Are transition season melt events on the Greenland Ice Sheet driven by Baffin Bay sea ice-atmosphere interactions?

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Thomas J. Ballinger[1,*], Thomas L. Mote[2], Kyle S. Mattingly[2], Edward Hanna[3], Angela C. Bliss[4,5], Dirk van As[6], Melissa Prieto[1], Saeideh Gharehchahi[1], Xavier Fettweis[7], Brice Noël[8], Paul C.J.P. Smeets[8], Mads H. Ribergaard[9]

[1]Department of Geography, Texas State University, San Marcos, TX, USA
[2]Department of Geography, University of Georgia, Athens, GA, USA
[3]School of Geography, University of Lincoln, Lincoln, UK
[4]NASA Goddard Space Flight Center, Greenbelt, MD, USA
[5]University of Maryland, Earth System Science Interdisciplinary Center, College Park, MD, USA
[6]Geological Survey of Denmark and Greenland, Copenhagen, Denmark
[7]Laboratory of Climatology, Department of Geography, University of Liège, Liège, Belgium
[8]Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, the Netherlands
[9]Danish Meteorological Institute, Copenhagen, Denmark

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***Corresponding Author Email: tballinger@txstate.edu**

Abstract

A number of insitu and passive microwave satellite sensors have observed Arctic sea ice and Greenland Ice Sheet (GrIS) mass loss trends over recent decades. Along with sea and land ice declines, above-freezing, near-surface air temperatures are observed earlier in boreal spring and later in autumn thus extending periods of melt beyond the core of summer (JJA). Little is known about whether lengthening periods of open ocean proximate to the ice sheet, for instance, demonstrably effect unseasonal GrIS melt events. Here, a new Baffin Bay sea ice advance dataset is utilized to determine dates of sea ice growth along Greenland's west coast for the 2011-2015 period. Preceding, multi-scale ocean-atmospheric conditions, including at the Baffin-GrIS interface, are analyzed and linked to unseasonal melt events observed at a series of on-ice automatic weather stations (AWS) along the K-transect in southwest Greenland. The local marine versus synoptic influence on the above and below freezing surface air temperature events is assessed through analyses involving AWS winds, pressure, and humidity observations. These surface observations are further compared against Modele Atmospherique Regional (MAR), Regional Atmospheric Climate Model (RACMO2), and ERA-Interim reanalysis fields to understand the airmass origins and (thermo)dynamic drivers of the melt events. Results suggest that the K-transect transition season melt events, primarily in the ablation zone, are strongly affected by ridging atmospheric circulation patterns that transport warm, moist air from lower latitude land-ocean areas toward west Greenland. While local conduction of oceanic surface heat appears to impact coastal air temperatures, consistent with previous studies, marine air incursions from Baffin waters onto the ice sheet are likely obstructed by barrier flows and the pressure gradient-driven katabatic regime off of central Greenland.

Research Questions

This study addresses two primary research questions:

- Does the Baffin Bay marine layer influence unseasonal (i.e. late summer and autumn) GrIS melt events?
- How does the mesoscale and synoptic environment support, or inhibit, an oceanic link with GrIS melt events?

