
Coral Reef Remote Sensing Science
Objectives and Requirements
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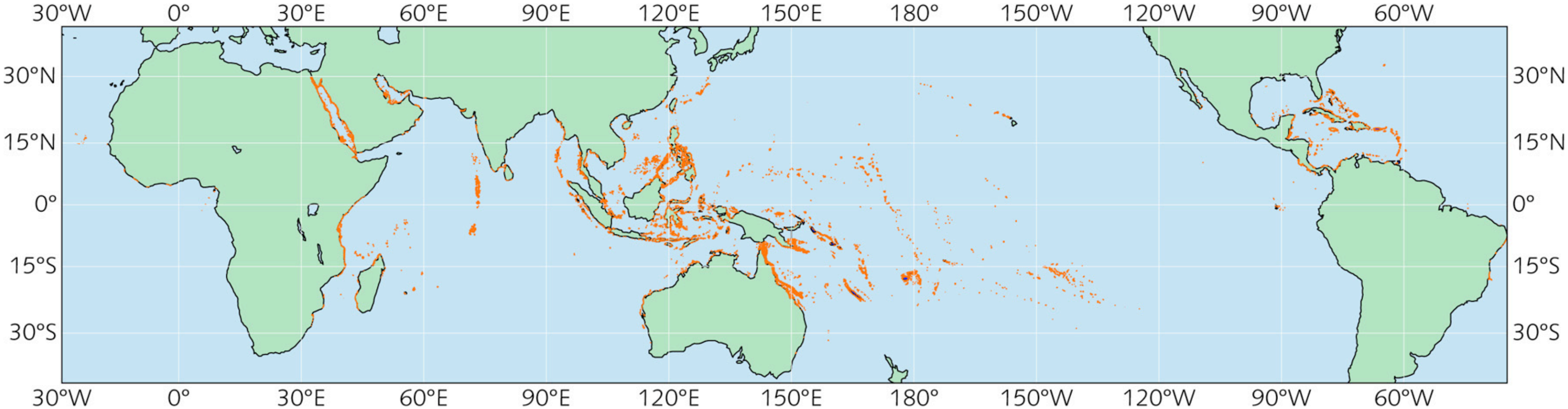
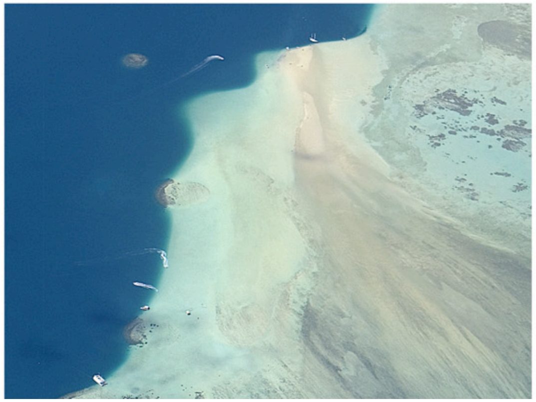
Coral Reefs: Global Distribution and Importance



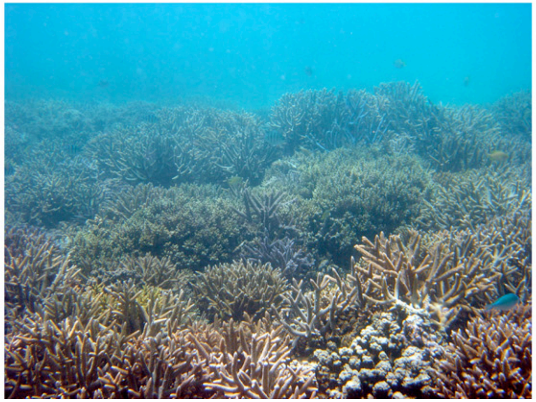
Focus for traditional culture and food source for innumerable small subsistence economies

Protection to shorelines from storm and wave damage and barriers that provide safe passage for shipping



Superlative recreational resource and the foundation of a multibillion dollar tourist industry worldwide

Major locus of global biodiversity, providing an ecological reserve of genetic complexity



IPCC AR4: Coral reefs are one of four cross-chapter case studies

Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., 2007: Cross-chapter case study. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 843-868.

C2 Impacts of climate change on coral reefs

C2.1 Present-day changes in coral reefs
- C2.1.1 Observed changes in coral reefs (Chapter 1, Section 1.3.4.1)
- C2.1.2 Environmental thresholds and observed coral bleaching (Chapter 6, Box 6.1)

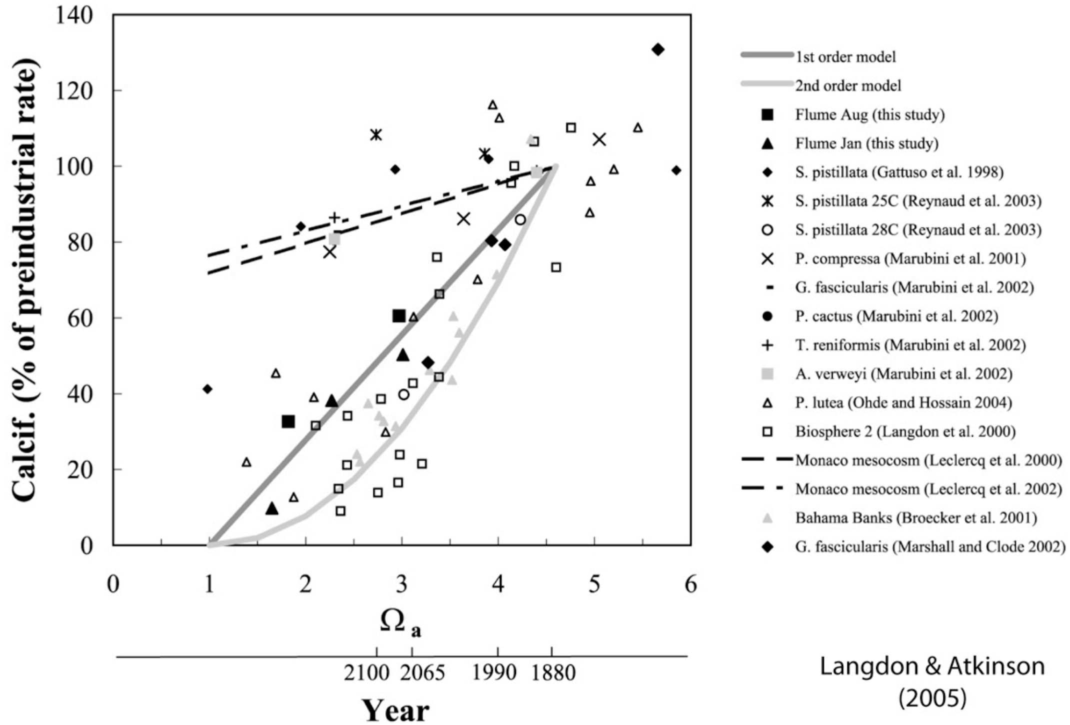
C2.2 Future impacts on coral reefs
- C2.2.1 Are coral reefs endangered by climate change? (Chapter 4, Box 4.4)
- C2.2.2 Impacts on coral reefs (Chapter 6, Section 6.4.1.5)
- C2.2.3 Climate change and the Great Barrier Reef (Chapter 11, Box 11.3)
- C2.2.4 Impact of coral mortality on reef fisheries (Chapter 5, Box 5.4)

C2.3 Multiple stresses on coral reefs
- C2.3.1 Non-climate-change threats to coral reefs of small islands (Chapter 16, Box 16.2)

Global Stresses to Reefs

SST: Increased Coral Bleaching

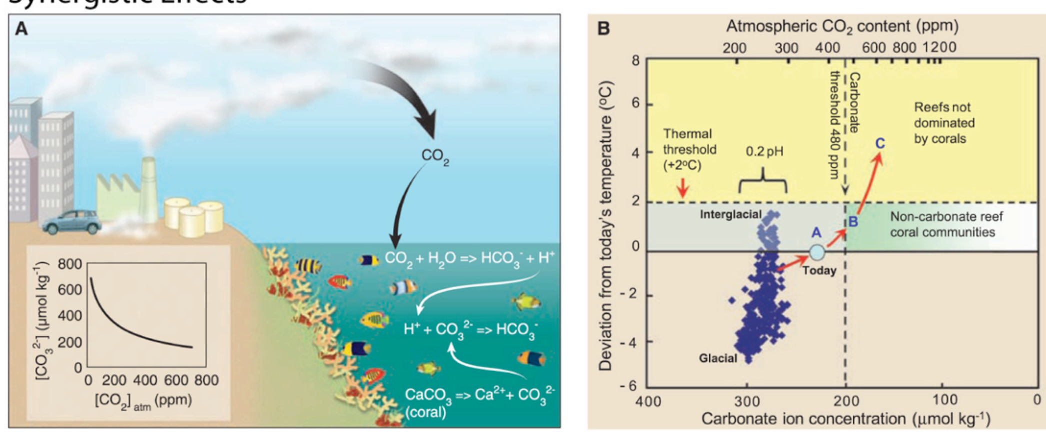
Ocean Acidicification: Decreases in Calcification Rates



