Saturation Correction Guidance

NSIDC DAAC recommends that users apply the saturation correction to ICESat laser elevations for cryospheric applications or for any study of high-albedo targets, especially for the higher laser-energy campaigns (e.g., Laser 1A/B, 2A, 2B, 3A, 3B), before analysis of relative surface elevations or surface elevation change. The saturation correction values are available for each derived elevation but are not automatically applied in the elevation-related data sets from ICESat (products GLA-05, -06, -12 through -15).

References to GLAS products GLA01—GLA15 refer to the original GLAS binary-formatted data. This information has been retained here to provide context and to maintain provenance. Access to GLAS binary data was discontinued on 01 August, 2017. However, all GLAS data are available in HDF5 format: products GLAH01—GLAH15.

A significant portion of the ICESat elevation and waveform data are impacted by GLAS detector saturation owing to stronger-than-expected received laser energy. The likelihood of saturation impact on the return waveform increases for campaigns with (1) higher laser transmit energy, and (2) high reflectivity surfaces (such as snow, sea ice, and ice sheets). Conversely, the impact is lessened for either low transmit energy campaigns or low reflectivity land and ocean surfaces, or when atmospheric transmission of laser energy is reduced (i.e. cloudy or hazy atmosphere). In addition, since the gain-setting algorithm is based on the received energy of the previous shot in the profile, the GLAS receiver can have 'single-shot' detector saturation due to strong transitions in received energy. In general, saturated GLAS waveforms produce a surface range measurement that is too long, making the elevation of the surface appear lower than it actually is. The scale of the effect can be many 10s of centimeters. The effect, and the development and validation of a correction, is discussed in detail in Sun et al. (2017, in press to TGARS).

An initial version of the saturation correction algorithm was established early in the mission (Sun et al., 2005). An improved version was developed for Laser 3 campaigns. Applying the correction, now using updated versions in the final releases of the GLA products, compensates for the impact of saturation on the reported range and the derived elevation when the correction is valid. Some unpublished analyses of full-mission data suggest that there is a residual laser-energy-related effect on the altimetry data throughout the mission. This is still under analysis.

If uncorrected, the saturation effect produces biases when comparing elevations between campaigns with very different laser energies. On a hypothetical unchanging Earth surface, elevations measured by the ICESat campaigns with high GLAS laser energy (e.g. L1a/B, L2a, L3a, L3b) will appear lower than the same laser locations measured by weaker-laser campaigns (L2c, L2d, L2e, L2f, L3h, L3i, L3j, L3k). As a rule of thumb, the saturation effect over bright surfaces is not significant for laser transmit energies below about 20 millijoules, assuming constant GLAS gain settings and surface albedo/reflectivity.

Residual laser-energy-related impacts on elevations over bright surfaces remaining even after application of the saturation correction (if any) can be addressed by applying inter-campaign bias corrections (ICBs), if users are concerned with very precise elevation change detection (centimeter-scale per year) over bright surfaces. NSIDC DAAC has published a Guide for Applying ICESat ICBs and how to use them; see: https://nsidc.org/data/icesat/technical-references Note that the saturation correction is not applied to any of the products (GLA-05, -06, or GLA 12-15). Guidance on its application is included in the data dictionary entries for the 'satElevCorr' parameter, excerpted below.

1 BINARY

1.1 i_elev

The saturation elevation correction (i_satElevCorr) can be larger than one meter and should be added to i_elev. It also provides important information about the quality of the elevation data: if the saturation elevation correction is set to invalid, then the elevation should not be used. In addition, the saturation index (i_satNdx) can be used to better understand data quality from saturation effects.

1.2 i_satElevCorr

This correction has not been applied to the data. To apply i_satElevCorr, subtract from the range estimate and add it to the elevation estimates.

2 HDF5

2.1 Data_40HZ/Elevation_Corrections/ group

2.1.1 d_satElevCorr

d_satElevCorr contains the correction to elevation for saturated waveforms. This correction has NOT been applied to the data. To apply it, subtract the value from the range estimate and add it to the elevation estimates.

2.2 Data_40HZ/Quality/ Group

2.2.1 sat_corr_flg

This group contains data quality flags and related parameters, including the saturation correction flag, sat_corr_flg (the value is the same in both the binary and HDF versions). The saturation correction flag indicates the one of the following five[1] conditions:

- not saturated (i_satNdx < 2) or no signal
- inconsequential (i_satNdx >= 2 & i_pctSat < 2.0)
- applicable (i_satNdx >= 2 & i_pctSat >= 2.0 & Full Width* < 100 ns)
- not computable
- not applicable (i_satNdx >= 2 & i_pctSat >= 2.0 & Full Width* >= 100ns)

[1]Note: The file-level metadata for all Level L1B and Level 2 GLAS HDF products state erroneously that sat_corr_flg comprises six values: 0, 1, 2, 3, 4, 5. Only five values are defined: 0, 1, 2, 3, 4.

Values in sat_corr_flg are stored as coded integers. The following table lists the valid integer values and their meanings:

Table 1. Flag Values and Meanings for sat_corr_flg

Flag Value	**Meaning**
0	not saturated
1	inconsequential
2	applicable
3	not computed
4	not applicable

3 REFERENCES:

Sun, X., Abshire, J.B., Yi, D. and Fricker, H.A., 2005. ICESat receiver signal dynamic range assessment and correction of range bias due to saturation. In AGU Fall Meeting Abstract C34A-07.

Sun, X., J. Abshire, A. Borsa, H. Fricker, D. Yi, J. DiMarzio, K. Brunt, D. Harding, and G. Neumann, 2017 in press. ICESat/GLAS Altimetry Measurements: Signal Dynamic

Sun, X., J. B. Abshire, D. Yi, H. A. Fricker. 2005. Range and Saturation Correction, *Trans. Geoscience and Remote Sensing*. Trans. Geoscience and Remote Sensing TGRS-2016-00302.R1.