Coral Reef Benthic Productivity Based on Optical Absorptance and Light-Use Efficiency

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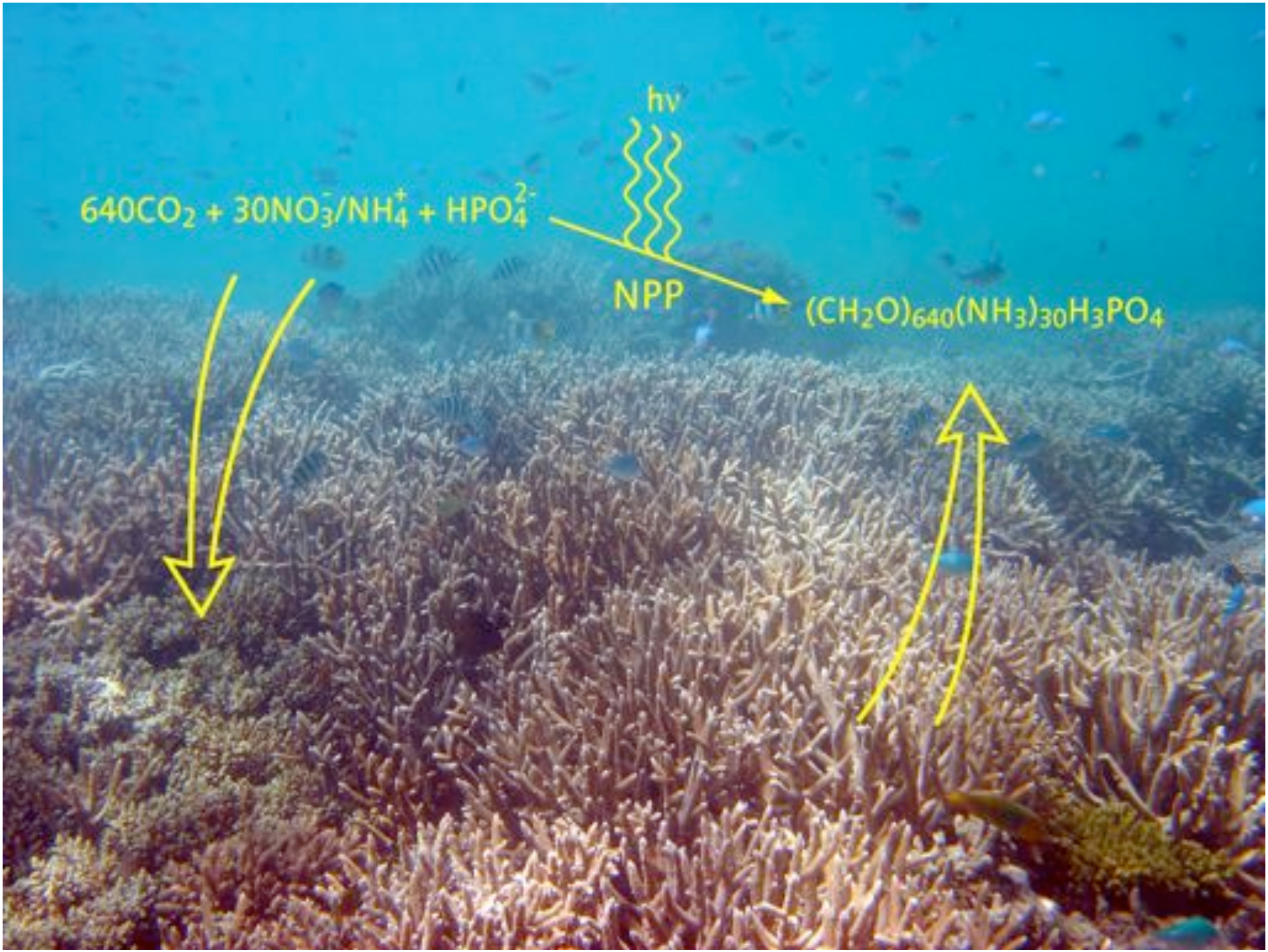
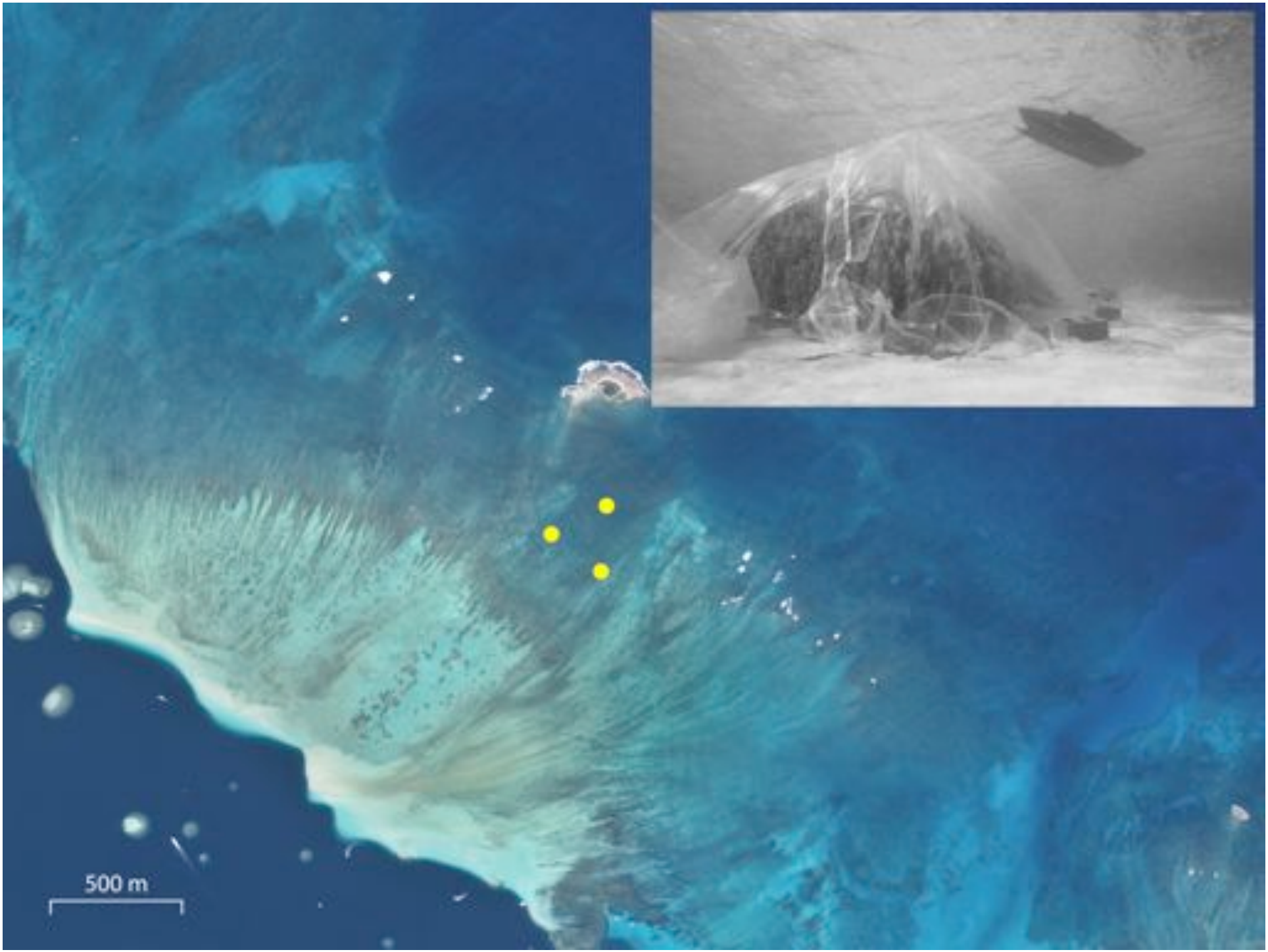
Ocean Color Research Team Meeting
13 April 2007, Seattle, WA


hν
$640CO_2 + 30NO_3^-/NH_4^+ + HPO_4^{2-}$
NPP
$(CH_2O)_{640}(NH_3)_{30}H_3PO_4$


500 m

Published values for specific biotopes in coral reef environments (after Kinsey 1984)

Reference	Location	P (mol O_2 m^{-2} d^{-1})
Algal turfs & algal/sand flats		
Smith (1973)	Enewetak	0.97
Smith & Marsh (1973)	Enewetak	0.87
Kinsey (1979)	Lizard Island	0.36
"	Kaneohe Bay	0.47
Hargraves (1982)	Carrie Bow Key	~1.67
Sorokin (1982)	Various Indo-Pacific	0.17-0.33
Vooren (1981)	Curacao	0.16
Hawkins & Lewis (1982)	Barbados	0.08
Rogers & Salesky (1981)	St. Croix (turf)	0.25
	" (macroalgae)	1.23
Coralline encrusting algae		
Vooren (1981)	Curacao	0.08
Hawkins & Lewis (1982)	Barbados	0.07
"Sand" areas		
Sournia (1976)	Takapoto	~0.17
Sorokin (1982)	Various Indo-Pacific	0.05-0.11
Kinsey (1977)	One Tree Island	0.08
Kinsey (1979)	Kaneohe Bay	0.23
Kinsey (1979)	One Tree Island	0.13
Coral outcrops		
Kinsey (1979)	6 sites GBR	1.42-3.08
"	*Leptoria phrygia* patch	0.67
"	*Acropora pulchra* patch	1.5
"	*Porites andrewsi* patch	1.17
Atkinson & Grigg (1984)	French Frigate Shoals	
	Porites compressa/lobata	~0.83

Coral Reefs (1984) 3:13–22

Coral Reefs

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Model of a Coral Reef Ecosystem

II. Gross and Net Benthic Primary Production at French Frigate Shoals, Hawaii

Marlin J. Atkinson and Richard W. Grigg

Coral Reefs (2000) 19:259–269
DOI 10.1007/s003380000117

REPORT

S. Andréfouët · C. Payri

Scaling-up carbon and carbonate metabolism of coral reefs using in-situ data and remote sensing