Langdon & Atkinson (2005)

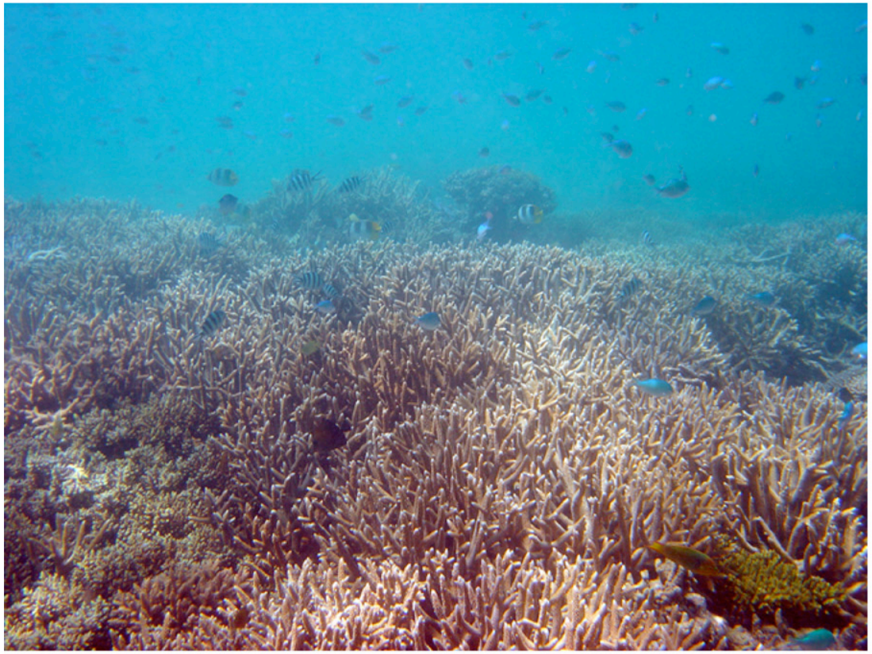
SST: Increased Coral Disease

Synergistic Effects

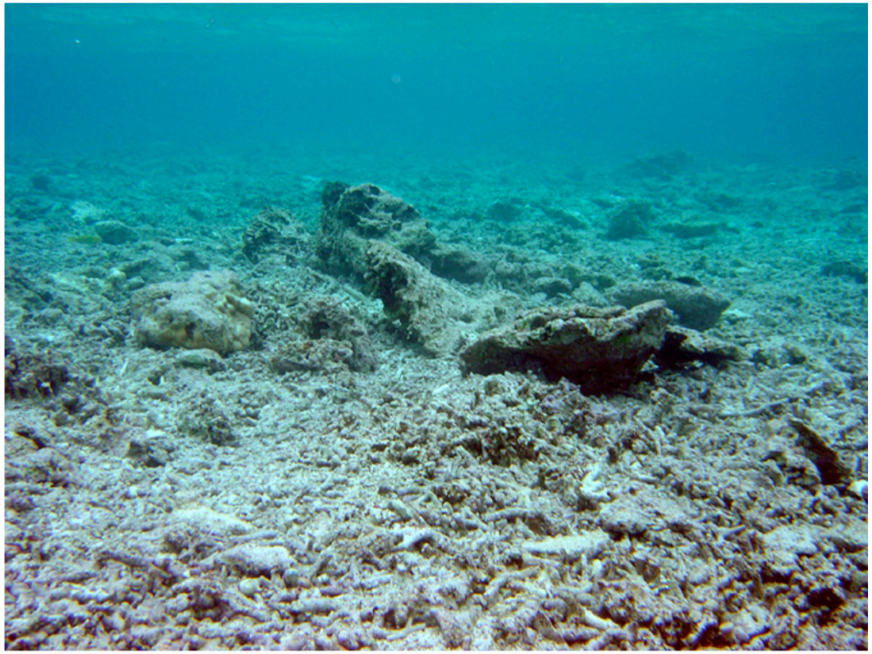


Hoegh-Gulberg et al. (2007)

The Primary Coral Reef Problem:
Phase Shifts from Coral-Dominated to Algae-Dominated

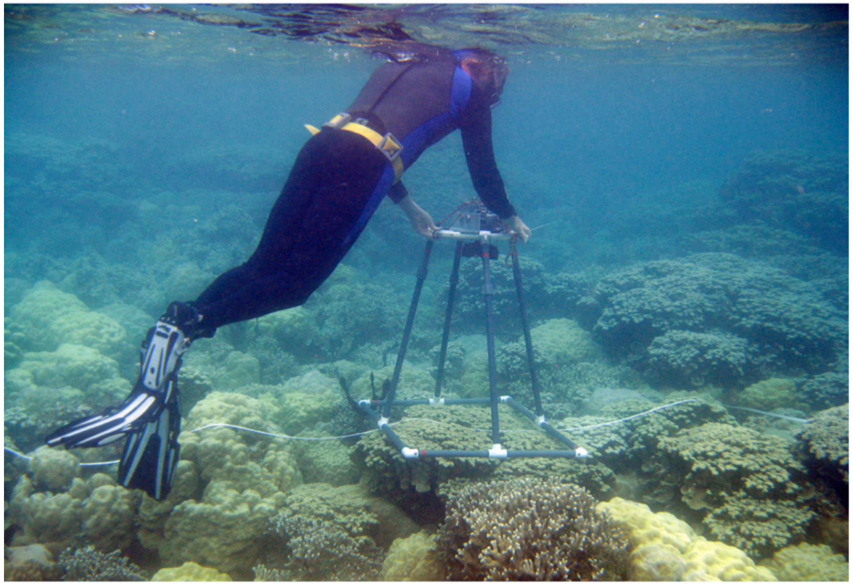


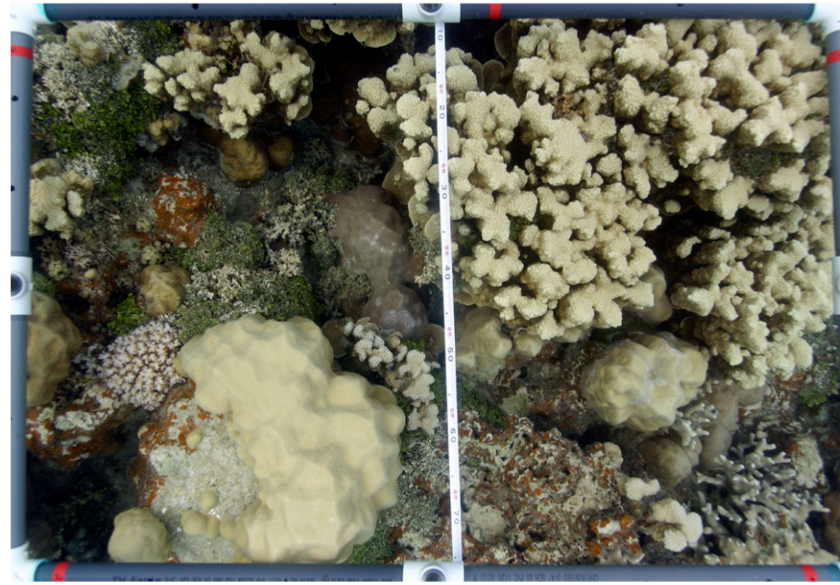
- Rough
- High productivity/calcification
- "Healthy"



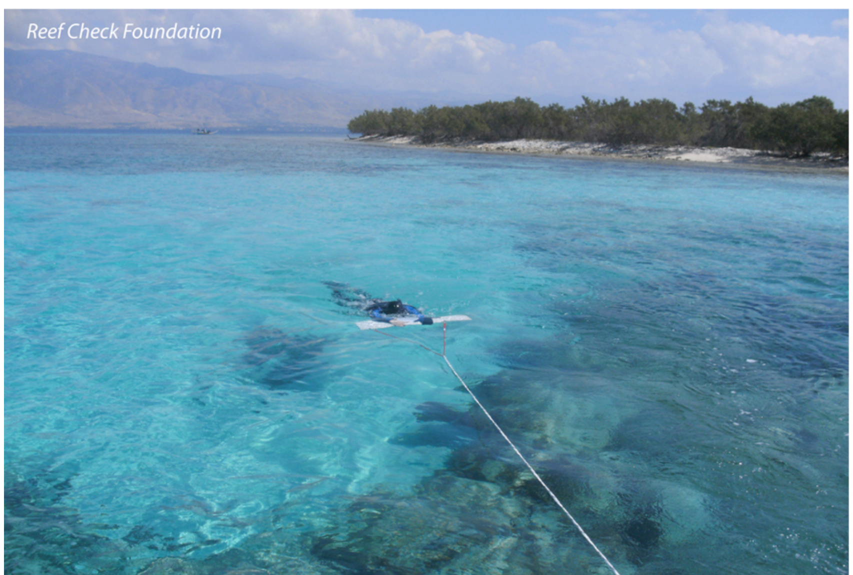
- Smooth
- Low productivity/calcification
- Not "healthy"

