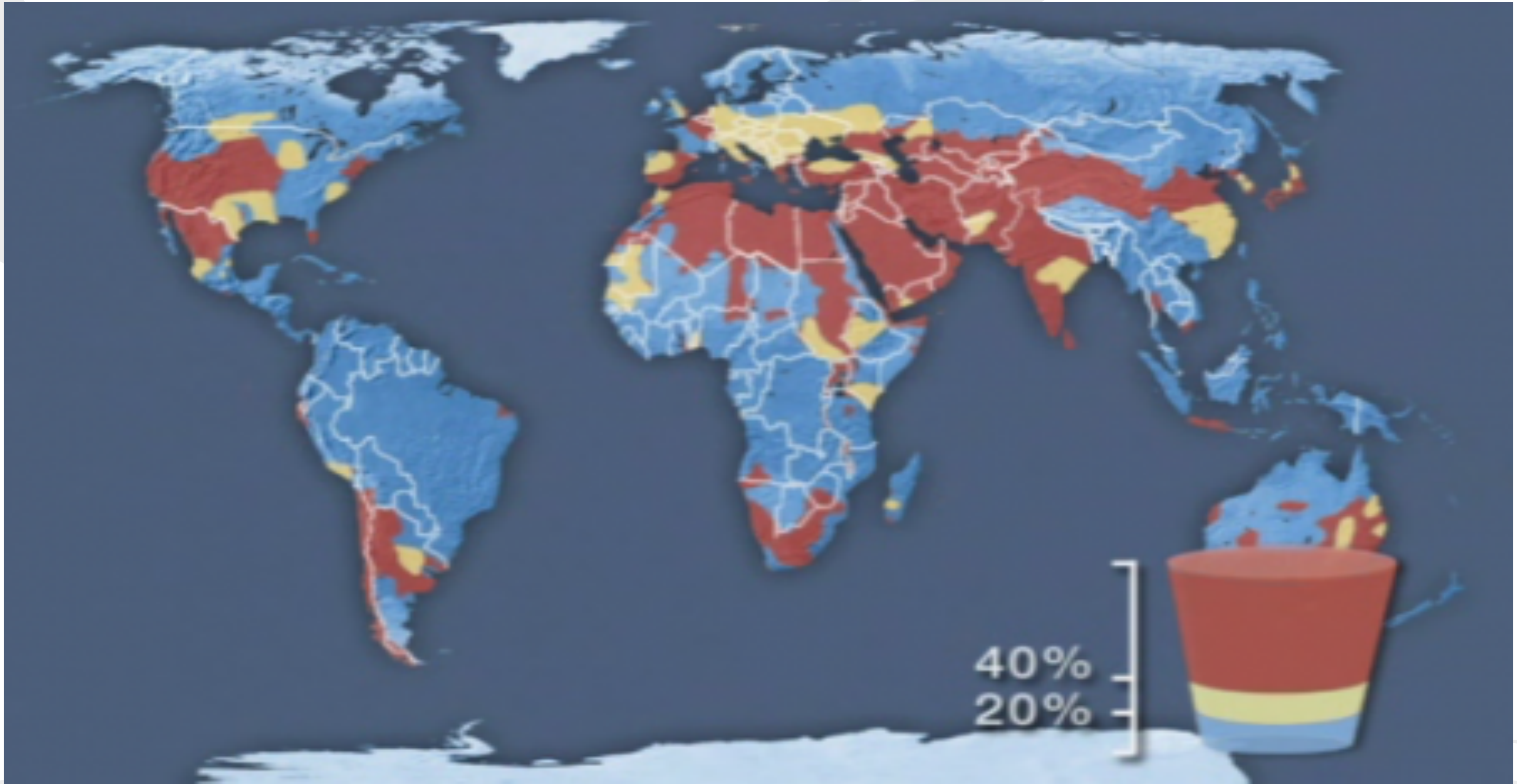
Review: A Hybrid System Model of Seasonal Snowpack Water Balance

