Spring 2017 IceBridge Arctic Flight Plans
24 January 2017 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 NASA's rewinged P-3B aircraft, beginning in early March and ending in May 2017. The material is shown on the following pages in the distilled form of a map and brief text description of each science flight.

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, Fairbanks, Alaska, and Longyearbyen, Svalbard. 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 and Sentinel 3a 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 2017. 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.

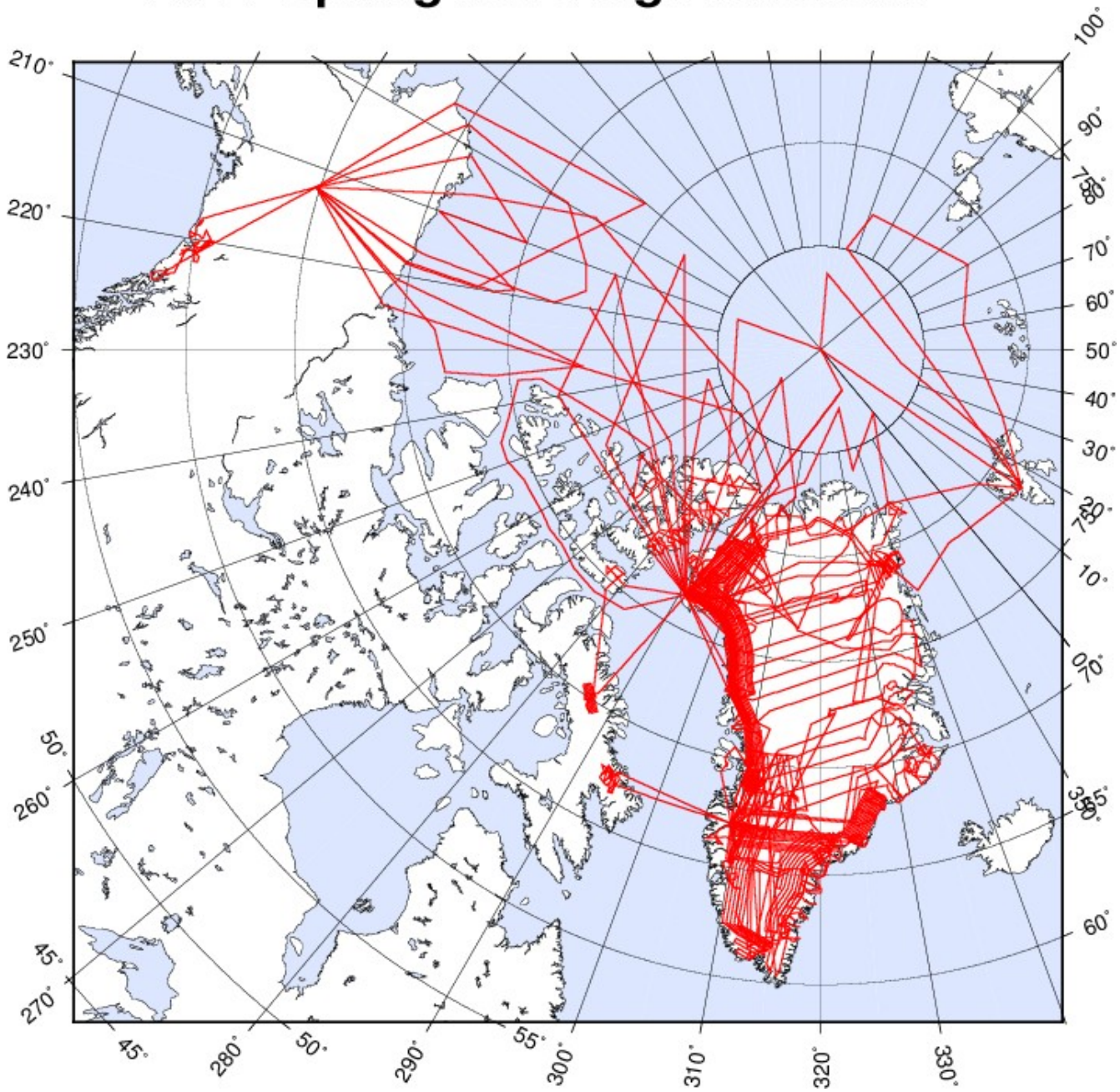
Note that this document shows 47 planned land ice and 16 planned sea ice missions, which is more than we expect to fly this year. The extra flight plans give us operational flexibility to fly as much as possible, and scientifically productive, while we are in the field. The entire suite of 63 flight 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 2017. 32 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 (or baseline) priority for spring 2017, in order to continue the uniquely valuable intra-annual time series for these lines.

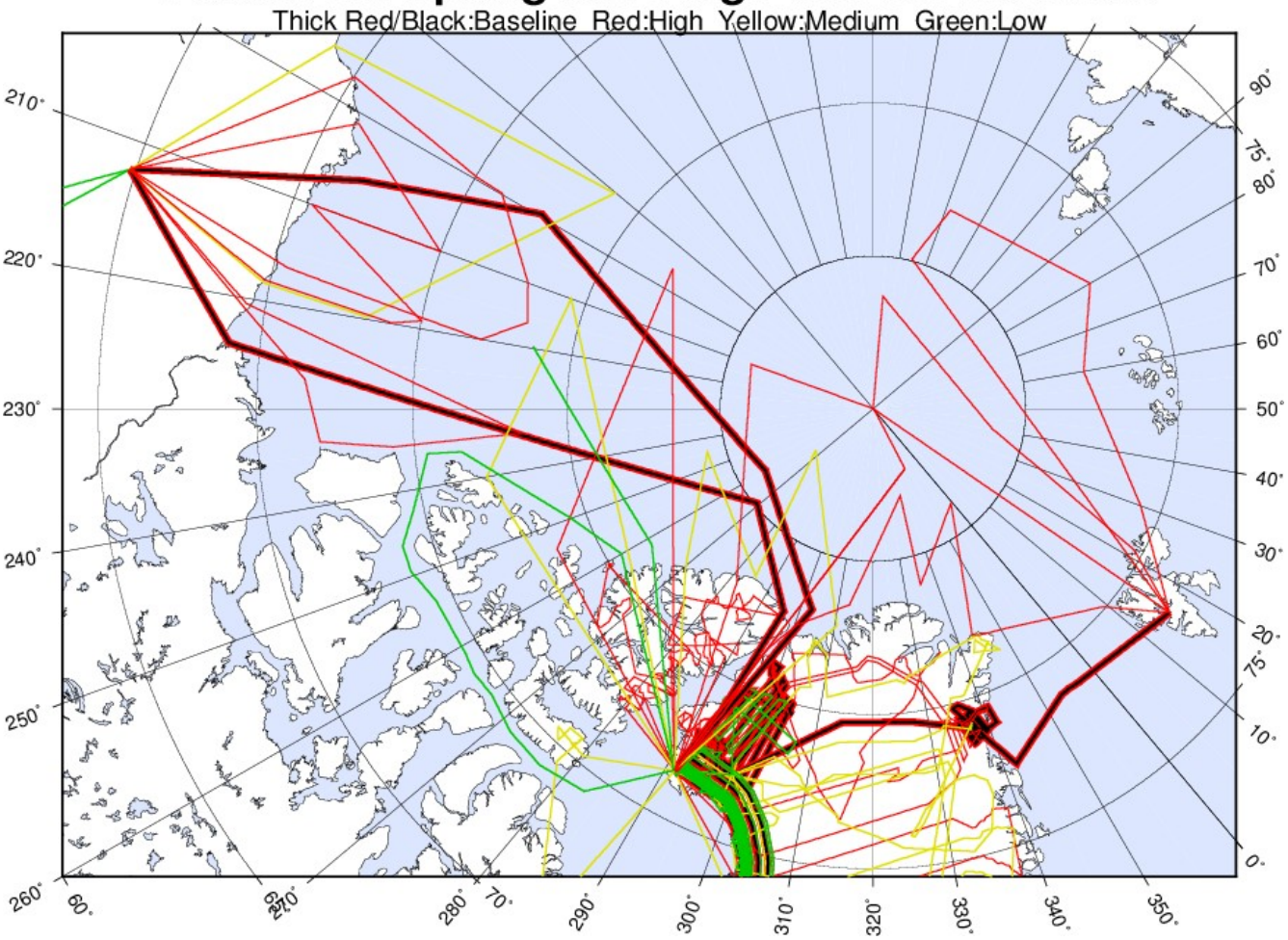
Finally, for spring 2017 a brief deployment from Thule to Longyearbyen, Svalbard is envisioned. The primary purpose of this deployment is to expand the area of Arctic sea ice sampled by OIB, in this case the area on the eastern hemisphere side of the Pole. This arrangement may also enable OIB to reap the benefits of a certain geographical economy, as Longyearbyen is closer to several of our land and sea ice targets than Thule ice. We believe it may thus be possible to expand our sea ice coverage area without adding to the total number of missions flown.

2017 Spring IceBridge Missions



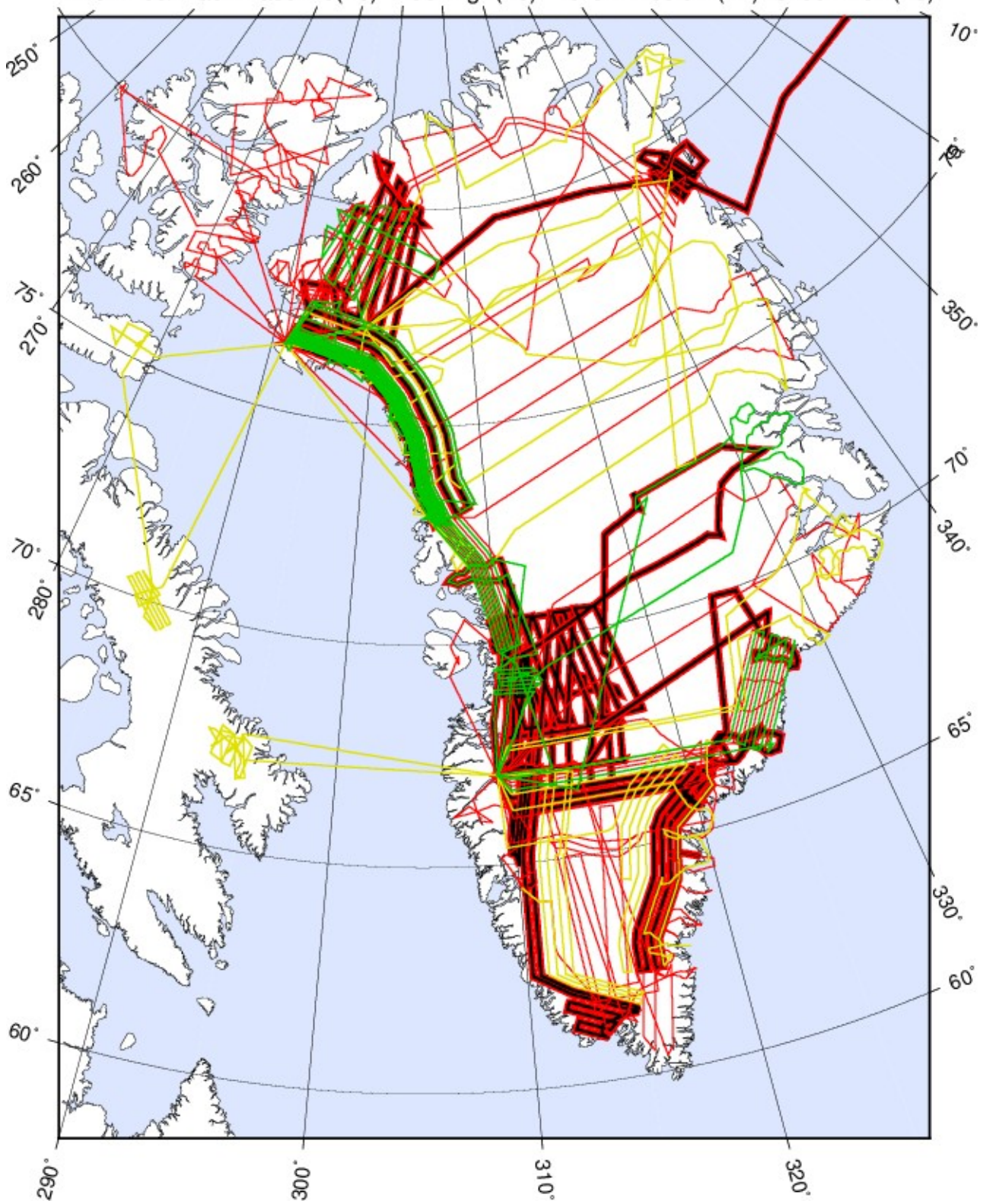
Prioritized Spring IceBridge Sea Ice Missions

Thick Red/Black:Baseline Red:High Yellow:Medium Green:Low



Prioritized Spring 2017 OIB Flight Lines

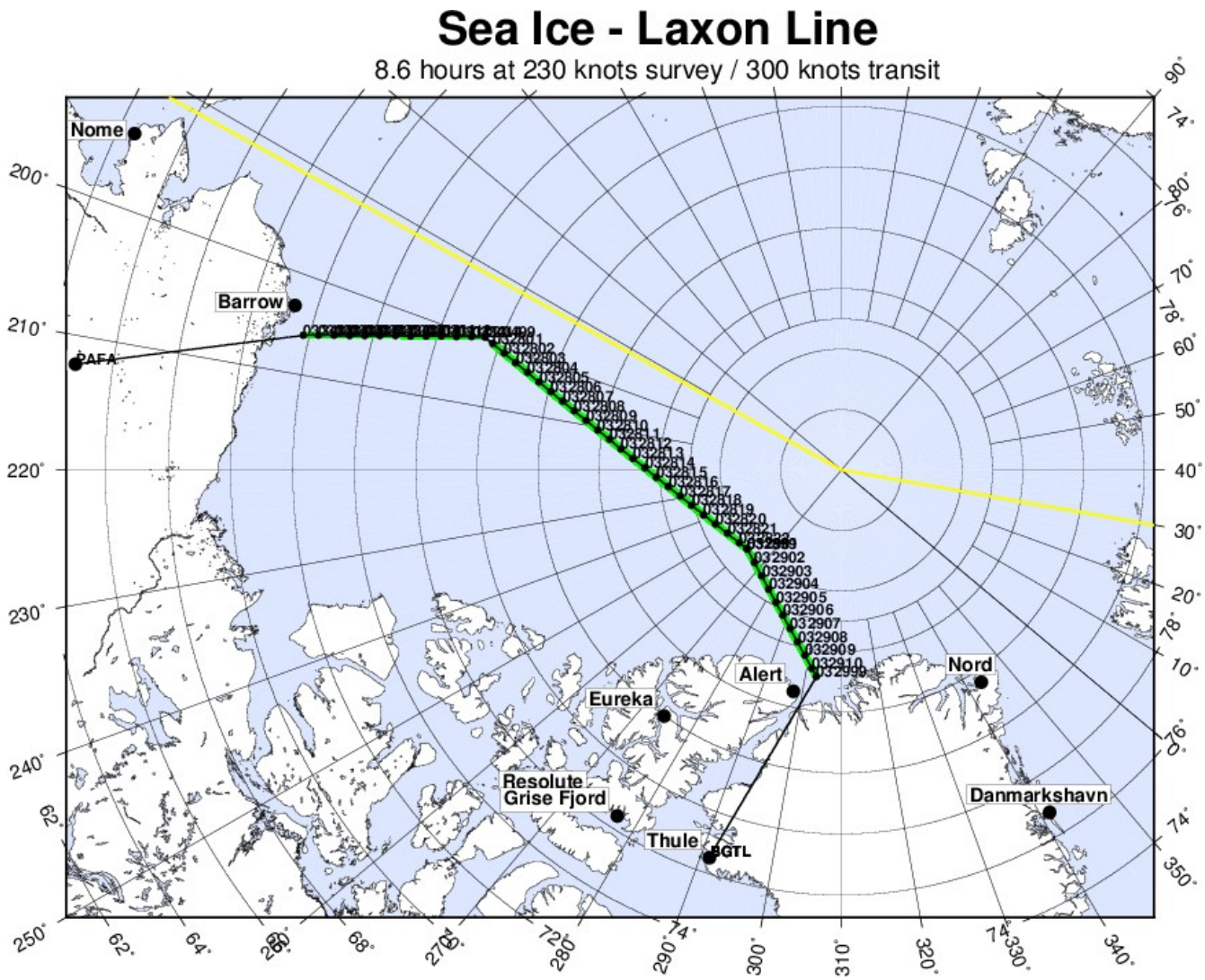
Thick Red/Black:Baseline(10) Red:High(16) Yellow:Medium(11) Green:Low(10)



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.

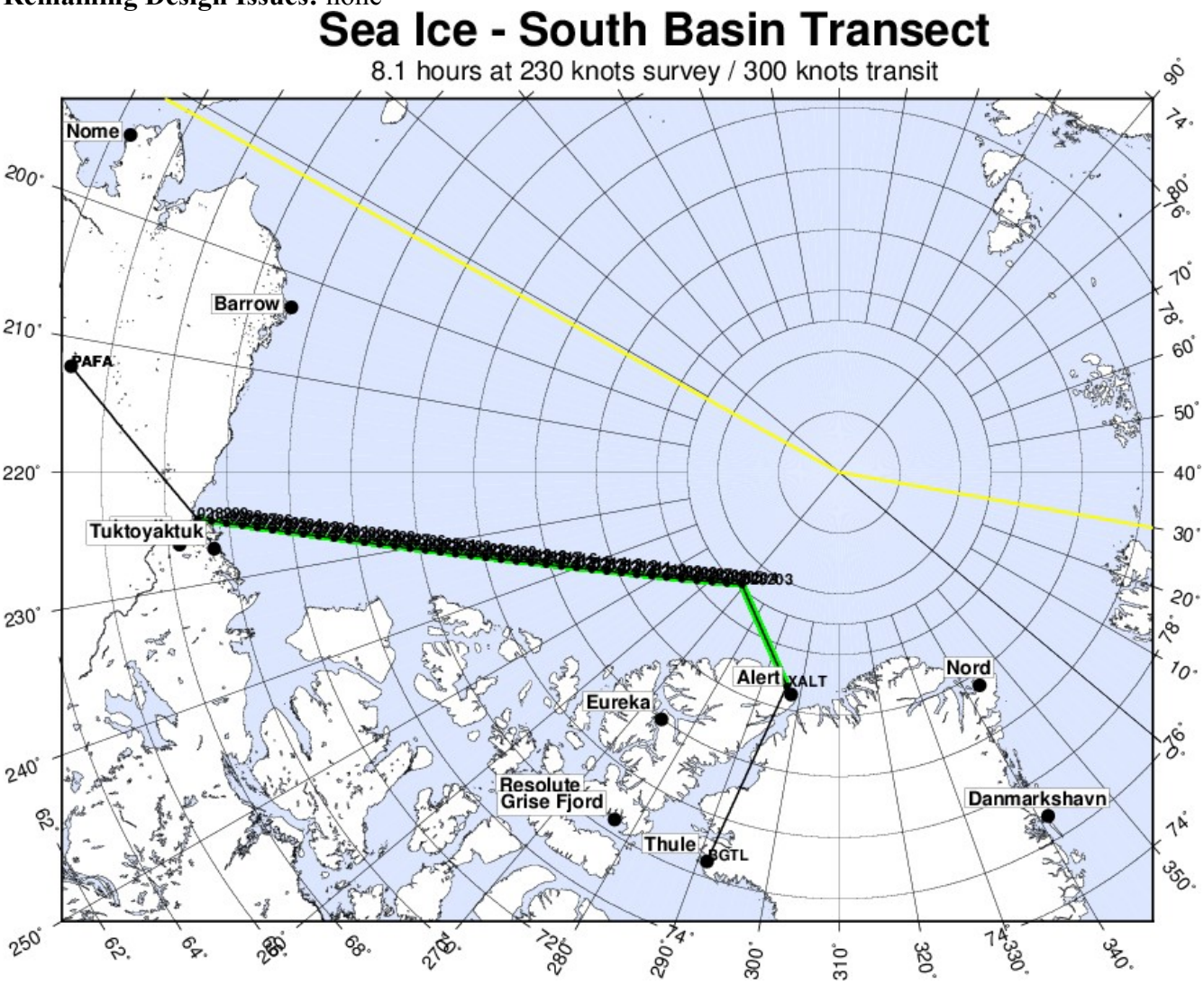
Flight Priority: baseline?
ICESat Tracks: 0329,0328,0334
Last Flown: 2016
Remaining Design Issues: none



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.

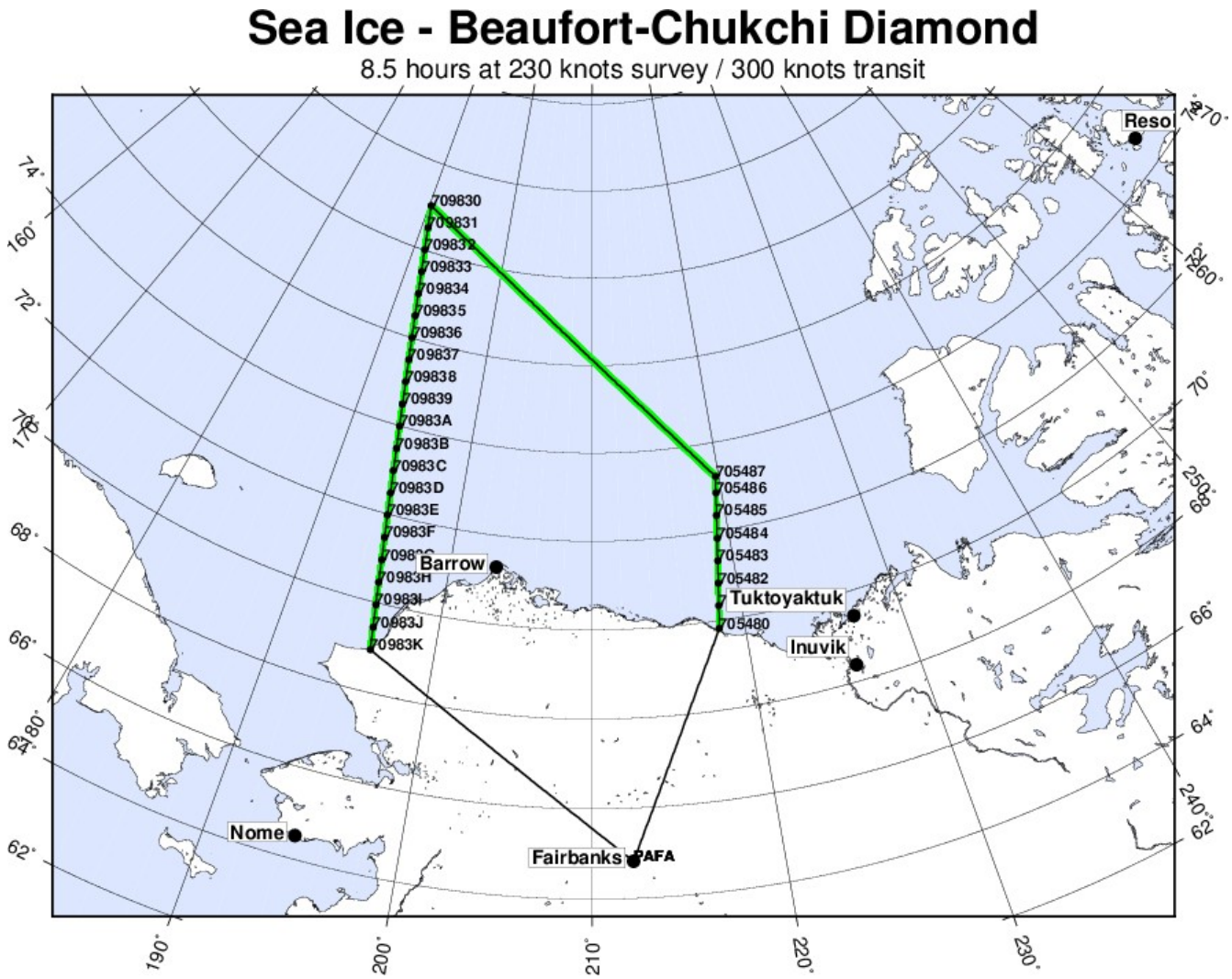
Flight Priority: baseline?
ICESat Tracks: 0282,0284
Last Flown: 2016
Remaining Design Issues: none



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. We fly IceSat-2 tracks on the far eastern and western segments. 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.

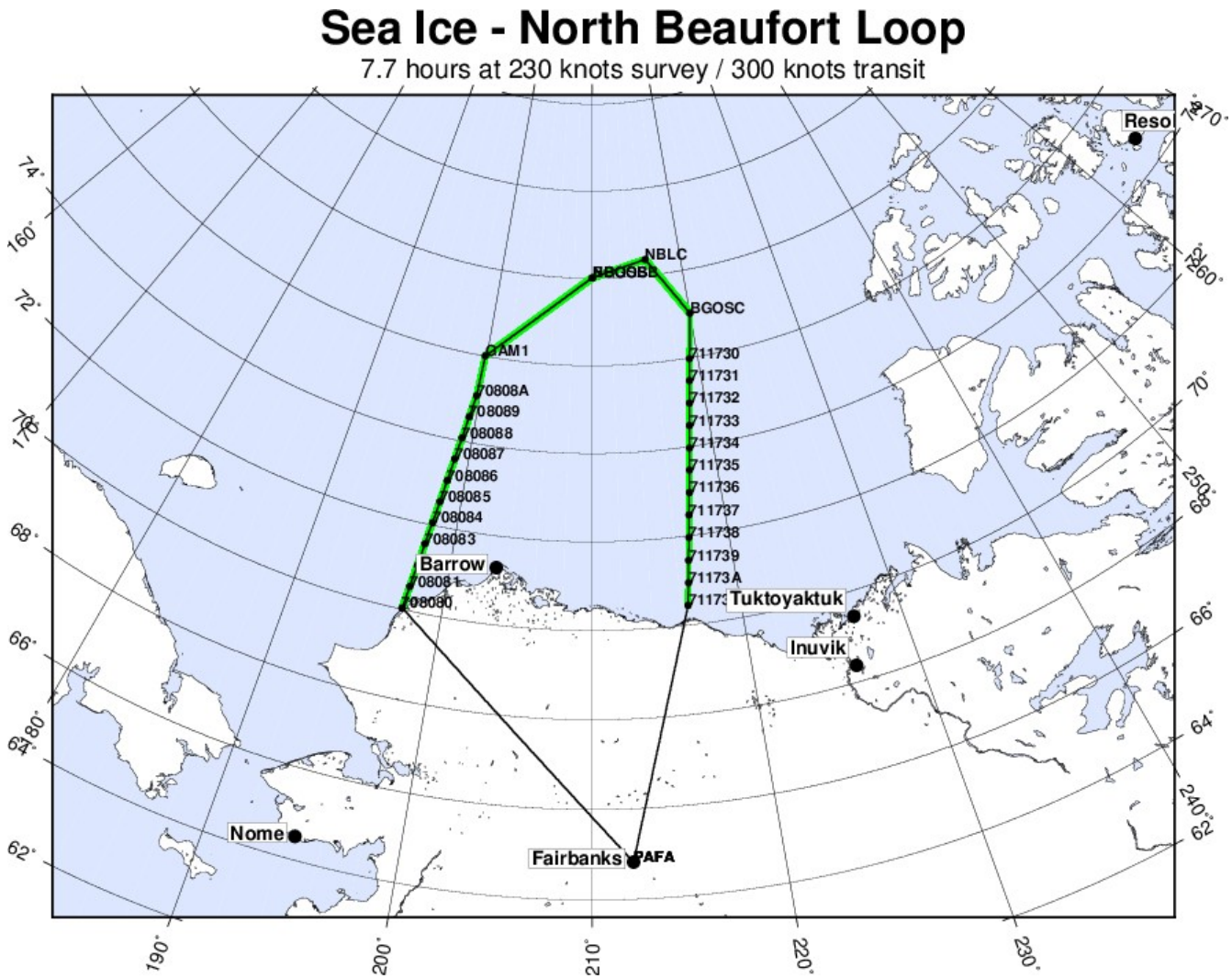
Flight Priority: medium?
ICESat Tracks: none
Last Flown: 2014
Remaining Design Issues: none



Sea Ice – 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. The eastern- and westernmost legs are flown along IceSat-2 ground tracks. 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.

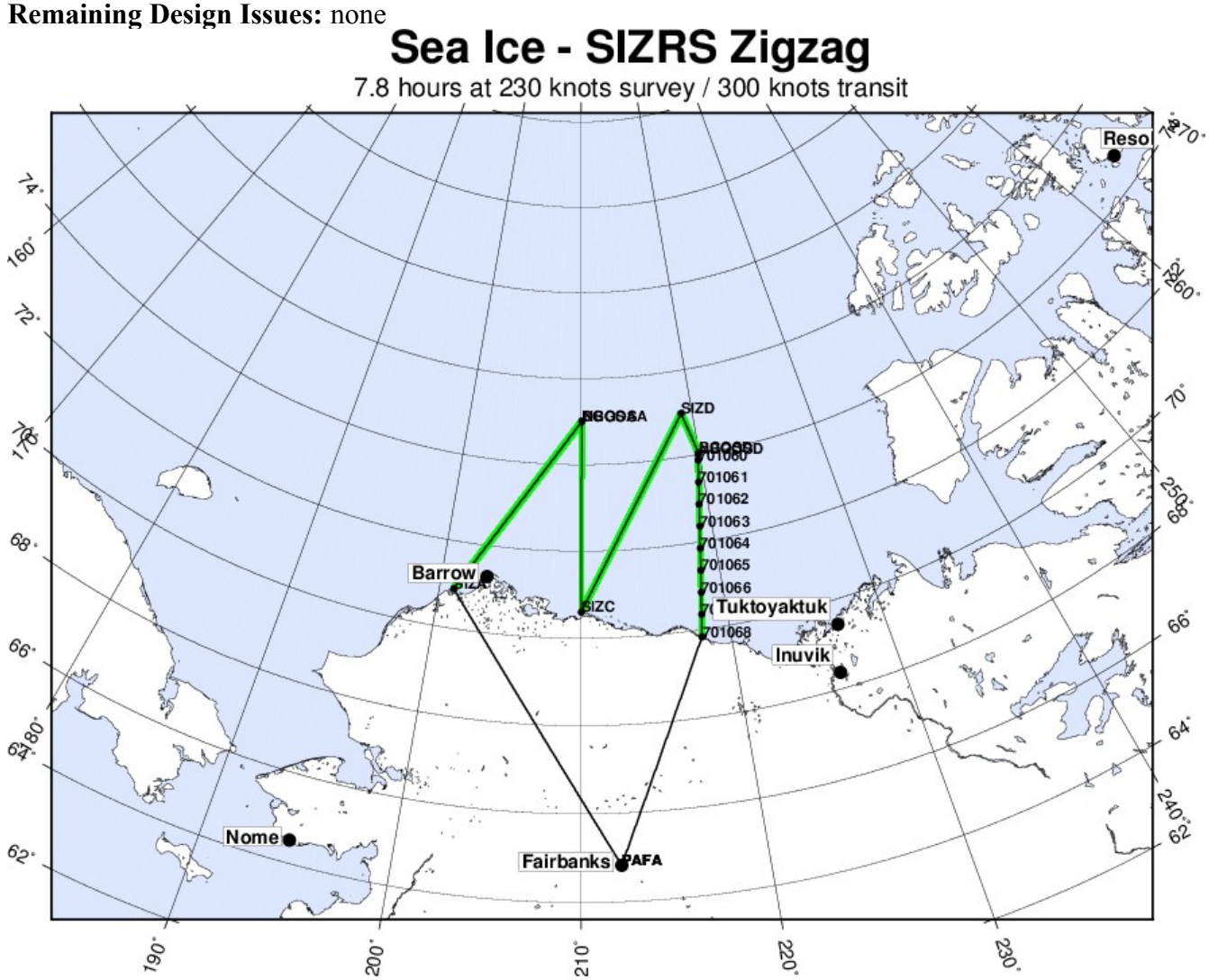
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: none



Sea Ice – 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 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). Finally, we fly an IceSat-2 ground track. 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.

