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Sea ice in the Laptev Sea might be thicker than you think (or satellites want to make you believe)

13-years of sea ice draft observations in the Laptev Sea from moored ADCPs and ULS

Motivation

- Laptev Sea is one of the most important source regions of Arctic sea ice
- In-situ observations of SIT are limited - only ULS data from 2013 to 2015
- ADCP data for potential sea ice draft derivation from 2003 to 2016
- Satellite SIT products are not validated in the Laptev Sea region

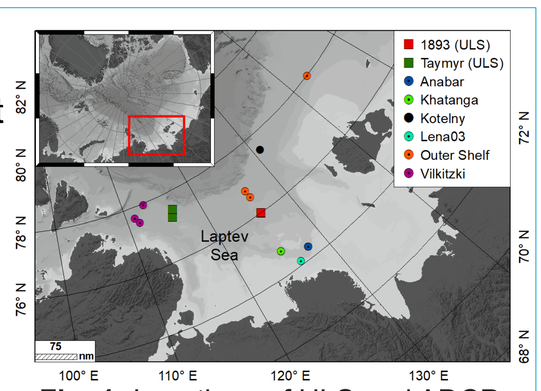
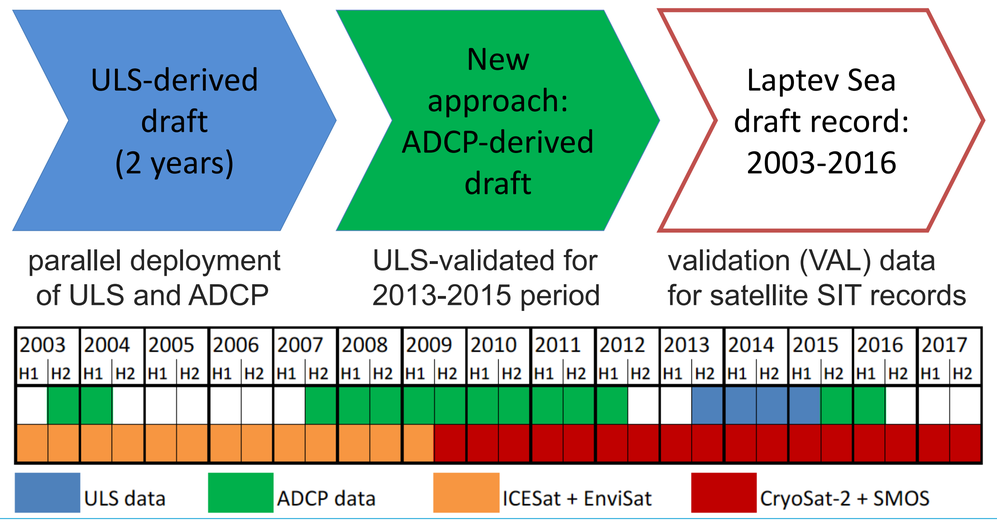


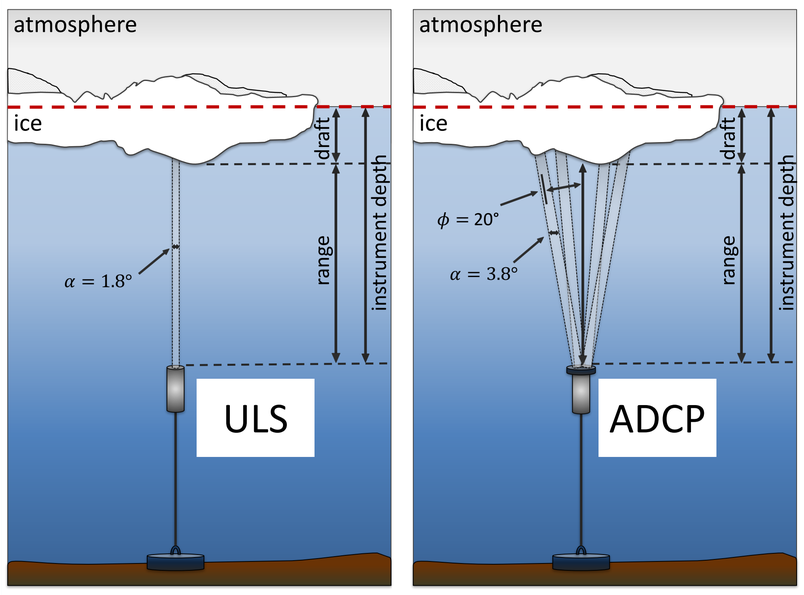
Fig. 1: Locations of ULS and ADCP moorings in the Laptev Sea

