FINNISH METEOROLOGICAL INSTITUTE

The effect of snow on boreal forest albedo

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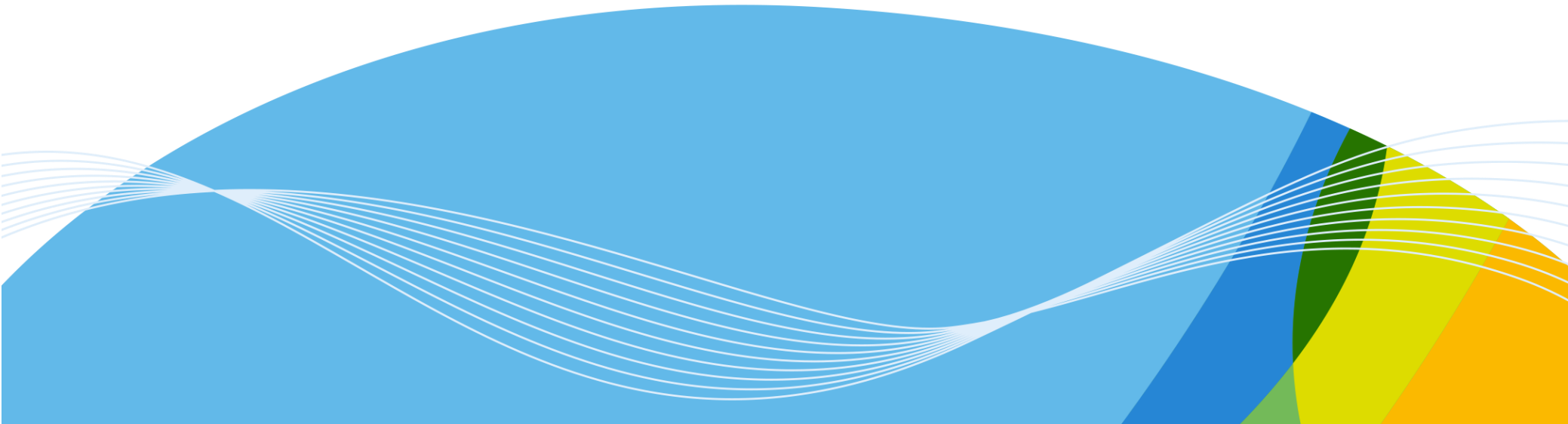
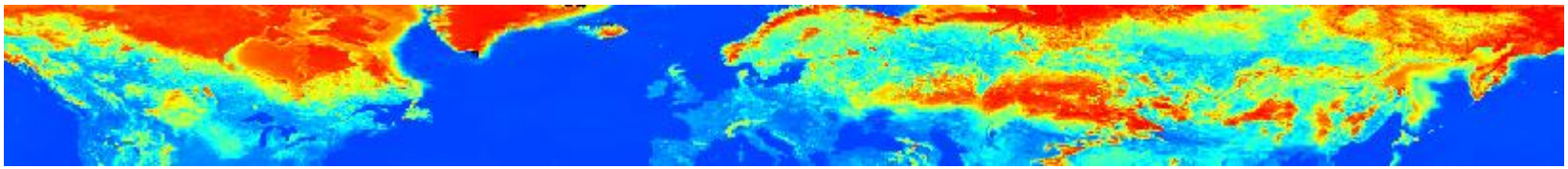


Surface albedo

- Surface albedo = the fraction of incoming solar radiation reflected hemispherically by the surface
- The surface albedo is an essential climate variable (ECV)
  - it is an indicator of climate change
  - changes in albedo will affect the climate



Surface albedo CLARA-A2-SAL, March 2010, (Anttila et al., 2017)

Surface albedo CLARA-A2-SAL, June 2010, (Anttila et al., 2017)

