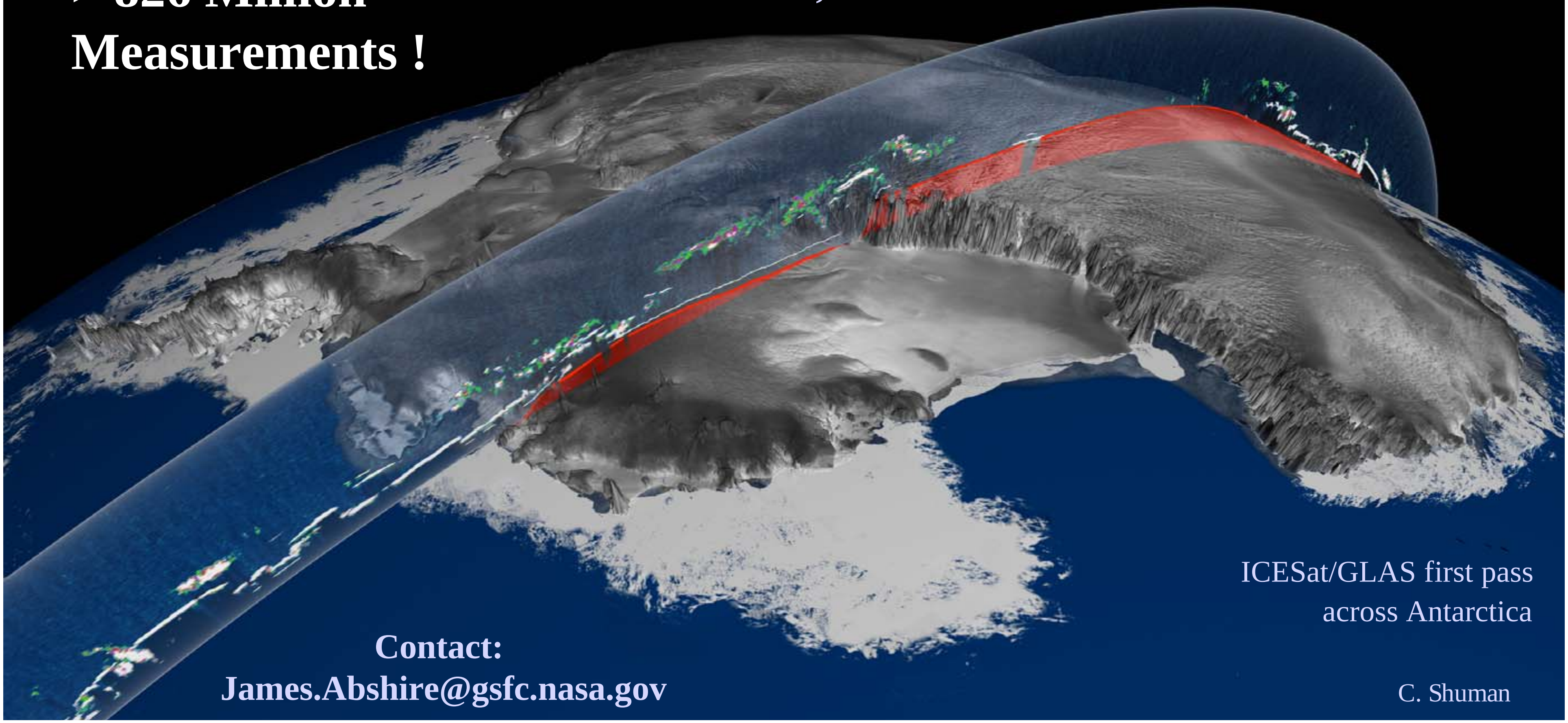
Geoscience Laser Altimeter System (GLAS) on the ICESat Mission: Science Team Update

GLAS Instrument Team and GARB3

June 2, 2005

> 826 Million Measurements !



ICESat/GLAS first pass across Antarctica

C. Shuman

Contact:
James.Abshire@gsfc.nasa.gov

Summary & Outline

Summary

- GLAS instrument now operating in ICESat Campaign 3C

- GLAS Laser 3 was re-activated on May 20th to begin ICESat campaign 3C, its seventh measurement campaign since launch.

- As of June 1, GLAS Laser 3 was emitting about 48 mJ pulse, in line with predictions from earlier this year. The altimetry and cloud lidar measurements are working well.

- Since its launch in January 2003, GLAS has made 826 million laser measurements of the Earth's surface and atmosphere.

Outline

- GLAS Laser Update - Abshire et al.

- GLAS Receiver Update - Xiaoli Sun

- GLAS Altimetry Echo Pulse Saturation Update - Xiaoli Sun et al.

Geoscience Laser Altimeter System (GLAS) on the ICESat Mission: Laser Update

James B. Abshire, Haris Riris, Pete Liiva, and GARB3

June 2, 2005

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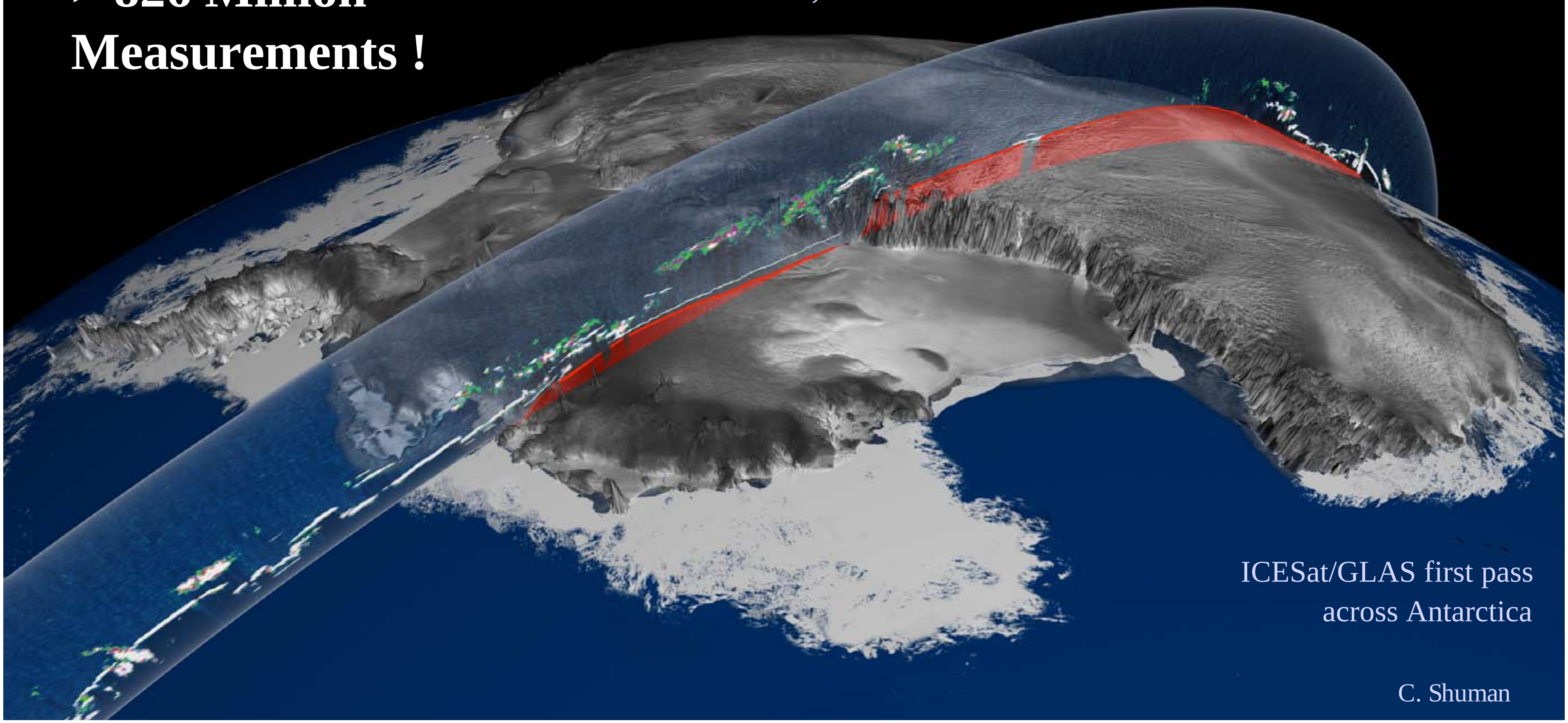
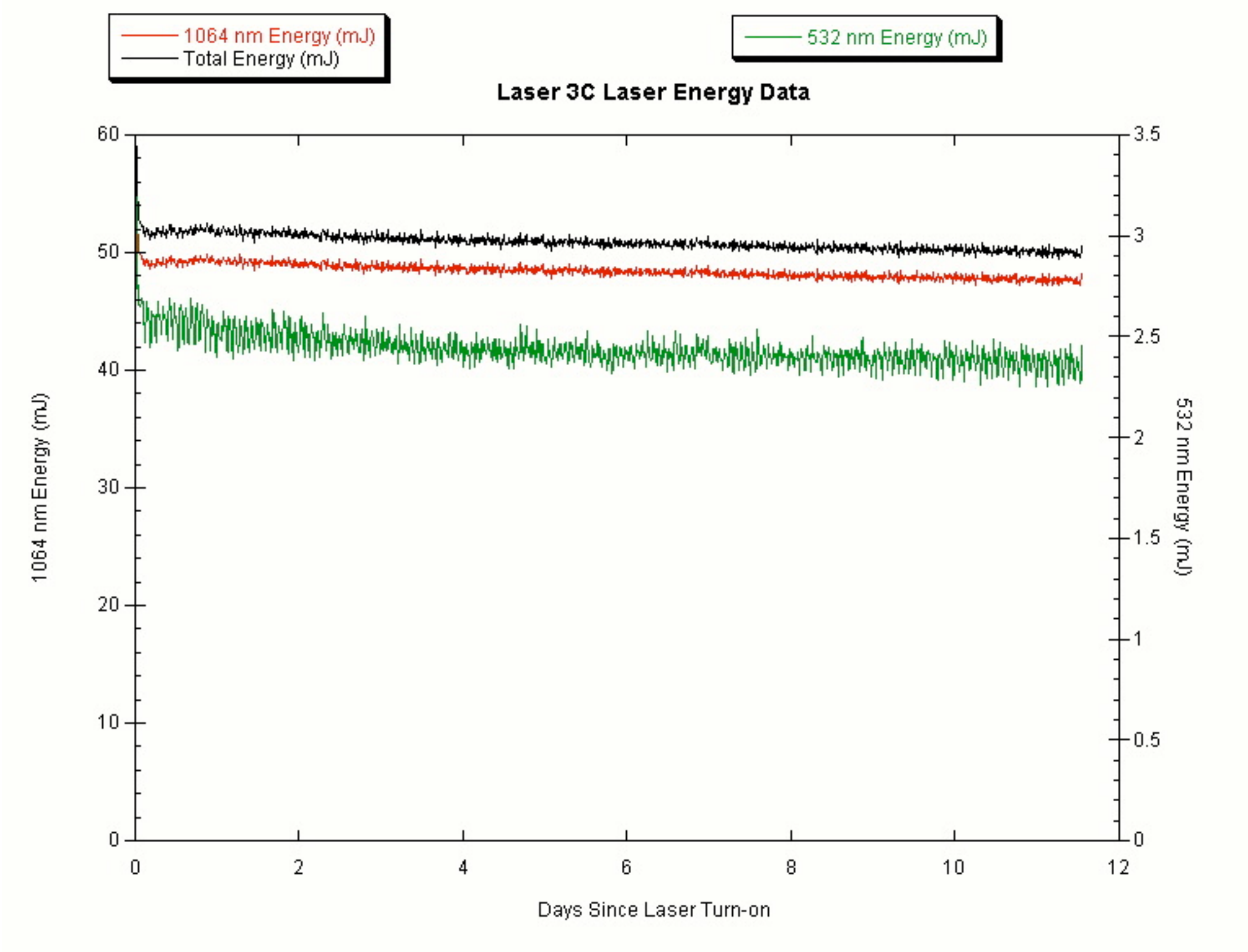


