

Spring 2015 IceBridge WP-3D Flight Plans
11 March 2016 Draft

compiled by

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Introduction to Flight Plans

This document is a translation of the NASA Operation IceBridge (OIB) scientific objectives articulated in the Level 1 OIB Science Requirements, at the January IceBridge Arctic planning meeting held at NASA GSFC, through official science team telecons and through e-mail communication and iterations into a series of operationally realistic flight plans, intended to be flown aboard NOAA's WP-3D aircraft, beginning in late-March and ending in mid-May 2016. The material is shown on the following pages in the distilled form of a map and brief text description of each science flight. Google Earth (KML) versions of these flight plans are available via anonymous FTP at the following address: <ftp://atm.wff.nasa.gov/outgoing/oibscienceteam/>. Note that some users have reported problems connecting to this address with certain browsers. Command-line FTP and software tools such as Filezilla may be of help in such situations.

For each planned mission, we give a map and brief text description for the mission. The missions are planned to be flown from Thule and Kangerlussuaq, Greenland, and Fairbanks, Alaska. A careful reader may notice that some of the mission maps in the main part of the document highlight flightlines in green, yellow, and red colors, while other only show the black lines. The colors are a refinement added to the flight plans at a late stage of design which help the field team navigate the aircraft properly to achieve specific science goals. The colors represent the degree of “straightness” of each flight segment, where straight segments are steered using an automated technique and curved sections using a specialized manual method. Not all of the flight plans shown here have necessarily reached that mature stage of design.

In fact, as a general rule the flight plans depicted here are all at varying stages of completeness. For each mission we note “Remaining Design Issues” to be resolved, if any exist. In most cases these are minor. CryoSat underflights are a major exception, since these have to be re-planned for each potential flight day (for sea ice) or within a window of several potential flight days (for land ice). Sea ice camp/site overflights are also an exception, since these move with the motion of the ice, unless they are situated on shore-fast ice.

In the past OIB has collected science data during transit flights between Thule and Kangerlussuaq, but we do not envision using this approach for 2016. We have found that using the transits as data-collection efforts is counterproductive to the total science return of a campaign. This is because a direct transit between the two air bases required only 2.5 hours, while a data-collecting mission along the way takes most of 8 hours, and also is very vulnerable to poor weather along the west coast of Greenland. By conducting direct transits, we can load and unload the aircraft on the day of the transit, and can use the previous and possibly the succeeding days as full data flights, which would otherwise have to be used for loading and unloading.

Note that this document shows 47 planned land ice and 18 planned sea ice missions, which is more than we expect to fly this year. The extra flight plans give us operational flexibility to fly as much as possible, and scientifically productive, while we are in the field. The entire suite of 65 flight plans is depicted in the introductory material following this text.

Each flight has a priority assigned to it by the OIB science team, either high, medium or low, and these are listed below with each mission. Both land and sea ice flights include some designated “baseline”, or highest, priority, which is reserved for flights intended to be flown each year. There are ten such flights for land ice and two for sea ice. The land ice team instituted a refined strategy starting in the

2014 season, which emphasized the need to conduct comprehensive dh/dt monitoring over a multi-year time scale. We continue this strategy for 2016. 31 flights have been identified as being suitable for inclusion into this strategy, and these are labeled as such in the text descriptions. In general the flights in this category which have not been flown recently are prioritized highest, while those flown last year are prioritized lowest. These priorities will be revisited each year, with the goal being to ensure all thirty-one of these flights will be flown on a rotating basis. This repeat strategy is depicted in the introductory material following this text. Several new flights are also shown, as well as several flights designed for previous years but never flown. Finally, the introduction of a regular post-melt season campaign in fall 2015 means that all flight lines flown in the fall campaign are assigned a high priority for spring 2016, in order to continue the uniquely valuable intra-annual time series for these lines.

For the sea ice flights, the OIB science team identified three missions which can be flown during the second Thule deployment in late April and May. These flights are prominently identified in the text accompanying each mission.

Ongoing improvements to the MCoRDS system, as well as temporary modifications needed to enable the system to operate successfully aboard the NOAA WP-3D aircraft, created a situation where the OIB science team's advice, as well as that of the CReSIS team, was solicited by the Project Science Office in order to determine the appropriate operating modes of the MCoRDS over Greenland's land ice. This group decided that the MCoRDS should be operated at a high bandwidth setting, which in most cases should maximize the recovery of internal layering while still obtaining bed echoes. It was recognized that expert operation of the system under varying conditions could result in changes to the operating settings in some situations. It was also determined that for flight lines targeted across glacier flux gates, the primary goal for the MCoRDS was recovery of the bed, and that the system settings should reflect this goal. Only one mission has such flux gates as a significant portion of the flight, and this flight is "North Flux 02".

IceBridge Mission Statement

Operation IceBridge will employ aircraft to monitor the most sensitive and critical areas of sea ice, ice sheets and glaciers during the gap in satellite coverage caused by the failure of ICESat-1, in 2009, and the launch of ICESat-2, planned for 2016. Sensitive and critical areas include coastal Greenland and especially its outlet glaciers, coastal Antarctica including the Antarctic Peninsula and ice shelves, the sea ice of the Arctic and Antarctic and the southeast Alaskan glaciers. Data collected by IceBridge will improve our knowledge of the contribution of the Greenland and Antarctic ice sheets to sea level rise and will make fundamental contributions to the understanding of changes occurring in the extent and thickness of the polar sea ice cover. Given the societal importance of understanding changes in sea level rise and sea ice extent, IceBridge data will monitor and improve modeling efforts for sea ice, ice sheet and glaciers. IceBridge will also prepare for the future of airborne monitoring efforts of the cryosphere by adapting existing instruments for high altitude unmanned aerial systems such as the NASA Global Hawk.

IceBridge Science Objectives

The following are the major science objectives of Operation IceBridge in priority order and are met by the following flight plans:

- 1) Make airborne laser altimetry measurements over the ice sheets and sea ice to fill in the data gap between the failure of ICESat-1 in 2009 and the launch of ICESat-2 planned for 2015.
- 2) Link measurements made by ICESat, ICESat-2, and CryoSat-2 to allow their comparison and the production of a long-term, ice sheet altimetry record.

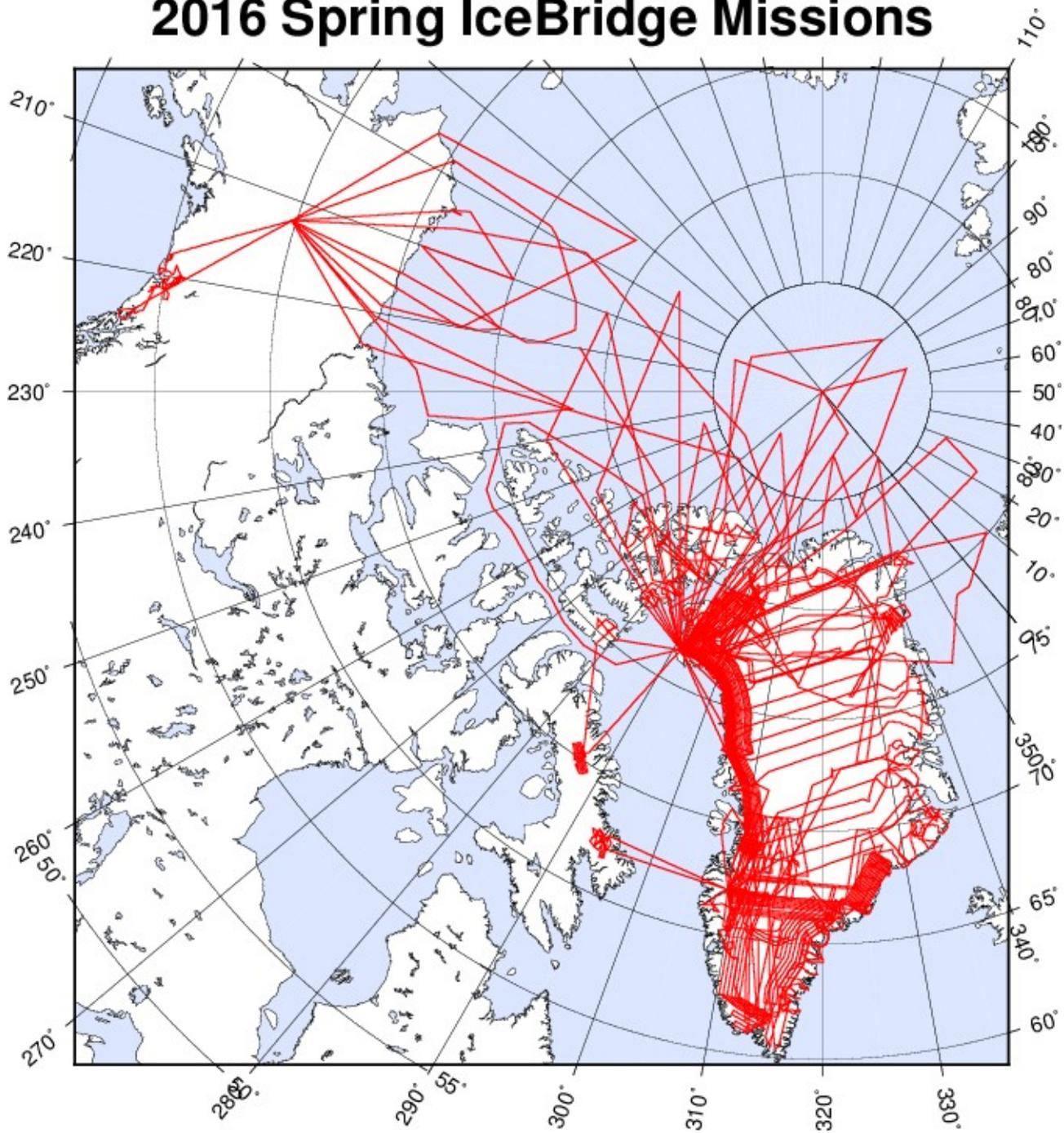
3) Use airborne altimetry and radar to monitor key, rapidly changing areas of ice, including sea ice, ice sheets and glaciers, in the Arctic and Antarctic to maintain a long term observation record, improve understanding of glacial dynamics, and augment predictive models of sea level rise and sea ice cover.

4) In conjunction with altimetry measurements, collect other remotely sensed data to improve predictive models of sea level rise and sea ice cover, especially the following:

- Ice sheet and sea ice thickness, structure and extent;
- Bed topography underlying land-based ice;
- Bathymetry beneath floating ice shelves;
- Snow accumulation and firn structure; and
- Other geophysical constraints that will improve estimates of the geothermal and oceanic heat flux

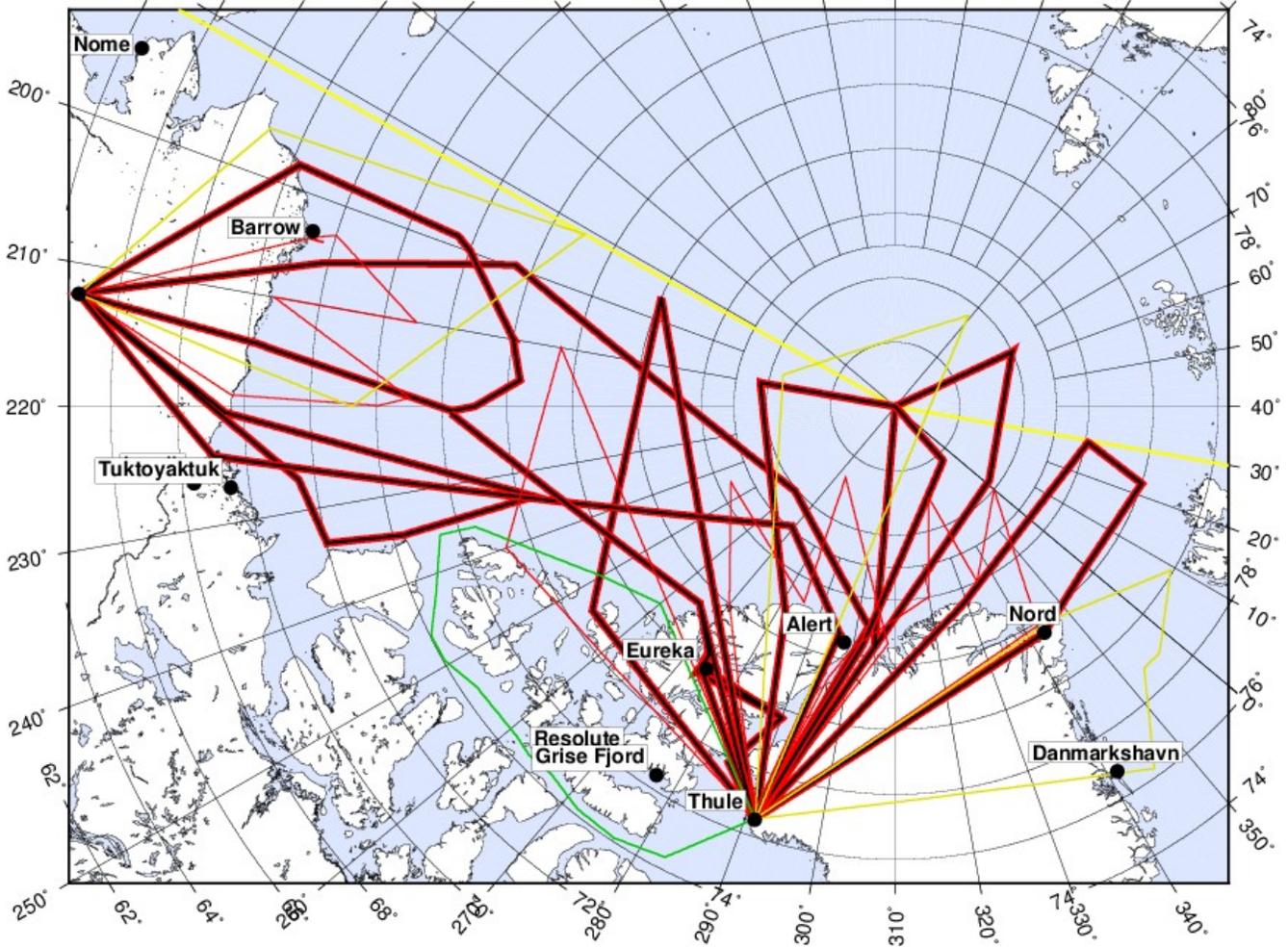
5) Adapt existing instruments for airborne remote sensing of ice by high altitude unmanned aerial systems such as the NASA Global Hawk.

2016 Spring IceBridge Missions



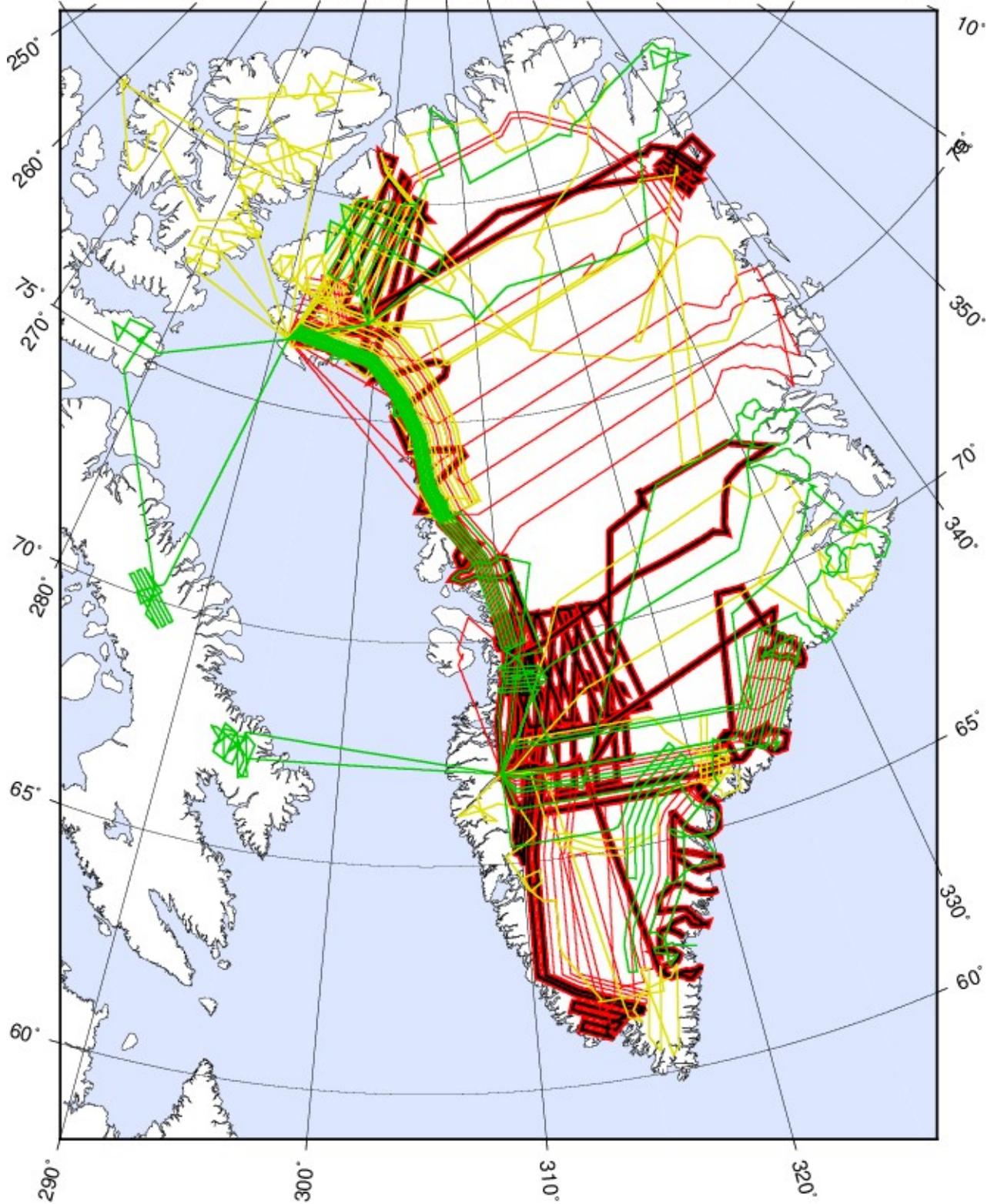
Prioritized 2016 Sea Ice Flights

Thick Red/Black: Baseline and High(10) Red: High/Med(4) Yellow: Medium(3) Green: Low(1)



Prioritized Spring 2016 OIB Flight Lines

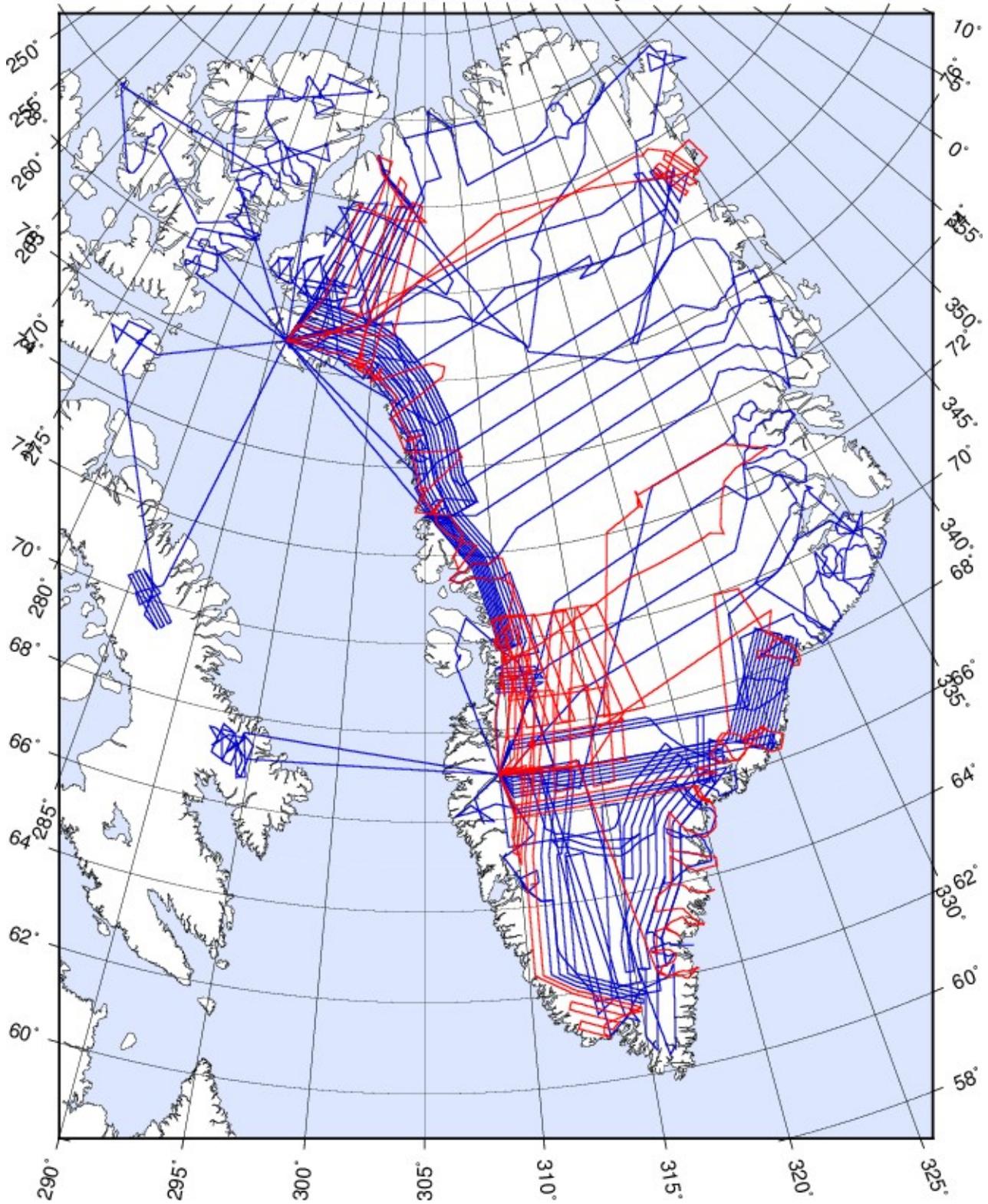
Thick Red/Black:Baseline(10) Red:High(10) Yellow:Medium(13) Green:Low(14)



Land Ice Repeat Strategy

OIB Greenland Spring 2015

Red: Annual Blue: Multi-year



Sea Ice – Laxon Line / Thule – Fairbanks

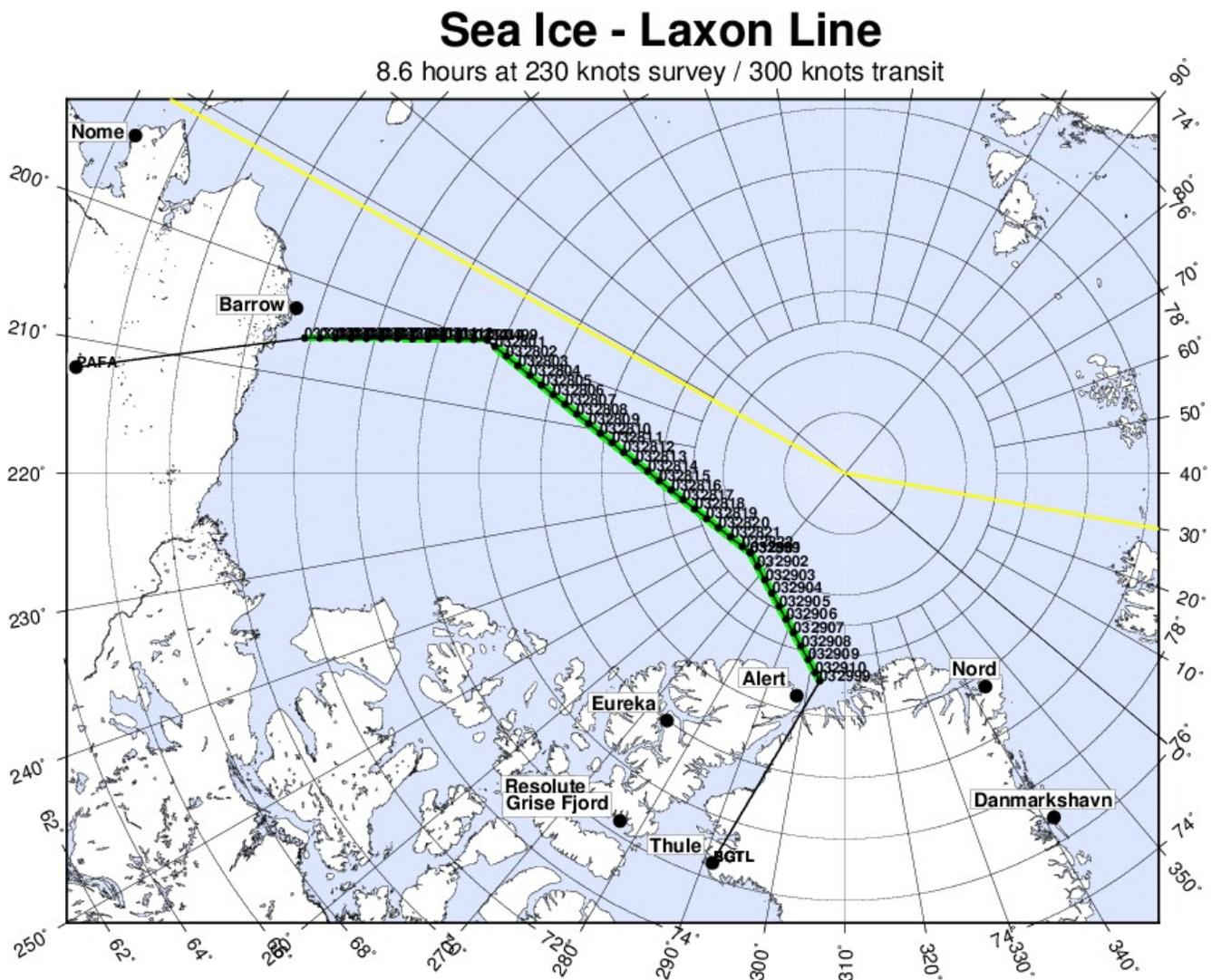
This mission is a near-exact repeat of similar missions flown each year of OIB beginning in 2009. In addition to Level-1 Requirements SI1 and SI2, the flight addresses sea ice level 1 baseline requirement SI3a by providing data on the thickness gradient and distribution of perennial and seasonal ice across the Arctic Basin.

Flight Priority: baseline

ICESat Tracks: 0329,0328,0334

Last Flown: 2015

Remaining Design Issues: none



Sea Ice – Laxon East / Thule

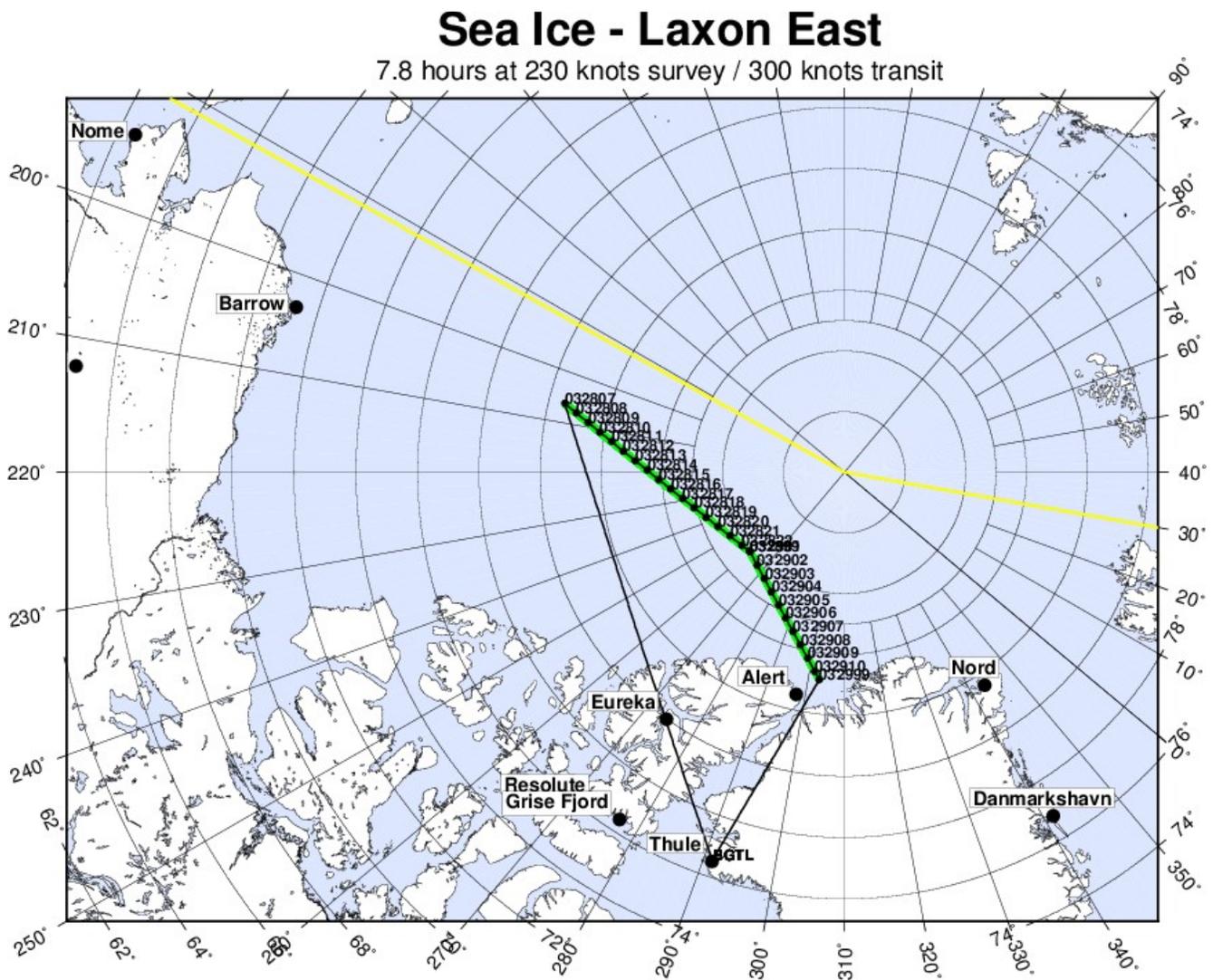
This mission, along with Laxon West, is a contingency mission to be considered in case the Laxon Line cannot be successfully flown during the Thule/Fairbanks transits. It is intended to capture the eastern portion of the line, then return direct to Thule at high-altitude.

