MINISTERIO DE FOMENTO

CEDEX
CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS

Title:

"Use of CHRIS imagery for Monitoring Ecological Water Quality in smallest Mediterranean Reservoirs integrated in the Intercalibration Exercise of WFD Implementation Process.
Final report." (AO 3123)

Authors:
Peña-Martínez. Ramón; Domínguez-Gómez. José-Antonio; Ruiz-Verdú. Antonio
Centre for Hydrographic Studies of CEDEX (Spain)

Topic/subtopic : Ecological Water Quality. Photosynthetic pigments. Remote sensing

CEDEX proposed CHRIS activities for 2005. trough two AO Projects (AO 2830 since 2004 and AO 3123 new for 2005) in the frame of a Project funded by the Spanish Environment Ministry.

for Monitoring the Water Quality. specifically Chlorophyll-a mean summer concentration assessment. in reservoirs included in the

Geographic Intercalibration Group for Mediterranean Lakes. leaded by Spain. in the *Common Implementation Strategy of European Union Water Framework Directive (WFD).*

DIRECTIVE 2000/60/EC OF THE AMENT[illegible]D OF THE COUNCIL

establishing a framework the field of water policy

1.4.1. Comparability of biological monitoring results

(i) Member States shall establish monitoring systems for the purpose of estimating the values of the biological quality elements specified for each surface water category or for heavily modified and artificial bodies of surface water. In applying the procedure set out below to heavily modified or artificial water bodies, references to ecological status should be construed as references to ecological potential. Such systems may utilise particular species or groups of species which are representative of the quality element as a whole.

(ii) In order to ensure comparability of such monitoring systems, the results of the systems operated by each Member State shall be expressed as ecological quality ratios for the purposes of classification of ecological status. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero.

(iii) Each Member State shall divide the ecological quality ratio scale for their monitoring system for each surface water category into five classes ranging from high to bad ecological status, as defined in Section 1.2, by assigning a numerical value to each of the boundaries between the classes. The value for the boundary between the classes of high and good status, and the value for the boundary between good and moderate status shall be established through the intercalibration exercise described below.

The purpose of the Intercalibration exercise is

to ensure comparable ecological quality assessment systems and harmonised ecological quality criteria for surface waters in the Member States.

This ensures a harmonised approach to define one of the main environmental objectives of the WFD. the "*good ecological status*". by establishing:

· Agreed ecological quality criteria for good quality sites. setting the targets for protection and restoration

· Agreed numerical Ecological Quality Ratio (EQR) values for two quality class boundaries (high/good and good/moderate)

Geographical Intercalibration Groups (GIG)

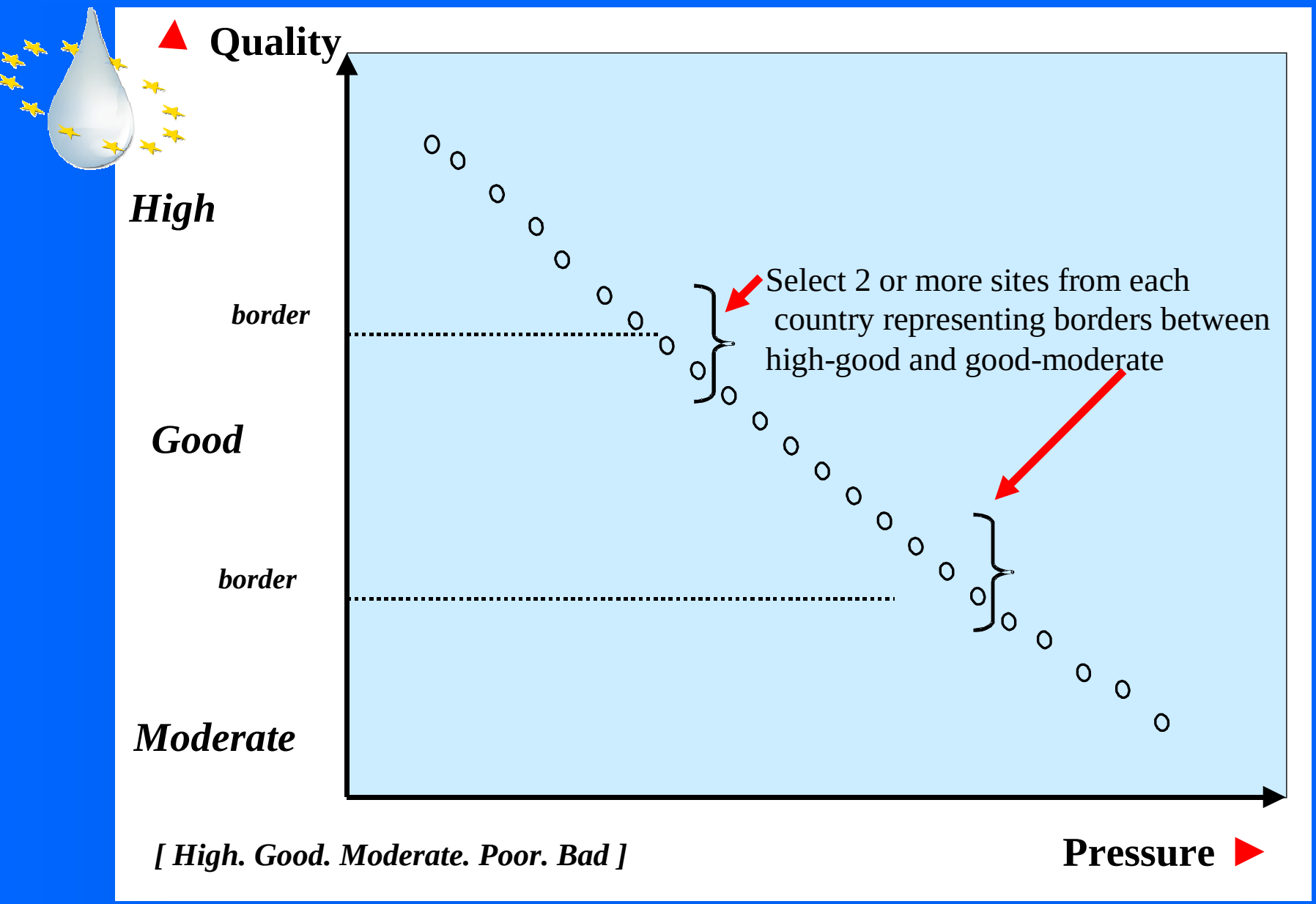
The intercalibration network must be confined to “ecoregions”.

“Ecoregions” can either be interpreted as those specified in Annex XI of the Directive (the Illies ecoregions for lakes and rivers. and much wider regions for coastal and transitional waters). or can be defined in a wider sense.

· For *lakes*: five intercalibration groups (Northern. Atlantic. Central. Alpine. *Mediterranean*).

GIG LM :

Spain (leader). Portugal. France. Italy. Greece. Cyprus and Romania


Quality
High
border
Good
border
Moderate
Select 2 or more sites from each country representing borders between high-good and good-moderate
[High. Good. Moderate. Poor. Bad]
Pressure

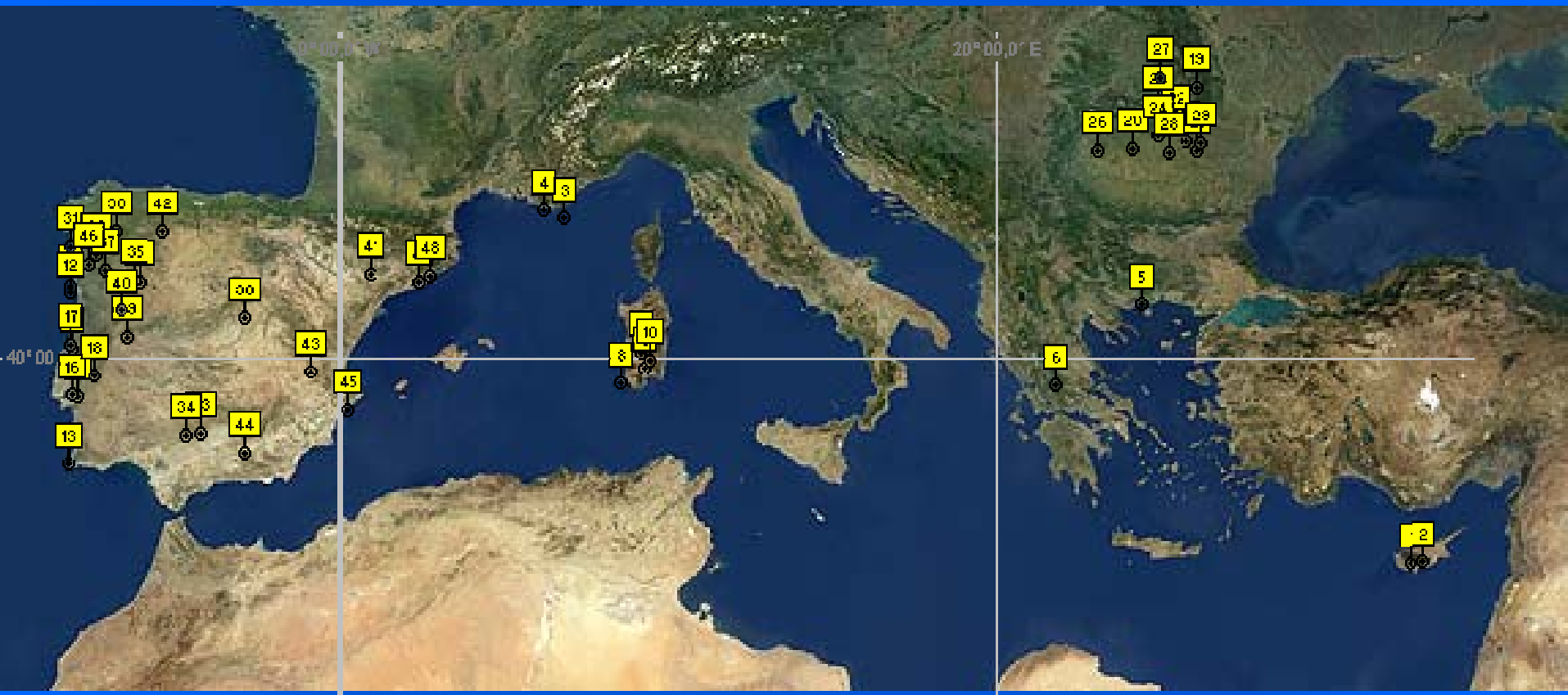
common “WFD assessment method” in the GIG.

In the L-M GIG. the common method comes to be the assessment of **chlorophyll concentration** from a sample collected at. or immediately below. the water **surface. once in summer** season.

… as an **interim common method** for IC purposes until a more sufficient method is implemented. in search of a more reliable outcome. More specifically. an **improved chlorophyll assessment** method could be agreed among the GIG countries. increasing somewhat the annual number of samples and adopting a common sampling strategy.

As an alternative approach to increased sampling. or in addition to it. satellite ***remote sensing imagery*** may provide a valuable tool in monitoring the **variability** of algal biomass and assessing the mean summer values of chlorophyll concentration at water surface.

European Union Water Framework Directive (EU WFD)
Common Implementation Strategy (CIS)
Intercalibration Exercise
Geographic Intercalibration Group



LM – Mediterranean Lakes and Reservoirs (ES leader. PT. FR. IT. GR. CY. RO)
50 reservoirs included in this process

Chlorophyll-a fit equation:

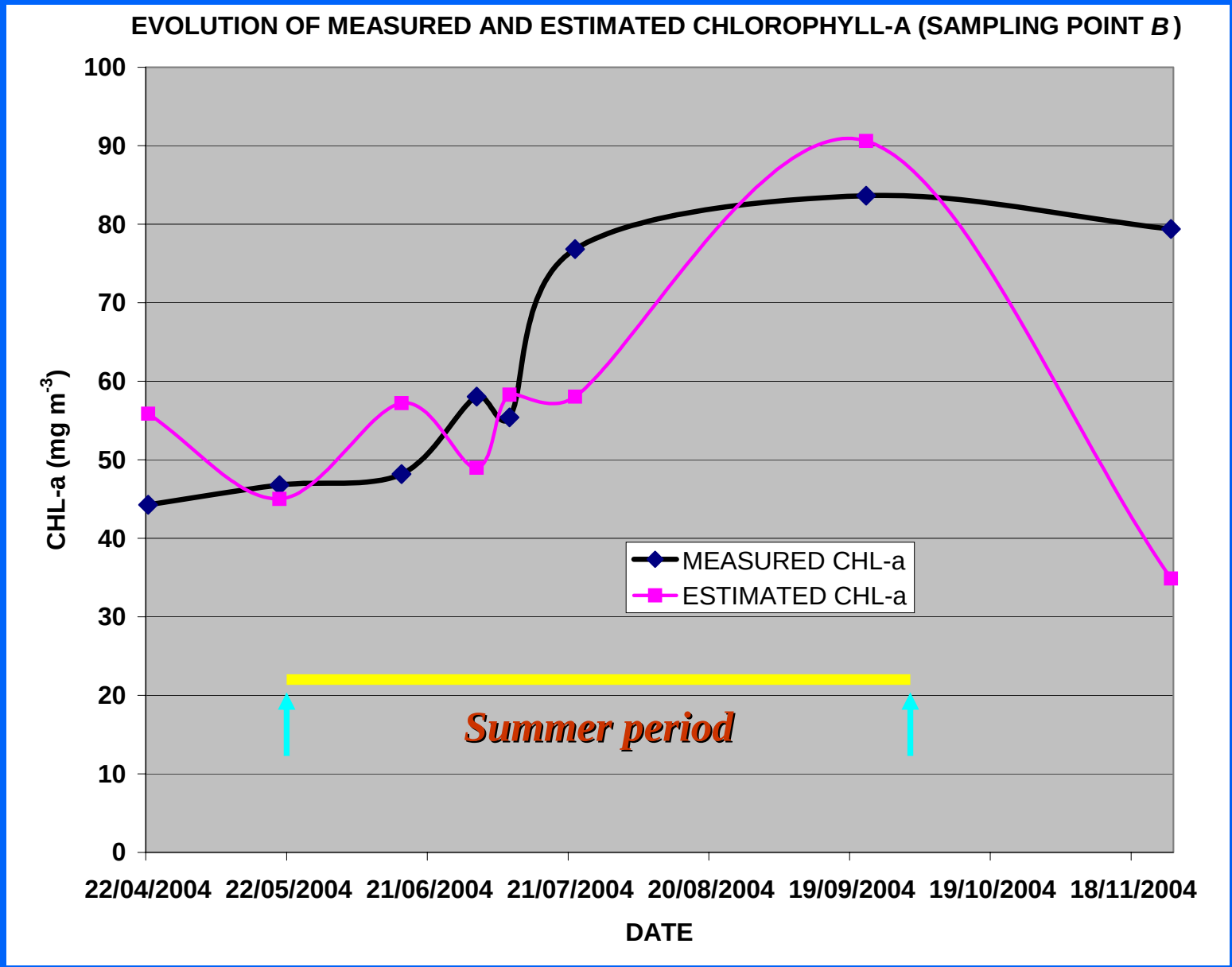
$[Chla] = 9.981\ e^{5.6743\ (W14-W12)/(W14+W12)}$ $R^2 = 0.8003$

Phycocyanin fit equation:

$[Phyc] = 46.478\ e^{5.1864\ (W14-W9)/(W14+W9)}$ $R^2 = 0.9211$

(W14 center corresponding with MERIS 9)

(W9 center corresponding with MERIS 6)


EVOLUTION OF MEASURED AND ESTIMATED CHLOROPHYLL-A (SAMPLING POINT B)
CHL-a (mg m-3)
100
90
80
70
60
50
40
30
20
10
0
22/04/2004
22/05/2004
21/06/2004
21/07/2004
20/08/2004
19/09/2004
19/10/2004
18/11/2004
DATE
MEASURED CHL-a
ESTIMATED CHL-a
Summer period

Ground campaigns tasks:

- Monthly in summer period from May 2005 until October 2005 (adapted to CHRIS-Proba calendar). measuring: Phytoplankton taxonomic composition and biomass; Chlorophyll-a and other Phytoplankton pigment composition; Nutrient concentration; Secchi disk depth transparency; Physicochemical parameters assessment.

[Member State Water Authorities Scientific Branch. responsible any case of Ecological Water Quality Assessment]

Imagery needs:

- Quantity: desirable 1 image per month. preferably may-october.

-Type: Water bands. Mode 2. Full Swath. High Resolution. Multiangular (5 angles)

Proposal AO 3123

The Area of work includes:

-Kouris reservoir and

Asprokremmos reservoir. in *Cyprus*;

-Sacele reservoir and

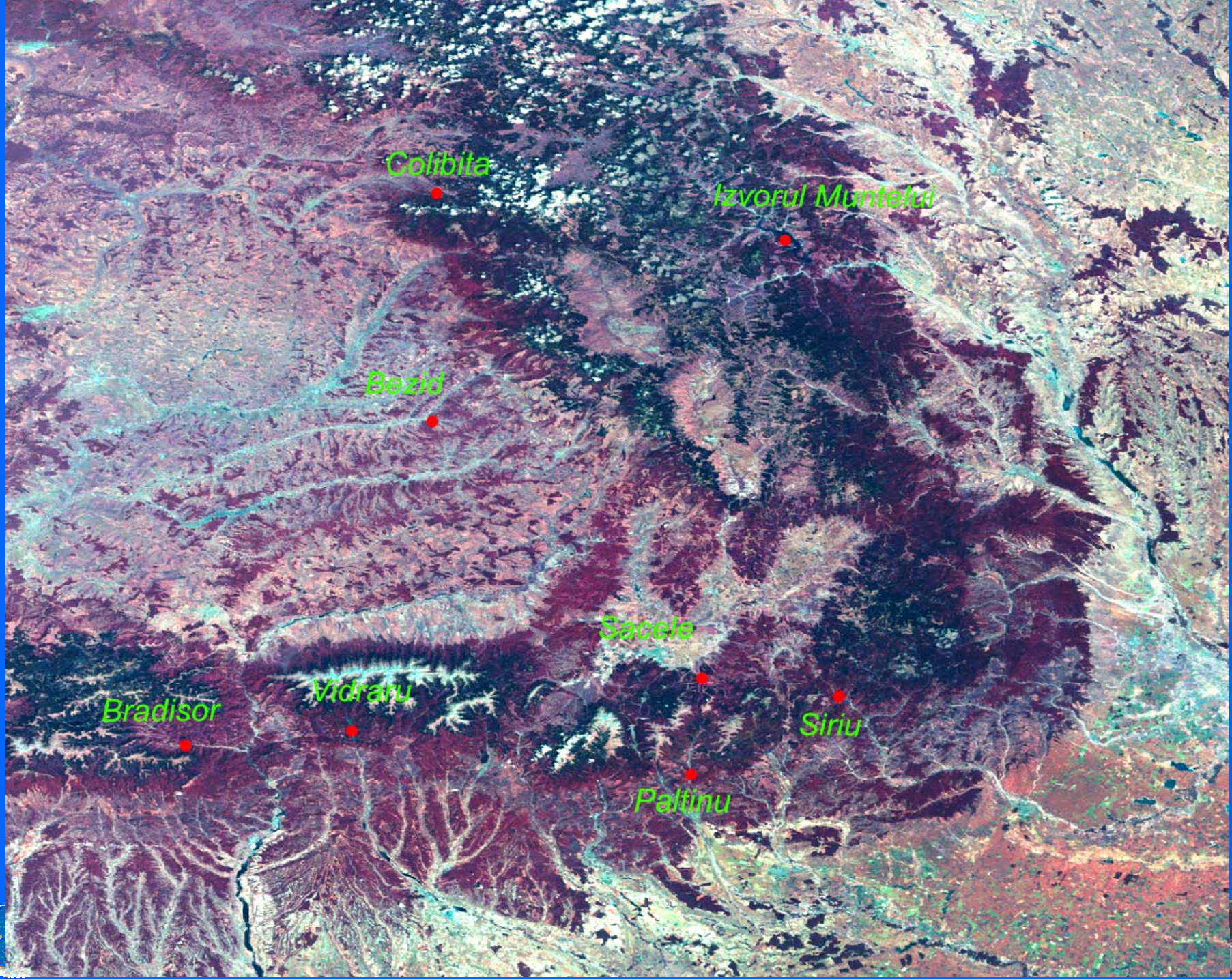
Bezid reservoir. in *Romania*;

