Fall 2010 IceBridge Flight Plans
19 October 2010 Draft

compiled by

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Introduction to Flight Plans

This document summarizes the flight plans for the fall 2010 Antarctic IceBridge deployment. These plans are the result of a lengthy process directed by the Operation IceBridge project scientists, and reflect formal and informal input from the cryospheric science community. They are also shaped by the need to conform to overall Operation IceBridge objectives (included below) and the requirement to make best use of NASA's large investment in the suite of remote sensing instruments aboard the project aircraft.

The 2010 Antarctic IceBridge missions will be flown using NASA's DC-8 aircraft. The DC-8 can safely fly for approximately 11 hours, and normally cruises at an average of 440 knots at high altitude, and at least 250 knots when in low-altitude science operations. The science instrument suite includes two NASA swath-mapping altimeters (ATM and LVIS), three University of Kansas radars (MCoRDS, KU-band, and snow radars), a Sander Geophysics / Lamont-Doherty Earth Observatory airborne gravimeter, the NASA DMS camera system, and several ancillary instruments which can also provide important scientific information.

In the primary section of flight plans, we present three sea-ice flights, nine low-altitude land ice flights and two high-altitude land ice flights, each ranked in scientific priority with low, medium and high priority designations. We expect a flight-hour budget of 140 hours, or 12-13 missions, so one or more of the lower-priority missions may be deferred to another year. We also present a number of “reserve” flights. The “reserve” designation represents a science priority lower than the primary missions, but which may be flown in the event extra schedule margin and flight budget materializes, as it did during the 2009 Antarctic IceBridge deployment. The reserve section includes low- and high-altitude land ice, plus sea ice, mission plans.

Each mission plan is represented by a map, in latitude/longitude for sea ice and polar stereographic (south polar aspect, projection center -71 S / 00 W) for land ice, showing the proposed flight path in black. For the land ice flights, we show the proposed flight path superimposed on a Rignot et. al. InSAR ice velocity field. We also show the Rignot et. al. grounding lines in thick light gray lines, and the 2009 IceBridge flight paths in thin dark gray lines. The proposed flight paths can also be made available as Google Earth KML file formats by request.

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 late 2015. Sensitive and critical areas include coastal Greenland and especially its outlet glaciers, costal 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 meet 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:

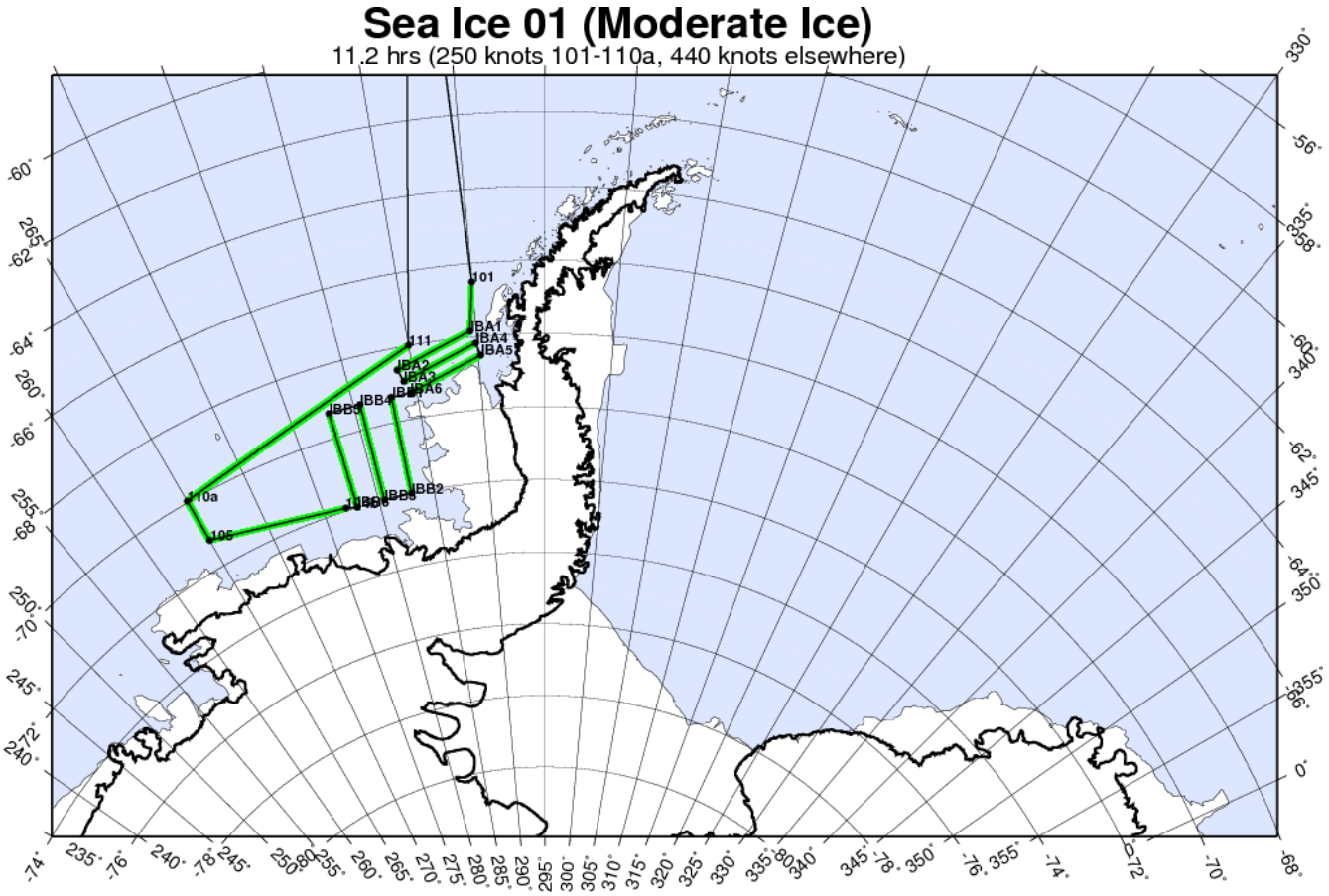
- Ice sheet and sea ice thickness, structure and extent;
- Bed topography underlying land-based ice;
- Bathymetry beneath floating ice shelves;
- Snow accumulation and firn structure; and
- Other geophysical constraints that will improve estimates of the geothermal and oceanic heat flux

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

Sea Ice 01 (Bellingshausen/ICEBELL)

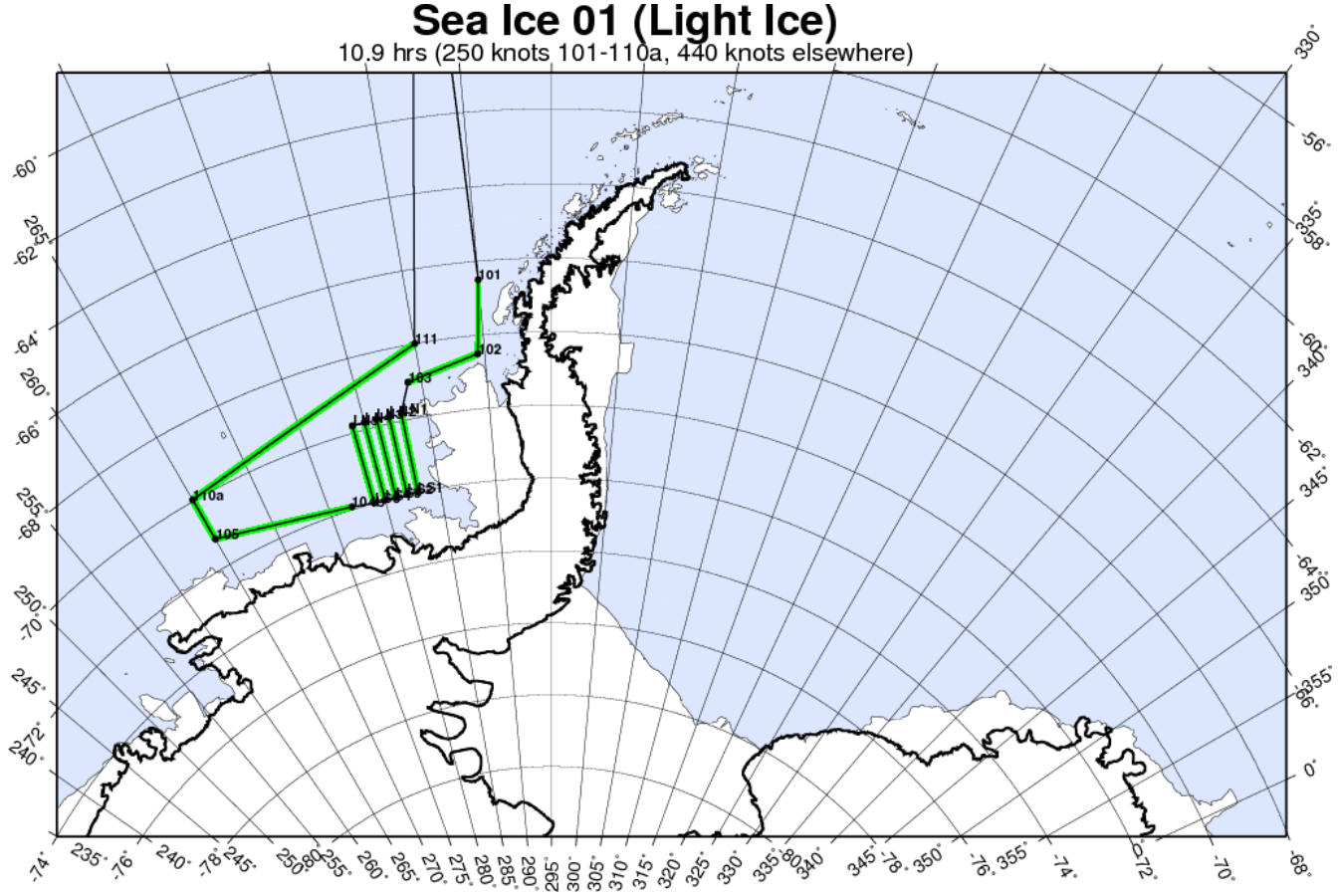
This mission is a partial repeat of the 091021 IceBridge flight. The Amundsen Sea segment of that flight has been removed and replaced with several grid lines north and west of Alexander Island, which are intended to mesh with the efforts of the ICEBELL ship-based project. The option shown immediately below applies to expected "moderate" ice conditions. On the following page we also show two additional options for this particular flight, one for light ice conditions and another for heavy ice conditions. The choice of which of the three versions to fly will be made once ice conditions closer to the date of the flight can be determined.

Flight Priority: High **Instrument Priority:** ATM, Snow Radar, Gravimeter
ICESat Track: none



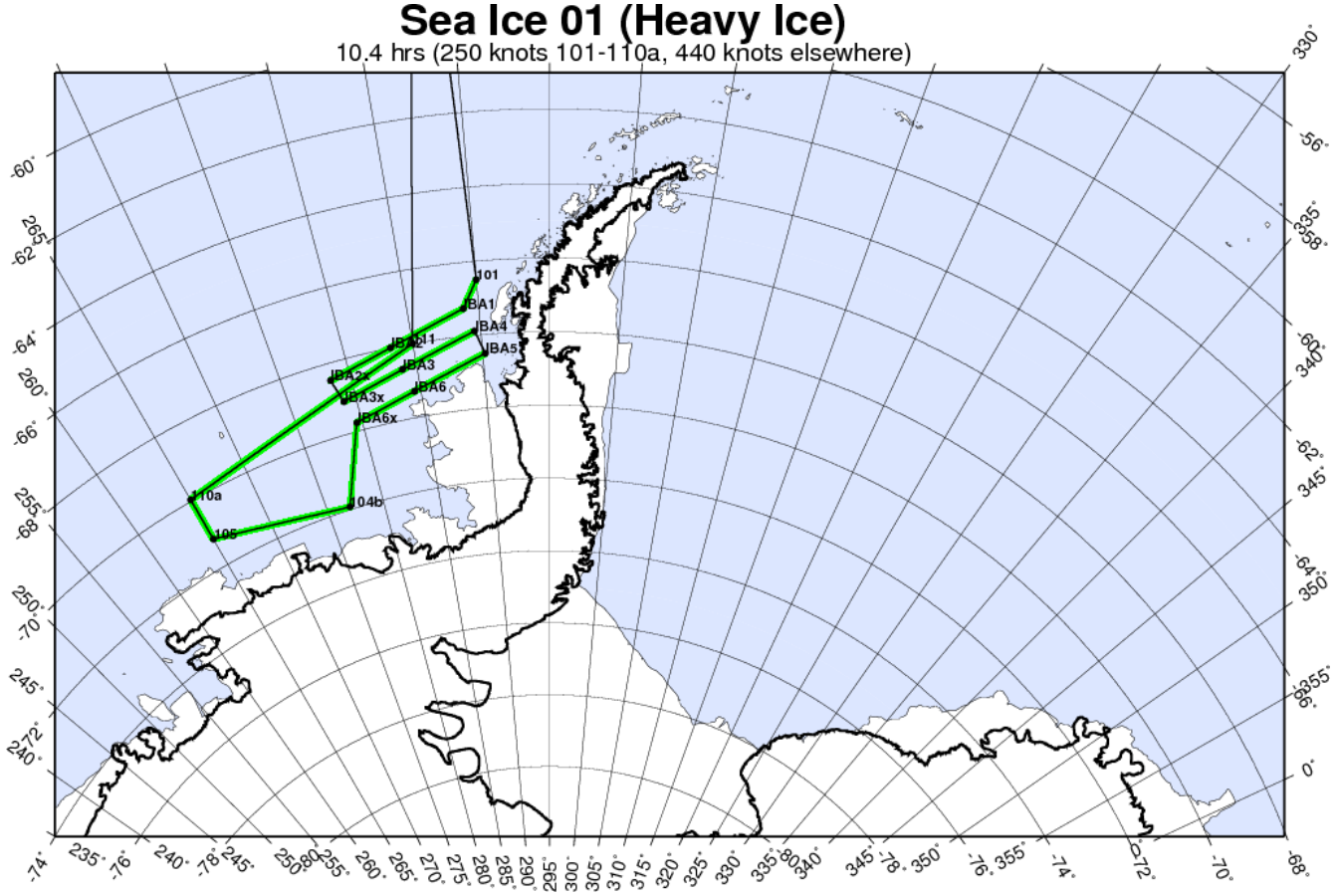
Sea Ice 01 (Light Ice)

