Parametrization of snow processes over complex landscapes

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Parametrization of:

• radiation balance of snow beneath discontinuous vegetation canopies

• topographic and vegetative control of snow redistribution

• heat fluxes to the atmosphere over discontinuous vegetation canopies

– enabled by LiDAR mapping of topography and vegetation

Sub-Canopy Radiation

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Sub-Canopy Radiation

Shortwave radiation $S_0(\theta,\varphi)$ and longwave radiation $L_0(\theta,\varphi)$ from sky element at elevation angle θ and azimuth φ.

Surface radiation at point (x,y) on level surface beneath vegetation with opaque, black canopy elements and gap fraction $\tau(x,y;\theta,\varphi)$:

$$S_{\downarrow} = \frac{1}{\pi}\int_0^{2\pi} d\varphi \int_0^{\pi/2} \tau\, S_0 \sin\theta\cos\theta\, d\theta$$

$$L_{\downarrow} = \frac{1}{\pi}\int_0^{2\pi} d\varphi \int_0^{\pi/2} [\tau\, L_0 + (1-\tau)\sigma\, T_c^4]\sin\theta\cos\theta\, d\theta$$

Divide shortwave radiation into direct and diffuse, assume homogeneous sky radiation, effective canopy temperature $T_{c,\mathrm{eff}}$:

$$S_{\downarrow} = f_v S_{\mathrm{dif}} + \tau\, S_{\mathrm{dir}} \qquad L_{\downarrow} = f_v L_0 + (1-f_v)\sigma\, T_{c,\mathrm{eff}}^4$$

f_v – sky-view factor

Canopy Characteristics

Transmissivity and sky view can be:

- measured optically (hemispherical photography, LAI-2000, radiometer array)
- simulated by ray-tracing
- related to leaf-area index

For homogeneous canopy ("green smear"), $\tau = \exp\left(-\frac{G(\theta)}{\cos\theta}\Omega\Lambda\right)$

$G(\theta)$ – projection function (orientation of canopy elements)

