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GOBIERNO DE ESPAÑA | MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO | CONFEDERACIÓN HIDROGRÁFICA DEL DUERO

An autonomous multisensorial device integrated in an e-infrastructure to monitor and forecast the dynamics of toxic cyanobacteriae in a drinking water supply reservoir

INGRID 2011

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Santander, June 7th 2011

DORII Deployment of Remote Instrumentation Infrastructure

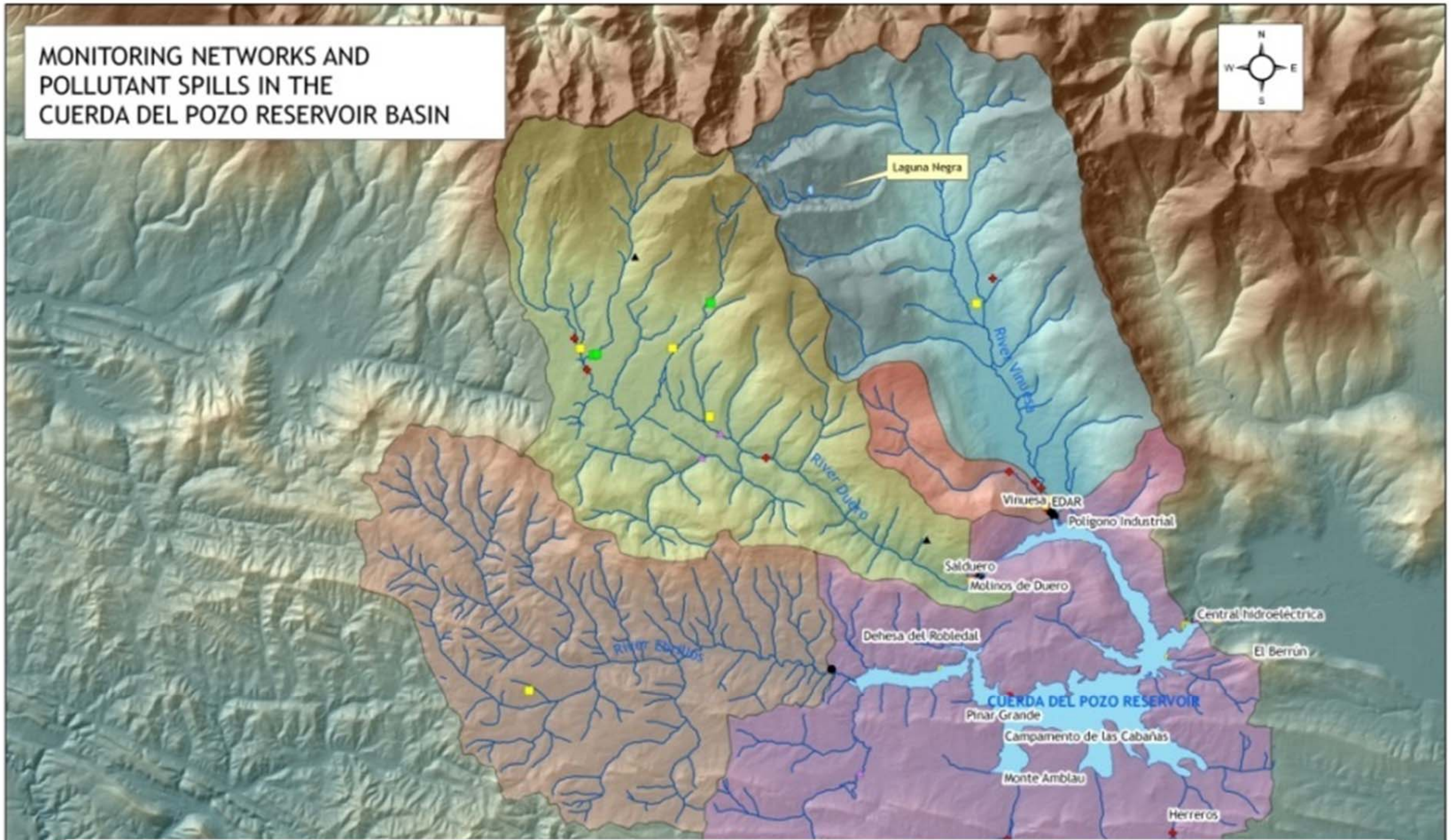
Introduction

WHAT: Monitoring and predicting water and ecosystem quality in a medium sized reservoir (1.200 ha) suffering harmful algae blooms (HABs) caused by cyanobacteria.

COMPLEX ecological problem with potential severe sanitary consequences.

