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MABEL Alaska 2014

Flight Report

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National Aeronautics and
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Level of Review: This material has been technically reviewed by technical management

Abstract

In July and August 2014, NASA conducted an airborne lidar campaign based out of Fort Wainwright, Fairbanks, Alaska, in support of Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) algorithm development. The survey targeted Alaskan glaciers and icefields and sea ice in the Arctic Ocean during the summer melt season. Ultimately, the mission, *MABEL Alaska 2014*, including checkout and transit flights, conducted 11 science flights, for a total of over 50 flight hours over glaciers, icefields, and sea ice.

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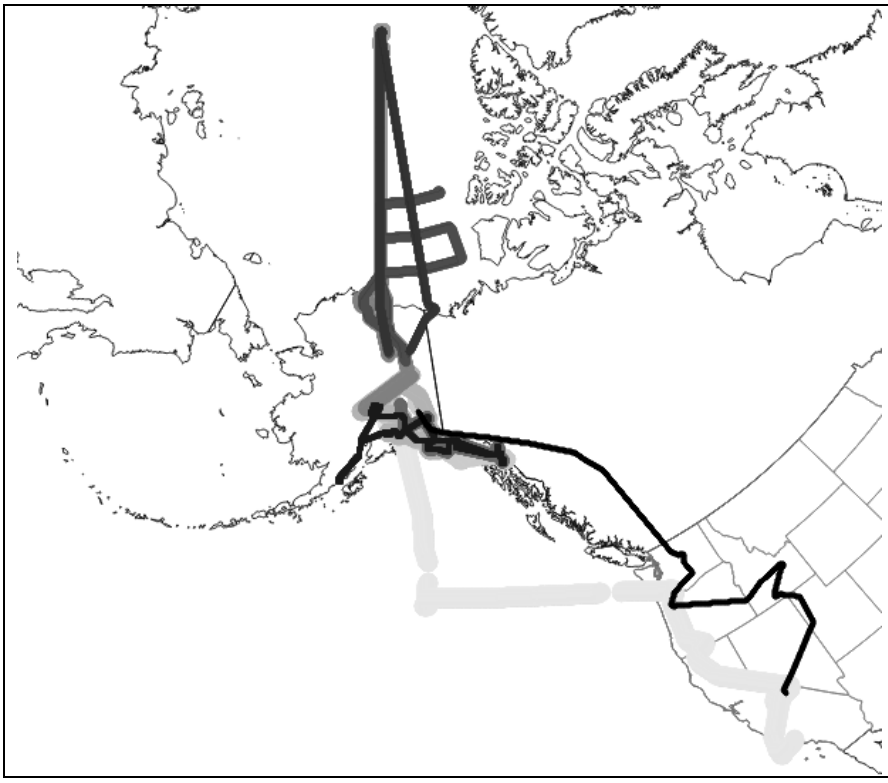
Introduction

In support of Ice, Cloud, and land Elevation Satellite-2 (ICESat-2; Markus et al., *submitted*), NASA has conducted a series of airborne campaigns primarily to enable the development of ICESat-2 geophysical algorithms prior to launch, which is scheduled for late 2017. ICESat-2 will carry the Advanced Topographic Laser Altimeter System (ATLAS), which will be a six-beam photon-counting laser altimeter using 532-nm wavelength pulses. Given this new approach to satellite surface elevation measurement, a series of airborne lidar campaigns were designed to: 1) enable the development of ICESat-2 geophysical algorithms prior to launch; 2) enable ICESat-2 error analysis; and 3) provide ATLAS model validation.

The primary airborne instrument used for algorithm development has been the Multiple Altimeter Beam Experimental Lidar (MABEL; McGill et al., 2013). Bill Cook is the MABEL Principal Investigator. MABEL is a photon-counting multibeam lidar sampling at both 532- and 1064-nm wavelengths. Previous airborne MABEL campaigns have included a series of engineering flights high-altitude aircraft based out of California (2010, 2011, and 2012). These campaigns were followed by deployments that surveyed: ice sheets and sea ice in winter conditions (based in Keflaik, Iceland, April 2012; Brunt et al., 2014; Kwok et al., 2014; Farrell et al., 2015) and vegetation 'leaf-on' conditions (based in Wallops Island, Virginia, September 2012 and Hampton, Virginia, September 2013). The Iceland 2012 campaign was intended to sample winter-like conditions; an Alaska 2014 campaign was followed this and was timed to collect data during the summer melt season (Brunt et al., 2016).

The mission, *MABEL Alaska 2014*, was based out of Fort Wainwright, Fairbanks, Alaska. Ultimately 11 science flights were conducted, for a total of over 50 flight hours over the glaciers, icefields, and sea ice.



Overview cartoon of MABEL Alaska 2014 science flights based out of Fort Wainwright, Fairbanks, Alaska. The various shades of gray are used to differentiate the flight lines. Darkest shades occurred earlier in the campaign.

Instrumentation and Aircraft

MABEL is optimized for high-altitude sampling (above 15 km) with a goal of sampling at about 20 km, or above more than 90% of the atmosphere. To accomplish this, MABEL has been deployed on 2 high-altitude aircraft: the NASA Armstrong ER-2 and the Scaled Composites Protues. For the Alaska 2014 deployment, MABEL was integrated into the nosecone of the ER-2 in July 2014. Flights with this aircraft were planned at about 7 to 8 hours, including takeoff and decent; data collection totaled about 6 to 7 hours per flight.

NASA Armstrong ER-2.

MABEL has beams at both 532 (green) and 1064 (near infrared) nm wavelengths. MABEL has as many as 16 green beams and as many as 8 near infrared beams. For the Alaska 2014 campaign, instrumentation issues limited MABEL to 15 green beams. MABEL beams are arranged in a linear array, perpendicular to the direction of flight. The system allows for beam-geometry changes between flights with a maximum view angle of ±1 km from a 20-km nominal altitude. For the Alaska 2014 campaign, the maximum across-track beam spacing was 200 m. The repetition rate of MABEL is variable (between 5 and 25 kHz); the Alaska 2014 campaign used 5 kHz. At this nominal altitude, repetition rate, and an aircraft speed of ~200 m/s, MABEL samples a ~2-m footprint every ~4 cm along track.

