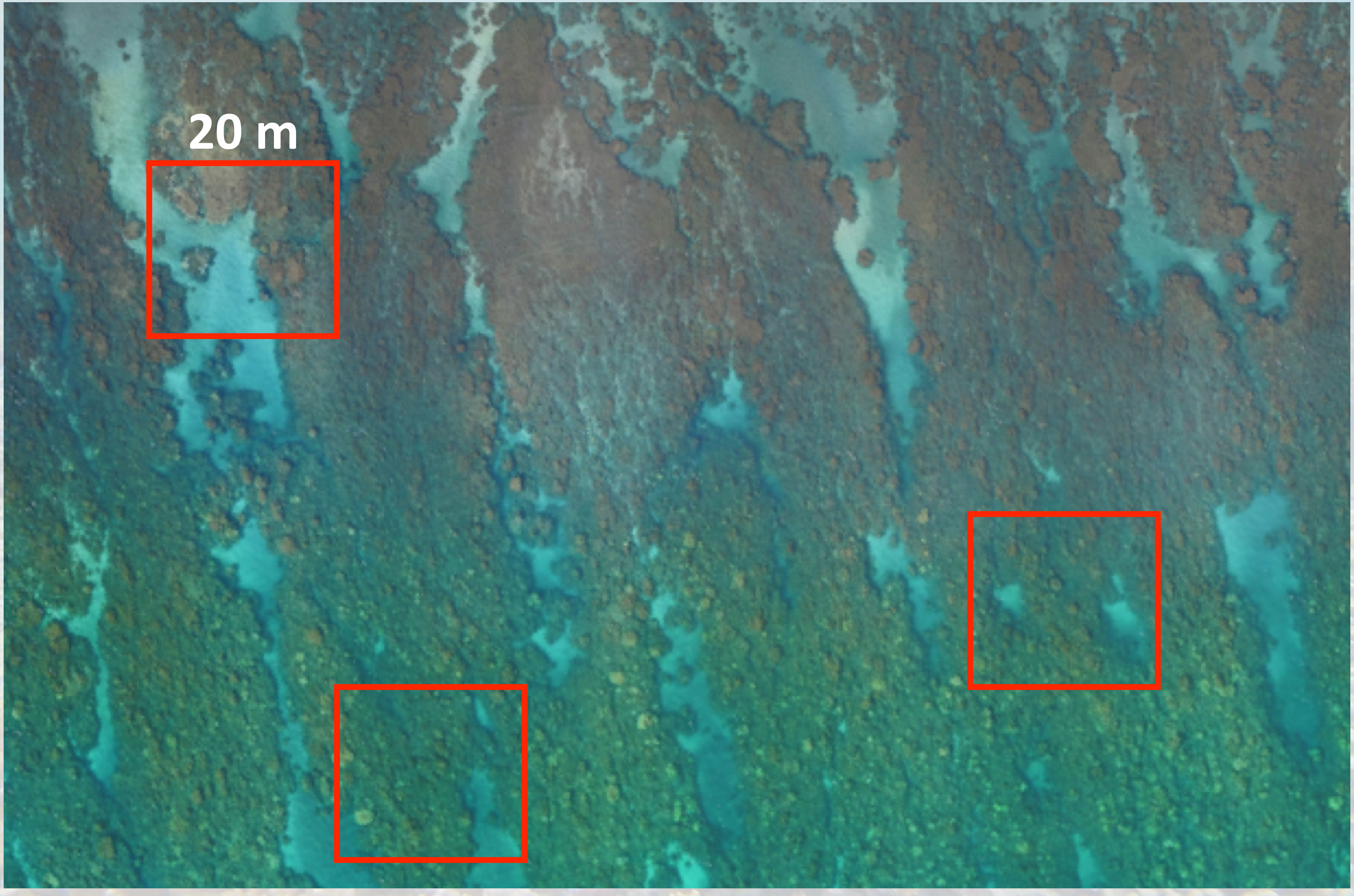
Using HyspIRI to Identify Benthic Composition in Shallow Coral Reef Ecosystems

Tom Bell

PIs: Kyle Cavanaugh & Greg Okin


20 m

Overarching Project Goals

Will the spectral characteristics of HyspIRI-like data allow for the accurate retrieval of reef benthic composition?

1. **Simulation analysis** to characterize the practical limits of discrimination of coral reef benthic composition.

2. **Validation** of benthic fractions from AVIRIS imagery using field observations.

Questions – Simulation Analysis

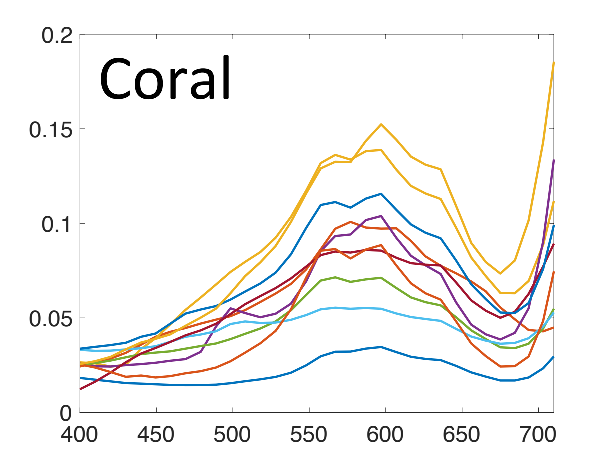
- Under what conditions can we expect good benthic discrimination – what are the no-go conditions?

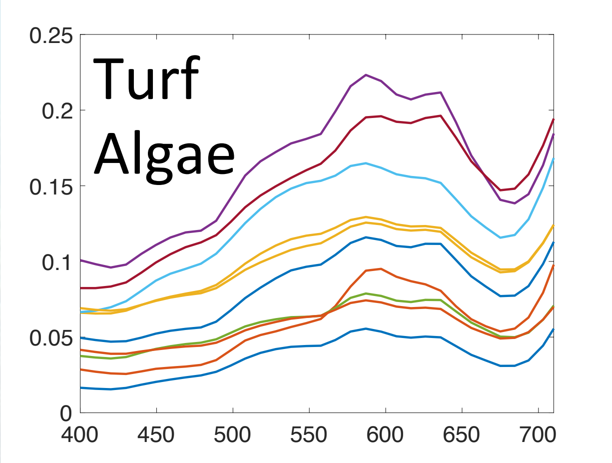
- Which benthic types are difficult to discriminate?

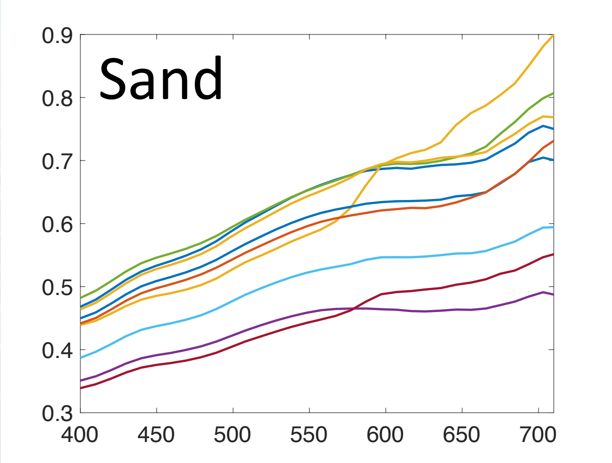
- What is the minimum fraction of live coral detectable under various water column conditions?

Answer these questions by examining errors related to unmixing, water conditions, inversion modeling, and atmospheric effects.

Multiple Endmember Spectral Mixing Analysis (MESMA)



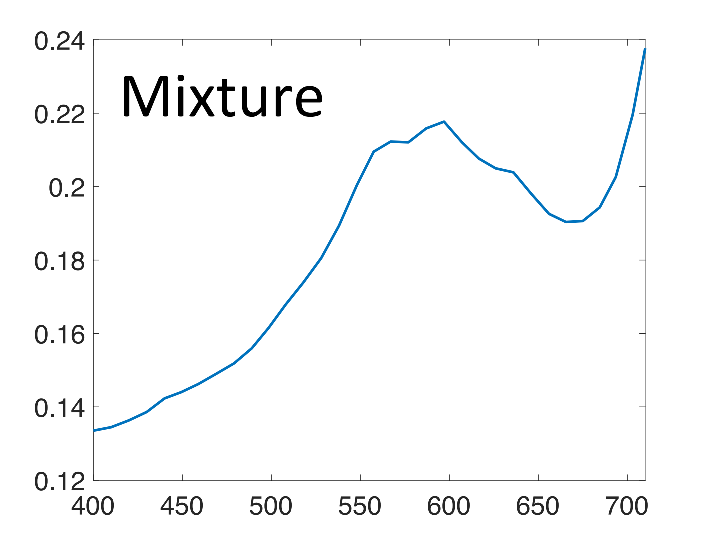




1/10 endmembers

1/10 endmembers

1/10 endmembers



Each Mixture Modelled w/
9^3 (729) Endmember
Combinations

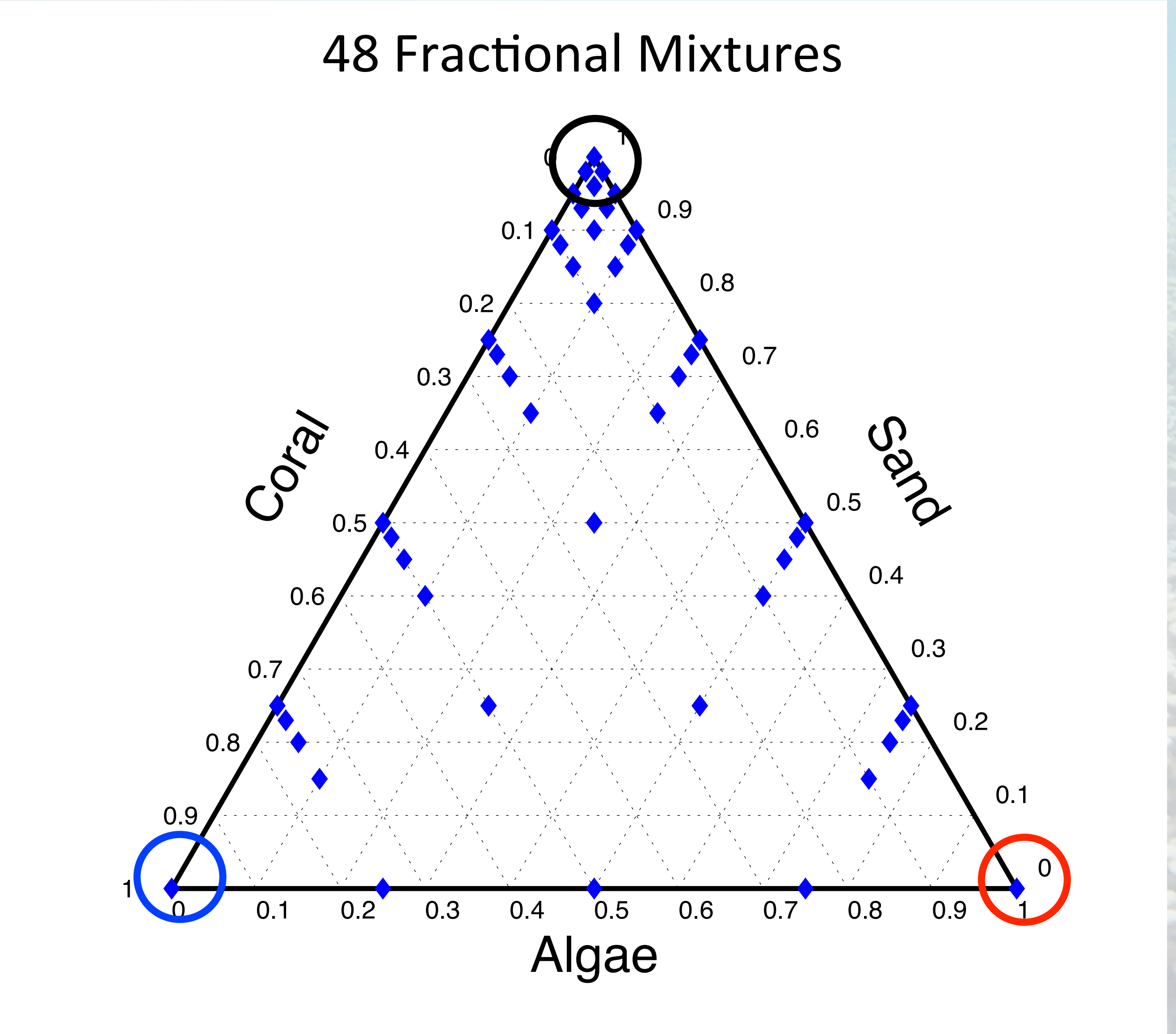
Mixtures including:

