Remote sensing of phytoplankton in Spanish lakes and reservoirs

Antonio Ruiz Verdú
National Institute for Aerospace Technology (INTA)

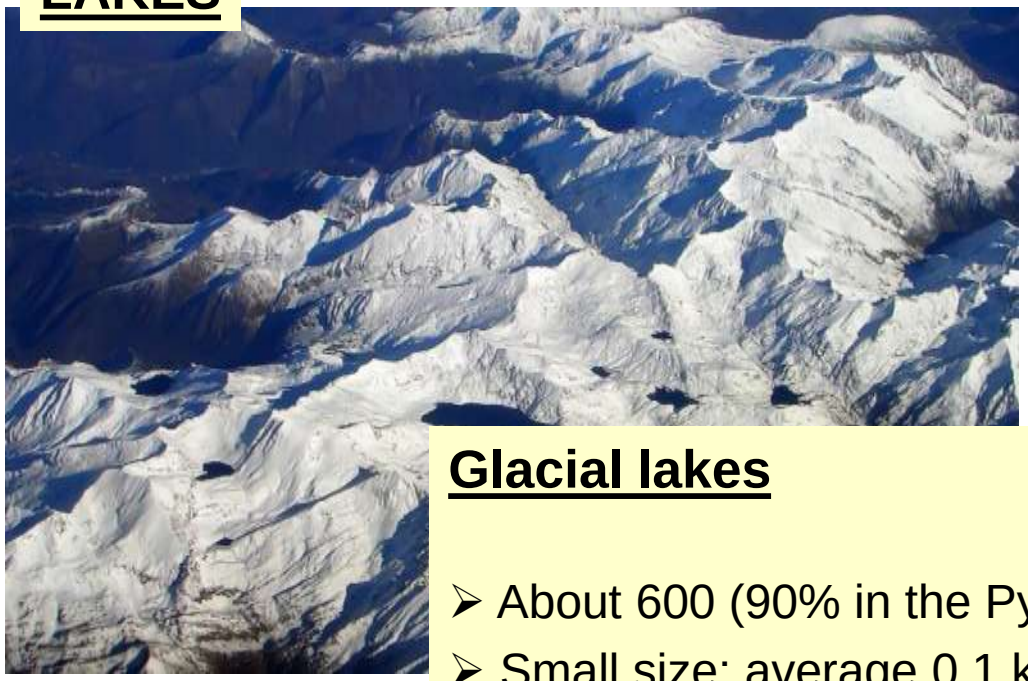
aruiver@gmail.com
crepadpt@inta.es

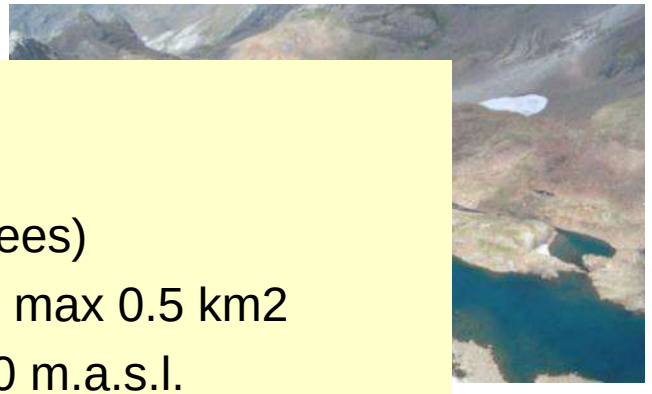
Summary

1. Overview of Spanish inland waters
2. Summary of remote sensing studies
3. Bio-optical characteristics
4. Usefulness of Spanish dataset for GloboLakes


Are there lakes in Spain?

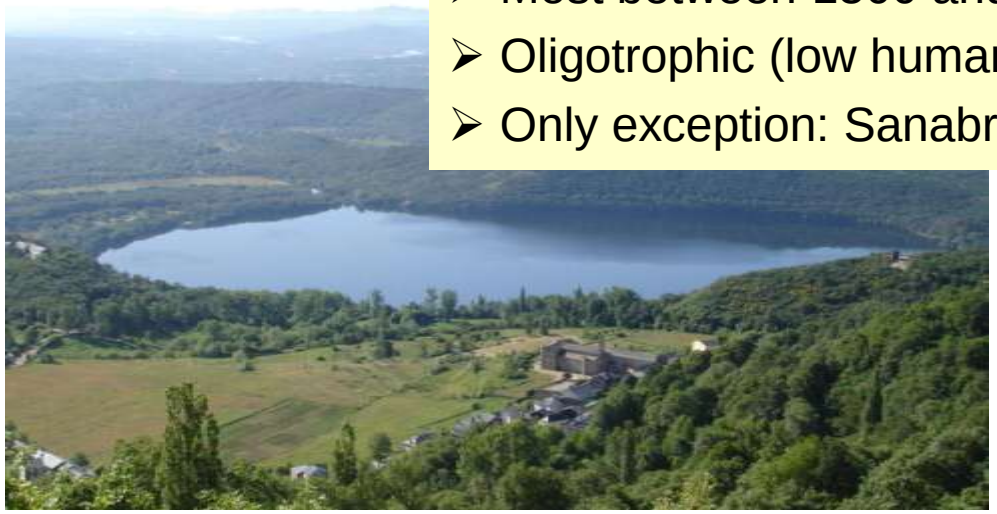
LAKES





Glacial lakes

- About 600 (90% in the Pyrenees)
- Small size: average 0.1 km2; max 0.5 km2
- Most between 1500 and 3000 m.a.s.l.
- Oligotrophic (low human pressure)
- Only exception: Sanabria lake (NW Spain): 4 km^2



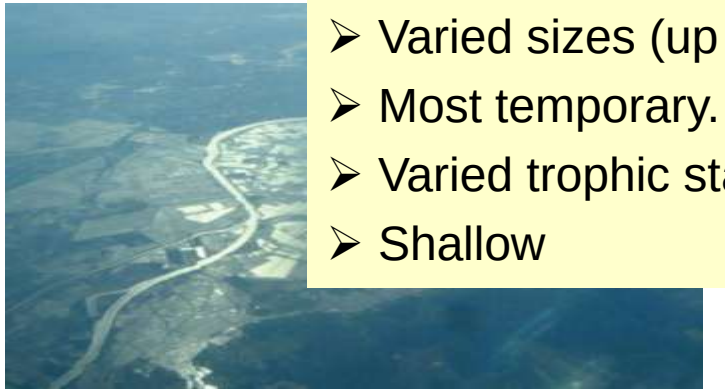
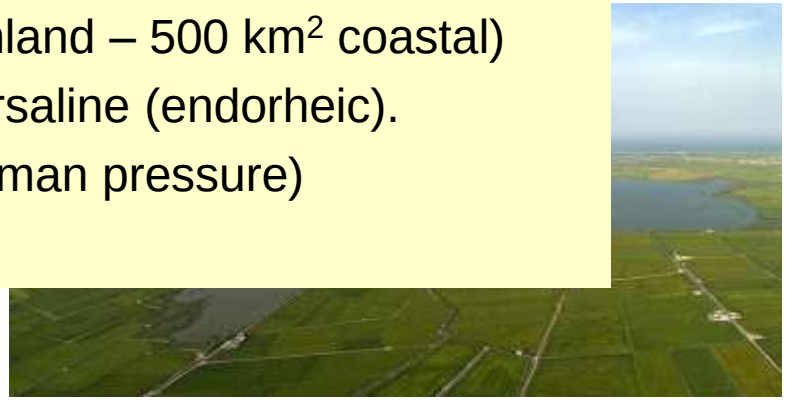
WETLANDS






