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The Cryosphere Discussions

Interactive comment on "Multi-scale spatialization of snow water equivalent (SWE) according to their spatial structures in eastern Canada" *by* Noumonvi Yawu Sena et al.

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Dear reviewer, I would like to thank you for the good reviews and comments you made to improve the article. I have provided each of your pertinent questions with essential answers for the understanding of the article. These questions have generated modifications and additions of ideas that you have suggested. Thank you for your contribution.

Question1 There are two major issues that are not technical issues, but presentation. First, the submission is clearly not written by a native English speaker and not edited. The second and third sentences of the abstract are identical and this type of repetition

occurs throughout the manuscript (see page 5).

Answer1 The paper entitled Multi-scale spatialization of snow water equivalent (SWE) according to their spatial structures in eastern Canada is reviewed by the experts of Catalytic Translation (http://www.traductioncatalytik.com/) in scientific paper revision. Corrections have been made in the abstract. On page 5 (line 23-31), the paragraph is corrected with more precision.

Question2 Terms including spatialize, physiographic regional factors, ubacs, etc. are not English terms and not defined. Answer2 The Âń physiographic regional factors Âż is never used in this document. We used physiographic factors, physiographic metavariables. Ubacs is the side of a mountain that is the least exposed to the sun, and therefore the coldest side (north-facing slope (page1 , line 28).

Question3 The writing is extremely rough making the work almost impossible to understand. An example is the presentation of the study goal "this study proposes to spatialize the SWE according to the structures of spatial variability of SWE. The main objective of this study is to develop a multi-scale spatialization approach by taking into account the structures delineated in the spatial variability analysis of the SWE at both scales (local and regional) by Sena et al. (2015). Second the manuscript depends heavily on an earlier manuscript (Sena et al. 2015). Sena et al. (2015) is written in French and thus is not readily accessible for reference the target audience. Adequate information is required for this manuscript to be an independent submission. For example, there is no map of the validation stations and the physiographic regional factors are never defined (instead generic variables are used).

Answer 3 The information on the environmental variables used at the scales (regional and local) in the previous work of Sena et al. (2015) has been recalled. The method used is mentioned (Page 3, line 4-20) to make the article independent. In section 2.1, the area summaries are presented (Page 5 line 1 -25). The map of the SWE measurement stations is added.

Question4 1. SWE and snow covered area are used interchangeably and it is not clear which is which Answer4 The Âń snow covered area Âż is never used in this document. We used snow cover, snow survey stations, snow accumulations.

Question5 The snow validation data set should be rewritten. Lead with a mapped set of stations that were used (move the second paragraph to the first). What was the time period? Then describe the sampling methods and the differences across the various networks

Answer5 The section 2.3 Snow data has been corrected. The stations for measuring the physical parameters of the snow have been displayed in Figure 1. The methods of sampling the snow water equivalent and the choice of stations are described.

Question6 It is not clear what the 10x10 km scale and 300 x 300 m scales mean. In part of the manuscript, it appears that there might have been an interpolation from the station data to a grid

Answer6 The scale of observation of the phenomenon must be chosen by taking into account previous studies and sufficiently large to cover the entire spatial variability of the phenomenon (Gustafson, 1998). In this study, the spatial variability of the SWE can only be measured at the scale that gives the spatial dimension of the data. At the local scale, the spatial variability of the physical parameters of the snow is measured on a 300 m line of snow (MDDEFP 2008). At this observation scale, local variability is under the influence of specific local underlying processes. The regional observation scale selected is between 10 and 100 km and corresponds to the regional scale where the processes of the major atmospheric circulation agents are observed (Marsh 1999, McKay and Gray 1981). (For information, see Sena et al. 2015).

Question7 Section 2.3 needs to be written. The figure is not a standalone figure and the variables need to be defined

Answer7 Section 2.3 explains the methodology adopted. Figure 2 shows the different

methods applied at the different scales of observation of the SWE. The variables used are described at each scale in the section (Page 7 line 1-3). In section 2.3.1, the variables are defined and further detailed in the results.

Question8 5. What are the physiographic metavariables U_l1,U_l2,U_l3,U_l4,U_l5,U_l6) and how were they calculated?

Answer8 The manuscript entitled "Multi-scale spatialization of snow water equivalent (SWE) according to their spatial structures in eastern Canada" is based on the results of the work of Sena et al.2015. Also, in the manuscript, we had provided details on the physiographic metavariables (page 3 line 1-19). The metavariables U_1 ãĂŰ,UãĂŮ_2,U_3 ãĂŰ,UãĂŮ_4 of the regional scale and U_l1,U_l2,U_l3,U_l4,U_l5,U_l6 of the local scale are variables obtained in the previous studies by Sena et al. (2015).

Question9 It is not clear that a step-wise linear regression is appropriate. Sena et al. (2015) used non-parametric methods. It does not appear that data were held back for validation purposes

Answer9 In this study, stepwise linear regression is justified because the goal is to estimate SWE based on explanatory environmental metavariables that coordinate the spatial variability of SWE. And to do this, they are introduced into the regression model step by step. These explanatory environmental metavariables are not identical at both of the regional and local scales. In Sena et al., (2015), the non -parametric Kruskal-Wallis approach used shows that the SWE values located in a bounded spatial structure is different from the next contiguous structure. These are two different methods in the two papers.

