Patrick Samuelsson, Stefan Gollvik, SMHI, March 2010

An idea about a continuous formulation of a double energy balance with varying snow depth.

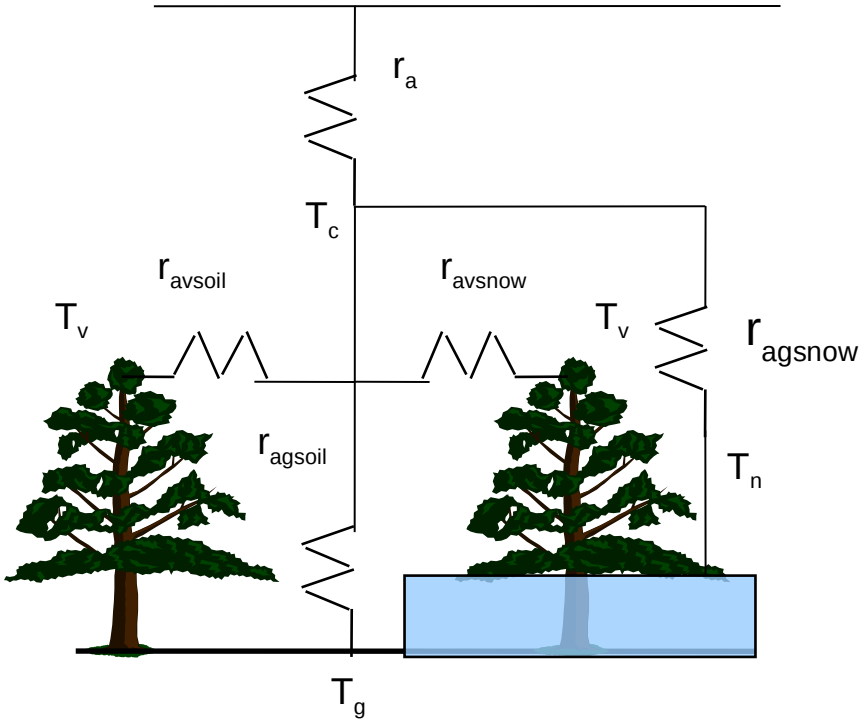
Motivation:

We have already coded a double energy balance in the RCA-model and in Hirlam, for forest only. An introduction in SURFEX, should also work with a vegetation that could be completely covered by snow.

A double energy balance implies that the vegetation has a separate temperature, different from the surface temperature, which is involved in the soil/snow heat conduction.

Here we define a canopy air temperature, without heat capacity (diagnostic), Tc, where the fluxes sum up to zero.

“Traditional” double energy balance



ravsoil, ravsnow = f (LAI, zcan, etc)

ragsoil, ragsnow Choudhury/Monteith, f(LAI, stability, etc)

If this approach is used also for low vegetation, we here try to formulate the case where a part of the vegetation gradually get more and more covered by snow.

We externally specify the following variables (200 days) :

Zcan, height of vegetation = 0.4 m
Znow, depth of snow = 0-0.5-0 m, (actual snowdepth)
LAI = 5-0
Ra =30
Z0can=0.05*Zcan
Z0snow=0.01
Wind speed at canopy top =3 m/s