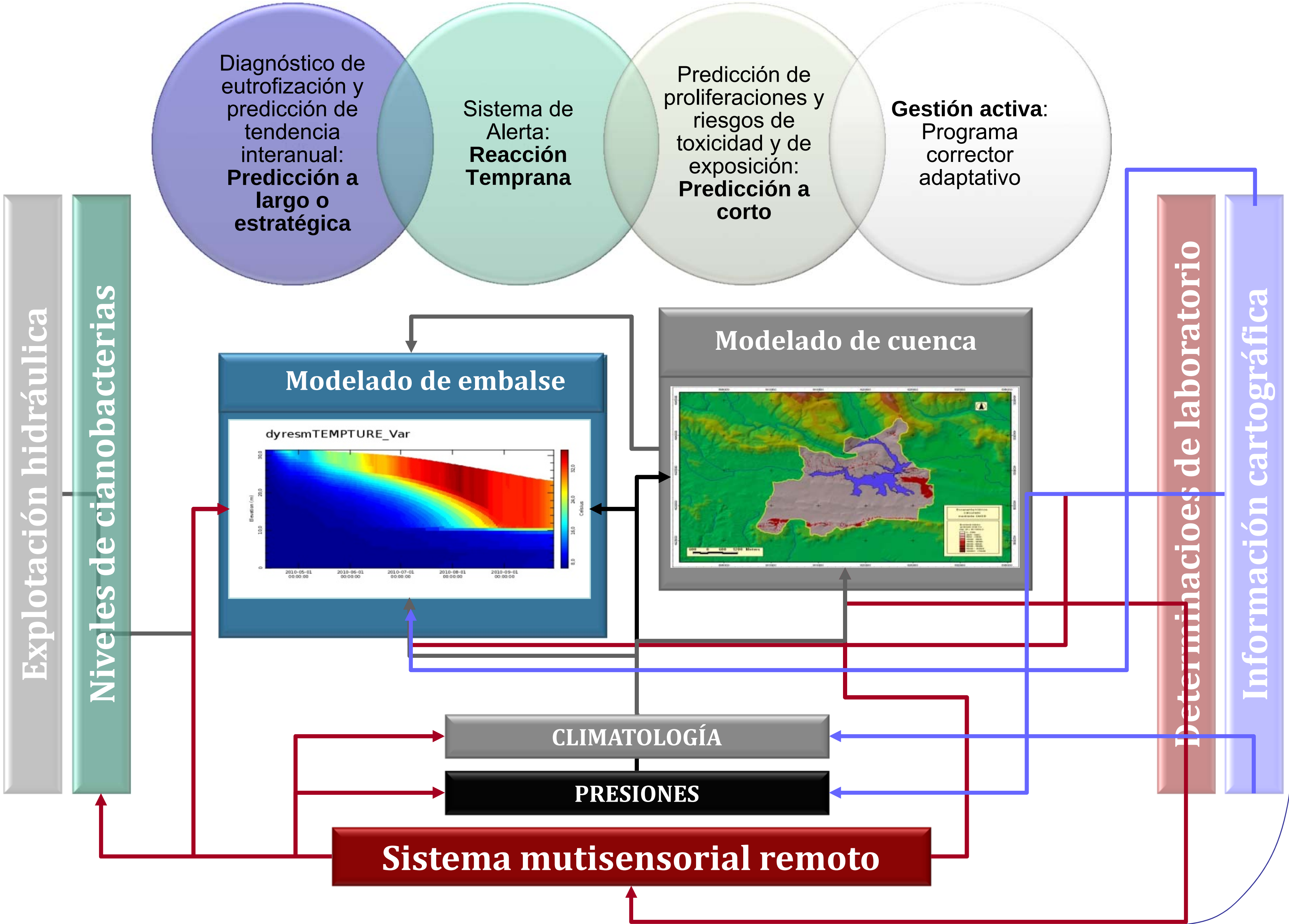
HOW: Use of e-Infrastructure for continuous monitoring using multi-sensor platforms (reservoir and river inflows) and coupling data to model simulations.
Additional discrete water, sediments and biota sampling to calibrate both, sensors and models.

WHERE: "Cuerda del Pozo" reservoir, 1.200 ha., water supply to Soria city (40K inh.)



Cuerda del Pozo" reservoir: drainage basin (550 km^2) scarcely populated and dominated by pine woodlands. Climate is cold Mediterranean, seasonal touristic activity and cattle livestock (some 1.200 units) around the reservoir. Direct wastewater discharge from the new wastewater treatment (secondary biological) plant at Vinuesa village (near the reservoir tail) serving 1.000 I.E. (5.000 I.E. in summer) and some tiny industrial plants.

The whole (complex) picture



Monitoring scheme I: direct sampling

External loads: flow and water sampling in 3 main inflow streams and 2 wastewater sewage.

In reservoir sampling (permanent and discretional water and sediment sampling stations).

Field work:

Multi-parametric probe profiling of water column (1 m resolution).

Water and sediment sampling (Van Dorn bottle, Ekman grab,…).