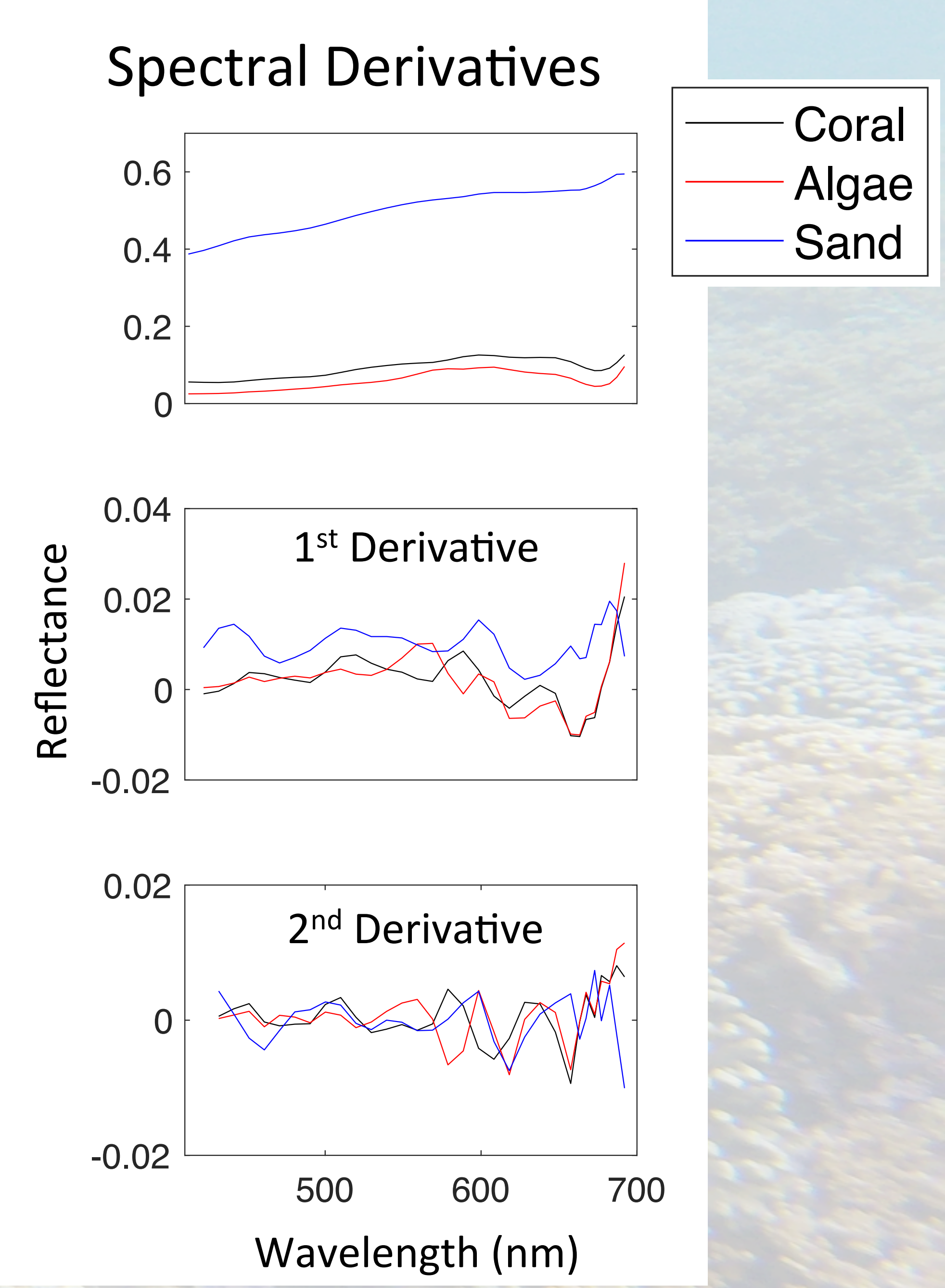
Live Coral

Sand

5 Algal Types

(Turf, Brown, Green, Red, CCA)


48 Fractional Mixtures
Coral
Sand
Algae
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

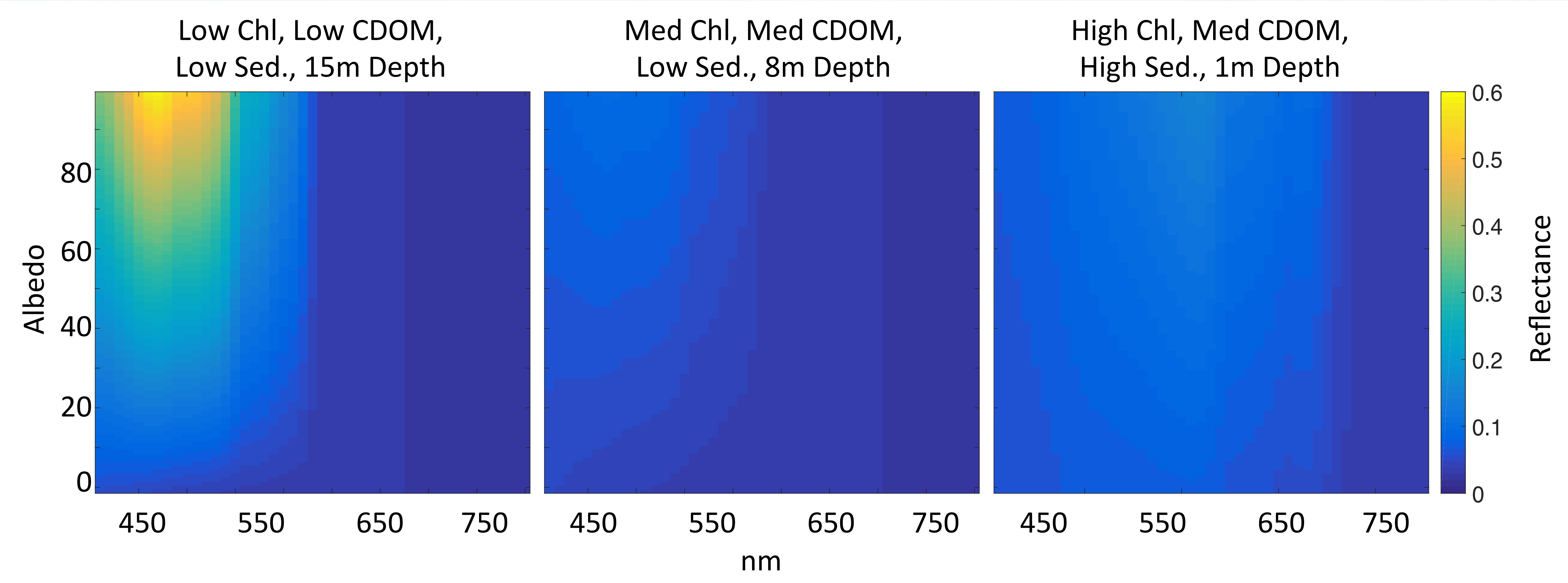

Spectral Derivatives
Coral
Algae
Sand
0.6
0.4
0.2
0
Reflectance
1st Derivative
0.04
0.02
0
-0.02
2nd Derivative
0.02
0
-0.02
500
600
700
Wavelength (nm)

Error Due to MESMA Unmixing

Spectral Mixtures → MESMA → Error

Changes in Reflectance Due to Water Properties

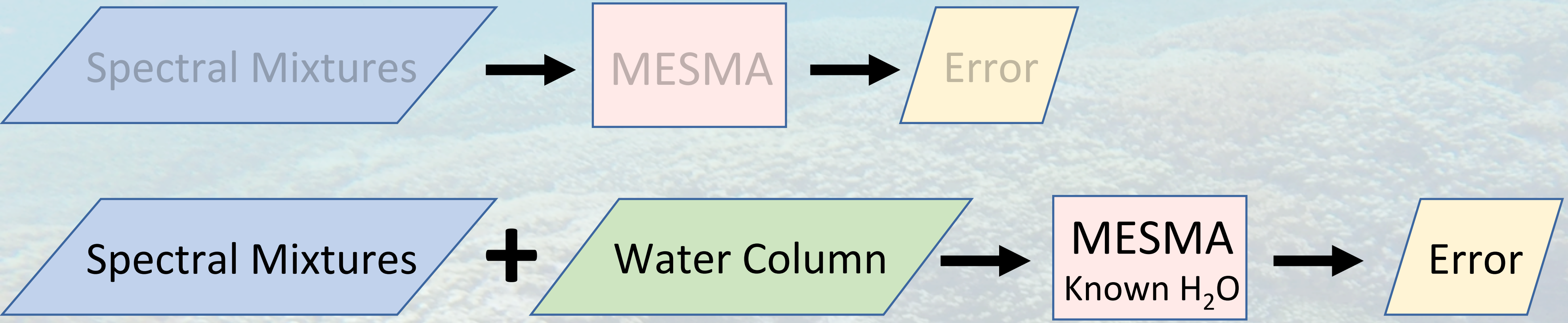
7000 Water Columns



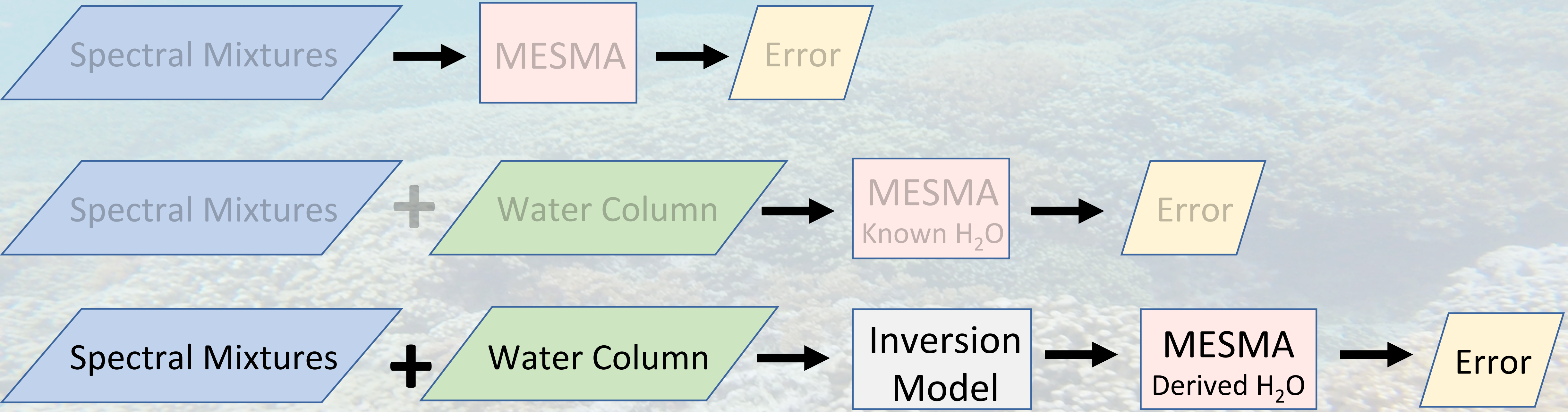
Realistic Range of Environmental Factors

Variable	Values for Simulation
Depth (m)	1, 2, 3, 5, 8, 10, 15
Wind Speed (m s^{-1})	0, 1, 2, 5, 10
CDOM (m^{-1})	0.01, 0.02, 0.05, 0.1, 0.5
Chlorophyll concentration (mg m^{-3})	0, 0.1, 0.25, 0.5, 1
Suspended carbonate sediment (g m^{-3})	0, 0.1, 0.2, 0.5, 1, 2, 5, 10

