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Airborne measurements of CO_2 and CH_4 fluxes over the Alaskan North Slope using the Flux Observations of Carbon from an Airborne Laboratory (FOCAL) system

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Notice

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List of Abbreviations and Acronyms

A/D	Analog-to-digital
ASCII	American Standard Code for Information Interchange
ATDD	Atmospheric Turbulence and Diffusion Division
BAT	Best Aircraft Turbulence (probe)
CG	Center of gravity
DSP	Design stagnation point
GaAs	gallium arsenide
GPS	Global Positioning System
ICOS	Integrated Cavity-Output Spectroscopy
INS	Inertial navigation system
IR	Infrared
KIAS	Knots indicated airspeed
MATLAB©	Matrix Laboratory
MEMS	Micro-machined Electro-Mechanical Sensor
NetCDF	Network Common Data Form
NRL	Naval Research Laboratory
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
PPS	Pulse per second
REM	Remote
SCBG	Semi-conductor band gap
SPAN	Synchronized Position Attitude Navigation
TTL	Transistor-transistor logic
VAC	Volts alternating current
VDC	Volts direct current

List of Symbols and Variables

C_l	Coefficient of lift
Px	Differential air pressure (x'-axis)
Py	Differential air pressure (y'-axis)
Pz	Differential air pressure (z'-axis)
Ps	Static (ambient) air pressure
Ax	BAT probe acceleration (x'-axis)
Ay	BAT probe acceleration (y'-axis)
Az	BAT probe acceleration (z'-axis)
Axb	Backseat acceleration, near center of gravity of the aircraft (x'-axis)
Ayb	Backseat acceleration, near center of gravity of the aircraft (y'-axis)
Azb	Backseat acceleration, near center of gravity of the aircraft (z'-axis)
DSP	Design Stagnation Point
Tbar	Air temperature (thermistor)
FOTemp	Air temperature (Fiber-optic)
x’	Aircraft coordinate reference axis
y’	Aircraft coordinate reference axis
z’	Aircraft coordinate reference axis
X_{ECEF}	Earth coordinate reference axis, Earth-centered, Earth-fixed
Y_{ECEF}	Earth coordinate reference axis, Earth-centered, Earth-fixed
Z_{ECEF}	Earth coordinate reference axis, Earth-centered, Earth-fixed
North (N)	Local North Earth coordinate
East (E)	Local East Earth coordinate
Up (U)	Local Up Earth coordinate
U	Earth-relative three-dimensional wind velocity vector
Va	Probe-relative air velocity vector
Vg	Ground-relative probe velocity vector
φ	Aircraft roll angle
θ	Aircraft pitch angle
ψ	Aircraft heading angle
α	Angle of attack
β	Angle of sideslip
Q	Dynamic pressure
U	East wind component
V	North wind component
W	Vertical wind component

Abstract

The Flux Observations of Carbon from an Airborne Laboratory (FOCAL) project is a cooperative effort among the Anderson Group from Harvard University, Aurora Flight Sciences, and NOAA's Atmospheric Turbulence and Diffusion Division (NOAA/ATDD) to add scientific instruments to a Diamond Aircraft DA-42 Twin Star aircraft to measure fluxes of CO_2 and CH_4 in the planetary boundary layer. The work, funded by the National Science Foundation in 2012, uses the Anderson Group's Integrated Cavity-Output Spectroscopy (ICOS) instrument suite to measure concentrations and isotopologues of CO_2 and CH_4, NOAA/ATDD's Best Airborne Turbulence (BAT) probe to measure atmospheric turbulence in 3-dimensions, and Aurora Flight Sciences' DA-42 Twin Star aircraft to carry the complete instrument package. The DA-42 collected 36.9 hours of research data based from Deadhorse Airport in Prudhoe Bay, Alaska in August, 2013. A flight track was created to compare the CO_2 and CH_4 flux measurements made by instruments aboard the DA-42 against a ground-based tower which made simultaneous CO_2 and CH_4 flux measurements. Flight tracks were then expanded to measure fluxes far beyond the tower comparison area. Tracks were flown over inland melt-pond lakes and the Arctic Ocean to monitor CH_4 concentrations and fluxes, as well as to compare coincident measurements of bulk water-column and in-situ tundra flux measurements made by the Naval Research Laboratory (NRL). Tracks were also flown to characterize the background CO_2 and CH_4 concentrations around the Prudhoe Bay oil fields. This report describes the NOAA/ATDD BAT probe instrumentation and the August 2013 Alaska flight campaign.

Figure 1. FOCAL-equipped DA-42 Twin Star.

1.0 Introduction

The impetus for developing the FOCAL system stemmed from observed loss of permanent floating ice in the high Arctic over the past 25 years (Holland *et al*., 2006, Boe *et al*., 2010). The loss of high Arctic ice initiates a feedback within the climate structure of the Arctic that may result in loss of stored carbon (in the form of CO_2 and CH_4 gases, primarily) to the atmosphere from the tundra and Arctic ocean systems (e.g. Tarnocai *et al*., 2009, Walter *et al*., 2007). Measurement of the release of these gases can provide a quantitative prognosis of the developing changes in the Arctic.

Because the Arctic is largely unpopulated with few roads and little infrastructure to support large-scale ground-based spatial measurements, the use of an aircraft was mandatory. Previous studies have used aircraft to measure boundary-layer fluxes over the North Slope on regional scales with good success (Brooks *et al*., 1996, Zulueta *et al*., 2011). This experiment leveraged experience by the NOAA/ATDD team that has previously made boundary-layer flux measurements in the high Arctic from small aircraft.

The aircraft carries three detection cells that measure gas concentrations in relatively small volumes of air using direct absorption using either a Harriett cell or ICOS cell (Witinski *et al*., 2010). These instruments were designed and built by the Anderson Group at Harvard University and measure concentrations of H_2O, N_2O, CO_2 ($^{12}CO_2$ and $^{13}CO_2$) and CH_4 at a rate of 10 Hz. Additionally, one of these cells can measure concentrations of $^{13}CH_4$ at a rate of 0.5 Hz. The Harvard group was also responsible for all data storage performed on-board the aircraft.

Three-dimensional turbulent winds were measured by the BAT probe. The BAT probe utilizes a 9-hole hemisphere to measure angle of attack and sideslip of the airstream relative to the probe. Air temperature is measured by an OpSens fiber-optic temperature sensor and a microbead thermistor. To measure winds with respect to Earth, simultaneous measurements of the aircraft's velocity and attitude are made with a NovAtel Synchronized Position Attitude Navigation (SPAN) system and two sets of three orthogonal accelerometers mounted in the BAT probe and at the aircraft's center of gravity (CG). The first field deployment of the aircraft occurred in August 2013 to the North Slope of Alaska.

The objectives of the August 2013 field study were to:

1) Prove the flux measurements of H_2O, CO_2, and CH_4 were being made successfully with the aircraft under operational field conditions.
2) Survey areas of emissions of CH_4 and CO_2 from inland melt-water lakes and the Arctic Ocean.
3) Provide data to characterize the representativeness of NRL bulk gas column measurements both in the Arctic Ocean and over the tundra to larger spatial scales.
4) Characterize the emissions of CO_2 and CH_4 around the Prudhoe Bay oil fields.

Additionally documentation flights were made to photograph the terrain below the tower transect to better characterize the structure of melt-pond lakes near the tower comparison area.

1.1 Wind Measurement System

The wind measurement system consists of sensors that measure air pressure, air temperature, and aircraft attitude, position, velocity, and acceleration. From these measurements winds with respect to Earth, and subsequently fluxes, can be calculated. These sensors are contained in a streamlined housing with a hemispherical nose and nine pressure ports. The theory of operation is covered in Crawford and Dobosy, 1992 and Leise, *et al.*, 2013. The BAT probe is the result of collaboration between NOAA/ATDD and Airborne Research Australia (Crawford and Dobosy, 1992, Hacker and Crawford, 1999).

The BAT probe housing consists of a 15 cm diameter aluminum hemisphere mounted on a constant-diameter aluminum

Figure 2. DA-42 with the universal nose and BAT probe.

cylinder that is fitted to a carbon fiber boom that protrudes from the nose of the DA-42. The boom is mounted to an adapter on the aircraft known as the universal nose that houses the structural support for the boom and couples it to the airframe as shown in Figure 2.

The hemisphere houses pressure transducers, accelerometers, temperature sensors, and related circuit boards. A BAT-REMote module (BAT-REM) located in the cylinder converts analog measurements made by the BAT sensors to digital signals. Having the analog-to-digital (A/D) conversion take place in close proximity to the sensors reduces the chance for electrical noise to degrade the analog signal. The digitized data are sent via serial stream directly into the aircraft data system at 50 Hz.

The BAT probe was tested in the Wright Brothers Wind Tunnel at the Massachusetts Institute of Technology in October, 2010 to verify its performance prior to installation on the DA-42 aircraft. The probe was found to perform satisfactorily through the range of angles of attack, sideslip, and airspeed that it would encounter while flying on the DA-42 (Dobosy, *et al.*, 2011).

The inertial measurements of aircraft attitude, position, and velocity are made using a NovAtel SPAN system that is located near the aircraft CG. The SPAN system combines a Global Positioning System and an Inertial Navigation System (GPS/INS) to measure the aircraft position, velocity, and attitude in one self-contained system. The GPS measures the aircraft position and velocity with high absolute accuracy. The INS uses a set of micro-machined electromechanical sensors (MEMS) to measure the rate of rotation of the aircraft about its primary axes, which are then integrated to calculate the attitude of the aircraft.

A NovAtel ALIGN® system is used to provide more accurate heading information to the GPS/INS system. This system uses an additional GPS receiver to calculate the heading of the aircraft based on the relative position of two antennae that are spaced approximately 5 meters along the longitudinal axis of the airplane. These low-frequency GPS heading measurements are used to provide a stable low-frequency reference for the high-frequency inertial heading measurement.

Winds are computed using air pressure, acceleration, velocity, and temperature measured by the BAT probe and the velocity vector of the aircraft measured by the NovAtel SPAN system at 50 Hz. From these measurements, two velocity vectors ***Va*** (velocity of the air with respect to the aircraft) and ***Vg*** (velocity of the aircraft with respect to the Earth) are derived. The result of adding these two vectors together is ***U***, the velocity of the wind with respect to the Earth (Crawford and Hacker, 2002). At typical flight speeds and in normal winds ***Va*** and ***Vg*** are opposite in direction and nearly equal in magnitude. They are related by the following equation and are shown in Figure 3:

$$\boldsymbol{U} = \boldsymbol{Vg} + \boldsymbol{Va}$$

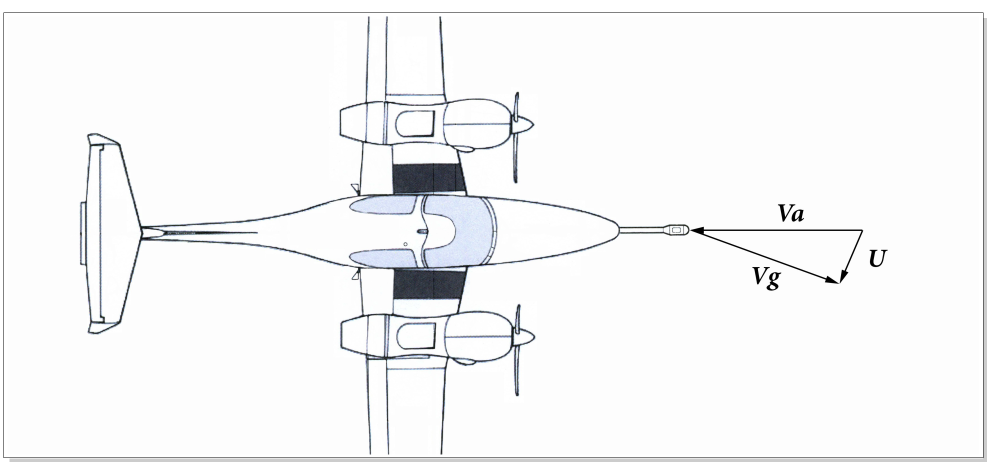

Figure 3. Wind vector diagram.

The details of converting the pressures, velocities, and accelerations measured by the BAT probe and its related components into the relative wind velocities ***Va*** and ***Vg***, and the resultant velocity ***U***, is beyond the scope of this paper. See Crawford and Dobosy, 1992 or Leise, 2013 for more detailed information.

1.2 Gas Concentration Measurement System

The carbon isotopologue instrument was first designed to provide a measurement of methane and the ^{13}C isotopologue of methane with the accuracy, precision, and frequency response necessary for flux measurements and the robustness to be used aboard an aircraft. In order to provide a full picture of greenhouse gas emissions, water vapor, carbon dioxide, and nitrous oxide were added to the measurement suite. The instrument uses three detection cells to sample CH_4, CO_2, N_2O, and H_2O. All three cells draw air from inlets located 20 cm aft of the BAT probe's turbulence measurements ports (Inset 1 in Figure 4). The methane isotopologue cell uses the ICOS technique to measure $^{12}CH_4$ and $^{13}CH_4$. The methane cell also uses ICOS to measure CH_4, N_2O, H_2O, and HDO. The carbon dioxide cell uses direct absorption and a small Harriett cell to measure $^{12}CO_2$, $^{13}CO_2$, and $^{12}CO^{18}O$. The two small detection cells are located in the forward compartments of the Centaur aircraft (Inset 2 in Figure 4) and the larger methane isotopologue cell, along with the main electronics and pumps, is housed behind the pilot's seat in the main cabin (Inset 3 in Figure 4).

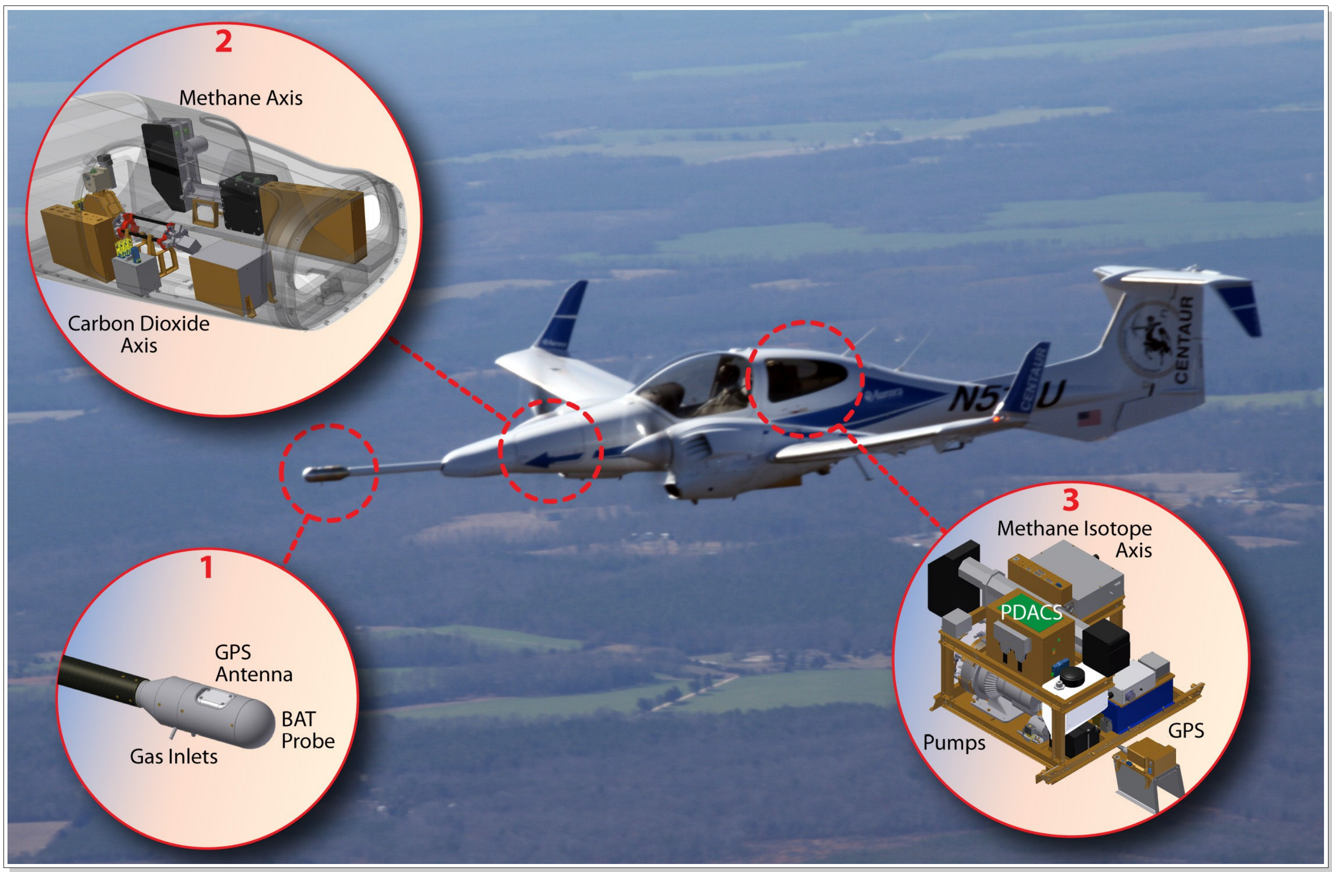

Figure 4. Diagram of the Harvard gas analyzer instruments and the ATDD BAT probe.

2.0 Aircraft Coordinate System

Probe-relative air velocity, sensed in the airplane's reference frame, is measured in the airplane's coordinate system: x', positive forward; y', to port; and z', toward the airplane's roof. Earth-relative probe velocity is measured in Earth's reference frame and coordinate system E, positive eastward; N, northward; and Up, upward. A transformation matrix, which is defined by measurements of the three conventional attitude angles: roll (φ), pitch (θ), and heading (ψ), accomplishes rotation from one coordinate system to the other. They must be applied in the proper order: roll, pitch, yaw to convert from airplane coordinates to Earth coordinates, and yaw, pitch, roll to convert the other way. These must be sampled simultaneously with all other quantities involved in wind computation. Their definition, including sign convention, is shown in Figure 5, along

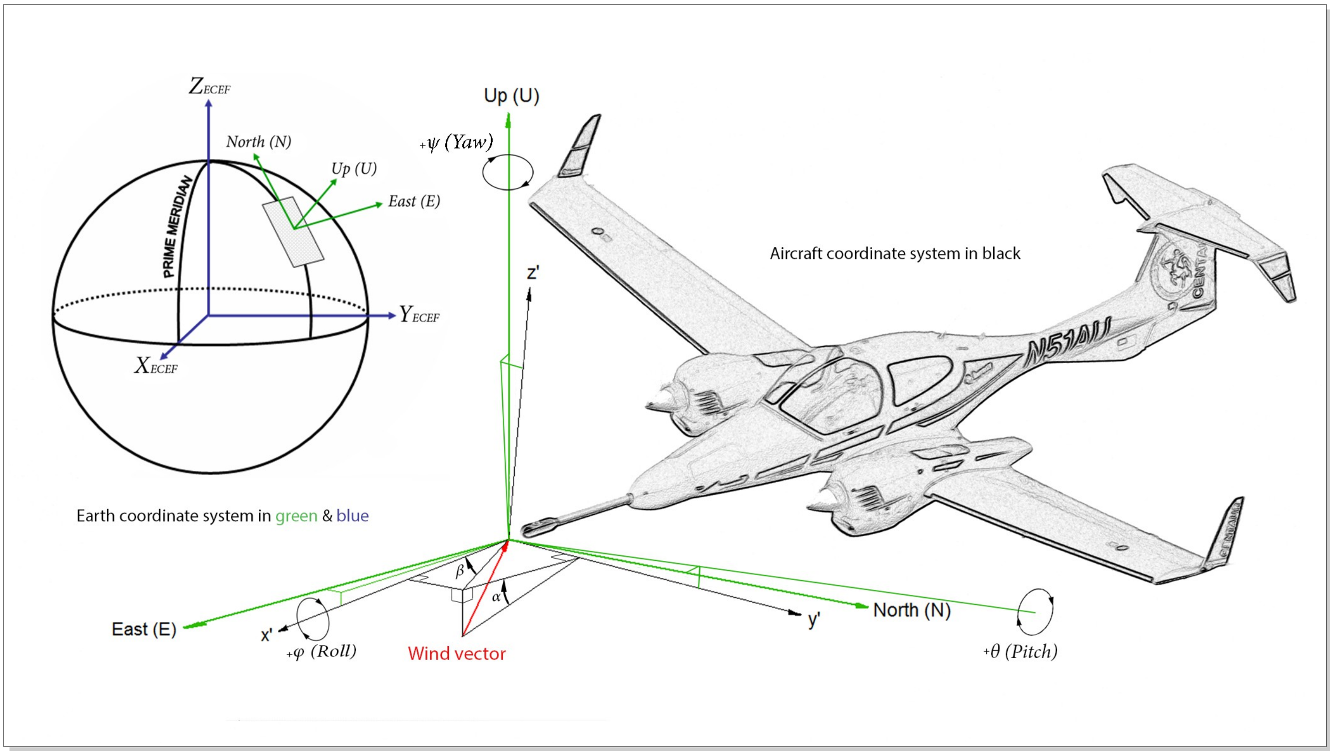

Figure 5. Diagram of Earth coordinate system and aircraft coordinate system.

with angles of attack (α) and sideslip (β). These angles define the direction of the wind vector with respect to the probe.

