1 Mission, campaign, and flight specific notes

The ATM elevation data have been shown to contain a small bias for data with a low return energy (*Kwok et al.*, 2012). We have utilized campaign specific bias corrections to account for this in the 2009 and 2010 campaigns. A new centroid fitting procedure was used for later campaigns which was found to eliminate the bias according to laboratory tests.

1.1 Arctic 2009 campaign

Identification of leads was accomplished using CAMBOT data, rather than DMS data which was not available for this campaign. Due to the orientation of the camera and time between images, the CAMBOT data do not cover the entire flight track. At the nominal flight altitude and speed, the images span about 70% of the flight track. For example, at a flight altitude of 450 m each image covers 340 m in the along track direction, while the plane covers ~490 m in the 5 seconds between images, thus about 150/490 = ~30% of each flight line missing in the imagery. The return flight on April 21, 2009 was at a high altitude and full coverage of the flight line was obtained.

Four fields are currently unavailable for this campaign: the KT19 surface temperature, KT19 internal temperature, and the radar derived snow-air and snow-ice interfaces. The KT19 instrument was not available during this campaign.

1.1.1 March 31, 2009: Fram Strait flight

No snow depths are reported for this day. This was the first flight with the snow radar and the radar transmit power was set to a level twice as high as was used in subsequent flights. Large sidelobes and receiver saturation probelms were present in the data files which lowers the quality of snow depth retrievals which can be obtained from this flight. The retrieved snow depth values were on average ~50 cm and frequently exceeded the retrieved sea ice freeboard. These large snow depths are also incompatible with in-situ measurements from studies in previous years (on the order of 30 cm) and also snow depth values retrieved from IceBridge flights in 2010 and 2011.

1.1.2 April 5, 2009

Due to a malfunction of the CAMBOT sensor, CAMBOT coverage for this day only spanned a limited portion of the flight line. This limited the amount of freeboard data which could be retrieved for this day.

1.1.3 April 21, 2009

Surface temperatures near the end of this flight reached as high as -4 °C which appeared to impact the snow radar data. These data have been discarded. This flight consisted of outbound and return sections where the same flight line was repeated at two different altitudes. On the higher altitude inbound portion of the flight the snow radar was unable to distinguish the snow-air interface from the noise level due to the lower return energy, no snow depth values are reported for the inbound portion of the flight.

1.1.4 April 25, 2009

Caution is urged when using data near landmasses during this flight, the use of an interpolated sea surface height over large distances may not be applicable in these instances due to local inaccuracies in the geoid and tide models. We have also attempted to remove all data which were over land during this flight.

1.2 Arctic 2010 campaign

Identification of leads was accomplished using DMS imagery for this campaign. The adjusted mean freeboard field (fb_{adj}) is now reported and represents the derived freeboard from the combined ATM and DMS data sets. Surface temperature data from the KT19 instrument is also reported in this data set, however the KT19 internal temperature was not recorded during this campaign. The surface temperature data were recorded using a 1 Hz averaging rate, thus the surface temperatures reported here are an average over an area equal to the distance the aircraft traveled in one second. The emissivity setting of the KT19 instrument was set to 1 for the surface temperature retrievals during this campaign. Published values for the surface emissivity of snow and sea ice are less than 1 (typically around 0.97) which will slightly bias the reported surface temperatures for this campaign. A bias of ~1.5 K is expected if the true surface emissivity is 0.97 instead of the value of 1 used in the temperature retrieval.

A modified low energy correction for the ATM elevation data was needed for this campaign due to the use of different laser components. The new low energy correction, h_{e-corr} (in units of meters) was derived using calibration data provided by the ATM instrument team. Similar to the low energy correction of *Kwok et al.*, [2012], the new correction is an 8th order polynomial fit of the calibration data which is added to the ATM elevation data:

$h_{e-corr} = 1.356\times10^{-26}r_s^8 - 1.51483\times10^{-22}r_s^7 + 7.48991\times10^{-19}r_s^6 - 2.16621\times10^{-15}r_s^5 + 3.97857\times10^{-12}r_s^4 - 4.61175\times10^{-9}r_s^3 + 3.17998\times10^{-6}r_s^2 - 0.00118755r_s + 0.2$

where r_s is the ATM relative reflected laser signal strength. This polynomial was chosen to correct for biases to the level of points with a relative received amplitude of 1100, which was the most frequently observed reflected signal strength during the 2010 Arctic campaign. A constant correction of 0.008 meters is added to points with a relative amplitude greater than 2500 to most accurately correspond with the calibration data set.

1.3 Arctic 2011 campaign

A centroid waveform fitting has been used in the surface elevation retrievals for the ATM data in this campaign. This method eliminates the 'range walk' associated with the previous leading edge fit procedure, and thus no low energy elevation correction scheme was applied for this campaign. The new ATM 'narrow-swath' data (Krabill, 2011) were used exclusively as the surface elevation data set, h_e, during this campaign. The narrow-swath instrument allowed for a much larger number of returns over leads and smooth ice surfaces to be used in the freeboard retrieval processes compared to previous campaigns.

