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Coastal Observations from a New Vantage Point

Teaser: The NASA GEOstationary Coastal and Air Pollution Events (GEO-CAPE) satellite mission will give new insights into transient processes that affect coastal ecosystems.

The world population was estimated at more than seven billion people as of 2015, and roughly half of them live within 100 kilometers of a coastline (UNEP, 2007). Human population growth and climate change have put increasing pressure on coastal ecosystems. Understanding water quality, ecological processes, and biogeochemical cycles in these ecosystems is essential to ensuring adaptation in these ecologically and economically important systems.

Coastal ecosystems are more complex than open-ocean ecosystems because currents, tides, diurnal winds, and light drive short-term variability in chemical and biological processes including phytoplankton growth and migration. The waters of coastal ecosystems are also complex because of their proximity to land—and by extension, the humans who inhabit the coastlines. This proximity subjects coastal ecosystems to such forces as variations in river and groundwater fluxes, along with varying pollutant inputs from human activities.

The value of coastal ecosystems and the pressures on them motivated scientists within the NASA GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission to investigate science questions centered on short-term biogeochemical processes, exchanges between land and ocean, the effects of climate change and human activity, the effects of airborne-derived fluxes, and episodic pollution events and coastal hazards.

The GEO-CAPE Mission

GEO-CAPE investigates atmospheric composition across North America using measurements of atmospheric trace gases and aerosols, along with remote sensing of phytoplankton, water quality, and biogeochemistry across northern and southern latitudes in the western hemisphere.

Because interactions of various processes in coastal ecosystems can be short-term, and many times unpredictable, the National Research Council's Earth Science Decadal Survey (NRC, 2007) recommended that the GEO-CAPE mission undertake ocean color remote sensing from a geostationary orbit. Ocean color information can aid in identifying algal blooms and oil spills, provide information on land use and coastal features, and spot changes in response to storms and other disruptive phenomena.

In 2008, two science working groups that focused on the ocean and the atmosphere convened to address land, ocean and atmosphere interactions. They have defined scientific questions and advised NASA on the spatial, spectral, temporal and radiometric attributes for the mission.

To reduce mission risk and cost, the working groups have endorsed the concept of phased implementation, or separate launches, of the ocean and atmospheric earth observing instruments, using commercial satellites. Although GEO-CAPE has an unspecified launch date, NASA has invested nearly $20 million (USD) to advance the science and technology of the mission. GEO-CAPE is planned as a two- or three-instrument payload mission with a distributed architecture to reduce risk and cost.

GEO-CAPE's Ocean Color Sensor

To achieve its scientific goals, GEO-CAPE developed ocean color sensor concepts uniquely designed to aid research into phytoplankton identification, estimate surface colored carbon stocks, resolve coastal features, and estimate biogeochemical fluxes. The sensor features a hyperspectral ocean color radiometer that senses energy emanating from the coastal ocean in the ultraviolet, visible, and near- and shortwave-infrared spectral ranges.

Geostationary orbit will keep the sensor at a fixed location above the earth (Figure 1). This allows frequent imaging within its fixed field of view of North and South America of vast coastal regions and the Laurentian Great Lakes, providing frequent measurements that will revolutionize scientific understanding of coastal dynamics and dramatically increase the societal value of coastal observations from space.

Current ocean color sensors on polar orbiters can only make measurements of the coastal ocean once every 1-2 days. Because of cloud cover and other limitations, valid ocean color retrievals over coastal waters are at most once per week, which is inadequate to quantify coastal ocean dynamics. GEO-CAPE’s high-frequency measurements (every one to three hours) will resolve rapidly changing conditions in coastal waters, making it possible to quantify ecosystem-rate processes and to reduce measurement uncertainties. (Figure 2)

By focusing on coastal environments, GEO-CAPE is poised to advance not only ocean science, but also terrestrial ecosystem science, greatly increasing the number of cloud-free observations of seasonal changes in coastal vegetation. This will enable new capabilities for studying agricultural productivity and stress, tidal inundation, disturbance of natural ecosystems, and responses to ephemeral phenomena such as storm events.

In addition, the spectral range and spatial resolution achievable with the sensor will provide data on atmospheric aerosols and potentially trace gases for studies of coastal emissions. This will allow GEO-CAPE to study interdisciplinary science topics including biogeochemical cycling in coastal ecosystems, blue carbon stocks and fluxes, coral reef health, coupled coastal air and water quality, the role of upwelling and bio-aerosols on meteorology and contributions of anthropogenic activities in aquatic environments.

Enhanced Operational Services

Humans benefit from coastal ecosystems economically and in their quality of life (Wheeler et al. 2012). To sustain healthy coastal systems, economic prosperity, and quality of life we will need the ability to monitor, assess, and disseminate information to the people who need it most.

The GEO-CAPE Ocean working group works closely with the satellite user community, including the National Oceanographic and Atmospheric Administration, the US Environmental Protection Agency, the US Navy, US Army Corps of Engineers, Bureau of Ocean Energy Management, and the Gulf of Mexico Fishery Management Council. We have compiled metrics to assess user data needs and measurement requirements for specific applications concepts.

Based on this assessment, proposed applications include tracking harmful algal blooms; managing fisheries; assessing water clarity, surface currents, and underwater visibility; improving search and rescue; navigation; monitoring coastal and estuarine acidification; quantifying large oil spill thickness and extent; and improving carbon modeling, benthic habitat monitoring, and disaster response.

