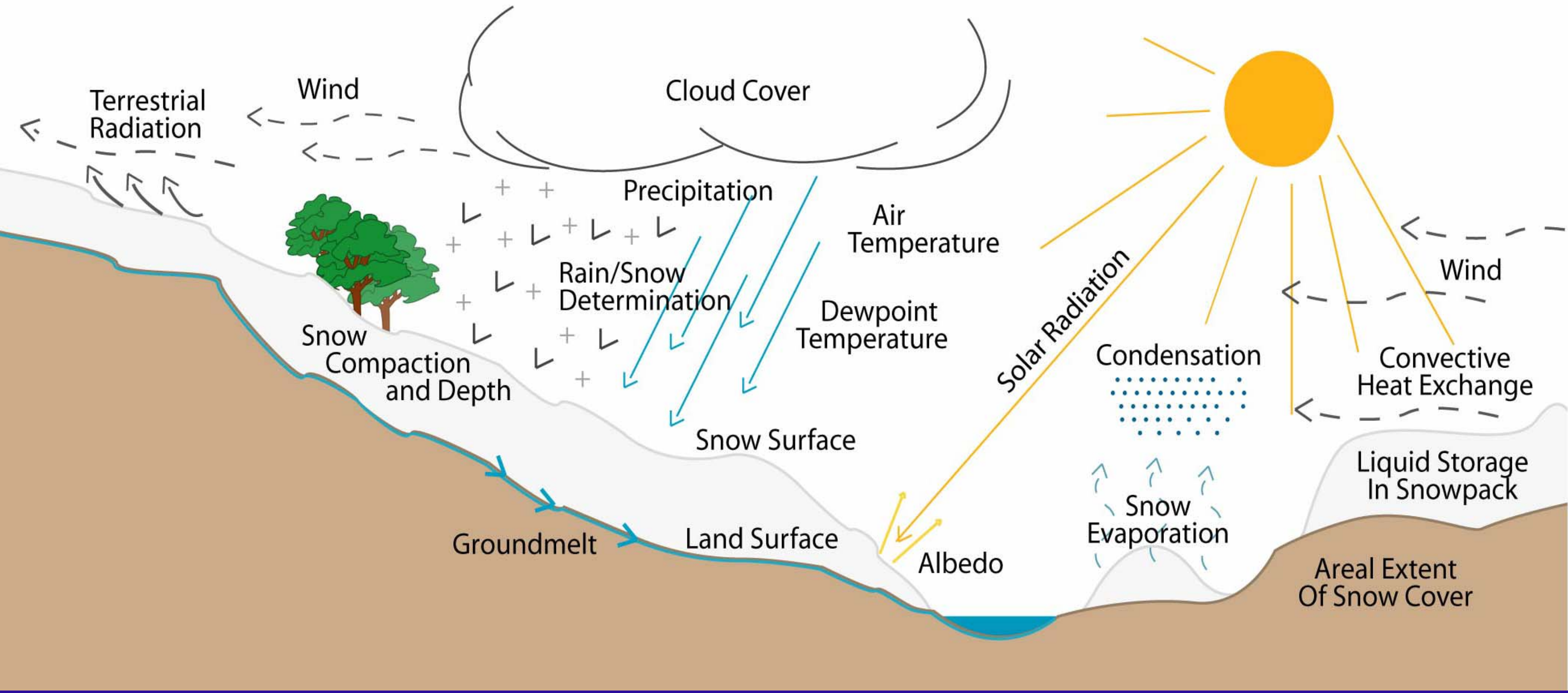