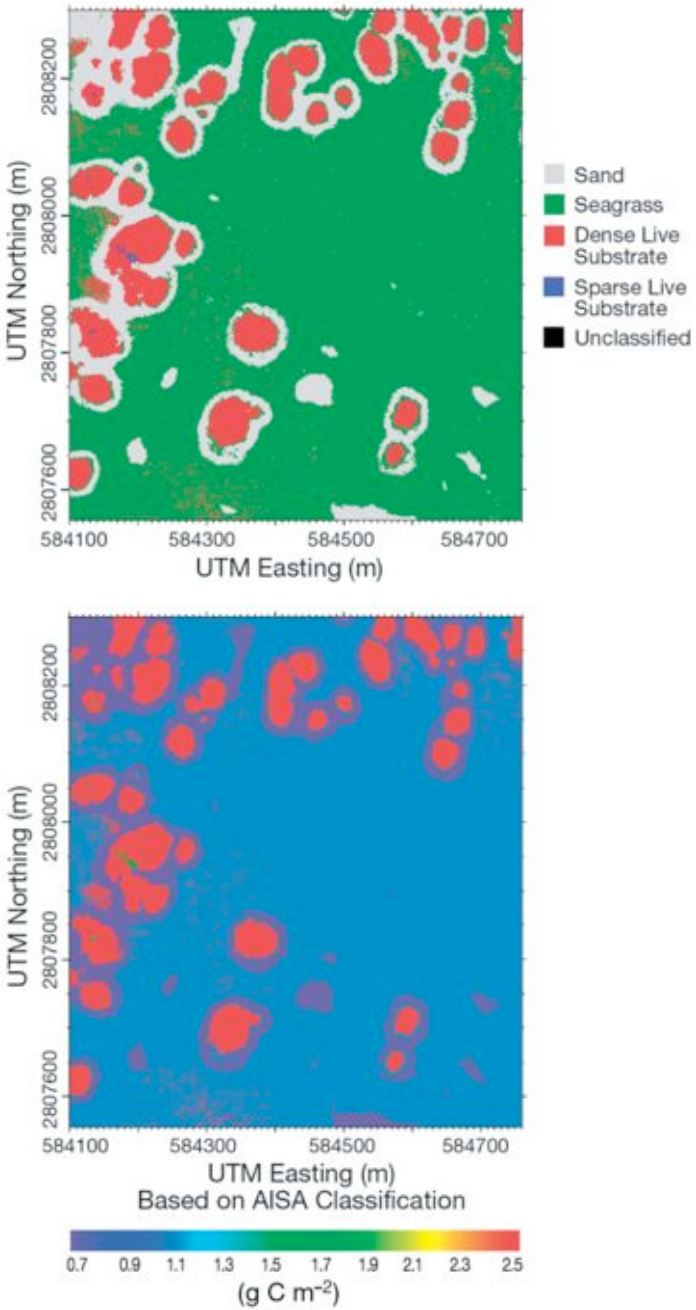
Vol. 312: 123–139, 2006 | MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser | Published April 24

Northern Florida reef tract benthic metabolism scaled by remote sensing

John C. Brock[1,*], Kimberly K. Yates[1], Robert B. Halley[1], Ilsa B. Kuffner[1], C. Wayne Wright[2], Bruce G. Hatcher[3]

Fig. 4. The Submersible Habitat for Analyzing Reef Quality (SHARQ), a large benthic incubation chamber that allows the 24 h monitoring of water chemistry variations driven by substrate carbon and carbonate metabolic processes

Brock et al. (2006)



$$GPP = E_d \times A \times \varepsilon$$

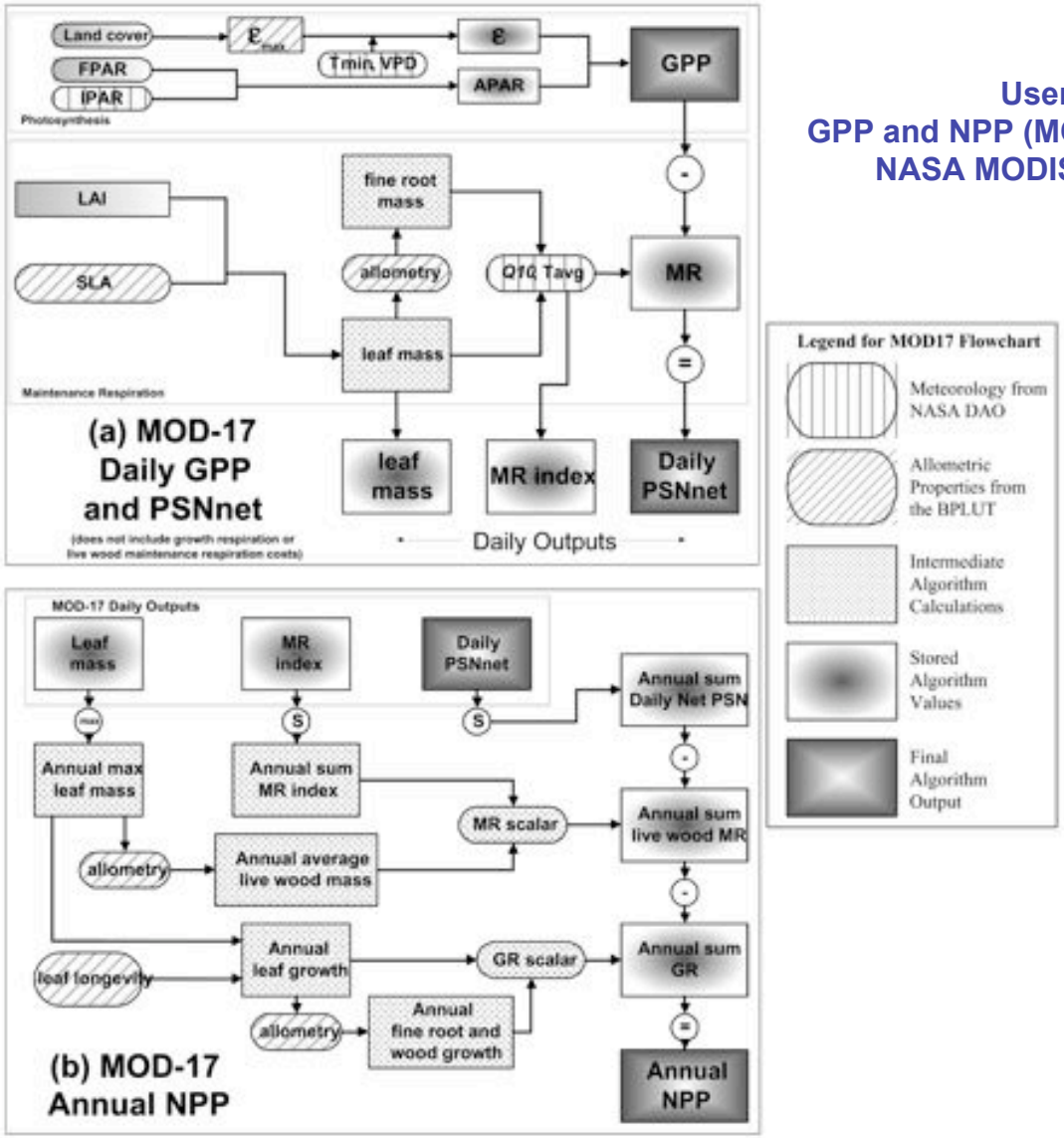
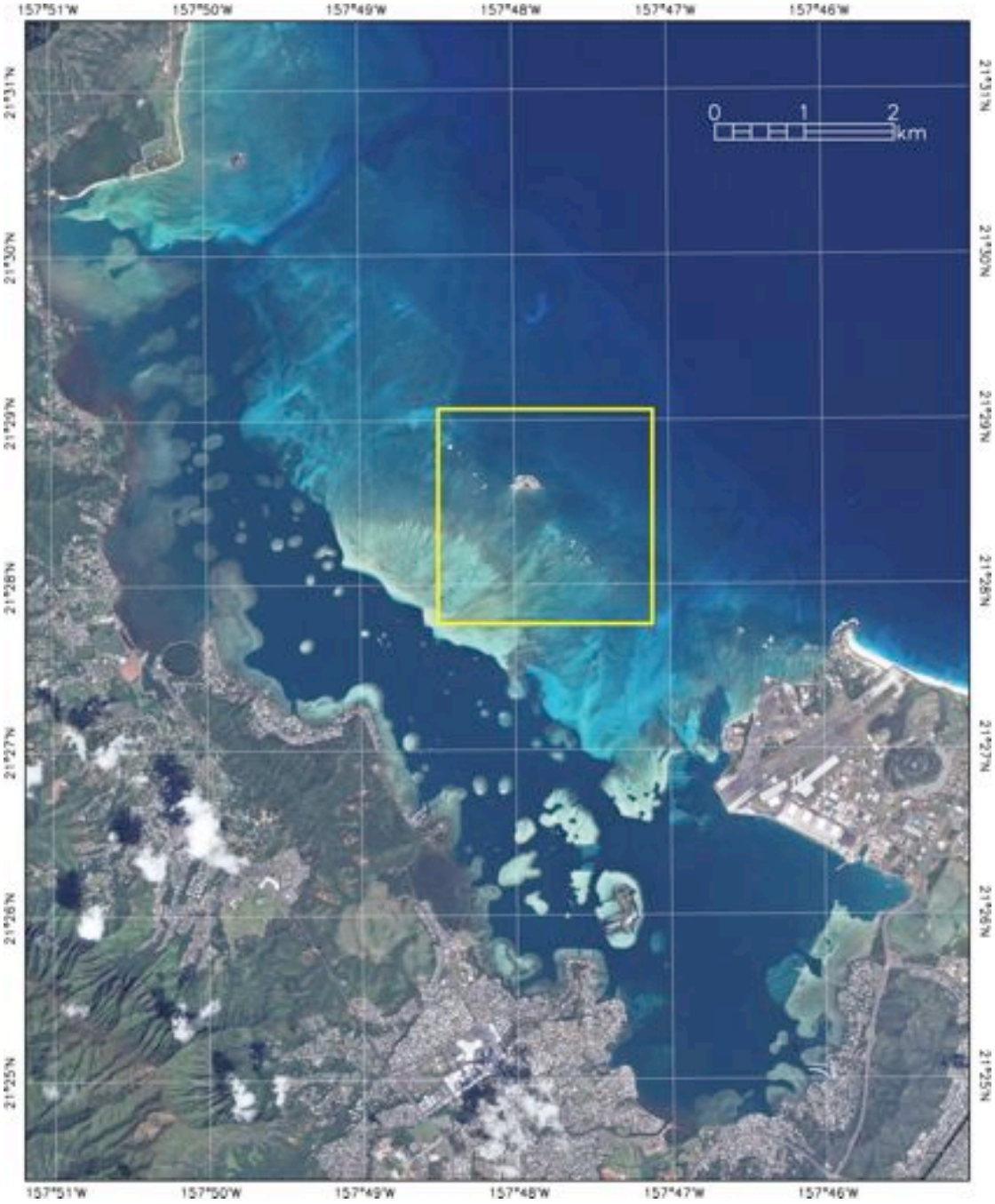
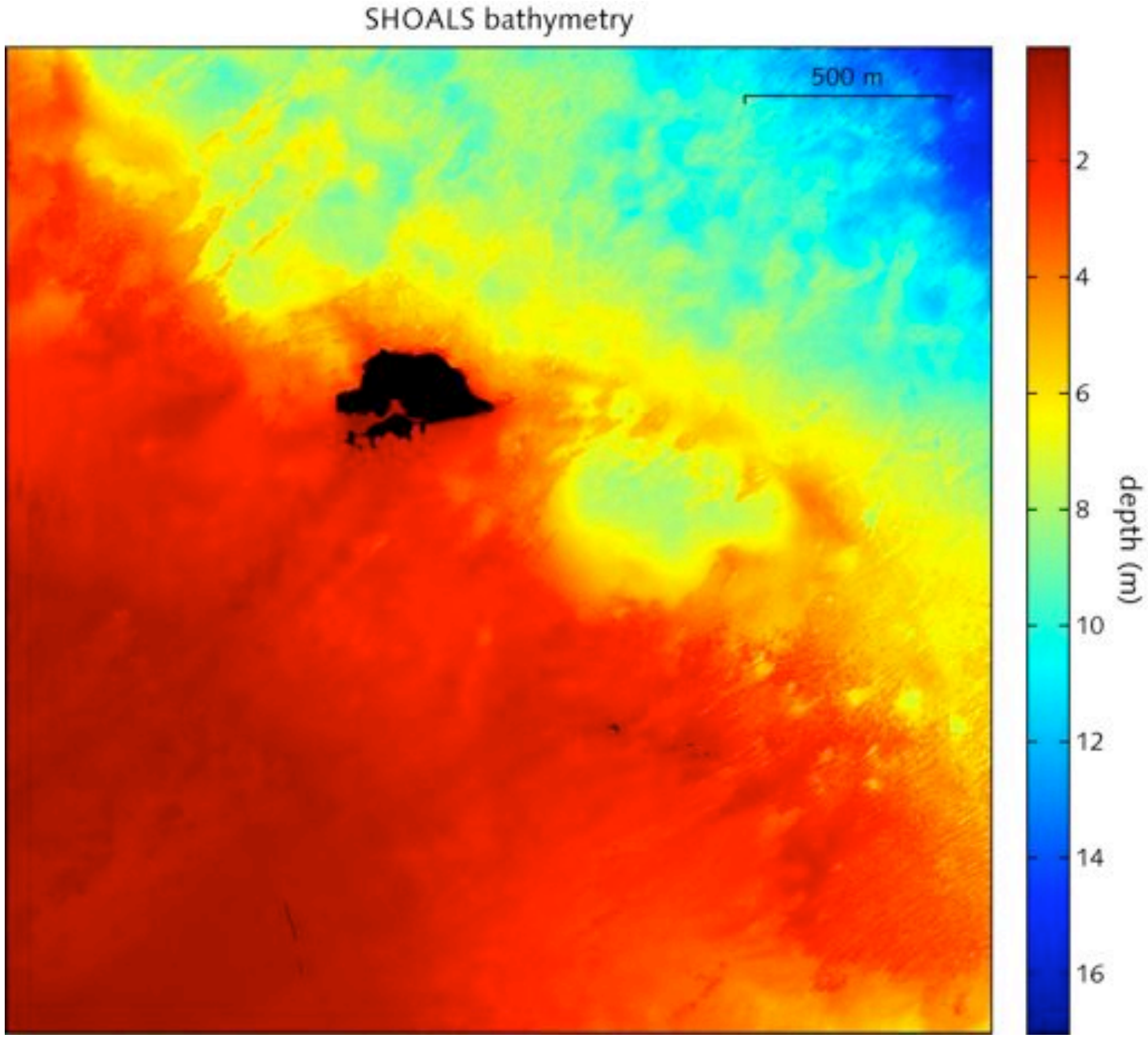


