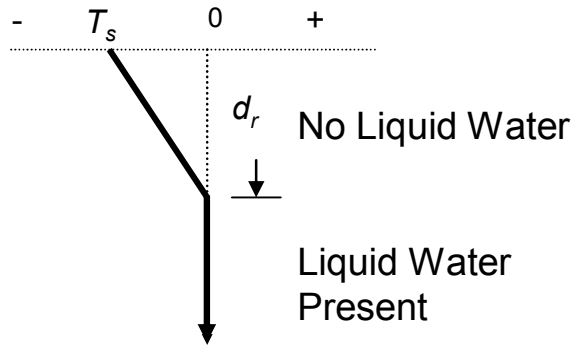

Figure 1 Schematic illustration of temperature profile during the downward propagation of a refreezing front.

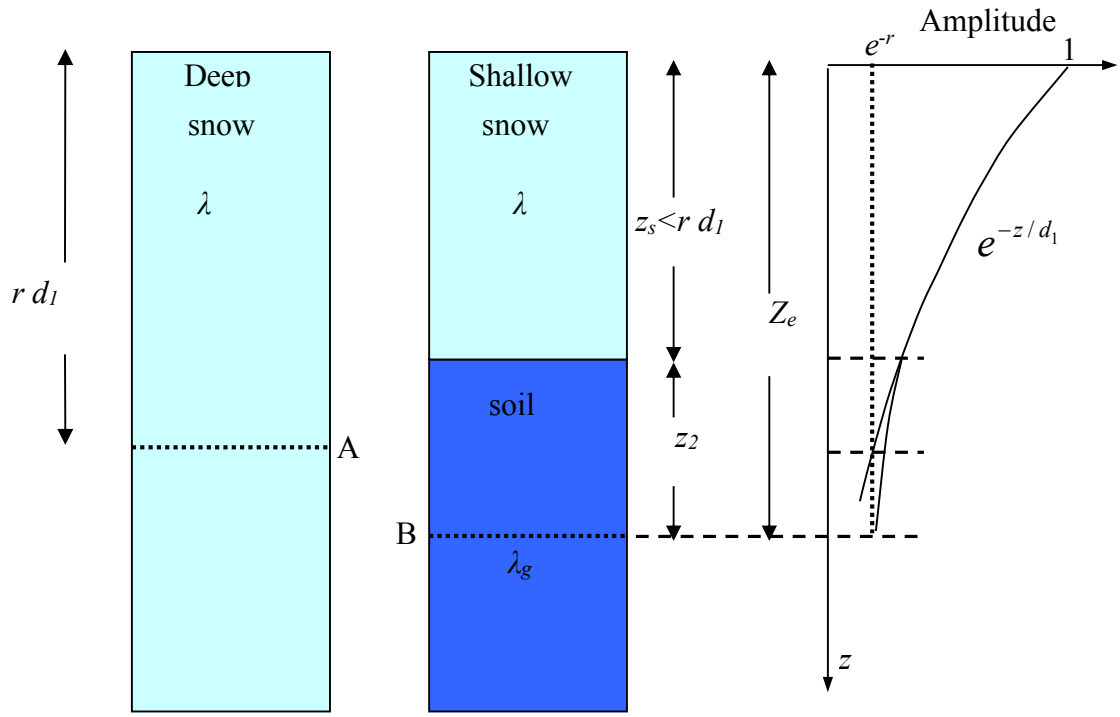

Figure 2 Heat conduction scheme for combined snow/soil system. The dashed lines at depths A and B indicate the depths at which temperature fluctuation amplitude is damped by e^{-r} in the deep snow and combined snow/soil system respectively.