10.9 hrs (250 knots 101-110a, 440 knots elsewhere)



Sea Ice 01 (Heavy Ice)

10.4 hrs (250 knots 101-110a, 440 knots elsewhere)

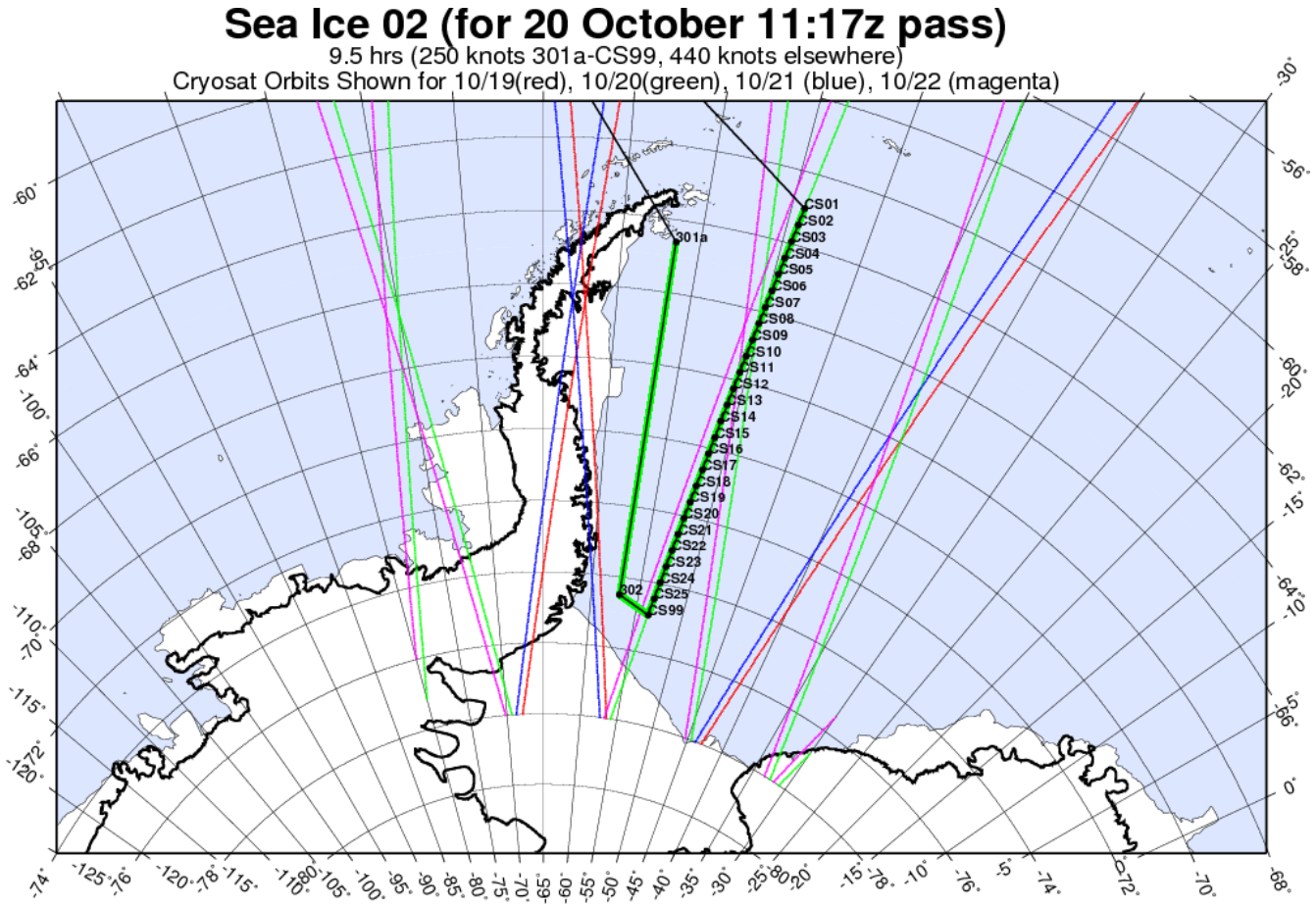


Sea Ice 02 (Ronne/CryoSat)

This mission is a partial repeat of the 091030 IceBridge flight, with one of the long legs replaced by a Cryosat orbit underflight. The map below depicts the Cryosat ground tracks in the region for four consecutive days, and for this mission draft we selected the 20 October pass with the best timing – a descending track with an overpass at 11:17z.

Flight Priority: High
ICESat Track: none

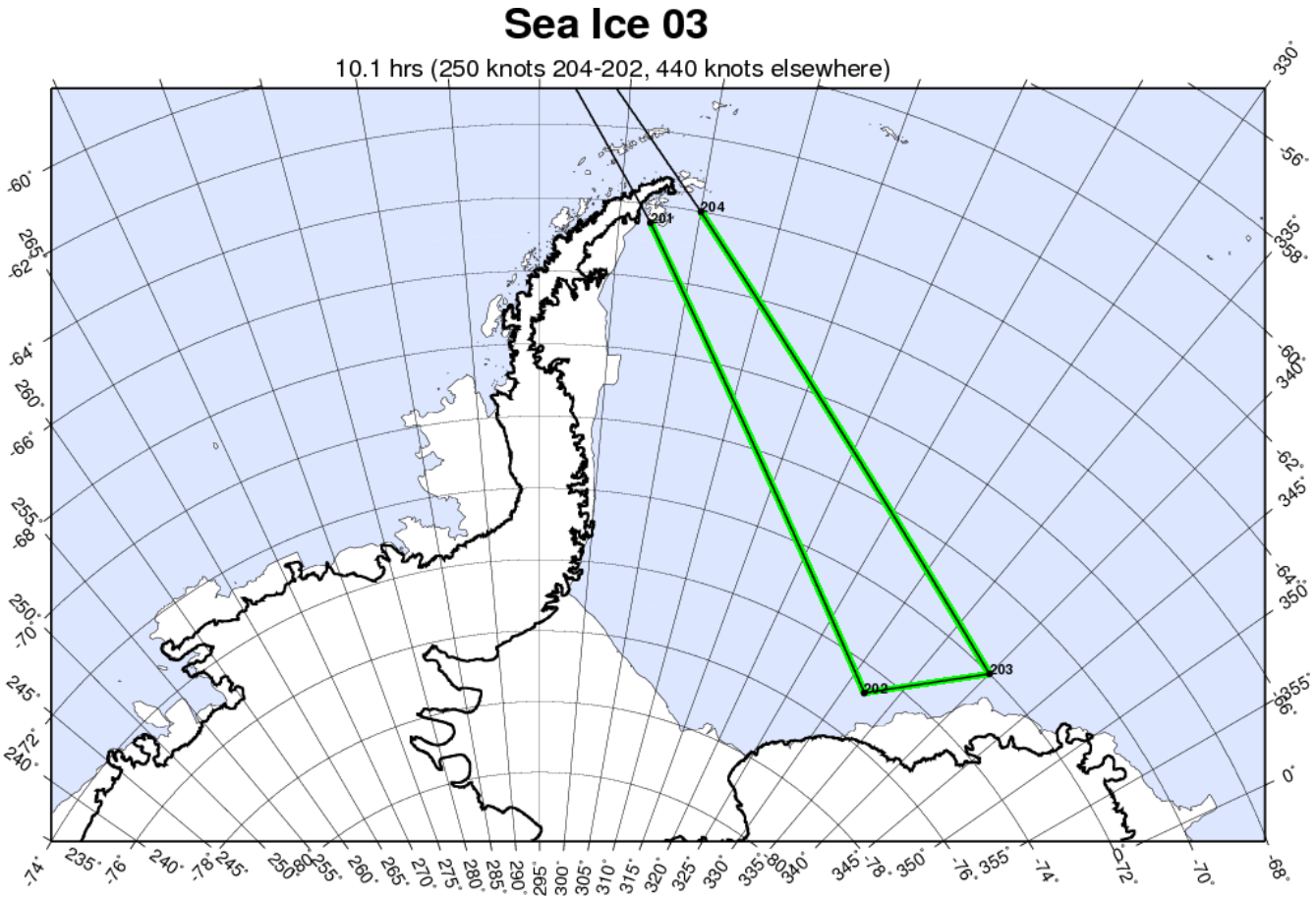
Instrument Priority: ATM, Snow Radar, Gravimeter



Sea Ice 03 (Cape Norvegia)

This mission is an exact repeat of the 091024 IceBridge flight. Its main purpose is to measure gradients in sea ice freeboard (and thickness) along the "gate" connecting the tip of the Peninsula with Cape Norvegia. This gate is the line across which ice export is typically computed, and the export from this area is a major contributor to total ice volume exported into the Antarctic Circumpolar Current.

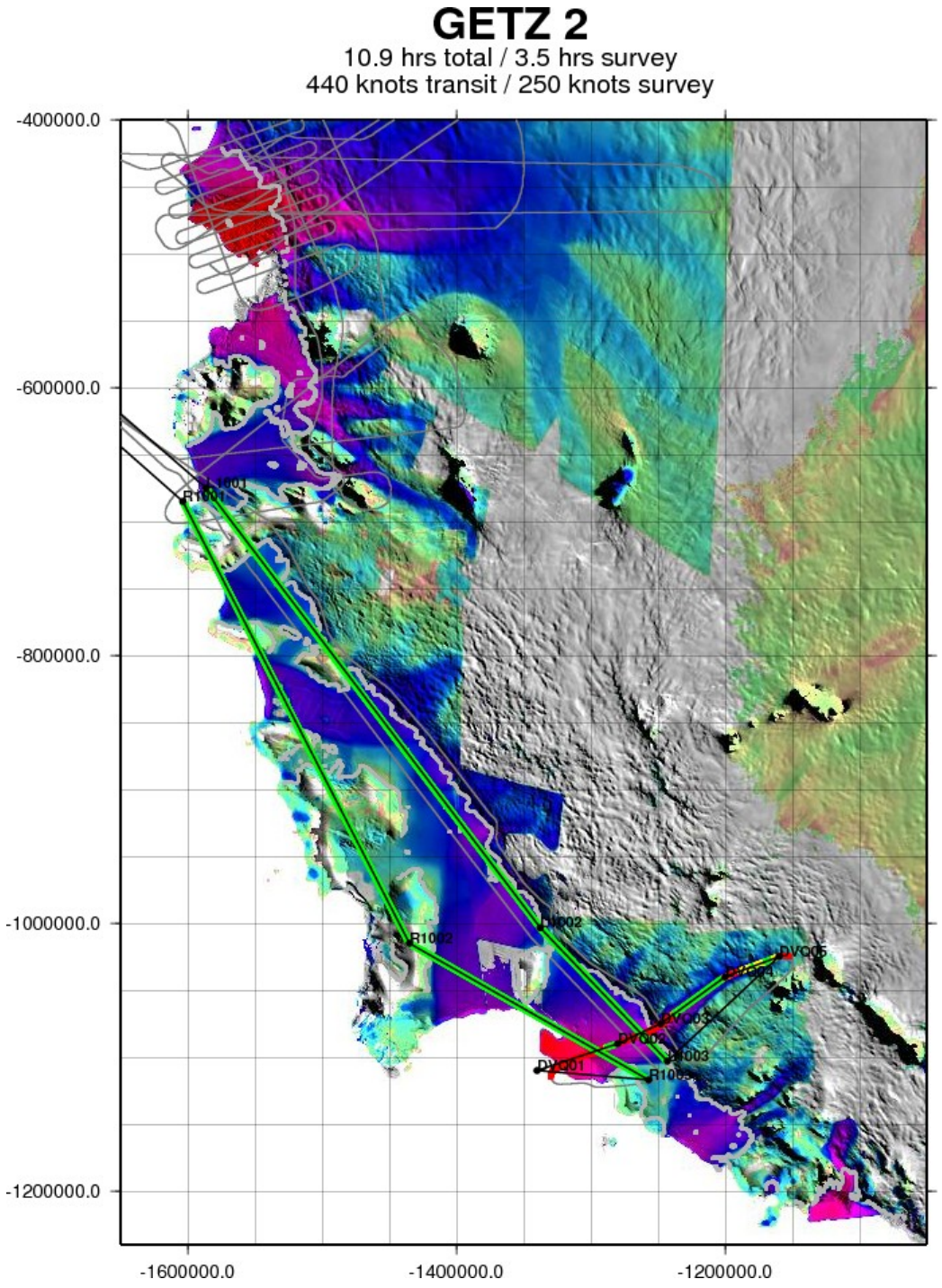
Flight Priority: High **Instrument Priority:** ATM, Snow Radar, Gravimeter
ICESat Track: none



