Inter-comparison of snow depth over sea ice from multiple methods

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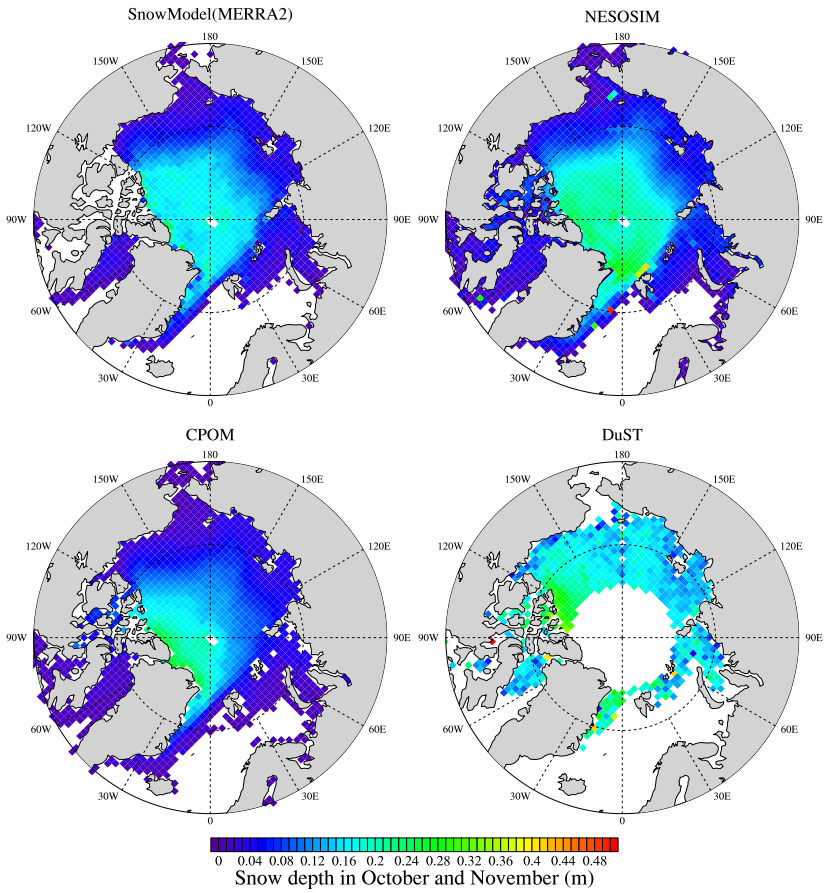
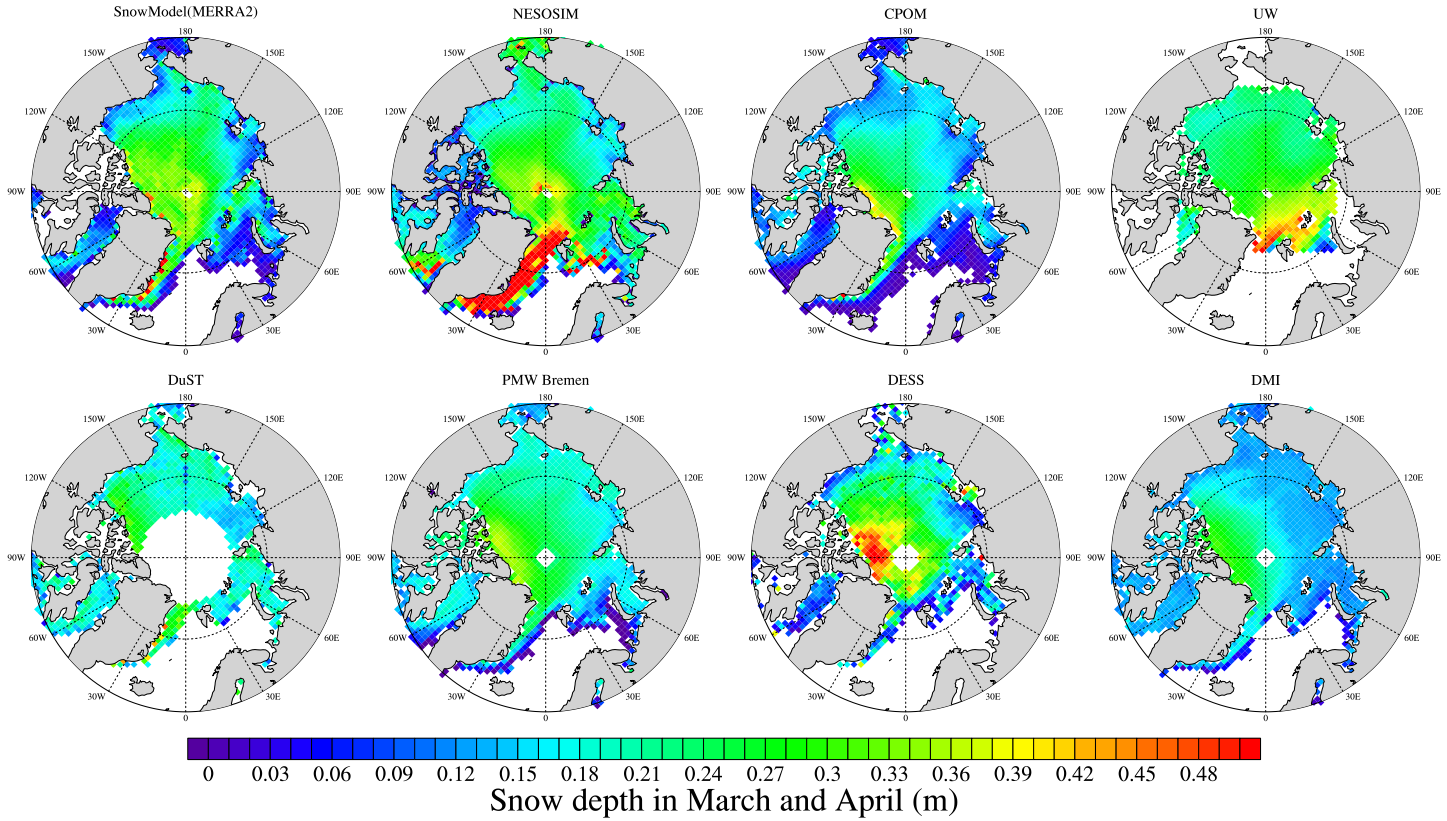
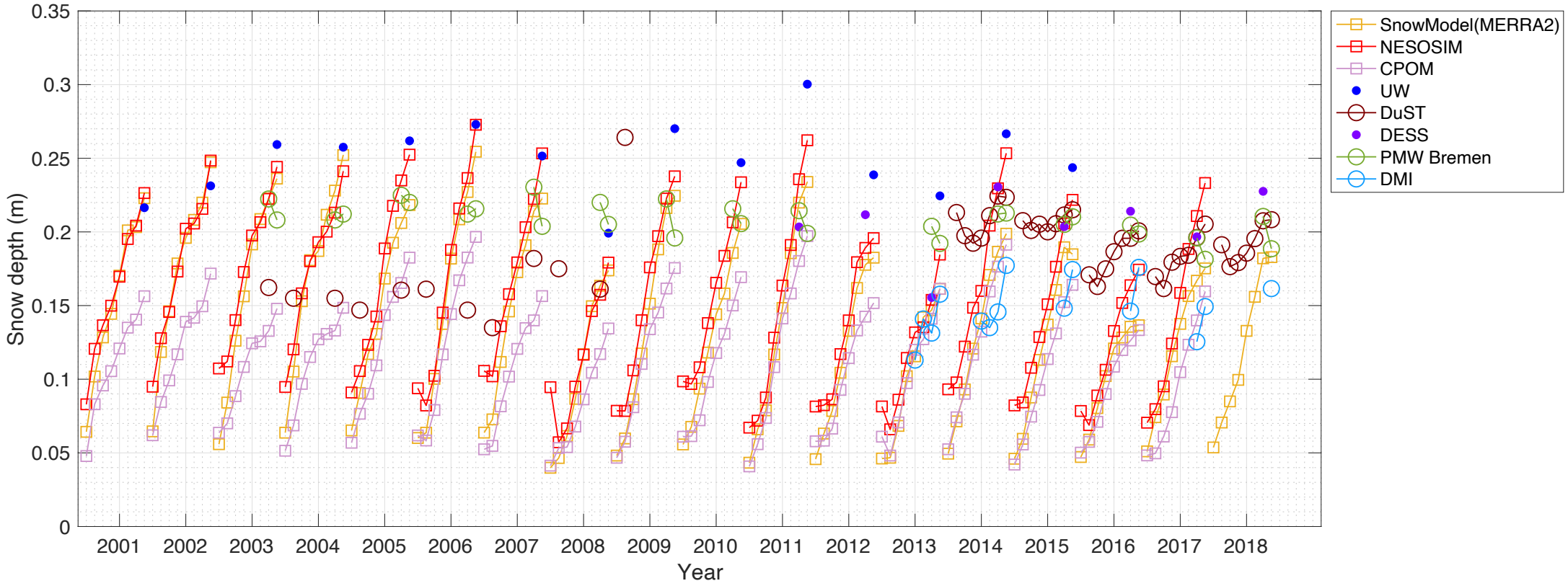
Snow Product	Method	Data Input	Spatial & Temporal Coverage	Temporal Frequency	Reference	Data Open Availability
SnowModel-LG	Sophisticated Lagrangian model	Reanalyses (MERRA2), SIE, NSIDC Drift	Whole basin, 1980-2018	Daily	Stroeve J C, Liston G E, et al. A Lagrangian Snow-Evolution System for Sea Ice Applications, submitted.	Yes
UW	Lagrangian tracking	ERA, SIE, NSIDC Drift	Whole basin, **Apr.** of 1980-2015	Monthly	Blanchard-Wrigglesworth E, Webster M A, Farrell S L, et al. Reconstruction of snow on Arctic sea ice[J]. Journal of Geophysical Research: Oceans, 2018, 123(5): 3588-3602.	Yes
NESOSIM	Eulerian snow model	ERA, SIE, NSIDC Drift	Whole basin, **Aug. to May.** of 2000-2017	Daily	Petty A A, Webster M, Boisvert L, et al. The NASA Eulerian Snow on Sea Ice Model (NESOSIM) v1. 0: initial model development and analysis[J]. Geoscientific Model Development, 2018, 11(11).	Yes
CPOM	Lagrangian tracking	ERA SWE, SIE, NSIDC Drift	Whole basin, 1980-2017	Daily	-	No