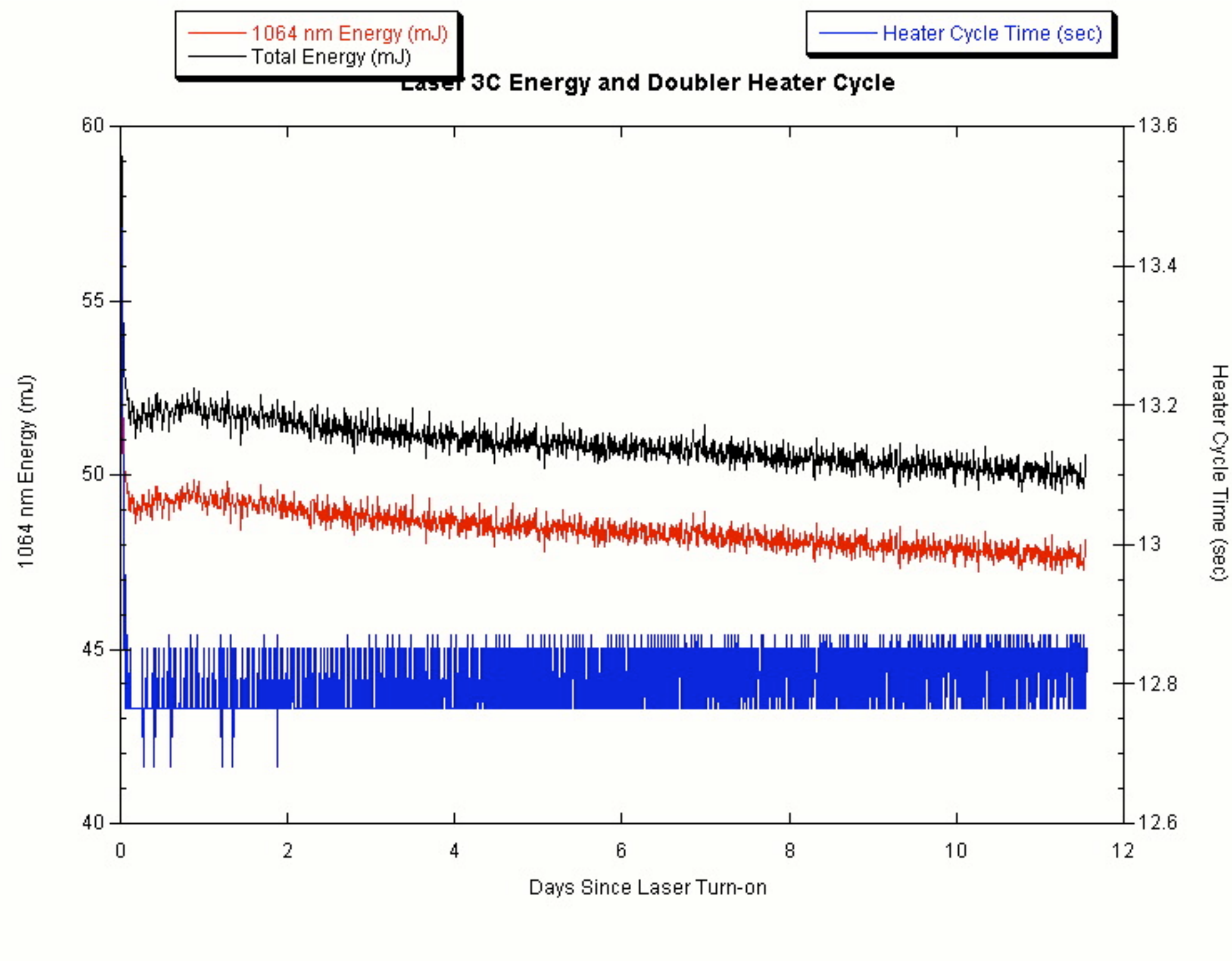
ICESat/GLAS first pass across Antarctica

