The Utah Snow Load Study

A report presented to the Structural Engineers Association of Utah

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DISCLAIMER

The ground snow load values (in pounds per square foot) represent 50 year ground snow load estimates for a particular site at the given elevation. Further details regarding the results outlined in this report are found in Bean et al. (2017a, 2017b, 2018).

The following analyses were performed using the R statistical software environment (R Core Team 2017) along with several ancillary software packages cited throughout this report. This software freely available and widely used, but does not come with any warranty.

While great efforts have been made to ensure these predictions are as accurate as possible, designers must use expert judgment to ensure that such predictions are appropriate for their particular project. The SEAU and the authors cannot accept responsibility for prediction errors or any consequences resulting therefrom. Responsibility for the final design snow loads rests with the builder or designer in charge of the project.

NOTATION

A common set of notation is used throughout the report as follows:

- $\boldsymbol{u}$ - Vector of latitude longitude coordinates.
    - $\boldsymbol{u}^*$ - Location of interest (i.e. for prediction).
    - $\boldsymbol{u}_\alpha$ - Location of an individual station α ($\alpha = 1, \cdots, N$)
    - $D(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta)$ - Geographic distance between locations $\boldsymbol{u}_\alpha$ and $\boldsymbol{u}_\beta$
- $A(\boldsymbol{u})$ - Elevation of location $\boldsymbol{u}$.
    - $\Delta z(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) = \left|A(\boldsymbol{u}_\alpha) - A(\boldsymbol{u}_\beta)\right|$.
- $p_g(\boldsymbol{u})$ - Ground snow load at a location $\boldsymbol{u}$.
    - p_g^* - Design (i.e. 50 year) ground snow load.

Additional notation beyond these definitions will be given as needed.

INTRODUCTION

Recent reports of snow related building collapses across the western United States in early 2017 (Lafferty 2017, Associated Press 2017, Mieure 2017, Kato and Florio 2017, Fisicaro 2017, Glover 2017) highlight the importance of snow load considerations in building design. Specifying such design snow loads requires a proper balance between safety and economy. As articulated by Nowak and Collins (2012): "Conceptually, we can design [a] structure to reduce the probability of failure, but increasing the safety...beyond a certain optimum level is not always economical." It is the search for this optimum level of safety that has motivated the development of design ground snow loads at state and local levels.

American Society of Civil Engineers (ASCE) ground snow load requirements have historically remained largely unspecified for the topographically complex western states up through ASCE 7-10 (ASCE 2013). In response to this ambiguity, many western states, including Utah, have recommended design snow loads in state specific reports, typically published by State Engineer Associations (SEAs) (NACSE 2012, SEAU 1992, Torrents et al. 2016, Al Hatailah et al. 2015, Theisen et al. 2004 SEAU 1992). The recently updated ASCE 7-16 requirements derive their recommended values from these reports (ASCE 2017).

The three major steps for estimating design snow loads for a given region are:

1. The development of a ground snow load dataset using daily weather station snow depth and snow water equivalent measurements.
2. The use of spatial method to predict design ground snow loads between station locations.
3. Conversion from ground load to roof load as appropriate for the building of interest.

Work flow diagrams illustrating each each step are given in Figures 1, 2, and 3. This report focuses on steps one and two. Information regarding step three can be obtained in ASCE 7-16 guidelines (ASCE 2017).

After a brief summary of the 1992 Utah snow load report, this report will proceed as follows.

- A brief summary of the snow load equations given in the 1992 snow load report.

- The development of a new Utah ground snow load dataset including:
    - data collection
    - snow depth to snow pressure estimation methods
    - data quality assurance measures
    - 50 yr ground snow load estimation via log-normal distribution fitting.
- The development of PRISM and Kriging for predicting ground snow loads in Utah.
- Comparison of several ground snow load prediction methods, their strengths and weaknesses, as well as comparisons of the cross validated accuracies of each.
- Application of new ground snow loads in building design.

THE 1992 UTAH REPORT

The Structural Engineers Association of Utah (SEAU) predict ground snow loads from elevation using the following equation (referred to hereafter as SNLW):

$$p_g^*(\boldsymbol{u}) = \begin{cases} \left(P_0^2 + S^2\left(A(\boldsymbol{u}) - A_0\right)^2\right)^{\frac{1}{2}} & A(\boldsymbol{u}) > A_0 \\ P_0 & A(\boldsymbol{u}) \leq A_0 \end{cases} \tag{1}$$

where P_0 (base ground snow load), S (change in ground snow load with elevation), and A_0 (base ground snow elevation) are parameters whose values are uniquely defined for each county (SEAU 1992). These county specific parameters help account for major difference in ground snow load trends across the state, particularly moving from north to south.

Underlying these equations were estimated 50 year ground snow loads at 413 stations located throughout Utah. These 50 year values were estimated by fitting a log-Pearson type III distribution to yearly maximums at each station location. For stations where only snow depth was measured, the snow load was estimated using the Rocky Mountain Conversion Density (RMCD) as given in the Idaho snow load report (Sack and Sheikh-Taheri 1986). The dataset associated with the 1992 report will be referred to hereafter as UT-1992, while the new dataset associated with this report will be referred to as UT-2017.

Prediction Discrepancies

These curves, along with associated 50 year ground snow load predictions from both the 1992 and 2017 reports, are given in Figure 4. Notice that some curves seem to be fit to minimize prediction error (such as Weber County), while other curves (such as Summit county) were fit to minimize under-predictions. This lack of consistency occasionally creates ground snow load discrepancies along county boundaries. An example of this is the sudden 40% decrease in ground snow load requirements when US Highway 89 crosses from Cache county into Box Elder county as observed in Figure 5.

Discrepancies in UT-1992

In addition to inconsistencies in snow load requirements from county to county, there are also unexplained inconsistencies in predicted 50 year ground snow loads within UT-1992.

One example of the instability in distribution fitting process for predicting 50 year ground snow loads can observed at stations 3929 and 1446 from UT-1992. Despite a geographic distance of a few hundred feet, an elevation difference less than 250 feet, and a max observed snow load within 20 psf, the 50 year snow load at the lower location is more than double the 50 year load at the higher location as observed below.

Name	Elevation	Latitude	Longitude	Max Observed	50 Year
High Line City Creek	5100	40.817	-111.833	103 psf	209 psf
City Creek Water Plant	5330	40.816	-111.832	84 psf	83 psf

Another example of the inconsistencies resulting from outlier values can be seen in comparisons of snow loads at Allen's Ranch in UT-1992 and UT-2017.

Dataset	Elevation	Latitude	Longitude	Max Observed	50 Year
UT-1992	5590	40.883	-109.133	178 psf	116 psf
UT-2017	5490	40.892	-109.143	26 psf	23 psf

The major difference in the max observed snow loads can be partially attributed to outlier snow depth measurements at Allen's Ranch in 1983 as shown below.

Date	Snow Depth (in)	RMCD (psf)
12-19-1983	8	7
12-20-1983	89	178
12-21-1983	8	7

Clearly this high snow depth measurement was in error, yet this erroneous measurement is given major consideration in the distribution fitting process and no doubt contributes to an estimated ground snow load in UT-1992 that is five times higher the estimated snow load in UT-2017. In the face of hundreds of millions of daily station measurements, detecting such inconsistencies can be difficult. Such inconsistencies motivate the set of automated quality assurance measures described later in this report.

Movement towards an updated report began in 2016, when many communities in Utah amended their snow load requirements from values given by the 1992 county specific equations. In some cases the newly amended values were significantly different from the 1992 requirements, as shown in the Results and Implications section of this report. This report aims to resolve many of the discrepancies and inconsistencies observed in the previous report through the use of a new dataset and new spatial methods for predicting ground snow loads. These improvements are made possible through and additional 25 years of high-quality automated snow load data and major advancements in data processing technology.

DATA SET DEVELOPMENT

Nearly all of the data for UT-2017 were obtained from daily snow depth and snow water equivalent (SWE) measurements from the the National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (NOAA 2018), as maintained by the National Climatic Data Center (NCDC).These measurements are comprised of two station types, one being the National Weather Service (NWS) cooperative observer network (COOP) stations, and the National Resources Conservation Service (NRCS) automated Snowpack Telemetry (SNOTEL) stations. Measurements from an additional five SNOTEL stations from Idaho and Colorado that

were not included in the NOAA network were also added to the dataset. The SNOTEL station network for Utah began in 1978 (NRCS 2017) to replace many of the now discontinued snow course stations used in the 1992 report. These SNOTEL stations measure SWE directly on a daily (or even hourly) basis, as opposed to the monthly measurements made at most snow course stations. Many COOP stations do not measure SWE directly, requiring a depth to pressure conversion as discussed later in this report. Despite this limitation, these COOP stations are essential in providing ground snow load measurements relevant to most populated locations in Utah. This is due to the fact that the elevation of the lowest SNOTEL station in Utah is approximately 6000 ft (STATION USS0011H30S), more than 1500 ft higher than most major state municipalities.

UT-2017 is comprised of 279 (192 COOP, 87 SNOTEL) Utah stations with an additional 136 stations (103 COOP, 33 SNOTEL), all located within 62 miles of the Utah border. The data include measurements from November 1, 1969 to May 31, 2017 for a total of 48 snow seasons. This dataset represents an effort to balance data quality and quantity. The initial data collection resulted in more than three million daily readings (from November 1 to May 31 for each snow year) at more than 950 unique station locations in seven different states. The final 415 stations all underwent a rigorous set of quality control measures described in the following subsections. These quality control measures are performed in R with the help of the fields (Douglas Nychka et al. 2015), sp (Pebesma and Bivand 2005) fitdistrplus (Delignette-Muller and Dutang 2015), plyr (Wickham 2011), dplyr (Wickham and Francois 2016) and data.table (Dowle and Srinivasan 2017) software packages. Visualizations and final map renderings are made with the help of the raster (Hijmans 2015), ggplot2 (Wickham 2009), and RcolorBrewer (Neuwirth 2014) packages.

Estimating SWE

Whenever possible, snow pressures were obtained directly from snow water equivalents (SWE) measurements at each station (using $62.426\frac{\text{lbs}}{\text{ft}^2}$ for the specific weight of water). In the absence of SWE measurements, snow loads were estimated using a snow depth to SWE conversion equation proposed by Sturm et al. (2010) and defined using the coefficients for "prairie" terrains at lower elevations and "alpine" terrains at higher elevations. This equation will be referred to as "Sturm's

equation" and can be expressed as

$$p_g(i) = \begin{cases} \frac{62.426h_i}{12}\left[.3608 * \left(1 - e^{(-.0016(2.54h_i)-.0031d_i)}\right) + .2332\right] & \text{Elevation} < 6935\text{ft} \\ \frac{62.426h_i}{12}\left[.3738 * \left(1 - e^{(-.0012(2.54h_i)-.0038d_i)}\right) + .2237\right] & \text{Elevation} \geq 6935\text{ft} \end{cases} \tag{2}$$

where h_i represents snow depth (in inches) and d_i represents the day of the snow year, ranging from -92 (October 1) to 181 (June 30), for any given observation i. Such an equation accounts for the fact that the density of snow typically increases throughout the snow season. This is in contrast to the time invariant Rocky Mountain Conversion Density (RMCD) defined in (Al Hatailah et al. 2015) as

$$p_g(i) = \begin{cases} 0.9h_i & h_i < 22\text{in} \\ 2.36h_i - 31.9 & h_i \geq 22\text{in} \end{cases} \tag{3}$$

where h_i is measured in inches.

Plots of snow depth to pressure estimates using the prairie and alpine equations, as well as RMCD predictions are observed in Figures 6 and 7. This figures show that depth to pressure estimates using the alpine and prairie coefficients are roughly similar, particularly at large snow depths. Both variants of Sturm's equations tend to estimate larger snow loads than the RMCD for snow depths between one and two feet, especially when such depths occur later in the snow season. This likely explains why the 50 year ground snow load estimates at stations in UT-2017 requiring depth to pressure conversions are on average 44% higher using Sturm's equation as opposed to the RMCD. The authors see the use of this more conservative depth to pressure conversion equation (when compared to the RMCD) as being favorable in the context building design.

A "prairie" terrain typically has between 0 to 20 inches of snow cover, while an "alpine" terrain has between 30 and 100 inches of snow cover (Sturm et al. 1995 as converted from the metric units). The separating elevation is selected by looking at a moving average (across elevation) of the mean annual maximum snow depth and determining when this moving average crossed between 25 and

30 inches. The separating elevation of 6935 ft roughly corresponds to the 75th percentile of the unfiltered list of station locations and is the same separating elevation used for the coverage filters described later in this report. Given that many of the high elevation locations are SNOTEL stations not requiring the use of the SWE conversion, the effect of adjusting the separating elevation for prairie and alpine designations would lead to minimal changes in final pressure estimates.

Remove Bad Measurements

Given that only the highest snow load measurements from each season are retained, high outlier snow depth or SWE measurements are very problematic, as observed in the Allen's Ranch example discussed previously. Fortunately, the NCDC provides a suite of data measurement and quality control flags to detect such outliers. These quality control flags identified suspect results in 1983 at Allen's Ranch as being problematic. A summary of these flags comes with the data download (NOAA 2016) with details also available in a formal report (Durre et al. 2010). Station readings failing any of the quality assurance flags are removed prior to analysis (6,375 observations). In addition, any station measurements flagged as "missing value presumed 0" are also removed (795,533 observations). After removing these measurements, the authors conducted a manual search for remaining outliers by flagging any set of three successive measurements within a 10 day with consecutive pressure differences of more than 30 psf. This led to the removal of 16 additional measurements at 9 different station locations. After the removal of missing and suspect results, there remained more than 2.15 million observations at 506 station locations.

Collect Yearly Maximums

Station yearly maximums were separated by water year as opposed to calendar year. For example, a 1995 yearly maximum for a given station would have come from measurements from November 1994 to May 1995. Two issues with grouping the yearly maximums from each station were as follows:

- The same station can have multiple set of location/elevation during the history of their measurements.

- Different stations can have the same location/elevation, most likely in situations where newer station replaced an older (and discontinued) station.

For this study, it was assumed that measurements with the same station number came from the same station location. Use of the median (rather than the mean) station latitude, longitude, and elevation information protects against anomalous meta-data values from having an undue influence on the consolidated location information.

There were three pairs of stations with identical station names yet very different locations or elevations (elevation differences of more than 330 ft and location differences of more than 3 miles). These locations were

- Brows Park Refuge, CO (USC00051020 and)
- Castle Valley, UT (USS0012M13S and)
- Snowbird, UT (USS0011J42S and).

In each case, the stations forming each pair were given unique names.

In addition there were two sets of stations with identical locations and station elevations having a relative difference within 2 percent. In both cases, the the readings from each pair of stations were considered as one combined station. These stations were

- Parachute, CO (USC00056311) and Grand Valley, CO (USC00053508)
- Snow Basin, UT (USC00427924) and Huntsville Snow Basin, UT (USC00424140).

After appropriately separating yearly maximums, additional data filtering techniques were required to ensure stability in the log-normal distribution fitting process.

Lognormal Distribution Fitting

A design ground snow load is a value for which there is an acceptable probability of exceedance during any given year. This typically corresponds to selecting values for which there is a two percent probability of exceedance, often called a 50 year event. Determining this value at any given station location requires fitting a distribution to yearly snow load maximums from which

percentiles can be computed. Current ASCE-7 standards use the log-normal distribution when defining ground snow loads. Alternatively, many western states (including the 1992 Utah report) use the log-Pearson type III distribution in their state-specific snow load reports (Al Hatailah et al. 2015 Theisen et al. 2004). The Montana report includes 50 year estimates from both a log-normal and a log-Pearson type III distribution. The authors chose to follow the precedent set by the ASCE in using the log-normal distribution for design ground snow load estimates. The parameters for each log-normal distribution were estimated using maximum likelihood estimation. Once parameter estimates had been obtained, the design ground snow load was obtained by solving for x_0 in the following equation.

$$p_g^*(\boldsymbol{u}_\alpha) = e^{x_0} \text{ where } \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^{x_0} e^{-\frac{(x-\mu_\alpha)^2}{2\sigma_\alpha^2}} dx = 0.98.$$

Sample histograms of yearly maximums and their associated log-normal distributions are given in Figure (8). The quality of the log-normal distribution fit is given in the associated Q-Q plots, where a good fit is one in which the empirical quantiles follow the theoretical quantiles (i.e. the points closely follow the given straight line). This figure illustrates the varying quality of log-normal distribution fits for different stations.

Apply Coverage Filters

The log-normal distribution fitting process used to estimate 50 year ground snow loads at each station location relies on the assumption that all yearly maximums come from the same log-normal distribution. Stations that lack adequate coverage of the snow season in a given year will often report an artificially low yearly maximum. Reported maximums falling well below the typical range of yearly maximums for a given station lead to unreasonably high estimates of the standard deviation of the log-normal distribution. This, in turn, leads to a poor distribution fit, which tends to produce unreasonably high estimates of the 98th percentile (i.e. a 50 year event). The use of coverage filters guards against the inclusion of these unreasonably low maximums in the distribution fitting process. An example of one of these poor fits, as compared to the improved fit after coverage filters

are applied, is given in Figure. The coverage filters applied were as follows:

- Stations must have readings from the four months in which a yearly maximum is most likely to occur. The most likely months were determined by considering all (non-zero) yearly maximums at stations having readings in every month from November to May. The frequencies of each month in which the maximum were recorded (as separated by elevation) are given in Figure 9.
- If a maximum comes from a year lacking adequate coverage as defined in the previous point, the maximum will still be retained if its value is in the upper half of all yearly maximums for that station.
- Finally, all maximums falling below the 10th percentile of maximums at a given station location are removed prior to distribution fitting. The removal of the smallest 10 percent of measurements further guards against the inclusion of low outliers that will invalidate the distribution fitting process.

A total of 10,450 yearly maximums at 415 station locations remained after applying these coverage filters (an average of 26 usable maximums at each location).

Log-normal Distribution Considerations

It is important to remember that the 50 year ground snow loads estimated from a log-normal distribution depend on key statistical assumptions. These assumptions include

- Yearly maximums are independent from year to year. In other words, there is no mechanism for modeling any trends in snow loads throughout the period of record.
- Yearly maximums at each station location all come from the same log-normal distribution.

There have been documented changes in measurement tools (such as updating components of a SNOTEL station) and sampling site conditions (such as the significant loss of tree cover due to logging or beetle infestation) at various station locations in Utah (Julander and Bricco 2006). These changes potentially invalidate both of the above described statistical assumptions for the log-normal

distribution. In addition, multiple sources claim that the snow fall and snow pack are experiencing a long term decline across the Pacific northwest (Mote 2006, Scott and Kaiser 2004) and in Utah specifically (Gillies et al. 2012). It is impossible to accommodate any long term climatic trends as part of any distribution fitting process. Lastly, the instability issues in the distribution fitting process described in the coverage filter section suggest that yearly maximums do not always follow a log-normal distribution at every station location. Such fitting problems are not unique to the log-normal distribution and is a shortcoming of any distribution fitting process. Trying to select a "best fit" distribution from a list of candidate distributions would be difficult as any measure of fit is not guaranteed to identify the true underlying distribution. As such, techniques involving the selection of a distribution from a list of candidate distributions would add unnecessary complexity to the estimation process with no guarantee of improvement.

The use of the log-normal distribution to estimate 50 year ground snow loads also has a strong precedent for use in predicting ground snow loads by the ASCE. Despite its limitations, this distribution fitting technique seems to, in most cases, provide reasonable estimates for 50 year ground snow load events. In addition, the use of multiple coverage filters helps to minimize instances of unstable or unreasonable estimates resulting from the log-normal distribution. The cautions outlined in this report do not invalidate the use of the log-normal distribution, but serve to give the 50 year estimates given in the final dataset proper context.

On average, the 50 year ground snow load estimate is within 15% of the maximum max on UT-2017. To guard against unstable distribution predictions, 50 year estimates were restricted be no more than 50% different than the maximum max at a particular station. In total, this led to the adjustment of 50 year estimates at seven stations (three Utah stations, four outside of Utah), all of which had 50 year estimates more than 50% larger than the maximum max. In addition, 100 year estimates were not allowed to be more than double the maximum max.

METHODS

Proper consideration of elevation is a vital to predicting ground snow loads in Utah. Plots of the relationship between ground snow loads and elevation, as well as a log transformation of ground

snow loads and elevation, is given for both UT-2017 and UT-1992 in Figure 10. These figures show that for both datasets, there is a log-linear relationship between ground snow loads and elevation. This relationship can be characterized by

$$\log(p_g^*(\boldsymbol{u})) = \beta_0 + \beta_1 A(\boldsymbol{u}) \tag{4}$$

where β_0 and β_1 are calculated via ordinary least squares regression (OLS). Predictions using OLS are reflected in the gray lines given as part of Figure 10. The red lines included in Figure 10 are calculated via generalized least squares regression (GLS), where the coefficients are calculated after accounting for the spatial correlations between observations. In both cases, final snow load predictions are made by exponentiating the linear predictions made on the log-scale.

The limitation with the linear models shown in Figure 10 is that they fail to account for the climatic properties of the location of interest. These other climatic factors likely explain the wide spread of the data points about each of the given lines. Both linear models would predict nearly identical snow loads for Park City and Loa, despite both locations having very different climates. The two proposed models for predicting ground snow loads extend the predictions in (4) by accounting for additional properties of the location of interest. These two methods are PRISM and Kriging.

PRISM

PRISM (Parameter-elevation Relationships on Independent Slopes Model) extends (4) by calculating the beta coefficients using weighted least squares regression. This model is represented as

$$\log(p_g^*(\boldsymbol{u})) = \beta_0(\boldsymbol{u}, \boldsymbol{X}) + \beta_1(\boldsymbol{u}, \boldsymbol{X}) A(\boldsymbol{u}) \tag{5}$$

The slope and intercept coefficients are now a function of station location and other metadata information (denoted by $\boldsymbol{X}$). These weights allow for a unique calculation of the regression parameters at each location of interest ($\boldsymbol{u}^*$). Thus, every prediction with PRISM is created using a

unique set of coefficients for (5). The weights allow for stations most relevant to the area of interest to have higher priority in the parameter calculations.

The regression weights are a function of several factors defined in this adaptation of the algorithm as

$$W(\boldsymbol{u}^*, \boldsymbol{X}) = W_c \left[F_d W_d^2 + F_z W_z^2\right]^{\frac{1}{2}} W_b, \tag{6}$$

where weights are a function of a cluster (W_c), distance (W_d), elevation (W_z) and basin W_b weights. F_d and F_z are importance factors that adjust the influence of distance and elevation weights with the stipulation that $F_d + F_z = 1$. Each weight is a vector containing one value for each station location. These vectors are scaled to individually and collectively sum to one. The matrix $\boldsymbol{X}$ contains relevant station meta-data used to calculate each of the weights, including:

- station coordinates (in decimal degrees longitude and latitude).
- station elevations
- station 12-digit hydrologic unit codes (HUC).

The weights given above are an adaptation of the original weighting scheme proposed by the authors of PRISM (Daly et al. 2002, Daly et al. 2008). These weights are described in Bean et al. (2017b) and are also summarized in the following subsections.

Distance Weighting

The closer a station lies to the area of interest, the more weight that station receives. Stations within a user defined minimum radius of influence (r_m) receive full weight, while stations outside the radius of influence receive a weight inversely proportional to their distance to the area of interest.

$$W_d(\boldsymbol{u}^*)[\alpha] = \begin{cases} 1 & D(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) - r_m \leq 0 \\ \frac{1}{(D(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) - r_m)^a} & D(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) - r_m > 0 \end{cases} \tag{7}$$

where (a) allows the user to control how quickly station influence decreases with increases in distance (Daly et al. 2008).

Elevation Weighting

Stations are given more weight if their elevation is similar to the elevation of the area of interest. The absolute elevation difference between the location of interest and each station (i.e. $\Delta z(\boldsymbol{u}^*, \boldsymbol{u}_\alpha)$) is compared to user specified minimum (Δz_m) and maximum (Δz_x) elevation thresholds.

$$W_z(\boldsymbol{u}^*)[\alpha] = \begin{cases} \frac{1}{\Delta z_m^b} & \Delta z(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) \leq \Delta z_m \\ \frac{1}{\Delta z(\boldsymbol{u}^*, \boldsymbol{u}_\alpha)} & \Delta z_m < \Delta z(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) < \Delta z_x \\ 0 & \Delta z(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) \geq \Delta z_x \end{cases} \tag{8}$$

where (b) allows adjust how quickly station influence decreases with increases in elevation difference (Daly et al. 2002).

Cluster Weighting

"Cluster weighting seeks to limit the influence of stations that are clustered with other nearby stations, which can lead to over-representation in the regression function" (Daly et al. 2008). This weight is computed as

$$W_c[\alpha] = \frac{1}{1 + S_c(\alpha)} \tag{9}$$

with

$$S_c(\alpha) = \sum_{\beta=1}^{n} h_{\alpha\beta} v_{\alpha\beta} \tag{10}$$

where ($h_{\alpha\beta}$) and ($v_{\alpha\beta}$) represent the horizontal and vertical cluster factors between station α and β respectively.

