A comparison between Cryosat-2 radar altimetry and MODIS imagery for monitoring thin ice in the Laptev Sea

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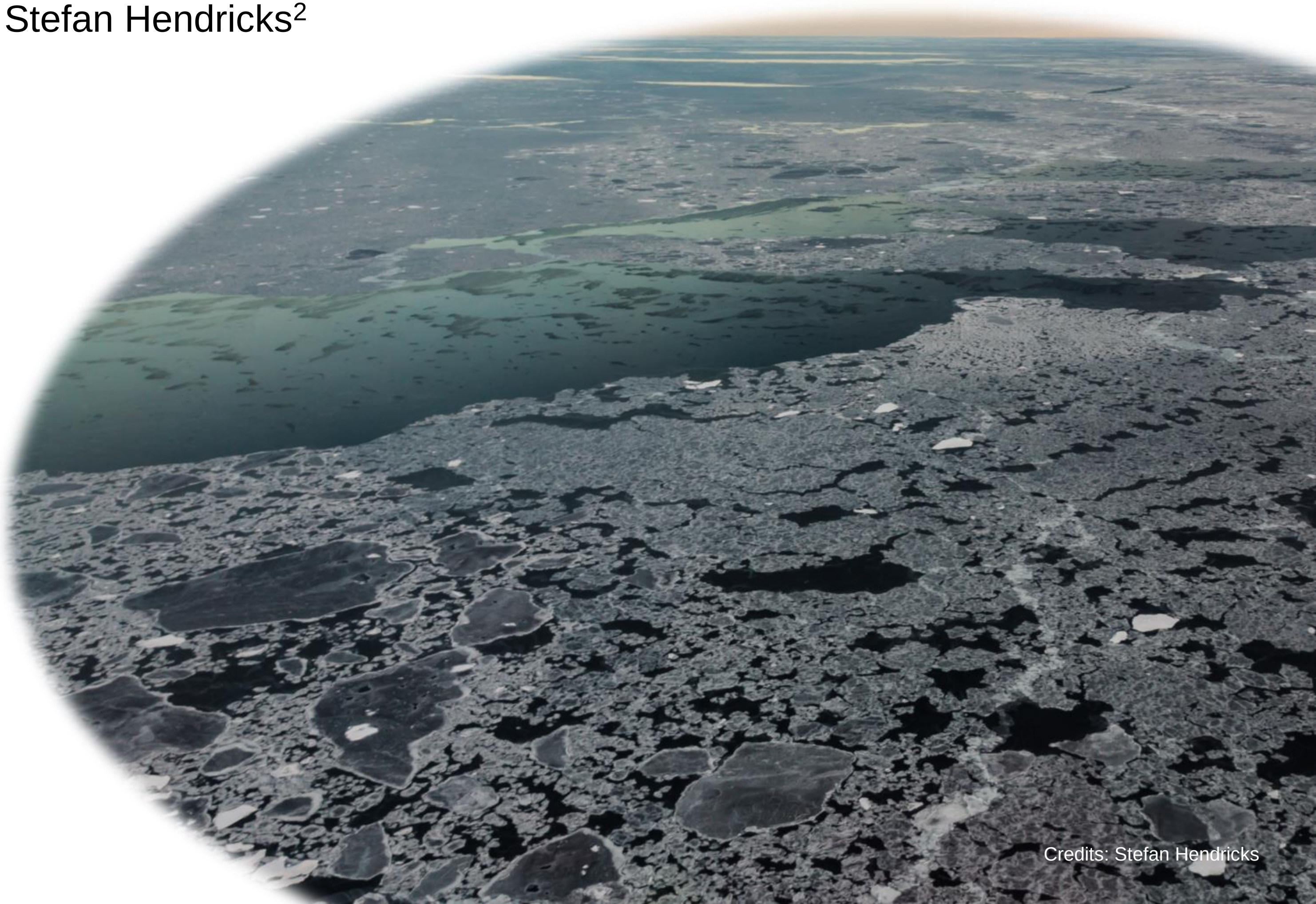