Ancillary instrumentation on the NASA ER-2 included Cloud Physics Lidar (CPL). Matt McGill is the CPL Principal Investigator. CPL is a 3-wavelength lidar (355, 532, and 1064 nm) for atmospheric applications with 30 m vertical resolution. Processed CPL is key for atmospheric validation of processed MABEL data. Further, real-time quick-look imagery telemetered from CPL provides an assessment of what MABEL is sampling in real-time. CPL is a very mature instrument; uncharacteristically, CPL had a couple of minor instrument issues during the Alaska 2014 campaign and filed on 2 different flights.

For the 2014 Alaska campaign, a camera was integrated with MABEL and was successful for over 40% of the campaign's duration. The images were typically used to visually confirm the type of surface being measured by MABEL (e.g., ice, open water, sea ice, or melt ponds) or to confirm the presence or absence of clouds. The MABEL camera was mounted on the same optical bench as the MABEL telescopes and shared the same portal in the aircraft. It is a Sony Nex7, with a 55 to 220 mm, f/4.5-6.6 telephoto lens. The camera produced 6000 by 4000-pixel color images. At a nominal aircraft altitude of 20 km, each image covers an approximately 2.25 by 1.5 km area, or approximately <3 m pixels at sea level and contained all MABEL ground tracks. Images were taken every 3 seconds, which provided

approximately 30% overlap at sea level. The images collected were not systematically georeferenced; however, they were time-stamped based on MABEL instrument timing to provide a first-order assessment of the surface that the lidar had surveyed.

Sample nadir-looking frame camera image of a melt pond on an Alaskan icefield. Camera images are approximately 2.25 by 1.5 km at a nominal altitude of 20 km ASL.

Discussion and Conclusions

The appendix of this document includes summaries associated with each individual mission flight. Details captured in these summaries include maps of flight tracks, comments about the instrumentation, and comments about weather.

MABEL requires clear sky conditions for sampling. This deployment experienced difficult weather conditions, as Alaska experienced an unseasonably wet and cold summer. The flight summaries make note of the general weather conditions. Additionally, the flight tracks are plotted on the MODIS Rapid Response imagery to provide a snapshot of the general cloud state (https://lance.modaps.eosdis.nasa.gov/imagery/subsets/?project=other).

A MABEL instrument checkout flight was conducted based out of Palmdale, California, and included targets over vegetated regions and Lake Mead. When MABEL transited from Palmdale, California to Fairbanks, Alaska, the flight included vegetated regions, Bonneville Salt Flats, and gaged lakes in Washington and British Columbia.

For land ice surveys, to address the science goals, a major flight objective was to acquire MABEL data over summer ice sheet conditions, including surface melt and melt ponds. The Bagley and Juneau icefields were used as ice-sheet like surfaces. On the Juneau Icefield, coordination with the Juneau Icefield Research Program (JIRP) led to *in situ* GPS measurements for direct comparison with MABEL elevation data. For sea ice surveys, to address the science goals, a major flight objective was to acquire MABEL data over summer sea ice conditions, including melt ponds on sea ice. Both targets proved challenging, as low pressure systems persisted in both the Beaufort Sea and the Gulf of Alaska.

Other targets of opportunity included flights over lakes with gages and vegetated regions near Denali. The Denali flights were also flown by 2014 Alaskan G-LiHT campaign and the 2014 Alaskan ARISE campaign.

All datasets associated with *MABEL Alaska 2014* are available on the ICESat-2 website (http://icesat.gsfc.nasa.gov/icesat2/data.php).

Acknowledgements
We thank the instrument field teams. MABEL field team: Eugenia DeMarco, Dan Reed. CPL field team: Andrew Kupchock, John Yorks, Scott Ozog, Dennis Hlavka, and Patrick Selmer. We thank the NASA Armstrong ER-2 pilots, Tim Williams and Denis Steele, and ER-2 Project Manager Tim Moes. We thank NASA Goddard Flight Center personnel David Hancock, Jeff Lee, Scott Luthcke, Charles Webb, and Kaitlin Walsh for data processing and analysis support.

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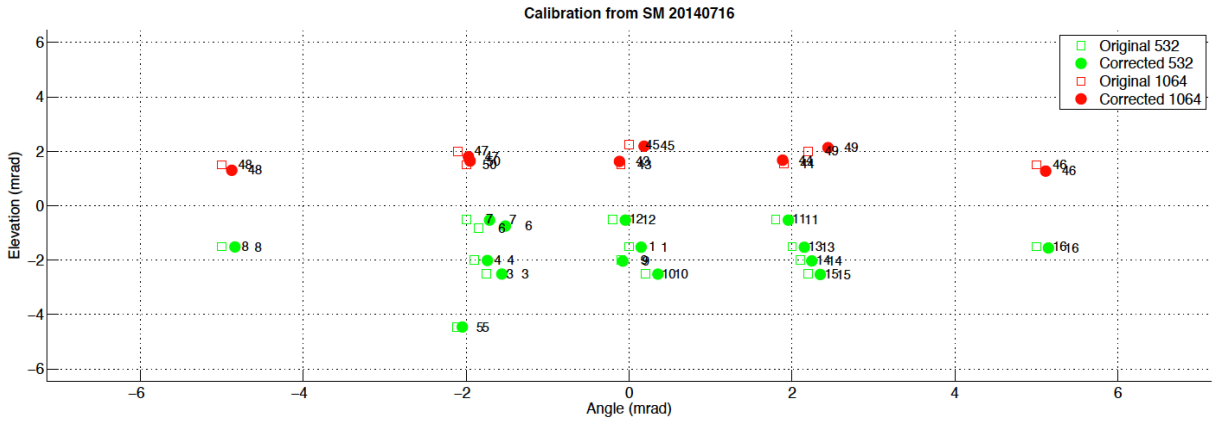
Appendix

The appendix of this document includes summaries associated with each individual mission flight. Details captured in these summaries include maps of flight tracks, comments about the instrumentation, and comments about weather. This document focuses on MABEL, as the primary instrument. As such, it includes flight summaries for all MABEL flights, including instrument check flights in California and transit flights to and from Alaska.

For the Alaska campaign, MABEL was configured with an etalon filter, to reduce solar background counts. All flights for the campaign were conducted during daylight. The repetition rate of MABEL for the Alaska 2014 campaign was 5 kHz.