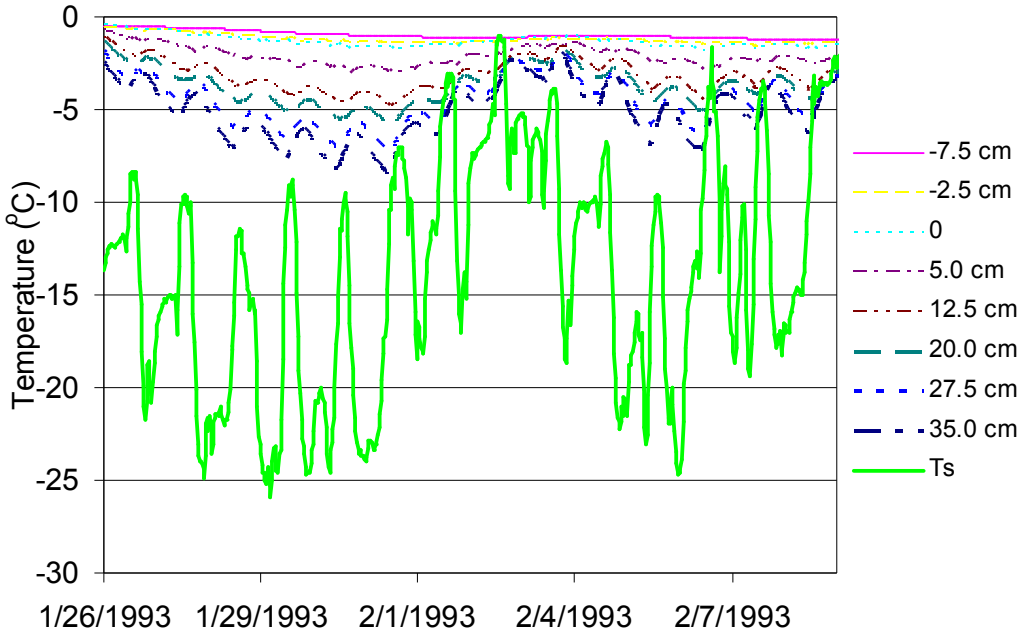

Figure 3 Measured snow, ground and snow surface temperatures. Ts is the measured surface temperature of snow from an infrared sensor. Other temperatures are from thermocouples labeled according to their height relative to the ground surface. Negative heights are below the ground surface and positive heights above the ground surface. 0 refers to the measured temperature at the ground surface.

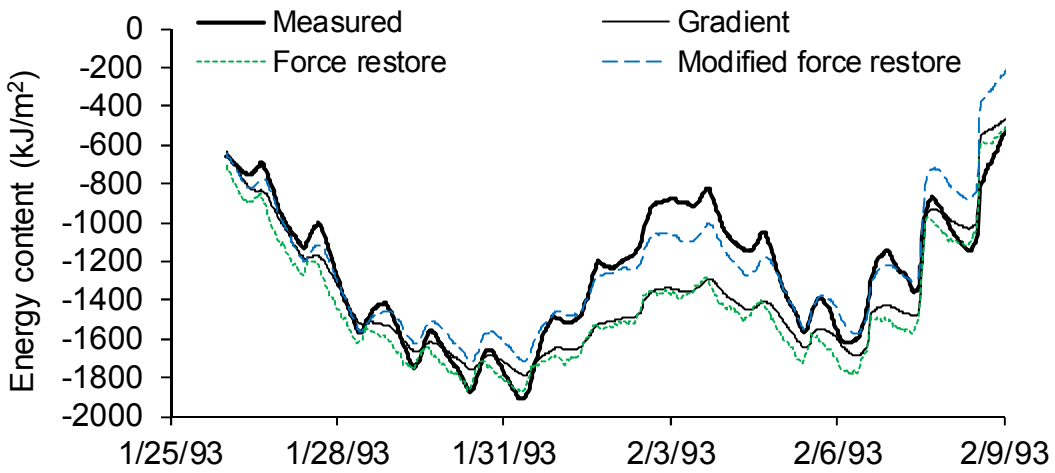

Figure 4 Comparisons of internal energy of snowpack during the first two freezing weeks at the USU Drainage Farm. Measured is the internal energy of snowpack calculated from the temperature profile (Figure 3). Gradient, Force restore, and Modified force restore represent the modeled internal energy of snowpack using the equilibrium approach, the force-restore approach, and the modified force restore approach respectively.

