Performance of Lifetime Histogram Statistics (LS) Derived Relative Gains for Landsat 8 OLI

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2016/04/11
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Outline

- Introduction
- Results from Current Lifetime Histogram Statistics Method
- Refinements to the Lifetime Histogram Statistics Method
- Edge vs Middle Detector Relative Gain

Acknowledgement:

This work was supported by the NASA Landsat Project Science Office and USGS EROS.

Introduction

- Relative Gains have become increasingly more important with the move to pushbroom sensors.
- Landsat 8 OLI has nearly 70,000 active detectors.
  - Each detector needs a separate relative gain.
- An error with one single detector is immediately visible.
  - This error is seen as a stripe in imagery.
- Current Landsat OLI Operations: Gains are calculated from Solar Diffuser Collects.
  - Vicarious techniques, such as lifetime statistics and side slither, are used as backup methodologies

Results from the Current Lifetime Histogram Statistics Method

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Methodology

Scene Selection

Scene Mean

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Scene St. Dev.

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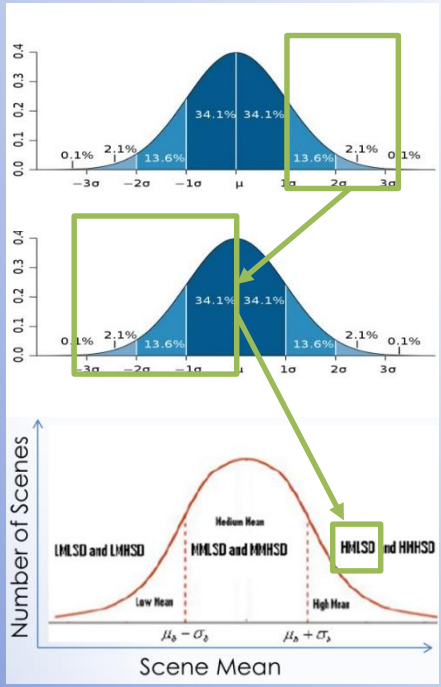


$$RG_i = \frac{\overline{DN_i}}{\overline{DN}}$$

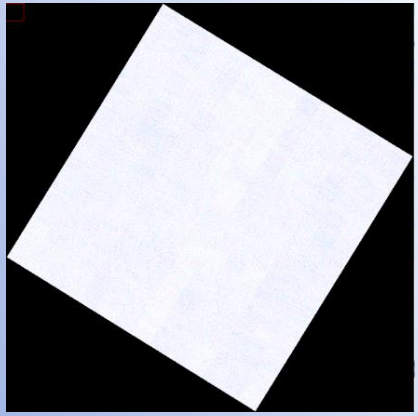
- RG_i: Relative Gain for the i^{th} detector
- $\overline{DN_i}$: Average DN for the i^{th} detector
- $\overline{DN}$: Average DN for all detectors within the sensor chip assembly

RG Validation

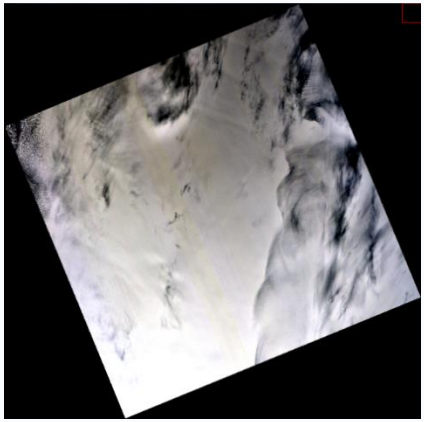
- HMLSD, MMLSD, and Diffuser relative gains were applied to 9 test sites for each collect obtained in 2014.
- This was done using the Landsat Image Assessment System (IAS) at USGS EROS
  - modify a Calibration Parameter File (CPF) template with relative gains derived by each method,
  - **ensure that the cycle over which the relative gains were derived included the scene acquisition date**
  - Use standard CPF for diffuser-derived relative gains