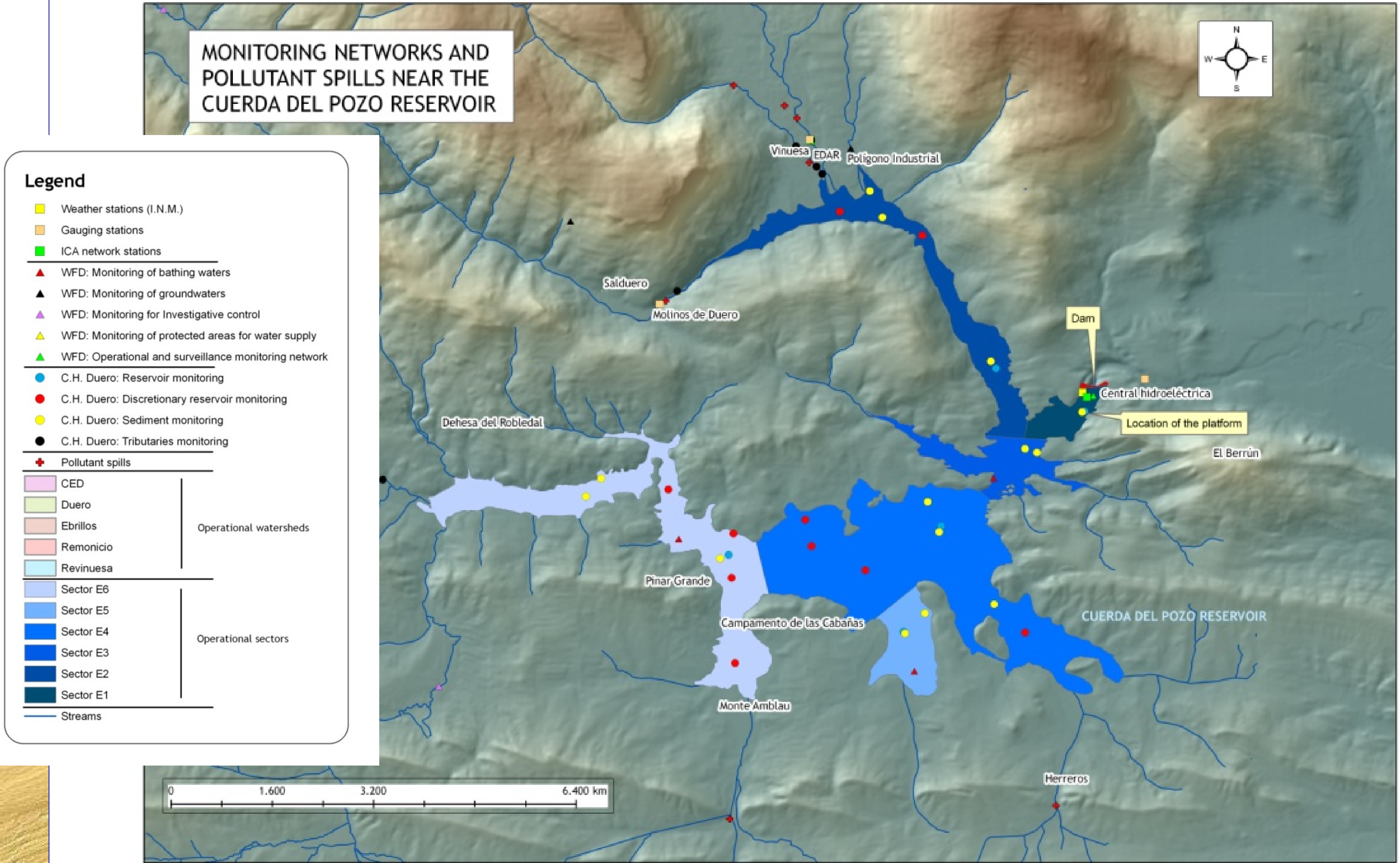
In situ sample management (filtration, fixation, cold chain).

Lab work:

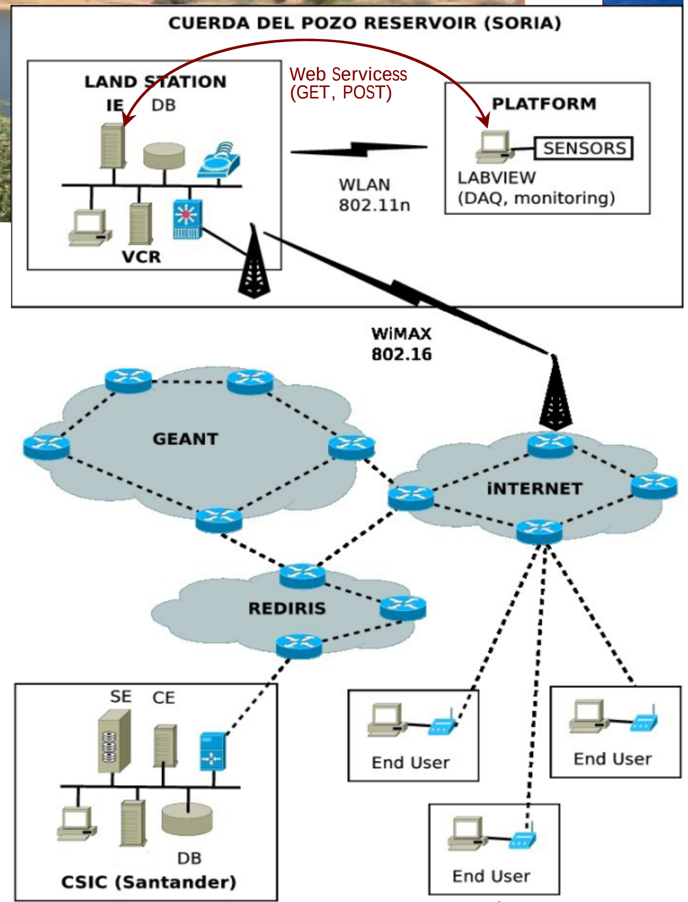
Chemical water and sediment analysis (see later).

Biological analysis: phytoplankton taxonomy and cyanobacteria biovolume, algae group biomass. (lab fluorometry) and total algae biomass (chlorophyll a).

Cyanobacteria sensor calibration using *Mycrocistis aeruginosa* cultures.


