The effects of phytoplankton absorption and scattering on forward and inversion modeling

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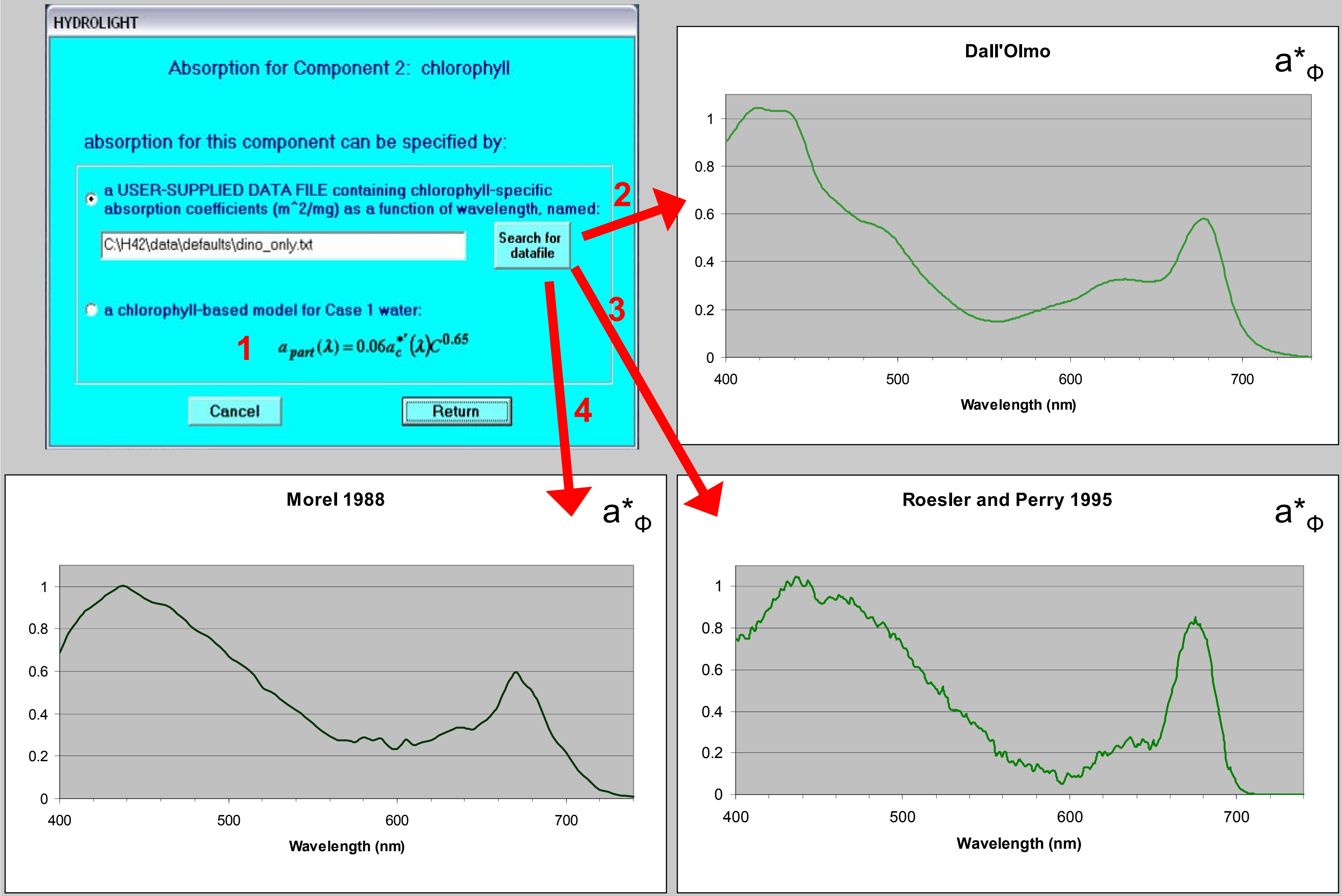
Ocean Optics 2004:

Radiative Transfer and Inversions of
Ocean Color Remote Sensing

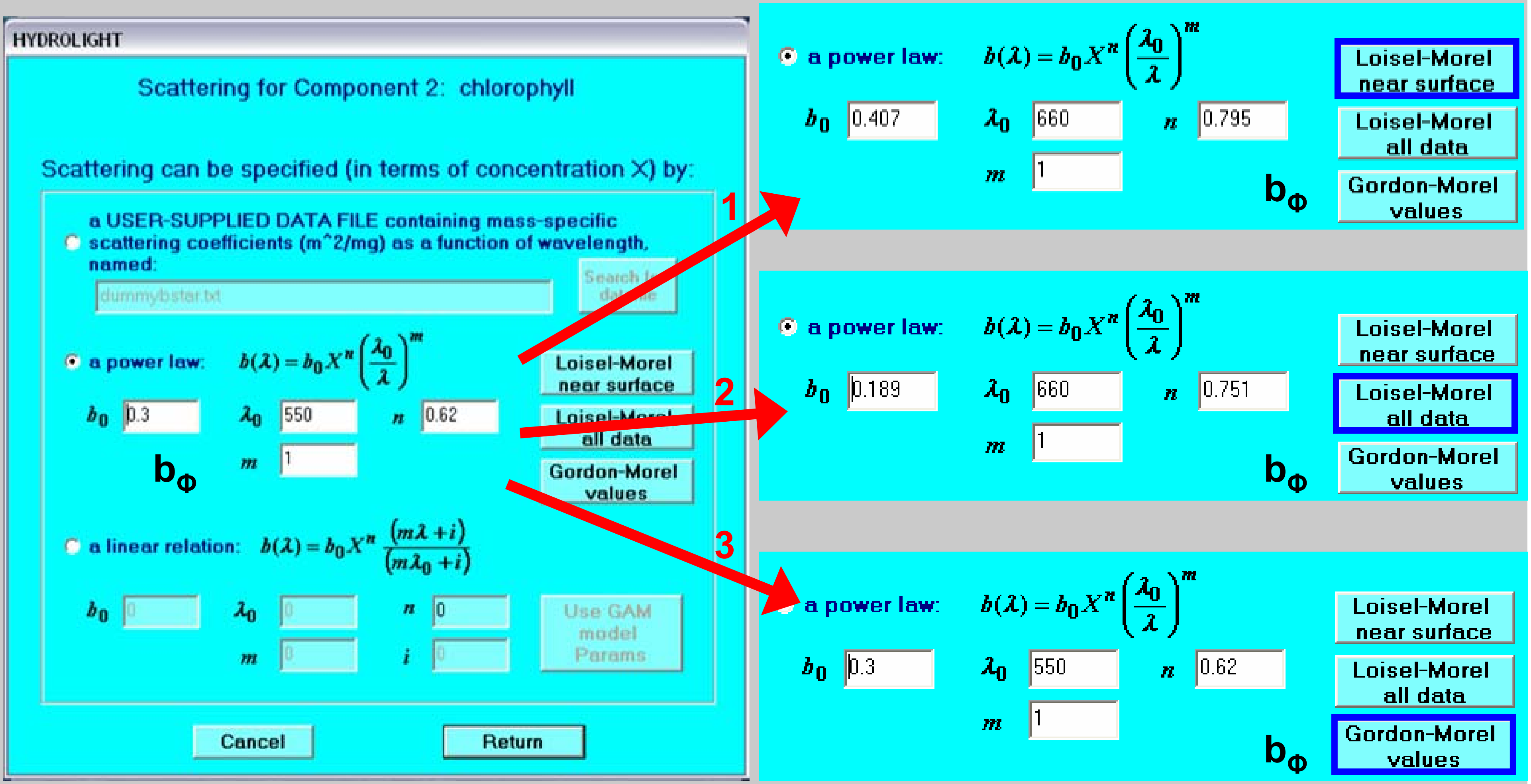
Forward model

- Hydrolight – ABCASE2
- Pope and Frey 1997
- Bb_{Φ}/b_{Φ} = 0.015
- a_{cdm} = 0.05
- Minerals = 0
- Infinite depth
- Sun 30^{o}, 0% clouds
- 400-700nm every 10nm, 700-750 every 2nm

