Automated High-Resolution Satellite-Derived Bathymetry

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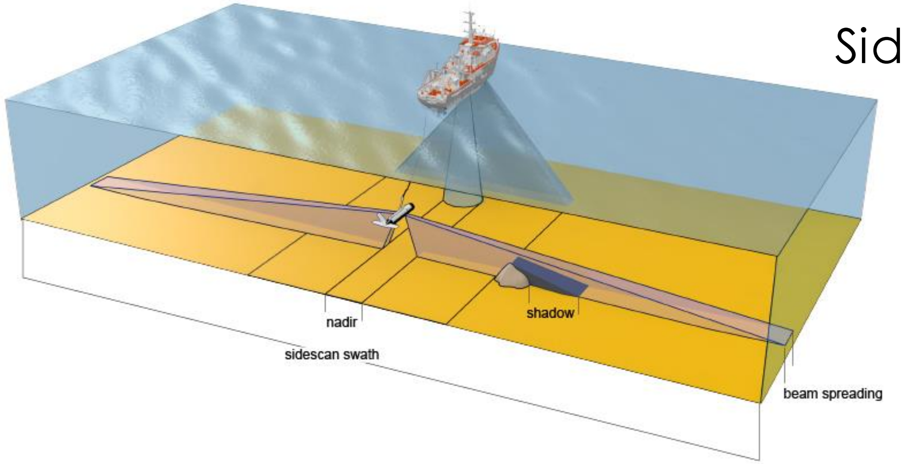
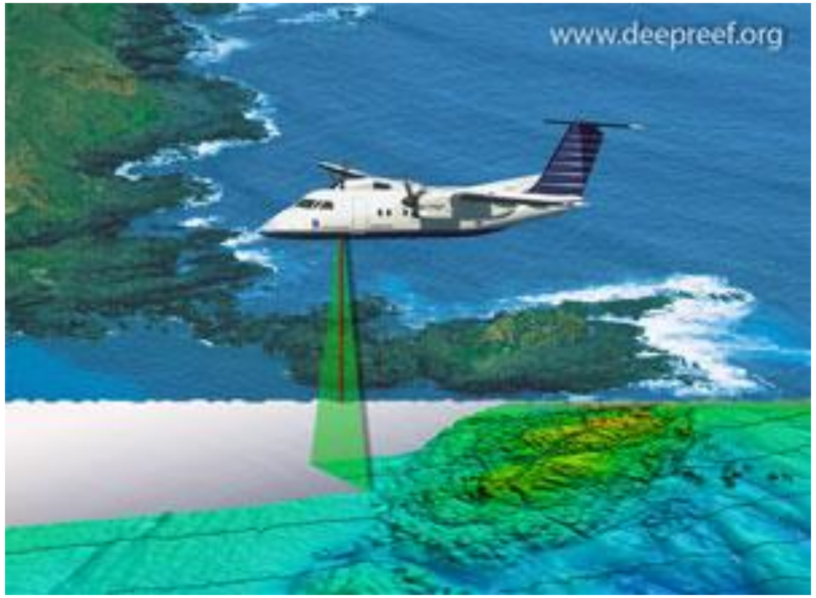
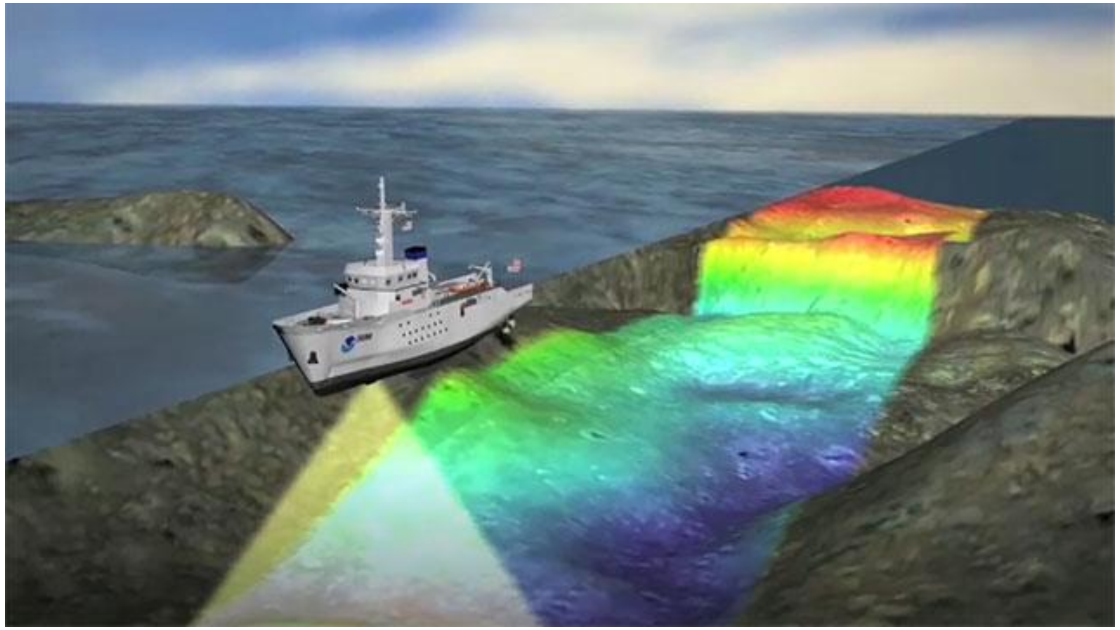
Coastal Bathymetry Background



