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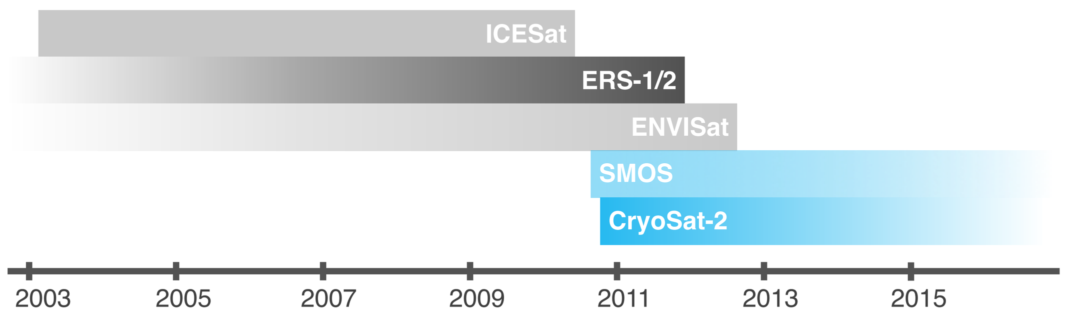
Arctic and Antarctic Sea-Ice Thickness Derived from CryoSat-2, SMOS, and Envisat

Introduction

Only remote sensing allows us to retrieve sea-ice thickness on a global scale. Altimeter range measurements provide surface elevations, which are referenced to the sea level to obtain ice freeboard that can be transformed into sea-ice thickness by assuming hydrostatic equilibrium [1]. In addition, radiometer measurements can be converted into ice thickness [2]. In order to derive long term trends, it is necessary to combine subsequent satellite mission retrievals (Figure 1).



Satellite	ERS-2	ENVISat	ICESat	SMOS	CryoSat-2
Sensor	Radar K_u-Band	Radar K_u-Band	Laser	Radiometer	Radar K_u-Band
Max Latitude	81.5°	81.45°	86°	81.6°	88°
Footprint	10 km	10 km	70 m	~40 km	300 x1650 m (Doppler Beam)

Figure 1: Satellite missions with capability to derive sea-ice thickness.

CryoSat-2 Sea-Ice Thickness Product

CryoSat-2 along-track measurements are averaged within 1 month (Figure 2). Time series from 2011-2016 reveal strong inter-annual variations and a substantial thickness decrease in 2016, caused by high melting rates in summer 2015 and an unlikely warm winter. Data are provided at http://www.meereisportal.de. The Applied Physics Laboratory (APL, University of Washington) incorporated the product in their Climate data record data base: http://psc.apl.uw.edu/sea_ice_cdr/Sources/CryoSat2-AWI.html.

