# FORECASTING AVALANCHES FROM ATMOSPHERIC CROSS-SECTIONS

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ABSTRACT: The weather fashions both weak and strong snow layers. The weather forecast and snowpack data are key ingredients to an accurate avalanche forecast. Of these two elements, a precise mountain weather forecast is perhaps the most difficult to attain.

Forecasters at the Colorado Avalanche Information Center use graphic cross-sections of the atmosphere to help forecast mountain weather and avalanche potential. This NOAA, National Weather Service product is compiled from balloon soundings and weather forecast models. It renders visual slices of the atmosphere above user-defined mountain locations.

Seven of 39 weather parameters can be overlaid on the cross-section at one time. Four of these, wind velocity, wind direction, relative humidity and temperature are used for this study. The weather pattern at a specific site is forecast out 72 hours. This provides insight for the potential of weather-induced avalanches. Model output is examined for biases to help forecasters fine-tune their weather and avalanche predictions. Data from two weather stations are compared to a shared cross-section forecast during the winter of 1997-98.

KEY WORDS: snow drifting, snow precipitation, avalanche forecasting

## INTRODUCTION

Data from two weather stations along the Continental Divide near Loveland and Berthoud passes are used to forecast avalanches for popular backcountry areas and two major highways. Located in central Colorado, they are 11 miles apart (more than 30 miles by road) and thus share a common cross-section forecast centered on a location between them.

This study focuses on the difference between atmospheric cross-section forecasts and actual data from these stations. If model biases exist, such as consistently forecasting a weather parameter too high or too low, adjustments can be made to achieve greater forecast accuracy and reduce the chance for avalanche accidents.

The Aviation (AVN) weather forecast model, one of six available, was chosen for its capability to project 72 hours into the future. Only the basic elements of wind, temperature and relative humidity were used for comparison in this study but other parameters, such as lapse rates and vorticity advection, are utilized for additional input when forecasting.

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## METHODOLOGY

Each cross-section was divided into six 12-hour periods. Except for relative humidity, forecast values were taken from approximately 650 mb, the weather station elevation just above timberline. The temperature forecasts (Tf) used were valid for 5:00 am and 5:00 pm each day. The 12-hour-average forecast for wind velocity (Vf), wind direction (Df) and relative humidity (Hf) were recorded. The 12-hour-average forecast for relative humidity (RH) was arrived at subjectively. I simply determined it by looking at the cross-section between 700 mb and 400 mb.

The forecast values were then compared to the actual 12-hour-average data for velocity (Va), direction (Da), and humidity (Ha). Actual temperatures (Ta) were taken at 5:00 am and 5:00 pm.

If Vf48 is the 48-hour velocity forecast then Va48 would be the actual velocity recorded for that period. The difference, Vf48 minus Va48, produces Vd48 (velocity difference), a value showing by how much the forecast was too high or too low.

An average of the differences between forecasts and data was calculated to find how much the forecast usually differed from reality and if it was generally too high or too low. The figures were then graphed for a visual comparison.

## RESULTS

*The temperature forecast*

Temperature forecasts were found to be the most reliable. At Loveland Pass, the average difference was less than 3°F between the forecast and actual temperature. The greatest difference was 15°F for a 72-hour forecast. Berthoud Pass was similar where the greatest difference was only 14°F for one of the 48-hour forecasts.

Temperature correlation coefficients were strong for both sites with "R" values measuring not lower than 0.85 at the Loveland station and 0.86 at the Berthoud station (1.0 being a perfect relationship between the forecast and actual data). Figure 1 below shows that the average forecast consistently fell below the actual temperature but well within acceptable limits.

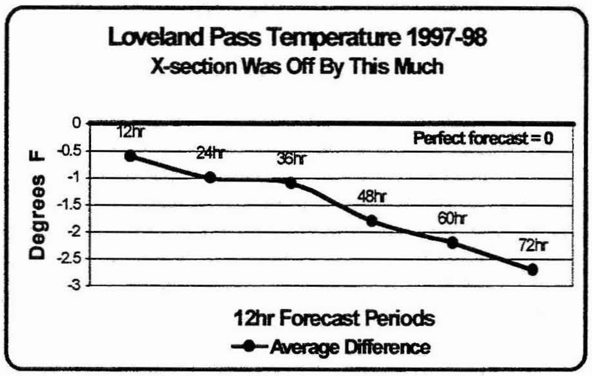


Figure 1. Average difference between forecast and actual temperatures – Loveland Pass, CO.

