Section 7-4

Initial Parameter Values for the SNOW-17 Model

Introduction

This section provides guidelines for assigning initial parameter values for the SNOW-17 snow accumulation and ablation model. These guidelines can also be used as an indication of whether parameter values being used for a given watershed or subarea are physically realistic. The snow model parameters are related to the physical and climatic features of the area being modeled. The main physical features that are important are vegetation cover and terrain features such as slope and aspect. The main climatic features are the typical amount of snow cover and the prevailing winter temperatures.

This section doesn't attempt to define the structure or the algorithms of the model. Readers are referred to section II.2-SNOW-17 of the NWSRFS Users Manual for a complete model description.

Form of Precipitation

The form of precipitation, i.e. rain or snow, can be specified in one of three ways for the SNOW-17 model. The methods of determining the form of the precipitation are:

1. By a threshold temperature which is the parameter PXTEMP. If the air temperature for the current time interval is less than or equal to PXTEMP, then the precipitation is assumed to be snow. If the temperature is greater than PXTEMP, then the precipitation is treated as rain.

2. By a rain-snow elevation time series. This time series specifies the elevation above which snowfall is occurring and below which the precipitation is in the form of rain. In this case an area-elevation curve is input to the snow model so that the fraction of the area with snow and the fraction with rain can be computed based on the rain-snow elevation value for each time interval. The rain-snow elevation time series can be generated by the RSNWELEV operation in NWSRFS. This operation uses either an air temperature time series for a specified elevation or a freezing level time series along with a user specified lapse rate and the PXTEMP parameter to calculate the elevation at which the PXTEMP temperature value occurs. The equation used by the RSNWELEV operation is:

$$E_{rs} = E_v + ((T_v - PXTEMP) \cdot (100/L_p)) \qquad (7\text{-}4\text{-}1)$$

where: E_{rs} = Rain-snow elevation (m),
E_v = Elevation associated with T (m),
T_v = Temperature at elevation E (°C),

L_p = Lapse rate during precipitation (°C/100m).

When air temperature is the input variable, T_v is the temperature for the time interval and E_v is the elevation associated with the time series. When freezing level is the input variable, E_v is the freezing level elevation and T_v is 0°C. The lapse rate used is typically the saturated adiabatic lapse rate (0.55°C/100 m or about 3°F/1000 ft) since the only relevant time periods are those when precipitation is occurring. If the value of the rain-snow elevation is missing for a given time interval, then method #1 is used to specify whether all the precipitation is rain or snow.

Generally when calibrating an MAT time series is used as the input to the RSNWELEV operation since historical freezing level data are seldom available. For watersheds with multiple elevation zones there is a question as to which MAT time series should be used to determine the rain-snow elevation for each zone. Physically there is only one rain-snow elevation for the watershed for a given time interval. This would suggest using the MAT time series for only one of the zones to compute a single rain-snow elevation to be used by all the zones. However, for example, if the rain-snow line was near the mid-point of the upper elevation zone and the MAT for the lower zone was being used to calculate the rain-snow line, the lapse rate would be applied over a considerable elevation range which would likely result in a less accurate estimate of the rain-snow line than if the upper area MAT was being used. This would suggest using the MAT time series for each elevation zone to compute the rain-snow elevation for that zone to minimize the elevation range over which the lapse rate was being applied. In this case when the actual rain-snow elevation is within a given elevation zone, the MAT for that zone would be used to estimate the elevation and although different rain-snow elevations would be calculated for the other zones, they would generally be outside the elevation range of those zones and not affect the form of the precipitation. Which MAT time series are used to estimate the rain-snow elevation for watersheds with multiple elevation zones is also dependent on the elevations of the stations used to compute the MAT values for each zone. If a zone has no temperature stations within its elevation range, the MAT has been calculated by applying seasonally varying lapse rates over a large elevation difference, and not the saturated adiabatic lapse rate. In this case, the MAT could be more likely to be in error during periods when precipitation occurs.

Based on the discussion in the previous paragraph, the following recommendations are offered for computing rain-snow elevations for watersheds with multiple elevation zones for use during calibration.

- If there are actual temperature stations within an elevation zone that were used to compute MAT, then the MAT time series for that zone should be used to calculate the rain-snow elevation for the zone.

- If there are no temperature stations within an elevation zone that were used to compute the MAT for the zone, then the MAT time series for the zone that has the smallest elevation difference to the zone in question and has actual temperature stations within its elevation range should be used to compute the rain-snow elevation.

Operationally a single rain-snow elevation should be used for all elevation zones so that only one value has to be changed to alter the division between rain and snow.

3. A time series can be used to specify the fraction of the precipitation that is in the form of snow during a given time interval. This time series is referred to as a percent snowfall time series. The values assigned to this time series are generated outside of the operations table. Historically the information needed to specify the form of precipitation might only be available for a research location. Operationally a procedure involving meteorological data, observations of the form of precipitation, and forecaster interaction could be devised to produce a percent snowfall time series. If the percent snowfall value is missing for any time interval, then method #1 is used to determining if all the precipitation is rain or snow.

