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# Monitoring Arctic thin ice: A comparison between Cryosat-2 SAR altimetry data and MODIS thermal-infrared imagery

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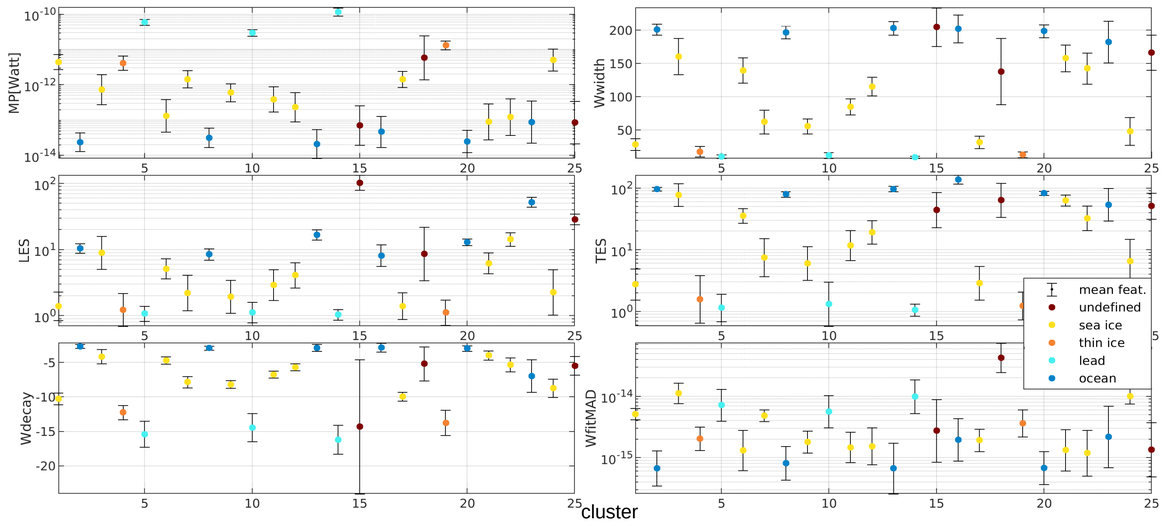
## Motivation:

- Sea ice thickness has significant impacts on the energy exchange between the atmosphere and the ocean and complicates model simulations and forecasting systems
- Thin ice detection by an unsupervised classification approach using Cryosat-2 waveforms (Müller et al., 2017, Dettmering et al., 2018)
- Waveform characteristics depend on thin ice thickness
- Thin ice thickness retrievals gathered from MODIS thermal images (Paul et al., 2015)
- Sentinel-1 SAR images as a basis for visual comparison
- Visual and quantitative comparisons of datasets close in time and space in the Laptev Sea

## Input datasets:

Satellite altimetry:

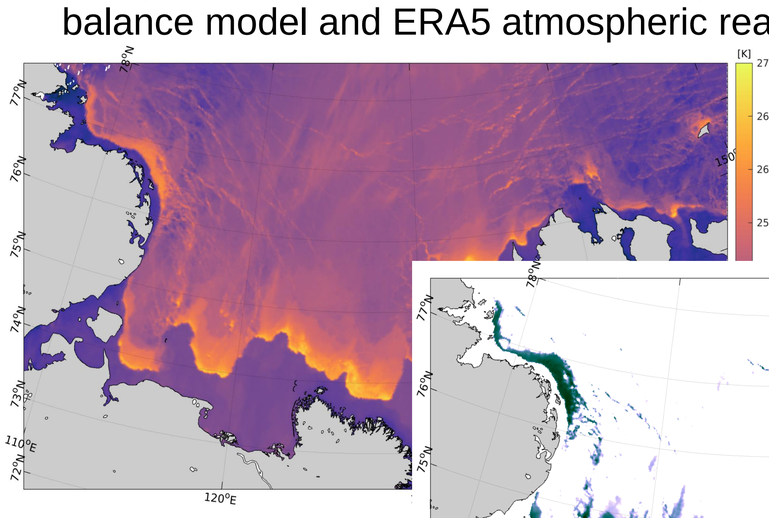
- Cryosat-2 L1B SAR Mode Baseline-D along-track altimetry data
- Identification of thin ice waveform clusters by analyzing shape and backscatter properties
- Thin ice properties are found between lead and sea ice characteristics




▲ *Averages and standard error of waveform features per cluster: Maximum Power (MP); Waveform Width (Wwidth); Leading-Edge Slope (LES); Trailing-Edge Slope (TES); Waveform decay (Wdecay) and median absolute deviation of fitted waveform (WfitMAD)*

Thermal imagery:

- MODIS ice-surface temperatures from MOD/MYD02 radiances
- Computation of thin ice thickness (TIT) using surface-energy-balance model and ERA5 atmospheric reanalysis data

