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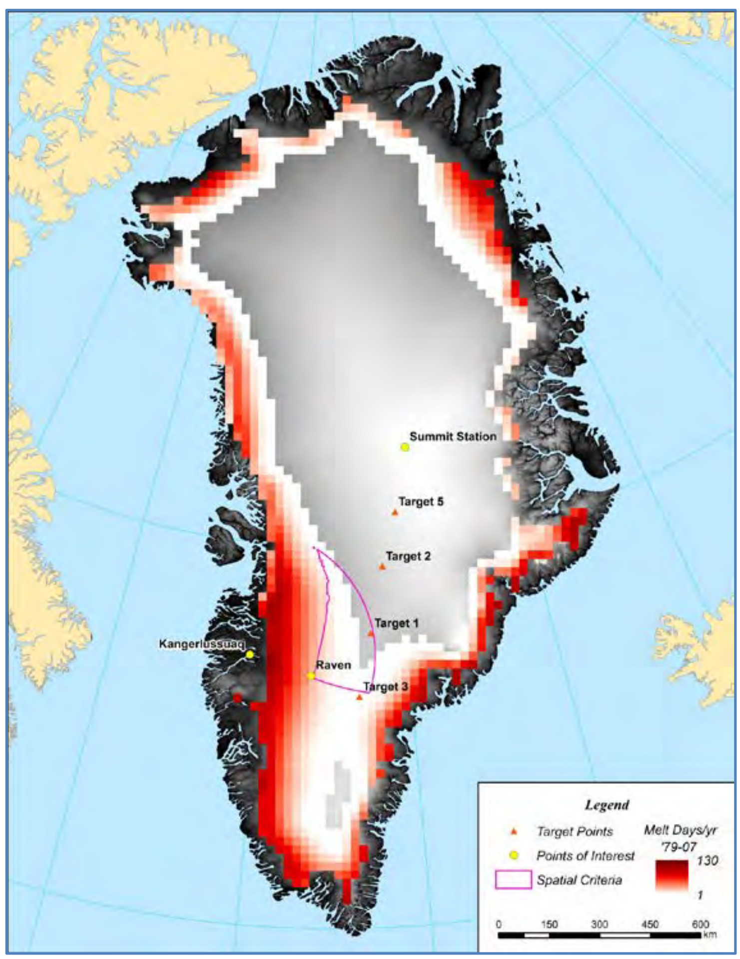
Site Assessment and Feasibility of a New Operations Base on the Greenland Ice Sheet

Addendum to Preliminary Report

Matthew Bigl and Elias Deeb

November 2015



Addendum to Site Assessment and Feasibility of a New Operations Base on the Greenland Ice Sheet

Addendum to Preliminary Report

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Final Report

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Arctic Research Support and Logistics Program
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Under Engineering for Polar Operations, Logistics, and Research (EPOLAR)
EP-ARC-14-31, “Raven Alternative Site Assessment”

Abstract

The New York Air National Guard (NYANG) 109th Airlift Wing training facility located at Raven in southwest Greenland experienced surface crevassing during the 2012 extreme Greenland melt event, which limited the use of the runway. Because of subsequent interest in relocating the runway, our study analyzed the runway's climatic, physical, and logistical factors, expanding on *Site Assessment and Feasibility of a New Operations Base on the Greenland Ice Sheet* by Burzynski et al. (2013). Their report identified a primary target region for relocating the runway based on stakeholder criteria and climatic data collected from across Greenland. We improved on this investigation by replacing the proxy (e.g., elevation) previously used for melt with newly released satellite estimates of melt. These new data used changes in microwave emissions from the surface and near surface of the Greenland Ice Sheet to estimate melt days across Greenland. By applying the Burzynski et al. (2013) criteria to the new melt data, we quantified melt days/year over the past 35 years. This improves the selection criteria for an appropriate relocation zone for the Raven runway, and the ArcGIS framework developed by this project provides the ability to incorporate future stakeholder needs into the site-selection analysis.

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Preface

This study was conducted for the National Science Foundation, Division of Polar Programs (NSF-PLR), Arctic Research Support and Logistics Program, under Engineering for Polar Operations, Logistics, and Research (EPOLAR) EP-ARC-14-31, "Raven Alternative Site Assessment." The technical monitors were Pat Haggerty and Renee Crain, NSF-PLR.

The work was performed by Matthew Bigl (Engineering Resources Branch, Jared Oren, Chief) and Dr. Elias Deeb (Terrain and Ice Engineering Branch, Stephen Newman, Chief), U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL). At the time of publication, Dr. Loren Wehmeyer was Chief of the Research and Engineering Division; and Timothy Pangburn was the Director of the Remote Sensing/GIS Center of Expertise. The Deputy Director of ERDC-CRREL was Dr. Lance Hansen, and the Director was Dr. Robert Davis.