C. Shuman

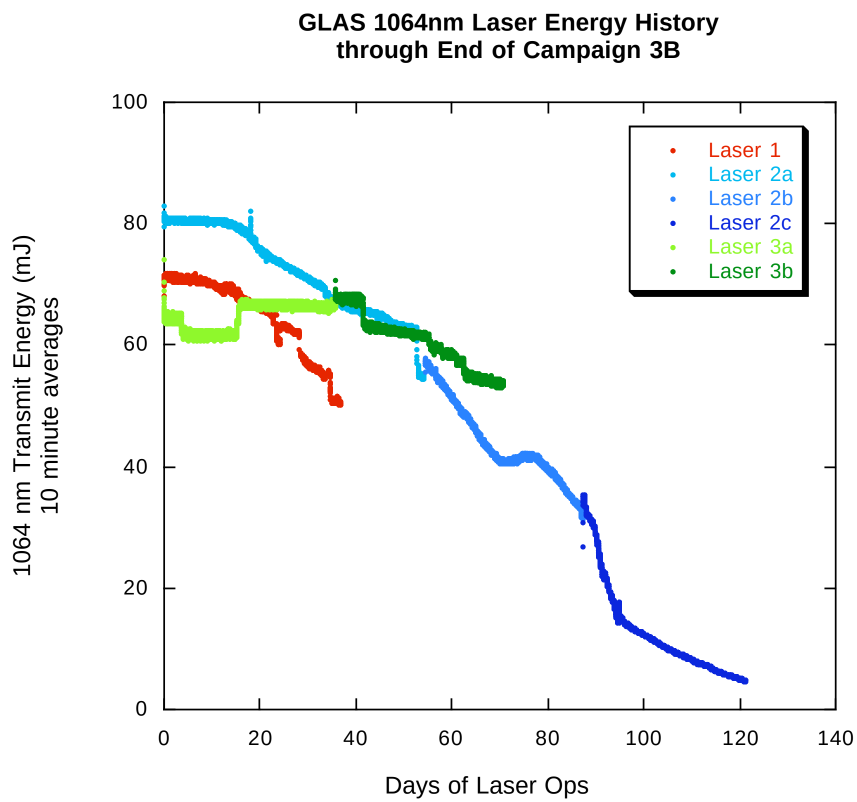
GLAS Laser 3C - Energy History to date

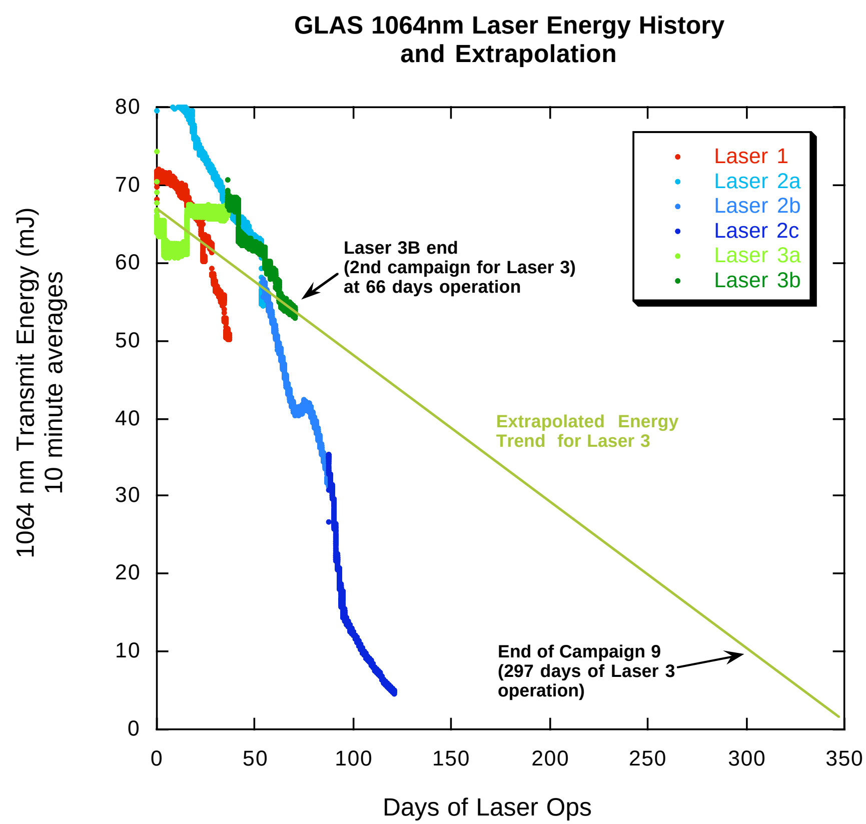


Detailed Laser 3C History & Doubler Heater Cycle

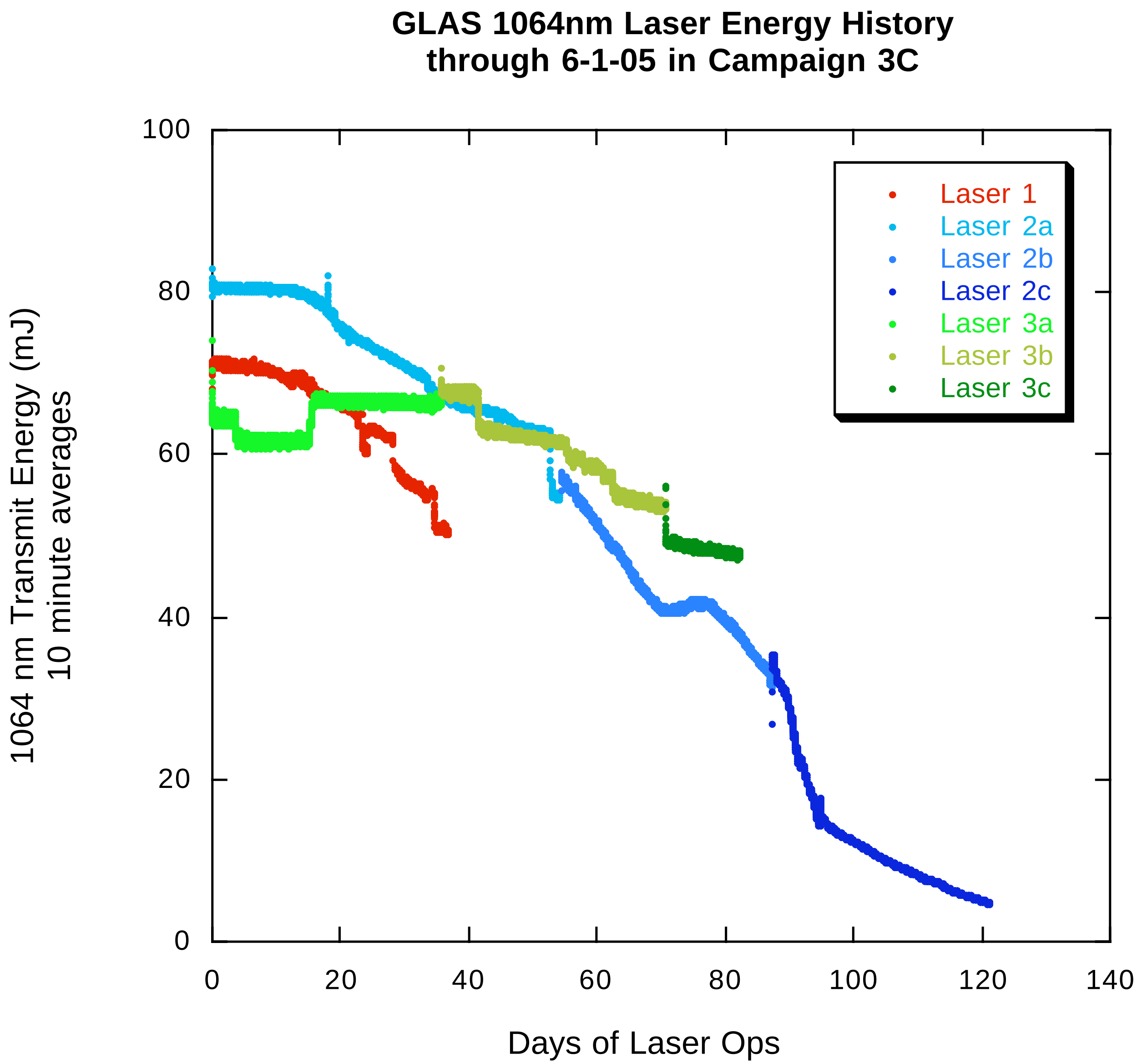


Previous - 1064 nm Energy History And Extrapolation (End of L3b)

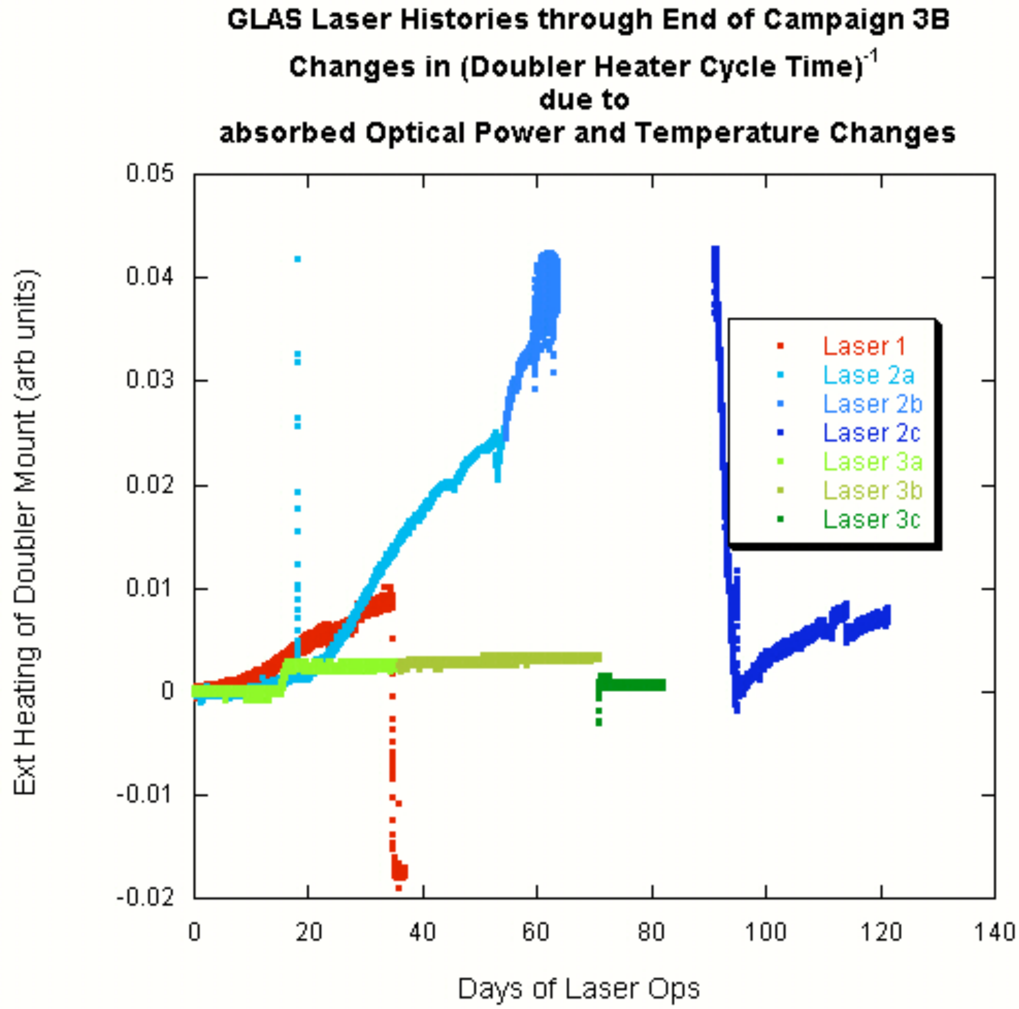




Laser Energy History - all campaigns to date

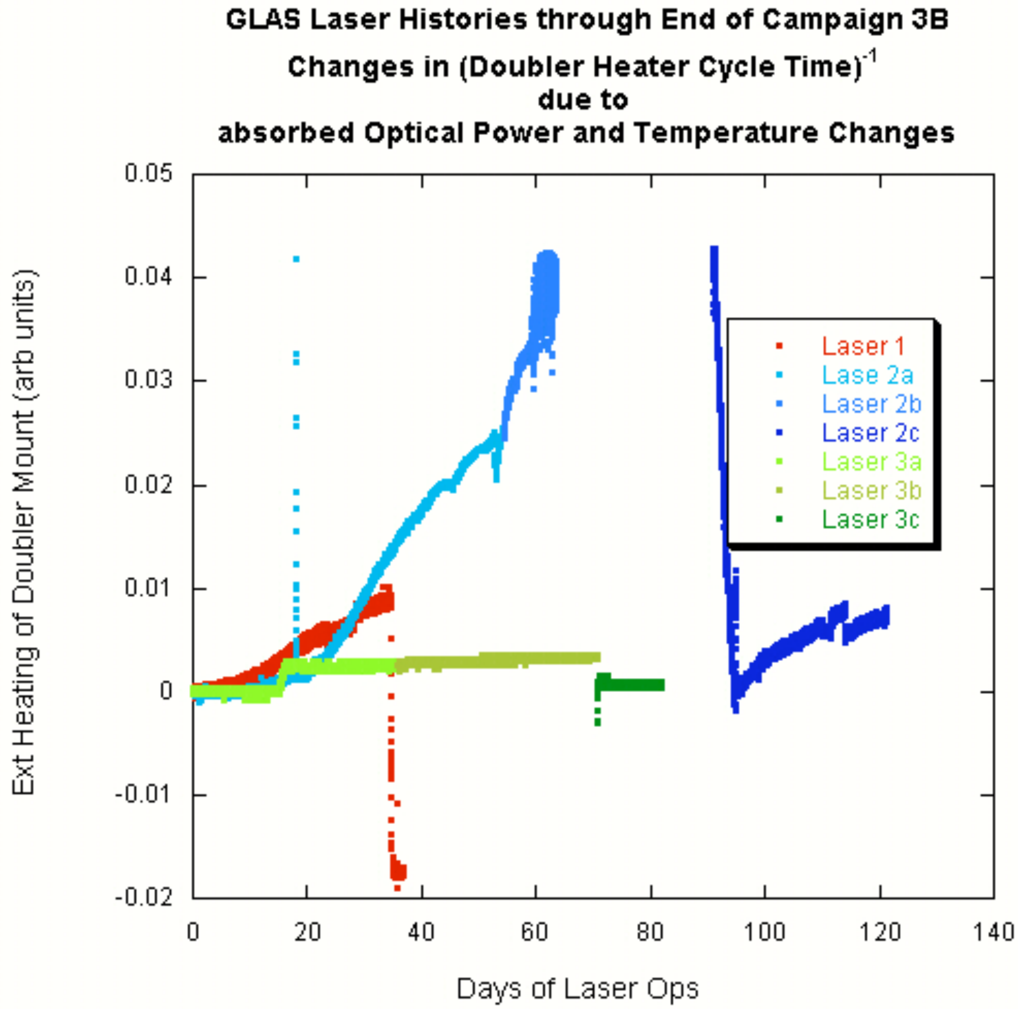


Laser Doubler External heating - All lasers to date



	Units	Laser 1	Laser 2A	Laser 2B	Laser 2C	Laser 3A	Laser 3B	Laser 3C
Time in space before 1st laser firing	Days	39	256			630		
Laser Reference Temp. Start	C	29.0	26.6	26.8	26.8	13.8	16.0	13.8
Time at Start Reference Temp.	days	34.5	54.2	32.8	2.0	15.0	35.0	13.6
Laser Reference Temp. End	C	22.0	26.8	26.9	16.8	16.0	16.0	13.8
532 nm Energy Start	mJ	28.0	21	12.9	0.0	5	5	2.6
532 nm Energy End	mJ	20.0	13.0	0	0.4	5.0	2.9	2.3

Laser Doubler External heating (doubler absorbing laser power): All lasers to date



Differences for Laser 3:

1. Longer in space before ops
2. Colder during all ops
3. Lower 532 nm energy

	Units	Laser 1	Laser 2A	Laser 2B	Laser 2C	Laser 3A	Laser 3B	Laser 3C
Time in space before 1st laser firing	Days	39	256			630		
Laser Reference Temp. Start	C	29.0	26.6	26.8	26.8	13.8	16.0	13.8
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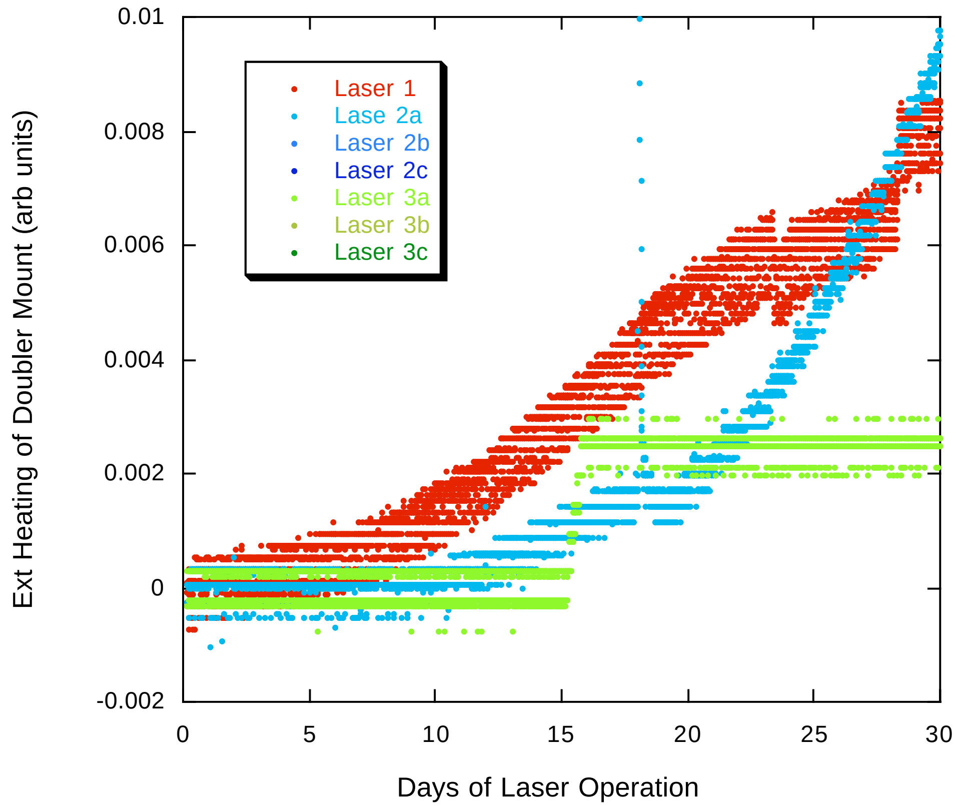
Laser Doubler External heating (ie doubler absorbing laser power): 1st 30 days of ops for each laser only

