University of Kadiz, Spain

Erasmus Mundus Joint Master in Water Coastal Management

Module: Coastal Flooding Hazards

Regional issues raised by sea-level rise and their policy implications

Supervisor: Prof. Laura Del Rio

Sobir Kodirov

1. Introduction

The causes of changes in sea level are not limited to those related to climate change. It is well known that the mean sea level has repeatedly had a large fluctuation due to the alternation of glacial and interglacial periods for the past several hundred thousand years in the Holocene. This fluctuation of mean sea level reached about 120 m. There are also much shorter-term fluctuations in sea level, such as tide, waves and tsunamis. Among such a wide range of fluctuations, climate change-related sea-level change has its own unique characteristics [2].

Any rise in sea level promotes land loss, increased flooding and salinisation. The impacts of and possible responses to sea-level rise differ at the local and regional scale due to variation in local and regional factors. Based on global reviews and analyses of relative vulnerability, the following four regions are selected and examined in more detail using local and national assessments: 1. Europe; 2. West Africa; 3. South, South-East and East Asia; 4. the Pacific Small Islands [1];

There are three main benefits of a regional perspective are apparent. Firstly, if critical impacts are shared between neighbouring countries, calls for mitigation can be articulated more effectively by a group of nations to the wider international community. Secondly, common impacts shared between countries provide opportunities to pool resources, share experience and integrate research efforts towards developing effective adaptive solutions. Lastly, a regional perspective is important for adaptation mitigation to anticipate a range of potential crossborder issues [1].

2. Global climate change and its coastal implications

Due to differences in land motion, estimates of future relative sea level rise vary for different regions. However, due to uncertainties about the response of ice sheets to warmer temperatures and future emissions of greenhouse gases, higher values are possible and cannot be excluded [3].

Presently, relative sea-level rise scenarios are difficult to develop due to our incomplete knowledge of the local and regional components (fig. 1).

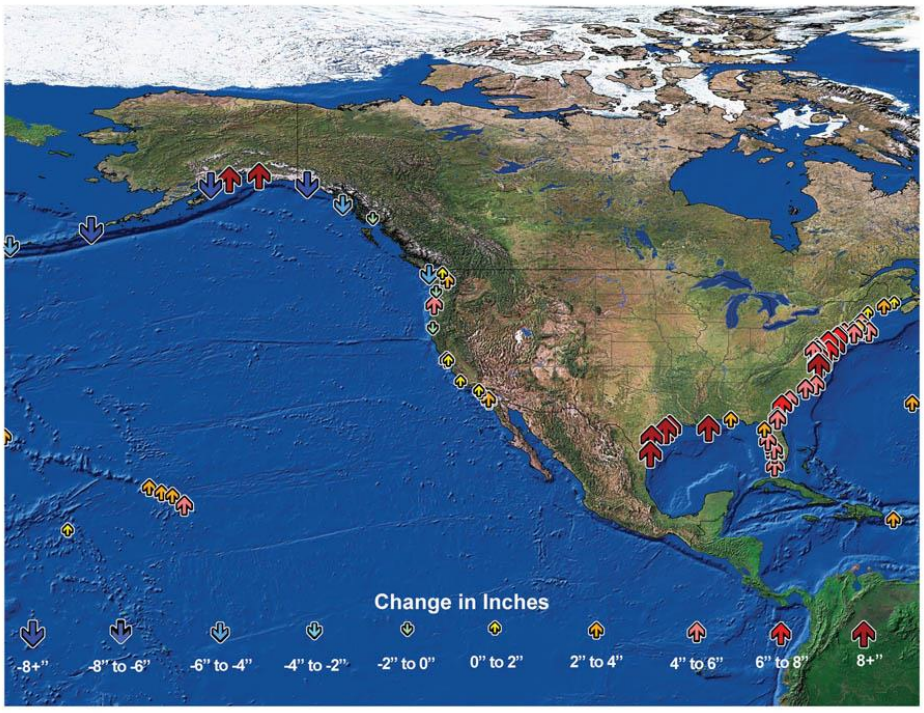

Fig. 1 Observed changes in sea level relative to land elevation in the United States between 1958 and 2008 (https://www3.epa.gov/climatechange/impacts/coasts.html).

