Reconnaissance Report

Type of Survey Hydrographic Lidar
Project No. N/A
Registry No. N/A

LOCALITY

State Alaska
General Locality Bering Sea
Sub-Locality Nunivak Island and St. Lawrence Island

2009

HYDROGRAPHER	**CHIEF OF PARTY**
MARK SINCLAIR	SCOTT RAMSAY

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DATE

HYDROGRAPHIC TITLE SHEET

REGISTRY No. **N/A**

State Alaska

General Locality Bering Sea

Sub-Locality Nunivak Island and St. Lawrence Island

Scale N/A **Date of Survey** August 6 to August 15, 2009

Instructions dated June 17, 2009 **Project No.** N/A

Vessel Fugro LADS Aircraft, call sign VH-LCL

Hydrographer M.J. Sinclair **Chief of Party** S.R. Ramsay

Surveyed by J.G. Guilford, W.T. Newsham, K.J. Oberhofer, B.A. Weidman, J.K. Young, N.J. Stricklin, R.J. Bertucci

Soundings by Laser Airborne Depth Sounder

Graphic record scaled by J.G. Guilford

Graphic record checked by S.R. Ramsay **Automated Plot** N/A

Verification by

Soundings in Meters

REMARKS Soundings are raw, with no observed or predicted tide corrections applied.

Requisition / Purchase Req. # NCNJ3000-9-15915

Contractor Fugro LADS, Incorporated, 925 Tommy Munro Dr., Suite J, Biloxi, MS 39532

Sub-Contractor N/A

Times All times are recorded in UTC.

Datum and Projection NAD83, UTM (N) Zone 2 and 3

Purpose The purpose of this survey is to provide NOAA with a written assessment of the conditions (e.g. water clarity, depth penetration, sea surface conditions, and coastal morphology) between the shoreline and the 20 meter depth contour of, and a graphic demonstrating coverage around, the perimeter of Nunivak and St. Lawrence Islands.

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RECONNAISSANCE SURVEY REPORT

SURVEYED IN 2009

FUGRO LADS AIRCRAFT, VH-LCL

FUGRO LADS, INC. (FLI)

MARK SINCLAIR, HYDROGRAPHER

PROJECT

Project Number: N/A
Original: DG 133C-06-CQ-0066
Date of Instructions: June 17, 2009
Task Order: T0007

A. AREA SURVEYED

Survey operations covered the perimeters of Nunivak Island and St. Lawrence Island in the Bering Sea, Alaska. A total of 367 lineal nautical miles were illuminated in the process of flying 11 reconnaissance survey lines at Nunivak Island. A total of 142 lineal nautical miles were illuminated in the process of flying / attempting 7 reconnaissance survey lines at St. Lawrence Island.

Between August 6 and August 15, 2009, the LADS Mk II aircraft conducted 2 sorties in the Bering Sea, based out of Sand Point, AK. The Nome, AK airport was also used as a forward base for refueling and two nights spent monitoring St. Lawrence Island weather.

The specific dates of data acquisition for the Bering Sea Reconnaissance Survey, hours flown and time on task were as follows:

Date (UTC)	Sortie No.	Hours Flown	Time on Task
6-Aug-09	1 (Sand Point to Nunivak Is. to Nome)	5:52	3:18
8-Aug-09	Transit (Nome to Sand Point)	2:04	0:00
15-Aug-09	2 (Sand Point to St. Lawrence Is. to Nome)	4:55*	1:49*
15-Aug-09	Transit (Nome to Sand Point)	2:10	0:00

Table 1: Specific Dates of Data Acquisition

* Note: Sortie aborted prematurely for adverse weather

The cloud base height influenced the area and duration of data acquisition during Sortie 2, around St. Lawrence Island. Prior to the commencement of this reconnaissance survey flight the cloud base was reported to be above 5000ft across the northern part of St. Lawrence Island. Some three hours later, following the transit from Sand Point, a low cloud base had moved in from the north, preventing operations along most of the northeastern and eastern coasts of the island. The weather deteriorated further during the reconnaissance flight, with low cloud covering the entire island 2 hours after arriving in the area.

This Reconnaissance Survey Report describes operations at Nunivak Island and St. Lawrence Island (see Figure 1 and Figure 2).

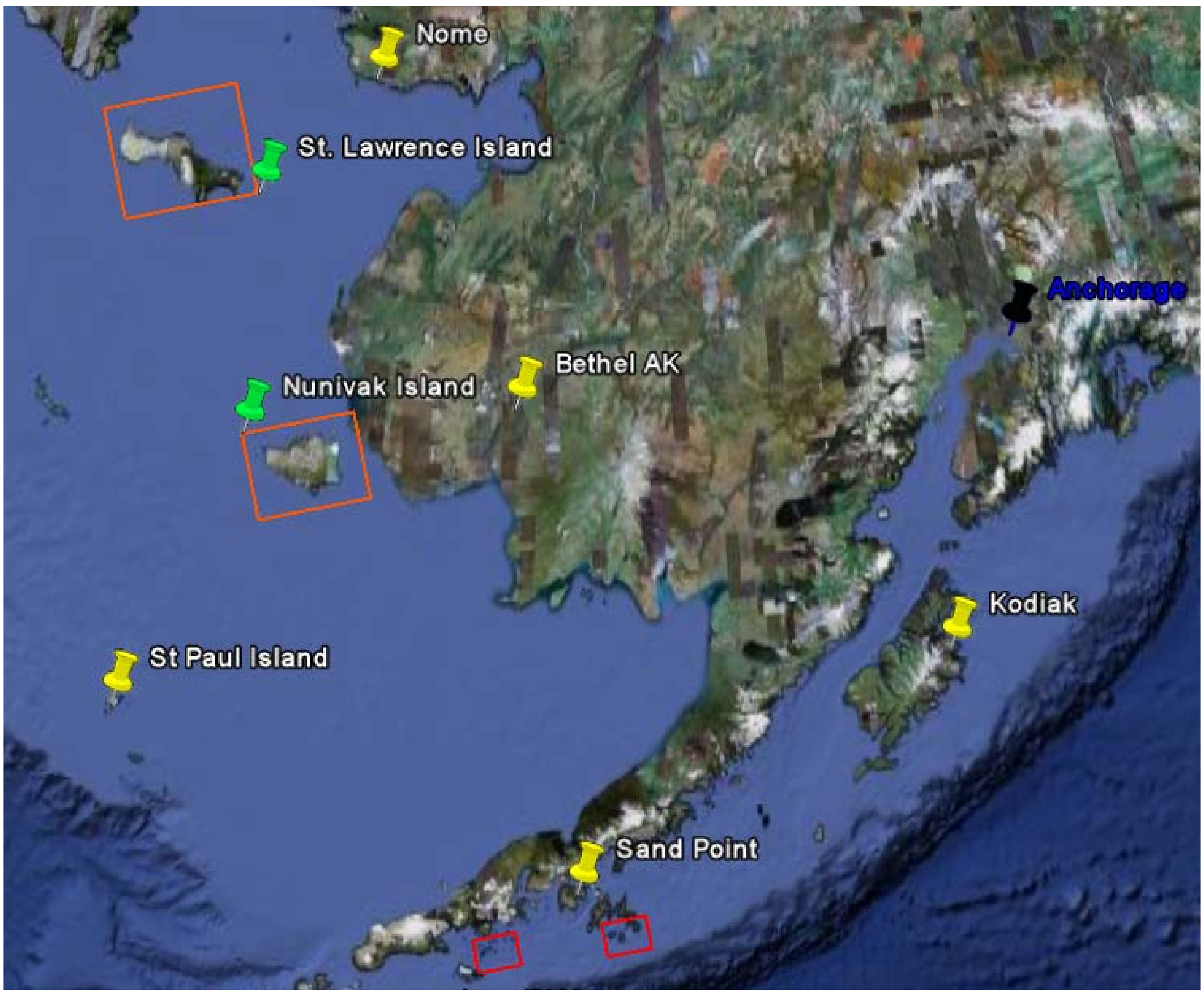

Figure 1 – General locality of Nunivak and St. Lawrence Islands in the Bering Sea. The main base of operations during 2009 was Sand Point, with refueling required at Nome following / during reconnaissance flights. Main project areas for 2009 are highlighted to the SE and SW of Sand Point

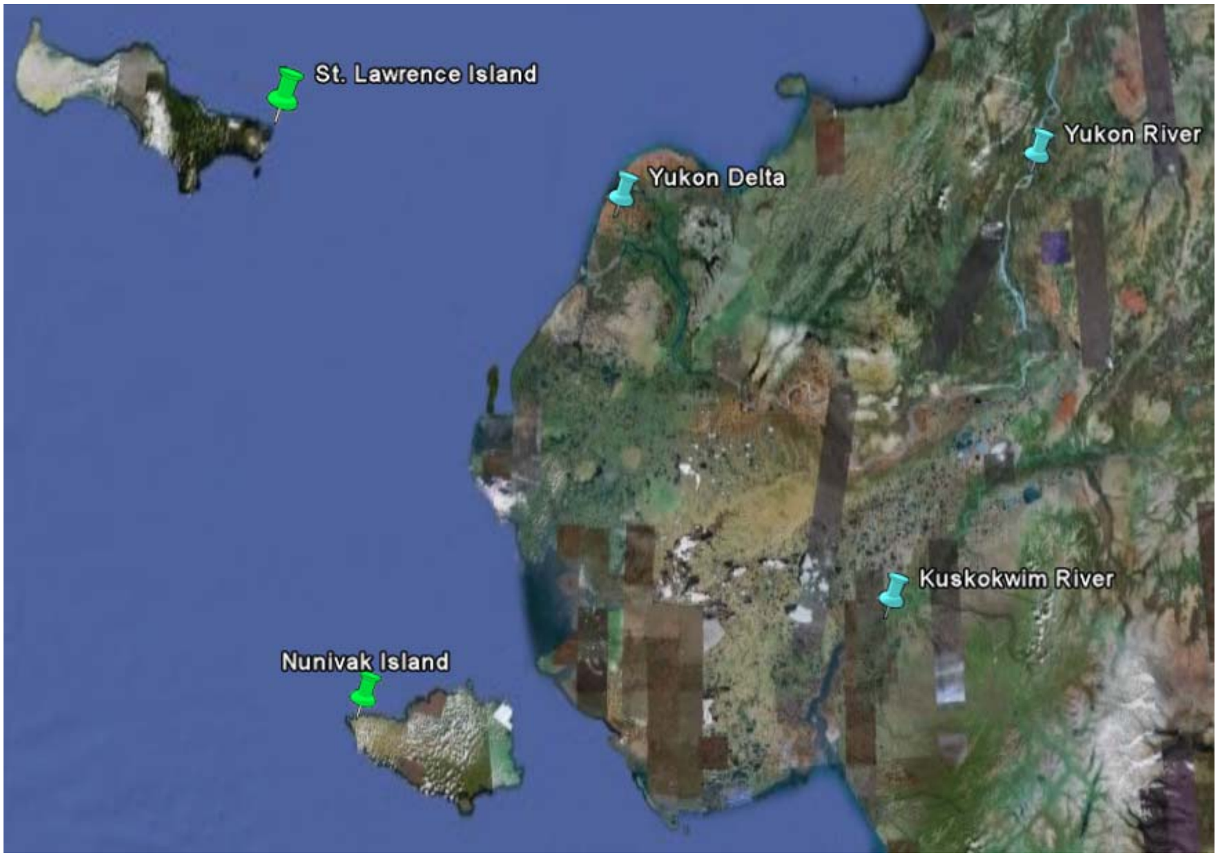

Figure 2 – Sub-Localities of Nunivak Island and St. Lawrence Island

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B. DATA ACQUISITION AND PROCESSING

B.1 EQUIPMENT

Data collection was conducted using the LADS Mk II Airborne System (AS), data processing using the LADS Mk II Ground System (GS), and data visualization using CARIS HIPS and SIPS 6.1 and CARIS BASE Editor 2.1.