$$zcan\_snow = \max(0, zcan - zsnow)$$

$$ratio = zcan\_snow / zcan$$

$$LAI\_snow = LAI * ratio$$

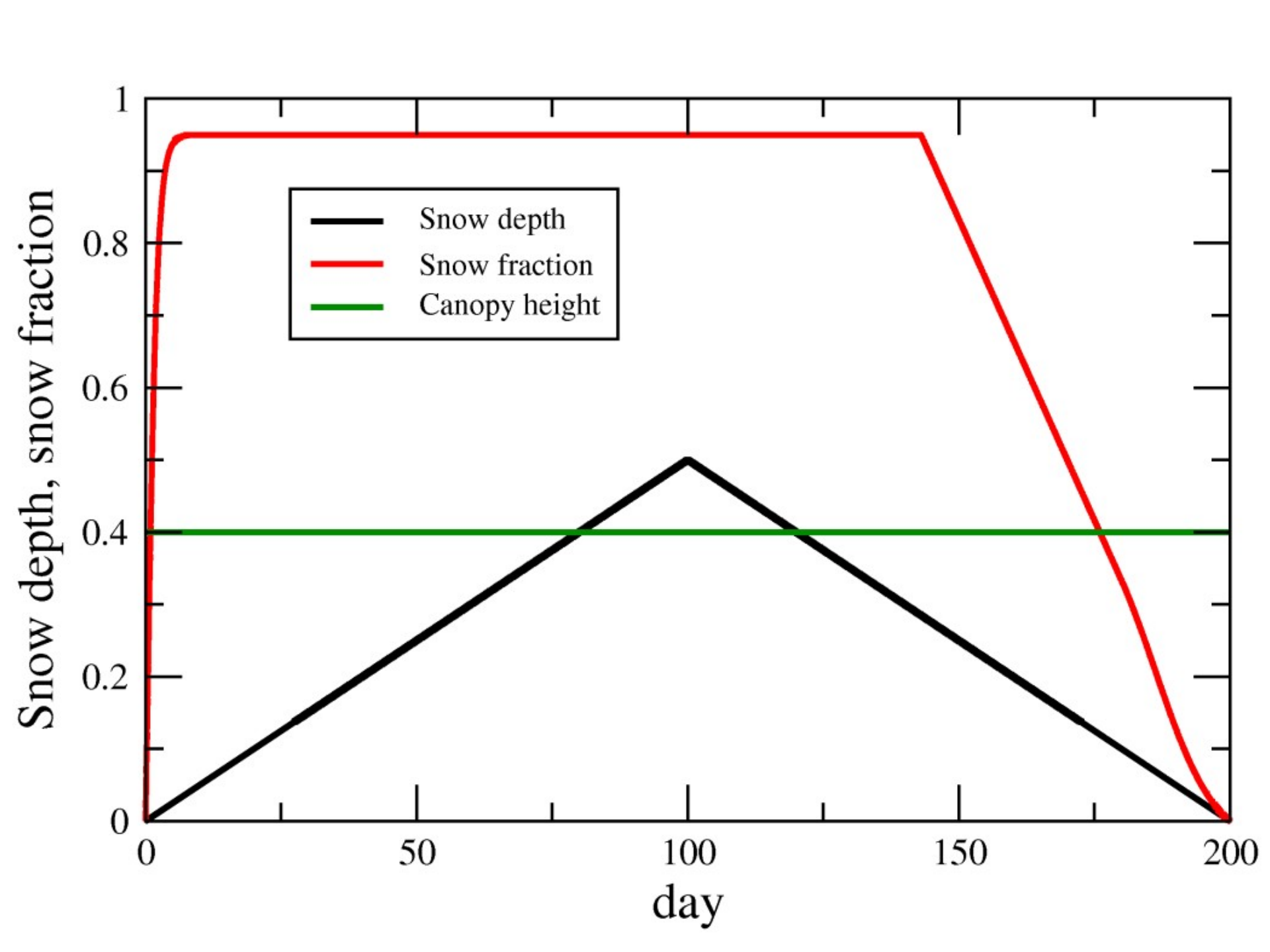
$$z0\_can\_snow = \max(z0\_can\_snow * ratio, z0\_snow)$$

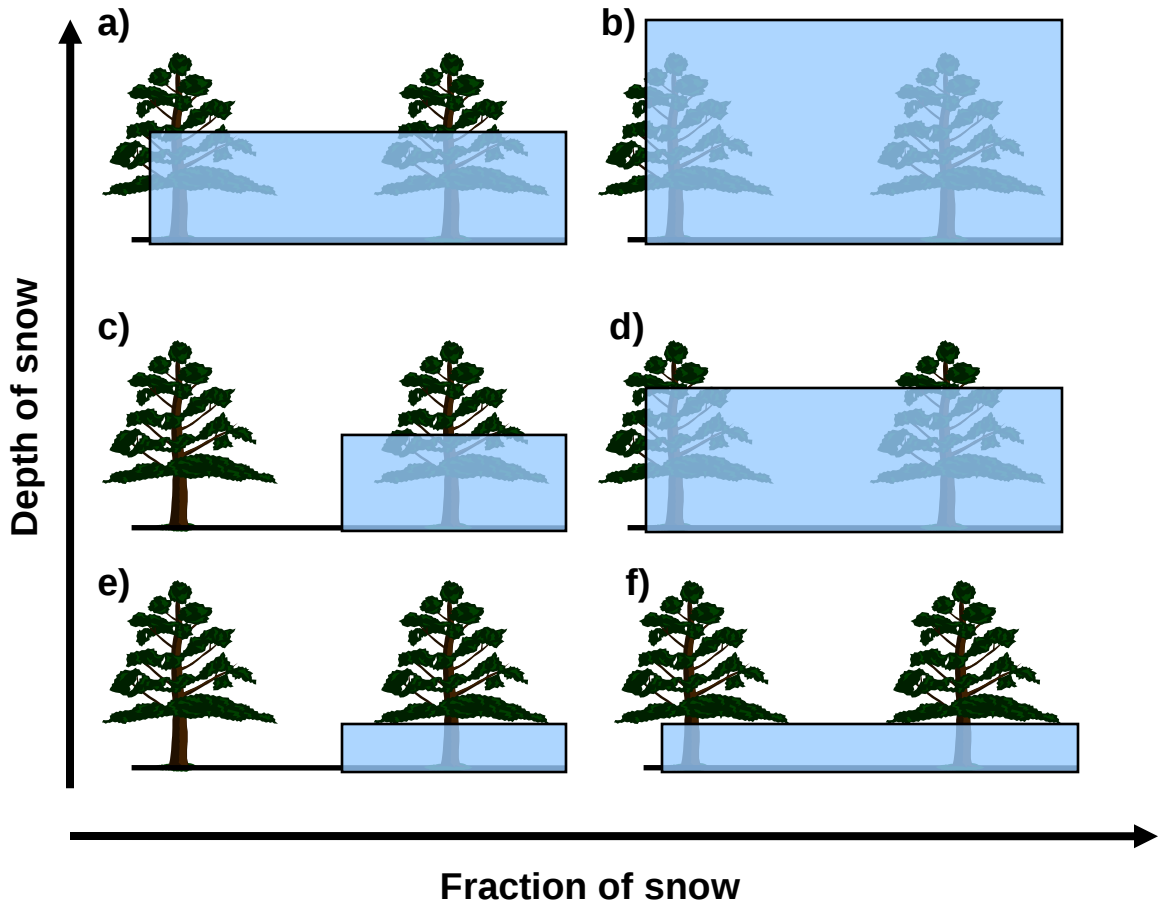
The formulation must be such that ravsnow $\rightarrow \infty$ when LAI_snow $\rightarrow 0$.

