The Coming Reality of Sea Level Rise Along the New Jersey Coast: Too Fast Too Soon**

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Summary
The reality of accelerating rates of sea level rise as the result of human-induced global warming is becoming increasingly dire and urgently needs to be addressed. In 2012, the National Oceanic and Atmospheric Administration (NOAA) published the most recent United States Government sea level rise projections as a part of the National Climate Assessment. Those projections that include acceleration in ice sheet melt from Greenland and Antarctica are for 4.1 to 6.6 feet of global sea level rise by 2100. That could mean 2 feet by as early as 2048 and 3 feet by 2063. The projected global sea level rise will create challenges for low-lying coastal zones, including maintaining community infrastructure and welfare, continuing viable agriculture, and assuring protection of life and property during hurricanes and other extreme events. For the New York/New Jersey region, significant regional influences must be added to the global rate. Thorough, transparent community planning for the coming reality is urgently needed now.

Current realities
In the New York-New Jersey-Delaware-Maryland region, additional regional influences on sea level must be added to the 4.1-6.6 feet global projection for 2100. These include the following: (i) vertical land motion as the uplifted bulge south of the former North American Ice Sheet continues to collapse (+5 to +7 inches per century); (ii) dynamic ocean rise because of anticipated slowing of the Gulf Stream flow (+5 to +8 inches per century); and (iii) redistribution of self-gravitation pull on ocean water as the vast polar ice sheets melt and weaken their pull (+25% to +37% of ice-melt sea level rise) (Lemonick, 2010).

Most of the models projecting future sea level assume a gradual acceleration of rise through this century and beyond as Greenland and Antarctic ice melt gradually accelerates. Our knowledge of how sea level rose in the past ice age paints a very different picture of how sea level responds to climate change. At the depth of the last ice age, about 18,000 years ago, sea level was some 420 feet below the present level as ice was taken up by large continental ice sheets. Subsequent ice melt and sea level rise was not a gradual acceleration and then deceleration; rather, it was a series of very rapid pulses of sea level rise followed by pauses. These rapid pulses of rise, ranging from 3 to 30 feet probably within a century, were fast enough to drown reefs, sandy barrier islands, tidal inlet deltas, and other coastal deposits and leave them abandoned across the continental shelves. As the climate warms, it destabilizes some ice sheet sector, which rapidly disintegrates, resulting in a rapid pulse of global sea level rise.

Our significantly warmed atmospheric climate is resulting in an accelerated melt of the surface of the Greenland Ice Sheet. Much of the surface of the Ice Sheet is darkening as the dust and black carbon in the ice concentrate on the melting surface. This accelerates heat adsorption, further accelerating surface ice melt — one of many feedbacks not in current models. More importantly, warmed ocean water is accelerating ice melt in both Polar Regions. The warming North Atlantic and Arctic Oceans have been accelerating ice melt all around Greenland since about 1995 as this dense, "warm" ocean water enters the deep outlet glacial fjords and penetrates far into and under the Ice Sheet. Warm ocean water is now also penetrating deeply into fjords under outlet glaciers and adjacent Ice Sheets of both West Antarctica and East Antarctica. Each of these warm waters is only 2 to 4 degrees Celsius, but they are causing a profound amount of melting. We are essentially providing an unlimited supply of warmth to the oceans for this melting to continue for centuries.

The beginning of this polar Ice Sheet melt is showing numerous reinforcing feedbacks, which are rapidly accelerating the rate of melt far beyond anything projected in current models. For example, because water on the ice surface absorbs more heat, surface melt is accelerated; this melted water percolates down through the ice and lubricates the base permitting faster motion, and culminating in more extensive fracturing. In addition to this, water percolating through the fractured ice accelerates ice melt and warms the ice, which results in the softening of the ice and even further acceleration of the melting process. With the rapid melting of pack ice and the warming of water in the Arctic Ocean, release of additional carbon dioxide and methane from decaying organics in the melted permafrost, and melting of methane hydrates on the Arctic continental shelf, the accelerating melt of the adjacent Greenland Ice Sheet seems irreversible. We are most certainly witnessing the onset of a rapid pulse of sea level rise.

In 2014, documentation came out showing that ice melt of the West Antarctic Ice Sheet is much less constrained by underlying bathymetry (underwater depth of the ocean floor) than previously considered (i.e., bottom substrate deepens inward below the ice). The documentation also demonstrates that the numerous fjords penetrating in from the Greenland coast are deeper and extend much further under the Ice Sheet than previously thought. In 2015, it was demonstrated that similar ice melt acceleration is occurring under the East Antarctic Ice Sheet. Each of these findings means that warmed ocean water is now more easily penetrating under these ice sheets and that accelerating ice melt will happen much faster than previously thought.

