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Snow Depth from AMSR-2 Using Multispectral Satellite Data in an Artificial Neural Network

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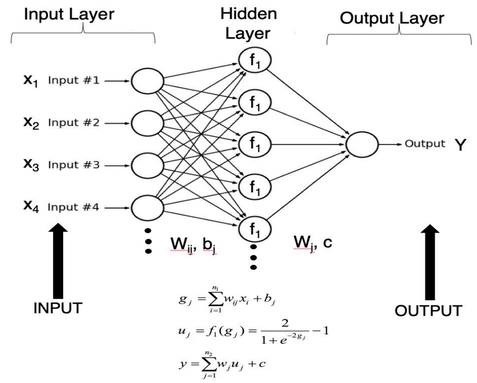
Introduction

By using diffusion theory and Monte Carlo lidar radiative transfer simulations, Hu[1] et al. (2022b) has derived snow depth from the first-, second- and third-order moments of the lidar backscattering pathlength distribution. Lu[2] et al. (2022,2024) calculated the snow depth by applying the methods to the satellite ICESat-2 lidar measurements over the Arctic sea ice, as well as land surfaces of Northern Hemisphere. In this paper, a neural network (NN) algorithm, employing several channels from AMSR-2 and the humidity vertical profiles GMAO GEOS-IT, is trained to determine snow depth identified by time and geolocation matched 2019 ICESat-2 snow-depth data during winter months over the Arctic sea ice. The trained NN snow-depth was applied to 2014-2020 AMSR-2 clear pixel data, although the algorithms perform reasonably well in thinner clouds. This paper used AMSR-2 data, a passive microwave instrument to generate a wide range of snow depth data, covering extensive spatial areas in the cross-orbit direction

Method



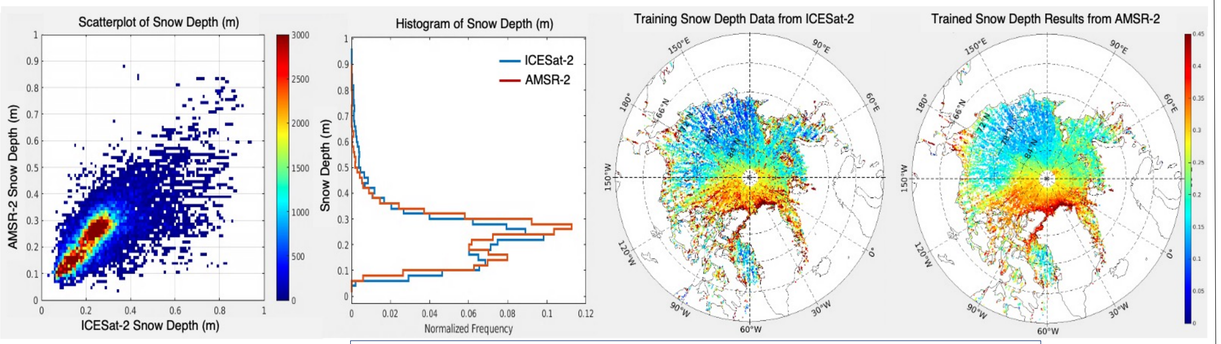
Input Layer:
- Latitude, longitude,
- AMSR-2 Brightness temperatures (10.65, 18.7, 23.8, 36.5, 89.0 GHz)
- Brightness temperature differences
- Atmospheric Vertical Humidity Profiles from GMAO-GEOSIT

Output Layer:
- Snow Depth

NN training:
- 2019 winter season of ICESat-2 snow depth[1,2], December 2018 - March 2019.