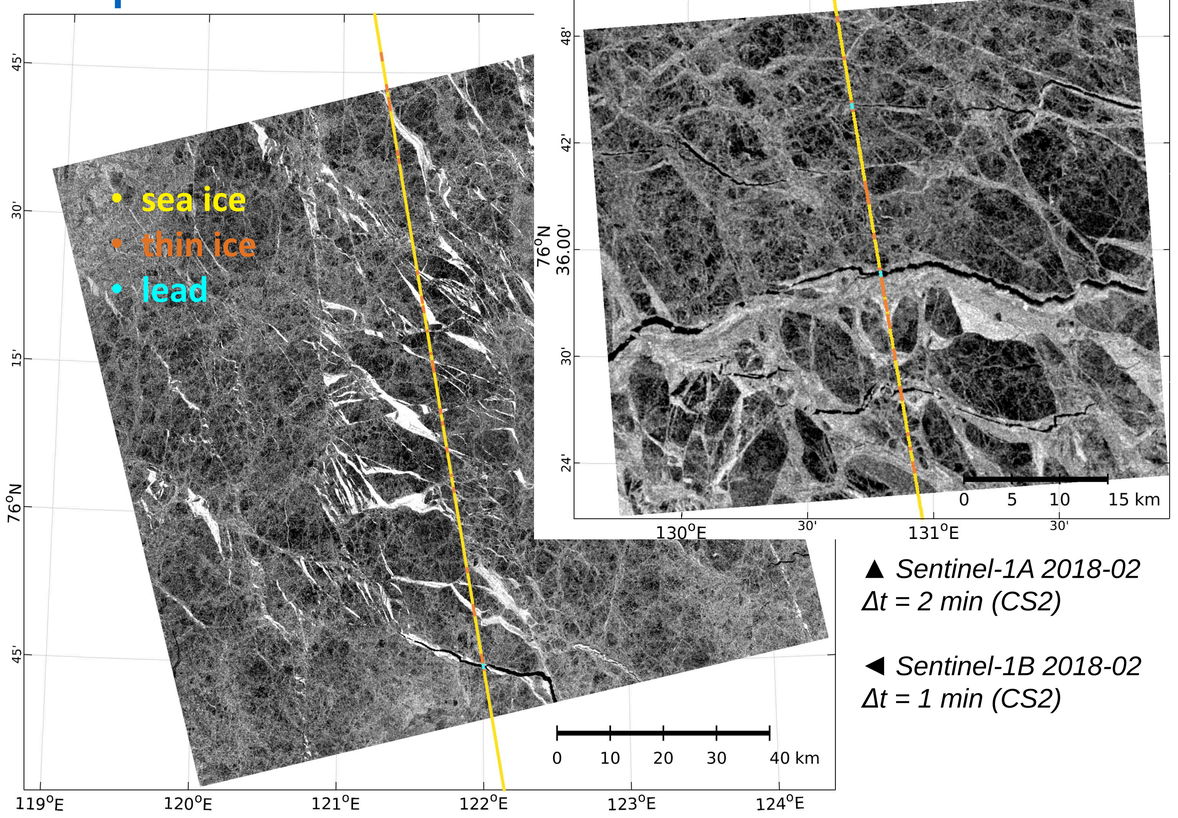



◄▼ *Example of MODIS ice-surface temperature (K) and associated thin ice thickness (m), 2011-03*

SAR imagery:

- Generated and edited by ESA SNAP Toolbox

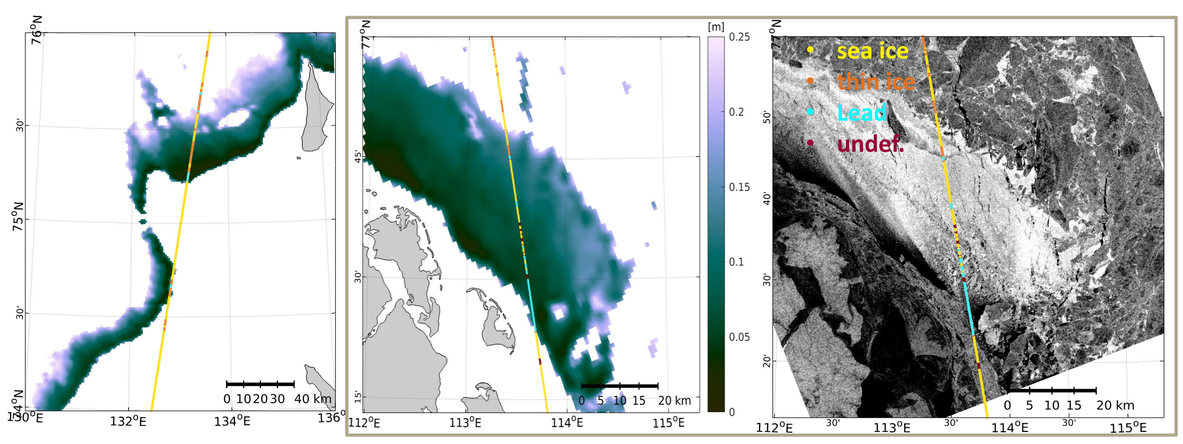
## Comparison:




▲ *Sentinel-1A 2018-02*
*Δt = 2 min (CS2)*

◄ *Sentinel-1B 2018-02*
*Δt = 1 min (CS2)*

- Visual comparison with Sentinel-1A/B confirms Cryosat-2 detection of open (dark) and re-frozen (bright) leads