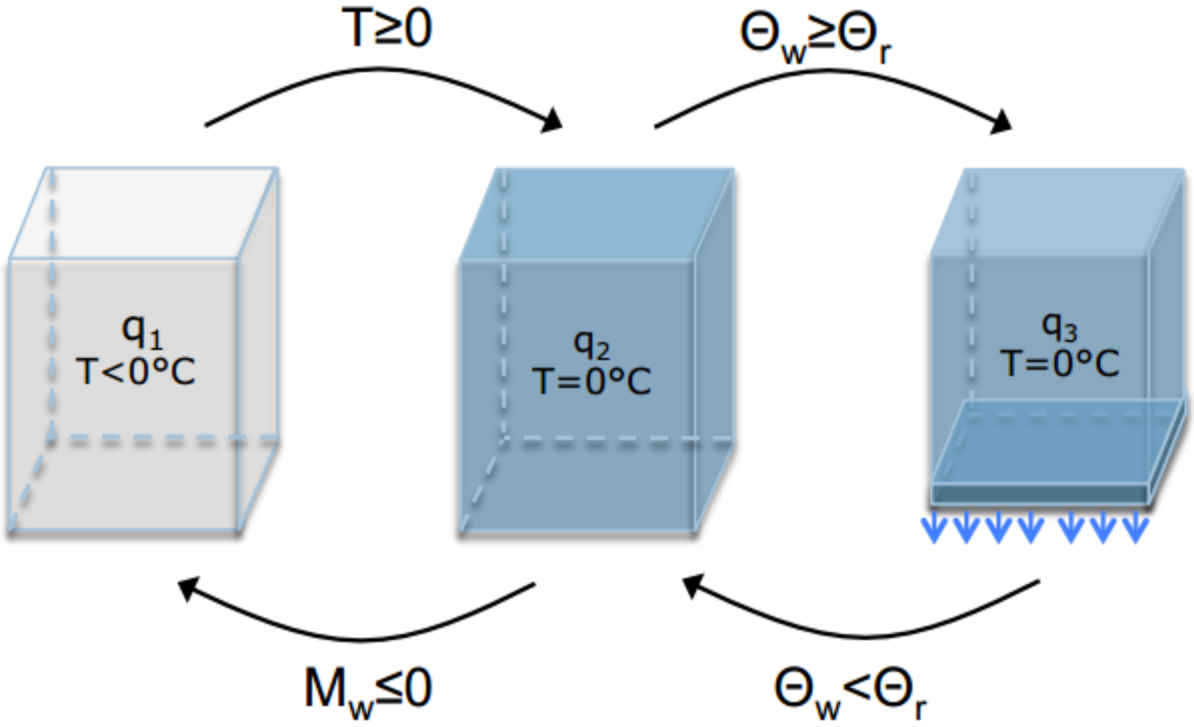
Application of hybrid modeling to natural systems

Personal Motivation

Motivation



The Discrete Model



M = 0

The Basics

$$\frac{dT}{dt} = \frac{u(t)}{M_{snow}C_{snow}}$$

$$\begin{aligned}\frac{dM_{water}}{dt} &= -\frac{dM_{ice}}{dt} \\ &= \frac{u(t)}{L_f}\end{aligned}$$

The Settling

$$\rho_{snow}(t) = \frac{A}{1 + B/t}$$

$$\frac{d\rho_{snow}(t)}{dt} = \frac{AB}{(B+t)^2}$$

$$t = \frac{\rho_{snow} B}{A - \rho_{snow}}$$

$$\frac{d\rho_{snow}(t)}{dt} = \frac{A}{B(1 + \frac{\rho_{snow}(t)}{A - \rho_{snow}(t)})^2}$$

B = 20 days
A = 450 kg/m^3

The Melting Sponge

$$\theta_{snow} = \frac{V_{water}}{V_{total}}$$

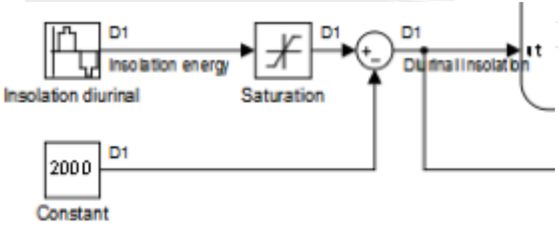
$$= \frac{M_{water}/\rho_{water}}{M_{snow}/\rho_{snow}}$$

$$M_{water} = \theta_r \rho_{water} \frac{M_{ice}}{\rho_{snow} - \theta_r \rho_{water}}$$