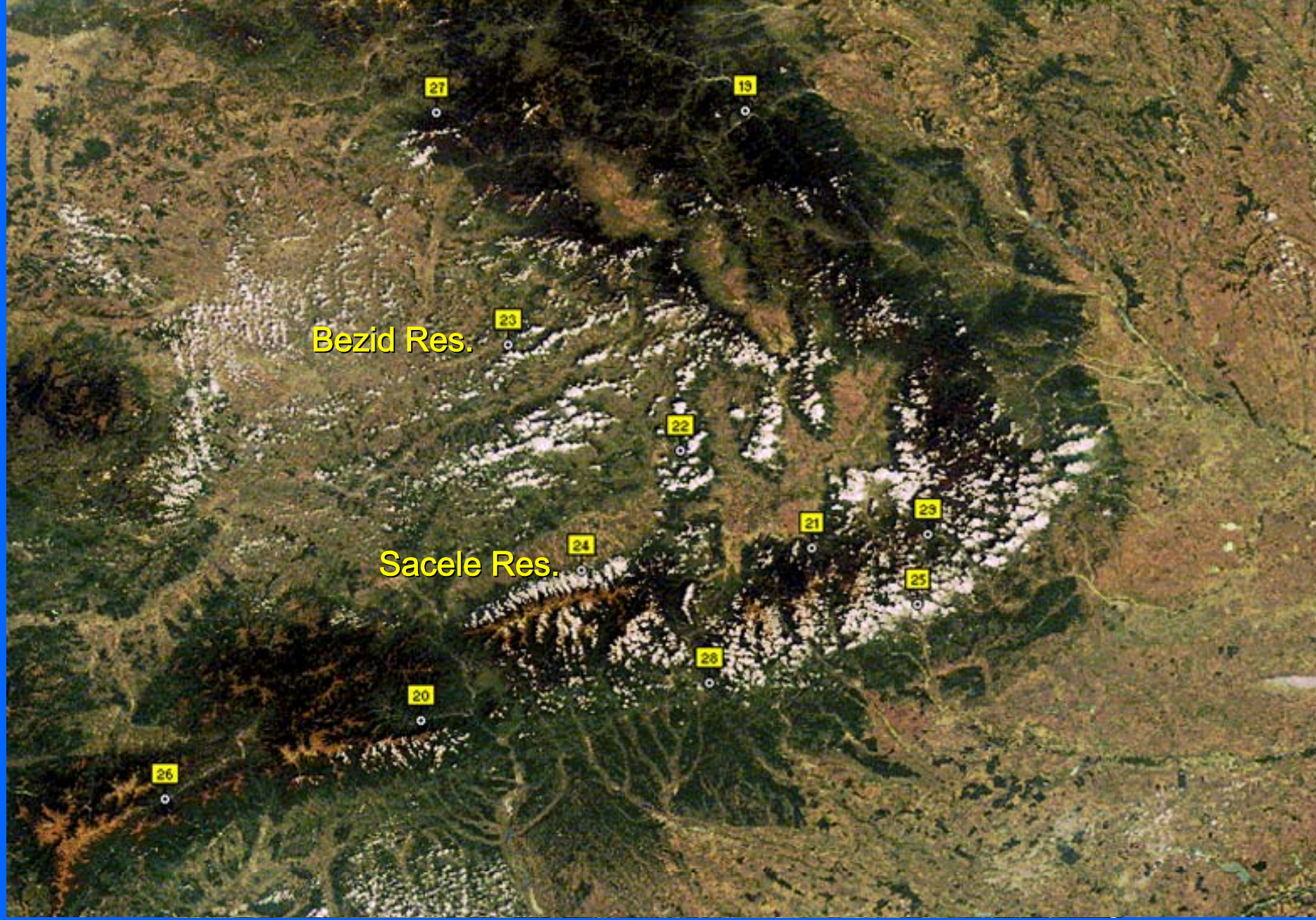
-Punta Gennarta reservoir and

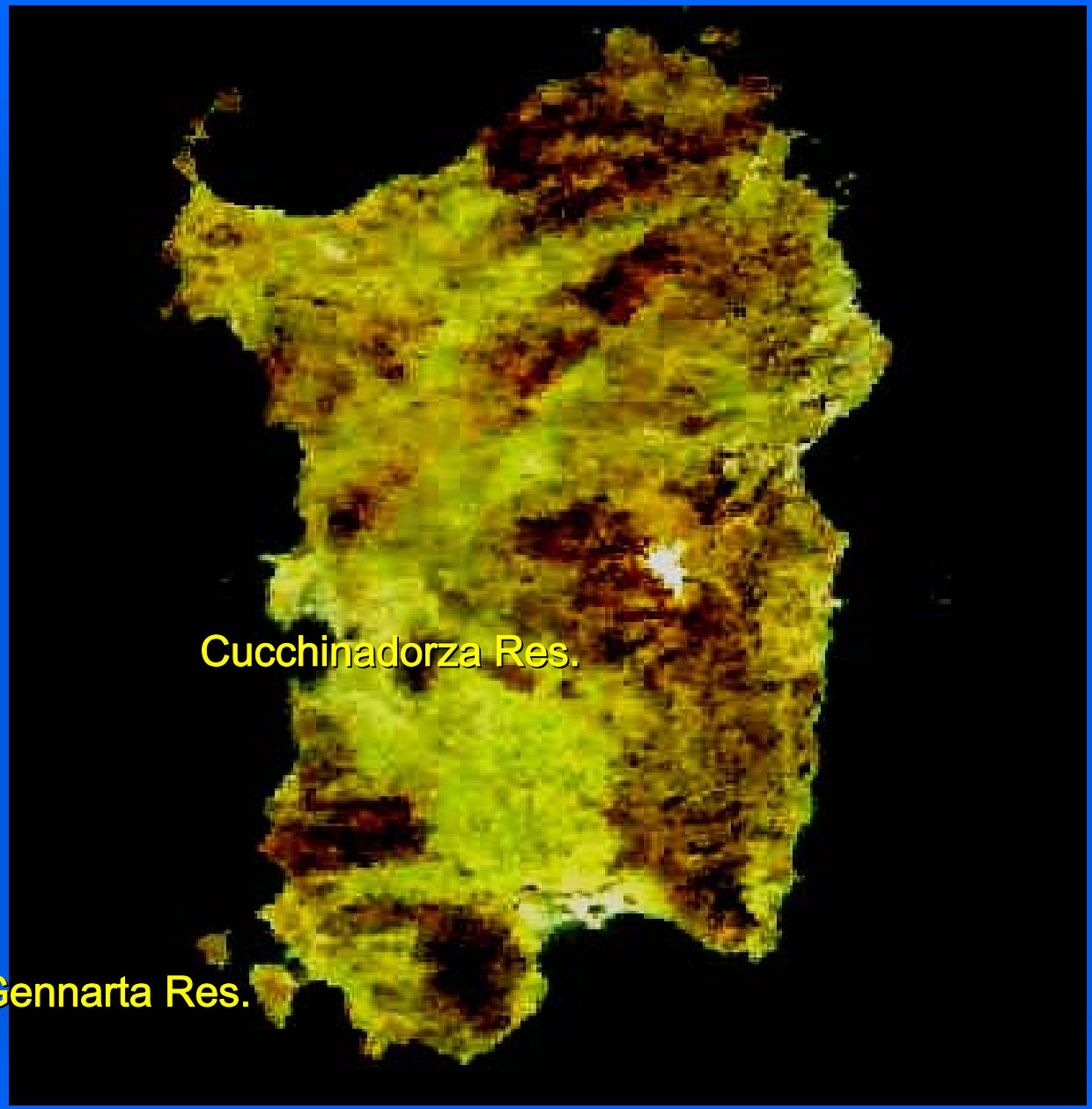
Cucchinadorza reservoir. in Sardegna Island. *Italy*


Bezid Res.
Sacele Res.
Cucchinadorza Res.
Punta Gennarta Res.
Kouris Res.
Asprokremmos Res.


Kouris Res.
Asprokremmos Res.


Colibita
Izvorul Muntelui
Bezid
Sacele
Vidraru
Bradisor
Siriu
Paltinu


27
19
Bezid Res.
23
22
21
23
24
Sacele Res.
25
28
20
26


Cucchinadorza Res.
Punta Gennarta Res.

Final proposal *ACCEPTED*

CHRIS / Proba Revised acquisition request for 2005

AO-ID *	Site	Nº Image Sets	Period
2830	Rosarito	8	abr-nov
3123	Kouris	5	may-oct
3123	Asprokremmos	5	may-oct
3123	Sacele	5	may-oct
3123	Bezid	5	may-oct
3123	Cucchinadorza	5	may-oct
3123	Punta Gennarta	5	may-oct

* PI: Peña-Martínez, Ramón (rpena@cedex.es)

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RESULTS FROM THE DATA ACQUISITION IN SOME GIG-LM RESERVOIRS BY SATELLITE REMOTE SENSING

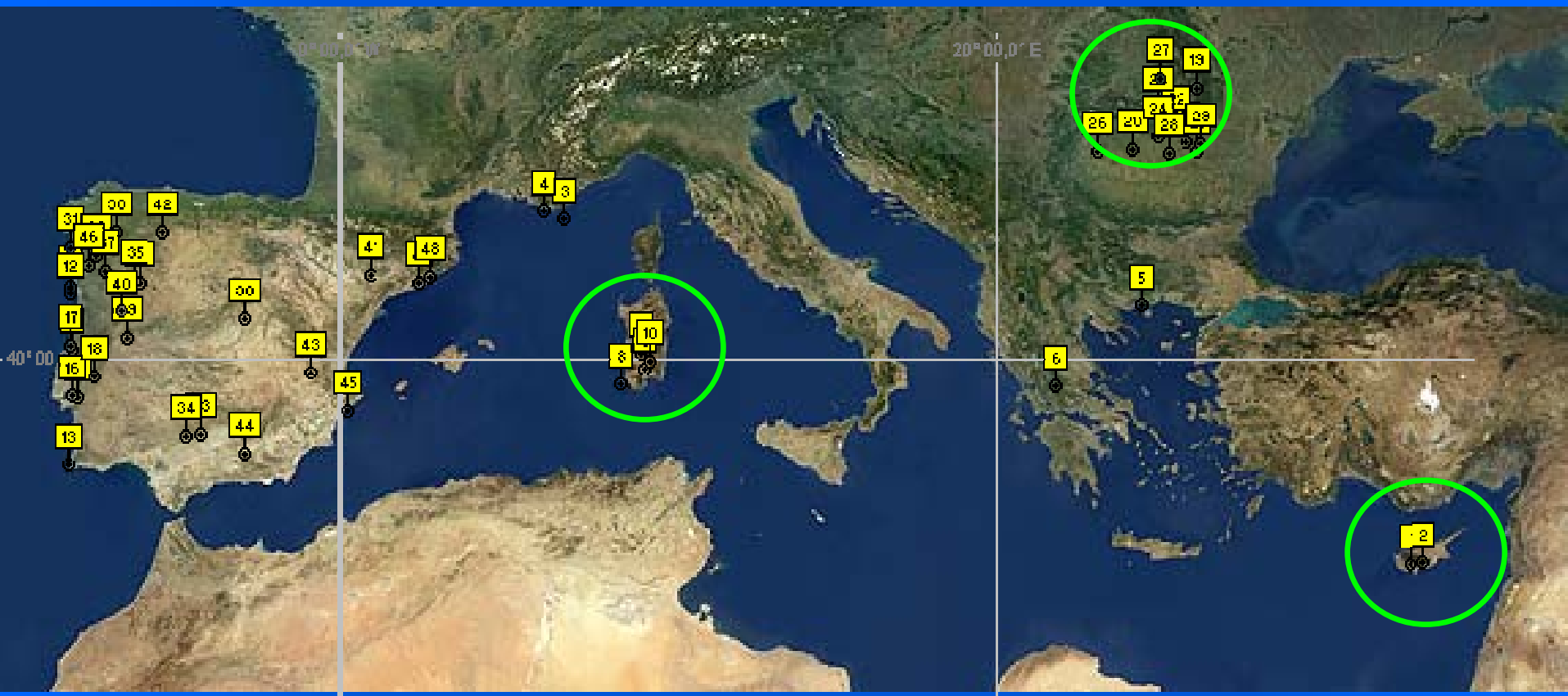
(*) External collaborator

From 1999 to 2005 CEDEX developed the ESA Project AOE-594 . "Development of an Operational System for direct Thematic Mapping of Photosynthetic Pigments in Lakes using MERIS. Application to the Spanish reservoirs".

In the working plan was included many field activities in order to built an comprehensive data bank of many spanish reservoirs integrating radiometric information on water optics. in situ profiling of several pigment and other parameters and integrated sampling in the 1st optical layer to analysis by HPLC method 19 pigments.

After CEDEX was developed ***reflectivity models*** to assess Chlorophyll a and other pigment concentration in water bodies to applied to MERIS imagery and to any other multi or hyperspectral images of reservoirs.

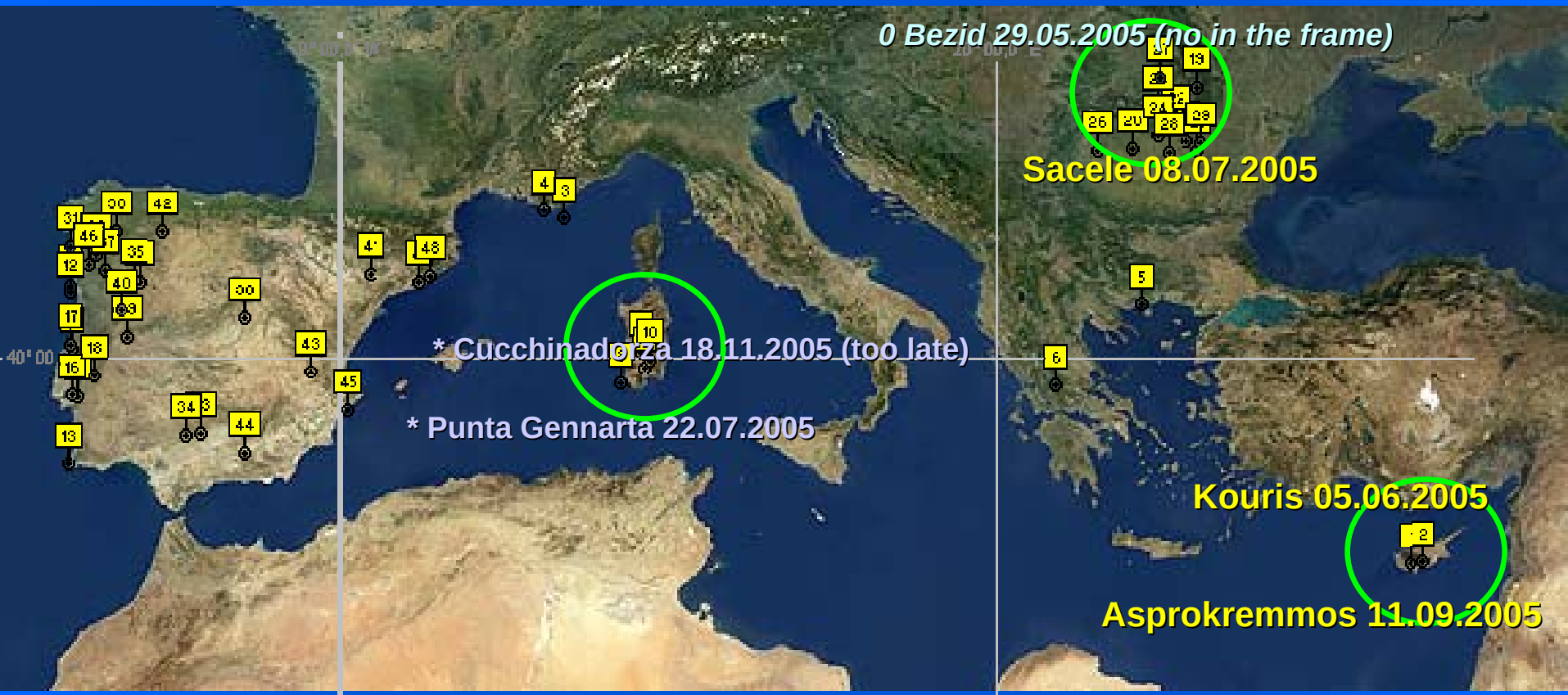
In that campaigns was used some ***device*** to assure the same conditions in the radiometric measurements by the field ***spectro-radiometer .*** In addition has used a *probe CTD and multiflorimeter* for pigments. (in the next slides)



Sensor CHRIS / Proba satellite : 17 m spatial resolution; 5 angles image set; 15 km frame; 18 spectral bands in the mode 2 water.

2005 CHRIS/Proba image set acquisition

Sensor CHRIS / Proba satellite : 17 m spatial resolution; 5 angles image set; 15 km frame; 18 spectral bands in the mode 2 water.



Only 3 available image sets along the summer

Then, to cover the summer season has been necessary to use with its limitations. ...

* Finally no included in the IC process

0 No image

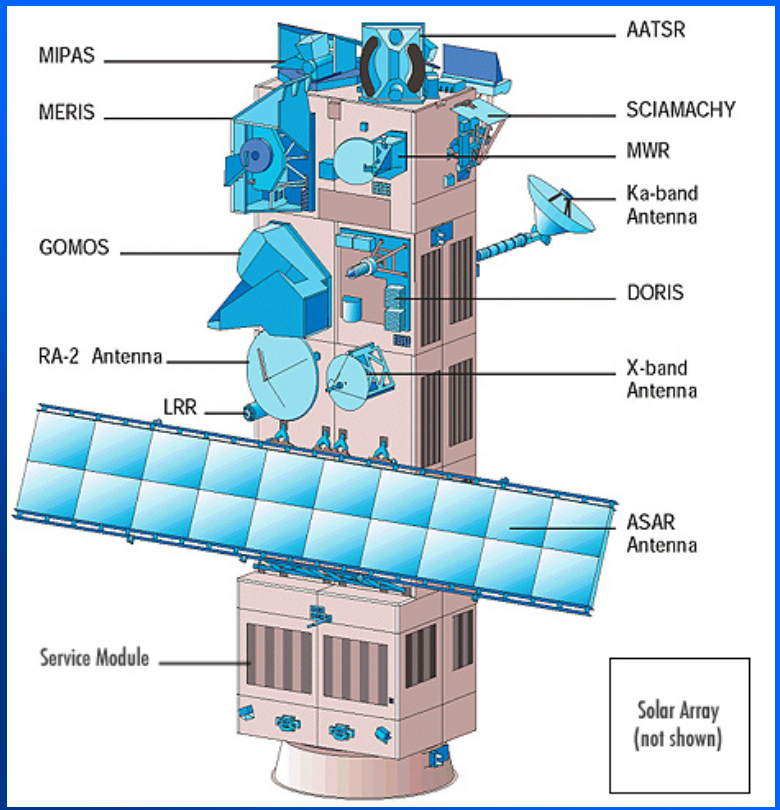
The Sensor MERIS / ENVISAT satellite :

300 m spatial resolution;

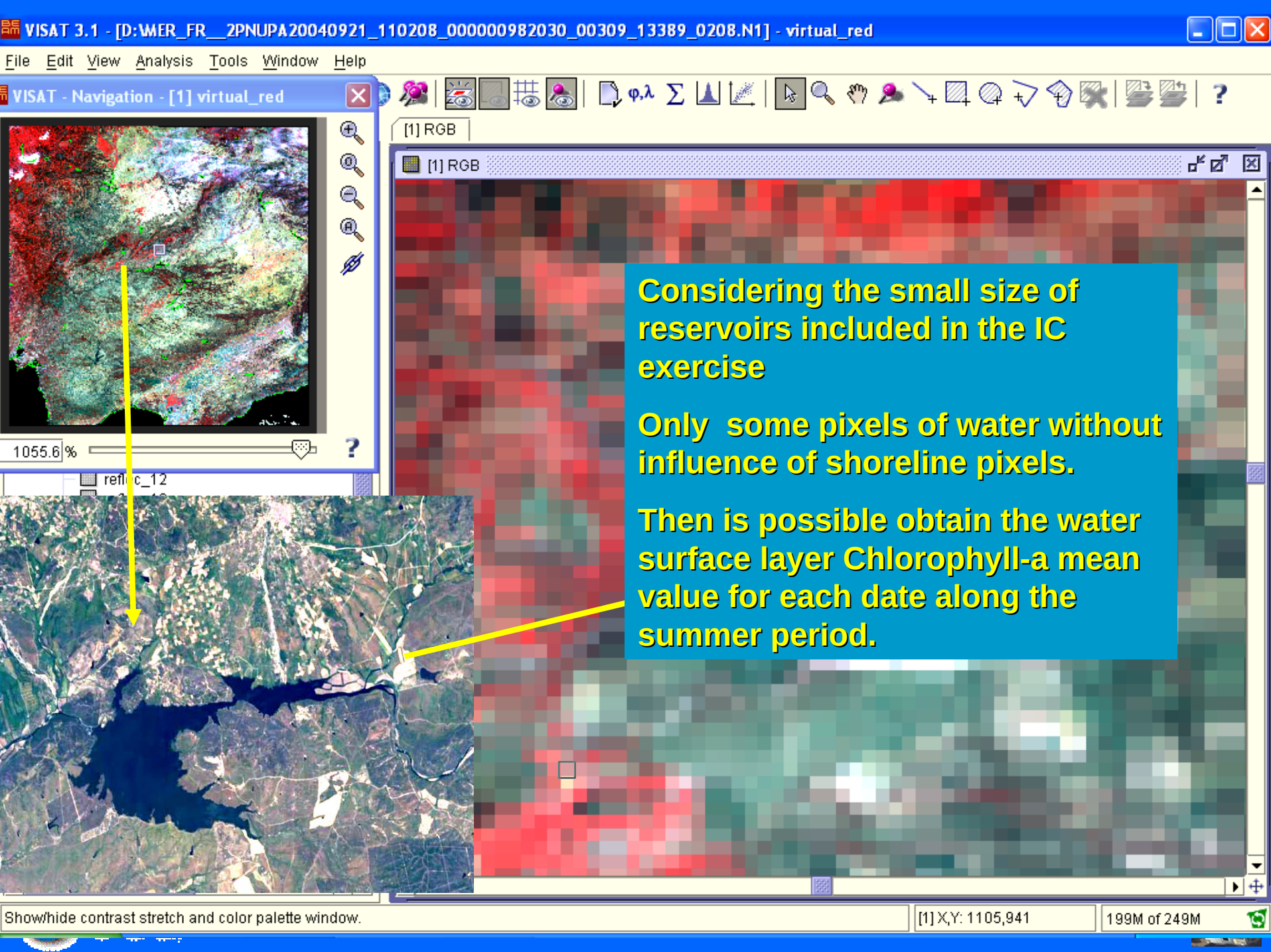
1050 km frame;

16 spectral bands in the visible spectrum specially focused on ocean colour and environmental applications.

High radiometric quality



ENVISAT-1
operational satellite :
10 sensors;
weigth 8500 kg;
ESA Earth Observation mission


VISAT 3.1 - [D:\MER_FR__2PNUPA20040921_110208_000000982030_00309_13389_0208.N1] - virtual_red
File Edit View Analysis Tools Window Help
VISAT - Navigation - [1] virtual_red
1055.6 %
[1] RGB
[1] RGB
Considering the small size of reservoirs included in the IC exercise
Only some pixels of water without influence of shoreline pixels.
Then is possible obtain the water surface layer Chlorophyll-a mean value for each date along the summer period.
Show/hide contrast stretch and color palette window.
[1] X,Y: 1105,941
199M of 249M

Satellite images orders (received R)

MERIS / ENVISAT-1 images

AOE594 *Ramon Pena-Martinez, P.I.*

	LM05R			LM05C			LM05I		
h]									
	01	31.07	R	01	04.05	R	01	18.06	R
	02	30.07	A	02	17.05	R	06	21.06	R
	03	27.07	R	03 *2	05.06	R	07	24.06	R
	04	26.06	R	04 *8	08.06	R	08	01.07	R
	05	17.06	R	05	18.06	R	09	04.07	R
	06	04.06	R	06	24.06	R	10	07.07	R
	07	22.06	R	07*6,7	07.07	R	11	20.07	R
	08	22.08	R	08	20.07	R	12	23.07	R
	08b	22.08	R	09	11.08	R	13	26.07	R
	08-22g	22.08	R	10	14.08	R	14	08.08	R
	09-29g	29.08	F	11	29.08	A	15	14.08	R
	2004	21.08	R	12	30.08	A	02	28.09	r
	10	03.09	R	13	05.09	A	03	01.10	R
	11	06.09	A	14	08.09	A	-	25.07	R
	12	10.09	A	15	12.09	A			
	13	03.10	r	16	15.09	R			
				17	18.09	R			
				18	04.10	A			

CHRIS/Proba images acquired:

Bezid	*29.05.05 bad pointing*
Kouris	**05.06.05**
Sacele	**08.07.05**
Punta Gennarta	*22.07.05 excluded IC*
Asprokremmos	**11.09.05**
Cucchinadorza	*18.11.05 excluded IC*

Reservoir	C.	Sensor	Image dates	Sampling date	Chl-a (mg/m^3)	Secchi (m)
Colibita	RO	ME	04.06.05 17.06.05 22.06.05 26.06.05 27.07.05 31.07.05 22.08.05	08.06.05 19.07.05 23.08.05	1.16 2.22 3.71	6.75 3.20 3.50
Izvorul Montelui	RO	ME	04.06.05 17.06.05 22.06.05 26.06.05 27.07.05 31.07.05 22.08.05	10.06.05 18.07.05 22.08.05	2.06 1.26 0.86	3.30 2.50 1.70
Bezid	RO	ME	04.06.05 17.06.05 22.06.05 26.06.05 27.07.05 31.07.05 22.08.05	06.06.05 20.07.05 24.08.05	2.07 1.76 1.26	2.00 1.50 1.50
Sacele	RO	ME CH ME 22.08.05 <	04.06.05 17.06.05 22.06.05 26.06.05 08.07.05 27.07.05 31.07.05 22.08.05	 17.06.05 08.07.05 19.08.05	 0.28 0.91 0.44	 1.90 1.70 4.00

