

Automated SNR Measurement for High-resolution Satellite Imagery

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Satrec Initiative

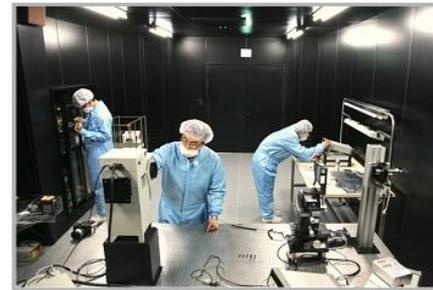
- Satellite Manufacturer in South Korea
 - Satellite platforms
 - Electro-optical instruments
 - Ground systems



Flight hardware assembly clean room



Optics assembly clean room



Sensor calibration clean room



Satellite integration clean room

Satrec Initiative

- Two satellites were launched
 - RazakSat-1
 - DubaiSat-1 - GSD 2.5m (Pan) 5.0m (MS)
- Two additional satellites will be launched
 - DubaiSat-2
 - Deimos-2 - GSD 1.0m (Pan) 4.0m (MS)
- Several ground systems for
 - LEO: KOMPSAT-1, 2, 3, 3A, 5
 - GEO: COMS
- UAVs in collaboration with Korean Air

Satrec Initiative



Chicago Midway Intl. Airport

DubaiSat-1 Pan sharpened (GSD 2.5m)

Image credit: EIAST

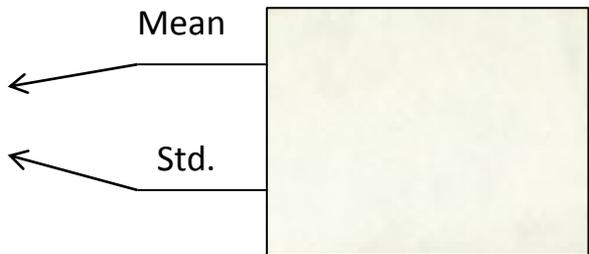
SNR

- SNR is a key index of image quality

$$SNR = \frac{Signal}{Noise} = \frac{m}{S}$$

Mean

Std.



- In-flight SNR
 - On-board Calibration HW
 - Homogeneous Area Images
eg. Natural Target (Dome-C), Artificial Object (Tarp)



Dome-C (Wikipedia)

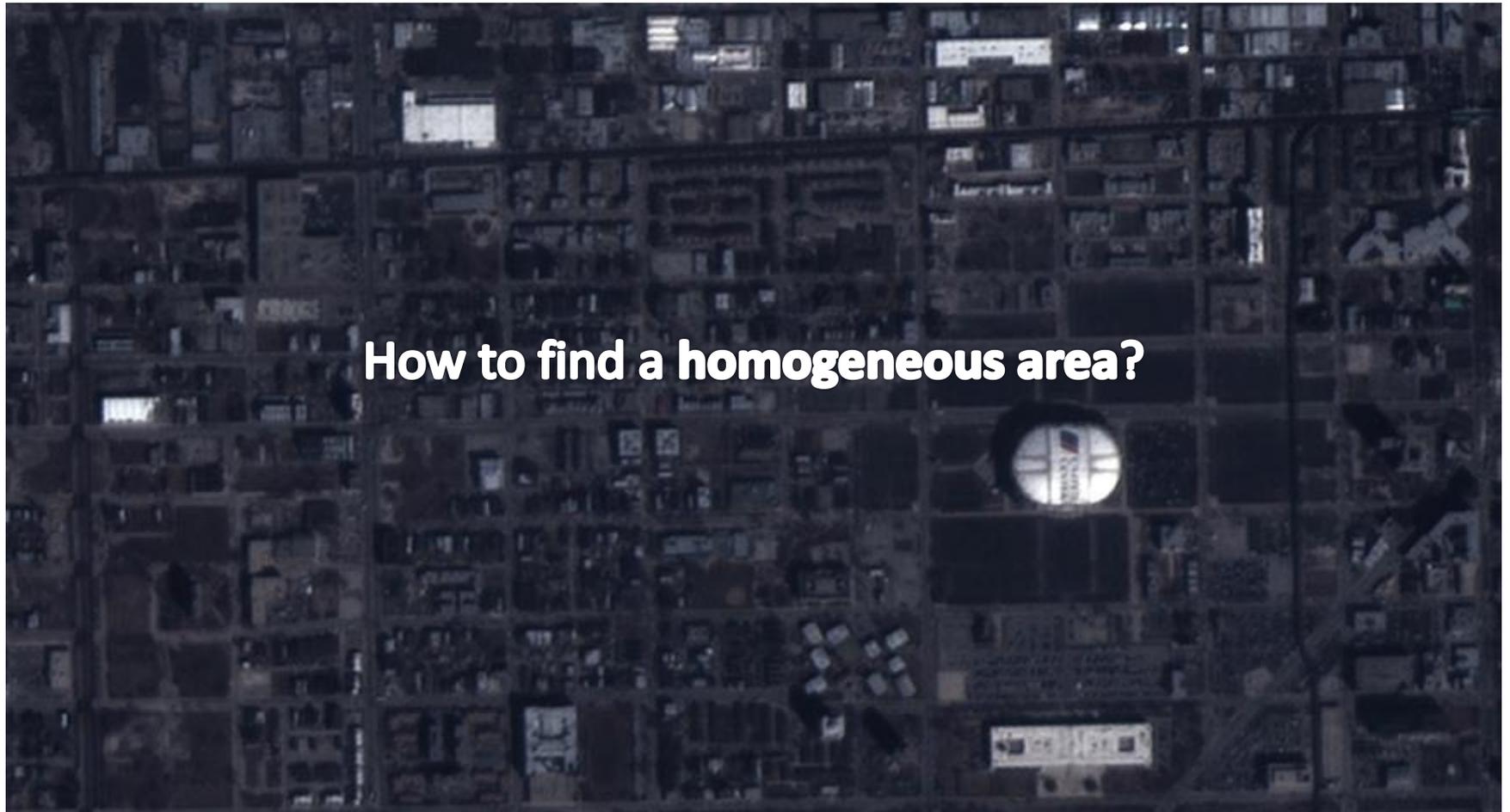
AutoSNR

- AutoSNR
 - Measures SNR from normal images taken during EO operation
- AutoSNR doesn't need
 - Additional HW
 - Satellite operation
- AutoSNR gives
 - SNR @ various radiance levels
 - SNR @ every image acquisition



➔ SNR

Major Challenge

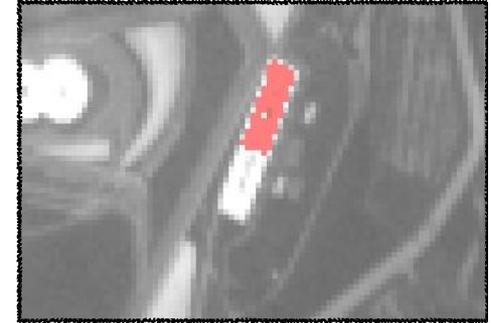


How to find a homogeneous area?

AutoSNR Procedure

Step 1 Homogeneous Area Detection

- Choose start points by Grid sampling
- Selects nearby pixels having the same DN
- Includes in-between hole pixels



Step 2 SNR @ DN calculation

$$SNR_i = \hat{a} \prod_{j=1}^N w_{ij} \frac{m_{ij}}{S_{ij}}$$

$$w_{ij} = \text{normalize}(|m_{ij} - c_i|)$$

N = num. of blocks in DN=i

i = bin index

j = block index in i-th bin

c = DN bin center

The SNR is valid only if N > 10

Step 3 Fit to Power function

- $SNR = a \times DN^b$
- Suitable for modeling SNR and DN in shot noise limited system