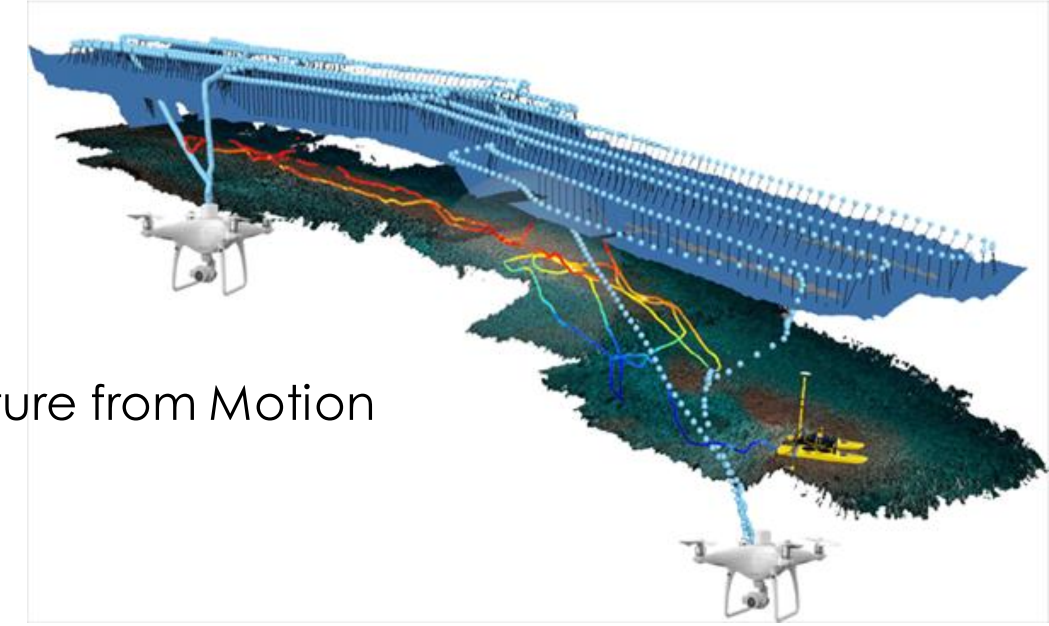
Sidescan Sonar

LiDAR





Multibeam Sonar



Structure from Motion

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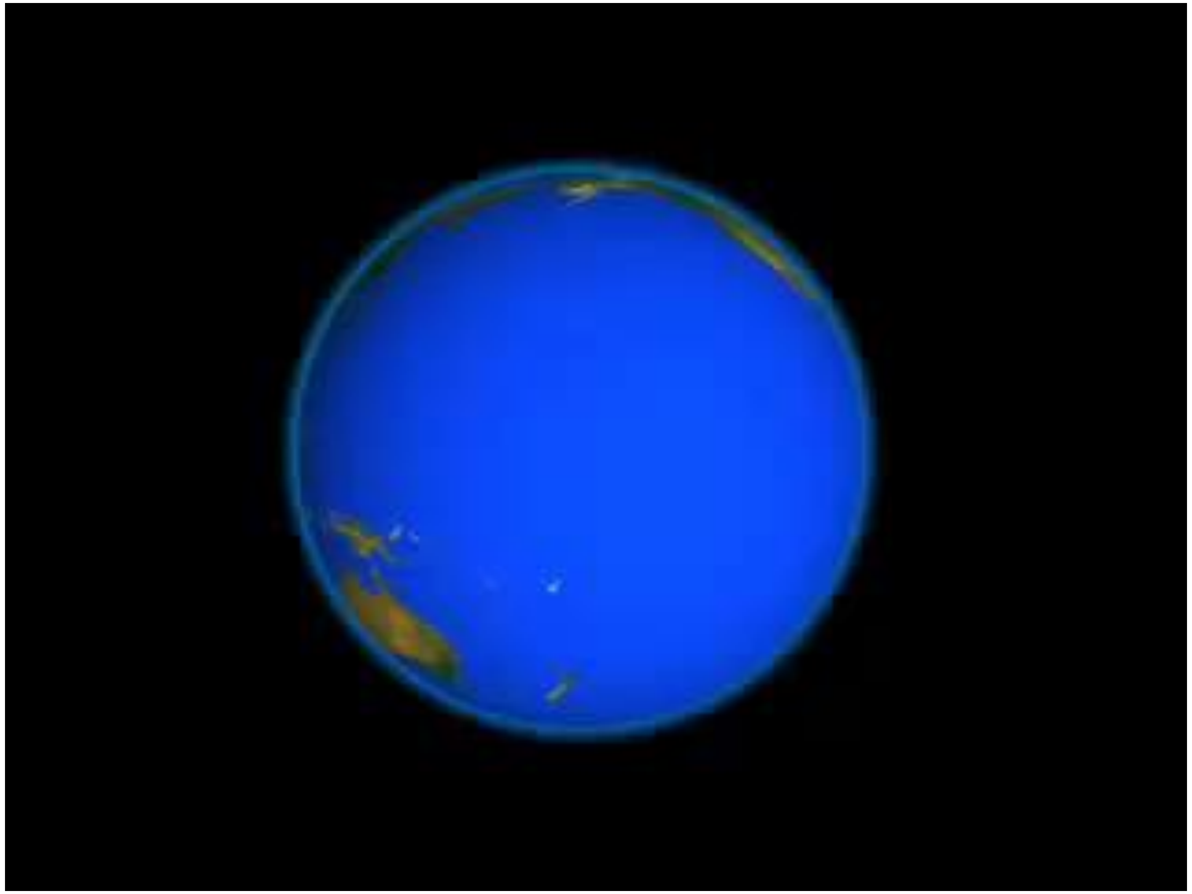
Data

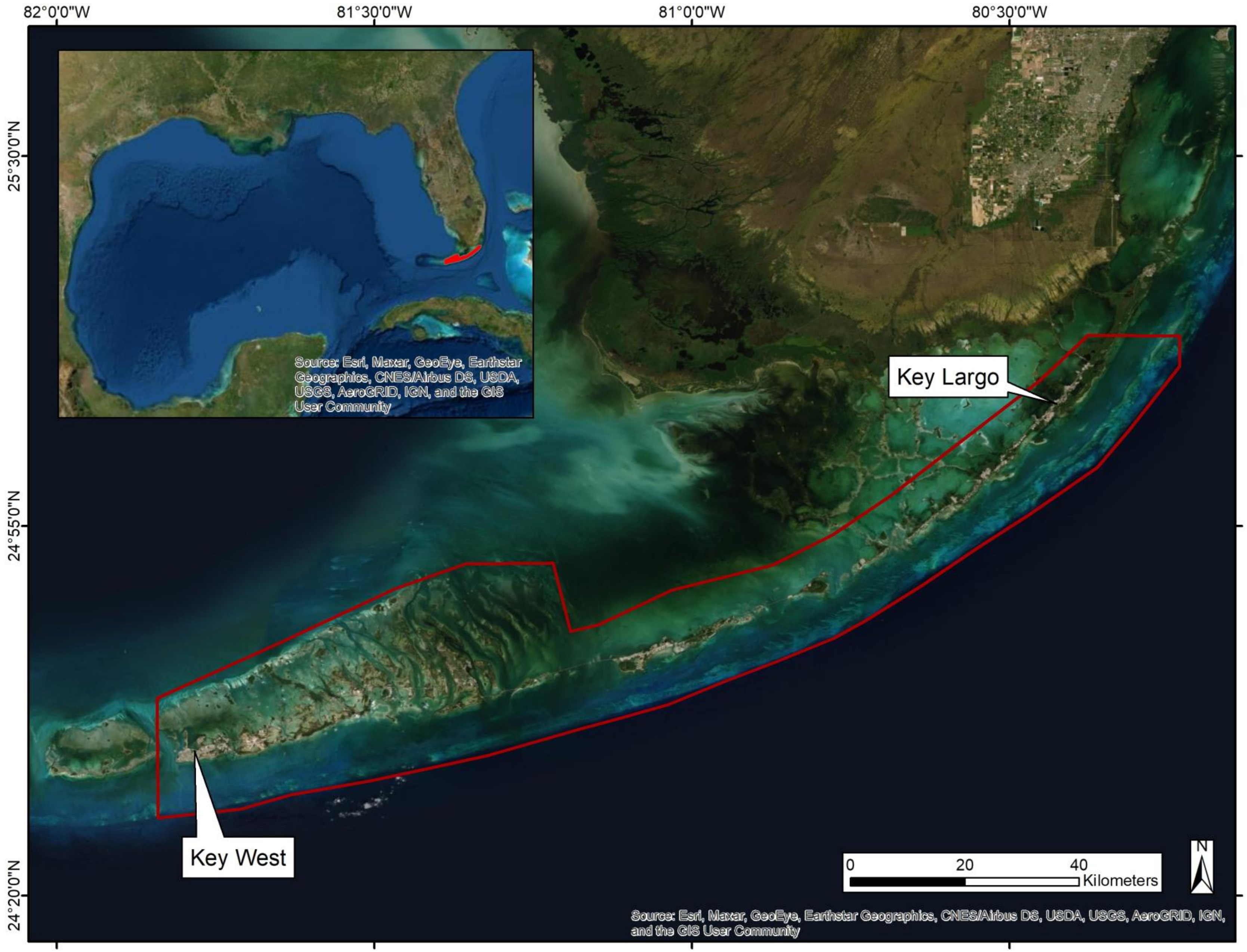
Satellite-Derived Bathymetry (SDB)



- WorldView-2 & WorldView-3
- Multispectral sensors
- 8 MS channels (Coastal-NIR)
- Dual-array sensor
- 2-meter spatial resolution
- Daily repeat acquisition
- 16-bit radiometric resolution
- Global access through license

Study Area

- Florida Keys
  - $3{,}700\ km^2$
  - Shallow reef
  - Sandy bottom
  - Steep reef edge
  - Case I water



