Benthic Retrieval – IOP and AOP Models

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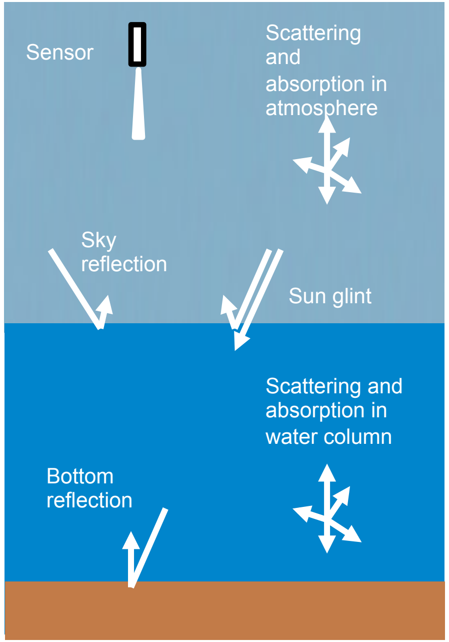
Outline

- Background
- Model Description
  - Apparent Optical Properties (AOP)
  - Inherent Optical Properties (IOP)
    - Nadir Assumption
    - View Angle Dependent
- Retrieval Algorithm
- Synthetic Experiments
- Real Data Experiments

Retrieval Background



Retrieved quantities

Step 1
Aerosol optical depth τ
Aerosol type ζ
Water leaving reflectance R_{rs}

Step 2
Glint-corrected R_{rs}

Step 3
Water column properties
Depth H
Benthic reflectance R_b

Subsurface Reflectance Model

- Consider the following from Lee et al, 1998[1]:

$$Rrs = R_{rs}^{deep}\left[1 - e^{-2KH}\right] + R_b e^{-2KH}$$

Reflectance just under water surface

Reflectance from optically deep water

Effective attenuation

Benthic reflectance

Depth

$$R_b = \sum e^{R_b^{coeff}} R_b \ldots$$

[1] Lee, Zhongping, et al. "Hyperspectral remote sensing for shallow waters. I. A semianalytical model." *Applied Optics* 37.27 (1998): 6329-6338.

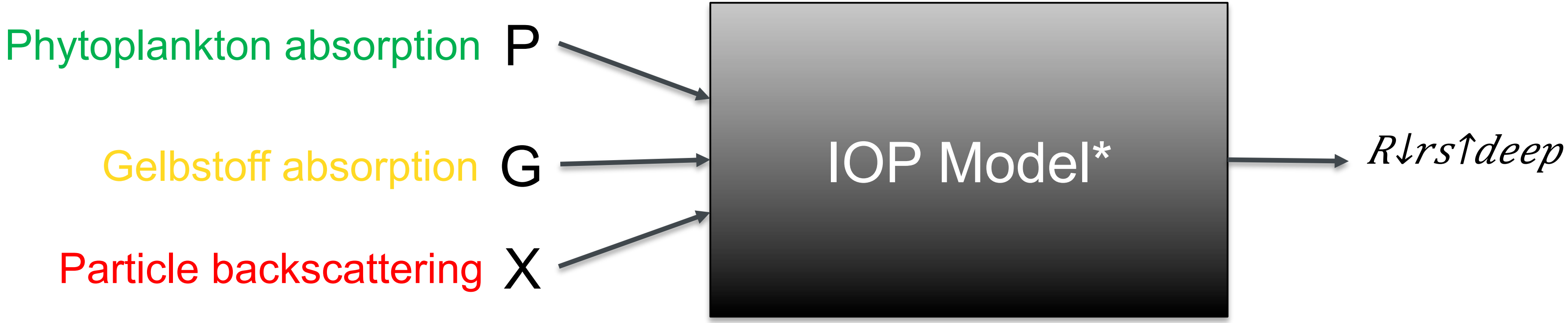
Apparent Optical Properties (AOP) Model

$$R_{rs}^{deep} = b_b / 2K_d$$ [2]

$$b_b = \sum_j b_b^{coeff} \, b_{b_j}^{library} \qquad K_d = \sum_k K_{d}^{coeff} \, K_{d_k}^{library}$$

[2] Maritorena, Stephane, Andre Morel, and Bernard Gentili. "Diffuse reflectance of oceanic shallow waters: Influence of water depth and bottom albedo." *Limnology and oceanography* 39.7 (1994): 1689-1703.