Most studies have indicated that a reasonable threshold temperature for separating rain from snow is around 1 - 1.5°C. The Snow Hydrology manual indicates about 45% snow, 25% mixed, and 30% rain at 34°F and 33% snow, 17% mixed, and 50% rain at 35°F. The Snow Hydrology manual also shows cases of rain occurring when the surface temperature is 29°F and snow at 40°F. In the intermountain west, at least at higher elevations, winter precipitation is almost always in the form of snow even when the temperature is near 40°F. Usually in this region the temperature drops fairly quickly after the onset of snowfall, but it may be fairly warm when the event begins. It is clear that air temperature measured at ground level is not a perfect indicator of the form of precipitation. In NWSRFS the problem is compounded by only using max/min air temperature to compute historical MAT time series. The assumptions of when the max and min occur and the use of a fixed diurnal temperature variation result in incorrect temperature values during certain periods (see section titled "Limitation of Current NWSRFS Historical MAT Program" in Section 6-4). This most commonly occurs when temperatures are changing substantially from one day to the next which typically occurs with a frontal passage which is also when precipitation is most likely. From experience it is clear that the use of historical MAT values computed from only max/min temperature results in more cases of the form of precipitation being in error than the use of a threshold temperature to separate rain from snow. The use of the threshold temperature in the snow model to determine the form of precipitation should be less of a problem operationally because the OFS MAT preprocessor uses both instantaneous and max/min temperature data during the observed data period. The instantaneous temperatures are used to determine the daily temperature variation for stations that only report max/min values.

It is recommended that a value of PXTEMP in the range of 0.5 to 2.0°C be used with the SNOW-17 model. Generally a value of 1.0°C should be adequate. In many intermountain west areas it may be necessary to use a considerably higher value, in the range of 3-5°C in order to minimize errors in the form of precipitation (in this region temperatures frequently go well above freezing during portions of days with snow showers, however, the temperature drops back to near freezing whenever the precipitation intensifies and generally in the winter and early spring all precipitation is in the form of snow). It is also recommended that once a value of PXTEMP is established for a given region, that it should be used for all areas within the region. It is not worth the effort to try to varying PXTEMP for each area to try to get a near equal number of cases when rain should have been snow and vice versa. Since most of the problems are caused by the use of o nly max/min temperatures, varying PXTEMP is generally not very productive. The use of only max/min temperatures also results in a bias in the form of precipitation determination in many regions, e.g. errors in the daily temperature variation result in more cases of rain being typed as snow than vice versa. Thus, there is a built-in bias that varying PXTEMP cannot correct. It is best to assign a reasonable value to PXTEMP and then correct the form of precipitation for individual events as needed. Also operationally it is much easier to deal with a single value of PXTEMP for all areas in a given region than to have to remember or look up a unique value for each area.

From a calibration standpoint, it is only necessary to correct the form of precipitation for individual events when the mistyping causes so much simulation noise that it is impossible to determine the other model parameters with confidence. Obviously having the correct form of precipitation for all events will produce the best results and minimize goodness of fit statistics, however, the aim of calibration is to determine the proper parameter values for operational use and not to minimize certain statistics. Thus, the form of precipitation only needs to be corrected for individual events when errors interfere with determining the proper values of other snow model parameters and parameters for the other models being used. It is not cheating to correct the form of precipitation when it interferes with determining parameter values. Operationally there should be much more information available, besides air temperature, to indicate whether it is raining or snowing at a given location. In many regions, especially those with temperatures below freezing during most precipitation events such as the north central states, the intermountain west, and Alaska, it is necessary to correct the form of precipitation for few, if any, events. Only events with a large of amount of precipitation that is in the wrong form typically need to be corrected in these regions. In other regions, where the temperature is frequently near freezing during periods of precipitation, there can be many events where the form of the precipitation is mistyped. This case is very common in the northeastern part of the United States. There can also be problems with the division of rain and snow west of the Cascade Range in the Pacific northwest due to errors in the diurnal temperature variation. In this region the rain-snow elevation option is generally used to separate rain from snow since rain occurs during most winter events at lower elevations whereas it is snowing higher up in the mountains.

