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Modelling climate change impacts on nutrients and primary production in coastal waters

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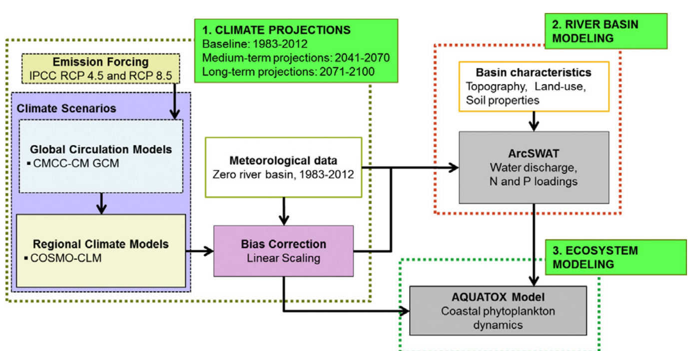
HIGHLIGHTS

- Integrated modelling methodology exploring the impacts of climate change on nutrient loadings and phytoplankton community.
- The nutrients loadings in the Zero river basin and the salt-marsh Palude di Cona in Italy were investigated.
- Integration of GCM-RCM climate projections with the hydrological model SWAT and the ecological model AQUATOX.
- Results show changes in the phytoplankton community: reduction in biodiversity and more intense blooms in the summer.

GRAPHICAL ABSTRACT



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ABSTRACT

There is high confidence that the anthropogenic increase of atmospheric greenhouse gases (GHGs) is causing modifications in the Earth's climate. Coastal waterbodies such as estuaries, bays and lagoons are among those most affected by the ongoing changes in climate. Being located at the land-sea interface, such waterbodies are subjected to the combined changes in the physical-chemical processes of atmosphere, upstream land and coastal waters. Particularly, climate change is expected to alter phytoplankton communities by changing their environmental drivers (especially climate-related), thus exacerbating the symptoms of eutrophication events, such as hypoxia, harmful algal blooms (HAB) and loss of habitat. A better understanding of the links between climate-related drivers and phytoplankton is therefore necessary for projecting climate change impacts on aquatic ecosystems.

Here we present the case study of the Zero river basin in Italy, one of the main contributors of freshwater and nutrient to the salt-marsh Palude di Cona, a coastal waterbody belonging to the lagoon of Venice. To project the impacts of climate change on freshwater inputs, nutrient loadings and their effects on the phytoplankton community of the receiving waterbody, we formulated and applied an integrated modelling approach made of: climate simulations derived by coupling a General Circulation Model (GCM) and a Regional Climate Model (RCM) under alternative emission scenarios, the hydrological model Soil and Water Assessment Tool (SWAT) and the ecological model AQUATOX. Climate projections point out an increase of precipitations in the winter period and a decrease in the summer months, while temperature shows a significant increase over the whole year. Water discharge and nutrient loads simulated by SWAT show a tendency to increase (decrease) in the winter

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(summer) period. AQUATOX projects changes in the concentration of nutrients in the salt-marsh Palude di Cona, and variations in the biomass and species of the phytoplankton community.

1. Introduction

There is high confidence that anthropogenic emissions of greenhouse gases (GHGs) are the main reason of the current Earth's energy imbalance (Hansen and Sato, 2004). As a consequence, this is causing the warming of the atmosphere (von Schuckmann et al., 2016) with an expected rise of the global mean temperatures by 0.3 to 4.8 °C by the end of the 21st century relative to the period 1986–2005 (IPCC, 2013), and the alteration of the water cycle as a result of changes in the global moisture recycling among atmosphere, lands and oceans (Levang and Schmitt, 2015).

Coastal ecosystems, together with the ecological and socio-economic services they provide, could be among those most affected by the ongoing climate change (Harley et al., 2006; IPCC, 2014). Coastal waterbodies such as estuaries, bays and lagoons, being transitional systems located at the interface between land and sea, will be subjected to the combined modifications taking place in the atmosphere, in the oceans, and over the land surface (Raimonet and Cloern, 2016).

In particular, a wide number of studies has shown the links between changes in climate and phytoplankton in coastal ecosystems (Harding et al., 2015; Holt et al., 2016; Quigg et al., 2013; Sommer and Lewandowska, 2011; Winder and Sommer, 2012). Phytoplankton is responsible for a large share of photosynthesis and primary production of coastal areas, and plays an essential role in several biogeochemical processes such as carbon, nutrient and oxygen cycles (Paerl and Justic, 2011; Winder and Sommer, 2012). Consequently, changes in phytoplankton dynamics and composition may have relevant repercussions on the higher trophic level of coastal ecosystems (Hernandez-Farinas et al., 2014; Schloss et al., 2014).