DuST	Calibrated Dual-Frequency Radar Freeboards	ENVISat & ICESat (2003~2008), CryoSat-2 & AltiKa (2013~2018)	Up to 80˚N, **Mar.-Apr. and Oct.-Nov.** for 2003-2008, **Oct. to Apr.** for 2013-2018,	Bi-Monthly & Monthly	Lawrence I R, Tsamados M C, Stroeve J C, et al. Estimating snow depth over Arctic sea ice from calibrated dual-frequency radar freeboards[J]. The Cryosphere, 2018, 12(11): 3551-3564.	Yes
DESS	Hydrostatic equilibrium & L-band radiation model	CryoSat-2 FBr (DESS-derived), SMOS TB	Up to 87.5˚N, **Mar.** 2011-2018	Monthly	Xu S M, Zhou L. Combined Retrieval of Sea Ice Thickness and Snow Depth using the Remote Sensing Data, in preparation.	No
PMW Bremen	Gradient Ratio fitting (19/7GHz)	AMSR-E/2 TB	Up to 87.5˚N **Nov. to Apr.** for 2002-2018	Near-daily	Rostosky P, Spreen G, Farrell S L, et al. Snow Depth Retrieval on Arctic Sea Ice From Passive Microwave Radiometers—Improvements and Extensions to Multiyear Ice Using Lower Frequencies[J]. Journal of Geophysical Research: Oceans, 2018, 123(10): 7120-7138.	Yes
DMI	Random forest regression model	AMSR-E and AMSR2 TB OIB snow depth	Whole basin, 2013-2018	Monthly	-	No