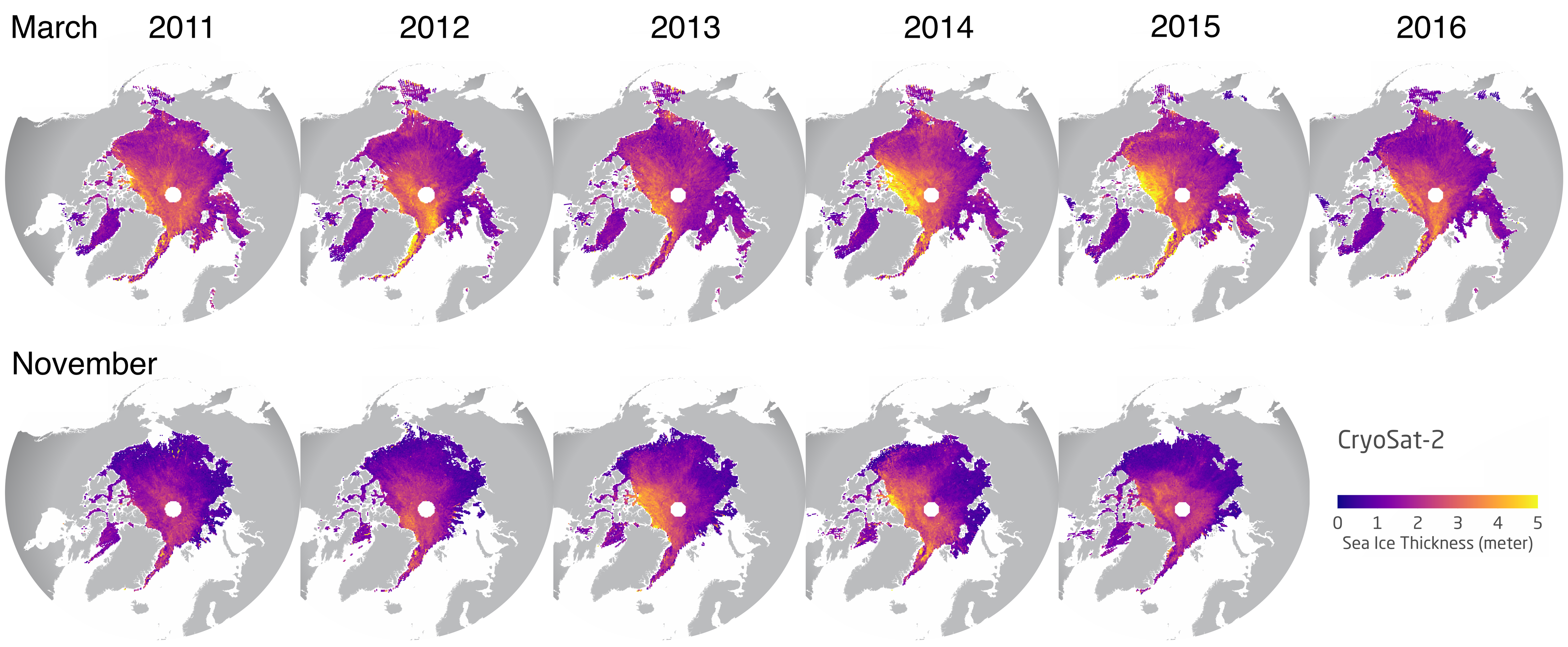


Figure 2: Sea-ice thickness distributions of monthly means from Mar/Nov 2011-2016, derived from CryoSat-2.

CryoSat-2—SMOS Data Fusion

We yield CryoSat-2—SMOS sea-ice thickness weekly products by using an iterative approach of optimal interpolation (Figure 3a), taking advantage of the complementary characteristics of the individual retrievals like the sensitivity according to different ice thickness regimes (CryoSat-2: thick ice, SMOS: thin ice) and the orbit coverage (high latitudes: CryoSat-2, low latitudes: SMOS). The obtained northern hemisphere ice volume shows a substantial decrease in winter 2016, compared to the last two seasons, caused by high melting rates in summer 2015, and amplified by the following unusual warm winter (Figure 3b).

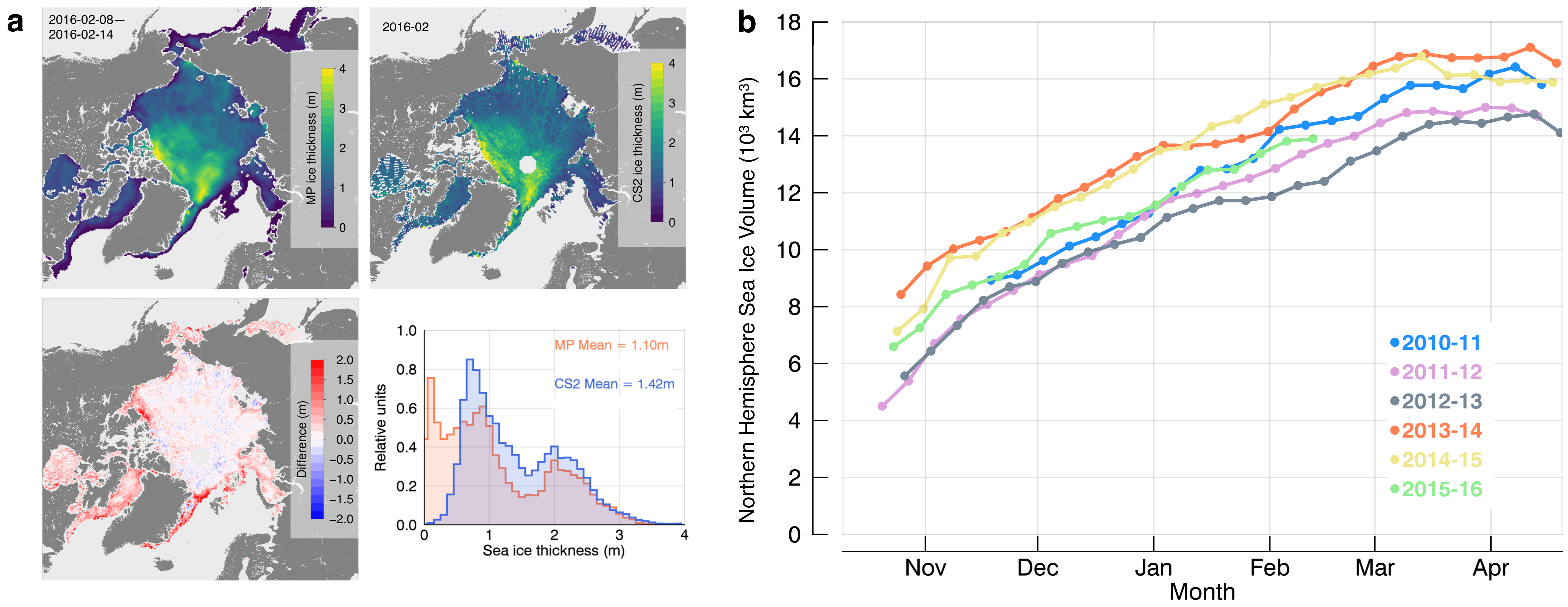


Figure 3: (a) Weekly ice thickness of the merged CryoSat-2—SMOS product (MP) and the difference to CryoSat-2 only (CS2). (b) northern hemisphere sea-ice volume time series over 6 winter seasons.