In addition to the forcing from the snow, we add a small diurnal temperature tendency to the canopy temperature Tv

The definition of alphasn:

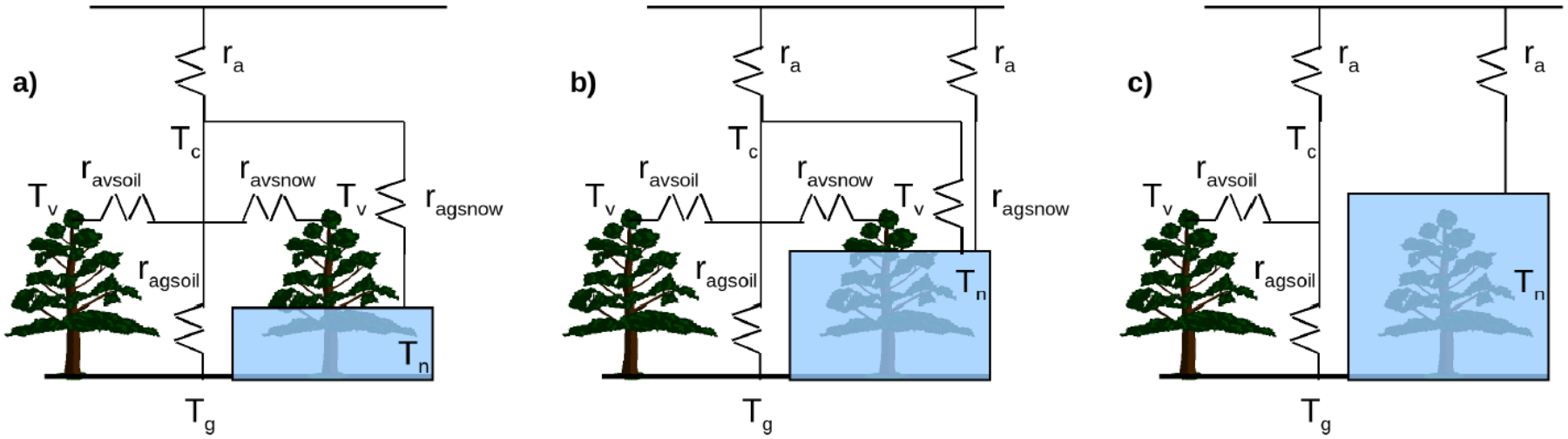
alphasn = 0 for zcan_znow $\leq$ 0.8 zcan and alphasn = 1 ,
for zcan_snow $\geq$ zcan, and linearily interpolated between.


Snow depth
Snow fraction
Canopy height
Snow depth, snow fraction
day
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200

