Joint GSA Penrose/AGU Chapman Conference Report

Coastal Processes and Environments under Sea-Level Rise and Changing Climate: Science to Inform Management

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CONVENERS:

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Acceleration of sea-level rise (SLR) in response to global climate change is well underway. Current global SLR averages ~3.0 mm/yr, although the actual rate varies globally. In comparison, sea-level curves indicate that SLR was only a fraction of a millimeter per year over the past few thousand years. The increased rate of global SLR is exacerbated on a regional scale by decadal-scale oscillations that are due to climatic and oceanographic controls, varying wave climate (wave height, period, and direction), increased subsidence due to subsurface fluid extraction, and anthropogenic alterations in sediment supply to coasts—in particular, the alteration of sediment delivery and distribution within deltas. Coastal response to these changes is occurring at alarming rates, resulting in billions of dollars in damage to infrastructure, massive taxpayer funding for recovery, degradation of ecosystems, and, in the worst case, loss of life, as experienced in major storms. Scientific understanding of the causes and magnitudes of coastal change is far from the level needed to confidently predict future change.

On 14–19 April 2013, 84 coastal scientists and social scientists from twelve countries gathered in Galveston, Texas, USA, for the first joint GSA Penrose/AGU Chapman Conference. The conference venue was the historic Strand Area of Galveston, where approximately 6,000 people perished during the "Great Storm" of 1900 and where SLR, diminished sediment supply, and human influence threaten the sustainability of the island.

The first four days of the conference were devoted primarily to talks and poster sessions aimed at synthesizing the state of knowledge on (1) the causes, impacts, and record of sea-level rise, coastal subsidence, severe storms, changes in wave climate, sediment delivery and dispersal in coastal systems, and biological influences on coastal sedimentology and morphology; (2) the status of numerical models needed to predict coastal change; and (3) societal impacts of coastal change. A half-day field trip focused on the upper Texas coastal barriers and bays and on sustainable strategies for Galveston Island. The final day was devoted to discussion of how science can and should inform the public and policy makers about the realities of SLR and coastal change and how scientists can be more effective in initiating appropriate policy responses.

At the beginning of the conference, it was determined that the results should be conveyed in a way that captured the essence of the presentations and discussions with minimal rhetoric. Scribes were assigned to highlight key findings, and their results were compiled into bullet statements that were discussed and agreed on by the group on the last day of the conference.

SEA-LEVEL CHANGE

1. Acceleration of SLR in response to global climate change is well underway; the rate of sea-level rise during the twentieth century is the highest rate in the past 2,000 years. The rate of global SLR is expected to increase in the twenty-first century, although the magnitude is uncertain.
2. Rates of sea-level rise are not constant. For example, at ca. 14.6 ka, a rapid rise of ~20 m occurred within ~340 years (Meltwater Pulse 1A, MWP-1A), highlighting the potential for rapid contributions to SLR by ice sheets.
3. Major challenges remain in understanding sea-level change at the regional level. This is due to uncertainties associated with glacial isostatic adjustment (GIA), steric changes and dynamic ocean processes, and tectonics.
4. The study of past sea-level changes is pertinent for testing climate and ice-sheet models under different forcing conditions. Estimations of past sea level during previous warm

periods provide constraints on the magnitudes of SLR and the ice mass balance of the Greenland and Antarctic ice sheets.

5. Oceanographic controls on oscillation in sea level exert significant control on coastal change at sub-centennial time scales. In some areas, these oscillations are driven by climatic oscillations that are understood and therefore predictable. In other areas, the causes are uncertain.

TROPICAL CYCLONES

1. It is unknown if the magnitude and intensity of tropical cyclones in the Atlantic and Gulf coasts will increase in the future. Nevertheless, SLR will exacerbate flooding from tropical cyclones.
2. Tropical cyclones result in punctuated response of coasts to SLR and variations in sediment supply (tipping points in coastal evolution). The relationships between storm magnitude and duration and sand erosion and transport, and hence shoreline recovery, are poorly understood.
3. Changes in wave climate (wave height, frequency, and direction) can profoundly impact coasts, even in a stable sea-level scenario. The relationships between wave regime and climate oscillations are well established in some regions, and therefore predictable, but in other regions, such as the U.S. West Coast, remain problematic.

COASTAL EVOLUTION

1. Vertical land motions are generally dominated by shallow processes over deep processes in low-gradient coastal settings, with locally significant, decadal-scale changes in subsidence driven by oil, gas, and water extraction.
2. Deltas of the world (e.g., Asia, Europe, Gulf of Mexico) are experiencing unprecedented change that is due to anthropogenic influence—in particular, alteration of sediment delivery and distribution, local land-use, and increased subsidence.
3. Sediment type and the volume of sediment delivery in response to climate change are important in both deltaic and non-deltaic coastal settings. Organic and terrigenous sediment accumulation determines the upper limits of accretion rates.
4. Sea-level rise leads to pervasive shoreline retreat. Numerical models indicate that that shoreline response can be as much as 1000 m per 1 m rise. However, actual rates of response have been highly variable in the past, and current rates of change are highly variable across relatively small stretches of coastline. This variability highlights the importance of other factors in regulating coastal response to SLR. These include sand availability, substrate conditions, frequency and magnitude of storm impacts, and the antecedent topography across which these shorelines are migrating.
5. Given the complex response of coastal systems to SLR, passive inundation models do not accurately portray magnitudes of change. Furthermore, these models convey the message that SLR is a prediction and not an ongoing process and detract from the importance of rates of rise in coastal change.
6. Biological processes are important to mitigate and control landform evolution and therefore coastal change.
7. The impacts of SLR include coastal flooding, groundwater contamination and saltwater intrusion, and related soil salinization that can extend tens of kilometers inland (e.g., in the Venice lagoon region).
8. Human modification can strongly modify natural functioning and response to climate change. Such modifications have resulted in accelerated erosion of shorelines, complete loss of wave-dominated and bayhead deltas, dramatic loss of wetlands, increased coastal flooding, and increased vulnerability to storm impact.

SOCIO-ECONOMIC IMPACTS OF SEA-LEVEL RISE AND COASTAL FLOODING

1. To understand vulnerability and resilience to environmental hazards, we must understand not just the physical impact of the hazard, but the way that physical impact affects the activities by which people make their livelihood. Well-intentioned policies and infrastructure projects that fail to understand these connections often end up futile or even counterproductive.
2. Coastal flooding poses significant socio-economic and environmental threats globally, and future climate and socio-economic change drivers will only exacerbate these impacts.
3. There is a need to generate geohazard and coastal vulnerability maps. These are user friendly and more useful to the public and planners than reports, figures, and model outputs. These maps must be updated using more sophisticated coastal monitoring that relies on the latest technologies in order to provide the best adaptive strategies for coastal sustainability.
4. Coastal protection involves maintenance costs that increase with time. Energy scarcity and cost need to be integrated into societal programs to deal with climate change.
5. Education and engagement of stakeholders is critical for success. Incorporating science into the decision-making process requires the identification of knowledge gaps and understanding of how these gaps can be filled.
7. Coastal sustainability requires coordination among governmental, regional, and municipal institutions and agencies with overlapping fields of interest and responsibility.
8. Coastal response to global climate change is a global issue. There is a need to increase international collaboration to expand our knowledge and to assist those countries where change is occurring at alarming rates but where scientific information is critically needed to mitigate change. An example would be the Philippines, with tens of thousands of kilometers of coastline and a large population that is subject to multiple geohazards, but with very few coastal scientists. Bangladesh is an example where international collaboration is working effectively, with UK-funded and U.S.-funded research being presented at the meeting.

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