Algorithm Specification – VIC State Updating

Version 2.0.1

June 5, 2015

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Record of Changes

Version	Date	Description of Change
1.0.0	May 14, 2015	Version 1 draft specification
2.0.0	June 3, 2015	Major revision of original specification
2.0.1	June 5, 2015	Updated logic for categorical constraints for SPEC-5

List of Symbols

Symbols	Description
	Variables
A	Grid cell area fraction [-]
H	Number of HRUs per band or cell
V	Number of non-vegetated HRUs per band
Θ	Cell state variable (generic)
Ω	HRU state variable (generic)
d	State variable (water depth or energy)
	Subscripts and indices
b	Band index
c	Cell ID
g	Glacier HRU
h	Generic HRU index
op	Open ground HRU
t	Initial model state index (i.e. prior to updating)
$t*$	Final model state index (i.e. after updating)
v	Vegetated HRU (i.e. not glacier or open ground)

1 INTRODUCTION/BACKGROUND

This specification details the method for updating the VIC state file following glacier updating. One of the main features in the coupling of the VIC model to the UBC Regional Glaciation model (RGM) is the feedback of glacier area and surface elevation from the RGM to VIC. Changes in glacier area (passed from RGM to VIC as an updated glacier mask) and surface elevation are incorporated into the VIC model via updating of the vegetation parameter file and the elevation band file. A side-effect of this updating step is the need to adjust certain state variables to ensure conservation of mass within the individual VIC cells as a result of area and elevation updating. Conceptually, this entails the redistribution of water and energy between individual HRUs. For example, the goal of water re-distribution between HRUs is to conserve the volume of water within a grid cell. In general, the following must hold for a given cell:

$$\sum_{h=1}^{H} \Omega_h(t) \cdot A_h(t) = \sum_{h=1}^{H^*} \Omega_h(t^*) \cdot A_h(t^*) \tag{1}$$

where H and H^* are the number of HRUs before and after glacier updating, respectively, Ω_h is a given state variable (e.g. water equivalent depth of snow) and A_h is the area fraction of HRU number h, and t and t^* represent the model state before and after glacier updating, respectively. The same concept holds for the conservation of energy. However, glaciers (more specifically, glacier HRUs) don't exist in every elevation band, furthermore, glacier changes also don't occur in every elevation band. Hence, state updating is more likely to occur on a band-by-band basis, and equation (1) is re-written as

$$\sum_{b=1}^{B} \sum_{h=1}^{H_b(t)} \Omega_{h,b}(t) \cdot A_{h,b}(t) = \sum_{b=1}^{B} \sum_{h=1}^{H_b(t^*)} \Omega_{h,b}(t^*) \cdot A_{h,b}(t^*) \tag{2}$$

where B is the number of elevation bands, and $H_b(t)$ and $H_b(t^*)$ are the number of HRUs in band b before and after glacier updating. Hence, state updating need only occur in elevation bands in which a glacier HRU undergoes an area change (i.e. $A_{h,b}(t) \neq A_{h,b}(t^*)$). One exception is the case where an elevation bands is created or disappears as a result of glacier HRU being created or removed, respectively; in these cases HRUs in both band b and it's neighboring band (b-1 or b+1, depending on situation), may also be affected.

The specifications described in the following sections for state updating is considered within the context of the pseudo-code shown in the text Box 1 below. The pseudo-code describes an algorithm for looping through cells and elevation bands within cells, and then checking within bands for different cases, or contexts, in which the area fraction of glacier HRUs can change, including the disappearance and initiation of glaciers. These are referred to as cases, of which seven have been indicated (which should cover all possibilities). The type of state updating required will depend on the context within which glacier area fractions change (the case). Of course, if a glacier HRU does not change its area, then no state updating is required for the HRUs in that particular elevation band.

The state variables being explicitly considered by this specification are summarized in Table 1. Table 2 list state variables that are considered miscellaneous at this time; they are not actually necessary for proper state updating (their inclusion in the state file is simply an artefact of earlier programming efforts) and they may be dropped from future implementations. Table 3 list state variables that are only required when certain code options are selected (i.e. *DIST_PRCP*, *EXCESS_ICE*, *LAKES*, *SPATIAL_FROST* and *SPATIAL_SNOW*). However, as these code options are currently untested and their use discouraged, these state variables are not explicitly updated.

The pseudo-code algorithm provides specifications for updating VIC cell and HRU metadata state variables (Section 4) and identifies three cases requiring unique specifications for updating HRU state variables:

1) Case 1: The *GLACIER* HRU and/or the elevation band changes area, and one or more HRUs occupy the elevation band at state *t* or *t**(Section 5).
2) Case 2[a]: A *GLACIER* HRU shrinks and disappears, and it is the only HRU occupying the current elevation band, hence the elevation band disappears as well (Section 6).
3) Case 3[b]: A *GLACIER* HRU appears/initiates in a new elevation band (Section 7).

[a] This case assumes that a *GLACIER* HRU already exists in the next lower elevation band.
[b] This case also assumes that a *GLACIER* HRU already exists in the next lower elevation band

```
for (c in cells) {
    if (num_HRU[cell, t] != num_HRU[c, t-1] {
        #UPDATE CELL & HRU METADATA
    }
    for (b in bands) {
        glac_area_change <- area_frac_glac[c,b,t] - area_frac_glac[c,b,t-1]
        band_area_change <- area_frac_band[c,b,t] - area_frac_band[c,b,t-1]
        if (glac_area_change != 0 || band_area_change != 0) {
            if (area_frac_band[c,b,t] > 0 {
                #UPDATE HRU STATE - CASE 1
            } else if (area_frac_band[c,b,t] == 0) {
                #UPDATE HRU STATE - CASE 2 //assume glacier HRU exists in next lower band
            } else if (area_frac_band[c,b,t-1] == 0) {
                #UPDATE HRU STATE - CASE 3 //assume glacier HRU exists in next lower band
            }
        } else {
            #NO CHANGE IN STATE FOR HRUs IN THIS BAND
        }
    }
}
```