MONITORING NETWORKS AND POLLUTANT SPILLS NEAR THE CUERDA DEL POZO RESERVOIR
Legend
Weather stations (I.N.M.)
Gauging stations
ICA network stations
WFD: Monitoring of bathing waters
WFD: Monitoring of groundwaters
WFD: Monitoring for Investigative control
WFD: Monitoring of protected areas for water supply
WFD: Operational and surveillance monitoring network
C.H. Duero: Reservoir monitoring
C.H. Duero: Discretionary reservoir monitoring
C.H. Duero: Sediment monitoring
C.H. Duero: Tributaries monitoring
Pollutant spills
CED
Duero
Ebrillos
Remonicio
Revinuesa
Operational watersheds
Sector E6
Sector E5
Sector E4
Sector E3
Sector E2
Sector E1
Operational sectors
Streams
N
W
E
S
Vinuesa
EDAR
Polígono Industrial
Salduero
Molinos de Duero
Dam
Central hidroeléctrica
Location of the platform
El Berrún
Dehesa del Robledal
Pinar Grande
Campamento de las Cabañas
Monte Amblau
CUERDA DEL POZO RESERVOIR
Herreros
0
1.600
3.200
6.400 km

Monitoring scheme II: remote application via e-infrastructure



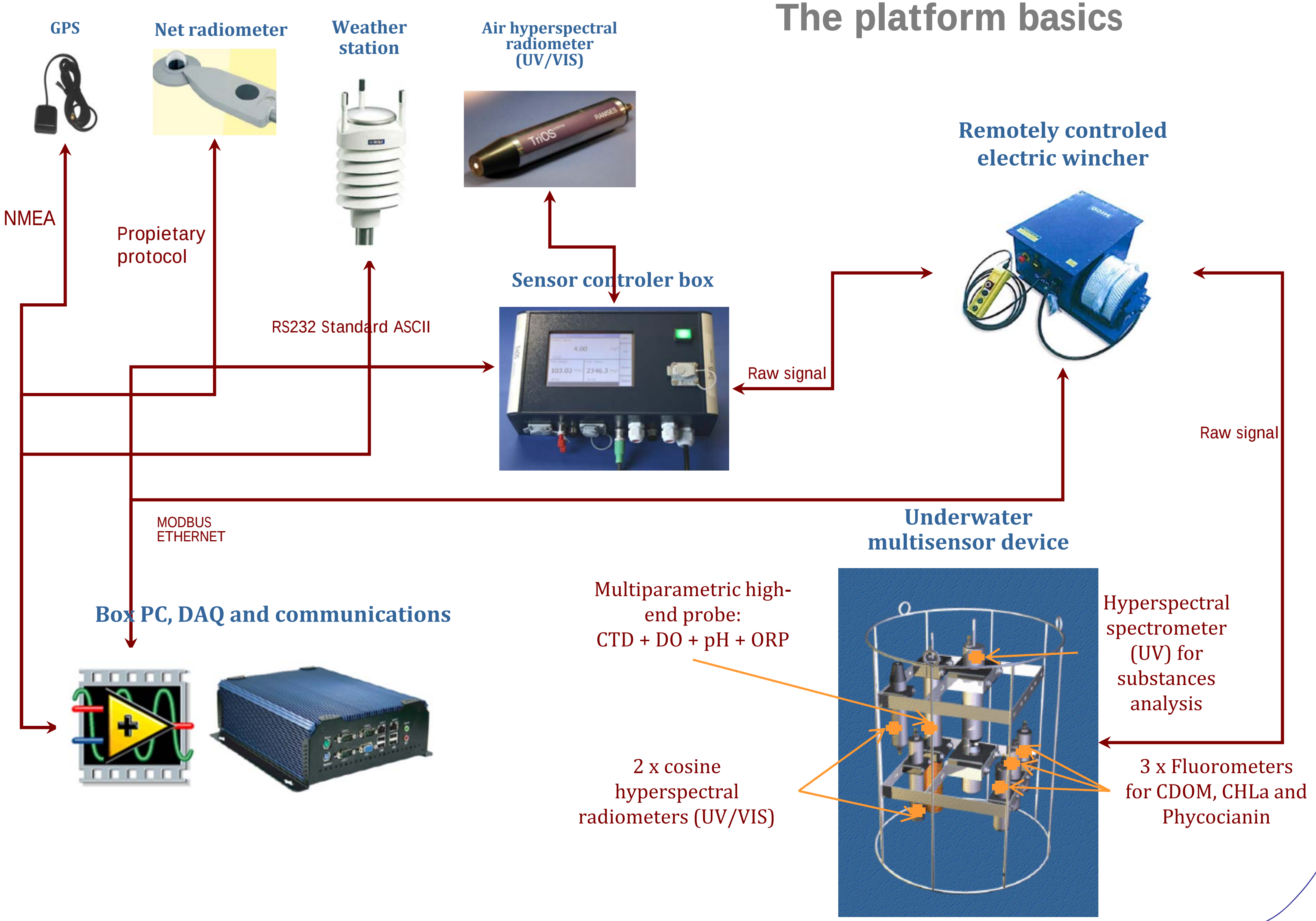
E-infrastructure description:

1- **Reservoir platform (next slide)**
2- **Land Station:** IE, Router Wifi, Wimax panel , DB, VCR
3- **IFCA:** SE, CE, DB → Modeling: Coupling to DYRESM-CAEDYM
4- **Real-time web page** for public water administration
5- **GISWEB tool** for data visualization and system management
6- **Proprietary river multisensorial device** being installed

Distributed computing capabilities, due to remote access to data, which allows us to model and predict reservoir behavior
(OUR MAIN OBJECTIVE)