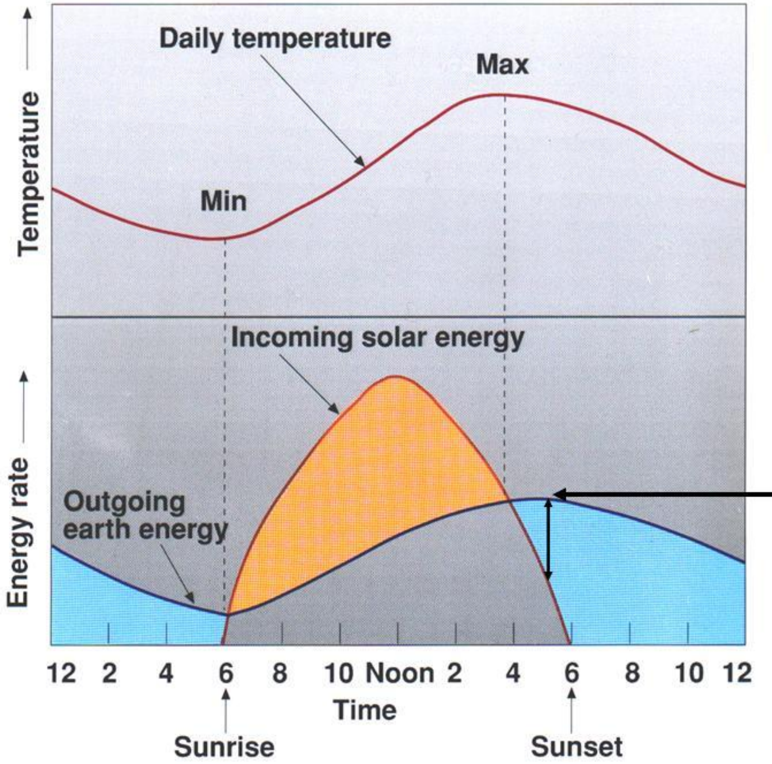
$$\frac{dM_{water}}{dt} = \theta_r \rho_{water} \left[\frac{\frac{dM_{water}}{dt}(\rho_{snow} - \theta_r \rho_{water}) - M_{ice}\frac{d\rho_{snow}}{dt}}{(\rho_{snow} - \theta_r \rho_{water})^2} \right]$$

Energy Input / Calibration

$$u(t)_{solar} = a \sin 2\pi t$$

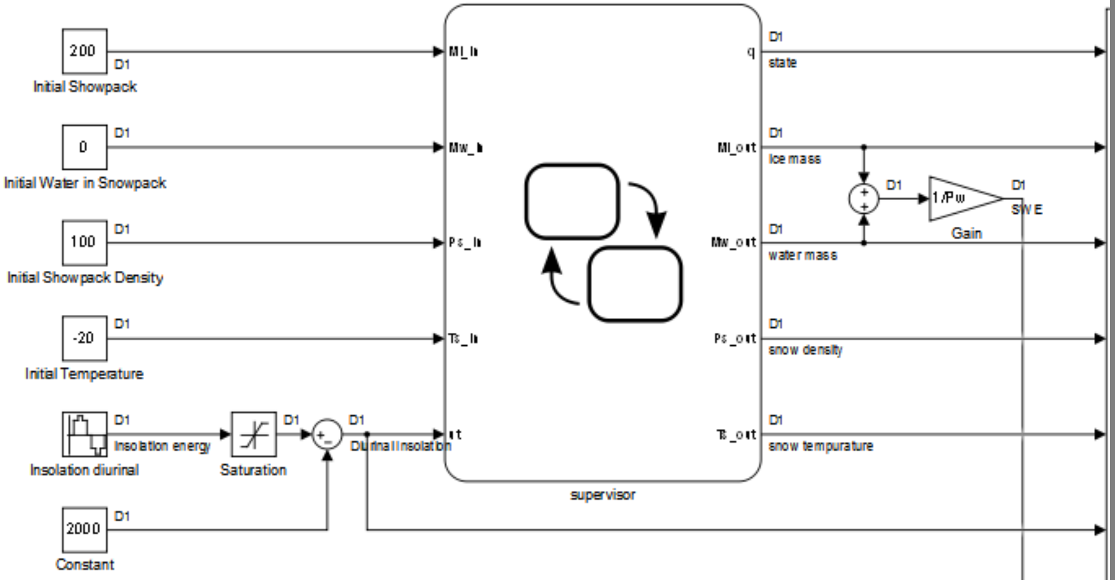


kJ / m / day (not kW)

