DOWNLOAD PDF THE IMPACT OF SEA-LEVEL CHANGE PAST, PRESENT, FUTURE

Chapter 1 : Sea Level Rise | Smithsonian Ocean

Visit interactive features about Earth's changing climate and see how scientists are gauging future sea level rise, at Climate Basics and Sea Change Science. Or, jump right in and watch the three Sea Change videos.

Venue Koningsbergerbuilding Logistics For this conference, the definition of an early-career researcher ECR is those who have obtained or expect to obtain their PhD in or later. The workshop will be limited to 75 participants. The selection procedure will be based on the quality of the abstract words max. Description The conference aims to facilitate scientific exchange between ECRs from a broad range of disciplines working with sea-level change. Koningsberger building â€" Utrecht University 9. Roland Gehrels "Salt marshes are palaeotide gauges" Talk 1 20 min: Rachael Lem "Sea-level changes in the Gulf of Guinea over the past , years: ECR Keynote 30 min: Geoffrey Richards "Exploiting new Holocene sea-level archives to inform future sea-level predictions: Maryam Yousefi "The contribution of glacial isostatic adjustment to past and future sea-level change along the west coast of North America" Talk 5 20 min: Ksenia Poleshchuk "Sea level changes in Dunderbukta west Svalbard based on diatom analysis" Marta Marcos "20th century sea-level change models and observations , contributions to sea-level change, future projections 21st century and beyond Talk 1 20 min: Roelof Rietbroek "Unravelling the present day sea level budget with geodetic datasets" Talk 3 20 min: Molly Keogh "Measuring rates of present-day relative sea-level rise in low-elevation coastal zones: A critical evaluation" Talk 4 20 min: A multi-proxy model" Talk 2 20 min: Erwin Lambert "The impact of changing wave setup on future extreme sea levels" Sanne Muis "Global modeling of storm surges and extreme sea levels" Talk 3 20 min: Yoann Poher "Impacts of sea-level rise and responses of Mediterranean coastal wetland biodiversity: Philip Minderhoud "The truth sinks in: Fraser Sturt "Submerged landscapes: Claire Mellet "Beyond Doggerland: Submerged landscapes of the southern North Sea" Talk 1 20 min: Onema Adojoh "Deltaic shift and vegetation response to sea level change during the Late Quaternary: Future concern for the Coastal Margin of the Niger Delta" Talk 2 20 min: Closing session Abstract submission and grant request: Friday 25 May Conference fees Conference and hostel shared-room accommodation: At abstract submission, participants are asked to indicate whether they require support. The outcome of the grant selection will be communicated to participants by 30 March Grants will be transferred after the conference, after submission of completed reimbursement forms to be handed out at conference and receipts of costs. Travel Excellent train connections between Amsterdam Schiphol Airport and Utrecht Central station 35 minutes, every minutes. Excellent international train connections within Europe. Organizing committee, consisting of ECRs Dr. Hijma Deltares and Dr. Further information Send queries to: This email address is being protected from spambots. You need JavaScript enabled to view it. Check the official website for updates:

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Chapter 2 : Climate Change: Global Sea Level | NOAA calendrierdelascience.com

Fisheries, Aquaculture and Climate Change: A New Jersey Perspective Rutgers University Plant Breeders Address Climate Change Living Shorelines and Sea Level Rise on New Jersey's Delaware Bayshore.

Atlantic Coast Sea Level Rise: Past, Present, and Future Published: June 21st, , Last Updated: June 21st, Three things you should know: East Coast, the sea level has been rising since the late s at a faster rate than at any other time during the past 2, years. According to a new study, in coastal North Carolina the sea level has been rising at an unprecedented rate during the past years. What the new science says: Atlantic Coast, sea level rise has been occuring at a faster rate during the past years than at any other time in the past 2, years. Historically, when global temperatures have been on the rise, sea level has increased. During cooler times on Earth, sea level has remained stable or has even decreased slightly. In other words, just because temperatures and sea level are both rising now, how do we know they are really connected? In this new study, researchers from the University of Pennsylvania along with colleagues from Finland, Germany, and Pensylvania State University have reconstructed a 2,year history of sea level changes along the North Carolina coast by studying markers that tide-sensitive creatures left behind in coastal sediments. Then, during a warm period between A. In the midst of a cooler period that followed, sea levels stabilized, and then around , they began to rise again as temperatures picked up. The rate of sea level rise during the past years, however, has been like nothing else recorded during the past 2, years, the study states. The warming that has taken place during the last century has caused seas to rise in North Carolina by an average of 0. Why the science is important: This new study of sea level rise is all about the past, describing how global temperature changes relate closely to sea level rise during the past 2, years. Key implications of the study, however, point firmly toward future sea level rise. Climate scientists project that average temperatures around the planet are going to keep climbing as greenhouse gas concentrations increase, so now this study adds more evidence to show that sea level rise will likely continue too, possibly at an accelerated rate. Most climate models project that global temperature will rise more quickly throughout the coming decades, though, so if sea levels follow suit â€” and this study suggests they will â€” we should expect sea level rise to be measured in feet, rather than inches, by the end of the century. Models devised specifically to project sea level rise also show that changes will speed up in the next century, rather than remaining steady. This new 2,year reconstruction, and the pattern of sea level rise it shows in North Carolina, in fact, is very consistent with a model proposed by a study , which shows that global sea levels could rise at least 3 feet by compared to current levels.