Validation:
- 2020 winter season, December 2019 – March 2020

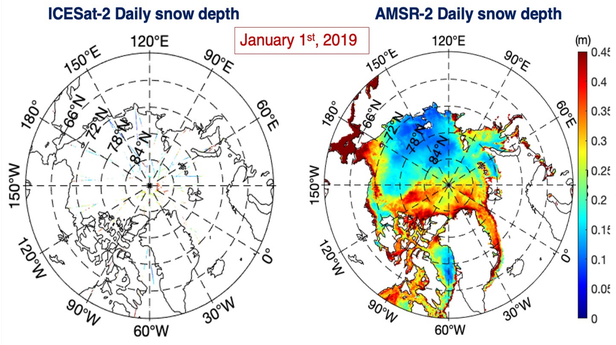
Neural Network Training



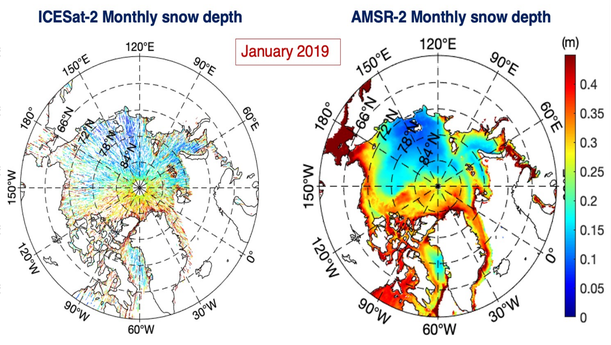
- Very little bias compared to ICESat-2 snow depth measurements
- MAE ~ 5 cm