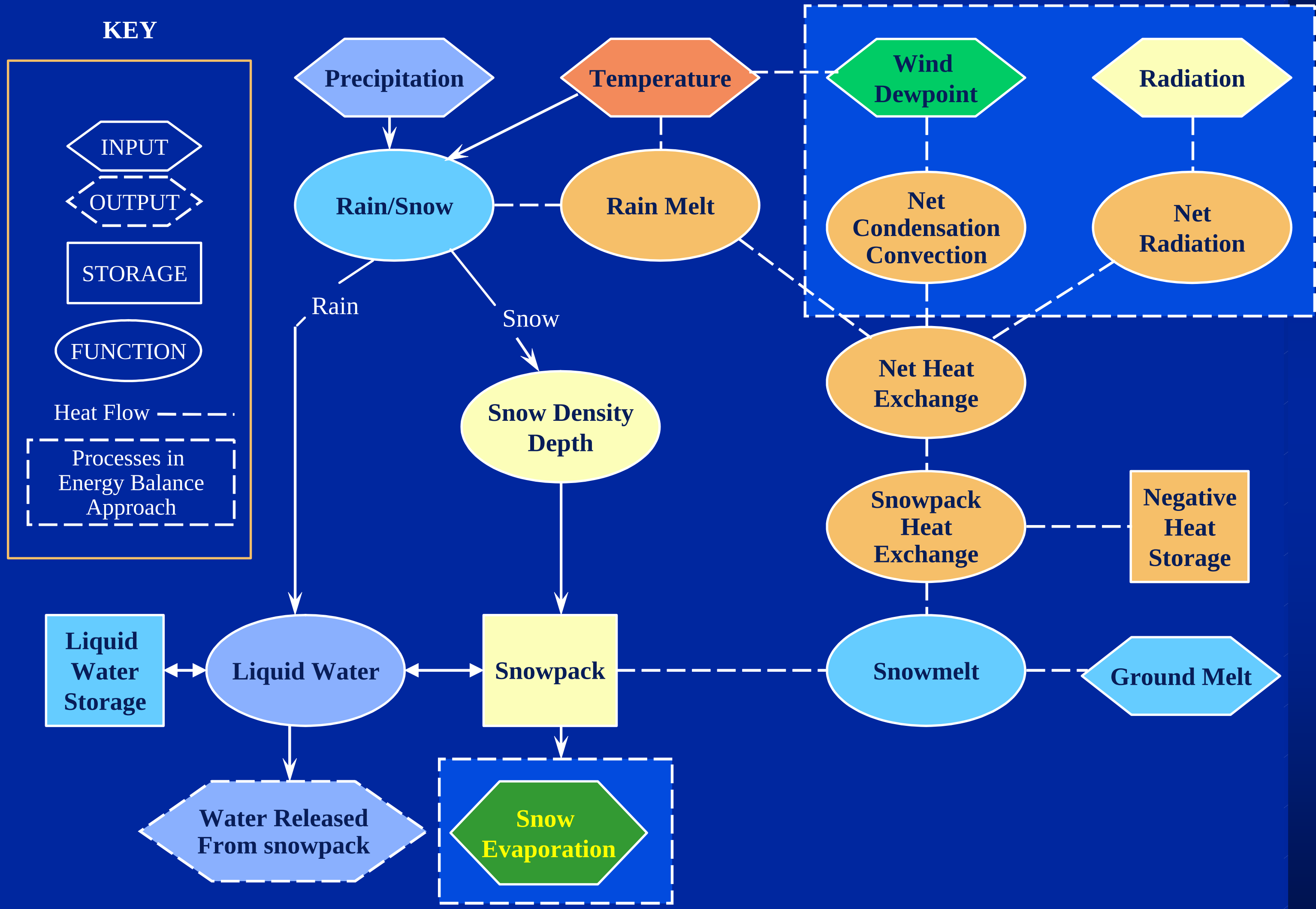
LECTURE #9