Kouris

Asprokremmos

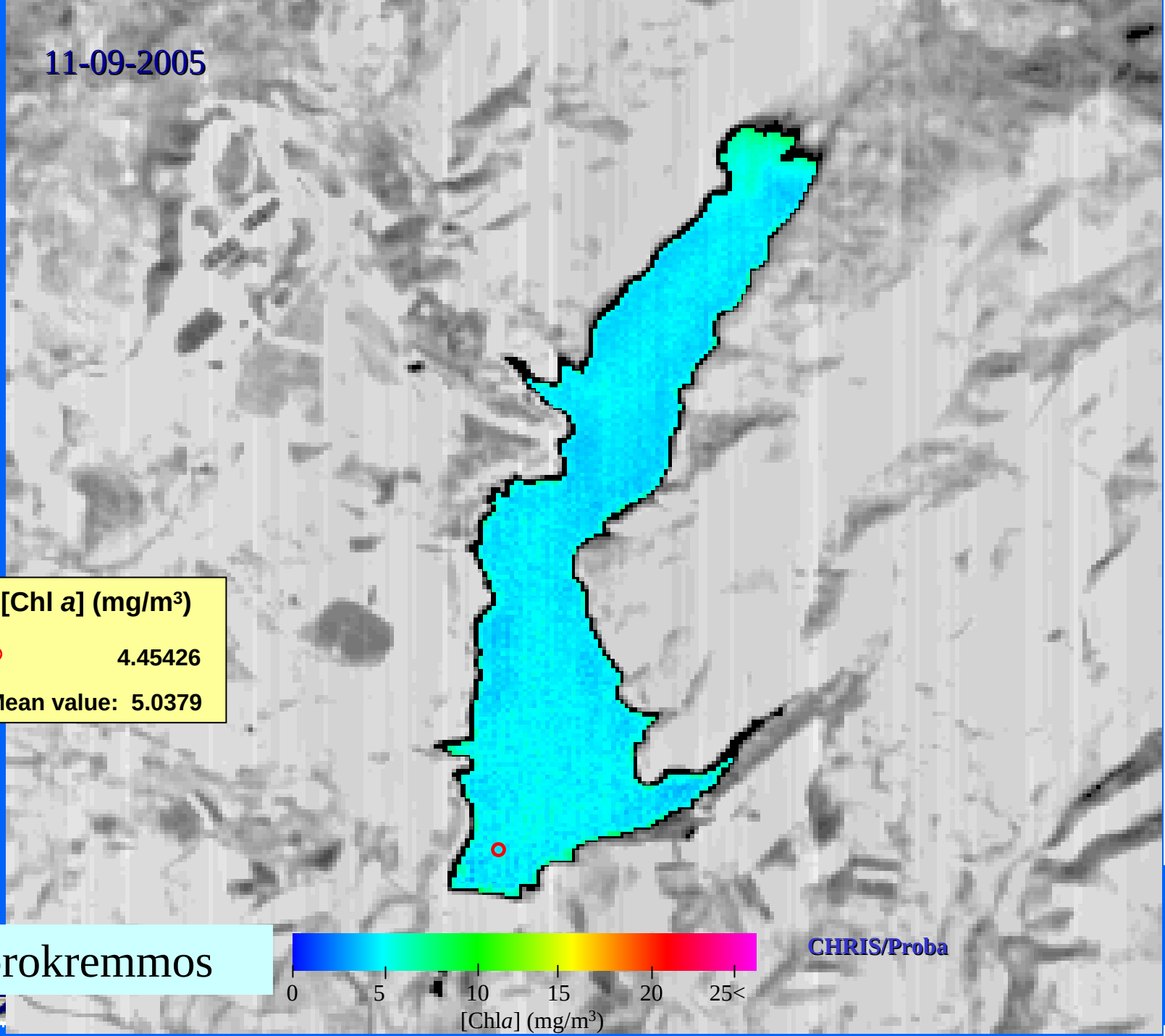
Lefkara

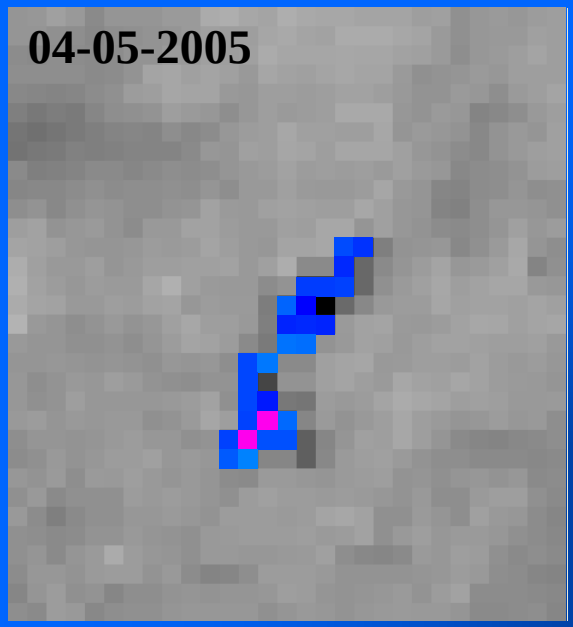
11-09-2005

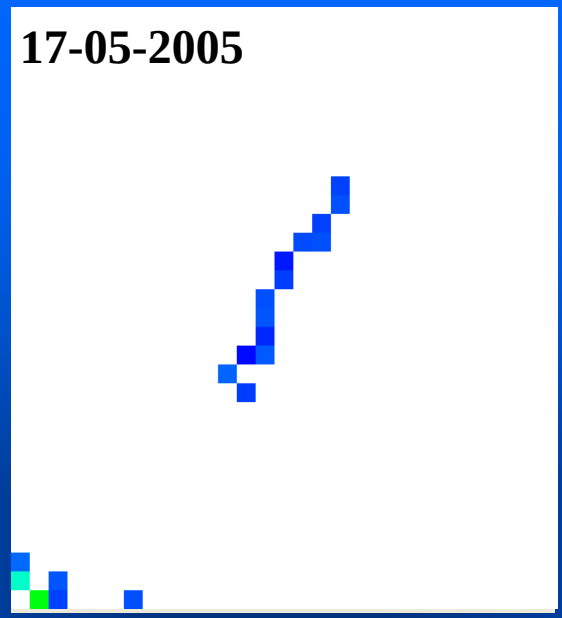
Asprokremmos

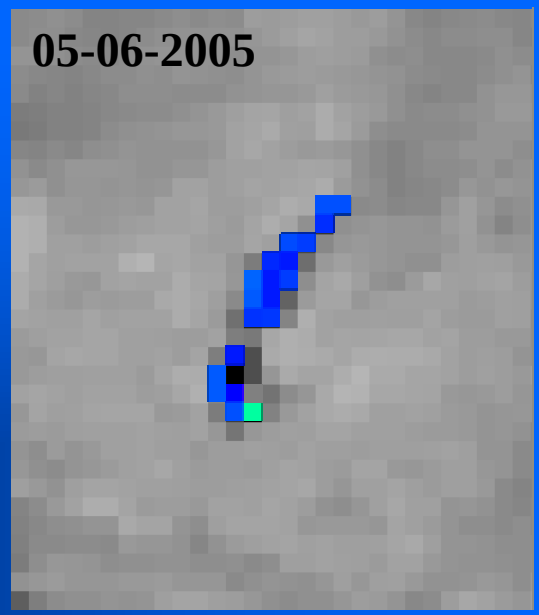
Italy)

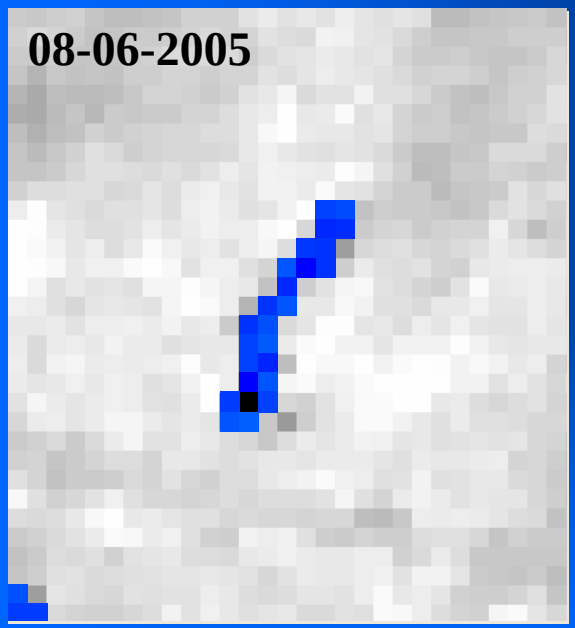
CHRIS/Proba

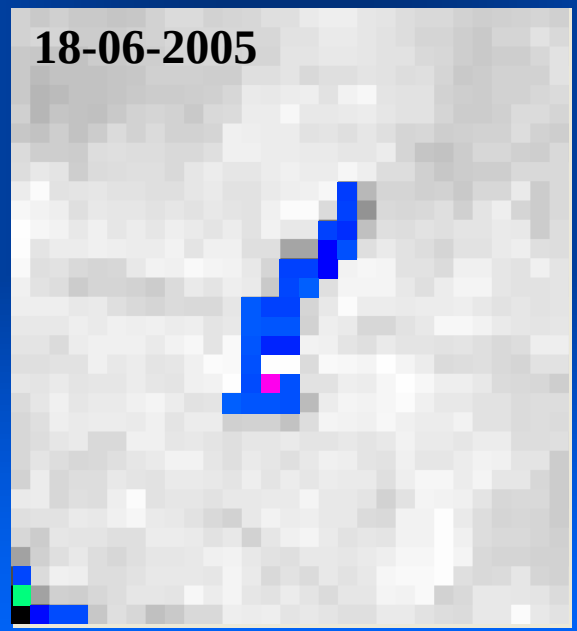

11-09-2005
[Chl a] (mg/m³)
4.45426
Mean value: 5.0379
Asprokremmos
0
5
10
15
20
25<
[Chla] (mg/m³)
CHRIS/Proba

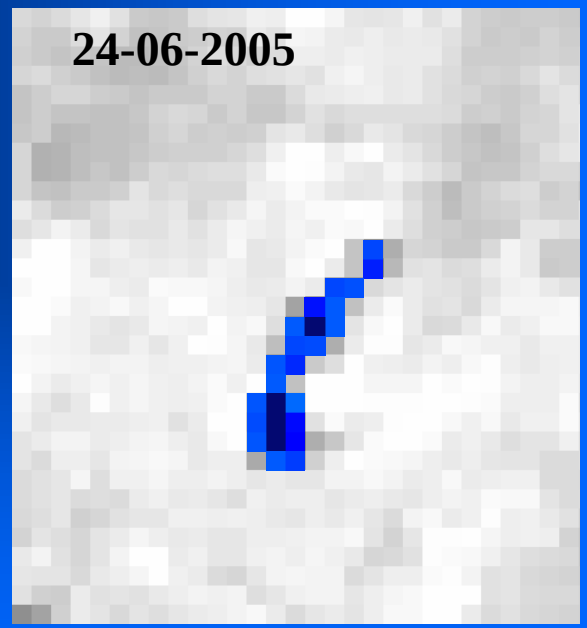












Asprokremmos

MERIS

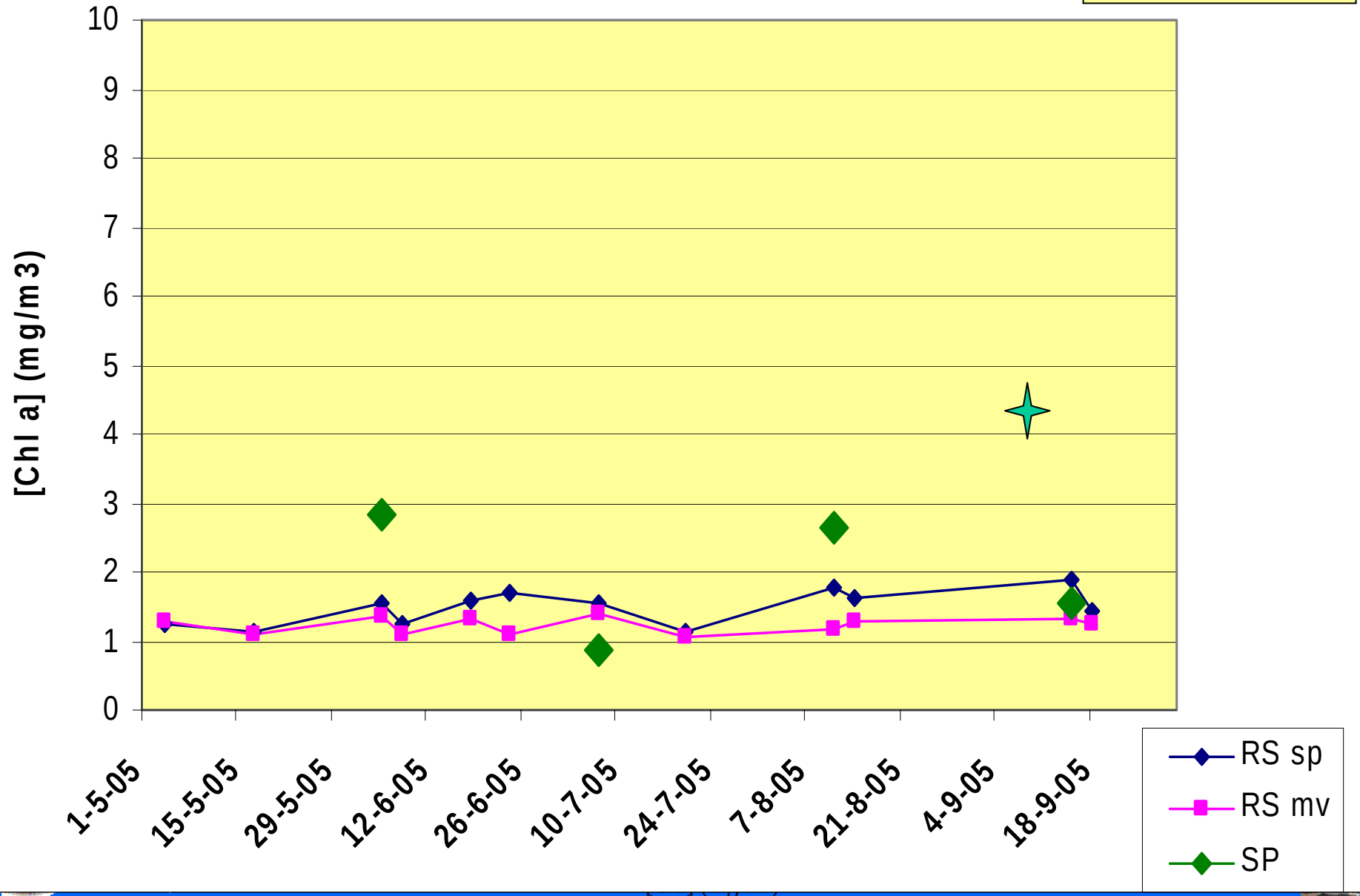
CHRIS (11.09.05)

4.45426

Mean value: 5.0379

ASPROKREMMOS Evolution

RS sp mean	1.490
RS mv mean	1.220
Photic l. mean	1.980

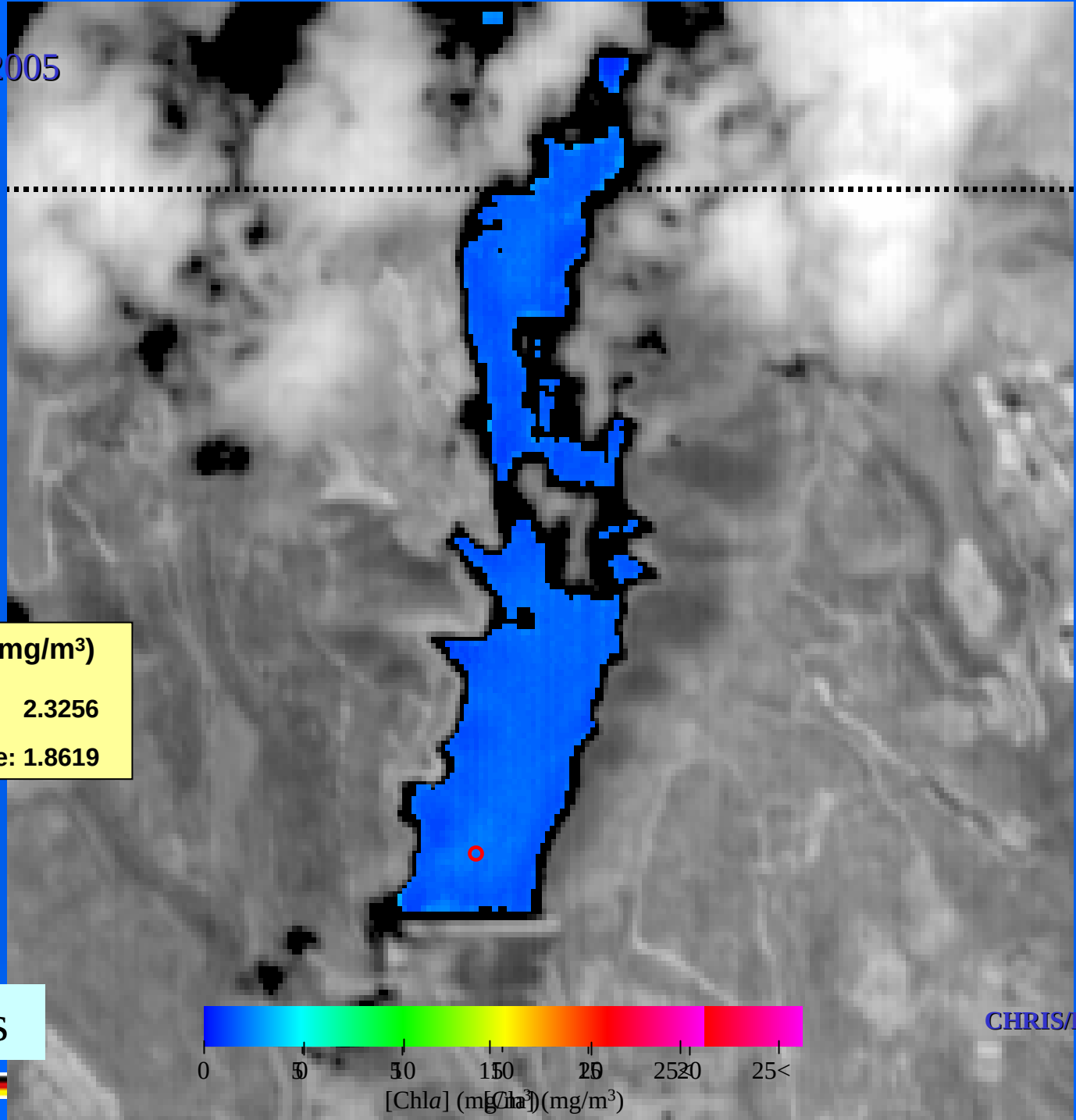


05-06-2005

Italy)

CHRIS/Proba

05-06-2005



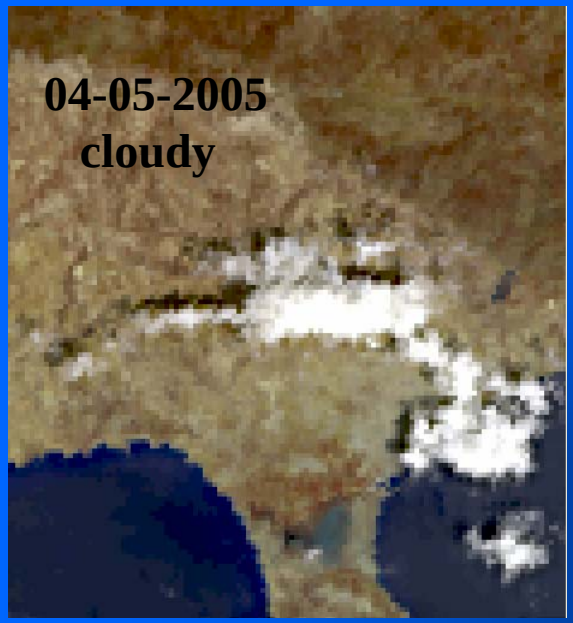
[Chl *a*] (mg/m³)

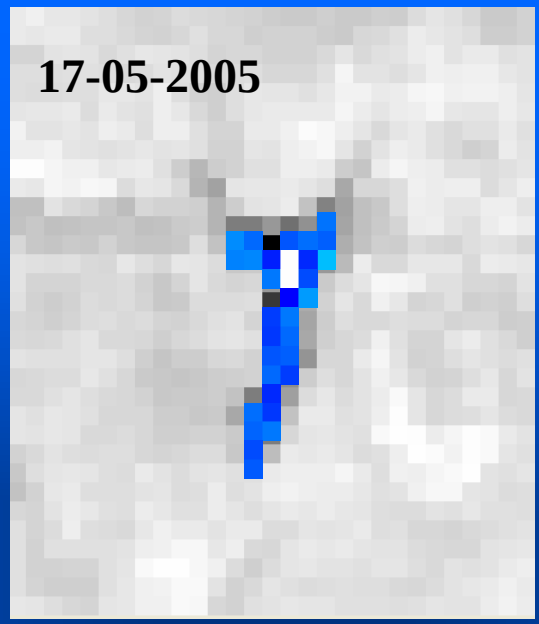
2.3256

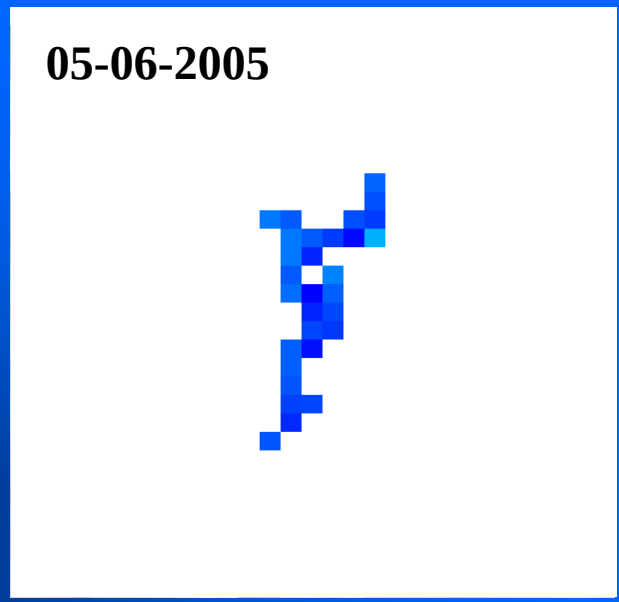
Mean value: 1.8619

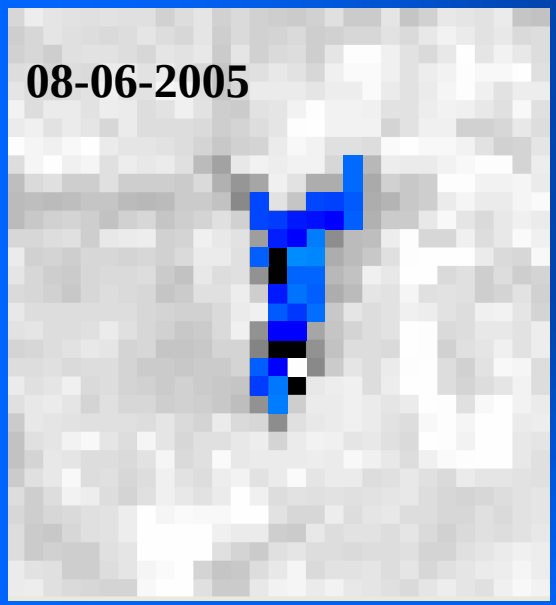
Kouris

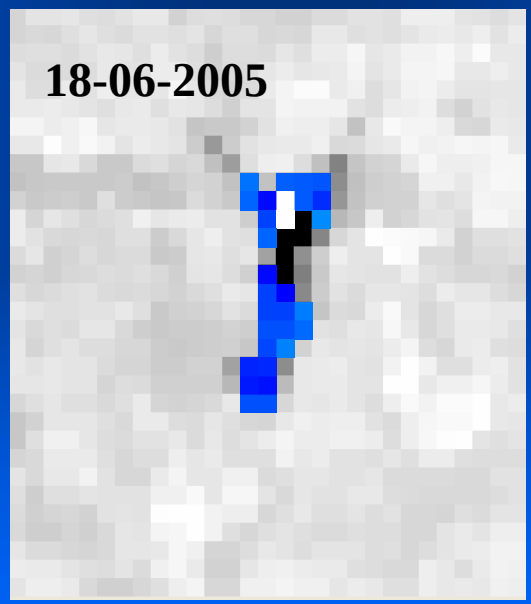
CHRIS/Proba
Italy)

