Evaluation of SNODAS snow depth and snow water equivalent estimates for Eastern Canadian watersheds: Ontario

Zahra Zahmatkesh; James Leach; Paulin Coulibaly, Trish Stadnyk

NSERC Canadian FloodNet , Water Resources and Hydrological Modeling Lab, McMaster University, Dept of Civil Engineering , University of Manitoba

Introduction

- The National Weather Service's SNOw Data Assimilation (SNODAS) modelling and data assimilation system provides daily, gridded estimates of snow products such as snow depth (SD), and snow water equivalent (SWE), at a 1-km2 resolution for conterminous USA since October 2003, and for Southern Canada since December 2009. These products could be used to support hydrologic modelling and analysis. [1]. Inclusion of correct estimates of SD and SWE in hydrological modeling, is of great value for the simulation and also prediction of flood events and streamflow [2]. Here, estimates of SD and SWE by SNODAS are compared with the observed ground-measured snow data for sample study locations in Eastern Canada.

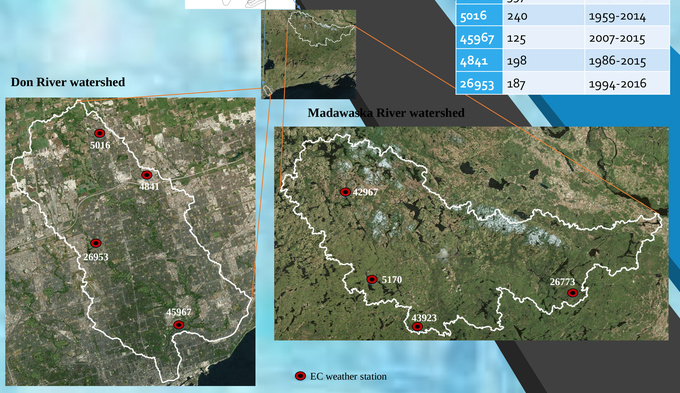
Objectives

- Evaluation of SD and SWE products of SNODAS against the observations for two watersheds with different land use.
- Adjustment of SNODAS estimates by bias correction.
- Statistical analysis of the SNODAS products for several grids all over the watershed to check how diverse/similar these products are.

Case Study and Data

- Sample study locations are two watersheds with different land-use in Ontario: Don River watershed (representative of urban areas), and Madawaska River watershed (representative of forest areas).
- Several stations over the watersheds are considered.
- SD data are obtained from Environment Canada and Global Historical Climatology Network.
- To estimate SWE in mm, observed SD in mm is divided by 10.

EC ID#	Elevation (m)	Data availability
5170	330	1987-2016
26773	276	1994-2016
43923	360	2005-2017
42967	397	2004-2017
5016	240	1959-2014
45967	125	2007-2015
4841	198	1986-2015
26953	187	1994-2016



Methods

a) Evaluation metrics

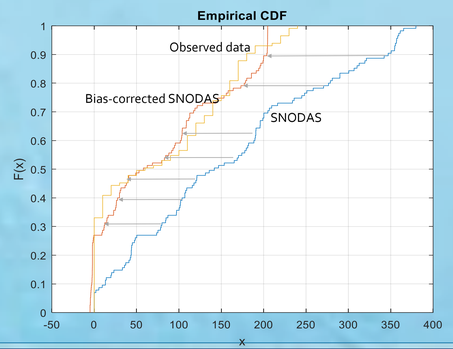
$$NSE = 1 - [\sum_{i=1}^{n}(O_i - S_i)^2 \Big/ \sum_{i=1}^{n}(O_i - \tilde{O})^2]$$

$$MAE = (n)^{-1}\sum_{i=1}^{n}|S_i - O_i|$$

$$d_2 = 1 - [\sum_{i=1}^{n}|S_i - O_i|^2 \Big/ \sum_{i=1}^{n}(|S_i - \tilde{O}| + |O_i - \tilde{O}|)^2]$$

b) Bias-correction: cdf-matching

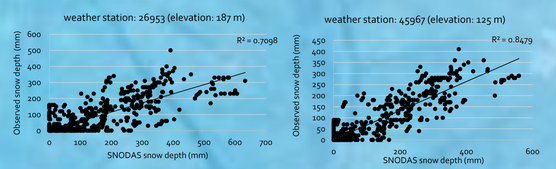
Matches the CDF of the SNODAS SWE and SD estimates to match that of the observations.