Getz 2

This mission is a new design. It is intended to supplement the Getz 1 flight from 2009 with more gravity-oriented lines along the Getz Ice Shelf, and particularly along the "flux gate" on the seaward edge of the shelf. We also repeat the line first flown in 2009 along the centerline of the Devicq Glacier for dh/dt purposes.

Flight Priority: medium **Instrument Priority:** Gravimeter, ATM, MCoRDS
ICESat Track: none

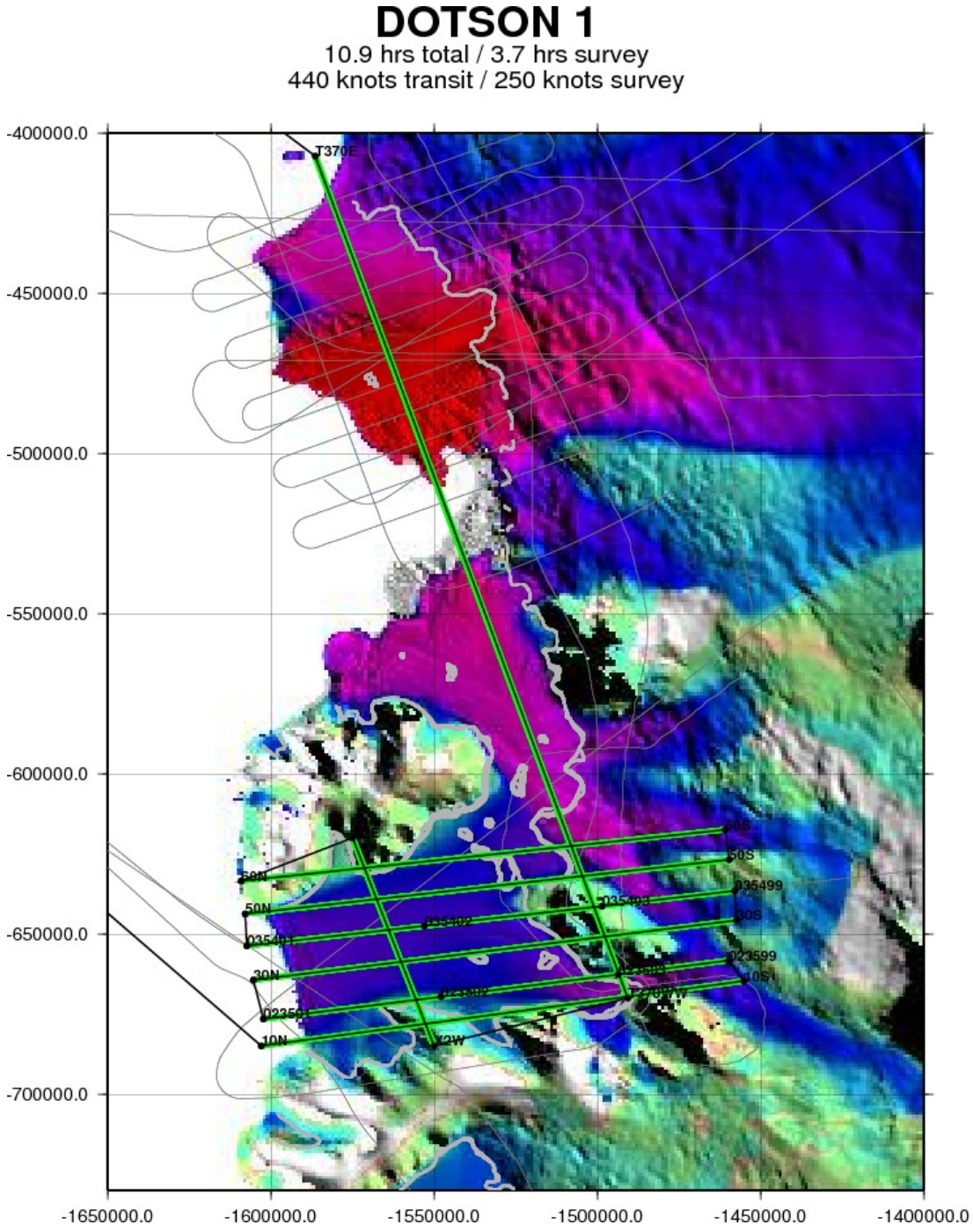


Dotson 1

This mission is a new design. It is intended to map the Dotson Ice Shelf and the bathymetry of the cavity beneath the floating ice tongue, using the gravimeter supplemented by radar and altimetry measurements. The grid lines are mostly spaced at 10 km. However we have aligned the grid along the ICESat tracks in the area and replaced two of the 10 km grid lines with ICESat tracks, so the grid is not perfectly uniform as a result.

Flight Priority: medium **Instrument Priority:** Gravimeter, MCoRDS, ATM

ICESat Track: 0235, 0354

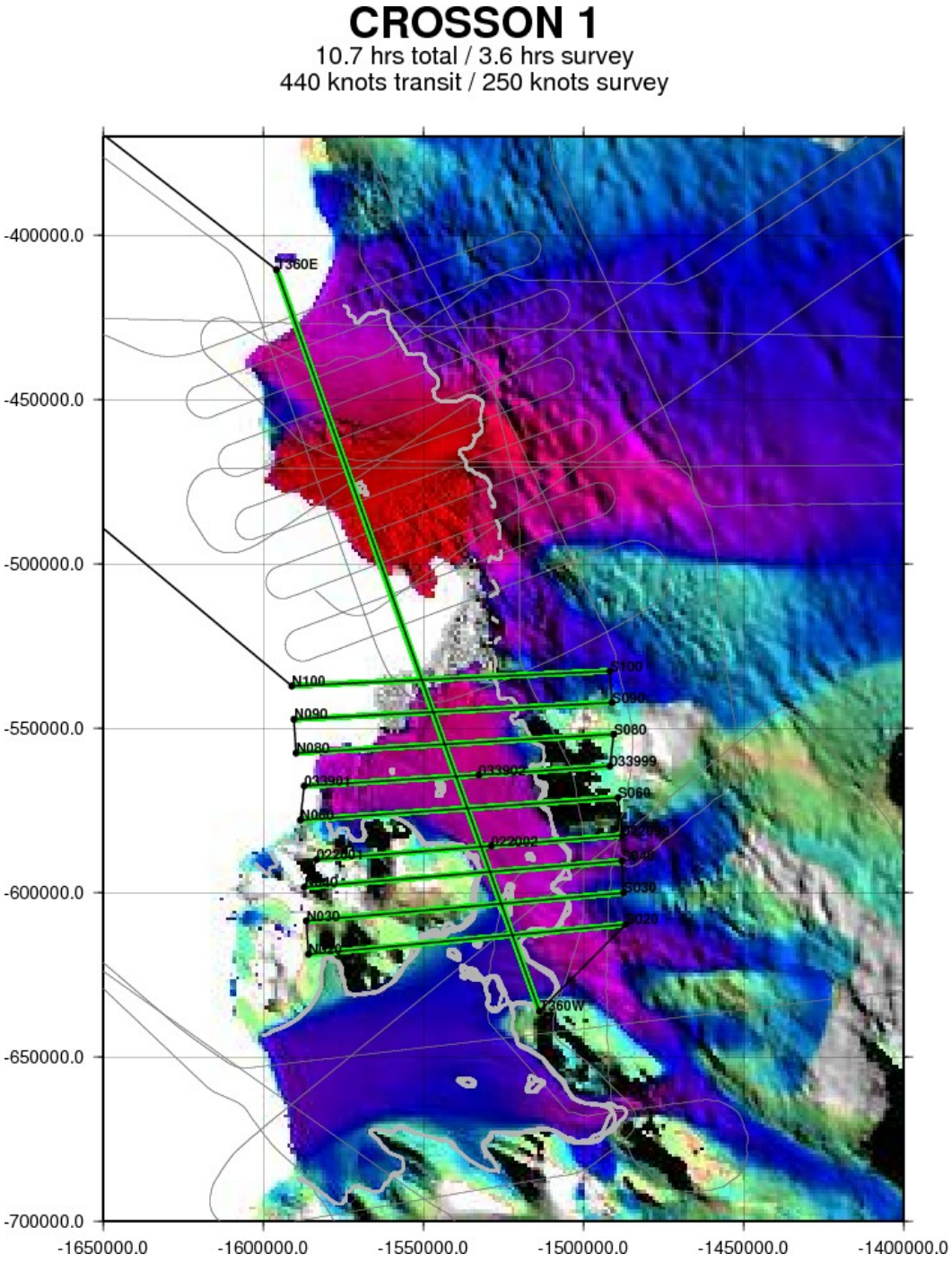


Crosson 1

This mission is a new design. It is intended to map the Crosson Ice Shelf and the bathymetry of the cavity beneath the floating ice tongue, using the gravimeter supplemented by radar and altimetry measurements. The grid lines are mostly spaced at 10 km. However we have aligned the grid along the ICESat tracks in the area and replaced two of the 10 km grid lines with ICESat tracks, so the grid is not perfectly uniform as a result.

