SAC-SMA with Heat Transfer (SAC-HT) Model

1. Description of the Algorithm

https://vlab.noaa.gov/documents/207461/1893022/NOAA_Technical_Report_NWS_53.pdf

1. Overview of SAC-HT
2. SAC-HT run options
3. Parameter STXT
4. Parameter TBOT
5. Description of output variable SFGD
6. Description of output variable FRAMT
7. Interpolation of soil moisture and temperature to user defined depths
8. Description of top 'residue' soil layer

2. Model Parameters

SAC-HT uses an xml representation of model parameters where each parameter is captured within a separate xml tag. The tags are closely related to the definition of SAC-SMA in CHPS. There are two new required parameters not included in the original SAC-SMA (TBOT and STXT) and two new optional parameters "MODEL_RUN_TYPE and "USER_DEFINED_SOIL_LAYERS".

The table below shows the available parameter tags. For the parameters with type of string, the values are case-insensitive. For example, "YES" and "Yes" are treated by the program as the same value, but "Y" will be treated as error. The sequence of parameters in the table below or in the xml file is not important.

Name	Type	Require Yes/No	Comment
MAPE_INPUT	string	No	○ It can be only “Yes” or “No”; ○ If absent or present with value of “No”, input MAPE time series is not used, regardless if it is present or not. Then etDemand 12 values represent ET-demand 16th of each month, daily values are computed by linear interpolation. ○ If present with value of “Yes”, use input MAPE time series, which is required to be present in input xml file. etDemand 12 values are PE-adjustment factor for the input MAPE time series.

ETTJAN ETTFEB ETTMAR ETTAPR ETTMAY ETTJUN ETTJUL ETTAUG ETTSEP ETTOCT ETTNOV ETTDEC	double	Yes	○ etDemand 12 values ○ If MAPE_INPUT is "Yes", they are PE-adjustment factor for the input MAPE time series; ○ If not using MAPE input time series, they are ET-demand 16th of each month. Daily values are computed by linear interpolation.
PXADJ	double	Yes	○ Precipitation adjustment factor
PEADJ	double	Yes	○ ET-demand adjustment factor
UZTWM	double	Yes	○ Upper zone tension water capacity; ○ Units of MM
UZFWM	double	Yes	○ Upper zone free water capacity; ○ Units of MM
LZTWM	double	Yes	○ Lower zone tension water capacity; ○ Units of MM
LZFSM	double	Yes	○ Lower zone supplemental free water capacity; ○ Units of MM
LZFPM	double	Yes	○ Lower zone primary free water capacity; ○ Units of MM; ○ LZFSM and LZFPM are input as total values and not just as the visible (channel component) portion.
UZK	double	Yes	○ Fractional daily upper zone free water withdrawal rate
LZSK	double	Yes	○ Fractional daily supplemental withdrawal rate
LZPK	double	Yes	○ Fractional daily primary withdrawal rate
PCTIM	double	Yes	○ Minimum impervious area; ○ Unit of percent/100
ADIMP	double	Yes	○ Additional impervious area; ○ Units of percent/100
RIVA	double	Yes	○ Riparian vegetation area; ○ Units of percent/100
EFC	double	Yes	○ Effective forest cover; ○ Units of percent/100
ZPERC	double	Yes	○ Maximum percolation rate

REXP	double	Yes	○ Exponent for the percolation equation
PFREE	double	Yes	○ Percent/100 of percolated water which always goes directly to lower zone free water storages
RSERV	double	Yes	○ Percent/100 of lower zone free water which cannot be transferred to lower zone tension water
SIDE	double	Yes	○ Ratio of non-channel baseflow (deep recharge) to channel (visible) baseflow
TBOT	double	Yes	○ Temperature (Celsius) at bottom layer
STXT	integer	Yes	○ Soil texture number
MODEL_RUN_TYPE	string	No	○
USER_DEFINED_SOIL_LAYER_DEPTH	double array	No	○

3. Model States

Like all the other models, SAC-HT model states are also defined in a property file format. An example is shown below. The sequence of property names in the state file or in the table is not important. The model state property names are:

Property Name	Description
UPPER_ZONE_TENSION_WATER_CONTENTS_UZTWC	Upper zone tension water contents; units of MM
UPPER_ZONE_FREE_WATER_CONTENTS_UZFWC	Upper zone free water contents; units of MM
LOWER_ZONE_TENSION_WATER_CONTENTS_LZTWC	Lower zone tension water contents; units of MM
LOWER_ZONE_FREE_SECONDARY_CONTENTS_LZFSC	Lower zone free supplemental contents; units of MM
LOWER_ZONE_FREE_PRIMARY_CONTENTS_LZFPC	Lower zone free primary contents; units of MM

