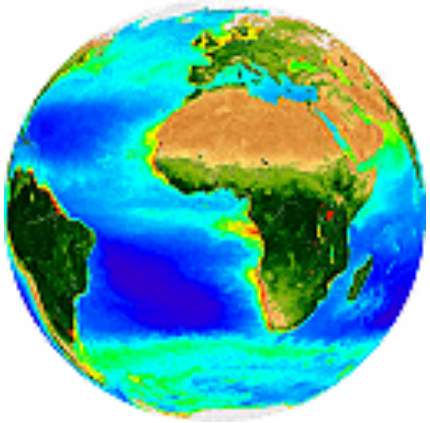


PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Remote sensing of Phytoplankton Functional Types in the Mediterranean Sea.

Gabriel Navarro[1], S. Alvain[2], V. Vantrepotte[2], L. Prieto[1] and E. Huertas[1]

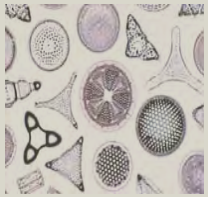
1. Instituto de Ciencias Marinas de Andalucía, ICMAN-CSIC, Spain
2. Laboratoire d'Océanologie et Géosciences, LOG, UMR 8187, CNRS, ULCO, France

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

WHAT ARE THE PHYTOPLANKTON FUNTIONAL TYPES?

- PFTs are conceptual groupings of several phytoplankton groups, which are supposed to have common functionalities.
- Criteria for this grouping are often based on functionalities or characteristics such as:

Biogeochemical Function



SILICIFIERS (diatoms…)

CALCIFIERS (Coccolithes..)

DMS producers (phaeocystis..)

…

Particle Size Classes (PSCs)

- Picoplankton < 2 mm
- Nanoplankton (2 to 20mm)
- Microplankton > 20mm

- In general, the choice of the grouping depends on the scientific question studied.
- For the observation by satellite it mainly depends on variable that can be derived from ocean color signal…

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

WHY IS IT IMPORTANT TO IDENTIFY PFT?

1. **Biogeochemical Cycles**
   Different PFTs have different impacts on various biogeochemical cycles.

2. Key elements required to calibrate/validate new **biogeochemical models**

3. **Fisheries**
   Some fish species feed on specific phytoplankton

4. **Tourism**
   Toxic blooms HABs (with sanitary and economic impacts)

5. **Marine Strategy Framework Directive, MFSD**
   Descriptor 4. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.
   Criterion 4.3: Abundance/distribution of key trophic groups/species
   Indicator 4.3.1. Abundance trends of functionally important selected groups

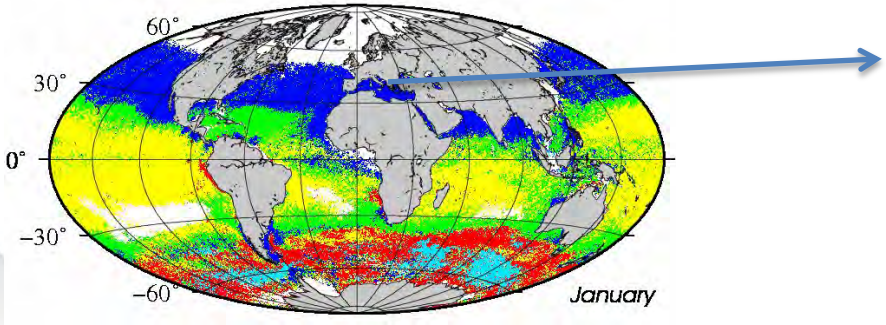
Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

THE MAIN OBJECTIVES OF THIS STUDY ARE:

- Adapt the original PHYSAT method (Alvain et al., 2005, 2008) to the Mediterranean Sea for MODIS satellite images dataset (2002- on going)

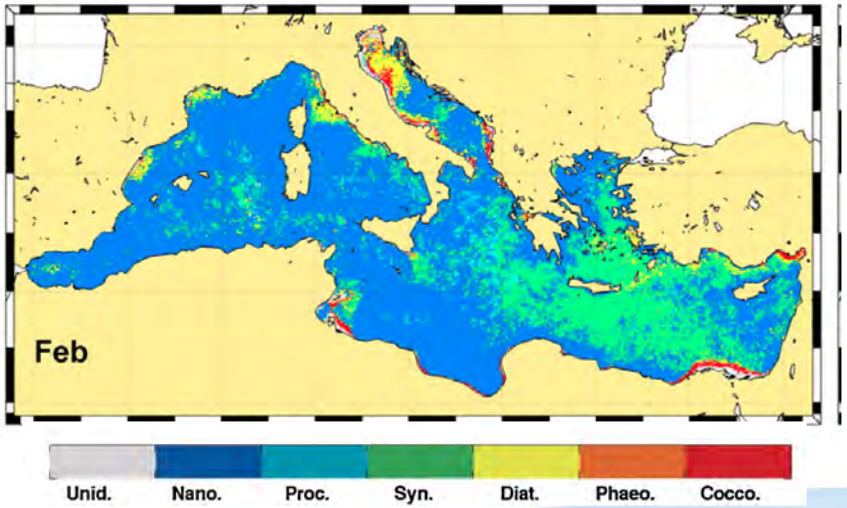
PHYSAT Method

Alvain et al. 2005 and 2008



Haptophytes *Prochlorococcus* *Synechococcus*
Diatoms *Phaeocystis* *Coccolithophorids*

PHYSAT-Med



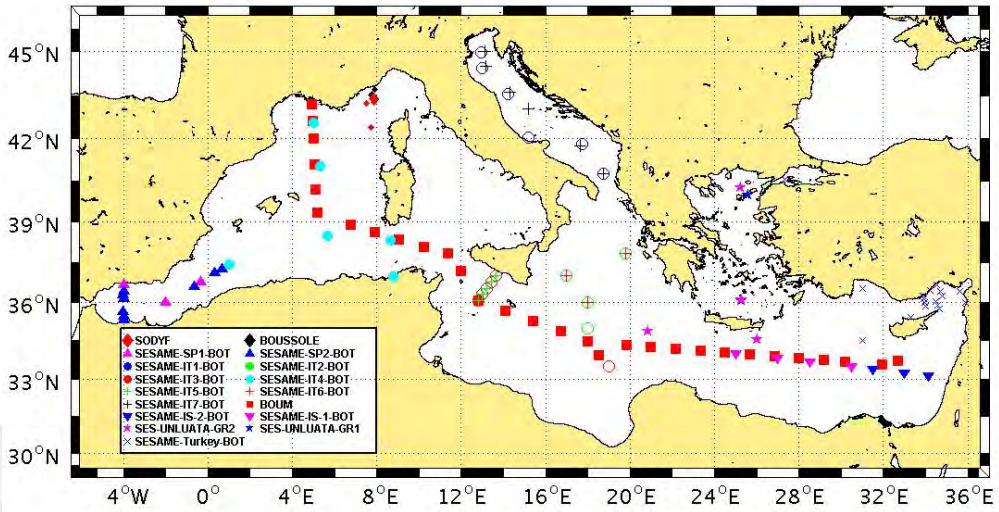
Navarro et al., 2014
Remote Sensing of Environment 152, 557-575

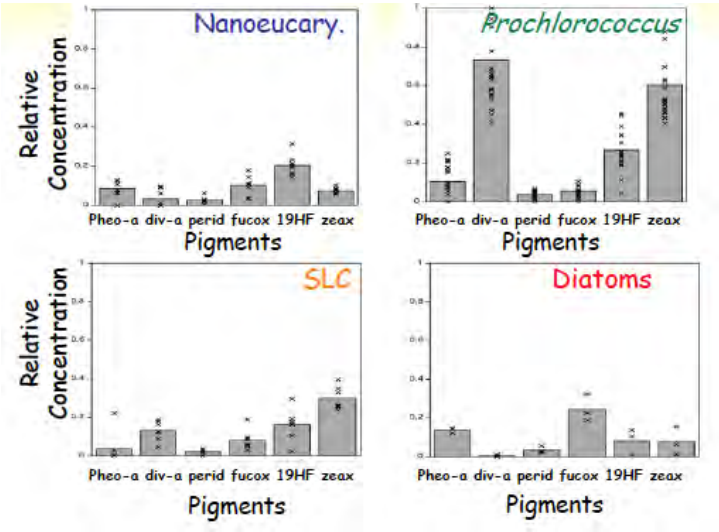
Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