Environmental drivers regulating phytoplankton dynamics such as water temperature, light penetration, tides, salinity and nutrient availability (Cloern, 1996), are highly sensitive to climate change. The interactions among these drivers, including their influence on primary production in coastal areas, form a complex, nonlinear system that can be defined by three main components: (1) Climate, which delineates changes in atmospheric conditions; (2) Coastal watershed hydrology, which describes the changes in the delivery of freshwater, nutrients, sediments and pollutants to coastal waters; and (3) coastal ecosystem, which combines changes in climate and watershed hydrology to identify the impacts on the coastal environments. As proposed by Xia et al. (2016) for freshwater ecosystems, the simplified conceptual model depicted in Fig. 1(a) describes the interactions among these components and their effects on the phytoplankton communities of coastal ecosystems.

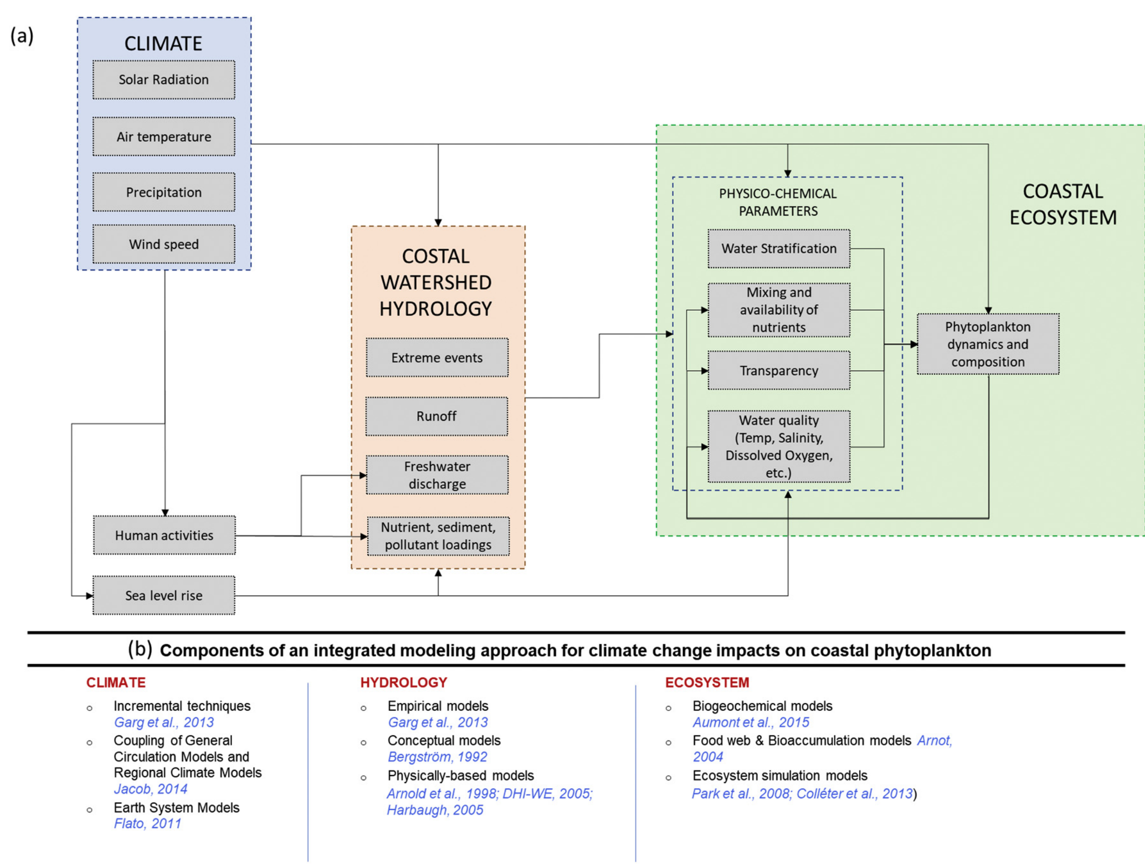

Fig. 1. (a) Conceptual model describing the complex interactions among environmental and climate drivers regulating phytoplankton dynamics in coastal areas. The model is composed of three parts: (1) climate, (2) coastal watershed hydrology; and (3) coastal ecosystem. (b) Examples of models able to represent the three components (climate, watershed hydrology, ecosystem) and that can be integrated to constitute a modelling approach for the assessment of the direct and indirect impacts of climate change on phytoplankton (and higher trophic levels) of coastal ecosystems.