In light of our improving understanding of ice melt, we should anticipate at least 7 to 30 feet of global sea level rise by the end of the century, regardless of any actions taken. This is because even if we stopped burning fossil fuels tomorrow, the greenhouse gases in the atmosphere will keep warming the atmosphere for at least another 30 years. Additionally, more than 90% of this global warming heat ends up in the oceans, which have the capacity to capture, store, and use the heat for centuries. Consequently, ice melt and sea level rise will continue for centuries. Most projections recognize sea level rise will accelerate through this century and the next. This level will continue to increase from ongoing acceleration of sea level rise stemming from the continuous acceleration of ice melt. Even if we encounter a minimal 5-foot increase in sea level at the end of the century, the rate of sea level rise will be a foot per decade!

There is currently a very aggressive building boom underway in many low-lying coastal areas of the nation. Most of this building is occurring without consideration for the viability of construction or the challenge of maintaining a functional infrastructure with the projected rates of sea level rise. There are areas that will be unlivable and properties that will be unsellable within a 30-year mortgage cycle all along the Atlantic coast, as hinted at by the recent repeated “king tide” floods (maximum tides when moon is closest and in full- or new-moon phase).

Scientific opportunities and challenges

Several recent papers, including one from the National Research Council, have suggested that current greenhouse gas levels are sufficient to cause a 70-foot rise in sea level. Our recorded history does not have direct observations as to how quickly destabilized ice sheet sectors can disintegrate. The past record and present trends indicate that pulses of sea level rise happen very fast (e.g., 3 to 30 feet per century).

Even with the current NOAA projection of 6.6 feet in sea level rise by the end of the century, it is beyond sobering to consider the risk in present infrastructure investments. With the distinct possibility of a 2-to-3 foot rise in sea level by 2065, most of the barrier islands of the world will become largely uninhabitable, displacing residing populations. At the same time, low mainland coastal communities, such as those along Barnegat Bay, will become flooded more frequently and therefore become increasingly difficult locations in which to live. Citizens in affected areas will (i) lose local freshwater resources; (ii) live in communities with a failing and disconnected infrastructure; and (iii) be at an increased risk from catastrophic storm surges, flooding from hurricane and rainfall events, and failing sewage treatment plants.

While many renowned scientists have concluded that global sea level may rise 15 to 30 feet by the end of the century, communities must, at a minimum, begin to plan for sea level rise using the 2012 NOAA projections (i.e., 4.1 to 6.6 feet by 2100) in conjunction with any regional influences (+1 to +2 feet for New Jersey). By doing so, communities will quickly realize that very serious problems will arise very soon. With accelerated sea level rise projected through this century and beyond, there is a need to focus on realistic plans for both the maintenance of community stability during relocation and environmental quality during inundation. Most of New Jersey's barrier islands and sandy coastal mainland, for example, cannot consider the option of living below sea level with levees and dikes because the sand substrate is much too porous and permeable. By planning with the NOAA projections, it will be easy to adapt preparation plans to higher and faster rates of sea level rise — or enjoy a few extra years of being prepared if actual rates are slower.

Policy issues

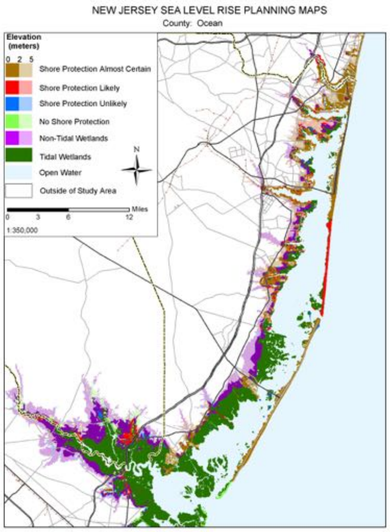
- Counties must aggressively and transparently plan for their future by integrating high-resolution maps of elevation, storm surge, flood risk, and infrastructure elevation to determine the timing, costs, and economic feasibility for maintaining functional infrastructure, viable insurance, and human safety. States normally provide calibrated LiDAR (airborne laser) maps (see figures), but some counties and cities fly their own.
- Produce maps for each 6 inches of further local relative sea level rise (global plus regional) up to a valid planning projection through this century. By doing so, intelligent planning can be done to determine what areas and infrastructures are currently at unacceptable risk, and at what thresholds and costs infrastructure will have to be modified to maintain functionality and acceptable risk. These maps can determine where and when infrastructure services will have to be discontinued because of unacceptable risk or cost.
- We must act within the framework of the reality before us. As there is little possibility that these sea level rise projections will diminish, it is imperative to:
    - Terminate long-term, infrastructure-intensive development of barrier islands and low-lying coastal zones.
    - Divert public money from future hard or soft shore protection measures (e.g., sea walls, sand renourishment, levees) into funds used for relocation assistance, cleaning low-lying polluted lands, and removing storm-damaged development and infrastructure.
    - Establish firm sea level rise thresholds for termination of infrastructure services, for permission to rebuild following storm destruction, for staging insurance withdrawals through cooperative public-private agreements.
    - Implement Local and Regional Climate Change recommendations, which have action items to help insure the stability of affected individuals and communities (e. g., Township of Toms River "Getting to Resilience" Recommendations Report, by the Jacques Cousteau National Estuarine Research Reserve, June 2015).
    - Initiate intensive education for the affected public to achieve an informed electorate.

