Gridded SNOW-17 Model

The Gridded SNOW-17 model, written in Java, uses the same algorithm as the lumped SNOW-17 model. The algorithm is applied at each pixel.

For example, there are 12210 single pixel basins in MARFC. Hence, the lumped SNOW-17 model is run up to 12210 times independently when Gridded SNOW-17 model is applied to MARFC. Every single pixel basin has its own SNOW-17 model parameters, states and input time series. Due to the huge amount of input/output data and the nature of grid, the binary file format NetCDF is used to store the data at the grid level.

Note: The model computation is skipped at the pixels when missing value(s) are found in their parameters, states, or input time series. In these cases a "Warning" message is logged.

The input files:
gridded SNOW-17 parameters in one NetCDF file,
gridded input time series(MAP and MAT) in one NetCDF file and
gridded input states in one NetCDF file.

The output files:
gridded ouput(for slim version: RAIM and SASC; for full version: 22 time series, see table below) in one NetCDF file and
gridded output states in one NetCDF file.

Use at MARFC

Initially the Gridded SNOW-17 model is only for MARFC to use and MARFC does not use some features in lumped the SNOW-17 model. The table below shows all the SNOW-17 parameters with un-used in MARFC in yellow.

1. MARFC only uses two input time series (MAP and MAT). It does not use the optional input time series (SASC or MAPE) so the parameters ("PERCENT_SNOWFALL_INPUT_OPTION", "RAIN_SNOW_ELEV_INPUT_OPTION", and "AREA_ELEV_CURVE") are not used.
2. MARFC does not use lapse rate so "TALMAX" and "TALMIN" are not used. "TAELEV" is still used and has the same value as "ELEV".
3. MARFC has the output time series (RAIM and SASC), not SWE or SNSG. All the output time series intervals are 6 HR. So these parameters ("SWE_OUTPUT_TS_INTERVAL", "SASC_OUTPUT_TS_INTERVAL", and "SNSG_OUTPUT_TS_INTERVAL") are not used.
4. MARFC does not use the parameters "WETOL" or "SCTOL" either.

1. Description of Algorithm

The lumped SNOW-17 algorithm is:

https://vlab.ncep.noaa.gov/documents/207461/1893022/22snow17.pdf

2. Model Parameters

SNOW-17 model parameters at individual pixels are stored in one NetCDF file, unlike the lumped SNOW-17 model, which stores its parameters in an xml file. Example: MARFC parameter NetCDF text format file

Notes:

1. Internally, double array ("AREA_DEPLETION_CURVE") is stored as a String, with space between numbers and exclamation mark as the end of String; A String in NetCDF is char array.
2. "MASK" is a layer indicating the grid is within the RFC boundary or not; when its value is 1.0, inside RFC boundary; when it is missing value, -999.0, outside the boundary.

Name	Type	Required [Yes/No]	Comment
PERCENT_SNOWFALL_INPUT_OPTION	String	No	○ Only two possibilities: "Yes" or "No". Default value is "No". ○ If set to "Yes", use the input percent-snow-fall time series, required to be present. ○ If absent or set to "No", don't use the input percent-snow-fall time series, regardless the time series is present or not. ○ Needs to be refactored to use boolean value.

Name	Type	Required [Yes/No]	Comment
RAIN_SNOW_ELEV_INPUT_OPTION	string	No	○ Only two possibilities: "Yes" or "No". Default value is "No". ○ If set to "Yes", use the input rain-snow-elevation time series (RSEL), which is required to be present then. The parameter AREA_ELEV_CURVE is required to be present too. ○ If absent or set to "No", don't use the input rain-snow-elevation time series, regardless the time series is present or not. ○ Needs to be refactored to use Boolean value.
ALAT	double	Yes	○ Latitude of the area. ○ If ≥ 54.0, use Alaskan seasonal melt-factor variation
PXADJ	double	Yes	○ Must be between 0.0 and 1.0. ○ Unitless
ELEV	double	Yes	○ Elevation of the area (Units of M).
TAELEV	double	No	○ Elevation associated with the air temperature time series (M). ○ Default value is same as ELEV. ○ When TAELEV ≠ ELEV, air temperature will be adjusted by using lapse rate, which is related to the local time zone.
TALMAX or TALMIN	double	No; Required when TAELEV ≠ ELEV	○ Lapse rate at time of maximum/minimum temperature, ○ Units of DEGC/100M.