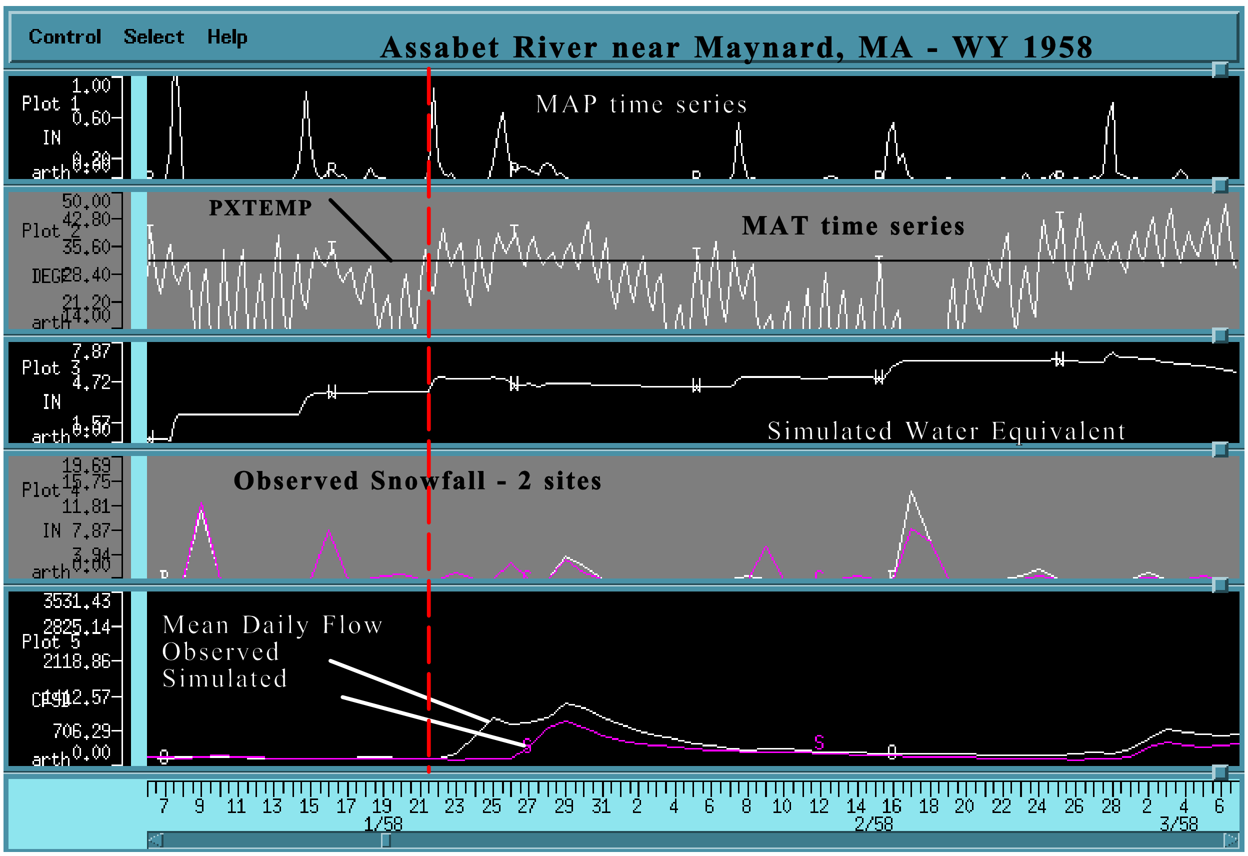
Correcting the form of precipitation is also needed when the historical time series are to be used for ESP applications. For calibration, significant errors in the form of precipitation only need to be corrected for the period used to calibrate the models. For ESP applications, the entire historical period of record should be corrected. If not, bias produced by an improper assignment of the form of precipitation will influence the probabilistic distribution of the ESP products. It is probably only necessary to correct larger events that are in error, just like calibration. Errors in small events shouldn't affect the probability distributions generated by an ESP application. It is especially important to correct the form of precipitation for watersheds where there is a tendency for the errors to be dominantly in one direction (e.g. many more cases of rain treated as snow than vice versa).

When attempting to correct the form of precipitation it should be done in a systematic manner and with as much information as possible to support any changes that are made. The form should not be changed just to get a better fit between simulated and observed flow values. Generally the form of precipitation is altered by changing the MAT value for one or more time intervals. The information that can be used to support the decision includes streamflow response, snowfall obs ervations, and water equivalent and depth data. In data sparse regions, such as portions of Alas ka, the decision may have to be solely based on streamflow response since the other data are not available. In that case changes should only be made when the streamflow response clearly indi cates that the form of precipitation is most likely in error.

The use of the PLOT-TS display in ICP can be very helpful when trying to determine when the f orm of precipitation is in error and what MAT values need to be changed to correct the problem. All of the data needed to decide whether the form of precipitation as determined by the model is correct or whether it needs to be changed can be shown on a single display. Figure 7-4-1 sho ws an example of such a PLOT-TS display. In this case 5 plots are included. The top plot sho ws the 6 hourly MAP time series. The next plot down contains the 6 hourly MAT values. The next plot is the 6 hourly simulated water equivalent. The next plot is daily snowfall observatio ns from 2 climatological stations near the watershed. The bottom plot shows the resulting simu lated and

Figure 7-4-1. Sample display for validating form of precipitation from the snow model.