Mean snow depth in each snow product

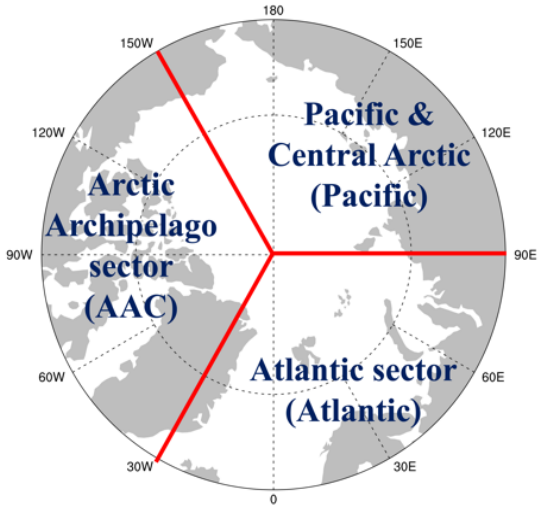


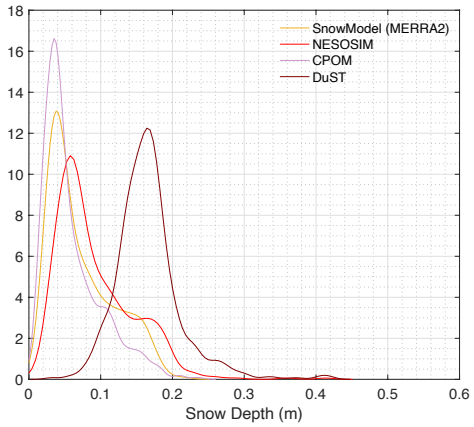


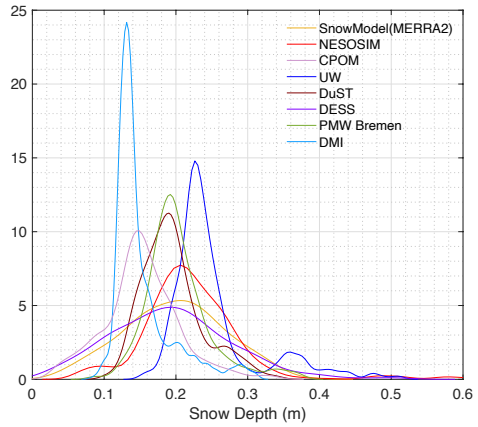
Time series of snow depth

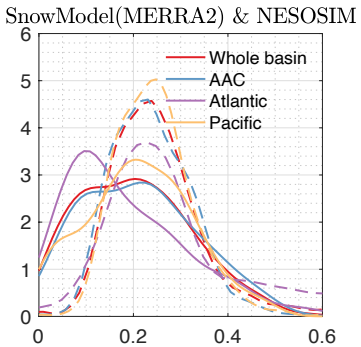


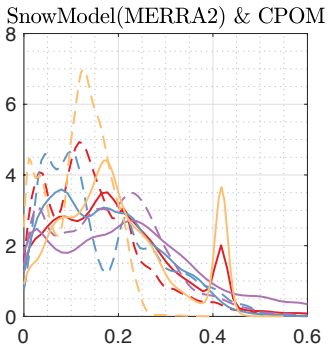
Different regions snow depth comparison

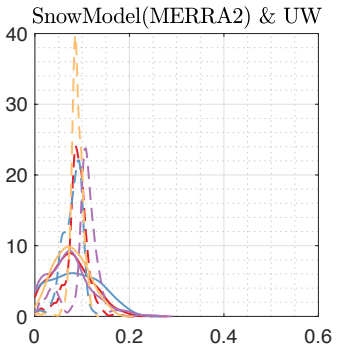


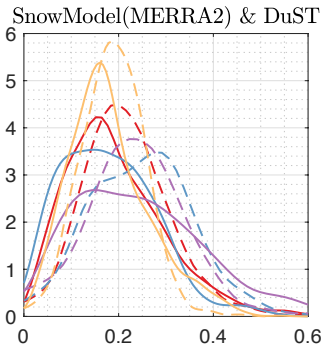