Flight Priority: high **Instrument Priority:** Gravimeter, MCoRDS, ATM

ICESat Track: 0220, 0339

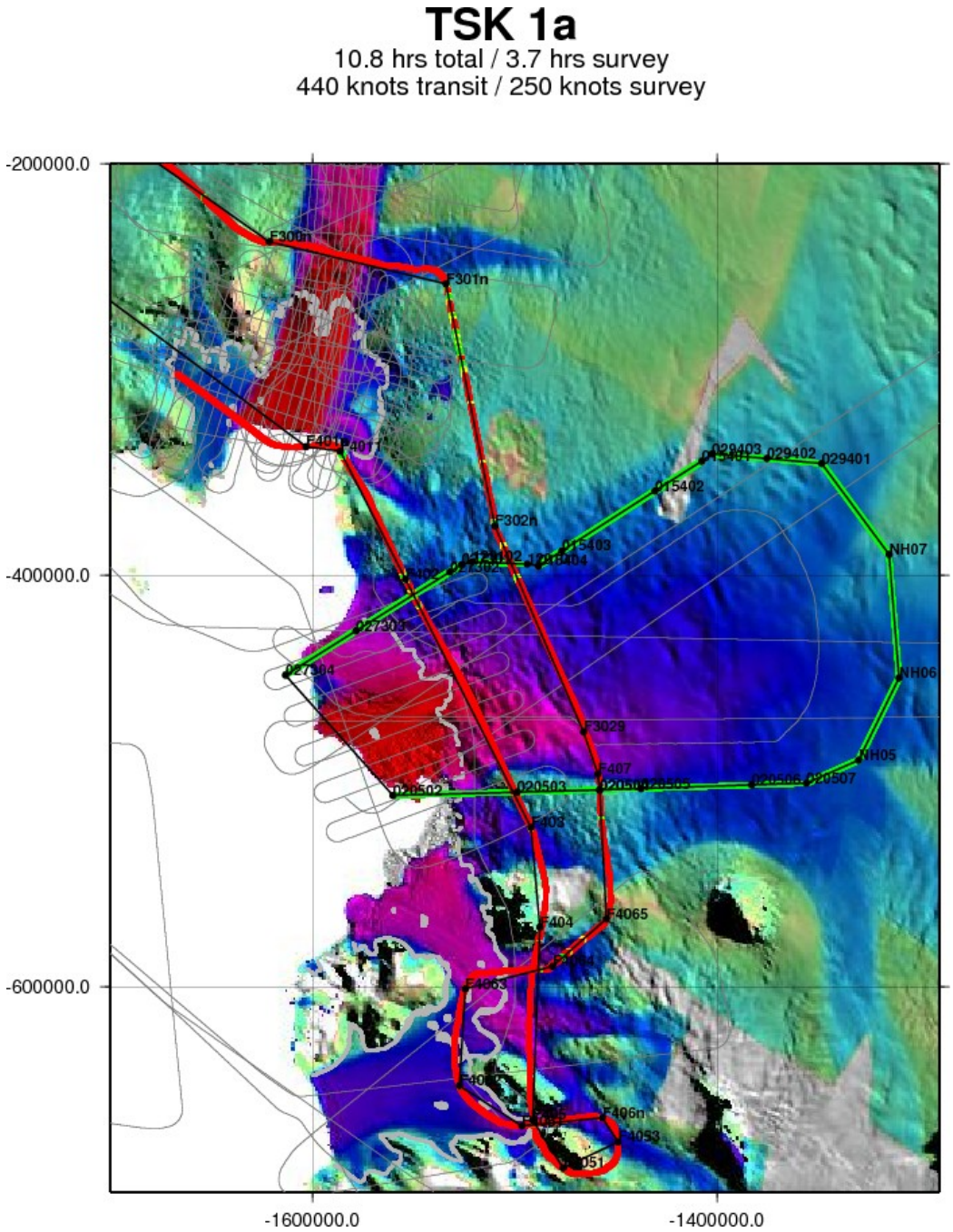


Thwaites-Smith-Kohler 1a

This flight is dedicated to overflying the lines over these three glaciers (plus one remaining line over Pine Island Glacier) originally flown by the NASA/CECS/Armada de Chile project in 2002. It is primarily intended to monitor changes in the surface elevation of these glaciers using the ATM, while also collecting depth, accumulation and gravity data at the same time. A change from the previous version of this mission (TSK1), which was last flown in 2009, is that the "horseshoe" portion of the Thwaites lines was widened inland from its previous position.

Flight Priority: high **Instrument Priority:** ATM, MCoRDS, Gravity

ICESat Track: 0205,0294,0154,1291,0273

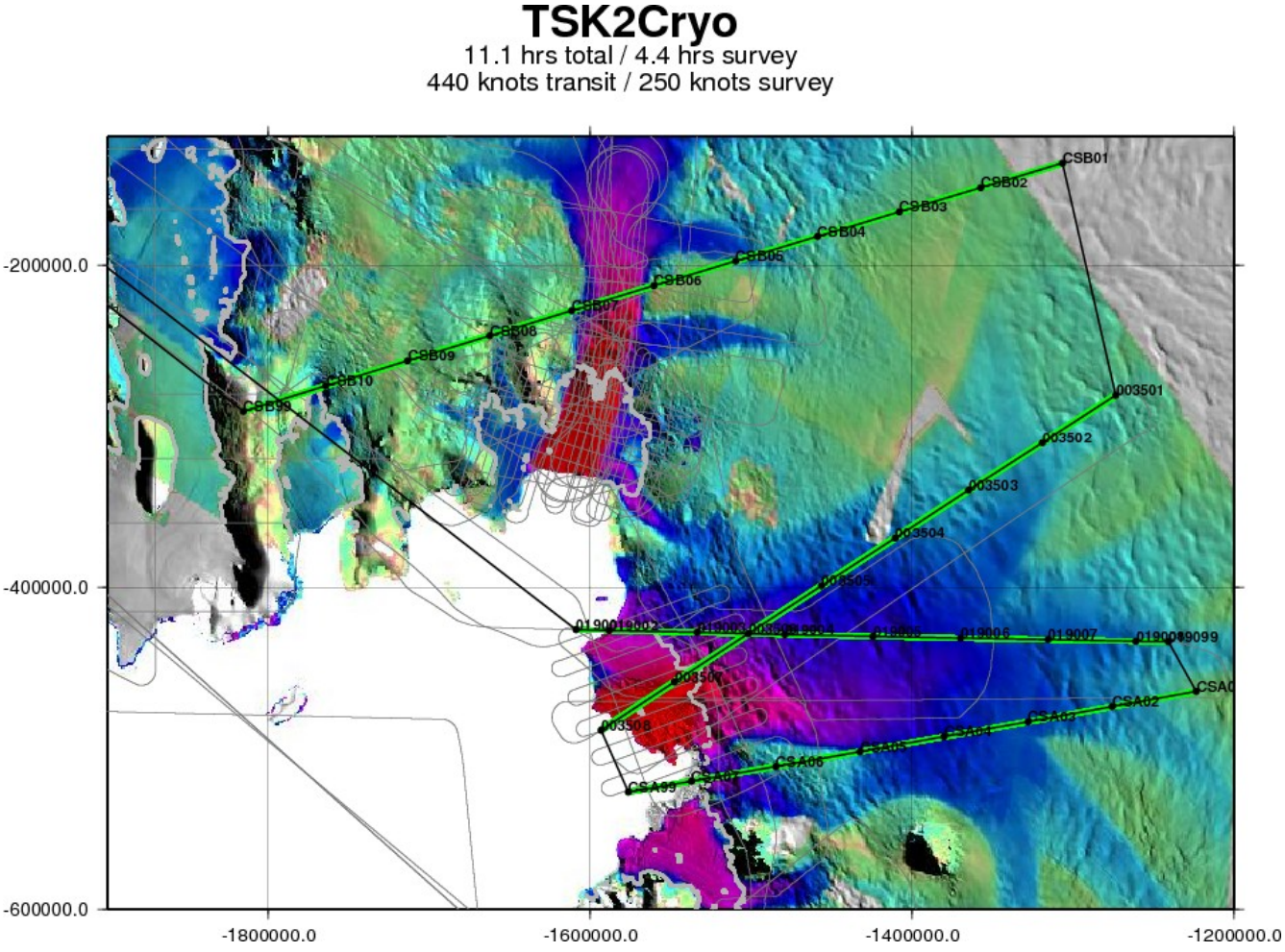


Thwaites-Smith-Kohler 2 Cryosat

This flight is a partial repeat of the 091018 IceBridge flight. It overflies two of the ICESat lines flown then, but replaces the other two with Cryosat ground tracks. One of these is a descending track over the western portion of the Thwaites catchment, which smoothly and monotonically descends from the plateau toward the Amundsen Sea. The other is an ascending track over the Pine Island catchment and occupies terrain which undulates with a variety of slopes and aspects. Cryosat overflies this Thwaites Cryosat line at 1424z on 1 November 2010, and overflies this PIG line at 0307 on 24 October 2010.

Flight Priority: high **Instrument Priority:** ATM, MCoRDS, Gravity

ICESat Track: 0035,0190

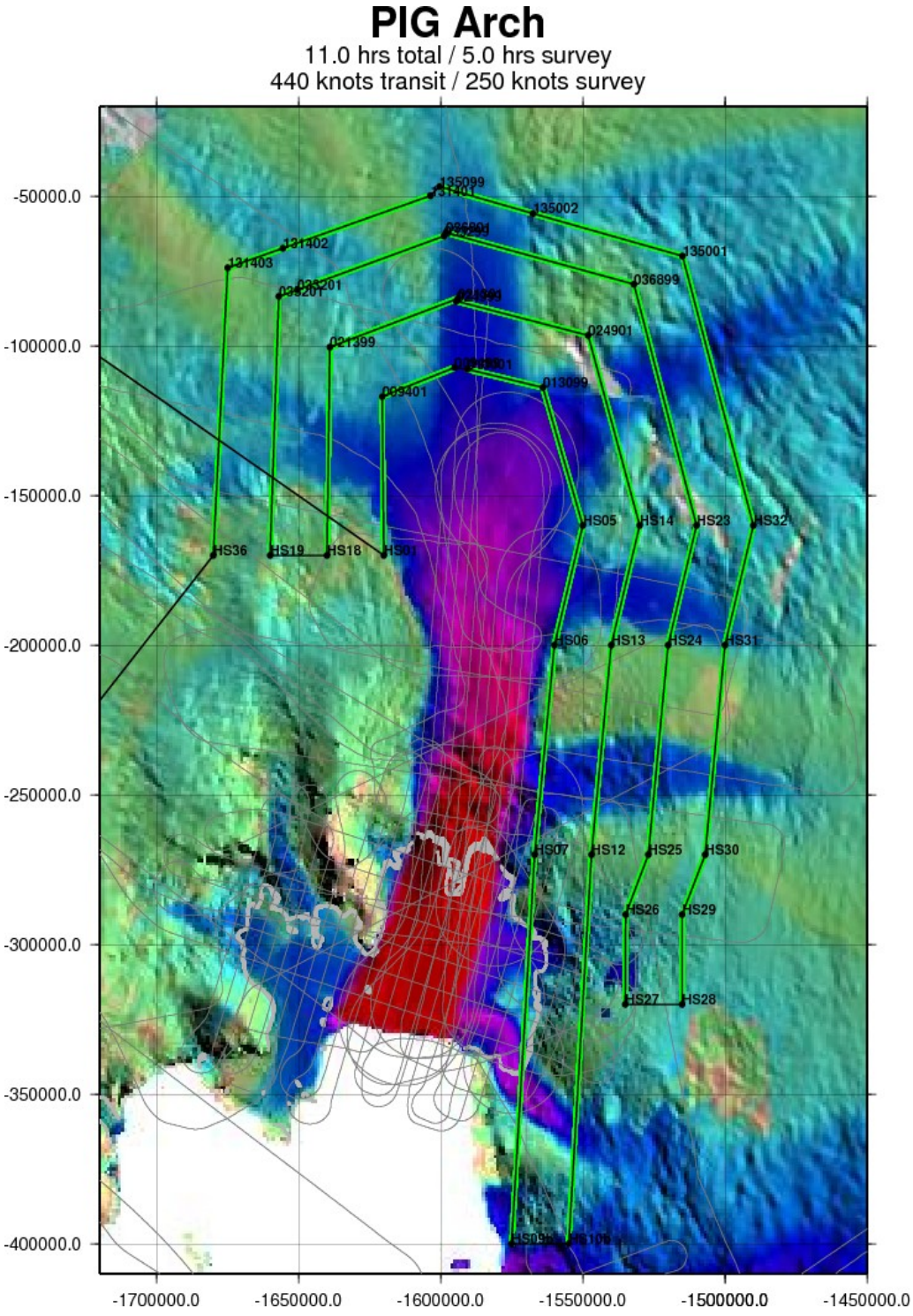


PIG Arch

This mission is a new design. It is intended to provide measurements of ice thickness and surface elevation beyond that provided by previous Pine Island Glacier IceBridge flights, primarily to sample the numerous tributaries feeding into the main Pine Island Glacier trunk.