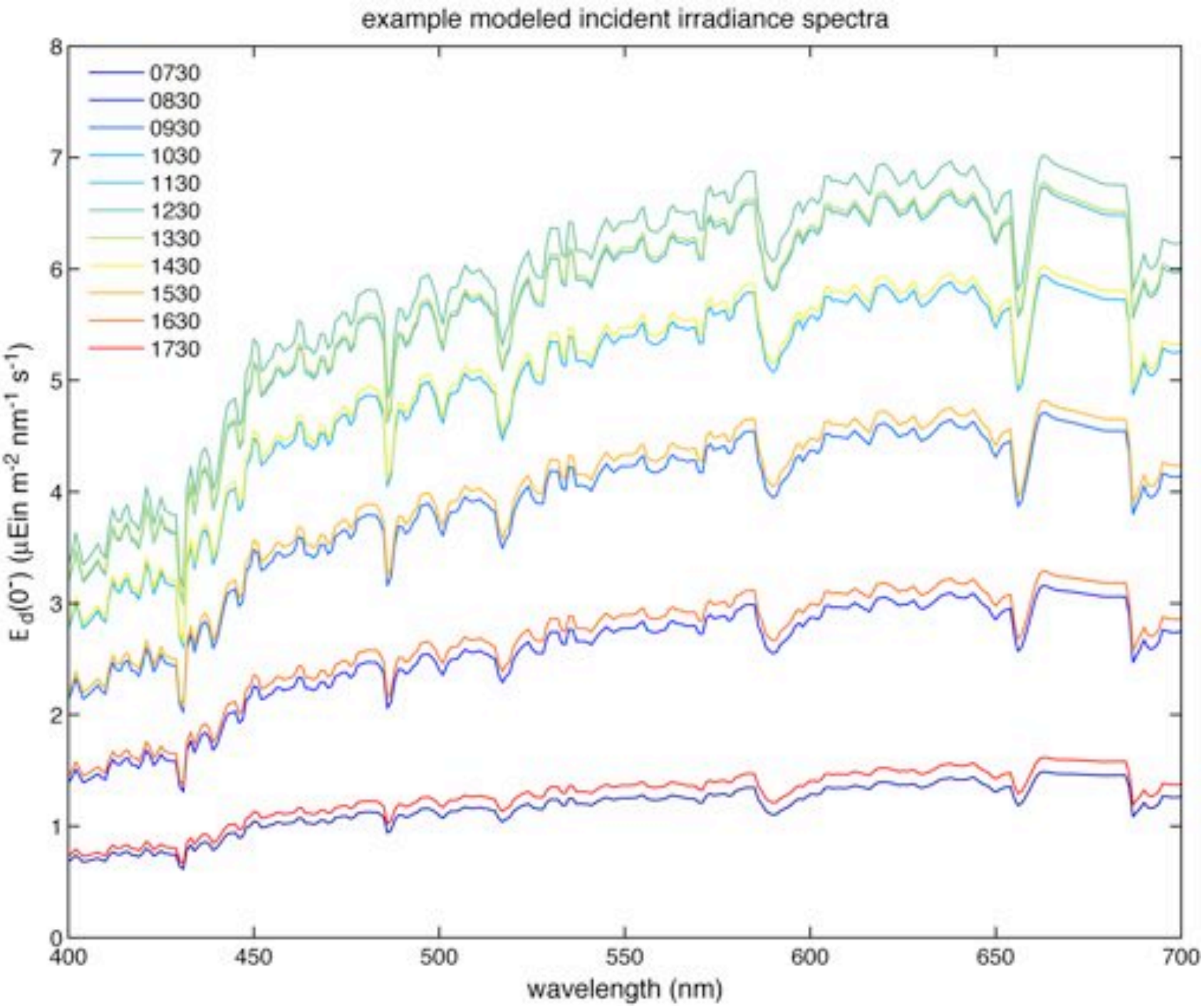
Figure 1.1. Flowcharts showing the logic behind the MOD17 Algorithm in calculating both (a) 8-day average GPP and (b) annual NPP.

