation.

Many of the documented failures occurred after warm or variable winters with frequent episodes of snow and glacier melt, freeze-thaw cycles, and rain-on-snow. Convective thunderstorms or large cyclonic storms were common at the time of the landslides. Our historical analysis shows landslides in northern British Columbia are vulnerable to climate variability. The frequency of landslides will probably increase if climate trends persist, which many climate models are predicting.

## References


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2. Geertsema, M., Egginton, V.N., Schwab, J.W., and Clague, J.J. 2007. Landslides and historical climate in northern British Columbia. *In* Proceedings of the International Conference on Landslides and Climate Change, Ventor, Isle of Wight, UK, 21-24 May 2007.
3. Egginton, V.N. 2005. Climate variability from the instrumental record in northern British Columbia and its influence on slope stability. *MSc Thesis*, Simon Fraser University.