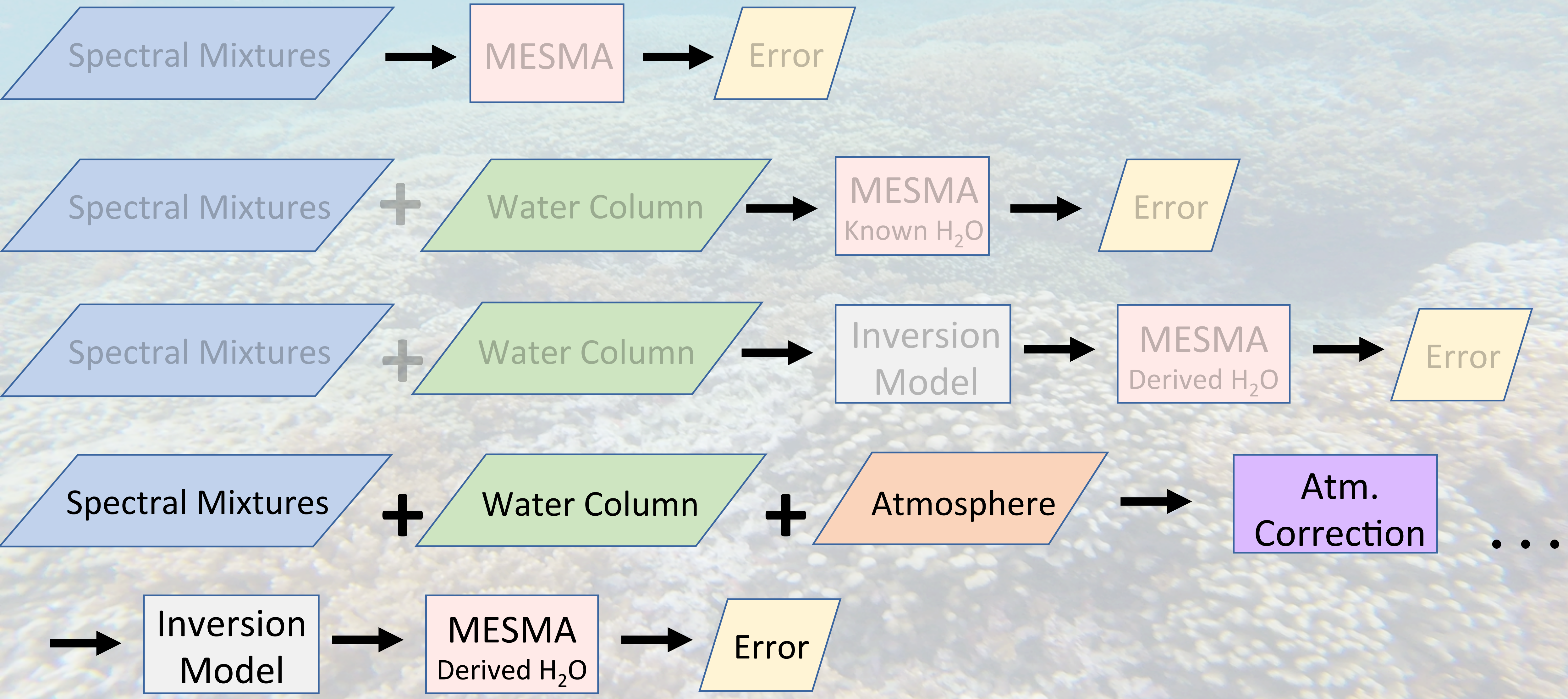
Error Due to Water Column



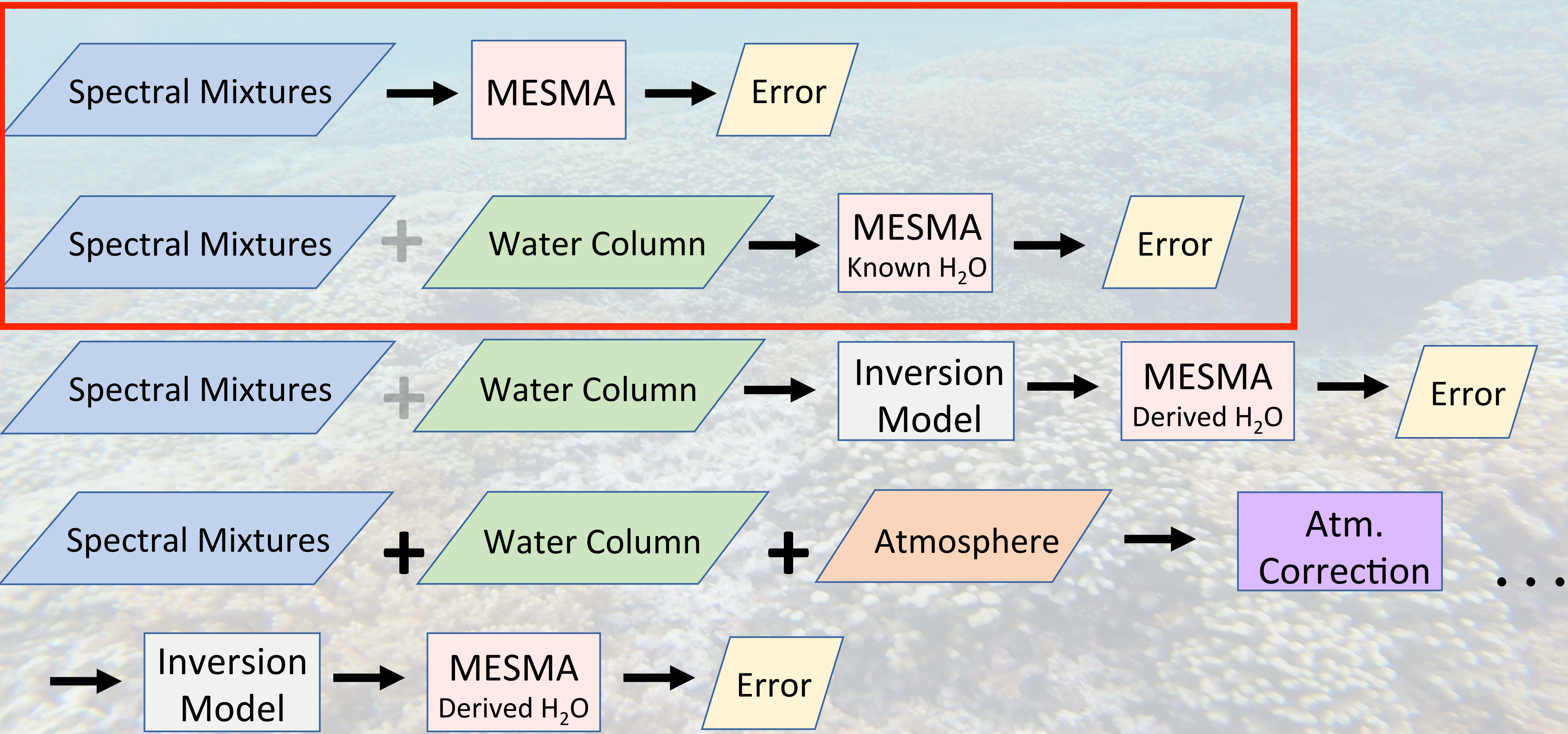
Error Due to Inversion Model



Error Due to Atmospheric Effects and Correction



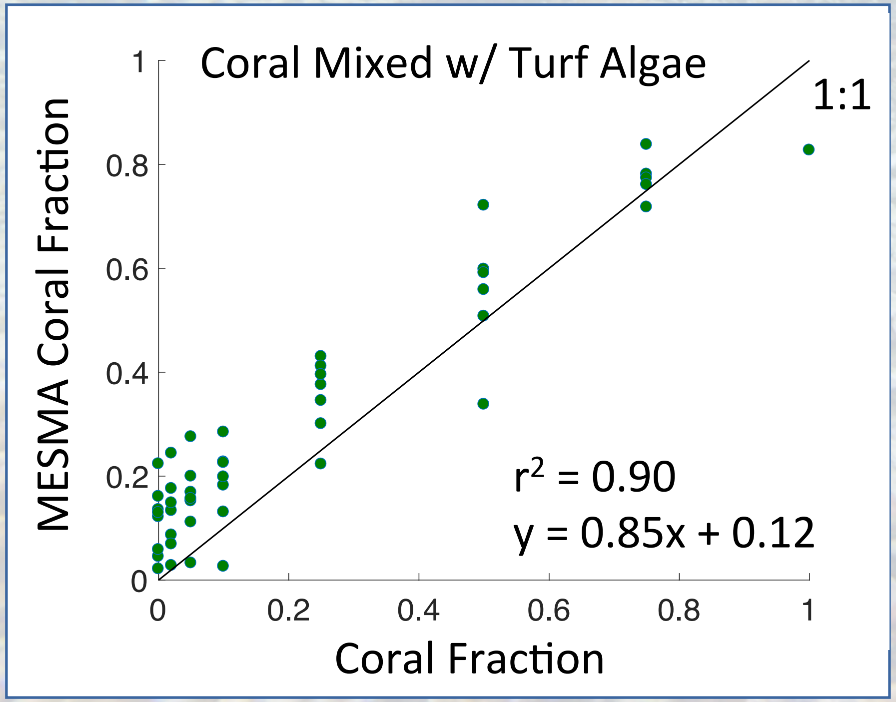
Error Due to Atmospheric Effects and Correction

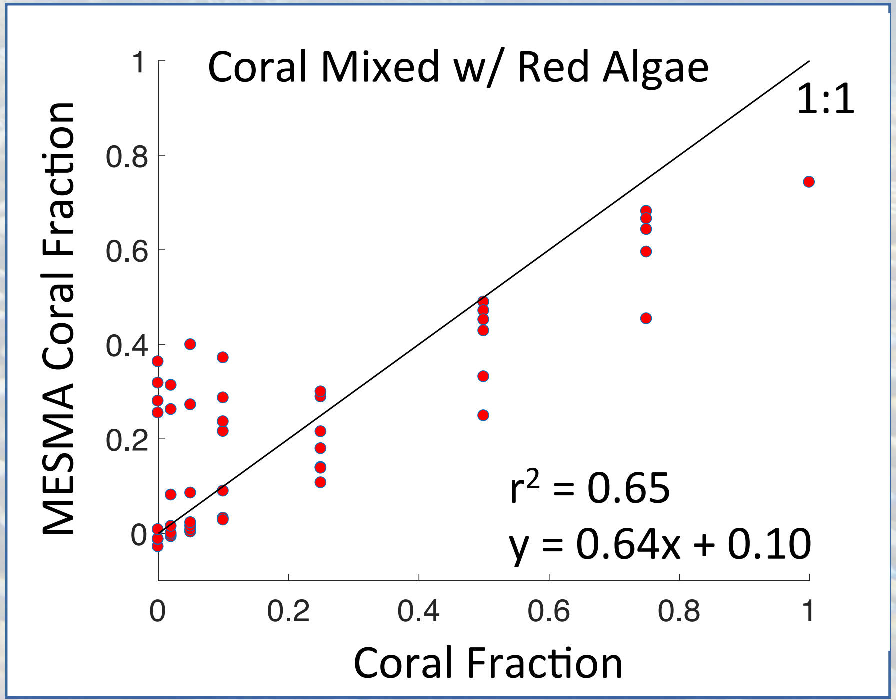


Results of MESMA/Derivatives

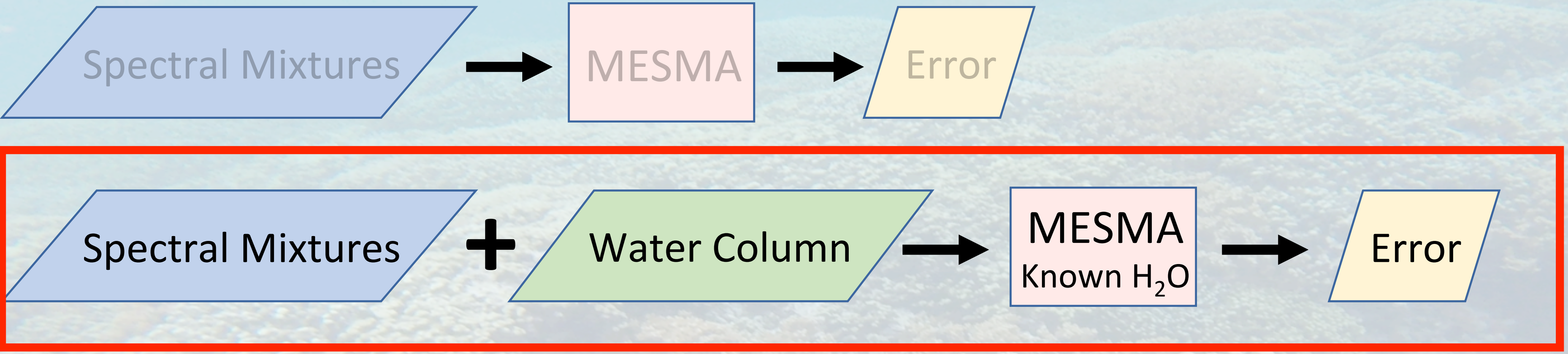
- Coral and algae are difficult to separate with MESMA, but not all algal types produce similar errors.

- Derivatives (1st & 2nd) of mixed spectra and endmembers produce better results.