Property Name	Description
ADDITIONAL_IMPERVIOUS_AREA_TENSION_WATER_CONTENTS_ADIMC	Tension water contents of the ADIMP area; units of MM. If not known then use UZTWC+LZTWC
FROST_AMOUNT	Total amount of frozen moisture in soil column; units of mm. If starting with no frozen ground the value is zero.
INIT_AIR_TEMPERATURE	
INIT_SNOW_WATER_EQUIVALENT	
INIT_SNOW_DEPTH	
NUMBER_SOIL_LAYER	0 for "cold" start 1-8 for "warm" start
Additional States for a "Warm" start	
DEPTH_TO_BOTTOM_OF_LAYER (1-N)	
SOILLAYER_MOISTURE_CONTENT_SMC (1-N)	
SOIL_LAYER_TEMPERATURE_TSOIL (1-N)	
SOILLAYER_UNFROZEN_WATER_SH2O (1-N)	
LOWER_ZONE_FREE_PRIMARY_UNFROZEN_WATER	
LOWER_ZONE_FREE_SECONDARY_UNFROZEN_WATER	
LOWER_ZONE_FREE_PRIMARY_UNFROZEN_WATER	
LOWER_ZONE_TENSION_UNFROZEN_WATER	
UPPER_ZONE_FREE_UNFROZEN_WATER	
UPPER_ZONE_TENSION_UNFROZEN_WATER	
UNIT	The state is always in METRIC units.

Sample "Cold" state file

UPPER_ZONE_TENSION_WATER_CONTENTS_UZTWC=58.7
UPPER_ZONE_FREE_WATER_CONTENTS_UZFWC=0.000
LOWER_ZONE_TENSION_WATER_CONTENTS_LZTWC=47.0
LOWER_ZONE_FREE_SECONDARY_WATER_CONTENTS_LZFSC=0.000
LOWER_ZONE_FREE_PRIMARY_WATER_CONTENTS_LZFPC=17.0
ADDITIONAL_IMPERVIOUS_AREA_TENSION_WATER_CONTENTS_ADIMC=113.0
INIT_AIR_TEMPERATURE=3.000
INIT_SNOW_WATER_EQUIVALENT=0.000
INIT_SNOW_DEPTH=0.000

FROST_AMOUNT=0.000000
NUMBER_SOIL_LAYER=0

Sample “Warm” state file

UNIT=METRIC
UPPER_ZONE_TENSION_WATER_CONTENTS_UZTWC=57.211407
UPPER_ZONE_FREE_WATER_CONTENTS_UZFWC=0.006564
LOWER_ZONE_TENSION_WATER_CONTENTS_LZTWC=80.9967728
LOWER_ZONE_FREE_SECONDARY_WATER_CONTENTS_LZFSC=1.3396038
LOWER_ZONE_FREE_PRIMARY_WATER_CONTENTS_LZFPC=10.9777098
ADDITIONAL_IMPERVIOUS_AREA_TENSION_WATER_CONTENTS_ADIMC=138.25451
7
FROST_AMOUNT=0.000000
UPPER_ZONE_TENSION_UNFROZEN_WATER=57.211407
UPPER_ZONE_FREE_UNFROZEN_WATER=0.006564
LOWER_ZONE_TENSION_UNFROZEN_WATER=80.9967728
LOWER_ZONE_FREE_SECONDARY_UNFROZEN_WATER=1.3396038
LOWER_ZONE_FREE_PRIMARY_UNFROZEN_WATER=10.9777098
INIT_AIR_TEMPERATURE=5.5440001
INIT_SNOW_WATER_EQUIVALENT=0.000000
INIT_SNOW_DEPTH=0.000000
NUMBER_SOIL_LAYER=4
DEPTH_TO_BOTTOM_OF_LAYER0=-0.030000
DEPTH_TO_BOTTOM_OF_LAYER1=-0.138146
DEPTH_TO_BOTTOM_OF_LAYER2=-0.403595
DEPTH_TO_BOTTOM_OF_LAYER3=-0.995121
SOILLAYER_TEMPERATURE_TSOIL0=5.665375
SOILLAYER_TEMPERATURE_TSOIL1=6.239410
SOILLAYER_TEMPERATURE_TSOIL2=4.7800598
SOILLAYER_TEMPERATURE_TSOIL3=1.1933594
SOILLAYER_MOISTURE_CONTENT_SMC0=0.087000
SOILLAYER_MOISTURE_CONTENT_SMC1=0.2997398
SOILLAYER_MOISTURE_CONTENT_SMC2=0.2994466
SOILLAYER_MOISTURE_CONTENT_SMC3=0.304128
SOILLAYER_UNFROZEN_WATER_SH2O0=0.087000
SOILLAYER_UNFROZEN_WATER_SH2O1=0.2997398
SOILLAYER_UNFROZEN_WATER_SH2O2=0.2994466
SOILLAYER_UNFROZEN_WATER_SH2O3=0.304128

4. Model Time Series

The number of input and output time series required or available for SAC-HT depends on the type of run (i.e. the value for MODEL_RUN_TYPE) and the number of layers used to model the soil.