The reservoir platform

The platform basics



MEDIA	INSTRUMENT	VARIABLE DEFINITION	MODE	ACRONYM	UNIT	DATA TYPE
AIR	METEOROLOGICAL STATION	Air temperature	AUTO	Ta	ºC	SINGLE
		Barometric pressure	AUTO	Pa	bar	SINGLE
		Relative humidity	AUTO	Ua	%RH	SINGLE
		Wind (velocity)	AUTO	Sm	m/s	SINGLE
		Wind (average direction)	AUTO	Dm	grados	SINGLE
		Rain (acumulation)	AUTO	Rc	mm	SINGLE
		Rain (duration)	AUTO	Rd	s	SINGLE
		Rain (intensity)	AUTO	Ri	mm/h	SINGLE
		Hail (acumulation)	AUTO	Hc	hits/cm^2	SINGLE
		Hail(duration)	AUTO	Hd	s	SINGLE
		Hail (intensity)	AUTO	Hi	hits/cm^{2}h	SINGLE
	NET RADIOMETER	Net global radiation (solar)	AUTO	Enetsw	W/m^2	SINGLE
		Net diffuse radiation (longwave)	AUTO	Enetlw	W/m^2	SINGLE
	RADIOMETER	Incident upcoming irradiance (air) in the photosynthetic active spectrum (planar)	AUTO/INDIR	QPARau	W/m2	SINGLE
		Incident upcoming irradiance (air) in each spectral range λ (planar)	AUTO	Qλau	W/m2/nm	SPECTRAL
		Incident downcoming irradiance (air) in the photosynthetic active spectrum (planar)	AUTO/INDIR	QPARad	W/m2	SPECTRAL
		Incident downcoming irradiance (air) in each spectral range λ (planar)	AUTO	Qλad	W/m2/nm	SPECTRAL
WATER	WATER LEVEL SENSOR	Stage	AUTO	QINS	m^3/s	SINGLE
		Total depth	AUTO	PROFMAX	m	SINGLE
	MULTIPARAMETRIC PROBE	Depth at measurement	AUTO	Z	m	SINGLE
		Water temperature	AUTO	TEMP	ºC	SINGLE
		Electrical conductivity	AUTO	COND	µS/cm	SINGLE
		Salinity	AUTO	SALT	ppt	SINGLE
		Dissolved oxygen concentration	AUTO	DO	mg/l	SINGLE
		Dissolved oxigen saturation	AUTO	DOSAT	%	SINGLE
		pH	AUTO	PH	ud.	SINGLE
		Oxido-reduction potential (ORP)	AUTO	ORP	mV	SINGLE
	RADIOMETER	Incident upcoming irradiance (water) in the photosynthetic active spectrum (planar)	AUTO/INDIR	QPARu	W/m2	SPECTRAL
		Incident upcoming watereach spectral range λ (planar)	AUTO	Qλu	W/m2/nm	SPECTRAL
		Incident downcoming waterphotosynthetic active spectrum (planar)	AUTO/INDIR	QPARd	W/m2	SPECTRAL
		Incident downcoming waterspectral range λ (planar)	AUTO	Qλd	W/m2/nm	SPECTRAL
	FLUOROMETER	Chlorophyll a (fluorescence)	AUTO	mFlu_chl	µg/l	SINGLE
		Ficocyanine (fluorescence)	AUTO	mFlu_blue	µg/l	SINGLE
		CDOM (Colored dissolved organic matter or yellow substance)	AUTO	mFlu_CDOM	µg/l	SINGLE
	UV SPECTROMETER	Suspended solids	AUTO	TSSeq	mg/l	SINGLE
		Chemical oxygen demand (eq)	AUTO	CODeq	mg/l	SINGLE
		Carbonate	AUTO	CO3	mg/l	SINGLE
		Nitrate	AUTO	N-NO3	mg/l	SINGLE
		Nitrite	AUTO	N-NO2	mg/l	SINGLE
		Spectrum	AUTO	Doλ	AU	SPECTRAL

