A decade of observations and achievements of the MOOSE observatory in the Northwestern Mediterranean Sea

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Abstract

MOOSE is a multi-disciplinary integrated Ocean observing system part of the French national Research Infrastructure for coastal ocean and seashore observations (ILICO-RI). It was established in 2010 to monitor the Northwestern Mediterranean Sea in the context of rapid climate change and its impacts on marine ecosystems.

Keywords: Ocean Observing System, Western Mediterranean Sea, Climate Change, Time series, Autonomous platforms, FAIR data

1. Introduction

Considered as a 'hot spot' of climate change, marine biodiversity and human activities, the Mediterranean Sea shows trends toward drier and extreme weather causing important human and economic losses. The Mediterranean Sea undergoes important physical and biogeochemical modifications, eventually impacting the health of its unique ecosystems.

Established in 2010, the Mediterranean Ocean Observing System for the Environment (MOOSE, https://www.moose-network.fr/, Coppola *et al.*, 2019) maintains long-term time series of essential oceanic variables in the Northwestern Mediterranean Sea in order to quantify present changes, anticipate future ones and assess their impacts for the benefit of society.authorities. Project results supported implementation of MSFD in Bulgarian marine waters for the benefit of coastal population, marine industry, tourism, marine research and marine spatial planning.

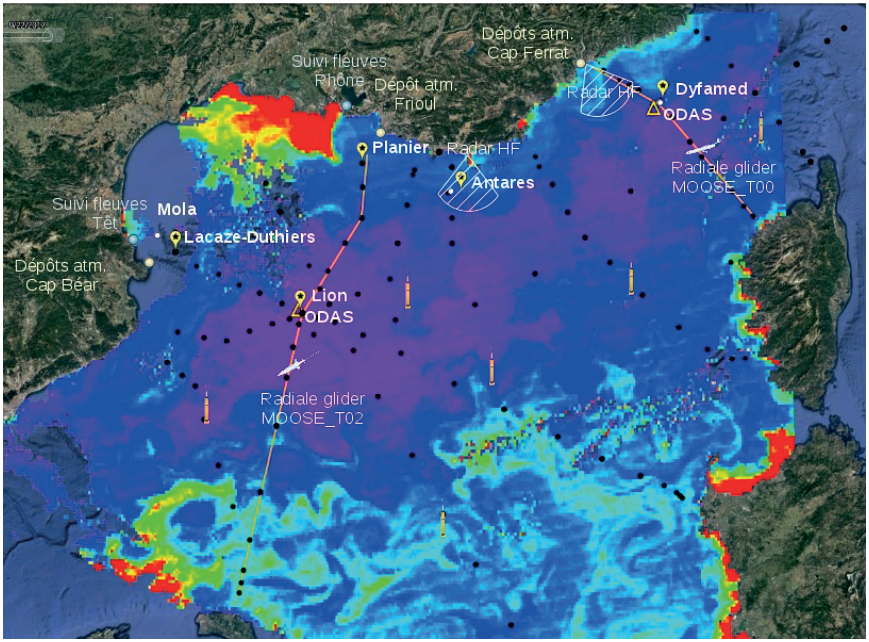

Fig. 1. Surface chlorophyll-a observed by satellite in February 2013 during a deep convection event (the dilution of phytoplankton is visible in purple). The MOOSE network: rivers and atmospheric deposit time series (blue/white dots on land), high-frequency radars (barred area), fixed mooring sites (yellow pins), surface meteorological buoys (ODAS triangles), autonomous platforms (endurance glider lines in orange, profiling floats drifting with currents) and ship-board surveys (black dots: yearly basin-scale cruise; white dots: monthly stations). LION, ANTARES & DYFAMED moorings are integrated in EMSO ERIC.

2. An integrated network from the coast to the deep ocean

MOOSE monitors long-term environmental trends, defines effective health and climatic indicators. It is based on a multi-disciplinary network of platforms maintained by the cooperation and coordination of national institutions and collaborators. This includes (Figure 1): river monitoring of the Rhône and Têt, particulate deposits at 3 sites (Cap Béard, Frioul and Cap Ferrat), physical and biogeochemical variables sampled by research vessels (yearly basinscale cruise MOOSE-GE and monthly open-sea stations at MOLA, ANTARES and DYFAMED), fixed-point observatories by deep moorings (EMSO-Ligure nodes: DYFAMED, ANTARES, LION) and coastal moorings deployed in the canyons (LACAZE and PLANIER), ODAS meteorological buoys (AZUR, LION), high-frequency radars off Toulon and Nice to map surface currents, as well as autonomous profiling platforms with two glider endurance lines (T00: Nice-Calvi and T02: Marseille-Menorca) and regular supply of Argo floats (including BGC-Argo) from EURO-ARGO ERIC.

3. Data Management and European Integration

MOOSE has significantly increased the data flow of essential oceanic variables in the region. The procedures and protocols have been homogenized following international best practices from sensor preparation to delayed-mode data quality control before these data are archived and released to the end-users with a digital object identifier via the Sea Scientific Open Data Edition repository (https://www.seanoe.org/). Data from MOOSE are available via the ODATIS ocean and coastal data cluster of the French DATA TERRA RI (Schmidt *et al.*, 2020). The MOOSE community contributed to and benefited from several EU programs: EuroSea (carbon audit, best practices), JERICO-s3 (NW MedSea coastal SuperSite), GROOM-II (glider community) and MONGOOS the regional alliance for the Mediterranean Sea of the Global Ocean Observing System (GOOS). MOOSE is part of the French ILICO-RI for coastal ocean and nearshore observations (Cocquempot *et al.*, 2019). It serves as reference deployment site for EURO-Argo floats and the development of new machine learning methods, fixed-point climatic trends (EMSO ERIC), description of biological diversity of plankton assemblages (EMBRC ERIC), air-sea CO_2 fluxes (ICOS ERIC). It also contributes to the GOOS's programs OceanGliders (endurance lines) and OceanSites (eulerian observatories).

4. Scientific breakthroughs and perspectives

By achieving a decade of multi-disciplinary observations, MOOSE has documented the recent decrease in deep water renewal to abrupt warming and salinification of intermediate waters, trends in ocean acidification and ventilation, as well as regional plankton community and coupling with atmospheric deposition and river inputs. In the future, MOOSE will sustain the ongoing long-term time series and tackle the challenge of integrating new variables (eg, genomic, pH), it will reinforce its interactions with

the EU partners (eg. Med-Ship) and the modelling community for the development of ocean climatic and ocean health indicators (CMEMS). It will serve as a benchmark for the development of new methodology applied to oceanography (eg, machine learning), as well as support and integrate the development of National and European Research Infrastructures (EOOS).

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