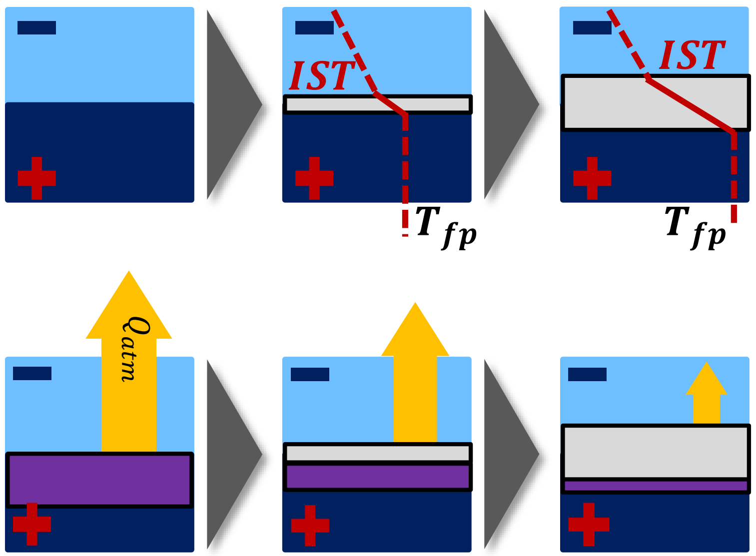
Credits: Stefan Hendricks

Sea Ice Type: Thin Ice – Why is it important?

- Generally associated with young/new-ice formation in large open-water areas ("polynyas") as well as leads, and the marginal ice
- Relationship between ice-surface temperature (IST) and the ice thickness [≤ 25 cm]
- Heat exchange (Q_{atm}) controls thermodynamic sea-ice growth and depends on ice thickness
- Amount of new-ice formation controls the flux of salt into the underlying ocean

➢ Thinning sea ice has significant impacts on the energy exchange between the atmosphere and the ocean and complicates model simulations and forecasting systems

Is it possible to identify thin ice using Cryosat-2 and compare the results with MODIS thermal imagery considering a short acquisition time gap?



adapted from Maykut (1978)

$$\boldsymbol{TIT} = \kappa_{ice} \frac{\boldsymbol{IST} - T_{fp}}{Q_{atm}}$$

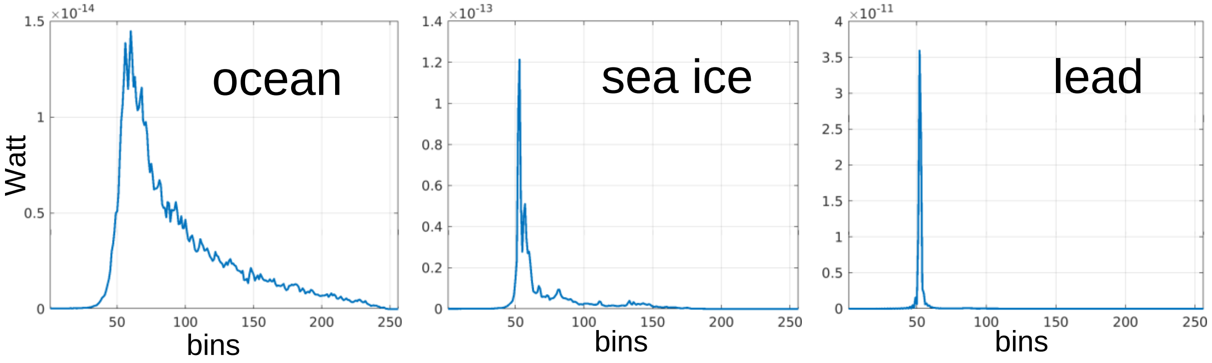
⇧

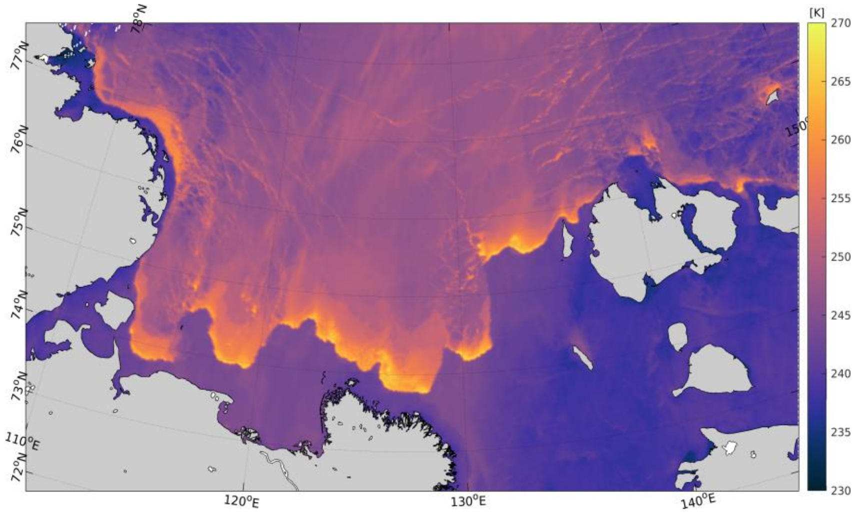
MODIS | Reanalysis

T_{fp} ice/ocean-interface temperature

Motivation - What to do?