COL Bryan S. Green was the Acting Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

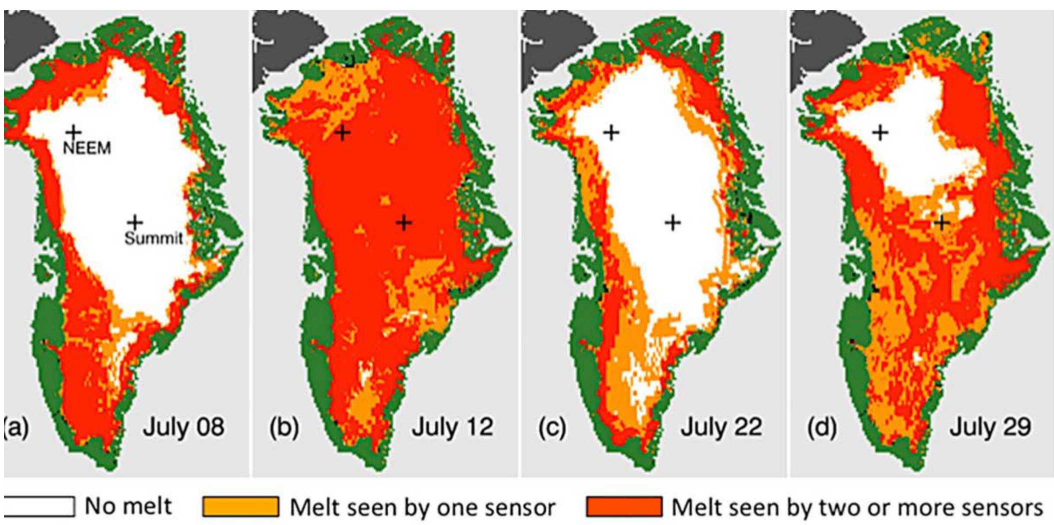
Acronyms and Abbreviations

CRREL	Cold Regions Research and Engineering Laboratory
EPOLAR	Engineering for Polar Operations, Logistics, and Research
ERDC	U.S. Army Engineer Research and Development Center
GIS	Geographic Information System
m.a.s.l.	Meters above Sea Level
nmi	Nautical Miles (1852 meters)
NSAT	Near-Surface Air Temperature
NSIDC	National Snow and ice Data Center
NSF	National Science Foundation
NYANG	New York Air National Guard
PLR	Division of Polar Programs
SMM/I	Special Sensor Microwave/Imager
SMMR	Scanning Multi-channel Microwave Radiometer

1 Introduction

Recent melt seasons in Greenland have called into question the feasibility of operating the New York Air National Guard (NYANG) 109th Airlift Wing training facility located at Raven (69°29′ N, 46°17′ W, 2100 m.a.s.l [meters above sea level]) in southwest Greenland. In recent years, the NYANG 109th has observed both surface crevassing across the current Raven skiway and surface melt and has expressed interest in evaluating a more suitable training location less prone to melt (Mercer 2012). Because of an extreme Greenland-wide melt event during summer 2012 (Figure 1), observed surface crevasses at Raven limited the use of the airfield; and surrounding training areas initiated a series of field efforts (e.g., ground-penetrating surveys and strain measurements) to better understand the ice sheet dynamics at this location.

Figure 1. Composite satellite maps of the Greenland 2012 melt event (Nghiem et al. 2012).



Burzynski et al. (2013) took into consideration the requirements for a new training site as indicated by various stakeholders, including but not limited to the NYANG 109th, the Government of Greenland, the Greenland science community, the Summit Science Coordination Office, and the National Science Foundation's partnering agencies. These criteria included the following:

- A slope less than 28°, based on the calculated slope at Raven using an existing digital elevation model

- A flight time from Kangerlussuaq less than or equal to 45 minutes, or approximately 200 nmi
- An elevation greater than 2100 m.a.s.l., the current elevation of Raven, below which melt conditions increase
- An elevation less than 2745 m.a.s.l., above which would require supplemental oxygen for the 109th's training (Bernasconi 2012)

The primary output of the Burzynski et al. (2013) study was a wedge-shaped target region 47,825 km^2 where all stakeholder requirements overlapped (Figure 2). The area includes the spine of the Greenland Ice Sheet and covers a region to the north and east of the current Raven site. Burzynski et al. (2013) used elevation as their proxy for surface melt. They reasoned that including only elevations above the current Raven site would ensure that areas have equal or less melt than Raven.

To narrow down an area for further site investigation, this was an appropriate method; however, since publication of the Raven site assessment, the National Snow and Ice Data Center (NSIDC) has published a methodology for determining seasonal surface melt for the entire Greenland Ice Sheet (Abdalati 2008). This provides an opportunity to update the results of Burzynski et al. (2013). Although the methodology for measuring melt in this manner has existed for several years, NSIDC did not make the entire data set available until 2014.

