WP3
Monitoring network improvement for coastal flooding and extreme weather risk management

Activity 3.1
Satellite monitoring for coastal impacts of flooding and extreme weather

D3.1.1 Chlorophyll trends and their statistical significance using GBSatAdria

PROJECT AND ACTIVITY DETAILS

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Activity	3.1.
Activity Title	Satellite monitoring for coastal impacts of flooding and extreme weather
Work Package	WP3: Monitoring network improvement for coastal flooding and extreme weather risk management
Executive Summary	Activity 3.1, within Work Package 3, is dedicated to satellite observation and statistical analyses of those parameters, such as suspended terrigenous material (TSM) and chlorophyll (Chl) concentration, that may mark desirable/undesirable effects along coasts.
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0. INTRODUCTION

Coastal regions are complex environments where geological, biological, and physical processes interact each other. About 50% of the European Union (EU) territory lies on shorelines, 27 member states have coastlines, nearly 50% of its citizens live within 50 km of the coast and 3.5 million EU inhabitants are directly employed in maritime activities. Despite of their importance, several coastal areas have been facing the persistent loss of land due to human interventions and/or natural causes.

Moreover, strong anthropization of coastal (and in-land) environment, over-exploitation of natural resources, and climate change affect the natural amount of phytoplankton along coasts and, therefore, represent a continuous threat to the biodiversity in coastal waters. In particular, a concerning risks for coastal waters is the increase in nutrient inputs of terrestrial/anthropogenic origin that can lead to undesirable modifications of phytoplankton concentration (i.e., eutrophication).

Long-term sustainability of coastal regions mostly depends on the maintenance of the fragile balance of bio-geochemical processes. Coastal plumes are therefore crucial pathways that need to be monitored and analysed. Their pathways and long-term evolution is a key challenge for a thorough understanding of what drives costal eutrophication. Monitoring chlorophyll (Chl) concentration, which is a proxy of phytoplankton biomass, is an efficient tool for recording and understanding the response of the marine ecosystem to human pressures and thus for detecting eutrophication.

1. CHLOROPHYLL TRENDS FROM REMOTE SENSING AND COASTAL EUTROPHICATION

Coastal waters are extremely sensitive to changes in nutrient inputs of terrestrial/anthropogenic origin that can lead to undesirable effects such as eutrophication (i.e., an increase in the rate of supply of organic matter to an ecosystem; see Nixon, 1995). Adequate indicators, which follow the evolution of the monitored water quality and eutrophication, are very important for the directive implementation of national directive, and for ensuring that human activities are pursued in a sustainable manner. Temporal and spatial sampling strategies of specific biogeochemical parameters are particularly important to monitor eutrophication. One of the best candidates for such a monitoring is the change in time of Chlorophyll (Chl) concentration, which represents the most direct indicator the marine ecosystem functioning [Roemmich and McGowan, 1995; Sabine et al., 2004; Boyce et al., 2010].

Satellite Ocean Colour (OC) data represent an essential observational tool that offers a unique view of the natural environment due to their synopticity and their high temporal and spatial resolution. These characteristics address, indeed, the spatial features of eutrophication phenomena, which cannot be detected from in situ, sparse monitoring stations. Offshore buoys are not often able to represent the complex spatial pattern of Chl concentration trends that are caused by a combination of different environmental factors (such as coastal currents, bathymetry, and river runoffs) and human pressures. At global scale, several works estimated biogechemical trends by using satellite data [Gregg et al., 2005; Behrenfeld et al., 2006; Barale et al., 2008; Colella et al., 2016]. Here we performed a satellite-based analysis in the Adriatic Sea.

1.1 Detecting Chl trends in the Adriatic Sea

In the Adriatic Sea, as for the whole Mediterranean basin, the amount of Phosphorous (P) and Nitrogen (N) discharges, due to the human activities along river basins and coasts, is significantly changed in the last decades [EEA Report, 2005]. The increase of N is mainly due to fertilizers that are used in agricultural and livestock while P is from industrial and urban wastewater discharges, as well as from agricultural activities. For this reason, significant Chl trends need to be detected from long time series that are able to capture biomass changes in coastal waters due to anthropic and/or climatic pressures. Therefore, the analysis of short time series can erroneously lead to interpret some spatial patterns produced by random processes (driven by local chemical or physical processes) as Chl concentration trends.