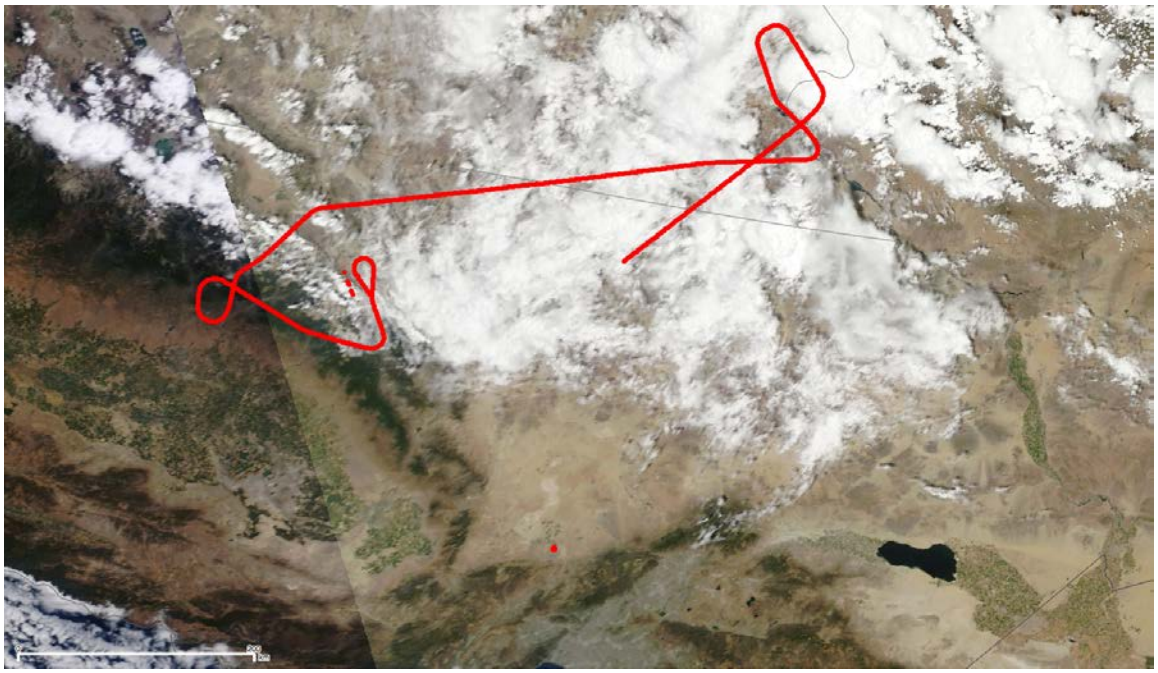
For the Alaska 2014 campaign, instrumentation issues limited MABEL to 15 green beams and 8 near infrared beams with a maximum across-track beam spacing was 200 m. Most MABEL flights included pitch and roll maneuvers; the times of these are indicated in the individual flight summaries. The relative spacing of those beams, after calibrations based on pitch and roll maneuvers over the open ocean, is in the figure below.



MABEL calirated beam spacing

07/10/2014

Mission: 'Checkout'



Weather: clouds over Lake Mead
Comments: Also included: CPL and the MABEL camera; the MABEL camera had a trigger rate that was insufficient to create overlap between frames.

MABEL sat on tarmac for too long and overheated. Took many circles over the Sierras to cool down.

Best flight for Teakettle, LVIS lines, and Glenn's California targets (these were also acquired on 8/1). No P/R maneuvers.

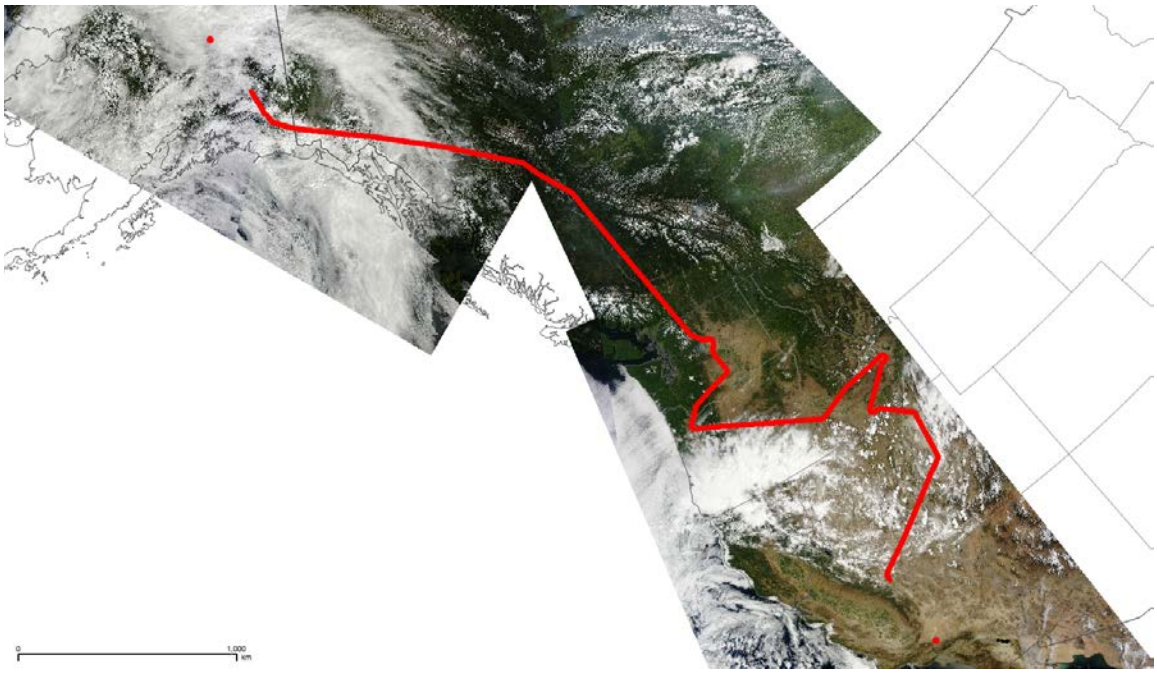
Day flight

Points of interest:

Time (UTC)	Description
19:13:15	Laser status healthy
19:57:15	Teakettle/LVIS start
20:06:15	Teakettle/LVIS end
20:10:45	Glenn CA site start
20:12:30	Glenn CA site end
21:10:45	Laser off

07/11/2014

Mission: 'Transit'



Weather: clouds over Portland and most of Alaska segment.
Comments: Also included: CPL and the MABEL camera; the MABEL camera was only operational for the first ~hour.