2.1 BAT Pressure Sensors

The BAT probe hemisphere has nine precisely machined holes that are connected to four solid-state pressure sensors. Reference pressure, (Pr) is measured by taking the pneumatic average of four off-axis pressure ports. This measurement is used to calculate the static air pressure. Dynamic pressure is computed from the raw differential impact pressure at the Design Stagnation Point (DSP) because when α and β are zero, the stagnation point of the flow is at the DSP. The Px pressure is measured using a differential pressure sensor between the DSP and the reference pressure ports.

Two additional differential pressure sensors measure the difference in pressure across the horizontal (Py) and vertical (Pz) axes. These pressure measurements are used to calculate the angles of attack (α) and sideslip (β). Pressure sensors are Honeywell Sursense ultra-low pressure sensors models DCXL05DN (Py, Pz), DCXL20DN (Px), and XCX15ANQ (Ps). These use micro-machined silicon sensors that form a piezo-resistive strain gauge (Crawford and Dobosy, 1992).

2.1.1 Pressure Sensor Calibration

The BAT pressure sensors are calibrated using National Institute of Standards and Technology (NIST) traceable pressure transducers. The BAT static pressure sensor is calibrated using an AIR Model DB-1B absolute pressure sensor and the differential pressure sensors are calibrated using an MKS Baratron type 398HD-00010 pressure sensor head and type 270B signal conditioner. A least-squares regression of the pressure input in millibars and BAT sensor output in millivolts is used to determine sensitivity and offset coefficients for each BAT transducer as shown in Figure 6.

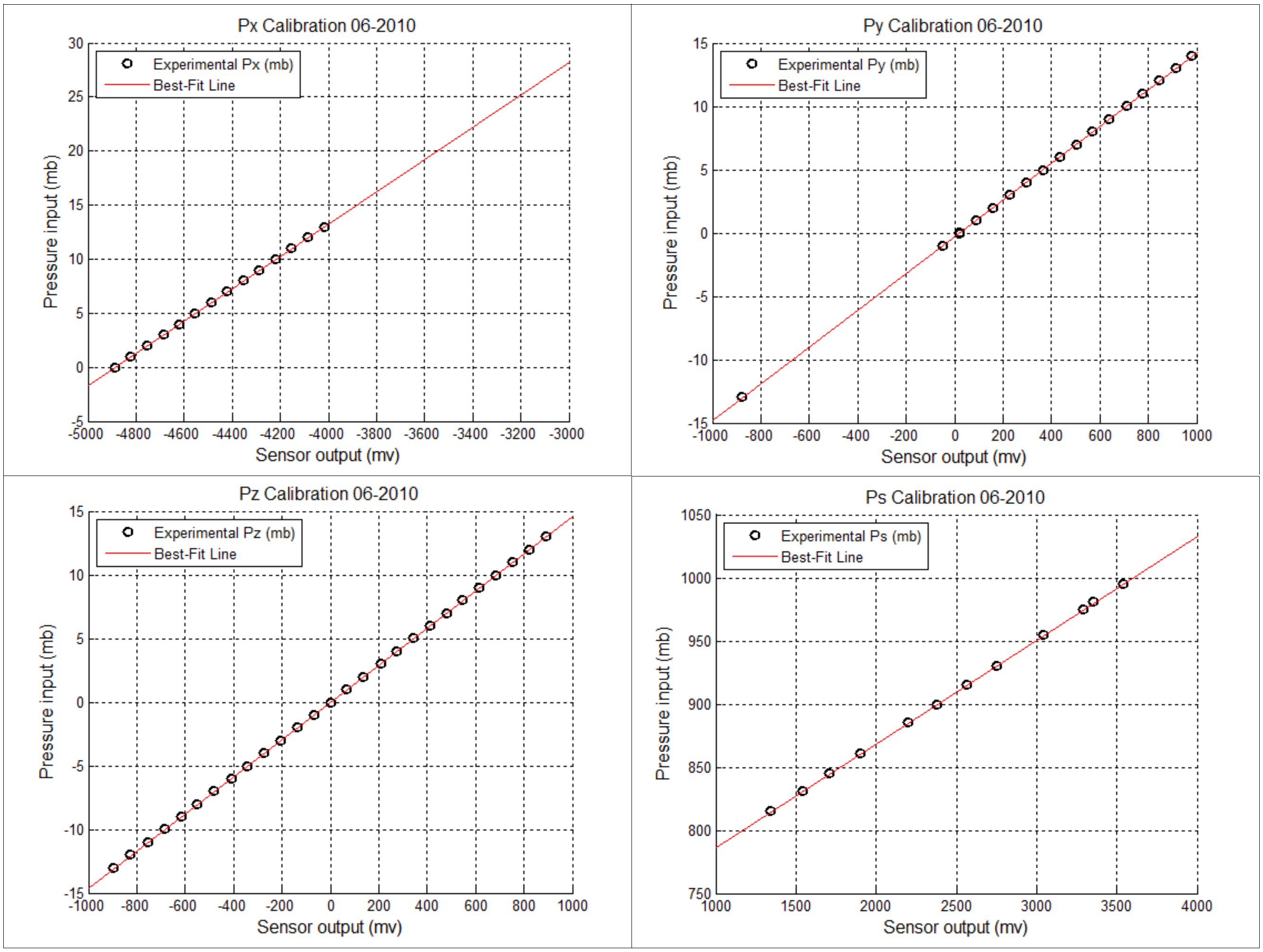

Figure 6. Pressure calibration data for Px, Py, Pz, and Ps.

2.2 BAT Accelerometers

Three orthogonal accelerometers mounted in the BAT hemisphere measure acceleration along the aircraft's axes x', y', z'. Another set of accelerometers located near the aircraft CG are aligned along the same axes, hereafter referred to as the 'backseat' accelerometers.

The probe and backseat accelerometers together provide a means for determining high-frequency variations in pitch and heading. The signals from accelerometers along the y' and z'-axes are subtracted, divided by their separation distance, twice integrated, and high-pass filtered. These measurements are used to enhance the attitude measurements made by the NovAtel SPAN system. The accelerometers are IC Sensors Model 3022 piezo-resistive silicon type with ±5 VDC output.

2.2.1 Accelerometer Calibration

The accelerometers are calibrated by tilting them using a custom fixture that measures the angle within ±0.2°. A least-squares regression of the gravity component (calculated using the accelerometer tilt angle) and BAT sensor output in m/sec^2 is used to determine sensitivity and offset coefficients for each BAT transducer as shown in Figure 7.

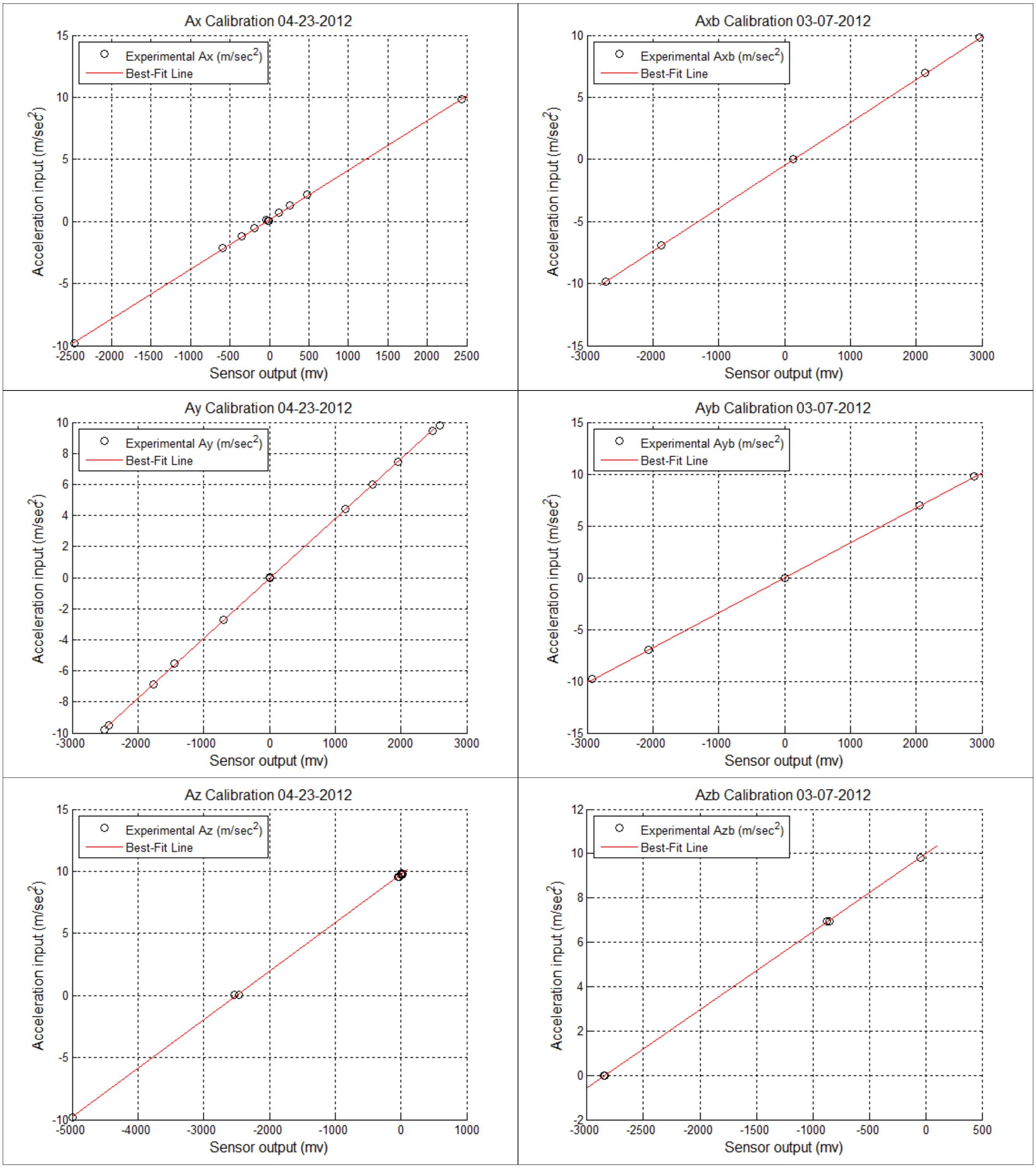

Figure 7. Accelerometer calibration data for Ax, Axb, Ay, Ayb, Az, Azb.

2.3 NovAtel SPAN GPS/INS System

The NovAtel SPAN GPS/INS system shown in Figure 8 is a self-contained system to measure the aircraft attitude, position, and velocity with respect to Earth. It utilizes a combination of GPS and MEMS to accomplish these measurements. Data from the BAT accelerometers are used in conjunction with the SPAN data to provide a complete measurement of the ***Vg*** vector from Figure 3.

The SPAN system is located approximately 1.1 meters aft of the aircraft's CG. The GPS master antenna, which is connected to the SPAN system, is mounted to the top of the fuselage above the rear passenger seat approximately 0.26 meters behind and 0.98 meters above the SPAN system. The SPAN unit and its antenna are rigidly mounted with respect to each other.

The NovAtel ALIGN GPS system and its GPS slave antenna are used to provide enhanced heading information to supplement the SPAN GPS/INS data. The GPS slave antenna is mounted on top of the BAT probe.

Figure 8. NovAtel SPAN GPS/INS.

The GPS slave antenna is located 4.9 meters forward and 0.76 meters below the master antenna as shown in Figure 10. This spacing provides an uncertainty of 0.140° in the measured heading as shown in Figure 9 (NovAtel, 2013). The GPS slave antenna is also mounted rigidly with respect to the GPS master antenna.

The GPS/INS data are output at 50 Hz and transmitted via RS-232 serial interface for recording by the data system. Each data package is time-tagged with GPS time. The GPS/INS data include the aircraft position, velocity, and attitude angles.

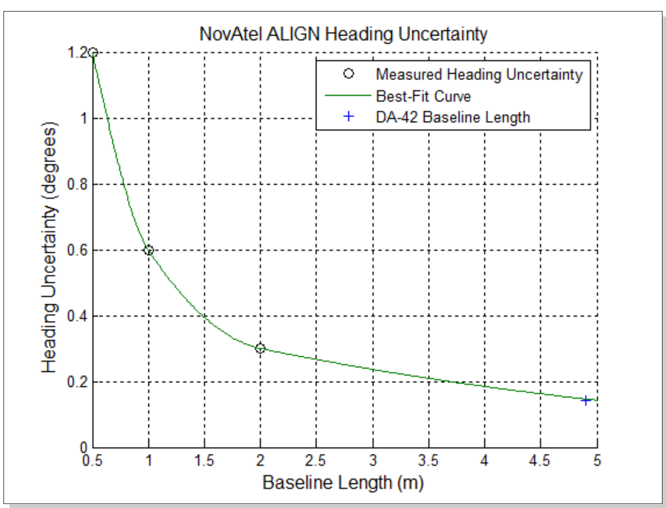

Figure 9. NovAtel ALIGN heading uncertainty.

Additionally, the NovAtel GPS 1 Hz timing pulse is used with a custom-designed circuit to generate a synchronized 50 Hz TTL signal to trigger the start of data acquisition by the BAT-REM module. This ensures that data packages from the BAT-REM module are synchronized in time with the NovAtel SPAN GPS/INS and the ICOS.

Data from the GPS/INS are then matched in time with data from the BAT-REM module and output to a Network Common Data Form (netCDF) file for storage and archival. Additional data from the Harvard instruments are recorded by the data system in separate files. Data are combined in post-processing following the flight.

Following each flight, additional text files are created to document the useful portions of the data files, such as transect start and stop times, positions, and comments. These are called marker files and are used for both data processing and documentation purposes. They are cataloged in Appendix B.

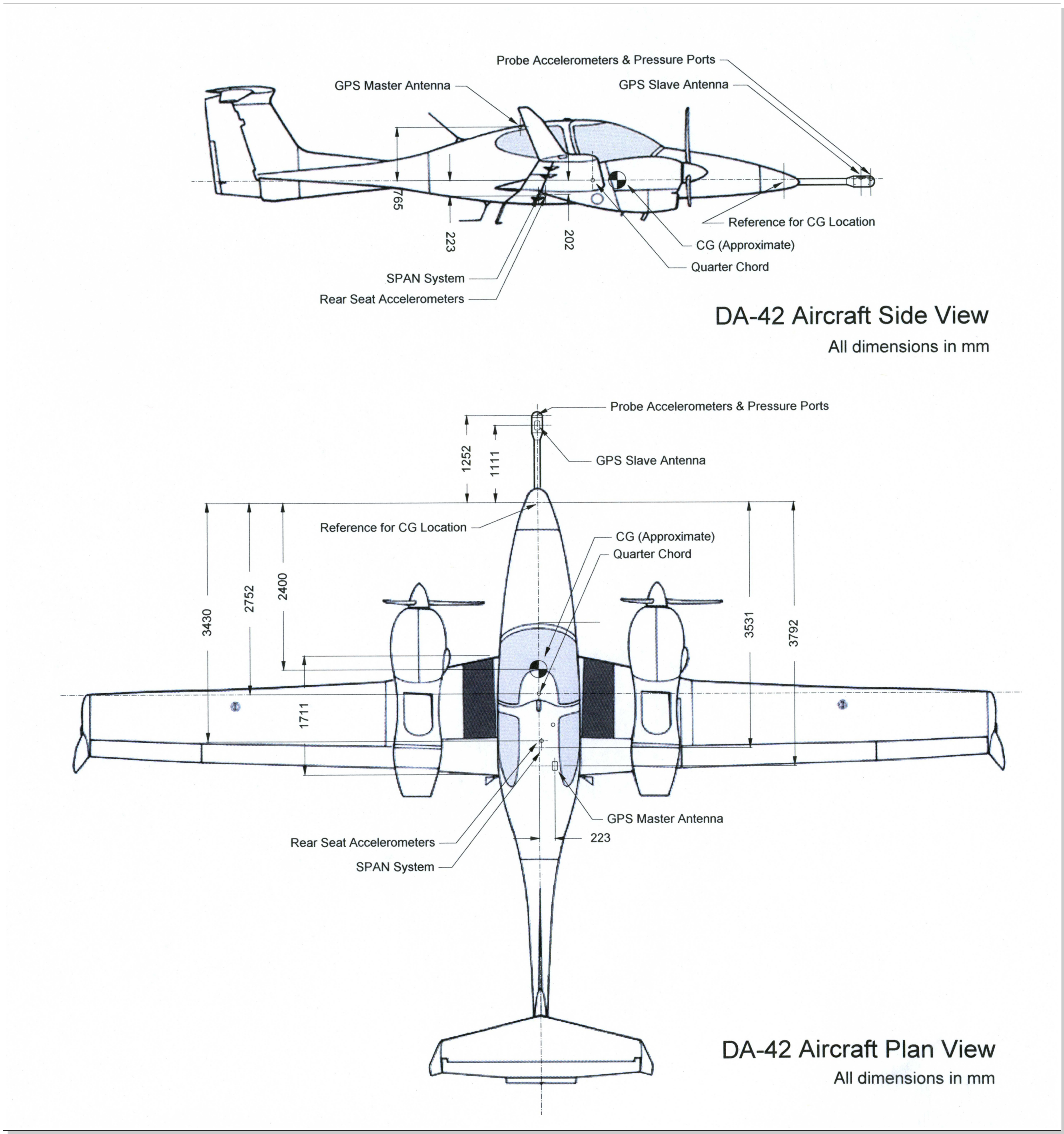

Figure 10. DA-42 GPS/INS configuration.

2.4 Temperature Sensors

Air temperature measurements are made using a YSI 44212 micro-bead thermistor and an OpSens fiber-optic temperature sensor. The micro-bead thermistor has the advantage of a linear temperature response over a large range compared to other thermistors. The fiber-optic temperature sensor uses the temperature dependence of the band gap of a gallium-arsenide

(GaAs) chip affixed to the end of a fiber-optic cable to measure the air temperature at the end of the fiber-optic cable. The frequency of light which is attenuated by the GaAs chip is in direct proportion to the temperature of the gallium arsenide chip.

2.4.1 Temperature Sensor Calibration

The voltage response of the micro-bead temperature sensor is compared with the temperature reading of a calibrated precision mercury thermometer (accuracy = ± 0.15°C). Five different temperatures are compared over a range of 0–30°C by immersion in a fluid bath as shown in Figure 11. The fiber-optic temperature sensor factory calibration is shown in Figure 12.

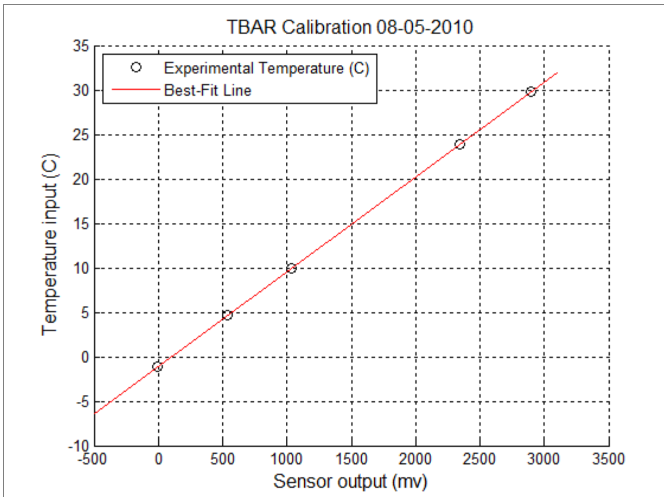

Figure 11. TBar calibration data.

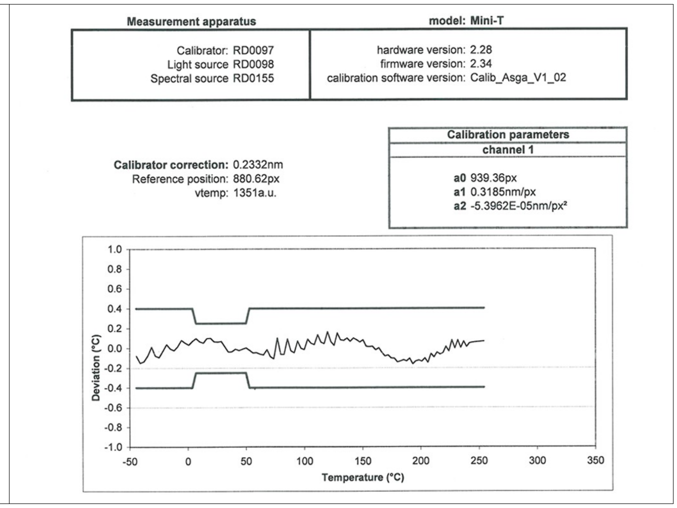

Figure 12. Fiber-optic temperature sensor calibration data.

