Comparing MOSAiC and ICESat-2 data: Thermal signatures and topography over sea ice features driven by convergence and divergence

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Thermal signatures and topography over sea ice features driven by convergence and divergence

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INTRODUCTION

In September 2019, the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) started its expedition to investigate the Arctic, an epicenter of global warming. During MOSAiC helicopter-borne thermal imagery (TIR; see Figure 1 and Figure 2) and laser scanner observations were acquired, which can capture the thermal signatures and topography of the underlying sea ice cover including sea ice leads and ridges. This study will investigate how thermal signatures correlates with laser topography data acquired from a satellite, using two elevation products from the photon-counting laser altimeter Ice, Cloud and snow Elevation Satellite-2 (ICESat-2) over sea ice ridges and leads.

35 MOSAIC/ICESat-2 near-coincident comparisons identified

17 MOSAIC/ICESat-2 ridge comparisons identified

8 MOSAiC/ICESat-2 (ATL07) lead comparisons identified

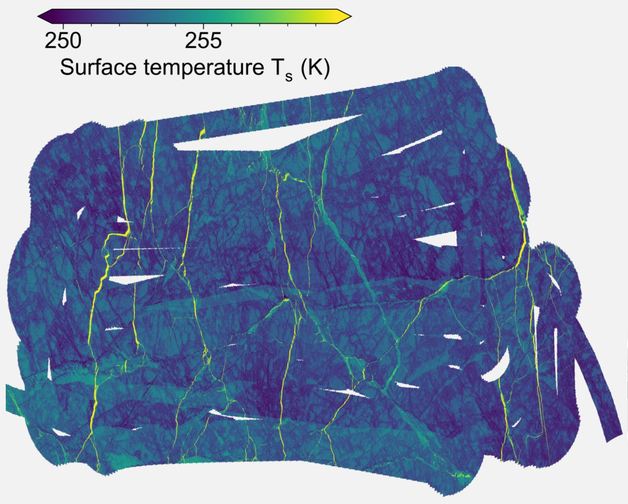

Figure 1. Surface temperature map generated from thermal imagery (TIR) images (version 2, 1m res) acquired during campaign "P-37_63".