B.1.1 Airborne System

The LADS Mk II AS platform consists of a De Havilland Dash 8-200 Series aircraft, which has a transit speed of 250kts at altitudes of up to 25,000ft, and an endurance of up to eight hours (refer to Photo 1). Survey operations are conducted from heights between 1,200 and 2,200ft, at ground speeds of between 140 and 210kts. The aircraft is fitted with an Nd: YAG laser, which is eye safe in accordance with ANSI Z136.1-2000, American National Standard for Safe Use of Lasers. The laser operates at 900 Hertz from a stabilized platform to provide a number of different spot spacings across the seabed.

Photo 1 – The LADS De Havilland Dash 8 survey platform

Green laser pulses are scanned beneath the aircraft in a rectilinear pattern. The pulses are reflected from the land, sea surface, within the water column and from the seabed. The height of the aircraft is determined by the infrared laser return, which is supplemented by the inertial height from the Attitude and Heading Reference System (AHRS) and a Global Positioning System (GPS) receiver. Real-time positioning is obtained by an Ashtech GG24 GPS receiver providing autonomous GPS, or is combined with WADGPS (Fugro Omnistar), to provide a differentially corrected position, when coverage is available. Ashtech Z12 GPS receivers are also provided as part of the AS and GS to log data on the aircraft and at a locally established GPS base station.

A digital camera installed on the LADS Mk II system platform allows high quality images to be captured in real-time. These images are georeferenced and can be overlaid with the processed survey data.

The reconnaissance survey lines were illuminated at 5x5m laser spot spacing, resulting in a 240m swath width. Blocks of reconnaissance lines were spaced at 220m, which provided 100% coverage where multiple adjacent lines were flown. For this survey, a 20m topographic height logging window was selected. As a result, the coastline was surveyed and elevations up to 20m were measured.

B.1.2 Ground System

Conversion of raw sounding data from the Airborne System to final data was accomplished on the new LADS processing system *hydra*. The GS supports survey planning, data processing, quality control and data export. The GS also includes Waypoint GrafNav software, which provides independent post-processed position and height data. Data processing was conducted in Sand Point, AK and data cleaning and visualization was completed in Biloxi, MS using the new GS.

B.2 VERTICAL CONTROL

No vertical control was established for this project as no tide requirements were specified in the Hydrographic Survey Project Instructions. No observed or predicted tide values were applied to the raw depth soundings acquired across the reconnaissance survey areas. The purpose of the reconnaissance was to ascertain general lidar depth capability in each area, not to provide final survey data to NOAA nautical charting standards.

B.3 HORIZONTAL CONTROL

Data collection and processing were conducted on the AS and GS in World Geodetic System (WGS84) on Universal Transverse Mercator (Northern Hemisphere) projection UTM (N) in Zone 2, Central Meridian 171° W (St. Lawrence Island) and Zone 3, Central Meridian 165° W (Nunivak Island). This data was post-processed and all soundings are positioned relative to the North American Datum 1983 (NAD83). All units are in meters.

B.3.1 CORS GPS Base Station – Bethel

Real-time positions were determined using an Ashtech GG24 GPS receiver on the aircraft, operating in autonomous GPS mode. Data from the CORS GPS Base Station at Bethel, AK were downloaded and processed against the airborne GPS data, using Waypoint GrafNav software, to provide more accurate KGPS positions following the reconnaissance survey flights. The post-processed KGPS positions were imported into the GS and applied to all soundings.

The NAD83 coordinates for the Bethel CORS GPS base station are:

NAD83		**UTM (N) Zone 3**		
Latitude (N)	**Longitude (W)**	**Easting (m)**	**Northing (m)**	**Ellipsoidal Height (m)**
60° 47' 16.5086"	161° 50' 30.1228"	671911.342	6743302.251	51.101

B.4 SEQUENCE OF EVENTS

The following events are relevant to the reconnaissance work conducted in the Bering Sea:

Date	Event
May 30 - July 30, 2009	Survey operations in support of OPR-P183-KRL-09 and OPR-P184-KRL-09, based out of Sand Point, AK.
July 31 - August 5, 2009	Very poor weather at Sand Point, main survey areas and reconnaissance areas – no flights conducted. Monitored current weather and forecasts for AK peninsula and Bering Sea.
August 5, 2009	Weather forecast for Bering Sea for next 2 days favorable. Flight planning completed for Sand Point – Nunivak Island – Nome for next day.
August 6, 2009	Conducted effective reconnaissance survey flight from Sand Point to Nunivak Island. Continued onto Nome and stayed overnight.
August 7, 2009	Weather report from St. Lawrence Island was 1200ft with descending cloud base. Dropped to 500ft by mid-morning. Reconnaissance flight cancelled. Stayed another night in Nome.
August 9, 2009	Weather report from St. Lawrence Island was 200ft cloud base. Weather report from Sand Point and main survey areas of clear skies. Refueled in Nome, transited to Sand Point, refueled again and conducted survey flight in support of P183 and P184. Nunivak Island reconnaissance data processed on GS.
August 9 - August 12, 2009	Survey operations to complete P183 and P184, based out of Sand Point.
August 13 – August 14, 2009	Poor weather reports and forecast for St. Lawrence Island. No flight conducted.
August 15, 2009	5000ft cloud base reported from St. Lawrence Island. Conducted mostly effective reconnaissance survey flight from Sand Point to St. Lawrence Island. Approximately 1/3 of island covered in low cloud throughout. Continued onto Nome, refueled and then transited back to Sand Point. St. Lawrence Island reconnaissance data processed on GS.
August 16, 2009	De-mobilization day.
August 17, 2009	LADS aircraft departed Sand Point.

C. ENVIRONMENTAL FACTORS

C.1 SEA CONDITIONS - SEA STATE, WAVES, SWELL, WHITE WATER

C.1.1 Nunivak Island

The sea state during the reconnaissance survey to Nunivak Island on August 6, 2009 ranged from 1 to 3. In general the sea state on the south side of the island was 2-3, and sea state 1 along the north coast. There was a 2m southerly swell along the south coast that could be directly attributed to strong southerly winds reported during the 4 days prior to the flight. This swell formed expansive lines of breaking waves along the southern sandy beaches of Nunivak Island (refer to Photo 2). There was considerable white water in these regions. Along the east, west, and north coasts of Nunivak Island there was minimal swell and white water around the generally rocky shoreline.

Photo 2 – Swell and surf along much of the south coast of Nunivak Island.

In some isolated regions along the south coast of Nunivak Island a sea state of 3 was observed, particularly where tidal currents, swell and wind coincided (refer to Photo 3).

Photo 3 - Sea state 3 east of Cape Mendenhall: swell, wind and tidal currents meet at the entrance to a large bay on the south coast of Nunivak Island.

C.1.2 St. Lawrence Island

Sea surface conditions at St. Lawrence Island were very calm during the reconnaissance flight conducted on August 15, 2009. In general the sea state was 1 with an underlying southerly swell of 0.5m (refer to Photo 4). No significant white water was observed along any of the coasts. In some isolated areas the absence of surface winds resulted in glassy seas, but this did not adversely affect the results of the reconnaissance survey.

Photo 4 – The calm before the storm: glassy seas visible inshore, in the vicinity of Siknik Cape, on the south coast of St. Lawrence Island, early in the reconnaissance flight.

C.2 WATER CLARITY

Water clarity was observed and noted in real-time during data acquisition and investigated more thoroughly on the Ground System following data processing of the reconnaissance data. Historically, the quality of water clarity observed during LADS Alaska surveys is conveyed as such:

- Very poor water clarity: little or no usable depth data collected.
- Poor water clarity: sparse, low amplitude laser returns between 5 and 10m depth.
- Marginal water clarity: slightly sparse, moderate amplitude returns to 15m depth.
- Good water clarity: full coverage, high amplitude returns to 20m depth.
- Very good water clarity: full coverage, high amplitude returns to 25m depth.
- Excellent water clarity: full coverage, depths exceeding 30m acquired.

C.2.1 Nunivak Island

The following general statements of Nunivak Island water clarity are true of conditions on August 6, 2009:

- NE coast, in the vicinity of Cape Manning – poor water clarity (no data acquired deeper than 5m).
- E coast – poor water clarity (no data acquired deeper than 5m). Refer to Photo 5.
- SE coast, in the vicinity of Cape Corwin – very poor water clarity (no usable depth data acquired).
- Shoaling to S of Cape Corwin – poor to marginal water clarity (noisy data to 10 - 15m depth acquired).
- Central S coast, in the vicinity of Cape Mendenhall – poor water clarity (no data acquired deeper than 5m).
- SW coast – poor water clarity (very noisy, sparse data to 5m depth acquired).
- W coast – very poor water clarity (very noisy data less than 5m depth acquired).
- NW coast, in the vicinity of Cape Mohican – poor water clarity (some noisy data 5-10m depth acquired).
- N coast, in the vicinity of Nash Harbor – marginal water clarity (some very sparse, low amplitude returns observed at 20m depth, noisy returns to 15m depth).
- Central N coast – marginal water clarity (cleaner data acquired to 15m depth).
- N coast, in the vicinity of Cape Etolin – marginal water clarity (data acquired to 15m depth, cleaner solid coverage in expansive shallow bays less than 10m depth).

Photo 5 – Visible by eye: extremely turbid water in the vicinity of Cape Corwin, Nunivak Island.

C.2.2 St. Lawrence Island

The following general statements of St. Lawrence Island water clarity are true of conditions on August 15, 2009:

- SE coast, in vicinity of SE Cape – poor to marginal water clarity (noisy data to 15m depth).
- Central S coast, in vicinity of Siknik Cape – poor water clarity (noisy data to 5m depth).
- Central S coast, in vicinity of Powoolliak Pt – poor water clarity (noisy beyond 10m depth, but good solid coverage from 5-10m depth).
- SW coast, in vicinity of Southwest Cape – poor water clarity (patchy data 5-10m depth).
- W coast – although a considerable proportion of this line was flown with low cloud below the aircraft, and little data acquired, what was observed during breaks in the cloud base was of poor to marginal quality (sparse, low amplitude returns around 15m depth).

- NW coast, in vicinity of Taphook Pt. – although some of this line was flown with low cloud below the aircraft, the laser was able to penetrate through some thinner layers in the cloud base and marginal water clarity was observed (solid data coverage to 15m depth).
- Central N coast, to the east of Savoonga – a line was attempted along this coast with a solid cloud base below and at aircraft altitude, with no data acquired.
- NE and E coasts could not be attempted due to thick cloud layers at operating altitudes (1200 – 2200ft) and the presence of high terrain.

C.3 KELP / SEAGRASS

The presence and extent of kelp and sea grass was difficult to ascertain from the 2 reconnaissance flights primarily due to:

- The limited number of lines flown in each area.
- Overcast conditions, resulting in little sea color variation between sandy seabed and kelp / sea grass areas in the digital imagery.
- Poor water clarity throughout the majority of areas, making differentiation between turbidity and kelp laser attenuation impossible.

Generally in Alaska, kelp is more localized along rocky coastlines, but expansive kelp / sea grass beds are sometimes observed around sandy areas, in depths generally less than 20m. One obvious area of localized kelp was along the rocky coastline of southwest St. Lawrence Island, in the vicinity of Southwest Cape.

C.4 HIGH GROUND AND CLOUD

C.4.1 Nunivak Island

The highest topographic point on Nunivak Island is Roberts Mountain at 1675ft, positioned almost in the centre of the island. There are some smaller peaks closer to the coast at elevations between 500 and 600ft. This was fortuitous, as LADS operates under a 500ft vertical clearance safety requirement and on August 6, 2009 the cloud base around Nunivak Island was generally between 1500 and 2000ft (refer to Photo 6). All reconnaissance lines had to be flown at the lowest operational altitude of 1200ft to keep out of the cloud. No laser dropouts attributed to low cloud occurred during this reconnaissance flight.

Photo 6 – Just high enough: cloud base at 1500 - 2000ft in vicinity of Cape Manning, Nunivak Island.