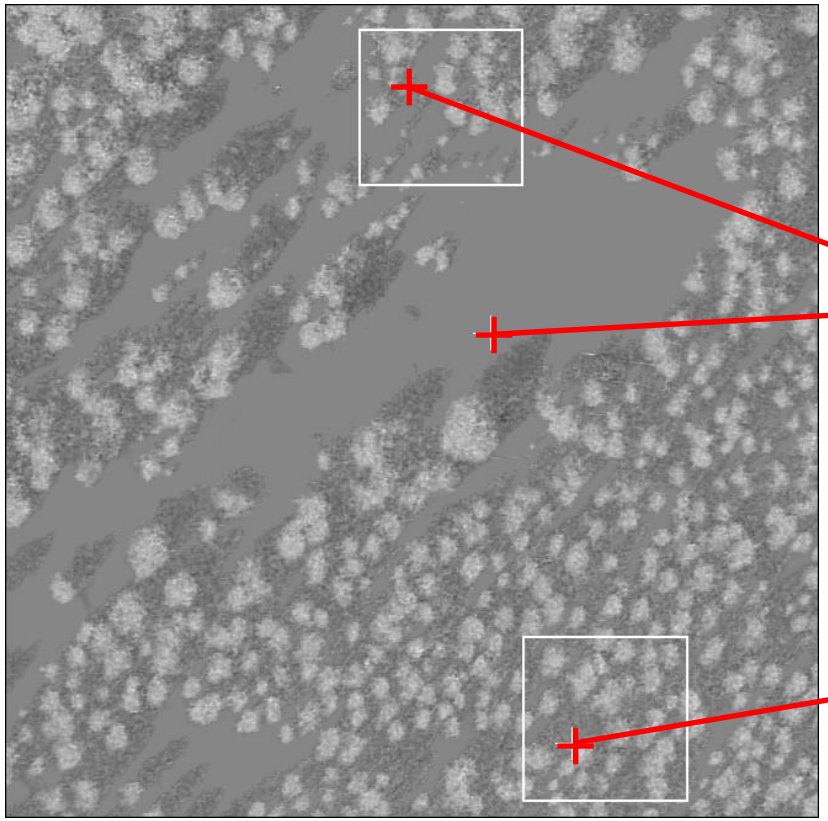
Ω – clumping factor

Λ – leaf-area index

In practice, fit to $G(\theta) = a + b\cos\theta + c\sin\theta$

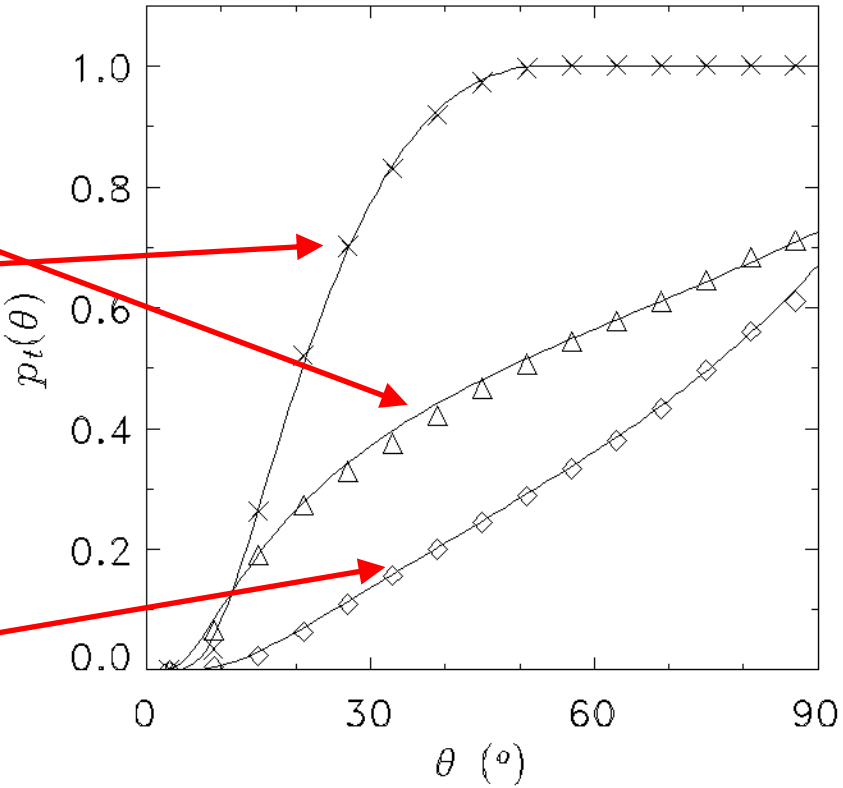
Gap Fractions in Discontinuous Canopy

