Selection of ICESat Calibration Orbits
Dec. 20, 2002
Impyeong Lee, Bea Csatho
Byrd Polar Research Center, The Ohio State University
[lee.1517, csatho.1]@osu.edu
William Krabill, NASA/WFF; Robert Thomas, EG&G

1 Introduction

Precise surface elevations were mapped by NASA’s Airborne Topographic Mapper (ATM) conical laser scanning system over several areas over and in the vicinity of McMurdo’s Dry Valleys, Antarctica in December 2001. ATM surveys were conducted in collaboration with NSF and USGS to survey candidate calibration/validation sites of NASA ICESat (Ice, Cloud and Land Elevation Satellite) mission (Zwally et al., 2002), to support ongoing NSF projects and to evaluate the potential of laser altimetry for topographic mapping in the Antarctica. The survey provided “blanket” coverage over several sites (Figure 1). The Dry Valleys are favorable for GLAS calibration/validation because they are located at high southern latitude, close to the East Antarctic Ice Sheet (EAIS), where

- the range between the satellite and the surface is maximum,
- the orbit track density is high,
- and the sites are close to one of the major science targets, the EAIS.

This document summarizes our recommendations of ICESat calibration/validation sites within the mapped area.

2 Orbit Selection Process

2.1 Selection criteria

The prime requirements for the selected orbit tracks are:

- stable surfaces that are unlikely to show changes over ICESat’s lifetime. The sites surveyed by ATM consist of mostly rocky outcrops and exposed soils on valley floors. Areas that should be excluded from cal/val. are snow and ice covered regions, lakes and areas with significant erosion,
• ATM survey that covers the orbit track and its vicinity (at least 300 m wide ATM covered swath centered on the orbit track),
• orbit segments that include a variety of surface topography, ranging from level to sloping, undulating and rough topography,
• orbit tracks that include surface slopes with different magnitudes and aspects (Filin, 2001),
• orbit segment to be along verification phase (8-day repeat) reference orbit tracks or along mapping orbit tracks close enough to verification phase orbits for minimum tilting of the spacecraft,
• orbit segments to be long enough to be used for estimation of GLAS error budget.

2.2 Selection process

2.2.1 Data sets used:
• low resolution Digital Elevation Model (low-res DEM) of McMurdo Dry Valleys compiled from 1:50,000 and 1:250,000 scale USGS topographic maps and other elevation data. For details on the DEM generation see Felus and Csatho, 2000,
• ground tracks of verification and mapping phase ICESat orbits generated by Utopia on July 27, 1999,
• ATM flight trajectories from John Sonntag, EG&G

2.2.2 Procedure:
First all data were re-projected into Lambert Conformal Conic projection system. The projection parameters are summarized as (false easting and false northing are equal to zero):

<table>
<thead>
<tr>
<th>Spheroid</th>
<th>WGS84</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum</td>
<td>WGS84</td>
</tr>
<tr>
<td>1st standard parallels</td>
<td>76:40:00 S</td>
</tr>
<tr>
<td>2nd standard parallels</td>
<td>79:20:00 S</td>
</tr>
<tr>
<td>Central meridian</td>
<td>162:00:00 E</td>
</tr>
<tr>
<td>Origin</td>
<td>78:00:00 S</td>
</tr>
</tbody>
</table>
The corner points of the area we examined are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Latitude</th>
<th>Longitude</th>
<th>X [km]</th>
<th>Y [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW</td>
<td>77.073371 S</td>
<td>157.99277 E</td>
<td>-100</td>
<td>100</td>
</tr>
<tr>
<td>NE</td>
<td>76.981976 S</td>
<td>169.97743 E</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>SE</td>
<td>78.754784 S</td>
<td>171.22228 E</td>
<td>200</td>
<td>-100</td>
</tr>
<tr>
<td>SW</td>
<td>78.860417 S</td>
<td>157.36021 E</td>
<td>-100</td>
<td>-100</td>
</tr>
</tbody>
</table>

Candidate ICESat validation sites were selected by evaluating the intersections of the 8-day and nearby 183-day repeat orbit tracks and the ATM coverage (Figure 2). Then surface elevation profiles along the selected orbit tracks were extracted from the low-res DEM (Figure 3). The criteria listed in Section 2.1 were used to select the best of the candidate sites for each geographic area.

