Snow Level in the NWS Western Region: Definition and Calculation Methodology

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ABSTRACT

Snow level is a simple way to communicate expected precipitation type of rain or snow in the complex terrain of the Western United States. An effort was undertaken in 2011 by the National Weather Service (NWS) Western Region (WR) to standardize the methodology used for snow level across NWS WR forecast offices. This effort lead to a standard definition for snow level and a standard methodology to calculate the snow level (the wet-bulb 0.5°C height). This tech attachment will explore the origins of both.

1. Background

Snow events in the western United States (US) have major economic impacts. Forecasting such snow is traditionally made up of several components: liquid amount, a snow-to-liquid ratio, and determination of precipitation type. One method for determination of precipitation type is the snow level concept, which has been used in complex terrain of the western US for many years. Precipitation in the western US frequently falls as either rain or snow, and the delineation between the two is often a function of elevation. Thus, an advantage of snow level is that it can easily communicate to the public where snow is expected, as the most common precipitation type regime is snow above the snow level and rain below. Therefore, snow forecasting in the western US typically consists of liquid equivalent (Quantitative Precipitation Forecast or QPF), snow-to-liquid ratio (SLR), and snow level.

2. Calculation Methodology

Despite the importance of snow level forecasts, scientific literature on methodologies to calculate this field are relatively scarce. White et al. (2002) found that the rain/snow line was on average ~700 feet below the melting level based on data from Doppler radars. Additionally, White et al. (2010) stated that the snow level, i.e. the level at which snow accumulates on the ground, could be anywhere from 500 feet to 1500 feet below the 0°C line. Lastly, Minder et al. (2013) found that snow levels can “bend” downwards towards higher terrain locations, resulting in lower observed snow levels than the free atmosphere would imply and that orographic enhancement could be the cause.

While the direct output of numerical weather prediction provides temperature forecasts at various geopotential heights and other vertical layers, the wet-bulb temperature is frequently more useful for delineating rain and snow. This is because the wet-bulb temperature takes into account the cooling that occurs due to evaporation as precipitation falls into a drier layer, typically near the surface, which allows snow to fall at warmer temperatures than would be expected by the height of the 0°C surface alone.

To investigate the usefulness of the wet-bulb temperature for estimating snow level, the Salt Lake City (SLC) Weather Forecast Office (WFO) performed a precipitation type study (namely rain versus snow) using data from upper-air soundings launched at their office. Specifically, they looked at the precipitation type from the 23Z KSLC surface observation and the 00Z sounding for balloon launches in the cool season (Oct-Mar) over a ten-year period (1996-2006). Figure 1 plots the observed precipitation type versus the surface wet-bulb temperature for ~230 such events. It was found that the greatest variability in the precipitation type and the highest likelihood of having mixed precipitation was consistently between a wet-bulb temperature of 0° and 1°. Based on this, a wet-bulb temperature of 0.5°C was determined to be a logical starting point for delineating snow from rain events. Further, the wet-bulb zero height was also compared to observed precipitation type in Figure 2. It was found that no snow events in that ten-year period occured when the wet-bulb zero height was more than 750 feet Above Ground Level (AGL). This result was in general agreement with the results of White (2002) discussed earlier, namely that no snow was observed when wet-bulb 0°C heights were greater than 750 feet AGL and events were exclusively rain when wet-bulb 0°C height was greater than 1000 ft AGL. The SLC office found these research results to be useful in creating local definitions and tools for handling snow level forecasts.