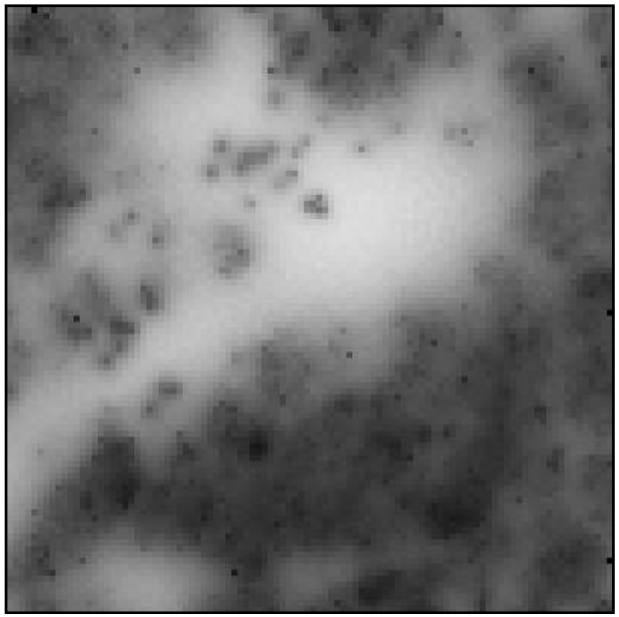
CLPX LSOS NDVI



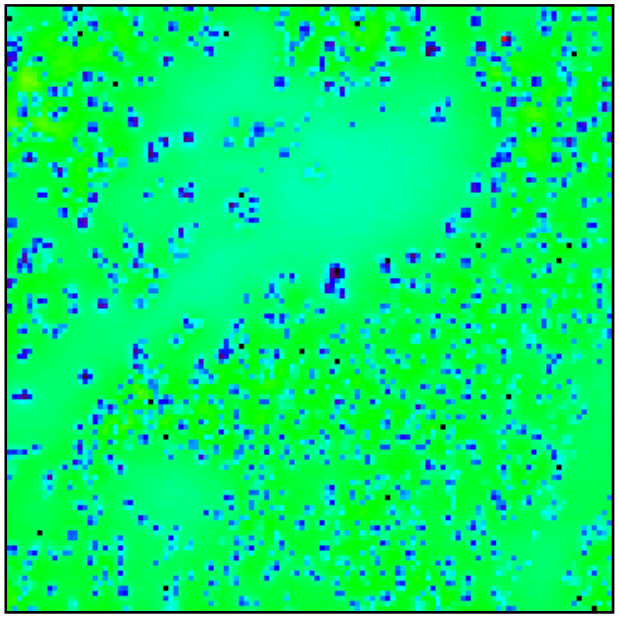
100 m

Gap fraction





f_v



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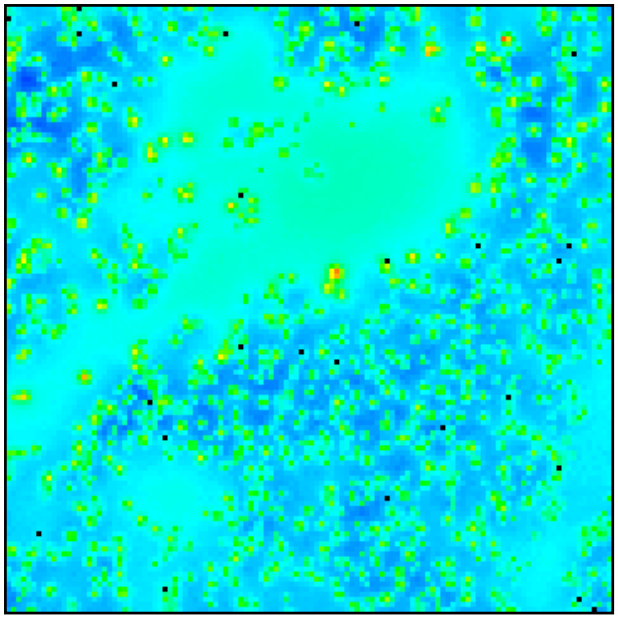