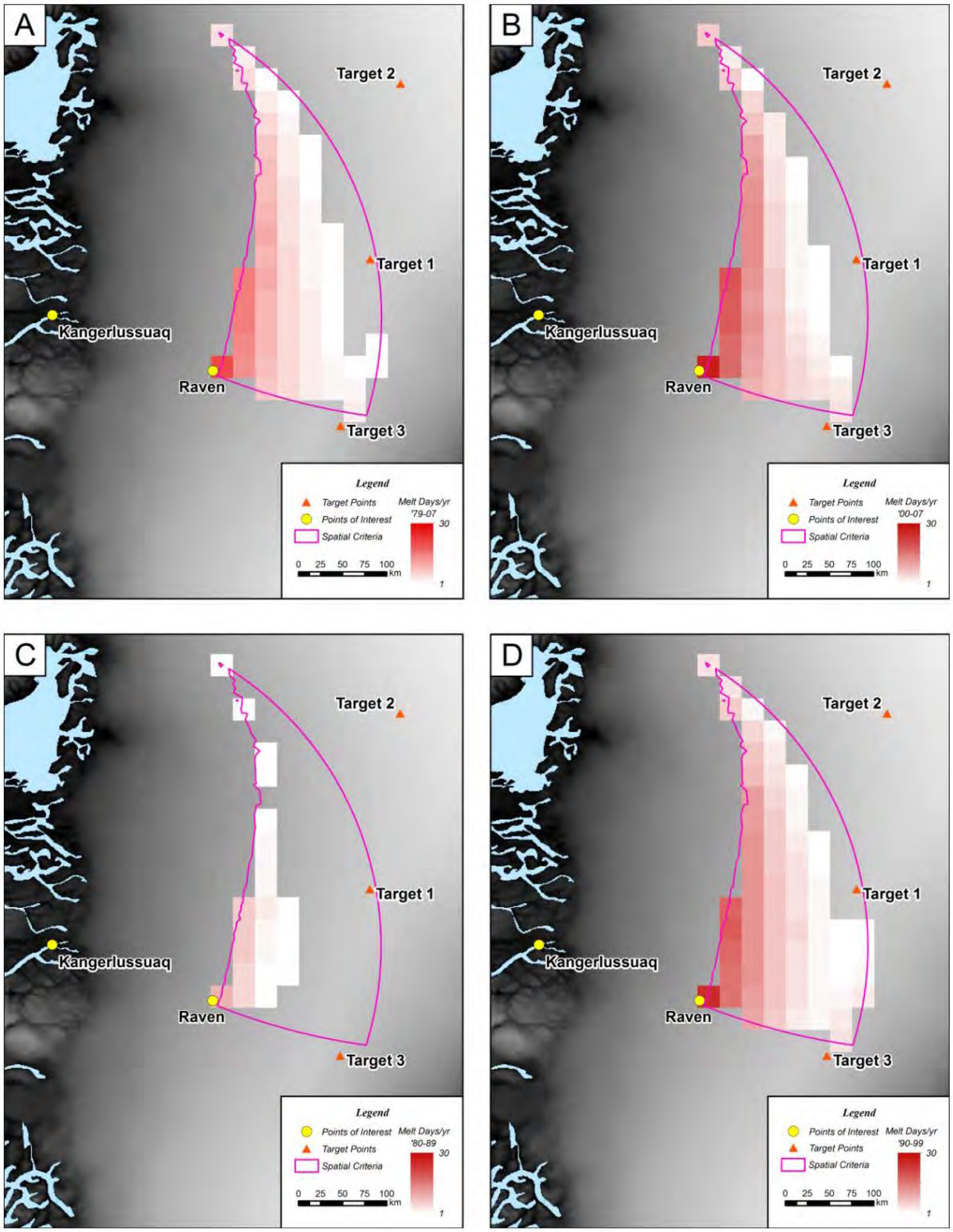
Figure 2. Target region (*fuchsia*) identified by Burzynski et al. (2013) for the Raven relocation.

2 Methodology: Incorporating Greenland Melt Data

To determine when surface snow melts, Abdalati (2008) used changes in microwave emissions from the surface and near surface of the Greenland Ice Sheet that were observable using both a Scanning Multi-channel Microwave Radiometer (SMMR) and the Special Sensor Microwave/Imager (SMM/I). The satellite-based technique uses a difference in the passive microwave brightness temperatures at a 25 km spatial resolution as a proxy for melt for each day of the year. These estimates were made every other day from 1979 to August 1987 and then daily from August 1987 to the present. To resolve the discrepancy between the temporal sampling, we created dummy files for the 1979 to August 1987 time period to complete the time series. These dummy files were copies of the melt data from the previous day. Processing the time series data provides a count of total annual melt days for each pixel across the entire Greenland Ice Sheet. NSIDC has processed and released data from only 1979 to 2007, and this serves as the temporal extent of our analysis.