Endorheic lakes and freshwater coastal wetlands

- About 2000
- Varied sizes (up to 15 km^2 inland – 500 km^2 coastal)
- Most temporary. Often hypersaline (endorheic).
- Varied trophic state (high human pressure)
- Shallow

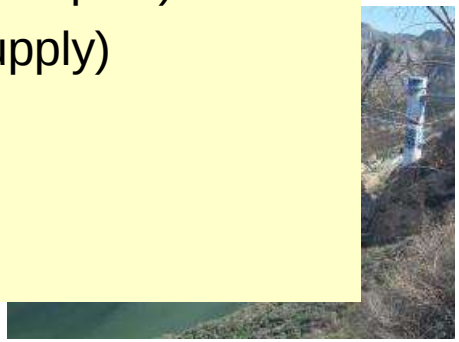
RESERVOIRS











Artificial reservoirs

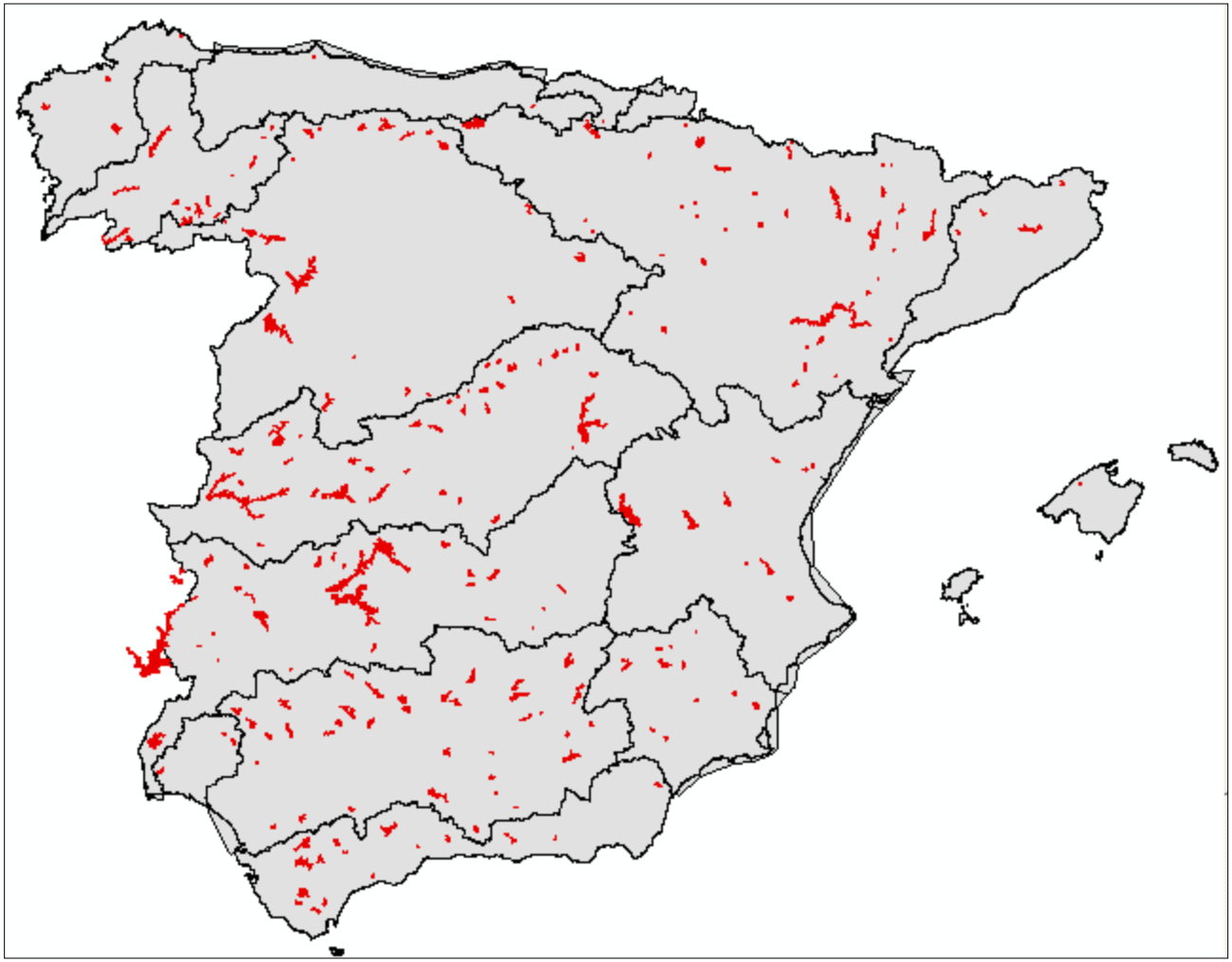
- **1280** “big” reservoirs (dam higher than 15 m)
- **66** bigger than 10 km^2 (at full capacity)
- Retention times: from days to years (up to 120 “hyperannual”)
- Diverse mineralization and catchment's geology
- Climatic gradient
- Varied trophic state (30% oligotrophic; 40% eutrophic)
- Multiple uses (irrigation, hydropower, water supply)
- Increasing human use (including recreational)
- Frequent HABs
- Understudied. Monitoring required by WFD