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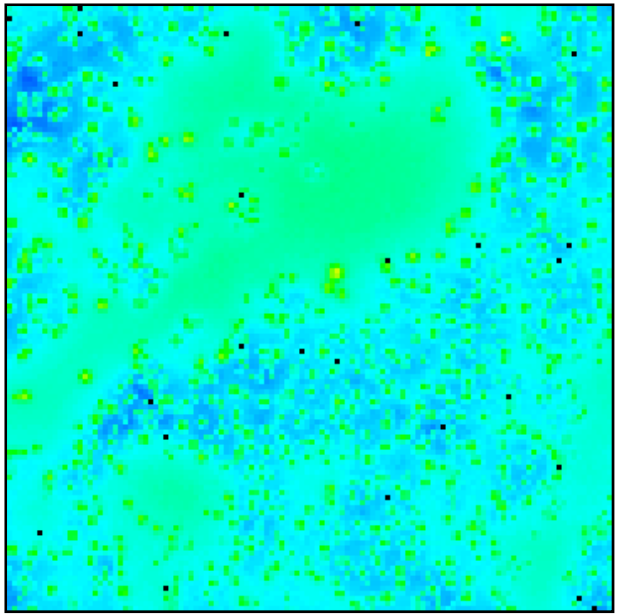
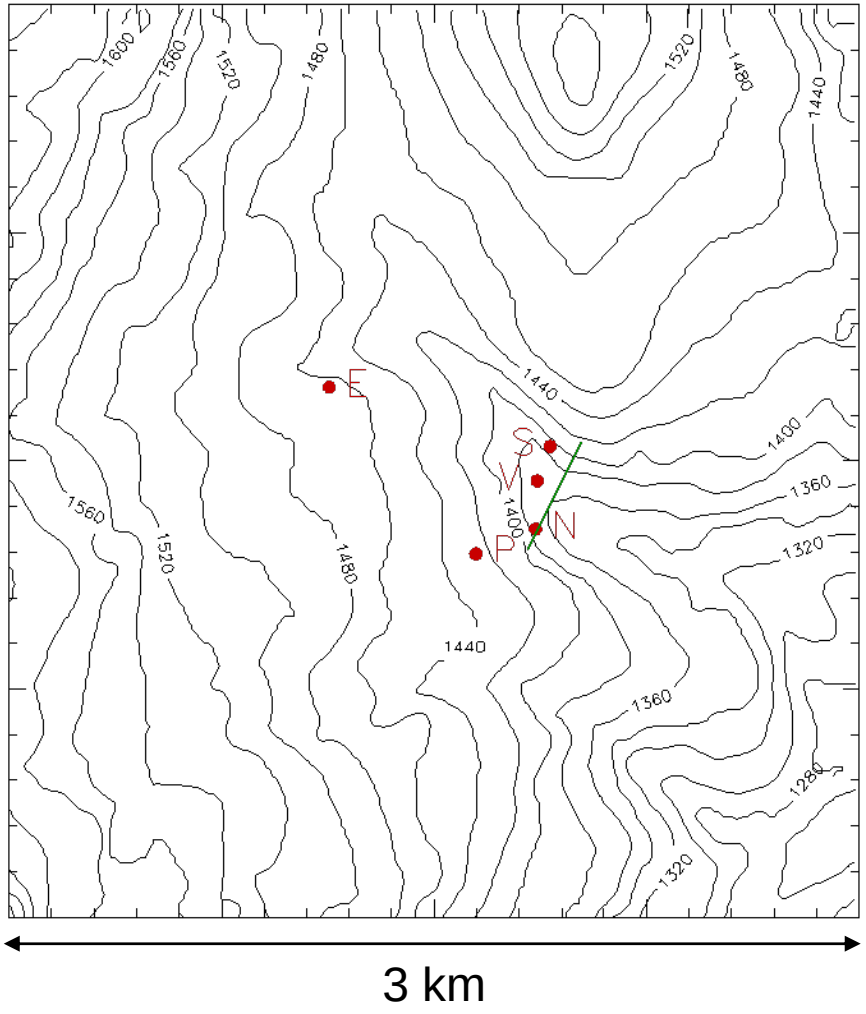
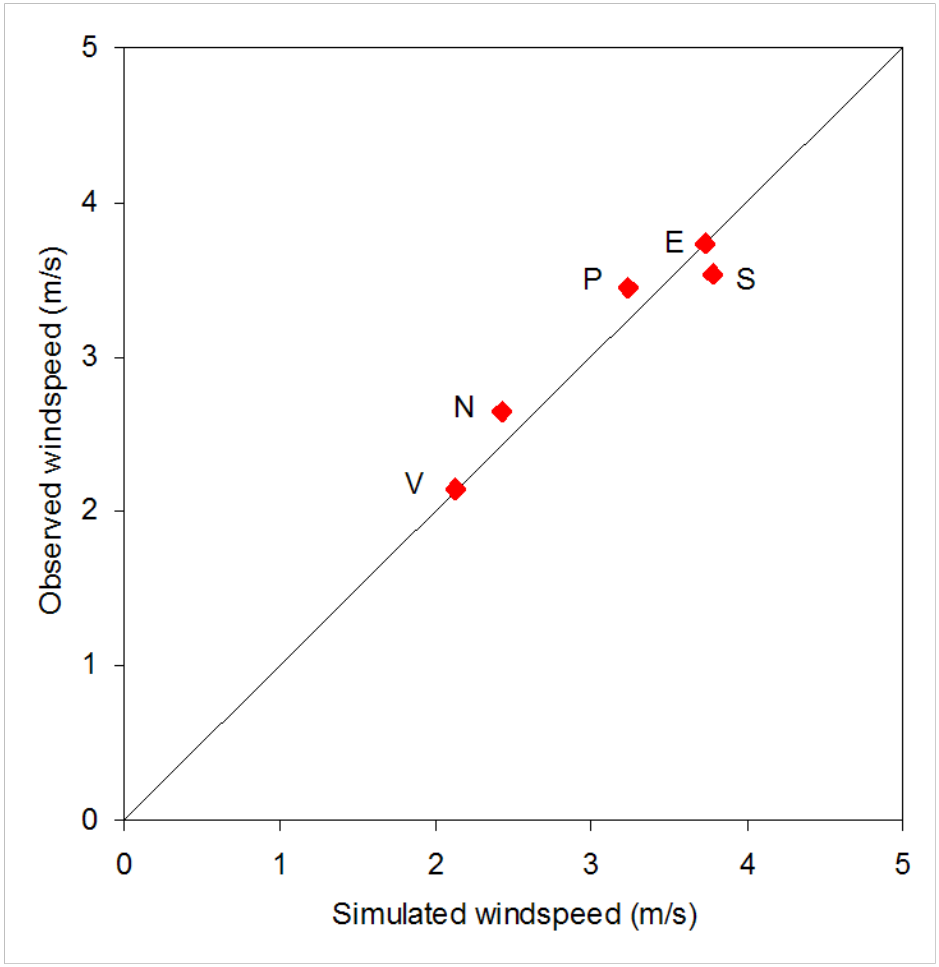