Effect of snow on boreal forest albedo

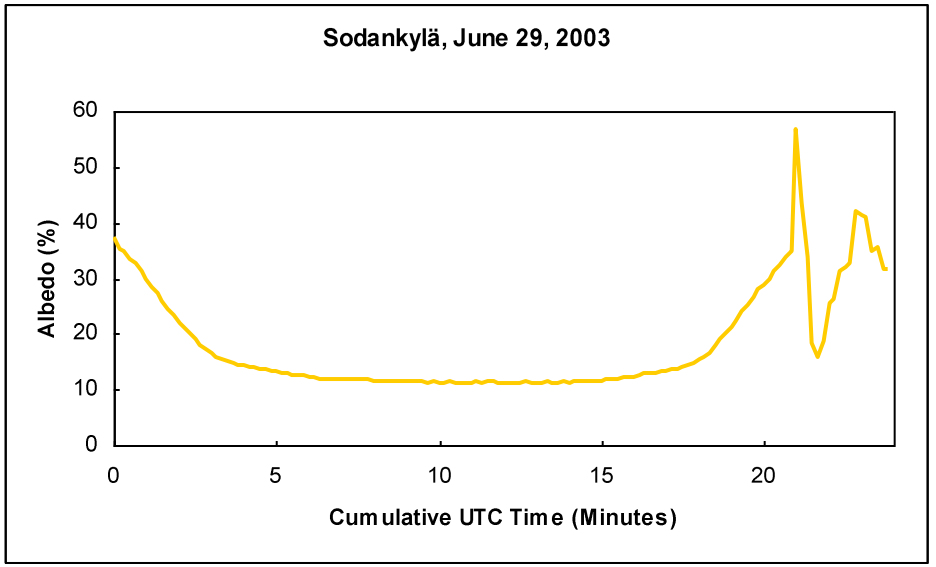
- In snow free conditions the coniferous forest albedo is ~12 %
- The pure snow albedo is in midwinter ~85%
- In snow covered conditions the albedo of forested area varies with the density of the forest and the snow properties (albedo)
- In a case of crown snow-load (’tykky’) even the structure of the canopy changes and snow dominates completely

Photo: Wikimedia commons by **Muu-karhu**

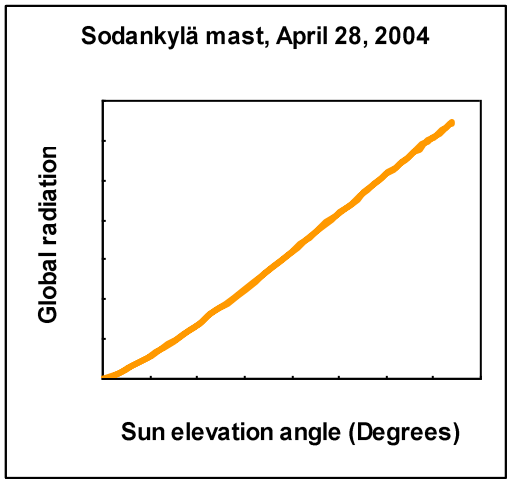
Effect of snow on forest albedo

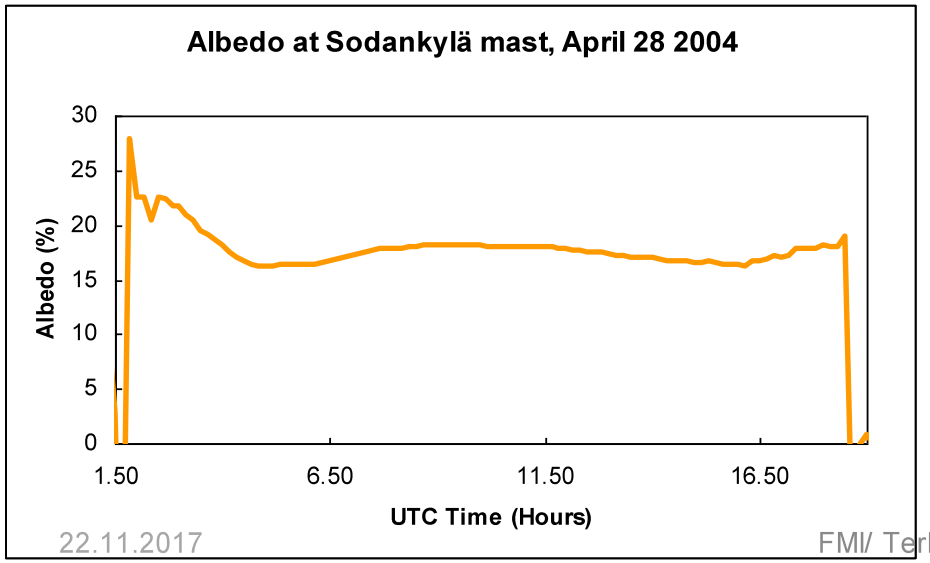
- Snow on the forest floor:
  - The snow on the forest floor causes single scattering without canopy interaction and multiple scattering between canopy and forest floor
- Diurnal variation:
  - Without snow on the forest floor the midday albedo is smallest
  - With snow on the forest floor the midday albedo is a local maximum
  - The relative error of not taking the snow into account can be ~40%