Coastal eutrophication is an inter-seasonal process that strongly depends on the anthropic activities and continuous river inputs. In the Adriatic Sea, river runoffs have maximum discharges during autumn/winter and their minima during summer [Gasith and Resh, 1999]. Here we use Chl products from the Coastcolour project, launched by ESA to fully exploit the potential of the MERIS instruments, provides us a complete (from 2003-01-04 to 2012-04-07, when the mission ended) series of ocean optics observation of a set of basins, where the presence of case 2, optically complex waters is important. The Coastcolour Product User Guide, available within, completely describes the scope, the reasons, the approach and the products of the project (http://www.coastcolour.org/).

Finally, removing seasonality is at the base of any methodology for trend detection [Gregg et al., 2005; Behrenfeld et al., 2006; Barale et al., 2008; Colella et al., 2016]. Here we use the so-called X-11 decomposition procedure for investigating the temporal variation of OC biogeochemical products. This approach allows variations in the annual cycle by decomposing the original time series into seasonal, irregular and trend-cycle terms.

1.2 Methods

For trend estimation we coupled the Mann-Kendall test and the Sens's method, which are here applied to a de-seasonalized monthly time series as obtained from the X-11 technique. The dataset covers the time period spanning from 2003-01-04 to 2012-04-07, with a daily temporal resolution and a spatial resolution of 300 m. Because the seasonal component can mask small movements in the trend signal, we remove the seasonal signal from Coastcolour chlorophyll dataset before determining the Chl trend. We use is the X-11 seasonal adjustment methodology (Shiskin, 1978; Dagum, 1980), which is similar to that described in the framework of the X-12-ARIMA seasonal adjustment program of the U.S. Census Bureau (Findley et al., 1998), and that it was already used by Pezzulli et al., (2005) to remove the seasonal signal from Sea Surface Temperature data. The full description of the Mann-Kendall test and the Sens's method, applied to the de-seasonalized dataset is provided in the Deliverable D3.1.3 "Manual on the developed GBSatAdria SW"

1.2 Results

We list below the main results of our analysis

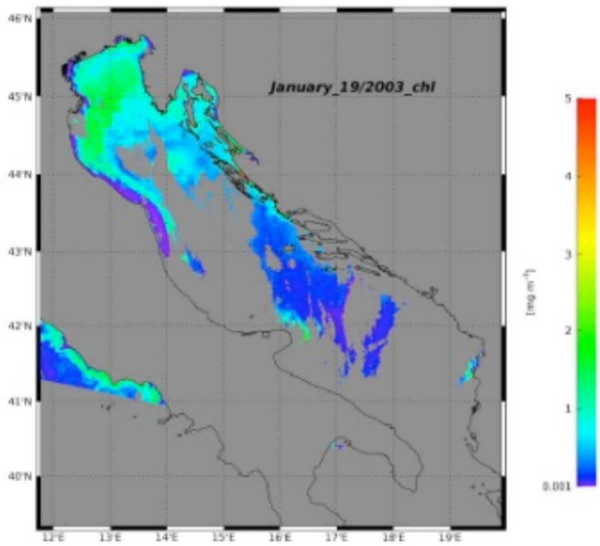

Figure 1.1. Daily Chl map over the Adriatic Sea (19 January 2003). High values of Chlorophyll concentration are observed off the Po River Delta. Daily maps a largely affected by cloud cover.