By making use of previous stakeholder criteria described by Burzynski et al. (2013) and by updating the Geographic Information Systems (GIS) framework for data organization, we were able to reconstruct the results of their study (Figure 2) by using the target region to extract the Greenland melt data (Abdalati 2008) for only this region of interest. Along with the entire period of record (1979–2007), we were able to divide the melt data into three separate decadal brackets for future use in determining sites for assessment. The temporal brackets for the melt data include the entire period of record currently available, 1979–2007 (Figure 3A), and decadal averages of melt days per year for the most recent seven years of data, from 2000 to 2007 (Figure 3B); for the 1980s (Figure 3C); and for the 1990s (Figure 3D). These brackets are averages of each year's total melt days in each pixel. For each year, there is a total count of melt days for each pixel; and for each of these periods of time, we averaged those counts for each pixel, resulting in the output shown in the figures. Although the final time period, 2000–2007, does not represent a full decade, it provides a valuable comparison to earlier brackets of data and to the dataset as a whole. Moreover, for a broader perspective, the Appendix presents Greenland-wide melt maps derived from this processing methodology.

Figure 3. Average Greenland melt days per year as estimated from passive microwave satellite data (Abdalati 2008) for the target region identified by Burzynski et al. (2013): (A) The available period of record (1979–2007); (B) The most recent seven years of data (2000–2007); (C) the 1980s; and (D) the 1990s.



3 Analysis

There is a clear increase in melt days per year that has occurred from the 1980s to the present. This is most evident when comparing the subsets of Figure 3. During the 1980s, the target region to the north and east of Raven experienced on average a maximum of 9 melt days/year whereas that average rose to 25 melt days/year in the 1990s and 27 melt days/year in the most recent period (2000–2007). This relative trend has also been observed in the near-surface air temperature (NSAT) of Greenland, increasing at a rate of 0.09 ± 0.01°C/year from 1982 to 2011 with an increase to 0.12 ± 0.01° C/year from 1992 to 2011 (McGrath et al. 2013). A direct spatial comparison of melt-days/year and coordinated NSAT as recorded by climate stations across Greenland would greatly benefit both the validation of the satellite-based method presented in this report and any future assessment for relocating Raven.

4 Conclusions and Future Work

By applying the criteria of Burzynski et al. (2013), we are able to make a simple depiction of annual Greenland melt over approximately the past 35 years. This allows for a more precise decision regarding allowable annual melt at any new proposed site. Future work regarding the Raven site assessment should include updates of the GIS framework with melt data post-2007 when it becomes available. It is important to note that the 2012 melt event will heavily influence averages for the current decade given the rarity and spatial impact of such an event. However, as Arctic climate appears to have moved from a steady state to a transient one (McGrath et al. 2013), continuing work on the site assessment should consider an increase in extreme melt events such as the 2012 season. Further investigations into contemporary ice sheet flow rates, crevassing evolution, and estimated melt days could also affect both the current site and a possible relocation area. If and when a decision is made to move forward with a new site selection, the ArcGIS framework built as part of our study can be used for site selection and for analysis of any new criteria that become important to stakeholders.

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Appendix A: Greenland-Wide Melt Maps

Figure A-1. Average Greenland melt days per year for 1979–2007 as estimated from passive microwave satellite data (Abdalati 2008) and using the target region identified by Burzynski et al. (2013).

