Assessing the Impact of Black Carbon Deposition from Wildfire Smoke on Greenland Surface Albedo and Melt Using Sentinel-3 Synergy

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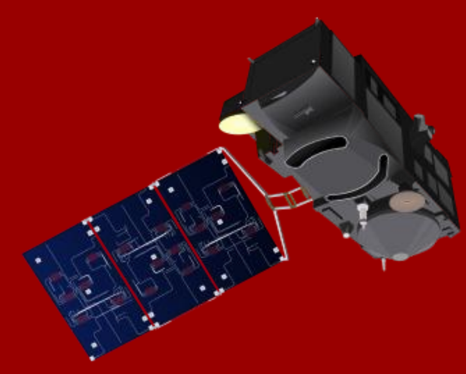
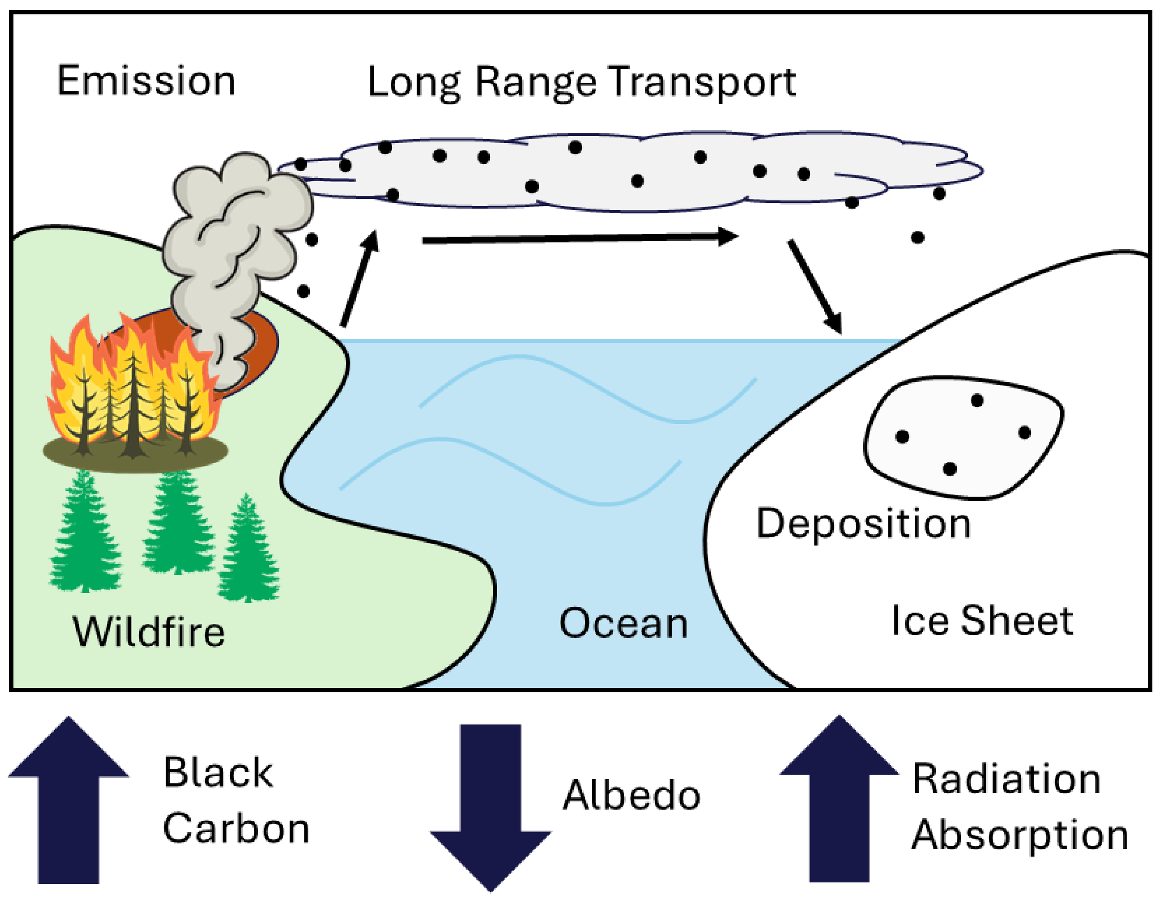
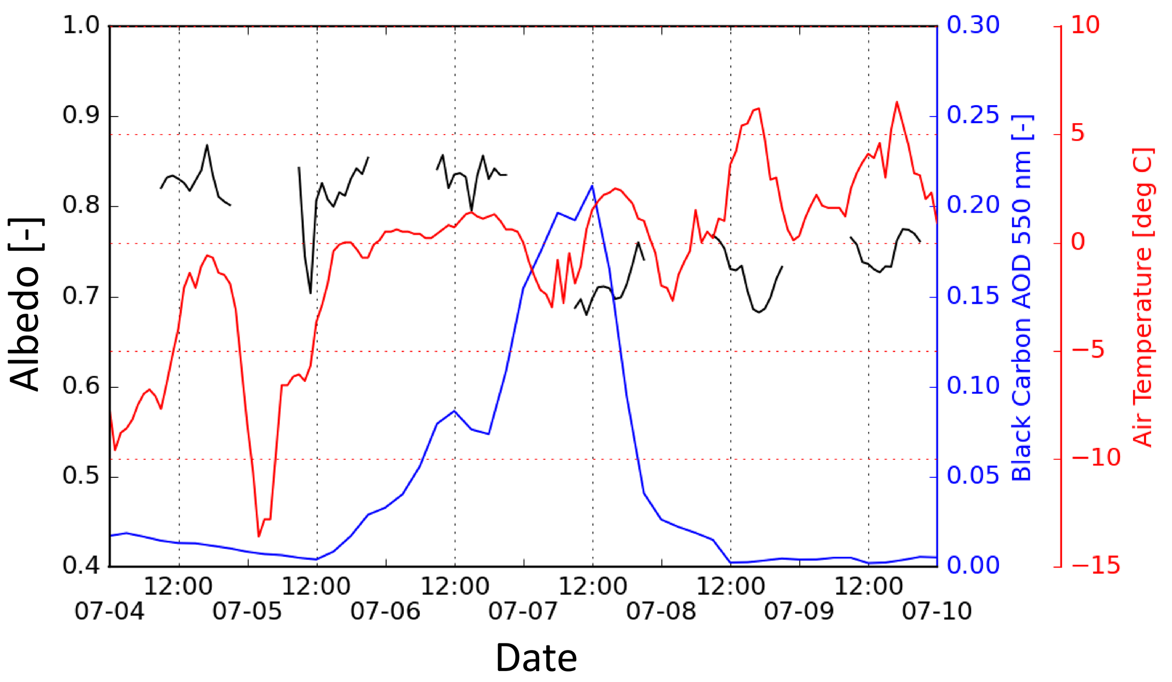


