Using Multi-Sensor Environmental Data to Investigate Debris Flow Hazards

Natalie Aguilera[1], Liam Toney[2], Kate Allstadt[2], Elaine Collins[2]

[1]RECCS Program, University of Colorado Boulder; [2]USGS Geologic Hazards Science Center, Golden, CO

Introduction

- At Chalk Cliffs, Colorado, sudden debris flows pose threats to hikers, roads, and local communities, often with little warning.
- These flows, consisting of soil, rock, and water, can move rapidly downslope, especially during summer monsoon rains.
- Seismometers and infrasound microphone arrays were installed to monitor ground motion and sound waves from debris flows, providing real-time data to the USGS office in **Golden, CO**.
- The goal of this research is to detect and study debris flow dynamics to understand these hazards.

Methods

Study Sites

Two monitoring stations at **Chalk Cliffs**:

- Upper site (station code **LSCCU**)
- Lower site (station code **LSCCL**)

Data Sources

- EarthScope Data Services
- Campbell Scientific Station

Sensor data

- Seismic
- Laser Displacement Data
- Weather (rain)

Tools & Workflow

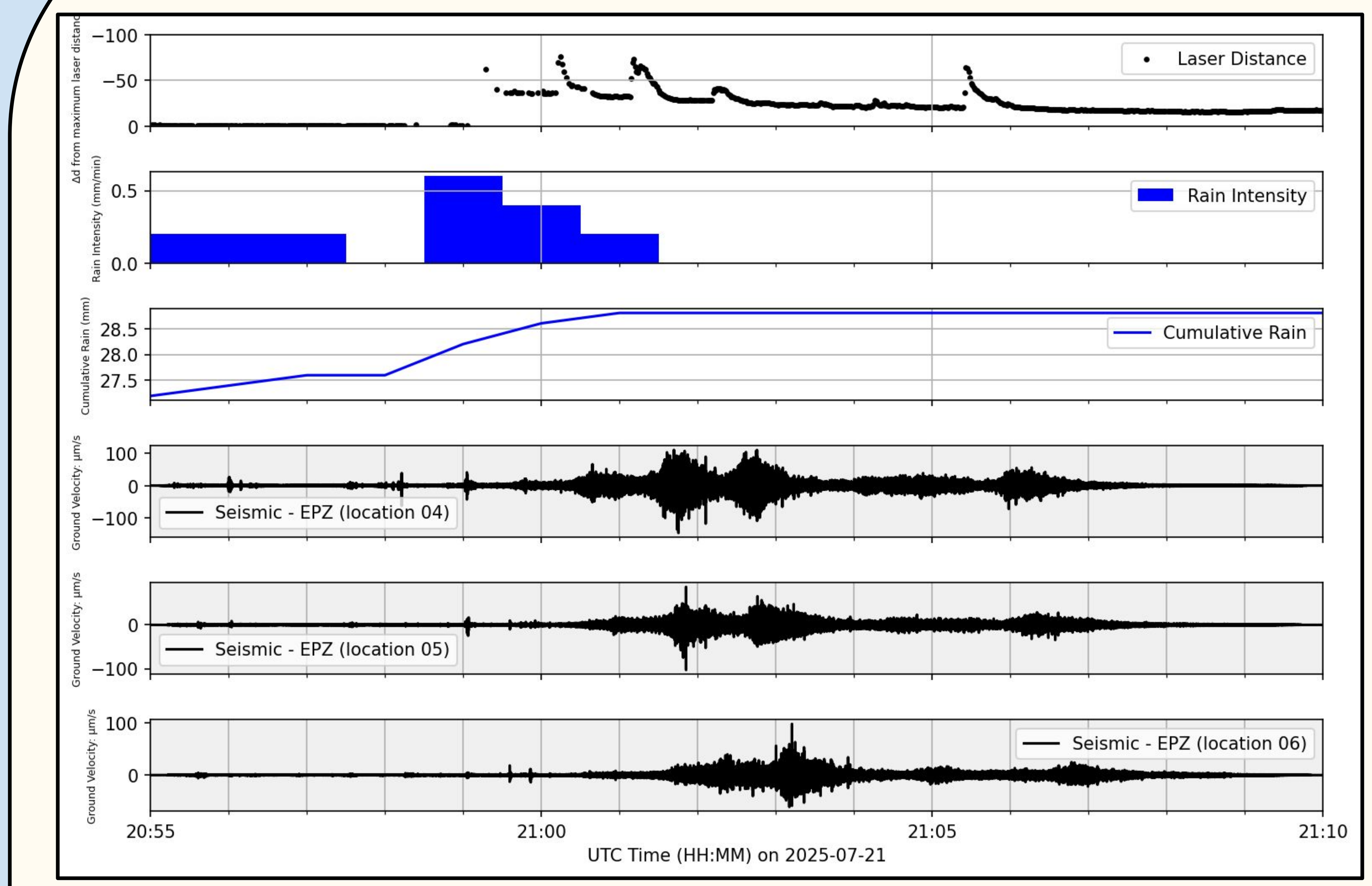
- ***Python*** (ObsPy, pandas, matplotlib)
- Plotting multi-sensor data around known or suspected flow times.
- Filtering and syncing time windows.

