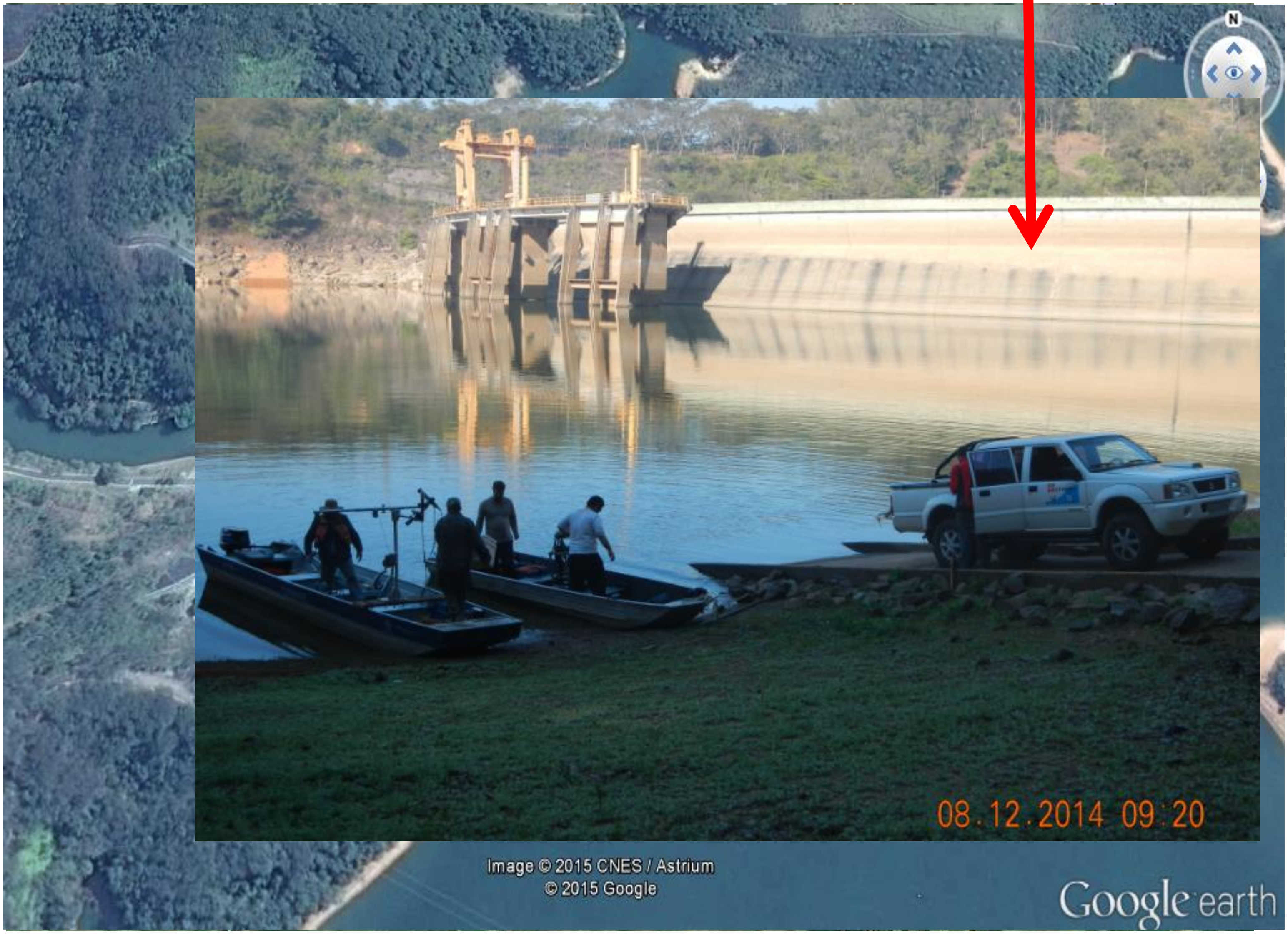
Comprehensive Bio-Optical Measurements in a eutrophic hydroelectric reservoirs

16 sampling stations

The Dam



Measurements

E_s ; E_d ; L_w ; L_u ; E_u ; L_{sky} ➔ RAMSES TriOs

L_w ; L_{sky} ➔ ASD Handheld 2

$c(\lambda)$ $a(\lambda)$ ➔ ACS 25 cm and 10 cm path length

$b_{b\ (420,\ 442,\ 470,\ 510,\ 590\ \text{and}\ 700\ \text{nm})}$ ➔ Hydroscat 6P

$a_{CDOM}(\lambda)$, $a_{ph}(\lambda)$, $a_{TP}(\lambda)$, $a_{NAP}(\lambda)$ ➔ UV-2600 Shimadzu

Dissolved oxygen, pH, turbidity, conductivity. ➔ YSI Probe

Ch-a , *TSM and DTC* (organic/inorganic fractions), NTK, PT

How profiles were done

RAMES TriOs :

- Cage was lowered from surface down to nearly 1% of E_d (z,550 nm) of subsurface stopping every meter/half meter or less.
- At each stop, on average 16 measurements were done

ACS, CTD, Hydroscat and Probe sensors :

- Casts were performed in continuous mode
- Measurements started at below the limit of euphotic zone depth.
- Two casts : one from maximum depth to subsurface and than from subsurface to initial depth.

Sequence of depth measurements for RAMSES

P4 Station (Secchi depth = 0.8 meter)

➔ Surface , subsurface, every 0.25 meter up to 2 meters depth.

P16 Station (Secchi depth = 1.6 meters)

➔ Surface , subsurface, every meter up to 13 meters depth.

Chl-a , TSM and DTC

➔ estimated in in three depths: subsurface, Secchi and 3*secchi)

OLI Image second day

Water

ACS & Hydroscat measurements

OAC concentration determined in three depth

Subsurface

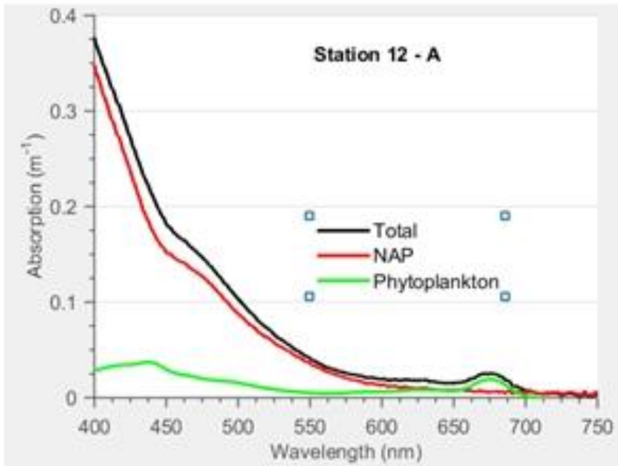
Secchi

Three Secchi

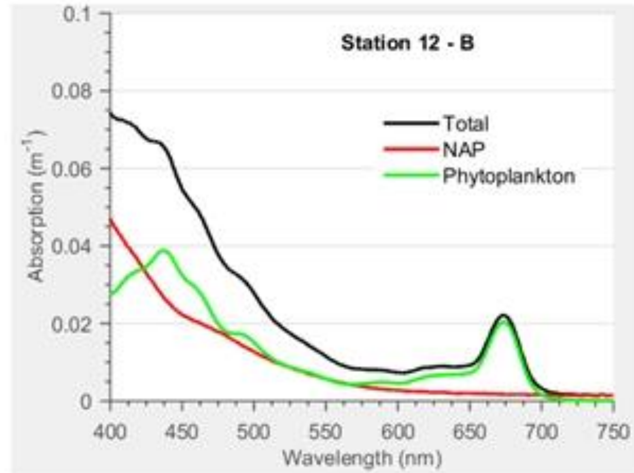
	P4			P15			P16		
	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)
sub	242.86	12.55		33.95	1.96		4.88	1.02	
secchi	435.55	106.84	0.80	269.29	9.10	1.20	63.01	4.09	1.60
3 secchi	146.72	7.54		53.06	2.38		5.06	3.36	
	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)
sub	18.60	0.80	17.80	7.38	3.13	4.25	0.88	0.38	0.50
secchi	54.60	3.60	51.00	40.00	1.52	38.48	5.20	1.20	4.00
3 secchi	39.00	1.40	37.60	3.13	2.50	0.63	1.50	0.62	0.88
	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)
sub	7.27	2.04	5.22	9.48	5.34	4.14	8.22	5.42	2.80
secchi	8.74	1.67	7.07	9.30	4.21	5.09	10.02	5.42	4.60
3 secchi	8.78	3.84	4.94	9.01	4.52	4.50	9.32	5.45	3.88
	NTK (mg/L)	PT (µg/L)		NTK (mg/L)	PT (µg/L)		NTK (mg/L)	PT (µg/L)	
sub	1.22	222.51		0.20	16.96		0.30	14.58	
secchi	2.53	562.30		0.51	133.96		0.10	40.68	
3 secchi	1.22	298.96		0.10	44.48		0.10	15.86	
	aCDOM (1/m)			aCDOM (1/m)			aCDOM (1/m)		
Kirk pg 76	**400**	**440**	**443**	**400**	**440**	**443**	**400**	**440**	**443**
sub	1.2474	0.6264	0.6034	1.4873	0.8893	0.8433	1.0409	0.5349	0.5119
secchi	1.37	0.65	0.63	1.57	0.88	0.86	1.07	0.54	0.52
3 secchi	1.54	0.89	0.85				0.87	0.47	0.45
	Slope_CDOM			Slope_CDOM			Slope_CDOM		
sub		0.0152			0.0112			0.0145	
secchi		0.0155			0.0121			0.0153	
3 secchi		0.0114						0.0130	

Ramses TriOs

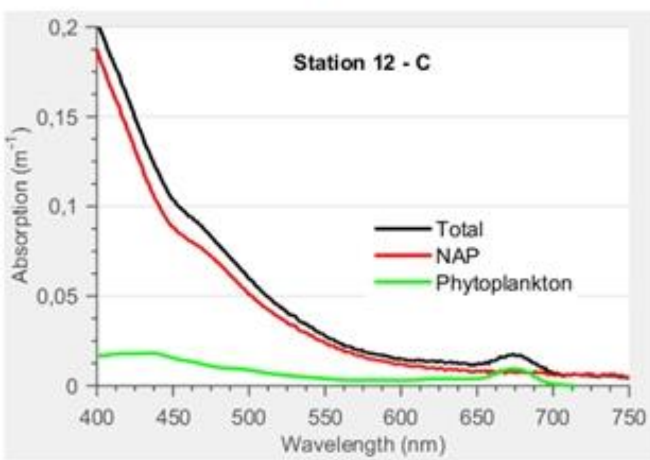
Sky


Station 12 - A
Total
NAP
Phytoplankton
Absorption (m⁻¹)
Wavelength (nm)

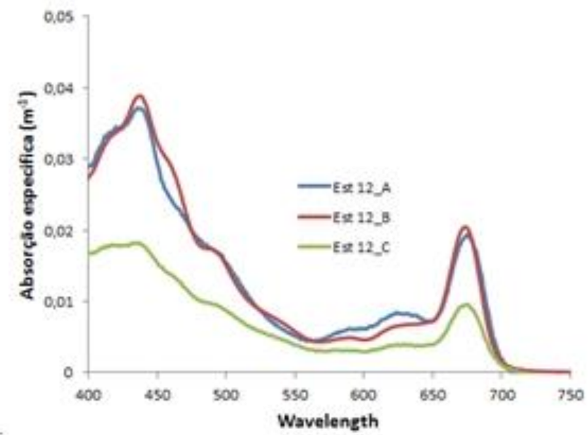
(a)


Station 12 - B
Total
NAP
Phytoplankton
Absorption (m⁻¹)
Wavelength (nm)

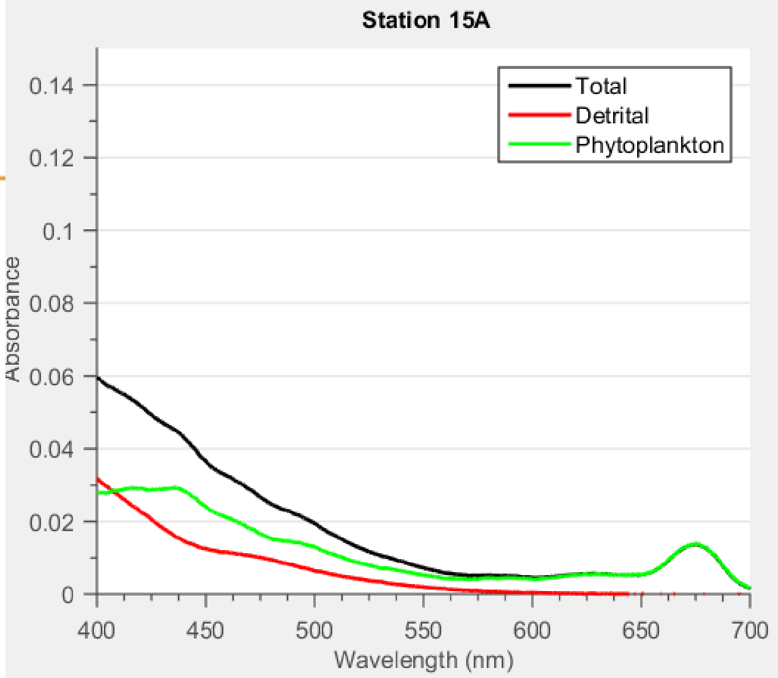
(b)

