Synthesis of Coastal Ecosystem Science Studies on Sensitivity and Spatial Resolution for GEO-CAPE

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Outline

- Background on GEO-CAPE Mission with focus on coastal waters
  - Science questions
  - Approach
  - Field of Regard
- Studies that inform on sensitivity and SNR issues for GEO-CAPE
  - Ltyp determination
  - SNR computation for heritage sensors
- Study on atmospheric corrections
- Studies that inform on spatial resolution requirements for GEO-CAPE
  - Spatial dynamics of an algal bloom
  - Spatial dispersion of suspended particles
  - Tidal exchanges across the land-ocean interface: time and space scales
- Synergies between PACE and GEO-CAPE

Background

- Mission provides high temporal, spatial, and spectral resolution observations that will resolve the diurnal evolution of North and South America
  - Coastal ocean ecology, biogeochemistry, water quality, event scale and sub-mesoscale biological/biogeochemical processes.
  - atmospheric composition (descoped to only North America)

Background

- Mission provides high temporal, spatial, and spectral resolution observations that will **resolve the diurnal evolution** of North and South America
  - coastal ocean ecology, water quality, event scale process & understanding, 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 500 m) – 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)
  - Thermal Infrared sensor

Pre-phase A formulation (science & engineering studies)

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

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?

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.

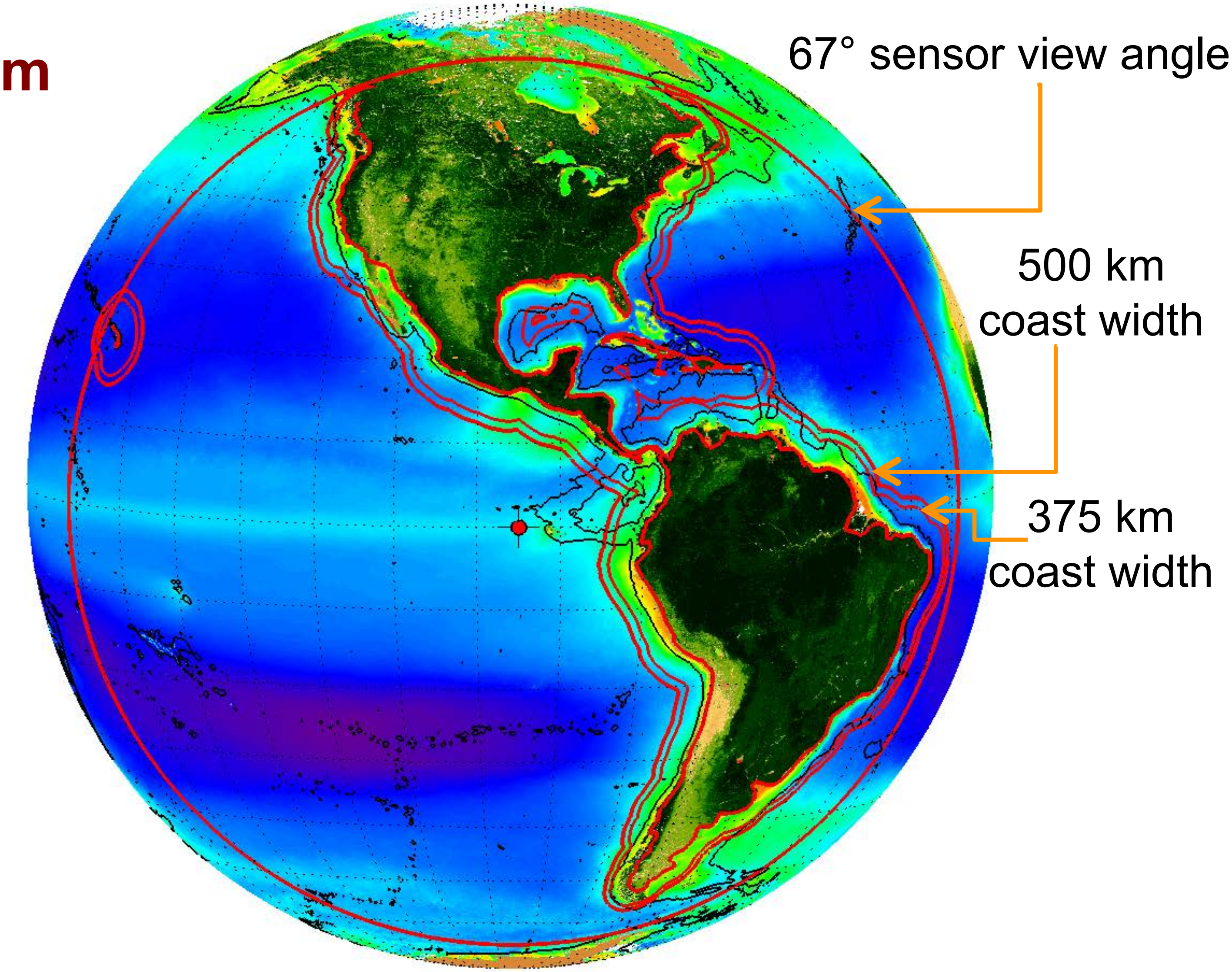
Two operational modes:

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 ~60°N to 60°S

2. **targeted, high-frequency sampling** for observing episodic events (and support for coastal and deep ocean cruises) ...

Geostationary view from 95°W

~36,000 km altitude



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

GEO vs LEO - SNR

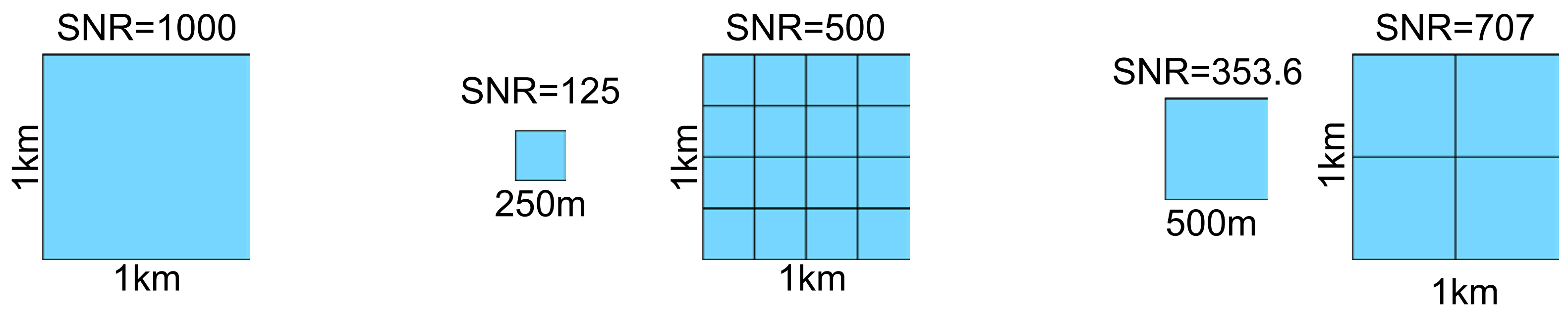
Integration time is key factor!

GEO – stare to >SNR = long integration times (GOCI integrates for 3-6 sec per band)
LEO – much shorter integration times (>10,000 times shorter)

Sample time MODIS 1km bands: 333 μsec (323 μsec integration time)
Sample time MODIS 500m bands: 167 μsec (157 μsec integration time)
Sample time MODIS 250m bands: 83 μsec (73 μsec integration time)

Source: Robert Wolfe

MODIS: 10 detector elements along track for each 1km band; 40 detectors for 250m bands.