Study Area

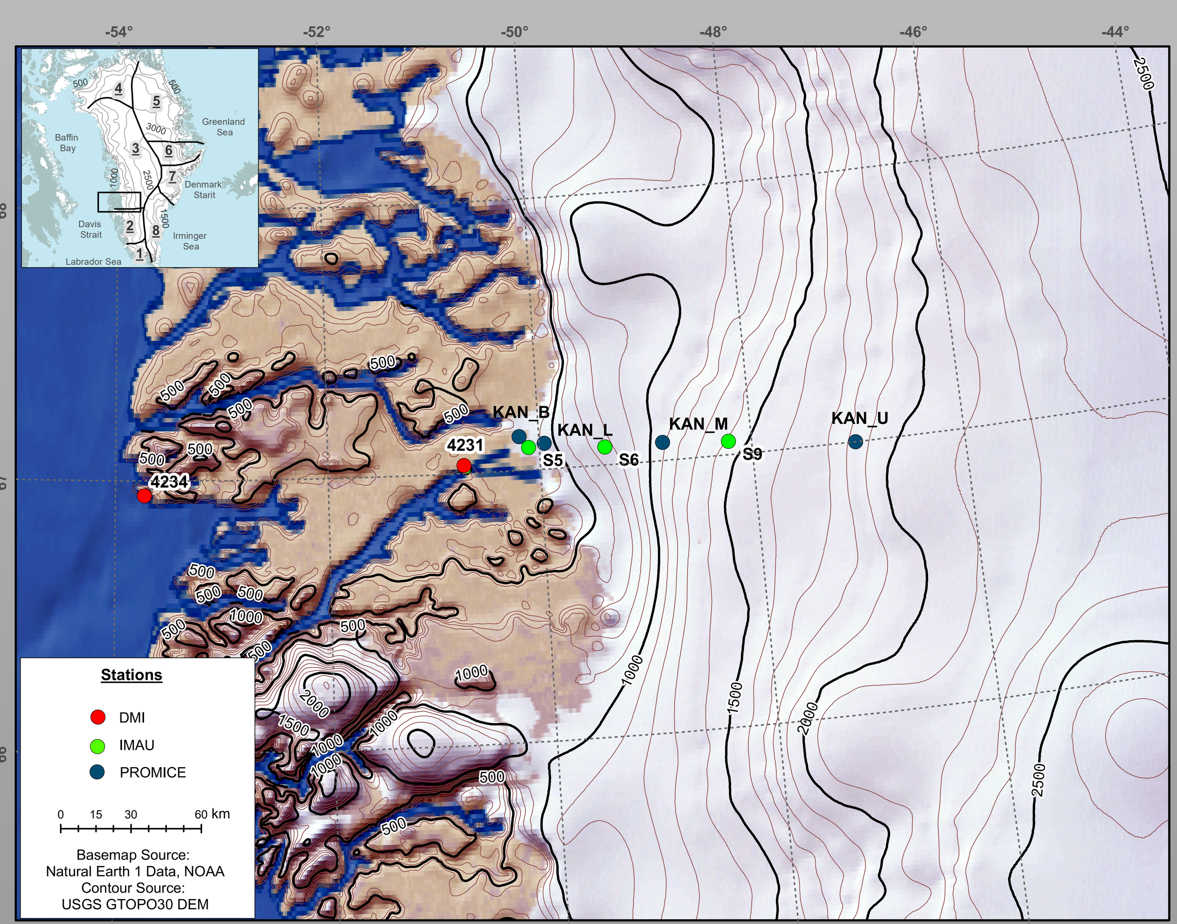

Figure 1. Study area map with PROMICE and IMAU K-transect sites and nearby terrestrial DMI stations at Kangerlussuaq (WMO code 4231) and Sisimiut (WMO code 4234). The inset displays the northwest Atlantic Arctic region with superimposed GrIS topographically-defined boundaries adopted from Ohmura and Reeh (1991).

Data and Methods

Daily observations and model output are used for the 2011-2015 study period:

- Passive microwave-derived (25 km) dates of Baffin Bay sea ice advance (DOA = SIC ≥ 15%; Bliss et al., in review)
- PROMICE ("KAN"; van As et al., 2011) and IMAU ("S"; Smeets et al., 2018) AWS records of daily mean air temperature, wind speed and direction (see **Figure 1** for locations)
- Daily Greenland Blocking Index (GBI; Hanna et al., 2018) and North Atlantic Oscillation Index (NAOI; Cropper et al., 2015)
- Integrated vapor transport (IVT), winds, and geopotential heights (GPH) from ERA-Interim (Dee et al., 2011) with a self-organizing map (SOM) classification applied to the former variable similar to Mattingly et al. (2016)
- RACMO2.3p2 (Noël et al., 2018) and MAR v3.9 (Fettweis et al., 2017) 10-m and 850 hPa wind fields

Composite analyses are based on KAN_B daily mean air temperatures of ≥0°C (T+) and <0°C (T-) observed over 60-31 day and 30-1 day bins preceding the Baffin Bay DOA; statistical differences between T+ and T- events are assessed by the Wilcoxon test under the null hypothesis of no difference (rejected when $p \leq 0.05$).