Inherent Optical Properties (IOP) Model – Nadir Viewed



*Full formulation provided in appendix

IOP Model – View Angle Dependent

$$R_{rs} \approx R_{rs}^{deep} \left[1 - e^{-\left[\frac{1}{\cos\theta_w} + \frac{D_u^C}{\cos\theta} \right] KH} \right] + R_b \, e^{-\left[\frac{1}{\cos\theta_w} + \frac{D_u^B}{\cos\theta} \right] KH}$$ [3]

Solar zenith angle

View angle from nadir

[3] Lee, Zhongping, et al. "Hyperspectral remote sensing for shallow waters: 2. Deriving bottom depths and water properties by optimization." *Applied Optics* 38.18 (1999): 3831-3843.

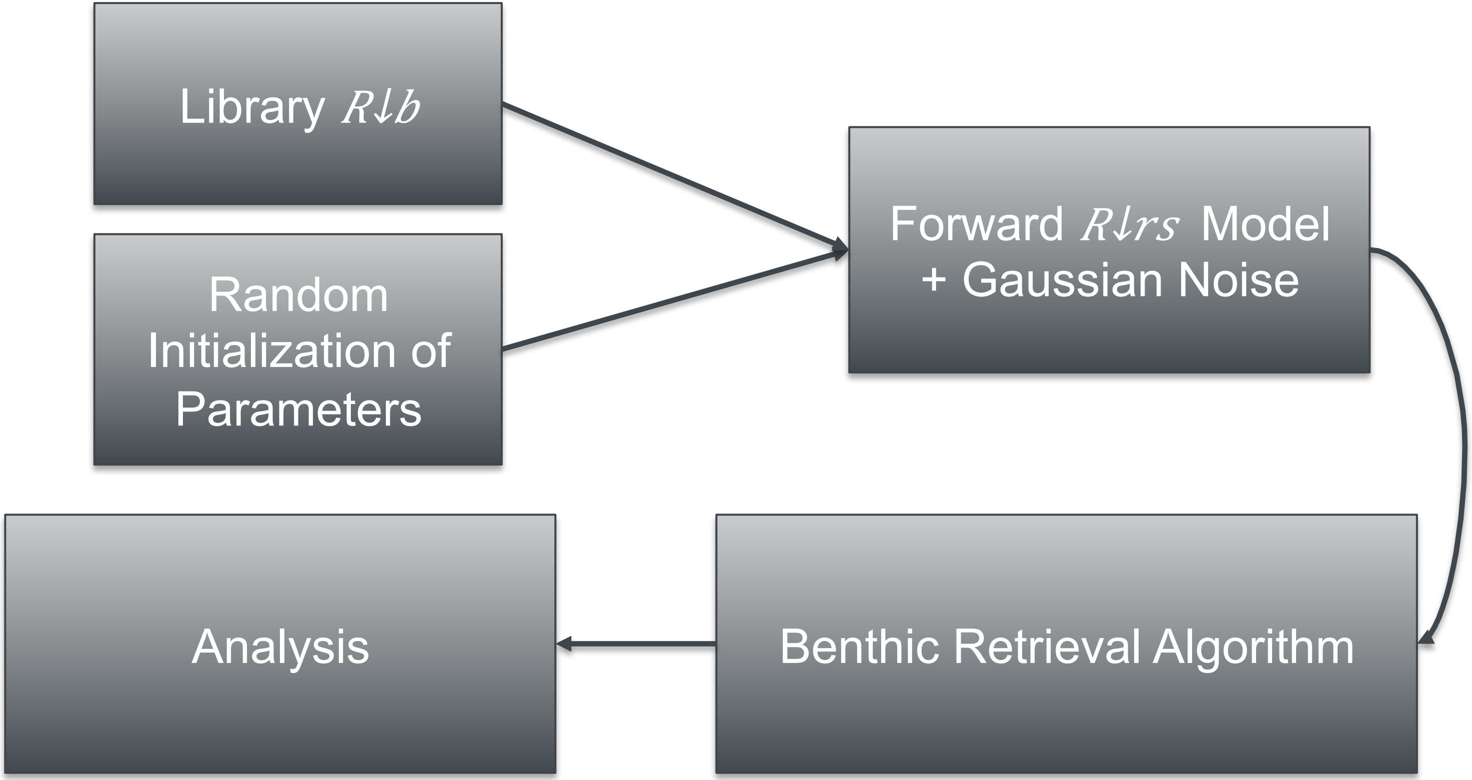
Retrieval Algorithm

Forward Model	Free Parameters
IOP	P G X H R_b^{coeff}
AOP	H b_b^{coeff} K_d^{coeff} R_b^{coeff}