THE MAIN OBJECTIVES OF THIS STUDY ARE:

- Adapt the original PHYSAT method (Alvain et al., 2005, 2008) to the Mediterranean Sea for MODIS satellite images dataset (2002- on going)

- Validate the new PHYSAT-Med method with in situ measurements





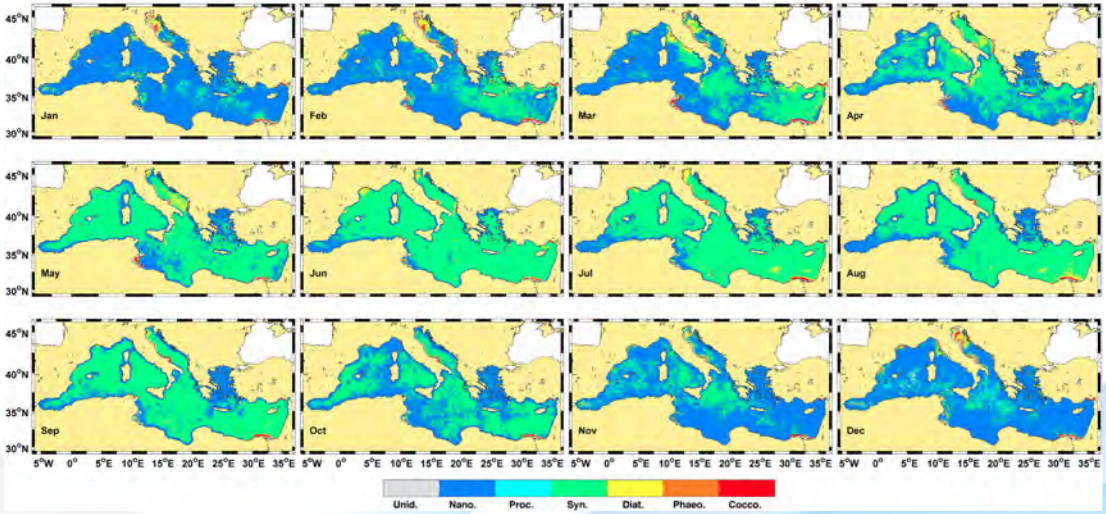
Alvain et al., 2005

High Performance Liquid Chromatography (HPLC)

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

THE MAIN OBJECTIVES OF THIS STUDY ARE:

- Adapt the original PHYSAT method (Alvain et al., 2005, 2008) to the Mediterranean Sea for MODIS satellite images dataset (2002- on going)
- Validate the new PHYSAT-Med method with in situ measurements
- Evaluate the spatio-temporal patterns of the PFTs in the Mediterranean Sea for MODIS era

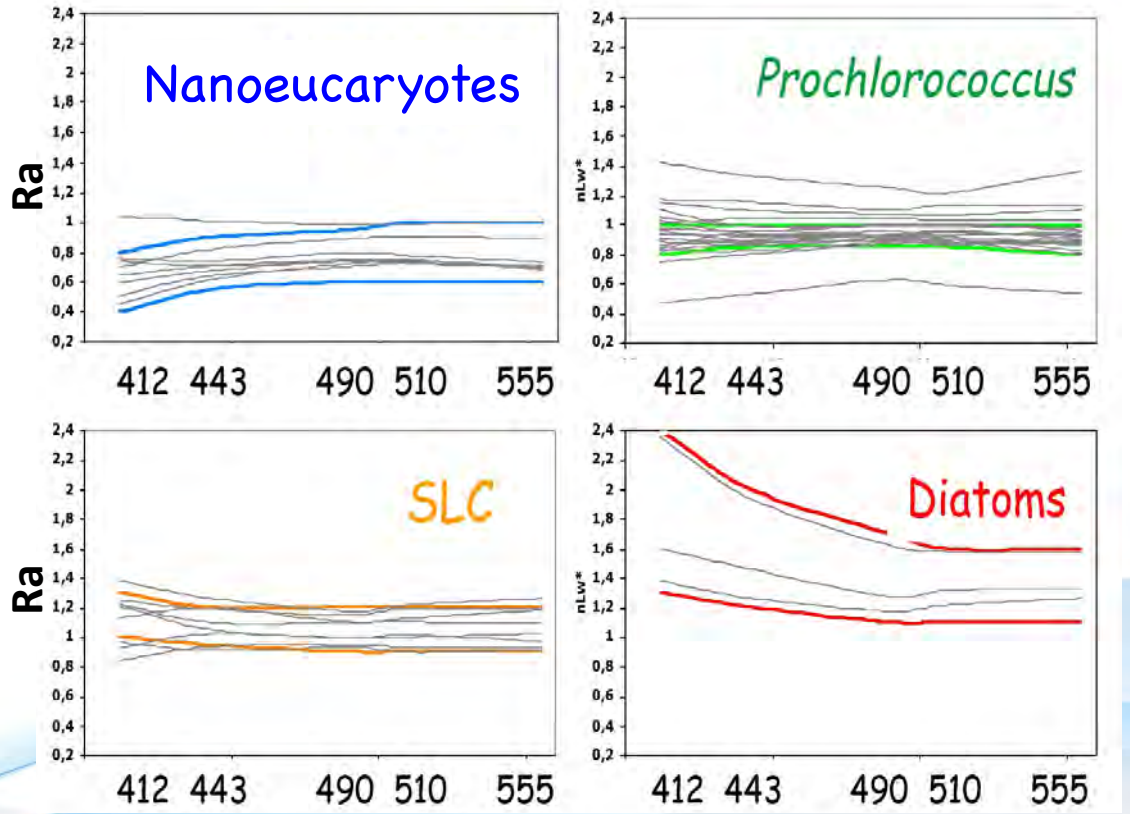


- Facilitate the dissemination of images and data trough WWW

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT Method (Global ocean, Alvain et al., 2005)

- PHYSAT was designed to detect satellite pixels of dominant phytoplankton groups
- PHYSAT is based on the analysis of nLw anomalies (Ra) computed after removal the impact of chlorophyll-a variations
- Specific nLw spectra anomalies (Ra, in terms of shapes and amplitudes) have been empirically associated to the presence of dominant phytoplankton groups, based on in situ biomarkers pigments observations.