Flight Priority: High **Instrument Priority:** ATM, MCoRDS, Gravimeter

ICESat Track: 0094,0130,0249,0213,0332,0368,1350,1314

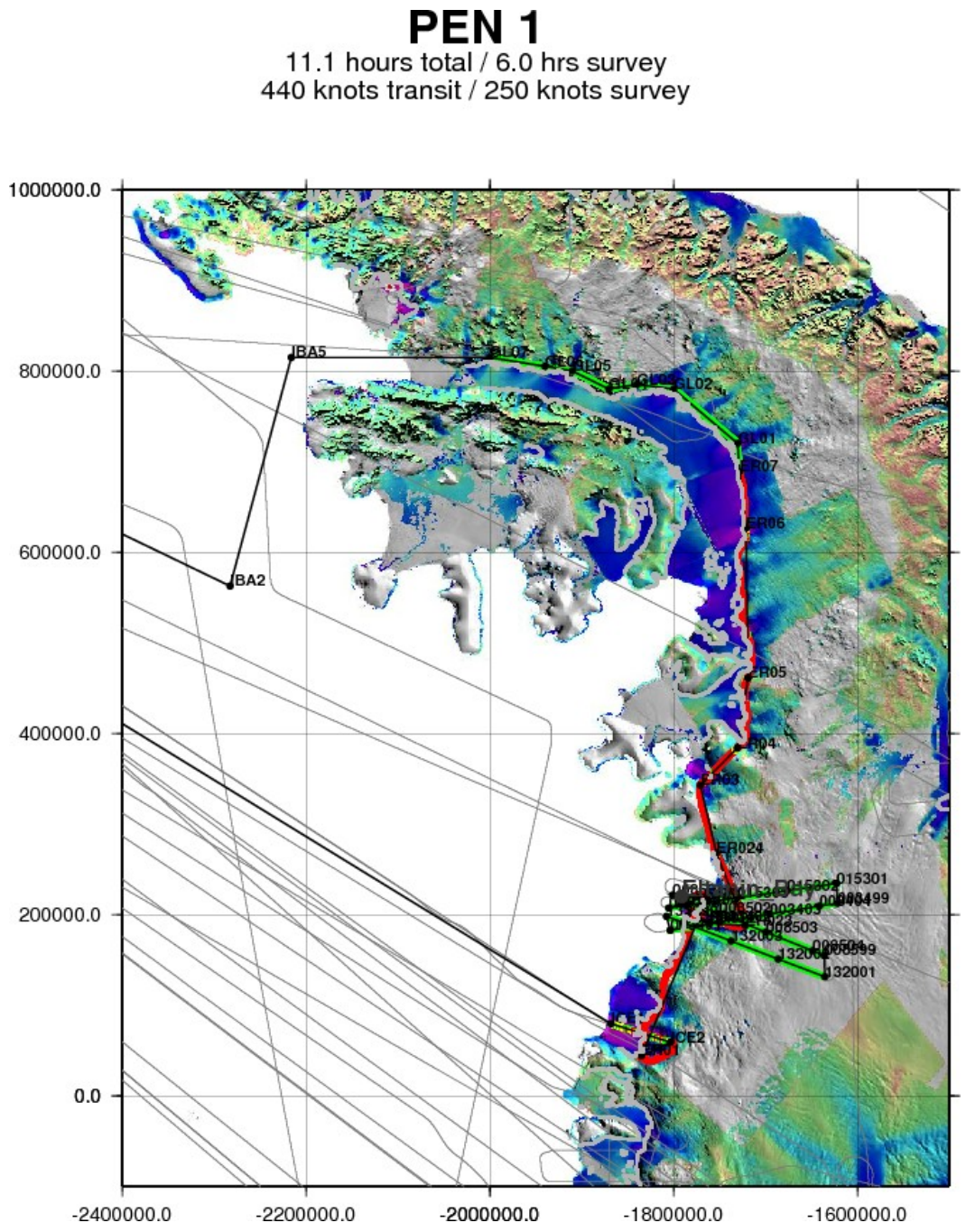


Peninsula 1

This flight is dedicated to (a) repeating the 081012 NASA/CECS/Armada de Chile mission, which continues the Amundsen coastal flux line north adjacent to the George VI Ice Shelf, and (b) occupying two ascending and two descending ICESat lines over the major glacier flowing into Eltanin Bay, plus occupies the centerline of that glacier. It is an exact repeat of the 091103 IceBridge mission, with the small addition of adding a pass over the ICEBELL sea ice site north of Alexander Island.

Flight Priority: high **Instrument Priority:** ATM, MCoRDS, Gravity

ICESat Track: 0034,0085,0153,1320

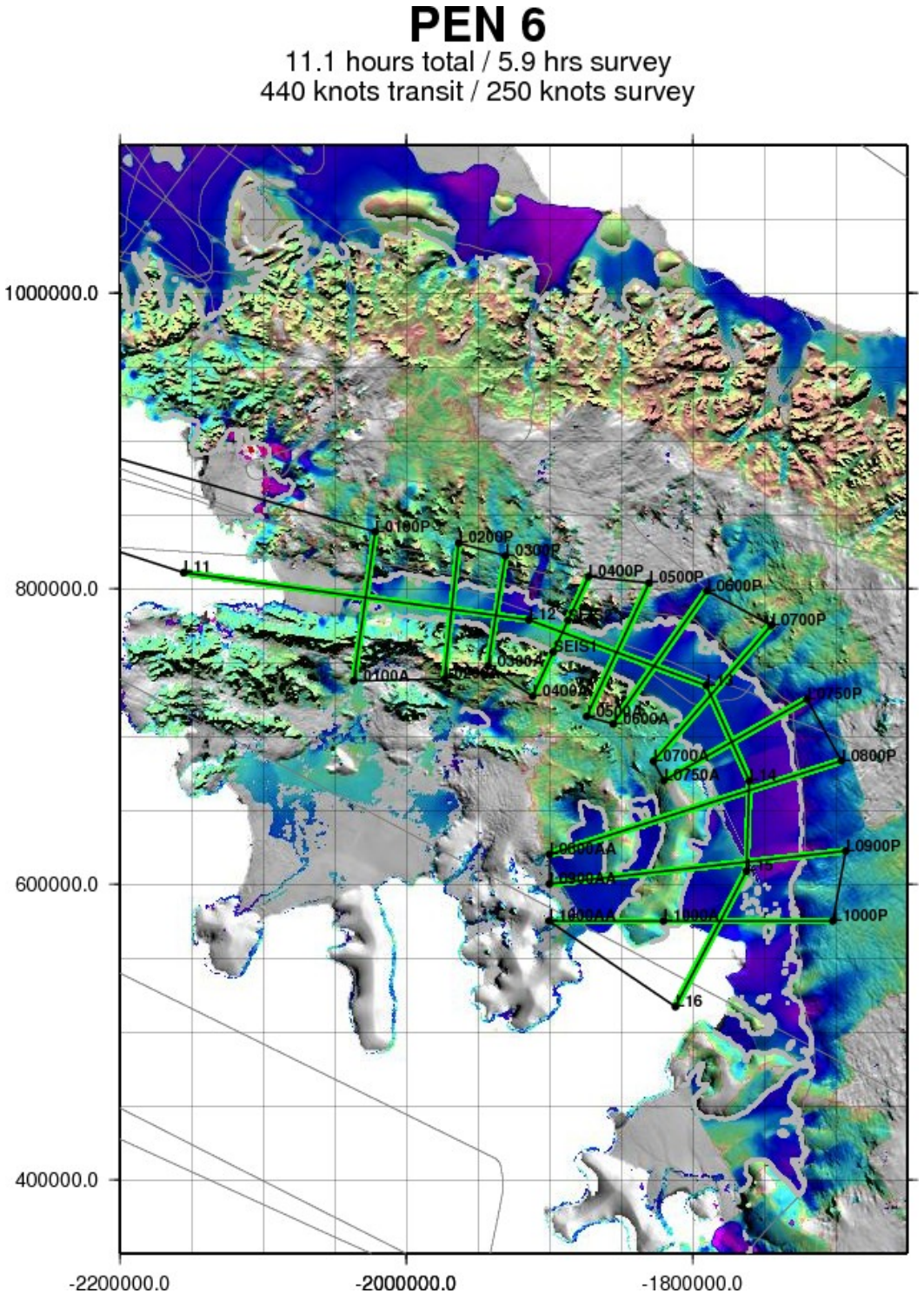


Peninsula 6

This is flight is a new design, and it is intended to coarsely map the sub- ice shelf bathymetry of the George VI ice shelf. The expectation is that the grid can be densified in future years of IceBridge.

Flight Priority: high
ICESat Track: none

Instrument Priority: Gravity, MCoRDS, ATM

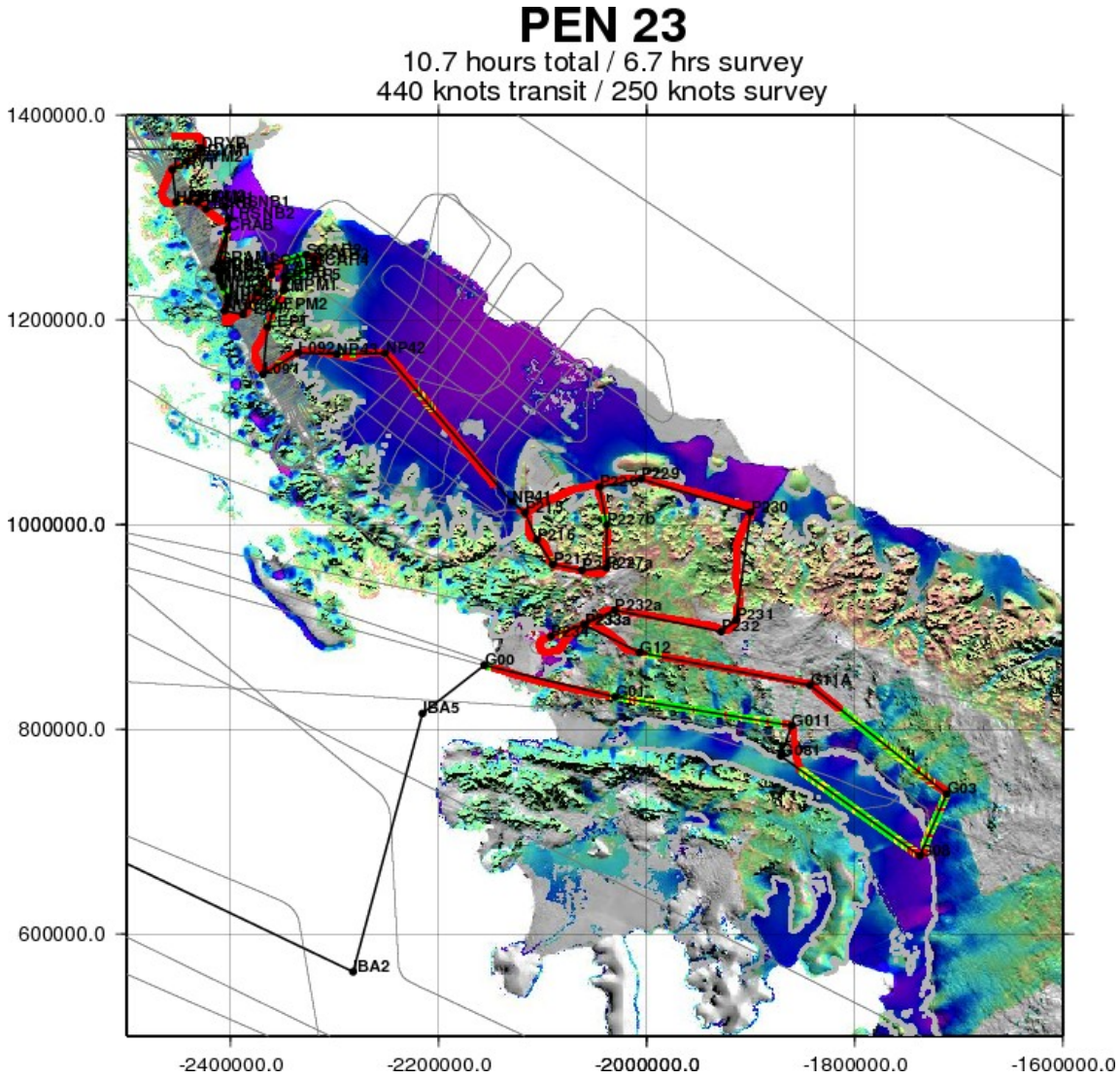


Peninsula 23

This is flight is an amalgamation of parts of the 2009 Peninsula 2 and 3 missions. We have removed most of the Larsen-C ice shelf lines from those two flights, with the exception of the one line shown below, which connects a number of field camps and AWS stations, some of which will be occupied during the 2010 season. The main purposes of this mission are to re-occupy many flight lines as follows: (1) a number of ICESat ground tracks over the Dyer Plateau (plus one on the George VI ice shelf); (2) a pair of lines over the Fleming Glacier, which feeds the remains of the Wordie Ice Shelf; (3) several glacier lines at the south end of the Larsen-C, and one at the north end; (4) several glaciers that feed into the old Larsen-B embayment, including Leppard, Flask, Crane, and Hektoria, and one into Larsen-A (Drygalski). Most of these lines were first occupied by ATM/KU in 2002, and all were occupied during 2009 IceBridge. We also include a pass over the ICEBELL sea ice site north of Alexander Island.