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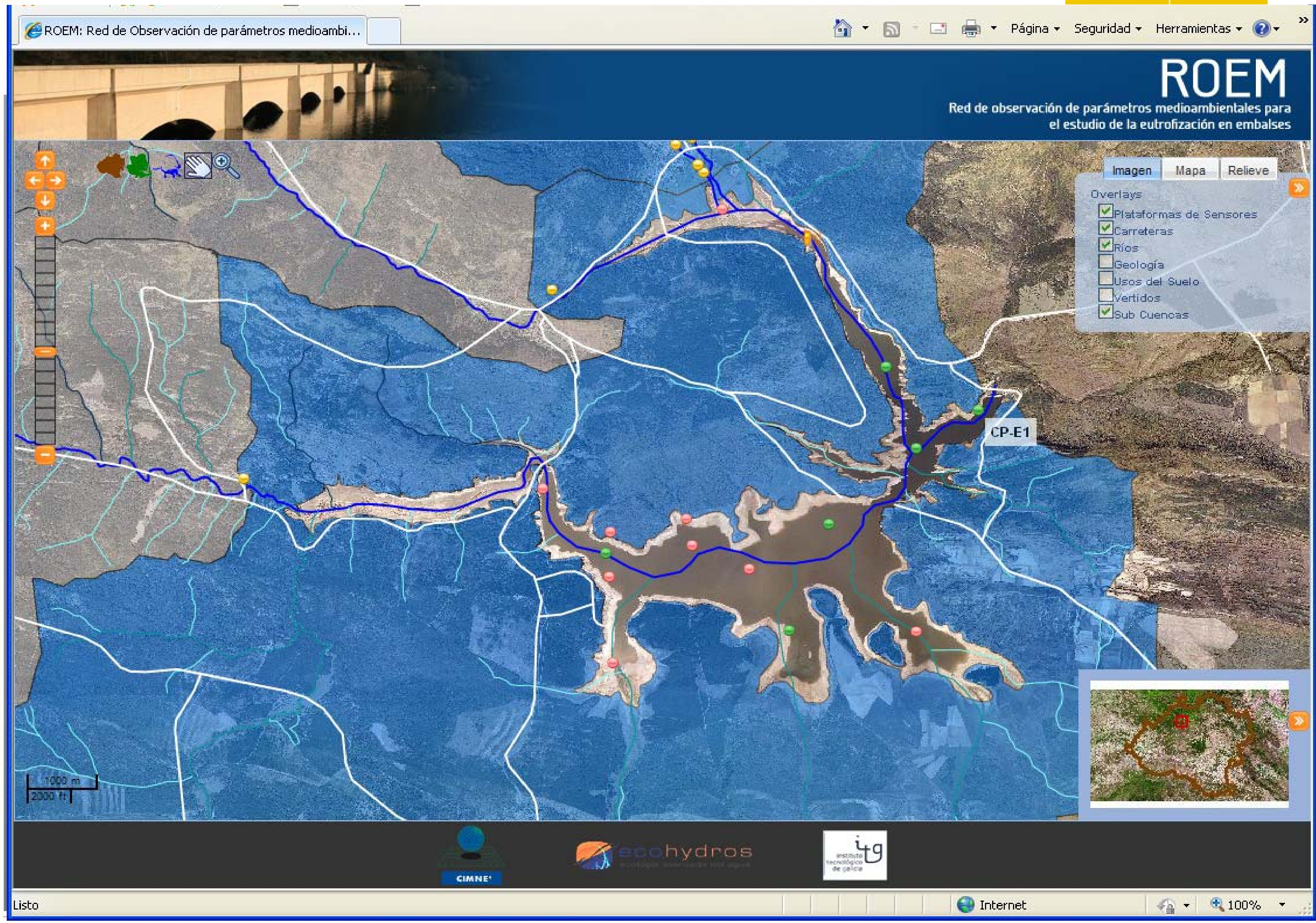

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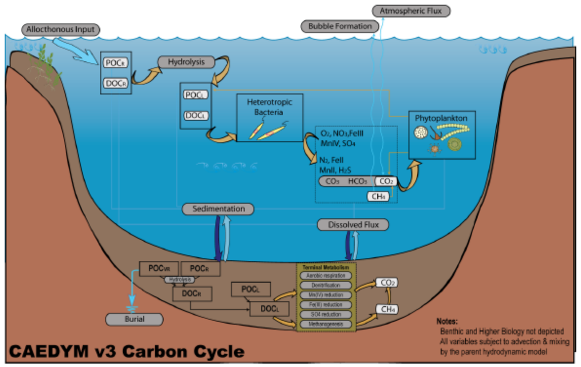
How the whole ecosystem is to be described by remote measurements (example of carbon cycle)



f(ProPS,pH)

DIC = ALK - CO_3^{2-} ← ProPS

PIC = TOC - POC ← f(ProPS,TOC,TSS)

TOC ← ProPS

DOC ← MicroFlu CDOM

TSS ← ProPS

$C_{BACTERIAS+DETRITOS}$ = POC - C_{FITO} + C_{ZOO}

PARAMETERS DIRECTLY MEASURED BY REMOTE SENSORS

PARAMETERS CALIBRATED BY MEANS OF BIOLOGICAL ANALYSIS

PARAMETERS ESTIMATED BY CHEMOMETRIC ADJUSTEMENT

PARAMETERS ESTIMATED BY DIFERENCE

Outstanding results: cyanobacterial evolution and key environmental parameters

- **A** Late summer (potentially toxic) cyanobacteriae bloom not detected by classical monitoring
- **B** Cyanobacteria biomass exceding 2,5 times the WHO limit of maximum risk for drinking and bathing waters
- **C** Peak algae biomass just before vertical water column mixing
- **D** Maximum algae growth linked to moderate temperature and light intensity conditions
- **E** Other water quality consequences like hypolimnetic oxygen depletion

Reservoir 1VD modeling (first calibration round results)

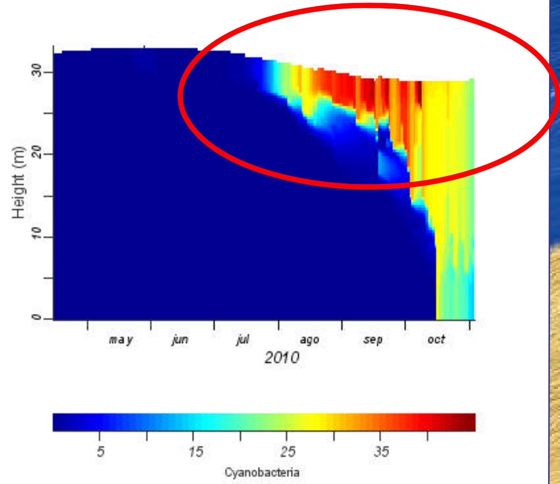
DYRESM 1DV uses a Lagrangian approach for simulation of the hydrodynamics of aquatic ecosystems