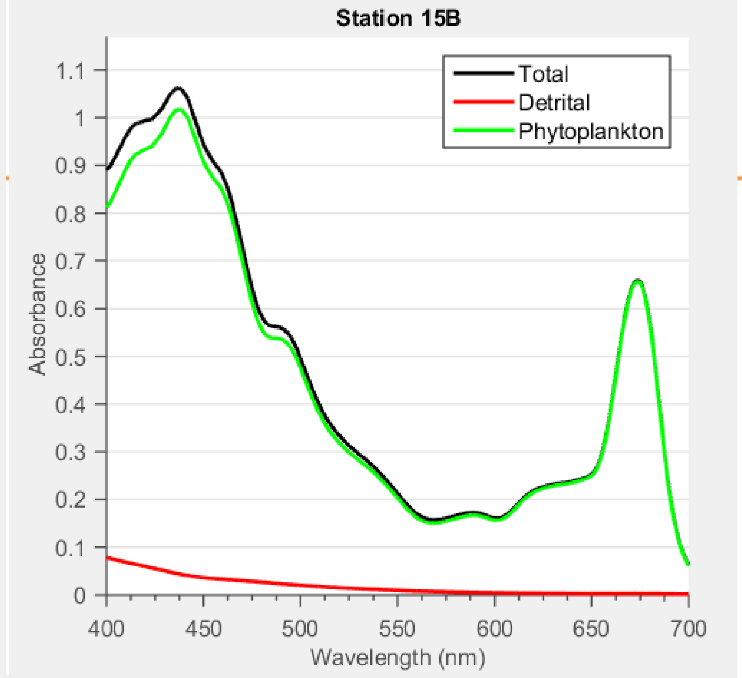

Station 12 - C
Total
NAP
Phytoplankton
Absorption (m⁻¹)
Wavelength (nm)

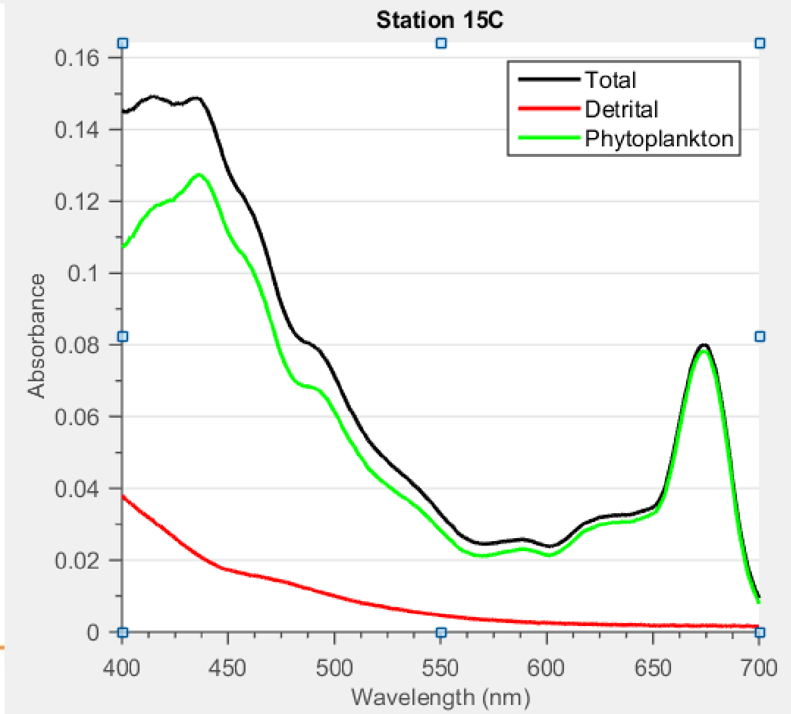
(c)


Est 12_A
Est 12_B
Est 12_C
Absorção especifica (m⁻¹)
Wavelength

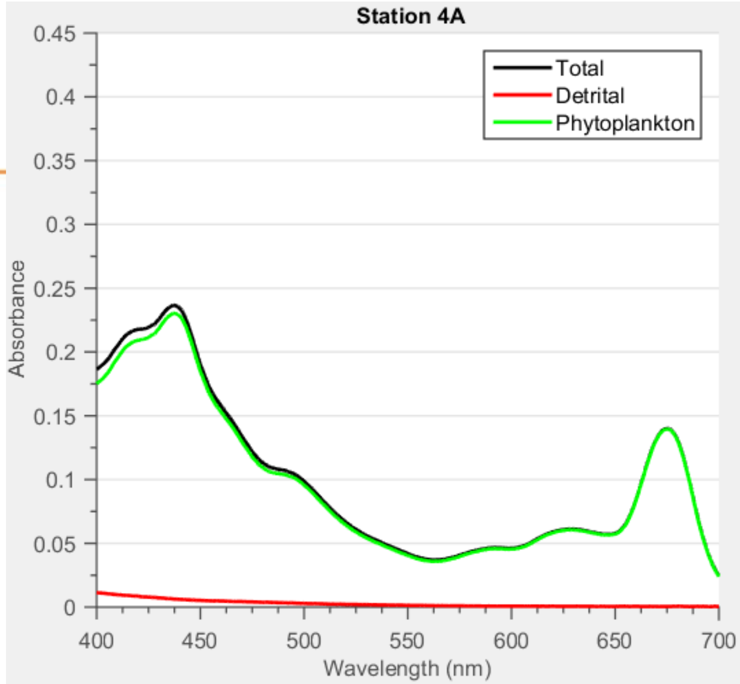
(d)

