

# Avalanche Fatalities In Relation To The Coverage Of Recreational Avalanche Forecasts In The United States

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## Investigative Questions

In 2024, recreational avalanche forecasts only covered about 3% of the mountainous regions in the United States, but 77% of fatal avalanche accidents occurred within the covered areas.

Does this mean that the coverage of avalanche forecasts in the US is adequate or inadequate?

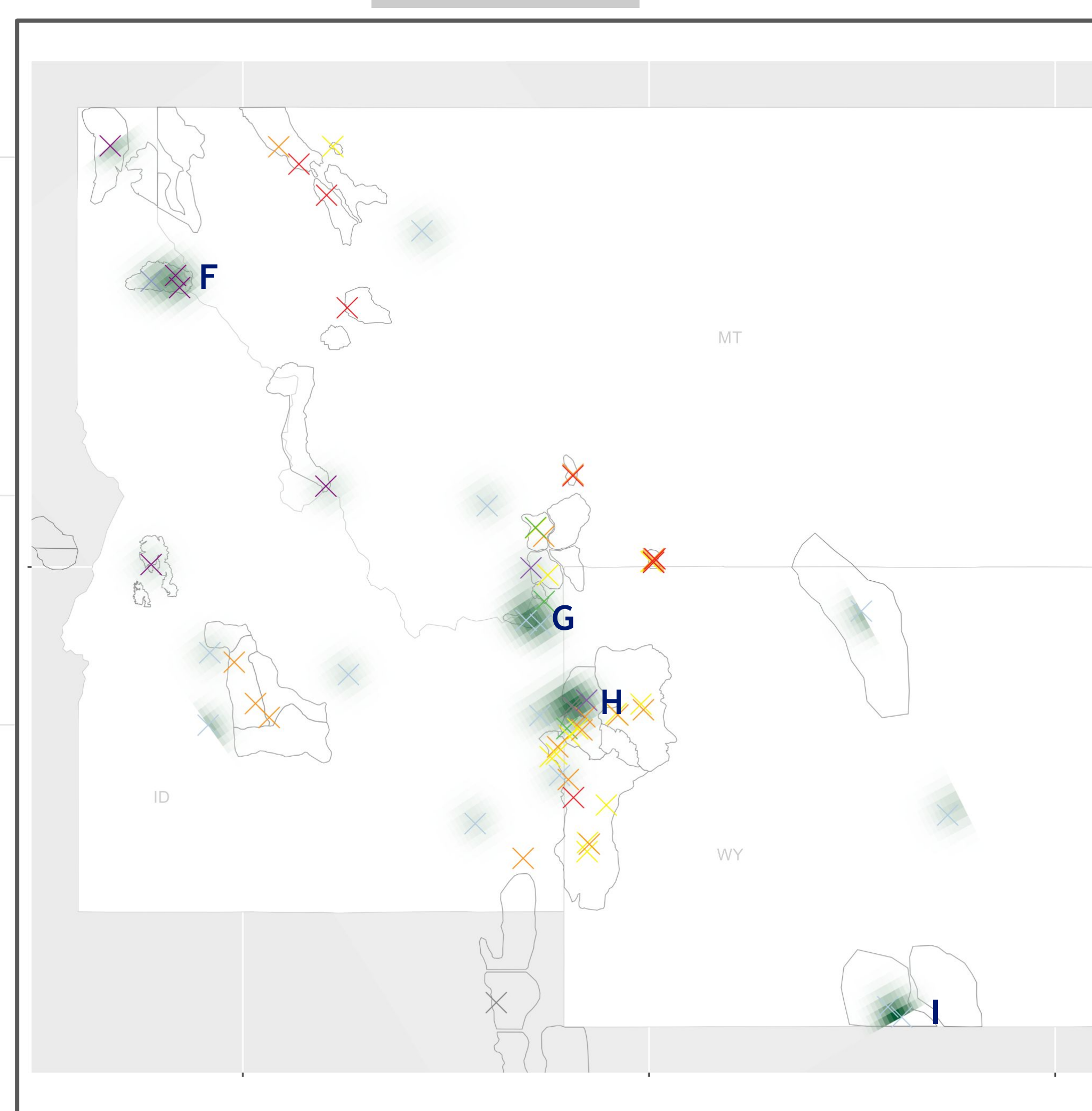