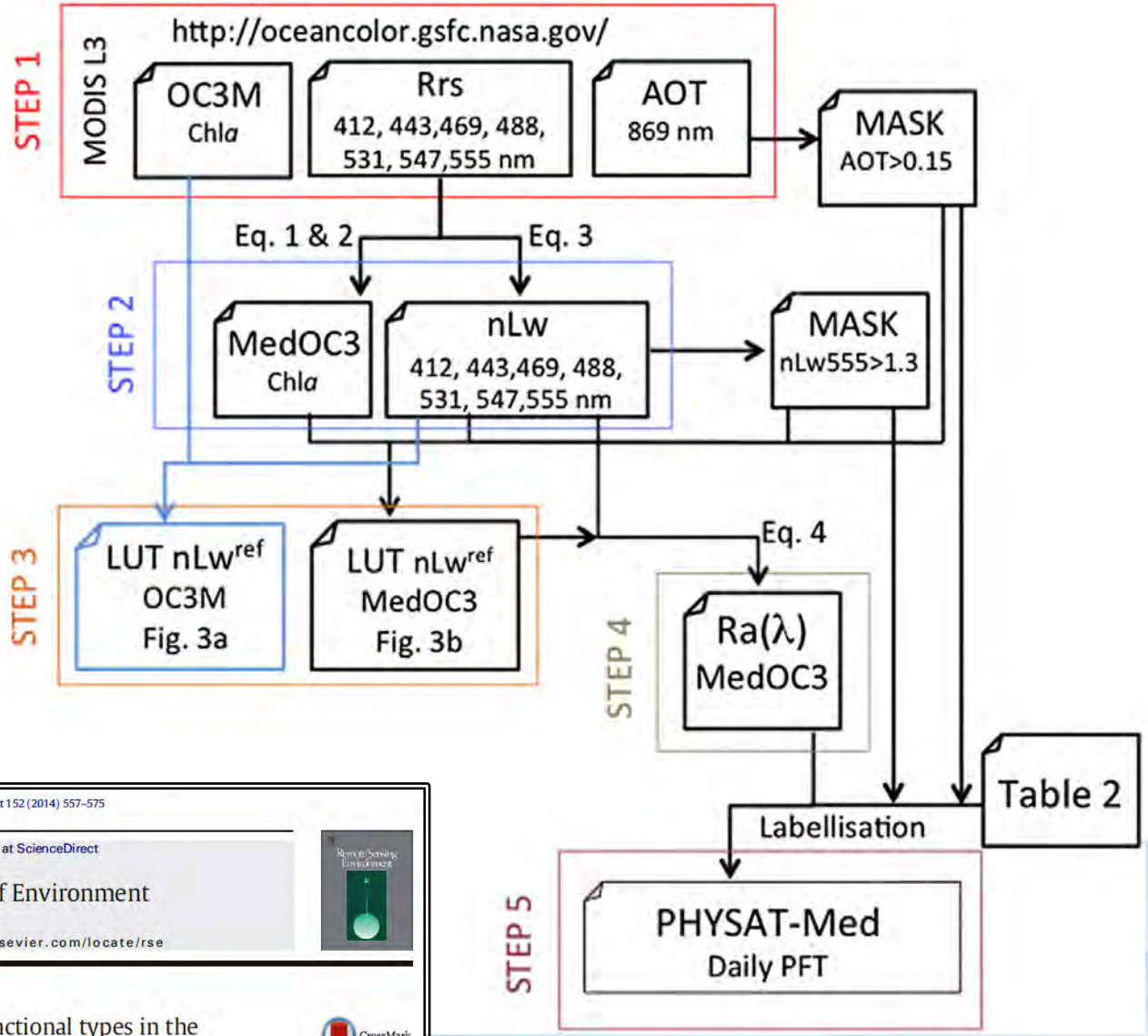


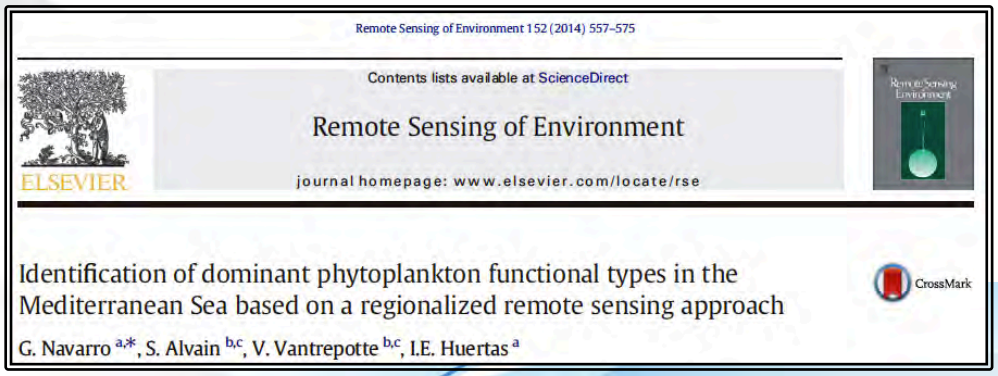
(Alvain et al., 2005)

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT-Med

- **Schematic view of steps followed to adapt PHYSAT-Med**




Remote Sensing of Environment 152 (2014) 557–575

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

ELSEVIER

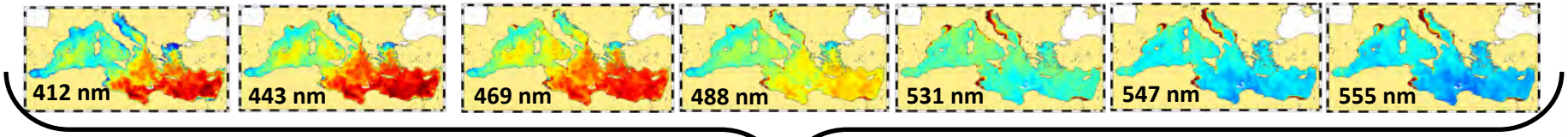
Identification of dominant phytoplankton functional types in the Mediterranean Sea based on a regionalized remote sensing approach

G. Navarro [a,*], S. Alvain [b,c], V. Vantrepotte [b,c], I.E. Huertas [a]

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

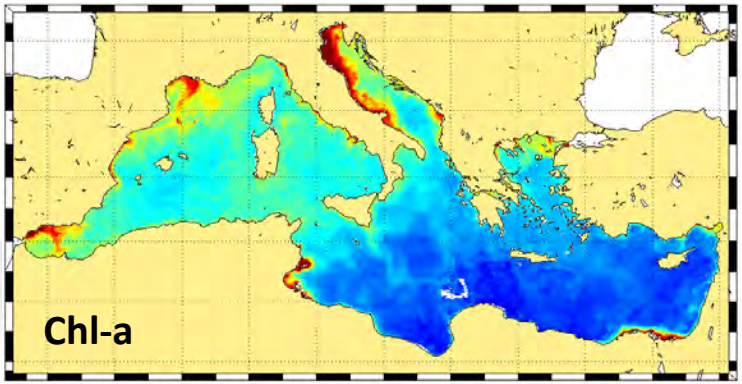
PHYSAT-Med

- Step 1: Satellite data (MODIS Daily 4 km)
  Download from oceancolor website
  Remote Sensing Reflectance: Rrs 412 443 469 488 531 547 555 nm



- Step 2: Calculate MedOC3-Chla (Santoleri et al., 2008)

$$\text{MedOC3-Chla} = 10^{(0.380 - 3.688R + 1.036R^2 + 1.616R^3 - 1.328R^4)} \qquad R = \log_{10}\left(\frac{\text{Rrs443>Rrs488}}{\text{Rrs555}}\right)$$



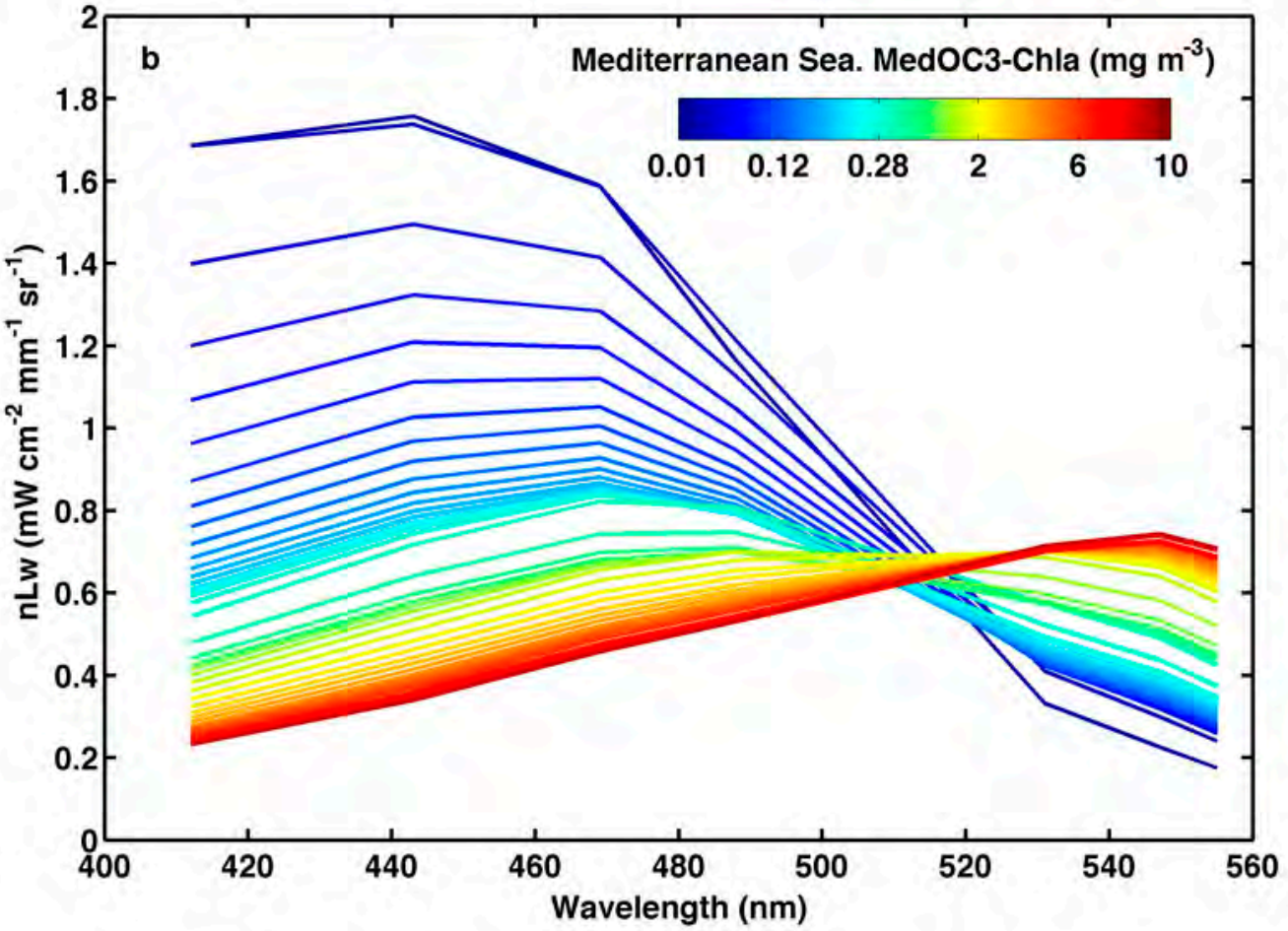
Convert Rrs to nLw using the nominal band solar irradiance (F_o)

