

The Cryosphere Discuss., author comment AC2
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Reply on RC2

Edoardo Raparelli et al.

Author comment on "Snow cover prediction in the Italian central Apennines using weather forecast and land surface numerical models" by Edoardo Raparelli et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-285-AC2>, 2022

REVIEW 2

Review of "Snow cover prediction in the Italian Central Apennines using weather forecast and snowpack numerical models", by Raparelli et al.

In "Snow cover prediction in the Italian Central Apennines using weather forecast and snowpack numerical models" the authors present an application of the Noah LSM and Alpine3D snowmodels forced with WRF 3km data. Overall this manuscript is well written and generally clear. Figures are mostly clear and I enjoyed the contextualization of the climate during the study period.

My main concern is that at the 3km lateral spatial resolution, we know a point-scale model is not representative of the sub-grid dynamics across such a large area -- blowing snow, canopy interactions, avalanching, sublimation on exposed ridges, variable compaction rates, surface exchange, etc. The authors note this but I'd like to see more attention drawn to it as a (major in my opinion) limitation. Indeed I would like to see more discussion on this scale mismatch between the vertical resolution -- O(mm) and O(cm) scales with SNOWPACK -- and the lateral O(km) scales. Reposed, is the computational effort of running Alpine3D warranted over a simpler snow model but at a finer spatial resolution? What are the process representations in SNOWPACK that have the largest impact on the simulations versus Noah? As there seems to be no treatment for sub-grid fractional snow cover, it isn't clear to me how the vegetation interactions are considered in this context. Lastly, I'd like to see a bit more detail regarding how wind downscaling was done as it wasn't completely clear -- is it straight out of WRF using the 3km topography? This is a large source of uncertainty with respect to surface exchanges.

In general I'm left a bit uncertain what the novel take away of this manuscript is. The application domain is certainly unique but I'm left feeling that there is a missing discussion

on the "why" of comparing these two models. Specifically, how the process representation in these models and the uncertainty in parameter estimation leads to "better" or "worse" process representation. Figure 15 suggests some very fundamental differences outside of the snow microstructure scheme resulting in such large SWE differences. I'm missing a deep understanding as to what is causing this.

I would suggest moderate revisions to contextualize the 'why' better.

We are very thankful to the reviewer for the time spent evaluating our work and we thank him/her for the useful and constructive comments. We have answered all comments.

Comments to reviewer's general comments:

"Is the computational effort of running Alpine3D warranted over a simpler snow model but at a finer spatial resolution?"

In this paper we wanted to investigate the performances of a simple and a more complex model in simulating snow height and snow cover extent on a regional scale at kilometric horizontal resolution. We chose as study domain Central Apennines, a territory characterized by complex topography where no one conducted this kind of study before. We showed that already looking at snow height and snow cover extent the models show different performances, but to increase the robustness of the analysis we will include in the revised manuscript also the comparison of simulated and measured snow density and snow water equivalent data. These further comparisons will show more evident differences between the model and it will help to conclude if it makes sense to run Alpine3D at 3km resolution for the estimation of snow height, snow density, snow water equivalent and snow extent, when already Noah simulations are available. However, we also think that thanks to the implementation in Alpine3D of more detailed physics processes, the model will benefit more than Noah in terms of performances if the spatial resolution of the meteorological forcing is increased, but this is an open question and it will be investigated in future works.

"What are the process representations in SNOWPACK that have the largest impact on the simulations versus Noah?"

We believe that the comparison of measured and simulated snow density and snow water equivalent will help to better understand which are the processes that cause the largest differences between the models. This aspect will be further investigated in the revised manuscript.

"As there seems to be no treatment for sub-grid fractional snow cover, it isn't clear to me how the vegetation interactions are considered in this context."

Actually, Noah already takes into account vegetation and computes fractional snow cover. The snow-canopy interaction was instead disabled in Alpine3D, but it will be activated in the simulations that we will show in the revised manuscript. Indeed we also want to extend the simulations to winter seasons 2019-2020 and 2020-2021, for a total of 3

simulated seasons, in order to take into account winter interannual variability and increase the robustness of the analysis.

"Lastly, I'd like to see a bit more detail regarding how wind downscaling was done as it wasn't completely clear -- is it straight out of WRF using the 3km topography?"

We didn't downscale wind, and we didn't downscale other variables. We just regridded on regular grid-spacing at a resolution of 0.03° , very close to the native horizontal grid adopted in WRF (about 3 km), which is curvilinear and not supported by Alpine3D.

Specific comments:

Abstract:

Can be tightened up with the results more succinctly summarized

The abstract will be summarized in the revised manuscript.

L8 "online" -> Is this a two-way coupling?

With online coupling, we mean that WRF drives Noah, which gives feedback to WRF. This is also called two-way coupling, as the reviewer suggests.

L 9 "LSM" remove.

This was a typo error and it will be removed.

L 9 "Alpine3D"

As I understand it Alpine3D is essentially met downscaling/interp + blowing snow + distributed SNOWPACK. I think this should clearly stated as to what the underlying snowmodel is as that is most relevant to this study.

