Report of the Breakout Session (I.3, April 28, 2008)

Science Enabled by New Measurements of Ocean Properties from Geostationary Orbit (GEO-CAPE)

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The ocean science enabled by a geostationary mission was discussed in the context of two broad scientific goals:

- to understand how coastal marine ecosystems respond to variability in physical and chemical environment: forcings >> phytoplankton >> higher trophic levels

- to understand and quantify carbon fluxes from the land to the ocean via riverine and atmospheric processes

The session began with a presentation by the co-chairs introducing the Decadal Survey mission GEO-CAPE and presenting the questions posed for discussion with some "straw" concepts to consider in answering the questions. This report will begin with a summary of that presentation, and then summarize the discussion and responses to the questions posed.

<u>What is GEO-CAPE?</u> The GEO-CAPE (Geostationary Coastal Air Pollution Event) Mission is one of the tier-II missions recommended by the Decadal Survey. It was recommended to be launched in the 2013-2016 timeframe into a geosynchronous orbit positioned near 80 W longitude. The payload consists of three instruments: a UV-visible-near-IR wide-area imaging spectrometer (7-km nadir pixel) capable of mapping North and South America from 45°S to 50°N at about hourly intervals, a steerable high-spatial-resolution (250 m) event-imaging spectrometer with a 300-km field of view, and an IR correlation radiometer for CO mapping over a field consistent with the wide-area spectrometer. The wide-area imaging spectrometer "will provide aerosol optical depth information for assimilation into aerosol models and downscaling to surface concentrations," and thus it might supply the information needed for coastal atmospheric correction. However, the coastal ocean science would benefit primarily from the high-resolution event imager.

The spectral characteristics of the event-imaging sensor were not specified in the 3-page Decadal Survey description, but Jay Herman who attended the session explained that the instrument must have 0.5-nm resolution to satisfy requirements for measuring trace gases. The current plan is to integrate over these bands to produce 10-nm with the needed signal-to-noise for coastal ocean color observations. Thus, it was assumed that the GEO-CAPE mission would provide 10-nm spectral resolution with the number and location of bands yet to be determined.

Three questions were posed to the Breakout Session. The first question was:

1. What are the priority science uses of the new measurements? Specifically, what ocean science will be derived *uniquely* by an GEO mission providing high temporal resolution, improved (250-350 m) spatial resolution, and 10-nm spectral resolution?

The case for a **geostationary** mission can be made based on:

a) Short time scales associated with dynamic coastal processes (tides, wind-driven currents, storm surges, and algal blooms).

A geostationary mission is the only satellite-based method able to discriminate physical from biological forcing in the surface ocean at size scales of kilometers and at temporal frequencies shorter than once per day. Physical forcings include the semi-diurnal and diurnal tides that affect lateral displacement, vertical mixing, and resuspension, and horizontal eddy diffusion. Biological processes include cell division and grazing, both of which have diel cycles. High temporal resolution is also needed to observe the effects of river discharge (buoyancy, turbidity, nutrients) on algal blooms.

The fundamental problem is that polar-orbiting sensors can acquire data at a frequency of 1/d (at best, but in practice much less frequently due to clouds). The Nyquist frequency would then indicate that the shortest resolvable frequency from polar orbiting sensors is once per 2d. Higher frequency events and variability simply cannot be resolved.

b) Improved spatial resolution (250-350 m) sufficient to resolve tidal fronts, river plumes, and phytoplankton patches in the coastal ocean.

The size (even existence) of phytoplankton patches is controlled by the competition of growth and horizontal diffusion. The theory of Okubo (1978) predicts critical patch size in terms of the rates of these processes, and whether physics or biology will dominate.

The spatial resolution of 250-350 m is ideal for moving much closer to the coast and into the estuaries. The resolution of today's ocean color sensors (1000 m) is too coarse.

c) Spectral resolution (10 nm) over the full UV-Vis-NIR spectral range is needed because of the optical complexity of Case-II waters.

Other arguments for a geostationary mission are:

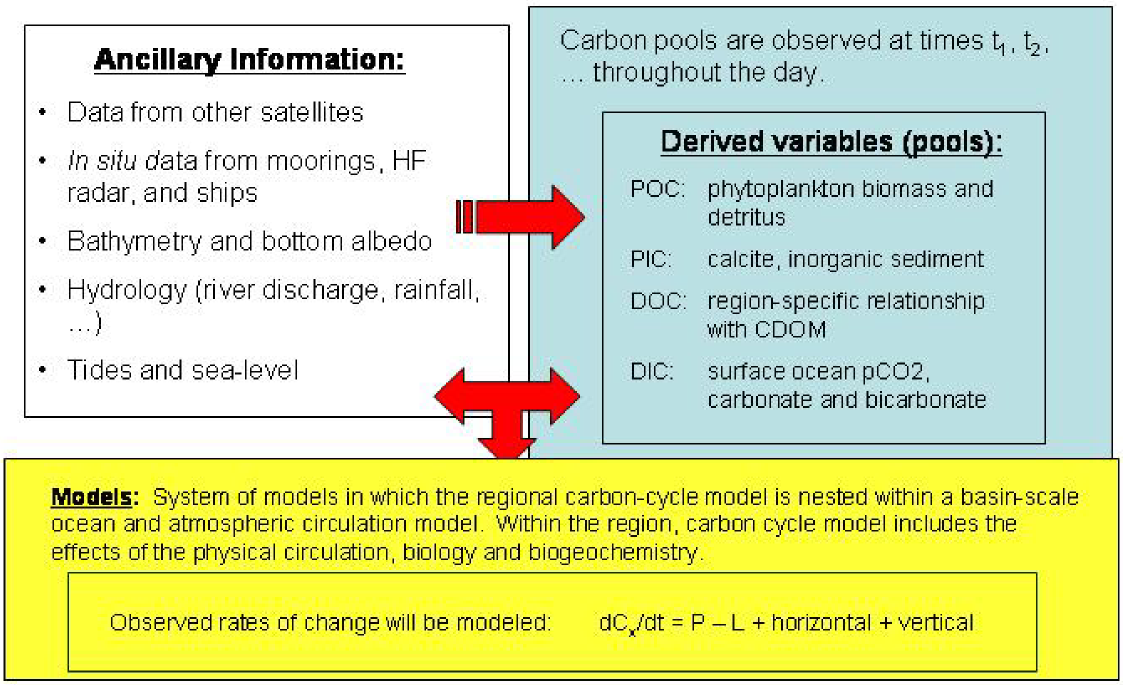
d) More opportunities for cloud-free viewing will occur throughout the day
e) High signal-to-noise can be achieved by longer integration times
f) Hazardous events need to be monitored on high frequency time scales.

The second and third questions posed were:

2. What do we need to do scientifically to use these new measurements and/or to get ready for the mission? Examples of what is needed include: algorithm development (e.g., carbon species such as PIC, POC, DIC, DOC), development of models that can assimilate satellite data, the

organization of coordinated field campaigns to provide in situ measurements, and the establishment of a sustained coastal ocean observing system. (see fig. 1)

Fig. 1. According to plans for the COCOA coastal carbon mission, observations made several times per day, together with ancillary information and models, would be used to quantify the pools and pathways of carbon in the coastal ocean.



3. What are the major issues that need to be resolved before this science is enabled, and what needs to be done?

Many of the issues are common to all missions (e.g., determining sensor characteristics, having an adequate ground data processing system, etc.). One major issue that is unique to an "Event Imager" is scheduling or tasking. How will decisions be made as to what areas are sampled? Who will make these decisions?

Scheduling of the COCOA mission (a mission concept white paper submitted by JPL to the Decadal Survey) was discussed. This involved 2 modes. The "default" synoptic mode would involve routine scans 4 times per day of the East Coast, Gulf Coast, and West Coast. This would be interrupted to carry out an "event/experiment" mode when there was need for more frequent observations of a particular location (e.g., due to storm or field experiment). In this mode, one coast would be scanned continuously over the optimal daylight period of the day. The other two coasts could still be scanned at least once.

Discussion

Jay Herman provided information about engineering considerations. He informed the group that the event imager will have 0.5-nm resolution to measure trace gases, and these data will be integrated into 10-nm bands for coastal applications. Data rate issues preclude continuous full-spectral coverage, thus there will be a number of discrete bands placed at selected locations in the spectrum. He also called for research on bi-directional reflectance properties. This will be much more important for a geostationary sensor compared with sun-synchronous orbit since the sun angles change throughout the day. When asked about the feasibility of onboard processing, he said it is unlikely. Because of instrument drift, onboard processing diminishes the ability to do reprocessing on ground.

Dick Barber pointed out that the spatial resolution will allow observations within a large percentage of the east coast estuaries, even if one pixel next to the shore is masked out. On the west coast, studies indicate that the most intense upwelling occurs 8-14 km from shore, but it would be good to get within 500m of shore to better understand dynamics. Knowledge gaps and misconceptions exist because they are based on only available satellite data greater than 1 km off shore. Resolving diurnal variability of upwelling would also be of great value. The currents can go from upwelling to downwelling in time spans of hours.

As for temporal resolution, it takes 2-3 hours for the tidal surge to go up the Chesapeake Bay. If we want to watch that surge then the time resolution has to be basically 20 minutes to an hour or better.

