

Methodology for PRISM SNOTEL Multi-Sensor QC System

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Unlike temperature and precipitation, which are mapped with PRISM on a regular basis, snow water equivalent and snow depth are not mapped with PRISM. This means that spatial QC (SPQC), which compares PRISM spatial estimates to station observations, is not available as a QC tool for snow water equivalent and snow depth. As an alternative, we developed a multi-sensor QC (MSQC) approach that takes QC'ed observations of daily maximum and minimum temperature (TMAX and TMIN) and incremental precipitation (IP) as inputs, uses a statistical model to estimate daily incremental changes in snow water equivalent (ISWE) and snow depth (ISNWD), and compares them to the station observations. If the observations fall within an acceptable range around the estimates, the observations are accepted as valid. If they fall outside the range, the observation is marked as failing MSQC and a replacement value is estimated. Values of ISWE and ISNWD, based on either valid observations or replacement values, are accumulated into values of ASWE and ASNWD to track snowpack conditions on the ground. (ASWE and ASNWD are termed WTEQ and SNWD, respectively, by the NRCS.) Procedures for the development and operation of MSQC are outlined in this document.

Note: It is important to remember that MSQC assesses daily *incremental changes* in SWE and SNWD, not the accumulations on the ground.

Statistical Snow Model

It was beyond the scope of this project to implement a physically based snow accumulation and melt model to provide estimates of daily snow conditions. Therefore, a statistical model was developed that is parameterized by a station's own historical behavior. The model consists of four steps, executed in the following order (see Figure 1):

1. Snowpack compaction: Applies a daily compaction factor to the snow depth.
2. Rain/snow apportionment: Divides daily precipitation into rain and snow portions.

3. Snow accumulation: Accumulates (or reduces) snow water equivalent and snow depth, based on the rain/snow components.
4. Snow melt: Reduces the snowpack based on a temperature-based melt rate.

MSQC Statistical Snow Model Process Flow PRISM SNOTEL QC System

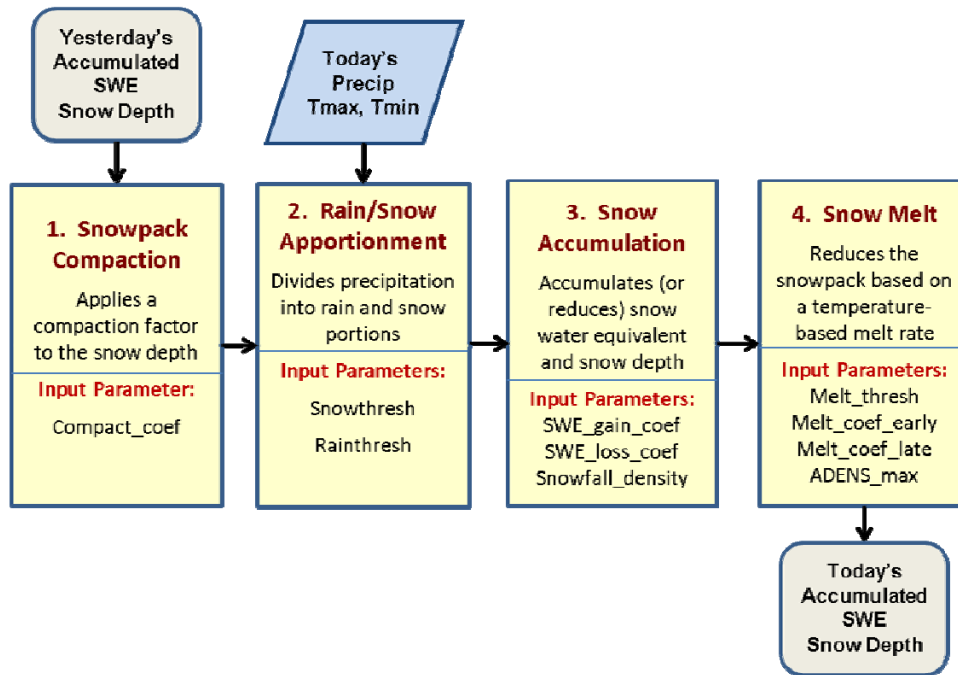


Figure 1. Daily process flow for the MSQC statistical snow model.