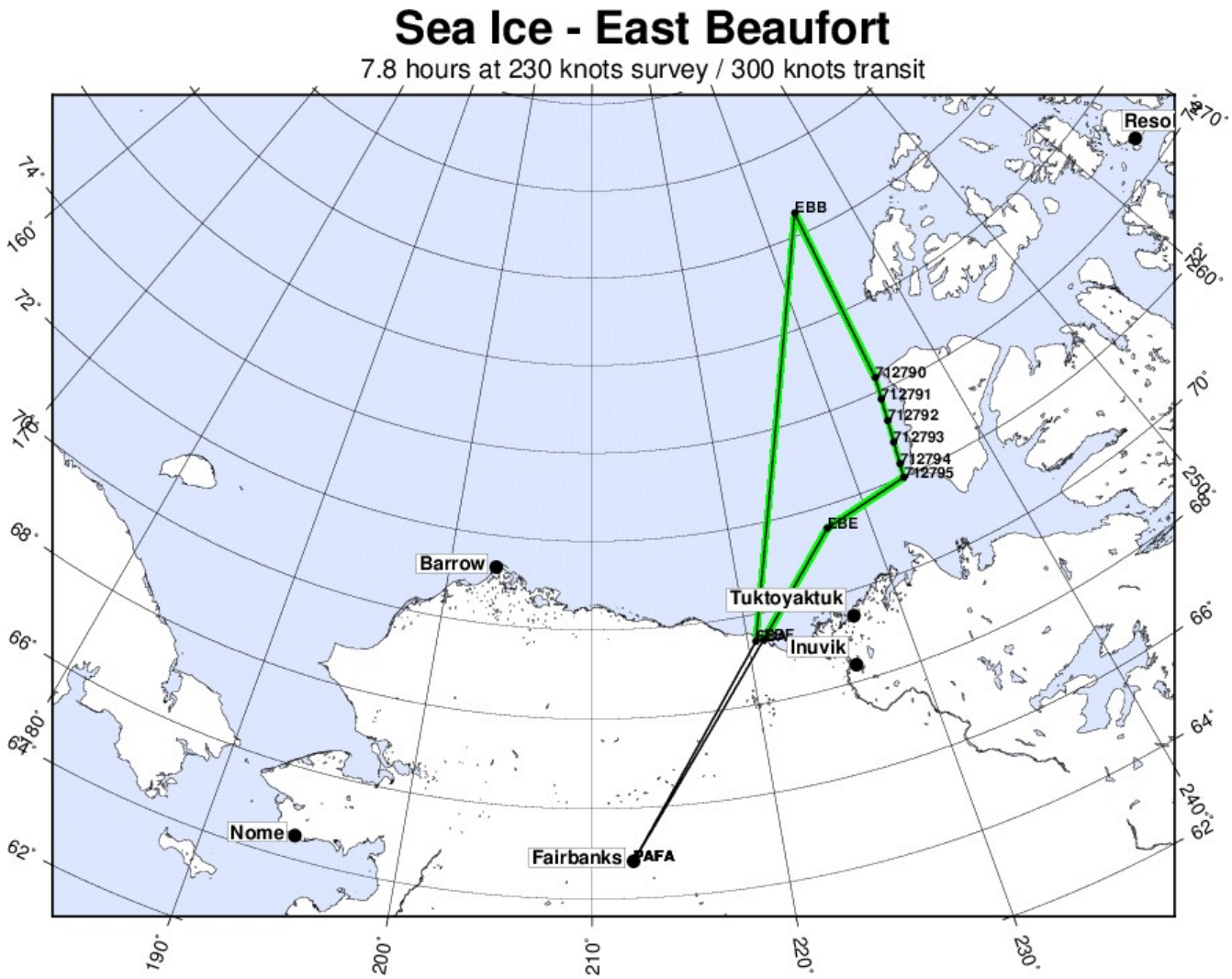
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2016
Remaining Design Issues: none



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. For 2017 we replace the segment just off Banks Island with an almost identical IceSat-2 ground track. 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.

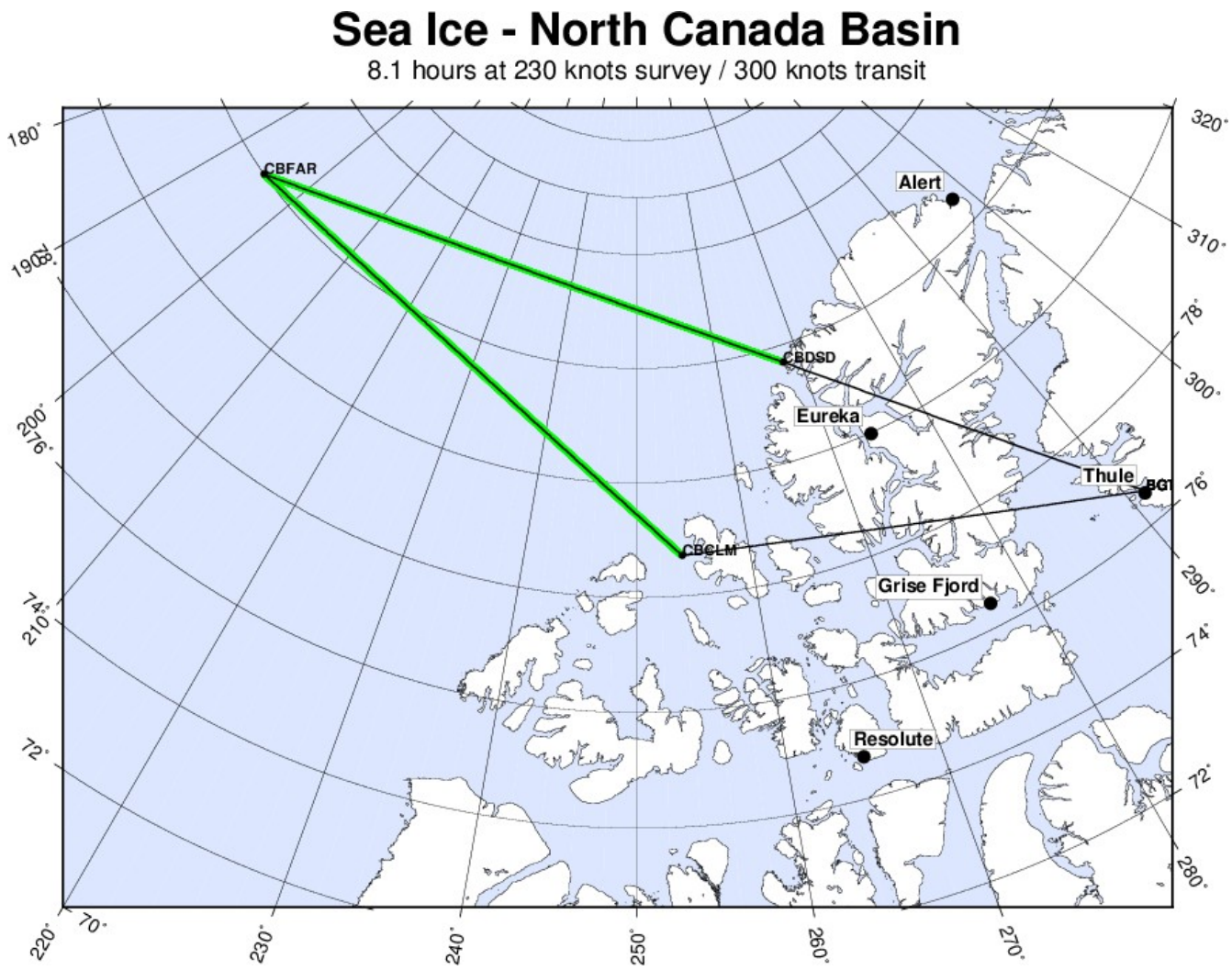
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: none



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.

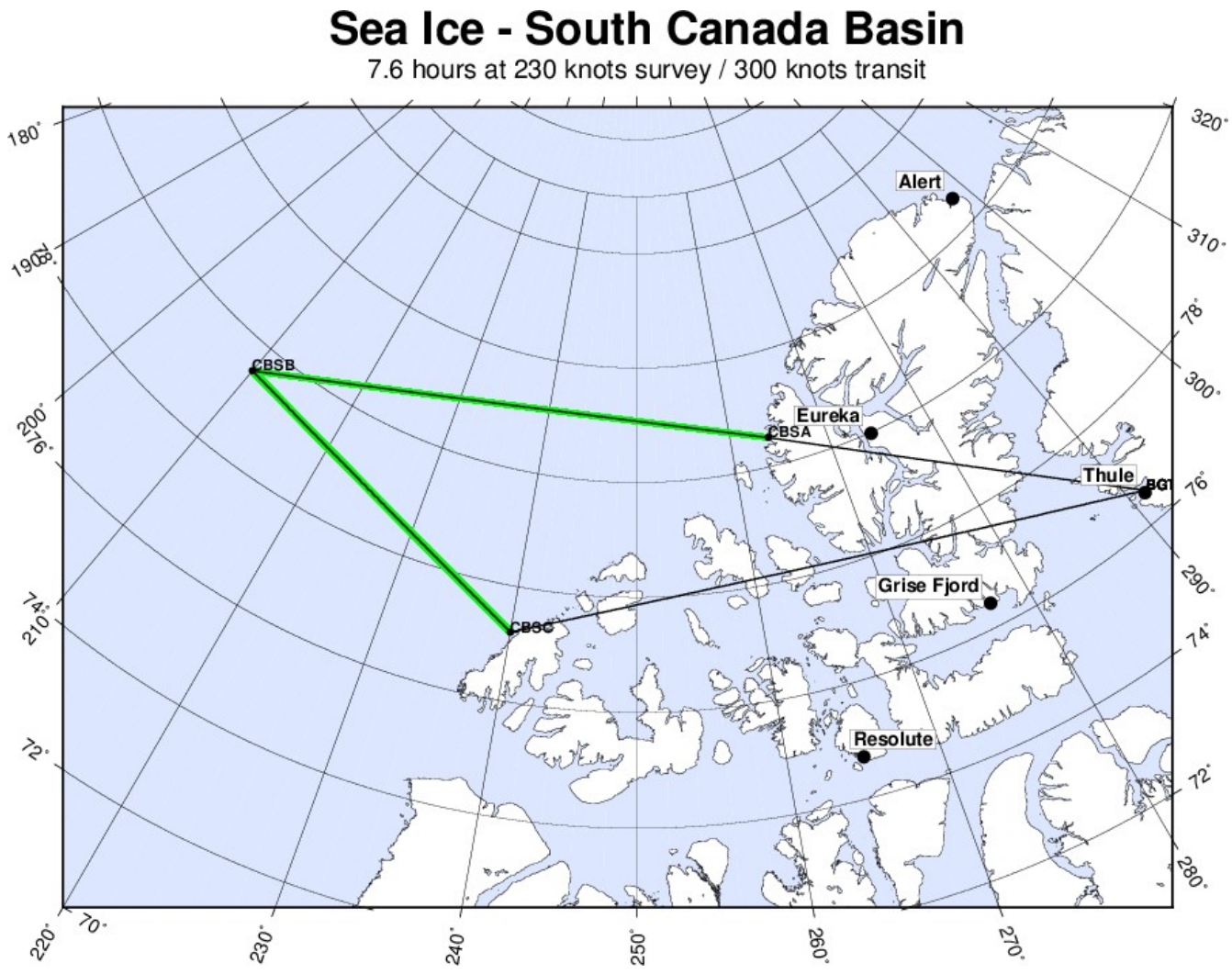
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2014
Remaining Design Issues: none



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.

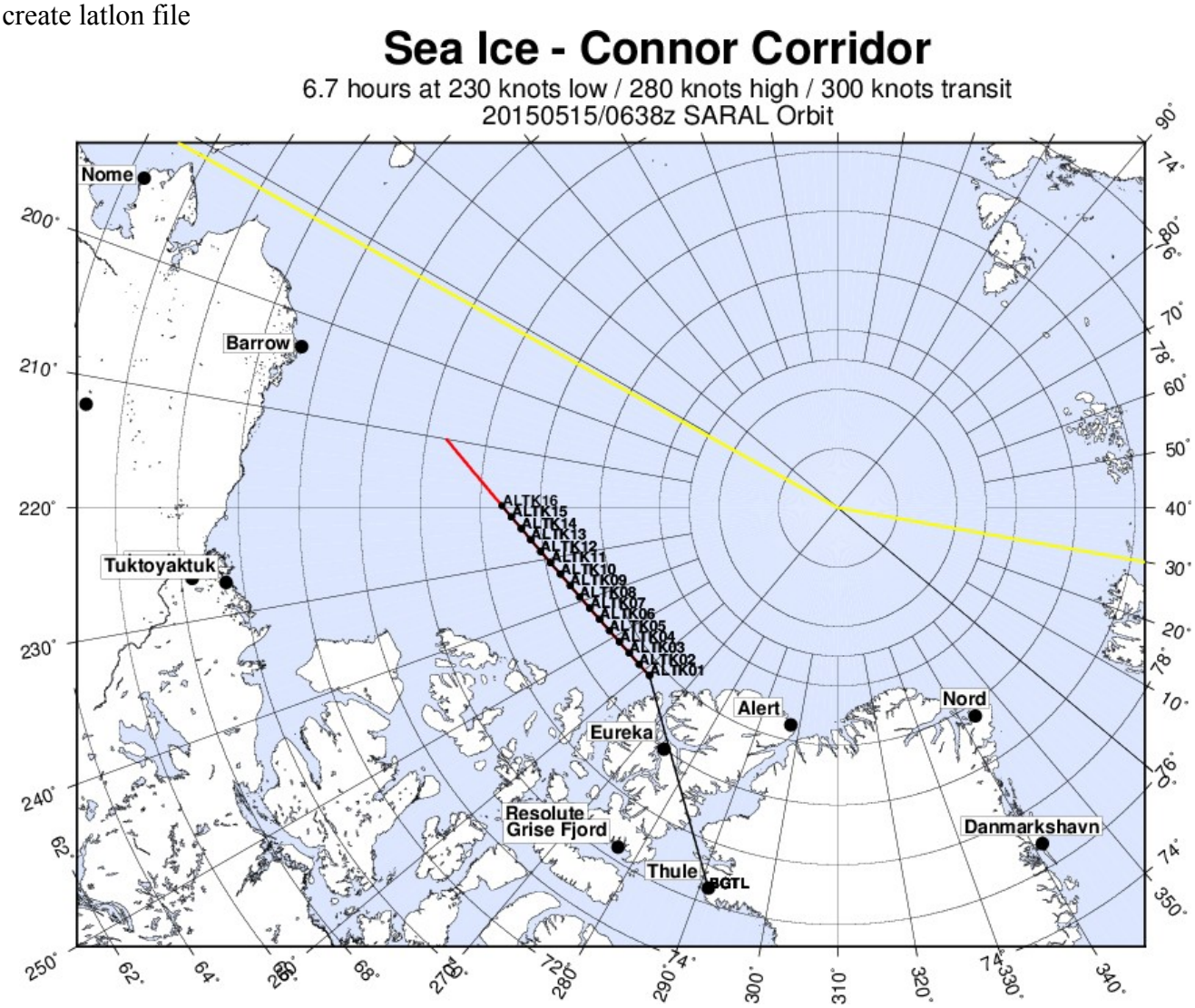
Flight Priority: medium?
ICESat Tracks: none
Last Flown: 2016
Remaining Design Issues: none



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.

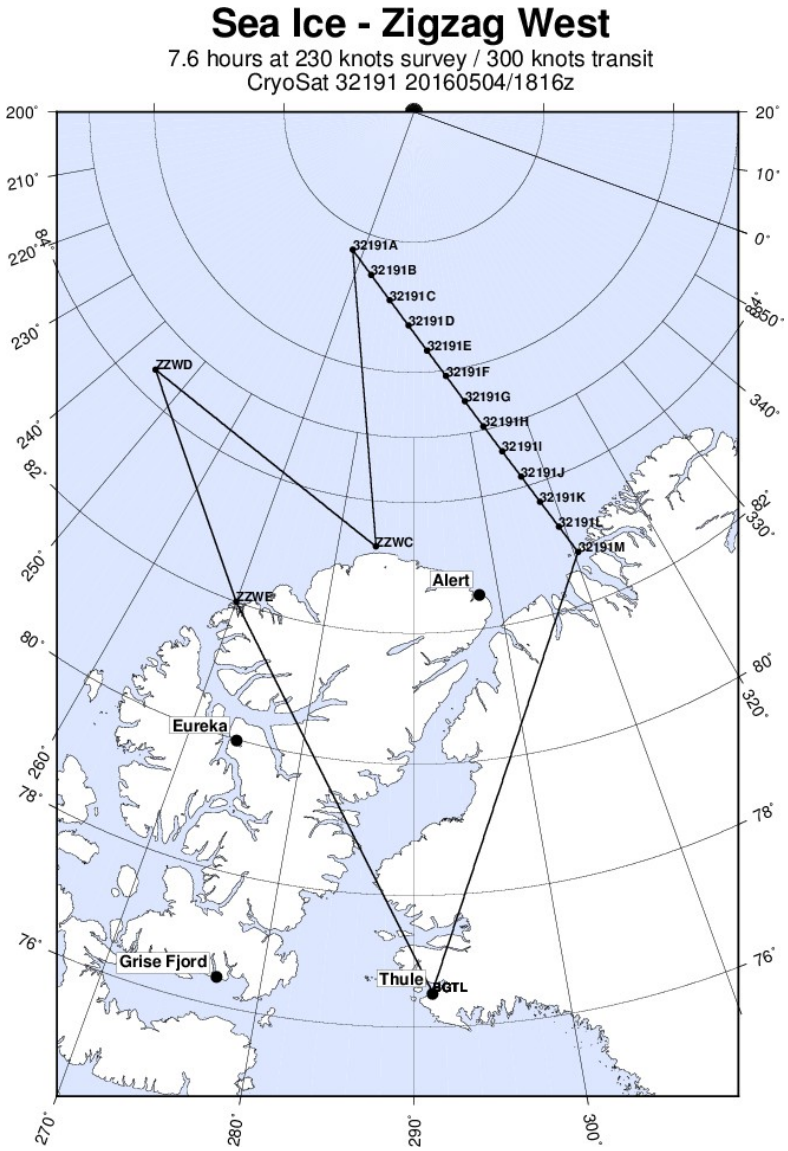
Flight Priority: low ?
ICESat Tracks: none
Last Flown: 2012
Remaining Design Issues: redesign along contemporaneous (within ~6 hr) Sentinal 3a groundtrack; create latlon file



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.

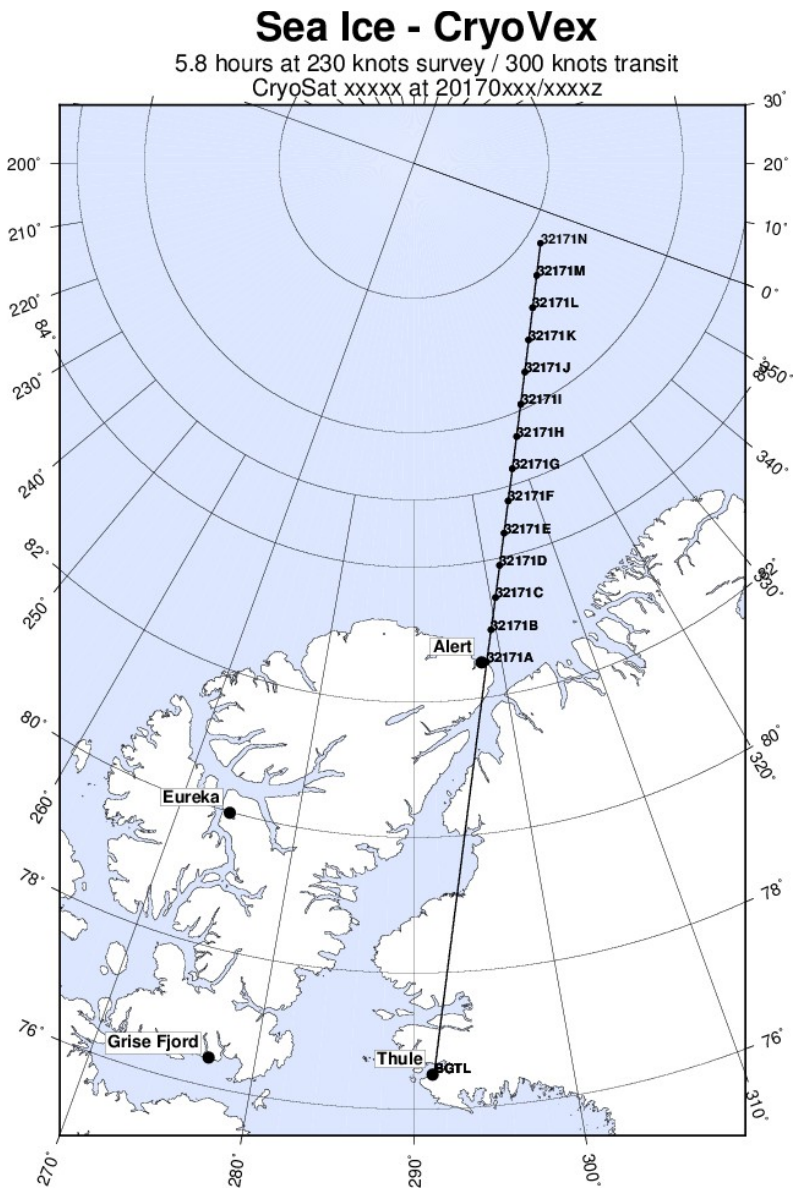
Flight Priority: medium?
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: select contemporaneous, nearby ascending CS-2 groundtrack if available.



Sea Ice – CryoVex / Thule

This mission is a coordinated flight with the CryoVex experiment. We anticipate that this effort will involve the flight in late March of a CryoSat-2 line between Alert and 88N, cooperating with DTU and AWI aircraft, and that this can be done as part of either our Sea Ice – Zigzag West or Sea Ice – North Pole Transect mission. The current plan is to repeat this line in April with a Christian Haas-led in-situ campaign along the same line. In addition to Level 1 Requirements SI1 and SI2, the mission addresses sea ice level 1 baseline requirement SI4 and SI9 by coordinating the mission with both CryoSat-2 and the CryoVex effort.

Flight Priority: high?
ICESat Tracks: none
Last Flown: new flight
Remaining Design Issues: This mission is a placeholder – details will be determined once the CryoVex teams are in the field.



Sea Ice – Northwest Passage / Thule

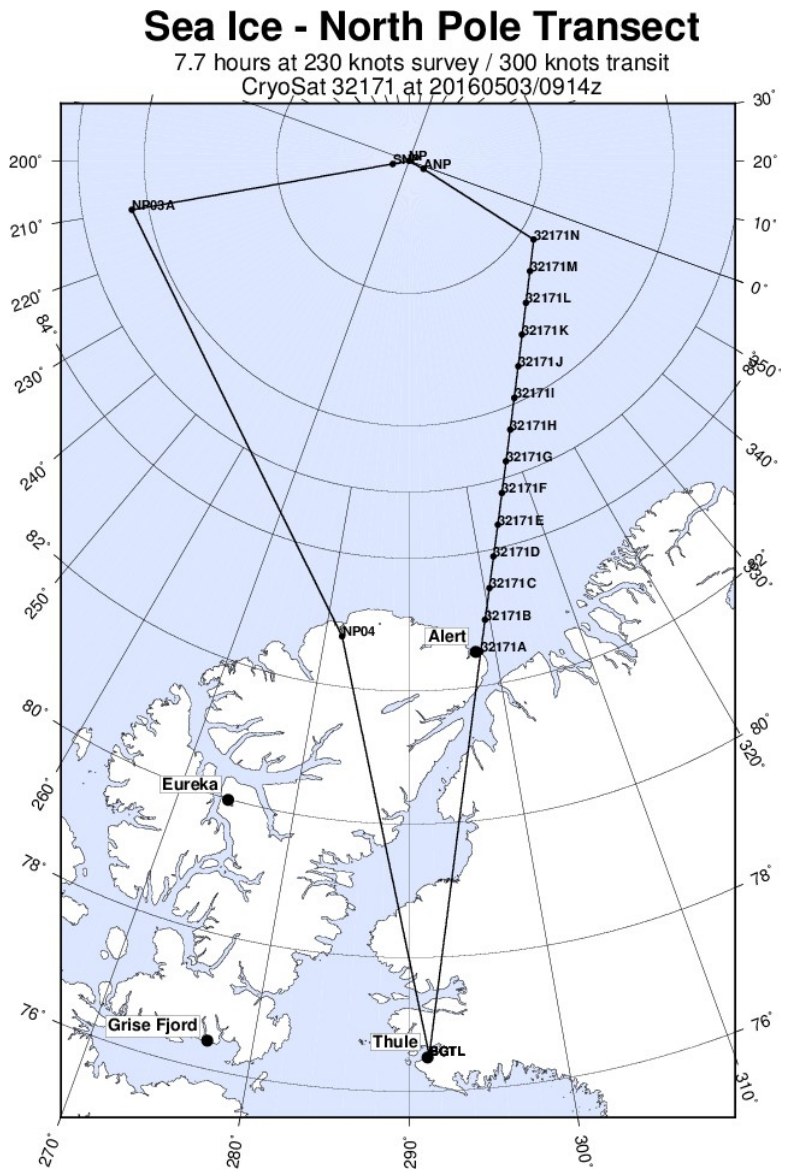
This mission is similar to the Sea Ice 08 flight from 2010, except that we now initiate the return to Thule by a path north of the Canadian Archipelago at low altitude, and transition to high altitude across Ellesmere Island. Observations in this region provide important support to seasonal sea ice forecasting 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: none

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.

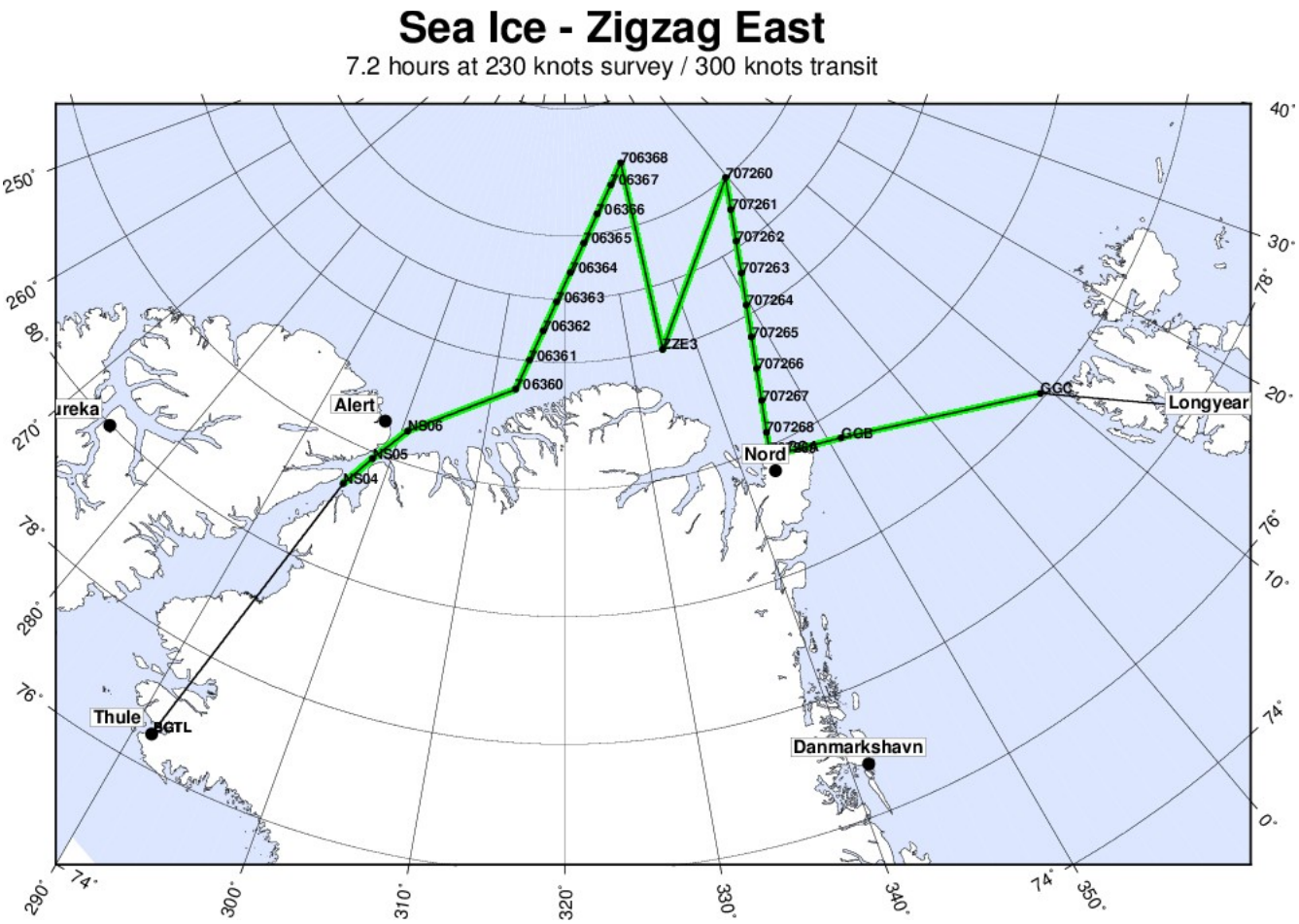
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2016
Remaining Design Issues: select contemporaneous, nearby descending CS-2 groundtrack if available



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. The eastern- and westernmost gradient lines are IceSat-2 ground tracks. 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. For 2017, we configure this mission as a transit mission between Thule and Longyearbyen, incorporating a low-altitude survey across the Fram Strait (copied from that portion of the Giles Gateway flight).

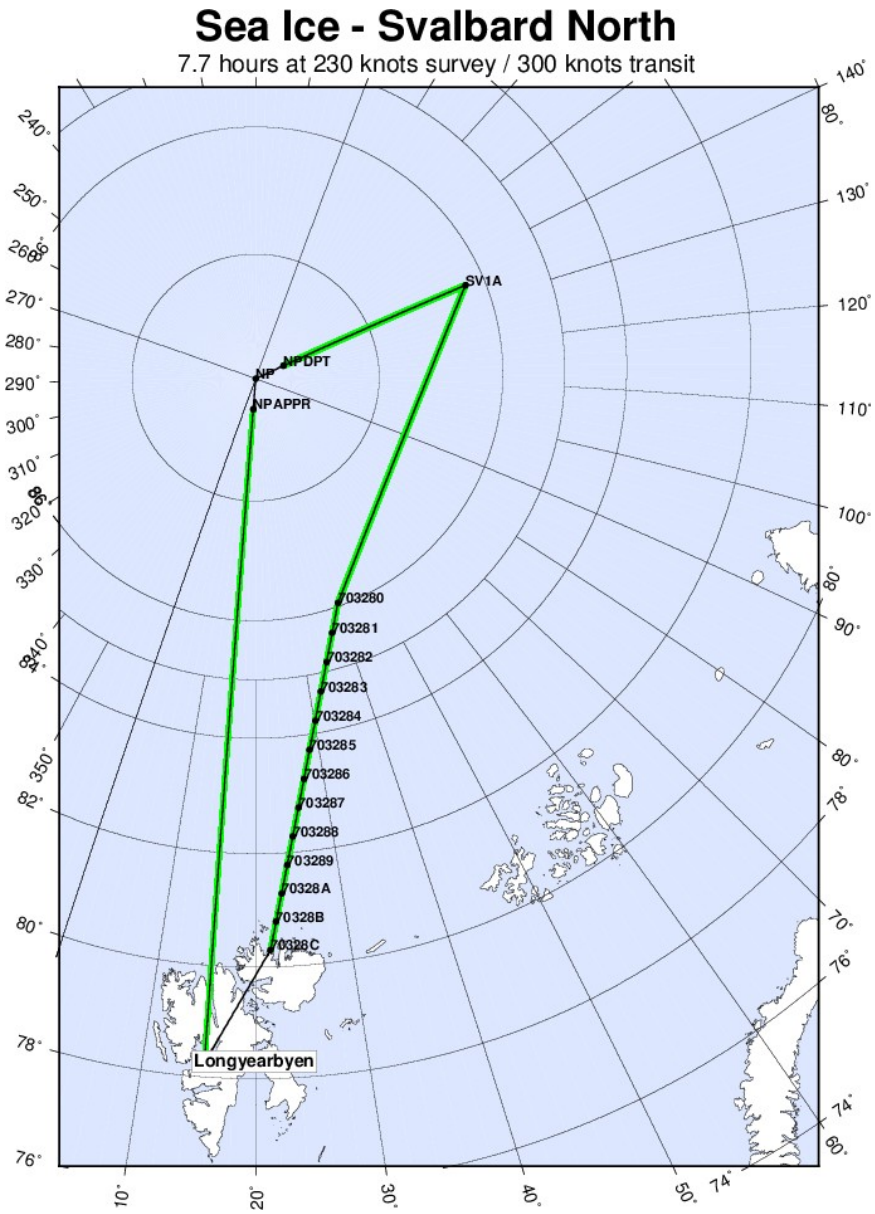
Flight Priority: high?
ICESat Tracks: none
Last Flown: 2015
Remaining Design Issues: none



Sea Ice – Svalbard North / Longyearbyen

This mission, and its companion flight "Sea Ice – Svalbard South", are designed to sample sea ice on the eastern hemisphere side of the Pole, within the Russian FIR boundary which had formerly been off-limits to OIB. This mission proceeds due north from Longyearbyen, crosses the Pole, and then forms a triangle before returning to base, with part of that leg along an IceSat-2 ground track. In addition to Level 1 Requirements SI1 and SI2, this mission addresses sea ice level 1 baseline requirement SI3d by sampling sea ice in the eastern Arctic.