Bror Jonsson pointed out that an important source of carbon exported to the ocean is from benthic macrophytes which die after winter storms, get exported – then regrow - this is another result of episodic events that requires high temporal resolution to observe. This suggests that the benthic community (human) should be brought in as users of the data, and also Landsat users.

John Moisan –Aerosols are an important but poorly understood source of nutrient fluxes to the coastal ocean. Productivity will likely increase in coastal zone from increased atmospheric deposition. There have been few studies to understand air movement from land over ocean and sinking rate of the materials deposited in the ocean.

Resolving the chlorophyll fluorescence peak requires high radiometric sensitivity.

Paula Bontempi advised the group not to limit the science solely to the GEO-CAPE design / specifications. Instead ask what are the topics we can tackle as scientists, then worry about specs.

Jay Herman – We should focus on sources – land (to water) and air (to water) – this is not being done from present LEO imagers.

Paula Coble – We need to learn more about land-ocean coupling but remember that the coupling goes both ways. Estimating CDOM requires more than one band (as is now the case). How much more can CDOM tell us about land-ocean coupling? Also submerged aquatic vegetation is important and can be mapped from higher resolution sensor. This will allow the determination of bottom albedo – by mapping the albedo over the course of week. Bottom albedo will be the constant background.

Barney Balch– Erosion events are highly episodic and important to understand / observe, especially with sea level rise.

Janet Campbell– There are other episodic events such as the runoff from land after a storm or spring snow melt. These have impacts on coastal phytoplankton blooms. Sediment loads can be dropped very quickly when plumes enter the ocean. One needs high temporal resolution to observe this process.

Randy Kawa – called our attention to his poster on GEO-CAPE (poster #174). He said the spectral range will be from the UV (340-345 nm) to 1100nm at 0.5 nm resolution, with 3 addition SWIR bands.

Heidi Sosik – She attended another breakout group to discuss the hyperspectral mission (HyspIRI) but realized that the swath width (10 km) is not suitable for our science. Revisit times are on the order of 19 days for that mission.

Bror Jonsson – The major strength of this mission will be in correlating/complementing other data sets – filling in gaps. Data need to be made readily accessible via an integrated framework. The framework would enable biologists / ecologists to use the data without having to hire a programmer to produce and integrate the data fields.

Robyn Conmy – Groundwater is often left out of these discussions. It is an important source of nutrients, metals etc. to the coastal ocean. Satellite temperature/color signals could be used to detect groundwater. High res SST would be very helpful.

Wayne Esaias – Applications are important (not just pure research). Is NASA ready to step up to this? We don't have the luxury of planning a 20-year research program – need to start providing answers now! e.g., to the decline in fisheries. This should be at the highest level in terms of the science questions/drivers. Janet pointed out that the GEO-CAPE front page lists practical uses of the data for societal benefit (e.g., tracking oil spills).

Paul DiGiacomo – This issue of humans and society and impacts to/from ecosystems was discussed to a great extent at the recent CC&E MOWG meeting.

Randy Kawa said he could use better understanding of how this mission would help address these issues – e.g., linkages with fisheries management.

John Moisan – We can track algal blooms (HABS, fish kills) but can't do fisheries per se.

Janet Campbell – Satellite obervations can provide the large-scale synoptic view to understanding coastal ecosystem variability over long periods of time. Variability in fish stocks is coherent over large scales suggesting environmental forcings at the interannual to decadal time scales. Satellite observations can be used to characterize environmental variability over time.

Then we need models to link environmental variability to primary producers and then to the higher trophic levels. The time scale for this process (transfer of energy up the food chain) is years. How does today's variability affect fish harvest 5-10 years from now?

Ivona Cetinic – Fisheries are collapsing off west coast. Some are saying that last year's upwelling was not as strong as usual so fisheries collapsed; but not true. Need the higher temporal variability and long time series. We need to understand what is forcing the collapse – is it human? Is it "natural" variability? Understanding small-scale upwelling and impacts on fisheries is important.

Wayne Esaias– We won't have the algorithms we need to address fisheries issues unless we get the mission up there, but that is not the purpose of the mission. Its purpose is to protect coastal resources, observe hazardous events, etc.

Conclusion: *With a geostationary mission we can do process studies*. Once per day satellite coverage has aliasing issues that can lead to completely wrong answers. More frequent observations will give us information about processes that are missing from models; once we know more about these processes (e.g., fluxes, growth rates) we can improve the models.

Other international space agencies are planning to do geostationary ocean color (e.g., Koreans are putting one up next year). Thus there could someday be a constellation of geostationary sensors with capability to observe the coastal ocean.