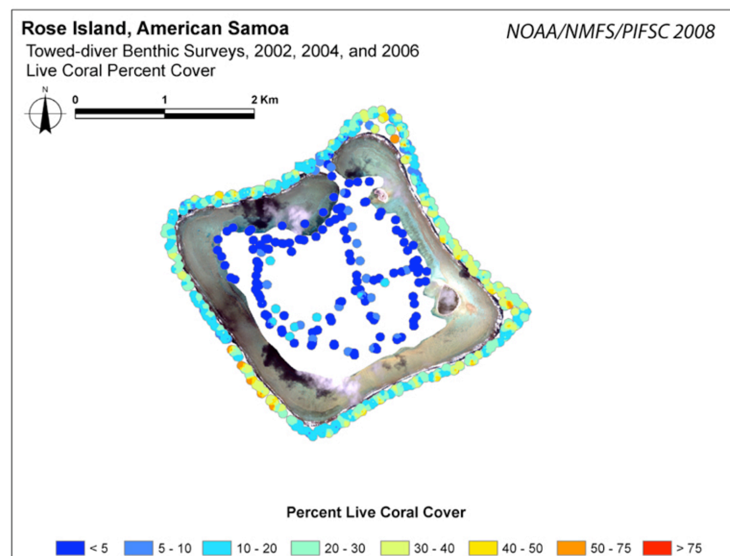
State of the Art in Coral Reef Structure Assessment: Resource Inventory



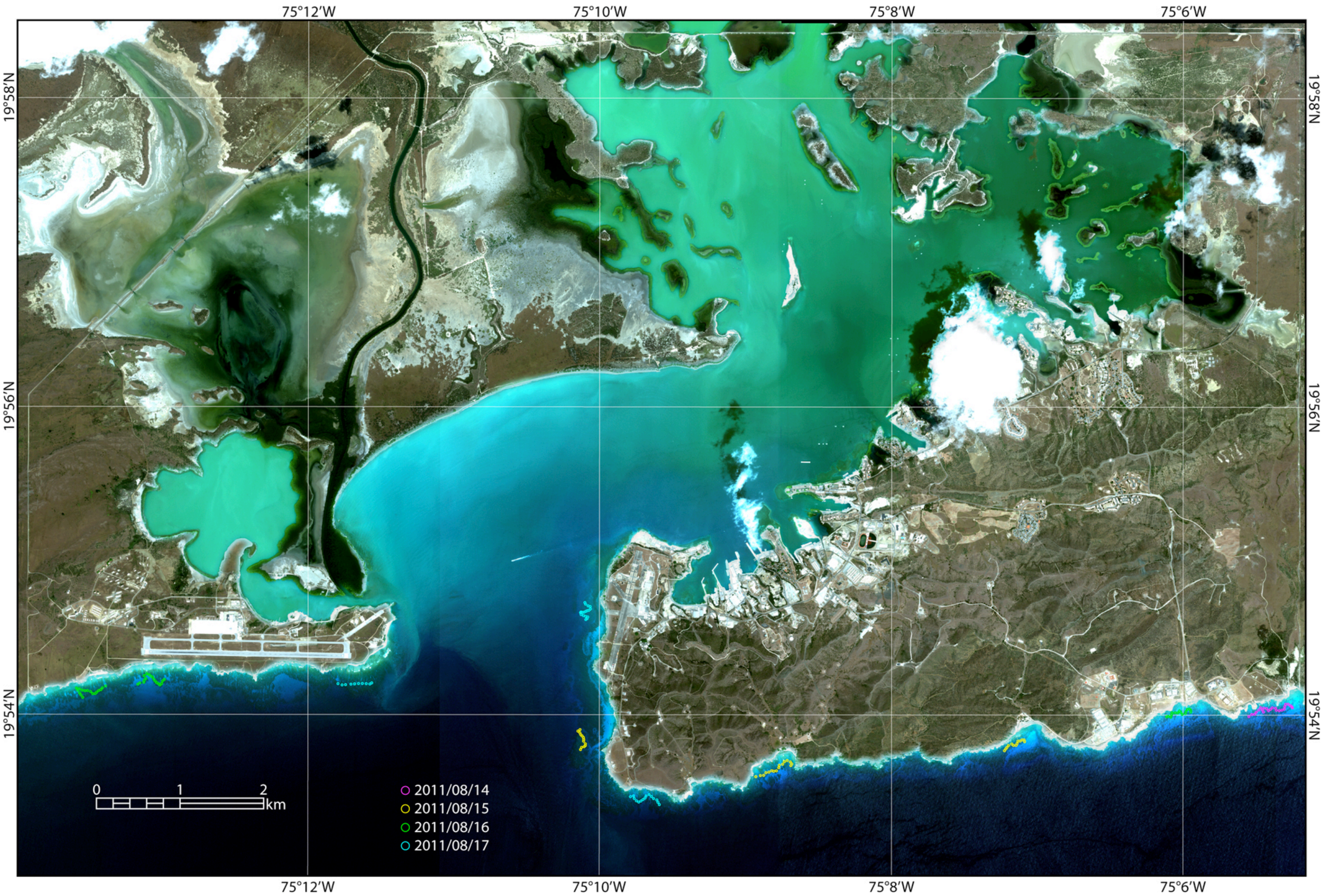


Photoquadrat Transects: detailed, laborious, small footprint

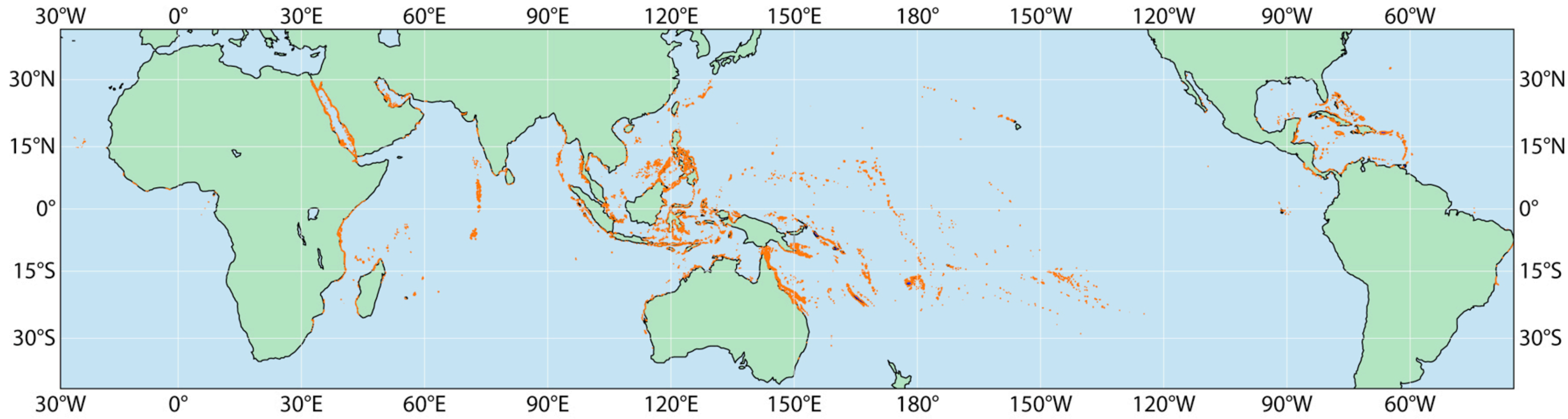




“Manta-Tows”: quick, semi-quantitative, large footprint


75°12′W
75°10′W
75°8′W
75°6′W
19°58′N
19°56′N
19°54′N
0
1
2
km
2011/08/14
2011/08/15
2011/08/16
2011/08/17