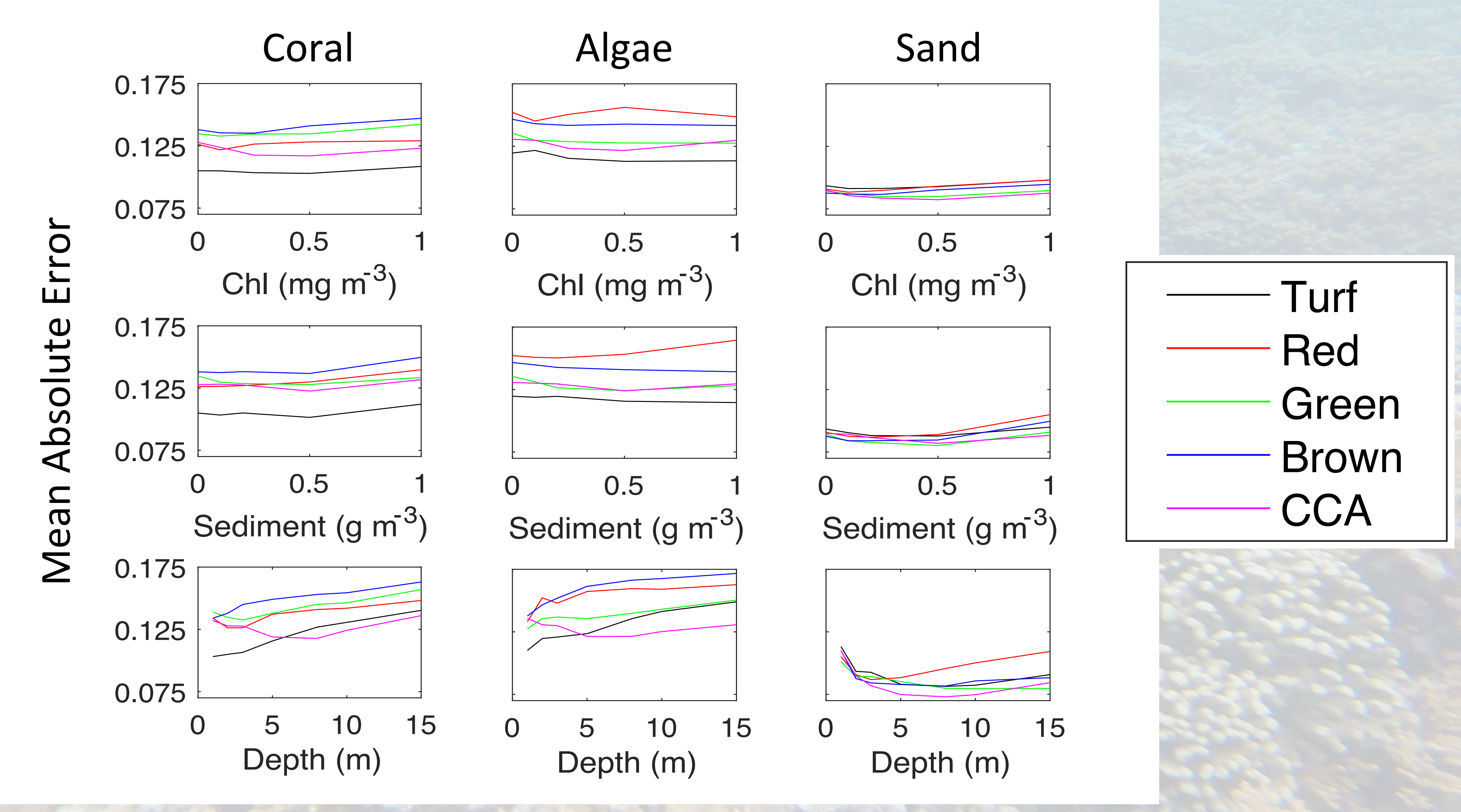




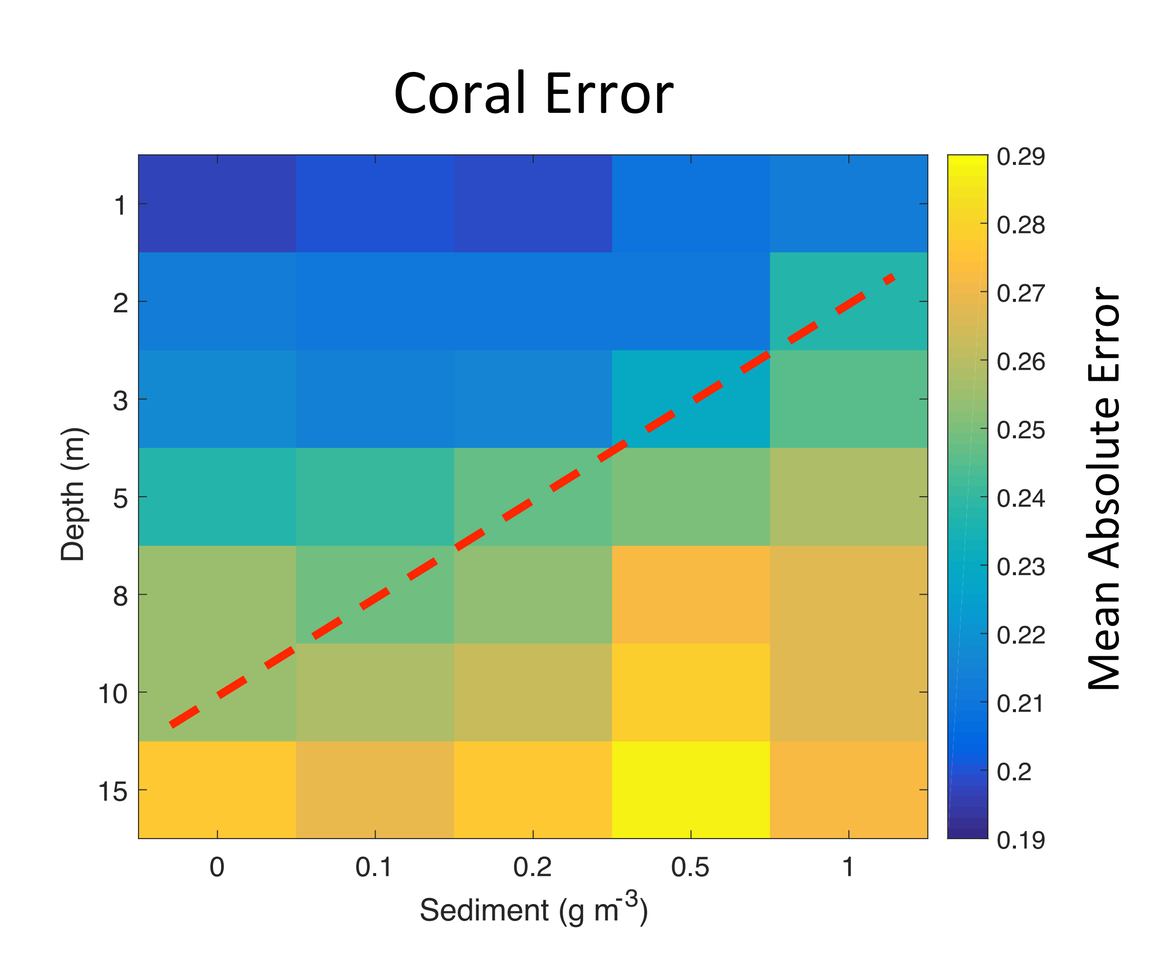
Error Due to Water Column

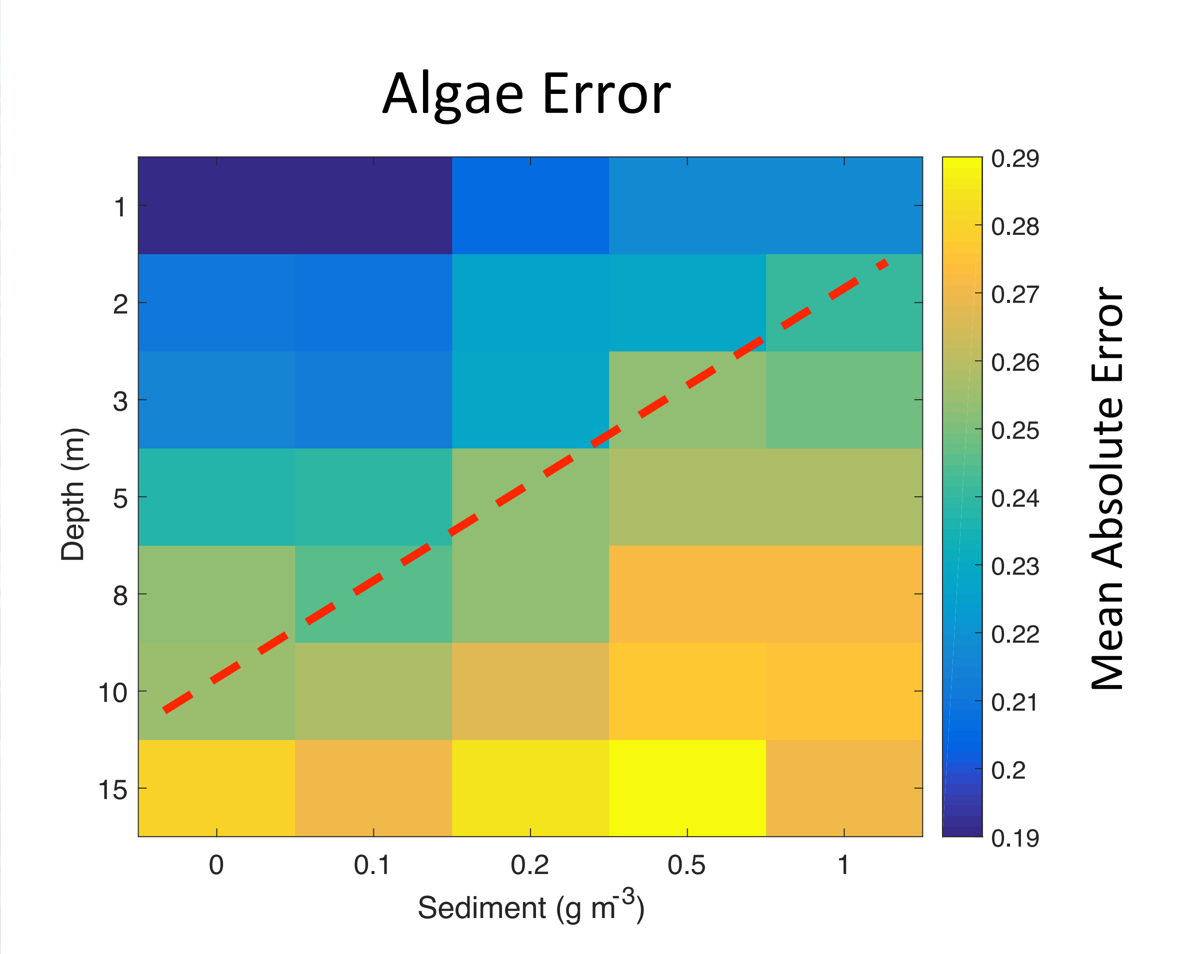


Effect of Water Constituents on Error

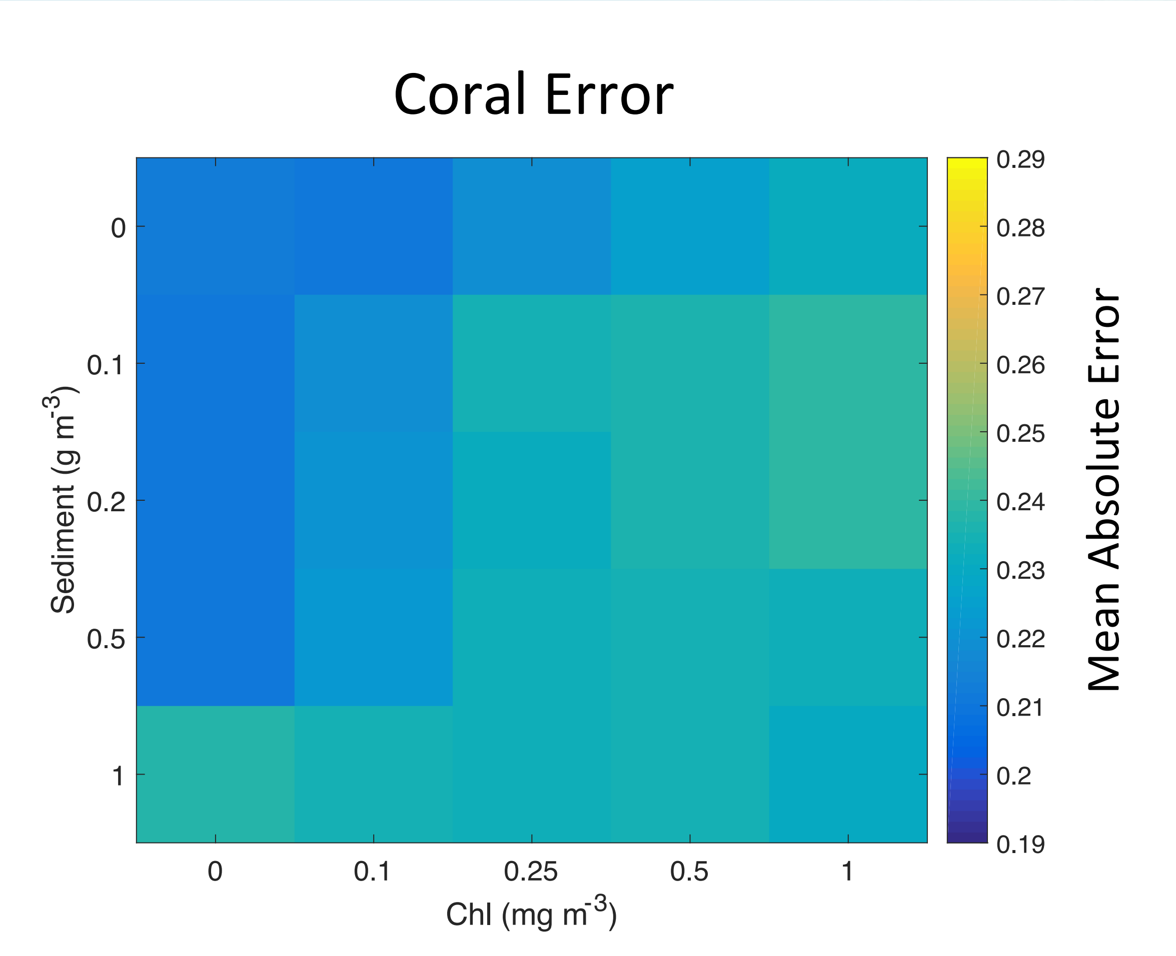


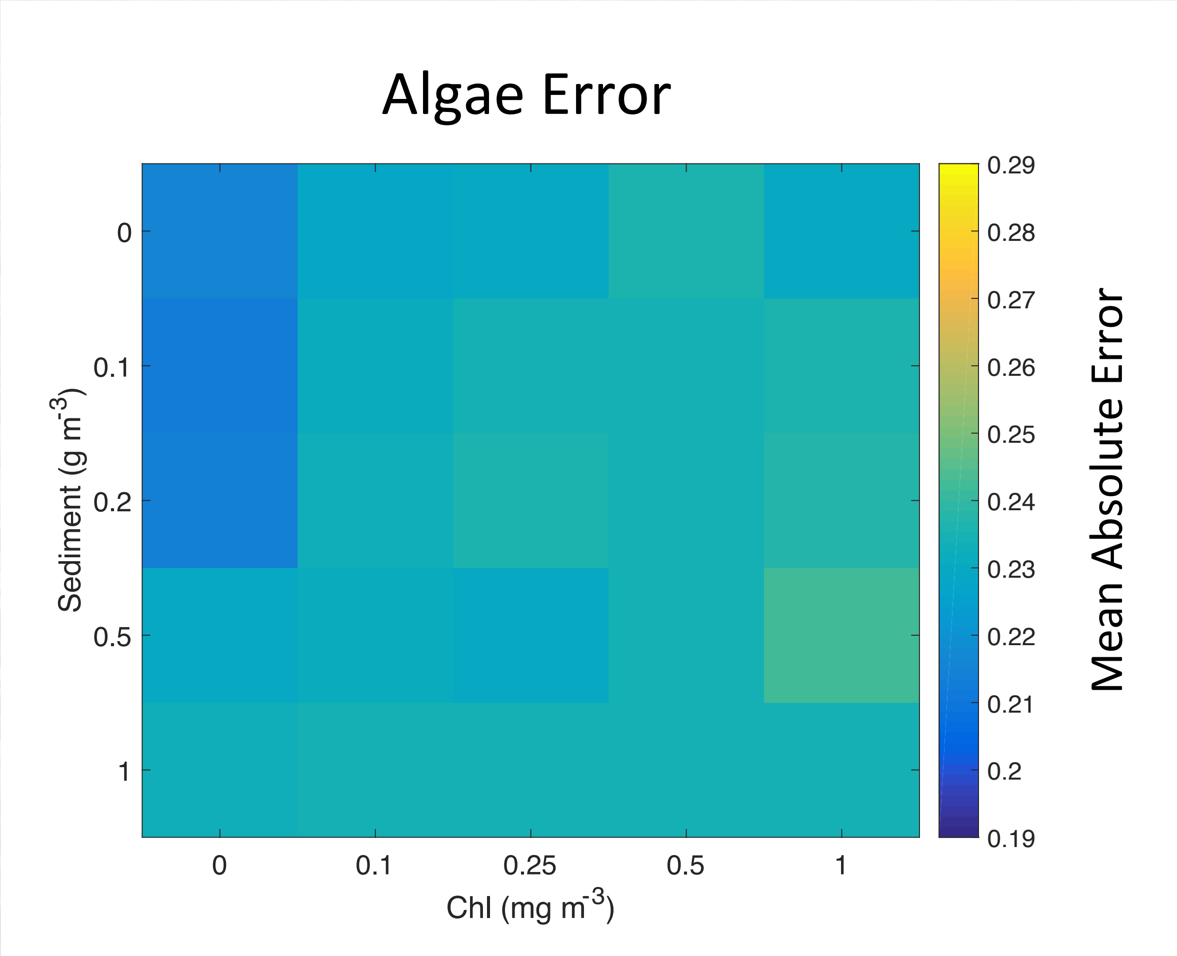
Effect of Sediment and Depth on Error



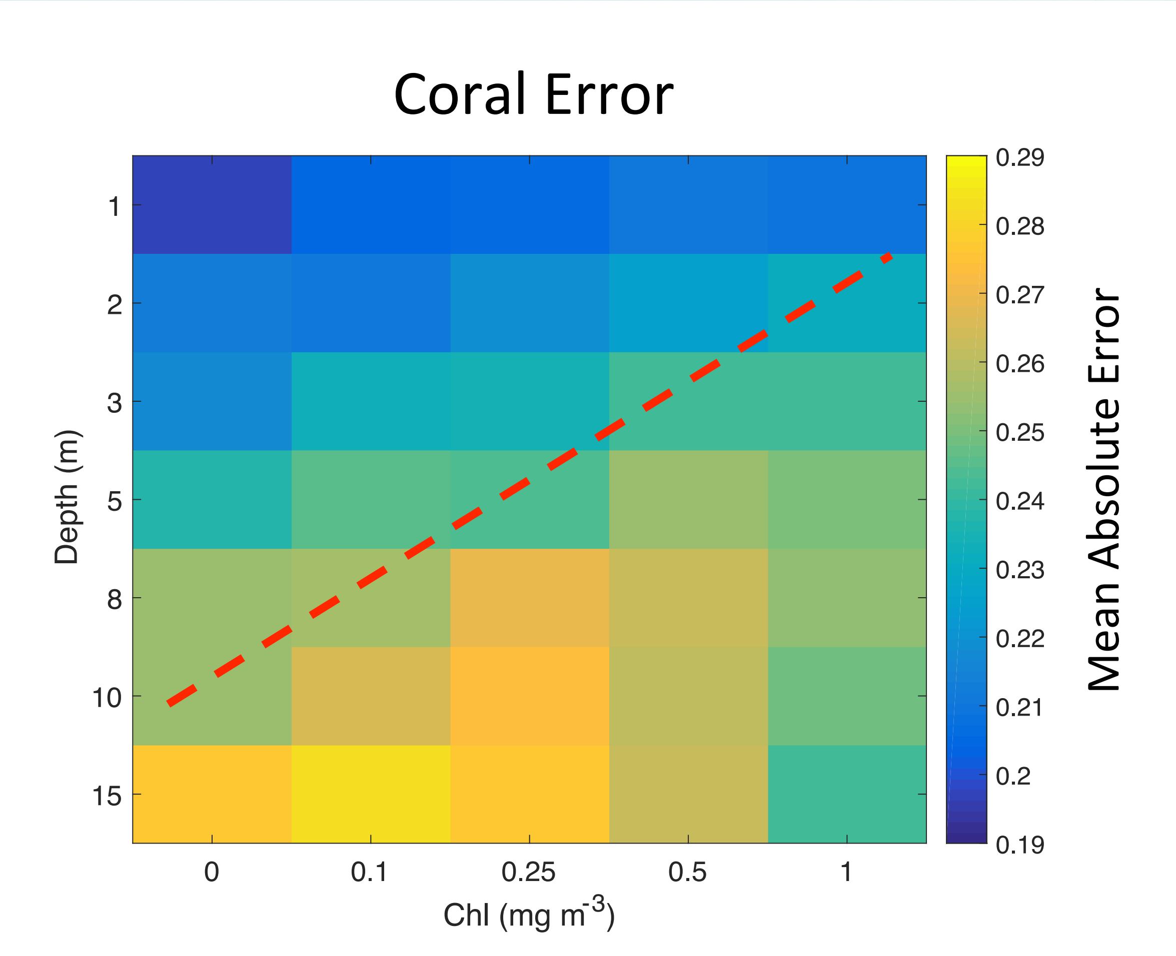


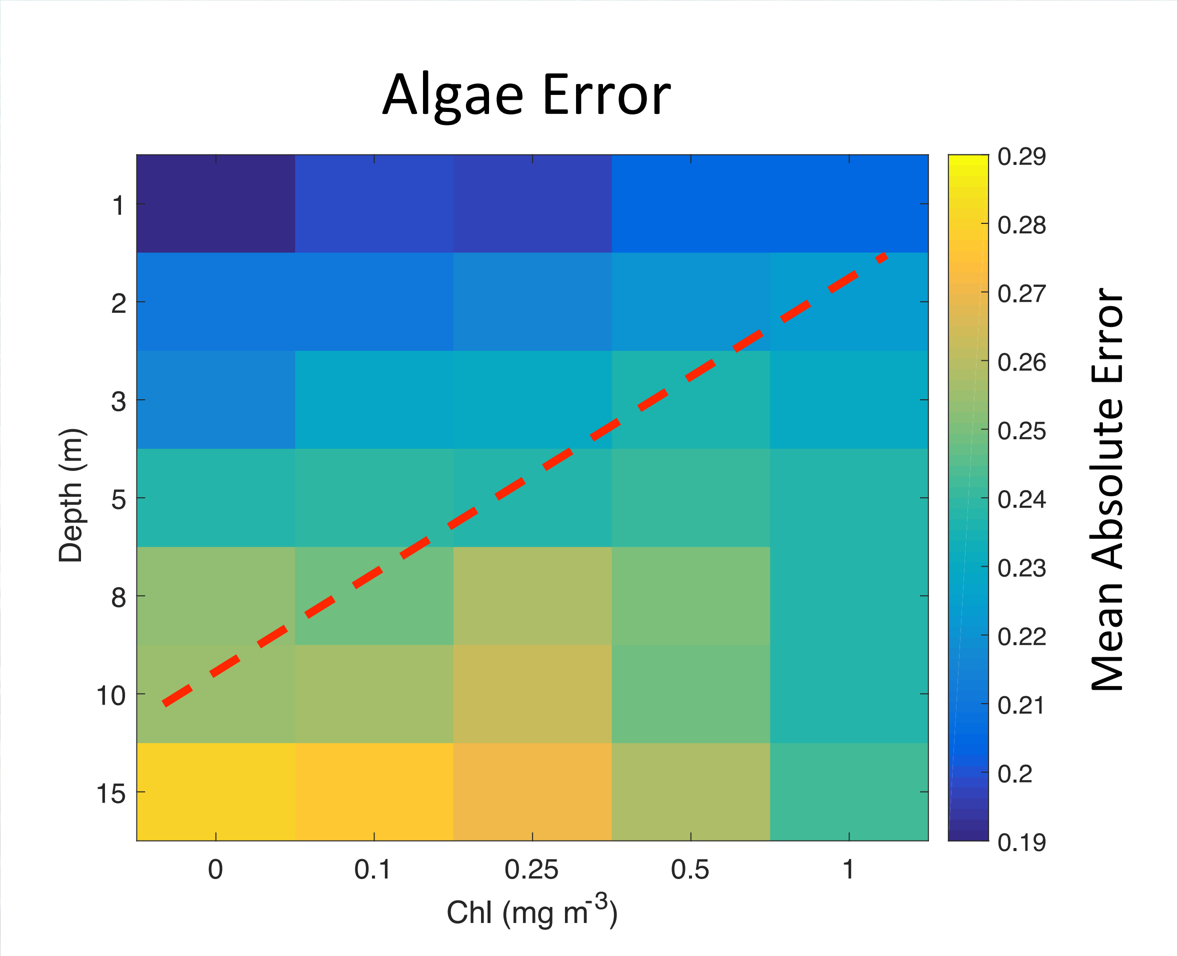
Effect of Chlorophyll and Sediment on Error



