SEA LEVEL RISE AND IMPLICATION ON COASTAL PROCESS: A REVIEW

Shatirah Akib
Senior Lecturer, University of Malaya
Kuala Lumpur, Malaysia

Afshin Jahangirzadeh
PhD Candidate, University of Malaya
Kuala Lumpur, Malaysia

Babak Kamali
Research Assistant, University of Malaya
Kuala Lumpur, Malaysia

Noor Liana Mamat
Bachelor Student, University of Malaya
Kuala Lumpur, Malaysia

ABSTRACT
The purpose of this review paper is to summarise the literature on sea level rise and its implication on coastal process. Sea level rise is the increase of volume of water in the oceans and seas relative to increase in height when compared to the ground level. Sea water covers increase when the sea level raises increase. Coastal process is the set of mechanisms that operate along a coastline, bringing about various combinations of erosion and deposition. Impacts in vulnerable regions of the Earth will be expected to have far reaching and dramatic by an accelerated global sea level rise. The other impacts of rising sea level are changes in salinity distribution in estuaries alteration in coastal circulation patterns, destruction of transportation infrastructure in low lying areas, and increase in pressure on coastal levee systems. The causes of a sea level rise are global warming and excessive extraction of groundwater in some areas.

Keywords: Global Warming; Sea Level; Coastal Process

INTRODUCTION
Sea level rise refers to the increase of water in the oceans and seas when compared to the ground level. Sea water covers increase when the sea levels raise increase. About 394 feet, 120 meters, global of a sea level rise rose during the several millennia that followed the end of the Ice Age almost 21,000 years ago before stabilizing between 3,000 and 2,000 years ago. When the instrumental record of modern sea level change shows evidence for the onset of the sea level rise, the indicators of sea level suggest that global of sea level did not change significantly from then until the late 19th century [1].

From the satellite observation that is available since the early 1990s, it provides more accurate sea level data with the nearly global coverage. Sea level has been rising at a rate around 3mm per annum. This record has been shown by the decade of long satellite alimentary data set since 1993. It is significantly higher than the average during the previous half century. Similar rates have been occurring in some earlier decades, and this observation has been confirming by coastal tide gauge measurements.

Two techniques have been used to determine the sea level rise. The techniques used are tide gauges and satellite alimentary [2]. Method of tide gauge provides sea level variations with respect to land on which they lie. The land motions need to be removed from the tide gauge measurement. This will extract the signal of sea level change resulting from ocean water volume and other oceanographic change. The satellite alimentary method is used to change the sea level respect to the earth’s center of mass and thus it is not distorting by land motions, except for small component resulting from large-scale deformation of ocean basins. The global average sea level rose at an average rate of 1.3 to 2.3 millimeter per year between 1961 and 2003. An estimate by Intergovernmental Panel on Climate Change (IPCC) within that period was reported that the rate of a rise was faster between 1993 and 2003 about 3.1 millimeters per year [3].

Overall from the IPCC conclusion, there is a high confidence that the rate of observation for the sea-level rise has risen from the 19th to the 20th century. Average of a global sea level rise at a rate of about 1.7 millimeter per annum shows the estimation for the 20th century. In 2001, IPCC projections for a sea level rise were between 9 and 88 cm between 1990 and 2100 and global average surface temperature rise of between 2.5 to 10.4 degrees C. In 2007, IPCC projections based on different scenarios predict that the sea level rise from 0.18 to up to 0.59 millimeter by 2099. With large populations, the project in the sea level rise will affect low-lying coastal areas toward the end of 21st centuries. Cost for adaptation was at least 5 to 10 percent of gross domestic product [4].
Coastal processes are the set of mechanisms that operate along a coastline, bringing about various combinations of erosion and deposition. The land water interface along the coastline is always in a highly dynamic state, and nature works towards maintaining an equilibrium condition. The energy due to tide, waves, wind, and currents are constantly working in the coastal zone. Dissipation of energy which is due to tide, wind, waves, and current is often provided by the beaches, mud flats, marshes and mangroves.