Any pair of stations α and β that have a geographic distance between them that is within 20%

of the minimum radius of influence (r_m) will have a non-zero horizontal cluster factor.

$$h_{\alpha\beta} = \begin{cases} 0 & D(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) > 0.2r_m \\ \frac{0.2r_m - D(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta)}{0.2r_m} & 0 \leq D(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) \leq .2r_m \end{cases} . \tag{11}$$

Similarly, any pair of stations α and β that have an absolute elevation difference between them that is within a user defined elevation precision (p) will have a non-zero vertical cluster factor.

$$v_{\alpha\beta} = \begin{cases} 0 & \left(\Delta z(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) - p\right) > p \\ \frac{2p - \Delta z(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta)}{p} & \left(\Delta z(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) - p\right) \leq p \end{cases} \tag{12}$$

Basin Weighting

It is well known that precipitation patterns can be significantly different on the windward and leeward side of mountain slopes. The original PRISM algorithm uses a set of weights that accommodate the influence of mountainous terrain on climate patterns. Unfortunately, these weights are difficult to replicate from the available literature. However, mountain slopes govern the flow of water in the state of Utah and these flow patterns determine the watershed boundaries of the state. A map of these watershed boundaries helps to separate the major ridges and valleys of Utah and is readily available through the USGS (USGS 2016b) as defined by a set of 12 digit Hydrologic Unit Codes (HUC). Each set of two digits defines a hierarchy of watersheds for a location of interest. The first two digits define the great water basins of North America, while the next two digits define a collection of individual watersheds within each HUC-2 watershed. This pattern continues for 12 digits with HUC-12 watersheds in and around Utah encompassing an average area of about 36 square miles. An example of HUC-4 water basins in Utah (as separated by color) is given in Figure 11. Differences between the ground snow loads in the Great Basin vs the Colorado River basin (both HUC-2 designations) are given in Figure 12. This figure highlights the differences in 50 year ground snow loads between these two basins, particularly at high elevations. These differences

motivate the authors' creation of the basin weight defined as

$$W_{b_i}(\boldsymbol{u}^*)[\alpha] = \left(\frac{s(\boldsymbol{u}^*, \boldsymbol{u}_\alpha) + 1}{5}\right)^c, \tag{13}$$

where $s(\boldsymbol{u}^*, \boldsymbol{u}_\alpha)$ represents the number of common watersheds (four levels ranging from HUC 2 through 8) shared by station i and the target grid cell, and c controls how quickly station influence decreases as the number of different HUC designations increases.

Final Weight Selections

In total there are eight different parameters that must be defined by the user in this adaptation of PRISM (there are several more parameters that must be defined in the original version). Typical values for many of these weights are given in Table 1 of Daly et al.(2002). The selection of these weights are usually selected with expert judgment or through cross validation. An initial set of parameters were determined by considering hundreds of thousands of combinations of all eight parameters, selecting a set of parameters that nearly minimized the cross validated error. These parameters are given in Table 2 of Bean et al. (2017b) and are used to calculate mean and median absolute errors provided in this manuscript. However, when tuning with so many dimensions, very different parameter combinations give almost identical cross validated errors, making it difficult to know what parameters are most appropriate for final predictions. In order to reduce the dimensionality of the tuning process, the authors fixed parameters for which Daly et al. (2002) suggested only one value (a, b, F_d). In addition, the authors required that the minimum elevation elevation parameter (Δz_m) and the elevation precision parameter (p) be identical. This reduces the dimensionality of the tuning process from eight dimensions to four. The final set of parameters are given below with tuned parameters denoted by an asterisk. Preference was given to tuned parameter values that fell within the typical parameter bounds provided in Daly et al. (2002).

Weight	Parameter	Tuned Value	Typical Value
F_d		0.8	0.8
W_b	c^*	3	n/a
W_c	$p = \Delta z_m$	330ft	n/a
W_c, W_d	r_m^*	31mi	19-62mi
W_d	a	2	2
W_z	b	1	1
W_z	Δz_m^*	330ft	330-985ft
W_z	Δz_x^*	4920ft	1640-8200ft

Illustrated Examples

PRISM predictions at some notable locations are visualized in Figure 13 and 14. This location information is made available through the USGS Domestic Name database (USGS 2018). In these plots, the 100 stations with the highest weights for the location of interest are plotted along with the weighted least squares regression line in red. The blue cross hairs represent the elevation and snow load prediction at each location. Figure 14 shows differences in ground snow load predictions at two pairs of locations with nearly identical elevations but very different climates. This illustrates PRISM's automatic recalculation of the linear model coefficients to accommodate the climate conditions of the location of interest. Keep in mind that the prediction values on the y-axis are on the log scale, meaning that small visual differences can imply major differences in final pressure estimates. For example, the final pressure estimates for Park City and Loa, UT are 104 psf and 27 psf respectively.

Kriging

The family of Kriging estimators leverage the spatial correlations between observations to make predictions. Details regarding this family of estimators are given in Goovaerts (1997). This project

uses Universal Kriging (UK) defined as

$$\log\left(\hat{p}_g^*(\boldsymbol{u}^*)\right) = \sum_{\alpha=1}^{N} \lambda_\alpha \log\left(p_g^*(\boldsymbol{u}_\alpha)\right) \tag{14}$$

where the weights λ are calculated to minimize the variance between the predicted and actual ground snow load values i.e. $\min\left[Q(\boldsymbol{\lambda})\right] = \min\left[E\left[\log\left(\hat{p}_g^*(\boldsymbol{u}^*)\right) - \log\left(p_g^*(\boldsymbol{u}^*)\right)\right]^2\right]$. The minimization of $Q(\boldsymbol{\lambda})$ is calculated by solving following system of equations

$$\begin{cases} \sum_\alpha \lambda_\alpha C_R(\boldsymbol{u}_\alpha - \boldsymbol{u}_\beta) + \sum_l \mu_l(\boldsymbol{u}) f_l(\boldsymbol{u}_\alpha) = C_R(\boldsymbol{u}_\beta - \boldsymbol{u}^*) \quad \beta = 1, \cdots, n. \\ \sum_\alpha \lambda_\alpha A(\boldsymbol{u}_\alpha) = A(\boldsymbol{u}^*) \\ \sum_\alpha \lambda_\alpha = 1 \end{cases} \tag{15}$$

where C_R represents the covariance of the residual differences between any two observations after accounting for the effect of elevation. Covariance is an unscaled version of correlation and can be used as a measure of similarity (in terms of behavior) between observations. This covariance is assumed to be a function of distance where the covariance between any two observations decreases as the distance between them increases.

It is necessary for the user to define the covariance function for use in kriging. In this case, these covariances are modeled through the use of a variogram. The variogram (or, alternatively, semi-variogram) is a theoretical function defined symbolically as

$$\gamma(\boldsymbol{u}_\alpha, \boldsymbol{u}_\beta) = \frac{1}{2} Var\left[r(\boldsymbol{u}_\alpha) - r(\boldsymbol{u}_\beta)\right]. \tag{16}$$

This variogram is inversely related to the covariance (i.e. increases in the variogram correspond with decreases in the covariance) and is also assumed to be a function of distance. In practice, this function can be estimated through an empirical variogram defined as

$$\hat{\gamma}(\boldsymbol{h}) = \frac{1}{2N_{\boldsymbol{h}_1}} \sum_{\alpha_{\boldsymbol{h}}=1}^{N_{\boldsymbol{h}}} \left[r(\boldsymbol{u}_{\alpha_{\boldsymbol{h}_1}}) - r(\boldsymbol{u}_{\alpha_{\boldsymbol{h}_2}})\right]^2 \tag{17}$$

where $\left[r(\boldsymbol{u}_{\alpha_{h_1}}), r(\boldsymbol{u}_{\alpha_{h_2}})\right]$ represents each pair of regression model residuals located $||\boldsymbol{h}||$ distance away from each other. It is the theoretical variogram that is used to determine the values of the covariance function given in (15).

While the above described prediction method seems to be very different than PRISM in terms of structure, the predictions made in (14) are mathematically equivalent to extending equation (4) as

$$\log\left(p_g^*(\boldsymbol{u})\right) = \beta_0^* + \beta_1^* A(\boldsymbol{u}) + \sum_{\alpha=1}^{N} \lambda_\alpha(\boldsymbol{u}) r(\boldsymbol{u}_\alpha) \tag{18}$$

where β_0^* and β_1^* are calculated using generalized least squares regression (GLS). Thus universal kriging predictions are made by

- estimating the ground snow load from elevation through generalized least squares regression
- determining the residual value (i.e. the difference between the actual 50 year ground snow load and the predicted 50 year ground snow load) at each station location
- updating the linear model prediction using a weighted average of the station residual values. Stations most closely correlated with the location of interest will have the most influence this weighted average calculation.

All of these steps are performed simultaneously within the universal kriging procedure. This method may also be referred to as "kriging with an external drift" or "regression kriging". The numerical implementation of the UK is performed using the gstat package (Pebesma 2004) in R. An example of the empirical and associated theoretical variograms used for UT-2017 and UT-1992 are given in Figure 15. The theoretical variogram shown for UT-2017 was used in final UK predictions.

Idaho's Inverse Distance Weighting

For purposes of comparison, the authors have implemented a version Idaho's inverse distance weighting based on normalized ground snow loads (NGSL) as described in the the 2015 Idaho snow load report (Al Hatailah et al. 2015). NGSL is simply snow load divided by elevation $\left(\frac{P_g(\boldsymbol{u}_\alpha)}{A(\boldsymbol{u}_\alpha)}\right)$ and is an alternative way of accounting for the effect of elevation on ground snow loads as compared to

the log-linear models described previously. In this method, snow load predictions are calculated as a weighted average of the NGSL of surrounding station locations, defined symbolically as

$$p_g^*(\boldsymbol{u}) = \frac{A(\boldsymbol{u})}{\sum_{\alpha=1}^{N} D\left(\boldsymbol{u}_\alpha, \boldsymbol{u}\right)} \sum_{\alpha=1}^{n} \left[\left(\frac{1}{D\left(\boldsymbol{u}_\alpha, \boldsymbol{u}\right)} \right)^c \frac{P_g(\boldsymbol{u}_\alpha)}{A(\boldsymbol{u}_\alpha)} \right]. \tag{19}$$

The variable c controls the rate at which station influence decreases as distance increases. The Idaho report separates the stations and corresponding area of interest into two layers above and below 4,0000 ft. In the lower layer, predictions are made use $c = 2$ while $c = 4$ is used for predictions in the upper layer.

ACCURACY COMPARISONS

One shortcoming of many state snow load reports is a lack of discussion regarding the accuracy of the selected spatial prediction method. One option for measuring method accuracy is through cross validation, where the data are randomly separated into k groups ($k = 10$ for this report) and $k - 1$ groups are used to fit a model that is then used to make predictions for the remaining group. This process is repeated k times until a prediction is made for each observation in the dataset. These predictions are then compared to the station observations, and the resulting errors serve as a measure of model accuracy. Cross validation is a widely used technique across many disciplines and detailed results for the ground snow load methods used in this report are given in Bean et al. (2017a, 2018). For convenience, relevant results are summarized below.

Cross validated errors are defined as

$$E(\boldsymbol{u}_\alpha) = \hat{P}_g(\boldsymbol{u}_\alpha) - P_g(\boldsymbol{u}_\alpha) \tag{20}$$

where $\hat{p}_g^*(\boldsymbol{u}_\alpha)$ and $p_g^*(\boldsymbol{u}_\alpha)$ are the predicted and actual ground snow loads at station location $\boldsymbol{u}_\alpha$ respectively. Using this definition, positive errors indicate over-predictions and negative errors indicate under-predictions.

These individual errors are summarized using (MAE) and mean error (ME) defined as

$$\begin{aligned} \text{MAE} &= \frac{1}{N}\sum_{\alpha=1}^{N} |E(\boldsymbol{u}_\alpha)| \\ \text{ME} &= \frac{1}{N}\sum_{\alpha=1}^{N} E(\boldsymbol{u}_\alpha) \end{aligned} \tag{21}$$

where N represents the total number of stations.

Figure 16 shows that cross-validated errors can become very large as elevation increases. This problem is exacerbated when trying to predict at locations on the outer-edges of the region encompassing the data. This causes the MAE to be strongly influenced by very high errors at a small group of locations. In addition, the random separation of groups causes the cross validation results to change slightly for each iteration. To account for these effects, cross validation is run 100 times for each method and MAE and median absolute error (Med-AE) is stored for each iteration. The mean MAE and Med-AE are plotted as bars in Figure 17, where the black whiskers represent the maximum and minimum values resulting from the 100 cross validation iterations. These whiskers help to visualize the variability resulting from various runs of cross validation.

Figure 17 shows that PRISM and Kriging has cross validated errors (using UT-2017) 40-45% lower than the current prediction methods used in Idaho and Utah. The results are similar for cross validated errors using UT-1992, which ensures that the results observed in UT-2017 are not simply a product of the dataset. In both cases, PRISM and UK have almost identical errors, although UK predictions have noticeably lower error when predicting on the dataset provided for the 2015 Idaho snow load report (Bean et al. 2018).

Results in Figure 18 are obtained by fitting a second-degree loess smoothing curve to the errors and absolute errors resulting from one iteration of cross validation. These curves plot a smooth local average of station errors across elevation and are calculated using the final set of PRISM parameter values given earlier in this report. Absolute errors help to visualize error magnitude and raw errors helps to visualize prediction bias (i.e. a tendency to under-predict or over-predict). Smoothed errors roughly equal to zero indicate that the method is unbiased for the respective elevation. All methods

except SNLW tend to slightly under-predict ground snow loads at elevations around 8000 ft. The rate of error for all methods except SNLW also seem to level off around 7000-9000 feet. On both datasets, IDW tends to over-predict at elevations of 4000-8000 ft and under-predict at elevations above 8000 ft. This is due to the fact that normalized ground snow loads do not fully account for the effect of elevation on ground snow loads, as articulated in Bean et al. (Bean et al. 2018). Both PRISM and UK tend to be roughly unbiased for all elevations except those between 6500-8500 ft. Recalling Figure 10, this roughly corresponds to the elevation range with the highest design snow loads in UT-2017. Any spatial model will struggle to accurately predict the highest valued snow loads when such observations are excluded during the model fitting process.

It could be argued that the cross-validated results for SNLW are not completely fair. These equations were developed without access to UT-2017 and in many cases were not designed to minimize error as discussed previously. Their asymmetrical errors make sense when considering the serious consequences associated with inadequate snow load design. However, any building design will necessarily involve the selection of load factors from a proper reliability analysis (Nowak and Collins 2012). This analysis will result in conservative adjustments to estimated loads to ensure building safety. This in mind, the authors believe that ground snow load estimates should be as accurate and reliable as possible, knowing that conservative adjustments will inevitably be made to these predictions.

These cross validation results provide vital information about the nature of the prediction errors for each method. They provide an objective measure for method comparison and greatly aid in final model selections. It is important to remember, however, that these cross validated results rely on station 50 year ground snow loads, which are estimates themselves subject to uncertainty. While these cross validated results help to detect general error patterns among methods, it is unclear whether the prediction error at an individual station location is due to a shortcoming in the model, or a shortcoming in the 50 year estimate. In addition, cross validation is no substitute for true test data (i.e. new data not considered during the model building process). This was not possible to accomplish for this report, as model development required every possible station satisfying the

rigorous filtering procedures described previously. Even with the limitations of cross validation in mind, these results provide a comprehensive and defensible analysis and comparison of ground snow load prediction methods not found in the current snow load literature.

FINAL RESULTS AND IMPLICATIONS

The final product resulting from this study is a 0.62 by 0.62 mile grid of snow load values for the entire state of Utah. Elevations for these grid cells were obtained by aggregating data from 100ft by 100ft (30m by 30m) digital elevation models as obtained from the National Map download manager (USGS 2016a). Snow load values from this map can be obtained from snow load website associated with this report. At this website, users can input their address and obtain the ground snow load requirement (along with the elevation used to calculate the ground snow load) for any location in Utah.

Practical Prediction Constraints

Final predictions given in this report are bounded below by 21 psf to meet ASCE 7 guidelines, but there is no well defined upper bound for snow load predictions. This become problematic when using PRISM and UK to estimate snow loads at elevations significantly higher than all nearby stations. In these instances, the extrapolation of the elevation relationship leads to unreasonably high snow load estimates. This is partially due to that fact that small variations in the log-scale predictions can lead to very large differences when transforming back to a standard scale. However, the use of a log-scale is imperative for ensuring accurate predictions at lower, populated, elevations for which design requirements will be more relevant.

To mitigate this "peak effect", PRISM and UK predictions are not allowed to extend beyond the highest 50 year station ground snow load, which is approximately 429 psf. For UK, the estimation of the trend (the linear model portion of the model) is not allowed to exceed the predicted trend for the highest elevation station. The effect of these restrictions is observed at several Utah mountain peaks in Figure 19. It is clear, particularly for the highest peaks along the Wasatch front, that the snow load restrictions are vital for sensible results at these locations. The peak effect is reduced in the final snow load map as grid cell predictions are made using the averaged elevations that smooth

out many mountain peaks. The snow load maps provided in this report reflect the upper and lower bound constraints described in this section. The city-specific comparisons provided in this report are made without applying these bounds.

Map Comparisons

Examples of snow load prediction maps are given in Figure 20 using a 2.2 by 2.2 mile grid rather than the finer grid used for the snow load website. Method predictions are compared to the 1992 equation predictions in Figure 21. This map shows that all considered methods generally predict lower ground snow loads, particularly in the northeastern corner of the state. Notable locations where ground snow load predictions are higher than the 1992 equations are the Ben Lomond Peak Area, the outer rim of the Uintah basin, and high elevation areas in and near Monticello and Enterprise Utah.

Differences for each prediction method using using UT-1992 instead of UT-2017 are given in Figure 22. This plot shows that each of the considered methods method would generally predict higher ground snow loads using UT-2017 as input, particularly in the Uintah basin area. This is likely due to the use of Sturm's equation to estimate SWE, which generally resulted in higher snow load predictions, and the use of the log-normal distribution instead of the log-Pearson type III distribution. Note that changes in predictions between datasets are most drastic using IDW. This is due to the fact that this method, by construction, must fit the input dataset exactly, as opposed to the smoothing that naturally occurs when using a regression based method such as PRISM or UK.

As a final check, differences in PRISM and UK predictions are compared to predictions made along the Colorado and Idaho borders as observed in Figures 23 and 24. Snow load requirements for these bordering states were obtained by the authors using information from the respective SEA websites and snow load reports (Torrents et al. 2016; Al Hatailah et al. 2015). Colorado predictions were made using their snow load prediction equation with the necessary parameter values obtained from a Google Earth contour map provided by the SEAC. Predictions for Idaho were made using the authors' implementation of IDW as applied to the Idaho dataset. The implementation of these two are similar, but not exact, to official ground snow load requirements in Colorado and Idaho.

Nevertheless, these figures aid in understanding the similarities and differences in ground snow load predictions made by neighboring states.

City Specific Comparisons

In addition to the state-level comparisons given in the previous section, changes in ground snow loads can be visualized on a community specific level. For these comparisons, current and historical post office locations in Utah were obtained from the USGS Domestic Name database (USGS 2018) and results were stored in table, rather than in map format. Figure 25 compares predictions for the 16 communities that amended their ground snow load requirements in 2016 (Utah 2016). The predicted values are generally lower than the original 1992 requirements, as are the amended values. In some cases the amended requirements are much lower than the original equation predictions, particularly in Rich county. As observed in Monticello, sometimes the spatial methods predict higher snow loads than those specified previously. Predictions for each of the northern and southern county seats are given in Figures 26 and 27 respectively. A list of communities in Utah that experience increases in ground snow load from this study are given in Figure 28. The exceptionally high ground snow load requirements in Farmington (Figure 26) and Willard (Figure 28) illustrate the instability of IDW when using normalized ground snow loads at high elevation stations to predict at low elevation locations (Bean et al. 2018). This is in contrast to the prediction issues UK and PRISM experienced at high elevations. Given that snow load predictions are more relevant for low elevation populated places like Farmington and Willard than they are for high elevation unpopulated places like Kings Peak, the authors feel these results are further evidence that the UK and PRISM predictions should be preferred to the current Idaho method when predicting ground snow loads for Utah.

CONCLUSION

This report has outlined the process underlying the new ground snow load predictions for Utah. These predictions were made with a new ground snow load dataset subject to a variety of quality assurance measures intended to stabilize 50 year estimates. Design ground snow loads were obtained using the 98th percentile of a log-normal distribution as fit to the yearly snow season

maximums at each station location. After developing this dataset, several spatial methods for predicting ground snow loads between station locations were compared via cross validation. These results indicated that PRISM and Universal Kriging had roughly similar cross validated errors that were lower than all other considered methods. Limitations of PRISM and UK at high elevation locations were explored and practical prediction constraints were described. Both PRISM and Kriging have limitations to their predictive power, as would any spatial method used for predicting ground snow loads. However, these methods have proven to provide more accurate ground snow load predictions than their counterparts. Location specific differences between predictions were compared using a variety of maps and tables. Predictions were also compared along the Idaho and Colorado borders using those states' respective snow load estimation methods. In most populated places, the predictions given by PRISM and UK were fairly similar. The final result of these efforts is a snow load prediction map that provides ground snow load requirements for any address/location in Utah. The details provided in this report provide a defense and justification for their use. In addition, the details for developing ground snow loads provided in this report will serve as a framework for the SEAU as they strive to ensure the safety and reliability of Utah building designs now and in the future.