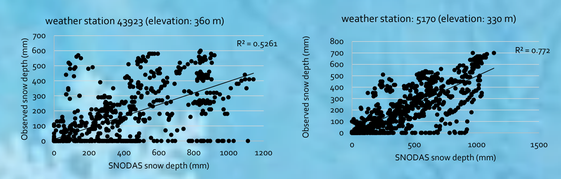
Results

Snow depth evaluation: SNODAS against observations

Don river watershed

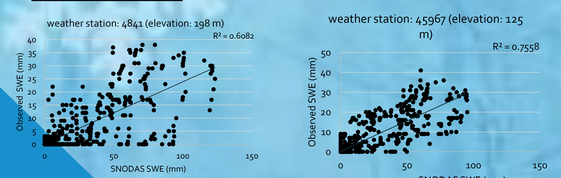


Madawaska river watershed

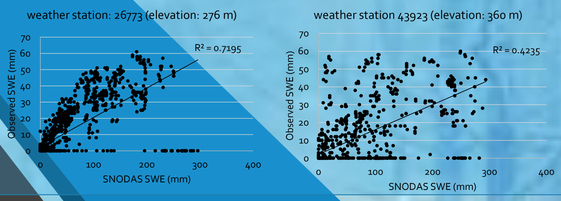


SWE evaluation: SNODAS against observations

Don river watershed

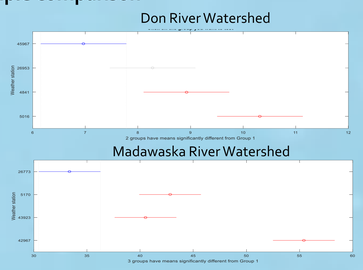


Madawaska river watershed



❑ SNODAS SD: multiple comparison

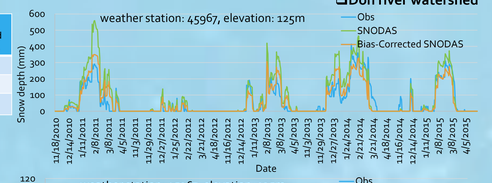
The means of the SWE outputs of SNODAS for different weather stations are meaningfully different, with an increasing trend accordance with the stations' elevations. (data: Jan-Dec)



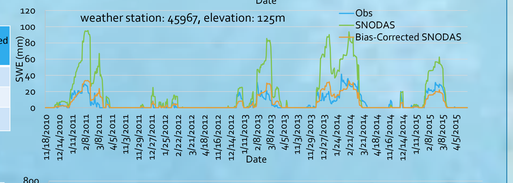
❑ SNODAS data adjustment: bias correction

❑Don river watershed

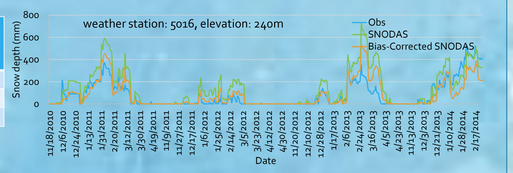
Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	0.499	0.819
MAE	33.845	20.460
d2	0.911	0.953



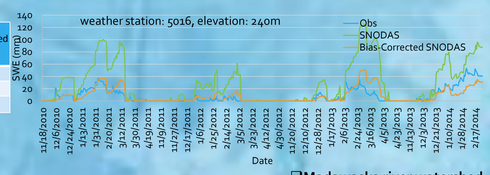
Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	-4.652	0.683
MAE	11.201	2.767
d2	0.634	0.915



Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	0.1706	0.6290
MAE	66.5714	39.9140
d2	0.8488	0.8984

