Control of phytoplankton bloom by winter conditions in a Mediterranean coastal area : results from a long-term study (1979-2011)

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CONTEXT

The occurrence of a late-winter (February-March) phytoplankton bloom is one of the most unifying features of Mediterranean pelagic ecosystems. However, very little is known about the mechanisms that regulate the interannual variability of this phytoplankton bloom in coastal areas.

OBJECTIVE

Through the analysis of a long-term time series of observations (32 years, 1979-2011), the objective of the present study is to show how winter physical forcing control the interannual variability of nutrient availability and winter-spring phytoplankton dynamics in a Mediterranean coastal zone unbiased by local anthropogenic activities (Bay of Calvi, Corsica, northwestern Mediterranean).

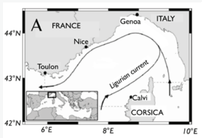
TIME SERIES (1979-2011)

- Location : PHYTOCLY station (Fig. 1), maximum depth : 40m;
- Data : water temperature, wind, phytoplankton from 1979, nutrients from 1988;
- High sampling frequency during the winter-spring period (1-7 times per week).

ENVIRONMENTAL CHARACTERISTICS

In the Bay of Calvi,

- wind-induced vertical mixing is the major mechanism of nutrient enrichment [1];
- the 13.5°C threshold can be used as a proxy for the vertical structure of the water column, i.e. subsurface water temperature <13.5°C indicates a vertically homogenous water column, and subsurface water temperature ≥13.5°C a (slightly) stratified and more stable vertical [2].



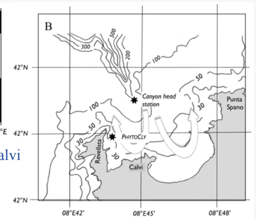


Figure 1. A : Location of Calvi in the Mediterranean Sea.
B : Map of the Calvi area, showing the location of the PHYTOCLY time series station, bathymetry and general directions of the mean horizontal currents (wide open arrows).

HIGH INTERANNUAL VARIABILITY

- NITRATE showed two contrasted patterns, which occurred repeatedly over the years although with high interannual variability. In the first pattern, nitrate was very low and quite constant throughout the year, and in the second, there was a large difference between the winter maximum and the following summer minimum. The high nitrate concentrations clearly occurred during cold-water periods (subsurface water < 13.5°C).
- PHYTOPLANKTON phenology showed large interannual variability, and a succession of years with and without a winter-spring phytoplankton bloom (Fig. 2). The latter are years with overall low phytoplankton biomass (e.g. 1997, 2007). During blooming years (e.g. 1979, 1999, 2009), increases in biomass were always observed during the cold-water period (subsurface water < 13.5°C).

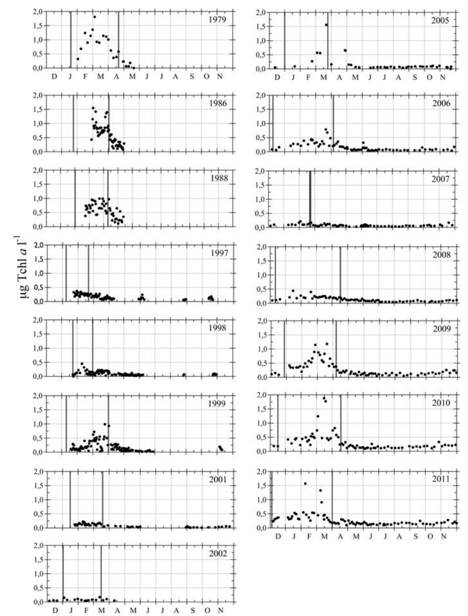


Figure 2. Time series of subsurface Tchl *a* (chl *a* + divinyl chl *a*) at the PHYTOCLY station. Each panel reports temporal changes from December of year x-1 to November of year x. Dark bars identify the limits of the cold-water periods (<13.5°C), from [2].