CAUSES OF SEA LEVEL RISE

The causes of a sea level rise are global warming and excessive extraction of groundwater in some areas, especially in East Asia. Global warming has led to the ice melting at both polar of regions, and that water is added to the existing bodies of water. Excessive extraction of groundwater in some areas especially in East Asia has caused the ground level to sink by up to one decimeter or more annually, and it is causing a similar effect to the rise in sea levels. There is also another cause of sea level, which is cause by thermal expansion of oceans, melting of glaciers and ice caps, melting of the Greenland and Antarctic ice sheets, and changes in terrestrial storage. The sea level changes when the intensity and frequency of storm surge and coastal flooding increases. The objectives of this review paper are to review the impacts of sea level rise on coastal processes and to suggest the future direction of this issue.

IMPACTS OF SEA LEVEL RISE

Sea level rose by 4 to 8 inches around 10 to 20 cm because of melting glacier ice and thermal expansion of warmer ocean water during the 20th century. It has been predicting that sea level rise will be even greater as the oceans warm along with the rest of the earth. When the temperature increases, the water will expand higher. Global mean sea level rise as much as 33 inches were predicted by climate change models during the 21st century. Impacts in vulnerable regions of the Earth, where subsidence and erosion challenges exist will be expected to have far-reaching and dramatic by acceleration in global sea-level rise [6]. Example for rising seawater is coastal wetlands and mangroves in southern Florida. Approximately one million acres of Louisiana wetlands have become open water since the mid-20th century [7].

The potential cause of increase in the intrusion of saltwater into coastal aquifers is a sea level rise. Sea level rise increases mortality of trees in coastal areas of Louisiana and southern Florida, where saltwater already intruded into groundwater. The other impacts of rising sea level are changes in salinity distribution in estuaries, alteration in coastal circulation patterns, destruction of transportation infrastructure in low-lying areas, and increase in pressure on coastal levee systems [8]. Atlantic and Gulf Coast shorelines are easier to be exposed to long-term sea-level rise, as well as any increase in the frequency of storm surges or hurricanes. A small rise in sea level may produce a large inland shift of the shoreline. This is caused by the slope of most erosion events on these coasts. This will increase the threats to coastal development, freshwater aquifers, fisheries, transportation, and infrastructure. These impacts can adversely affect the quality of resources of water. Moreover, reductions in stream flows, increasing in storm surges, and higher water temperatures are the potential negative implications of climate change for water quality. An increase in the number of intense precipitation days could lead to increases in the variety of agricultural and municipal polluting substances being washed into rivers, streams, estuaries, and lakes. Sea-level rise causes saltwater intrusion into rivers, estuaries, and coastal aquifers [9].

COASTAL PROCESS

Coastal processes are the set of mechanisms that operate along a coastline, bringing about various combinations of erosion and deposition. The land water interface along the coastline is always in a highly dynamic state, and nature works towards maintaining an equilibrium condition. The energy due to tide, waves, wind, and currents are constantly working in the coastal zone. Dissipation of energy due to tide, wind, waves, and current is often provided by the beaches, mud flats, marshes, and mangroves [10].

Human use of the coasts also requires space which results in unstable coastal systems. This induces coastal erosion, sediment transport and accretion. This process is highly unpredictable, and it is a challenge to coastal scientists. Some of the coastal processes are sediment transport, currents, denudation, deposition, flooding, diffraction, refraction, and erosion. The analysis and prediction of sediment transport have a great commercial, aesthetic, social, and scientific importance owing to the sustainable development and coastal zone management.

