

Supplement

Predictions

LHI can also be used to identify fruitful topics of future research, including landslide inventory work and triggering analyses. We have provided Table S1 to help researchers identify 50 cases where historical landslides were probable.

Table S1: The 50 dates and locations with the highest probability of landslide occurrence. Although no landslides were recorded on many of these dates, the PNLI is certainly incomplete. Thus, these sites represent locations where future research might reveal unrecorded landslides. (Each latitude and longitude pair represents the center of a 0.125-degree grid cell, not a single point in space.)

Latitude	Longitude	Date	LHI	Landslide
42.3125	-122.6875	1/1/1997	0.515	Not recorded
42.4375	-122.5625	1/1/1997	0.487	Not recorded
44.8125	-122.6875	1/19/2012	0.479	Recorded
44.4375	-123.6875	12/28/1998	0.479	Not recorded
44.4375	-123.5625	12/28/1998	0.479	Recorded
44.0625	-123.8125	1/19/2012	0.478	Recorded
44.6875	-122.6875	1/19/2012	0.476	Recorded
44.4375	-123.4375	1/19/2012	0.476	Recorded
42.8125	-123.8125	1/14/2000	0.476	Not recorded
42.6875	-123.8125	1/14/2000	0.476	Not recorded
42.1875	-122.8125	1/1/1997	0.475	Recorded
44.1875	-123.6875	1/19/2012	0.474	Not recorded
44.1875	-123.8125	1/19/2012	0.469	Not recorded
44.6875	-122.9375	1/19/2012	0.442	Recorded
42.1875	-122.9375	1/1/1997	0.425	Recorded
42.1875	-122.5625	1/1/1997	0.412	Recorded
44.6875	-123.5625	1/19/2012	0.403	Recorded
44.5625	-123.4375	1/19/2012	0.401	Not recorded
44.6875	-123.3125	1/19/2012	0.396	Recorded
42.9375	-123.8125	1/14/2000	0.387	Not recorded
43.4375	-122.8125	1/14/2000	0.381	Not recorded
43.4375	-122.9375	1/14/2000	0.377	Not recorded
47.8125	-124.1875	12/17/1979	0.368	Not recorded
45.1875	-122.5625	1/13/1980	0.352	Not recorded
44.6875	-123.6875	1/19/2012	0.351	Not recorded
46.5625	-123.1875	2/8/1996	0.351	Not recorded
45.8125	-123.3125	2/8/1996	0.350	Not recorded
47.9375	-122.1875	1/1/1997	0.339	Not recorded
47.9375	-124.3125	12/17/1979	0.337	Not recorded
44.6875	-122.5625	12/28/1998	0.334	Not recorded
43.6875	-122.9375	1/14/2000	0.334	Not recorded
44.6875	-123.4375	2/6/1996	0.329	Recorded

43.3125	-122.9375	1/14/2000	0.318	Not recorded
43.5625	-123.0625	1/14/2000	0.318	Not recorded
42.3125	-124.1875	12/29/2008	0.315	Not recorded
45.8125	-123.1875	2/8/1996	0.312	Not recorded
44.8125	-123.4375	1/19/2012	0.311	Not recorded
45.3125	-123.0625	2/8/1996	0.311	Not recorded
43.3125	-122.8125	1/14/2000	0.307	Not recorded
44.9375	-123.8125	2/7/1996	0.299	Not recorded
44.4375	-122.1875	12/28/1998	0.298	Not recorded
42.5625	-122.4375	1/1/1997	0.297	Not recorded
45.4375	-121.6875	3/29/2010	0.290	Not recorded
44.4375	-122.4375	12/28/1998	0.289	Not recorded
44.0625	-123.6875	1/19/2012	0.289	Recorded
44.4375	-122.5625	1/19/2012	0.288	Not recorded
44.5625	-123.8125	2/6/1996	0.288	Recorded
44.5625	-122.6875	1/19/2012	0.285	Not recorded
44.1875	-123.5625	12/28/1998	0.283	Not recorded
46.4375	-123.0625	2/8/1996	0.281	Not recorded

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11 Model interpretation

12 While we have provided a model dump file to ensure replicability of these results, the complexity of the
13 GBM structure precludes an intuitive understanding of the model's function. Therefore, we have provided
14 illustrations that show how the model behaves under historical and hypothetical conditions.