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TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00420519	BEAVER	01	38.283	−112.633	5,932	12	25	28	31
USC00420527	BEAVER CANYON PH	01	38.267	−112.482	7,275	38	122	114	122
USS0012L07S	BIG FLAT	01	38.300	−112.360	10,349	39	194	206	222
USS0012L12S	MERCHANT VALLEY	01	38.300	−112.440	8,703	37	130	128	137
USC00425654	MILFORD	01	38.400	−113.017	5,025	39	30	35	41
USC00429152	WAH WAH RANCH	01	38.483	−113.426	4,880	29	35	30	35
USC00420506	BEAR RIVER REFUGE	02	41.467	−112.267	4,213	12	34	33	39
USC00420928	BRIGHAM CITY WASTE PLANT	02	41.520	−112.044	4,230	32	36	38	44
USC00421731	CORINNE	02	41.550	−112.114	4,230	22	36	40	45
USC00421918	CUTLER DAM	02	41.833	−112.053	4,290	31	71	66	77
USC00423486	GROUSE CREEK	02	41.714	−113.883	5,320	38	43	48	55
USC00426658	PARK VALLEY	02	41.800	−113.333	5,525	14	32	33	37
USC00426938	PLYMOUTH	02	41.872	−112.149	4,470	14	30	31	35
USC00427931	SNOWVILLE	02	41.967	−112.717	4,561	12	25	36	41
USC00428668	THIOKOL PROPULSION F S	02	41.717	−112.433	4,600	37	31	36	42
USC00428817	TREMONTON	02	41.711	−112.164	4,310	29	35	45	53
USC00428978	UTAH TEST RANGE	02	41.050	−112.937	4,440	16	18	18	21
USS0011H55S	DRY BREAD POND	03	41.410	−111.540	8,350	39	212	223	244
USC00423671	HARDWARE RANCH	03	41.600	−111.567	5,561	17	45	66	74
USS0011H25S	LITTLE BEAR	03	41.410	−111.830	6,544	39	133	141	155

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00425194	LOGAN 5 SW EXPERIMENTAL FARM	03	41.667	−111.891	4,490	44	40	46	51
USC00425182	LOGAN RADIO KVNU	03	41.735	−111.839	4,499	35	47	39	44
USC00425186	LOGAN UT STATE UNIVERSITY	03	41.750	−111.803	4,790	44	34	35	38
USS0011H57S	MONTE CRISTO	03	41.470	−111.500	8,960	39	258	282	304
USC00427271	RICHMOND	03	41.903	−111.813	4,680	47	45	44	48
USS0011H58S	TEMPLE FORK	03	41.790	−111.550	7,406	16	151	152	163
USS0011H36S	TONY GROVE LAKE	03	41.900	−111.630	8,474	39	344	357	385
USC00428828	TRENTON	03	41.917	−111.913	4,455	33	48	53	61
USC00423836	HELPER CARBON PLANT	04	39.730	−110.866	6,100	22	27	29	34
USC00423896	HIAWATHA	04	39.483	−111.017	7,230	14	41	45	50
USC00426340	NUTTERS RANCH	04	39.800	−110.250	5,790	13	34	50	59
USC00427026	PRICE BLM	04	39.608	−110.809	5,613	27	30	34	39
USC00427720	SCOFIELD	04	39.717	−111.150	7,717	12	108	103	108
USC00427724	SCOFIELD DAM	04	39.785	−111.118	7,632	20	96	111	122
USC00427729	SCOFIELD SKYLINE MINE	04	39.684	−111.205	8,710	33	146	140	156
USC00428474	SUNNYSIDE	04	39.567	−110.367	6,729	12	44	56	63
USC00429368	WELLINGTON 3 E	04	39.545	−110.686	5,400	27	28	38	44
USC00420050	ALLEN S RANCH	05	40.892	−109.143	5,490	21	26	23	27
USC00422864	FLAMING GORGE	05	40.932	−109.412	6,270	46	34	33	37
USS0009J08S	HICKERSON PARK	05	40.910	−109.960	9,145	32	80	71	75

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00424321	JARVIE RANCH	05	40.899	−109.179	5,512	12	12	16	18
USC00425377	MANILA	05	40.990	−109.726	6,442	24	26	24	27
USC00420820	BOUNTIFUL VAL VERDA	06	40.854	−111.890	4,540	32	41	39	44
USS0011J11S	FARMINGTON	06	40.990	−111.820	8,000	39	348	354	381
USC00422726	FARMINGTON 3 NW	06	41.018	−111.925	4,380	39	46	38	42
USS0011J12S	FARMINGTON LOWER	06	40.970	−111.810	6,779	14	168	218	237
USS0011J68S	PARRISH CREEK	06	40.930	−111.810	7,740	18	230	234	250
USC00427318	RIVERDALE	06	41.150	−112.000	4,400	13	21	23	24
USC00429346	WEBER BSN PUMP PLANT 3	06	41.113	−111.912	4,900	24	68	58	64
USC00420074	ALTAMONT	07	40.361	−110.283	6,375	43	42	51	58
USS0010J30S	BROWN DUCK	07	40.580	−110.590	10,600	39	209	206	223
USS0010J43S	CHEPETA	07	40.770	−110.010	10,592	37	187	156	168
USC00422253	DUCHESNE	07	40.167	−110.400	5,520	36	26	35	40
USS0010J26S	FIVE POINTS LAKE	07	40.720	−110.470	10,940	37	195	186	200
USC00423624	HANNA	07	40.400	−110.767	6,745	15	96	89	106
USS0010K01S	INDIAN CANYON	07	39.890	−110.750	9,175	39	236	147	163
USS0010J10S	LAKEFORK 1	07	40.600	−110.430	10,415	39	134	140	152
USS0010J25S	LAKEFORK BASIN	07	40.740	−110.620	10,966	26	243	216	233
USC00425969	MYTON	07	40.195	−110.062	5,081	21	29	27	33
USC00426123	NEOLA	07	40.417	−110.050	5,950	35	43	44	51

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USS0010J18S	ROCK CREEK	07	40.550	−110.690	7,889	36	93	90	98
USC00421214	CASTLE DALE	08	39.208	−111.015	5,620	36	24	29	33
USC00421216	CASTLEDALE HTR UP AND L	08	39.180	−111.033	5,660	23	34	31	38
USC00422798	FERRON	08	39.087	−111.132	5,930	42	30	33	38
USC00423418	GREEN RIVER AVIATION	08	38.995	−110.152	4,071	32	26	32	40
USS0011K28S	RED PINE RIDGE	08	39.450	−111.270	9,009	39	176	171	186
USC00420849	BOULDER	09	37.905	−111.420	6,680	40	61	51	60
USW00023159	BRYCE CANYON ARPT	09	37.700	−112.150	7,587	13	67	93	110
USC00421008	BRYCE CANYON NATIONAL PARK HQS	09	37.641	−112.168	7,915	43	109	110	125
USS0011M06S	CLAYTON SPRINGS	09	37.970	−111.830	10,049	17	131	119	128
USC00422592	ESCALANTE	09	37.768	−111.598	5,810	38	45	41	47
USC00423776	HATCH	09	37.650	−112.433	6,899	22	62	49	56
USC00426601	PANGUITCH	09	37.817	−112.439	6,647	25	30	29	33
USC00428847	TROPIC	09	37.626	−112.082	6,281	21	43	39	43
USS0011M03S	WIDTSOE 3	09	37.840	−111.880	9,640	39	152	148	163
USC00429514	WIDTSOE 3 NNE	09	37.875	−111.973	7,540	18	44	41	47
USC00420336	ARCHES NATIONAL PARK HQS	10	38.617	−109.619	4,130	29	14	16	20
USC00421241	CASTLE VALLEY	10	38.651	−109.399	4,720	20	24	19	22
USS0009K01S	EAST WILLOW CREEK	10	39.310	−109.530	8,301	31	79	86	93
USC00425733	MOAB	10	38.574	−109.546	4,048	35	11	17	21

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00428705	THOMPSON	10	38.967	−109.717	5,100	13	26	32	37
USC00420757	BLOWHARD MOUNTAIN RADAR	11	37.596	−112.865	10,694	35	327	326	352
USC00420900	BRIAN HEAD	11	37.693	−112.847	9,770	21	304	345	378
USS0012M13S	CASTLE VALLEY UT US	11	37.660	−112.740	9,580	36	162	158	173
USC00421259	CEDAR CITY	11	37.708	−113.119	6,045	16	29	34	37
USC00421260	CEDAR CITY 5 E	11	37.653	−112.996	6,450	34	48	39	43
USW00093129	CEDAR CITY MUNICIPAL ARPT	11	37.700	−113.100	5,610	33	20	27	31
USC00421273	CEDAR CITY STEAM PLA	11	37.667	−113.033	5,994	13	26	26	28
USC00422561	ENTERPRISE BERYL JCT	11	37.767	−113.650	5,150	23	24	26	30
USS0013M05S	KOLOB	11	37.530	−113.050	9,206	38	288	284	316
USS0012M23S	MIDWAY VALLEY	11	37.570	−112.840	9,800	37	366	290	320
USW00023177	MODENA	11	37.800	−113.926	5,460	23	30	26	30
USC00426686	PAROWAN POWER PLANT	11	37.850	−112.832	6,000	32	31	30	32
USC00428456	SUMMIT	11	37.800	−112.933	6,000	31	27	28	30
USS0012M03S	WEBSTER FLAT	11	37.580	−112.900	9,203	37	178	185	205
USC00421144	CALLAO	12	39.900	−113.713	4,330	33	26	21	24
USC00422625	EUREKA	12	39.950	−112.117	6,471	13	58	84	97
USC00422852	FISH SPRINGS NWR	12	39.840	−113.398	4,340	30	12	17	19
USC00425065	LEVAN	12	39.554	−111.867	5,299	30	30	37	40
USC00425138	LITTLE SAHARA DUNES	12	39.729	−112.307	5,235	26	33	30	33

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00426135	NEPHI	12	39.708	−111.833	5,130	41	34	32	35
USC00426708	PARTOUN	12	39.631	−113.885	4,780	36	18	17	19
USS0012M26S	AGUA CANYON	13	37.520	−112.270	8,900	23	121	113	124
USC00420086	ALTON	13	37.440	−112.482	7,040	40	96	96	110
USC00420688	BIG WATER	13	37.080	−111.664	4,100	16	10	12	14
USC00421020	BULLFROG BASIN	13	37.530	−110.720	3,822	29	12	18	22
USS0012M05S	HARRIS FLAT	13	37.490	−112.580	7,800	38	127	143	168
USC00424508	KANAB	13	37.045	−112.533	4,940	45	29	22	26
USC00424755	KODACHROME BASIN PARK	13	37.517	−111.985	5,808	20	38	35	40
USS0012M06S	LONG VALLEY JCT	13	37.490	−112.510	7,464	31	127	103	119
USC00426534	ORDERVILLE	13	37.268	−112.633	5,460	25	48	41	46
USC00420730	BLACK ROCK	14	38.708	−112.953	4,900	38	36	30	34
USC00421500	CLEAR LAKE REFUGE	14	39.100	−112.617	4,603	15	21	23	27
USW00023162	DELTA	14	39.337	−112.586	4,623	36	16	19	21
USC00422101	DESERET	14	39.287	−112.652	4,590	29	25	31	37
USC00422116	DESERT EXPERIMENTAL RANGE	14	38.600	−113.750	5,251	14	25	26	31
USC00422607	ESKDALE	14	39.109	−113.953	4,980	31	20	24	27
USC00422828	FILLMORE	14	38.966	−112.328	5,120	48	33	32	35
USC00423138	GARRISON	14	38.933	−114.033	5,276	17	32	48	65
USC00424527	KANOSH	14	38.800	−112.433	4,995	37	35	37	40

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00426357	OAK CITY	14	39.379	−112.334	5,082	34	32	29	33
USS0012L15S	PINE CREEK	14	38.880	−112.250	8,790	33	194	180	189
USC00427714	SCIPIO	14	39.250	−112.100	5,307	37	40	36	40
USS0011J37S	HARDSCRABBLE	15	40.870	−111.720	7,250	24	168	173	185
USC00425826	MORGAN POWER AND LIGHT	15	41.043	−111.683	5,090	33	41	40	45
USC00420168	ANGLE	16	38.249	−111.961	6,400	19	35	27	32
USC00421432	CIRCLEVILLE	16	38.169	−112.273	6,056	27	24	15	17
USS0012L06S	KIMBERLY MINE	16	38.480	−112.390	9,129	37	169	144	152
USC00425477	MARYSVALE	16	38.450	−112.229	5,910	33	43	23	27
USC00420487	BEAR LAKE STATE PARK	17	41.966	−111.400	6,000	24	56	84	111
USS0011H37S	BUG LAKE	17	41.680	−111.420	7,950	39	190	200	216
USC00424856	LAKETOWN	17	41.825	−111.321	5,980	44	48	51	58
USC00427165	RANDOLPH	17	41.665	−111.185	6,270	29	45	46	52
USC00429595	WOODRUFF	17	41.533	−111.150	6,316	46	47	42	48
USC00420072	ALTA	18	40.600	−111.633	8,730	40	388	405	430
USS0011J57S	BRIGHTON	18	40.600	−111.580	8,750	31	200	221	236
USC00421446	CITY CRK WATER PLANT	18	40.828	−111.832	5,331	45	71	94	108
USC00421759	COTTONWOOD WEIR	18	40.619	−111.783	4,960	44	60	50	55
USC00422235	DRAPER POINT OF MOUNTAIN	18	40.486	−111.900	4,500	21	24	22	24
USS0012J09S	DRY FORK	18	40.570	−112.170	7,093	23	135	123	130

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00423097	GARFIELD	18	40.723	−112.198	4,330	31	33	23	25
USS0011J64S	LOOKOUT PEAK	18	40.840	−111.710	8,200	29	288	258	276
USS0011J69S	LOUIS MEADOW	18	40.830	−111.760	6,700	18	163	166	177
USS0011J65S	MILL D NORTH	18	40.660	−111.640	8,967	29	230	238	254
USC00425892	MOUNTAIN DELL DAM	18	40.750	−111.722	5,420	39	58	61	66
USS0011J52S	PARLEY S SUMMIT	18	40.760	−111.630	7,500	39	176	150	160
USC00427655	SALT LAKE CITY E BENCH	18	40.743	−111.817	4,870	13	38	52	59
USW00024127	SALT LAKE CITY INTL ARPT	18	40.778	−111.967	4,222	48	23	22	25
USC00427606	SALT LAKE TRIAD CTR	18	40.771	−111.896	4,280	30	33	31	36
USC00427578	SALTAIR SALT PLANT	18	40.767	−112.100	4,212	21	23	23	26
USC00427846	SILVER LAKE BRIGHTON	18	40.600	−111.584	8,740	48	277	291	309
USS0011J42S	SNOWBIRD UT US	18	40.560	−111.660	9,640	28	391	424	457
USC00428922	UNIVERSITY OF UTAH	18	40.767	−111.850	4,734	17	47	42	48
USC00420738	BLANDING	19	37.615	−109.481	6,040	28	42	42	50
USC00420788	BLUFF	19	37.283	−109.558	4,319	33	17	14	17
USS0009M02S	CAMP JACKSON	19	37.810	−109.490	8,968	32	186	164	181
USC00421163	CANYONLANDS THE NECK	19	38.455	−109.821	5,930	43	34	25	29
USC00421168	CANYONLANDS THE NEEDLES	19	38.151	−109.782	5,002	40	26	21	24
USC00421308	CEDAR POINT	19	37.716	−109.083	6,760	45	70	65	74
USC00423980	HITE RANGER STATION	19	37.875	−110.384	4,000	17	10	14	16

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00424100	HOVENWEEP NATIONAL MONUMENT	19	37.386	−109.077	5,240	39	26	24	29
USC00424947	LA SAL 1 SW	19	38.301	−109.234	6,785	25	39	31	33
USS0009L03S	LASAL MOUNTAIN	19	38.480	−109.270	9,560	37	138	125	134
USC00425582	MEXICAN HAT	19	37.150	−109.868	4,127	25	11	9	11
USC00425805	MONTICELLO 2 E	19	37.870	−109.307	6,820	41	92	82	96
USC00425812	MONUMENT VLY MISSION	19	37.017	−110.217	5,300	15	11	16	21
USS0011K13S	BEAVER DAMS	20	39.140	−111.560	7,990	37	131	102	110
USS0011K31S	BUCK FLAT	20	39.130	−111.440	9,430	39	170	185	200
USS0011K15S	DILL S CAMP	20	39.050	−111.470	9,182	39	147	150	164
USC00422578	EPHRAIM USFS	20	39.358	−111.586	5,510	12	41	46	53
USC00422700	FAIRVIEW	20	39.617	−111.433	5,961	12	42	42	45
USC00422702	FAIRVIEW 8 N	20	39.748	−111.416	6,750	36	78	78	85
USS0011K03S	MAMMOTH COTTONWOOD	20	39.680	−111.320	8,727	38	190	207	225
USC00425402	MANTI	20	39.258	−111.631	5,740	46	29	28	31
USC00425837	MORONI	20	39.530	−111.585	5,560	24	29	33	39
USS0011K09S	SEELEY CREEK	20	39.310	−111.430	9,910	39	190	172	188
USS0012L04S	BOX CREEK	21	38.510	−112.020	9,828	38	136	141	153
USS0011L01S	FARNSWORTH LAKE	21	38.770	−111.680	9,682	37	205	178	187
USC00423012	FREMONT INDIAN S P	21	38.578	−112.335	5,920	27	40	36	40
USS0011L12S	GOOSEBERRY RANGER STATION	21	38.800	−111.680	7,950	37	138	98	107

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00424764	KOOSHAREM	21	38.511	−111.884	6,931	37	34	40	47
USS0011K39S	PICKLE KEG	21	39.010	−111.580	9,600	39	217	161	172
USC00427260	RICHFIELD RADIO KSVC	21	38.762	−112.078	5,300	39	29	22	25
USC00427557	SALINA	21	38.959	−111.867	5,131	19	20	30	39
USC00427559	SALINA 24 E	21	38.914	−111.416	7,560	24	46	36	40
USC00427800	SIGURD U P AND L	21	38.850	−112.000	5,311	13	21	22	25
USS0011J46S	BEAVER DIVIDE	22	40.610	−111.100	8,280	39	111	115	124
USS0011J01S	CHALK CREEK 1	22	40.850	−111.050	8,993	38	238	231	247
USS0011J02S	CHALK CREEK 2	22	40.890	−111.070	8,158	38	138	134	141
USW00024120	COALVILLE	22	40.914	−111.398	5,550	31	45	44	50
USC00421590	COALVILLE 13 E	22	40.936	−111.150	6,510	35	40	44	47
USC00422385	ECHO DAM	22	40.967	−111.433	5,470	48	38	38	42
USS0010J44S	HAYDEN FORK	22	40.800	−110.880	9,212	39	161	151	162
USS0010J04S	HEWINTA	22	40.950	−110.480	9,519	32	95	95	100
USS0010J01S	HOLE IN ROCK	22	40.920	−110.190	9,150	32	62	63	66
USC00424467	KAMAS 3 NW	22	40.650	−111.283	6,475	38	62	56	61
USS0010J35S	LILY LAKE	22	40.860	−110.800	9,156	37	144	123	130
USS0011J53S	SMITH AND MOREHOUSE	22	40.790	−111.120	7,600	38	123	126	134
USC00426639	SNYDERVILLE	22	40.700	−111.533	6,460	25	84	89	96
USS0010J20S	STEEL CREEK PARK	22	40.910	−110.500	10,200	38	154	157	166

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USS0011J56S	THAYNES CANYON	22	40.620	−111.530	9,230	29	235	237	255
USS0010J52S	TRIAL LAKE	22	40.680	−110.950	9,992	39	291	281	307
USC00429165	WANSHIP DAM	22	40.791	−111.404	5,940	38	50	59	69
USC00421149	CALLISTER RANCH	23	40.683	−112.667	4,262	12	23	30	33
USC00422257	DUGWAY	23	40.183	−112.919	4,340	25	18	19	22
USC00423260	GOLD HILL	23	40.167	−113.833	5,319	18	22	32	37
USC00423348	GRANTSVILLE 2 W	23	40.601	−112.486	4,392	37	26	24	27
USC00424174	IBAPAH	23	40.038	−113.988	5,279	41	28	29	32
USC00424362	JOHNSON PASS	23	40.333	−112.600	5,630	40	57	45	50
USS0012J07S	MINING FORK	23	40.490	−112.610	8,221	29	190	192	207
USS0012J06S	ROCKY BASIN SETTLEME	23	40.440	−112.240	8,900	37	324	269	293
USC00428771	TOOELE	23	40.528	−112.297	5,070	48	45	40	44
USC00429133	VERNON	23	40.090	−112.443	5,478	36	23	24	26
USS0012K01S	VERNON CREEK	23	39.940	−112.410	7,401	39	133	139	154
USC00420802	BONANZA	24	40.017	−109.183	5,451	15	54	49	58
USC00422996	FORT DUCHESNE	24	40.284	−109.861	5,050	23	24	26	30
USC00424342	JENSEN	24	40.364	−109.345	4,750	35	29	38	43
USS0009J01S	KING S CABIN	24	40.720	−109.540	8,724	39	107	108	116
USC00425268	MAESER 9 NW	24	40.560	−109.664	6,440	25	60	58	65
USS0009J05S	MOSBY MTN	24	40.610	−109.890	9,510	37	158	154	169

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00426568	OURAY 4 NE	24	40.135	−109.644	4,671	39	31	29	34
USC00427395	ROOSEVELT RADIO	24	40.288	−109.959	5,050	40	29	44	53
USS0009J16S	TROUT CREEK	24	40.740	−109.670	9,518	39	120	111	119
USC00429111	VERNAL 1 S	24	40.440	−109.521	5,287	25	31	32	36
USC00420061	ALPINE	25	40.451	−111.777	5,005	32	43	39	43
USC00420449	BARTHOLOMEW PWRHS	25	40.167	−111.500	5,140	20	66	74	81
USC00420716	BIRDSEYE	25	39.867	−111.533	5,732	12	69	65	74
USS0011J70S	CASCADE MOUNTAIN	25	40.280	−111.610	7,774	15	140	170	182
USS0011K21S	CLEAR CREEK 1	25	39.870	−111.280	8,908	39	160	187	201
USS0011K22S	CLEAR CREEK 2	25	39.890	−111.250	7,659	39	118	139	150
USC00422418	ELBERTA	25	39.950	−111.950	4,690	22	26	31	36
USC00422696	FAIRFIELD	25	40.267	−112.087	4,880	41	25	28	32
USC00423183	GENEVA STEEL 2	25	40.300	−111.733	4,554	12	21	20	22
USC00426455	OLMSTEAD P H	25	40.317	−111.654	4,820	21	37	41	46
USC00426538	OREM TREATMENT PLANT	25	40.278	−111.737	4,510	26	28	30	36
USC00426726	PAYSON 1 SE	25	40.033	−111.717	4,803	14	39	40	44
USS0011K52S	PAYSON RANGER STATION	25	39.930	−111.630	8,066	36	214	183	198
USC00426919	PLEASANT GROVE	25	40.367	−111.733	4,714	46	24	23	26
USC00427064	PROVO BYU	25	40.246	−111.651	4,570	36	41	32	37
USC00427686	SANTAQUIN CHLOR	25	39.958	−111.781	5,160	31	49	41	46

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00428119	SPANISH FORK POWER HOUSE	25	40.083	−111.600	4,720	39	43	35	38
USC00428733	TIMPANOGOS CAVE	25	40.445	−111.707	5,640	37	74	73	81
USS0011J21S	TIMPANOGOS DIVIDE	25	40.430	−111.620	8,140	38	248	278	310
USC00428939	UPPER AMERCN FORK PH	25	40.433	−111.717	5,331	12	56	57	62
USC00428973	UTAH LAKE LEHI	25	40.363	−111.899	4,501	24	25	23	26
USS0011J32S	CURRANT CREEK	26	40.360	−111.090	8,000	39	106	130	146
USS0011J23S	DANIELS STRAWBERRY	26	40.300	−111.260	8,037	39	156	185	203
USC00422057	DEER CREEK DAM	26	40.400	−111.533	5,270	37	64	73	81
USC00423809	HEBER	26	40.500	−111.417	5,630	44	63	70	80
USC00427909	SNAKE CREEK PWRHSSE	26	40.550	−111.500	6,001	25	126	145	160
USS0011J08S	STRAWBERRY DIVIDE	26	40.160	−111.210	8,123	39	167	181	196
USS0010K02S	WHITE RIVER 1	26	39.960	−110.990	8,641	39	124	134	146
USC00422558	ENTERPRISE	27	37.570	−113.716	5,320	35	44	42	48
USS0013M07S	GARDNER PEAK	27	37.400	−113.460	8,322	13	137	141	154
USC00423506	GUNLOCK PH	27	37.283	−113.728	4,110	22	21	30	38
USS0013M06S	GUTZ PEAK	27	37.500	−113.940	6,763	13	113	168	196
USC00424968	LA VERKIN	27	37.202	−113.268	3,220	31	7	7	9
USS0013M04S	LITTLE GRASSY	27	37.490	−113.850	6,100	32	116	88	103
USS0013M02S	LONG FLAT	27	37.510	−113.400	8,000	36	126	116	131
USC00426181	NEW HARMONY	27	37.483	−113.300	5,265	36	48	49	56

TABLE 1. Ground snow loads (in psf) of Utah Stations.