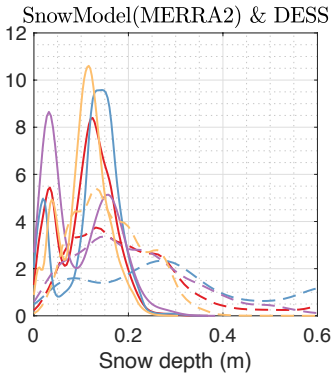


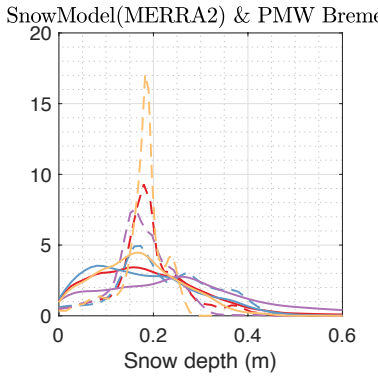


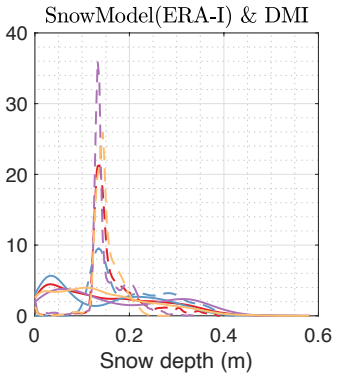




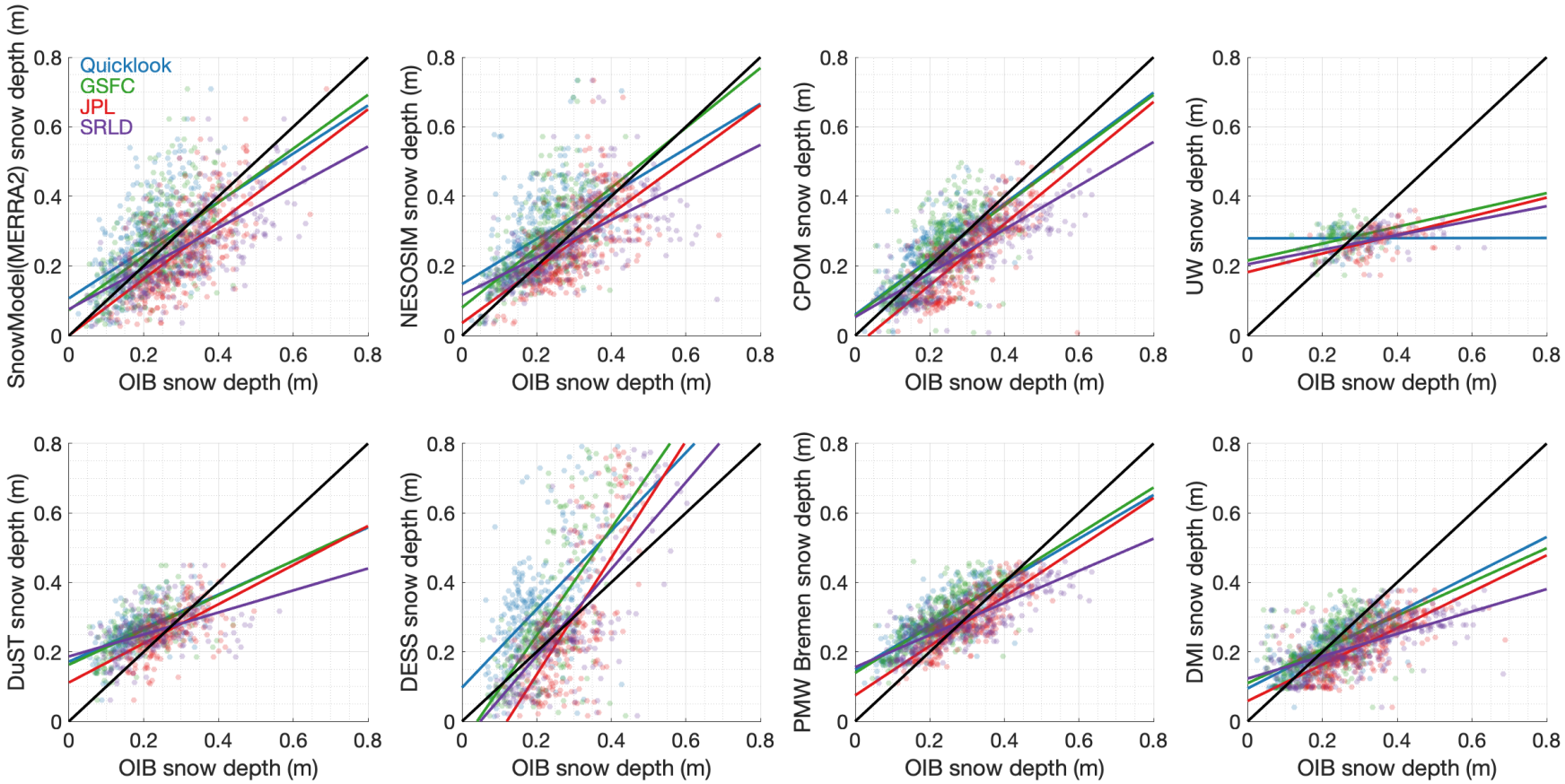








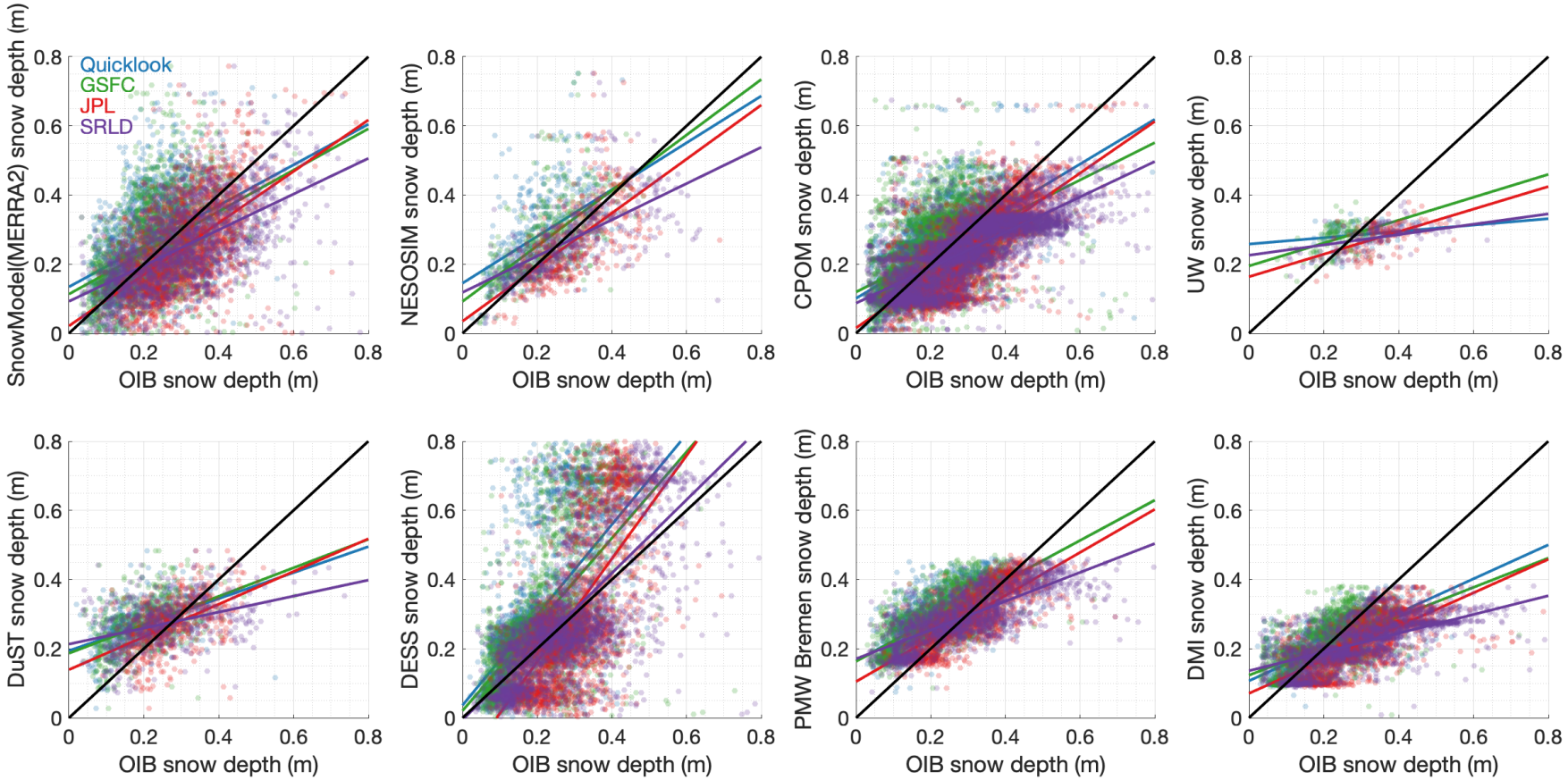
OIB 100km×100km monthly comparison (2014-2015)



R^2 and RMSE (in bracket, units: cm) in comparison with four OIB products for different spatio-temporal resolution

OIB Product	SnowModel (MERRA2)	NESOSIM	CPOM	UW	DuST	DESS	PMW Bremen	DMI
Quicklook	0.27(9.5)	0.23(10)	0.54(6.2)	0(3.1)	0.36(4.6)	0.26(14.0)	0.59(4.4)	0.54(4.4)
GSFC	0.30(9.5)	0.39(9.0)	0.43(7.4)	0.10(3.6)	0.30(5.2)	0.48(12.4)	0.56(4.8)	0.37(5.4)
JPL	0.41(8.7)	0.38(9.0)	0.59(6.2)	0.17(3.5)	0.35(5.0)	0.51(12.2)	0.70(4.0)	0.52(4.8)
SRLD	0.47(8.4)	0.38(9.1)	0.61(6.1)	0.31(3.2)	0.21(5.6)	0.59(11.1)	0.63(4.4)	0.43(5.2)