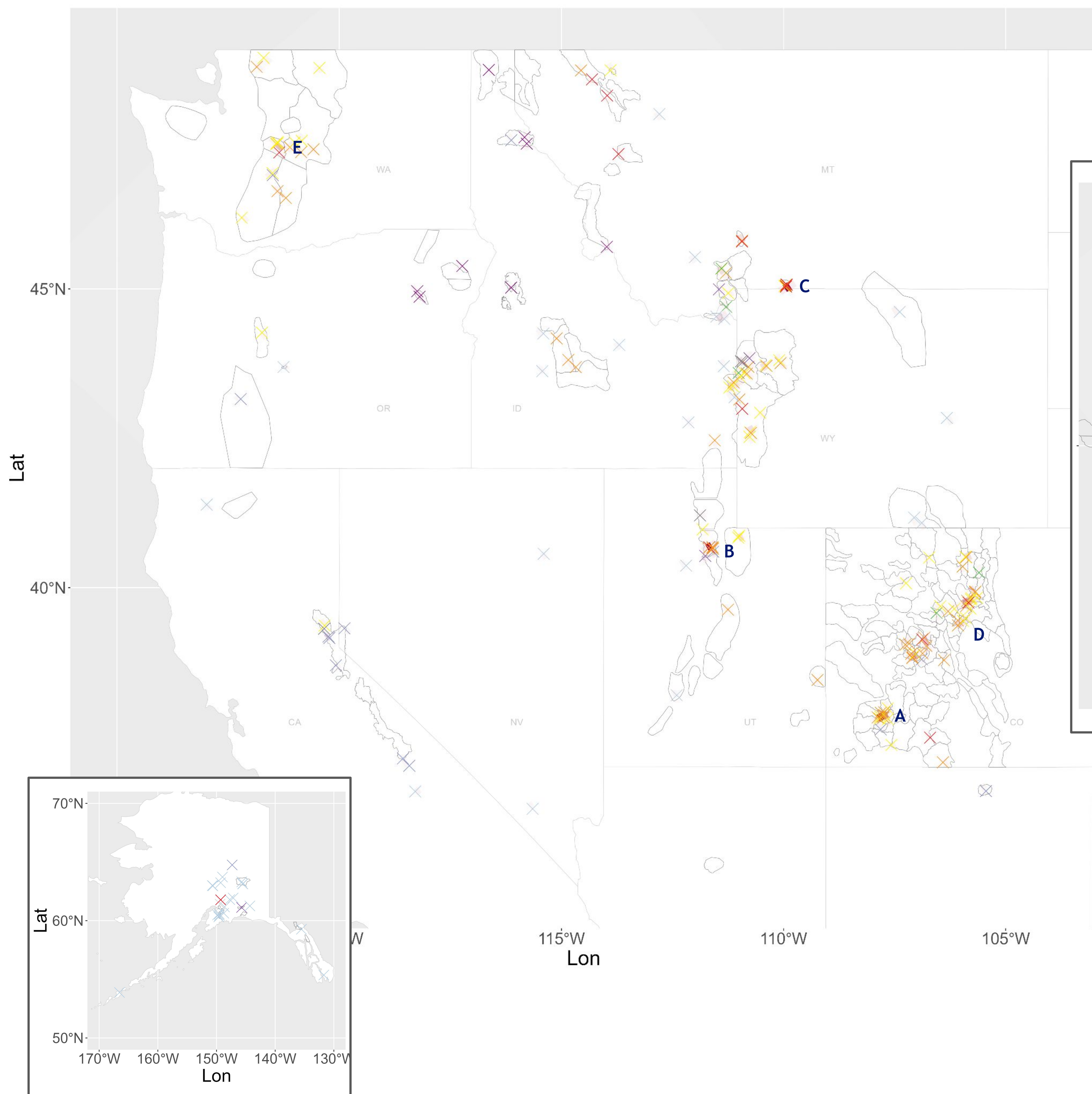
We examined spatial patterns of accidents to provide decision-makers with objective information to guide improvements to public avalanche

## Data

The Colorado Avalanche Information Center (CAIC) maintains records of avalanche fatalities in the United States. We used fatal avalanche events from ten years between October 1, 2014, and September 30, 2024 (avalanche years 2015 to 2024). Our data set included 197 avalanches that resulted in 225 deaths.