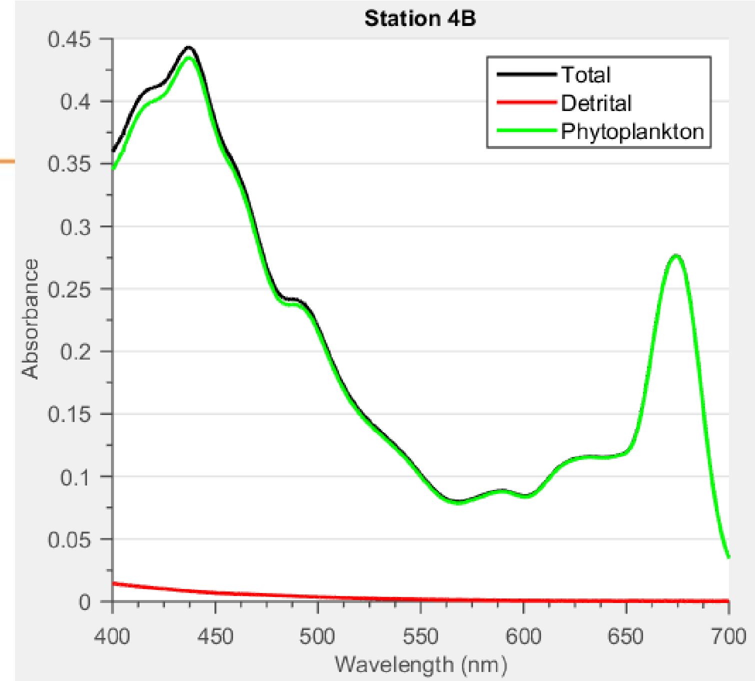


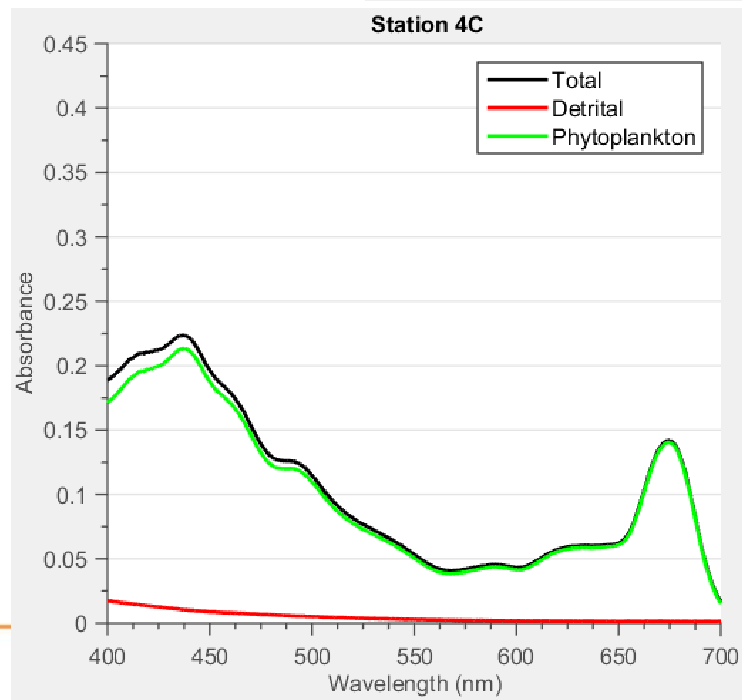




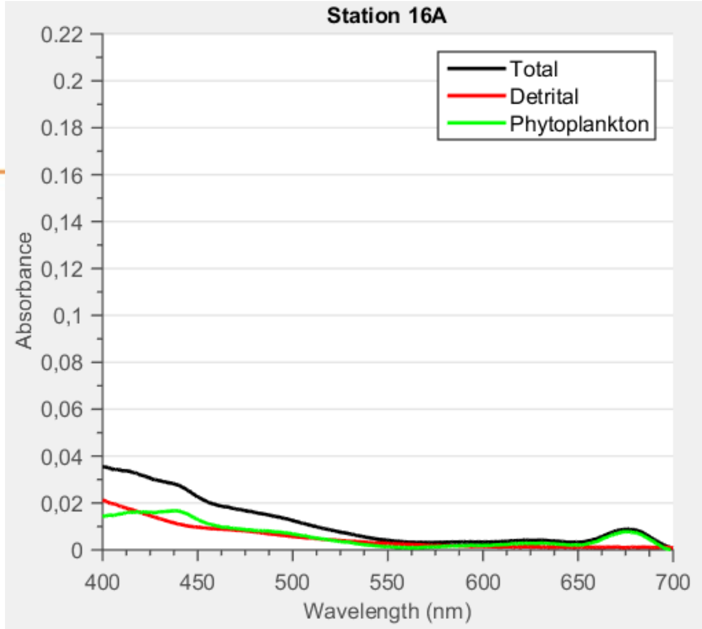
33.95	1.96	
269.29	9.10	1.20
53.06	2.38	

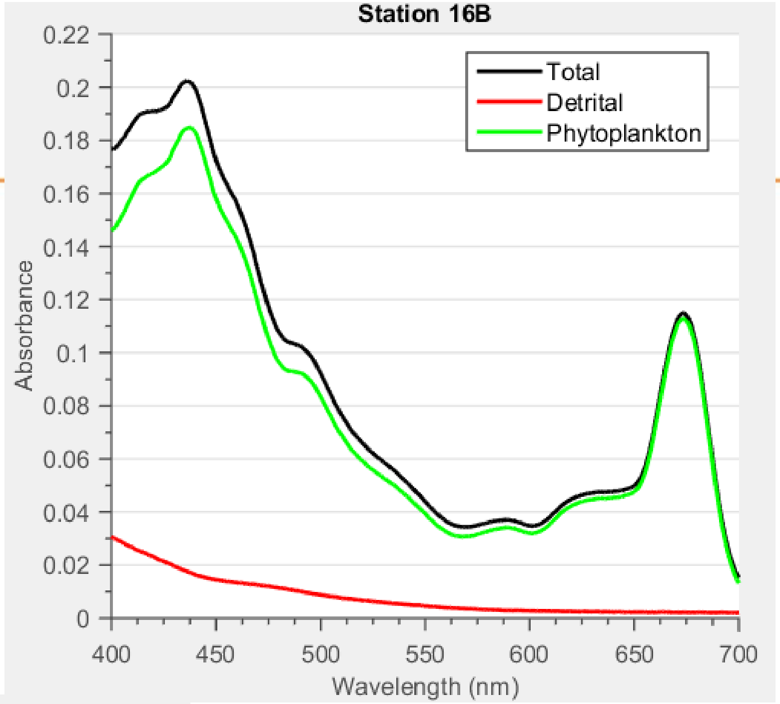


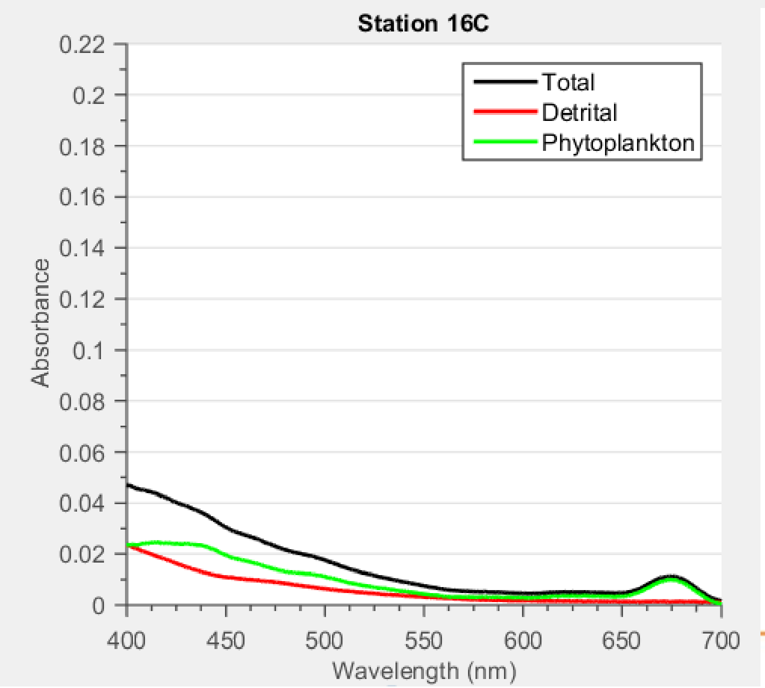




242.86	12.55	
435.55	106.84	0.80
146.72	7.54	

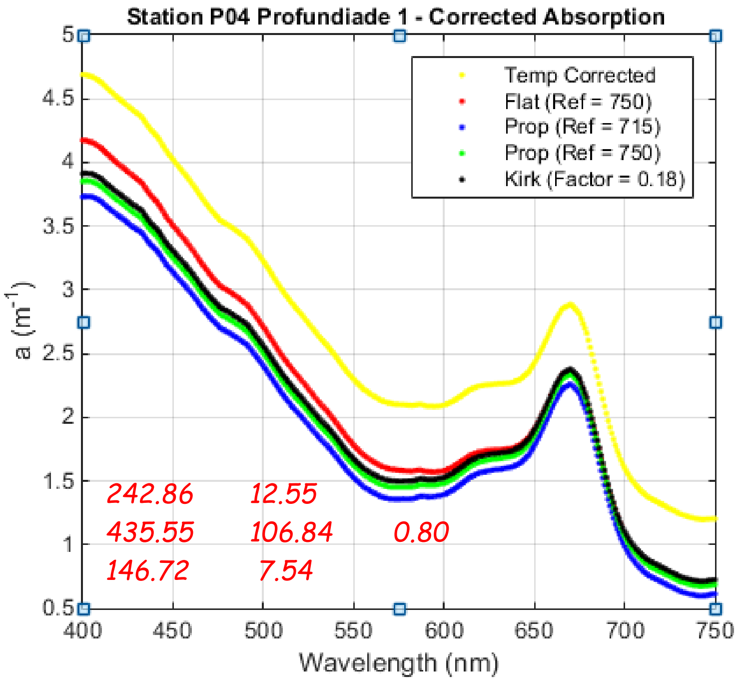


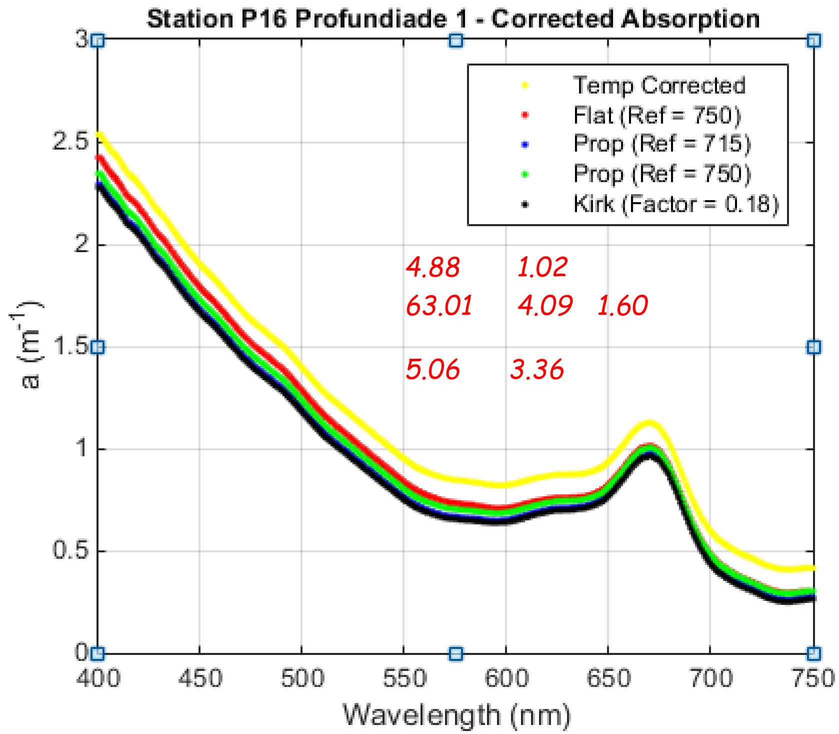


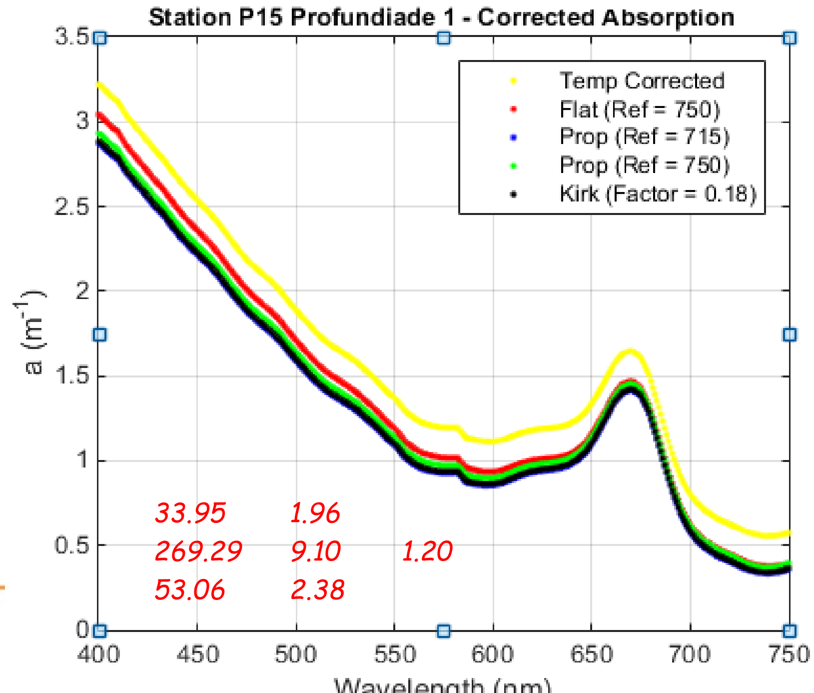


4.88 1.02
63.01 4.09 1.60

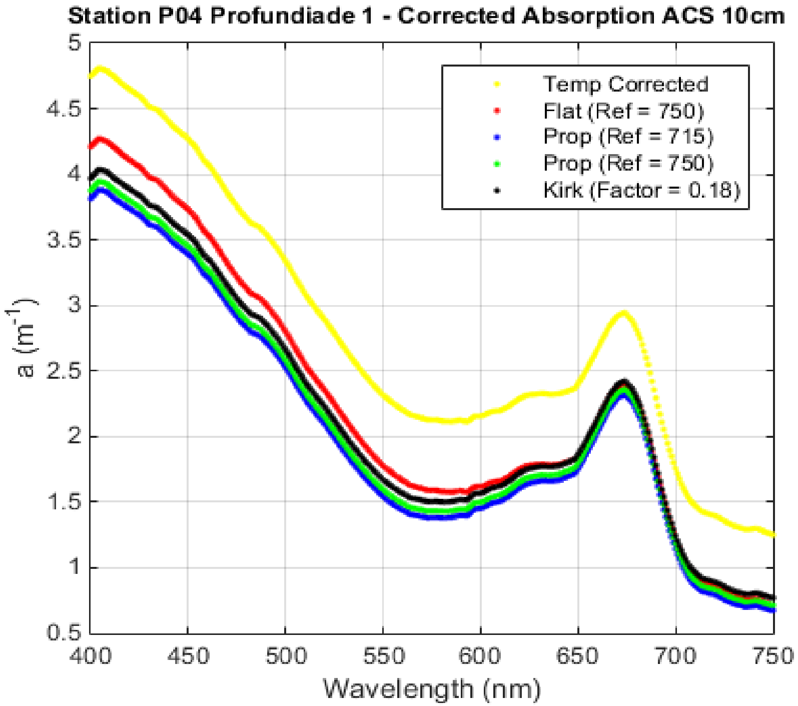
5.06 3.36

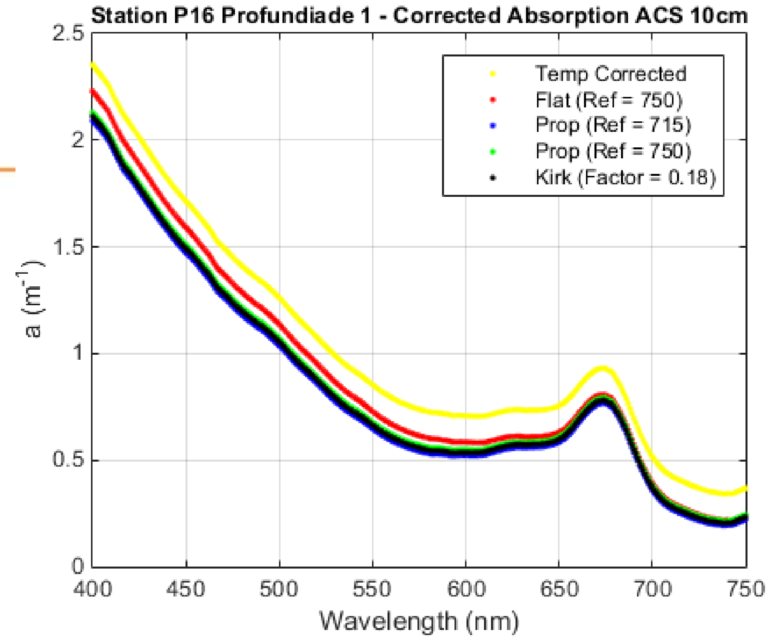

Station P04 Profundiade 1 - Corrected Absorption
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
242.86
12.55
435.55
106.84
0.80
146.72
7.54
a (m^{-1})
Wavelength (nm)

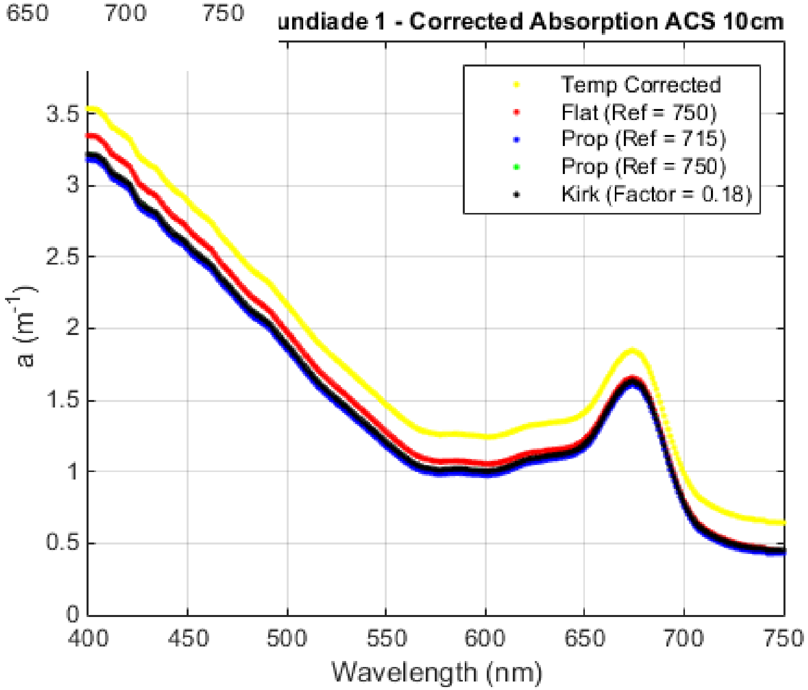

Station P16 Profundiade 1 - Corrected Absorption
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
4.88
1.02
63.01
4.09
1.60
5.06
3.36
a (m^{-1})
Wavelength (nm)


Station P15 Profundiade 1 - Corrected Absorption
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
33.95
1.96
269.29
9.10
1.20
53.06
2.38
a (m^{-1})
Wavelength (nm)

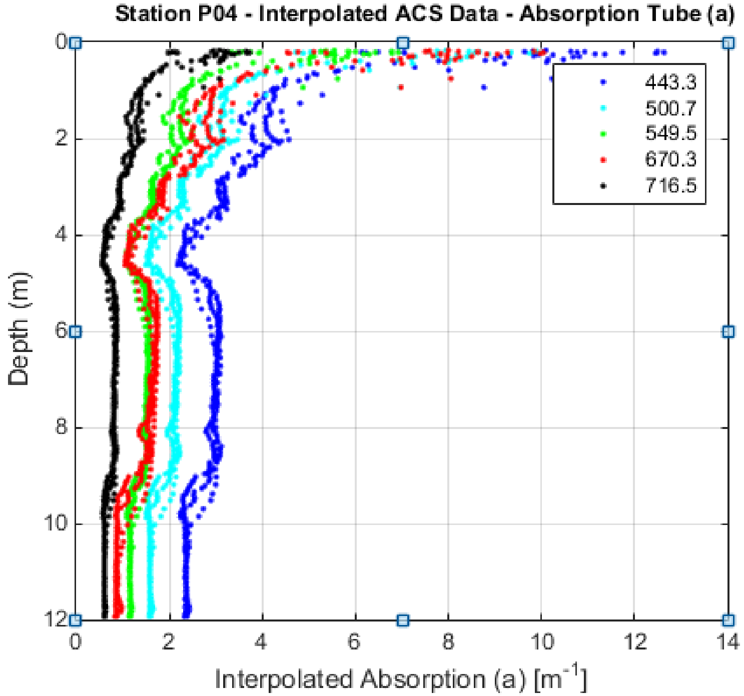
ACS 25 cm

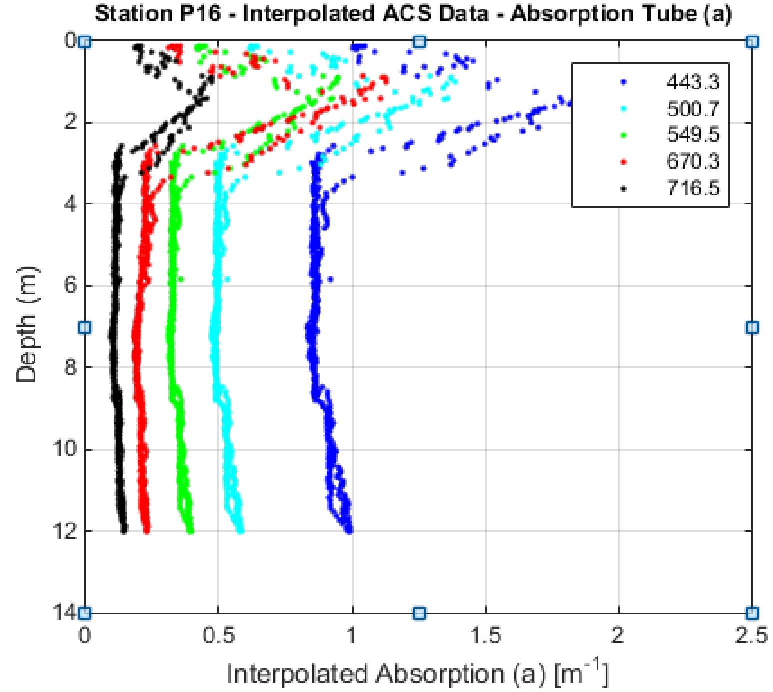

Station P04 Profundiade 1 - Corrected Absorption ACS 10cm
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
a (m^{-1})
Wavelength (nm)