Test Scenes

Central Greenland
LC80110072014006LGN00



Dome C
LC80110072014006LGN00



Niger
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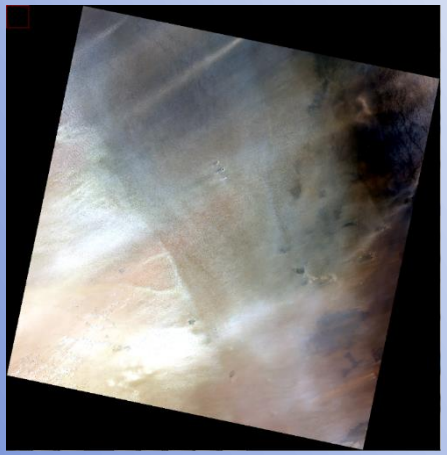
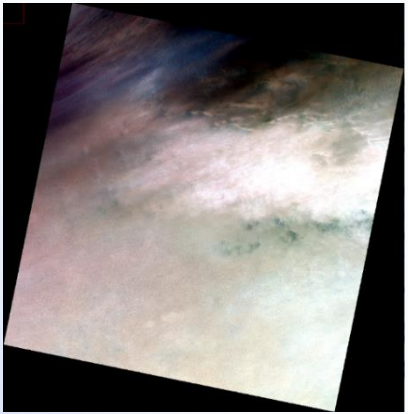
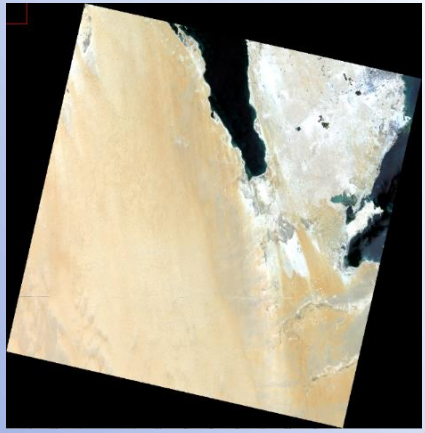


Mauritania/Mali
LC81990462014155LGN00



Test Scenes

Saudi Arabia
LC81630432014191LGN00



Brazil
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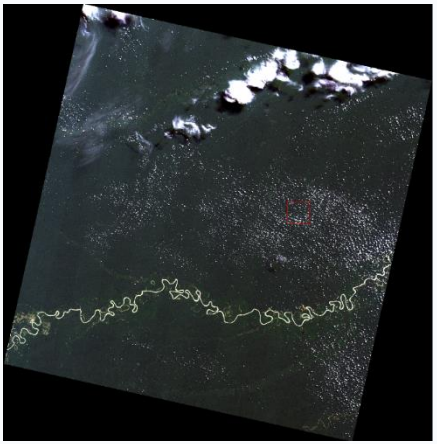

Congo
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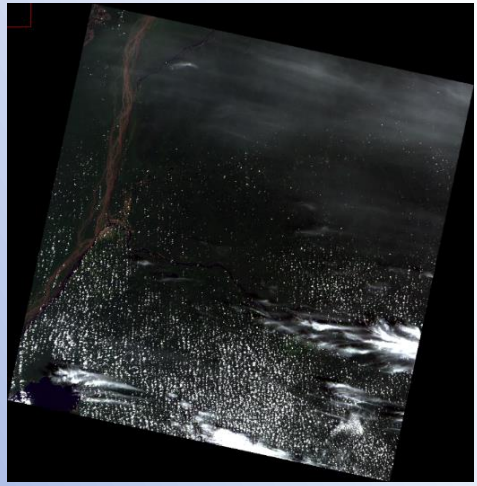
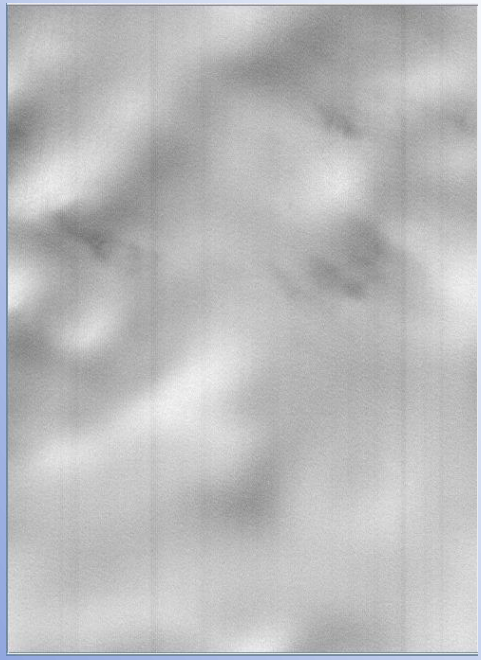