Extension of the Laptev Sea sea ice draft record



ULS versus upward-looking ADCP

- Parallel deployment of ULS and ADCP between 2013-2015



ULS	ADCP
Purpose	
• Ice draft	• Currents • Ice drift
Beams	
1	4
Beamwidth	
1.8°	3.8°
Default beam angle	
0°	20°
Sampling frequency	
Range: 1s Tilt: 1min	Range: 1h Tilt: 1h
Pressure data	
YES (1min)	NO

- Sea ice draft equation:

$$d = \eta - \beta \cdot r \cdot \cos\theta$$

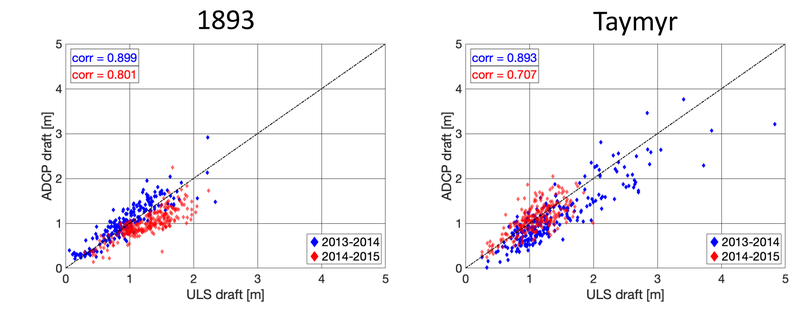
d - draft
η - instrument depth
β - sound speed correction
r - range
θ - sonar tilt

- ULS setup is superior for sea ice draft derivation
- Deficiency the Laptev Sea ADCPs:
  - no pressure sensors to determine instrument depth

New approach to derive sea ice draft from ADCPs

- ADCP bottom track measurements of error velocity and range provide: instrument depth for each of the four beams
- Most frequent open water range value = instrument depth (constant)
- Final data product: **daily mean sea ice draft (uncertainty: 0.1 m)**

ADCP draft validation



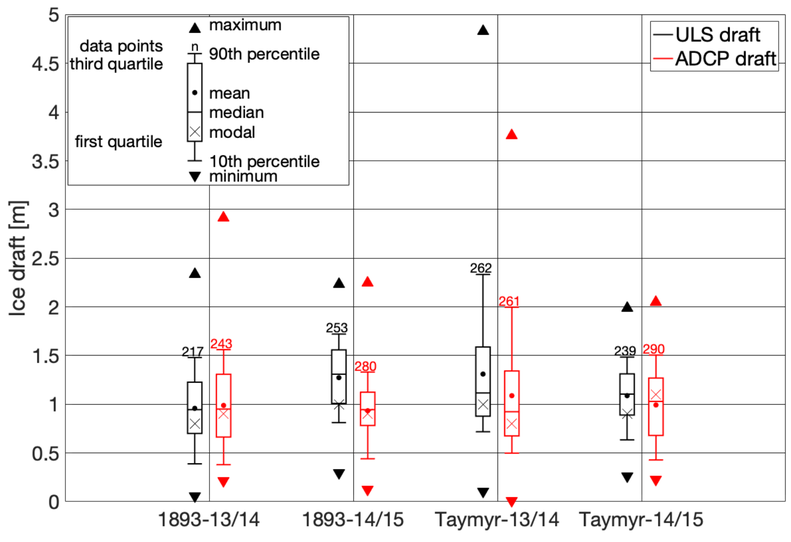


Fig. 2: ADCP versus ULS-derived daily mean sea ice draft for the 1893 (left) and Taymyr (right) stations between 2013 to 2015. Correlation coefficients are given in the top left.