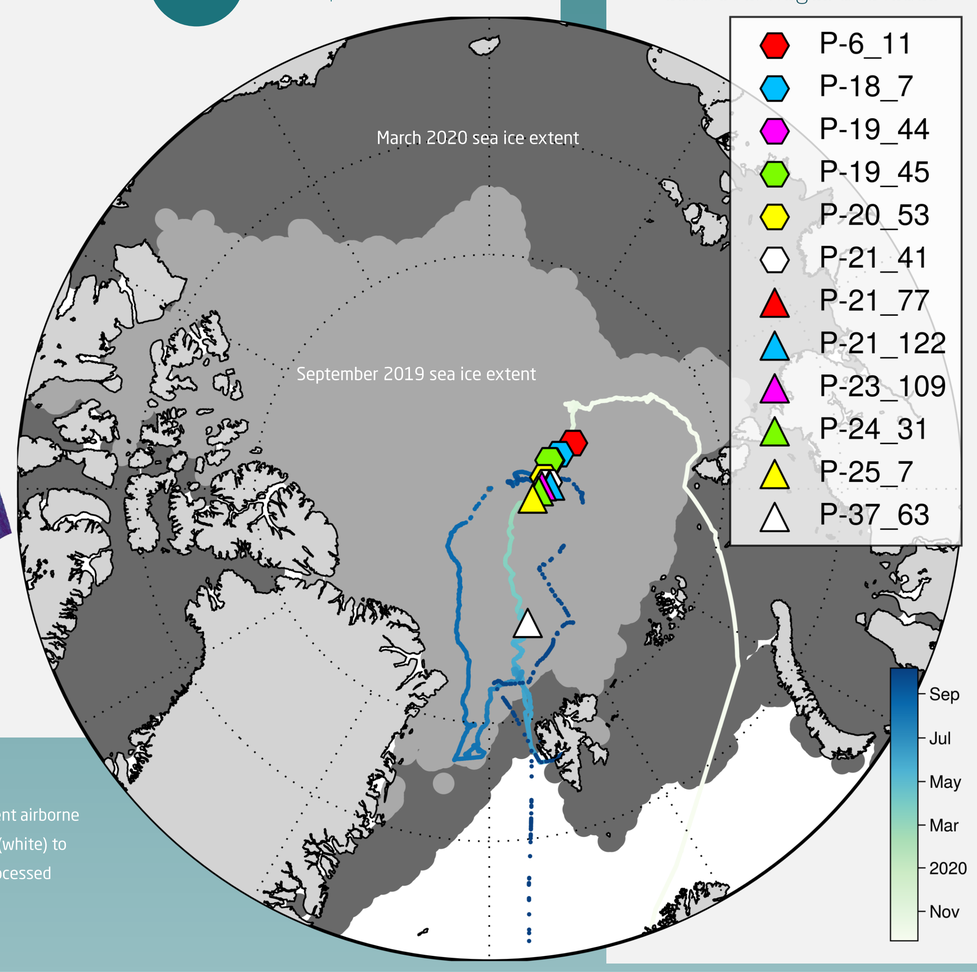

Figure 2. Relevant MOSAiC helicopter campaigns with thermal imagery (TIR) instrument airborne acquiring data along with the Polarstern *RV* drift-track shown from September 2019 (white) to the end of the campaign in October 2020 (dark blue), with airborne TIR campaigns processed until April.

DATA AND METHODS

Currently, the tasks are:

- Perform a sea ice drift-correction to make ICESat-2 and MOSAiC data comparable
- Investigate performance of the drift correction by identifying coincident leads
- Compare drift-corrected data over ridges and leads

Table 1. Data products used in this study.

Data	Instrument	Spatial resolution	Drift corrected	Parameter
MOSAIC surface temperature maps	Thermal imagery data	1m, 5m grid	Campaign referenced to a target time	Surface temperature [kelvin]
MOSAIC binary lead maps	Thermal imagery data, threshold method	1m, 5m grid	Campaign referenced to a target time	Binary map [lead or no lead]
ICESat-2 ATL07 operational product	Photon-counting laser altimeter (ATLAS)	Varying spatial resolution (20-200 m)	To be corrected for drift using Polarstern *RV* as reference	Elevations w.r.t tide-free mean sea surface [meters]
ICESat-2 University of Maryland (UMD) algorithm	Photon-counting laser altimeter (ATLAS)	Per pulse-shot (~0.7 m)	To be corrected for drift using Polarstern *RV* as reference	Elevations w.r.t DTU18 MSS [meters]

Table 2. Data comparisons identified for this study. Drift correction currently only computed for identified lead studies.

MOSAIC campaign	Date and time	IS2 date and time	Δt (hr)	Ridge/lead study	Drift: vx, vy (km/d)	Comparison nr.
P-6_11	05/11/2019 07.01 AM	05/11/2019 03.08 AM	3.89	Yes/Yes	10.15, 0.22	#1
P-18_7	30/12/2019 08.48 AM	29/12/2019 08.19 AM 31/12/2019 01.12 AM	24.48 16.40	Yes/Yes Yes/Yes	3.98, 6.49 7.21, 6.68	#7 #8
P-19_44	07/01/2020 10.08 AM	07/01/2020 01.20 AM 07/01/2020 07.36 AM	8.81 2.54	Yes/No Yes/No	No ATL07 leads No ATL07 leads	#9 #10
P-19_45	07/01/2020 12.59 PM	07/01/2020 01.20 AM 07/01/2020 07.36 AM	11.66 5.39	Yes/No Yes/Yes	No ATL07 leads 0.80, 0.95	#11 #12
P-20_53	16/01/2020 10.03 AM	16/01/2020 02.12 AM 16/01/2020 06.54 AM	7.86 3.16	Yes/No Yes/Yes	No ATL07 leads 5.95, 9.83	#18 #19
P-21_41	21/01/2020 11.33 AM	22/01/2020 07.29 AM	19.92	Yes/No	No ATL07 leads	#20
P-21_77	23/01/2020 11.13 AM	23/01/2020 02.21 AM	8.87	Yes/Yes	5.80, 0.06	#21
P-21_122	25/01/2020 01.34 PM	25/01/2020 07.46 AM	5.80	Yes/No	No ATL07 leads	#23
P-23_109	09/02/2020 11.51 AM	09/02/2020 02.56 AM 09/02/2020 06.05 AM	8.92 5.77	Yes/Yes Yes/Yes	0.62, 7.67 0.56, 7.59	#26 #27
P-24_31	12/02/2020 09.41 AM	12/02/2020 03.14 AM	6.45	Yes/No	No ATL07 leads	#28
P-25_7	17/02/2020 07.34 AM	17/02/2020 04.14 AM	3.33	Yes/No	No ATL07 leads	#30
P-37_63	23/04/2020 08.42 AM	23/04/2020 10.34 AM	1.87	Yes/Yes	1.68, 3.44	#35