Best flight for Bonneville, Glenn's Idaho targets, and the lakes in WA and BC. No P/R maneuvers.

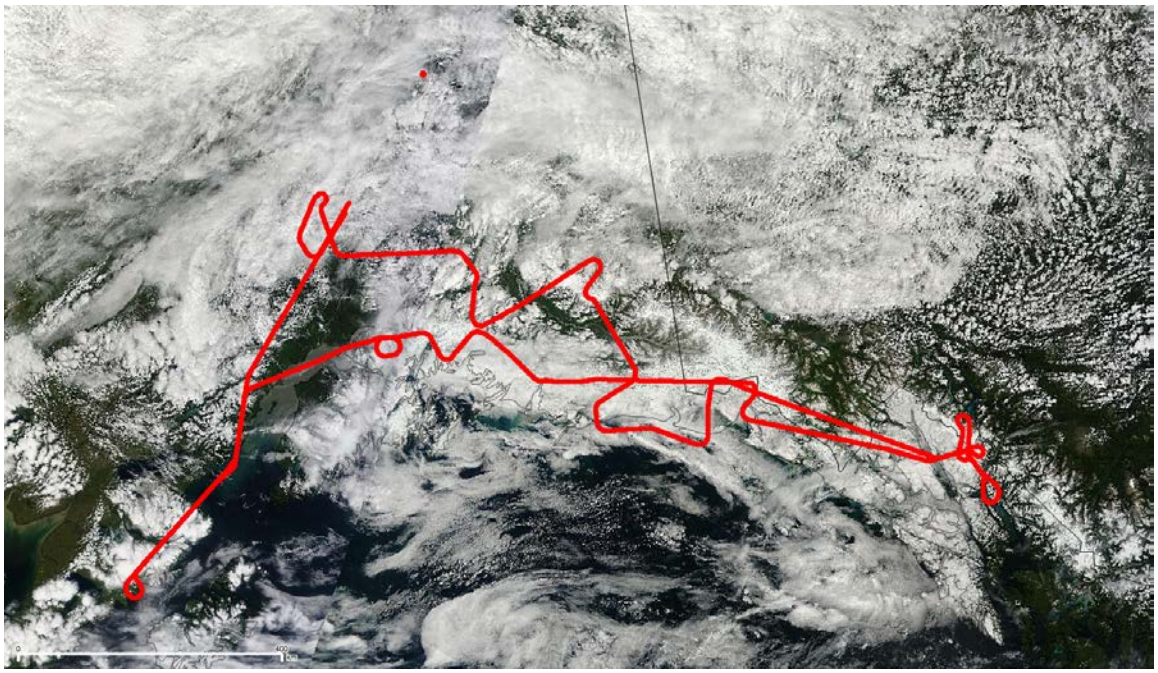
Day flight

Points of interest:

Time (UTC)	Description
17:27:15	Laser status healthy
18:18:00	Bonneville
18:36:15	Idaho start
19:26:00	Idaho end
20:29:00	Washington lakes start
20:50:00	Washington lakes end
21:47:00	BC lakes start
22:09:00	BC lakes end
23:45:00	Laser off

07/16/2014

Mission: 'Land Ice 1'



Weather: patchy clouds throughout.
Comments: Also included: CPL and the MABEL camera.

Best flight for Bagley Icefield, Seward, Llewellyn, Kennicott, and Nabesna glaciers, Redout Volcano, and Taslina Lake. Bagley Icefield, Seward and Nabesna glaciers also successfully acquired on 7/31.

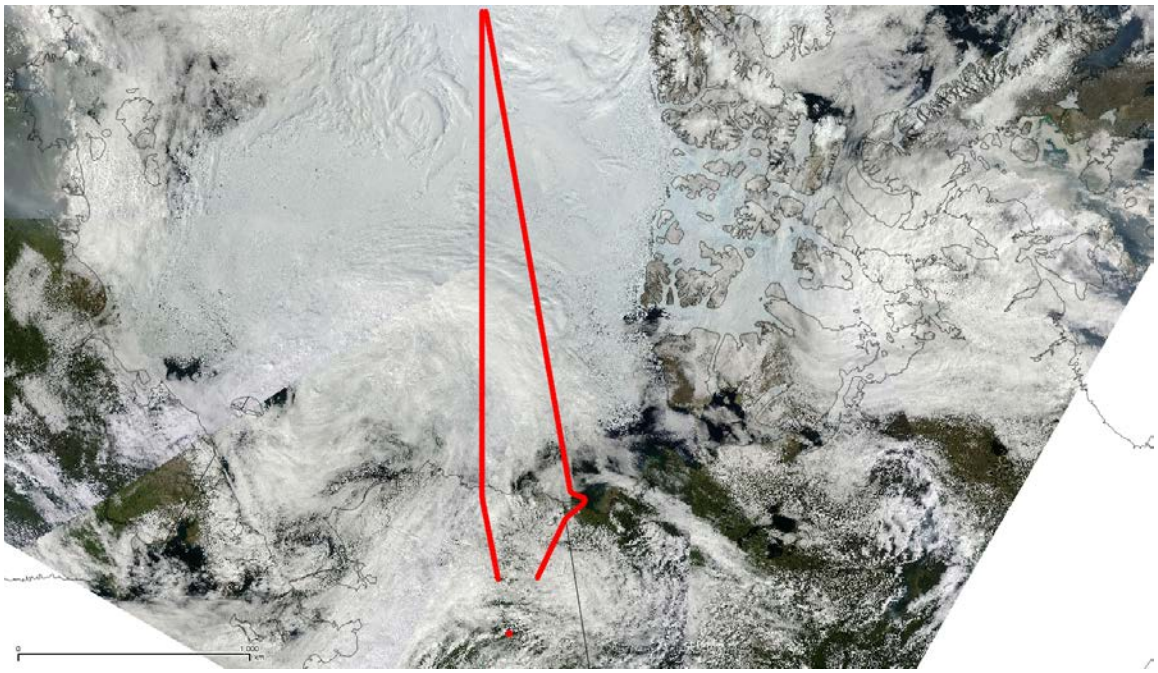
Day flight

Points of interest:

Time (UTC)	Description
18:27:30	Laser status healthy
18:52:00	Volcano start
19:50:00	Volcano end
19:57:00	P/R maneuvers over water
20:44:00	Bagley Icefield start
20:58:45	Bagley Icefield end
21:32:30	Llewellyn Glacier start
21:39:30	Llewellyn Glacier end
23:08:00	Kennicott/Nabesna glaciers start
23:15:30	Kennicott/Nabesna glaciers start
23:34:30	Taslina Lake start
23:37:30	Taslina Lake end
00:19:00	Laser off

07/17/2014

Mission: ‘Sea Ice 1’



Weather: patchy clouds throughout. Flight path was out on the 150* longitude line and returned on the 140* longitude line.
Comments: Also included: CPL and the MABEL camera.

