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Drone-based sea ice albedo measurements and photogrammetry during the Arctic freeze-up in the MOSAiC expedition

Roberta Pirazzini[1], Henna-Reetta Hannula[1], David Brus[1], Ruzica Dadic[2,3], Martin Schneebeli[3]

[1]Finnish Meteorological Institute, Helsinki, Finland
[2]Victoria University of Wellington, New Zealand
[3]WSL Institute for Snow and Avalanche Research SLF, Switzerland

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Research questions

- How surface-based albedo measurements (with footprint of few tens of square meters) relate to larger (satellite) scale observations?
- What is the role of the various surface features (melt pond, ridges, leads) on the areal averaged albedo in the observed phases of the freeze up period?
- What is the surface roughness defined at different scales (from mm to couple hundred meters) and its role for albedo?

Datasets

- Drone-based albedo observations
- Drone-based maps (DEM, areal representation of different surface types)
- Fixed FMI radiation station
- Structure from Motion (SfM) DEMs

Drone-based observations

Payload: **Broadband albedo**: paired Kipp and Zonen CM4 pyranometers

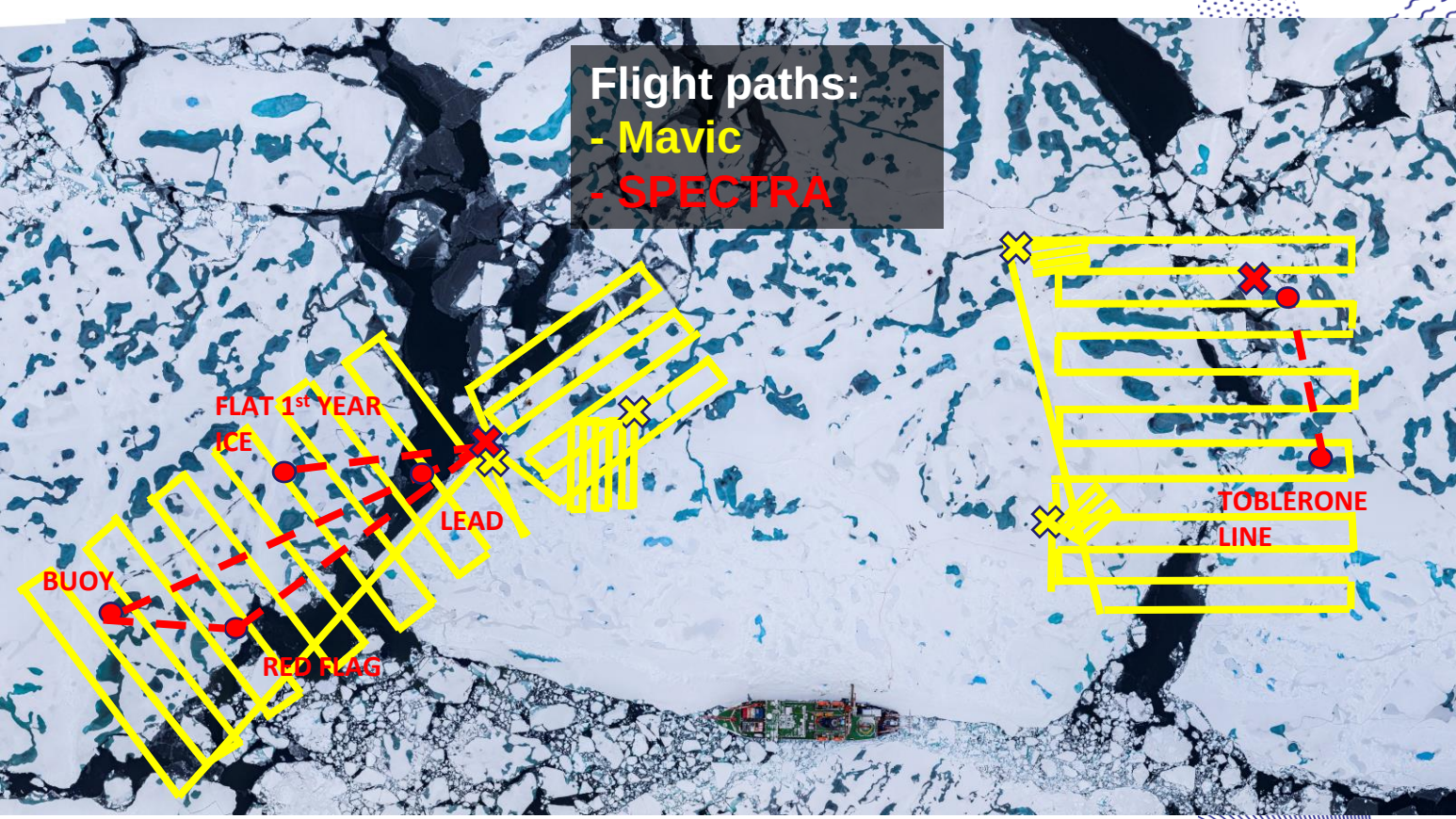
Spectral albedo: paired Ocean Optics STS VIS (350 – 800 nm) and NIR (650-1100 nm) micro-radiometers