2.5 Auxiliary Instruments

Additional instruments were installed in the aircraft to provide remote sensing capability. A downward-looking camera was installed in the universal nose just below the root of the BAT probe boom to make visible-light photos of the terrain directly below the aircraft. The purpose was to document lakes along transects that would be flown periodically, such as the ATDD tower transect.

A Canon Powershot G15 camera was selected because of its high pixel resolution (4000x3000), its ability to shoot RAW format images, its built-in optical image stabilization, its low power consumption, and its compact size. The camera was configured to be actuated by a remote trigger (Vello Shutterboss) from the cockpit of the aircraft.

Figure 13 shows the plan view of the Canon Powershot G15 viewing angle drawn to scale. The ratio of the width of the camera's frame to the lens focal length is fixed, which is 35/28 or 1.25. This is also the ratio of the height of the aircraft to the width of the field of view below the aircraft, as shown in the horizontal dimension, 1.25 * h. The camera frame aspect ratio is 4:3, which gives a ratio of 0.9375 * h to the length of the field of view below the aircraft.

At an altitude of approximately 1500 meters AGL the length of the camera field of view below the aircraft is approximately 1400 meters. With a zero-wind flight speed of 60 m/s, the time required to transit the entire length of the field of view is approximately 23 seconds. To give a good overlap of successive pictures and to account for winds that will affect the ground speed of the aircraft a 10 second interval was used to create a mosaic of the terrain below the aircraft.

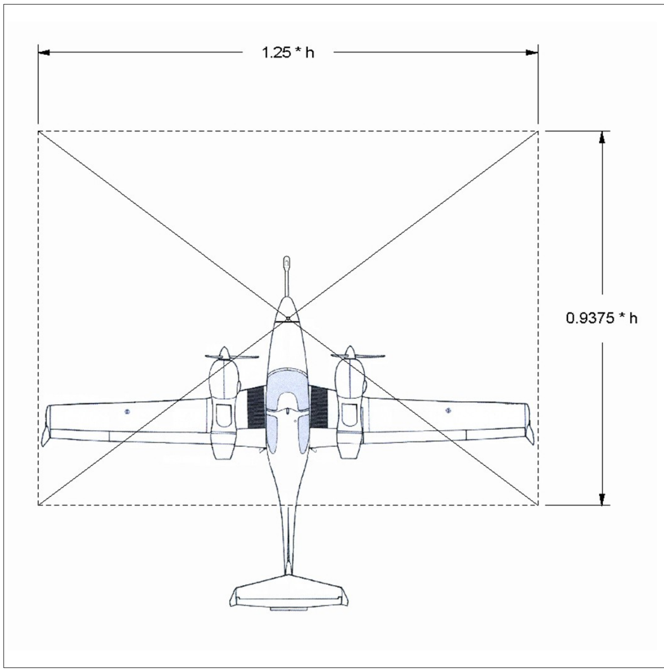

Figure 13. Canon Powershot G15 plan view of camera viewing angle from the DA-42.

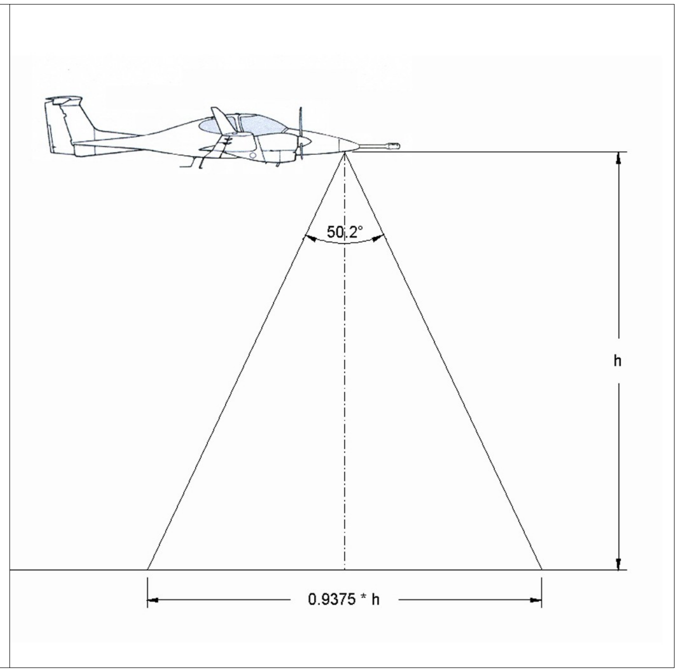

Figure 14. Canon Powershot G15 profile view of camera viewing angle from the DA-42.

The signal from the remote trigger was routed into an A/D channel on the BAT-REM to record the time the shutter was actuated so that pictures from the camera could be linked to data collected by the FOCAL system. This technique worked well for making a mosaic of pictures over the tower transect.

Another auxiliary function of the BAT probe was a pump to flush water from the tubes between the pressure ports and the pressure transducers. This was done to allow the pilot to clear the lines in case rain or visible moisture was encountered during flight while collecting data. A set of six solenoid valves (Angar Scientific Model AL1112) were used to connect each of the tubes through a manifold to a diaphragm pump (Sensidyne Model 800358) that was plumbed to blow air (and hence water) out the front pressure ports of the hemisphere. The pump voltage was routed into an A/D channel to record the state of the pump.

A list of each analog and digital channel is shown in Table 1.

Table 1. ATDD instrumentation on the FOCAL DA-42 aircraft.

Variable	Units	Freq	Digital/Analog	Description
Px	mb	50	A	Delta Px air pressure measurement
Py	mb	50	A	Delta Py air pressure measurement
Pz	mb	50	A	Delta Pz air pressure measurement
Ps	mb	50	A	Static air pressure measurement
Ax	m/sec^2	50	A	Ax acceleration measured from probe
Ay	m/sec^2	50	A	Ay acceleration measured from probe
Az	m/sec^2	50	A	Az acceleration measured from probe
Tbar	°C	50	A	TBar thermistor temperature sensor
FOTemp	°C	50	A	OpSens fiber-optic temperature sensor
Camera	-	50	A	Downward-looking camera trigger
Pump	-	50	A	BAT probe purge pump indicator

Axb	m/sec^2	50	A	Axb acceleration measured from the back seat
Ayb	m/sec^2	50	A	Ayb acceleration measured from the back seat
Azb	m/sec^2	50	A	Azb acceleration measured from the back seat
Slat	°	50	D	NovAtel SPAN GPS/INS latitude measurement
Slon	°	50	D	NovAtel SPAN GPS/INS longitude measurement
Salt	m	50	D	NovAtel SPAN GPS/INS altitude measurement
Su	m/sec	50	D	NovAtel SPAN GPS/INS U velocity component
Sv	m/sec	50	D	NovAtel SPAN GPS/INS V velocity component
Sw	m/sec	50	D	NovAtel SPAN GPS/INS W velocity component
Spitch	°	50	D	NovAtel SPAN GPS/INS pitch measurement
Sroll	°	50	D	NovAtel SPAN GPS/INS roll measurement
Shdg	°	50	D	NovAtel SPAN GPS/INS heading measurement
Sstatus	-	50	D	NovAtel SPAN GPS/INS INS status
Stime	sec	50	D	NovAtel SPAN GPS/INS time (sec since midnight Sat GMT)

2.6 BAT Data Collection System

The rear half of the BAT probe consists of a constant-diameter aluminum housing that contains a remote module (REM) to perform analog-to-digital (A/D) conversion for signals from instruments located in the front of the aircraft. The REM, designed and built by Graham Wilkins of Airborne Research Australia, filters and digitizes analog signals (French *et al.*, 2004).

The REM consists of a 16-channel A/D board with 16-bit resolution. The analog input voltage range is ±5 VDC which gives a digital resolution of approximately 0.1526 mV. The incoming analog signals are filtered using a 5-pole Butterworth anti-aliasing filter with a low-pass cutoff frequency of 30 Hz. The signals are over-sampled 32 times before being output for storage. The A/D conversion process is driven by a 50 Hz timing pulse synchronized to the NovAtel SPAN GPS/INS 1 PPS signal. The digital data from the BAT-REM module are transmitted to the computer for storage via an RS-422 serial interface that operates at 460,800 baud (Crescenti *et al.*, 2001).

2.6.1 BAT-REM Calibration

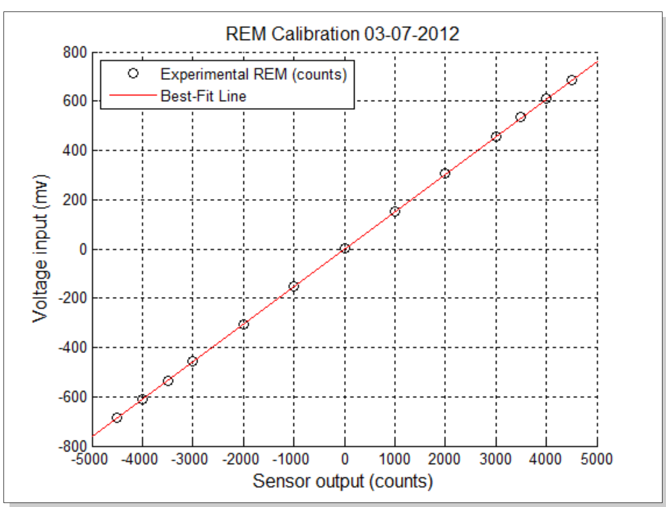

Figure 15. BAT-REM Calibration Data.

The conversion of input voltage to output digital data is calibrated by applying a precise voltage to each channel. The voltage is varied between ±5 VDC in discrete increments. The output is a 2-byte integer between -32,768 and +32,767 (hereafter referred to as a count) which is recorded for each voltage input. A linear regression is performed to obtain coefficients to convert counts to voltage. Figure 15 shows the calibration data for the BAT-REM module used in the FOCAL system.

3.0 Alaska Field Study 2013

The August 2013 field study was based from Deadhorse Airport in Prudhoe Bay, Alaska and resulted in 14 data collection flights. A total of 65 hours were flown between the start and end of the experiment to get 36 hours of scientific data.

To review, the objectives of the August 2013 field study were to:

1) Prove the flux measurements of H_2O, CO_2, and CH_4 were being made successfully with the aircraft under operational field conditions.
2) Survey areas of emissions of CH_4 and CO_2 from inland melt-water lakes and the Arctic Ocean.
3) Provide data to characterize the representativeness of NRL bulk gas column measurements both in the Arctic Ocean and over the tundra to larger spatial scales.
4) Characterize the emissions of CO_2 and CH_4 around the Prudhoe Bay oil fields.

To meet these objectives several flight plans were designed. The first objective was met by comparing the fluxes measured by the aircraft to those measured by a meteorological tower located at 70.08545° North latitude, 148.57016° West longitude. This location is approximately 10 miles south of Prudhoe Bay and lies adjacent to an access road approximately halfway between the Dalton Highway and the trans-Alaska pipeline.

The meteorological measurements made by the ATDD meteorological tower include fluxes of H_2O, CO_2, and CH_4, global incoming and outgoing radiation, air temperature, and various soil properties, including moisture and temperature at three depths. The instruments used to collect the tower data are listed in Table 2.

Table 2. Instrumentation on the ATDD meteorological tower.

Instrument	Manufacturer	Model	Height
Data logger	Campbell Scientific	CR3000	1 m
Fast-response CH_4	Li-Cor	Li-7700	3 m
Fast-response CO_2 /H_2O	Campbell Scientific	EC-155	3 m
Ultrasonic anemometer	Campbell Scientific	CSAT-3	3 m
Mean wind	R.M. Young	Wind Monitor Jr.	3 m
Four-component net radiation	Huskeflux	NR01	2.75 m
Photosynthetically Active Radiation	Li-Cor	Li-190	2.75 m
Temperature / dew point	Vaisala	DRD11A	2.75 m
Radiation shield	MetOne	076B-7398	2.75 m
Air temperature	Thermometrics	PRT	2.75 m
Precipitation gauge	Hydrological Services	TB3	0 m
Wetness sensor	Vaisala	DRD11A	2.75 m
Soil temperature	Measurement Specialties	44034 Thermistors	-0.02 m
Soil temperature	Measurement Specialties	44034 Thermistors	-0.05 m
Soil temperature	Measurement Specialties	44034 Thermistors	-0.10 m
Soil temperature	Measurement Specialties	44034 Thermistors	-0.20 m
Soil moisture	Acclima Probe	ACC-SEN-SDI	-0.05 m
Soil moisture	Acclima Probe	ACC-SEN-SDI	-0.10 m
Soil moisture	Acclima Probe	ACC-SEN-SDI	-0.20 m
Soil thermal conductivity	East 30 Sensors	Specific Heat Probe	-0.05 m

Figure 16. The DA-42 passes near the ATDD tower.

The tower was powered by a bank of four deep-cycle Sun Xtender PXV-1040T batteries charged by three 145 Watt solar panels in an array. The tower is shown, along with the DA-42 passing nearby, in Figure 16.

In general flight tracks were designed so that the aircraft could fly straight and level for as long a distance as practical. This allowed the turbulent winds and gas concentrations to be measured with minimum aircraft motion during data collection.

A procedure turn was used to reverse the course of the aircraft over the original flight track. The aircraft made a 30° heading change and was then flown straight and level until it passed a point that allowed a standard-rate turn (3°/second) to be made that placed the aircraft over the original flight track, on a heading 180° from the original direction. The location of the turn points were dependent on the airspeed of the aircraft.

To perform the tower comparison, two flight paths were designed to accommodate different surface wind directions. Each path consisted of a straight segment 37 km in length that was flown repeatedly at approximately 10 meters above ground level (AGL). One segment passed roughly north and east of the tower, shown in red, while the other passed approximately south and west of the tower, shown in yellow, in Figure 17.

The northeast portion of each leg passed over the Sagavanirktok River, while the southwest portions passed over several small melt-pond lakes. The path also passed over the trans-Alaska pipeline, just south of the Alyeska trans-Alaskan Pipeline System Access Road 135.

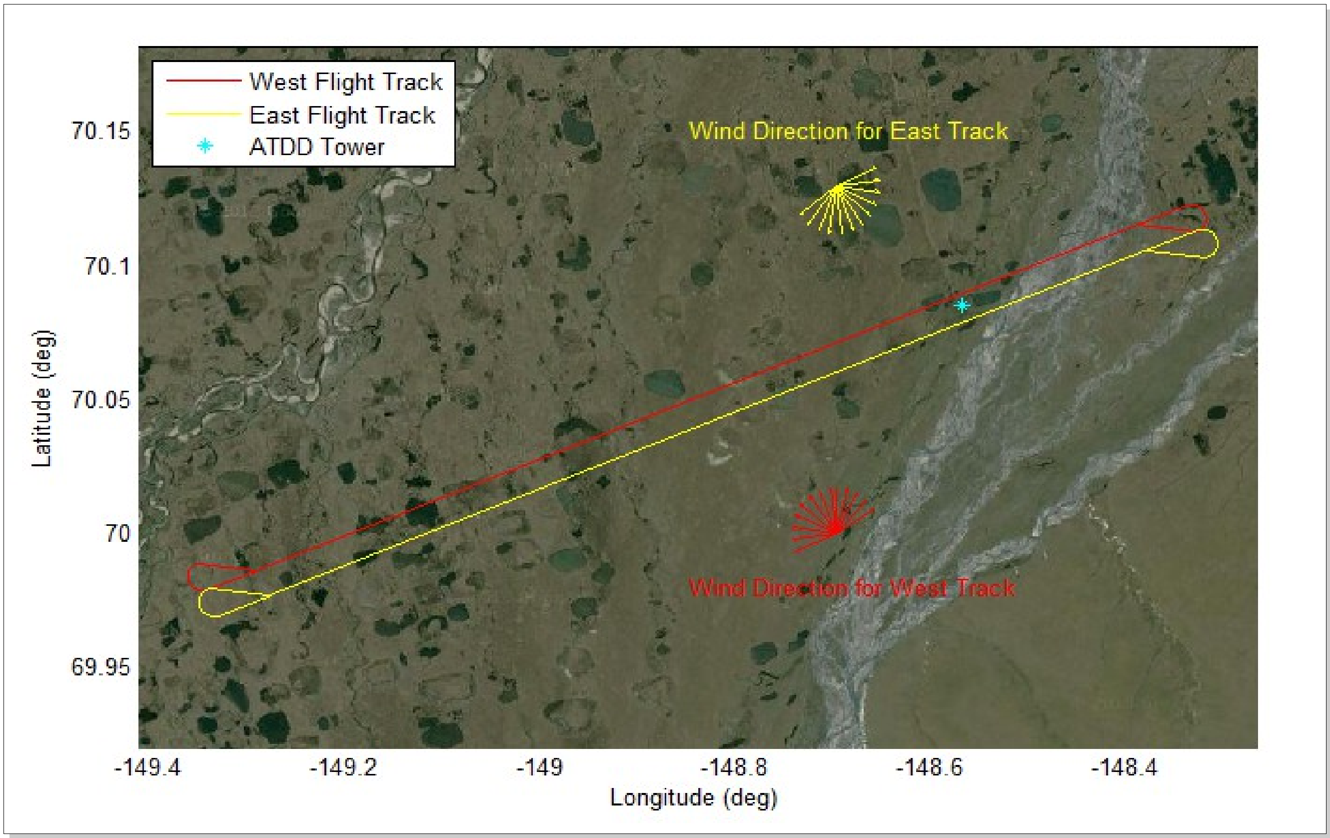

Figure 17. Flight tracks for ATDD tower comparison flights.

The procedure turns at each end of the track are shown in Figure 17. When predicted mean wind directions were 68°-247° true the red (West) tower track was selected. When predicted mean wind directions were 248°-67° true the yellow (East) tower track was selected. This was done to ensure the aircraft would sample air downwind of the tower. In each case the aircraft passed the tower approximately 0.5 km northwest (red) or 0.5 km southeast (yellow) so as to allow for the difference between sampling heights of the tower and the aircraft. Please note that the background maps in Figure 17 and all figures in Appendix A are from Google© Maps.

Flights that included passes over the ATDD tower were flights 1, 2, 3, 7, 8, 12, and 15. All tower tracks except those on flight 12 were East tower tracks. Flight 12 used the West tower track.

The second objective was addressed by designing flight tracks to fly over lakes in the open tundra and ice in the Arctic Ocean. Several grid patterns were flown over the tundra (flights 10, 11, 13, and 14), and one flight was designed to look for ice north of Prudhoe Bay in the Arctic Ocean (flight 4). It must be noted that the attempt to fly over pack ice during flight 4 was unsuccessful despite flying approximately 185 km off-shore to the north of Prudhoe Bay. No ice was spotted during the entire flight.

The third objective was to support the Naval Research Laboratory's effort to measure bulk fluxes in the tundra and water. One flight (flight 9) was flown over NRL sites in both the tundra northwest of Prudhoe Bay and the Arctic Ocean north of Nuiqsut during the NRL sampling period.

The fourth objective was addressed by flying a large box around Prudhoe Bay at low altitude (< 50 meters) to measure CO_2 and CH_4 concentrations. This was attempted on flights 6 and 7 (unsuccessful due to low ceilings and visibility) and flown successfully on flights 8 and 12.

One flight attempt to measure fluxes on a north-south transect east of the Deadhorse airport was unsuccessful due to cloudy conditions (flight 5). Low clouds forced the flight to be made at higher altitude than is appropriate for flux measurements.

Additionally, one flight included maneuvers used to calibrate the BAT probe (portion of flight 12). Maneuvers included straight and level flight, a wind box, one yaw left/right maneuver, two wind circles, four phugoid oscillations, three pitch up/down maneuvers, two rapid acceleration/deceleration maneuvers, and two pitch calibration maneuvers. Table 3 shows a summary of the DA-42 flights during the August 2013 campaign in Alaska.

Table 3. Summary of DA-42 flights during the August 2013 campaign in Alaska.

Flight	Date	File name	Start (ADT)	End (ADT)	Scans	Hours	Flight Pattern
1	10 AUG 13	130810.1F	15:18:06	17:51:38	9211	2.56	East tower track
2	12 AUG 13	130812.4F	14:23:53	16:31:13	7639	2.12	East tower & photo
3	13 AUG 13	130813.2F	10:19:11	12:21:21	7329	2.04	East tower track
4	13 AUG 13	130813.4F	14:59:12	17:32:58	9225	2.56	Ice flight
5	16 AUG 13	130816.2F	11:56:11	13:35:07	5935	1.65	North-South
6	17 AUG 13	130817.2F	13:38:15	16:15:22	9426	2.62	Aborted Barrow flight
7	18 AUG 13	130818.2F	14:31:40	17:33:11	10890	2.99	E. tower & aborted box
8	25 AUG 13	130826.1F	19:42:42	21:48:40	7557	2.10	E. tower & complete box
9	26 AUG 13	130826.2F	10:32:40	11:56:42	5041	1.40	NRL flight
10	26 AUG 13	130826.4F	13:43:17	19:17:01	16567	4.60	Barrow lakes
11	27 AUG 13	130827.1F	11:39:58	14:59:25	11967	3.32	Western grid
12	27 AUG 13	130828.1F	18:45:25	22:01:29	11763	3.27	Cal, W. tower & partial box
13	28 AUG 13	130828.3F	10:38:27	13:39:14	10846	3.01	Western grid
14	28 AUG 13	130828.4F	15:59:12	17:43:21	6249	1.74	Western grid
15	29 AUG 13	130829.1F	09:36:26	10:28:38	3131	0.87	East tower track

The start and end times shown in the table above are Alaska Daylight Time (ADT). ADT time is 8 hours behind UTC. Dates are also in Alaska Daylight Time. The File name dates, however, are derived from UTC time. This accounts for the discrepancy between the Date and File name dates given in Flights 8 and 12. Some calculation schemes utilize sun time, which is UTC-10 hours, or ADT-2 hours.