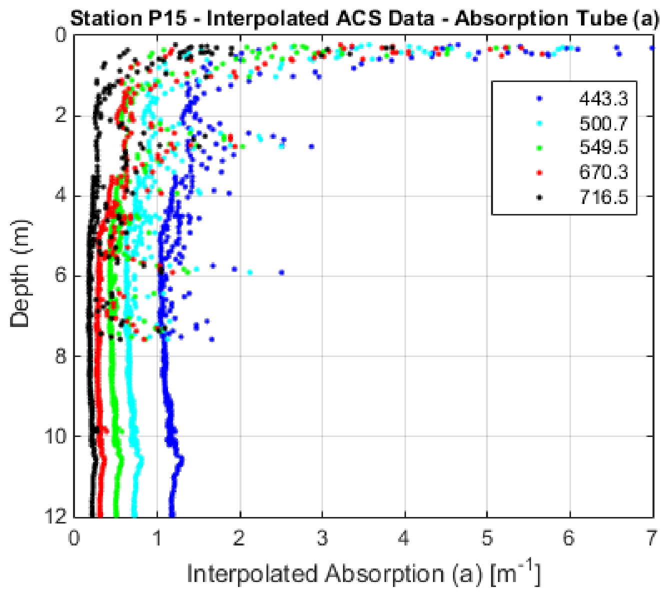

Station P16 Profundiade 1 - Corrected Absorption ACS 10cm
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
a (m^{-1})
Wavelength (nm)


undiade 1 - Corrected Absorption ACS 10cm
Temp Corrected
Flat (Ref = 750)
Prop (Ref = 715)
Prop (Ref = 750)
Kirk (Factor = 0.18)
a (m^{-1})
Wavelength (nm)

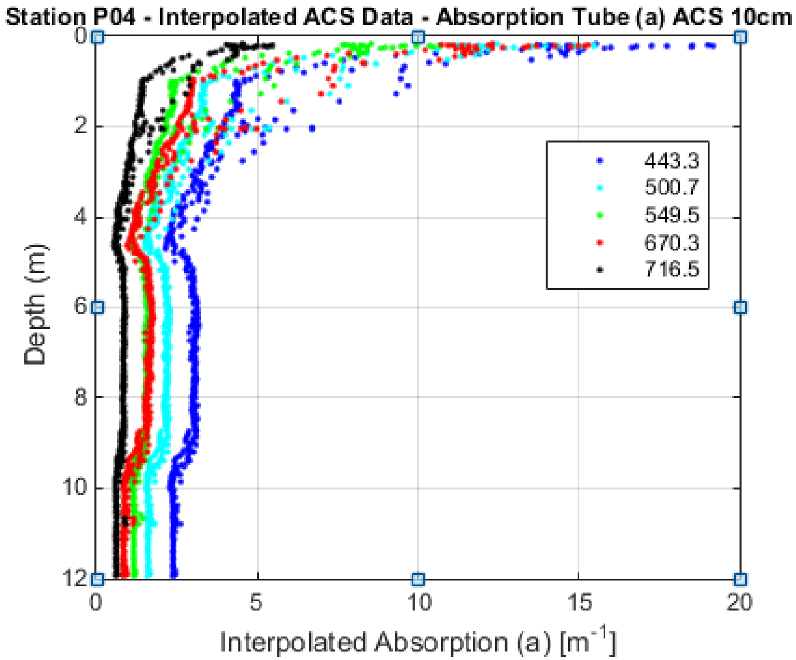
ACS 10 cm

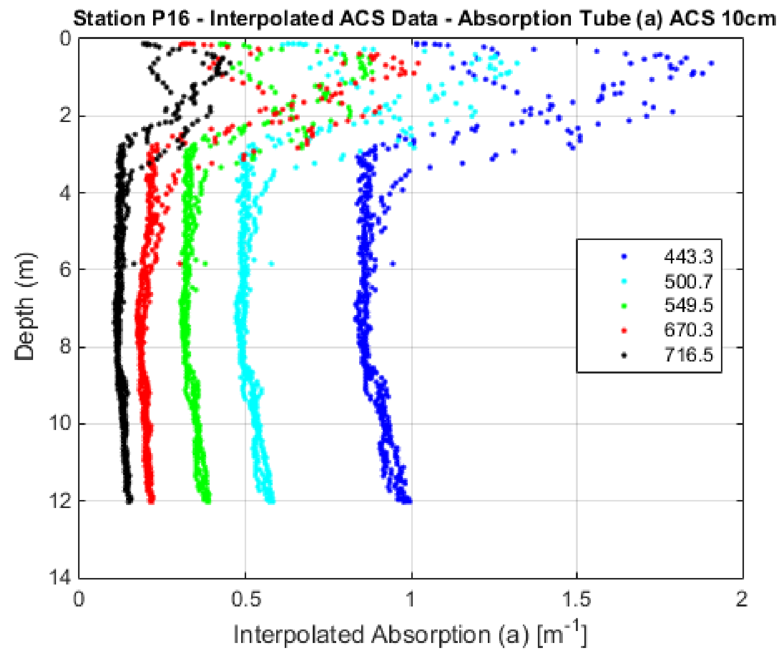

Station P04 - Interpolated ACS Data - Absorption Tube (a)
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5

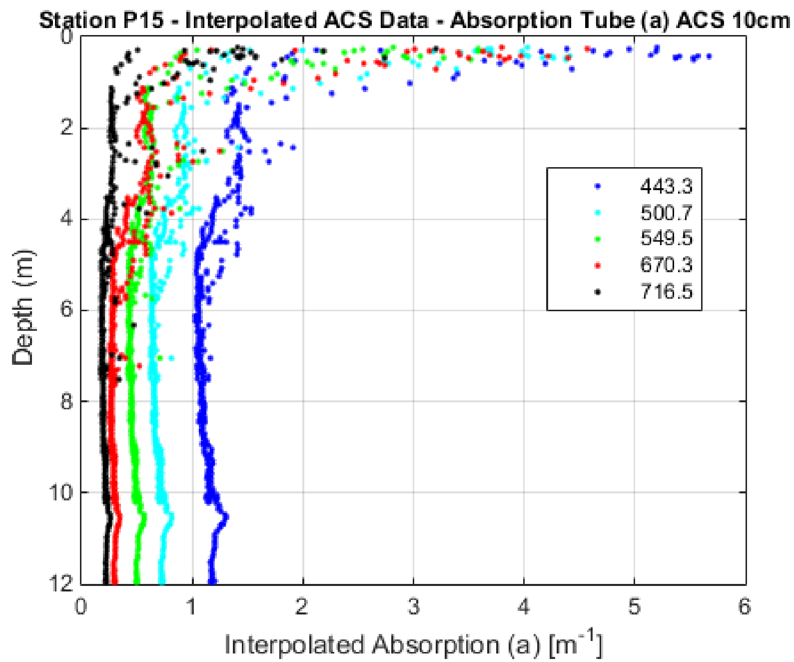

Station P16 - Interpolated ACS Data - Absorption Tube (a)
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5


Station P15 - Interpolated ACS Data - Absorption Tube (a)
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5

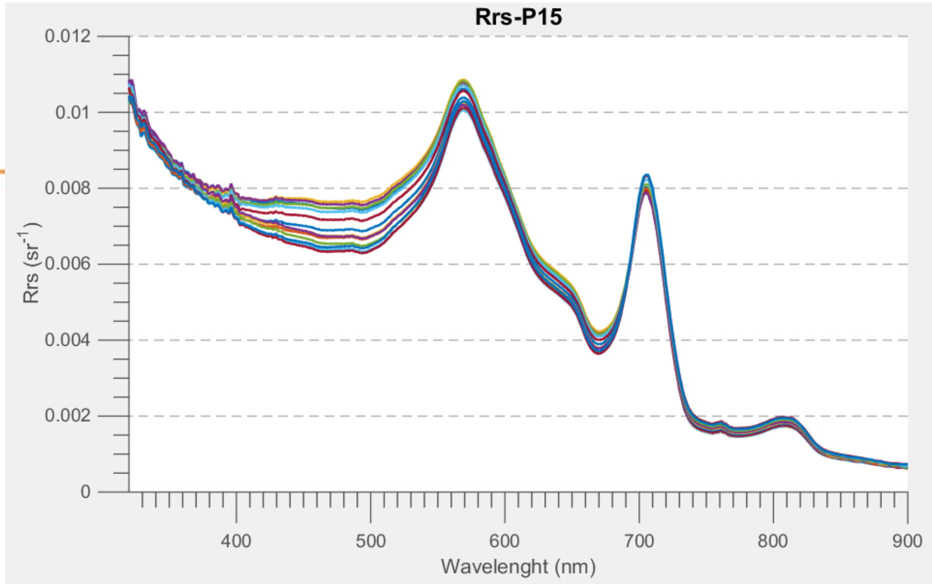
ACS 25 cm

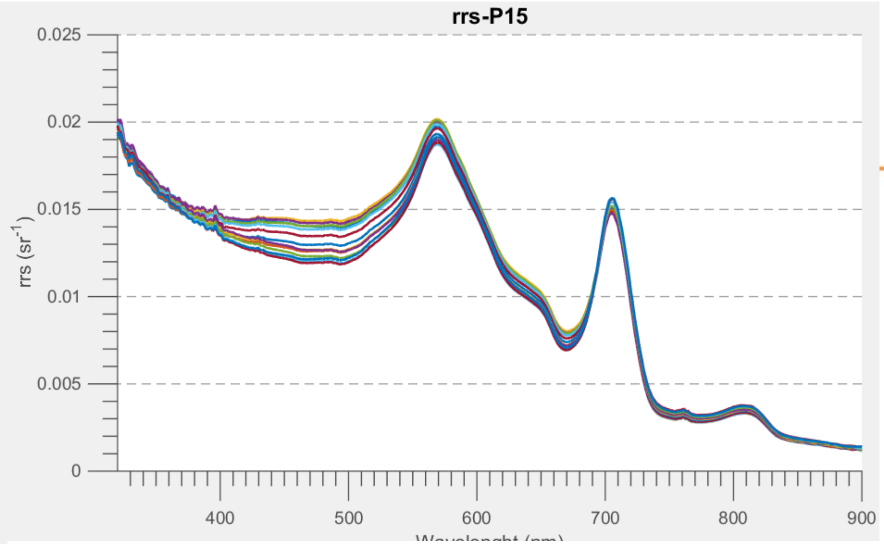

Station P04 - Interpolated ACS Data - Absorption Tube (a) ACS 10cm
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5

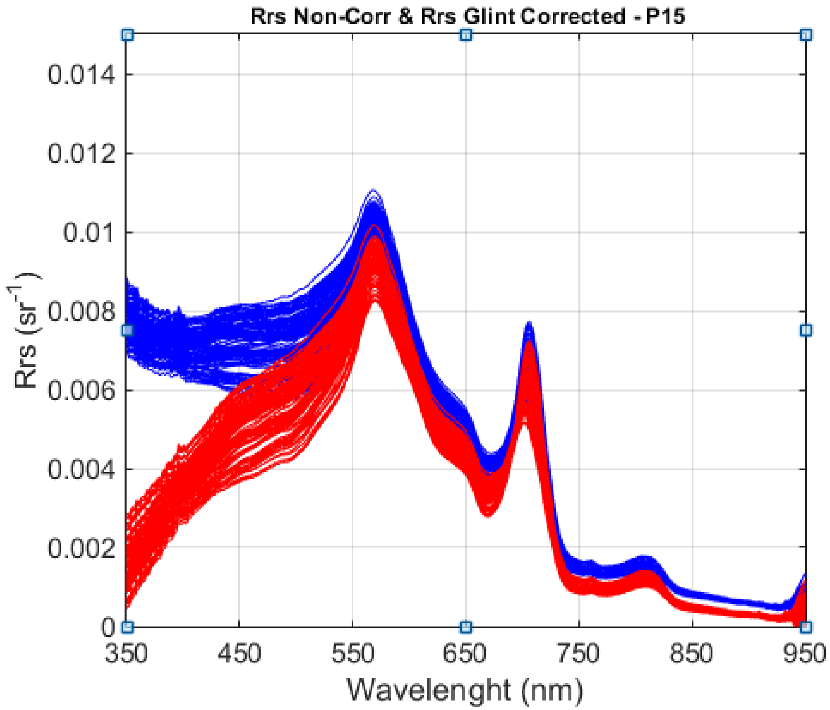

Station P16 - Interpolated ACS Data - Absorption Tube (a) ACS 10cm
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5