Visual Comparison

LC80030142014110LGN00

Band 1
SCA 1

Diffuser based Rel. Gains



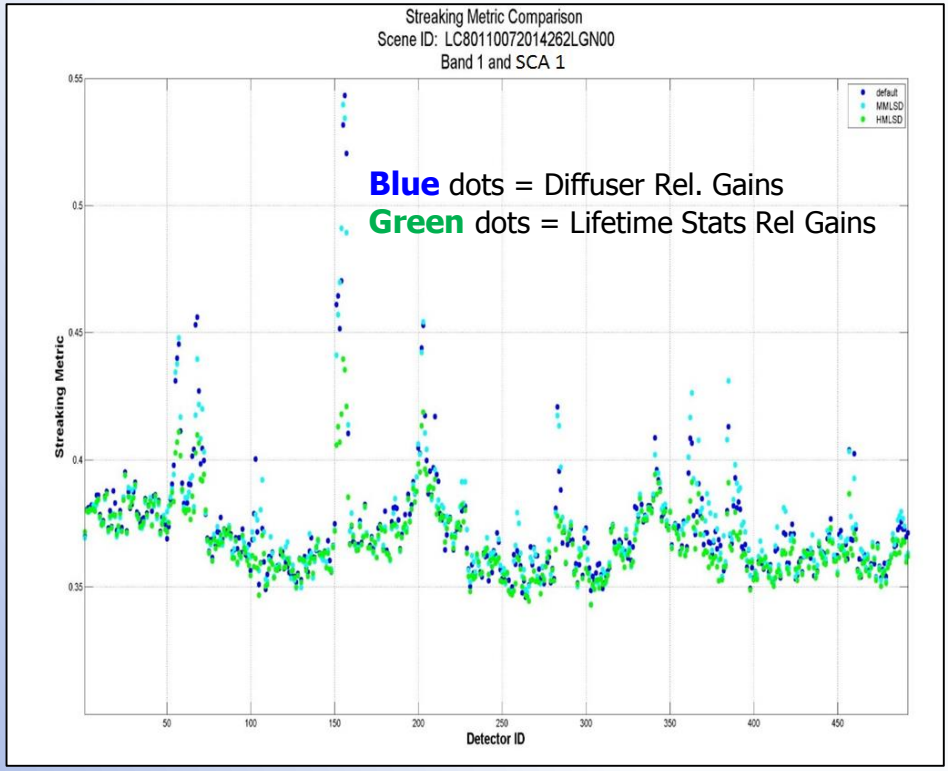
Lifetime Stats (HMLSD) based Rel. Gains

Statistical Comparison

Striping Metric

$$S_i = \frac{\left|\overline{L_i} - \frac{1}{2}\left(\overline{L_{i-1}} + \overline{L_{i+1}}\right)\right|}{\overline{L_i}}$$

This difference is calculated for each detector excluding the two at the ends of the SCA.



Which approach is statistically better: Paired T-Test

- $T_0 = \frac{\bar{D}}{S_D/\sqrt{n}}$,where
- $D_i = X_{1i} - X_{2i}$,
- $S_D^2 = \frac{\sum_{i=1}^{n} D_i^2 - \left[\frac{\left(\sum_{i=1}^{n} D_i\right)^2}{n}\right]}{n-1}$

- T_0: Test Statistic
- (X_{1i},X_{2i}): Represent the observed striping metric where 'i' corresponds to the same detector and the same scene
- n: Represents the number of samples

Statistical Comparison

T-Test

166 Test scenes using Diffuser, HMLSD, and MMLSD Rel. Gains. Striping metrics from the three sets were compared.

$$|T| = 3.291 \Rightarrow \textbf{Certainty = 99.95\%}$$

- HMLSD – Diffuser: T = -195.0368
- MMLSD – Diffuser: T = -55.7899
- HMLSD – MMLSD: T = -199.4528
- Number of samples = 8,003,856 (166*492*14*7)
- This includes bands 1-7

Results of the T-Test indicate that HMLSD Rel. Gains performed best, followed by MMLSD Rel. Gains, and then diffuser Rel. Gains.