SNOW PROCESSES, PARAMETERS, AND CALIBRATION

SNOW ACCUMULATION AND MELT PROCESSES - THE SNOW CYCLE



FLOWCHART OF SNOWMELT PROCESSES IN HSPF



SNOW SIMULATION OPTIONS IN HSPF, VERSION No. 12

	ENERGY BALANCE APPROACH	TEMPERATURE INDEX/DEGREE-DAY METHOD
	SNOPFG = 0	SNOPFG = 1
Rain/Snow Determination	✔	✔
Snow Pack Depth & Density	✔	✔
Snow Pack Liquid Storage	✔	✔
Rain Melt	✔	✔
Radiation Melt	✔	
Condensation/ Convection	✔	
Snowpack Heat Exchange	✔	✔
Ground Melt	✔	✔
Snow Evaporation	✔	

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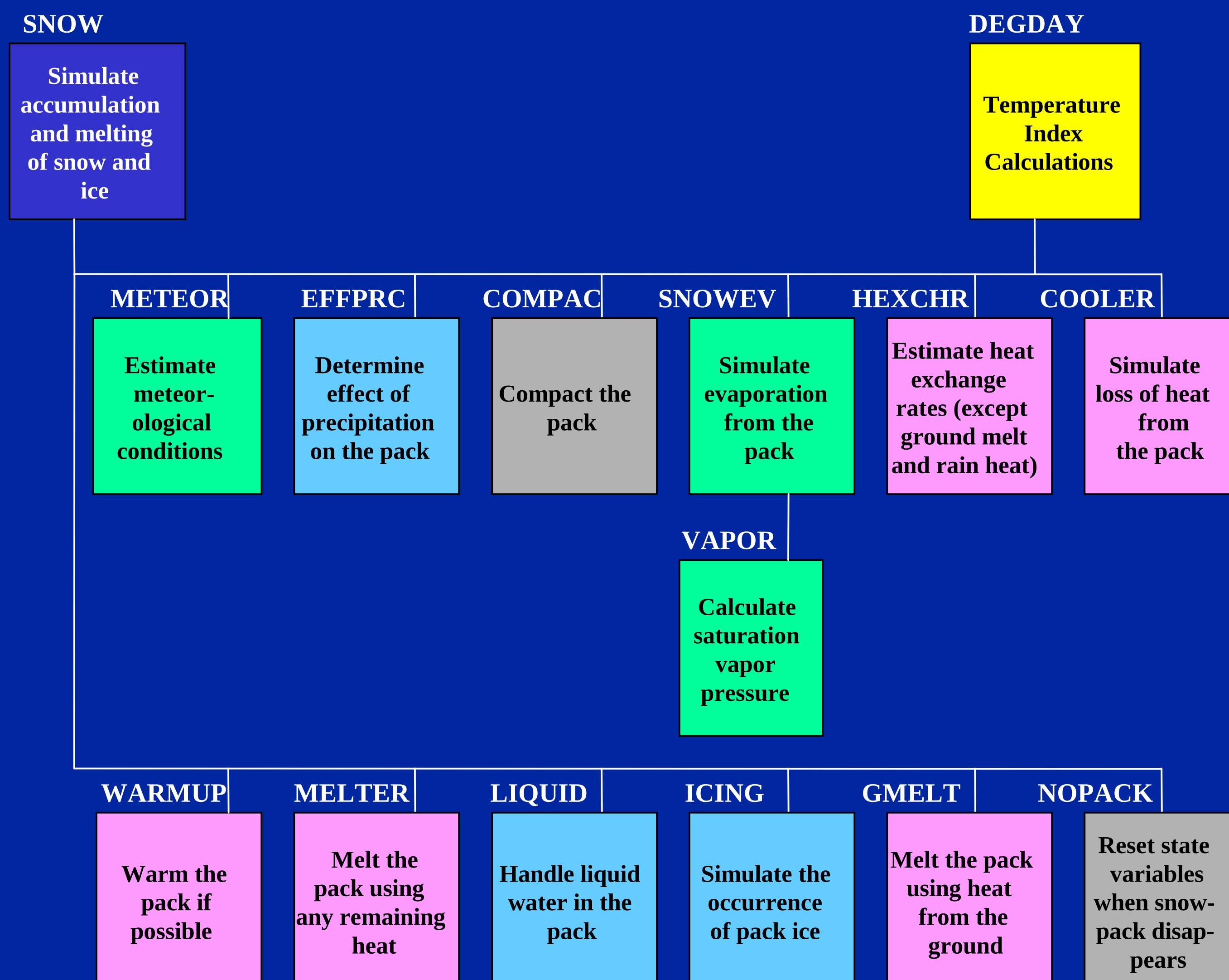
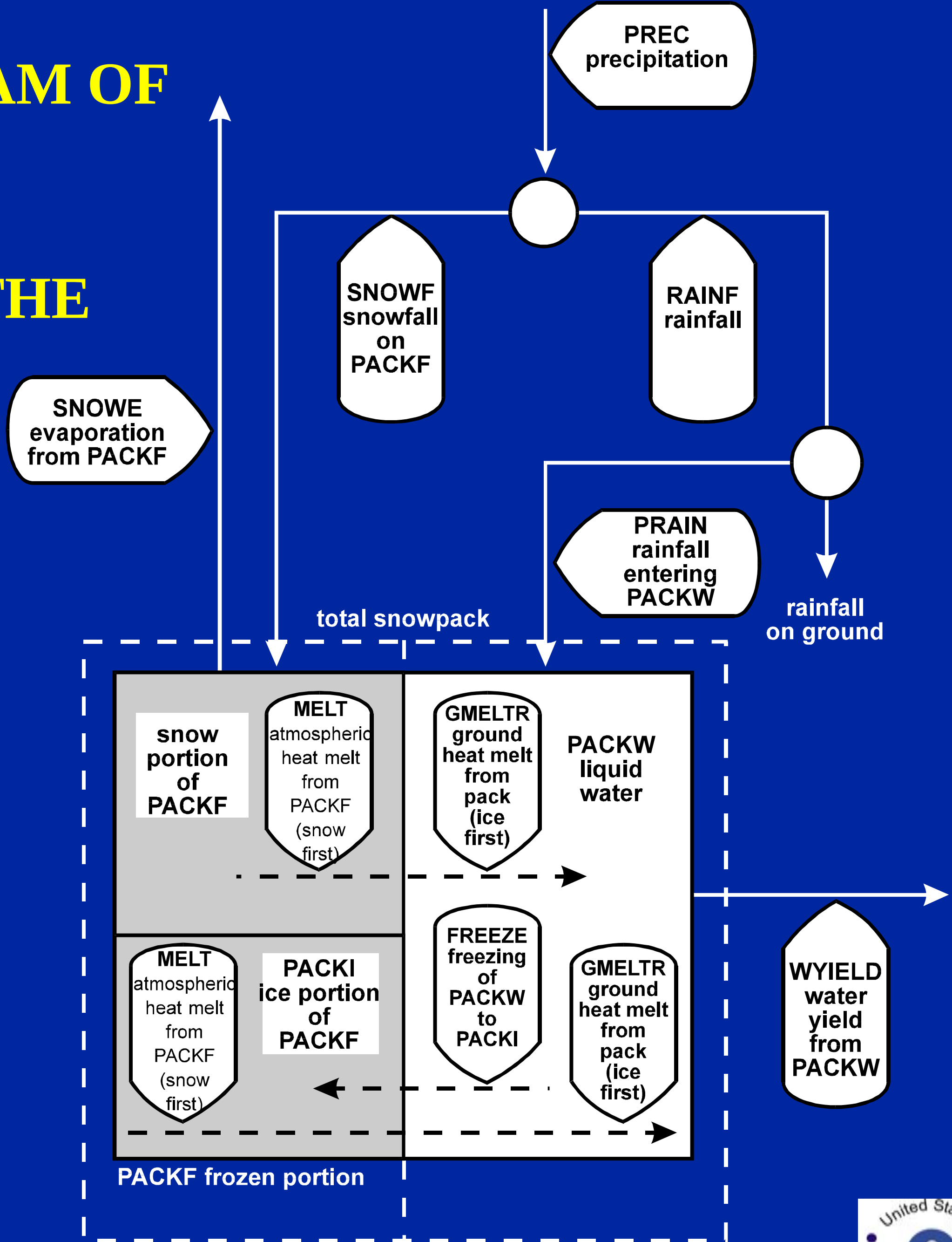
METEOROLOGIC DATA REQUIREMENTS FOR SNOW SIMULATION