INPUT TIME SERIES:

Time Series Type	Expected Units	Time Series Interval(HR)	Missing Values Allowed	Required [Yes or No]
MODEL_RUN_TYPE=SOIL_AND_HEAT_TRANSFER				
RAIM	MM	Any	No	Yes
SASC	PCTD	Any 2/	No	Yes
SNSG	MM	Any 2/	No	Yes
SWE	MM	Any 2/	No	Yes
MAT	DEGC	Any 2/	No	Yes
MAPE	MM	Fixed to 24	No	No
MODEL_RUN_TYPE=ONLY_SOIL				
MAT	DEGC	Any 2/	No	YES
SWE	MM	Any 2/	No	No
MAPE	MM	Fixed to 24	No	No
MODEL_RUN_TYPE=SOIL_AND_HEAT_TRANSFER_UNAFFECTED_RUNOFF				
RAIM	MM	Any	No	Yes
SASC	PCTD	Any 2/	No	Yes
SNSG	MM	Any 2/	No	Yes
SWE	MM	Any 2/	No	Yes
MAT	DEGC	Any 2/	No	Yes
MAPE	MM	Fixed to 24	No	No

OUTPUT TIME SERIES:

Time Series Type	Expected Units	Time Series Interval(HR)	Missing Values Allowed
MODEL_RUN_TYPE=SOIL_AND_HEAT_TRANSFER			
TCI	MM	Any 2/	No
FRAMT	MM	Any 2/	No
SSM (1-N) 1/	MM/MM	Any 2/	No
SST (1-N) 1/	DEGC	Any 2/	No
SFGD	CM	Any 2/	Yes
UZTWC	MM	Any 2/	No
UZFWC	MM	Any 2/	No
LZTWC	MM	Any 2/	No
LZFPC	MM	Any 2/	No
LZFSC	MM	Any 2/	No

Time Series Type	Expected Units	Time Series Interval(HR)	Missing Values Allowed
ADIMC	MM	Any 2/	No
MODEL_RUN_TYPE=ONLY_SOIL			
TCI	MM	Any 2/	No
SSM (1-N) 1/	MM/MM	Any 2/	No
UZTWC	MM	Any 2/	No
UZFWC	MM	Any 2/	No
LZTWC	MM	Any 2/	No
LZFPC	MM	Any 2/	No
LZFSC	MM	Any 2/	No
ADIMC	MM	Any 2/	No
MODEL_RUN_TYPE=SOIL_AND_HEAT_TRANSFER_UNAFFECTED_RUNOFF			
TCI	MM	Any 2/	No
FRAMT	MM	Any 2/	No
SSM (1-N) 1/	MM/MM	Any 2/	No
SST (1-N) 1/	DEGC	Any 2/	No
SFGD	CM	Any 2/	Yes
UZTWC	MM	Any 2/	No
UZFWC	MM	Any 2/	No
LZTWC	MM	Any 2/	No
LZFPC	MM	Any 2/	No
LZFSC	MM	Any 2/	No
ADIMC	MM	Any 2/	No

Notes:
1/: one time series for each soil layer, where N represents the number of soil layers;
2/: Must be a multiple of RAIM interval.

5. Modifications (Mods)

The SAC-HT model has seven mods it accounts for. All of the mods alter the internal state values (upper and/or lower zone moisture contents).

Parameter Id	Internal Model Units	Time Step	Description
UZTWC	MM	any[1]	Changes the upper zone tension water contents at a given model time step to the specified value
UZFWC	MM	any[1]	Changes the upper zone free water contents at a given model time step to the specified value
LZTWC	MM	any[1]	Changes the lower zone tension water contents at a given model time step to the specified value
LZFPC	MM	any[1]	Changes the lower zone free primary water contents at a given model time step to the specified value
LZFSC	MM	any[1]	Changes the lower zone free secondary water contents at a given model time step to the specified value
ADIMC	MM	any[1]	Changes the additional impervious water contents at a given model time step to the specified value
SACBASEF	MM	any[2]	Multiplies the lower zone free and secondary water contents at a given model time step by the specified value

[1] a non-equidistant time series; the date and time must coincide with a model time step

[2] an equidistant time series; the date and time must coincide with a model time step

6. Notes about configuring Model in FEWS workflow

None noted.

7. FEWS Adapter Used

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