Results: On-Ice AWS and Regional Model Composites

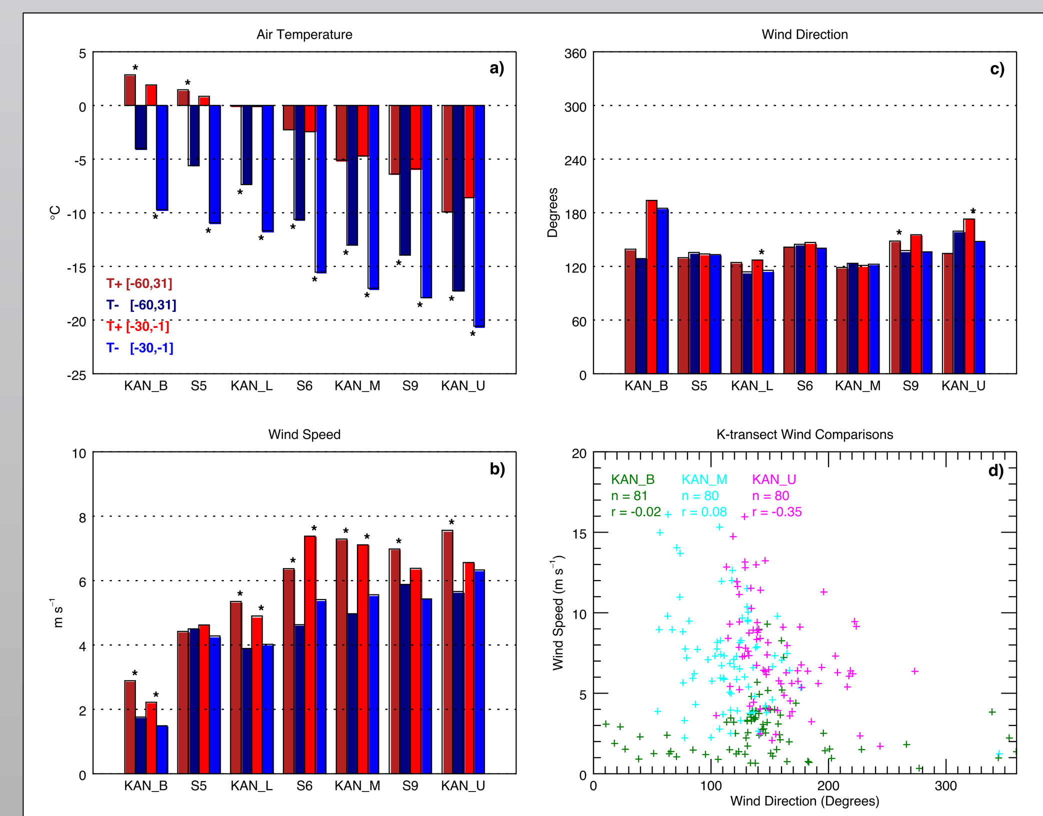

Figure 2. Composites of a) air temperature, b) wind speed, and c) wind direction for the KAN_B T+ and T- events preceding Baffin DOA, 2011-2015. Significant differences ($p \leq 0.05$) between T+ and T- composites for similar bins are shown by asterisks (*) between the bars. Panel d) shows wind speed as a function of direction for select PROMICE stations.