- Thin ice detection by an unsupervised classification approach using **Cryosat-2 SAR waveforms** (Müller et al., 2017, Dettmering et al., 2018)
- Thin ice thickness retrievals gathered from **MODIS thermal images** (Paul et al., 2015)
- **SAR images (Sentinel-1 EW GRD)** as a basis for visual comparison
- Finding suitable overlaps of Cryosat-2, MODIS (Terra/Aqua), and Sentinel-1A/B (<30 minutes) during (*cloud-free*) thin ice conditions
- Observation of waveform-derived characteristics w.r.t. a changing thin ice thickness





Cryosat-2 Unsupervised Classification

- **Input: Original L1B SAR radar waveform**

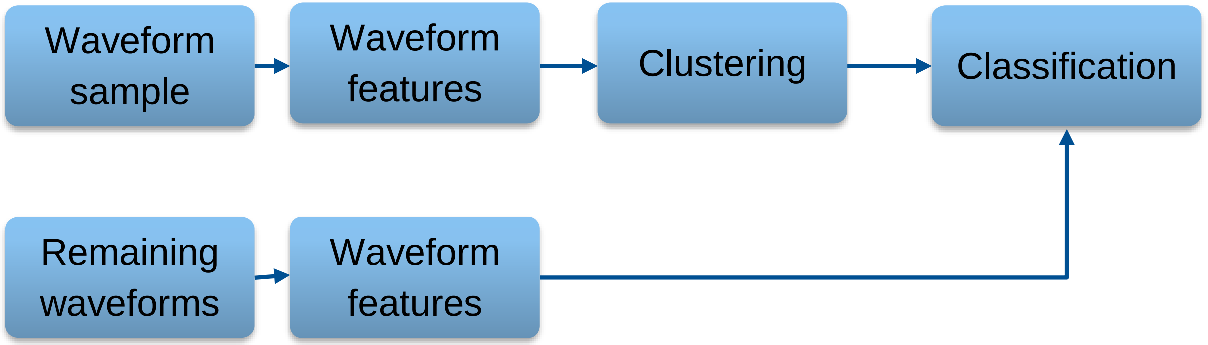
- Computation of waveform features

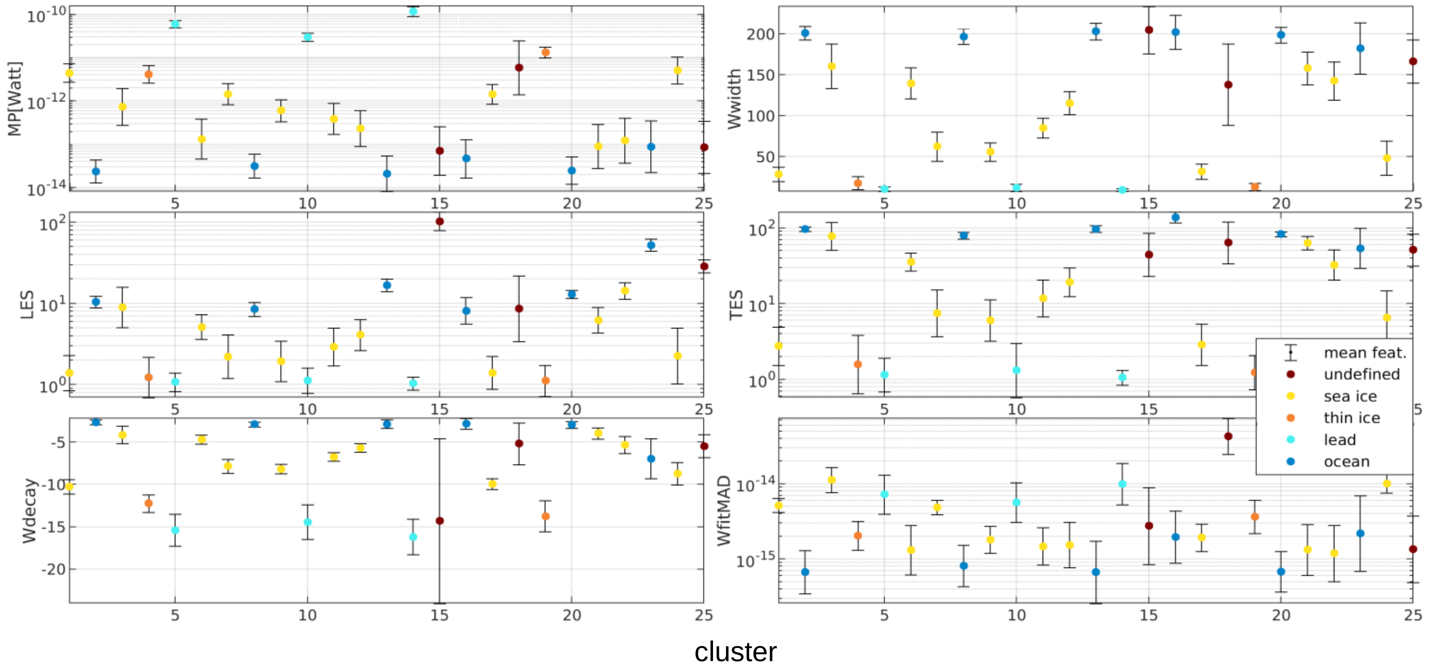
  1. Generation of waveform reference model using K-medoids clustering
  2. Assignment of waveform clusters to surface conditions
  3. Classification of remaining waveforms using reference model and K-nearest neighbor (K-NN)