Meteorologic Data	Energy Balance	Temperature Index
Precipitation	Required	Required
Air Temperature	Required	Required
Solar Radiation	Required	Not Used
Dewpoint	Required	Optional
Wind Velocity	Required	Not Used
Cloud Cover	Optional	Not Used

SNOW STRUCTURE CHART



FLOW DIAGRAM OF WATER MOVEMENT/ STORAGE IN THE PACK



SNOWMELT - TIME SERIES INPUTS, RAIN/SNOW DETERMINATION, DENSITY EQUATION

Time series inputs

- precipitation
- air temperature
- dewpoint temperature
- wind movement
- solar radiation

RAIN or SNOW

SNOTMP = **TSNOW** + (AIRTMP - DEWTMP) * (0.12 + 0.008 * AIRTMP)

max adjustment 1 degree F

SNOTMP = air temperature below which is snow
TSNOW = input parameter
AIRTMP = air temperature
DEWTMP = dew point temperature

Density of new snow

RDNSN = **RDCSN** + (AIRTMP / 100.0 $)^2$

RDCSN = input parameter (density at zero degrees F and lower)
AIRTMP = air temperature

SNOWPACK HEAT GAIN AND LOSS - RAIN HEAT, CONDENSATION, CONVECTION, RADIATION, AND GROUND HEAT

from rain

RNSHT = (AIRTMP - 32.0) * RAINF/144.0

AIRTMP = air temperature
RAINF = rain in inches

from condensation (Energy Balance Only)

CONDHT = 8.59 * (VAP - 6.108) * **CCFACT** * 0.00026 * WINMOV

VAP = vapor pressure at current air temperature
CCFACT = input parameter to adjust to local conditions
WINMOV = wind movement in miles/interval

from convection (Energy Balance Only)

CONVHT=(AIRTMP-32)*(1-0.3***MELEV**/10000)***CCFACT***0.00026 * WINMOV

AIRTMP = air temperature
MELEV = mean elevation above sea level in feet
CCFACT = input parameter to adjust to local conditions
WINMOV = wind movement in miles/interval

from radiation (Energy Balance Only)

RADHT = (SHORT - LONG)/203.2

SHORT = net solar radiation in langleys/interval
LONG = net longwave radiation in langleys/interval

from ground

function of maximum rate (**MGMELT**) when snow pack is 32 degrees F, but reduced for colder snow packs

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SHORT AND LONG WAVE RADIATION-CALCULATIONS

SHORT WAVE

SHORT = SOLRAD * (1.0 - ALBEDO) * (1.0 - **SHADE**)

SOLRAD = solar radiation in langleys/interval
ALBEDO = albedo (reflectivity of snow pack)
$= 0.85 - 0.007 * (DULL/24)^{0.5}$
DULL = index which is increased with age of snowpack and decreased with new snowfall
SHADE = input parameter for effect of shading by vegetation

LONG WAVE

air temperature above freezing
LONG = **SHADE** * 0.26 * RELTMP + (1 - **SHADE**) * (0.2 * RELTMP - 6.6)

air temperature below freezing
LONG = **SHADE** * 0.20 * RELTMP + (1 - **SHADE**) * (0.17 * RELTMP - 6.6)

SHADE = same as above
RELTMP = air temperature - 32.0 degrees F

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TEMPERATURE INDEX/DEGREE APPROACH: EQUATION, INPUTS, PARAMETERS

Standard Equation

Q= Kmelt * (Tair – Tbase)

where:
Q= runoff (in)

Kmelt= degree-day factor (in/day F)

Tair= daily mean temperature (F)

Tbase= reference temperature, often taken to be 32 F

HSPF Algorithm

MOSTHT= KMELT*(AIRTEMP-TBASE)*SNOCOV

where:
MOSTHT=net heat exchange (equivalent melt), exclusive of rain sensible heat and ground melt (in)