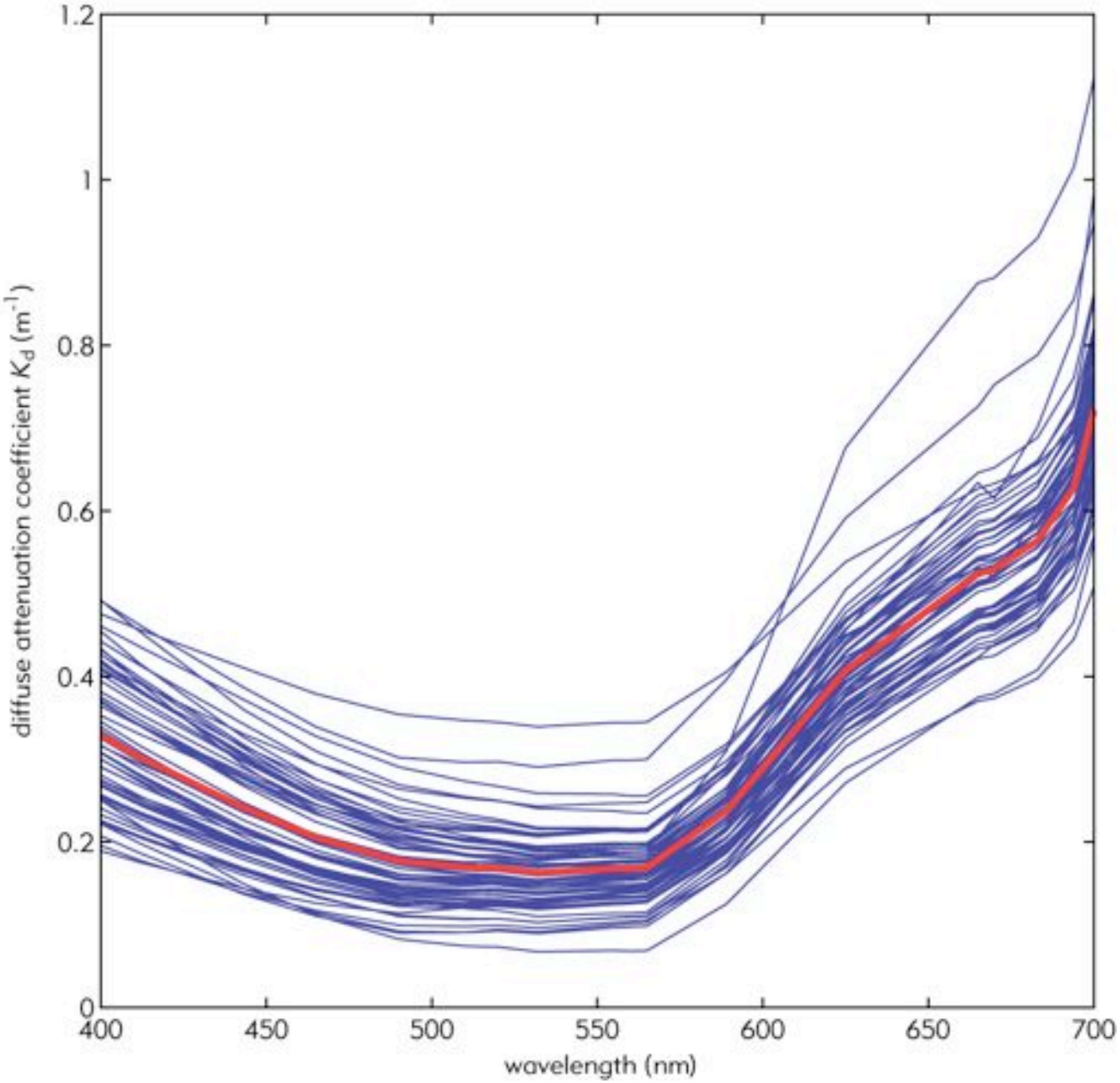

157°51'W
157°50'W
157°49'W
157°48'W
157°47'W
157°46'W
21°31'N
21°30'N
21°29'N
21°28'N
21°27'N
21°26'N
21°25'N
0
1
2
km

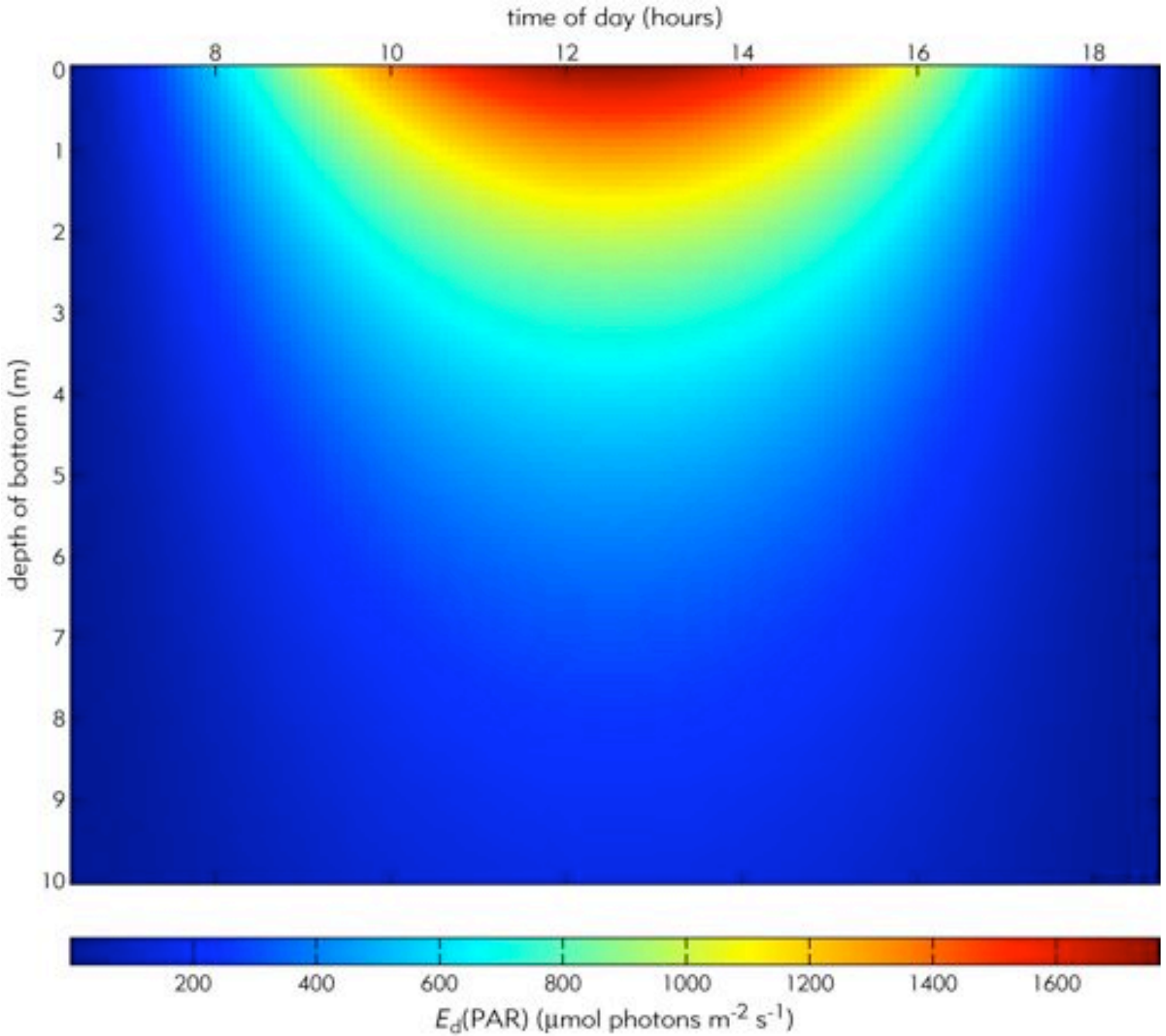
500 m


SHOALS bathymetry
500 m
2
4
6
8
10
12
14
16
depth (m)

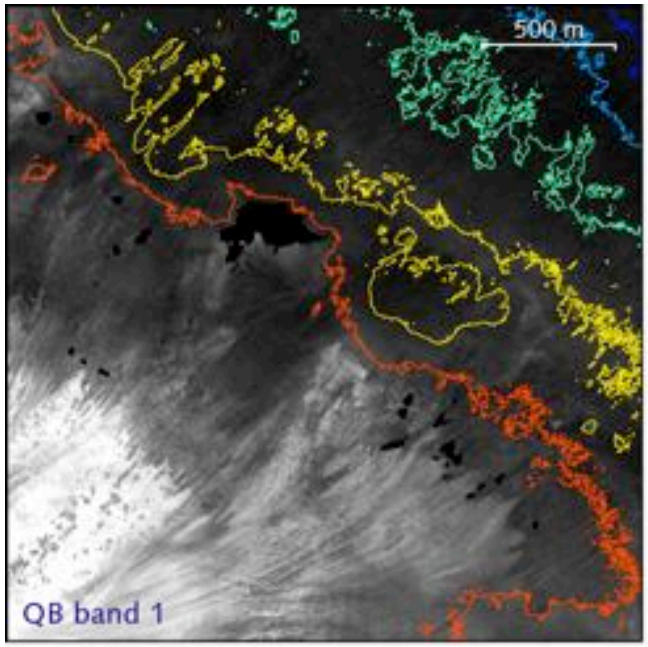
$$GPP = E_d \times A \times \varepsilon$$

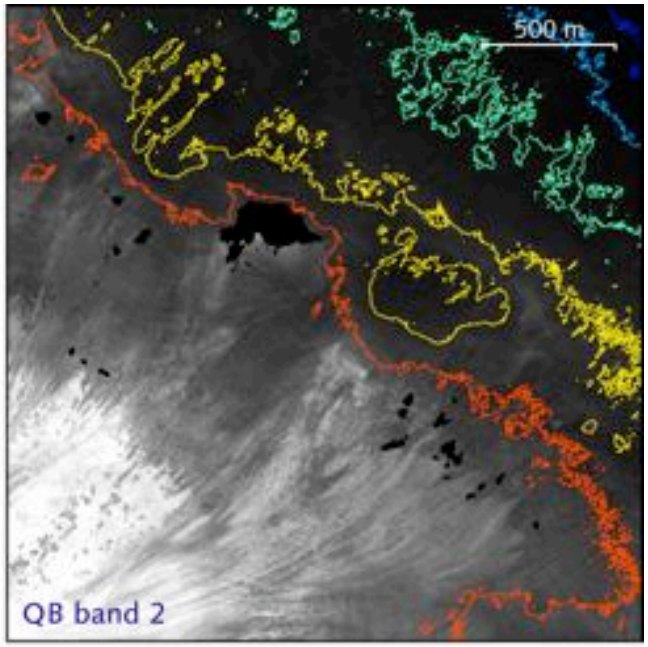

example modeled incident irradiance spectra
0730
0830
0930
1030
1130
1230
1330
1430
1530
1630
1730
$E_d(0^-)$ (µEin m^{-2} nm^{-1} s^{-1})
wavelength (nm)
0
1
2
3
4
5
6
7
8
400
450
500
550
600
650
700

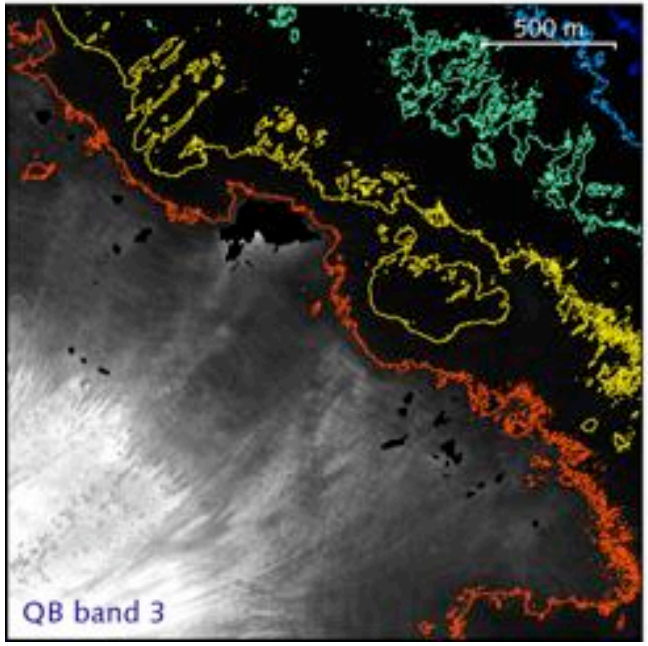

1.2
1
0.8
0.6
0.4
0.2
0
400
450
500
550
600
650
700
diffuse attenuation coefficient K_d (m^{-1})
wavelength (nm)


time of day (hours)
8
10
12
14
16
18
depth of bottom (m)
0
1
2
3
4
5
6
7
8
9
10
200
400
600
800
1000
1200
1400
1600
E_d(PAR) (µmol photons m^{-2} s^{-1})