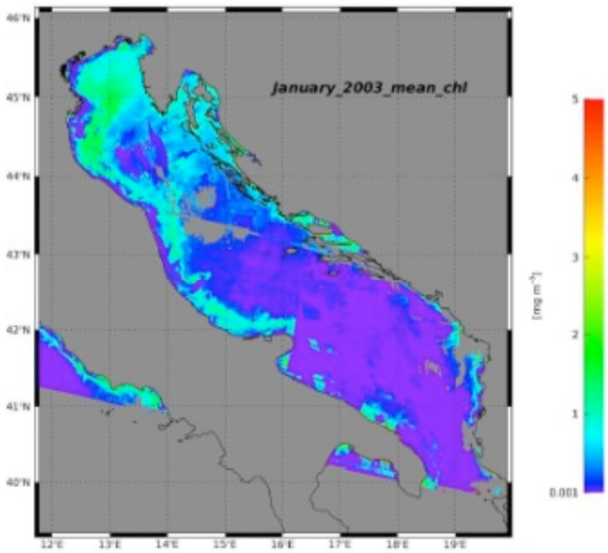

Figure 1.2. Monthly averaged Chl map over the Adriatic Sea (January 2003). The averaging process lowers the cloud cover issue, providing a better view of Chl concentration pattern in the whole Adriatic basin. However, some voids (i.e., missing values) are still present.

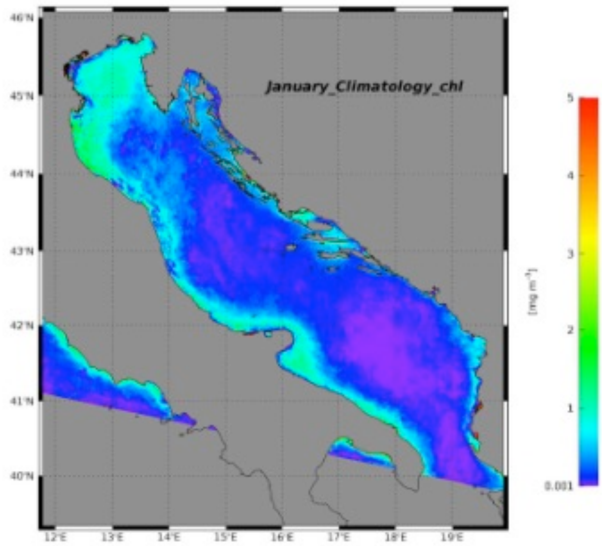

Figure 1.3. Chl concentration map for the climatologic January. Missing pixels, still present in the monthly averaged maps (see Fig. 1.2), are here filled by using climatologic months (e.g., the average value of all Januaries, from 2003 to 2012). This technique will produce L4 monthly maps.

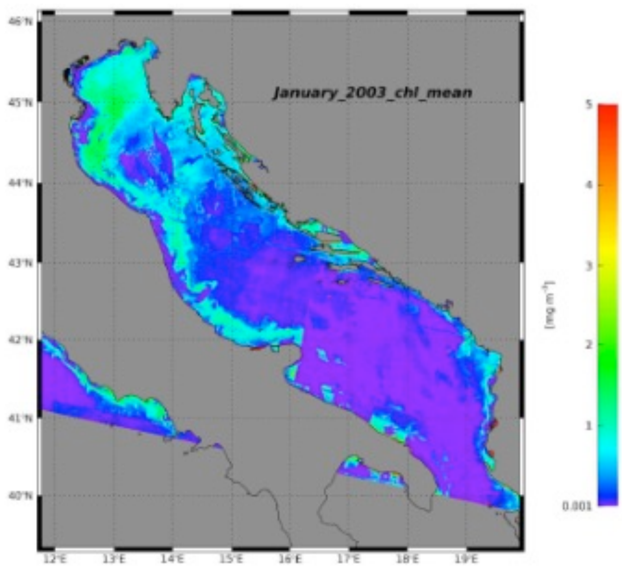

Figure 1.4. L4 monthly map of Chl concentration for January 2003, with no missing values. This L4 product can be used to evaluate statistical trends.