KMELT= degree-day factor, possibly interpolated from monthly values (in/day/F), PARAMETER

AIRTMP= current air temperature (F)

TBASE= reference temperature for snowmelt (F), PARAMETER

SNOCOV= fraction of land segment covered by snow

WATER LOSSES FROM SNOWPACK

<u>Evaporation</u>

SNOWEP = **SNOEVP** * 0.0002 * WINMOV * (SATVAP - VAP) *SNOCOV

SNOEVP = input parameter
WINMOV = wind movement in miles/interval
SATVAP = saturated vapor pressure at current air temperature
VAP = vapor pressure at current air temperature
SNOCOV = fraction of land segment covered by snowpack

<u>Snow cover</u>

100% until frozen content (snow and ice) of snowpack less than input parameter **COVIND**.

<u>Snowmelt losses to land surface</u>

When liquid water in snowpack exceed capacity

if snow density > 0.91
PACKWC = 0.0

if 0.6 < snow density < 0.91
PACKWC = **MWATER** * (3.0 - 3.33 * snow density)

if snow density < 0.6
PACKWC = **MWATER**

MWATER = input parameter for maximum liquid water content of snowpack (in/in)

FROZEN GROUND, INFILTRATION REDUCTION

Conditions: ***SNOW is simulated, CSNOFG=1***
Icing is simulated, ICEFG=1

***TWO OPTIONS* (PWAT-PARM1) -**

IFFCFG= 1:

INFFAC = max (1.0 – **FZG***PACKI, **FZGL**)

INFFAC = Fraction reduction in Infiltration/Percolation

FZG = Impact of icing on infilt/percolation, 1/in (WE)

PACKI = Ice in snowpack, in (WE)

FZGL = Minimum value of INFFAC

(WE = Water Equivalent)

IFFCFG= 2:

$$\text{INFFAC} = \begin{cases} 1.0\text{, when LZ soil temp} \geq \text{freezing} \\ \textbf{FZGL}\text{, when LZ soil temp} < \text{freezing} \end{cases}$$

(Section PSTEMP must be active)

SNOW PARAMETERS - SNOW-PARM1

SNOW-PARM 1

LAT - Latitude of the PLS, positive for the northern hemisphere, negative for the southern hemisphere (used when SNOPFG = 0)

MELEV - Mean elevation of the PLS (used when SNOPFG = 0)

SHADE - Fraction of the PLS shaded from solar radiation (used when SNOPFG = 0)

SNOWCF - Correction factor to account for poor catch efficiency of the gage

COVIND - Maximum pack (water equivalent) at which the entire PLS will be covered with snow

KMELT - Degree-day factor (used when SNOPFG = 1); need table (Mon-Melt- Fac) of monthly values if VKMFG = 1

TBASE - Reference temperatures for snowmelt (used when SNOPFG = 1)

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SNOW PARAMETERS - SNOW-PARM2

SNOW-PARM 2

RDSCN - Density of cold, new snow relative to water

TSNOW - Air temperature below which precipitation will be snow

SNOEVP - Parameter which adapts the snow evaporation (sublimation) equation to field conditions (used when SNOPFG = 0)

CCFACT - Parameter which adapts the snow condensation/convection melt equation to field conditions (used when SNOPFG = 0)

MWATER - Max water content of the snow pack, in depth water per depth water equivalent

MGMELT - Max rate of snowmelt by ground heat, in depth of water equivalent per day