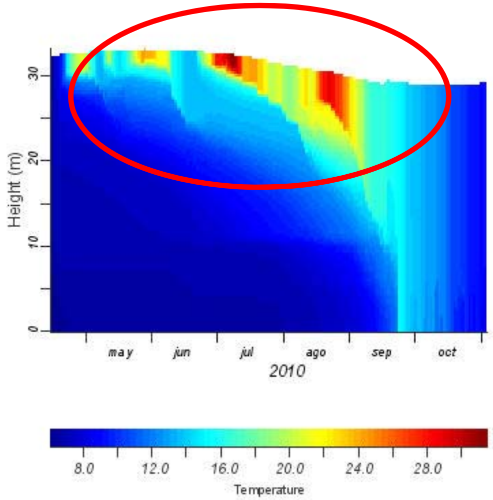
CAEDYM dynamically couples with DYRESM to simulate nutrient cycling and various plankton groups using a series of partial differential equations

No bad performance but wind driven effects over the whole reservoir needed to improve thermal regimen simulation: 3D model

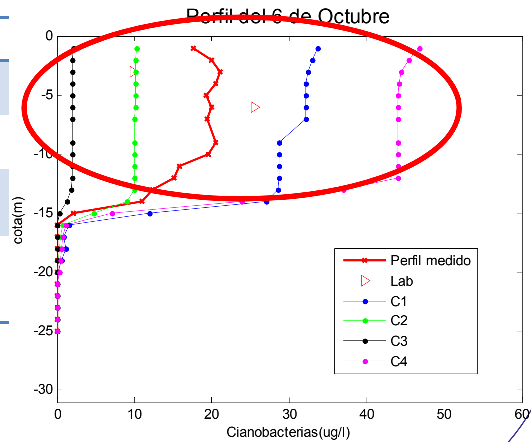
Temperature and light deviations are important for better algae simulation

More knowledge needed about the ecology of these species/strains because its high plasticity





Parameters	C1	C2	C3	C4
Photoinhibition function	No	Yes	Yes	Yes
Respiration coeficient (d^{-1})	0.08	0.08	0.08	0.08
Maximum growth rate (d^{-1})	1	1	0.678	1.076
Optimum Irradiance ($\mu E/m^2.s$)	130 0	130 0	99.83 8	238.3 4



Conclusions

NEW TOOLS FOR WATER MANAGEMENT: REMOTE INSTRUMENTATION AND ECOSYSTEM MODELING

✓This transdiciplinary and technological based approach represents a qualitative step forward in the potential to control and manage the inland water quality: the century of "ecosystem undersampling" can be overcome.

✓Monitoring: Sampling and analizing efforts are minimized in a factor of 3-4 compared with classical sampling approachs

✓Once properly calibrated, these near realtime data can be used for alert systems, forecasting and prevention measures.

✓Optimization of reservoir eutrophication problem: the key variables and pollutans are not able to be controlled by classical remediation measures alone (wastewater treatment stations) but using alternative and inexpensive limnological restoration measurements.

✓Longer series of data, continuos monitoring of inflows and 3D and watershed modeling are needed to properly model the system and designing such measures.