STATION	STATION NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00427516	ST GEORGE	27	37.107	−113.567	2,762	26	15	20	25
USC00429136	VEYO PWRHSSE	27	37.352	−113.667	4,600	30	20	30	36
USC00429717	ZION NATIONAL PARK	27	37.209	−112.984	4,050	35	22	17	21
USC00421171	CAPITOL REEF NATIONAL PARK	28	38.283	−111.267	5,500	40	35	25	29
USS0011L05S	DONKEY RESERVOIR	28	38.210	−111.480	9,800	32	93	80	86
USW00023170	HANKSVILLE	28	38.371	−110.715	4,308	32	26	28	34
USC00423600	HANS FLAT RANGER STATION	28	38.250	−110.180	6,600	36	33	28	31
USC00425148	LOA	28	38.400	−111.650	7,070	26	34	28	33
USS0011H08S	BEN LOMOND PEAK	29	41.380	−111.940	8,000	39	385	429	471
USS0011H30S	BEN LOMOND TRAIL	29	41.380	−111.920	5,829	37	178	221	244
USS0011H21S	HORSE RIDGE	29	41.310	−111.450	8,160	39	209	225	243
USC00424135	HUNTSVILLE MONASTERY	29	41.237	−111.715	5,140	30	81	90	103
USS0011H59S	LIGHTNING RIDGE	29	41.360	−111.490	8,215	13	188	212	230
USC00426404	OGDEN PIONEER P H	29	41.244	−111.947	4,350	32	35	40	46
USC00426414	OGDEN SUGAR FACTORY	29	41.233	−112.031	4,280	18	21	20	22
USC00426869	PINE VIEW DAM	29	41.258	−111.838	4,940	44	110	102	114

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00020750	BETATAKIN	AZ	36.683	−110.533	7,286	39	41	41	46
USC00021001	BRIGHT ANGEL RANGER STATION	AZ	36.214	−112.067	8,400	41	171	181	199
USC00021248	CANYON DE CHELLY	AZ	36.150	−109.533	5,610	31	12	11	13
USC00021920	COLORADO CITY	AZ	36.994	−112.974	5,010	32	19	19	22
USC00024849	LEES FERRY	AZ	36.864	−111.602	3,210	16	5	6	7
USC00025129	LUKACHUKAI	AZ	36.418	−109.229	6,520	12	21	32	42
USC00025665	MONUMENT VALLEY	AZ	36.983	−110.114	5,564	12	12	18	23
USC00026180	PAGE	AZ	36.921	−111.448	4,270	21	12	16	19
USC00026471	PHANTOM RANCH	AZ	36.107	−112.096	2,530	27	10	11	14
USC00026616	PIPE SPRINGS NATIONAL MONUMENT	AZ	36.867	−112.733	4,920	35	25	24	29
USC00028468	TEEC NOS POS	AZ	36.917	−109.087	5,290	28	13	15	17
USC00028792	TUBA CITY	AZ	36.133	−111.242	4,988	17	14	14	17
USC00028895	TUWEEP	AZ	36.283	−113.067	4,776	12	15	22	29
USC00050214	ALTENBERN	CO	39.500	−108.383	5,678	48	62	57	67
USC00050825	BONHAM RESERVOIR	CO	39.102	−107.898	9,850	25	202	223	234
USC00051017	BROWNS PARK REFUGE	CO	40.800	−108.917	5,354	16	21	27	32
USC00051741	COLLBRAN	CO	39.238	−107.967	5,980	20	38	33	37
USC00051743	COLLBRAN 1 WSW	CO	39.237	−107.980	6,100	17	34	39	43
USC00051772	COLORADO NATIONAL MONUMENT	CO	39.101	−108.734	5,780	43	23	27	31
USS0008L02S	COLUMBINE PASS	CO	38.420	−108.380	9,400	31	191	161	171

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
904	COLUMBUS BASIN	CO	37.441	−108.024	10,785	23	230	231	246
USC00051886	CORTEZ	CO	37.344	−108.595	6,167	39	29	24	27
USC00052286	DINOSAUR NATIONAL MONUMNT	CO	40.244	−108.972	5,921	35	37	41	46
USC00052326	DOLORES	CO	37.475	−108.498	6,950	27	55	56	62
US1CODR0003	DOVE CREEK 124 SSW	CO	37.601	−108.995	6,604	12	56	53	61
USS0008M06S	EL DIENTE PEAK	CO	37.790	−108.020	10,000	31	139	138	148
USC00053146	FRUITA	CO	39.165	−108.733	4,505	19	20	24	27
USC00053246	GATEWAY	CO	38.683	−108.973	4,564	33	21	18	22
USC00053307	GLADE PARK 17 W	CO	38.954	−109.053	6,385	18	38	41	45
USC00053489	GRAND JUNCTION 6 ESE	CO	39.042	−108.466	4,760	37	18	19	22
US1COME0003	GRAND JUNCTION 8 NNW	CO	39.178	−108.619	4,751	14	17	23	27
USW00023066	GRAND JUNCTION WALKER FIELD	CO	39.134	−108.537	4,843	48	25	19	23
USC00053508	GRAND VALLEY CO US	CO	39.450	−108.050	5,092	18	41	48	59
USC00055048	LITTLE HILLS	CO	40.000	−108.200	6,140	18	34	39	43
USS0007M29S	LIZARD HEAD PASS	CO	37.800	−107.920	10,200	37	138	144	153
USS0008M07S	LONE CONE	CO	37.890	−108.200	9,600	37	151	145	154
USS0008M02S	MANCOS	CO	37.430	−108.170	10,000	23	146	156	168
USC00055327	MANCOS 1 SW	CO	37.335	−108.316	6,897	29	31	36	41
US1COMZ0013	MANCOS 38 WNW	CO	37.376	−108.352	7,050	12	46	54	60
USC00055422	MASSADONA 3 E	CO	40.284	−108.602	6,185	22	40	51	57

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00055446	MAYBELL	CO	40.516	−108.095	5,908	38	43	43	48
USC00055484	MEEKER	CO	40.036	−107.906	6,229	24	44	40	45
USC00055487	MEEKER 2	CO	40.033	−107.917	6,347	20	45	42	47
USS0008K04S	MESA LAKES	CO	39.060	−108.060	10,000	31	173	171	182
USC00055531	MESA VERDE NATIONAL PARK	CO	37.200	−108.489	7,142	47	57	68	77
US1COMT0009	MONTROSE 40 NW	CO	38.525	−107.922	5,729	13	19	17	20
USC00055970	NORTHDALE	CO	37.817	−109.033	6,680	24	37	39	42
USC00056012	NORWOOD	CO	38.133	−108.285	7,020	19	20	28	33
USC00056266	PALISADE	CO	39.115	−108.350	4,805	33	17	18	21
USC00056318	PARADOX 1 W	CO	38.383	−108.983	5,530	17	36	31	36
USC00056320	PARADOX 2 N	CO	38.390	−108.949	5,440	12	32	37	43
USC00056520	PLACERVILLE	CO	38.018	−108.051	7,383	39	69	68	77
USC00056832	RANGELY 1 E	CO	40.089	−108.773	5,277	38	38	38	43
USC00057017	RICO	CO	37.683	−108.033	8,800	29	184	240	285
USW00024027	ROCK SPRINGS SWEETWATER CO ARPT	CO	41.597	−109.066	6,742	29	35	34	38
USS0008M08S	SCOTCH CREEK	CO	37.650	−108.010	9,100	31	113	115	123
USS0008M04S	SHARKSTOOTH	CO	37.500	−108.110	10,720	13	163	190	203
USC00058560	URAVAN	CO	38.376	−108.742	5,010	21	16	14	16
USC00059275	YELLOW JACKET 2 W	CO	37.521	−108.756	6,860	23	58	63	69
USC00100803	BERN	ID	42.335	−111.385	5,964	25	82	88	97

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USS0014G01S	BOSTETTER RANGER STATION	ID	42.160	−114.190	7,500	36	298	207	228
USW00024133	BURLEY MUNICIPAL ARPT	ID	42.539	−113.767	4,157	30	18	21	24
USS0011G06S	EMIGRANT SUMMIT	ID	42.360	−111.560	7,390	36	248	256	280
USS0011G32S	FRANKLIN BASIN	ID	42.050	−111.600	8,170	39	273	298	324
USS0011G33S	GIVEOUT	ID	42.410	−111.170	6,930	36	113	99	107
USS0013G01S	HOWELL CANYON	ID	42.320	−113.620	7,980	37	255	277	301
USC00105275	LIFTON PUMPING STATION	ID	42.123	−111.314	5,926	48	53	50	57
610	MAGIC MOUNTAIN	ID	42.181	−114.287	6,880	37	190	172	183
USW00024151	MALAD CITY	ID	42.167	−112.283	4,471	27	37	51	59
USC00105567	MALTA	ID	42.301	−113.334	4,540	14	28	36	45
USC00105563	MALTA 4 ESE	ID	42.300	−113.304	4,590	24	27	26	29
USC00105980	MINIDOKA DAM	ID	42.677	−113.500	4,164	27	35	30	36
USC00106053	MONTPELIER R S	ID	42.317	−111.300	5,960	22	47	63	69
USC00106542	OAKLEY	ID	42.234	−113.892	4,560	38	21	19	21
USS0012G18S	OXFORD SPRING	ID	42.260	−112.130	6,740	37	111	119	130
USC00107346	PRESTON	ID	42.093	−111.867	4,800	20	43	57	66
USS0011G05S	SLUG CREEK DIVIDE	ID	42.560	−111.300	7,225	37	167	151	162
USC00108535	SODA SPRINGS ARPT	ID	42.651	−111.583	5,874	28	60	76	87
USW00024158	STREVELL	ID	42.017	−113.250	5,280	15	24	25	27
867	WILDHORSE DIVIDE	ID	42.757	−112.478	6,490	35	153	163	177

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
871	WILSON CREEK	ID	42.013	−115.003	7,120	27	121	125	134
USC00290692	AZTEC RUINS NATIONAL MONUMENT	NM	36.834	−108.000	5,644	38	16	16	18
USC00422173	DINOSAUR NM QUARRY AREA	NM	40.438	−109.304	4,800	32	28	37	42
USC00293142	FARMINGTON AG SCI CTR	NM	36.695	−108.313	5,625	29	13	15	17
USC00293340	FRUITLAND	NM	36.733	−108.358	5,150	29	13	15	18
USC00426053	NATURAL BRIDGES NM	NM	37.609	−109.977	6,502	39	37	38	43
USC00298284	SHIPROCK	NM	36.789	−108.688	4,938	20	10	11	14
USC00260438	ARTHUR 4 NW	NV	40.782	−115.184	6,292	26	85	90	106
USS0014K02S	BERRY CREEK	NV	39.320	−114.620	9,100	37	208	186	202
USC00261358	CALIENTE	NV	37.617	−114.517	4,400	29	19	23	27
USC00261590	CATHEDRAL GORGE STATE PARK	NV	37.804	−114.407	4,830	13	15	15	17
USC00261905	CONTACT	NV	41.777	−114.751	5,360	18	29	29	34
USS0015J01S	DORSEY BASIN	NV	40.890	−115.200	8,100	39	197	154	167
USW00023154	ELY YELLAND FIELD ARPT	NV	39.295	−114.847	6,262	46	36	30	36
USC00263114	GIBBS RANCH JARBIDGE 24 SE	NV	41.570	−115.215	6,000	28	46	46	55
USC00263340	GREAT BASIN NATIONAL PARK	NV	39.007	−114.224	6,830	45	50	46	50
USS0015J15S	HOLE IN MOUNTAIN	NV	40.940	−115.100	7,900	35	409	330	382
USC00264016	JACKPOT	NV	41.986	−114.674	5,290	22	17	21	24
USC00264341	LAGES	NV	40.057	−114.616	5,960	25	35	25	29
USC00264384	LAKE VALLEY STEWARD	NV	38.317	−114.650	6,352	16	44	53	61

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USC00264745	LUND	NV	38.862	−115.009	5,560	33	20	18	20
USC00264950	MCGILL	NV	39.401	−114.774	6,300	38	27	25	28
USC00265092	METROPOLIS	NV	41.283	−115.017	5,800	19	62	61	70
USC00265352	MONTELLO 2 SE	NV	41.250	−114.174	4,890	25	30	35	46
USC00265722	OASIS	NV	41.033	−114.472	5,830	17	44	35	41
USC00265880	PAHRANAGAT WILDLIFE REFUGE	NV	37.269	−115.120	3,400	26	5	7	7
USC00266148	PEQUOP	NV	41.067	−114.533	6,033	13	29	33	36
USC00266252	PIOCHE	NV	37.933	−114.450	6,170	20	30	42	48
USS0015H14S	POLE CREEK RANGER STATION	NV	41.870	−115.250	8,330	37	204	186	197
USC00267175	RUTH	NV	39.281	−114.990	6,845	38	39	44	49
USC00267750	SPRING VALLEY ST PK	NV	38.037	−114.182	5,950	36	36	34	38
USS0014K05S	WARD MOUNTAIN	NV	39.130	−114.960	9,200	37	158	153	168
USC00268988	WELLS	NV	41.105	−114.967	5,653	34	57	40	46
USS0011L04S	BLACK FLAT UM CK	UM	38.680	−111.600	9,462	37	106	101	109
USC00480027	AFTON	WY	42.733	−110.933	6,210	41	68	64	69
USC00480603	BEDFORD 3 SE	WY	42.870	−110.917	6,423	37	93	99	104
USC00480761	BITTER CREEK 4 NE	WY	41.583	−108.517	6,720	14	23	22	25
USC00480915	BORDER 3 N	WY	42.250	−111.033	6,119	24	65	79	88
USC00481131	BUCKBOARD MARINA	WY	41.247	−109.597	6,080	15	18	18	21
USC00481736	CHURCH BUTTES GAS PLANT	WY	41.399	−110.084	7,075	21	22	28	31

TABLE 2. Ground snow loads (in psf) of non-Utah stations.

STATION	STATION NAME	STATE	LATITUDE	LONGITUDE	ELEVATION	n	maxobs	yr50	yr100
USS0010G25S	COTTONWOOD CREEK	WY	42.650	−110.810	7,670	33	194	197	209
USC00483100	EVANSTON 1 E	WY	41.267	−110.950	6,820	30	43	46	51
USC00483396	FONTENELLE DAM	WY	41.983	−110.067	6,480	22	36	31	35
USC00483582	FOSSIL BUTTE	WY	41.837	−110.770	6,780	27	59	59	64
USC00484065	GREEN RIVER	WY	41.531	−109.470	6,093	33	40	27	30
USS0010G24S	HAMS FORK	WY	42.150	−110.680	7,840	31	98	103	109
USS0010G22S	INDIAN CREEK	WY	42.300	−110.680	9,425	36	232	257	276
USS0010G12S	KELLEY RANGER STATION	WY	42.270	−110.810	8,180	37	160	153	164
USC00485105	KEMMERER 2 N	WY	41.817	−110.533	6,942	27	51	56	62
USC00485252	LA BARGE	WY	42.267	−110.200	6,600	26	34	35	39
USC00486555	MOUNTAIN VIEW	WY	41.267	−110.339	6,800	41	35	33	37
USC00487847	ROCK SPRINGS FIRE DEPARTMENT	WY	41.578	−109.239	6,270	12	28	24	27
USC00487955	SAGE 4 NNW	WY	41.867	−111.000	6,209	15	40	48	57
USS0010G08S	SALT RIVER SUMMIT	WY	42.510	−110.910	7,760	37	117	122	130
US1WYLN0002	SMOOT 49 SSE	WY	42.552	−110.888	7,005	13	111	119	124
765	SNIDER BASIN	WY	42.495	−110.532	8,060	36	127	133	144
USS0010G20S	SPRING CREEK DIVIDE	WY	42.530	−110.660	9,000	37	259	258	277
831	TRIPLE PEAK	WY	42.764	−110.591	8,500	32	220	224	239
USS0010G23S	WILLOW CREEK	WY	42.820	−110.840	8,380	36	254	273	292

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Beaver	1	38.274	−112.642	5,886	35	33
Minersville	1	38.216	−112.925	5,272	31	28
Newhouse (historical)	1	38.481	−113.342	5,151	34	33
Milford	1	38.393	−113.012	4,967	30	29
Park Valley	2	41.817	−113.319	5,531	40	36
Grouse Creek	2	41.706	−113.888	5,302	39	38
Howell	2	41.796	−112.441	4,587	36	39
Snowville	2	41.965	−112.714	4,534	35	34
Plymouth	2	41.877	−112.143	4,524	45	44
Brigham City	2	41.510	−112.018	4,423	42	47
Fielding	2	41.814	−112.117	4,370	42	43
Riverside	2	41.790	−112.150	4,363	42	42
Garland	2	41.741	−112.163	4,344	42	41
Willard	2	41.406	−112.037	4,324	37	47
Tremonton	2	41.710	−112.166	4,318	41	41
Honeyville	2	41.636	−112.080	4,281	40	41
Bear River City	2	41.617	−112.126	4,262	39	40
Corinne	2	41.550	−112.111	4,232	39	40
Paradise	3	41.571	−111.836	4,915	51	58
Clarkston	3	41.922	−112.046	4,839	53	55
Logan - USU Station	3	41.741	−111.814	4,777	48	48
Hyrum	3	41.634	−111.854	4,692	46	50
Richmond	3	41.922	−111.808	4,642	46	49
Smithfield	3	41.840	−111.832	4,603	46	47
Millville	3	41.685	−111.825	4,600	44	46
North Logan	3	41.763	−111.824	4,544	43	43
Newton	3	41.863	−111.988	4,534	45	48
Logan	3	41.736	−111.837	4,531	43	43
Wellsville	3	41.639	−111.931	4,528	44	47

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Providence	3	41.711	−111.828	4,521	43	43
Lewiston	3	41.974	−111.856	4,508	43	48
Mendon	3	41.711	−111.979	4,491	43	46
Hyde Park	3	41.799	−111.825	4,488	43	43
Trenton	3	41.917	−111.943	4,465	44	47
Sunnyside	4	39.552	−110.387	6,522	49	57
East Carbon	4	39.544	−110.421	6,256	43	50
Panther Carbon (historical)	4	39.708	−110.867	6,069	40	38
Helper	4	39.687	−110.854	5,843	36	35
Ewell (historical)	4	39.665	−110.854	5,777	35	34
Price	4	39.598	−110.811	5,558	31	32
Wellington	4	39.542	−110.726	5,403	30	31
Manila	5	40.992	−109.722	6,368	26	23
Dutch John	5	40.931	−109.401	6,286	28	29
Hill Air Force Base	6	41.117	−111.998	4,751	46	43
Clearfield	6	41.115	−112.025	4,501	39	37
Layton	6	41.076	−111.951	4,488	39	41
Freeport Center	6	41.089	−112.019	4,406	36	36
Bountiful	6	40.889	−111.881	4,377	34	41
Kaysville	6	41.039	−111.941	4,360	35	39
North Salt Lake	6	40.848	−111.907	4,334	31	37
Farmington	6	40.981	−111.884	4,318	35	42
Centerville	6	40.920	−111.880	4,288	33	41
Hanna	7	40.439	−110.813	6,926	68	68
Tabiona	7	40.352	−110.710	6,509	61	55
Altamont	7	40.359	−110.285	6,381	51	46
Neola	7	40.434	−110.030	6,027	43	39
Duchesne	7	40.164	−110.397	5,508	39	34
Myton	7	40.194	−110.062	5,085	32	30

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Roosevelt	7	40.299	−109.987	5,082	32	30
Emery	8	38.923	−111.248	6,250	27	31
Ferron	8	39.091	−111.134	5,948	34	32
Clawson	8	39.132	−111.097	5,942	34	33
Huntington	8	39.329	−110.964	5,794	34	33
Orangeville	8	39.223	−111.054	5,791	34	31
Cleveland	8	39.349	−110.857	5,741	34	33
Elmo	8	39.389	−110.817	5,699	33	33
Castle Dale	8	39.211	−111.020	5,669	32	30
Green River	8	38.995	−110.161	4,075	31	21
CPU Ruby's Inn	9	37.674	−112.157	7,664	71	77
Hatch	9	37.653	−112.434	6,929	52	53
Boulder	9	37.909	−111.423	6,706	45	44
Panguitch	9	37.824	−112.438	6,630	41	36
Antimony	9	38.117	−112.000	6,453	34	26
Tropic	9	37.624	−112.082	6,309	41	41
Henrieville	9	37.563	−111.994	6,001	37	36
Cannonville	9	37.566	−112.055	5,892	36	34
Escalante	9	37.771	−111.605	5,843	39	31
Moab	10	38.574	−109.550	4,029	15	14
Parowan	11	37.841	−112.830	6,007	32	32
Summit	11	37.801	−112.936	5,994	32	33
Paragonah	11	37.887	−112.776	5,869	30	29
Cedar City	11	37.683	−113.063	5,800	30	32
Kanarraville	11	37.537	−113.183	5,554	39	37
Newcastle	11	37.671	−113.549	5,295	30	34
Eureka	12	39.959	−112.103	6,588	69	76
Levan	12	39.558	−111.864	5,302	34	35
Nephi	12	39.709	−111.836	5,131	39	34

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Mona	12	39.818	−111.856	4,957	38	34
Alton	13	37.440	−112.482	7,087	88	79
Glendale	13	37.318	−112.597	5,774	42	42
Orderville	13	37.276	−112.639	5,463	35	36
Mount Carmel	13	37.242	−112.671	5,292	31	33
Kanab	13	37.047	−112.528	4,964	25	25
Big Water	13	37.081	−111.664	4,111	13	13
Ibex (historical)	14	38.883	−113.442	5,440	35	39
Garrison	14	38.933	−114.033	5,276	33	33
Fillmore	14	38.969	−112.322	5,138	30	30
Oak City	14	39.376	−112.336	5,098	31	30
Kanosh	14	38.800	−112.438	5,026	28	29
Meadow	14	38.888	−112.410	4,842	27	27
Lynndyl	14	39.519	−112.373	4,787	26	27
Delta	14	39.351	−112.569	4,632	24	25
Hinckley	14	39.324	−112.672	4,600	24	26
Morgan	15	41.039	−111.678	5,062	52	55
Circleville	16	38.171	−112.276	6,069	27	23
Junction	16	38.244	−112.221	6,030	27	23
Marysvale	16	38.451	−112.231	5,866	30	26
Woodruff	17	41.523	−111.163	6,339	50	51
Randolph	17	41.664	−111.185	6,286	50	53
Garden City	17	41.947	−111.395	5,971	73	72
Laketown	17	41.825	−111.325	5,971	69	59
Brighton (historical)	18	40.604	−111.582	8,707	277	272
Bingham Canyon	18	40.566	−112.095	5,446	54	48
Foothill	18	40.751	−111.826	4,819	39	46
Alta Canyon	18	40.583	−111.833	4,806	38	39
Millcreek Branch	18	40.699	−111.806	4,800	38	44

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Millcreek	18	40.699	−111.810	4,783	38	43
Kearns	18	40.651	−111.986	4,577	34	33
Kearns Branch	18	40.654	−111.991	4,567	34	33
Cottonwood	18	40.627	−111.826	4,564	33	37
Sandy	18	40.591	−111.873	4,514	33	33
West Jordan	18	40.608	−111.967	4,485	32	32
Riverton	18	40.520	−111.947	4,465	32	29
South Jordan	18	40.568	−111.940	4,465	32	31
Holladay Branch	18	40.666	−111.823	4,455	32	36
Holladay	18	40.666	−111.823	4,455	32	36
Draper	18	40.529	−111.882	4,442	32	30
Cottonwood Branch	18	40.647	−111.835	4,416	31	34
Midvale	18	40.610	−111.892	4,396	31	32
Sandy City Centre	18	40.569	−111.897	4,380	30	30
Sugar House	18	40.728	−111.859	4,363	30	35
Pioneer Station	18	40.767	−111.887	4,301	30	34
Murray	18	40.663	−111.888	4,295	29	31
Downtown Salt Lake City	18	40.766	−111.898	4,278	29	33
Downtown Station	18	40.761	−111.891	4,268	29	33
West Valley	18	40.697	−111.997	4,268	28	29
Magna	18	40.712	−112.094	4,265	28	27
Downtown Station	18	40.761	−111.892	4,262	29	33
South Salt Lake	18	40.702	−111.893	4,252	28	31
Salt Lake City	18	40.727	−111.941	4,239	28	30
Airport	18	40.776	−111.978	4,226	28	29
Graebers - Addition	18	40.764	−111.925	4,226	28	31
Fairgrounds Station	18	40.787	−111.939	4,219	28	31
Northwest	18	40.787	−111.940	4,216	28	31
Monticello	19	37.870	−109.343	7,064	67	68

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
La Sal	19	38.312	−109.250	6,995	44	46
Blanding	19	37.627	−109.478	6,092	39	41
Aneth	19	37.216	−109.186	4,521	14	15
Montezuma Creek	19	37.261	−109.307	4,445	13	14
Mexican	19	37.125	−109.889	4,386	11	11
Bluff	19	37.283	−109.554	4,321	13	13
Mexican Hat	19	37.149	−109.860	4,196	10	11
Fairview	20	39.628	−111.440	5,958	45	46
Mount Pleasant	20	39.548	−111.458	5,899	42	42
Fountain Green	20	39.627	−111.635	5,889	43	47
Spring City	20	39.479	−111.496	5,843	41	39
Manti	20	39.267	−111.637	5,620	37	32
Mayfield	20	39.115	−111.709	5,564	34	30
Sterling	20	39.195	−111.693	5,564	35	31
Moroni	20	39.526	−111.576	5,561	36	36
Ephraim	20	39.362	−111.585	5,538	36	34
Chester	20	39.465	−111.572	5,482	36	34
Axtell	20	39.055	−111.821	5,151	27	25
Gunnison	20	39.153	−111.821	5,115	29	26
Centerfield	20	39.129	−111.818	5,102	27	25
Koosharem	21	38.510	−111.882	6,922	45	37
Elsinore	21	38.683	−112.149	5,354	27	24
Monroe	21	38.641	−112.122	5,351	27	23
Richfield	21	38.769	−112.085	5,338	27	24
Annabella	21	38.709	−112.060	5,298	27	23
Glenwood	21	38.763	−111.988	5,282	27	22
Sigurd	21	38.839	−111.968	5,226	27	23
Aurora	21	38.921	−111.937	5,213	28	25
Salina	21	38.958	−111.859	5,161	27	25

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Redmond	21	39.006	−111.866	5,111	27	25
Park City - Old Town Station	22	40.644	−111.496	7,064	104	116
Park CIty	22	40.664	−111.512	6,795	105	102
Kamas	22	40.644	−111.282	6,473	76	70
Oakley	22	40.715	−111.300	6,430	76	69
Snyderville	22	40.723	−111.541	6,391	87	85
Coalville	22	40.917	−111.398	5,581	57	48
Echo	22	40.978	−111.444	5,456	54	48
Henefer	22	41.016	−111.498	5,335	50	50
Vernon	23	40.093	−112.433	5,515	40	36
Stockton	23	40.456	−112.361	5,141	35	39
Rush Valley	23	40.355	−112.454	5,075	33	35
Tooele	23	40.532	−112.299	5,029	35	38
Dugway	23	40.222	−112.748	4,846	29	27
Dugway (historical)	23	40.221	−112.744	4,842	29	27
Grantsville	23	40.600	−112.465	4,308	25	26
Wendover	23	40.737	−114.036	4,288	23	18
Whiterocks	24	40.466	−109.931	6,020	44	37
Tridell	24	40.452	−109.850	5,627	39	33
Lapoint	24	40.404	−109.796	5,558	39	35
Vernal	24	40.456	−109.544	5,384	39	34
Fort Duchesne	24	40.302	−109.863	5,052	33	30
Jensen	24	40.370	−109.337	4,744	32	30
Vivian Park (historical)	25	40.355	−111.574	5,200	48	52
Cedar Valley	25	40.325	−112.103	5,079	39	35
Santaquin	25	39.976	−111.786	4,967	39	38
Mountain Shadows	25	40.276	−111.674	4,764	38	36
Orem	25	40.298	−111.702	4,764	35	34
Elberta	25	39.953	−111.957	4,701	30	31

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
American Fork	25	40.378	−111.800	4,606	32	30
Payson	25	40.045	−111.717	4,606	34	34
Salem	25	40.057	−111.671	4,600	33	34
Utah Valley University	25	40.283	−111.718	4,600	32	31
Springville	25	40.167	−111.609	4,580	34	36
Pleasant Grove	25	40.362	−111.743	4,577	32	31
Goshen	25	39.951	−111.901	4,557	28	30
Spanish Fork	25	40.122	−111.652	4,557	33	34
Lehi	25	40.388	−111.843	4,554	32	29
Uinta	25	40.235	−111.660	4,554	31	33
Provo	25	40.232	−111.660	4,541	31	33
East Bay	25	40.222	−111.655	4,508	30	33
Wallsburg	26	40.387	−111.421	5,699	61	67
Wallsburg	26	40.388	−111.425	5,650	60	65
Heber City	26	40.509	−111.411	5,604	60	63
Midway	26	40.512	−111.475	5,590	59	66
Pine Valley (historical)	27	37.391	−113.514	6,535	76	71
Zion National Park (historical)	27	37.300	−113.051	6,152	55	48
Enterprise	27	37.574	−113.722	5,321	35	42
New Harmony	27	37.480	−113.308	5,308	40	36
Veyo	27	37.338	−113.693	4,462	29	31
Springdale	27	37.191	−112.994	3,904	16	16
Rockville	27	37.161	−113.041	3,740	16	14
Leeds	27	37.243	−113.353	3,573	17	15
Virgin	27	37.204	−113.189	3,537	16	13
Toquerville	27	37.250	−113.284	3,389	15	13
Hurricane	27	37.177	−113.308	3,215	14	12
La Verkin	27	37.203	−113.272	3,189	14	11
Ivins	27	37.158	−113.674	2,986	14	16

TABLE 3. Design ground snow load predictions for Utah post office locations.

