

Review of “Using MODIS estimates of fractional snow cover extent to improve streamflow forecasts in Interior Alaska” by K. E. Bennett, J. E. Cherry, B. Balk and S. Lindsey

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### **Summary:**

In this paper, the authors employ daily Moderate Resolution Spectroradiometer (MODIS) fractional snow cover extent (SCE) data to improve streamflow simulations in several Alaskan sub-watersheds of the Tanana River. The study period covers 2000-2010 with simulations with the SAC-SMA conceptual rainfall-runoff model that also incorporates the one-layer SNOW17 model for the representation of snowpack conditions. Runoff simulations that include MODIS-derived snow areal depletion curves (ADCs) in SNOW17 are compared with baseline simulations with the standard model formulation for ADCs in the five sub-basins of the Tanana River. The authors conclude that the assimilation of the MODIS SCE data leads to better representation of snow conditions and runoff simulations in Interior Alaska.

This paper presents interesting results on the potential application of MODIS SCE data in operational models for improved runoff simulations in Interior Alaskan watersheds where in situ data remain sparse. The paper is generally well-written and illustrated, but the paper requires some revisions prior to publication. The following provides a list of suggestions that may be helpful to the authors in revising their paper:

### **General Comments:**

- 1) The paper includes non-metric units including feet for elevations and inches for snow water equivalent (SWE). Please convert all non-metric units to metric and adjust Equation (1) accordingly.
- 2) A considerable amount of effort has been placed into ingesting the MODIS SCE data into SAC-SMA model simulations of runoff in five sub-watersheds of the Tanana River. The authors should be commended for this effort. Nonetheless, the results shown in Figure 9 show little differences between the simulations that incorporate the MODIS data versus those with the standard model formulation. Table 4 confirms there are only very modest gains to be made by ingesting the MODIS data into the runoff simulations. As stated by the authors, more significant gains would be obtained by having more accurate forcing data (air temperature and precipitation) in the remote and complex terrain of these Alaskan watersheds. Further to this, SNOW17 incorporates only one snow layer which may miss some of the snow dynamics at play within the thin snowpack layer than interacts with the atmosphere. As such, why spend so much effort in trying to improve the runoff simulations with the data assimilation strategy when more

- significant gains may be obtained by improving other aspects of the modeling framework?
- 3) Why does the study period cover only 2000-2010 when MODIS data are available up to present? Further to this, how are gaps in the MODIS data in-filled? For instance, persistent cloud cover can lead to a significant reduction in the available snowcover data from optical remote sensing. Is any gap-filling procedure used to address this issue (see for example Hall et al., 2010 and Tong et al., 2009).
  - 4) Hydrological simulations such as those presented in Figure 9 are averaged over 10 water years. Results for each individual year should also be presented to illustrate the model's ability to represent interannual variability in the discharge patterns.
  - 5) The references need to be fully revised and presented in the journal's standard format.
  - 6) Note that Déry et al. (2005) used MODIS ADCs to improve their simulations of runoff on the Alaskan North Slope and may be a relevant reference to this study.

### **Specific Comments:**

- 1) P. 2, Abstract: Include the study period within the abstract.
- 2) P. 2, lines 5 and 25: Define "US".
- 3) P. 2, lines 29/30: Have both snow cover extent and duration in Alaska indeed declined by 18% from 1966 to 2012?
- 4) P. 2, line 31: What aspect of permafrost has declined in response to warmer air temperatures in Alaska? Its depth, extent, or other characteristic?
- 5) P. 2, line 34: Change to "North American".
- 6) P. 3, line 3: "Extremes" should be singular.
- 7) P. 3, line 16: Delete the extra "model output".
- 8) P. 3, line 20: Define "NOAA".
- 9) P. 3, line 30: Change to "these data have".
- 10) P. 5, line 15: Why does the study period end in 2010 although MODIS data are available up to present?
- 11) P. 5, line 27: Define "SWE" upon first usage rather than in the following line.
- 12) P. 5, line 35: Perhaps number the equations, depending on the journal's formatting guidelines. Convert the equation to metric units and ensure the elevation  $e$  is in meters, not feet.
- 13) P. 6, line 3: Define "SAC-SMA".
- 14) P. 6, line 17: Should the air temperature lapse rate be  $0.6^{\circ}\text{C}/100\text{ m}$ ? Insert a space in "100 m".
- 15) P. 6, line 23: The journal may prefer dates in a format such as "21 December".
- 16) P. 6, line 29: Insert a space in "100 m".
- 17) P. 6, line 31: What atmospheric temperature is used to compute incoming longwave radiation with the Stefan-Boltzmann Law?
- 18) P. 6, line 32: Why assume a constant relative humidity (RH) at 90%? Is this relative to a water (and not an ice) surface even when air temperatures are subfreezing? How does RH enter the calculation of the simplified energy balance, through the latent heat flux?

