Evaluation of Dual-Pol Snow QPE Methods as an Alternative to the NEXRAD Snow Accumulation Algorithm

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Introduction

- Three snow QPE methods were evaluated in this study: 1) the NWS operational SAA (right), which is based on a few pre-selected S(Z) relations, where S is the snow liquid water equivalent rate and Z reflectivity, 2) Bukovcic 2020 (Bu20) and 3) 2022 (Bu22), which are based on S(KDP, Z) relations where KDP is the specific differential phase.
- Bu22 dynamically estimates the degree of riming (frim) and orientation/shape (FoFs) of snow using ASOS precipitation and extinction coefficient measurements to calculate QPE.
- Including KDP and accounting for the shapes and densities of snow particles should, in theory, result in more accurate QPE for snow events.

SSAA

"Simulated" Snow Accumulation Algorithm

Region	$S(Z)$	Snow-water ratio	Range correction
Northeast	$Z = 120S^2$	11.8	$\alpha = 0.8414 + 0.004r$
Great Lakes	$Z = 180S^2$	16.7	$\alpha = 0.8414 + 0.004r$
North plains	$Z = 180S^2$	11.8	$\alpha = 1.097 + 0.0069r$
High plains	$Z = 130S^2$	13.3	$\alpha = 1.097 + 0.0069r$
Inter-mountain west	$Z = 40S^2$	14.3	$\alpha = 0.358 - 0.002r + 0.0003r^2$
Sierra Nevada	$Z = 222S^2$	8.0	$\alpha = 2.4371 - 0.064r + 0.0007r^2$

Bu20

Bukovcic 2020

$$S(K_{DP}, Z) = 1.45126 \cdot \left(\frac{p_0}{p}\right)^{0.5} K_{DP}{}^{0.615} Z^{0.33}$$

Bu22

Bukovcic 2022

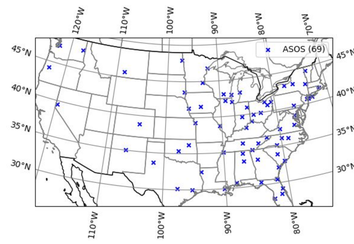
$$S(K_{DP}, Z) = \frac{38 \times 10^{-3}}{f_{rim}{}^{0.23} (F_o F_s)^{0.62}} \left(\frac{p_0}{p}\right)^{0.5} (K_{DP}\lambda)^{0.62} Z^{0.3}$$

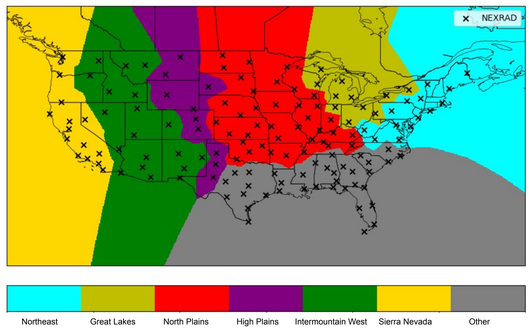
$$f_{rim} = \alpha \frac{S_{asos}{}^{a}}{(\sigma^e_{asos})^b Z^c}$$

$$F_o F_s = \beta \frac{Z^g (K_{DP}\lambda)^h}{(f_{rim})^i (\sigma^e_{asos})^j}$$

Next Steps - Snow Regime Analysis

- Create a long-term dataset of co-located dual-pol radar, environmental and ASOS surface station variables.
- Collected dual-pol radar data from gridded Multi-Radar Multi-Sensor (MRMS) above 69 ASOS sites.
- The ASOS sites are a subset of the national network that contain all of the following: an all-weather rain gauge, human observer, and snow depth reports.