NAME	COUNTY	LATITUDE	LONGITUDE	ELEVATION	PRISM	UK
Downtown Saint George	27	37.111	−113.582	2,789	13	14
Saint George - Hurst Station	27	37.111	−113.593	2,782	13	14
Washington	27	37.130	−113.510	2,779	12	13
Santa Clara	27	37.132	−113.654	2,756	13	14
Saint George	27	37.088	−113.559	2,585	12	12
Lyman	28	38.394	−111.590	7,169	38	36
Teasdale	28	38.284	−111.477	7,142	40	36
Bicknell	28	38.341	−111.543	7,123	40	35
Loa	28	38.402	−111.643	7,060	37	33
Bicknell	28	38.341	−111.562	6,991	39	33
Torrey	28	38.299	−111.422	6,840	37	33
Hanksville	28	38.374	−110.712	4,295	26	19
Eden	29	41.306	−111.828	4,974	54	70
Huntsville	29	41.255	−111.762	4,938	52	66
Mount Ogden	29	41.179	−111.951	4,737	46	46
Roy	29	41.159	−112.027	4,541	41	37
Roy	29	41.175	−112.027	4,528	41	37
Ogden	29	41.197	−111.985	4,334	37	37
Town	29	41.216	−111.970	4,318	37	38
Ben Lomond	29	41.264	−111.970	4,295	37	41
Hooper	29	41.164	−112.124	4,242	33	31

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27 Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to reference lines for the 1992 snow load predictions. 92

28 Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to reference lines for the 1992 snow load predictions. 93

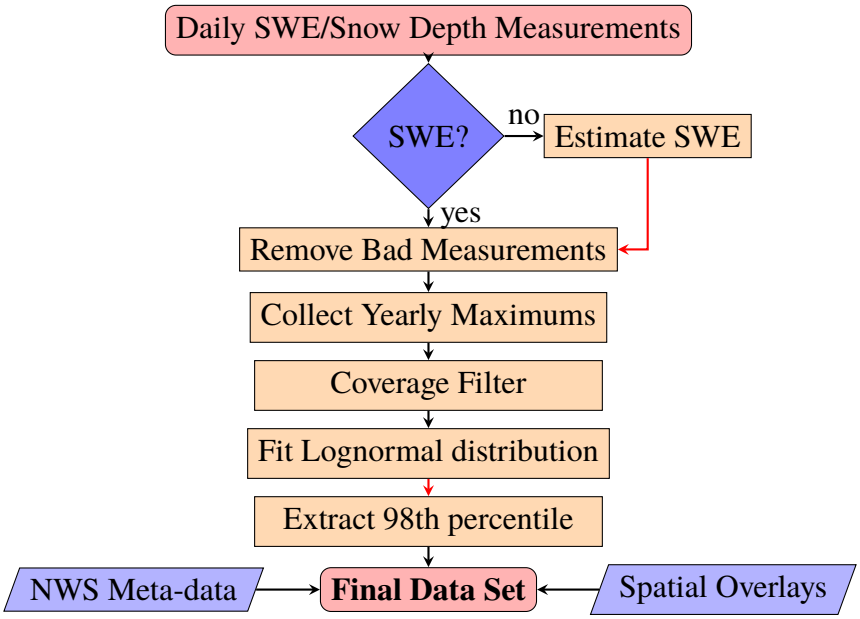

Fig. 1. Diagram of data processing procedures for the new Utah dataset.

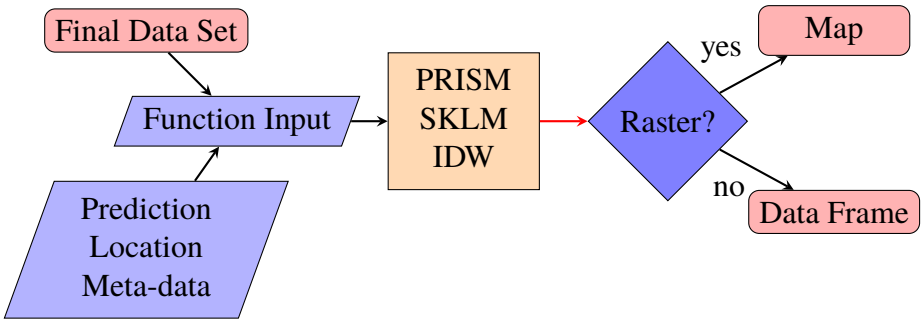

Fig. 2. Diagram illustrating the use of spatial methods in predicting ground snow loads.

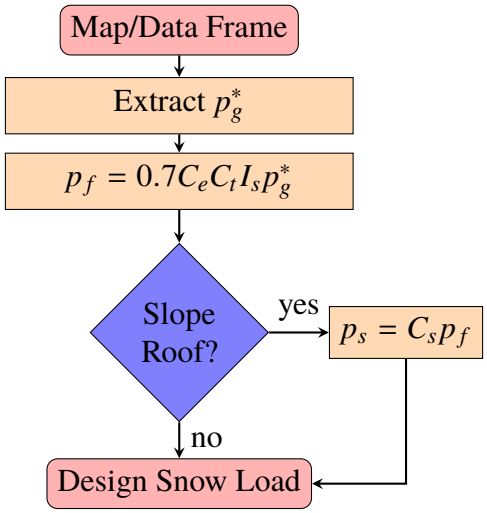

Fig. 3. Diagram illustrating ground to roof conversions for snow loads.

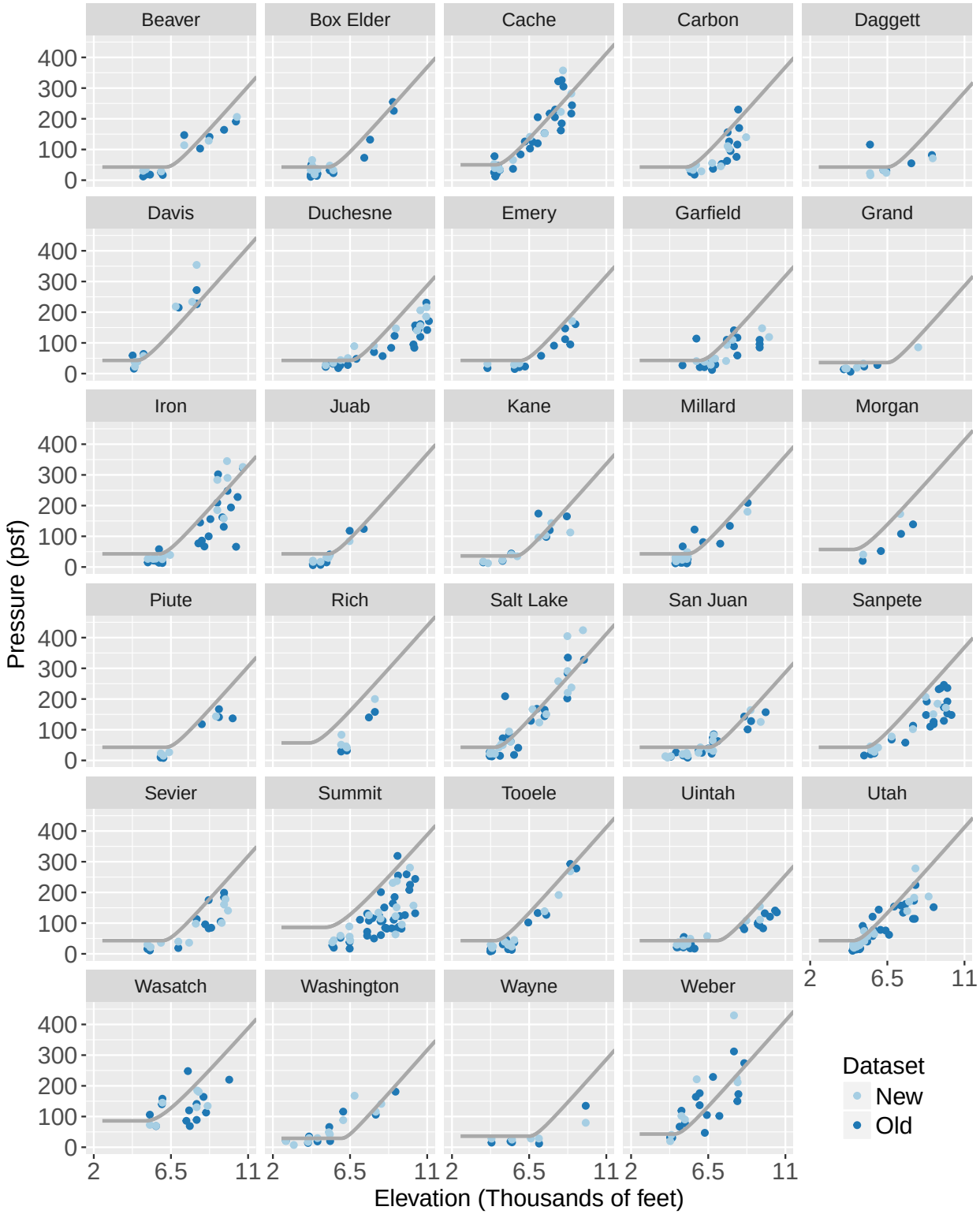

Fig. 4. Ground snow load predictions by county as obtained from the 1992 report equations.

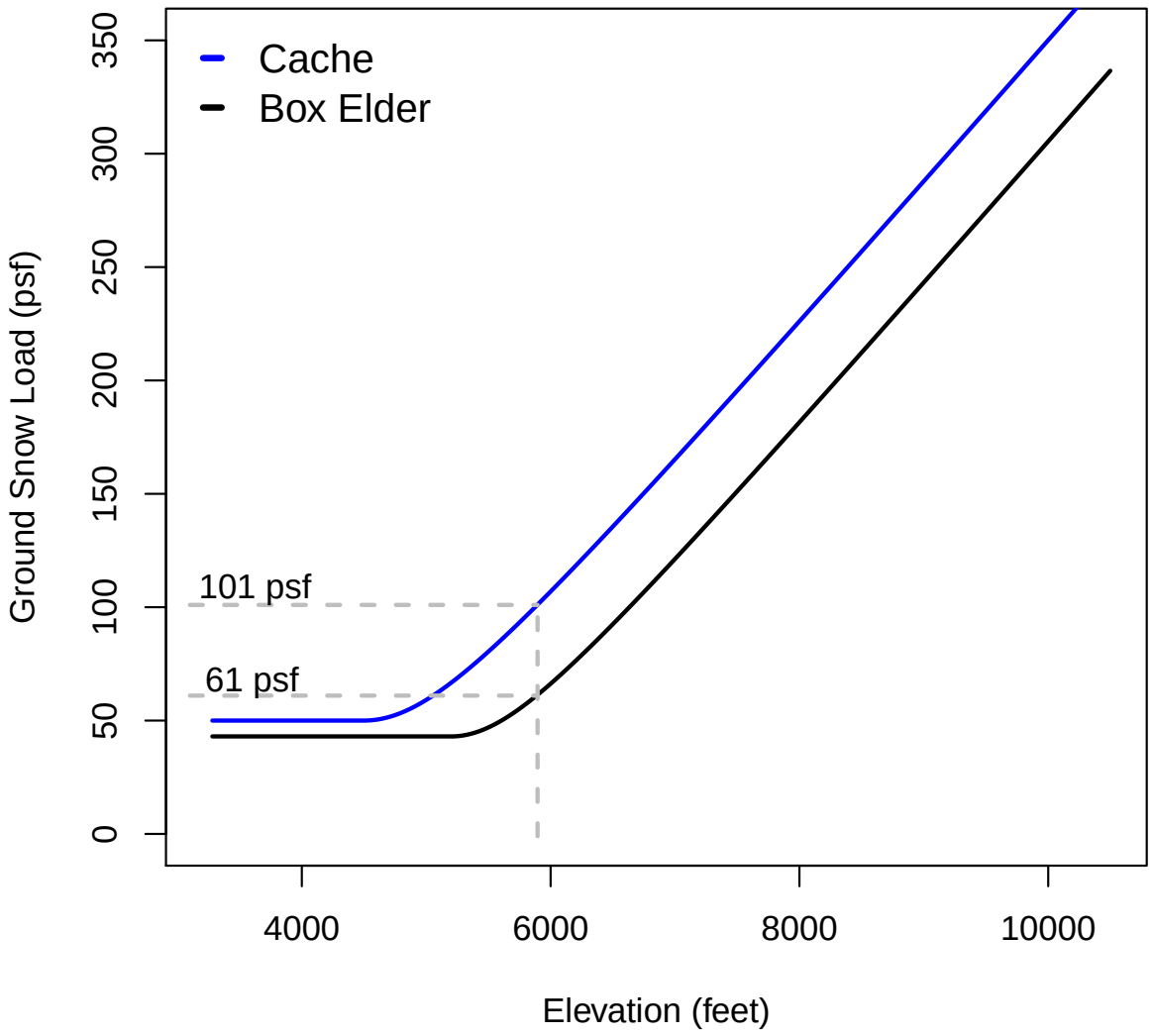

Fig. 5. Ground snow load predictions by county as obtained from the 1992 report equations.

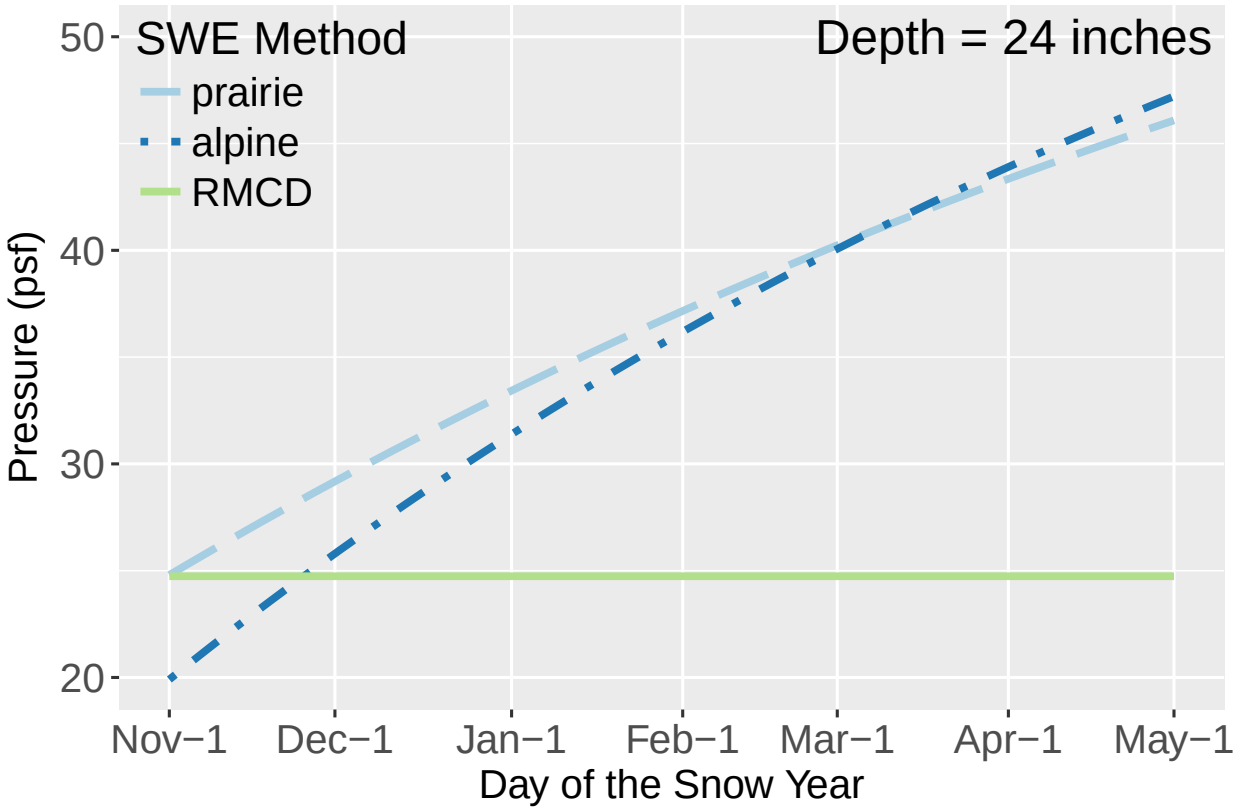

Fig. 6. Comparison of depth to pressure conversions using Sturm's equations and the RMCD for two feet of snow across time.

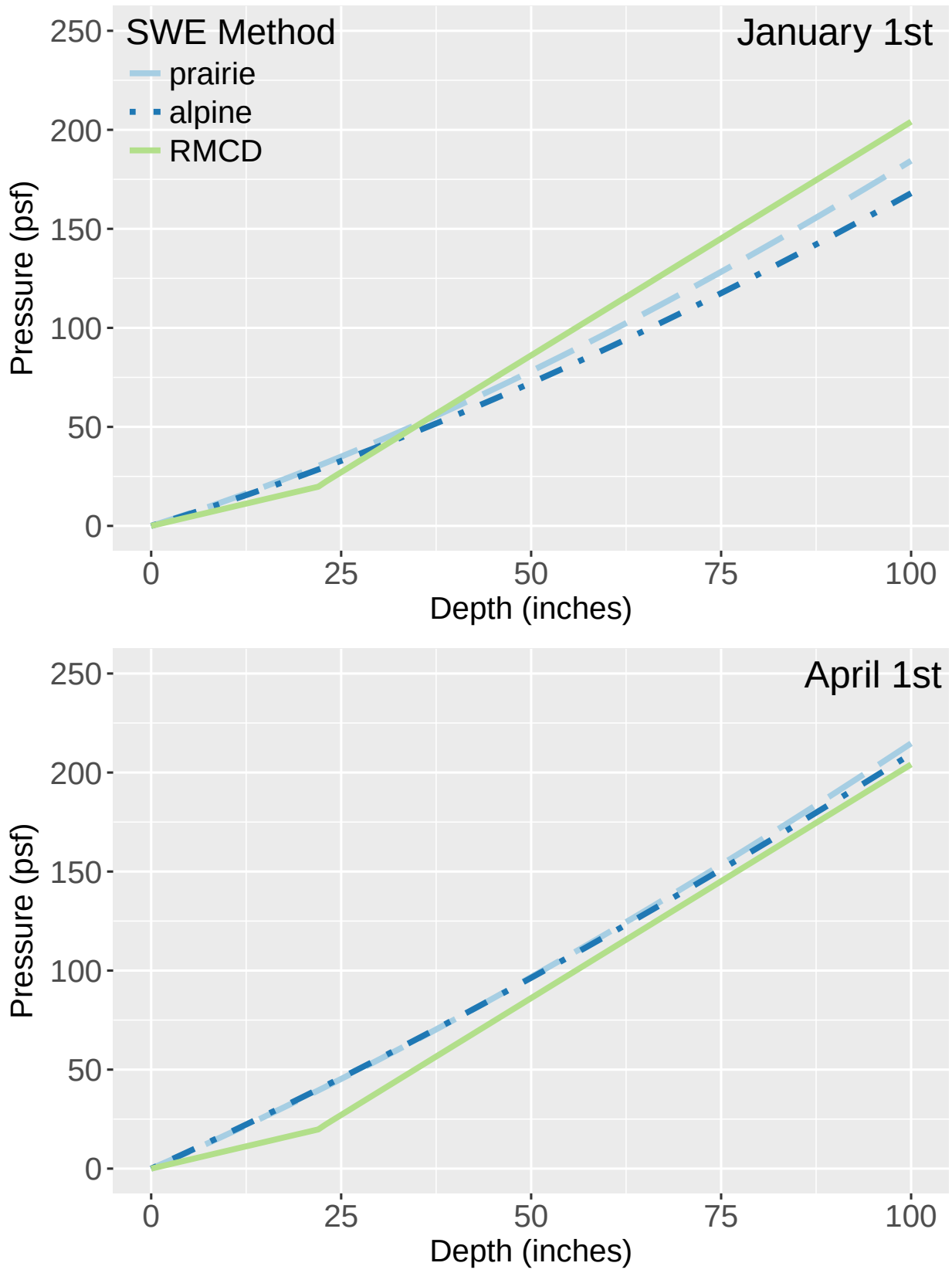

Fig. 7. Comparison of depth to pressure conversions using Sturm's equations and the RMCD across snow depths.

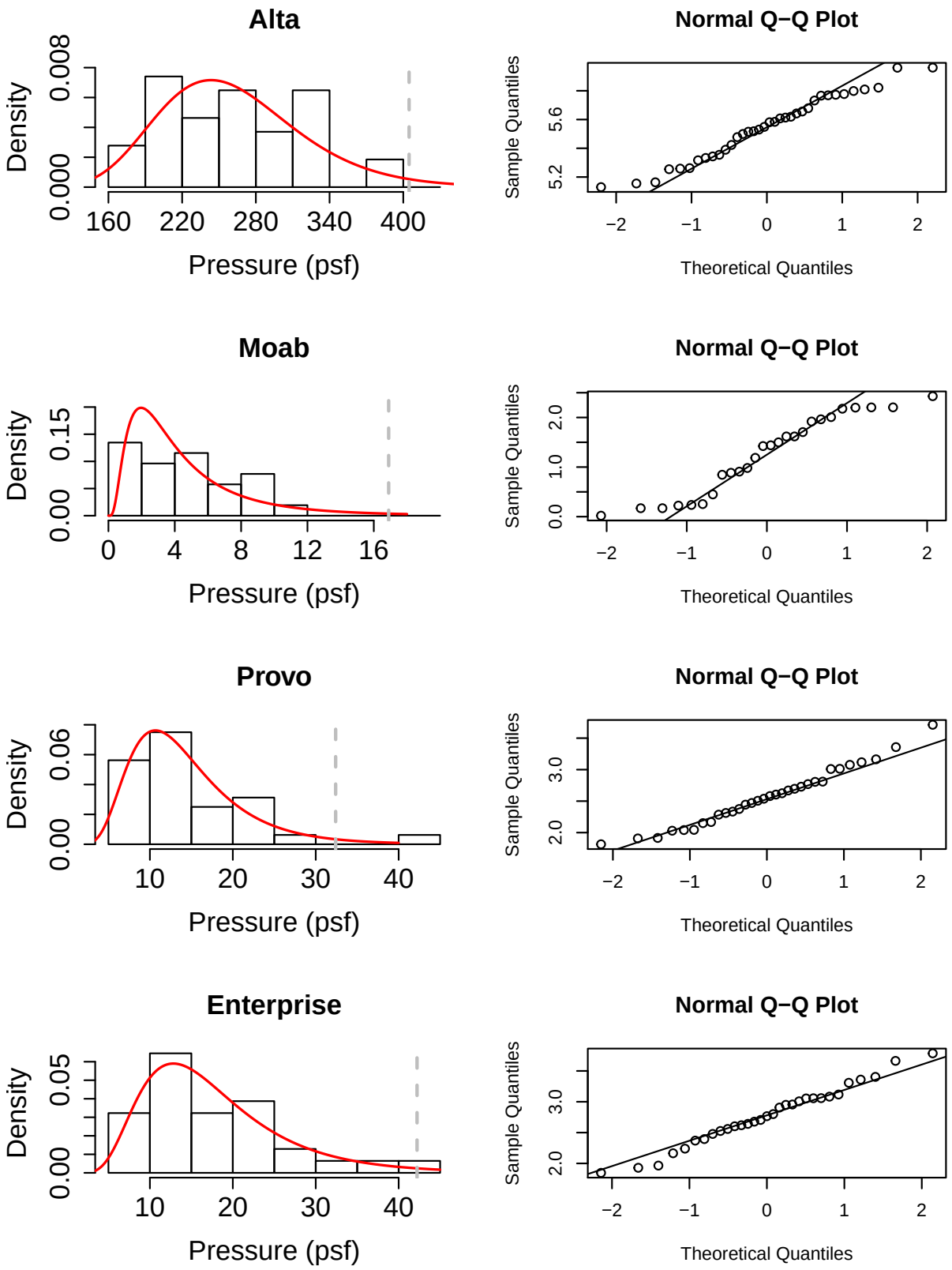

Fig. 8. Sample histograms with associated log-normal distributions at select station locations. The associated Q-Q plots visualize the quality of log-normal distribution fit. A good fit is one in which the points closely follow the straight line.

