Topobathymetric Lidar Waveform Features for Habitat Mapping and Hurricane Sandy Response

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JALBTCX Workshop
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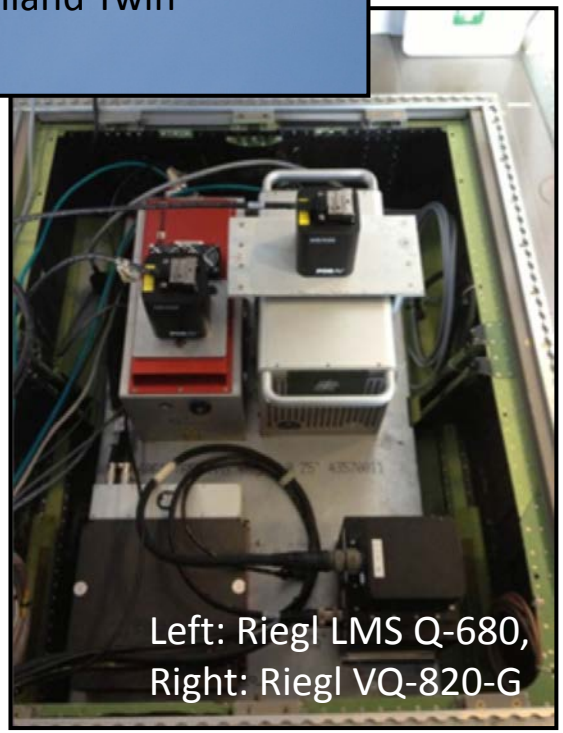
Picking up from last year's JALBTCX Workshop presentation…

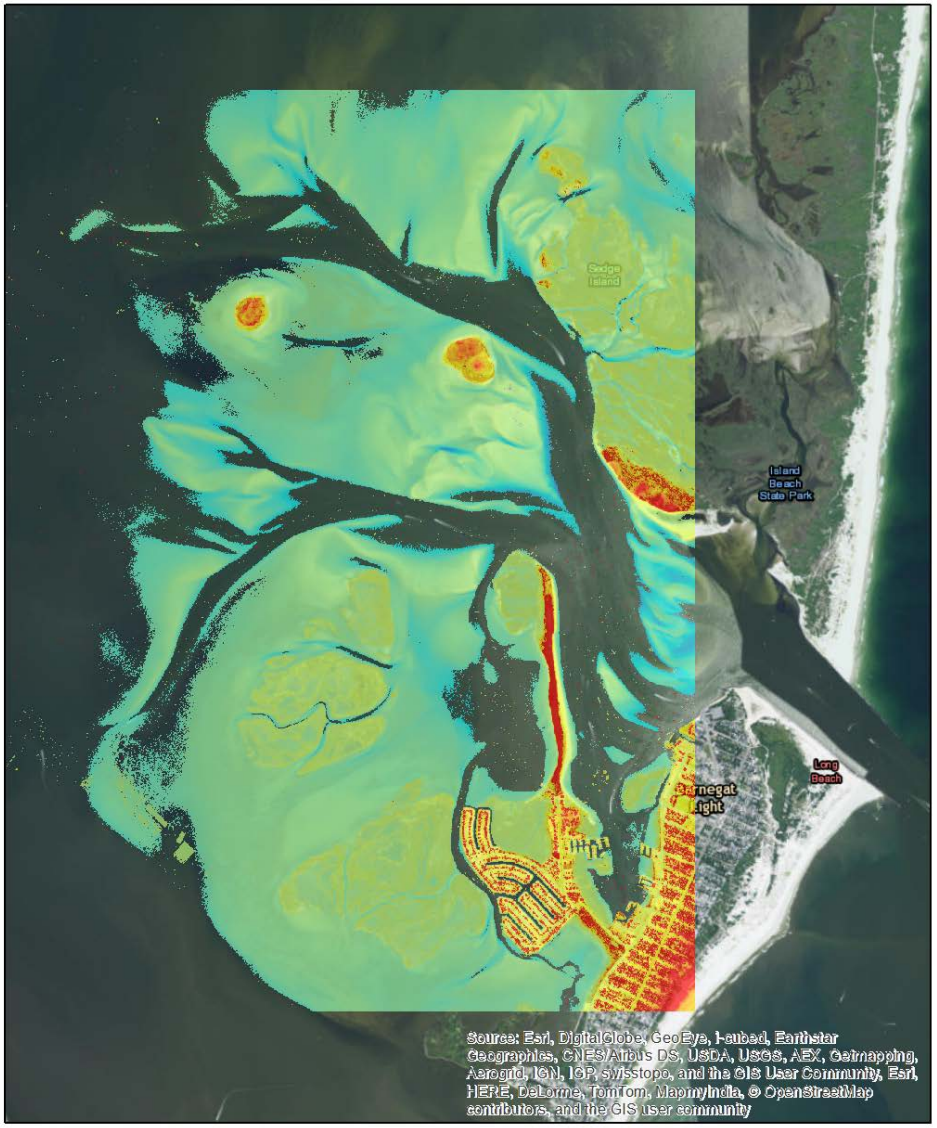
NOAA NGS Riegl VQ-820-G Barnegat Bay Data

NOAA DeHavilland Twin Otter (DHC-6)



Left: Riegl LMS Q-680,
Right: Riegl VQ-820-G

Sept 2013 NOAA/NGS data of Barnegat Inlet flood tidal delta complex



Riegl waveform features

- Waveform features included as standard output from "V-line" systems and provided via LAS ExtraBytes

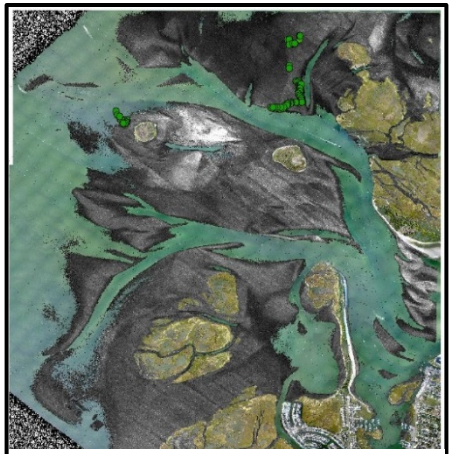
1. Riegl Reflectance
   - Ratio of signal amplitude to amplitude of signal from a white reference target at same range, given in dB

$$A_{dB} = 10 \cdot \log_{10}\left(\frac{P_{echo}}{P_{DL}}\right)$$

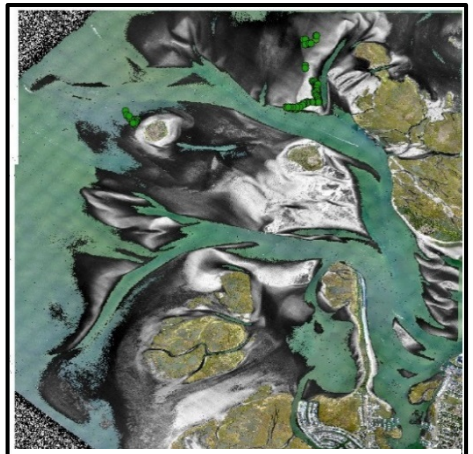
$$\rho = A_{dB} - A_{dB,ref}(R)$$

2. Pulse Shape Deviation
   - Measure of the discrepancy between the digitized waveform *y*[*n*] and a stored, system-specific reference pulse, *p*[*n*]