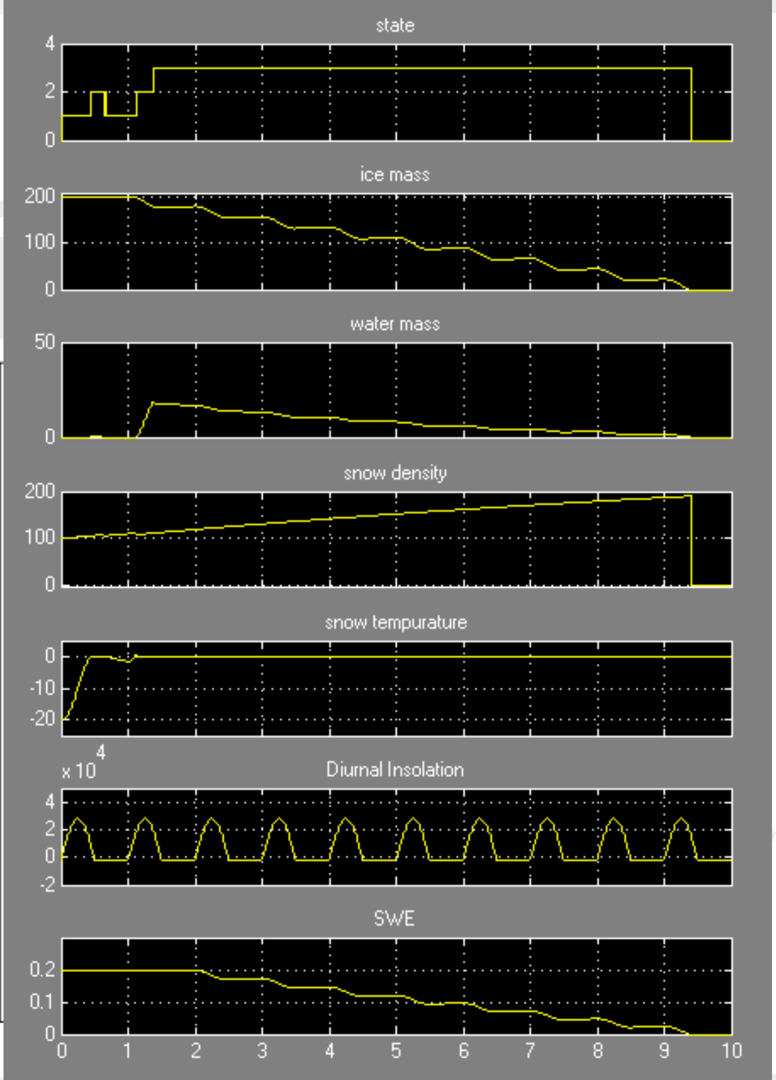


http://courses.knox.edu/envs150/overheads/dailytvariation.JPG

Main Model

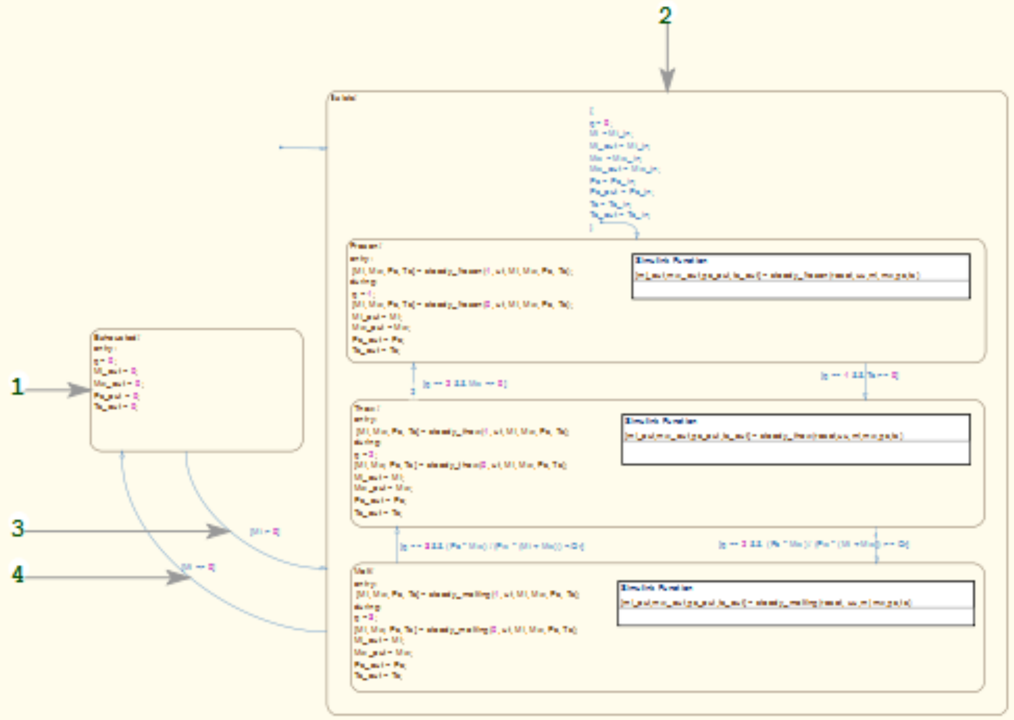


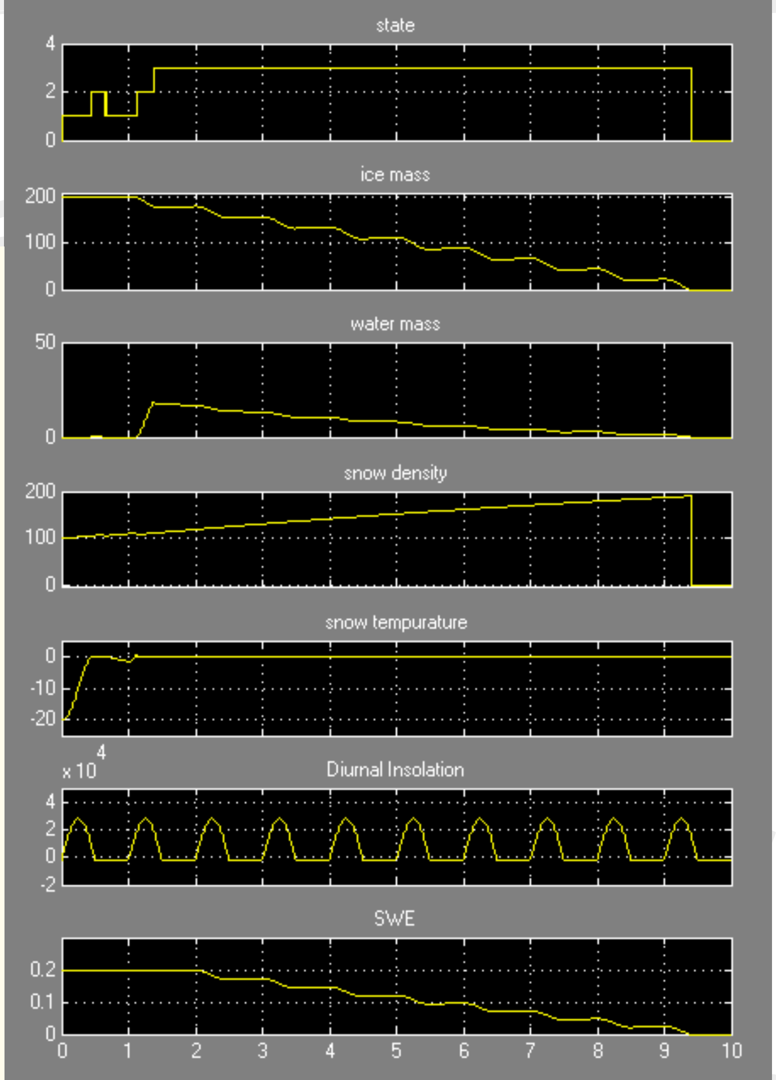
200
Initial Showpack
0
Initial Water in Snowpack
100
Initial Showpack Density
-20
Initial Temperature
Insolation diurinal
Insolation energy
Saturation
2000
Constant
Diurnal Insolation
supervisor
Gain
SWE
state
ice mass
water mass
snow density
snow tempurature