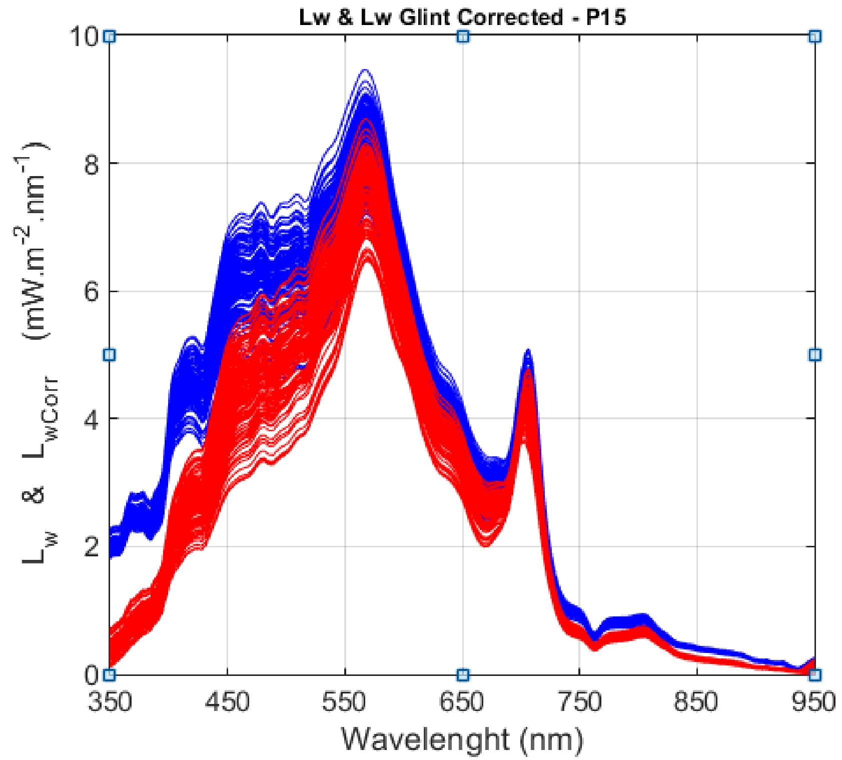

Station P15 - Interpolated ACS Data - Absorption Tube (a) ACS 10cm
Depth (m)
Interpolated Absorption (a) [m-1]
443.3
500.7
549.5
670.3
716.5

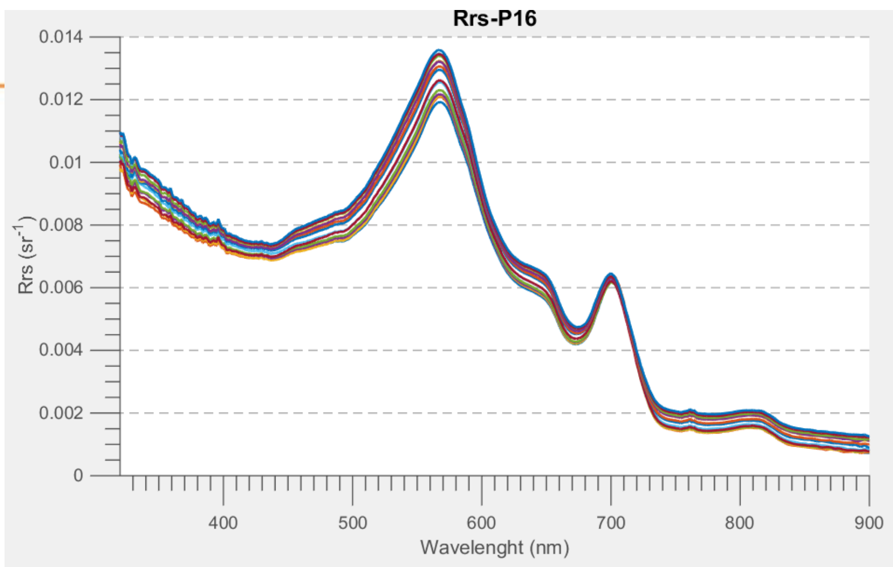
ACS 10 cm


Rrs-P15
Rrs (sr-1)
Wavelenght (nm)

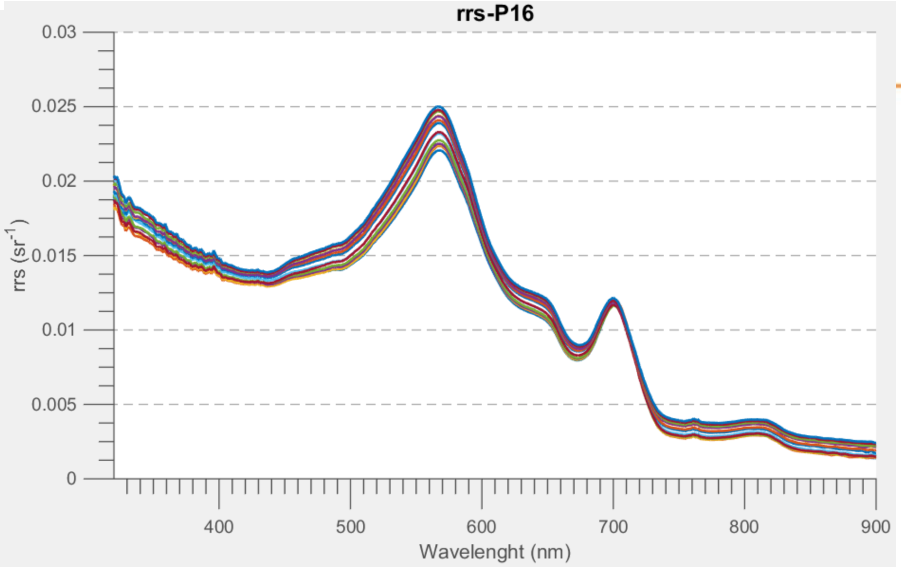

rrs-P15
rrs (sr-1)


Rrs Non-Corr & Rrs Glint Corrected - P15
Rrs (sr-1)
Wavelenght (nm)

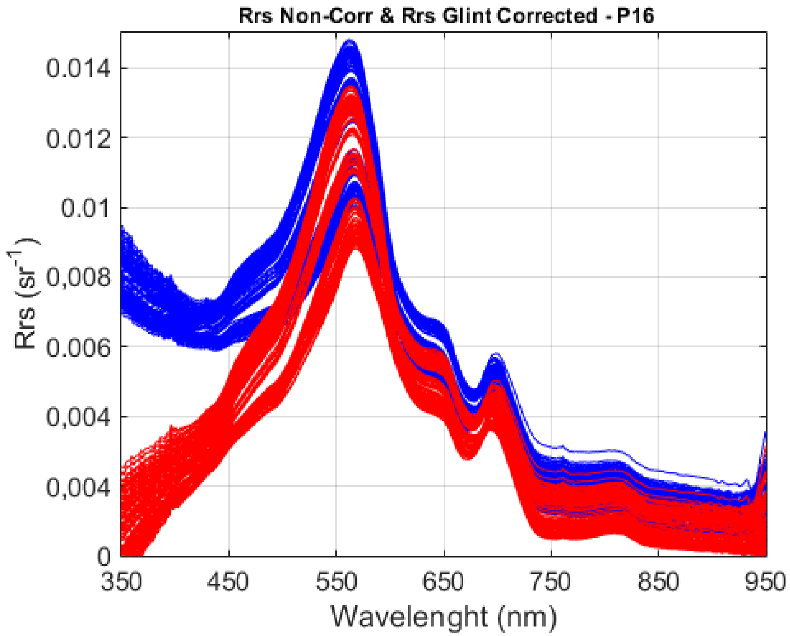

Lw & Lw Glint Corrected - P15
Lw & LwCorr (mW.m-2.nm-1)
Wavelenght (nm)



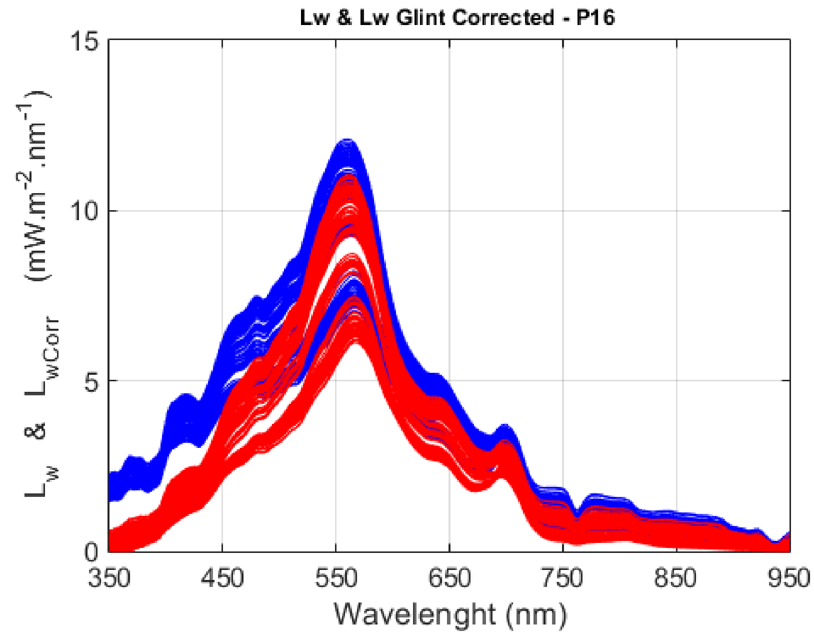
Rrs-P16
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Rrs (sr-1)
400
500
600
700
800
900
Wavelenght (nm)



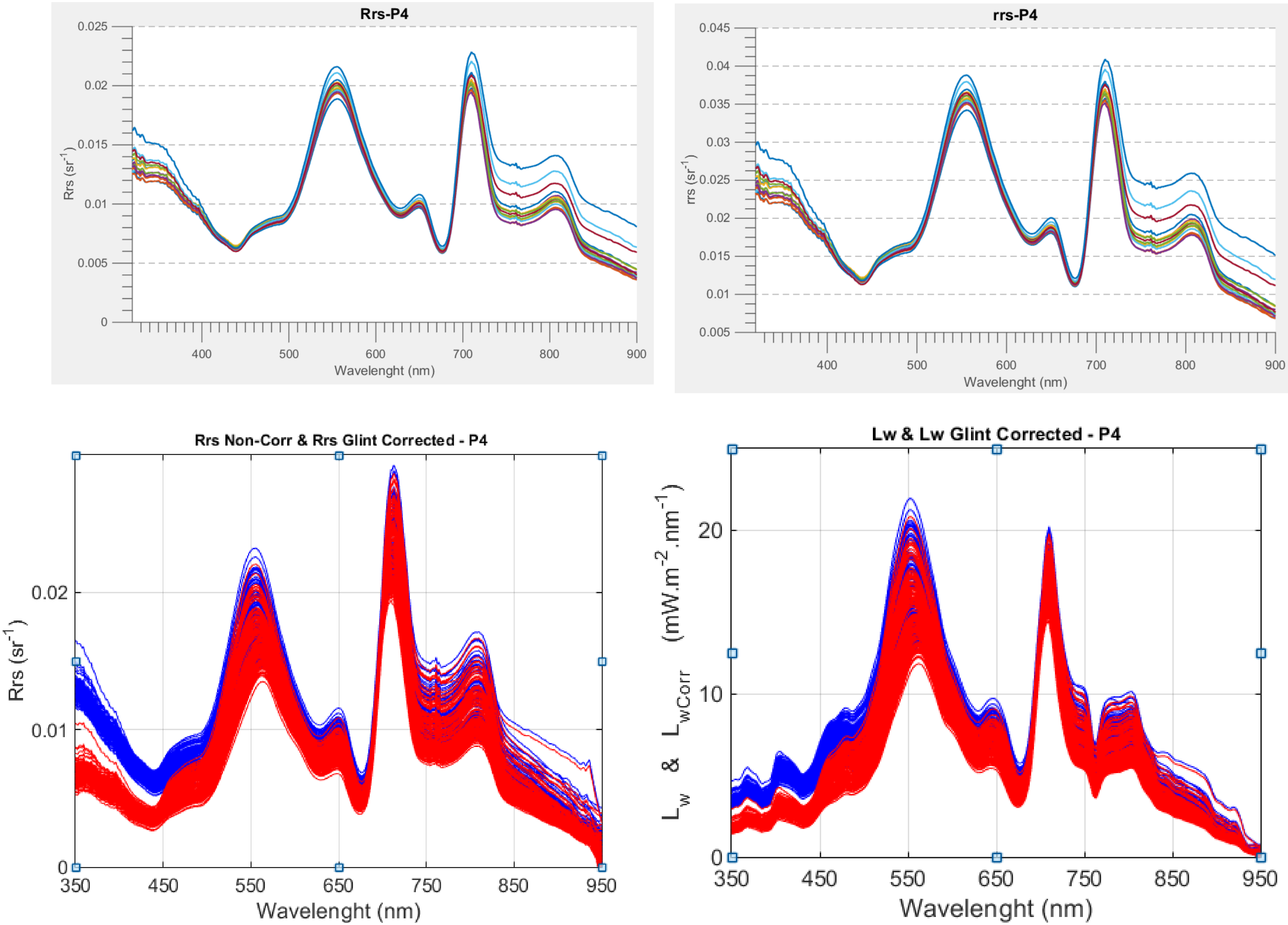
rrs-P16
0.03
0.025
0.02
0.015
0.01
0.005
0
rrs (sr-1)
400
500
600
700
800
900
Wavelenght (nm)



Rrs Non-Corr & Rrs Glint Corrected - P16
0.014
0.012
0.01
0,008
0.006
0,004
0,004
0
Rrs (sr-1)
350
450
550
650
750
850
950
Wavelenght (nm)



Lw & Lw Glint Corrected - P16
15
10
5
0
Lw & LwCorr (mW.m-2.nm-1)
350
450
550
650
750
850
950
Wavelenght (nm)



Rrs-P4
0.025
0.02
0.015
0.01
0.005
0
Rrs (sr-1)
400
500
600
700
800
900
Wavelenght (nm)
rrs-P4
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
rrs (sr-1)
400
500
600
700
800
900
Wavelenght (nm)
Rrs Non-Corr & Rrs Glint Corrected - P4
0.02
0.01
0
Rrs (sr-1)
350
450
550
650
750
850
950
Wavelenght (nm)
Lw & Lw Glint Corrected - P4
20
10
0
Lw & LwCorr (mW.m-2.nm-1)
350
450
550
650
750
850
950
Wavelenght (nm)

Funil reservoir: dataset

Scientific objective suggested by ZhongPing Lee

Can I get vertical distribution of chlorophyll concentration from this dataset?