Initial Results

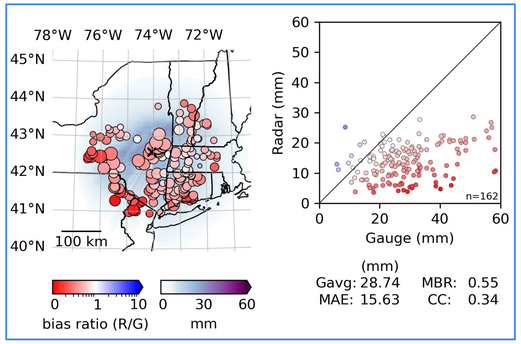
- The three snow QPE schemes were evaluated using 4 example events (see Table 1).
- Bu20/22 provided improvements over the SAA for heavy snow events (e.g., for the 17 Dec. 2020 event, see figures below), while SAA performed better for light events (see Table 1)
- The results indicated a snow regime dependency of the S(KDP, Z) relationships.

Gavg: mean CoCoRaHS gauge value for the entire domain.
MBR: mean bias ratio; radar/gauge.
MAE: mean absolute error.
CC: correlation coefficient.

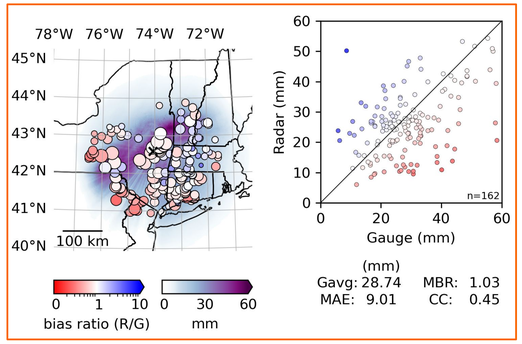
Table 1 (SSAA, Bu20, Bu22)

	Snow Intensity	Gavg (mm)	MBR	MAE (mm)	CC
2020-12-17 KENX	heavy	28.74	0.55 1.03 1.09	15.63 9.01 9.01	0.34 0.45 0.45
2020-12-17 KBGM	heavy	29.91	0.62 1.05 1.07	13.49 6.93 6.95	0.64 0.72 0.70
2022-01-07 KBGM	light	3.69	0.80 1.46 1.80	1.62 1.59 2.49	0.60 0.64 0.70
2022-01-30 KBOX	light	16.19	1.06 1.61 0.86	5.55 7.62 6.97	0.69 0.76 0.71

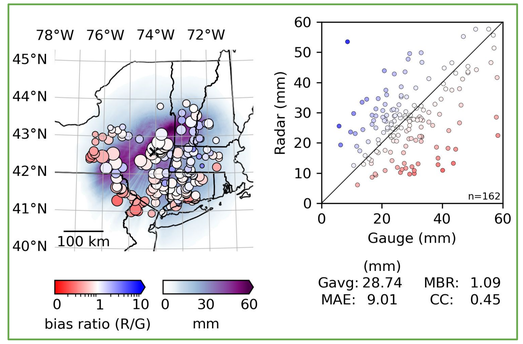
SSAA



Bu20



Bu22



Conclusions and Future Work

- Bu22 performs better than SSAA for high KDP events and vice versa, indicating a regime-dependent dual-pol snow QPE
- A large data set is collected for a "snow regimes" analysis to identify predictable Z, KDP, and frim fingerprints associated with each regime.
- Employ machine learning methods to explore the dataset and understand the tendencies of the variables vs. the QPE.
- End goal is an operational dual-pol radar snow QPE that provides accurate estimates for snow liquid water across all regimes.

References

Bukovčić, P., Ryzhkov, A., & Zrnić, D. (2020). Polarimetric Relations for Snow Estimation—Radar Verification. Journal of Applied Meteorology and Climatology, 59(5), 991–1009. https://doi.org/10.1175/JAMC-D-19-0140.1

Bukovčić, P., Ryzhkov, A., Zrnić, D., & Zhang, G. (2018). Polarimetric Radar Relations for Quantification of Snow Based on Disdrometer Data. Journal of Applied Meteorology and Climatology, 57(1), 103–120. https://doi.org/10.1175/JAMC-D-17-0090.1