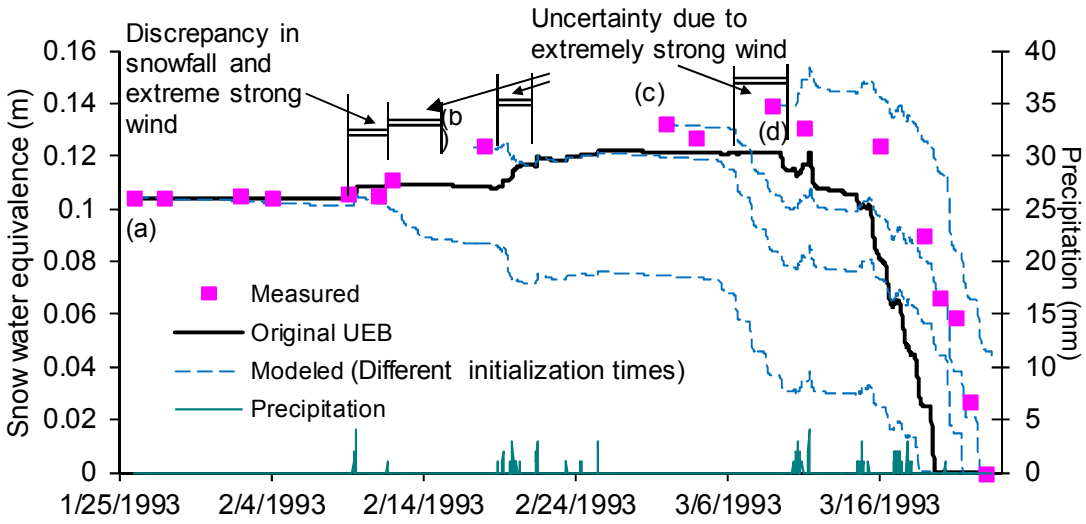

Figure 5 Comparisons of snow water equivalent in 1993 at USU Drainage Farm. The dashed lines are the modeled values with new model starts at different times. Precipitation input is shown (spiky line at the bottom) relative to the axis at the right. Letters (a) through (d) indicate points where the model was re-initialized following periods of likely erroneous inputs due to severe weather.

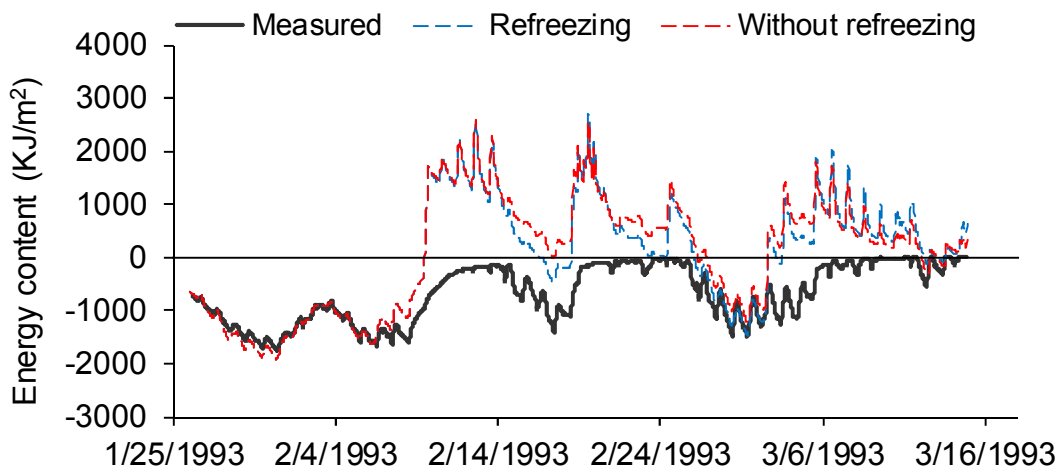

Figure 6 Comparisons of internal energy of snowpack in 1993 at USU Drainage Farm. The wide solid line is the measured values. "Refreezing" represents the modeled internal energy of snowpack with new UEB model. "Without refreezing" represents the model without the refreezing scheme.