C.4.2 St. Lawrence Island

The highest topographic point on St. Lawrence Island is 2070ft, to the south of Savoonga. There are numerous peaks along some coastlines, some as high as 1600ft. Reconnaissance lines were planned to minimize proximity to the highest peaks. Initial weather reports on August 15, 2009 from 2 stations on the north coast of St. Lawrence Island indicated a stable 5000ft cloud base. However, following the transit from Sand Point it was apparent conditions had deteriorated rapidly, with isolated thin cloud layers below 1200ft along the south coast (refer to Photo 7) and solid cloud bases around high terrain along the west and north coasts (refer to Photo 8).

Photo 7 – Laser dropouts in cloud: operating at 1200ft with cloud base layers at 800ft and 1500ft in vicinity of Siknik Cape, on the central south coast of St. Lawrence Island.

Laser dropouts due to cloud below the aircraft were frequent and increased significantly as reconnaissance lines along the west and north coasts were conducted. A line flown to the east of Savoonga resulted in no data collected due to a solid cloud base below the aircraft. The reconnaissance flight was ultimately aborted early due to the deteriorating weather conditions, and concerns in operating safely around cloud obscured high terrain.

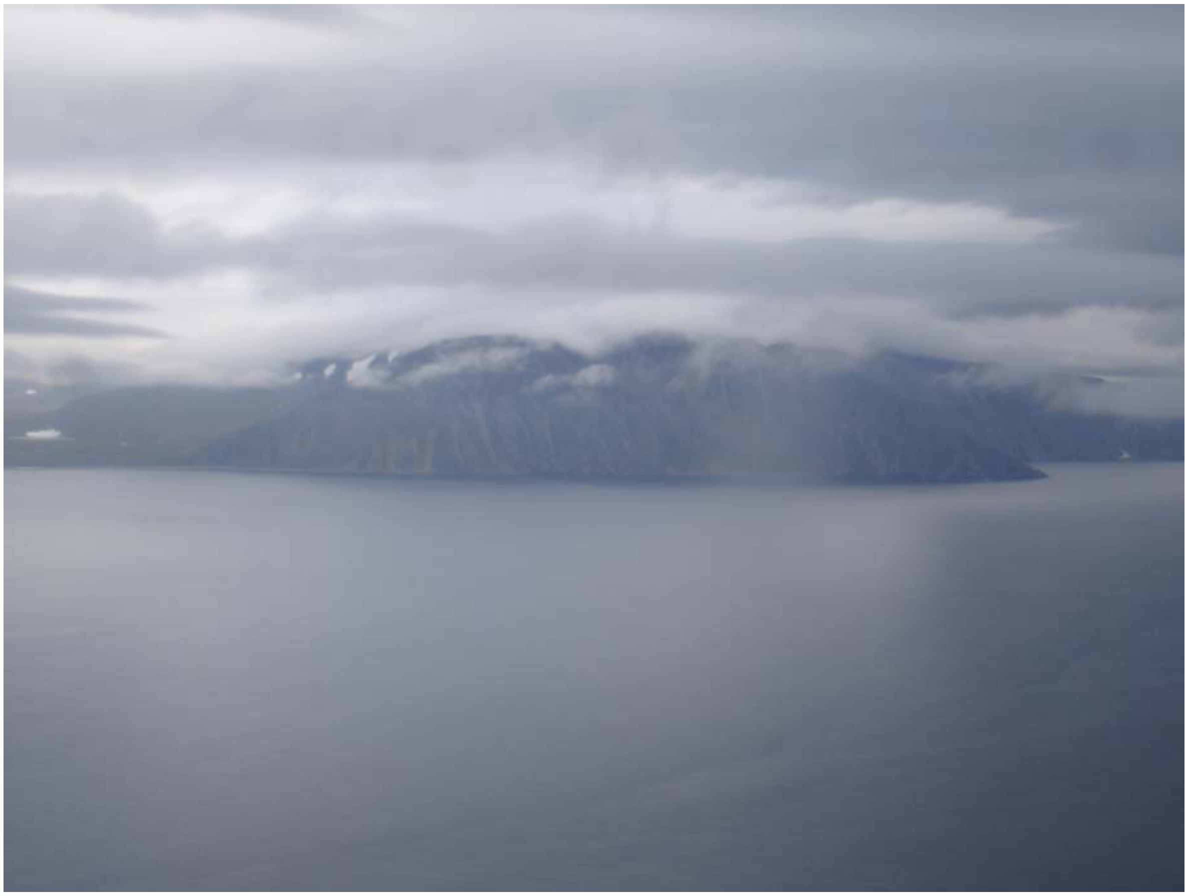


Photo 8 – Safety concerns with low cloud around high terrain: operating at 1200ft with solid cloud draped over the west coast of St. Lawrence Island.

D. RESULTS AND RECOMMENDATIONS

D.1 RESULTANT SEABED LIDAR COVERAGE

D.1.1 CARIS BASE Surface

A BASE surface covering each of the reconnaissance survey areas was created using CARIS to demonstrate resultant coverage. A grid resolution of 5m was used for the BASE surfaces. Grid resolution does not change relative to depth, as the laser pulse footprint stays relatively constant regardless of depth, and the laser spot spacing is constant irrespective of aircraft altitude. The 5m grid provides the largest amount of detail that can be supported by the lidar density (5x5m laser spot spacing). The BASE Surfaces are provided in addition to this report on a DVD.

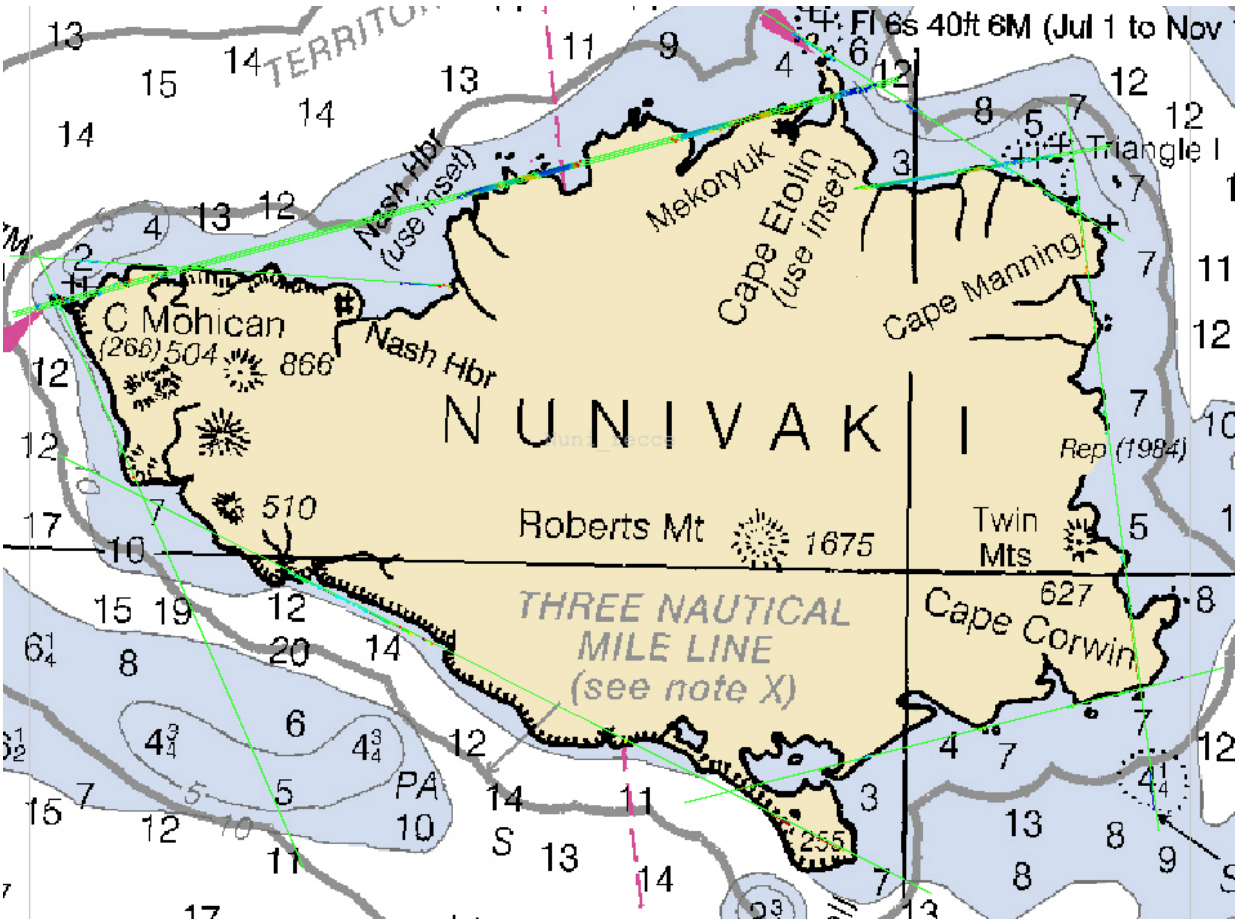


Figure 3 – CARIS BASE Surface image demonstrating limited lidar coverage and reconnaissance flight lines at Nunivak Island.

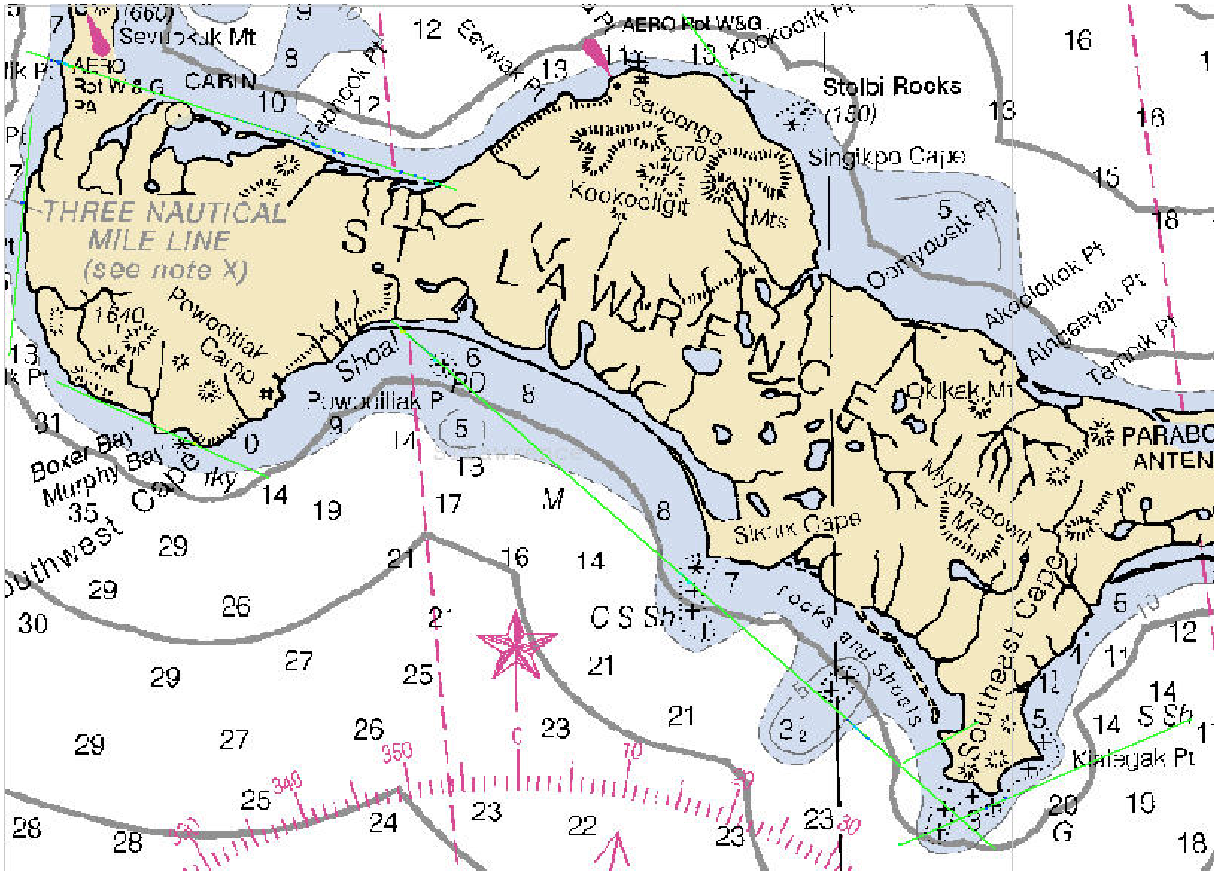


Figure 4 – CARIS BASE Surface image demonstrating limited lidar coverage and reconnaissance flight lines at St. Lawrence Island.