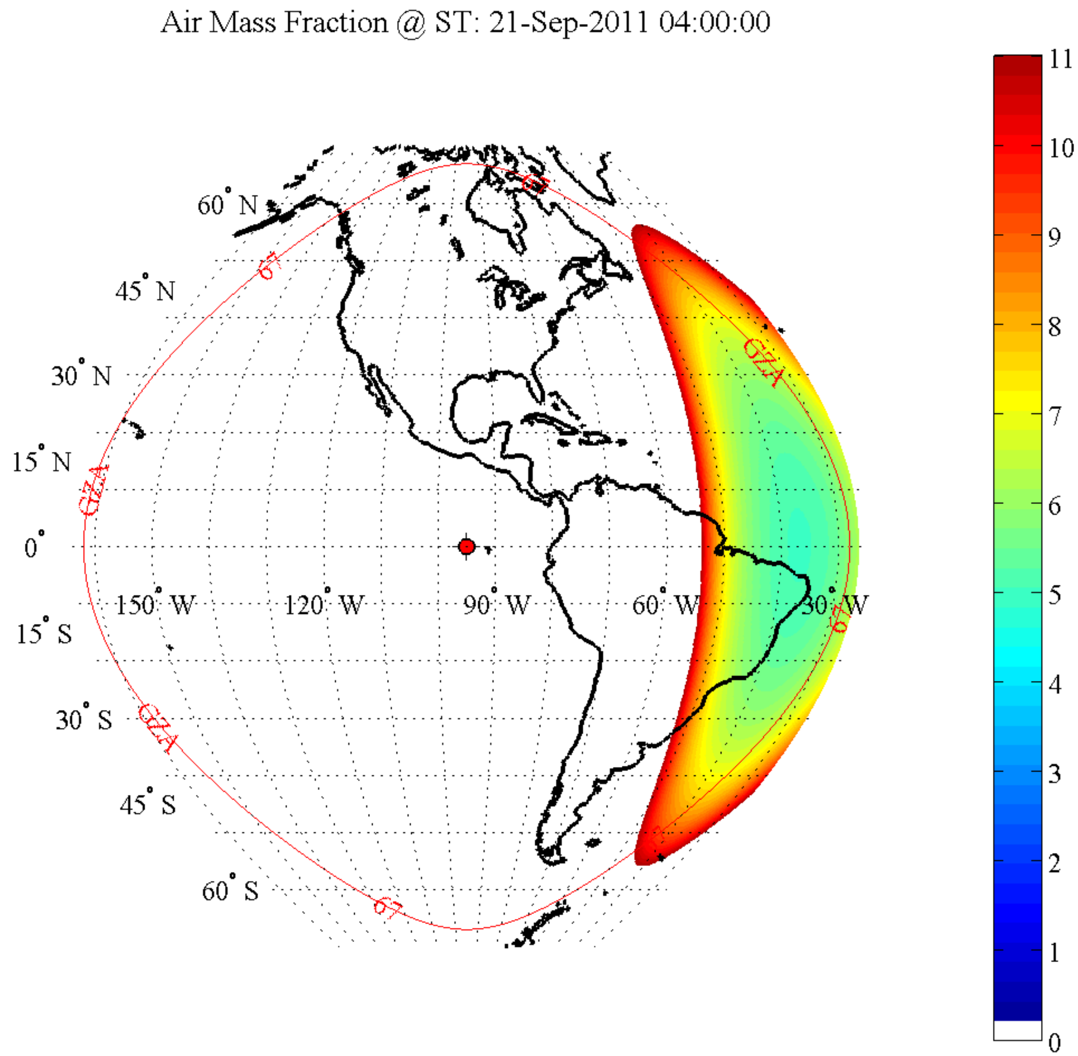


Air Mass Fraction at Equinox for 95°W

- ~16 hours of scan time available each day from ~30ºW to ~155º W.