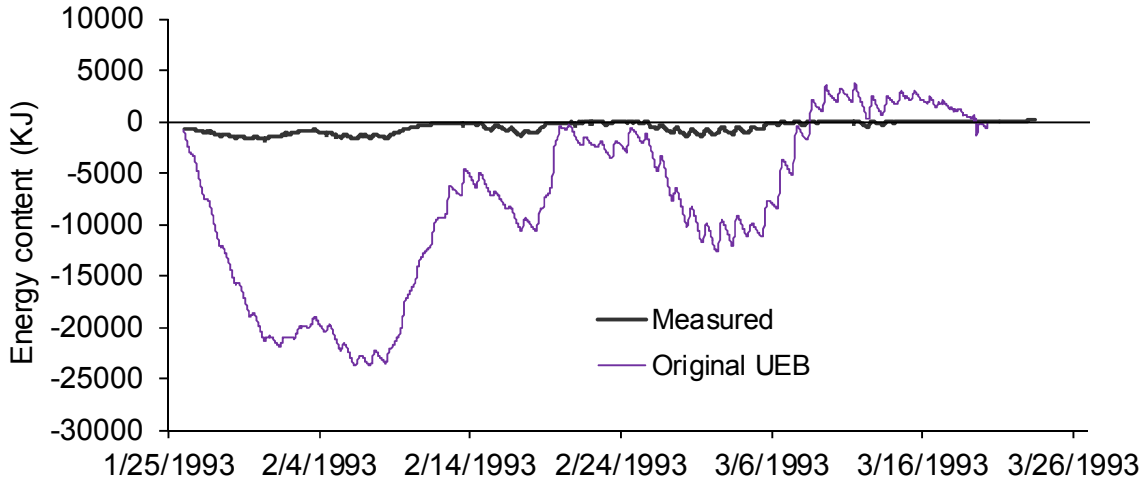

Figure 7 Comparisons between the measured and modeled internal energy of the snowpack at USU Drainage Farm in the original model.

