CABLE has two bugs related to soil thermal properties, found by Anne during SOIL-MIP

BUG #1: Uses bulk density when actual density is the correct parameter.

BUG #2:The min/max/if/else statements create nonphysical decreasing conductivity as moisture increases, contrasting what I believe is the actual equation

BUG #1

EQN 1: $C_{soil,i} = \Delta z_i * [\rho_{mrl} * (1 - \Theta_{sat})*C^v_{mrl} + \rho_{mrl} * \Theta_{liq} *C^v_{liq} + \rho_{mrl} * \Theta_{ice} *C^v_{ice}$

ρ_{mrl} is the actual density of the minerals (universally taken as 2700.0 kg/m3 (though really +-100.0)). ρ_{liq} and $\#961_{ice}$ are the actual density of liquid and ice water

CABLE mistakenly reads the bulk density of the soil and uses this value in (1). The density of the mineral material itself is the correct parameter. def_soil_params.txt lists values of soil density (actually ρ_{bulk} not $\rho_{\{mrl\}}$) around 1300.0-1700.0.

These are unphysically small for ρ_{mrl} but in the ball park of observed ρ_{bulk}.

The relationship bewteen actual and bulk soil density is:

EQN 2: $\rho_{\{bulk\}} = \rho_{\{mrl\} * (1 - \Theta_{sat})}$

So it seems CABLE reads in the bulk density, then incorrectly multiplies the bulk density by the total volume $(1 - \Theta_{sat}$.

However Eqn 1 as coded in CABLE introduces a max statement into Eqn 1:

EQN 3: $C_{soil,i} = MAX [\Delta z_i * [\rho_{mrl} * (1 - \Theta_{sat})*C^v_{mrl} + \rho_{mrl} * \Theta_{liq} *C^v_{liq} + \rho_{mrl} * \Theta_{ice} *C^v_{ice} , \rho_{mrl} *C^{\{v\}}_{mrl}]$

giving the correct values for $C_{\{soil,i\}}$ when total moisture goes to zero, but neglecting the initial increase in $C_{soil,i}$ when wetting occurs.

BUG #2

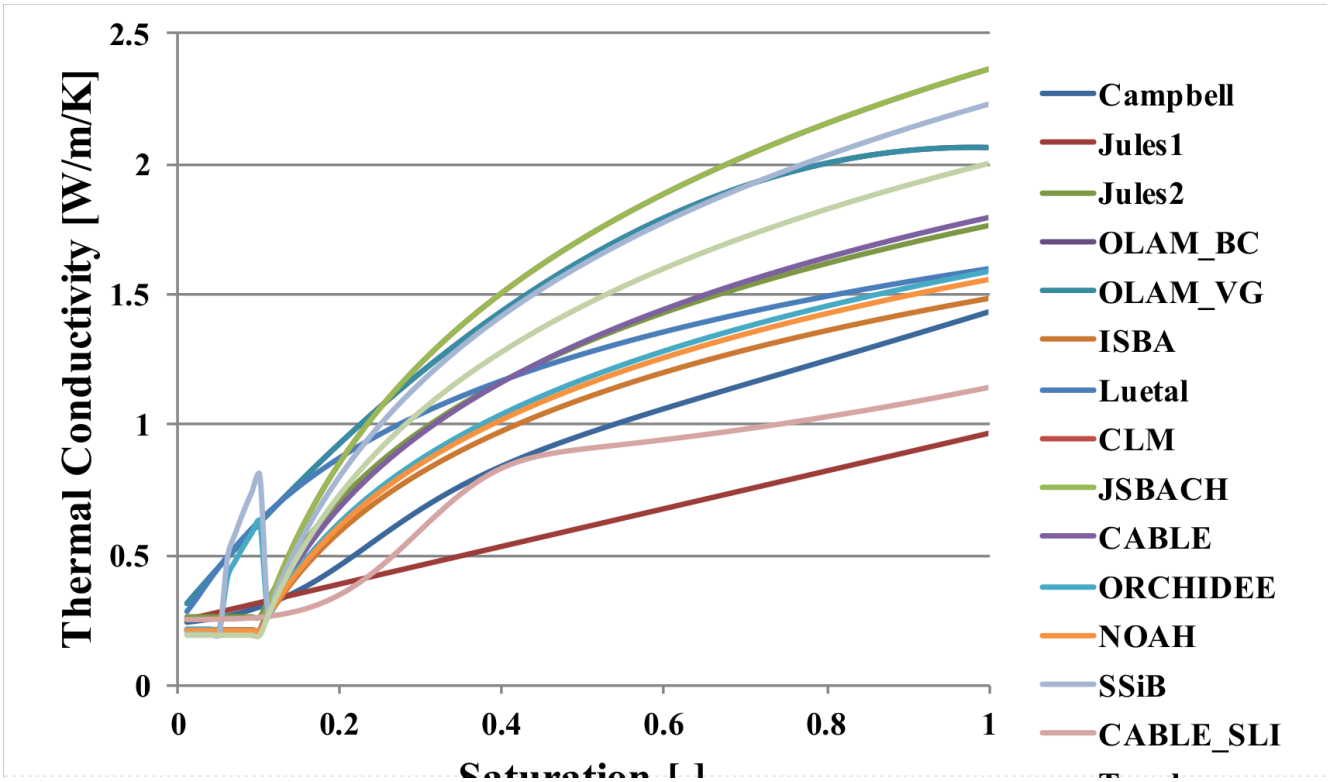
Well the equation to calculate thermal conductivity as a function of soil liquid and ice has no relation to the 2006 documentation, is not from a published method, and was made to match some curves.