Chapter 3 : Sea Level: Past, Present and Future â€” Sea Change

Chapter C. Past, Present, and Future Sea Level Rise and Effects on Coasts Under Changing Global Climate By S. Jeffress Williams1 Abstract Coastal regions, at the interface between the land, oceans.

The authors have declared that no competing interests exist. Conceived and designed the experiments: Received Aug 20; Accepted Dec Abstract Intertidal rocky reefs are complex and rich ecosystems that are vulnerable to even the smallest fluctuations in sea level. We modelled habitat loss associated with sea level rise for intertidal rocky reefs using GIS, high-resolution digital imagery, and LIDAR technology at fine-scale resolution 0. The results indicate that changes to habitat extent will be variable across different shores and will not necessarily result in net loss of area for some habitats. In addition, habitat modification will not follow a regular pattern over the projected sea levels. Two of the headlands included in the study currently have the maximum level of protection within the SIMP. However, these headlands are likely to lose much of the habitat known to support biodiverse assemblages and may not continue to be suitable sanctuaries into the future. The fine-scale approach taken in this study thus provides a protocol not only for modelling habitat modification but also for future proofing conservation measures under a scenario of changing sea levels. Introduction There is strong consensus that sea levels will rise by as much as 1 m by in response to a warming climate [1]. However, this condition of relative stasis changed during the 19th and early 20th centuries when the first indications of a rising sea level became evident [2] , [3]. Recent sea level rise SLR is a result of both ocean thermal expansion and the melting of glaciers and ice caps, and accelerated rates of SLR are likely to be largely attributable to the liberation of water comprising polar ice sheets [2] , [4] â€” [6]. According to Church et al. Current rates of SLR are at the upper limit of the projections of the Third Assessment Report of the Intergovernmental Panel on Climate Change IPCC [7] , and there is strong concern that the contribution of shrinking ice sheets will push these even higher, especially if greenhouse gas emissions continue to increase [2]. Most of the climate models indicate that the increase in temperature over Greenland is one to three times higher than the global average. Also, the West Antarctic Ice Sheet could potentially contribute about 6 m to the sea level. The entire Antarctic ice sheet holds enough water to raise global sea levels by 62 m [5]. As current predictive models have a high level of uncertainty, there is concern that the estimates of mean SLR by could be considerably underestimated [7] , [11]. Future SLR is not expected to be globally uniform due to ocean circulation, wind pressure patterns and geological uplift [7] , [11] â€” [14]. Effects operating over local or regional scales, such as storm surges and spring tides, will add further variability [11]. While the magnitude of SLR is clearly difficult to predict with certainty, there is little doubt that intertidal habitats are likely to be the first to experience sea level rise-related effects [15]. As one of the most accessible, diverse marine habitats, rocky shores are important features for education, recreation and harvesting [17] â€” [19]. When compared to other intertidal habitats such as beaches, mangroves and estuaries, and due to their geological nature, erosion processes are relatively slow on intertidal rocky reefs obviating the creation of new habitat over short periods of time: Indeed, habitat loss and change is potentially one of the greatest threats to biodiversity conservation in a changing world [20] , [21] , and is a key challenge for the management of biodiversity through static systems such as Marine Protected Areas MPA [22] , [23]. Predicting the magnitude of changes to intertidal rocky reefs, however, relies not only on accurate predictions of SLR, but also on the development of technologies to map and quantify habitats and environmental processes at appropriate spatial scales, in an efficient and cost-effective way [24]. Tools such as remote sensing and modelling, are becoming increasingly available [8] , [25] â€” [27] and are already being applied to the assessment of risk associated with SLR [28]. To date, LIDAR Light Detection and Ranging has the highest horizontal resolution and vertical accuracy [24] , [29] and is the only technology suitable for analyzing sea-level changes in the range predicted for the next years [30] , [31]. Specifically, we evaluated seven categories of rocky shore habitat lower shallow pools, upper shallow pools, deep pools, upper boulder fields, lower boulder fields, upper platform and lower platform and the current area of each habitat type was compared to future modelled scenarios to determine the likely changes to these intertidal rocky ecosystems and the possible consequences for biodiversity conservation. The five headlands chosen for this research were: The region has a 2 m, semi-diurnal tidal cycle, a Mean Sea Level of 0. Each of the five headlands is composed of metamorphic greywacke deposits from the late Carboniferous, approximately â€" million years old [33]. The headland landscape comprises cliffs, bedrock and scree boulder fields with variable wave-driven erosional patterns and areas of sand accumulation. The region is renowned for the overlap of tropical and temperate currents [34] , facilitating a high biodiversity due to the presence of tropical, temperate and endemic species [35] â€" [38]. There have been few published studies on the biodiversity and ecology of rocky shore habitats within the region, but those that have been conducted, indicate a high diversity, and distribution patterns that are largely driven by habitat type and exposure to wave energy [36]. The total intertidal rocky shore mapped area for each headland was:

Chapter 4 : Atlantic Coast Sea Level Rise: Past, Present, and Future | Climate Central

Past sea-level trends are dominated by global tectonics, geoid changes, eustasy and global isostatic adjustments. Most of these factors have a global impact, but at rates differing in time and place.