Chlorophyll absorption

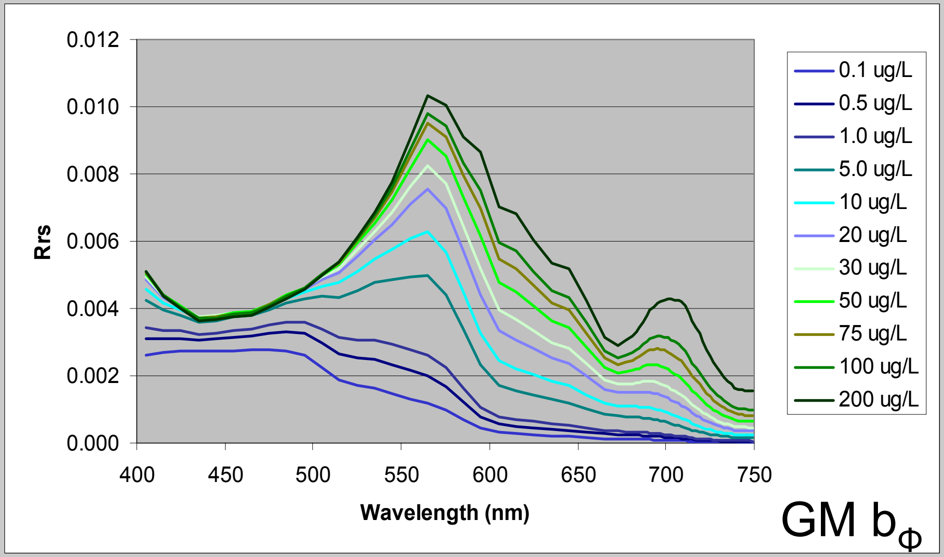


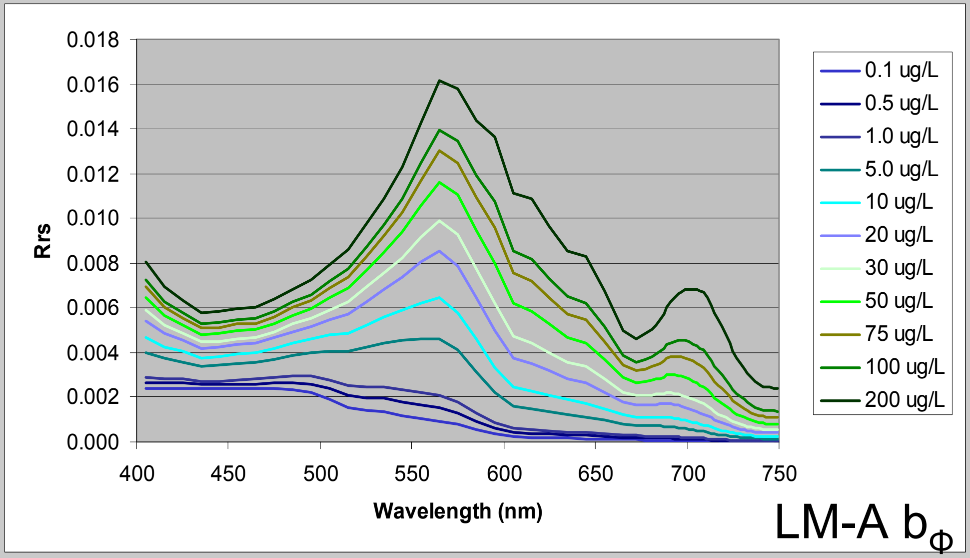
Chlorophyll scattering

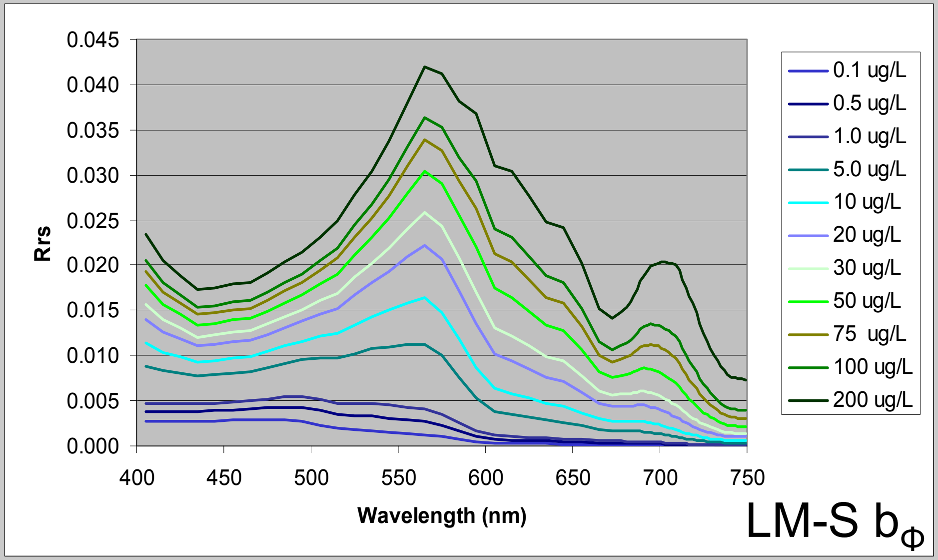


	C1 a^*_Φ			M a^*_Φ	RP a^*_Φ	D a^*_Φ
Chl (μg/L)	LM-S b_Φ	LM-A b_Φ	GM b_Φ	LM-S b_Φ		
0.1	X	X	X	X	X	X
0.5	X	X	X	X	X	X
1	X	X	X	X	X	X
5	X	X	X	X	X	X
10	X	X	X	X	X	X
20	X	X	X	X	X	X
30	X	X	X	X	X	X
50	X	X	X	X	X	X
75	X	X	X	X	X	X
100	X	X	X	X	X	X
200	X	X	X	X	X	X

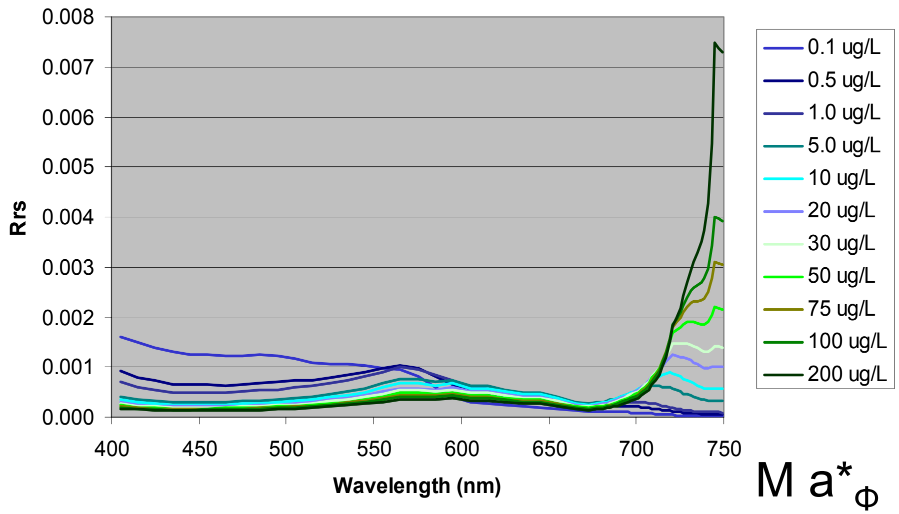
C1 a^*_Φ


0.012
0.010
0.008
0.006
0.004
0.002
0.000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
GM bΦ