Alpine3D is a snowpack and soil numerical model. It includes models for snow cover (SNOWPACK), vegetation and soil, snow transport, radiation transfer, and runoff which can be enabled or disabled on demand. In our setup Alpine3D is forced with the 1-hour meteorological data taken from WRF outputs. These data were not downscaled, but they were only regridded on regular grid-spacing at a resolution of 0.03° , very close to the native horizontal grid adopted in WRF (about 3 km), which is curvilinear and not supported by Alpine3D. Moreover, the aeolian snow transport and radiation transfer modules were not activated in our Alpine3D configuration. This point will be clarified in the revised manuscript.

L23 "at moderate spatial resolution (3 km)"

Be explicit that the snowmodel was run at this resolution.

It will be explicitly stated in the revised manuscript

L31 snowpacl -> spelling

It will be corrected in the revised manuscript

L35 precipitations -> No s

It will be corrected in the revised manuscript

L55 Suggest you include Vionnet, 2021 (<https://doi.org/10.5194/tc-15-743-2021>)

We were not aware of this paper, and we thank the reviewer for the suggestion. The paper will be included in the revised manuscript

L100 "Classified as Cfs"

Please remind the read what Cfs stands for.

It is actually a typo, since the inner, mountain part of central Italy is Cfb, which means temperate oceanic climate (C="temperate", f="no dry season", b="Warm summer"). It will be better specified in the revised manuscript. The Cfs is not actually an acronym, but a standard climate classification proposed by Koppen (referenced in the manuscript)

L103 "thermal excursion"

is not clear to me in this context. word choice or can you clarify?

It refers to the difference between the minimum and the maximum temperature value observed in one day (24h). To better clarify it is referred to the air temperature, we change it with "temperature excursion"

L111 "being the yearly maxima mainly localized in the western slope"

This is not clear

The Apennine mountain chain crosses the Italian peninsula from north-west to south-east, facing the Adriatic sea at the east side and the Tyrrhenian sea at the west side. It is the west side of the Apennines that experiences the maximum yearly precipitation. It will be clarified also in the revised manuscript.

L114 "it is worth to mention"

-> It is worth mentioning

although this is a bit colloquial. I suggest you change.

It will be corrected in the revised manuscript

L117 "the same"

The same as what?

The same Apennine area described in the previous paragraph (Central Apennines). We will better clarify in the revised manuscript

L118 "on annual basis"

On /an/ annual basis

It will be corrected in the revised manuscript

L135 "the second decade"

Decade? Do you mean "the second half"?

The sentence will be rewritten as: Between 10th and 20th December...

L137 "small cold"

Small, cold

It will be corrected in the revised manuscript

L 137 "impulse"

Uncertain of meaning in this context. Word choice?

The sentence will be rewritten as: In the middle of December, cold air advection from Northern and Northern-Eastern Europe leads ...

L137 leaded

It will be corrected in the revised manuscript

L140 "determined"

Caused?

The revised manuscript will be corrected according to the reviewer's suggestion

L 142 "impulse"

Uncertain of meaning in this context. Word choice?

The sentence will be rewritten as: when cold air advection from North Atlantic...

L152 automatic weather stations and use previously defined AWS only

It will be corrected in the revised manuscript

L154 "The measured variables"

List units and how frequently they were visited please

The civil protection weather station network includes automatic stations which measures surface air temperature (°C), relative humidity (%), wind speed (m/s), incoming shortwave radiation (W/m²), precipitation (mm/1h) and snow height (cm). Data acquisition is automatic and all measurements are transmitted every 15 minutes through GMS or radio links to a central server, thus the data were not collected manually. That information will be specified in the paragraph.

L190 "for WRF,"

remove comma

It will be corrected in the revised manuscript

L190 "it resulted the best"

Resulted in

It will be corrected in the revised manuscript

L199 "is run from 1 December 2018"

Why not the commonly used October 1? Can the authors confirm there were no missed snowfall events? How does this impact soil temperature?

We confirm that at automatic weather station locations the first snowfall occurred around mid-December, thus we didn't miss previous snowfall at weather station sites. Moreover, the soil conditions were initialized with NCEP reanalysis and afterwards driven by WRF simulations. Thus the first snowfall wasn't right after the soil initialization.

L220 "After a sensitivity test (not shown here)"

What forcing variables/parameters were tested? How was this done?

The sensitivity test was conducted using several combinations of different parameterizations available in Alpine3D. A more detailed description on the methods used for the sensitivity test and the parameters involved will be added to the supplementary material

L221 "as well as the selection of the "Zwart" and "Lehning new""

Please describe what these are including the associated references. How do these compare to what was selected in Noah?

Actually, the parametrization used was "Lehning_1" and not "Lehning new", However, to the author's knowledge, there are no papers where these parameterizations are explicitly described. They can be found in SNOWPACK/Alpine3D source code, and will be explicitly described in the supplementary material

L224 "of the simulation results"

Of what, specifically?

In terms of snow cover runoff. It will be specified in the revised manuscript

L417 "lower part"

Lower elevation?

With lower part we ment southern part. It will be corrected in the revised manuscript.

Figures:

All timeseries figures need a starting x=0 tick and in general all would benefit from more x-axis ticks

The reviewer suggestions will be applied in the revised manuscript.

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