Name	Type	Required [Yes/No]	Comment
AREA_ELEV_CURVE(METR) Or AREA_ELEV_CURVE(ENGL)	table	No; Required when RAIN_SNOW_ELEV_INPUT_OPTION is "Yes"	o A series pairs of numbers (double values). o 1st number in the pair is elevation of the area (units of M or FT, corresponding to METR or ENGL). o 2nd number of a pair is the decimal fraction of area below the elevation. o 1st number of 1st pair is minimum elevation; the decimal fraction is fixed to be 0.0. o 1st number of last pair is maximum elevation; the decimal fraction is fixed to be 1.0.
AREA_DEPLETION_CURVE	table	Yes	o Areal snow cover at WE/Ai ratios of 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0; Total 11 numbers. o Decimal fraction.
SWE_OUTPUT_TS_INTERVAL Or SASC_OUTPUT_TS_INTERVAL Or SNSG_OUTPUT_TS_INTERVAL	integer	No	o The output time series interval. Default value is input air temperature time series interval. o If present, must be an even multiple of air temperature time series interval.
SCF	double	Yes	o Snowfall correction factor.
MFMAX Or MFMIN	double	Yes	o Maximum/minimum non-rain melt factor. o Units of MM/DEGC/6HR.
UADJ	double	Yes	o Average value of the wind function during rain-on-snow events. o Units of MM/MB.
SI	double	Yes	o Areal water-equivalent above which there is always 100%.

Name	Type	Required [Yes/No]	Comment
MV	integer	Yes	○ Flag to indicate seasonal melt-factor variation. Only 2 choices: 0 or 1. ○ 0: use normal SMFV, based on latitude ○ 1: use specified SMFV ○ Needs to be refactored to use string value: “normal” or ”specified”.
SMFV	table	No; Required when MV is 1	○ User specified seasonal melt-factor variation; ○ 12 values: the decimal fraction of where the melt-factor is between MFMIN and MFMAX on the 16th of each month.
NMF	double	Yes	○ Maximum negative melt factor. ○ Units of MM/DEGC/6HR.
TIPM	double	Yes	○ Antecedent snow temperature index parameter. ○ Range is 0.1 to 1.0.
MBASE	double	Yes	○ Base temperature for non-rain melt factor. ○ Units of DEGC.
PXTEMP	double	Yes	○ Temperature that separates rain from snow. ○ Units of DEGC.
PLWHC	double	Yes	○ Maximum amount of liquid water held against gravity drainage-decimal fraction.
DAYGM	double	Yes	○ Daily melt at the snow-soil interface. ○ Units of MM.
WETOL[0., 1.0] Or SCTOL[0., 1.0]	double	Yes	○ Tolerance used when updating water-equivalent or areal extent of snow cover with observed data. ○ Range is 0.0 to 1.0. ○ Updates when |Simulated-Observed| > tolerance * Observed

Name	Type	Required [Yes/No]	Comment
MASK	double	Yes	○ If the value is 1.0, this grid is within the RFC boundary; if the value is missing value, -999.0, outside of RFC.

3. Model States

Model states at individual pixels are stored in one NetCDF file, unlike the lumped SNOW-17 model which stores its states in a property file format. Example: MARFC states NetCDF file text format file.

Notes:

1. On the time dimension, there is one value, the minutes since the Epoch time (1970-01-01 00:00:00). This is the time the state corresponds to.
2. Internally, double array ("EXLAG_ARRAY") is stored as a String, with space between numbers and exclamation mark as the end of String; A String in NetCDF is char array.
3. "MASK" is a layer indicating the grid is within the RFC boundary or not: when its value is 1.0, inside RFC boundary; when it is missing value, -999.0, outside the boundary.