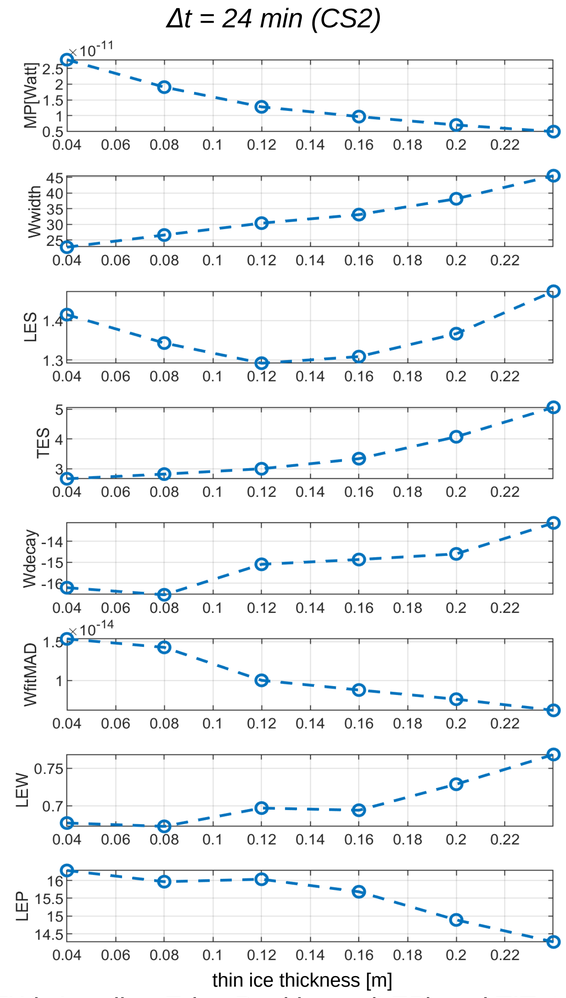



▲ *MODIS 2014-01*
*Δt = 8.5 min (CS2)*

▲ *MODIS 2018-03-01*
*Δt = 7 min (CS2)*

▲ *Sentinel-1A 2018-03-01*
*Δt = 24 min (CS2)*

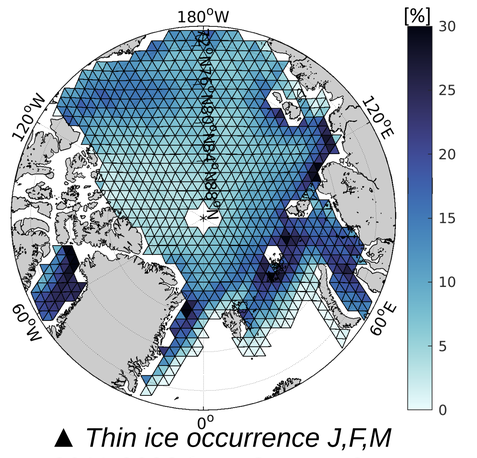
- Analysis of ~160 MODIS scenes within 30 minutes time window
- Visual comparison confirms good agreement of thin ice surfaces and classification
- Lead detections are found in areas with very thin ice
- Different spatial resolution of used sensors prevents more detailed visual analysis
- Three-sensor comparison shows interpretation issues of all sensors
- Quantitative comparison indicates strong linear dependency between TIT and waveform features




*Relationship of features & Leading-Edge Width (LEW), Leading-Edge Peakiness (LEP) and TIT ▲*

## Summary:

- Cryosat-2 can identify thin ice
- In addition to existing products Cryosat-2 can help to bring thin ice and lead information to a larger scale
- Linear dependency of wvf. features and TIT brings benefits for retracker algorithms or sea surface corrections
- Thin ice class. can be extended to entire Arctic Ocean




▲ *Thin ice occurrence J,F,M 2011-2020 from Cryosat-2*

**References and Acknowledgements:**

More information shortly available in: **Müller, F.L., Paul S., Hendricks S., Dettmering D. (2022): Monitoring Arctic thin ice: A comparison between Cryosat-2 SAR altimetry data and MODIS thermal-infrared imagery, sub. to TC**

Müller F.L., Dettmering D., Bosch W., Seitz F. (2017): *Monitoring the Arctic Seas: How Satellite Altimetry Can Be Used to Detect Open Water in Sea-Ice Regions*. RS 9(6), 551, doi: 10.3390/rs9060551
Paul, S., Willmes, S., and Heinemann, G. (2015): *Long-term coastal-polynya dynamics in the southern Weddell Sea from MODIS thermal-infrared imagery*, TC, 9, 2027–2041, doi: 10.5194/tc-9-2027-2015
Dettmering, D., Wynne, A., Müller, F. L., Passaro, M., and Seitz, F. (2018): *Lead Detection in Polar Oceans—A Comparison of Different Classifi-cation Methods for Cryosat-2 SAR Data*, RS 10, doi: 10.3390/rs10081190, 2

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