SNOW 17 MODEL

The SNOW-17 snow accumulation and ablation model was first described by Anderson (1973) as a component of the National Weather Service River Forecast System (NWSRFS). SNOW-17 is a conceptual model.

SNOW-17 is an index model using air temperature as an index to determine the energy exchange across the snow-air interface (Anderson, 2006). In addition to temperature, the only other input variable needed to run the model is precipitation. Air temperature is also used as an indicator to estimate snowmelt. Air temperature is a commonly measured and operationally available variable. The estimation of the spatial variation of air temperature in most cases is associated with other meteorological variables that affect the snow energy balance. Elevation differences is a dominant factor that explains the temperature variability over an area. The ability to reasonably extrapolate air temperature data to higher elevations is critically important for snow modelling since in many mountainous regions, most of the snow runoff comes from areas that are higher than any measurement site (Anderson, 2006).

SNOW-17 was primarily designed for use in river forecasting (Anderson, 2006). This means that the model needs to use both historical data for calibration and real-time data for operational applications. SNOW-17 is typically applied on an areal basis to estimate the contribution of melt from the snow pack to a rainfall/runoff model, as well as the amount of snow water equivalent. In flat terrain, SNOW-17 is typically applied to a headwater drainage or local area though in some cases large drainages may be divided into several sub-areas. In mountainous regions, due to the significant variation in the amount of snow and the timing of melt with elevation, watersheds are typically divided into 2 or 3 elevation zones when using SNOW-17.

While some guidelines have been developed relating SNOW-17 model parameters to physiographic factors, the model needs to be calibrated to produce quality simulation results (Anderson, 2006). Recommendations for determining initial parameter values and for calibrating the SNOW-17 model are included in a comprehensive guide for historical data analysis and model calibration for river forecasting applications (Anderson, 2002). In order to optimize the SNOW-17 simulations for river forecasting applications, three things must occur:

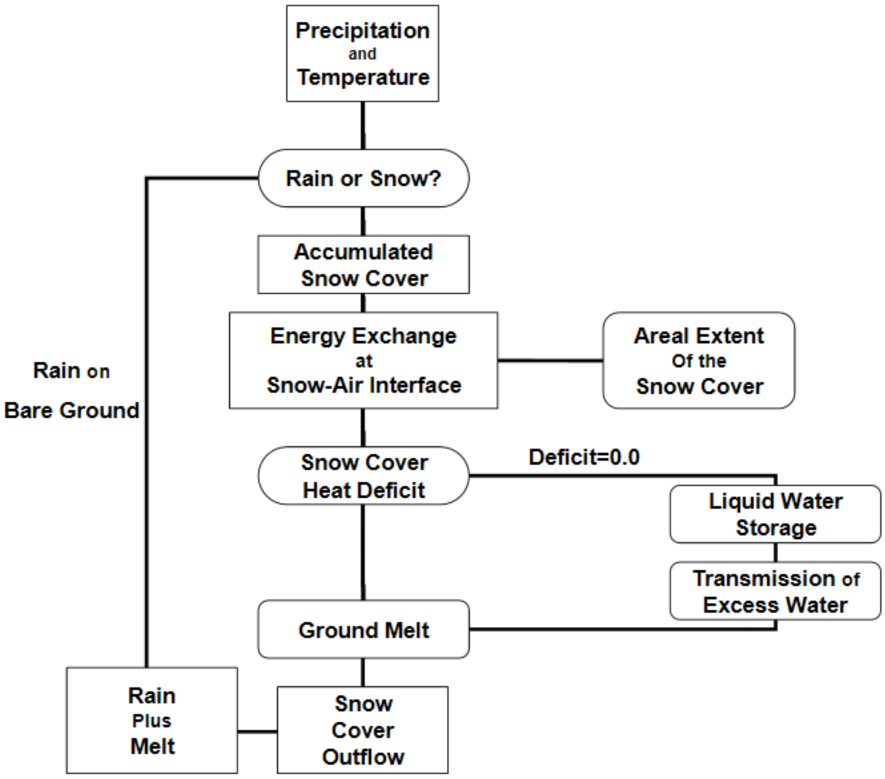
1. The model must be properly calibrated;
2. The input data (precipitation and temperature) used operationally must be unbiased compared to that used for calibration; and
3. Well devised, ideally objective, updating schemes must be used to remove bias and to minimize random errors to the maximum extent possible.

The approach used when developing SNOW-17 was to first try to represent the physical processes that occur in a column of snow. Then, features were added so that the model could be applied to an area. This is a similar approach to that later used when the Sacramento Soil Moisture model was developed. The main processes included in the model for a column of snow are:

- Form of precipitation,

- Accumulation of the snow pack,
- Energy exchange at the snow-air interface,
- Internal state of the snow pack,
- Transmission of water through the snow pack, and
- Heat transfer at the soil-snow interface.

In order to apply the model to an area, the areal extent of the snow pack is computed and used to determine the fraction of the area from which melt and outflow from the snow cover can occur. When the model is applied at a point location, the algorithm used to compute the areal extent of the snow cover is not used. When applied to an area, SNOW-17 keeps track of mean areal values of variables such as water equivalent. In order to get the average over the snow-covered area, one must divide these mean areal values by the areal extent of the snow cover (Anderson, 2006). In the SEEFFGS because of relatively small basin areas, whenever the simulated SWE is above 2 mm the snow model is applied over the entire drainage area of the basin. Figure below shows a basic flowchart of the SNOW-17 model.



