Water Column, Bottom Type, Bottom Depth

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NRL Research in Remote Sensing of Coastal Water Column and Bottom Characteristics

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07 Aug 2018; Chesapeake Bay Workshop; NASA Goddard

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Relevant NRL Research Emphases

- Algorithm development to retrieve
  - Water column properties
  - Bottom characteristics

- Sensor design analysis
  - Spatial resolution
  - Spectral resolution
  - Signal-to-Noise Ratio (SNR)

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Algorithm Development

Types of algorithms:

- Spectral band ratios
- Look-Up Table (LUT)-based approach
- Optimal Estimation

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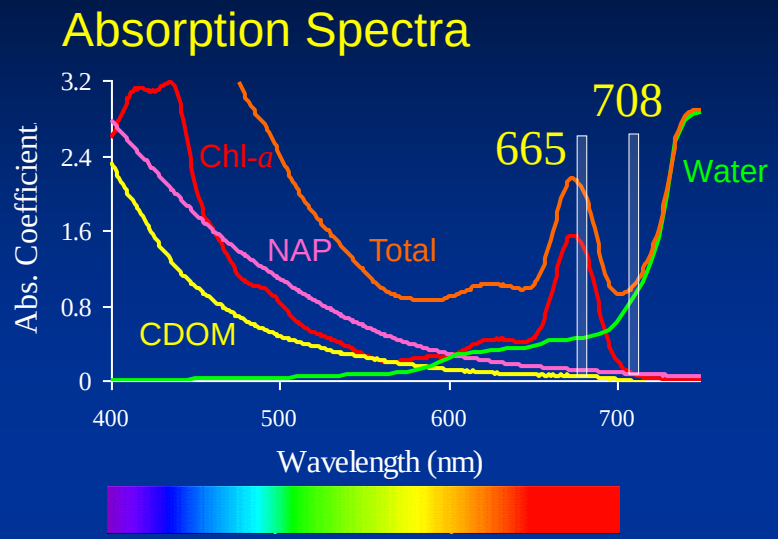
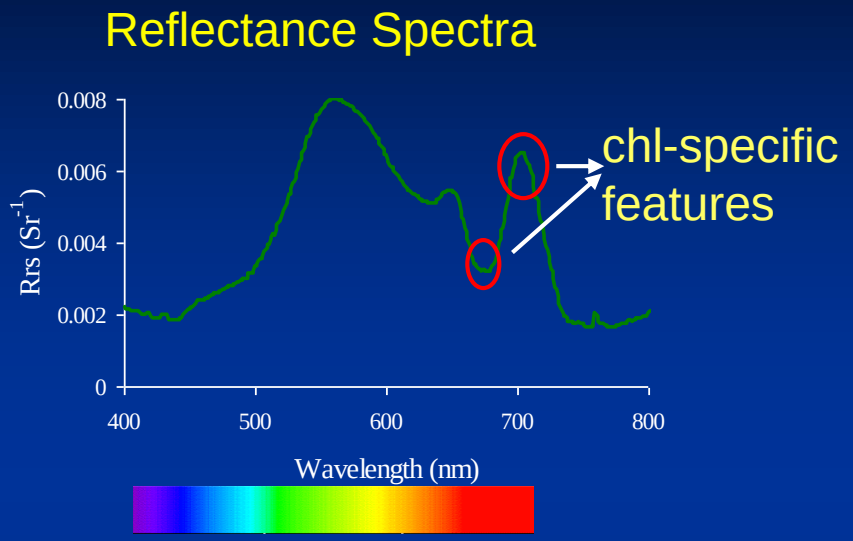
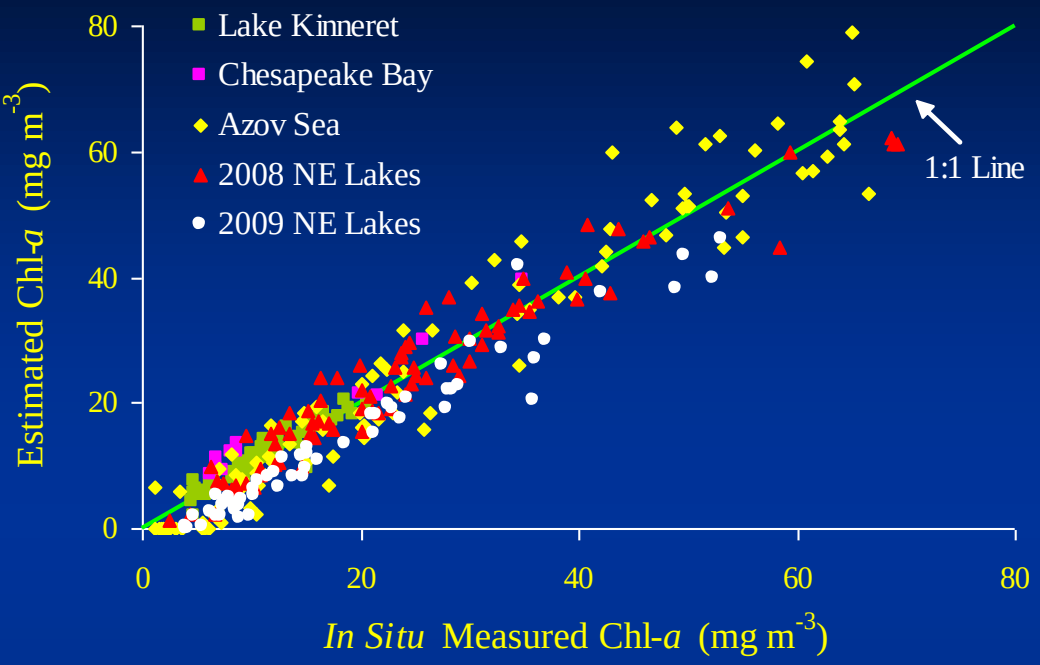
Algorithms – Band Ratios





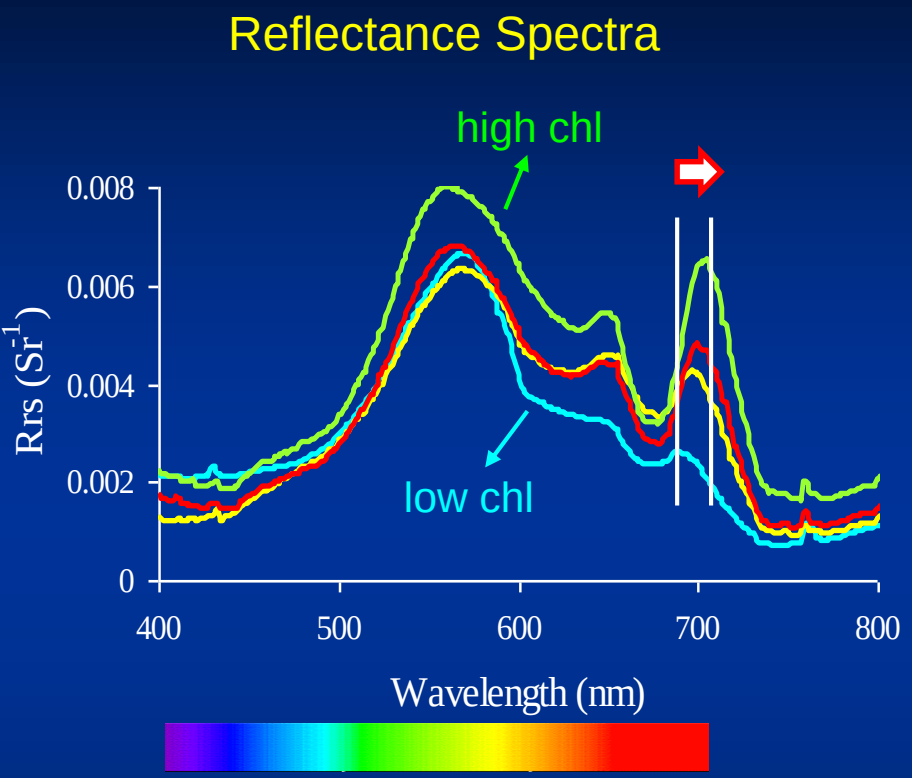
$$R_{\lambda_1}^{-1} \times R_{\lambda_2} \propto \text{chl-}a$$ (Gitelson 1992)

Successful Performance of NIR-red Model

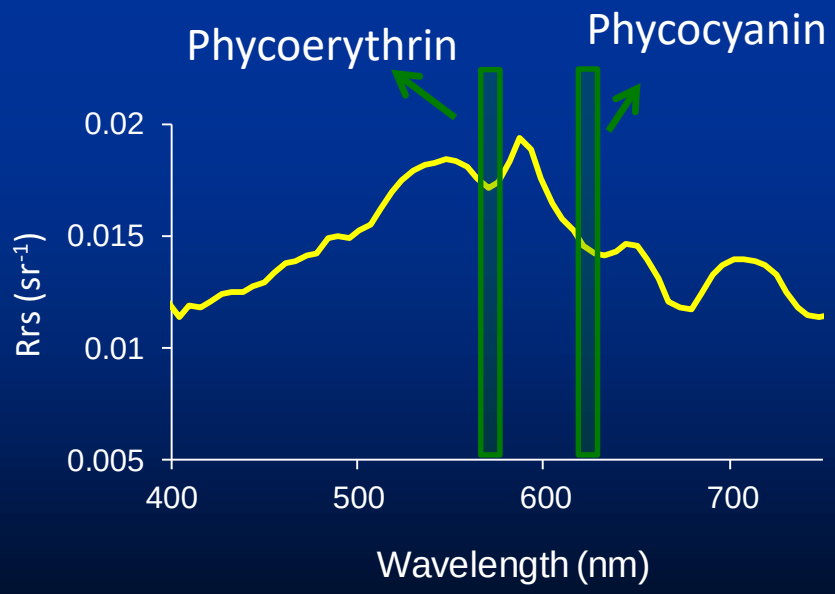


Water Body	Chl-*a* mg m^{-3}	Chl_{meas} vs. Chl_{est}	RMSE mg m-3
NE Lakes 2008	2.1 – 69.2	0.9315x + 1.7169	3.9
NE Lakes 2009	4 – 53	0.9204x – 3.2713	5.7
Chesapeake Bay 2006	6.2 – 35	1.0002x + 3.0447	3.4
Kinneret 2009	4.6 – 21	0.9618x + 0.8356	1.46
Azov Sea 2008 – 2010	1.1 – 66.5	1.075x - 2.1475	5.6