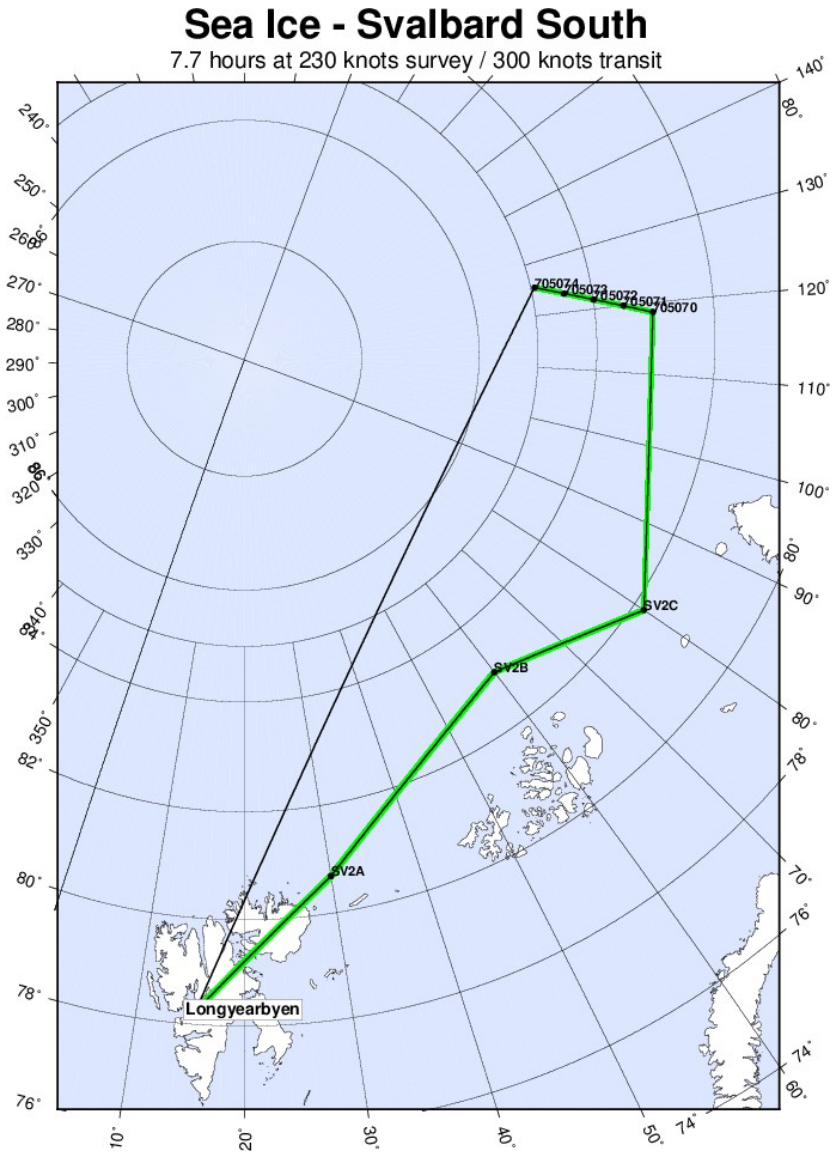
Flight Priority: high
ICESat Tracks: none
Last Flown: new flight
Remaining Design Issues: none



Sea Ice – Svalbard South / Longyearbyen

This mission, and its companion flight "Sea Ice – Svalbard North", are designed to sample sea ice on the eastern hemisphere side of the Pole, within the Russian FIR boundary which had formerly been off-limits to OIB. This mission fills in the gap between the "Sea Ice – Svalbard North" mission and the Russian islands of Franz Josef Land, Severnaya Zemlya and other minor islands, remaining at least 50 nm away from all Russian land masses (comfortably beyond the 12 mile sovereign limit). We fly an IceSat-2 ground track at the far end of the flightline. The return leg from waypoint SV2E is flown at high altitude. This leg is somewhat redundant to a similar leg from the Sea Ice – Svalbard North mission, and flying it at high altitude here enables us to cover more ground to the east with the other legs. In addition to Level 1 Requirements SI1 and SI2, this mission addresses sea ice level 1 baseline requirement SI3d by sampling sea ice in the eastern Arctic.

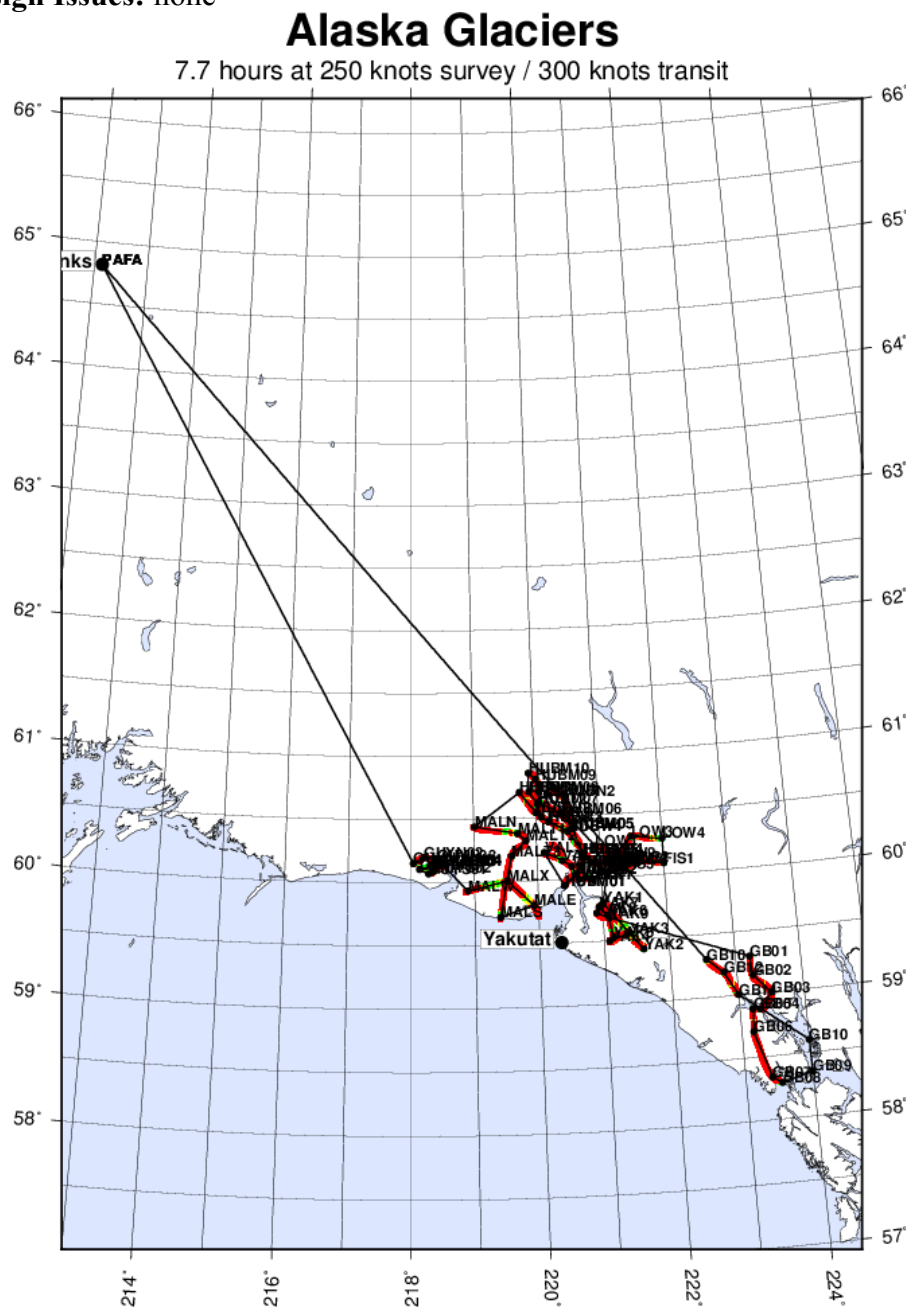
Flight Priority: high
ICESat Tracks: none
Last Flown: new flight
Remaining Design Issues: none



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.

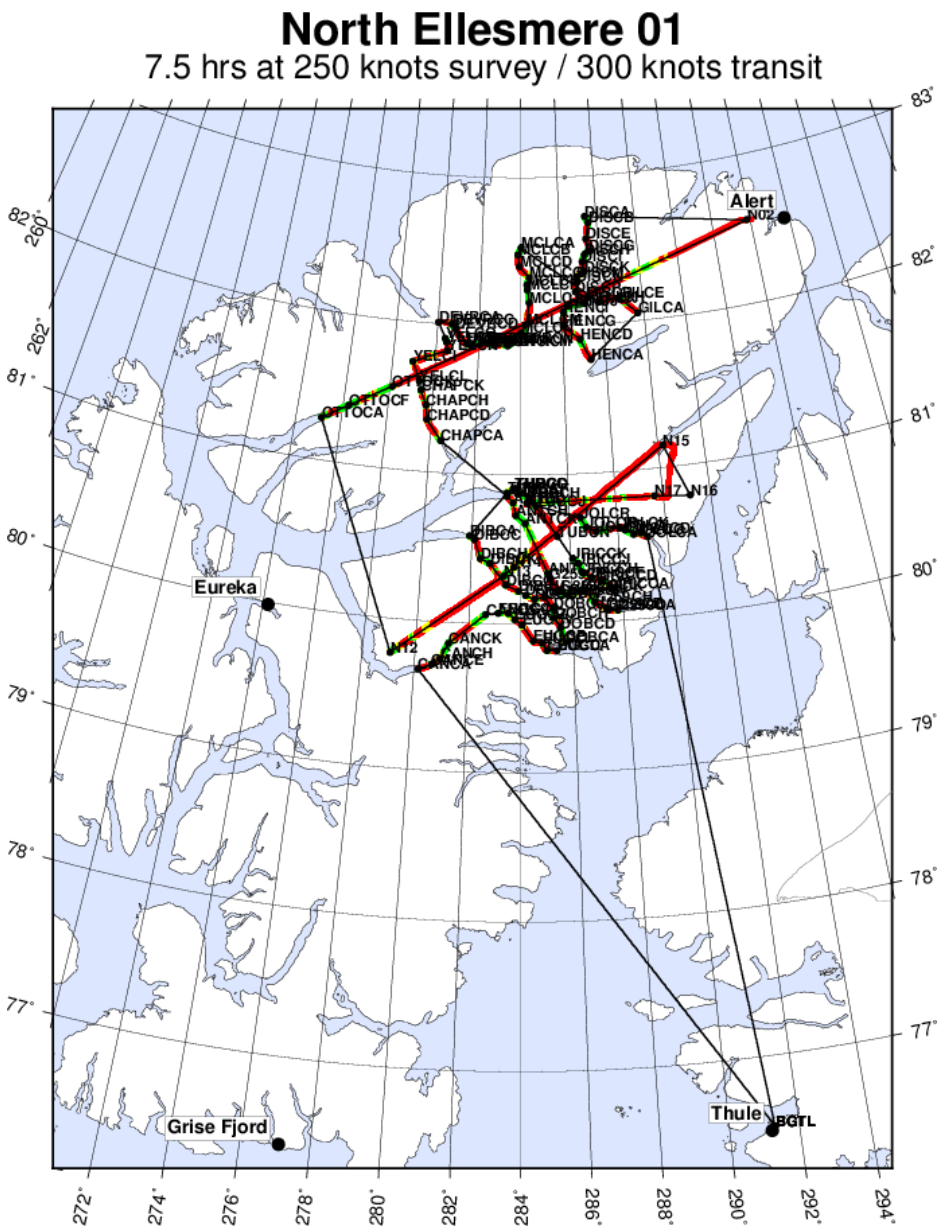
Flight Priority: low
ICESat Track: none
Last Flown: 2005
Remaining Design Issues: none



Land Ice – North Ellesmere 01 / Thule

This is a new mission, designed as part of OIB's multi-year dh/dt repeat strategy, and based both on the ATM surveys of the Canadian ice caps dating back to 1995, and to flightlines designed with Dave Burgess and Martin Sharp as part of a CSA/NASA agreement in 2014 and flown that same year. This mission concentrates on the northern Ellesmere ice field and on the Agassiz Ice Cap in east-central Ellesmere. For the northern ice field, we fly a historical ATM line traversing the ice from southwest to northeast plus centerlines of the major glaciers draining the ice field. We also fly a number of such glaciers on Agassiz, along with a pair of historical ATM lines.

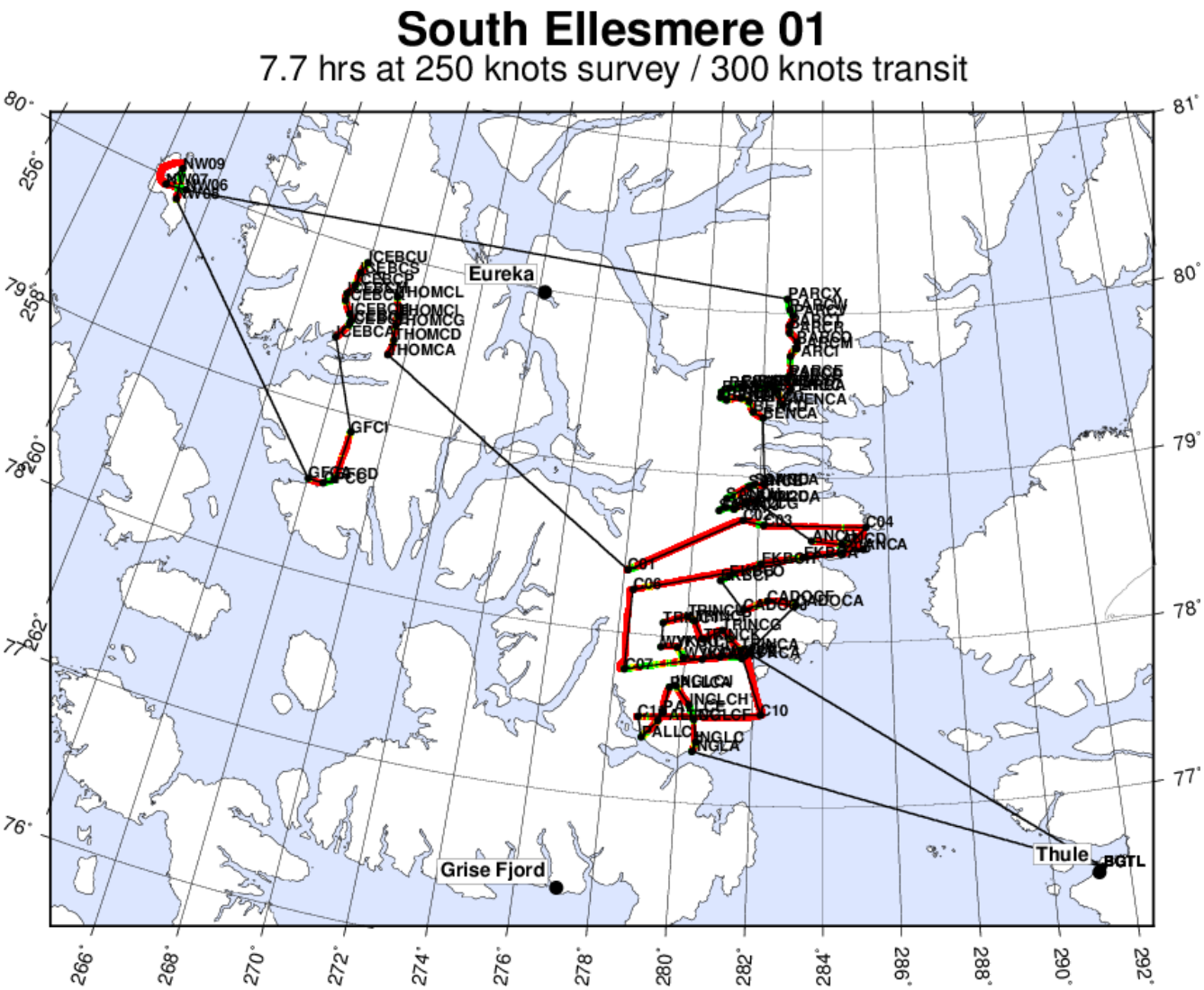
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: most in 2014, the historical Agassiz lines in 2012
Remaining Design Issues: none



Land Ice – South Ellesmere 01 / Thule

This is a new mission, designed as part of OIB's multi-year dh/dt repeat strategy, and based both on the ATM surveys of the Canadian ice caps dating back to 1995, and to flightlines designed with Dave Burgess and Martin Sharp as part of a CSA/NASA agreement in 2014 and flown that same year. This mission surveys the Prince of Wales ice cap on southeastern Ellesmere, including a number of glacier centerlines from the 2014 effort and four transects from the historical ATM lines, three glacier centerlines on the southern Agassiz ice cap, three on Axel Heiberg Island, and two crossing tracks in the Meighen Island ice cap.

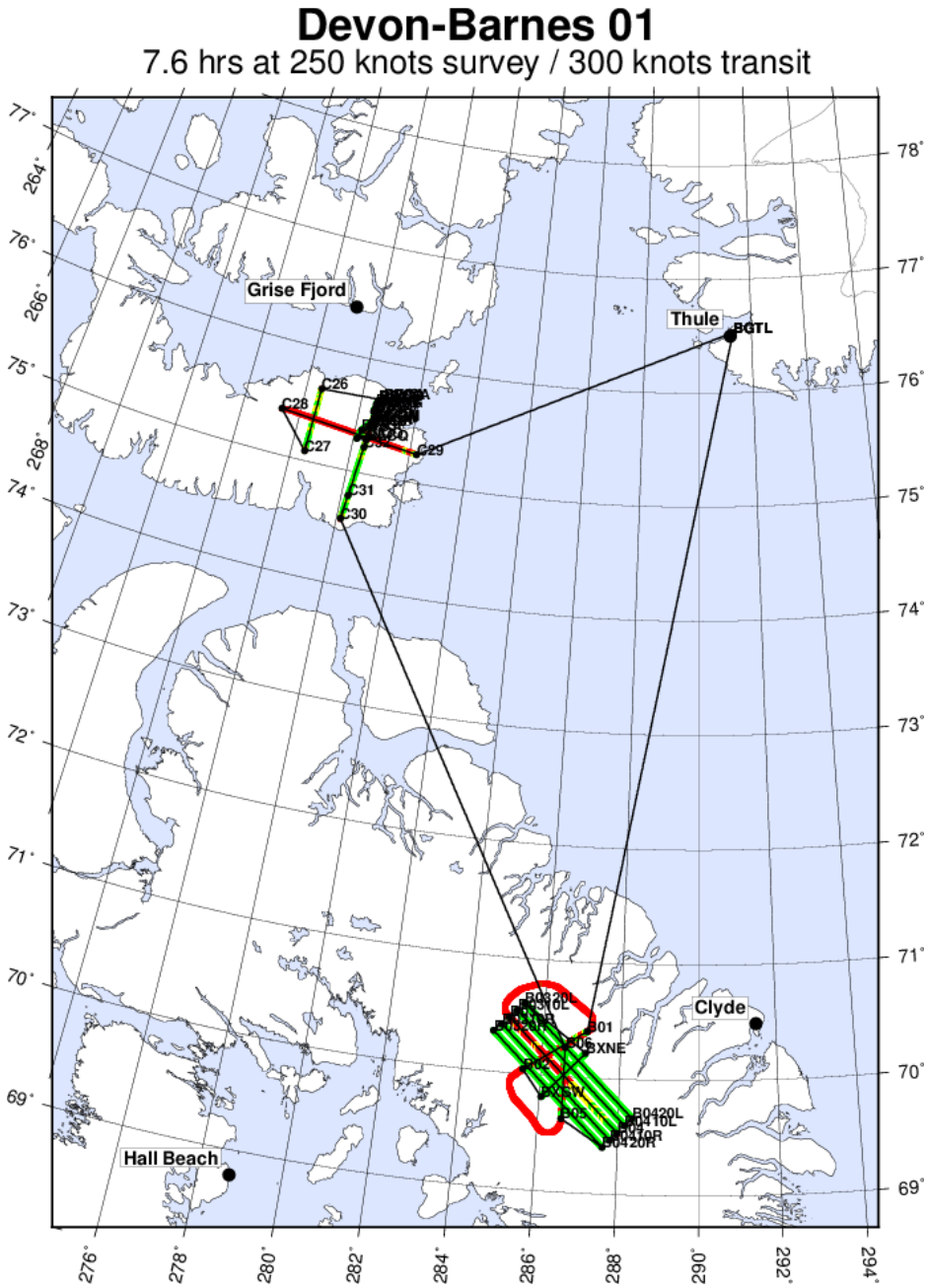
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: centerlines in 2014, historical Meighen and Prince of Wales lines in 2012
Remaining Design Issues: none



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.

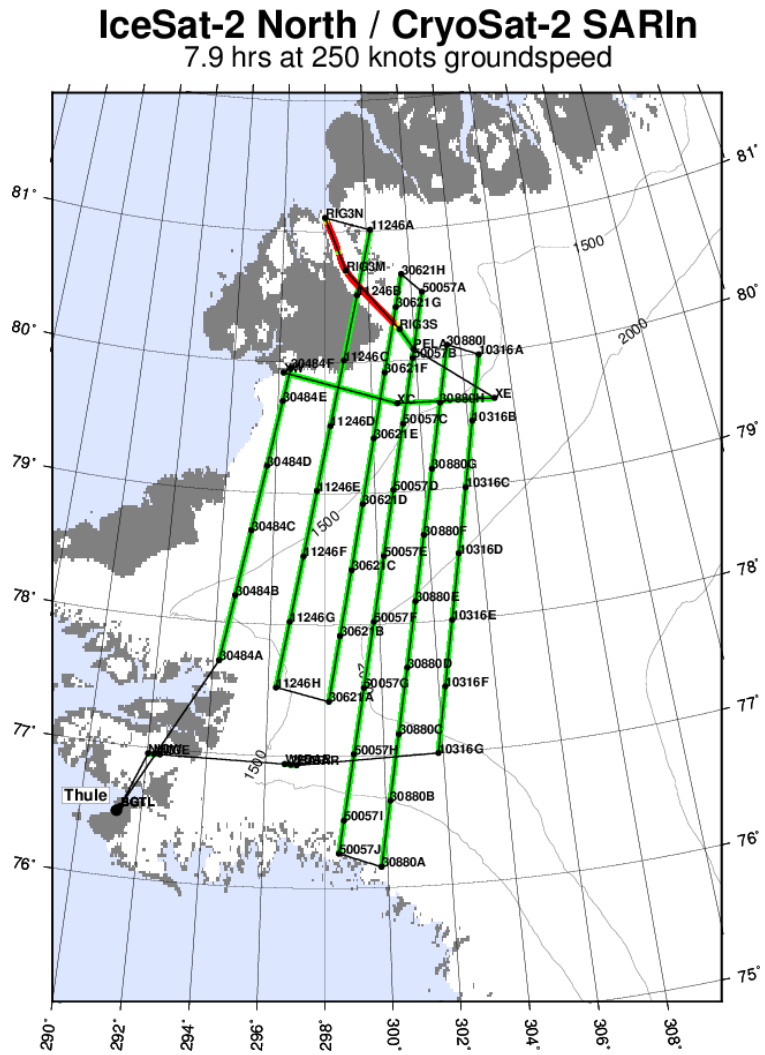
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



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.

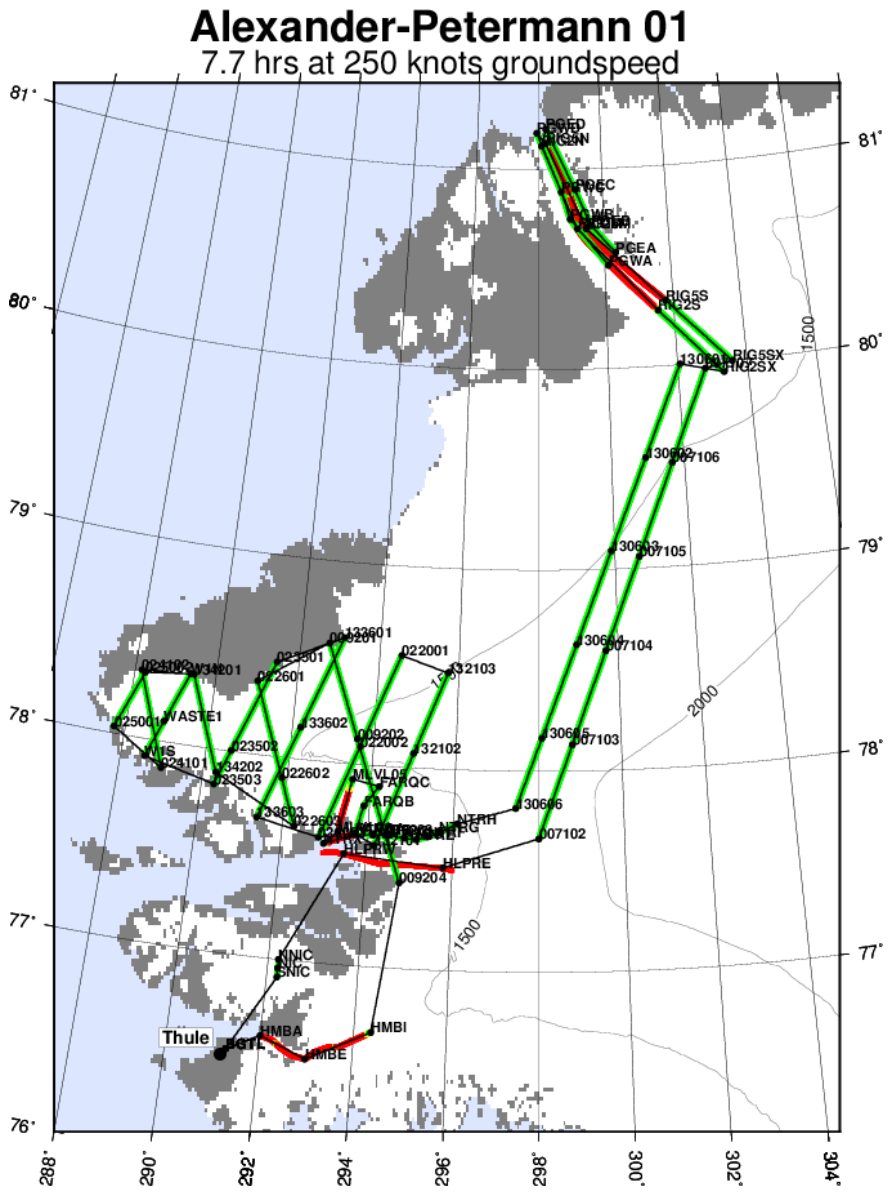
Flight Priority: baseline (annual repeat flight)
IceSat-2 Track: 0484,1246,0621,0057,0880,0316
Last Flown: 2015
Remaining Design Issues: none



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. We also overfly a possible Cold War-era waste site, to help assess the possibility that the waste may be liberated by ongoing ice loss in the area. Finally, we fly two new longitudinal Petermann lines, for the purpose of collecting gravity data.

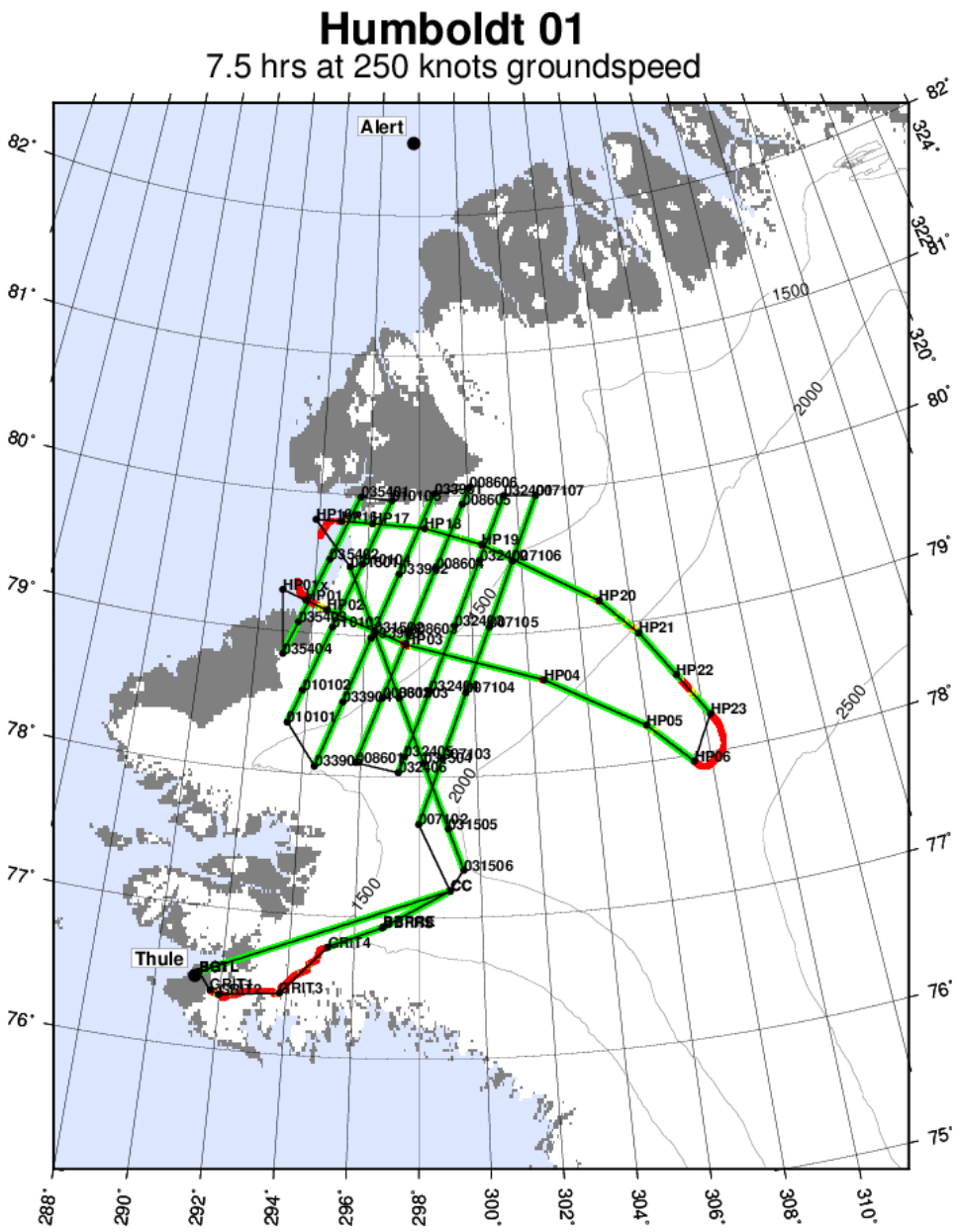
Flight Priority: high (multi-year repeat flight)
ICESat Track: 1306,0071,1321,0220,1336,0235,0250,1342,0226,0092,
Last Flown: 2014
Remaining Design Issues: refine Petermann gravity lines with Tinto/Rignot



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”.

