CONCEPTUALIZATION OF THE SNOW ACCUMULATION PROCESS*

*Kokkonen, T., Koivusalo, H., Jakeman, T., & Norton, J. P. (2006). Construction of a degree-day snow model in the light of the ten iterative stepsin model development (International Congress on Environmental Modelling and Software, Vol. 73). Retrieved from https://scholarsarchive.byu.edu/iemssconference/2006/all/73

Parameters names used in the model and the following equations slightly differ:

Model	Equations	Function
DDF	k_d	Degree day factor (snow melt rate)
TT	T_p	Base temperature below which snow forms
Kf	k_f	Degree day factor (refreezing)
TM	T_{melt}	Base temperature above which melt forms
r	r	Retention coefficient

Form of precipitation

Below a certain threshold temperature T_p (°C), all precipitation is assumed to fall as snow, and above the same temperature as rain. In mathematical terms,

$$f_r = \begin{cases} 0 & T \leq T_p \\ 1 & T < T_p \end{cases}$$

$$f_s = 1 - f_r$$

where f_r (-) is the fraction of rainfall, f_s (-) is the fraction of snowfall, and T (°C) is the air temperature.

Snowmelt

It is proposed that the rate of snowmelt is linearly related to the air temperature above the melting temperature. This can be written as

$$\begin{cases} m = k_d(T - T_{melt}) & T > T_{melt} \\ m = 0 & T \leq T_{melt} \end{cases}$$

where m (mm/d) is the melt rate, k_d (mm/(°C d)) is the degree-day factor for melt, and T_{melt} (°C) is the temperature where melting of snow is initiated. The value of T_{melt} is close to 0 °C, but can be allowed to differ slightly from it. Such a deviation can, for instance, account for a systematic difference between the air temperature at the measurement station and the temperature at the site where snow water equivalent is modelled. Air temperature has a strong relationship with altitude, and hence a difference in the elevation of the weather station and the modelling site easily results in a systematic bias of temperature measurements. Bergström (1990)* reports that the degree-day factor for melt ranges from 1.5 to 4 mm/(°C d) in operational streamflow forecasting applications in Sweden.

*Bergström, S. (1990). Parametervärden för HBVmodellen i Sverige (in Swedish). SMHI Hydrologi. Nr 29, 1990.

Freezing

Analogously to snowmelt, the rate of freezing f (mm/d) is written as

$$\begin{cases} f = k_f(\ T_{melt} - T) & T < T_{melt} \\ f = 0 & T \geq T_{melt} \end{cases}$$

where k_f (mm/(°C d)) is the degree-day factor for freezing.

Liquid water retention capacity of a snowpack

The liquid water retention capacity of a snowpack is related to the water equivalent of ice in the snowpack, i.e.

$$L_{max} = r\, I$$

where L_{max} (mm) is the maximum amount of liquid water in the snowpack, r (-) is the retention parameter, and I (mm) is the water equivalent of ice in the snowpack.

Mass balance for the snowpack

The following equation gives the mass balance for the water equivalent of ice in the snowpack:

$$\frac{dI}{dt} = P_s + f - m$$

The following equation gives the mass balance for the liquid water L (mm) retained in the snowpack:

$$\frac{dL}{dt} = P_r + m - f \qquad L \leq L_{max}$$

When liquid water input ($P_r + m - f$) cannot fit into the liquid water store, i.e. the value of L exceeds L_{max}, the excess liquid water above L_{max} becomes snowmelt discharge d (mm/d).

Rain/melt

Rain/melt is snowmelt discharge when there is snow on the ground, and rainfall in snow-free periods.