- Identification of thin ice waveform clusters by analyzing shape and backscatter properties

- **Output: 5 classes** (lead, ocean, thin ice, sea ice and undefined)

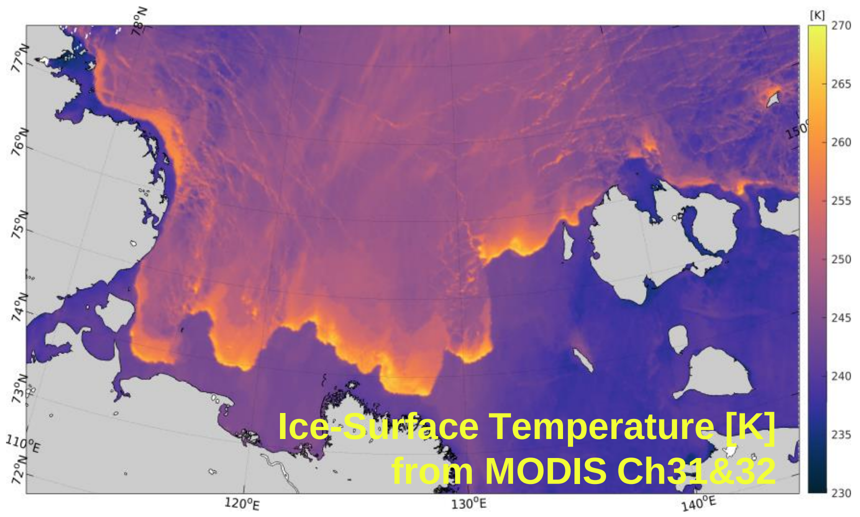
- Thin ice properties are found between lead and sea ice waveform characteristics