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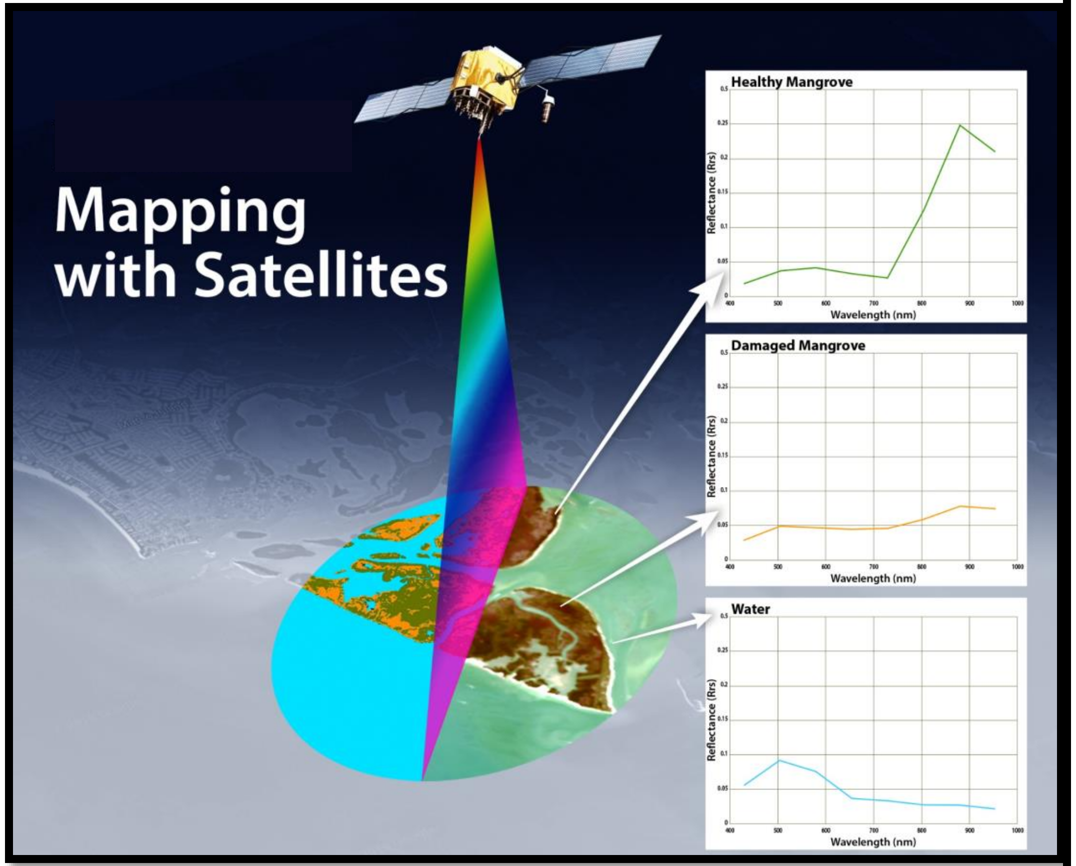
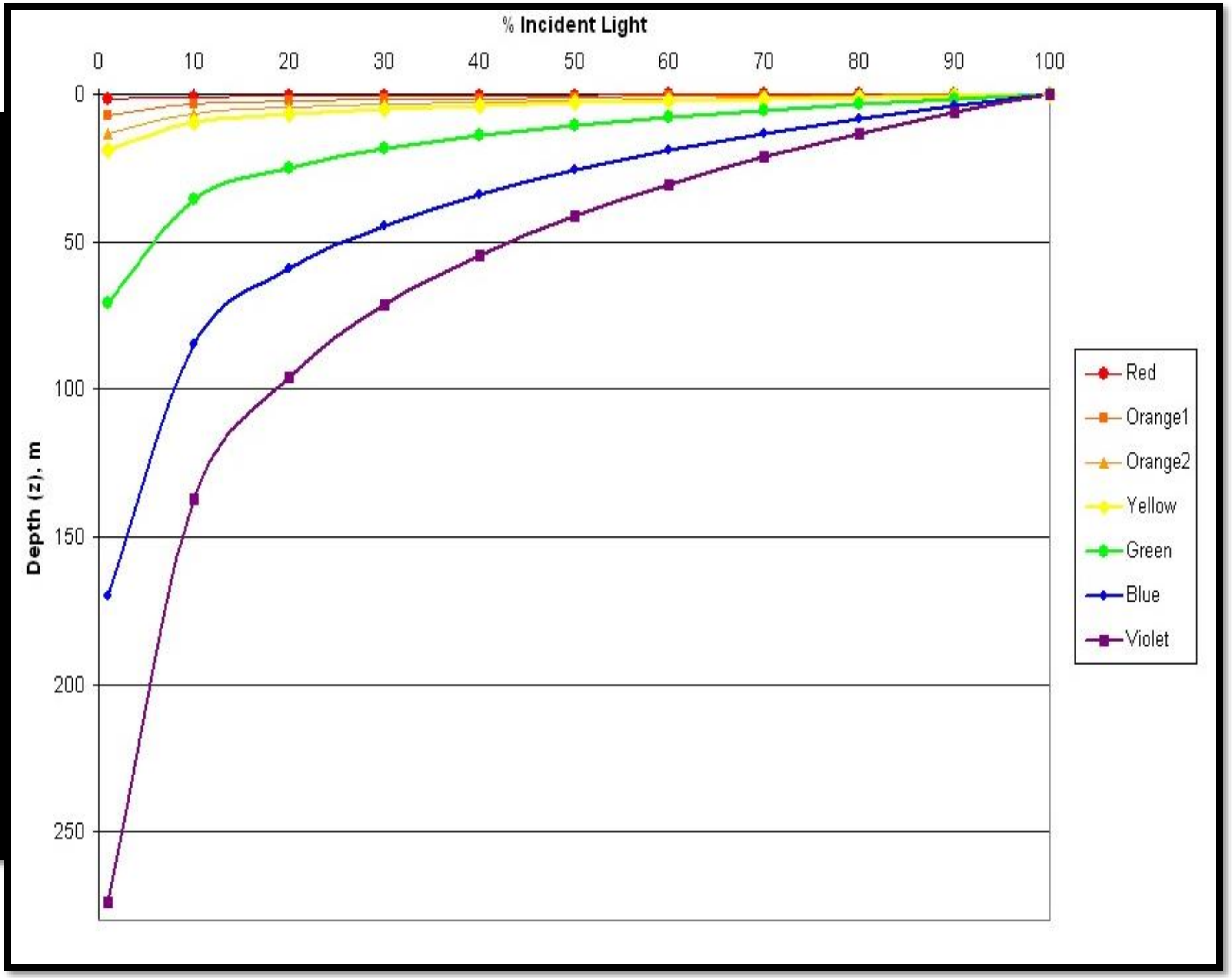
SDB: Light Attenuation





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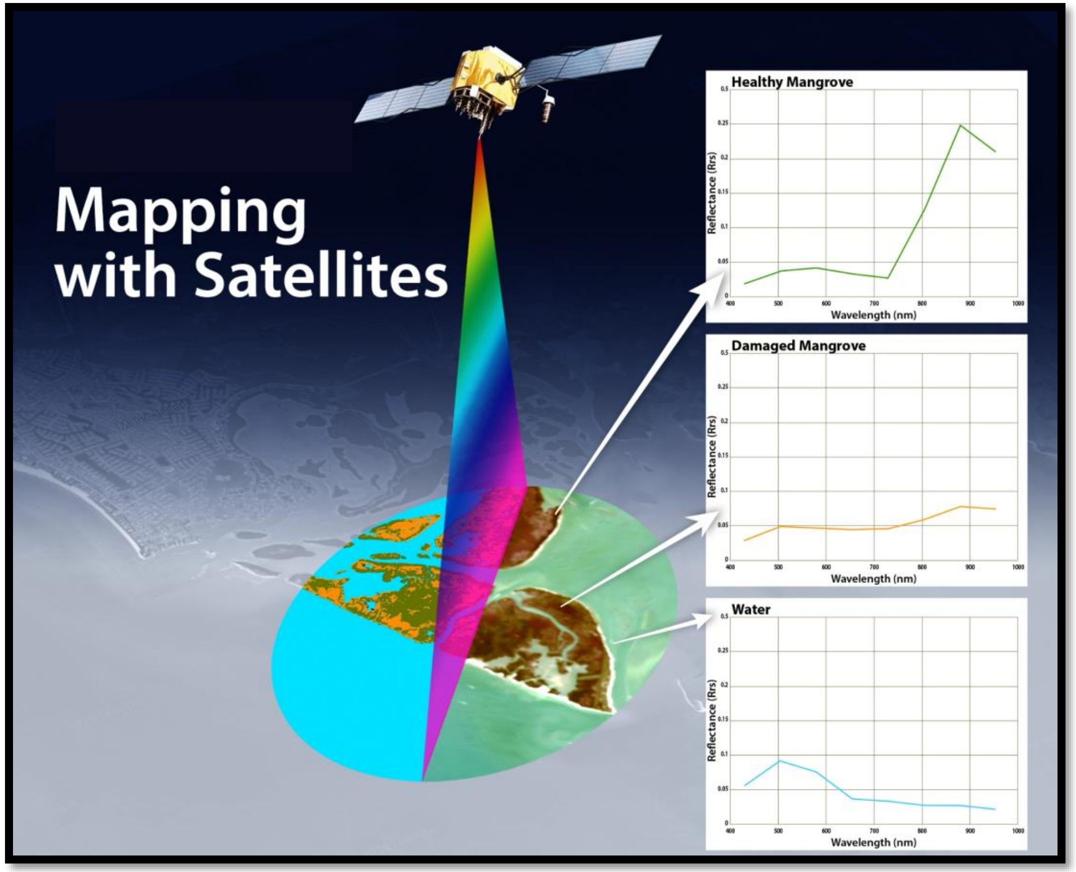