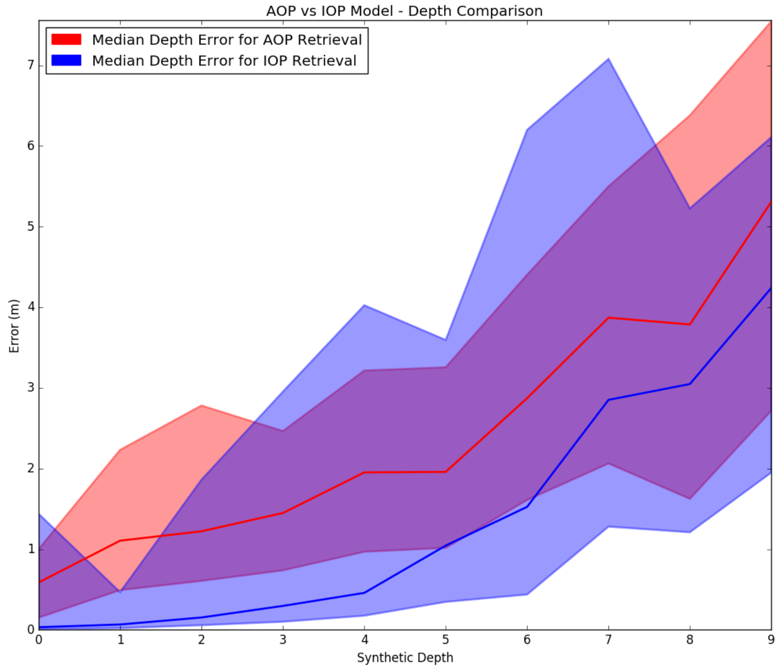
Free parameters are fit by optimizing the following objective function via the Levenberg-Marquardt Algorithm:

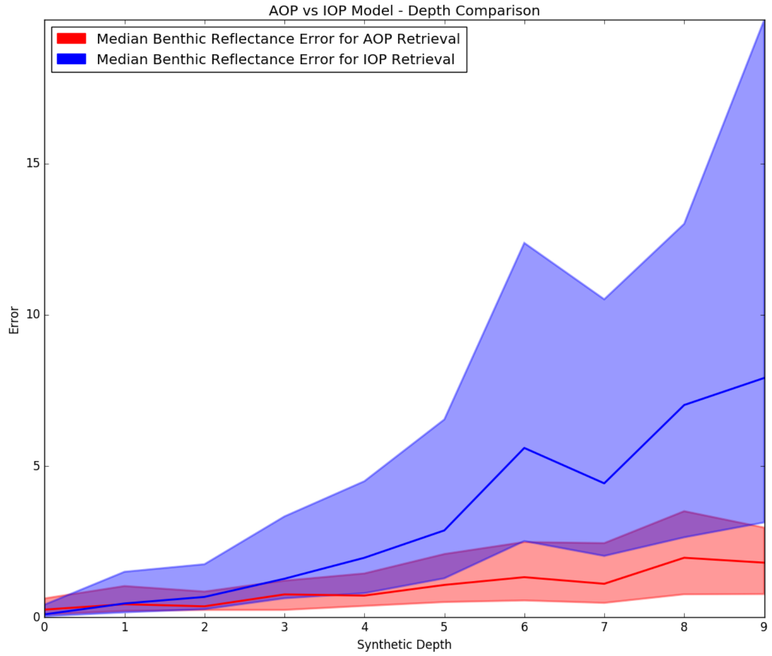
$$Error = (R_{rs} - R_{rs}^{*})^2 + Priors$$