- Scan Atlantic coastal & deep ocean waters in early morning

- Scan Pacific coastal & deep ocean waters in late afternoon



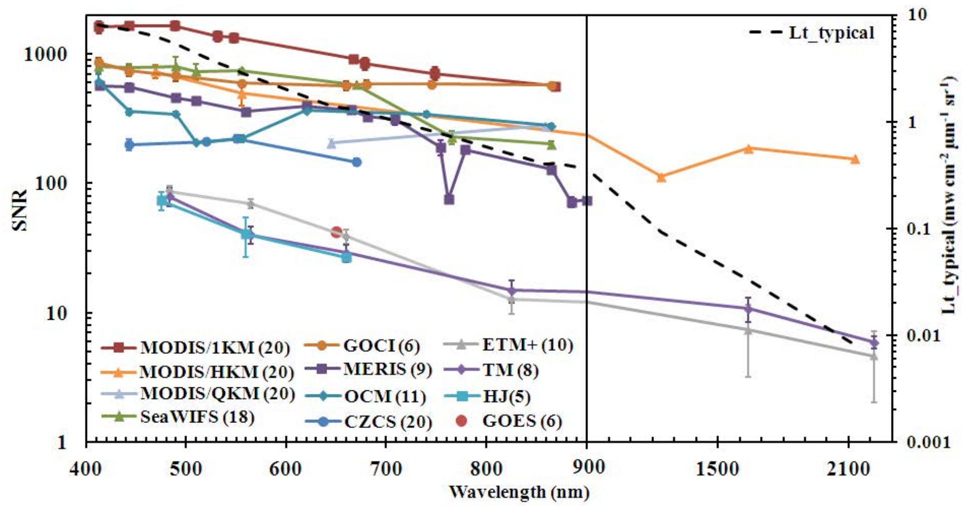
D. Aurin & A. Mannino

GEO-CAPE Measurement Requirements: Practical Considerations on Solar Irradiance, Sensitivity, Cloud Cover and Sun Glint

Chuanmin Hu - University of South Florida

Summary of Activity

- Quantified spectral $L_{typical}$ and L_{max} under various SZA (70º - 0º) using MODIS/Aqua measurements.
- Quantified SNR for several ocean color sensors (MODIS, SeaWiFS, MERIS, CZCS) under identical $L_{typical}$ input
- Estimated R_{rs} uncertainty induced by using ozone climatology instead of real-time ozone
- Documented signal changes of solar stimulated fluorescence due to efficiency changes at low-light levels
- Provided figures and text to the Geo-CAPE whitepaper (submitted)
- Attended GEO-CAPE workshops and most weekly telecons.

