Geostationary Coastal & Air Pollution Events

GEO-CAPE Mission status

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Acknowledgments
GEO-CAPE Oceans SWG
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Background

- Mission provides high temporal, spatial, and spectral resolution observations that will **resolve the diurnal evolution** of North and South American
  - Coastal ocean ecology, biogeochemistry, water quality, event scale and sub-mesoscale biological/biogeochemical processes.
  - atmospheric composition (descoped to only North America)
- Multiple Instruments (TBD) – selection by open competition
  - UV-VIS-NIR hyperspectral sensor plus SWIR bands with high spatial resolution (250 to 375 m) for Ocean Color
  - UV-VIS hyperspectral sensor with coarser resolution (2 to 7 km) for atmospheric trace gas composition and aerosols
  - IR gas correlation sensor (for CO) or Thermal Infrared sensor
- TEMPO (Tropospheric Emissions: Monitoring of Pollution)
  - Hosted payload mission - Earth Venture Instrument selection
  - UV-Vis hyperspectral sensor (290-690 nm); 2 x 4.5km; hourly NA

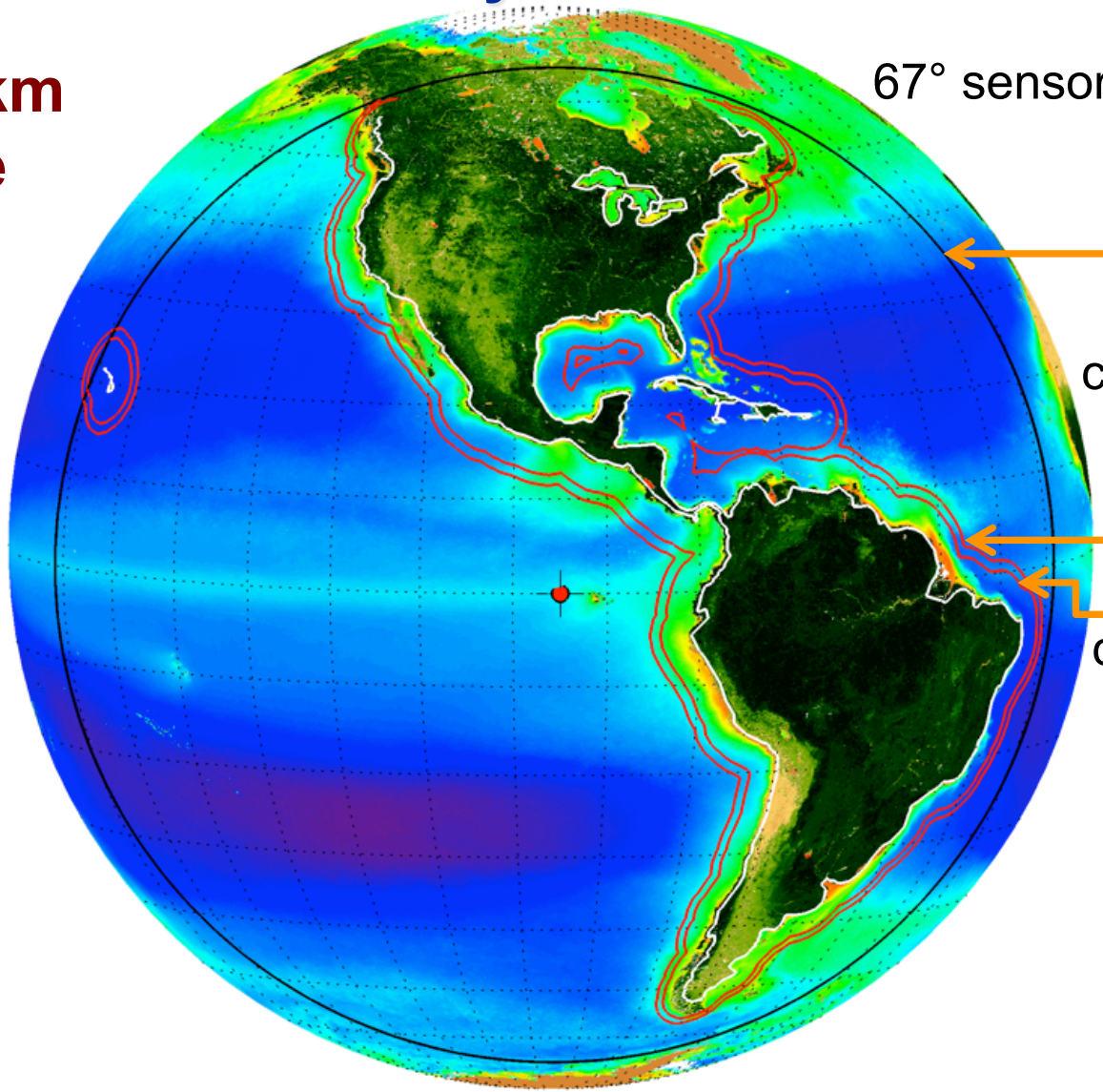
http://geo-cape.larc.nasa.gov

Mission Status

- Currently in Pre-formulation – Pre-Phase A ($2M to $3M per year)
- Recommendation to implement mission as secondary payloads hosted on commercial geostationary satellites (Fishman et al., BAMS, 2012)
- TEMPO - ~2019 launch on geo communications satellite
- GEO-CAPE is presently planned to launch no earlier than 2022
- Engineering and science studies to guide recommendations on ocean color requirements
- Planning field campaign in northern Gulf of Mexico for September 2013
- White paper describing and justifying coastal ocean color mission science and requirements to be published as NASA TM (May/June 2013)
- Collaboration between KOSC GOCI team and NASA GSFC moving forward for data mirror site & SeaDAS processing of GOCI data