observed mean daily flow. The exact value and time of any plotted value can be displayed by c licking on the display. By examining all of this information it can be decided as to whether the



form of precipitation needs to be altered. For example, in the figure during the first period on t he 22nd of January a large amount of precipitation is typed as snow since the MAT value is well below PXTEMP. This causes the simulated water equivalent to increase. However, the climate observers reported very little snowfall during the event and the observed streamflow showed a considerable increase in the subsequent days, both indicating that the precipitation was most likely predominately rain. Thus, the MAT value was changed to be greater than PXTEMP with an editor. The MAT was most likely in error during this case due to the minimum temperature recorded on the morning of the 22nd actually occurring on the previous morning. By proceeding through the period of record using such a display, problems caused by the form of precipitation being in error can be systematically corrected before continuing with the calibration.

<u>Major Snow Model Parameters</u>

The major parameters of the SNOW-17 model are the snow correction factor SCF, the non-rain melt factors MFMAX and MFMIN, the areal depletion curve and the related SI parameter, and sometimes the average wind function during rain-on-snow events UADJ. These are the parameters that typically have the greatest effect on model results and are the only ones generally modified during calibration.

<u>SCF</u> – SCF is the only parameter in the snow model that has a significant effect on the volume of water available for snowmelt runoff. It is used to adjust any precipitation that is typed as snow. The main reason for SCF is that most precipitation gages under catch snowfall as shown in Figure 7-4-2. The under catch is related to the wind speed at the orifice of the gage and the effect can be reduced by the installation of a windshield. The wind speed at the gage is influenced greatly by the exposure of the site. Most climatological stations are situated where there is protection from the wind whenever possible. A site with a good exposure doesn't need a windshield. Of course the MAP time series generally involves the weighing of a number of gages with different exposures and possibly some with and some without wind shields.

The SCF parameter is related to the average wind effect on snowfall catch over all the events during the period of record. The catch deficiency varies from event to event, and even within an event, as the wind speed at the orifice changes. If there are a large number of events involved in the build up of the snow cover, the effect of variations in catch deficiency from event to event tend to cancel out, though there may be some years when there is more wind during snow storms than other years.

Besides explicitly trying to account for the average catch deficiency during snowfall events, the SCF parameter implicitly includes other factors that affect the accumulation of a snow cover that are not included in the snow model. This includes sublimation losses, both from the snow surface, from snow intercepted by the forest, and from wind blown snow, and snow

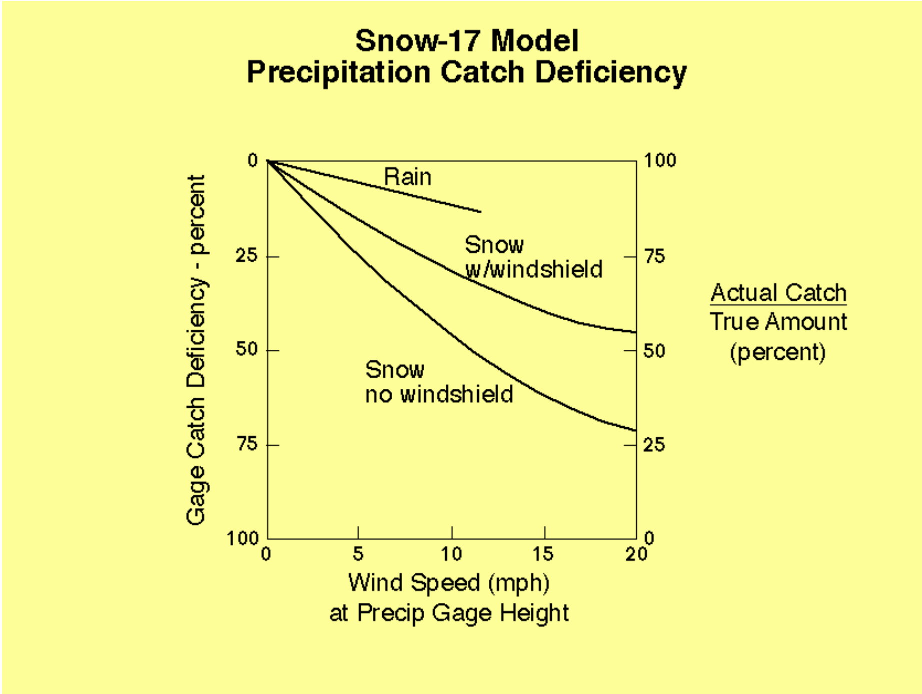


Figure 7-4-2. Typical precipitation catch deficiency due to wind.

blown across the watershed divide. Sublimation losses tend to be small in most areas, but can be moderately significant in places with low humidity and high wind speeds during the winter. Generally the amount of snow transported from one watershed to another is negligible in most regions.