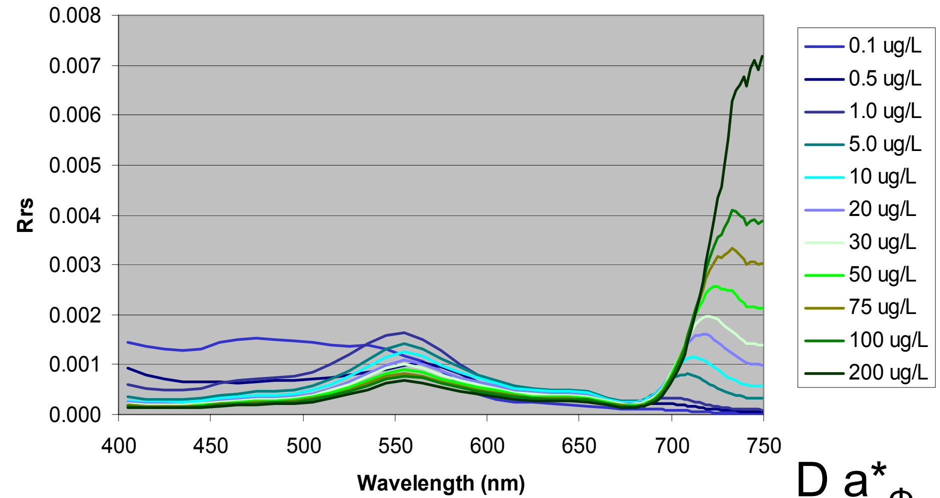

0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
LM-A bΦ


0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
LM-S bΦ

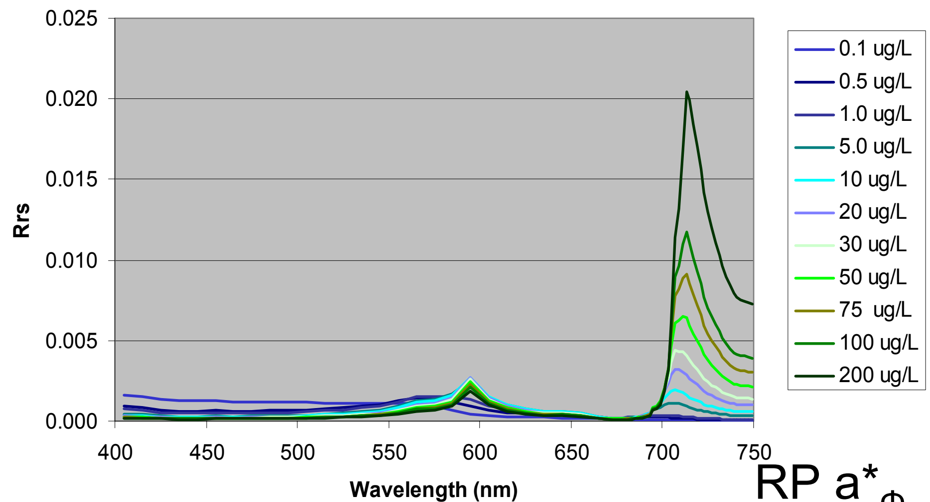
LM-S b_{Φ}



M a^*_{Φ}

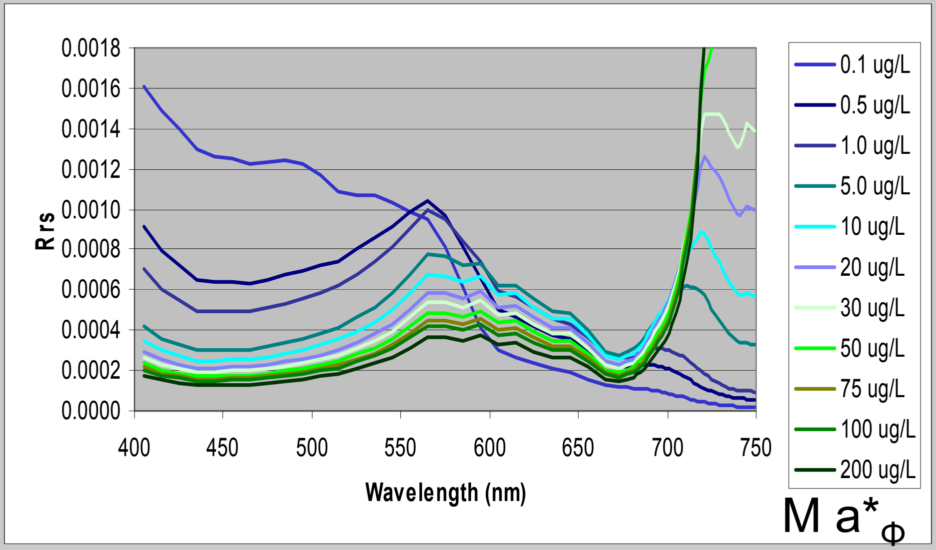


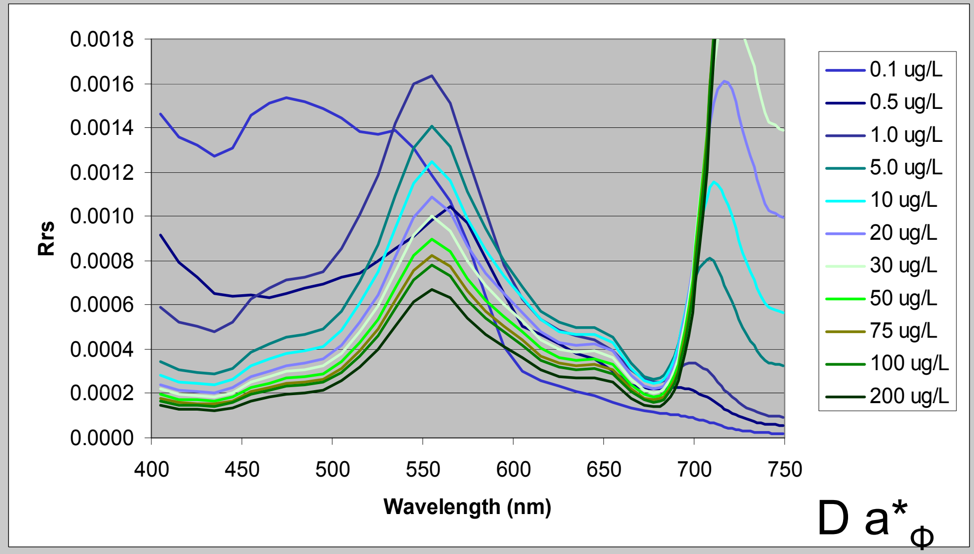
D a^*_{Φ}

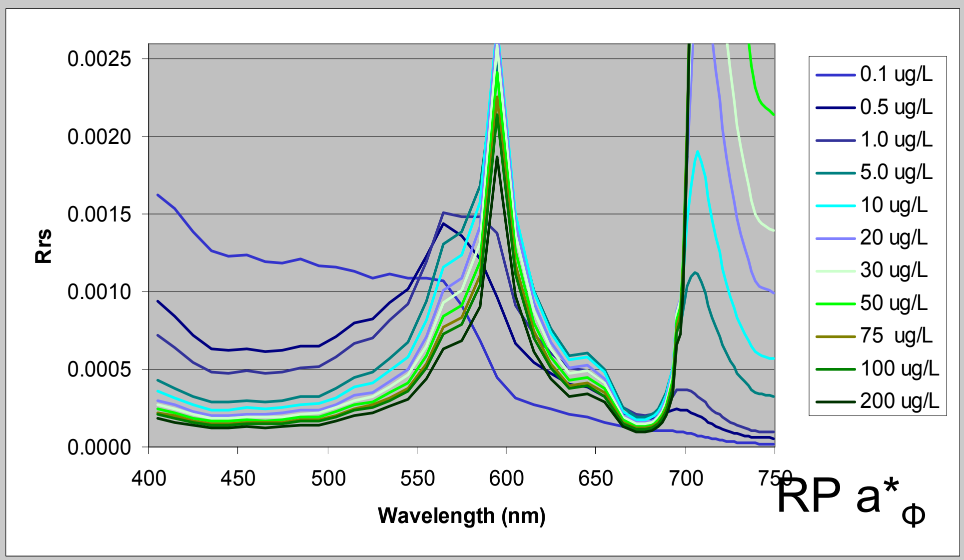


RP a^*_{Φ}

LM-S b_{Φ}


0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
M a^*_{Φ}


0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
D a^*_{Φ}


0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Rrs
400
450
500
550
600
650
700
750
Wavelength (nm)
0.1 ug/L
0.5 ug/L
1.0 ug/L
5.0 ug/L
10 ug/L
20 ug/L
30 ug/L
50 ug/L
75 ug/L
100 ug/L
200 ug/L
RP a^*_{Φ}