3.2 Flight Calibrations

The BAT probe is used to measure probe-relative air velocity while the GPS/INS measures Earth-relative probe velocity. Together these measurements are used to calculate winds with respect to Earth. The technique used to derive the probe-relative air velocity from the BAT probe pressure measurements must include corrections due to the flow distortion caused by the aircraft and any position, angular and phase errors between the instruments that make those measurements. Since flow distortion is unique to each particular aircraft, calibration flights were used to characterize the errors of the BAT probe and GPS/INS installation on this aircraft *in-situ*.

The measurement of vertical wind must take upwash into consideration. Upwash is the vertical component of the probe-relative air velocity vector due to the generation of lift by the wing. Vertical flow distortion at the BAT probe caused by upwash can be modeled and removed after first determining sensitivity coefficients that are dependent on the aircraft's probe and wing geometry and vertical load factor (Crawford *et al.*, 1996, Garman *et al.*, 2007).

The following calibration maneuvers were conducted in flight at a safe altitude and in atmospheric conditions where turbulence was minimal. Assumptions were made regarding the uniformity of the air mass in which the maneuvers were flown and these conditions could only be determined by the pilot at the time the maneuvers were being flown. While this can introduce some subjectivity to the measurement, the results are generally worthwhile. All maneuvers were flown at constant pressure altitude and at 120 knots indicated airspeed (KIAS) unless otherwise noted. The maneuvers described here were derived with some modification from Lenschow, 1986, Bögel and Baumann, 1991, Kalogiros and Wang, 2002, and Garman *et al.*, 2007.

3.2.1 Wind Box

The wind box was flown on cardinal headings (90°, 180°, 270°, 360°) with standard-rate turns (3°/second) between each leg. The mean and fluctuating components for the measured winds were calculated for the entire maneuver, then separated into along-wind and cross-wind components relative to the instantaneous heading of the aircraft. Heading errors were determined from the cross-wind variance and the dynamic pressure errors were determined from the along-wind variance, which were both ideally zero in this case.

3.2.2 Yaw Left / Right

The yaw maneuver was used to vary the heading angle (ψ) of the aircraft through a small range while maintaining constant airspeed, altitude, roll angle, and pitch angle. Similar in principal to the pitch calibration maneuver described below, the purpose of this maneuver was to minimize the variance in the horizontal wind vector with steady-state heading angle changes. These maneuvers were flown both to the left and the right.

3.2.3 Wind Circle Left / Right

The wind circle maneuver is a standard-rate turn flown through at least 360° of heading change. The purpose was to minimize the variance in the horizontal wind vector with constantly changing heading angle. This was done by adjusting the heading offset and dynamic-pressure correction in a manner similar to the wind box. These maneuvers were flown both to the left and the right.

3.2.4 Phugoid Oscillation

The phugoid oscillation was used to produce a repeatable, damped pitch oscillation that allowed the variation in upwash strength as a function of angle of attack and the aircraft's load factor (determined from gravity and the vertical acceleration) to be determined. It was also used to characterize phase errors between the probe-relative air velocity and Earth-relative probe velocity (Garman *et al.*, 2007).

3.2.5 Pitch Up / Down Maneuver

The pitch up / down maneuver was used to identify sources of contamination due to aircraft motion in the vertical wind. The pitch angle (θ) was varied through a small range while maintaining reasonably constant airspeed and altitude. A pitch up/down cycle was performed at three different frequencies (1/10 Hz, 1/5 Hz, and 1 Hz) and the amplitude of the maneuver was decreased as the pitching frequency was increased such that the airspeed and altitude were minimally affected.

3.2.6 Rapid Acceleration / Deceleration Maneuver

The goal for the rapid acceleration / deceleration maneuver was to determine the contribution of the fuselage and propeller to the measurements made by the BAT probe. The maneuver was flown at constant pressure altitude with an initial airspeed of 120 KIAS. Throttles were then rapidly applied to accelerate the aircraft to 140 KIAS, then rapidly retarded to decelerate the aircraft to 110 KIAS while altitude and heading were held constant (Kalogiros and Wang, 2002).

3.2.7 Pitch Calibration Maneuver

The pitch calibration maneuver was used to determine the adjustment to the theoretical relation of the vertical pressure difference Pz and dynamic pressure Q to the angle of attack (α), as well as to quantify the effect of upwash on the vertical wind measurement. Starting at constant pressure altitude and constant heading, the airspeed was gradually reduced from 140 KIAS to 100 KIAS over a 5 minute period. Airspeed was then slowly increased to 140 KIAS over another 5 minute period, making the duration for the total maneuver about 10 minutes. During the entire maneuver altitude and heading were held constant. Because the aircraft was flown in a quasi steady-state, lift was assumed to equal the weight of the aircraft, which allowed the coefficient of lift (C_l) and upwash velocity for the aircraft to be determined as a function of angle of attack (α).

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Appendix A – Catalog of flight tracks from the August 2013 Alaska campaign

```
File: BAT_SPAN_130810.1F_despike

File opened on 08/10/2013
File opened at 602303 GPS  06:23:18:06 UTC  06:15:18:06 Local Time
File closed at 006715 GPS  00:01:51:38 UTC  06:17:51:38 Local Time
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Scans:   9212
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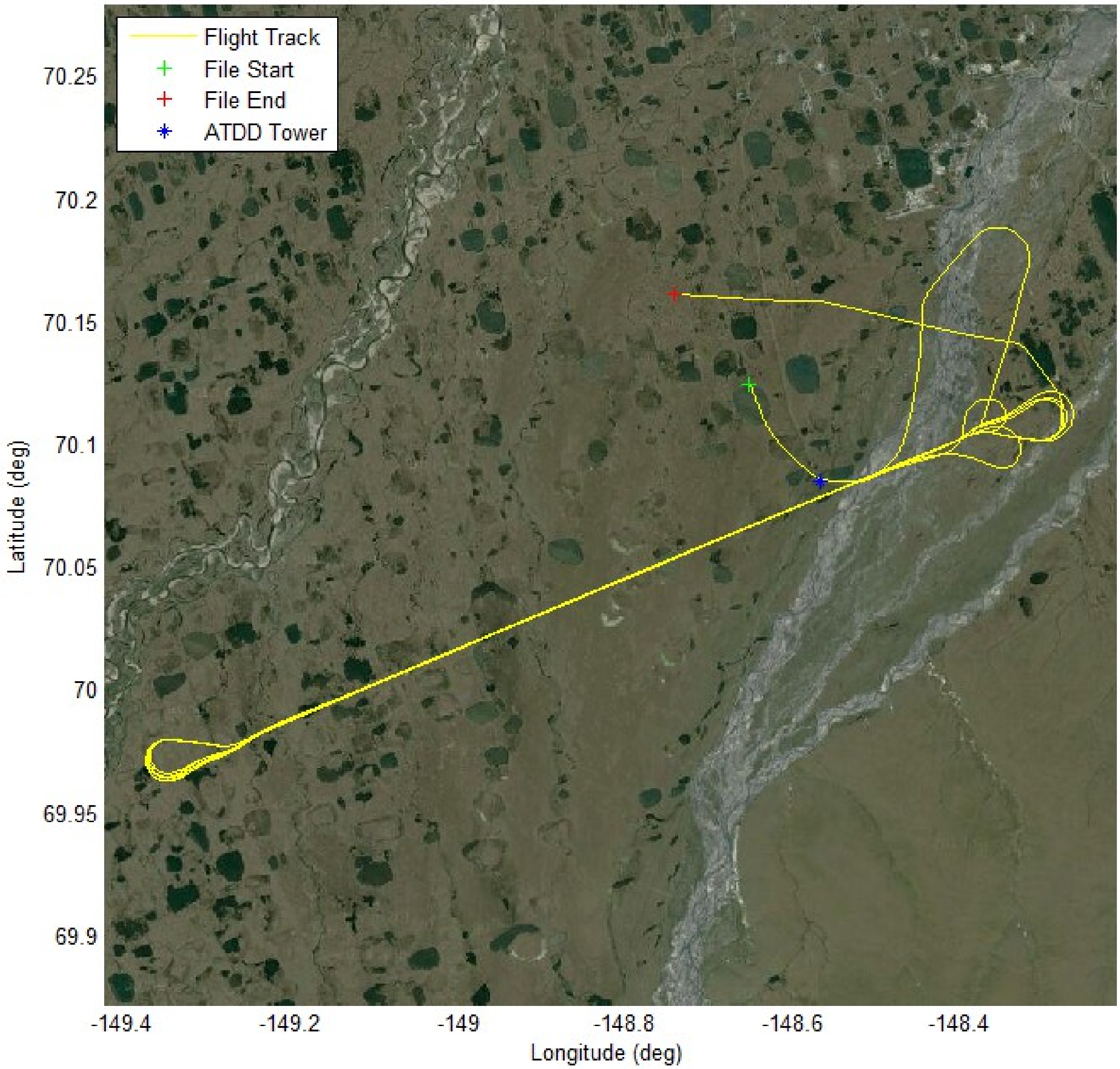

Figure A.1 – Flight 1, Saturday 10 August 2013. Tower East flight.

```
File: BAT_SPAN_130812.4F_despike

File opened on 08/12/2013
File opened at 167050 GPS  01:22:23:53 UTC  01:14:23:53 Local Time
File closed at 174690 GPS  02:00:31:13 UTC  01:16:31:13 Local Time
Flight Duration: 02:07:20 (2.12 Hours)
Scans:    7640
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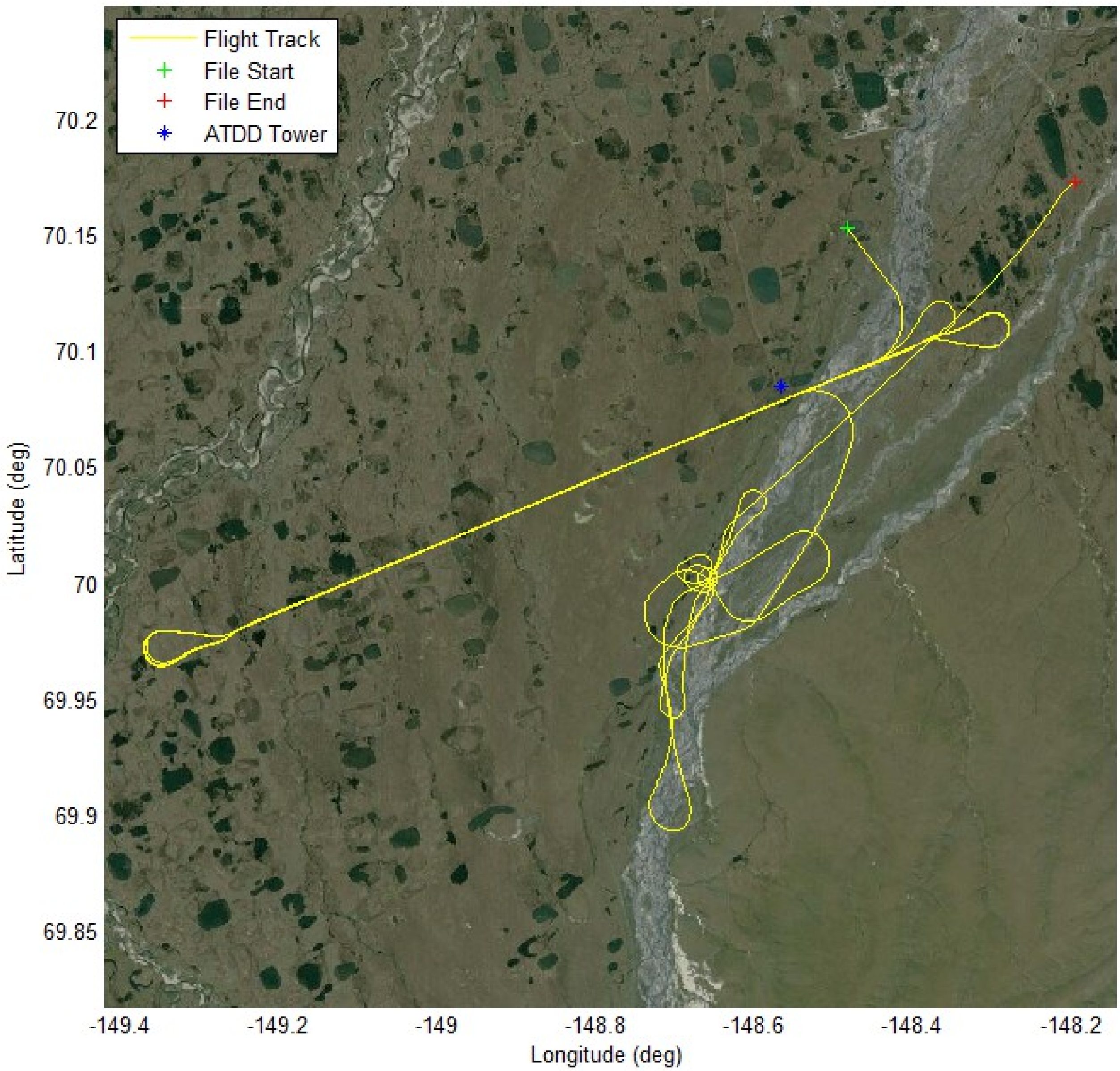

Figure A.2 – Flight 2, Monday 12 August 2013. Tower East and photo flight.

```
File: BAT_SPAN_130813.2F_despike

File opened on 08/13/2013
File opened at 238768 GPS  02:18:19:11 UTC  02:10:19:11 Local Time
File closed at 246098 GPS  02:20:21:21 UTC  02:12:21:21 Local Time
Flight Duration: 02:02:10 (2.04 Hours)
Scans:   7330
```

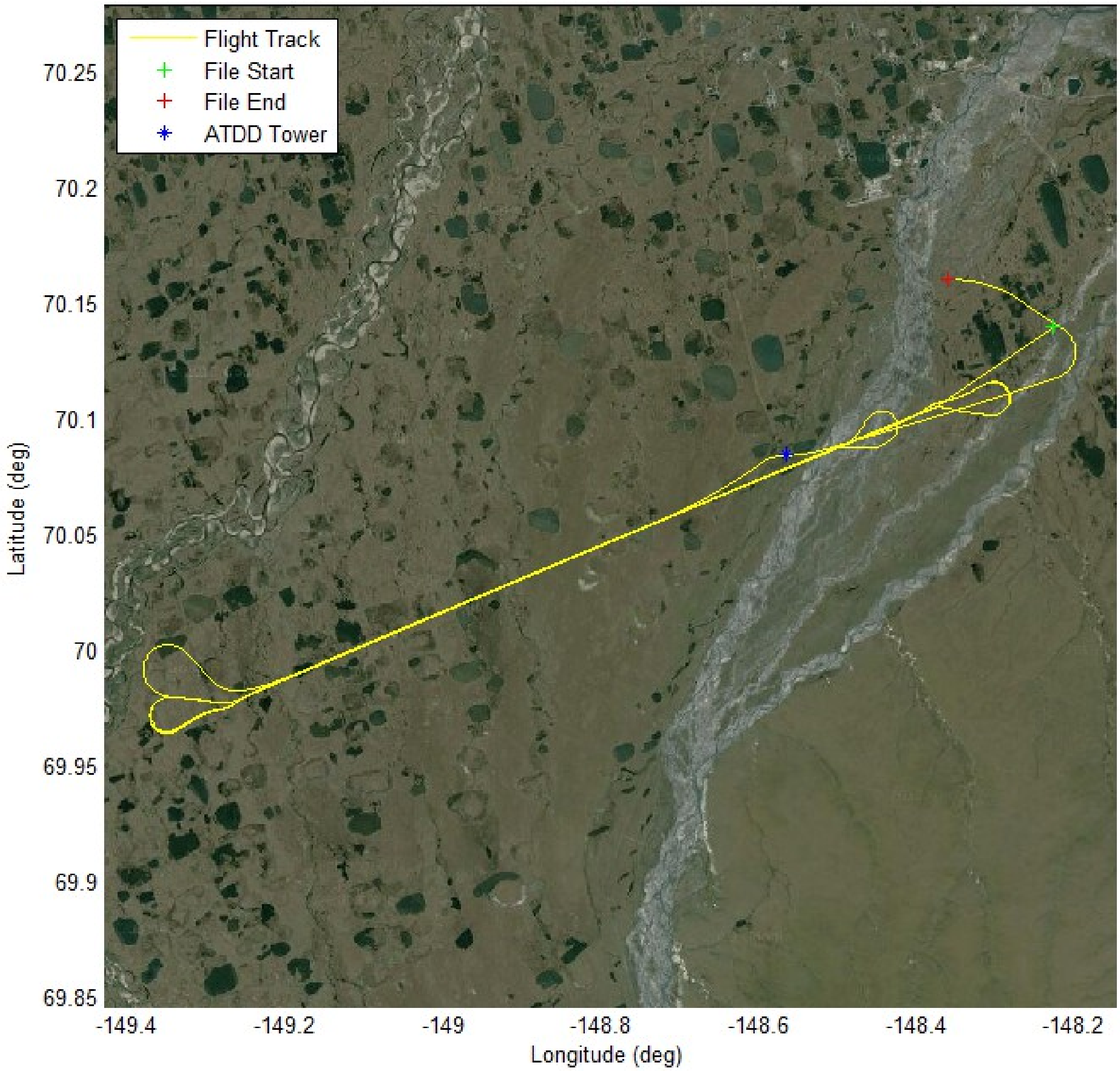

Figure A.3 – Flight 3, Tuesday 13 August 2013. Tower East flight.

```
File: BAT_SPAN_130813.4F_despike

File opened on 08/13/2013
File opened at 255569 GPS  02:22:59:12 UTC  02:14:59:12 Local Time
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Flight Duration: 02:33:46 (2.56 Hours)
Scans:    9226
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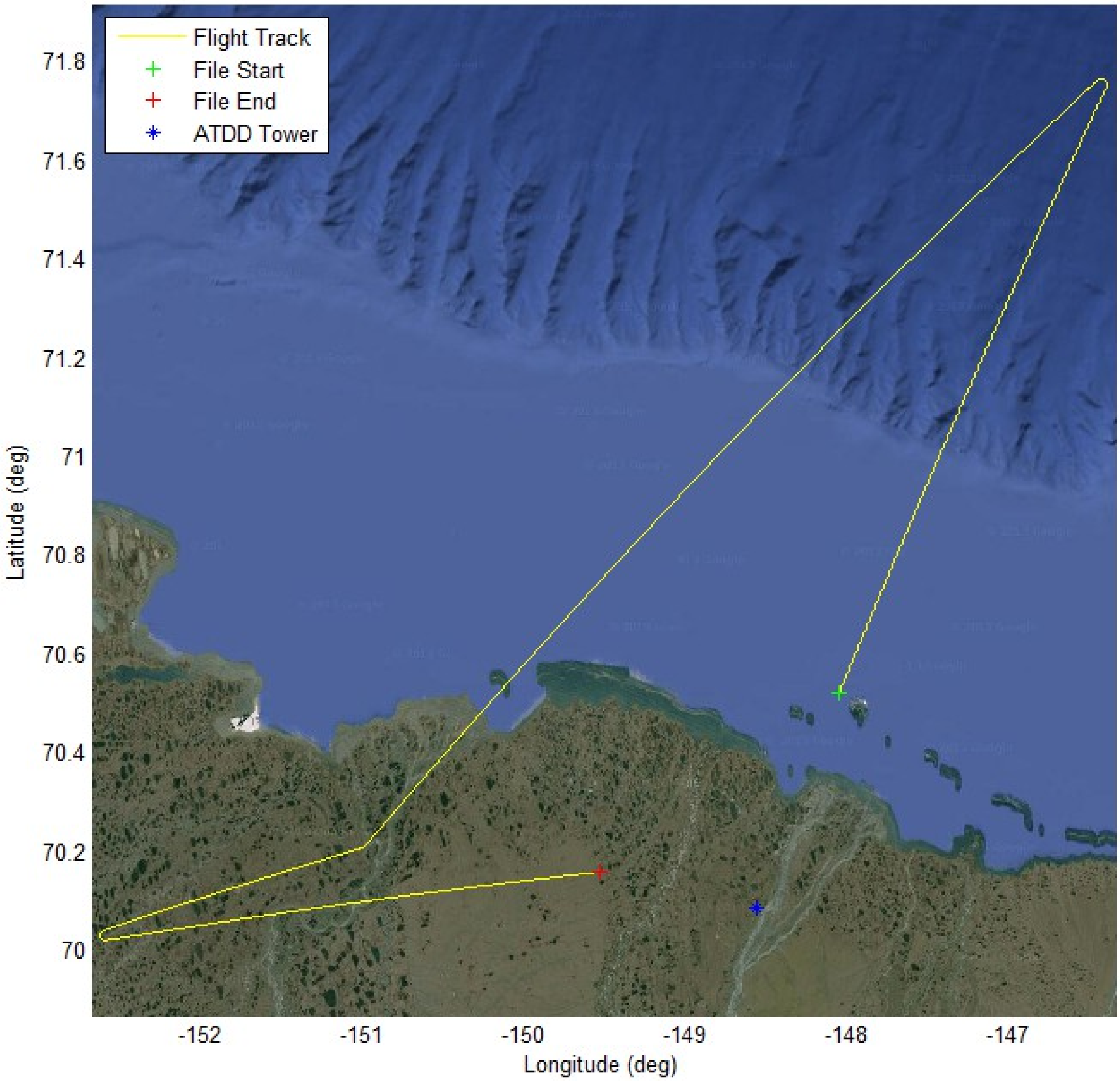

Figure A.4 – Flight 4, Tuesday 13 August 2013. Ice flight.