Refinements to the Lifetime Histogram Statistics Method

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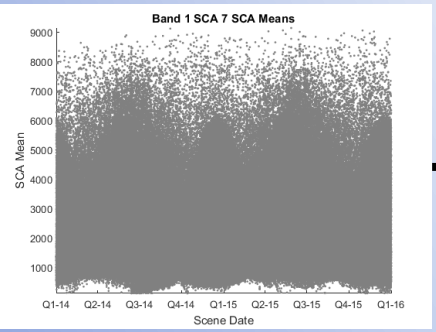
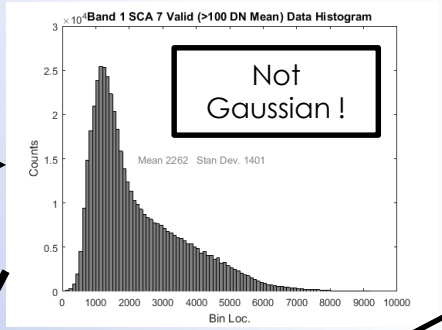
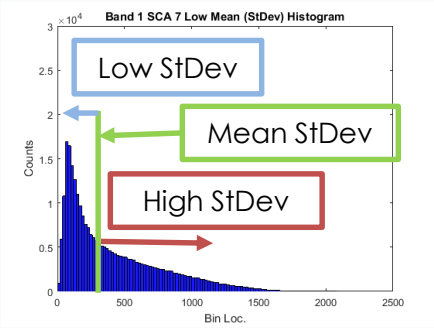
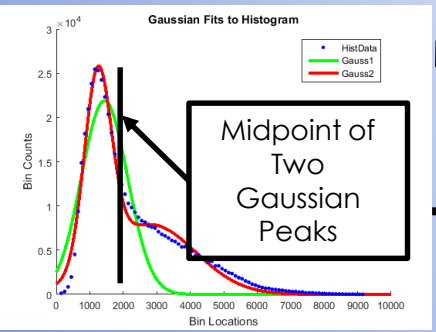
Methodology