GLAS Laser Histories through End of Campaign 3B

Changes in (Doubler Heater Cycle Time)$^{-1}$ due to Absorbed Optical Power and Temperature Changes



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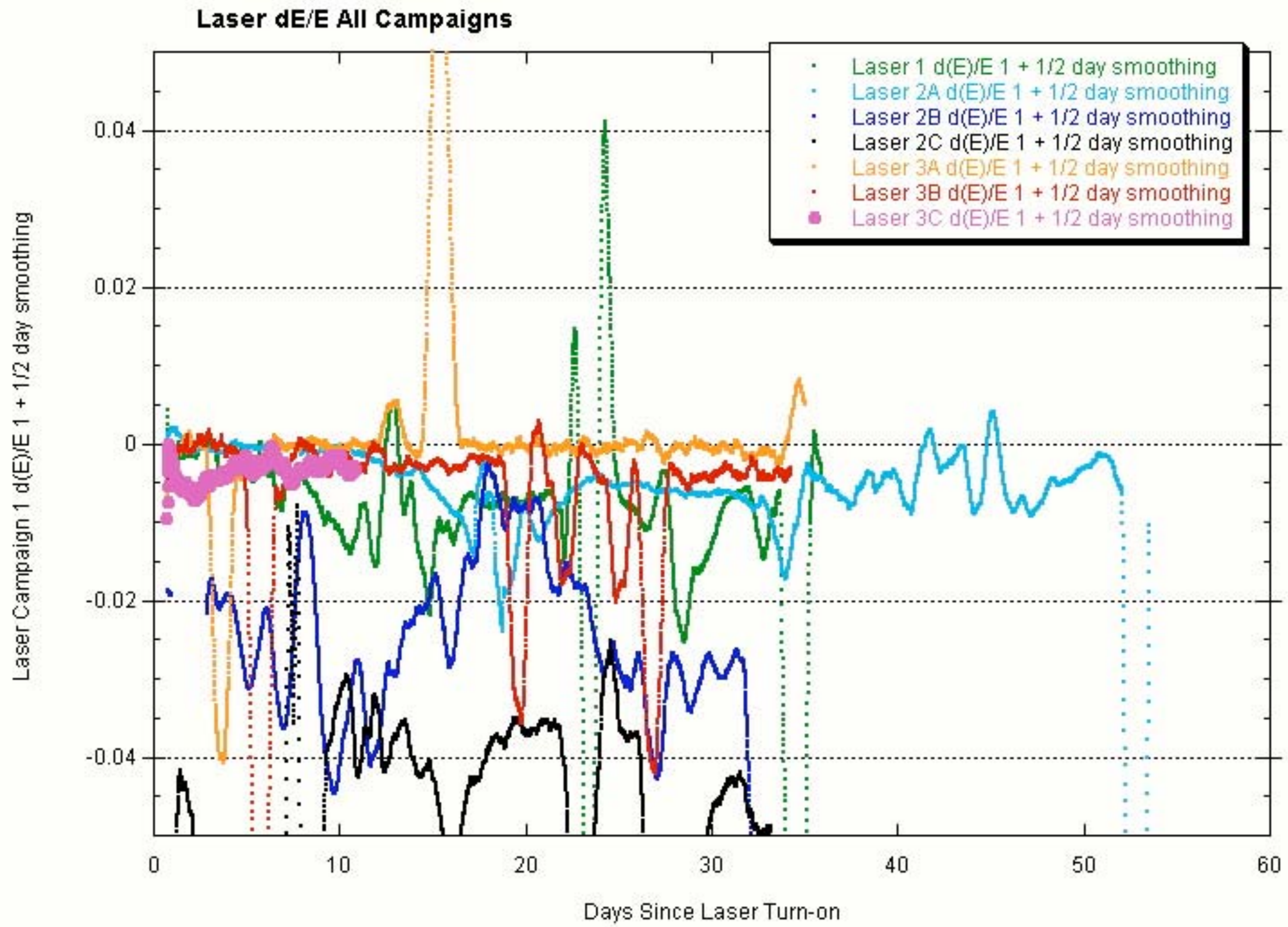
Relative rates of Laser Energy change - All campaigns to date



GLAS Receiver Performance Assessment Update

GLAS Science Team Meeting
Upper Marlboro, MD
6/2/2005

Xiaoli Sun et al
NASA GSFC, Code 694

Outline

- GLAS receiver performance assessment
  - 1064nm channel receiver performance assessment with the OTS test data, Laser 3c
  - Clock oscillator frequency trend since launch
  - 532 nm channel detector (SPCM) performance assessment
  - 532 nm channel Etalon filter performance assessment

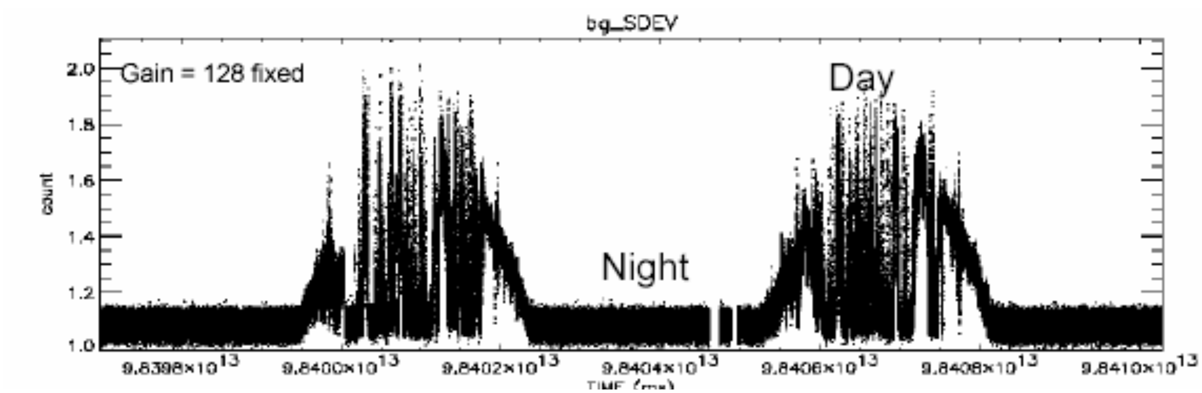
GLAS Altimeter Detector Output Noise in Response to Sunlit Earth

- Comparison to Initial GLAS Operation on 2/12/2003

GLAS
1st power on
in orbit
(2/12/2003)

Test results during on orbit OTS test, 2-12-03, at approximately 20:46 (UTC)

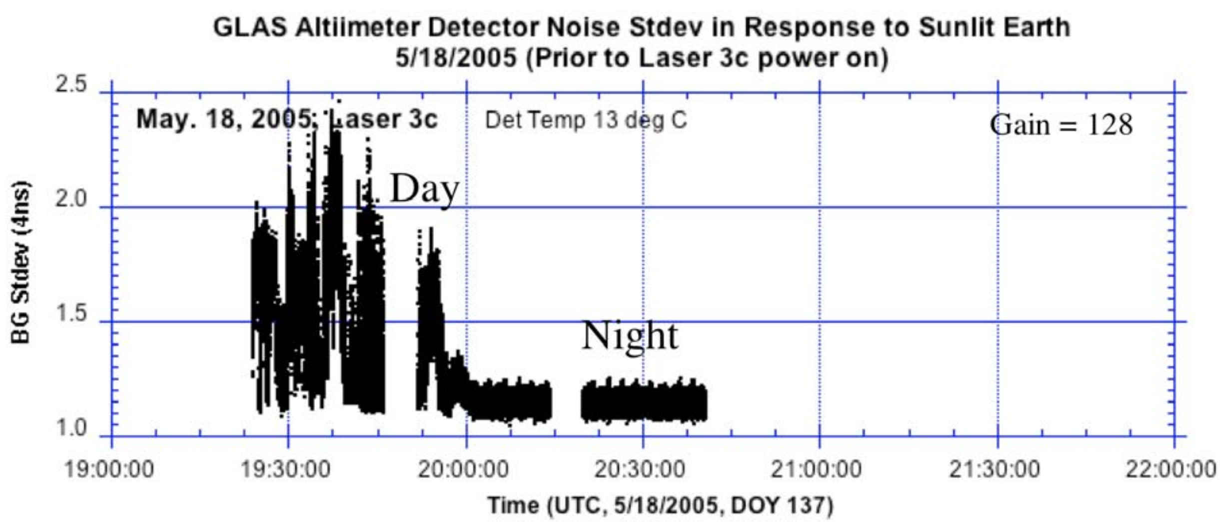
Waveform noise stdev for the 1km segment after Rmax



Det @ 22 deg C
Dig @ 51 deg C

Average
Dark noise
Stdev = 1.09

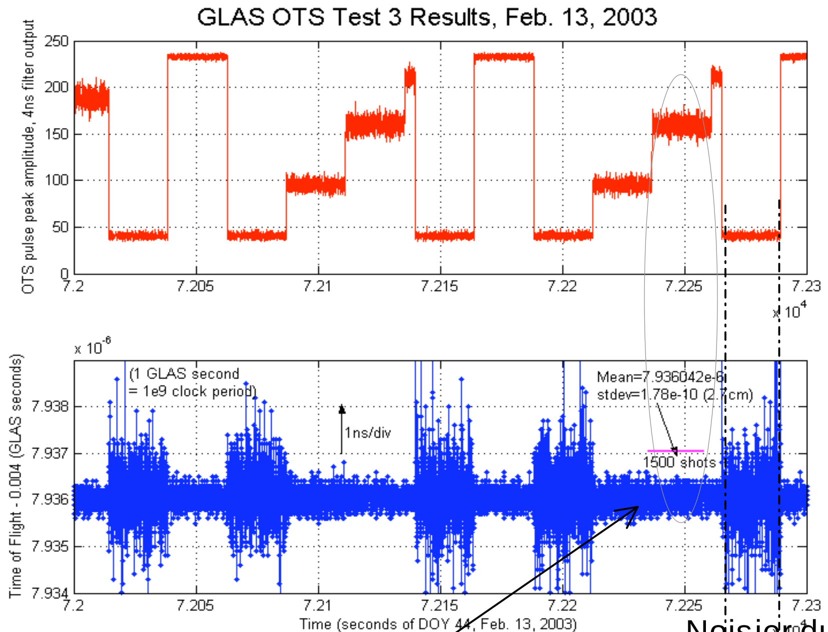
Laser 3c
power on
(5/18/2005)