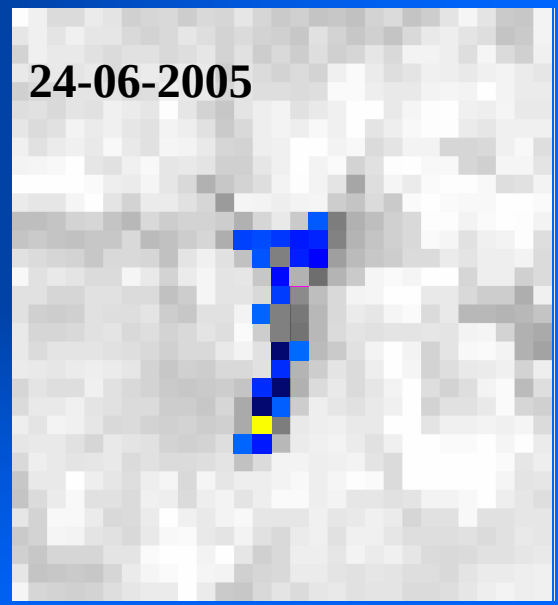












Kouris

MERIS

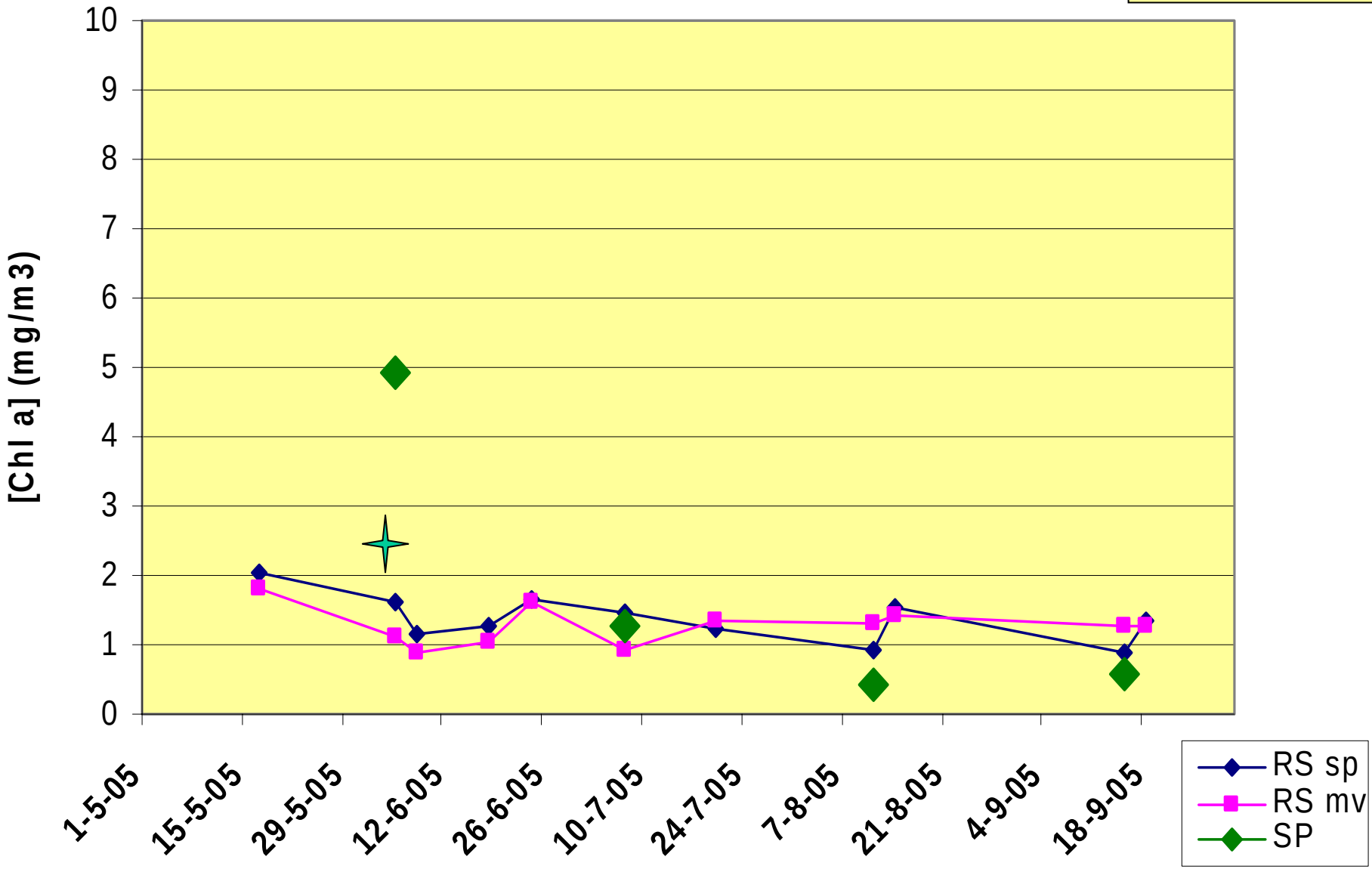
CHRIS (05.06.05)

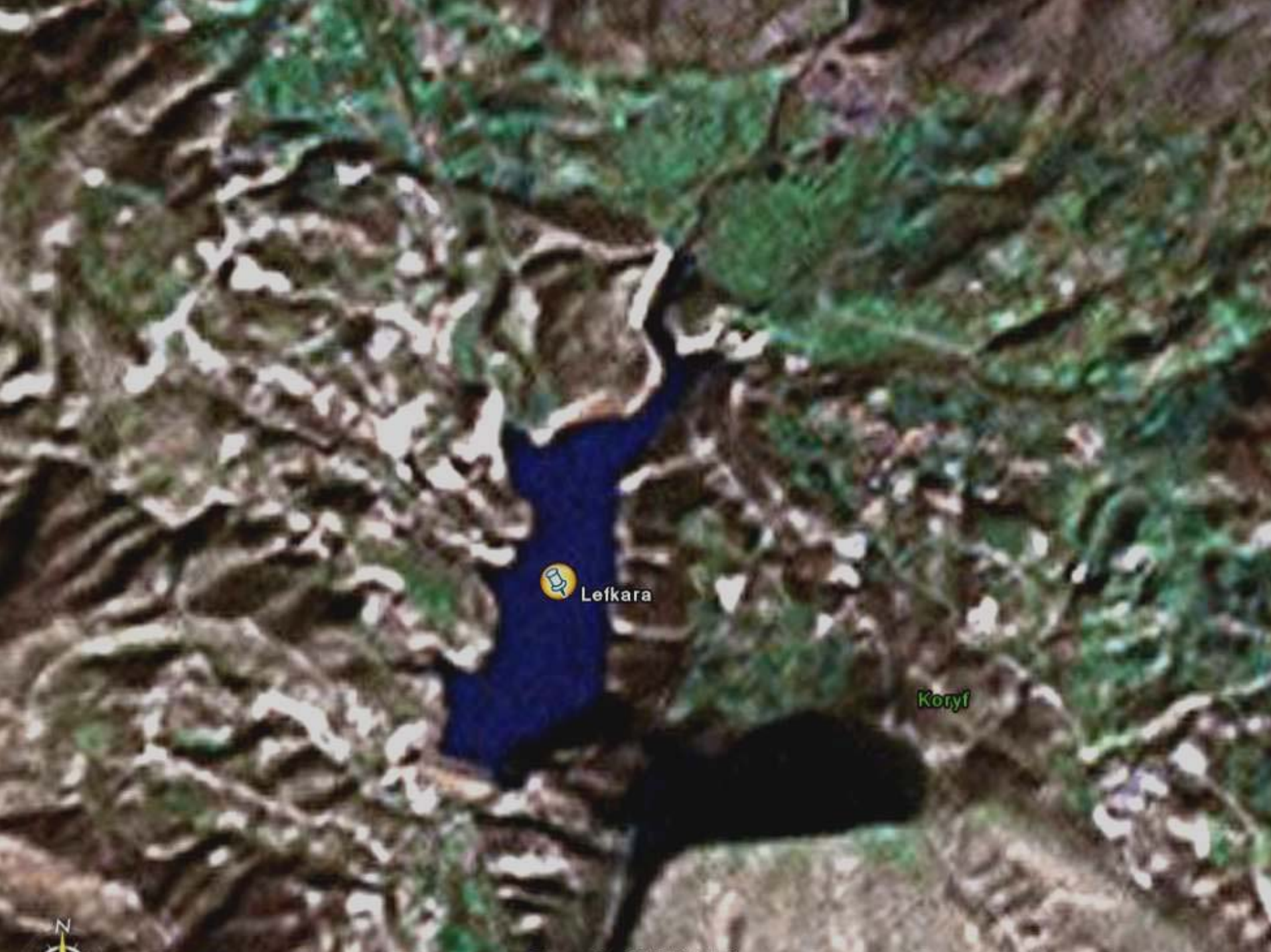
2.3256

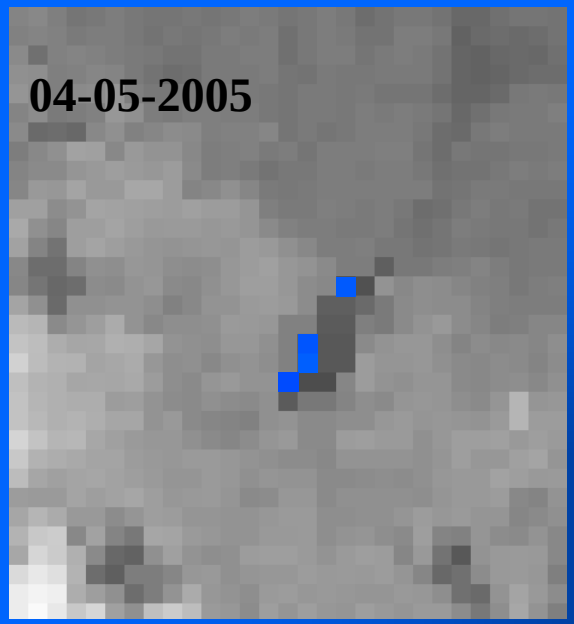
Mean value: 1.8619

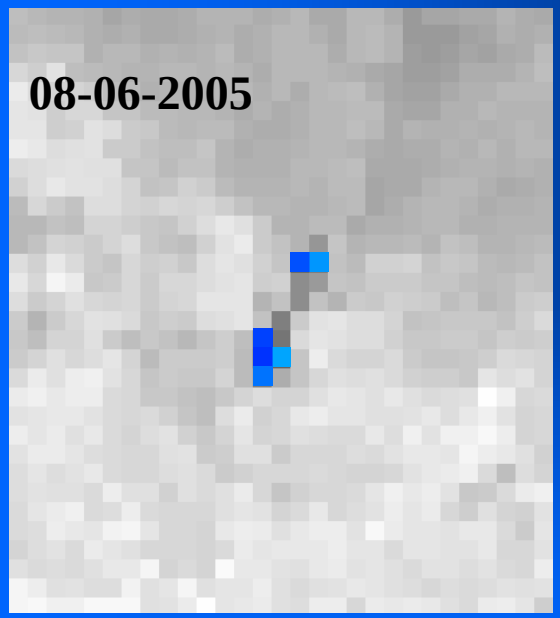
KOURIS Evolution

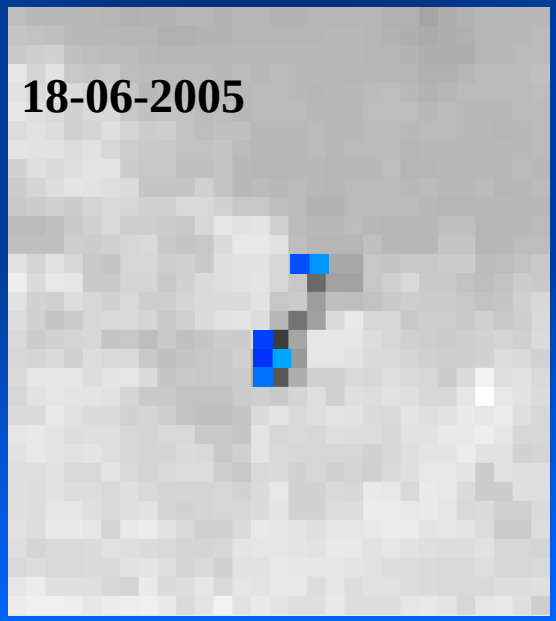
RS sp mean	1.367
RS mv mean	1.272
Photic l. mean	1.800

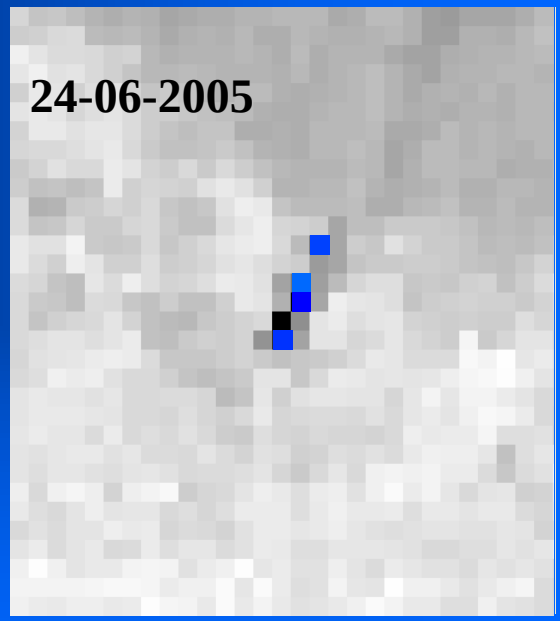



Lefkara
Koryf
N









Lefkara

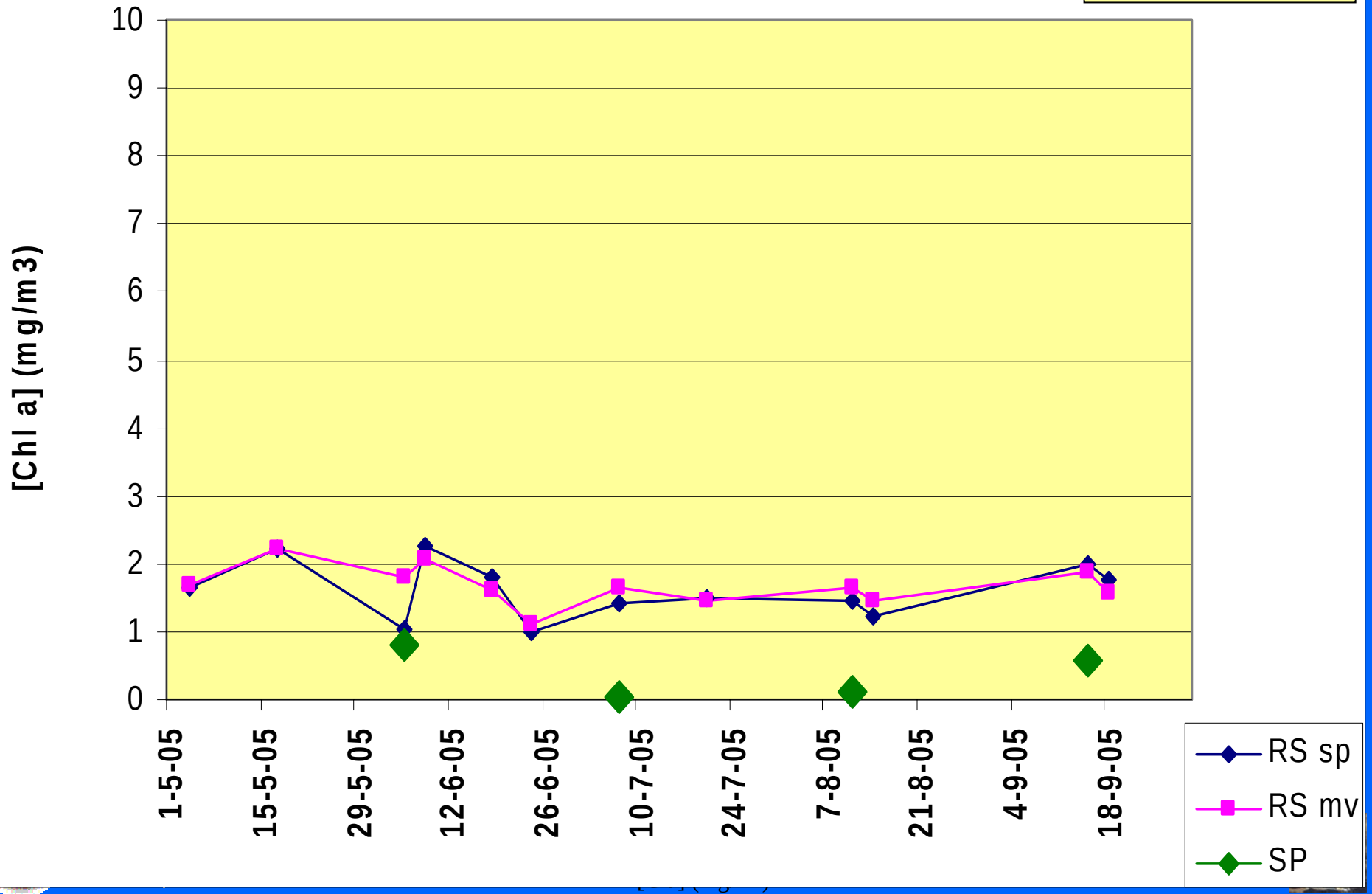
0 5 10 15 20 25<

[Cla] (mg/m^3)