Accretion is defined as a natural deposition of sediment in a particular location. Beach nourishment is the restoration of a beach by the mechanical placement of sand on the beach for recreational or shore protection purposes. Erosion is the removal of sediment from a particular location by the action of wind or water. The definition of a groin is shoring not parallel structure, install singly or as a field of groins, design to trap sand from the littoral drift system. Long shore transport or littoral drift is the displacement of sediment down the shore where it is parallel to the shore. Tombolo is the combination of an offshore rock or island which is connected to the beach by a sand spit. Sand spit is the low tongue of land or a relatively long narrow shoal extending from the land. Gabions are boulders and rocks wired into mesh cages and usually placed in front of areas vulnerable to heavy to moderate erosion. Onshore transport is movement of sediment or water towards the shore. There are four main parts in coastal profile, which are the offshore, near shore, beach, and coast (Figure 1) [11].

The processes initiate sediment transportation changes in the water level, tides, waves, currents, and then stream outflow. The areas affected by the forces of the sea are the beaches, the gulf, and the near shore zone regions that
experience the full impact of the sea’s energy. There are two
general types of dynamic beach response to wave motion,
which are the response to normal condition and response to
storm condition. Normal condition prevails most of the time.
The wave energy is easily dissipating by the beach and natural
defense mechanisms. When storm conditions generate waves
containing increase amount of energy, the coast must respond
with extraordinary measures, such as sacrificing large section
of beach and dune [12].

Figure 1: Coastal Profile

Alternate erosion and accretion may be seasonal on
some beaches which are the winter storm waves erode the
beach, and the summer waves rebuild it. Another near shore
dynamical system is littoral transport, which is the movement
of sediments in the near-shore zone by waves and currents.
Littoral transport is divided into two general classes, which are
long shore and onshore offshore transport. Long shore transport is transported parallel to the shore, and onshore-
offshore transport is transported perpendicular to the shore.

SEA LEVEL RISE ON COASTAL PROCESS AT
CALIFORNIA

One of the statewide agencies is California Coastal
Commission. It is responsible for planning and regulation
within the California Coastal Zone. Changes in the future of
sea level may affect the entire coastal zone. The effects of this
global rise in sea level have been dampening by uplift of the
land and tectonic forces along the California coast. Since
much of the California coast is experiencing uplift often due to
tectonic forces, the relative sea level rise has been less than the
rate of sea level change. Evidence of this uplift is the coastal
marine terraces, inland of the California shoreline. Some uplift
or subsidence events occur fairly slowly also can occur very
fast. Localized uplift of over 3 feet had occurred in Ferndale
Earthquake. The cause of gradual localized subsidence or
sinking of the land surface is fluid withdrawals from some
southern California oil fields. Before the fluid injection halting
or slowing these effects, the shore area of Long Beach
experienced up to 3 meters of subsidence [13].

Mean of sea level is the one component of tidal
record. The information of all tidal constituents which are
higher high water, lower high water, higher low water, and
lower low water, extreme high and low water, and mean sea
level for day to day activities are recorded by a full tidal
record. The elevation of mean sea level is the second
important than the tidal range and elevations of the high and
low tide. The intertidal zone is more critical than the elevation
of mean sea level for the design of wetland restoration
projects.

All the tidal components have not changed
uniformly. For all the stations in California except Crescent
City, the tidal record shows an increase in mean sea level,
some show an increase in tidal range, and others show a
decrease. The diurnal range increased at a rate of 0.199 feet
per 100 years and the mean range at a rate of 0.192 feet per
100 years. The rise in MHHW and MHW for the same period
is 0.259 meter per 100 year and 0.82 feet per 100 years. The
rise in mean sea level is about 0.219 meter per 100 years. It
appears that the tidal wave where it is not to be confused with
a tsunami wave that is often incorrectly called a tidal wave
changes over time, possibly caused by changes in ocean
temperature, water density or depth of the thermocline.

Future sea level will depend on several factors. The
factors are future global temperature, lag time between
atmospheric changes and oceanic reactions, thermal expansion
of ocean water, effects of atmospheric temperature changes on
Antarctica, Greenland and other glaciers, and local subsidence
and uplift. There are two methods for viewing the future sea
level. The first method is a high rate of a sea level rise, a
medium rate, and a low rate. The second method for viewing
the future sea level rise is to develop probability in based
estimates [14].