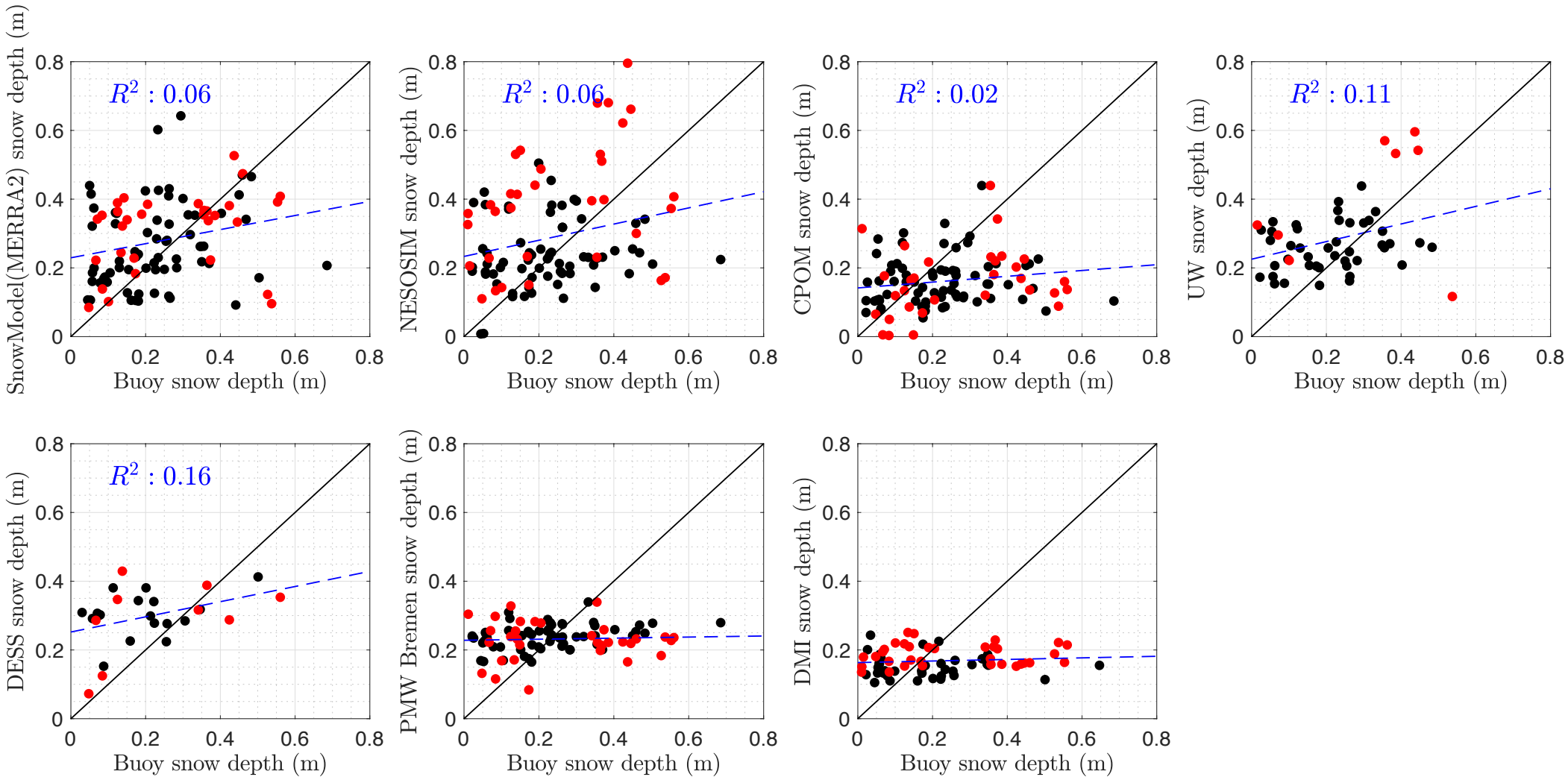
OIB native resolution comparison (2014-2015)



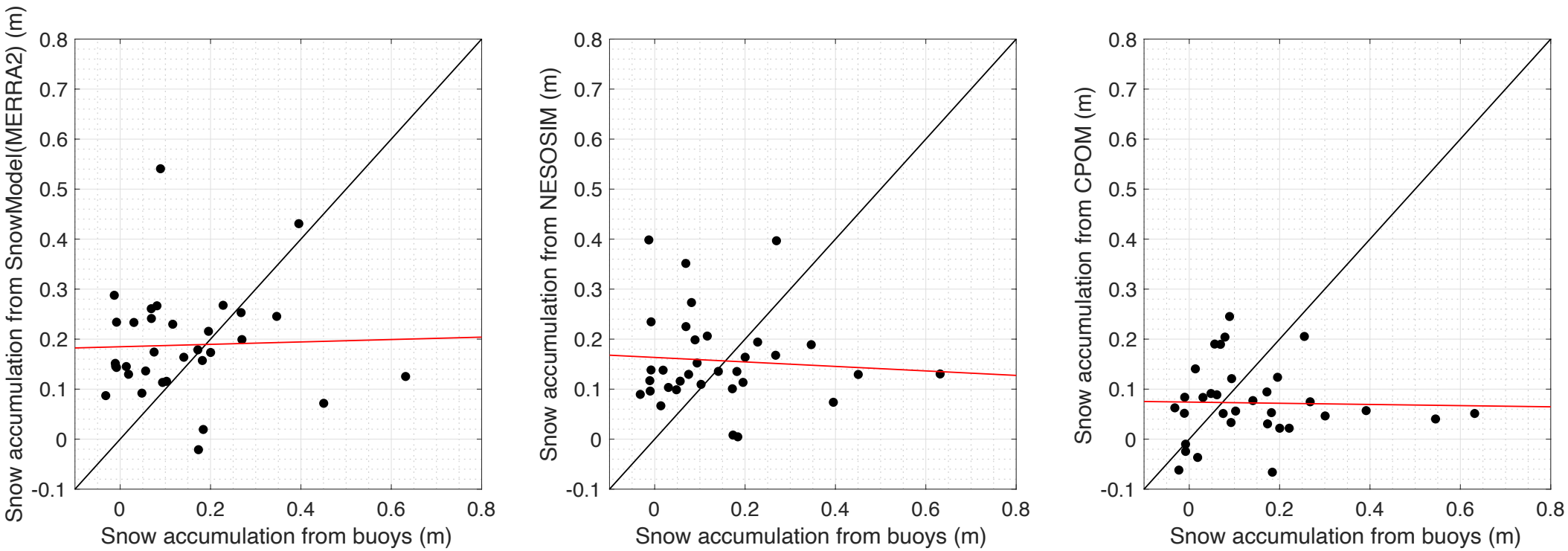
R^2 and RMSE (in bracket, units: cm) in comparison with four OIB products for different spatio-temporal resolution