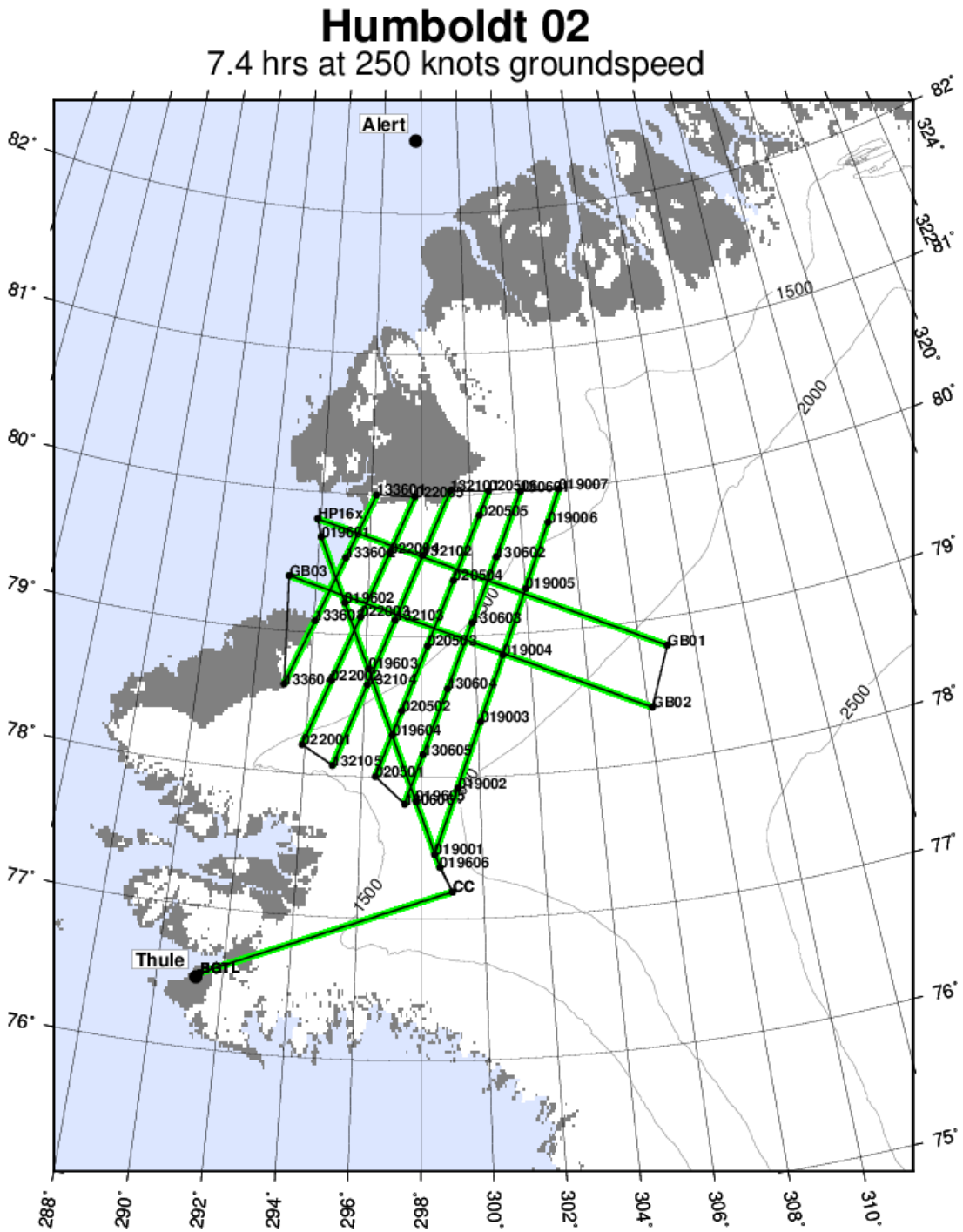
Flight Priority: high (multi-year repeat flight)
ICESat Track: 0071,0324,0086,0339,0101,0354,0315
Last Flown: 2014
Remaining Design Issues: none



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.

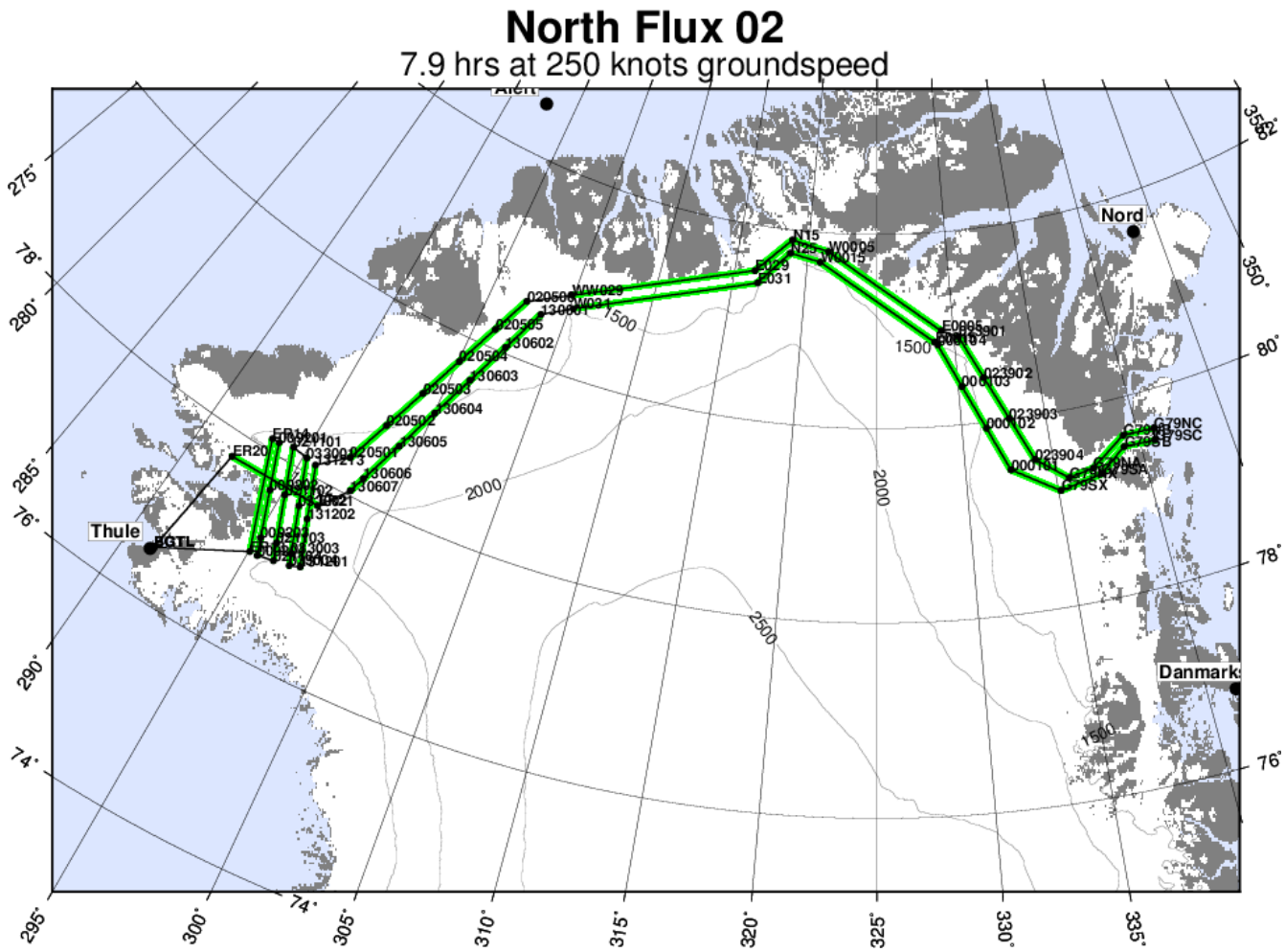
Flight Priority: low
ICESat Track: 0190,1306,0205,1321,0220,1336,0196
Last Flown: new flight
Remaining Design Issues: none



Land Ice – North Flux 02 / Thule

This is a new mission for 2015, designed to improve bedrock mapping coverage across the Tracy and Heilprin Glacier catchments, and across the northern Greenland coast. The lines across northern Greenland are interlaced with other coast-parallel lines flown there by OIB in 2012. Finally, we fly a pair of longitudinal lines down 79N Glacier, primarily for the purpose of acquiring new gravity data there.

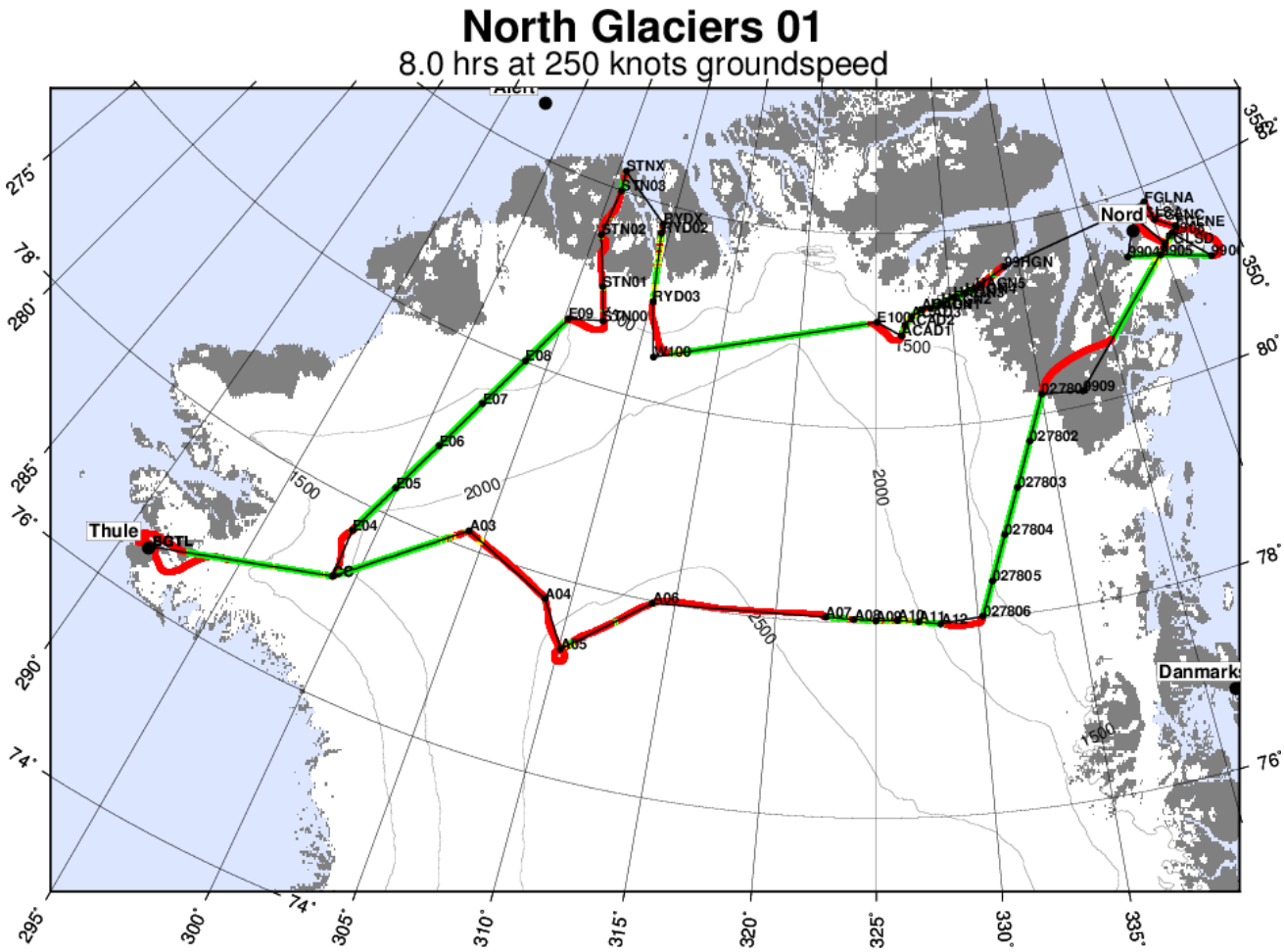
Flight Priority: high
ICESat Track: 0092,0211,0330,1312,0205,0239,0001,1306
Last Flown: new flight
Remaining Design Issues: refine 79N gravity lines with Tinto/Rignot



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.

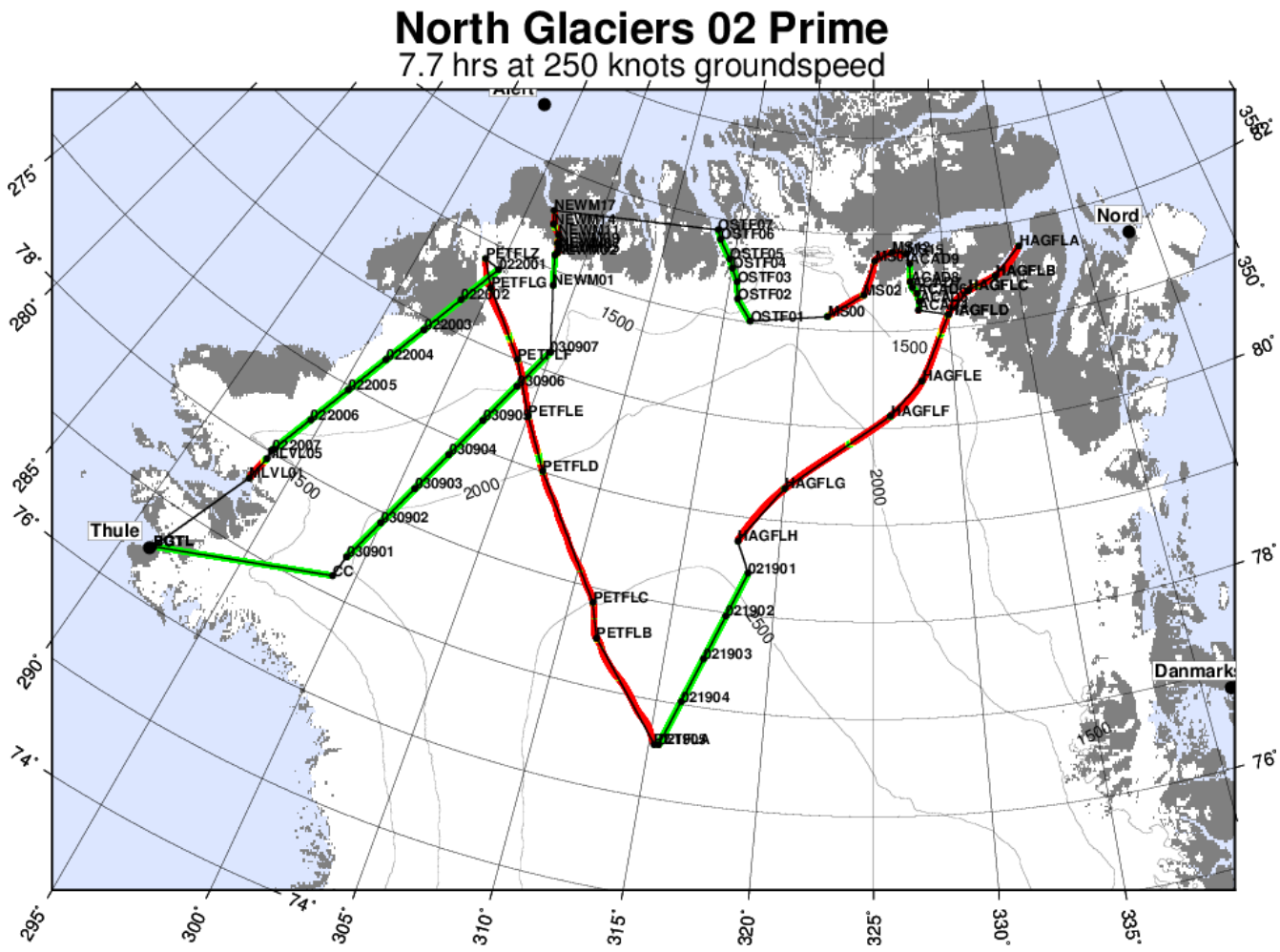
Flight Priority: medium (multi-year repeat flight)
ICESat Track: 0278
Last Flown: 2015
Remaining Design Issues: none



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.

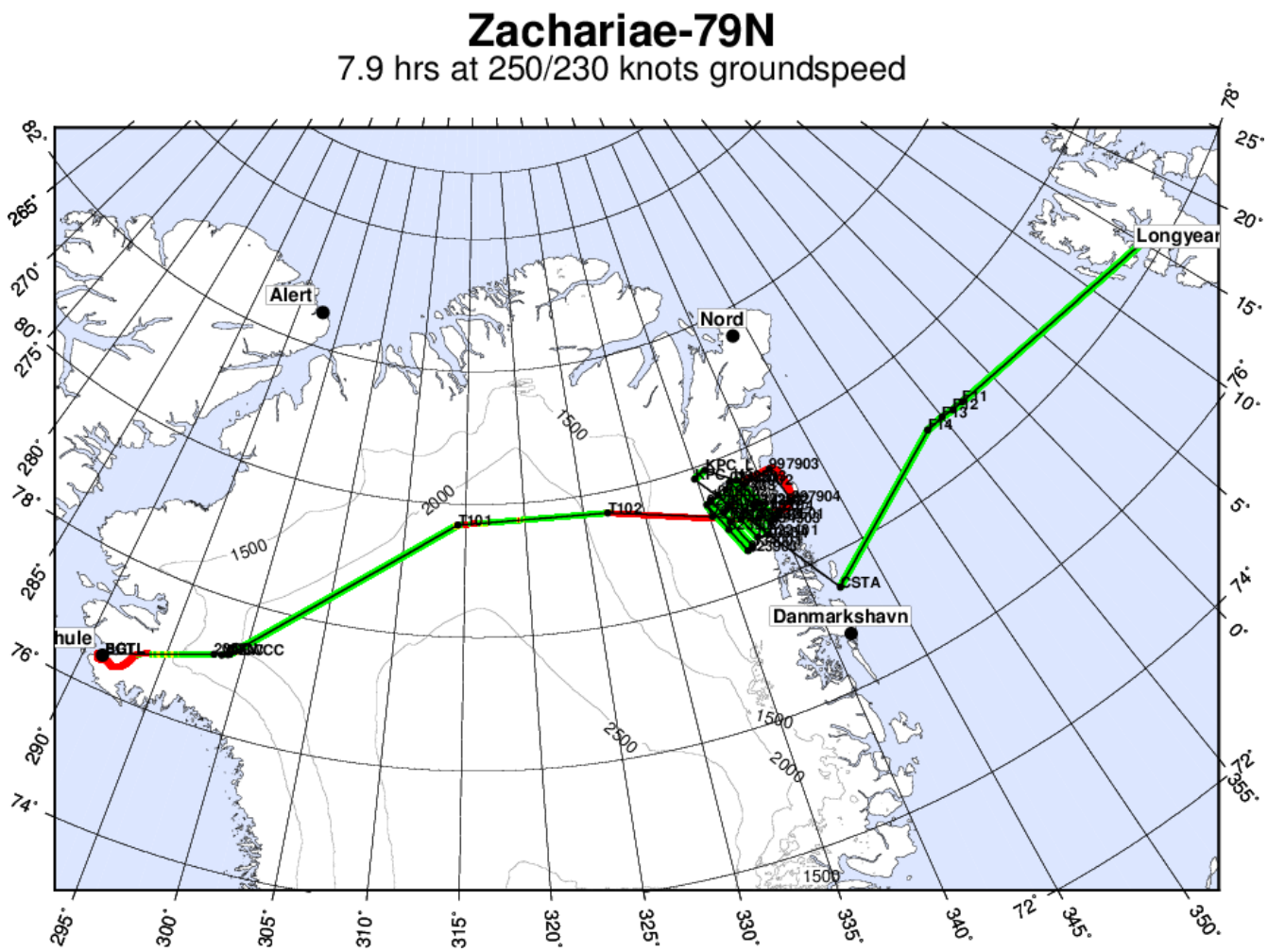
Flight Priority: high (multi-year repeat flight)
ICESat Track: 0220,0309,0219
Last Flown: 2014
Remaining Design Issues: none



Land Ice – Zachariae-79N / Thule

This mission reoccupies the centerlines of the Zacharaie 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 line dating back to 1994. For 2017 this mission is configured as a transit flight between Thule and Longyearbyen, and as such it also contains a sea ice survey across the Fram Strait, including overflights of four underwater moorings with upward-looking sonar (ULS) sensors. These moorings are known as F11, F12, F13, and F14. It can also be configured as a round-trip from Thule, with a return along a master grid line.

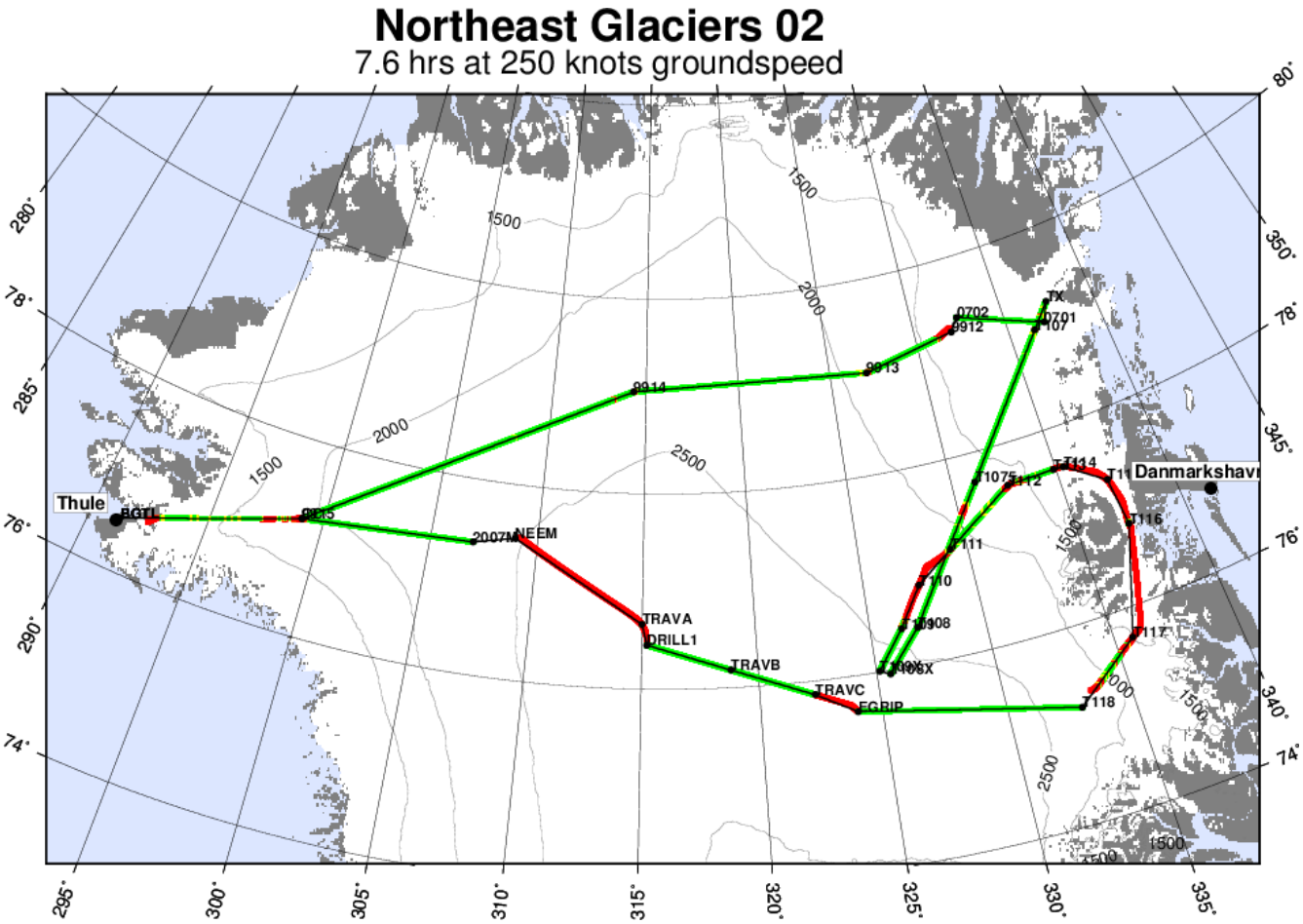
Flight Priority: baseline (annual repeat flight)
ICESat Track: 0105,0224,0239,0343,1325,1340
Last Flown: 2016
Remaining Design Issues: none



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 reflies 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.

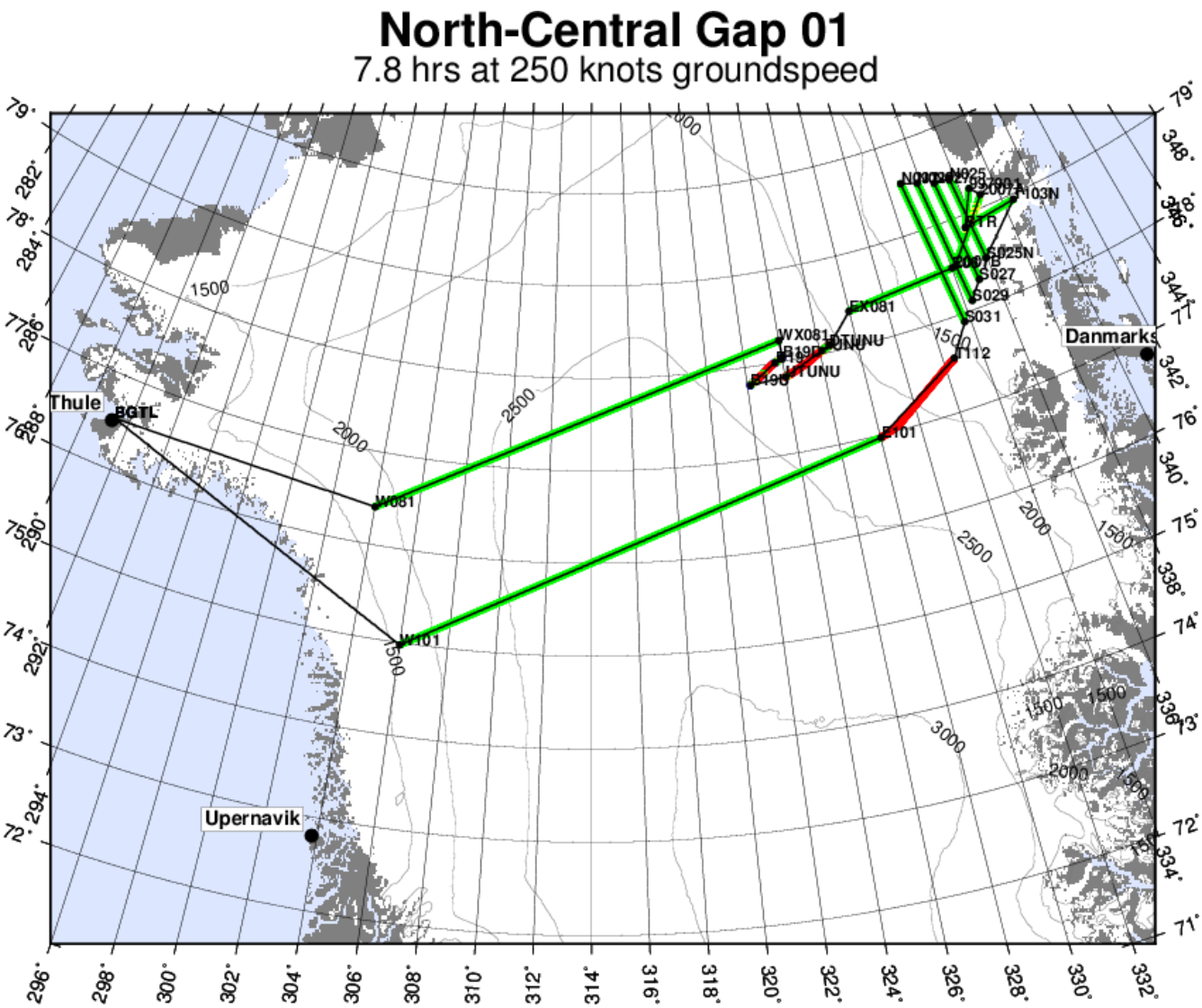
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: portions in 2014
Remaining Design Issues: none



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.

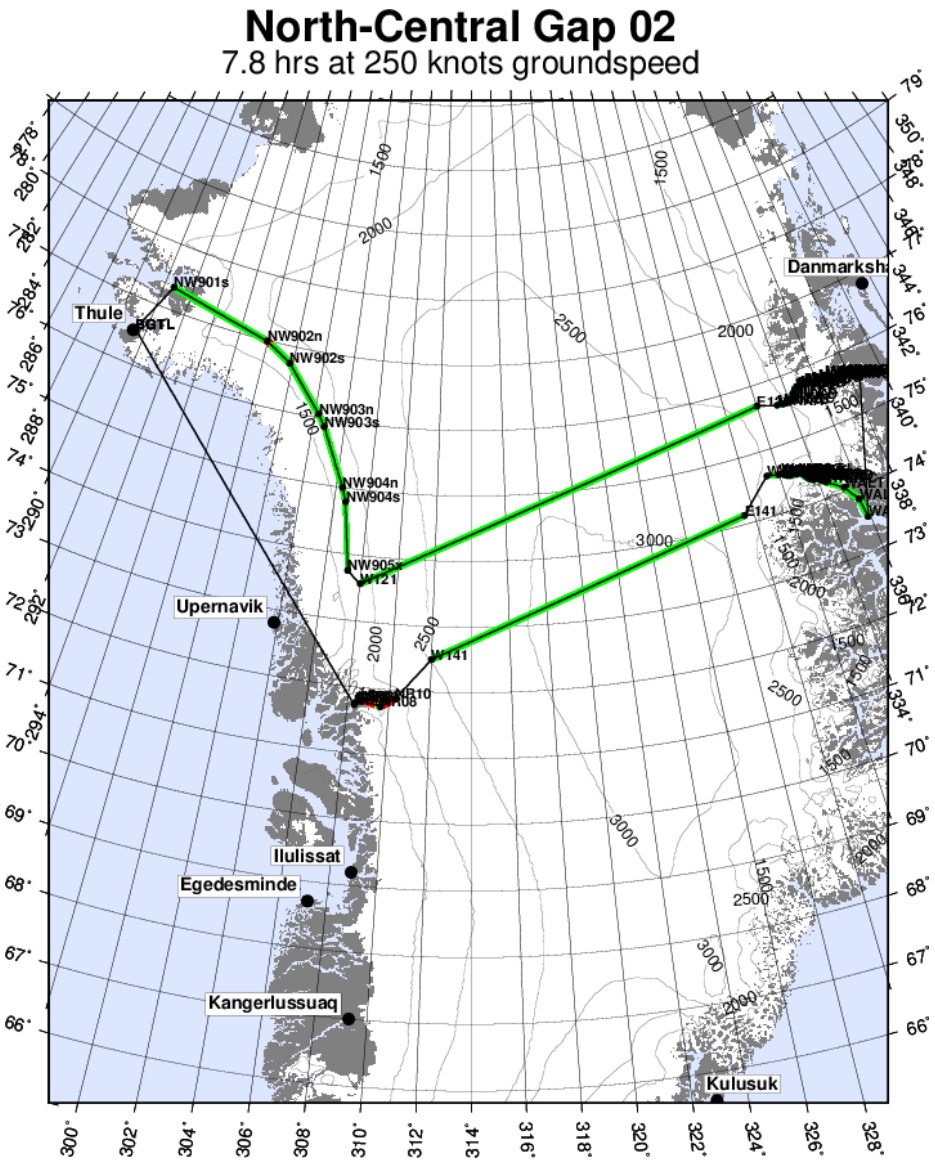
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



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.