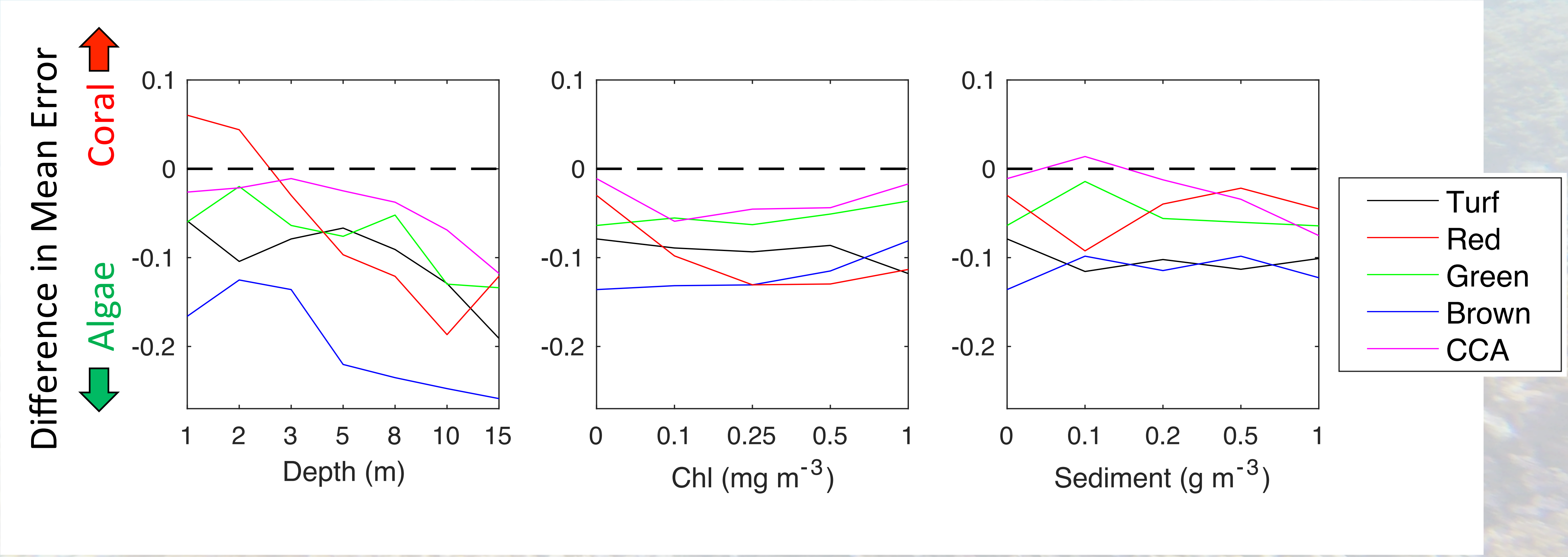


Effect of Chlorophyll and Depth on Error

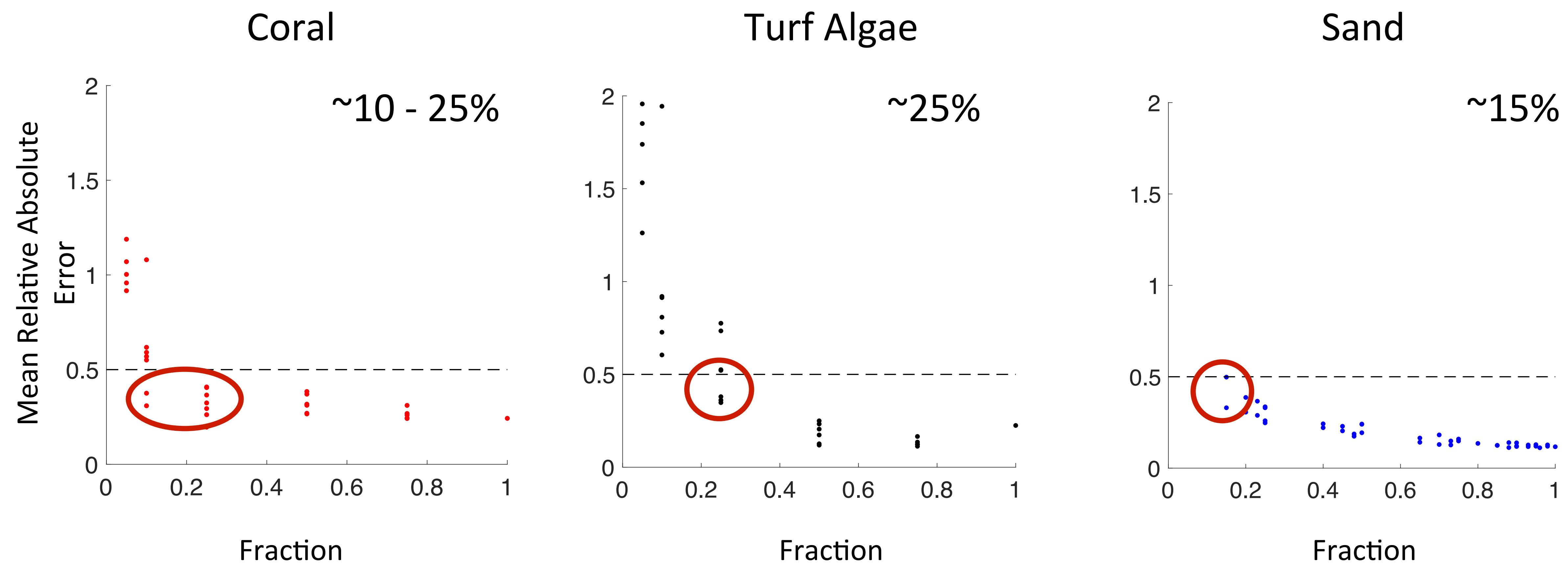




Confusion between Coral and Algal Types



Minimum Benthic Fraction Thresholds



Depth = 3 m, clear water

Conclusions so far…

- Deep water areas consistently have the most error, but this is modulated by suspended sediment and chlorophyll concentration. No go conditions will be dependent on the level of acceptable error.