Best flight for the 140* longitude line.

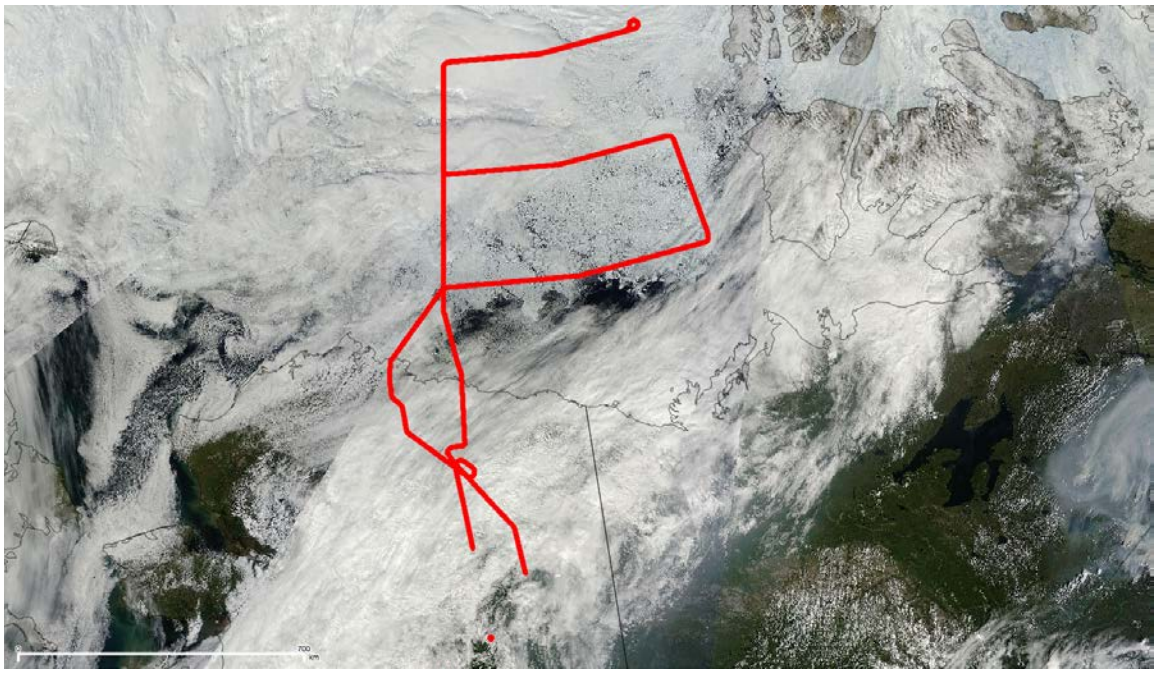
Day flight

Points of interest:

Time (UTC)	Description
19:24:30	Laser status healthy
22:40:00	P/R maneuvers over sea ice
01:47:00	P/R maneuvers over water
02:22:30	Laser off

07/22/2014

Mission: ‘Sea Ice 2’



Weather: patchy clouds throughout.
Comments: Also included: CPL and the MABEL camera.

Best flight for extended Marginal Ice Zone sampling (especially along the 72.5* line of latitude).

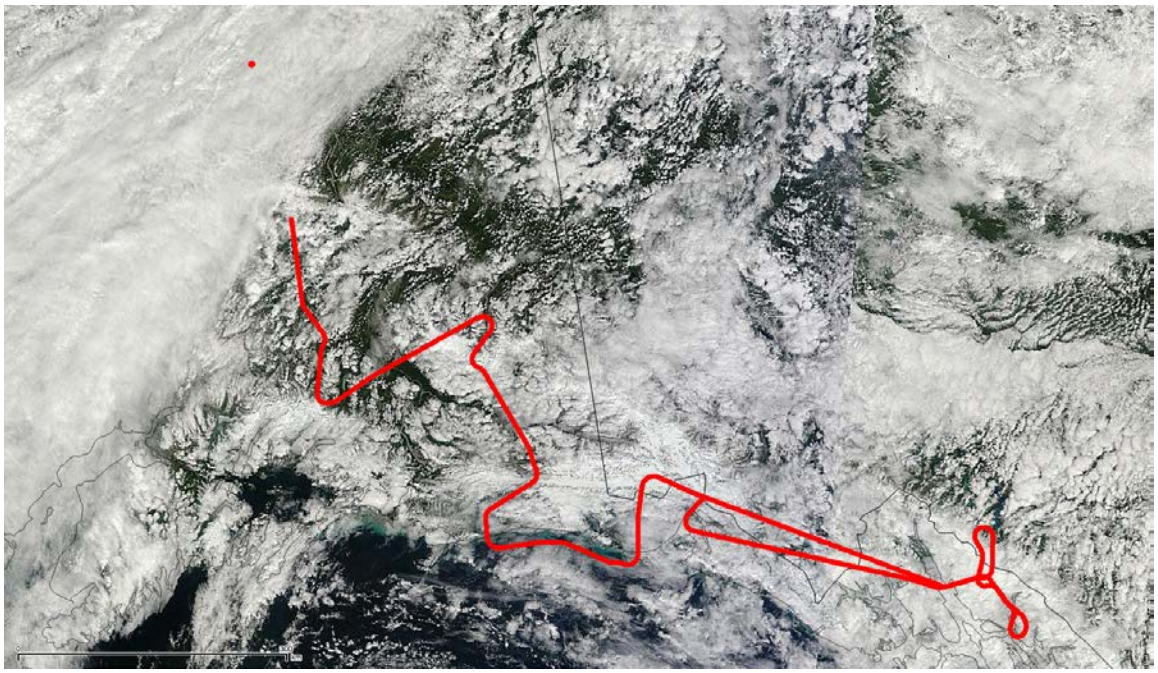
Day flight

Points of interest:

Time (UTC)	Description
18:19:00	Laser status healthy
19:53:00	P/R maneuvers over water
00:42:00	P/R maneuvers over water, but possibly cloudy
00:49:45	Laser off

07/24/2014

Mission: 'Land Ice 2'



Weather: Very cloudy throughout; most of the targets in this flight were acquired in better weather on other flights. MABEL over-write issue; lost data before Bagley Icefield.
Comments: Also included: CPL; MABEL camera failure.