$$\delta = \sum_{n=0}^{N-1} |y[n] - p[n]|$$



Pulse Shape Deviation

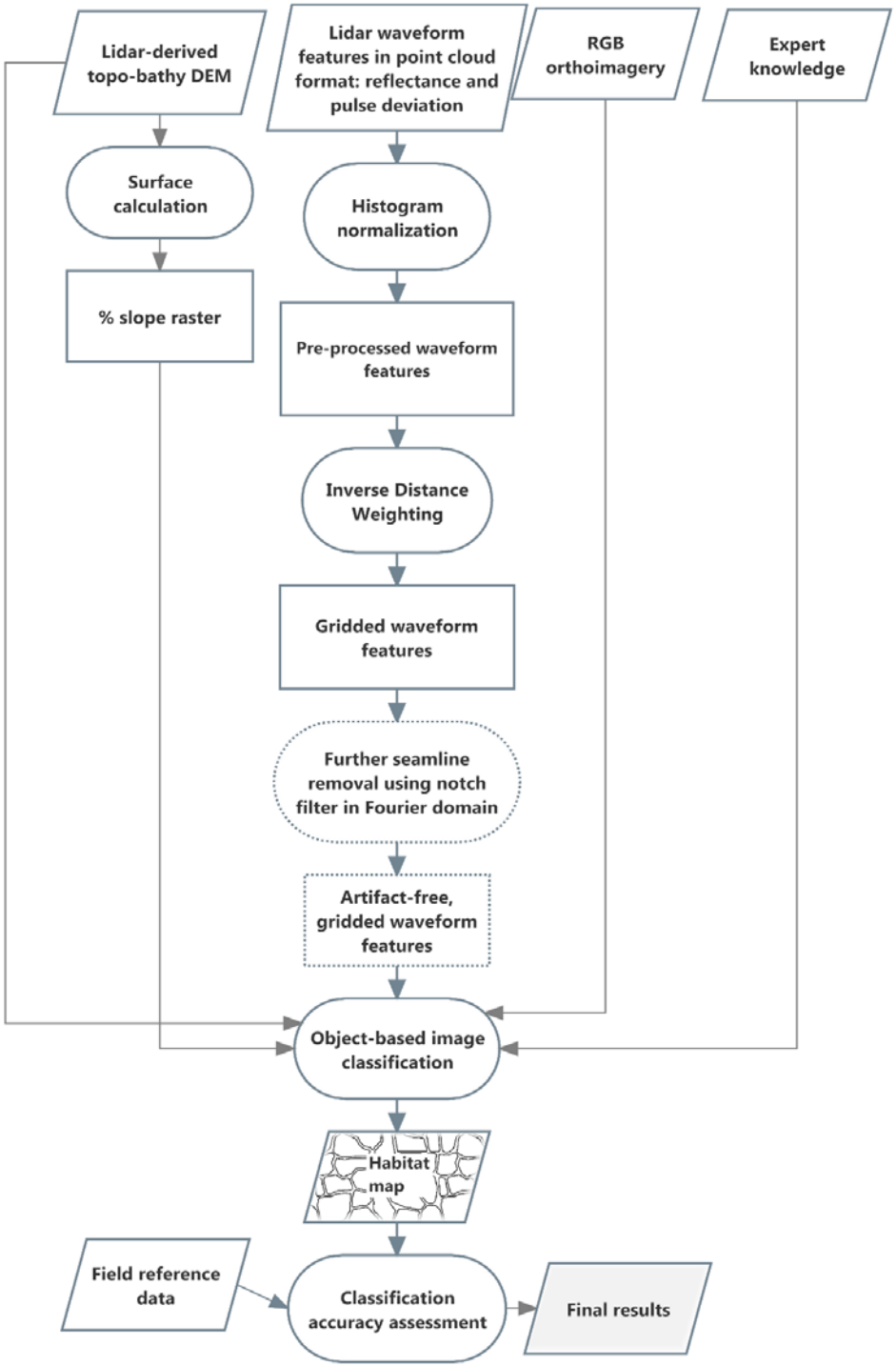


Riegl Reflectance

Pfennigbauer, M. and A. Ullrich, 2010. Improving quality of laser scanning data acquisition through calibrated amplitude and pulse deviation measurement. *Proc. SPIE Defense, Security, and Sensing*, pp. 76841F-76841F.

Workflow: Habitat Mapping with Riegl Waveform Features

- Goal: Use waveform features essentially "as is"
  - Relatively little preprocessing, beyond swath-to-swath histogram normalization

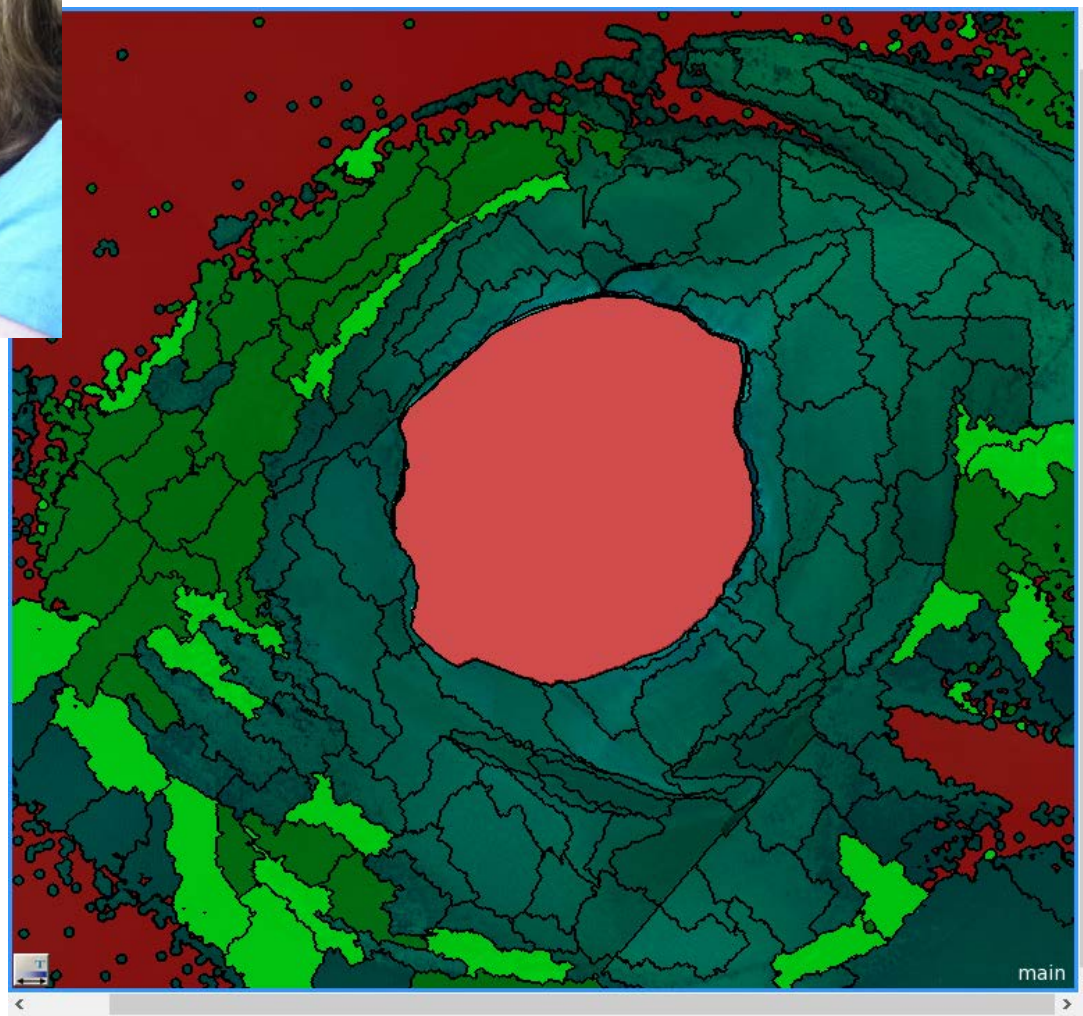


Parrish, C.E., J.A. Dijkstra, J.P.M. O'Neil-Dunne, L. McKenna, and S. Pe'eri, 2015. Post-Sandy Benthic Habitat Mapping Using New Topobathymetric Lidar Technology and Object-Based Image Classification. *Journal of Coastal Research*, SI (in minor revision).