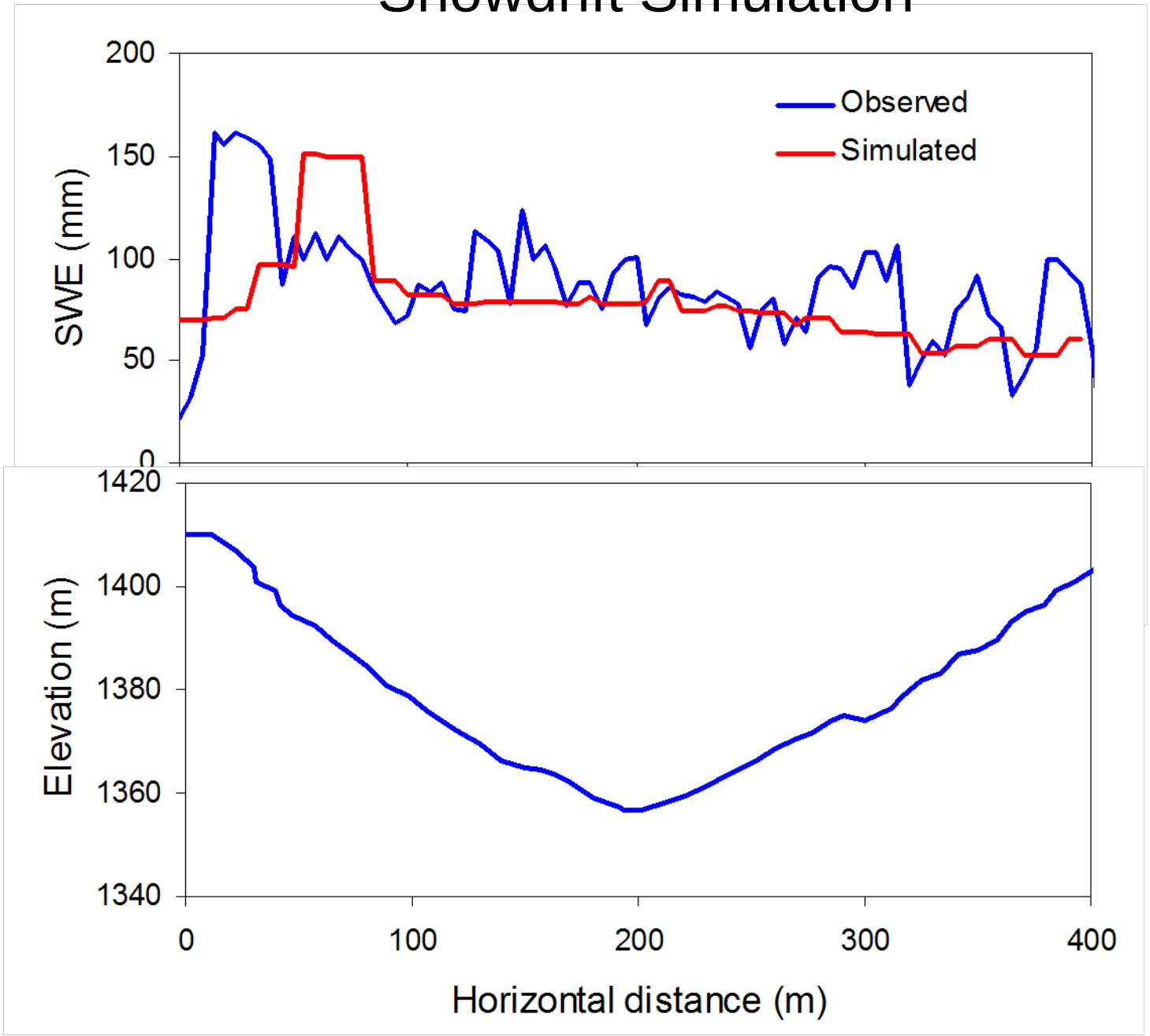
c

Windflow Simulation

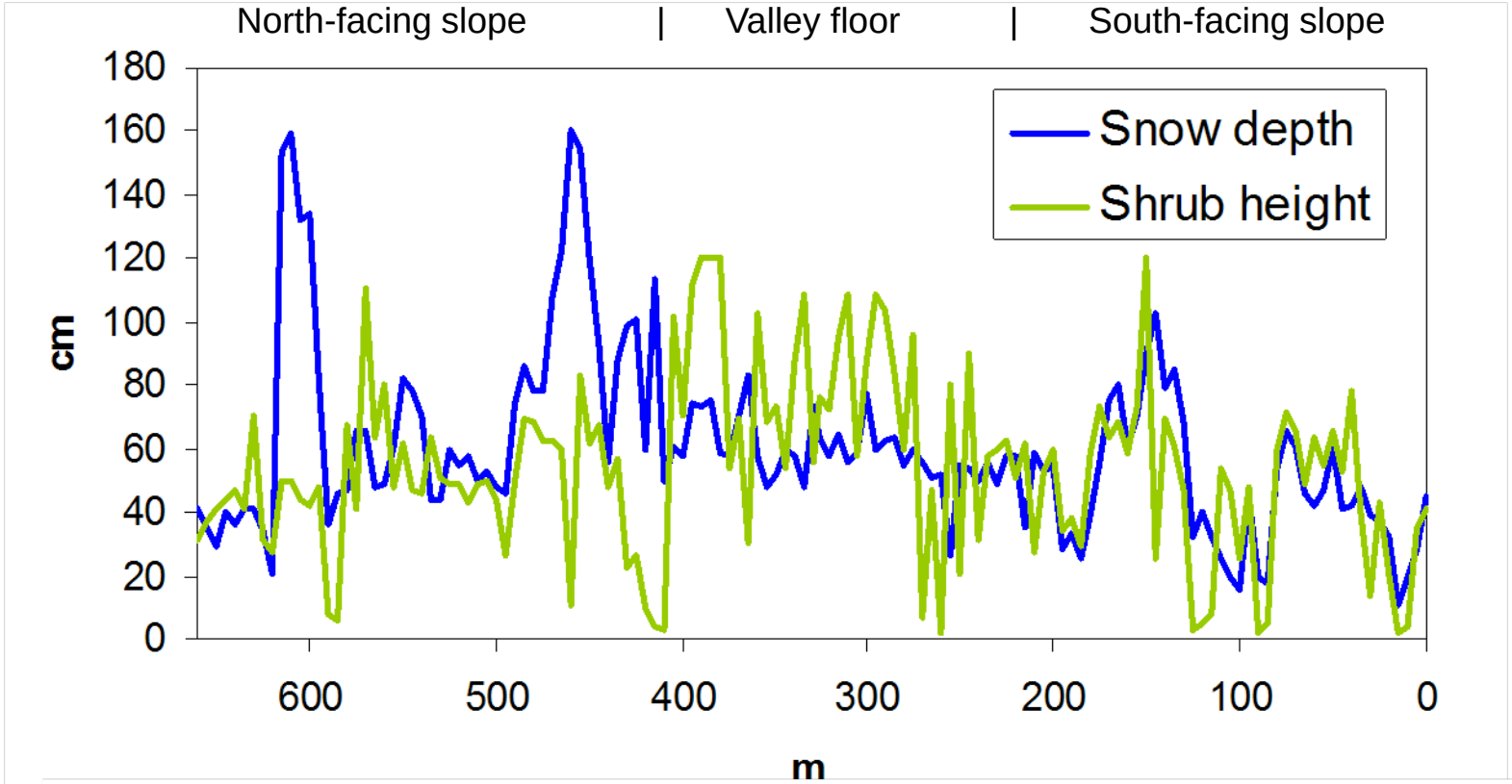


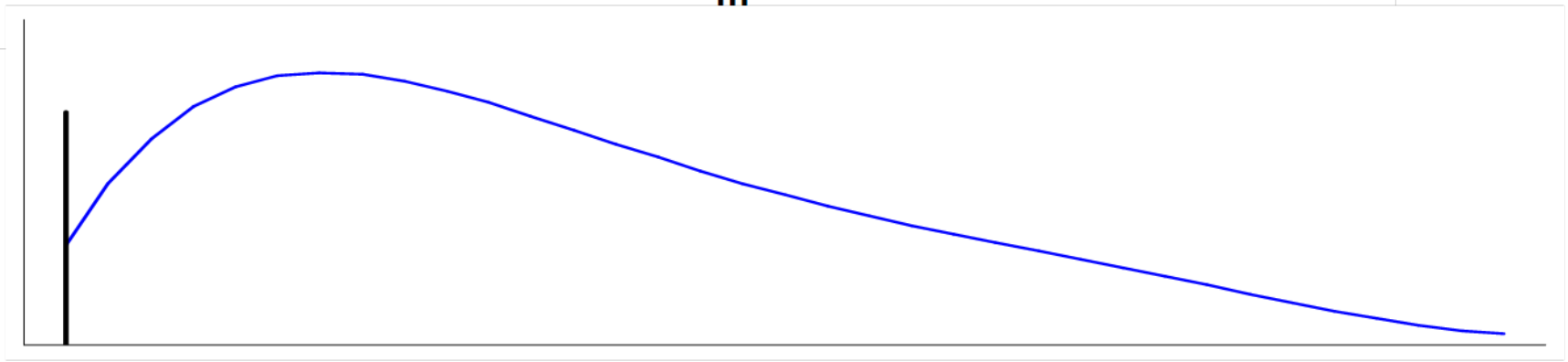


Snowdrift Simulation