$$GPP = E_d \times A \times \varepsilon$$



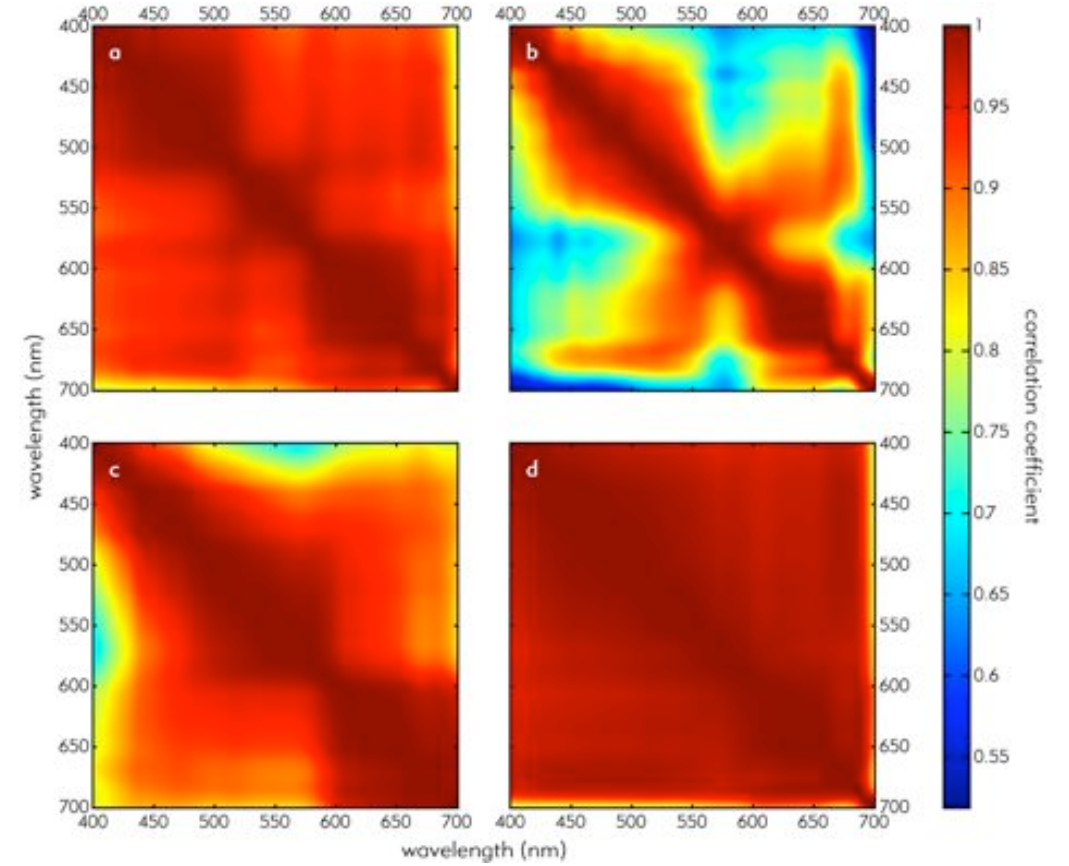


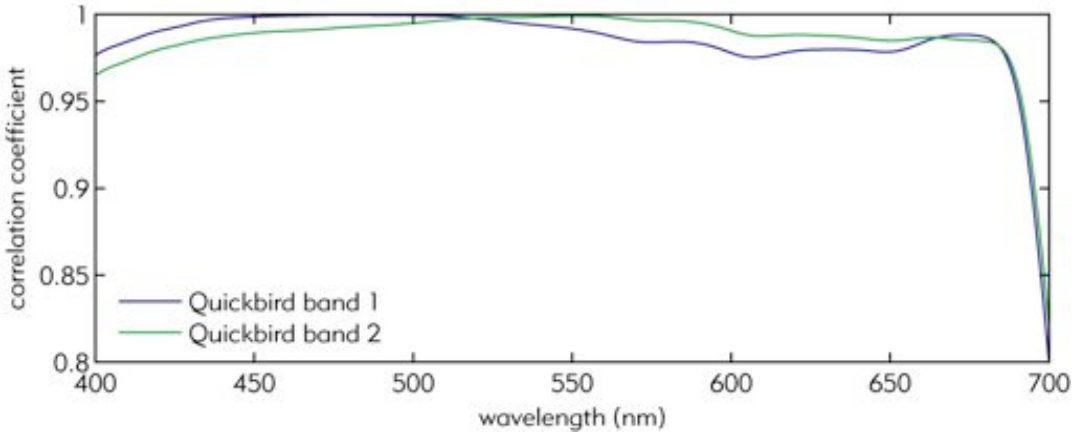


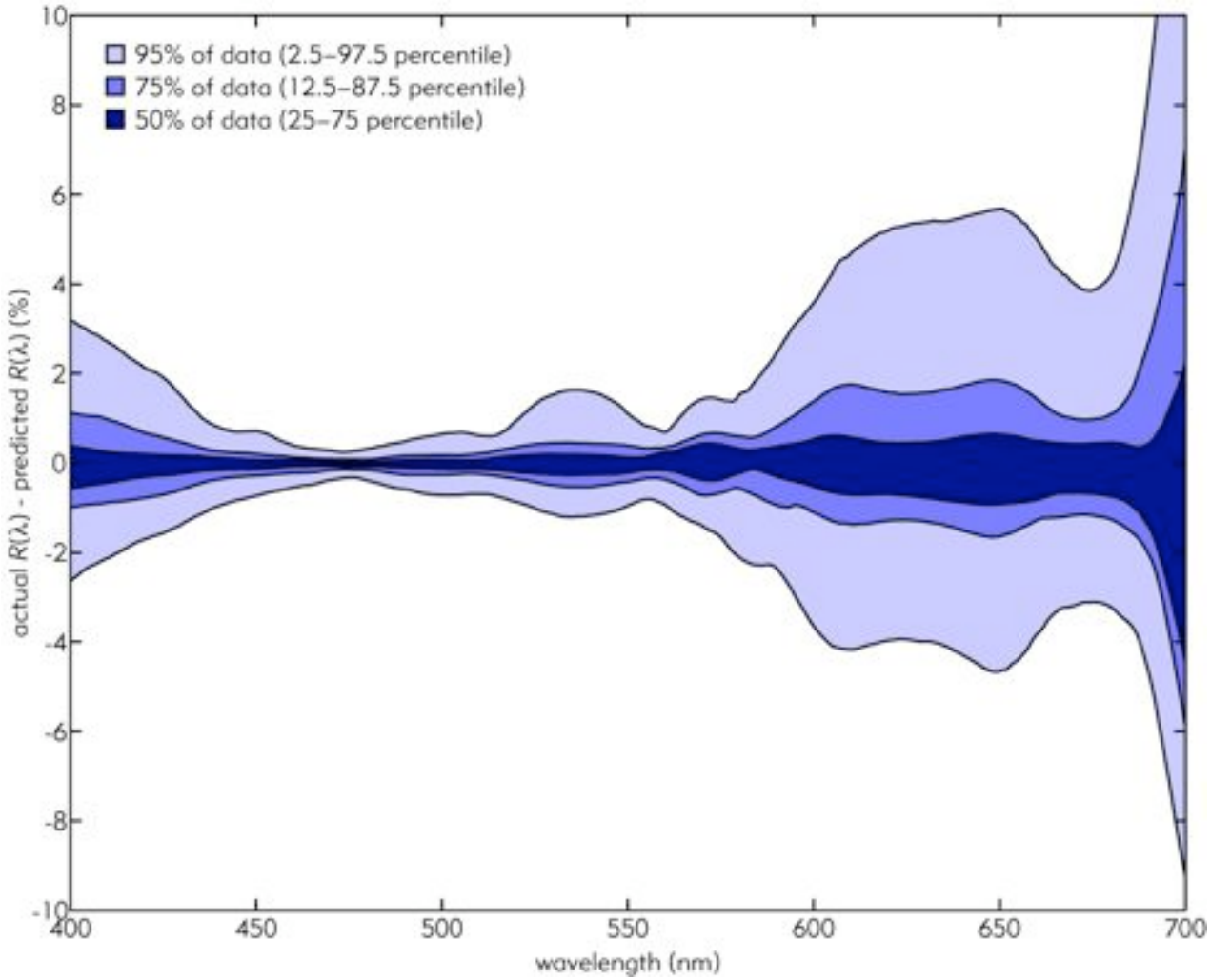
3 m
6 m
9 m
12 m
15 m

Depths of Penetration

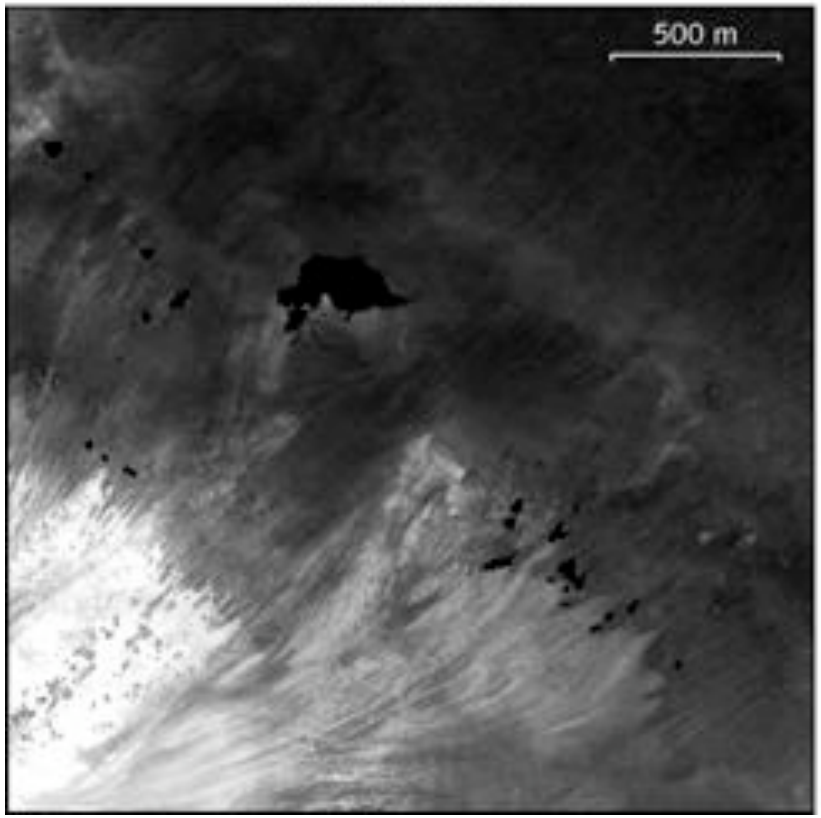
Band 1	>40 m
Band 2	>25 m
Band 3	~5 m


a
b
c
d
wavelength (nm)
wavelength (nm)
correlation coefficient
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
400
450
500
550
600
650
700

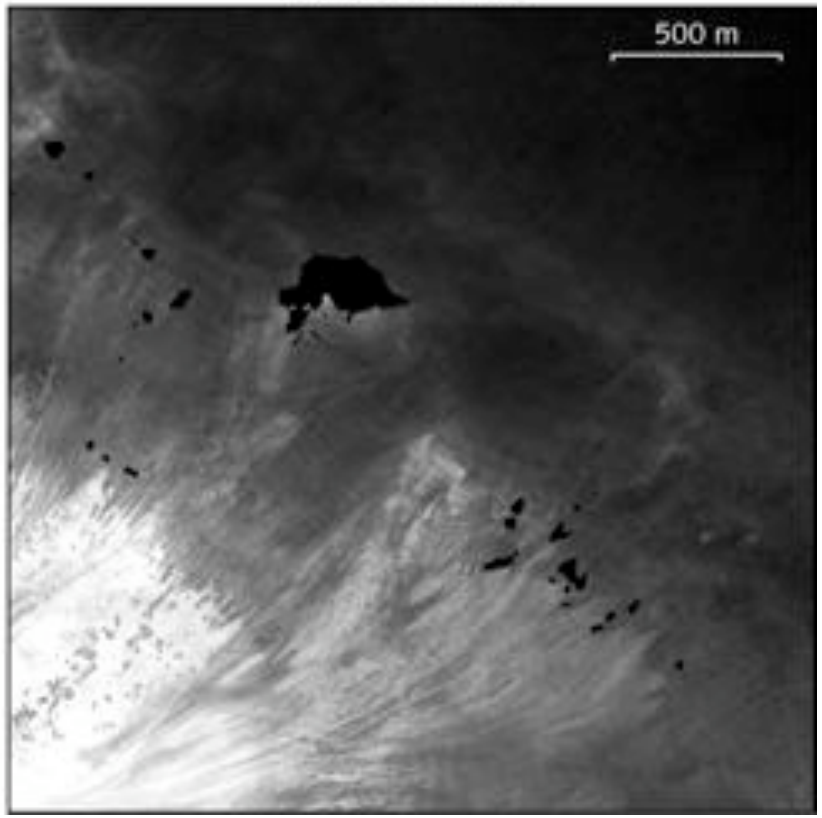

correlation coefficient
wavelength (nm)
Quickbird band 1
Quickbird band 2
1
0.95
0.9
0.85
0.8
400
450
500
550
600
650
700