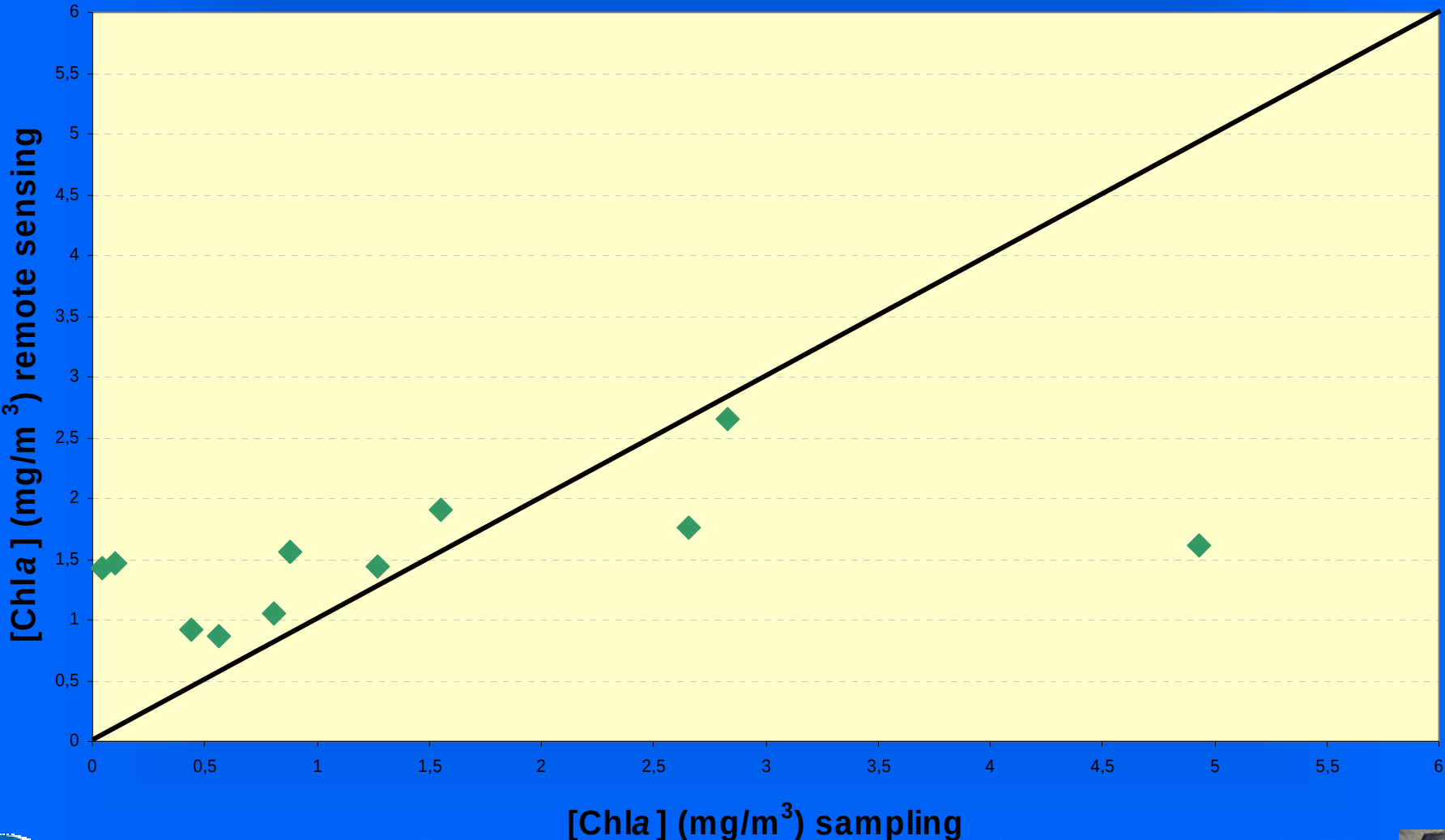
MERIS

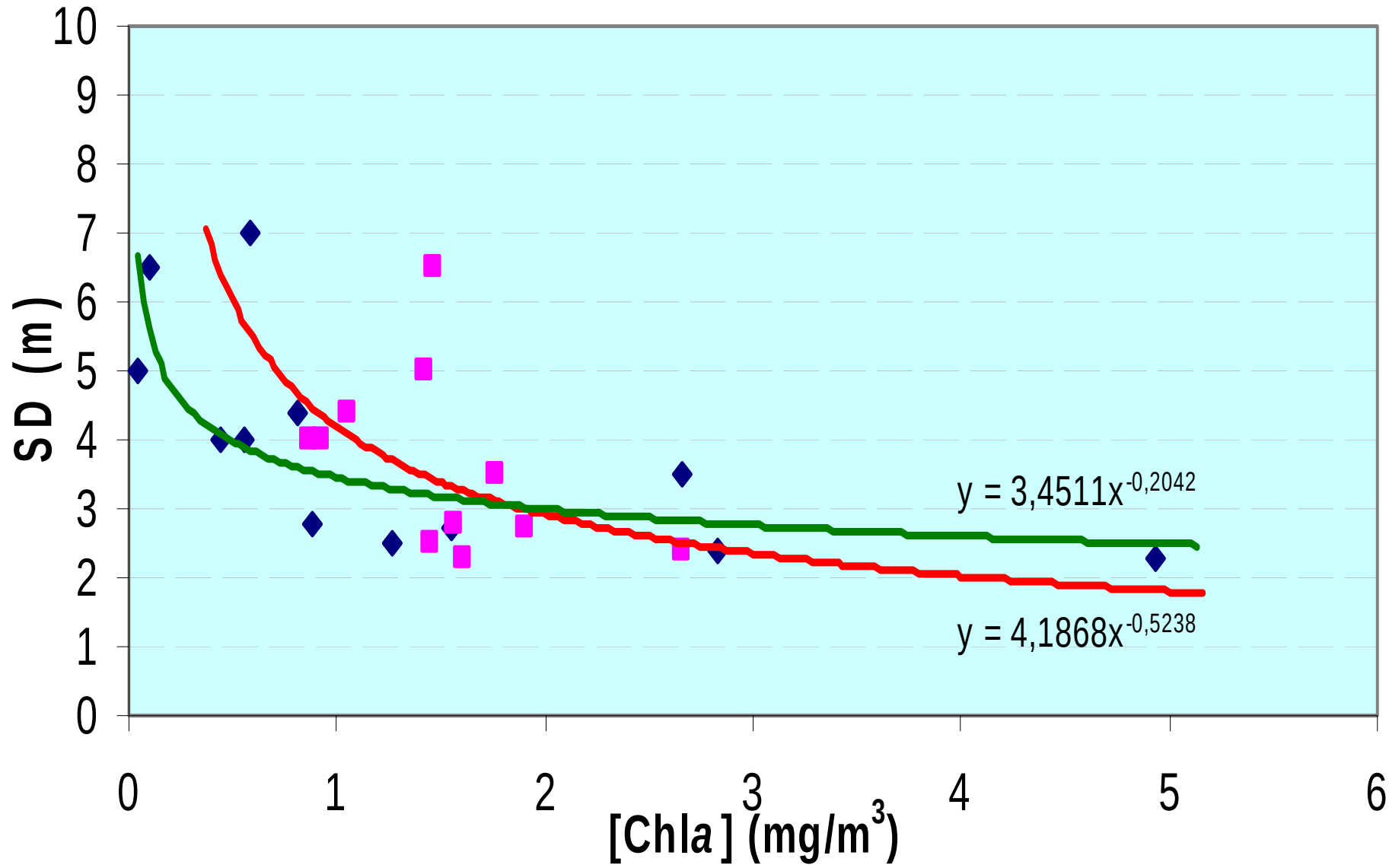
LEFKARA Evolution

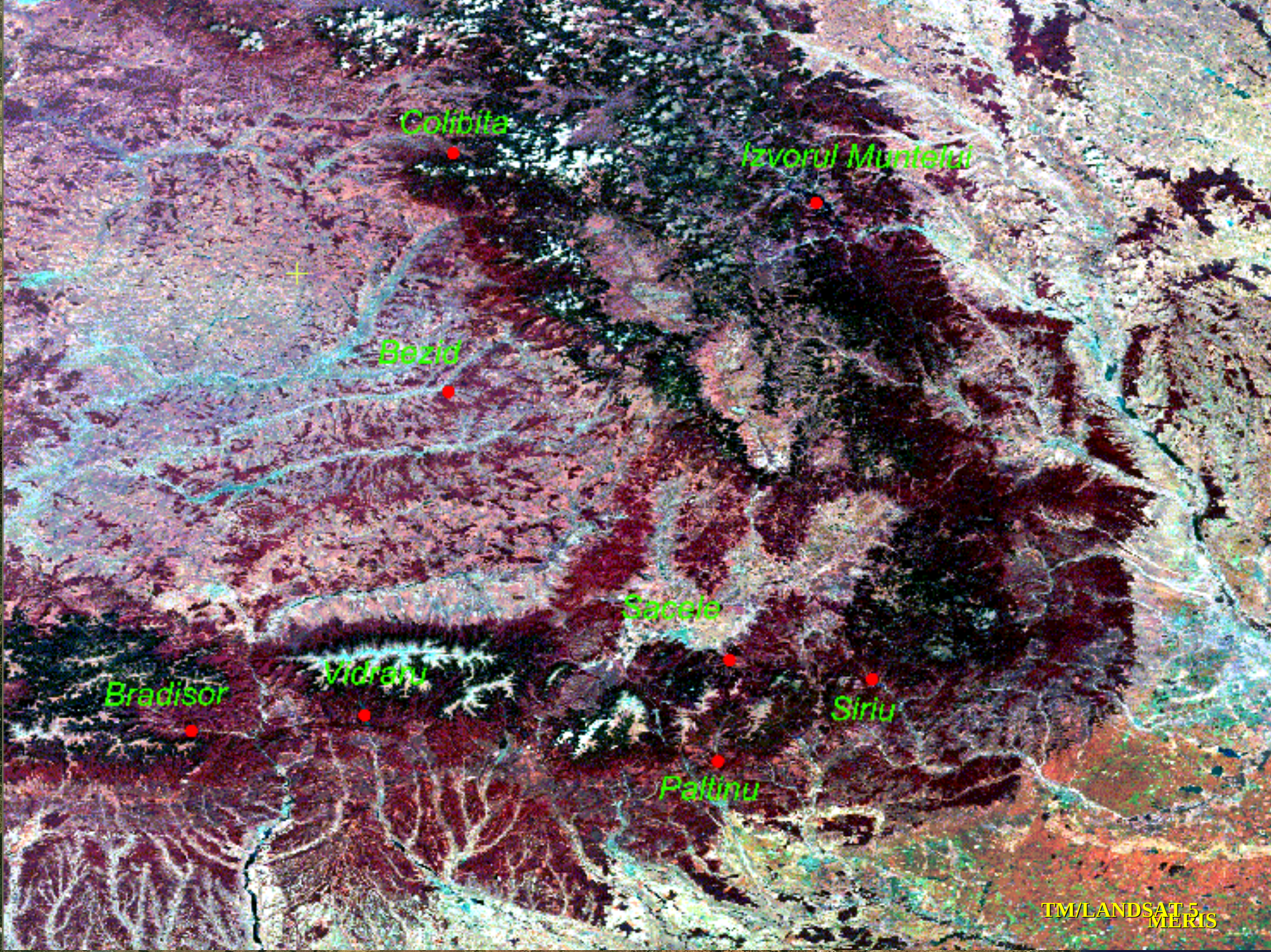
RS sp mean	1.607
RS mv mean	1.677
Photic l. mean	0.383

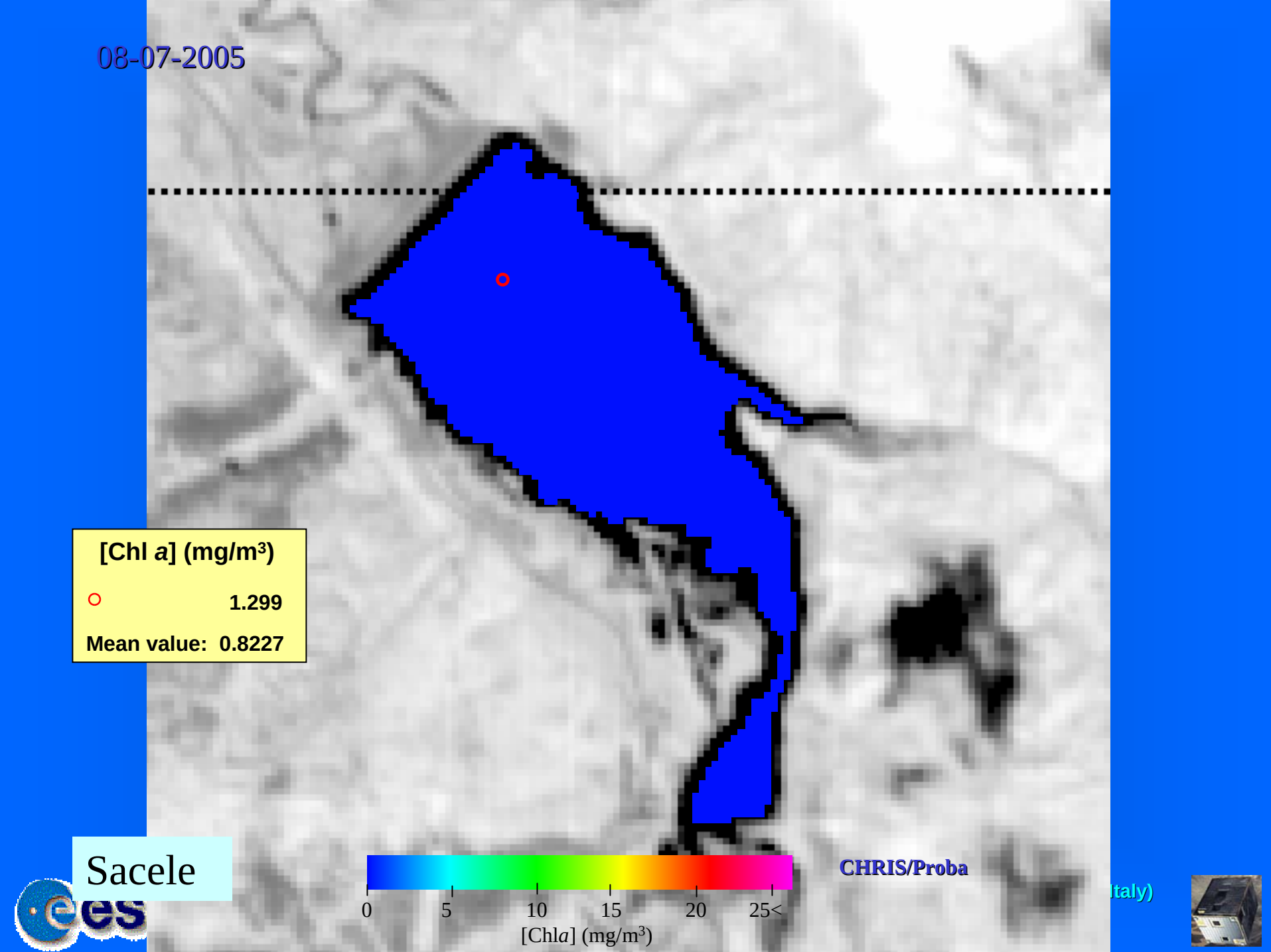


Cyprus Reservoirs
[Chla] sampling data vs. [Chla] remote sensing data




SD vs. Chla Sampling R. Sensing
SD (m)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
[Chla] (mg/m3)
y = 3,4511x-0,2042
y = 4,1868x-0,5238


Colibita
Izvorul Muntelui
Bezid
Sacele
Vidraru
Bradisor
Siriu
Paltinu
TM/LANDSAT 5
MERIS


08-07-2005
[Chl a] (mg/m³)
1.299
Mean value: 0.8227
0
5
10
15
20
25<
[Chla] (mg/m³)
CHRIS/Proba
Sacele
Italy)

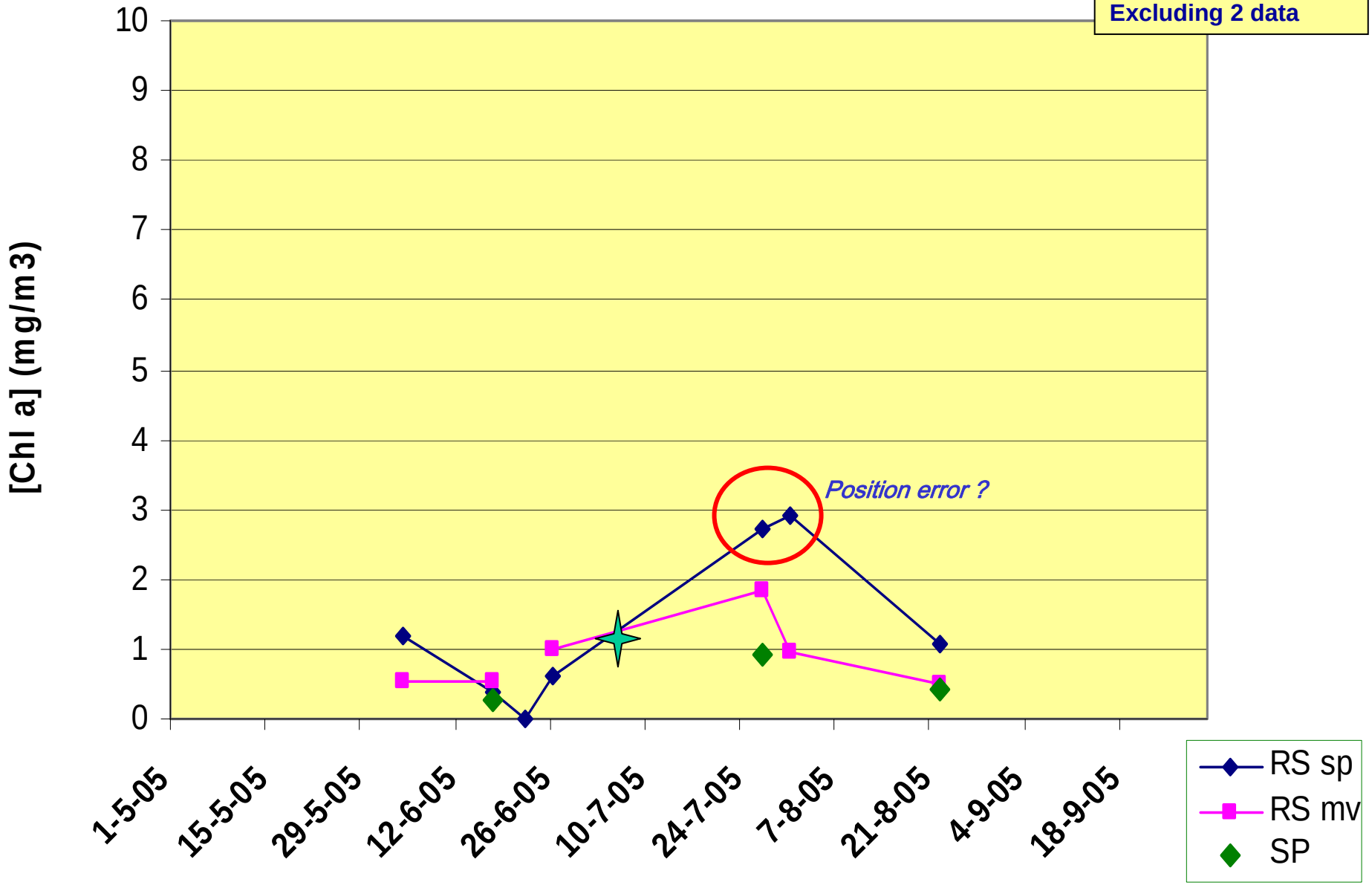
CHRIS (08.07.05)

