Remote Sensing and Emergency Management for Coastal Environmental Disasters

By: Oscar KI. Huh, Ph.D.
Coastal Studies Institute
Louisiana State University, Baton Rouge, LA

Coastal Environmental Problems

It is estimated that approximately 50% of the worlds population live on the coastal fringes of landmasses and the likely trend is for this number to increase to 75% within a decade. For centuries people have been drawn to coastal regions for the rich soils for agriculture (of deltas and lowlands), the extensive fisheries resources, transportation opportunities and recreation, and just for the natural beauty of living on beachfronts. However, the air-sea-land boundary referred to as the coastal zone is dangerous, comprised of an extremely dynamic, complex physical / biological set of environments. Worldwide, the coastal zone is characterized by high population densities, extremely varied and important biological diversity, including coastal fisheries, rich agricultural lands, and economically important major ports and rivers arteries to the continent'' interior. Such economically significant regions located on the fringes of the continents are prone to major catastrophic hazards that immediately affect large segments of the population and have lasting impacts on a nation's economy.

The coastal zones are adversely affected by global sea level changes that are beyond man's control. In addition, storm surges and storm waves from the seaward side and runoff flooding plus "waves of humanity" and anthropogenic pollutants form the landward side constantly pose severe threats to the population. Locally, steep gradients of salinity, temperature, wetness, wind, water circulation, and sediment transport velocity plus geomorphic irregularities occur. Thus, small changes in sea level, topographic elevation, erosive power, or movement of water can induce major environmental changes and crate hazards to human activities.

Natural coastal hazards inevitably involve air-sea-land interactions on a multitude of scales, from meter to multiple kilometer sizes. By "coastal" we mean the domain from the inner continental shelf across the strand into the coastal adjacent wetlands, and river flood plains. In coastal environments we have an array of oceanic, hydrological, atmospheric, erosion, depositional, and biological events operating at man levels of scale.

The natural coastal hazards, tentatively in order of importance include the following.

Coastal Inundation Events and Trends

- Storm surges and accompanying waves
- River flooding
- Extreme rainfall events
- Coastal winds, strong persistent
- Tsunami / seiches
- Relative Sea-level rise
- Perigean tides
- Salt water intrusion, rivers, and estuary aquifers

Coastal Erosion Events or Trends

- Beach and barrier island erosion
- Near shore erosion
- Coastal dune erosion / migration
- Sea cliff erosion
- Mass movement processes, both sub-aerial and sub-aqueous

Coastal Circulation and Depositional Processes

- Maintaining navigable waters, siltation, shoaling etc.
- Storm deposits on shore face and inland
- Migration of large bed forms
- Catastrophic down-welling (the internal cascading of high density water down steep bathymetric slope)
- Currents associated with impinging ocean eddies
- Upwelling events
- Distribution of coastal/marine, flotsam such as debris, logs, etc.
- Water quality hazards (spilled oil, hazardous waste, disease-laden waters transported through coastal environments)

Coastal Biological Hazards

- Red tides water borne diseases
- Vector borne diseases
- Large predators
- Venomous marine life
- Catastrophic fish / wildlife kills (pollution related)
- Massive habitat destruction of economically valuable living resources

One of the primary hazard related problems in coastal regions has to do with the effects of severe storms – generally tropical cyclones (hurricanes) and synoptic scale systems related to large scale atmospheric circulation patterns (e.g. Northeasters, cold front passages). Hurricanes affecting the south and eastern portions of the United States originate in the Gulf of Mexico, off the coast of West Africa, the Equatorial Atlantic or the Caribbean during the season from June1st to November 31st. Hurricanes are a regional phenomenon, each potentially affecting millions of lives and billions of dollars invested in coastal zone cities and settlements. For example, Hurricane Andrew caused $25 billion in damages in 1992. Hurricanes are typically 400 miles in diameter, moving at speeds of 1 to 60 mphs, and have life spans of as much as 9 days. Imbedded in them are individual cumulus cloud towers that can extend up to 10 miles into the atmosphere marking zones of extreme winds and precipitation. The most destructive hurricane driven process is the storm surges (combined with large waves on its surface), the large powerful, dome of water hurricanes propel from sea to land. As they approach shorelines, surging waters may reach and flood low lying areas much ahead of the storm eye landfall. The surge is driven by wind set-up, the inverse barometer effect (dropping atmospheric pressure generates a "lifting" force on the sea surface), and wave set-up. If the configuration of the adjacent coastal and continental self bathymetry is broad, shallow and gently sloping the surge rises steeper and propels even more water into the coastal environment. Hurricane related coastal hazards include physical impact of the surge (a cubic yard of water weighs 1700 lbs.), wind driven waves, high winds, extreme rainfall rates, and river flooding. Additional impacts may include on a much smaller scale, tornadoes, levee collapse, pollution of surge waters, and the effects of wind or water borne " missiles:"

> The impacts from coastal storms, and especially the associates surges, can hardly be overemphasized because storm surges are the worlds foremost natural hazard of geophysical origin (even surpassing earthquakes) (Finkl 1994).