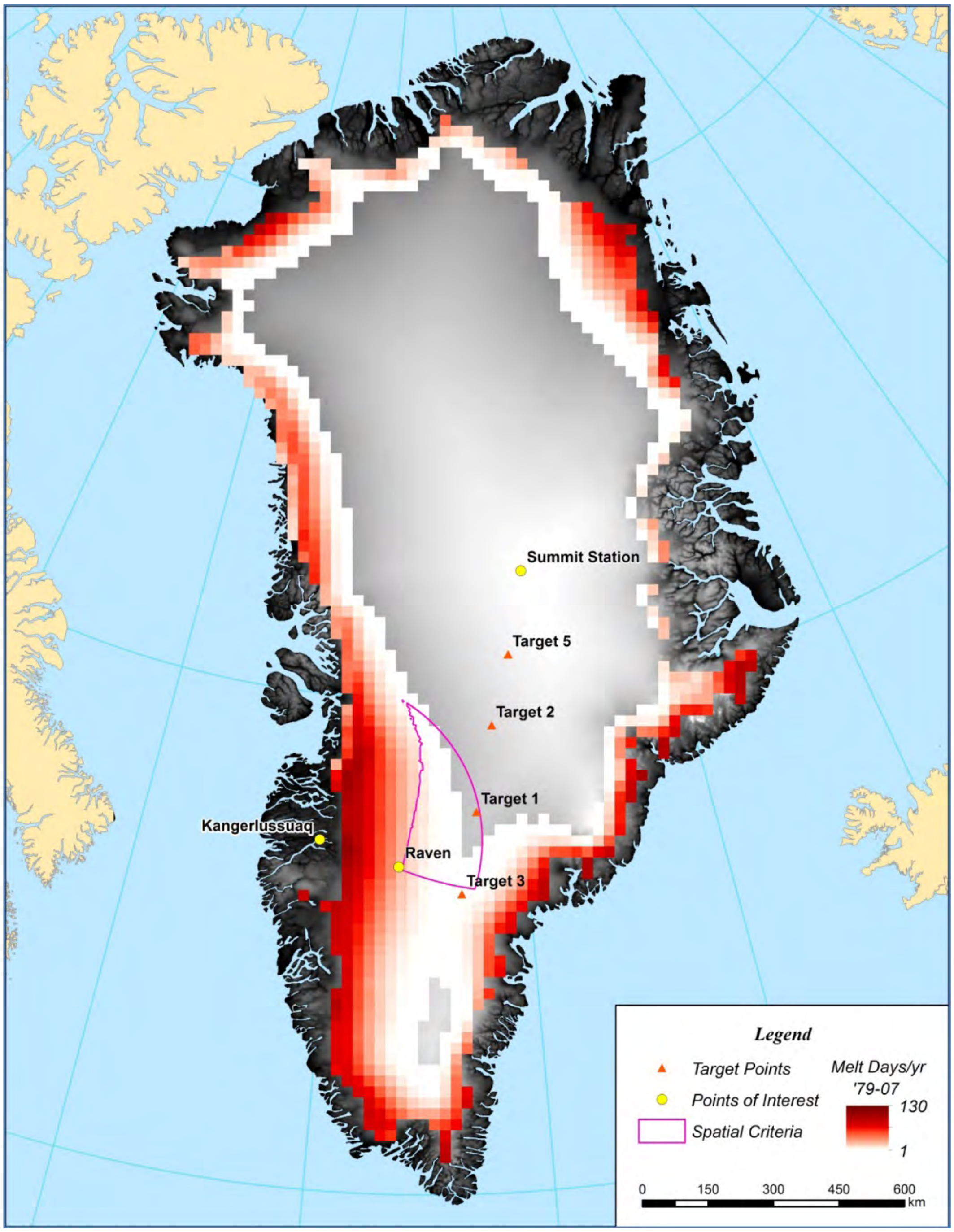


Figure A-2. Average Greenland melt days per year for the 1980s as estimated from passive microwave satellite data (Abdalati 2008) and using the target region identified by Burzynski et al. (2013).