1. Overview of Spanish inland waters

TOTAL

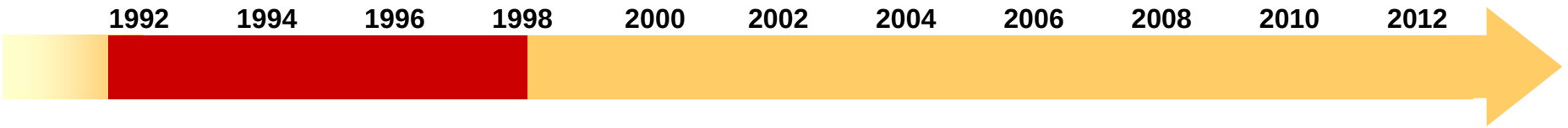
1280 RESERVOIRS

> 10 “pure water pixels” in MERIS imagery

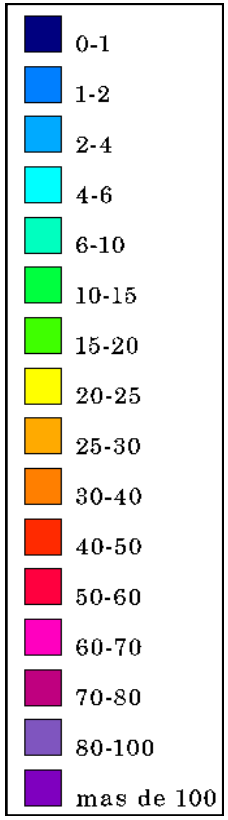


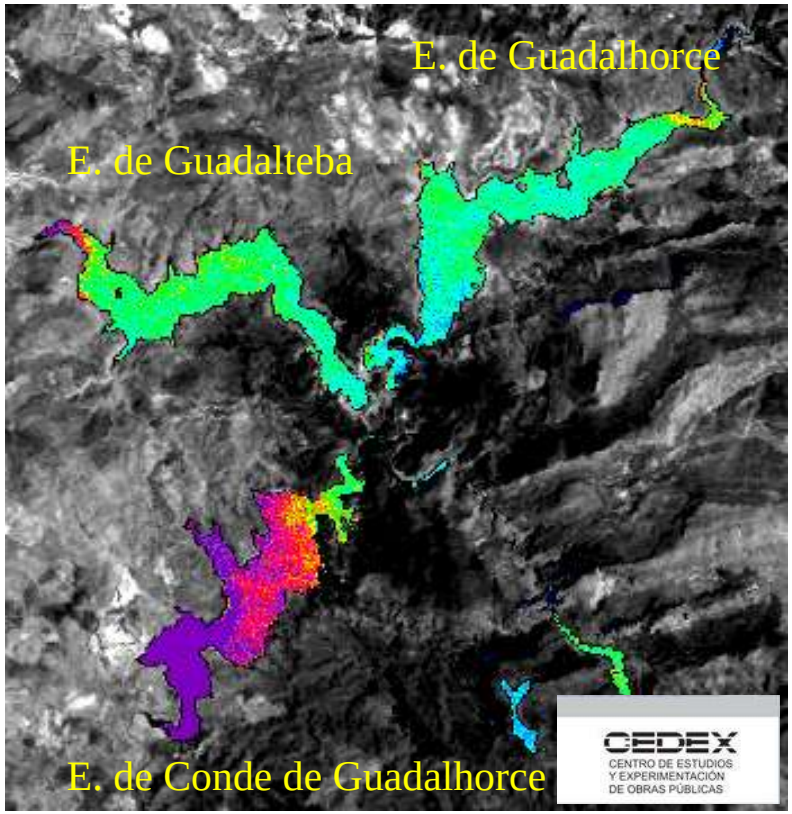
130 RESERVOIRS

2. Summary of remote sensing studies



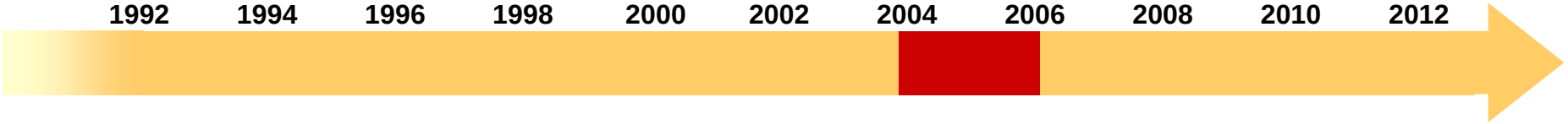
First steps: River basin surveys with Landsat-TM



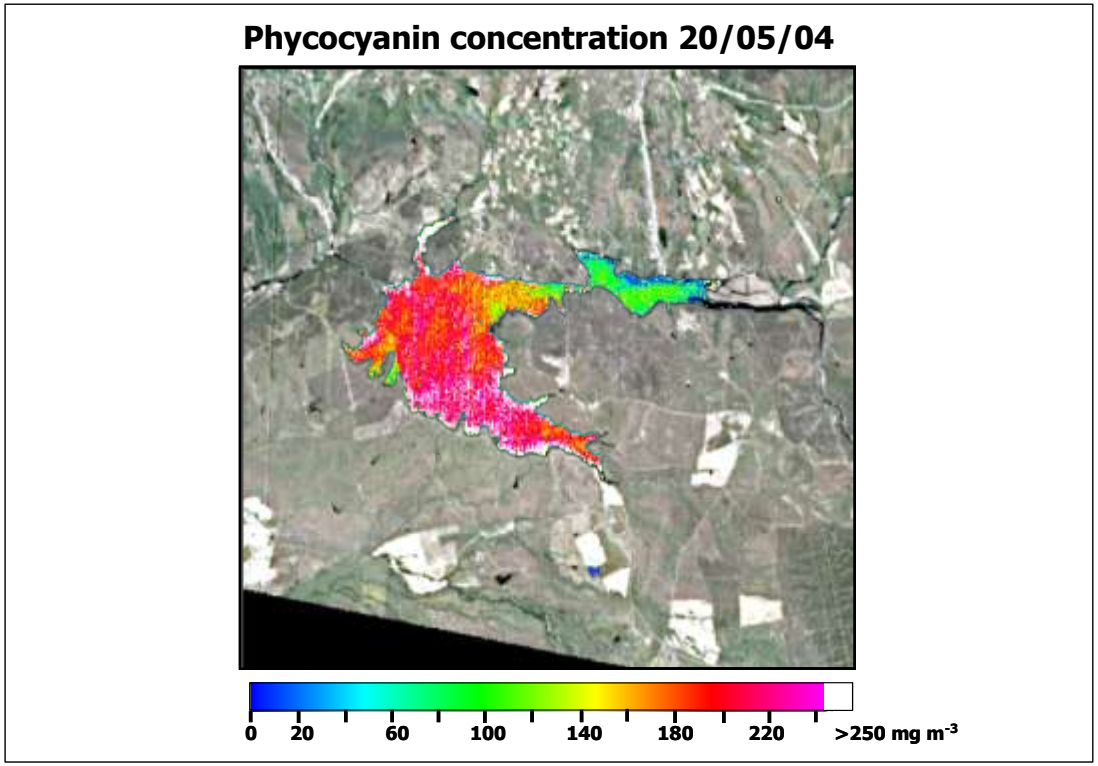


- Eutrophication monitoring
- In situ measurements:
  - [Chl-a]
  - Secchi disk
  - Temperature
  - TSM (few points)
- 778 match-up points
- Empirical approach (scene-based multiple regressions without proper AC)
- Potential for image re-processing

Peña, R. y Serrano, M.L., 1992. Evaluación del estado trófico de los embalses mediante imágenes digitales. Ingeniería Civil, 86, 37-44.