```
File: BAT_SPAN_130816.2F_despike

File opened on 08/16/2013
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Scans:   5936
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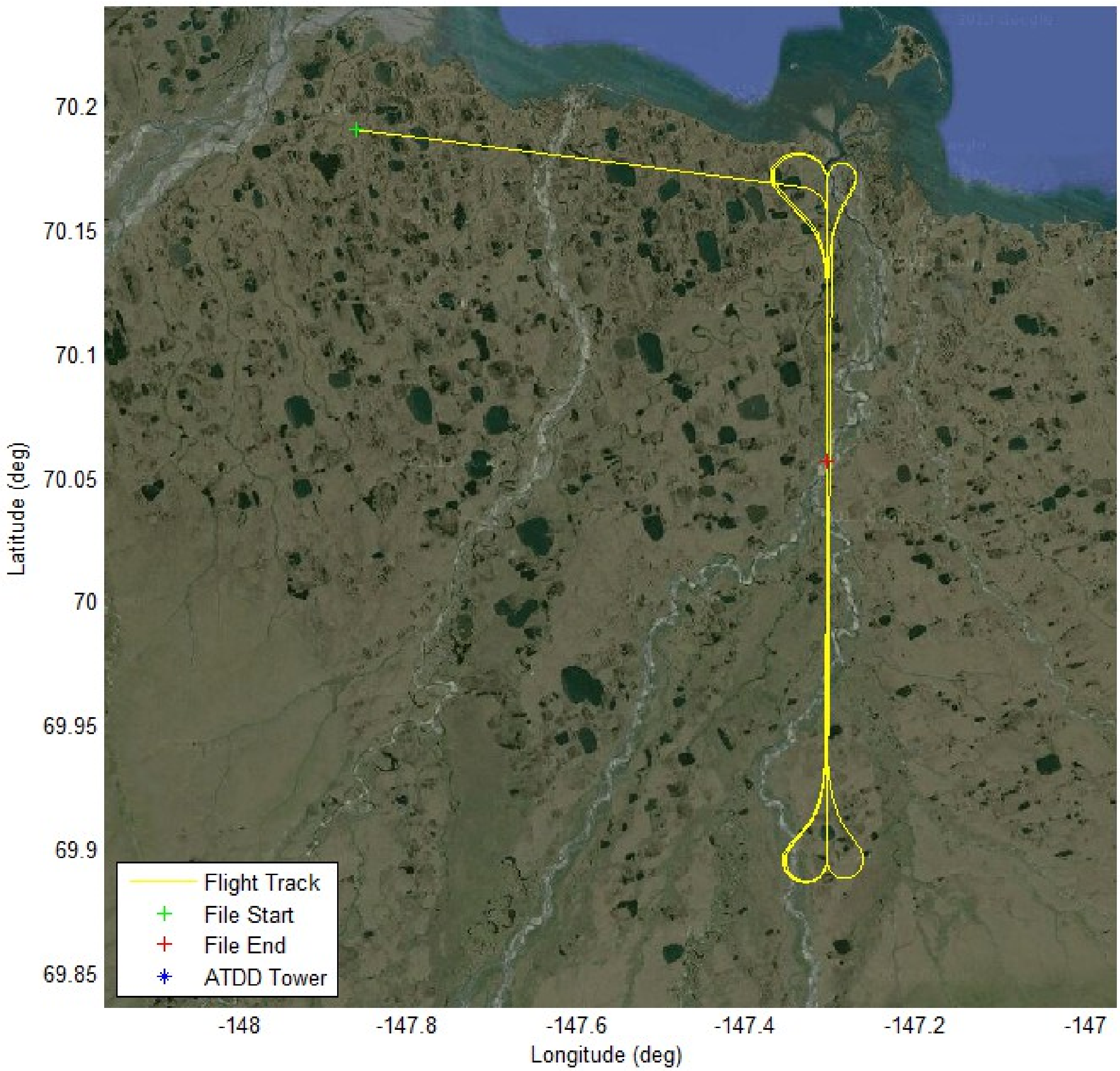

Figure A.5 – Flight 5, Friday 16 August 2013. North-South flight.

```
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File opened on 08/17/2013
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File closed at 000939 GPS  00:00:15:22 UTC  06:16:15:22 Local Time
Flight Duration: 02:37:07 (2.62 Hours)
Scans:   9427
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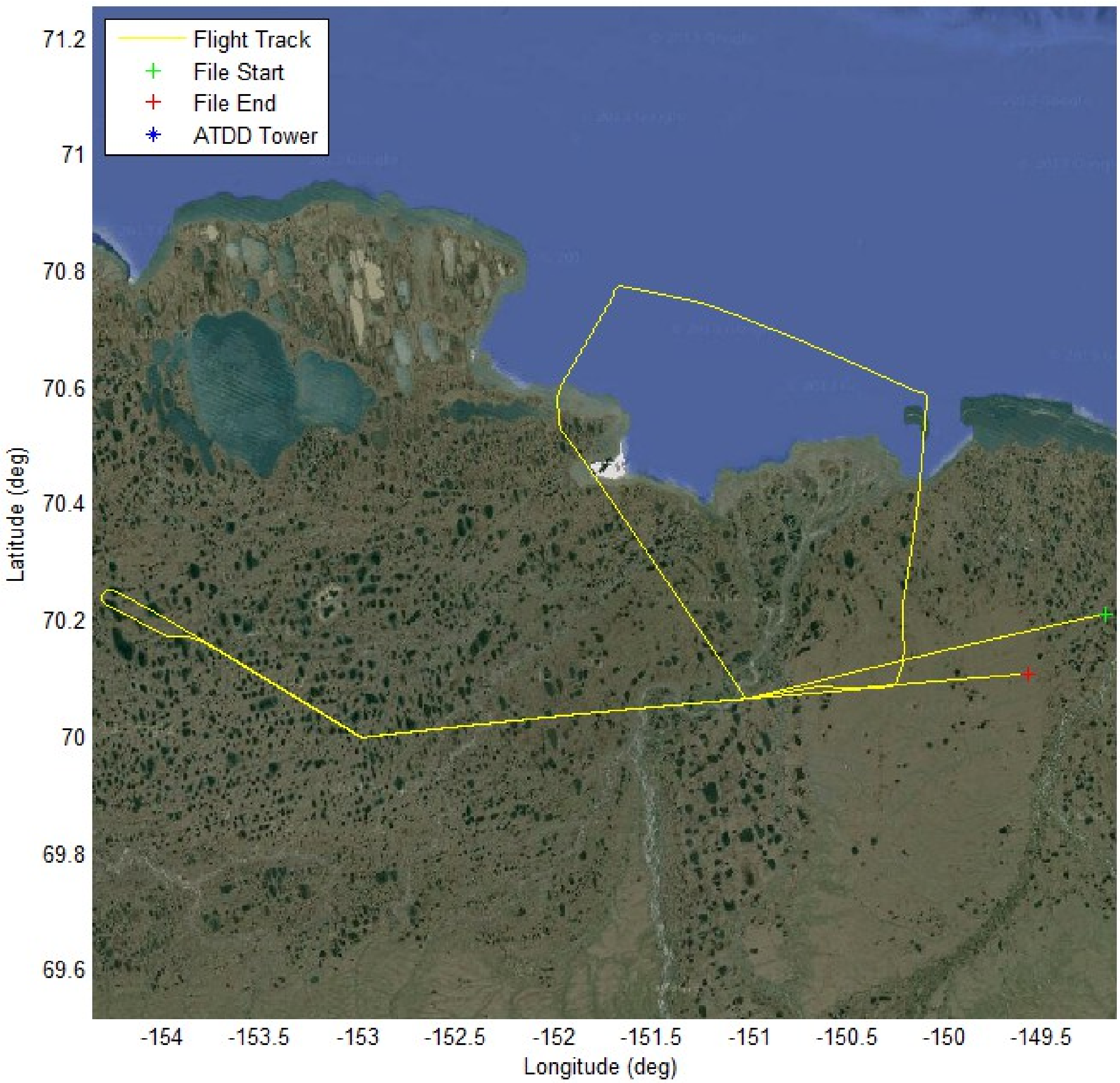

Figure A.6 – Flight 6, Saturday 17 August 2013. Aborted Barrow flight.

```
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File opened on 08/18/2013
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File closed at 092008 GPS  01:01:33:11 UTC  00:17:33:11 Local Time
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Scans:  10757
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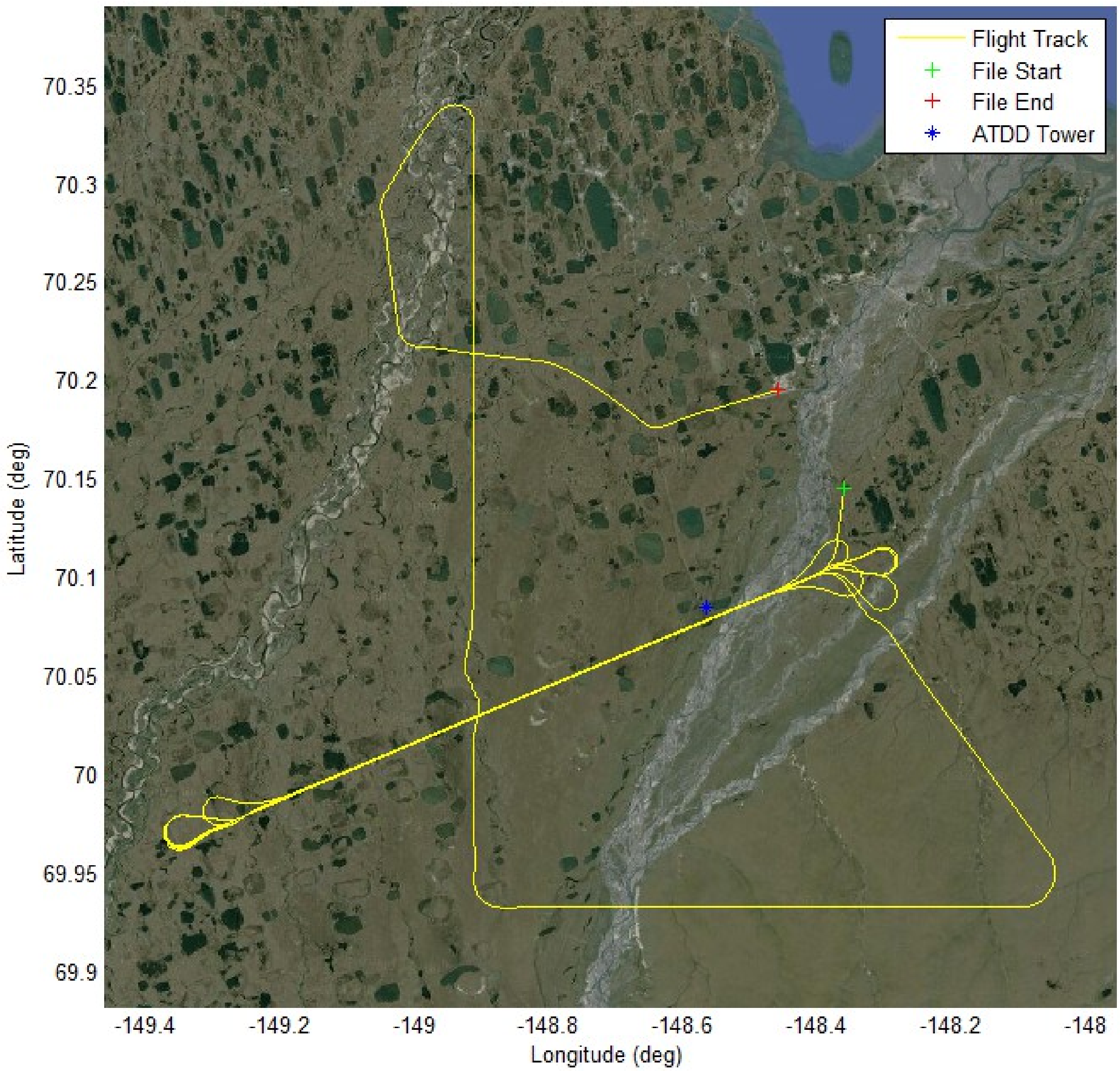

Figure A.7– Flight 7, Sunday 18 August 2013. East tower and aborted box flight.

```
File: BAT_SPAN_130826.1F_despike

File opened on 08/26/2013
File opened at 099779 GPS  01:03:42:42 UTC  00:19:42:42 Local Time
File closed at 107337 GPS  01:05:48:40 UTC  00:21:48:40 Local Time
Flight Duration: 02:05:58 (2.10 Hours)
Scans:    7558
```

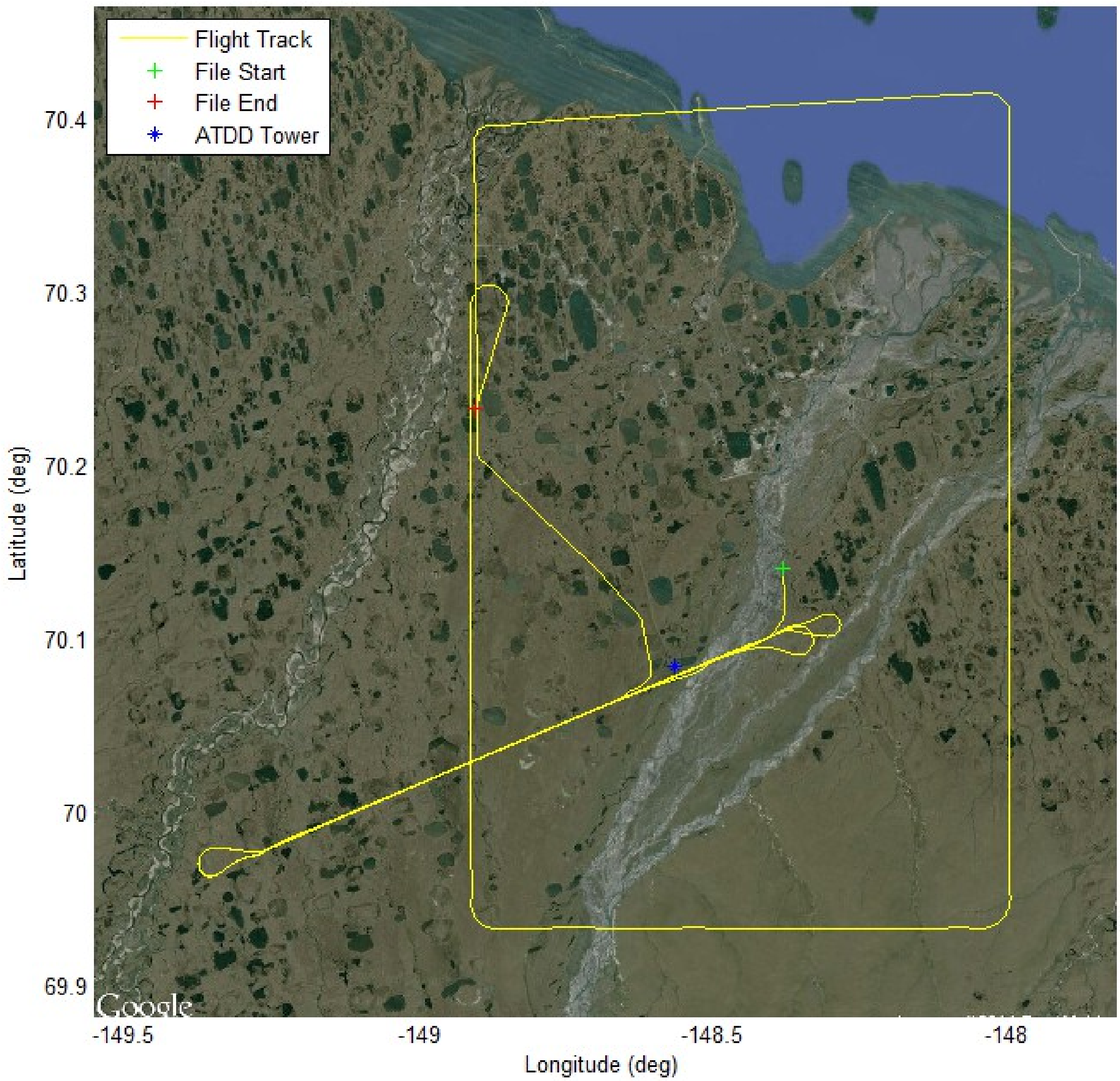

Figure A.8– Flight 8, Monday 26 August 2013. East tower and complete box flight.

```
File: BAT_SPAN_130826.2F_despike

File opened on 08/26/2013
File opened at 153177 GPS  01:18:32:40 UTC  01:10:32:40 Local Time
File closed at 158219 GPS  01:19:56:42 UTC  01:11:56:42 Local Time
Flight Duration: 01:24:02 (1.40 Hours)
Scans:   5042
```