95% of data (2.5–97.5 percentile)
75% of data (12.5–87.5 percentile)
50% of data (25–75 percentile)
actual R(λ) - predicted R(λ) (%)
wavelength (nm)
10
8
6
4
2
0
-2
-4
-6
-8
-10
400
450
500
550
600
650
700

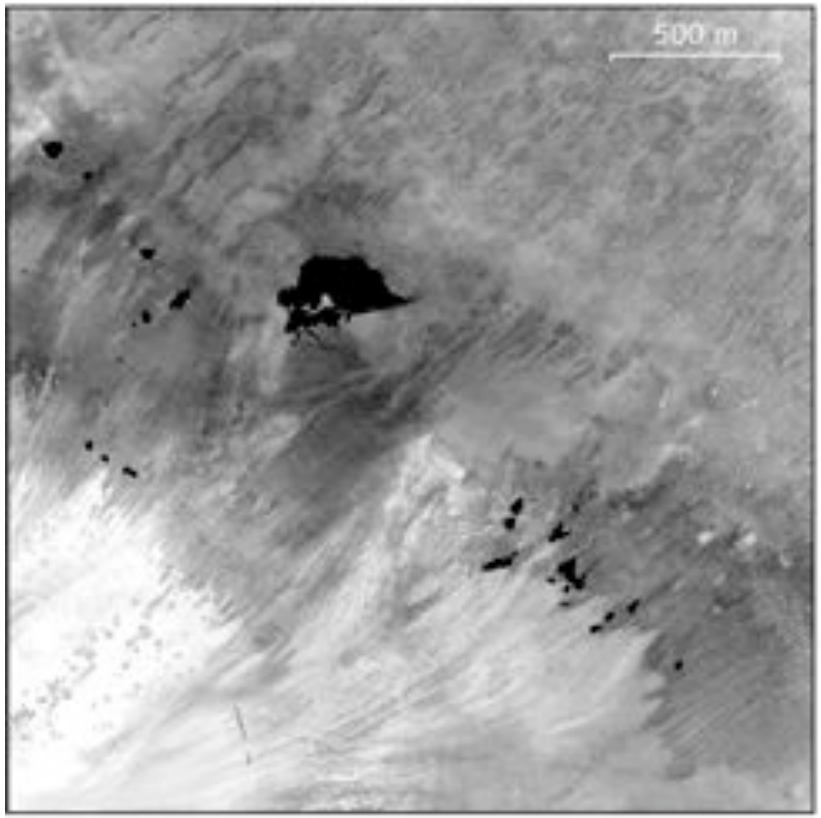
Quickbird Band 1



Quickbird Band 2



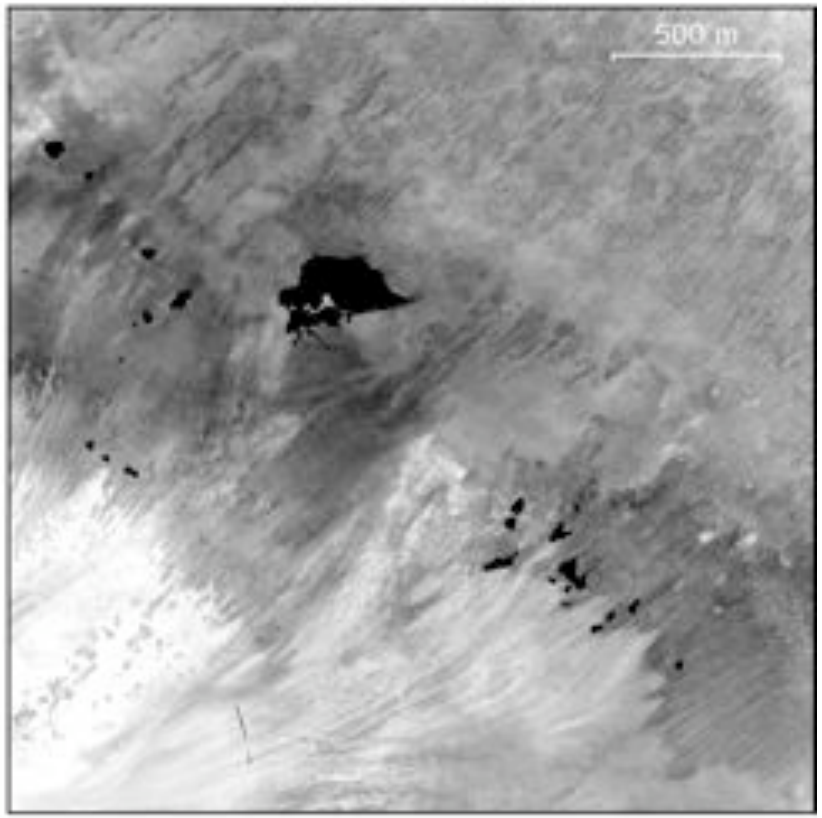
Quickbird Band 1



0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5

reflectance

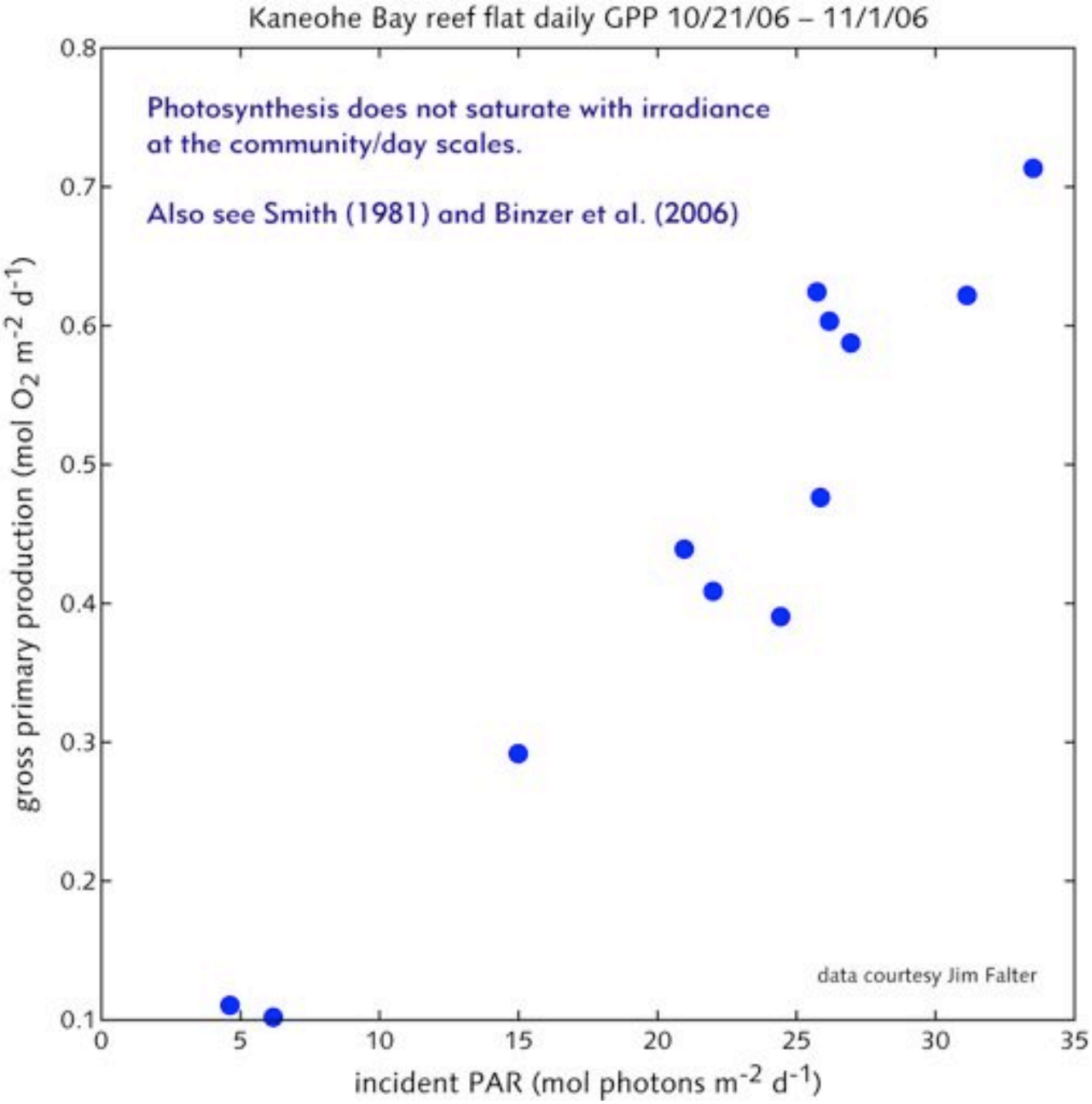
Quickbird Band 2

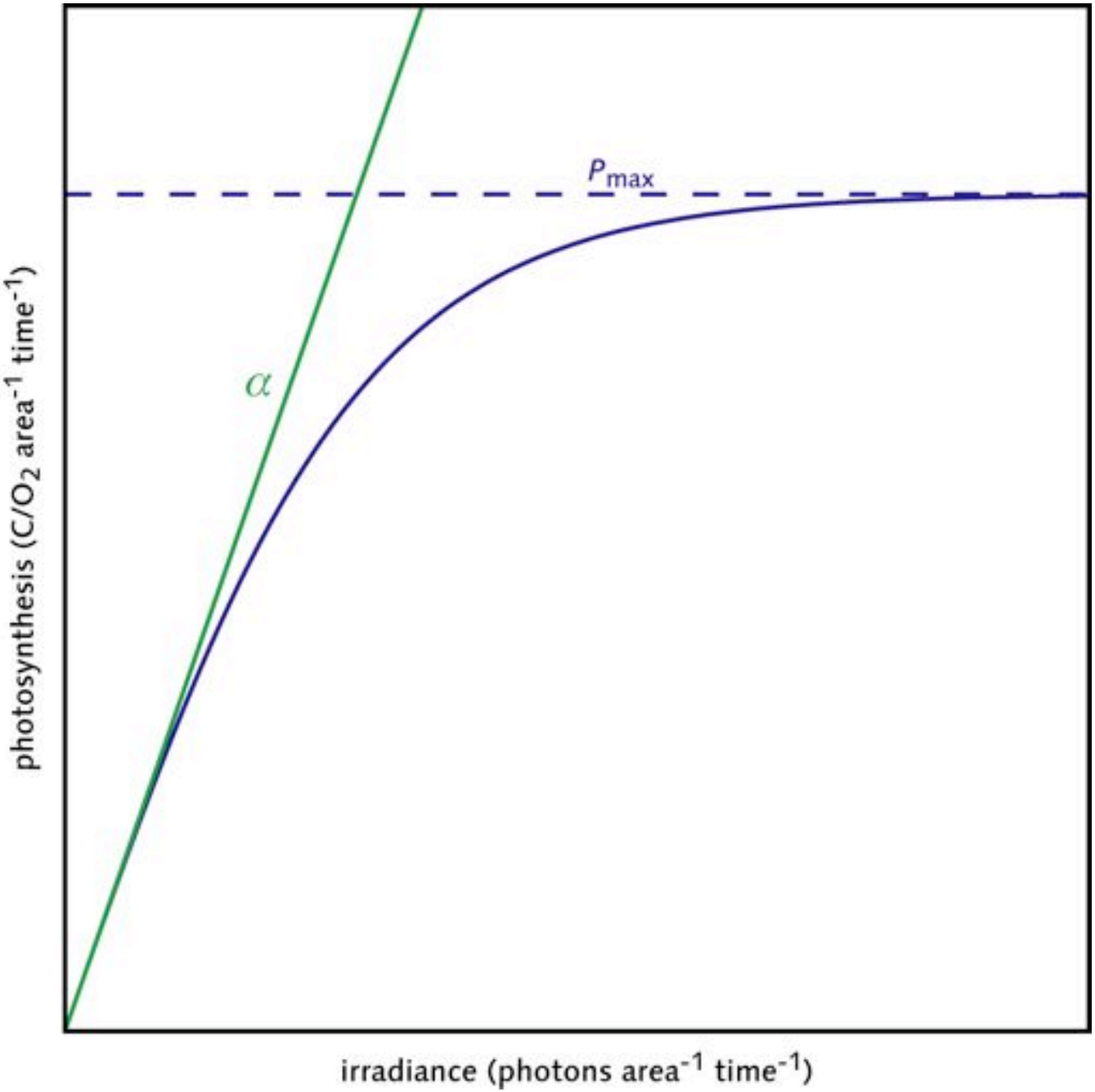