Input parameters used in the model are made up of a combination of station-specific statistics, and global values that function reasonably well for all SNOTEL stations. The model is run in three modes simultaneously, using three sets of parameters. “Estimate” parameters are calibrated to a station’s behavior, and are used to produce the model’s replacement values, “High Snow” parameters produce snowpack accumulations that are considered to be the upper bound of acceptability, and “Low Snow” parameters produce the lower bound of acceptability. Input parameter definitions and values are listed in Table 1. Note that these parameters are simple metrics that represent complex physical processes, and thus their values may deviate from what would be considered most physically meaningful.

Calculations for the day begin with $ASWE_{d-1}$ and $ASNWD_{d-1}$, which are observed accumulated SWE and snow depth from the previous day (if observations are missing, estimated values are

used). Meteorological inputs are the current day's IP, TMAX, and TMIN, each of which has passed through the other three QC components of the SNOTEL QC system (SSQC, PROF, and SPQC). TMAX and TMIN are averaged to estimate a daily mean temperature (TMEAN).

Each of the four model steps is discussed below in the order in which they are executed each day.

Step 1. Snowpack Compaction

Snowpack compaction is applied to the prior day's snow depth to account for settling over the previous 24 hours. The actual rate of compaction varies in complicated ways with snow density, snowfall, rainfall, and other factors. Here, a constant compaction rate is assumed, where each day the accumulated snow depth from the previous day is reduced by a set proportion of the total depth:

$$ASNWD_c = ASNWD_{d-1} * Compact_coef$$

Where $ASNWD_c$ is the snow depth resulting from compaction over the previous day, $ASNWD_{d-1}$ is the snow depth from the previous day, and $Compact_coef$ is the compaction coefficient, specified as a global input parameter (see Table 1).

The resulting snow density is also calculated as

$$ADENS_c = ASWE_{d-1} / ASNWD_c$$

where $ASWE_{d-1}$ is the previous day's snow water equivalent.

Step 2. Rain/Snow Apportionment

IP is divided into rain and snow portions using a linear apportionment between upper and lower TMEAN thresholds:

$$\text{If } TMEAN < Snowthresh, SNOW = IP;$$

$$\text{If } Snowthresh \leq TMEAN \leq Rainthresh, SNOW = IP * (1 - (TMEAN - Snowthresh) / (Rainthresh - Snowthresh));$$

$$\text{If } TMEAN > Rainthresh, SNOW = 0$$

where SNOW is the portion of IP estimated to be snow, $Snowthresh$ is the threshold TMEAN below which IP is assumed to be all snow, and $Rainthresh$ is the threshold TMEAN above which IP is assumed to be all rain. $Snowthresh$ and $Rainthresh$ are global input parameters (see Table 1).

The rain portion is then calculated simply as

$$\text{RAIN} = \text{IP} - \text{SNOW}$$

Step 3. Snow Accumulation

The snow accumulation section accumulates (or reduces) snow water equivalent and snow depth, based on values of the RAIN and SNOW components. The change in SWE (ISWE_s) is calculated as

$$\text{ISWE}_s = (\text{SNOW} * \text{SWE_gain_coef}) - (\text{RAIN} * \text{SWE_loss_coef})$$

SWE_gain_coef is a station-specific input parameter that represents precipitation gauge catch efficiency during snowfall (see Table 1). For example, a $\text{SWE_gain_coef} > 1.0$ means that more snowfall is typically accumulated on the snow pillow than is caught by the rain gauge.

SWE_loss_coef represents the rate of SWE loss per unit rainfall during rain-on-snow events.

This input parameter is the result of complex physical interactions, but here is typically set as a global constant (see Table 1).

The change in snow depth is calculated as

$$\text{ISNWD}_s = ((\text{SNOW} * \text{SWE_gain_coef}) / \text{Snowfall_density}) - (\text{RAIN} / \max(0.1, \text{ADENS}_c))$$

where Snowfall_density represents the density (ISWE/ISNWD) of daily snowfall,

Snowfall_density is a station-specific input parameter (see Table 1). ADENS_c is restricted to be at least 0.1 to avoid excessive loss of snow depth if the density of the pack is very low.