Flight Priority: high **Instrument Priority:** ATM, MCoRDS,, Gravity

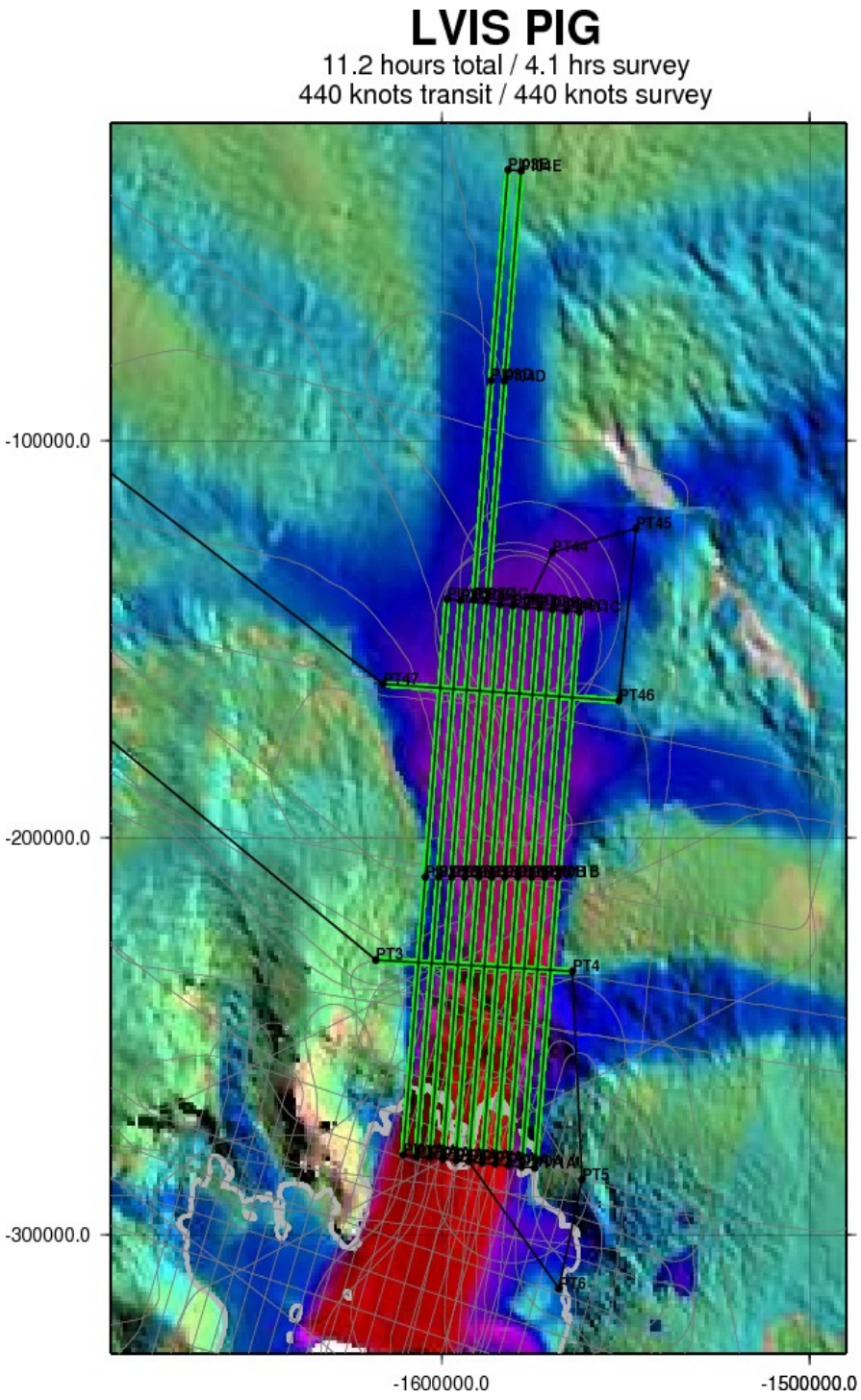
ICESat Track: several 183-day ICESat tracks (which were first flown prior to the 2003 launch)



LVIS PIG

This mission is a repeat of the 091020 IceBridge mission. It is intended to provide wide-swath altimetry coverage of the lower Pine Island Glacier.

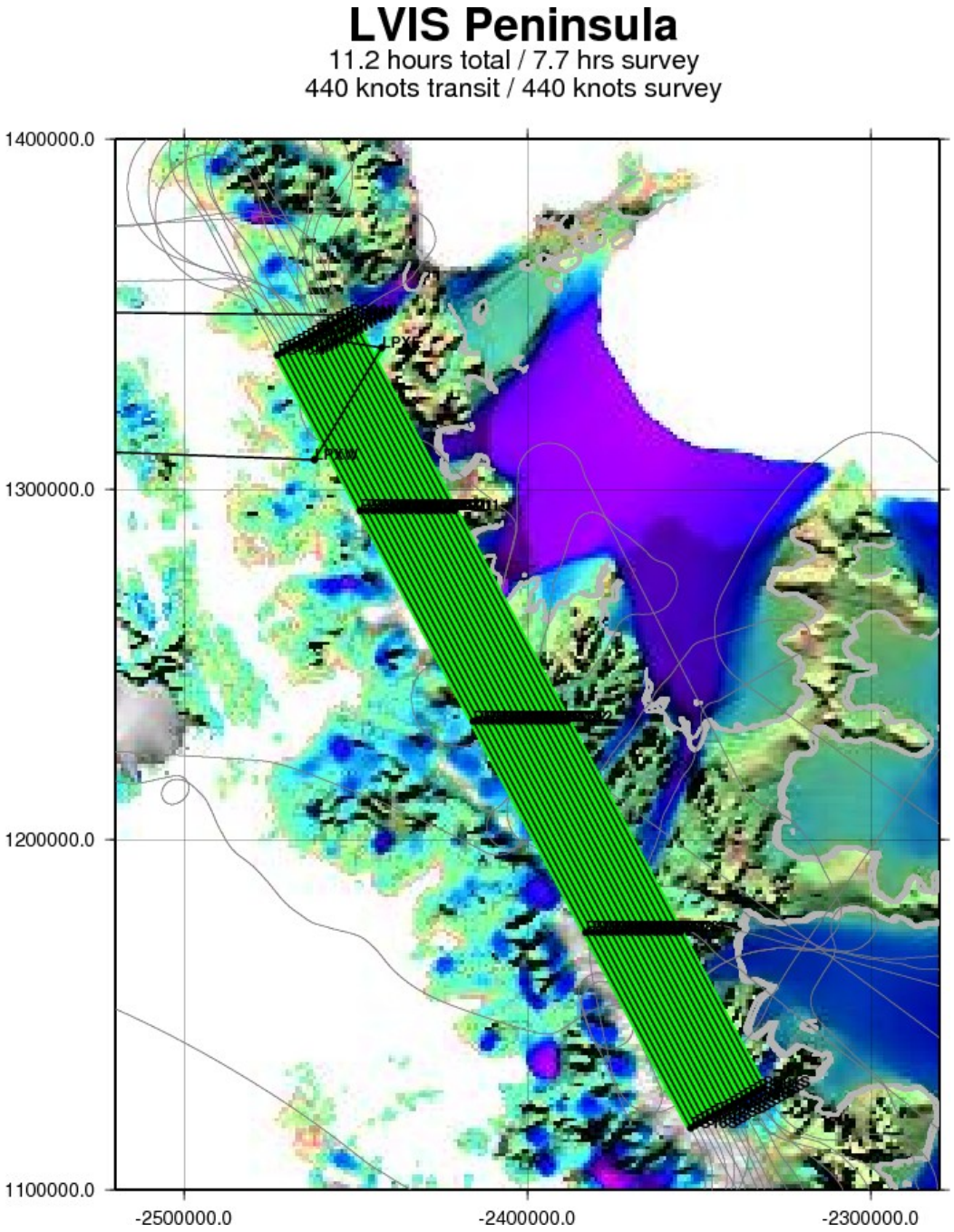
Flight Priority: High **Instrument Priority:** LVIS
ICESat Track: none



LVIS Peninsula

This mission is a repeat of the 091105 IceBridge mission, with the addition of one crossing line to assess data quality. It is intended to provide wide-swath altimetry coverage of the Crane Glacier and surrounding areas.

Flight Priority: High **Instrument Priority:** LVIS
ICESat Track: none



Reserve Missions

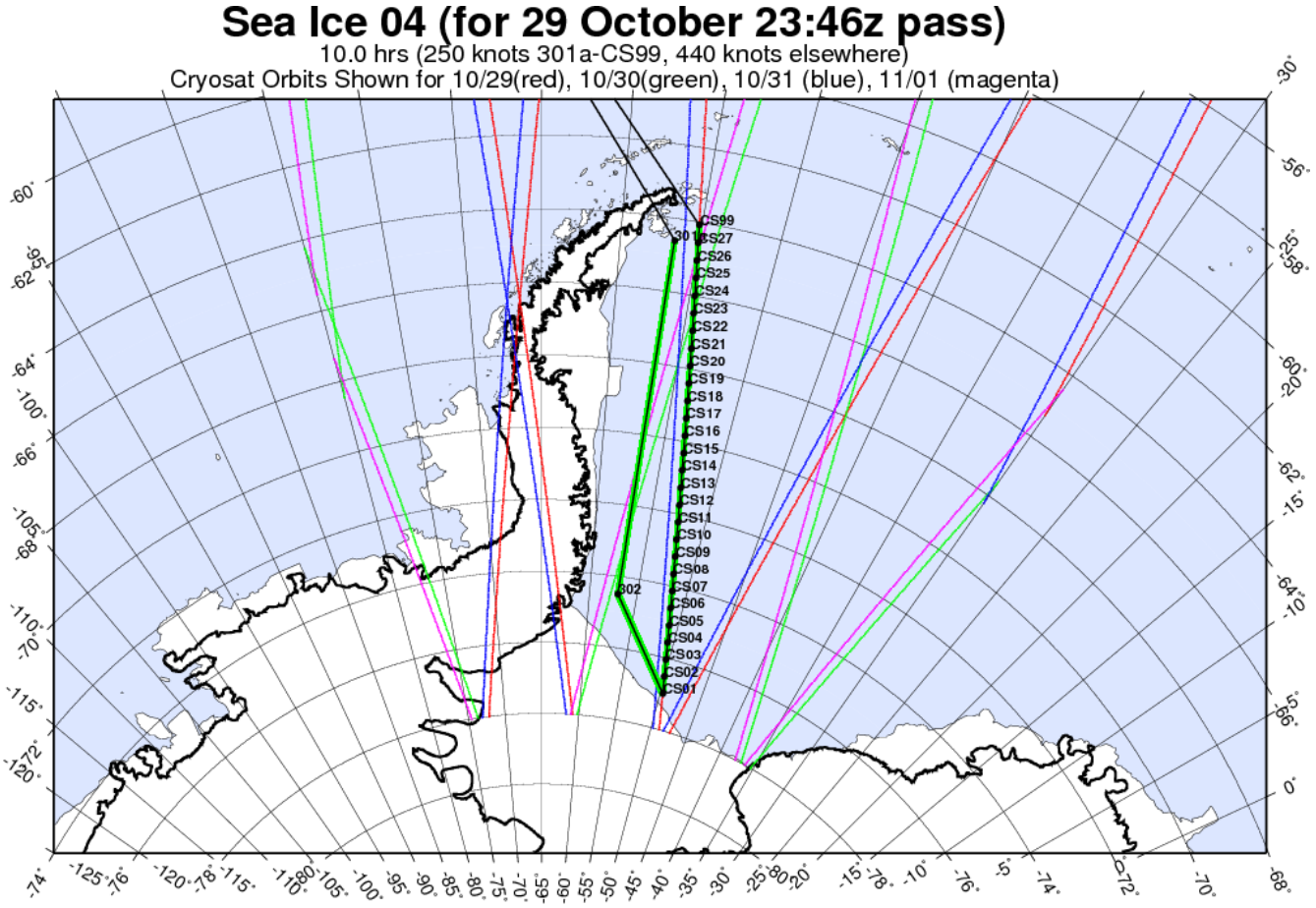
A number of “reserve” mission plans follow. These are flight concepts which were not prioritized over the missions listed previously during science priority deliberations, but which the IceBridge project team considers worthy of consideration for flight in case additional funds for flight hours, and schedule margin, become available once the flight team is in the field. They may also be flown late in the campaign if sustained poor weather precludes flights into higher-priority areas. Many of these plans are repeats of missions flown during the 2009 Antarctic IceBridge deployment, while others are intended to augment those flights.

Sea Ice 04

This mission is an alternative plan for the Sea Ice 02 flight shown previously. It is a partial repeat of the 091030 IceBridge flight, with one of the long legs replaced by a Cryosat orbit underflight. The map below depicts the Cryosat ground tracks in the region for four consecutive days, and for this mission draft we selected the 29 October pass with the best timing – an ascending track with an overpass at 23:46z.