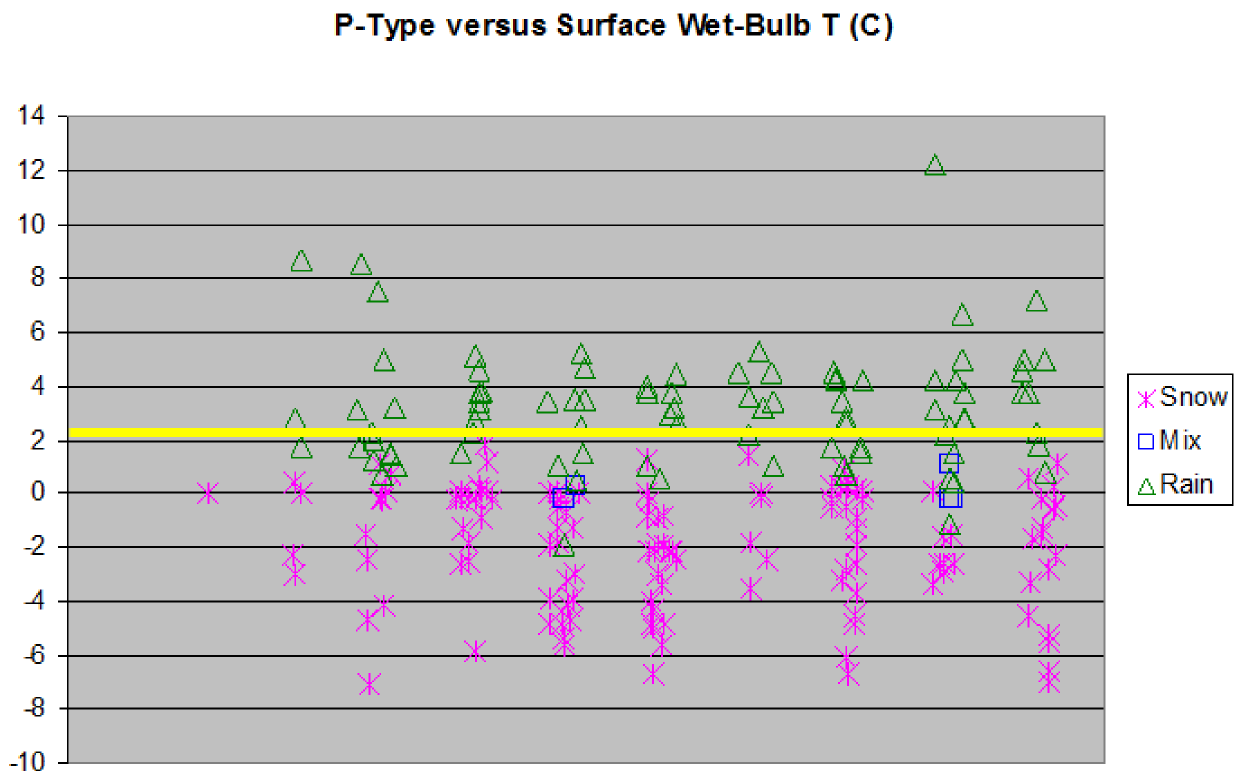

Figure 1 - Precipitation type (rain, snow, or mixed rain and snow) versus surface wet-bulb temperature for ~230 soundings from October-April of 1996-2006 at Salt Lake City, UT. No snow observations occurred at temperatures above the yellow line.