Flight Priority: high if Laxon Line not flown, otherwise discard

ICESat Tracks: 0329,0328

Last Flown: new flight

Remaining Design Issues: none



Sea Ice – Laxon West / Fairbanks

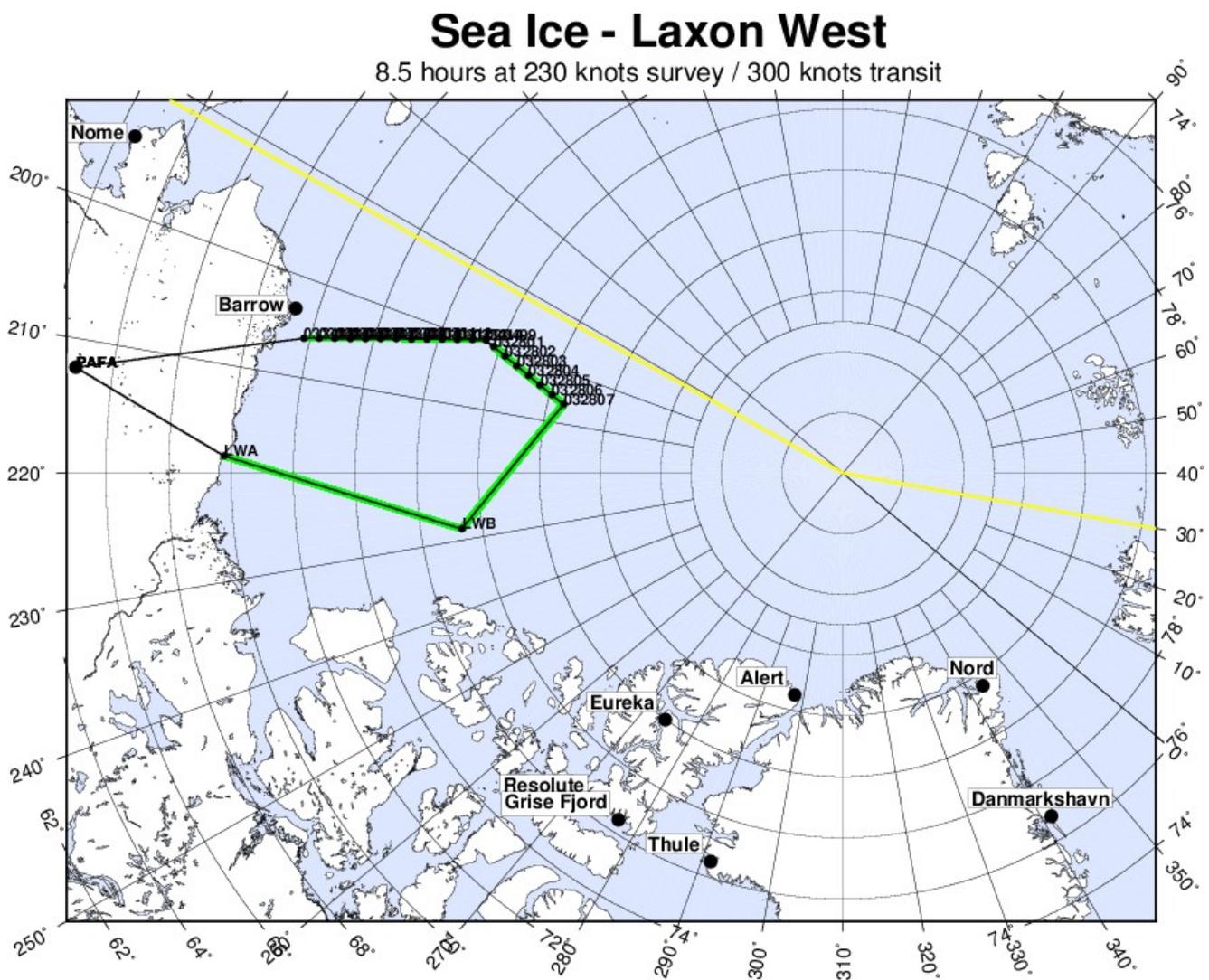
This mission, along with Laxon East, is a contingency mission to be considered in case the Laxon Line cannot be successfully flown during the Thule/Fairbanks transits. It is intended to capture the western portion of the line, then returns to the eastern Alaska coast along a productive route at low-altitude.

Flight Priority: high if Laxon Line not flown, otherwise discard

ICESat Tracks: 0328,0334

Last Flown: new flight

Remaining Design Issues: none



Sea Ice – South Basin Transect / Fairbanks - Thule

This mission is a repeat of missions flown each year of OIB beginning in 2009. Timing on this flight is challenging because we must land at Thule before the airfield closes at 1600 local time, which is five hours ahead of Fairbanks local time. This means that we must depart Fairbanks before approximately 0200 local time, and this in turn means that we must fly the first few hours of this flight in darkness. For 2016 the portion of this flight north of Ellesmere Island was slightly modified to improve the distribution of coverage in that area. In addition to Level-1 Requirements SI1 and SI2, it addresses sea ice level 1 baseline requirement SI3a by providing data on the thickness gradient and distribution of perennial and seasonal ice across the Arctic Basin.

Flight Priority: baseline

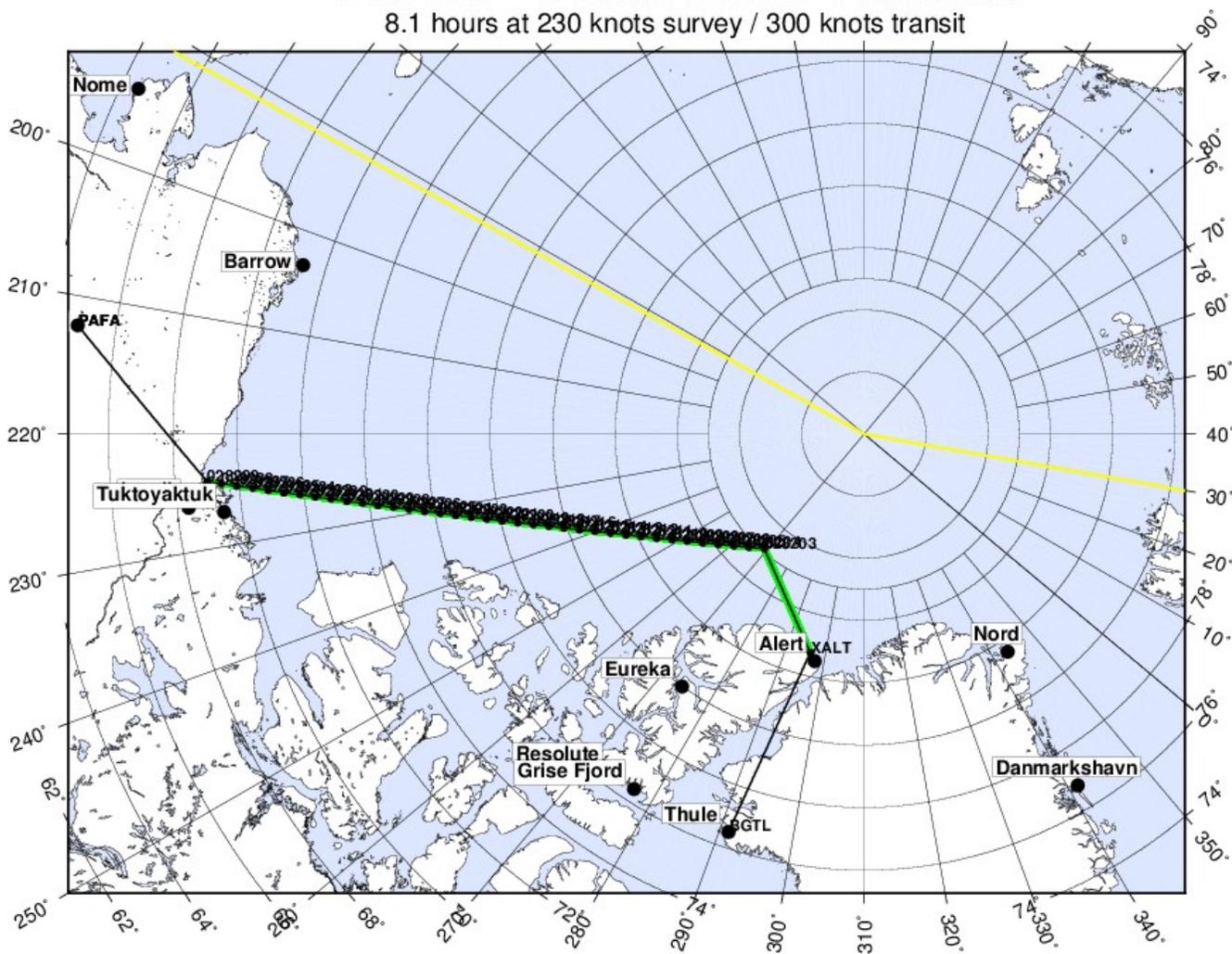
ICESat Tracks: 0282,0284

Last Flown: 2015

Remaining Design Issues: none

Sea Ice - South Basin Transect

8.1 hours at 230 knots survey / 300 knots transit



Sea Ice – Beaufort-Chukchi Diamond / Fairbanks

This is a repeat of a mission first flown in 2012. It is designed to sample sea ice in the western Arctic Basin along north-south gradients in the Chukchi and Beaufort Seas. In addition to Level-1 Requirements SI1 and SI2, it addresses sea ice level projected requirement SIP2d by extending sea ice baseline observations to the southern Chukchi Sea north of the Bering Strait.

Flight Priority: medium

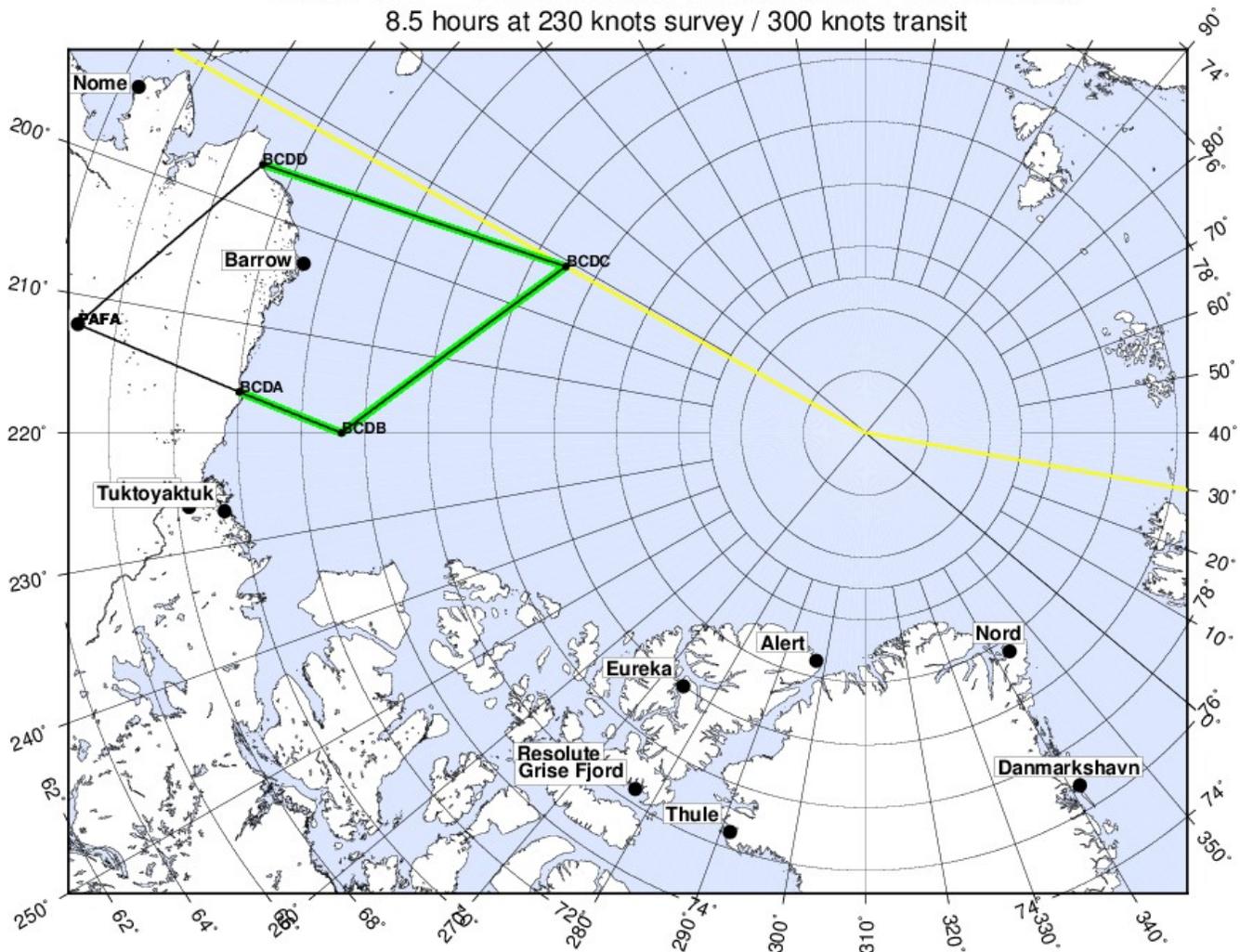
ICESat Tracks: none

Last Flown: 2014

Remaining Design Issues: none

Sea Ice - Beaufort-Chukchi Diamond

8.5 hours at 230 knots survey / 300 knots transit



Sea Ice – North Beaufort Loop / Fairbanks

This flight is intended to sample sea ice in the western Arctic Basin along north-south gradients in the Beaufort Sea, and to improve gaps in previous coverage primarily in the northeastern Beaufort. We also overfly three mooring sites of the Beaufort Gyre Exploration Project equipped with upward-looking sonar, known as GAM-1, BGOS-B (old and new locations) and BGOS-C. In addition to Level-1 Requirements SI1 and SI2, it addresses sea ice level projected requirement SIP2d by extending sea ice baseline observations to the southern Chukchi Sea north of the Bering Strait. This mission serves as a backup for the “UAF Racetrack coordinated activity, in the event it is not flown as part of the SIZRS Zigzag flight.

Flight Priority: high

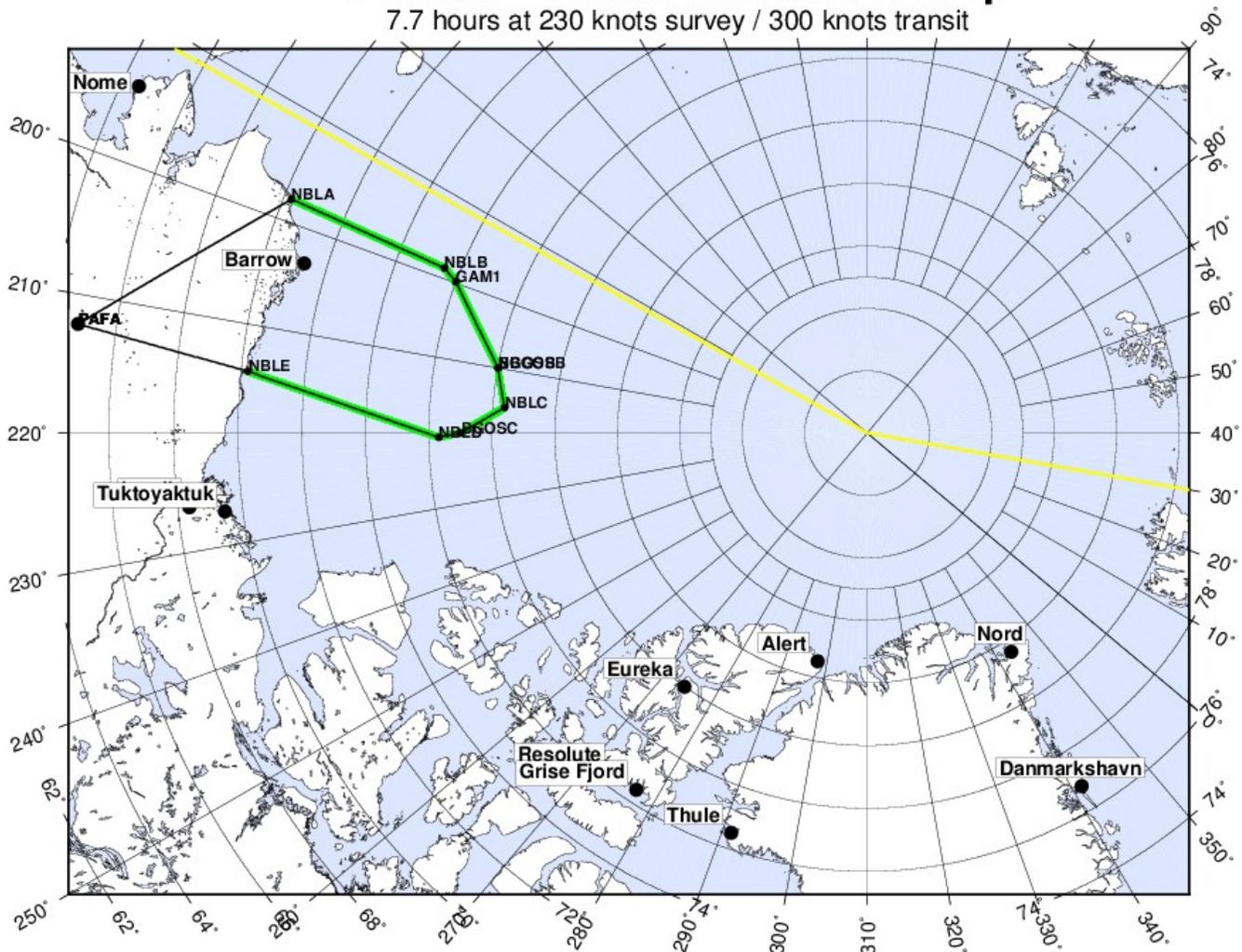
ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: none

Sea Ice - North Beaufort Loop

7.7 hours at 230 knots survey / 300 knots transit



Sea Ice – SIZRS Zig-Zag / Fairbanks

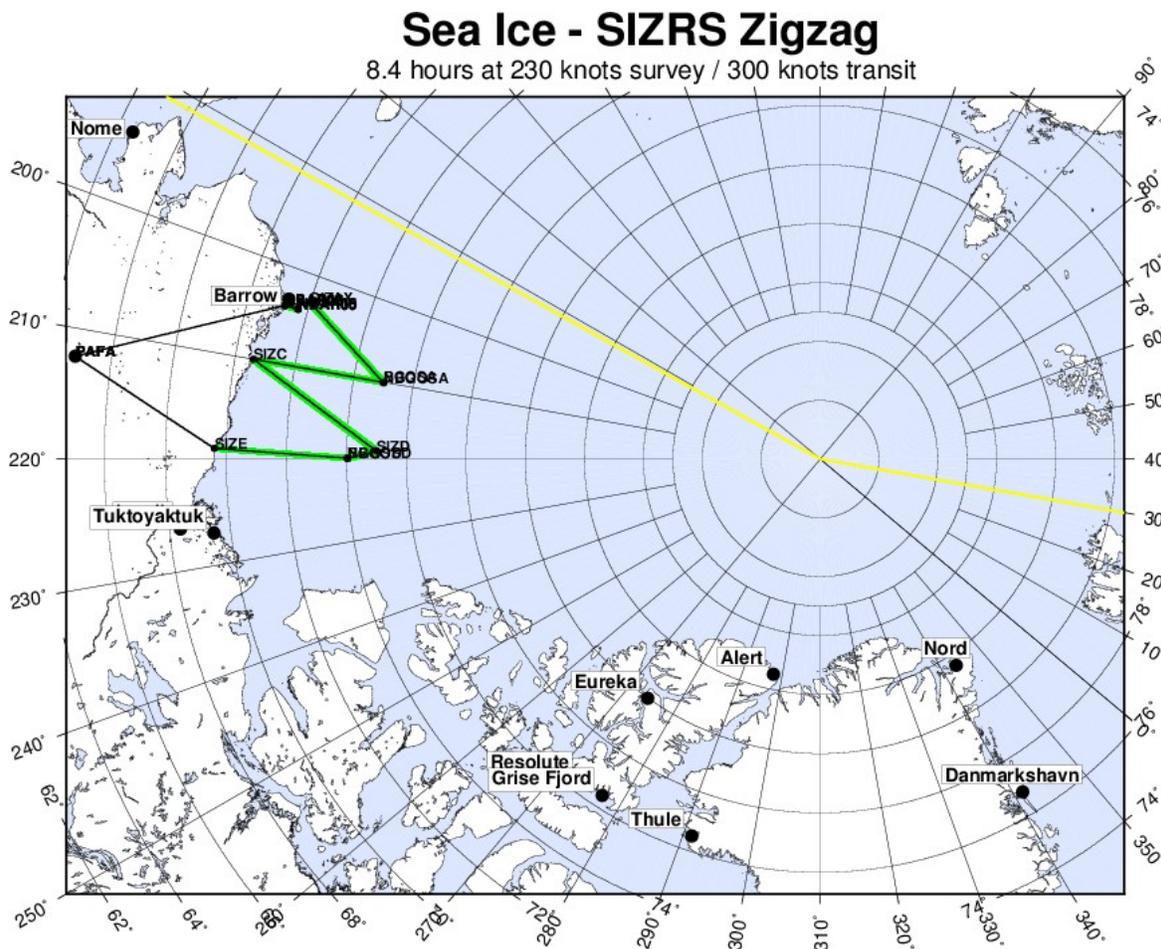
This mission is designed to sample sea ice along the north-south gradient in the southern Beaufort Sea. The leg flown along the 210th meridian facilitates a collaboration between OIB and the Seasonal Ice Zone Reconnaissance Surveys (SIZRS) program, and it improves the temporal extent of the SIZRS time series into early spring. We also fly four parallel lines (the “UAF Racetrack”) extending from shore-fast ice adjacent to Elson Lagoon north into the drifting pack, in support of an IceSat-2 “early Adopter” project, aimed at assessing the ability to infer the extent of landfast sea ice via the along-track correlation of IceSat-2 altimetry data. We also overfly two moorings of the Beaufort Gyre Exploration Project equipped with upward-looking sonar, known as BGOS-A and BGOS-D (old and new positions for both). In addition to Level-1 Requirements SI1 and SI2, this mission addresses sea ice level 1 projected requirement SIP2d by extending sea ice baseline observations to the southern Beaufort and Chukchi Seas; sea ice baseline level-1 requirement SI9 by coordinating with a field campaign which complements the IceBridge measurements.

Flight Priority: high/medium

ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: none



Sea Ice – East Beaufort / Fairbanks

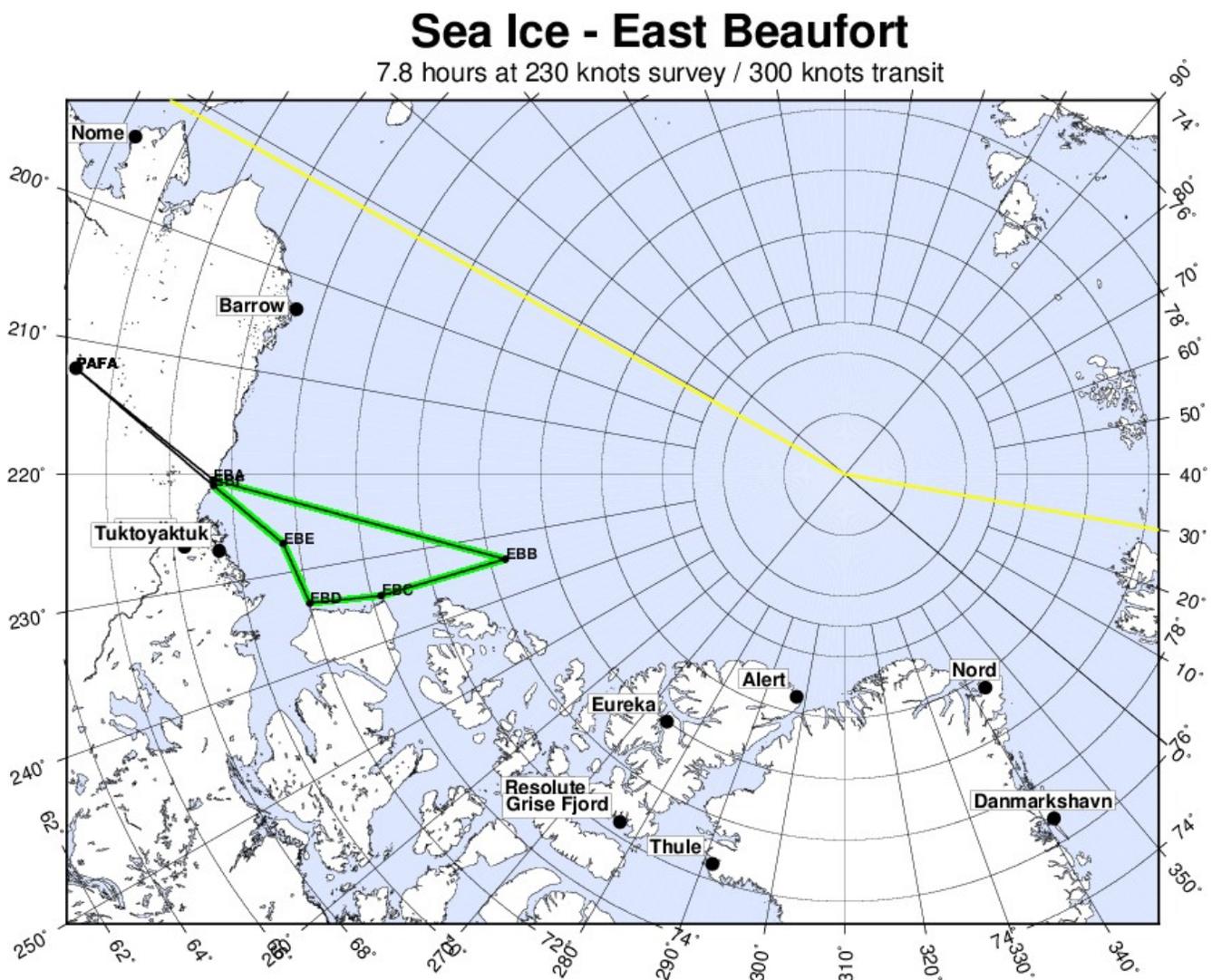
This mission is designed to sample sea ice in the eastern Beaufort Sea in an area which lacked OIB coverage prior to 2013, which is also of priority interest to the Canadian Space Agency. The design is the same as the 2013 version, with the exception of the segment near Banks Island (EBC to EBD), which is from the 2014 version and lies closer to the island. In addition to Level-1 Requirements SI1 and SI2, it addresses sea ice level 1 projected requirement SIP2b by extending sea ice baseline observations to the southern Beaufort Sea, west of Banks Island. Once flown, flight line coordinates will be provided to C. Haas (York University) in support of a complementary EM campaign. This will enable a comparison of ice thickness products.

Flight Priority: high

ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: none



Sea Ice – North Canada Basin / Thule

This is a repeat of a mission first flown in 2012. It is designed to sample sea ice in a large region between the North Basin Transect and the Beaufort-Chukchi Diamond that had been poorly sampled by OIB prior to 2012. This mission is of high importance, because it reaches across the central pack, documenting the thickness gradient of multi-year ice, to the edge of the seasonal ice zone which is dominated by first-year ice. In addition to Level 1 Requirements SI1 and SI2, the mission addresses sea ice level 1 projected requirement SIP2 by extending the baseline observations into other regions of the Arctic Basin. **This mission can be flown as late as early May if necessary.**

Flight Priority: high

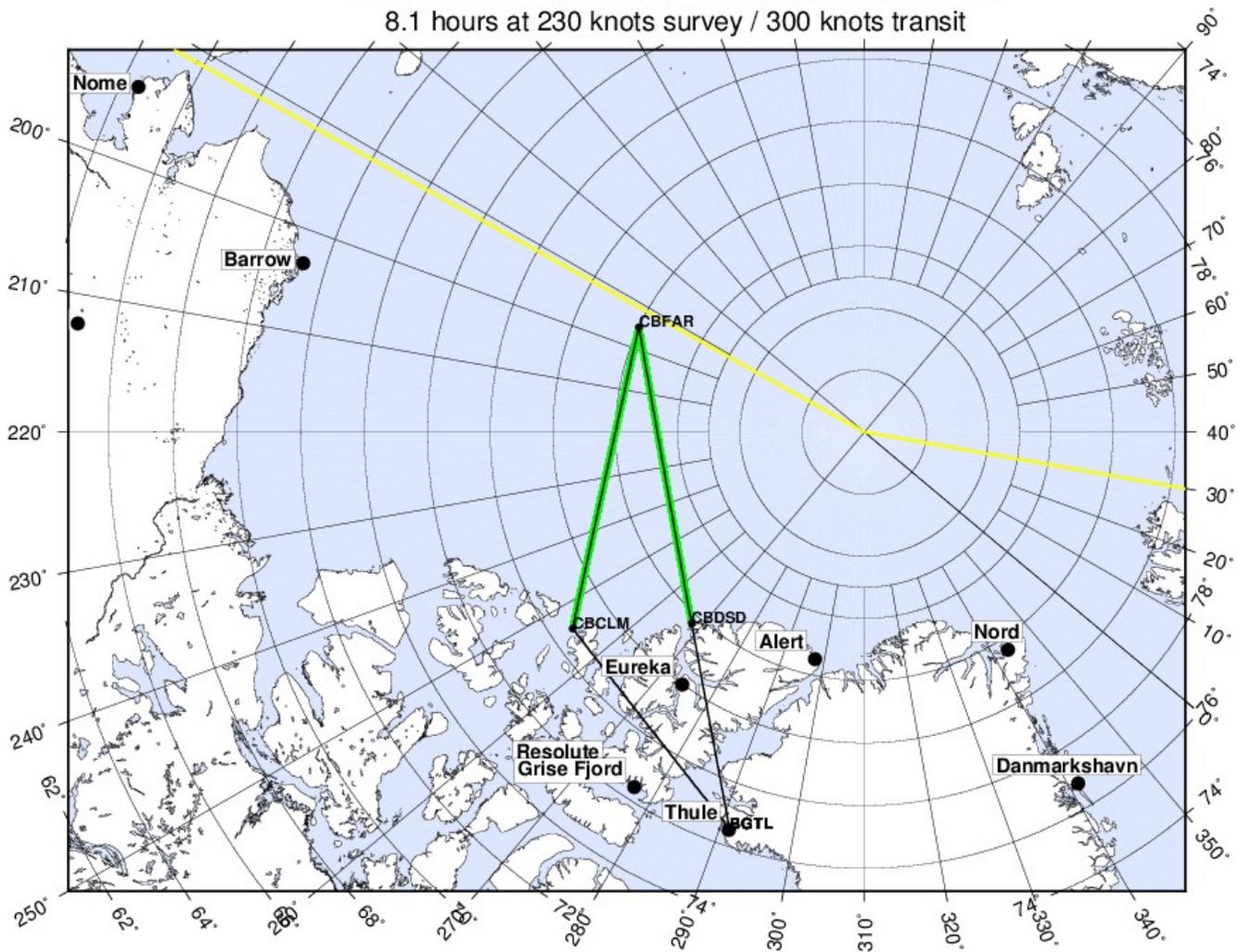
ICESat Tracks: none

Last Flown: 2014

Remaining Design Issues: none

Sea Ice - North Canada Basin

8.1 hours at 230 knots survey / 300 knots transit



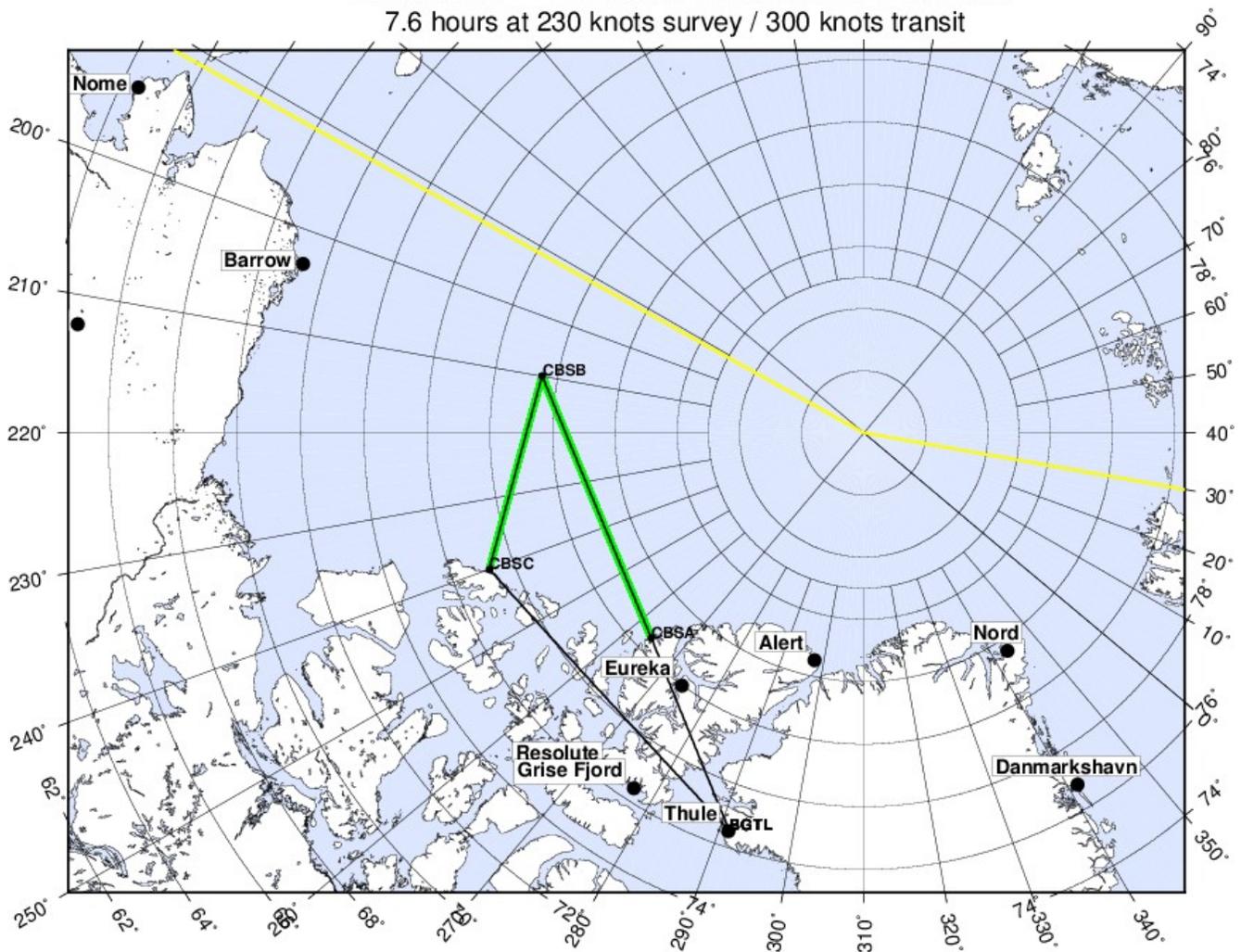
Sea Ice – South Canada Basin / Thule

This mission is designed to enhance the sampling in the large region between the North Basin Transect and the Beaufort-Chukchi Diamond that had been poorly sampled by OIB prior to 2012. In addition to Level 1 Requirements SI1 and SI2, the mission addresses sea ice level 1 projected requirement SIP2 by extending the baseline observations into other regions of the Arctic Basin. **This mission can be flown as late as early May if necessary.**