After considering all these factors, a reasonable initial value for the SCF parameter is in the range of 1.1 - 1.2. Higher values would be expected in watersheds where there are few gage locations with good exposures such as in the northern plains. In such a region SCF values could start in the range of 1.3 - 1.6. In regions where all the precipitation stations have good exposures and there are significant sublimation losses, SCF could be equal to 1.0 or even slightly less without being physically unrealistic.

The value of SCF can also be affected by whether water balance computations were used to determine the magnitude of the MAP input for the model. When mean annual precipitation is estimated directly from the water balance as in the method described in Section 6-3 under "Determination of the Average Mean Areal Precipitation in Data Sparse Regions", the processes related to SCF are implicitly absorbed in the MAP values. In this case in order for the precipitation used by the model to be the same as the amount computed by the water balance, SCF should be initially set to 1.0. Since gage catch deficiencies are not considered when deriving the average annual precipitation with this method, the net result could be not enough snowfall and too much rain. When a water balance analysis is used primarily to identify portions of the basin where the isohyetal analysis needs to be modified as described in Section 6-3 under 'Determination of Average Mean Areal Precipitation for Each MAP Area", there is less chance that the value of SCF will be affected. In any case SCF should not be used in regions dominated by snowmelt runoff to correct for volume problems resulting from an inadequate precipitation analysis.

<u>MFMAX and MFMIN</u> – These are the maximum and minimum values of the seasonally varying non-rain melt factor. MFMAX occurs on June 21st and MFMIN on December 21st. In regions where the snow cover generally builds up throughout the winter and doesn't melt until mid or late spring, MFMAX dominates the computations of melt. In regions where snow melt periods can occur anytime throughout the cold season, both factors are important.

The non-rain melt factor determines the melt rate when the area is completely covered by snow, thus it has a controlling effect from when melt first begins until significant bare ground exists. This melt factor is based on the average relationship between air temperature and melt at the surface of the snow cover over the entire period of record. It is to be expected that there will be situations when the actual melt rate is greater or less than the average. Adjustments can be made during these situations operationally as discussed in Section 8-1, but during calibration it is the average melt rate that is sought. The average value of the melt factors are physically related to forest cover, slope and aspect, and typical meteorological conditions. Some items to consider when choosing or evaluating values for the melt factors are:

- If an area had an extremely dense forest cover, i.e. so dense that no sunlight reached the forest floor and calm conditions always prevailed such that only longwave radiation exchange between the forest canopy and the snow below caused melt, a lower limit for the melt factor could be computed. This value would be about 0.32 mm/°C/6 hr and there would be no seasonal variation. Such a situation doesn't exist for an area of any reasonabl e size.

• If a region, such as the north Pacific coast, has persistent cloud cover most of the time, this will act similarly to a dense forest cover. It would be expected that the maximum melt rate would be relatively low and there wouldn't be a pronounced difference between MFMAX and MFMIN. If cloud cover generally persists for some months, but not for others, the seasonal melt factor variations built into the model (normal sinusoidal or Alaska, northern latitude, pattern) may not be appropriate. In this situation there is an option in the SNOW-17 operation for the user to specify the seasonal variation pattern. This option should be used only when it can be substantiated that the seasonal variations built into the model are not adequate.

• The melt rate should be the greatest for a large open area in a region where dew-points typically exceed 0°C and windy conditions prevail during periods of substantial melt. In such an area all forms of energy exchange could contribute to melt. In general, in an area with low humidity, solar radiation will be the dominate cause of melt as atmospheric radiation will be less than that emitted by the snow surface due to generally clearer skies and negative latent heat exchange will tend to offset positive sensible heat exchange. This would result in a lower average melt rate than for an area with generally higher humidity for the same amount and type of forest cover.

• Open zones in the mountains, such as above tree line, generally have lower melt rates than a flat open area due to variations of slope and aspect caused by the rugged terrain. This is especially true early in the melt season when the non-rain melt factor controls the computations as melt is typically not occurring over an entire mountainous zone.

•In northern and high elevation regions where the snow ages slowly and melt seldom occurs during the mid-winter period, the MFMIN parameter will tend to have lower values than in regions where substantial melt frequently occurs at various times throughout the winter.

• The largest ratio of MFMAX to MFMIN should occur in mostly open areas in regions with generally low humidity levels and infrequent mid-winter melt periods, such as high elevation zones of the intermountain west, portions of interior Alaska, and other places where MFMIN tends to have low values. The smallest ratios of MFMAX to MFMIN are expected in heavily forested areas in regions with more humid climates and periodic mid-winter melt, such as coastal areas and much of the eastern continental United States.

Based on these considerations and prior calibration results the following recommendations are offered for selecting initial values for the MFMAX and MFMIN parameters.