The model computation is skipped at the pixels when missing value(s) are found in their states. Two states in lumped SNOW-17 model, "UNIT" and "MAP_INTERVAL", are not used in the gridded model, since the states are in METRIC units and the carryover is not applied.

Property Name	Description
ACCMAX	Maximum water-equivalent that has occurred since snow began to accumulate (units of MM).
AEADJ	Areal extent of snow cover adjustment; units of MM.
EXLAG_ARRAY	Lagged excess water (units of MM); number of values is 5/timeint +2 where timeint is the precipitation time series interval (MAP_INTERVAL).
LIQW	Initial amount of liquid-water held against gravity drainage (units of MM).
NEGHS	Initial heat deficit (units of MM).
SB	Areal water equivalent just prior to the new snowfall (units of MM).
SBAESC	Areal extent of snow cover just prior to the new snowfall (units of PCT).
SBWS	Water equivalent above which 100 percent areal snow cover temporarily exists (units of MM).
SNDPT	Snow depth; units of CM, however, the snow depth output time series is in unit of MM, because FEWS expects it in MM.

Property Name	Description
SNTMP	Average snow cover temperature (units of DEGC).
STORGE	Excess liquid water in storage (units of MM).
TAPREV	Previous air temperature (units of DEGC).
TINDEX	Initial antecedent snow temperature index (units of DEGC).
WE	Initial water equivalent of solid (ice) portion of the snow cover (units of MM).
MASK	If the value is 1.0, this grid is within the RFC boundary; if the value is missing value, -999.0, outside of RFC.

4. Model Time Series

Model time series at individual pixels are stored in one NetCDF file, unlike the lumped SNOW-17 model which stores its timeseries in an xml file. Example: input time series NetCDF text format file.

Gridded SNOW-17 has fixed two input time series, without any optional input time series. The precip time series can be any length unit (CM, M etc). The temperature time series can be DEGC or DEGF. The program will internally convert the input time series to expected units. Both time series do not allow missing values. If a missing value is found within the time series, the model computation at this pixel will be skipped.
The "Units" columns in the tables below indicate the input and output time series for the internal Model units.

INPUT TIME SERIES (not-used in Gridded SNOW-17 colored in yellow):

Time Series Type	Units	Time Series Interval (HR)	Missing Values Allowed	Required [Yes or No]
MAP	MM	Any	No	Yes
MAT	DEGC	Same as MAP	No	Yes
PTPS	PCTD	Any	Yes	No
RSEL	M	Any	No	No
SNWE	MM	Any	Yes	No
AESC	PCTD	Any	Yes	No
SNOG	CM	Any	No	No

OUTPUT TIME SERIES:

Time Series Type	Units	Time Series Interval (HR)	Missing Values Allowed	Description
Primary Time Series*:				
RAIM	MM	Same as input	No	Rain plus melt.
SASC	PCTD	Same as input	No	Snow covered area percentage.
Secondary Time Series*:				
SWE	MM	Same as input	No	Snow water equivalent.
SNSG	MM	Same as input	No	Snow depth.
PRAIN	MM	Same as input	No	Precip as rain.
PSFALL	MM	Same as input	No	Precip as snow fall.
PROBG	MM	Same as input	No	Rain on bare ground within MAT interval.
PSNWRO	MM	Same as input	No	Snow pack outflow within MAT interval (note: the sum of PROBG and PSNWRO equals to RAIM).
ACCMAX	MM	Same as input	Yes	Maximum water-equivalent that has occurred since snow began to accumulate (units of MM).
AEADJ	MM	Same as input	Yes	Areal extent of snow cover adjustment; units of MM.
LIQW	MM	Same as input	Yes	Initial amount of liquid-water held against gravity drainage (units of MM).
NEGHS	MM	Same as input	Yes	Initial heat deficit (units of MM).
PQNET	MM	Same as input	Yes	State.
SB	MM	Same as input	Yes	Areal water equivalent just prior to the new snowfall (units of MM).
SBAESC	PCTD	Same as input	Yes	Areal extent of snow cover just prior to the new snowfall (units of PCT).
SBWS	MM	Same as input	Yes	Water equivalent above which 100 percent areal snow cover temporarily exists (units of MM).