1.299

Mean value: 0.8227

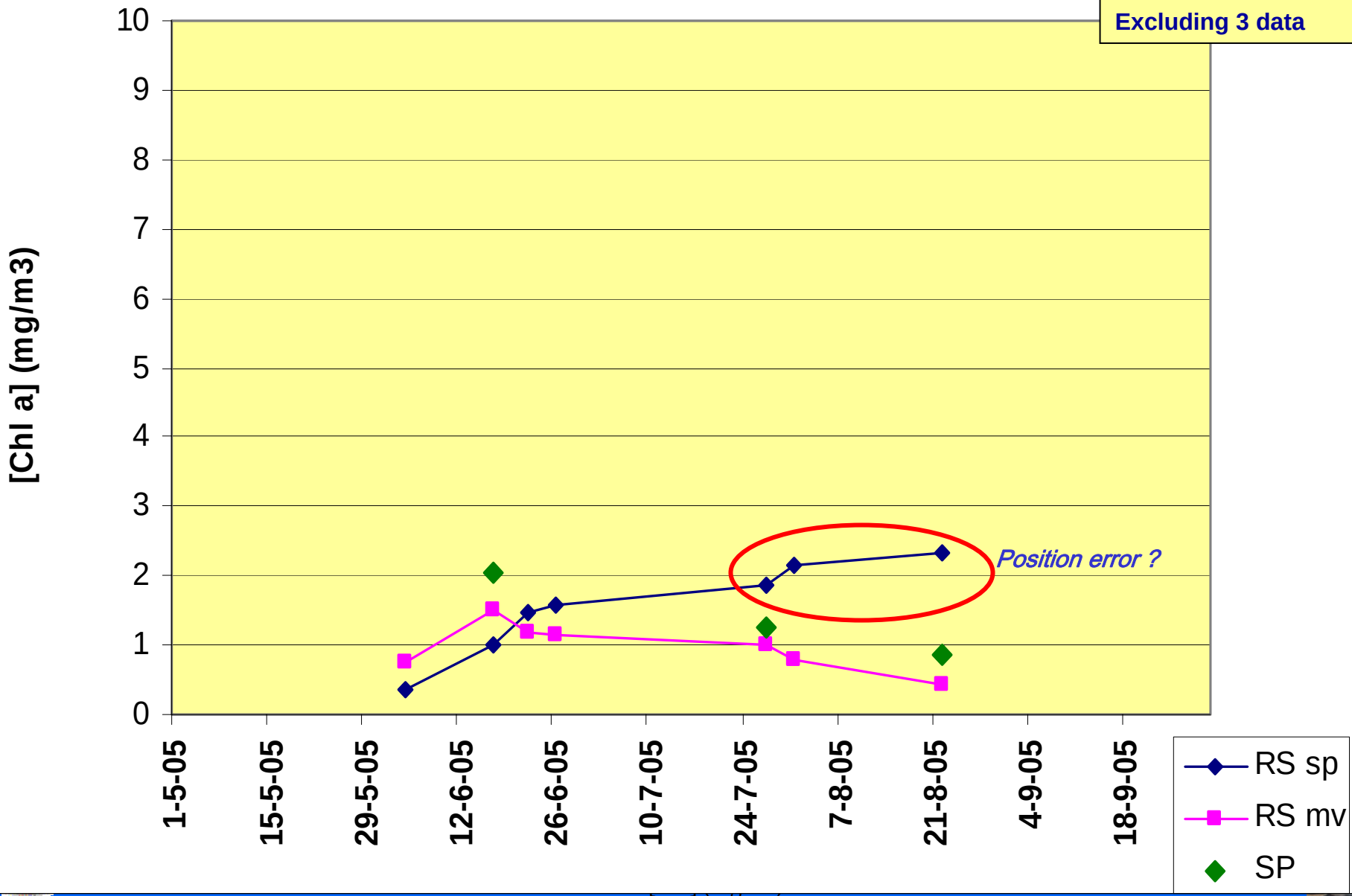
Sacele evolution

RS sp mean	1.010
RS mv mean	0.886
Photic l. mean	0.543
Excluding 2 data	



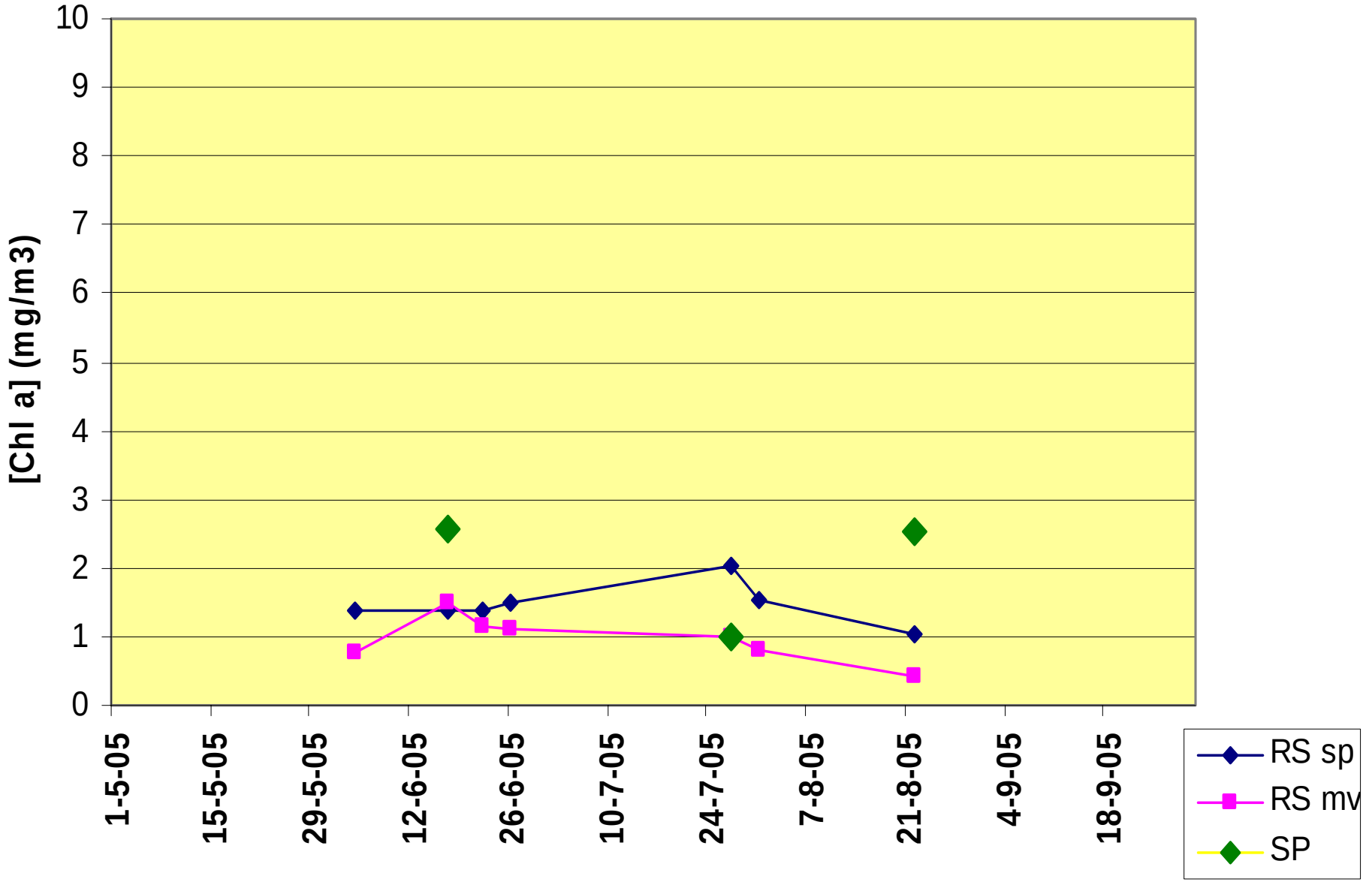
Izvorul Montelui evolution

RS sp mean	0.952
RS mv mean	0.969
Photic l. mean	1.393
Excluding 3 data	



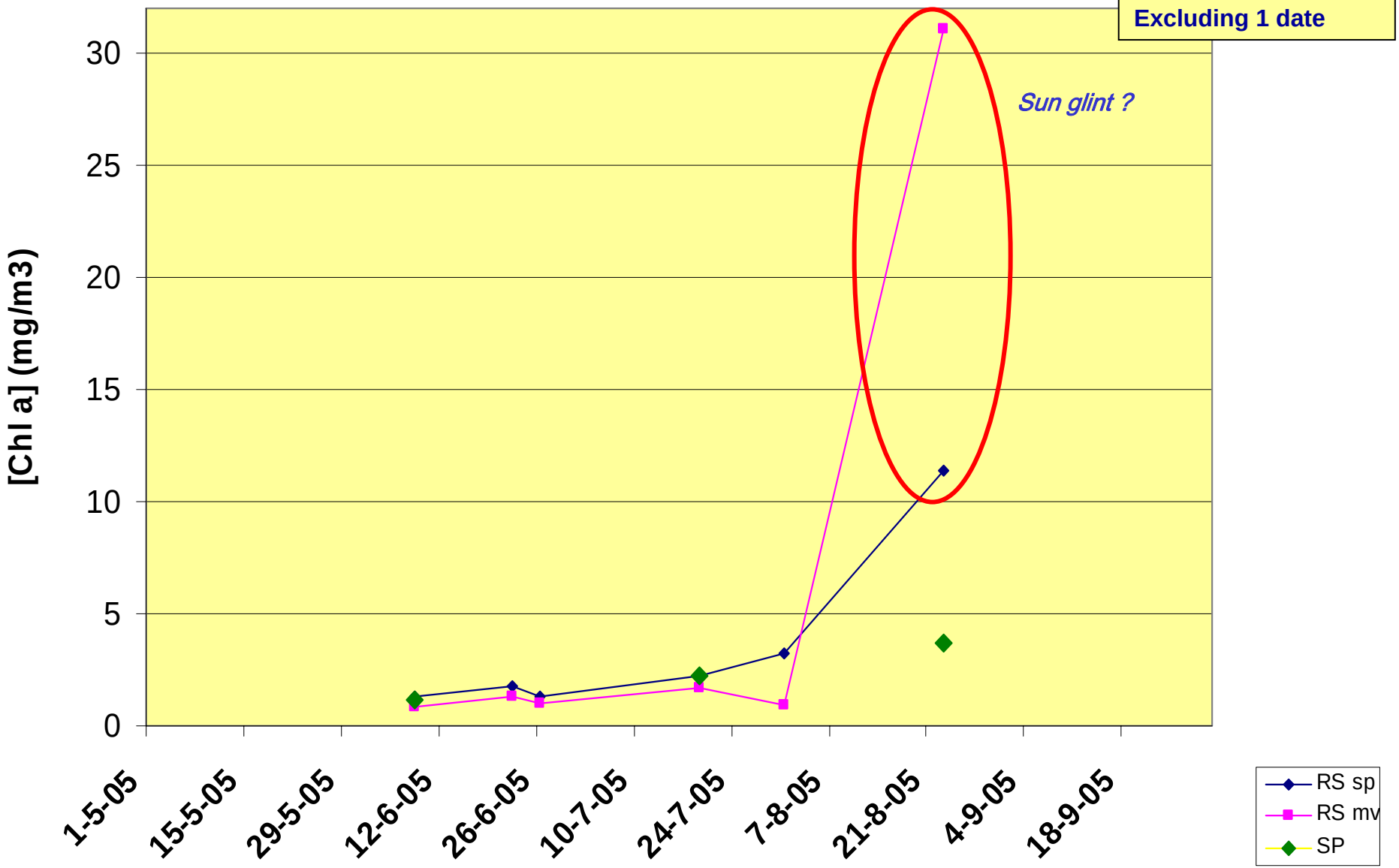
Siriu evolution

RS sp mean	1.467
RS mv mean	0.969
Photic l. mean	2.027



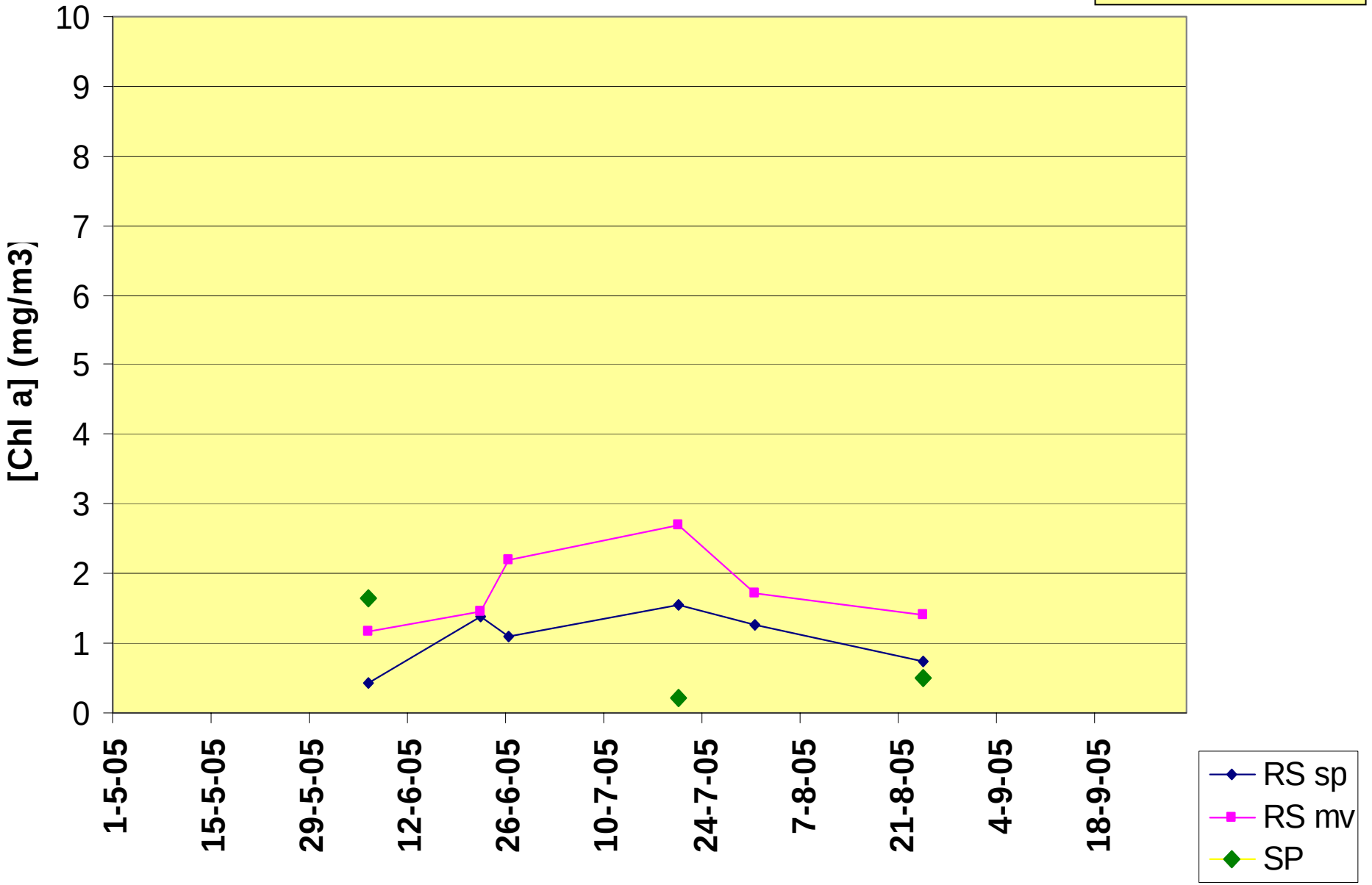
Colibita evolution

RS sp mean	1.978
RS mv mean	1.147
Photic l. mean	2.363
Excluding 1 date	



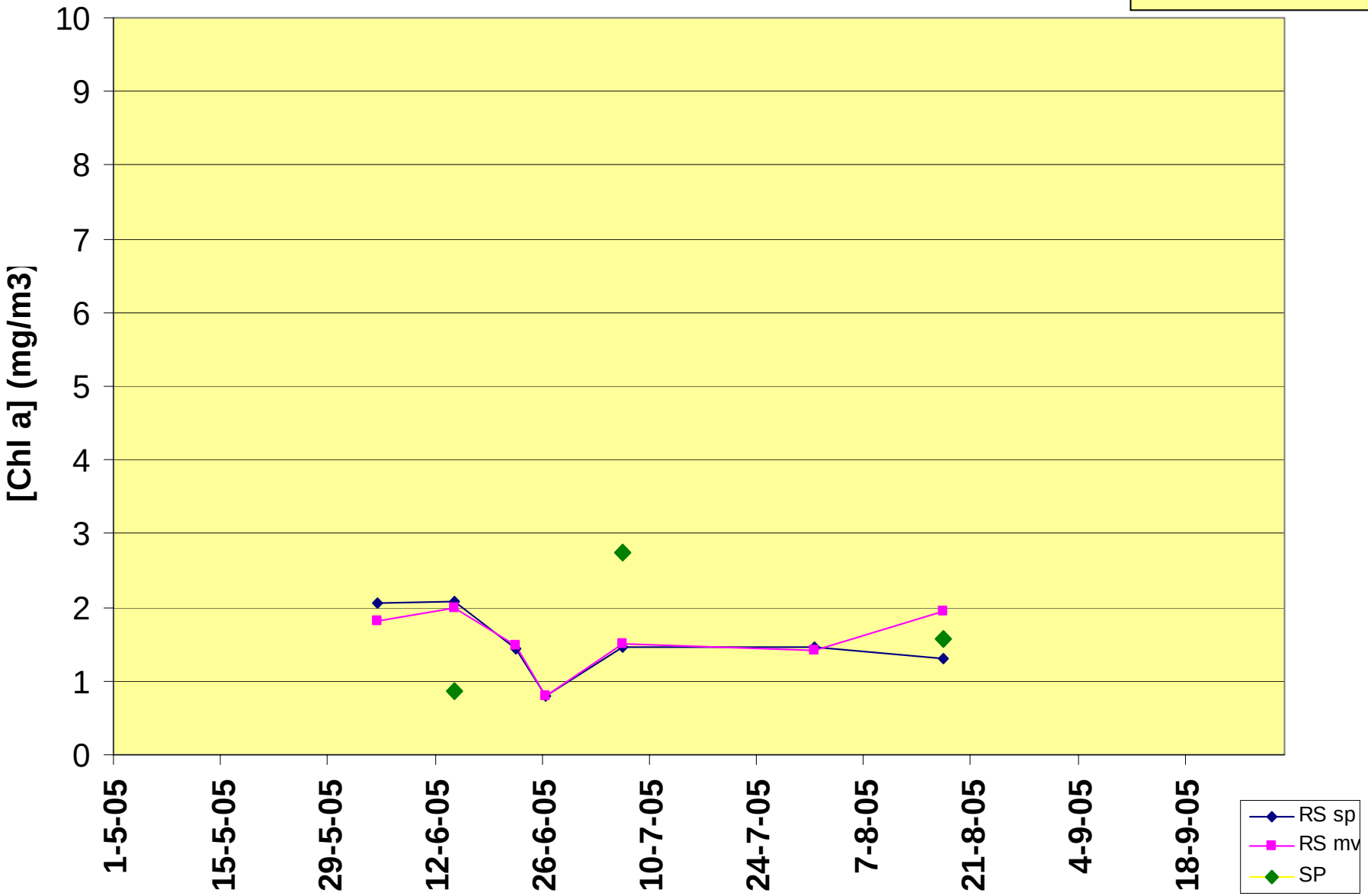
Bezid evolution

RS sp mean	1.081
RS mv mean	1.775
Photic l. mean	0.787



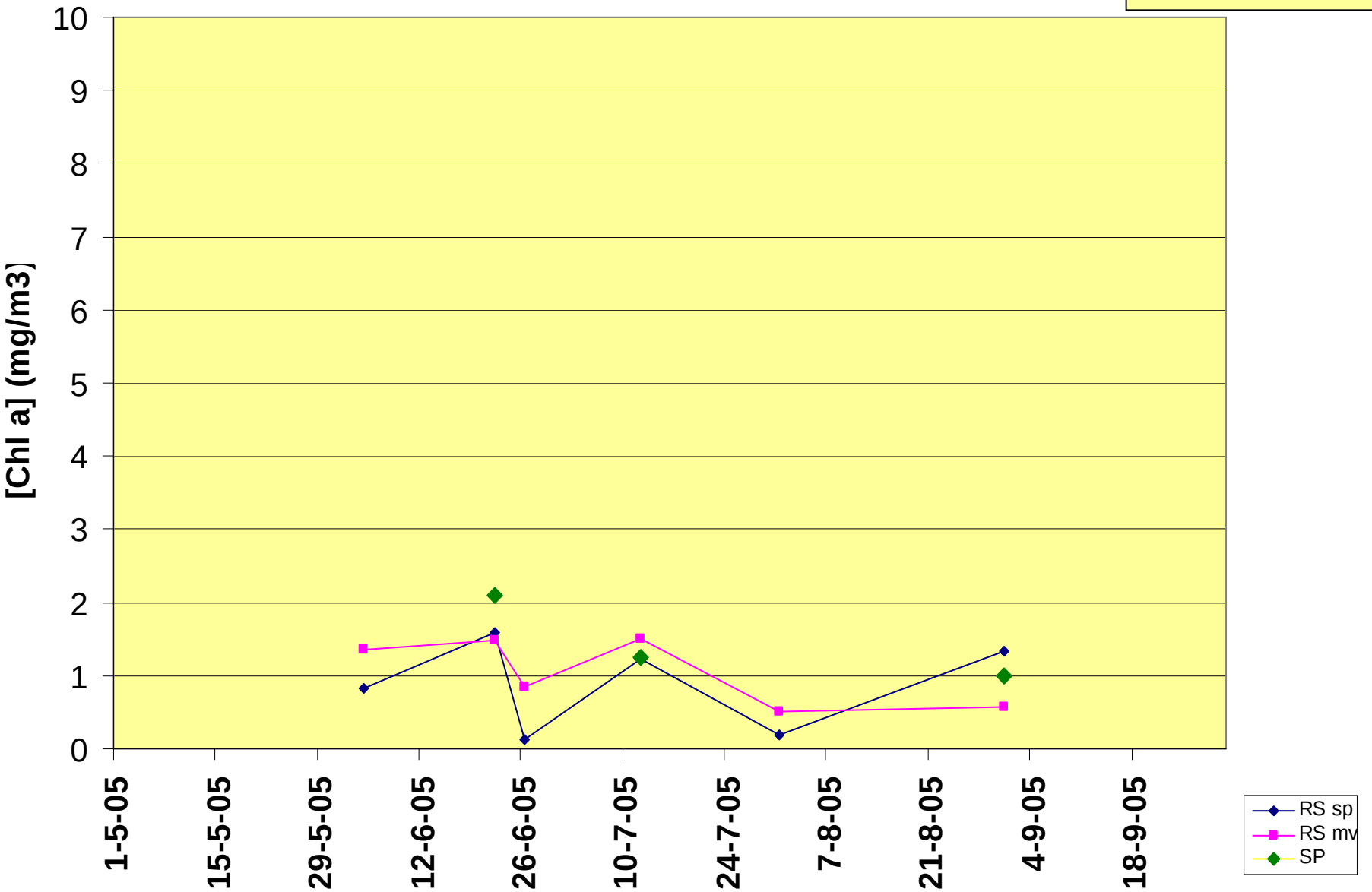
Paltinu evolution

RS sp mean	1.487
RS mv mean	0.886
Photic l. mean	0.543



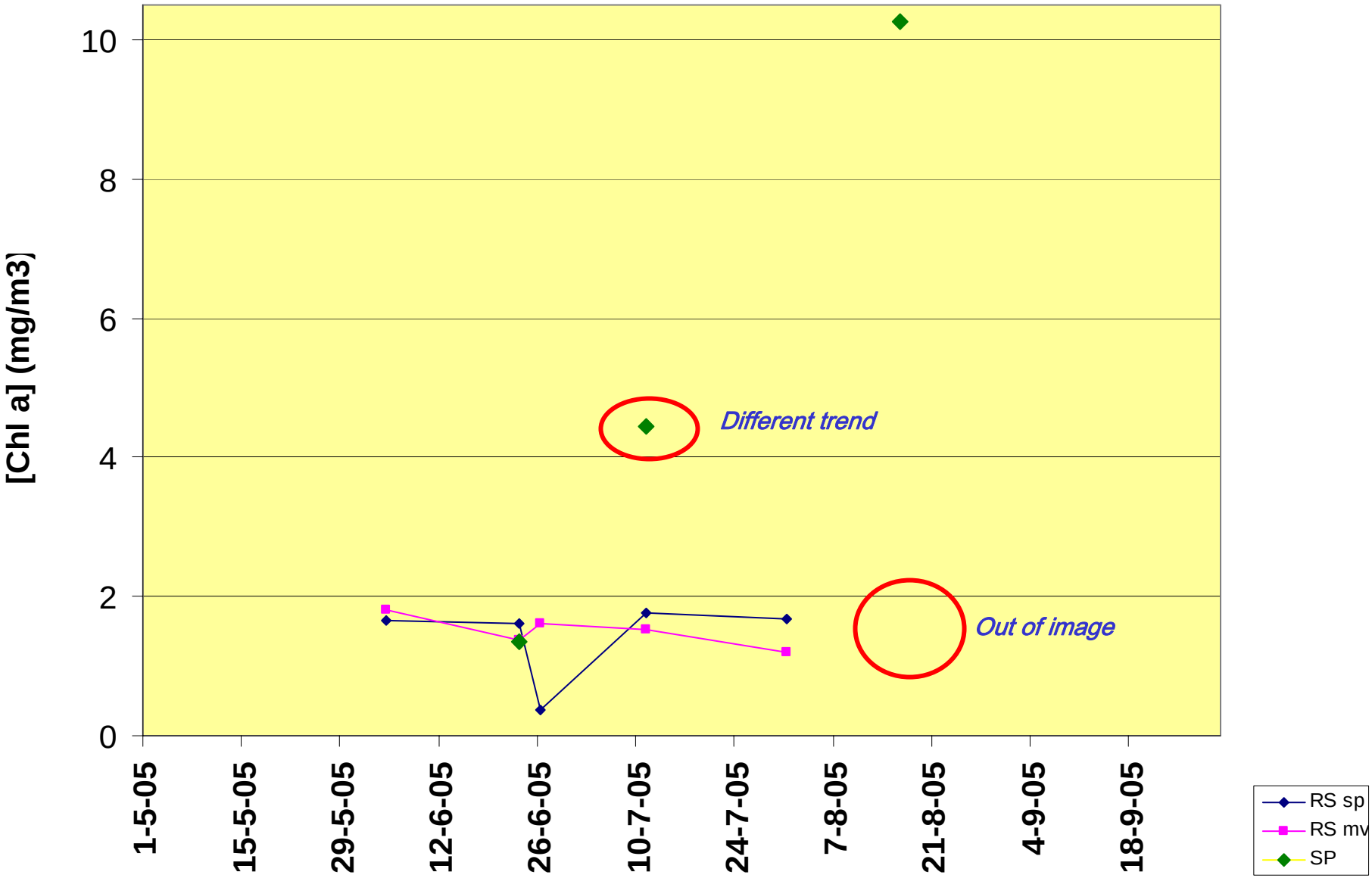
Vidraru evolution

RS sp mean	0.885
RS mv mean	1.049
Photic l. mean	1.453

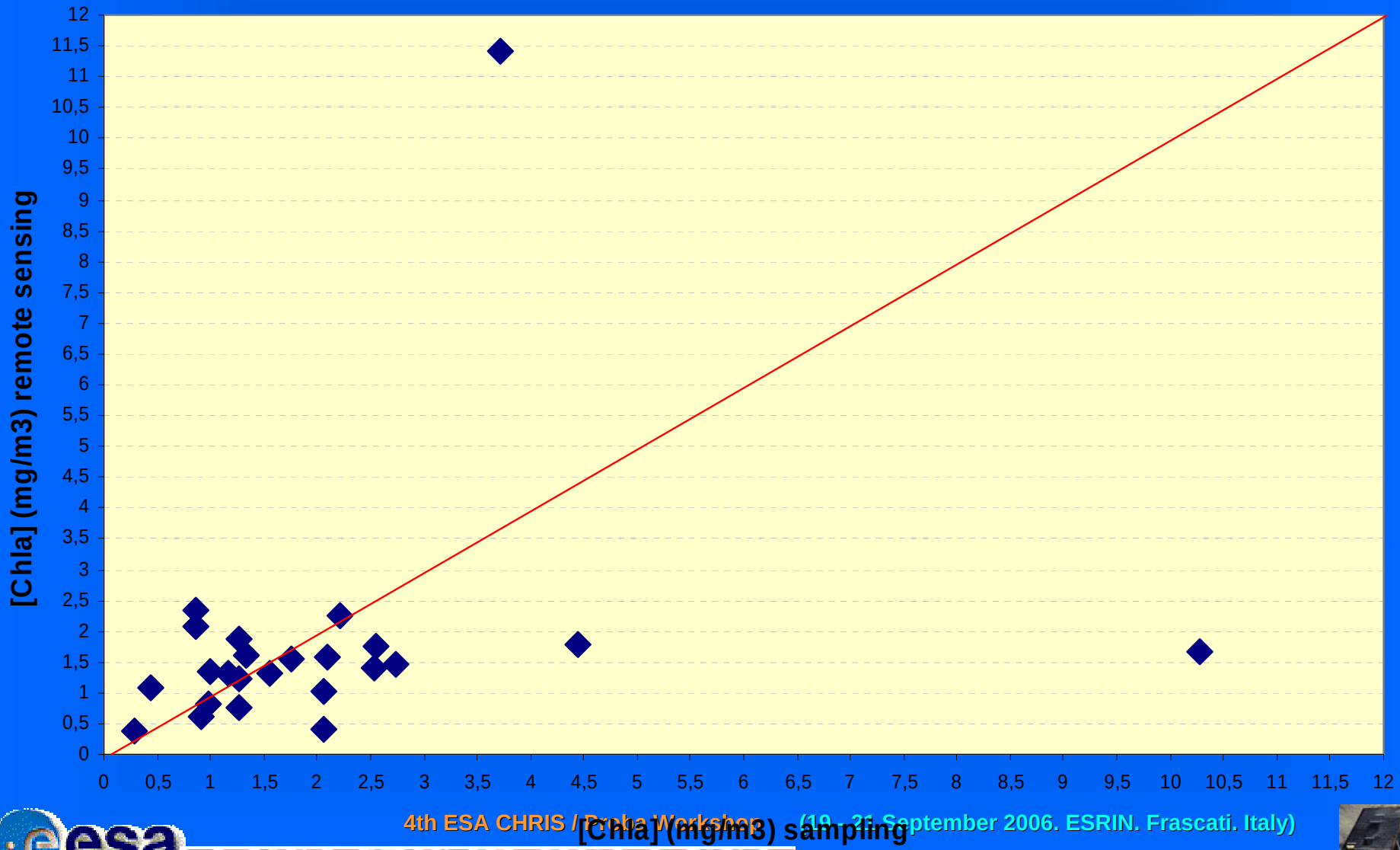


Bradisor evolution

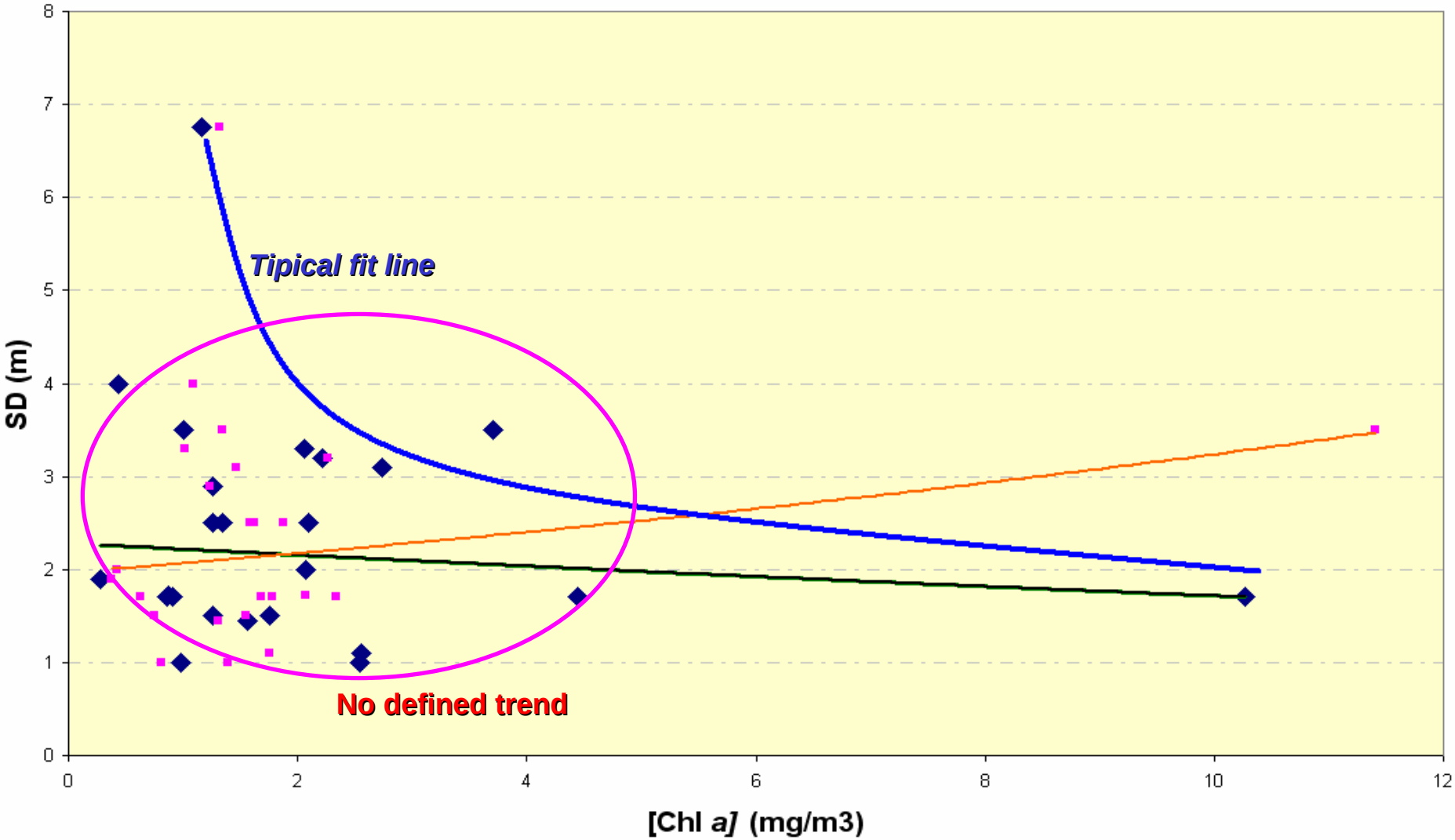
RS sp mean	1.420
RS mv mean	1.502
Photic l. mean	5.353