- Coral cover is consistently confused as algal cover, and this effect increases with depth. Brown algae leads to the most confusion.

- At a relative absolute error level of 0.5, there will need to be around 25% of coral or algae fraction, and 15% sand fraction for acceptable discrimination.

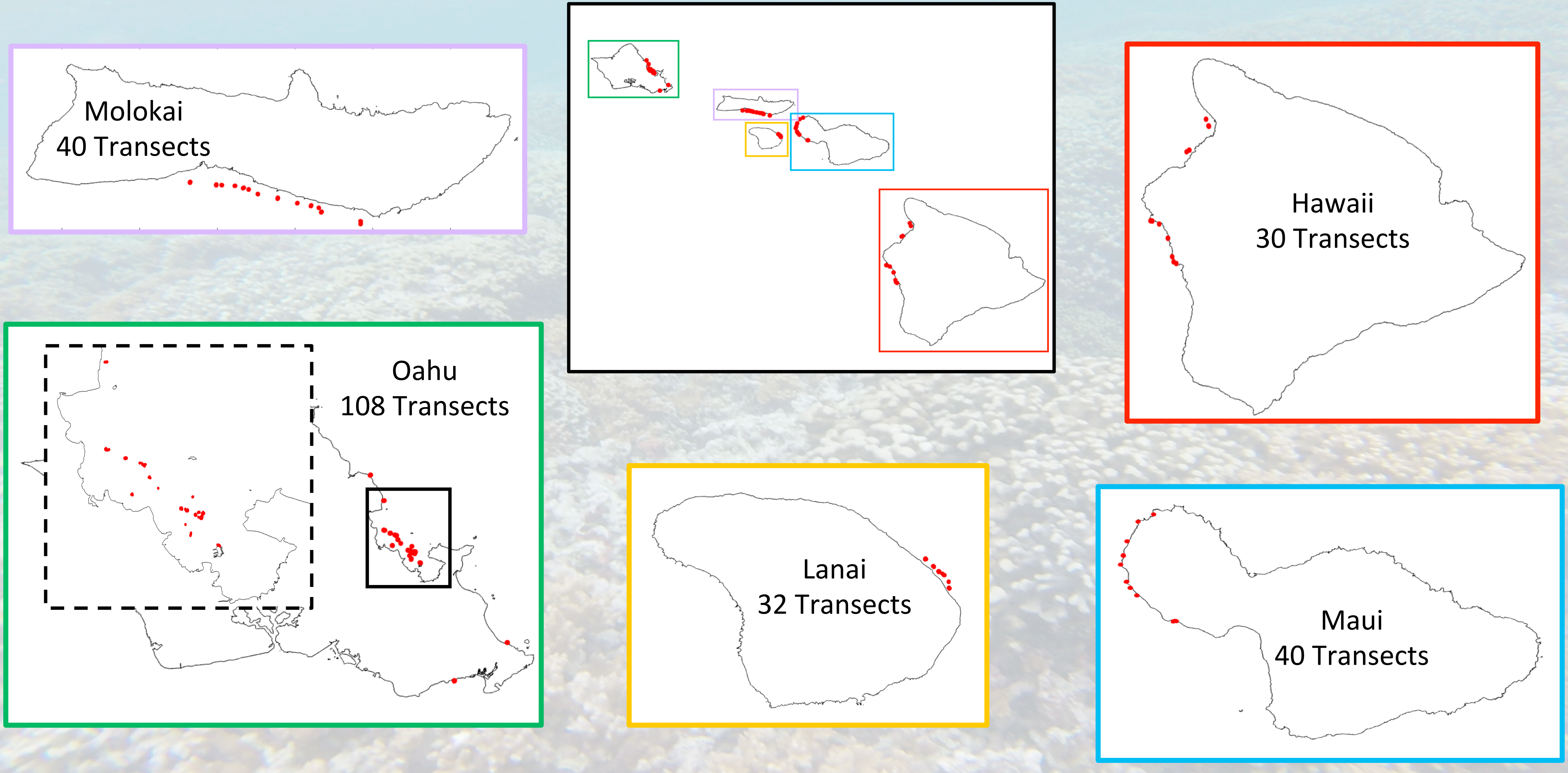
Ongoing work…

- Water column inversion & atmospheric effects will help refine no go conditions

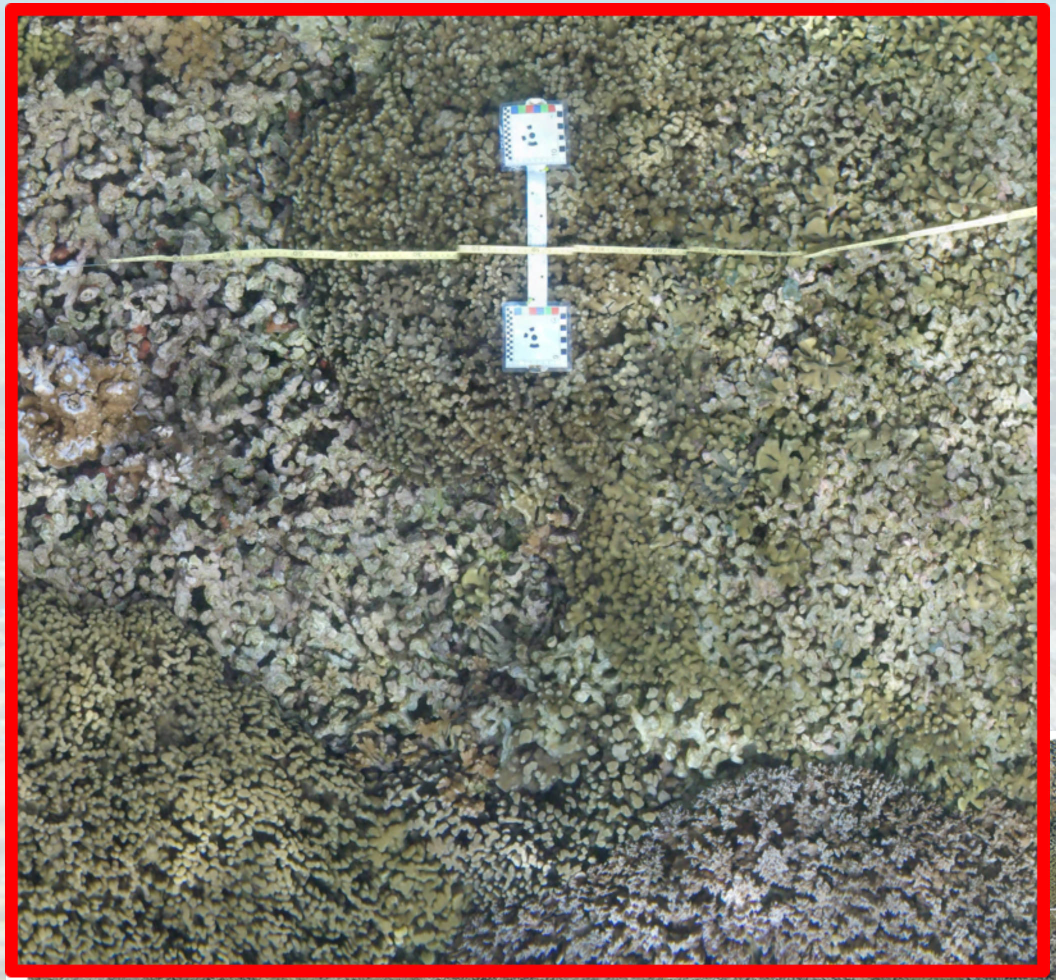
- Use MESMA to detect the correct **algal type** in a mixed pixel

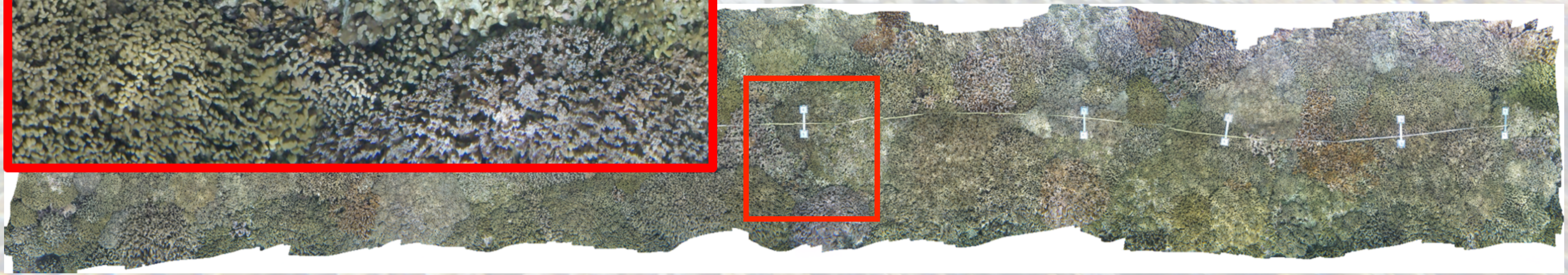
- Validation of optimized unmixing algorithm with in water photomosaics

250 Phototransects Across 5 Hawaiian Islands

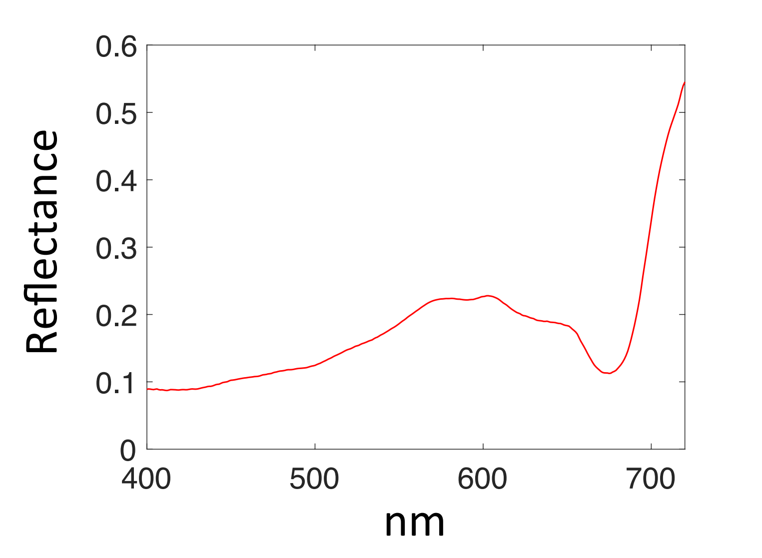


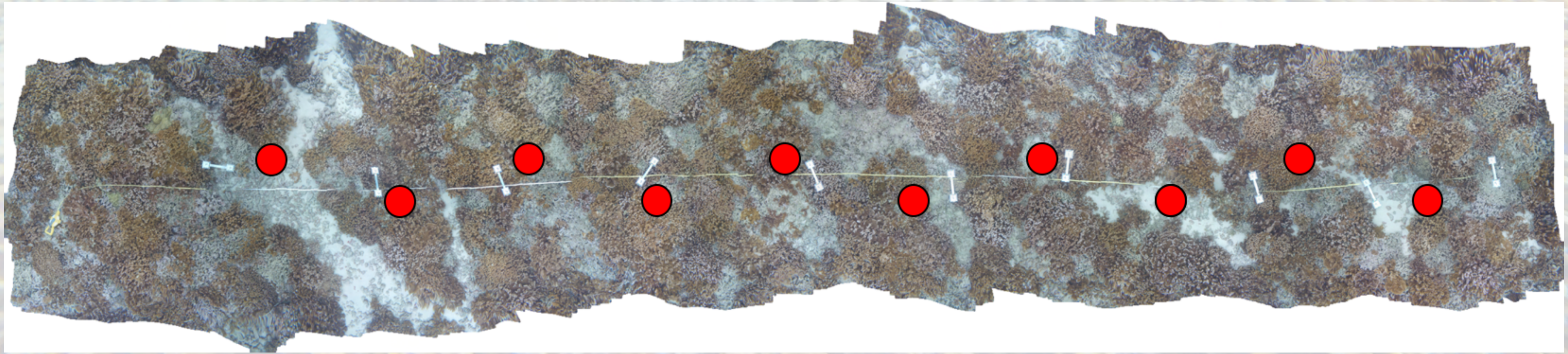
Phototransect Collection (250)



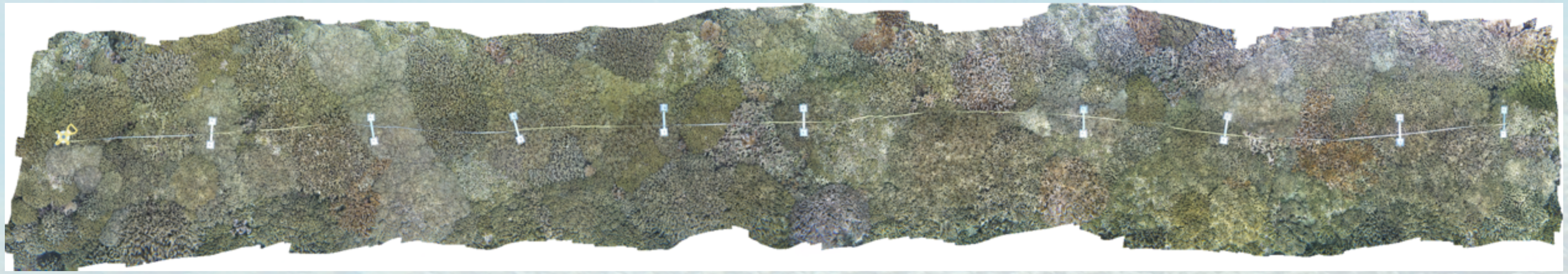


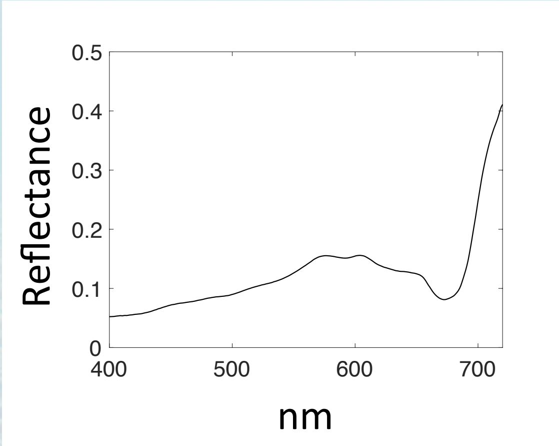
Spectral Transects (56/250)