Band Ratios – still relevant in HSI era



HICO image of Sea of Galilee; 11 Mar 2013



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LUT-Based Approach
Coastal Waters Spectral Toolkit (CWST):

Parameters:
Phytoplankton
Sediment
CDOM
Depth
Bottom Rrs

Input into Radiative Transfer Model

3 Component Radiative Transfer Model (EcoLight)→ Remote Sensing Reflectance Spectrum (R_{RS})

Database

Bottom	Reflectance
Pigment	Absorption

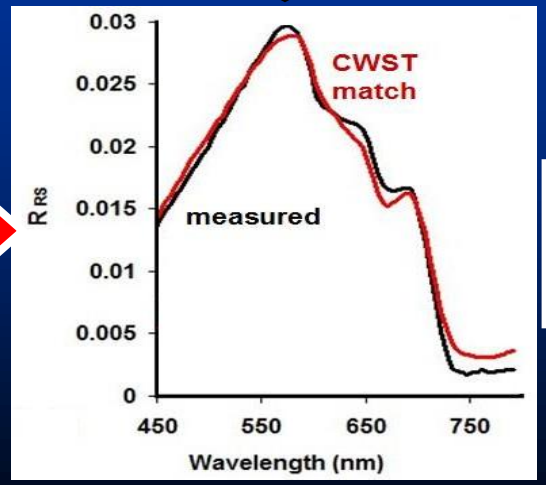
Index	Depth	Bottom	Pigment
111	0.0	14	1
112	0.5	3	1
113	1.0	14	4
114	2.0	14	2

Extract subset of parameters expected to be found in area [index, parameters, R_{RS} spectra]

Calibrated At Sensor Radiance

Lee Stocking Island, The Bahamas

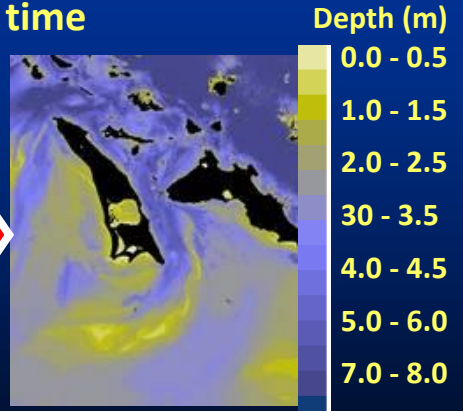
Atmospheric Correction



Metric is Euclidean Distance

Compare measured spectrum to selected spectra to find best match - takes time

Phytoplankton
Sediment
CDOM, Depth
Bottom Type



Depth (m)
0.0 - 0.5
1.0 - 1.5
2.0 - 2.5
30 - 3.5
4.0 - 4.5
5.0 - 6.0
7.0 - 8.0
> 20.0

Courtesy: Jeffrey Bowles, NRL

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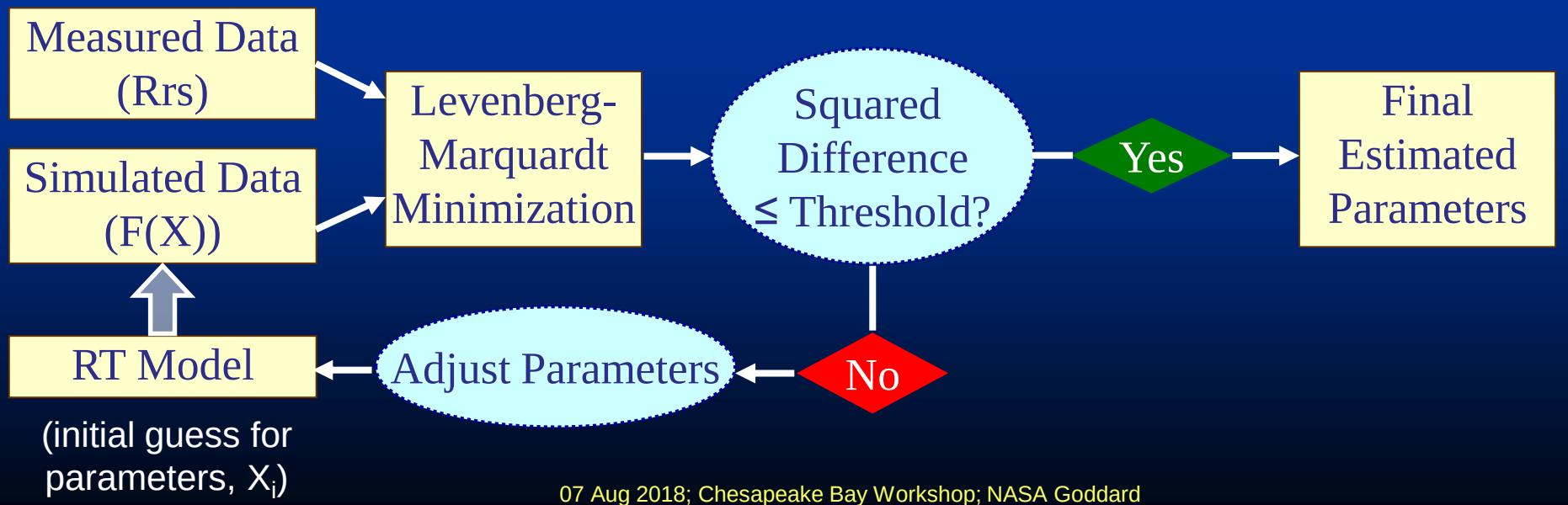
Optimal Estimation

Measured Reflectance, Rrs = F(X)

X { Bottom characteristics (depth, bottom type)
  { Water-column properties (chl-*a*, CDOM, SPM concentrations
  { Atmospheric characteristics (aerosol type, optical thickness, etc.)

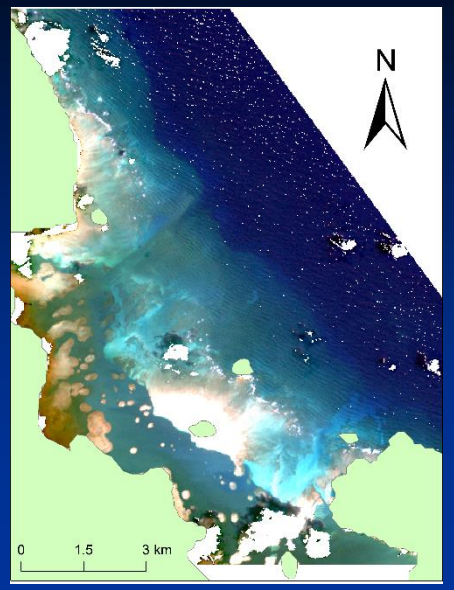
F → Radiative transfer model (e.g., Hydrolight-Ecolight)