Inverse models

- Band ratios
  - SeaWIFS OC4.4, MODIS 3, 21-26, 21-27

- Inversion model
  - a^*_{Φ} from Roesler *et al.* 1989

Band ratios

M ODIS OC3M **(M3)**

$$C_a = 10.0^{(0.2830 - 2.753R_{3M} + 1.457R_{3M}^2 + 0.659R_{3M}^3 - 1.403R_{3M}^4)}$$

where $R_{3M} = \log_{10}(R_{550}^{443} > R_{550}^{490})$

M ODIS MOD 21, 26 **(M21-26)**
(O'Reilly et al. 2000)

$$\text{chlor\_a\_2} = 10^{(0.2830-2.753X+1.457X^2+0.659X^3-1.403X^4)}$$

$X = \log_{10}[\max(r_{25}, r_{35})]$ where $r_{25} = R_{rs}(443)/R_{rs}(551)$, $r_{35} = R_{rs}(488)/R_{rs}(551)$

M ODIS MOD 21, 27 **(M21-26)**
(O'Reilly et al. 2000)

$$\text{chlor\_a\_3} = 10^{(0.289-3.20X+1.2X^2)}$$

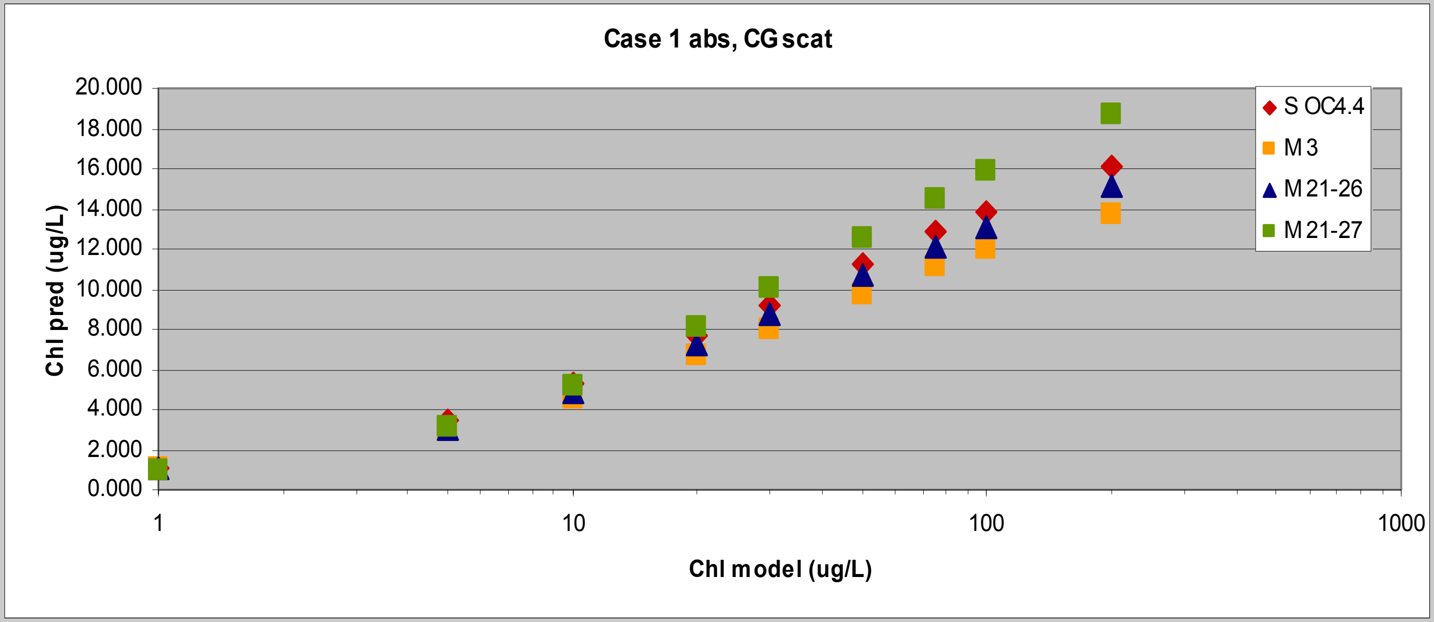
where $X = \log_{10}[R_{rs}(488)/R_{rs}(551)]$

SeaWiFS OC4v4 **(SOC4.4)**
(O'Reilly et al. 2000)

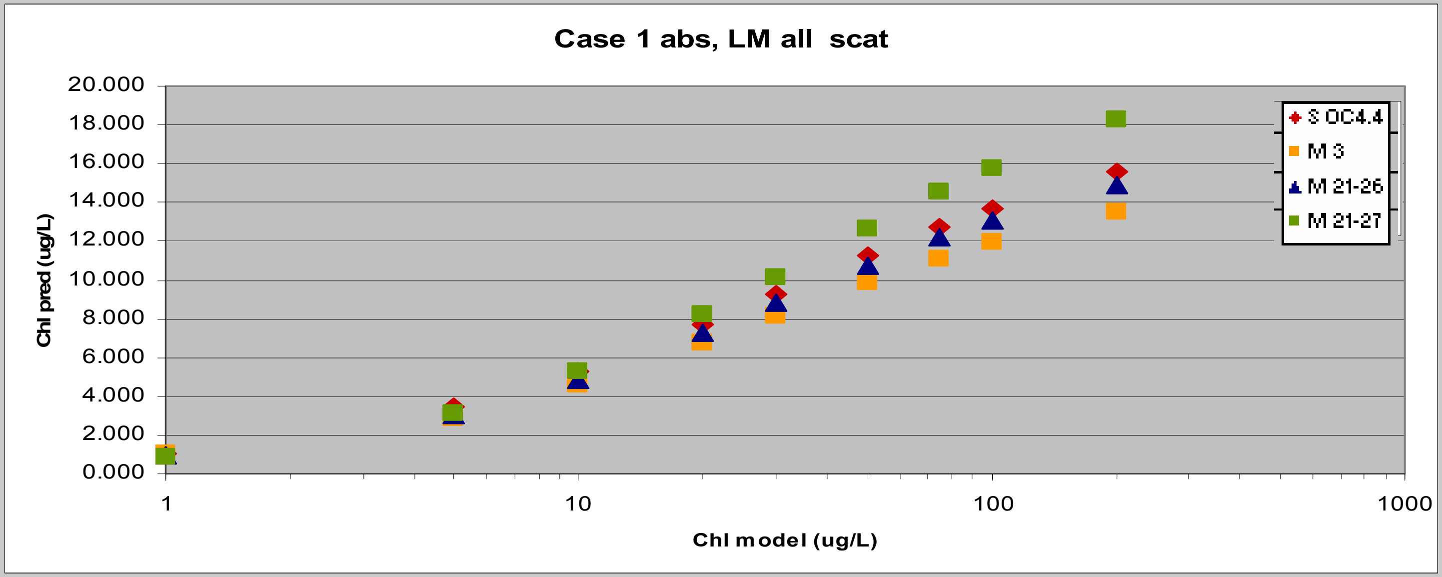
$$\text{chlor\_OC4v4} = 10^{(0.366-3.067X+1.930X^2+0.649X^3-1.532X^4)}$$

$X = \log_{10}\{\max[R_{rs}(443)/R_{rs}(555), R_{rs}(490)/R_{rs}(555), R_{rs}(510)/R_{rs}(555)]\}$