We categorized the forecast relevance for each accident (right). If the avalanche occurred within a forecast area with an issued danger rating, we recorded the danger relevant to the accident.

Category and Color in map	Description	Number of events
Danger rating not applicable	Inside a municipality or within the boundary of an operating ski resort.	14
Outside forecast area	In a backcountry location not covered by an avalanche center.	42
Inside forecast area - no valid danger	Inside the forecast area of an avalanche center, but when there was no valid avalanche danger rating. Often before or after the main season of forecasting.	4
Inside forecast area - multi-day forecast	Inside the forecast area of an avalanche center, but in a place covered by a multi-day description of the avalanche conditions, with no valid avalanche danger rating.	10
Inside forecast area - valid danger rating		
High (4)	Inside the forecast area of an avalanche center when there was a valid avalanche danger rating for the accident location.	126
Considerable (3)		
Moderate (2)		
Low (1)		
Unknown	Location and other details were insufficient to determine if there was a valid avalanche danger rating at the time and place of the accident.	1



## Clustering

Kernel density estimates identified five high-intensity clusters. All intense clusters are included within avalanche center forecast areas.

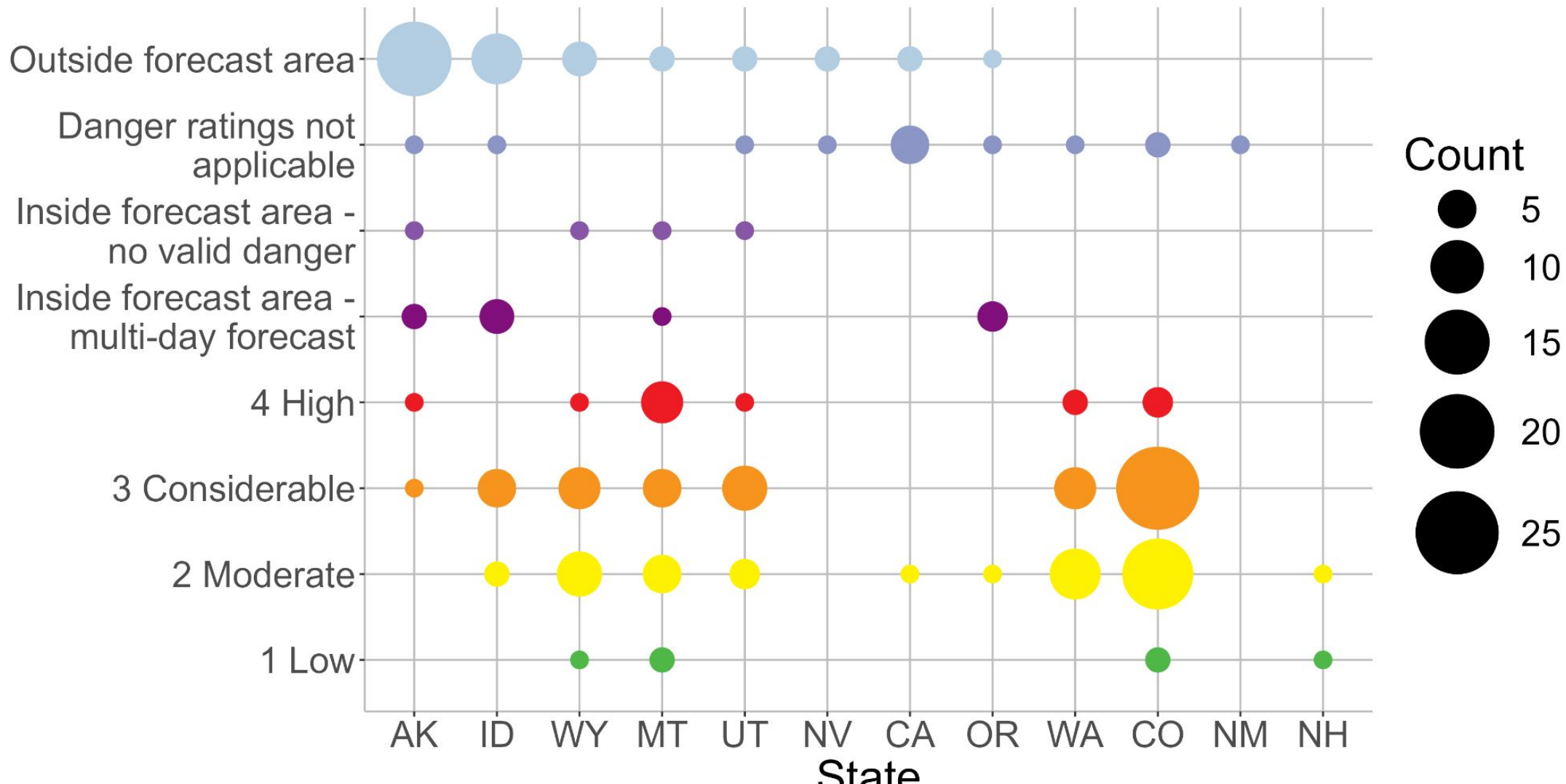
- A. Southern Colorado, CAIC's Southern Mountains region
- B. Northern Utah, Utah Avalanche Center's Salt Lake Area Mountains
- C. Southeastern Montana, the Gallatin National Forest Avalanche Center's (GNFAIC) Cooke City area
- D. Central and Northern Colorado, CAIC's Central and Northern Mountain regions
- E. Northwest Avalanche Center's Snoqualmie Pass zone