Goal: Find the set of x_i that correspond to Rrs

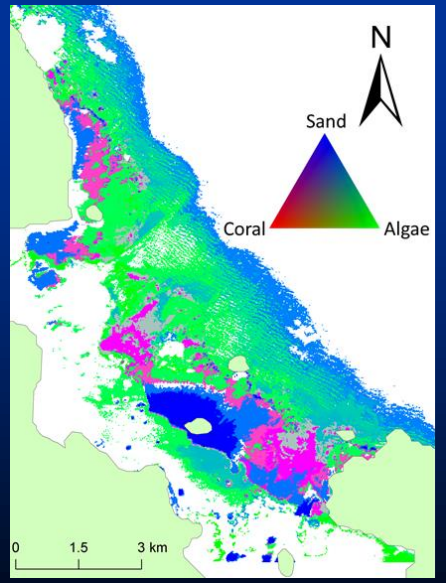


Optimal Estimation

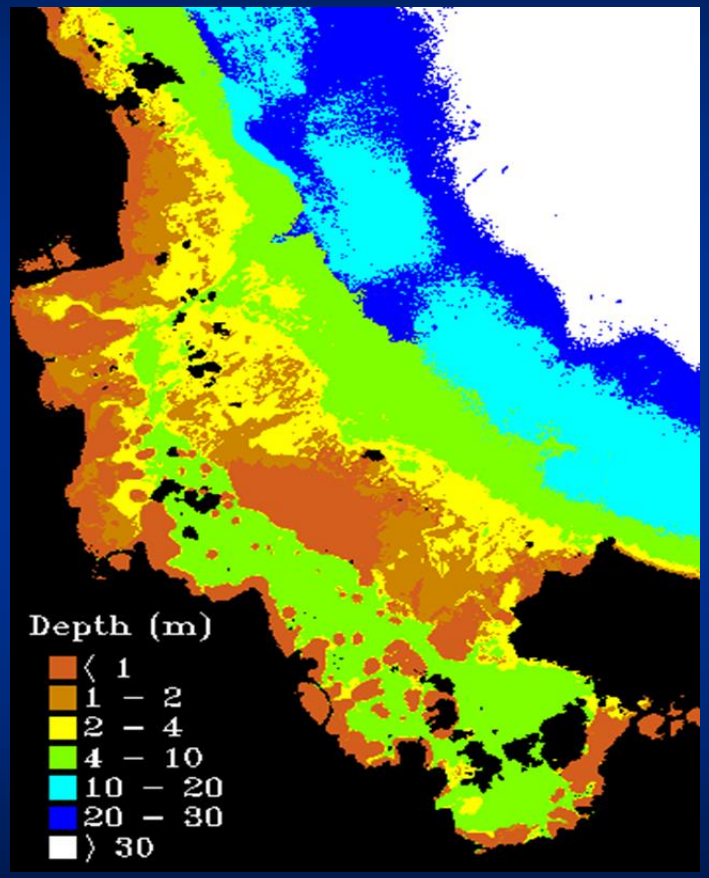
12 Apr 2000 AVIRIS; Kaneohe Bay, HI



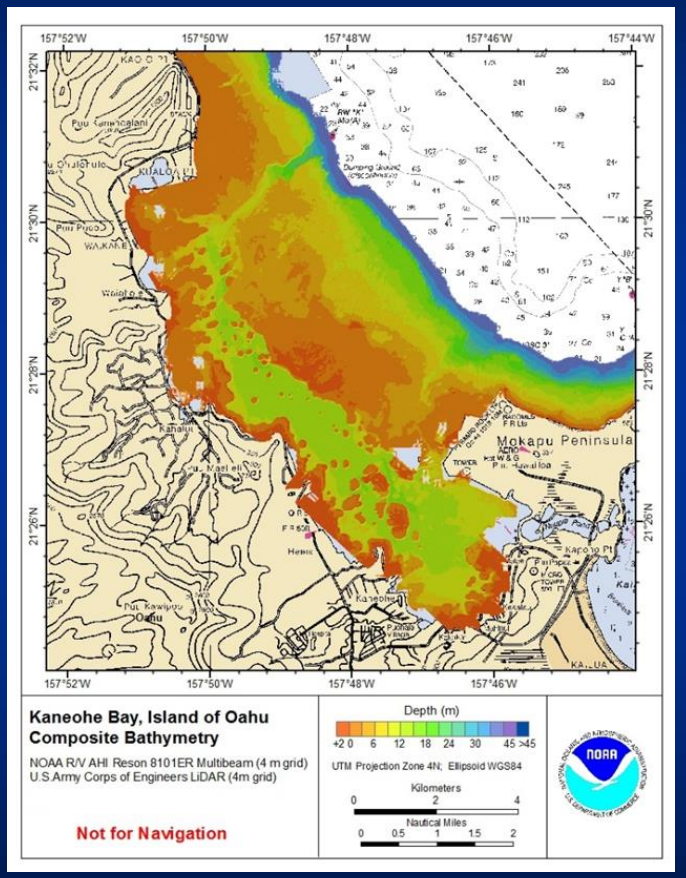
Bottom Type Map



Bottom Depth from a Landsat-8 Image



Bottom Depth from Lidar Data



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Sensor Design Analysis

- Spatial resolution
- Spectral resolution
- Signal-to-Noise Ratio (SNR)

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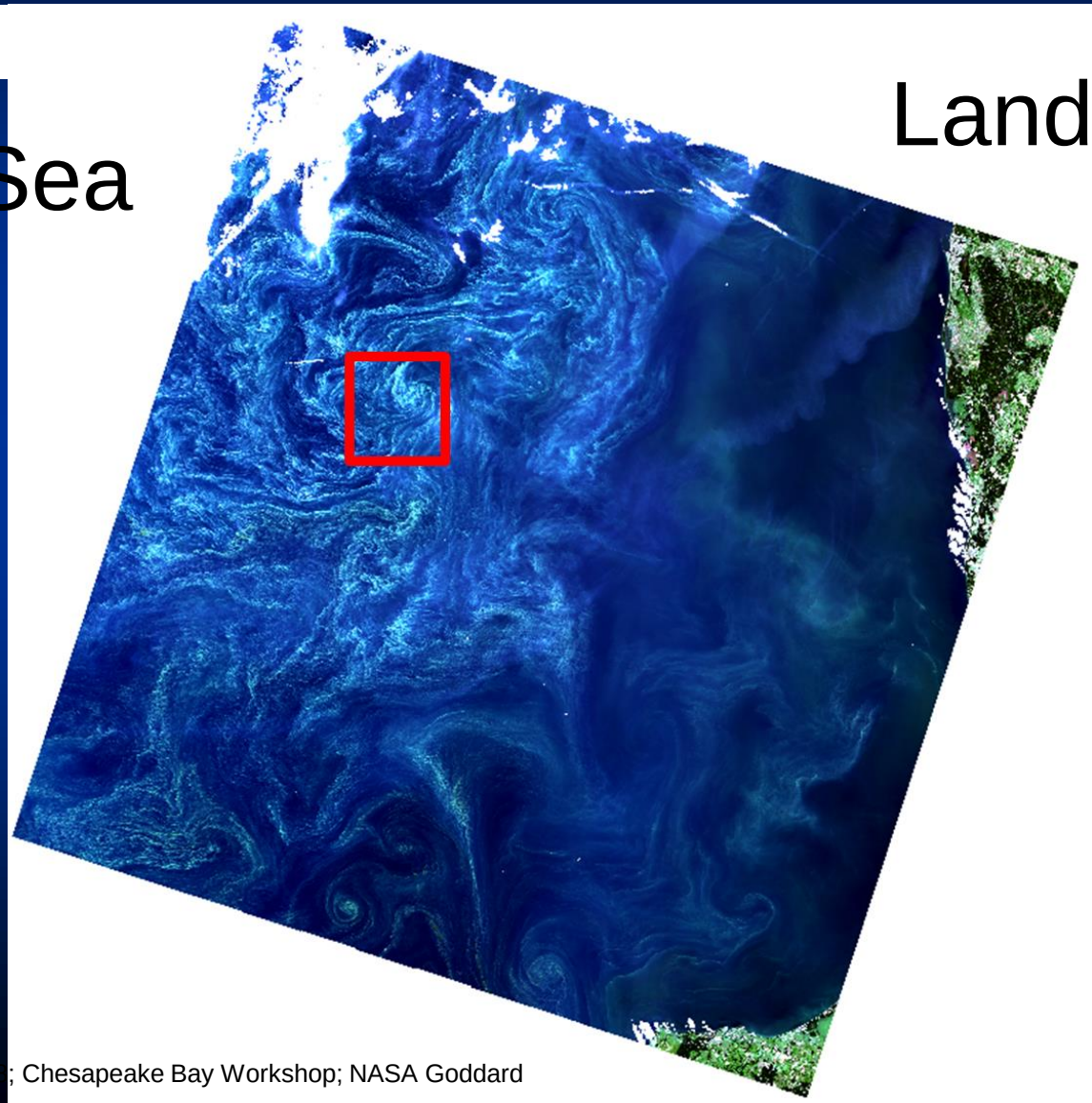
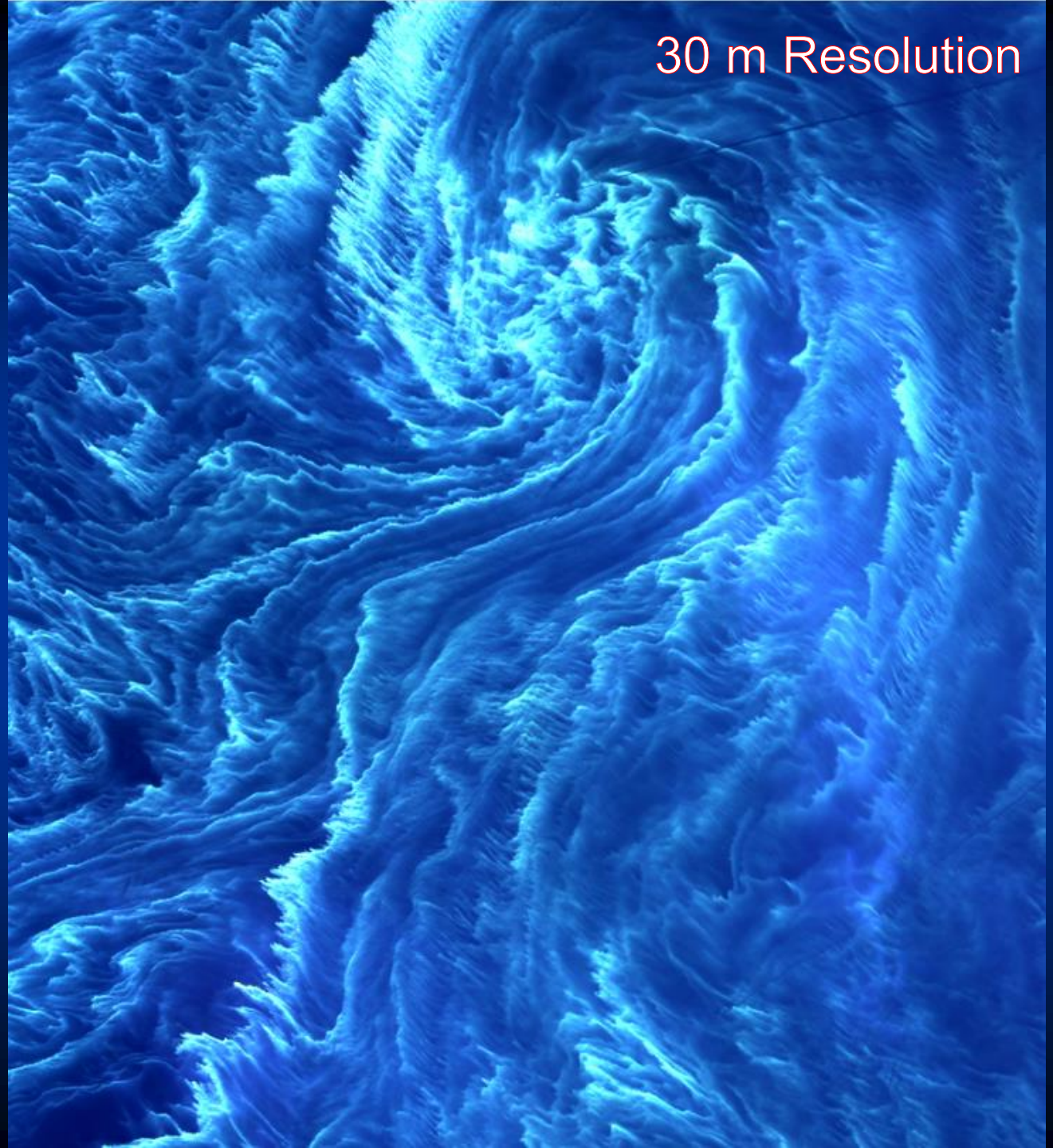
Spatial Resolution