    - NASA proposal funded to support GSFC collaboration with KOSC
- Promote further dialogue with international community in 2013
- GEO-CAPE meeting May 21-23, 2013 at NASA Ames

Geostationary view from 95°W

~36,000 km altitude



• Within AMF ≤ 5, where atmospheric correction is feasible, coverage extends to nearly ~60º latitude in summer and ~50º in winter and from ~30ºW to ~155º W (at equator).

Measurement & Instrument Requirements

	Threshold (minimum)	Baseline (goal)
Temporal Resolution Targeted Events	1 hour	0.5 hour
Survey Coastal U.S.	<3 hours	0.5 hour
Region of Special Interest (RSI)	≥1 RSI at 3 scans/day	multiple RSI
Other Coastal & Inland waters		≤3 hours
Spatial Resolution (nadir)	375 m x 375 m	250 m x 250 m
Field of Regard for OC retrievals	~60°N to 60°S; ~155°W to 35°W	same as threshold
Coastal Coverage (coast to ocean)	375 km	500 km
Spectral Range	345-1050 nm; 2 SWIR bands 1245 and 1640 nm	340-1100 nm; 3 SWIR bands 1245, 1640, 2135 nm
Spectral Resolution	**UV-VIS-NIR: ≤5 nm**; 400-450nm: ≤0.4 (NO_2); SWIR: ≤20-40 nm	**UV-VIS-NIR: ≤0.75 nm**; SWIR: ≤20-50 nm
Signal-to-Noise Ratio (SNR) for Ltyp at 70° SZA	**1000:1 for 350-800 nm (10nm FWHM)**; 600:1 for NIR (40nm FWHM); 250:1 & 180:1 for 1245 & 1640 nm (20 & 40nm FWHM); ≥500:1 NO_2	**1500:1 (350-800 nm)**; 100:1 for 2135nm (50nm FWHM); NIR, SWIR and NO_2 same as threshold
Onboard Calibration	Lunar monthly	Lunar monthly; Solar daily
Lifetime Design	3 years	5 years

GEO-CAPE Ocean Science Questions

Short-Term Processes

1. How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics?

Land-Ocean Exchange

2. How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics?

Impacts of Climate Change & Human Activity

- How are the **productivity and biodiversity of coastal ecosystems** changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability?