Background

Wildfires are increasing in frequency and intensity, transporting black carbon (BC) to the Arctic. When deposited on snow and ice, BC reduces albedo and increases solar absorption, potentially accelerating melt. However, it is difficult to isolate BC-driven albedo changes because albedo, temperature, and melt are tightly coupled.

This study uses a Sentinel-3 multi-sensor synergy (SLSTR, OLCI, & SRAL) to explore how wildfire smoke may drive surface albedo and melt changes.





In-situ data of surface albedo (black) & 2m air temperature (red) from a GC-NET Automated Weather Station (AWS) (South Dome) during a high BC event in 2023 (blue; data from Copernicus Atmospheric Monitoring Service) [Fausto et al., 2021; Inness et al., 2019].

Methodology

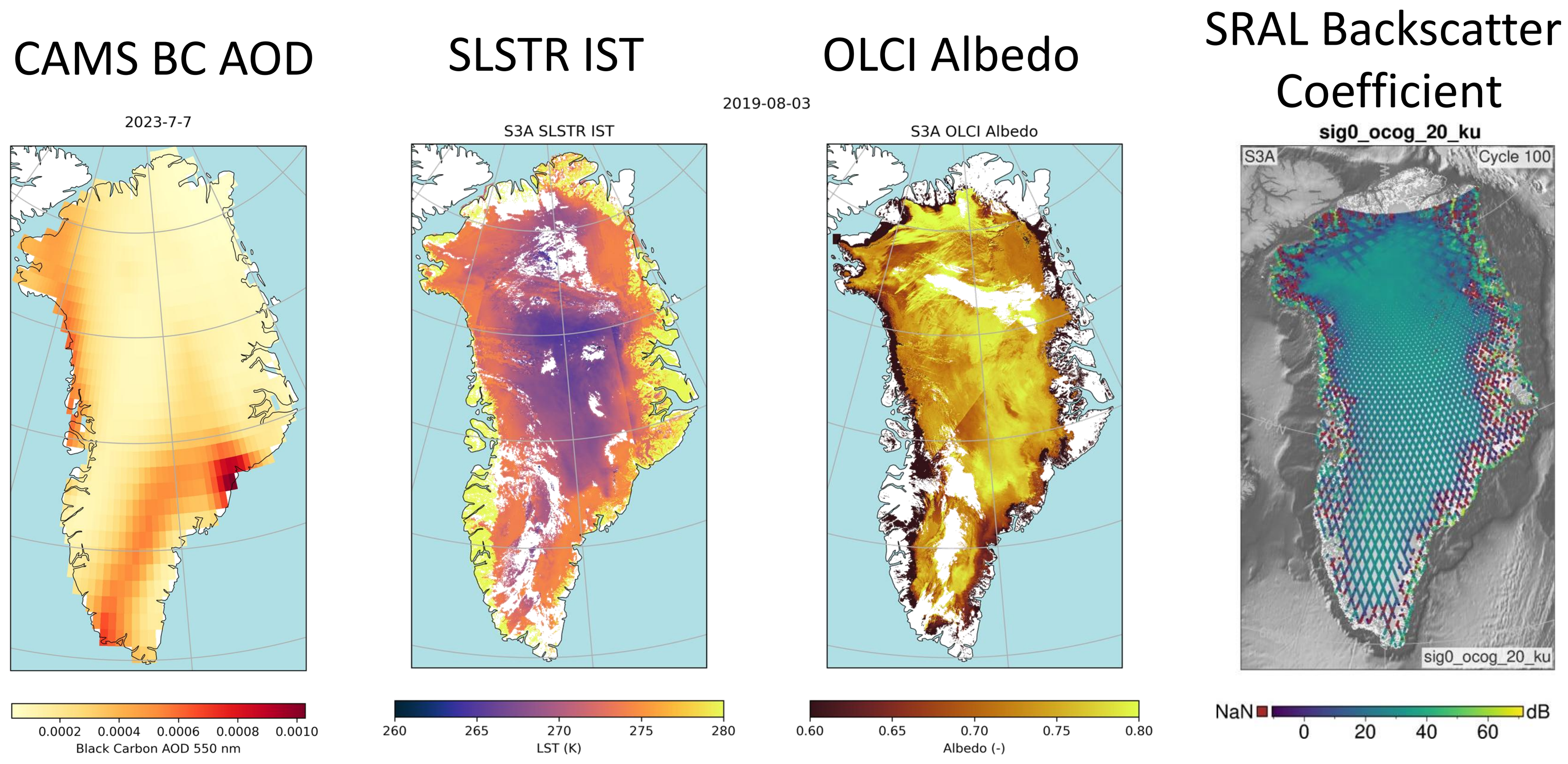
1. Establish a baseline temperature-albedo relationship from SLSTR & OLCI in non-fire years $\alpha_{EXP} = f(T_{IST})$