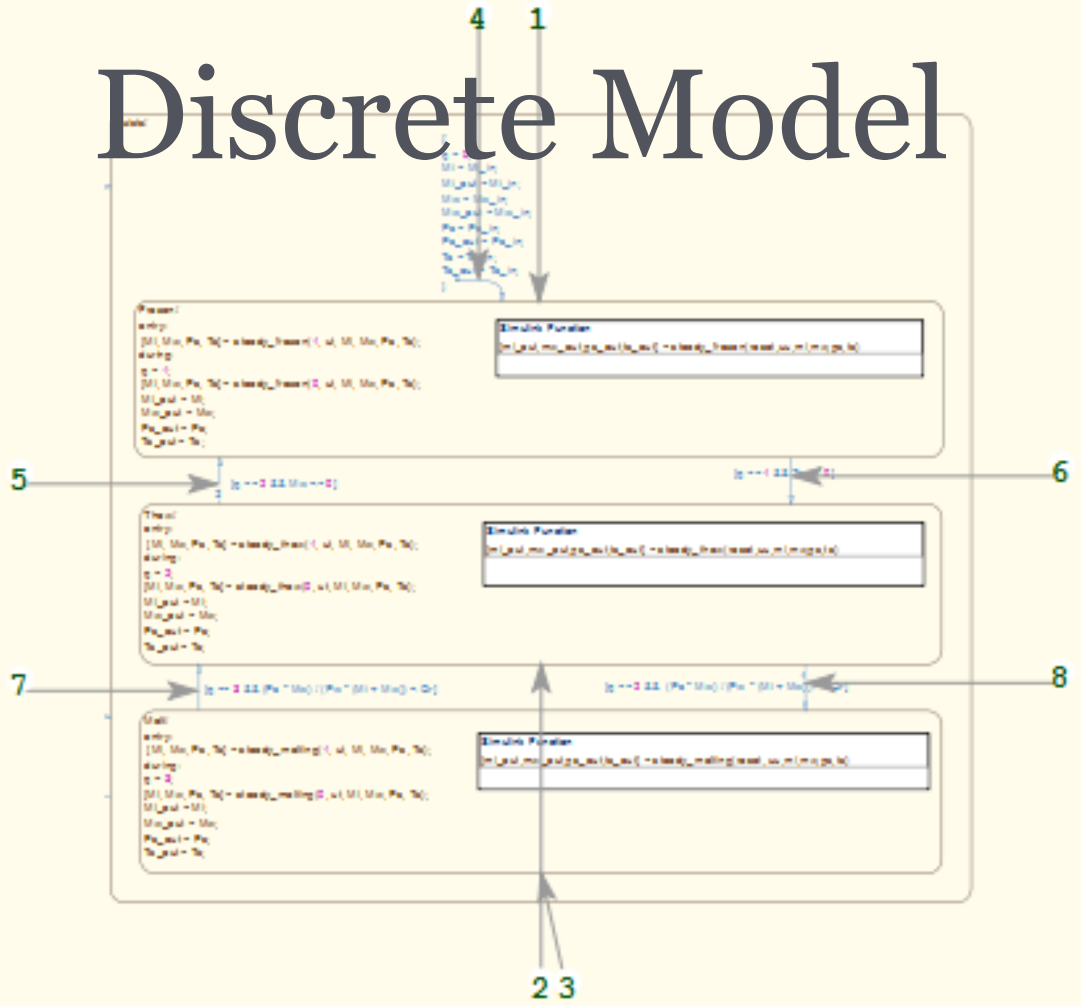
state
ice mass
water mass
snow density
snow tempurature
Diurnal Insolation
x 10^4
SWE