Synthetic Experiments

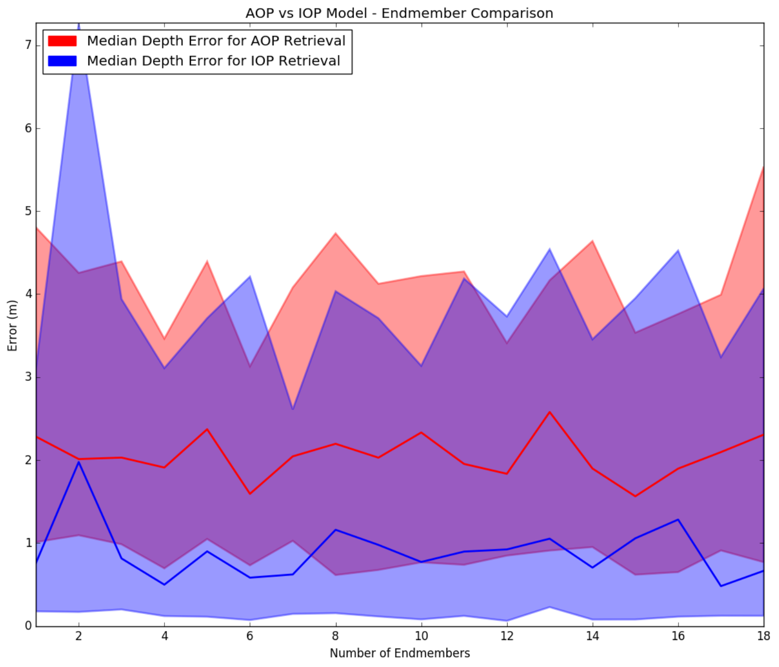


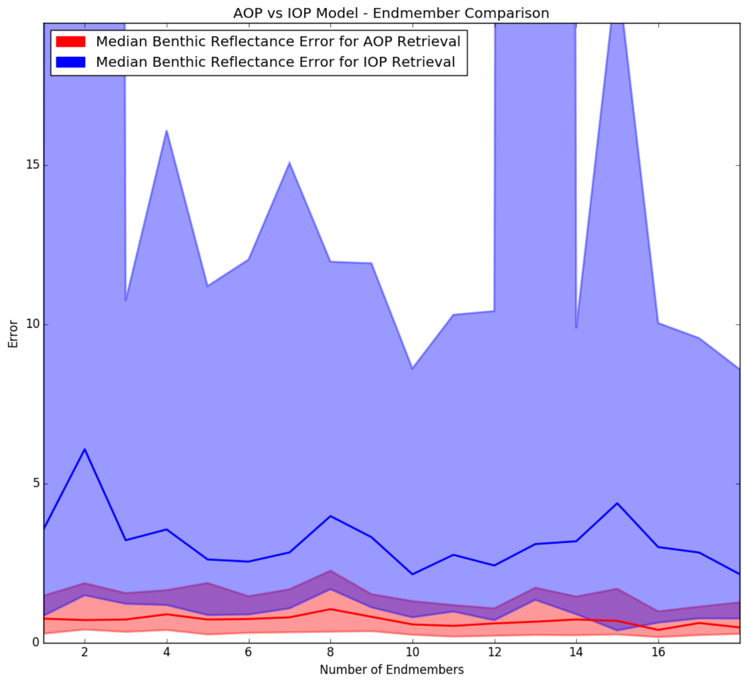
Synthetic Comparison – Depth





Synthetic Comparison – Endmembers