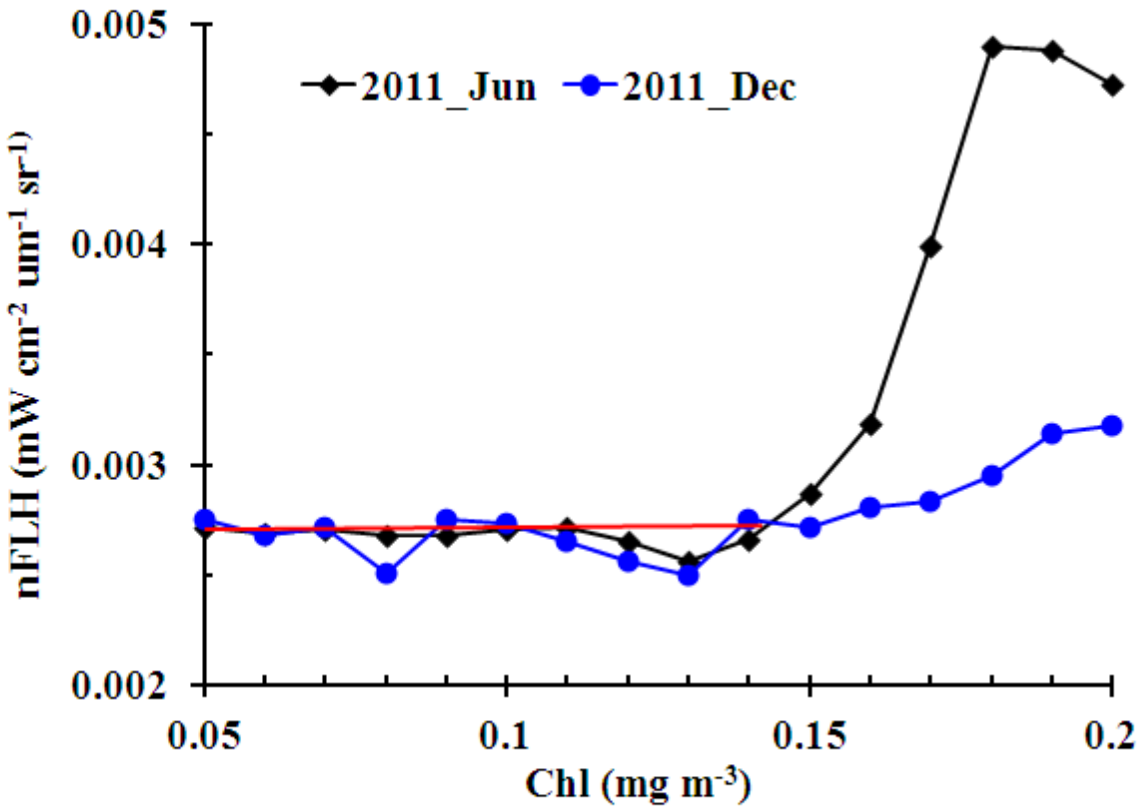


Impact & recommendations for GEO-CAPE

- $L_{typical}$ and L_{max} estimated from MODIS and extrapolated to other were used for GEO-CAPE sensor specifications
- SNRs from heritage sensors were used as reference to specify GEO-CAPE SNR under given radiance input ($L_{typical}$).
- Glint distributions in space and time for GEO-CAPE coverage were obtained. These will be used for mission planning