$$nLw_{(\lambda)} = Rrs_{(\lambda)} * F_{o(\lambda)}.$$

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT-Med

- Step 3: Generate empirically the Look-Up-Table for Mediterranean Sea



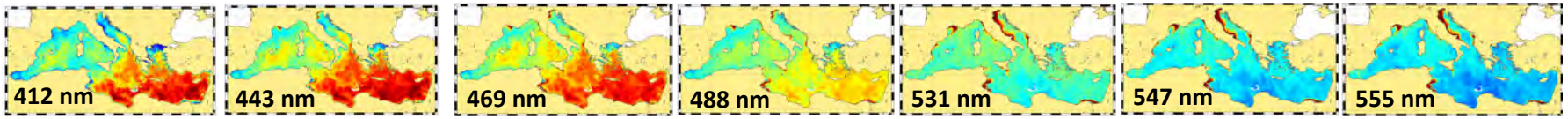
nLw_{ref} (λ,Chla) was calculated from nLw data and associated Chl-a computed from MedOC3 algorithm within the chl-a range between 0.01 and 10 mg/m^3 (41 intervals)

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT-Med

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

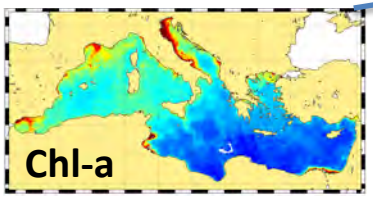
- Step 4. For daily images, calculate the Radiance anomalies (Ra):

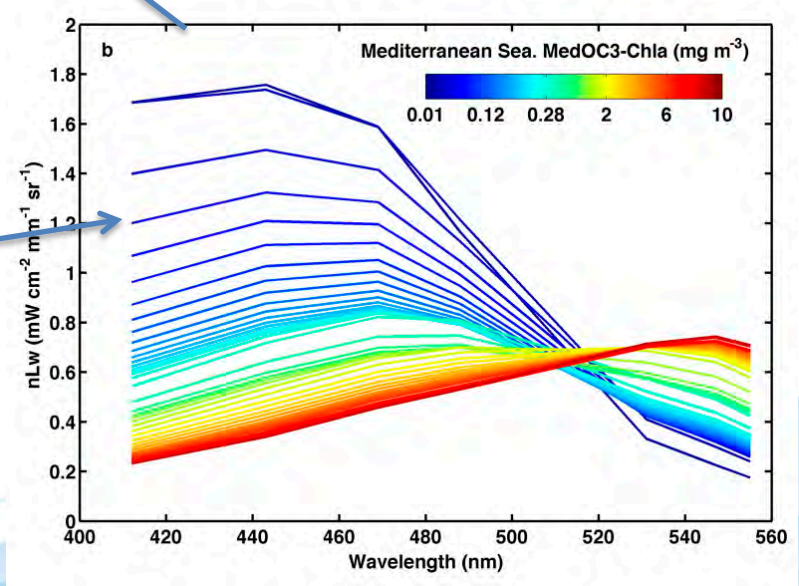


$$Ra\ (\lambda) = nLw(\lambda) / nLw_{ref}\ (\lambda, Chla)$$

Ra represents the second order variation of the nLw after removal the first order effect of ch- la variation.

Ra is an adimensional unit parameter and is independent of chl-a level





Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT-Med

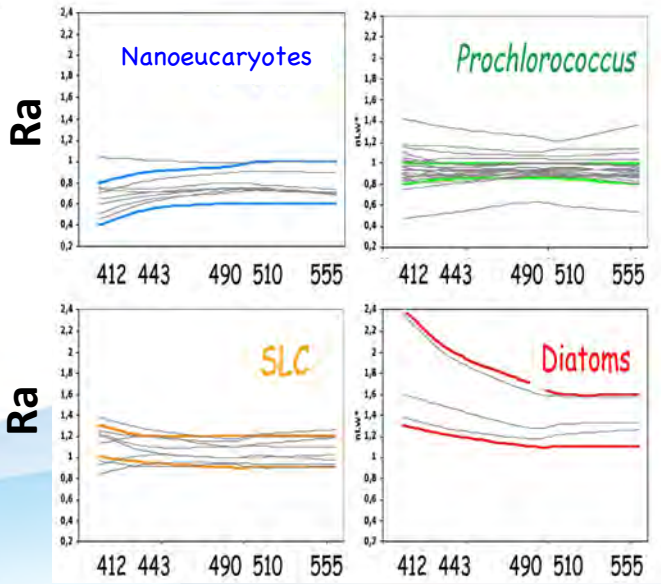
- Step 5. Labellisation a specific Ra with each dominant PFT

Table 2
Characteristics of acceptable Ra spectra for each phytoplankton groups.

MODIS wavelengths (nm) Phytoplankton groups	412	443	469	488	531	547	555	Additional criteria
Nanoeucaryotes min.	0.4	0.55	0.5777	0.5979	0.6	0.6	0.6	nLw*412 < nLw*443
Nanoeucaryotes max.	0.8	0.9	0.9277	0.9479	1	1	1	nLw*443 < nLw*488
Prochlorococcus min.	0.8	0.9	0.9	0.9	0.9	0.9	0.9	
Prochlorococcus max.	1	1	1	1	1	1	1	
Synechococcus min.	1	1	1	1	1	1	1	
Synechococcus max.	1.2	1.2	1.1723	1.1521	1.15	1.15	1.15	
Diatoms min.	1.2	1.2	1.1723	1.1521	1.15	1.15	1.15	nLw*412 > nLw*488
Diatoms max.	2.2	1.8	1.6340	1.5128	1.4	1.4	1.4	nLw*555 < nLw*488
Phaeocystis min.	1.3	1.4	1.4	1.4	1.4	1.4	1.4	nLw*412 < nLw*443
Phaeocystis max.	1.5	1.6	1.6	1.6	1.6	1.6	1.6	nLw*443 < nLw*488
								nLw*531 > nLw*555
Coccolithophorids min.	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Coccolithophorids max.	6	6	6	6	6	6	6	

These thresholds have been fixed in order to avoid any overlapping.

To be associated with one group, a spectra must full-filled each criteria.