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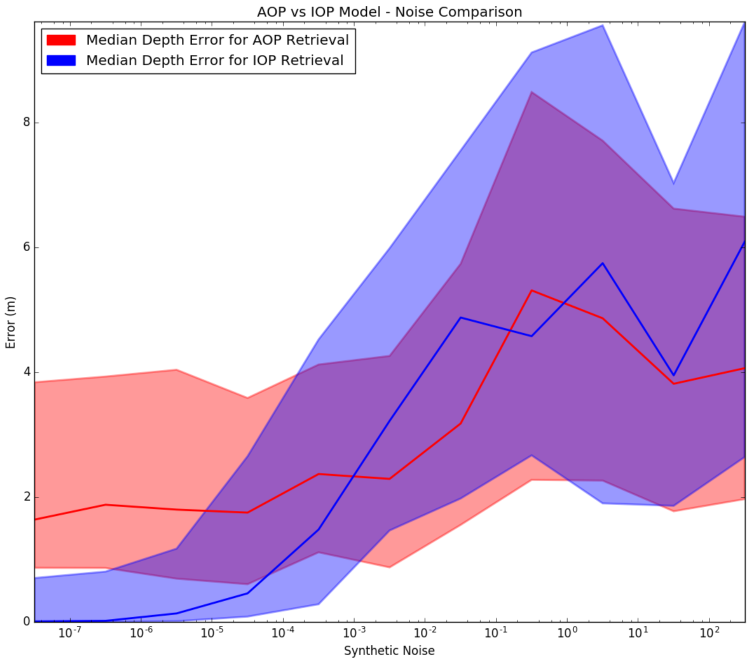
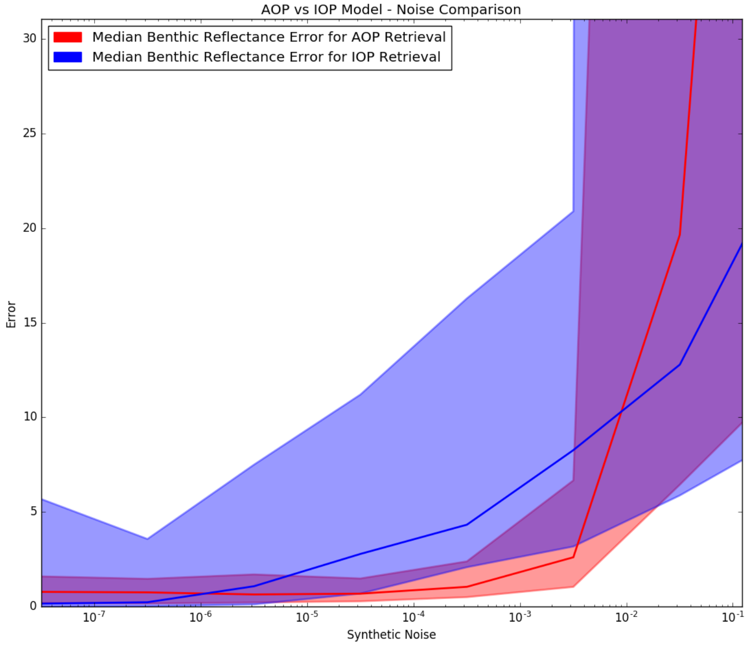
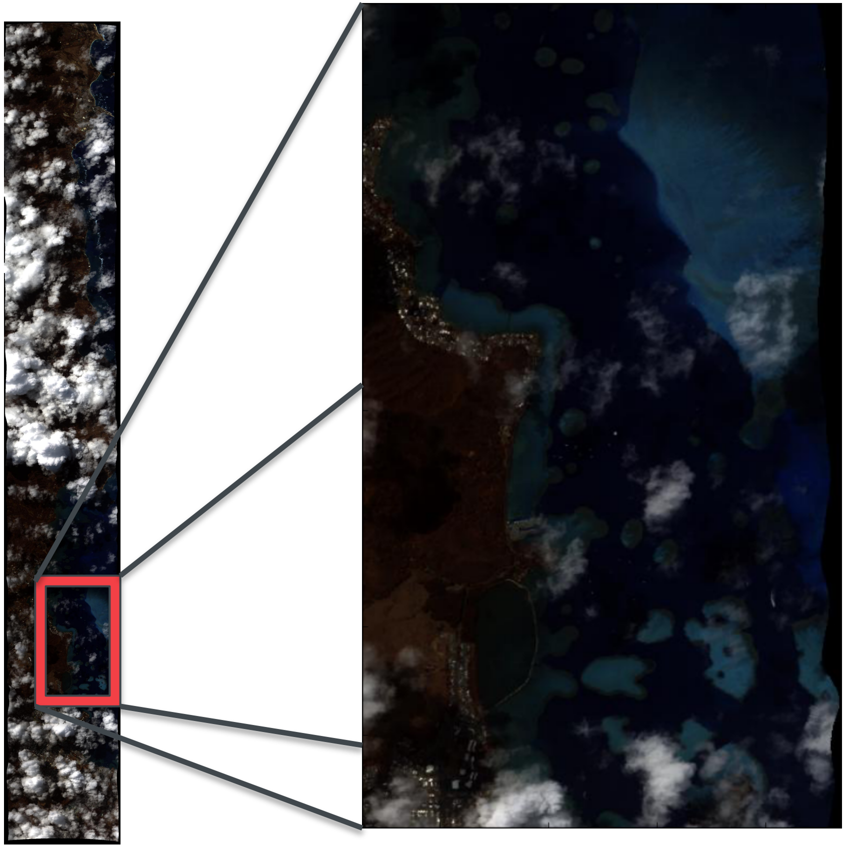
Synthetic Comparison – Noise