Figure 1. Site installation at Chalk Cliffs field site, June 2025. Seismic node deployed to capture subsurface signals associated with debris flow events. *Photo Credit: Elaine Collins*

Figure 2. Seismic node about to be installed at the LSCCL site, Chalk Cliffs. *Photo Credit: Natalie Aguilera*

Results

Figure 3. Laser Distance, Rain Intensity, Cumulative Rainfall, and Seismic LSSCU Geophones on July 21, 2025 (Local: 1:55–2:10 pm / UTC: 20:55–21:10)



Multi-sensor data from Chalk Cliffs captured a notable event on July 21, 2025.

- As seen above rain intensity at 20:59 UTC hits a peak at 0.6 mm/min, this sudden rainfall appears to be the trigger for slope destabilization.
- After the rain peak the laser displacement data decreases rapidly. This indicates a rapid increase in flow stage height.

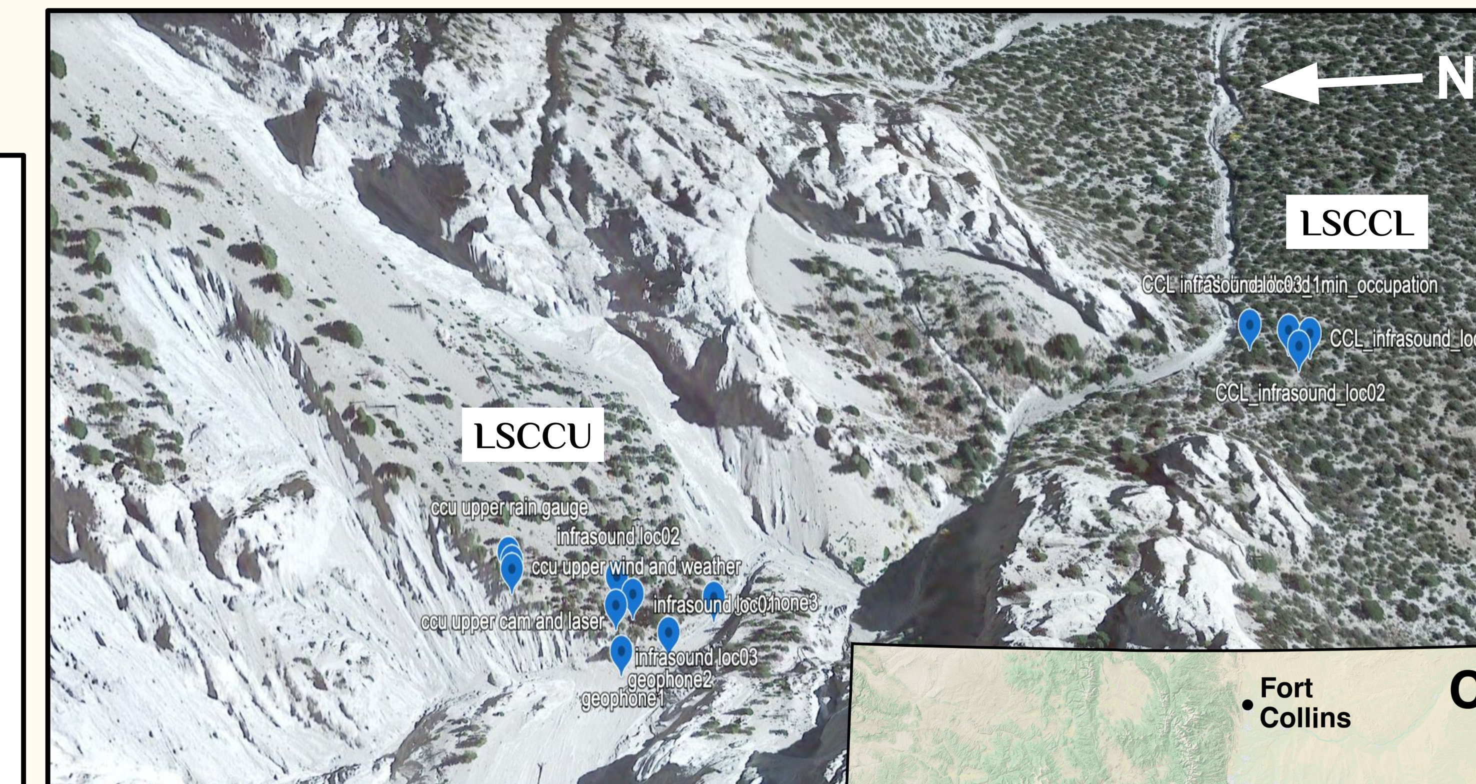


Figure 4. Aerial map of the upper site (LSCCU) and lower site (LSCCL) shows sensor locations along the monitored drainage basin and location of Chalk Cliffs in central Colorado.

- Within minutes geophones **EPZ locations 04 through 06** begin registering ground motion, characterized by high-frequency pulses and increasing amplitude.
- The seismic signals imply that ground motion intensified as the material moves downslope, supporting evidence of a debris flow.
- Lastly, notably the time-aligned pattern of the rain spike, laser signal drop, and seismic surges reflects a short lag between the rainfall signal, laser displacement, and the seismic trigger.