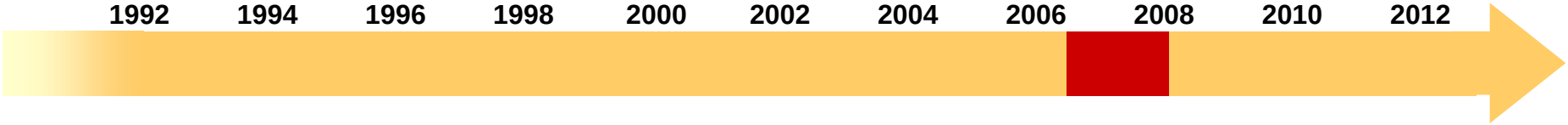


CHRIS/PROBA in Rosarito reservoir

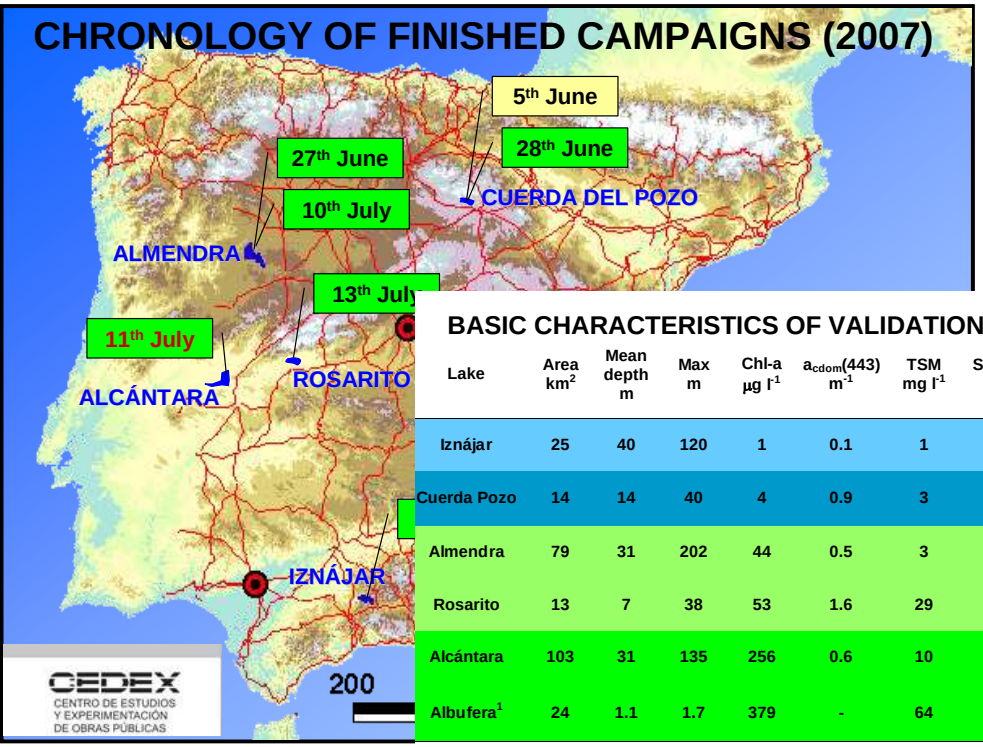


- 9 cloud-free image sets
- 46 sampling points
- In situ measurements:
  - Above water radiometry (46)
  - [HPLC] phyto pigments (33)
  - In situ fluorescence (PC, PE, Chl, CDOM; 46)
  - Phytoplankton taxonomy (3)
  - TSM; Temp; cond.; wind; other
- Empirical models and calibration of semi-empirical algorithms
- [Chl-a] and [PC] mapping

Ruiz-Verdú, A., Domínguez, J.A. & Peña-Martínez, R. (2005) Use of CHRIS for monitoring water quality in Rosarito reservoir. Proceedings of the Third Chris/Proba Workshop. ESA-ESRIN, Frascati, Italy, 21 -23 March 2005 (ESA SP-593, June 2005)



MERIS-Lakes: Validaton of MERIS Lake Water Algorithms

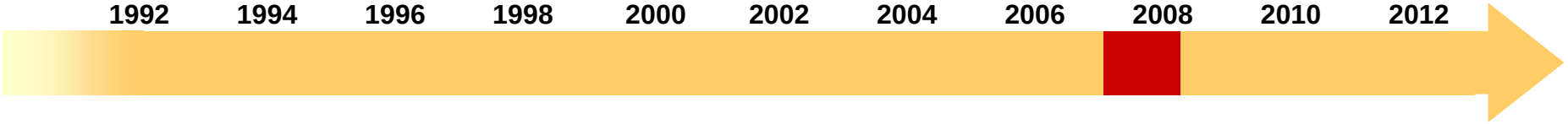


BASIC CHARACTERISTICS OF VALIDATION LAKES

Lake	Area km^2	Mean depth m	Max m	Chl-a $\mu g\ l^{-1}$	$a_{cdom}(443)$ m^{-1}	TSM $mg\ l^{-1}$	Secchi m	Water picture
Iznájar	25	40	120	1	0.1	1	4.8	
Cuerda Pozo	14	14	40	4	0.9	3	3.2	
Almendra	79	31	202	44	0.5	3	2.0	
Rosarito	13	7	38	53	1.6	29	0.5	
Alcántara	103	31	135	256	0.6	10	1.1	
Albufera[1]	24	1.1	1.7	379	-	64	0.2	

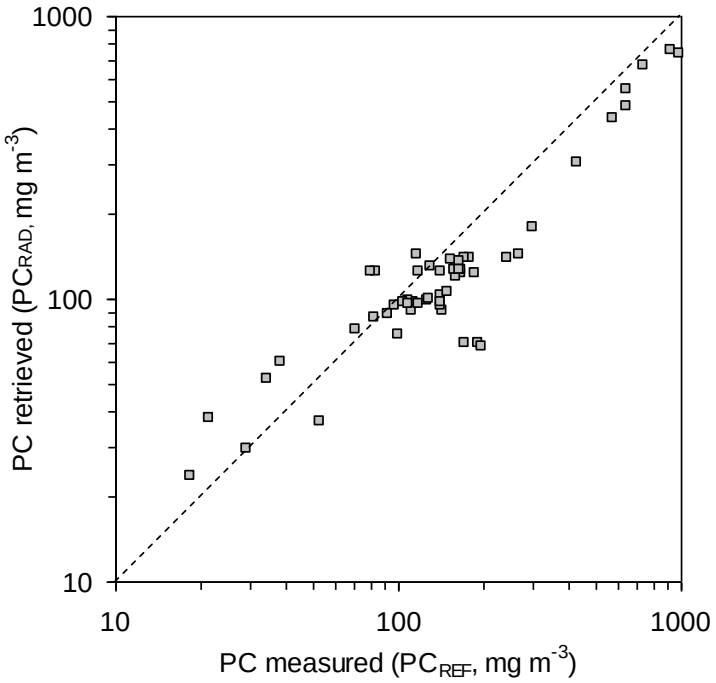
- 5 reservoirs and 1 lake
- 55 sampling points
- In situ measurements:
  - Above water radiometry (55)
  - In situ (AC-s) and lab IOPs (a_{phyto}; a_{CDOM}; a_{DET}; b_b; 35)
  - [HPLC] phyto pigments (35)
  - In situ fluorescence (PC, 46)
  - AOT (6)
  - TSM; Temp; cond.; wind; other
- 7 match-ups with MERIS
- Algorithm validation (EUL+ICOL)

Ruiz-Verdú, A., Koponen, S., Heege, T., Doerffer, R., Brockmann, C., Kallio, K., Pyhälahti, T., Peña, R., Polvorinos, A., Heblinski, J., Ylöstalo, P., Conde, L., Odermatt, D., Estellés, V. and Pulliainen, J. (2008) Development of MERIS Lake Water Algorithms: Validation results from Europe. 2nd MERIS/AATSR User Workshop. ESA ESRIN. Frascati, Italy. 22 - 26 September 2008 (ESA SP-666, November 2008)