In polar coastal regions, of most importance are the extra tropical cyclones / frontal passages of storms and associated winds, waves and water level set up as well as icebergs and calving of coastal ice sheets. Of particular advantage of polar coasts is the fact that the polar orbiting satellites, and their imaging sensors (radar, Vis. Ir, and NIR) have a revisit rate of circa 100 minutes, and with two in orbit the result is data received almost hourly.

Another major impact is short-term climatic variations, which are responsible for the upsurge of diseases associated with changes in temperature, precipitation, humidity or storm patterns. Cycles of flooding and drought directly affect activity of disease vectors and water borne diseases. Man made changes such as development, changes in agricultural processes, disruption of natural ecosystems can also impact disease spread. Of most concern in tropical regions are:

- Water borne diseases: hepatitis, dysentery, typhoid and cholera.
- Vector borne diseases: malaria, dengue, yellow fever, encephalitis, schistosomiasis and hantavirus.

> . . an enhanced understanding of the connections between climate and health provides regional and national decision-makers and planners with insight into disease outbreak and spread in a warmer world projected by the Intergovernmental Panel on Climate Change (IPPC). It is important to document, through rigorous scientific studies, the connections between specific climatic events such as prolonged drought or flooding episodes, and disease outbreaks in the Americas (Diaz et al. 1998).

Emergency Management, Long and Short Term

Emergency management plans are a critical component of the coastal hazards preparedness. Additionally, a well-conceived plan can lead to developing pre-planning for post-disaster redevelopment in hazardous areas. This will reduce future risk to life and infrastructure development. The emergency or disaster management model has four component kinds of activities (modified from Godschalk, et al., 1989).

Near Real Time Activities

<u>Emergency Preparedness</u> – near real-time activities can lead to earlier advance warning times in the event of impending disaster. After disaster warning is sounded, continuous real-time risk assessment, storm tracking, rainfall, wave, and water level surveillance) will undoubtedly lengthen the lead time for emergency management such as evacuation of communities, protection of properties, saving endangered lives and minimizing disaster damage.

<u>Emergency Response</u> – this phase involves short-term emergency aid and assistance following disaster event. It includes damage assessment, search and rescue, feeding, sheltering, medical assistance to refugees. Restoration of public services, eliminating health hazards and clearing debris.

Long Term Management Activities

<u>Recovery Management</u> – includes both immediate actions to restore minimum operating conditions and longer term tasks to return the community to normal plus planning any dealing with a repeat.

<u>Mitigation of Hazards / Disasters</u> – defined as sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects. This includes reversal of long-term trends that are detrimental to social welfare.

Many U.S. government agencies are involved in emergency management. FEMA has originated and issued a "National Mitigation Strategy, Partnerships for Building Safer Communities." NOAA has its Coast Watch program, and manages the operational environmental satellites, and maintains National Weather Service, National Ocean Service, and Climate Data Centers. USGS maintains a Coastal Geology Program from St. Petersburg, Florida. However, unique to NASA is access to the most advanced, even experimental remote sensing/ aerospace technology to serve the decision-maker in time of emergency.

What Does the Decision-Making Manager Need?

Most succinctly the emergency manager needs a thorough grounding in regional environments and communities plus an information system that is fully responsive to decision making information needs, with information that is:

- Timely
- Easily understandable
- Displayed clearly
- Of the right space and time scales.

Information must be provided that is adequate and in time for action. The decision-maker needs up to date maps most readily derived from aerospace systems on a great variety of themes that vary from region to region.

All coastal states have emergency management agencies, headed by a decision-maker, often the governor with a special staff and facility. The decisions makers "call" may affect thousands of people, their lives, homes, industries / economies and huge costs. His / her position is not enviable. If they set off a false alarm they may initiate a costly and possibly dangerous evacuation. Additional, they lose credibility. If they underestimate the danger, massive tragedy can result. Correct decisions mean avoiding losses involving millions of dollars and thousands of lives. So what does the emergency manager need? Very accurate environmental, demographic, and real-time information and best possible forecasts on the development of physical conditions. They need easy to understand information on the "hot spots" or areas of particular vulnerability. They need this information base graphically displayed plus time and technical assistance to comprehend and synthesize the information into a realistic concept of what is happening and the developing options that are opening and closing with time. They need up to date maps most readily derived from aerospace systems. Parameters of emergency conditions which need to be assessed include:

<u>Circulation of Coastal Waters (image analysis) direction and speed for</u>

- Search and rescue,
- Water and air pollution transport
- Identifying air and water pollution sources.