Depth limited is the influence by bottom depths and
for most locations along the coast, the heights of near-shore
wave of the wave heights along the California coast. The wave
height can be higher when the water depth increases. During
high tide than low tide, the occurrence that will impact the
coast is higher wave. Wave energy increases double of the
wave height. Thus, 0.6 meter wave would have four times the
energy of a 1 foot wave. Change in wave energy and the
potential for shoreline damage from wave forces due to small
changes in water level. 1 to 3 foot rise in sea level, such as a
project to occur over the next 100 years, would cause
enormous changes in near shore wave energy.

The consequences of a 0.3 to 0.9 meter rise in sea
level are far reaching. Factors that contribute to the amount of
damage cause by the 1982/83 El Nino, was several storms
coincide with high-tide events. Besides, the elevate water
levels from the tides and low pressure system combine
brought waves further inland than would have occur
otherwise. Some global circulation models predict significant
increases in run-off from coastal watersheds in California.
These increases in run off could increase supplies of sediment
to the coast. It occurred along sections of the coast where
sediment supplies are not restricted by dams or reservoirs. The
amount of increases in sediment supply would not necessarily
 correlate with the percent increase in run off where the
quantitative changes to sediment supply cannot be determined at this time. To provide even a general estimate of how sediment supply could change for possible changes in run-off are additional studies at the watershed level.

Over 25 million people lived in the coastal counties of California. By 2025, the coastal population is expected to grow by 27 percent, to over 32 million people. Except for San Diego which is expected to have a 60 to 90 percent growth, coastal counties are expected to have a 20 to 60 percent increases in economic growth. Current patterns in land use and development of coastal lands are the base of the economic losses. The coast is at the intersection of increase development pressure, water elevation, wave energy, and coastal erosion.

Hard engineering such as seawall, revetments, breakwaters, levees, and other structures are built to protect inland area. Soft engineering such as beach nourishment or vegetate buffers, accommodation, and retreat are the actions that can be taken in response to sea level rise. Some responses such as hard engineering immediately can be applied to individual properties, regardless of the actions taken on surrounding properties, while soft engineering or retreat are often best apply on a large scale. Because of the uncertainty associated with sea level change, most of the experts who develop sea level response scenarios recommended that solutions should be as flexible as possible. It is not just to accommodate a single prediction of the future sea level rise [14].

There are a few ways California Coastal Commission currently addresses the sea level rise in its planning and regulatory process. The Commission requires setbacks to assure site stability for the foreseeable future conditions and review engineering designs for new development. To allow future inland or upland migration of wetlands, wetland buffers could be established. The current and future properties owners, the conditions at a site may worsen with time have been notified by various permits. It also has applied a condition for the assumption of risk or conditions that prohibit future seawalls. For example, an oil development project in Hermosa Beach, the Commission required fluid injection to prevent subsidence. It was combined with a monitoring program to ensure that the injection was effective. On the planning side, the Commission has been involved with several states, local studies of shoreline change that have improved overall understanding of the components that contribute to shoreline retreat. The Commission has a very strong public education program. It can be used to provide information on a sea level rise, as well as other coastal hazards. Finally, to promote vacant the acquisition lands in high-hazard areas, the Commission can coordinate with the California Coastal Conservancy.

States have not passed special regulations to address a sea level rise. Most coastal states have coastal programs that address the sea level rise in a manner. It is similar to California where they modify or adapt current regulatory mechanisms to cover the effects of a sea level rise. Texas has a program of rolling easement that relocates the public land boundary to the current line of vegetation. The construction of any hard shoreline armoring has been prohibiting by states like South and North Carolina and Massachusetts. The responses that can be used to address the sea level rise to soft engineering, accommodation, and retreat are these limits. Maine has regulations that prohibit rebuilding structures that have been damaged by storms. The new structure could reasonably be expected to be damaged within the next 100 years. This regulation covers damage from sea level rise or other coastal hazards [15].