Classification in eCog

1. Raster processing
2. Segmentation
3. Primitive object classification
4. Primary object classification
5. Context-based refinement
6. Minimum mapping unit

Jarlath O'Neil-Dunne Jenn Dijkstra



Subset of final habitat classification map for Barnegat Bay

Pink = land

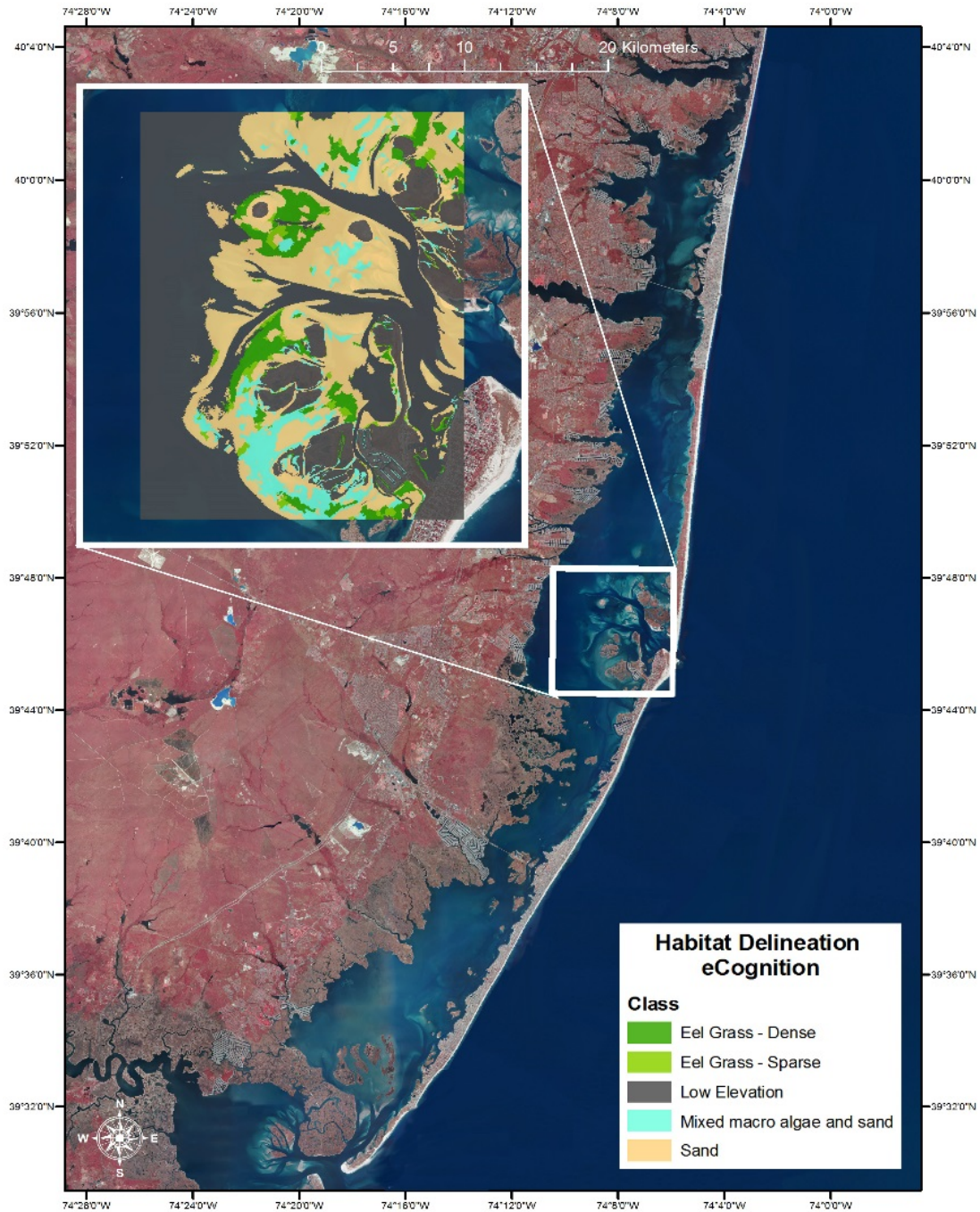
Dark green = dense eelgrass

Light green = sparse eelgrass

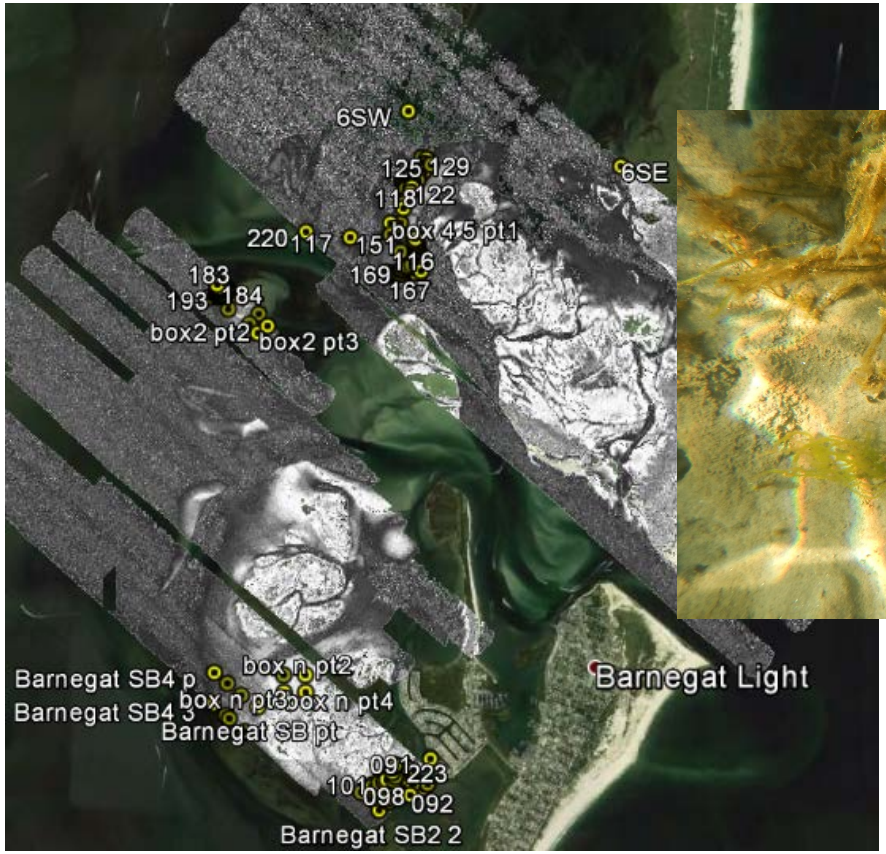
Aqua = sand

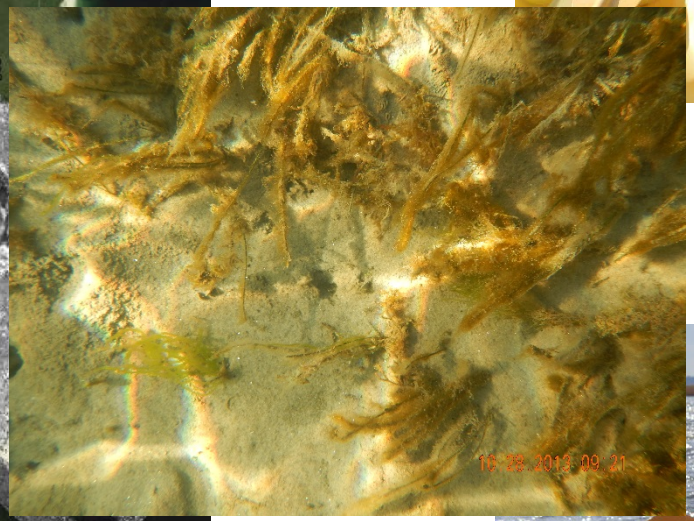
Red = "deep" water

Final Habitat Map



Reference Data for Assessing Classification Accuracy





October 2013 Field Campaign

Confusion matrix with all 4 classes

	Reference Data (Known Cover Types)				
	Eelgrass Dense	Eelgrass Sparse	Mixed Macroalgae & Sand	Sand	Row total
Classification Data					
Eelgrass Dense	28	0	0	0	28
Eelgrass Sparse	1	2	0	0	3
Mixed Macroalgae & Sand	0	0	24	0	24
Sand	0	7	9	35	51
Column Total	29	9	33	35	106