Box 1. Pseudo-code for VIC state updating

Table 1. Summary of State Variables with Explicit Updating

State Variable	Description
	Cell Metadata
lat	Grid cell centre latitude
lon	Grid cell centre longitude
GLAC_MASS_BALANCE_INFO	Cell ID, mass balance polynomial terms and error
GRID_CELL	Grid cell ID number
NUM_BANDS	Number of bands (set in global file)
NUM_GLAC_MASS_BALANCE_INFO_TERMS	
SOIL_DZ_NODE	Soil thermal node deltas [EXCESS_ICE = TRUE???]
SOIL_ZSUM_NODE	Soil thermal node depths [EXCESS_ICE = TRUE???]
VEG_TYPE_NUM	Number of HRUs in grid cell
	HRU Metadata
HRU_BAND_INDEX	Band index
HRU_VEG_INDEX	HRU vegetation class
	HRU Water Balance
LAYER_ICE_CONTENT	Ice content in each soil layer [*SPATIAL_FROST* = FALSE]
LAYER_MOIST	Total soil moisture in each layer
HRU_VEG_VAR_DEW	Water stored on surface/vegetation
SNOW_CANOPY	Snow stored in the canopy
SNOW_SWQ	Total snow water equivalent
SNOW_PACK_WATER	Water stored in snow pack layer
SNOW_SURF_WATER	Water stored in snow surface layer
	HRU Glacier Water Storage
GLAC_WATER_STORAGE	Water stored in the glacier
	HRU Glacier Mass Balance
GLAC_CUM_MASS_BALANCE	Glacier cumulative mass balance
	Snow Pack Properties
SNOW_DENSITY	Snow density
SNOW_DEPTH	Snow depth
	HRU Snow Pack, Glacier and Soil Energy
ENERGY_T	Soil temperature at each soil node
ENERGY_TFOLIAGE	Vegetation temperature
GLAC_SURF_TEMP	Temperature of glacier surface Layer
SNOW_COLD_CONTENT	Cold content of snow surface layer
SNOW_PACK_TEMP	Temperature of snow pack layer
SNOW_SURF_TEMP	Temperature of snow surface layer
	HRU Snow Surface Properties
SNOW_ALBEDO	Albedo of snow
SNOW_LAST_SNOW	Days since last snowfall
SNOW_MELTING	Snow melting flag [TRUE or FALSE]
	HRU Program Terms
ENERGY_TCANOPY_FBCOUNT	*TCANOPY* fallback count
ENERGY_T_FBCOUNT	*T* fallback count
ENERGY_TFOLIAGE_FBCOUNT	*TFOLIAGE* fallback count
ENERGY_TSURF_FBCOUNT	*TSURF* fallback count
GLAC_SURF_TEMP_FBCOUNT	*GLAC_SURF_TEMP* fallback count

State Variable	Description
SNOW_SURF_TEMP_FBCOUNT	*SNOW_SURF_TEMP* fallback count

Table 2. Summary of Miscellaneous State Variables with Default Values

State Variable	Description	Default Value
GLAC_QNET	Glacier surface net energy balance	0
GLAC_SURF_TEMP_FBFLAG	*GLAC_SURF_TEMP* fallback flag	0
GLAC_VAPOR_FLUX	Glacier vapor flux	0
NONE	???	0
SNOW_CANOPY_ALBEDO	Albedo of snow stored in the canopy	0
SNOW_SURFACE_FLUX	Sublimation from blowing snow	0
SNOW_SURF_TEMP_FBFLAG	*SNOW_SURF_TEMP* fallback flag	0
SNOW_TMP_INT_STORAGE	Temporary canopy interception storage	0
SNOW_VAPOR_FLUX	Snow evaporation and sublimation	0

Table 3. Summary of Deferred State Variables (for Untested Code Paths) with Default Values

State Variable	Description	Default Value
	Option.DIST_PRCP = TRUE	
PRCP_MU	Fraction of grid cell that receives precipitation	1
INIT_STILL_STORM	Storm continuity flag [*TRUE* or *FALSE*]	"FALSE"
INIT_DRY_TIME	Time since last storm	0
	EXCESS_ICE = TRUE	
SOIL_DEPTH	Soil moisture layer depths	0
SOIL_EFFECTIVE_POROSITY	Soil porosity when soil pores expanded due to excess ground ice for each soil layer	0
SOIL_DP	Soil damping depth	0
SOL_MIN_DEPTH	Soil layer depth as given in the soil file	0
SOIL_POROSITY_NODE	Soil porosity at each node	0
SOIL_EFFECTIVE_POROSITY_NODE	Soil porosity when soil pores expanded due to excess ground ice for each soil thermal node	0
SOIL_SUBSIDENCE	Subsidence of soil layer	0
	Option.LAKES = TRUE[c]	
LAKE_LAYER_MOIST	Total soil moisture in each layer	0
LAKE_LAYER_SOIL_ICE	Ice content in each soil layer [*SPATIAL_FROST* = TRUE]	0
LAKE_LAYER_ICE_CONTENT	Ice content in each soil layer [*SPATIAL_FROST* = FALSE]	0
LAKE_SNOW_LAST_SNOW	Days since last snowfall	0
LAKE_SNOW_MELTING	Snow melting flag [TRUE or FALSE]	"FALSE"
LAKE_SNOW_COVERAGE	Snow coverage fraction	0
LAKE_SNOW_SWQ	Total snow water equivalent	0
LAKE_SNOW_SURF_TEMP	Temperature of surface snow layer	0
LAKE_SNOW_SURF_WATER	Water stored in snow surface layer	0
LAKE_SNOW_PACK_TEMP	Temperature of pack snow layer	0
LAKE_SNOW_PACK_WATER	Water stored in snow pack layer	0
LAKE_SNOW_DENSITY	Snow density	0
LAKE_SNOW_COLD_CONTENT	Cold content of snow surface layer	0
LAKE_SNOW_CANOPY	Snow stored in the canopy	0
LAKE_ENERGY_T	Soil temperature at each soil node	0
LAKE_ACTIVENOD	Number of nodes whose corresponding layers contain water	0
LAKE_DZ	Thickness of all water layers below surface layer	0
LAKE_SURFDZ	Thickness of surface (top) water layer	0
LAKE_LDEPTH	Depth of liquid water in lake	0
LAKE_SURFACE	Horizontal x-section area at each lake node	0
LAKE_SAREA	Lake surface area of (ice + liquid)	0
LAKE_VOLUME	Lake water volume (including w.e. of lake ice)	0
LAKE_TEMP	Lake water temperature at each node	0
LAKE_TEMPAVG	Average water temperature of entire lake	0
LAKE_AREAI	Area of ice coverage at beginning of time step	0
LAKE_NEW_ICE_AREA	Area of ice coverage at end of time step	0

[c] Many of the *LAKE* state variables are redundant

LAKE_ICE_WATER_EQ	Water equivalent of lake ice	0
LAKE_HICE	Height of lake ice at thickest point	0
LAKE_TEMPI	Lake ice temperature	0
LAKE_SWE	Water equivalence of lake snow cover	0
LAKE_SURF_TEMP	Temperature of surface snow layer	0
LAKE_PACK_TEMP	Temperature of pack snow layer	0
LAKE_SALBEDO	Albedo of lake snow	0
LAKE_SDEPTH	Depth of snow on top of ice	0
	SPATIAL_FROST = TRUE	
LAYER_SOIL_ICE	Ice content of the frozen soil sublayer	0
	SPATIAL_SNOW = TRUE	
SOIL_DEPTH_FULL_SNOW_COVER	Minimum depth for full snow cover	0
SNOW_COVERAGE	Snow coverage fraction	1

2 General Specifications

This specification will often distinguish between *GLACIER*, *OPEN* (i.e. bare soil) and *VEGETATED* Hydrologic Response Units (HRUs). *GLACIER* and *OPEN* HRUs are explicitly identified by land cover classification; this is done by the user in the global parameter file. By inference, *VEGETATED* HRUs are all land cover classes other than *GLACIER* or *OPEN* classes. Note that the *OPEN* class is not to be confused with the VIC model's default bare soil land cover classification.