In Idaho, Montana, and Wyoming, there were a number of accidents outside of, but near, forecast areas with valid danger ratings.

- F. Bitterroot Mountains along the northern Idaho-Montana border. Although the current forecast boundaries encompass all of these accidents, the cluster includes accidents that occurred before the zone was designated.
- G. Island Park along the Idaho-Montana border, an area now covered by GNFAIC. This area includes an accident in a residential area, accidents prior to daily forecasts, and accidents 5 to 10 km outside current forecast zones.
- H. Big Hole Mountains along the Idaho-Wyoming border, near areas covered by the Bridger-Teton Avalanche Center (BTAC). Accidents about 10 km outside current forecast boundaries drive cluster intensity.
- I. Snowy Range of southeastern Wyoming, near but outside of the CAIC's forecast area. The region is now covered by an information-sharing area operated by the BTAC.

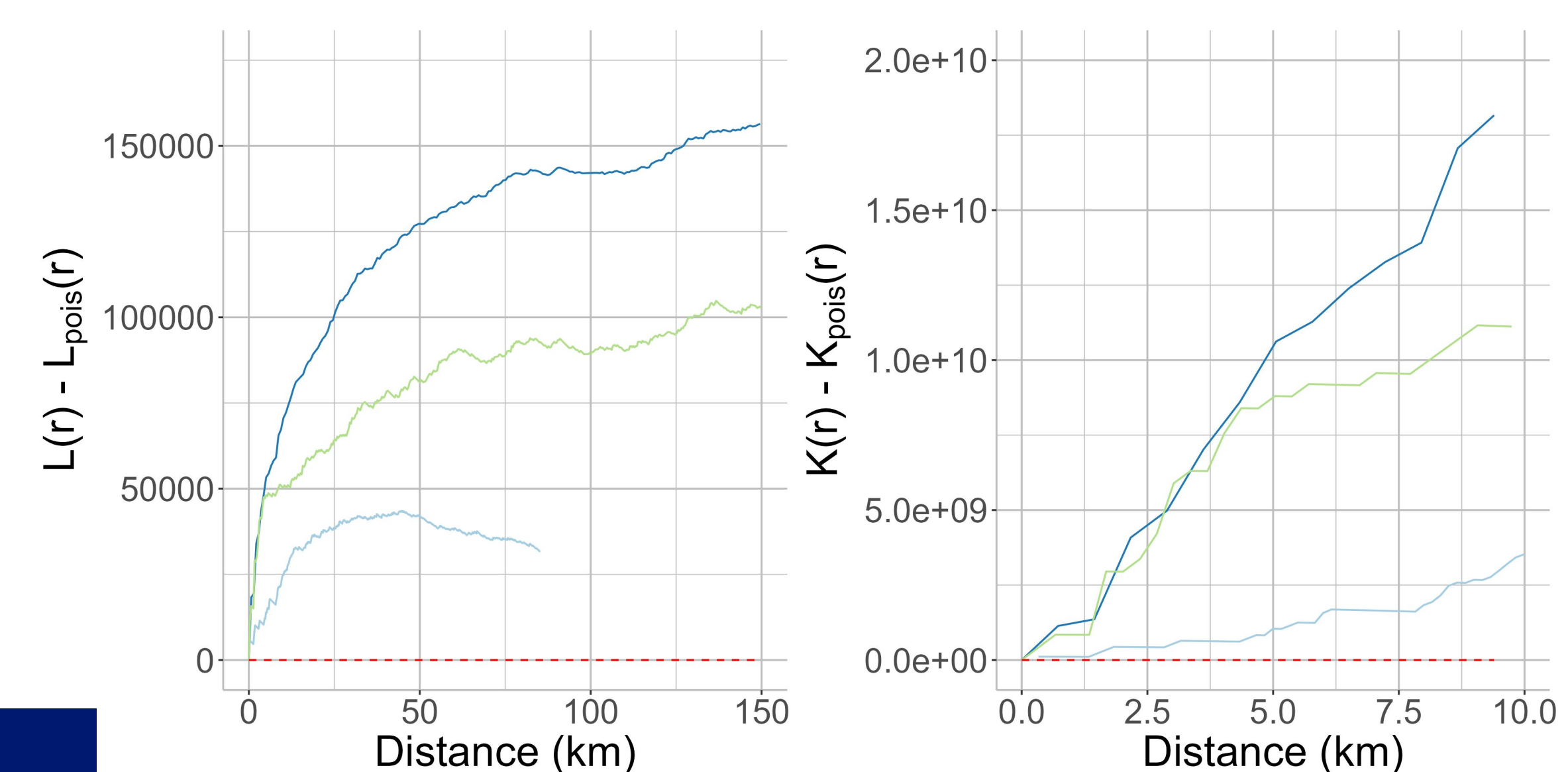
## By State

About 23% of accidents occurred outside a forecast area, with the most in Alaska and Idaho (lower left). During our study period, Washington, Colorado, and New Hampshire did not have accidents outside of a forecast area. The annual number of accidents outside forecast areas did not significantly ( $p > 0.1$ ) change over time during this period.



## Spatial autocorrelation

The empirical K and L functions for the western US, a subset of accidents in Idaho, Wyoming, and Montana, and a subset of accidents in Colorado (right) indicate strong spatial autocorrelation for avalanche accidents. The spatial autocorrelation suggests size breaks for forecast areas that would most effectively capture avalanche accident clusters. The similarity in the three subsets suggests that the spatial scale of topographic factors like drainage size, regional climate zones, and human factors like distance traveled from access points may be similar across the western United States.



## APPLICATIONS

- Fatal avalanche accidents in the United States have high spatial autocorrelation and are tightly clustered. The source of autocorrelation in avalanche fatalities likely includes both human and physiographic processes.
- Most accident clusters fall within avalanche center forecast areas.
- In areas with accident clusters outside of avalanche center forecast areas, the avalanche safety community has recently implemented other approaches — such as observation sharing and education programs — to address known avalanche safety issues.