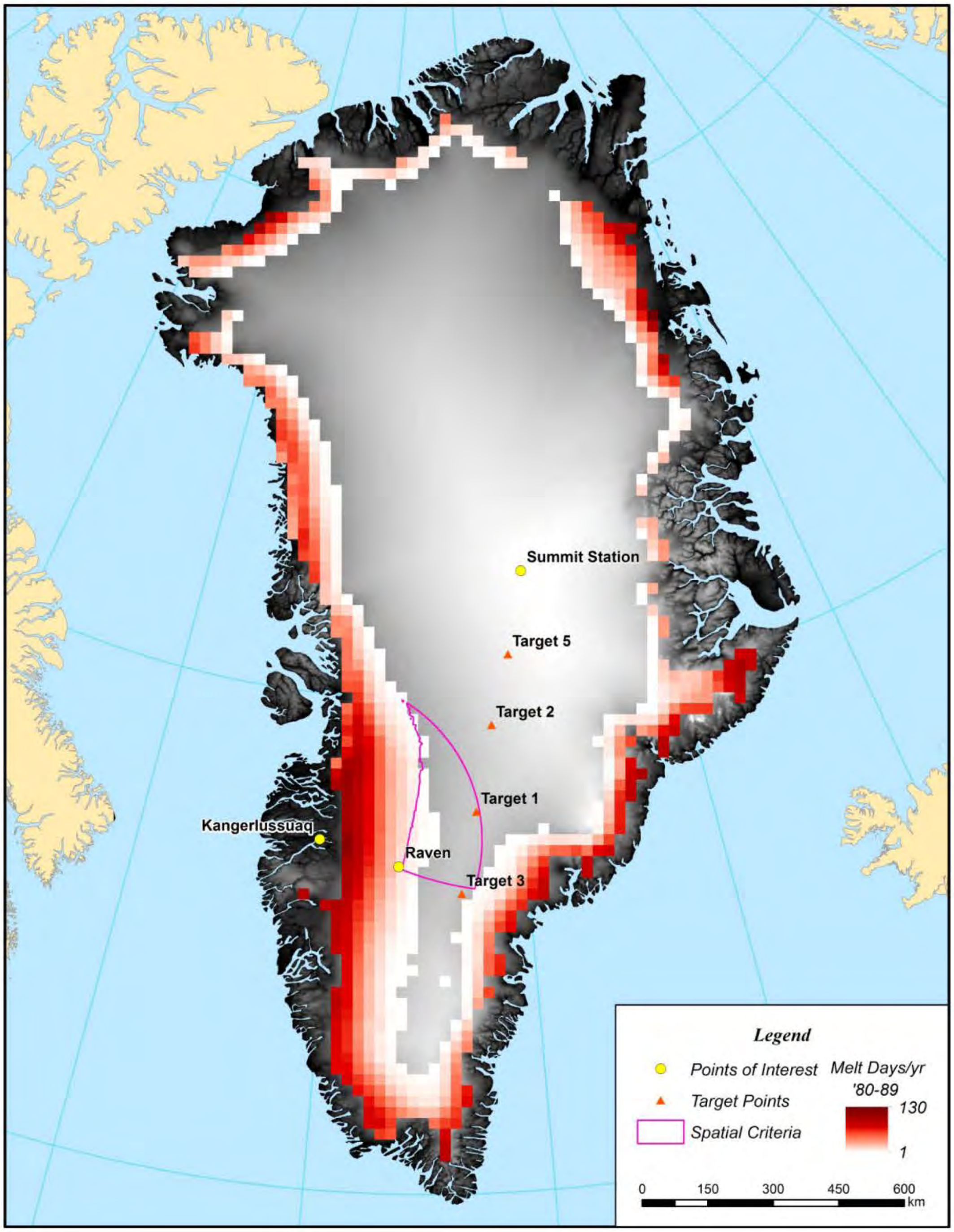


Figure A-3. Average Greenland melt days per year for the 1990s as estimated from passive microwave satellite data (Abdalati 2008) and using the target region identified by Burzynski et al. (2013).

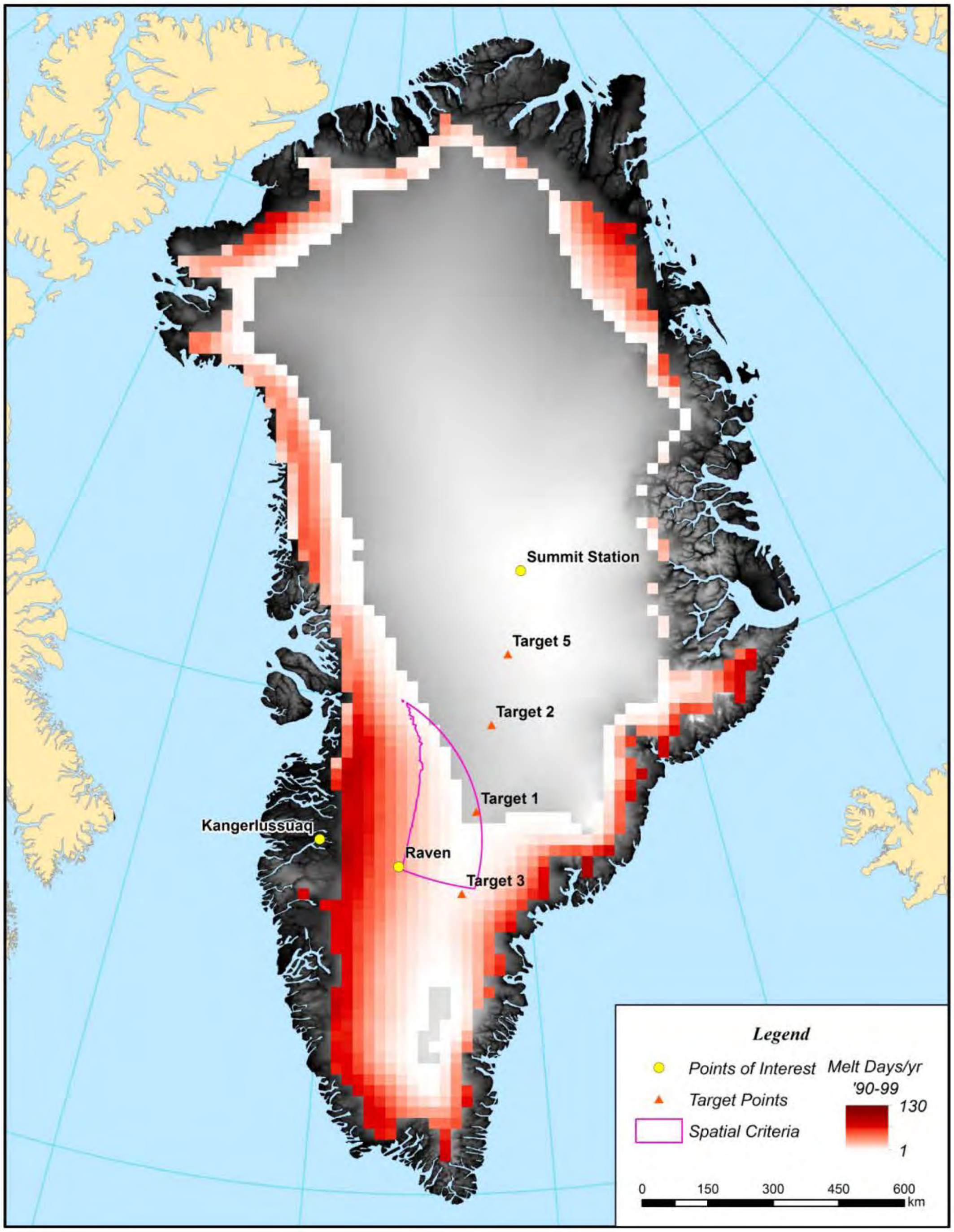


Figure A-4. Average Greenland melt days per year for 2000–2007 as estimated from passive microwave satellite data (Abdalati 2008) and using the target region identified by Burzynski et al. (2013).