Band ratios

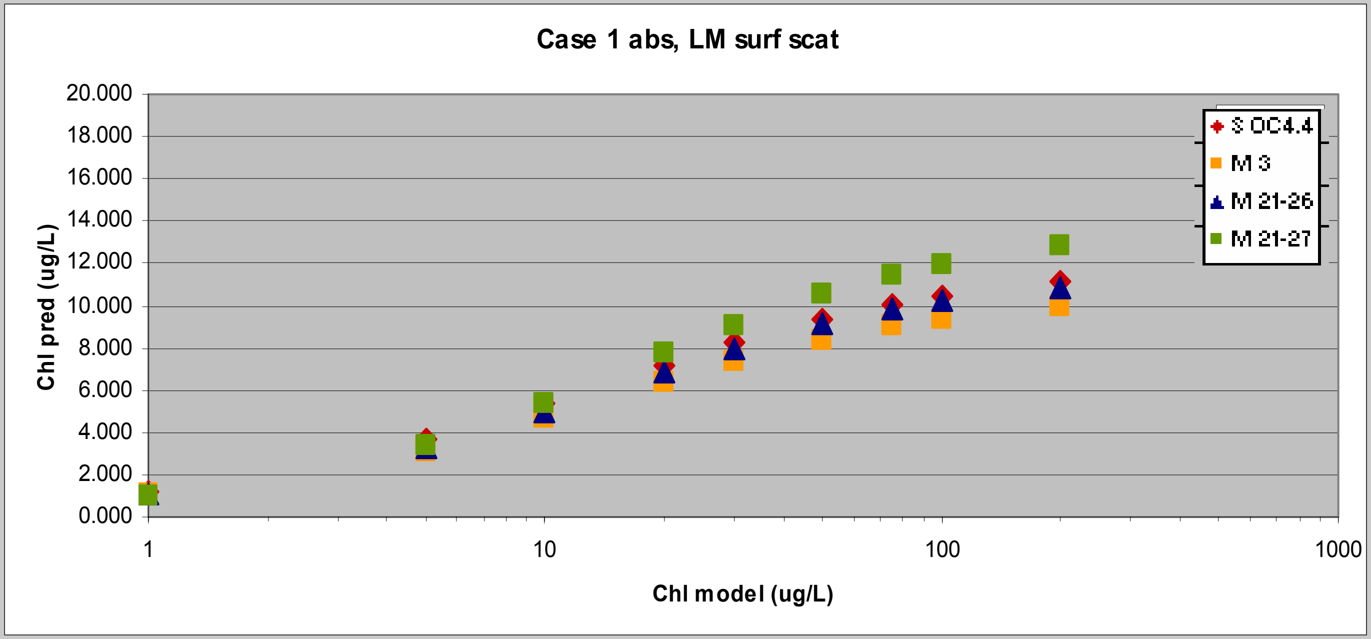


Case 1 abs, CG scat
Chl pred (ug/L)
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27

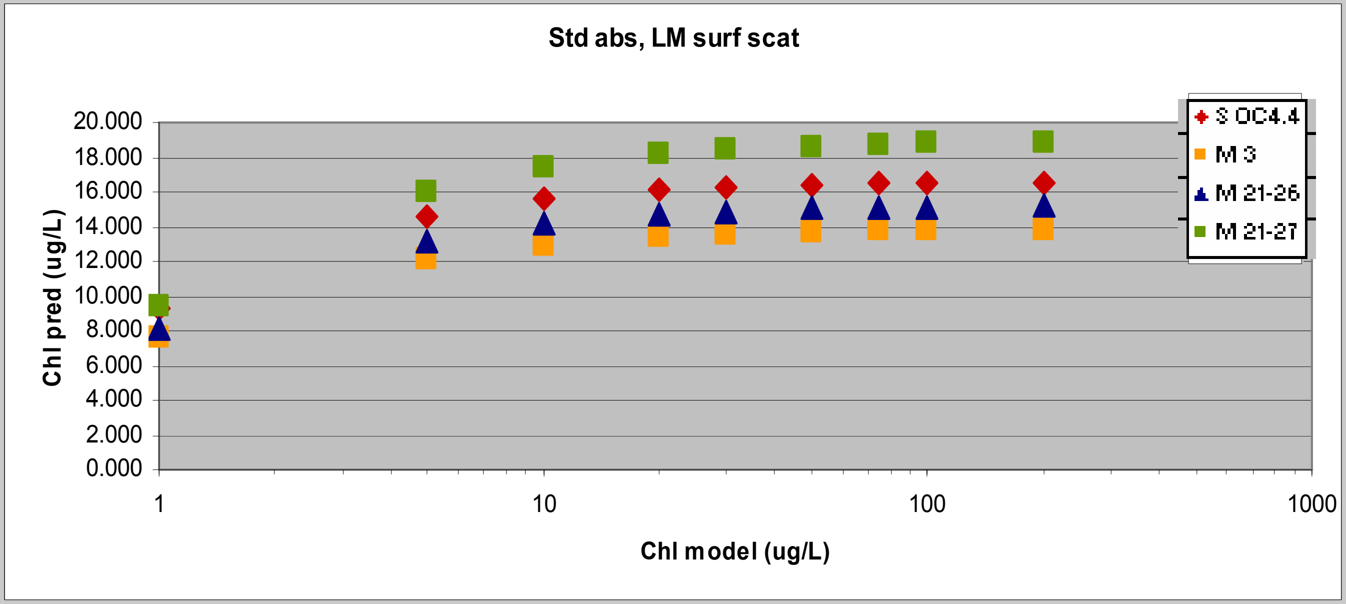


Case 1 abs, LM all scat
Chl pred (ug/L)
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27