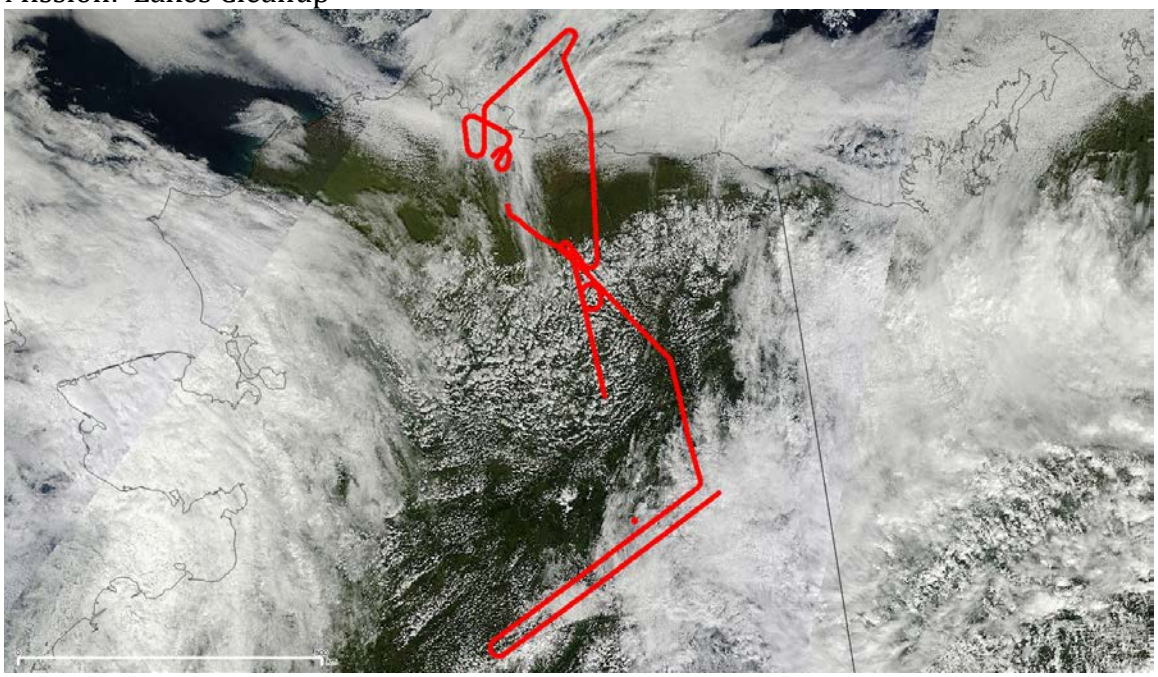
Day flight

Points of interest:

Time (UTC)	Description
20:29:15	Laser status healthy
22:03:00	P/R maneuvers over water
23:10:15	Laser off

07/27/2014

Mission: 'Lakes Cleanup'



Weather: patchy clouds throughout; very cloudy over G-LiHT lines, therefore, we aborted end of mission.
Comments: Also included: CPL and the MABEL camera.

Best flight for both Teshekpuk and Toolik lakes, the Deadhorse lidar area, and Neilson's survey region.

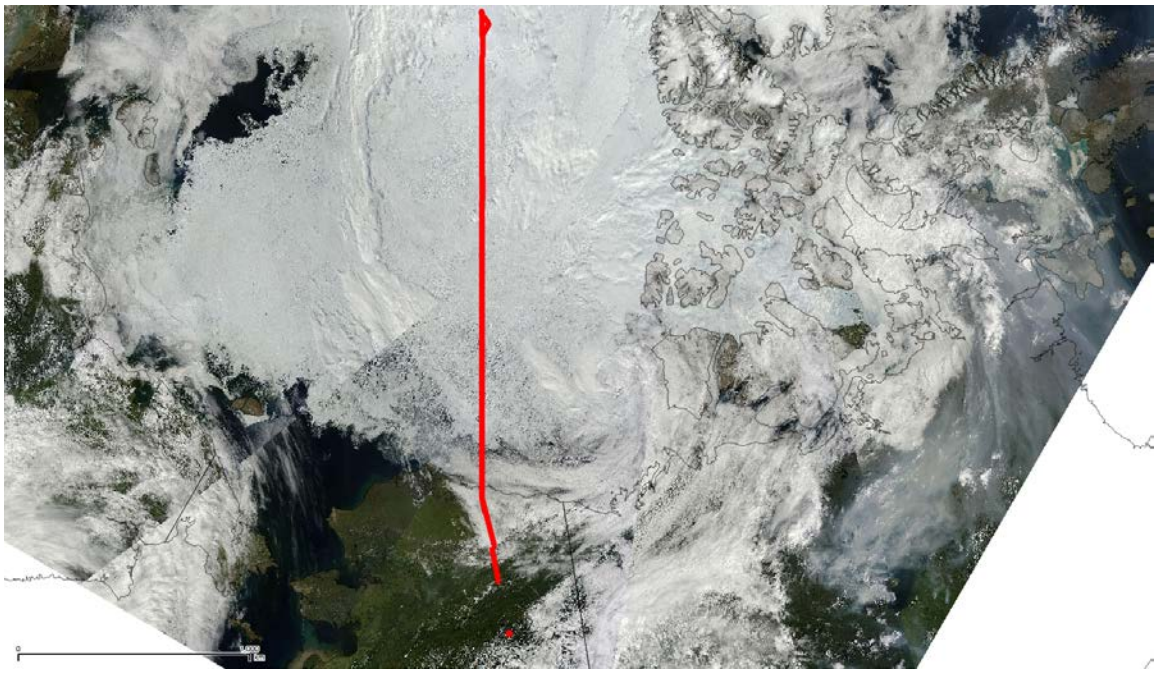
Day flight

Points of interest:

Time (UTC)	Description
19:18:30	Laser status healthy
20:15:30	Teshekpuk Lake start
20:33:30	Teshekpuk Lake end
20:49:00	P/R maneuvers over water
21:02:00	Deadhorse start
21:15:30	Deadhorse end
21:22:30	Neilson Flightline start
21:45:30	Neilson Flightline end
21:28:15	Toolik Lake start
21:29:15	Toolik Lake end
21:47:00	P/R maneuvers over land (flat Fort Yukon)
23:11:30	Laser off

07/29/2014

Mission: ‘Pole Return’



Weather: patchy clouds throughout.; clearest sea ice flight.
Comments: Both CPL and the MABEL camera experienced failures.

Best flight along the 150* line of longitude.

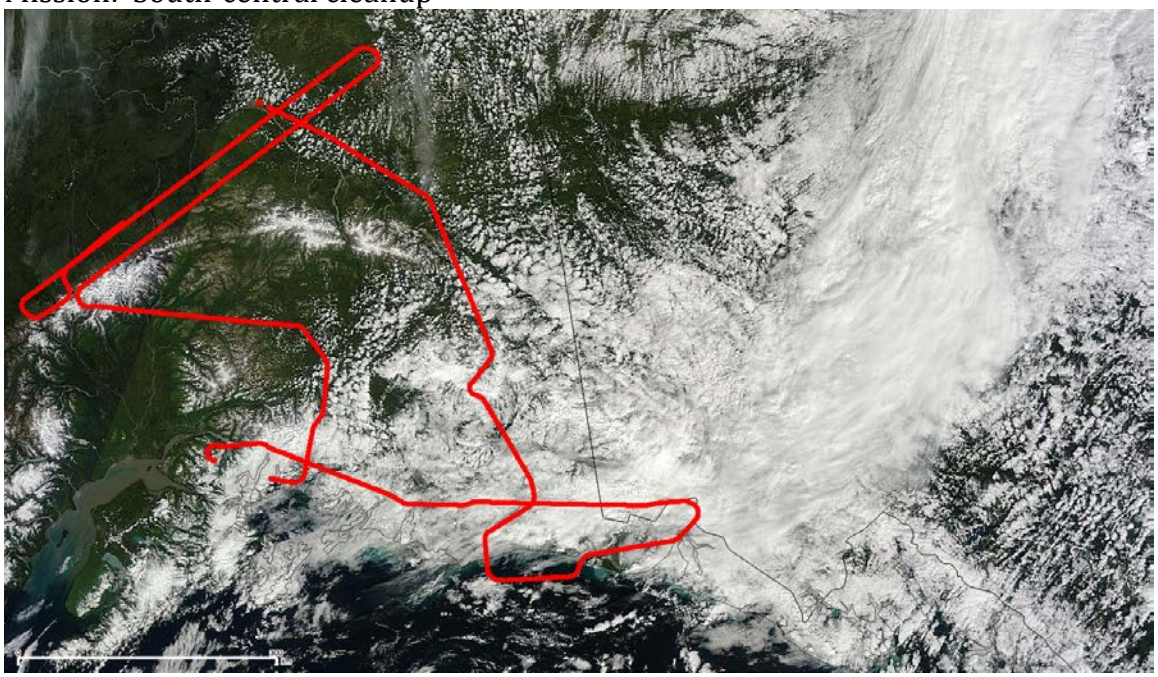
Day flight

Points of interest:

Time (UTC)	Description
18:41:15	Laser status healthy
21:25:25	P/R maneuver 1 starts somewhere in here
21:38:00	P/R maneuver 1 ends somewhere in here
21:53:15	P/R maneuver 2 starts somewhere in here
22:03:00	P/R maneuver 2 ends somewhere in here
00:15:15	Laser off

07/30/2014

Mission: 'South-central cleanup'



Weather: patchy clouds on southeaster part of the flight.
Comments: Both CPL and the MABEL camera experienced failures.

Best flight for G-LiHT lines 1 and 2 and Knick Glacier. This flight crosses the Kahiltna and Ruth glaciers.

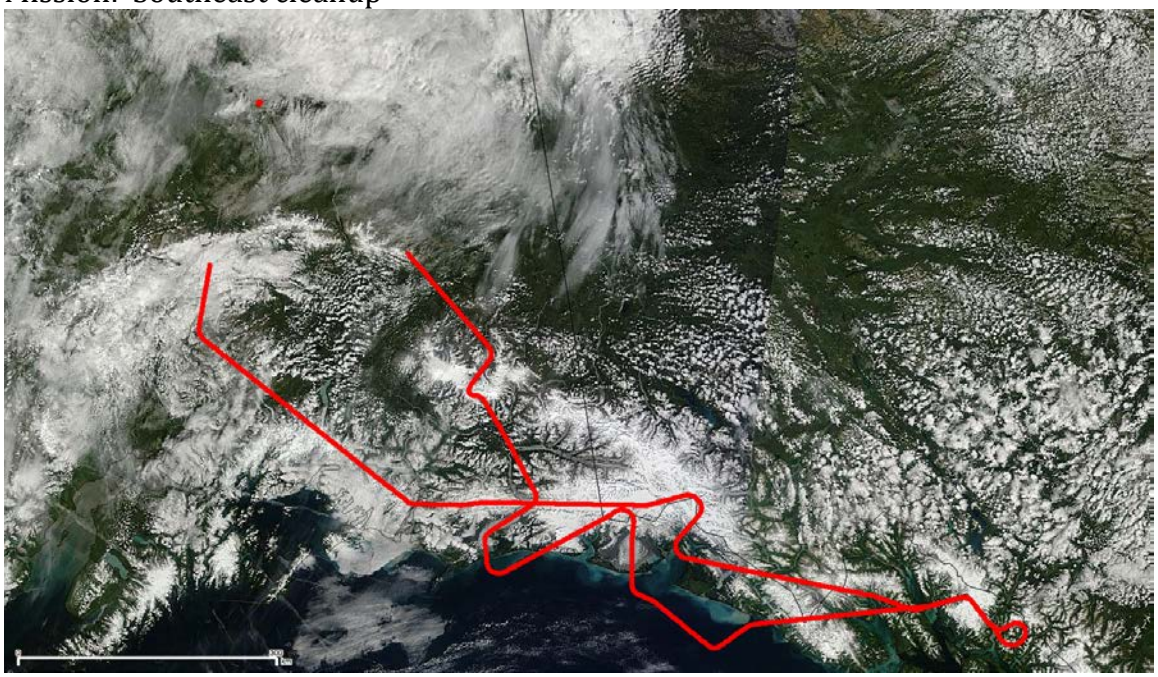
Day flight

Points of interest:

Time (UTC)	Description
19:09:45	Laser status healthy
19:23:45	G-LiHT lines start
20:39:00	G-LiHT lines end
20:41:15	Kahiltna and Ruth glacier-crossings start
20:46:00	Kahiltna and Ruth glacier-crossings end
20:30:15	Knick Glacier start
21:33:30	Knick Glacier end
22:29:00	P/R maneuver over water
23:32:15	Laser off

07/31/2014

Mission: 'Southeast cleanup'



Weather: patchy clouds on southeaster part of the flight.
Comments: Also included: CPL; MABEL camera failure.

Best flight for Miles, Hubbard, Malispina, and Bering glaciers, Gilkey and Taku glaciers, and auxiliary dataset for Bagley Icefield and Kennicott, Nabesna, and Seward glaciers (with 7/16).

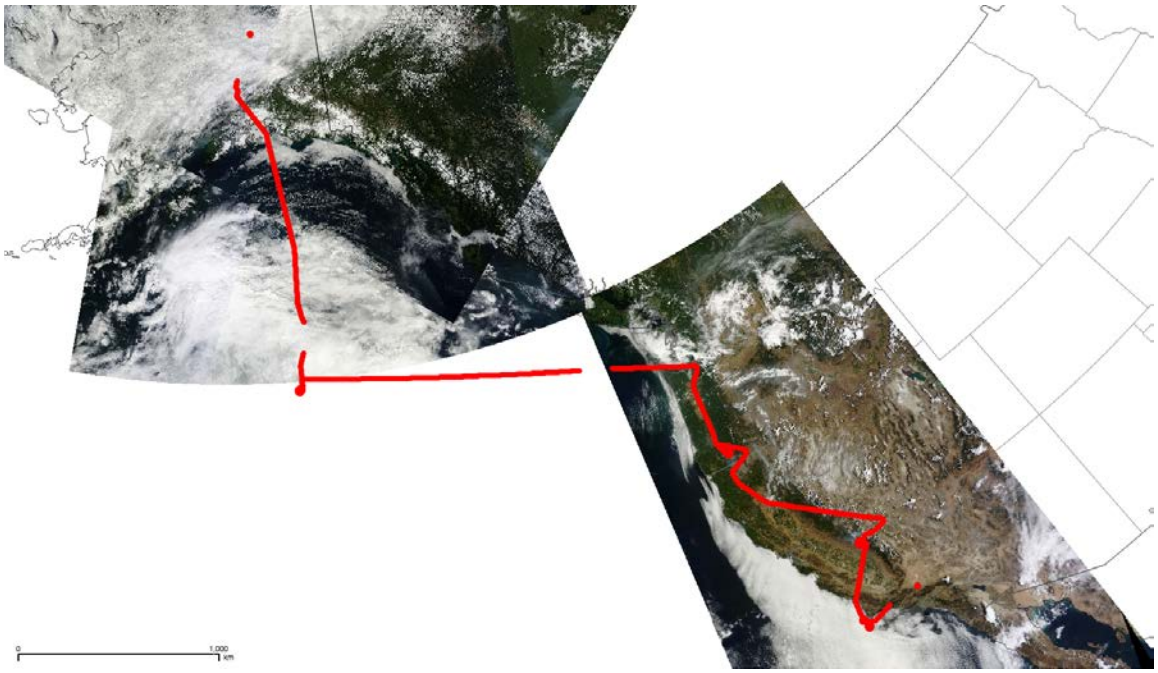
Day flight

Points of interest:

Time (UTC)	Description
18:04:15	Laser status healthy
18:35:00	Miles, Bagley, Hubbard start
19:04:30	Miles, Bagley, Hubbard end
19:28:30	Gilkey and Taku start
19:49:30	Gilkey and Taku end
20:05:15	P/R maneuver starts somewhere in here
20:18:00	P/R maneuver ends somewhere in here
20:19:00	Malaspina and Seward start
20:24:30	Malaspina and Seward end
20:39:45	Bering start
20:48:00	Bering end
20:55:00	Kennicott and Nabesna start
21:04:00	Kennicott and Nabesna end
21:14:15	Laser off

08/01/2014

Mission: 'Transit'



Weather: patchy clouds throughout AK and Pacific; clear over CONUS.
Comments: Also included: CPL; MABEL camera failure.

Best flight for Portland, Teakettle, LVIS lines, and Glenn's California targets (these were also acquired on 7/10). Pilot reports 'scattered clouds' over Ocean Station Papa and 'overcast' over Platform Harvest. CPL could see both clouds and surface over Papa; surface acquisition over Platform Harvest is less certain.
We also targeted wildfires in OR and northern CA, for ACATS.

Day flight

Points of interest:

Time (UTC)	Description
17:21:45	Laser status healthy
17:45:00	P/R maneuvers over water; small gap in clouds
18:07:00	P/R maneuvers over water; slower
19:17:00	Papa start
19:32:00	Papa end
21:18:00	P/R maneuvers over water
21:57:30	Portland start
22:03:15	Portland end
22:26:00	OR wildfire start
22:38:00	OR wildfire end
22:49:00	CA wildfire 1 start
22:55:45	CA wildfire 1 end

22:57:15	CA wildfire 2 start
23:01:30	CA wildfire 2 end
23:57:45	Glenn CA site start
23:59:15	Glenn CA site end
00:03:30	Teakettle/LVIS start
00:12:00	Teakettle/LVIS end
00:37:00	Platform Harvest start
00:47:00	Platform Harvest end
01:00:00	Laser off