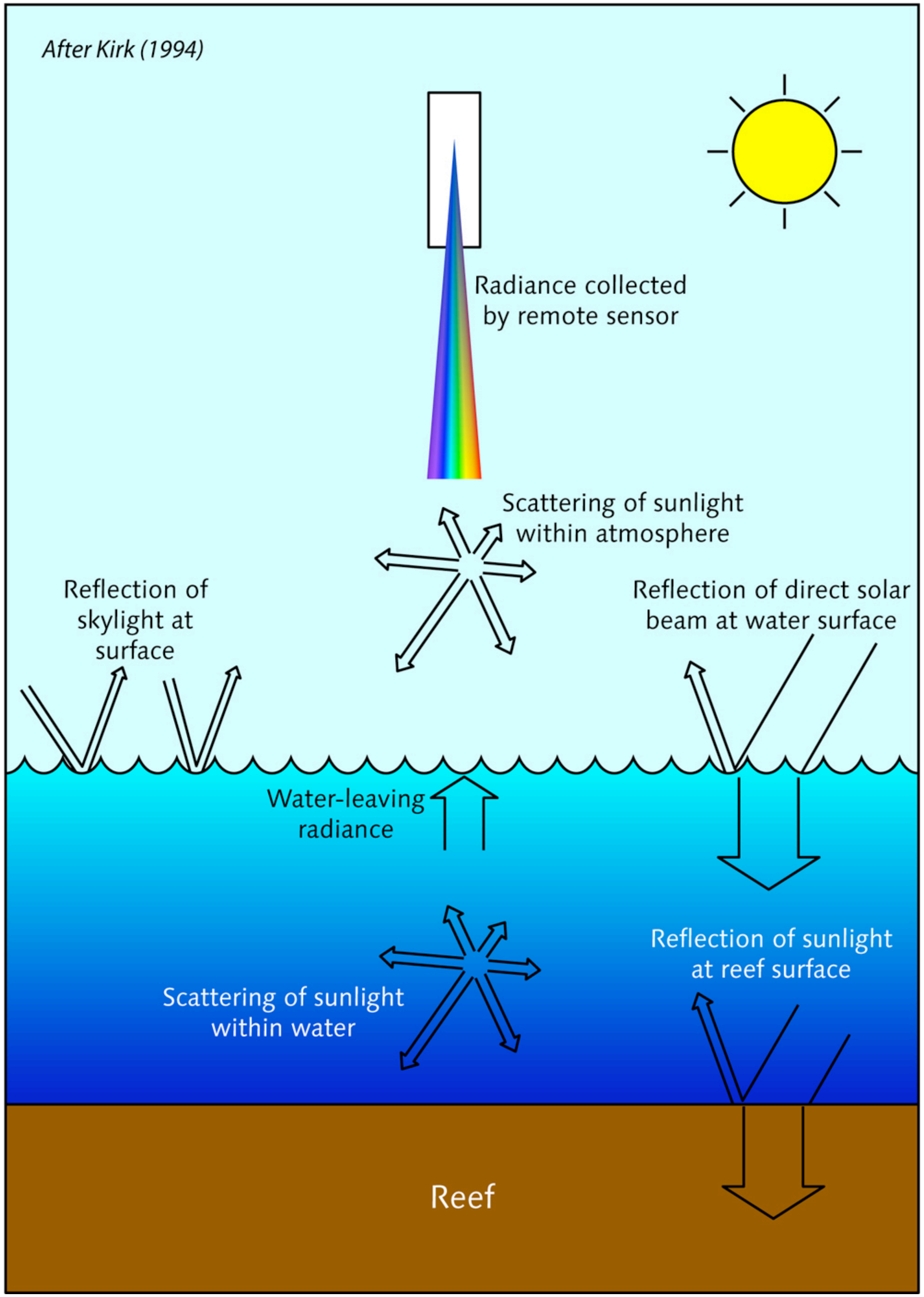
Coral Reefs: Sampling Problem



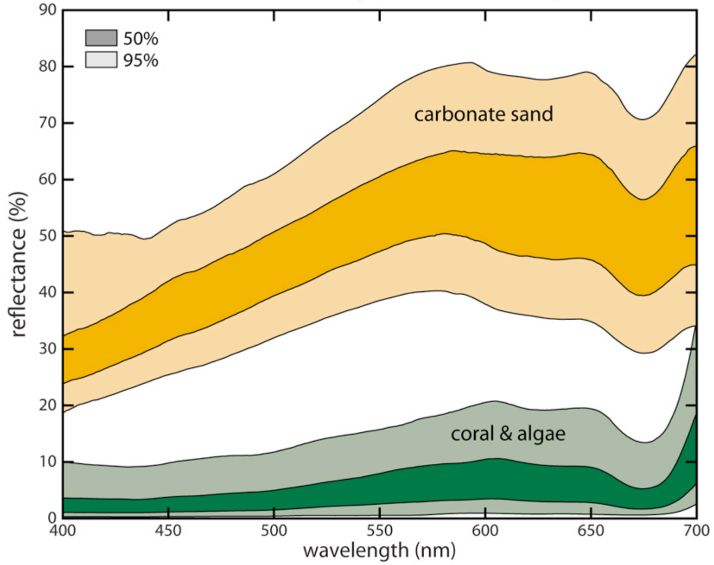
- ~9,000 reefs in the world, covering 500,000 km^2
- spread across 200,000,000 km^2 of ocean
- Quantitative in situ surveys cover only 10s to 100s of km^2 worldwide
- *Current estimates of reef loss are based on direct observation of only 0.01–0.1% of the world's reef area*
- **Only satellite remote sensing can provide the uniform data set required for assessment of the global status of coral reefs**

Five sources of light received by a remote sensor pointed at a coral reef.

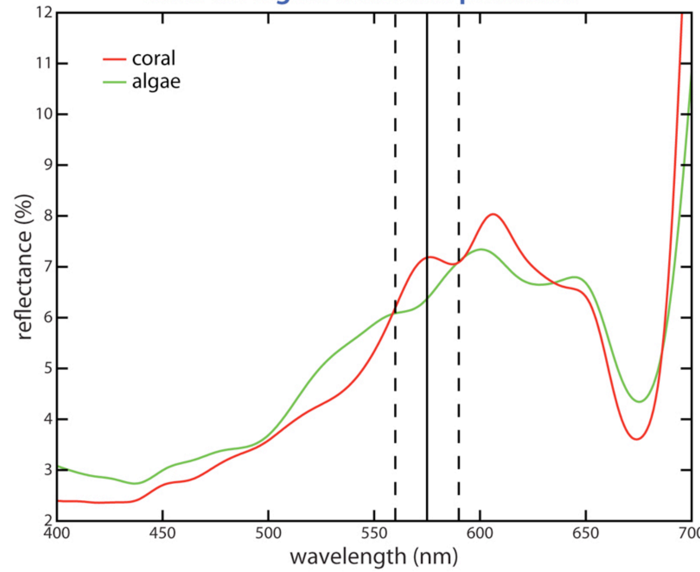
Only light reflected at the reef surface can provide information about the reef.



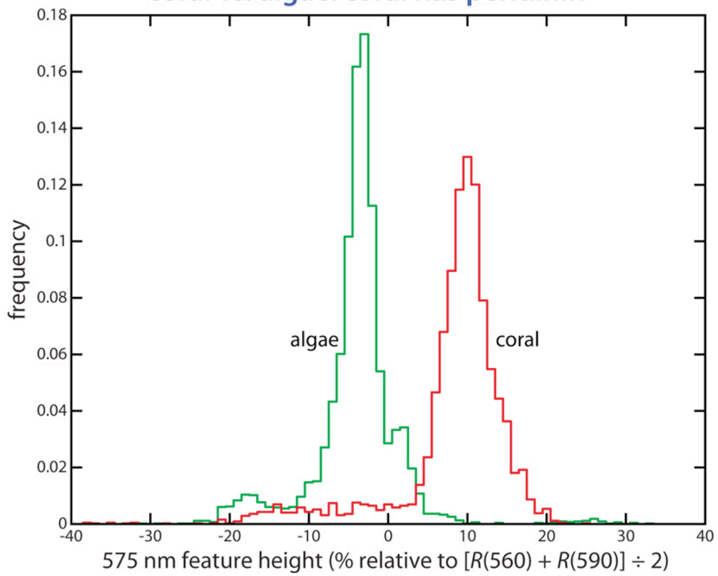
sand vs. coral+algae: sand is bright



coral vs. algae: coral has peridinin



coral vs. algae: coral has peridinin



overall classification rates: very good for four wavebands

		Actual Class		
		algae	coral	sand
Predicted Class	algae	5,086 (92.5)	556 (12.4)	0 (0.0)
	coral	407 (7.4)	3,934 (87.6)	0 (0.0)
	sand	7 (0.1)	0 (0.0)	642 (100.0)

Integer values are numbers of spectra classified. Decimal values are classification rates in percent.