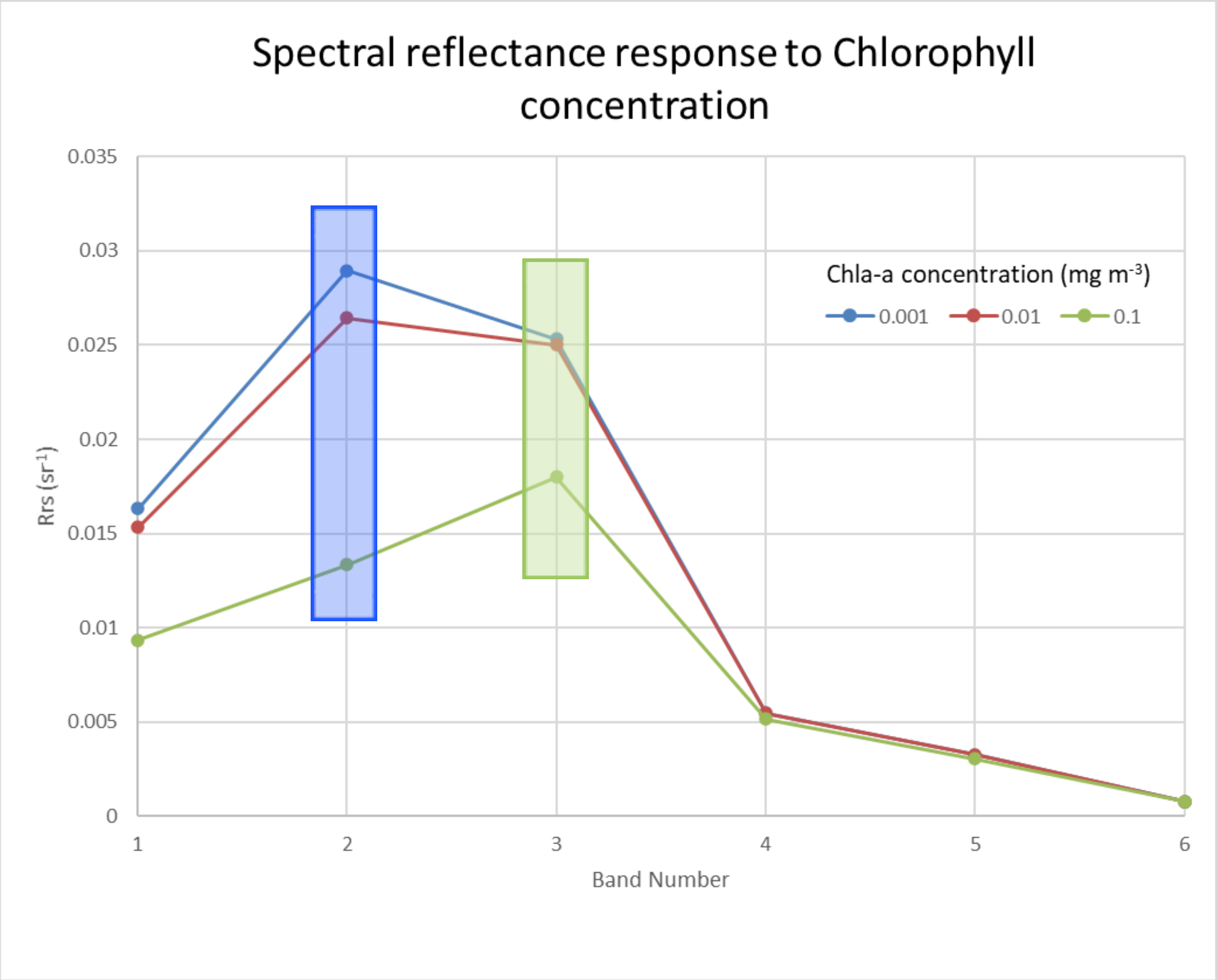

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Satellite-Derived Bathymetry (SDB) Method:

- Band-ratio approach:

$$\text{Depth} = m1 * \frac{\ln(1000*\text{Blue})}{\ln(1000*\text{Green})} - m0$$

Stumpf et al. (2003)

Objective:

- Develop automated SDB pipeline that:
  - Estimates Chlorophyll-a concentration
  - Calculates coefficients
  - Maps bathymetry

Approach

1. Radiometrically calibrate
2. Correct for atmosphere
    1. Rayleigh scattering
    2. Convert to Rrs

Li et al. (2019)

Dash et al. (2012)

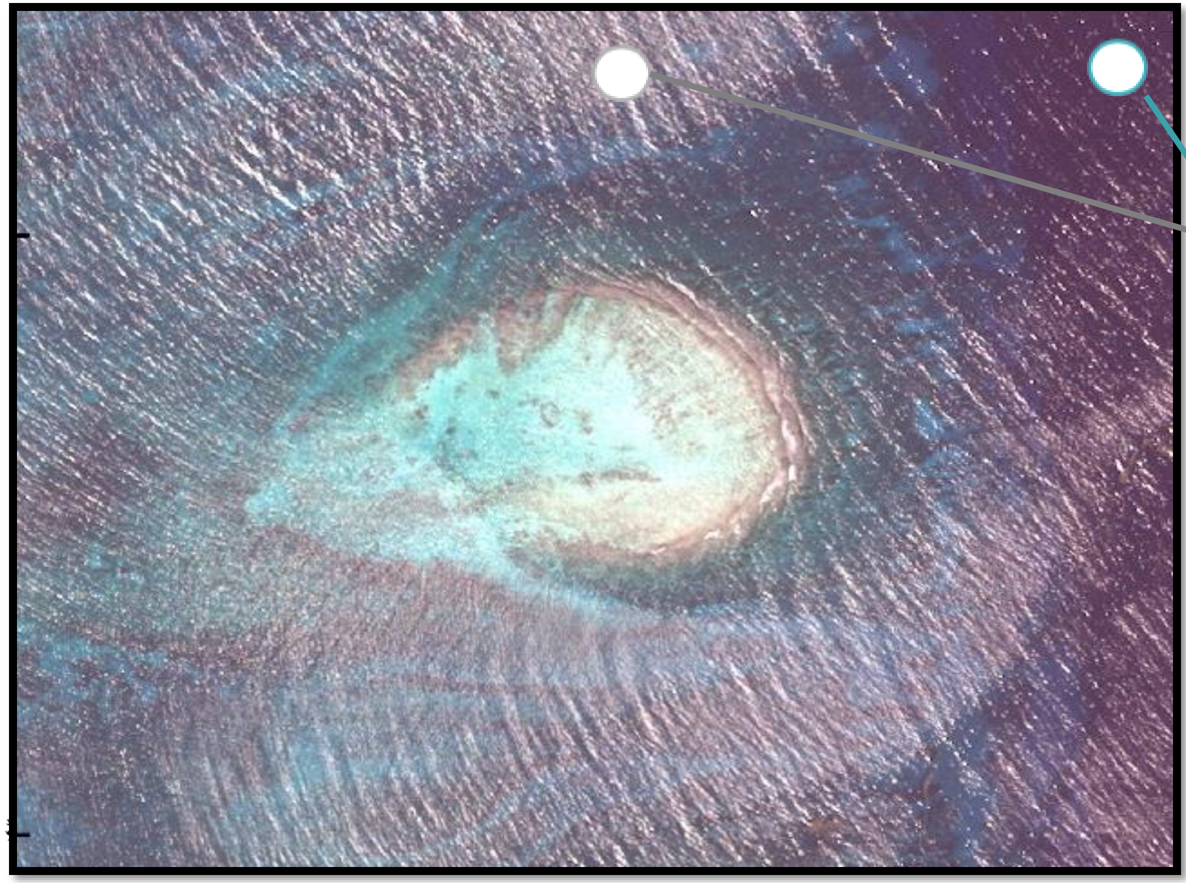
$$Rrs = \frac{(\pi^*(L - L_{Ray})^*ESd^2)}{(E^*TZ^*TV)}$$