Discussion

- This research highlights the value of combining environmental (rainfall, displacement) and sensor (seismic) data to identify debris flow events. A key finding is that high-intensity, short-duration rainfall is sometimes followed closely by debris flow activity which is well-recorded by seismic data.
- Aligning multi-sensor data in time reveals distinct patterns that may precede or coincide with debris flow activity. This approach strengthens detection capabilities and supports potential early warning systems for at-risk areas.

Conclusion

- Multi-sensor data integration reveals consistent patterns between rainfall and seismic/infrasound signals associated with debris flows.
- These findings improve our understanding of flow dynamics and support hazard mitigation through real-time monitoring strategies.

References/ Acknowledgments

Iverson, Richard M. "Debris Flows: Behaviour and Hazard Assessment." *Geology Today*, vol. 30, no. 1, Jan. 2014, pp. 15–20, https://doi.org/10.1111/gto.12037.

Hungr, Oldrich, et al. "The Varnes Classification of Landslide Types, an Update." *Landslides*, vol. 11, no. 2, 30 Nov. 2013, pp. 167–194, https://doi.org/10.1007/s10346-013-0436-y.

Special thanks to: Alicia Christensen, Karla Lemus, and Madison Payne.

The RECCS Program is funded by the National Science Foundation (grant number EAR 1757930).

For more information contact:
naguilera2@student.cccs.edu