AMSR-2 Daily & Monthly Products

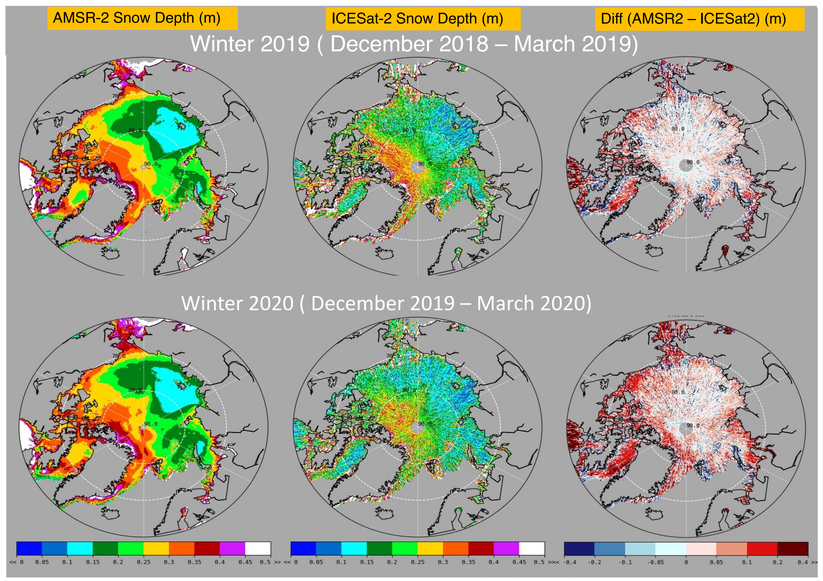
Daily Snow Depth



Monthly Snow Depth



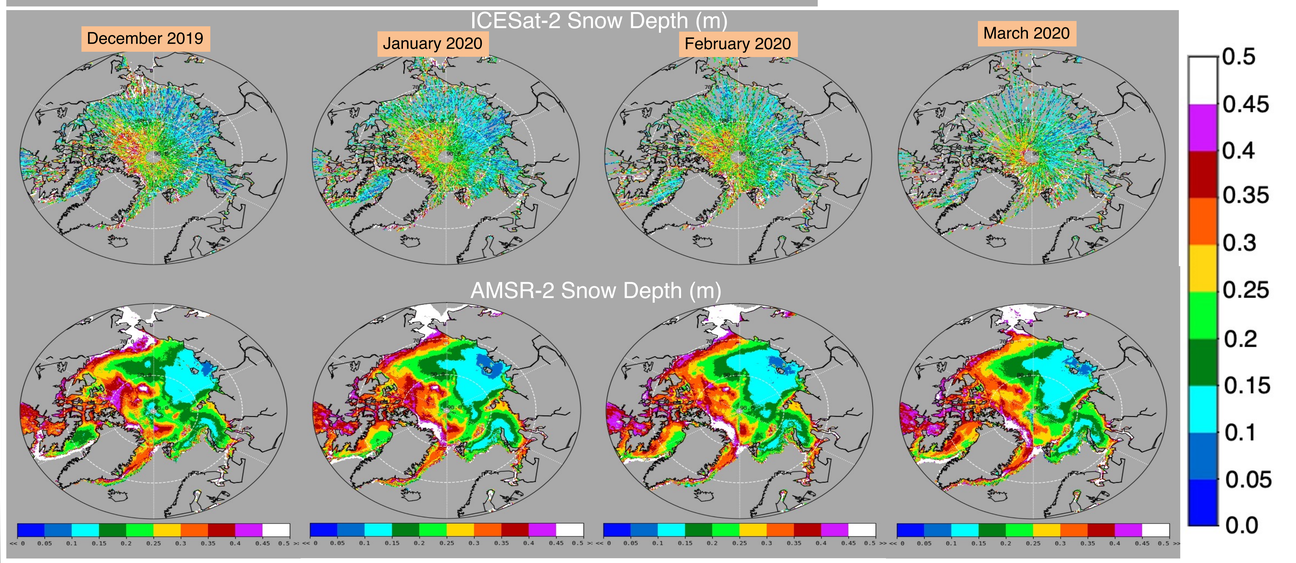
Validation



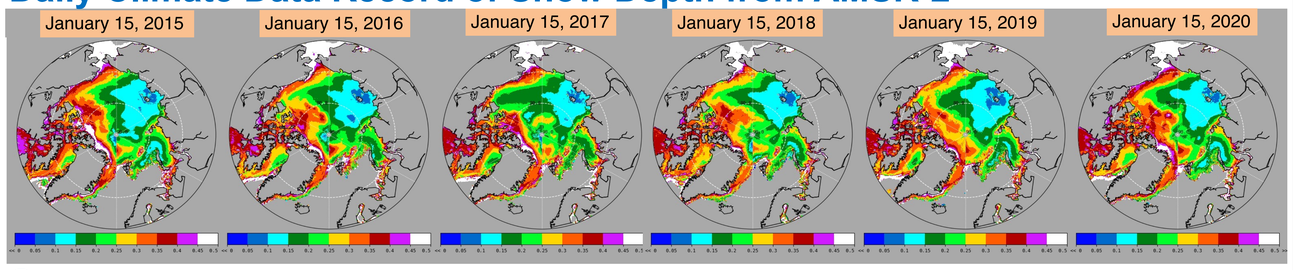
Winter 2019:
ICESat-2 (m): mean 0.26 , STDev 0.11
AMSR-2 (m): mean: 0.26 , STDev 0.08
Diff (AMSR2-ICESat2) (m): mean 0, STDev 0.09

- Good agreement North of 75N
- Larger bias south of 75N. Can be improved in the future by increasing training data at lower latitude.

Winter 2020:
ICESat-2 (m): mean 0.24 , STDev 0.11
AMSR-2 (m): mean: 0.27 , STDev 0.08
Diff (AMSR2-ICESat2) (m): mean 0.02, STDev 0.1



Daily Climate Data Record of Snow Depth from AMSR-2



Summery

- The new daily high resolution snow depth product provides constraints to physical processes in weather and climate models, e.g. snowfall & snow melting processes.
- Monthly Arctic ocean agreement with ICESat-2 within 3-5 cm & STDev ~ 10 cm. Better agreement North of 75N
- Larger bias, 10 – 20 cm, south of 75N. Can be improved in the future by increasing training data for lower latitudes.

Reference

1. *Hu, Y., Lu, X., Zeng, X., Stamnes, S. A., Neuman, T. A., Kurtz, N. T., et al.. Deriving Snow Depth From ICESat-2 Lidar Multiple Scattering Measurements. Front. Remote Sens. 3. doi: 10.3389/frsen.2022.855159 (2022)*
2. *Lu, X., Hu, Y., Zeng, X., Stamnes, S. A., Neuman, T. A., Kurtz, N. T., et al.. Deriving Snow Depth From ICESat-2 Lidar Multiple Scattering Measurements: Uncertainty Analyses. Front. Remote Sens. Accepted (2022)*