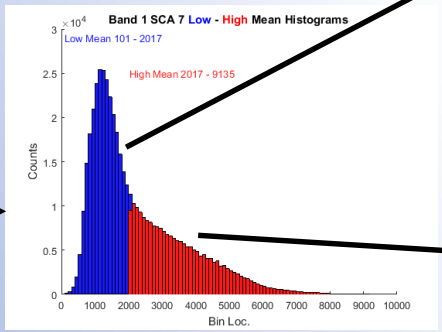
Scene Selection

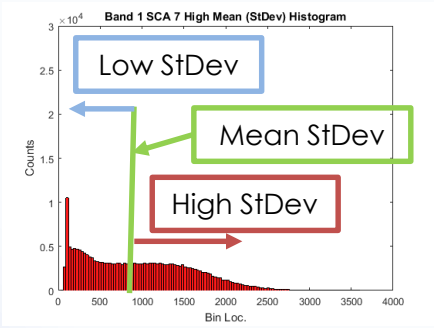




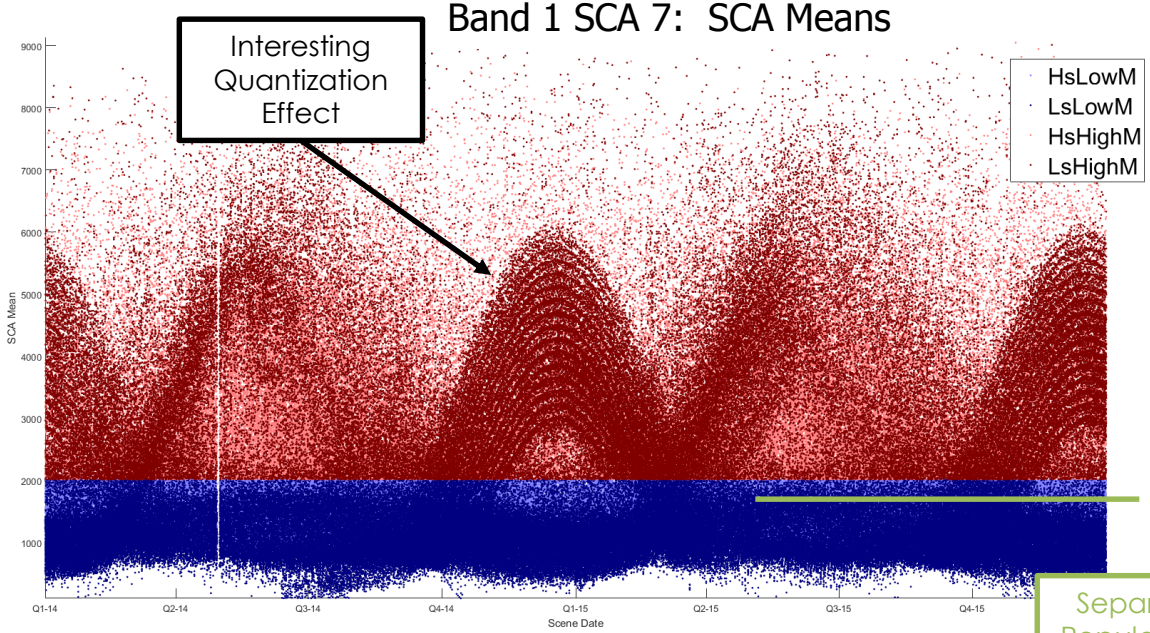








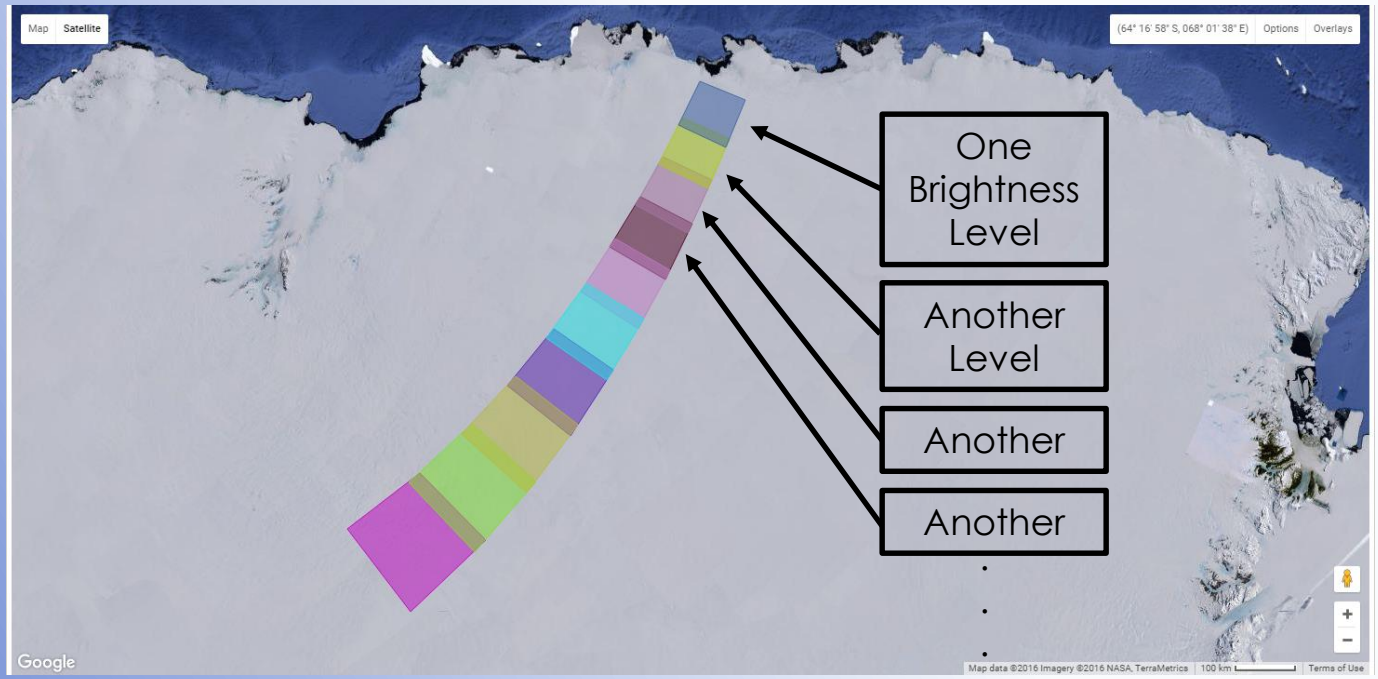
Scene Selection Cont.