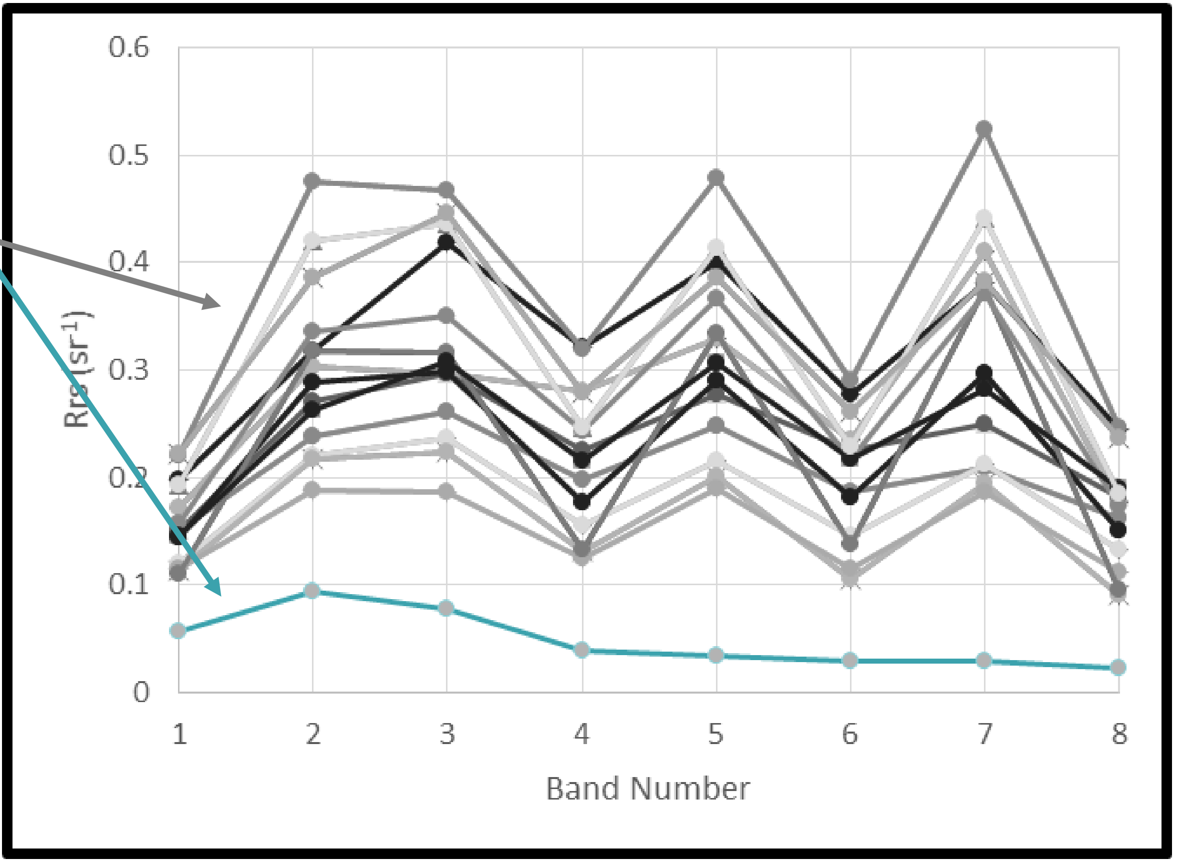
L	At-sensor radiance
L_{ray}	Rayleigh path radiance
ESd	Earth-Sun distance
E	Irradiance
TZ	Atmospheric transmittance (solar path)
TV	Atmospheric transmittance (view path)

Approach

1. Radiometrically calibrate
2. Correct for atmosphere
3. Correct for sunglint (as needed)

Band Name	Band Number	Center Wavelength (nm)	Band Coverage (nm)	Array
Coastal	B1	427	396–458	2
Blue	B2	478	442–515	1
Green	B3	546	506–586	1
Yellow	B4	608	584–632	2
Red	B5	659	624–694	1
Red Edge	B6	724	699–749	2
NIR I	B7	833	765–901	1
NIR II	B8	949	856–1043	2





Approach

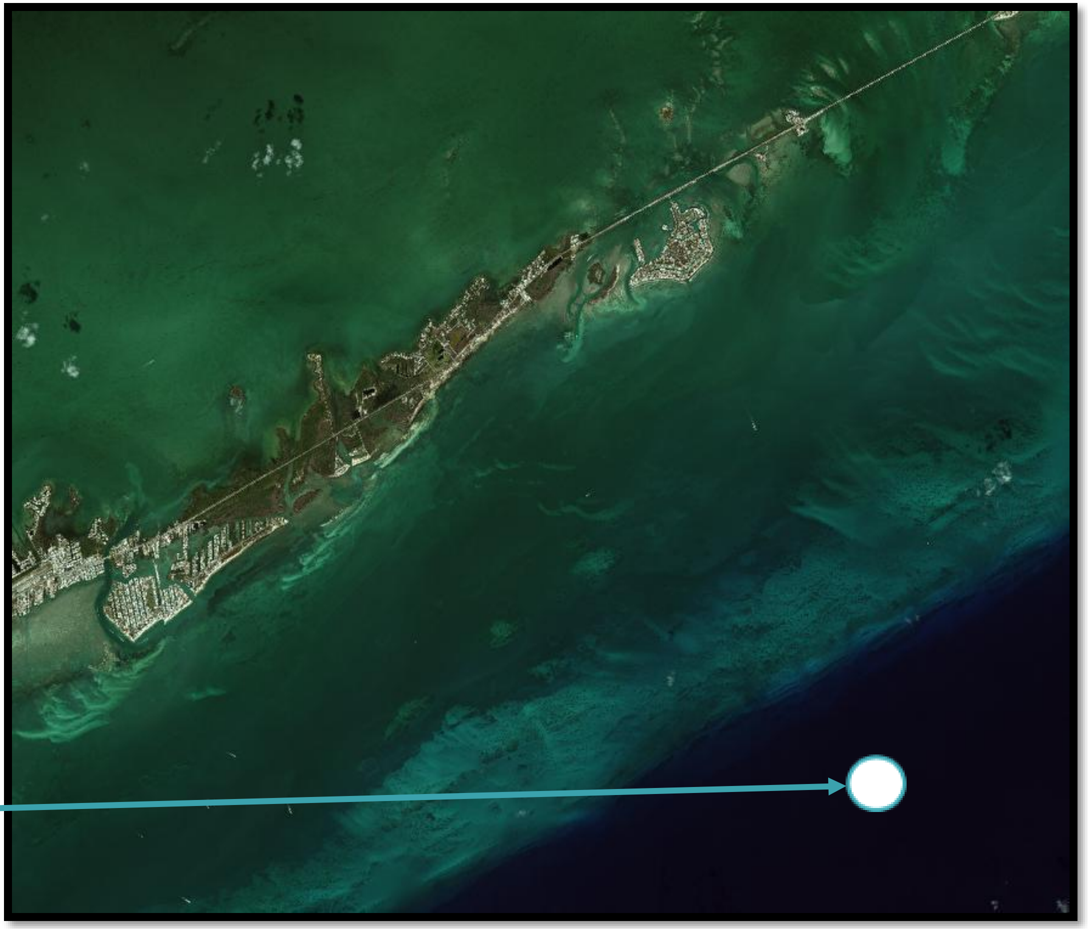
1. Radiometrically calibrate
2. Correct for atmosphere
3. Correct for sunglint (Rrs_{dg})
4. Correct for surface reflectance

$$rrs = \frac{Rrs_{dg}}{(z * 1.7 * Rrs_{dg})}$$

z = Coefficient from Snell's Law

Approach

1. Radiometrically calibrate
2. Correct for atmosphere
    1. Rayleigh only
3. Correct for sunglint (as needed)
    1. WorldView-specific algorithm
4. Correct for surface reflectance
5. Identify optically deep water (ODW)
    1. Estimate turbidity (chlorophyll concentration)



$$ODW = Water_{5\text{-}10\%}$$

$$w = rrs_{ODW}(B3) - 0.46 * rrs_{ODW}(B4) - 0.54 * rrs_{ODW}(B1)$$

$$Chl = 10^{(-0.4909 + 191.659 * w)}$$

Hu et al. (2012)