Question 10 Section 3.1.2 is not a validation of the results, but a summary of the variogram metrics. This summary would be best provided in a Table. 8

Answer10 Section 4.2 is changed to variogram and cross-validation analysis, as it ex-

plains the results of the variogram models and the cross-validation of the residuals under the variogram model. Table 2 of the indices of the residuals variograms and cross-validation rho of the zones presents the summaries.

Question11 In section 3.1.3, the stepwise linear regression does not provide information about the explanatory variables and the difference in model performance for equations (5) to (9) is not reported

Answer11 Some details on the metavariables used are given. Equations 5 to 9 represent the regression models of the zones (A, B, D, E, F) with the metavariables considered in each zone. In the analysis of each model and the corresponding figures, the performances of Table 1 that are Nash, R2, RMSE and Biais are presented and discussed in the text. The difference in the performance of the models is mentioned (page 20, line 1-6).

Question12 Section 3.14 figures could be condensed by putting figures b and c together. Again, create a table of results rather than writing out in tabular form. Figure 8a, b, and c are identical and appear to be the same as Figure 7.

Answer12 Tables (2, 3 and 4) of results are created to summarize the performance indices of the models. Figures 8a, b and c are corrected.

Question13 Section 3.2 leads with “At the regional scale (10 km x 10 km), the SWE spatialization was performed in each of the delimited structure.“ It is not clear what analysis was conducted. The entirety of section 3.2 both at the local and regional scale seem to describe how much SWE there is where without any support. There is a tremendous amount of granularity that does not seem to be supported in many of the regions. In region A there are either 8 or 18 stations (both numbers were given) and region C has three stations

Answer13 The mapping of the SWE to the delineated spatial structures is presented at the beginning of the paragraph (Page 22, line 3-4). In the methodology, information

about the data and the tool used is mentioned (page 9 and 10, line 20 -23). In area A, there are 18 stations and 3 stations in area C (Page 10, line 10-11).

Question14 The conclusions clearly indicate that there are physical factors that drive these variations but they are never described in the body of the text. In the conclusion, it is suggested that the authors have insights to what those physical features are “At the local scale (300 m x 300 m), these zones were segmented into small homogeneous SWE structures corresponding to the roles of slope morphology, vegetation height, slope, solar radiation and distance to lakes in accumulating and retaining snow on the ground.” This is extremely valuable and important as compared to the average annual maximum values

Answer14 This manuscript derived from the results of the work of Sena et al.2015, which explicitly delineated the different structures of spatial variability at the regional and local scales. The physical factors guiding the spatial variability of SWE are described in the work of Sena et al.(2015) and their roles studied in explicitly delineating the structures of spatial variability of SWE. Meta-variables are obtained from these variables. In this work, the continuous mapping of SWE values in each structure is done by considering the contained data of each zone. This work allowed us to estimate the role of major factors such as altitude, longitude, latitude and distance from the ocean in the spatial variability of snow cover at 68%. To this is added the 21% variance of local factors (slope, distance to lakes etc.) in coordinating the spatial variability of snow cover on the ground.

Question15 The conclusions introduce new information. The finding that “The adapted methodology and the results of this work offer several perspectives that can contribute to the study of the spatial variability of snow in a context of climate change.” is not correct because there is no metric that would change due to a changing climate.

Answer15 The spatialisation in this study is based on the homogeneous spatial structures in terms of the SWE. These structures are different from each other at both scales

(regional and local) (Sena., 2015). In case we will have simulated data of climate variables (density, height, EEN, rainfall) produced by the Canadian Regional Climate Model for example, or simulated data on the evolution of vegetation formations (plant heights) in context of climate change, the limit of structures can be modified or changed. The method can be used to compare the evolution of spatial structures with the spatial variability of the natural phenomenon in a future climate (Page 33, line 27-31). This may induce a change in the spatialisation of the physical parameters of the snow cover.

Question16 Table 1 does not match the statistics that are reported.

Answer16 In all model figures the statistic indices in Table 1 are presented and discussed. Question17 Units are missing in the nugget and variance; axes on various figures (Figure 3) are not labeled. Scatterplots should have the same size on the x and y-axis. Figure 3 has 3 subfigures but only (a) and (b) are labeled.

Answer17 Units of variance and nugget effect are added (Figure 3). In Figure 3 the scatter plots have the same size. Figure 3 is corrected.

Question18 Overall, the methods could not be fully evaluated due to the deficiencies with the discussion. The findings appear to show spatial variability that is not warranted by the analysis. There is not compelling evidence that the kriging improves the models. The concept of variations that are driven at two different scales is reasonable and worthy of exploring, but the resulting models needed to be validated and the physical drivers of those models need to be identified at both scales and differentiated between scale.

Answer18 The regression method has two components: the deterministic part and the random part (residuals). This random part is studied by the variogram to demonstrate the existing spatial structure. Those that show spatial structure are kriged to account for the random component and improve the SWE estimated. The use of regression kriging allows the estimation of the average annual maximum of the SWE at all points in the territory at the regional and local scales. The regression model explains 65% of

the variance (Nashr = 56%). With the addition of the kriged residuals of area E, this variance is reduced to 68% with a Nashr of 83%. The physical factors that affect the spatial variability of the snow cover (in this case the SWE) are not identical at both scales (regional and local). They have been identified, analyzed, and validated in the previous work of Sena et al.2015. These physical factors allowed to explicitly delineate the structures of the variability of the SWE. And this manuscript proposes to spatialise the SWE according to these structures.

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