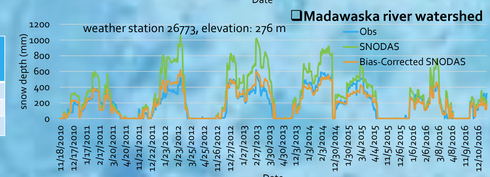


Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	-5.9135	0.4757
MAE	19.1910	4.7375
d2	0.5657	0.8503

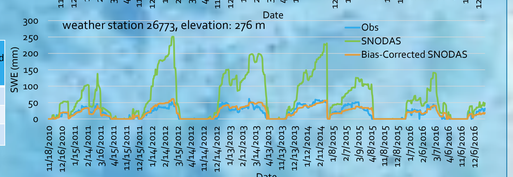


❑Madawaska river watershed

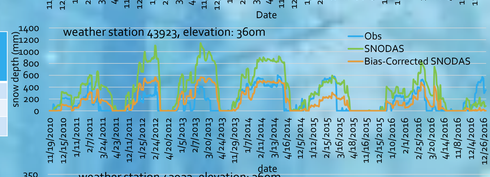
Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	0.084	0.873
MAE	106.040	41.671
d2	0.867	0.967



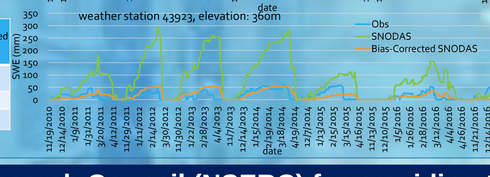
Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	-12.671	0.820
MAE	42.170	4.878
d2	0.489	0.953



Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	-1.841	0.229
MAE	209.784	105.384
d2	0.648	0.783



Evaluation metric	SNODAS	Bias-Corrected SNODAS
NSE	-27.723	0.054
MAE	65.864	12.008
d2	0.306	0.728



Discussion

- For all weather stations there is a correlation of more than 0.9 between the SNODAS SWE and SNODAS SD.
- The correlation is more significant between the SNODAS and observed snow depth, rather than SNODAS and observed SWE.
- Comparing SNODAS products with the observations indicates that values for both SNODAS SWE and SD are overestimated, as large as twice, in comparison with the observations.
- By increasing the elevation, the correlations would be decreased:
- For SD, the highest correlation of 0.85 is observed for station 45967 in the Don watershed with the lowest elevation of 125 m, while the lowest values of correlation (0.5-0.6) are for stations in the Madawaska watershed with high elevations of up to 397 m.
- For SWE, correlations for Don River watershed stations are more than those observed for the Madawaska River watershed (0.6 to 0.75 vs 0.4 to 0.7), where more correlations correspond to stations with lower elevations.
- For Madawaska river watershed, SNODAS SD and SWE products tend to be considerably high in April (even after the mid-month) while in most the days in April, recorded observation for the snow depth is zero or fairly low.

Some challenges and Next steps

- Challenges:
- Lack of stations with continuous observations all over the watershed (e.g., Madawaska river)
- In one of the Madawaska river watershed stations, even after the bias correction the agreement between the observations and SNODAS estimates is weak.
- SNODAS estimates include sublimation and snow pack temperature as well. How to incorporate those data in runoff estimation to check the reliability of SNODAS data? How to do bias correction to those data?
- Next steps:
- Investigating if other adjustment techniques can be developed or used to modify the SNODAS estimates.
- Investigating if a general equation can be developed to adjust SNODAS SD and SWE for the whole watershed.
- Investigating if land use and elevation data could be incorporated in the adjustment process.

References

- [1] Clow, D. W., Nanus, L., Verdin, K. L., & Schmidt, J. (2012). Evaluation of SNODAS snow depth and snow water equivalent estimates for the Colorado Rocky Mountains, USA. Hydrological Processes, 26(17), 2583-2591.
- [2] Jörg-Hess, S., Griessinger, N., & Zappa, M. (2015). Probabilistic Forecasts of Snow Water Equivalent and Runoff in Mountainous Areas. Journal of Hydrometeorology, 16(5), 2169-2186.

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