Description of Area	MFMAX	MFMIN

Dense conifer forest or persistent cloud cover	0.5 - 0.7	0.2 - 0.4
Mixed cover - conifer, deciduous, open	0.8 - 1.2	0.1 - 0.3
Mostly deciduous	1.0 - 1.4	0.2 - 0.6
Mostly Open		
flat terrain	1.5 - 2.2	0.2 - 0.6
mountainous terrain	0.9 - 1.3	0.1 - 0.3

Table 7-4-1. Suggested initial values for MFMAX and MFMIN.

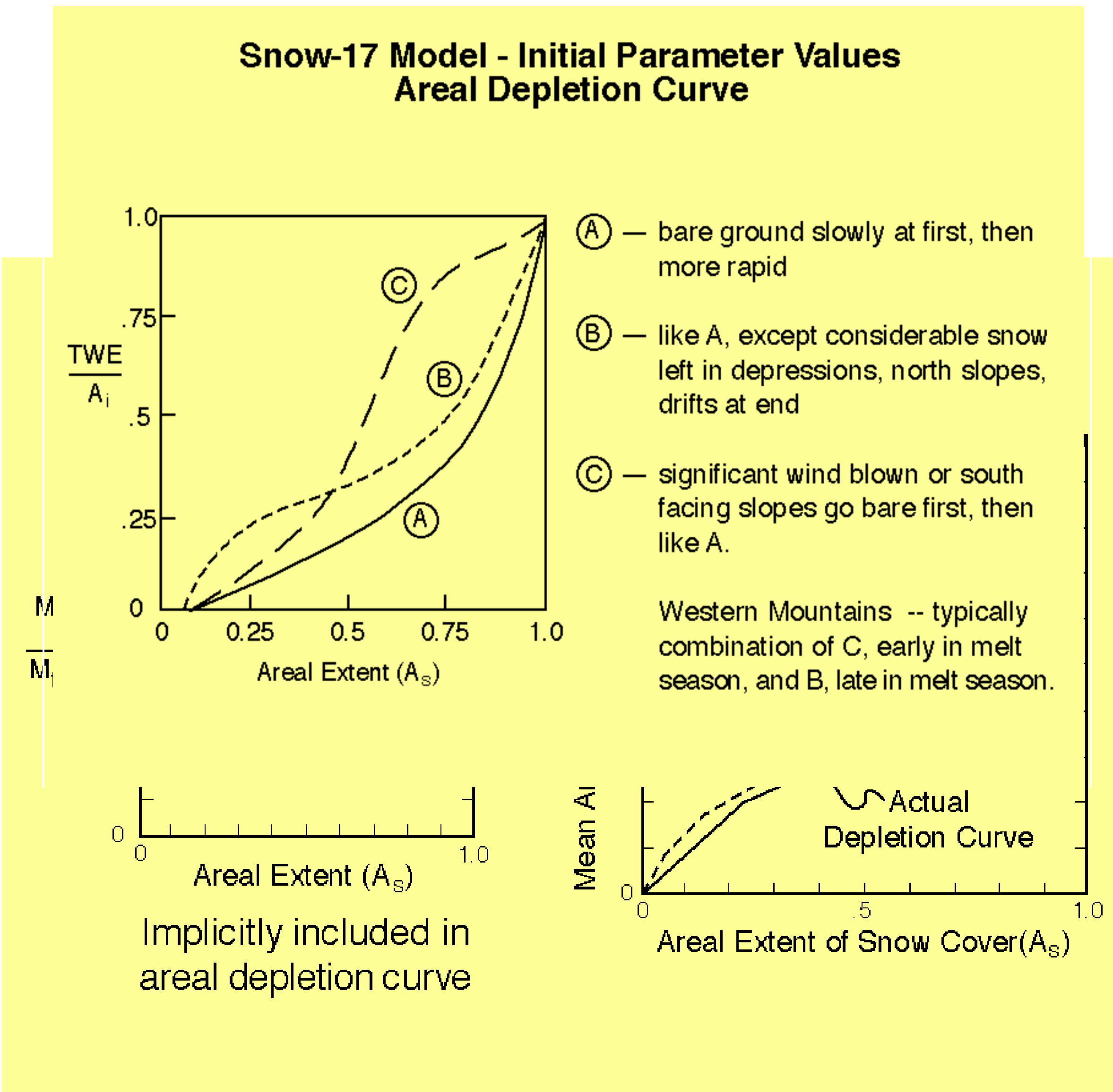
These guidelines can also be used to decide if the parameter values determined during calibration are reasonable. If the calibrated values fall significantly outside these ranges, it could be due to biased temperature data, i.e. the MAT values being used are warmer or cooler than what actually occurred in nature.