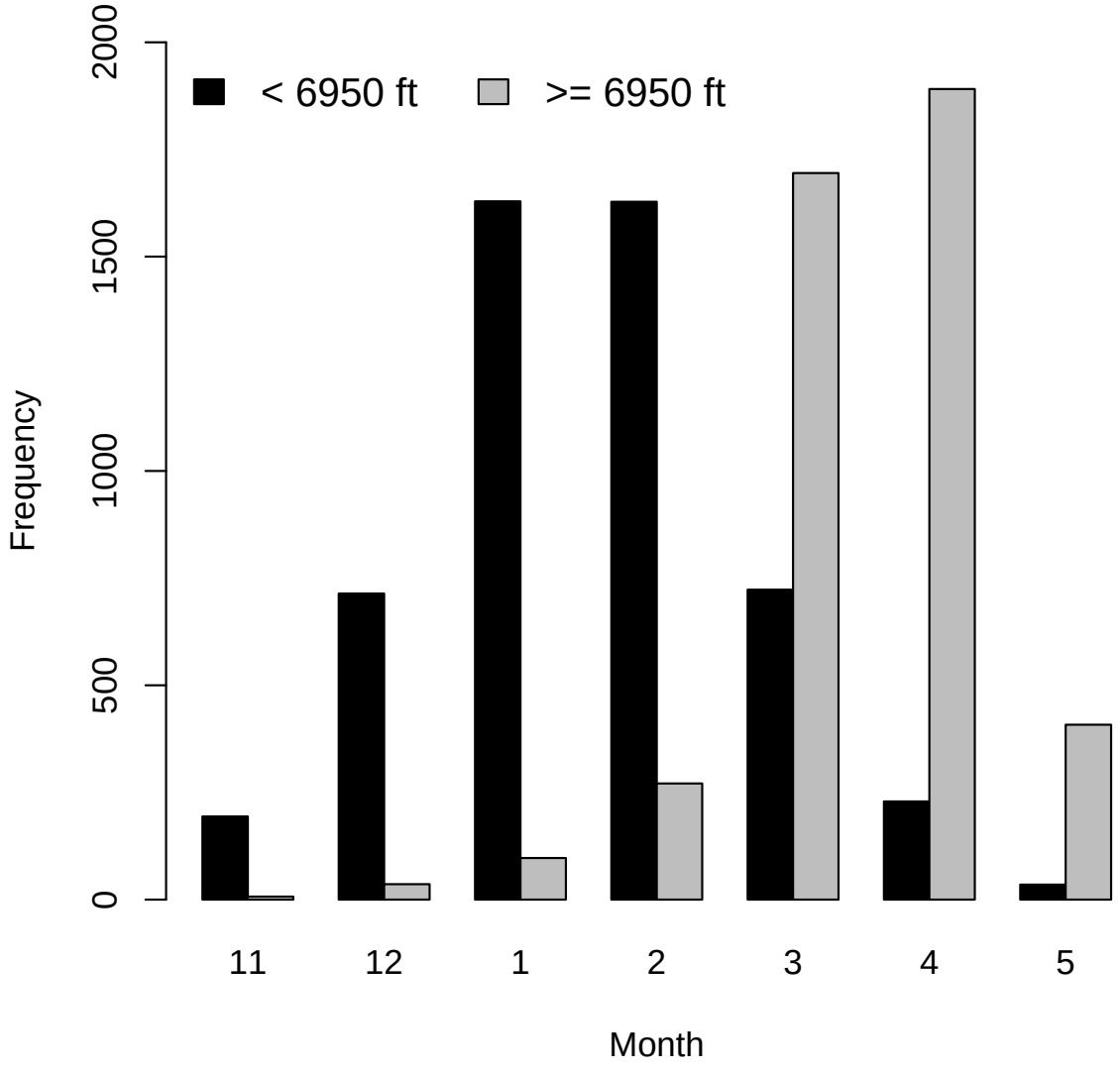

Fig. 9. Month in which yearly maximum ground snow load occurred as separated by elevation.

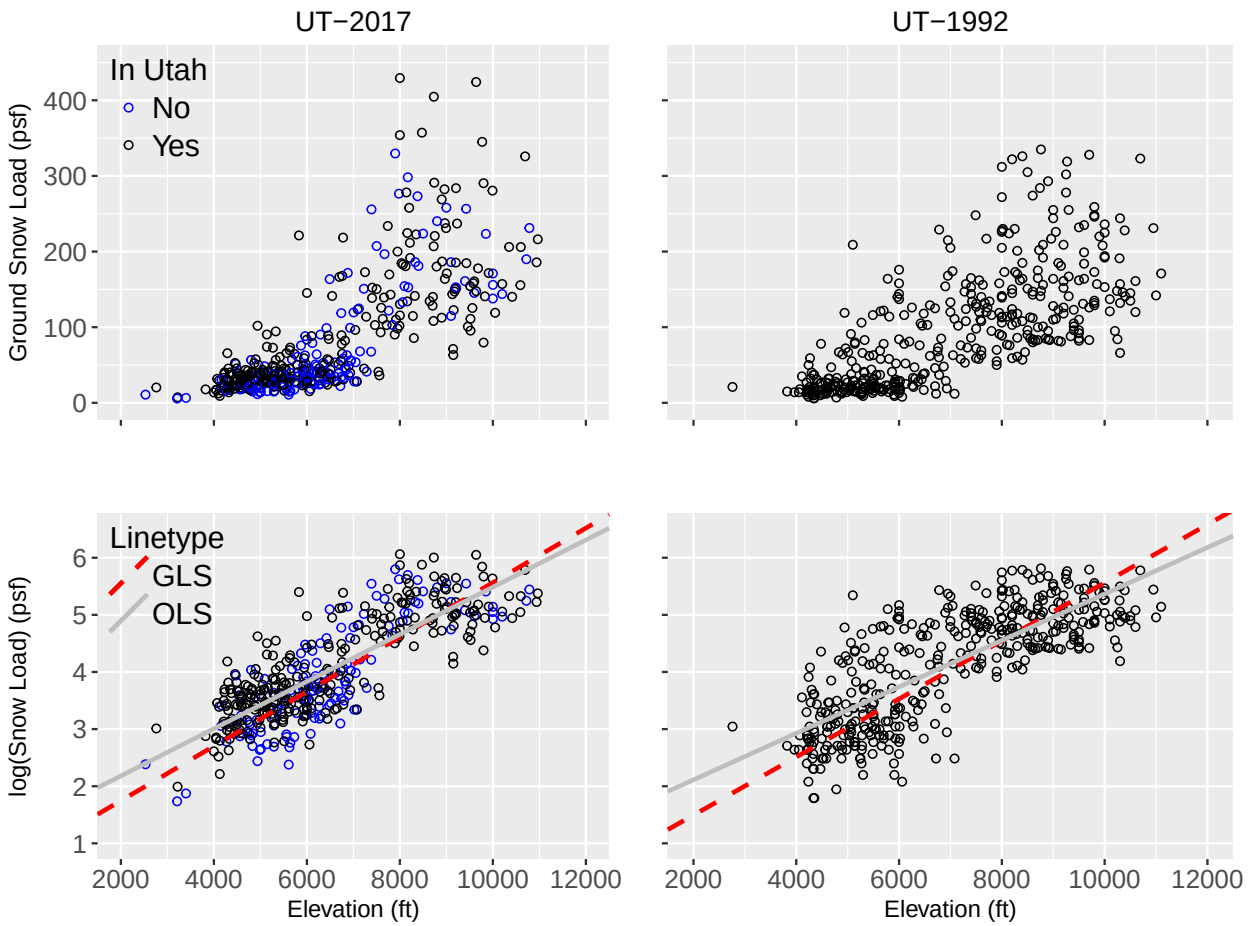

Fig. 10. Plot of the relationship between ground snow loads and elevation for UT-2017 and UT-1992. Also, visualization of log-linear trend lines as computed using ordinary and generalized least squares regression.

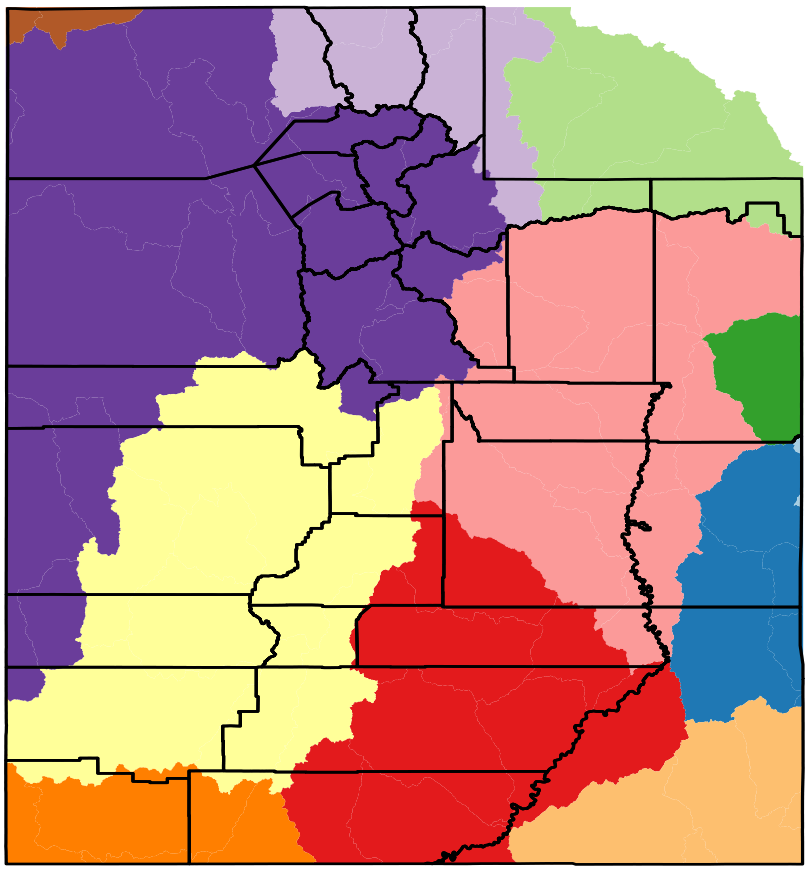

Fig. 11. Map of the HUC-4 watersheds of Utah, as separated by color.

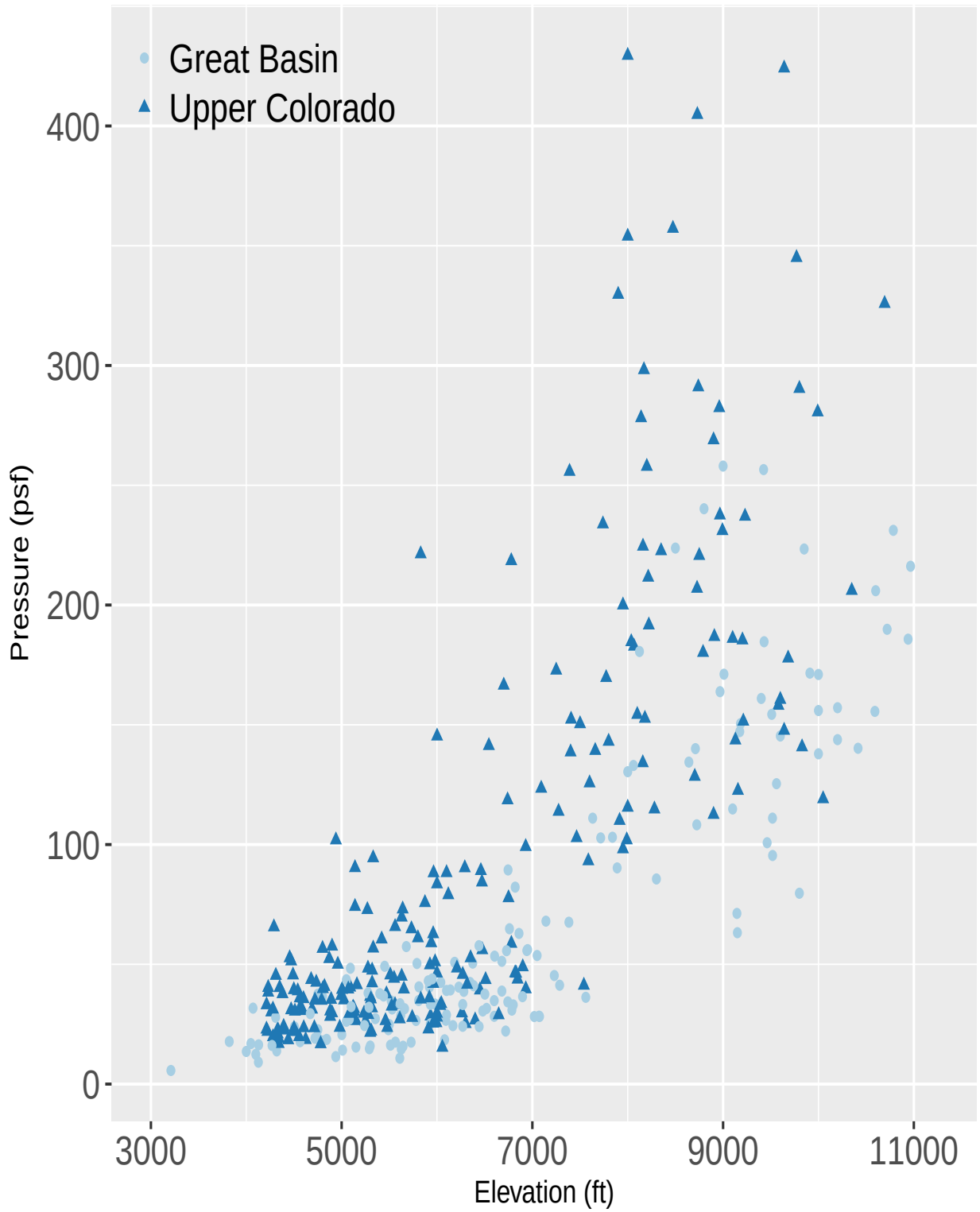

Fig. 12. Ground snow loads vs elevation on UT-2017 for stations located in the Great Basin and Upper Colorado River watersheds.

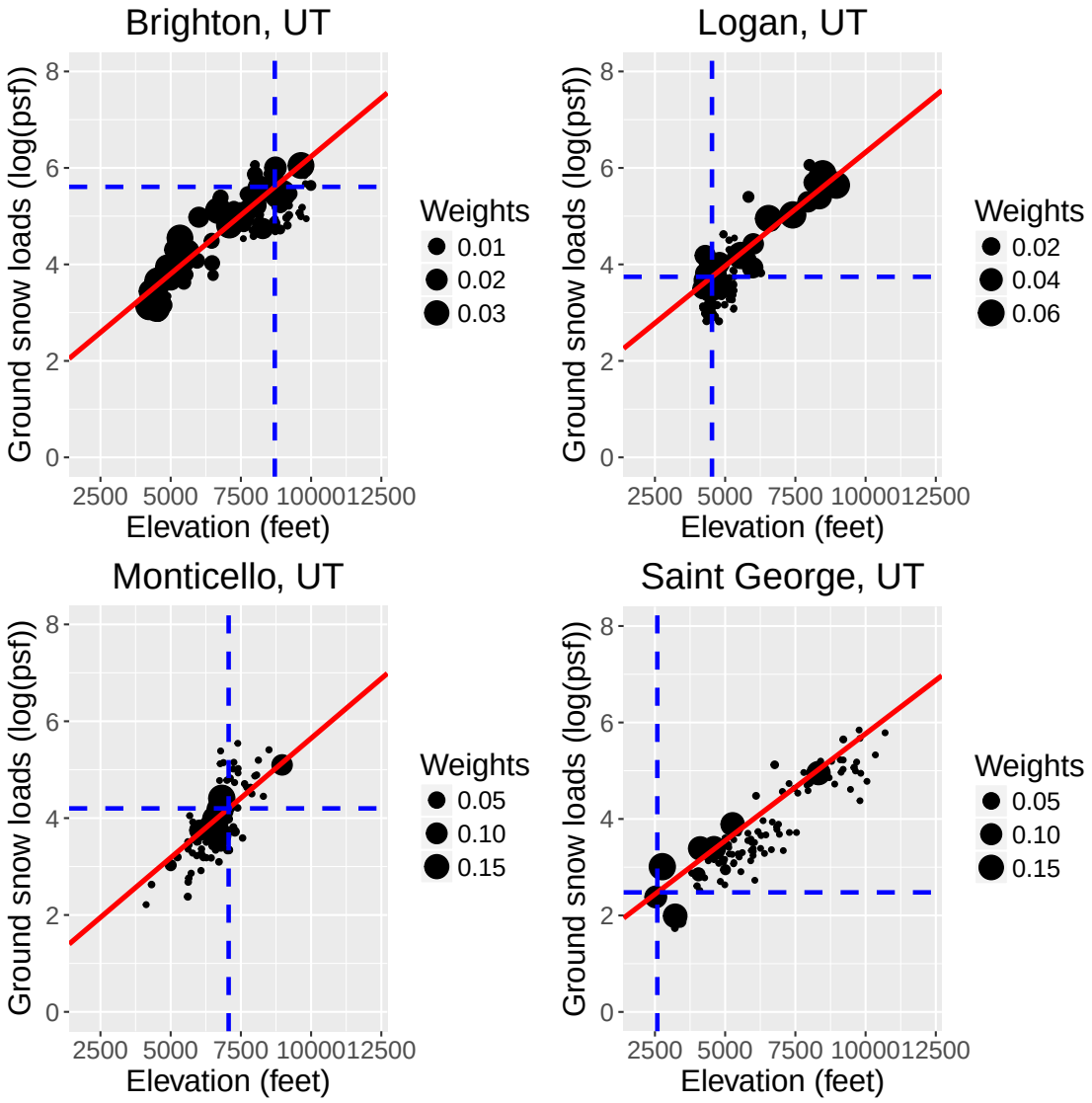

Fig. 13. Illustrations of PRISM model predictions at notable locations in Utah.

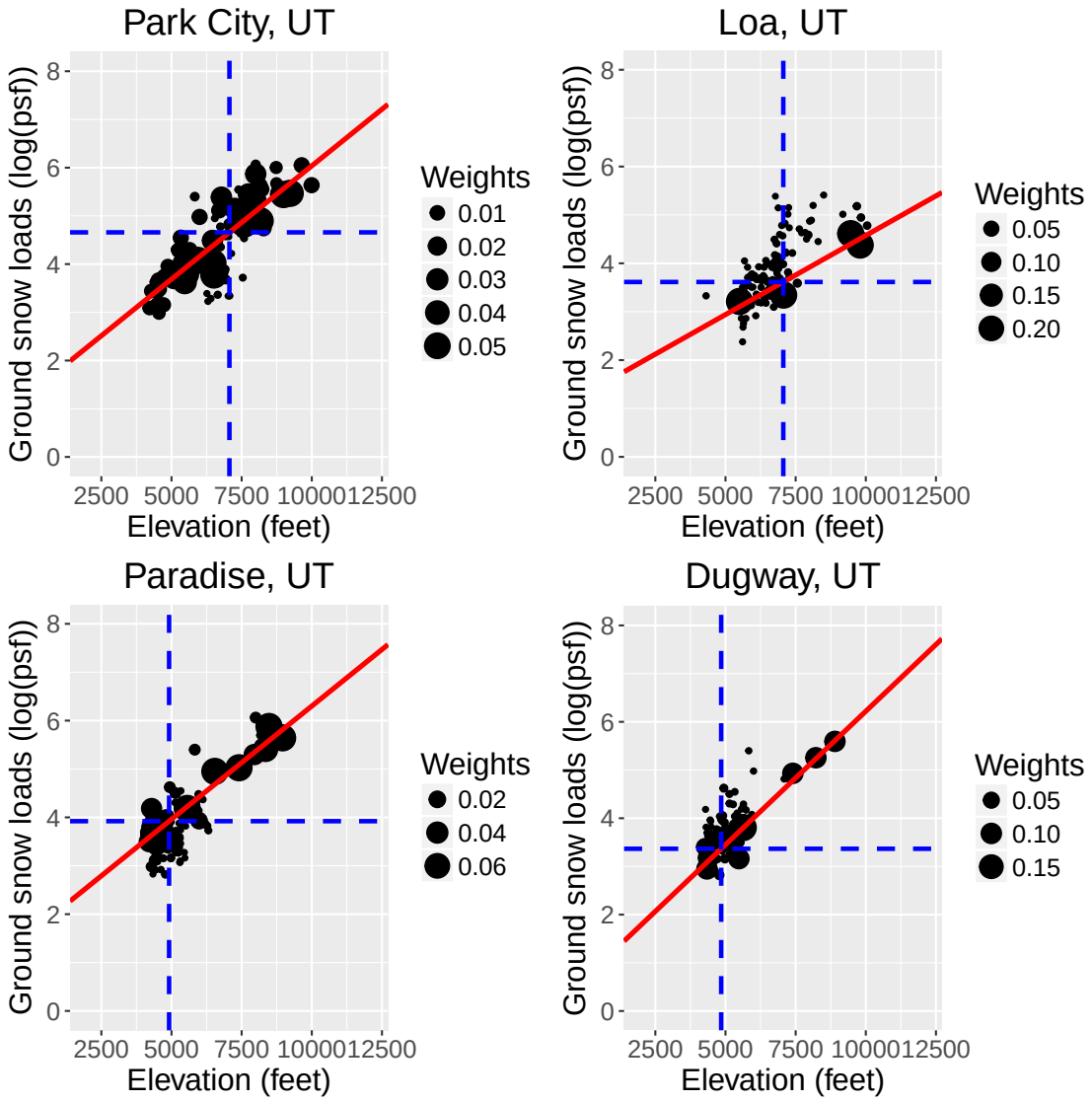

Fig. 14. Illustrations of PRISM model predictions at notable locations in Utah, second set.