Baltic Sea

11th Aug 2015



Landsat-8


30 m Resolution

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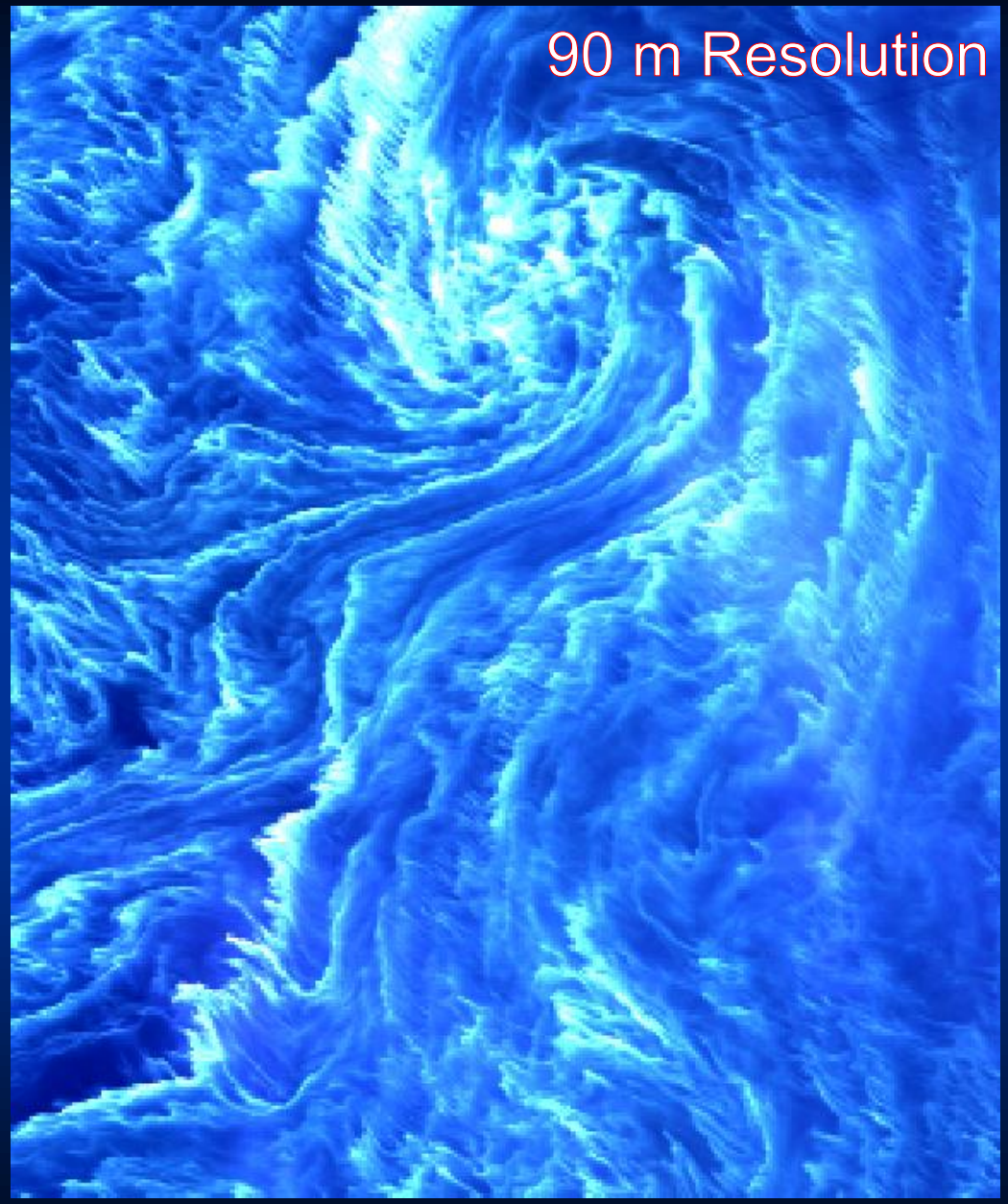

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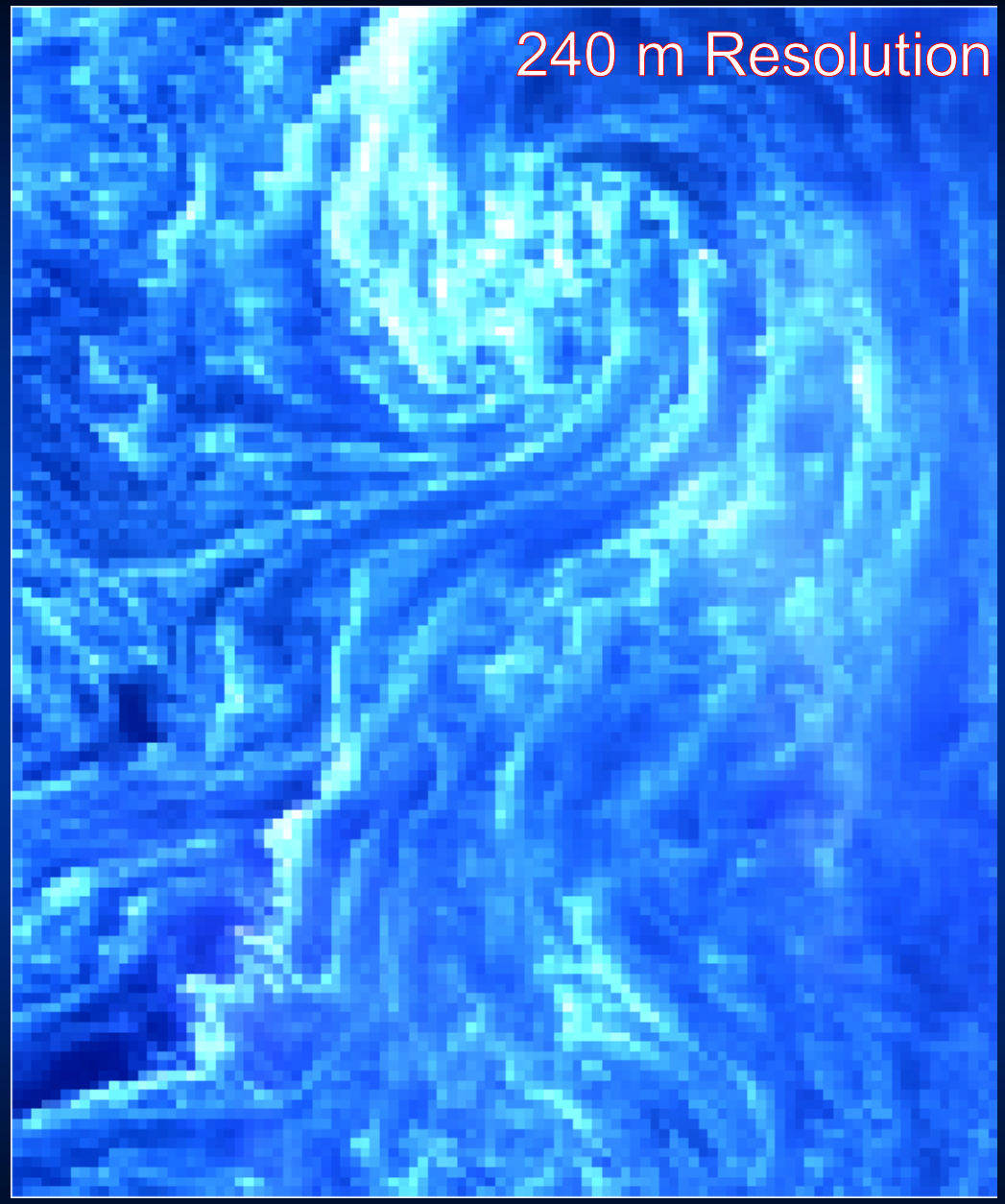