Homogeneous Area Detector

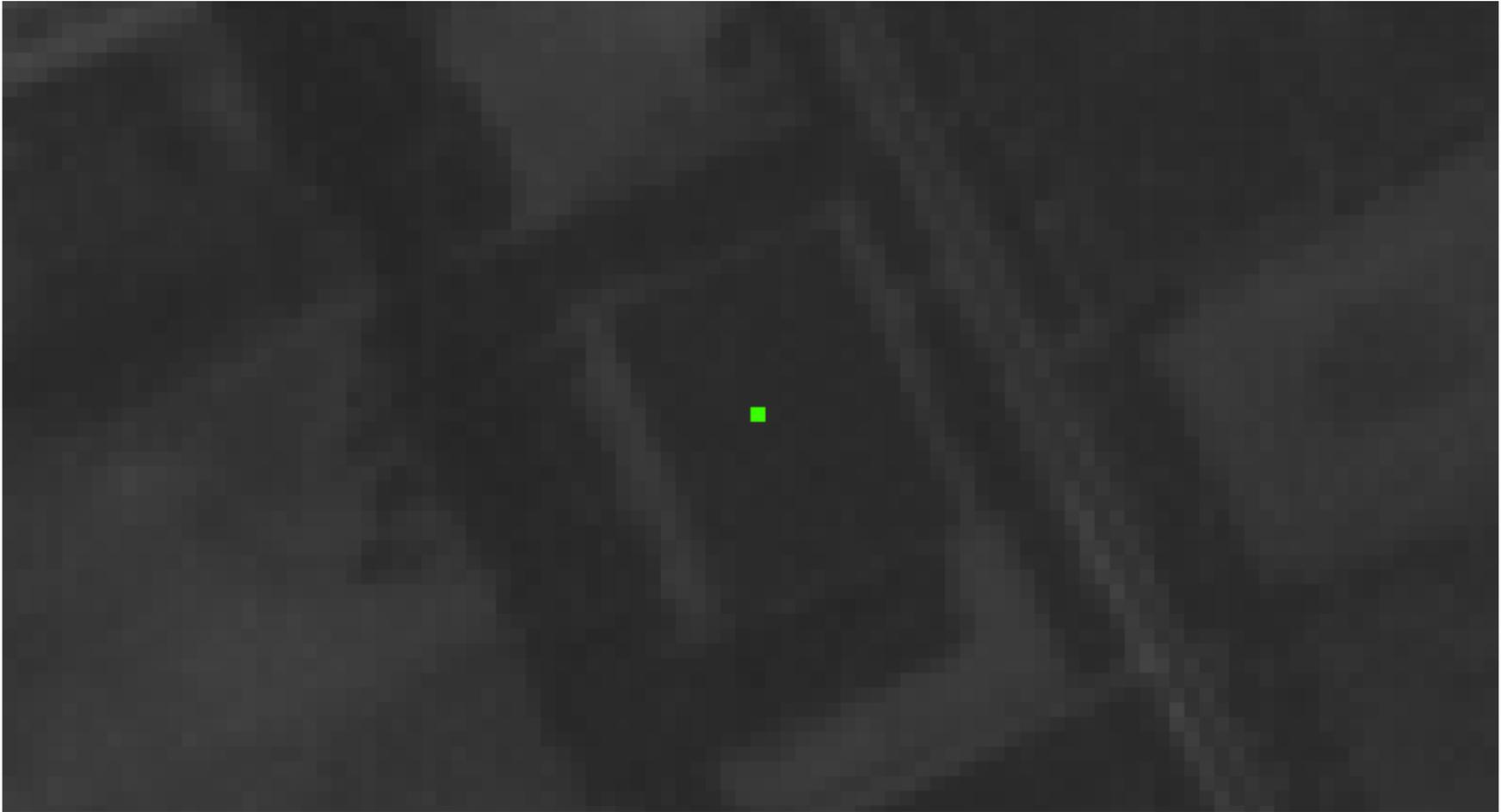
Assumption

- If a region is homogeneous, a pixel in it has at least one neighbor pixel which has the same DN value
- A pixel surrounded by homogeneous pixels may also be homogeneous but has different DN due to noise