Flight Priority: High
ICESat Track: none

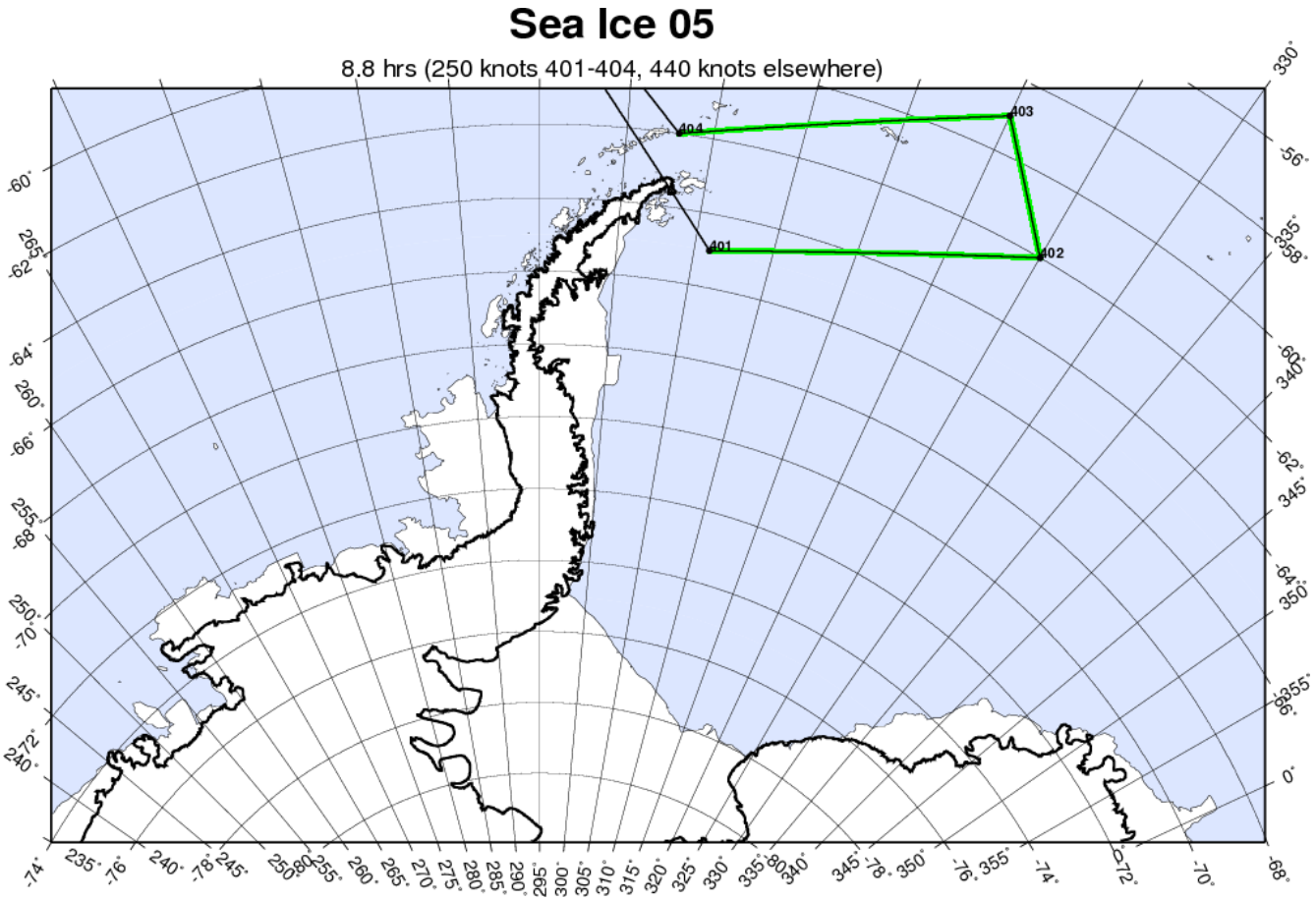
Instrument Priority: ATM, Snow Radar, Gravimeter



Sea Ice 05 (Weddell Sea Ice Margin)

This mission was planned for the 2009 IceBridge campaign, but not flown because of persistently poor low-level weather conditions near the ice edge. The purpose is to better characterize the general ice conditions and compactness of ice cover near the ice margin.

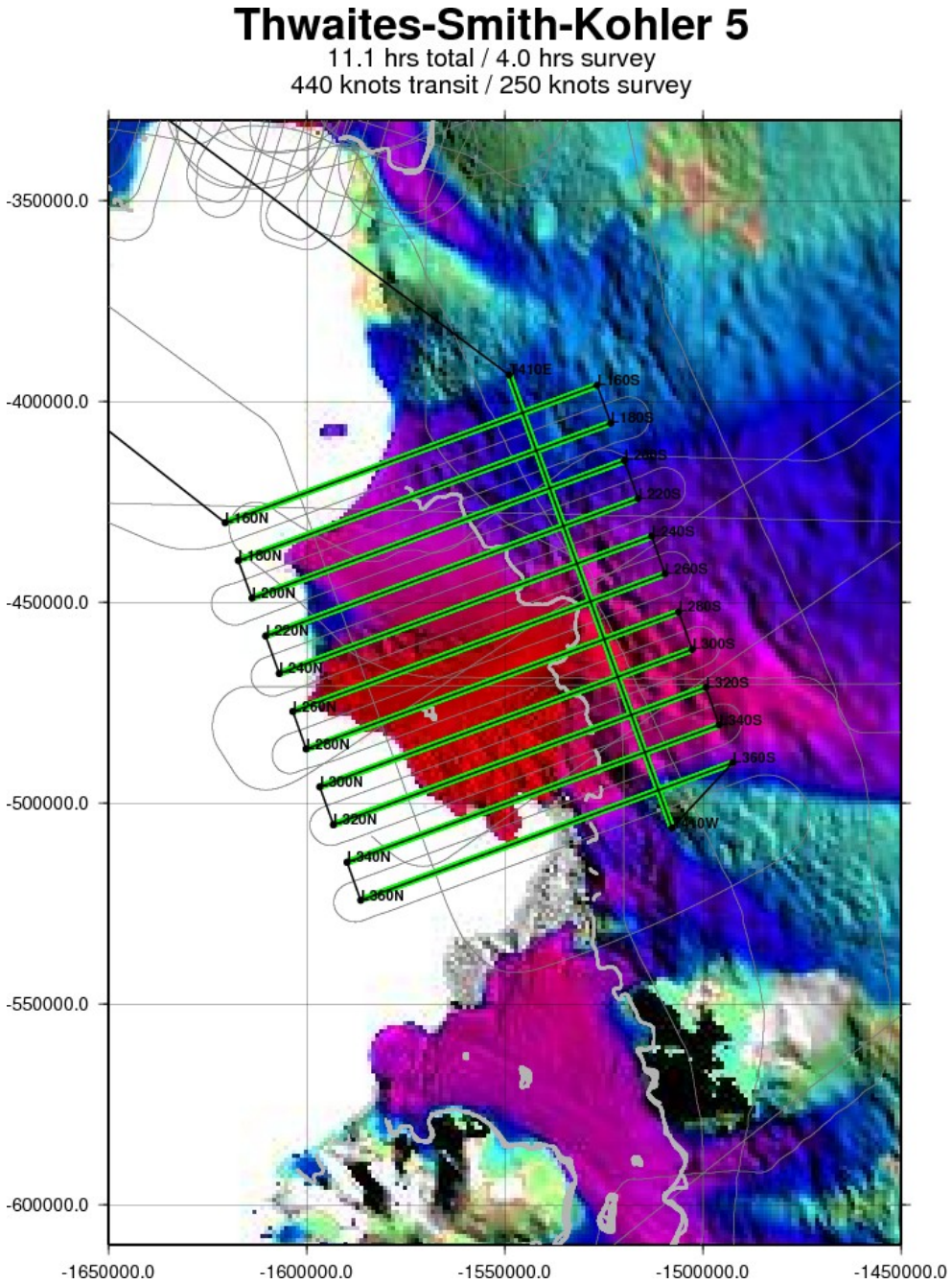
Flight Priority: reserve
Instrument Priority: ATM, Snow Radar, Gravimeter
ICESat Track: none



TSK 5

This is flight is a continuation of the effort to map the bathymetry under the Thwaites ice tongue, using the gravimeter supplemented by the other low-altitude instruments. The grid lines in this mission are offset from each other by 10 km, but when combined with the 091118 IceBridge mission the resulting grid will be at 5 km, which is the same resolution as the Pine Island gravity grid flown in 2009.

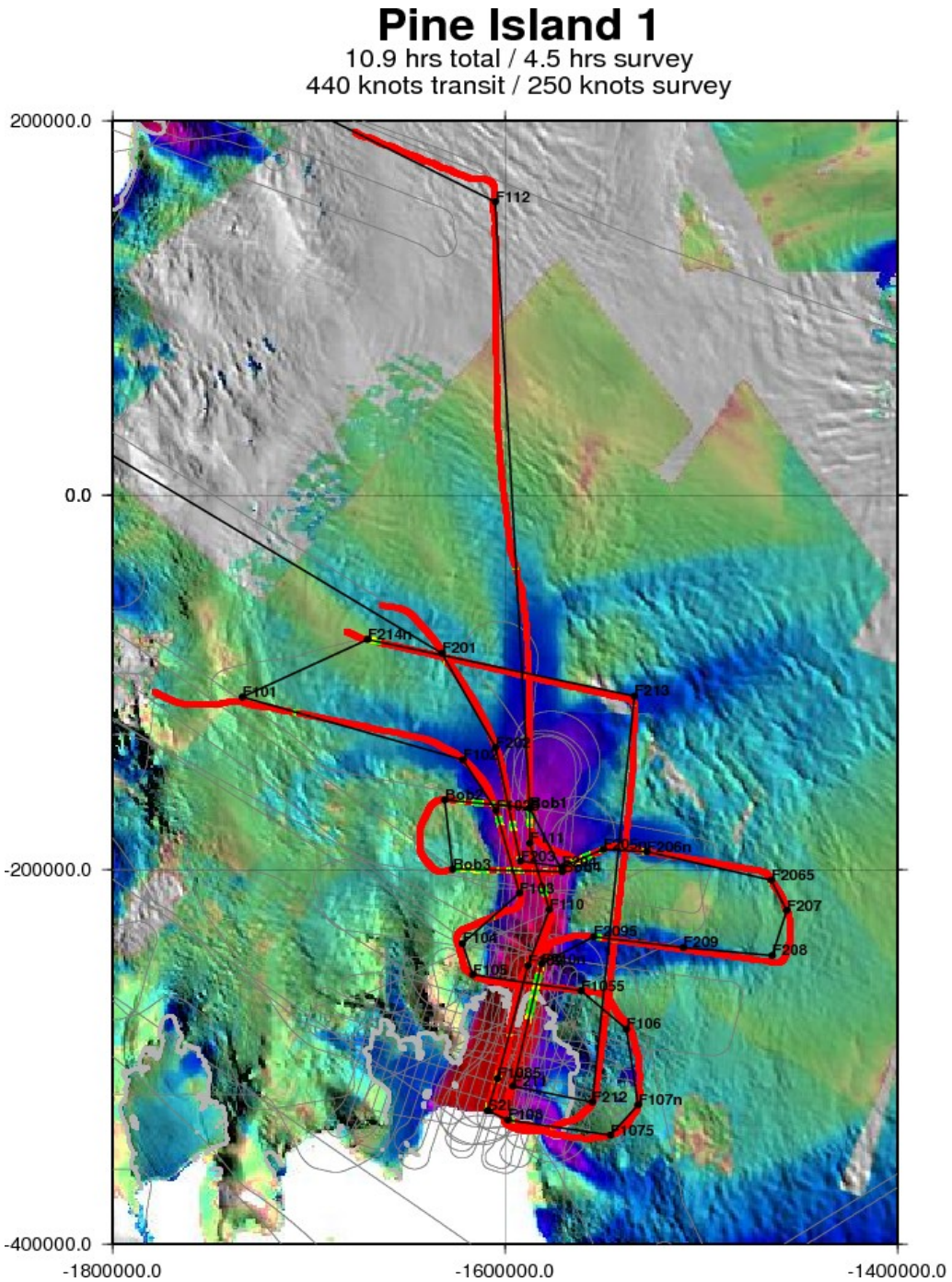
Flight Priority: reserve **Instrument Priority:** Gravity, MCoRDS, ATM
ICESat Track: none



Pine Island 1

This flight is a repeat of the 091029 IceBridge flight, which itself was a repeat of flight lines flown a number of times since 2002 by the ATM/KU teams. It is intended to track ongoing changes in the Pine Island Glacier trunk.