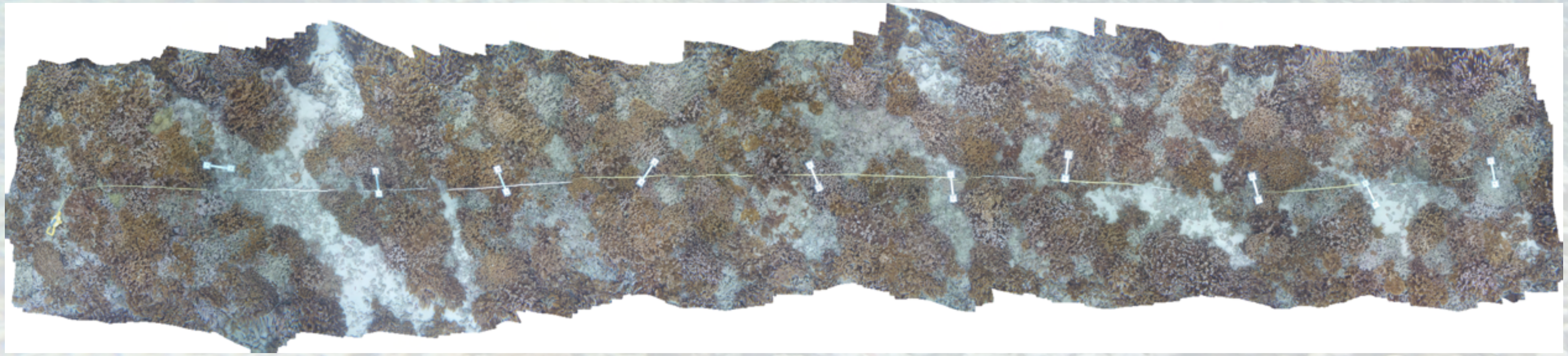


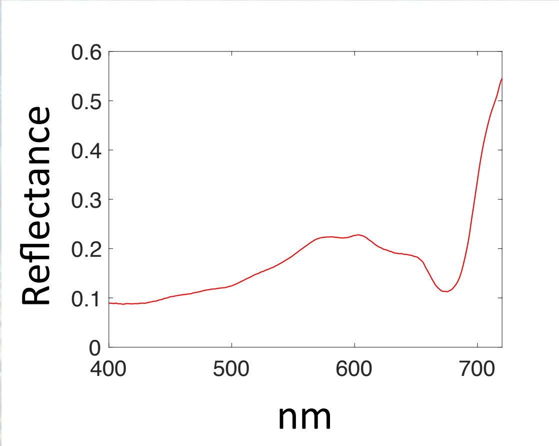


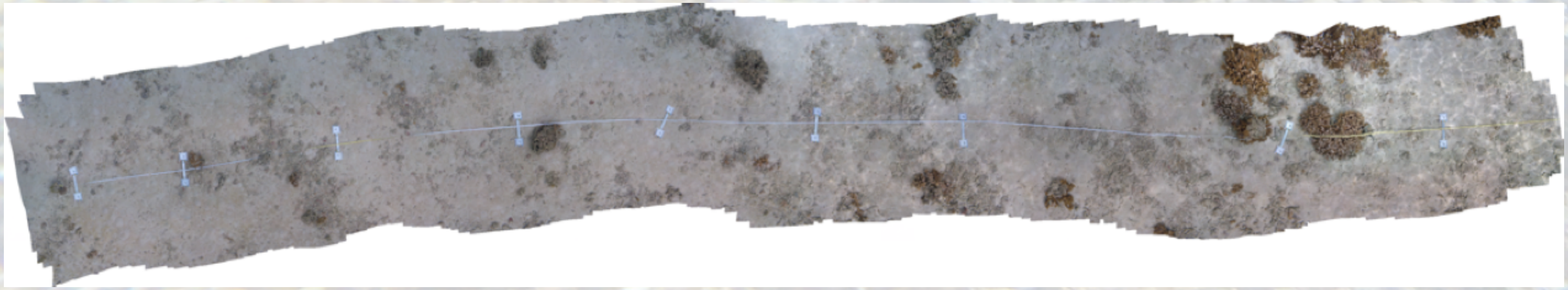
Phototransects w/ Spectra

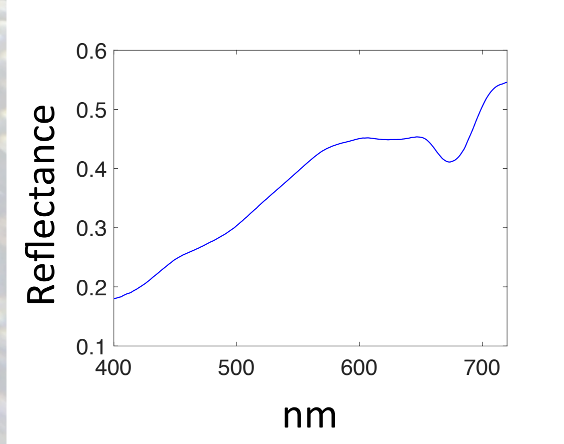












Questions?

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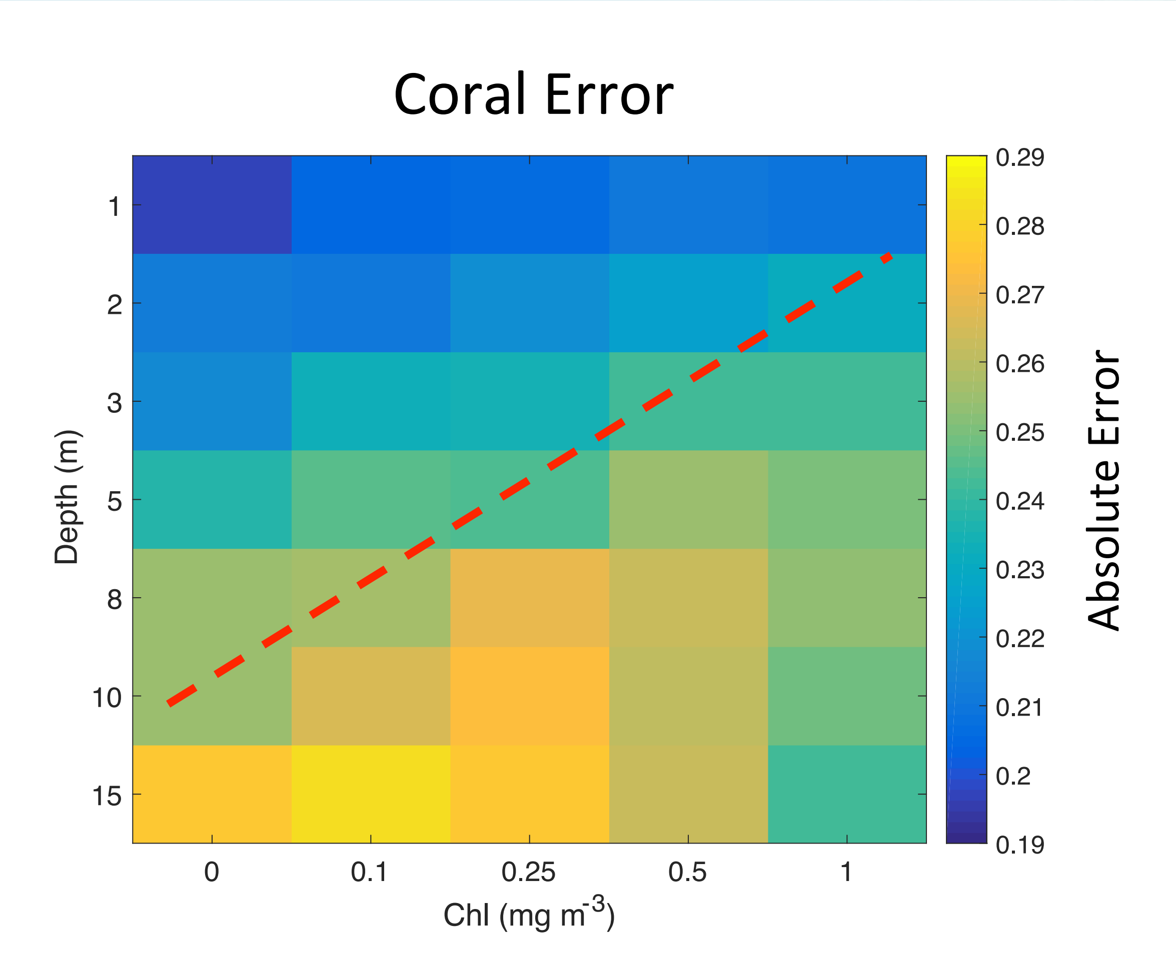
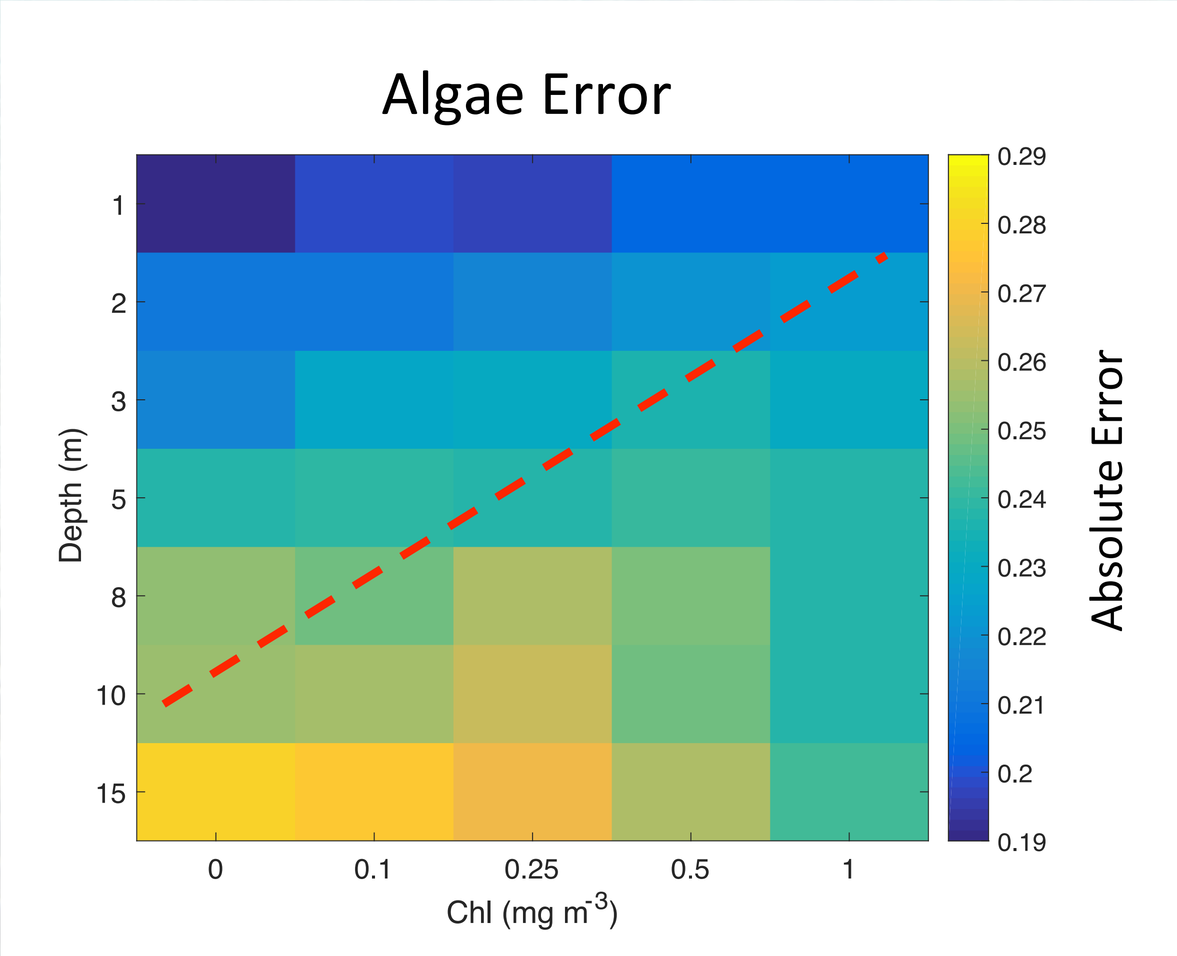
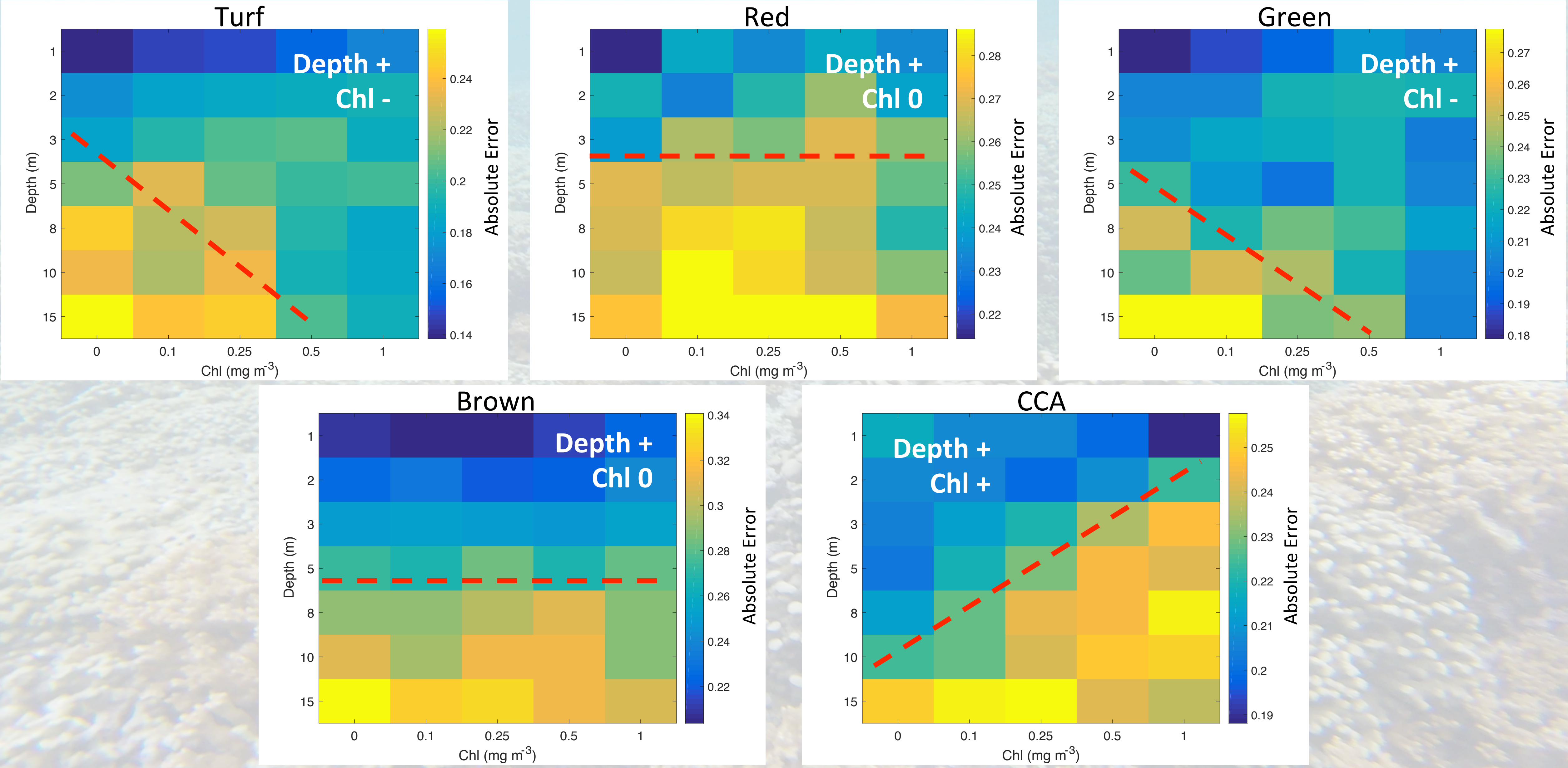
Effect of Chlorophyll and Depth on Error