Measurements

- 17 flights with SPECTRA in 8 days, ~5 flight h.
- 35 flights (maps) with Mavic in 18 days, ~11,5 flight h.,24 maps produced

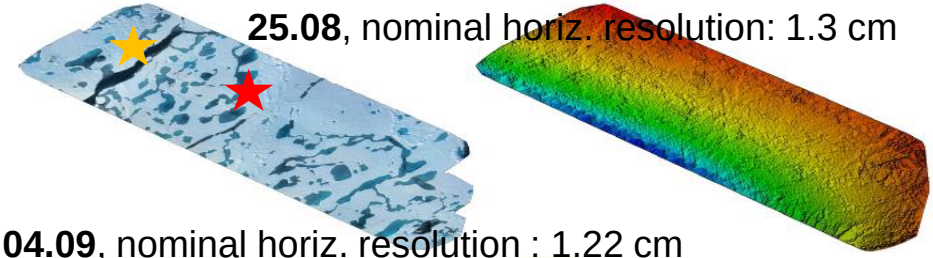
Main problems

No compass at North Pole -> manual operations
Cold and moist air -> freezing blades and fingers
Little solar radiation -> high noise in albedo data

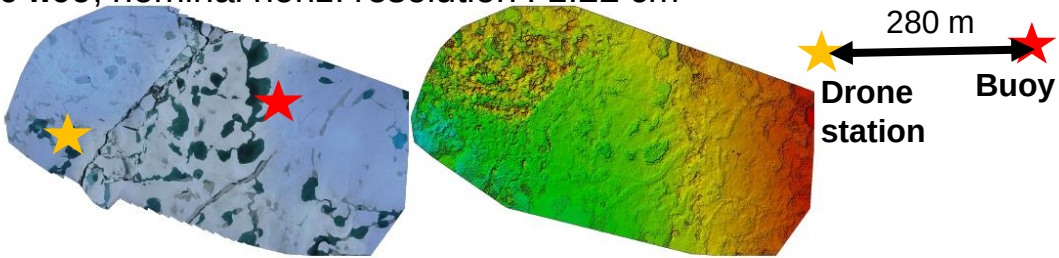

Flight paths:
- Mavic
- SPECTRA
FLAT 1st YEAR ICE
LEAD
BUOY
RED FLAG
TOBLERONE LINE

Drone-based DEMs of main surveyed areas in leg 5

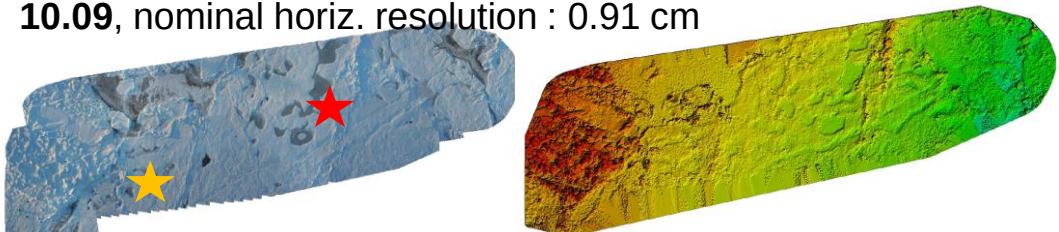
25.08, nominal horiz. resolution: 1.3 cm