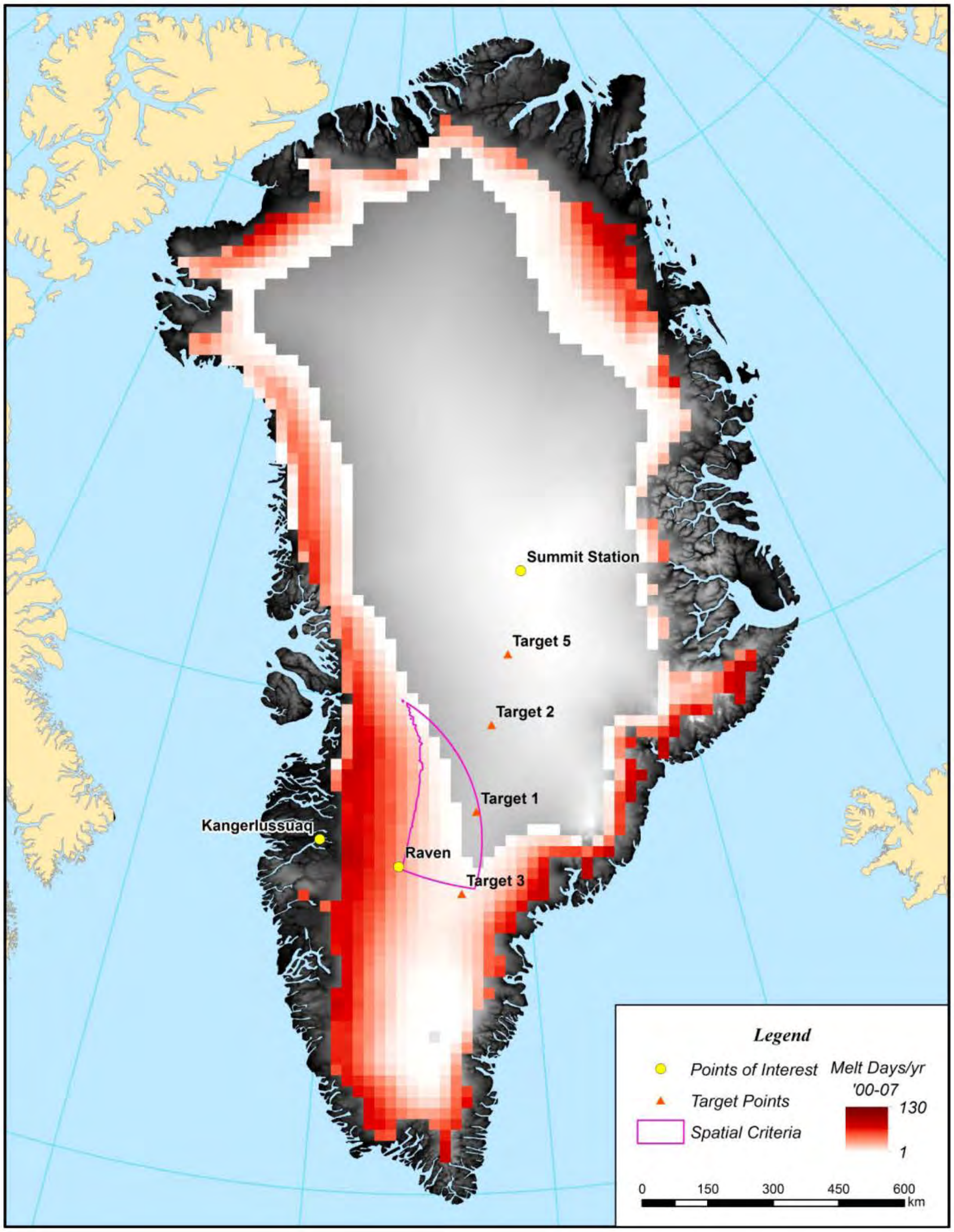
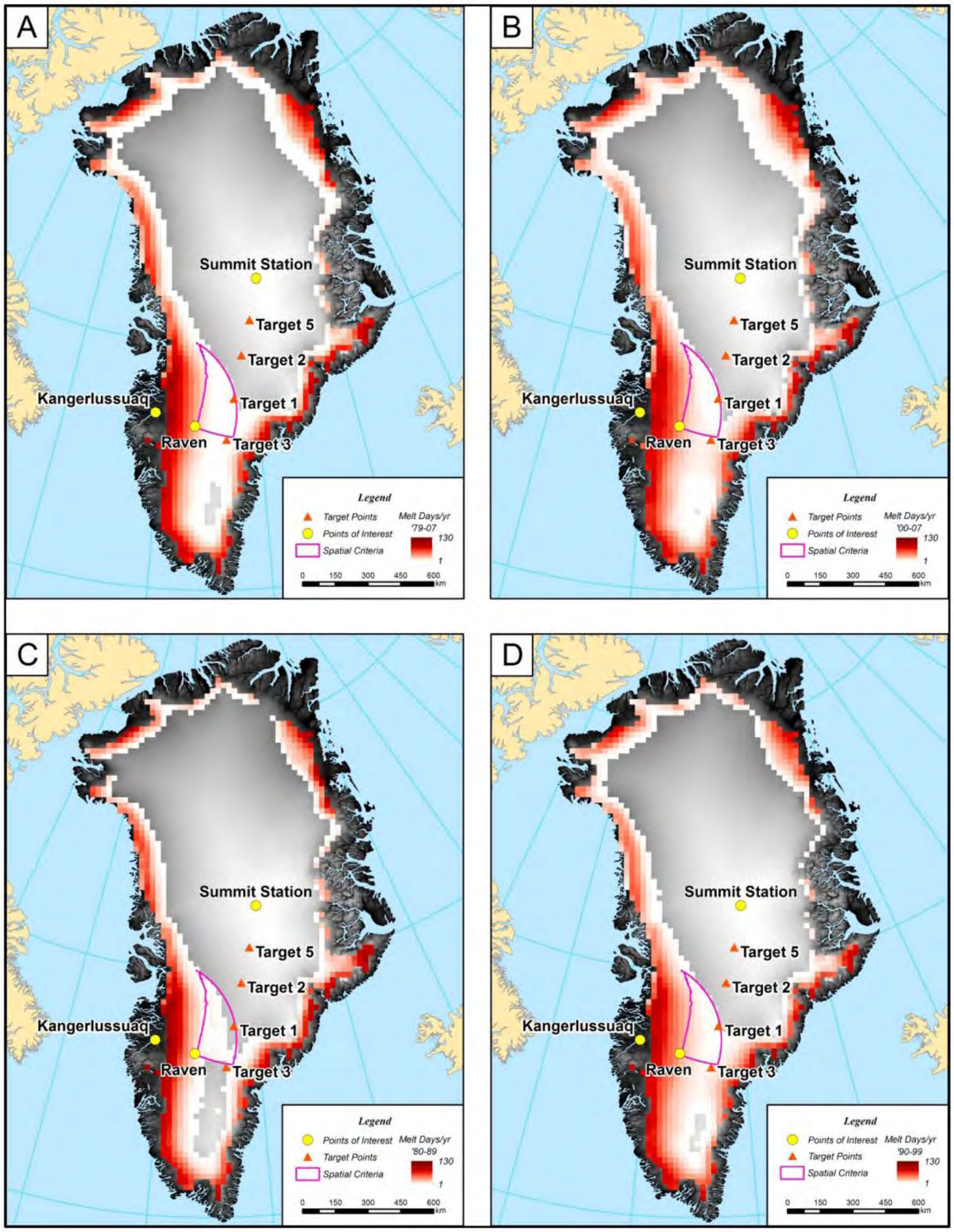