Romania Reservoirs
[Chla] sampling data vs. [Chla] remote sensing data

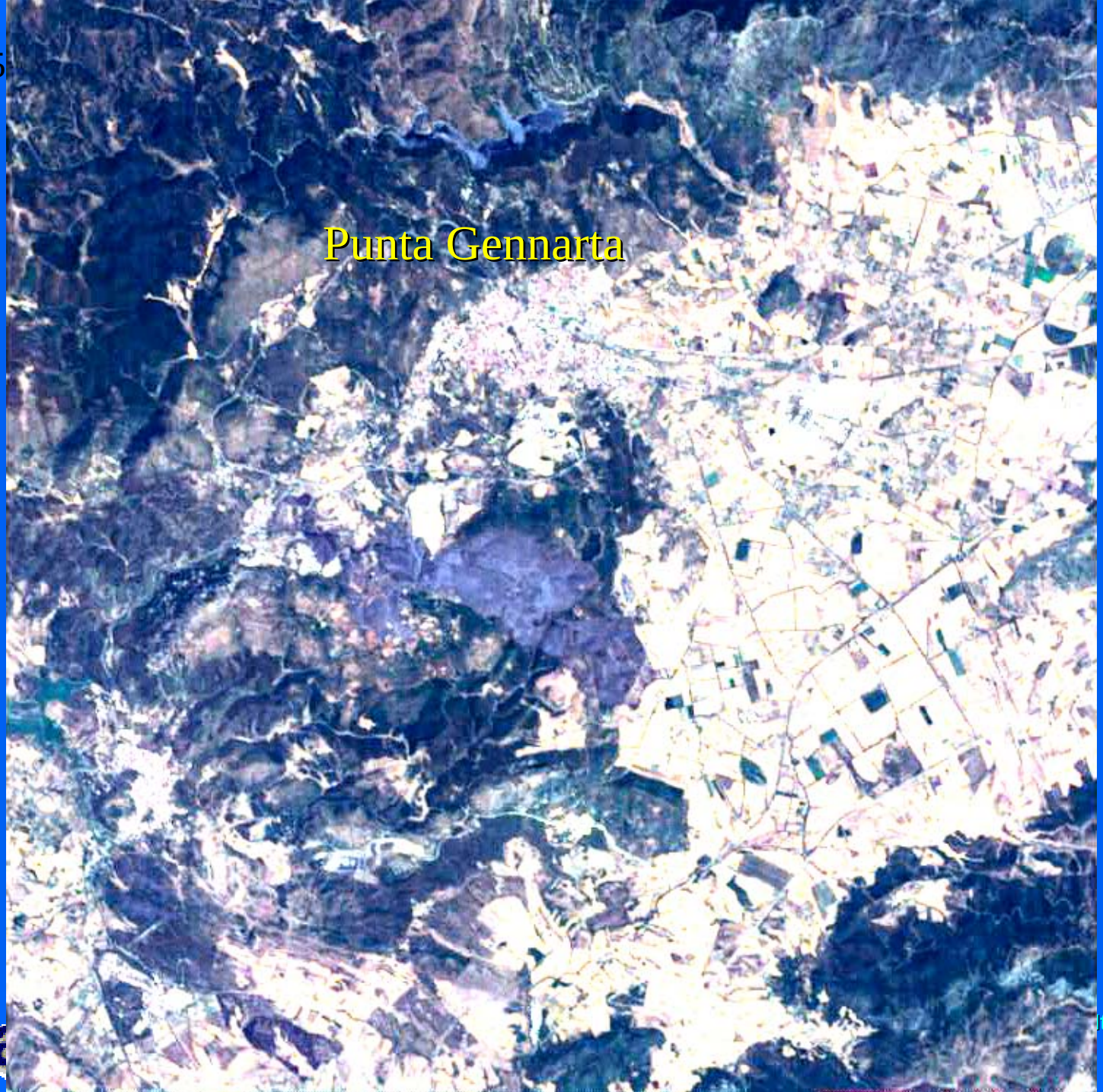


SD vs. Chl *a* Sampling --- R. Sensing ---



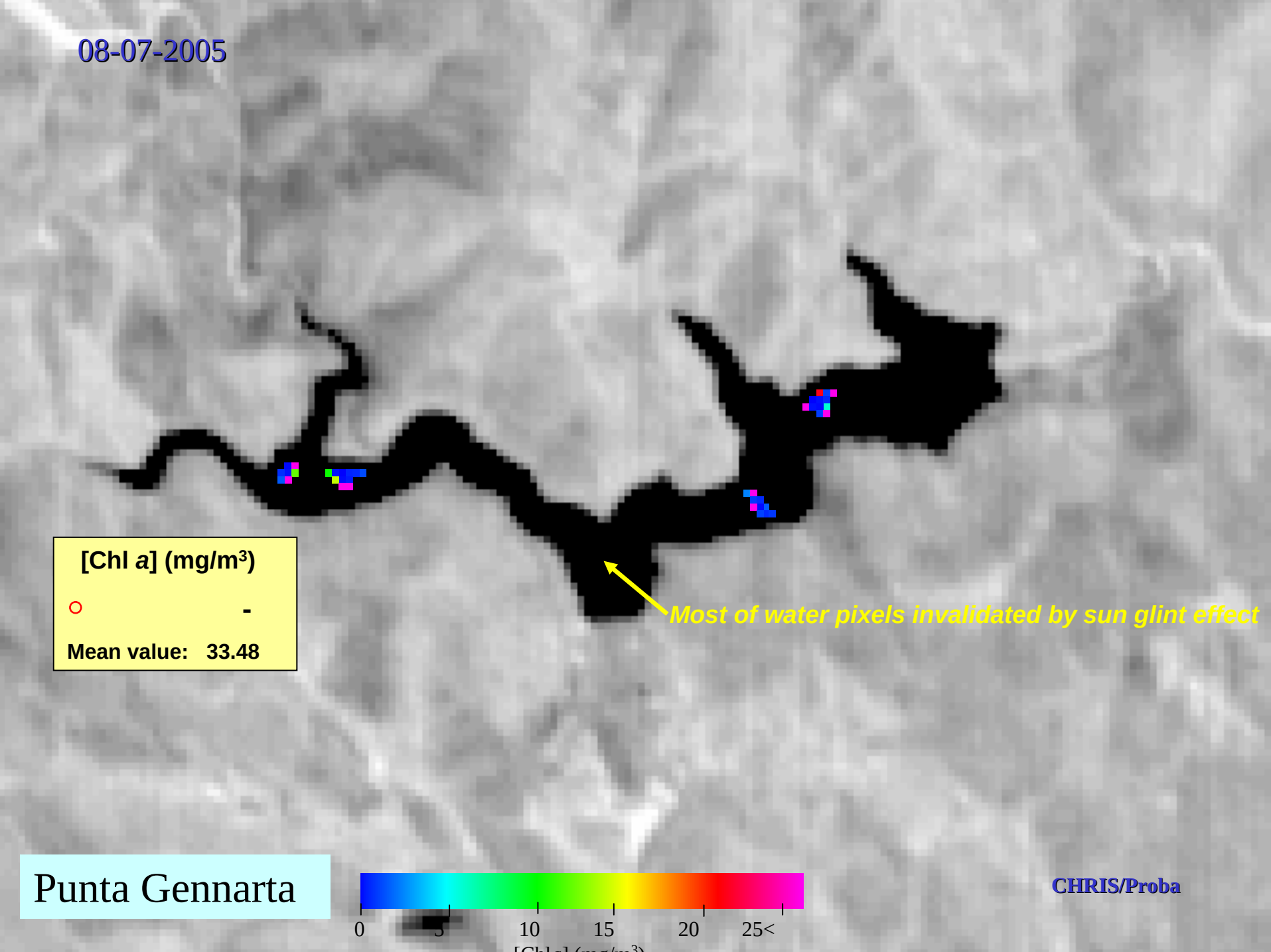
aly)

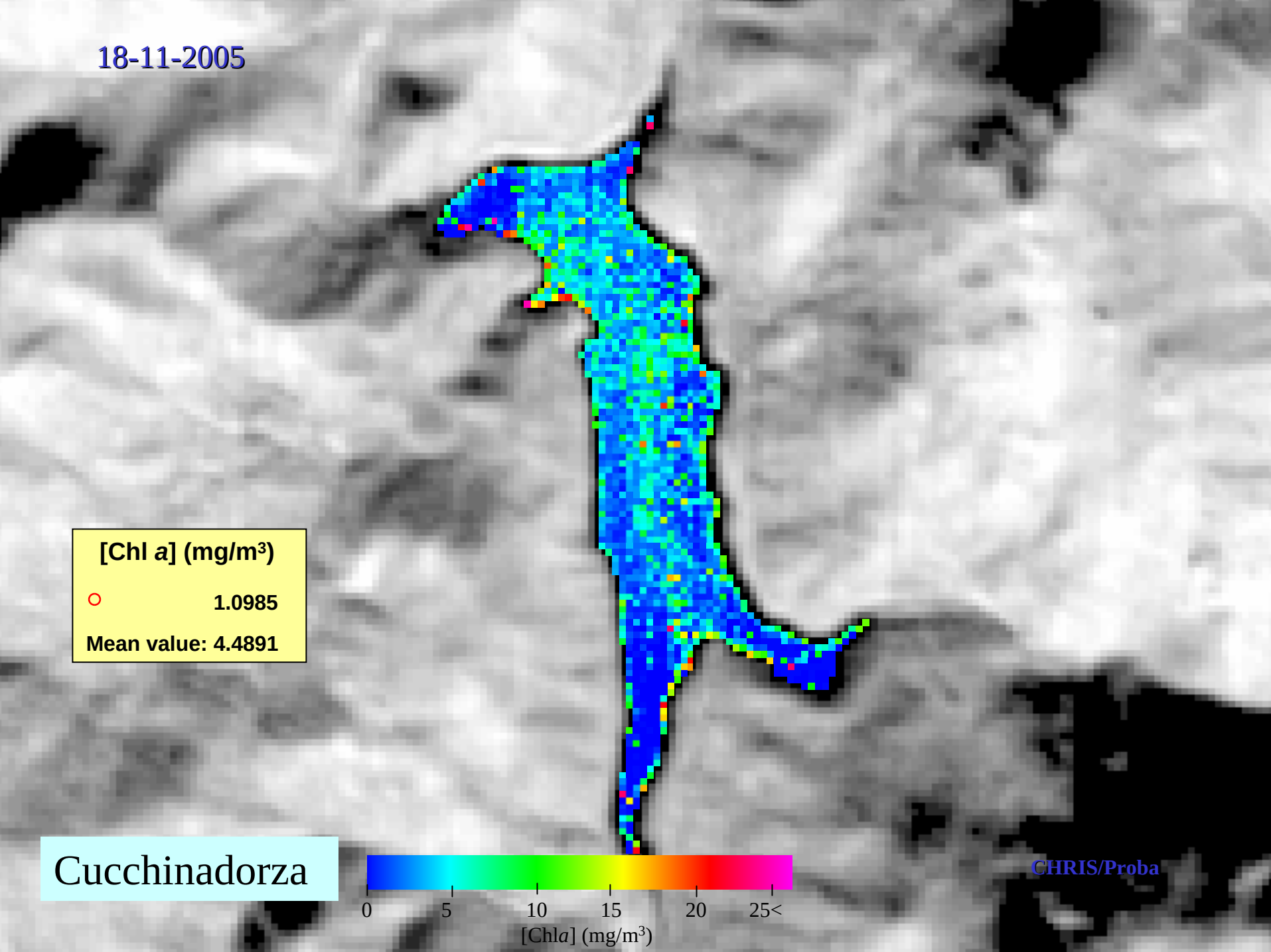
22-07-2005



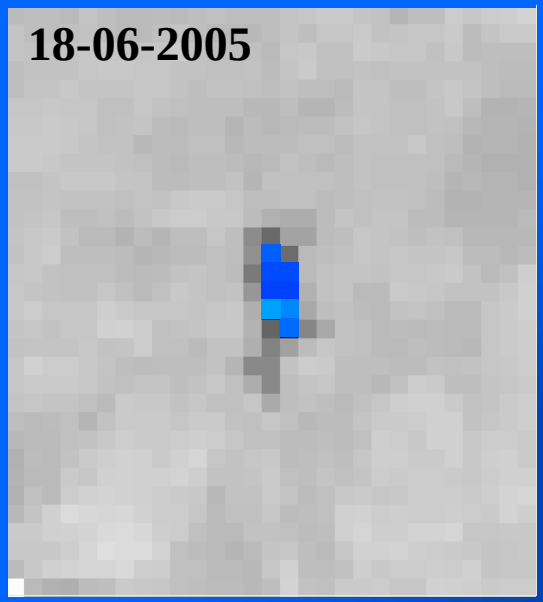
Italy)

CHRIS/Proba


08-07-2005
[Chl a] (mg/m³)
-
Mean value: 33.48
Most of water pixels invalidated by sun glint effect
Punta Gennarta
0
5
10
15
20
25<
CHRIS/Proba


18-11-2005
[Chl a] (mg/m3)
1.0985
Mean value: 4.4891
Cucchinadorza
0
5
10
15
20
25<
[Chla] (mg/m3)
CHRIS/Proba

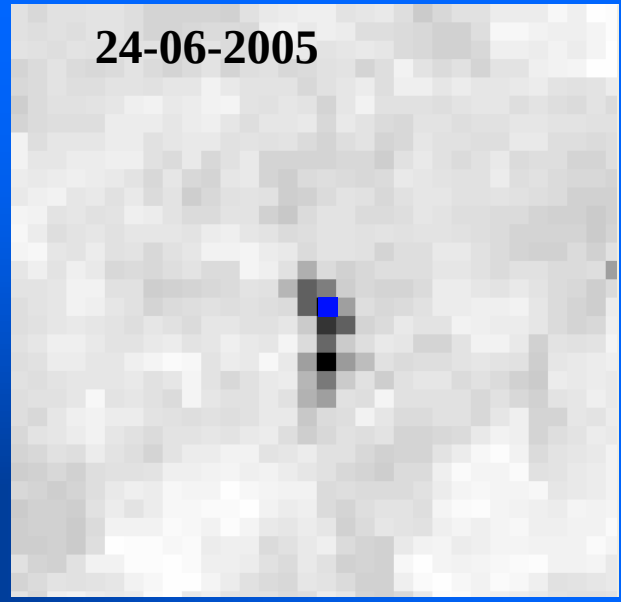
18-06-2005



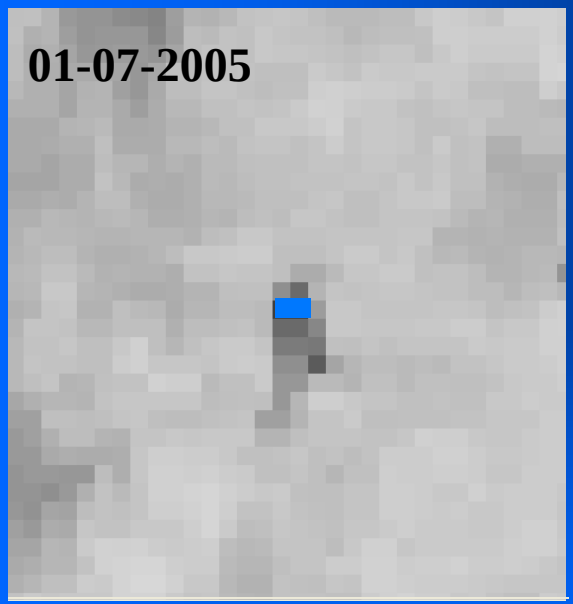
21-06-2005

No image

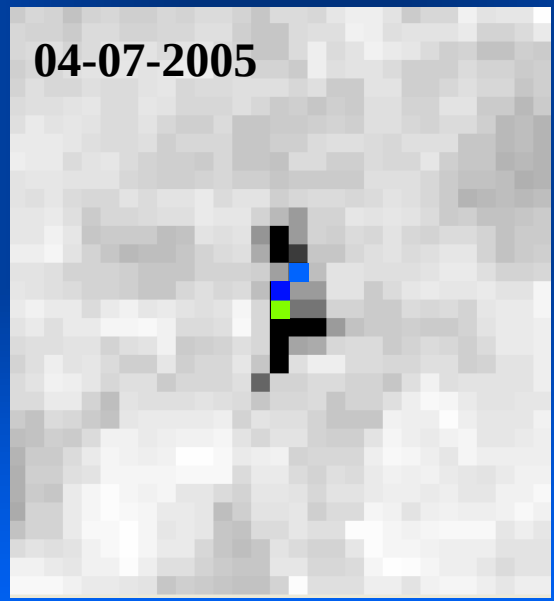
24-06-2005



01-07-2005



04-07-2005



07-07-2005

No image

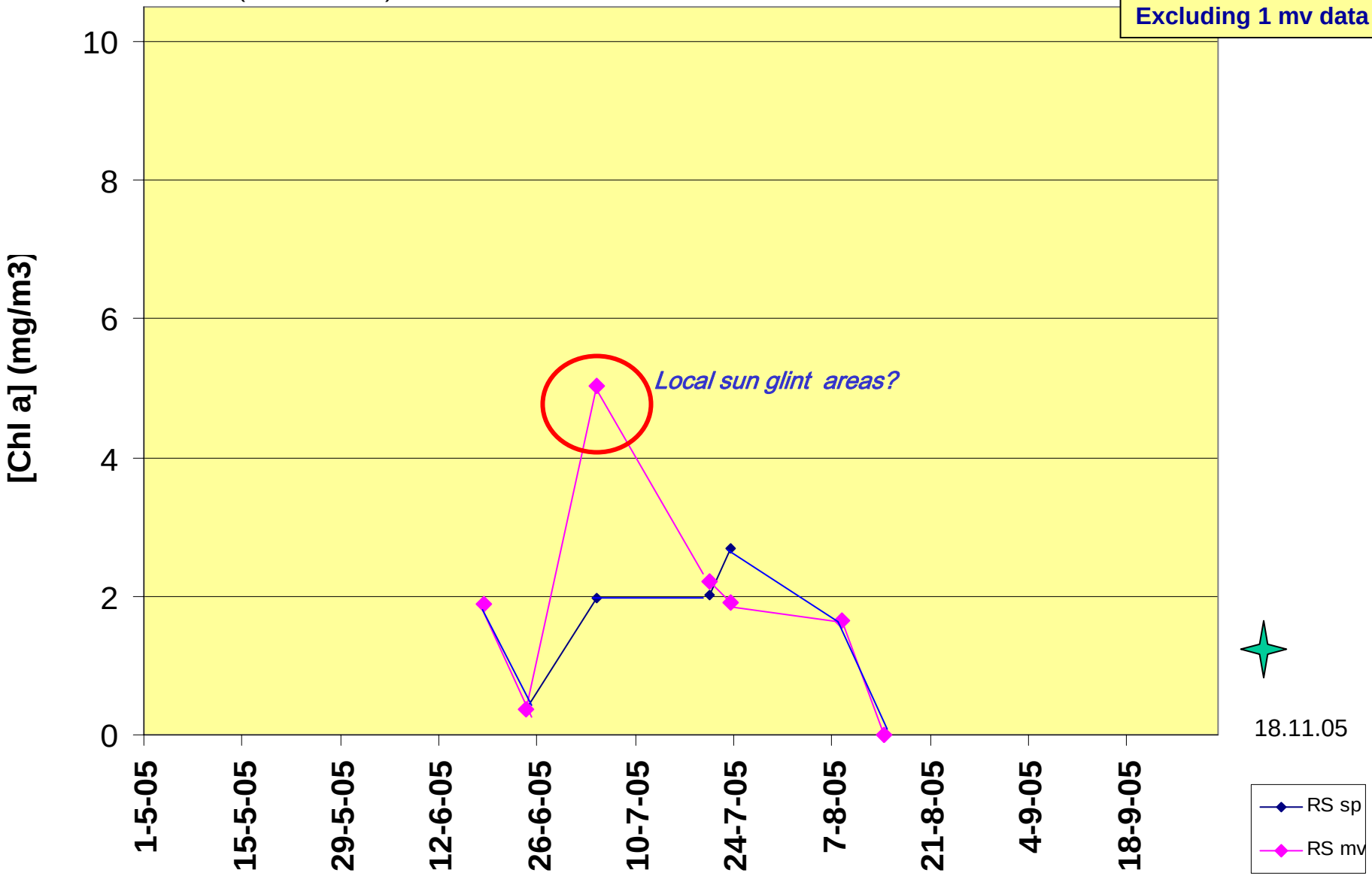
Cucchinadorza evolution

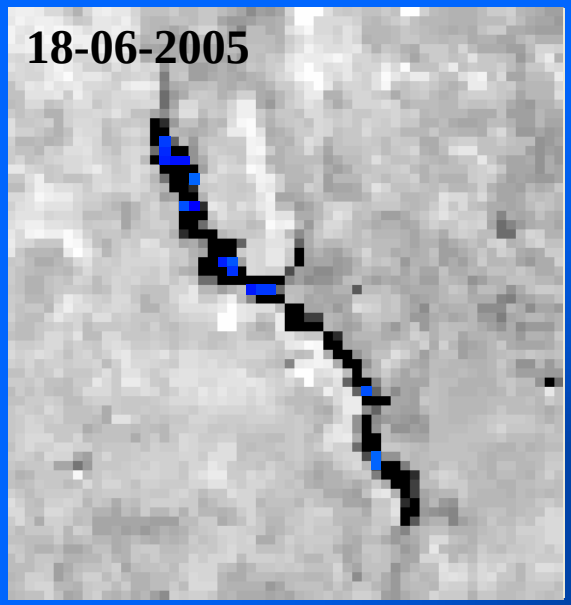
No sampling data

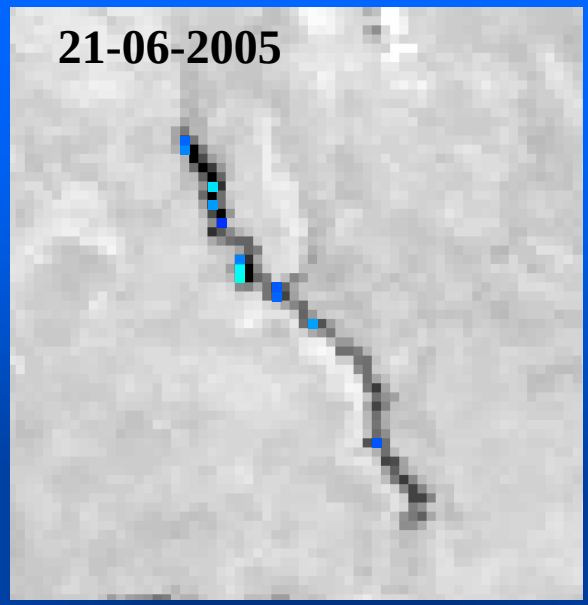
18.11.05

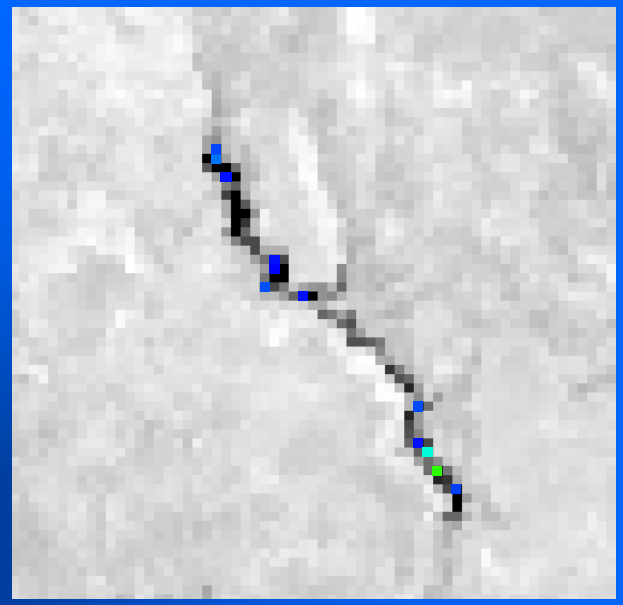
CHRIS 1.0985 (mean 4.4891)

