Institute on Science for Global Policy

Shoreline Adaptation Land Trusts: A Concept for Rising Sea Level**

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Summary
Rising sea level is now unstoppable despite the important work to reduce greenhouse gas (GHG) emissions, and the international goals to limit "global warming." Regardless of those efforts, we must begin adapting to a new era that will feature a substantially higher ocean, with many shorelines moving markedly inland. Financial and tax policies could be an efficient tool for the transition into this new era with multiple meters of sea level rise (SLR). A special purpose entity is hereby proposed, the *Shoreline Adaptation Land Trust* (SALT). SALTs could provide vehicles to facilitate the vast adjustments that catastrophic coastline changes will necessitate.

Current realities
For context, three erroneous concepts need to be clarified: 1) confusion of SLR with storms, extreme tides, other types of flooding, or beach erosion, 2) the idea that it is possible to stop SLR by slowing global warming through GHG reduction or implementing other sustainable behaviors (e.g. conservation, recycling), and 3) a belief that the worst possible sea level this century is 3 feet, or even 6 feet above present. Each of these concepts will be addressed in turn.

Coastal flooding can occur for a variety of reasons that are often confused, but have totally unrelated magnitudes, locations, and timescales. Storm surge, extreme high tides, heavy rainfall, downstream flooding, land subsidence, coastal erosion, and SLR all are different. Tsunamis, caused by seismic activity, would be yet another type and cause. Characteristics such as predictability, relative vertical change, and permanence are quite different for each flood type and need to be understood to have effective policy that is both *resilient* and *adaptive* — two terms that are often interchanged, but here are used with important distinction. *Resiliency* connotes recovering to the pre-event condition, whereas *adaptation* is changing to accommodate a new state of normalcy or stability. Storms, extreme high tides ("king tides"), heavy rainfall, and downstream flooding are familiar events that quickly recede, making it possible to recover and rebuild. They are appropriate to think of in terms of *resiliency*. Beach erosion is different from flooding, being caused either by storm action, routine ocean currents, or the effect of interrupted sand movement along the shore (as happens with construction of groins or waterway inlets). Such erosion is not actually flooding, though rising sea level and erosion can each increase the effects of the other.

Sea level rises for entirely different reasons. Mostly it is the melting of glaciers and ice sheets on land, plus the thermal expansion of seawater as the ocean warms. As the Earth's average temperature changes over centuries, these forces move sea level up or down by astonishing heights, even hundreds of feet. It is worth noting that contrary to popular belief, sea level does *not* change because of the melting of *floating ice*, whether in the form of icebergs, the solid polar ice cap around the North Pole, or the fringing sea ice around the island-continent of Antarctica.

All forms of flooding are *additive*. For example, a severe storm will reach greater height and move further inland if it hits at an unusually high tide. Over time, all of those temporary events will be lifted even higher as the base sea level moves upward. SLR and land subsidence are special as the effects will not be reversed for centuries or millennia and therefore should be considered *permanent* flooding or inundation. As the planet warms, melting the great ice sheets and glaciers, we need to recognize this as lasting change to ocean height, which will inexorably work to reshape all the continents. That requires *adapting* to a new normal: an ocean that will rise higher unstoppably, which brings us to the second point of confusion.

Average global temperature has already risen approximately 0.85 degrees C (nearly 1.5 degrees

F) over preindustrial levels. Current international efforts are striving to set a goal to keep the average global temperature from rising no more than 2 degrees C over preindustrial levels, primarily by reducing carbon emissions. Yet, from geologic history we know that when ice sheets and glaciers have fully adjusted to temperature changes over centuries, the sea level changes by roughly 20 meters per degree C of average global temperature, or about 35 feet per degree F (Archer & Brovkin, 2008). Thus, even the present elevated ocean temperature means that rising sea level is now unstoppable, even with 100% conversion to sustainable, noncarbon-based energy — a point made in the 2015 high-profile paper "Ice melt, sea level rise and superstorms" by Dr. James Hansen *et al*.

Our ignorance about SLR stems from the fact that it has hardly changed in the last 5,000 years, roughly the span of our civilization's written history. Yet, geologically it is clear that sea level varies in a rather regular pattern — roughly on a 100,000-year natural cycle following the "ice ages" (see below graph spanning 400,000 years). That pattern has been repeating for several million years. Sea level moved up and down 300 to 400 feet with each ice age cycle as global temperature changes by 5 degrees C (9 degrees F). For example 120,000 years ago, sea level was 25 feet higher than present. Now, the truly extraordinary level of carbon dioxide (CO_2) a potent GHG, has triggered a "super warming" phase, putting us on path back towards that previous high-water mark.