D.1.2 Nunivak Island

Due to poor water clarity along the east, south and west coasts of Nunivak Island, good lidar coverage was generally only achieved in very shallow water, typically between 5 and 10m depth. Water clarity improved along the north coast of Nunivak Island, with some marginal seabed coverage achieved. Upon completion of the priority reconnaissance lines an additional 3 lines were flown along the north and northeast coasts to demonstrate how areas of 100% lidar coverage would appear from this area (refer to Figure 5).

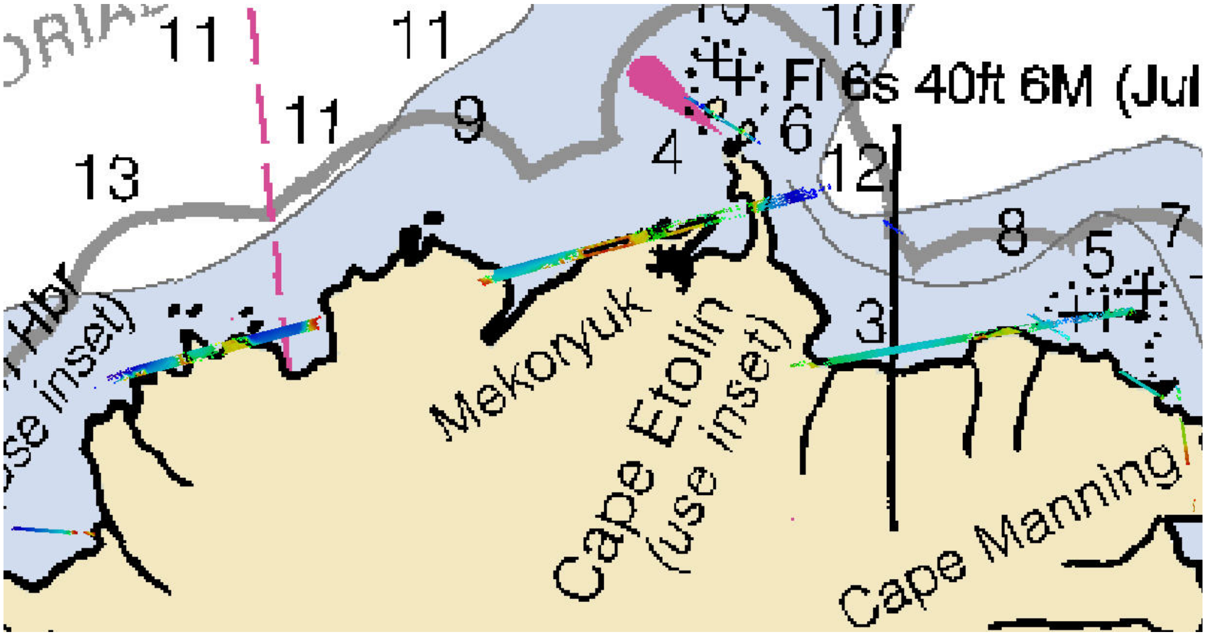


Figure 5 – CARIS BASE Surface image demonstrating lidar coverage from Nash Harbor to Cape Manning on Nunivak's north coast.

The area covered in flying the 3 lines along the northern section of coast resulted in lidar coverage approximately 650m wide. The figure below shows a sub-section of this area, to the NE of Nash Harbor, on Nunivak Island's central north coast.

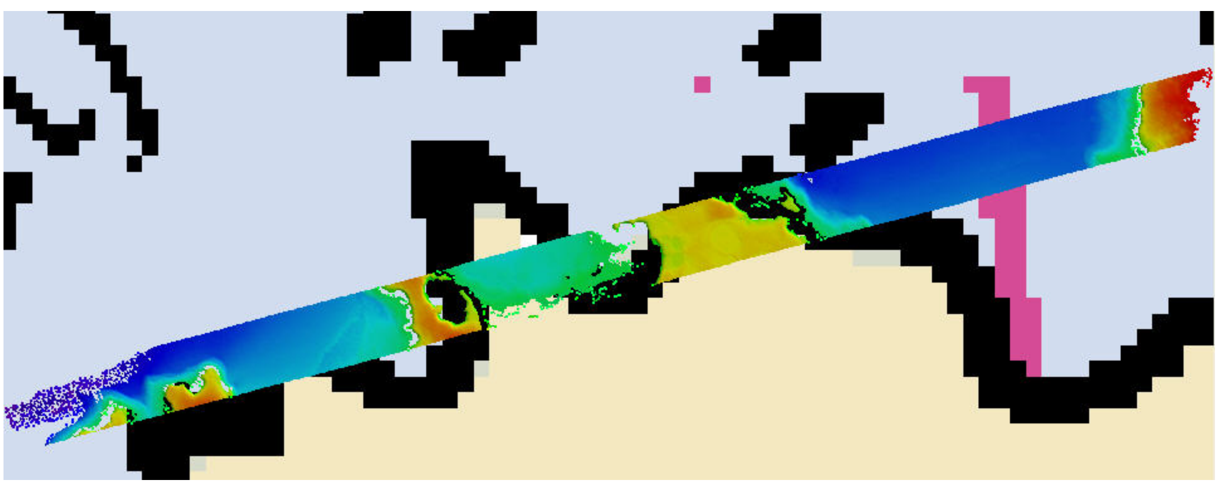


Figure 6 – Sub-section of CARIS BASE Surface image demonstrating lidar coverage to the NE of Nash Harbor, central north coast of Nunivak Island.

Lines flown in the vicinity of Cape Etolin also resulted in some good lidar coverage, particularly in the expansive shallow bays less than 10m depth (refer to Figure 7).

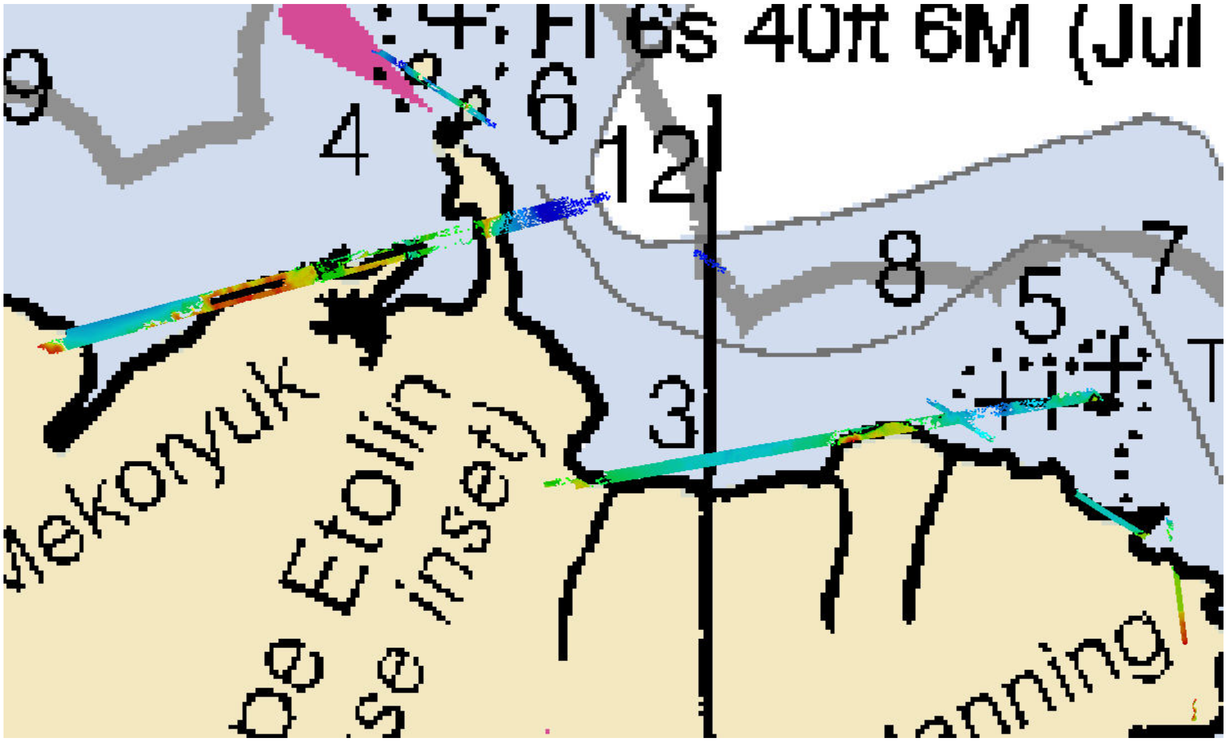


Figure 7 – Sub-section of CARIS BASE Surface image demonstrating lidar coverage from Cape Etolin to Cape Manning, northeast coast of Nunivak Island.

D.1.3 St. Lawrence Island

Due to poor to marginal water clarity along the south and west coasts of St. Lawrence Island, good lidar coverage was generally only achieved in shallow water, typically between 5 and 10m depth. Water clarity improved along the northwest coast of St. Lawrence Island, with some marginal seabed coverage achieved. Coverage in the vicinity of Taphook Pt. was generally solid to 15m depth. Where gaps and areas of attenuated returns existed, this was directly attributed to thin layers of cloud below the aircraft. Unfortunately, due to this increasing cloud base, lidar coverage was impossible to acquire on the NE coast of St. Lawrence Island, but similar water clarity conditions were expected to those along the NW shoreline.

D.2 NATURE OF THE COASTLINE

D.2.1 Coastal Morphology

D.2.1.1 Nunivak Island

The east coast of Nunivak Island is generally comprised of low lying rocky headlands and bays. There are numerous areas of intertidal rocky areas and offlying isolated drying rocks (refer to Photo 9). There are numerous muddy bays along the southeast coast of Nunivak Island. The central south coast of Nunivak Island is generally comprised of long sandy beaches and coastal sand dunes (refer to Photo 10).

Photo 9 – Low lying rocky coastline in vicinity of Cape Corwin, east coast of Nunivak Island

Photo 10 - Expansive sandy beaches along most of the south coast of Nunivak Island.

The morphology of the Nunivak Island shoreline changes dramatically along the West and North West coasts, where high vertical rock cliffs protrude out of the Bering Sea (refer to Photo 11).

Photo 11 - High vertical rock cliffs at Cape Mohican looking south: these cliffs extend along the northeast coast of Nunivak Island to Nash Harbor.

From west of Nash Harbor to Cape Manning, the shoreline of Nunivak Island is low lying, with sandy beaches and mud flats backed by tundra (refer to Photo 12).

Photo 12 – Low lying tundra at Cape Etolin: the township of Mekoryuk is in on the left.

D.2.1.2 St. Lawrence Island

The south coast of Nunivak Island is generally comprised of expansive beaches, broken by occasional large volcanic rock headlands (refer to Photo 13).

Photo 13 – the rocky Southeast Cape on St. Lawrence Island

The beaches along the St. Lawrence Island's south coast are generally very long and thin, with small dune formations before large estuaries and lakes (refer to Photo 14).

Photo 14 – long, thin, sandy beaches on St. Lawrence Island's central south coast.

The beaches on the central south coast are replaced by very high rock cliffs on the southwest and west coasts of St. Lawrence Island (refer to Photo 15). The high cliffs are home to thousands (if not hundreds of thousands) of small birds, that posed a significant safety risk when they decided to get a closer look at the LADS Dash 8 aircraft. The line flown along the SW coast was aborted early due to the high probability of a bird strike.

Photo 15 – high rock cliffs along Southwest Cape on St. Lawrence Island.

Unfortunately, due to the expansive cloud layers on the north coast of St. Lawrence Island, there was very limited visibility and no further comments on the shoreline morphology are possible.

