

The Cryosphere Discuss., referee comment RC1
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Comment on tc-2021-225

Anonymous Referee #1

Referee comment on "Propagating information from snow observations with CrocO ensemble data assimilation system: a 10-years case study over a snow depth observation network" by Bertrand Cluzet et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-225-RC1>, 2021

Summary of the paper

Cluzet et al. present an evaluation of the CrocO snow data assimilation system which is based on a Particle Filter technique that propagates information spatially from areas with observations (e.g., height of snow, HS) to unobserved areas. Using leave-one-out validation, the performance of this system is compared to that of the ensemble (i.e., open-loop) and operational model counterpart at hundreds of snow depth stations in the French Alps, Pyrenees, and Andorra over 10 years. Different localization schemes (rlocal vs. klocal) and radii are tested, and showed only minor changes in skill. All Particle Filter configurations showed improvements relative to the open-loop but no clear improvement over the operational model. Using the klocal scheme at 35 km for the rest of the study, the authors show it tends to mitigate the negative bias in the open-loop at certain elevations (1500-2500 m) and locations (e.g., Central-East Pyrenees). The klocal scheme shows the highest skill at locations where the open-loop has negative bias, with reduced skill when the open-loop has positive bias. The skill of the klocal PF was found to be insensitive to the density of HS observations, but the magnitude of open-loop bias decreased with increasing HS observations (a peculiar result). The study suggests there is complementarity in that areas with high errors in meteorological data (due to low station data) may be mitigated by a Particle filter with spatial propagation of snow information.

Recommendation

Overall, I find that this paper is of good quality and provides additional application and evaluation of the CrocO Particle Filter developed in recent work by the authors. It is conducted at a more coarse model scale (and less dense observation network) than previous studies (e.g., Magnusson et al 2014; Winstral et al., 2019) and is hence a unique, complementary contribution. I think there are some aspects that could be strengthened in the discussion and possibly the presentation of results, depending on what information is available about the HS stations. The issue is that the stations may

benefit both the open-loop and oper (through providing meteorological data to the reanalysis) as well as the PF (through providing HS observations for assimilation). Disentangling these competing contributions to the model configurations could be useful in a revised manuscript.

Comments

- A result highlighted in the paper is that the open loop has lower performance in areas with fewer stations and decreased bias as station density increases (L. 299-301 and Fig. 10), but this seems coincidental, as the open loop does not integrate HS observations. Is this more suggestive of reduced quality in the reanalysis forcing data, given the lower availability of surface stations? Alternatively, I wonder how many of the HS stations include meteorological observations that are integrated into the reanalysis data (see lines 92-93)? Overall, the authors should carefully consider the two sources of data offered by stations (meteorology and HS). It might seem that a lack of stations would influence both the open loop and DA for that reason. The authors seem to understand this later in the paper (L. 458-459), so a consistent viewpoint should be included through the paper. Is it possible to identify which HS stations have met data that are being integrated into the reanalysis forcing data? If so, it may be necessary to differentiate the results based on whether the HS stations have met data that are contributing to the forcing data or not.
- The leave-one-out validation (L. 63-65, 166-169) should be clarified whether this is done spatially (e.g., one station is removed) or temporally (e.g., individual HS data are removed at a station). I am still unsure after re-reading these parts.
- The study highlights a range of elevations (1500-2500 m) where is a strong negative bias in the open loop and oper simulations. The role of gauge undercatch is discussed as the most likely cause of this bias (L. 351-353). However, I do not find this convincing, as gauge undercatch is likely a universal problem for measuring precipitation and snowfall in mountain environments. Is there another factor that might explain the bias in this specific elevation zone? Are the wind speeds higher, and hence larger undercatch errors at these elevations? Or is this suggestive of an oddity in the HS station data, for example, more ski area observations in these zones, which may be biased toward higher snow depths?
- In the discussion, the authors discuss variability of snow redistribution by wind in the context of error compensation with the DA system (L. 423-432). One aspect that is missing here is the impact of scale – both the process scale and the model scale – and this is something that should be identified and discussed. The resolution of the model in this study is quite large, such that a process like wind redistribution cannot be represented explicitly, and ultimately the variability must be handled in other manners (e.g., as a sub-grid parameterization, see Clark et al., 2011 for example; or improving the model resolution to a finer scale). Please comment more on this issue.

General comments

- The argument that weather stations provide better estimates of surface meteorology than NWP may not be a widely supported viewpoint, for instance see Lundquist et al. 2019. Please comment.

- There are many instances where papers that are "in prep" or "in review" are cited, for instance Vernay et al., Deschamps-Berger et al., etc. Please check with the TC journal guidelines on whether these types of papers (not yet published) are permitted to be cited.

Technical corrections

- Line 13: Add "of" after "strategy".

- Lines 53: Add "the" before "Météo-France".

- Line 71: Replace "Does" with "Can". Also, delete "manage to".

- Line 84: Add "Alps" after "Northern".

- Line 104: Replace "less" with "fewer".

- Line 137-142: Can you include a brief summary of the key elements of the ensemble generation technique? This would be useful for someone who has not read Cluzet et al. (2020, 2021) or who needs a reminder about the methods.

- Line 151: Replace "radius" with "radii".

- Line 152: Should be "size" instead of "sizes".

- Line 156: Suggest replacing "remind" with "note".

- Line 157: Should be "rlocal".

- Line 166: Should be "requires use of independent data".

- Line 202: Add "of" at the end of this line.

- Line 203: Remove "If".

- Line 218: Replace "Despite" with "Although".

- Line 228: A final sentence is needed here to offer an explanation for interpreting the new formulation of the skill score.

- Line 236-237: This argument is not reliable, as the 2012 year looked to be snowier but the bias was lower (0.11 vs. 0.16). Please remove example or provide better justification/explanation.

- Lines 239-240 and Table 1: Suggest adding a column with SS so the reader does not have to do the simple math.

- Line 242: Add "negative" before "biases".

- Line 250: Replace "radius" with "radii".

- Line 292: Remove "Then".

- Line 295: Please revise the phrasing "pointed as", this is unclear to me.

- Line 309: Please clarify which simulation is being referred to here when discussing the "simulation bias".

- Line 316: Replace "inferior to" with "less than".

- Line 335: The phrasing is awkward here and I suggest rewording "enables to satisfactorily account for".

- Line 402: Replace "Despite" with "Although".

- Line 423: Delete "Then,".

- Line 431: Delete "of course".

TABLE AND FIGURE COMMENTS

- Figure 2 could be simplified into two panels: 2009-2015 and 2016-2018, since 2016 seems to be the most major change in the station network in the study period. Otherwise, the histograms appear to be similar.

REFERENCES

Clark, M. P., Hendrikx, J., Slater, A. G., Kavetski, D., Anderson, B., Cullen, N. J., et al. (2011). Representing spatial variability of snow water equivalent in hydrologic and land-surface models: A review. *Water Resources Research*, 47(7), W07539. <https://doi.org/10.1029/2011WR010745>

Lundquist, J., Hughes, M., Gutmann, E., & Kapnick, S. (2019). Our Skill in Modeling Mountain Rain and Snow is Bypassing the Skill of Our Observational Networks. *Bulletin of the American Meteorological Society*, 100(12), 2473–2490. <https://doi.org/10.1175/BAMS-D-19-0001.1>