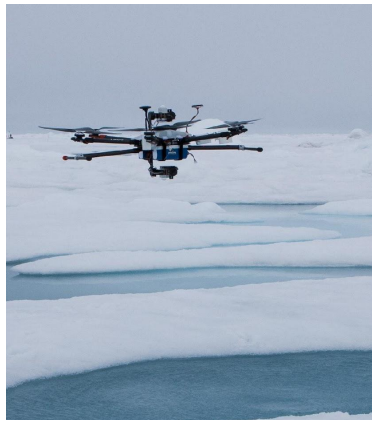
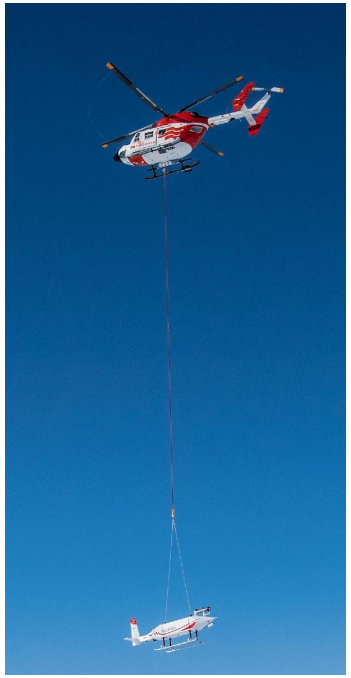
Spatial scale of surface albedo from surface-based, airborne and satellite measurements for the melting season during the MOSAiC expedition.

MOSAiC
International Arctic Drift Expedition







Radiance Calmer[1],
G. de Boer[1,2,5], J. Hamilton[1,2,4], D. Lawrence[4], M. Shupe[1,2], C. Cox[2], M. Webster[6],
N. Wright[7], N. Fuchs[8], P. Taylor[9], M. Lonardi[10], M. Smith[11], J. Cassano[1,3] , et al.

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[11]Woods Hole Oceanographic Institution

CIRES
University of Colorado Boulder
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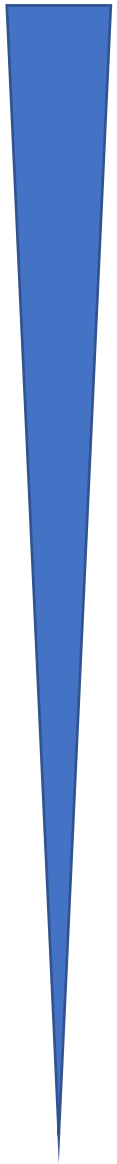
Perspectives on broadband albedo measurements based on special and temporal scales



Multiple floes

SkySat (50 cm/pix) pixel-based albedo?

Model grid cell

MOSAiC floe

SkySat (50 cm/pix) pixel-based albedo?
Helicopter (50 cm/pix) pixel-based albedo

Model grid cell ?

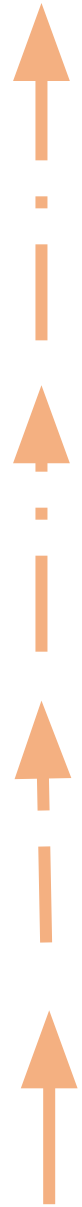
In-floe

HELiX hemispherical sensors + images (1 cm/pix) pixel-based albedo?
BELUGA balloon hemispherical sensors
Albedo lines hemispherical sensors

Sub-grid parameterization?