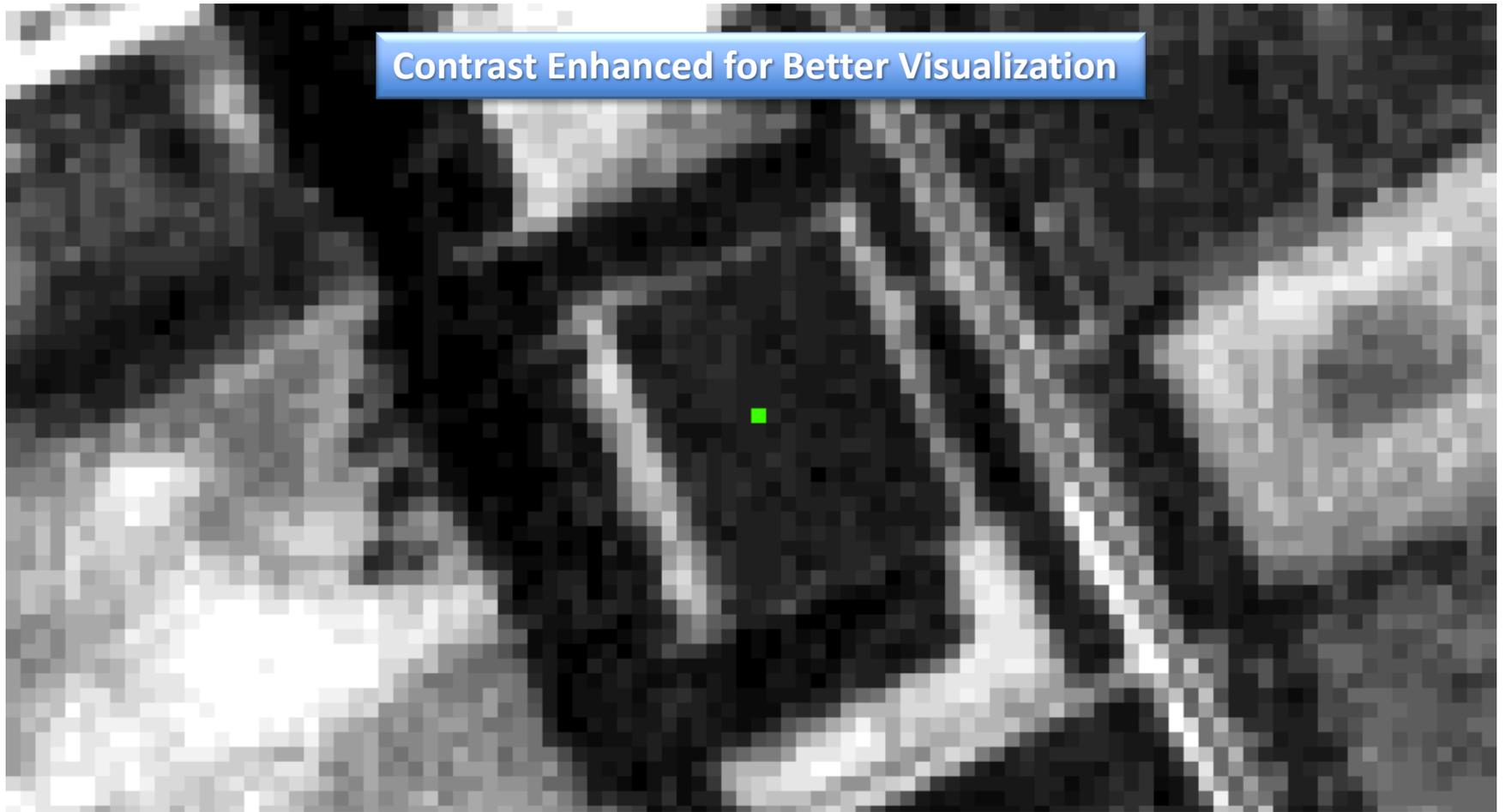
Detection Algorithms

1. Flood Fill
2. In-between Hole Filling (101 mask)

Homogeneous Area Detector



Homogeneous Area Detector



Contrast Enhanced for Better Visualization

Homogeneous Area Detector

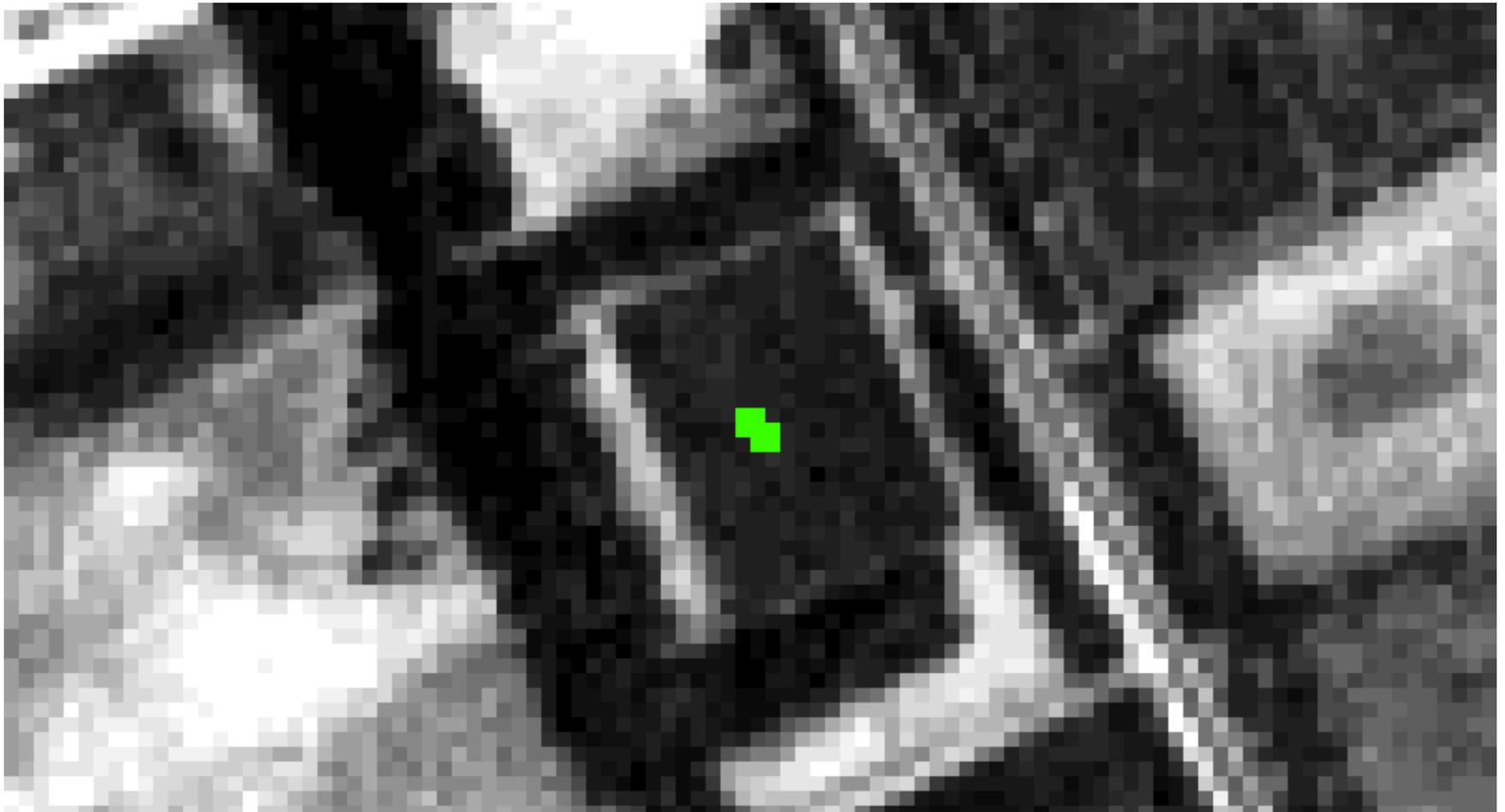
Search for nearby regions



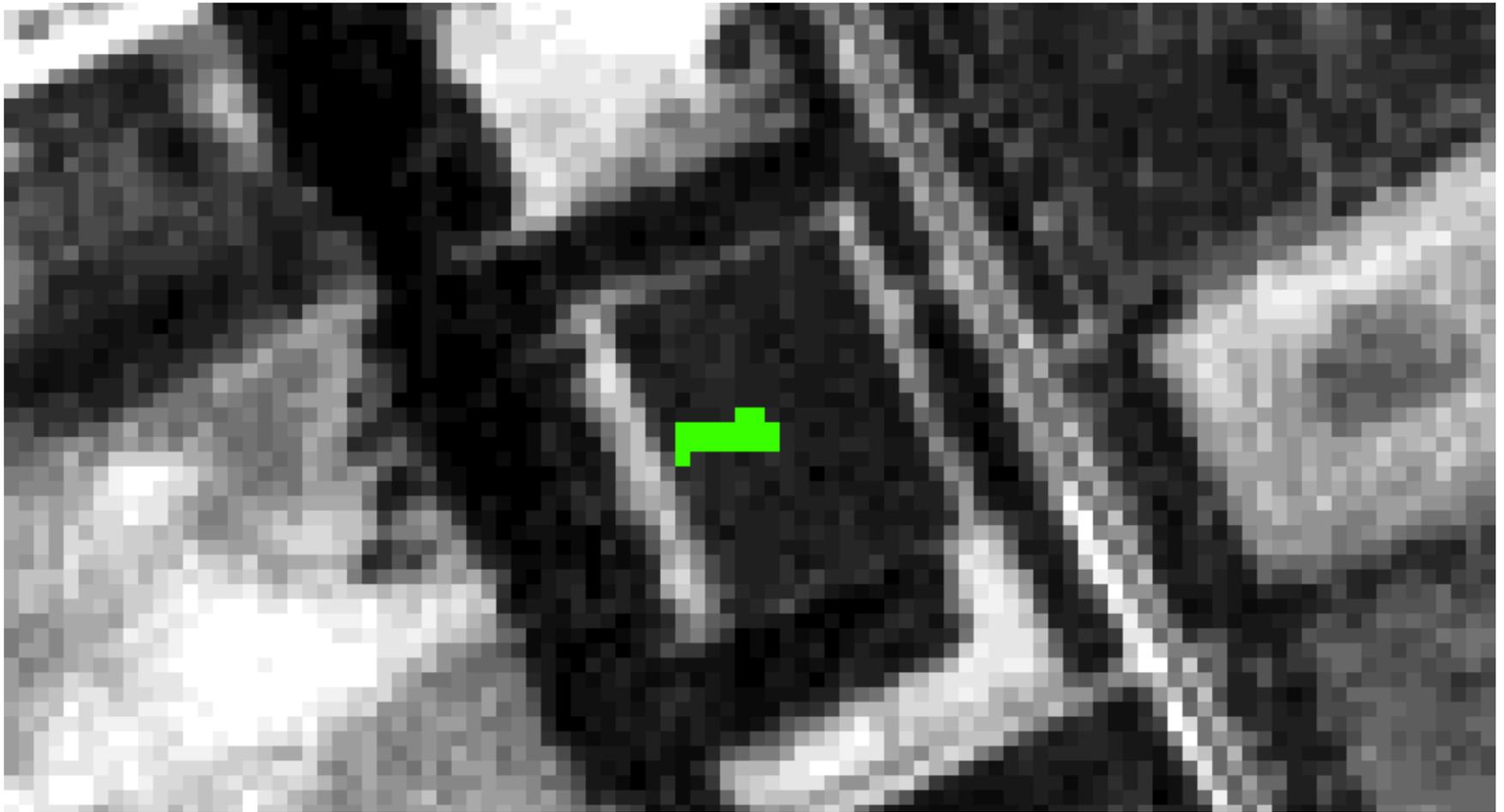
Fill pixel at (i, j) if the difference of DN from its neighbor pixel.