Validation of C-PC retrieval Algorithms

Nested Semiempirical Band Ratio

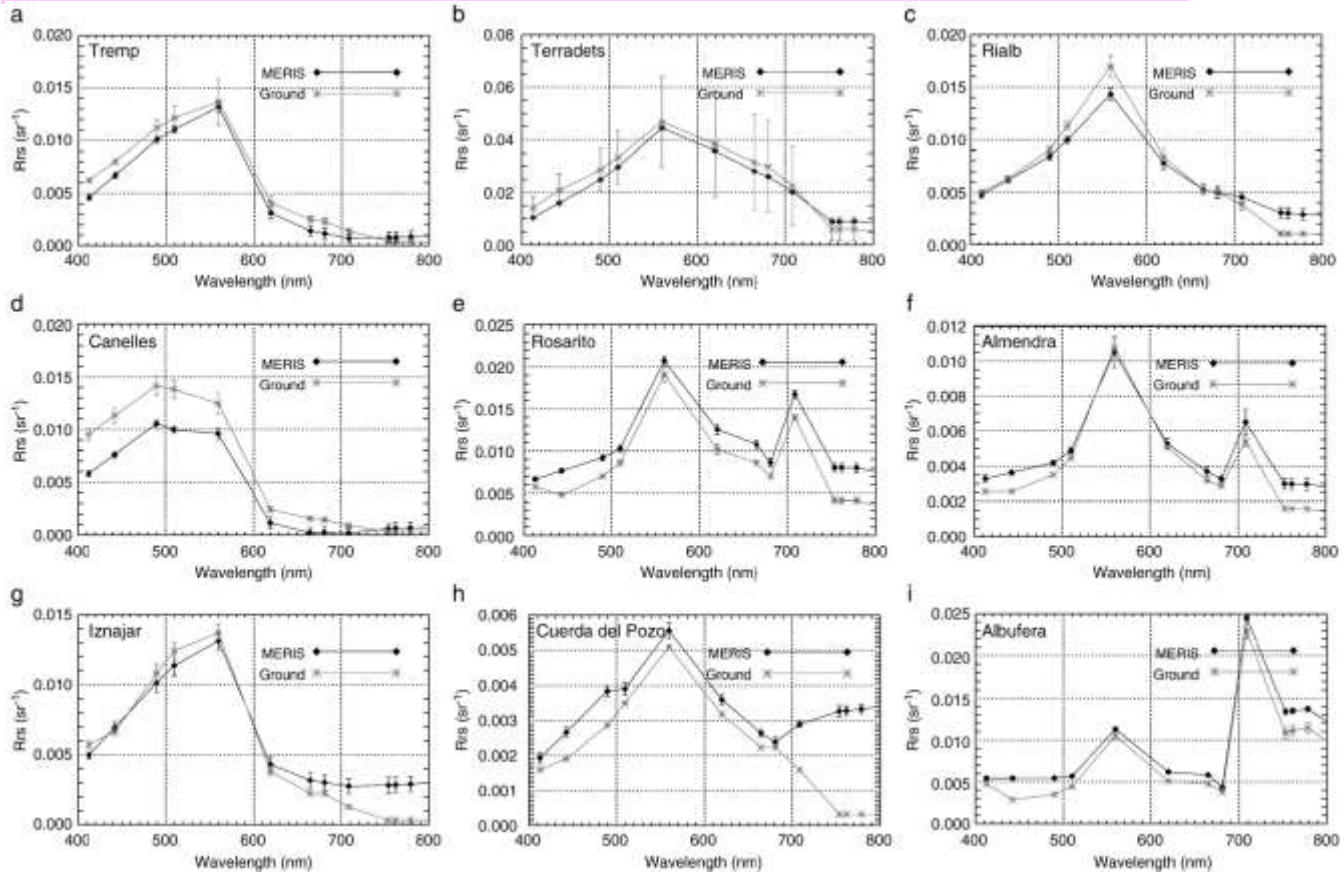


- Common database of Spanish and Dutch lakes
- 193 sampling points (Spain)
- Evaluation of algorithms:
  - Single Reflectance Ratio
  - Baseline Semiempirical
  - Nested Semiempirical Band Ratio

Ruiz-Verdú, A., Simis S.G.H., de Hoyos, C., Gons, H.J., Peña-Martínez, R. (2008) An evaluation of algorithms for the remote sensing of cyanobacterial biomass. Remote Sensing of Environment 112: 3996-4008

1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

Validation of MERIS AC algorithm (SCAPE-M)



Guanter, L., Ruiz-Verdú, A., Odermatt, D., Giardino, C. Simis, S., Estellés, V., Heege, T., Domínguez-Gómez, J.A., Moreno, J. (2010) Atmospheric correction of ENVISAT/MERIS data over inland waters: Validation for European lakes. Remote Sensing of Environment 114: 467-480

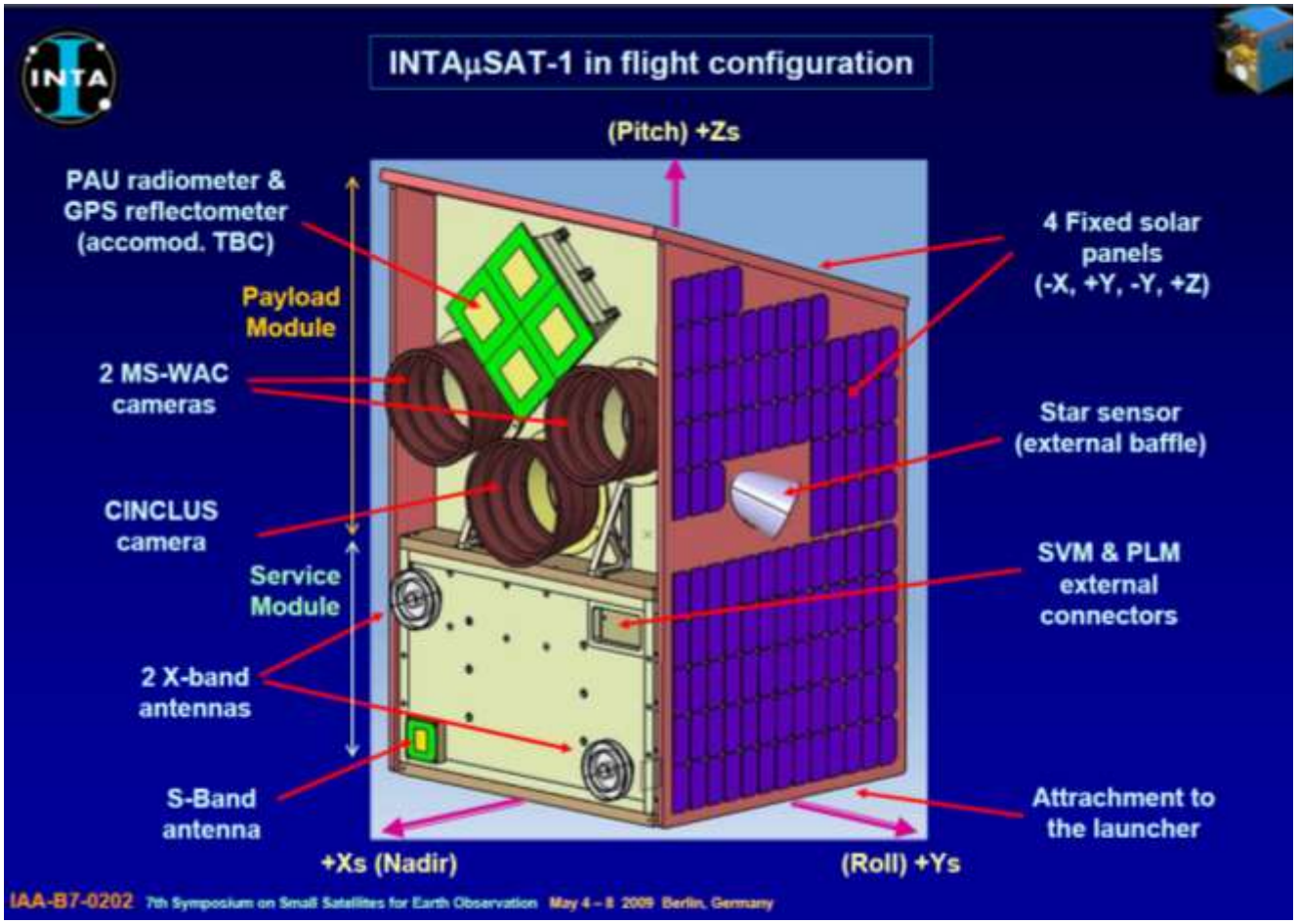
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

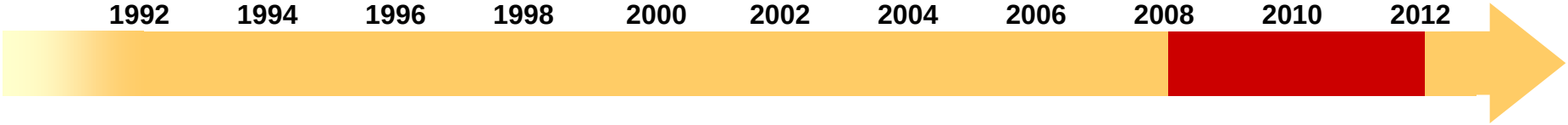
Hyperspectral airborne campaigns of inland water quality