Can I determine the depth of maximum chlorophyll concentration?

	P4			P15			P16		
	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)	chlorophyll-a (µg/L)	phaeophytin (µg/L)	Secchi (meter)
sub	242.86	12.55		33.95	1.96		4.88	1.02	
secchi	435.55	106.84	0.80	269.29	9.10	1.20	63.01	4.09	1.60
3 secchi	146.72	7.54		53.06	2.38		5.06	3.36	
	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)	TSM (mg/l)	TSIM (mg/l)	TSOM (mg/l)
sub	18.60	0.80	17.80	7.38	3.13	4.25	0.88	0.38	0.50
secchi	54.60	3.60	51.00	40.00	1.52	38.48	5.20	1.20	4.00
3 secchi	39.00	1.40	37.60	3.13	2.50	0.63	1.50	0.62	0.88
	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)	DTC (mg/L)	DIC (mg/L)	DOC (mg/L)
sub	7.27	2.04	5.22	9.48	5.34	4.14	8.22	5.42	2.80
secchi	8.74	1.67	7.07	9.30	4.21	5.09	10.02	5.42	4.60
3 secchi	8.78	3.84	4.94	9.01	4.52	4.50	9.32	5.45	3.88

Effective sea-surface reflectance ρ (defined as the ratio of the surface-reflected radiance at the specular direction corresponding to the downwelling sky radiance from one direction) **varies not only for different measurement scans**, but also can differ by a factor of 8 between 400 nm and 800 nm for the same scan. (Lee at al. 2010)

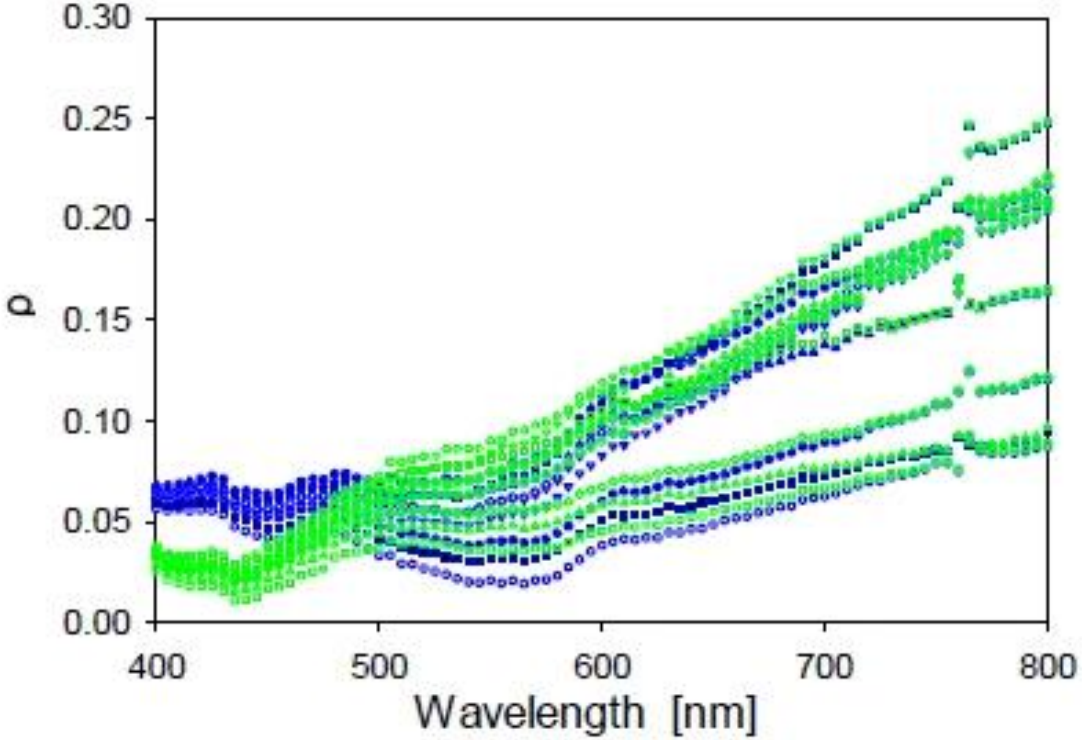


Fig. 4. Similar as Fig. 3, but with two different Chl values. Green: Chl = 0.05 mg m^{-3}; blue, Chl = 0.1 mg m^{-3}.

First steps for a better understand of the dataset

1-Removal of surface-reflected light of remote-sensing reflectance

Lee et al, Optics Express 2010 ➔ Lee et al, Applied Optics, 1999.

Spectral optimization approach

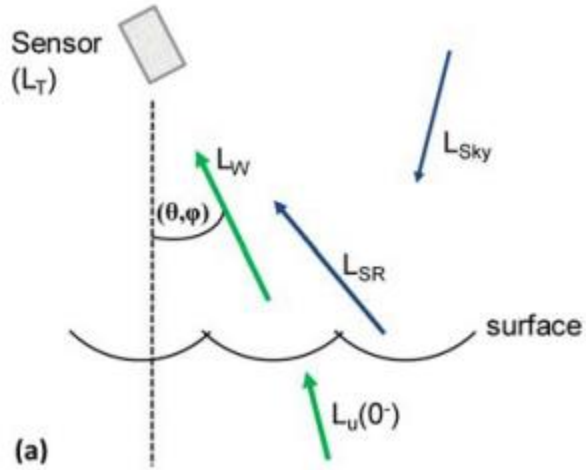
2-Determined Total absorption ➔ QAA

Lee et al, Applied Optics, 2002.

Removal of surface-reflected light of R_{rs}

Lee et al, Optics Express 2010 ➔ Lee et al, Applied Optics, 1999.

Correcting for the reflected skylight and solar glint



$$T_{rs}(\lambda) \approx R_{rs}(\lambda) + F(\theta)S_{rs}(\lambda) + \Delta,$$

$$R_{rs}^{\text{raw}}(\lambda) = T_{rs}(\lambda) - F(\theta)S_{rs}(\lambda),$$

$$R_{rs}^{\text{raw}}(\lambda) \approx R_{rs}(\lambda) + \Delta.$$

T_{rs} =Total remote-sensing reflectance

S_{rs} = Surface-reflected =Lsky/Ed

Δ is a spectrally constant

Spectral optimization approach

Excel template of the processing scheme

Lee et al, Optics Express 2010

- Trs and Srs ➔ median of 16 measurements
- $a_{ph}^*(\lambda)$
- P = Chl-a concentration

Removing surface-reflected light

Station 16

Focus mimic above 670 nm ➔ heterogeneous water column

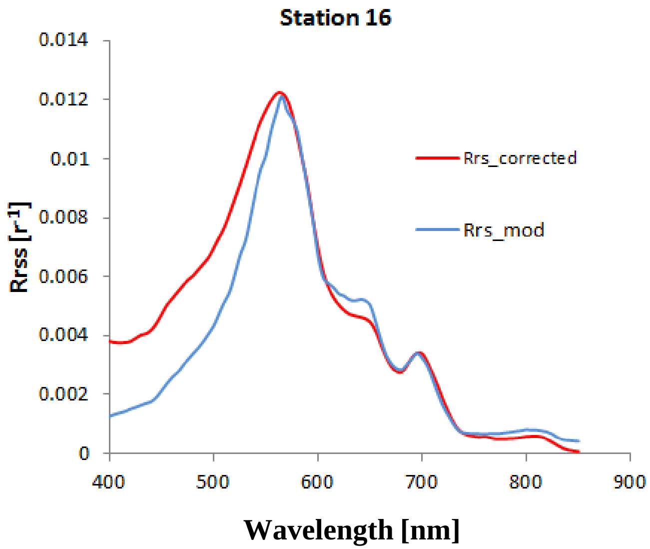
Optimization input

P =	18	P = Chl-a conc
G =	0.74	G = adg440
X =	0.049	X = bbp440
delta =	0.0015	delta

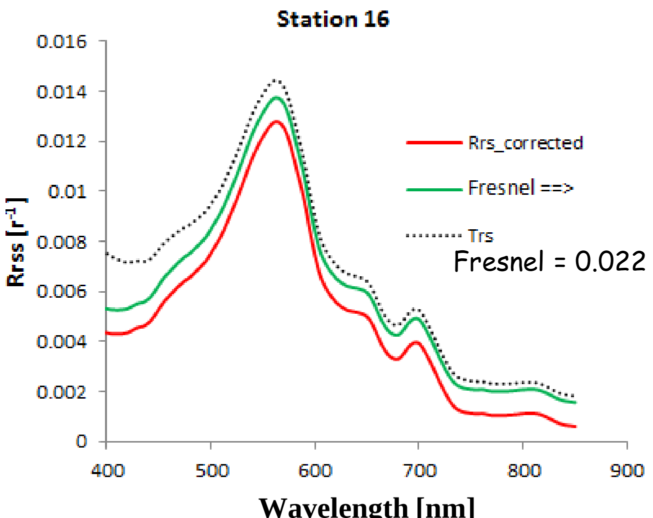
Water sampled

Depth (meter)	chlorophyll-a (µg/L)
0.3 m	4.88
1.6 m	63.01
4.8 m	5.06

Secchi → 1.6 m



P = 18 ug/l



Removing surface-reflected light

Station 12

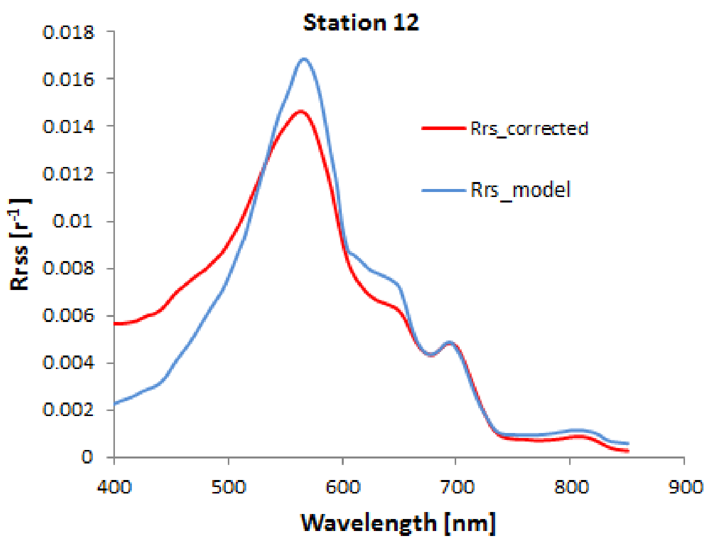
Optimization input

P =	12	P = Chl-a conc
G =	0.67	G = adg440
X =	0.074	X = bbp440
delta =	0.00052	delta