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Approach

1. Radiometrically calibrate
2. Correct for atmosphere
3. Correct for sunglint (as needed)
4. Correct for surface reflectance
5. Identify optically deep water (ODW)
    1. Estimate turbidity (chlorophyll concentration)
6. Derive tuning coefficients
7. Apply band-ratio algorithm

$$Chl = 10^{(-0.4909 + 191.659*w)}$$

$$\mathbf{m1} = 52.083*e^{(1.7*chl)}$$

$$\mathbf{m0} = 50.156*e^{(1.7*chl)}$$

Scalars are from Li et al. (2019) and were derived from the simulation model of pure water by Mobley (1995)

We calculated new exponential scalars using the same WV image as in Kerr and Perkis (2018) setting m1 and m0 to their derived values and solving for exponentials using our Chla estimate.

$$Depth = \mathbf{m1} * \frac{\ln(1000*B2)}{\ln(1000*B3)} - \mathbf{m0}$$

Li et al. (2019)

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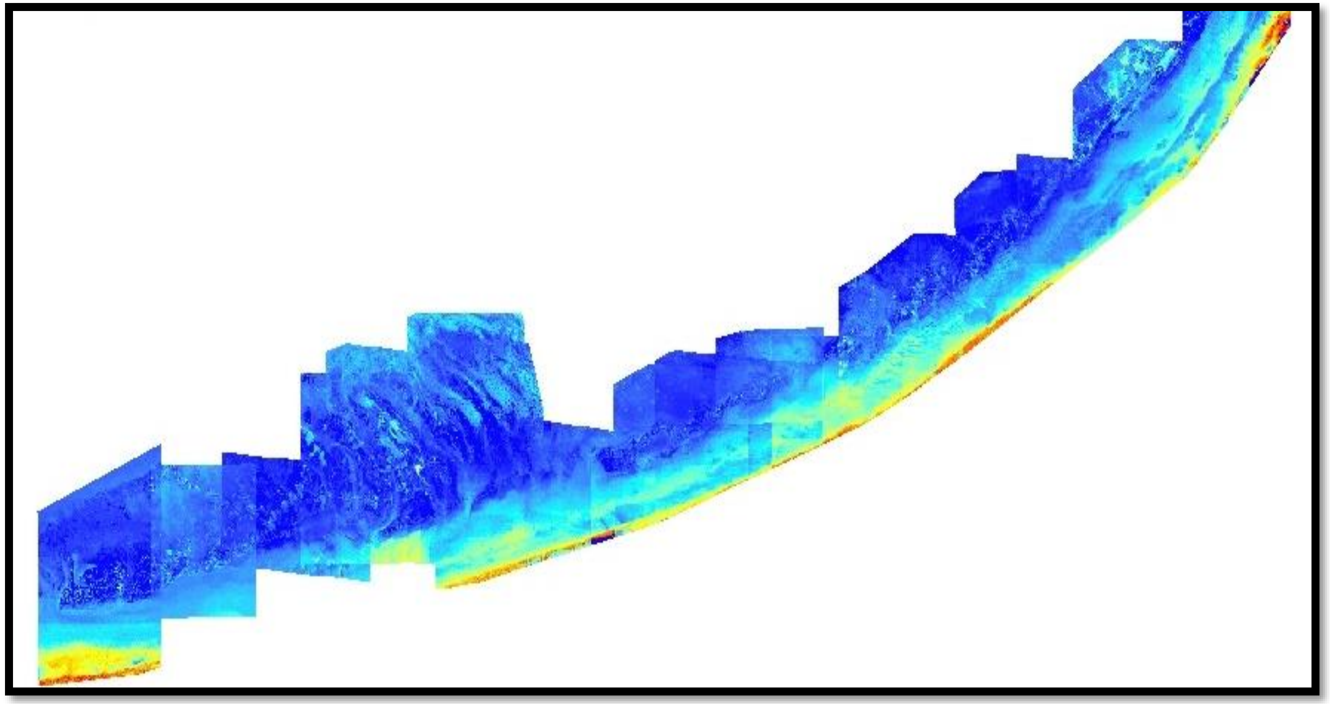
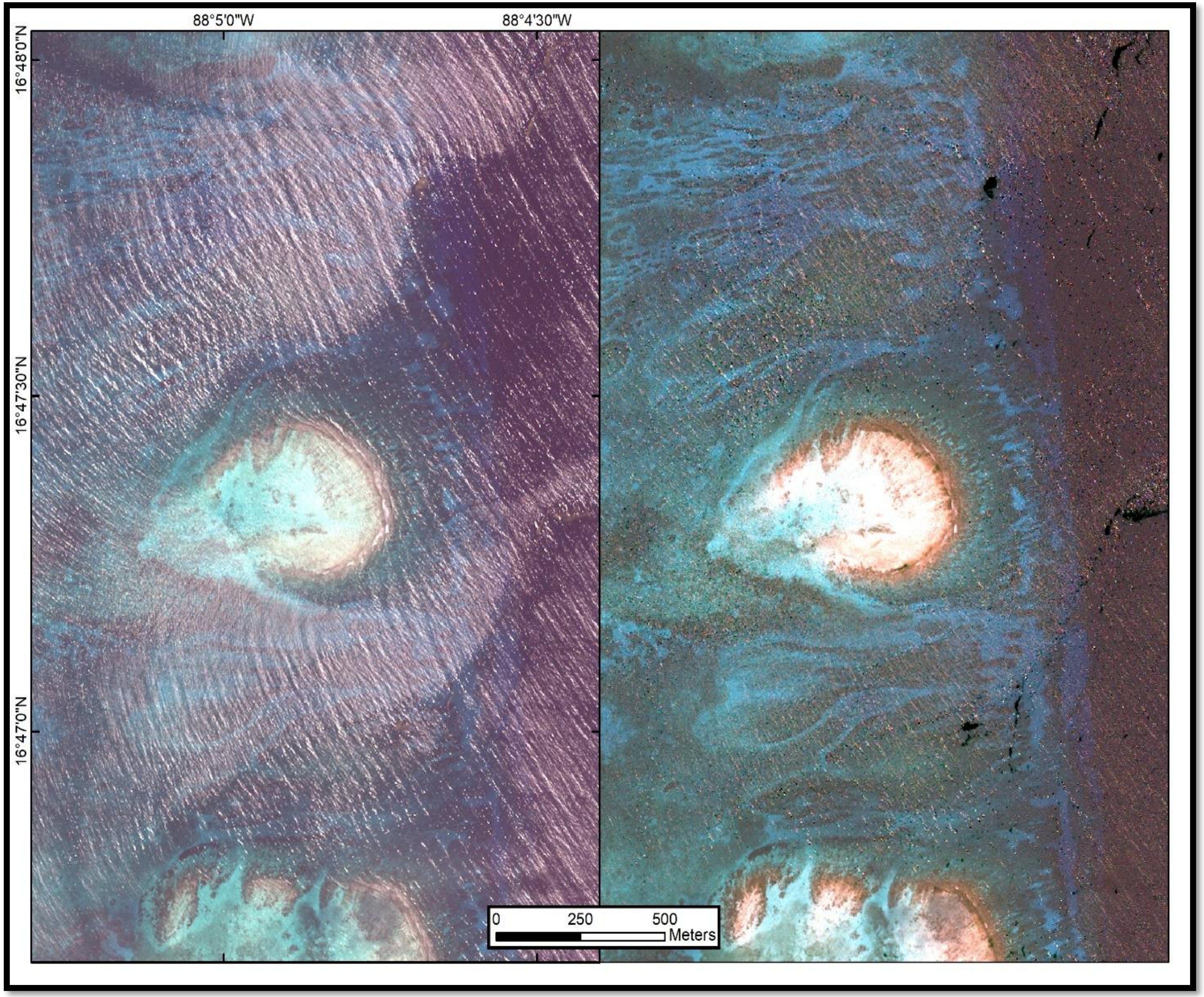
Approach