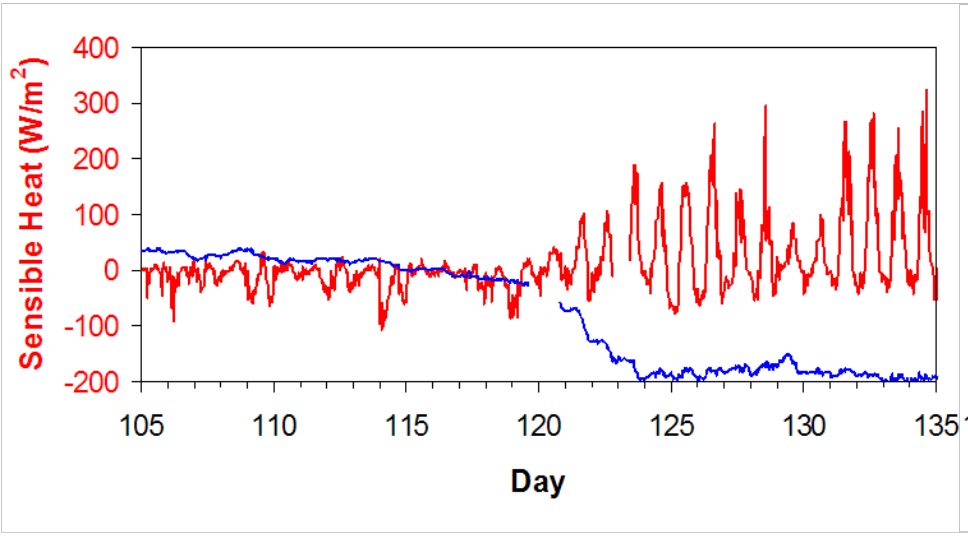
Snow and Shrubs

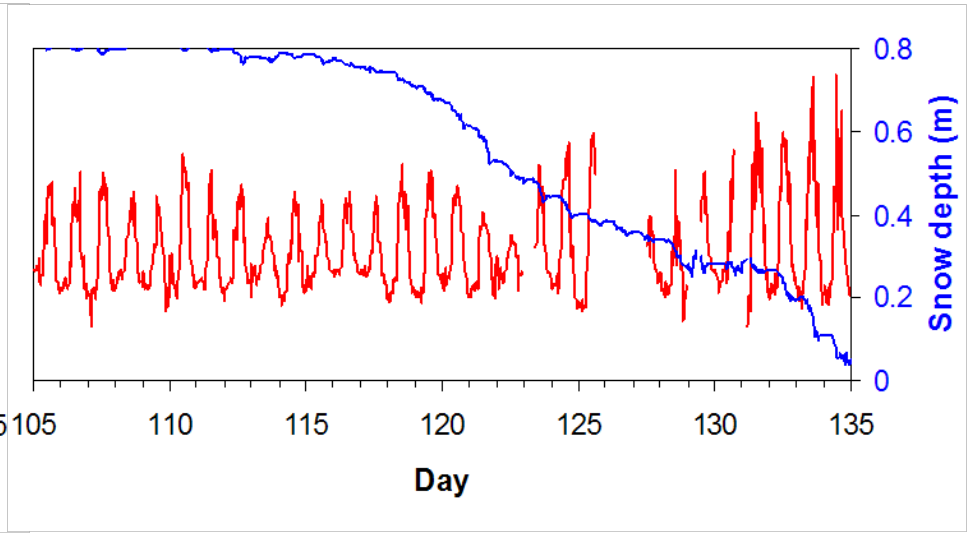




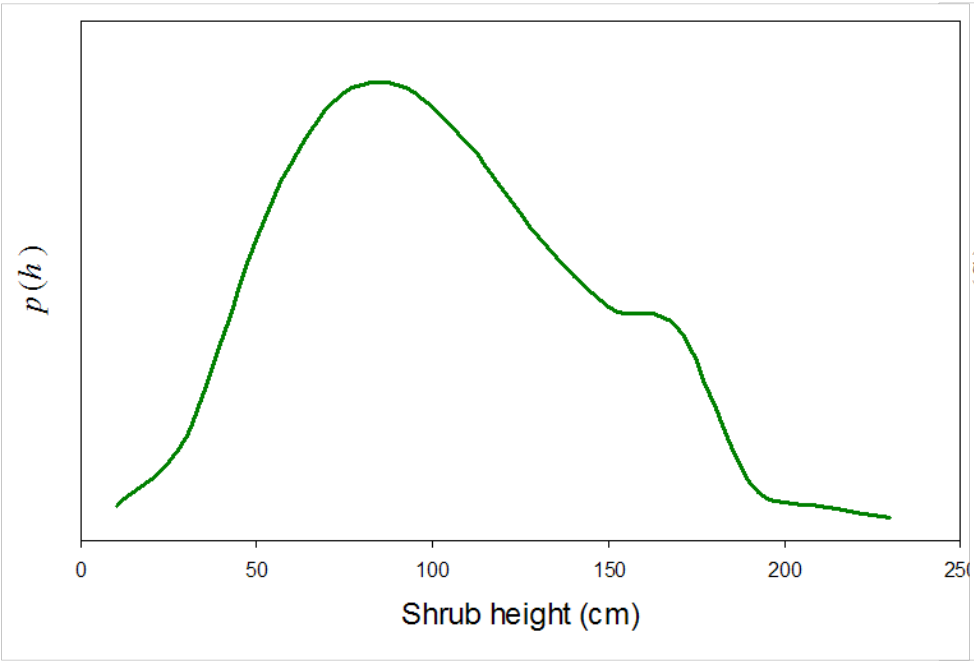
Plateau

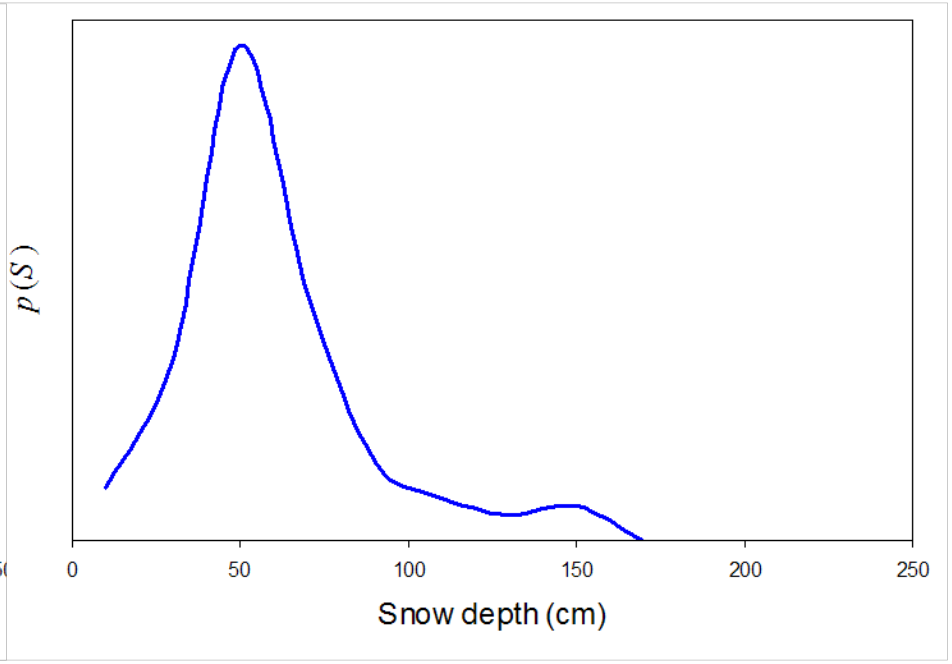
Valley





SWE and Shrub Distributions





Snowcover depletion curve $f_s(SWE) = \int_0^{\infty} dM \int_0^{M} dS\ p(S,h)$

Shrub exposure curve $v(SWE)$?