Point measurements

ASFS sleds hemispherical sensors
Met City hemispherical sensors



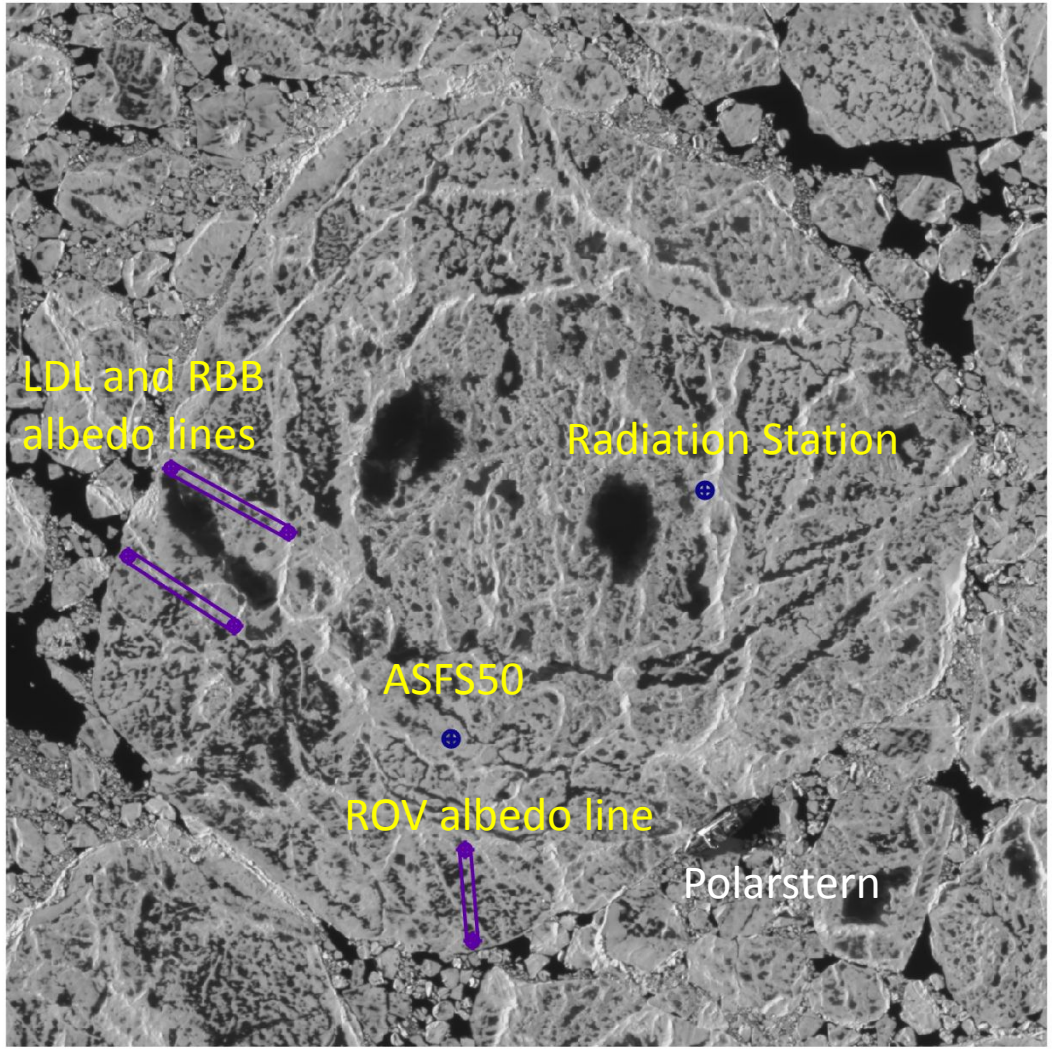
Continuous in time

Motivations

- Climate models predict that summers may be completely free of ice prior to 2050 (IPCC, 2021)
- The ice albedo feedback is described as one of the main processes spurring the melt of sea ice.

- How can these datasets help to better represent the model internal processes?
- Can models fill the temporal gaps for large scale albedo?
- How can these datasets be leveraged to document albedo feedback?
- How to improve the representation of melt ponds?

1. Spatial scale: Footprint associated with each hemispherical albedo measurements



Cosine response : weighted average over the sensor footprint

Footprint calculation : Height/Diameter = 10

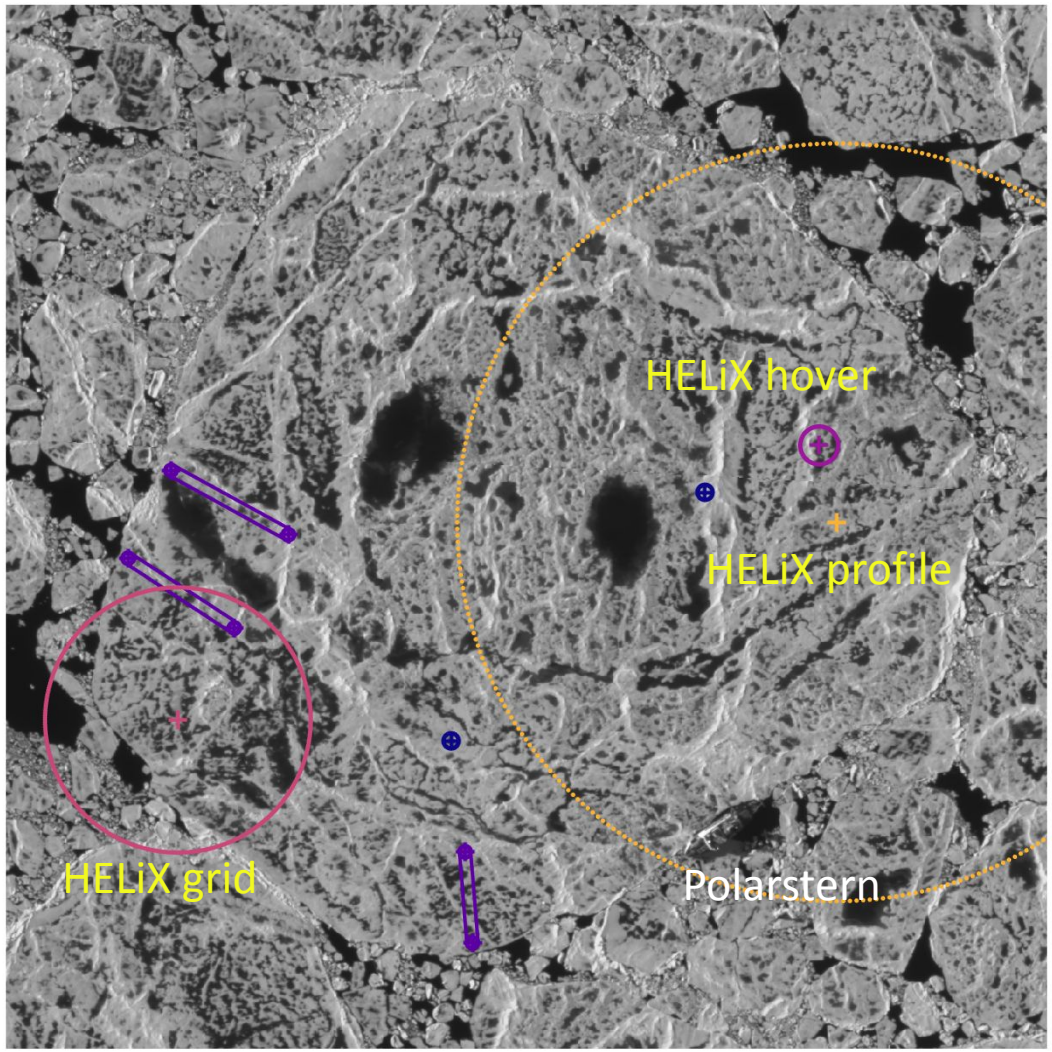
Surface based measurements :

Radiation Station : height ~ 2 m, diameter = 20 m

ASFS50 : height ~ 2 m, diameter = 20 m

Albedo lines : height ~ 1.5 m, length = 200 m

1. Spatial scale: Footprint associated with each hemispherical albedo measurements



Imagery © 2022 Planet Labs Inc.