1. Radiometrically calibrate
2. Correct for atmosphere
3. Correct for sunglint (as needed)
4. Correct for surface reflectance
5. Identify optically deep water (ODW)
    1. Estimate turbidity (chlorophyll concentration)
6. Derive tuning coefficients
7. Apply band-ratio algorithm
8. Postprocessing
    – Mosaic mapped tiles (ArcMap)



Results

- **Deglinting**



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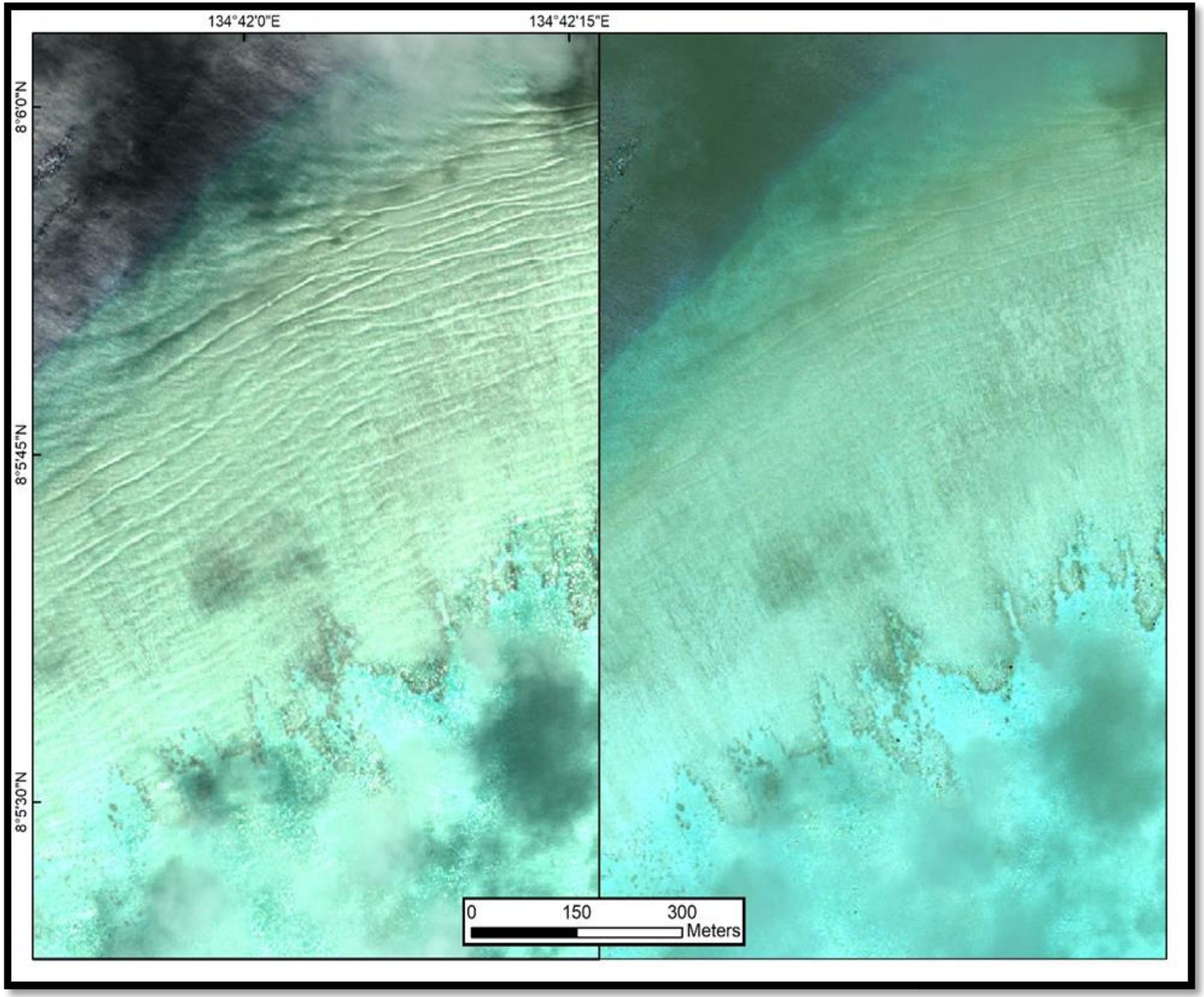
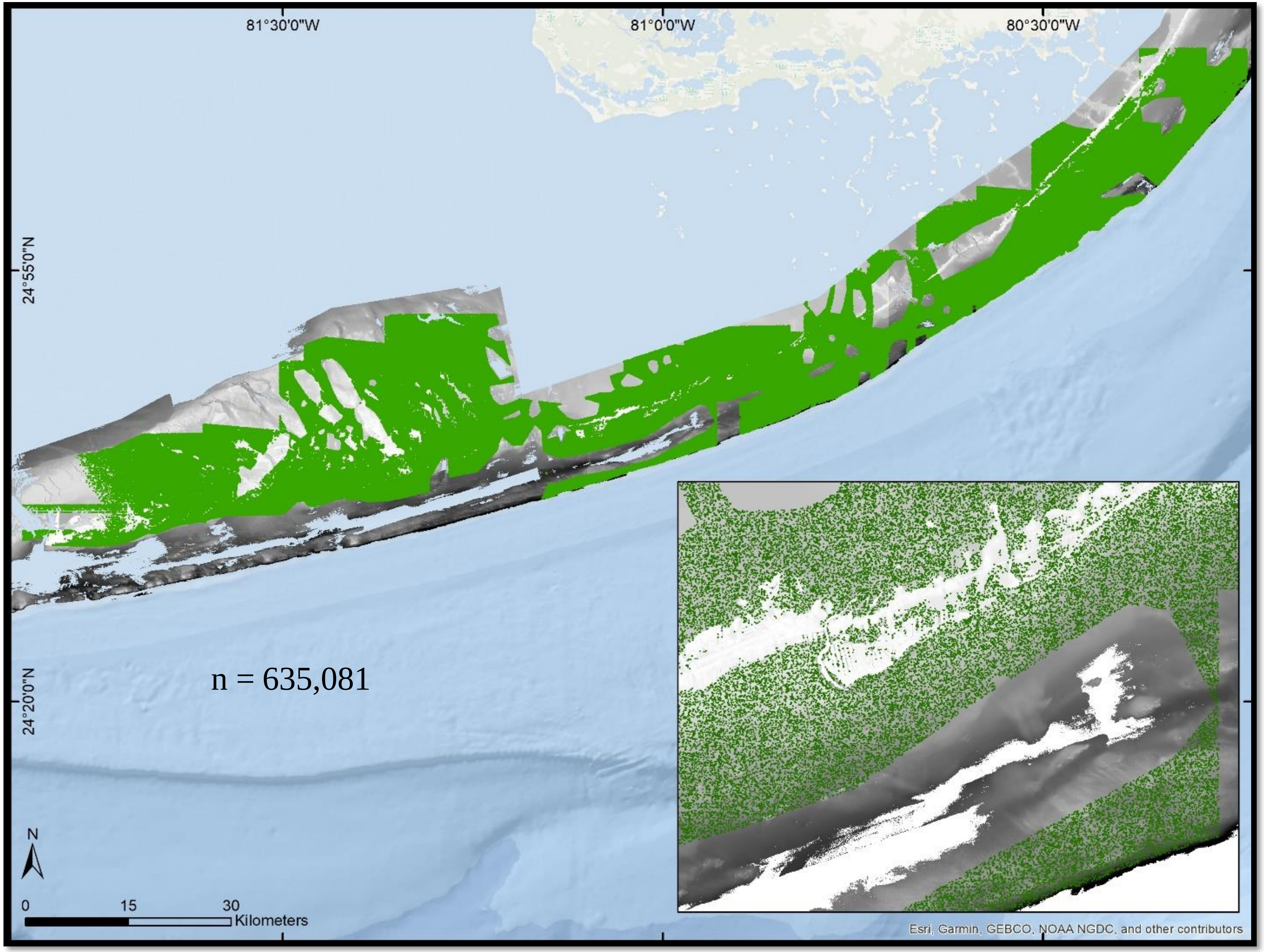
Results