Diurnal variation of boreal forest albedo in summer



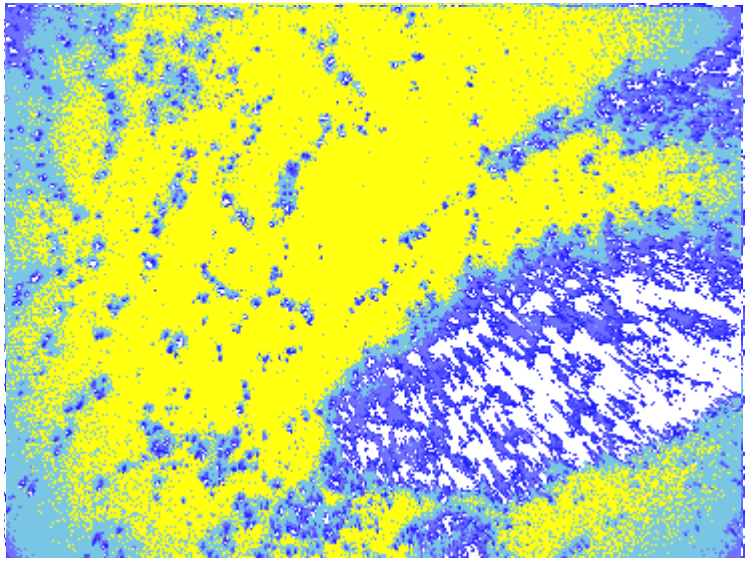
Diurnal variation of boreal forest albedo in winter





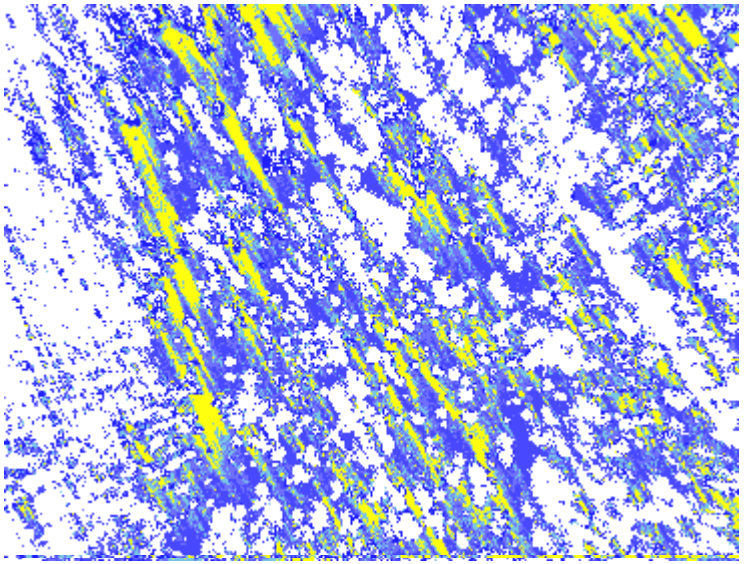
Unsupervised classification of the forest floor, cloudy sky

- 8 classes: three for canopy (white), 5 for forest floor
- Highest snow reflectance class
- Lowest snow reflectance class