OIB Product	SnowModel (MERRA2)	NESOSIM	CPOM	UW	DuST	DESS	PMW Bremen	DMI
Quicklook	0.19(11.2)	0.26(9.8)	0.42(7.3)	0.03(3.3)	0.25(5.5)	0.34(15.1)	0.51(5.1)	0.53(4.3)
GSFC	0.21(11.2)	0.41(8.6)	0.30(8.6)	0.22(3.5)	0.21(6.2)	0.41(14.8)	0.54(5.1)	0.38(5.3)
JPL	0.33(10.4)	0.41(8.6)	0.55(7.0)	0.29(3.4)	0.26(6.1)	0.46(14.2)	0.61(4.8)	0.52(4.7)
SRLD	0.35(10.4)	0.42(8.6)	0.52(7.1)	0.19(3.6)	0.15(6.5)	0.50(13.7)	0.56(5.1)	0.37(5.3)

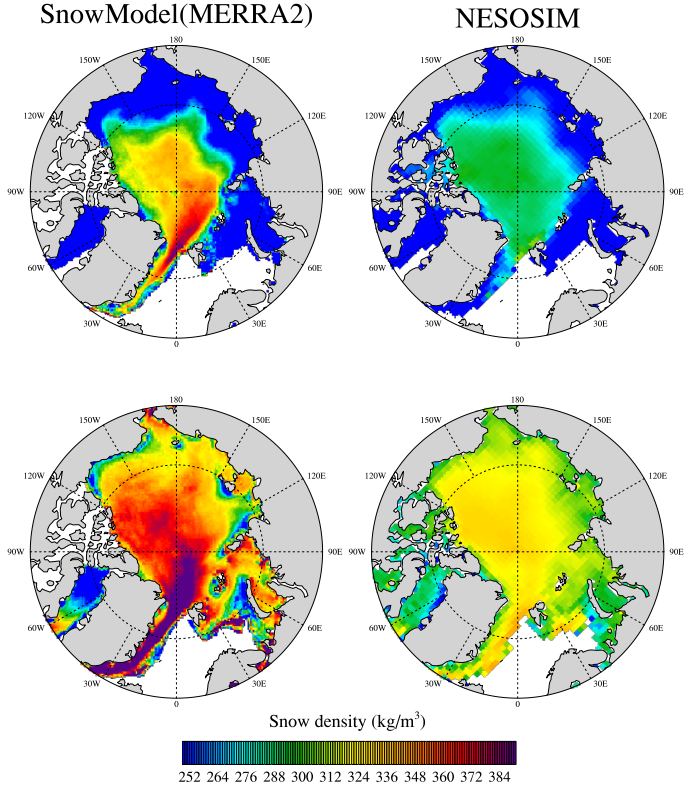
Validation with IMB and CRREY buoys mean snow depth