*The wind velocity forecast*

Wind velocity data revealed that the average forecast was consistently higher than the average actual wind speed for each site. However, the forecast was generally within acceptable limits. The greatest difference was 33 mph for a 72-hour forecast at Loveland Pass and 30 mph at a 24- and 36-hour forecast at Berthoud Pass.

Interestingly, the forecast was actually closer to the peak gusts. It was consistently lower than the average gust and within 5 mph.

The correlation coefficient between the forecast and actual velocity was not impressive for the Berthoud site. The R-value was only 0.67 in the short-term, 12-hour forecast. This dropped to a discouraging low of 0.17 at the 48-hour forecast. Loveland Pass fared better but dropped below 0.7 after 24 hours and was a mere 0.31 at 72 hours.

The graph below shows the average velocity forecast was a little high, but that it was just below the average peak gusts for the same 12-hour periods.

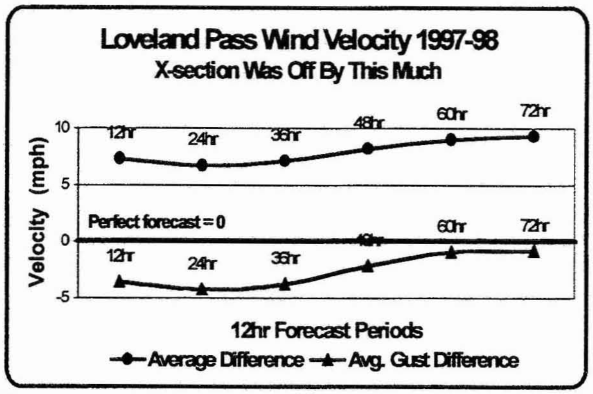


Figure 2. Average difference between forecast and actual wind velocities – Loveland Pass, CO.

*The wind direction forecast*

Of the parameters measured, wind direction varied the most when comparing the forecast with actual data. There were wide discrepancies at Berthoud Pass but Loveland Pass did much better. The average 60-hour forecast period at the Berthoud site was off by 54 degrees. At Loveland the widest difference was small by comparison, only 20 degrees at the 72-hour forecast period.

Figures 3 and 4 below show the average forecast difference was on the *positive* side of zero. In other words, the forecast direction was typically too far clockwise—a forecast for winds out of the northwest may actually turn out to be west or southwest winds drifting snow onto different aspects than anticipated from the cross-section forecast.

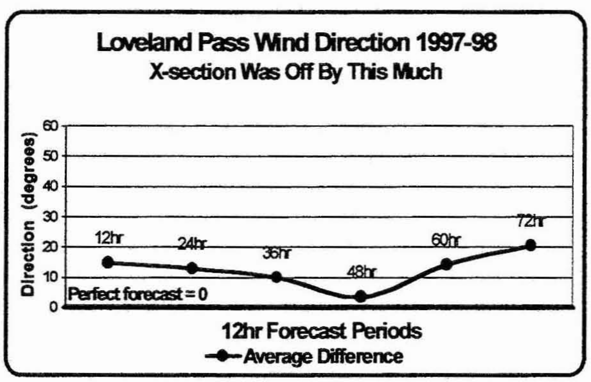


Figure 3. Average difference between forecast and actual wind directions – Loveland Pass, CO.