$$Dv < wS \quad (w = 0.01 \times DN_{\max})$$

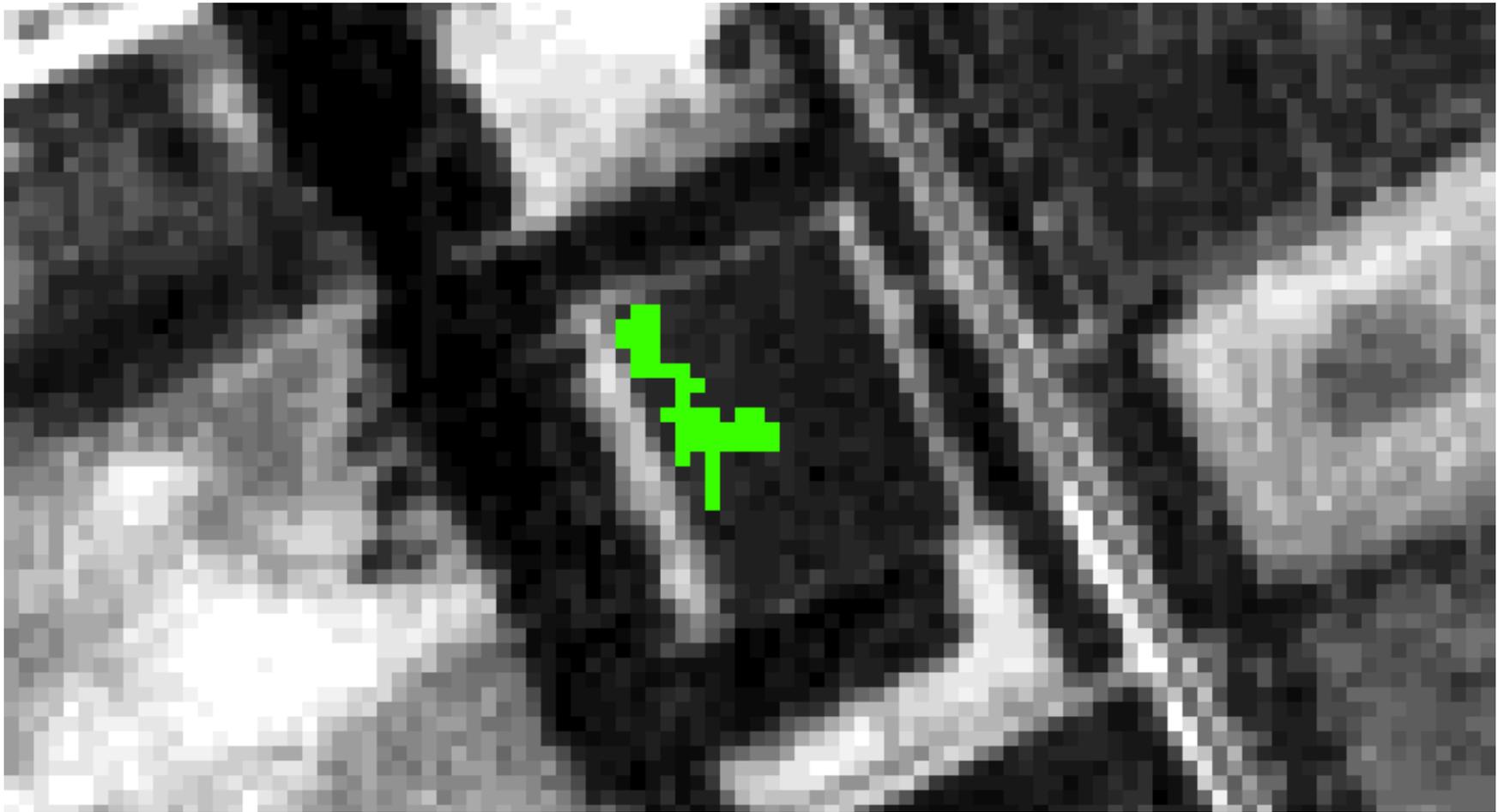
Homogeneous Area Detector



Homogeneous Area Detector



Homogeneous Area Detector



Homogeneous Area Detector



Homogeneous Area Detector

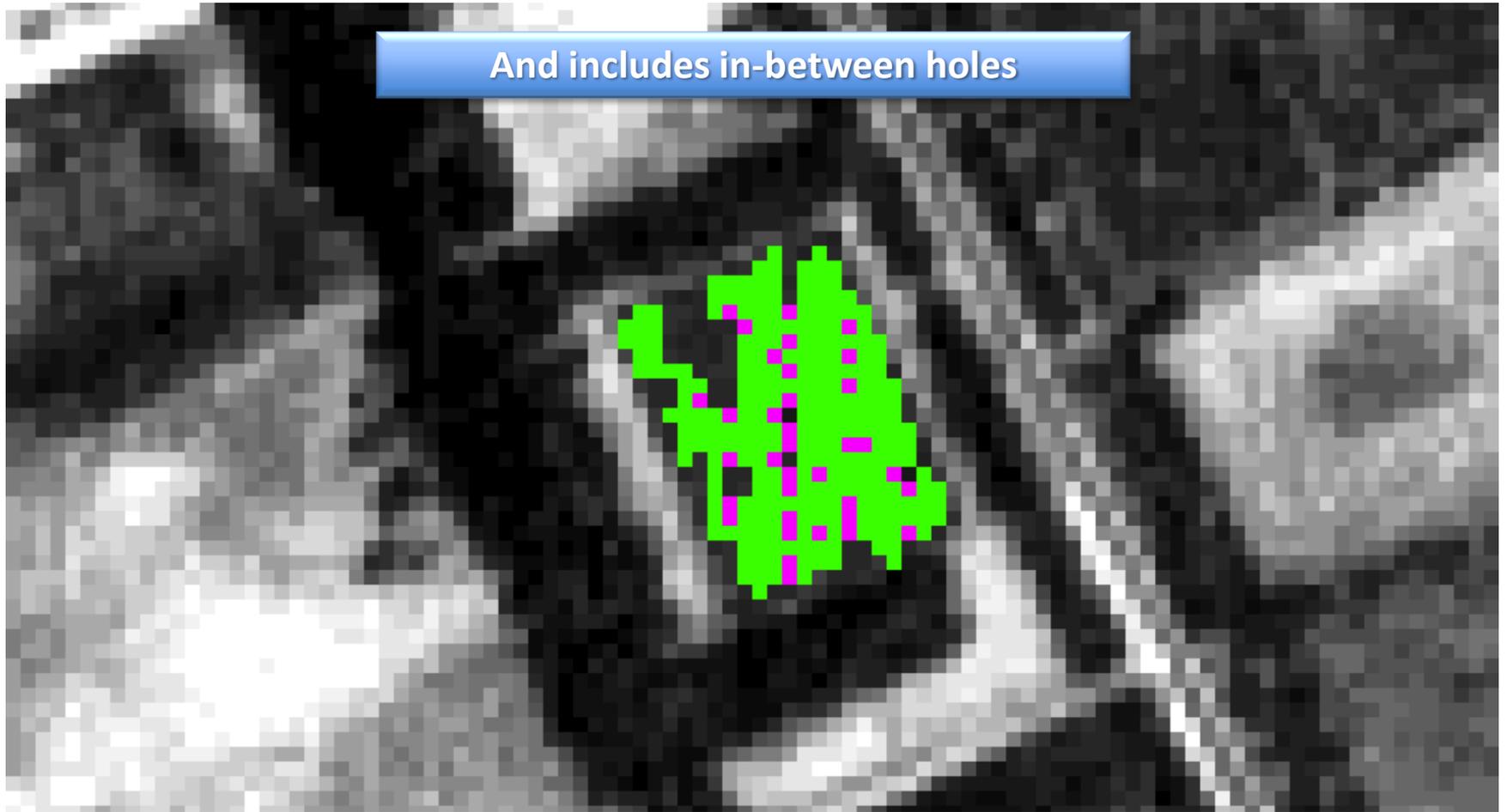


Homogeneous Area Detector



Homogeneous Area Detector

And includes in-between holes



Homogeneous Area Detector

Final Homogeneous Patch



Experiments

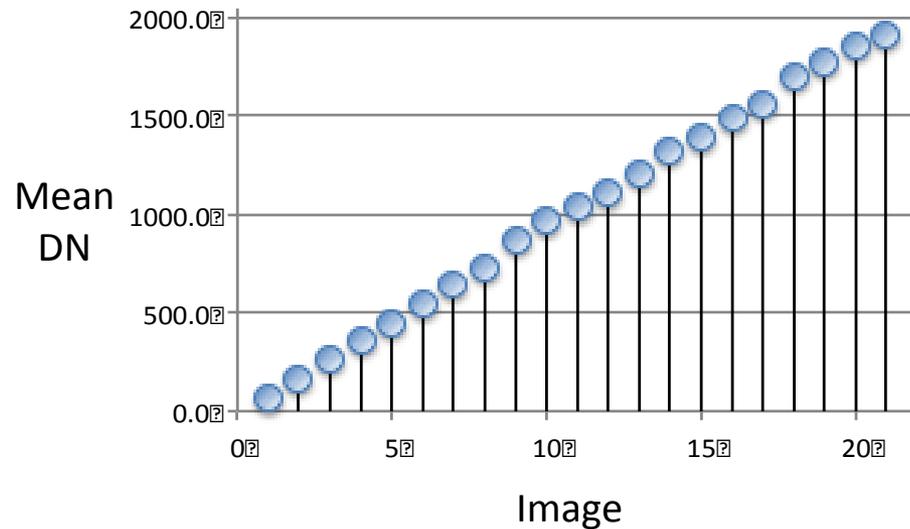
- Experiments
 - Flat-field Image
 - Synthesized Image
 - Flight Image
- Image Source
 - **DubaiSat-1** (Pan GSD = 2.5m)
 - **GIS** (Pan GSD = 2.5m)

Flat-field Image

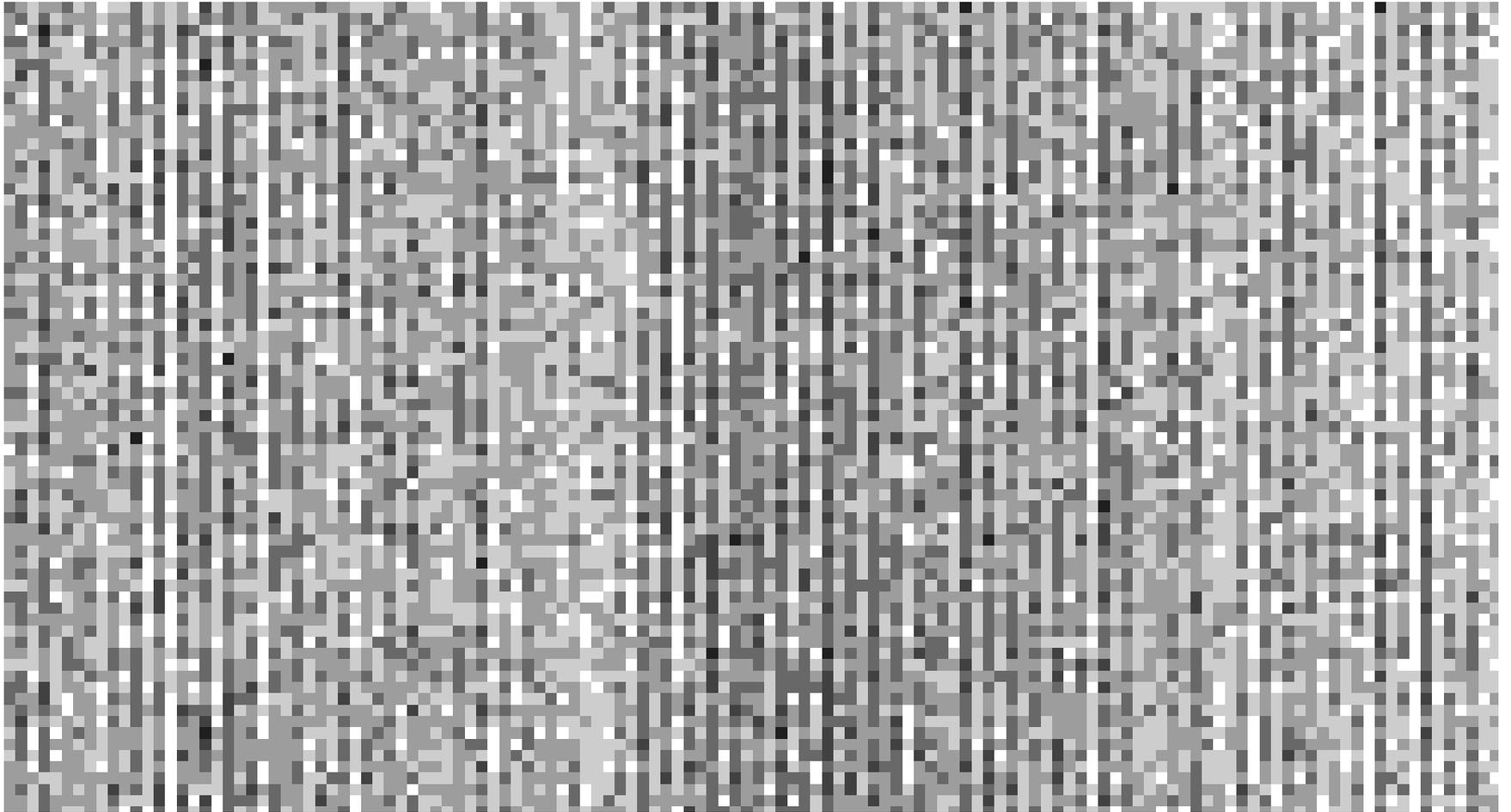
- 21 Flat-field images were generated using an integrator before launch



GIS Flat-field Images (MSB)