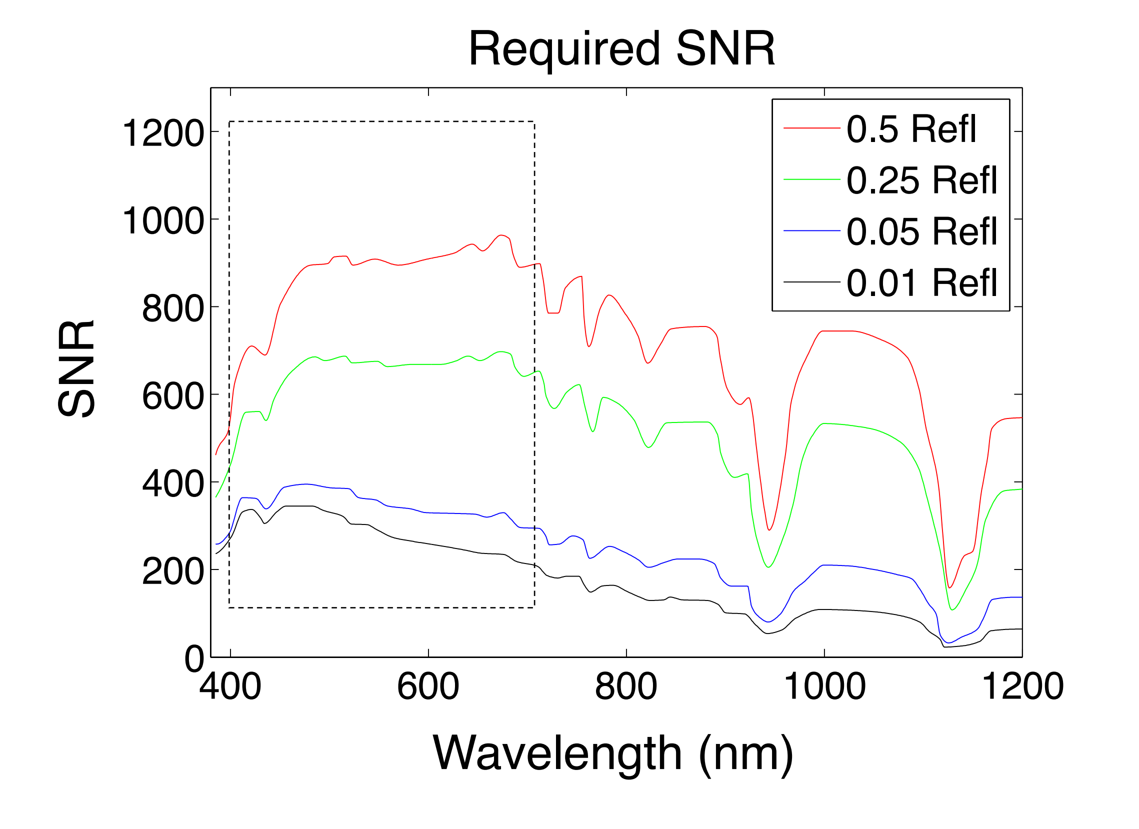


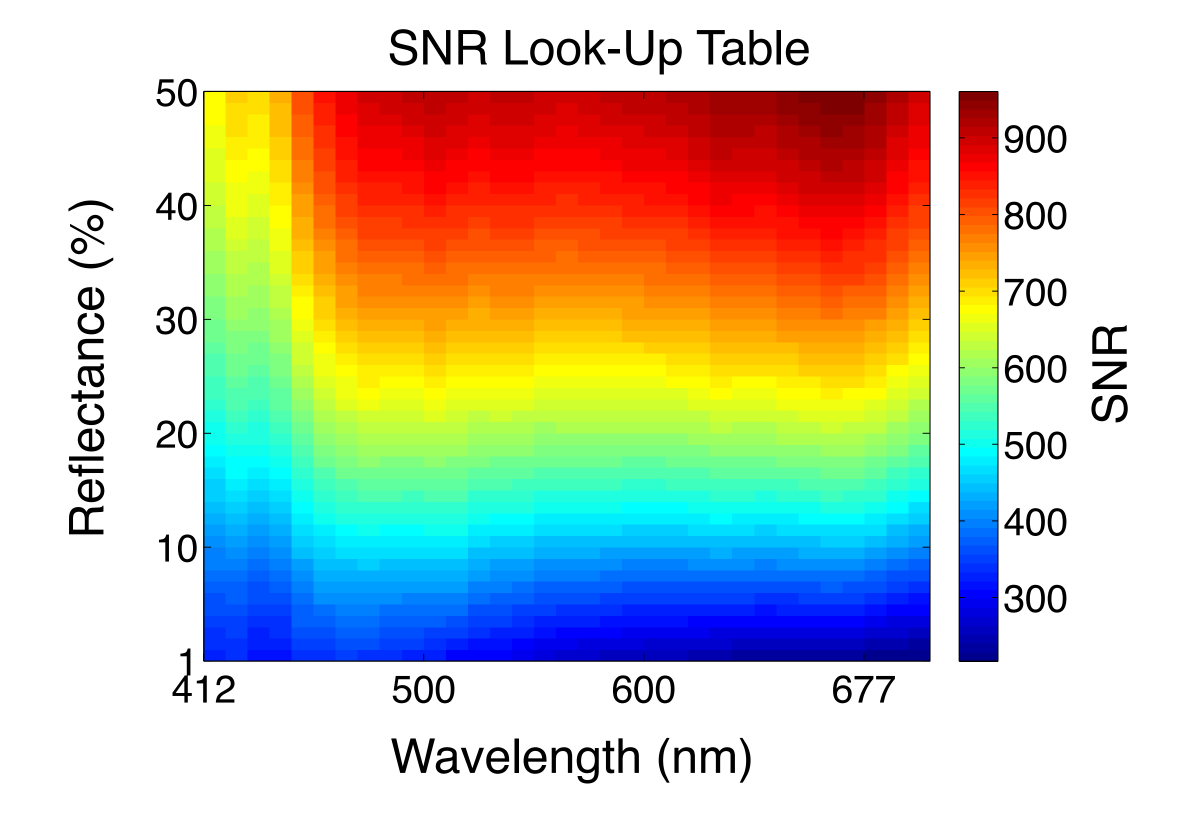


Effect of Different Algal Types on Error



Examine effect of noise on unmixing





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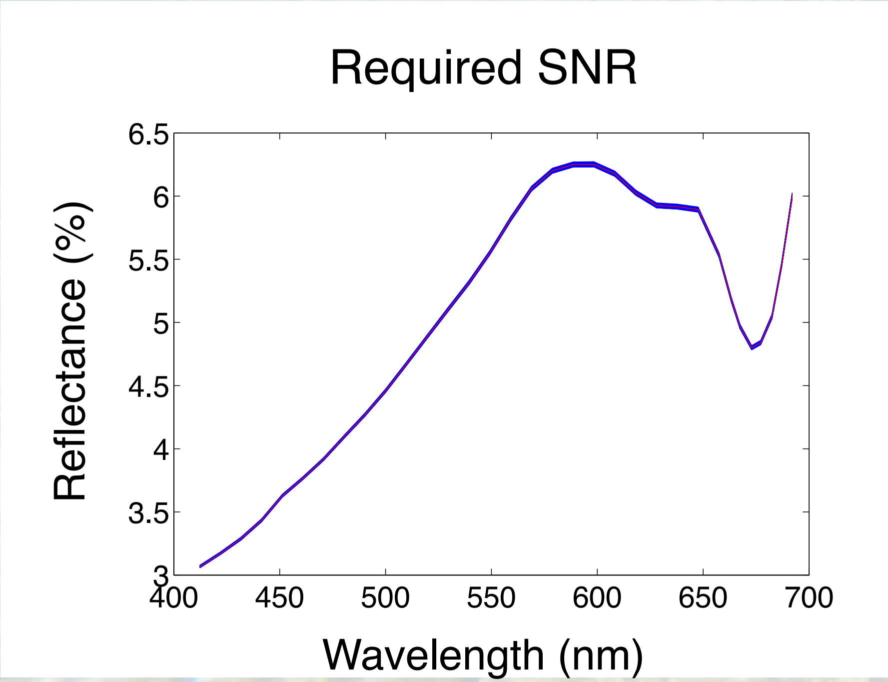
Required SNR has negligible effect on unmixing

$$\mathrm{Refl}_{Noisy} = \mathrm{Refl}(1 + 0.5\ N(0,1)/SNR)$$



		Brown	Red	Green	Turf	CCA
Brown Coral	Coral:	4×10^{-4}	7×10^{-4}	3×10^{-4}	4×10^{-4}	5×10^{-4}
	Bleached:	7×10^{-4}	7×10^{-4}	7×10^{-4}	7×10^{-4}	7×10^{-4}
	Algae:	9×10^{-4}	7×10^{-4}	8×10^{-4}	6×10^{-4}	5×10^{-4}
	Sand:	5×10^{-4}	5×10^{-4}	6×10^{-4}	6×10^{-4}	6×10^{-4}
	Shade:	1×10^{-3}	1×10^{-3}	1×10^{-3}	1×10^{-3}	1×10^{-3}
Blue Coral	Coral:	6×10^{-4}	6×10^{-4}	4×10^{-4}	7×10^{-4}	6×10^{-4}
	Bleached:	8×10^{-4}	8×10^{-4}	8×10^{-4}	8×10^{-4}	8×10^{-4}
	Algae:	1×10^{-3}	5×10^{-4}	9×10^{-4}	1×10^{-3}	1×10^{-3}
	Sand:	6×10^{-4}	6×10^{-4}	6×10^{-4}	7×10^{-4}	7×10^{-4}
	Shade:	1×10^{-3}	3×10^{-3}	1×10^{-3}	1×10^{-3}	1×10^{-3}
Soft Coral	Coral:	3×10^{-4}	5×10^{-4}	2×10^{-4}	3×10^{-4}	4×10^{-4}
	Bleached:	7×10^{-4}	8×10^{-4}	7×10^{-4}	8×10^{-4}	7×10^{-4}
	Algae:	1×10^{-3}	9×10^{-4}	9×10^{-4}	6×10^{-4}	5×10^{-4}
	Sand:	5×10^{-4}	5×10^{-4}	6×10^{-4}	6×10^{-4}	6×10^{-4}
	Shade:	1×10^{-3}	8×10^{-4}	1×10^{-3}	1×10^{-3}	1×10^{-3}

How is this analysis unique and useful?

- Unmixing benthic fractions: MESMA and spectral derivative techniques
- Focus on AVIRIS/HyspIRI-like bands
- Full quantification of error related to:
  - spectral unmixing techniques
  - effects of a range of water constituents on error
  - error related to water inversion and atmospheric effects
- Examine different classes of algae