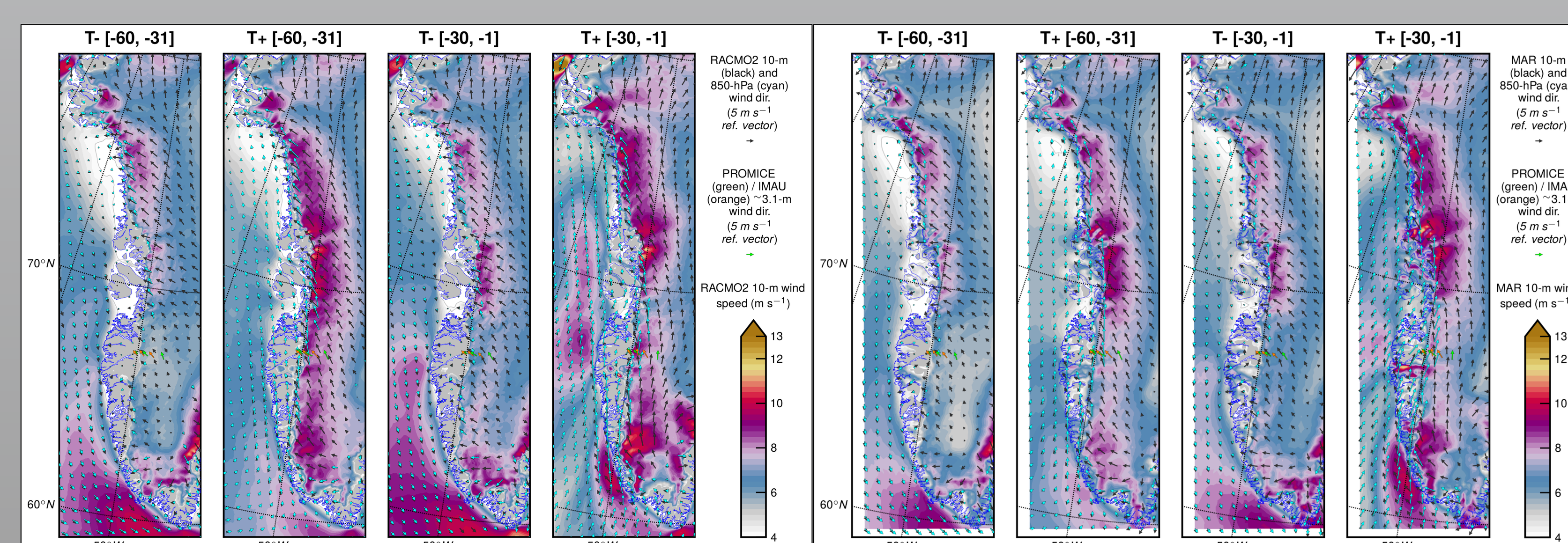

Figure 3. Composites of RACMO2 (left) and MAR (right) 10-m (black arrows) and 850 hPa (cyan arrows) vector winds for the KAN_B T+ and T- events preceding Baffin DOA, 2011-2015. Wind observations from PROMICE (green arrows) and IMAU (orange arrows) are overlaid for reference.