All the above uncertainties must be considered when interpreting impact and response assessments [1].

The most serious physical impacts of sea-level rise are: 1. inundation and displacement of wetlands and lowlands; 2. coastal erosion; 3. increased coastal storm flooding; 5. salinisation (Barth & Titus 1984). As we noted before, that the impact would differ from place to place and depend on the magnitude of relative sea level rise. Many other climate chnge factors could also have significant coastal implications at the regional scale. However, with a few exceptions, the future changes to these climate factors are less certain, with a possibility of either increase or decrease. For the purposes of this paper, other climate factors are not considered further, although it is our expectation that they would raise similar issues [1].

3. Impact assessment for sea level rise

The IPCC Common Methodology (CM) was developed to improve understanding of societal vulnerability to sea-level rise (IPCC CZMS 1992). Additionally, the generic IPCC technical guidelines for assessing climate change impacts and adaptations have been developed (Carter et al. 1994, Parry & Carter 1998) and then transformed into a form appropriate for coastal regions (Klein & Nicholls 1998a, b) [1].

Collectively, this experience has shown that there are still some obstacles to the conduct of comprehensive impact and response analyses due to: 1) incomplete knowledge of the relevant processes affected by sea-level rise and their interactions; 2) insufficient data on existing conditions; 3) difficulty in developing the local and regional scenarios of future change; and the last but not least the lack of appropriate analytical methodologies for some impacts. Nevertheless, if interpreted with the appropriate assumptions in mind these studies can provide important ideas into the potential impacts of sea-level rise [1].

3.1. National assessments: susceptible coastal areas

Nineteen national vulnerability assessment studies are compared in a relative sense in Fig. 2 using a vulnerability profile (cf. IPCC CZMS 1992). Table 1 gives the class definitions, which should be interpreted in a relative rather than an absolute sense. The results show considerable variation in the degree of impacts from country to country, reflecting that certain settings are more vulnerable than others. All river deltas naturally subside and thus experience a relative rise in sea level without any global rise. Based on above mentioned conditions, options to respond to sea-level rise are limited, and many highly populated river deltas appear highly vulnerable to sea-level rise [1].

Coastal wetlands and tidal flat areas on the other hand, appear to be threatened with loss or significant change in most locations as their present location is closely related with the present sea level. Flood and coastal erosion protection structures cause coastal squeeze and remove the possibility of wetland migration. Therefore, vulnerable wetlands may be lost before being adversely impacted by sea-level rise [1].

Sharing scientific data and management experience concerning wetlands within a region would improve vulnerability assessments and long-term wetland management [1].

3.2 Regional assessment: Europe

In Europe, important population and economic centres are concentrated in the coastal zone. Some coastal areas, such as much of The Netherlands, the fens in eastern England and the Po River Plain (Italy), are already beneath mean sea level, while many more areas are vulnerable to flooding from storm surges.

In some EU countries, coastal infrastructure has been planned for sea-level rise for many decades and now similar adaptation which anticipates accelerated sea-level rise is also being implemented [1].

Fig. 2. Vulnerability profiles for national assessments (from Nicholls 1995b)

However, maintaining and raising existing lines of flood defences does nothing to stop coastal squeeze [1].

But nowadays, Across Europe, a more strategic and integrated perspective to coastal management is being developed, which includes adaptation to climate change. The EU is presently promoting demonstration projects in Integrated Coastal Zone Management (ICZM) across the member states.

In conclusion, Europe's vulnerability to sea-level rise is relatively low due to its wealth, its historic investment in coastal and flood protection, and its active evaluation of coastal management approaches, including anticipation of sea-level rise [1].

3.3 Regional assessment: West Africa

Unlike Europe, the West African coast is relatively undeveloped and there is limited coastal engineering, except at harbours. Large areas of land could be lost in all these countries. Most of the threatened land is wetland areas within river deltas, or around estuaries and lagoons. Moreover, important resources to human society could also be affected. For instance, in Senegal, most tourist facilities could be destroyed and up to 180 000 people could lose their homes. In Benin, the coastal zone is densely populated and 1.35 million people (or 25% of the population) could lose their homes and economically important infrastructure would be lost or damaged. In Nigeria, it is estimated that 3.2 million people could be displaced from their homes [1].