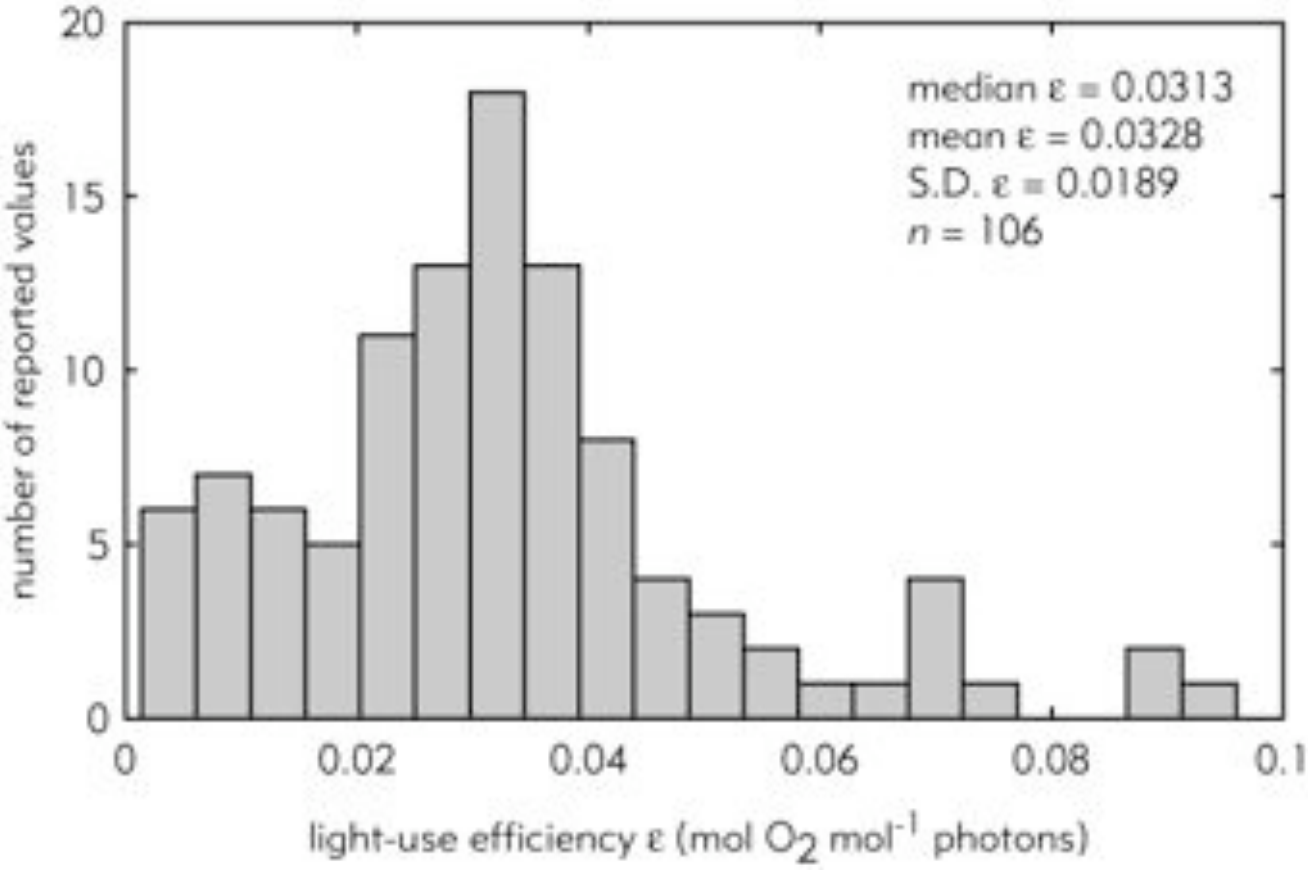
0.2 0.3 0.4 0.5 0.6

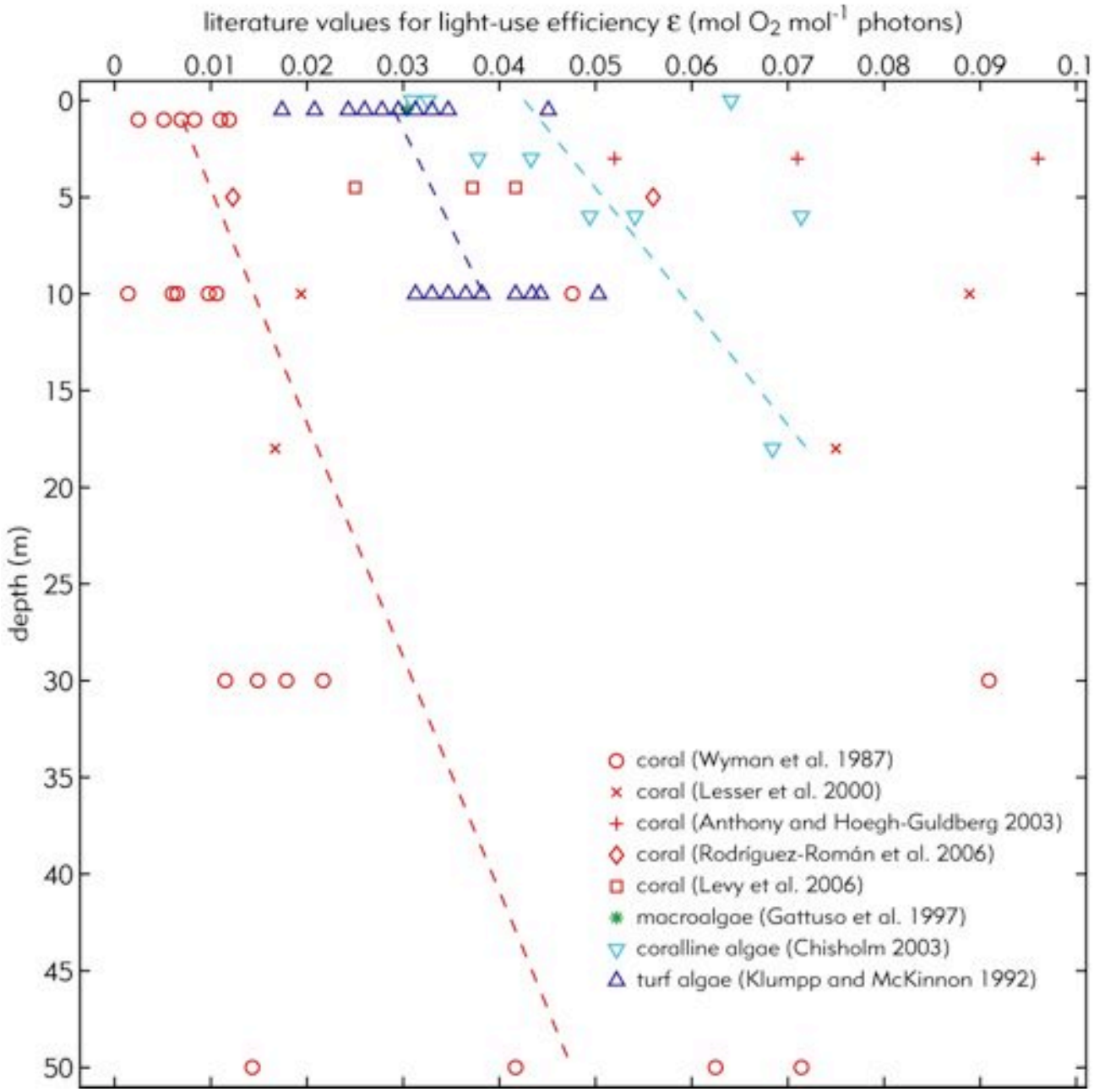
reflectance

$$GPP = E_d \times A \times \varepsilon$$


Kaneohe Bay reef flat daily GPP 10/21/06 – 11/1/06
Photosynthesis does not saturate with irradiance
at the community/day scales.
Also see Smith (1981) and Binzer et al. (2006)
data courtesy Jim Falter
gross primary production (mol O2 m-2 d-1)
incident PAR (mol photons m-2 d-1)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
35