- CASA C-212 aircraft
  - CASI 1500i (VNIR)
  - AHS (VNIR-SWIR-TIR)
- Field measurements (ASD-FR; Cimel)
- Calbration facilities
- Image processing laboratories
- L1b (geolocated at-sensor radiances)
- L2 (geolocated reflectances)

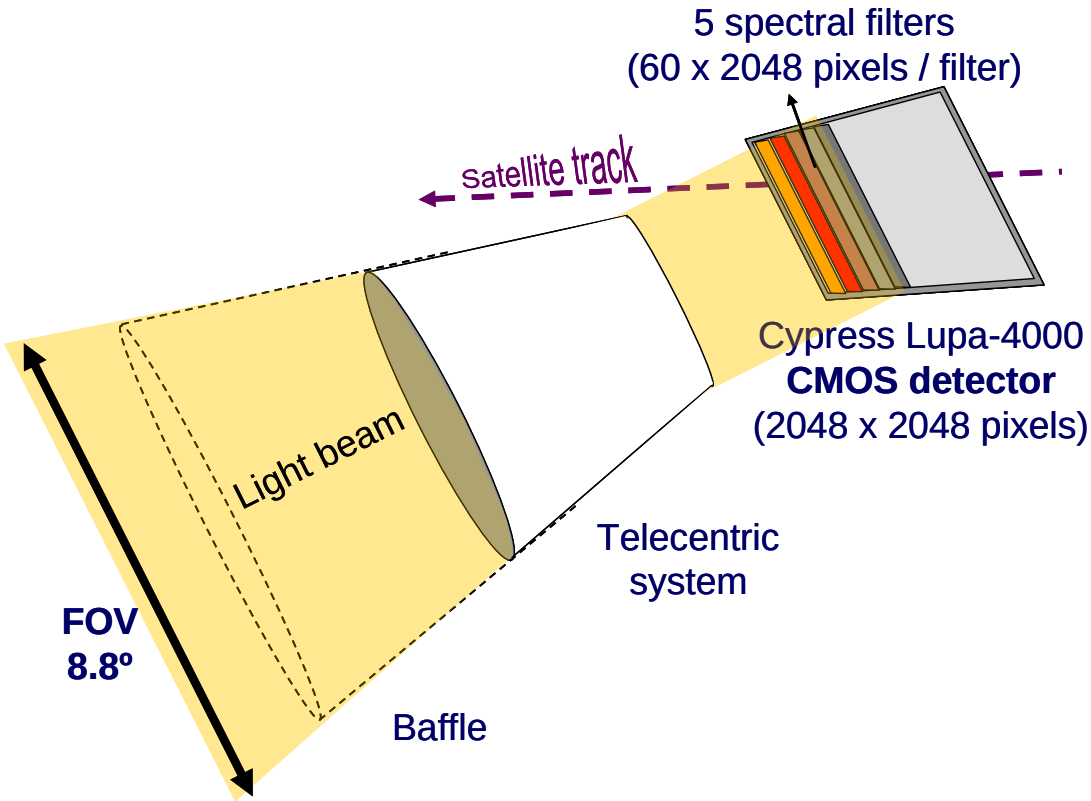
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

CINCLUS: A new satellite sensor for inland water quality monitoring?





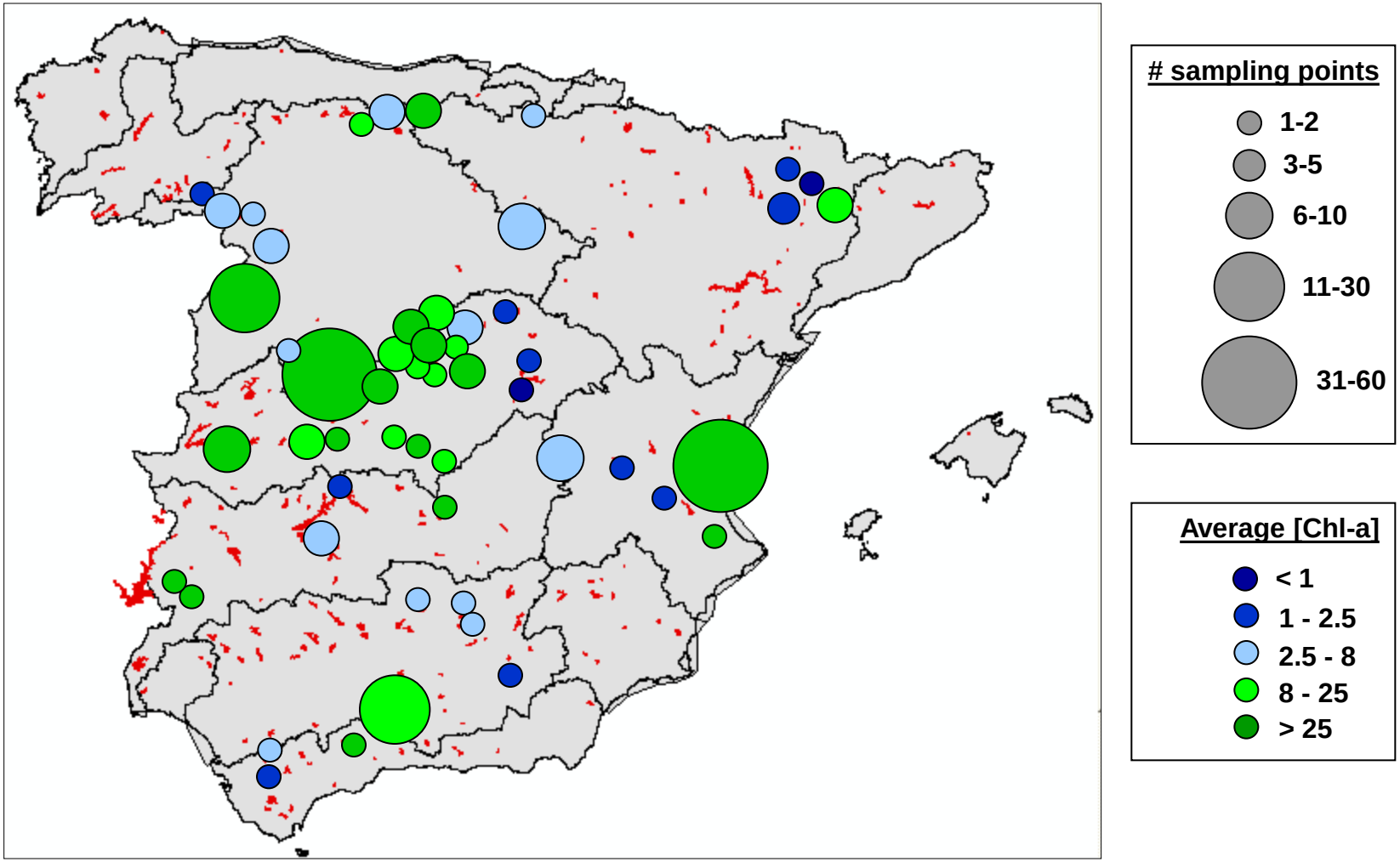
CINCLUS: A new satellite sensor for inland water quality monitoring?