Drift correction

Here, we use the Polarstern *RV* GPS track. We identify the closest time-point in the GPS track for the campaign and ICESat-2 data and determine the shift in X and Y direction, which is applied to every data point of the ICESat-2 data covering the campaign area.

Lead identification

To investigate whether the drift correction has been successfully applied, one can compare binary lead/no-lead maps identified from TIR with identified leads from ICESat-2Using a 70m-rolling average (10 points) and using lowest elevations (0.01 quantile) and small surface roughness (0.10 quantile), we identify leads to compare with binary maps.

RECENT FINDINGS AND OUTLOOK

Are MOSAiC and ICESat-2 observing the same sea ice? Application of drift correction

A drift correction must be applied to take into account the drift occurring between acquisitions. Along-track comparison between drift-corrected ICESat-2 elevations, identified TIR leads and identified ATL07 leads is shown in Figure 3 shows more work is needed.

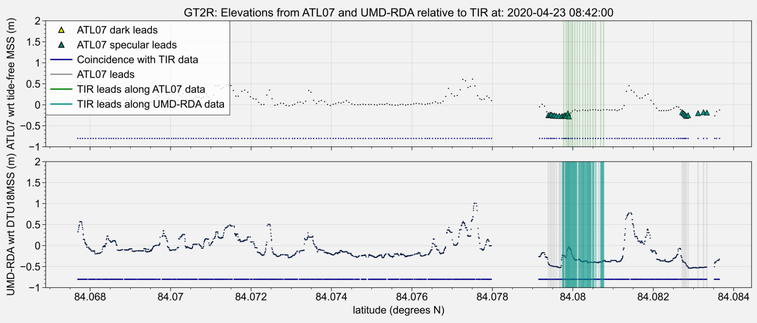

Figure 3. Zoom-in of part of the drift-corrected track (shaded box in Figure 5) along the ICESat-2 track with coincidence (nearest-neighbour) in TIR map (version 2, 5m res): showing the location of identified specular leads in ATL07 and corresponding identified leads in binary TIR maps.

Potential way forward includes a manual correction, however this will be a tedious process.

Limitations

- No elevation data (not ready yet) to compare with to identify other features (e.g., ridges) to align with

Options to be explored

- Version 2 of TIR maps with better georeferencing
- Buoys deployed during MOSAiC

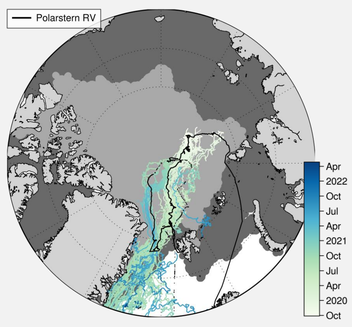

Figure 4. Buoys deployed during MOSAiC to be investigated for aiding the drift correction. In total, 200 buoys identified.

Is the lead-identification approach of ICESat-2 observing enough leads and correctly?

Studies (e.g., Kwok et al., 2021) have shown that the use of dark leads in freeboard calculations of ATL07 was likely to bias the results and dark leads had a higher variability and abundance than specular leads. Statistics based on TIR data, showed an expected lead fraction of ~1.1%. Using only specular leads along the ICESat-2 track, the overall lead fraction was 0.05% (using dark and specular leads, it was 4.01%).