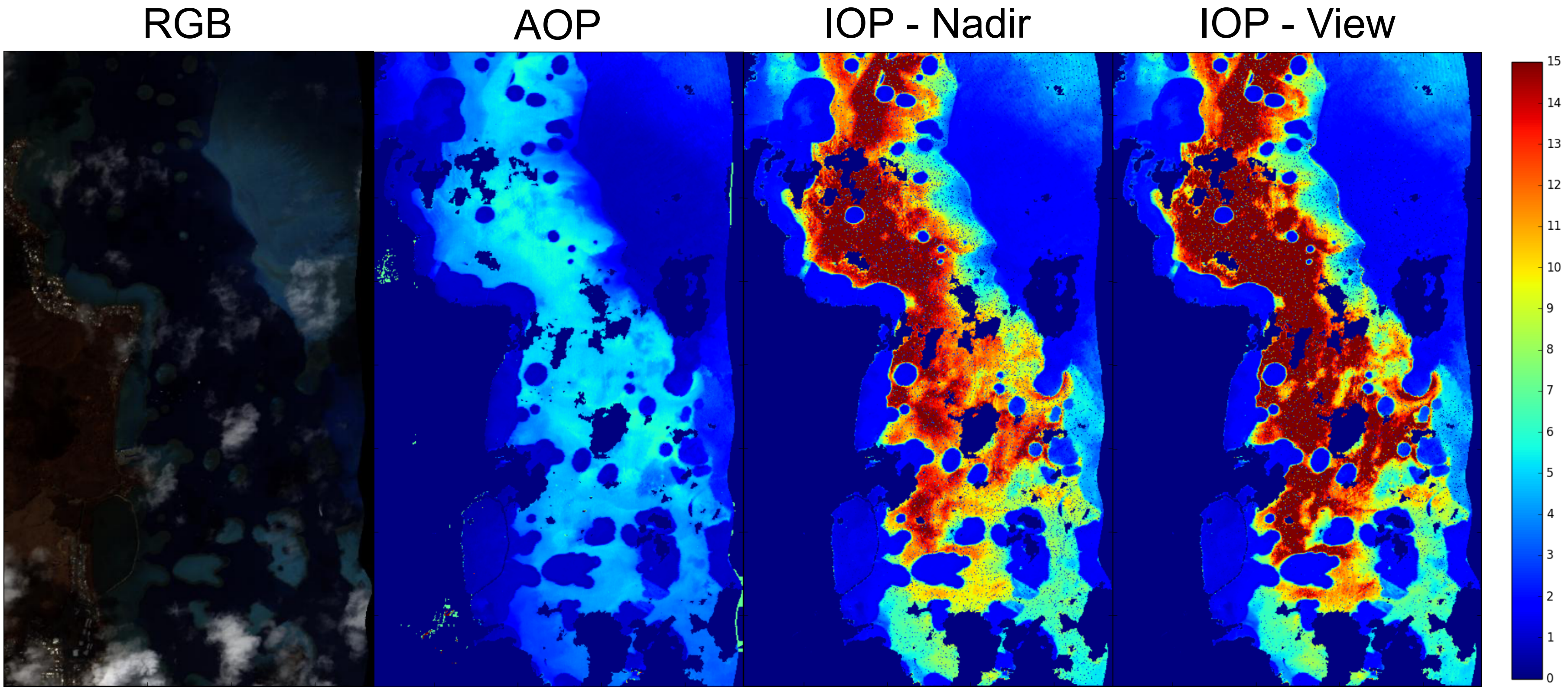


CORAL ORT Data – Kaneohe Bay, HI

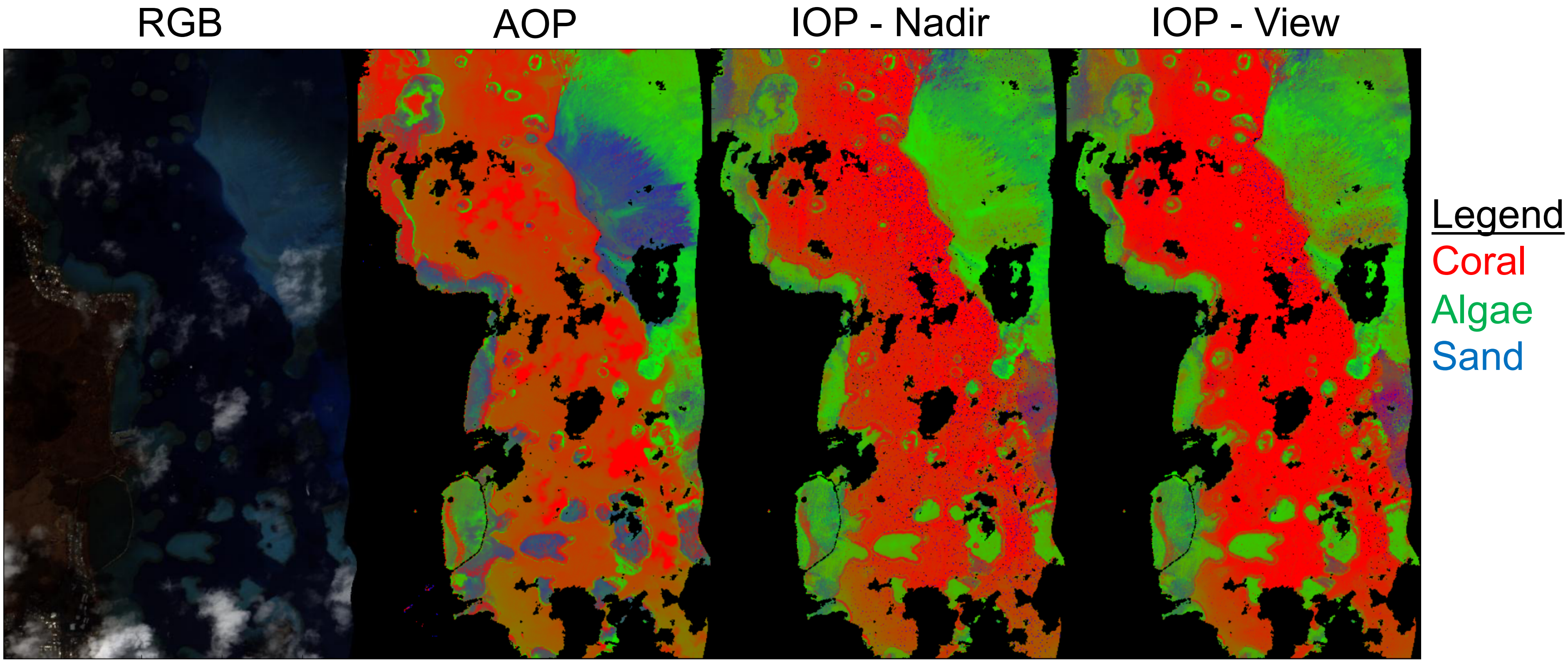
PRISM Flight:
prm20160620t
Run ID:
013600



June 20th Flight – Depth Estimation



June 20th Flight – R_b Estimation



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Appendix: IOP Model Formulation

$$R_{rs}^{deep} = g_w \frac{b_{bw}}{a+b_b} + g_p \frac{b_{bp}}{a+b_b}$$

$$g_p = G_0 \left[1 - G_1 e^{-G_2 \frac{b_{bp}}{a+b_b}}\right]$$

$$a = a_w + a_\phi + a_g$$

$$b_b = b_{bw} + b_{bp}$$

$$a_\phi = [a_0 + a_1 \ln(P)]P$$

$$a_g = G e^{-S(\lambda-440)}$$

$$b_{bp} = X\left(\frac{400}{\lambda}\right)^Y$$

$$Y = 3.44[1 - 3.17 e^{-2.01\chi}]$$

$$\chi = R_{rs}^{in}(440)/R_{rs}^{in}(490)$$

$$R_{rs}^{in}(\lambda) = R_{rs}^{raw}(\lambda) - R_{rs}^{raw}(750)$$

Assuming Nadir:

$g_w = 0.113$, $G_0 = 0.197$

$G_1 = 0.636$, $G_2 = 2.552$