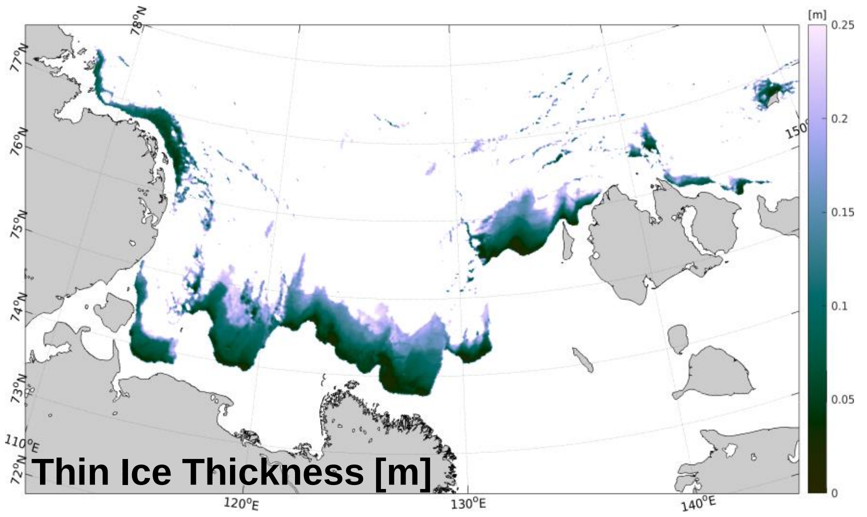


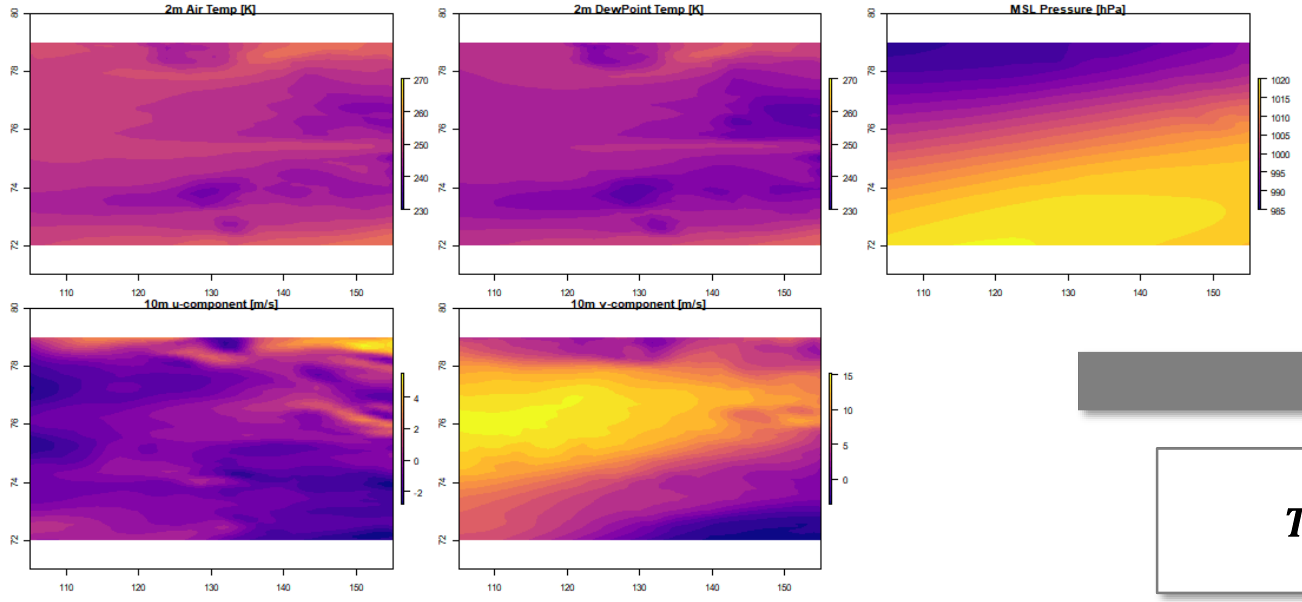


MODIS Thin Ice Thickness

How to get to thin ice thickness…

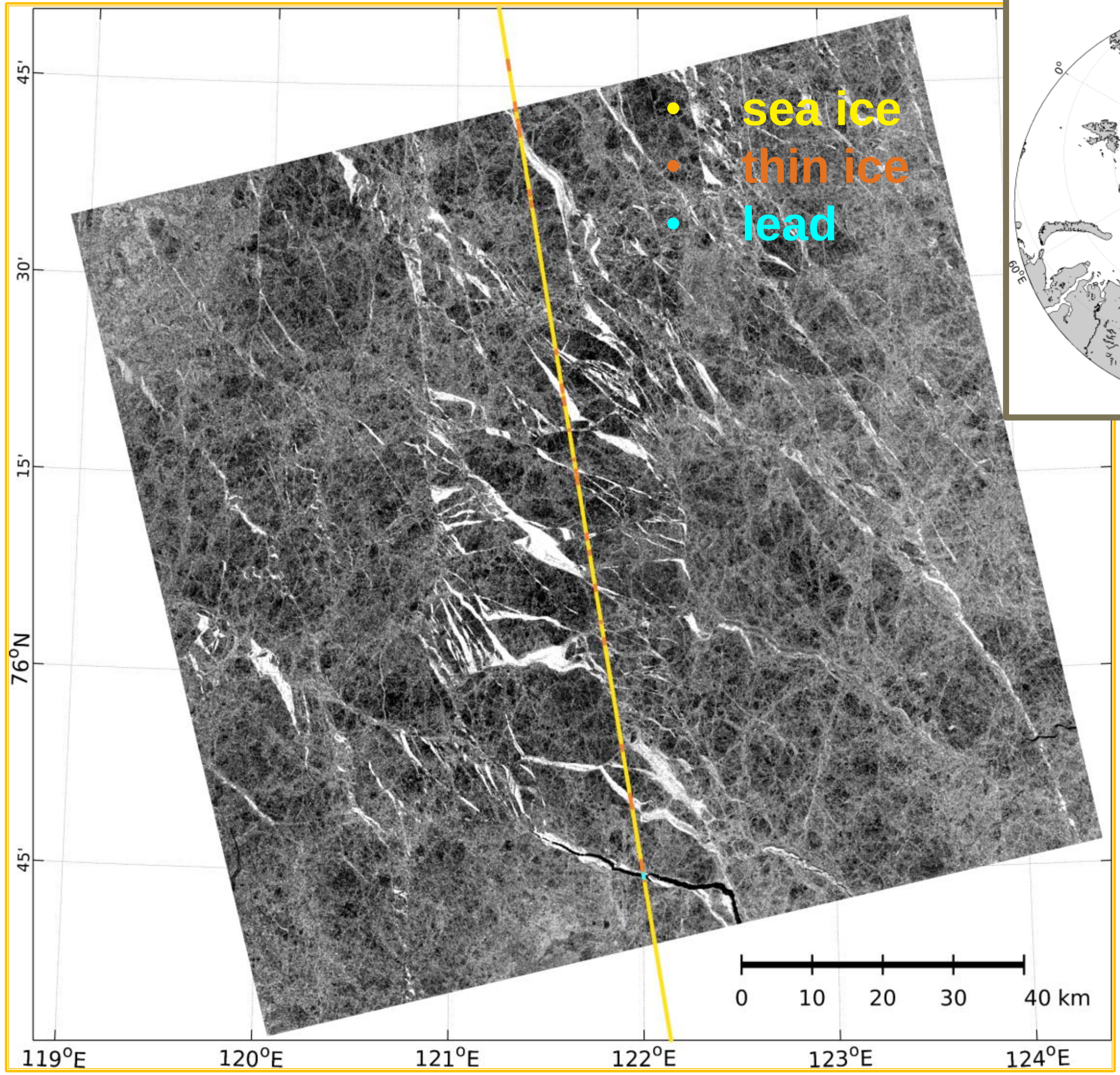