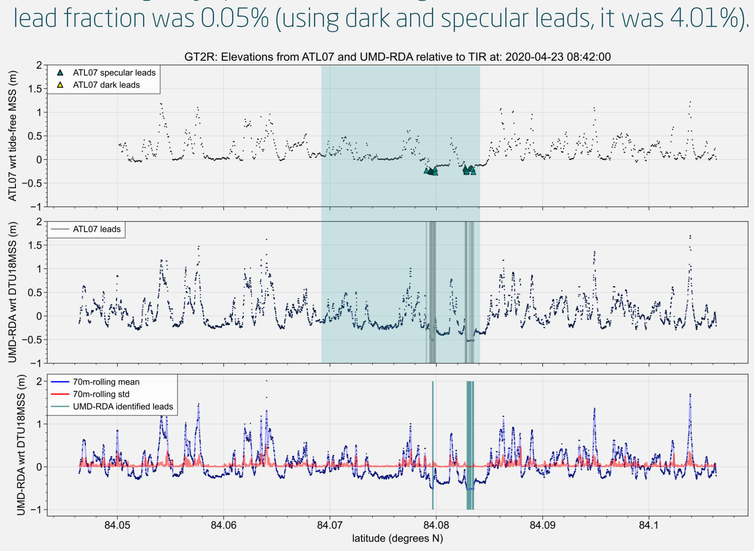

Figure 5. Full-resolution along-track ICESat-2 surface elevations using ATL07 and UMD product, with ATL07 identified leads and suggested UMD-based identification-approach.

Utilizing UMD-RDA data, we identify leads based on the lowest elevations along the track with the smallest surface roughness (given by standard deviation).

- Depends on distribution of the surface elevations: rougher open water and too many low/high elevations affects results
- Apparent surface reflectance using photon count might be relevant here.

Direct orbit comparison or statistical approach when comparing with leads and ridges?

The current study aim to compare along-track measurements with corresponding lead/thermal data directly to investigate the thermal signatures. But is this feasible? If a proper co-location cannot be achieved and a direct orbit comparison not be performed, what could be the next steps? The potential for doing a statistical analysis is currently being discussed.

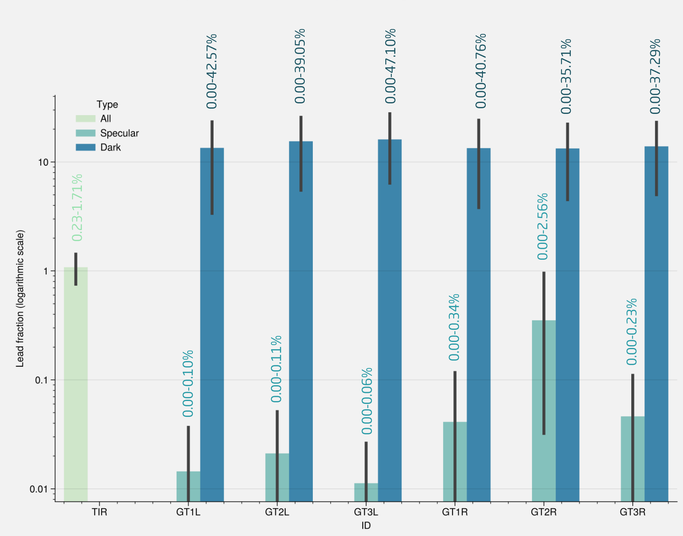

Figure 6. Lead fractions calculated for the 8 identified lead comparisons for both the thermal imagery data TIR (all the leads identified, version 1, 5m res) and the ATL07 identified leads (separated into specular and dark leads) shown by the specific beam. Note the logarithmic scale and how all ATL07 beam have tracks with no identified leads covering the campaign area (0.00%).

Such statistical analysis could be e.g., time-series of lead fraction from the TIR vs. ICESat-2, or potentially investigating thermal intervals over or close to ridged ice (identified using UMD-ridge detection algorithm) vs. level ice.

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REFERENCES: Kwok, R., Petty, A. A., Bagnardi, M., Kurtz, N. T., Cunningham, G. F., Ivanoff, A., and Kacimi, S.: Refining the sea surface identification approach for determining freeboards in the ICESat-2 sea ice products, The Cryosphere, 15, 821–833, https://doi.org/10.5194/tc-15-821-2021, 2021