Band 1 SCA 7: All Means from 2014-2015

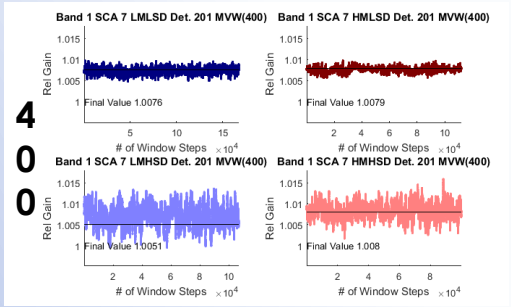
Separate Populations ?

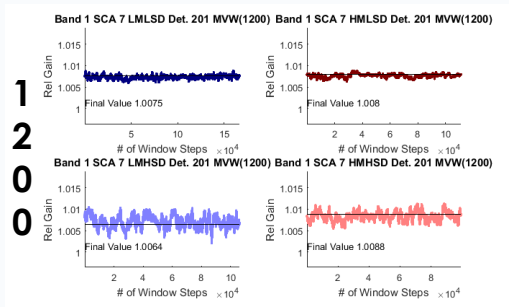
Antarctica Paths



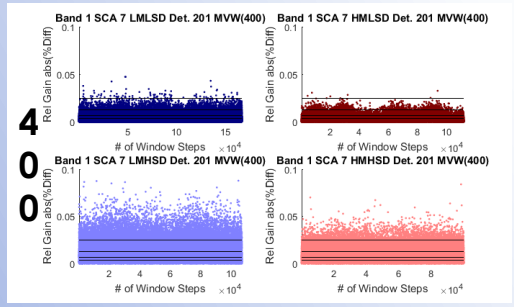
Number of Images Required

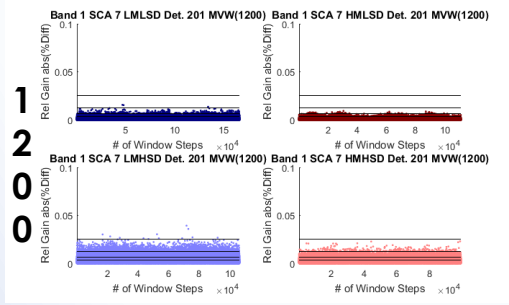
Moving Window Relative Gains: The variation decreases as the number of images used increases. High Mean Low StDev have the least amount of variation.





1st Degree Difference: The black horizontal lines are 0.025%, 0.0125%, 0.00625%, and 0.003125% corresponding to 4 DNs, 2 DNs, 1 DN, and 0.5 DNs, respectively.

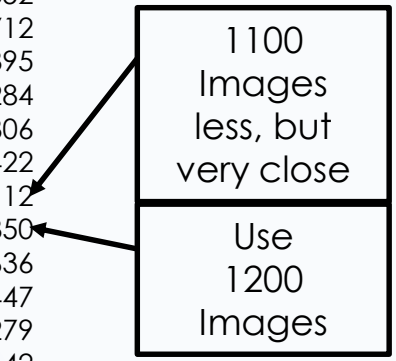




Mean RG Difference + 1 StDev

- When is enough enough?
- Moving windows from 100-2000 images were used.
- The mean 1st degree difference + 1 StDev of the 1st degree difference was evaluated.
- When this sum was less than 0.003125%, we considered this the threshold.

0.034548
0.017131
0.011422
0.008561
0.006852
0.005712
0.004895
0.004284
0.003806
0.003422
0.003112
0.002850
0.002636
0.002447
0.002279
0.002142
0.002012
0.001901
0.001803
0.001711