Confusion matrix with “eelgrass sparse” and “eelgrass dense” classes merged

	Reference Data (Known Cover Types)			
	Eelgrass	Mixed Macroalgae & Sand	Sand	**Row total**
Classification Data				
Eelgrass	31	0	0	31
Mixed Macroalgae & Sand	0	24	0	24
Sand	7	9	35	51
Column Total	38	33	35	106

Results summary

Class	Producer's Accuracy	User's Accuracy
Eelgrass	82%	100%
Mixed Macroalgae & Sand	73%	100%
Sand	100%	69%

Overall accuracy = 85%

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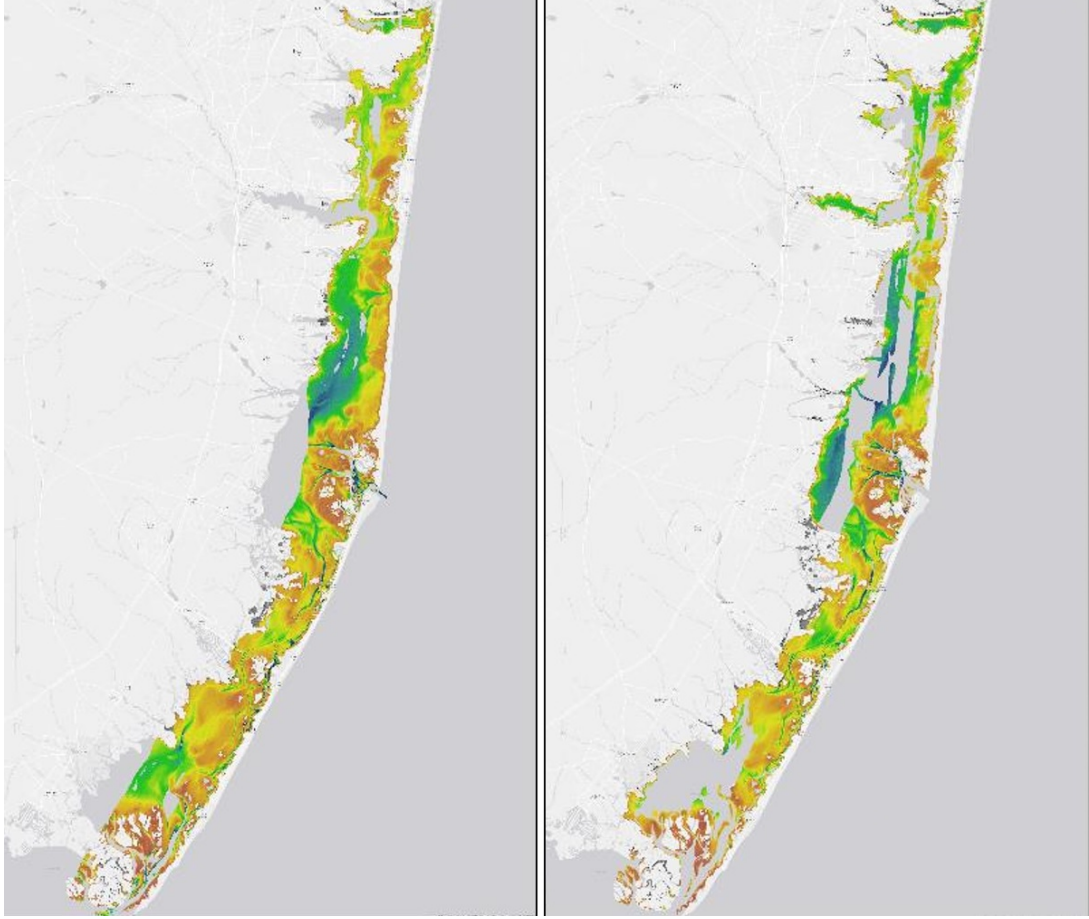
Other findings/outputs:

- Riegl reflectance proved valuable benthic habitat classification
  - All 18 segmentation and classification rules in eCognition made use of Riegl reflectance and derived features
- Pulse shape deviation was less useful
  - Only used in one rule
- eCognition rule set is being made publicly available via ScholarsArchive@OSU