GEO-CAPE will also be unique in its ability to monitor anthropogenic emissions and smoke plumes from fires on regional scales throughout the day. This offers considerable potential for quantifying changes in coastal air quality, smoke plume evolution, and fire emissions, which have direct and significant effects on atmospheric and biogeochemical cycles, the Earth's radiation budget, and human lives.

Access to information on other important abrupt disturbances—snow and ice melt, river ice damming and spring flush, storm impacts, and coastal flooding—will also aid in resource monitoring and relief distribution. Improved temporal, spatial and spectral resolution will contribute to coastal land monitoring, including rapid assessments of storm damage to coastal ecosystems, agriculture, human habitation and businesses.

Recent GEO-CAPE Ocean Activities

GEO-CAPE is on track to join the global constellation of geostationary atmospheric chemistry and coastal ocean color sensors. The working group has carried out several engineering laboratory studies and field measurements over the past five years to ensure appropriate instrument designs that meet science requirements while maintaining reasonable cost and risk profiles of the GEO-CAPE ocean color sensor.

Engineering studies were conducted to determine how to resolve stability requirements to image pixels on the order of 250 m over an integration period of <1 to 10 seconds—a situation GEO-CAPE is likely to face while in orbit. The studies concluded that platform jitter and roll disturbances imparted on the ocean color instrument can be resolved with existing technologies. These studies focused on developing technologically viable and low-cost instrument concepts while also exploring the sensor cost versus capability (spatial and spectral and scanning range). Three categories of instrument concepts were deemed viable: (1) 2D imaging filter wheel radiometer, (2) wide-angle spectrometer and (3) multi-slit spectrometer. Spatial resolution was the largest cost driver. The 2D imaging filter wheel radiometer was the lowest cost concept but would not provide the full spectral information provided by the two hyperspectral designs.

Oceanographic cruises in the Chesapeake Bay (July, 2011) and the northern Gulf of Mexico (September, 2013) obtained comprehensive high temporal-, spectral- and spatial-resolution datasets, to capture patterns and scales of variability in coastal water ecosystems, which are needed to evaluate the temporal, spatial, and spectral resolution requirements of the sensor.

Another field experiment (May-June, 2016) was designed to collect additional measurements in the field of view of the Korean Geostationary Ocean Color Imager (GOCI), a pathfinder geostationary ocean color satellite currently in orbit. This collaborative field study with Korean scientists focused on diurnal dynamics of dissolved and suspended organic and inorganic materials, with special attention to ocean-color radiometry. These data will be used to evaluate what can be resolved with hourly data in complex coastal environments in preparation for algorithm development for GEO-CAPE.

A Leap Ahead for Coastal Science

With its unique imaging capabilities and vantage point, the GEO-CAPE ocean color sensor will do for coastal science and applications what the Geostationary Operational Environmental Satellite system (GOES) has done for weather prediction. GOES satellites, the most widely used environmental satellites in the world, have led to improved forecasts that save lives, preserve property, benefit agriculture and spawned new commercial ventures. In a similar fashion, a quality geostationary ocean color satellite positioned over the western hemisphere will revolutionize the science of coastal processes, allow for more precise ecosystem modeling and deliver products and information needed for societal health, coastal protection, businesses and efficient use of Earth resources.

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References:

NRC, 2007. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. The National Academies Press, Washington, D.C.

UNEP, 2007. United Nations Environment Programme Annual Report. Nairobi: UNEP.

Wheeler, B.W., M. White, W. Stahl-Timmins, and M. H. Depledge. 2012. "Does Living by the Coast Improve Health and Wellbeing?" Health and Place 18: 1198–1201.

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Figure 1: The GEO-CAPE satellite's field of regard will cover North and South America. The satellite's geostationary view from 95° W at the equator (red circle) for the GEO-CAPE coastal ecosystem sensor is overlain on a color map from the Sea-Viewing Wide

Field-of-View Sensor (SeaWiFS) chlorophyll-a/biosphere mission composite. The black outer circle encompassing much of North and South America represents the 67° sensor viewing angle, which is the approximate limit to ocean color retrievals from 95° W. The red lines extending beyond the continental landmasses represent 375-kilometer (acceptable) and 500-kilometer (mission goal) distances away from the shore (white lines). Credit: Dirk Aurin, using SeaWiFS chlorophyll-a data courtesy of the NASA GSFC Ocean Biology Processing Group and graphic development by the Environmental Protection Agency.

Description: geocape-satellite-ocean-color-chlorophyll-coastal-ecosystem
Alt text: The GEO-CAPE sensor will measure ocean colors to monitor ecosystem changes, especially in coastal regions.

Figure 2: Low Earth orbiting satellites, including Terra and Aqua, provide at best a single measurement per location per day. GEO-CAPE would provide multiple views throughout the day to measure coastal dynamics and help to avoid loss of information caused by cloud cover (e.g., at 21:00). Here, GEO-CAPE data are simulated with frequent airborne hyperspectral data showing the movements of a potentially harmful algal bloom in Monterey Bay, California. Times are in GMT (+8 hours local Pacific time). Credit: Monterey Bay images courtesy of Paul Bissett, Trimble Navigation, and graphic development was provided by the Environmental Protection Agency.

Description: geocape-satellite-ocean-color-hyperspectral-data-algal-bloom
Alt text: GEO-CAPE will provide multiple satellite views of coastal areas throughout the day.