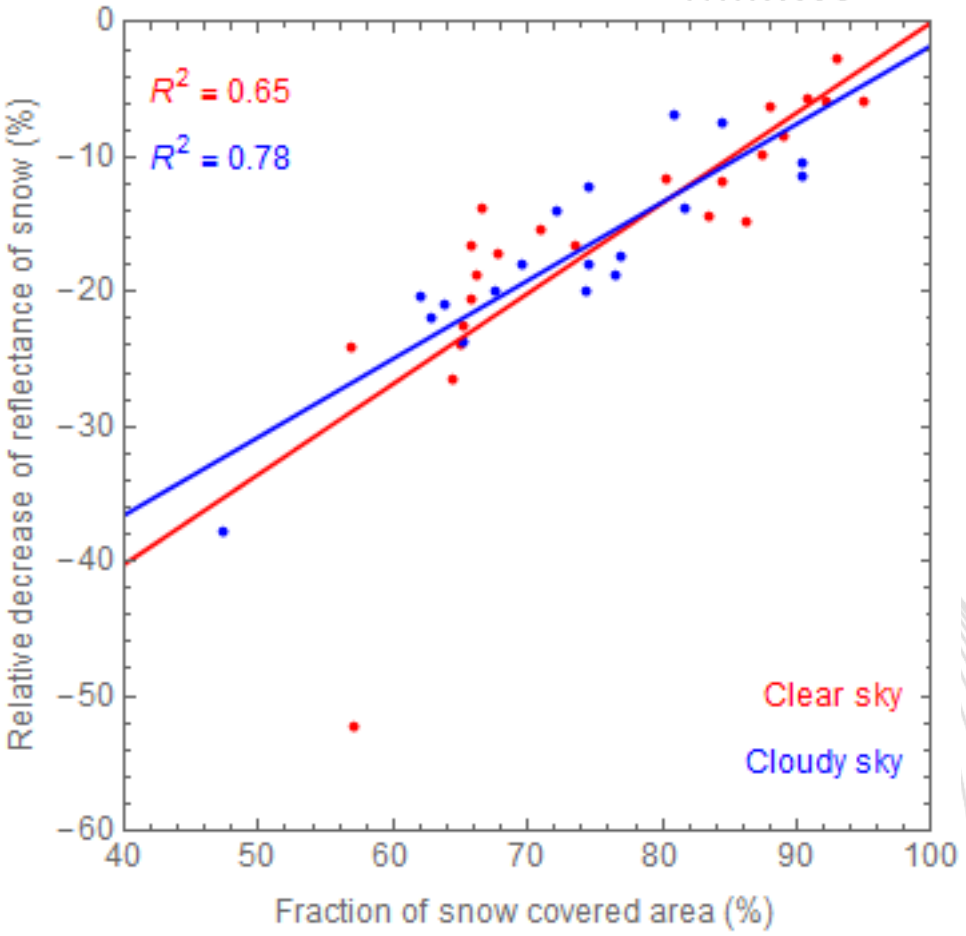
Unsupervised classification of the forest floor, clear sky

- 8 classes: three for canopy (white), 5 for forest floor
- Highest snow reflectance class
- Lowest snow reflectance class



Effect of not taking into account multiple scattering from forest floor and canopy

18 cloudy images,
23 clear sky images



Black sky forest albedo

Only forest floor scattering α_{tt}

Only canopy scattering α_s

Multiple canopy and forest floor scattering, last reflection from the floor α_{st}

Multiple canopy and forest floor scattering, last reflection from the canopy α_{ss}

$$\alpha = \alpha_{tt} + \alpha_s + \alpha_{st} + \alpha_{ss}$$

$$\alpha_{tt} = k\alpha_b t_0^2 + (1-k)\alpha_b t_0 t_1$$

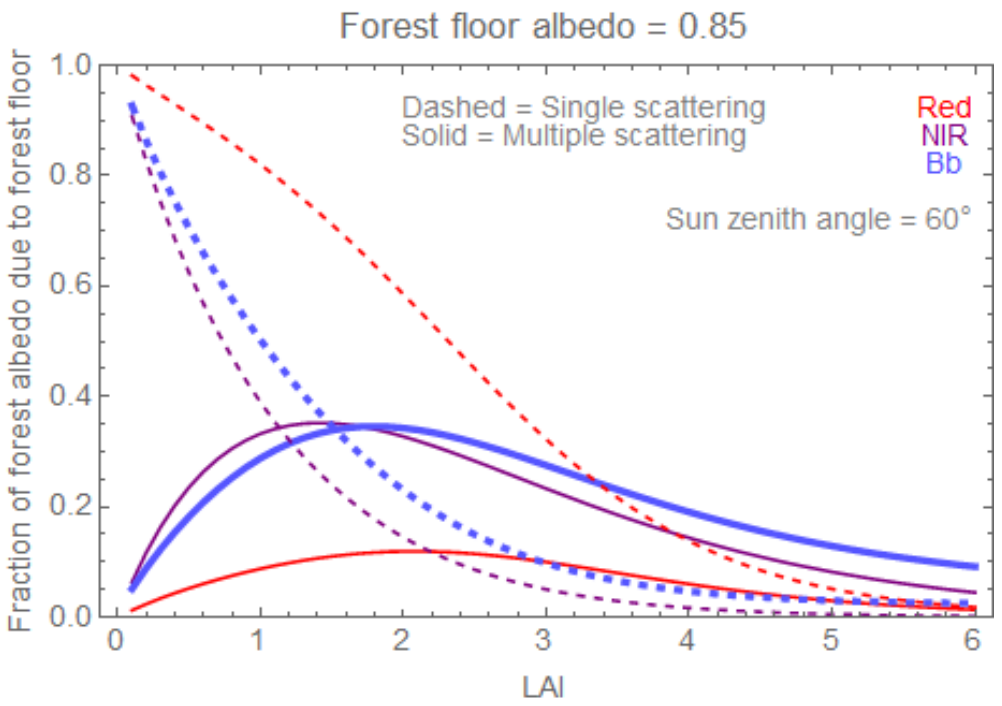
$$\alpha_s = q(1-t_0)\frac{\omega_L - p\omega_L}{1-p\omega_L}$$