15 While the standard metrics from XGBoost give a rough sense of how the model uses each input,
16 sensitivity contour plots show the interaction between variables in more detail. Contour plots can provide
17 greater transparency of research decisions to regulators and other stakeholders (Zink and Jiang, 2016).
18 When combined with 2-factor sensitivity analysis, contour plots reveal both the interaction between
19 variables and the strength of each predictor's influence. Figure S1 shows the conditions under which a
20 landslide occurred near Mukilteo, Washington. The LHI for this historical event was 0.006. We varied
21 rainfall and surface soil moisture over the full range of historical conditions, while keeping all other
22 inputs constant; then we plotted the model output as contours. The range of possible LHI for this date and
23 location spans two orders of magnitude. As with topographic maps, tightly spaced contours indicate steep
24 gradients—of changing hazard, in this case. In Figure S1, the steeper gradient over rainfall indicates that
25 this variable exerts greater influence over the model than surface soil moisture, at least under these
26 conditions. Holding the surface soil moisture constant, varying rainfall changes LHI by at least 2 orders of
27 magnitude; holding rainfall constant, variations in surficial soil moisture change LHI by less than an order
28 of magnitude. In addition to comparing predictors, contour plots can show the relative effects of change
29 within a variable. The tight spacing of contours at the base of Figure S1 indicate that the biggest changes
30 to LHI come from the change between no rain and some rain, rather than the difference between high and
31 extremely high rainfall. Again, we note that this relationship is for a specific set of antecedent conditions
32 and might not hold true at other places and times. In addition, we have provided animations that show
33 how the model behaves over time (Figure S2 and Figure S3). Review of many such plots serves as a “gut
34 check” on the quantitative metrics described in the results section; we believe that the model's behavior is
35 reliable and largely consistent with prior knowledge about the Pacific Northwest.