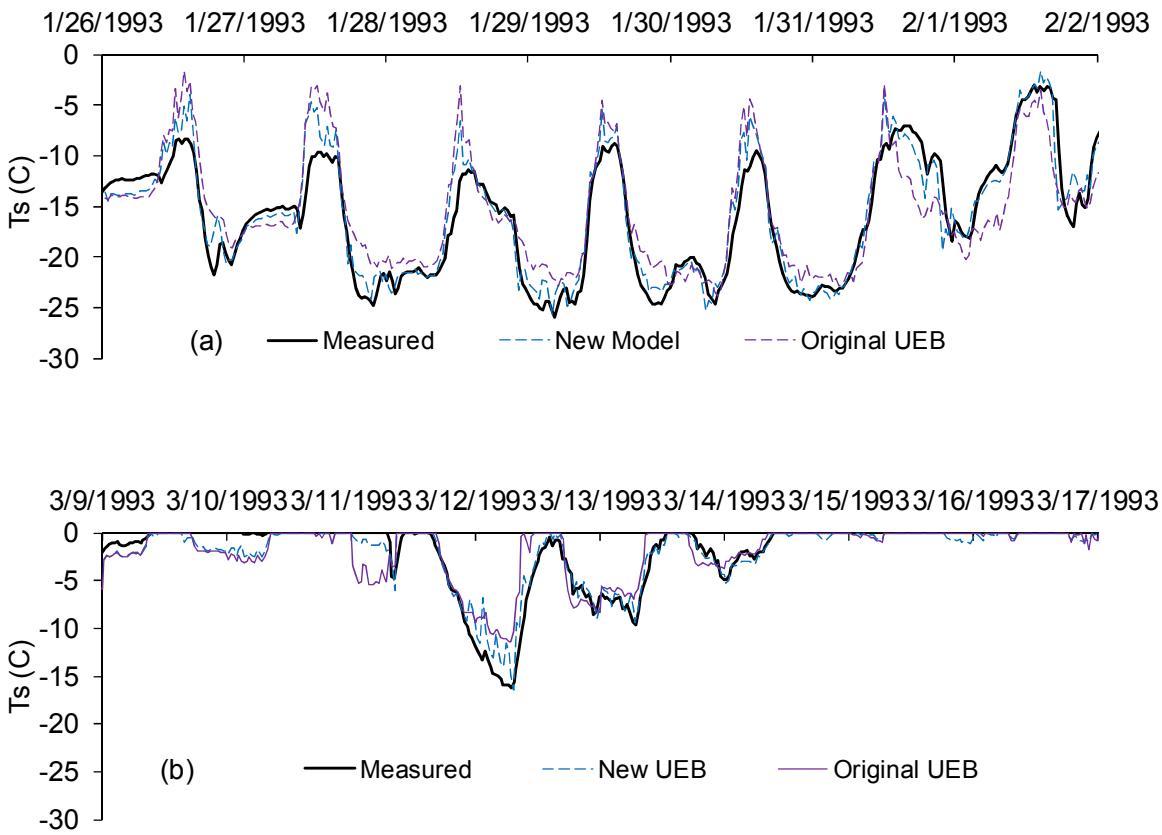

Figure 8 Comparisons of snow surface temperature in 1993 at USU Drainage Farm. (a) the first two subfreezing weeks, and (b) end of the modeling period when the snowpack is occasionally in an isothermal state.

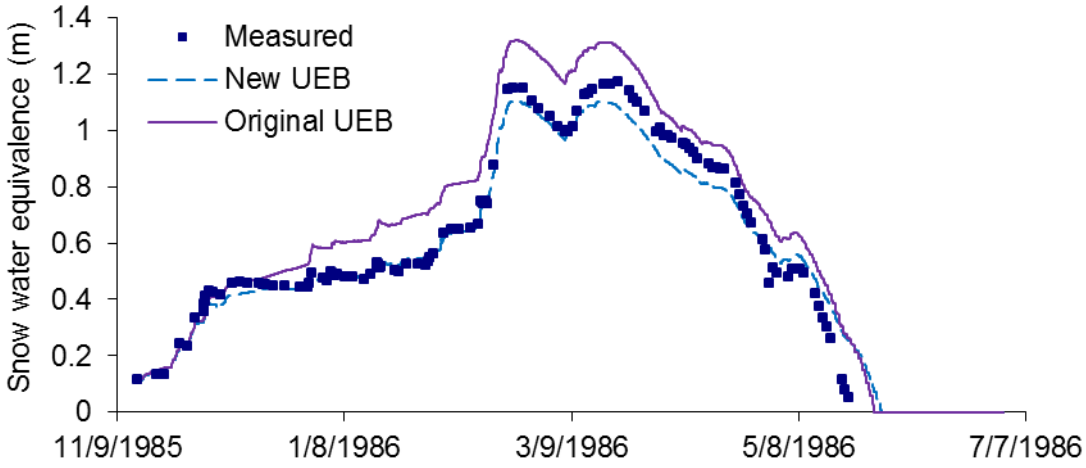

Figure 9 Comparisons of snow water equivalent in 1986 at CSSL.

