

*This paper provides exhaustive (and quite exhausting!) documentation of Crocus, historically and still currently one of the most important models of snow on the ground. I have never before reviewed a manuscript with so few figures or so many nested braces! The authors do not follow the GMD encouragement that “Examples of model output should be provided, with evaluation against standard benchmarks, observations, and/or other model output”, but they do review other published evaluations and applications. The documentation collates developments in several previous publications and corrects errors in some of them. As such, this is an essential reference for users of Crocus. I recommend that it should be published with minor changes. A table of all the options and their dependencies would be a useful addition.*

We would like to sincerely thank Richard Essery for the time dedicated to this review, his positive appreciation and very useful remarks. We are fully aware that the length of the model description and the number of equations make the review process especially difficult. We highly appreciate the accuracy of the comments which testifies the great attention paid to reading the manuscript.

In addition to our review of existing model evaluations and applications, and accounting for a similar comment of Anonymous Referee 2 and following GMD recommendations, we added a new Appendix in the revised version of the manuscript with an overview of simulation results at the 10 ESM-SnowMIP reference sites corresponding to the published code version. This can be considered as a benchmark of the model skill that can be useful to assess the impact of future model developments.

As suggested, we also added a table summarizing all options and dependencies (Table 1).

*Specific comments:*

70

*Parametrizations which do not make this assumption that the diffuse fraction depends on solar zenith angle only are available. How much difference does using this parametrization make in simulations when data are available?*

In the extreme case where the sky is fully overcast, the error of Equation 1 can obviously be high in terms of diffuse / global radiation ratio as the direct component can be close to 0 regardless the value of the solar zenithal angle. In many cases, only global radiation data are available and it is unfortunately not possible to parameterize differently the diffuse/global ratio from cloudiness data or atmospheric optical depths. The impact in terms of error in the simulated broadband albedo is an underestimation of about 0.07 for fully overcast sky, from literature comparing snow albedo in different cloud conditions (Gardner and Sharp, 2010, Fig. 9). This error would be more or less of the same magnitude than ignoring the dependency of the solar zenithal angle in clear sky conditions, but with a lower impact in the snow energy balance as the incoming energy is generally lower in cloudy conditions. For these reasons, forcing the model with direct and diffuse components should be preferred when the data are available from measurements or from radiative transfer modelling in the atmosphere.

The text of the manuscript was adjusted to make the readers aware of this limitation when the diffuse / global ratio has to be parameterized.

95

*At atmospheric pressures, should  $T_0$  not be the melting point of water rather than the triple point?*

Thanks for pointing out this detail. Indeed,  $T_0$  represents the melting point temperature at atmospheric pressure. In SURFEX, it has always been assumed to be equal to the triple point value (273.16 K) and this assumption was kept for Crocus for the consistency between the different components of the land surface model. Although this inaccuracy of 0,01 K is not expected to have a significant impact on simulation results, the revised manuscript now explicitly mentions this approximation.

264

*Why are values 3 and 5 not included here in “occurrence of depth hoar at any time since the layer creation”?*

Indeed, the sentence has been changed as all odd values (1, 3, 5) correspond to the occurrence of depth hoar at any time since the layer creation.

469

*For vertical heat transport between layers, the harmonic weighted mean to add conductivities in series seems more natural.*

486

*What is the justification for now using the harmonic mean between the bottom snow layer and the ground?*

Since the origin, arithmetic means have been used in Crocus to compute the thermal conductivity at the interface between snow layers while harmonic means were used in other components of SURFEX (ISBA-ES snow scheme or ISBA-DIF soil scheme). The choice of Vionnet et al., 2012 was to maintain the arithmetic means when Crocus was implemented within SURFEX. However, as suggested by Richard Essery, the literature now tends to converge towards harmonic means expected to make the numerical schemes converge more quickly. Moreover, as also mentioned by Richard Essery, this arithmetic mean is inconsistent with the thermal conductivity used at the soil-snow interface and also with the computations of MEB. Therefore, following this remark, we decided to modify the code and the paper by using harmonic means. A new release referred as Crocus3.0.1 is provided with this modification. The impact on simulations was found to be very low in our test cases, except for some transient events where a thin snow layer only stays a few hours on the ground.

737

*SOF and HAR are not explained.*

These acronyms refer to soft and hard, and the discrimination is based on a threshold on the maximum penetration resistance (Table H1). This is added in the revised manuscript.

1026

*The Clausius-Clapeyron equation gives  $de_{sat}/dT$ . Equation (F6) is an approximate integral of the formula.*

Absolutely, we corrected this inaccuracy in the text.

1040

*Is there any justification for adjusting the Richardson number for slope? Atmospheric stability adjustment has bigger issues on slopes than the component of gravity.*

The Richardson number is defined as the ratio between buoyancy and flow shear. As buoyancy is a vertical strength, it is natural to project the vector perpendicular to the slope to characterize turbulence over a tilted surface. However, we fully agree that numerous other uncertainties are involved in the case of slopes and not accounted for in this parameterization, for instance the wind speed profiles associated with catabatic and anabatic winds.

1049

*Letter gamma is used on this page for both slope angle and psychrometric constant without distinction.*

We apologize for this inconsistency in notations. Slope angle was replaced by letter Theta as in Vionnet et al., 2012 to remove this ambiguity, as the psychrometric constant is always symbolised by letter gamma. To avoid confusion with grain type referred as Theta\_i in the preprint, we now use letter Psi for grain type.

*Minor corrections:*

*48 delete “make”*

Corrected

*160 “is split”*

Corrected

*307 “dependence on snow microstructure”*

Corrected

*372 Start a new line before “where”.*

Corrected

*373 “volumetric mass” is more commonly called density.*

Corrected

*394 “The last modification is”*

Corrected

*411 “at Col de Porte”*

Corrected

*430 “a homogeneous repartition is applied”*

Corrected

*432 “the highest integer such that”*

Corrected

*434 “not incorprated in”*

Corrected

441 Strictly,  $q_{sat}$  is also a function of pressure.

We replaced  $q_{sat}(T)$  by  $q_{sat}(T, P_s)$  everywhere.

531 “This allows representation of”

Corrected

558 “cannot”

Corrected

567 missing )

Corrected

578 “either by the heating energy or by ...”

Corrected

598 “either by the layer colling after diffusion or by ...”

Corrected

640 “accounted for by adding”

Corrected

695 “a shear resistance  $R_{s_i}$  is diagnosed”

Corrected

709 “for slope angle  $\gamma$ ”

Corrected

714 and throughout “indice” should be “index”

Corrected everywhere

786 “it can vary significantly from one domain to another”

Corrected

812 “an independent package called snowtools with full user documentation”

Corrected

851 “discrepancies”

Corrected

883 “adequation” is a very uncommon word in English. I think that the simplest fix would be “to reproduce the properties of ..., or complex remote sensing signals”

Corrected

904 “make the application of a number of data assimilation algorithms to this model challenging”

Corrected

921 “discrepancies”

Corrected

946 “are repeated here”

Corrected

967 “cannot”

Corrected

968 “between dendritic and non-dendritic cases”

Corrected

1036 “The derivative”

Corrected

1092 “preventing the vectorization”

Corrected

1096 “prevents vectorization”

Corrected