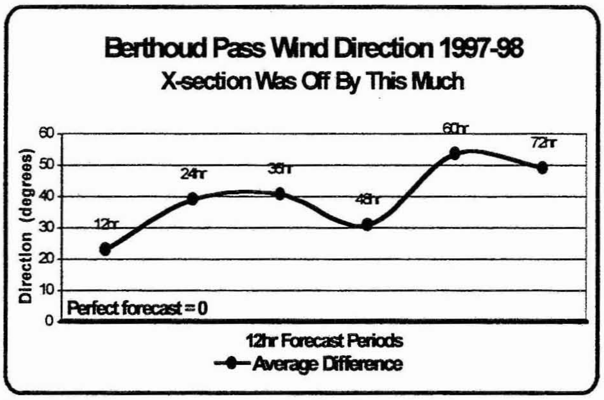


Figure 4. Average difference between forecast and actual wind directions – Berthoud Pass, CO

*The relative humidity forecast*

Moisture layers in the atmosphere vary in thickness and elevation. High RH values do not necessarily mean precipitation is imminent or already occurring. For example, a layer of clouds rubbing the top of a mountain may not be producing snow, but an RH sensor on the ridge will record high relative humidity. The same RH values could give several inches of snow when other factors are involved, such as orographic lifting. Simply comparing RH and new snow data was inconclusive.

The average RH for two 24-hour periods (4 days apart) at Loveland Pass was 80%. One period produced 1 inch of snow while the other produced 7 inches. The one inch fell when winds were light from the southeast. The 7 inches fell with the same RH but when winds were moderate from the northwest. Orographics played a key role here. Temperatures were similar on both occasions.

CONCLUSIONS

Comparing RH data alone with actual new snow was the most elusive part of the study. The numbers were misleading until they were aligned with other weather parameters, namely wind speed and direction. The key to a good snow forecast is not to rely on RH values alone. At Loveland Pass, the forecast RH averaged slightly higher than the recorded RH. The weather station, however, lies about 1 mile east of the Continental Divide and is some 500-700 feet lower than the surrounding ridgetops. Down-slope warming may have a drying effect on the air parcel before it reaches the RH sensor. At Berthoud Pass, the forecast average and actual RH were also close and in the acceptable range.

Temperature forecasts were very reliable. There provides a comfort factor when predicting snowpack conditions based on ambient air temperatures, even out to 72 hours.

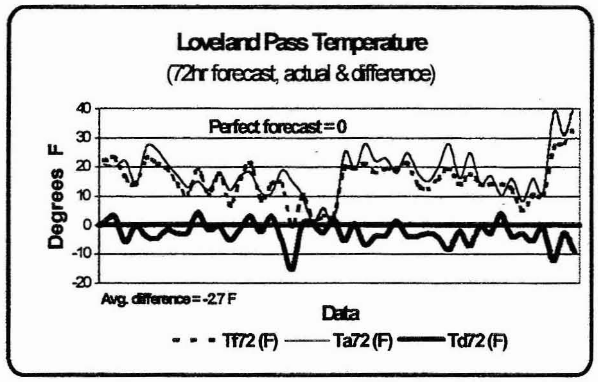


Figure 5. Average difference between forecast and actual temperatures – Loveland Pass, CO

Wind velocity compared well to actual data. On average, the forecasts were 7 mph too high. They were close to the average peak gusts, but lower by some 3 mph. The forecast should be trimmed back slightly for this elevation.

Wind direction forecasts were more variable. Avalanche forecasts may be inaccurate if the forecaster relies solely on the cross-sections, especially for the Berthoud Pass area. Terrain features at this site likely affect the free flow air where the instruments straddle the Continental Divide above timberline at 11,900 feet. A forecast direction of 350°, valid for March 31st, was consistent on four consecutive forecast updates. The actual wind direction on the 31st was 125°. Thus, forecast consistency does not necessarily mean forecast accuracy. Comparing data from a similar weather station 5 miles to the north may help determine if the discrepancy is from the terrain or is in the forecast.

Atmospheric cross-sections can be used to help forecast avalanches. For example, a reliable temperature forecast will give insight into prolonged cold periods that could enhance kinetic metamorphism, or foretell of a rapid rise in temperature that might trigger wet snow avalanches. The samples showed that wind speed and direction from the cross-section can be adjusted for greater accuracy. Combine this with reliable snowpack data to arrive at a valid avalanche forecast.

As always, learn from the lessons in humility. They are not that uncommon in this profession.