Average
Dark noise
Stdev = 1.17

GLAS Altimeter Performance Verification Using the On Board Optical Test Source (OTS)

2/12/2003
(GLAS first power on in orbit)

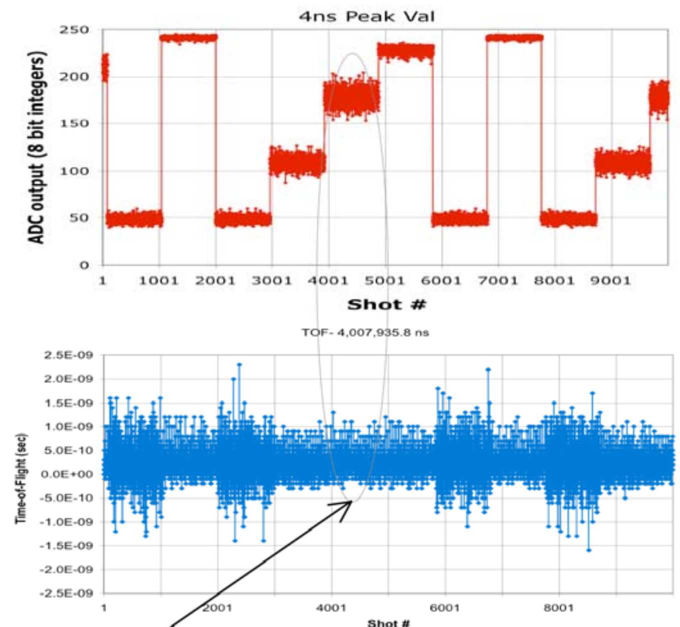


Noisier due to weak signal

Amplitude noise
at mid signal level: ~4.2%

Time of flight measurement stdev:
0.18 ns (2.7 cm)
(except for very weak signal).

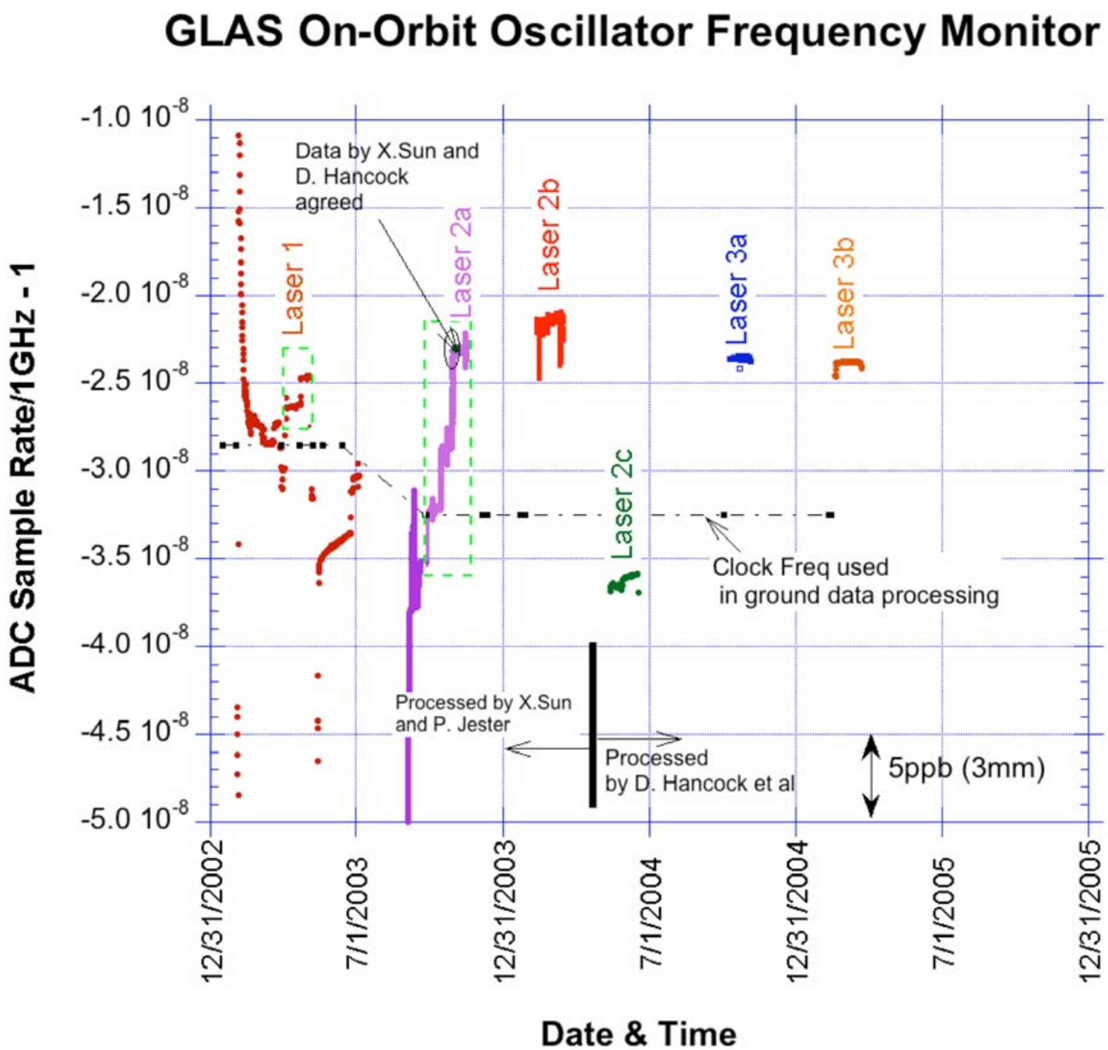
5/18/2005
(Laser 3c power on in orbit)



Amplitude noise
at mid signal level: ~4.4%

Time of flight measurement stdev:
0.21 ns (3.1 cm)
(except for very weak signal).

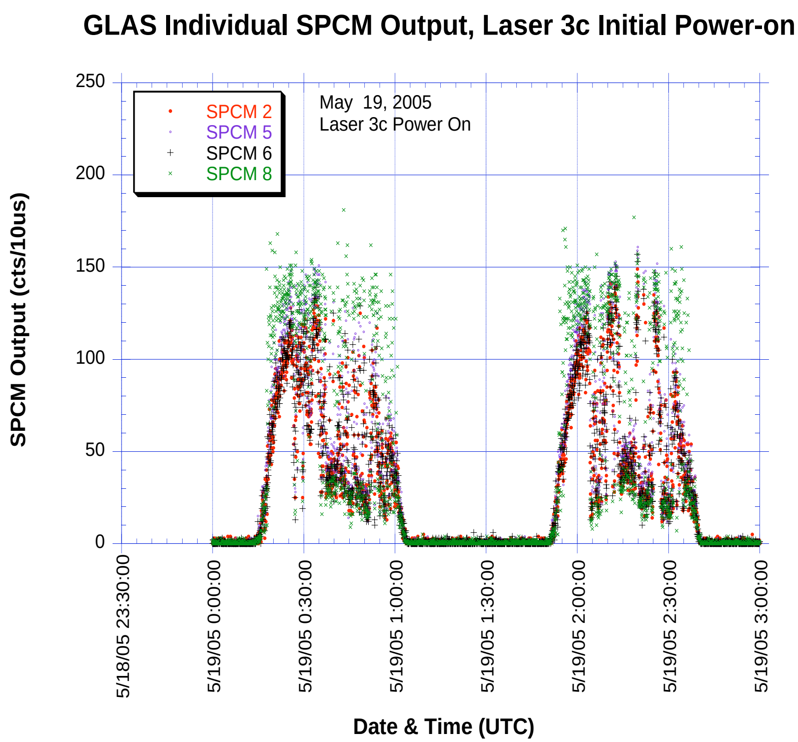
GLAS Clock Frequency Trend



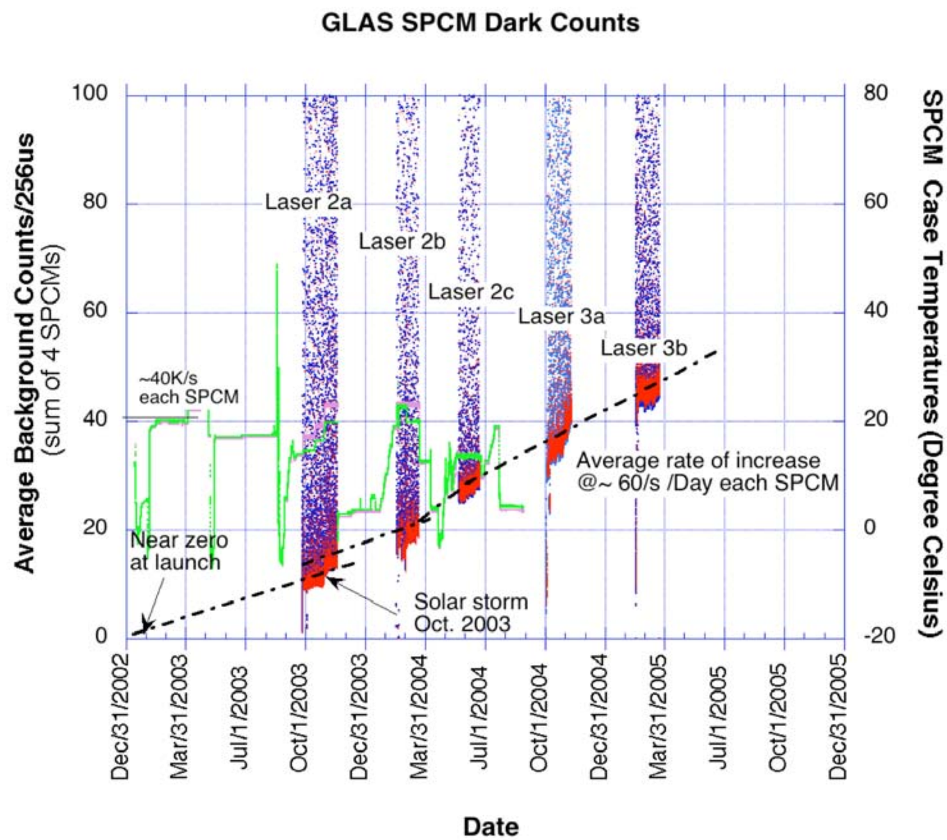
- Clock frequency varied by ~1.5e-8 (0.9 cm) pk-pk during Lasers 1 and 2 operation periods, mostly due to the changes in the bench temperature;
- Automatic clock frequency monitor has been included in ISF software since Laser 2c.
- Total ranging error due to clock frequency uncertainty is <1cm
- A more accurate clock frequency update table needs to be used in ground data processing.

GLAS Clock Frequency Trend

- SPCM radiation damage appeared to follow a linear model and the decay rate is sufficiently low to last the entire mission
- The 1064nm detector radiation damage should follow the same model and predicted to be negligible at the end of the five year mission.