2. Use this relationship to identify anomalous non-temperature driven albedo changes in fire years $\Delta\alpha_{BC} = \alpha_{EXP} - \alpha_{OBS}$

3. Use SRAL to assess changes in melt-related signals between fire and non-fire years/events

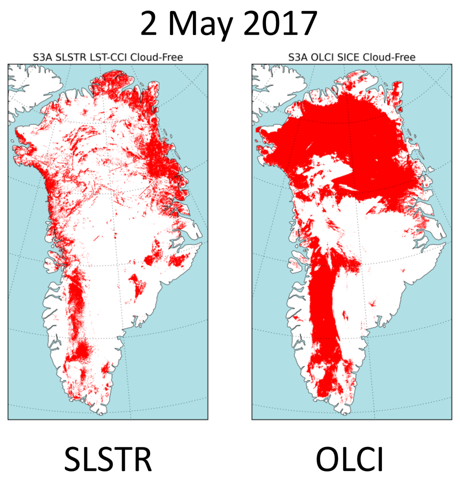
Data

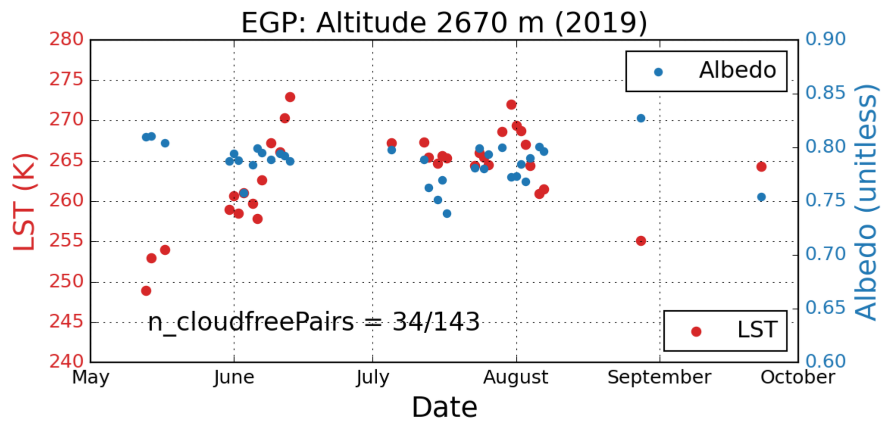
Sensor/ Product	Contribution	Source
CAMS Black Carbon AOD 550 nm	Identify fire and non-fire years	Inness et al. (2019)
S3A SLSTR (LST CCI Product)	Ice Surface Temperatures	Ghent et al. (2025)
S3A OLCI SICE v3.0 Greenland Snow & Ice Albedo	Surface Albedo	Bahbah et al. (2023)
S3A SRAL Land Ice Product	Melt confirmation via elevation change & waveform melt indicators	Aublanc et al. (2025)