PHYTOPLANKTON BLOOMS IN A HOMOGENOUS WATER COLUMN

- A detailed survey performed in a blooming year (1999) showed that the bloom at the PHYTOCLY station developed in a vertically homogeneous water column <13.5°C and was homogenously distributed down to the bottom. During the bloom, diatoms and nanoflagellates were the most abundant groups, while cyanobacteria developed later (Fig. 3).
- As the phytoplankton bloom at station PHYTOCLY always occurred within the cold-water period over 32 years, this leads us to hypothesize that, in years when it when occurs, the phytoplankton bloom at station PHYTOCLY develops reccurently in a homogenous water column, with temperature <13.5°C.

INTERANNUAL CONTROL OF NUTRIENT AVAILABILITY AND PHYTOPLANKTON DEVELOPMENT BY WINTER INTENSITY

In order to assess the intensity of winter vertical mixing that could affect subsurface nutrient enrichment and subsequent phytoplankton development, the following Winter Intensity Index (WII) was defined [2] :

$$WII = (CW \times WE) / 1000,$$

where CW is the duration (number of days) of the cold-water period (subsurface water < 13.5°C), and WE is the number of wind events during the cold-water period (mean daily wind speed >5 m s^{-1}).

It follows from the relationships in Fig. 4 that, at the interannual scale,

- nutrient enrichment of surface waters, although variable interannually in intensity, was driven every year by wind forcing during the cold-water period,
- much of the interannual variability of phytoplankton bloom dynamics at the PHYTOCLY station can be interpreted as responses to interannual differences in WII during winter.

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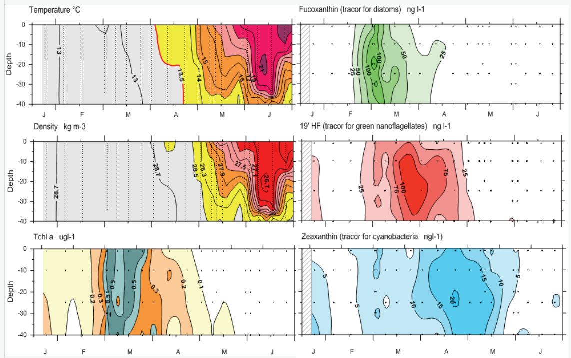
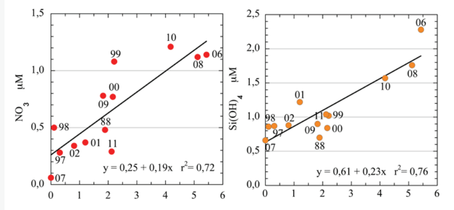


Figure 3. Contour plots at the PHYTOCLY station from January to June 1999 (0-bottom).



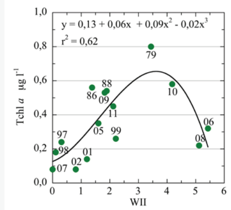


Figure 4. Relationships between mean subsurface nutrient and Tchl *a* over the cold-water periods and the Winter Intensity Index (WII). Numbers on graphs refer to years. r² : coefficient of determination, from [2].

Over the >30 years of observation, there were two main drivers of nutrient replenishment and phytoplankton development, i.e. the duration of the cold-water period (subsurface water <13.5°C) and the number of wind events (mean daily wind speed >5 m s^{-1}) within that period.

REFERENCES

[1] Goffart, A., Hecq, J.H., Legendre, L., 2002. Changes in the development of the winter-spring phytoplankton bloom in the Bay of Calvi (NW Mediterranean) over the last two decades : a response to changing climate? Marine Ecology Progress Series 236, 45-60.

[2] Goffart, A., Hecq, J.H., Legendre, L. Drivers of phytoplankton blooms in the oligotrophic Bay of Calvi (Corsica, NW Mediterranean): long-term study (1979-2011). Submitted to Progress in Oceanography.