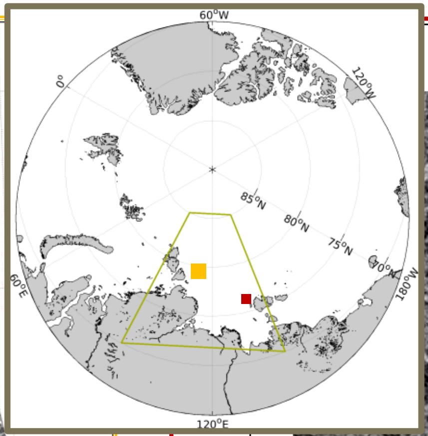


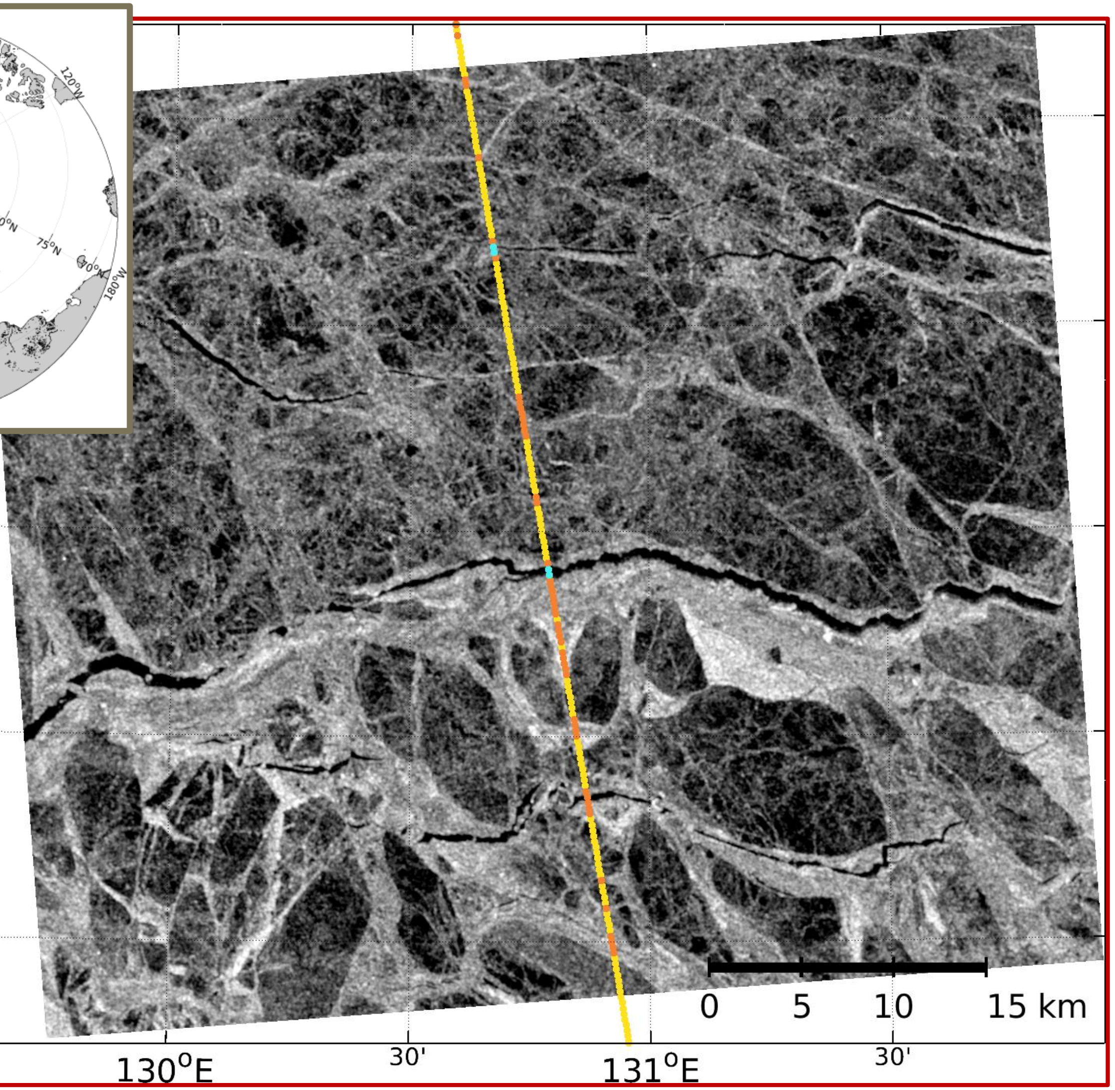


$$TIT = \kappa_{ice} \frac{IST - T_{fp}}{Q_{atm}}$$

Visual comparison – Sentinel-1 A/B



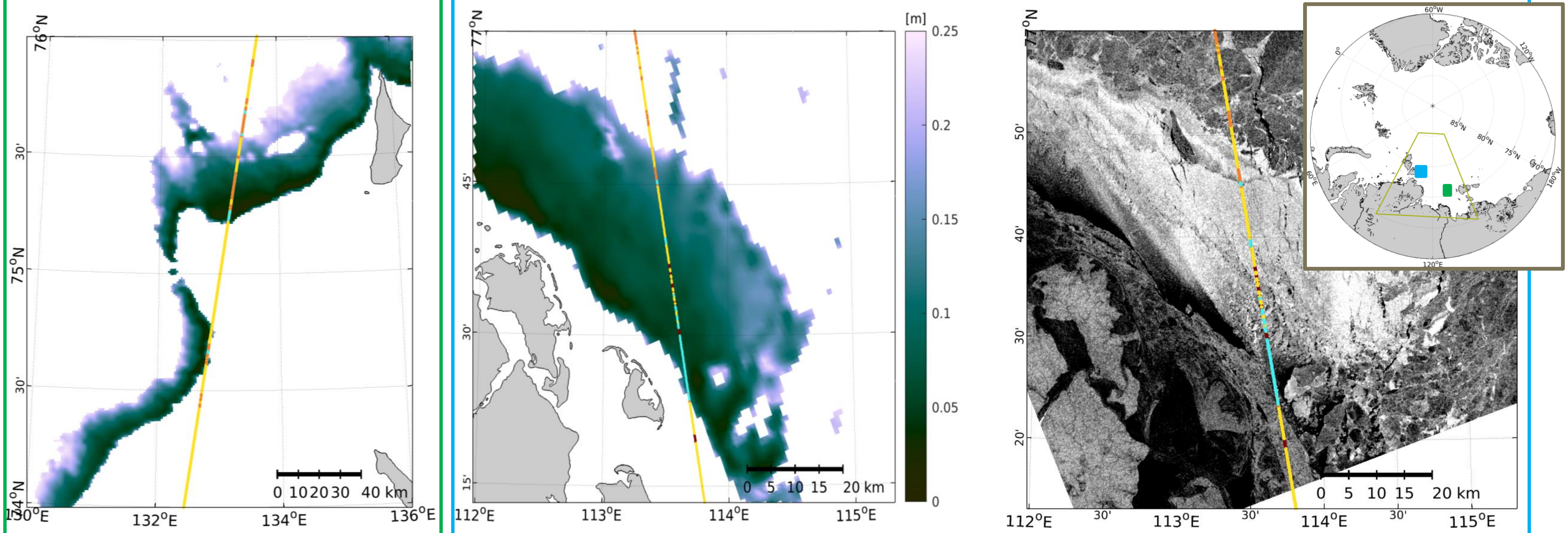




▲ *Sentinel-1B 2018-02-11 Δt = 1 min (CS2)*

▲ *Sentinel-1A 2018-02-18 Δt = 2 min (CS2)*

Visual comparison – MODIS & Sentinel-1 A/B



▲ *MODIS 2014-01*
Δt = 8.5 min (CS2)