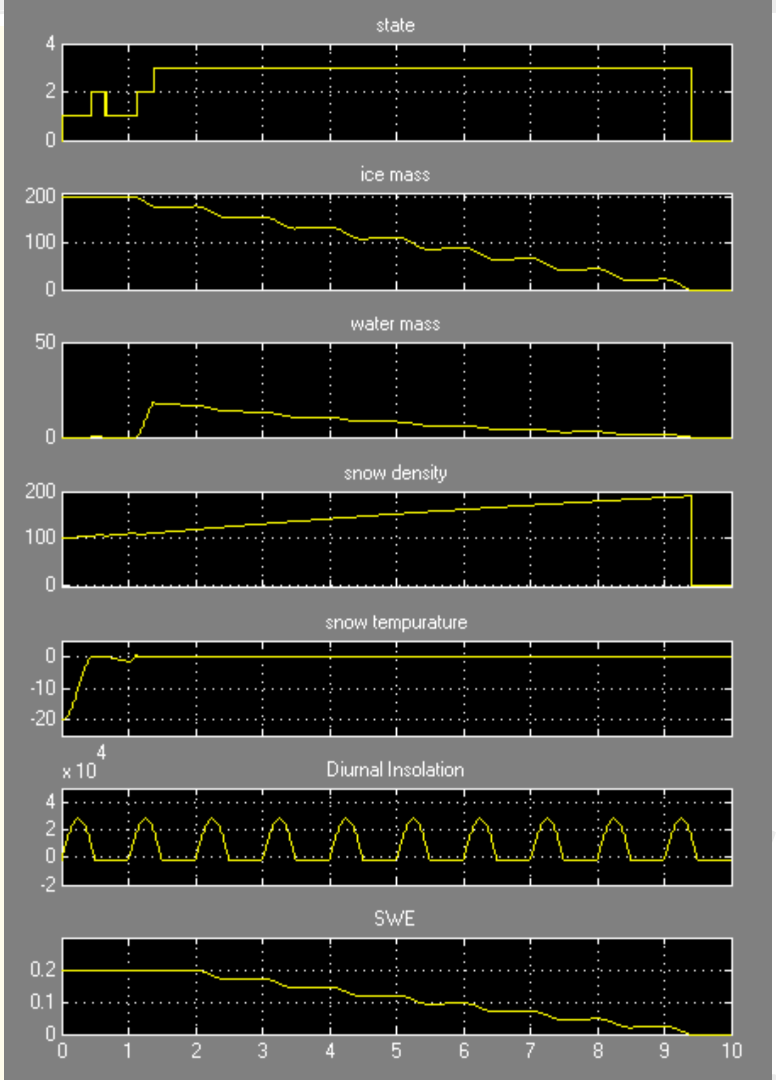
Discrete Model





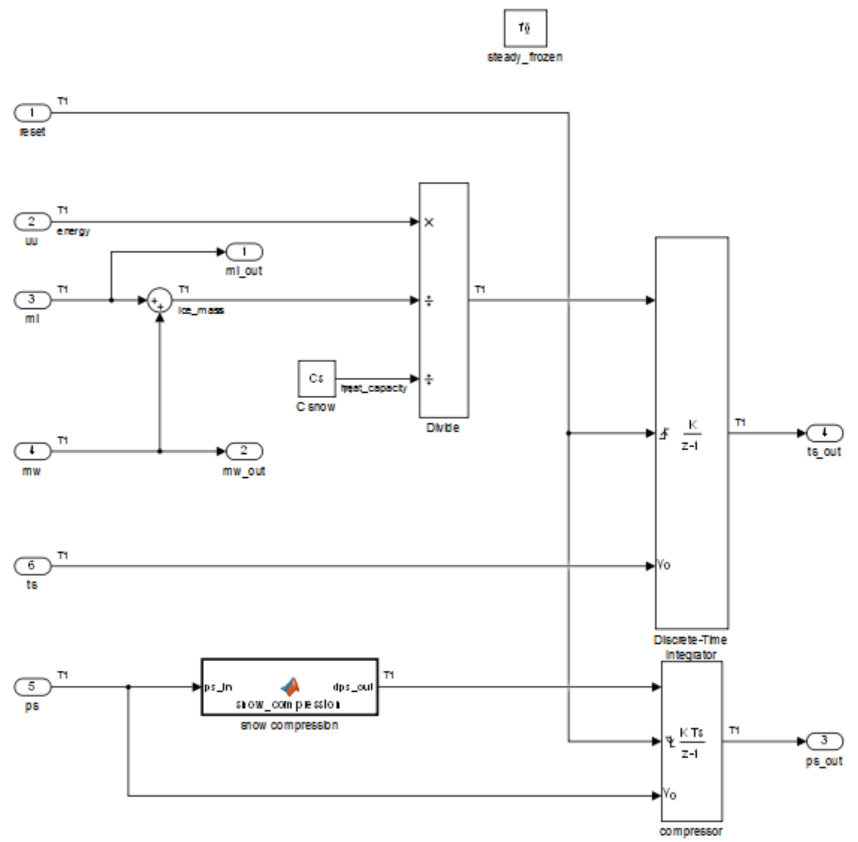
Discrete Model





Dynamic Model / Frozen

$$\frac{d\rho_{snow}(t)}{dt} = \frac{A}{B(1+\frac{\rho_{snow}(t)}{A-\rho_{snow}(t)})^2}$$




Lake effect snow
heading south-east
NASA's Earth Observatory

Questions