For clarity the band index b is dropped from future specifications, however it remains implied (unless specifically stated otherwise; e.g. Cases 2 and 3) that conservation of mass and energy principles as described apply within a given elevation band.

2.1 Cell Metadata

Generally cell metadata values will remain unchanged between state t and t^*. Hence the spec for generic cell metadata state variable Θ for cell c is

$$\boxed{\Theta_c(t^*) = \Theta_c(t).} \qquad \text{SPEC- 1}$$

An exception is the *VEG_TYPE_NUM* state variable, which must be updated if $H_c(t^*) \neq H_c(t)$, such that

$$\boxed{VEG\_TYPE\_NUM_c(t^*) = H_c(t^*).} \qquad \text{SPEC- 2}$$

2.2 HRU Metadata

If $H_c(t^*) \neq H_c(t)$, then *HRU_VEG_INDEX* must be updated for each HRU h follows

$$\boxed{HRU\_VEG\_INDEX_h(t^*) = vegClass_h(t^*)} \qquad \text{SPEC- 3}$$

where $vegClass_h(t^*)$ is the vegetation class of the current HRU at state t^* (i.e. taken from the updated vegetation parameter file). Also, If $H_c(t^*) \neq H_c(t)$, then *HRU_BAND_INDEX* must be updated for each HRU h as follows

$$\boxed{HRU\_BAND\_INDEX_h(b,t^*) = bandIndex_h(t^*)} \qquad \text{SPEC- 4}$$

where *bandIndex* is the index of the elevation band b.

2.3 Conservation of Mass and Energy

2.3.1 Water Balance, Glacier Water Storage and Glacier Mass Balance

Water Balance, *Glacier Water Storage* and *Glacier Mass Balance* state variables are updated under the principle of conservation of mass and energy. For a given elevation band b equation (1) is re-written as

$$A_g(t^*)d_g(t^*) + A_{op}(t^*)d_{op}(t^*) + \sum_{v=1}^{V_b(t^*)} A_v(t^*)d_v(t^*) = A_g(t)d_g(t) + A_{op}(t)d_{op}[b,t] + \sum_{v=1}^{V_b(t)} A_v(t)d_v(t)$$

subject to the following categorical constraints

$$\begin{cases} n/a & if\ A_{op}(t^*) = 0\ or\ \Delta A_{op}(t^*) = 0, \quad else \\ d_g(t^*) = 0 & if\ A_g(t^*) = 0, \quad else \\ d_g(t^*) = d_g(t) & if\ \Delta A_g(t^*) = 0, \quad else \\ \dfrac{d_g(t^*) - d_g(t)}{A_g(t^*)} = \dfrac{d_{op}(t^*) - d_{op}(t)}{A_{op}(t^*)} & if\ \Delta A_g(t^*) \neq 0 \end{cases}$$

$$\begin{cases} n/a & if\ A_{v=1}(t^*) = 0\ or\ \Delta A_{v=1}(t^*) = 0, \quad else \\ d_{op}(t^*) = 0 & if\ A_{op}(t^*) = 0, \quad else \\ d_{op}(t^*) = d_{op}(t) & if\ \Delta A_{op}(t^*) = 0, \quad else \\ \dfrac{d_{op}(t^*) - d_{op}(t)}{A_{op}(t^*)} = \dfrac{d_{v=1}(t^*) - d_{v=1}(t)}{A_{v=1}(t^*)} & if\ \Delta A_{op}(t^*) \neq 0 \end{cases}$$

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$$\vdots$$

$$\begin{cases} n/a & if\ A_V(t^*) = 0\ or\ \Delta A_V(t^*) = 0, \quad else \\ d_{V-1}(t^*) = 0 & if\ A_{V-1}(t^*) = 0, \quad else \\ d_{V-1}(t^*) = d_{V-1}(t) & if\ \Delta A_{V-1}(t^*) = 0, \quad else \\ \dfrac{d_{V-1}(t^*) - d_{V-1}(t)}{A_{V-1}(t^*)} = \dfrac{d_V(t^*) - d_V(t)}{A_V(t^*)} & if\ \Delta A_{V-1}(t^*) \neq 0 \end{cases}$$

$$\begin{cases} n/a & if\ A_g(t^*) = 0\ or\ \Delta A_g(t^*) = 0, \quad else \\ d_V(t^*) = 0 & if\ A_V(t^*) = 0, \quad else \\ d_V(t^*) = d_{op}(t) & if\ \Delta A_V(t^*) = 0, \quad else \\ \dfrac{d_V(t^*) - d_{V-1}(t)}{A_V(t^*)} = \dfrac{d_g(t^*) - d_g(t)}{A_g(t^*)} & if\ \Delta A_V(t^*) \neq 0 \end{cases}$$

where A is HRU area (as fraction of the grid cell), $\Delta A(t^*) = A(t^*) - A(t)$, d is a generic variable representing the specific depth of a given water balance component (i.e. depth per unit area), subscripts g, op and v denote *GLACIER*, *OPEN* and *VEGETATED* HRUs, respectively, V_b is the number of *VEGETATED* HRUs in band b, where $V_b \leq H_b$ (where H_b is the total number of HRUs in band b), and t and t^* are the model state before and after glacier updating, respectively. Note that SPEC- 5 is a system of linear equations that must be solved simultaneously.

For many of the specific cases that follow, SPEC- 5 can be simplified considerably. These case specific details are provided in the relevant sections of this document.

2.3.2 Snow Pack Properties

Most of the variables categorized under *Snow Pack Properties* are updated based on conservation of mass. The state variable *SNOW_DEPTH* is updated as

$$\boxed{SNOW\_DEPTH_h(t^*) = [SNOW\_SWQ_h(t^*) \cdot 1000]/SNOW\_DENSITY_h(t^*)} \qquad \text{SPEC- 6}$$

where *SNOW_SWQ* and *SNOW_DENSITY* are updated according to SPEC- 5. Exceptions occur when a *GLACIER* HRU is created. Details for such instances are given in for Cases 2 and 3 (see Sections 6 and 0).

2.3.3 Snow Pack, Glacier and Soil Energy

For state variables grouped under the *Snow Pack, Glacier and Soil Energy* category, variable updating is applied under the principle of conservation of energy. However, the variables *COLD_CONTENT*, *ENERGY_T* and *GLAC_SURF_TEMP* are treated differently, as described in the following paragraphs.

Given the updated *SNOW_SURF_TEMP*, for an HRU h *COLD_CONTENT* is updated as

$$COLD\_CONTENT_h(t^*) = SNOW\_SURF\_TEMP_h(t^*) \cdot SNOW\_SURF\_SWQ_h(t^*) \cdot CH\_ICE$$

where *CH_ICE* is the volumetric heat capacity of ice[d] and

$SNOW\_SURF\_SWQ_h(t^*) = \min[MAX\_SURFACE\_SWE, SNOW\_SWQ_h(t^*)]$ SPEC- 7

where *MAX_SURFACE_SWE* is the maximum snow water equivalent of the surface layer[e].