Hochberg & Atkinson (2003)

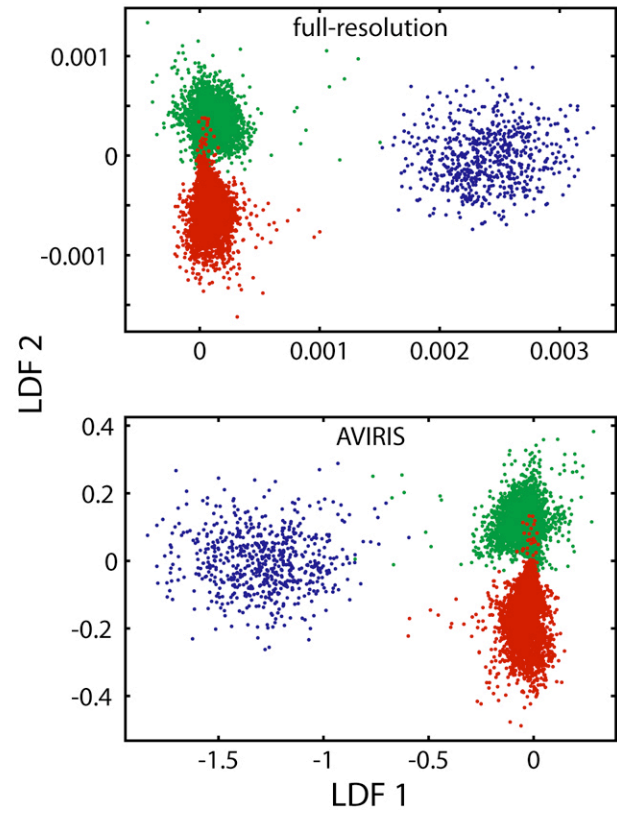
Table 1
Classification error matrices for in situ spectral reflectances of three coral reef classes: coral, algae, and carbonate sand

(A) Full-resolution: overall accuracy = 98%

		Actual class		
		Algae	Coral	Sand
Predicted class	Algae	2726 (99.2)	75 (3.3)	1 (0.3)
	Coral	23 (0.8)	2168 (96.6)	0 (0.0)
	Sand	0 (0.0)	1 (0.0)	320 (99.7)

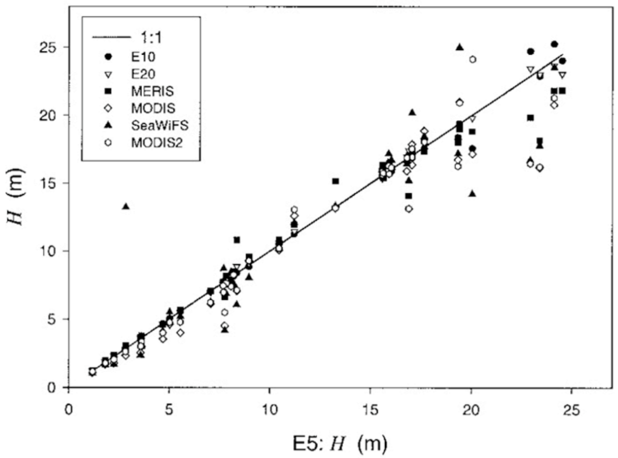
(C) AVIRIS: overall accuracy = 98%

		Actual class		
		Algae	Coral	Sand
Predicted class	Algae	2725 (99.1)	74 (3.3)	1 (0.3)
	Coral	24 (0.9)	2170 (96.7)	0 (0.0)
	Sand	0 (0.0)	0 (0.0)	320 (99.7)

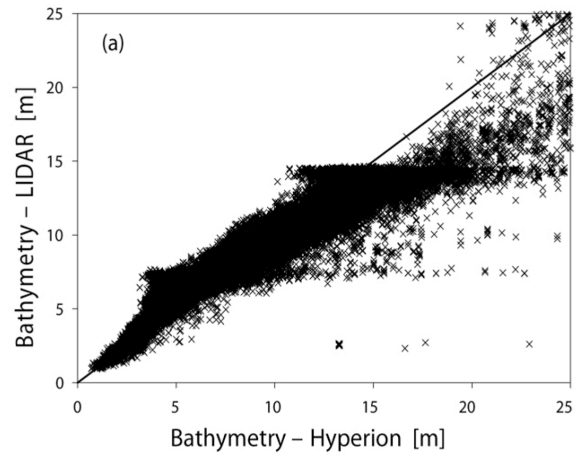


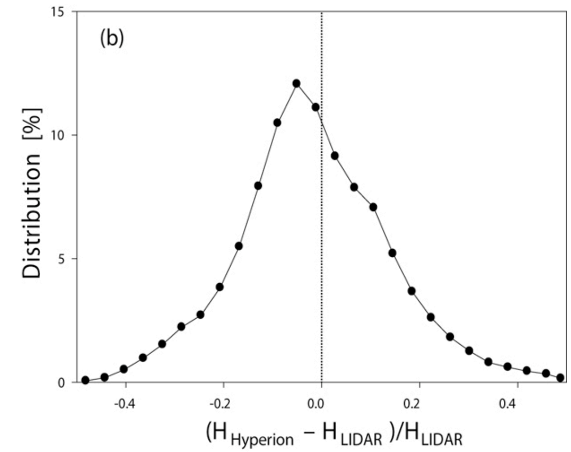
Conclusion: Contiguous, 10-nm-wide wavebands over range 400–700 nm provides excellent spectral discrimination between coral, algae, and sand

Lee & Carder (2002)



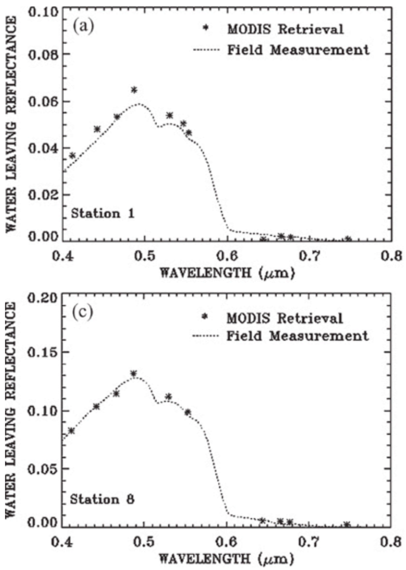
Lee et al. (2007)