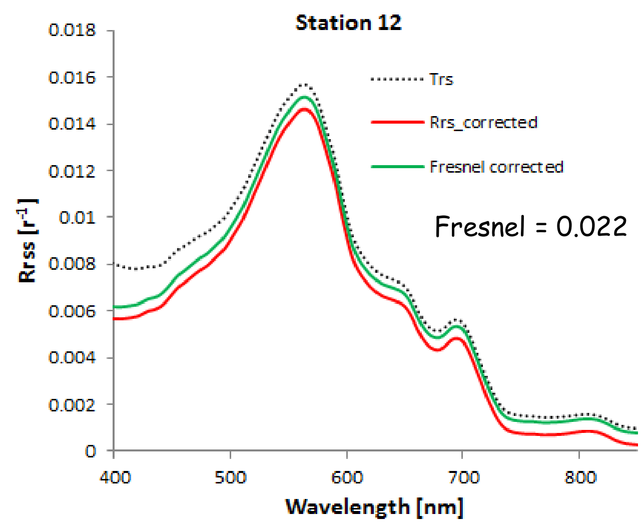
Water sampled

Depth (meter)	chlorophyll-a (µg/L)
0.3 m	8.53
2.2 m	114.03
6.6 m	13.83

Secchi →



P = 12 ug/l



Removing surface-reflected light

Station 15

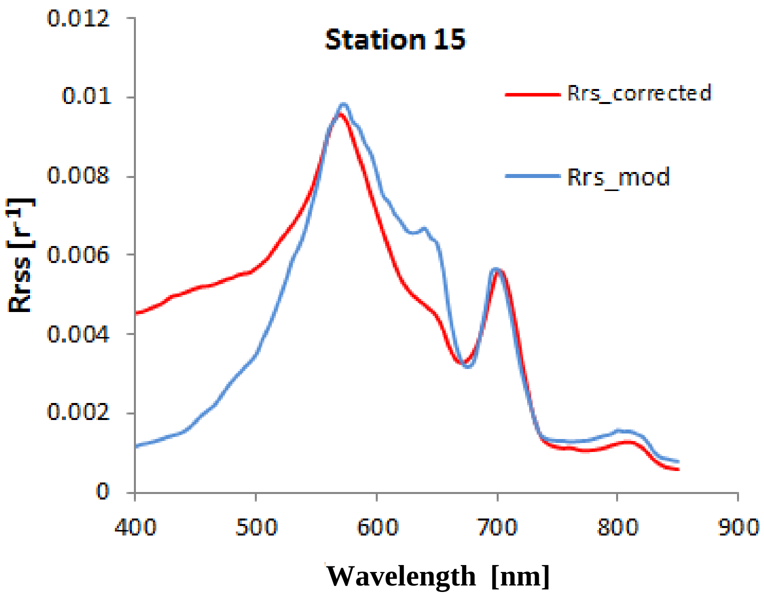
Optimization input

P =	230	P = Chl-a conc
G =	1.5	G = adg440
X =	0.11	X = bbp440
delta =	0.00001	delta

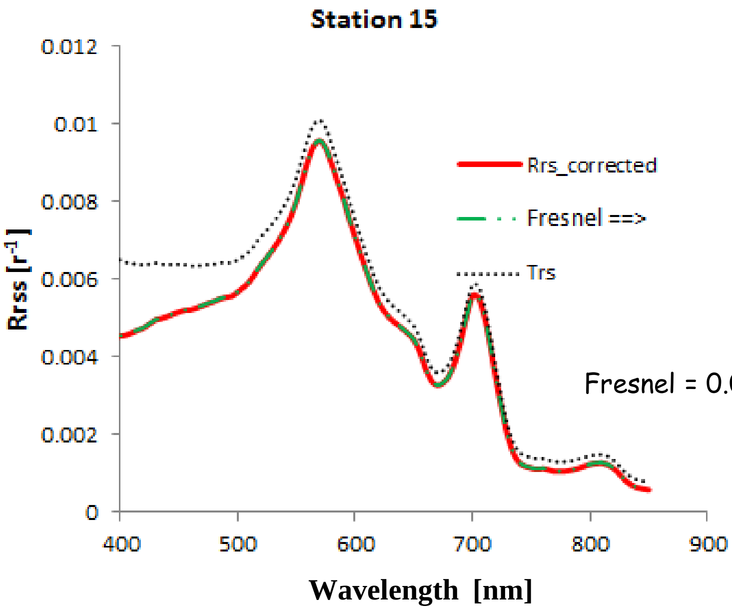
Water sampled

Depth (meter)	chlorophyll-a (µg/L)
0.3 m	33.95
1.2 m	269.29
3.6 m	53.06

Secchi → 1.2 m



P = 230 ug/l



Total absorption → ACS versus "Lab"

