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Review

Ecosystem-based management of coastal zones in face of climate change impacts: Challenges and inequalities

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ABSTRACT

Climate change effects have the potential of affecting both ocean and atmospheric processes. These changes pose serious threats to the millions of people that live by the coast. Thus, the objective of the present review is to discuss how climate change is altering (and will continue to alter) atmospheric and oceanic processes, what are the main implications of these alterations along the coastline, and which are the ecosystem-based management (EBM) strategies that have been proposed and applied to address these issues. While ocean warming, ocean acidification and increasing sea level have been more extensively studied, investigations on the effects of climate change to wind and wave climates are less frequent. Coastal ecosystems and their respective natural resources will respond differently according to location, environmental drivers and coastal processes. EBM strategies have mostly concentrated on improving ecosystem services, which can be used to assist in mitigating climate change effects. The main challenge for developing nations regards gaps in information and scarcity of resources. Thus, for effective management and adaptive EBM strategies to be developed worldwide, information at a local level is greatly needed.

Contents

1. Introduction

The 21st century has so far demonstrated a clear trend of increase in both atmospheric and ocean temperature (Semedo et al.,

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2013). Greenhouse gas emissions have reached unprecedented atmospheric concentrations due to human activities, as shown in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). Increases in carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) combined to other human-originated factors have been labeled as extremely probable causes for the global warming phenomenon observed since the mid-20th century (IPCC, 2014).

The upper 75 m of the global ocean has warmed 0.11 °C per decade over the period between 1971 and 2010 (IPCC, 2013). IPCC projections also indicate that oceans will continue to warm until the end of the century, affecting the deep ocean and altering ocean circulation. Moreover, human alterations in atmospheric composition can lead to a series of impacts, such as the heat waves and floods recently experienced in Europe (2003), Pakistan and Russia (2010), and Texas (2011) (Mann et al., 2017).

Since the 1990s, studies such as that by Nicholls and Leatherman (1995) have indicated and alerted to possible impacts caused by climate change to the natural resources of coastal zones. These findings have led to great concern regarding public policies and coping strategies, particularly considering that, as the aforementioned authors also reported, developing countries present incomplete databases on the various aspects of their coastal zones. More than 20 years later, this lack of long-term temporal and spatial data series remains an issue in these countries (i.e. Almeida et al., 2015; Blankespoor et al., 2017), implicating in their ability to understand, predict, evaluate and, therefore, either mitigate or adapt to future conditions. Thus, the decision-makers of the majority of all coastal zones across the globe present inherent difficulties to assess climate change impacts over the coastline and propose adequate management and adaptation strategies. This situation was also observed by Bergillos et al. (2018) regarding the efficiency of nourishment strategies in eroding deltas.

Martínez et al. (2007) identified that 84% of all countries in the world have coastlines, with a large percentage of their population (80–100%) living within 100 km of the shoreline. More recently, Neumann et al. (2015) projected coastal population growth scenarios for 2030 and 2060 and observed a global growth in the population living in low-elevation coastal zones, especially in Asia. Thus, a scenario of rising mean sea level, for example, would imply in a future reallocation of millions of people.

In addition to population growth, population migration is also an important factor contributing towards an increasing coastal population (Martínez et al., 2007). Hugo (2011) shows that human migration may be a reflection of climate change effects. Moreover, during the past few years, civil conflicts and poverty have caused an intense migration of thousands of people from African and Middle Eastern countries towards Mediterranean European countries. Between January 2014 and June 2015 alone, 356,000 refugees and migrants arrived in Europe by sea (Cogolati et al., 2015). This massive short-term population increase may represent an additional pressure to the coastal zones of the countries where immigrants and refugees are settling in. Moreover, refugee settlements have been shown to cause a series of impacts, such as surface and subsurface water depletion and pollution, degradation of agricultural lands, deforestation, etc. (Hoerz, 1995). Thus, effective management of natural resources has become an increasingly pressing matter for countries in this situation.

At the beginning of the 21st century, more than 100 million people were reported to be living in places located merely 1 m above current mean sea level (Douglas and Peltier, 2002). This position would definitely leave these people vulnerable to coastal flooding and to loss of property in ongoing and future climate change scenarios. Inundations are particularly concerning for low lying island countries, which face the risk of disappearing (Albert et al., 2016). Moreover, 13% of the world's population is estimated to live in coastal areas at risk and 75% of this population is located in Asia, in areas between 0 and 10 m above sea level (Smith, 2011). On the other hand, a greater population density could attract more easily financial resources to be used towards management strategies, particularly within an ecosystem-based framework.

The full range of impacts that climate change can impose to coastlines around the world are not fully understood, let alone addressed in coastal management strategies. Thus, the present review has the objective of discussing how climate change is altering (and will continue to alter) atmospheric and oceanic processes, what are the main implications of these alterations along the coastline, and which are the ecosystem-based management (EBM) strategies that have been proposed and applied to address these issues in different contexts.

2. Global climate change effects

2.1. Wind climate

While some consequences of a changing climate have been more deeply explored, such as global warming, less attention has been given to the impact of climate change on wind patterns, for example, despite the great potential for geophysical and societal negative effects (McInnes et al., 2011).

Wind climate is expected to experience either intensification or weakening over various systems in future scenarios. Sydeman et al. (2014) evaluated patterns observed from reanalysis models and identified wind intensification over most latitudes of the Benguela and California systems, as well as for the southern portion of the Humboldt system. However, these same authors observed a weakening in wind intensity in most latitudes of the Iberian system and in the southern half of the Canary system. McInnes et al. (2011) and Gallagher et al. (2016) also observed decreases in wind speeds at 10 m of altitude among most of the models investigated for equatorial ocean regions, and for the North Atlantic, respectively. However, Pryor and Barthelmie (2010) observed that mean wind speeds are unlikely to change more than the current inter-annual variability rate over the majority of Europe and North America during the present century. More recently, Davy et al. (2018) observed a decrease in wind intensity over Europe and an increase over North Africa and Barents Sea, and no negative impact of climate change on wind resources in the Black Sea region. On the other hand, regarding South America, Pryor and Barthelmie (2010) identified that variations may be greater than other regions of the world, but these data were considered uncertain.

Significant variations in wind intensity would imply in changes to the wave climate that is generated by these systems. Wind-generated waves are formed from the transference of momentum from the atmosphere to the ocean surface. Once they are generated, these waves are responsible for the distribution of heat and momentum between these two compartments (Semedo et al., 2013; Dobrynin et al., 2015). Thus, these altered wind-generated waves could propagate across ocean basins and lead to changes in the regional wave climate of places far away from the origin of this alteration.

Nevertheless, wind intensity is not the only wind parameter that can change in future climate scenarios. As described by McInnes et al. (2011), in the case of an intensification of a specific wind directional component (i.e. north component in the Northern Hemisphere), the angle of incidence of this wind system will vary (i.e. clockwise rotation, following the Coriolis Effect). Moreover, these authors also state that changes in the direction of winds are particularly concerning in coastal regions where wind influences hydrodynamic agents. Thus, meteorological tides, waves and the