Cosine response : weighted average over the sensor footprint

Footprint calculation : Height/Diameter = 10

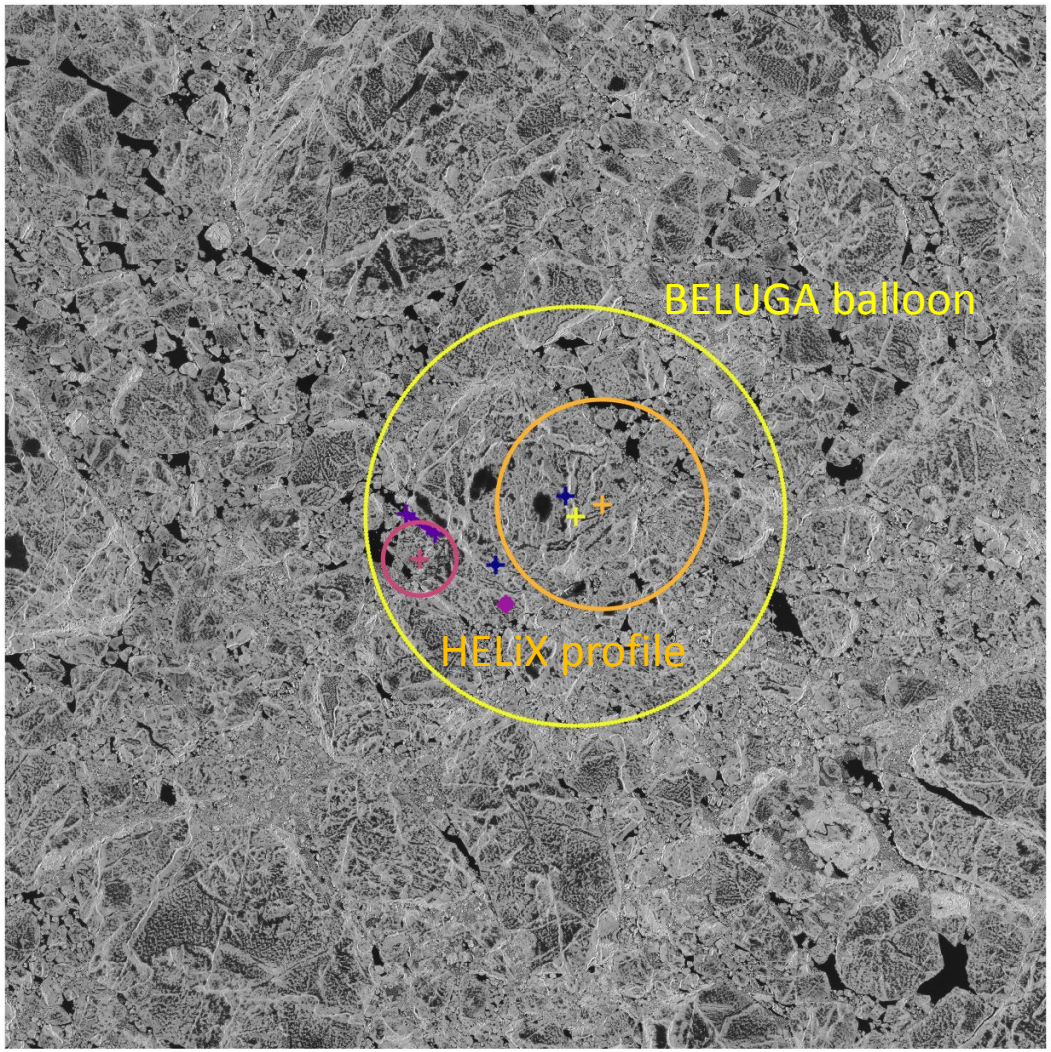
Airborne measurements :

HELiX hover : height ~ 5 m, diameter = 50 m

HELiX grid : height ~ 15 m, area ~ 30 000 m^2

HELiX profile : height = 100 m, diameter = 1 000 m

1. Spatial scale: Footprint associated with each hemispherical albedo measurements



Cosine response : weighted average over the sensor footprint

Footprint calculation : Height/Diameter = 10

Airborne measurements :

HELiX profile : height = 100 m, diameter = 1 000 m

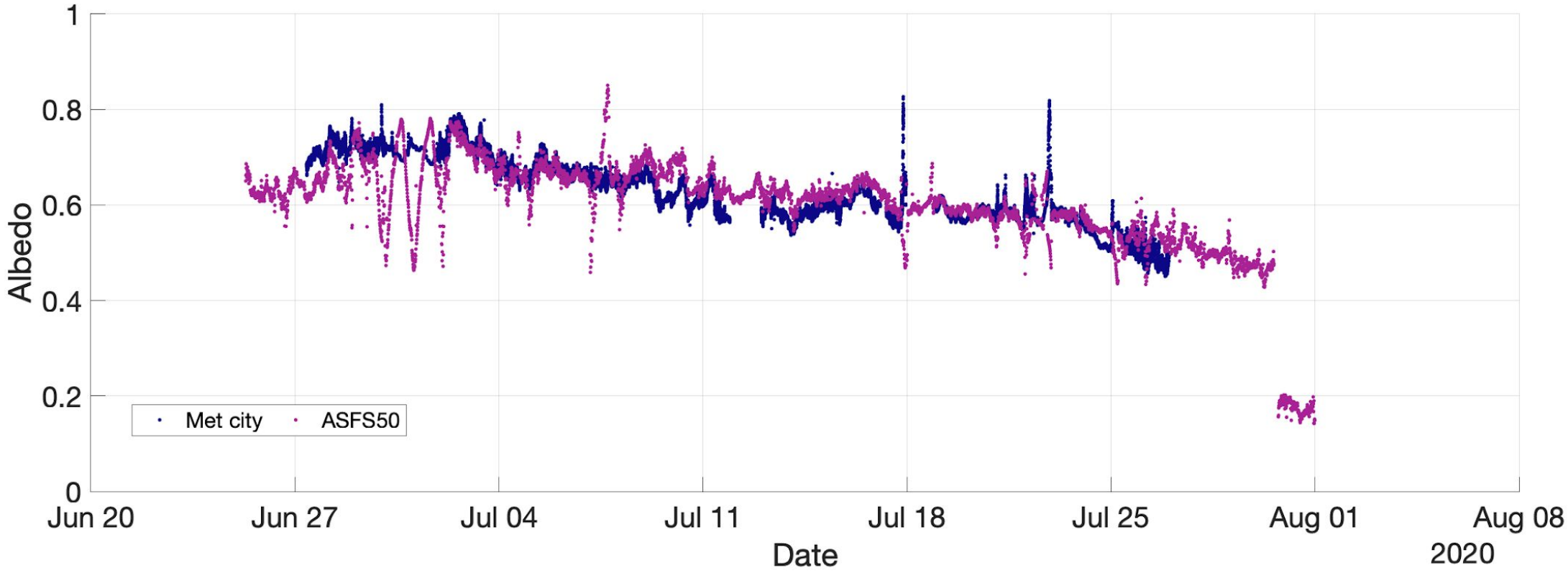
BELUGA balloon : height = 200 m, diameter = 2 000 m