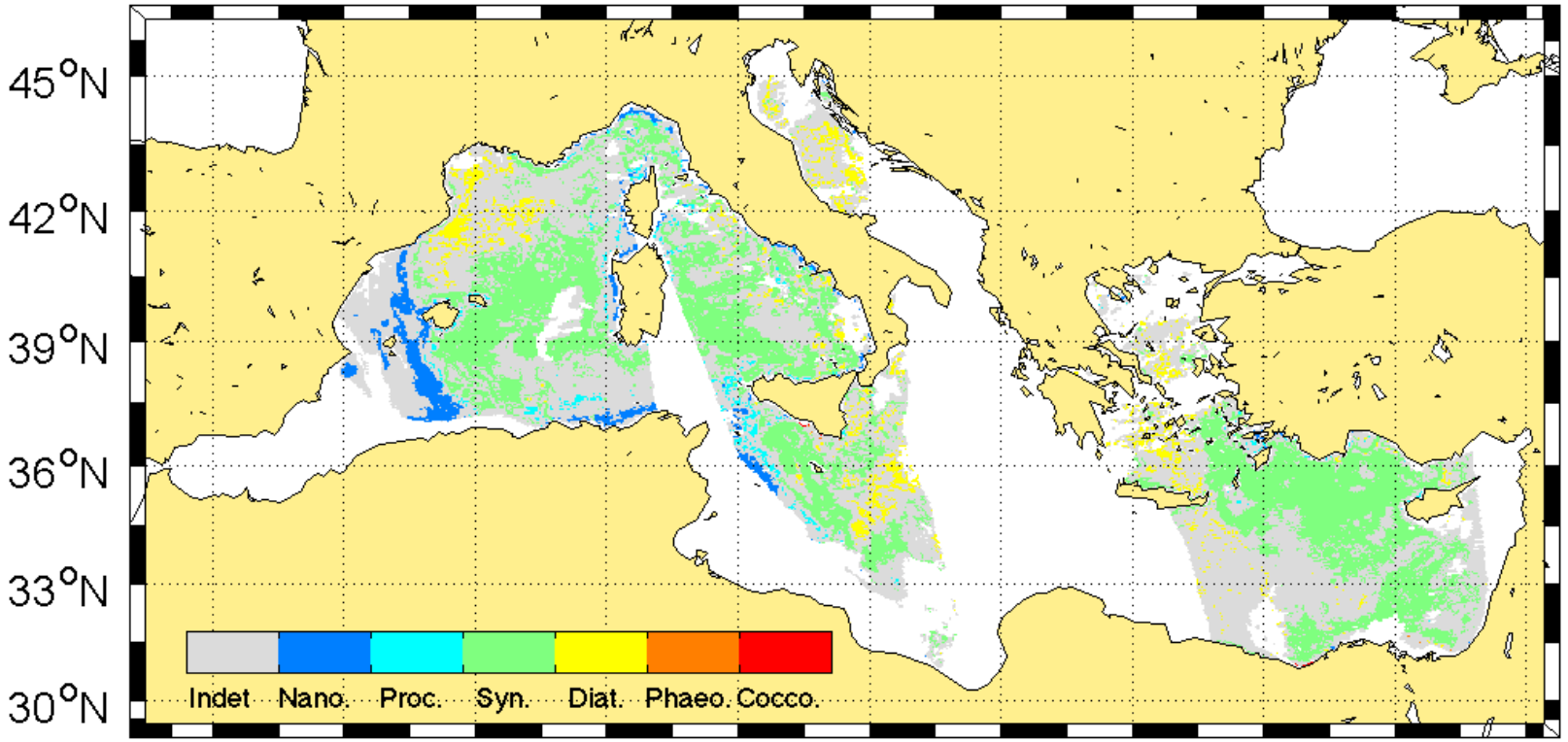


(Alvain et al., 2005)

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PHYSAT-Med

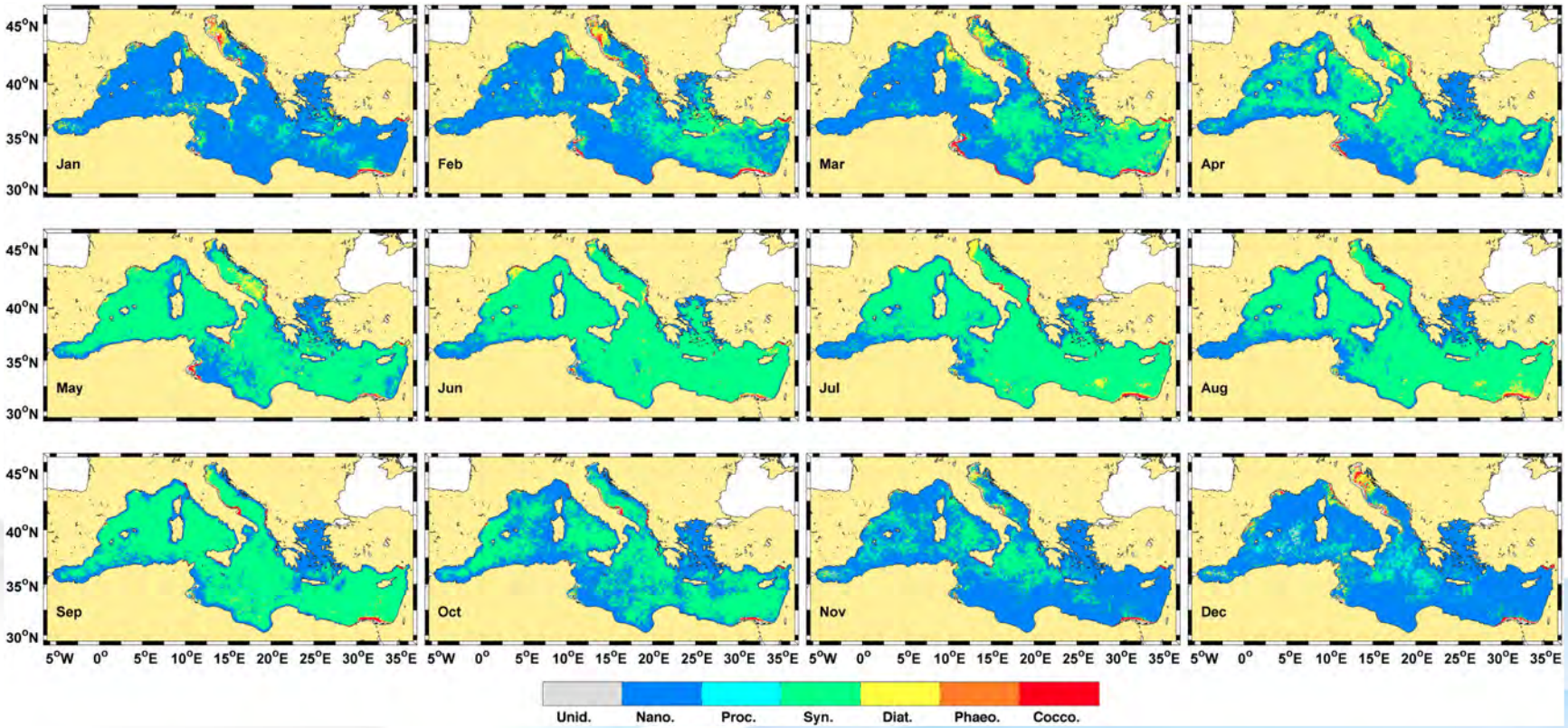
- Calculate the daily dominant group → Composite (8D, monthly, annually, yearly, …)



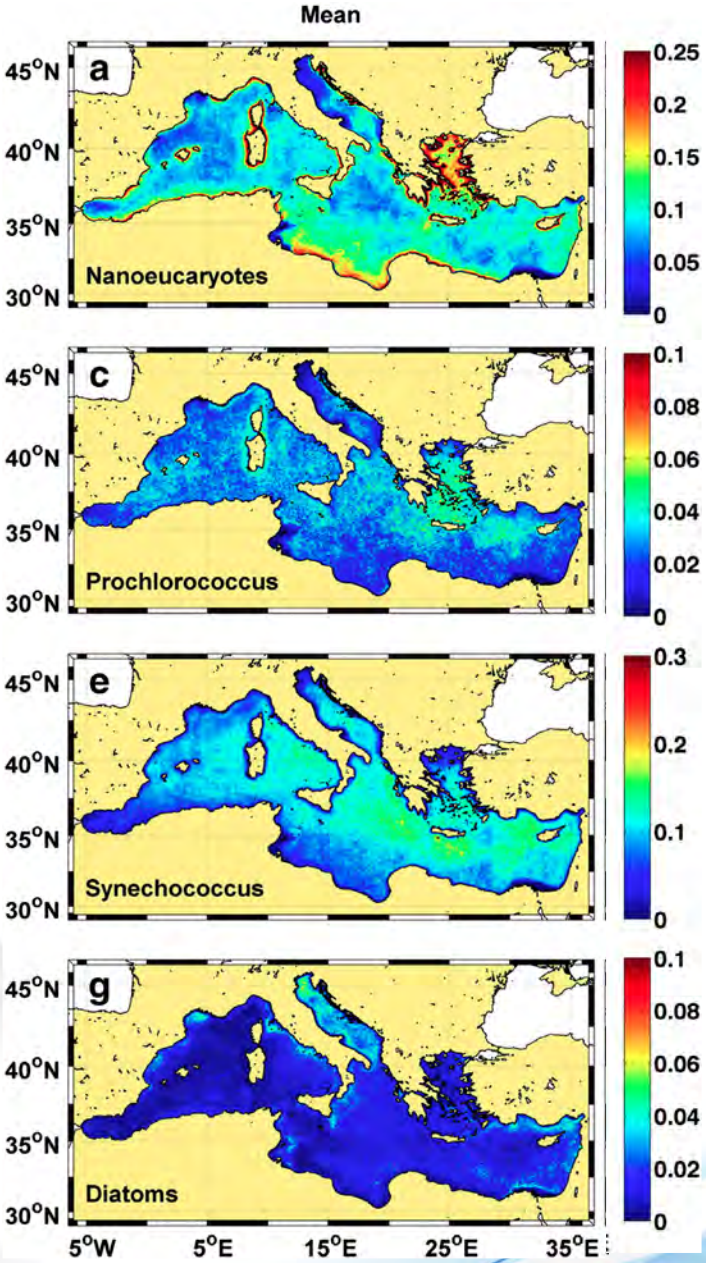
Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

PHYSAT-Med allow us display the monthly climatology of the most frequent phytoplankton group in Mediterranean Sea (2002-2013).



Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es



Map of detection frequencies for four PTF groups considering the unidentified pixels: nanoeukaryotes, Prochlorococcus, Synechococcus and diatoms.

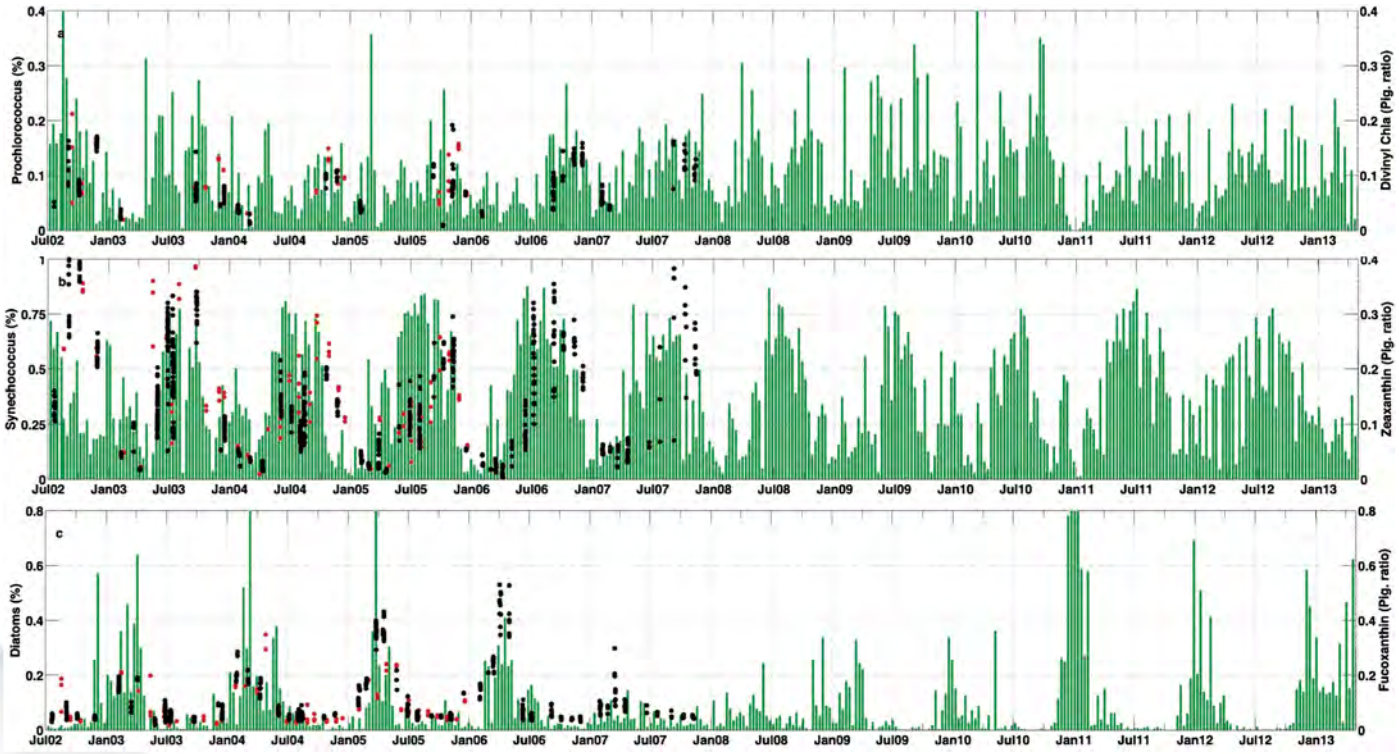
Synechococcus is the most frequent PFT in the basin mainly in the eastern half, being twice or three fold higher than the presence of **Prochlorococcus**.

However **diatoms** dominated in the northern Adriatic Sea and Gulf of Lions and **nanoeukaryotes** presented a high frequency along the coastal fringe and the Aegean Sea.

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

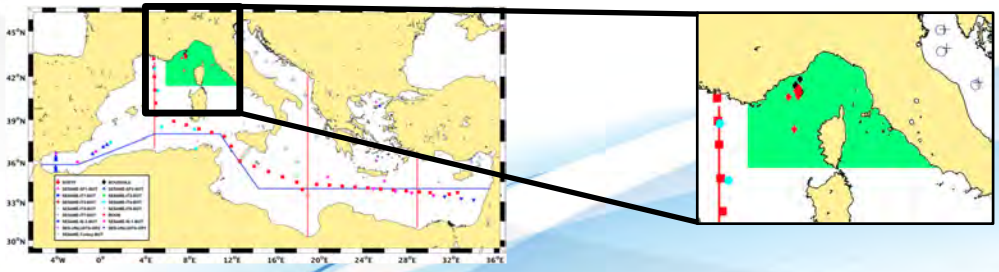
Validation PHYSAT-Med method with in situ HPLC measurements (Temporal)



Maxima at the end of stratification period (October). Agreement with max. pigment ratio of Divinyl chl-a

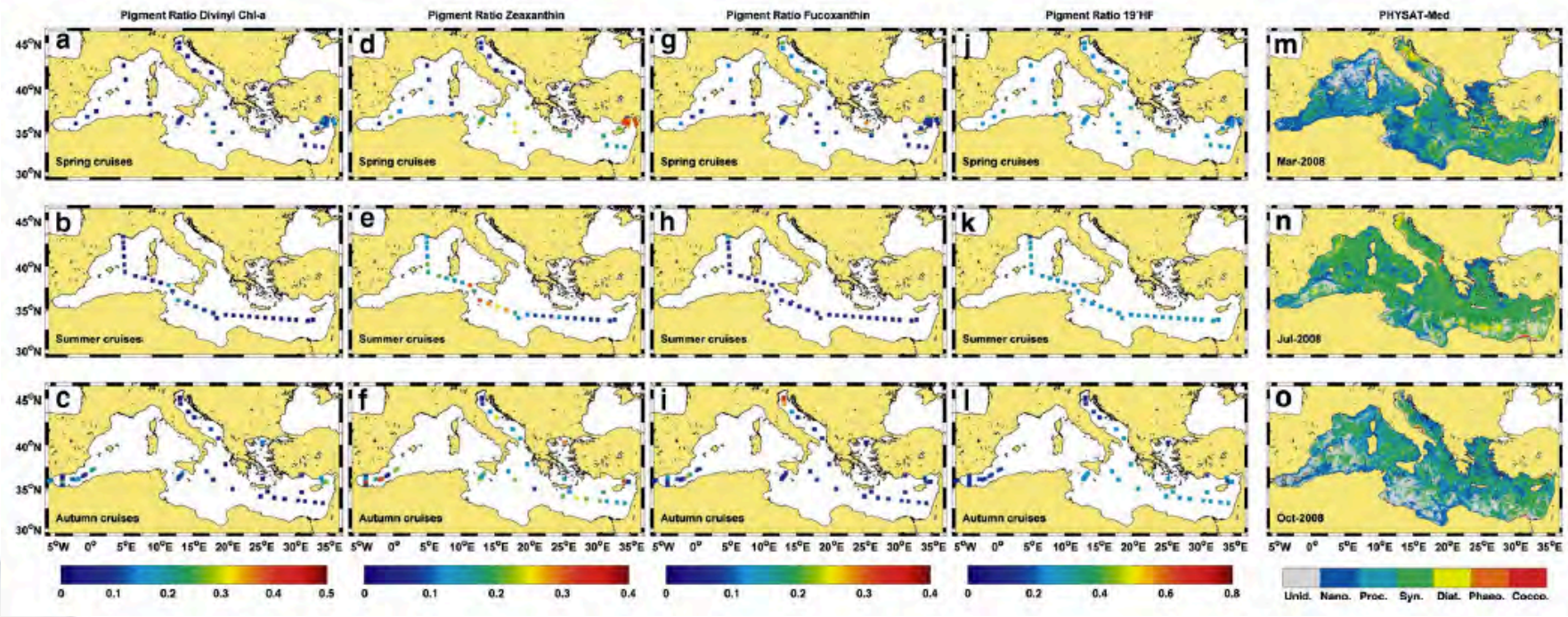
Syn. most abundant during stratification period (July - October)