Posted on 7 December by Rob Painting Key points An accurately dated, near-continuous, history of sea level variations for the last , years has been compiled. The Greenland ice sheet responding virtually straight away years lag time , and a lag for the Antarctic ice sheet. These response times are much faster than was previously commonly suspected, and implies that once sufficient polar warming is underway, future ice sheet collapse may be unavoidable. During all episodes of major global ice loss, sea level rise has reached rates of at least 1. This is 4 times the current rate of sea level rise. Figure 1 - Sea level reconstruction from , years ago to the present. The downward-pointing red arrows indicates peaks in sea level rise exceeding 1. The break in the record is due to the absence of foraminifera upon which the reconstruction is based as a result of excessively salty seawater during the last ice age. Adapted from Grant These consisted of long cool periods glacials where giant icesheets have grown on the continental land masses at, and near, the poles. With the water evaporated off the oceans being locked up as ice on land, this ice sheet build-up substantially lowered global sea level. During the shorter, warmer, intervals interglacials the ice sheets have disintegrated, and with their glacial meltwater draining back into the oceans, sea level has risen. From the coldest part of the last ice age roughly 20, years ago to present, global sea level has risen an astounding metres. For the current interglacial, the orbitally-driven warming eventually came to an end after the Holocene Climatic Optimum HCO , and by years ago all the vulnerable land-based ice had disappeared. The volume of the global ocean was static until the arrival of the Industrial Revolution , and by the 19th Century global sea level had begun to rise again. Figure 2 - Global mean sea level from to with one standard deviation error estimates Church With some metres worth of global sea level equivalent locked up in the vast ice sheets of Greenland and Antarctica, and with global warming well underway, it raises the question of how much sea level rise we are likely to see this century and beyond , and just how fast this might happen. Because the dynamics of ice sheet disintegration are only very crudely known, and ice sheet modelling is in its infancy, there is a large range of estimates of future sea level rise. Many now seem to converge on metres of sea level rise by - much higher than current rates. But is this realistic? A recent paper, examining past ice sheet disintegrations, lends credence to these estimates. Rapid Coupling Between Ice Volume and Polar Temperature A peer-reviewed paper, Grant , outlines how the authors created a well- dated, and near-continuous, record of sea level over the last , years, a period which spans the last interglacial the Eemian , and the last glacial maximum. Of particular interest is the finding that, during all periods of major global ice volume loss, rates of sea level rise reached at least 1. An arguably more important finding that the more finely resolved dating uncovered, was that major ice sheet reductions as implied by sea level rise followed polar warming much quicker than had previously been suspected. Because they utilize minerals dissolved in the surrounding seawater to build their shells, forams incorporate elements into their shells which can provide information about the climate at the time in which they lived. Although a near-continuous record of relative sea level for the Red Sea has been constructed Rohling [] , accurate, and independent, dating for comparison with ice-core data has proven problematic. Grant , however, came up with a clever way around this roadblock. This "basin effect" was exploited to build a sea level history in the Red Sea, because the extremely slow exchange of seawater within the basin means long local seawater residence times. In other words, changes in the oxygen isotopes ratios, found in Red Sea foram fossils, are extremely sensitive to sea level variations. So the isotopes are, in effect, recorders of local sea level. Grant likewise created a sea level history for the eastern Mediterranean Sea, with one distinct improvement; they were able to independently date the sea level variations by taking advantage of oxygen isotopes stored in cave mineral deposits speleothems on land downwind of the eastern Mediterranean surface waters. With oxygen isotopes in fossilized forams, and in the cave deposits Soreq Cave , linked via the hydrological cycle, Uranium-Thorium dating of the cave deposits therefore gave an accurate date for both, and consequently the timing of sea level variations. Because of the more complicated weather patterns in the Mediterranean however, the Mediterranean sea level history cannot be used to determine sea level variations with sufficient precision Rohling To do that, the authors transferred their new Mediterranean chronology to the Red Sea sea level history. The validity of this newly-dated sea level reconstruction was confirmed by comparison to other dated sea level benchmarks. Figure 3a - Correlation of Soreq Cave red line and eastern Mediterranean black line oxygen isotope signals. The coloured dots and grey-shaded columns denote other paleodata used to validate and synchronize the reconstructions. Sea Level Rise Closely Follows Polar Warming With an accurately dated sea level reconstruction now available, the authors were able to compare these sea level variations in time with that of polar temperature, as ascertained by ice cores extracted from the Greenland and Antarctic ice sheets. Within the sea level reconstruction there are 6 periods where sea level rose rapidly, reaching rates of at least 1. Considering that humans have been warming the climate for several centuries, a more significant finding was the short time lag between warming at the poles as shown in the ice cores , and the response of sea level rise - which implies the disintegration of the ice sheets. In the case of Antarctica, large ice reductions occur within years, and for Greenland, ice reductions occur very quickly - within years. Learning From Sea Level History Despite glacial periods having much more vulnerable ice at lower elevation, and closer to the equator than interglacials, the orbitally-driven warming which eventually disintegrated the ice sheets was a leisurely affair. Ice sheet collapse came quickly due to the greater proportion of vulnerable ice. By comparison; today there is far less vulnerable ice, but the warming has been virtually instantaneous, in geological terms. The altered characteristics of the background climate state, from glacial to interglacial, makes a direct comparison for modern-day difficult. But current sea level rise estimates, and the rates of rise shown in the reconstruction, are in the same ballpark. With global warming having been underway for several centuries now, and with the Antarctic and Greenland ice sheets undergoing accelerated ice mass loss due to polar warming, the past , years of sea level history suggests we should expect much higher rates of sea level rise in the future.

Chapter 5 : INQUA-PAGES ECR workshop: Impacts of sea-level rise from past to present (iSLR)

science and impacts of climate change Sea Level Rise: Past, Present, and Future. showing that along part of the U.S. Atlantic Coast, sea level rise has been occuring at a faster rate.