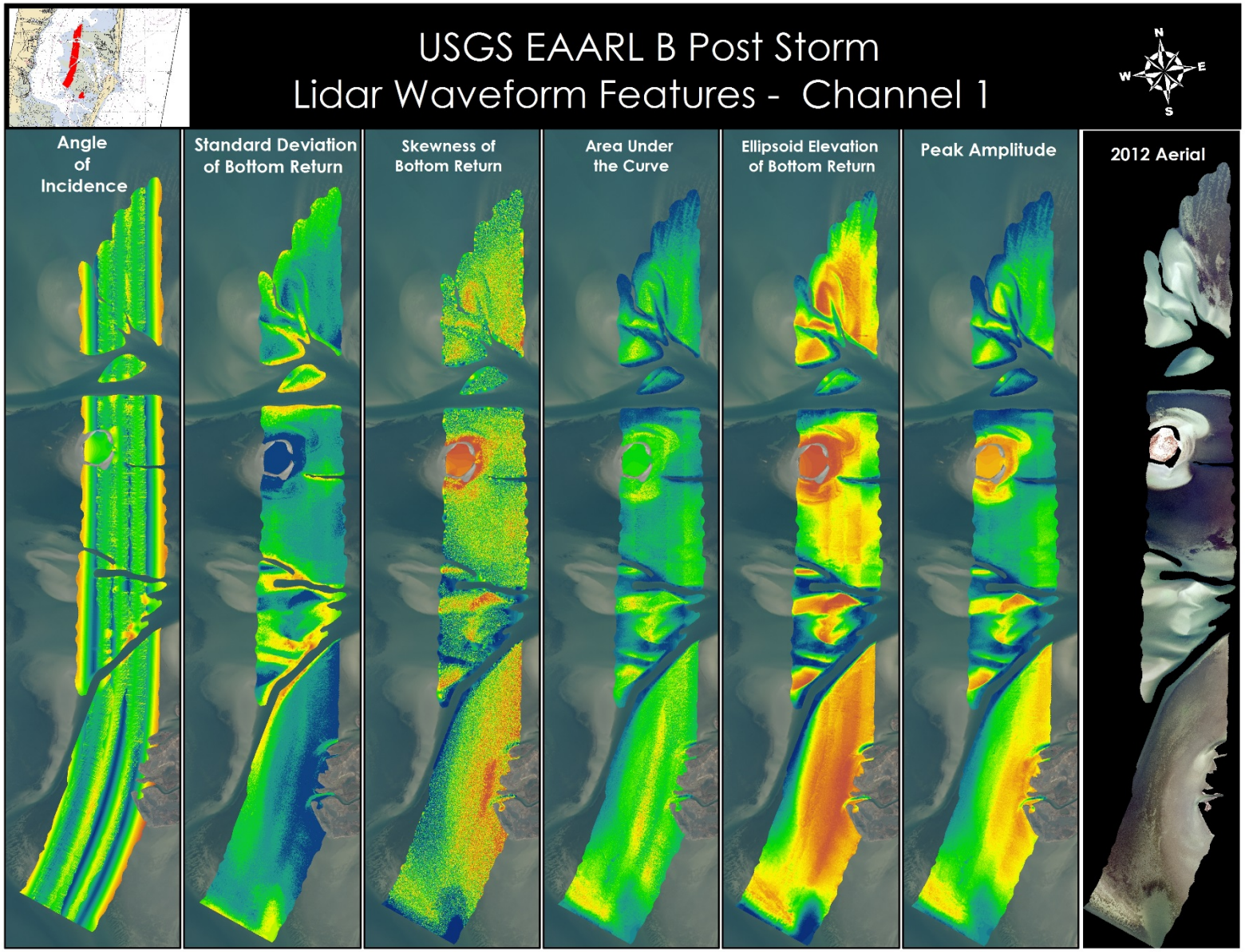
USGS EAARL-B Barnegat Bay Sandy Data

Courtesy: Wayne Wright

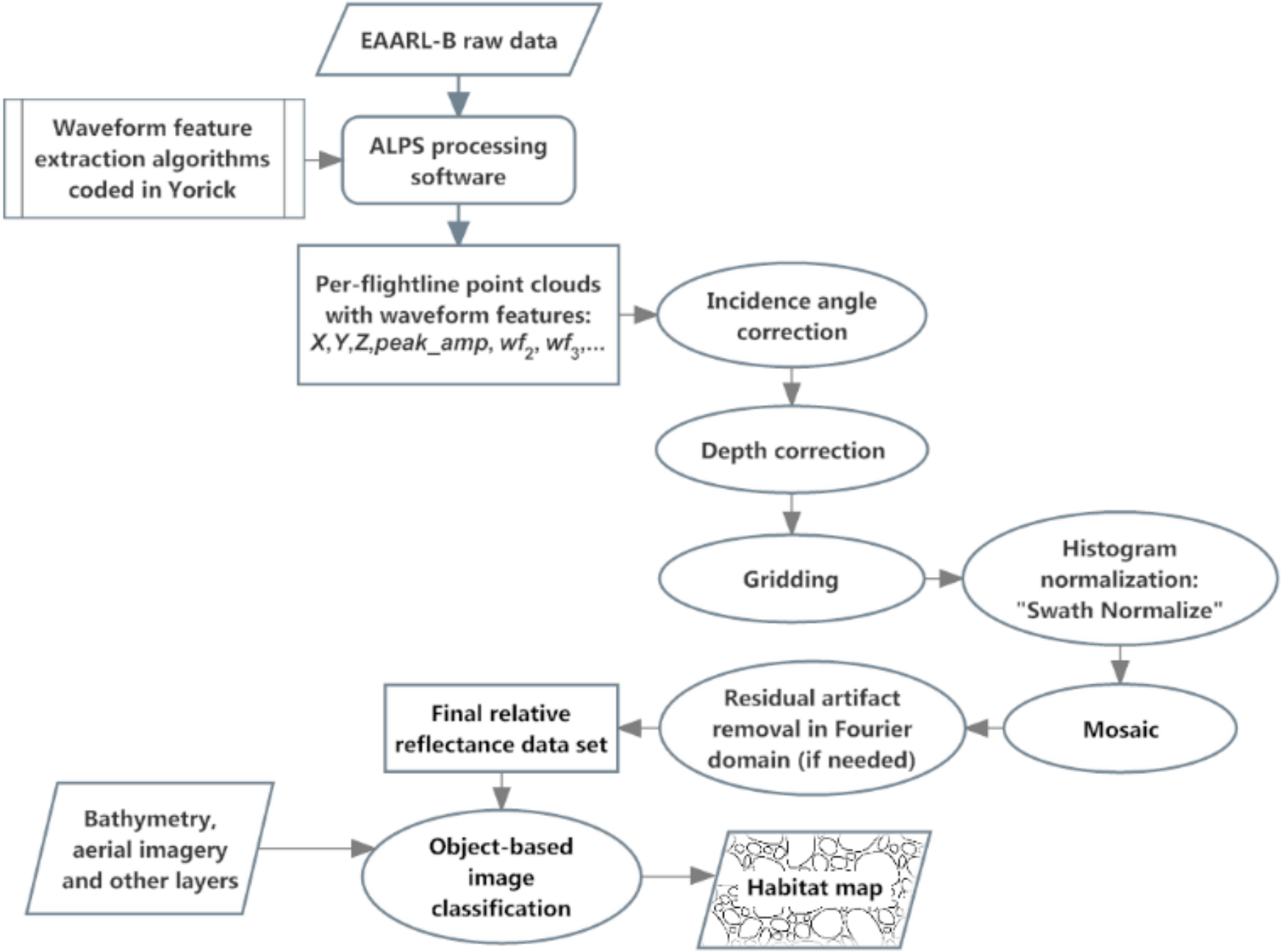


Event	Date	Days before (-) or after (+) Sandy
Pre-storm EAARL-B Barnegat Bay acquisition completed	October 26, 2012	-3
Sandy landfall near Brigantine, NJ	October 29, 2012	0
Post-storm EAARL-B Barnegat Bay acquisition completed	November 1-5, 2012	3-7

Plotted waveform features:
Juliet Kinney and Erin Nagel (JHC-CCOM)