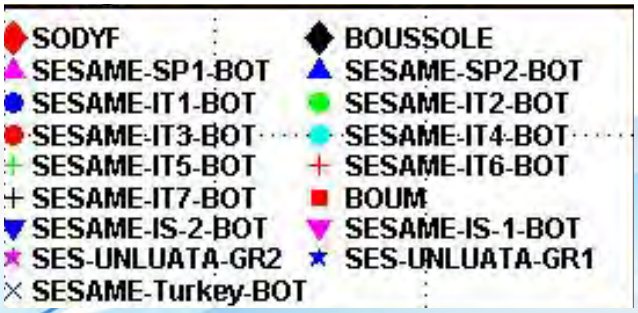
Diatoms and Fucox. maxima during spring bloom



PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Validation PHYSAT-Med method with in situ measurements (Spatial)



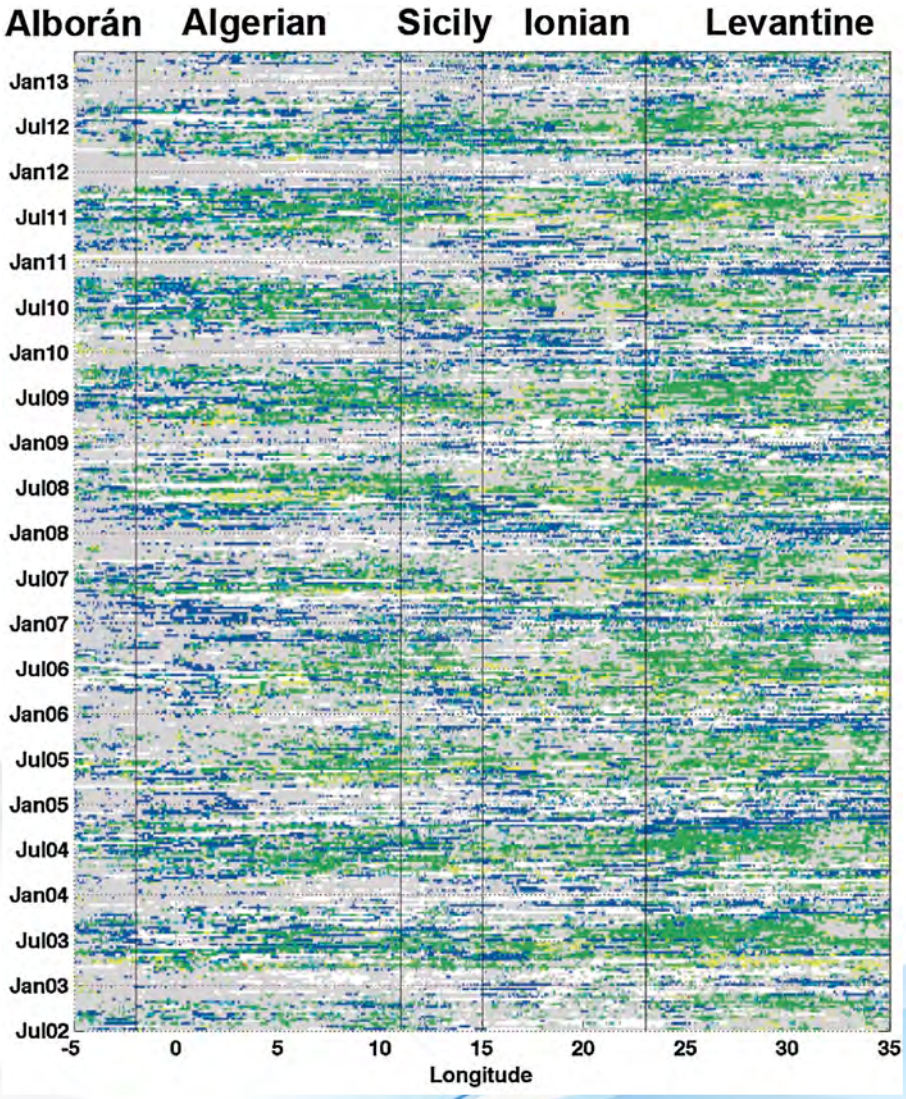


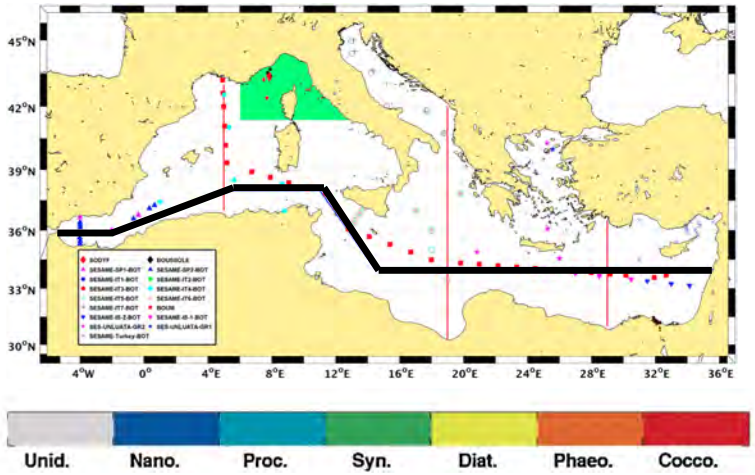
SESAME

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

- Hoevmöeller diagram on the west-east transect for the PFTs



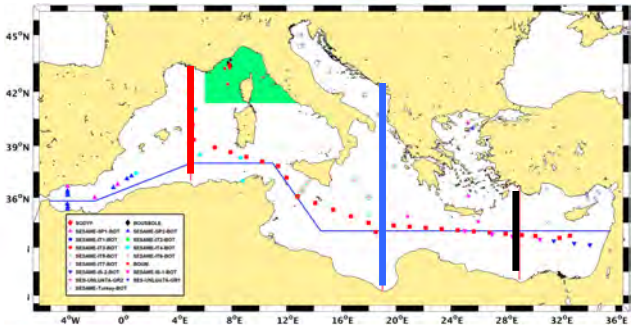


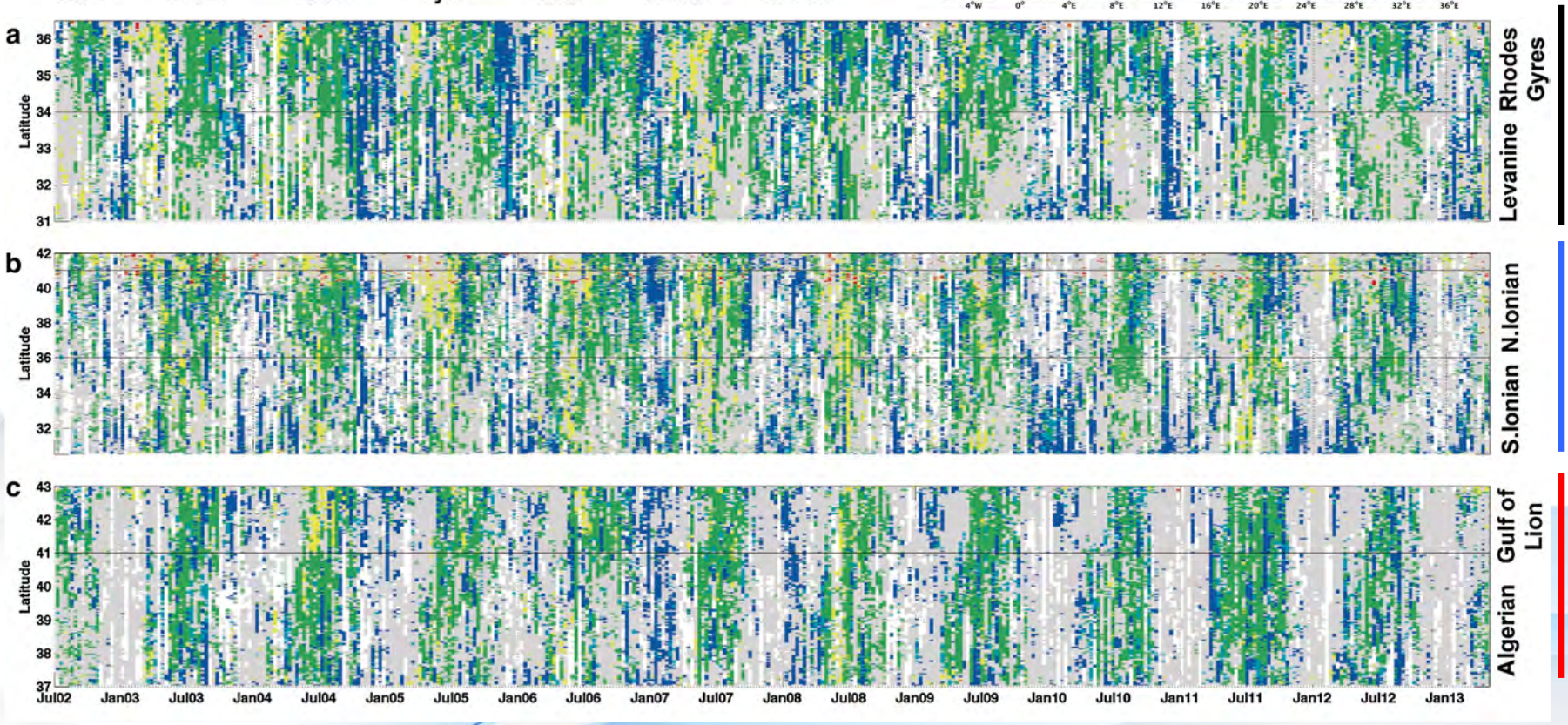
W-E transect shows differences mainly between the two sub-basins. Nanoeukaryotes appear in the whole Med whereas in the Levantine basin Synechococcus is the most abundant, specially during summer.
Diatoms are observed in spring, prior of Syn.
After stratification period (autumn), Proch. appear over the whole zonal transect.
In winter there are large number of unidentified pixels.

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

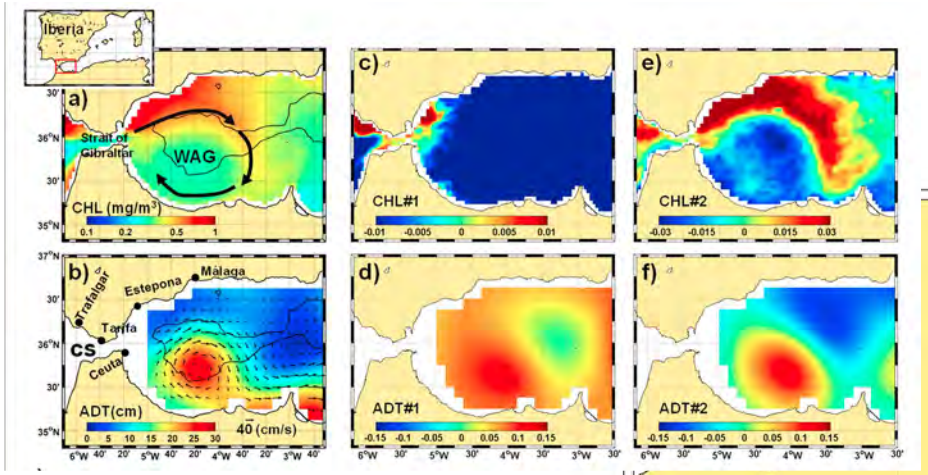
Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

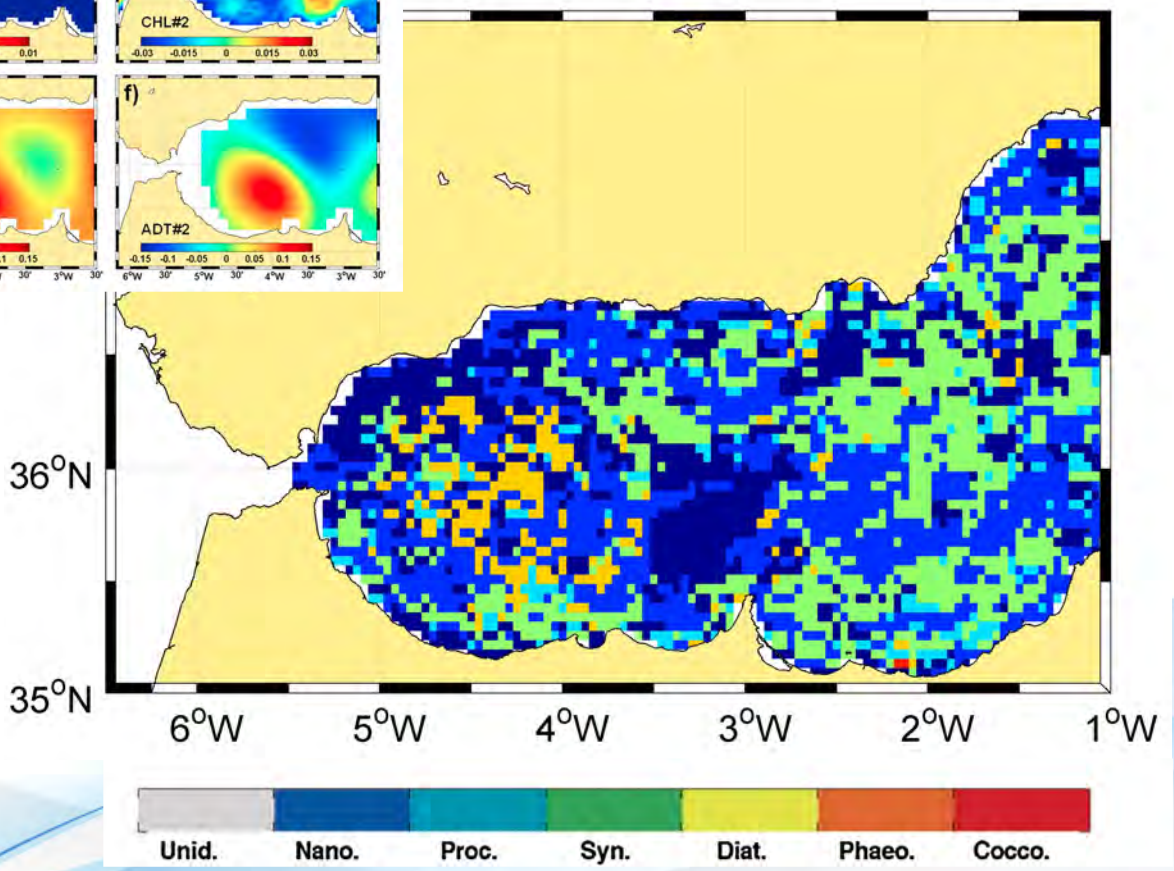