Global Sea Level Author: Rebecca Lindsey August 1, Sea level has been rising over the past century, and the rate has increased in recent decades. It was the sixth consecutive year, and the 22nd out of the last 24 years in which global mean sea level increased relative to the previous year. Global map showing where sea level in was higher blue or lower brown than the average. Since the start of the satellite sea level record in , the average rate of sea level has been about one-eighth of an inch 3. The rising water level is mostly due to a combination of meltwater from glaciers and ice sheets and thermal expansion of seawater as it warms. Global sea level since Explore this interactive graph: Click and drag either axis to display different parts of the graph. To squeeze or stretch the graph in either direction, hold your Shift key down, then click and drag. The light blue line shows seasonal 3-month sea level estimates from Church and White The darker line is based on University of Hawaii Fast Delivery sea level data. For more detail on the data sources, see the end of the article. Atlas of the Oceans. South Beach, Miami on May 3, In urban settings along coastlines around the world, rising seas threaten infrastructure necessary for local jobs and regional industries. Roads, bridges, subways, water supplies, oil and gas wells, power plants, sewage treatment plants, landfillsâ€"the list is practically endlessâ€"are all at risk from sea level rise. Nuisance flooding in Annapolis in Photo by Amy McGovern. In the natural world, rising sea level creates stress on coastal ecosystems that provide recreation, protection from storms, and habitat for fish and wildlife, including commercially valuable fisheries. As seas rise, saltwater is also intruding into freshwater aquifers, many of which sustain municipal and agricultural water supplies and natural ecosystems. Sea level is rising for two main reasons: A third, much smaller contributor to sea level rise is a decline in water storage on landâ€"aquifers, lakes and reservoirs, rivers, soil moistureâ€"mostly as a result of groundwater pumping, which has shifted water from aquifers to the ocean. From the s up through the last decade, melting and thermal expansion were contributing roughly equally to the observed sea level rise. But the melting of glaciers and ice sheets has accelerated, and over the past decade, the amount of sea level rise due to meltingâ€"with a small addition from groundwater transfer and other water storage shiftsâ€"has been nearly twice the amount o f sea level rise due to thermal expansion. Melt streams on the Greenland Ice Sheet on July 19, Ice loss from the Greenland and Antarctic Ice Sheets as well as alpine glaciers has accelerated in recent decades. The pace of global sea level rise nearly doubled from 1. Sea level rise at specific locations may be more or less than the global average due to local factors: Measuring sea level Sea level is measured by two main methods: Tide gauge stations from around the world have measured the daily high and low tides for more than a century, using a variety of manual and automatic sensors. Using data from scores of stations around the world, scientists can calculate a global average and adjust it for seasonal differences. Since the early s, sea level has been measured from space using laser altimeters, which determine the height of the sea surface by measuring the return speed and intensity of a laser pulse directed at the ocean. The higher the sea level, the faster and stronger the return signal is. To estimate how much of the observed sea level rise is due to thermal expansion, scientists measure sea surface temperature using moored and drifting buoys, satellites, and water samples collected by ships. Temperatures in the upper half of the ocean volume are measured by a global fleet of aquatic robots. Observed sea level since the start of the satellite altimeter record in black line , plus independent estimates of the different contributions to sea level rise: When water shifts from land to ocean, the increase in mass increases the strength of gravity over oceans by a small amount. From these gravity shifts, scientists estimate the amount of added water. Future sea level rise As global temperatures continue to warm, sea level will continue to rise. How much it will rise depends mostly on the rate of future carbon dioxide emissions and future global warming. How fast it will rise depends mostly on the rate of glacier and ice sheet melting. The pace of sea level rise accelerated beginning in the s, coinciding with acceleration in glacier and ice sheet melting. In , at the request of the U. Do you have feedback to offer on this or another article? Let us know what you think. It is based on a weighted average of global tide gauge records collected by the U. The weights for each gauge in the global mean are determined by a cluster analysis that groups gauges from locations where sea level tends to vary in the same way. This prevents over-emphasizing regions where there are many tide gauges located in close proximity. The values are shown as change in sea level in millimeters compared to the average. Surveys in Geophysics, 32 , â€" The Physical Science Basis. Accessed November 2, The budget of recent global sea level rise: Published by the National Oceanic and Atmospheric Administration. Sea level variability and change [in State of the Climate in]. More sea level data and information from NOAA and partners.

Chapter 6 : Sea Level Change - The British Geographer

Impacts of sea-level rise are determined by the relative sea-level change, reflecting not only the global-mean trend in sea level, but also regional and local variations in sea-level change and in geological uplift and subsidence.

Sea Level in the Past Tidal gauges and, more recently, satellite-mounted instruments, show that global sea level has been rising steadily for about the last years. More recently, the rate of rise has increased. Image created by Robert A. Precise measurements of global sea level began in , after NASA and the French space agency deployed a satellite-borne radar altimeter. For sea level estimates prior to , researchers generally rely on measurements of tide heights recorded at ports. Such records must be carefully adjusted to be useful. To gauge sea level before reliable tidal records existed, some scientists, including the Pliomax team, locate and date sites of past shorelines when the sea was above or below its present height. Other scientists study clues to past sea level found in the shells of ancient organism buried in ocean sediments and elsewhere. Scientists know the most about recent sea level trends. Also, the increase appears to be speeding up. Much further back in time, less is known, especially concerning the rate of sea level change. What is certain is that sea level was about feet lower at the peak of the last ice age, around 20, years ago. The sea rose rapidly as the ice age waned sometimes at rates greater than 3 meters, or 10 feet, per century until about 8, years ago when climate stabilized and the rate slowed dramatically. Researchers believe that sea level has been virtually constant since about 2, years ago, up until the late 19th century when the current warming trend began. Climate researchers are especially interested in how high the sea rose during previous warmer periods, prior to the last ice age. Such periods could shed light on future sea level, as global temperatures rise to equal or above the warmth of these earlier times. Earth has experienced dozens of ice ages separated by intervening warm periods, some hotter than today. The most recent warm period, about , years ago was 2â€”4 degrees Fahrenheit warmer than today. Convincing geological evidence suggests that sea level was at least 15â€”20 feet higher then. The Pliomax team seeks firm evidence of sea level during the Pliocene period, the last time Earth was as warm as is predicted, due to global warming, for later this century. Going Global The Pliomax team is looking around the world for clues to sea level during the warm Pliocene period. Click for interactive map. Expedition to Oz The Pliomax team traveled through southern and western Australia on its first field trip. Or, jump right in and watch the three Sea Change videos.