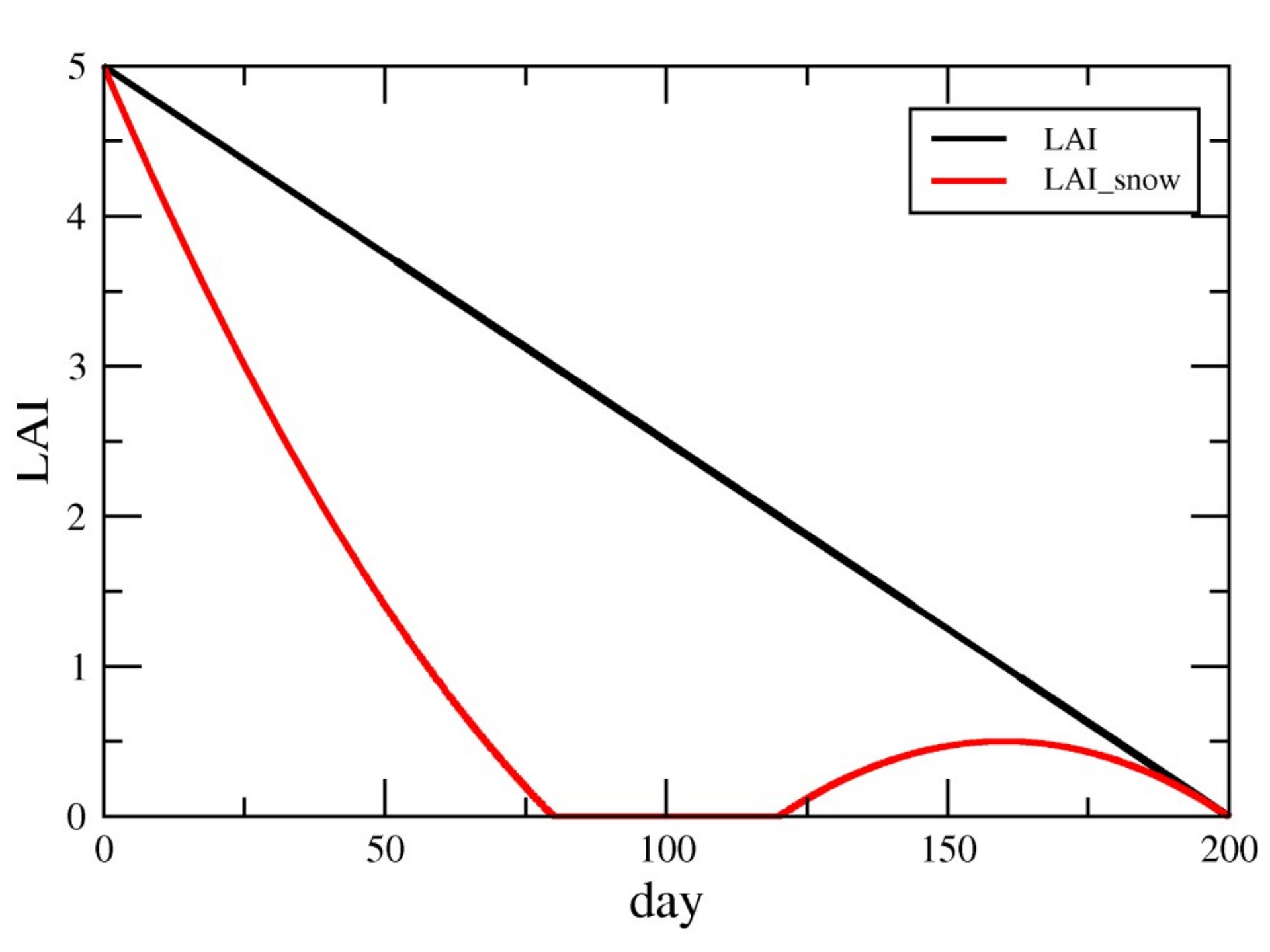


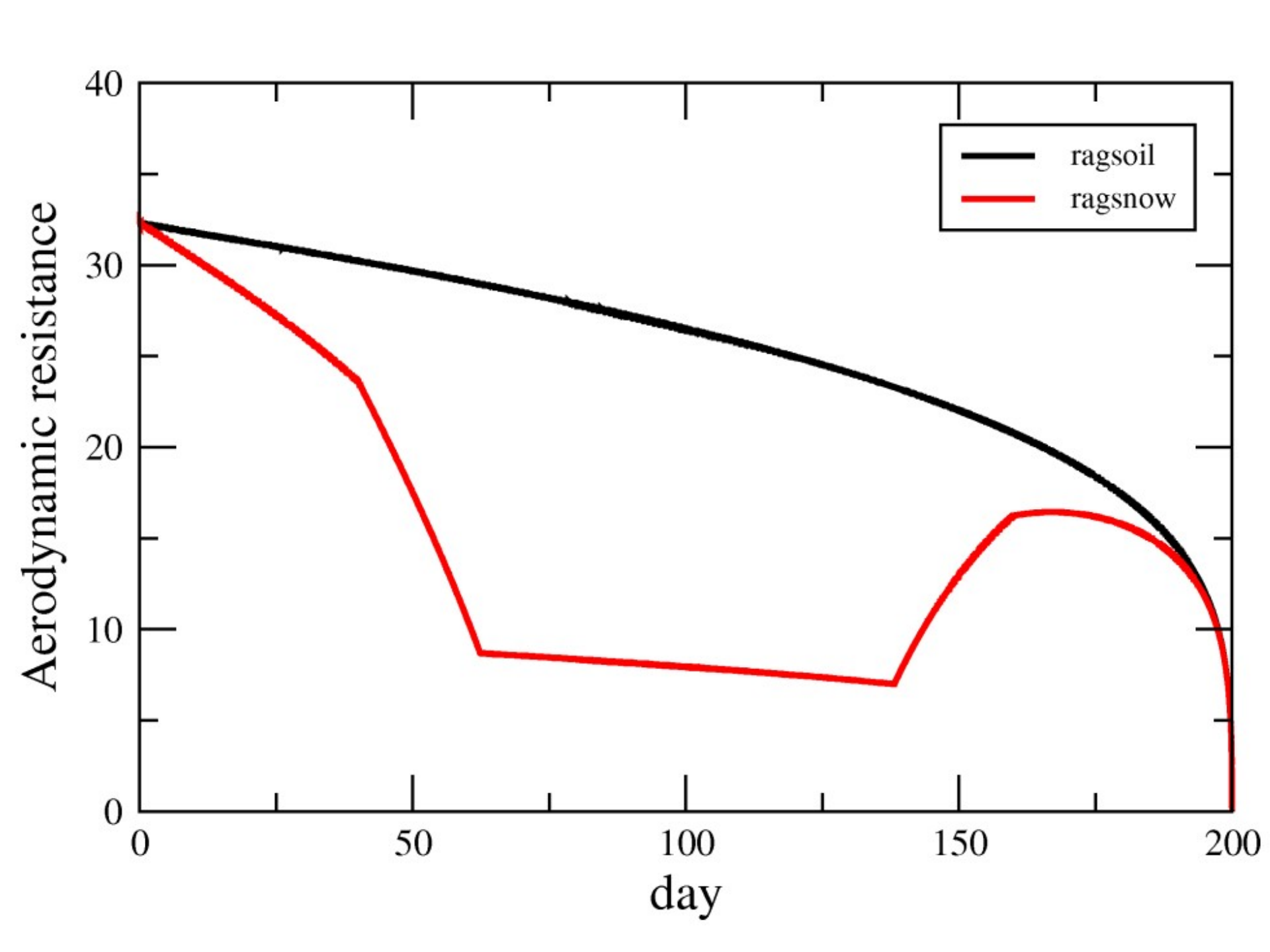
Let the snow vary counter-clockwise starting with figure e:

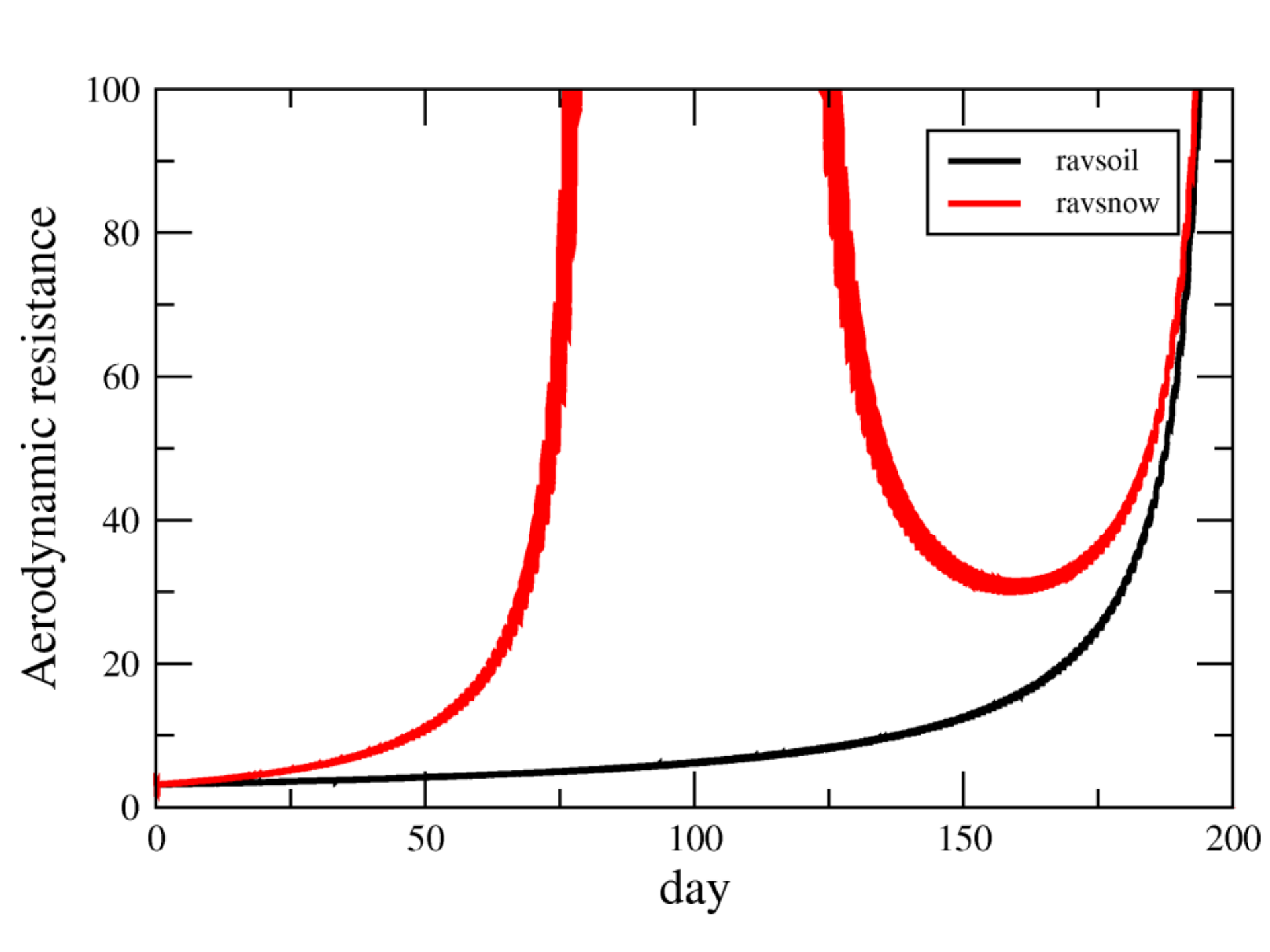
Dependent on the snow height and fraction we have different resistances:
(We don't allow for a completely snow covered ground, <95%)