Flight Priority: high/medium
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: none

Sea Ice - South Canada Basin

7.6 hours at 230 knots survey / 300 knots transit



Sea Ice – Connor Corridor / Thule

This is a modified version of the Connor Corridor mission last flown in 2012. This time we underfly ESA's Sentinel-3A spacecraft which was launched on 16 February 2016. Sentinel-3A flies in an orbit similar to that of Envisat and operates the same radar altimeter (operating in SAR mode) flown on CryoSat-2. We fly the same line out and back, flying the out leg at 1800' altitude, and the return leg at 10,000'. This flight allows continuation of a data set collected many times along similar lines since 2006. In addition to Level 1 Requirements SI1 and SI2, the flight addresses sea ice level 1 baseline requirement SI4 by conducting a sampling mission that is time-coincident with a Sentinel-3A track, and sea ice level 1 projected requirement SIP2f by extending sea ice baseline observations to the Canadian Archipelago. **This mission can be flown as late as early May if necessary.**

Flight Priority: high

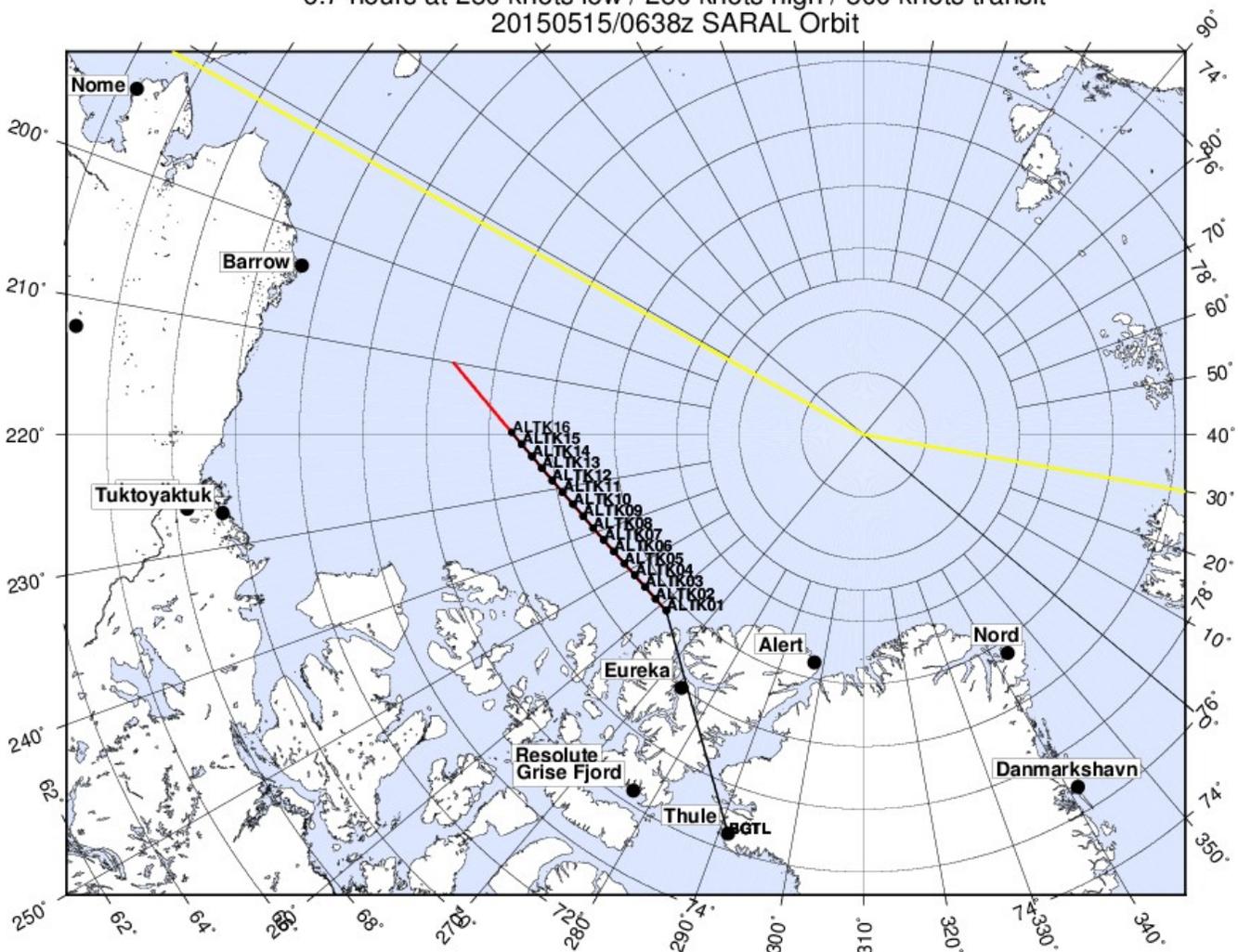
ICESat Tracks: none

Last Flown: 2012

Remaining Design Issues: redesign along contemporaneous (within ~6 hr) Sentinel 3a groundtrack; create latlon file

Sea Ice - Connor Corridor

6.7 hours at 230 knots low / 280 knots high / 300 knots transit
20150515/0638z SARAL Orbit



Sea Ice – Eureka / Thule

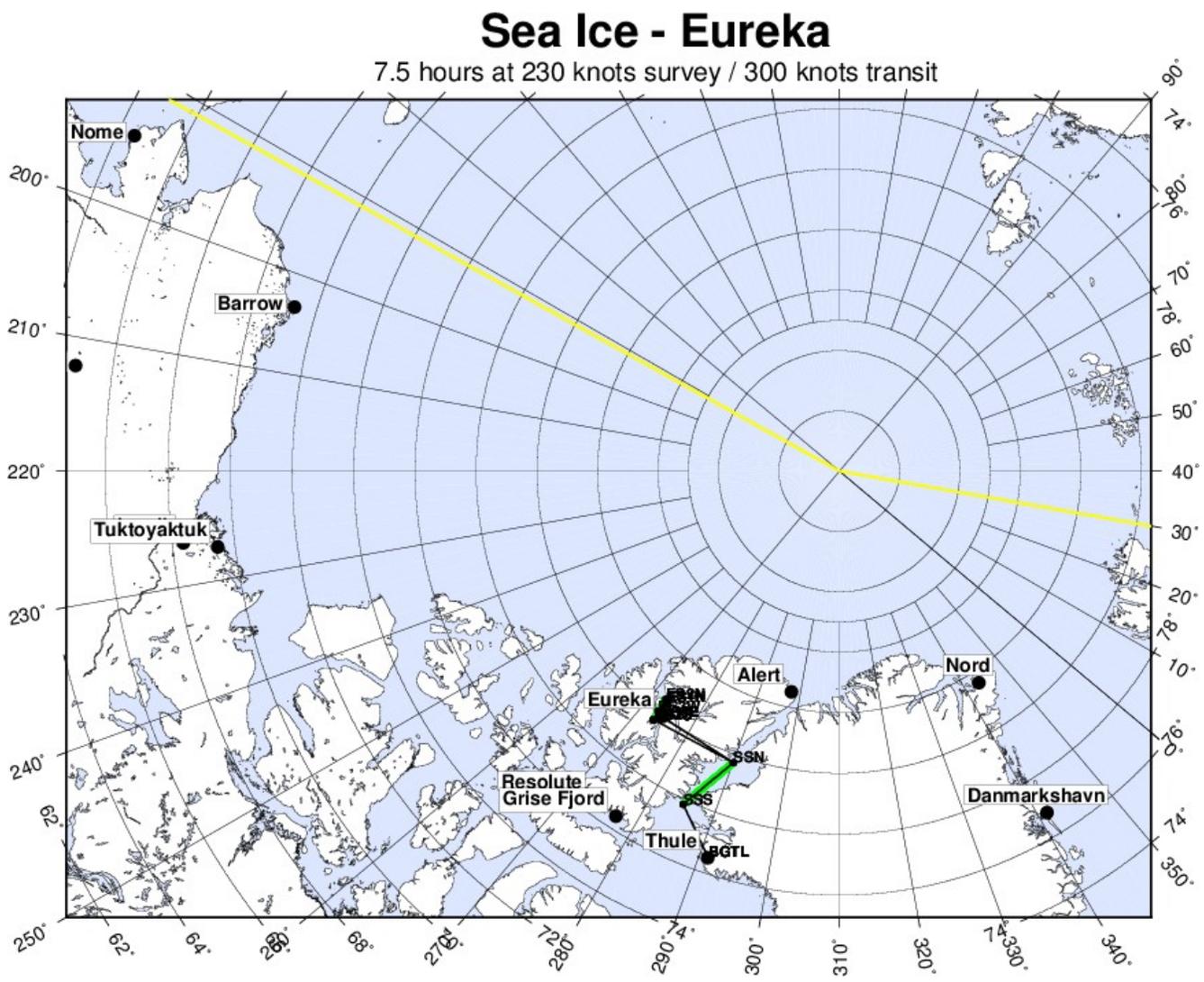
This is a dedicated mission to overfly the Environment and Climate Change Canada (ECCC) field site located in Eureka Sound. The goal is to improve the understanding of three-dimensional variability in snow properties and improve understanding of the accuracy of OIB snow radar retrievals in areas with rough surface topography. This mission addresses sea ice baseline level-1 requirement SI9 by coordinating with a field campaign that complements the IceBridge measurements. Further details are provided in separate field plan coordinating document. **For the snow radar, the DDC setting should be “off”. Altitude for the survey portions of this mission should be held constant at 1640' AGL. It is critical that the Smith Sound segment of this flight pass over ~30 km of open water areas with minimal wave action.**

Flight Priority: high

ICESat Tracks: none

Last Flown: 2014 and 2015

Remaining Design Issues: none



Sea Ice – Zigzag West / Thule

This mission is a repeat or near-repeat of an OIB flight first flown in 2010. It is intended to sample the thick multi-year ice near the Ellesmere coast as well as the gradient to thinner ice closer to the pole. A nearby ascending CryoSat-2 ground track may be substituted for one of the tracks shown below if a nearly contemporaneous one is available when this flight is conducted (e.g. close to leg ZZWA/ZZWB). In addition to Level 1 Requirements SI1 and SI2, the mission addresses sea ice level 1 baseline requirement SI3b by sampling thick multi-year ice near the northern coast of Ellesmere Island and the poleward gradient towards thinner ice. **This mission can be flown as late as early May if necessary.**

Flight Priority: high/medium

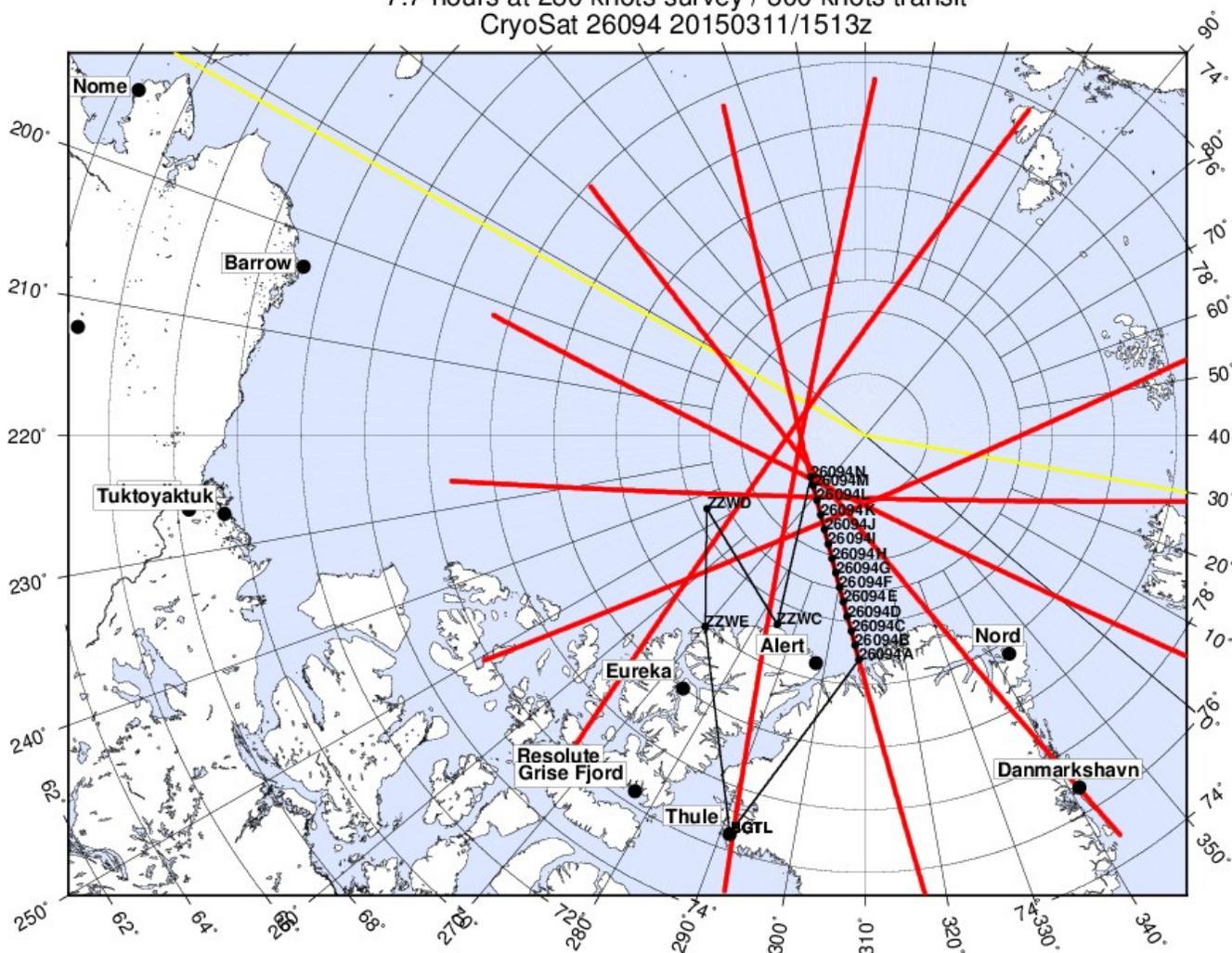
ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: select contemporaneous, nearby ascending CS-2 groundtrack if available.

Sea Ice - Zigzag West

7.7 hours at 230 knots survey / 300 knots transit
CryoSat 26094 20150311/1513z



Sea Ice – Northwest Passage / Thule

This mission is similar to the Sea Ice 08 flight from 2010, except that we now initiate the return to Thule by a path north of the Canadian Archipelago at low altitude, and transition to high altitude across Ellesmere Island. Observations in this region provide important support to seasonal sea ice forecasting tools, used to guide commercial shipping operations in the summer months. In addition to Level 1 Requirements 4.1.1.A.3a and b, the flight addresses sea ice level 1 projected requirement 4.1.1.B.2b by conducting a sampling mission in the Canadian Archipelago in the region of the Northwest Passage route.

Flight Priority: low

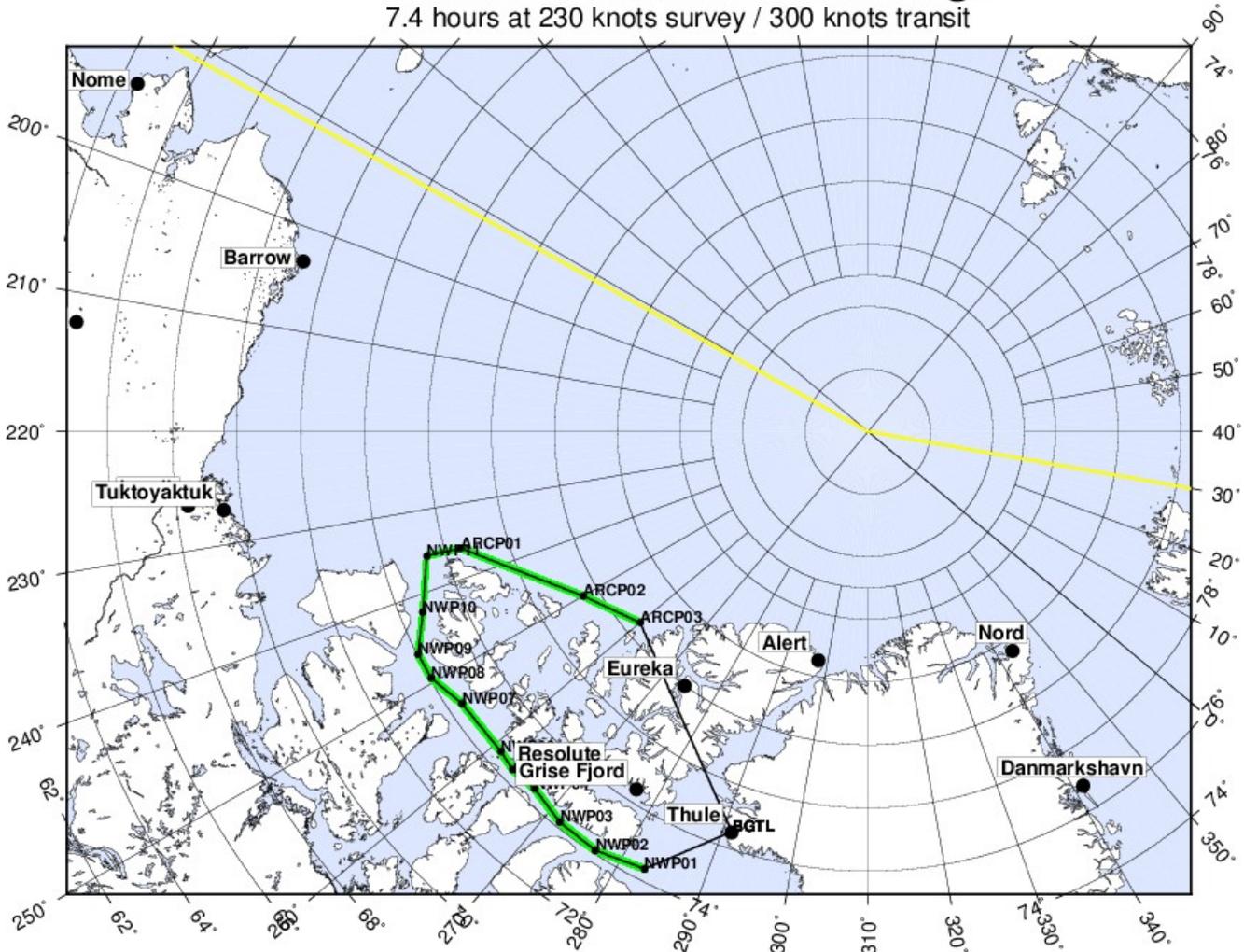
ICESat Tracks: none

Last Flown: 2010

Remaining Design Issues: exact location of line may be adjusted pending Radarsar-2 image in late Feb.

Sea Ice - Northwest Passage

7.4 hours at 230 knots survey / 300 knots transit



Sea Ice – North Pole Transect / Thule

This mission is a repeat or near-repeat of an OIB flight flown every years since 2013. The intention is to sample ice in the vicinity of the Pole and also the gradient of that ice between the Pole and Ellesmere Island. This area had been undersampled by OIB prior to 2012. A nearby descending CryoSat-2 ground track may be substituted for one of the tracks shown below if a nearly contemporaneous one is available when this flight is conducted, preferably one close to the 10346 line. In addition to Level-1 Requirements SI1 and SI2, this mission addresses sea ice level 1 projected requirement SIP2a by extending sea ice baseline observations to the North Pole region, and sea ice level 1 baseline requirement SI4 by conducting a sampling mission that is time-coincident with a CryoSat-2 track. **This mission can be flown as late as early May if necessary.**

Flight Priority: high

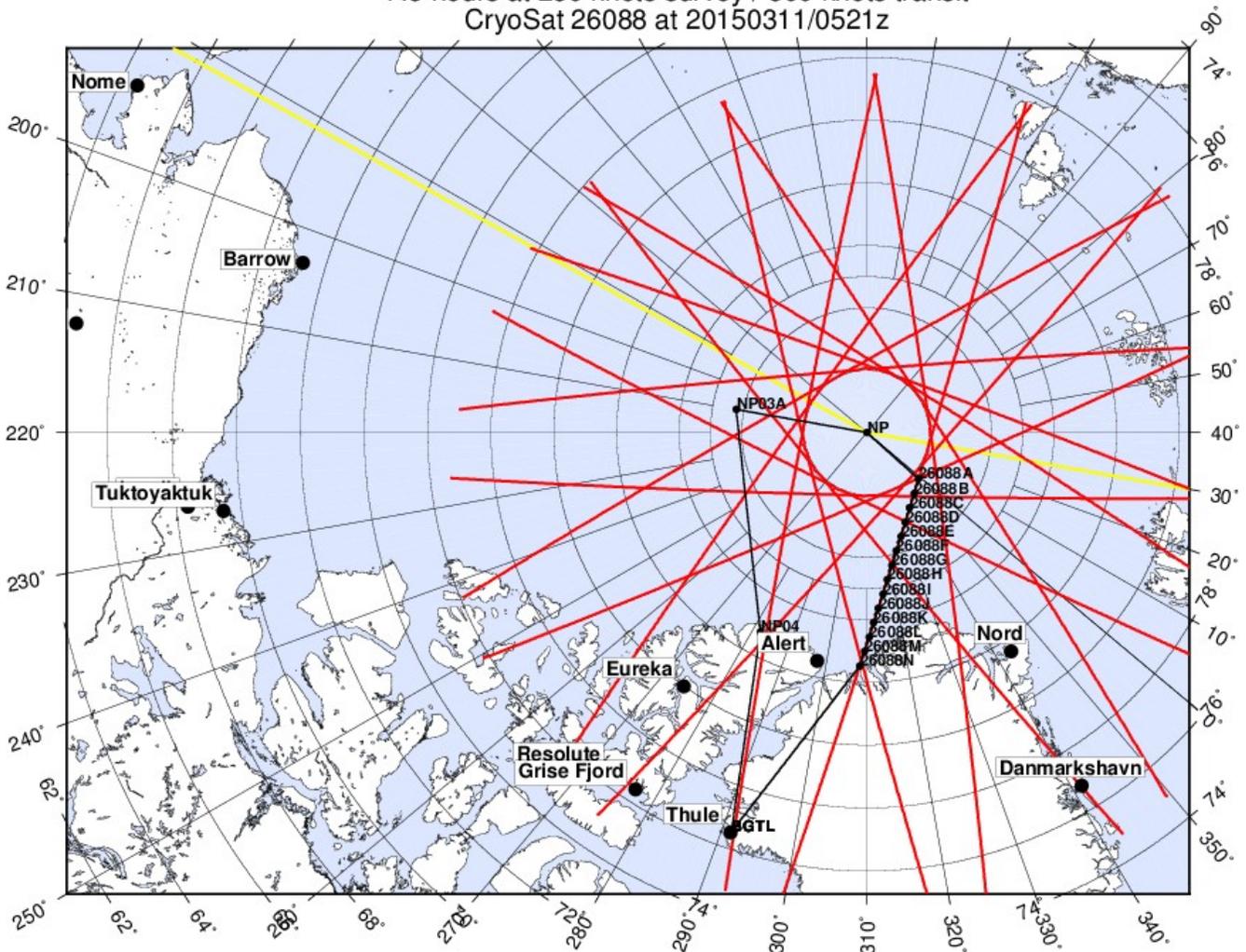
ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: select contemporaneous, nearby descending CS-2 groundtrack if available

Sea Ice - North Pole Transect

7.8 hours at 230 knots survey / 300 knots transit
CryoSat 26088 at 20150311/0521z



Sea Ice – North Pole East / Thule

This is a new mission for 2016. The intention is to sample ice in the vicinity of the Pole and also the gradient of that ice from the Lincoln Sea toward the Pole, and then extending these measurements in the direction of the eastern Russian Arctic islands. The western portion of this flight fills in a small gap in existing IceBridge sea ice measurements, and the eastern portion extends the measurements across the Russian FIR boundary. In addition to Level-1 Requirements SI1 and SI2, this mission addresses sea ice level 1 projected requirement SIP2a by extending sea ice baseline observations to the North Pole region. **This mission can be flown as late as early May if necessary.**

Flight Priority: high

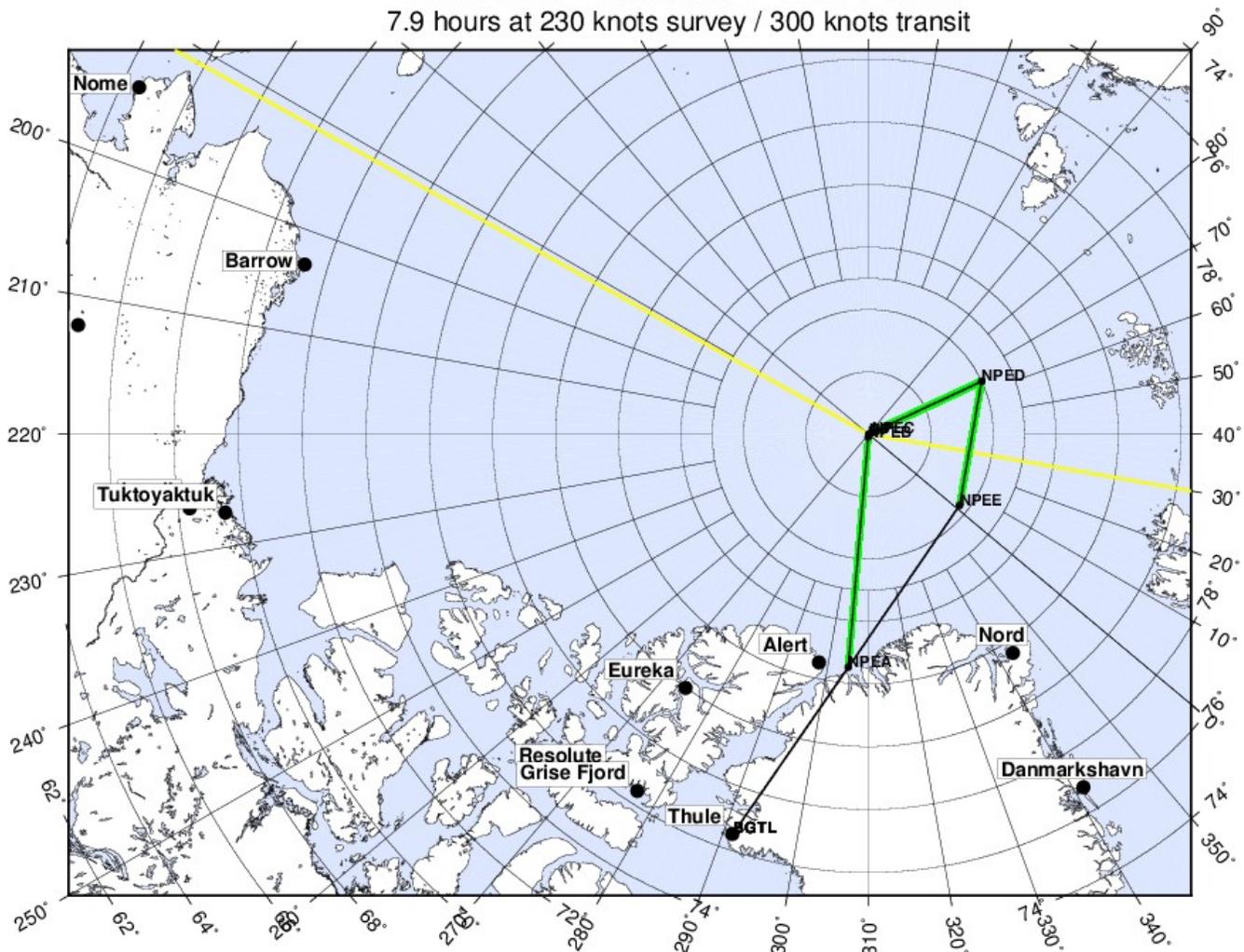
ICESat Tracks: none

Last Flown: new flight

Remaining Design Issues: none

Sea Ice - North Pole East

7.9 hours at 230 knots survey / 300 knots transit



Sea Ice – CryoSat-2 East / Thule

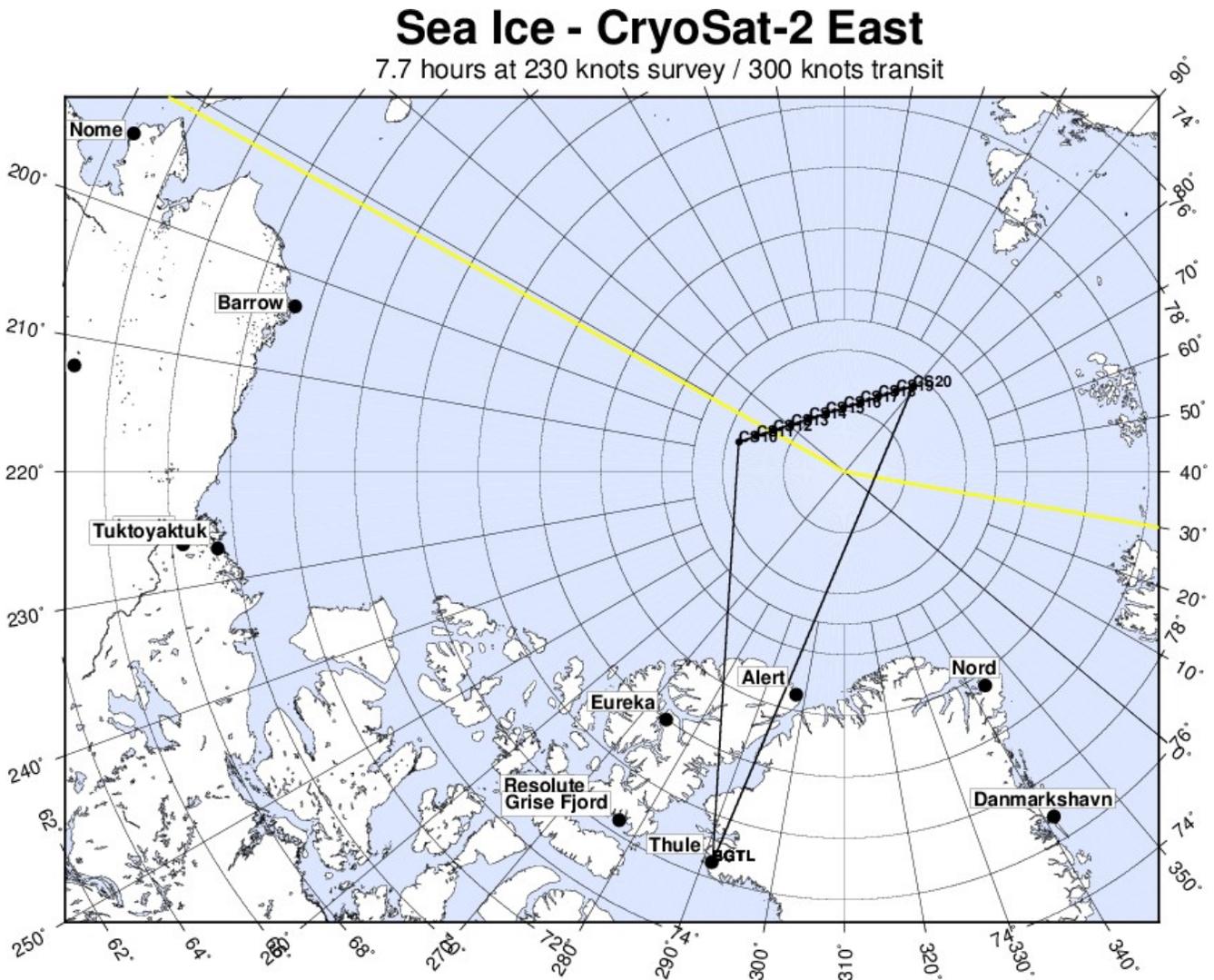
This is a new mission in 2016. The intention is to sample ice in the vicinity of the Pole along a CryoSat-2 ground track that is most time coincident with the flight, at a location that extends measurements across the Russian FIR boundary. Transit to and from the line is at high altitude to maximize its northerly extent. In addition to Level-1 Requirements SI1 and SI2, this mission addresses sea ice level 1 projected requirement SIP2a by extending sea ice baseline observations to the North Pole region, and sea ice level 1 baseline requirement SI4 by conducting a sampling mission that is time-coincident with a CryoSat-2 track. **This mission can be flown as late as early May if necessary.**