THANKS

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itg

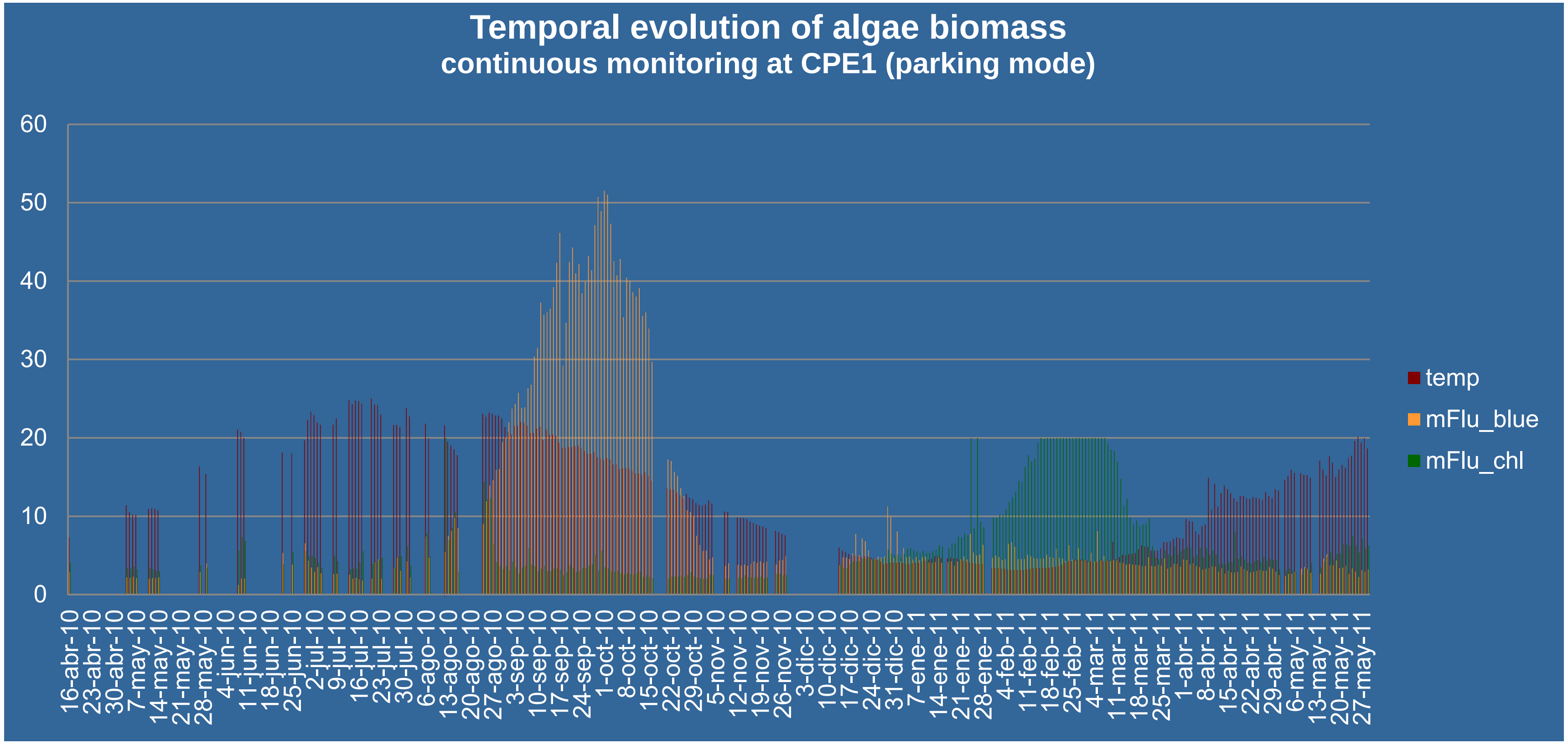
instituto tecnológico de galicia

20 ANIVERSARIO

plan avanza

CIMNE

Continuous monitoring data



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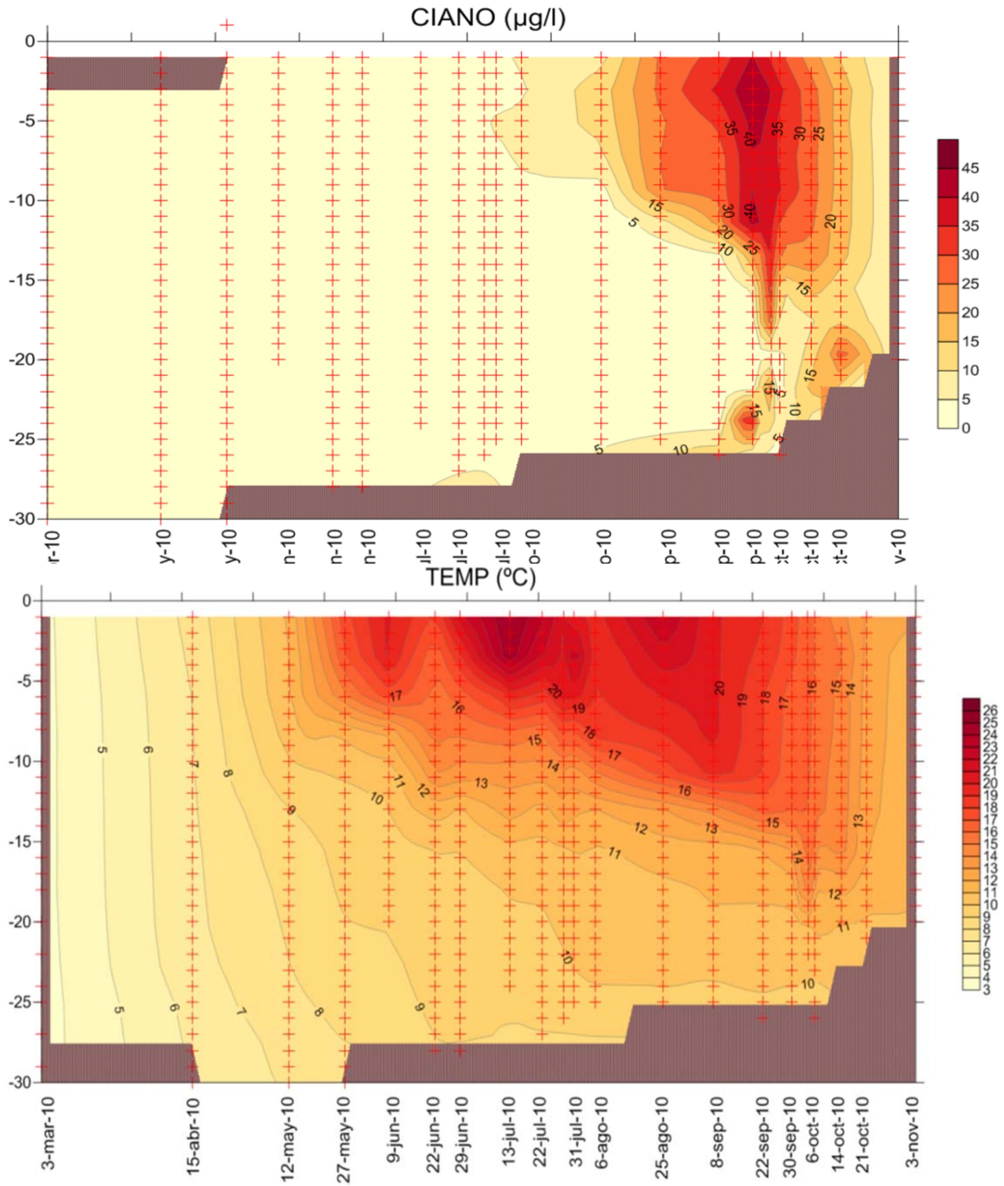
Cyanobacteria and temperature



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Dissolved oxygen