# A landslide climate indicator from machine learning

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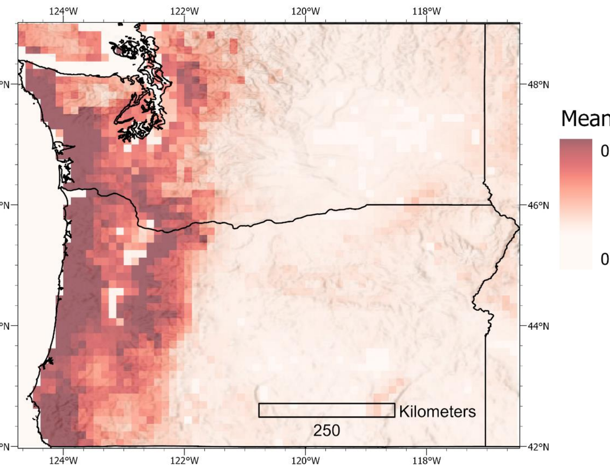
In order to create a Landslide Hazard Index, we accessed rain, snow, and a dozen other variables from the National Climate Assessment Land Data Assimilation System. These predictors were converted to probabilities of landslide occurrence with XGBoost, a major machine-learning tool. The model was fitted with thousands of historical landslides from the Pacific Northwest Landslide Inventory (PNLI).

**AR**: Atmospheric Rivers landfalling within the states of Washington and Oregon
**IVT**: Monthly maximum Integrated Vapor Transport
**ROS**: Monthly mean frequency of Rain on Snow
**PNLI**: Monthly mean frequency of landslides in the gridded Pacific Northwest Landslide Inventory
**LHI**: Monthly mean Landslide Hazard Index




LHI is usually highest west of the Cascade Range

## How the model works

First, XGBoost builds a decision tree of a depth specified by the user. Next, it builds a second tree that reduces the classification errors of the previous tree. This process repeats for as many iterations as the user specifies. Once all the trees are built, the model determines the leaf in each tree to which a data point belongs. The listed value for all the leaves is summed, then transformed with a sigmoid function to determine the probability that a landslide has occurred on that day at that location (LHI).

Although atmospheric rivers are an important trigger of landslides, these events happen most frequently in the autumn months, while landslides are most common in the winter. This suggests the important role of antecedent conditions to landslide hazard.

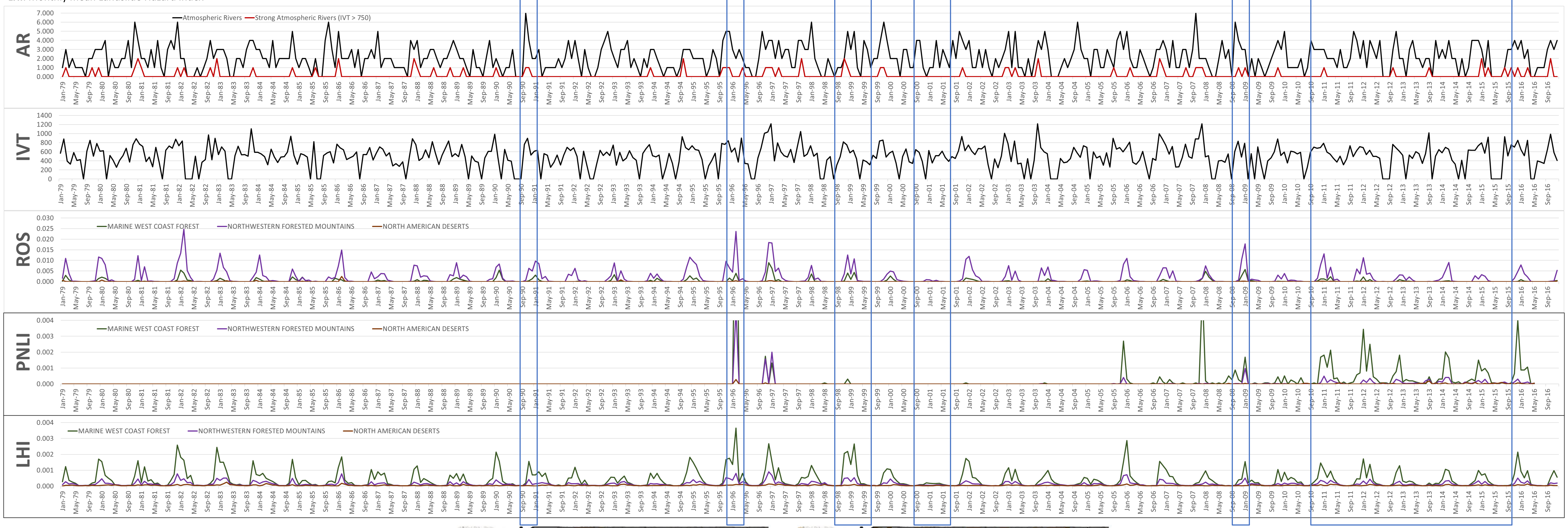
The highest LHI value for the time period 1979-2016 coincides with the largest landslide event recorded in the PNLI. Rain on snow played an important role in this disaster.

LHI can identify dates on which landslides were probable, but few landslides were recorded.