Considering the unstoppable aspect of rising sea level and the scale of what lies ahead, many current policies are not sustainable financially. Examples include subsidies to the National Flood Insurance Program, using Federal Emergency Management Agency (FEMA) funds for to protect buildings that are in flood zones, approval of new projects in vulnerable zones, or the concept of "buying out" homeowners from their coastal properties at prestorm values, as was done after Hurricane Sandy in New York. With more frequent flooding events and the increasing awareness of unavoidable submergence, property values will likely start to "go under" before the land actually does. Long before the water rises, we need to chart a course for better public policy recognizing the new reality. Delay will only make things worse for establishing expectations.

Scientific opportunities and challenges

To address the third point of confusion presented in this paper, SLR will be more severe than most people realize. Due to scientific protocol, most numerical projections leave out the largest potential cause of higher sea level — the melting of the West Antarctic glaciers. For example, the authoritative 2013 United Nations Intergovernmental Panel on Climate Change (UN-IPCC) points to as much as 3 feet of SLR by the year 2100, but omits the 10 feet of potential SLR from just the most unstable glaciers (Bamber, *et al.*, 2009) on the basis that it cannot be precisely quantified with probabilities. That inability to quantify does not mean that the risk is not real. We simply cannot predict collapse points for the miles of ice. Also, the wishful idea of a technology "fix" for sea level ignores some basic laws of physics.

One scientific opportunity is to better refine the measurements of melting ice in Greenland and Antarctica. Such research is now one of the highest priorities for the National Science Foundation (NSF), which should improve the models. Nonetheless there are severe limits to what modeling can achieve. Real modeling of *tipping points* (i.e., a *nonlinearity*, or *discontinuity*) generally requires a large data set of measured-samples, or the ability to put the system in a laboratory for test and measurement under controlled variables, something not possible with the Greenland or Antarctica ice sheets. We must recognize that SLR will very likely exceed the projections, due to the uncertainties that cannot be programmed into models. Our challenge is to find ways to facilitate the adaptation that is now inevitable, even if the precise rate of rise is unknowable. Shifting the focus to economics could be one pragmatic path towards adaptation. While real estate write-offs, relocations, and business interruptions will be valued in the trillions of dollars, there will also be opportunities.

Policy issues

As sea level rises, the options to avoid going underwater are to *elevate, isolate, or relocate*. Isolate often means levees (as used in New Orleans and the Netherlands), though that approach will not work in areas with a porous structure (e.g., much of south Florida, coral-based islands). In limited areas it will be possible to elevate vulnerable land and defend against temporary storm surges. Where that is not feasible, there exists a need for strategic relocation. A Shoreline Adaptation Land Trust (SALT) is one concept that warrants consideration. In brief:

- A SALT is a nonprofit public land trust established *pro bono* for any defined area, (e.g., state, county, community, or in the case of island nations, perhaps the entire country). It follows a well-established concept of conservation land trusts (landtrustalliance.org).
- The purpose is to get property into the public sector in anticipation of its submergence.
- Private and commercial property owners will be encouraged to donate coastal real estate that is vulnerable to erosion and sea level rise, per criteria that may be adjusted.
- The owner would be allowed to continue full use for his/her lifetime, subject only to the progress of SLR and other intermittent flooding.
- The immediate benefit to the donor would be to terminate property taxes.
- A second benefit would be a tax-deductible gift donation for the value of the property, including the land, buildings and infrastructure. To encourage early participation, the percentage of deductibility would decline 2% every year from the inception of the SALT (e.g., 30 years from inception the rate would be 60% less).
- As a further benefit of donating the land to the SALT, there could be a variance to allow certain extraordinary measures to shore up the property from erosion for a limited number of years, suggested to be no more than 30 years from the SALT inception.
- At such time as the relevant jurisdiction declares the property to be uninhabitable, the SALT will endeavor to remove any built structures and remediate environmental damage, recognizing that the property will eventually be part of the marine environment.
- As a means of developing further value and working capital, the SALT could rent out properties it acquires, after the donating owner dies or abandons the property.
- In addition to such rental income, the SALT could get working capital from the government to facilitate an orderly transition inland. Also, there could be deductible charitable donations from the public, philanthropic and civic organizations.
- The concept and establishment of SALTs could be accomplished at any level of government, though the tax benefits would likely require federal and state legislation.
- Having an actual SALT would be extremely helpful as a model. Accordingly some vulnerable and progressive jurisdiction should be solicited as a prototype. The UN might be a forum to recommend the concept for adaptation internationally.