Flight Priority: medium

ICESat Tracks: none

Last Flown: 2010

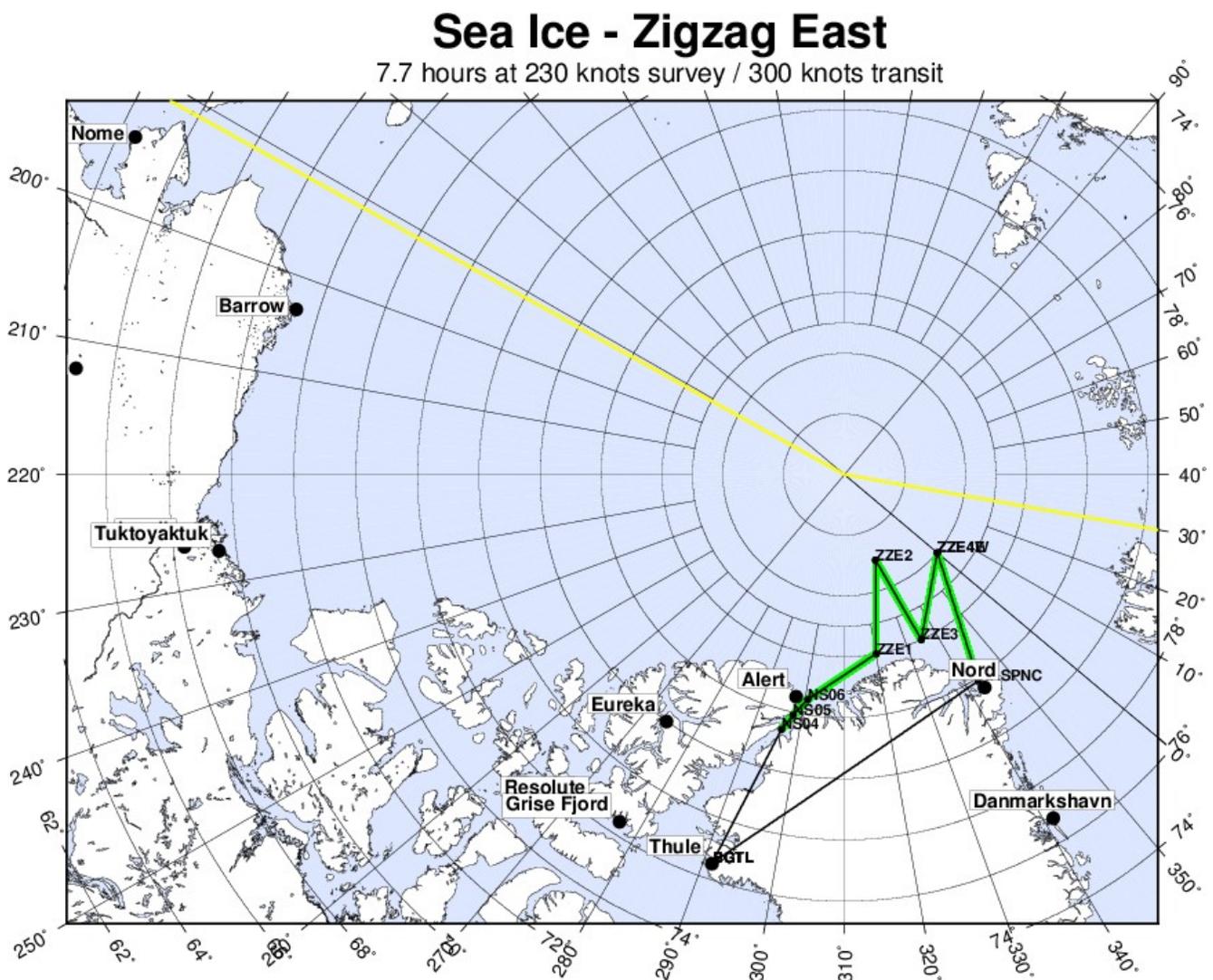
Remaining Design Issues: CS-2 line must be along a contemporaneous groundtrack



Sea Ice – Zigzag East / Thule

This mission is a repeat or near-repeat of an OIB flight flown in prior years. It is intended to sample the thick multi-year ice near the Greenland coast as well as the gradient to thinner ice closer to the pole. In addition to Level 1 Requirements SI1 and SI2, the mission addresses sea ice level 1 baseline requirement SI3b by sampling thick multi-year ice near the northern coast of Greenland and the poleward gradient towards thinner ice.

Flight Priority: high/medium
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: none



Sea Ice – Nansen Gap / Thule

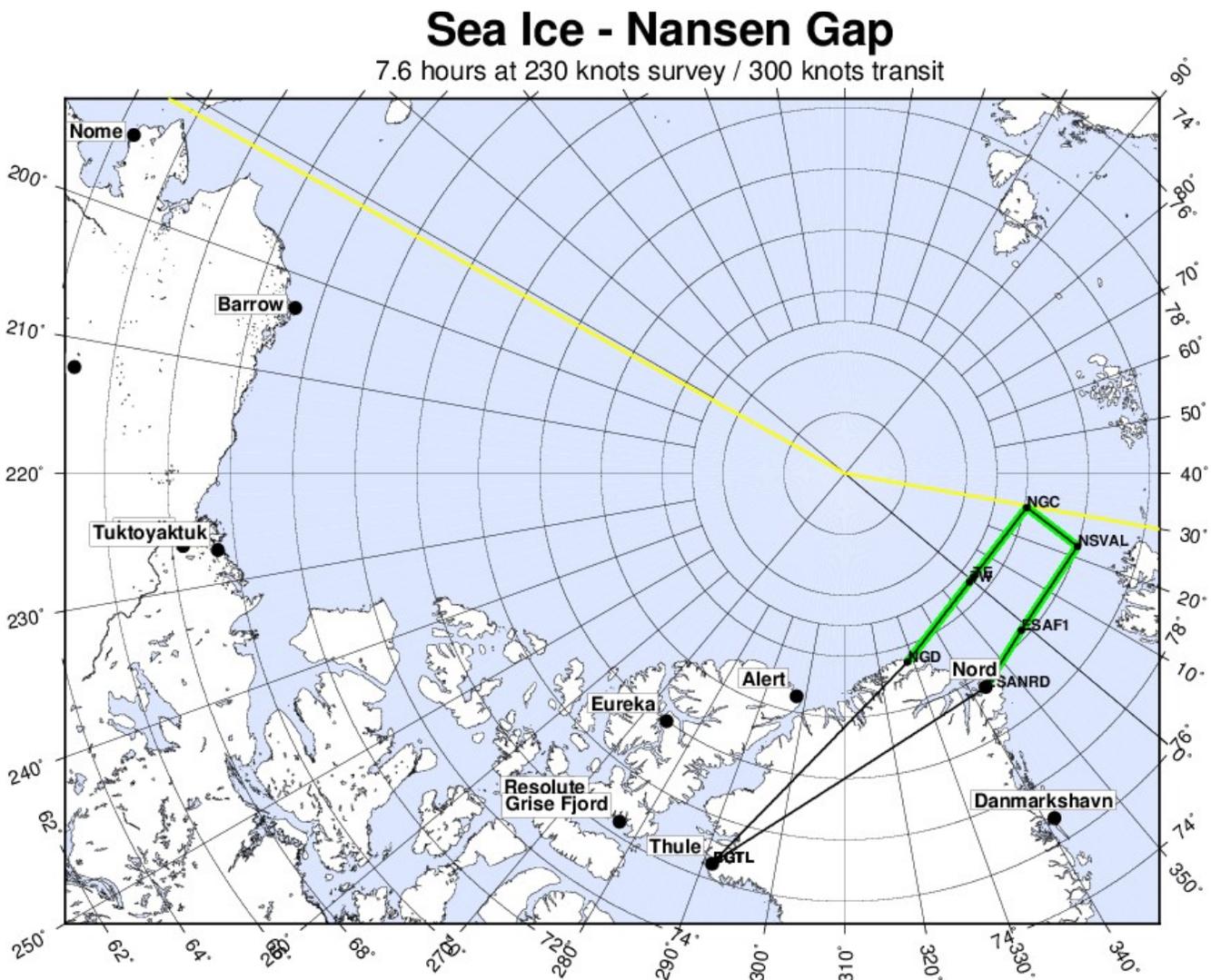
This is a modified version of the Fram Gateway missions flown in several of the past years. It differs from them in that it transits to and from the area of the Fram Strait at high-altitude, leaving more time to sample ice farther north and east than in prior years. The southeastern leg crossing Fram Strait has been adjusted to be spatially and temporally coincident over a 250-km distance with an ESA airborne mission planned as part of CryoVEx in 2016, and conducted by DTU. In addition to Level 1 Requirements SI1 and SI2, this mission addresses sea ice level 1 baseline requirements SI3c and d by sampling sea ice north of Fram Strait, and baseline level-1 requirement SI9 by coordinating with a field campaign that complements the IceBridge measurements.

Flight Priority: high

ICESat Tracks: none

Last Flown: 2015

Remaining Design Issues: coordinate easternmost leg with CryoVex flight (est to be flown 7 April)



Sea Ice – Giles Gateway / Thule

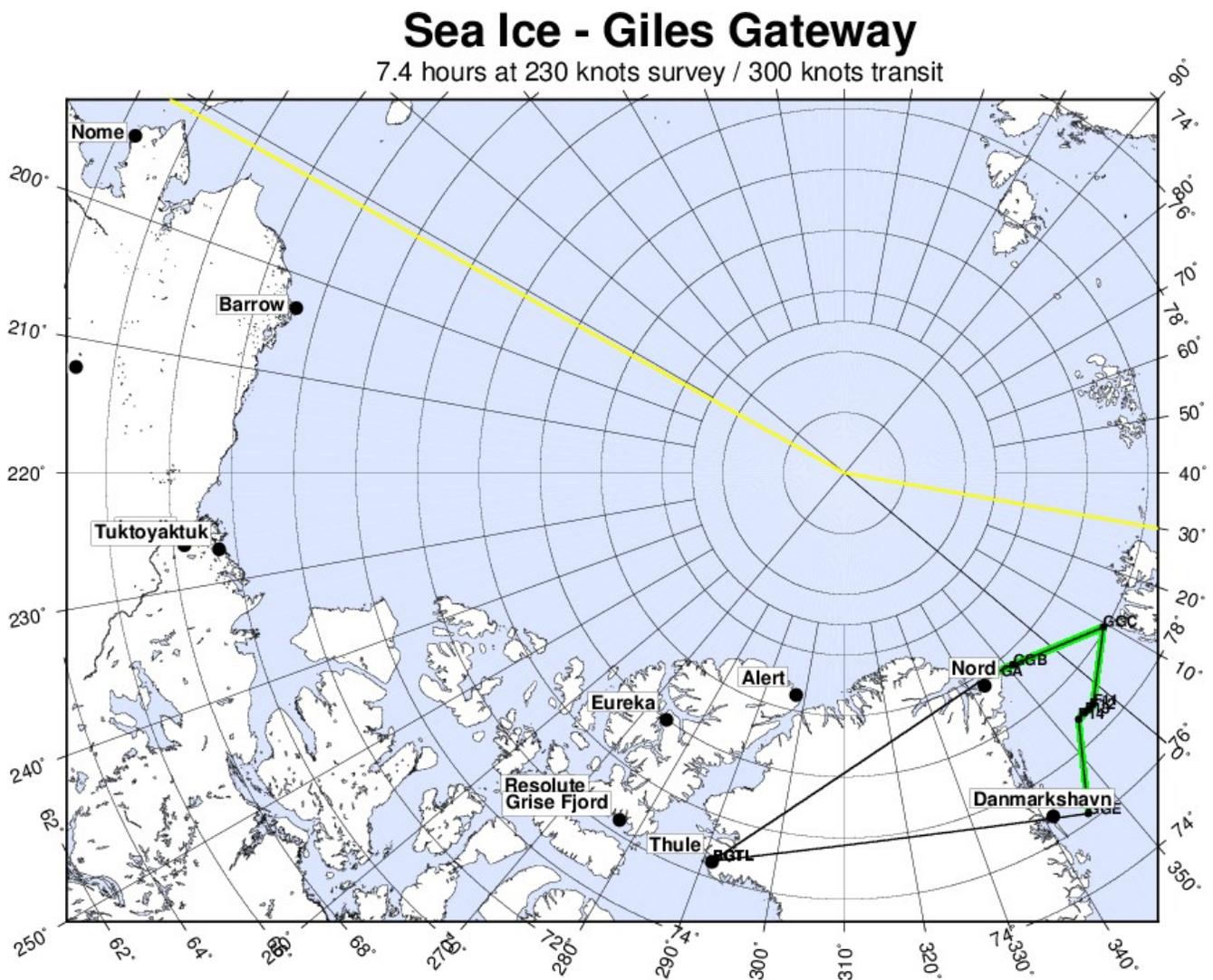
This mission is designed to sample ice passing through the Fram “gateway” between northeast Greenland and Svalbard, and to sample ice south of the gateway as it is transported south along the Greenland coast. We also overfly the four underwater moorings with upward-looking sonar (ULS) sensors in the Fram Strait. These moorings are known as F11, F12, F13, and F14. In addition to Level 1 Requirements SI1 and SI2, this mission addresses sea ice level 1 baseline requirements SI3c and d by sampling sea ice in and south of Fram Strait.

Flight Priority: medium

ICESat Tracks: none

Last Flown: 2014

Remaining Design Issues: none



Land Ice – Alaska Glaciers / Fairbanks

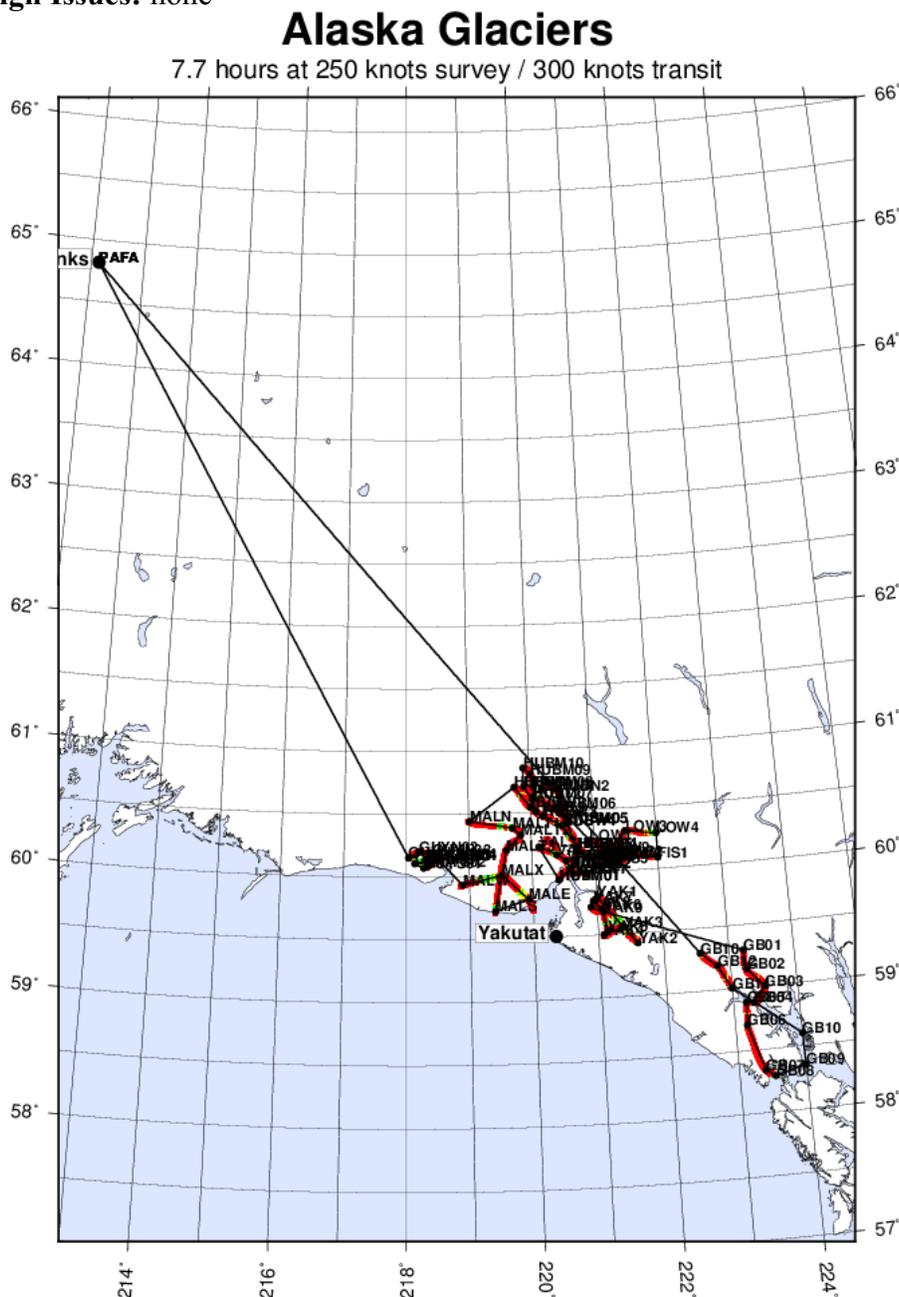
This mission repeats dh/dt survey lines over in the St. Elias mountains and in the Glacier Bay area which were surveyed by ATM in 2005, and by the University of Alaska a number of times. Specific glaciers we survey are Hubbard, Valerie, Variegated, Guyot, the Yakutat Icefield, Fisher, Lowell, and three glaciers in Glacier Bay National Park. This mission is intended to be flown only if the aircraft is “stranded” in Fairbanks during the sea ice portion of the survey, and unable to transit back to Thule due to weather across the western Arctic basin.

Flight Priority: low

ICESat Track: none

Last Flown: 2005

Remaining Design Issues: none



Land Ice – Devon-Barnes 01 / Thule

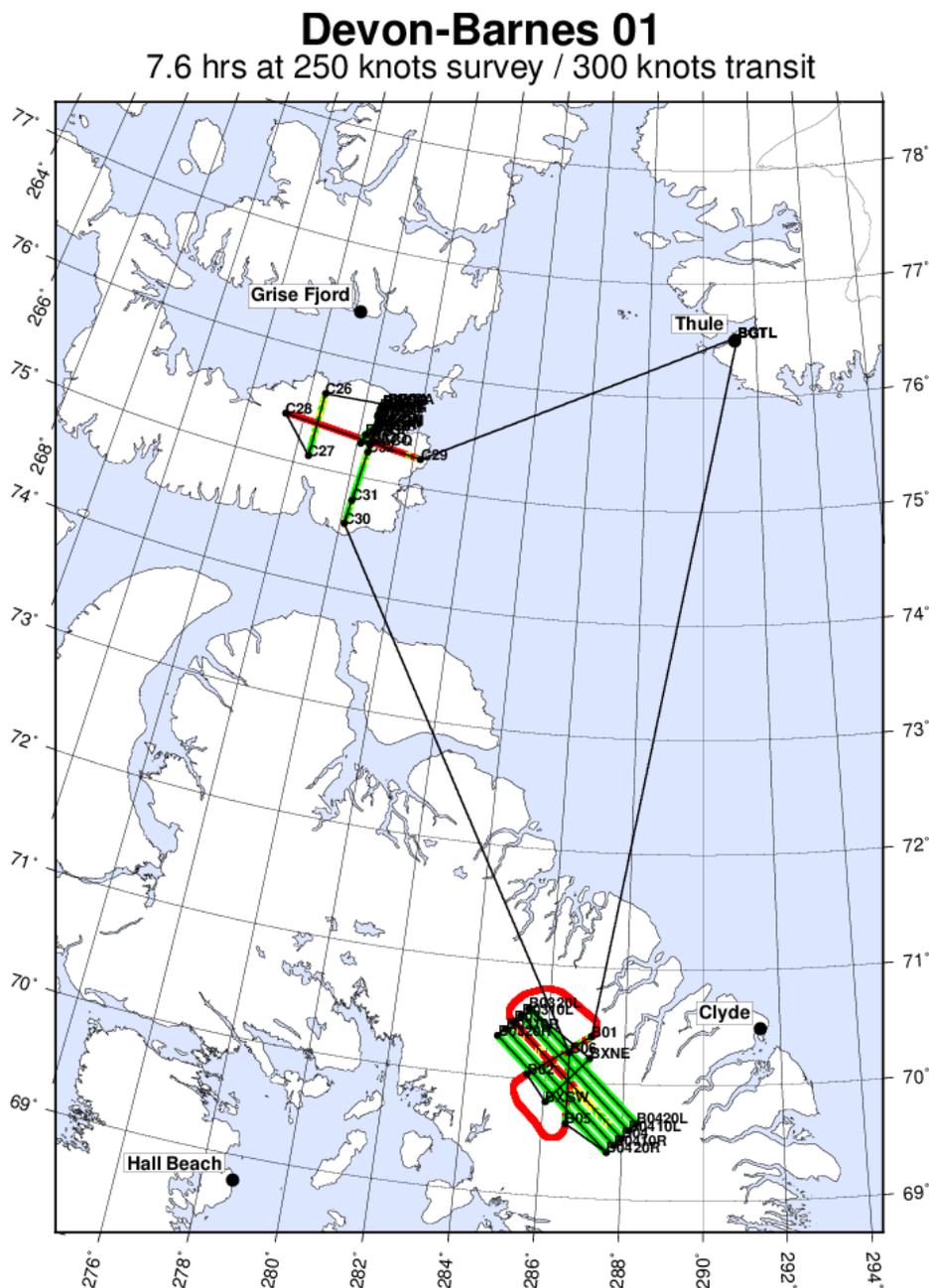
This mission repeats survey lines over the Barnes and Devon Ice Caps previously surveyed by the ATM/KU teams in 1995, 2000, and 2005, and adds several new lines over the Barnes Ice Cap. We also fly the East and West channels of the Belcher Glaciers, draining the northeastern Devon Ice Cap.

Flight Priority: low (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – IceSat-2 North/CryoSat-2 SARIn / Thule

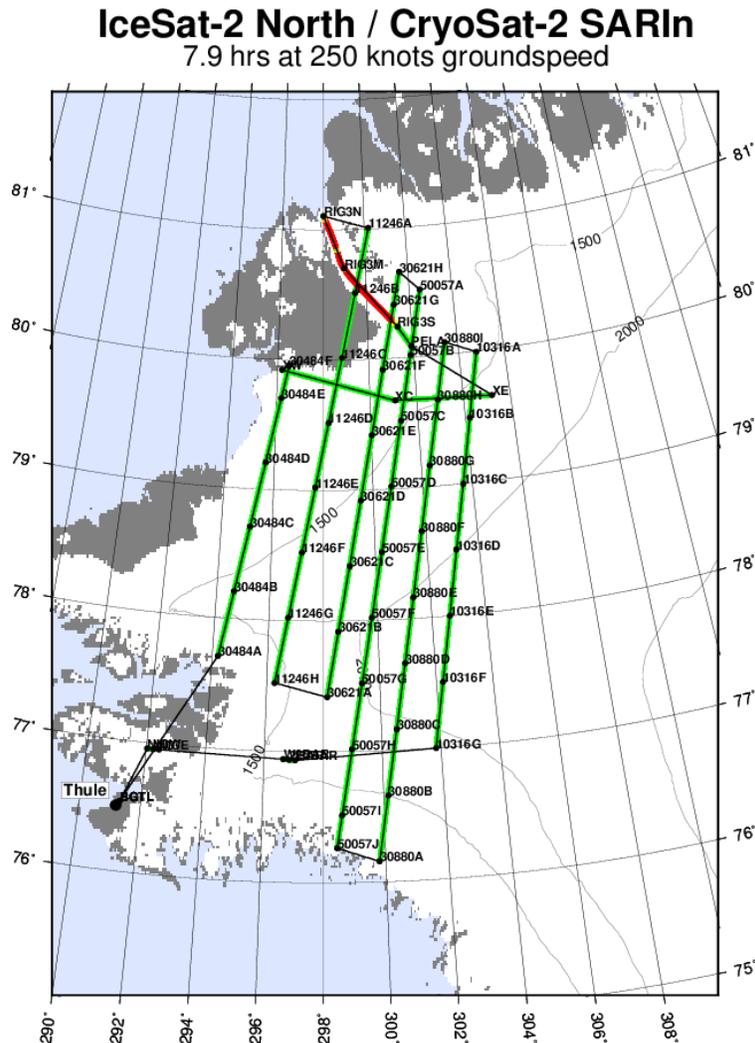
This mission is designed to overfly planned IceSat-2 ground tracks over a wide range of ice regimes near Thule. We center some of the flightlines on each of three beam pairs (left, nadir and right) in turn, sampling at least one of each beam pair during this mission. The east-west crossing line is designed to capture as many ascending/descending crossovers as possible. We also fly a particular flowline of Petermann Glacier which has been sampled intermittently during the ATM and OIB eras, overflying two GCNet sites in the process. Finally we overfly two core sites near Thule, known as “2Barrels” and “North Ice Cap”. The flight also crosses the CryoSat-2 SARIn mode pass in this area.

Flight Priority: baseline (annual repeat flight)

IceSat-2 Track: 0484,1246,0621,0057,0880,0316

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Alexander-Petermann 01 / Thule

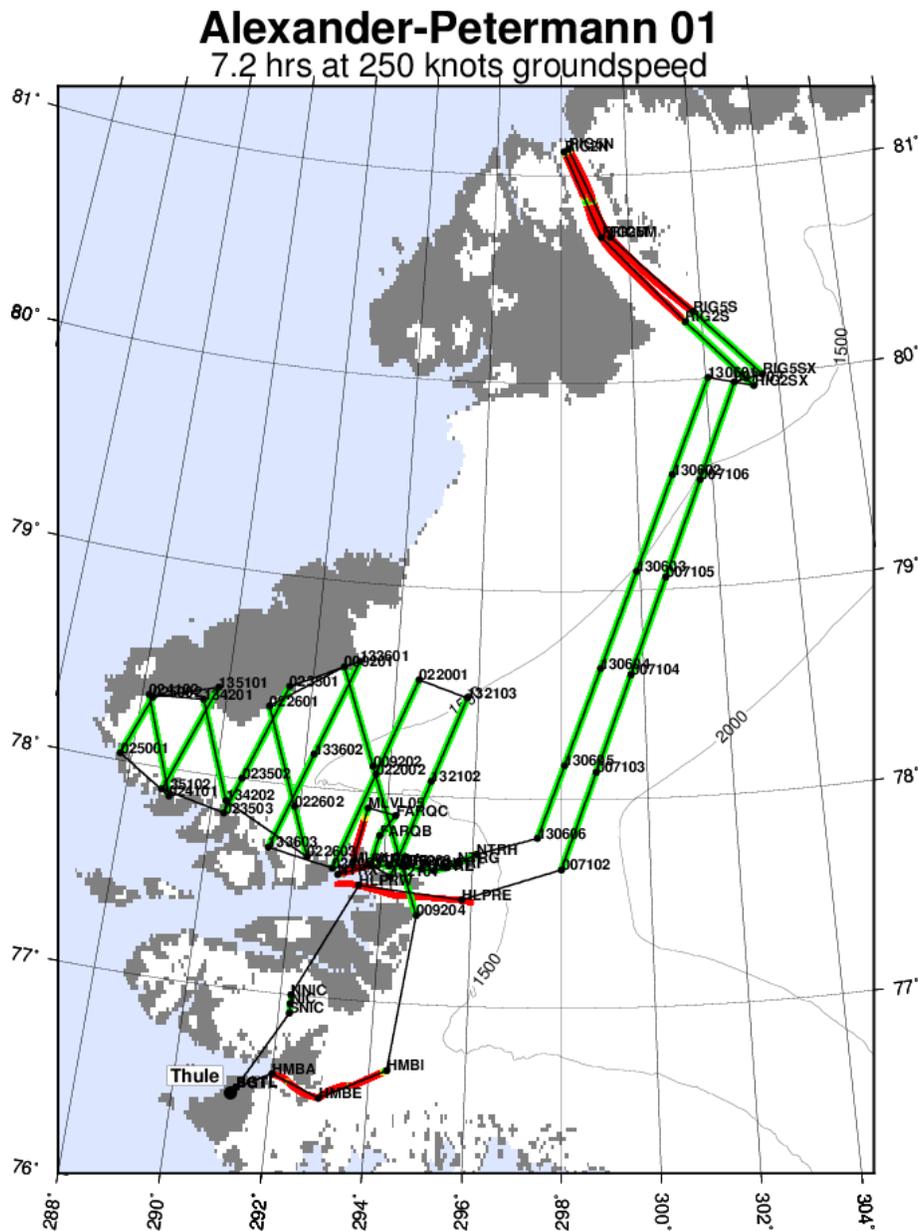
This mission reflies most of the Cape Alexander IceSat-1 groundtracks flown in 2012, reflies two flowlines of Petermann Glacier which OIB flies almost every year., reflies the centerlines of Melville, Tracy and Heilprin Glaciers, and flies new flowlines of Farquhar Glacier and Harald Moltke Brae.

Flight Priority: medium (multi-year repeat flight)

ICESat Track: 1306,0071

Last Flown: 2014

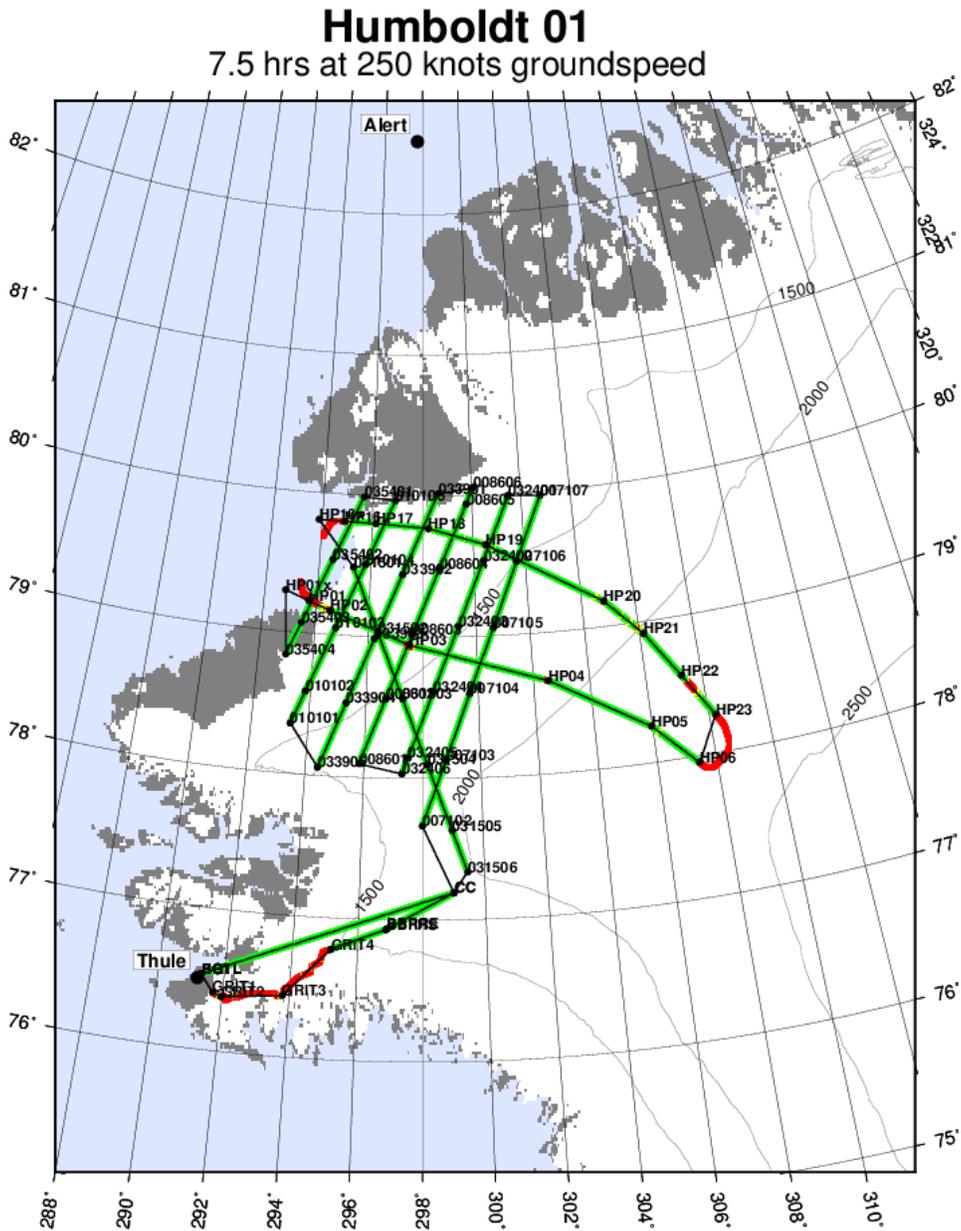
Remaining Design Issues: none



Land Ice – Humboldt 01 / Thule

This mission is designed to repeat two historical ATM lines which follow flowlines down the Humboldt Glacier, and several descending ICESat tracks which parallel the terminus. We also fly the GrIT traverse route between Thule and Camp Century, as well as an associated and collocated field site known as “2 Barrels”.

