Comparison and evaluation of Arctic sea ice thickness products derived from CryoSat-2

Li Mengmeng, Chang-Qing Ke

School of Geographic & Oceanographic Sciences, Nanjing University, 210023, China

(1007589079@qq.com, kecq@nju.edu.cn)

Introduction

Sea ice is an important and sensitive indicator of global climate changes. Based on remote sensing and submarine upward looking sonar data during the past five decades, Arctic winter sea ice thickness have shown nearly a 2-fold thinner in mean winter thickness (Kwok and Rothrock, 2009; Kurtz et al., 2014), while multi-year ice (MYI) extent showed a 15.1% decline per decade in the past three decades (Comiso, 2011).

Currently, three CS-2 sea ice products are available for the Arctic sea ice: the AWI (the Alfred-Wegener-Institute) one based on TFMRA, the NSIDC (the National Snow and Ice Data Center) one based on the waveform fitting method (Kurtz et al., 2014), and the ESA Level-2 Interim. Due to the uncertainty of SIT estimations from each method, it is essential to quantify discrepancies among the three products. In this study, based on IceBridge (OIB) sea ice products, we compare the above-mentioned three products, not only their differences in space and magnitude, but also their interannual and seasonal differences.

Data & Methods

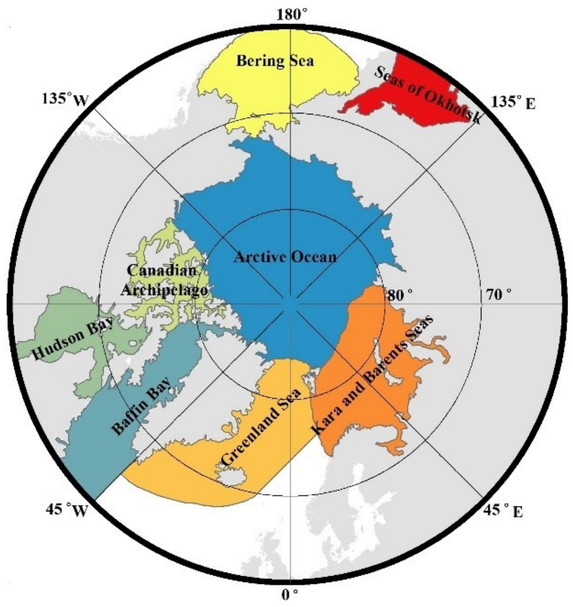

Fig. 1 Study area of Arctic Ocean (blue) and its adjacent sea regions

the hydrostatic balance equation to convert ESA CS-2 L2I freeboard to sea ice thickness:

- $T = F_R \times \frac{\rho_W}{\rho_W - \rho_I} + S \times \frac{\rho_S}{\rho_W - \rho_I}$

Sea ice thickness uncertainties:

- $\frac{\partial T}{\partial F_R} = \frac{\rho_W}{\rho_W - \rho_I}$
- $\frac{\partial T}{\partial \rho_S} = \frac{S}{\rho_W - \rho_I}$
- $\frac{\partial T}{\partial \rho_I} = \frac{F_R \times \rho_W + S \times \rho_S}{(\rho_W - \rho_I)^2}$
- $\frac{\partial T}{\partial S} = \frac{\rho_S}{\rho_W - \rho_I}$

Results & Analysis

Table 1 CryoSat-2 sea ice thickness (SIT) from NSIDC, AWI and ESA compared to OIB SIT for the period 2011- 2015, 2017, for first-year ice (FYI), multi-year ice (MYI), and all ice together (ALL).