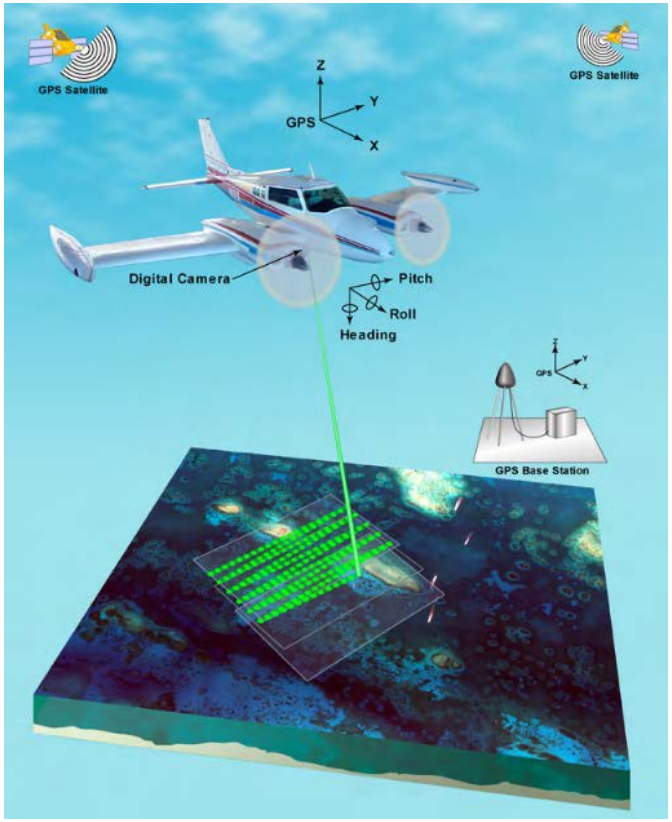


EAARL-B relative reflectance mapping workflow

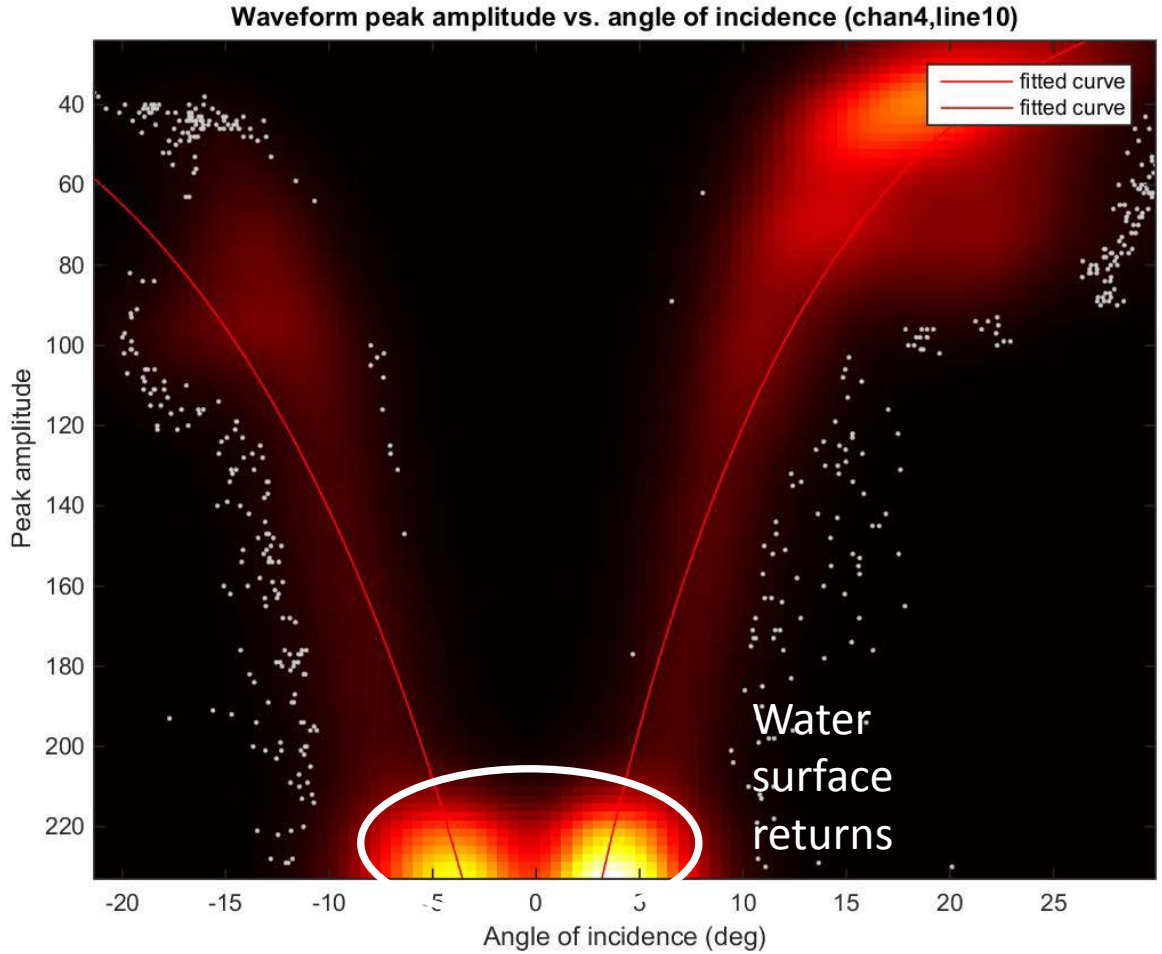


Incidence angle correction

EAARL-B scan pattern



http://pubs.usgs.gov/of/2009/1078/pdf/OFR2009-1078.pdf

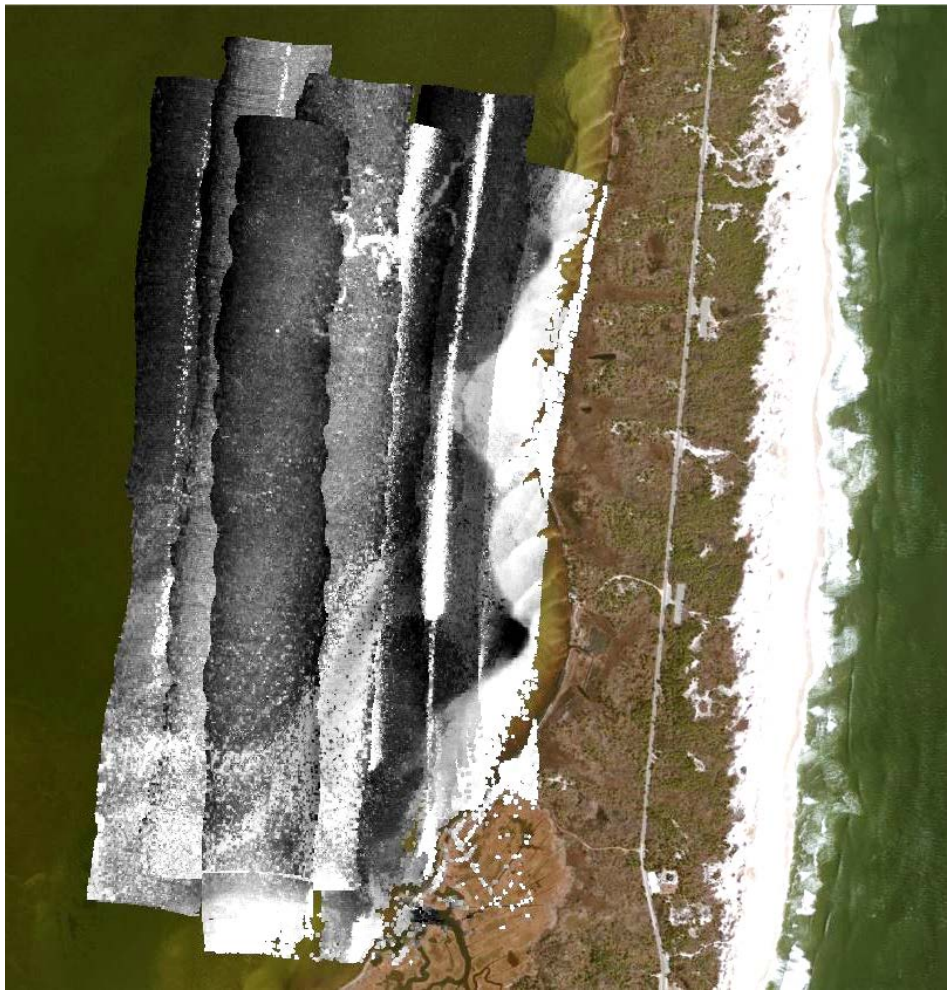


$$f(\theta) = \begin{cases} c_1 e^{c_2 \theta}, -90° < \theta \leq 0 \\ c_3 e^{c_4 \theta}, 0 < \theta \leq 90° \end{cases}$$