- Flight Priority:** medium (multi-year repeat flight)
- ICESat Track:** 0071,0324,0086,0339,0101,0354,0315
- Last Flown:** 2014
- Remaining Design Issues:** none



Land Ice – Humboldt 02 / Thule

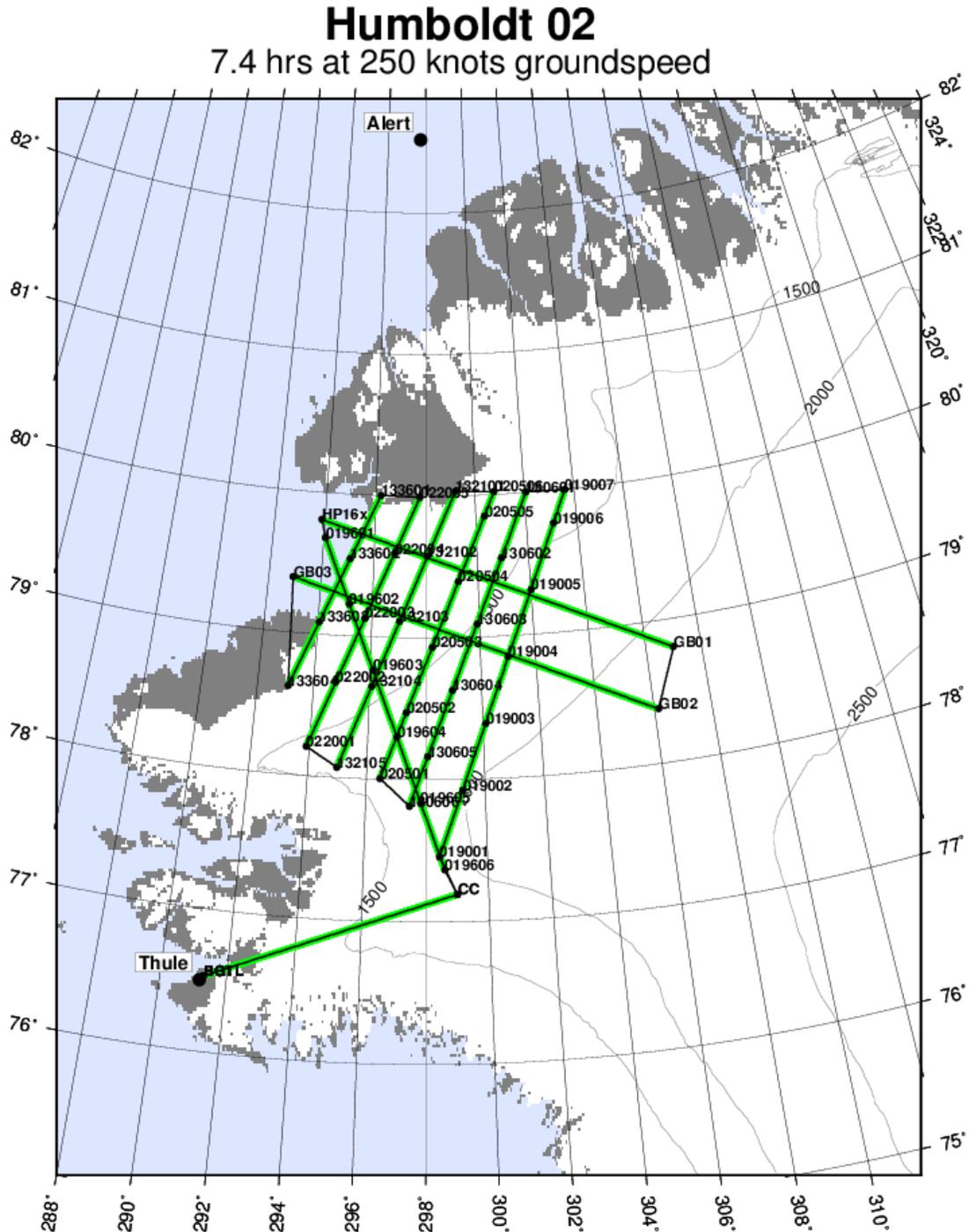
This is a new mission, designed to establish two new along-flow lines and interlace the ICESat lines flown in Humboldt 01 with the intervening ICESat tracks.

Flight Priority: low

ICESat Track: 0190,1306,0205,1321,0220,1336,0196

Last Flown: new flight

Remaining Design Issues: none



Land Ice – North Glaciers 01 / Thule

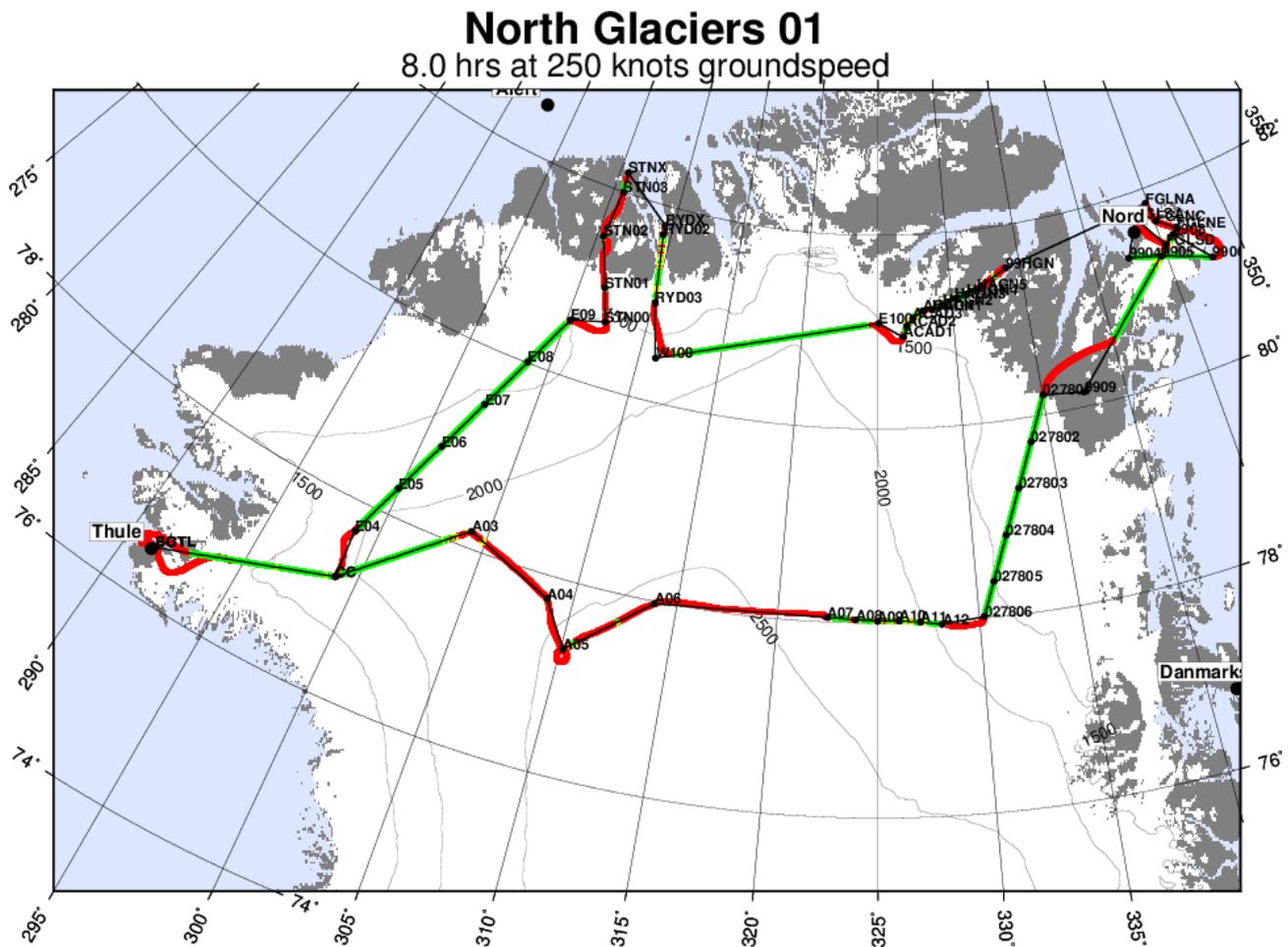
This mission is designed to resurvey historical ATM longitudinal surveys of several glaciers in northern Greenland, including Steensby, Ryder, and Hagen Glaciers. The maneuver connecting lower Steensby and Ryder glaciers has been modified to collect straight-line data over the fjords for better gravity data. It also re-occupies ATM lines on the Flade Ice Cap, near Station Nord, and returns to Thule along the British North Greenland Expedition traverse line, which was also flown by ATM in 2002. We also add two new glacier centerlines for small glaciers draining the Flade Isblink.

Flight Priority: low (multi-year repeat flight)

ICESat Track: 0278

Last Flown: 2015

Remaining Design Issues: none



Land Ice – North Glaciers 02 Prime / Thule

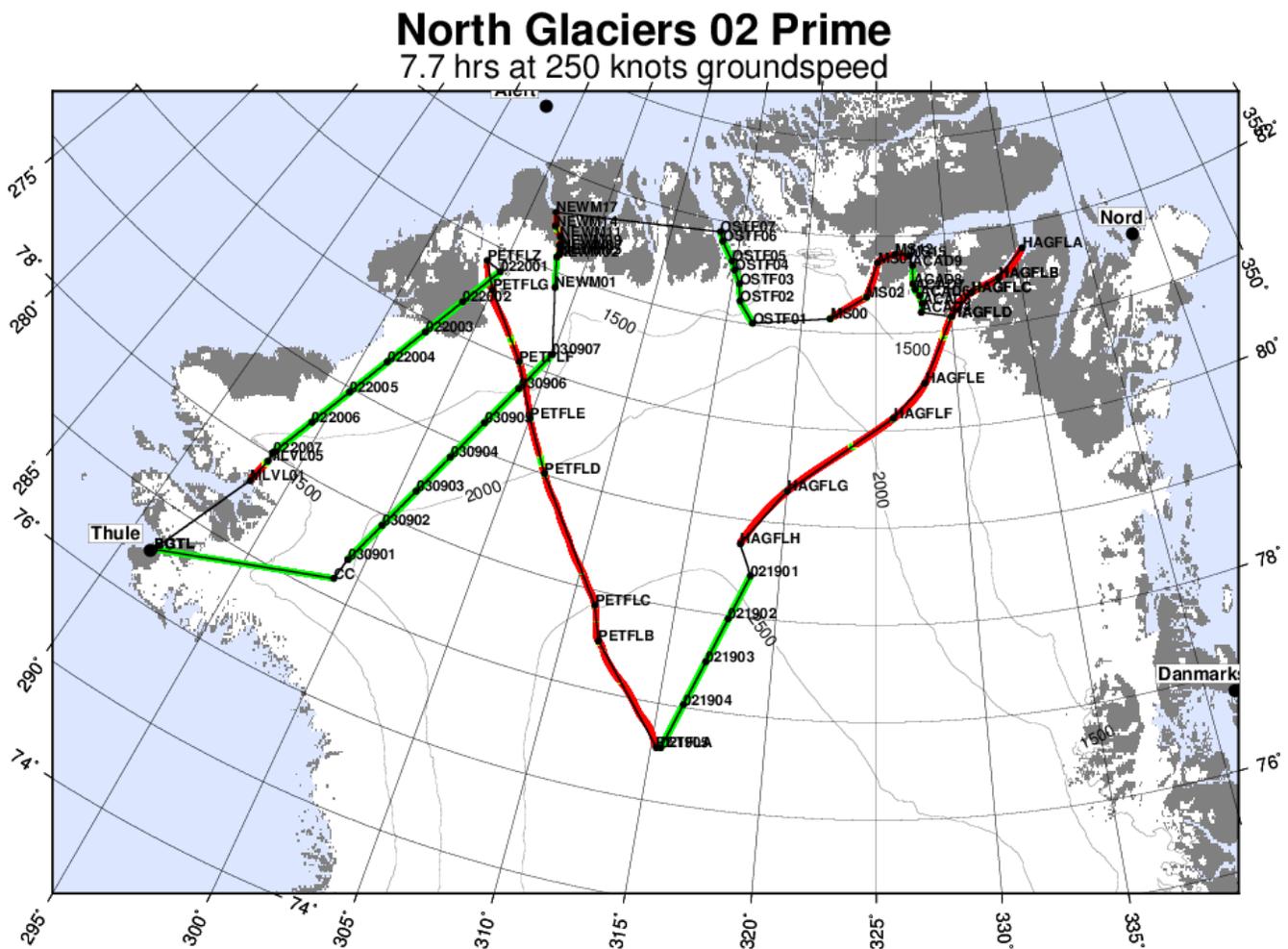
This mission is designed to resurvey a historical ATM longitudinal survey of Academy Glacier, plus several other glaciers. These include Ostfjord, Maria Sophia, and a (possibly unnamed) glacier emptying into Newman Bay. We also survey flowlines of the Hagen and Petermann glaciers all the way from their termini to the ice divide.

Flight Priority: medium (multi-year repeat flight)

ICESat Track: 0220,0309,0219

Last Flown: 2014

Remaining Design Issues: none



Land Ice – Zachariae-79N / Thule

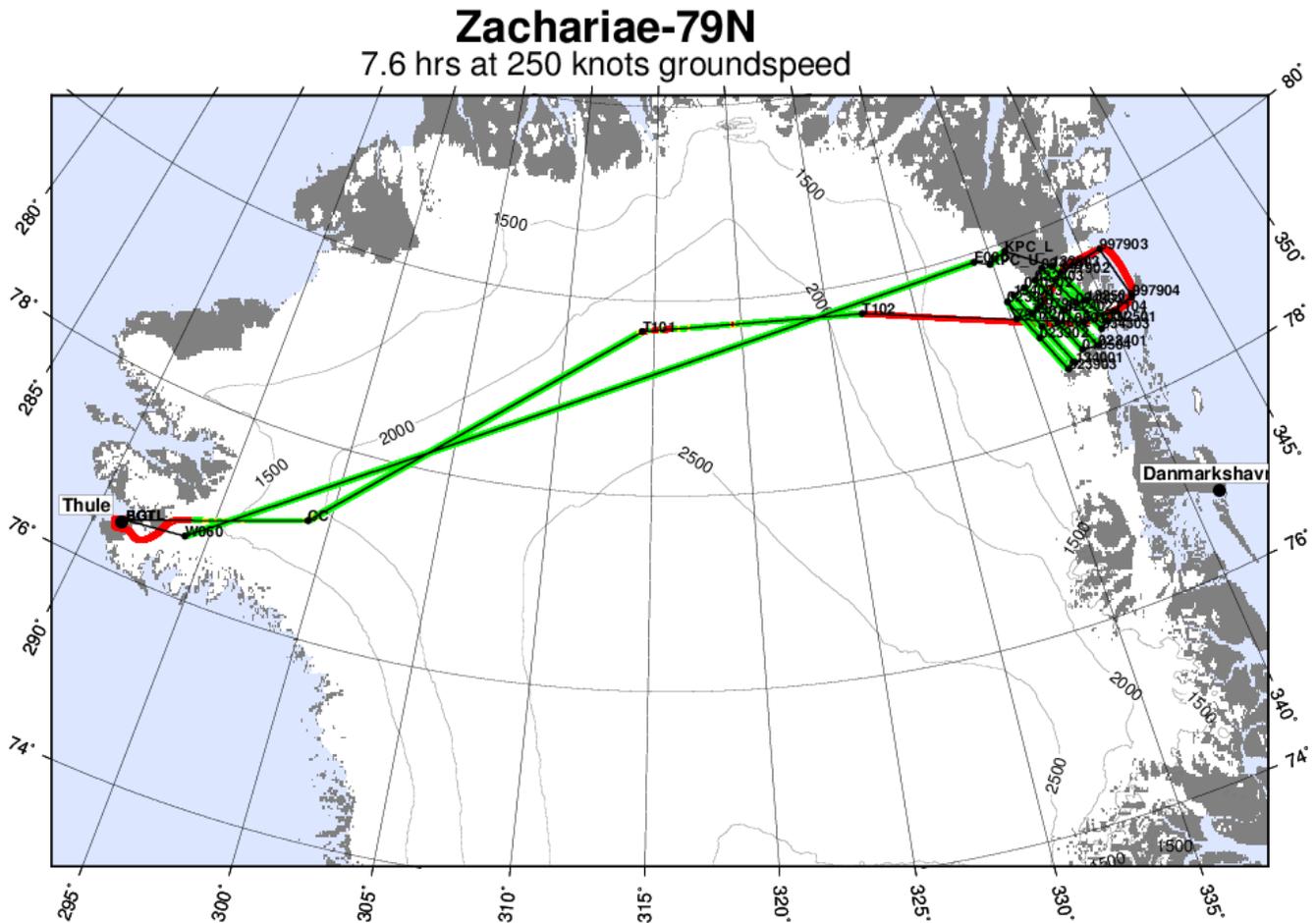
This mission reoccupies the centerlines of the Zachariae and 79N glaciers, plus flies a grid of six ascending IceSat-1 tracks similar to one originally flown by OIB in 2012, but moved upstream by two IceSat-1 groundtracks to account for the breakup of the lower ice shelf. It also overflies a pair of PROMICE sites immediately north of 79N Glacier. We transit to and from the northeast region along a historical ATM lines dating back to 1994, and along an as-yet unflown master grid line.

Flight Priority: baseline (annual repeat flight)

ICESat Track: 0105,0224,0239,0343,1325,1340

Last Flown: IceSat grid lines in 2012, centerlines in 2014

Remaining Design Issues: none



Land Ice – Northeast Glaciers 02 / Thule

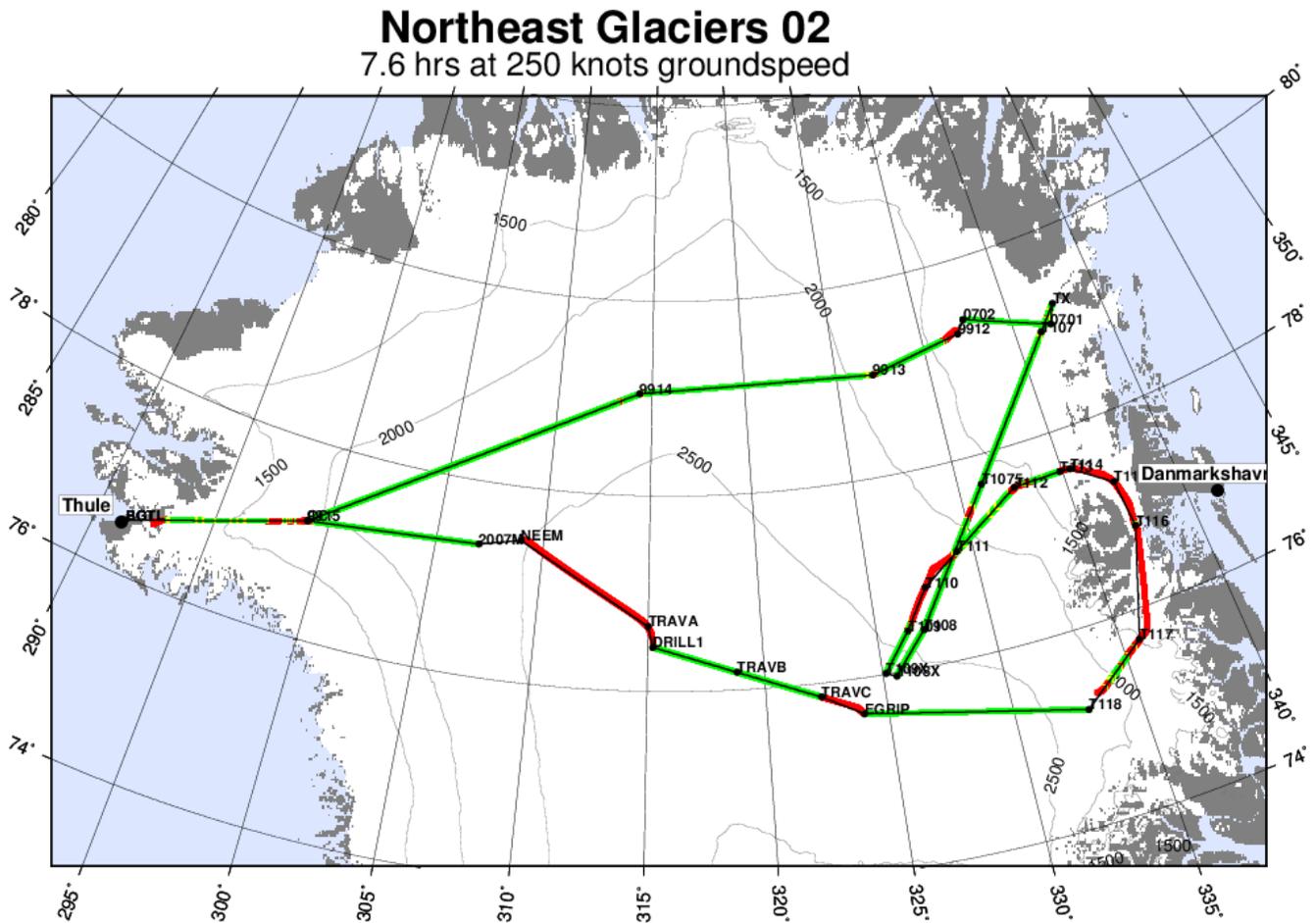
This mission reoccupies the centerlines of the Storstrommen and L Bistrup glaciers, as well as an extension of the Northeast Greenland Ice Stream from Zachariae and 79N Glaciers into the main ice sheet. This southward extension along the ice stream reflects the 2 May 2007 lines, and extends them 60 km farther up the trunk of the ice stream. We transit to and from the northeast region along a historical ATM line dating back to 1994, and along a Danish ground traverse route connecting NEEM and EGRIP core sites. Measurements collected during the ground traverse may permit enhanced interpretation of shallow radar data from OIB.

Flight Priority: medium (multi-year repeat flight)

ICESat Track: none

Last Flown: portions in 2014

Remaining Design Issues: none



Land Ice – North Central Gap 01 / Thule

This mission, along with the North Central Gap 02 and 03 missions, are primarily designed to fill a gap in altimetry and radar coverage of the north-central portion of the ice sheet. The flight was modified for 2015, where we removed the centerlines of Zachariae and Storstrommen Glaciers (covered in other flights), and added reflights of four 2010 grid lines on the upper Zachariae/79N catchment, extended upstream centerlines of both glaciers, and flowlines passing through the TUNU and B19 core sites. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

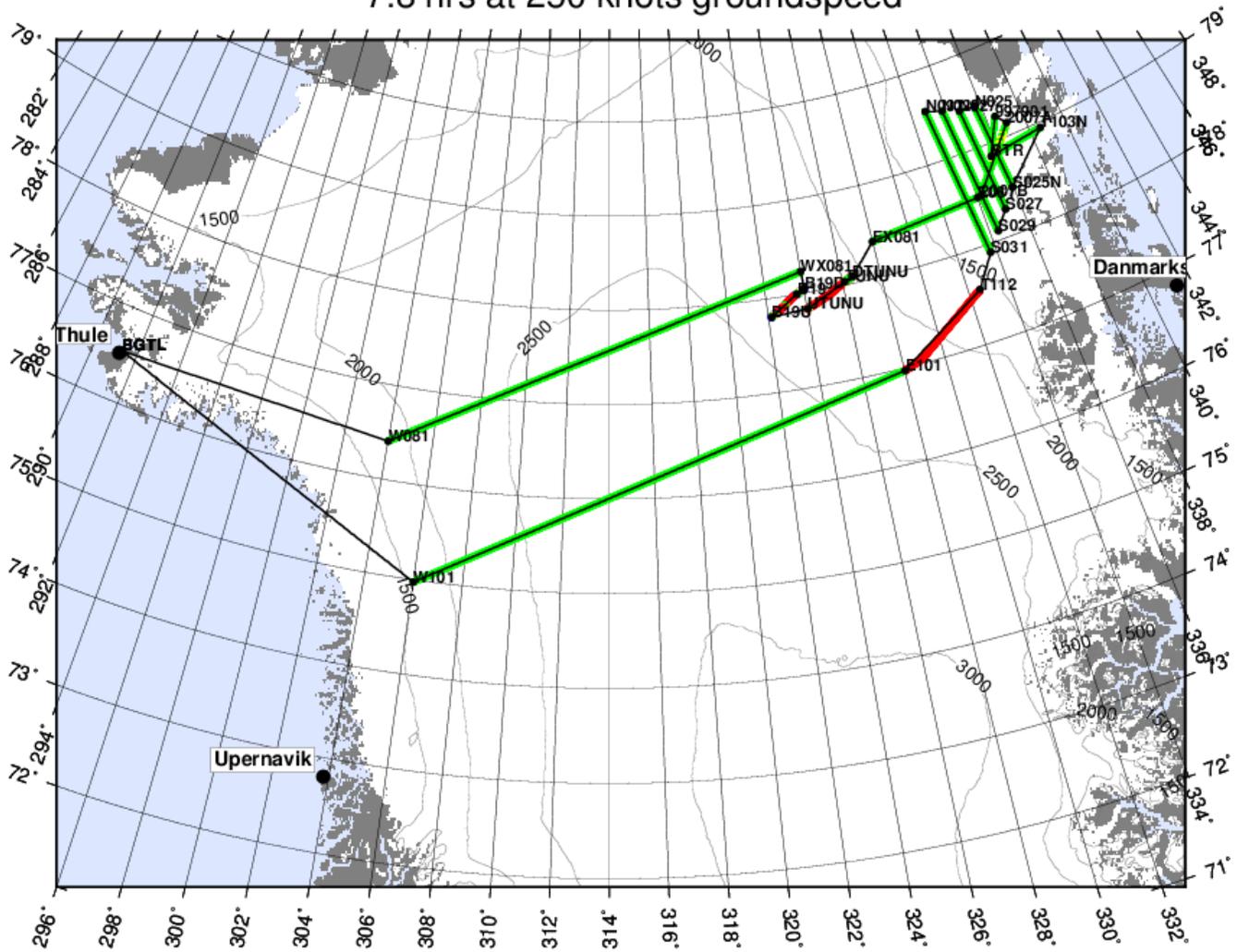
Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none

North-Central Gap 01 7.8 hrs at 250 knots groundspeed



Land Ice – North Central Gap 02 / Thule

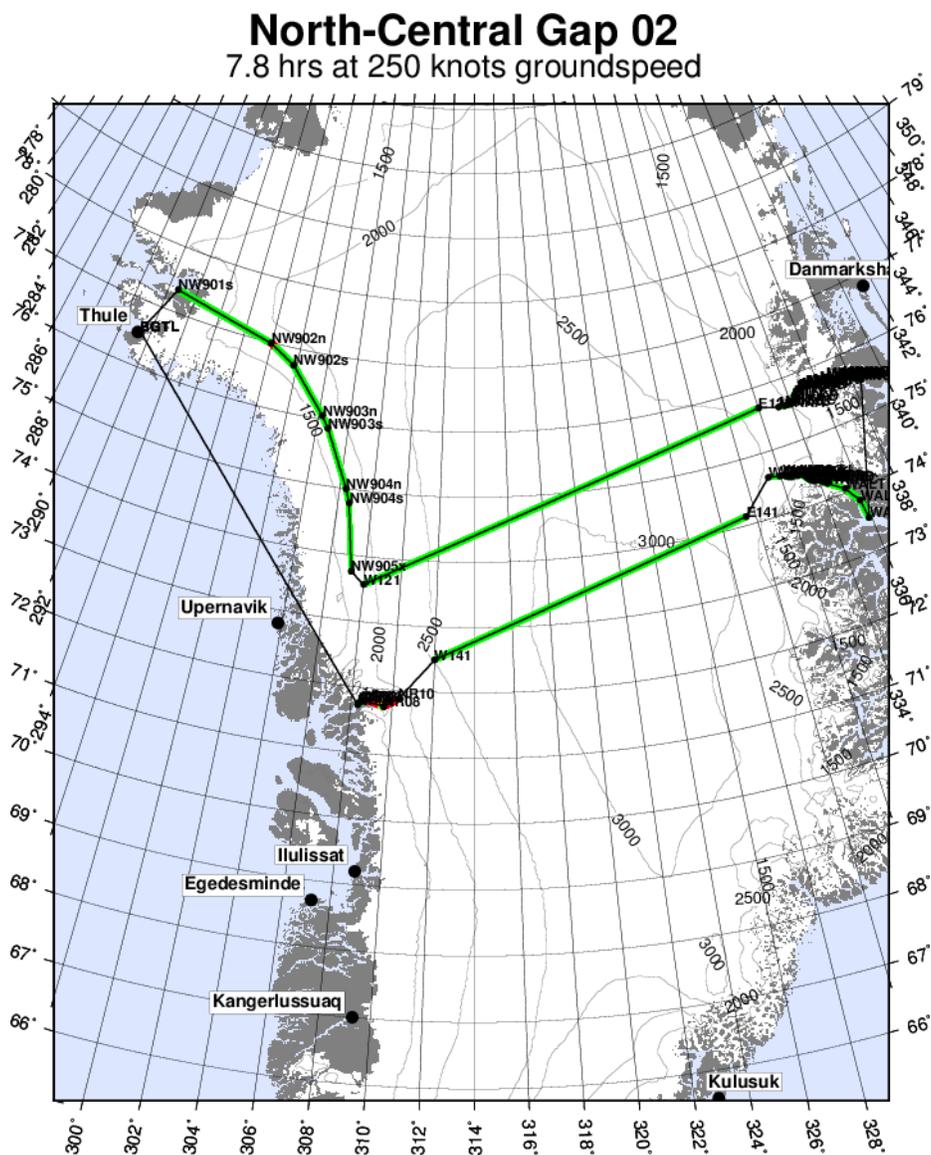
This mission, along with the North Central Gap 01 and 03 missions, are primarily designed to fill a gap in altimetry and radar coverage of the north-central portion of the ice sheet. In this flight, we also re-occupy centerlines of the Rink and Upernavik (central), glaciers, we establish new centerlines of the Mikkelsen and Waltershausen glaciers, and we refly portions of the northwest coast-parallel grid flown from 2010-2012. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – North Central Gap 03 / Thule

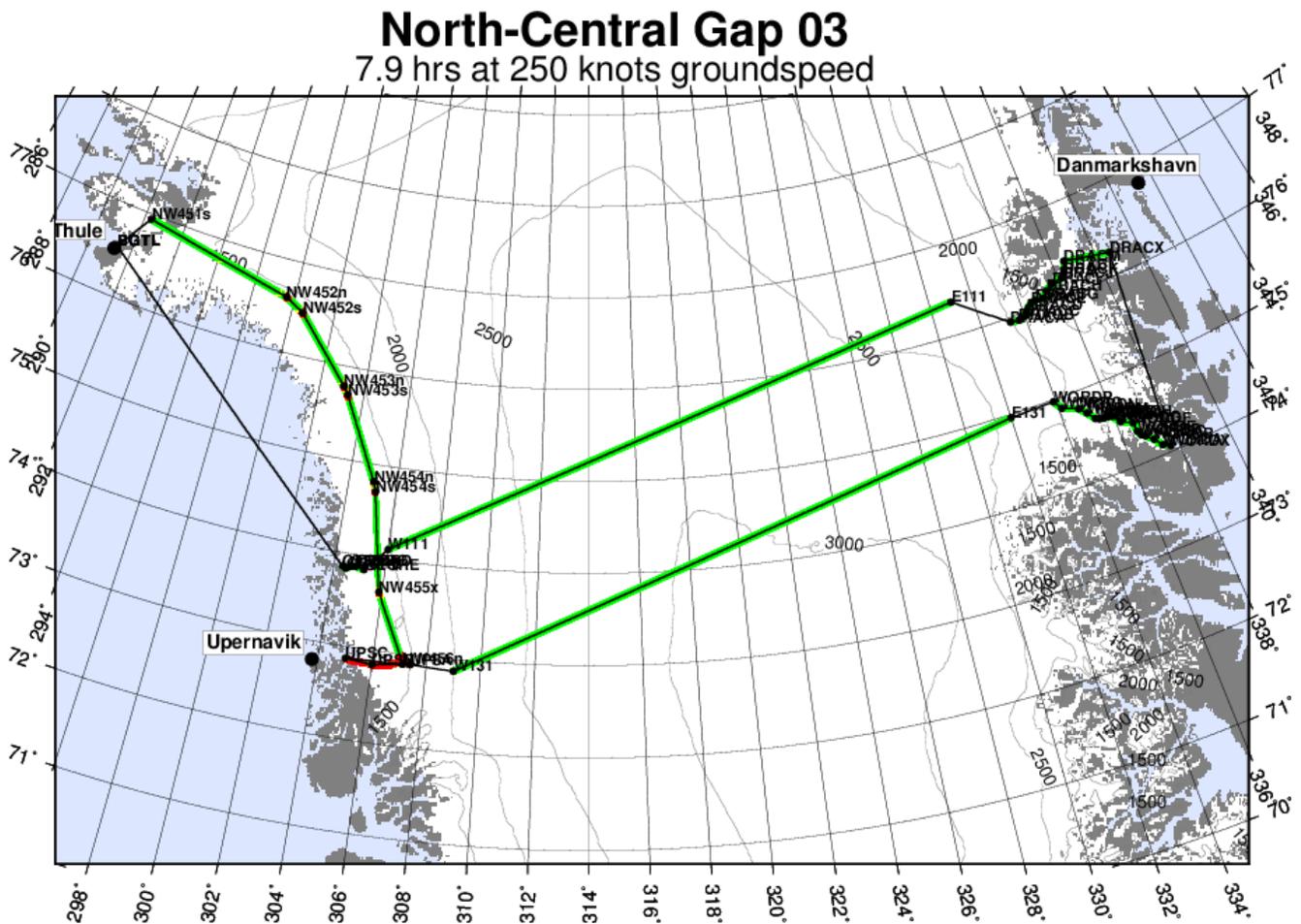
This mission, along with the North Central Gap 02 and 03 missions, are primarily designed to fill a gap in altimetry and radar coverage of the north-central portion of the ice sheet. In this flight, we also re-occupy centerlines of the Qeqertarsuap and Upernavik (south), glaciers, we fly centerlines of the Drachmann and Wordie glaciers, and we re-fly portions of the northwest coast-parallel grid flown from 2010-2012.

Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2013

Remaining Design Issues: none



Land Ice – Northeast Grid 05 / Thule

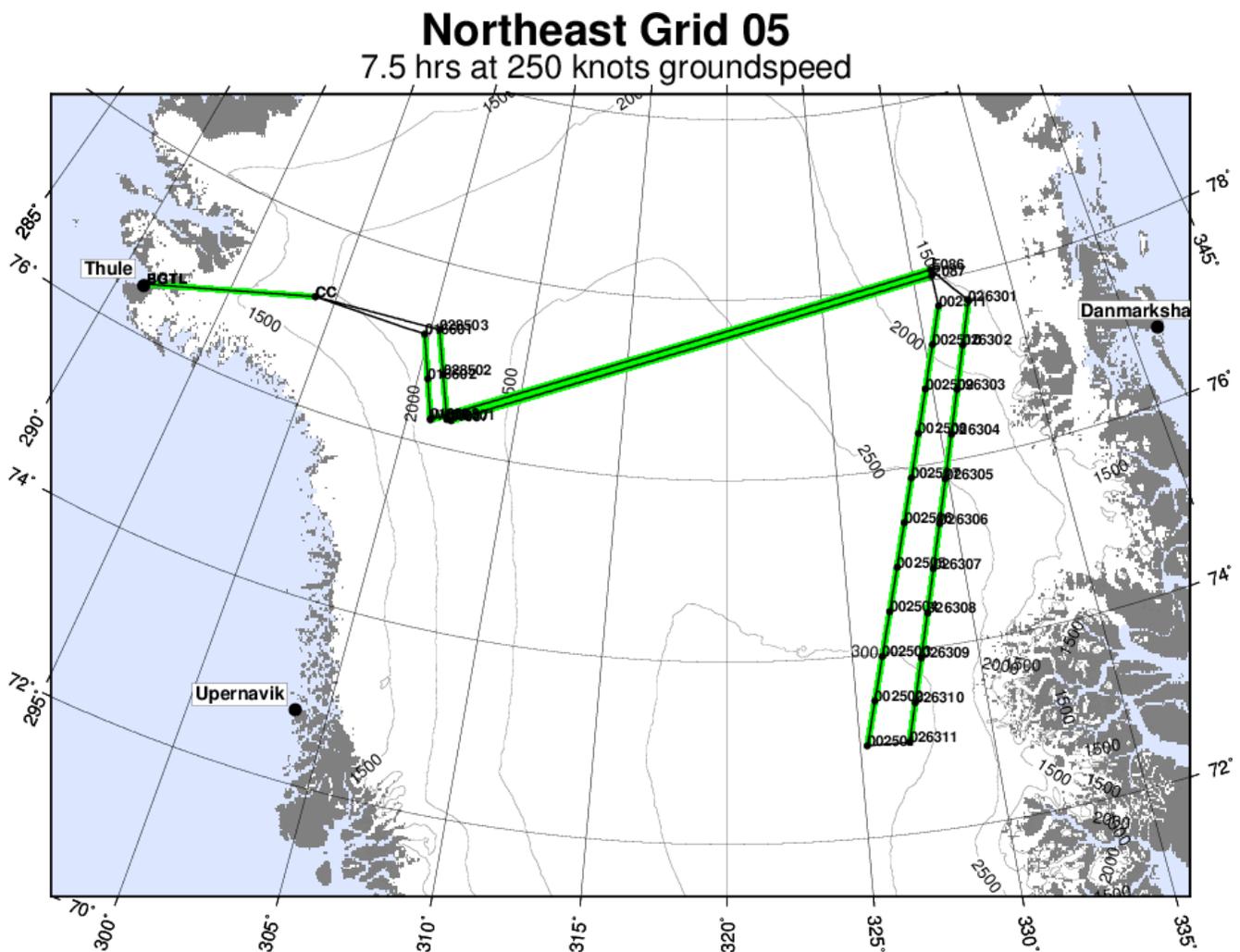
This is a new mission, one of a suite of six flights intended to thoroughly sample the bedrock topography of northeast Greenland along a series of nearly coast-parallel ICESat lines. At the same time we obtain altimetry measurements along the ICESat tracks which will enable the calculation of dh/dt over a broad area and a significant time span. This particular mission complements the Northeast Grid 01/02/03/04 missions with the next two tracks in the inland direction. It transits to the area along short ICESat tracks in the west and new east-west master grid lines.

Flight Priority: medium

ICESat Track: 0166,0263,0025,0285

Last Flown: new flight

Remaining Design Issues: none



Land Ice – Northwest Glaciers 01 / Thule

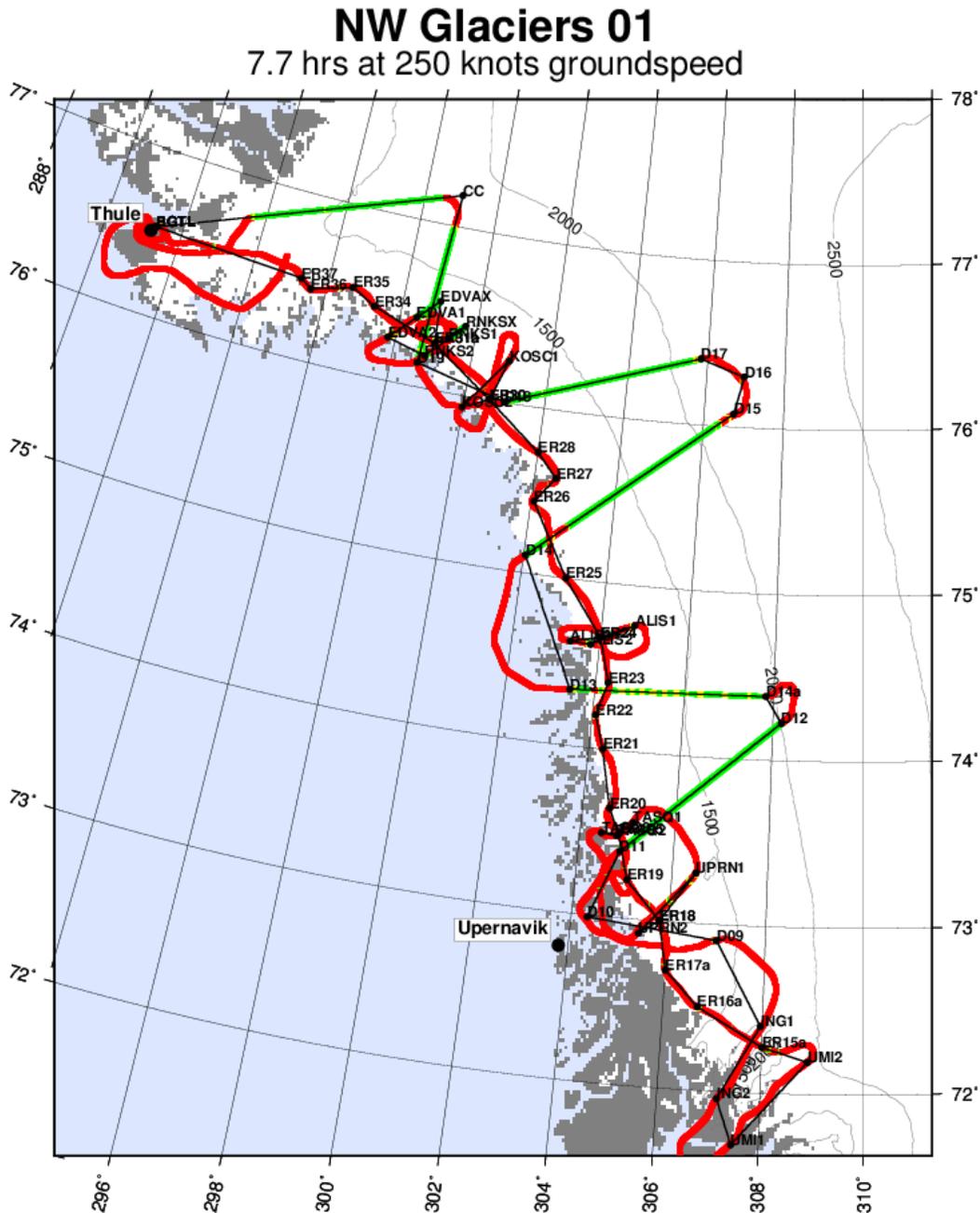
This mission is a repeat of a 2009, 2010, 2011, 2012 and 2014 IceBridge mission. It focuses on the upper Baffin Bay coast, with targeted longitudinal surveys of 12 glaciers in the region and repeats of long-established ATM dh/dt lines which were not targeted at outlet glaciers, but instead were intended to track inland spread of coastal thinning.

Flight Priority: baseline (annual repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Northwest Coastal A / Thule

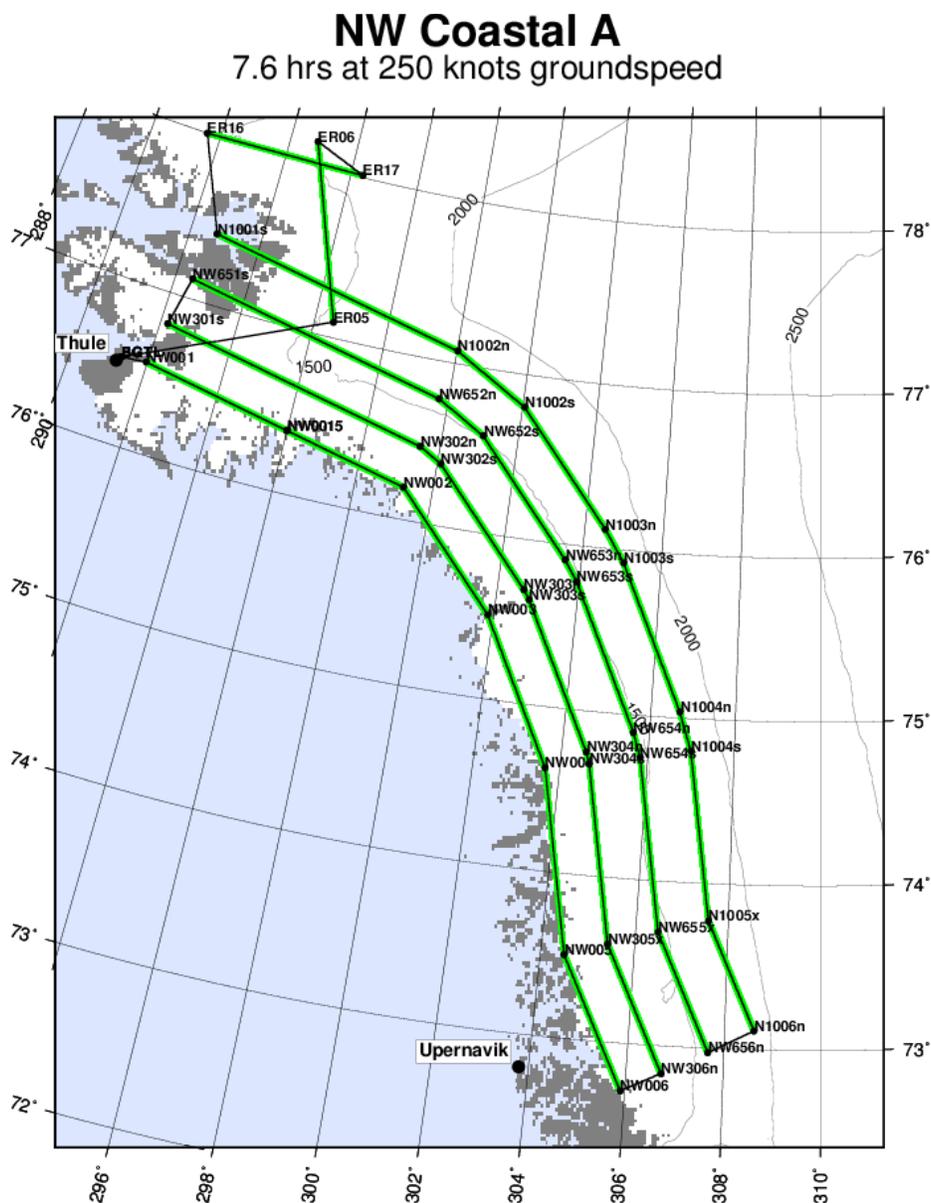
This is a new mission, created from the 2010-2012 “Northwest Coastal” suite of missions by sampling individual coast-parallel lines from those flights to form a grid spaced at 30-35 km from the coast to near the 2000m contour line. This is one of three missions designed in this way, which together form a 10 km grid in the area. The others are Northwest Coastal B and C. We also add two additional bedrock-mapping lines in the Tracy/Heilprin catchment. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat mission)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Northwest Coastal B / Thule

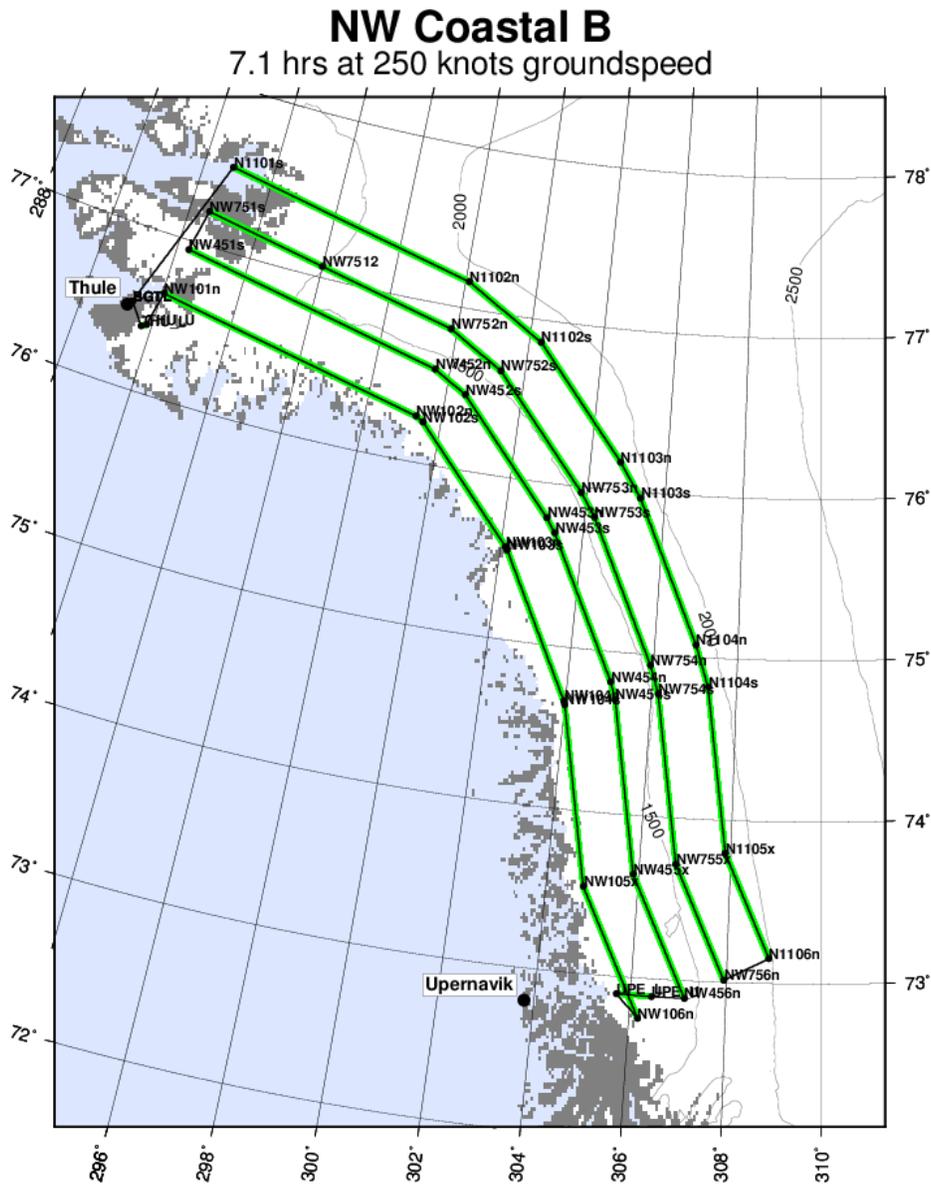
This mission was created from the 2010-2012 “Northwest Coastal” suite of missions by sampling individual coast-parallel lines from those flights to form a grid spaced at 30-35 km from the coast to near the 2000m contour line. This is one of three missions designed in this way, which together form a 10 km grid in the area. The others are Northwest Coastal A and C. This particular mission also overflies four PROMICE sites, two near Thule and two near Upernavik.

Flight Priority: medium (multi-year repeat mission)

ICESat Track: none

Last Flown: 2014

Remaining Design Issues: none



Land Ice – Northwest Coastal C / Thule

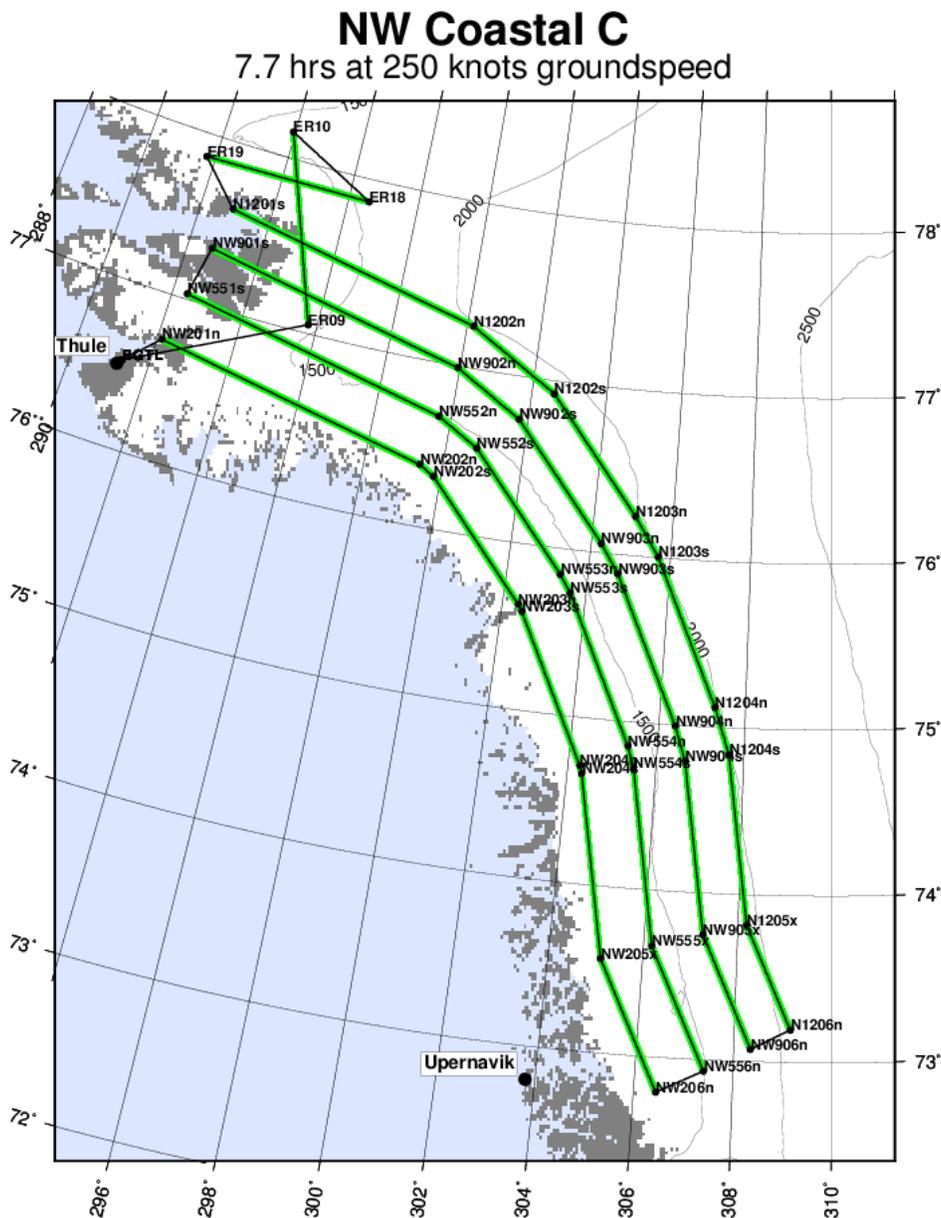
This mission was created from the 2010-2012 “Northwest Coastal” suite of missions by sampling individual coast-parallel lines from those flights to form a grid spaced at 30-35 km from the coast to near the 2000m contour line. This is one of three missions designed in this way, which together form a 10 km grid in the area. The others are Northwest Coastal A and B. We also add two additional bedrock-mapping lines in the Tracy/Heilprin catchment.

Flight Priority: medium (multi-year repeat mission)

ICESat Track: none

Last Flown: 2014

Remaining Design Issues: none



Land Ice – Northwest Coastal 06 / Thule

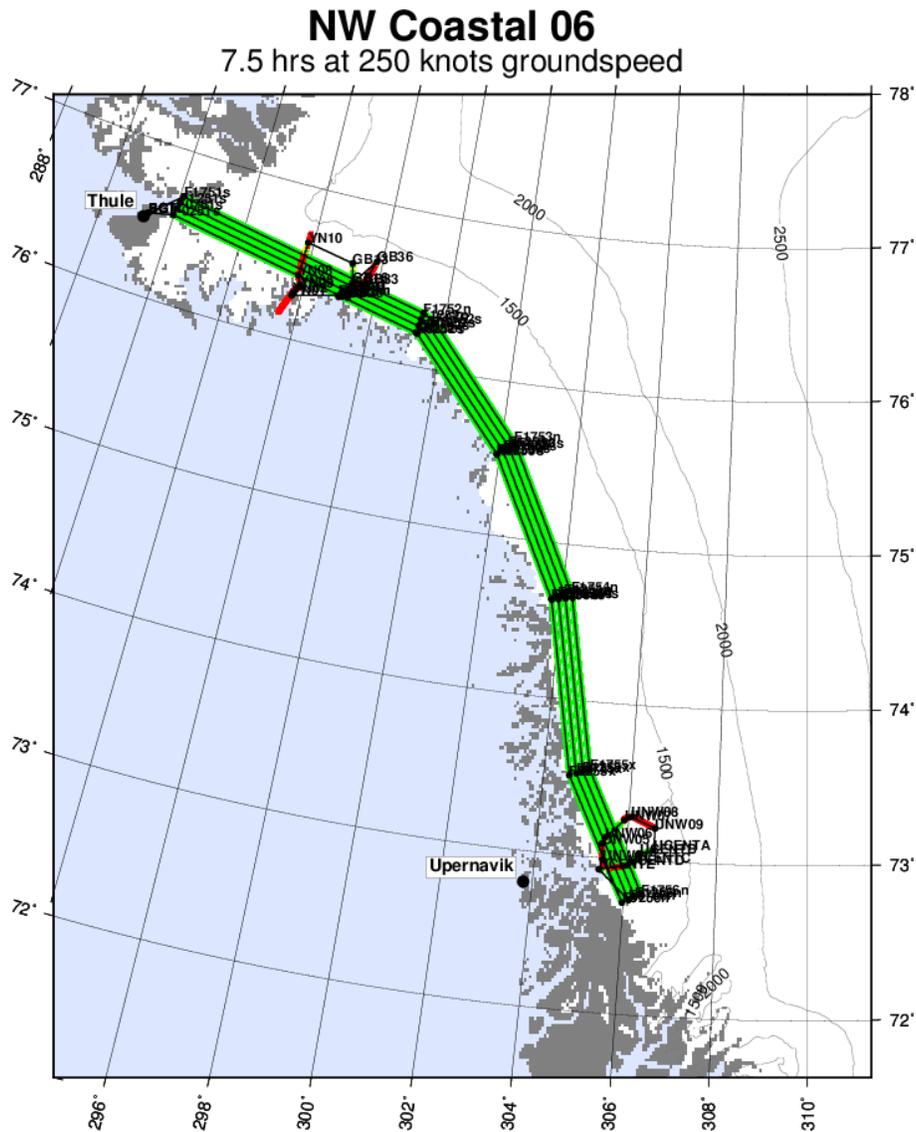
This is a new mission which interlaces the 2010-2011 Northwest Coastal coast-parallel grid, which had a spacing of 5 km, to 2.5 km. This flight also reoccupies the centerlines of the Upernavik Northwest and Yngvar Nielsen glaciers, and establishes new centerlines along the Upernavik middle ice stream, and both branches of the wishbone-shaped Gades Brae glacier. The companion Northwest Coastal 07 mission performs the same interlace strategy but farther inland.

Flight Priority: low

ICESat Track: none

Last Flown: new flight

Remaining Design Issues: none



Land Ice – Northwest Coastal 07 / Thule

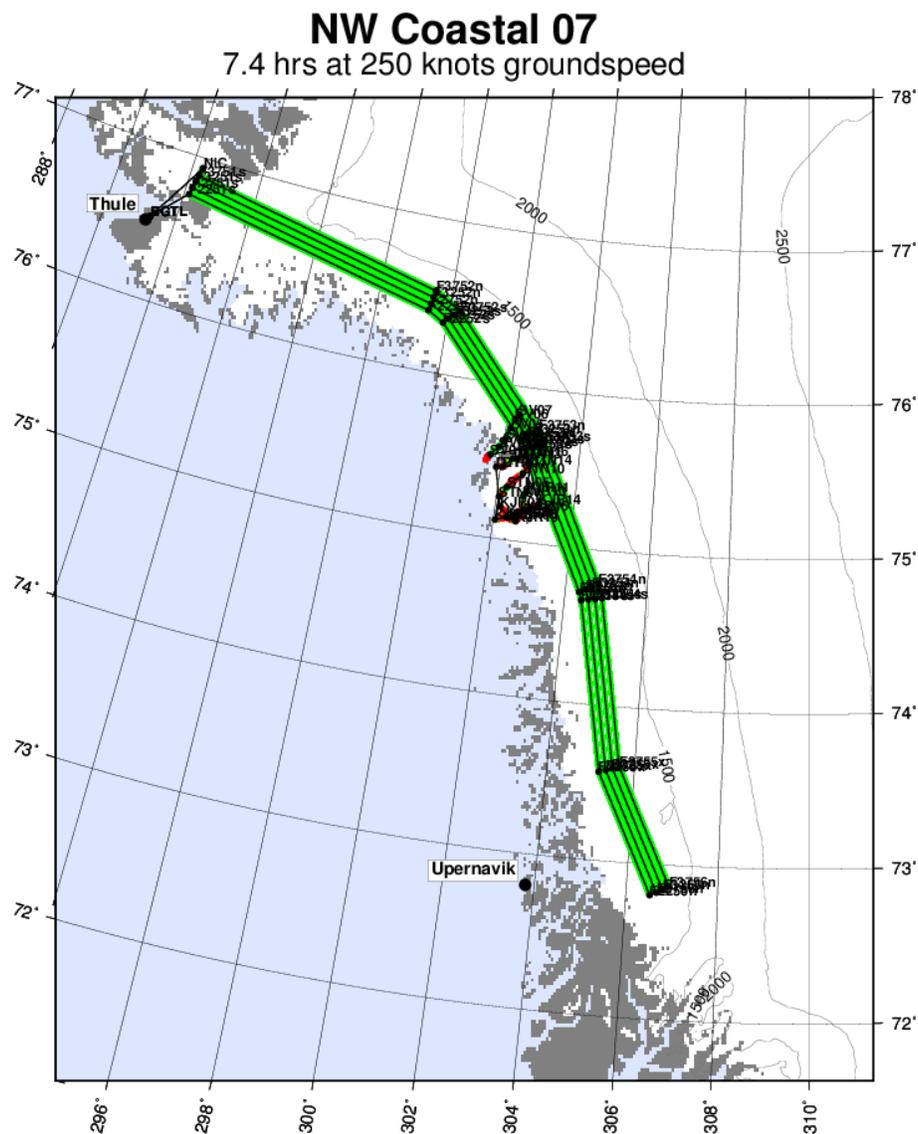
This is a new mission which interlaces the 2010-2011 Northwest Coastal coast-parallel grid, which had a spacing of 5 km, to 2.5 km. The companion Northwest Coastal 06 mission does the same but farther to seaward. We also re-fly the centerline of the Sverdrup Glacier, and fly new centerlines on Dietrichson, Steenstrups, and a pair of centerlines on Kjaer Glacier.