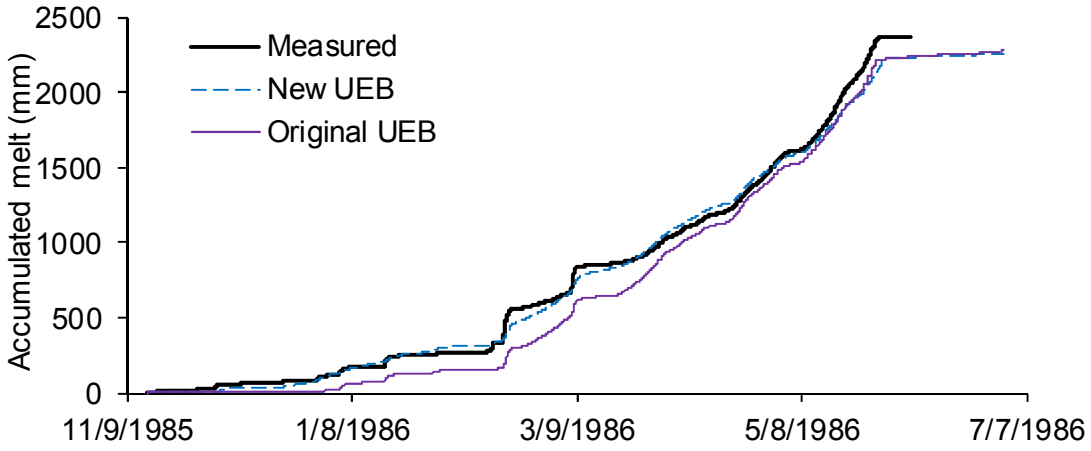

Figure 10 Comparisons of accumulative melt in 1986 at CSSL.