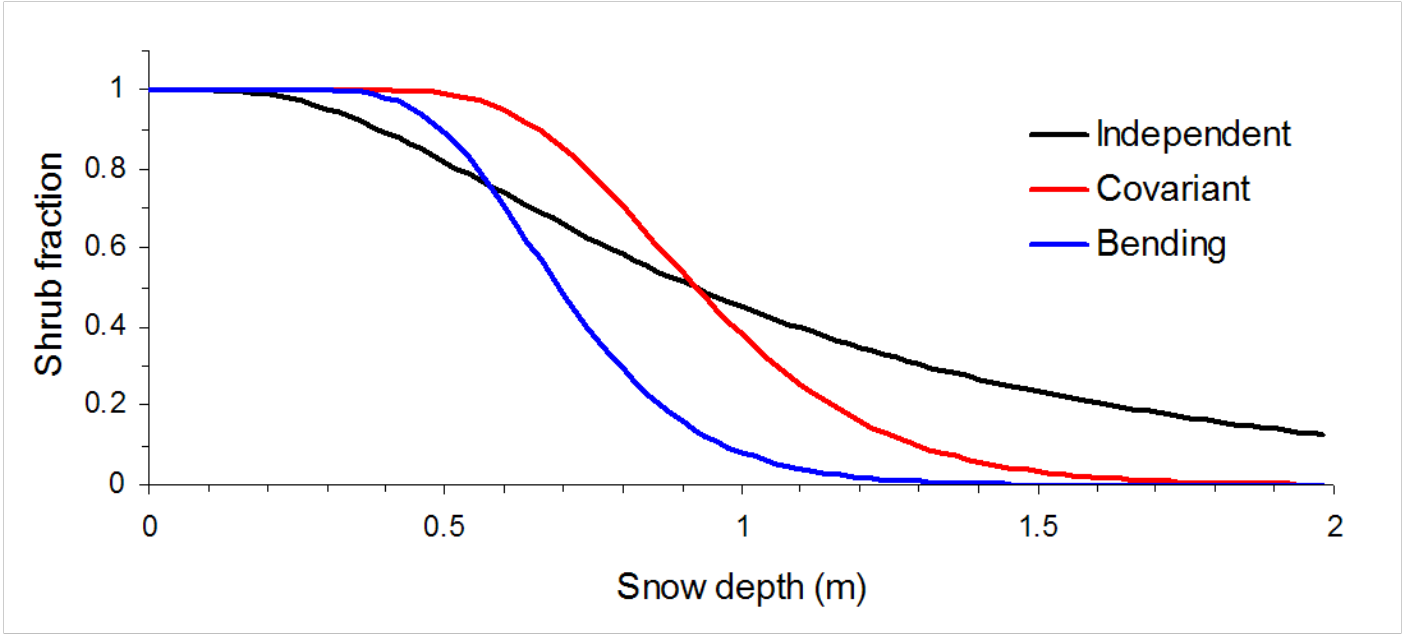
Shrub Burial

No bending

$$v = \int d\mathbf{r}\,\theta(h - S) = \int_0^\infty dh \int_0^h dS\; p(S,h)$$

Bending by critical mass $S_c(h)$

$$v = \int d\mathbf{r}\,\theta(h - S)\theta(S_c - h) = \int_0^\infty dh \int_0^{S_c(h)} dS\; p(S,h)$$



Shrub Exposure Experiment

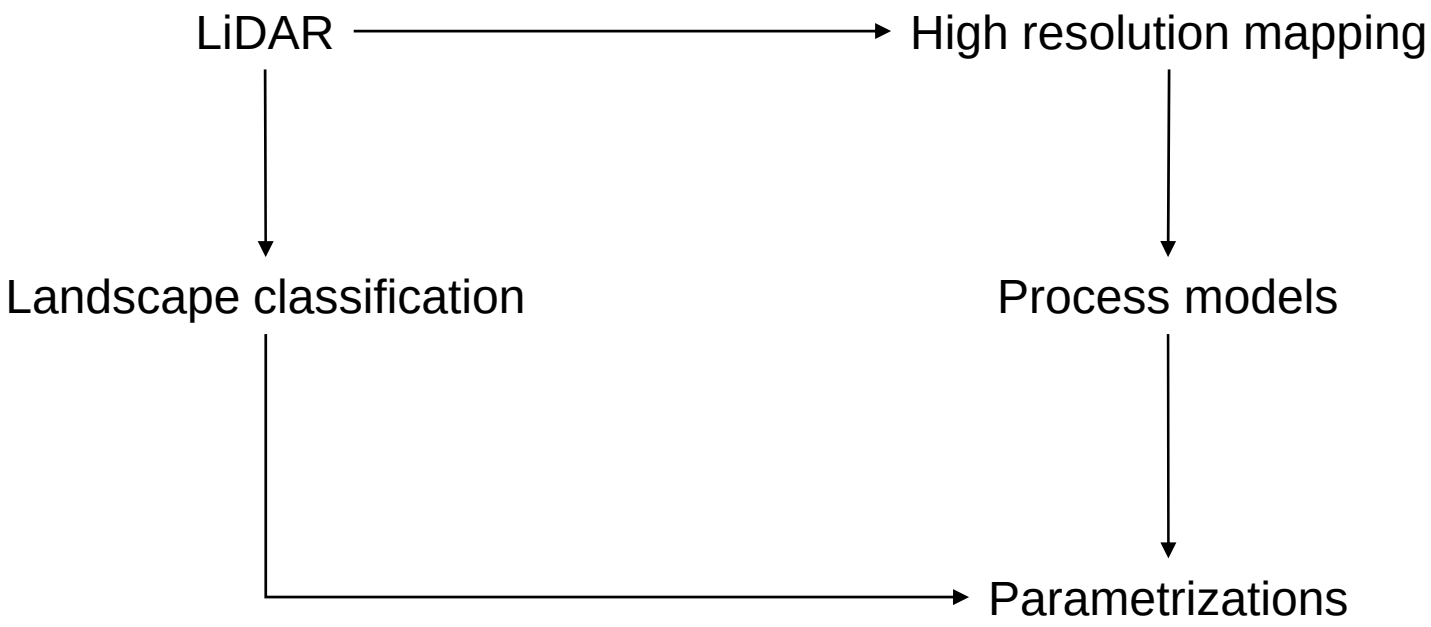
SWE(x,y) from USDGs assimilated into distributed melt model

Shrub heights $h(x,y)$ from lidar
(and species from classified imagery? – Carey student project)

Exposure timeseries $v(x,y,t)$ from photogrammetry
(new automatic cameras or archive photographs with ground control points? – Quinton student project)

Hemispherical photography on snow survey transects – repeat snow-free and with snow

Summary


LiDAR
High resolution mapping
Landscape classification
Process models
Parametrizations