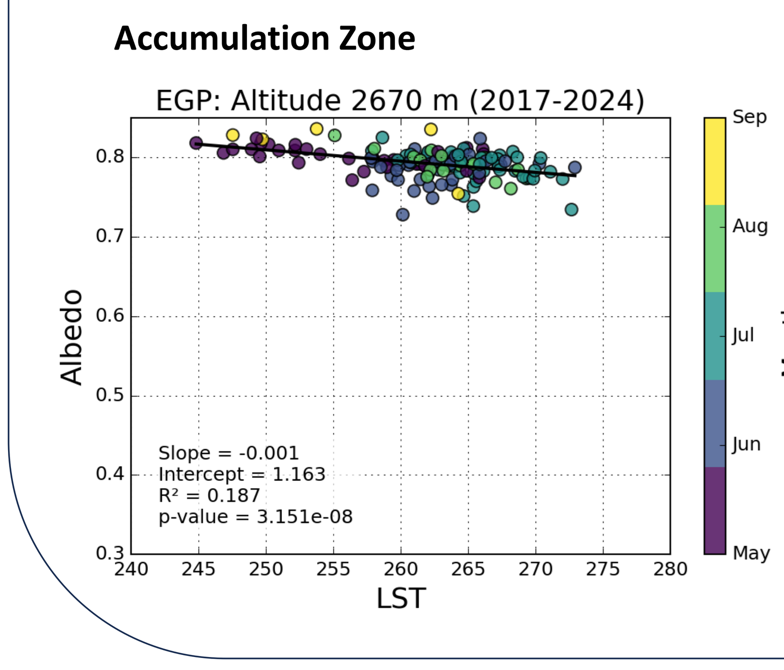


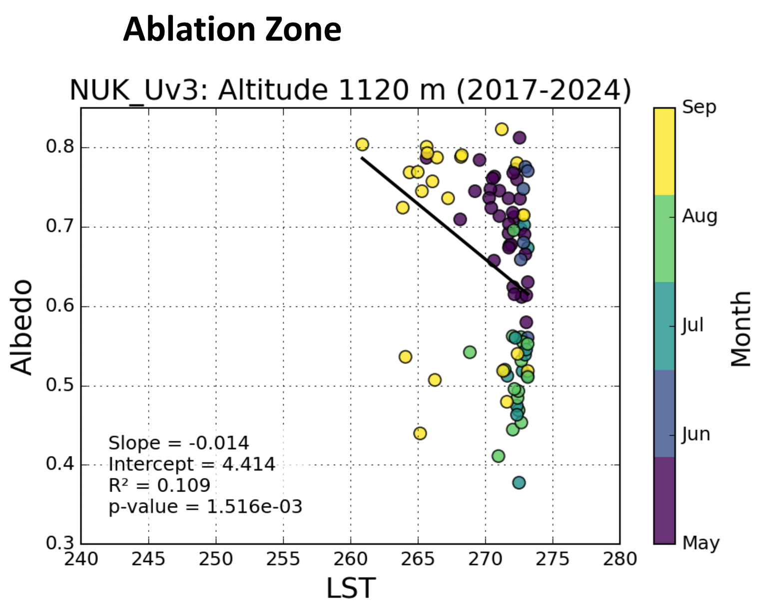
Preliminary Results: Developing Temperature-Albedo Baseline

(1) Initial assessment of the availability of cloud-free pairs, with noticeable differences apparent in the cloud-masking techniques.









(2) From temperature & albedo pairs at selected PROMICE/GC-NET AWS (Fausto et al., 2021), we see trends are spatio-temporally dependent, indicating a need to stratify by surface type & state.

Next Steps

Baseline relationship development
- ❖ Data segregation to consider seasonality & different types of snow/ice
- ❖ Assessment of the impact of scale

Assessment of BC-induced albedo anomalies
- ❖ Application of baseline to fire event conditions

Suggested thresholds for albedo anomaly detection

$\Delta\alpha < -0.05$	Strong negative anomaly
$\Delta\alpha < -0.02$	Moderate anomaly
$\Delta\alpha > 0$	No impact

- ❖ Quantification of anomaly decay time (does it last until snowfall or is it transient?)

References:
- Aublanc et al. (2025) Sentinel-3 Altimetry Thematic Products for Hydrology, Sea Ice and Land Ice, doi: 10.1038/s41597-025-04956-3
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- Fausto et al. (2021) Programme for Monitoring of the Greenland Ice Sheet (PROMICE) automatic weather station data, doi.org/10.5194/essd-13-3819-2021
- Ghent et al. (2025): ESA Land Surface Temperature Climate Change Initiative (LST_cci): Daily land surface temperature from SLSTR (Sea and Land Surface Temperature Radiometer) on Sentinel 3A, level 3 collated (L3C) global product (2016-2023), version 4.00, doi:10.5285/4a40c6fe12cc4c0786608065da06d287
- Inness et al. (2019) The CAMS reanalysis of atmospheric composition, doi.org/10.5194/acp-19-3515-2019

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