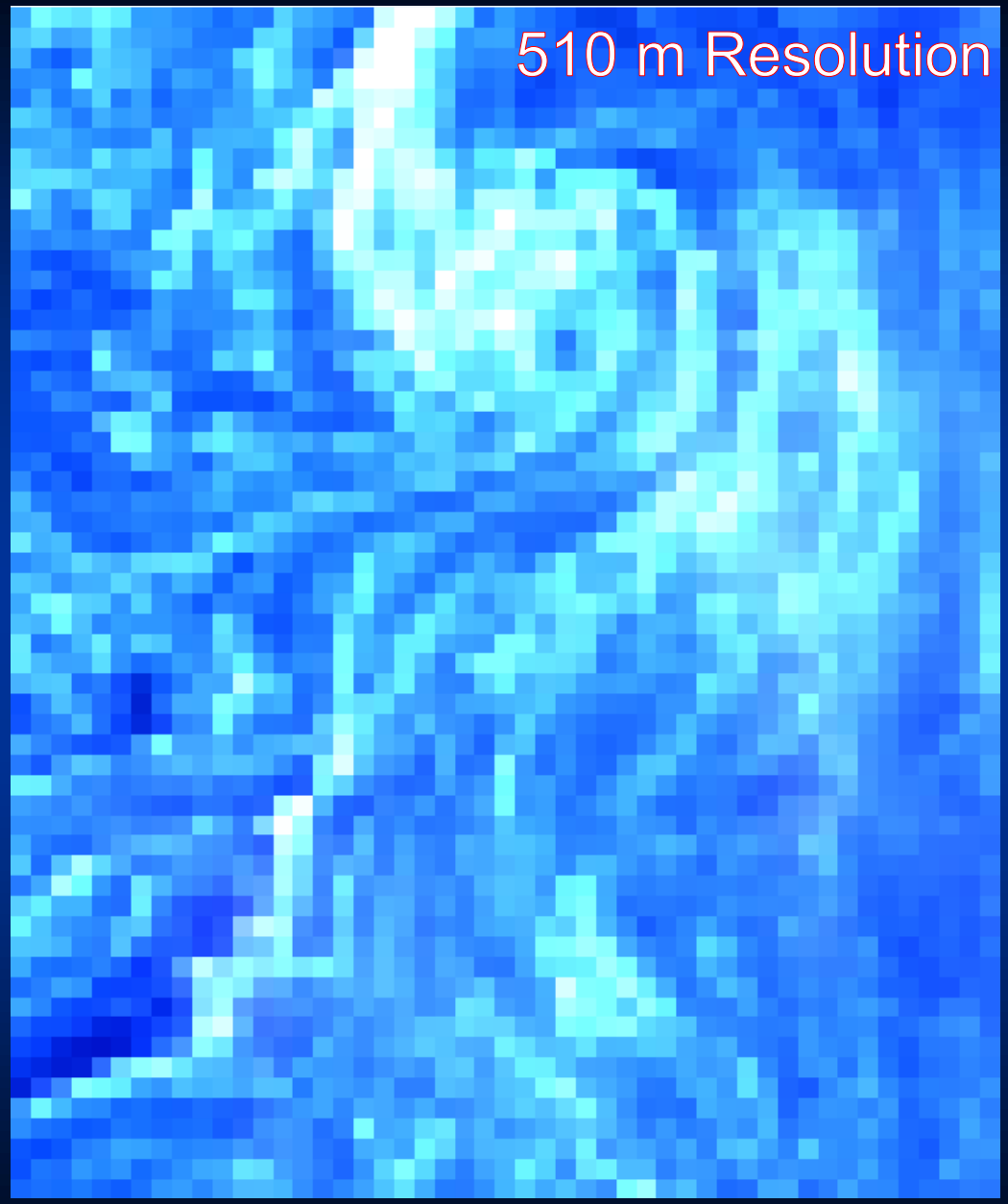
510 m Resolution

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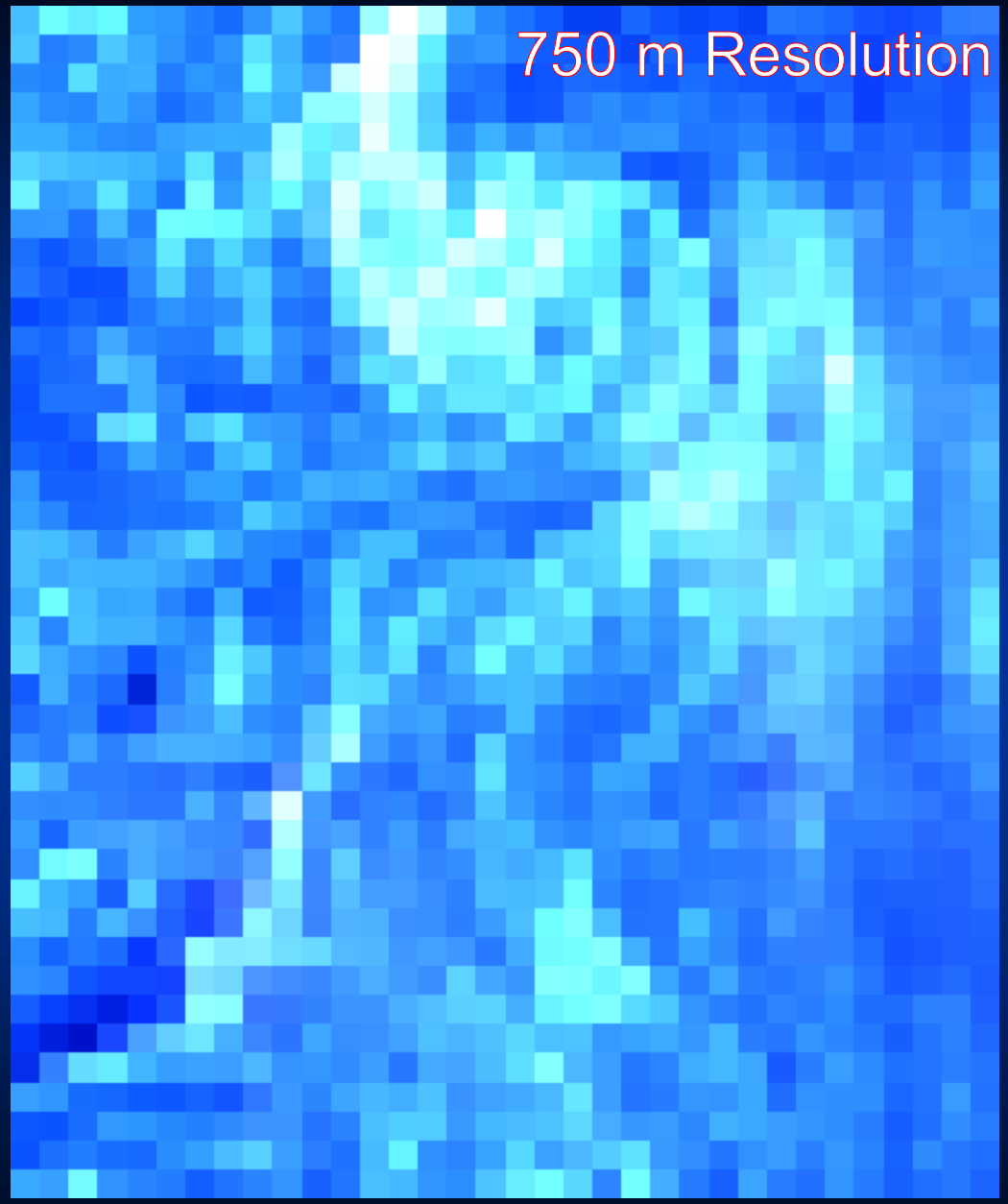