Flight Priority: low

ICESat Track: none

Last Flown: new flight

Remaining Design Issues: none



Land Ice – IceSat-2 Central / Kangerlussuaq

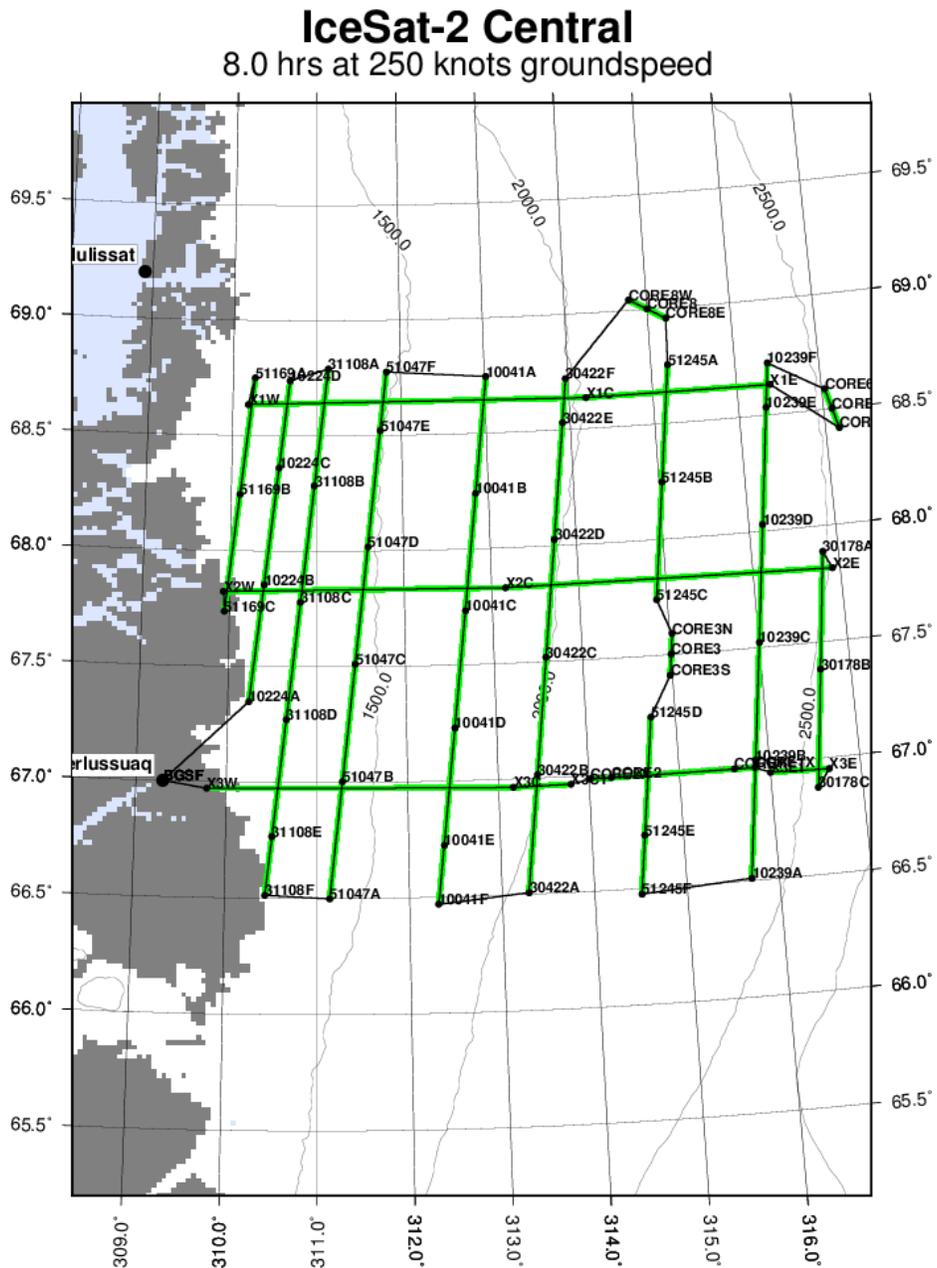
This mission was designed to overfly planned IceSat-2 ground tracks over a wide range of ice regimes near Kangerlussuaq. We center some of the flightlines on each of three beam pairs (left, nadir and right) in turn, sampling three of each beam pair during this mission. The east-west crossing lines are designed to capture as many ascending/descending crossovers as possible. We modified and augmented the mission in 2016 to overfly five GreenTrACS core sites.

Flight Priority: baseline (annual repeat flight)

IceSat-2 Track: 1169,1022,1047,0041,0422,1245,0239,0178

Last Flown: 2014

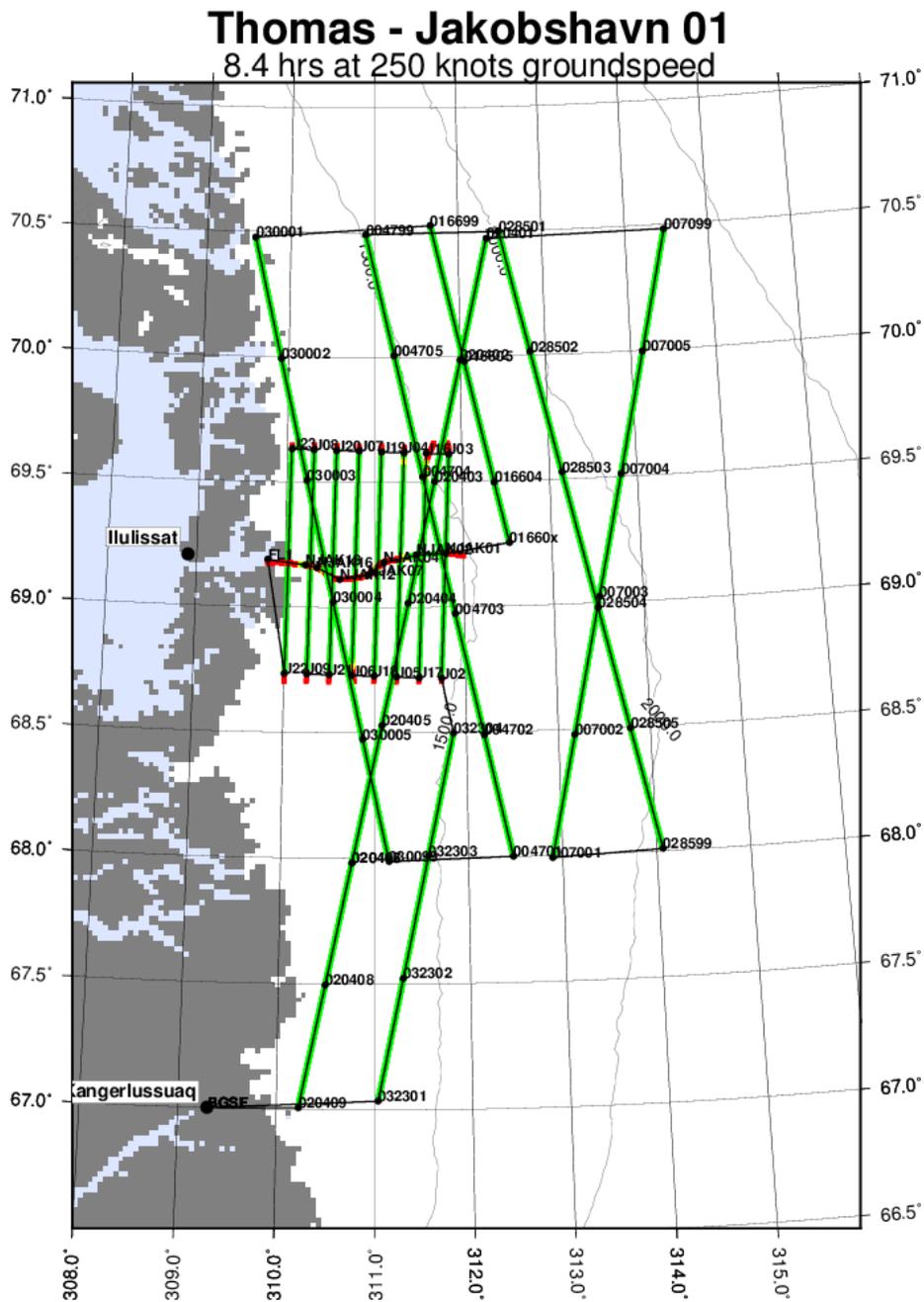
Remaining Design Issues: none



Land Ice – Thomas-Jakobshavn 01 / Kangerlussuaq

This is a repeat of 2009, 2010, 2011, 2012, 2013 and 2014 IceBridge missions. Its purpose is to re-survey the highest-priority lines of the historical ATM 10-km Jakobshavn grid, the main flowline of Jakobshavn. It also extends that grid with a broader array of ICESat ground tracks over the larger Jakobshavn basin. Renamed in 2015 in honor of Robert H. Thomas.

- Flight Priority:** baseline (annual repeat flight)
- ICESat Track:** 0323,0300,0047,0285,0070,0204
- Last Flown:** 2015
- Remaining Design Issues:** none



Land Ice – Jakobshavn 02 / Kangerlussuaq

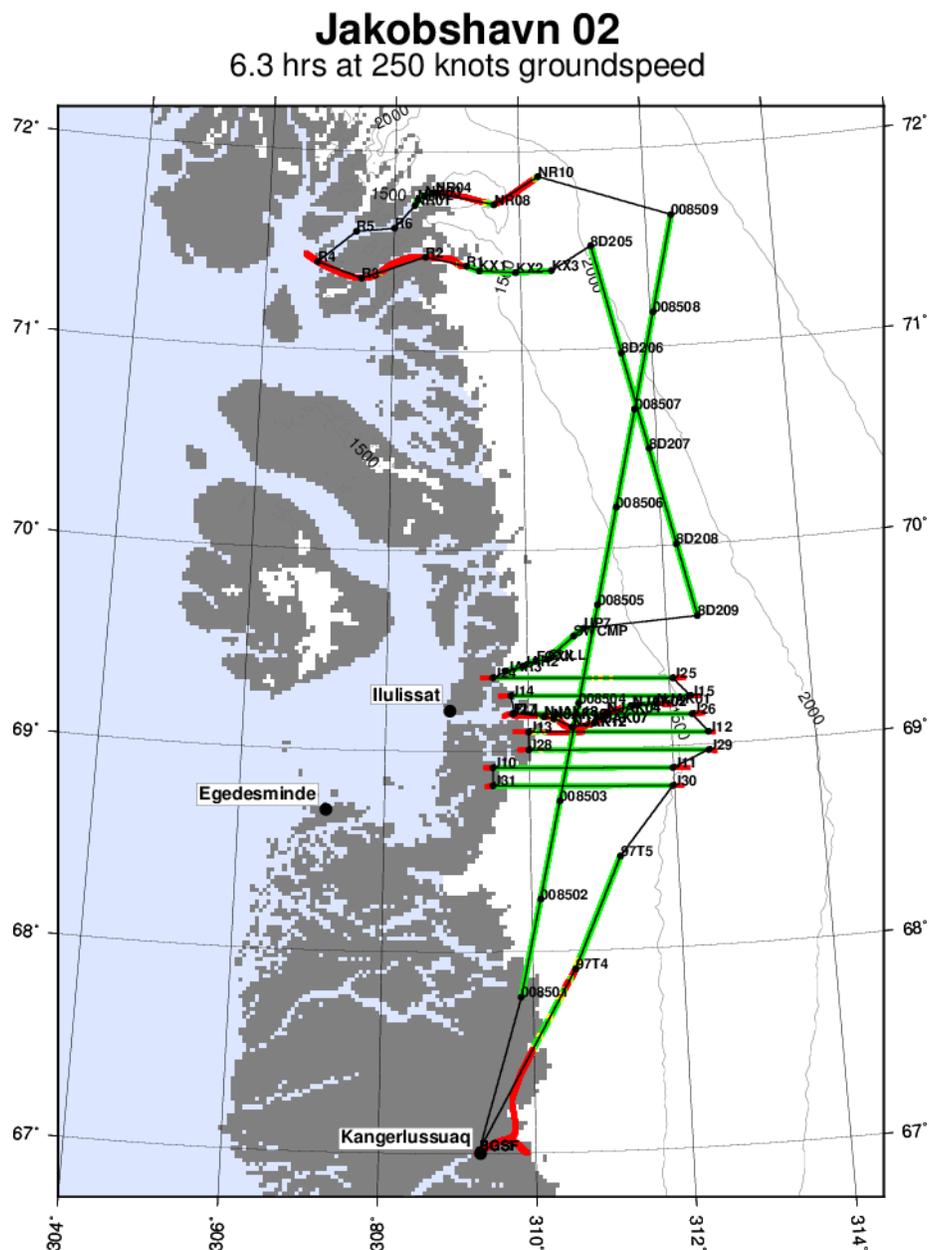
This mission is a repeat of similar 2009, 2010, 2011, 2012, 2013 and 2014 OIB flights. The primary science objectives are to (a) complete the basic Jakobshavn grid, specifically the east-west lines, and (b) repeat longitudinal surveys of the Rink and Kangerdlugssup Glaciers. We also occupy a line connecting Swiss Camp and a pair of Eric Lutz-requested points nearby. Finally we fly the main Jakobshavn centerline twice, once at normal speed and altitude, and again as low and slow as possible, for MCoRDS radar assessment. We also include centerlines of Rink and Kangerdlugssup Glaciers, which can be eliminated if these glaciers were flown as part of the Jakobshavn-Eqip-Store flight.

Flight Priority: low (multi-year repeat flight)

ICESat Track: 0181

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Jakobshavn-Eqip-Store / Kangerlussuaq

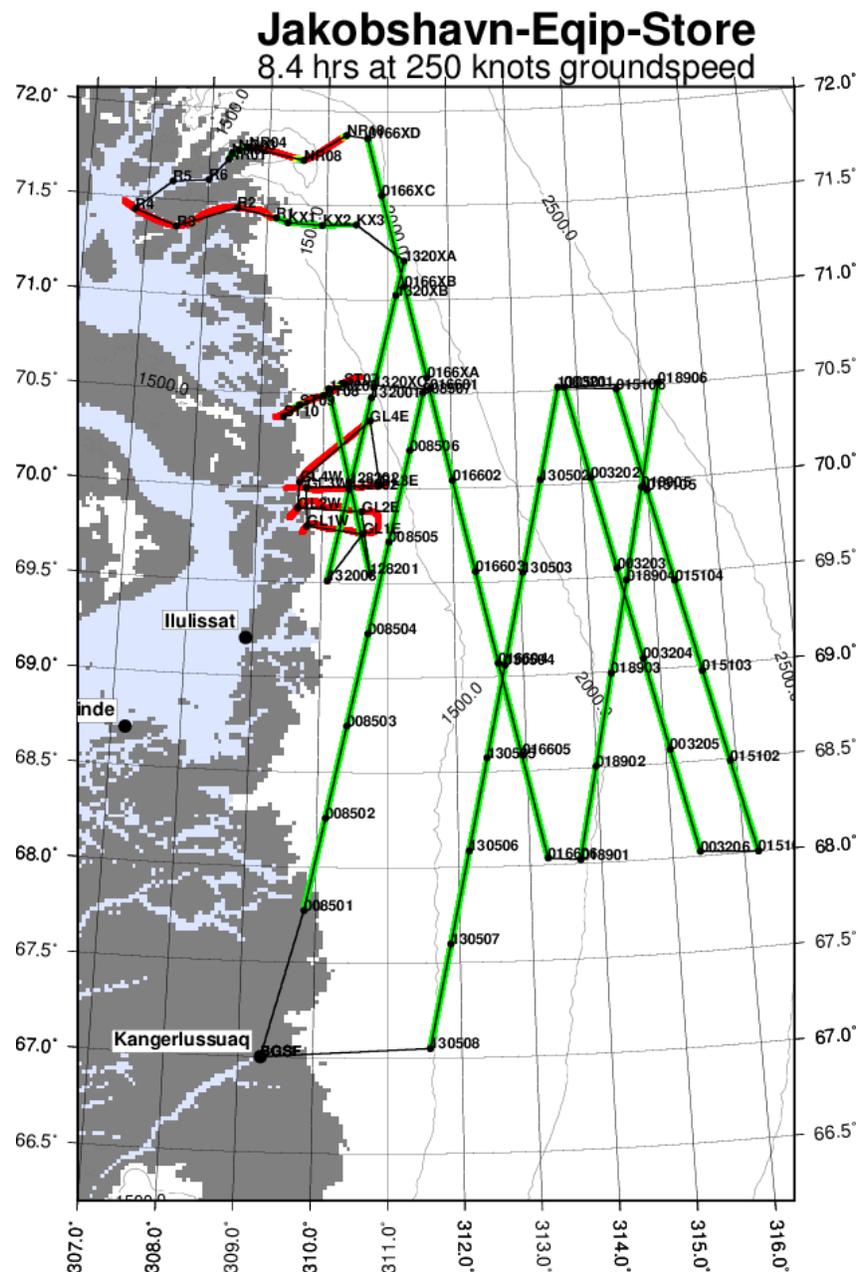
This is a modified version of the 2011 Jakobshavn-Lake mission, whose main purpose it to extend the ICESat grid begun with Jakobshavn 01 farther upstream. We also densify the ICESat grid over the Eqip Sermia catchment area north of Jakobshavn, and we re-fly the centerlines of Eqip Sermia, Kangilerngata Sermia, Sermeq Kujalleq and Store Glaciers. Finally we re-fly the Rink and Kangerdlugssup centerlines.

Flight Priority: baseline (annual repeat flight)

ICESat Track: 0085,1320,1282,0166,0189,0032,0151,1305

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Umanaq A / Kangerlussuaq

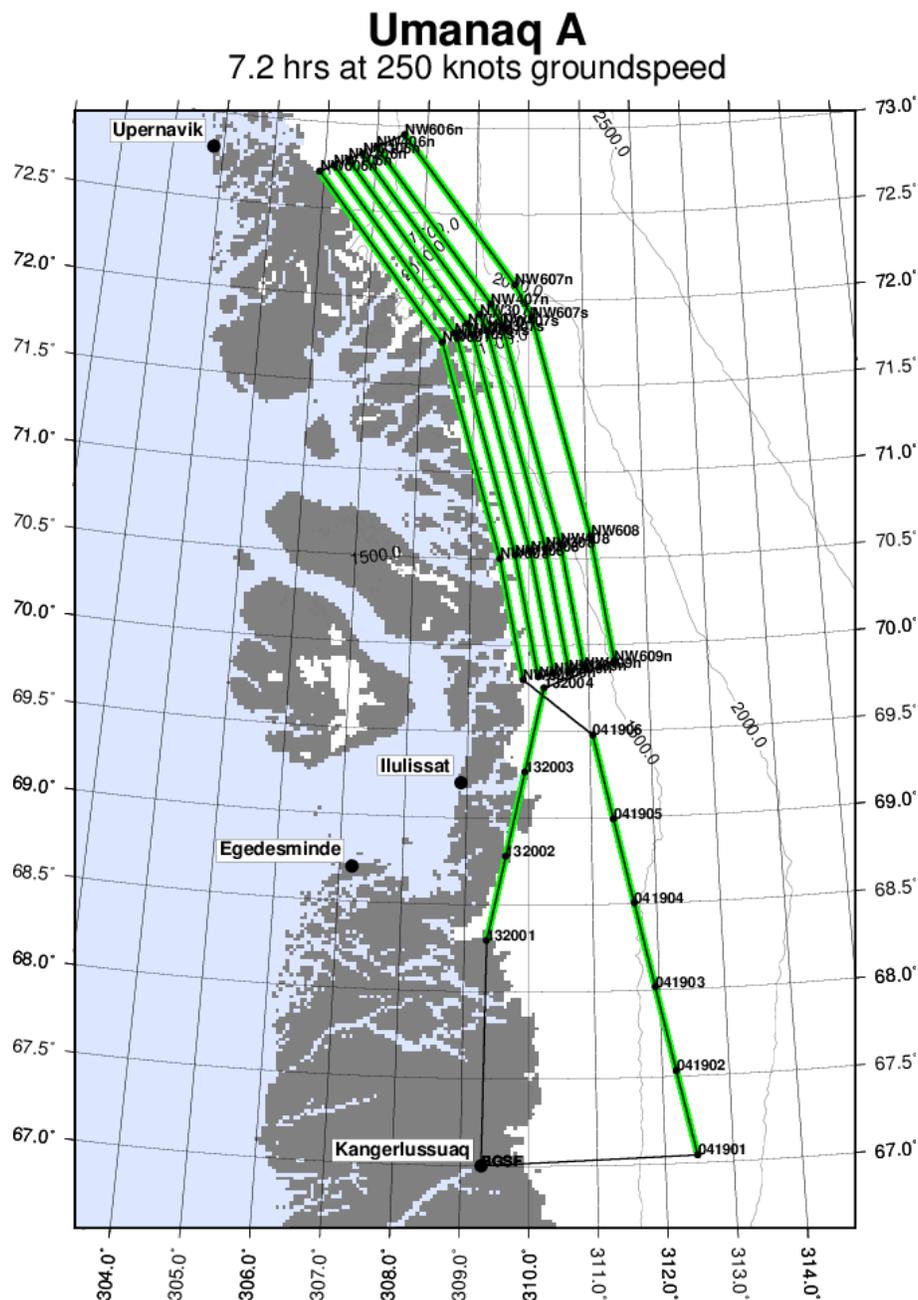
This mission was designed (along with Umanaq B) to re-fly the 2012 Umanaq coast-parallel grid with a pair of interlaced missions. This mission by itself reoccupies a grid spaced at 10 km near the coast, widening to 20 km upstream. The two flights together establish a grid at half this spacing.

Flight Priority: low (multi-year repeat flight)

ICESat Track: none

Last Flown: 2012

Remaining Issues: none



Land Ice – Umanaq B / Kangerlussuaq

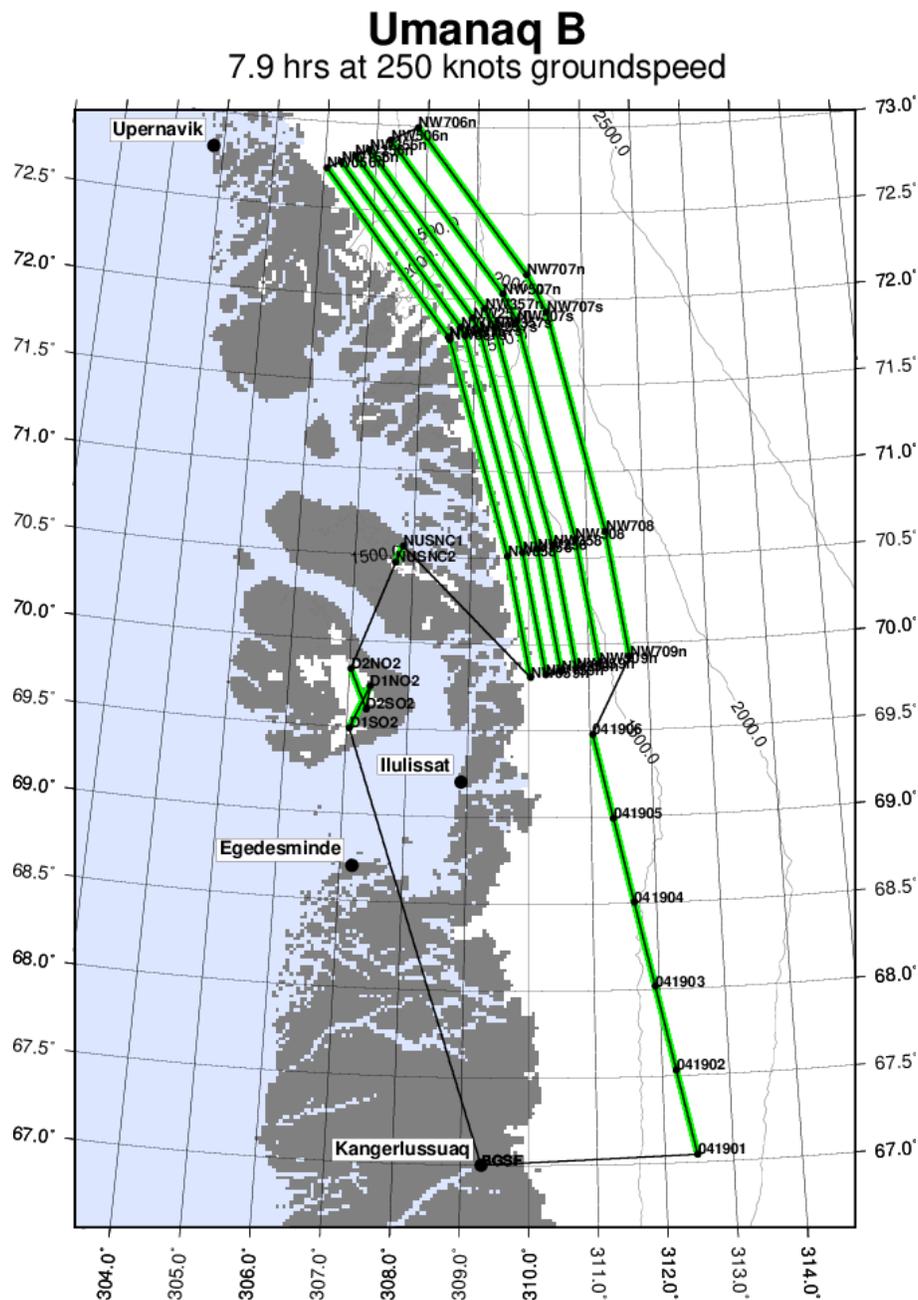
This mission is designed (along with Umanaq A) to re-fly the 2012 Umanaq coast-parallel grid with a pair of interlaced missions. This mission by itself reoccupies a grid spaced at 10 km near the coast, widening to 20 km upstream. The two flights together establish a grid at half this spacing. We also fly a pair of lines over the Disko Island ice cap, and another over the Nuussuaq Peninsula. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Issues: none



Land Ice – East Glaciers 01 / Kangerlussuaq

This mission maps the centerlines of several glaciers on the central east coast of Greenland. This particular draft captures the centerlines of six glaciers: DeGeer, Jaette, Nordenskiold, Wahlenberg, Violin and Nord Glaciers. The first two were originally flown during the 2009 OIB campaign, and all were flown in 2012. The Violin centerline passes within 1 km of two PROMICE sites. We transit to the area along a line connecting the DYE2 and GRIP drill sites, and return along a historical ATM line dating to 1993.

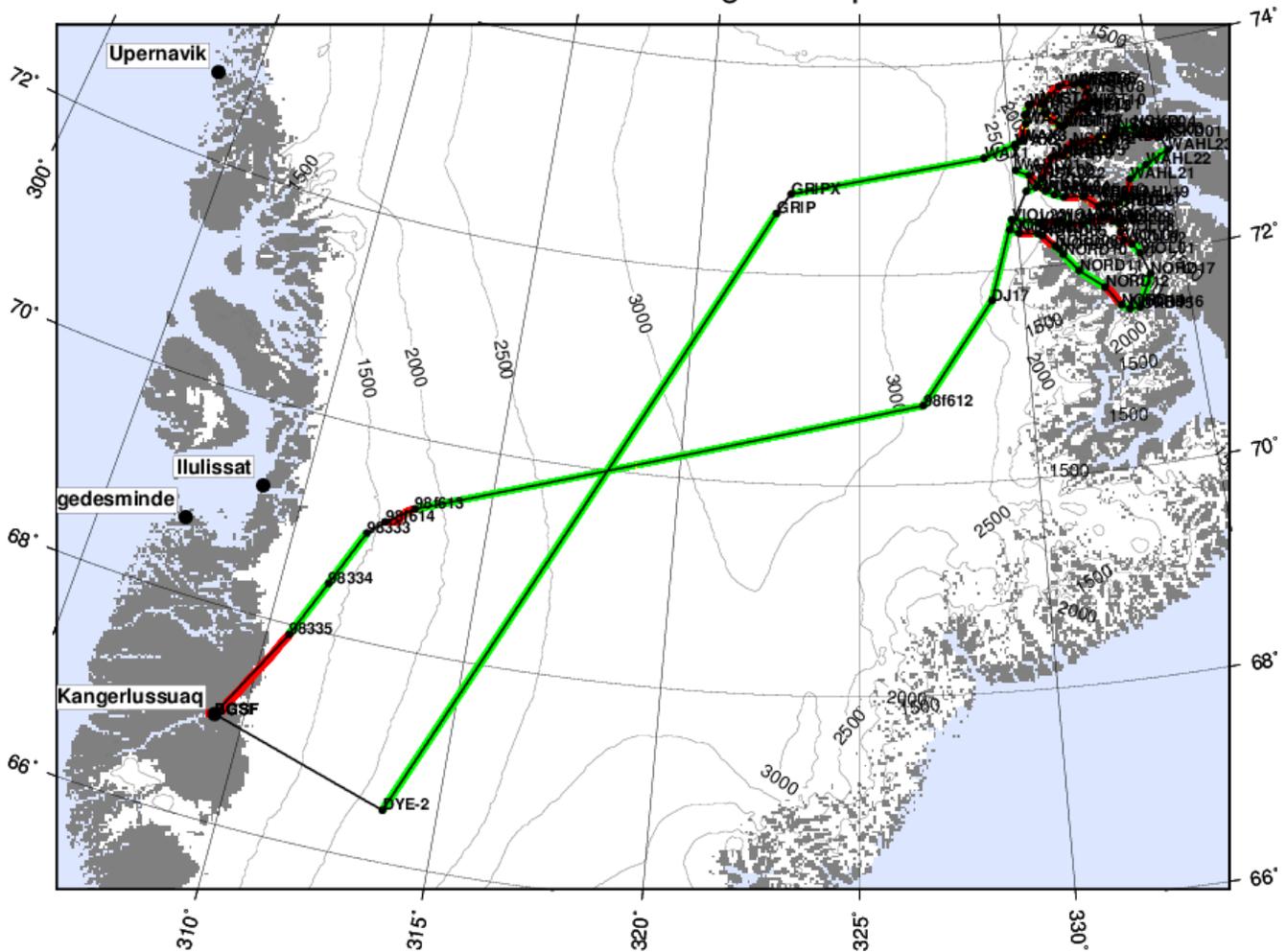
Flight Priority: low (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Issues: none

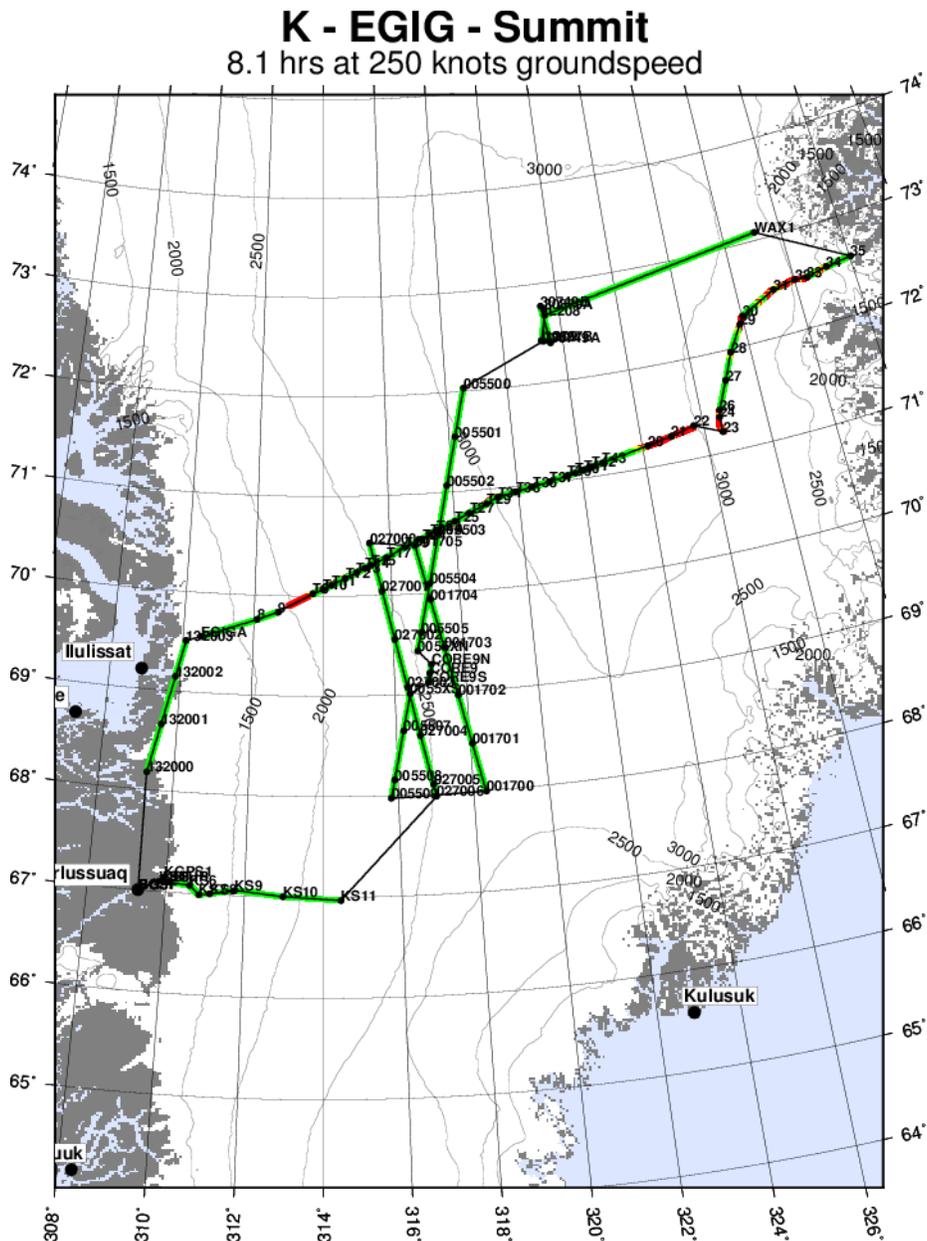
East Glaciers 01 7.5 hrs at 250 knots groundspeed



Land Ice – K-EGIG-Summit / Kangerlussuaq

This mission was designed to accomplish a number of high-priority tasks. First, we re-fly the van den Broeke “K-Transect” in the Russell Glacier catchment, consisting of several sites where comprehensive glaciological measurements are collected annually. We also fly the EGIG traverse line, which is expected to be occupied as part of the CryoVex effort in spring 2014. We overfly the IceSat-1 track 412 Summit calibration site, and we fly two IceSat-2 groundtracks in the same area near Summit, with the expectation that these will become regular calibration sites as well. For 2016, we add an overflight of a GreenTrACS core near IceSat track 0055. Finally we extend the coverage of the Jakobshavn basin upstream along IceSat-1 tracks, to capture continued inland progression of thinning there.