For the state variables *GLAC_SURF_TEMP* and *ENERGY_T*, we don't strictly adhere to the conservation of energy principle and simply maintain constant values between state t and t^* (continuity principle, see Section 2.5). Exceptions occur when a *GLACIER* HRU is created; see the Sections 3 for details.

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[d] This value for *CH_ICE* is set in the header file vicNl_def.h; currently set to 2100E+03.
[e] This value is set in the header file snow.h; currently set at 0.125 m

2.4 Weighted Assignment

2.4.1 Snow Surface Properties

For variables in the *Snow Surface Properties* category, state variables are typically updated based on an area weighting of values at state *t*. For example, the updating of generic state variable *Ω* for HRU *h*=1 is given by

$$\begin{cases} \Omega_{h=1}(t^*) = \Omega_{h=1}(t) & if\ \Delta A_{h=1} \geq 0 \\ \Omega_{h=1}(t^*) = \\ \dfrac{\Omega_{h=1}(t) \cdot A_{h=1}(t) \cdot f_{h=1}(t, \mathrm{I}_{SWQ}) + \sum_{h=2}^{H} \Omega_h(t) \cdot [A_h(t) - A_h(t^*)] \cdot f_h(t, \mathrm{I}_{SWQ})}{A_{h=1}(t) \cdot f_{h=1}(t, \mathrm{I}_{SWQ}) + \sum_{h=2}^{H} [A_h(t) - A_h(t^*)] \cdot f_h(t, \mathrm{I}_{SWQ})} & if\ \Delta A_{h=1} < 0 \end{cases}$$

where $f_h(t, \mathrm{I}_{SWQ})$ is

$$f_h(t, I_{SWQ}) = \mathrm{I}[SNOW\_SWQ_h(t)) > 0]$$

and I(·) is the indicator function, such that

$$\mathrm{I}(X > 0) \coloneqq \begin{cases} 1 & if\ X > 0 \\ 0 & if\ X \leq 0 \end{cases},$$

and for *SNOW_MELTING*$_h$(·) (which must be converted from character to integer)

$$\Omega_h(\cdot) = \begin{cases} 1 & if\ SNOW\_MELTING_h(\cdot) = "TRUE" \\ 0 & if\ SNOW\_MELTING_h(\cdot) = "FALSE" \end{cases}.$$

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Exceptions to SPEC- 8 will occur in certain cases, and these are detailed in Section 3.

For the state variables *SNOW_LAST_SNOW* and *SNOW_MELTING* (which are integer), SPEC- 8 is further modified as

$$z_h(t^*) = ceil[\Omega_h(t^*)]$$

and

$$SNOW\_LAST\_SNOW_h(t^*) = z_h(t^*)$$

$$SNOW\_MELTING_h(t^*) = \begin{cases} "TRUE" & if\ z_h(t^*) = 1 \\ "FALSE" & if\ z_h(t^*) = 0 \end{cases}.$$

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2.5 Continuity

2.5.1 Program Terms

For HRU variables in the *Program Terms* category (and certain variables from other categories), state variables are typically updated under the continuity principle. Simply stated, values remain constant between state *t* and *t**. For example, for generic state variable *Ω*

$$\Omega_g(t^*) = \Omega_g(t)\,,$$

$$\Omega_{op}(t^*) = \Omega_{op}(t)\,,\ \ and$$

$$\Omega_v(t^*) = \Omega_v(t)\ for\ all\ v = 1, \ldots, V.$$

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2.6 Miscellaneous Variables

The *Miscellaneous* state variables (Table 2) are not specifically dealt with on a case-by-case basis. In future implementations these variables may actually be removed from state capture. Currently, the *Miscellaneous* state variables are always updated using the default values given in Table 2. Hence, the specification is as follows

Ω = *default* (*Table 2*).

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2.7 Deferred Variables

The *Deferred* state variables (Table 3) are not specifically dealt with on a case-by-case basis. These state variables represent state that must be captured only when specific VIC options are set, either in the global file or in the user_def.h file. These options (i.e. *DIST_PRCP*, *EXCESS_ICE*, *LAKES*, *SPATIAL_FROST* and *SPATIAL_SNOW*) employ un-tested code paths and their use is discouraged. Consequently, the *Deferred* state variables are currently updated using the default values given in Table 3. Hence, the specification is as follows

Ω = *default* (*Table 3*).

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3 Detailed Specifications

The specifications that follow are case specific and typically derived by simplifying SPEC- 5 and SPEC- 8, depending upon the specific constraints and conditions.

3.1 GLACIER HRU

3.1.1 Conservation of Mass and Energy

For water balance variables SPEC- 5 for the *GLACIER* HRU reduces to several forms, depending upon the specific case. In certain situations the updated state value for a *GLACIER* HRU is given as

$$d_g(t^*) = d_g(t)\frac{A_g(t)}{A_g(t^*)}. \qquad \text{SPEC- 13}$$

When mass-related state variables need to be re-distributed between *GLACIER* HRUs in neighbouring bands, SPEC- 5 is simplified to the following single equation when the glacier in band *b* disappears

$$d_g(b-1,t^*) = d_g(b,t)\frac{A_g(b,t)}{A_g(b-1,t^*)} + d_g(b-1,t). \qquad \text{SPEC- 14}$$

and when the *GLACIER* HRU in band *b* newly appears, we solve the following system of equations for $d_g(b,t^*)$ and $d_g(b\text{-}1,t^*)$

$$A_g(b,t^*)\cdot d_g(b,t^*) + A_g(b-1,t^*)\cdot d_g(b-1,t^*) = A_g(b-1,t)\cdot d_g(b-1,t)$$

and

$$\frac{d_g(b,t^*)}{A_g(b,t^*)} = \frac{d_g(b-1,t^*) - d_g(b-1,t)}{A_g(b-1,t^*)} \qquad \text{SPEC- 15}$$

where

$$A_g(b-1,t^*) = A_g(b-1,t)$$

3.1.2 Weighted Assignment

For updating snow surface properties for the special case when a *GLACIER* HRU in band *b* shrinks and disappears into a glacier HRU in band *b*-1 (or other state variables ion certain cases), state is updated as follows

$$\Omega_g(b-1,t^*) = \frac{\Omega_g(b-1,t)\cdot A_g(b-1,t)\cdot f_g(b-1,t,\mathrm{I}_{SWQ}) + \Omega_g(b,t)\cdot[A_g(b,t)-A_g(b,t)]\cdot f_g(b,t,\mathrm{I}_{SWQ})}{A_g(b-1,t)\cdot f_g(b-1,t,\mathrm{I}_{SWQ}) + [A_g(b,t)-A_g(b,t)]\cdot f_g(b,t,\mathrm{I}_{SWQ})}$$

and for $SNOW\_MELTING_g(\cdot,\cdot)$ (which must be converted from character to integer)

$$\Omega_g(\cdot,\cdot) = \begin{cases} 1 & if\ SNOW\_MELTING_g(\cdot,\cdot) = "TRUE" \\ 0 & if\ SNOW\_MELTING_g(\cdot,\cdot) = "FALSE" \end{cases}.$$