SNDPT	MM	Same as input	No	Snow depth; in unit of MM.
SNTMP	DEGC	Same as input	Yes	Average snow cover temperature (units of DEGC).
STORGE	MM	Same as input	Yes	Excess liquid water in storage (units of MM).
TAPREV	DEGC	Same as input	Yes	Previous air temperature (units of DEGC).
TINDEX	DEGC	Same as input	Yes	Initial antecedent snow temperature index (units of DEGC).
WE	MM	Same as input	Yes	Initial water equivalent of solid (ice) portion of the snow cover (units of MM).

*There are two versions for the model to run – "slim version" or "full version", determined by the technique "SACSNOW" (default value is false). When SACSNOW is true, the model runs the "full version" and both the primary and secondary output time series, 22 in total, are generated. When the value is absent or false, the "slim version" with only primary output time series is generated. This technique is used by both SNOW-17 and SAC-SMA model. The slim version is much faster than the full version, because it only produces the three primary output time series (RAIM, SASC, and SWE). The rest are the secondary output time series and only generated when running in "full version".

5. Modifications (Mods)

Gridded SNOW-17 does not accept any Mods.

6. Notes about configuring Model in FEWS workflow

Run Time Options (known as TECHNIQUES in NWSRFS).
The lumped SNOW-17 allows six run-time options. The gridded SNOW-17 only has three run-time options. When specified they should appear in the run_info.xml file.

Example run info (The ones in yellow are automatically set to "FALSE"):

```
<properties>
    <int key="printDebugInfo" value="0"/>
    <string key="rootDir" value="Modules/gridded_snow17/marfc/"/>
   <string key="model"
   value="ohd.hseb.ohdgriddedmodels.snow17.GriddedSnow17ModellDriver"/>
   <string key="PRINTSNW" value="TRUE"/>
   <string key="SACSNOW" value="TRUE"/>
   <string key="SNOW" value="TRUE"/>
   <string key="precipIsAllRain" value="TRUE"/>
```

<string key="UPSC" value="FALSE"/>
<string key="UPSNW" value="FALSE"/>
</properties>

1. SACSNOW – This technique is used by both the SNOW-17 and the SAC-SMA model. It determines running the model in "slim version" or "full version". See the notes about the output time series above for more details. The default value is "FALSE" (slim version).
2. SNOW – controls whether the snowmelt algorithm should be used. **Note:** when setting to "FALSE", the model computation is skipped and only the primary output time series is generated. The output time series, RAIM, has the same value as the input MAP time series. The other output time series, SASC, as well as all output states, have the value of "0.0". The default value is "TRUE" (doing the model computation).
3. precipIsAllRain – default value is "FALSE". When the value is "TRUE", the precipitation is forced to be 100% rain, regardless of the air temperature. When the property is absent or "FALSE", the precipitation being rain or snow is determined by the air temperature. (Note: this feature is similar to RAINSNOW MOD available in lumped SNOW-17 model. However, RAINSNOW MOD is an input time series which dictates at each time step the precipitation being rain or snow. This property, if present and with value of "TRUE", forces the precipitation at all the time steps be rain.)

Note: for gridded model, "printDebugInfo" value can only be "0". If it is higher value, it will be re-set to 0 to avoid huge number of logging messages printed.

Module Parameter Files

Gridded SNOW17 module parameter files,……. ModuleDataSets

SOMETHING ABOUT STATE FILE

Examples:

Module Configuration File: ModuleConfigFiles\Gridded_SNOW17_Forecast.xml

7. FEWS Adapter Used

The SNOW-17 model uses the OHDFewsadapter to communicate. Information about this adapter can be found at OHDFewsadapter.