D.2.2 Georeferenced Imagery

Digital imagery was captured during each reconnaissance sortie. The images were combined to produce georeferenced mosaics of the reconnaissance areas to demonstrate costal morphology, flight lines conducted and areas where low cloud limited or prevented data acquisition. The mosaics are provided in addition to this report on a DVD.

D.3 DELIVERABLES

Additional results for the reconnaissance survey are submitted separately to this Reconnaissance Report as the CARIS BASE Surfaces, and georeferenced imagery mosaics from each flight.

D.4 RECOMMENDATIONS

Water clarity and weather are typically the greatest limiting factors to a successful airborne bathymetric lidar survey, particularly in Alaska. In the case of operations in the Bering Sea, the limitations imposed by the presence of sea ice and limited daylight hours are also pertinent. A comprehensive weather study has been compiled as part of this reconnaissance report and is provided at Appendix I.

D.4.1 Sea Ice

Sea ice is present in the Bering Sea from January to May each year and extends south of St. Lawrence and Nunivak Islands (refer to Figure 8). Lidar operations would not be possible until the survey area was free from sea ice.

D.4.2 Daylight Hours

Lidar operations are restricted to daylight hours in Alaska due to presence of high terrain. This is applicable to Nunivak and St. Lawrence Islands, where terrain above 1000ft exists on both islands. There is sufficient daylight between the months of March and October to conduct daylight operations.

D.4.3 Water Clarity

After observing the morphology of the reconnaissance areas, analyzing the data acquired from the reconnaissance flights in August 2009 and conducting substantial research into river discharges, Bering Sea surface circulation, and weather patterns it is believed:

- Water clarity at Nunivak Island is influenced by localized weather conditions, such as southerly winds driving large southerly swell onto the south coast beaches.
- Water clarity at Nunivak Island is also susceptible to suspended sediments created along the main Alaska coastline by localized swell conditions.
- Water clarity at Nunivak Island is influenced by the discharge of large volumes of sediment rich water from the Kuskokwim River. Although this river is a considerable distance to the east of Nunivak Island, the volume discharged and general surface circulation westward and northwestward in this region means that there is a likely impact on water clarity (refer to Figure 8). Maximum discharge from the Kuskowim River occurs in the months of May and June, following the major annual snow melt.
- Water clarity at St. Lawrence Island is influenced by localized weather conditions, such as southerly winds driving large southerly swell onto the south coast beaches.
- Water clarity at St. Lawrence Island may also be influenced by the discharge of large volumes of sediment rich water from the Yukon and Kuskokwim Rivers. Although these rivers are a considerable distance to the east and southeast of St. Lawrence Island, the volume discharged and general surface circulation northward and northwestward in this region means that there is likely impact on water clarity (refer to Figure 8). Maximum discharge from the Yukon River occurs in the months of June and July, following the major annual snow melt.

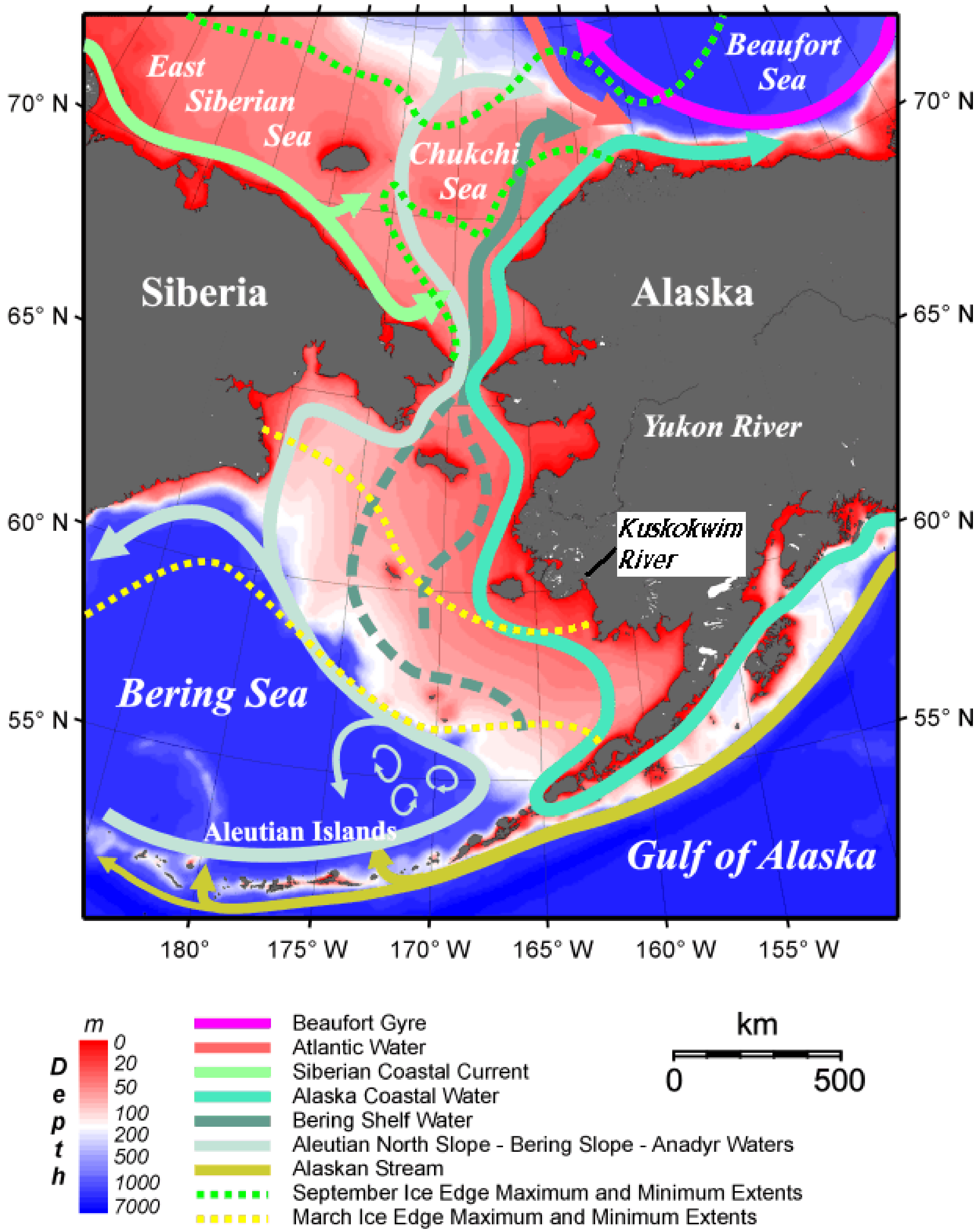


Figure 8 – Bering Sea surface circulation and March sea ice edge

D.4.4 Weather

The observed daily weather records for Mekoryuk, on Nunivak Island's north coast, were compiled for the past 12 years and analyzed with respect to LADS operational requirements. Each day's records, for the months of May, June, July, August, September and October were scrutinized for wind strength and cloud base. If winds exceeded 25 knots for most of the day it was attributed as a "no fly day", due the high likelihood of significant sea state and turbulence. If the cloud base was below 1500ft for most of the day it was attributed as a no fly day, due to the high likelihood of laser dropouts. However, if the cloud base was mostly above 1500ft and winds were below 25 knots, the day was attributed as a "fly day". Some of the records were incomplete and where data was not present for a particular month, this month was not used in the derivation of statistics. The final results for the 12 years of potential "fly days" per month are presented in the table below:

MONTH	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**TOTAL**
MIN	6	9	4	3	6	9	45
MAX	16	18	14	21	20	18	82
MEAN	**10**	**14**	**9**	**10**	**12**	**13**	**61**

Table 1 – Number of potential "fly days" at Nunivak Island for each month between 1998 and 2009

Realistically, lidar operations would not be fully effective on every potential fly day due to poor water clarity caused by prolonged bad weather. Historically, survey flights in Alaska have not been fully effective until 1-3 days following severe weather. Lidar surveys can also be affected adversely by weather that is "too good", when the absence of any surface winds can result in glassy seas and limited shallow water coverage.

Taking into consideration the necessity to wait for water clarity to improve following severe weather and estimated 2-3 days of glassy sea conditions each month, one could expect the following productivity at Nunivak Island and St. Lawrence Island for each month of the year:

January – lidar operations not possible due to build up of sea ice and very limited daylight.

February – lidar operations not possible due to presence of sea ice and limited daylight.

March – lidar operations not possible due to presence of sea ice.

April - lidar operations not possible due to presence of sea ice.

May - lidar operations may not be possible due to presence of sea ice.

June – lidar operations may be impacted due to turbidity caused by maximum river discharge following annual snow melt.

July – lidar operations possible at Nunivak Island – less than 5 effective flights estimated for July due to historical weather records and typical Kuskokwim River discharge. Lidar operations at St. Lawrence Island may be impacted due to turbidity caused by Yukon River discharge.

August – lidar operations possible at Nunivak Island and St. Lawrence Island – 5 effective flights estimated in the month.

September – optimal month for lidar operations considering weather, river discharge and daylight hours – 7 effective flights estimated in the month.

October – lidar operations possible at Nunivak Island and St. Lawrence Island – 6 effective flights estimated in the month, considering more limited daylight hours.

November - lidar operations not possible due to limited daylight.

December - lidar operations not possible due to very limited daylight.

D.4.5 Discussion

It is considered that the timing of the reconnaissance flights to Nunivak and St. Lawrence Islands was ideal during the LADS 2009 summer survey season. There were few days during June and July, 2009 when weather conditions were suitable to conduct the reconnaissance surveys in the Bering Sea. Generally on those days, conditions were favorable for operations in the main survey areas in the Shumagin and Pavlof Islands. Had the flights to the Bering Sea been conducted during these months it would have been highly likely that little or no data would have been collected due to the prolonged severe weather, and maximum annual Kuskokwim and Yukon River discharges. Executing the flights in August meant that there was a reasonable chance of success. While the water clarity and resultant seabed lidar coverage was far from ideal, both flights followed long periods of adverse weather and very good water clarity was not anticipated.

It is LADS' experience conducting lidar operations in Alaska over the past 7 summers, under contract to NOAA, that ALB surveys can be effective, but it is always a challenge. Potential operations in the Bering Sea will pose an even greater test of the system's capabilities. The success of a lidar survey at Nunivak and / or St. Lawrence Island will be a direct result of the environmental conditions over the survey period. From a logistics perspective, the work could certainly be conducted successfully from Bethel, Dillingham or Nome. The airport infrastructure is in place to support a lidar survey platform such as the LADS aircraft. From any of these airports, transit distance to and from the potential project areas is a consideration, and long aircraft endurance would be a necessity for effective time on task spent during those few days each month where environmental conditions are just right.

It is apparent that a shallow water lidar survey of Nunivak and St. Lawrence Islands would be advantageous to NOAA prior to multibeam junctioning. Both islands are extremely large and would take many seasons to complete by both airborne and surface platforms. There are significant risks to surface vessels in the vicinity of both island's coastlines that would best be defined safely by lidar, prior to ship junctioning. There are also expansive shallow areas along each island that would be more efficiently surveyed by lidar than multibeam, when the water clarity conditions are suitable.

However, water clarity could prove to be poor the majority of the time, or similar to most Alaska lidar survey areas – highly variable. There could be localized water clarity variability, like that observed at both Nunivak and St. Lawrence Islands, where no depth data can be acquired along one coast, but solid coverage to 15m is attainable along another.

D.4.6 Conclusion

A potential lidar survey at St. Lawrence Island is considered very high risk. The impact of the Yukon River on water clarity, typical weather conditions in the region and presence of high terrain along many of the coastlines are considered significant limitations. A cloud base above 2000ft would be required to complete many of the areas along the St. Lawrence Island coastline. The considerable transit distance from the Alaska mainland to St. Lawrence Island also means that flights aborted due to weather or water clarity, would result in higher operational costs and impact on pilot flying hours.