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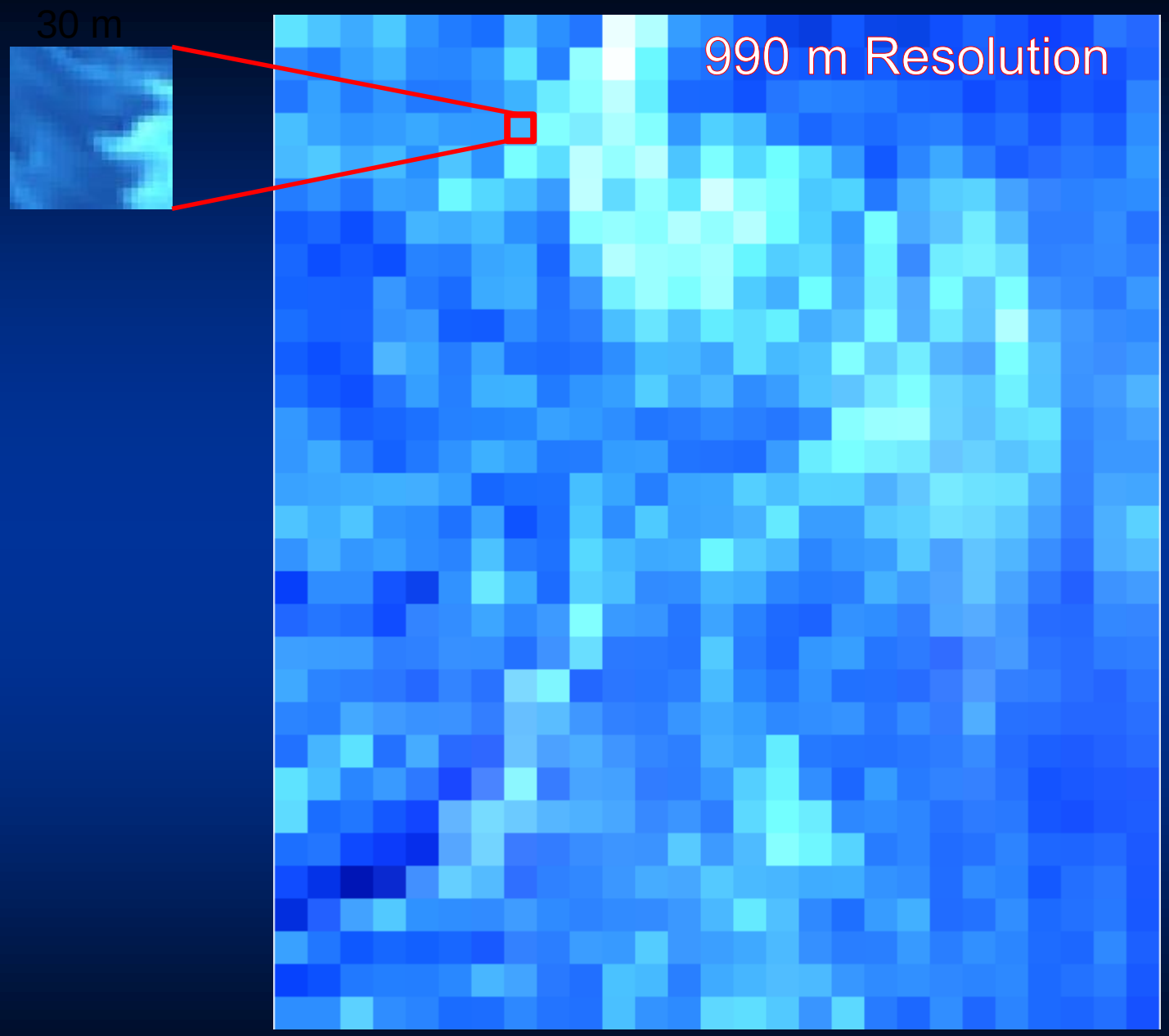
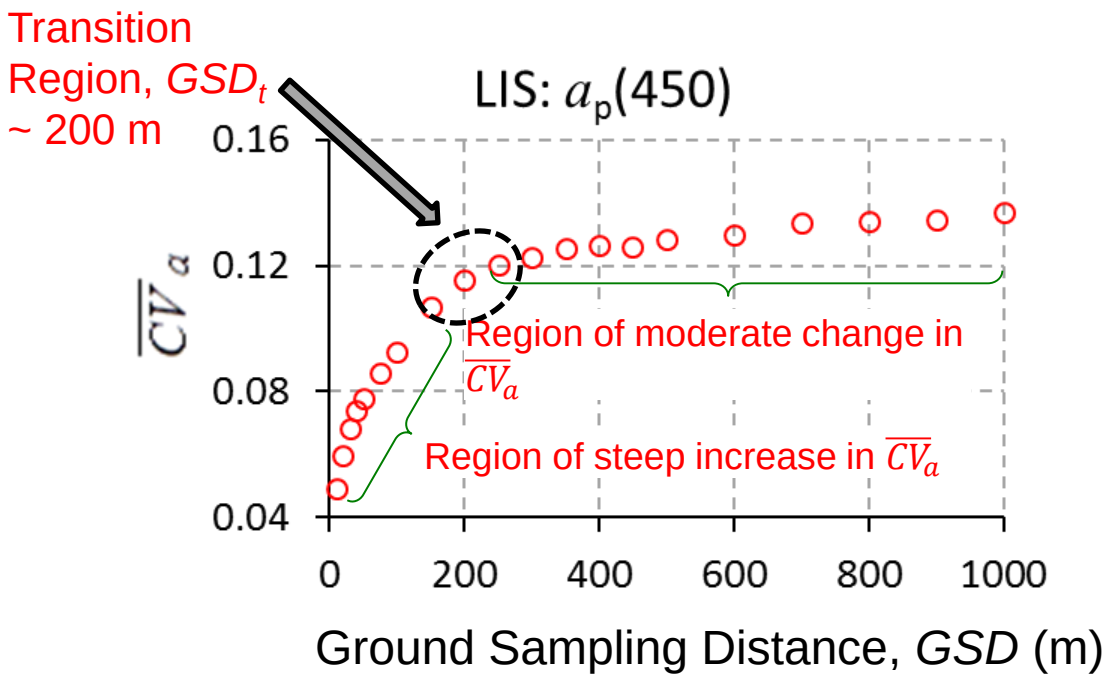


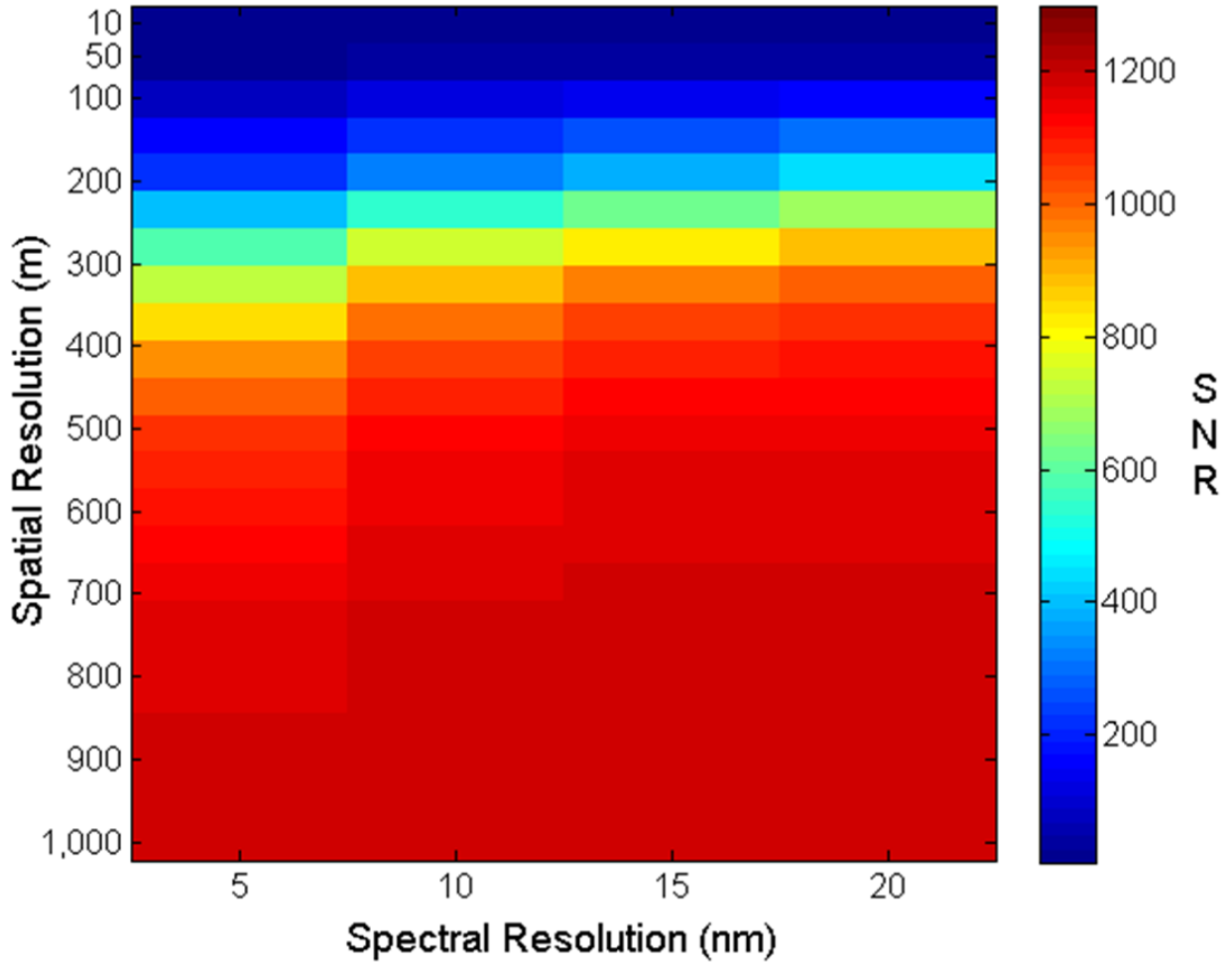
Spatial Resolution for Coastal Remote Sensing