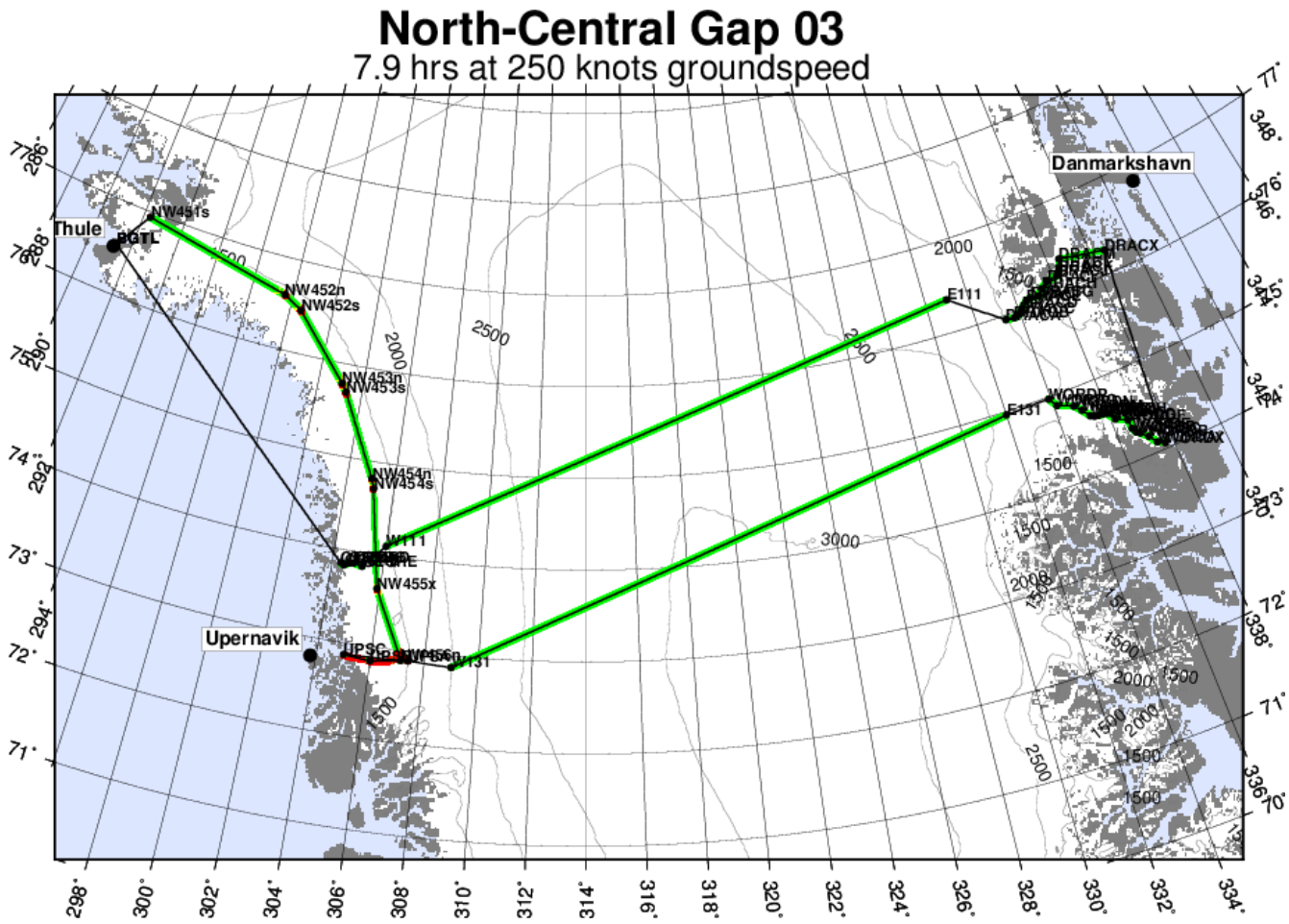
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



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 refly portions of the northwest coast-parallel grid flown from 2010-2012.

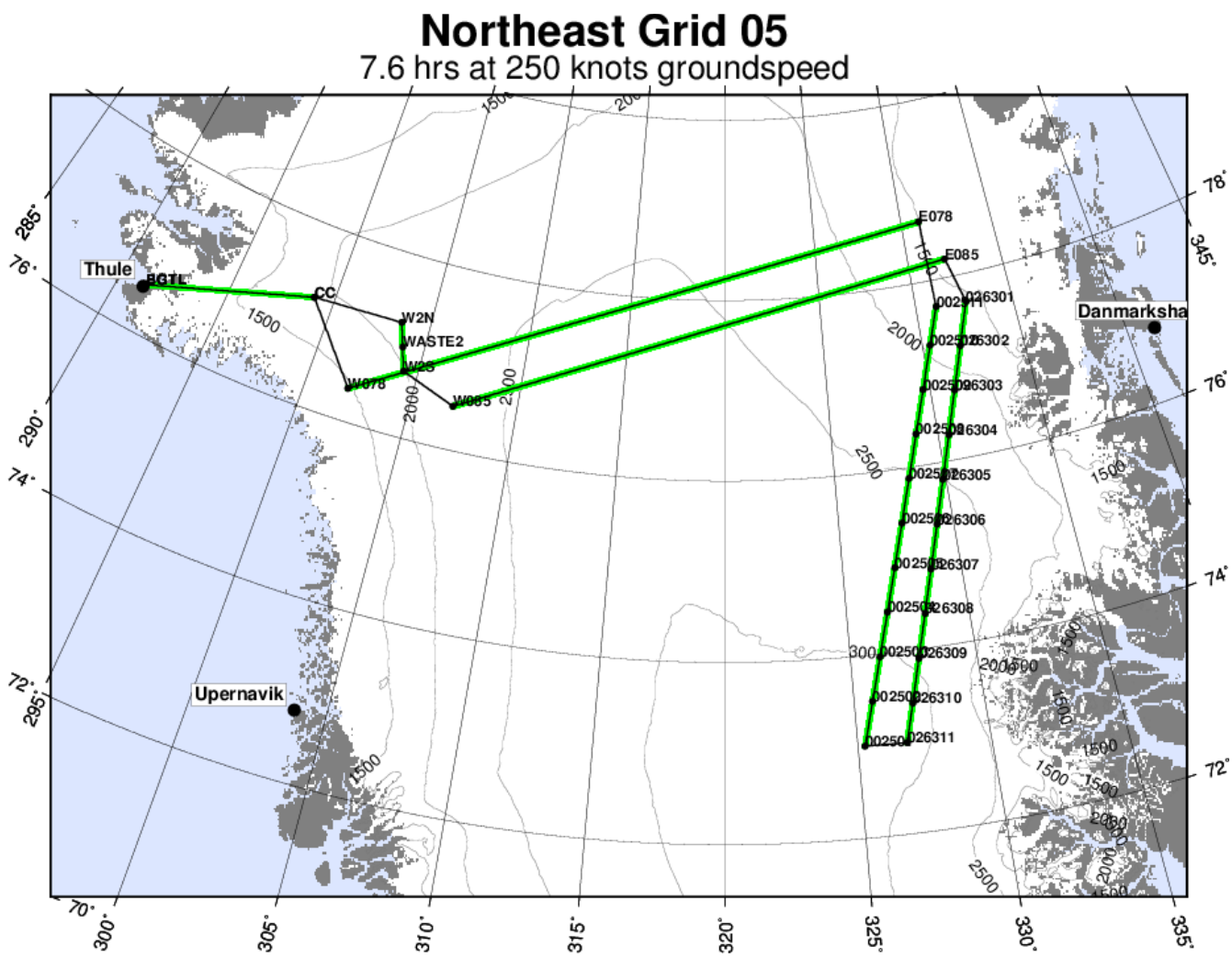
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: 2013
Remaining Design Issues: none



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 new east-west master grid lines, selected to best fill existing gaps in the master grid in this area. Finally, we overfly a possible Cold War-era waste site, to help assess the possibility that the waste may be liberated by ongoing ice loss in the area.

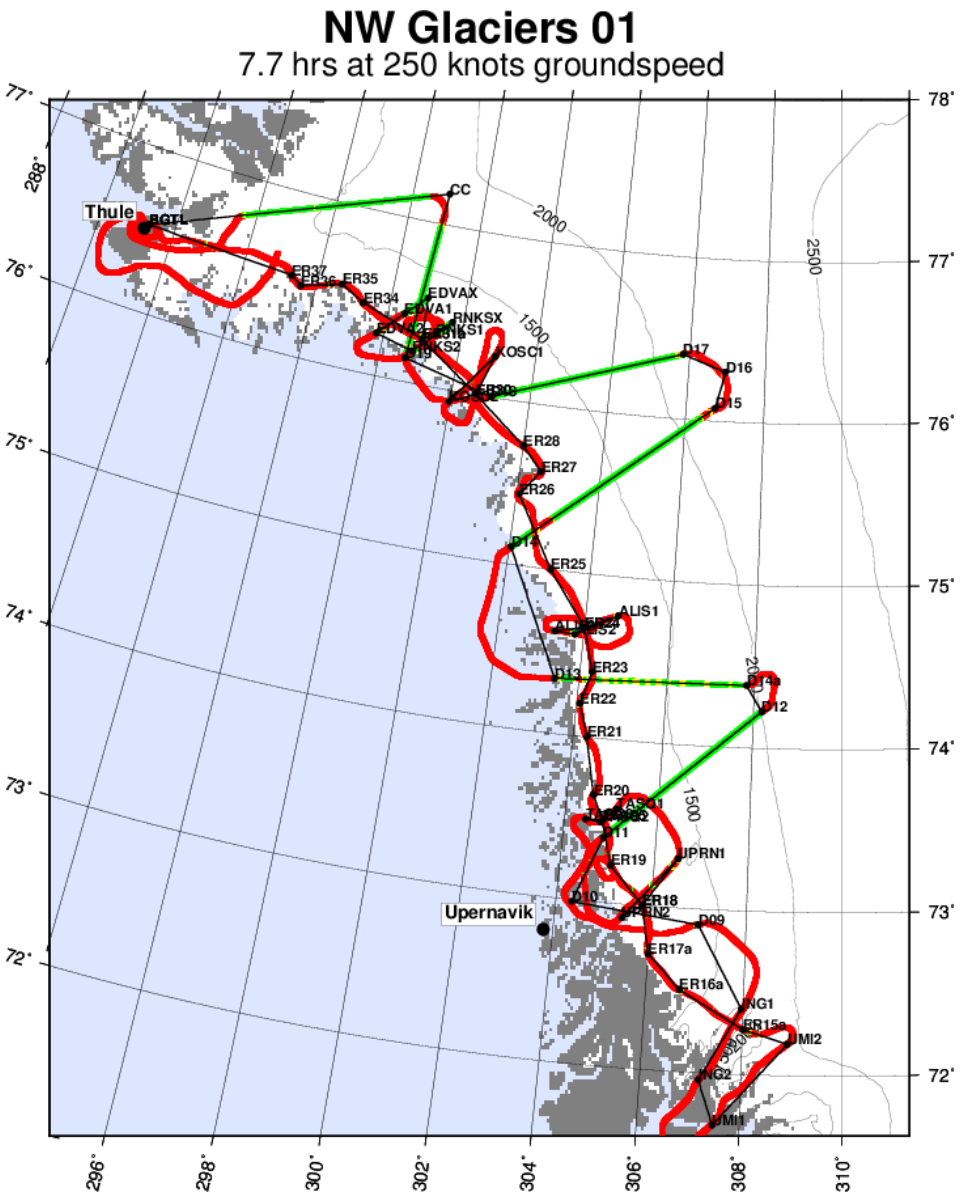
Flight Priority: medium-high
ICESat Track: 0263,0025
Last Flown: new flight
Remaining Design Issues: none



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. This had been a baseline OIB flight, but was demoted in 2016 because of its unsuitability to be flown from high altitude during the melt season campaigns.

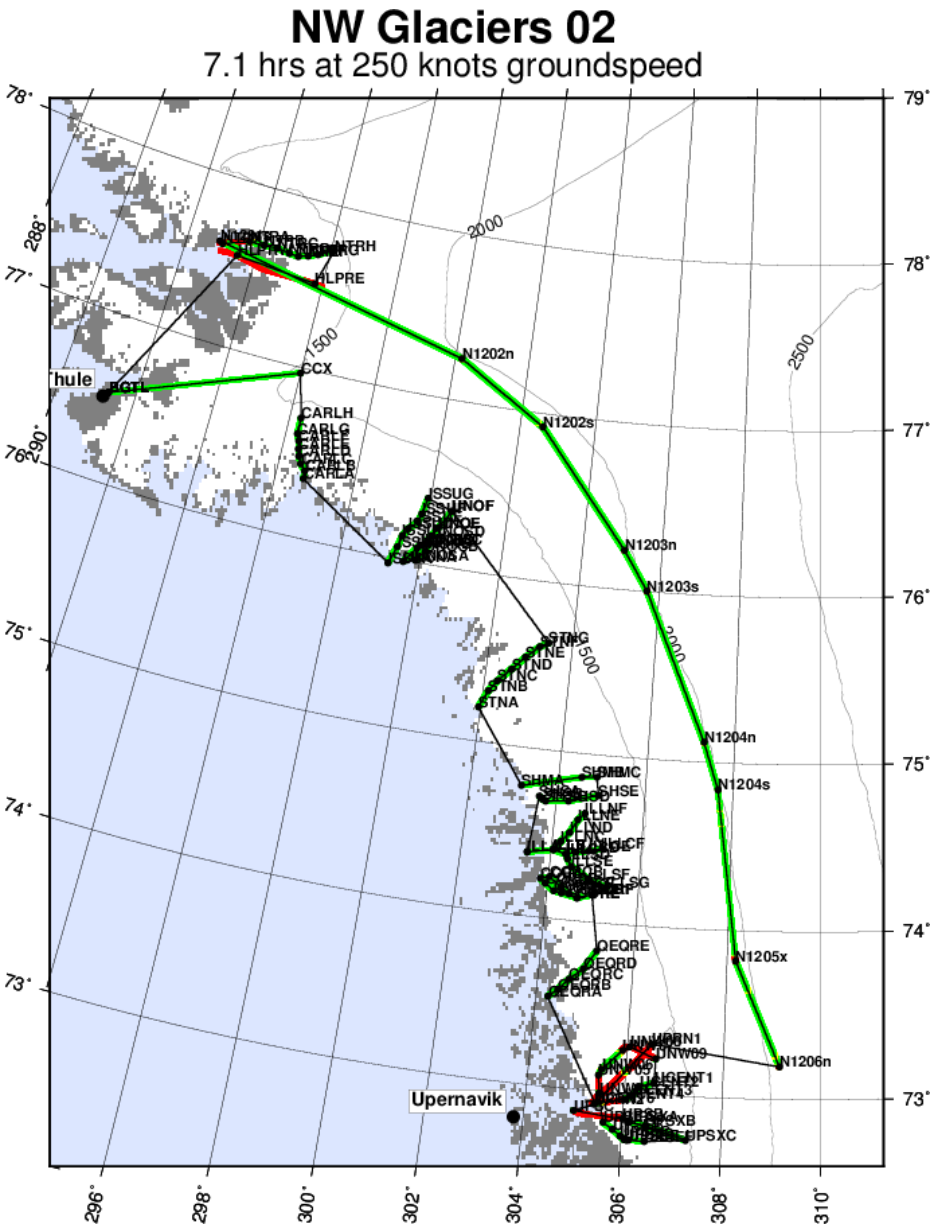
Flight Priority: medium (multi-year repeat mission)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



Land Ice – Northwest Glaciers 02 / Thule

This mission focuses on the upper Baffin Bay coast, with targeted longitudinal surveys of the most significant glaciers in the region not flown prior to this flight's first implementation in 2014. We also resurvey the centerlines of the Tracy and Heilprin glaciers, and we refly a previously-flown inland line from the “northwest coastal” suite of missions.

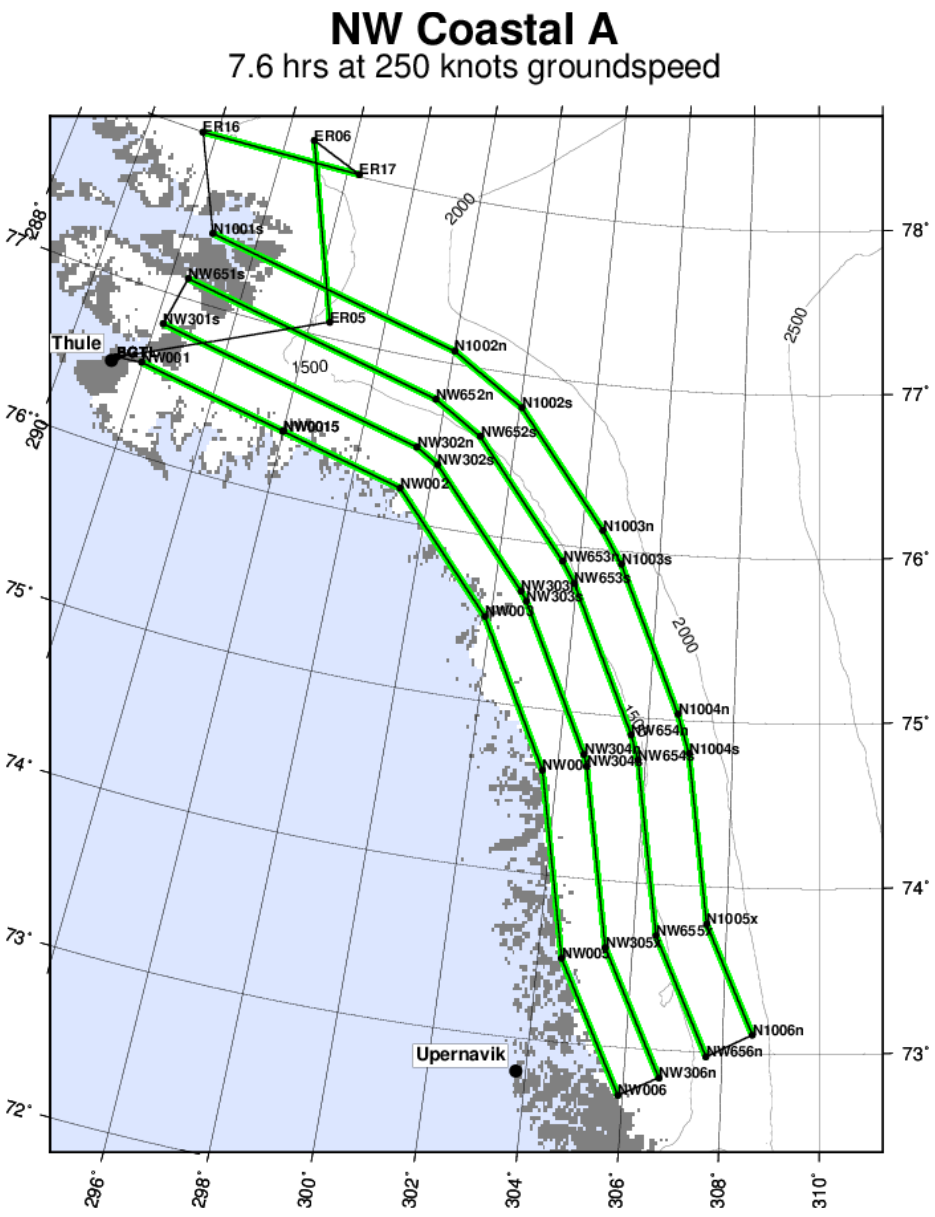
Flight Priority: low (multi-year repeat mission)
ICESat Track: none
Last Flown: 2014
Remaining Design Issues: none



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 is assigned a baseline priority for 2016 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

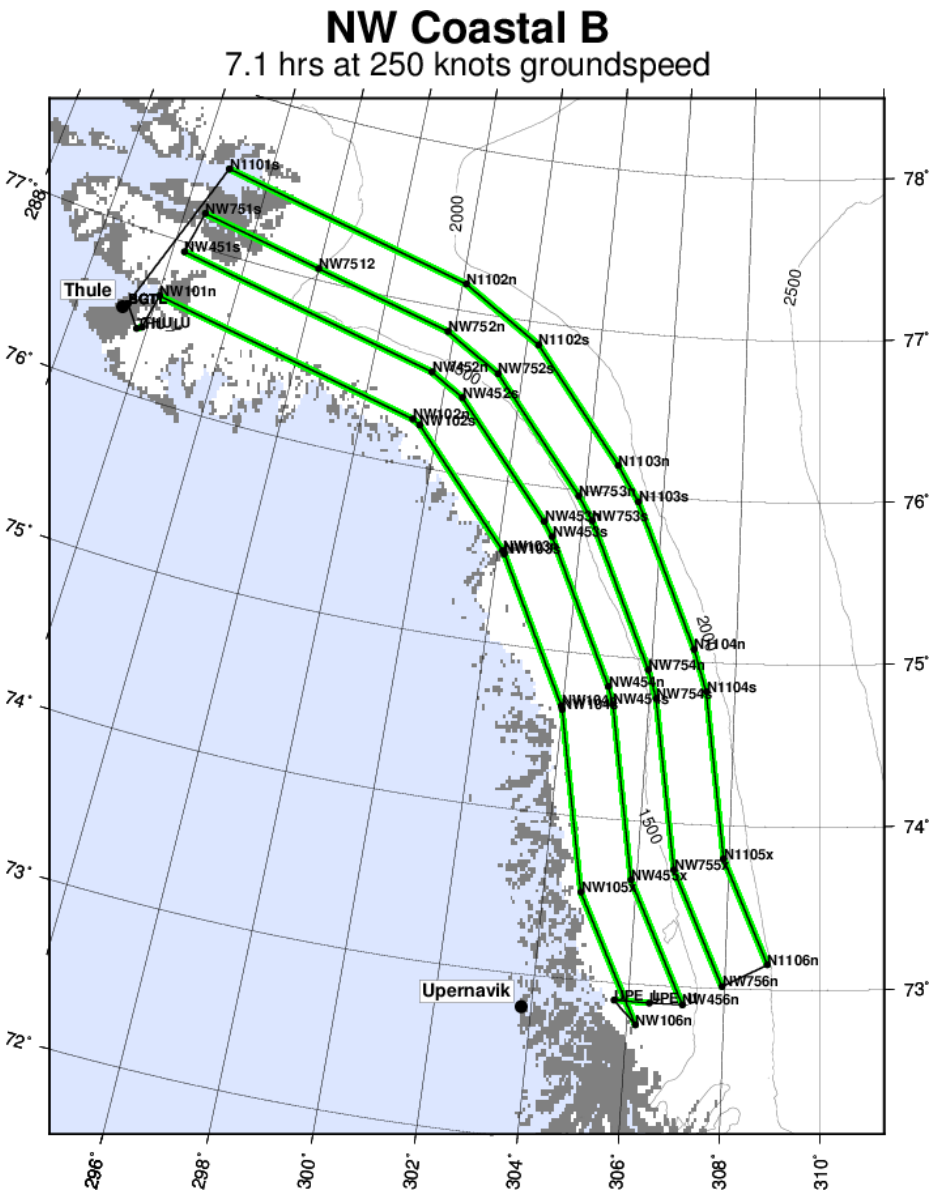
Flight Priority: baseline (annual repeat flight)
ICESat Track: none
Last Flown: most in 2016
Remaining Design Issues: none



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.

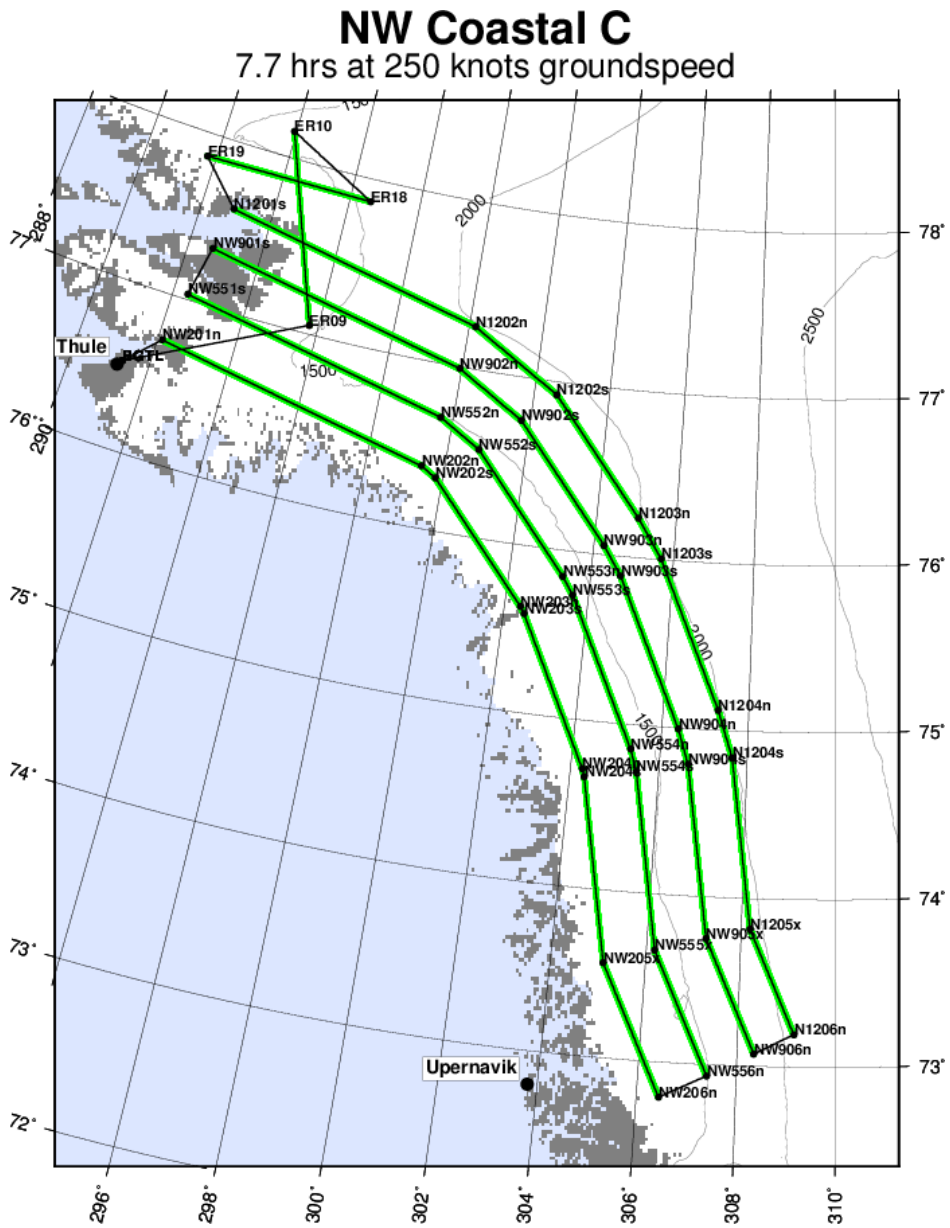
Flight Priority: low (multi-year repeat mission)
ICESat Track: none
Last Flown: 2014
Remaining Design Issues: none



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.

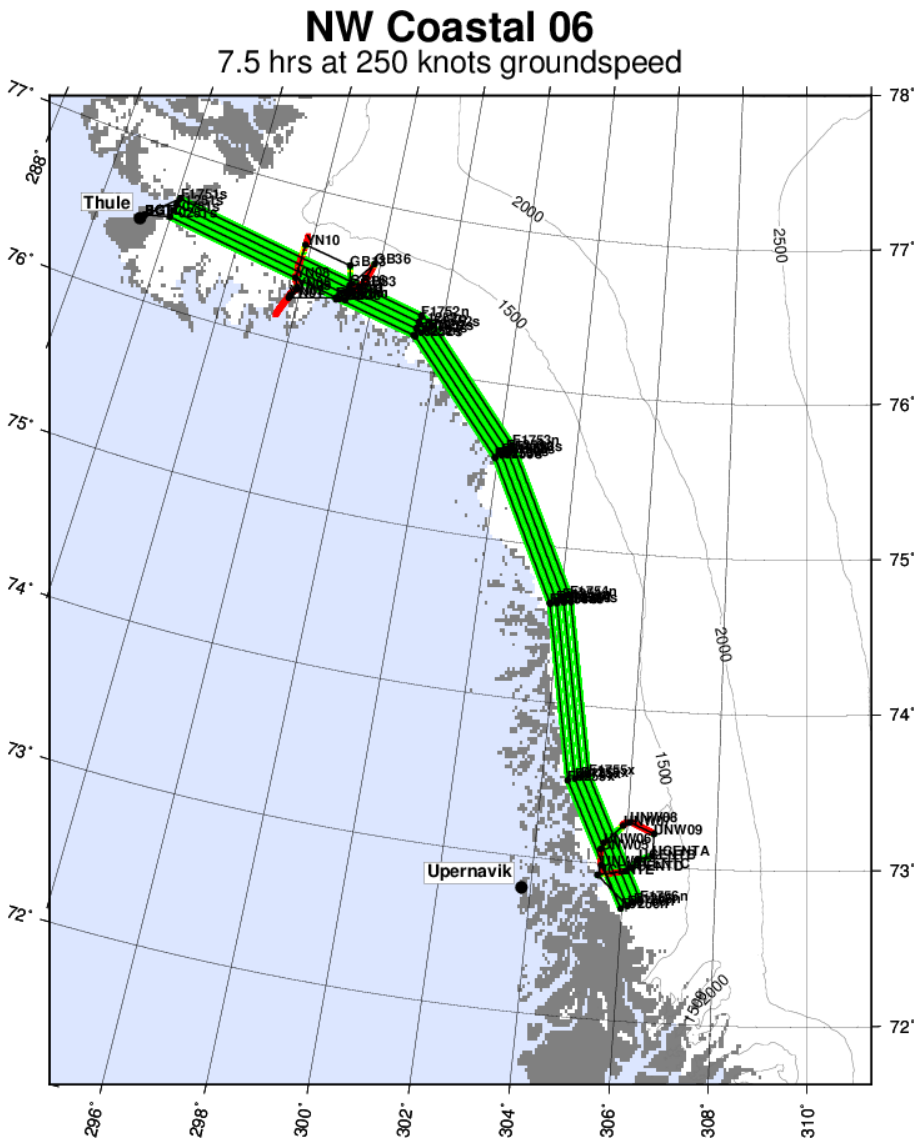
Flight Priority: high (multi-year repeat mission)
ICESat Track: none
Last Flown: 2014
Remaining Design Issues: none



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.