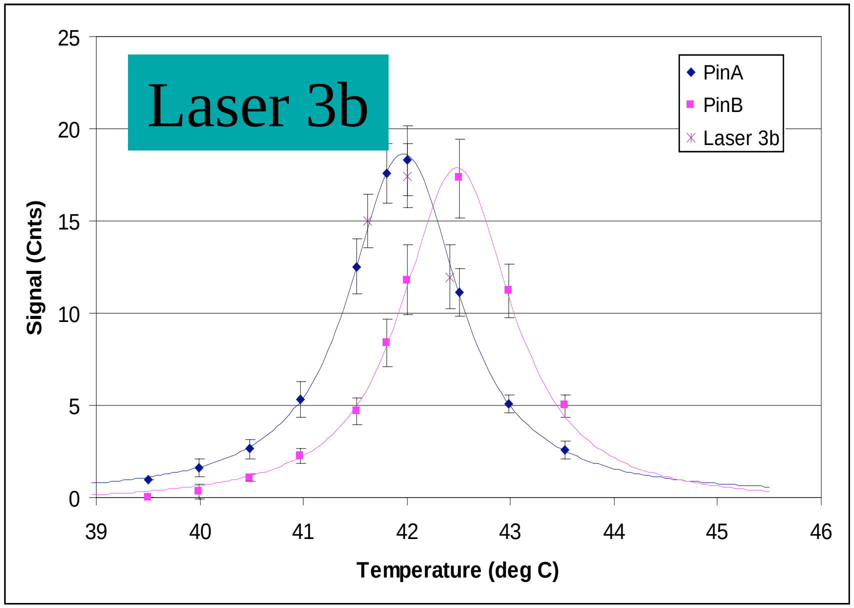


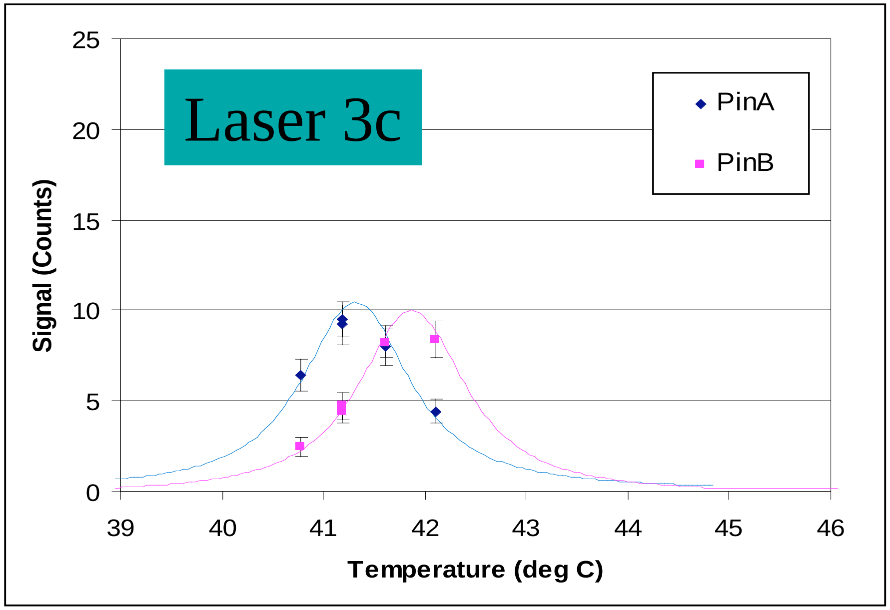
- SPCM #8 appeared to have a higher afterpulsing rate and needs close monitoring.



532 nm channel Etalon Temperature Scan Results

- The Etalon system is performing within specification (28pm FWHM)
- Etalon may be used as a spectrometer to monitor the laser spectral linewidth
  - Laser 3 linewidth appeared to be the same as Laser 2a
  - Laser 3b and 3c linewidth appeared to be the same but lower pulse energy





GLAS 1064nm Altimeter Channel Echo Pulse Saturation Correction

Xiaoli Sun and Donghui Yi

6-2-05

GLAS Altimetry Saturation Correction Approach

- Understanding the causes of detector saturation
- Identification of saturated waveforms
- Classification of saturated waveforms
- Laboratory measurements of detector characteristics and development of saturation correction algorithms
  - Given in details of this presentation
- Validation of algorithm using GLAS in orbit data at selected calibration sites
  - e.g., salar de Uyuni by Helen Fricker
- Working group to recommend final approach and formulas to science team
- Implement timing corrections for saturated echo pulse waveforms in science data processing (David Hancock)

GLAS Altimetry Saturation Correction
Ice sheet Saturation & Causes

- Altimetry receiver:
  - Has ~x260 dynamic range in peak echo signal power
  - Onset of nonlinear response (saturation) set to x2 higher than the highest peak power signal expected pre-launch
- On-orbit measurements show that with full energy & clear atmosphere the echo pulse peak powers from flat Antarctic icesheets are ~4x stronger than pre-launch expectation
- Causes:
  - Surface reflectance x2 stronger than Lambertian surface; due to
    - Opposition effect of fine snow powder (most likely)
    - Possibly some specular reflection
  - Best case roundtrip atmosphere transmission ~ x2 higher than expected
    - Design based on 70% (one way); Actual seems > 95%
- Results - peaks of strongest ice sheet echo pulses are x2 over receiver saturation threshold
  - Occurs when over flat surfaces & clearest atmospheric conditions & strongest laser energies
- Echo pulse returns to linear range of detector once peak signal reduces x2, due to any combination of reductions in laser energy, surface slope or atmospheric transmission

Characteristics of saturated waveforms

- Pulse peak amplitude (detected power) exceeds 220 counts
- Gain <13 (for Laser 1 only)
- Nonlinear detector response to incident laser power
- Others features?

GLAS Altimetry Saturation Correction - Identification of Saturated Waveforms

Types of saturated waveforms

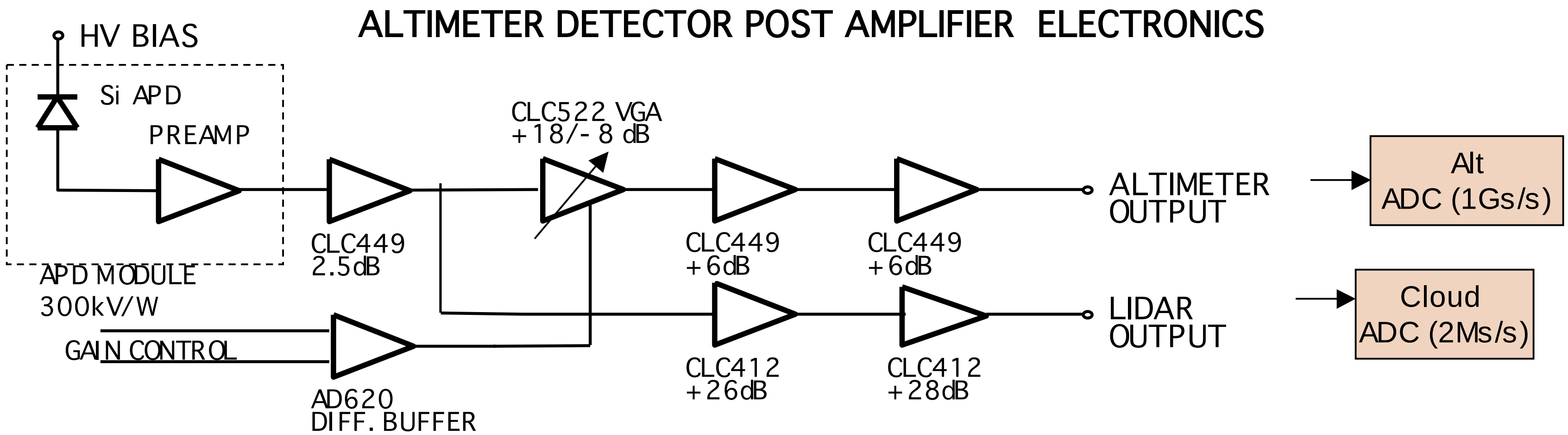
- "Low gain saturation" over flat (<0.5 deg) surface
  - Gain = 13 for a number of consecutive shots
- "Low gain saturation" over sloped surface
  - Same as above but over over sloped surface (>0.5 deg)
- "High gain saturation" over flat surface
- "High gain saturation" over sloped surface
- Temporary saturation due to the limited response time of the automatic gain control loop
- High energy waveforms from still water surface
- Others

Laboratory Measurements of GLAS 1064 nm Detector Saturation Characteristics for Echoes from Flat surfaces

GLAS Altimeter Detector Characterization under Saturation

- Tests were conducted in the Code 694 detector development laboratory with the GLAS flight spare detector and well controlled test conditions;
- Both Gaussian fits and pulse centroid timing approaches used to determine the time of flight and range changes
- Only 6 nsec FWHM input pulse width has been used at so far
- To date the resultant correction algorithms apply only to flat surface echoes
- A special test was conducted to reproduce the pulse waveforms seen from still water surface in order to estimate the likelihood of damaging the detector from them