Chuanmin Hu, et al., TBS March 2012

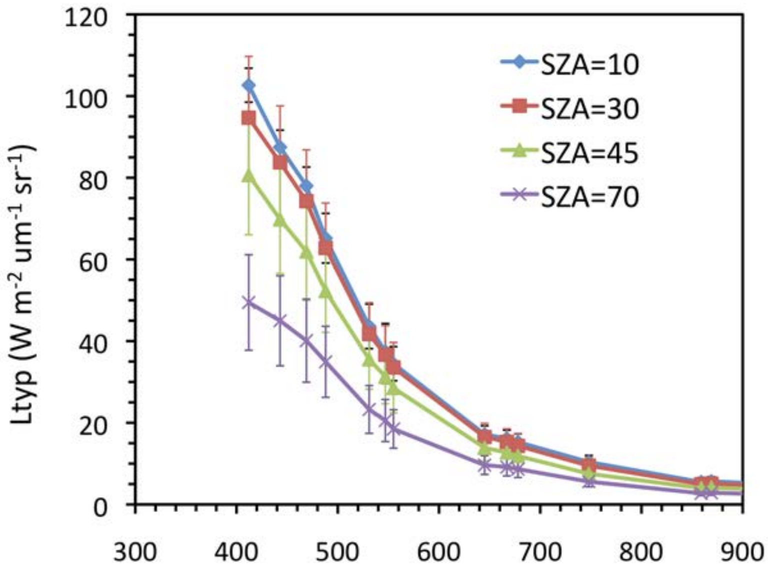
Sensitivity MODISA FLH

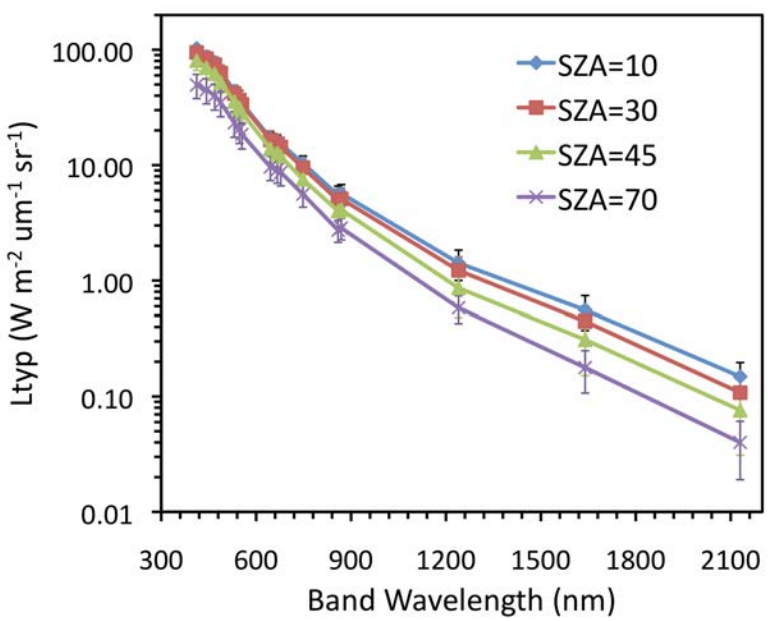


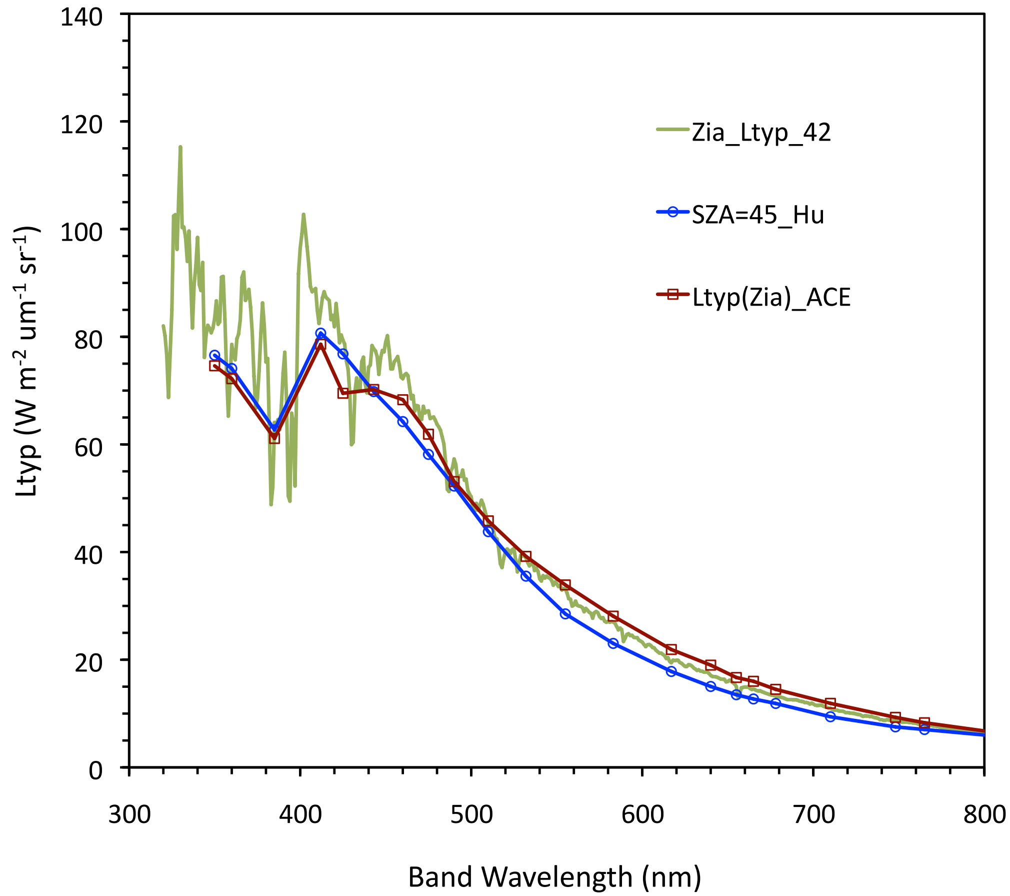
- Sensitivity of MODISA FLH in detecting Chl changes at low concentrations.
- FLH remains stable for Chl <0.14 – 0.15 mg m^3, suggesting that FLH is unable to resolve Chl in a local region for low concentrations.
- Data were extracted from a 10° x 10° (60 – 50°W, 30 – 40°N) region near the North Atlantic Gyre, with > 300 (often > 3000) valid pixels used in the calculation for each concentration.