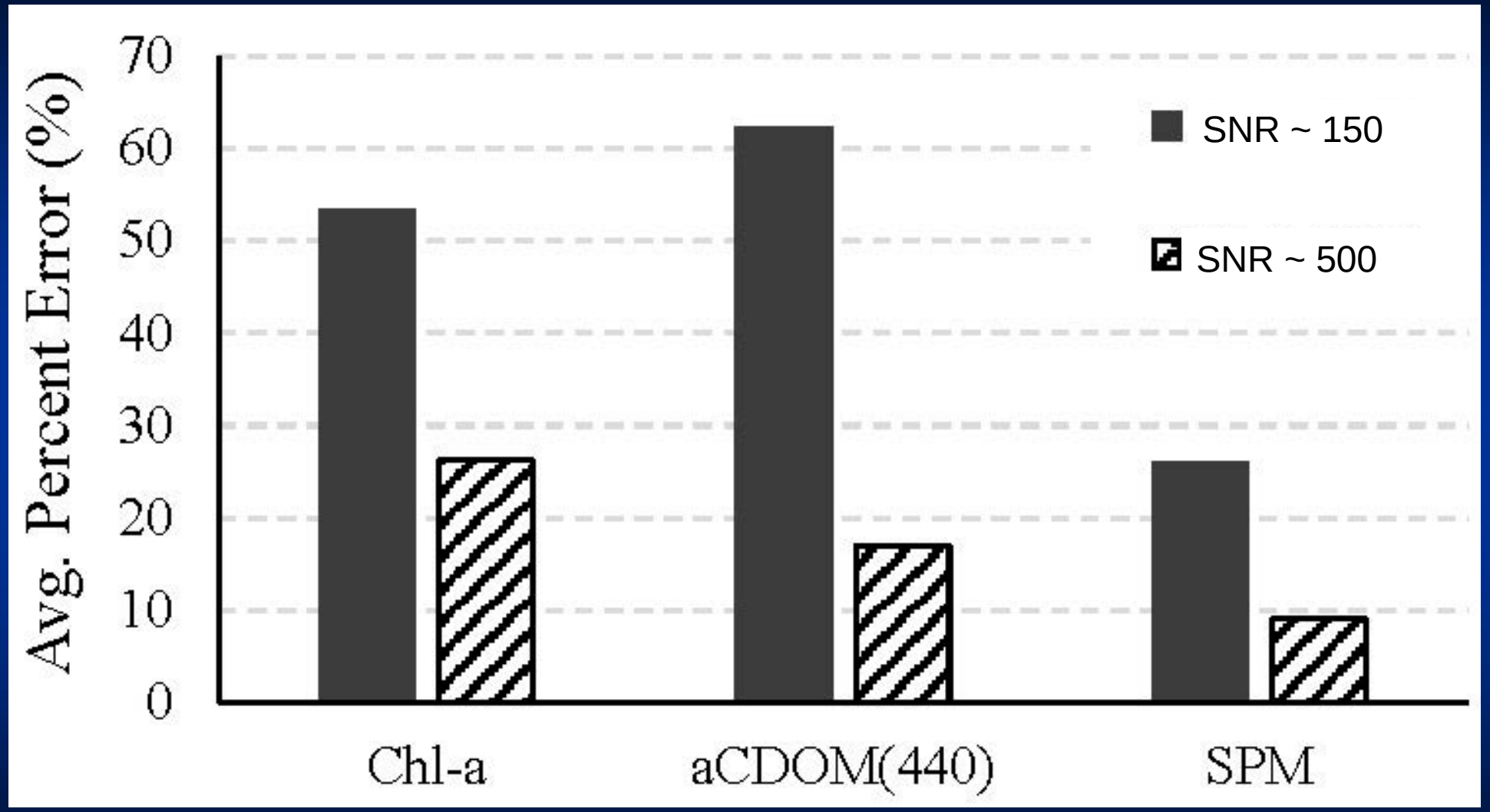
- Beyond GSD_t, decreasing the GSD results in only marginal gain in spatial information
- Below GSD_t, there is significant gain in spatial information
- Ideally, spatial resolution should be much lower than GSD_t.

Signal-to-Noise Ratio

Trade-Off



Impact of Signal-to-Noise Ratio



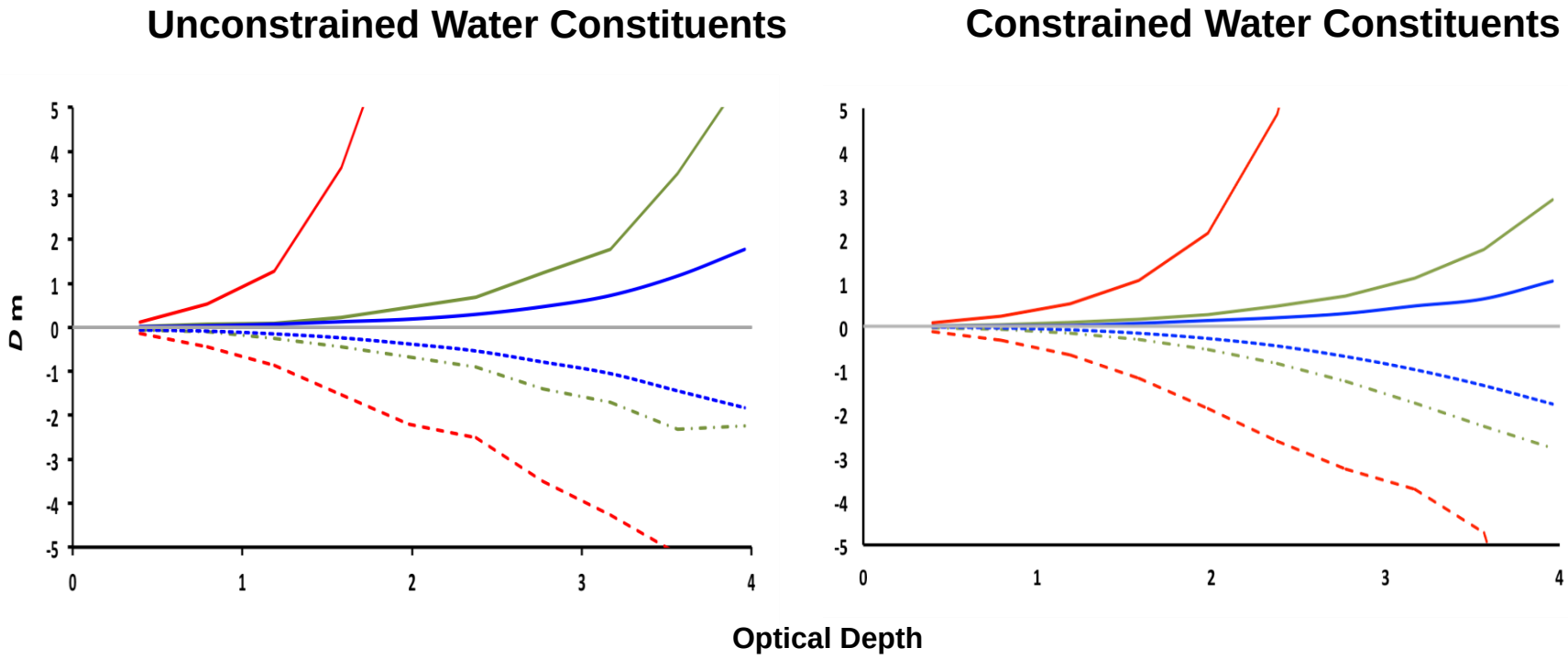
Bottom Depth Retrieval Uncertainties Imposed by SNR

Reference: Water: C_{chl} = 0.1 mg m^{-3}; $a_{g,450}$ = 0.2 m^{-1}; C_{cal} = 0.3 g m^{-3} Bottom: 100% Coral