Extending the Time Series with Envisat

In order to combine Envisat and CryoSat-2 time series, the consistency between both retrievals has to be considered. A comparison of radar freeboard, which is the height of the radar main scattering horizon above the water level, has been conducted during the overlap period in 2011 [3]. Envisat shows higher freeboard in the seasonal ice zone, while CryoSat-2 freeboards are higher in the perennial ice zone and near the coasts (Figure 4). Such anomalies are caused by different sensor characteristics (Figure 1) and different processing algorithms.

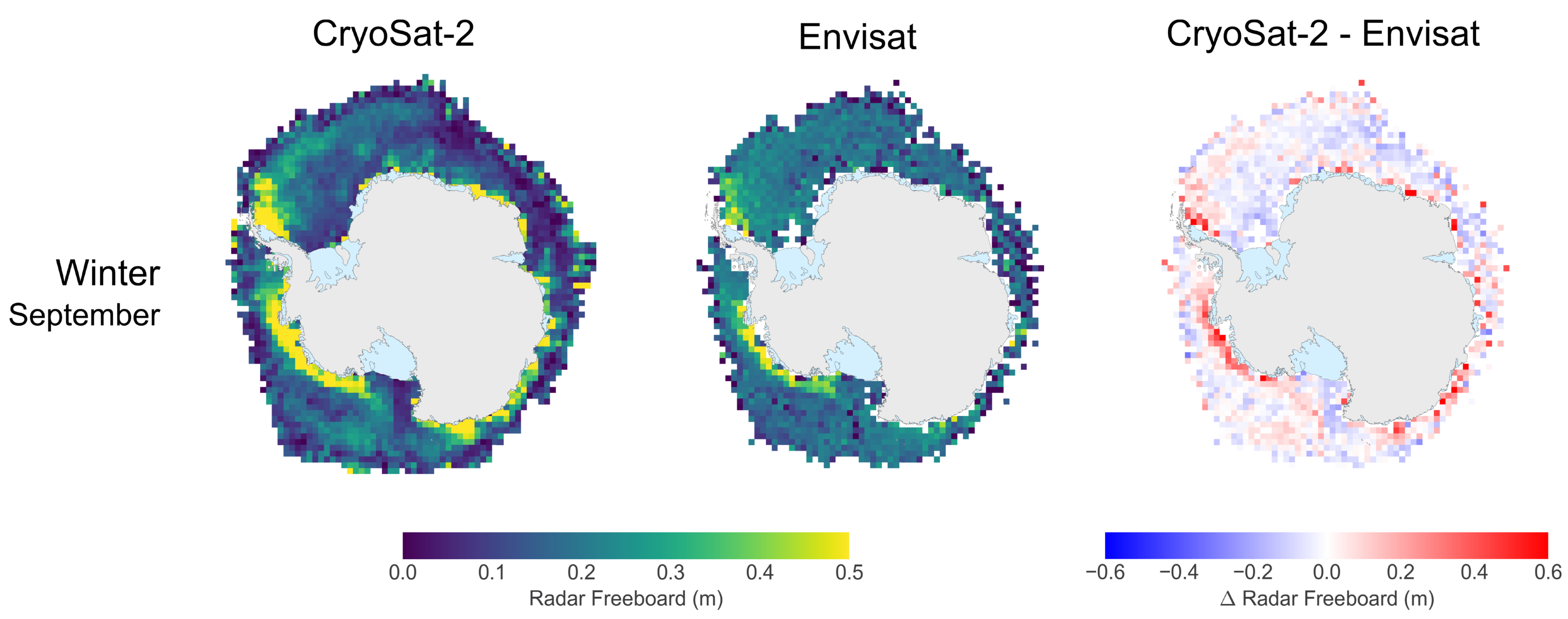


Figure 4: Comparison of winter radar freeboard of CryoSat-2 and Envisat.

Conclusions

- High melt rates during summer 2015 and a warm winter lead to reduced sea-ice thickness and ice volume in March 2016.
- The CryoSat-2—SMOS data fusion takes advantage of the complementary characteristics of both products.
- The optimal interpolation approach can be adopted for the combination with other sea-ice thickness products (e.g. **Sentinel-3** in the future).
- A comparison between Envisat and CryoSat-2 freeboard retrievals over Antarctic sea ice shows similar patterns but differences in magnitudes.

References

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Acknowledgments

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