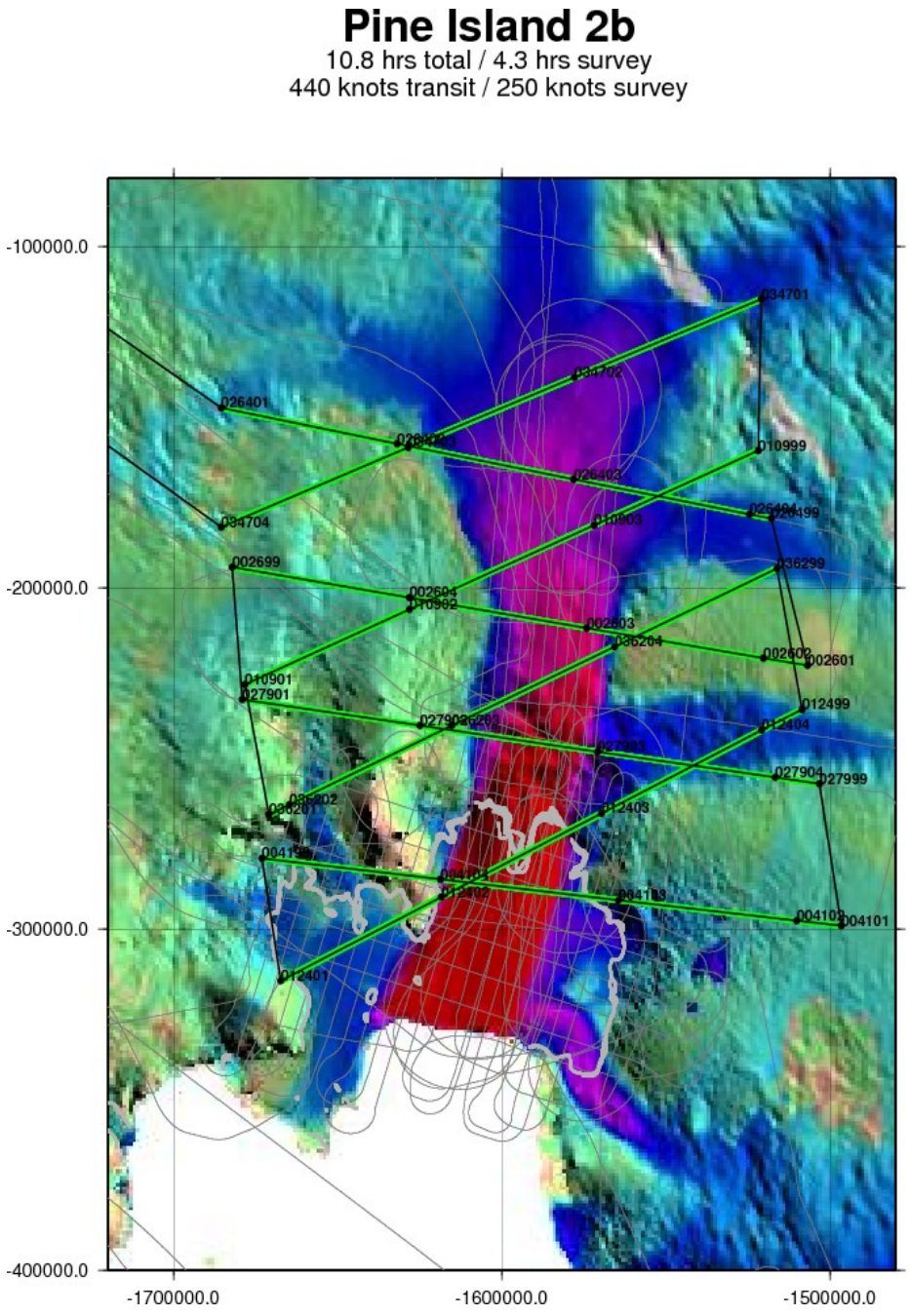
Flight Priority: reserve **Instrument Priority:** ATM, MCoRDS, Gravity
ICESat Track: none



Pine Island 2b

This flight is a near repeat of the 091027 IceBridge flight. It is intended to track ongoing changes in the Pine Island Glacier trunk, by comparison along ICESat ground tracks. This version differs slightly from the 2009 flight, in that three lines on the floating shelf of the glacier, intended to target the gravimeter to the findings of the BAS auto-sub, have been removed and replaced with two additional ascending ICESat lines on the upper trunk of the glacier. The original purpose of the "autosub" lines was superseded when we flew a 5 km grid over the shelf in 2009.

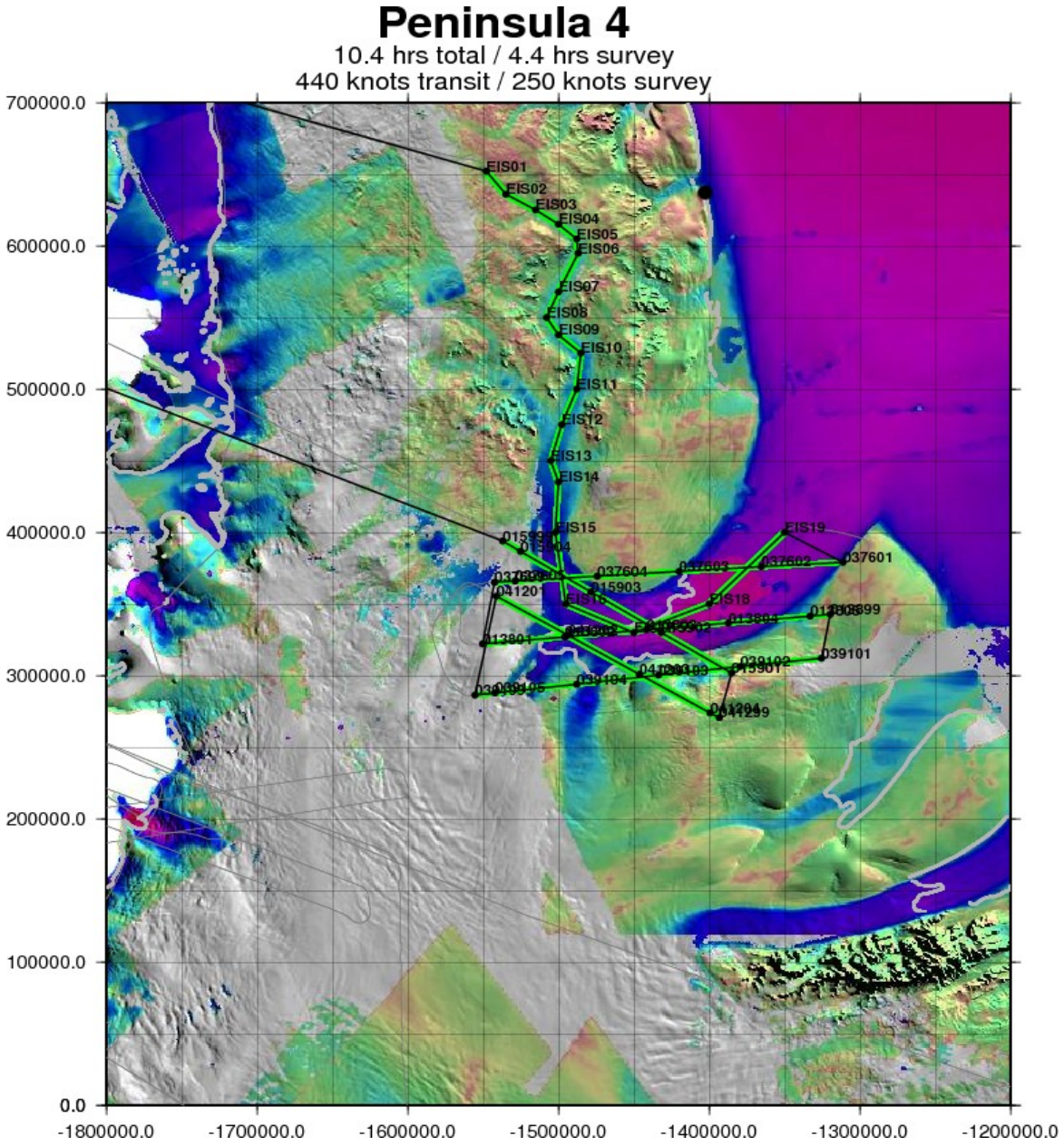
Flight Priority: reserve **Instrument Priority:** ATM, MCoRDS, Gravity
ICESat Track: 0026,0041,0124,0264,0279,0362,0109,0347



Peninsula 4

This flight is a repeat of the 091115 IceBridge flight. It is intended to track changes in the Evans Glacier area, by comparison mainly along ICESat ground tracks,

Flight Priority: reserve **Instrument Priority:** ATM, MCoRDS, Gravity
ICESat Track: 0138,0159,0376,0391,0412

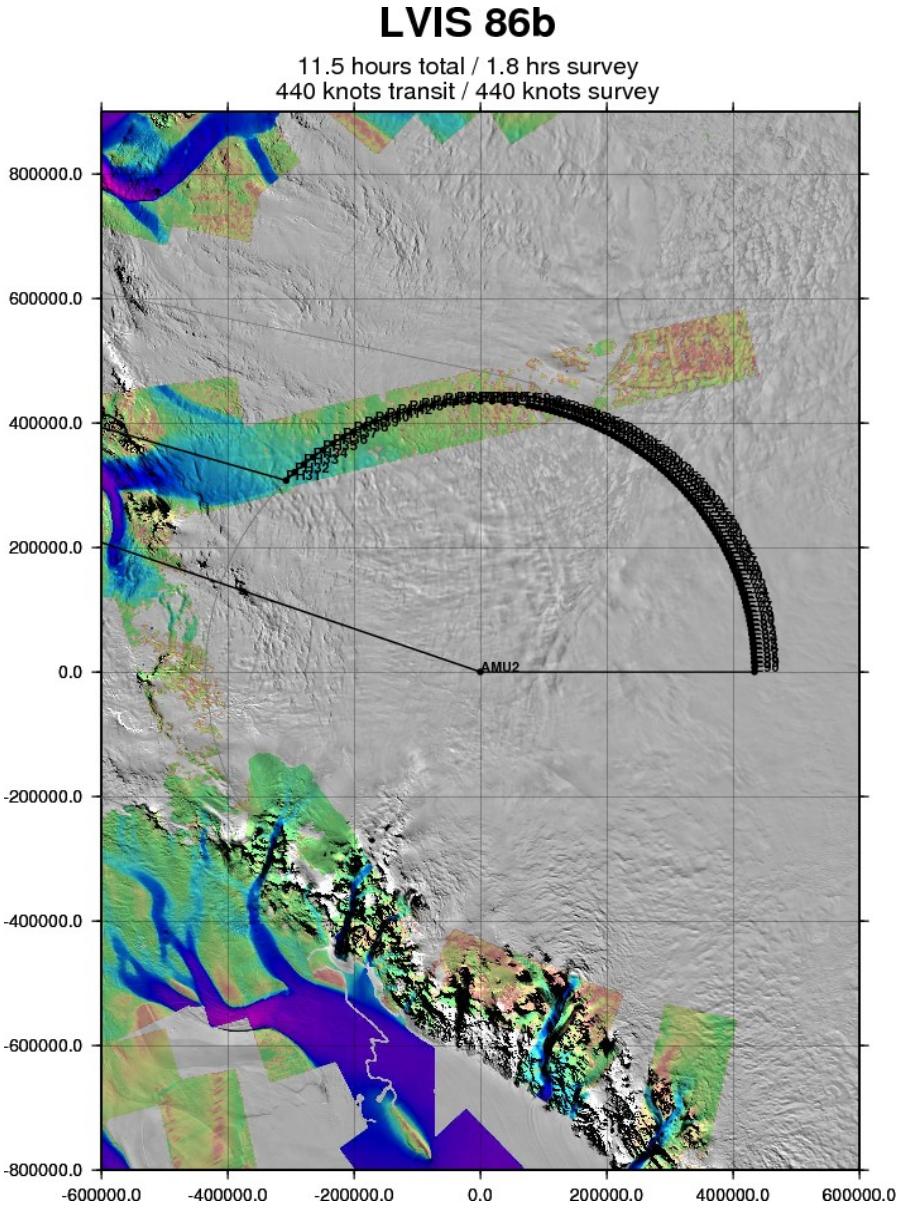


LVIS 86b

This flight continues the LVIS86 ICEBridge flight from 2009. The goal is to allow intercomparison of LVIS and ICESat altimetry over small portions of hundreds of ICESat orbits, where they are concentrated in a small area. Coincident LVIS and ICESat footprint elevation differences will be derived as a function of ICESat campaign in order to investigate the magnitude of the ICESat inter-campaign biases. The repeat of a portion of the data collected in 2009 enables an estimate of the magnitude of the annual signal to be made. The extension of the data to a previously unsampled section enables a further validation of the LVIS-ICESat vertical biases as a function of ICEsat campaign and facilitates a comparison to existing LVIS-ICESat differences along ICESat tracks that were sampled in Greenland in 2009 and 2010. Finally we include an optional overpass of the Amundsen-Scott South Pole Station, in order to best utilize the high-rate GPS data being collected there for our trajectory computations.

Flight Priority: reserve **Instrument Priority:** LVIS

ICESat Track: hundreds



LVIS Pen 2

This flight is intended to broaden the wide-swath coverage of several Peninsula glaciers draining into the Larsen-B embayment and Larsen-C ice shelf beyond the coverage provided in the LVIS Pen 2 flight. It also provides coverage over a number of glaciers draining from the west side of the Peninsula.
Flight Priority: reserve **Instrument Priority:** LVIS
ICESat Track: none