	AWI - OIB			ESA – OIB			NSIDC - OIB		
	FYI	MYI	ALL	FYI	MYI	ALL	FYI	MYI	ALL
Number of grid points	220	478	698	220	478	698	220	478	698
Mean difference (m)	0.23	-0.17	-0.04	0.95	0.02	0.31	0.26	0.11	0.01
RMSE (m)	0.64	0.89	0.82	1.14	0.94	1.00	0.64	0.87	0.81
Correlation	0.71	0.55	0.66	0.6	0.46	0.49	0.67	0.57	0.68

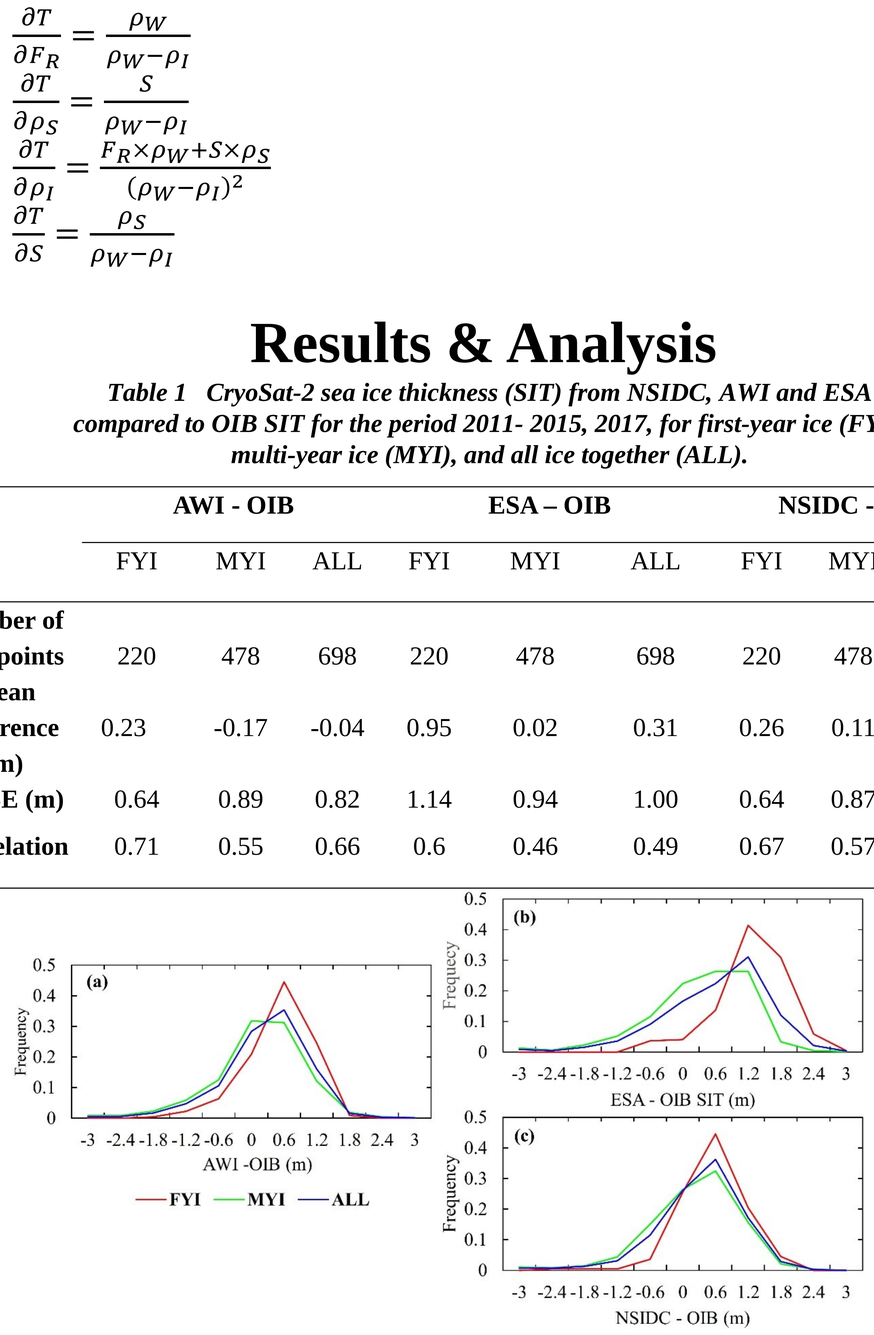

Figure 2. Histograms of the gridded sea ice thickness differences between CS-2 and OIB for the period 2011- 2015, 2017. Differences are shown separately for FYI, MYI, and all data, with (a) for the differences between AWI and OIB, (b) the differences between ESA and OIB, and (c) the differences between NSIDC and OIB.