Accumulated ASWE, ASNWD, and ADENS are updated as follows

$$\text{ASWE}_s = \text{ASWE}_{d-1} + \text{ISWE}_s$$

$$\text{ASNWD}_s = \text{ASNWD}_c + \text{ISNWD}_s$$

$$\text{ADENS}_s = \text{ASWE}_s / \text{ASNWD}_s$$

Step 4. Snow Melt

The snow melt section reduces the snowpack when temperatures exceed a specified melting point. The loss of SWE is calculated as

$$\text{If } \text{TMEAN} \leq \text{Melt_thresh}, \text{ISWE}_m = 0$$

$$TMEAN > Melt_thresh, ISWE_m = (TMEAN - Melt_thresh) * Melt_coef;$$

where *Melt_thresh* is the TMEAN value above which melt occurs, and *Melt_coef* is the melt rate coefficient, expressed as mm/°C above *Melt_thresh*. *Melt_thresh* is typically set as a global value. *Melt_coef* is divided into two station-specific input parameters: *Melt_coef_early*, used during the period Oct 1 – Mar 31 (representing a relatively low melt rate during winter accumulation), and *Melt_coef_late*, used during the period Apr 1 – Sep 30 (representing the relatively high melt rate during spring ablation).

Accumulated ASWE is updated as

$$ASWE_m = ASWE_s + ISWE_m$$

Before $ASNWD_m$ is calculated, snowpack density from step 3 is reduced if it exceeds the valid maximum:

$$ADENS_m = \min(ADENS_s, ADENS_max)$$

where *ADENS_max* is a global input parameter.

Snow depth resulting from melt is calculated as the depth of snow that maintains the snow density on the ground after melt, $ADENS_m$:

$$ASNWD_m = ASWE_m / ADENS_m$$

Final Daily Values

The final daily values of snow depth and water equivalent are:

$$ASWE_{final} = ASWE_m$$

$$ASNWD_{final} = ASNWD_m$$

Table 1. MSQC model parameters. “Estimate” parameters are calibrated to the station’s historical behavior, and used to produce the model’s replacement values; ranges of values for the SNOTEL stations queried are given in parenthesis. “High Snow” and “Low Snow” parameters represent combinations of parameter values that result in the upper and lower bounds of valid ISWE and ISNWD observations.

Parameter	Estimate	High Snow	Low Snow	Description
<i>Compact_coef</i>	0.99	1.00	0.94	Proportion of ASNWD remaining after a day of compaction (e.g., 0.99 = 99% remaining)
<i>Snowthresh</i> (°C)	0	2	-2	Temperature below which IP is assumed to be all snow
<i>Rainthresh</i> (°C)	6	7	4	Temperature above which IP is assumed to be all rain
<i>SWE_gain_coef</i>	Station POR mean (1.0-1.44)	2.0	0.5	ISWE/SNOW; represents precipitation gauge catch efficiency during snowfall
<i>SWE_loss_coef</i>	0.25	0.25	0.25	ISWE/Rain; represents ASWE loss per unit rainfall
<i>Snowfall_density</i>	Station POR mean (0.08-0.33)	0.05	0.5	ISWE/ISNWD; represents density of daily snowfall
<i>Melt_thresh</i> (°C)	0	1	-1	Threshold temperature (TMEAN) above which snow melt occurs
<i>Melt_coef_early</i> (mm/°C)	Station POR mean (-2.3 - -0.01)	0	-3	ASWE melt rate coefficient during the period Oct 1 – Mar 31; represents melt rate during the winter accumulation period
<i>Melt_coef_late</i> (mm/°C)	Station POR mean (-5.78 - -0.86)	-0.5	-6	ASWE melt rate coefficient during the period Apr 1 – Sep 30; represents melt rate during the spring ablation period
<i>ADENS_max</i>	0.7	0.7	0.7	Maximum allowable density of snow on the ground

Estimation of Model Parameters

Values of MSQC model parameters are a combination of global and station-specific values. Global parameters are those that were found to be relatively similar from station to station, or those to which MSQC was not unduly sensitive. These parameters are *Compact_coef*, *Snowthresh*, *Rainthresh*, *SWE_loss_coef*, and *Melt_thresh*.