04.09, nominal horiz. resolution : 1.22 cm



10.09, nominal horiz. resolution : 0.91 cm



Data cleaning (QC) to be done:

- Correct the digital elevation models from artifacts (tilt) using ground check points and assess for horiz. and vertical uncertainty
- Convert lat/lon to x/y floenavi system to overly SPECTRA and Mavic data

Data products to be derived:

- Surface **roughness**
- **Fraction of melt ponds**, ridges, leads
- In overcast conditions, **broadband albedo maps** (calibrated with the 30m SPECTRA broadband albedo) and the **RGB albedo maps** (calibrated with the 30m SPECTRA spectral albedo).

Drone-based albedo measurements

Measurement strategy

- **Transects**: horizontal transects at the height of 5, 10, and 30m, from the drone station to reference points (buoy, red flags)
- **Vertical profiles**: above the reference points, from 5 to 30m.

Data processing and QC

Sensor's characterization:

- Sensor's re-calibration
- Correction of the sensitivity drift caused by temperature change
- Correction of the deviation from perfect cosine response

Data comparison:

- Comparison of incoming irradiance (spectral and broadband) with measurements from fixed instruments.

Uncertainty assessment

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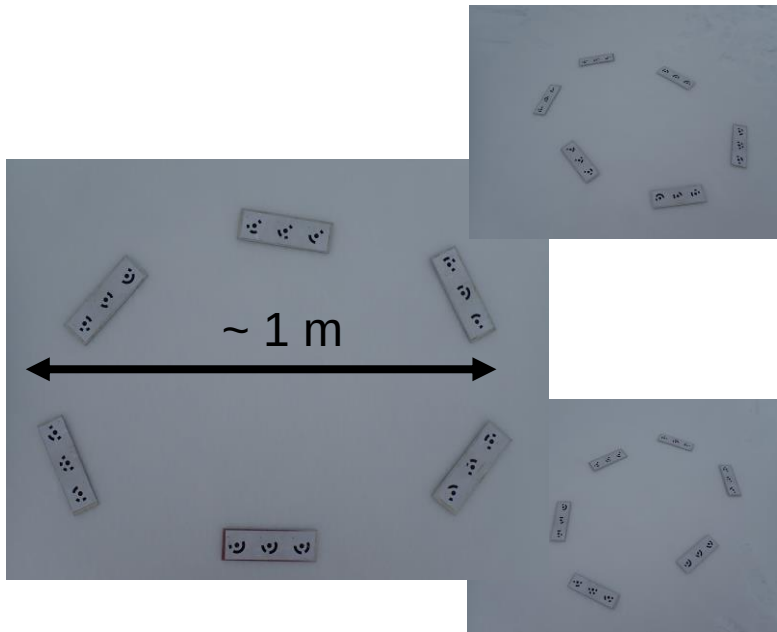
Surface roughness: from mm to 150 m scales

Roughness affects the surface-electromagnetic interaction and the horizontal air flow

We combine drone-based DEMs with SfM DEMs (obtained from manual photos of a target area of ~1m diameter) to get roughness at various scales:

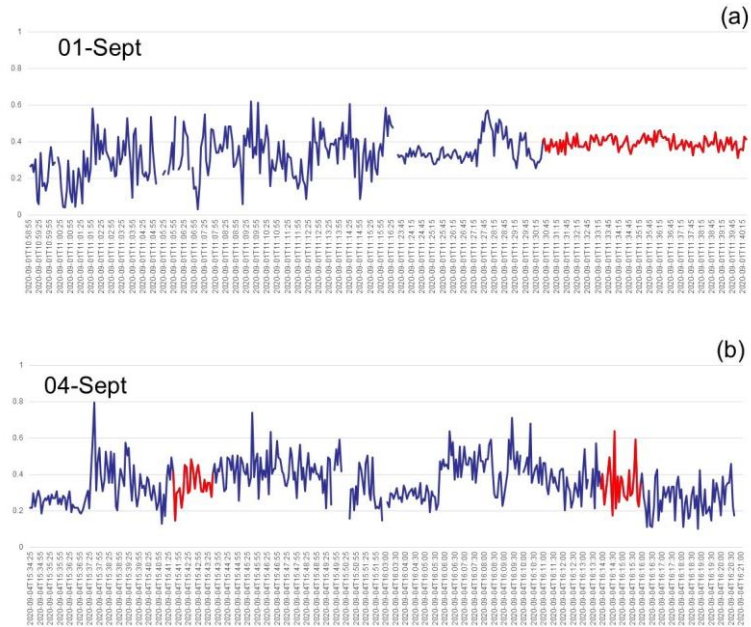
- **mm scale** → optical and near-infrared wavelengths
- **cm scale** → optical and microwave wavelengths
- **dm – m scales** → all wavelengths and air flows

Structure from Motion (SfM) DEMs:

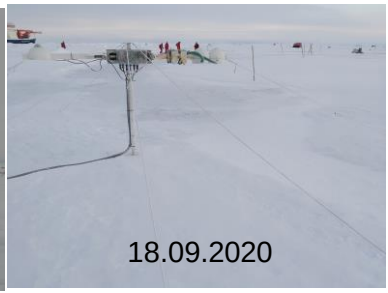


First look into SPECTRA broadband albedo

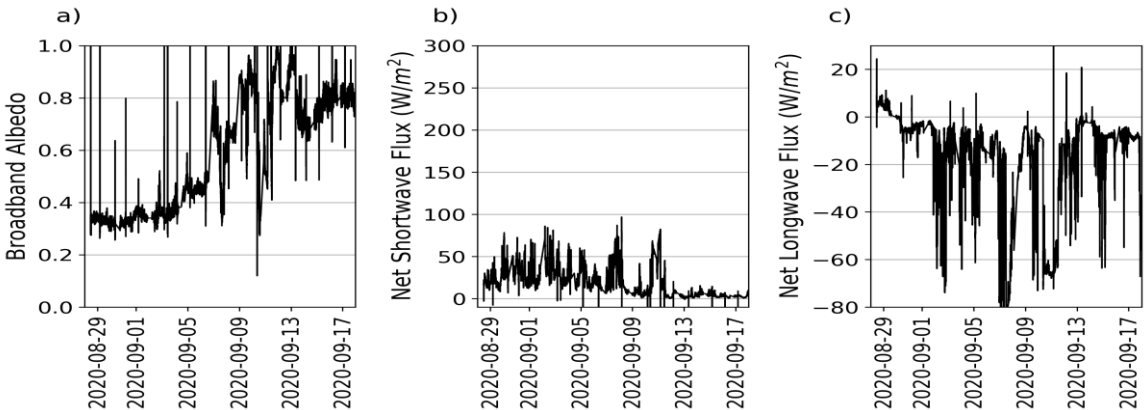
- Areal-averaged albedos measured at 5m and 10m asl (blue lines) have a larger variability than the areal-averaged albedo measured at the elevation of 30m (red lines).
- A certain degree of albedo variability is unavoidable even during hovering at 30m because it is not possible to keep the drone over the same surface while the ice is drifting.
- On 1st and 4th of September (overcast conditions) the 30m albedo was similar even over different surface types -> **the 30m albedo is not significantly affected by the individual surface features and, therefore, it is potentially representative for satellite footprint and model grid area**.
- The 30m albedo measured on 1st and 4th of September was around 0.4, consistently with the averaged albedo value measured along the Kinder line in the same period.



Broadband drone observations will be compared with data from fixed surface stations, e.g. the FMI radiation station:



Uncleaned measurements during Leg5:



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Outlook

After the cleaning, quality check and uncertainty assessment of the measurements, we plan to:

- Compare the drone-based albedo observations with:
  - surface-based measurements from fixed stations and portable devices operated along transects
  - Helicopter-based observations

- Assess the role of the various surface features (melt pond, ridges, leads) on the areal averaged albedo in the observed phases of the freeze up period.

- Study the relationship between surface microstructure properties, surface roughness, and measured albedo.