Variability in Atmospheric Conditions Among Widespread Landslide Events in California

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Our goal in this study is to Identify and describe atmospheric and rainfall conditions associated with widespread shallow landslide events in California. We seek to assess similarities and differences across events to facilitate improved understanding of atmospheric triggers and enhance early warning.

We identified a total of 18 landslide events to analyze associated with 12 storms. To relate the meteorological characteristics of the landslides to storm characteristics, reasonably constrained initiation times (e.g., within 6h) were needed. We estimated landslide time based on written reports and news articles, social media, and communication with local agencies. Where timing remained uncertain, we looked to peaks of moderate-to-high intensity in hourly rain gauge data in the vicinity of the landslide events within the general event window described in reports.

Meteorological information from the ERA-5 Reanalysis product is used to assess each event including radar reflectivity, wind and geopotential height fields at several levels, moisture transport, divergence, convective available potential energy, and analysis of frontal boundaries. A case study was conducted for each event (an example for February 10 2017 in the Redding area shown in Figure 1) to describe characteristics of each event and compare and contrast their features.

Summary of findings thus far in our work:

- All events assessed are associated with atmospheric rivers, though their strength (defined by moisture and wind) varies across events
- Most events have an identifiable “pulse” of short-duration moderate-to-high rainfall intensity rainfall. The few that did not tend towards occurring where there was persistent rainfall during many days preceding the event, or, for areas with higher terrain, in the cases where a rain-on-snow event occurred.
- Initial analyses do not suggest a single most common mesoscale trigger (i.e., feature driving a period of intense rainfall, but rather several types of features including convergence bands, isolated thunderstorms, favorable conditions for orographically-forced intense rainfall, and mesoscale vortices.
- Accurate records of landslide initiation time are extremely valuable for research directed at understanding conditions driving landslide events. Efforts should be made to educate those working in the field (highway patrol, state transportation agencies) and public on reporting observations.

Next steps include: 1) building a comparative table of quantitative atmospheric characteristics across events, including things like upper-level wind speed, magnitude of moisture transport, and 2) assessing season-to-date rainfall variability across events to assess the role of antecedent rainfall versus in-storm rainfall totals and rainfall intensity.

Additional information on two of the other events included for analysis in our study can be found here:

- March 22 2018, Tuolumne River Canyon: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JF005675
- April 10 2020, Encinitas: https://cw3e.ucsd.edu/characteristics-and-impacts-of-the-april-4-11-2020-cutoff-low-storm-in-california/

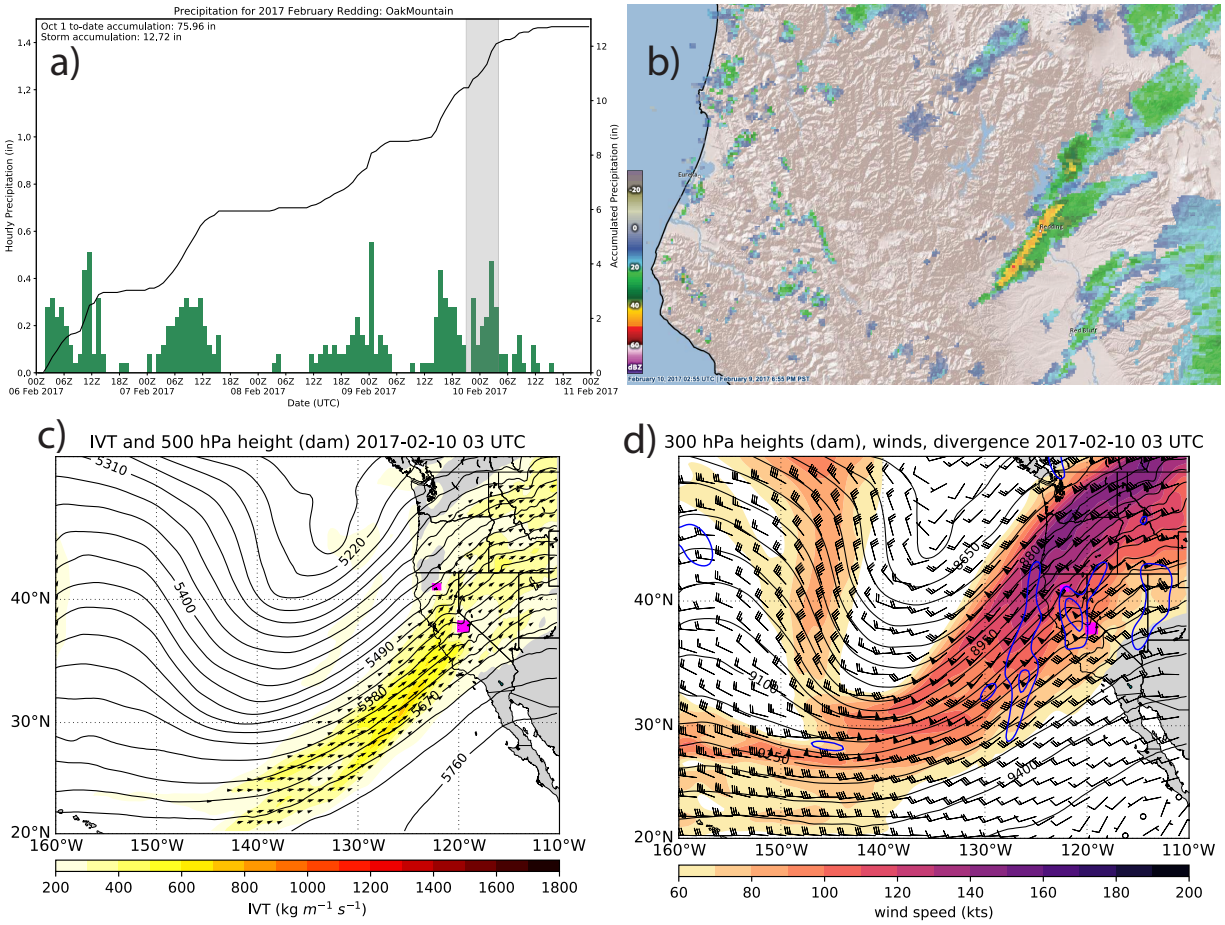

Figure 1: Example of a few figures produced for a case study of the February 10 2017 landsliding event near Redding, California: a) Hourly rainfall timeseries at a gauge near the affected area, showing the landslide event time derived from reports shaded in grey. b) Radar reflectivity of the feature that triggered the landslides, a band of intense rainfall (yellow band in center of image) occurring due to the "Shasta County Convergence Zone". c) Integrated water vapor transport shows a moderate atmospheric river extending from ~140 west northeastward to California. The SCCZ band is occurring on the poleward side of this band. Pink squares on the map indicate the location of landslide events. d) Upper-level winds (color fill and vectors) and divergence (blue contours, indicative of areas of enhanced upward vertical motion). The situation of the Redding landslide area is in the right entrance to a jet streak (area of very strong wind speeds within the upper-level jet stream), an area favored for strong upward motions and enhanced rainfall.