2. Temporal scale: time series of broadband albedo measurements during summertime

Met City DOI:
10.18739/A2PV6B83F
ASFS50 DOI:
10.18739/A2FF3M18K

Time series of albedo for Leg 4 :

- 1 min albedo from the **Radiation Station** at Met City, SYI (footprint = 20 m diameter)
- 10 min albedo from the **ASFS50** over the FYI (footprint = 20 m diameter)

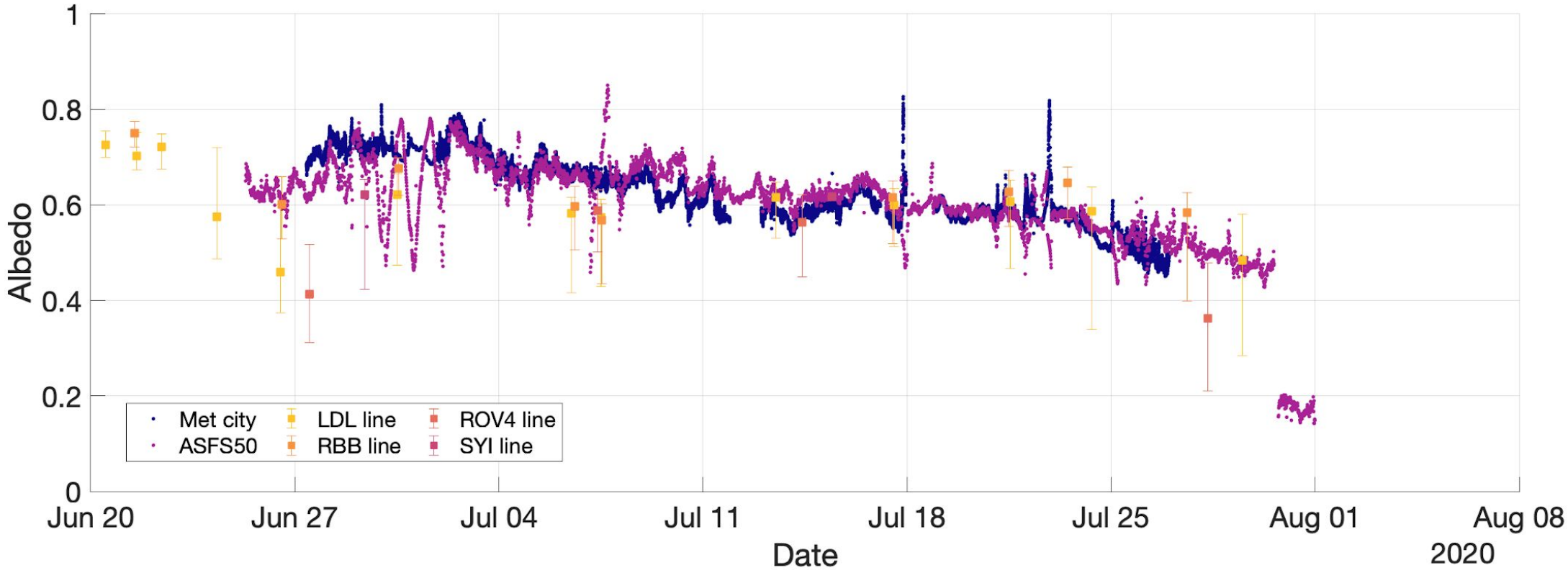


2. Temporal scale: time series of broadband albedo measurements during summertime

Time series of albedo for Leg 4 :

Albedo lines DOI: 10.18739/A2416T11W

- **Albedo lines** represented by **the median and the 25th and 75th percentiles** at 4 locations on the floe (total area covered by the sensors along the lines between 2 400 m^2 (location: ROV4) and 3 225 m^2 (location: LDL and RBB), footprint=15 m diameter)

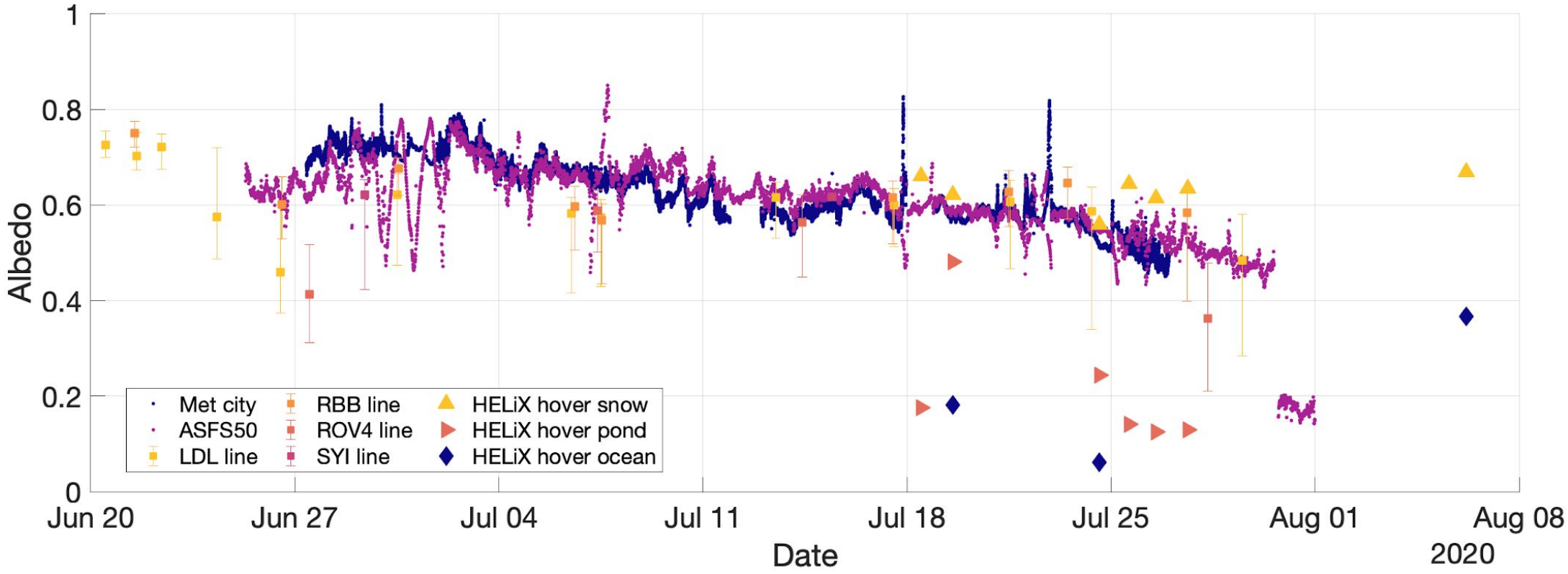


2. Temporal scale: time series of broadband albedo measurements during summertime

Time series of albedo for Leg 4 :