MSQC parameter values listed in Table 1 as “station POR mean” in the Estimate column are those obtained by developing summary statistics for each station over its period of record. Some stations had very few qualifying days for some parameters, either because the conditions requested occurred infrequently (e.g., few days available for *Melt_coef_late* because snow had typically melted off before April 1), or the POR was short, or both. Stations with fewer than 20 qualifying days were considered to have too few days to form a stable POR average for given parameter; these “short-record” stations were assigned default values.

Below are the conditions and formulas used for each parameter. Parameter values for “short-record” stations are also given.

SWE_gain_coef

If (TMEAN < 0 and IP > 0 and ISWE > 0) $SWE_gain_coef = ISWE / IP$

Note: The mean *SWE_gain_coef* value for a given station was not allowed to fall below 1.0, because the snow pillow should, on average, be a more efficient collector of snowfall than the rain gauge. A *SWE_gain_coef* value of exactly 1.0 was noted on many days for many stations, likely due to data edits.

Short-record value = 1.05 (mean of all stations)

Snowfall_density

If (TMEAN < 0 and ISNWD > 0 and ISWE > 0) $Snowfall_density = ISWE / ISNWD$

Note: A *Snowfall_density* value of exactly 0.1 was noted on many days for many stations, likely due to data edits.

Short-record value = $-0.0041 * Longitude - 0.3211$; derived from a linear regression function between *Snowfall_density* and longitude (Figure 2)

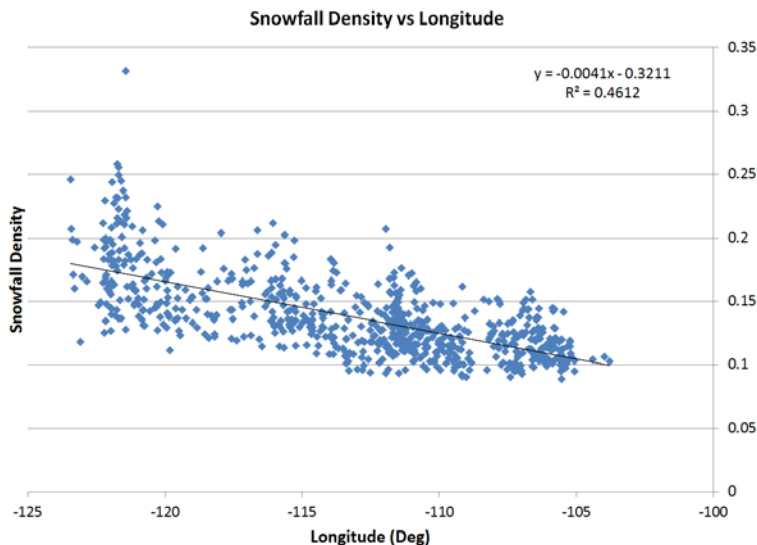


Figure 2. Regression function between snowfall density and latitude.

Melt_coef_early

If (MONTH <= 3 and MONTH >= 10 and ISWE<=0 and ASWE >= 50 mm and IP=0 and TMEAN>0.5C) *Melt_coef_early* = ISWE/TMEAN

Short-record value = -0.52 (mean of all stations)

Melt_coef_late

If (MONTH > 3 and MONTH < 10 and ISWE<=0 and ASWE >= 50 mm and IP=0 and TMEAN>0.5C) *Melt_coef_early* = ISWE/TMEAN

Note: An April 1 cutoff between early and late melt coefficients was chosen as the approximate date that divides the snow accumulation period, when melt rates are relatively low, from the snow ablation period, when melt rates are relatively high. It was not possible to dynamically set the threshold date to the start of the ablation period each year, because, in near real-time operation, the start of the ablation period will be unknown to the model.

Short-record value = -2.74 (mean of all stations)

Parameter values on days that met these stated conditions were averaged over the station's period of record to obtain the final average parameter values. Ranges of average parameter values across the SNOTEL stations queried are given in parenthesis in the "Estimate" column of Table

1. The POR average values of some of these parameters have likely been influenced by data edits, which may have masked actual sensor behavior. The effect this will have when applied to unedited data QC'ed in near real-time is yet to be determined.

The “High Snow” and “Low Snow” values in Table 1 are used by MSQC to create the highest and lowest limits for valid ISWE and ISNWD values on a given day. ISWE and ISNWD values that fall outside this range are flagged by MSQC and assigned a replacement value using the “Estimate” parameter values. The high and low parameters are initial values that may change as we gain experience with the QC system.