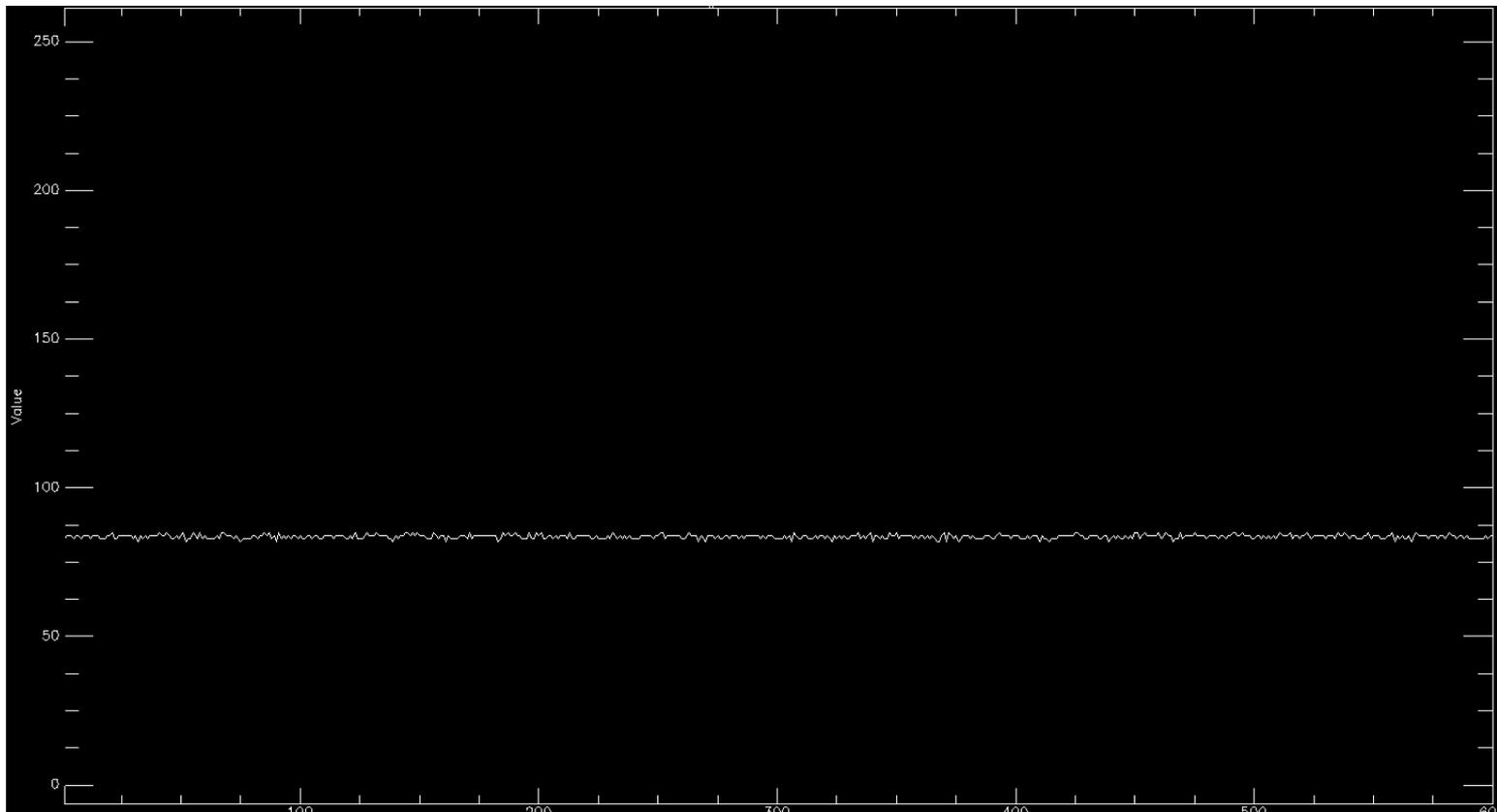
Flat-field Image (GIS MSB)



* Contrast enhanced for presentation

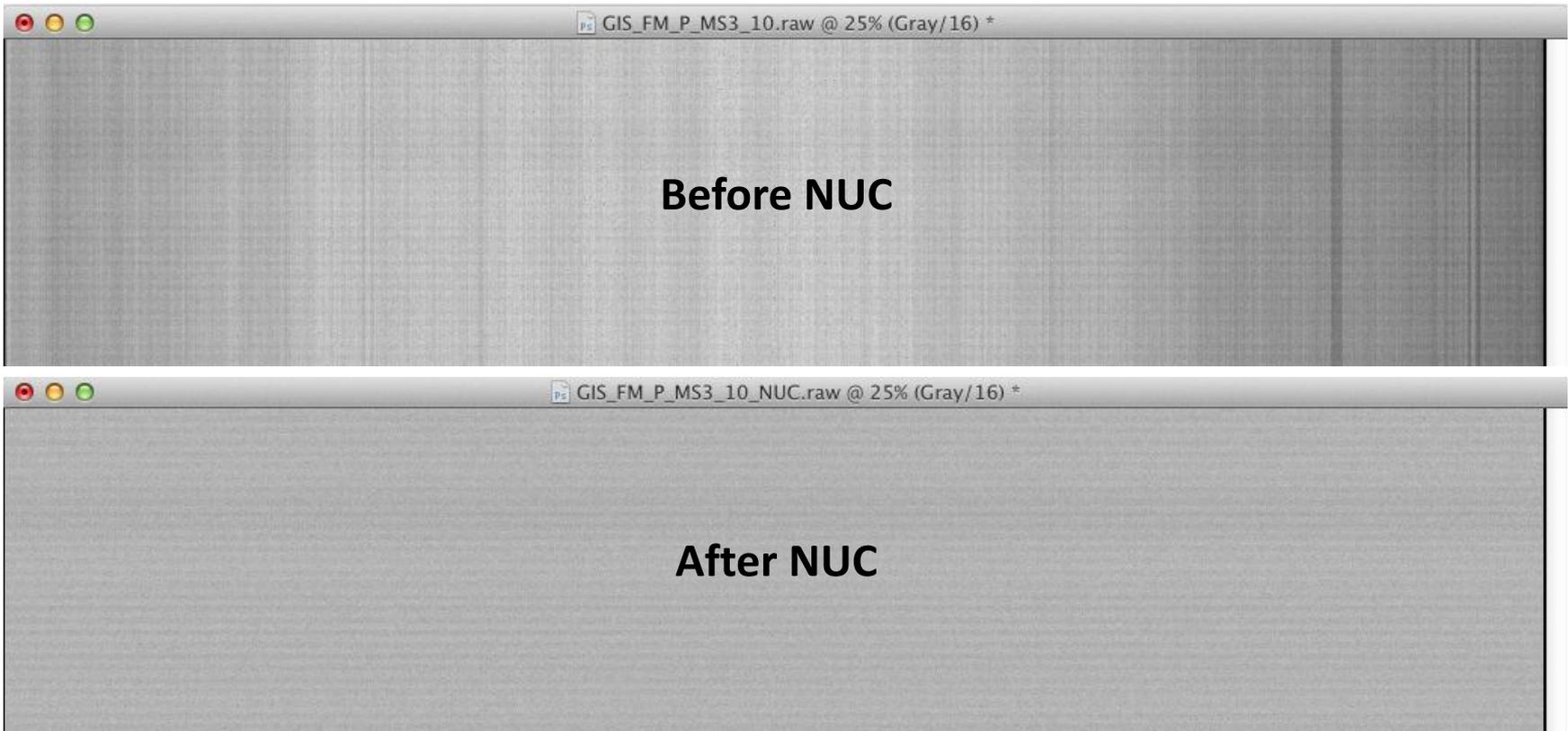
Flat-field Image (GIS MSB)