Band ratios

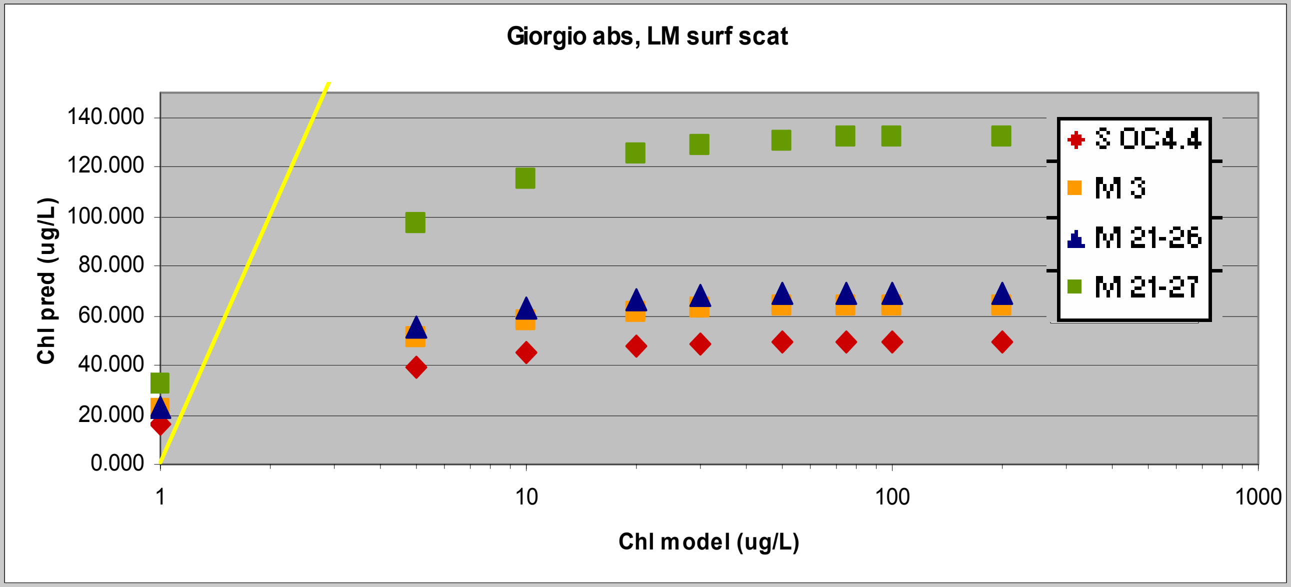


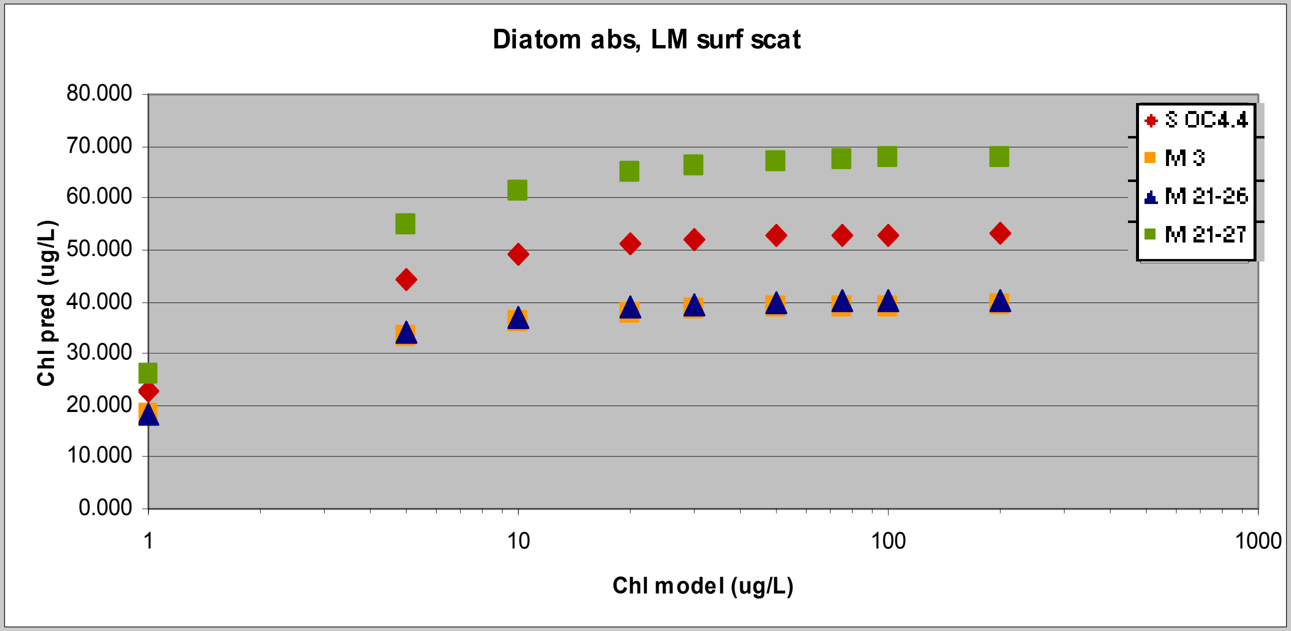
Case 1 abs, LM surf scat
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
Chl pred (ug/L)
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27



Std abs, LM surf scat
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
Chl pred (ug/L)
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27

Band ratios

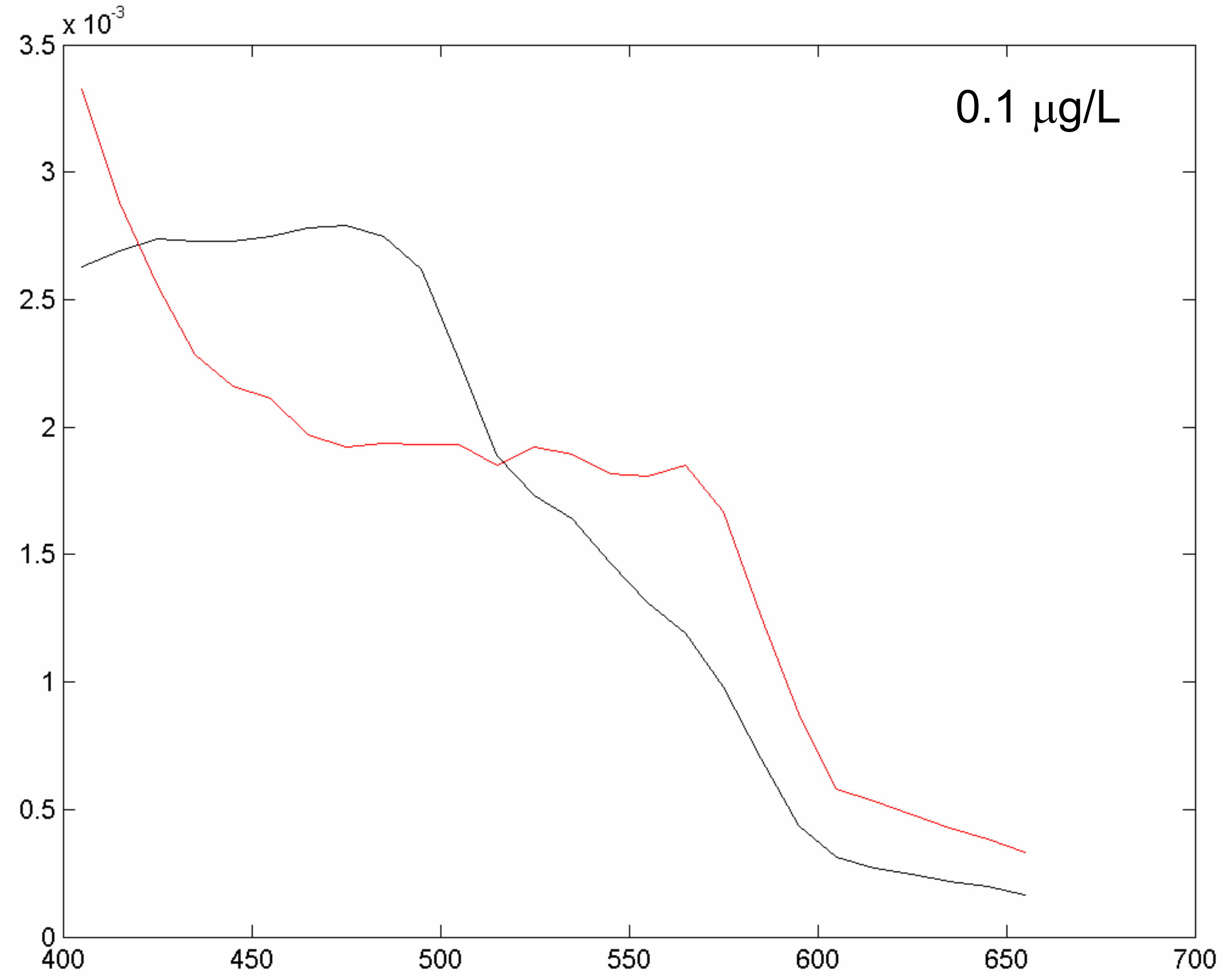

Giorgio abs, LM surf scat
Chl pred (ug/L)
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27


Diatom abs, LM surf scat
Chl pred (ug/L)
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
1
10
100
1000
Chl model (ug/L)
S OC4.4
M 3
M 21-26
M 21-27