Coastal Meteorology

- Hurricane storm windfield (high resolution wind speed and direction)
- Hurricane storm associated precipitation / rainfall zones
- Dry vs. saturated soils to anticipate runoff
- Coastal wildfires

Hurricane Storm Wave Field

- Waves and swell sea-state and its areal variability

Hurricane Storm Driven Storm Surge

- Flooding areas

Extent of Flooding in the Various Coastal Environments

Condition of Transportation Routes

Because continuous input of measurements for these data fields is not usually available or practical, the need is for numerical models for interpolating conditions between measurement events and for forecasting environmental conditions and events of concern. Local area responsiveness is critical to both emergency management and to research in coastal processes where motion and change occur on such a range of scales.

Conclusions and Recommendations

It is clear that many planned and present satellite systems are, for the most part, not responsive enough in the temporal and spatial domains for both emergency management and many kinds of coastal research. This is a serious deficiency, as here remote sensing is needed as a vital management decision-making tool as well as for observation and measurement. One approach is an acceleration of aircraft programs to enable them to respond to emergencies and also loiter to provide time lapse imagery. Without a crisis the platform is in use for instrument development and regional mapping projects. The capability to loiter and provide time lapse imagery is critically important. Time lapse imagery is significantly more useful and interpretable, as the behavior or life cycle of a detected feature greatly improves our interpretation and understanding. Richard Helmes Director of the CIA from 1966 through 1973 explains.

> There is no way to replace the initial data provided by piloted airplanes. Satellites lack flexibility and the immediacy that only a spy plane like the U-2 can provide (Rich and Janos 1994).

The alternative is to acquire a number of duplicate satellites in blocks. This involves planning for adequate temporal as well as spatial and radiometric sampling that a “constellation” of spacecraft, and or pointable sensor systems can provide.

References

Anderson, D. M. and D. J. Garrison, 1997 "Thematic issue." *Oceanography and Limnology*, Vol. 42, No. 5, Part 2.

Beal, R.C., P.S. DeLeonibus, and Isadore Katz. 1981. *Spaceborne Synthetic Aperture Radar for Oceanography*. The Johns Hopkins University Press, Baltimore, Md.

Byrnes, M. and R. McBride. 1997. Coastal Erosion Hazards in Louisiana. *Natural Coastal Environmental Hazards,* Ed. O.K. Huh, LSU Coastal Studies Institute Technical Report TR 654.

Diaz, H. R., P. R. Epstein, J. L. Aron, and U. Confalonieri. 1997. Workshop Focuses on Study of Climate's Effects on Health. *EOS Transactions of the American Geophysical Union*, Vol. 78, No. 45.

FEMA (11995) *National Mitigation Strategy, Partnerships for Building Safer Communities*. Prepared in support of the International Decade for Natural Disaster Reduction. Washington, DC.

Finkl, Jr. C.W. (1994) "Coastal hazards perception, susceptibility and mitigation." *Journal of Coastal Research*. The Coastal Education & Research Foundation (CERF), Special Issue No. 12.

Garvin, J. B. (1997). "Coastal hazards monitoring and topographic characterization by means of laser altimetry." Natural Coastal Environmental Hazards. Ed. O.K. Huh, LSU coastal Studies Institute Technical Report. TR 654.

Huh, O.K., G.A. Mastin, and J.N. Suhayda (1984). "Synthetic aperture radar (SAR) imagery of storm induced seas around the goto islands, Japan." *Ocean Hydrodynamics of the Japan and East China Seas*, Ed. T. Ichiye, Elsevier.

Huh, O.K., C. Moeller, W. P. Menzel, L. Rouse, and H. Roberts 91996). "Remote sensing of turbid coastal and estuarine waters: a method of multi-spectral water type analysis. *Journal of Coastal Research.* Vol. 12, No. 4.

Johannessen, J.A., et. Al (1996). "Coastal fronts and eddies imaged with ERS-1 synthetic aperture radar" *Journal of Coastal Research*. Vol. 9, No. 2.

Stumpf, R. (1988). "Sediment transport in chesapeake bay during floods: analysis using satellite and surface observations," *Journal of Coastal Research*. Vol. 4, No. 1.

Ransey, E. (1997) "Dynamic flood monitoring in coastal environments," *Natural Coastal Environmental Hazards.* Ed. O.K. Huh, LSU Coastal Studies Institute Technical report TR 654.

Rich, B. L. Janos (1994). *Skunk Works.* Little Brown and Company, New York, NY p. 372.