Fig. 3: Boxplots for daily mean ice draft derived from ULS (black) and ADCP (red). Sampling periods: from 2013 to 2014 (13/14) and 2014 to 2015 (14/15).

Comparison to satellite-based (SAT) SIT products

- Analysed SAT SIT data sets:
  - Gridded ESA SICCI-2, CS2 trajectory (orbit) data, merged CS2SMOS
- Thickness-dependent agreement between SAT and VAL data

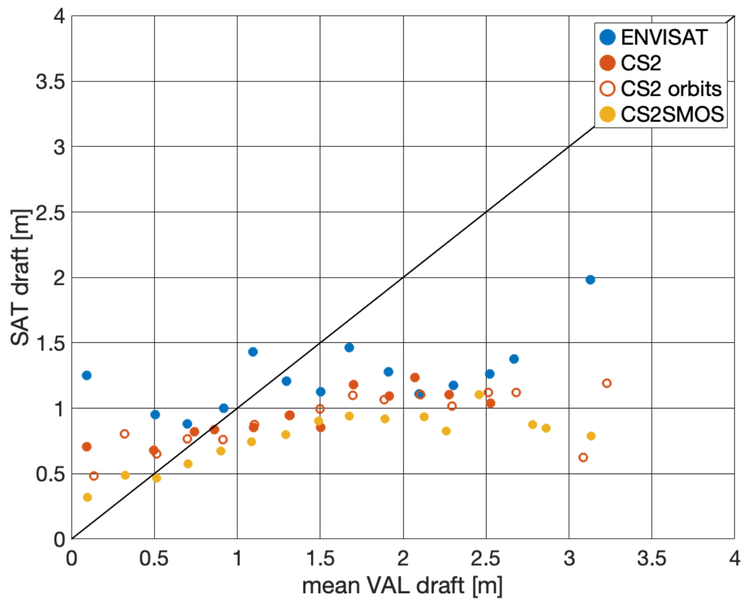
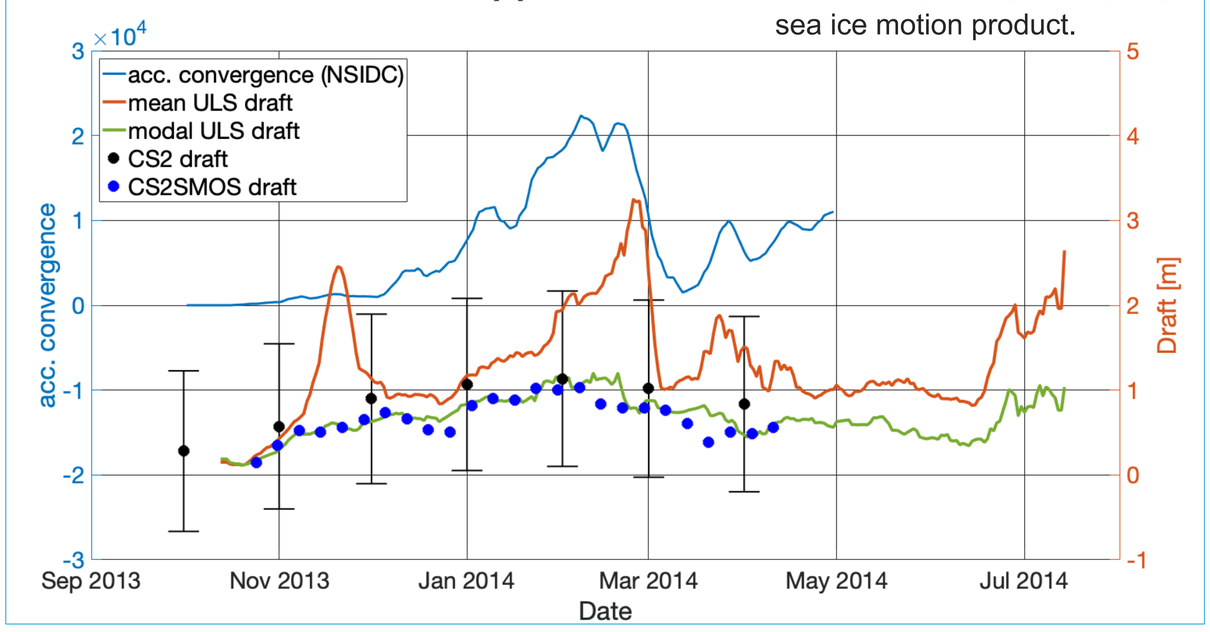


