Improved Crocus snow reflectance

Kristian Pagh Nielsen (1), Gabriel Stachura (2), Ulrika Willén (3) and Patrick Samuelsson (3),

(1) Danish Meteorological Institute, Copenhagen, Denmark
(2) Institute of Meteorology and Water Management, National Research Institute, Poland
(3) Swedish Meteorological and Hydrological Instiute, Norrköping, Sweden

Abstract

Absorbed solar irradiance is the primary energy source to the Earth system. Most incoming solar irradiance is absorbed at the surface. Here, particularly deviations in the snow reflectance can cause errors.

We study the impact on the snow itself and the atmospheric surface fields. We use the generalized surface scheme SURFEX, in which different variants of the Crocus snow albedo scheme can be chosen. The Crocus albedo scheme is used in some weather and climate models, and in detailed offline snow simulations. We find that the spectral coupling to the atmospheric radiation is of particular importance.

We show that the current default parametrization leads to a positive bias in the reflectance. Correcting this not only leads to a higher surface temperatures but also causes positive feedback effects that enhances the snow melt further.

Crocus snow albedo

Spectral band	Albedo α	Absorption coefficient β (m^{-1})
0.3–0.8 µm	$\max(0.6, \alpha_i - \Delta\alpha_{age})$ where: $\alpha_i = \min\left(0.92, 0.96 - 1.58\sqrt{d_{opt}}\right)$ and: $\Delta\alpha_{age} = \min\left(1., \max\left(\frac{P}{P_{CDP}}, 0.5\right)\right) \times 0.2\frac{A}{60}$	$\max\left(40, 0.00192\rho/\sqrt{d_{opt}}\right)$
0.8–1.5 µm	$\max(0.3, 0.9 - 15.4\sqrt{d_{opt}})$	$\max\left(100, 0.01098\rho/\sqrt{d_{opt}}\right)$
1.5–2.8 µm	$346.3d' - 32.31\sqrt{d'} + 0.88$ where: $d' = \min(d_{opt}, 0.0023)$	$+\infty$

Table 1: Temporal evolution of snow albedo and absorption coefficient β (Vionnet et al. 2012). $P_{CDP} = 870$ hPa. Spectral band weights: 71%, 21% & 8%. MEB: 48% & 52%

Differences in the HARMONIE-AROME model (cy46h):

$$P_{\text{rel. max}} = 1.0 \rightarrow 1.5, \quad \beta_{1.5-2.8\mu m} = +\infty \text{ m}^{-1} \rightarrow 2000 \text{ m}^{-1},$$
$$\text{age, coef.}_{\text{glacier}} = 60 \text{ day}^{-1} \rightarrow 900 \text{ day}^{-1}, \quad \alpha_{min,glacier} \rightarrow 0.8 \text{ (in Crocus)}$$