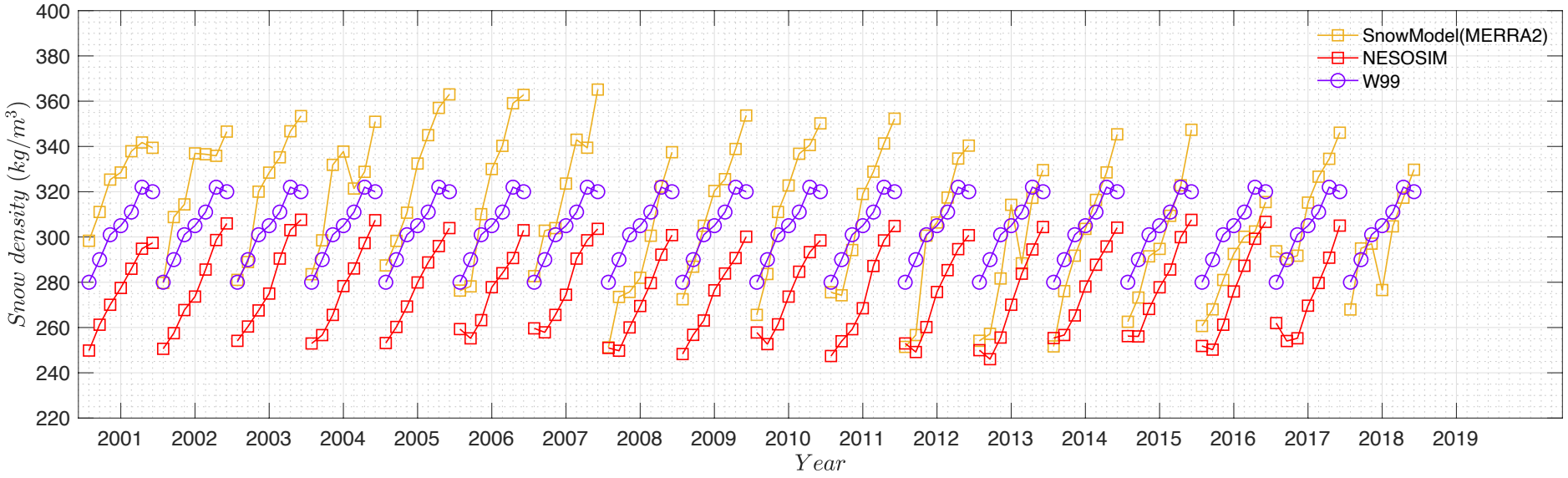


Validation with IMB and CRREY buoys accumulation

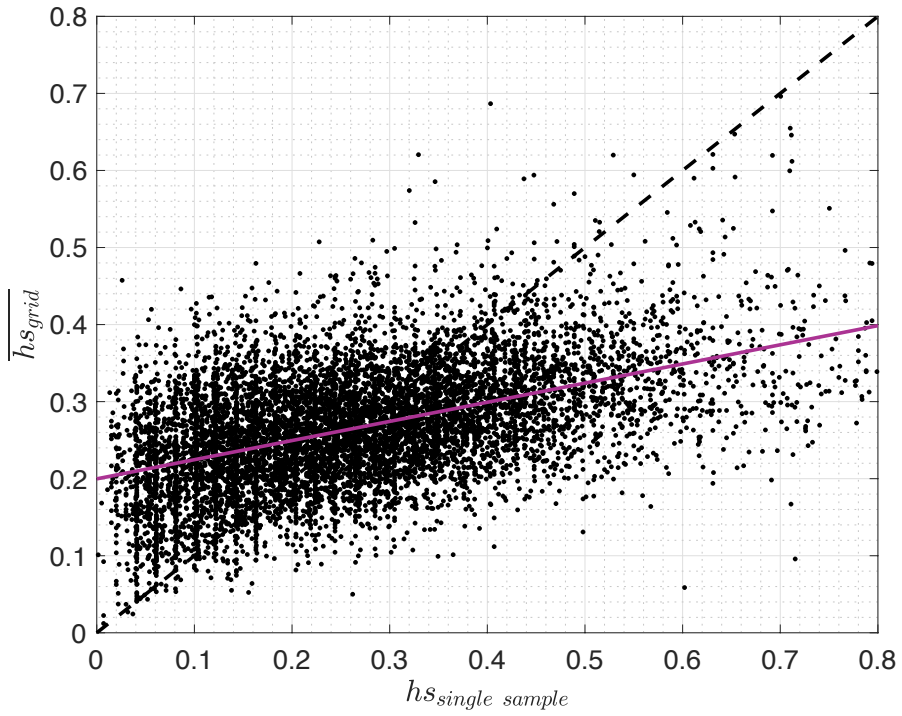


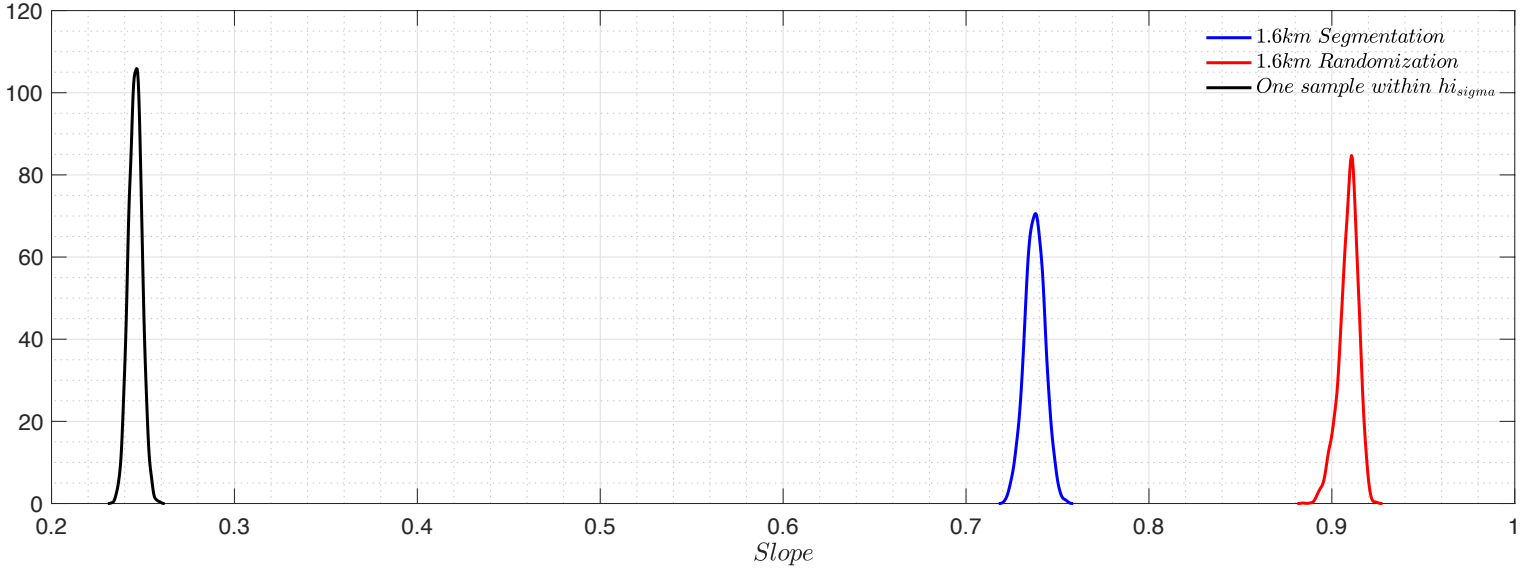
Snow density comparison





How to compare in-situ/small-scale measurement and satellite/large-scale retrieval





Conclusion

- Large differences among the snow products especially over the north Atlantic and the Canadian Arctic Archipelago
- Among all snow products, snow depth product from UW produces the overall deepest snow packs, while snow depths from CPOM provide the shallowest snow depths
- Although large discrepancies in different OIB products, all snow products except for UW have the ability to align with OIB observations
- However, it is limited to compare well with buoys mean snow depth and snow accumulation for snow products.
- Satellite-based snow products usually underestimate snow over the north of Svalbard the based on N-ICE 2015 observations
- More Arctic surveys are needed over different spatial and temporal scales for a more systematic comparison and fusion of airborne, in-situ and remote sensing observations.