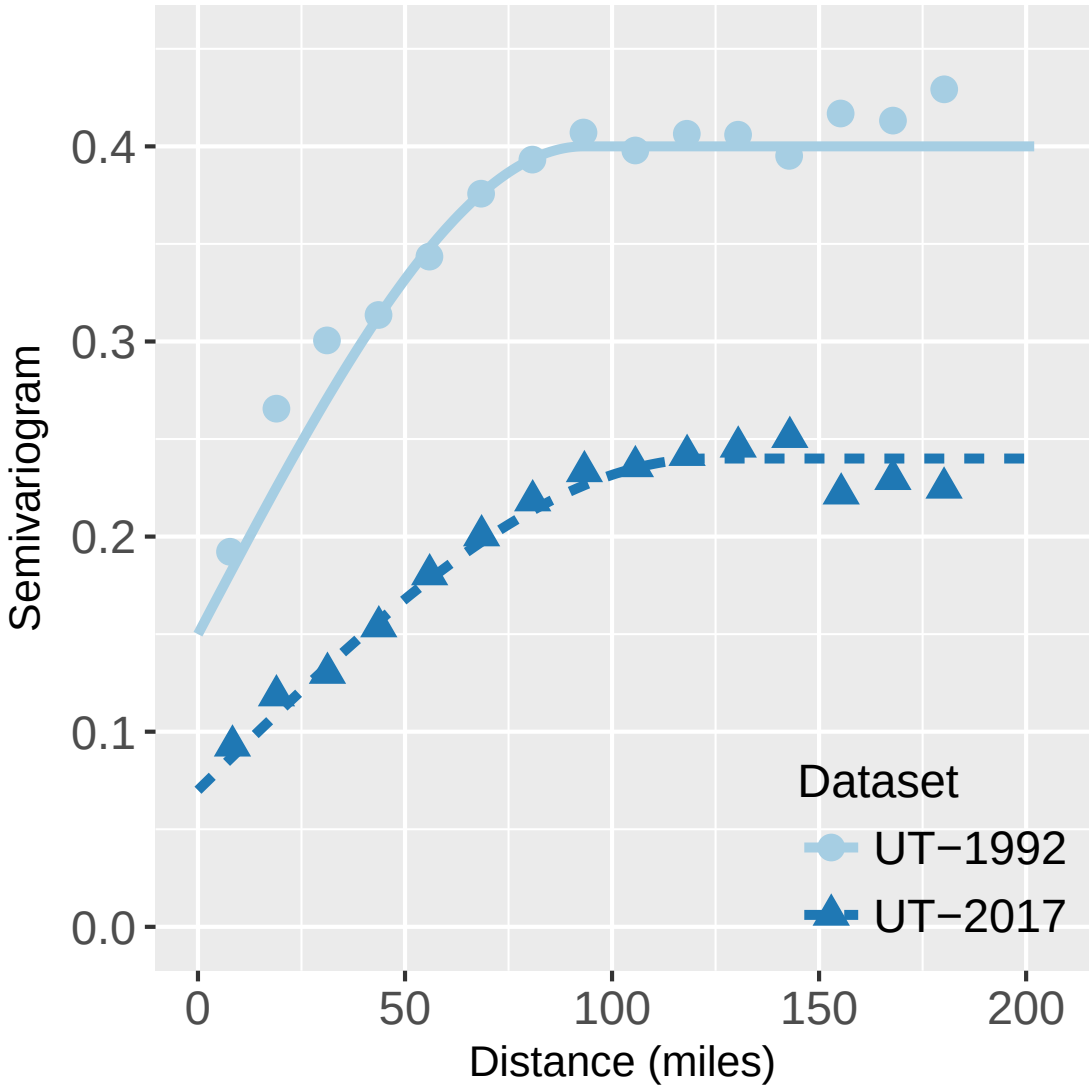

Fig. 15. Sample empirical (points) and theoretical (lines) variograms for UT-2017 and UT-1992.

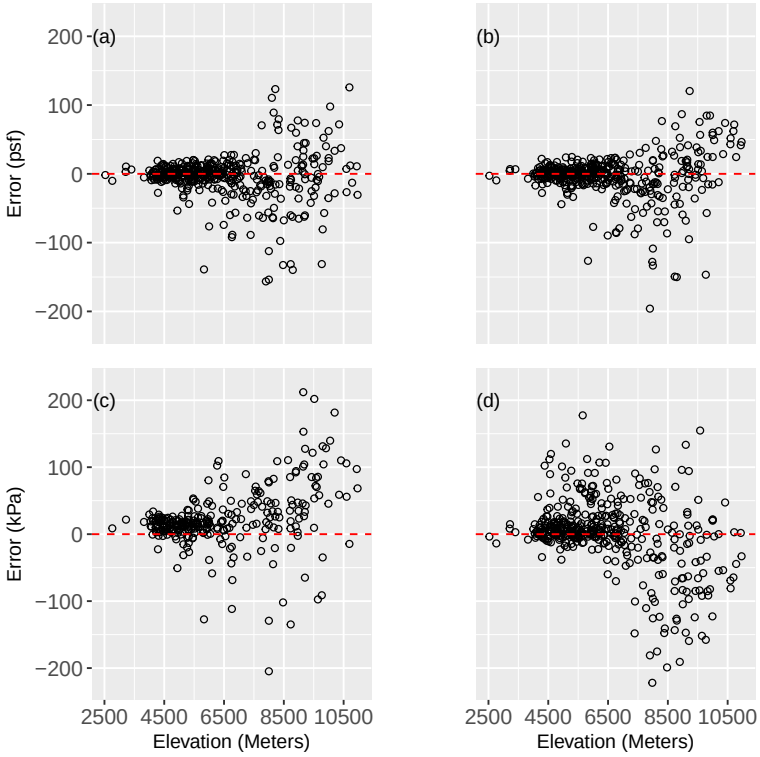

Fig. 16. Scatter plot of cross validated errors for (a) PRISM, (b) SKLM, (c) SNLW, and (d) IDW on UT-2017.

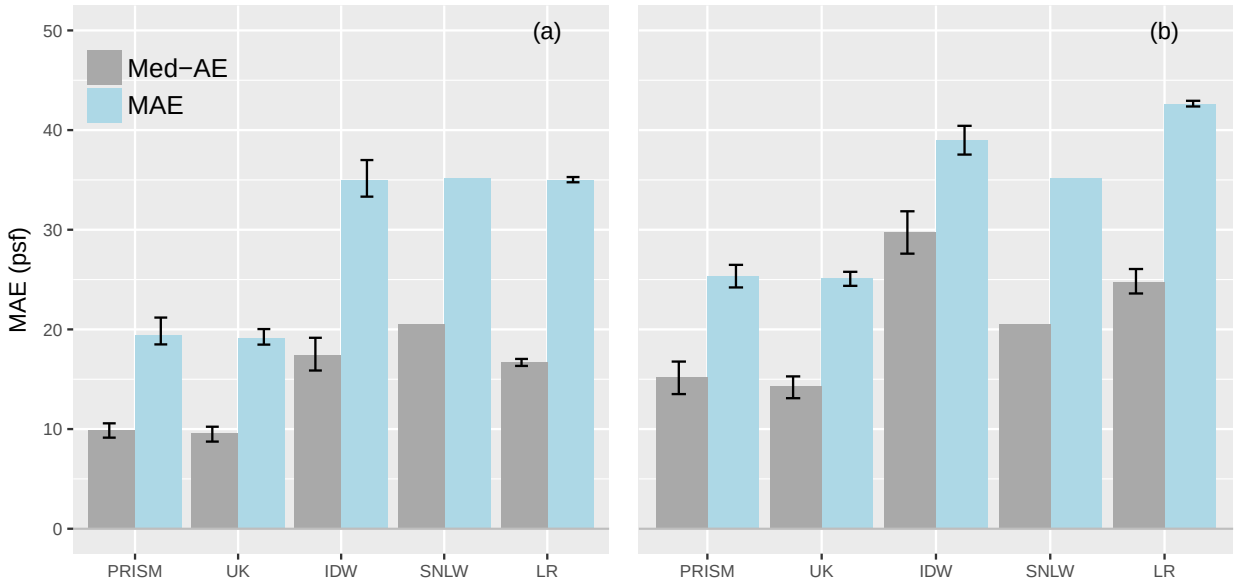

Fig. 17. Bar-plots of the mean absolute error (MAE) and median absolute error (Med-AE) on (a) UT-2017 and (b) UT-1992. Whiskers represent the highest and lowest values of each statistic resulting from 100 iterations of cross validation.

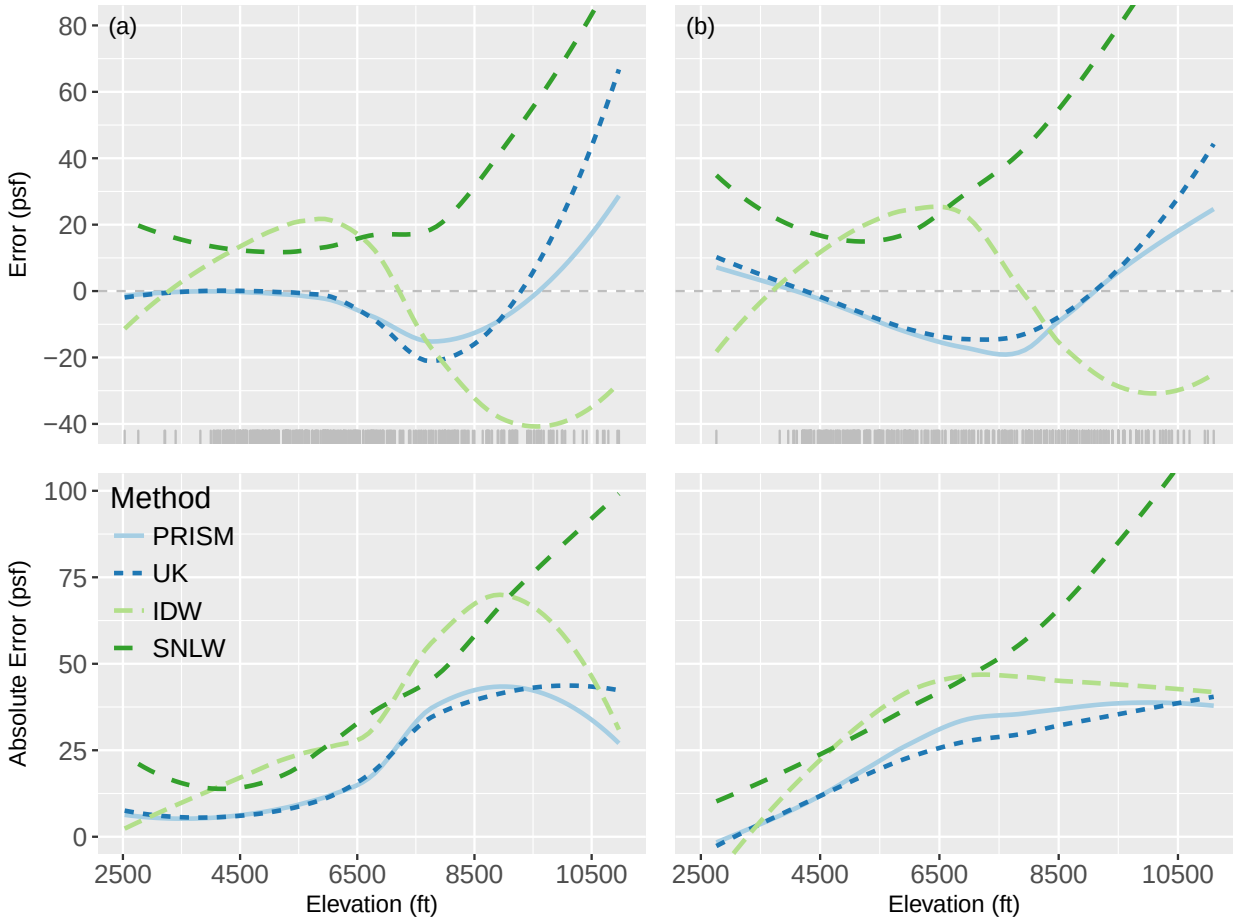

Fig. 18. Second degree loess smoothing curves of error and absolute error on (a) UT-2017 and (b) UT-1992. These curves represent smoothed local averages of the prediction error across elevation. Grey tick marks indicate the density of stations across elevations.

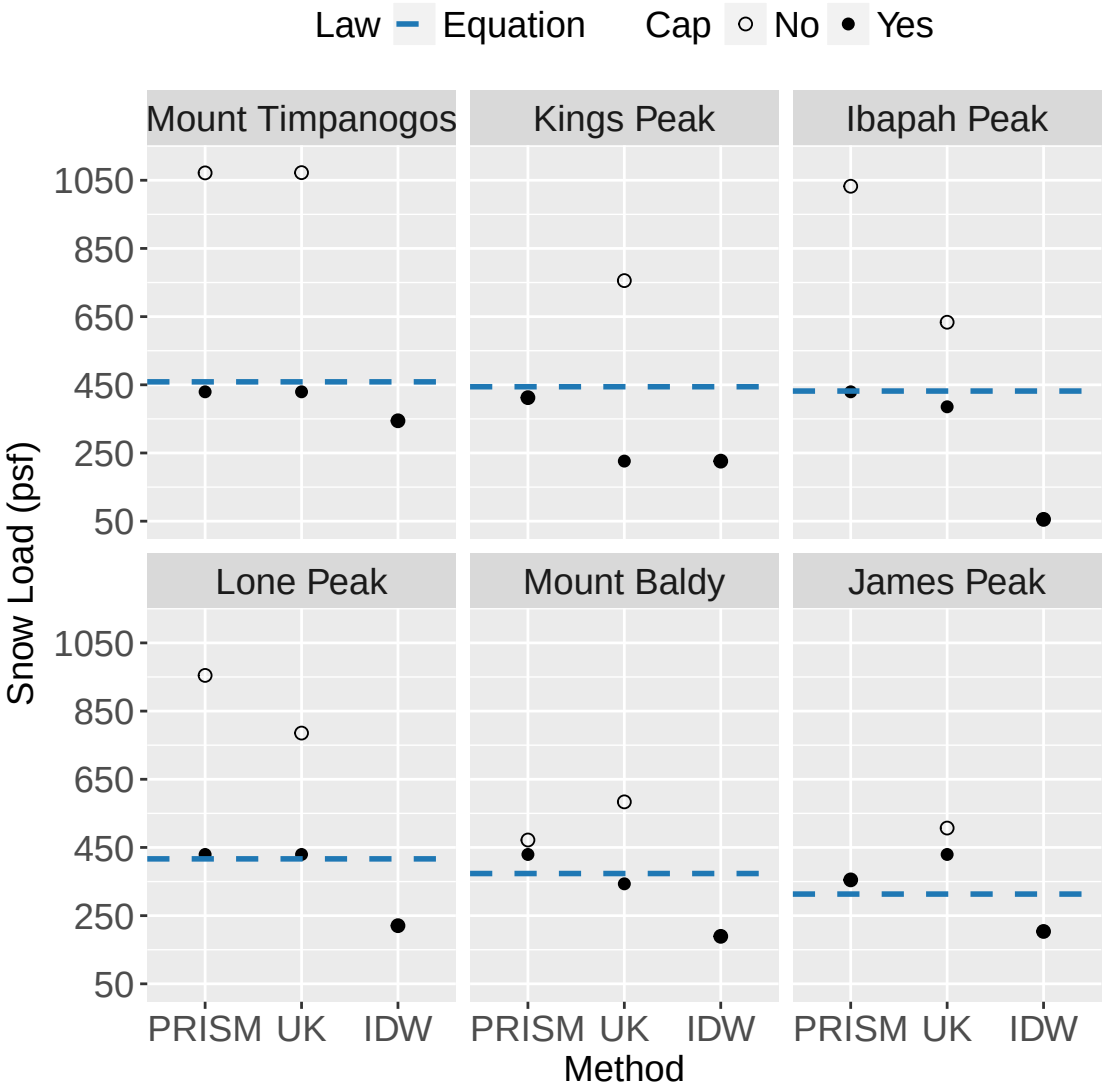

Fig. 19. Predicted ground snow load at various mountain peaks in Utah.

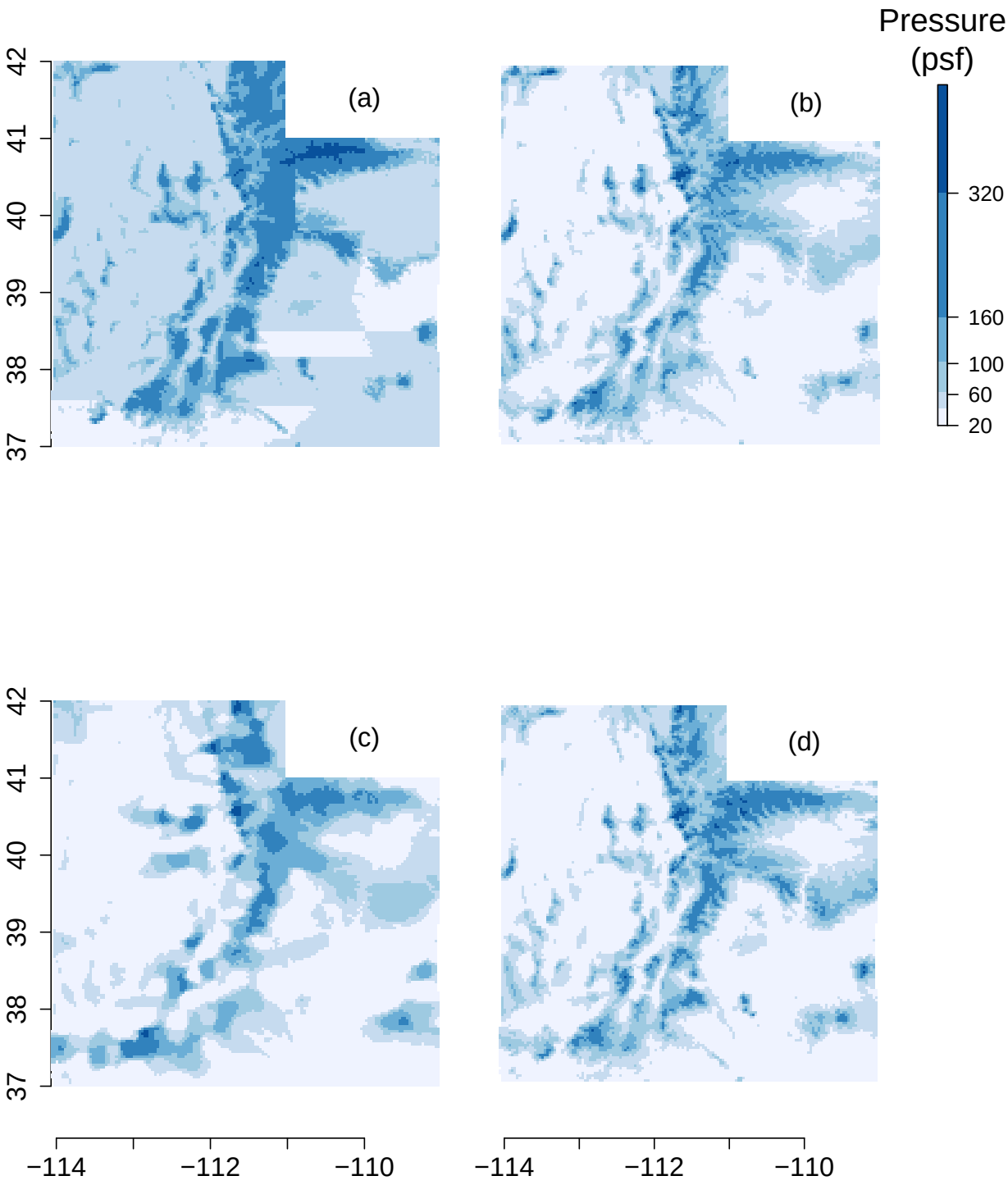

Fig. 20. Sample snow load maps created using (a) SNLW, (b) PRISM, (c) IDW and (d) UK.

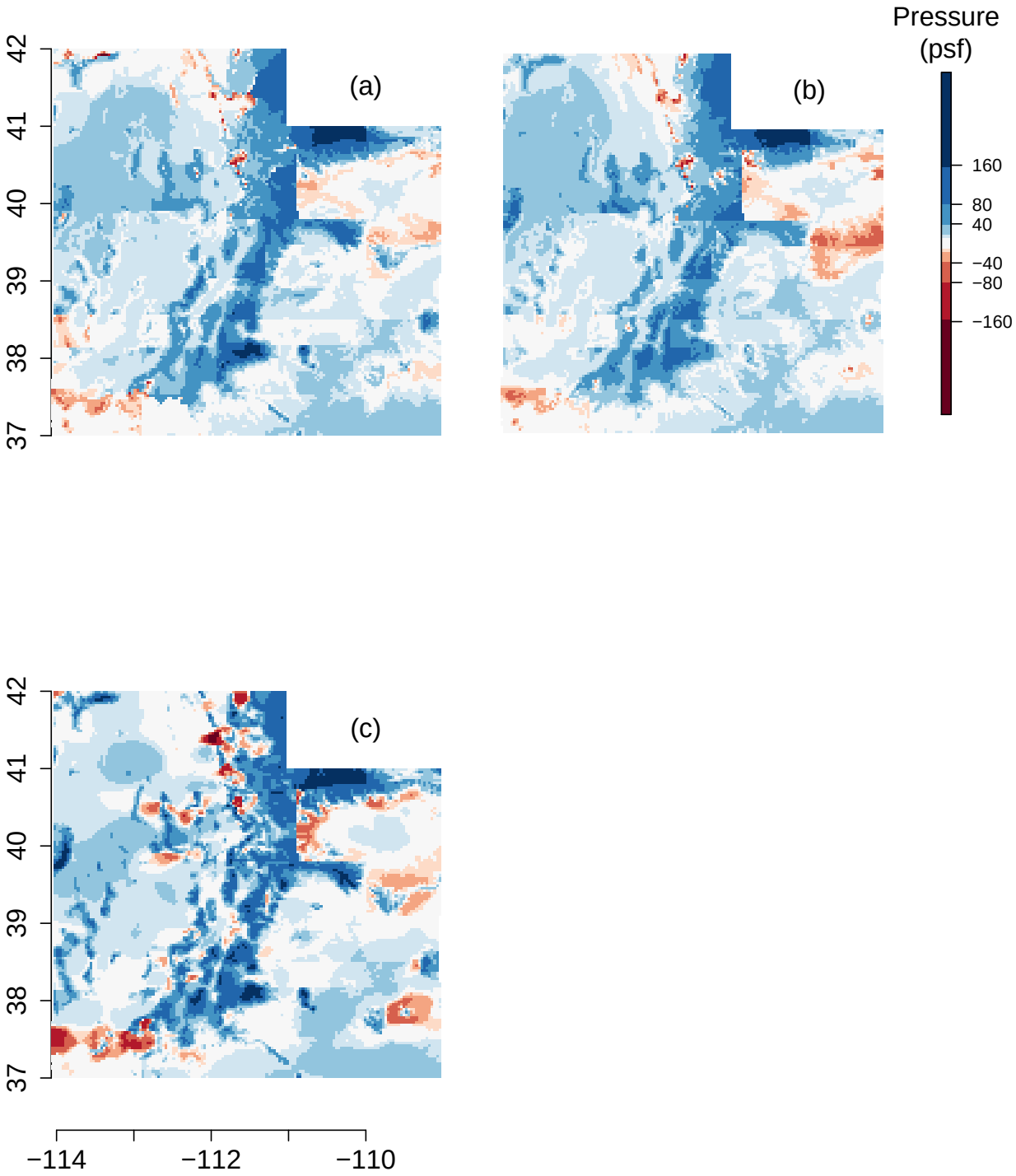

Fig. 21. Differences in snow load predictions between the 1992 equations and (a) PRISM, (b) UK, and (c) IDW. Blue represents areas where the 1992 equations predict higher ground snow loads than the respective methods.

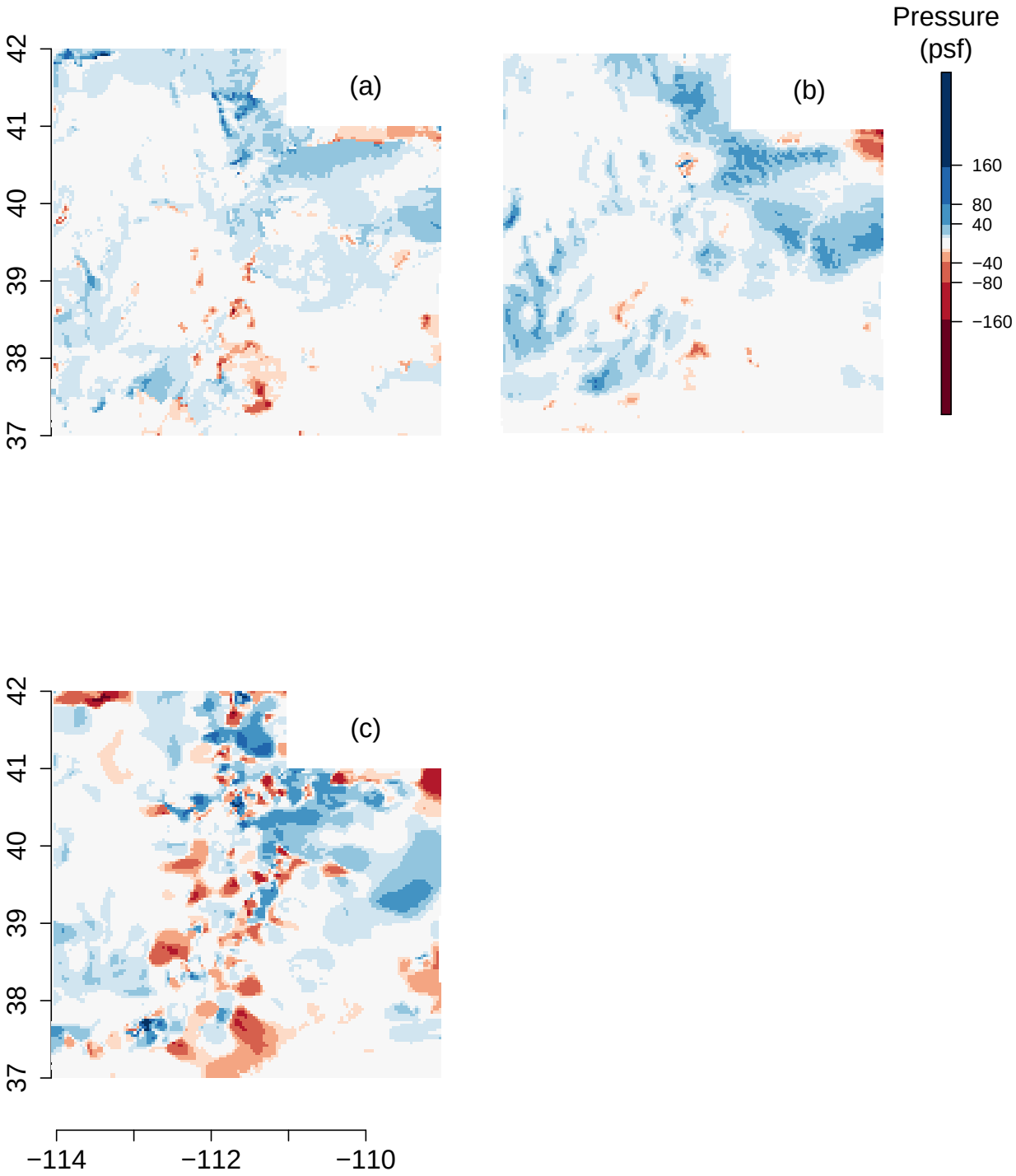

Fig. 22. Differences in ground snow load predictions using UT-1992 vs UT-2017 for (a) PRISM, (b) UK, and (c) IDW. Blue represents areas where predictions using UT-2017 predict higher snow loads than predictions using UT-1992.