Ruiz-Verdú, A., de Miguel, E., Robles-González, C. y Fernández-Renau, A. (2010) Cinclus: An instrument for the remote sensing of inland water quality. Proc. 'ESA Living Planet Symposium', Bergen, Norway. 28 June – 2 July 2010 (ESA SP-686, December 2010).

3. Bio-optical characteristics (2001-07 dataset)

BIO-OPTICAL SAMPLING CAMPAIGNS 2001-2007

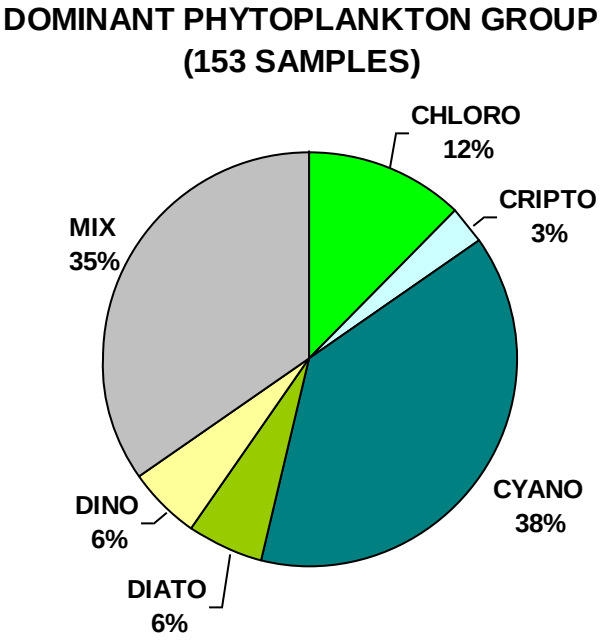


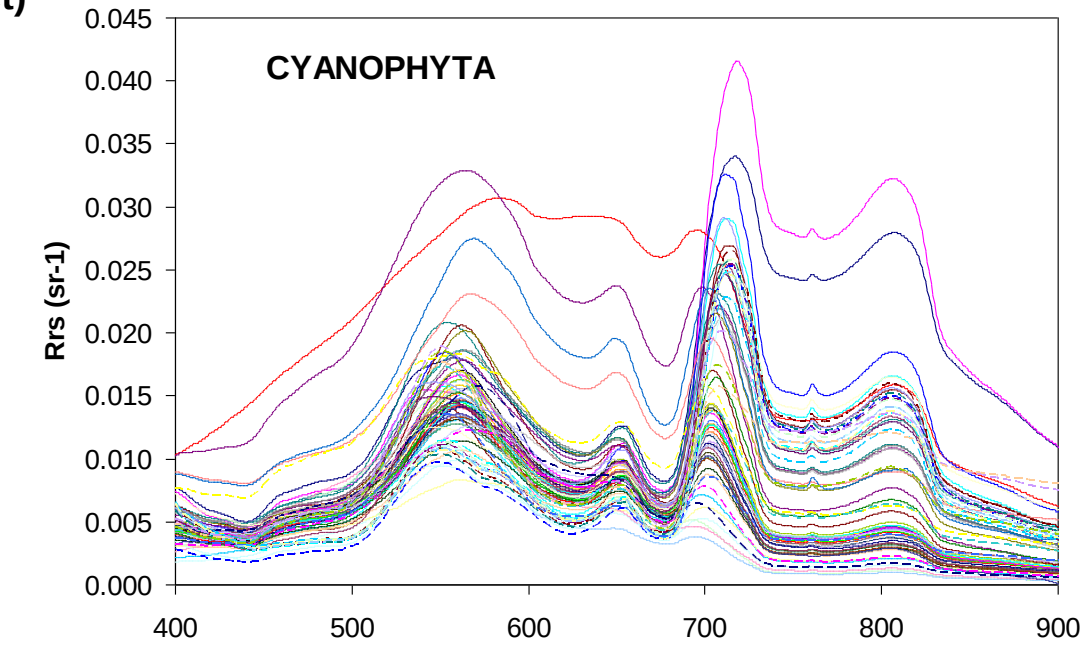
56 RESERVOIRS AND 2 LAKES

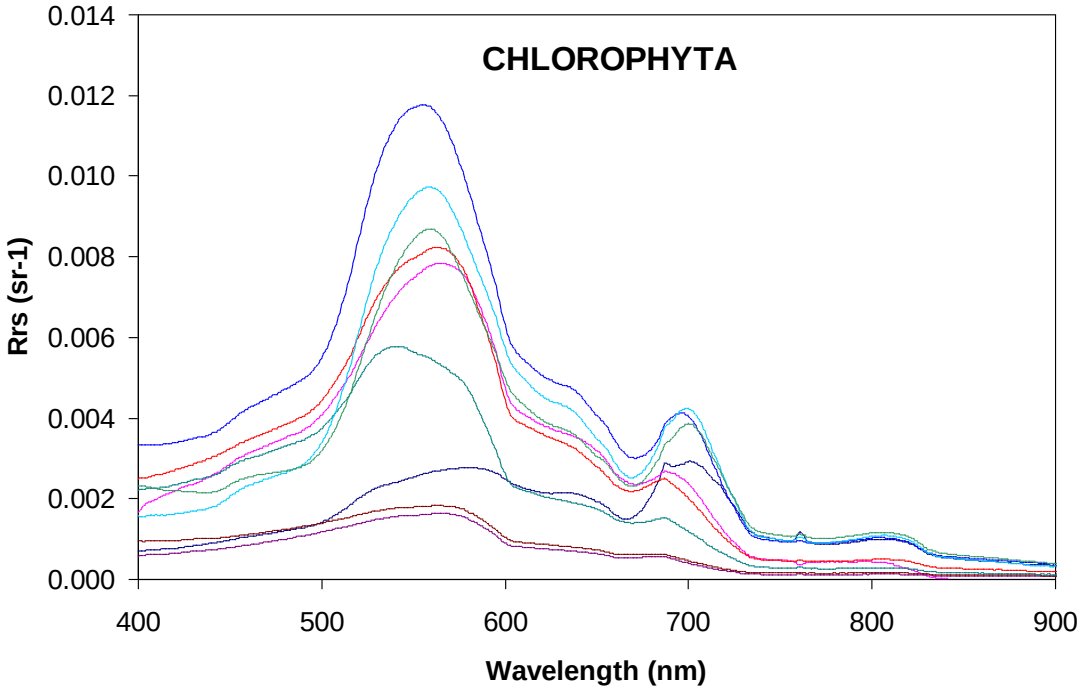
STATISTICS OF MAIN WATER QUALITY VARIABLES

	a_{440_CDOM} (m^{-1})	[Chl-a] ($mg\ m^{-3}$)	[PC] ($mg\ m^{-3}$)	[TSM] ($g\ m^{-3}$)	Z_SECCHI (m)
N	193	204	156	139	221
MIN	0.05	0.5	0.0	0.2	0.1
10 PERCENTILE	0.23	1.4	0.0	0.7	0.3
MEDIAN	0.64	23.2	29.8	2.8	1.7
MEAN	0.67	65.8	102.8	6.9	2.1
90 PERCENTILE	1.09	191.3	199.8	11.1	4.8
MAX	4.80	705.0	1040.0	78.8	11.5