Station 12

$$a_t\ (lab) = a_w + a_{ph}^* * C_{ph} + a_d^* * C_{TSS} + a_{CDOM}$$

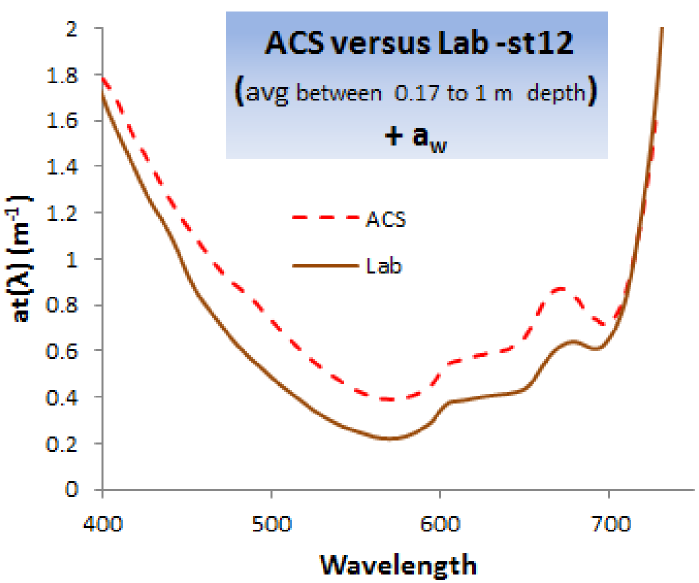
For QAA validation

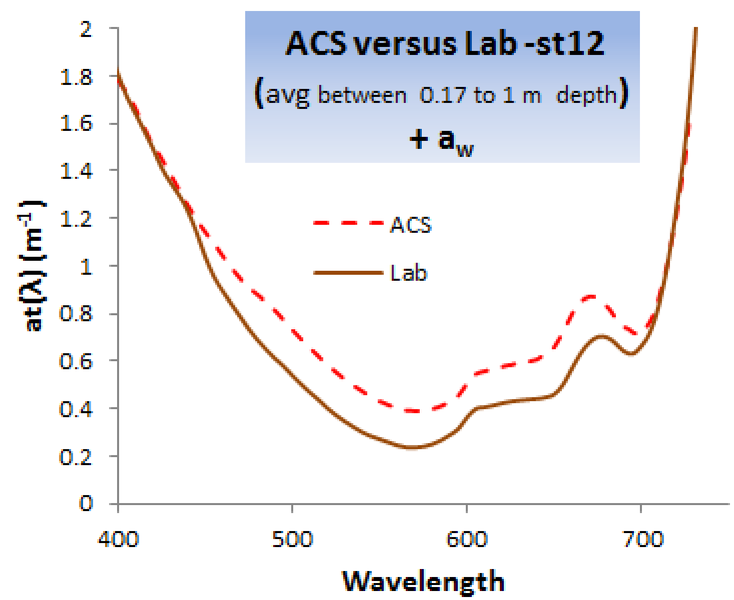
Chl-a = 8.5 µg/L
Subsurface value

Water sampled

Depth (meter)	chlorophyll-a (µg/L)
0.3 m	8.53
2.2 m	114.03
6.6 m	13.83

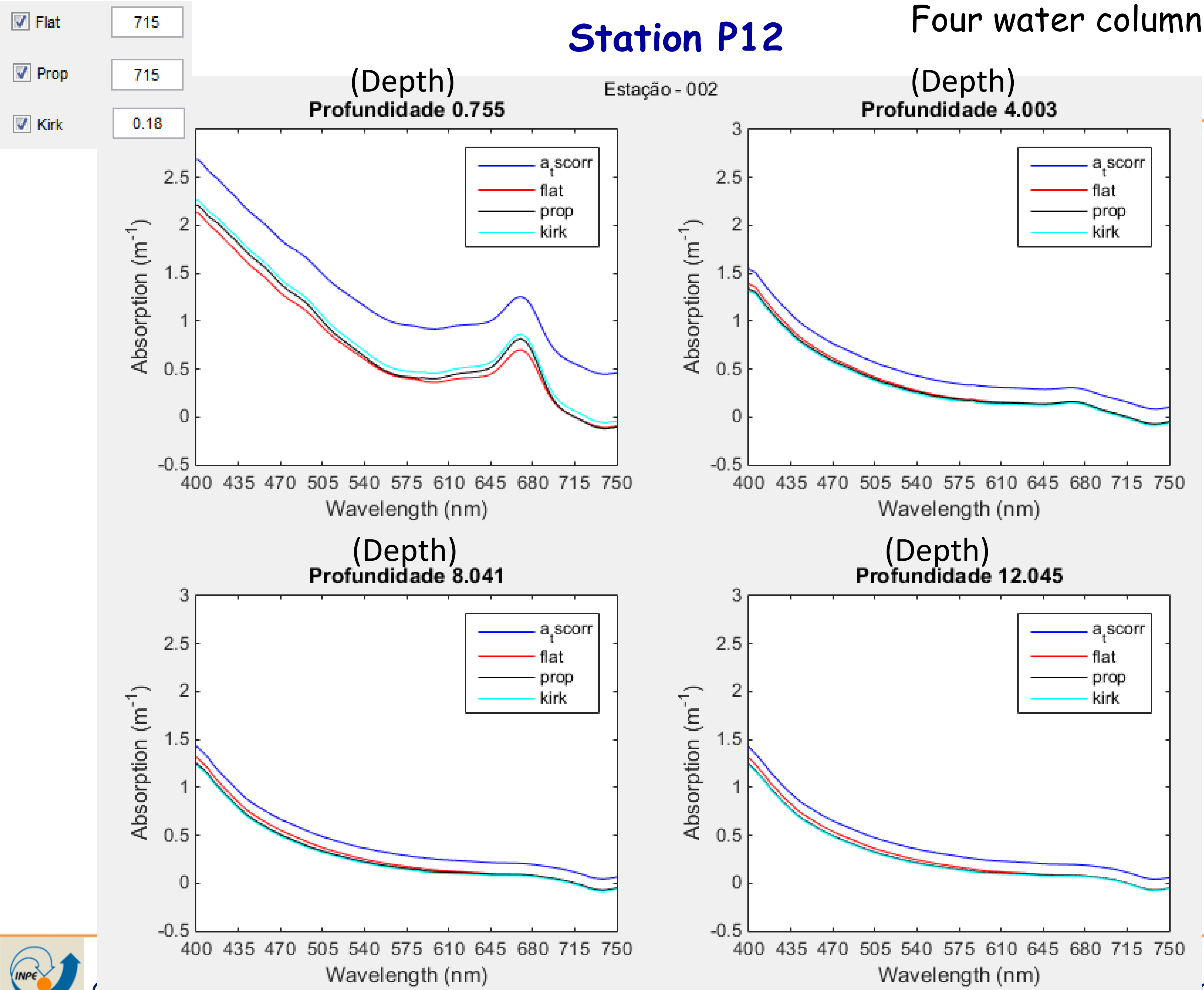
Chl-a = 12 µg/L
Spectral optimization





Station P12

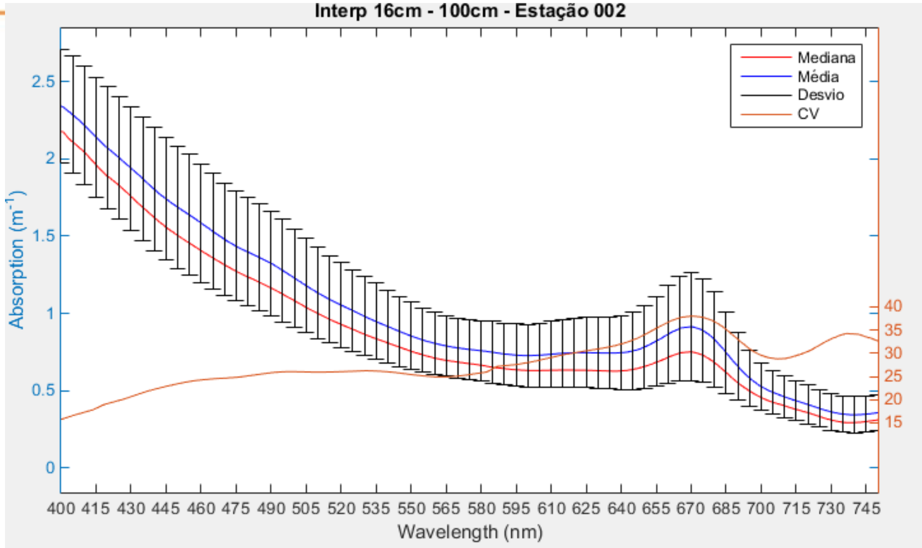
Four water column depth

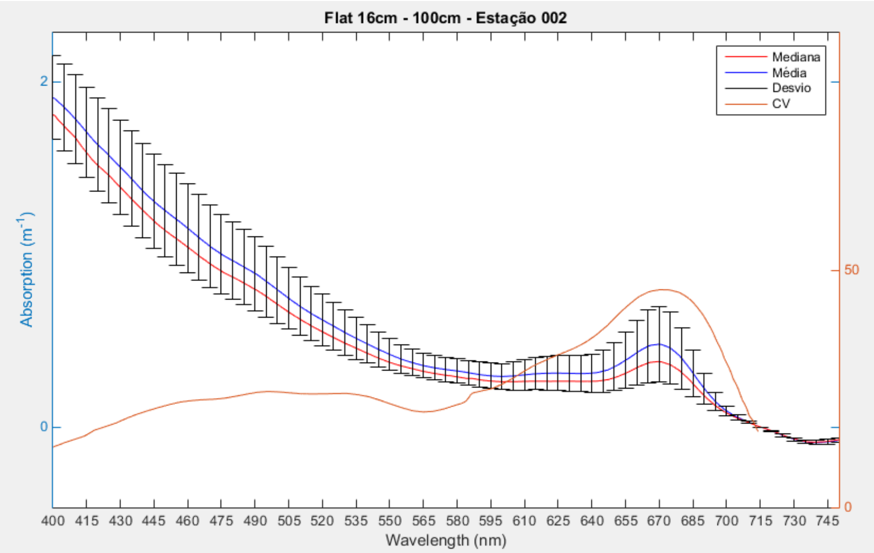


Station P12

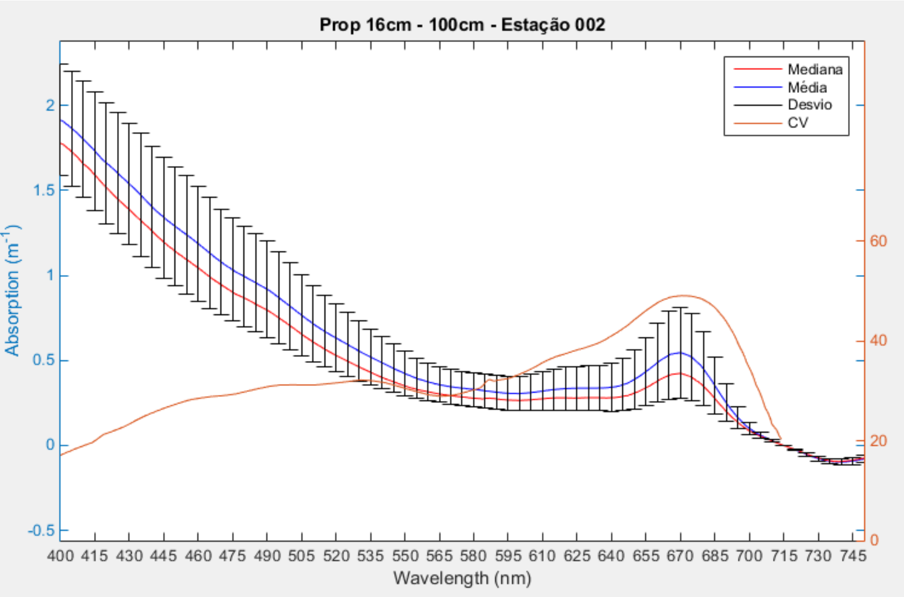
File 002 ACS

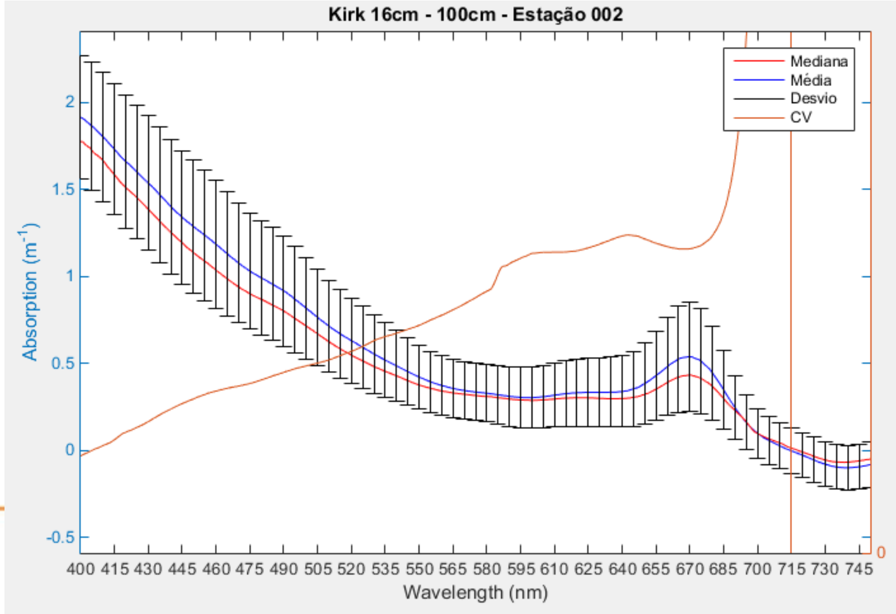
uncorrected





Median & Mean between 0.16 to 1 m depth



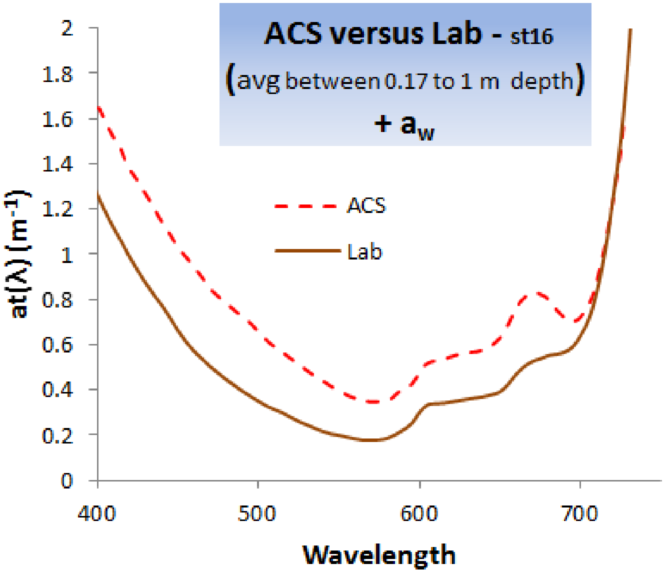


Total absorption ➔ ACS versus "Lab"

Station 16

$$a_t\ (lab) = a_w + a_{ph}^{*} * C_{ph} + a_d^{*} * C_{TSS} + a_{CDOM}$$

Chl-a = 4.8 μg/L
Subsurface value



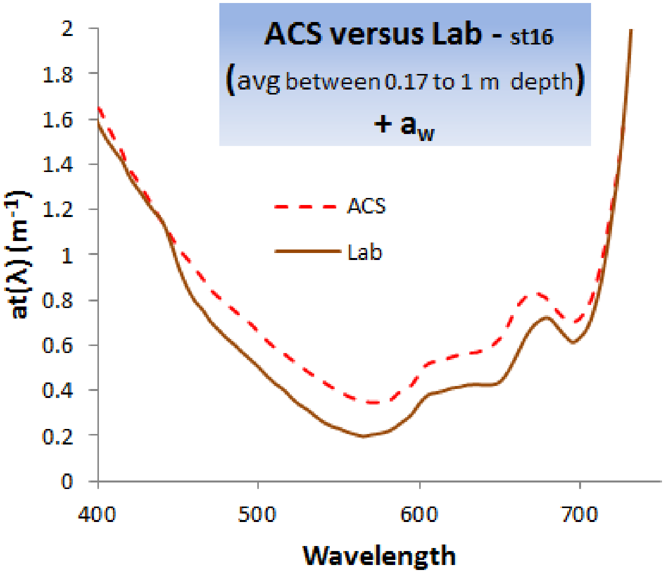
Water sampled

Depth (meter)	chlorophyll-a (μg/L)
0.3 m	4.88
1.6 m	63.01
4.8 m	5.06

TSM (mg/l)
0.88
5.20
1.50

TSM = 0.88 mg/L

Chl-a = 18 μg/L
Spectral optimization value

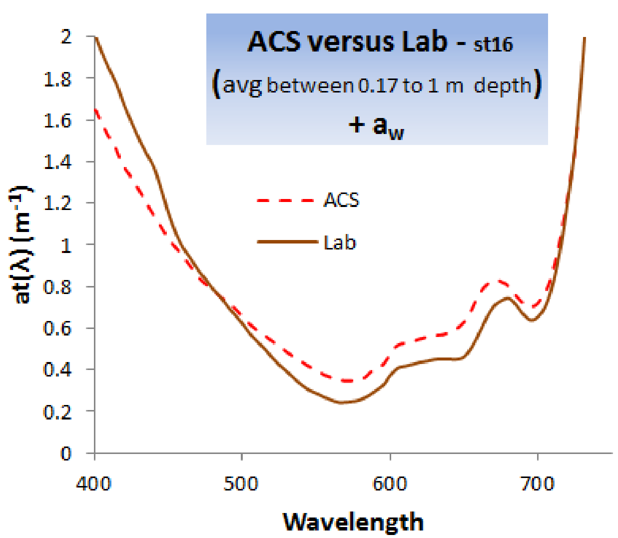


Total absorption → ACS versus "Lab"

Station 16

$$a_t\ (\text{lab}) = a_w + a_{ph}^{*} * C_{ph} + a_d^{*} * C_{TSS} + a_{CDOM}$$

Chl-a = 4.8 µg/L
TSM = 3.04 mg/L

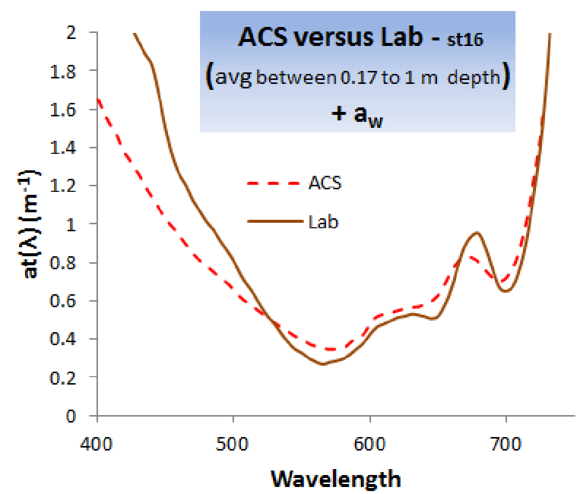


Water sampled

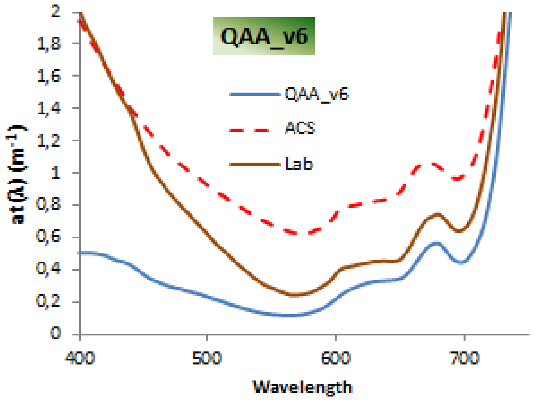
Depth (meter)	chlorophyll-a (µg/L)
0.3 m	4.88
1.6 m	63.01
4.8 m	5.06

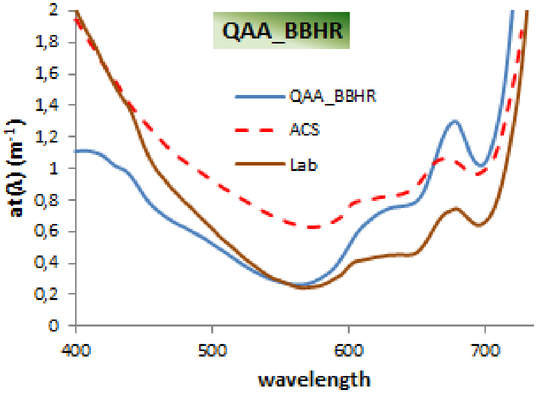
TSM (mg/l)
0.88
5.20
1.50

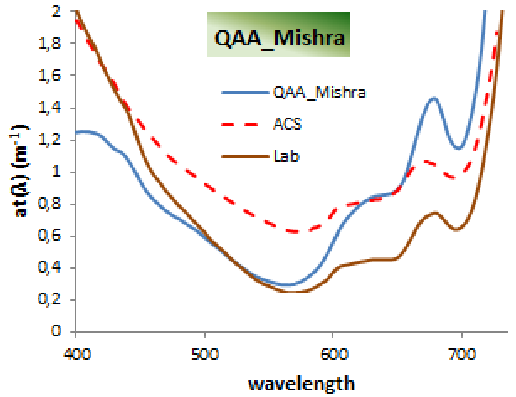
Chl-a = 33.94 µg/L
TSM = 3.04 mg/L



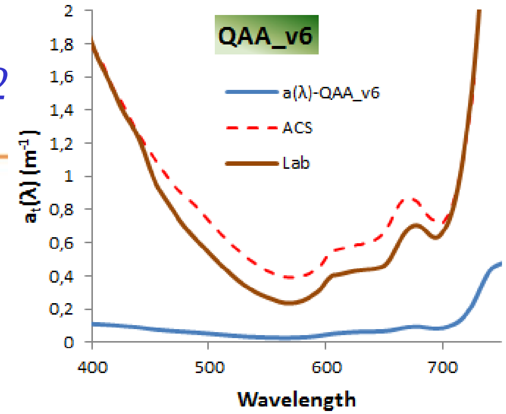
Estação 16

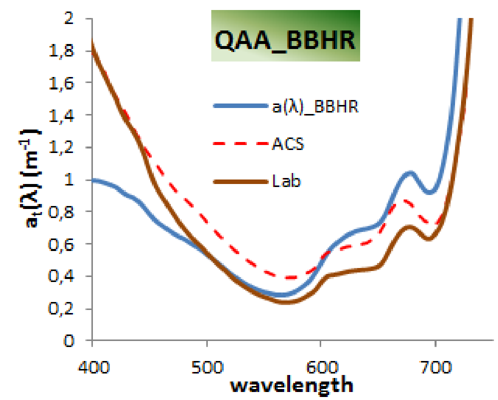


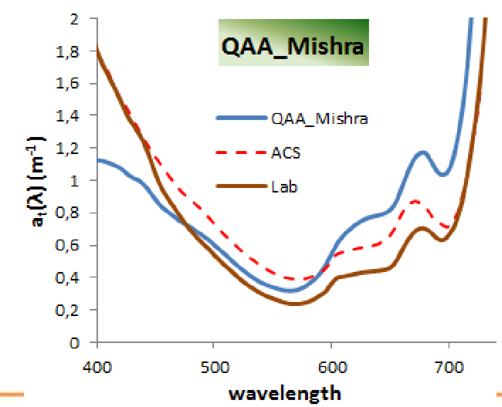




Estação 12







obrigado