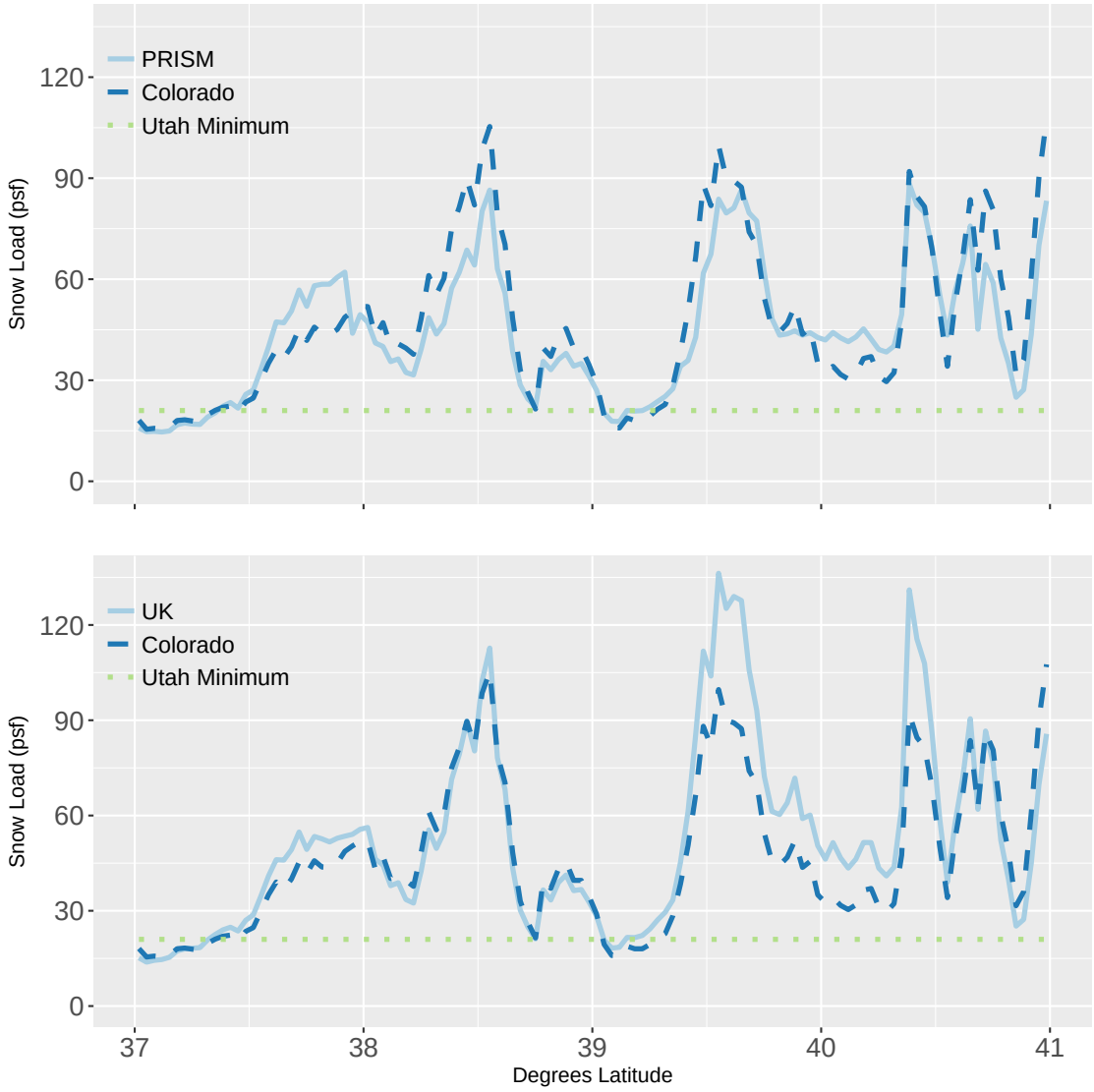

Fig. 23. Comparison of ground snow load predictions to the current method found in the 2016 Colorado Snow Load Report.

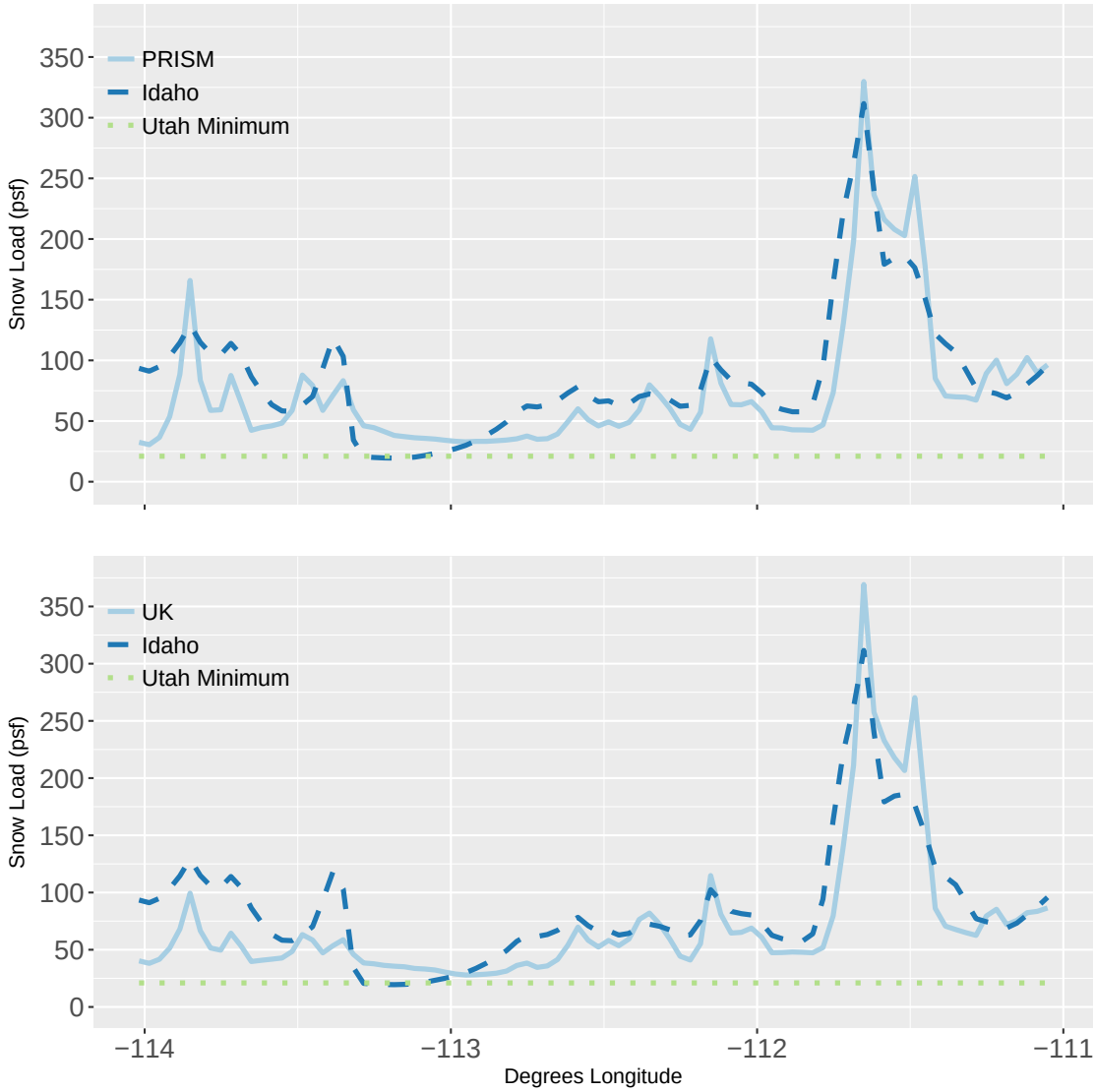

Fig. 24. Comparison of ground snow load predictions to the current method found in the 2015 Idaho Snow Load Report.

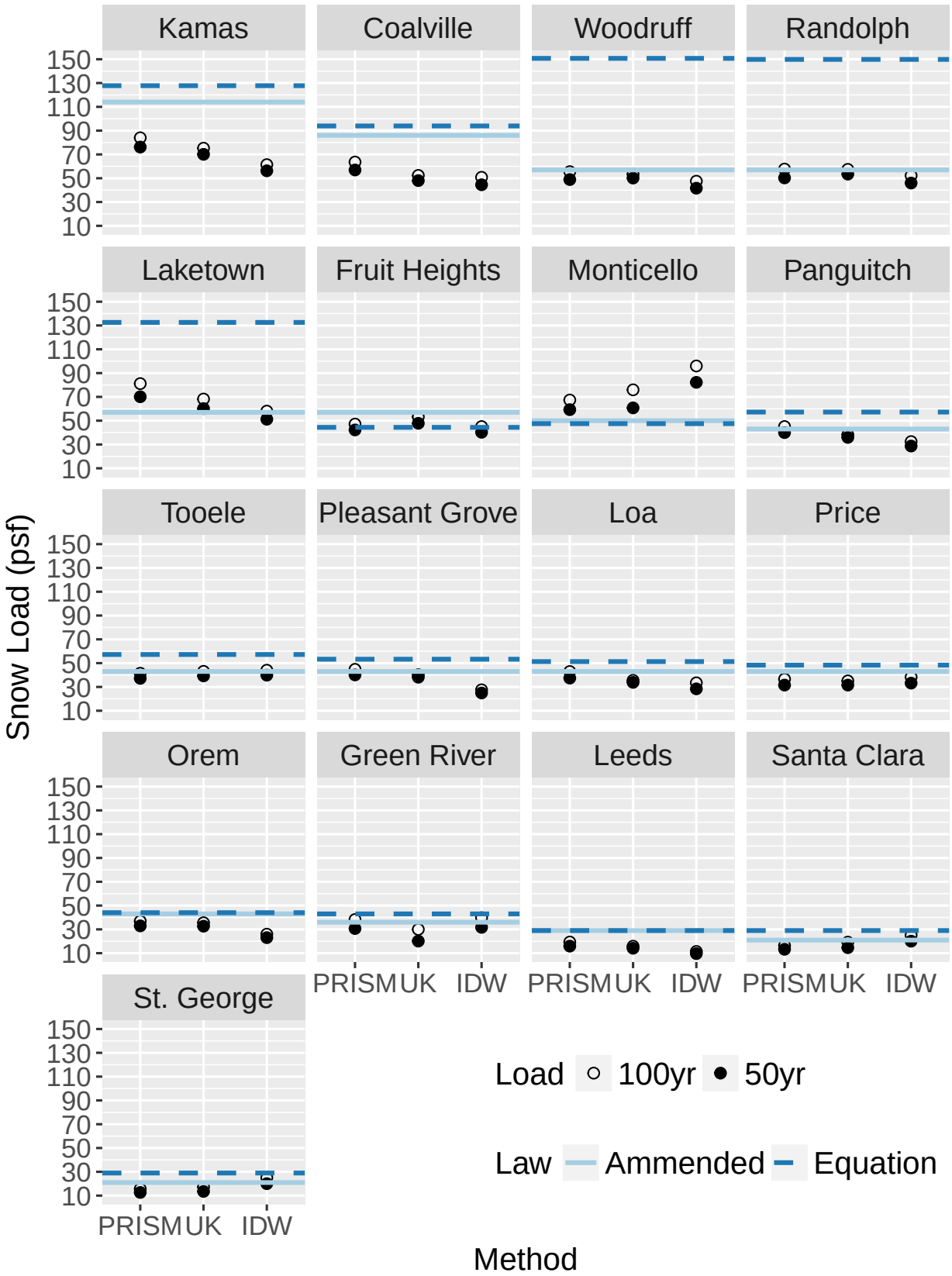

Fig. 25. Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to the reference lines for the amended requirements and 1992 snow load predictions.

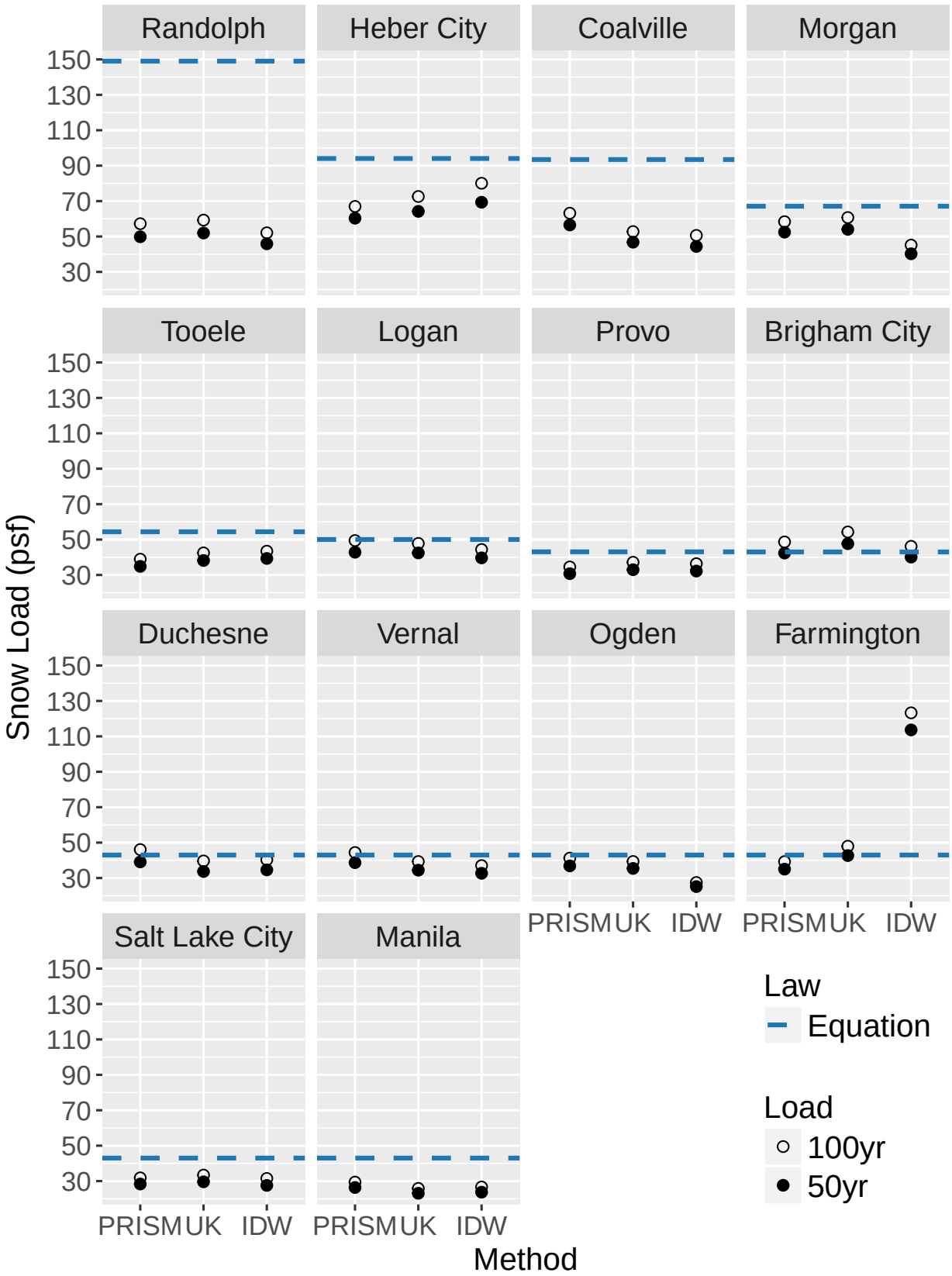

Fig. 26. Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to reference lines for the 1992 snow load predictions.

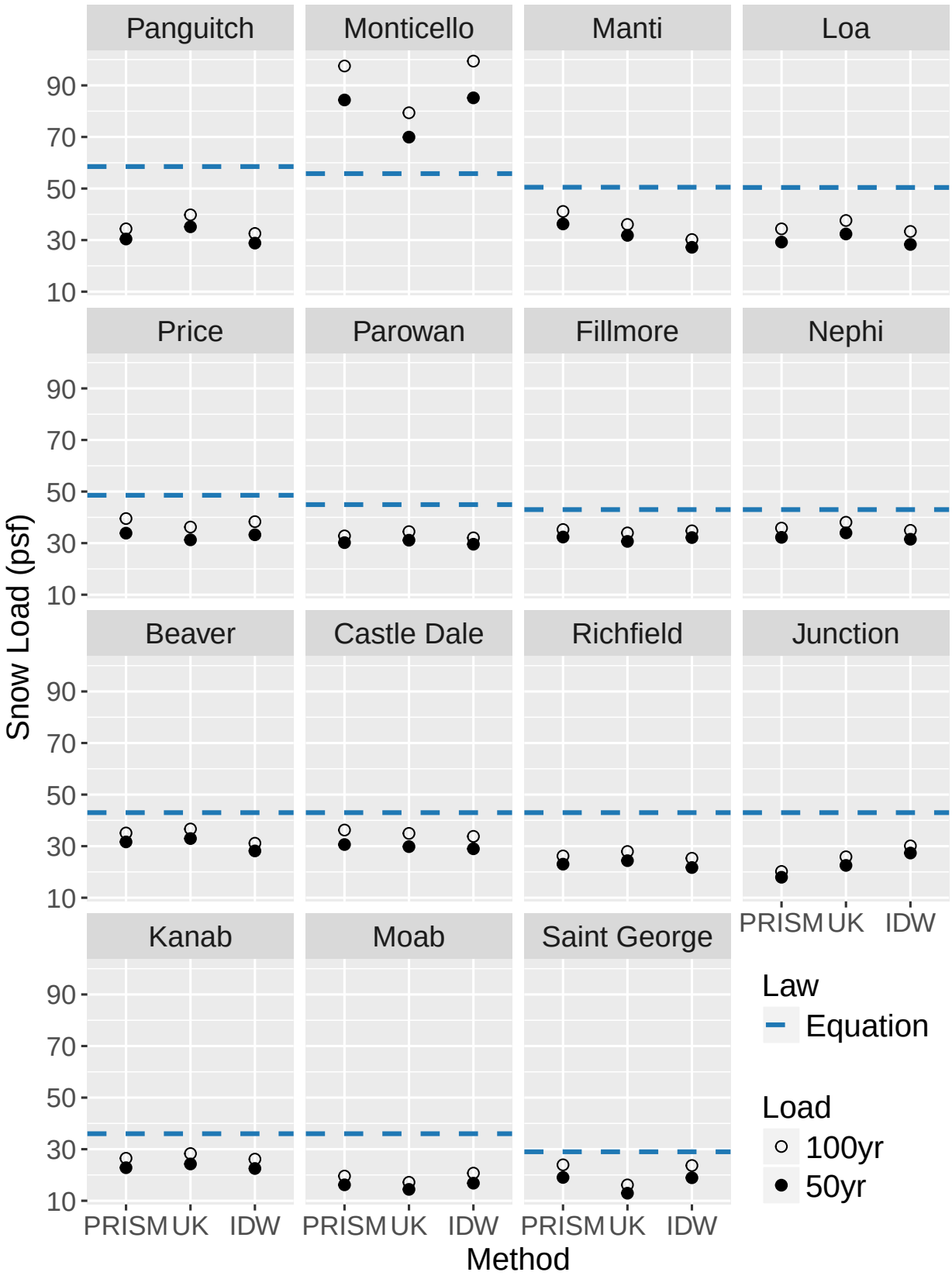

Fig. 27. Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to reference lines for the 1992 snow load predictions.

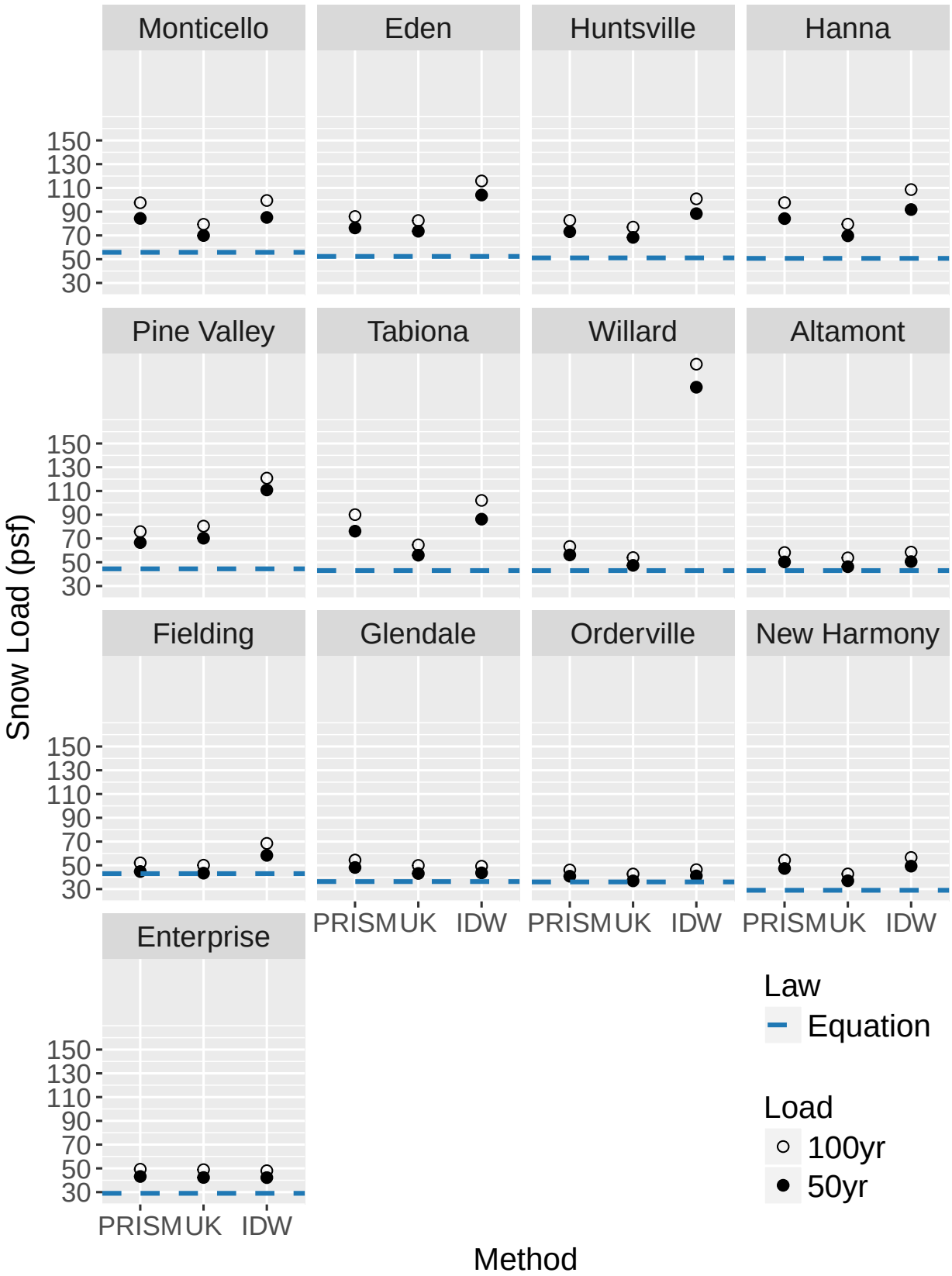

Fig. 28. Predicted ground snow loads at locations with amended ground snow loads in 2016. Here dots represent the predicted ground snow loads for each respective method as compared to reference lines for the 1992 snow load predictions.