where θ = ALPS signed incidence angle

Adapted from Wang and Philpot, 2007

Barnegat Bay – Johnny Allens Cove: Preliminary Results



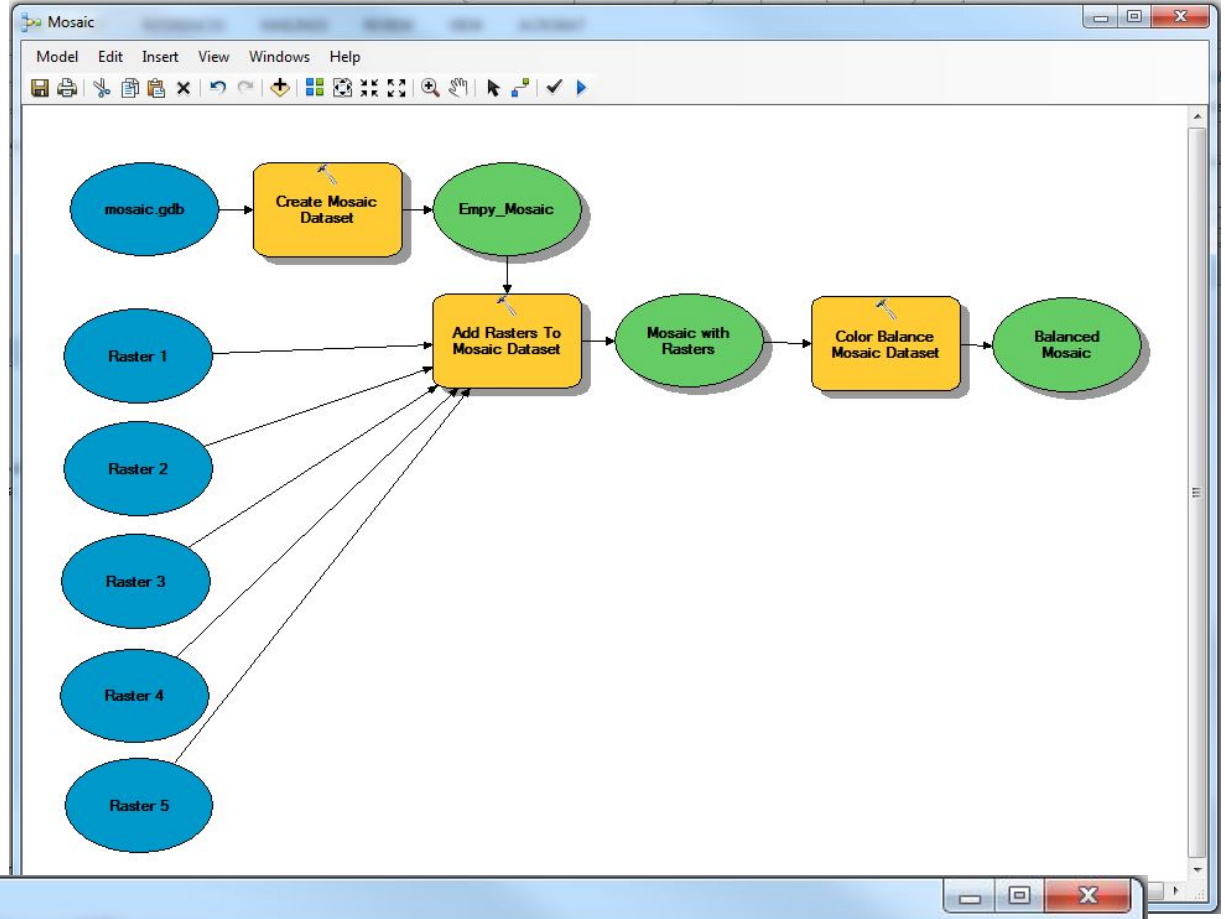
Input

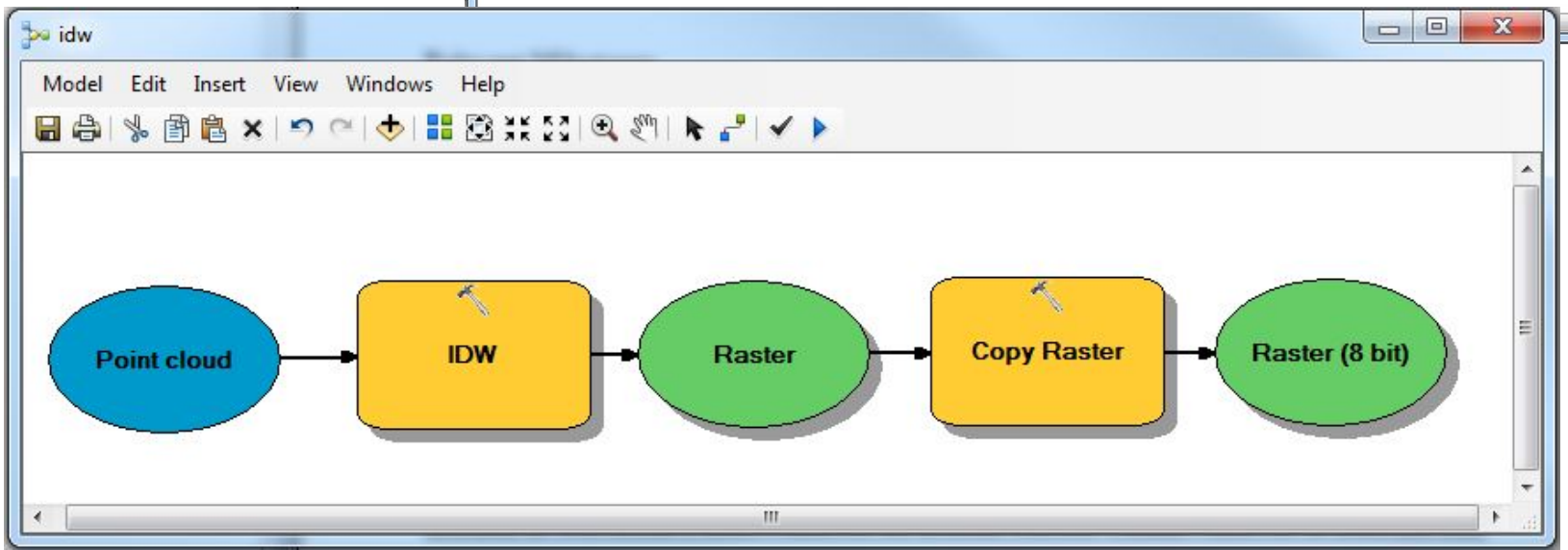
Output

Swath Normalize Tool

- Semi-automated, human-driven histogram shift and scaling
- Live demo…

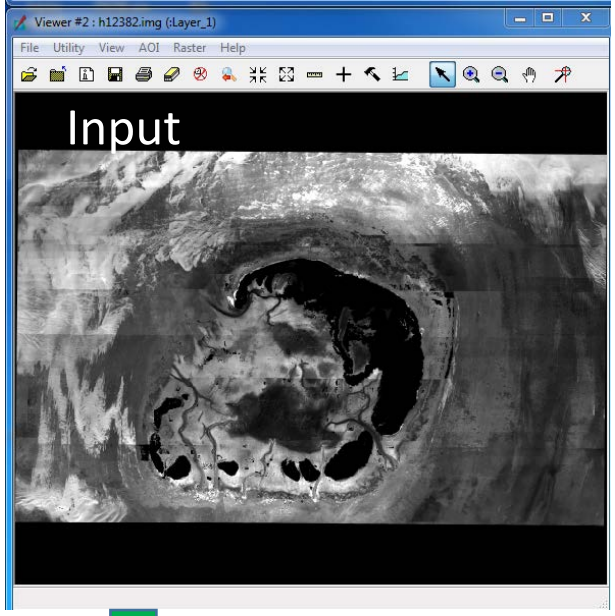
Automation through ArcGIS Model Builder and custom scripts



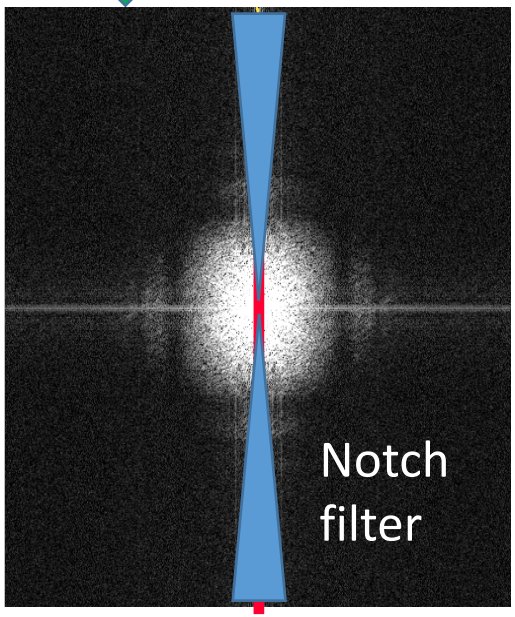


Residual artifact removal in Fourier domain (if needed)

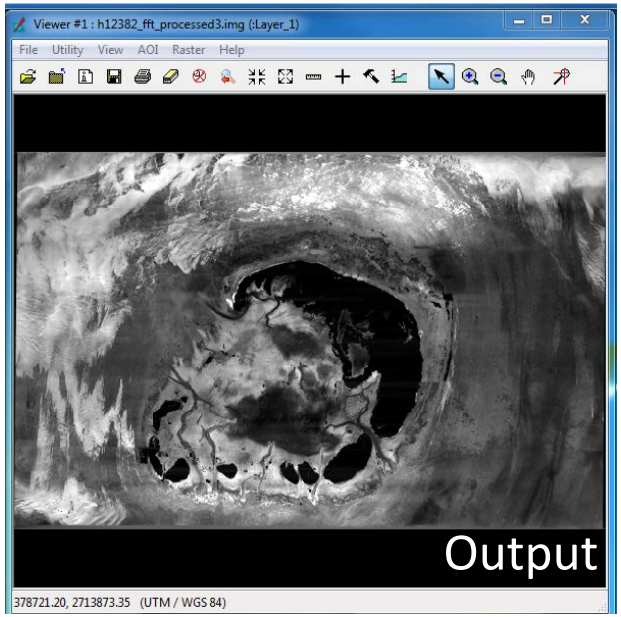
- Remove any remaining artifacts (e.g., seamlines between swaths) from waveform feature mosaics in the frequency domain using ERDAS Imagine