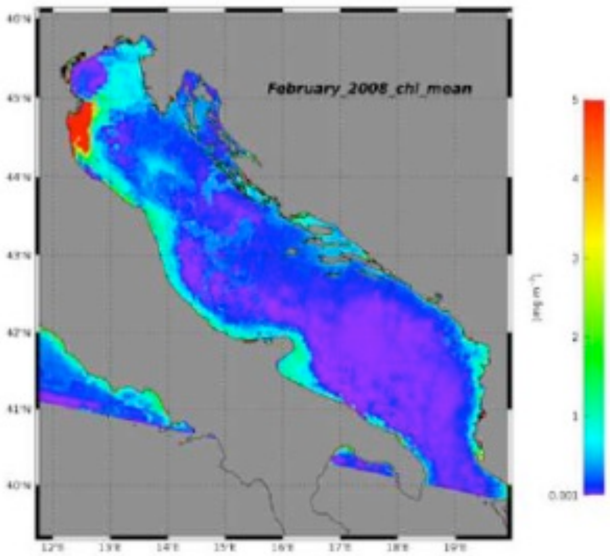

Figure 1.5. L4 monthly map of Chl concentration for February 2008, with no missing values. This L4 product highlights the high values of Chl concentration off the Po River Delta due to phytoplankton biomass, enhanced by the river inputs, which may bring to eutrophication.

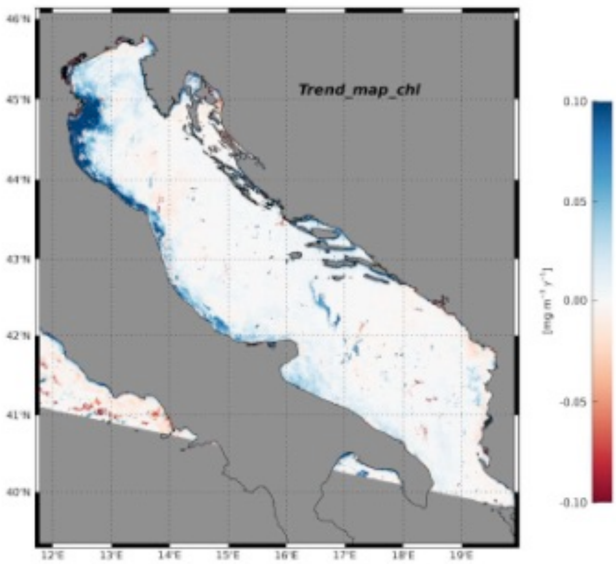

Figure 1.6. Statistical trend for Chl concentration over the period 2003-2012. We observe a general positive trend all along the Italian Adriatic coast. Values of trend are higher off the main river mouths. This values mark the presence of eutrophicated areas.

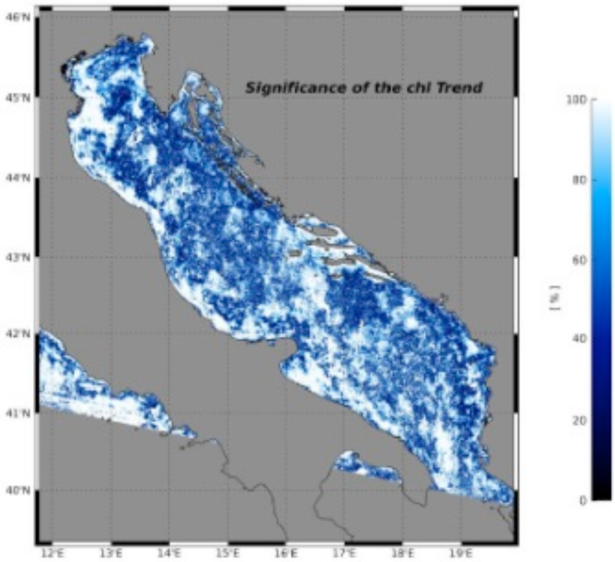

Figure 1.7. Statistical significance of the Chl trend. White pixels mark significant values of Chl concentration trend (Fig. 1.6). We note that the majority of coastal pixels are statistically significant.

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