- Flight Priority:** baseline (annual repeat flight)
- ICESat Track:** 0055,0017,0270
- Last Flown:** 2015
- Remaining Design Issues:** none



Land Ice – Helheim-Kangerdlugssuaq Gap A / Kangerlussuaq

This mission is designed (along with Helheim-Kangerdlugssuaq Gap B) to re-fly a 2012 grid over the area of complex terrain between the Helhim and Kangerdlugssuaq Glaciers. Each of these new missions alone forms a coast-parallel grid spaced at 20 km, and the two flights together interlace to form a 10-km grid. This particular mission also reoccupies the centerline of the Hutchinson Glacier.

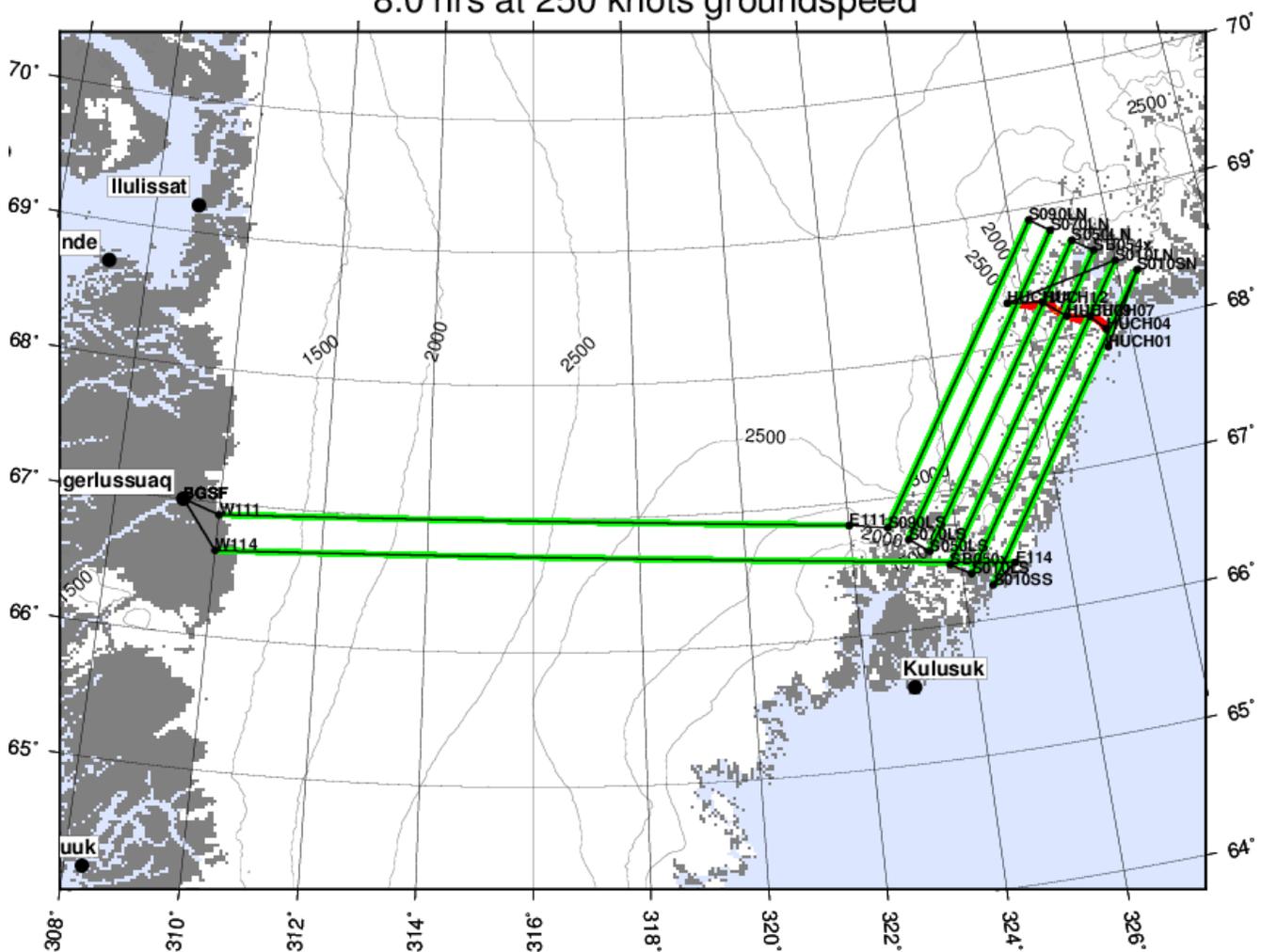
Flight Priority: low (multi-year repeat flight)

ICESat Track: none

Last Flown: 2012

Remaining Design Issues: none

Helheim-Kangerdlugssuaq Gap A 8.0 hrs at 250 knots groundspeed



Land Ice – Helheim-Kangerdlugssuaq Gap B / Kangerlussuaq

This mission is designed (along with Helheim-Kangerdlugssuaq Gap A) to re-fly a 2012 grid over the area of complex terrain between the Helhim and Kangerdlugssuaq Glaciers. Each of these new missions alone forms a coast-parallel grid spaced at 20 km, and the two flights together interlace to form a 10-km grid. This particular mission also reoccupies the centerlines of two glaciers in the area (names unknown). This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat flight)

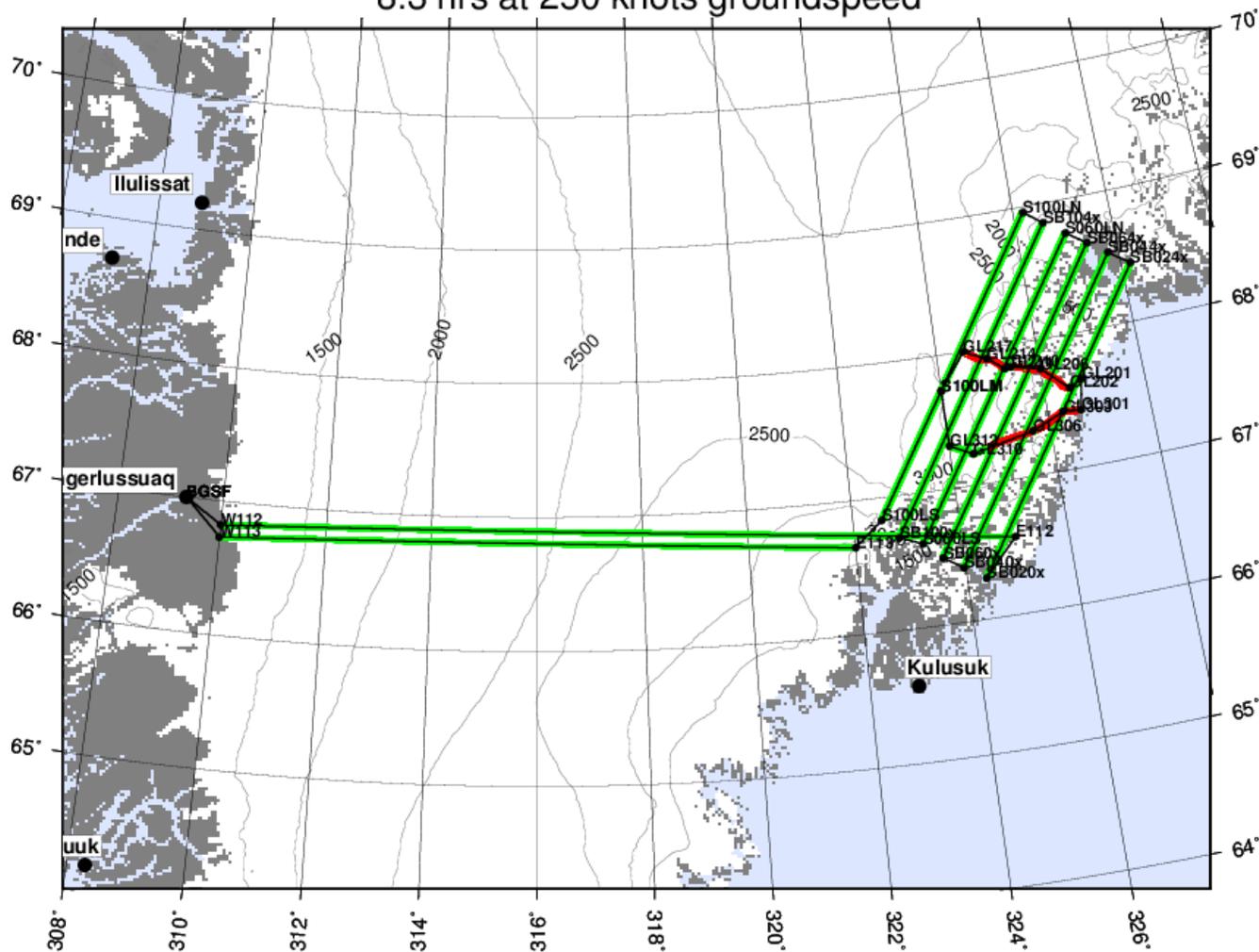
ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none

Helheim-Kangerdlugssuaq Gap B

8.3 hrs at 250 knots groundspeed



Land Ice – OSU Clusters / Kangerlussuaq

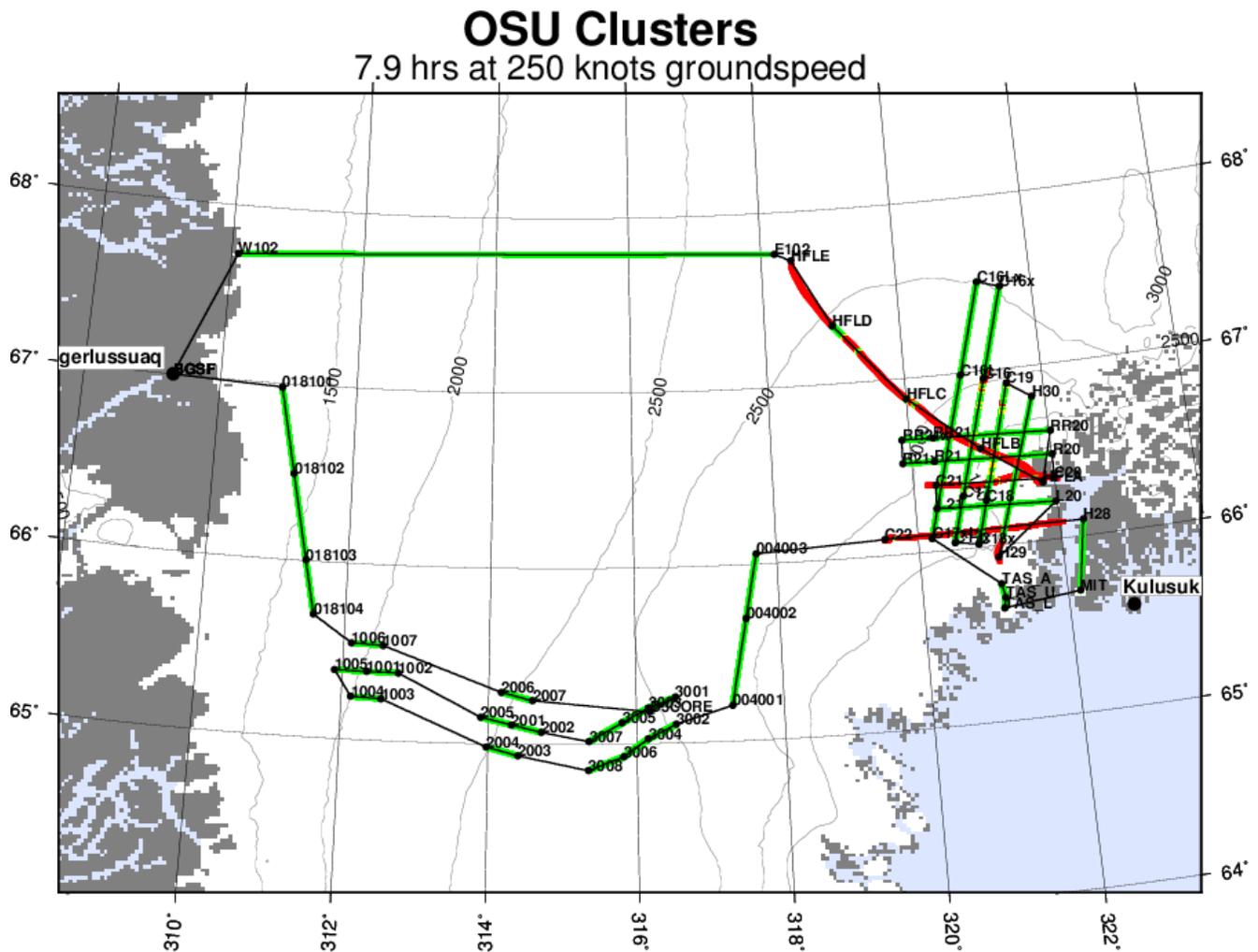
This mission was designed with several goals in mind. First, we re-fly the OSU Cluster sites straddling the ice divide southeast of Kangerlussuaq. We also fly a centerline of Helheim Glacier from the terminus all the way to the ice divide, and we re-fly a ~15-km grid pattern over the lower Helheim catchment last flown by the ATM/KU teams in 2008. Finally we overfly four PROMICE sites straddling the mouth of Sermilik Fjord, and we overfly the DYE-3 core.

Flight Priority: medium (multi-year repeat flight)

ICESat Track: 0040,0181

Last Flown: 2014

Remaining Design Issues: none



Land Ice – Southeast Coastal / Kangerlussuaq

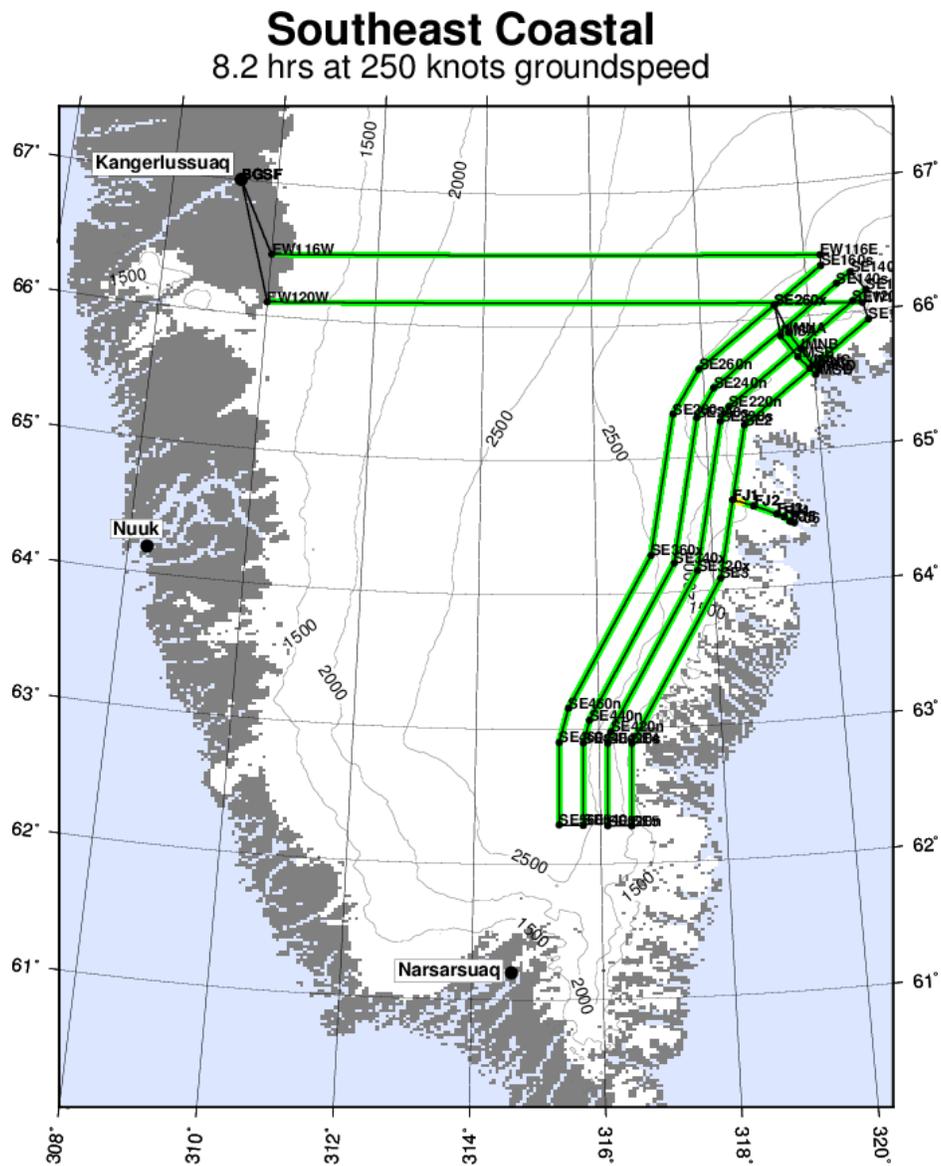
This mission reflies a 20-km coast-parallel grid along the southeast Greenland coast, enabling direct measurement of dh/dt in the catchment areas of the many major glaciers in the area across a range of surface elevations. It also reflies the centerlines of the Fridtjof Glacier, as well as the two central branches of the Ikertivaq Glaciers. The Ikertivaq centerlines are new for 2015. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Southeast Flank 01 / Kangerlussuaq

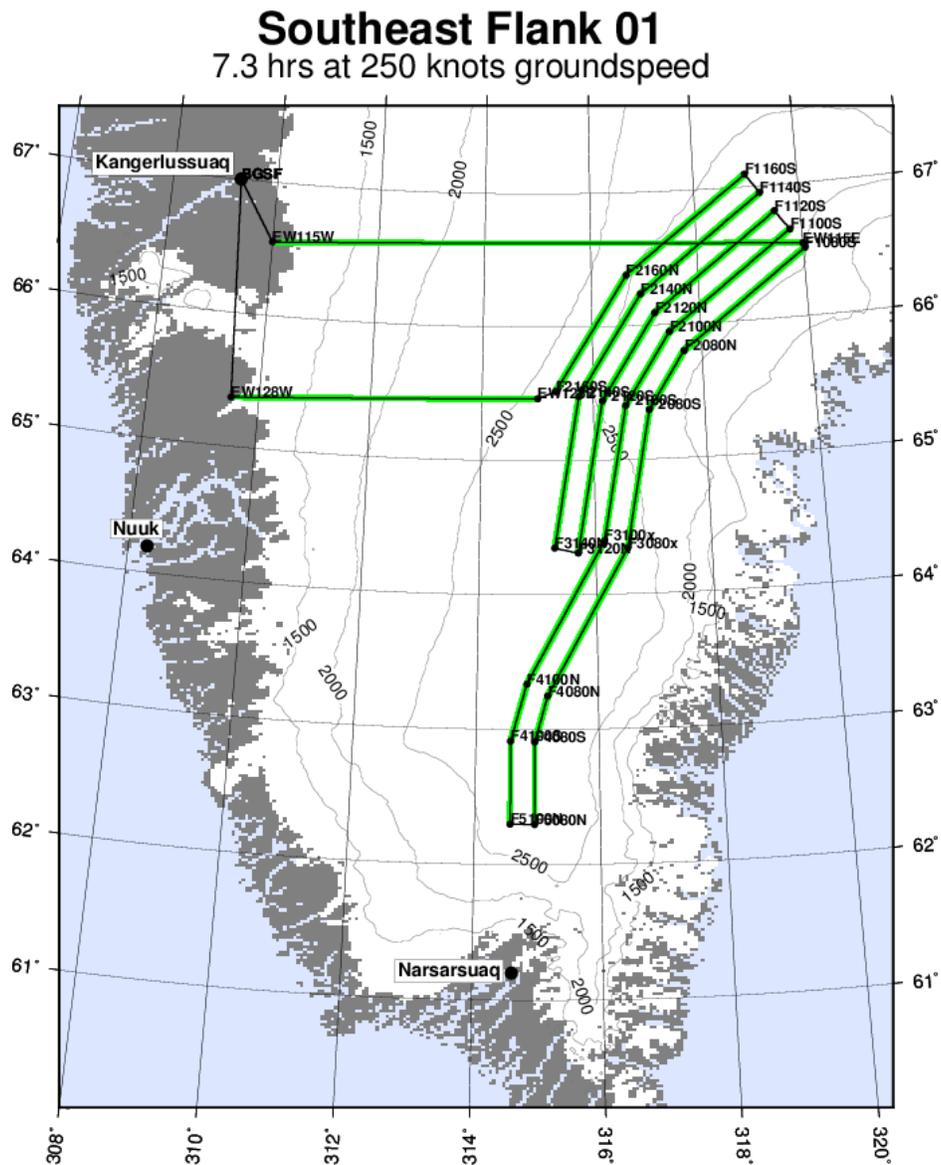
This mission reflies a 20-km coast-parallel grid along the upper southeastern flank of the ice sheet, enabling direct measurement of dh/dt in the catchment areas of the many major glaciers in the area across a range of surface elevations. It continues the dh/dt record of the Southeast Coastal mission up to the ice divide in this area.

Flight Priority: low (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

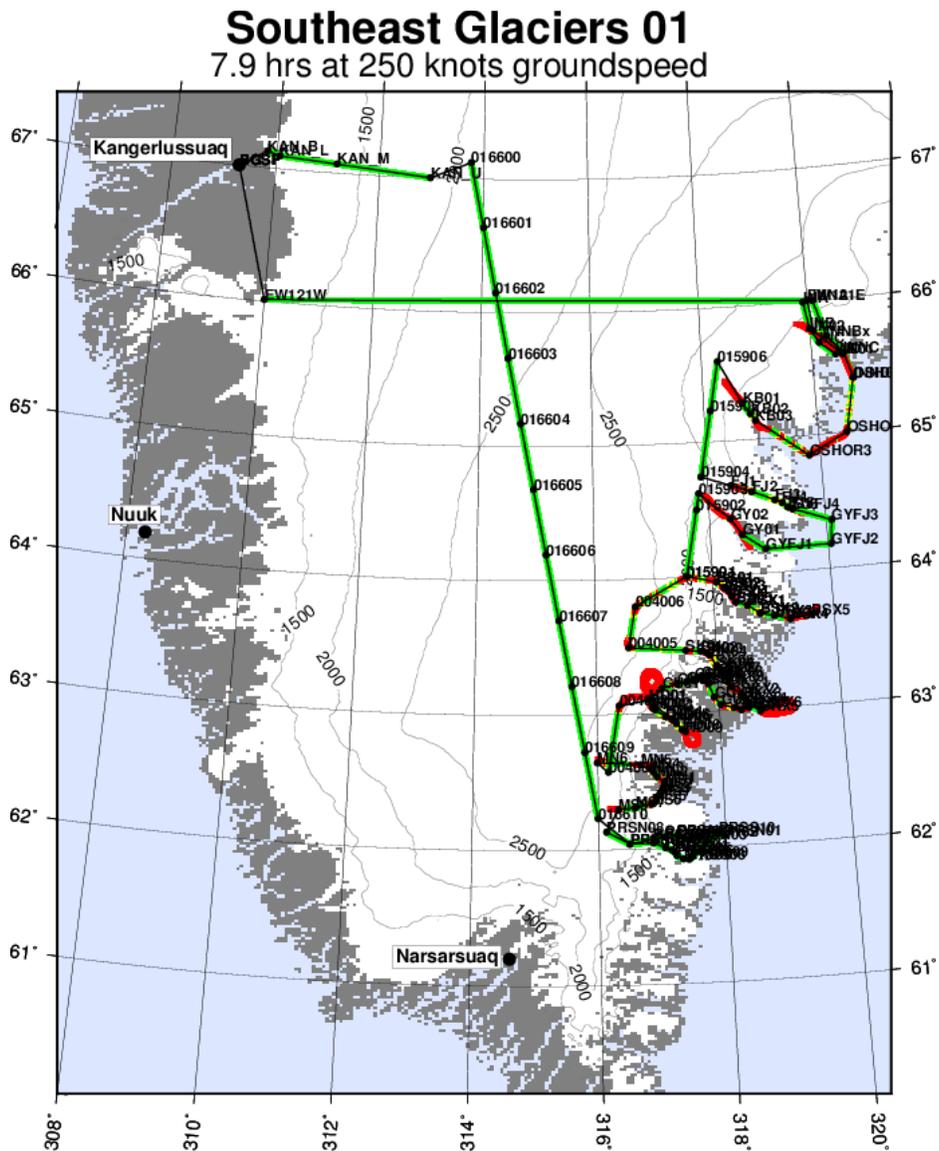
Remaining Design Issues: none



Land Ice – Southeast Glaciers 01 / Kangerlussuaq

This mission is a near-repeat of the 2012/2013/2014 Southeast Glaciers mission. Its primary purpose is to continue dh/dt monitoring of 10 glaciers in the southeast which have been flown since 2008, and two additional glaciers in the south near the Pursortoq peninsula first flown in 2012. We also occupy an ICESat line between the southernmost glacier and Kangerlussuaq, and an east-west master grid line between the northernmost glacier and Kangerlussuaq. We overfly four PROMICE sites near Kangerlussuaq. For 2015 we added new lines on the Ikertivaq-N and Ikertivaq-NN channels of Ikertivaq Glacier, since the original line was not optimally placed. The original line is nevertheless retained here for dh/dt continuity purposes.

- Flight Priority:** baseline (annual repeat flight)
- ICESat Track:** 0166,0040,0159
- Last Flown:** 2015
- Remaining Design Issues:** none



Land Ice – Southwest Coastal B / Kangerlussuaq

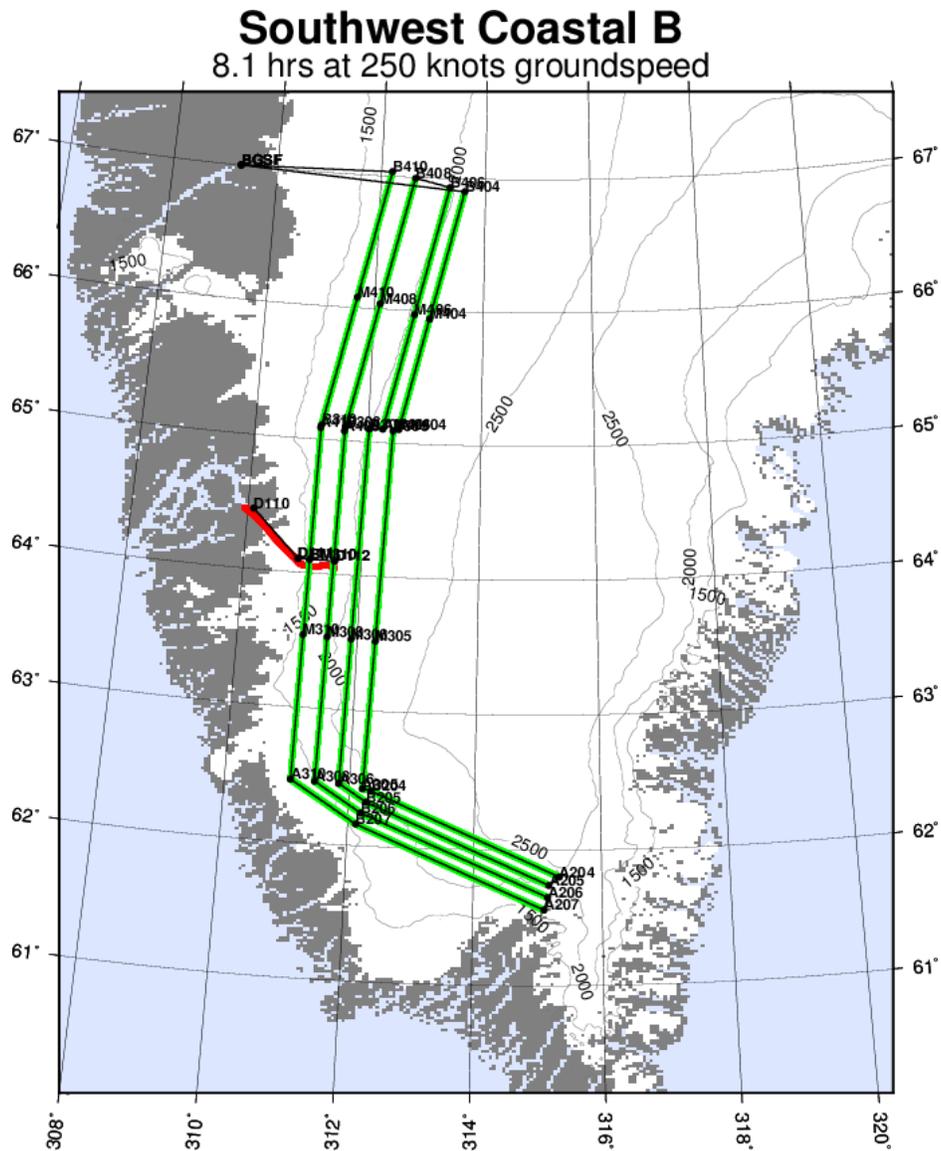
This is a new mission, one of two (with Southwest Coastal A) designed to mirror the southeastern coast-parallel coverage in the southwest, along 2011 LVIS flight lines. This particular flight captures the higher-altitude portion of this part of the ice sheet. We also fly an out-and-back pattern on the Kangiata Nunaata Sermia glacier, first at normal speed/altitude and second as low and slow as possible, in order to explore differences in MCoRDS radar performance on a difficult target. This flight retains a high priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

Flight Priority: high (multi-year repeat flight)

ICESat Track: none

Last Flown: 2015

Remaining Design Issues: none



Land Ice – Southwest Glaciers 01 / Kangerlussuaq

This mission incorporates previously-flown lines over Sukkertoppen Ice Cap and over four glaciers near Nuuk, including Kangiata Nunaata Sermia, Tasersuaq, Narsap Sermia, and Akugdlerupasermia. We also re-fly a series of ICESat lines covering the southernmost lobe of the Greenland Ice Sheet. We return to Kangerlussuaq along a lengthy ICESat track over southern Greenland.

Flight Priority: medium (multi-year repeat mission)

ICESat Track: 0040,0412,0047,0159,0300

Last Flown: 2014

Remaining Design Issues: none

