Response of phytoplankton to climate-driven changes in a Mediterranean coastal area : results from 4 decades of observations (1979 - 2018)

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1. Context

A good understanding of phytoplankton dynamics is crucial for improving our knowledge of the marine environment in a context of multiple and increasing anthropogenic pressures.

In the Western Mediterranean Sea, a hotspot for climate change, previous work performed in a coastal area unbiased by local anthropogenic pressure (PHYTOCLY station, Bay of Calvi, Corsica, Fig. 1) has shown that much of the interannual variability of the winter-spring phytoplankton bloom is controlled by interannual differences in winter intensity (1).

2. Objectives

From a long-term *in situ* time series acquired at the PHYTOCLY station, which combines environmental parameters and HPLC pigments, we aimed to :

- provide a simplified scheme of changes in winter conditions occurring over four decades of observations;
- demonstrate the importance of winter conditions to determine the state of phytoplankton biomass and composition in surface waters;
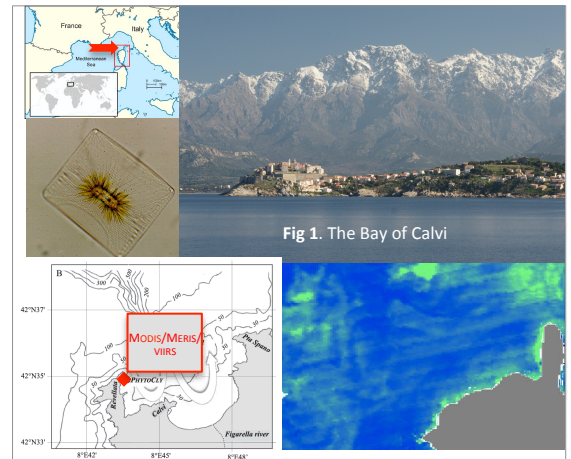- compare *in situ* surface temperature and Tchl *a* to data obtained by remote sensing.

Fig 1. The Bay of Calvi

Winter index intensity
WII = (CW x WE) / 1000

CW : duration (nb of days) of the cold-water period (surface water ≤13.5°C)
WE : nb of wind events (mean daily wind speed > 5 m s^{-1}) during the cold-water period.

3. Methods

Mean wind speed, recorded by Météo France at the Calvi airport, and subsurface water temperature were measured daily from 1979, except in 1980 and 1981. Subsurface sampling was performed the PHYTOCLY reference site (Fig. 1). Phytoplankton time series include Tchl *a* (22 years) and HPLC pigments (19 years). Sampling frequency ranged from daily to biweekly. From 1979 to 2005, sampling focused on the winter-spring period. From 2006, it was performed continuously (Fig. 2). Here we used 3 key photosynthetic pigments (hexanoyloxyfucoxanthin, fucoxanthin and zeaxanthin) to identify prymnesiophytes, cyanobacteria and diatoms, which are the phytoplankton dominant groups in the Bay of Calvi. The OC5 algorithm developed at IFREMER (2) was used to retrieve surface temperature and Tchl *a* from MODIS/AQUA + MERIS (2003-2012) + VIIRS (2012-2018) in front of the Bay of Calvi (Fig. 1).
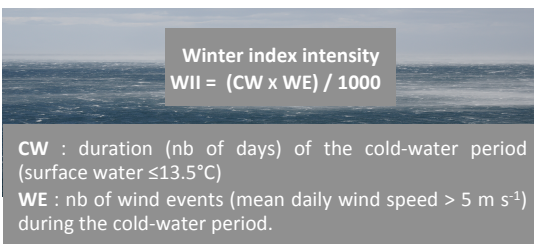
4. Highlights

① There was a long-term variability in WII, with **three distinct periods** : the 1980s (until 1988), the 1990s (1989-1998) and the 2000s (1999-2018), which were characterized by moderate, mild and highly variable winters, respectively (Fig 2). There are evidences that breaks between the periods resulted in **ecosystem shifts**.

② Winter intensity is a key driver of phytoplankton biomass and composition during the winter-spring period over the 40 years of observations. It influences both winter-spring phytoplankton distribution and community structure (Fig. 3). It is likely to have strong consequences on the entire food web. Among the dominant phytoplankton functional groups, **diatoms** are very sensitive to winter intensity, while prymnesiophytes and cyanobacteria are not correlated with it.

③ There is **no continuous long-term trend** (increase, decrease) in phytoplankton biomass and composition over the 4 decades of observations.
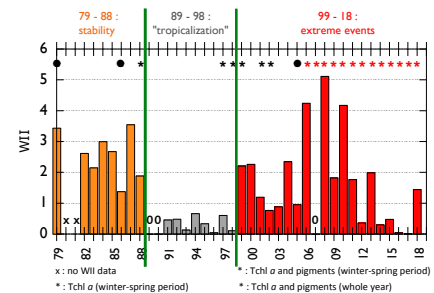

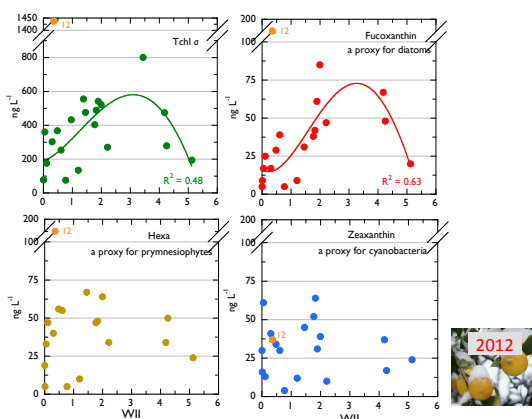Fig. 2 Temporal changes in Winter Intensity Index (WII) in the Bay of Calvi (1979-2018)

④ There are **strong similarities** between *in situ* measurements and satellite-derived temperature (data not shown) and Tchl *a* (Fig. 4). This will increase our capacities to monitor phytoplankton dynamics in the Mediterranean coastal areas at lower costs when compared to traditional survey and to track potential signs of changes as required by the Marine Strategy Framework Directive.

Fig 3. Scatter diagrams of mean subsurface Tchl *a*, fucoxanthin, hexanoyloxyfucoxanthin (hexa) and zeaxanthin during the cold-water periods as a function of the Winter Intensity Index (WII). Data acquired between 1979 and 2018.
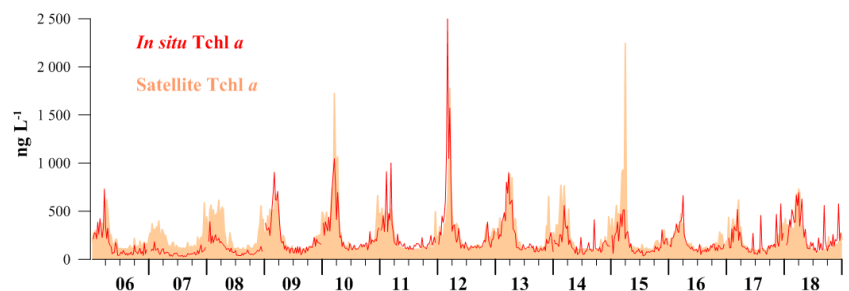

Fig. 4 : Time series (2006-2018) of *in situ* and satellite derived Tchl *a* in Calvi area (weekly averages).

1 Goffart et al. 2015, Progr in Oceanography
2 Gohin et al. 2008, Remote Sensing of Environment