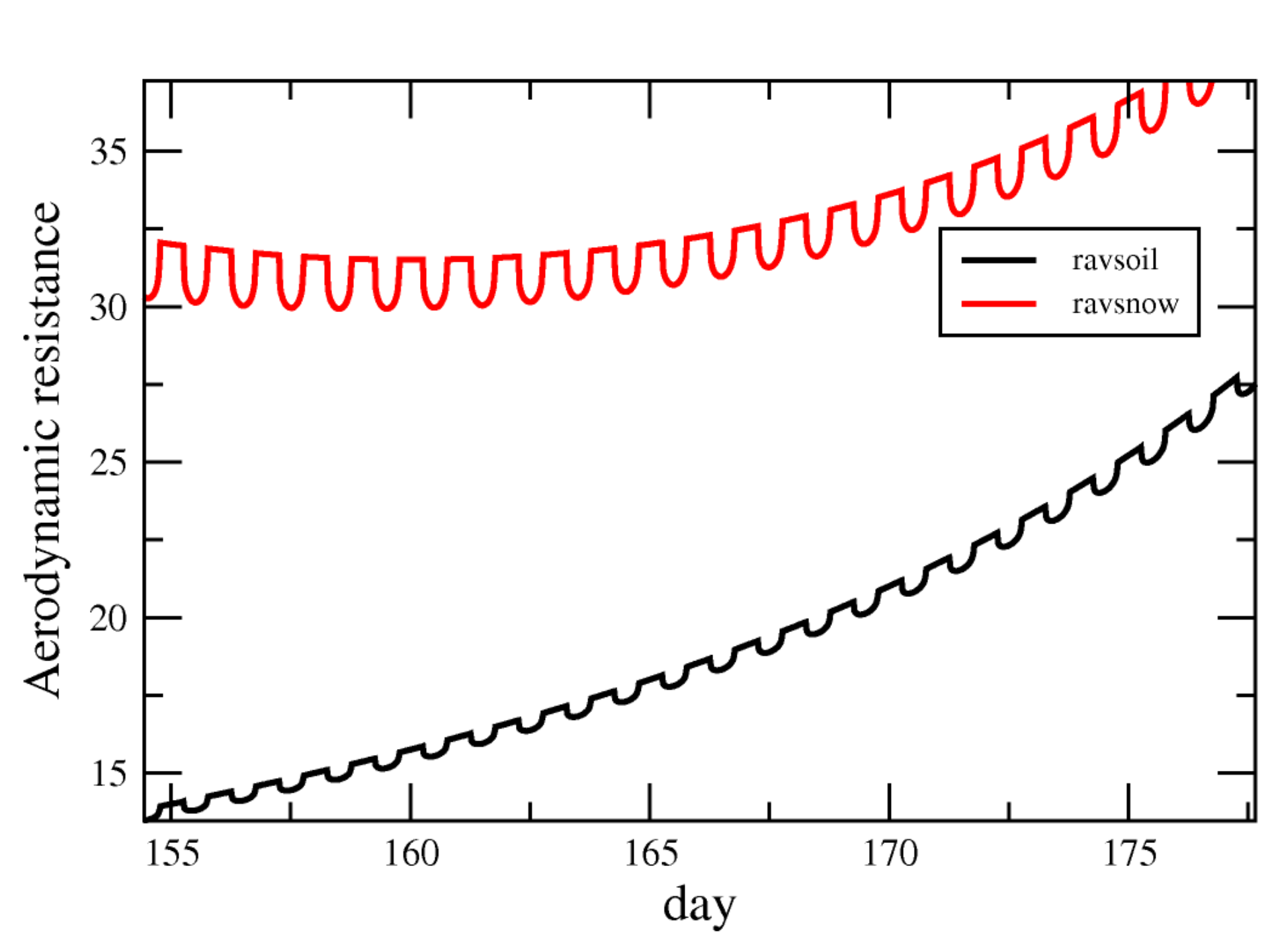


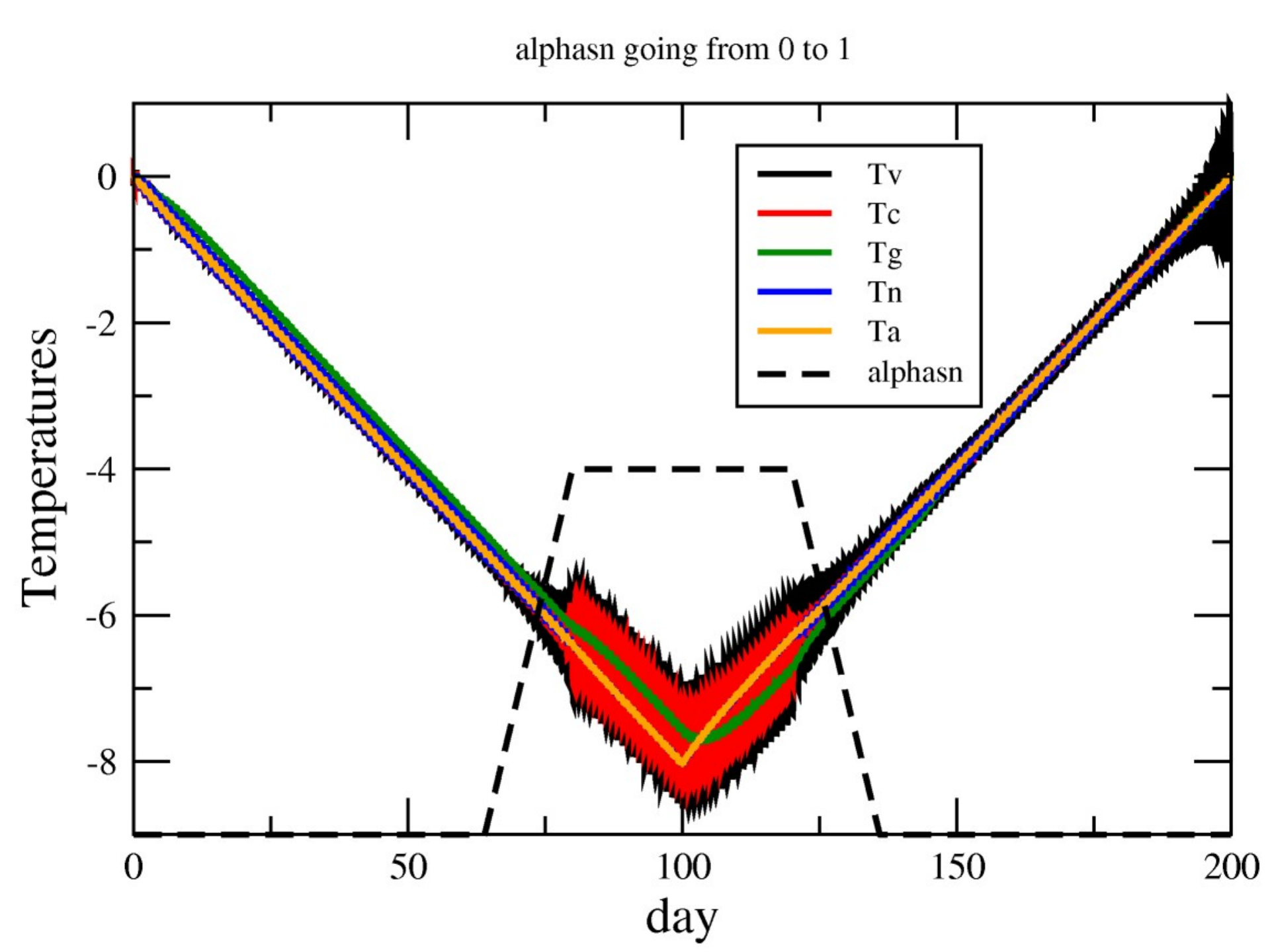
The resistances ravsoil and ragsoil are functions of the LAI, which in turn are dependent of the height above the snow (zcan_snow). Also the roughness lengths are dependent on zcan_znow, modifying ragsoil and ravsoil. We also define alphasn, a weight between double energy flux and direct flux from the snow.