<u>Areal Depletion Curve</u> -- The areal depletion curve controls the melt rate when only portions of the area being modeled are covered by snow. The idea behind the areal depletion curve is that the pattern of snow accumulation and ablation is similar from one year to the next. For example, during the accumulation period the variation in the amount of snow on the ground, including the location of drifts and shallow places, is similar each year due to terrain and vegetation effects and prevailing storm and wind directions. Also, the melt pattern is similar with lower elevation, south facing, bare slopes melting first and higher elevation, north facing, forested or sheltered areas retaining snow the longest. The main function of the depletion curve is to account for how much of the area is covered by snow, however, like in any conceptual model, everything that is occurring in nature is not explicitly being modeled. Besides accounting for the areal extent of the snow cover, the depletion curve also absorbs variations in the melt rate over the snow covered portion of the area. The non-rain melt factor determines the melt rate when there is 100 percent cover, but as the snow cover depletes the melt rate over the area that still has snow is reduced. This occurs because the portions of the area with the highest melt rates, such as south facing slopes, typically go bare first. The areas where snow generally remains the longest are forested or sheltered north facing slopes with much lower melt rates. This variation in melt rates ends up being

Figure 7-4-3. Model versus actual snow cover depletion curve.

implicitly included in the areal depletion curve. Thus, the areal depletion curve is really cal culating an “effective” areal extent of snow cover and not the actual areal extent. This is ill ustrated in Figure 7-4-3. This figure shows a possible variation in the ratio of the actual mel

t rate to the 100 percent cover rate as a function of the areal extent of the snow cover and how that relationship would cause the depletion curve needed by the model t o differ from that which would be constructed based on detailed measurements of water equi valent and the fraction of the areal actually covered by snow. The areal depletion curve for the model should indicate a lower areal extent of snow cover than would be determined by sa



tellite or other aerial observations.

Figure 7-4-4. Typical shapes of areal depletion curves.

The factors that affect both the pattern of areal snow cover and the variation in melt rates as the snow cover depletes are primarily controlled by terrain, vegetation, and climatic conditions. Thus, the shape of the areal depletion curve for a given area can be estimated based on a knowledge of these factors. Figure 7-4-4 shows some typical shapes for areal depletion curves. The “A” curve represents an area with generally flat to hilly terrain, either uniform or randomly mixed vegetation cover, and not an excessive amount of redistribution of snow due to blowing and drifting. In this case bare ground shows up slowly at first and then more rapidly as the snow cover depletes. Curve “B” represents a flat to hilly area where the terrain and redistribution pattern results in portions of the area having more snow, typically in sheltered depressions or drifts, than other parts. These parts of the area with disproportionally more snow are typically the last portions to go bare. Curve “C” represents an area that has wind blown portions with little snow cover or significant south facing slopes that go bare fairly quickly after melt begins. Thus, the areal cover depletes rapidly at first and then the remaining portion of the area has a depletion pattern similar to the “A” curve. Mountainous regions, especially in the western states and Alaska, typically have a depletion curve that is a combination of the “B” and “C” curves. In the mountains there are frequently portions of the area with south facing slopes or shallow cover due to wind effects that go bare quickly after melt begins and also sheltered depressions and conifer forested, north facing slopes that still retain snow well after most of the area is bare.

SI – The SI parameter is the mean areal water equivalent above which the area essentially has 100% snow cover. The easiest way to determine the appropriate value for SI is to set the initial value greater than any average areal water equivalent that ever occurs during the period of record. Then during calibration the years with the greatest amount of snow are examined to determine if the areal cover needs to remain at 100% for some time period after the beginning of melt. By analyzing these years as described in Section 7-7 one can arrive at the value to assign to the SI parameter. Typically the initial SI is set to 999 mm or 9999 mm depending on the amount of water equivalent expected. By using all 9's for the initial value, it is easy to later tell whether a value for the SI parameter was assigned during calibration or whether bare ground begins to show as soon as melt starts every year, i.e. the area doesn't remain at 100% cover once melt starts and thus the value of SI is left as all 9's.

UADJ – The UADJ parameter represents the average wind function during rain-on-snow events. The wind function is involved in the latent and sensible heat, i.e. turbulent transfer, terms in the energy balance. The UADJ parameter will not affect the longwave radiation and heat from rain water terms in the rain-on-snow melt equation used in the model. Based on energy balance studies [*Anderson*, 1976] the wind function parameter can be computed as:

$$UADJ = 0.002 \cdot u_1 \qquad (7\text{-}4\text{-}1)$$

where: u_1 = 6 hr. wind travel in km at a 1 meter height above the snow surface.

Thus, if one can estimate the average wind speed over the entire area being modeled during significant rain-on-snow events at one meter above the snow surface, then an initial value for UADJ can be computed. Significant rain-on-snow events are those that occur when the air temperature is well above freezing. Clearly it is difficult to estimate the average wind speed at one meter for a forested, mountain watershed, but generally a rough guess is sufficient for an initial value. Also the UADJ parameter is not real sensitive for most regions. Typical values for UADJ range from about 0.05 (2.5 mi/hr wind speed) to 0.20 (10 mi/hr wind speed). Forested areas will tend to have lower wind speeds than mostly open areas.