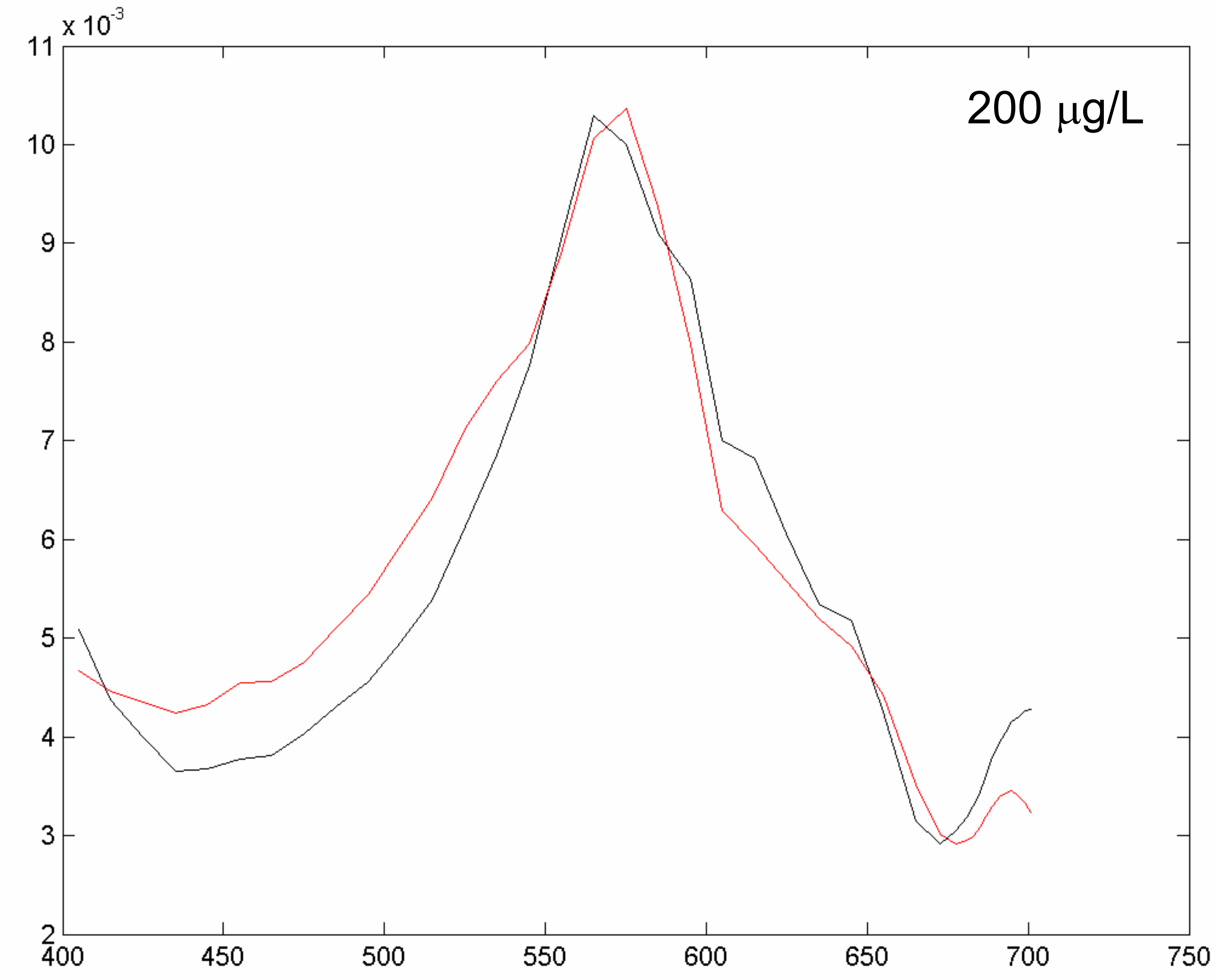
Inversion model

- Inversion model
  - Technique and code from Roesler and Perry 1995
  - Average chl from Roesler et al. 1989 (species?)
  - $\hat{R} \sim (f/Q) * (Bb / Bb+a)$
  - Experimented with CDM and backscattering