1.3.1 March 17, 2011

There was significant data loss due to clouds leading to gaps in the data for part of this flight. Additionally, DMS data were not available for the entire flight for the detection of leads. Where available the DMS data were used, but CAMBOT data were used for the time period spanning approximately 14:00-16:30 UTC time.

1.3.2 March 22, 2011

Cloudy conditions were present during much of this flight which led to only sparse data coverage for this flight (see the mission flight report for more details: http://nsidc.org/data/ifltrpt.html). CAMBOT data were used for the detection of leads up to approximately 17:25 UTC time due to the absence of DMS data.

1.3.3 March 23, 2011

A timing error in the snow radar data files led to a 15 second offset between the matching of the time stamp and geolocation data in the original data files. This error was corrected in the final processing of the data products. (Thanks to Tom Newman for discovering the error.)

1.3.4 March 25, 2011

CAMBOT data were used for the detection of leads up to approximately 14:50 UTC time due to the absence of DMS data. The first ~2 hours of the data line were flown in darkness and no visible imagery was available for lead detection and retrieval of freeboard.

1.3.5 March 28, 2011

Due to large errors in the EGM08 data set for the Nares Strait region the freeboard and thickness retrievals are only valid very close to sea surface tie points. We have set the freeboard and thickness retrievals for the first 10 minutes of the flight to invalid values due to this issue.

1.3.6 April 15, 2011

No leads were identified in the DMS and CAMBOT images for the determination of sea surface height, thus no sea ice freeboard and thickness estimates were made.

1.4 Arctic 2012 campaign

The ATM 'narrow-swath' data (Krabill, 2011) were used for all but two flights (listed below) as the surface elevation data set, h_e, during this campaign.

The KT19 infrared pyrometer was also operated during this campaign, the response setting was 3 Hz which allowed for higher resolution surface temperature measurements to be made. The KT19 emissivity was set to 0.97 for this campaign.

Ice type data from AMSR-E was not available for this campaign due to the failure of the AMSR-E instrument. The ice type flag data are taken from the nearest grid data on ice type from the Norwegian Met. Service OSI SAF system (http://www.osi-saf.org/). The gridded data products contain invalid data which are set to a value of -999, additionally, ice type data with a confidence level less than 50% were also set to -999.

The atmospheric load, $h_{pressure}$, was previously taken assuming an isostatic response to surface pressure fields from ECMWF reanalysis data. This has been replaced by a new dynamic atmospheric correction term taken from the MOG2D model (Carrère and Lyard, 2003) provided by Meteo France.

1.4.1 March 14 (North Basin Transect, Thule-Fairbanks)

A hardware failure by the snow radar data recording system led to a section of missing data during the flight.

1.4.2 March 15 (Beaufort-Chukchi Zig Zag)

An undetermined source of coherent noise was present in the snow radar data throughout the flight. This noise impacts the quality of the retrievals and thus the quality of the snow depth data may be lower for this flight. The additional noise led to the original snow depth retrieval algorithm to incorrectly identify areas with high noise as the location of the snow-air interface. To mitigate this, we have added additional requirements for the selection of the snow-air interface for this flight. Equation 18 has been changed to

$$\overline{P_{s-a}} \geq \hat{P}_{s-a}^{min} + 10 \tag{1}$$

An additional requirement following equation 18 for the identification of the snow-air interface has been added:

$$\overline{\overline{P_{s-a}}} \geq \hat{P}_{s-a}^{min} + 10 \tag{2}$$

where $\overline{\overline{P_{s-a}}}$ is the mean power in range bins 7-14 that follow $\hat{P}_{s-a}^{min}$. Since the additional noise for this flight occurs as areas of moderately high power levels followed by a return to a low level background noise, these additional requirements reduce the likelihood that areas of high noise will be selected as the snow-air interface while keeping the core snow depth retrieval algorithm intact.

1.4.3 March 17 (Alaska Coastal Zig Zag A) and March 19 (South Basin Transect, Fairbanks-Thule)

Due to an instrument failure, the narrow scan ATM was not available for these flights. The wide scan ATM was used instead.

1.4.4 March 16 (Alaska Diamond), 17 (Alaska Coastal Zig Zag A), and 22 (Connor Corridor)

Only several leads were found in these flights for the retrieval of freeboard and sea surface height. The correlation length and maximum uncertainty of the sea surface height observations are thus not well known and the freeboard and sea ice thickness uncertainty fields should be treated with caution.

1.4.5 March 26 (Wingham Box), March 28 (CryoSat-2 underflight)

No snow depth retrievals are reported for the high altitude portion of these flights since the noise level is expected to exceed the estimated return power from the snow-air interface.