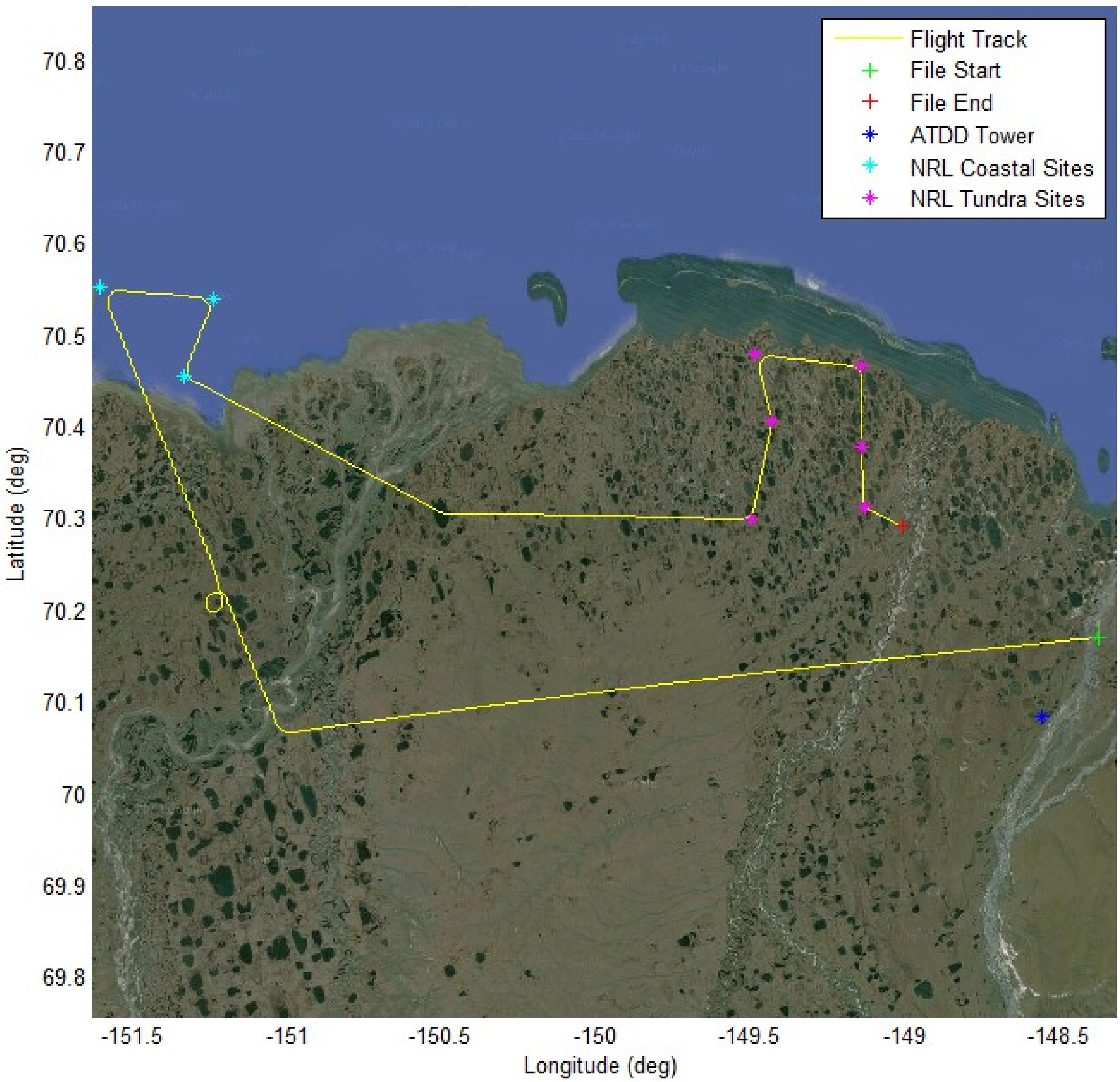

Figure A.9– Flight 9, Monday 26 August 2013. NRL flight.

```
File: BAT_SPAN_130826.4F_despike

File opened on 08/26/2013
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File closed at 184638 GPS  02:03:17:01 UTC  01:19:17:01 Local Time
Flight Duration: 04:36:08 (4.60 Hours)
Scans:  16568
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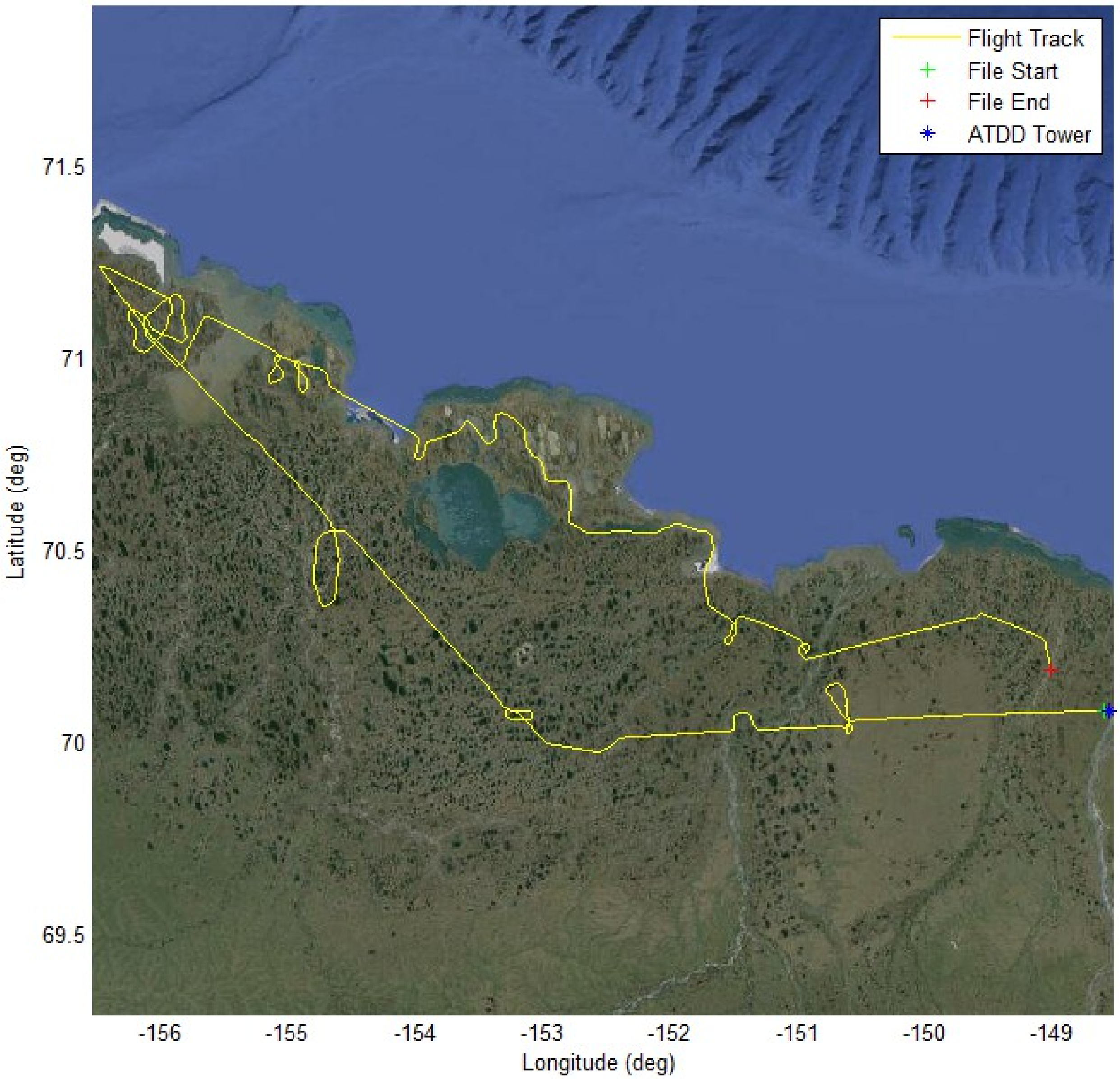

Figure A.10– Flight 10, Monday 26 August 2013. Barrow lakes flight.

```
File: BAT_SPAN_130827.1F_despike

File opened on 08/27/2013
File opened at 243614 GPS  02:19:39:58 UTC  02:11:39:58 Local Time
File closed at 255582 GPS  02:22:59:25 UTC  02:14:59:25 Local Time
Flight Duration: 03:19:28 (3.32 Hours)
Scans:  11968
```

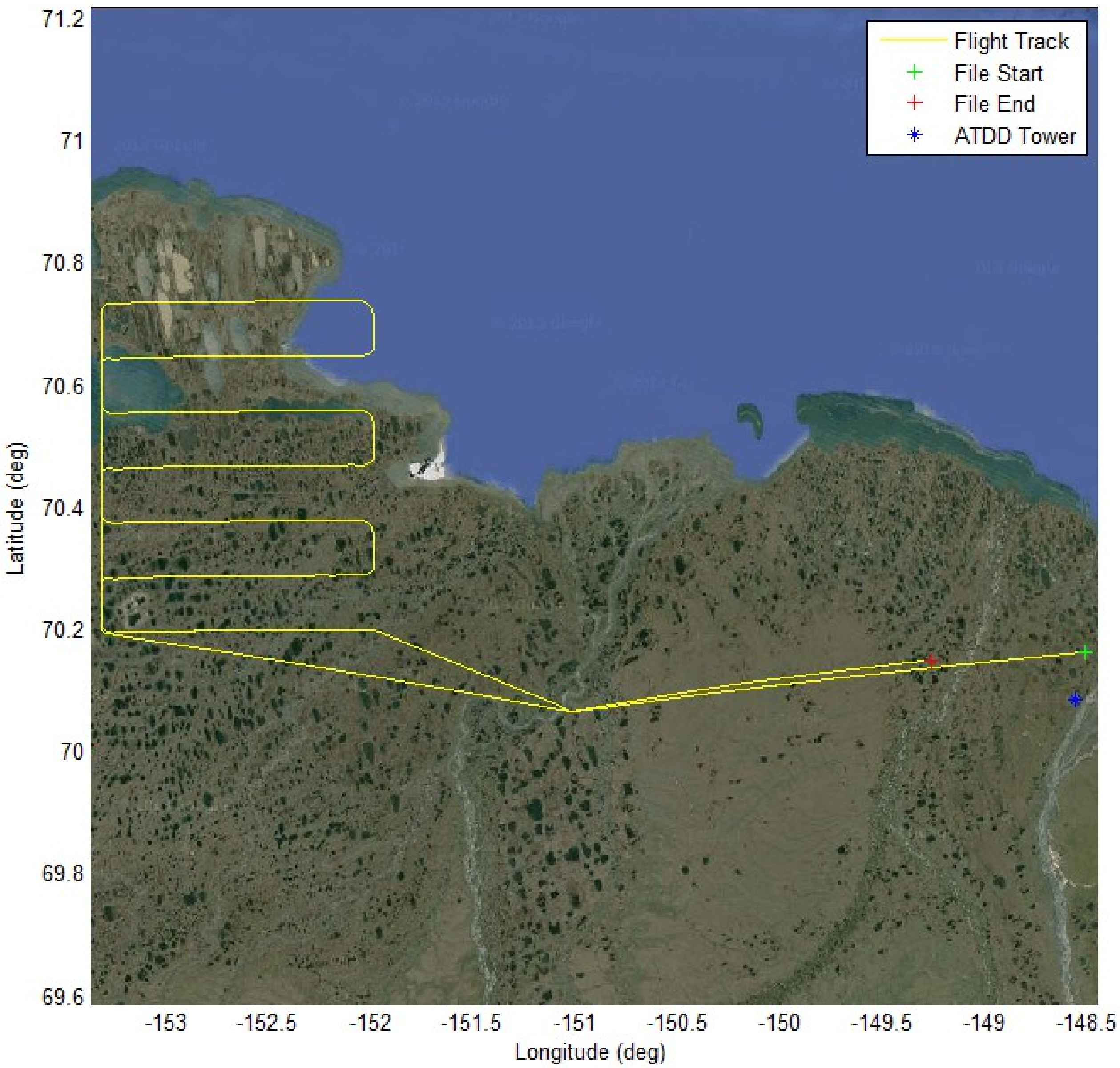

Figure A.11- Flight 11, Tuesday 27 August 2013. Western grid flight.

```
File: BAT_SPAN_130828.1F_despike

File opened on 08/28/2013
File opened at 269142 GPS  03:02:45:25 UTC  02:18:45:25 Local Time
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Flight Duration: 03:16:04 (3.27 Hours)
Scans:  11764
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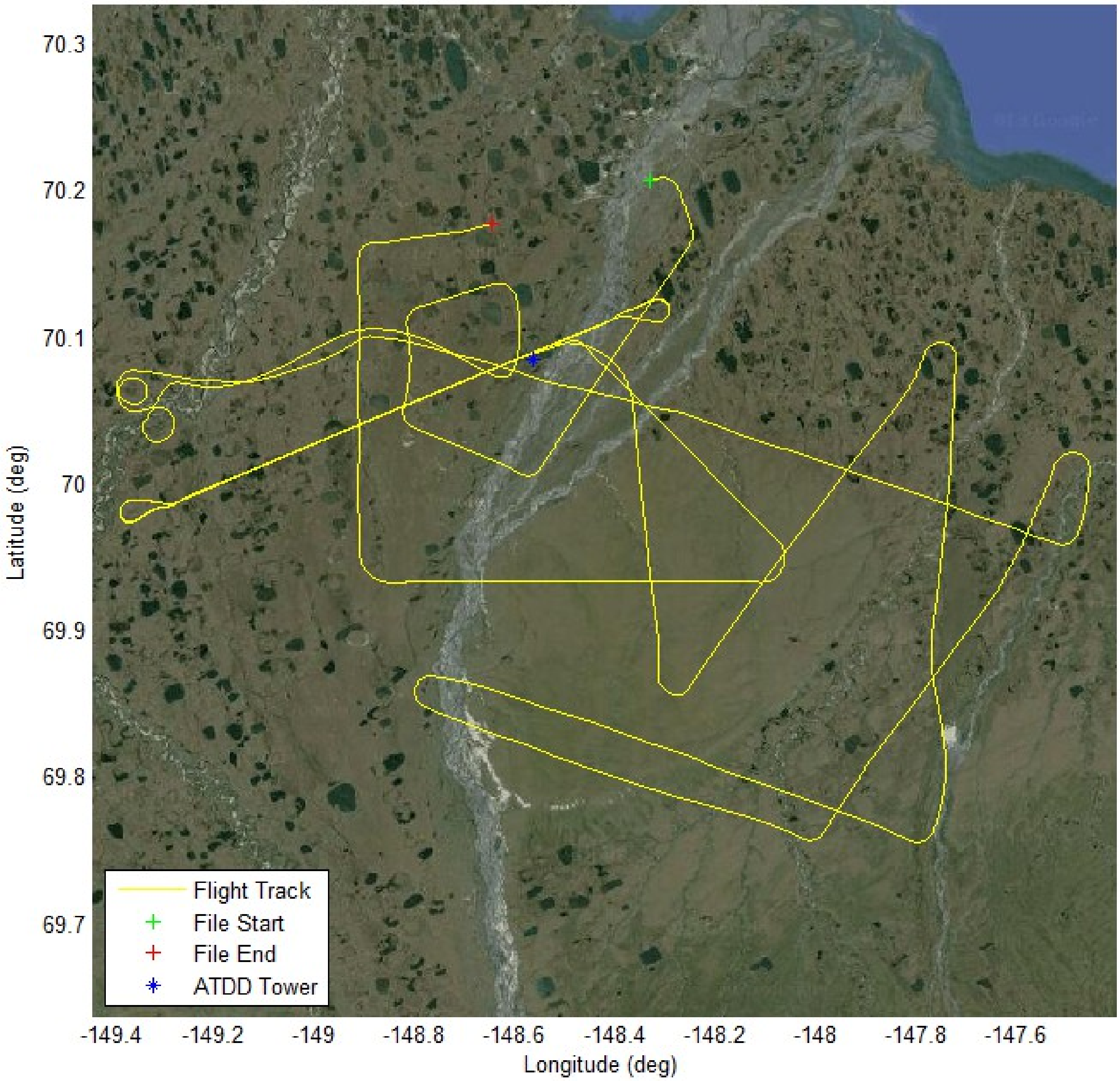

Figure A.12- Flight 12, Wednesday 28 August 2013. Calibration, West tower, and aborted box flight.

```
File: BAT_SPAN_130828.3F_despike

File opened on 08/28/2013
File opened at 326324 GPS  03:18:38:27 UTC  03:10:38:27 Local Time
File closed at 337171 GPS  03:21:39:14 UTC  03:13:39:14 Local Time
Flight Duration: 03:00:47 (3.01 Hours)
Scans:  10847
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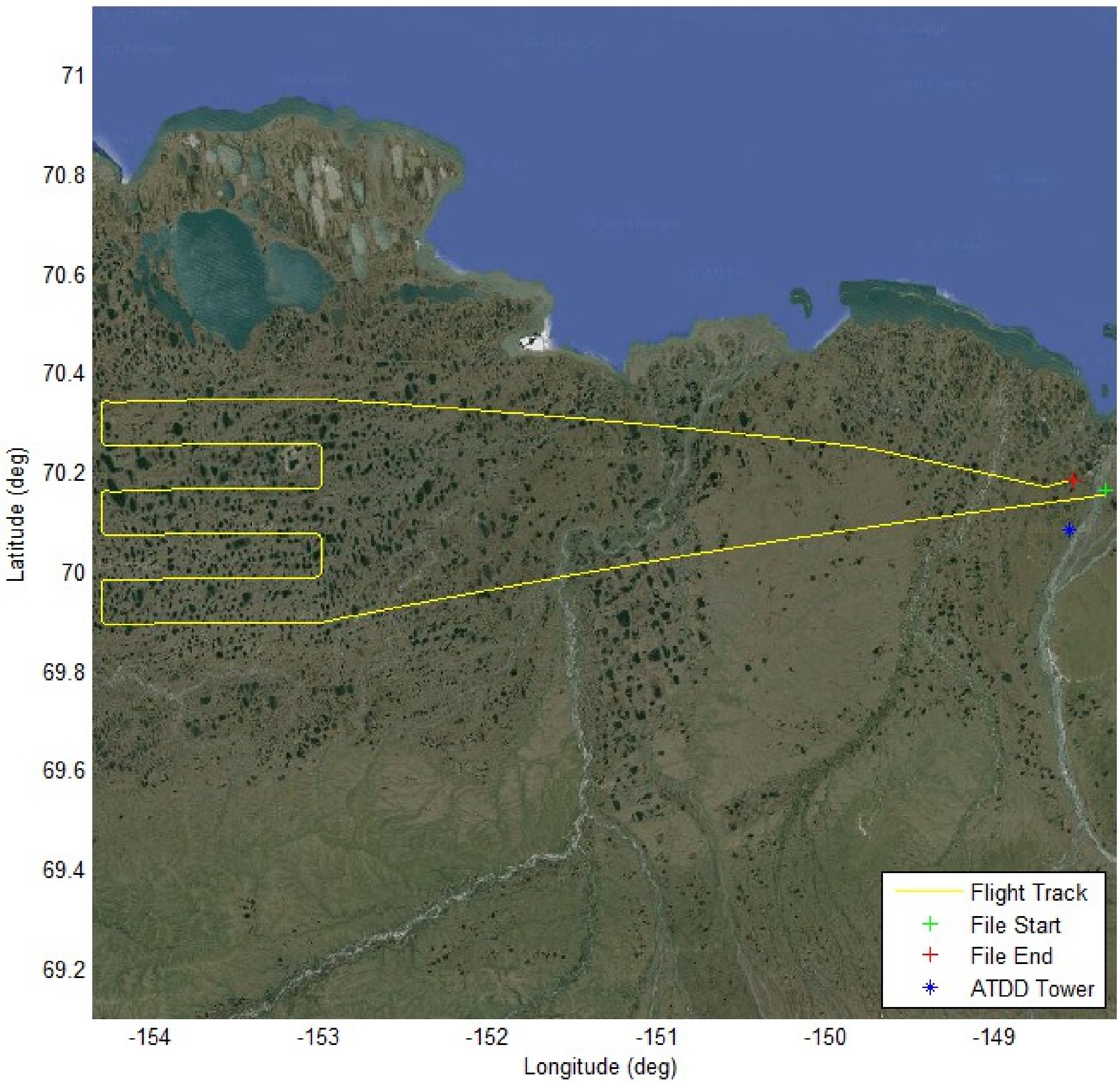

Figure A.13- Flight 13, Wednesday 28 August 2013. Western grid flight.

File: BAT_SPAN_130828.4F_despike

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File closed at 351818 GPS 04:01:43:21 UTC 03:17:43:21 Local Time
Flight Duration: 01:44:10 (1.74 Hours)
Scans: 6250

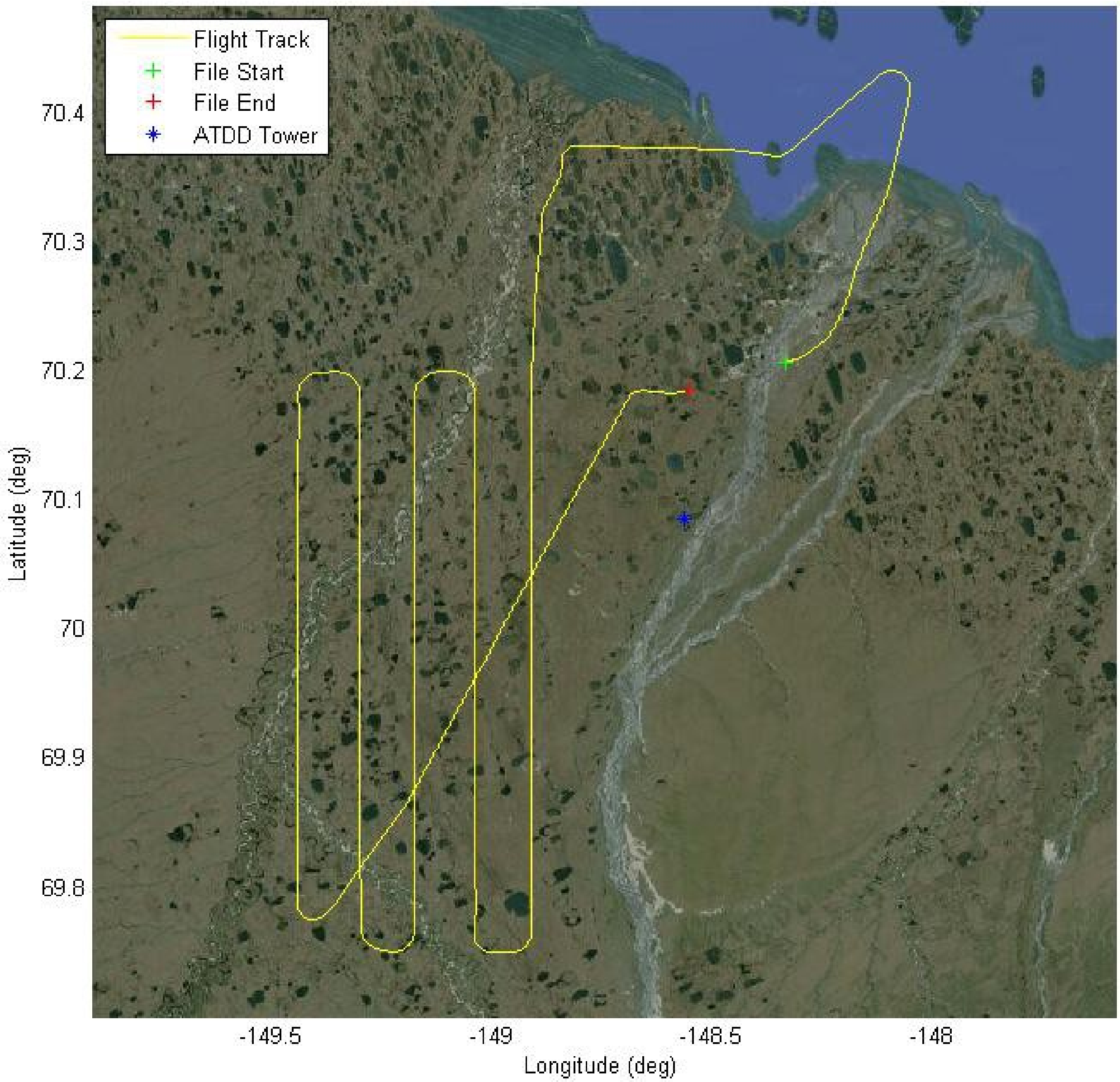

Figure A.14-Flight 14, Wednesday 28 August 2013. Western grid flight.