Chapter 7 : Past , Years of Sea Level History Suggests High Rates of Future Sea Level Rise

INQUA and PAGES will conduct a four-day conference for early-career researchers, titled "Impacts of sea-level rise from past to present (iSLR18)", in Utrecht, The Netherlands, from August

Submergent Coastlines Fjords, Norway Submergent coastlines form as a result of sea level rise. The current period of sea level rise, caused by melting ice sheets and thermal expansion of the ocean is called eustatic change. As a result of eustatic change, a number of coastal features develop, including the formation of fjords, rias and fjards. Fjords are narrow, lengthened and steep marine gulfs that result from the inward movement of the sea into U-shaped valleys deeped by a glacier, during the last glacial period. They have a symetrical valley shape and vast channel depth that enables inland navigation. They are a renowned physical feature of the Norwegian coastline. A rias is a deep, sunken river valley drowned by the sea. They form funnel-shaped branching inlets, decreasing in depth and width inland. A good example can be found in the Solva in Pembrokeshire. Rias are different to Fjords in that the valley was previously shaped by river processes rather than glacial processes. Rias may show a meandering form as they navigate around spurs. Fjards are drowned glacial lowlands like thos found in western Scotland. They are typically punctuated by small islands, called skerries that result from isostatic recovery. Skerries and Fjard, Isle of Islay Rias: The main problem is our lack of understanding of how ocean temperature reacts to atmpspheric temperature change. In addition, there is great uncertainty over what carbon emission track we will take in the future. The graph to the left shows projected sea level rise for three different emission scenarios. The semi-empirical method predicts sea level rise roughly 3 times greater than the IPCC predictions. Note the IPCC predictions are shown as vertical bars in the bottom right. It is generally thought that the IPCC has made very conservative predictions for future sea level change. The maps below show a realistic outcome of a 1meter rise in sea level, should global efforts to curb carbon emission continue to delay. North Europe, especially the Netherlands and South Asia, in particular the Sunderbans region of West Bengal and Bangladesh will lose large quantities of land. Millions has already been invested in the Deltaworks in the Netherlands and vast public funds are earmarked for continued maintenance and improvements to safeguard this densely populated region of North Europe. Elswehere, the Sunderbans region of West Bengal and the low lying delta of Bangladesh is amongst the fastest eroding coastlines in the world, with some places experiencing more than 20 meters of erosion each year. There appears to be an increasing frequency of cyclones with their associated tidal surges. In the Pacific Ocean, low lying island states are already suffering the worst affect of sea level rise, with increased rates of salinisation, coastal erosion and storm surges forcing many to consider migration. The following videos show the problems for Pacific islanders and people living in the Sunderbans. The following link to the PowerPoint on the potential impacts of sea level rise on East Anglia provides a useful regional case study for the UK. In adddition to impacts of flooding, governments and regional authorities need to make concrete and lasting decisions on how to manage the increasing rates of coastal erosion. Coastal erosion will have major impacts on local, regional and national economies. With the consequence of land loss and inundation a real possibility, very big decisions will have to be made on how to safeguard populations. Alternatively, decision makers may opt for softer approaches such as coastal reallignment, like that seen at Wallasea, described on the next page for case studies or even the abandoning of some coastal regions.

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Chapter 8 : Sea Level in the Past â€” Sea Change

Future research will rely on interdisciplinary investigations of the many parts of the earth system so that we can better understand how sea level may respond to global environmental change in the future.