Impacts of Airborne-Derived Fluxes

- How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes significantly affect the ecology and biogeochemistry of coastal and open ocean ecosystems?

Episodic Events & Hazards

- How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone?

GEO-CAPE Oceans STM

Draft v.4.6 - Feb. 28, 2013

Science Focus	Science Questions	Approach (Maps to Science Question)	Measurement Requirements	Instrument Requirements	Platform Requirem.	Ancillary Data Requirem
Short-Term Processes **Land-Ocean Exchange** **Impacts of Climate Change & Human Activity** **Impacts of Airborne-Derived Fluxes** **Episodic Events & Hazards**	**1** How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics? (OBB 1) **2** How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics? (OBB 1 & 2; CCSP 1 & 3) **3** How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability? (OBB 1, 2 & 3; CCSP 1 & 3) **4** How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes affect the ecology and biogeochemistry of coastal and open ocean ecosystems? (OBB 1 & 2; CCSP 1) **5** How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone? (OBB 4)	GEO-CAPE will observe coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, and track carbon pools and pollutants. Two complementary operational modes will be employed: (1) survey mode for evaluation of diurnal to interannual variability of constituents, rate measurements and hazards for estuarine and continental shelf and slope regions with linkages to open-ocean processes at appropriate spatial scales, and (2) targeted, high-frequency sampling for observing episodic events including evaluating the effects of diurnal variability on upper ocean constituents, assessing the rates of biological processes and coastal hazards. (1 2 3 4 5) *Measurement objectives for both modes include:* (a) Quantify dissolved and particulate carbon pools and related rate measurements such as export production, air-sea CO2 exchange, net community production, respiration, and photochemical oxidation of dissolved organic matter. (1 2 3) (b) Quantify phytoplankton properties: biomass, pigments, functional groups (size/taxonomy/Harmful Algal Blooms (HABs)), daily primary productivity using bio-optical models, vertical migration, and chlorophyll fluorescence. (1 2 3 4 5) (c) Measure the inherent optical properties of coastal ecosystems: absorption and scattering of particles, phytoplankton and detritus, CDOM absorption. (1 2 3 4) (d) Estimate upper ocean particle characteristics including particle abundance and particle size distribution. (1 2 3 5) (e) Detect, quantify and track hazards including HABs and petroleum-derived hydrocarbons. (5) GEO-CAPE observations will be integrated with field measurements, models and other satellite data: (1) to derive coastal carbon budgets and determine whether coastal ecosystems are sources or sinks of carbon to the atmosphere, (2 3) (2) to quantify the responses of coastal ecosystems and biogeochemical cycles to river discharge, land use change, airborne-derived fluxes, hazards and climate change, and (1 2 3 4 5) (3) to enhance management decisions with improved information on the coastal ocean, such as required for Integrated Ecosystem Assessment (IEA), protection of water quality, and mitigation of harmful algal blooms, oxygen minimum zones, and ocean acidification. (3 