GLAS Detector Assembly
Dynamic Range and Saturation Level

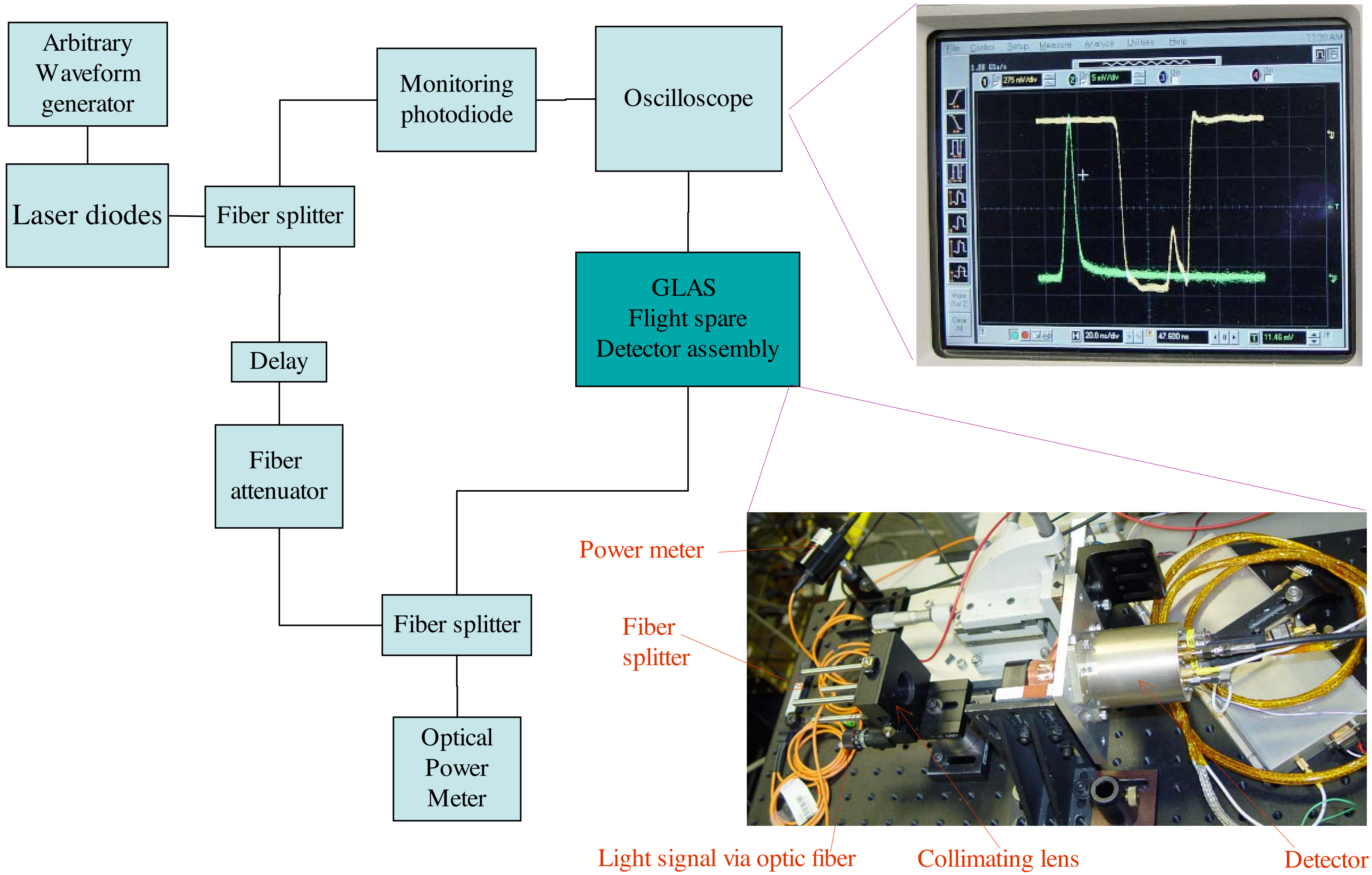


The maximum non saturation input signal level considered in the detector design was 12fJ/pulse. The actual maximum non saturation input signal level was tested to 13fJ in the lab without any distortion and the saturation level appeared to be 15fJ by observation from the actual flight data

The detector assembly was designed such that all components saturate at the same time, different component has different effect on waveform distortion

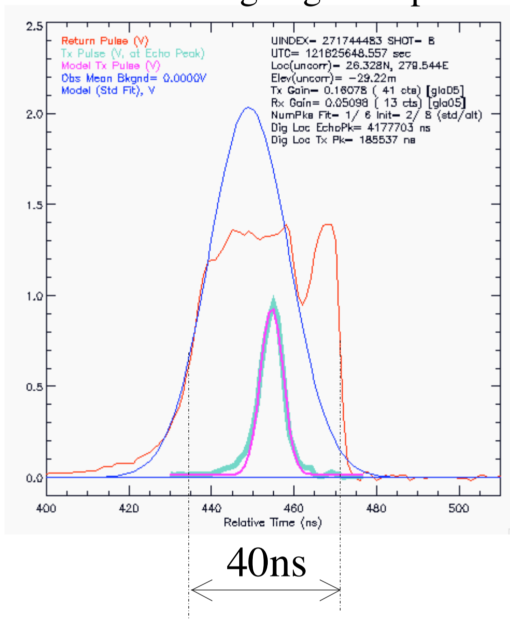
- “High gain saturation” is caused by the final amplifier stage
- “Low gain saturation” is caused by the Si APD preamp module (2.0uW max linear response pulse peak power)
- Non linear distortion by VGA for gain <13.

Lab Measurement Setup for GLAS detector

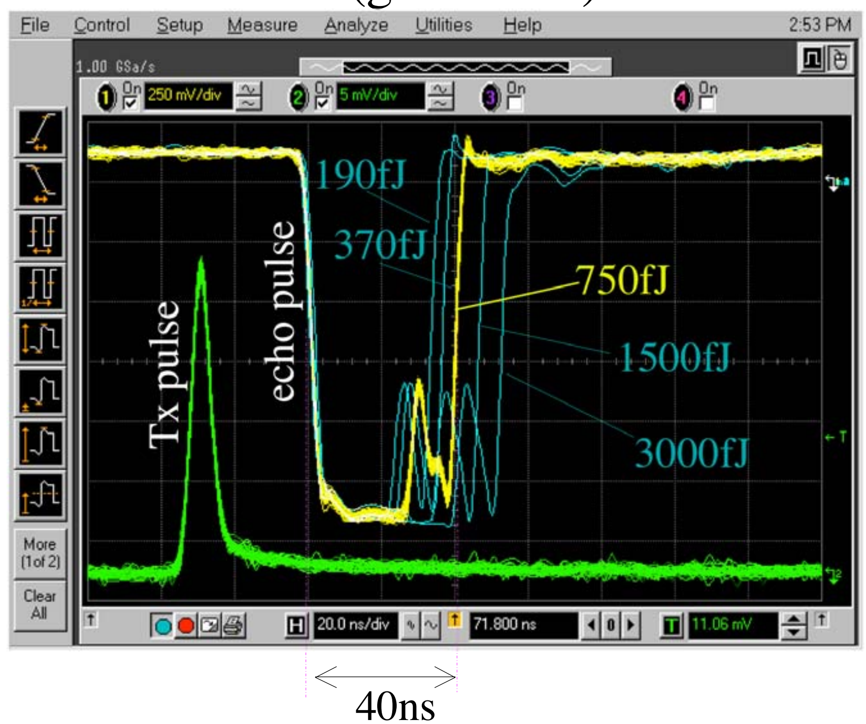


Estimate of the Echo Pulse Energy from Smooth Water Surfaces

Severely Saturated Waveforms
From Smooth Water in Fl. Everglades
(Gaussian fit to leading edge and preserve area)

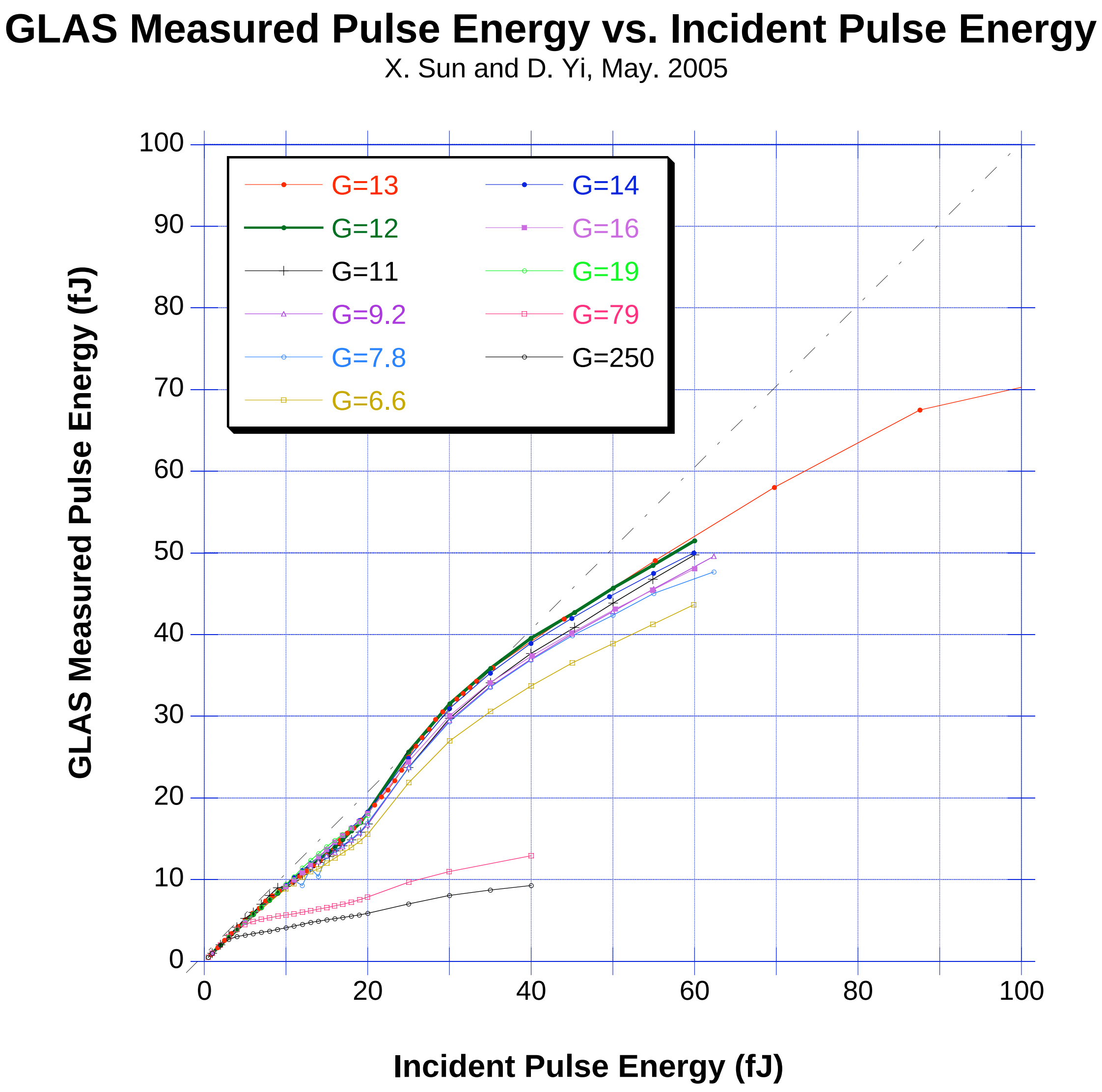


Lab test results (gain=10.5)



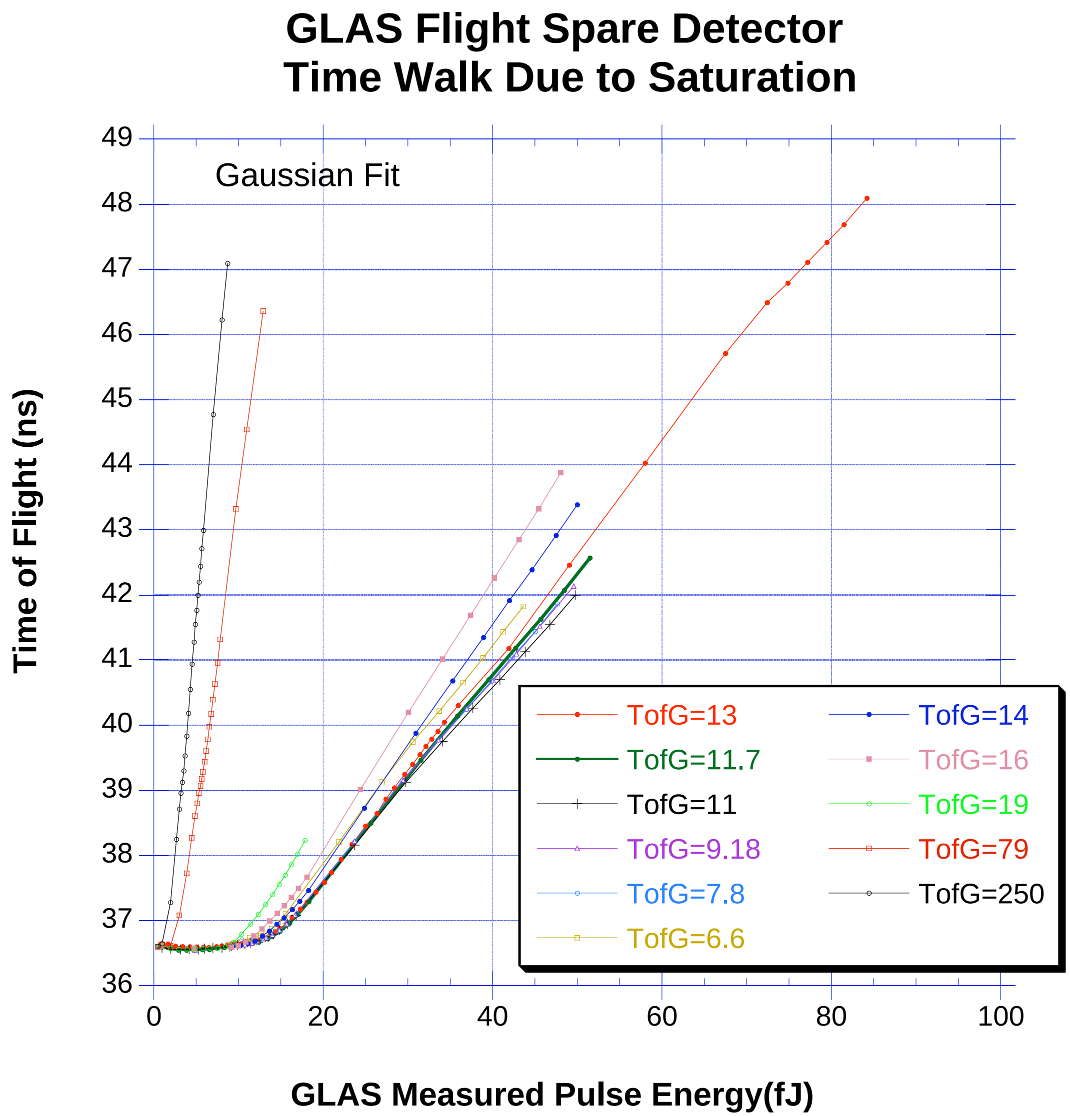
- The water surface echo appeared to be 500-1,000 fJ/pulse, still a factor of 10 from the detector damage threshold given by the manufacturer;
- Lab measurement of water reflectance at 0.5 deg incident angle was about 310 times that of an 100% diffusive calibration standard, which corresponds to 2,500 fJ/pulse on the detector