QC Feedbacks between Meteorological Inputs and Snow Observations

The statistical snow model described above is designed to assess the validity of each day’s ISWE and ISNWD observations (daily incremental values). If the observed ISWE or ISNWD fall outside the valid range as defined by the statistical snow model, replacement observations are estimated by the model. This procedure assumes that the meteorological input values of IP, TMAX, and TMIN have passed all QC tests. If, however, one or more of these values fail the spatial QC (SPQC) component, some additional MSQC assessments are made.

Upon entering MSQC, IP, TMAX, and TMIN would have undergone tests within single-station QC (SSQC), profile QC (PROF), and SPQC. Failures within any of these three QC components results in the observation flagged as invalid, and replacement observations estimated by SPQC. SSQC or PROF failures are considered fatal, because it is highly unlikely that a valid observation would fail these tests. Therefore, we treat these observations as essentially missing, and our only recourse is to use values estimated by SPQC. However, if an observation passes SSQC and PROF, but fails only SPQC, it is considered a reduction in confidence, but not necessarily fatal. This is because accurate spatial estimation of daily values of temperature, and especially precipitation, from other stations in the area, can be difficult, and can occasionally make valid values appear bad. Therefore, if either ISWE or ISNWD fail MSQC, and if one or more observations of IP, TMAX and TMIN are being estimated by SPQC due to SPQC failure, we go back and replace the SPQC estimates, one by one, with the original meteorological observations that were flagged invalid by SPQC, and re-run MSQC with these new input values. If, using an original observation, either ISWE or ISNWD now pass MSQC, it is accepted by MSQC. If ISWE and ISNWD now both pass MSQC, they are both accepted, and the SPQC flag for the replaced observation is noted as potentially erroneous.

MSQC Examples

Two spreadsheets have been prepared to demonstrate how MSQC functions. The calculations in these spreadsheets are simplified, in that the feedbacks described in the previous “QC Feedbacks” section are not included, but they are otherwise accurate.

Example of Estimating Missing Observations

The spreadsheet “MSQC_example.xlsx,” shows how MSQC would estimate SWE and SNWD during the water years 2005-2013 for SNOTEL station Jump Off Joe, OR, given only observed daily precipitation and temperature inputs, and no observed SWE and SNWD data whatsoever. This could be considered a hypothetical “worst case” scenario, where the station’s SWE and SNWD sensors went offline for nine years! The spreadsheet mimics how MSQC was run in the absence of observations during model testing and evaluation. Jump Off Joe was chosen for this example because it experienced a mixed bag of rain-on-snow, rain-only, and snow-only events, and thus was challenging to simulate.

In the upper left hand corner of the sheet labeled “JOJ Daily Calcs,” the MSQC input parameters are listed, and their values given. Values for parameters of type “Station” were obtained using the station POR calculations in the “Estimation of Model Parameters” section above. To the right of the parameter listing are scatterplots and regression functions of observed versus estimated ISWE and ISNWD, and summary performance statistics for each between the two plots. For example, the bias is 0 for ISWE, meaning that over the water years 2005-2013, the estimates were, on average, neither too high nor too low. The MAE (mean absolute error) is 4.63 mm (0.18 inches), meaning that, on average, the absolute difference between the observation and the estimate was 4.63 mm. To make the performance statistics more meaningful, days when the daily ISWE or ISNWD was zero were omitted from the calculations.

The daily MSQC calculations appear below the parameter list and scatterplots. The calculations are divided into the four steps discussed in the Statistical Snow Model section of this document, plus Final Estimates, Observations, and Evaluation. The calculations begin on September 30, 2004 with starting values of 0 ASWE and 0 ASNWD (cells W18-AA18). These are used to initialize October 1 calculations, which are used to initialize October 2 calculations, and so on. Whenever possible we used Excel named variables in the cell formulas to make it easier to follow the calculations, but there were some exceptions where references to the named variables caused errors, and normal cell references had to be used.

The tabs labeled “JOJ ASWE Plot” and “JOJ ASNWD Plot” show observed and estimated ASWE and ASNWD, respectively, for water years 2005-2013. The tabs labeled “JOJ ISWE Plot” and “JOJ ISNWD Plot” show five-day moving average observed and estimated ISWE and ISNWD, respectively, for water year 2013. A moving average plotted over just one water year

was used to make the plot more readable; the plot settings can be changed to show other water years, if desired.

