Notes on the Top Soil 'Residue' Layer in the SAC-HT

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Built into the structure of the SAC-HT physical soil column is a top-layer 'residue' layer having a thickness of 0.03m. This layer was used by Koren et al. (2009) to model the insulating effects of ponded surface melt water on infiltration of moisture in the Red River of the North flooding in 2008. The residue layer is not used in any water balance calculations. It is only used to determine the heat exchange between the soil column and the atmosphere. Only the temperature of the residue layer is explicitly computed and updated.

The residue layer does not evaporate any water nor is it involved in any other water balance calculations. The porosity of the soil in this layer is prescribed as 0.58. The soil moisture contents of this residue layer are set by prescribing a value of "percent saturation." Currently, this value is hard-coded as 0.15. Thus, the volumetric soil moisture contents (state ssm0) will be a temporally constant value of 0.15 x 0.58 = 0.087. This value will be seen if the soil moisture ssm0 for the top layer is output (with no interpolation to user defined soil depths). Keep in mind that this residue layer is not produced by the derivation of *a priori* SAC-SMA parameters from soils data. While the residue layer is not used in the water balance calculations of the physical soil layers, the temperature of the residue layer is computed in the heat transfer component in the same way the other soil layer temperatures are computed. Note also that the soil moisture in the residue layer is not allowed to freeze as is allowed in the other physical soil layers.

The volumetric water content of 0.087 in the residue layer is not used when interpolating soil moisture to user-specified depths. When interpolating, the soil moisture content in the layer just below the residue layer is assigned to the residue layer. On the other hand, the temperature computed in the residue layer is used to interpolate temperatures to user-specified depths. See the document entitled "Interpolation of soil moisture and temperature to user-defined depths."

The residue layer depth of 0.03m is not included in the adjustment of default physical soil depths to correspond to the storages of the Sacramento model in soilpar1.f. (SacSmaHTModelDriver). Its depth remains at 0.03m. This adjustment is described in the document "Interpolation of soil moisture and temperature to user-defined depths."

The residue layer volumetric soil moisture of 0.087 can be seen by writing out/plotting ssm0 when <u>not</u> specifying depths for interpolation. In this case, the SAC-HT will output the soil moisture in the residue layer (and others) as computed in the model's internal soil layers. Figure 1 shows the values of ssm0, ssm1, ssm2 and ssm3 for a location.

GMT	A SSM3 (PCTD) PWGM7: Powell PWGM7 [1] 12-31-2020 12:00:00	B SSM0 (PCTD) PWGM7: Powell PWGM7 [1] 12-31-2020 12:00:00	C SSM1 (PCTD) PWGM7: Powell PWGM7 [1] 12-31-2020 12:00:00	D SSM2 (PCTD) PWGM7: Powell PWGM7 [1] 12-31-2020 12:00:00
Mean	0.354	0.087	0.306	0.306
Sum	296.247	72.906	256.833	256.687
Min	0.290	0.087	0.182	0.182
Max	0.395	0.087	0.468	0.468
06-16-2012 06:00	0.395	0.087	0.307	0.307
06-16-2012 12:00	0.394	0.087	0.304	0.304
06-16-2012 18:00	0.394	0.087	0.302	0.302
06-17-2012 00:00	0.394	0.087	0.299	0.299
06-17-2012 06:00	0.394	0.087	0.297	0.297
06-17-2012 12:00	0.393	0.087	0.294	0.294
06-17-2012 18:00	0.393	0.087	0.292	0.292
06-18-2012 00:00	0.393	0.087	0.289	0.289

Figure 1. Listing of smc0-3 showing the constant value of 0.087 for ssm0 in the residue layer

References

Koren, V., Smith, M., Cosgrove, B., Mizukami, N., Cui, Z. and Zhang, Z., 2009. Surface water freezing experiments for the Red River of the North using SAC-HT. PowerPoint presentation prepared for NCRFC; presented at HIC conference

Appendix
Notes on java code related to the residue layer

1. The thickness is of the residue layer is explicitly defined with other initial default soil layer depths in line 942 in SacSmaHTModelDriver.java as shown below.

```
        * C DEFINITION OF DEFAULT SOIL LAYER THICKNESS - FIVE LAYERS ARE
        DEFINED. IF IT'S DESIRABLE TO USE MORE OR LESS
        * LAYERS, SDPTH SHOULD BE CHANGED, HOWEVER, THE FIRST LAYER
        (VERY THIN RESIDUE LAYER) SHOULD NOT BE CHANGED
        */

942     final double[] defaultLayerDepths = {0.03, 0.14, 0.41, 0.81, 1.51, 0., 0., 0., 0., 0.};
```

2. The porosity of the residue layer is set at 0.58 as defined on line 73 in SacSmaHTModelConstants.java as seen below.

```
    /*
        * Based on Victor's change 6/15 - frozen ground parameters for which science to
        calibrate doesn't exist
        */
73      public final static double MAX_SOIL_POROSITY = .58; // rsmax
```

3. The volumetric soil moisture content of the residue layer is set in lines 715-719 of SacSmaHTModelDriver as 0.58 x 0.15 = 0.087 computed as follows:

```
715     sacHTData.getSacSmaHtState()
                    .setSoilLayerMoistureContent(0,
                (float)SacSmaHTConstants.MAX_SOIL_POROSITY * 0.15f);
719     sacHTData.getSacSmaHtState().setSoilLayerUnfrozenWater(0,
                                                _sacHTData.getSacSmaHtState()
```

Note that statements 715-710 above also fix the unfrozen water contents to be equal to the total water contents in the residue layer, so that there is no frozen water in the residue layer. Both thermal conductivity and heat capacity of a soil layer are based on the amounts of ice, air, liquid water, and soil in the layer. Thus, the ice terms in the computation of thermal conductivity and heat capacity are zero for the residue layer. Thermal conductivity and heat capacity for the layers are computed in routine HeatTransferSimulation.java