Introduction One of the most dire impacts of anthropogenic climate change is a rise in the global sea level caused by the melting of glaciers and land-based ice caps, as well as a smaller increase from expansion due to the higher temperature of the water itself. Unlike some other predicted effects of climate change, this impact has already been observed for some time. Indeed, not only is there evidence that sea levels are rising; there is also evidence both that the rate of sea level rise has been increasing in recent years and that it will continue to increase. Figure 1 shows the average sea level increase from its midpoint. National Oceanic and Atmospheric Administration, Climate. Some locations experience greater rise than others because of local terrain, local hydrological factors, and oceanic currents, among other regional factors. Unfortunately, many large cities are located on coastlines that are particularly vulnerable to sea level rises. Improvements in high-resolution modeling have made it possible for the expected sea level rises in specific locations to be mapped, both in worst-case and expected-case scenarios. This very detailed awareness of the hazard has, in many locations, led to positive planning and actions to mitigate the impact. This article will describe the latest scientific thinking about the magnitude of global sea level rise, detail some solutions that coastal cities around the globe are implementing to mitigate risk, and offer general suggestions for good resilience planning for locations that will be impacted by this threat. A Growing Concern Recently, a team of scientists published a study that found that the rate of sea level rise in the 20th century was greater than it had been in 2, years. Melting land ice is responsible for a largerâ€”and ever-increasingâ€”amount of the global sea level rise in recent decades, as opposed to thermal expansion of seawater. A compounding problem with ice melt is that it can accelerate through positive feedback. Snow-covered ice has a high reflectivity or albedo, which means that radiation is reflected back from it and not as much is absorbed as heat. Once ice has started melting, the process accelerates without an external influence to cause refreezing. The current best estimates predict that sea level will rise up to 6. Until recent years, this figure was viewed as pessimistic, with a rise of 3 feet considered more likely. Recent studies raise the concern that the 6. Earlier work accounted for glacial and Arctic melt, but had greater uncertainty about the West Antarctic Ice Sheet. The new research, developed in the last three years, modeled that the West Antarctic sheet would be undermined by warmed seawater, accelerating its decline. Nonetheless, even in this optimistic case, some sea level rise will continue to occur due to current greenhouse gas levels in the atmosphere and the attendant warming. Coastal Resilience in the United States Several American coastal cities have begun plans to minimize the effects of sea level rise. Figure 2 shows a map of New York City with expected flood zones that are based on the projection of 2. Current and projected future flood risks for New York City assuming 2. In this plan, the city specifically analyzed the effects of Sandy as a near-worst-case impact and the projected future flood zones. It determined several actions to take to minimize the risks. To protect coasts against tidal flooding, the city plans to reinforce beaches, build bulkheads, and protect sand dunes that act as natural barriers. The city may also enact rock breakwaters offshore to attenuate waves associated with storms, and erect storm walls and levees in areas that are particularly vulnerable to storm surge. Boston is another American city that has developed a comprehensive climate resiliency plan. Low-income residents in particular utilize public services such as buses more than other residents, and as the tragedy of Hurricane Katrina in New Orleans showed, these residents are most vulnerable in the event of a needed evacuation. Cities that have smaller populations than the East Coast metropolises and rely heavily on tourism for economic development are also making preparations. Tybee Island, a barrier island near Savannah, Georgia, is a popular tourist destination during the summer months. The city, also named Tybee Island, developed a resilience plan to cope with rising sea levels. The city has a single road that allows access on and off the island, so shoring up this roadâ€"U. Coastal Resilience around the Globe Cities elsewhere around the world have begun to grapple with the risks of sea level rise as well. In Australia, coastal cities face the threats of tidal flooding, non-tropical storm flooding, and tropical cyclone storm surge just as cities in the U. Australian states and municipalities also have significant authority over their own policies, comparably to the U. The national government of Australia has issued a strategic plan for climate resilience and adaption, which recommends procedures to states and municipalities. The Australian resilience plan acknowledged that coastal cities were built with the assumption that weather and tidal conditions would fall within a known historical range that includes a stable sea level, and therefore that expected rises from climate change pose a threat. The government of Australia is in the process of developing an online tool, known as CoastAdapt, that will help local officials understand specific risks their areas face and provide specialized information about resilience options. A specific example of this type of local resilience planning is the analysis of seawalls in Sydney. The city has several older seawalls, and authorities were unsure of their reliability in the face of climate change and extreme events. The government of Australia oversaw a project to assess the seawalls for their current condition that included analysis of the materials used in the seawalls, maintenance, stability, and strength. The project officials then proposed improvement suggestions for each seawall examined. Many cities in Europe are also vulnerable to sea level rise. European cities are not at risk of hurricane storm surge due to their northerly latitudes and location on coastlines that do not experience tropical cyclones, but they are vulnerable to tidal flooding and non-tropical storm flooding. Some are also built below sea level and rely on levees for protection. An example of the latter is the city of Rotterdam in the Netherlands, which is 90 percent below sea level and surrounded by several rivers. Dikes protect the city from inundation. In , Rotterdam suffered an extremely deadly flood that breached the dikes, killing 1, people, a tragedy that foreshadowed Hurricane Katrina in New Orleans fifty-two years later. In response, the Dutch government directed funding to a massive project to build dikes around areas of the city. Unfortunately, over the years the structures have damaged the environment and aquatic ecosystems. In a more sustainable, ecologically sound, and physically robust plan, the government is now shoring up the natural coastline of the city by rebuilding sand dunes and expanding shores with sediment. Lessons and Strategies for Resilience As we have seen, governments at all levels are assessing the dangers for specific locations and analyzing the current infrastructure the world over. It is possible to model expected flood risk at an extremely high resolution and perform engineering analyses on existing infrastructureâ€"natural and manmadeâ€"with a great degree of precision. The results are a set of plans tailored for the specific needs and capabilities of each location. Climate change does not affect all parts of the earth in the same way, and even sea level rise will not be globally uniform, so highly individualized resilience planning is a must. Their diversity notwithstanding, however, the plans do have some things in common. The ideas that appear repeatedly, in resilience plans around the globe, do so because they are broadly applicable, and in many cases, planners have arrived at them through past experience. Cities that wish to develop their own coastal resilience plans should look to these repeat ideas as guidance. First, coastal cities at particular risk of flooding should protect any natural barrier islands that are present. These islands are the first line of defense against storm surge, whether from tropical cyclones or other storms at sea. Cities that can afford it, and can do so in an environmentally friendly way, might follow the example of New York City and erect artificial breakwaters offshore if they do not have any natural barrier islands. These structures could also serve as artificial reefs for marine life if oceanic conditions permit. Many coastal cities have artificial seawalls and levee structures. These structures tend not to be as robust against extreme events as natural barriers, but cities that have them should follow the example of Sydney and examine them in close detail to determine their robustness. Of course, to be fully effective, civil authorities should conduct this type of analysis with an eye to the specific level and type of risk that a given city is expected to face from sea level rise. Resilience planners in very low-lying locations should also keep in mind the lessons of New Orleans and Rotterdam, emphasizing shoreline and wetland restoration as the first and best defense instead of relying wholly on a system of levees to fight the natural course of rivers. For locations that are below sea level, natural restoration approaches are more robust against flooding and have proved far better for surrounding ecosystems. Cities should not neglect existing seawalls and levee structures, but they should be part of a broader strategy. Finally, resilience analysts should always consider the human factor, particularly in the context of extreme flood events that would pose a high threat to life and require partial or full evacuation of the city during the emergency. This type of risk is especially acute for cities that are low-lying, prone to storms, or located at the mouths of significant river systems. The plan for Tybee Island, a much smaller municipality, takes into account its reliance on tourism and the dependence of its evacuation route on a single highway. Planners should always consider the specific local needs of a city, whatever its size. Climate change is already causing sea levels worldwide to rise, and we can only expect this trend to continue. Our best, most current science predicts that ice cap melting and thermal expansion of seawater will produce a combined average rise of up to 6. This level of rise would inundate some beaches and overflow many barrier islands that serve as natural protection against storm surge from tropical and non-tropical cyclones. It would also raise the risk of tidal flooding, and in areas that are expected to see an increase in rainfall, flash flooding and river flooding would compound the flood risk associated with coastal waters. The risks of sea level rise to coastal cities must be taken seriously, and the kinds of concrete, specific, individually tailored flood resilience plans illustrated here are a very positive step. While emissions reductions can lessen the magnitude of this impact, some rise is going to occur. It is imperative for areas at risk to adapt to this new hazard, and fortunately, they are beginning to do just that. These pioneering coastal cities have created plans that offer excellent guidance. Hopefully, resilience planners in other locations around the world will follow their lead.