A potential lidar survey at Nunivak Island is considered high risk. There is a little more room to operate here, due to the ability to fly at the lowest operational altitude of 1200ft over all coastlines. The typical weather conditions are considered similar to St. Lawrence Island, but flights could be conducted in marginal conditions, such as a cloud base of 1500ft. Operations may be most effective during the months of August, September and October, minimizing the impacts of poor weather and water clarity. However, operations in June and July may still be possible dependent on the weather at the time and the availability of alternative areas.

In order to effectively manage poor water clarity, it would be advisable to establish a number of potential lidar survey areas around all coasts (alternates), instead of the typical sheet specific area limits, so that the most suitable areas are surveyed on the optimal day. Registered NOAA sheets could be established following data acquisition, based on the resultant lidar seabed coverage achieved for each “area of opportunity” surveyed. The work could be priced under an “effective time on task” or “effective sorties conducted” basis, in lieu of a “survey until a specific area is complete” approach.

It is highly advisable that any lidar survey defined for the Bering Sea be conducted in conjunction with other project areas elsewhere in Alaska, such as Kodiak, or the southeast, in order to effectively manage weather and water clarity at each project location. This would in turn increase the average “flights per week” project pricing estimate. For example, a single project area at Nunivak Island would result in an estimate of less than 2 effective flights per week and a high cost per flight based on the duration required to complete the work. However, shared across one or more alternate AK project areas, the average flights per week calculation could be estimated at more than 2, resulting in a more cost-effective lidar survey season.

E. APPROVAL SHEET

LETTER OF APPROVAL
NUNIVAK AND ST. LAWRENCE ISLANDS RECONNAISANCE SURVEY

This report and the accompanying LADS survey deliverables are respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying LADS survey deliverables have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Report	Submission Date
Alaska Reconnaissance Report 2009	October 6, 2009

Mark Sinclair
Hydrographer
Fugro LADS, Incorporated

Date: October 6, 2009

APPENDIX I

Nunivak Island and Yukon Delta Weather Study

Prepared by Jeff Young: October 2, 2009

The purpose of this study is to determine the optimal timing for airborne lidar operations in the vicinity of Nunivak Island, Alaska, with respect to environmental constraints. The environmental constraints considered are river discharge and sea surface circulation (water clarity impact), wind strength, ice, daylight, and cloud base. The majority of the data was accumulated from a website (seen below) with the airport code being PAMY, also known as the town of Mekoryuk, AK.

http://www.wunderground.com/history/airport/PAMY

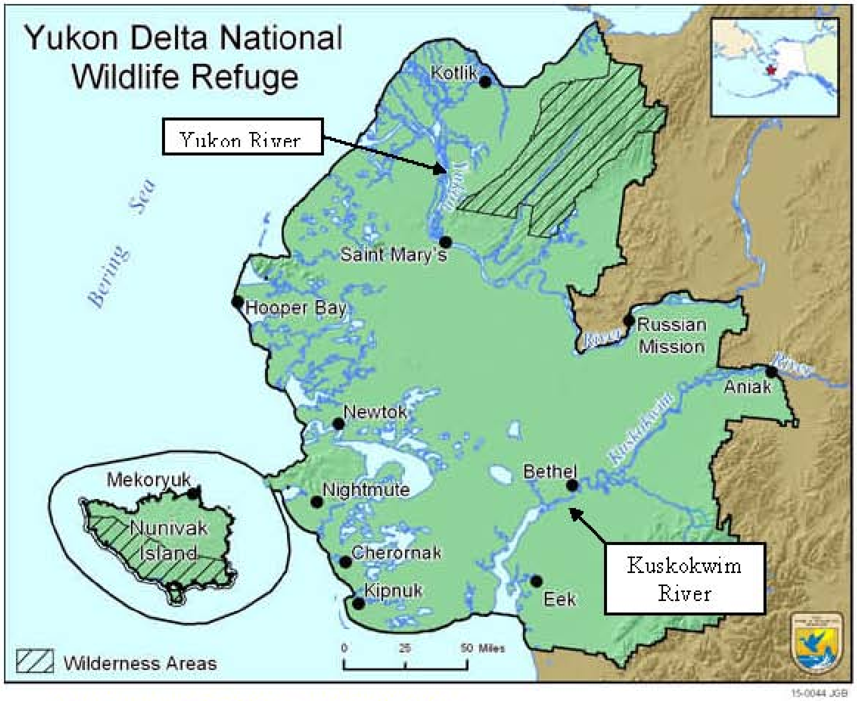
Study Area:

A 19.6 million acre wildlife refuge, The Yukon Delta National Wildlife Refuge, was created in 1909 by President Theodore Roosevelt. This area is home to about 35 villages and 25,000 people, many of Yup'ik Eskimo origin and dependent on a subsistence lifestyle. Most of the refuge is a vast, flat wetland/tundra complex dotted by countless ponds, lakes, and meandering rivers. Approximately half of the refuge is covered by water, with innumerable ponds, lakes, and sloughs. Flooding of riverine and lowland areas is common, particularly in spring. The refuge's extensive tidal wetlands are scarcely above sea level and are frequently inundated by Bering Sea tides.

Nunivak Island is included within the Refuge (see Figure 1). The million-plus acre Nunivak Island lies 20 miles off the coast and is of volcanic origin, with several peaks from 1,000 to 1,600 feet. Coastal bluffs range from 100 to 450 feet high. Sandy beaches along the southern coast merge into active sand dunes greater than 100 feet in height. These dunes are particularly susceptible to erosion because protective foredunes and extensive beaches are absent.

Nunivak Island and Yukon Delta Weather Study

Figure 1 - The Yukon River Delta, Alaska



http://www.pixdatabase.com/photo/4019/

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Nunivak Island and Yukon Delta Weather Study

River Discharge:

Analysis of discharge from rivers adjacent to Nunivak Island was considered necessary to understand possible water clarity impacts on lidar operations. The Yukon and Kuskokwim rivers traverse thousands of miles to form a massive delta, known as the Y – K Delta or the Yukon Delta. The delta has an area of 5,280 sq. km and protrudes into the Bering Sea.

Much of the delta plain is inactive and active deposition takes place mostly at the aforementioned active river mouths. Along the shoreline are ice-pushed beach ridges that contain a large volume of woody debris in the form of large logs. For some 180 days, the entire delta plain is frozen solid and permafrost occurs almost throughout the delta.

The Yukon River drainage basin covers some 829,700 sq. km and the river flows some 3,219 km west where it empties into the Bering Sea. The Kuskokwim drainage basin is roughly 1/8 the size of the Yukon and sits at 124,320 sq. km. The length and discharge of the Kuskokwim is considerably less then the Yukon River. The length of the Kuskokwim, from source to mouth, is 1,165 km and the average discharge is 1,897 cubic meters per second. Nonetheless, the Kuskokwim puts forth significant discharge into the Bering Sea. The average discharge of the Yukon River is 6,115 cu m/sec (1 cubic meter per second converts to 1000 liters per second) with a maximum of 12,988 cu m/sec and a minimum of 895 cu m/sec. Discharge peaks in May/June/July, following thawing in the basin and declines over the next few months until November when the basin again freezes. During the winter months, discharge averages less than a 1,000 cu m/sec. Mostly all of this discharge is naturally occurring as there is very little, if any, human industrial development near the delta. For discharge statistics in monthly increments, refer to Table 1 and Table 2, and also Graph 1 and Graph 2.

Nunivak Island and Yukon Delta Weather Study

Table 1 – Monthly Discharge Stats for Yukon River at Pilot Station, AK
Discharge data presented in cubic feet per second.

YEAR	Monthly mean in cfs (Calculation Period: 2001-04-01 -> 2008-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001				47,530	204,500	796,400	537,100	440,900	373,300	201,300	96,170	60,650
2002	51,520	45,790	40,770	39,030	399,100	544,000	344,000	315,200	377,900	294,600	211,800	83,870
2003	64,520	55,790	50,680	48,430	335,200	482,600	389,000	390,600	420,300	231,800	107,400	72,760
2004	59,020	51,220	47,470	49,020	399,000	600,400	378,600	312,500	226,700	150,600	107,700	62,000
2005	48,470	42,950	41,480	58,970	784,400	656,900	424,500	332,300	328,800	344,900	154,100	87,740
2006	71,450	53,390	48,550	45,900	352,000	570,100	498,100	390,100	397,600	300,200	152,400	60,520
2007	47,000	42,570	39,400	44,030	339,800	401,000	366,400	411,500	344,200	282,700	143,200	81,580
2008	63,290	51,810	43,670	40,880	367,700	509,000	408,000	444,500	334,200			
Mean of monthly Discharge	57,900	49,100	44,600	46,700	398,000	570,000	418,000	380,000	350,000	258,000	139,000	72,700

* Table 1 Data compiled from www.waterdata.usgs.gov

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Nunivak Island and Yukon Delta Weather Study

Table 2 – Monthly Discharge Stats for Kuskokwim River at Crooked Creek, AK
Discharge data presented in cubic feet per second.

YEAR	Monthly mean in cfs (Calculation Period: 1998-01-01 -> 2008-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	11,480	10,410	9,306	29,550	69,600	87,830	106,400	104,100	86,220	50,960	22,050	12,130
1999	10,060	9,179	8,323	9,900	93,190	96,530	76,430	91,020	58,450	48,710	20,000	13,130
2000	10,840	9,938	9,697	20,700	85,720	60,120	60,280	68,480	73,020	44,980	25,600	19,030
2001	14,350	11,540	9,984	13,080	78,060	100,900	74,070	87,510	58,970	38,940	21,800	13,190
2002	10,040	9,136	8,542	8,637	104,300	84,500	52,970	53,630	58,730	61,610	43,110	31,100
2003	23,030	19,110	15,610	28,700	70,180	68,770	76,750	88,850	51,710	61,010	31,340	14,650
2004	12,650	11,860	11,000	47,570	89,210	70,730	57,880	47,030	29,770	40,630	23,520	18,190
2005	15,160	13,390	12,060	15,480	148,900	71,000	58,930	46,330	72,900	53,670	20,250	13,920
2006	12,180	11,500	11,320	11,030	75,690	72,650	62,610	86,560	60,390	73,510	24,560	14,920
2007	10,850	9,321	8,903	27,960	54,760	43,660	59,100	74,290	65,720	53,430	28,530	21,890
2008	16,010	11,920	10,460	9,777	90,280	73,030	76,540	50,450	45,920			
Mean of monthly Discharge	13,300	11,600	10,500	20,200	**87,300**	**75,400**	**69,300**	**72,600**	**60,200**	**52,700**	26,100	17,200

* Table 2 Data compiled from www.waterdata.usgs.gov

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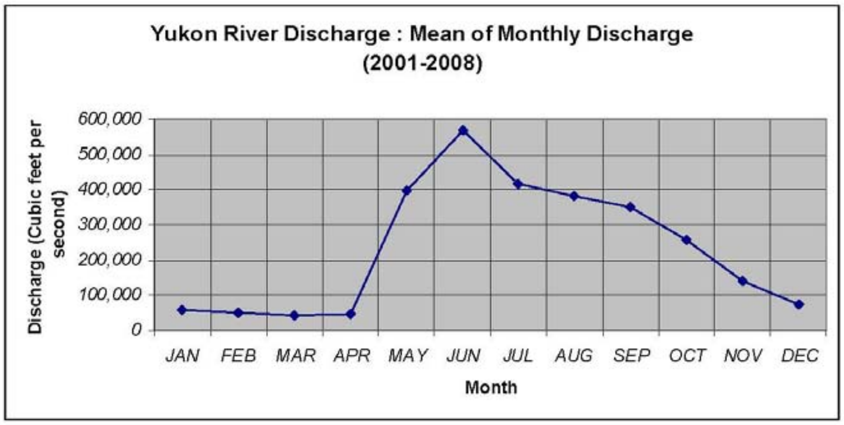
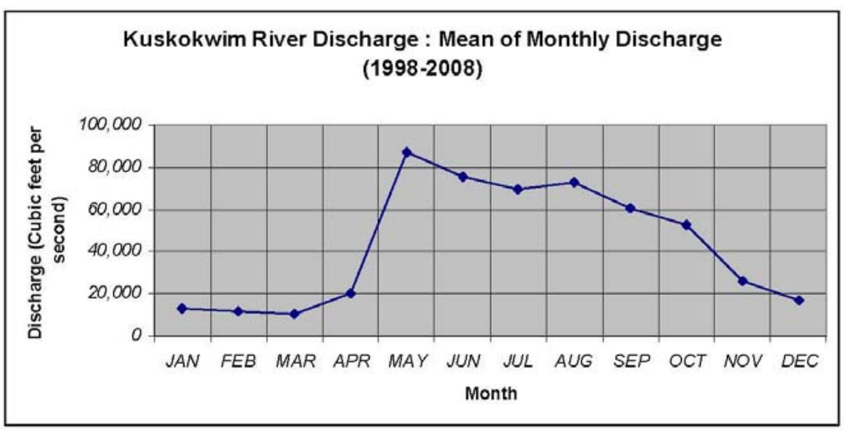
Nunivak Island and Yukon Delta Weather Study