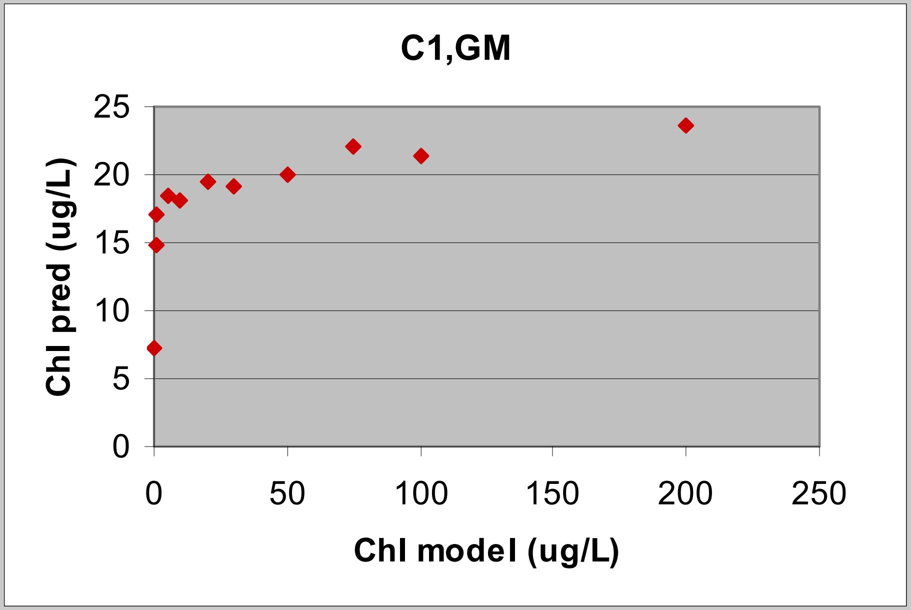
Inversion model

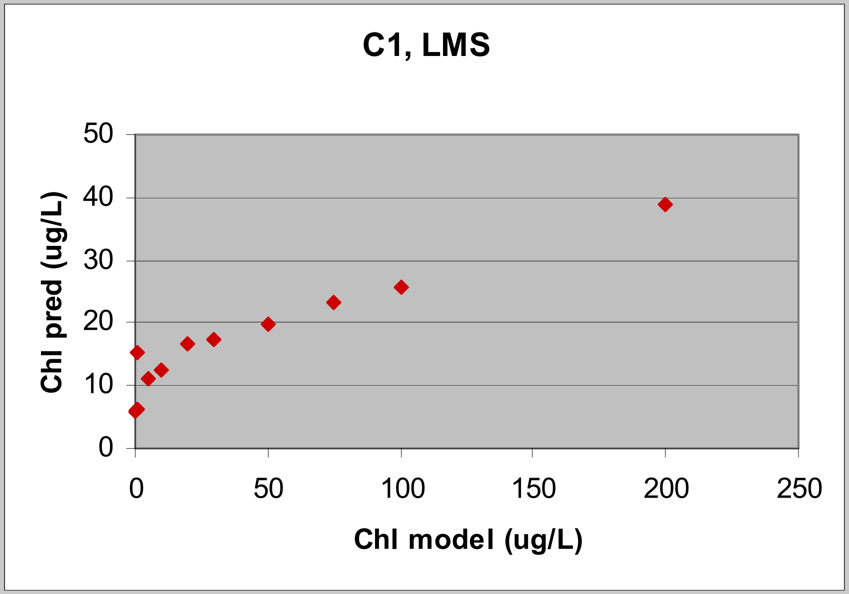


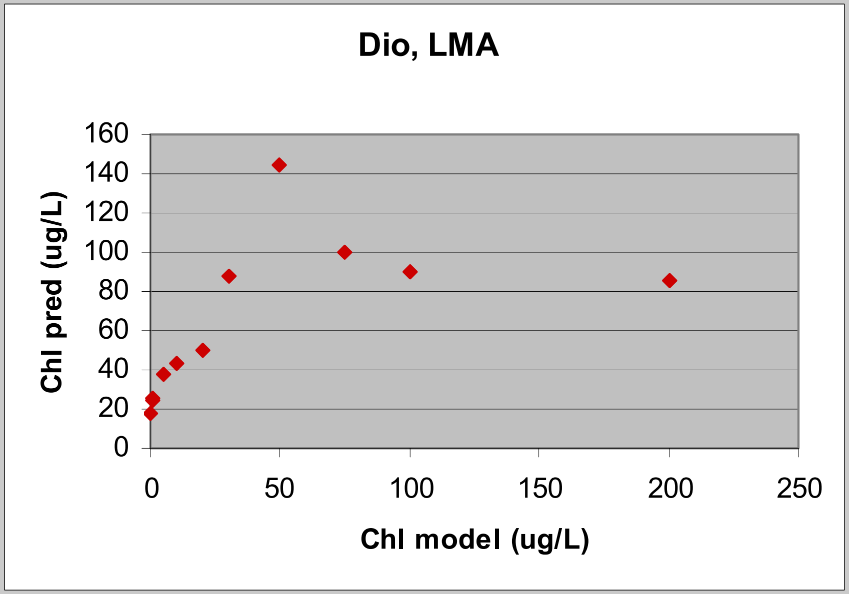
Inversion model



Inversion model

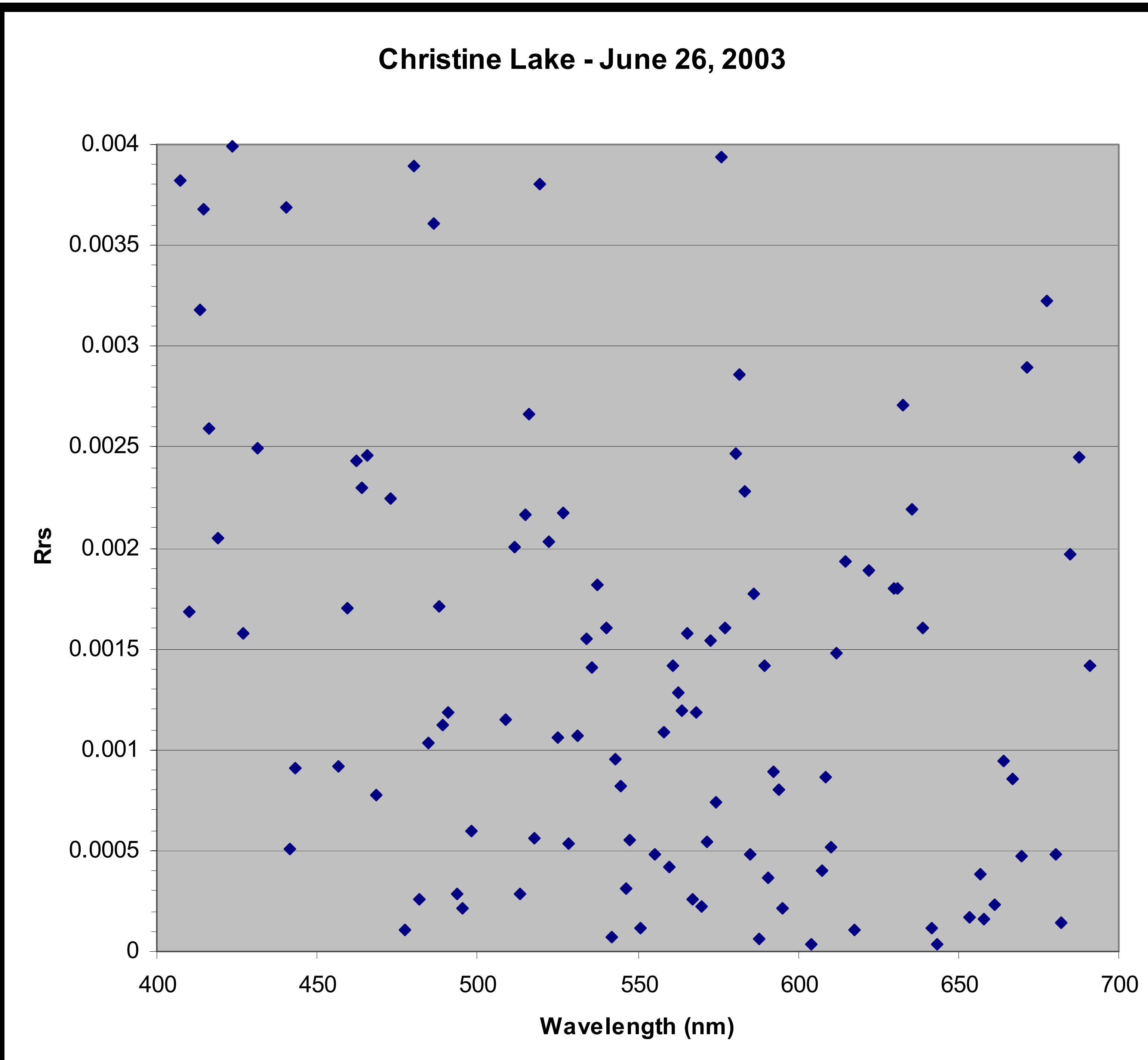




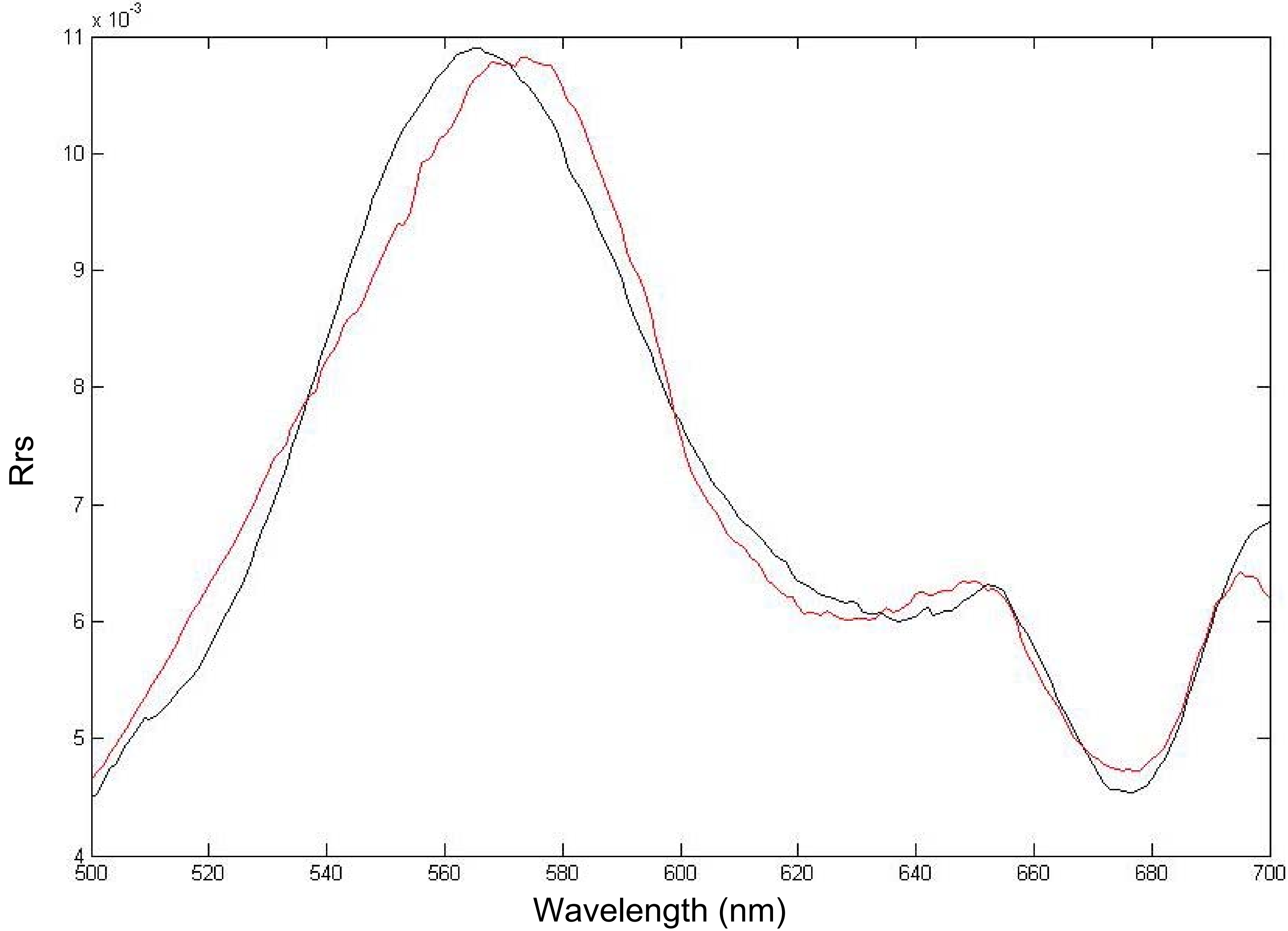


Conclusions

- Scattering and absorption characteristics of phytoplankton can have a large influence on Rrs
- Satellite algorithms systematically underestimated chlorophyll
  - MODIS MOD 21-27
- Inversion model systematically underestimated chlorophyll
  - More time could be spent in optimazation
- Colin makes modeling look easy . . .



Christine Lake - June 26, 2003
Rrs
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
400
450
500
550
600
650
700
Wavelength (nm)



x 10^-3
11
10
9
8
7
6
5
4
Rrs
500
520
540
560
580
600
620
640
660
680
700
Wavelength (nm)