- 19) P. 6, line 33: How can wind have units of “mm/mb/6 hr”?
- 20) P. 6, lines 34/35: Write “snowpack” as one word.
- 21) P. 8, line 30: Revise to: “Three additional objectives”
- 22) P. 9, lines 1 through 9: Equations numbers run on two lines and are missing for the last three equations.
- 23) P. 9, line 10: The units should be “m<sup>3</sup>/s”.
- 24) P. 9, line 17: Provide probability values for all correlation coefficients reported in the study.
- 25) P. 10, line 18: What are the units for snow density, listed here only as 0.2?
- 26) P. 10, line 19: Insert a space in “6 hr”.
- 27) P. 10, line 35: Insert a space in “850 m”.
- 28) P. 10, line 36: Should this be “SNOW17’s”?
- 29) P. 11, lines 1 and 11: Write “snowpack” as one word.
- 30) P. 11, line 10: Date format may need to be revised to “15 May 2001”. Please also change to “is shown in Figure 5b”.
- 31) P. 11, line 13: Change to “watershed’s”.
- 32) P. 11, lines 20 to 22: Convert SWE from inches to mm.
- 33) P. 11, line 33: Change to “improve”.
- 34) P. 12, lines 4/5 and 13/15: Avoid sentences that just describe the figures – this is what figure captions are for.
- 35) P. 12, line 35: Delete “Because this.”
- 36) P. 13, line 14: Change to “SNOW17’s”.
- 37) P. 13, line 17: Revise to “data are temporally”.
- 38) P. 14, line 11: Write “snowpack” as one word.
- 39) P. 14, line 19: Change to “are adding”.
- 40) P. 14, line 20: Change to “data appear”.
- 41) P. 15, line 22: Change to “have improved”.
- 42) P. 16, line 11: For consistent language, change to “floods and droughts”.
- 43) P. 16, line 27: Delete “to” before “during”.
- 44) P. 16, lines 32 to 34: This sentence is long and confusing. Consider revising it and perhaps dividing it into two sentences.
- 45) P. 17, line 1: Delete the space after the hyphen in “high-quality”.
- 46) P. 17, line 8: Change to “Natural Sciences”.
- 47) P. 18, line 1: Note that the references do not generally follow the format used by HESS; for instance, journal names should be abbreviated, not listed in full. The year of publication should be listed at the end of the reference, not after the list of authors.
- 48) P. 18, line 4: Is this a journal article, technical report or book? Please provide full details of the Anderson (1976) reference.
- 49) P. 18, line 14: Provide the full range of pages for this article.
- 50) P. 18, line 16: Add the article # for this reference.
- 51) P. 18, line 26: Provide the full range of pages for this article.
- 52) P. 20, lines 8/9: Why is the journal name in italics?
- 53) P. 20, line 11: Is the French name of the journal needed here?
- 54) P. 21, line 6: Provide the full range of pages for this article.
- 55) P. 21, line 8: There is a period missing after “design”.

- 56) P. 21, line 13: Provide the full range of pages for this article.
- 57) P. 21, line 31: Is there an appropriate issue number (other than zero) for this article?
- 58) P. 22, line 9: Provide the range of pages for this article.
- 59) P. 22, line 19: Use upper case “H” in “Journal of Hydrology”.
- 60) P. 23, line 16: Why is this “Woo et al. (2008a)” when there is no corresponding “Woo et al. (2008b)”?
- 61) P. 24, Figure 1: I presume the upper and lower divisions shown in each catchment are delineated by the black contours? If so, the figure caption should clearly state this. The range of colors is misleading since there does not appear to be elevations above 1000 m. As such, consider using a shorter range of elevations for the map with more distinctive colors.
- 62) P. 25, Figure 2: For which year(s) are these results valid for? Is this for a given year or a climatology over the study period?
- 63) P. 26, Figure 3: Here snow cover extent is expressed as a percentage in the color legend but in Figure 2 it was shown as a fraction from 0 to 1. Use a consistent parameter for the presentation of the results. The range of elevations for each zone should be provided in a table.
- 64) P. 27, line 27: The date format may need revisions.
- 65) P. 28, line 34: Same comment.
- 66) P. 29, Figure 6: Convert the SWE data from inches to mm and redraft the figures accordingly.
- 67) P. 30, Figure 7: Provide units for RMSE on the y-axis. Would it be possible to have ovals around the different clusters to identify specific basins on the plot?
- 68) P. 31, line 51: Change to “on the plots”.
- 69) P. 32, Figure 9: Discharge should be in units of  $\text{m}^3/\text{s}$  on the y-axis. Rather than presenting the average results over 10 water years, why not depict results for each ablation season?
- 70) P. 33, Table 1: For the upper Little Chena, provide the air temperature with one decimal, i.e. “-21.0” for consistency with values reported elsewhere.
- 71) P. 34, Table 2: Is the average SWE reported here the annual average, or the average annual peak value?
- 72) P. 35, Table 3: There are a couple extraneous numbers in the table just under “Max” (“13” and “14”, which appear to be line numbers. The maximum MBASE temperature should read “0.00”.
- 73) P. 36, Table 4: Probability values should be reported for the correlation statistics.

### **New References:**

Déry, S. J., Salomonson, V. V., Stieglitz, M., Hall, D. K., and Appel, I. 2005: An approach to using snow areal depletion curves inferred from MODIS and its application to land surface modelling in Alaska, *Hydrol. Proc.*, 19, 2755-2774, doi: 10.1002/hyp.5784.

Hall, D. K., Riggs, G. A., Foster, J. L., Kumar, S. V. 2010: Development and evaluation of a cloud-gap-filled MODIS daily snow-cover product, *Remote Sens. Env.*, 114(3), 496-503.

Tong, J., Déry, S. J., and Jackson, P. L., 2009: Topographic control of snow distribution in an alpine watershed of western Canada inferred from spatially-filtered MODIS snow products, *Hydrol. Earth Syst. Sci.*, 13, 319-326.