3  **Orbit track segments recommended for ICESat cal/val., McMurdo Dry Valleys, Antarctica**

The recommended sites are shown in Figure 4 and their characteristics are summarized in Figure 5.1-5.4. The orbit segments are described by the following parameters:

- 8-day repeat, verification phase reference orbit number,
- reference orbit time,
- start and end of the ground track segments,
- off-nadir pointing angle and direction.

The sites are the following (Figure 4, Figure 5.1-5.4):

A. Dry Valleys, Site 1, 8-day repeat reference orbit #30, descending, off-nadir pointing 1.003 east along 183-day repeat reference orbit track #1399 (Figure 5.1)

B. Mount Erebus, 8-day repeat reference orbit #119, descending, off-nadir pointing 1.067 east along 183-day repeat reference orbit track #625 (Figure 5.2)

C. Mount Discovery, 8-day repeat reference orbit track #119, descending, no off-nadir pointing (Figure 5.3)

D. Mount Discovery, 8-day repeat reference orbit track #9, ascending, no off-nadir pointing
E. Dry Valleys, Site 2, 8-day repeat reference orbit #24, ascending, off-nadir pointing to E, TBD

There are several candidate orbit track segment for Dry Valley, Site 2. We currently analyze the 3-D slope distribution along these orbits to select the most suitable orbit to recover the GLAS error budget.

4. Status of compilation of DEMs from ATM data

OSU’s digital photogrammetry group is currently compiling high resolution, precise DEMs for each Dry Valley site (OSU subcontract from USGS, PI: Prof. Tony Schenk). A new software is being developed to remove outlier observation by pre-processing ATM point cloud prior to interpolation. The interpolation procedure is a slightly modified version of the solution developed to create urban DEMs from ATM data for the validation of NASA’s scanning airborne photon-counting laser altimeter (Csatho et al., 2001). At the heart of the interpolation procedure is a bilinear interpolation that determines the surface elevation at the grid posts from planes fitted through the points located in a small neighborhood. The effect of still present outlier observations is reduced by using a robust estimator for the plane fitting.

The DEMs have high resolution (2-3 meter, depending on ATM point density) and their expected accuracy is 0.3 meter or better. The DEMs are planned to be released by USGS at the end of January 2003. Selected DEMs can be obtained for ICESat cal/val. purposes before the data release by contacting Cheryl Hallam, USGS (challam@usgs.gov).

List of figures:

**Figure 1** ATM flight trajectories and 8-day validation phase ICESat orbits in the vicinity of the McMurdo Dry Valleys. Sites surveyed by ATM: 1: Wright Valley-Victoria Valley; 2: Taylor Valley; 3: Radian glacier - Portal; 4: Denton Hills; 5: Mount Morning 6: Mount Discovery; 7: White Island, 8: Mount Erebus, 9: Hut Peninsula – McMurdo station (1:1,000,000 topographic map from USGS).

**Figure 2** ATM flight trajectories with 8-day verification phase and 183-day mapping phase orbit tracks. Ground tracks recommended for cal/val. are highlighted.

**Figure 3** Digital Elevation Model of McMurdo Dry Valleys (courtesy of NSF’s TAMARA
project; Felus and Csatho, 2000) with ATM flight trajectories. Surface elevation ranges from 0 (dark grey) to 3794 meter (peak of Mount Erebus, light grey). Please note that a mask is applied over the Ross sea (black).