HELiX DOI: 10.18739/A2GH9BB0Q

- The **HELiX hover flights** for snow/melt pond/ocean surfaces (altitude 2-5m, footprint = 20-50 m diameter)

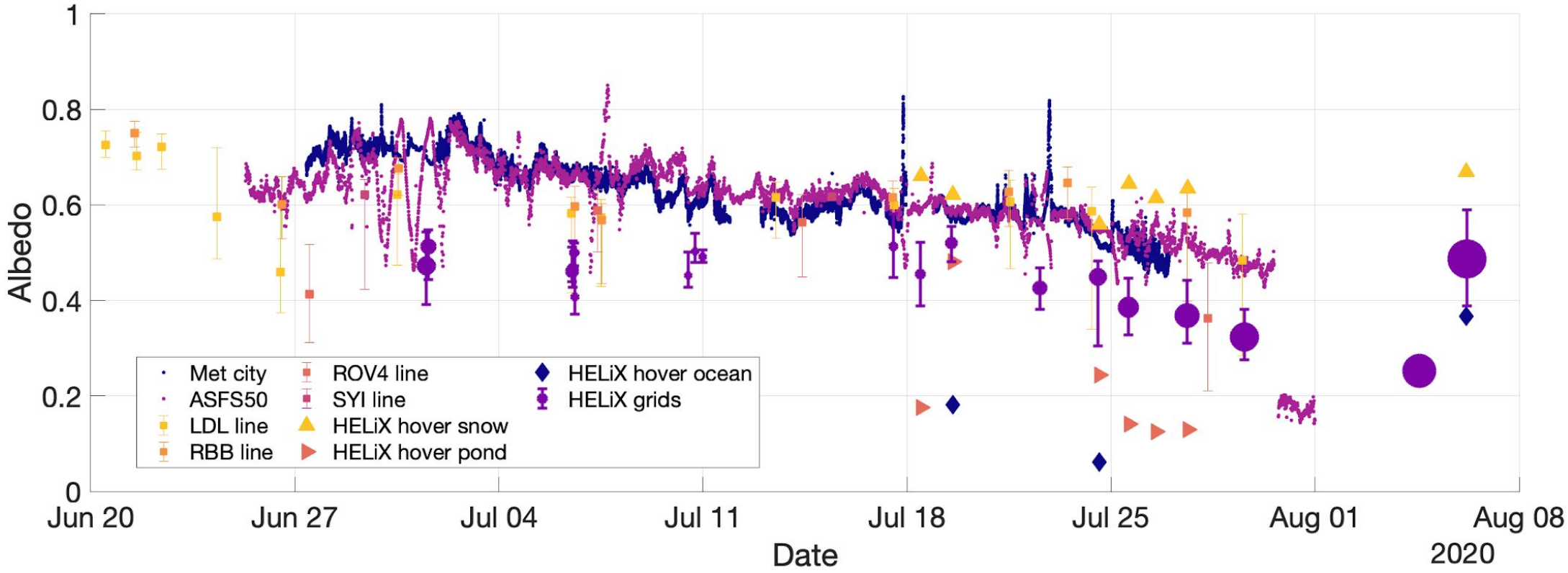


2. Temporal scale: time series of broadband albedo measurements during summertime

Time series of albedo for Leg 4 :

HELiX DOI: 10.18739/A2GH9BB0Q

- The **HELiX grid flights** represented by **the median and the 25th and 75th percentiles** (marker size proportional to grid area, > 10 000 m^2)

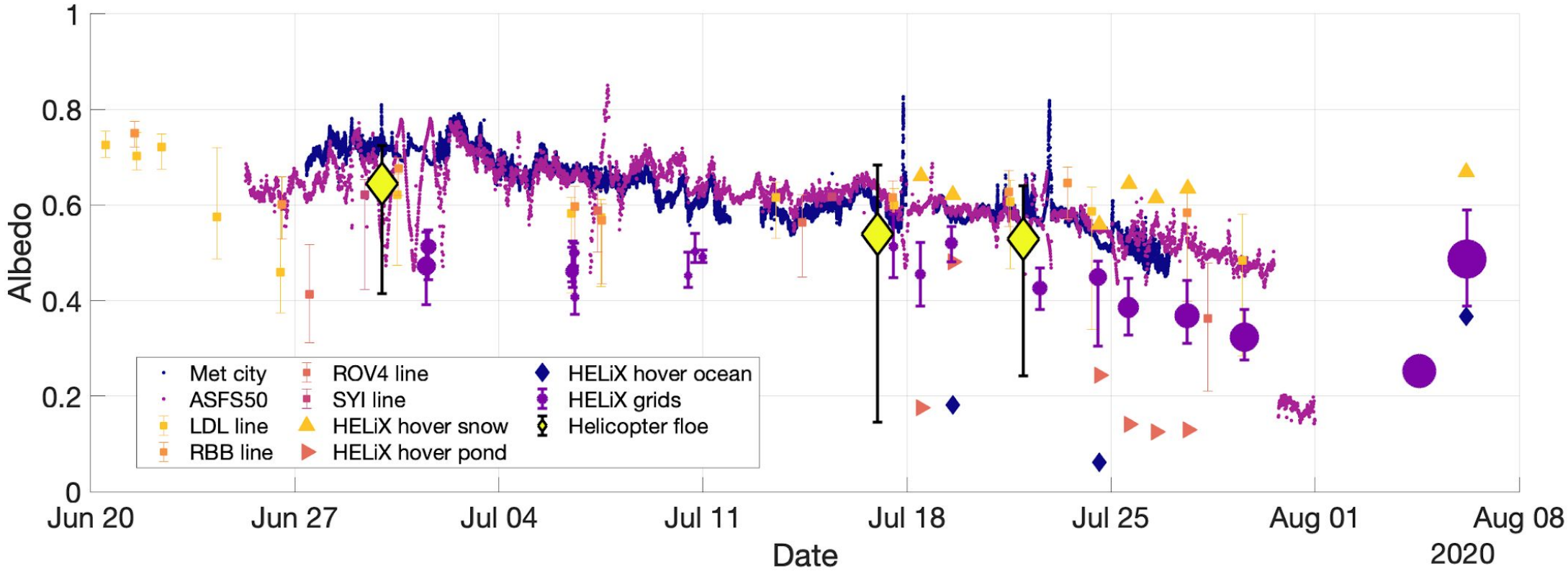


2. Temporal scale: time series of broadband albedo measurements during summertime

Time series of albedo for Leg 4 :

