WEATHER FORECASTS FOR AVALANCHE PREDICTION

by
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EXTENDED ABSTRACT

From its inception in 1975, the Northwest Avalanche Center (NWAC) has emphasized the development and operational production of micro- and mesoscale weather forecasts for the surrounding mountains. This service is designed to meet the critical needs of local avalanche forecasters and controllers who are challenged by rapid changes in snow stability caused by the frequent storms and fluctuating freezing levels of a maritime climate.

This portion of NWAC's program sets it apart from other avalanche programs in that a substantial amount of time and expertise is employed to develop a detailed mountain weather forecast. This forecast is then used to predict changes in snow layering and subsequent instability. In addition, the snowpack is meteorologically reconstructed to provide forecasters estimates of snow stratigraphy in areas of the backcountry that have no regular observer. In this way, a meaningful regional summary of snow stability and a two to three day forecast of changes can be provided to the public. This is important since the forecast region covers over 50,000 square km of mountainous terrain and backcountry users often leave civilization for extended two and three day trips.

A variety of other groups and individuals also use NWAC avalanche weather forecasts. For example, state and local avalanche control personnel use the forecasts to plan their control methods that protect developed ski areas and highways. The National Park and Forest Services and State Parks use avalanche weather forecasts to better advise visitors on expected hazards. In addition, State highway crews use NWAC products to plan maintenance schedules and local ski schools, clubs, and guide services use the avalanche weather forecast to help avoid impending hazards.

To provide this mountain weather forecasting service, the Center employs four forecasters who have at least a Master's level training in meteorology, snow physics, and avalanche mechanics. This allows forecasters to combine traditional weather analysis and forecasting tools with a

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knowledge of terrain effects on local weather and subsequent effects on avalanche conditions.

Over 60 mountain observation stations combined with synoptic prognostic charts, mesoscale empirical guidelines, and a large amount of subjective experience are used to create a meaningful mountain weather forecast. The basic parts of the forecast include: 1) A weather synopsis of current and expected synoptic- scale conditions; 2) A meso-scale weather forecast for days 1-2, separated into expected climate regimes; 3) The expected freezing/snow levels for 6 to 12 hour periods for days 1-2, separated into climate regimes; 4) 24-hour micro-scale forecasts of water equivalent precipitation for days 1-2; 5) Wind forecasts at the pass level for major east-west oriented Cascade Passes; 6) Wind forecasts for free-air flow at 1500 m and 2700 m; and 7) an extended forecast for 3 to 5 days.

For those who are familiar with US National Weather Service Mountain Zone forecasts the second part of NWAC's mountain forecast may appear similar. The difference is that, instead of one mountain zone, the Cascades and Olympics are often divided into several zones. The areas of division depend upon the current and expected weather patterns. This is because the influence of each storm can vary dramatically over the large forecast region. For example, storms passing to the north may influence only the northern forecast region, storms recirculating around a low centered in Oregon or California may influence only the east slopes of the Cascades, and storms stalled over the coast may influence only the Olympics. When there are strong temperature inversions, elevation distinctions are also made for each weather forecast.

Specific climatic regimes are identified whenever possible for other forecast items as well. For example, it is not unusual to explain that winds will be stronger in the Olympics if an associated Jet Stream is held just offshore. Or freezing levels may be several hundreds of feet lower on the east side of the Cascades and through the Cascade passes because of a stagnant pool of cold arctic air. These are just a few examples of how a "zone" forecast is different than NWAC's "mesoscale" forecast. The former has fixed geographic boundaries and the latter has boundaries that change depending upon weather.

Although many of the techniques used by NWAC forecasters follow standard methods of synoptic weather analysis, forecasting for micro- and mesoscale features within mountainous terrain requires the use of special tools and analytic methods. By utilizing specifically designed methodologies in an operational mountain weather forecast program, the NWAC has been able to observe and forecast local weather phenomena that may have otherwise been overlooked.

For example, a flow of easterly air through the Cascade Passes often keeps snow falling at low elevations long after free-air freezing levels have risen enough to cause rain at higher elevations. This occurs when east-west surface pressure gradients pull cold, arctic air across the Cascades. Snow turns to rain at the pass level when a low pressure center and its associated "cold" front move east of the Cascades. This switches the surface gradient to west-east and may erode the pool of arctic air enough to warm the eastern slopes as well.

The timing of this change is critical since rain on new snow often causes large and destructive avalanches that block the major east-west transportation corridors, sometimes for days at a time. NWAC forecasters have installed automated weather stations at each major pass to record wind direction, precipitation, and temperature from several elevations. With this data and as NWAC forecasters gain experience, they are able to give 12 to 24 hour warnings of these rapid warming events and may suggest the potential for such an event as much as 3 to 5 days ahead. It is not uncommon for 12 hour forecasts to be accurate within an hour or two of the warming occurrence.

Another example of small scale events that fall below the resolution of synoptic analysis and forecasting tools are convergence zones. Major convergence of winds around the Olympic Mountains can cause snowfall differences of 20 cm or more to occur over the space of a few kilometers. Minor convergence also occurs around the several volcanic peaks that protrude 1000 to 2000 meters above the Cascade crest. Although the exact timing and areal extent of each convergence episode remains very difficult, NWAC forecasters have learned to recognize atmospheric conditions that favor convergence and can offer mountain personnel enough warning to prepare for the possibility of increased precipitation.

In addition to mesoscale forecasts of wind, freezing levels, cloud cover, and precipitation type and rate, NWAC offers a microscale forecast of precipitation amount for 10 specific stations. Although this portion of the forecast is often the most critical, it also has the least guidance available. To aid quantitative precipitation forecasts (QPF's) the local climatology of each mountain station has been cataloged. This information includes the influence of surrounding terrain and the exposure to dominant air masses (e.g., cold, dry continental air and/or warm, moist marine air). Storm patterns are also characterized so the forecaster can refer to similar situations that may provide a guideline for expected precipitation.

Although development of meaningful QPF's remain largely subjective, when compared with computerized QPF models developed for other mountainous terrain, NWAC forecasters appear more accurate for a greater number of weather situations. Even so, there is a vital need for improved QPF guidance and the NWAC is currently developing a computer model that would apply to the Cascades and Olympics.

As with any weather forecast, the overall accuracy of NWAC's avalanche weather forecasts depend upon the type of storm, the accuracy of the theoretical modeling or available guidance, and the forecaster's experience. In addition, with very little observation data within the upwind Pacific Ocean, many storms are not completely analyzed until they reach the coast. At that time a storm's characteristics may change rapidly as it loses its over-water trajectory and moves over complex terrain. Rapid and subtle changes often occur below the resolution of prognostic model grids. These can cause large enough variations in the weather pattern to upset the accuracy of subsequent model outputs, causing an increased burden on the avalanche weather forecaster's own analytic abilities.

Despite these difficulties forecasters at NWAC strive to provide a useful program for avalanche control workers and highway maintenance personnel throughout the Cascades and Olympics. Instrument designs, forecast models, and functions within NWAC's entire program are continually modified and updated as new ideas and needs are expressed. This makes the Northwest Avalanche Center a constantly changing program. Hopefully the usefulness of avalanche weather forecasting can be realized for other avalanche afflicted areas that currently lack the support of micro- and mesoscale weather forecasting.

If you would like more information on mountain weather forecasting at the Northwest Avalanche Center, or are curious about its avalanche forecast program, please write: Northwest Avalanche Center, 7600 Sandpoint Way NE, Box C-15700, Seattle, Washington, USA 98115.