In California, it is likely that a combination of hard engineering, soft engineering, accommodation and retreat responses will be considered to address a sea level rise. There are situations where each response may be appropriate and well suited. The important thing in all coastal projects is to recognize and accept that there will be changes in sea level and other coastal processes over time. Careful review, siting and permitting of new projects on the coast can increase the likelihood that these projects will be able to adapt and change to accommodate future coastal hazards. It will be important that the Commission continues to be involved in studies of the California coast, coastal hazards and changes in coastal processes. Public education programs and efforts to alert coastal property owners to the dynamic and changing natural of the coast will be important.

SEA LEVEL RISE ON COASTAL PROCESS AT VIETNAM

Vietnam is located on the Indochinese peninsular of South East Asia. Mainland stretches from 08° 10' to 23°24' north latitude and widens from 102°09' to 109°30' east longitude. It is mainland frontier amount to 4, 510 (km), of which 1, 306 (km) are adjacent to China in the north, 2, 067 (km) to Laos in the west and 1,137 (km) to Cambodia in the west south. Vietnam embraces around 3,260 (km) of coastline from Mong Cai in the north to Ha Tien in the south. It is excluded the coastline of islands with two fertile deltas of Red river and Mekong river discharges into the sea. It is bordered by the Gulf of Tonkin and the South China Sea to the east and the Gulf of Thai Lan to the south. Offshore Vietnam's continental shelf, there are thousands of islands and islets lying scatter from the northern to the southern end [16].

There are various tidal system and always changes in South China Sea, but almost coastal zones are influences by diurnal tide, some other places are influences by semi-diurnal tide and mix. The tide range reaches about 4.0 in the north (Red River Delta) and decreases to 0.5 in the central area, then increases up to 3.5 in the south (Mekong River Delta). The difference in the tide range and character are caused by different geographical conditions. According to season and location, the coastal current are varies in velocity and direction. The largest is along the central coast, and the second largest is offshore of the Mekong deltas.

Relative sea level rise in Vietnam is calculated from tide-gauge data collected by the Marine Hydro meteorological
Centre at the chief stations. The figure illustrates sea level varying for the period of 1960 to 2000 at Hon Dau station. It is the longest clear typical data of sea level rise. Rise about 1.9 millimeters per year has been observed in this period. Different trend has been shown at the Vung Tau station in South Vietnam. This maybe an unreliable result as the sitting of this station has changed, although Da Nang station in Centre Vietnam also shows a different trend from Hon Dau. Up to now scientific researches in Vietnam have been examined for evidence of sea level rise. Tuong recorded increments in sea level varying from 1.75 to 2.56 millimeter per year at chief stations. This is in broad agreement with the observed rise in global mean sea level.

Loss of wetland and other low land and population displacement, increase vulnerability to flooding, including storm events, accelerated erosion along the coasts and in river mouths, increased salinity of estuaries, saltwater intrusion into freshwater, aquifers, and degradation of water quality are the serious physical impacts of sea level rise on the coastal zone [17].

INNOVATION AND FUTURE DIRECTION

Sea level rise could be reduced if global warming is prevented. The pace of global warming can accelerate Global protocol against depletion of the ozone layer which was called to the attention was implemented earlier than expectation. As a result, chlorofluorocarbons have remarkably decreasing from the atmosphere, and ozone layer can be restored in another 50 to 60 years. Dealing with CO2 may not be as easy as the ozone, but the important thing is the best prevention against global warming. One of the effects of the sea level rise is flooding. To prevent flood from occur, a good drainage system has to be a planned. Function of the drainage system is to smooth the movement of water to the ocean or sea. The good drainage system will allow the water to move smoothly to the reservoir.

CONCLUSION

Global warming caused the sea level rise to increase. Preventions are very essential to reduce the impact of sea level rise. This review paper summarized the literature on sea level rise and implication on coastal process. Recent innovations and their potential for further research work are needed to reduce the impact of sea level rise.

REFERENCES