Helicopter images: courtesy of N. Fuchs

- The **helicopter MOSAiC floe** represented by **the median and the 25th and 75th percentiles.**



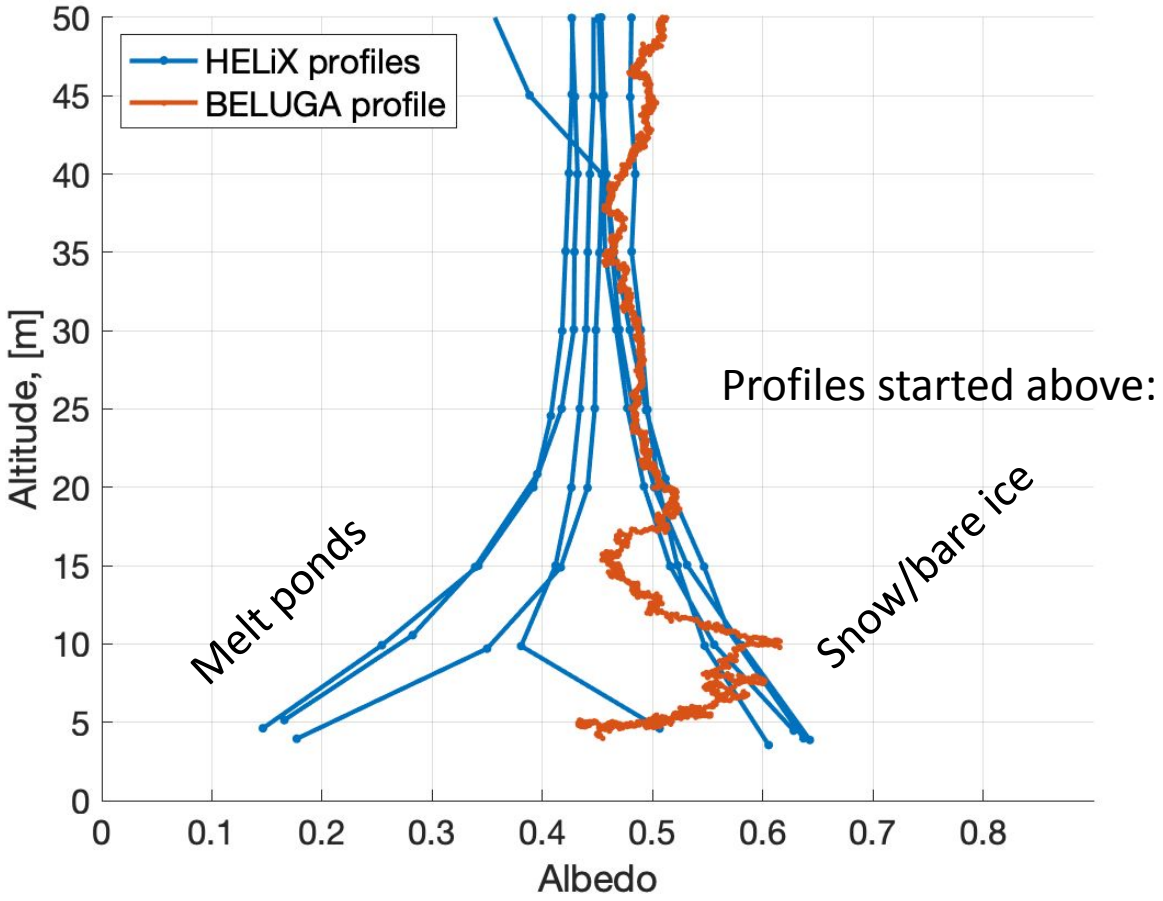
3. Profiles: Comparison of hemispherical sensors measurements and pixel-based calculated albedo on 2020-07-22

BELUGA DOI: 10.1594/PANGAEA.944232
HELiX DOI: 10.18739/A2833N04M

Broadband pyranometers on the HELiX UAS and the BELUGA tethered balloon:

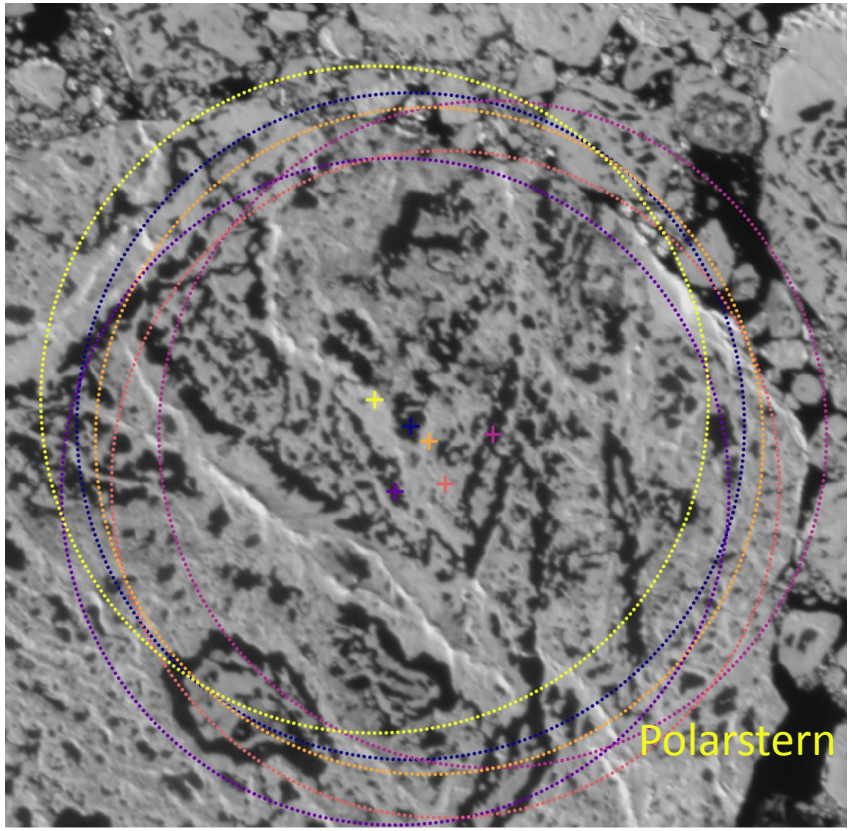
- Location: SYI, near Met City
- HELiX profiles started above melt ponds and snow/bare ice surfaces