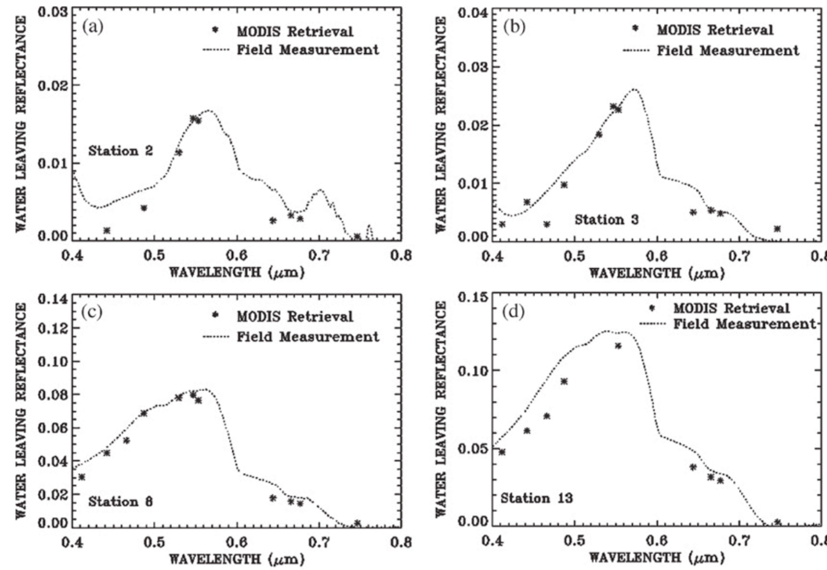




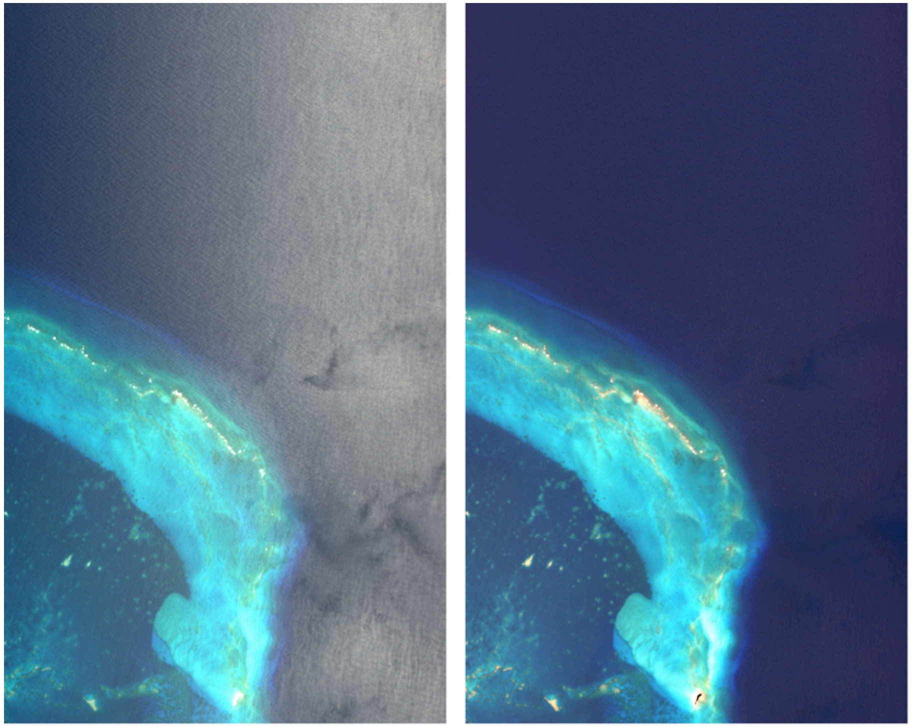
Conclusion: Contiguous, 10-nm-wide wavebands over range 400–800 nm is excellent band set for retrieval of shallow water bathymetry

Gao et al. (2007)



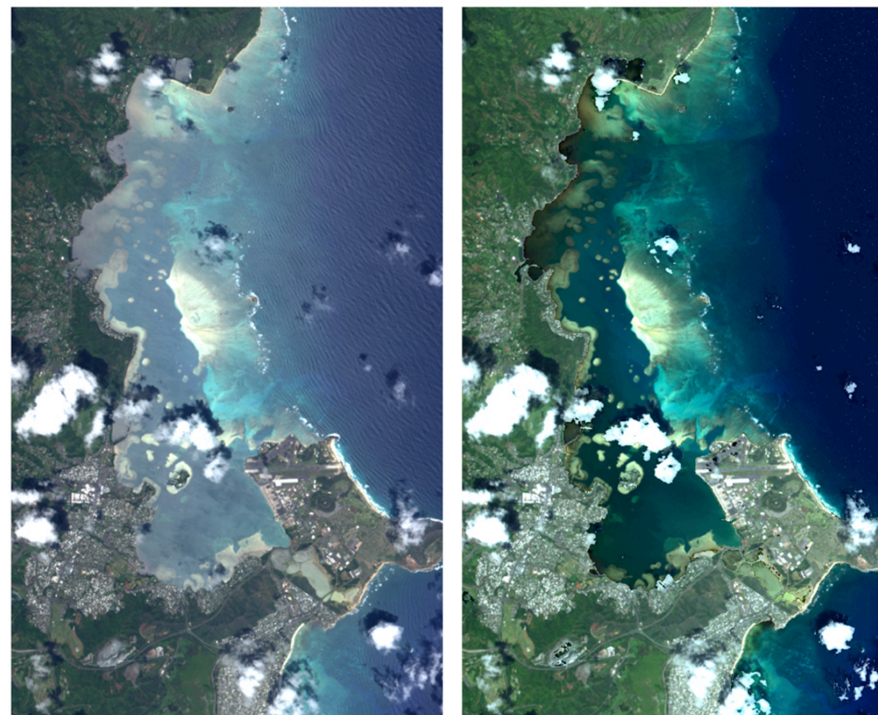


Conclusion: Combined wavebands across both NIR and SWIR (i.e., 0.865, 1.04, 1.24, 1.64, and 2.25 μm) provide very good atmospheric correction



Various Workers & HyspIRI Sun Glint Subgroup

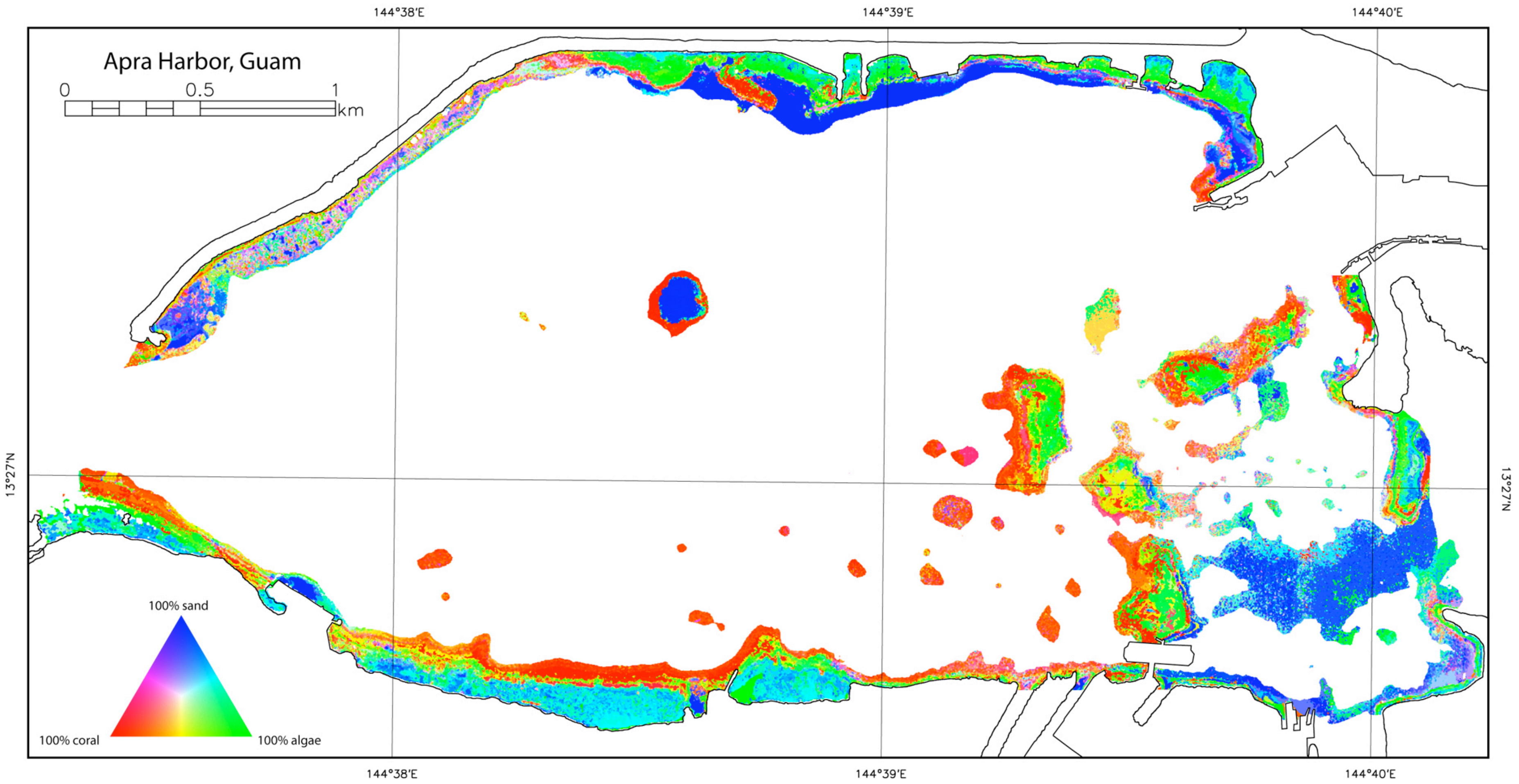
Conclusion: Glint is readily correctable, provided (1) suitable reference waveband(s) at wavelengths > 900 nm and (2) good atmospheric correction



Summarizing Waveband Requirements for a Coral Reef Satellite

- Accurate atmospheric correction is crucial to provide accurate water-leaving radiances in the VIS that are used as input to water column correction.
- Accurate water column correction is crucial to provide accurate seafloor optical properties that are used to discriminate between coral reef bottom-types.
- The most accurate atmospheric correction for shallow waters—including coral reefs requires SWIR wavebands. NIR wavebands can be used alone, but the guaranteed result is underestimates of VIS water-leaving radiance. Errors in VIS water-leaving radiance will cascade to errors in retrieval of seafloor optical properties. Errors in seafloor optical properties will result in misclassifications of coral reef bottom-types.
- The most accurate water column correction for shallow waters—including coral reefs—requires wavebands distributed across VIS wavebands. A narrower range of wavebands can be used, but the result will be less accurate retrievals of seafloor optical properties. Errors in seafloor optical properties will result in misclassifications of coral reef bottom-types.
- **Using a wavelength range 0.4-2.5 μm does not guarantee perfect classification of coral reef bottom-types, but it does guarantee the best possible results.**