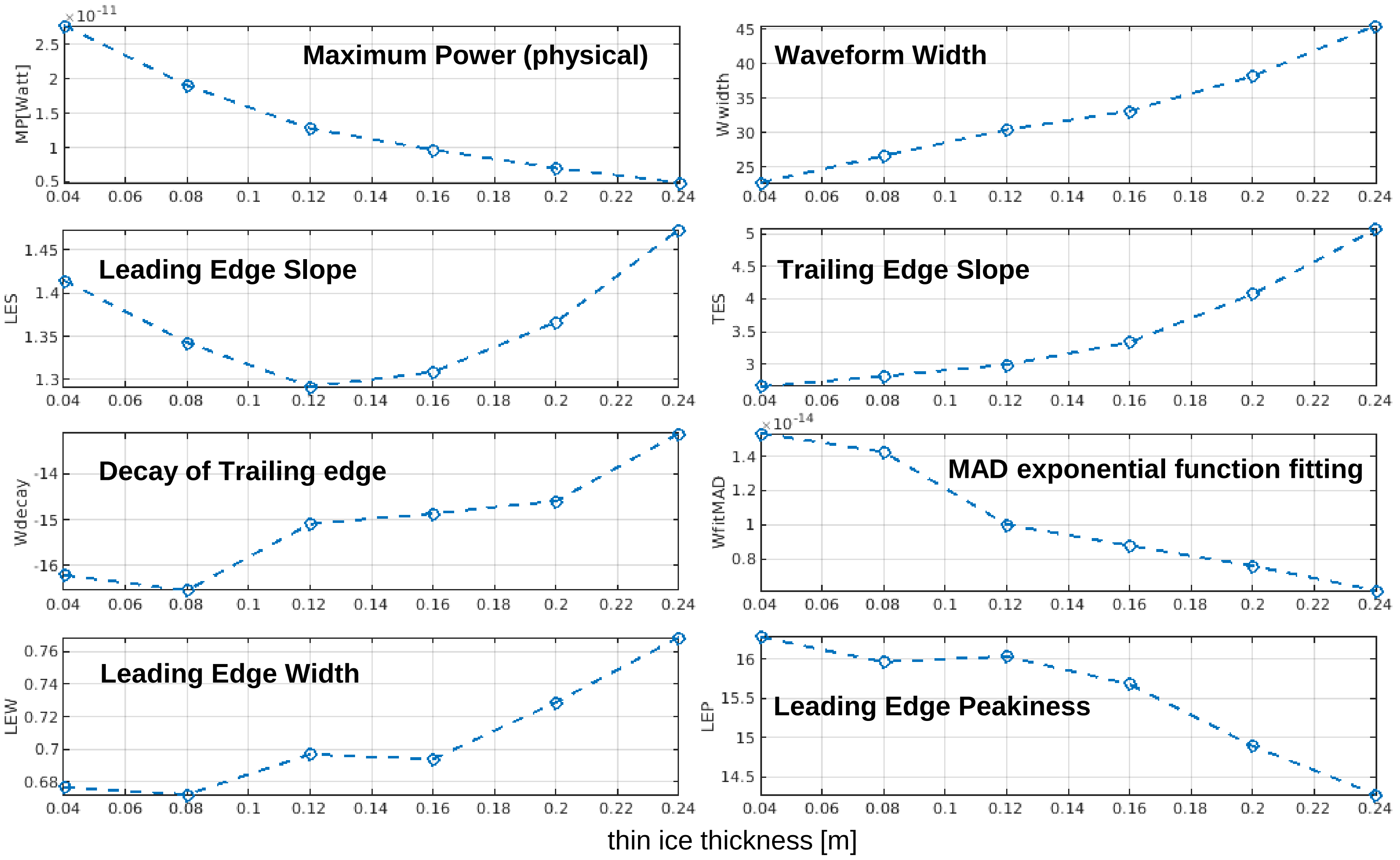
▲ *MODIS 2018-03-01*
Δt = 7 min (CS2)

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

sea ice thin ice lead undef.

Quantitative comparison

- Analysis of 160 MODIS scenes within 30 minutes time window
- Thin ice thickness vs. features
- Features from unsupervised classification + from AWI pysiral toolbox* (used in retracking process)
- Computation of mean values per thin ice thickness (0.02:0.04:0.24 m)



*python sea ice radar altimetry (pysiral) toolbox (https://pysiral.readthedocs.io/en/latest/)

Summary

- Visual comparison with Sentinel-1A/B confirms Cryosat-2 detection of open and re-frozen leads
- Visual comparison shows good agreement of thin ice surfaces and classification
- Increased 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

➢ 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 waveform features and TIT brings benefits for retracker algorithms or sea surface corrections

Questions?

Credits: Stefan Hendricks

References

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