Chapter 9 : Sea Level Rise: Risk and Resilience in Coastal Cities â€“ Climate Institute

Researchers study sea level of the past in order to interpret present trends in the sea's height, and to forecast future changes. Precise measurements of global sea level began in , after NASA and the French space agency deployed a satellite-borne radar altimeter.

Higher water levels erode beaches, dunes, and cliffs; inundate wetlands and other low-lying areas; and increase the salinity of estuarine systems, displacing existing coastal plant and animal communities. These coastal environments provide a protective buffer to areas further inland, as wetlands can reduce flooding and cliffs, beaches, and dunes protect coastal property from storm waves. The distribution and character of coastal habitats and geomorphic environments varies along the California, Oregon, and Washington coasts, as does their response to sea-level rise. The coast of California is dominated by uplifted terraces fronted by low cliffs, but also includes steep coastal mountains and areas of coastal lowlands and dunes. The southern coast of Washington is dominated by low relief sand spits, occasionally backed by bays. The northern coast and Olympic Peninsula are rocky and rugged, whereas Puget Sound retains the signature of Ice Age glaciationâ€”a crenulated coastline with islands, embayments, and typically sandy bluffs. This chapter summarizes what is known about 1 the responses of coastal habitats and geomorphic environmentsâ€”including coastal cliffs and bluffs, beaches, dunes, estuaries, and marshesâ€—to future sea-level rise and storminess along the west coast of the United States and 2 the role of coastal habitats including benthic habitats , natural environments, and restored tidal wetlands in providing protection from future inundation and the impact of waves. The objective was to summarize existing knowledge, not to predict specific future shoreline responses or to assess coastal impacts of sea-level rise and storminess see Box 1. The rate of coastal cliff and bluff retreat is controlled by the properties of the rock materials and the physical forces acting on the cliffs. Important rock properties include the hardness or degree of consolidation or cementation, the presence of internal weaknesses e. Rates of cliff retreat are generally well documented along the California coast Dare, ; Hapke and Reid, , and range from a few cm per year in granitic or volcanic rock to tens of cm per year or more in sedimentary rocks or unconsolidated materials Griggs, ; Griggs et al. In California, cliffs and bluffs made of sedimentary rocks typically erode at rates of 15â€”30 cm yr-1 Griggs and Patsch, Fewer bluff retreat rates are available for the Oregon and Washington coasts. Komar and Shih and Komar described the temporal and spatial variability in cliff and bluff erosion along the Oregon coast, Page Share Cite Suggested Citation: Past, Present, and Future. The National Academies Press. Priest found that cliffs and bluffs in Lincoln County, Oregon, generally retreated at rates less than 19 cm yr-1 for â€” In landslide areas, bluff retreat rates were somewhat higher, ranging from 11â€—50 cm yr The physical forces driving cliff and bluff erosion include marine processesâ€—primarily wave energy and impact, but also tidal range or sea-level variationsâ€—and terrestrial processes, such as rainfall and runoff, groundwater seepage, and mass movements such as landslides and rockfalls. Increased wave heights mean that more wave energy is available to erode the coastline. Rising sea level would exacerbate this effect because waves will break closer to the coastline and will reach the base of the cliff or bluff more frequently, thereby increasing the rate of cliff retreat. Cliff and bluff retreat is an episodic process whereby large blocks fail suddenly under conditions of heavy rainfall, large waves at times of elevated sea levels or high tides, or earthquakes, followed by periods of little or no failure. In steep, mountainous areas, failure is often through large landslides or rock falls Figure 6. With very large landslides, such as the Portuguese Bend slide on the Palos Verdes Peninsula, the shoreline may actually be extended seaward for a decade or more before basal wave action removes the protrusion Orme, The episodic nature of cliff retreat, combined with the frequent absence of an identifiable edge or reference feature, makes it difficult to quantify or verify cliff erosion rates in mountainous areas over short time intervals, such as a few decades, or to project future erosion rates Priest, Some evidence suggests that waves have been increasing in height off the west coast. Page Share Cite Suggested Citation: Cliff and bluff erosion is not reversible. The most common human response has been to armor the cliff base with rock revetments Figure 6. Ten percent of the California coastline has now been armored, including 33 percent of the coastline of the four most developed southern California counties Ventura, Los Angeles, Orange, and San Diego; Griggs, Shoreline armoring also has increased over the past several decades in Oregon and Washington. Approximately one-third of the Puget Sound shoreline is now armored Shipman et al. Moreover, while seawalls and revetments may provide current protection for oceanfront development and infrastructure, they are usually designed for a particular set of wave and sea-level conditions. If sea level increases substantially and wave