Results: Synoptic Factors

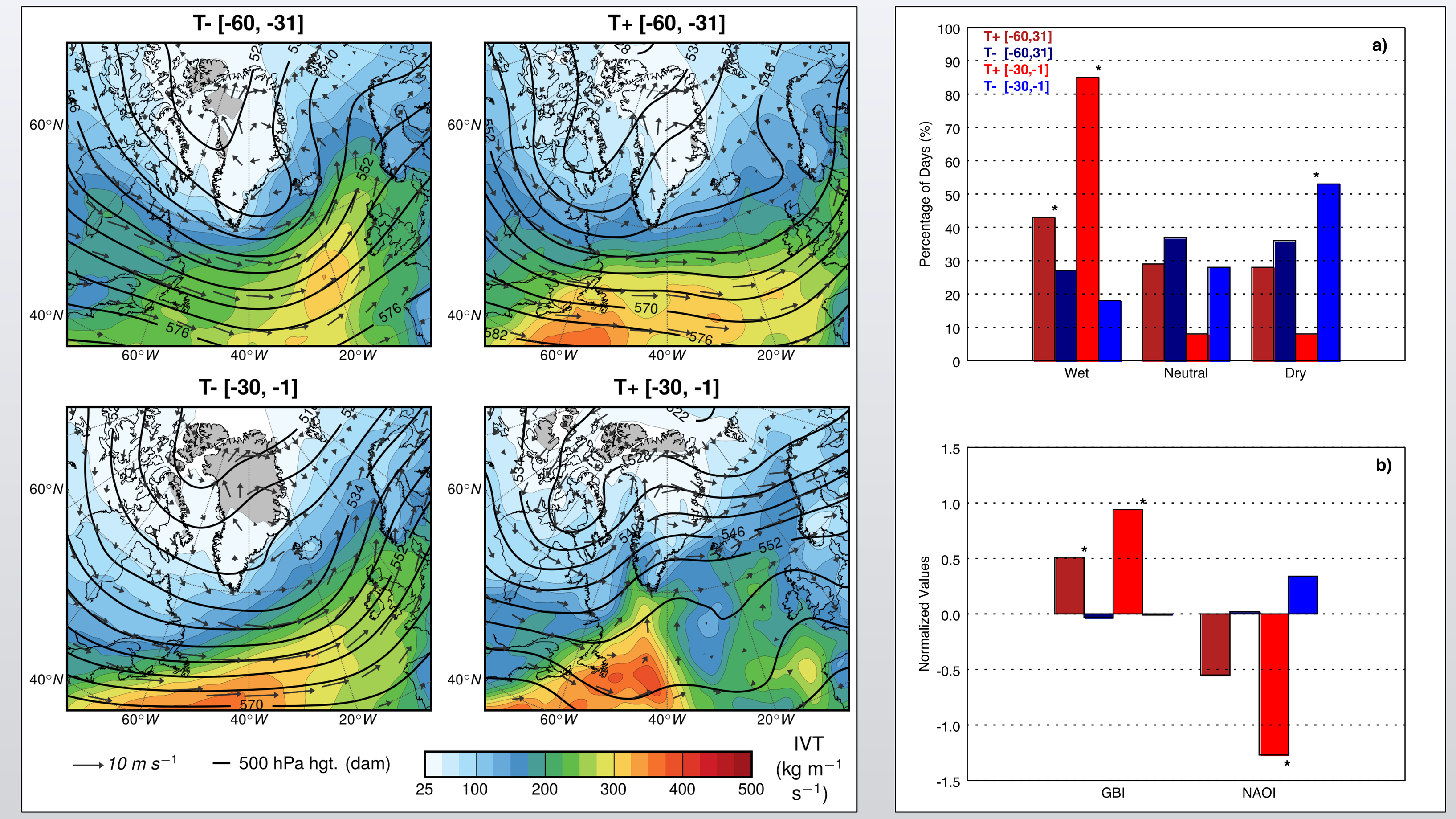

Figure 4. Composite plots of IVT, 1000-700 hPa winds, and 500 hPa GPH for T+ and T- events at KAN_B for the two periods preceding DOA (left). Bar graphs on the right represent composites of a) SOM nodes by wet, neutral and dry types (%) and b) normalized GBI and NAO values (unitless) for T+ and T- events at KAN_B for the two periods preceding DOA. SOM aggregates represent the ratio of each pattern's occurrence to the sum of all patterns for each time period and similarly colored bars sum to 100%. Significant differences ($p \leq 0.05$) between T+ and T- composites by time bins are shown by asterisks (*) between the bars.

Conclusions

Three main conclusions emanate from this study:

- While longer autumn open water conditions on Baffin Bay likely impact coastal air temperature and tidewater glacier behaviors, heat and moisture advection off these waters does not appear to influence unseasonal GrIS melt events.
- Observational and model composites suggest that SSE barrier and katabatic winds over the western slope of the GrIS "block" the Baffin marine layer from penetrating inland during periods of autumn surface melt.
- Unseasonal ablation area melt appears driven by synoptic forcing, namely meridional circulation patterns and southerly winds that transport warm, moist air masses across the southwestern portion of the GrIS.

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