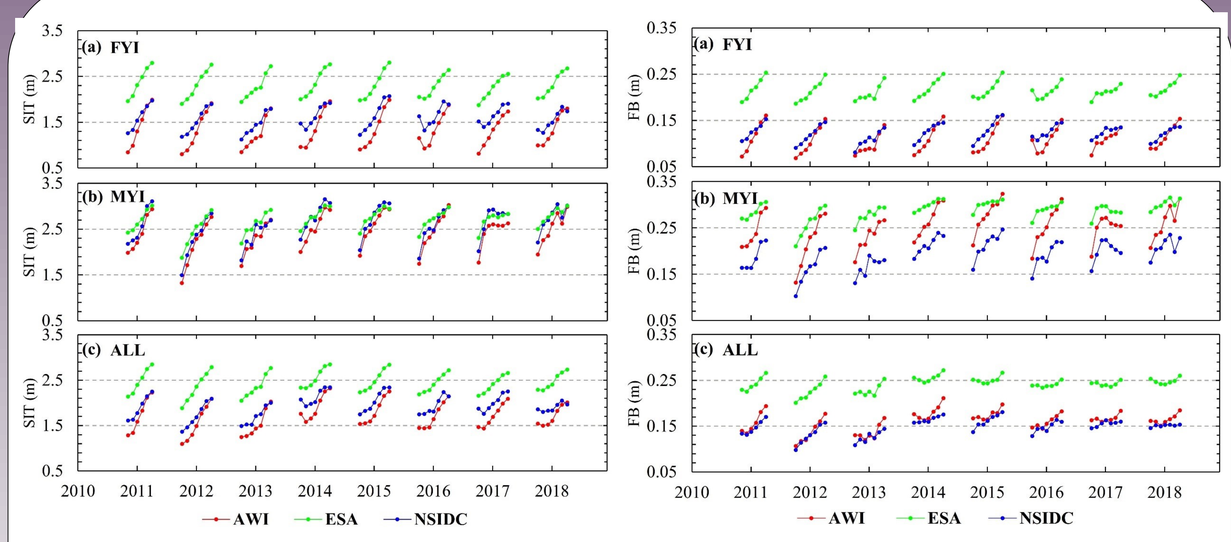

Figure 3. The three monthly mean SIT and FB (freeboard) are plotted from October to next April in 2010 - 2018. The ice extent is unified. The FB of FYI, MYI, and combined ALL sea ice are plotted from top to bottom.

Table 2 The input parameters used to convert FB to SIT for AWI, ESA and NSIDC.

SIT Products	Freeboard retrackers	[3]Sea ice density (kg/m^3)	[3]Snow depth	Sea water density (kg/m^3)	Snow density (kg/m^3)	Sea ice type
AWI	[1]TMFRA	916.7 (882)	1/2W99(W99)	1024	W99	OSI-SAF
ESA	Unknown	916.7 (882)	1/2W99 (W99)	1024	W99	OSI-SAF
NSIDC	[2]WfF	915	1/2W99 (W99)	1024	W99	OSI-SAF

1TMFRA: threshold first-maximum retracker algorithm.
2WfF: physical waveform fitting retracker.
3FYI parameters are listed, followed by MYI parameters inside parentheses.

Table 3 CryoSat-2 sea ice freeboard from NSIDC, AWI and ESA compared to OIB ice freeboard for the period 2011 - 2015 and 2017

	AWI - OIB			ESA – OIB			NSIDC - OIB		
	FYI	MYI	ALL	FYI	MYI	ALL	FYI	MYI	ALL
Number of grid points	220	478	698	220	478	698	220	478	698
Mean difference (m)	0.004	0.05	0.04	0.09	0.06	0.07	-0.004	-0.03	-0.02
RMSE (m)	0.07	0.10	0.09	0.11	0.10	0.10	0.06	0.08	0.08