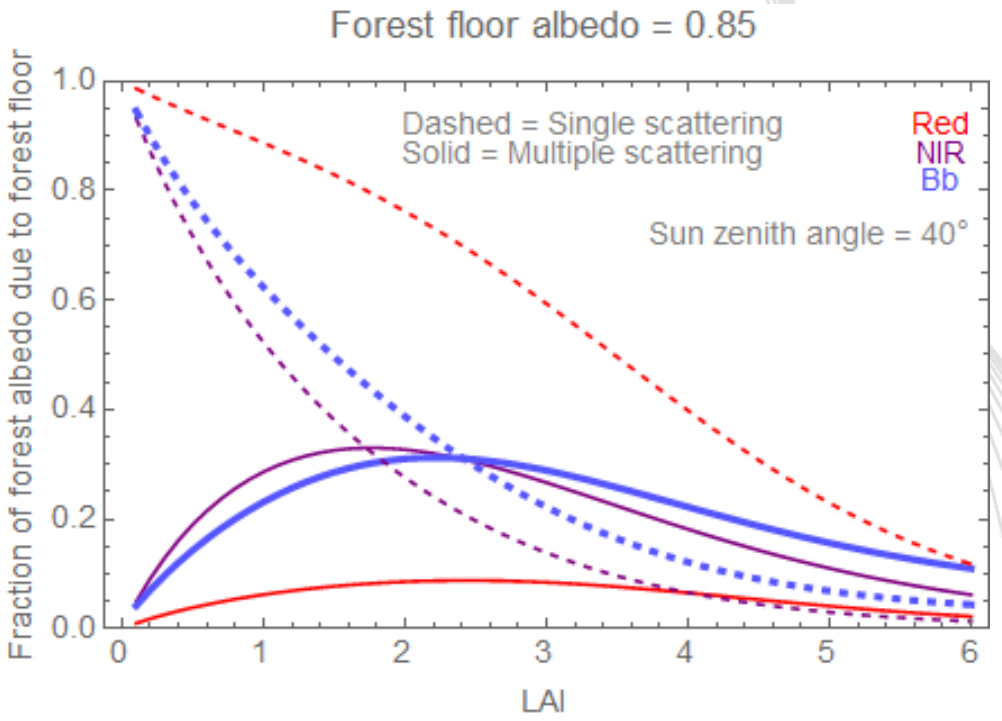
$$\alpha_{st} = \alpha_b(1-q_b)\left[t_0(1-t_0) + (1-k)t_0(1-t_1)\right]\frac{\omega_L - p\omega_L}{1-p\omega_L}$$

$$\alpha_{ss} = \left\{\alpha_b\left[(1-q)(1-t_0) + q_b\alpha_b t_0\left[(1-t_0) + (1-k)(1-t_1)\right]\frac{t_1(1-\omega_L + q_b\omega_L - q_b p\omega_L) + (1-q_b)(\omega_L - p\omega_L)}{1-p\omega_L - q_b\alpha_b(1-t_1)(\omega_L - p\omega_L)}\right\}\right.$$
$$\left.\cdot\frac{\omega_L - p\omega_L}{1-p\omega_L}\right.$$

Manninen and Stenberg, AFM 2009

Fraction of total forest albedo due to snow





Importance of snow/forest albedo

- The snow cover has a marked effect on the albedo also in coniferous forests: 12 % -> 22 % (LAI ~2.5)
- If the length of the snow covered season decreases and snow melts earlier due to climate change, the albedo of forested areas becomes lower earlier in spring, which enhances the climate change.

- The coniferous canopy has a marked effect on the snow covered area albedo: 85 % -> 22 % (LAI: 0 -> 2.5)
- If the northern forest edge moves further north due to the climate change, the winter time albedo will decrease markedly, which will enhance the climate change.

Thank you for your attention!