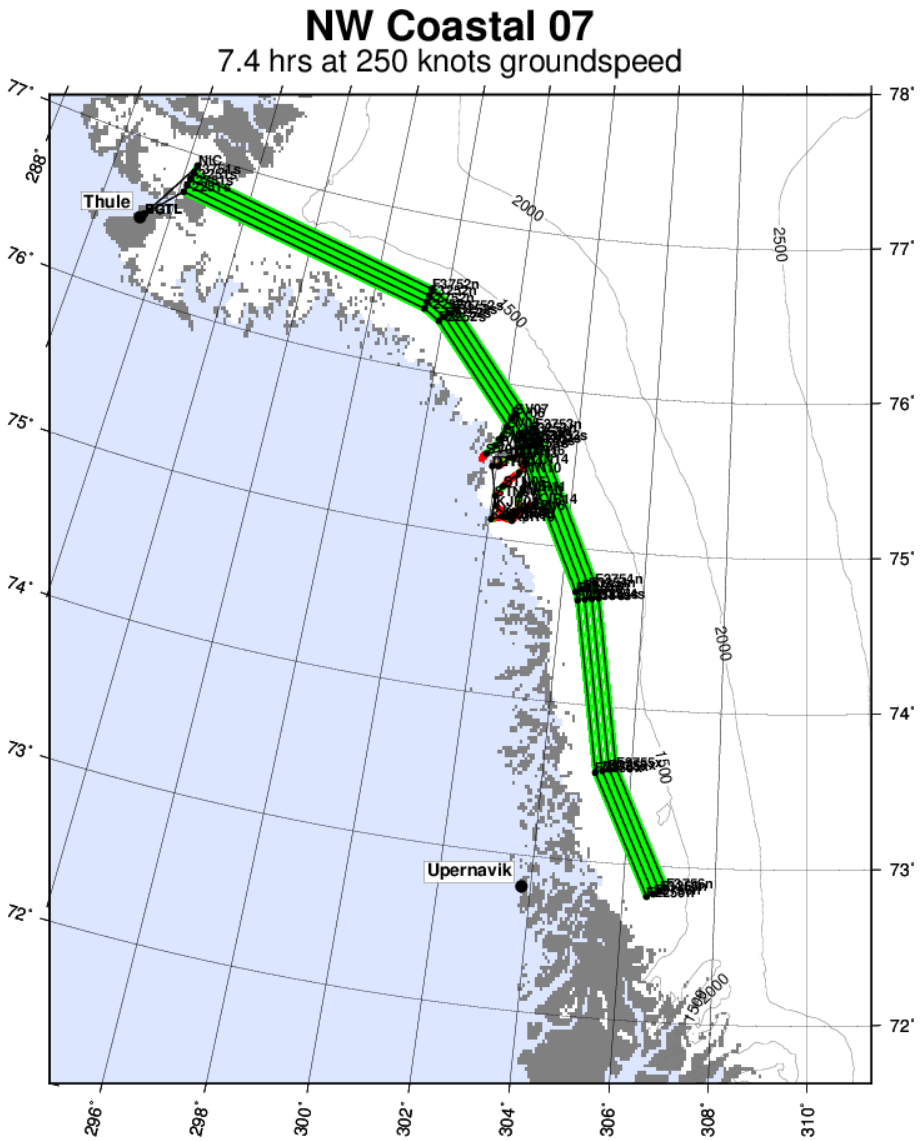
Flight Priority: low
ICESat Track: none
Last Flown: new flight
Remaining Design Issues: none



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 refly the centerline of the Sverdrup Glacier, and fly new centerlines on Dietrichson, Steenstrups, and a pair of centerlines on Kjaer Glacier.

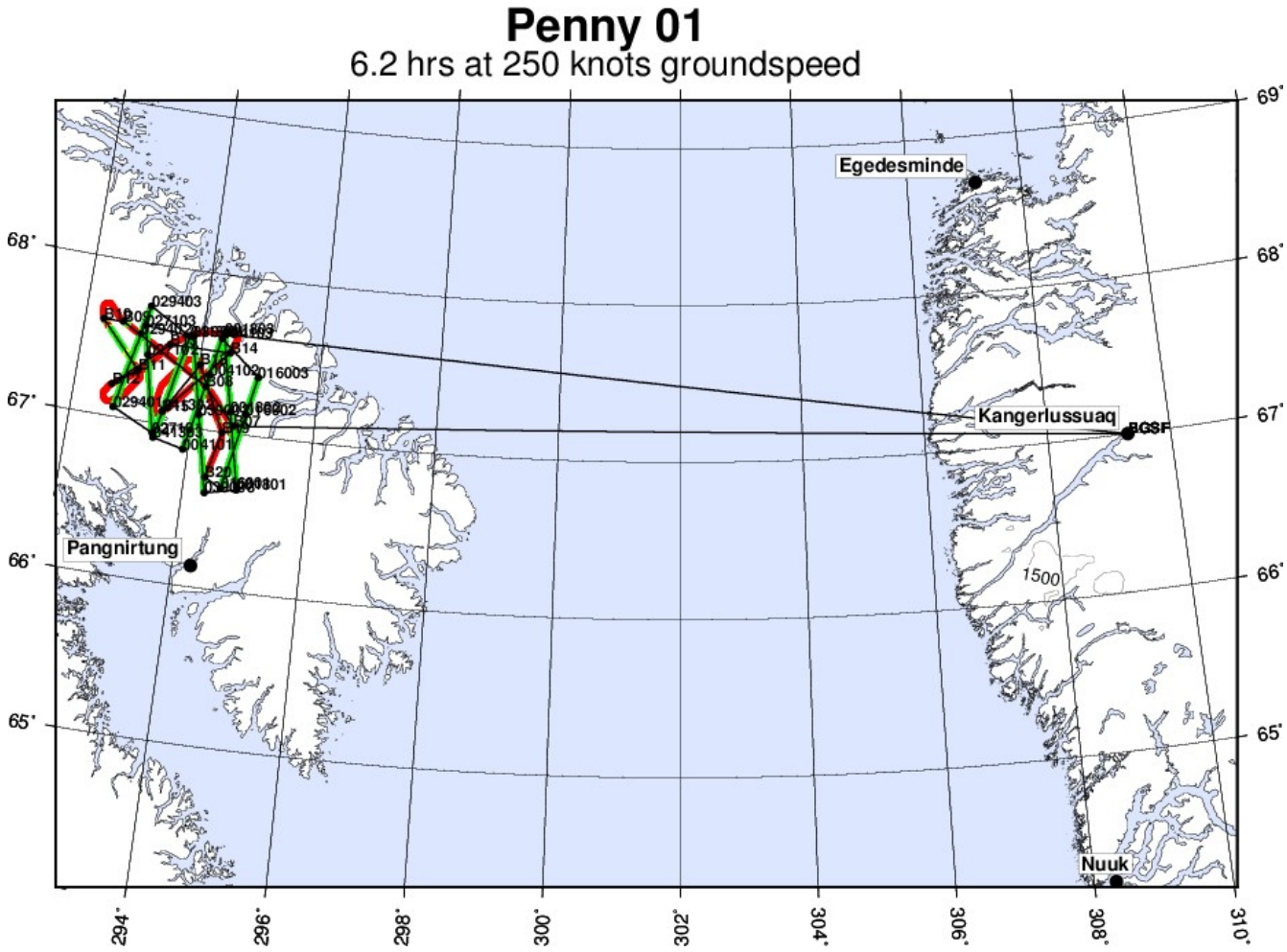
Flight Priority: low
ICESat Track: none
Last Flown: new flight
Remaining Design Issues: none



Land Ice – Penny 01 / Kangerlussuaq

This mission repeats survey lines over the Penny Ice Cap previously surveyed by the ATM/KU teams in 1995, 2000, and 2005, and adds several new lines along ICESat ground tracks over the ice cap. **This mission can be configured as a transit flight between Thule and Kangerlussuaq.**

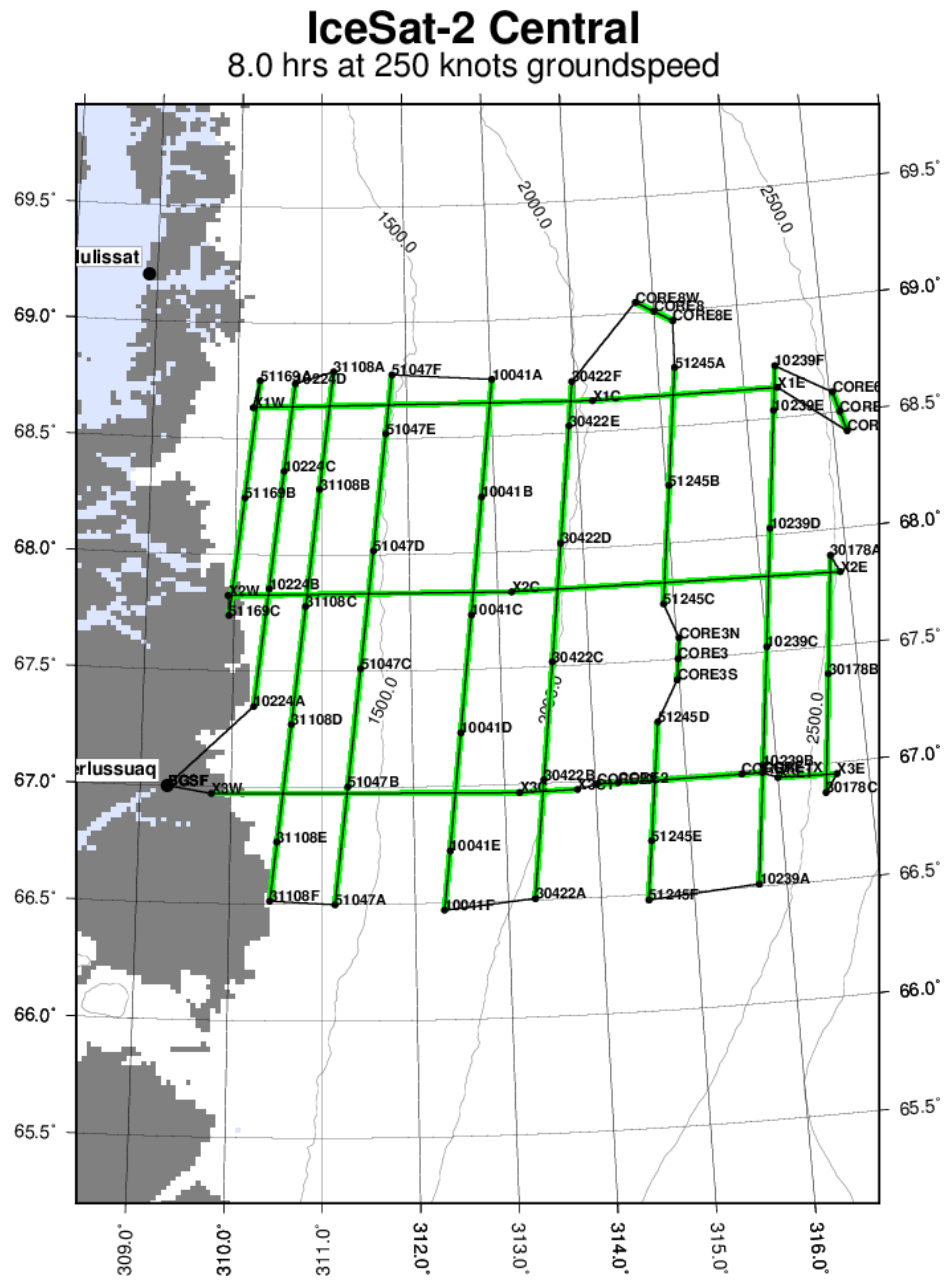
Flight Priority: medium (multi-year repeat flight)
ICESat Track: 0160/0041/0413/0294/0271/0390/0018
Last Flown: 2015
Remaining Design Issues: none



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.

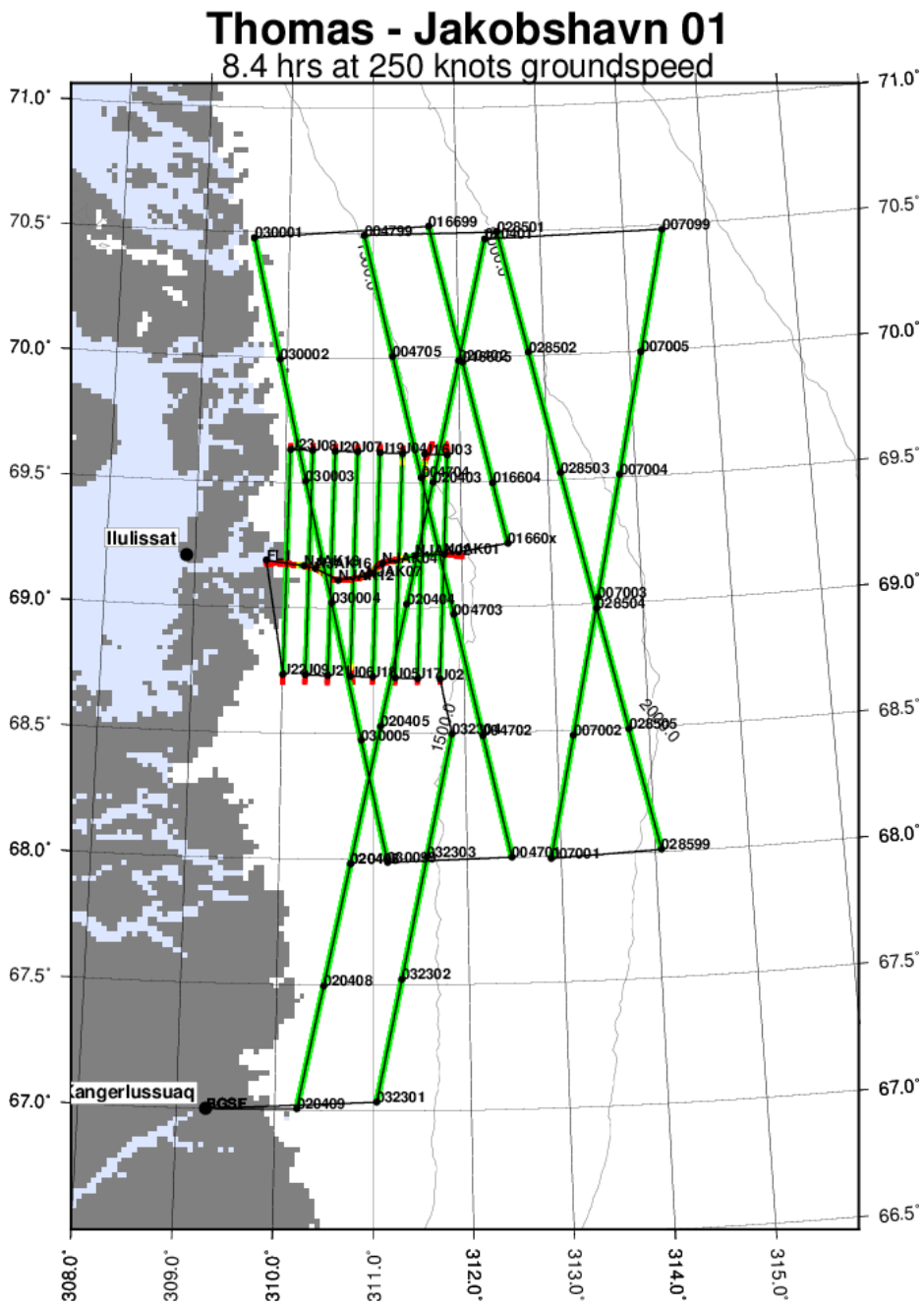
Flight Priority: baseline (annual repeat flight)
IceSat-2 Track: 1169,1022,1047,0041,0422,1245,0239,0178
Last Flown: 2016
Remaining Design Issues: none



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.

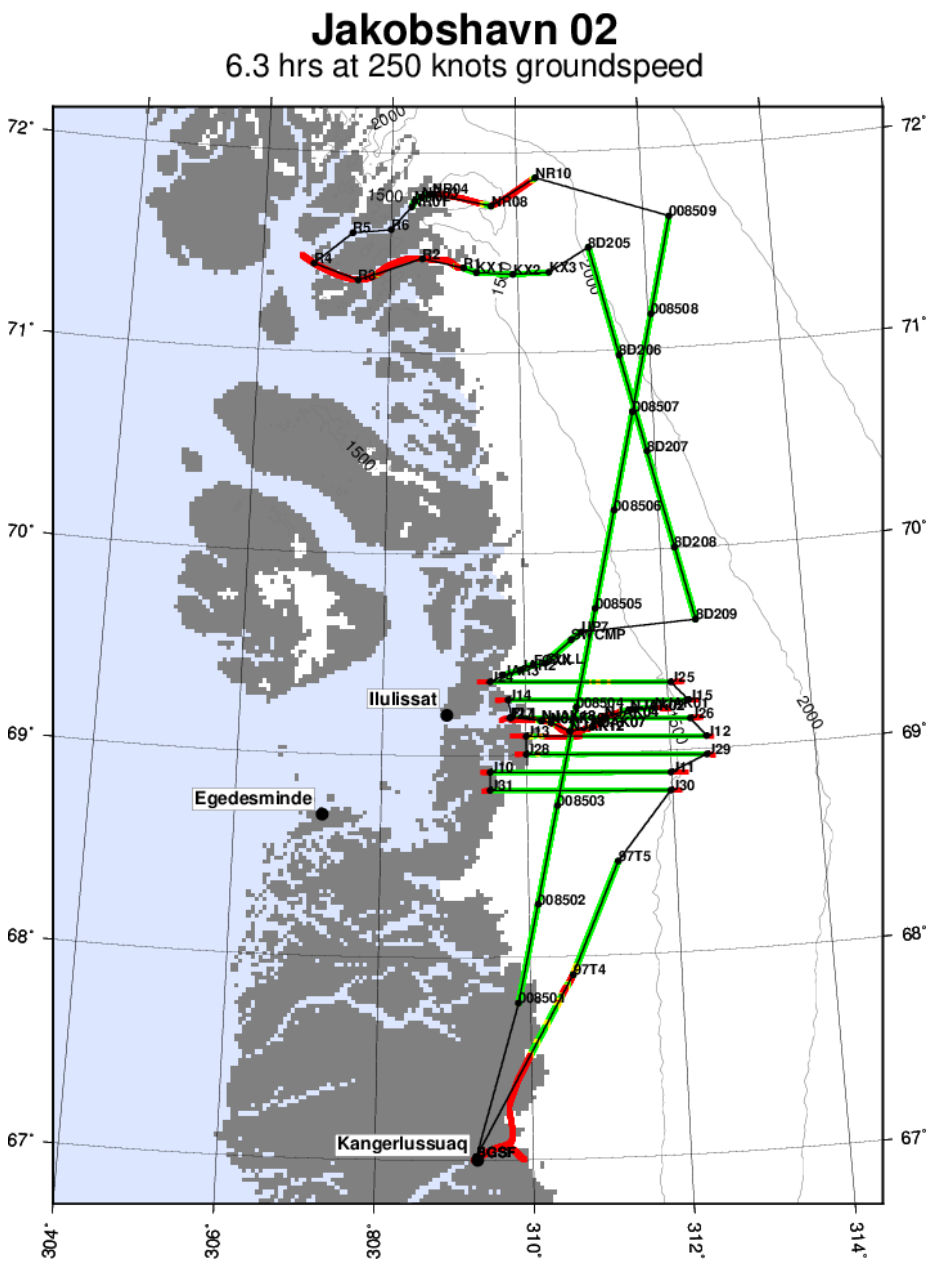
Flight Priority: baseline (annual repeat flight)
ICESat Track: 0323,0300,0047,0285,0070,0204
Last Flown: 2016
Remaining Design Issues: none



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.

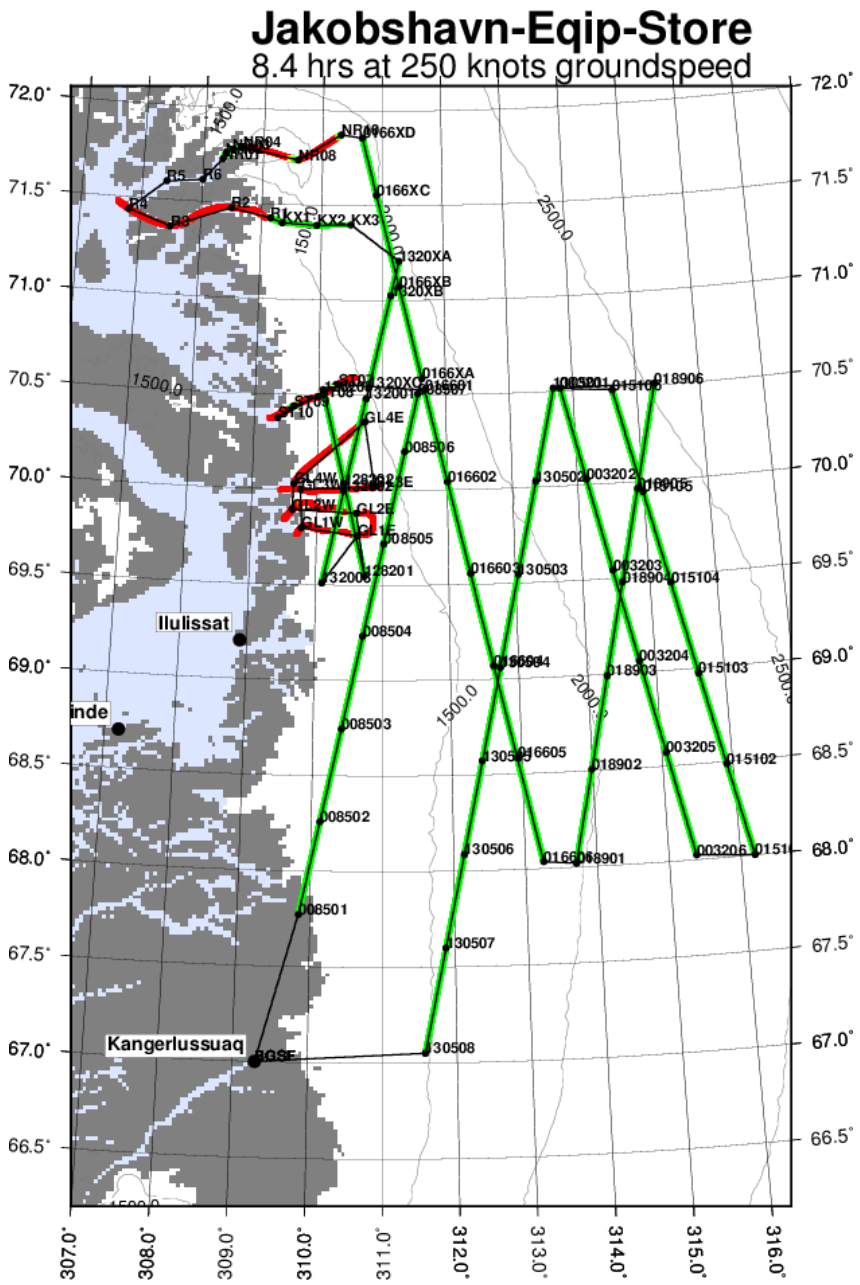
Flight Priority: low (multi-year repeat flight)
ICESat Track: 0181
Last Flown: 2015
Remaining Design Issues: none



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 refly the centerlines of Eqip Sermia, Kangilerngata Sermia, Sermeq Kujalleq and Store Glaciers. Finally we refly the Rink and Kangerdlugssup centerlines.

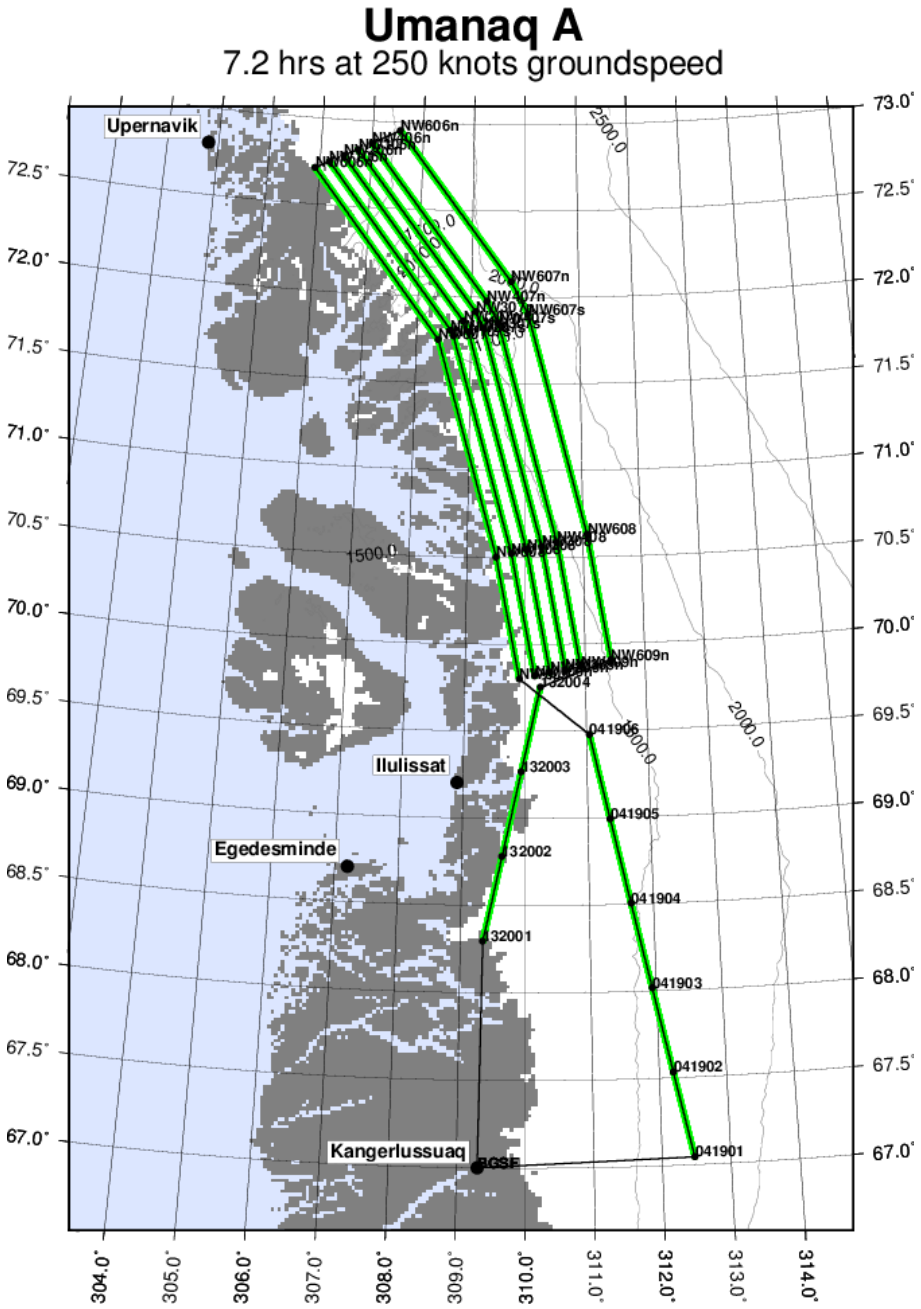
Flight Priority: baseline (annual repeat flight)
ICESat Track: 0085,1320,1282,0166,0189,0032,0151,1305
Last Flown: 2015
Remaining Design Issues: none



Land Ice – Umanaq A / Kangerlussuaq

This mission was designed (along with Umanaq B) to refly 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.

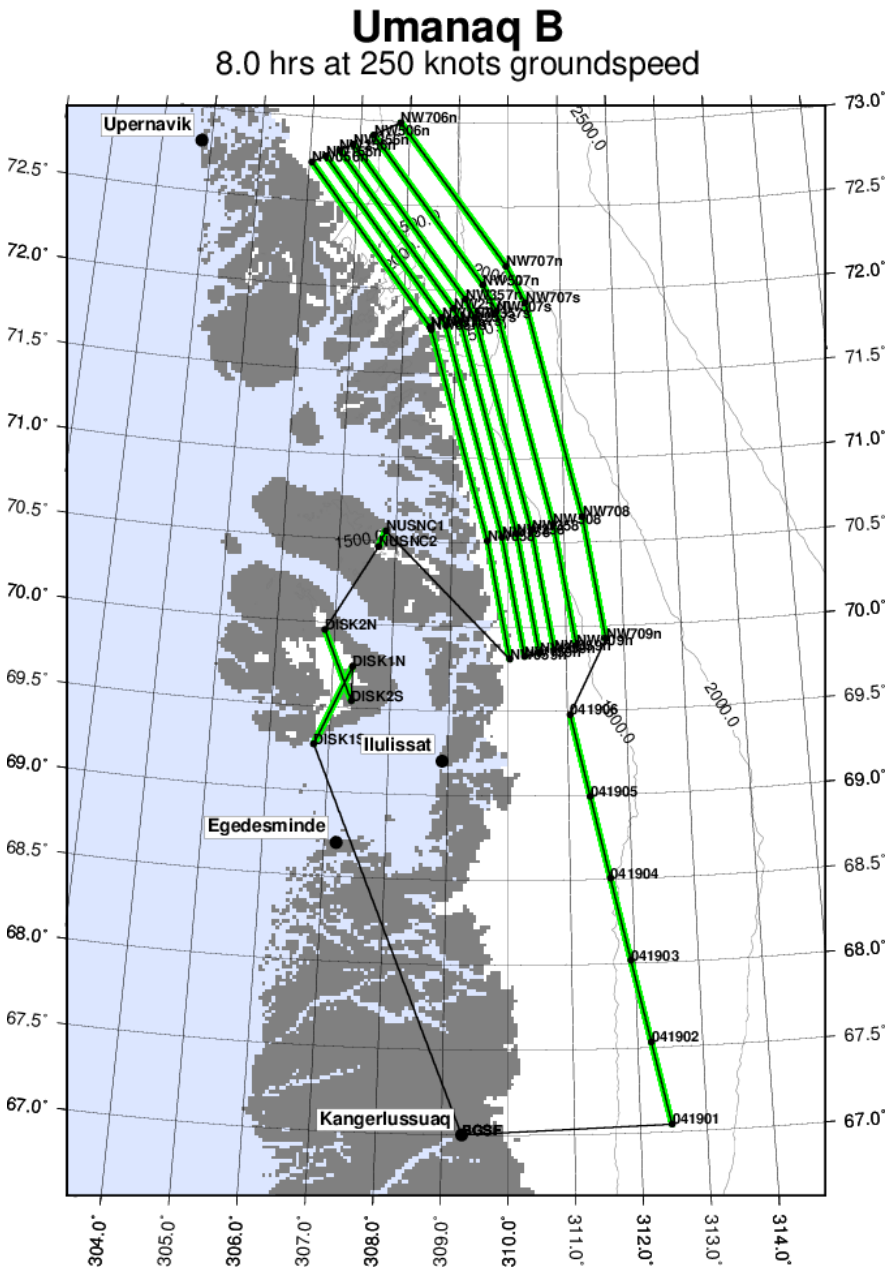
Flight Priority: low (multi-year repeat flight)
ICESat Track: none
Last Flown: 2012
Remaining Issues: none



Land Ice – Umanaq B / Kangerlussuaq

This mission is designed (along with Umanaq A) to refly 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 refly a pair of 2012 lines over the Disko Island ice cap, and another 2016 line over the Nuussuaq Peninsula. This flight retains a high priority for 2017 because it continues an intra-annual time series with the spring and fall 2015 campaigns along these lines.

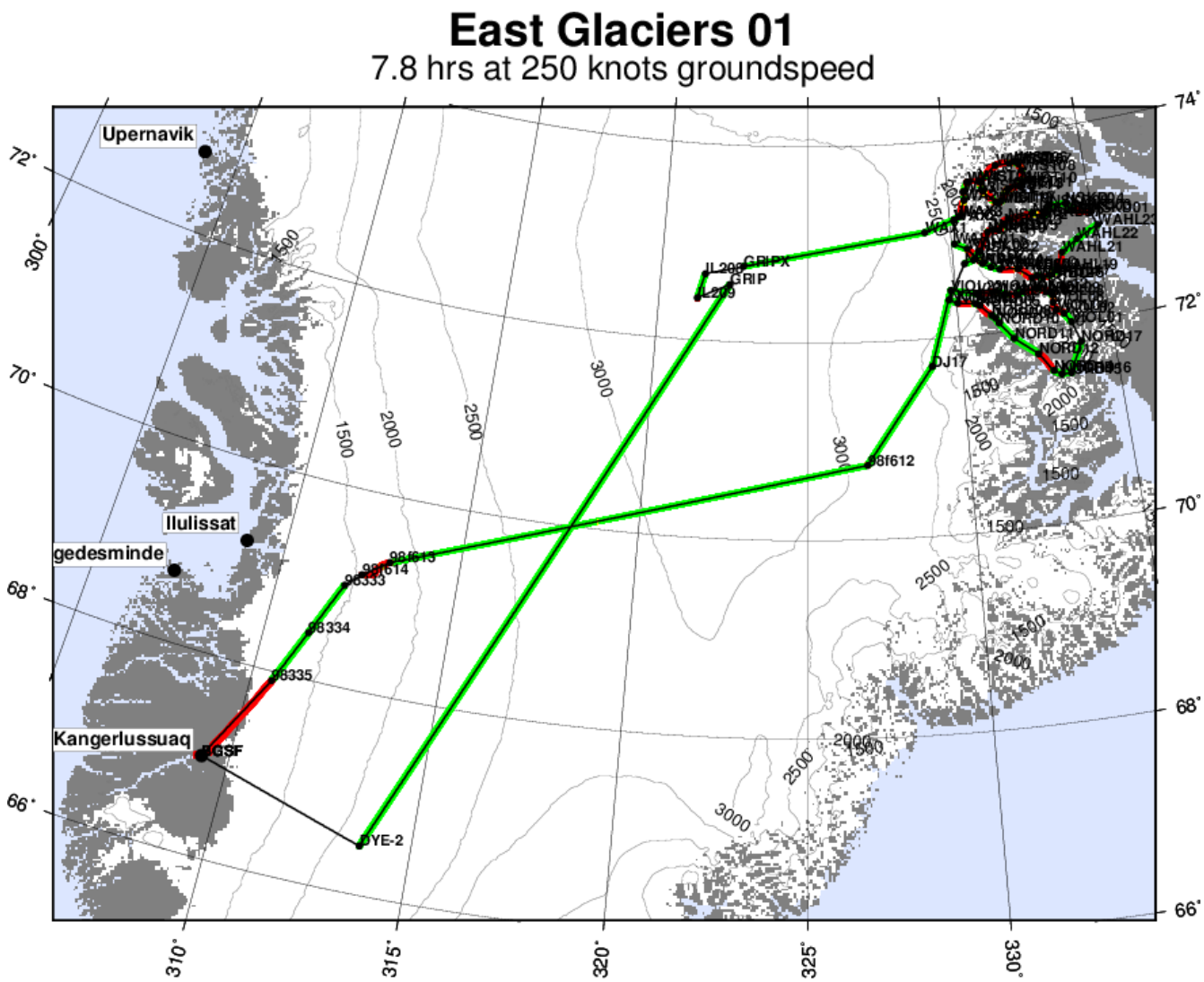
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: 2016
Remaining Issues: none



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. We also overfly the IceSat 0412 Summit calibration line.