Recommendation: Use 1200 scenes to calculate Relative Gains

Edge vs Middle Detector Relative Gains

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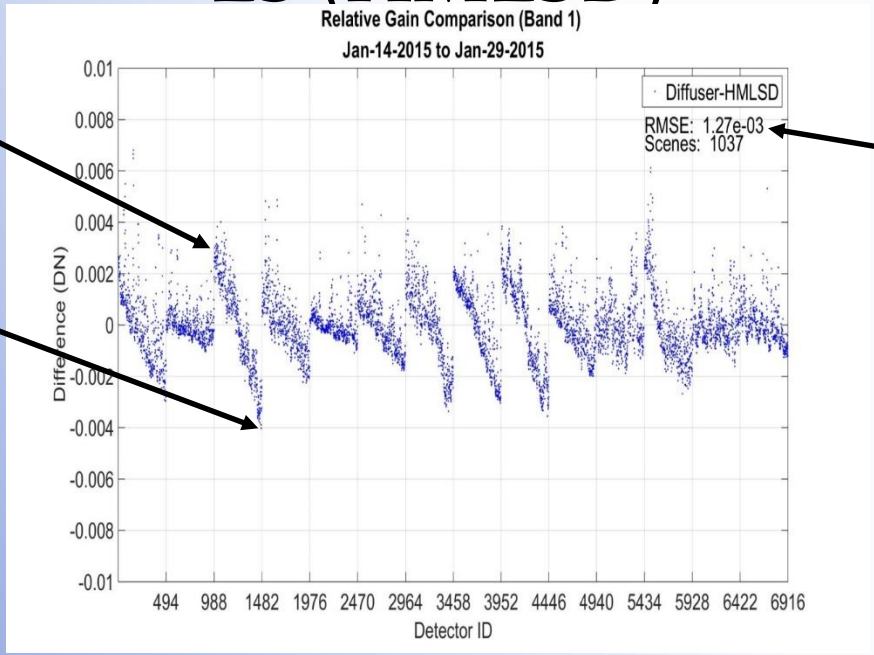
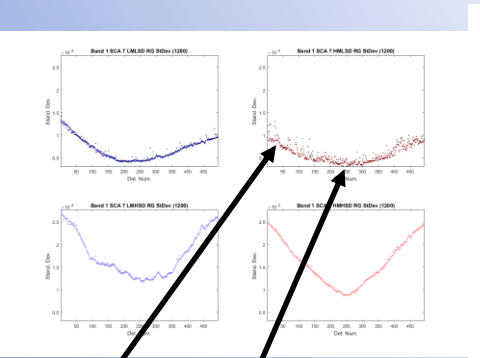
Differences Between Diffuser and LS (HMLSD)

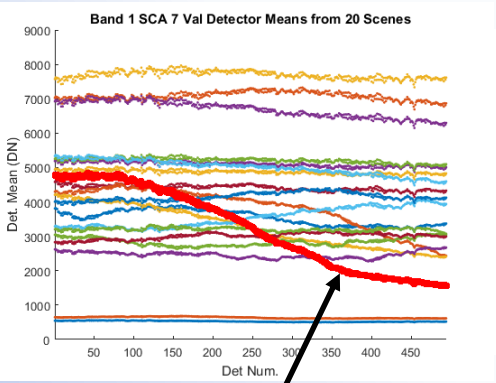


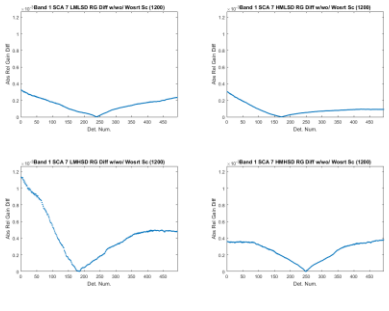
Linear Structure Across an SCA

$2^{14} \bullet 1.27e\text{-}3 = 20.8$

Standard Deviation of Edge Dets. vs Middle Dets.







StDev Higher for Edge Dets than Middle Dets

The "Worst" Scene in the Collection

Difference Between RGs calculated with and without the "worst" scene. Larger differences in Edge Dets.

Conclusions

- The current lifetime histogram statistics method is at least as good as the diffuser based method
- The current method can be improved with selecting better data
  - At least 1200 scenes should be used to calculate relative gains
  - Bad scenes have a larger effect than expected due to affecting edge detectors more than middle detectors
- The SCA-SCA discontinuity needs to be considered
  - Especially with the linear structure in the relative gains

Future Work

- Provide stronger evidence to support 1200 scene minimum
  - Apply relative gains to imagery
- Determine a relative gain update schedule
  - How often do new relative gains need to be calculated?
- Calculate SCA-SCA discontinuity ratios from database statistics