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For the state variables *SNOW_LAST_SNOW* and *SNOW_MELTING,* which are integer and character, respectively, SPEC- 16 is further modified as

$$z_g(b-1,t^*) = ceil\left[\Omega_g(b-1,t^*)\right]$$

and

$$\mathrm{SNOW\_LAST\_SNOW}_g(b-1,t^*) = \mathrm{z}_g(b-1,t^*)$$

$$\mathrm{SNOW\_MELTING}_g(t^*) = \begin{cases} "TRUE" & if\ \mathrm{z}_g(b-1,t) = 1 \\ "FALSE" & if\ \mathrm{z}_g(b-1,t) = 0 \end{cases}$$

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For updating snow surface properties for the special case when a *GLACIER* HRU in band *b* is created from a glacier HRU in band *b*-1 (or other state variables in certain cases), state is updated as follows

$$\Omega_g(b,t^*) = \Omega_g(b-1,t)$$

SPEC- 18

4 CELL and HRU Metadata Specifications

4.1 Description

This specification for updating cell and HRU metadata state variables occurs when the conditions given in Table 4 are met.

Table 4. Case 1 constraints and conditions

Component	State *t*	State *t**
Number of HRUs in Cell	$H_c(t) > 0$	$H_c(t^*) \neq H_c(t)$

4.2 Specification Summary

This specification deals with the state variables summarized in Table 5 for existing VIC computational cells.

Table 5. State variable and specification summary for cell/HRU metadata

Target State Variable	Specification
Cell Metadata	
lat	SPEC- 1
lon	SPEC- 1
GLAC_MASS_BALANCE_INFO	SPEC- 1
GRID_CELL	SPEC- 1
NUM_BANDS	SPEC- 1
NUM_GLAC_MASS_BALANCE_INFO_ TERMS	SPEC- 1
SOIL_DZ_NODE [Nnodes]	SPEC- 1
SOIL_ZSUM_NODE [Nnodes]	SPEC- 1
VEG_TYPE_NUM	SPEC- 2
HRU Metadata	
HRU_BAND_INDEX	SPEC- 3
HRU_VEG_INDEX	SPEC- 4

5 CASE 1 HRU Specifications

5.1 Description

Case 1 is the most generic case and is expected to be the situation that occurs most often when state updating needs to take place. This case occurs when a *GLACIER* HRU in a given elevation band *b* changes size (i.e. shrinks or expands) and/or the band area changes size and a GLACIER HRU plus one or more additional HRUs are present in the band at state *t* and/or state *t**. This case specification is described by the constraints and conditions given in Table 6.

Table 6. Case 1 constraints and conditions

Component	State *t*	State *t**
GLACIER HRU Area	$A_g(t) \geq 0$	$A_g(t^*) \neq A_g(t)$
OPEN HRU Area	$A_{op}(t) \geq 0$	$A_{op}(t^*) \geq 0$
VEGETATED HRU Areas	$A_v(t) \geq 0$	$A_v(t^*) \geq 0$
BAND Area	$A_b(t) > 0$	$A_b(t^*) > 0$
GLACIER HRU Specific Depth	$d_g(t) > 0$	$d_g(t^*) \neq d_g(t)$
OPEN HRU Specific Depth	$d_{op}(t) \geq 0$	$d_{op}(t^*) \geq 0$
VEGETATED HRU Specific Depths	$d_v(t) \geq 0$	$d_v(t^*) \geq 0$

5.2 Specification Summary

This specification deals with the state variables for the *GLACIER*, *OPEN* and *VEGETATED* HRUs as summarized in Table 7 for existing HRUs and Table 8 for new *GLACIER* and *OPEN* HRUs.

Table 7. Case 1 state variable and specification summary for existing HRUs (i.e. present at state *t*)

Target State Variable	Source HRU	Source State Variable	Specification
		GLACIER, OPEN and VEGETATED HRUs - Common Specs	
ENERGY_T [Nnodes]	G / O / V	ENERGY_T [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE	G / O / V	ENERGY_TFOLIAGE	SPEC- 10
LAYER_MOIST [Nlayers]	G / O / V	LAYER_MOIST [Nlayers]	SPEC- 5
LAYER_ICE_CONTENT [Nlayers]	G / O / V	LAYER_ICE_CONTENT [Nlayers]	SPEC- 5
HRU_VEG_VAR_WDEW [dist]	G / O / V	HRU_VEG_VAR_WDEW [dist]	SPEC- 5
SNOW_SURF_WATER	G / O / V	SNOW_SURF_WATER	SPEC- 5
SNOW_PACK_WATER	G / O / V	SNOW_PACK_WATER	SPEC- 5
SNOW_DEPTH	G / O / V	SNOW_DEPTH	SPEC- 6
SNOW_DENSITY	G / O / V	SNOW_DENSITY	SPEC- 5
SNOW_COLD_CONTENT	G / O / V	SNOW_COLD_CONTENT	SPEC- 7
SNOW_SURF_TEMP	G / O / V	SNOW_SURF_TEMP	SPEC- 5
SNOW_PACK_TEMP	G / O / V	SNOW_PACK_TEMP	SPEC- 5
SNOW_ALBEDO	G / O / V	SNOW_ALBEDO	SPEC- 8

Target State Variable	Source HRU	Source State Variable	Specification
SNOW_LAST_SNOW	G / O / V	SNOW_LAST_SNOW	SPEC- 9
SNOW_MELTING	G / O / V	SNOW_MELTING	SPEC- 9
ENERGY_TCANOPY_FBCOUNT	G / O / V	ENERGY_TCANOPY_FBCOUNT	SPEC- 10
ENERGY_T_FBCOUNT [Nnodes]	G / O / V	ENERGY_T_FBCOUNT [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE_FBCOUNT	G / O / V	ENERGY_TFOLIAGE_FBCOUNT	SPEC- 10
ENERGY_TSURF_FBCOUNT	G / O / V	ENERGY_TSURF_FBCOUNT	SPEC- 10
GLAC_SURF_TEMP_FBCOUNT	G / O / V	GLAC_SURF_TEMP_FBCOUNT	SPEC- 10
SNOW_SURF_TEMP_FBCOUNT	G / O / V	SNOW_SURF_TEMP_FBCOUNT	SPEC- 10
GLACIER HRU - Unique Specs			
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G / O / V	SNOW_SWQ	SPEC- 5
	V	SNOW_CANOPY	SPEC- 5
GLAC_WATER_STORAGE	G	GLAC_WATER_STORAGE	SPEC- 13
GLAC_CUM_MASS_BALANCE	G	GLAC_CUM_MASS_BALANCE	SPEC- 10
GLAC_SURF_TEMP	G	GLAC_SURF_TEMP	SPEC- 10
OPEN HRU - Unique Specs			
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G / O / V	SNOW_SWQ	SPEC- 5
GLAC_WATER_STORAGE	n/a	GLAC_WATER_STORAGE	0
GLAC_CUM_MASS_BALANCE	n/a	GLAC_CUM_MASS_BALANCE	0
GLAC_SURF_TEMP	n/a	GLAC_SURF_TEMP	0
VEGETATED HRUs - Unique Specs			
SNOW_CANOPY	V	SNOW_CANOPY	SPEC- 5
SNOW_SWQ	G / O / V	SNOW_SWQ	SPEC- 5
GLAC_WATER_STORAGE	n/a	GLAC_WATER_STORAGE	0
GLAC_CUM_MASS_BALANCE	n/a	GLAC_CUM_MASS_BALANCE	0
GLAC_SURF_TEMP	n/a	GLAC_SURF_TEMP	0