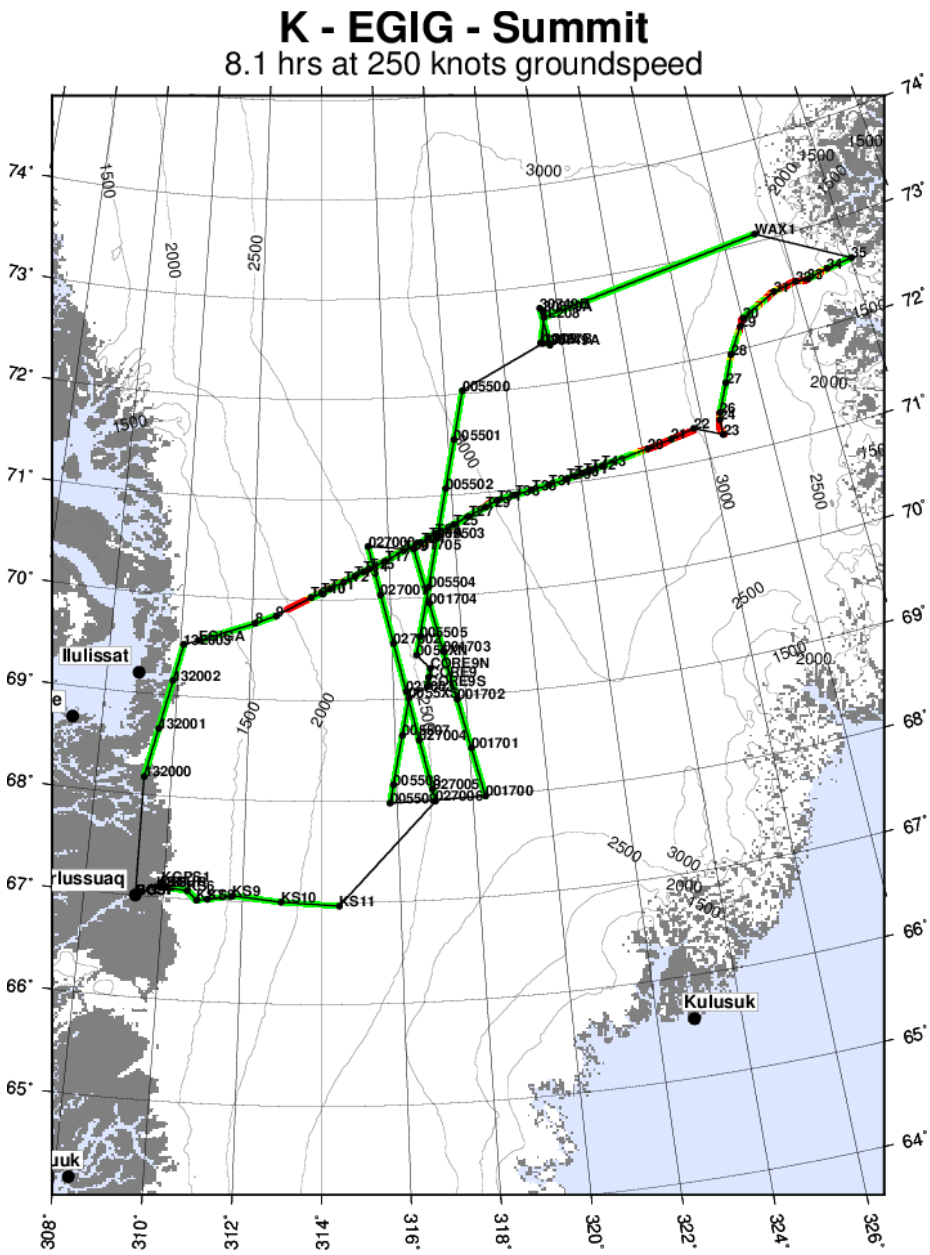
Flight Priority: low (multi-year repeat flight)
ICESat Track: none
Last Flown: 2016
Remaining Issues: none



Land Ice – K-EGIG-Summit / Kangerlussuaq

This mission was designed to accomplish a number of high-priority tasks. First, we refly 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 calibrations 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.

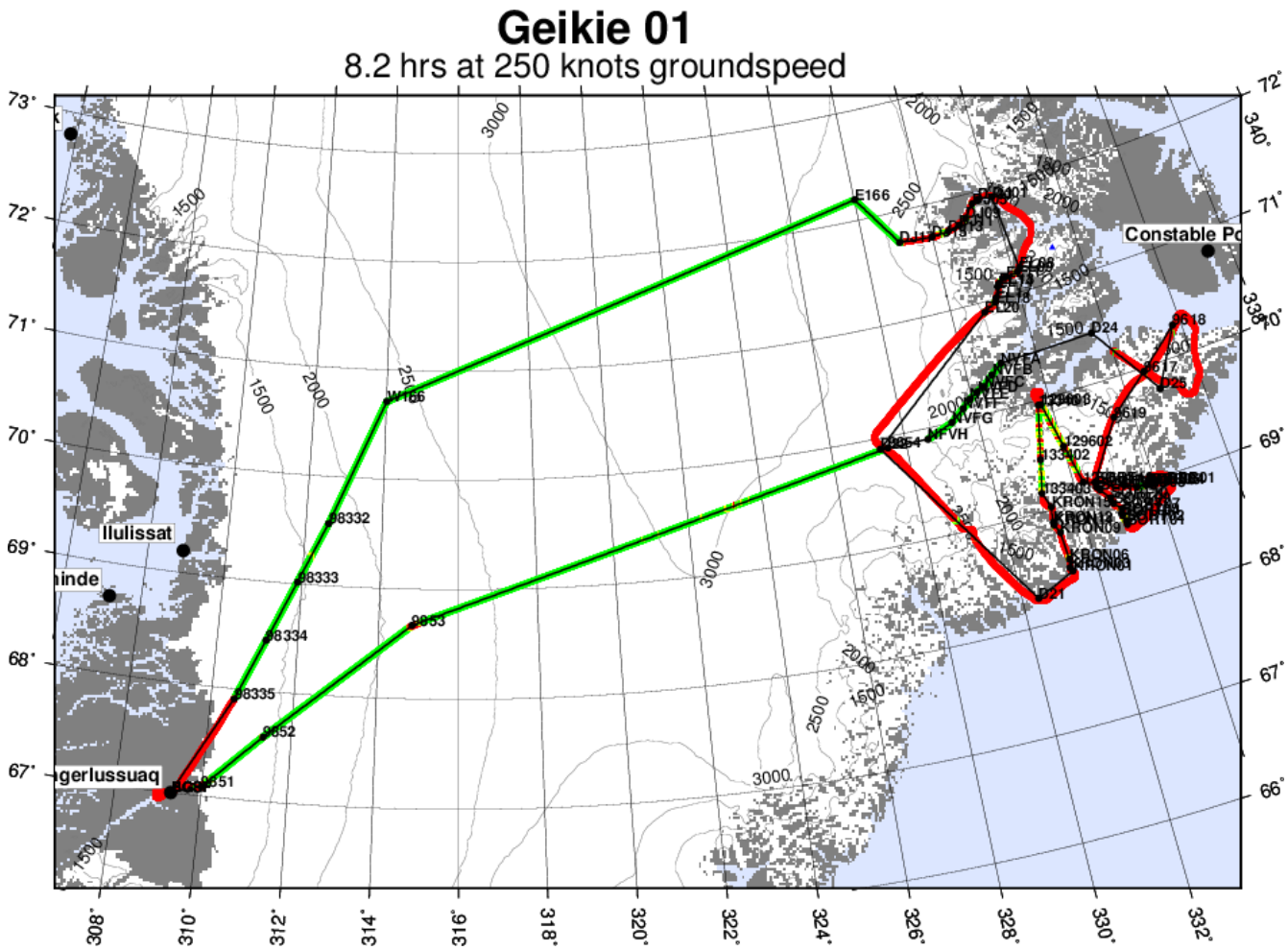
Flight Priority: baseline (annual repeat flight)
ICESat Track: 0055,0017,0270
Last Flown: 2015
Remaining Design Issues: none



Land Ice – Geikie 01 / Kangerlussuaq

This mission is a repeat of 2010, 2011 and 2014 IceBridge missions. It includes reflights of the Daugard-Jensen, Vestfjord and Kong Christian IV glaciers, and the "X" pattern over the Geikie Plateau, all of which have pre-IceBridge altimetry from ATM. It also reflies the Eielson, De Reste Bugt, Sortebrae and Kronborg glaciers, first flown in 2010. Finally, the northern transit line across the ice sheet is a master grid line, which has not been flown prior to 2014.

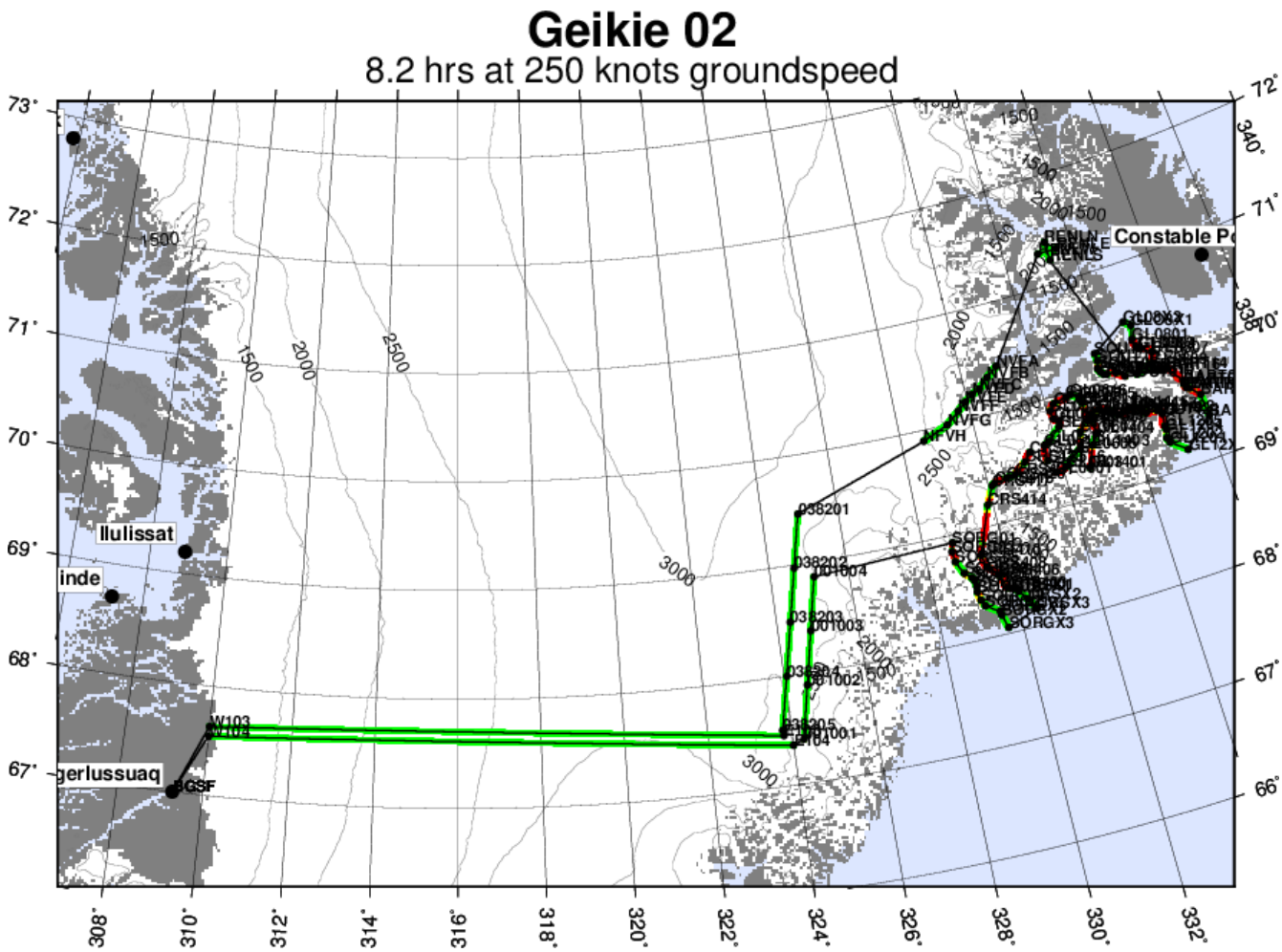
Flight priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: 2014
Remaining Design Issues: use improved Vestfjord CL from 2015 Geikie 02



Land Ice – Geikie 02 / Kangerlussuaq

This mission flies the centerlines of eight Geikie peninsula glaciers. These are Sorgenfri, Christian IV, Bartholins, and South glaciers, plus five more glaciers with unknown names. We transit to and from the Geikie area along master grid lines and IceSat-1 ground tracks. For 2015 we add a crossing of a proposed core site on the Renland ice cap, plus an improved centerline of the Vestfjord Glacier.

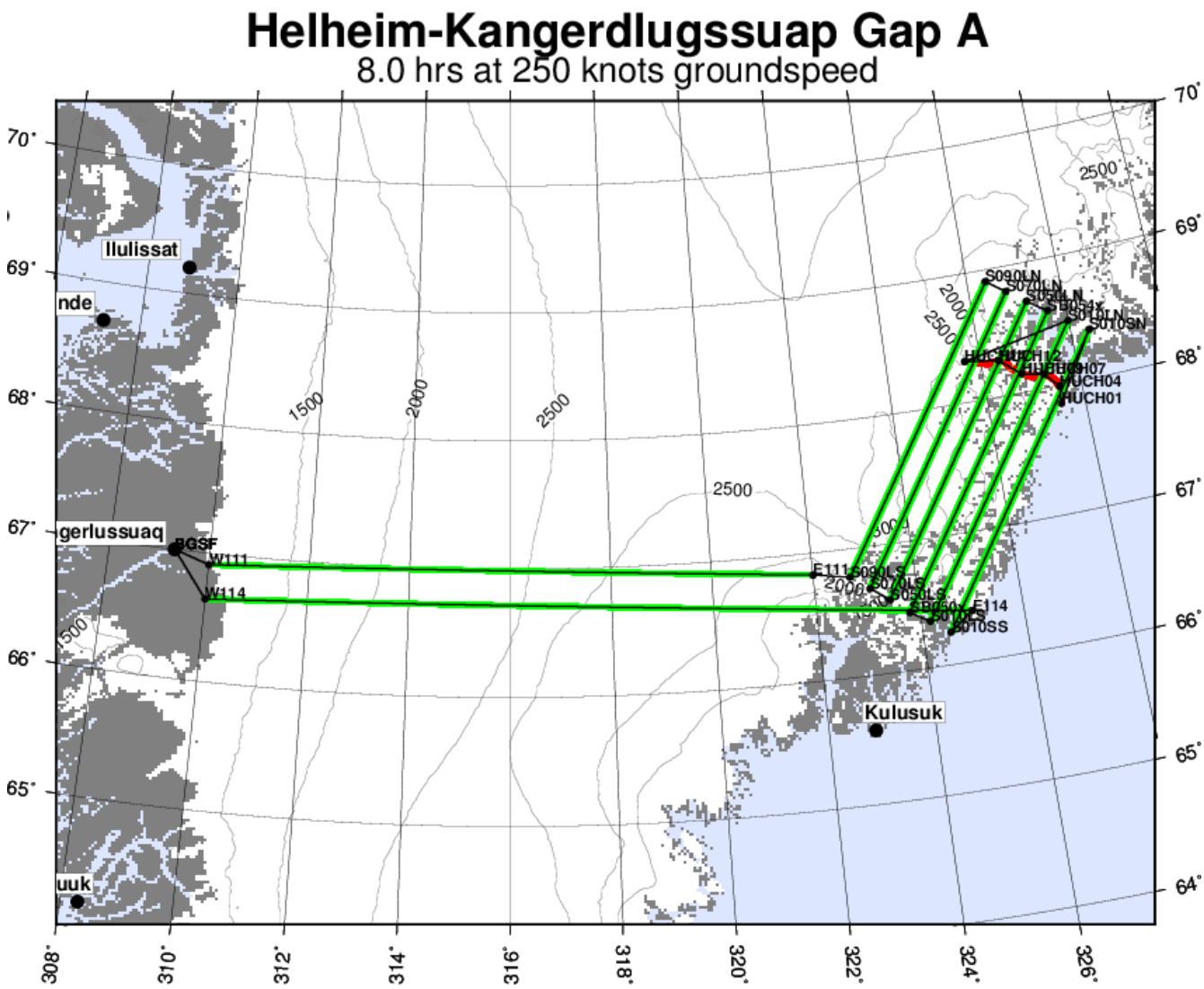
Flight Priority: medium (multi-year repeat flight)
ICESat Track: 0010,0382
Last Flown: 2015
Remaining Design Issues: confirm coordinates of Renland core site are current



Land Ice – Helheim-Kangerdlugssuaq Gap A / Kangerlussuaq

This mission is designed (along with Helheim-Kangerdlugssuaq Gap B) to refly a 2012 grid over the area of complex terrain between the Helhim and Kangerdlugssuaq Glaciers. Each of these news 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.

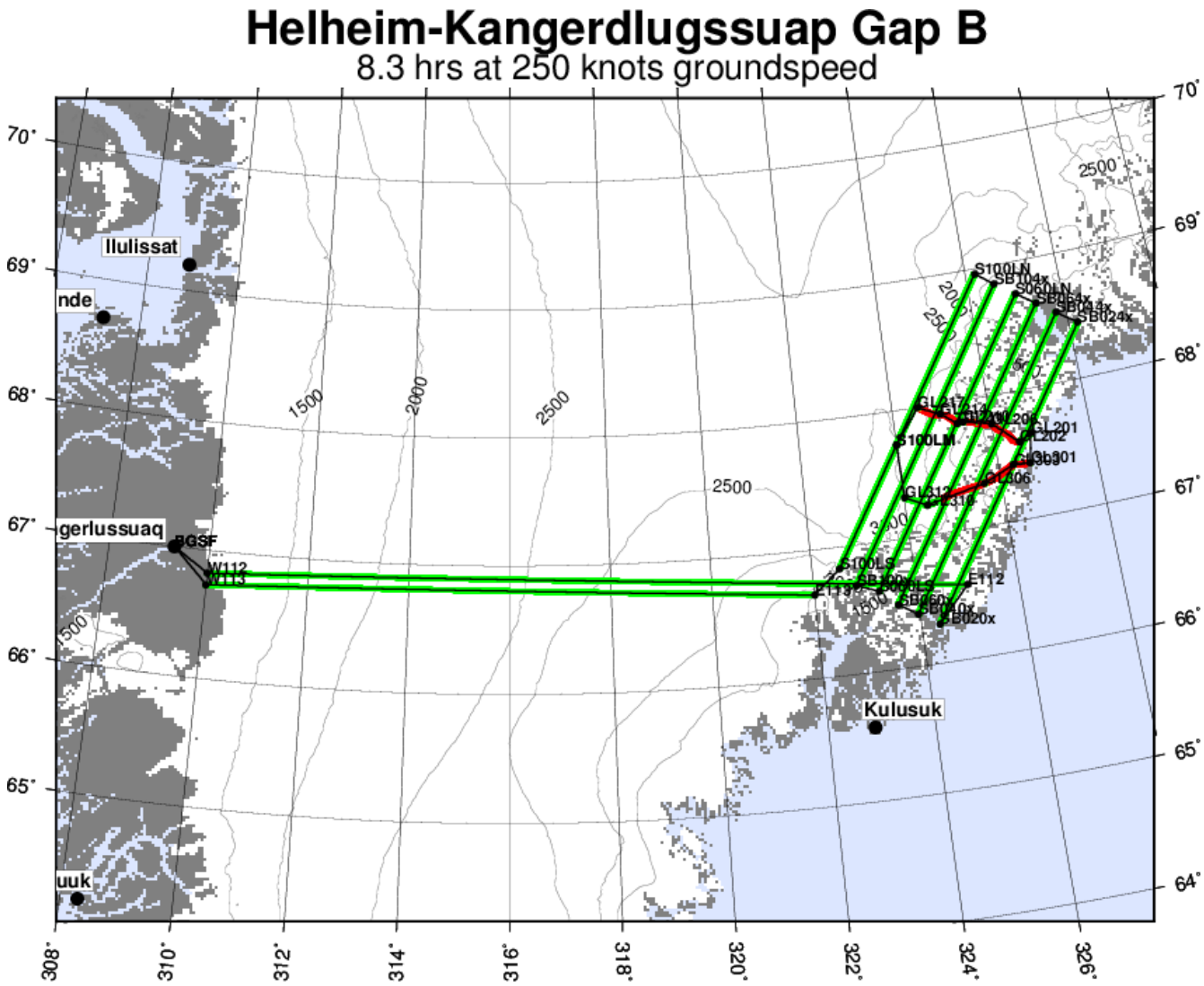
Flight Priority: low (multi-year repeat flight)
ICESat Track: none
Last Flown: 2012
Remaining Design Issues: none



Land Ice – Helheim-Kangerdlugssuaq Gap B / Kangerlussuaq

This mission is designed (along with Helheim-Kangerdlugssuaq Gap A) to refly a 2012 grid over the area of complex terrain between the Helhim and Kangerdlugssuaq Glaciers. Each of these news 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.

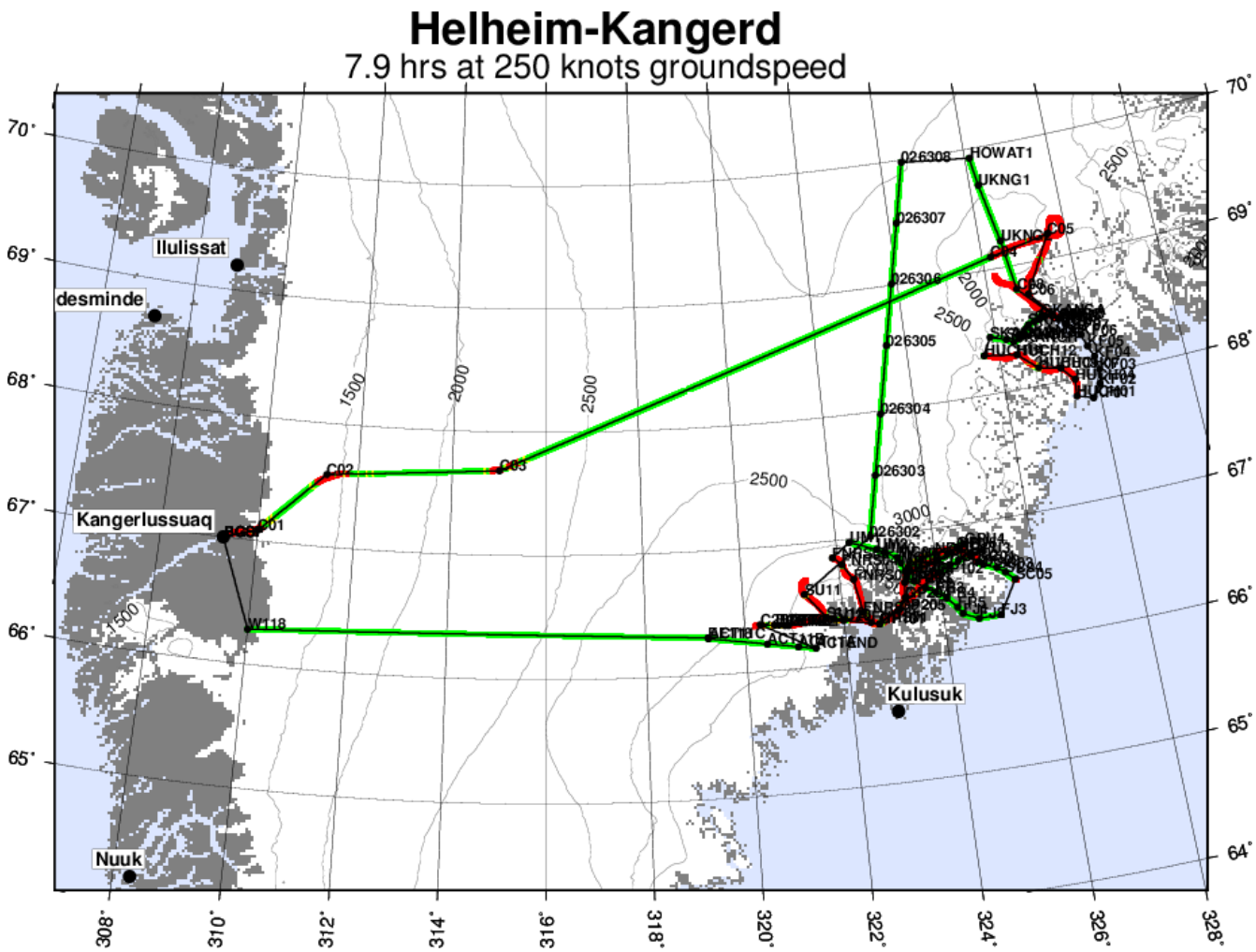
Flight Priority: high (multi-year repeat flight)
ICESat Track: none
Last Flown: 2016
Remaining Design Issues: none



Land Ice – Helheim-Kangerdlugssuaq / Kangerlussuaq

This is a repeat mission, and is very similar to missions flown in 2010, 2011, 2012 and 2013. It captures centerline surveys of the two main branches of Helheim, of Kangerdlugssuaq, Fenris and of several branches of Midgard glaciers. We also refly the centerline of the Hutchinson Glacier, and establish a new centerline of a glacier which empties into the fjord of Kangerdlugssuaq Glacier just beyond its terminus.

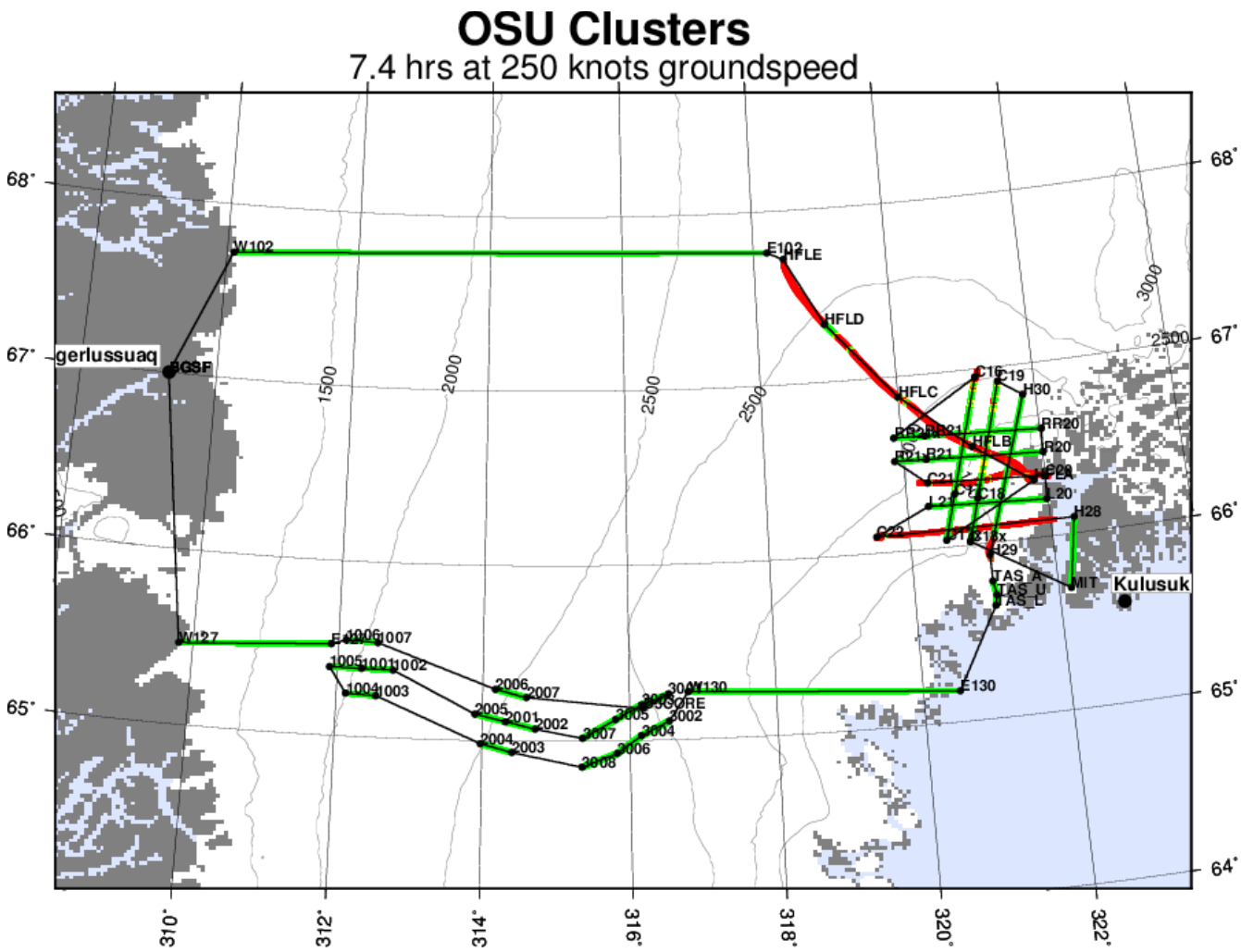
Flight Priority: baseline (annual repeat flight)
ICESat Track: 0263
Last Flown: 2016
Remaining Design Issues: none



Land Ice – OSU Clusters / Kangerlussuaq

This mission was designed with several goals in mind. First, we refly 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 refly 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. For 2017 we slightly redesign the mission to remove the uppermost NS Helheim grid line, replacing it with master grid lines connecting the Cluster sites with the eastern and western ice margins.