 Profiles within the same range



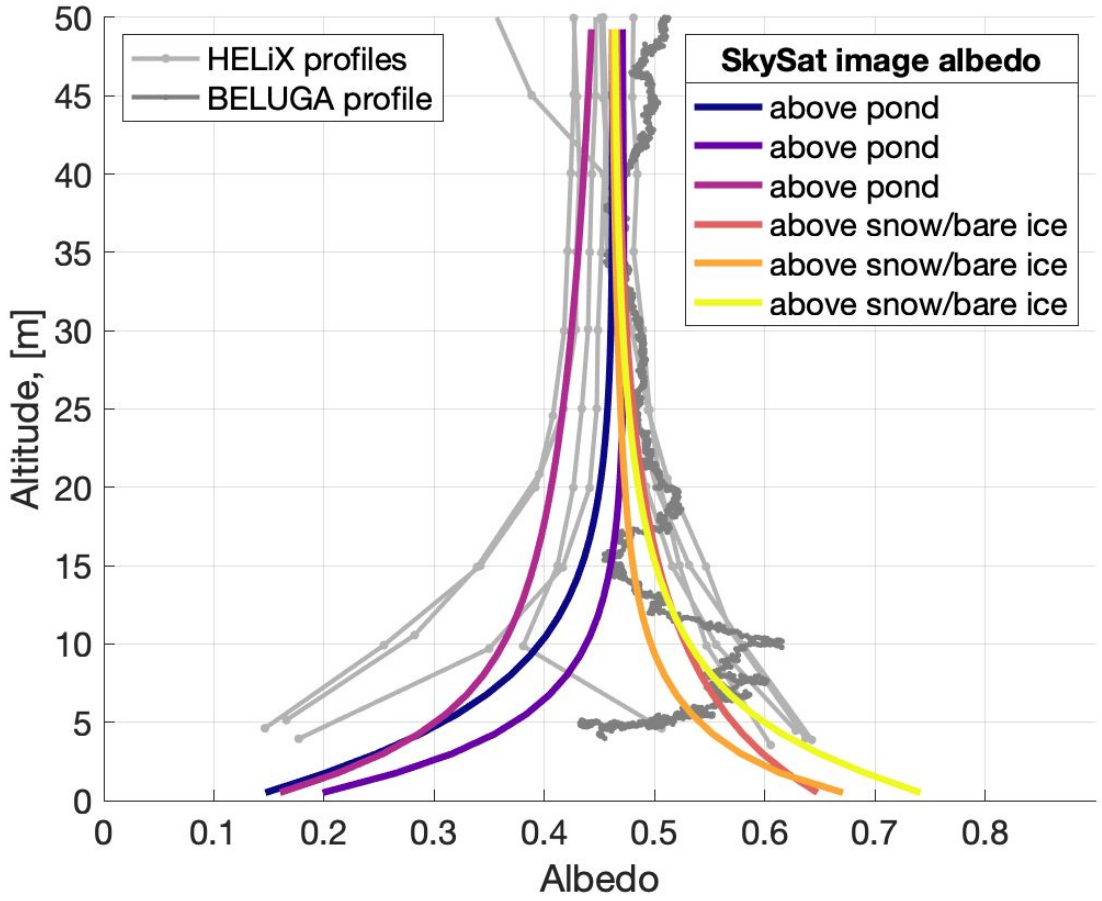
3. Profiles: Comparison of hemispherical sensors measurements and pixel-based calculated albedo on 2020-07-22

Selection of 6 locations above pond and snow/bare ice



SkySat Satellite DOI: [10.18739/A2833N04M](https://doi.org/10.18739/A2833N04M)

Altitude, footprint and cosine function used to calculate a virtual albedo based on image pixel color.