Figure A-5. Average Greenland melt days per year as estimated from passive microwave satellite data (Abdalati 2008) and using the target region identified by Burzynski et al. (2013). (A) The available period of record (1979–2007); (B) the most recent seven years of data (2000–2007); (C) the 1980s; and (D) the 1990s.



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14. ABSTRACT

The New York Air National Guard (NYANG) 109th Airlift Wing training facility located at Raven in southwest Greenland experienced surface crevassing during the 2012 extreme Greenland melt event, which limited the use of the runway. Because of subsequent interest in relocating the runway, our study analyzed the runway's climatic, physical, and logistical factors, expanding on *Site Assessment and Feasibility of a New Operations Base on the Greenland Ice Sheet* by Burzynski et al. (2013). Their report identified a primary target region for relocating the runway based on stakeholder criteria and climatic data collected from across Greenland. We improved on this investigation by replacing the proxy (e.g., elevation) previously used for melt with newly released satellite estimates of melt. These new data used changes in microwave emissions from the surface and near surface of the Greenland Ice Sheet to estimate melt days across Greenland. By applying the Burzynski et al. (2013) criteria to the new melt data, we quantified melt days/year over the past 35 years. This improves the selection criteria for an appropriate relocation zone for the Raven runway, and the ArcGIS framework developed by this project provides the ability to incorporate future stakeholder needs into the site-selection analysis.

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