5)	Water-leaving radiances in the near-UV, visible & NIR for separating absorbing & scattering constituents & chlorophyll fluorescence Product uncertainty TBD **Temporal Resolution:** *Targeted Events:* • Threshold: ≤1 hour • Baseline: ≤0.5 hour *Survey Coastal U.S.:* • Threshold: ≤3 hours • Baseline: ≤1 hour *Regions of Special Interest (RSI): Threshold: ≥1 RSI 3 scans/day* • Baseline: multiple RSI 3 scans/day *Other coastal and large inland bodies of water within ocean color FOR:* • Baseline: ≤3 hours **Spatial Resol. (nadir):** • Threshold: ≤375 x 375 m • Baseline: ≤250 x 250 m **Field of Regard for Ocean Color Retrievals:** 60°N to 60°S; 155°W to 35°W **Coastal Coverage*:** width from coast to ocean: • Threshold: min 375 km • Baseline: min 500 km **Scanning Priority:** •Threshold: 1. U.S. Coastal Waters* 3 to 8 times per day 2. Other coastal and large inland bodies of water 3. Open ocean waters within FOR	**Spectral Range:** Hyperspectral UV-VIS-NIR • Threshold: 345-1050 nm; 2 SWIR bands 1245 & 1640 nm • Baseline: 340-1100 nm; 3 SWIR bands 1245, 1640, 2135 nm **•Spectral Sampling & Resolution:** • Threshold: UV-Vis-NIR: ≤2 & ≤5nm; 400-450nm: ≤0.4 & ≤0.8nm (for NO_2 at spatial resolution of 750x750m at nadir); SWIR resolution: ≤20-40 nm • Baseline: UV-ViS-NIR: ≤0.25 & 0.75 nm; SWIR: ≤20-50 nm **Signal-to-Noise Ratio (SNR) at Ltyp(70° SZA):** • Threshold: ≥1000 for 10 nm FWHM (350-800 nm); ≥600 for 40 nm FWHM (800-900 nm); ≥300 for 40 nm FWHM (900-1050 nm); ≥250 and ≥180 for 1245 & 1640 nm (20 & 40 nm FWHM); ≥500 NO_2 band. • Baseline: ≥1500 for 10 nm (350-800 nm); NIR, SWIR and NO_2 bands same as threshold; ≥100 for the 2135nm (50nm FWHM) • Threshold: Aggregate SWIR bands to 2x2 GSD pixels to meet SNR; Baseline: No aggregation. **Scanning area per unit time:** Threshold: ≥25,000 km²/min; Baseline: ≥50,000 km²/min **Field of Regard:** • Full disk: 20.8° E-W and 19° N-S imaging capability from nadir for Lunar & Solar Calibrations **Non-saturating detector array(s) at Lmax** **On-board Calibration:** • Lunar: Threshold: minimum monthly; Baseline: same as threshold • Solar: Threshold: none; Baseline: daily **Polarization Sensitivity:** <1.0% **Relative Radiometric Precision:** • Threshold: ≤1% through mission lifetime • Baseline: ≤0.5% through mission lifetime **Mission lifetime:** Threshold: 3 years; Goal: 5 years	Geostationary orbit at 95W longitude to permit sub-hourly observations of coastal waters adjacent to the continental U.S., North, Central and South America Storage (up to 1 day) and download of full spatial data and spectral data.	Western hemisphere data sets from models, missions, or field observations **Measurement Requirements** (1) Ozone (2) Total water vapor (3) Surface wind velocity (4) Surface barometric pressure (5) Vicarious calibration & validation - coastal (6) Full prelaunch characterization (7) Cloud cover **Science Requirements** (1) SST (2) SSH (3) PAR (4) UV solar irradiance (5) MLD (6) Air/Sea pCO2 (7) pH (8) Ocean circulation (9) Tidal & other coastal currents (10) Aerosol deposition (11) run-off loading in coastal zone (12) Wet deposition in coastal zone (13) Wave height & surface wind speed **Validation Requirements** Conduct high frequency field measurements and modeling to validate GEO-CAPE retrievals from river mouths to beyond the edge of the continental margin.