Table 8. Case 1 state variable and specification summary for new *GLACIER* or *OPEN* HRUs (i.e. not present at state *t*)

Target State Variable	Source HRU	Source State Variable	Specification
	GLACIER and OPEN HRUs - Common Specs		
ENERGY_T [Nnodes]	n/a	ENERGY_T [Nnodes]	0
ENERGY_TFOLIAGE	n/a	ENERGY_TFOLIAGE	0
LAYER_MOIST [Nlayers]	G / O / V	LAYER_MOIST [Nlayers]	SPEC- 5
LAYER_ICE_CONTENT [Nlayers]	G / O / V	LAYER_ICE_CONTENT [Nlayers]	SPEC- 5
HRU_VEG_VAR_WDEW [dist]	G / O / V	HRU_VEG_VAR_WDEW [dist]	SPEC- 5
SNOW_SURF_WATER	G / O / V	SNOW_SURF_WATER	SPEC- 5
SNOW_PACK_WATER	G / O / V	SNOW_PACK_WATER	SPEC- 5
SNOW_DEPTH	G / O / V	SNOW_DEPTH	SPEC- 6
SNOW_DENSITY	G / O / V	SNOW_DENSITY	SPEC- 5
SNOW_COLD_CONTENT	G / O / V	SNOW_COLD_CONTENT	SPEC- 7
SNOW_SURF_TEMP	G / O / V	SNOW_SURF_TEMP	SPEC- 5
SNOW_PACK_TEMP	G / O / V	SNOW_PACK_TEMP	SPEC- 5
SNOW_ALBEDO	G / O / V	SNOW_ALBEDO	SPEC- 8
SNOW_LAST_SNOW	G / O / V	SNOW_LAST_SNOW	SPEC- 9
SNOW_MELTING	G / O / V	SNOW_MELTING	SPEC- 9
ENERGY_TCANOPY_FBCOUNT	n/a	ENERGY_TCANOPY_FBCOUNT	0
ENERGY_T_FBCOUNT [Nnodes]	n/a	ENERGY_T_FBCOUNT [Nnodes]	0
ENERGY_TFOLIAGE_FBCOUNT	n/a	ENERGY_TFOLIAGE_FBCOUNT	0
ENERGY_TSURF_FBCOUNT	n/a	ENERGY_TSURF_FBCOUNT	0
GLAC_SURF_TEMP_FBCOUNT	n/a	GLAC_SURF_TEMP_FBCOUNT	0
SNOW_SURF_TEMP_FBCOUNT	n/a	SNOW_SURF_TEMP_FBCOUNT	0
	GLACIER HRU - Unique Specs		
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	O/V	SNOW_SWQ	SPEC- 5
	V	SNOW_CANOPY	SPEC- 5
GLAC_WATER_STORAGE	G	GLAC_WATER_STORAGE	0
GLAC_CUM_MASS_BALANCE	G	GLAC_CUM_MASS_BALANCE	0
GLAC_SURF_TEMP	G	GLAC_SURF_TEMP	0
	OPEN HRU - Unique Specs		
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G / V	SNOW_SWQ	SPEC- 5
GLAC_WATER_STORAGE	n/a	GLAC_WATER_STORAGE	0
GLAC_CUM_MASS_BALANCE	n/a	GLAC_CUM_MASS_BALANCE	0
GLAC_SURF_TEMP	n/a	GLAC_SURF_TEMP	0

6 CASE 2 HRU Specifications

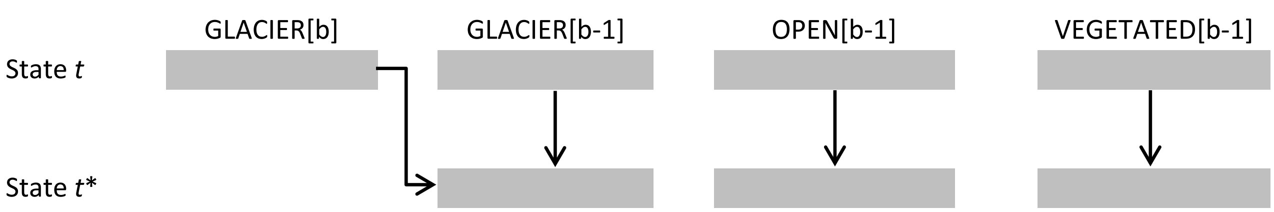
6.1 Description

This specification is for the exceptional case when a *GLACIER* HRU shrinks and disappears from band, *b*, and band *b* disappears. In this case we assume that a *GLACIER* HRU exists in next lower band, *b*-1 and the glacier in band *b* "shrinks into" the glacier in band *b*-1. This case specification is described by the constraints and conditions given in Table 9.

Table 9. Case 2 constraints and conditions

Component	State *t*	State *t**
	Band b	
GLACIER HRU Area	$A_g(b,t) > 0$	$A_g(b,t^*) = 0$
OPEN HRU Area	$A_{op}(b,t) = 0$	$A_{op}(b,t^*) = 0$
VEGETATED HRU Areas	$A_v(b,t) = 0$	$A_v(b,t^*) = 0$
BAND Area	$A_b(b,t) = A_g(b,t)$	$A_b(b,t^*) = 0$
GLACIER HRU Specific Depth	$d_g(b,t) > 0$	$d_g(b,t^*) = 0$
OPEN HRU Specific Depth	$d_{op}(b,t) = 0$	$d_{op}(b,t^*) = 0$
VEGETATED HRU Specific Depths	$d_v(b,t) = 0$	$d_v(b,t^*) = 0$
	Band b-1	
GLACIER HRU Area	$A_g(b\text{-}1,t) > 0$	$A_g(b\text{-}1,t^*) = A_g(b\text{-}1,t)$
OPEN HRU Area	$A_{op}(b\text{-}1,t) \geq 0$	$A_{op}(b\text{-}1,t^*) = A_{op}(b\text{-}1,t)$
VEGETATED HRU Areas	$A_v(b\text{-}1,t) \geq 0$	$A_v(b\text{-}1,t^*) = A_v(b\text{-}1,t)$
BAND Area	$A_b(b\text{-}1,t) > 0$	$A_b(b\text{-}1,t^*) = A_b(b\text{-}1,t)$
GLACIER HRU Specific Depth	$d_g(b\text{-}1,t) > 0$	$d_g(b\text{-}1,t^*) \neq d_g(b\text{-}1,t)$
OPEN HRU Specific Depth	$d_{op}(b\text{-}1,t) \geq 0$	$d_{op}(b\text{-}1,t^*) = d_{op}(b\text{-}1,t)$
VEGETATED HRU Specific Depths	$d_v(b\text{-}1,t) \geq 0$	$d_v(b\text{-}1,t^*) = d_v(b\text{-}1,t)$

The HRU state updates map between the different HRU classes as follows:



6.2 Specification Summary

This specification deals with the following state variables for the *GLACIER*, *OPEN* and *VEGETATED* HRUs as summarized in Table 10.