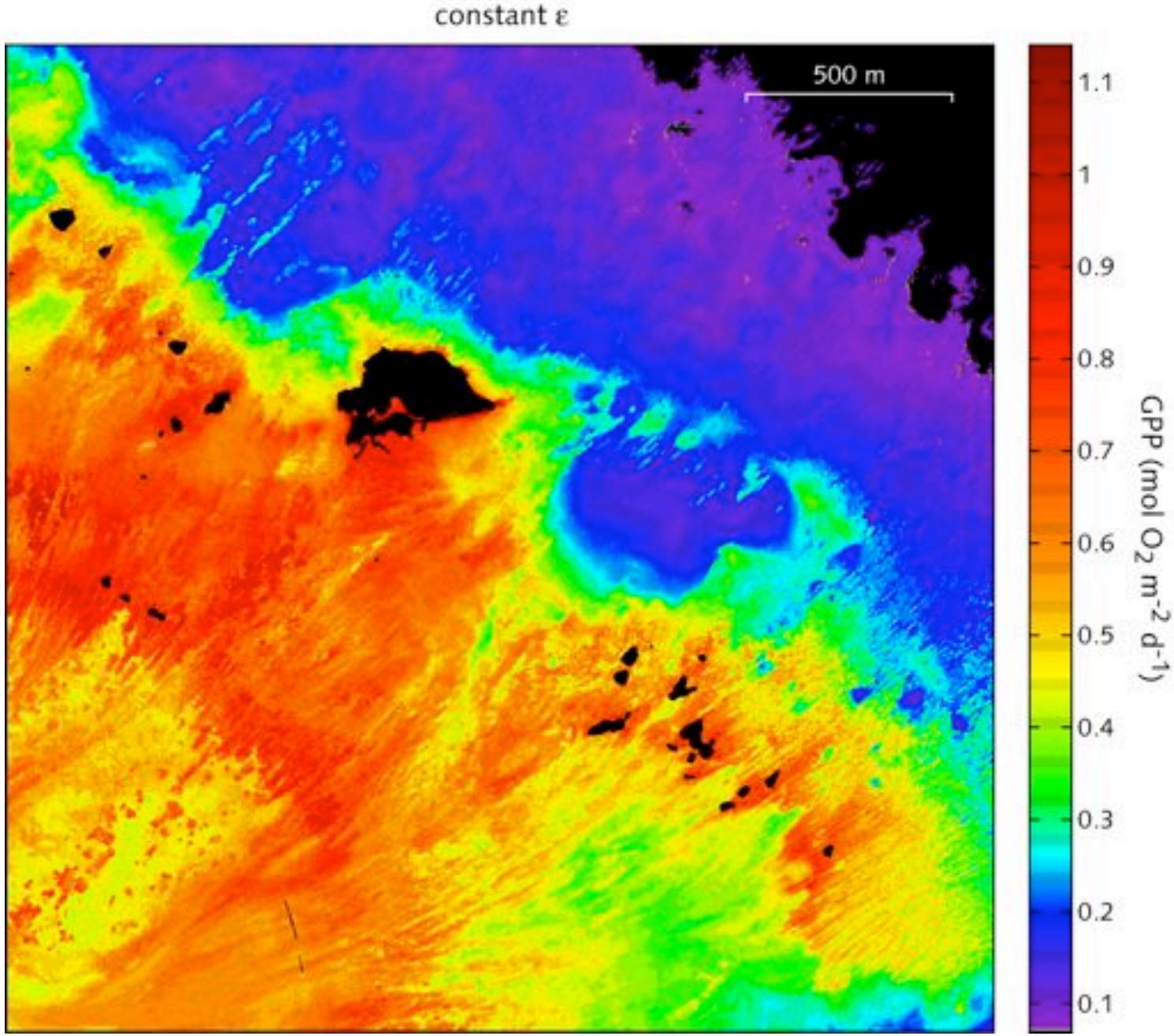

P_{max}
α
photosynthesis (C/O_2 area^{-1} time^{-1})
irradiance (photons area^{-1} time^{-1})

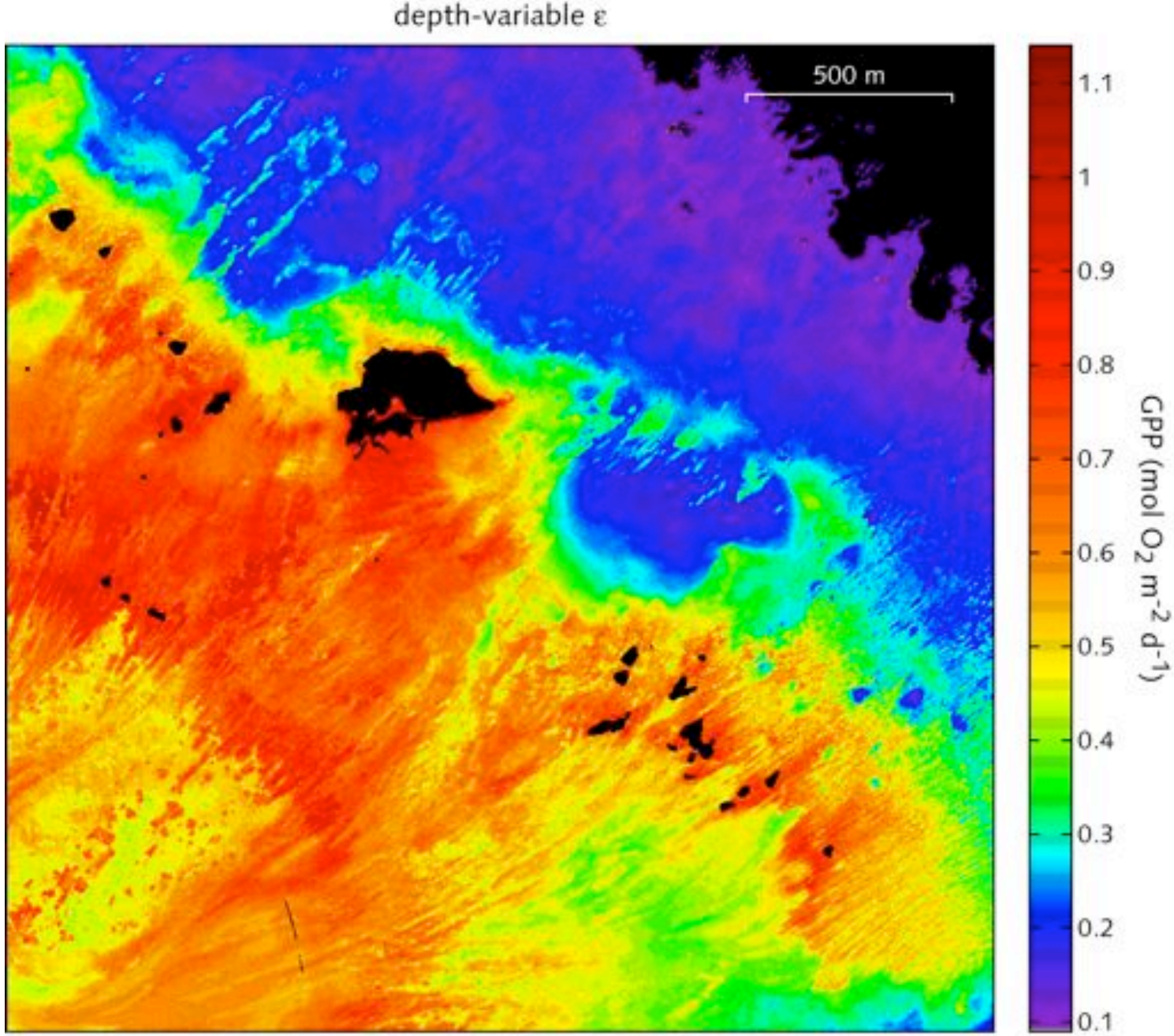

median ε = 0.0313
mean ε = 0.0328
S.D. ε = 0.0189
n = 106
number of reported values
light-use efficiency ε (mol O2 mol-1 photons)
0
5
10
15
20
0
0.02
0.04
0.06
0.08
0.1

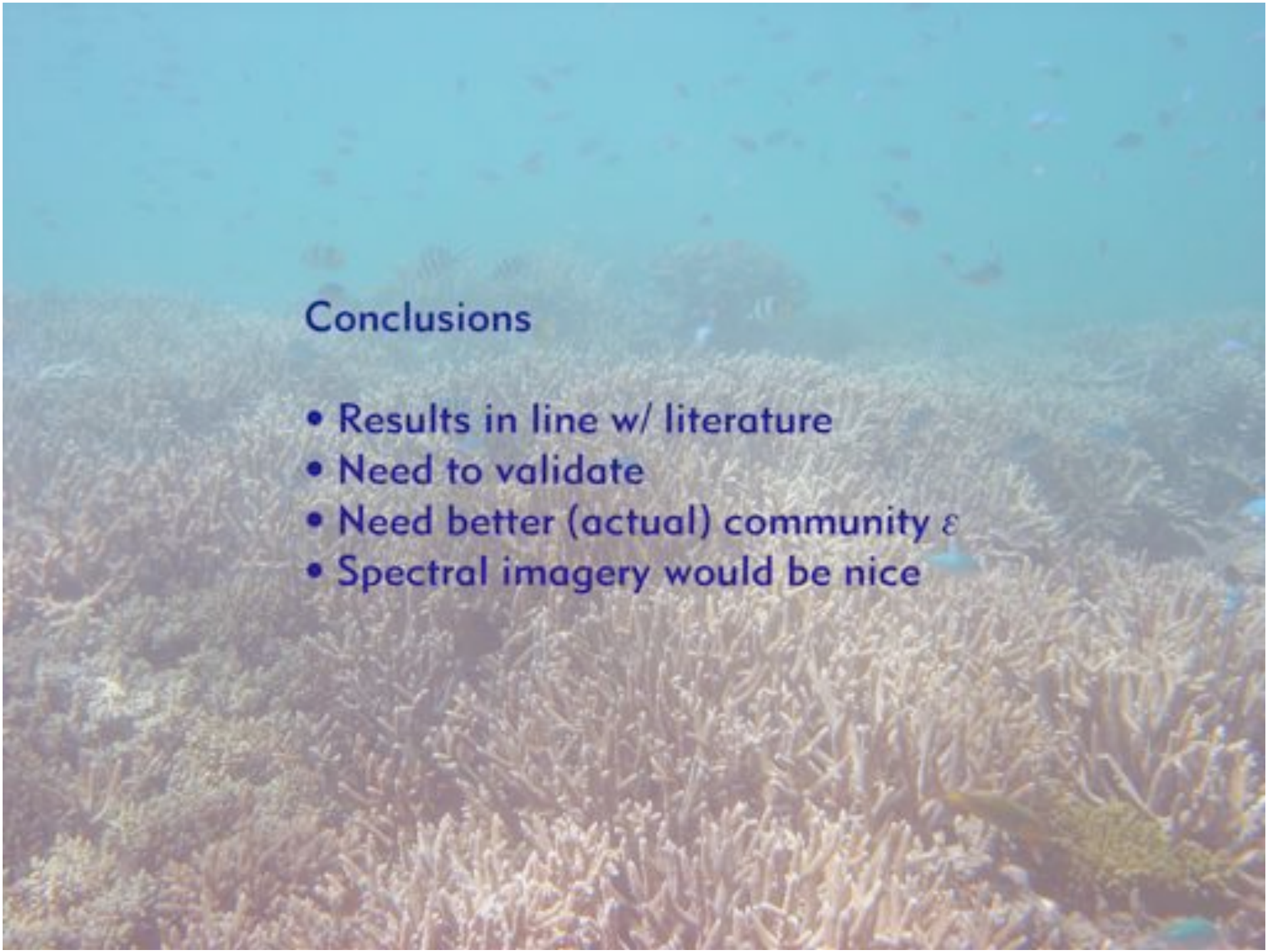

literature values for light-use efficiency ε (mol O_2 mol^{-1} photons)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
depth (m)
0
5
10
15
20
25
30
35
40
45
50
coral (Wyman et al. 1987)
coral (Lesser et al. 2000)
coral (Anthony and Hoegh-Guldberg 2003)
coral (Rodriguez-Román et al. 2006)
coral (Levy et al. 2006)
macroalgae (Gattuso et al. 1997)
coralline algae (Chisholm 2003)
turf algae (Klumpp and McKinnon 1992)

$$GPP = E_d \times A \times \varepsilon$$

500 m
30
25
20
15
10
5
absorbed quanta (mol photons m-2 d-1)


constant ε
500 m
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
GPP (mol O2 m-2 d-1)


depth-variable ε
500 m
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
GPP (mol O2 m-2 d-1)


Conclusions
• Results in line w/ literature
• Need to validate
• Need better (actual) community ε
• Spectral imagery would be nice