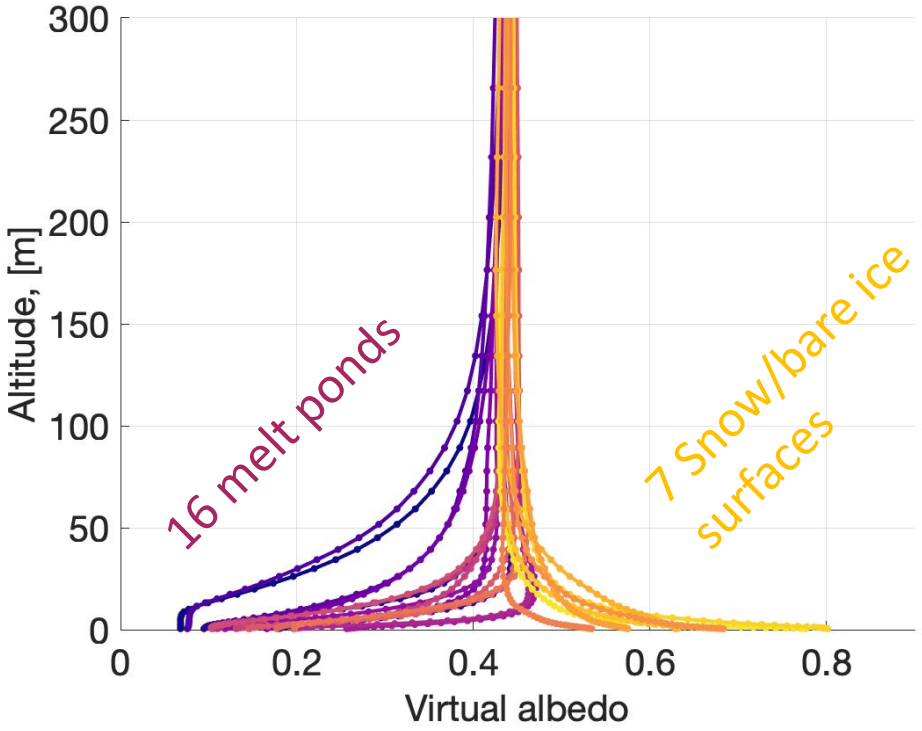


☐ Profiles within the same range

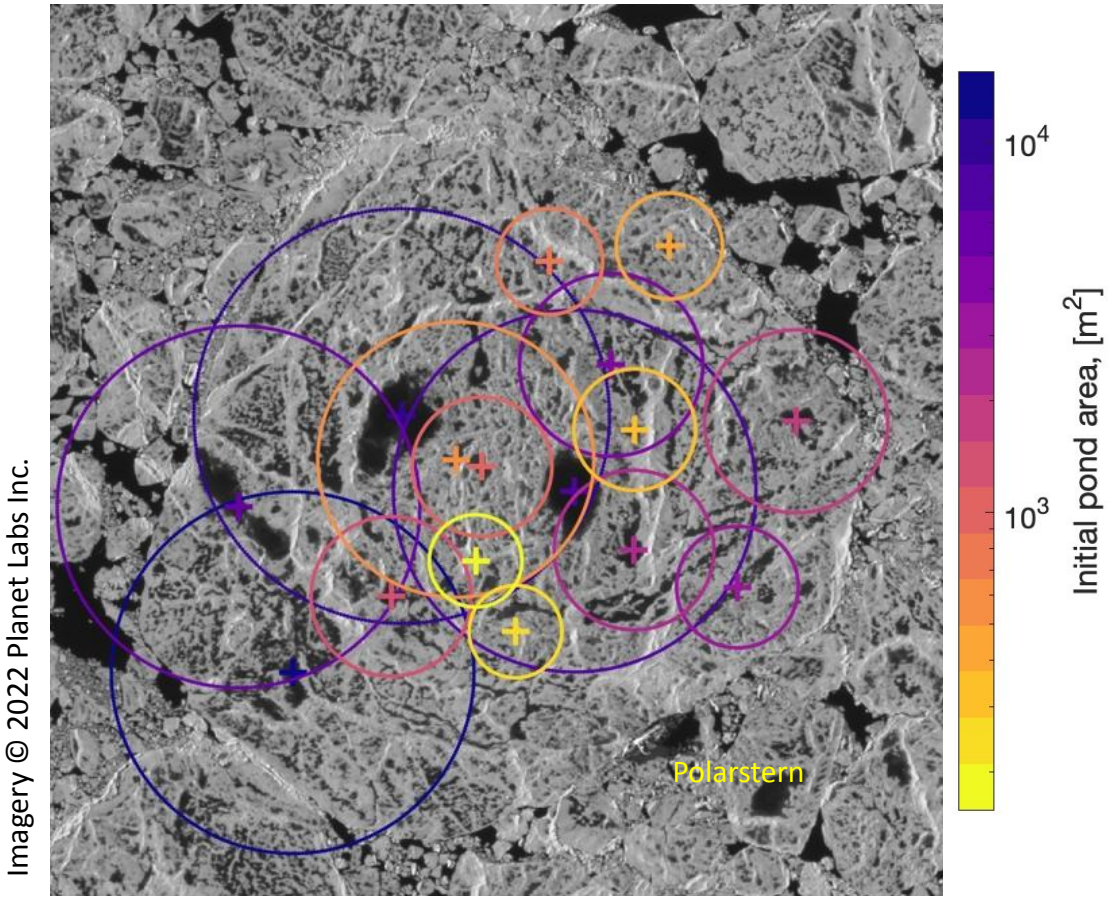
Calmer et al., 2023, in review

3. Profiles: Statistical analysis of profiles

Virtual albedo profiles are calculated and merge toward a similar value at different altitudes. Below the **aggregate scale**, the albedo measurements are biased by the surface feature directly beneath the sensor.



Footprints are calculated at the aggregate scale of albedo.



☐ Variation of albedo with the fractional dimension of melt ponds?

Calmer et al., 2023, in review

Conclusions

- Observations of spatial, temporal, and vertical variabilities of broadband albedo provide a global perspective surface radiations during summertime.
- Focus on case studies, before drainage : 06/30-07/01, after drainage : 07/17and 07/22.
- Working toward surface energy budget.

Acknowledgements:

AWI, all persons involved in the expedition of the Research Vessel Polarstern during MOSAiC, National Science Foundation (OPP 1805569), *Imagery © 2022 Planet Labs Inc.*

Task groups have been created!

Datasets:

- ASFS50 data: ftp://ftp2.psl.noaa.gov/Projects/MOSAiC/asfs50/2_level_product_asfs50/version3/
- Met City, Radiation Station: ftp://ftp2.psl.noaa.gov/Projects/MOSAiC/tower/2_level_product/version3/
- Albedo lines: https://doi:10.18739/A2416T11W
- BELUGA balloon: https://doi.pangaea.de/10.1594/PANGAEA.944232
- Helicopter images: Courtesy of N. Fuchs
- HELiX B1 data (quality controlled and synchronized data) :https://doi.org/10.18739/A2GH9BB0Q
- HELiX orthomosaic images : https://doi.org/10.18739/A2RV0D21Z
- SkySat surface map : https://doi.org/10.18739/A2833N04M

Calculation of footprint diameter as a function of height

Diameter / height ratio as a function of the radiation view factor (RVF)

From **Langleben (1968)**: $RVF = sin^2\left(arctan(w_1)\right)$, where $w_1 = radius/height$

From **Siegel and Howell (1981)**: $RVF = \frac{{w_2}^2}{{w_2}^2+4}$, where $w_2 = diameter/height$

From **Roberts et al. (2008)**: $RVF = 1 + \frac{2\,w_3}{({w_3}^2+4)^{1/2}}$, where $w_3 = height/diameter$