- Hoevmöeller diagram on the north-south transect for the PFTs





PFT IN ALBOREX.
WP1. ALBORAN SEA AND STRAIT OF GIBRALTAR EXPERIMENT





Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es

Conclusions

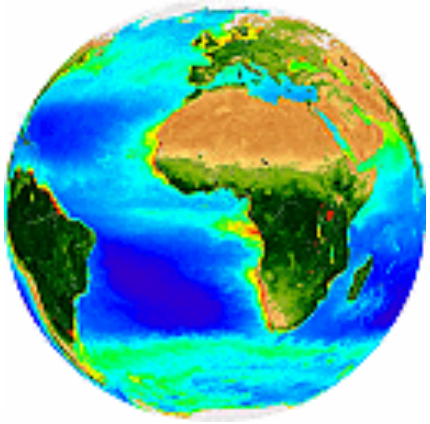
- PHYSAT-Med provides us a regionalized algorithm to estimate dominant phytoplankton groups (nanoeukaryotes, Prochlorococcus, Synechococcus, diatoms) for Med Sea.

- The comparison exercise presented here using in situ HPLC datasets and previous measurements shows a reasonable agreement.

- Our study evidences the dominance of Synechococcus over prochlorophytes throughout the year, whereas nanoeukaryotes were more abundant during winter months. However, diatoms seemed to augment during the spring period (March to April), especially in the Ligurian and Adriatic seas.

- PHYSAT-Med could potentially be also used to implement the MSFD and used to verify PFTs in ecological models.

Gabriel Navarro Almendros, ICMAN-CSIC. Gabriel.navarro@icman.csic.es



PERSEUS

POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Thank you !!!!