3. Bio-optical characteristics (2001-07 dataset)







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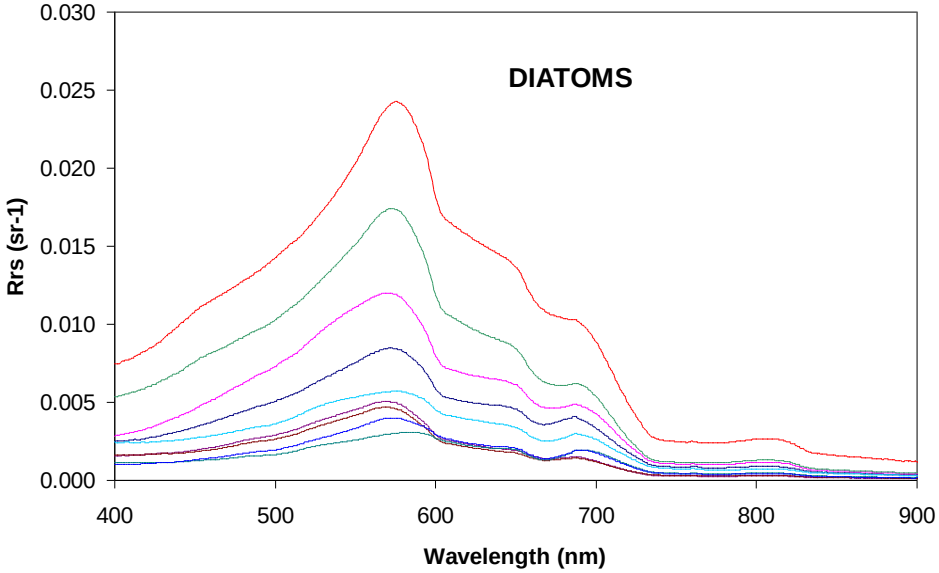

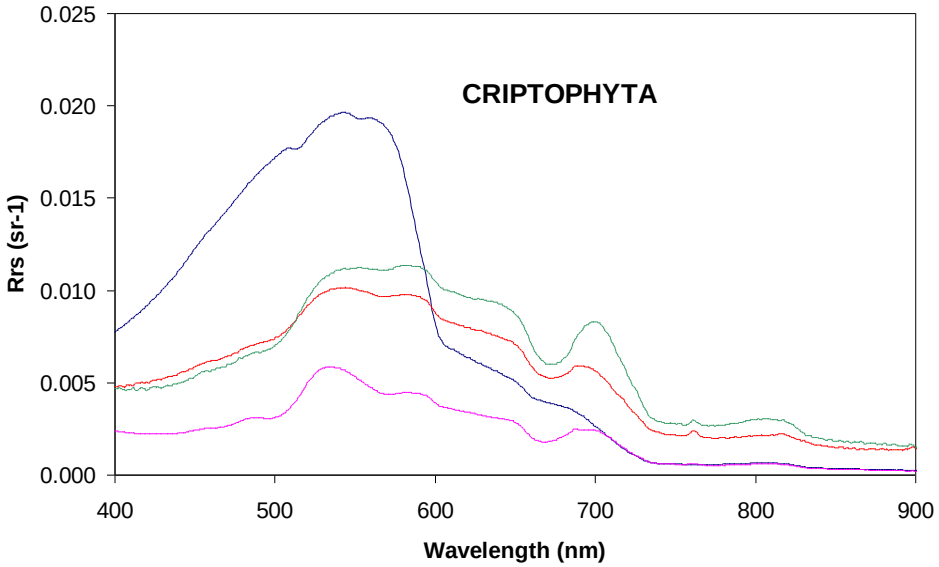

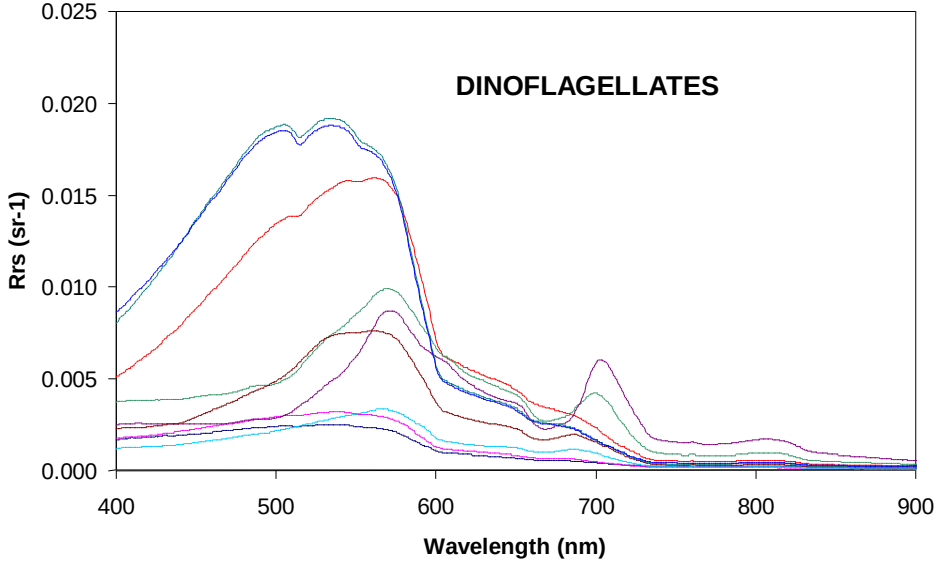

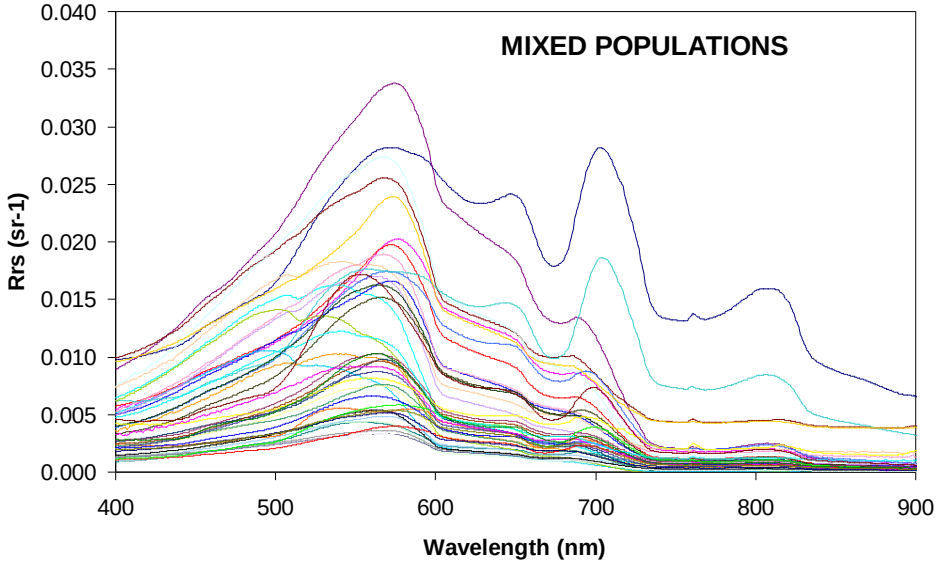

4. Concluding remarks

(usefulness for GloboLakes)

Usefulness of Spanish dataset for GloboLakes

- Diverse dataset (wide gradient of environmental variables)
- Adequate for phytoplankton studies
  - Reservoir shape and hydrologic / climate regime favour sedimentation in tail and stratification in open waters
  - Semi-arid climate favours low CDOM
  - Eutrophication is widespread: High phytoplankton biomass
  - Phytoplankton dominates RS signal (“pseudo case 1 waters”)
- Adequate for cyanobacteria studies (C-PC retrieval)
- Dataset comprising radiometric, pigment and taxonomic data
- 23 MERIS match-up dates (24 for Landsat-TM)
- 9 CHRIS/Proba match-up dates
- Hyperspectral airborne data

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