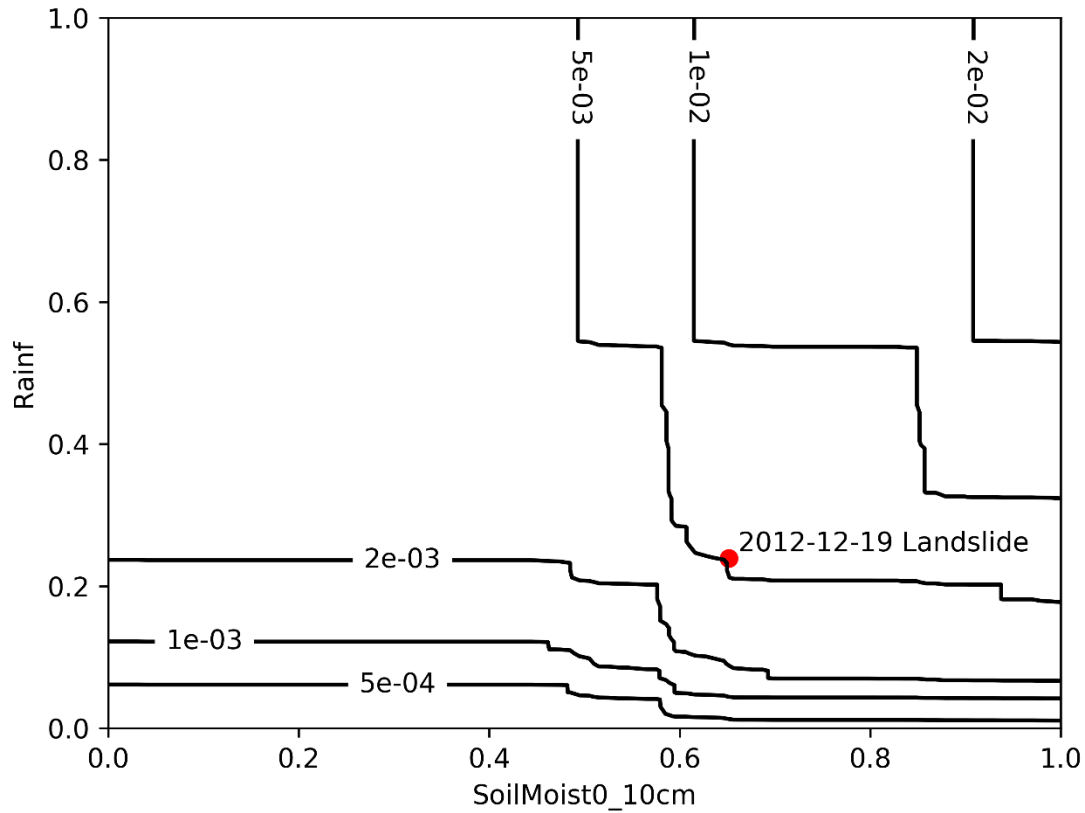
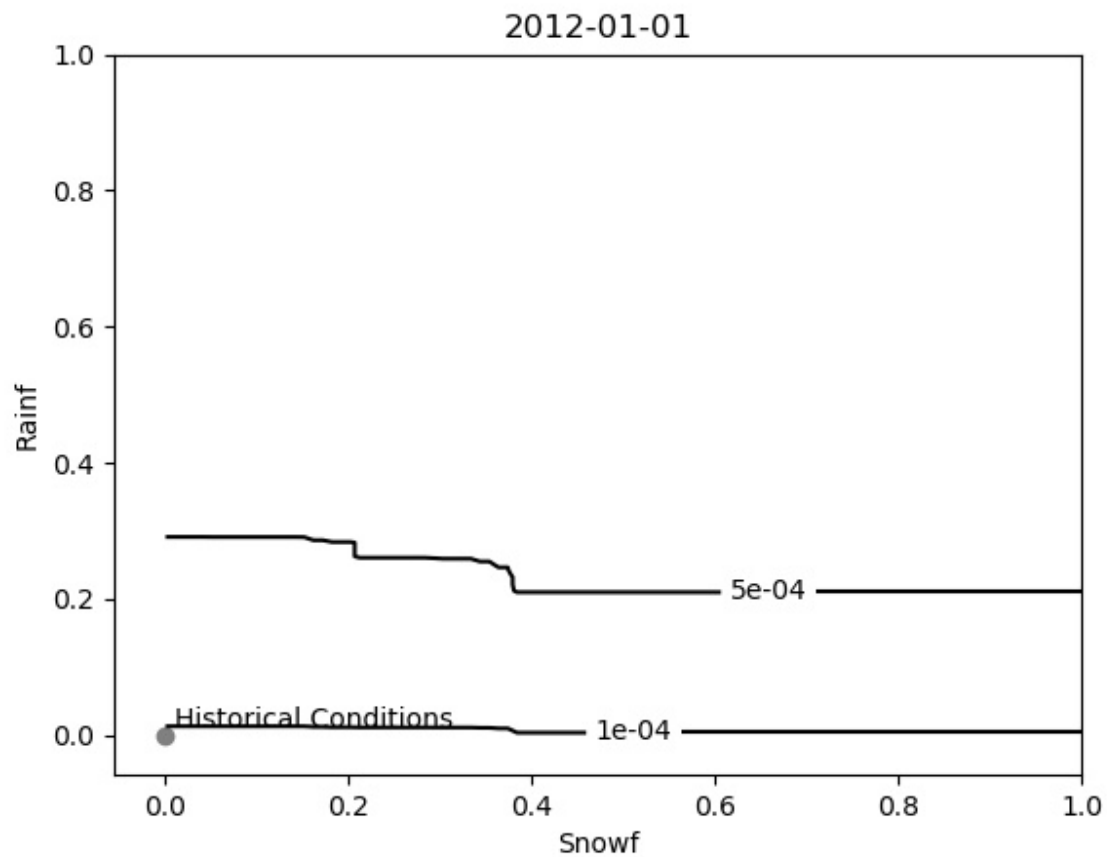


Figure S1: This sensitivity contour plot shows the LHI produced by varying two inputs and holding all other predictors constant. A red dot shows the historical conditions under which a landslide occurred near Mukilteo, Washington on December 19, 2012. For this plot, rescaled rainfall and soil moisture were varied from local minimums to local maximums, while all other variables were kept equal to the historical values for that date. Black contours show the resulting LHI for each combination of rainfall and surface soil moisture. Closer contours indicate steeper gradients in LHI, and thus more influence for changes to a variable.