- **Deglinting**



Validation



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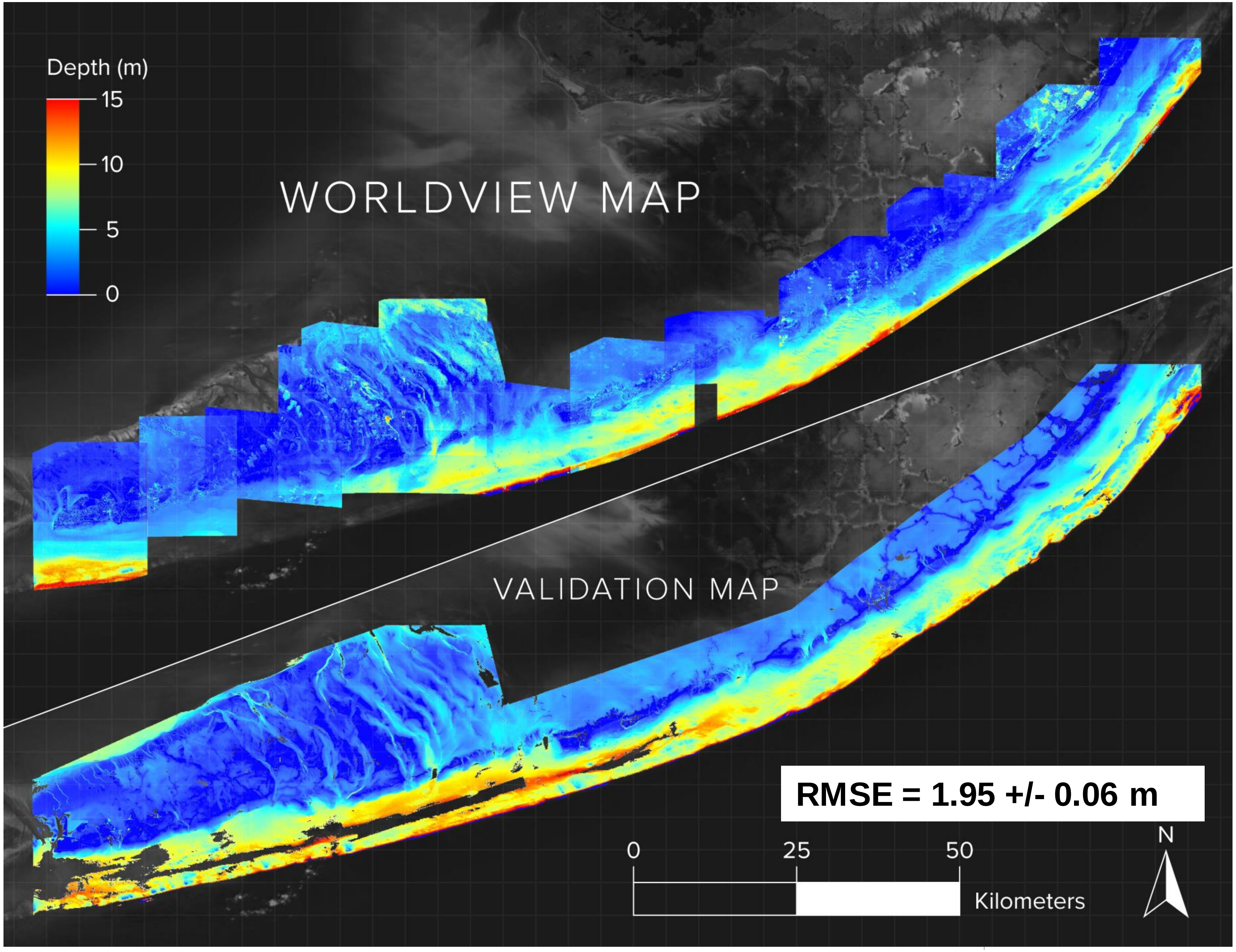
Results

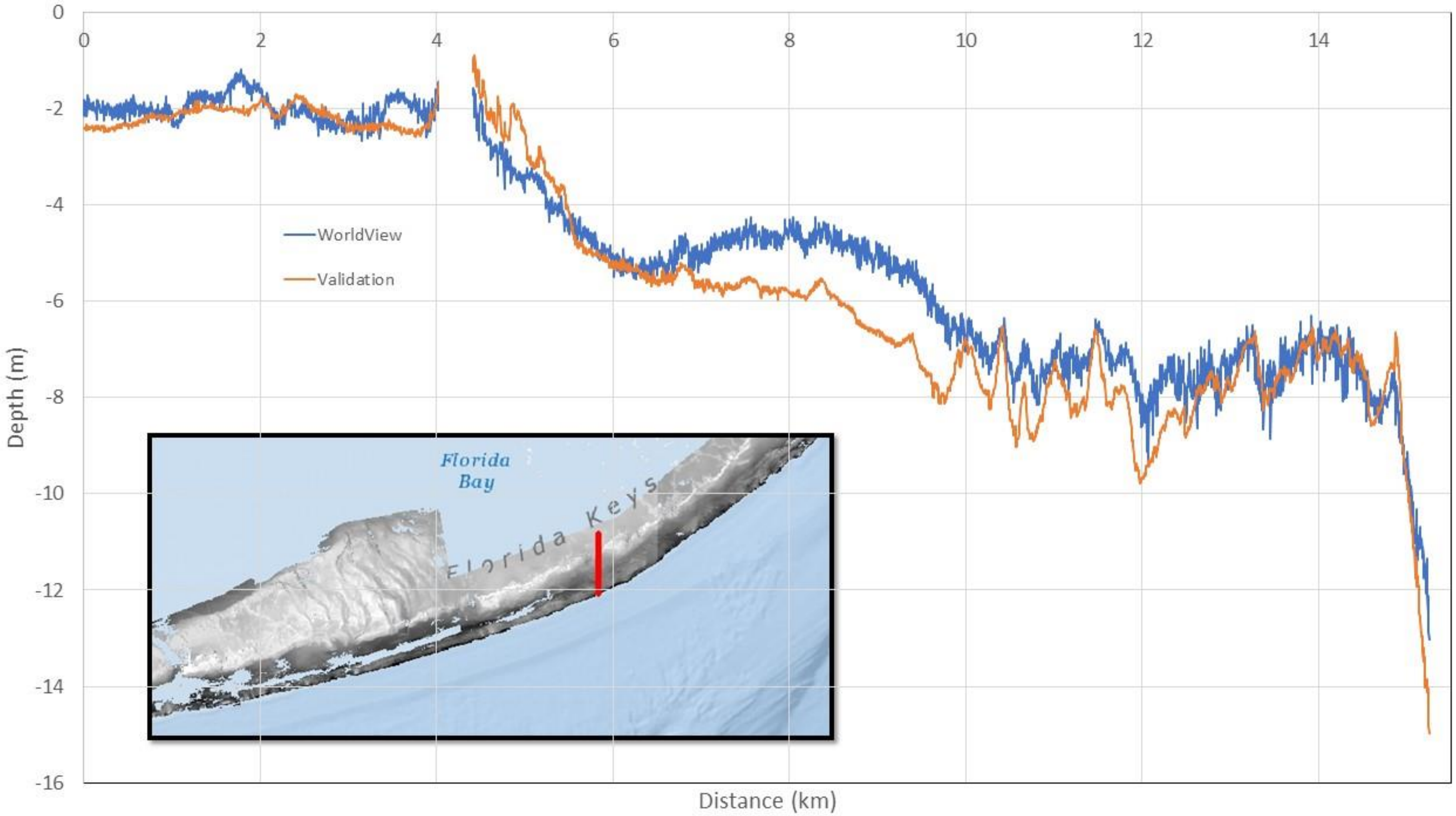
Depth	RMSE (m)	n
All	1.95	635,081
<12m	1.90	629,169
<10m	1.85	620,387
<8m	1.73	583,292
<6m	1.52	500,988
<4m	1.28	397,549
<2m	1.16	173,431



<u>Processing efficiency:</u>

- ~47 seconds per image
- 27 minutes total
- 138 km^2 mapped per minute

Results



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Summary

- Accuracy (RMSE) = 1.95 m
  - Li et al. (2019): 1.22-1.86 m
  - Kerr et al. (2018): 0.89-2.62 m
  - Zhu et al. (2020): 3.829 m
  - DEM: 1.96 m
- Speed
  - < 1-minute per image
  - > 100 km^2 per minute
- Future work:
  - **Atmospheric correction enhancement**
  - **IOP modeling enhancement**