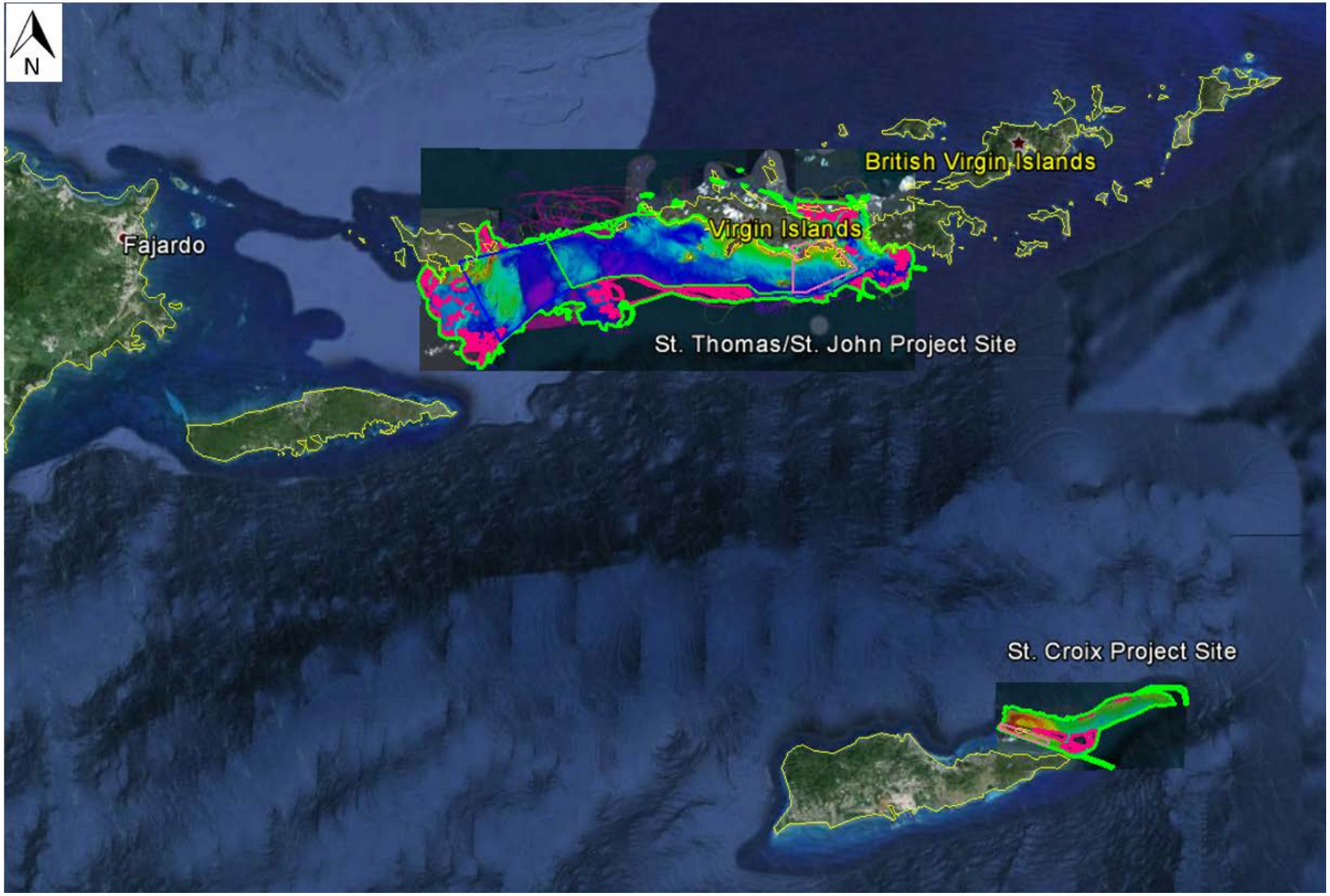
$$f(x,y) \xrightarrow{\mathcal{F}} F(u,v)$$



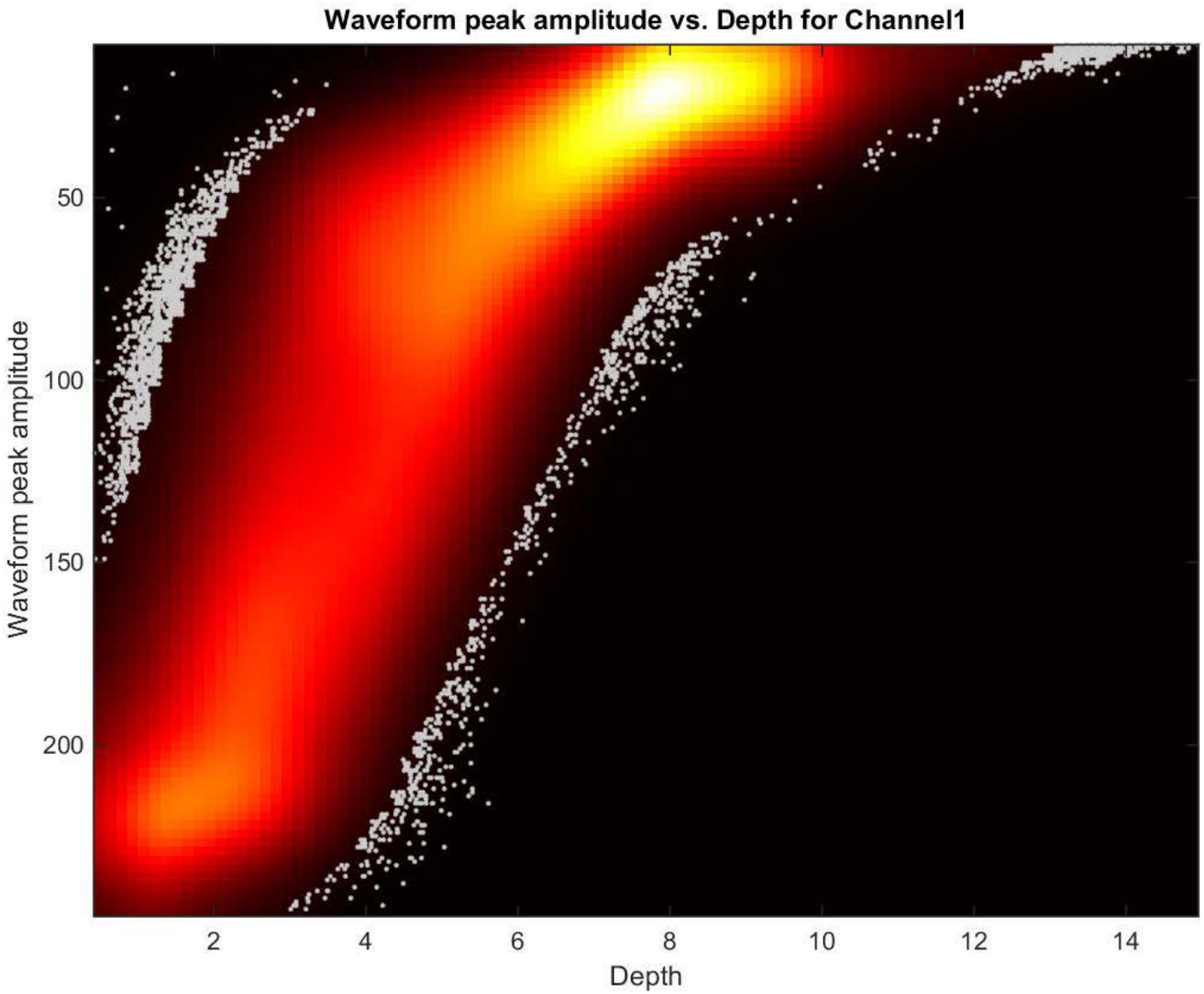
$$F_c(u,v) \xrightarrow{\mathcal{F}^{-1}} f_c(x,y)$$



USVI project sites



Next Step: Depth Correction



Similar approach: exponential model with empirically-determined coefficients

Where we are headed:

- Barnegat Bay: complete relative reflectance mapping from both pre- and post-Sandy data for high-priority test sites
  - Transition procedures to JHC-CCOM at UNH
- Continue to test and refine EAARL-B relative reflectance mapping procedures over the summer
- Produce relative reflectance products for full USVI sites
  - >600 km^2!
- Test ability to use additional waveform features (return pulse width, AUC, skewness, etc.) to enhance seafloor characterization/habitat mapping

Questions and Additional Information

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