Actual equation is very complex (at end of message), with numerous min/max/if conditions, but removing these and simplifying the log raised to exp nonsense gives:

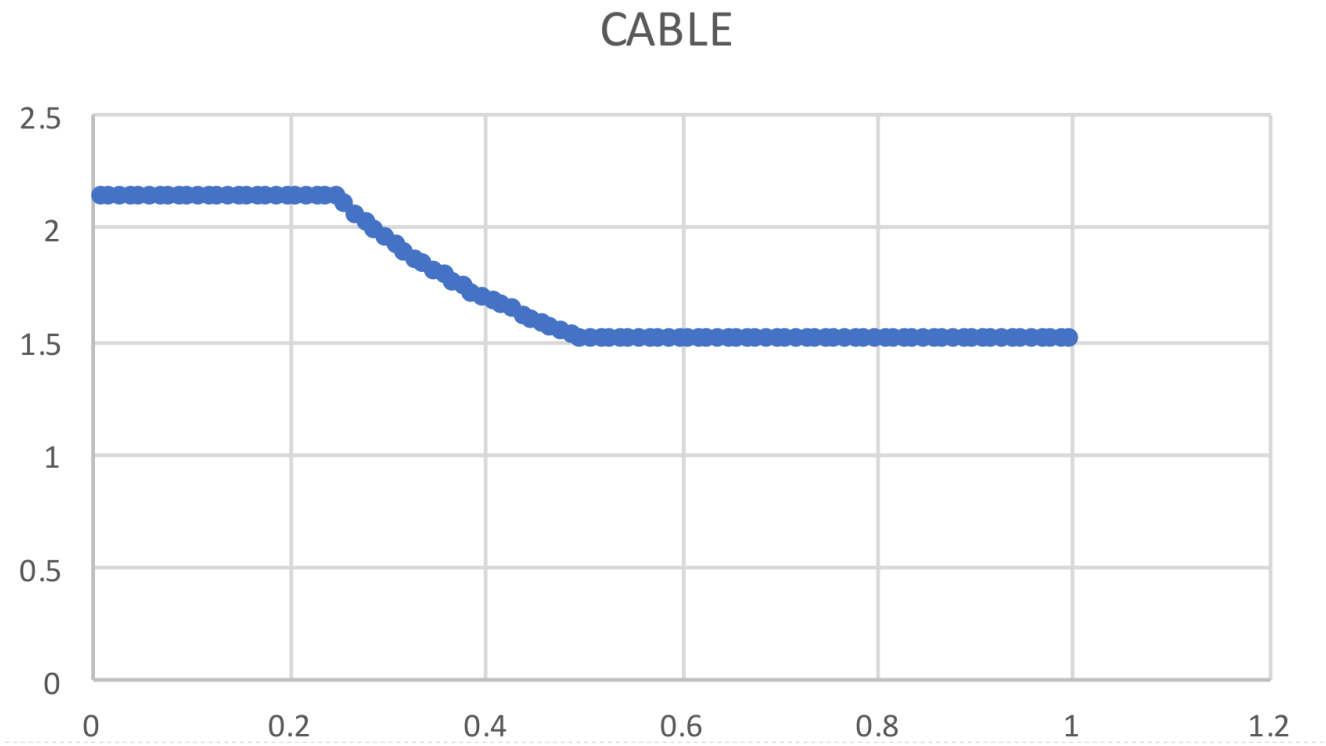
EQN 3: $\Lambda_{soil} = \Lambda_{dry,soil} * 1.41 * 60.0^{\Theta_{liq}} * 250^{\Theta_{ice}} * \Theta_{liq}^{-1}$

Note: I made the simplifications and this is not in the code. Figures below are made with actual code. The above simplified code produces physically reasonable conductivity values (increases with liq or ice)

Compared to other parameterizations, cable is the odd one out. Below is how thermal conductivity increases with liquid for many LSMs (CABLE is plotted using the equations from the documentaion:



LSM thermal conductivity as a function of relative saturation, CABLE from 2006 reference.



CABLE thermal conductivity as a function of relative saturation using actual code, well a direct translation.

I just retested a brand new rewrite using NCL opf the CABLE conductivity code. I get the same results Anne did.

I set up simulations, offline and coupled, to test the impact of Bug #1 and Bug#2, seperately and together. My Bug#2 fix was to replace the CABLE formulation with a simple method common to LSMs. I have not had time to check what the model did, but it is at the top of my to do list.