The net solar spectrum

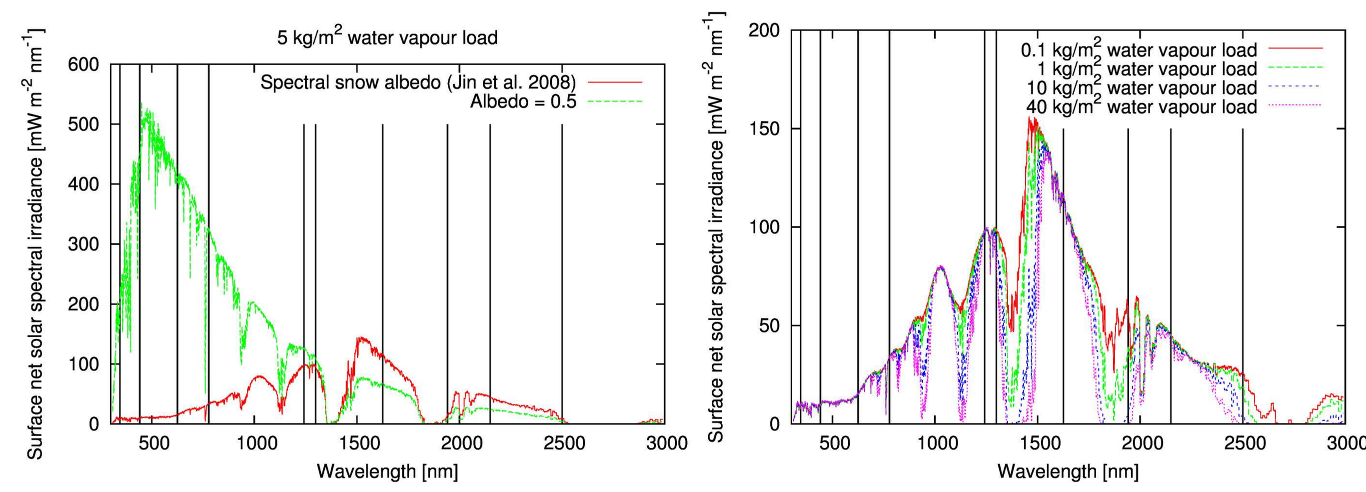

FIGURE 1: Net solar spectra at the surface. Left: Constant albedo (green). Jin et al. (2008) albedo spectrum of aggregate snow particles (red). Right: Spectra for varying atmospheric water vapour loads.

Results

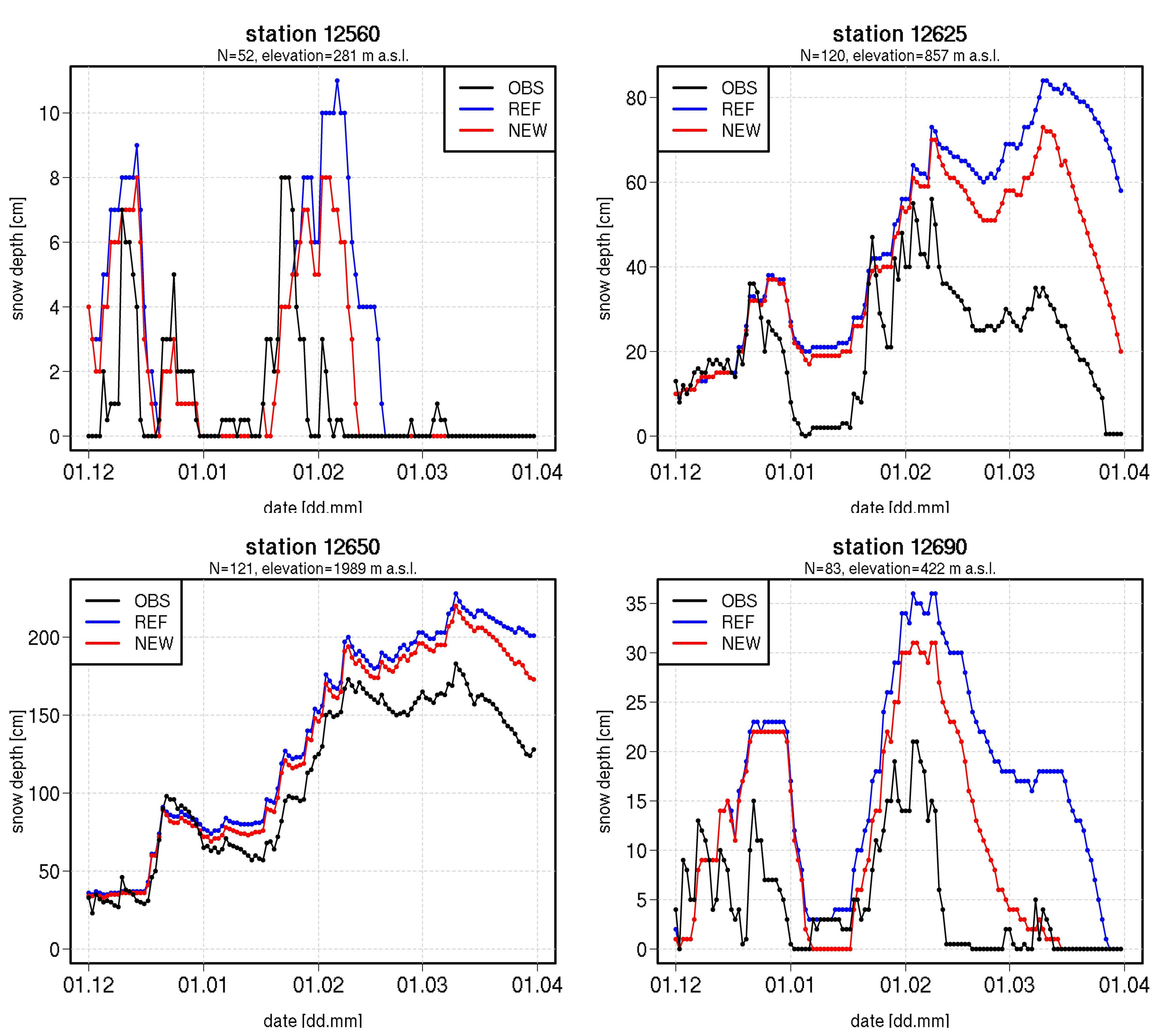

FIGURE 2: From left to right and top to bottom results from the 2021/2022 Winter for the four Polish stations Katowice, Zakopane, Kaspowy Wierch and Lesko and are shown. Observed snow depths are shown with black curves, the reference run with blue curves, and the run with modified spectral weights with red curves.