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HSPF SNOW PARAMETERS AND TYPICAL/POSSIBLE VALUE RANGES

			RANGE OF VALUES					
NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			MIN	MAX	MIN	MAX		
SNOW - PARM1								
LAT	Latitude of watershed segment	degrees	30.0	50.0	-90.0	90.0	Location	Positive for northern hemisphere
MELEV	Mean elevation of watershed segment	feet	50.0	3000	0.0	7000	Topography	Used in convective heat flux equation
SHADE	Fraction shaded from solar radiation	none	0.1	0.5	0.0	0.8	Forest cover, topography	Controls radiation to and from the snowpack
SNOWCF	Snow gage catch correction factor	none	1.1	1.5	1.0	2.0	Gage type, characteristics, location	**Calibrate** to snow depth observations
COVIND	Snowfall required to fully cover surface	inches	1.0	3.0	0.1	10.0	Topography, climate	Higher for mountainous watersheds
SNOW - PARM2								
RDCSN	Density of new snow	none	0.10	0.20	0.05	0.30	Climate, air temperature	Adjust with field snow density data, if available
TSNOW	Temperature at which precip becomes snow	deg. F	31.0	33.0	30.0	40.0	Climate, topography	Precip. is snow when temperature below TSNOW
SNOEVP	Snow evaporation factor	none	0.10	0.15	0.0	0.5	Climate, topography	Only important in windy, low humidity conditions
CCFACT	Condensation/convection melt factor	none	1.0	2.0	0.5	8.0	Climate	**Calibrate** to change rate/timing of snowmelt
MWATER	Liquid water storage capacity in snowpack	in/in	0.01	0.05	0.005	0.2	Climate	Adjust to change timing of snowmelt
MGMELT	Ground heat daily melt rate	in/day	0.01	0.03	0.0	0.1	Climate, geology	Usually small under frozen ground conditions

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SNOW CALIBRATION

- Estimate initial parameters from watershed characteristics, previous applications, and past experiences
- Evaluate transference of meteorological data from observation sites to the model segment:
  - Precipitation and evaporation
  - Air temperature
  - Wind movement
  - Solar radiation
  - Dewpoint temperature
- Adjust **TSNOW** and/or air temperatures to mimic observed rain and/or snow events
- Adjust **SNOWCF** to calibrate snow depths and melt volumes
- Adjust **CCFACT/KMELT** to improve timing of snow melt events
- **MGMELT** can be adjusted if there is evidence of a constant melt component
- **MWATER** can be adjusted if melt water is being retained in the snow pack until major spring melt events

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LITERATURE RANGES FOR DEGREE-DAY FACTOR

Reference	Degree-day Factor (in/day•F)		Notes
Single constant values			
Zingg (1951)	.10		Lysimeter test at Weissfluhjoch
McCallister & Johnson (1962)	.06		Plains *
Pyskylwec (1968)	.040		Eastern Canada, forested
Quick & Pipes (1975)	.066		Western Canada mountains
Ranges for constant values			
Horton (1945)	.06	.09	Typical range *
USACE (1956)	.020	.039	Forested *
Linsley (1958)	.06	.15	Typical range *
Martinec (1960)	.077	.131	1.1 * relative snow density * (usually .30 - .55)
Granger & Male (1978)	.033	.153	6-hourly values for prairie *
Kuusisto (1978)	.055	.071	Depending on choices of internal snowpack processes being modeled
Ranges for seasonal values			
Linsley (1943)	.022 (Mar)	.153 (Jun)	San Joaquin River Basin
Clark (1955)	.020 (early)	.059 (late)	Southern Manitoba - Red River
USACE (1956)	.089 (Apr)	.100 (May)	Montana Rockies, partial forest
	.037 (Apr)	.072 (May)	Western Cascades, heavy forest
	.039 (Apr)	.042 (May)	Sierra Nevada, light forest
Weiss & Wilson (1958)	.040 (Apr)	.081 (Jun)	Forested *
	.081 (Apr)	.162 (Jun)	Open *
WMO (1964)	.044 (Apr)	.087 (Jun)	Moderate forest *
	.066 (Apr)	.131 (Jun)	Partial forest *
	.087 (Apr)	.153 (Jun)	Open *
Bruce & Clark (1966)	.080 (early)	.125 (late)	Southern Ontario
Bengsston (1980)	.066 (Mar)	.131 (Jun)	Northern Sweden
Gray & Prowse (1993)	.013 (mid)	.040 (late)	Boreal forest *
	.020 (mid)	.036 (late)	Taiga *