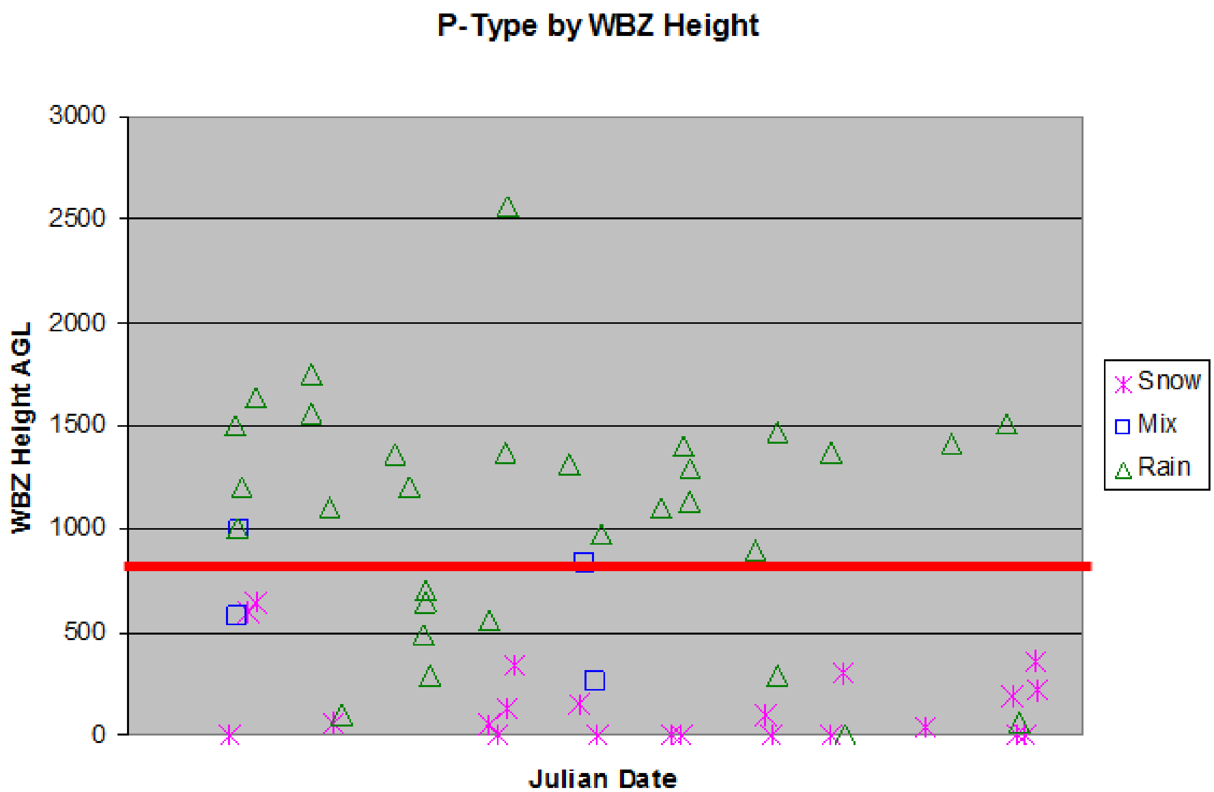

Figure 2 - Precipitation type (rain, snow, or mixed rain and snow) versus wet-bulb zero height for the same dataset presented in Figure 1. Snow alone was not observed at wet-bulb zero heights greater than the red line.

3. Standard for NWS Western Region

The concept of a snow level grid (i.e. a geospatial representation of snow level at various forecast hours) was born in the early 2000s when Western Region (WR) forecast offices developed smart tools to control the elevation of the rain/snow line in Graphical Forecast Editor (GFE) weather grids. An informal survey of 24 WR forecast offices in the Fall of 2009 identified at least 10 different definitions for the snow level and nearly two dozen methods for populating snow level grids in GFE. Several offices used the snow level information in their recreation and backcountry forecasts, resulting in queries on the accessibility of these grids by external partners.

To address these inconsistencies, NWS WR formed a team in early 2010 to develop a regional definition and common calculation methodology for snow level grids. An initial literature review revealed the lack of both snow level definition and methodology described earlier. The team spent a considerable amount of time debating a scientific definition that could be understood by forecasters, core partners and the public. The team settled on a common definition for the snow level, which was approved by the WR Regional Labor Council in the Fall of 2011:

> *The snow level is the elevation above which snow will fall, and below which rain will fall. A mix of rain and snow may be observed at elevations within a few hundred feet of the snow level. Snow will not accumulate on the ground below the snow level and may not even accumulate at elevations above the snow level.*

The WR Snow Level Team reviewed techniques used across Western Region to populate snow level grids. Many of the techniques leveraged were a modification of the web-bulb zero height as a proxy for the snow level. Based on the local study from the Salt Lake City WFO, the team identified the web-bulb zero height plus 0.5°C as the best proxy for snow level in WR. While the 10-year precipitation type study in SLC was relatively small and local, it was determined to provide a fitting starting point. This approximation for the snow level was standardized in GFE model smart initialization calculations and tested at 12 forecast offices during the winter of 2010-11 and across all of WR during the winter of 2011-12. Before standardization, an adjustment was made to the snow level calculation to account for dry sub-cloud layers, nudging the snow level towards the freezing level.

4. Usage Across the NWS

The concept of snow level and the associated wet-bulb 0.5°C methodology has spread across the NWS and is now used in multiple ways. First, as of winter 2018, it is the standard method employed by the software each WFO runs to initialize (i.e. post-process) raw model data into grids for forecast use in GFE. Second, it is the methodology employed by the NWS National Blend of Models. Lastly, it is used by the Weather Prediction Center’s Winter Weather Ensemble to delineate rain and snow, which in turn provides the initialization dataset for the Probabilistic Winter Precipitation Forecasting experiment.

5. Summary

Snow level is a practical way to communicate precipitation type in the complex terrain of the western US. Historically, local methods have been used at NWS WFOs to create such snow level forecasts. In 2011, WR formed a team to formally define snow level and suggest a standard methodology. Based on results from a study and WFO SLC, the wet bulb 0.5°C method was selected. This method is now used in several efforts across the NWS including the standard software suite each WFO uses to post-process models, in the National Blend of Models, and in the Weather Prediction Center’s Winter Weather Ensemble.

REFERENCES

Minder, J. R., and D. E. Kingsmill, 2013: Mesoscale variations of the atmospheric snow line over the northern Sierra Nevada: Multiyear statistics, case study, and mechanisms. *J. Atmos. Sci*., 70, 916–938, https://doi.org/10.1175/JAS-D-12-0194.1.

White, A. B., D. J. Gottas, E. T. Strem, F. M. Ralph, and P. J. Neiman, 2002: An automated brightband height detection algorithm for use with Doppler radar spectral moments. *J. Atmos. Oceanic Technol.*, 19, 687–697, https://journals.ametsoc.org/doi/10.1175/1520-0426%282002%29019%3C0687%3AAABHDA%3E2.0.CO%3B2.

White, A. B., D. J. Gottas, A. F. Henkel, P. J. Neiman, F. M. Ralph, and S. I. Gutman, 2010: Developing a performance measure for snow-level forecasts. *J. Hydrometeor.*, **11**, 739–753. https://journals.ametsoc.org/doi/10.1175/2009JHM1181.1.