Strategic Adaptation Land Trusts could be a useful tool and catalyst for this unprecedented transition upwards and inland. We can rise with the tide — if we anticipate it in time.

References

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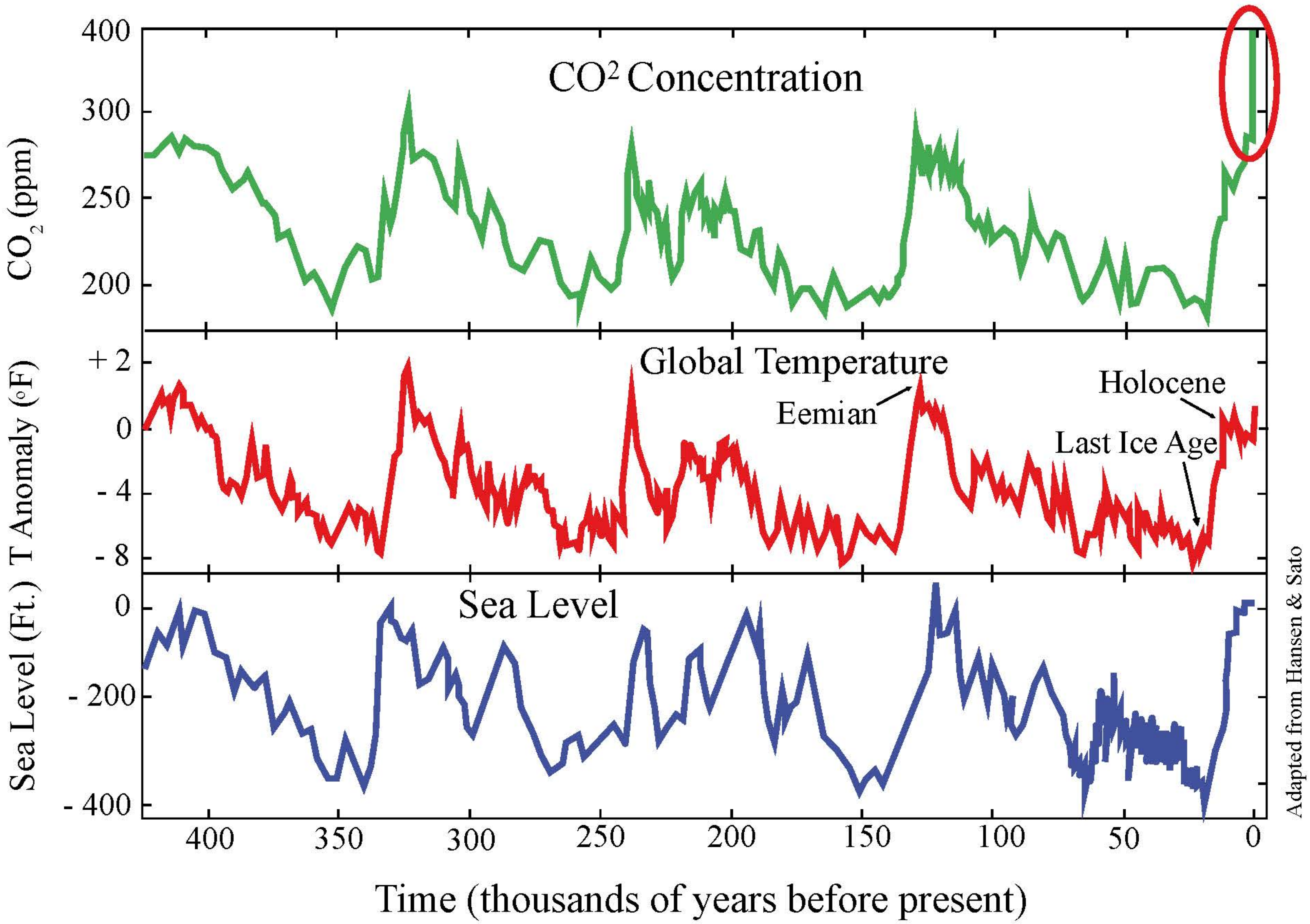
CO2 Concentration
CO2 (ppm)
400
300
250
200
Global Temperature
T Anomaly (°F)
+ 2
0
- 4
- 8
Eemian
Holocene
Last Ice Age
Sea Level
Sea Level (Ft.)
0
- 200
- 400
400
350
300
250
200
150
100
50
0
Time (thousands of years before present)
Adapted from Hansen & Sato