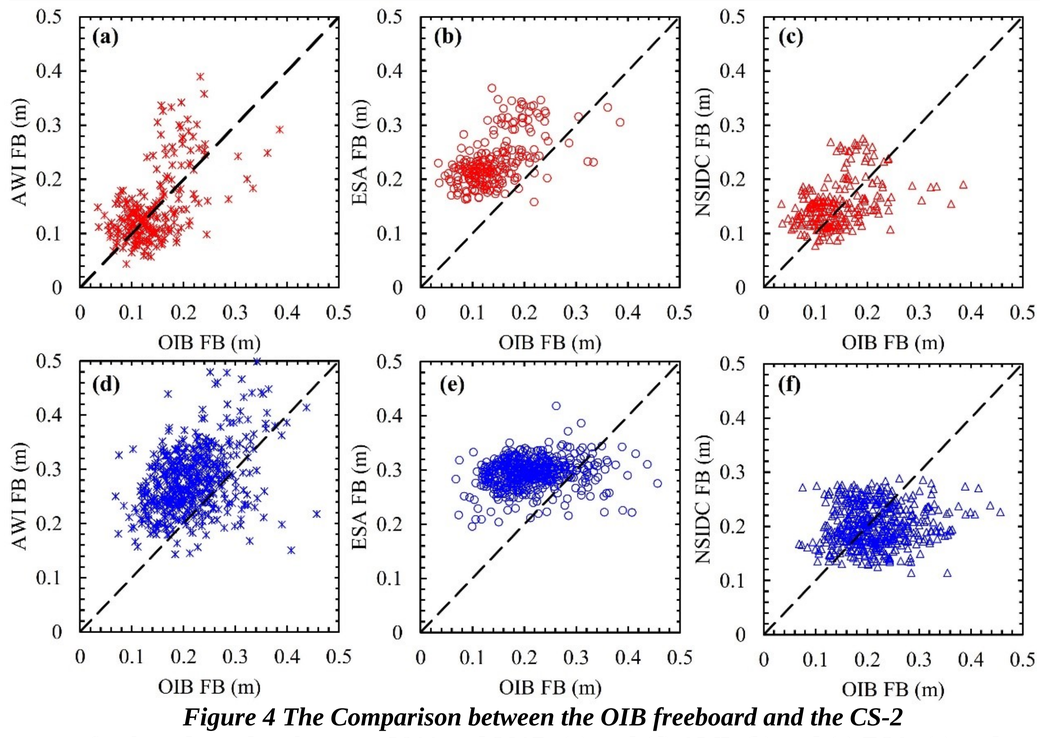

Figure 4 The Comparison between the OIB freeboard and the CS-2 freeboard product between 2011 and 2017: (a) and (d) AWI, (b) and (e) ESA, (c) and (f) NSIDC. The top row (a, b, c) is for FYI freeboard, and the bottom row (d, e, f) is for MYI freeboard.

Conclusions

- The SIT difference between OIB and L2I is the biggest while the difference between OIB and NSIDC is the smallest. CS-2 L2I SIT is the highest; there is little difference between AWI and NSIDC SIT.
- Sea ice density and freeboard dominate the sources of thickness discrepancy.
- 50% threshold is shown to be too low for the radar pulse penetrating into the snow layer.
- L2I FYI freeboard should be regarded as snow freeboard.
- NSIDC CS-2 sea ice product is the nearest to OIB and applying different freeboard retrievals depending on sea ice type is necessary in the future.

References

- Kurtz N T, Galin N, Studinger M. An improved CryoSat-2 sea ice freeboard retrieval algorithm through the use of waveform fitting, The Cryosphere, 8, 1217-1237, doi: 10.5194/tc-8-1217-2014, 2014.
- Kwok R, Rothrock D A. Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008, Geophysical Research Letters, 36,1958-2008, doi: 10.1029/2009GL039035, 2009.
- Comiso J C. Large Decadal Decline of the Arctic Multiyear Ice Cover, Journal of Climate, 25, 1176-1193, doi: 10.1175/JCLI-D-11-00113.1, 2011.