- Horizontal Profile



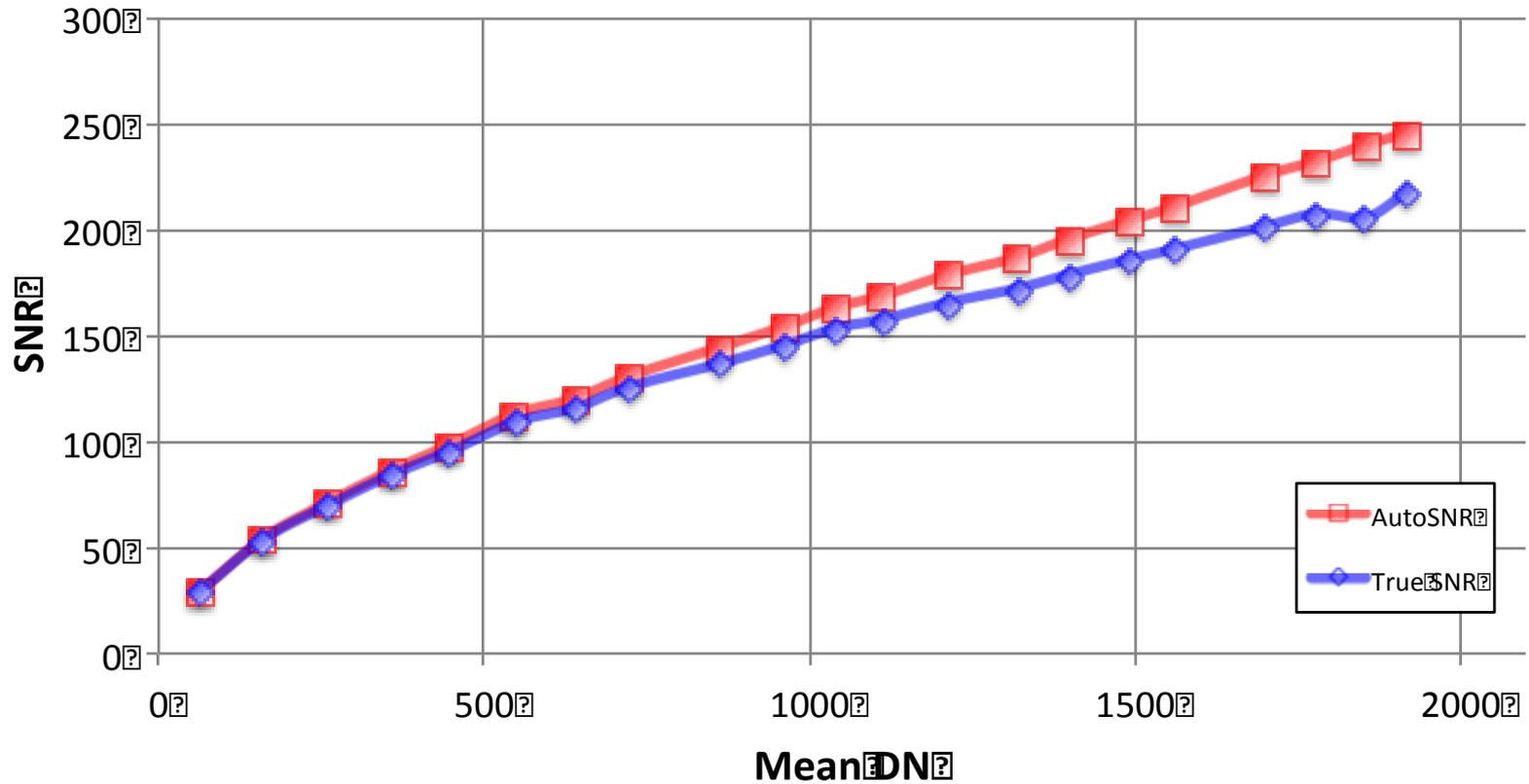
Flat-field Image

- NUC (PRNU Correction) was applied



Flat-field Image

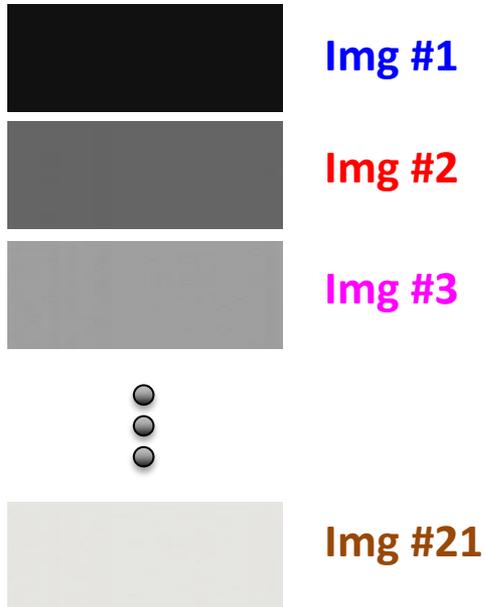
Comparison of AutoSNR and the truth



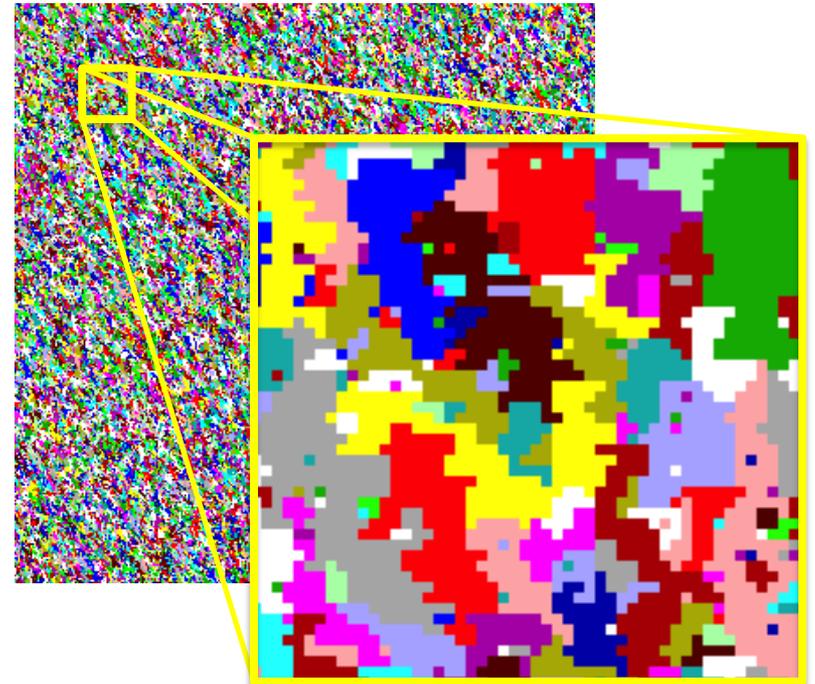
AutoSNR on Synthesized Image

- Synthesize an image from 21 flat-field images using probabilistic random continuity