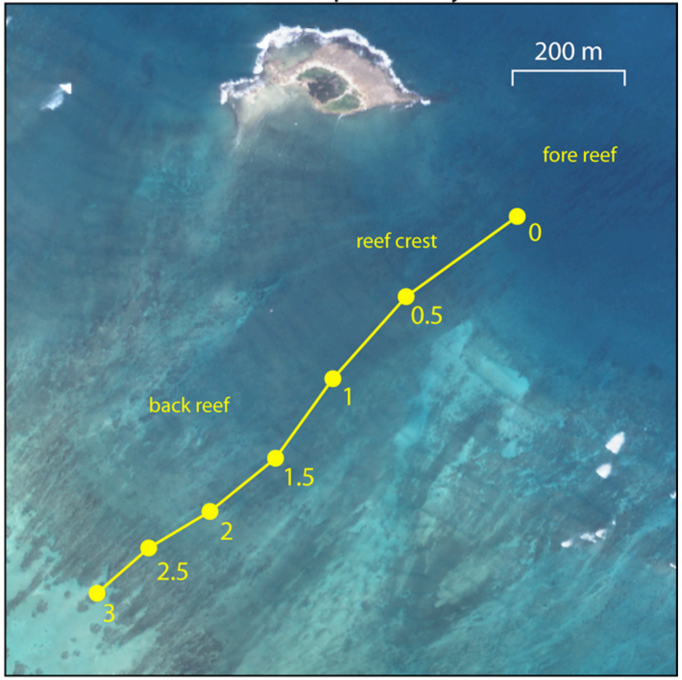
Reef Remote Sensing Map Product



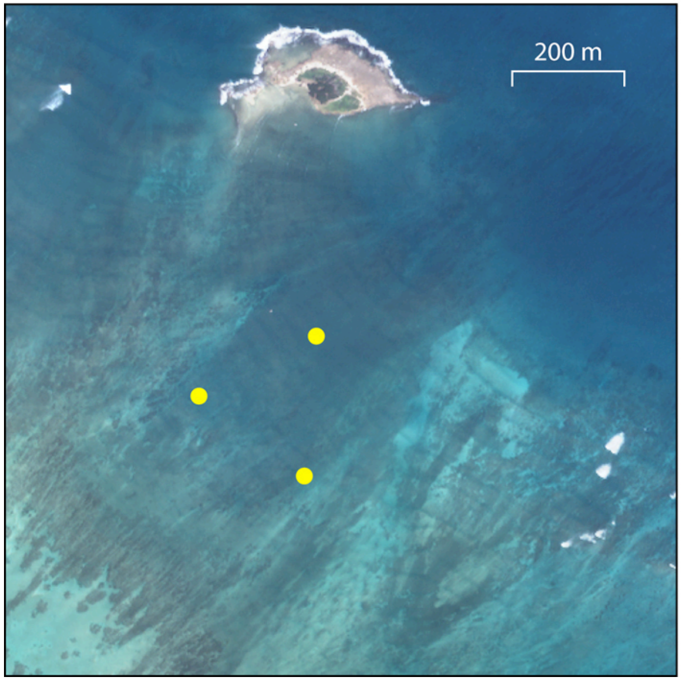
State of the Art in Coral Reef Functional Assessment: Biogeochemistry