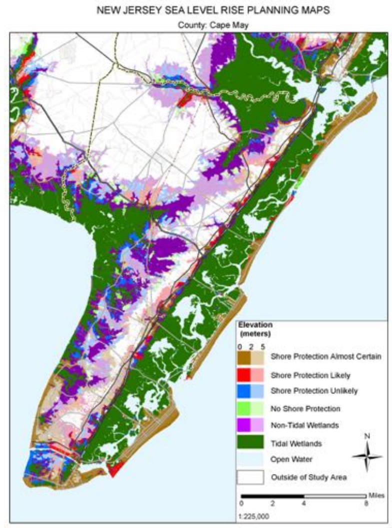
Without planning, there will come a point where society and civilization as we know it will collapse into chaos. We can only prevent this scenario with serious planning and effort. Our children and future civilization deserve much better than what we are presently doing.

References

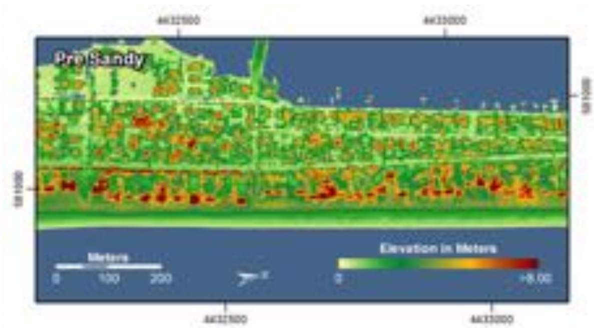
Lemonick, M.D., 2010. The secret of sea level rise: It will vary greatly by region. http://e360.yale.edu/feature/the_secret_of_sea_level_rise_it_will_vary_greatly_by_region/2255/ .

(*This paper is adapted from a policy position paper prepared for presentation at the conference on Sea Level Rise: What's Our Next Move, convened by the ISGP, October 2–3, 2015, in St. Petersburg, Florida)*

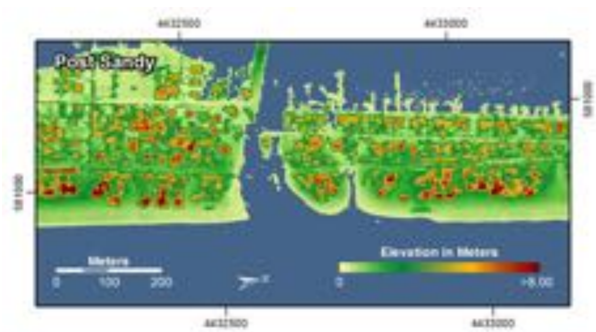




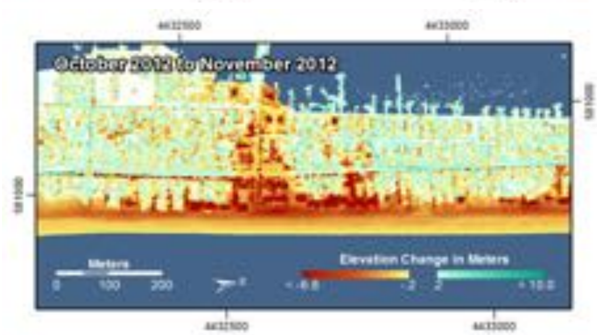
Examples of sea level planning maps easily available for the New Jersey shore. Planning maps for Ocean County (left) and Cape May County (right) show areas less than 2 meters (6.6 feet) above sea level in bold colors and areas of likely protection efforts in brown and red (e.g.. sea walls, elevation of land, beach fill) (from: http://plan.risingsea.net/NJ/).



Pre-Storm Elevation



Post-Storm Elevation



Elevation Difference

Elevation maps of the sandy barrier island at Mantoloking, New Jersey, pre- and post-Hurricane Sandy, showing the spatial and elevation resolution possible with LiDAR imaging. (From: http://coastal.er.usgs.gov/hurricanes/sandy/lidar/newjersey.php).