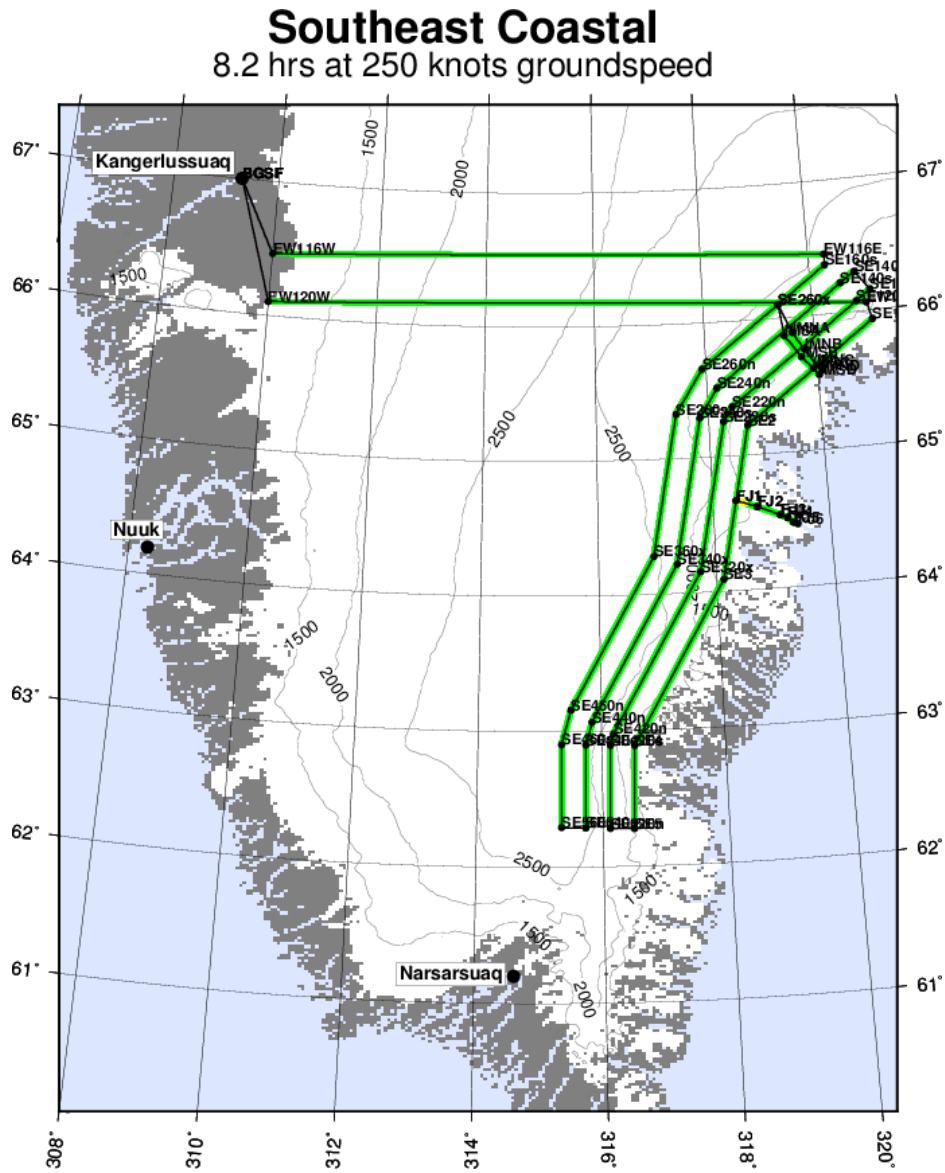
Flight Priority: high (multi-year repeat flight)
ICESat Track: 0040,0181
Last Flown: 2014
Remaining Design Issues: none



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 Fritdjof 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.

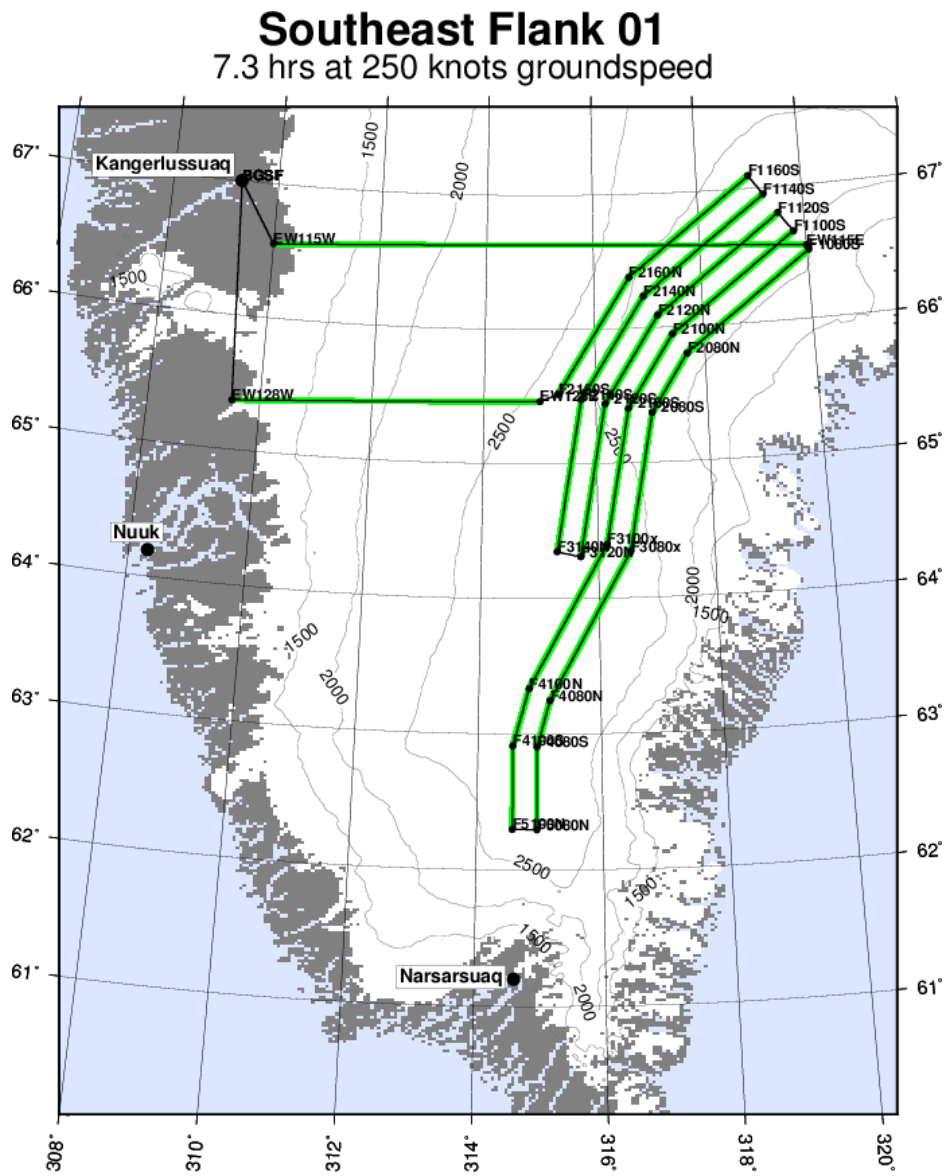
Flight Priority: baseline (annual repeat flight)
ICESat Track: none
Last Flown: 2016
Remaining Design Issues: none



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.

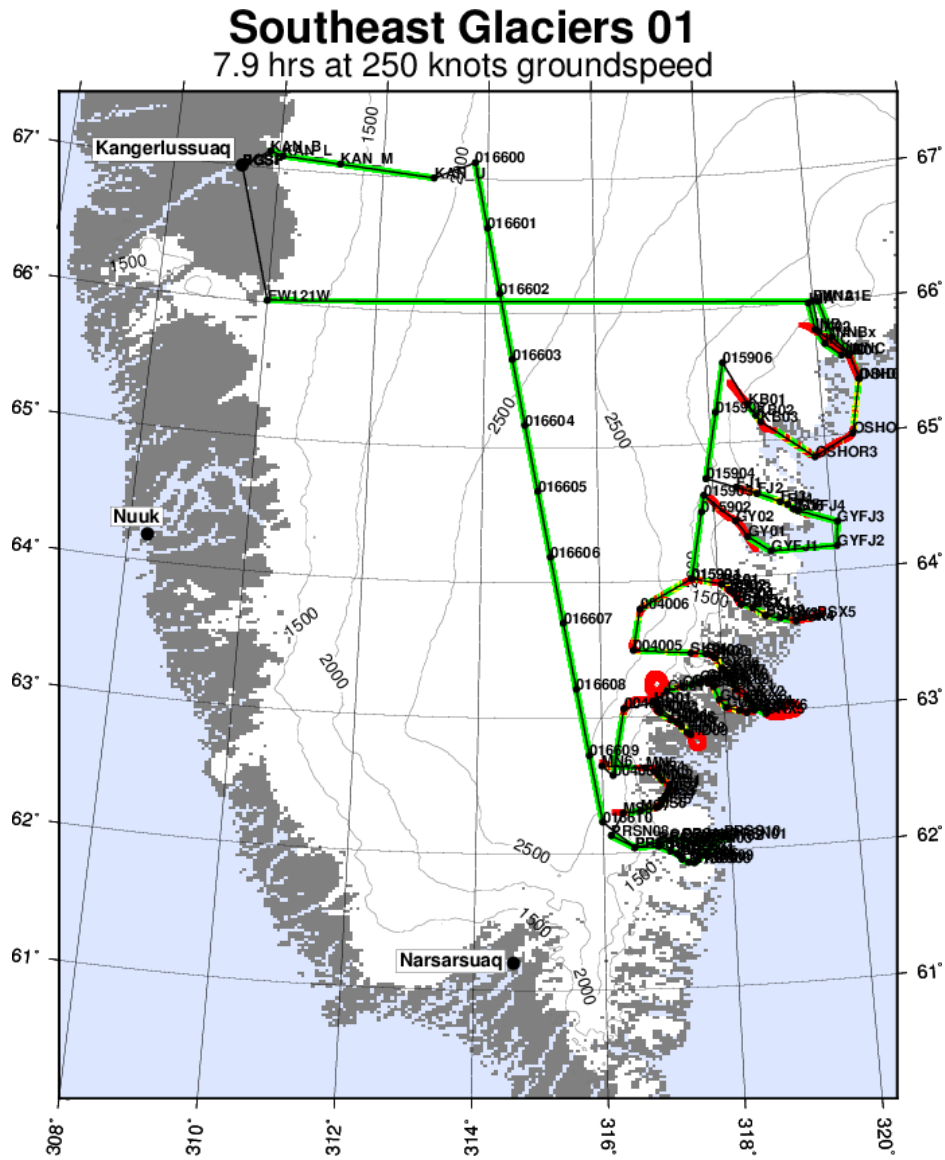
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



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. This had been a baseline OIB flight, but was demoted in 2016 because of its unsuitability to be flown from high altitude during the melt season campaigns.

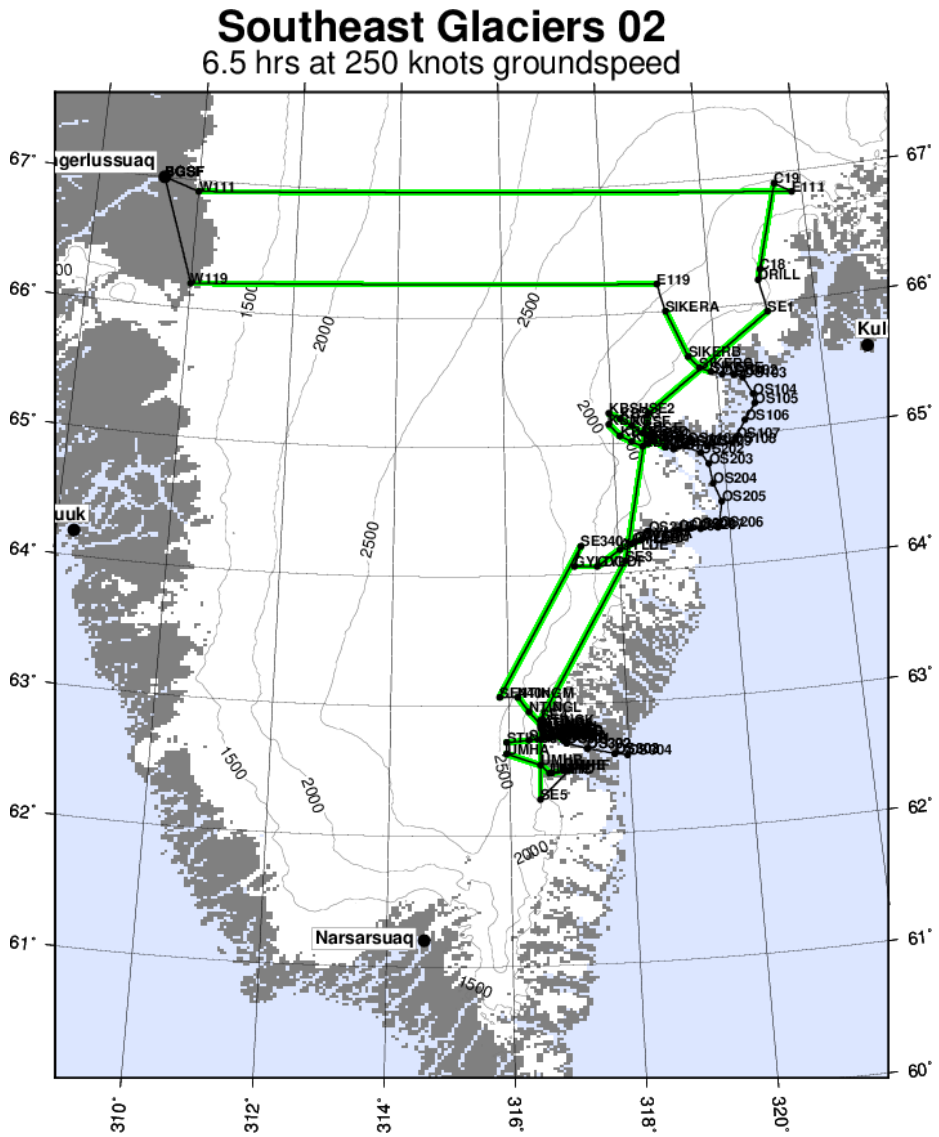
Flight Priority: high (multi-year repeat flight)
ICESat Track: 0166,0040,0159
Last Flown: 2015
Remaining Design Issues: none



Land Ice – Southeast Glaciers 02 / Kangerlussuaq

This mission is designed to fly the centerlines of the largest glaciers in the southeast not included in other OIB missions flown prior to this one. These include a southern branch of Ikertivaq, a wishbone-shaped glacier emptying into Koge Bay, Gyldenlove, the Tingmiarmiut wishbone, and an unnamed glacier emptying into Mogens-Heinesen Fjord. We transit to and from the area on new east-west master grid lines, and we transit between the glaciers on lines previously flown in the Southeast Coastal suite of missions.

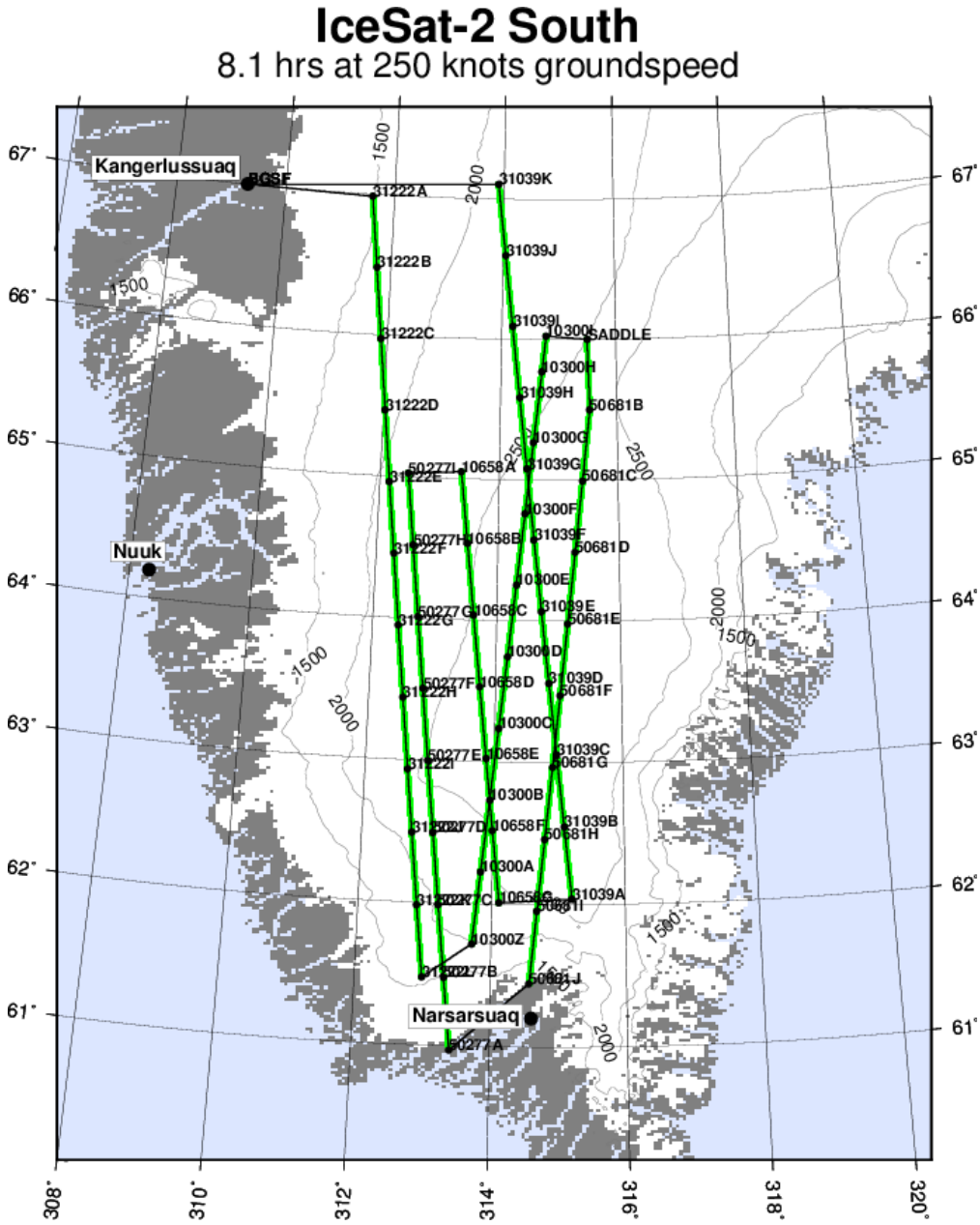
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



Land Ice – IceSat-2 South / Kangerlussuaq

This is a new mission, designed along IceSat-2 ground tracks to fill the gap between the southeastern and southwestern suites of missions. We sample a total of six IceSat-2 orbits, mixing left, nadir, and right beam pair overflights. We also overfly a firn compaction study site at point Saddle.

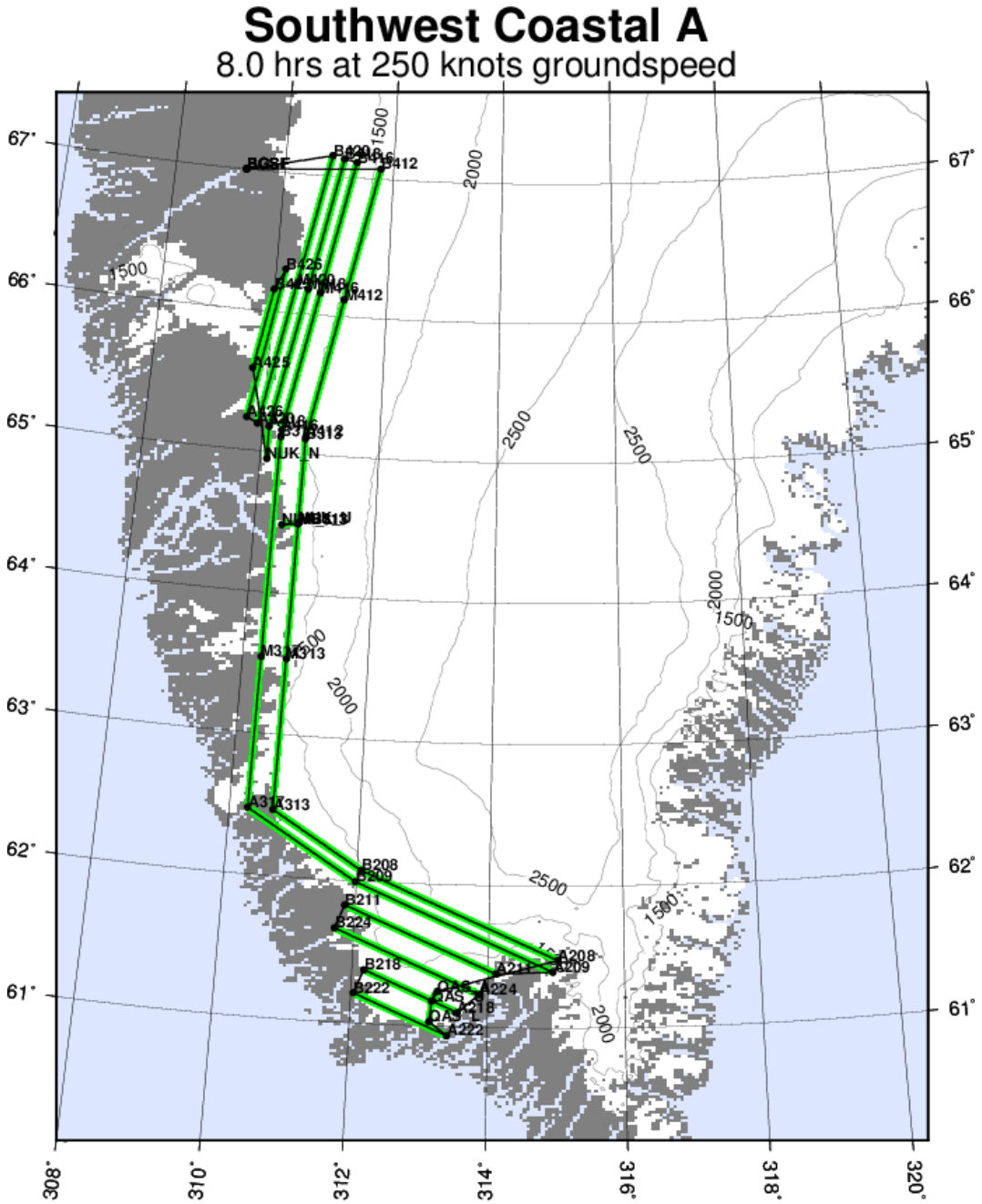
Flight Priority: high (multi-year repeat flight)
ICESat-2 Track: 1222,0300,0681,0277,0658,1039
Last Flown: new flight
Remaining Design Issues: none



Land Ice – Southwest Coastal A / Kangerlussuaq

This mission is one of two (with Southwest Coastal B) designed to mirror the southeastern coast-parallel coverage in the southwest, along 2011 LVIS flight lines. This particular flight captures the lowest-altitude portion of this part of the ice sheet. We also overly a total of six PROMICE sites.

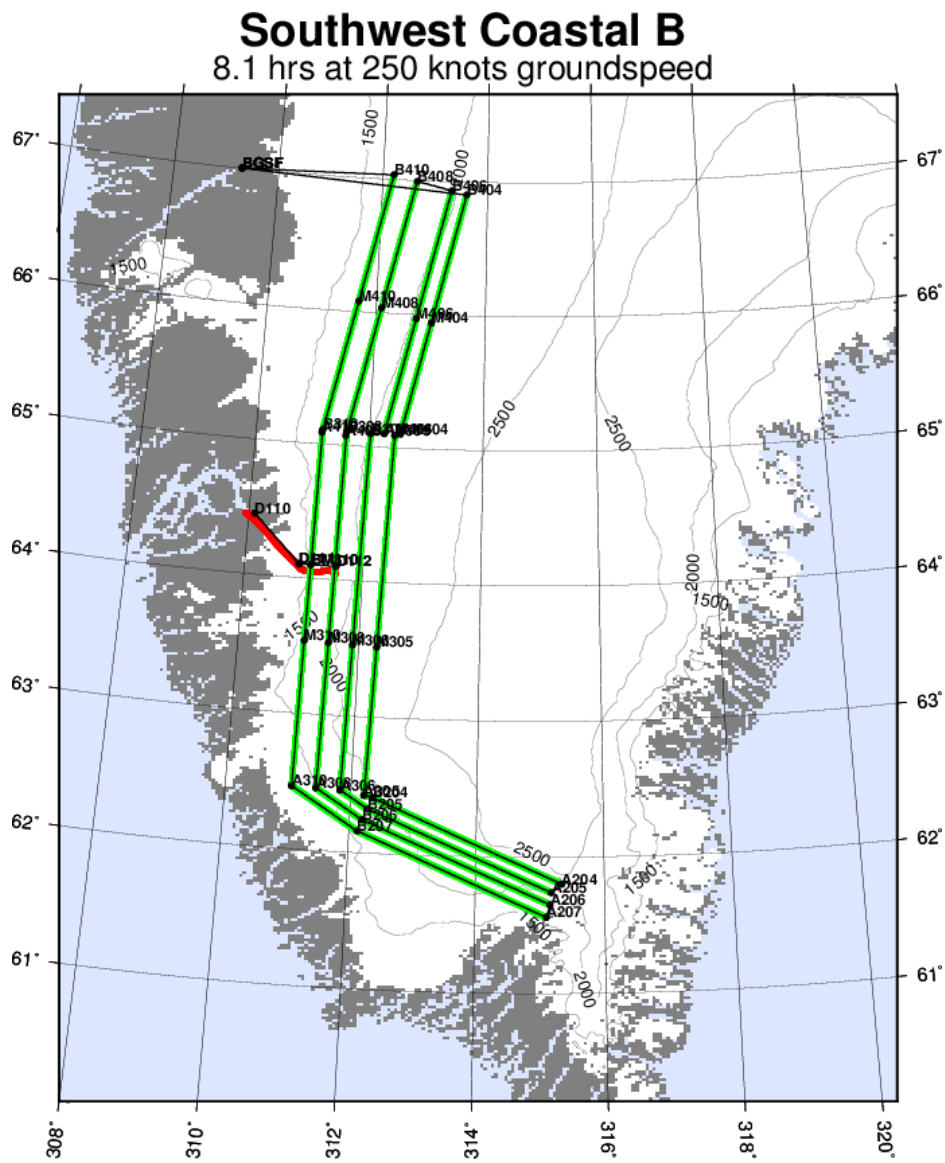
Flight Priority: baseline (annual repeat flight)
ICESat Track: none
Last Flown: 2016
Remaining Design Issues: none



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.

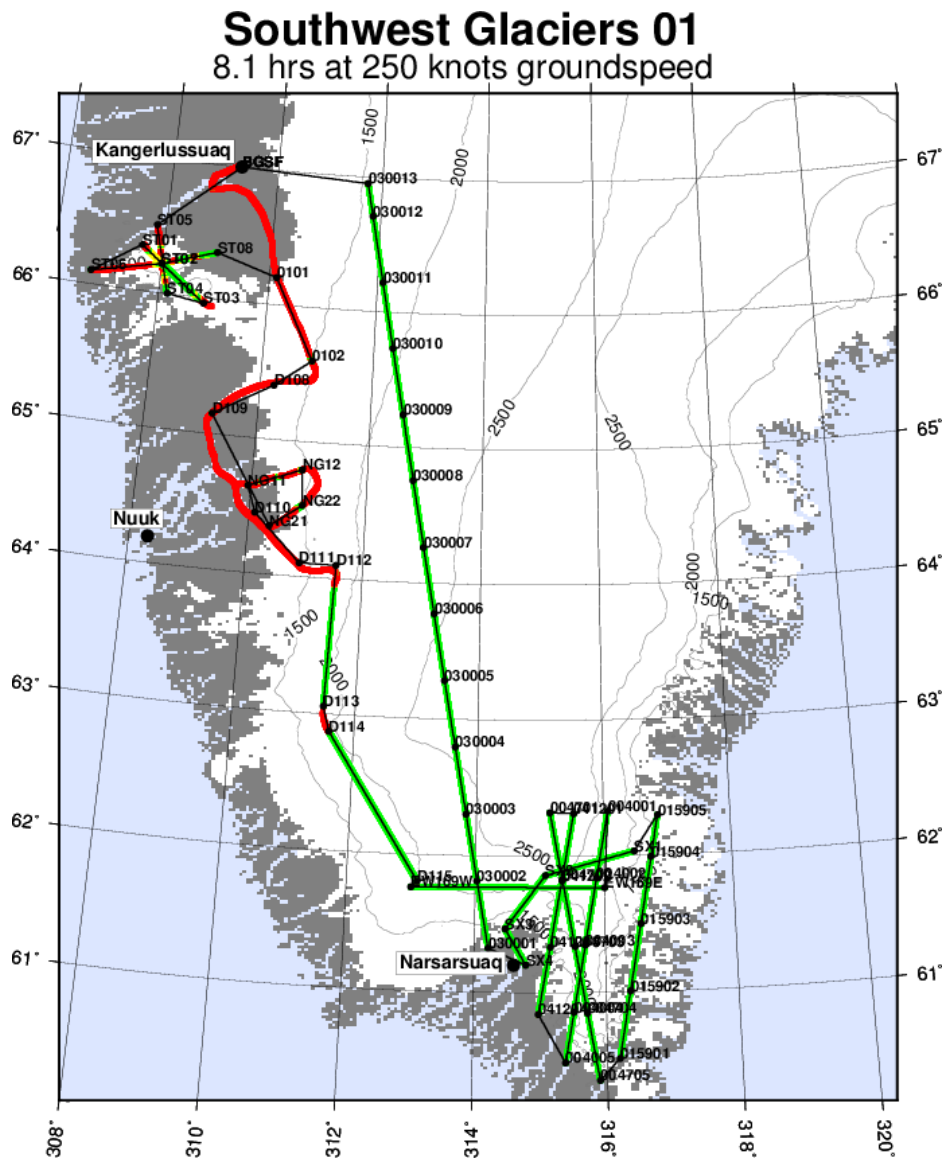
Flight Priority: medium (multi-year repeat flight)
ICESat Track: none
Last Flown: 2015
Remaining Design Issues: none



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 Akugdlersupasermia. We also refly 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: high (multi-year repeat mission)
ICESat Track: 0040,0412,0047,0159,0300
Last Flown: 2014
Remaining Design Issues: none



Appendix: Status of External Flight Requests

Requests for flight line modifications from the OIB science team are incorporated into the flight lines, in an interactive manner with the team through telecons and the planning meeting. The status of requests from other researchers, which are by nature less interactive, are summarized below.

1. Medley and MacFerrin requested OIB overflights of several firn densification sites around Greenland. Each are overflown in particular flights as follows.
    1. EGRIP: overflown within 500 m in Northeast Glaciers 02
    2. Summit: overflown within 100 m in K-EGIG-Summit
    3. KAN-U: overflown directly in both K-EGIG-Summit and Southeast Glaciers 01
    4. DYE-2: overflown within 1.5 km in East Glaciers 01
    5. EKT: overflown directly in IceSat-2 Central
    6. NASA-SE: overflown within 5 km in Southeast Flank and within 3 km in Southeast Coastal
    7. Saddle: modified IceSat-2 South to overfly directly
    8. Crawford Point: Overflown within 1.5 km in both K-EGIG-Summit and Geikie 01
    9. W111-E111: Overflown directly in Helheim-Kangerdlugssuaq Gap A

2. Sutterley recommended several land ice missions which would be most useful for evaluation of surface mass balance models. He also requested a modification to the Alexander-Petermann 01 mission to include a portion of the 20090422 flight, but this was difficult to accommodate in the mission without major reductions elsewhere. The flights he singled out, and their priorities, are as follows:
    1. Alexander-Petermann 01 – high
    2. North Glaciers 01 – medium
    3. K-EGIG-Summit – baseline
    4. Southwest Coastal A – baseline

3. Dahl-Jensen requested reflights of 2012 Disko Island lines. These were inserted into the Umanaq B flight, with the requested 2012 lines replacing two nearby lines which were flown in 2016.

4. Colgan requested single-pass overflights of two sites which may contain Cold War-era waste in Northwest Greenland. To accommodate this, we replaced one short IceSat-1 line near Cape Alexander with a pass over their "Site 1" in the Alexander-Petermann 01 mission. We replaced another short IceSat-1 line in the Northeast Grid 05 flight with a pass over their "Site 2".

5. CryoVex has requested a co-flight with DTU and AWI aircraft along a to-be-determined CryoSat-2 track between Alert and 88 N, and a second overflight of the same track a few weeks later to coincide with in-situ work to be performed on it. We propose to accommodate the co-flight with AWI and DTU as part of either our "North Pole Transect" or "Zigzag West" flight, and then the re-flight later as part of a dedicated mission. The details are in flux but will be determined once all teams are in the field.

6. ABOVE snow survey sites near Fairbanks – in work. These small sites will be addressed shortly after takeoff and before landing at Fairbanks, and will not significantly affect the sea ice missions.

7. Svalbard historical ATM/Kansas lines – in work. These will be addressed in transits between the existing flights and Longyearbyen airport, and will not adversely affect the flights.