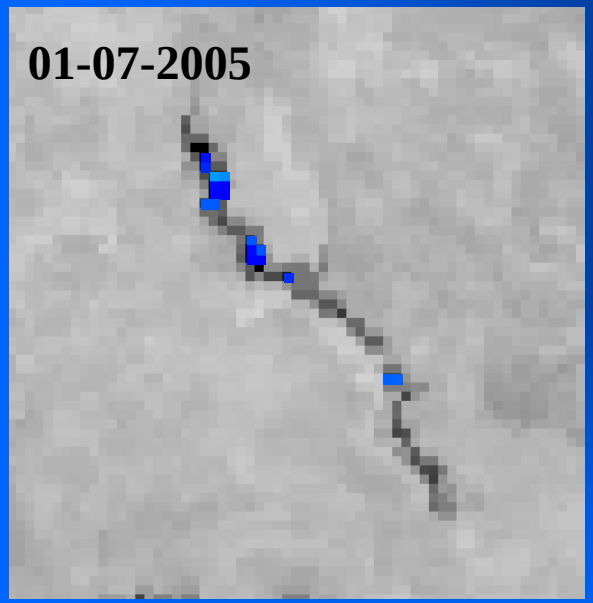
RS sp mean	1.847
RS mv mean	1.730
Photic l. mean	-.---
Excluding 1 mv data	

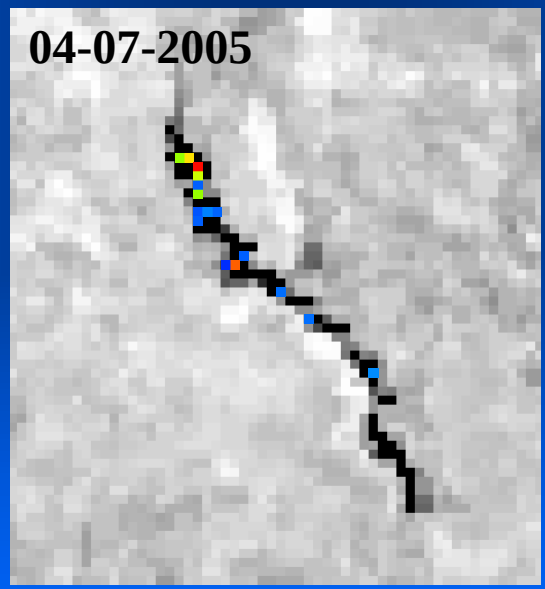


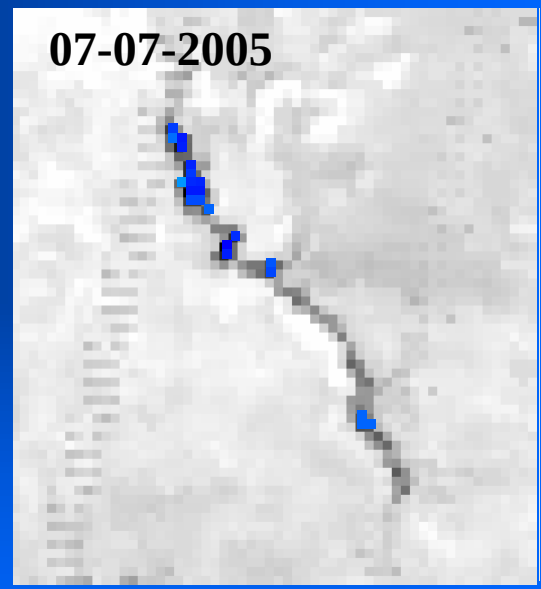












Medio Flumendosa

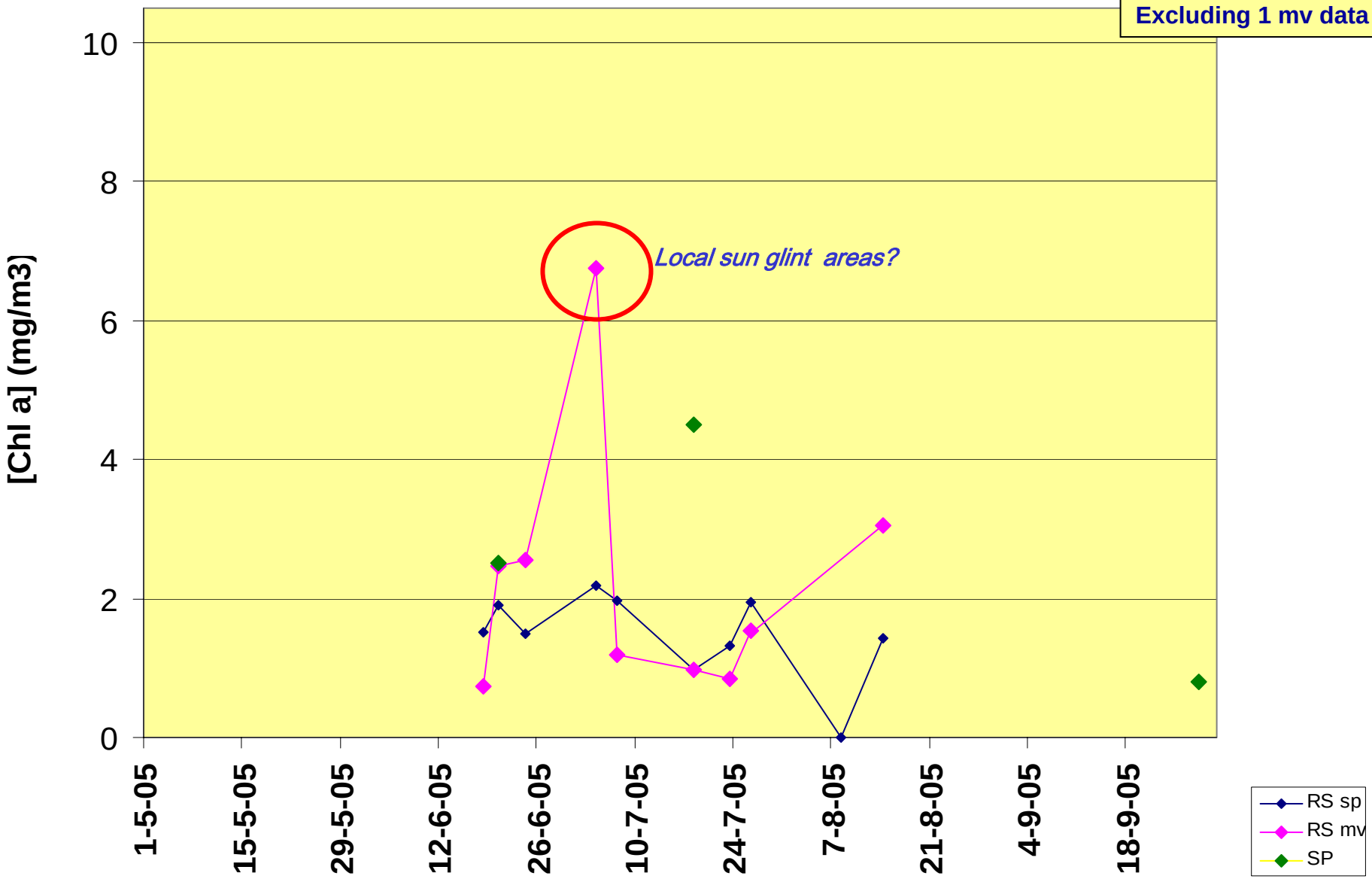
0 5 10 15 20 25<

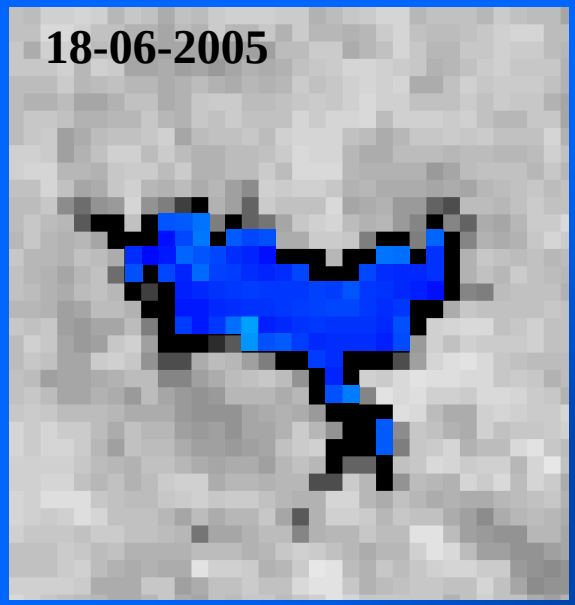
[Cla] (mg/m^3)

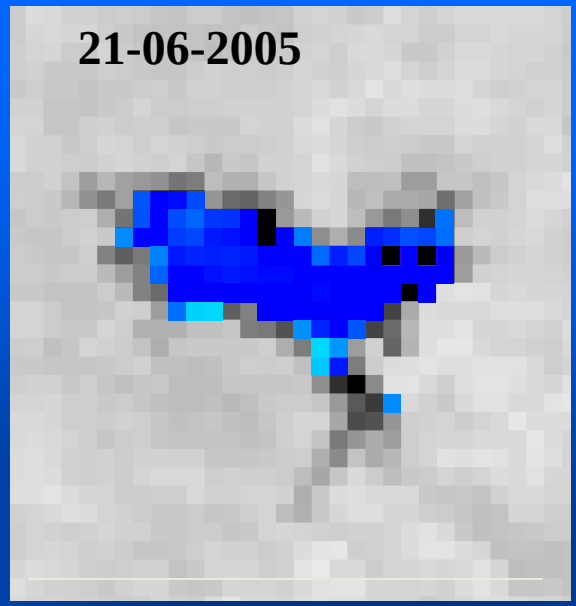
MERIS

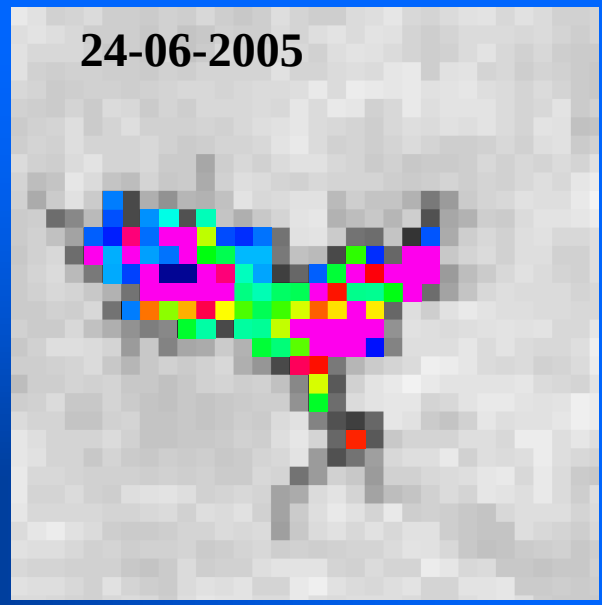
Medio Flumendosa evolution

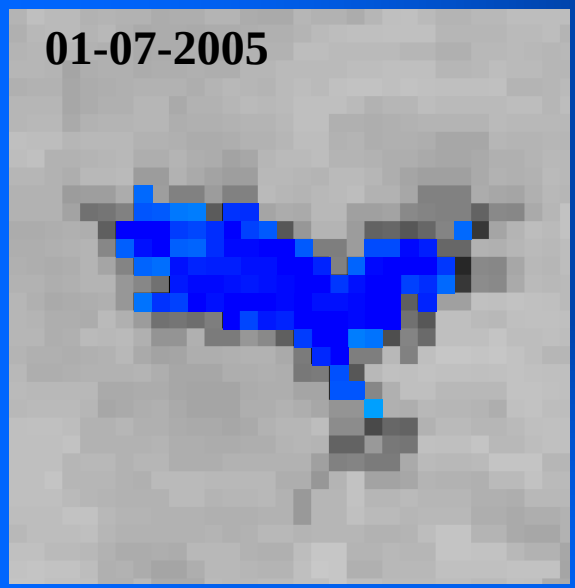
RS sp mean	1.635
RS mv mean	1.580
Photic l. mean	2.600
Excluding 1 mv data	

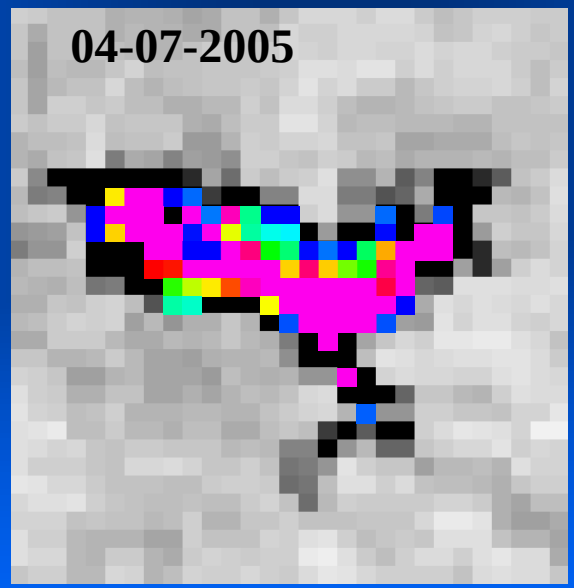


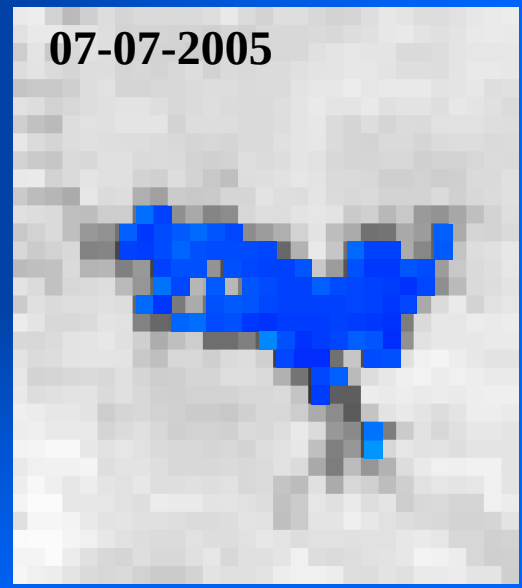










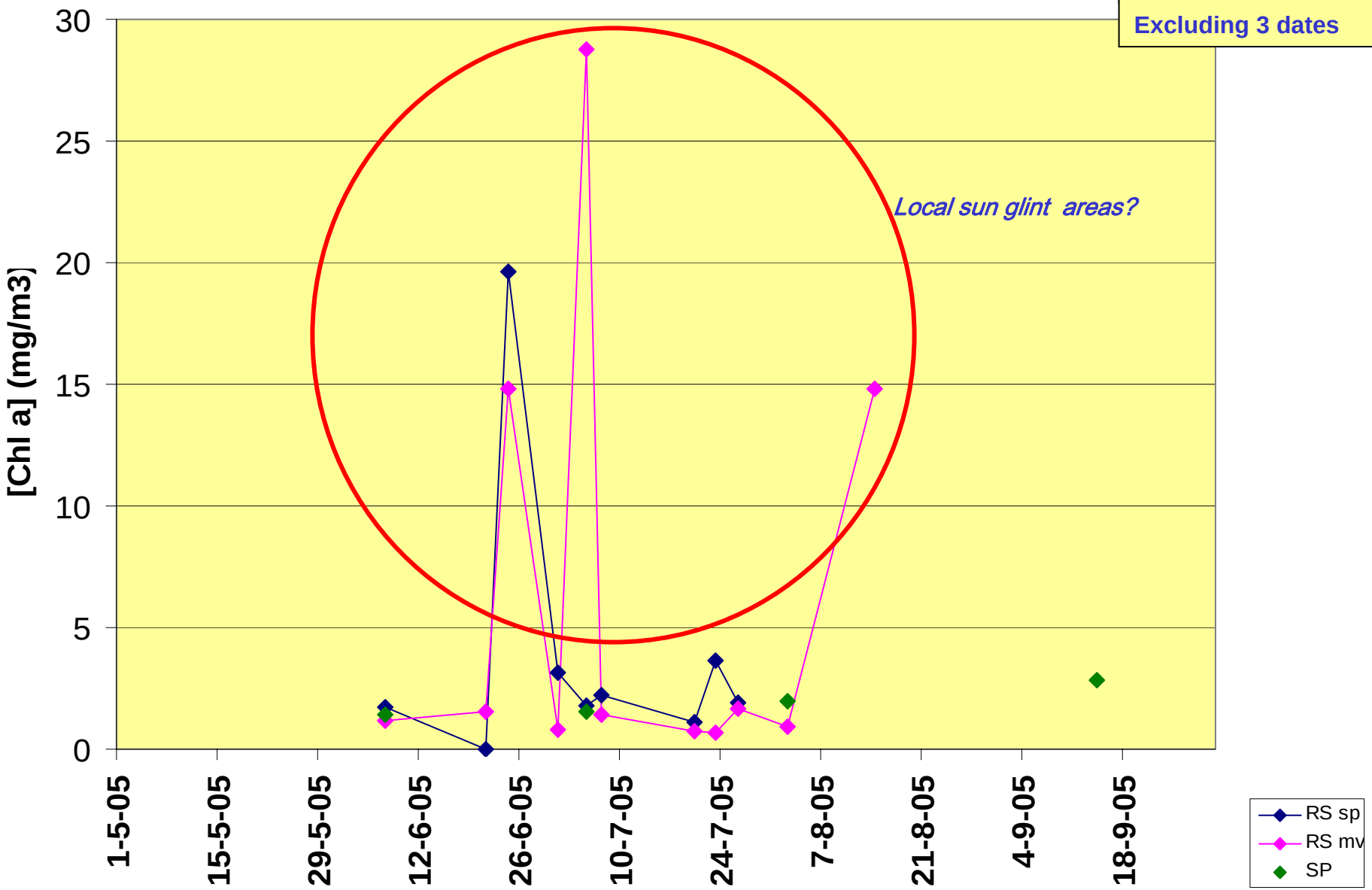


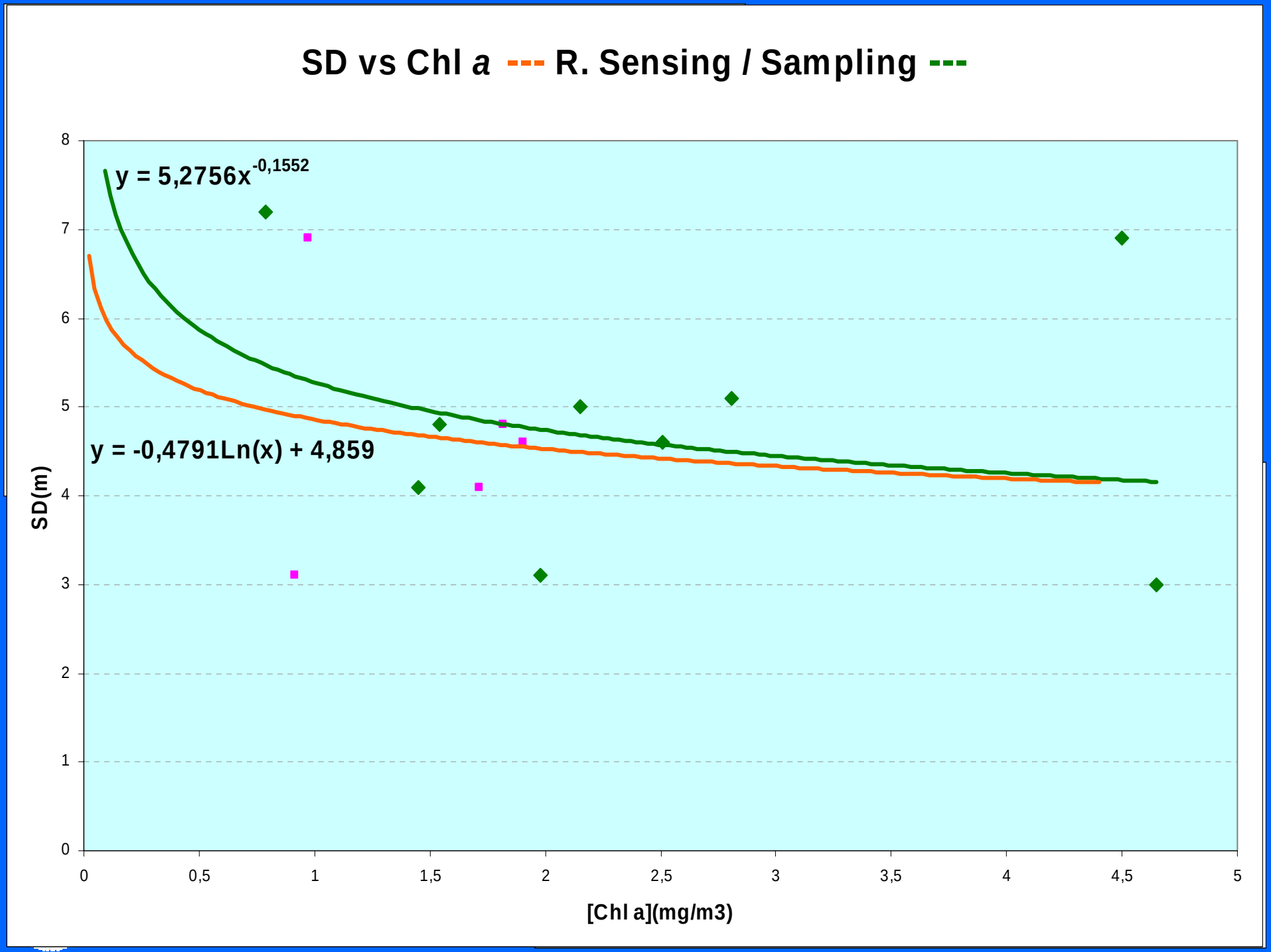
Mulargia

MERIS

Mulargia evolution

RS sp mean	1.808
RS mv mean	1.067
Photic l. mean	1.938
Excluding 3 dates	




SD vs Chl a --- R. Sensing / Sampling ---
y = 5,2756x-0,1552
y = -0,4791Ln(x) + 4,859
SD(m)
[Chl a](mg/m3)
0
1
2
3
4
5
6
7
8
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5

Type	Country	Reservoir name	Chlorophyll-a (mg/m3) Sampling #	RS sp	RS mv	CH sp	CH mv
LM8	CYPRUS	Asprokremmos	1.979	1.490	1.220	4.454	5.038
LM8	CYPRUS	Kouris	1.800	1.367	1.272	2.326	1.862
LM8 RC	CYPRUS	Lefkara	0.381	1.607	1.677		
LM8	ITALY	Medio Flumendosa	2.600	1.635	1.580		
LM8	ITALY	Mulargia	1.853	1.808	1.067		
LM7	ITALY	Sos Canales	3.395	-	-		
LM8	ROMANIA	Bezid	1.699	1.081	1.775		
LM7	ROMANIA	Bradisor	5.353	1.420	1.502 *		
LM7	ROMANIA	Colibita	2.365	1.978	1.147		
LM8	ROMANIA	Izvorul Muntelui	1.392	0.952	0.969		
LM8	ROMANIA	Paltinu	1.721	1.487	0.886		
LM8	ROMANIA	Sacele	0.542	1.010	0.886	1.299	0.823
LM8	ROMANIA	Siriu	2.024	1.467	0.969		
LM7	ROMANIA	Vidraru	1.678	0.885	1.049		

* till 31.07.05

CH : CHRIS/Proba

[summer photic layer mean concentration]

Conclusions:

This application of remote sensing using satellite imagery CHRIS and MERIS to complement and expand the monitoring effort, showed the possibility to assess the values and trend of the Chlorophyll-a in any period, and at any water body.

-The remote sensing techniques can reduce the monitoring needs in terms of number of sampling points and number of dates.

-In the operational phase of WFD implementation, remote sensing can provide an useful tool to assess the Ecological Quality/Potential of entire water bodies, integrated in the water districts. This allows to check for the efficiency achieved in the programs of measures.

-Is very important for the scientific and water management community to can use a satellite as Proba with a sensor as CHRIS, but operational, in order to complement and improve the information on ecological quality/potential of water bodies, following the objectives of the EU Water Framework Directive.

MINISTERIO DE FOMENTO

CEDEX
CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS

Title:

"Use of CHRIS imagery for Monitoring Ecological Water Quality in smallest Mediterranean Reservoirs integrated in the Intercalibration Exercise of WFD Implementation Process.
Final report." (AO 3123)

Authors:
Peña-Martínez. Ramón; Domínguez-Gómez. José-Antonio; Ruiz-Verdú. Antonio
Centre for Hydrographic Studies of CEDEX (Spain)

Topic/subtopic : Ecological Water Quality. Photosynthetic pigments. Remote sensing