Table 10. Case 2 state variable and specification summary

Target State Variable	Source HRUs	Source State Variable	Specification
		GLACIER[*b*] *HRU - Unique Specs*	
ALL	n/a	ALL	All values zeroed / nulled
		GLACIER[*b*-1] *HRU - Unique Specs*	
ENERGY_T [Nnodes]	G[b-1]	ENERGY_T [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE	G[b-1]	ENERGY_TFOLIAGE	SPEC- 10
LAYER_MOIST [Nlayers]	G[b] / G[b-1]	LAYER_MOIST [Nlayers]	SPEC- 14
LAYER_ICE_CONTENT [Nlayers]	G[b] / G[b-1]	LAYER_ICE_CONTENT [Nlayers]	SPEC- 14
HRU_VEG_VAR_WDEW [dist]	G[b] / G[b-1]	HRU_VEG_VAR_WDEW [dist]	SPEC- 14
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G[b] / G[b-1]	SNOW_SWQ	SPEC- 14
SNOW_SURF_WATER	G[b] / G[b-1]	SNOW_SURF_WATER	SPEC- 14
SNOW_PACK_WATER	G[b] / G[b-1]	SNOW_PACK_WATER	SPEC- 14
GLAC_WATER_STORAGE	G[b] / G[b-1]	GLAC_WATER_STORAGE	SPEC- 14
GLAC_CUM_MASS_BALANCE	G[b-1]	GLAC_CUM_MASS_BALANCE	SPEC- 10
SNOW_DEPTH	G[b-1]	SNOW_DEPTH	SPEC- 6
SNOW_DENSITY	G[b] / G[b-1]	SNOW_DENSITY	SPEC- 14
GLAC_SURF_TEMP	G[b-1]	GLAC_SURF_TEMP	SPEC- 10
SNOW_COLD_CONTENT	G[b-1]	SNOW_COLD_CONTENT	SPEC- 7
SNOW_SURF_TEMP	G[b] / G[b-1]	SNOW_SURF_TEMP	SPEC- 14
SNOW_PACK_TEMP	G[b] / G[b-1]	SNOW_PACK_TEMP	SPEC- 14
SNOW_ALBEDO	G[b] / G[b-1]	SNOW_ALBEDO	SPEC- 16
SNOW_LAST_SNOW	G[b] / G[b-1]	SNOW_LAST_SNOW	SPEC- 17
SNOW_MELTING	G[b] / G[b-1]	SNOW_MELTING	SPEC- 17
ENERGY_TCANOPY_FBCOUNT	G[b-1]	ENERGY_TCANOPY_FBCOUNT	SPEC- 10
ENERGY_T_FBCOUNT [Nnodes]	G[b-1]	ENERGY_T_FBCOUNT [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE_FBCOUNT	G[b-1]	ENERGY_TFOLIAGE_FBCOUNT	SPEC- 10
ENERGY_TSURF_FBCOUNT	G[b-1]	ENERGY_TSURF_FBCOUNT	SPEC- 10
GLAC_SURF_TEMP_FBCOUNT	G[b-1]	GLAC_SURF_TEMP_FBCOUNT	SPEC- 10
SNOW_SURF_TEMP_FBCOUNT	G[b-1]	SNOW_SURF_TEMP_FBCOUNT	SPEC- 10
		OPEN[*b*-1] HRU - *Unique Specs*	
ALL	O[b-1]	ALL	SPEC- 10

Target State Variable	Source HRUs	Source State Variable	Specification
	VEGETATED[*b*-1] *HRUs - Unique Specs*		
ALL	V[b-1]	ALL	SPEC- 10

7 CASE 3 HRU Specifications

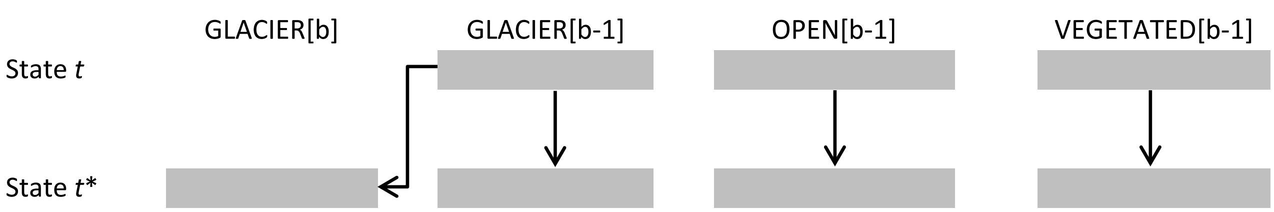
7.1 Description

This specification is for the exceptional case when a *GLACIER* HRU appears in new elevation band *b.* In this case we assume that *a GLACIER* HRU exists in next lower band, *b*-1 and the glacier in band *b* "expands from" the glacier in band *b-1*. This case specification is described by the constraints and conditions given in Table 11.

Table 11. Case 3 constraints and conditions

Component	State *t*	State *t**
	Band b	
GLACIER HRU Area	$A_g(b,t) = 0$	$A_g(b,t^*) > 0$
OPEN HRU Area	$A_{op}(b,t) = 0$	$A_{op}(b,t^*) = 0$
VEGETATED HRU Areas	$A_v(b,t) = 0$	$A_v(b,t^*) = 0$
BAND Area	$A_b(b,t) = 0$	$A_b(b,t^*) = A_g(b,t^*)$
GLACIER HRU Specific Depth	$d_g(b,t) = 0$	$d_g(b,t^*) > 0$
OPEN HRU Specific Depth	$d_{op}(b,t) = 0$	$d_{op}(b,t^*) = 0$
VEGETATED HRU Specific Depths	$d_v(b,t) = 0$	$d_v(b,t^*) = 0$
	Band b-1	
GLACIER HRU Area	$A_g(b\text{-}1,t) > 0$	$A_g(b\text{-}1,t^*) = A_g(b\text{-}1,t)$
OPEN HRU Area	$A_{op}(b\text{-}1,t) \geq 0$	$A_{op}(b\text{-}1,t^*) = A_{op}(b\text{-}1,t)$
VEGETATED HRU Areas	$A_v(b\text{-}1,t) \geq 0$	$A_v(b\text{-}1,t^*) = A_v(b\text{-}1,t)$
BAND Area	$A_b(b\text{-}1,t) > 0$	$A_b(b\text{-}1,t^*) = A_b(b\text{-}1,t)$
GLACIER HRU Specific Depth	$d_g(b\text{-}1,t) > 0$	$d_g(b\text{-}1,t^*) \neq d_g(b\text{-}1,t)$
OPEN HRU Specific Depth	$d_{op}(b\text{-}1,t) \geq 0$	$d_{op}(b\text{-}1,t^*) = d_{op}(b\text{-}1,t)$
VEGETATED HRU Specific Depths	$d_v(b\text{-}1,t) \geq 0$	$d_v(b\text{-}1,t^*) = d_v(b\text{-}1,t)$

The HRU state updates map between the different HRU classes as follows:



7.2 Specification Summary

This specification deals with the following state variables for the *GLACIER* HRUs as summarized in Table 12.