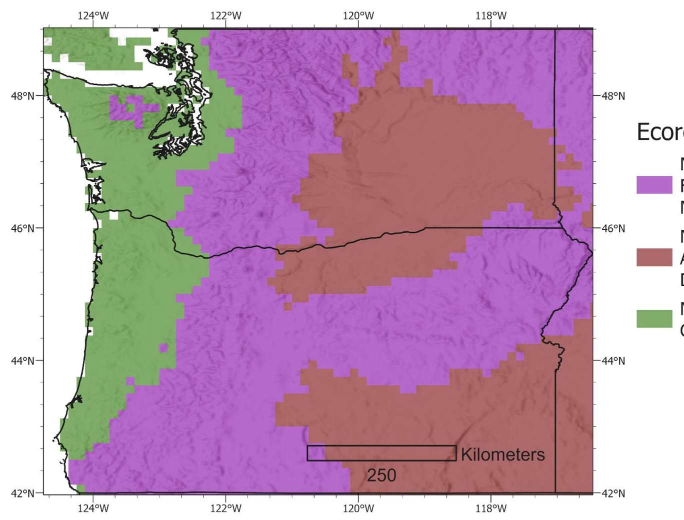
LHI can also identify time periods in which landslides were improbable.

Strong (IVT > 750) atmospheric rivers trigger major landslide events, such as slides in Western Washington in early January 2009.

The landslides were recorded more consistently for the last decade of the PNLI, so this time period was used to train the XGBoost model.




## Analysis by Major Ecoregions

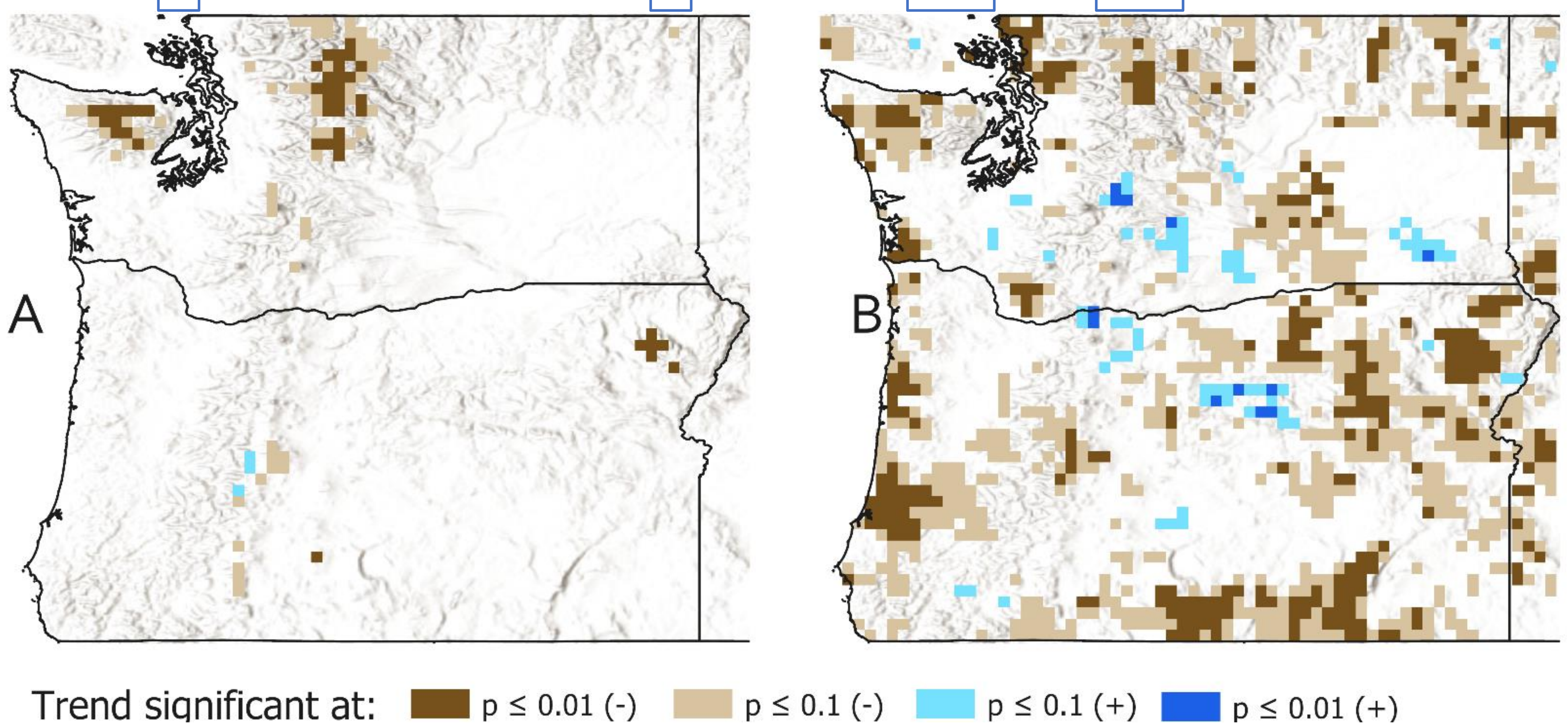



Monthly means for PNLI, LHI, and ROS are shown by EPA Level I Ecoregions.

## Historical Trends

**A:** Paralleling declines in both rain and snow (Jasinski et al., 2019), statistically significant declines in ROS occurred in a few mountainous areas (brown); significant increases in ROS were rare (blue).

**B:** Statistically significant declines in LHI (brown) greatly outnumbered increases (blue). However, risk could be increasing, due to steady population growth in this region.

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