Graph 1 – Yukon River - Mean of Monthly Discharge



Graph 2 – Kuskokwim River - Mean of Monthly Discharge



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Nunivak Island and Yukon Delta Weather Study

Sea Surface Circulation:

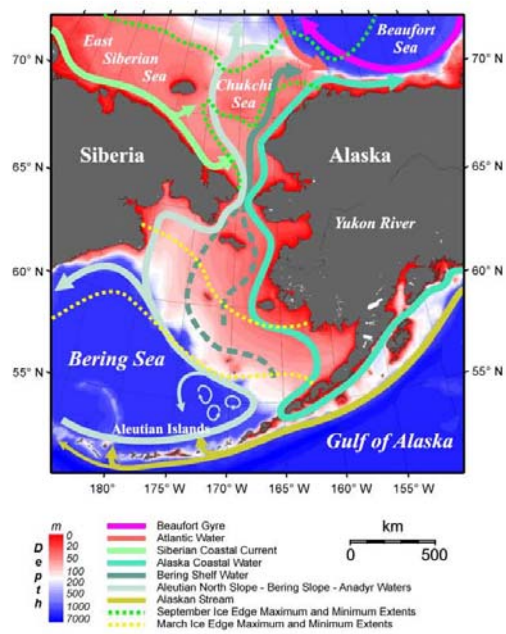
Analysis of Bering Sea surface circulation in the vicinity of Nunivak Island was considered necessary to understand possible water clarity impacts from adjacent rivers on lidar operations. Throughout the last decade, various teams of scientists have used satellite tracked oceanic drifters to compile data in the Bering Sea. The focus of the drifter studies in the Bering Sea has been on the nearshore circulation. These drifters provide an informative (and nearly real-time) depiction of surface circulation that complements other measurements collected by shipboard sampling, instrumented moorings, and numerical models. The circulation data has been utilized to better understand the ocean currents in these poorly sampled coastal regions. This project is ongoing and is being researched and supported by various organizations including; NOAA, Arctic Yukon-Kuskokwim Sustainable Salmon Initiative, North Pacific Research Board, and the Institute of Marine Science at the University of Alaska-Fairbanks. The research and the figures have been referenced using the following links:

http://mather.sfos.uaf.edu/drifters/Yukondrifters/index.html

http://www.ims.uaf.edu/NPRBdrifters/

http://mather.sfos.uaf.edu/drifters/

Figure 2 – Sea Surface Circulation and Ice Edge



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Nunivak Island and Yukon Delta Weather Study

Wind:

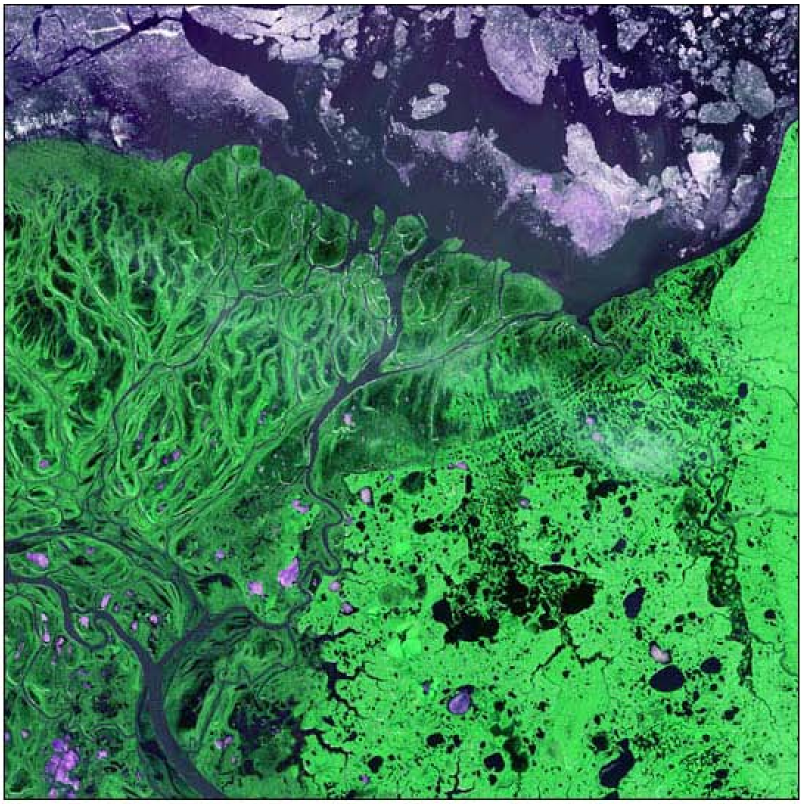
The Bering Sea is recognized as one of the harshest bodies of water in the world. Arctic hurricanes are not uncommon. Predominant wind direction was analyzed as part of this study to ascertain if there may be localized affects on water clarity, but there was no evidence of a typical trend. Wind strengths above 25 mph are considered too high for lidar operations, due to the corresponding sea state and possible turbulence. The predominant wind direction could be from the north, south, east or west on any given day and also could vary throughout a day. Certainly, a major storm may move in from a certain direction which would limit flying for 5 - 10 days, but a favorable weather pattern may prevail and provide good flying weather for 5 -10 days.

Ice:

May, June, July, August, September, and October were chosen for this study. This is mainly due to the fact that Nunivak Island has major ice flow through to May and high ice-melt in June (refer to Figure 3). Also of note, October will provide much colder weather with potential of temperatures reaching below the freezing point. This coupled with high winds can lead to tricky conditions for lidar operations.

Nunivak Island and Yukon Delta Weather Study

Figure 3 – Yukon River Delta, Alaska



An intricate maze of small lakes and waterways define the Yukon Delta at the confluence of Alaska's Yukon and Kuskokwim Rivers with the frigid Bering Sea. Wildlife abounds on the delta and offshore where sheets of sea ice form during the coldest months of the year.

This scene was acquired by the ASTER instrument on NASA's Terra satellite on May 26, 2002.

http://earthobservatory.nasa.gov/IOTD/view.php?id=4761

Nunivak Island and Yukon Delta Weather Study

Daylight:

April through October would allow a solid block of time where enough daylight exists to conduct survey operations. However, by the end of October, daylight hours are only around ten hours per day. In October, one can see that if weather conditions were not good in the morning, it could be much more difficult to attempt a full-length survey flight.

Analysis of Nunivak Island Daily Weather Data:

A variety of factors were chosen to assess if a sortie could be conducted on a given day. The three main climatic factors determining a "fly day" at Nunivak Island are as follows;

1) A cloud base at or above 1,500 ft.
2) Wind speeds under 25 mph
3) The cloud base and wind speed criteria had to exceed an 8 hour period, within that particular day's daylight window.

If any particular day's observations failed to meet these criteria, the day was considered as a "no fly day". In some instances, the website provided no data for a certain day, or limited data, with observations too far apart to interpolate accurately. These were considered "no data days", were totaled for each month, but not used in the generation of important statistics.

Other Sources:

http://yukondelta.fws.gov/wildlands.htm
http://www.geol.lsu.edu/WDD/N_AMERICAN/Yukon/yukon.htm
http://pubs.usgs.gov/of/1987/ofr87-242/

Nunivak Island and Yukon Delta Weather Study

The number of potential fly days, based on predominant weather, were totaled for each month within the study window, and minimum, maximum and mean statistics compiled. A total of potential fly days were also calculated for the 6 month study period of each year. Provided below is Table 3, which gives a thorough representation of the analysis. Refer to Appendix 1 for more specifics on yearly and monthly statistical totals

Table 3: Monthly Number of fly days by Year
(Number of no data days in Parentheses).

YEAR	MAY	JUNE	JULY	AUGUST	SEPT	OCT	TOTAL
1998	3 (10)	14	10	11	12	16	63
1999	13	12 (3)	5	7	11	15	51
2000	14 (3)	14 (9)	14	4 (19)	13	13	72 +
2001	10	9	5	3	15	11	53
2002	8	18	12	21	13	10	82
2003	16	13	10	11	20	7 (3)	77 +
2004	10	16	4	15	16	11	72
2005	15 (3)	18	9	6	6	6 (14)	60 +
2006	5 (19)	0 (27)	3 (9)	10 (7)	7 (5)	11 (10)	N/A
2007	6	9	7	8	6	9	45
2008	6	14	11	10	7 (8)	18	66 +
2009	13	12	9	8 (2)	7	N/A	N/A
* MEAN	10	14	9	10	12	13	61
* MIN	6	9	4	3	6	9	45
* MAX	16	18	14	21	20	18	82

* Mean, minimum and maximum value excludes days with incomplete records (no data days)

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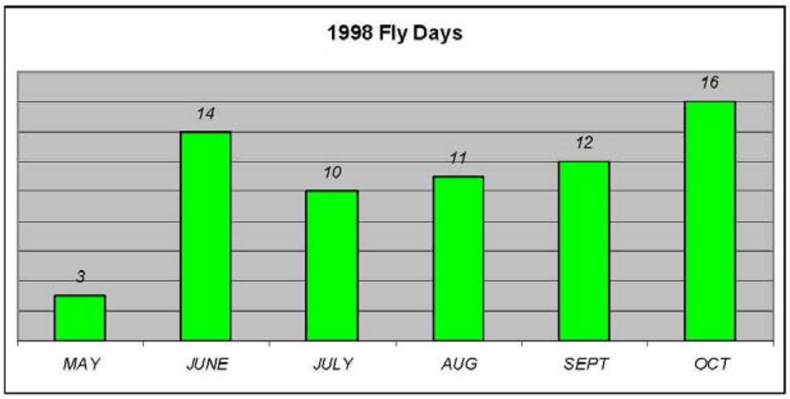
Nunivak Island and Yukon Delta Weather Study

APPENDIX 1 – Fly Days vs. No Fly Days (1998-2009)

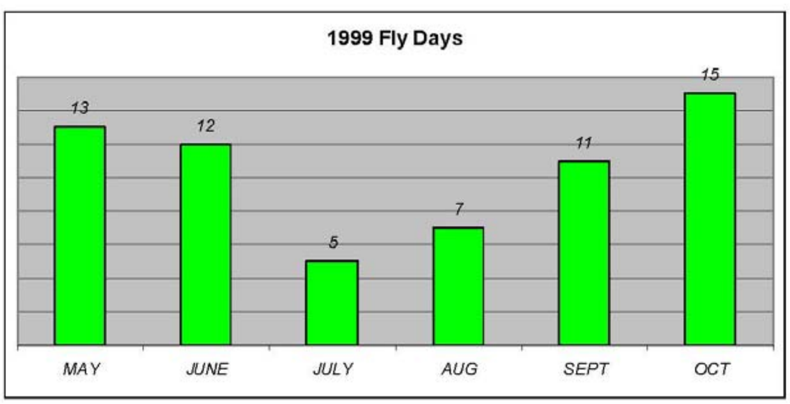
1998

FLY DAYS	66	38%
NO FLY DAYS	108	62%
NO DATA DAYS	10	



1999

FLY DAYS	63	35%
NO FLY DAYS	118	65%
NO DATA DAYS	3	



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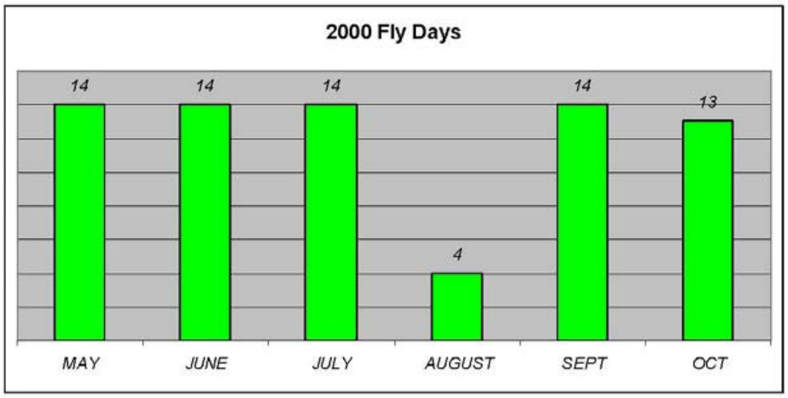
Nunivak Island and Yukon Delta Weather Study