Table 12. Case 3 state variable and specification summary

Target State Variable	Source HRUs	Source State Variable	Specification
		GLACIER[b] HRU - Unique Specs	
ENERGY_T [Nnodes]	G[b-1]	ENERGY_T [Nnodes]	SPEC- 18
ENERGY_TFOLIAGE	G[b-1]	ENERGY_TFOLIAGE	SPEC- 18
LAYER_MOIST [Nlayers]	G[b] / G[b-1]	LAYER_MOIST [Nlayers]	SPEC- 15
LAYER_ICE_CONTENT [Nlayers]	G[b] / G[b-1]	LAYER_ICE_CONTENT [Nlayers]	SPEC- 15
HRU_VEG_VAR_WDEW [dist]	G[b] / G[b-1]	HRU_VEG_VAR_WDEW [dist]	SPEC- 15
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G[b] / G[b-1]	SNOW_SWQ	SPEC- 15
SNOW_SURF_WATER	G[b] / G[b-1]	SNOW_SURF_WATER	SPEC- 15
SNOW_PACK_WATER	G[b] / G[b-1]	SNOW_PACK_WATER	SPEC- 15
GLAC_WATER_STORAGE	G[b] / G[b-1]	GLAC_WATER_STORAGE	SPEC- 15
GLAC_CUM_MASS_BALANCE	G[b]	GLAC_CUM_MASS_BALANCE	0
SNOW_DEPTH	G[b]	SNOW_DEPTH	SPEC- 6
SNOW_DENSITY	G[b] / G[b-1]	SNOW_DENSITY	SPEC- 15
GLAC_SURF_TEMP	G[b]	GLAC_SURF_TEMP	0
SNOW_COLD_CONTENT	G[b]	SNOW_COLD_CONTENT	SPEC- 7
SNOW_SURF_TEMP	G[b] / G[b-1]	SNOW_SURF_TEMP	SPEC- 15
SNOW_PACK_TEMP	G[b] / G[b-1]	SNOW_PACK_TEMP	SPEC- 15
SNOW_ALBEDO	G[b-1]	SNOW_ALBEDO	SPEC- 18
SNOW_LAST_SNOW	G[b-1]	SNOW_LAST_SNOW	SPEC- 18
SNOW_MELTING	G[b-1]	SNOW_MELTING	SPEC- 18
ENERGY_TCANOPY_FBCOUNT	G[b]	ENERGY_TCANOPY_FBCOUNT	0
ENERGY_T_FBCOUNT [Nnodes]	G[b]	ENERGY_T_FBCOUNT [Nnodes]	0
ENERGY_TFOLIAGE_FBCOUNT	G[b]	ENERGY_TFOLIAGE_FBCOUNT	0
ENERGY_TSURF_FBCOUNT	G[b]	ENERGY_TSURF_FBCOUNT	0
GLAC_SURF_TEMP_FBCOUNT	G[b]	GLAC_SURF_TEMP_FBCOUNT	0
SNOW_SURF_TEMP_FBCOUNT	G[b]	SNOW_SURF_TEMP_FBCOUNT	0
		GLACIER[b-1] HRU - Unique Specs	
ENERGY_T [Nnodes]	G[b-1]	ENERGY_T [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE	G[b-1]	ENERGY_TFOLIAGE	SPEC- 10
LAYER_MOIST [Nlayers]	G[b] / G[b-1]	LAYER_MOIST [Nlayers]	SPEC- 15
LAYER_ICE_CONTENT [Nlayers]	G[b] / G[b-1]	LAYER_ICE_CONTENT [Nlayers]	SPEC- 15

Target State Variable	Source HRUs	Source State Variable	Specification
HRU_VEG_VAR_WDEW [dist]	G[b] / G[b-1]	HRU_VEG_VAR_WDEW [dist]	SPEC- 15
SNOW_CANOPY	n/a	SNOW_CANOPY	0
SNOW_SWQ	G[b] / G[b-1]	SNOW_SWQ	SPEC- 15
SNOW_SURF_WATER	G[b] / G[b-1]	SNOW_SURF_WATER	SPEC- 15
SNOW_PACK_WATER	G[b] / G[b-1]	SNOW_PACK_WATER	SPEC- 15
GLAC_WATER_STORAGE	G[b] / G[b-1]	GLAC_WATER_STORAGE	SPEC- 15
GLAC_CUM_MASS_BALANCE	G[b-1]	GLAC_CUM_MASS_BALANCE	SPEC- 10
SNOW_DEPTH	G[b-1]	SNOW_DEPTH	SPEC- 6
SNOW_DENSITY	G[b] / G[b-1]	SNOW_DENSITY	SPEC- 15
GLAC_SURF_TEMP	G[b-1]	GLAC_SURF_TEMP	SPEC- 10
SNOW_COLD_CONTENT	G[b-1]	SNOW_COLD_CONTENT	SPEC- 7
SNOW_SURF_TEMP	G[b] / G[b-1]	SNOW_SURF_TEMP	SPEC- 15
SNOW_PACK_TEMP	G[b] / G[b-1]	SNOW_PACK_TEMP	SPEC- 15
SNOW_ALBEDO	G[b-1]	SNOW_ALBEDO	SPEC- 10
SNOW_LAST_SNOW	G[b-1]	SNOW_LAST_SNOW	SPEC- 10
SNOW_MELTING	G[b-1]	SNOW_MELTING	SPEC- 10
ENERGY_TCANOPY_FBCOUNT	G[b-1]	ENERGY_TCANOPY_FBCOUNT	SPEC- 10
ENERGY_T_FBCOUNT [Nnodes]	G[b-1]	ENERGY_T_FBCOUNT [Nnodes]	SPEC- 10
ENERGY_TFOLIAGE_FBCOUNT	G[b-1]	ENERGY_TFOLIAGE_FBCOUNT	SPEC- 10
ENERGY_TSURF_FBCOUNT	G[b-1]	ENERGY_TSURF_FBCOUNT	SPEC- 10
GLAC_SURF_TEMP_FBCOUNT	G[b-1]	GLAC_SURF_TEMP_FBCOUNT	SPEC- 10
SNOW_SURF_TEMP_FBCOUNT	G[b-1]	SNOW_SURF_TEMP_FBCOUNT	SPEC- 10
OPEN[*b*-1] *HRU - Unique Specs*			
ALL	O[b-1]	ALL	SPEC- 10
VEGETATED[*b*-1] *HRUs - Unique Specs*			
ALL	V[b-1]	ALL	SPEC- 10