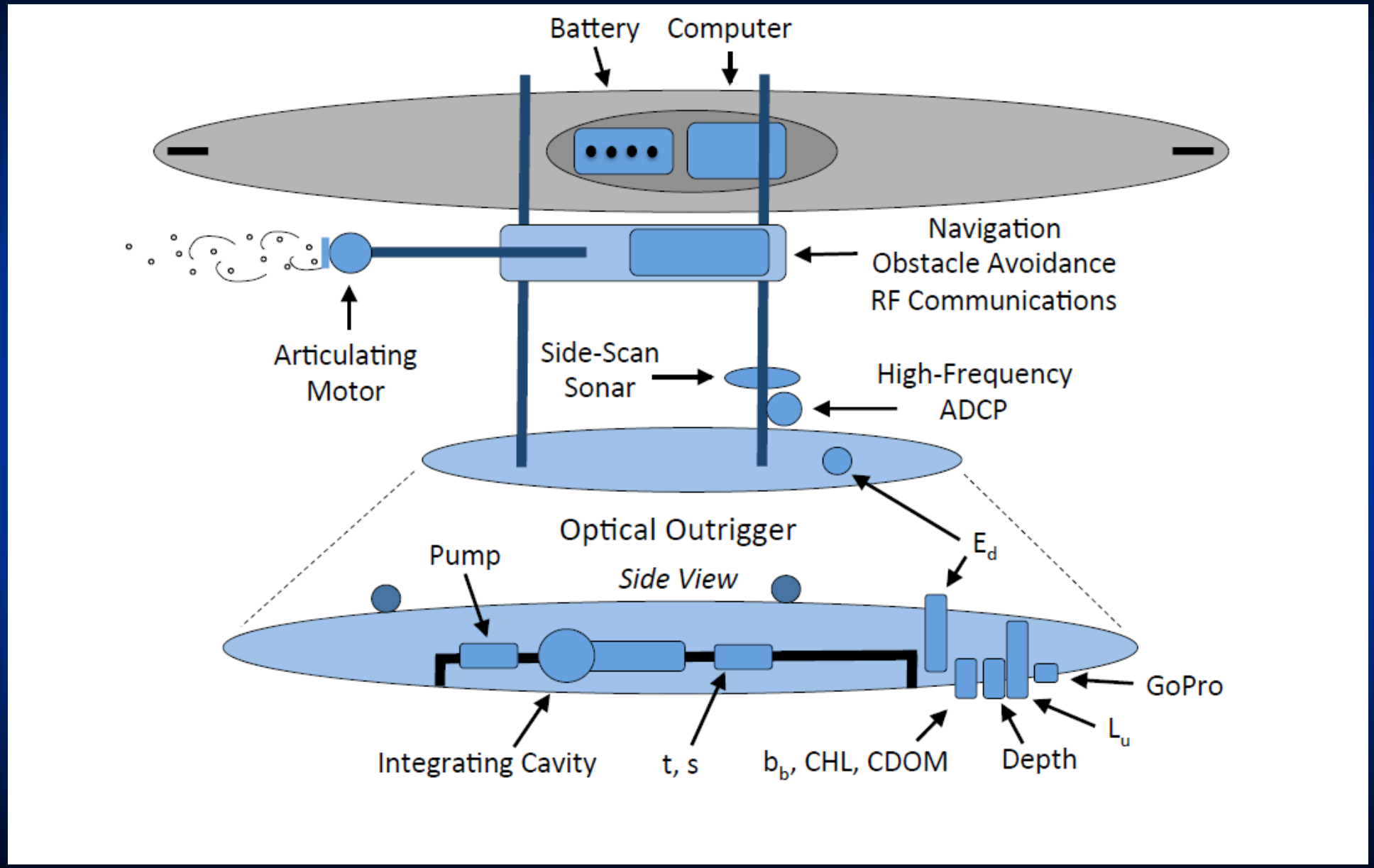
SNR = 100 — Max, Min

SNR = 500 — Max, Min

SNR = 1000 — Max, Min



Shallow Water Autonomously Navigating Surveyor



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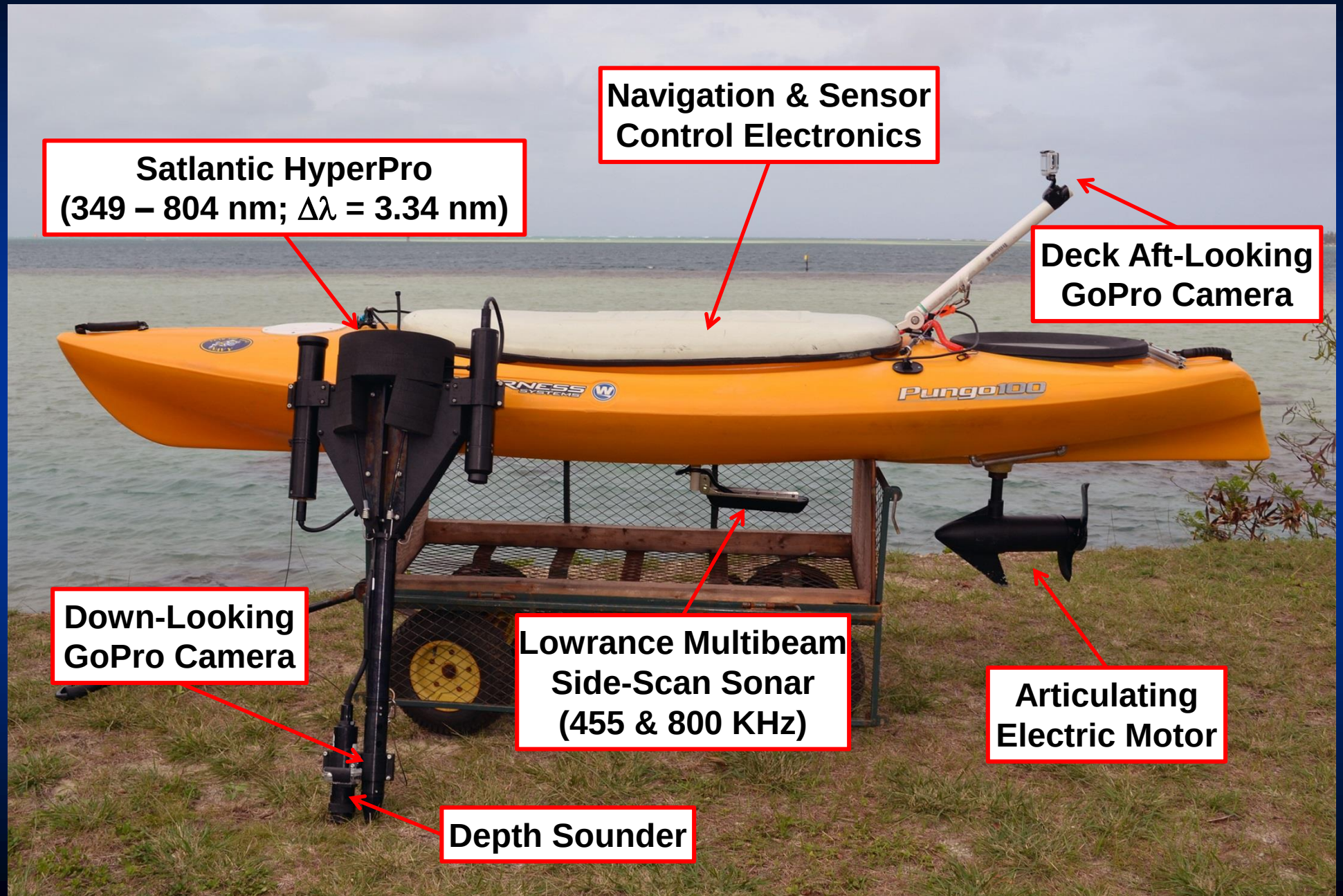
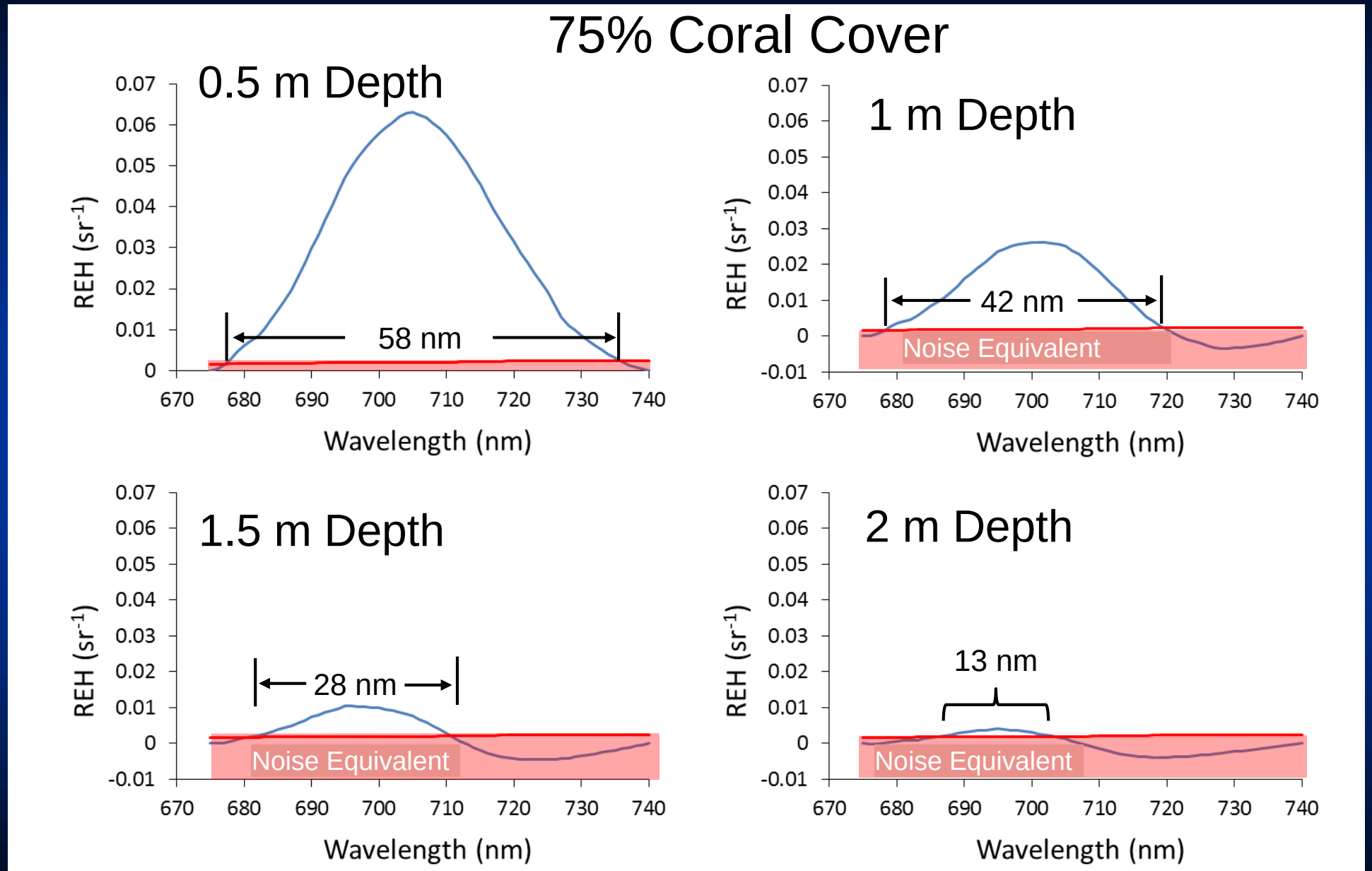
Autonomous Kayak and Sensors



Thank You!

Contact:

wesley.moses@nrl.navy.mil

Spectral Resolution for Bottom Detection at SNR = 400