The statistical model simulates observed snow accumulation and melt reasonably well, given only daily precipitation and temperature (which have their own uncertainties) as inputs. Accurate accumulation estimates can be difficult to maintain over a snow season, because a difference on any one day propagates to the subsequent days, which can cause the estimates and observations to diverge. For example, the ASNWD plot for WY13 shows that ASNWD was over-estimated for most of the season; however, the ISNWD plot for WY13 reveals that the model over-estimated the first substantial snowfall in late December 2012 by about 50 mm (two inches), which was subsequently carried through the rest of the snow season.

Note that the parameter values used here are those derived from Jump Off Joe station statistics, and are not necessarily those that give the best performance. For example, the average *Snowfall_density* of 0.11 calculated from the station data is too low for optimum performance for ASNWD over these years; a value closer to 0.18 gives better results.

Example of High Snow and Low Snow Thresholds

The spreadsheet “MSQC_example_highlow.xlsx,” shows how MSQC estimates a daily range of valid values with which to compare the observations during the water years 2005-2013 for SNOTEL station Jump Off Joe, OR. The mode of operation here is very different from that in the MSQC_example_JOJ.xlsx spreadsheet. In this case, the goal is to evaluate each day’s observations of ISWE and ISNWD to determine if they fall within their respective valid ranges. Therefore, a day’s calculations are initialized with yesterday’s observations, rather than yesterday’s MSQC estimates. The tab labeled “JOJ Daily Calcs – LowSnow” contains daily calculations using Low Snow parameter settings, and the tab labeled “JOJ Daily Calcs – HighSnow” contains daily calculations using High Snow parameter settings. The calculations section is similar to that in the MSQC_example_JOJ.xlsx spreadsheet, except that the evaluation section, scatter plots, and performance statistics are absent. (The high and low snow thresholds are not supposed to agree with the observations, so evaluation statistics are not useful.) ISWE and ISNWD plots for WY 2013 are shown in the “JOJ ISWE Plot” and “JOJ ISNWD Plot” tabs, respectively. The ISWE plot indicates that the daily observations fell within the high and low range of valid values (at least for five-day moving averages). The High Snow valid values for ISNWD are much higher than the observations, because the High Snow snowfall density of 0.05, which is a snow depth-to-SWE ratio of 20:1, is a plausible value generally, but far higher than what occurred at Jump Off Joe.

Future Work

The MSQC system presented here greatly simplifies complex snow dynamics by using global or station-specific parameters and metrics. While the model performs well overall, there are numerous opportunities to improve the model, and link the results to the wider QC and PRISM modeling system. Below we discuss potential future improvements.

QC'ing Accumulations

At present, the PRISM SNOTEL QC system assesses TMAX and TMIN, and daily incremental changes in precipitation (IP), snow water equivalent (ISWE), and snow depth (ISNWD). Assessing day-to-day changes is the most effective method of QC in most situations. However, there are some instances where it is advantageous to also QC accumulations. For example, consider the hypothetical time series of snow water equivalent in Table 2. In the middle of summer, the snow pillow reading jumps from 0 inches to 15 inches, stays there for two days, then drops back down to 0 inches. The two days with 15-inch readings are clearly erroneous. The current incremental QC system would see the 15-inch jump on August 13 as erroneous; the observation would fail PROF because it exceeds the maximum SWE increase for that day of the year, and would also fail MSQC because there is no precipitation and temperatures are well above freezing. However, the second 15-inch SWE value on August 14 results in an incremental change of 0, which would pass incremental QC. The subsequent drop back to zero on the 15th would be marked bad, because the drop would exceed the maximum daily decrease in SWE for that date. Now, if a profile was available for maximum ASWE (SWE accumulation) on these dates, it is likely that the observations on August 13 and 14 would have been marked bad, because a value of 15 inches of SWE on the ground would have exceeded the maximum ASWE profile. This example suggests that there is a benefit to adding accumulation profiles for SWE and SNWD, and possibly precipitation, as well.

Table 2. Hypothetical time series of snow water equivalent, with incremental and accumulation QC results.