SNOW-17 algorithm flowchart (Anderson, 2006)

The computational time interval, i.e. the minimum period for which the model can be run, is the time interval associated with the temperature data. An appropriate time interval for the snow model should represent the diurnal cycle of temperature. For river forecasting, the model has most frequently been applied at a 6-hour interval. Many of the model parameters are defined for that period and are then adjusted if computations are done at a different interval.

The input data for SNOW-17 is precipitation and temperature. The precipitation is the total over a specified time interval. When doing areal computations, the precipitation is normally the mean amount over the area though the code does include a multiplying factor, PXADJ, that can be applied to all precipitation values entering the model (PXADJ is usually equal to 1.0).

Snow Model Parameters and State Variables

Ground level temperature is a good, but not perfect, indicator as to whether precipitation is falling as rain or snow. The form of precipitation can vary with surface level temperature. The variation of the form of the precipitation at a given location is based on data from the Snow Investigations (Snow Hydrology, 1956). It shows that rain can occur at temperatures below 1˚C and snow can occur when the air temperature is 4˚C. From that study, the typical temperature separating rain from snow is around 1.5˚C.

The temperature of precipitation, whether rain or snow, can probably best be approximated by the wet bulb temperature. When precipitation is occurring, the relative humidity is generally quite high and thus under these conditions the wet bulb temperature is close to the air temperature. When snow falls at temperatures below freezing, it must eventually be warmed to 0˚C before melting.

The SNOW-17 model has 12 parameters. This counts the areal depletion curve as one parameter though it is input as a series of nine values used to define the shape of a curve. Some of the parameters have more influence on the simulation results than others. The most sensitive parameters are those that typically should be determined through calibration even though some guidelines are available to obtain initial estimates (Anderson, 2002). The others less sensitive parameters typically can be assigned values based on the climatological conditions at the location being modelled.

The major parameters for the SNOW-17 model are:

1. SCF – The multiplying factor which adjusts precipitation that is determined to be in the form of snow. SCF primarily accounts for gauge catch deficiencies, but also implicitly includes the net effect of vapour transfer (sublimation and condensation, including from intercepted and blowing snow) and transfers across areal divides.
2. FMAX – Maximum melt factor during non-rain periods (mm·°C-1·6 hr-1).
3. MFMIN – Minimum melt factor during non-rain (mm·°C-1·6 hr-1).
4. UADJ – The average wind function during rain-on-snow periods (mm·mb-1). UADJ is only a major parameter when there are frequent rain-on-snow events with relatively warm temperatures.
5. SI – The mean areal water equivalent above which there is always 100 percent areal snow cover (mm). SI is not a major parameter when the model is applied at a point location or when significant bare ground appears soon after melt begins, no matter the magnitude of the snow cover.
6. PXTEMP – The temperature that separates rain from snow (°C). If the air temperature is less than or equal to PXTEMP, the precipitation is assumed to be in

the form of snow. The PXTEMP parameter, as defined for SNOW-17, is not used if a rain-snow elevation time series is used to determine the form of precipitation.

7. MBASE – Base temperature for snowmelt computations during non-rain periods (°C). Typically, a value of 0 °C is used.

The minor parameters for the SNOW-17 model are:

1. NMF – Maximum negative melt factor (mm·°C-1·6 hr-1). The negative melt factor has the same seasonal variation as the non-rain melt factor.
2. TIPM – Antecedent temperature index parameter (real – range is 0.01 to 1.0). Controls how much weight is put on temperatures from previous time intervals when computing ATI. The smaller the value of TIPM, the more previous time intervals are weighted.
3. PLWHC – Percent liquid water holding capacity (decimal fraction). Indicates the maximum amount of liquid water, as a fraction of the ice portion of the snow, that can be held against gravity drainage (maximum allowed value is 0.4)

DAYGM – Constant daily amount of melt which takes place at the snow-soil interface whenever there is a snow cover (mm·day$^{-1)}$

The SNOW-17 model has 14 state variables. These are as follows:

1. Water equivalent of the ice portion of the snow cover (mm),
2. Heat deficit (mm),
3. Antecedent temperature index (°C),
4. Liquid water held by the snow (mm),
5. The maximum amount of water equivalent that existed during an accumulation period (mm),
6. The water equivalent when new snowfall first occurs on a partly bare area, i.e. the water equivalent at the point where the areal cover leaves the depletion curve (mm).

This document was prepared by WMO-FFGS team using South East Europe Flash Flood Guidance System Forecaster Guide[1], FFGS Operational Output Product Descriptions available in the FFGS Real-Time Product Console developed by the Hydrologic Research Center and National Oceanic, Atmospheric Administration (NOAA) materials and above-mentioned documents.

[1] https://www.wmo.int/pages/prog/hwrp/flood/ffgs/documents/SEEFFGS_Forecaster_Guide-Final_ES_TM-AS-PM.pdf