```
File: BAT_SPAN_130829.1F_despike

File opened on 08/29/2013
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File closed at 412135 GPS  04:18:28:38 UTC  04:10:28:38 Local Time
Flight Duration: 00:52:12 (0.87 Hours)
Scans:   3132
```

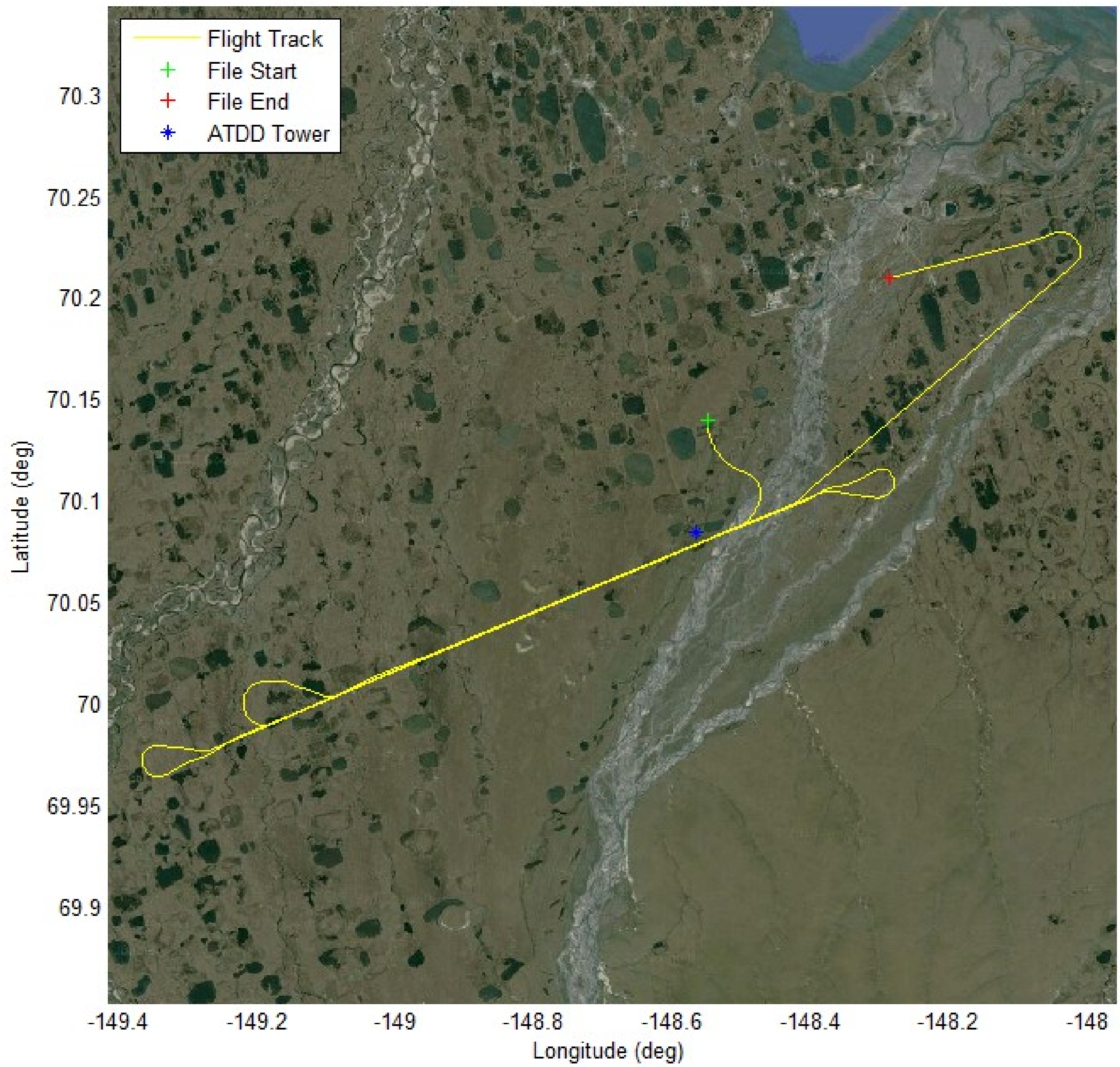

Figure A.15- Flight 15, Thursday 29 August 2013. East tower flight.

Appendix B – Catalog of flight marker files from the 2013 Alaska campaign

Listed below are the marker files that show the start and stop time, position, and comments of transect legs on each flight. The first line of each file shows the file name and time stamp for the time the file was opened. The last two lines of each file show the file name and time stamp for the time each file was closed, and the total number of seconds (scans) in each file.

The middle of each file shows a line for the start and end of each flight leg or transect. Each line represents an event of significance during the flight. The first column contains a descriptor for the transect, followed by the start/stop indicator (-1 or 0, respectively), the number of seconds (scans), the GPS time, the latitude, and longitude, and finally a comment field. The marker files are listed in the order in which they were flown.

```
                                       Flight 1
File BAT_SPAN_130810.1F_despike.ncr, 08102318 OPENED at 602303
FLX -1 00520 23:26:46 70.097264 -148.443741 Tower East N-S Alt=1080 m MSL
     0 01019 23:35:05 69.988135 -149.203069
FLX -1 01251 23:38:57 69.988898 -149.201270 Tower East S-N Alt=1080 m MSL
     0 01713 23:46:39 70.103181 -148.398754
FLX -1 01907 23:49:53 70.097234 -148.441576 Tower East N-S Alt=1080 m MSL
     0 02408 23:58:14 69.988562 -149.200111
FLX -1 02643 00:02:09 69.989203 -149.201209 Tower East S-N Alt=1080 m MSL
     0 03122 00:10:08 70.103090 -148.398876
FLX -1 03318 00:13:24 70.097996 -148.434317 Tower East N-S Alt=300 m MSL
     0 03824 00:21:50 69.988501 -149.200568
FLX -1 04059 00:25:45 69.988898 -149.200019 Tower East S-N Alt=300 m MSL
     0 04556 00:34:02 70.103120 -148.399333
FLX -1 04724 00:36:50 70.088358 -148.505107 Tower East N-S Alt=300 m MSL
     0 05182 00:44:28 69.988562 -149.200538
FLX -1 05421 00:48:27 69.988623 -149.201392 Tower East S-N Alt=150 m MSL
     0 05938 00:57:04 70.103029 -148.400065
FLX -1 06127 01:00:13 70.098240 -148.432426 Tower East N-S Alt=88 m MSL
     0 06633 01:08:39 69.988379 -149.200721
FLX -1 06874 01:12:40 69.988959 -149.198952 Tower East S-N Alt=88 m MSL
     0 07402 01:21:28 70.103212 -148.398754
FLX -1 07557 01:24:03 70.088816 -148.497940 Tower East N-S Alt=88 m MSL
     0 08024 01:31:50 69.988593 -149.200355
FLX -1 08269 01:35:55 69.988928 -149.200355 Tower East S-N Alt=88 m MSL
     0 08809 01:44:55 70.102907 -148.400523
File BAT_SPAN_130810.1F_despike.ncr, 08102318 CLOSED at 006715
Total scans    : 09212

                                       Flight 2
File BAT_SPAN_130812.4F_despike.ncr, 08122223 OPENED at 167050
FLX -1 00135 22:26:08 70.091256 -148.487051 Tower East N-S Alt=150 m MSL
     0 00635 22:34:28 69.988715 -149.198891
FLX -1 00876 22:38:29 69.988898 -149.199928 Tower East S-N Alt=150 m MSL
     0 01387 22:47:00 70.102785 -148.401377
FLX -1 01574 22:50:07 70.098667 -148.426875 Tower East N-S Alt=130 m MSL
     0 02115 22:59:08 69.988928 -149.197823
FLX -1 02363 23:03:16 69.988898 -149.198982 Tower East S-N Alt=130 m MSL
     0 02869 23:11:42 70.103181 -148.398601
FLX -1 03018 23:14:11 70.092262 -148.476376 Tower East N-S Alt=130 m MSL
     0 03518 23:22:31 69.988806 -149.198525
FLX -1 03762 23:26:35 69.988989 -149.199836 Tower East S-N Alt=120 m MSL
     0 04268 23:35:01 70.102815 -148.401072
FLX -1 04453 23:38:06 70.099155 -148.423611 Tower East N-S Alt=120 m MSL
     0 04994 23:47:07 69.988837 -149.198189
```

```
FLX -1 05238 23:51:11 69.988959 -149.199318 Tower East S-N Alt=120 m MSL
     0 05651 23:58:04 70.081404 -148.553145
File BAT_SPAN_130812.4F_despike.ncr, 08122223 CLOSED at 174690
Total scans    : 07640
```

Flight 3

```
File BAT_SPAN_130813.2F_despike.ncr, 08131819 OPENED at 238768
FLX -1 00137 18:21:28 70.096136 -148.449658 Tower East N-S Alt=1530 m MSL
     0 00598 18:29:09 69.988471 -149.200812
FLX -1 01033 18:36:24 70.038186 -148.857870 Tower East S-N Alt=70 m MSL
     0 01345 18:41:36 70.103151 -148.398693
FLX -1 01529 18:44:40 70.097905 -148.433920 Tower East N-S Alt=70 m MSL
     0 02020 18:52:51 69.989935 -149.190686
FLX -1 02271 18:57:02 69.988684 -149.200477 Tower East S-N Alt=50 m MSL
     0 02813 19:06:04 70.103029 -148.399699
FLX -1 02998 19:09:09 70.097966 -148.432670 Tower East N-S Alt=50 m MSL
     0 03499 19:17:30 69.988532 -149.200507
FLX -1 03743 19:21:34 69.988623 -149.202002 Tower East S-N Alt=60 m MSL
     0 04214 19:29:25 70.086955 -148.514257
FLX -1 04359 19:31:50 70.084973 -148.525268 Tower East N-S Alt=60 m MSL
     0 04800 19:39:11 69.988654 -149.199531
FLX -1 05043 19:43:14 69.988562 -149.201788 Tower East S-N Alt=60 m MSL
     0 05584 19:52:15 70.102724 -148.401987
FLX -1 05778 19:55:29 70.096227 -148.444534 Tower East N-S Alt=60 m MSL
     0 06270 20:03:41 69.988684 -149.200080
FLX -1 06513 20:07:44 69.988349 -149.202337 Tower East S-N Alt=60 m MSL
     0 06835 20:13:06 70.056577 -148.728764
EVT    06901 20:14:12 70.073291 -148.635647 Tower Pass Alt=60 m MSL
File BAT_SPAN_130813.2F_despike.ncr, 08131819 CLOSED at 246098
Total scans    : 07330
```

Flight 4

```
File BAT_SPAN_130813.4F_despike.ncr, 08132259 OPENED at 255569
ICE -1 00039 22:59:51 70.545309 -148.033638 Ice Leg Alt=1500 m MSL
     0 02325 23:37:57 71.739171 -146.424336
ICE -1 02447 23:39:59 71.749266 -146.518124 Ice Leg Alt=1500 m MSL
     0 06130 00:41:22 70.321256 -150.713978
PRO -1 06140 00:41:32 70.317200 -150.724745 Ice Profile Alt=1500-1200 m MSL
     0 06465 00:46:57 70.196054 -151.147902
ICE -1 06470 00:47:02 70.195200 -151.156350 Ice Leg Alt=1200 m MSL
     0 07340 01:01:32 70.046604 -152.578748
ICE -1 07456 01:03:28 70.024583 -152.539403 Ice Leg Alt=1200 m MSL
     0 08645 01:23:17 70.119865 -150.546655
PRO -1 08650 01:23:22 70.120231 -150.538024 Ice Profile Alt=1200-1500 m MSL
     0 08833 01:26:25 70.133986 -150.204232
ICE -1 08858 01:26:50 70.135877 -150.159854 Ice Leg Alt=1500 m MSL
     0 09200 01:32:32 70.158051 -149.581239
File BAT_SPAN_130813.4F_despike.ncr, 08132259 CLOSED at 264795
Total scans    : 09226
```

Flight 5

```
File BAT_SPAN_130816.2F_despike.ncr, 08161956 OPENED at 503788
NST -1 00485 20:04:16 70.122884 -147.308013 North-South Transect N-S Alt=900 m MSL
     0 00798 20:09:29 69.944063 -147.308501
NST -1 01011 20:13:02 69.943483 -147.309141 North-South Transect S-N Alt=900 m MSL
     0 01326 20:18:17 70.122762 -147.308318
```

```
NST -1 01570 20:22:21 70.124623 -147.308440 North-South Transect N-S Alt=900 m MSL
     0 01884 20:27:35 69.944978 -147.308348
NST -1 02114 20:31:25 69.948943 -147.309934 North-South Transect S-N Alt=900 m MSL
     0 02409 20:36:20 70.120444 -147.308196
NST -1 02619 20:39:50 70.125080 -147.302614 North-South Transect N-S Alt=900 m MSL
     0 02931 20:45:02 69.946686 -147.307403
NST -1 03168 20:48:59 69.951108 -147.309690 North-South Transect S-N Alt=900 m MSL
     0 03460 20:53:51 70.121420 -147.308043
NST -1 03713 20:58:04 70.118828 -147.308409 North-South Transect N-S Alt=900 m MSL
     0 04010 21:03:01 69.945039 -147.308257
NST -1 04249 21:07:00 69.954860 -147.309934 North-South Transect S-N Alt=900 m MSL
     0 04534 21:11:45 70.123037 -147.308165
NST -1 04750 21:15:21 70.117150 -147.308379 North-South Transect N-S Alt=900 m MSL
     0 05052 21:20:23 69.943148 -147.308257
NST -1 05272 21:24:03 69.945557 -147.310178 North-South Transect S-N Alt=900 m MSL
     0 05572 21:29:03 70.119804 -147.308257
NST -1 05829 21:33:20 70.117821 -147.308196 North-South Transect N-S Alt=900 m MSL
     0 05936 21:35:07 70.057309 -147.308440
File BAT_SPAN_130816.2F_despike.ncr, 08161956 CLOSED at 509724
Total scans    : 05936

                                     Flight 6
File BAT_SPAN_130817.2F_despike.ncr, 08172138 OPENED at 596312
EWT -1 00002 21:38:17 70.212737 -149.200568 East-West Transect W-E Alt=1500 m MSL
     0 02415 22:18:30 70.001311 -152.967318
EWT -1 02530 22:20:25 70.028090 -153.136258 East-West Transect W-E Alt=1500 m MSL
     0 02632 22:22:07 70.058865 -153.284488
PRO -1 02640 22:22:15 70.061274 -153.296139 Profile Alt=1500-1650 m MSL
     0 02842 22:25:37 70.117821 -153.573262
EWT -1 02848 22:25:43 70.119529 -153.581588 East-West Transect W-E Alt=1650 m MSL
     0 03089 22:29:44 70.191936 -153.941915
PRO -1 03110 22:30:05 70.198341 -153.974245 Profile Alt=1650-2000 m MSL
     0 03255 22:32:30 70.241529 -154.207296
EWT -1 03380 22:34:35 70.221613 -154.261128 East-West Transect W-E Alt=2000 m MSL
     0 03539 22:37:14 70.175619 -153.996358
PRO -1 03755 22:40:50 70.128557 -153.626484 Profile Alt=2000-1800 m MSL
     0 04055 22:45:50 70.026016 -153.125034
EWT -1 04169 22:47:44 70.002928 -152.933036 East-West Transect E-W Alt=1800 m MSL
     0 04920 23:00:15 70.052826 -151.499872
PRO -1 04930 23:00:25 70.053436 -151.480260 Profile Alt=1800-1650 m MSL
     0 05101 23:03:16 70.063775 -151.134482
EWT -1 05112 23:03:27 70.064385 -151.112857 East-West Transect W-E Alt=1650 m MSL
     0 05242 23:05:37 70.071583 -150.862818
PRO -1 05260 23:05:55 70.072529 -150.827499 Profile Alt=1650-1500 m MSL
     0 05520 23:10:15 70.086559 -150.321901
BOX -1 05580 23:11:15 70.108915 -150.247054 Box Transect North Alt=1500 m MSL
     0 06300 23:23:15 70.565378 -150.111939
BOX -1 06372 23:24:27 70.595329 -150.167998 Box Transect Northwest Alt=1500 m MSL
     0 07293 23:39:48 70.774517 -151.659112
BOX -1 07368 23:41:03 70.744291 -151.736643 Box Transect Southwest Alt=1500 m MSL
     0 07627 23:45:22 70.608810 -151.973079
BOX -1 07675 23:46:10 70.581330 -151.995100 Box Transect South Alt=1500 m MSL
     0 07745 23:47:20 70.538447 -151.986469
PRO -1 07768 23:47:43 70.525606 -151.970243 Profile Alt=1500-1700 m MSL
     0 07858 23:49:13 70.480863 -151.874290
BOX -1 07870 23:49:25 70.474549 -151.861114 Box Transect South Alt=1700 m MSL
```

```
     0 08280 23:56:15 70.265136 -151.431064
PRO -1 08285 23:56:20 70.262574 -151.425848 Profile Alt=1700-1500 m MSL
     0 08485 23:59:40 70.160369 -151.219943
BOX -1 08718 00:03:33 70.072041 -150.944223 Box Transect East Alt=1500 m MSL
     0 09032 00:08:47 70.088633 -150.344257
PRO -1 09050 00:09:05 70.089670 -150.309762 Profile Alt=1500-1100 m MSL
     0 09427 00:15:22 70.109586 -149.587491
File BAT_SPAN_130817.2F_despike.ncr, 08172138 CLOSED at 000939
Total scans    : 09427
```

Flight 7

```
File BAT_SPAN_130818.2F_despike.ncr, 08182231 OPENED at 081117
FLX -1 00085 22:33:05 70.100680 -148.417786 Tower East N-S Alt=95 m MSL
     0 00590 22:41:30 69.988837 -149.198342
FLX -1 00838 22:45:38 69.989294 -149.199196 Tower East S-N Alt=60 m MSL
     0 01343 22:54:03 70.093452 -148.468019
FLX -1 01536 22:57:16 70.091561 -148.479304 Tower East N-S Alt=60 m MSL
     0 02004 23:05:04 69.988745 -149.199135
FLX -1 02252 23:09:12 69.988806 -149.199623 Tower East S-N Alt=95 m MSL
     0 02746 23:17:26 70.094001 -148.463902
FLX -1 02970 23:21:10 70.100802 -148.413668 Tower East N-S Alt=115 m MSL
     0 03484 23:29:44 69.988684 -149.199287
FLX -1 03656 23:32:36 69.990118 -149.194011 Tower East S-N Alt=115 m MSL
     0 04179 23:41:19 70.097661 -148.437672
FLX -1 04379 23:44:39 70.100131 -148.418335 Tower East N-S Alt=150 m MSL
     0 04887 23:53:07 69.988562 -149.199897
FLX -1 05137 23:57:17 69.988745 -149.199775 Tower East S-N Alt=150 m MSL
     0 05639 00:05:39 70.093940 -148.463932
FLX -1 05812 00:08:32 70.093421 -148.470764 Tower East N-S Alt=180 m MSL
     0 06288 00:16:28 69.988532 -149.200416
FLX -1 06538 00:20:38 69.989050 -149.199897 Tower East S-N Alt=180 m MSL
     0 07031 00:28:51 70.093147 -148.469971
FLX -1 07290 00:33:10 70.091713 -148.479335 Tower East N-S Alt=210 m MSL
     0 07756 00:40:56 69.988989 -149.197610
FLX -1 08009 00:45:09 69.989233 -149.199043 Tower East S-N Alt=210 m MSL
     0 08508 00:53:28 70.092872 -148.471923
BOX -1 08642 00:55:42 70.072468 -148.294657 Box Transect NW-SE Alt=210 m MSL
     0 08870 00:59:30 69.963766 -148.064809
BOX -1 08949 01:00:49 69.934059 -148.113853 Box Transect E-W Alt=210 m MSL
     0 09412 01:08:32 69.933479 -148.873029
BOX -1 09459 01:09:19 69.949522 -148.915454 Box Transect North Alt=210 m MSL
     0 09597 01:11:37 70.020679 -148.915790
BOX -1 09728 01:13:48 70.085613 -148.917467 Box Transect North Alt=210 m MSL
     0 09824 01:15:24 70.134749 -148.916522
File BAT_SPAN_130818.2F_despike.ncr, 08182231 CLOSED at 092008
Total scans    : 10890
```

Flight 8