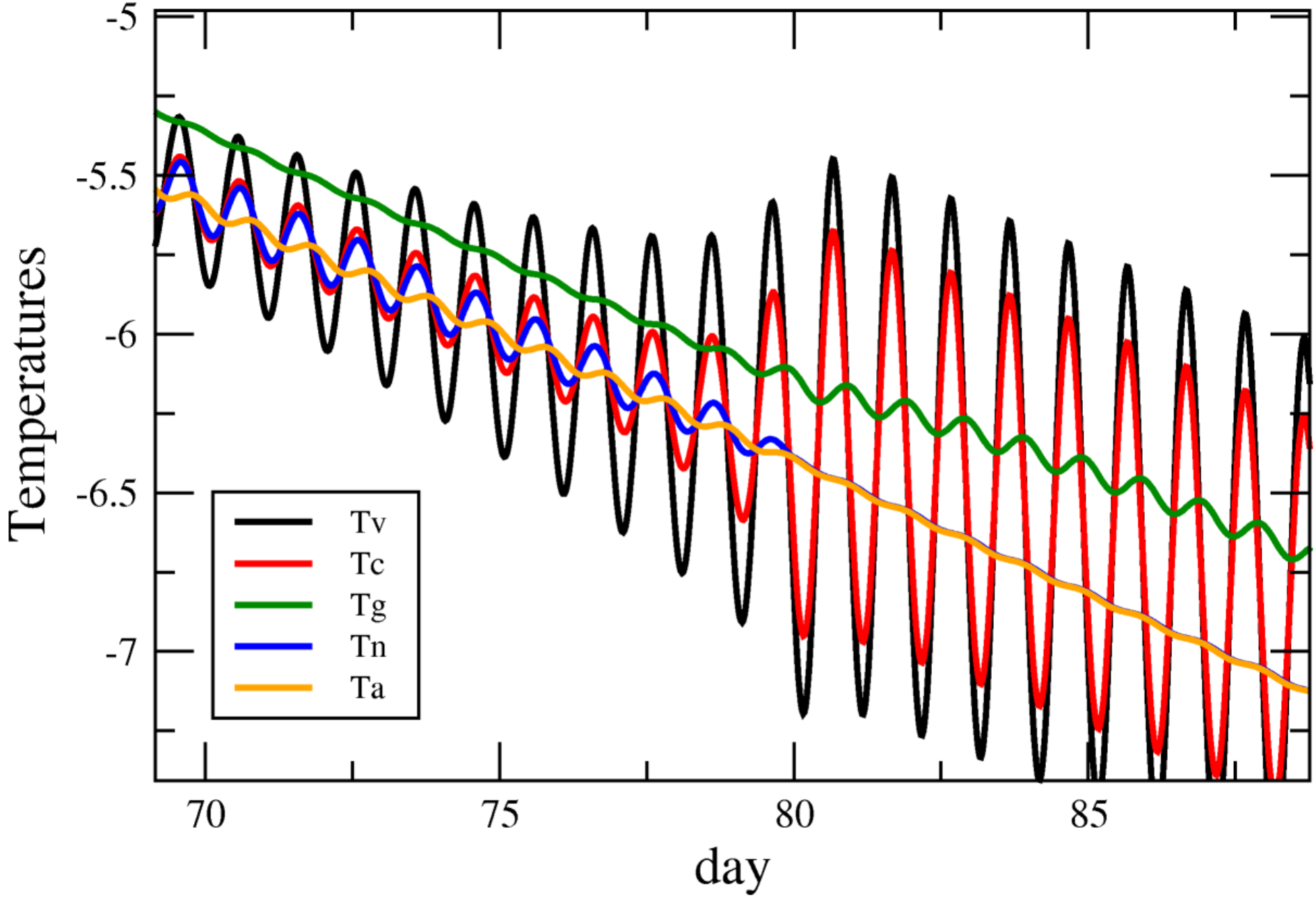

LAI
LAI_snow
LAI
day
0
1
2
3
4
5
0
50
100
150
200

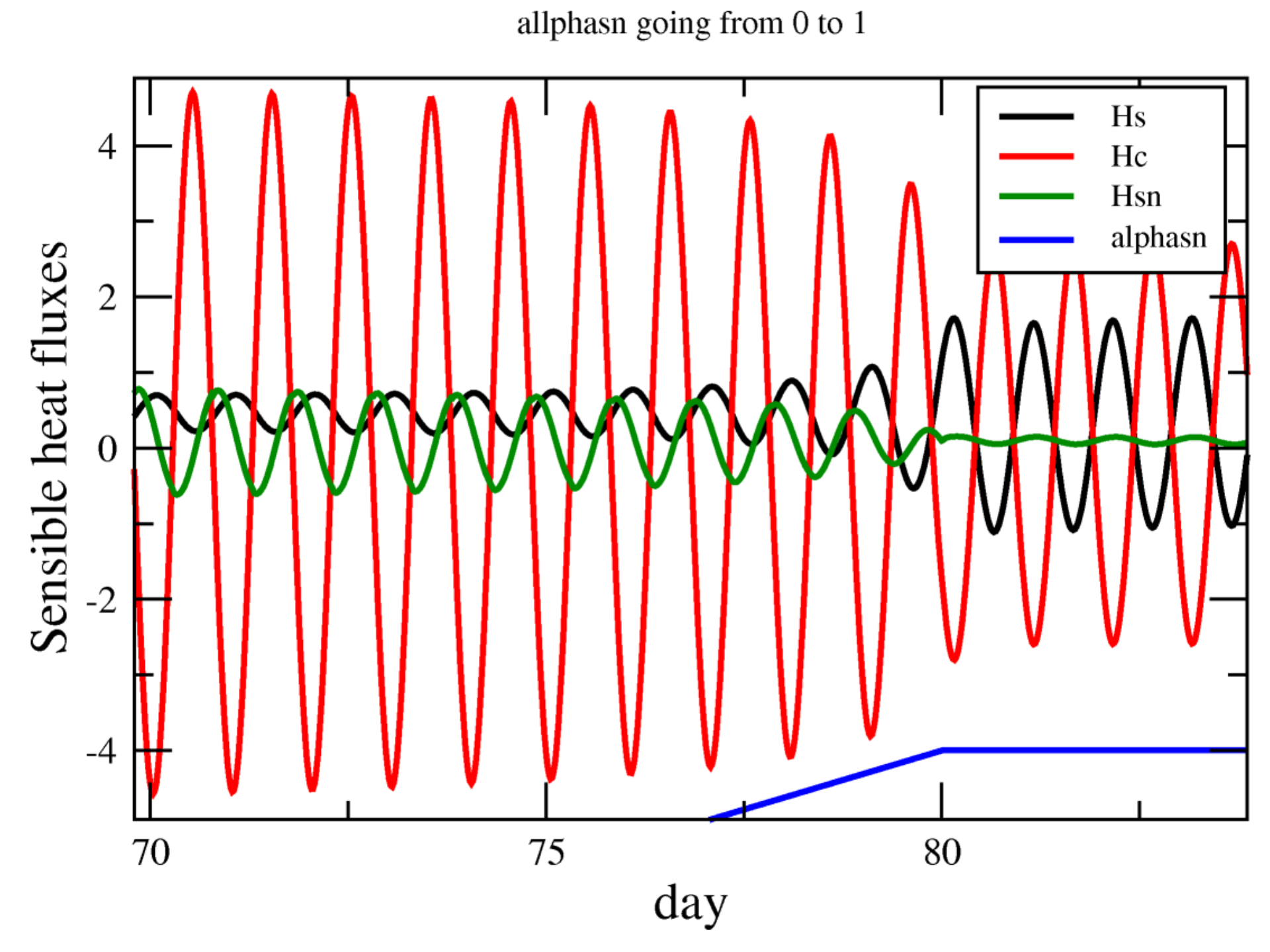

ragsoil
ragsnow
Aerodynamic resistance
day
0
10
20
30
40
0
50
100
150
200


Aerodynamic resistance
day
ravsoil
ravsnow
0
20
40
60
80
100
0
50
100
150
200


Aerodynamic resistance
35
30
25
20
15
155
160
165
170
175
day
ravsoil
ravsnow


alphasn going from 0 to 1
Tv
Tc
Tg
Tn
Ta
alphasn
Temperatures
0
-2
-4
-6
-8
0
50
100
150
200
day


-5
-5.5
-6
-6.5
-7
Temperatures
70
75
80
85
day
Tv
Tc
Tg
Tn
Ta


allphasn going from 0 to 1
Hs
Hc
Hsn
alphasn
Sensible heat fluxes
4
2
0
-2
-4
70
75
80
day

Conclusion:

This simple and partly unrealistic (no feedbacks with the atmosphere, no vertical diffusion and not varying ra, and no radiation included) indicates that:

With a careful formulation of resistances it is possible to describe a smooth transition between a double and a single energy balance, when the snow gradually covers the vegetation.

kiitos!