Flat-field Images

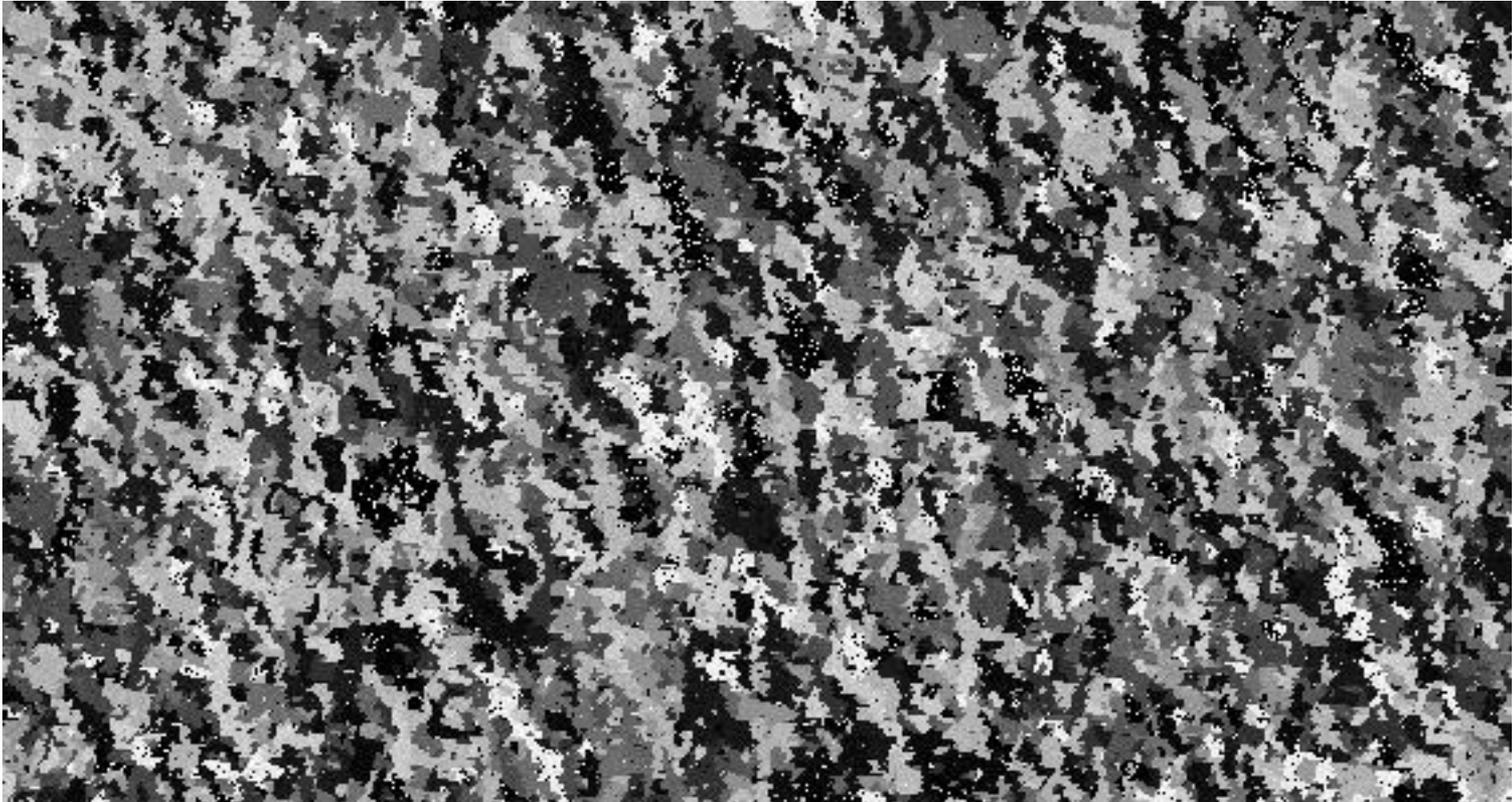


Mapping of Image



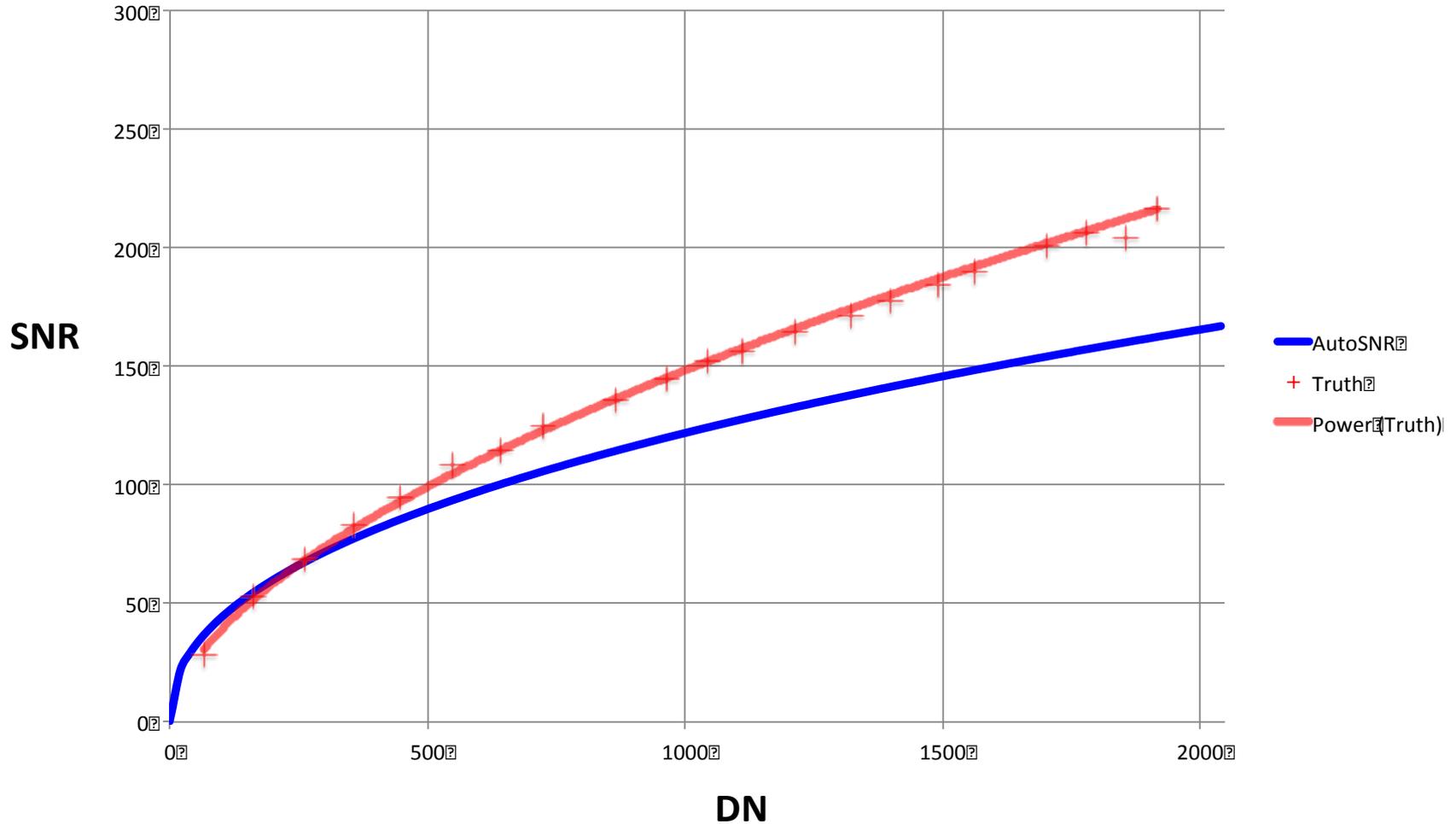
AutoSNR on Synthesized Image

- Image Synthesis Result

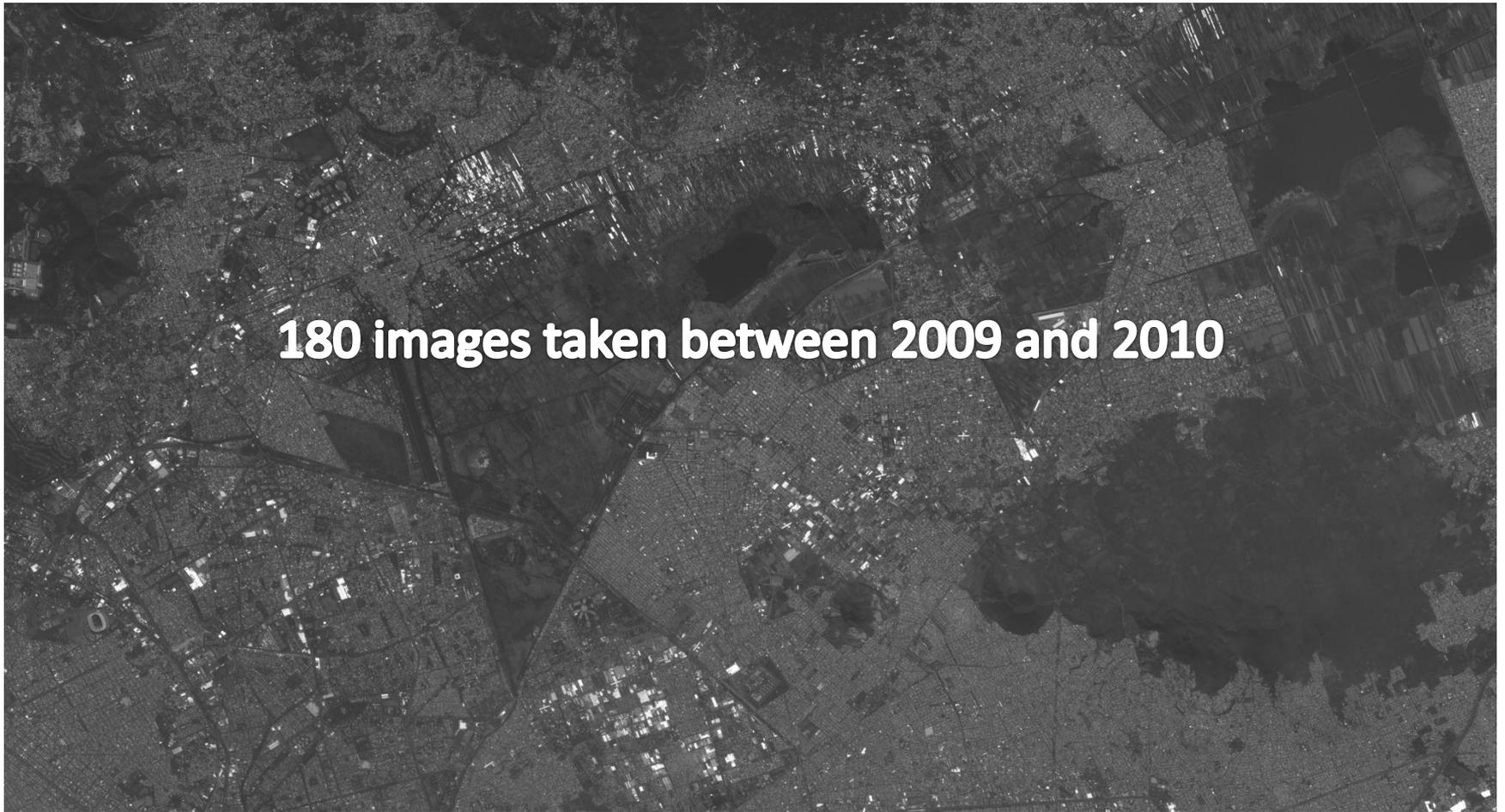


AutoSNR on Synthesized Image

Comparison of AutoSNR and the truth

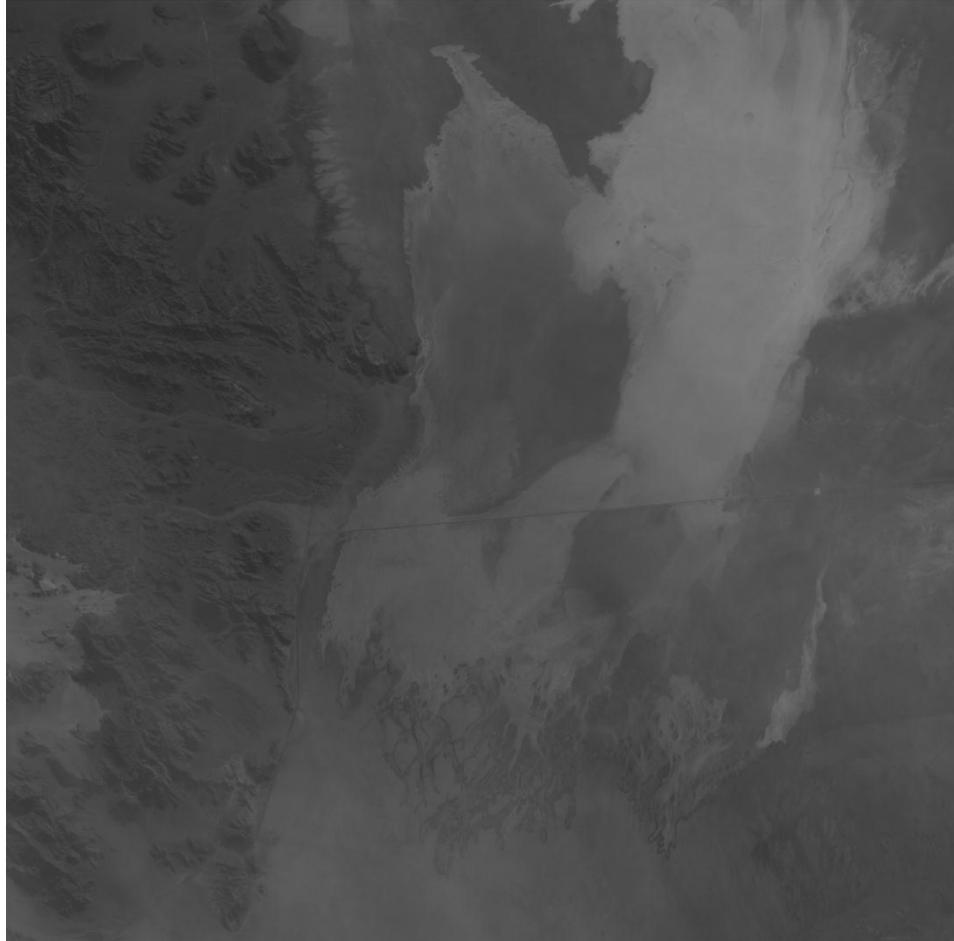


AutoSNR on DubaiSat-1 Image



AutoSNR on Single DubaiSat-1 Image

Input Image

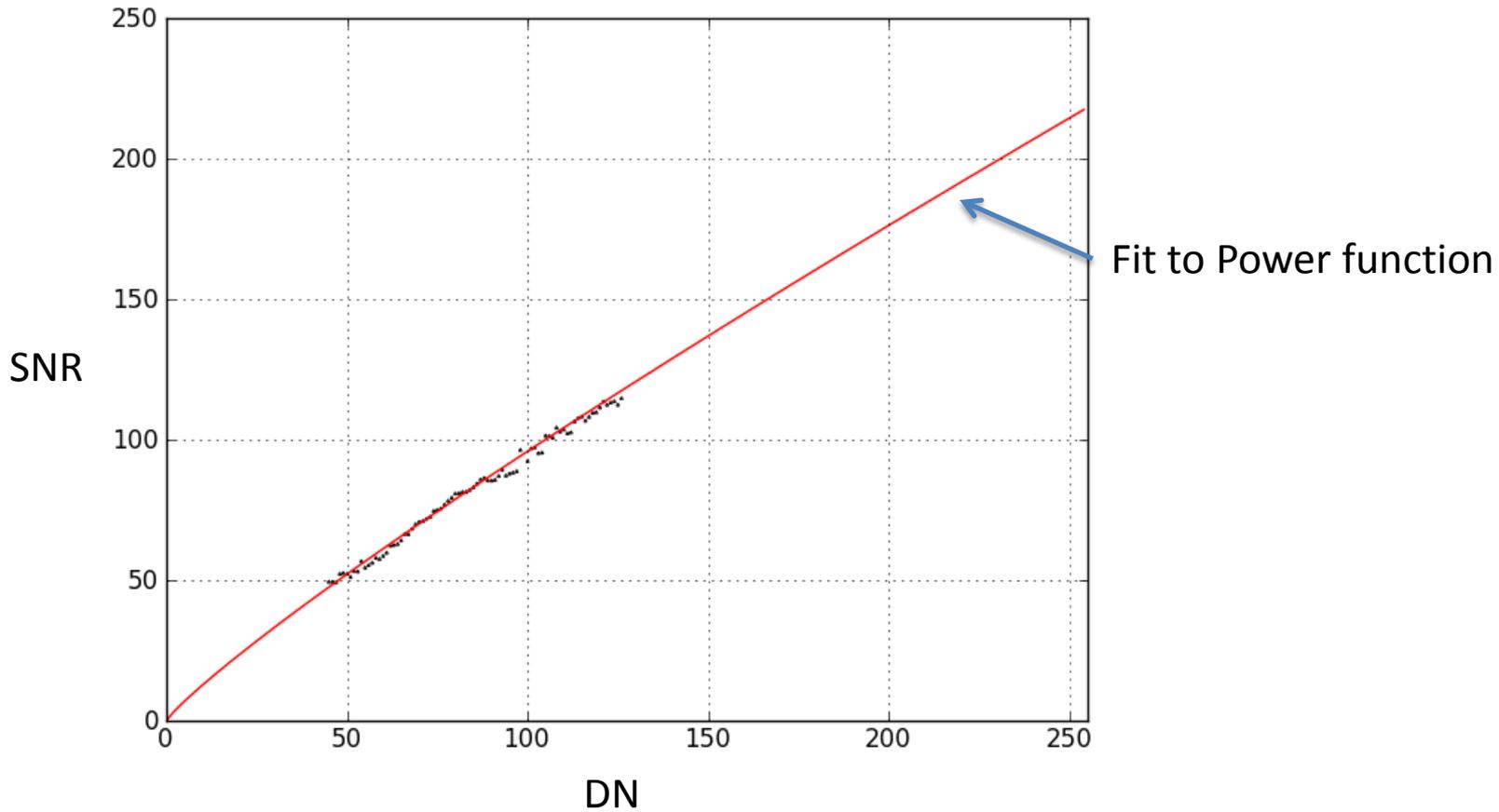


WORAS_100108054230-1_2_msb.raw.NUC_ImageOnly.png

AutoSNR on Single DubaiSat-1

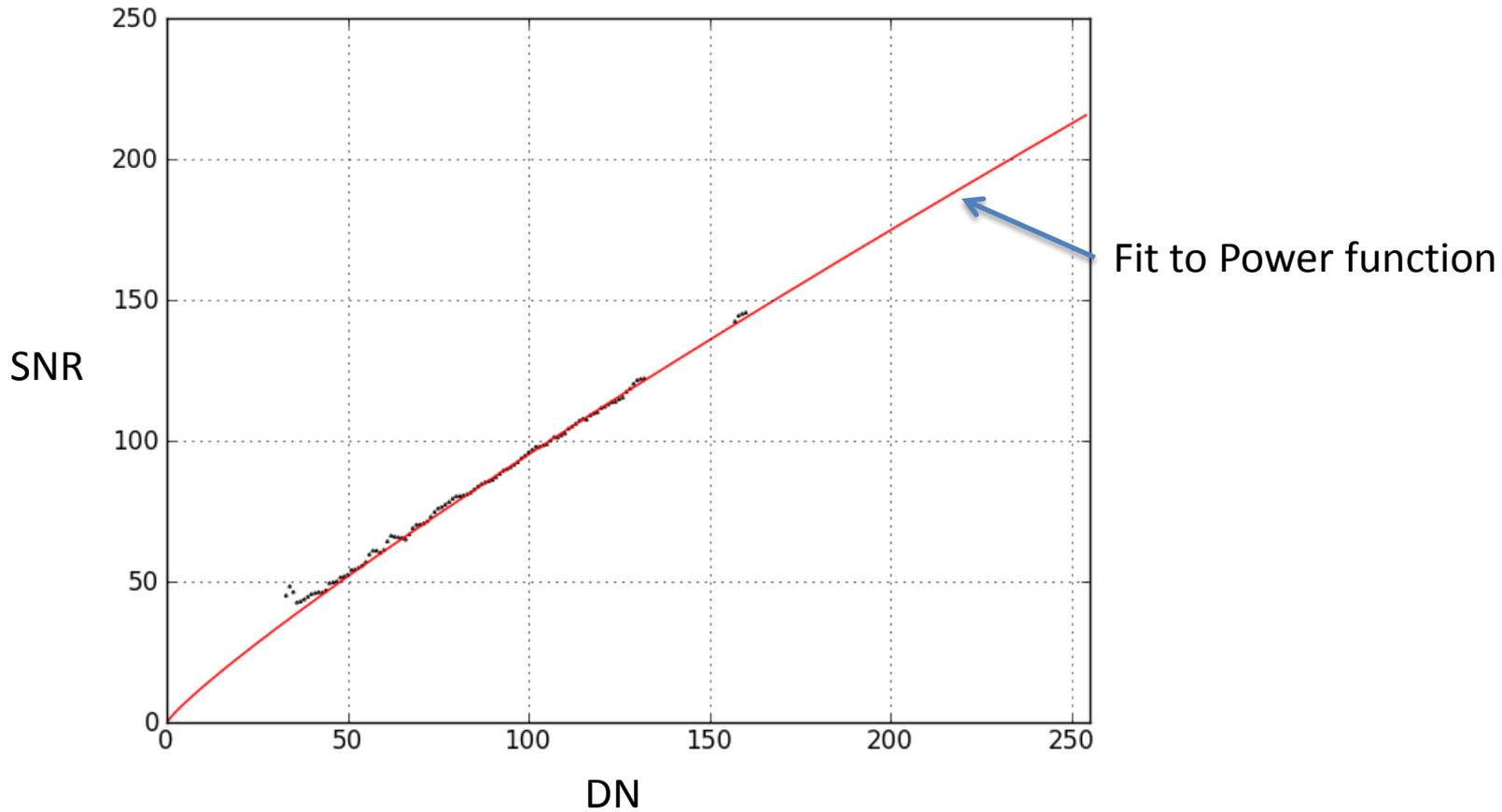
Image

DN – SNR



AutoSNR on 180 DubaiSat-1 Image

DN – SNR



Conclusion

- AutoSNR
 - Input: Satellite image
 - Output: DN-SNR table
- Experiments
 - Flat-field Image
 - Measured SNR was higher than the truth
 - Homogeneous Detection is likely to include homogeneous pixels rather than noisy pixels
 - Synthesized Image
 - Measured SNR was lower than the truth
 - Noise pixels included by hole filling in homogeneous detection are often really a different object
 - Flight Image
 - The SNR plot was linear while it is supposed to have a $\wedge 0.5$ power function graph
- In conclusion...
 - The homogeneous detection is not working effectively

What To Do Next

- Improve Homogeneous Area detector
 - Should not rely on a predefined value (threshold)
 - Add more natural constraints for homogeneous area modeling
 - Flatness (plane fitting)
- Noise simulation
 - Simulate various noises
 - Additive, Multiplicative, Periodic, Impulsive Noises
 - Verify AutoSNR with noise images

Thank you

- Any question
- Open to any suggestion