The rapid increase of population in Lagos city (Nigeria), suggests that vulnerability to sea-level rise will also increase substantially over the next few decades, unless these changes are carefully planned.

West Africa appears to be vulnerable to accelerated sea-level rise, but there are insufficient national or regional studies to reach more precise conclusions and therefore, planned relocation of development inland out of the coastal zone can only be a partial solution. [1].

3.4 Regional assessment: South, South-East and East Asia

Comparing to West Africa, this region has been more extensively studied, particularly the consequences of sea-level rise for the low-lying deltaic plain of the Ganges-Brahmaputra in Bangladesh. Assuming no adaptation activities, estimated land loss due to sea-level rise and the present population of these areas are given in Table 1. Most of the threatened land is in deltaic settings and these impacts could be exacerbated by subsidence and human modifications to the deltaic sediment budget. Results are most dramatic in Bangladesh and Vietnam, where 15 million and 17 million people, respectively, could be displaced [1].

Country	SLR scenario (cm)	Land loss km²	Land loss %	People displaced Millions	People displaced %
Bangladesh	45	15668	10.9	5.5	5.0
Bangladesh	100	29846	20.7	14.8	13.5
India	100	5763	0.4	7.1	0.8
Indonesia	60	34000	1.9	2.0	1.1
Malaysia	100	7000	2.1	>0.05	>0.3
Pakistan	200	1700	0.2	na	na
Vietnam	100	40000	12.1	17.1	23.1

Table 1. Asia. Land loss and population displaced (1990s population) in South, South-East and East Asia for various sea-level rise (SLR) scenarios and no adaptation.Source: Nicholls et al. (1995).

Agriculture presently plays a major role in the economies of the region. Direct loss of land combined with less favourable hydraulic conditions may reduce rice production yields by 4% if no adaptation measures are taken into account.

In conclusion, the region is vulnerable to sea-level rise and nevertheless, climate change is recognised and the subject of ongoing investigation [1].

3.5 Regional assessment: Pacific Small Islands

In these areas the risk of inundation and flooding has been intensified by population migration from the outer islands to the capitals in each island country. Due to the traditional system of land ownership in the south Pacific, migrants cannot buy or rent land and they often settle in the areas most likely to be affected by sea-level rise such as on low-elevation reclamations. Moreover, beach erosion is

already a problem and most coastal villages studied in Fiji have built seawalls since 1960.

Vulnerability is produced by several factors, including a low resilience and therefore, enhancing natural and human resilience is an effective adaptation to sea-level rise.

Finally, the Pacific Small Islands came up with highly vulnerable to sea-level rise due to a range of physical, social and cultural factors. For the Pacific Small Islands, regional cooperation in developing vulnerability assessment and response strategies have particularly important role as the commonality of the problems is high, and many of the countries are too small to solve them alone [1].

4. Discussion

It is important to note that the fact, there are no winners given sea-level rise, rather there are small losers and big losers.

In case of Pacific Small Islands for instance, who have limited adaptation options, particularly the islands composed of coral atolls, lobbying will be an effective long-term strategy for mitigation of sea level rise.

In terms of scale there are two types of issues that we can differentiate and need to be solved: the problems of national level and the problems of regional level. And obviously, the regional collaboration would be more efficient. However, 2 sets of problems could not be solved at the national level: small islands due to their limited resources and the management of cross-border sediment transfer. Deltaic management must be linked to catchment management, which raises similar problems if the river catchment crosses frontiers.

Several activities would be helpful to improve our insight of local, national and regional vulnerability to sea-level rise. In particular, there is a need for more assessment of the impacts of sea-level rise, including: (1) better integration of the natural and social sciences so that the relative role of climate change to non-

climate-change factors can be more fully considered; and (2) more realistic evaluation of the range of possible response strategies [1].

5. Conclusions

The key issues raised by future sea-level rise display significant variation by region from an increased flood risk and coastal squeeze in the EU to the possibility of island abandonment in some cases in the Pacific small Islands. The clear boundary between what is appropriate at the national and regional level may be fuzzy, but in the most cases, regional efforts will be more efficient in terms of developing, assessing and solving an adaptation options. These regional models require further national assessments for validation purposes. In the end, a regional perspective provides a useful link between research and policy at the national and global scales [1].

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