Fig. 4 (left): Mean sea ice drafts per 0.2 m VAL data bin from ENVISAT, CS2, CS2 trajectory and merged CS2SMOS data products

Fig. 5 (below): Taymyr 2013 to 2014 comparison between VAL mean and modal sea ice draft to mean CS2 and CS2SMOS sea ice draft. A Lagrangian ice tracking tool (Krumpen, 2017) provided trajectories of the ice that passed by the mooring on a daily basis. Accumulated convergence was calculated along each track and is based on the NSIDCs Polar Pathfinder sea ice motion product.



Conclusions

❖ Upward-looking ADCPs can be used to derive: daily mean sea ice draft time series (uncertainty 0.1 m)

❖ Agreement between Laptev Sea SAT and VAL data is strongly dependent on thickness of the sampled sea ice

Data access

Belter, H. J., M. A. Janout, T. Krumpen, J. A. Hoelemann, L. Timokhov, A. Novikhin, H. Kassens (2019): Raw bottom track error velocity and range data from moored upward-looking Acoustic Doppler Current Profilers in the Laptev Sea between 2013 and 2015. PANGAEA DATA: https://doi.org/10.1594/PANGAEA.899269

Belter, H. J., M. A. Janout, T. Krumpen, E. Ross, J. A. Hoelemann, L. Timokhov, A. Novikhin, H. Kassens, G. Wyatt, S. Rousseau, D. Sadowy (2019): Daily mean sea ice draft from moord Upward-Looking Sonars in the Laptev Sea between 2013 and 2015. PANGAEA DATA: https://doi.org/10.1594/PANGAEA.899275

ESA SICCI-2 gridded SIT product (ENVISAT and CS2) available at: https://cci.esa.int/seaice

Ricker, R., Hendricks, S., Kaleschke, L., Tian-Kunze, X., King, J. and Haas, C. (2017), A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 11, 1607-1623, doi:10.5194/tc-11-1607-2017. Weekly updated CS2SMOS product: https://data.seaiceportal.de/data/cs2smos/

References

Belter, H. J., T. Krumpen, M. A. Janout, E. Ross and C. Haas (2019): Sea ice draft from upward-looking Acoustic Doppler Current Profilers (ADCPs): an adaptive approach, validated by Upward-Looking Sonar (ULS) data. **in review** at the Journal of Atmospheric and Oceanic Technology

Krumpen, T. (2018): AWI ICETrack: Antarctic and Arctic Sea Ice Monitoring and Tracking Tool. hdl:10013/epic.9ee550b6-5966-4db6-a042-f4256810ec3f

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The 2013/2014 ULS data sets were processed by ASL Environmental Sciences Inc., Victoria, BC, Canada. ASL also provided valuable support and the toolboxes for the processing of the 2014/2015 ULS data sets. Additionally, the ECMWF provided ERA-Interim reanalysis surface pressure data (Dee et al., 2011) that was valuable for the ULS processing.

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