Date	PRCP	TMEAN	WTEQ Observation (inches)	Incremental Change (inches)	Incremental QC Result	Accumulation QC Result
11 Aug	0	16	0			
12 Aug	0	17	0	0	Good	Good
13 Aug	0	18	15	15	Bad	Bad

14 Aug	0	18	15	0	Good	Bad
15 Aug	0	19	0	-15	Bad	Good

Improving Parameterizations

At present, the station-specific parameter values for making estimates of ISWE and ISNWD when an observation is bad or missing are derived from station statistics. It may be possible to also tailor the High Snow and Low Snow parameter settings more closely to a station’s behavior, rather than use the current “one size fits all” approach as shown in Table 1. For example, as shown in the ISNWD plot in the spreadsheet MSQC_example_highlow_JOJ.xlsx, the High Snow *Snowfall_density* value of 0.05 is a valid value, but probably much lower than what is likely to ever occur at Jump Off Joe. However, it may be very reasonable lower bound for a SNOTEL station in Wyoming.

Closer analysis of station behavior could also identify inconsistencies between sensors that may indicate calibration issues or mechanical problems. Also, detecting changes in some coefficients over time may identify sensor drift. There is likely much information to be mined from MSQC that can shed light on station idiosyncrasies. For example, spatial plots of various parameters may reveal inconsistencies among stations that cannot be easily explained by climatology.

Feeding Back to the Wider QC and Modeling System

The current philosophy of MSQC is to use “stable” inputs of IP, TMAX, and TMIN to assess the quality of ISWE and ISNWD. This is because we map IP, TMAX, and TMIN with PRISM, and hence can invoke a spatial QC component, which can be very powerful. However, this places a heavy reliance on these input variables to be accurate. TMAX and TMIN are likely to be reasonably good, but the highly variable nature of IP makes it challenging. If the daily precipitation is incorrect, erroneous IP values could end up being used in other QC components and in the PRISM mapping process itself. NRCS personnel have indicated that during snowfall events, accumulation on the snow pillow is often a more accurate reflection of the actual precipitation received than the rain gauge measurement. This is reasonable, given the many ways that rain gauges can undercatch snowfall. Below we discuss three ways that results from MSQC could potentially feed back to the wider system and improve estimates of IP, each of increasingly greater scope.

The first approach is to modify QC flags. As discussed in the section “QC Feedbacks between Meteorological Inputs and Snow Observations,” the SPQC flag is not necessarily the last word on validity for IP, TMAX, and TMIN. In the current formulation, SPQC flags for these elements

can be ignored for purposes of evaluating ISWE and ISNWD, if they pass MSQC using the original observations. However, there is not yet a capability for actually changing the SPQC flags from FALSE to TRUE, and accepting IP, TMAX, or TMIN, and allowing their use in subsequent QC and modeling activities. We intend to implement this capability in a future version of the system.

One weakness in the first approach above is that in some cases, neither the observed nor the SPQC-estimated IP values are correct, and as a result, ISWE and ISNWD are flagged as bad because they do not agree with the erroneous IP values. As a second approach, ISWE and ISNWD, if consistent with each other, could provide grounds for estimating a new IP value. The new IP value would be estimated from ISWE and ISNWD using, for example, the average *SWE_gain_coef* or *Snowfall_density*, or a combination of the two. This kind of approach would require further development and testing to determine usefulness, as well as changes to the current QC and database structure.

The third approach would be to address the issue of rain gauge undercatch directly by modifying the SNOW component of every daily IP based on the *SWE_gain_coef*, which is the average ratio of SWE/SNOW. For example, if the average *SWE_gain_coef* for a station is 1.15, the SNOW portion of IP could be increased by 15% during snowfall. The idea would be that, on average, the rain gauge is undercatching snowfall by 15%, and by not adjusting for undercatch, IP values used in mapping are too low. The strength of this approach is that one would not need valid ISWE and ISNWD values to make the adjustment on a given day. There are two weaknesses to this approach. The first is that adjusting all days based on a mean value without understanding individual storm behavior will mean that sometimes the adjustment will be too little (such as in very windy storms) or too much (such as in calm conditions). The second is that the *SWE_gain_coef* is calculated from historical station data, which has likely been affected by edits that may mask the true behavior of the sensors.