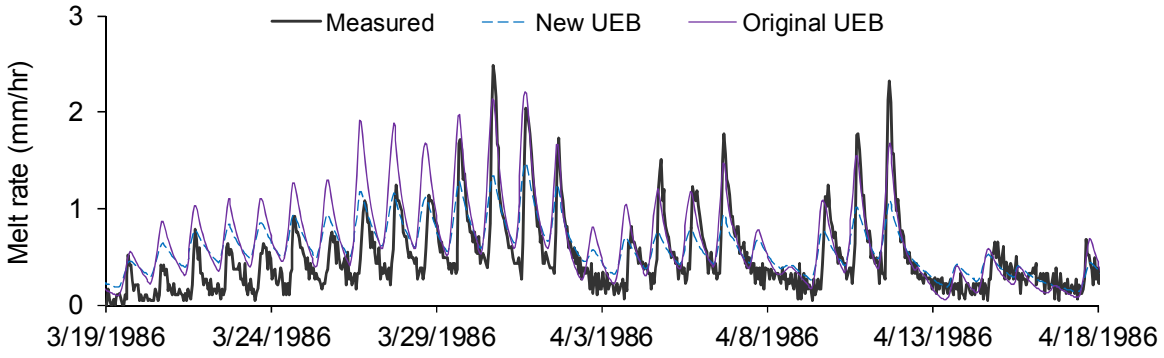

Figure 11 Comparisons of meltwater outflow rate in 1986 at CSSL

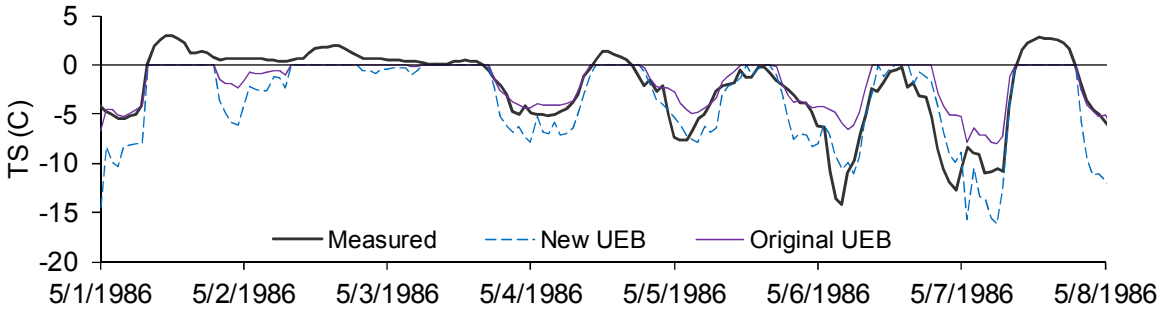

Figure 12 Comparisons of surface temperature of snow in 1986 at CSSL

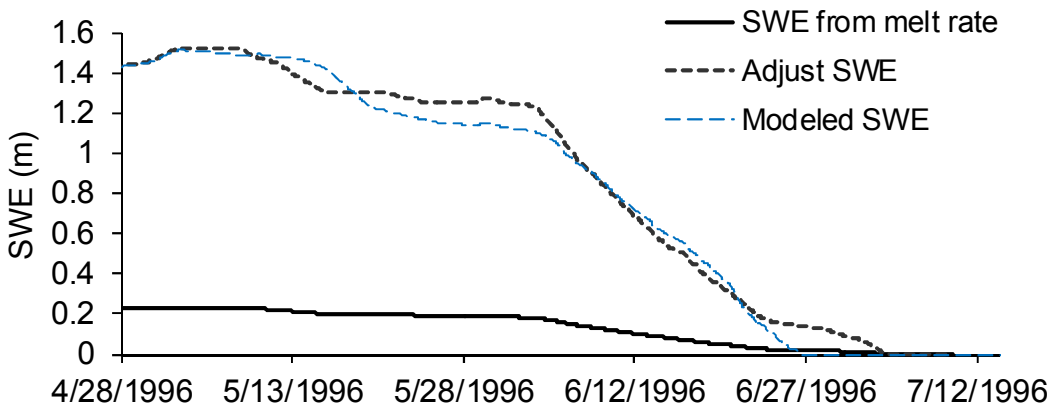

Figure 13 Comparisons of snow water equivalent in 1996 at Subnivean Snow Laboratory at Niwot Ridge watershed, CO.

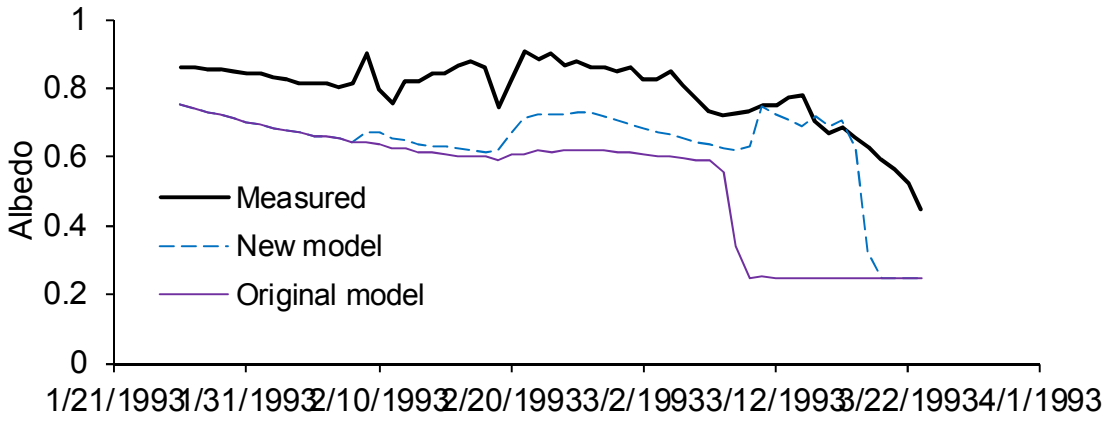

Figure 14 Comparison of albedo at USU drainage farm.

Table 1 Model parameter values

Parameters	Value
Thermal conductivity of snow λ_s	**0.33 kJ m^{-1} K^{-1} h^{-1}
Thermal conductivity of soil λ_g	**6.5 kJ m^{-1} K^{-1} h^{-1}
Low frequency forcing frequency ω_{lf}	**0.0654 radians h^{-1} ($\omega_1/4$)
Dimensionless damping depth factor r	**1
Threshold depth for fresh snow d_{NewS}	**0.002 m
Saturated hydraulic conductivity K_{sat}	*200 m h^{-1}
Surface aerodynamic roughness z_o	*0.01 m
Capillary retention fraction L_c	*0.02
Soil effective depth D_e	*0.1 m
Snow density ρ_s	*200 kg m^{-3}
Ground heat capacity C_g	2.09 kJ kg^{-1} K^{-1}
Density of soil layer ρ_g	1700 kg m^{-3}
Emissivity of snow ε_s	0.99
Temperature above which precipitation is rain T_r	3°C
Temperature below which precipitation is snow T_{sn}	-1 °C
Wind/air temperature measurement height z_m	2 m
Bare ground albedo α_{bg}	0.25
New snow near infrared band reflectance α_{iro}	65%
New snow visible band reflectance α_{vo}	85%

** These parameters are new, i.e., they were not present in the Original UEB

* These parameters were calibrated to have new values.

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