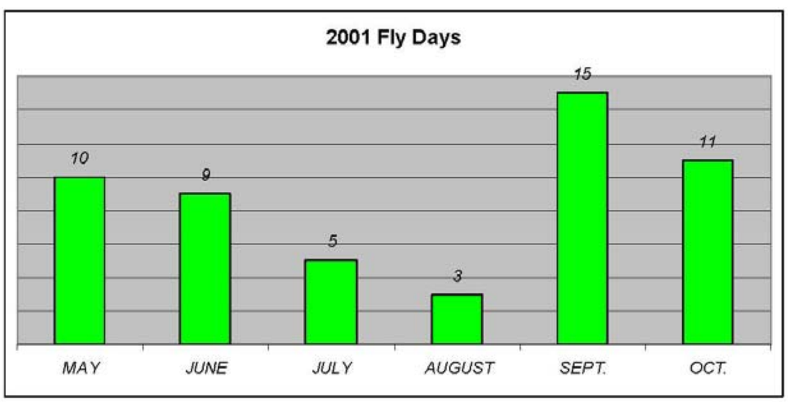
2000

FLY DAYS	73	48%
NO FLY DAYS	80	52%
NO DATA DAYS	31	



2001

FLY DAYS	53	29%
NO FLY DAYS	131	71%
NO DATA DAYS	0	



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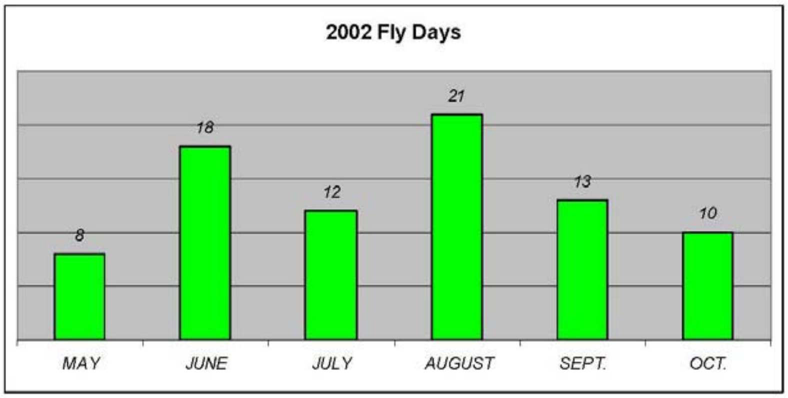
Nunivak Island and Yukon Delta Weather Study

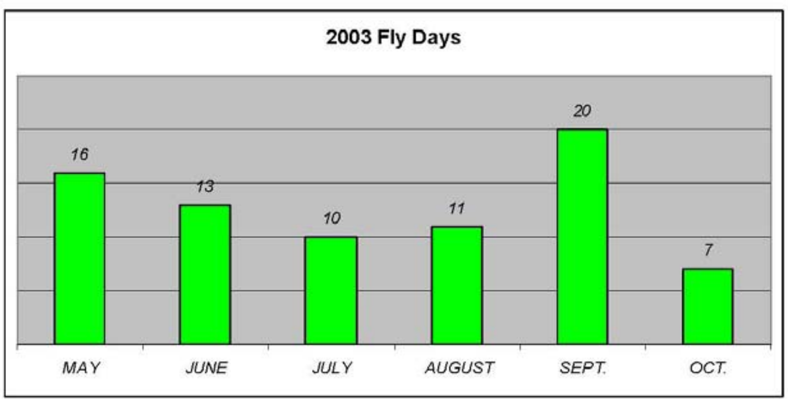
2002

FLY DAYS	82	45%
NO FLY DAYS	102	55%
NO DATA DAYS	0	



2003

FLY DAYS	77	42%
NO FLY DAYS	104	57%
NO DATA DAYS	3	



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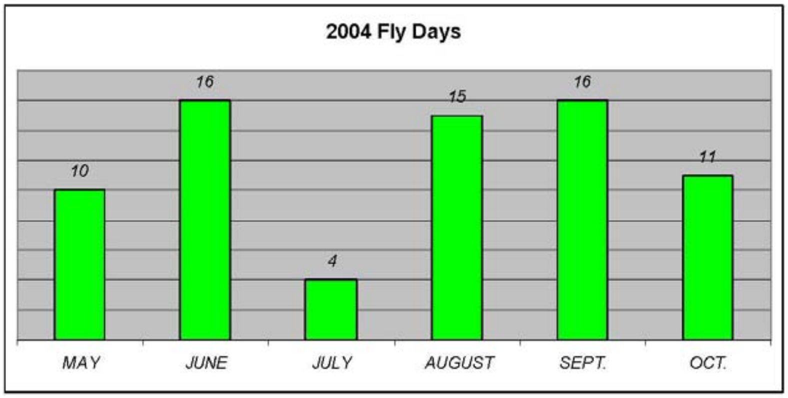
Nunivak Island and Yukon Delta Weather Study

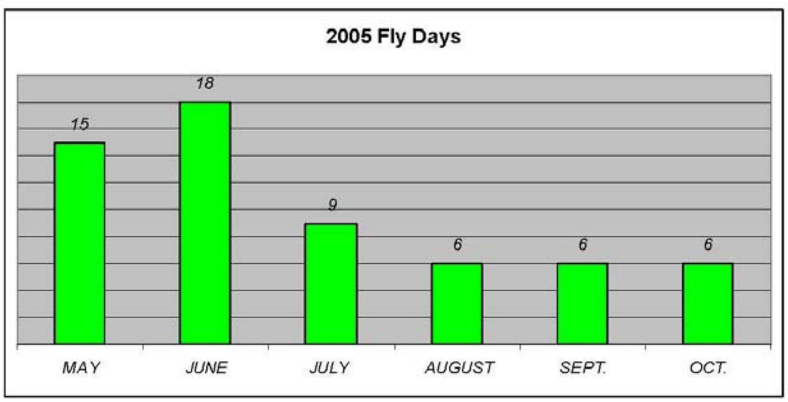
2004

FLY DAYS	72	39%
NO FLY DAYS	112	61%
NO DATA DAYS	0	



2005

FLY DAYS	60	35%
NO FLY DAYS	110	65%
NO DATA DAYS	14	



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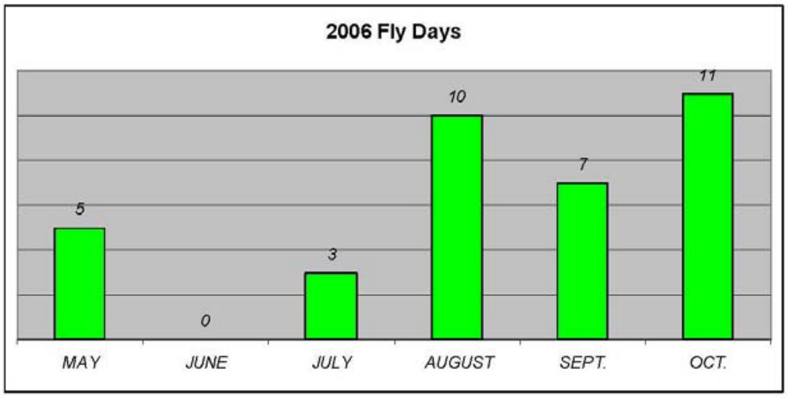
Nunivak Island and Yukon Delta Weather Study

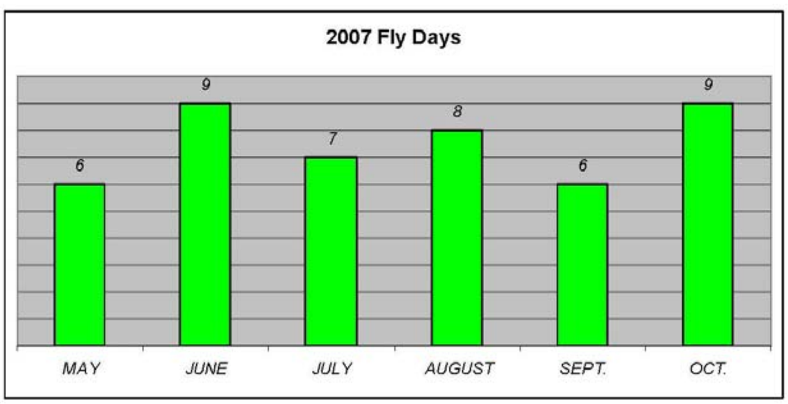
2006

FLY DAYS	36	34%
NO FLY DAYS	71	66%
NO DATA DAYS	77	



2007

FLY DAYS	45	24%
NO FLY DAYS	139	76%
NO DATA DAYS	0	



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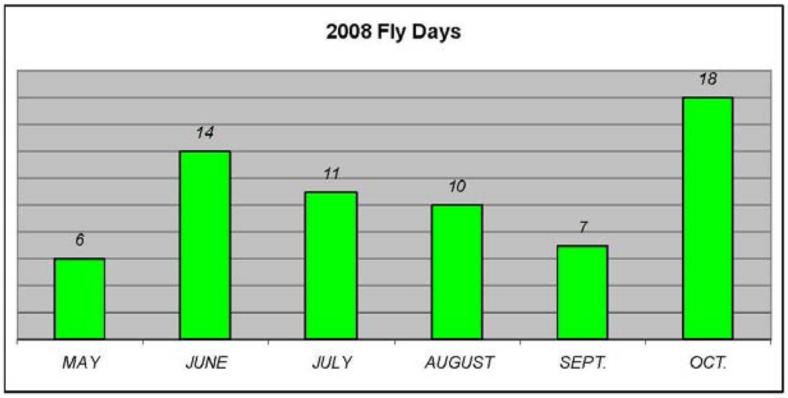
Nunivak Island and Yukon Delta Weather Study

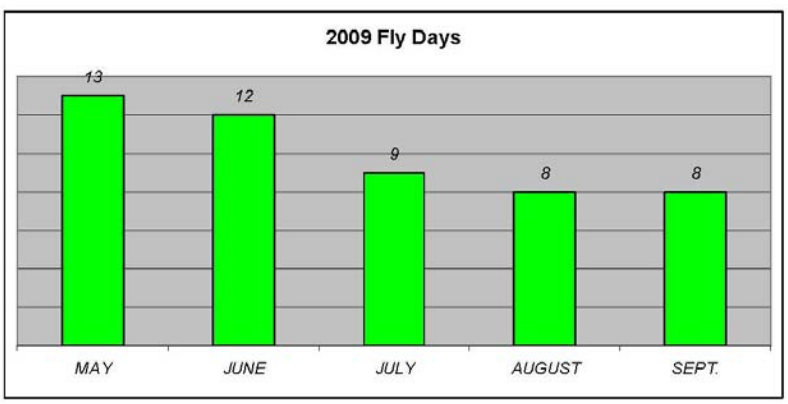
2008

FLY DAYS	66	36%
NO FLY DAYS	110	64%
NO DATA DAYS	8	



2009

FLY DAYS	50	33%
NO FLY DAYS	101	77%
NO DATA DAYS	2	



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