Benthic Chamber

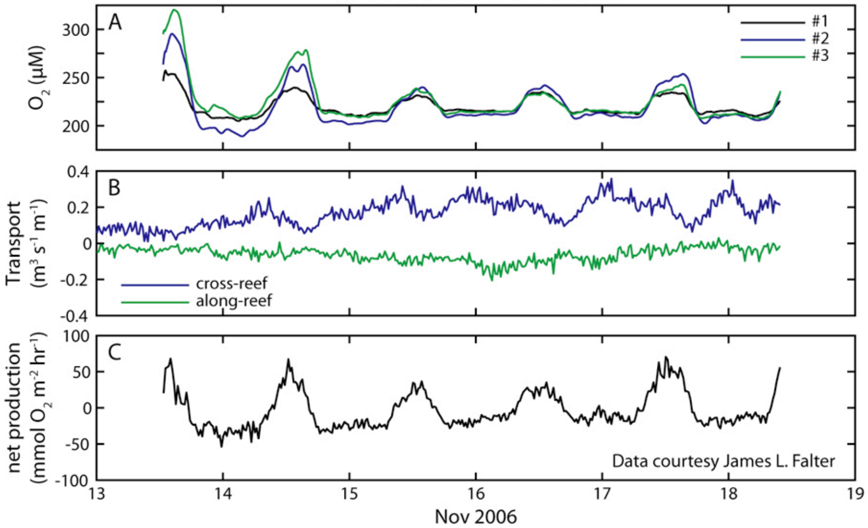
Flow Respirometry



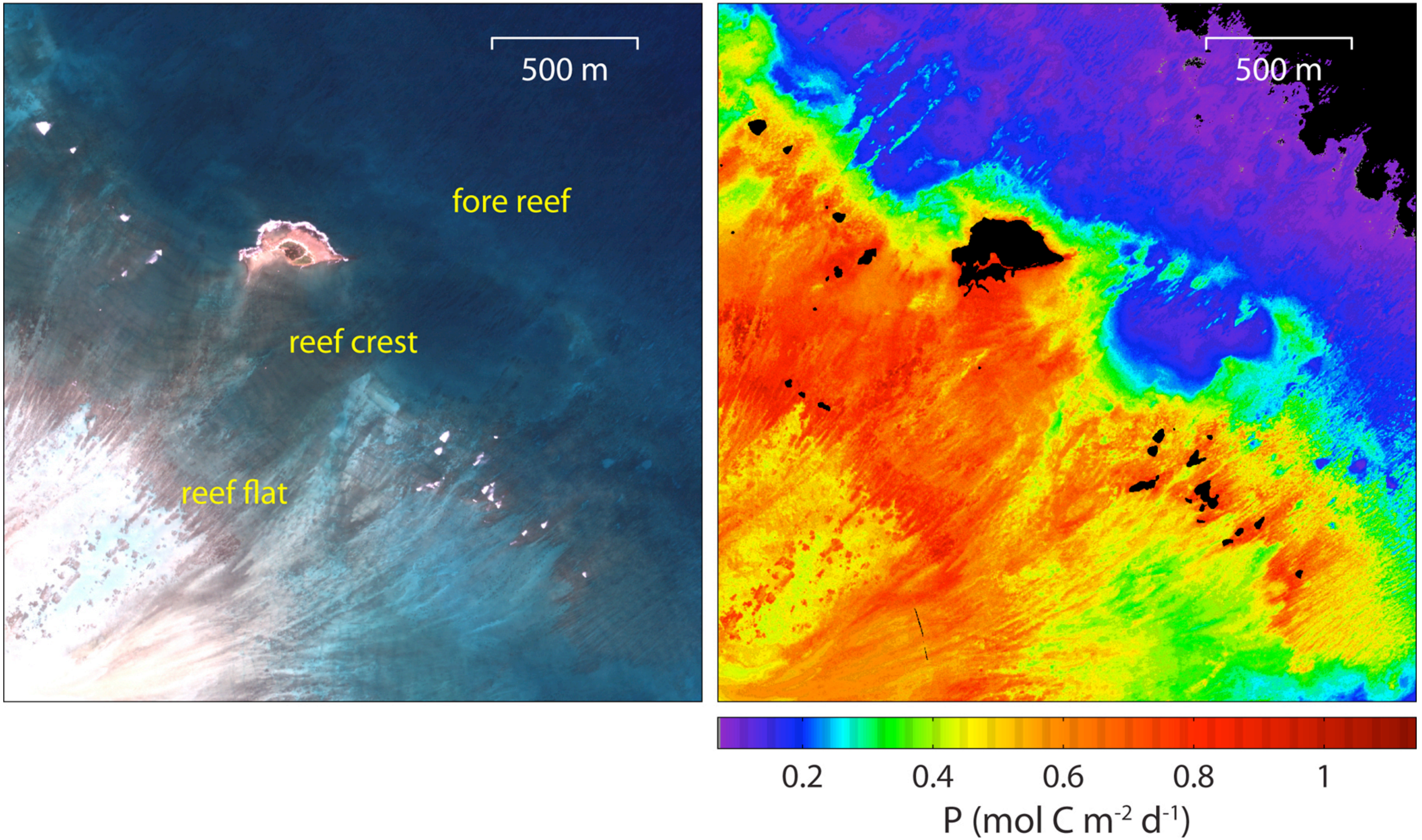
Control Volume



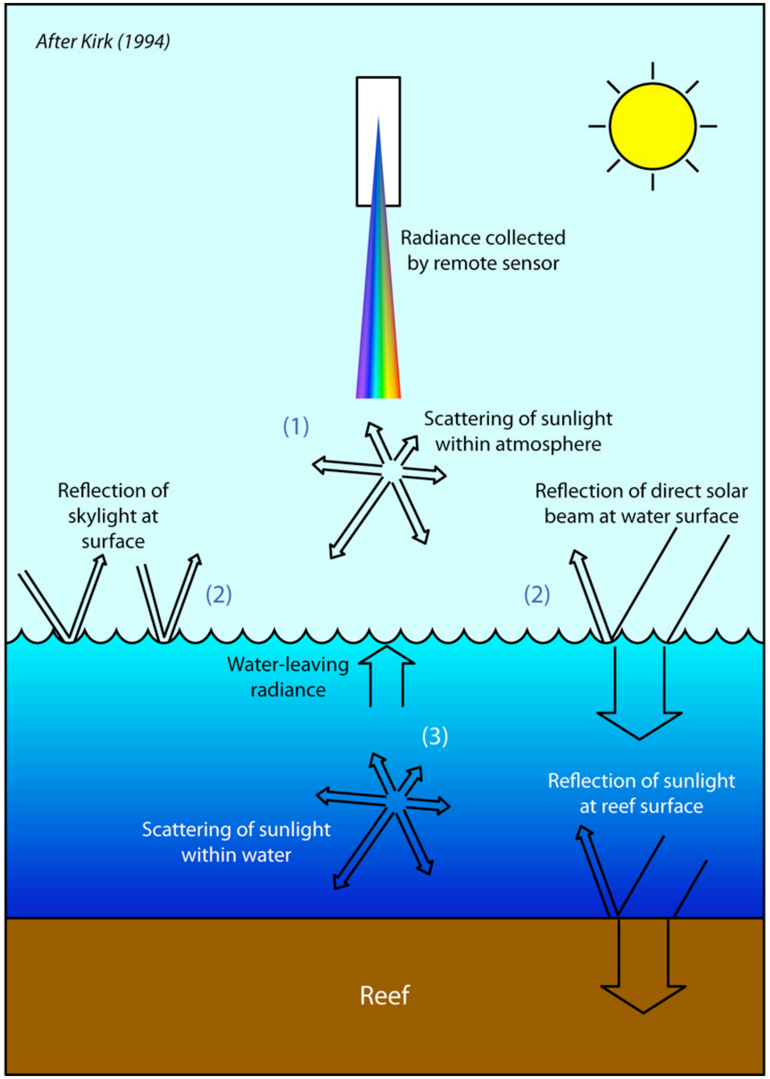
Control Volume Data



Remote Sensing of Reef Biogeochemistry



Reef Remote Sensing: Next Steps

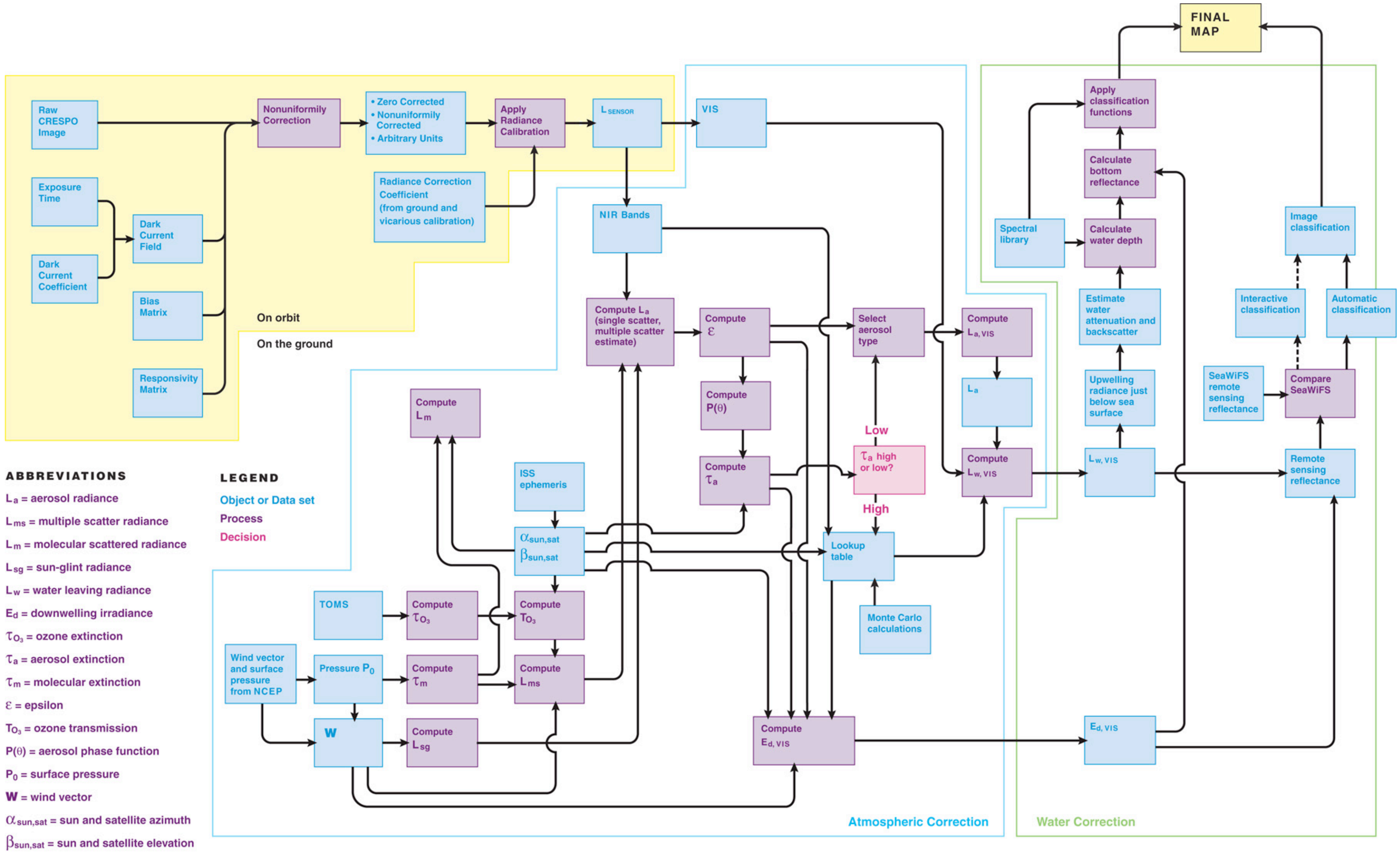


(1) Atmospheric Correction
- ATREM
- FLAASH
- Tafkaa
- Glint-Aerosol Discrimination
- ???

(2) Glint Correction
- NIR-VIS Empirical Linear Relationship
- Subtraction of NIR Reflectance
- Uniform Spectral Offset Approach
- Glint-Aerosol Discrimination

(3) Water Column Correction
- Optimization
- Look-Up Tables
- ???

(4) Successful Integration of 1 + 2 + 3
- ???



FO2-2: Algorithm Processing Flow

HyspIRI Coral Reef Science

HyspIRI data will be used to pursue the following objectives:

- Measure distributions of coral, algae and sand for ≥25% of reefs worldwide. This will be an unprecedented survey of the current status of coral reefs, and the results will serve as a baseline for future change detection.
- Examine trends of coral, algae and sand for pristine reefs versus human-impacted reefs. This comparison of reefs will enable scientists to identify a set of conditions that define a "healthy" reef (no such definition exists).
- Determine how distributions of coral, algae and sand vary with reef morphology, underlying geology, latitude, and oceanographic conditions of wind, waves, and nutrients. To understand reef health, it is important to understand how environmental factors influence the amounts of coral, algae and sand that are present.
- Generate map products to help regional and local monitoring and scientific investigation. Such maps can be used to identify sites that are crucial for conservation, as well as sites that require more intensive study to understand the ecosystem.
- Provide ancillary data for management and science. Several secondary products will be of great use for monitoring and investigating hydrodynamics and biogeochemistry of reef systems.

Coral Reef Satellite Mission Success Criteria

Minimum Success

Maps showing the distributions of coral, algae and sand for 10% of the world's reefs over the course of a single year

Targeted Success

Maps and secondary products for 25% of the world's reefs over a two-year period

Ideal Success

Maps and secondary products for 50% of the world's reefs over a two-year period