SEA LEVEL RISE: A GLOBAL NATURAL HAZARD

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SEA LEVEL RISE AS A SEVERE THREAT

Today more than 100 million people worldwide live on coastlines within one meter of mean sea level, and five times as many people live within 5 meters above sea level. Any short-term or long-term sea level change relative to vertical ground motion is of great societal and economic concern. The very survival of many island states and deltaic coasts is threatened by sea-level rise. In the United States alone, beach and coastal properties that are potentially threatened are valued in literally trillions of dollars. In many countries, shoreline erosion and regression along the coast as a result of the sea level rise relative to the land has been a pressing problem. In addition, higher relative sea levels often exacerbate damages caused by storms, hurricanes and typhoons along the coasts, let alone tsunamis.

CAUSES OF SEA LEVEL RISE

Inasmuch as paleo-environment and historical data have clearly indicated the existence and prevalence of such changes in the past, new scientific information regarding to the nature and causes and a prediction capability are of utmost importance for the future. The 10-20 cm global sea-level rise recorded over the last century has been broadly attributed to two effects: (1) the steric effect (thermal expansion and salinity-density compensation of sea water) following global climate; (2) mass-budget changes due to a number of competing geophysical and hydrological processes in the Earth-atmosphere-hydrosphere-cryosphere system, including water exchange from polar ice sheets and mountain glaciers to the ocean, atmospheric water vapor and land hydrological variations, and anthropogenic effects such as water impoundment in artificial reservoirs and extraction of groundwater. These exchanges are all superimposed on the vertical motions of solid Earth due to tectonics, rebound of the mantle from past and present deglaciation, and other local ground motions.

THE NECESSITY AND OUR PRESENT (LACK OF) KNOWLEDGE

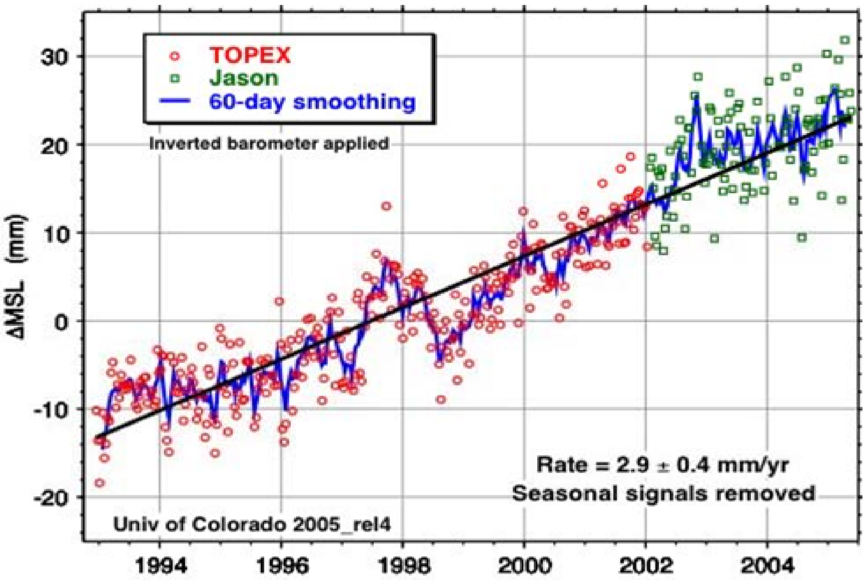
Globally sea level is estimated to rise by 1.5 - 2 mm/year at present, but few details are known. The relative contributions of the steric and mass-budget effects are under debate, as are their spatial and temporal variations. We are presently not certain whether Greenland and Antarctica are gaining or losing net ice mass. Estimates of mountain glacier melting are quite incomplete. The global land hydrology budget is not well known. Even the amount of artificial reservoir water impoundment is uncertain by perhaps a factor of two. If global warming continues, a most immediate and potentially dominant mass-budget contribution to sea level change is likely to come from the melting of ice masses. The melting of temperate glaciers could raise sea level by a few tens of centimeters; the melting of the ice sheet in West Antarctica could raise sea level by several meters. Global and temporally continuous monitoring of sea-surface topography, ice mass, gravity, and ground motions is needed. Knowing how the present ocean "container" deforms is also necessary to predict the consequences of sea-level change. On a global scale, that requirement calls for an accurate post-glacial rebound model incorporating knowledge of the Earth's internal mechanical properties and the history of past ice ages. At any given location along the coastline, additional tectonic motion and environmental impacts such as groundwater withdrawal need to be monitored and understood.

MEASURING AND MODELING SEA LEVEL CHANGES

In light of the above, understanding sea level changes "anywhere, anytime" in terms of climate change and interactions among ice masses, oceans, and the solid Earth, and being able to predict them, emerge as one of the scientific focuses for the next 25 years in NASA's Earth Science Vision (ESV) study as well as the Solid Earth Science Working Group (SESWG) conclusions (see URL <solidearth.jpl.nasa.gov>). Measuring absolute as well as relative sea-level change is a geodetic endeavor. As remote-sensing tools, a number of space geodetic measurements of sea surface topography (e.g., TOPEX/Poseidon, Jason), ice mass (e.g., ICESat), time-variable gravity (e.g. GRACE), and ground motions (satellite laser ranging, very-long-baseline interferometry, the Global Positioning System, Interferometric synthetic aperture radar, laser altimetry and lidar, etc.) become directly relevant. Further advances in geodetic measurement techniques must provide information on sea-level changes and consequences in a routine fashion, with enhanced geographical coverage, spatial and temporal resolution, and measurement accuracy. Research is needed to integrate the various relevant measurements-- changes in sea- and ice-surface topography, time-variable gravity, deformation of the surface of the solid Earth (particularly along coastlines), all under a uniform terrestrial reference frame, together with *in situ* measurements from tide gauges and buoys, remote sensing data such as sea-surface temperature and salinity, and global atmosphere-hydrosphere-cryosphere models that assimilate diverse climatic data types.

CONCLUSIONS

Being able to monitor, understand, and model the sea-level changes "anywhere, anytime" is the key that will eventually lead to prediction of sea-level rise relative to the worldwide coastal communities. Only with such knowledge can public policies and legislatures be effective in mitigating and preventing the sea-level rise as a natural hazard. Space geodetic research and technology development under the Earth Sciences enterprise are poised to make that happen in the coming years.



Global Sea Level Rise From Topex/Poseidon
(courtesy S. Nerem)