```
File BAT_SPAN_130826.1F_despike.ncr, 08260342 OPENED at 099779
FLX -1 00144 03:45:06 70.080672 -148.562935 Tower East N-S Alt=75 m MSL
     0 00537 03:51:39 69.988562 -149.200050
FLX -1 00791 03:55:53 69.988806 -149.200324 Tower East S-N Alt=60 m MSL
     0 01314 04:04:36 70.094184 -148.462865
FLX -1 01555 04:08:37 70.094519 -148.457924 Tower East N-S Alt=55 m MSL
     0 02019 04:16:21 69.989752 -149.192028
FLX -1 02281 04:20:43 69.989691 -149.196298 Tower East S-N Alt=50 m MSL
```

```
     0 02797 04:29:19 70.093330 -148.468995
FLX -1 03044 04:33:26 70.078690 -148.558208 Tower East N-S Alt=50 m MSL
     0 03417 04:39:39 69.994815 -149.157594
FLX -1 03698 04:44:20 69.988959 -149.199135 Tower East S-N Alt=50 m MSL
     0 04065 04:50:27 70.062067 -148.690364
EVT    04110 04:51:12 70.072651 -148.631408 Tower Alt=52 m MSL
BOX -1 04471 04:57:13 70.223229 -148.903895 Box Transect S-N Alt=50 m MSL
     0 04777 05:02:19 70.381677 -148.910178
BOX -1 04822 05:03:04 70.397140 -148.874767 Box Transect W-E Alt=50 m MSL
     0 05332 05:11:34 70.415654 -148.048705
BOX -1 05393 05:12:35 70.392352 -148.001491 Box Transect N-S Alt=50 m MSL
     0 06027 05:23:09 70.021929 -148.000088
PRO -1 06030 05:23:12 70.020160 -148.000088 Profile Alt=50-100 m MSL
     0 06145 05:25:07 69.954311 -147.999753
BOX -1 06205 05:26:07 69.933754 -148.060783 Box Transect E-W Alt=100 m MSL
     0 06676 05:33:58 69.933479 -148.867173
BOX -1 06735 05:34:57 69.954006 -148.914905 Box Transect S-N Alt=75 m MSL
     0 07364 05:45:26 70.282369 -148.916766
File BAT_SPAN_130826.1F_despike.ncr, 08260342 CLOSED at 107337
Total scans    : 07558

                                       Flight 9
File BAT_SPAN_130826.2F_despike.ncr, 08261832 OPENED at 153177
PRO -1 00086 18:34:06 70.165859 -148.557659 Profile Alt=100-50 m MSL
     0 00185 18:35:45 70.159515 -148.740842
PRO -1 00200 18:36:00 70.158569 -148.767773 Profile Alt=50-95 m MSL
     0 01227 18:53:07 70.089487 -150.533723
PRO -1 01230 18:53:10 70.089273 -150.538939 Profile Alt=95-50 m MSL
     0 01469 18:57:09 70.070211 -150.955904
FLX -1 01539 18:58:19 70.083448 -151.051156 SE-NW Alt=50 m MSL
     0 01781 19:02:21 70.207156 -151.197281
FLX -1 01942 19:05:02 70.228140 -151.231289 SE-NW Coastal 8 Alt=50 m MSL
     0 02121 19:08:01 70.320768 -151.332152
PRO -1 02125 19:08:05 70.322812 -151.334562 Profile Alt=50-30 m MSL
     0 02231 19:09:51 70.378383 -151.400564
FLX -1 02240 19:10:00 70.383110 -151.406267 SE-NW Alt=30 m MSL
     0 02518 19:14:38 70.527589 -151.580605
FLX -1 02593 19:15:53 70.548939 -151.520886 W-E Alt=30 m MSL (NRL C8-C10)
     0 02736 19:18:16 70.542839 -151.300585
FLX -1 02793 19:19:13 70.520848 -151.269505 N-S Alt=30 m MSL (NRL C10-C9)
     0 02881 19:20:41 70.472902 -151.325564
FLX -1 02950 19:21:50 70.446032 -151.274080 NW-SE Alt=30 m MSL (NRL C9-P1)
     0 03486 19:30:46 70.310429 -150.522713
FLX -1 03522 19:31:22 70.307074 -150.468270 W-E Alt=30 m MSL (NRL P1-T10)
     0 04123 19:41:23 70.300913 -149.552935
FLX -1 04175 19:42:15 70.315461 -149.498065 S-N Alt=70 m MSL (NRL T10-T9-T8)
     0 04449 19:46:49 70.460123 -149.479887
FLX -1 04512 19:47:52 70.477294 -149.421114 NW-SE Alt=70 m MSL (NRL T8-T5)
     0 04663 19:50:23 70.468327 -149.188673
FLX -1 04708 19:51:08 70.451247 -149.154361 N-S Alt=70 m MSL (NRL T5-T6-T7)
     0 04936 19:54:56 70.324428 -149.144936
File BAT_SPAN_130826.2F_despike.ncr, 08261832 CLOSED at 158219
Total scans    : 05042
```

```
                                     Flight 10
File BAT_SPAN_130826.4F_despike.ncr, 08262143 OPENED at 164614
FLX -1 03871 22:47:48 70.112758 -153.369095 SE-NW Alt=60 m MSL
     0 04850 23:04:07 70.540551 -154.538892
FLX -1 05850 23:20:47 70.603259 -154.750013 SE-NW Alt=50 m MSL
     0 06850 23:37:27 71.037396 -156.022411
File BAT_SPAN_130826.4F_despike.ncr, 08262143 CLOSED at 184638
Total scans    : 16568

                                     Flight 11
File BAT_SPAN_130827.1F_despike.ncr, 08271939 OPENED at 243614
FLX -1 00048 19:40:45 70.161131 -148.613108 PASC-ED1 Alt=50 m MSL
     0 01416 20:03:33 70.067039 -151.016325
FLX -1 01439 20:03:56 70.069265 -151.054053 ED1-P1 Alt=100 m MSL
     0 02010 20:13:27 70.197182 -151.978874
FLX -1 02039 20:13:56 70.200232 -152.026851 P1-P2 Alt=26 m MSL
     0 02760 20:25:57 70.195596 -153.265303
FLX -1 02820 20:26:57 70.215848 -153.325632 P2-P3 Alt=85 m MSL
     0 02914 20:28:31 70.269803 -153.327889
FLX -1 02974 20:29:31 70.284168 -153.266584 P3-P4 Alt=70 m MSL
     0 03777 20:42:54 70.290055 -152.054026
FLX -1 03835 20:43:52 70.308995 -152.000316 P4-P5 Alt=40 m MSL
     0 03916 20:45:13 70.354501 -152.000285
FLX -1 03985 20:46:22 70.379969 -152.075315 P5-P6 Alt=40 m MSL
     0 04664 20:57:41 70.375455 -153.268597
FLX -1 04723 20:58:40 70.397079 -153.325114 P6-P7 Alt=50 m MSL
     0 04814 21:00:11 70.449966 -153.326700
FLX -1 04878 21:01:15 70.464057 -153.256275 P7-P8 Alt=25 m MSL
     0 05675 21:14:32 70.469700 -152.050580
FLX -1 05735 21:15:32 70.491324 -152.000590 P8-P9 Alt=25 m MSL
     0 05810 21:16:47 70.534055 -152.000377
FLX -1 05884 21:18:01 70.559797 -152.085899 P9-P10 Alt=25 m MSL
     0 06538 21:28:55 70.555222 -153.265029
FLX -1 06595 21:29:52 70.575260 -153.325602 P10-P11 Alt=10 m MSL
     0 06693 21:31:30 70.630160 -153.327249
FLX -1 06747 21:32:24 70.644282 -153.273660 P11-P12 Alt=10 m MSL
     0 07576 21:46:13 70.649650 -152.059516
FLX -1 07645 21:47:22 70.671305 -152.000529 P12-P13 Alt=10 m MSL
     0 07718 21:48:35 70.712175 -152.000468
FLX -1 07800 21:49:57 70.739930 -152.102155 P13-P14 Alt=10 m MSL
     0 08413 22:00:10 70.735202 -153.260484
PRO -1 08475 22:01:12 70.716536 -153.327554 Profile Alt=30-115 m MSL
     0 08613 22:03:30 70.647179 -153.327066
PRO -1 08615 22:03:32 70.646203 -153.327096 Profile Alt=115-15 m MSL
     0 08752 22:05:49 70.570350 -153.327035
PRO -1 08755 22:05:52 70.568642 -153.327005 Profile Alt=15-120 m MSL
     0 08980 22:09:37 70.452315 -153.327188
PRO -1 08982 22:09:39 70.451278 -153.327218 Profile Alt=120-47 m MSL
     0 09136 22:12:13 70.367525 -153.327096
PRO -1 09138 22:12:15 70.366427 -153.327096 Profile Alt=47-140 m MSL
     0 09334 22:15:31 70.265746 -153.327249
PRO -1 09336 22:15:33 70.264709 -153.327218 Profile Alt=140-60 m MSL
     0 09507 22:18:24 70.191662 -153.245570
PRO -1 09645 22:20:42 70.180438 -153.033991 Profile Alt=60-610 m MSL
     0 10810 22:40:07 70.078751 -151.228391
PRO -1 10812 22:40:09 70.078568 -151.225097 Profile Alt=610-105 m MSL
```

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     0 11857 22:57:34 70.144356 -149.450424
File BAT_SPAN_130827.1F_despike.ncr, 08271939 CLOSED at 255582
Total scans    : 11968

                                    Flight 12
File BAT_SPAN_130828.1F_despike.ncr, 08280245 OPENED at 269142
CAL -1 00116 02:47:21 70.159667 -148.264950 Straight & Level Alt=605 m MSL
     0 00429 02:52:34 70.013908 -148.549637
CAL -1 00469 02:53:14 70.008906 -148.604476 Wind Box Leg 1 Alt=605 m MSL
     0 00597 02:55:22 70.038064 -148.803519
CAL -1 00639 02:56:04 70.059017 -148.822704 Wind Box Leg 2 Alt=605 m MSL
     0 00716 02:57:21 70.104981 -148.819715
CAL -1 00756 02:58:01 70.122122 -148.784792 Wind Box Leg 3 Alt=605 m MSL
     0 00835 02:59:20 70.136396 -148.652209
CAL -1 00883 03:00:08 70.122000 -148.599596 Wind Box Leg 4 Alt=605 m MSL
     0 00953 03:01:18 70.083265 -148.604293
CAL -1 01000 03:02:05 70.077104 -148.664805 Yaw left/right Alt=605 m MSL
     0 01373 03:08:18 70.068228 -149.249917
CAL -1 01460 03:09:45 70.040626 -149.344925 Wind circle left Alt=605 m MSL
     0 01543 03:11:08 70.052033 -149.305305
CAL -1 01582 03:11:47 70.050294 -149.370270 Wind circle right Alt=605 m MSL
     0 01737 03:14:22 70.077073 -149.377346
CAL -1 01806 03:15:31 70.072742 -149.263215 Phugoid oscillation Alt=605 m MSL
     0 02106 03:20:31 70.093177 -148.766797
CAL -1 02114 03:20:39 70.091896 -148.753499 Phugoid oscillation Alt=605 m MSL
     0 02600 03:28:45 70.013023 -147.968917
CAL -1 02656 03:29:41 70.002196 -147.877021 Phugoid oscillation Alt=605 m MSL
     0 02876 03:33:21 69.960899 -147.532615
CAL -1 03088 03:36:53 69.992375 -147.554910 Phugoid oscillation Alt=605 m MSL
     0 03287 03:40:12 69.890352 -147.726808
CAL -1 03312 03:40:37 69.878396 -147.752550 Phugoid oscillation Alt=605 m MSL
     0 03548 03:44:33 69.765546 -147.986363
CAL -1 03621 03:45:46 69.767834 -148.094516 Pitch up/dn Alt=605 m MSL
     0 03755 03:48:00 69.790160 -148.314421
CAL -1 03789 03:48:34 69.796199 -148.369413 Pitch up/dn Alt=605 m MSL
     0 03900 03:50:25 69.817915 -148.550003
CAL -1 03972 03:51:37 69.831792 -148.663372 Pitch up/dn Alt=605 m MSL
     0 04025 03:52:30 69.842864 -148.748009
CAL -1 04186 03:55:11 69.856040 -148.612589 Rapid accel/decel Alt=605 m MSL
     0 04282 03:56:47 69.838990 -148.458320
CAL -1 04283 03:56:48 69.838777 -148.456490 Rapid accel/decel Alt=605 m MSL
     0 04395 03:58:40 69.817396 -148.277272
CAL -1 04397 03:58:42 69.816969 -148.273734 Rapid accel/decel Alt=605 m MSL
     0 04601 04:02:06 69.771189 -147.909900
CAL -1 04798 04:05:23 69.828559 -147.753831 Pitch calibration Alt=605 m MSL
     0 05098 04:10:23 70.004117 -147.740350
CAL -1 05100 04:10:25 70.005459 -147.740015 Pitch calibration Alt=605 m MSL
     0 05585 04:18:30 69.940220 -148.098512
PRO -1 05707 04:20:32 69.878518 -148.225849 Profile Alt=605-100 m MSL
     0 05994 04:25:19 70.002897 -148.356603
FLX -1 06231 04:29:16 70.085491 -148.603134 Tower West N-S Alt=50 m MSL
     0 06645 04:36:10 69.989233 -149.270993
FLX -1 06828 04:39:13 69.991978 -149.253486 Tower West S-N Alt=50 m MSL
     0 07414 04:48:59 70.110349 -148.426448
FLX -1 07612 04:52:17 70.106780 -148.448957 Tower West N-S Alt=50 m MSL
     0 08118 05:00:43 69.991429 -149.255651
```

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FLX -1 08313 05:03:58 69.991490 -149.256627 Tower West S-N Alt=50 m MSL
     0 08900 05:13:45 70.111599 -148.417694
FLX -1 09095 05:17:00 70.106109 -148.454050 Tower West N-S Alt=50 m MSL
     0 09592 05:25:17 69.991338 -149.256353
FLX -1 09792 05:28:37 69.993595 -149.244122 Tower West S-N Alt=50 m MSL
     0 10254 05:36:19 70.088175 -148.576874
BOX -1 10360 05:38:05 70.084058 -148.435903 Tower West to ALFSE Alt=50 m MSL
     0 10685 05:43:30 69.963247 -148.085397
BOX -1 10763 05:44:48 69.933662 -148.125779 ALFSE-ALFSH Alt=50 m MSL
     0 11166 05:51:31 69.933510 -148.835361
BOX -1 11254 05:52:59 69.970018 -148.915515 ALFSH-ALFSA Alt=50 m MSL
     0 11560 05:58:05 70.146217 -148.916705
File BAT_SPAN_130828.1F_despike.ncr, 08280245 CLOSED at 280906
Total scans    : 11764

                                     Flight 13
File BAT_SPAN_130828.3F_despike.ncr, 08281838 OPENED at 326324
PRO -1 00056 18:39:23 70.153171 -148.436726 Profile Alt=600-1525 m MSL
     0 00327 18:43:54 70.133224 -148.882362
PRO -1 00401 18:45:08 70.127185 -149.016104 Profile Alt=1525-140 m MSL
     0 00989 18:54:56 70.078354 -150.026112
PRO -1 00994 18:55:01 70.077927 -150.034194 Profile Alt=140-1545 m MSL
     0 01506 19:03:33 70.033733 -150.859555
PRO -1 01627 19:05:34 70.023210 -151.044263 Profile Alt=1545-45 m MSL
     0 02279 19:16:26 69.959404 -152.106395
FLX -1 02877 19:26:24 69.899929 -153.028227 P1-P2 Alt=90 m MSL
     0 03653 19:39:20 69.895629 -154.255638
FLX -1 03711 19:40:18 69.912587 -154.308403 P2-P3 Alt=70 m MSL
     0 03815 19:42:02 69.968951 -154.309074
FLX -1 03890 19:43:17 69.984323 -154.218215 P3-P4 Alt=80 m MSL
     0 04555 19:54:22 69.990179 -153.075593
FLX -1 04631 19:55:38 70.013938 -153.001905 P4-P5 Alt=50 m MSL
     0 04706 19:56:53 70.057126 -153.002424
FLX -1 04790 19:58:17 70.079391 -153.088373 P5-P6 Alt=70 m MSL
     0 05550 20:10:57 70.075426 -154.258292
FLX -1 05615 20:12:02 70.097630 -154.305719 P6-P7 Alt=70 m MSL
     0 05714 20:13:41 70.150700 -154.308861
FLX -1 05794 20:15:01 70.163602 -154.207662 P7-P8 Alt=50 m MSL
     0 06472 20:26:19 70.169793 -153.046313
FLX -1 06530 20:27:17 70.190686 -152.999374 P8-P9 Alt=50 m MSL
     0 06615 20:28:42 70.237991 -153.001417
FLX -1 06713 20:30:20 70.260561 -153.118629 P9-P10 Alt=60 m MSL
     0 07427 20:42:14 70.255224 -154.258322
FLX -1 07484 20:43:11 70.274561 -154.306421 P10-P11 Alt=50 m MSL
     0 07589 20:44:56 70.330315 -154.308220
FLX -1 07665 20:46:12 70.342972 -154.210712 P11-P12 Alt=50 m MSL
     0 08377 20:58:04 70.349652 -152.985649
PRO -1 08386 20:58:13 70.349469 -152.970917 Profile Alt=50-1500 m MSL
     0 08966 21:07:53 70.325038 -151.980430
PRO -1 09120 21:10:27 70.317047 -151.690314 Profile Alt=1500-155 m MSL
     0 09675 21:19:42 70.285205 -150.674206
PRO -1 09710 21:20:17 70.283070 -150.612505 Profile Alt=155-1520 m MSL
     0 10293 21:30:00 70.235155 -149.542107
PRO -1 10399 21:31:46 70.220789 -149.345108 Profile Alt=1520-83 m MSL
     0 10847 21:39:14 70.186965 -148.550674
File BAT_SPAN_130828.3F_despike.ncr, 08281838 CLOSED at 337171
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Total scans    : 10847

                                     Flight 14
File BAT_SPAN_130828.4F_despike.ncr, 08282359 OPENED at 345567
PRO -1 00001 23:59:12 70.207308 -148.338791 Profile Alt=286-1525 m MSL
     0 00337 00:04:48 70.388295 -148.073380
PRO -1 00450 00:06:41 70.428067 -148.133129 Profile Alt=1450-17 m MSL
     0 01068 00:16:59 70.295026 -148.898557
FLX -1 01244 00:19:55 70.192729 -148.917498 P1-P2 Alt=50 m MSL
     0 02013 00:32:44 69.771341 -148.916796
FLX -1 02078 00:33:49 69.750327 -148.975631 P2-P3 Alt=100 m MSL
     0 02099 00:34:10 69.750388 -149.007717
FLX -1 02157 00:35:08 69.773568 -149.045262 P3-P4 Alt=100 m MSL
     0 02857 00:46:48 70.177662 -149.046635
FLX -1 02921 00:47:52 70.200171 -149.110959 P4-P5 Alt=40 m MSL
     0 02928 00:47:59 70.200049 -149.122610
FLX -1 02996 00:49:07 70.174490 -149.181201 P5-P6 Alt=40 m MSL
     0 03727 01:01:18 69.770945 -149.182055
FLX -1 03859 01:03:30 69.777838 -149.304146 P7-P8 Alt=100 m MSL
     0 04550 01:15:01 70.177113 -149.306464
FLX -1 04619 01:16:10 70.199775 -149.371216 P8-P9 Alt=40 m MSL
     0 04633 01:16:24 70.199683 -149.392413
FLX -1 04710 01:17:41 70.169732 -149.445300 P9-P10 Alt=50 m MSL
     0 05383 01:28:54 69.793057 -149.447374
PRO -1 05408 01:29:19 69.779851 -149.441061 Profile Alt=96-1530 m MSL
     0 05924 01:37:55 70.024186 -148.946839
PRO -1 05926 01:37:57 70.025345 -148.944917 Profile Alt=1530-67 m MSL
     0 06249 01:43:20 70.185836 -148.559550
File BAT_SPAN_130828.4F_despike.ncr, 08282359 CLOSED at 351817
Total scans    : 06249

                                     Flight 15
File BAT_SPAN_130829.1F_despike.ncr, 08291736 OPENED at 409002
FLX -1 00127 17:38:33 70.086528 -148.522340 Tower East N-S Alt=60 m MSL
     0 00621 17:46:47 69.983011 -149.238297
FLX -1 00821 17:50:07 69.985390 -149.223535 Tower East S-N Alt=60 m MSL
     0 01325 17:58:31 70.098820 -148.429711
FLX -1 01540 18:02:06 70.097112 -148.438831 Tower East N-S Alt=60 m MSL
     0 02035 18:10:21 69.994632 -149.158448
FLX -1 02200 18:13:06 70.007594 -149.071645 Tower East S-N Alt=60 m MSL
     0 02600 18:19:46 70.097173 -148.441667
File BAT_SPAN_130829.1F_despike.ncr, 08291736 CLOSED at 412134
Total scans    : 03131
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