heights continue to increase, the original freeboard will be gradually exceeded and overtopping will become more frequent. Along the west coast, beaches change seasonally in response to the different winter and summer wave climates. These fluctuations in beach width are predictable and temporary, and the losses of sand experienced each winter are normally recovered the following summer. Riprap protection has been placed at the toe of the bluff in an attempt to slow the erosion. Left Concrete and timber seawalls protecting cliff top homes in Solana Beach, California. Right Rip rap protecting bluff top housing along the central Oregon coast. More frequent storms during warmer PDO cycles can lead to extended periods when beach widths are narrower than average. Over the long term, rising sea level will cause landward migration or retreat of beaches. The retreat is caused partly by inundation of the beach by the rising sea and partly by offshore transport of sand to maintain the beach profile. Because the berm or back beach is essentially a horizontal surface, even a small rise in sea level may lead to a horizontal retreat that is considerably larger than the sea-level rise Edelman, Beaches also can undergo erosion or long-term retreat in response to a reduction of sand supply. Coastal rivers and streamsâ€"many of which have been dammed for water supply, food control, hydroelectric power, or recreationâ€"provide most beach sand along the west coast. Statewide, approximately million m3 of sand that would have been delivered to the shoreline to nourish beaches since has been trapped by coastal dams Slagel and Griggs, The long-term effect of declining sand supply works in concert with rising sea level to progressively narrow beaches. Barrier spits or other sandy peninsulas, which are common along the northern Oregon and southern Washington coastlines Figure 6. Long sand spits commonly form at the mouths of estuaries along the central and northern Oregon coasts and Washington coast. Erosion or landward migration of sand spits or barrier bars will occur more frequently with sea-level rise Pilkey and Davis, Back-beach barriers can slow or halt the natural inland migration of beaches because of rising sea level. Where a seawall, revetment, or structure exists, the shoreline cannot advance landward and the beach is progressively inundated Figure 6. This process, known as coastal squeeze or passive erosion, has been documented in a number of locations along the west coast. Similarly, barrier spits that have been developed and then protected with revetments cannot migrate with sea-level rise Figure 6. Depending on the rate of sea-level rise, all west coast beaches with hardened or constrained back beach edges will gradually be inundated. Only a few studies have quantified rates of change along the sandy shoreline of the U. Sand spits eroded or accreted, depending on sand supply, wave energy, and relative sea level. Coastal land change along the sandy shoreline of California was assessed as part of the U. Maps, aerial photographs, and, more recently, lidar light detection and ranging were used to determine both long-term s to â€" and short-term sâ€"s to â€" rates of shoreline or beach change. More than 16, transects revealed that the shoreline eroded 0. The average rate of long-term change was 0. This net accretional trend was attributed to the large volumes of sediment that were added to the system from large rivers and to the impact of coastal engineering and beach nourishment projects Hapke et al. A similar assessment effort is planned for the Oregon and Washington coasts. Large dune fields are best preserved in areas that have undergone either net subsidence or limited uplift during the Quaternary Orme, The beach continues to migrate inland on either side of the revetment. Right Recovery of the beach following removal of the revetment and bluff top structure. This spit cannot migrate with sea-level rise. Washington coast Komar, Many of the dune areas exposed along and inland from the west coast shoreline today formed during the lower sea levels of the past. At the end of the last ice age, when sea levels were about m lower than today, the entire continental shelf was exposed. Sand from rivers and streams was deposited across this extensive plain, and onshore winds produced large dune fields, such as those in the Coos Bay area of central Oregon, which extend along the coast for nearly km and are encroaching into some developed areas Figure 6. As sea level rose, many of the dunes were cut off from their vast reservoir of offshore sand. Dunes still form and are active today along the shorelines of all three states, but they have a lower supply of sediment and are much less extensive than those that formed in the past. Decades of observations of coastal dunes around the world have shown that the frontal dune, which is closest to the beach, is an ephemeral and unstable feature e. Sand dunes typically accrete or expand under the force of onshore winds and an ample supply of sand, but they can erode quickly under severe wave attack at times of high tide or elevated sea level. The hazards of building on the frontal dune have been known for centuries McHarg, Nevertheless, many housing developments in California, Oregon, and Washington have been constructed on dunes and are periodically threatened or damaged Figure 6. Dunes, whether modern or Pleistocene, can be expected to retreat quickly under rising sea levels and larger waves.