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44 *Figure S2: This animation shows how the model responds to changes in antecedent conditions over time. These results show LHI*
 45 *at Mukilteo, Washington, USA. The horizontal orientation of the contours indicate that the model is much more responsive to*
 46 *rainfall than snowfall, and the tighter spacing at the bottom of the plot indicates that the change from low to moderate rainfall*
 47 *totals has more impact than a change from moderate to high rainfall. The LHI starts at relatively high values, falls to low values*
 48 *during summer, then rises again with the return of winter storms; the seasonality of landslide hazard at this site mirrors that of*
 49 *the Pacific Northwest as a whole.*

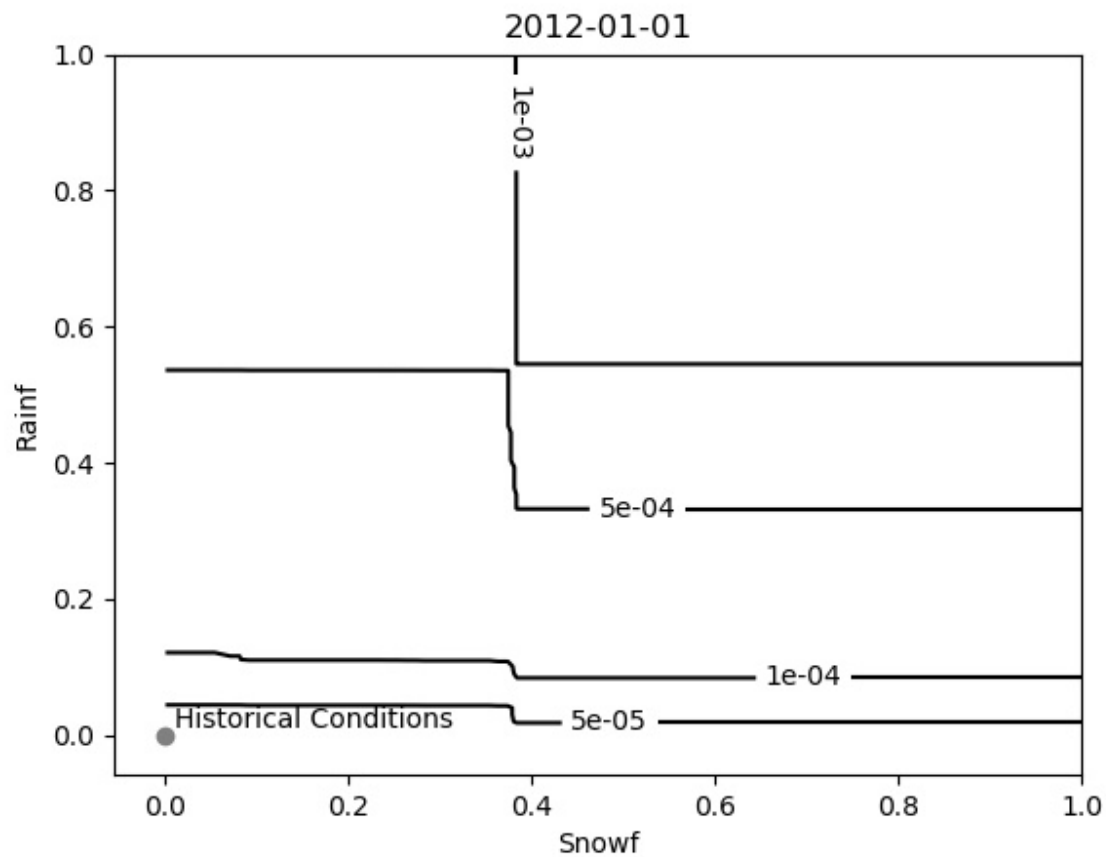


Figure S3: This animation shows how the model responds to changes in antecedent conditions over time. These results show LHI at Mt Rainier, Washington, USA. The seasonality of landslide hazard at Mt Rainier is somewhat different from lowland sites like Mukilteo, probably due to the low temperatures at high elevations.

References

Zink, R.C., Jiang, X., 2016. Using Contour Plots to Assess the Sensitivity of Clinical Trial Design Assumptions. Ther. Innov. Regul. Sci. 50, 496–509. <https://doi.org/10.1177/2168479016654738>