GLAS Measured vs. Incident Laser Pulse Energies



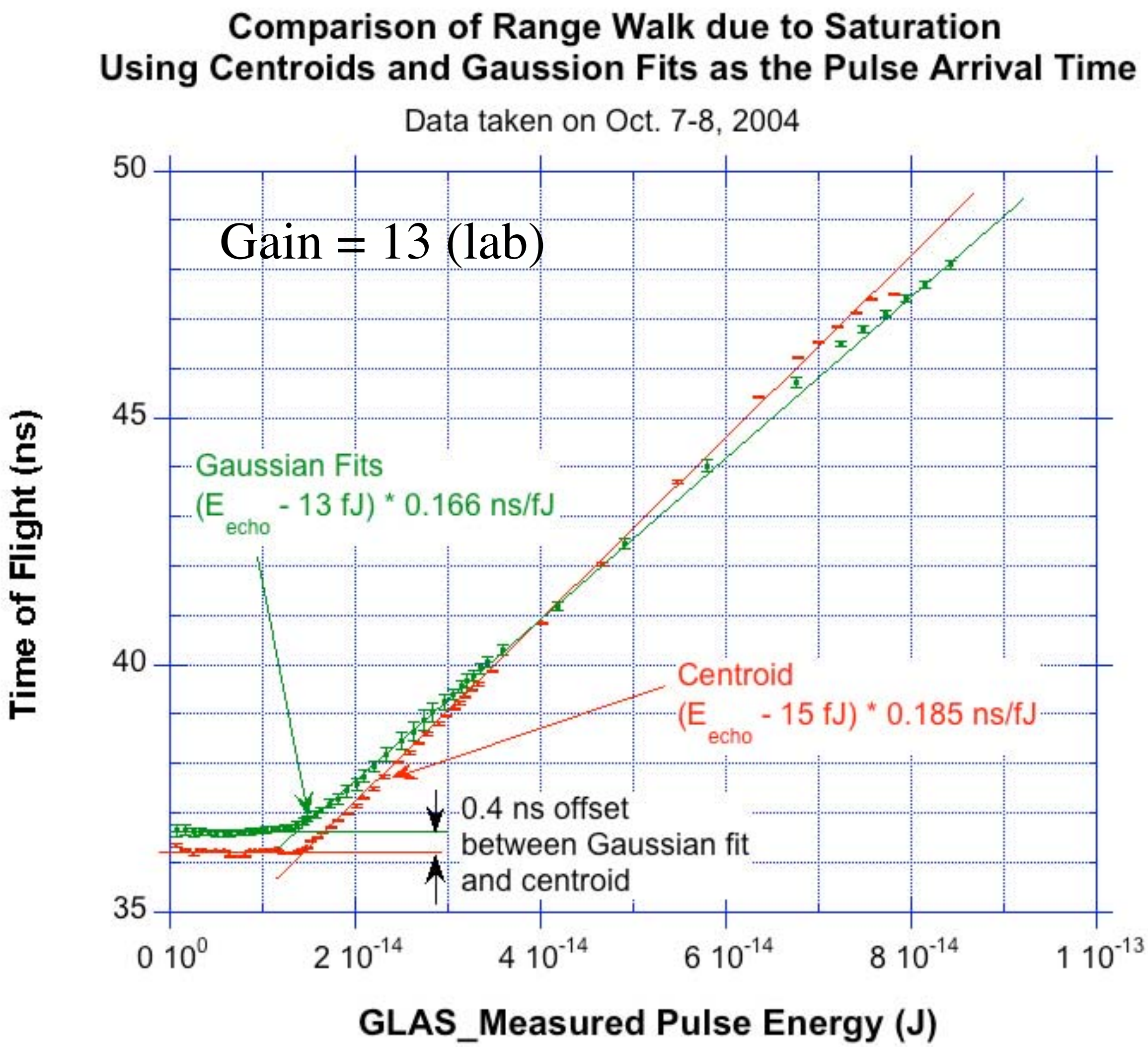
- Estimate (ie measured) the GLAS received echo pulse from the area of the detected echo pulse
- Pulse energy correction is needed for surface reflectance measurement
- Lab tests show that:
  - GLAS measured pulse energy is linear with incident pulse energy to ~8fJ/pulse
  - GLAS measured pulse energy is monotonic function of incident pulse energy under saturation (the latter can be uniquely solved from the former)

Range Walk due to Saturation at Different Gain



- Range walk is the apparent range change due to amplitude
- No measurable range walk until saturation occurs
- Is a monotonic function of the measured pulse energy for all values of gains;
- Range walk vs. measured pulse energy follows the same function form for gain = 8 to 13;
- Different correction coefficients are needed for other gain values
- Gain of 10.45 in the lab corresponds to gain of 13 in the instrument.

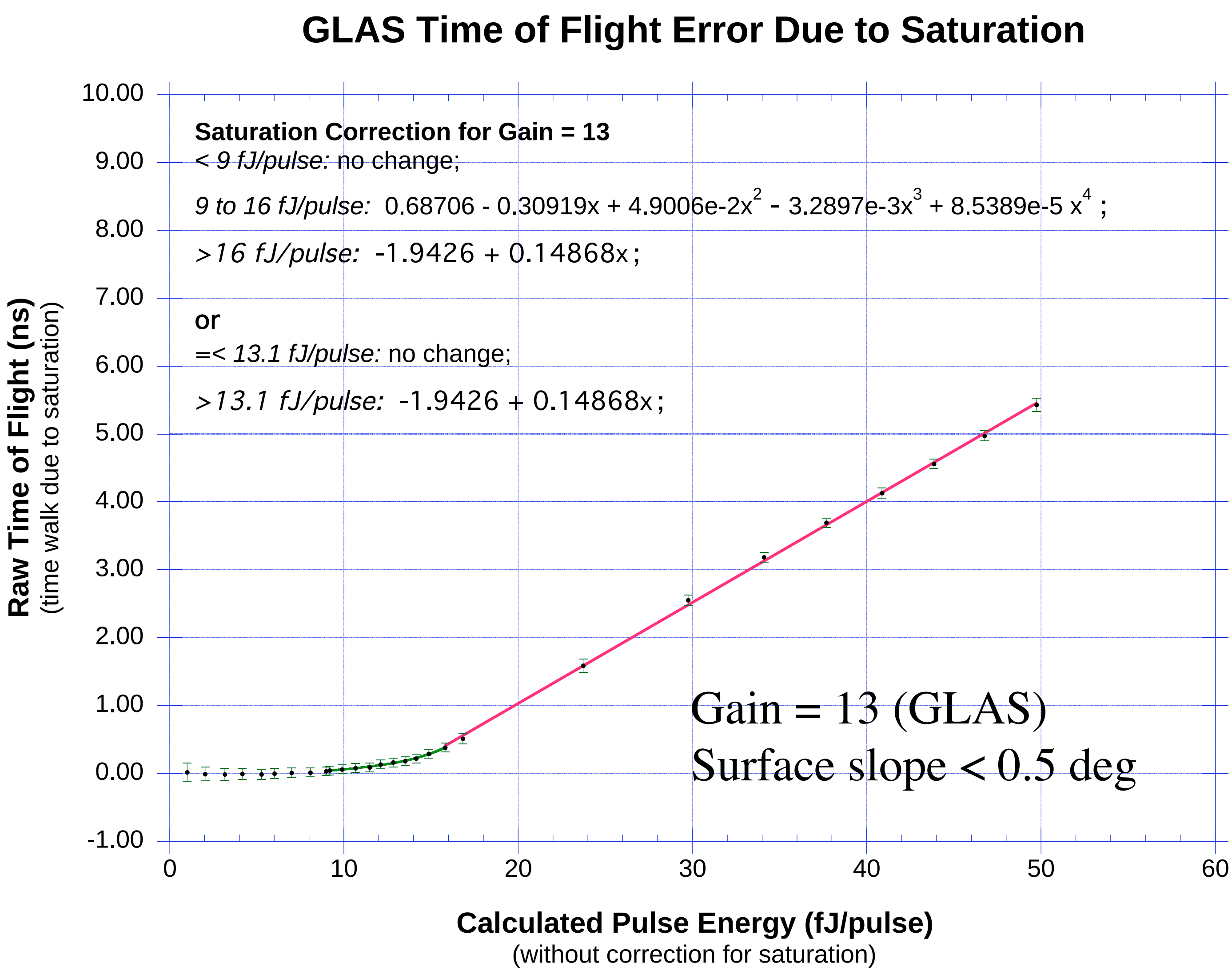
Range Walk due to Saturation - Gaussian Fit vs. Centroid



- Pulse timing via Gaussian fits give nearly the same results as the pulse centroids
- The flight spare detector may have a slightly different characteristics

Range Walk due to Saturation

- Recommended Correction Algorithm for Flat Surfaces & Gain=13



Saturation Corrections - Plans

- Perform additional tests and data analysis at other detector gain values
- Generate a look-up table of pulse energy correction coefficients for each gain value
- Generate a look-up table of range walk correction coefficients for representative gain values, and a means to interpolate
- Conduct tests for wider input pulse widths, representing echoes over sloped surfaces, at fixed detector gains
- Develop saturation correction algorithm for sloped surface echoes
- Develop saturation correction algorithm for higher energy echo pulses, like those from still water surfaces