**Figure 4** Selected 8-day and 183-day ICESat reference orbit track segments overlaid on topographic map.

**Figure 5.1-5.4** Characterization of selected cal/val sites. a. Detailed map; b. Surface elevation along ground track; c. Table with reference orbit time, ground track location and off-nadir pointing. Note that sites are sorted from west to east along the ground track.

- Dry Valleys, Site 1, orbit #30, descending, off-nadir pointing (Figure 5.1),
- Mount Erebus, orbit #119, descending, off-nadir pointing (Figure 5.2),
- Mount Discovery, orbit #119, descending (Figure 5.3),
- Mount Discovery, orbit #9, ascending (Figure 5.4).

**References:**


Figure 1 ATM flight trajectories and 8-day validation phase ICESat orbits in the vicinity of the McMurdo Dry Valleys.
Figure 2 ATM flight trajectories with 8-day verification phase and 183-day mapping phase orbit tracks. Ground tracks recommended for cal/val. are highlighted.
Figure 3 Digital Elevation Model of McMurdo Dry Valleys (courtesy of NSF’s TAMARA project; Felus and Csatho, 2000) with ATM flight trajectories. Surface elevation ranges from 0 (dark grey) to 3794 meter (peak of Mount Erebus, light grey). Please note that a mask is applied over the Ross sea (black).
Figure 4 Selected 8-day and 183-day ICESat reference orbit track segments overlaid on topographic map.
Tables (Figure 5.1-5.4) include the reference orbit time, the length, and the start and end positions of the ground track segments. X and Y coordinates are in Lambert Conformal Conic projection system (Section 2.2.2). Sites are sorted from west to east along the ground track.
Figure 5.2 Mount Erebus, 8-day repeat reference orbit #119 (descending), off-nadir pointing 1.067E along 183-day repeat reference orbit track #625

1. Hut Point Peninsula
2. Mount Erebus

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>Time X</th>
<th>Y</th>
<th>Long.</th>
<th>Lat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.8</td>
<td>529129.4</td>
<td>108629.929</td>
<td>8227.801</td>
<td>166.641848 E</td>
</tr>
<tr>
<td></td>
<td></td>
<td>529125.3</td>
<td>120218.086</td>
<td>33529.573</td>
<td>167.041817 E</td>
</tr>
<tr>
<td>2</td>
<td>6.4</td>
<td>529123.6</td>
<td>125120.113</td>
<td>44232.739</td>
<td>167.206537 E</td>
</tr>
<tr>
<td></td>
<td></td>
<td>529122.7</td>
<td>127803.700</td>
<td>50092.127</td>
<td>167.295619 E</td>
</tr>
</tbody>
</table>
Figure 5.4 Mount Discovery, 8-day repeat reference orbit track #119 (descending), no off-nadir pointing

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>Time</th>
<th>X</th>
<th>Y</th>
<th>Long.</th>
<th>Lat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.2</td>
<td>529138.4</td>
<td>-44011.935</td>
<td>165.236340 E</td>
<td>78.376296 S</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>529136.2</td>
<td>-30175.791</td>
<td>165.474542 E</td>
<td>78.249365 S</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.8</td>
<td>529127.1</td>
<td>27012.841</td>
<td>166.407485 E</td>
<td>77.722723 S</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>529126.7</td>
<td>29581.087</td>
<td>166.447533 E</td>
<td>77.699001 S</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.4 Mount Discovery, 8-day repeat reference orbit track #9 (ascending), no off-nadir pointing

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>Time</th>
<th>X</th>
<th>Y</th>
<th>Long.</th>
<th>Lat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.4</td>
<td>581702.6</td>
<td>72625.554</td>
<td>-26803.573</td>
<td>165.188452 E</td>
<td>78.222426 S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>581699.6</td>
<td>78789.359</td>
<td>-46301.266</td>
<td>165.509679 E</td>
<td>78.393666 S</td>
</tr>
</tbody>
</table>