It can be seen that the snow melt rates are more realistic for the modified runs in these four examples.

Discussion

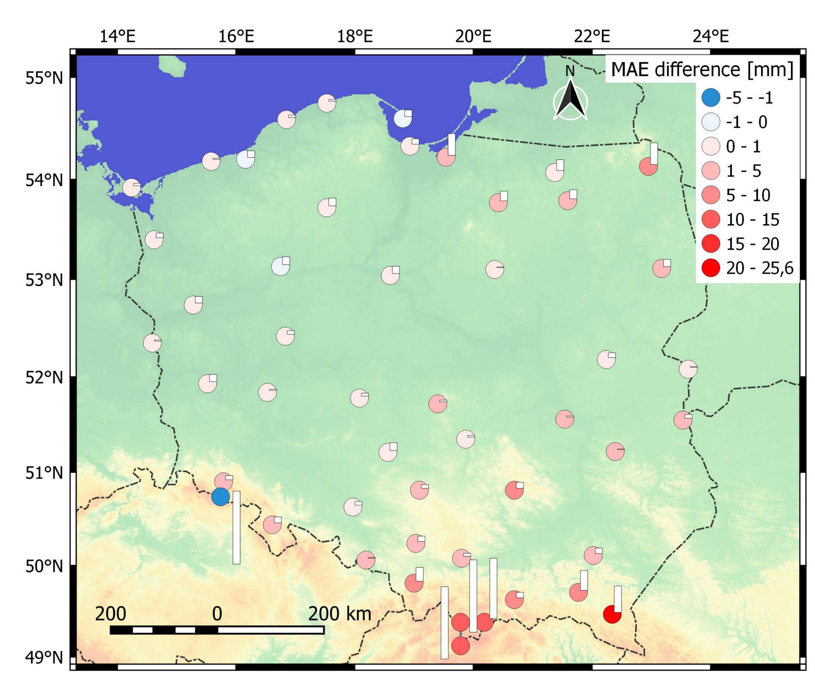

FIGURE 3: Snow water equivalent [mm] mean absoluty error (MAE) differences for all Polish snow stations between the reference and experiment run. Increases here show improvements.

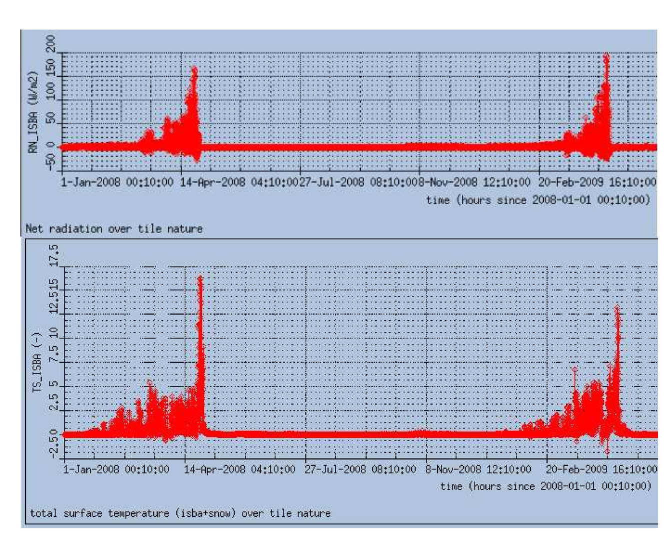

FIGURE 4: Differences in surface (skin) net radiation and temperature during two Winters for a test case from Sodankylä, Finland.

In Fig. 3 it can be seen that the improvement to the resulting modelling of snow water equivalent is consistent or neutral for all Polish snow stations but one. In Fig. 4 another test case is shown for a location in Northern Finland. Here is can be seen how differences in the net radiation and skin temperature increase during the Winter. The likely cause is a positive albedo feedback effect due to snow metamorphism, and, at the end of winter, earlier final snow melt.