Minor Snow Model Parameters

The remaining parameters in the snow model are assigned based on climatic information and are typically not changed during the calibration process. These parameters generally do not have a very significant effect on the simulation results as long as the value is in the right ballpark.

TIPM – The TIPM parameter is used to compute an antecedent temperature index that is intended to represent the temperature inside the snow cover but near the surface. The gradient defined by the antecedent index and the air temperature (used to estimate the temperature at the snow surface) determines the direction of heat flow during periods when melt is not occurring. The lower the value of TIPM the more weight is assigned to the temperatures from pr evious time intervals and the antecedent index then represents the temperature of the snow further below the surface. For areas with generally shallow snow cover the antecedent index should represent a temperature fairly close to the surface in order to best estimate the direction of heat flow. For regions that typically have a deep pack, the antecedent index should represent the temperature further below the snow surface. It is recommended that a value of TIPM = 0.05 be used for areas that experience a deep snow cover (greater than 3 feet maximum depth during most years). A value of TIPM = 0.20 is appropriate for areas with shallow (generally less than 1 foot depth) or intermittent snow cover. Intermediate values should be used for other areas.

<u>NMF</u> – The negative melt factor determines the amount of energy exchange that occurs when melt is not taking place at the snow surface. The NMF parameter is the maximum value of the negative melt factor. The seasonal variation in the negative melt factor is the same as for the non-rain melt factor. A seasonal variation is needed since density is the primary factor that affects the thermal conductivity of the snow and the snow density generally varies in a seasonal manner. The density is lowest during periods of accumulation and increases as the snow ages during melt periods. Simplified heat transfer calculations indicate that a reasonable value for NMF is around 0.15 mm/°C/6 hr. This value is generally independent of the typical amount of snow that occurs in an area. It is based on a maximum snow density of 0.3 for shallow snow cover and 0.5 for a deep pack. If an area generally has a maximum density less than these values, NMF should be decreased and if the maximum density is typically greater than these values, NMF would be increased. A maximum reasonable range for the NMF parameter is from 0.05 to 0.30.

<u>MBASE</u> – The MBASE parameter is the base temperature used to determine the temperature gradient for non-rain melt computations. When modeling an area with a variety of vegetation cover, slopes, and aspects, the value of MBASE is almost always 0°C. This includes most watersheds where snowmelt runoff is significant. Generally if a non 0°C value of MBASE is needed for most watersheds in order to properly simulate snowmelt, there is a good chance that there is a bias or error in the MAT computations. Thus, before using a non 0°C value for MBASE, in most cases, one should carefully check and reevaluate the MAT calculations. There is a chance that a MBASE greater than 0°C is needed in high elevation, open areas with generally clear skies and relatively low humidity during the melt season. Under such conditions negative longwave radiation and latent heat exchange can offset solar radiation and sensible heat exchange at temperatures slightly above 0°C during the day and refreezing of the water in the upper snow layers occurs at night even though the temperature is above freezing. MBASE values greater than 0°C are frequently needed when applying the snow model to a open, high elevation point location such as a snow course site. Non 0°C values are also frequently needed when modeling other point locations due to site specific factors that control the relationship between measured air temperature and melt amounts.

<u>PLWHC</u> – The PLWHC parameter controls the maximum amount of liquid water that can be retained within the snow cover expressed as a decimal fraction of the amount of ice in the snow cover. The PLWHC parameter should be selected based on ripe snow cover conditions,

i.e. the snow is well aged, isothermal at 0°C, and has its liquid water capacity full. Fresh (i.e. newly fallen, low density snow) snow can hold more liquid water than ripe snow, however, the existence of the liquid water will cause metamorphism to begin and within hours, if sufficient water is applied, the snow will become ripe. Most studies indicate that the maximum liquid water holding capacity for ripe snow is in the order of 2 to 5 percent. Thus, the PLWHC parameter should be assigned a value in the range of 0.02 to 0.05 with generally the lowest values being used for areas with very deep snow covers. In addition to snow retaining liquid water throughout the pack, a slush layer generally builds up at the snow-soil interface. For a deep snow cover the amount of water held in this slush layer is inconsequential, but for a shallow snow cover it can be significant. To account for the slush layer, it has been found that in areas with shallow snow covers, especially in the plains and open agricultural areas of the midwest, that a higher value is needed for the PLWHC parameter in order to properly delay the onset of melt water entering the soil. In such areas values for PLWHC in the range of 0.1 to 0.3 are quite common.

<u>DAYGM</u> – The DAYGM parameter controls the amount of melt per day that occurs at the snow-soil interface. This is a constant amount of melt that takes place whenever there is a snow cover. The following values are recommended for the DAYGM parameter:

DAYGM = 0.0 for areas with generally frozen soils under the snow, and
DAYGM = 0.3 for areas with intermittent snow cover or with fairly temperate climates, such as the Sierra Nevada mountains in California, during the winter.

Other areas would use DAYGM values somewhere in between these limits.