Error (as % of nadir pixel)	Threshol	Baselin
Pointing Knowledge LOS	<50%	<10%
Pointing Accuracy LOS	<100%	<25%
Pointing Stability LOS	<50%	<10%
Geolocation Reconstr.	<100%	<10%

Intelligent Payload Module Baseline only: Near Real-Time satellite data download from other sensors (GOES, etc.) for on-board autonomous decision making.

Pre-launch characterization: Adequate to achieve the required on-orbit radiometric precision

GEO-CAPE Science Questions are traceable to NASA's OBB Advanced Planning Document (OBB) and the U.S. Carbon Cycle Science Plan (CCSP).

* Coastal coverage within field-of-view (FOV) includes major estuaries and rivers such as Chesapeake Bay, Lake Pontchartrain/Mississippi River delta and the Laurentian Great Lakes, e.g., the Chesapeake Bay coverage region would span west to east from Washington D.C. to several hundred kilometers offshore (total width of 375 km threshold).

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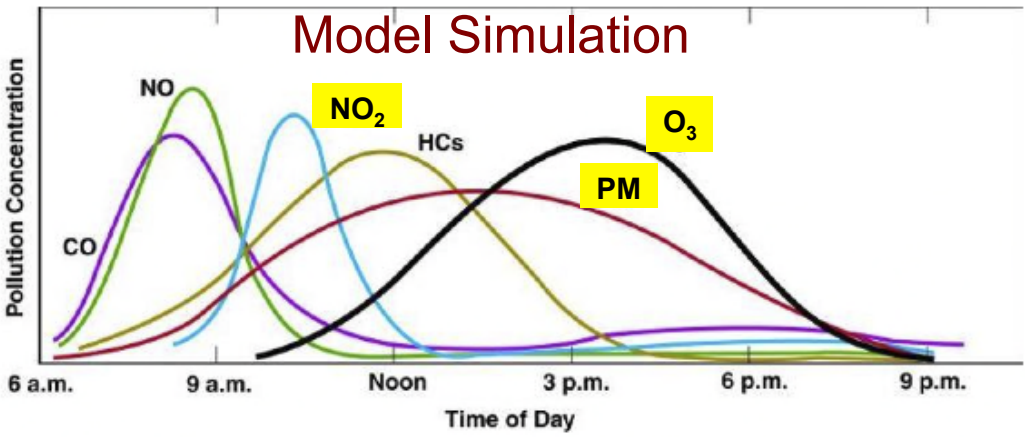
Backup

Synthesis of Science Study Recommendations on Requirements

- **Temporal resolution:** <3 hour frequency needed; <1-2 hour desirable
- **Spatial resolution:** <500 x 500m (local) needed; 250 x 250m desirable
- If uncorrected, atmospheric variability (aerosols, NO_2, O_3, etc.) will lead to a false estimate of time-dependent underwater processes in coastal areas.
  - **Spectral resolution** of 0.8 nm (spectral sampling of 0.4 nm) would be required, at least in the 400-450 nm spectral range, for NO_2 correction.
  - Retrieval of aerosol properties (SSA and aerosol layer height) critical for nLw retrievals; Detection (& correction) of absorbing aerosols necessary
- Strong need for in situ data sets with high temporal resolution (15-30 min) & spectral resolution (2-5nm) and range (up to 750nm); above water Rrs to 1670nm.



Tropospheric chemistry evolves rapidly during the day

Ocean Color & Related Products

Mission Critical Products (drive requirements; heritage algorithms)

- Spectral remote sensing reflectances - Rrs
- Chlorophyll-a, Primary Productivity
- Particulate Organic Carbon, Dissolved Organic Carbon, Particulate Inorganic Carbon (coccolithophore blooms)
- Total Suspended Matter
- Absorption coefficients of Colored Dissolved Organic Matter, Particles & Phytoplankton; Particle backscatter coefficient
- Water clarity (k_d[490nm]; euphotic depth)
- Photosynthetically Available Radiation
- Fluorescence Line Height, Phytoplankton Carbon
- Functional/taxonomic group distributions
- Harmful Algal Bloom detection & magnitude
- *Aerosols, NO_2 & other products for atmospheric corrections*

Highly Desirable Products (experimental products)

- Particle size distributions & composition, other plant pigments, phytoplankton physiological properties, vertical migration detection
- Net Community Production, Export Production, Respiration, Photooxidation
- Air Sea CO_2 fluxes, pCO_2(aq)
- Terrigenous Dissolved Organic Carbon
- Petroleum detection and thickness

Approach

GEO-CAPE will observe coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, and track carbon pools and pollutants.

Two modes of operation:

1. **survey mode** for evaluation of diurnal to interannual variability of constituents, rate measurements and hazards ...
    - U.S. coastal waters
    - Regions of special interest
    - All other coastal waters from ~50°N to 50°S
2. **targeted, high-frequency sampling** for observing episodic events (and support for coastal and deep ocean cruises) ...