Chuanmin Hu, et al., TBS March 2012

Sensitivity - Ltyp



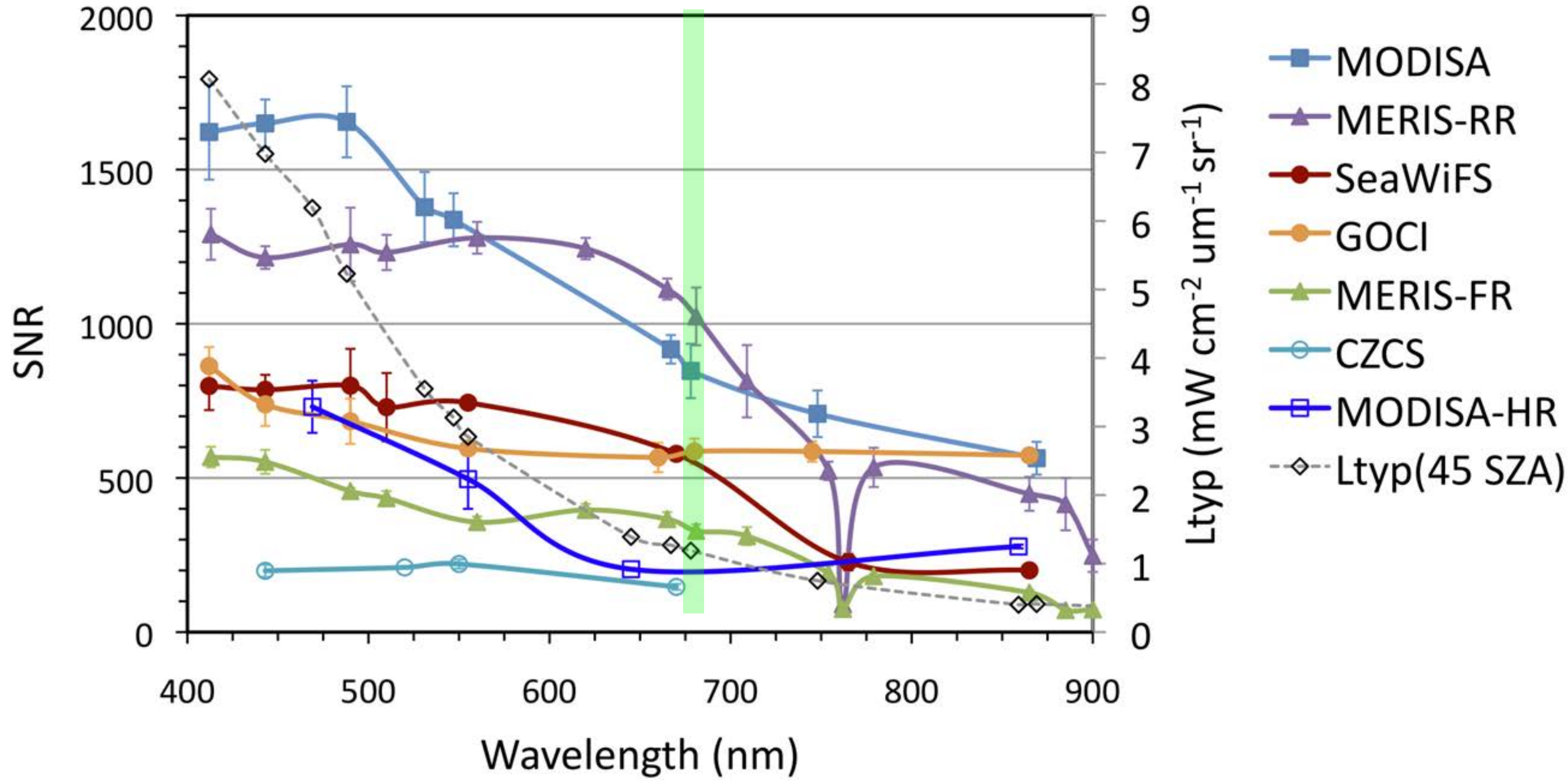




Chuanmin Hu, et al., TBS March 2012

Z. Ahmad, A. Mannino & C. Hu

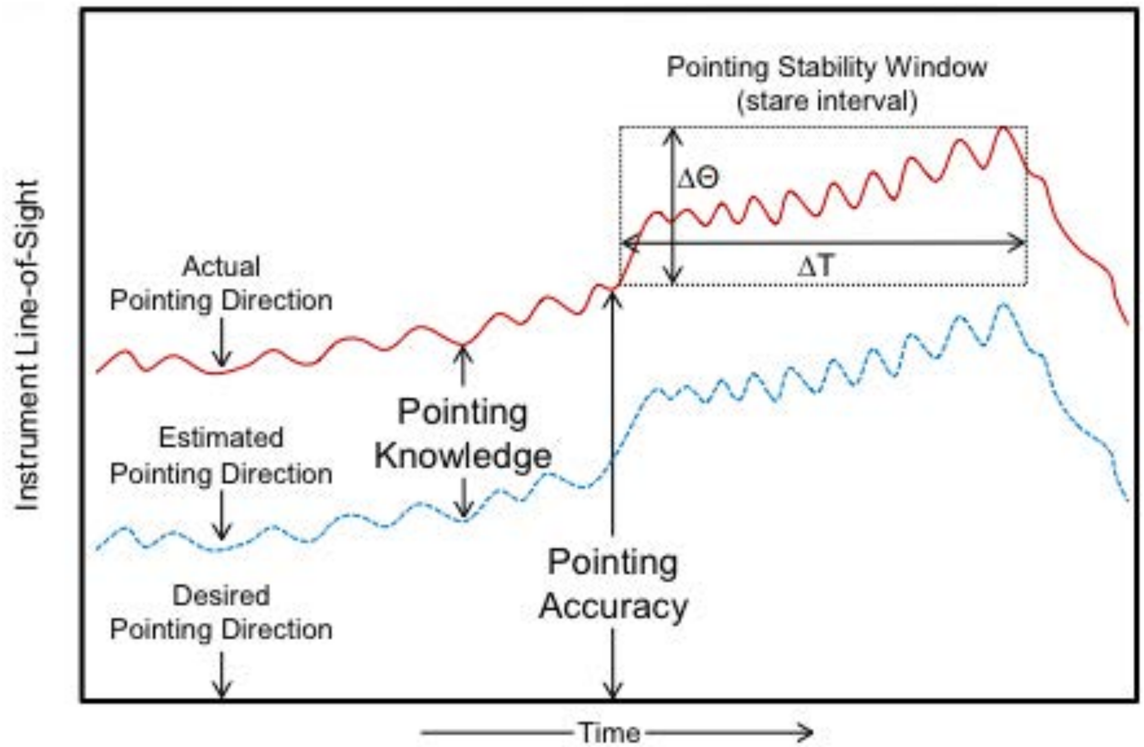
SNR of Heritage Sensors from identical Ltyp



Chuanmin Hu, L. Feng, Z. Lee, C. Davis, A. Mannino, C. McClain, TBS March 2012

Spatial Resolution & Pointing Requirements

With spatial resolution, must also consider line-of-sight pointing accuracy, knowledge, stability and post-processing geolocation



- Line-of-Sight Pointing Accuracy: Ability to point a pixel at a specific target location (e.g. a specific latitude / longitude)
- Line-of-Sight Pointing Stability: Ability to keep a pixel pointed to its target during a science observation ($\Delta\Theta/\Delta T$)
- Line-of-Sight Pointing Knowledge: Ability to determine a pixel's geo-location after it is pointed to the target (onboard)
- Pointing Geo-Location Reconstruction: Ability to determine the pixel geo-location from the science observation data

Source: Richard Key

Atmospheric Correction for Oceans - Applications to GEO-CAPE

Jay Herman (UMBC, NASA/GSFC) and Maria Tzortziou (UMCP, NASA/GSFC)

- **Summary of Activity**

Variability in atmospheric aerosols and trace gasses is one of the largest sources of uncertainty for satellite ocean color retrievals, especially in coastal waters that are close to heavily polluted areas.

We performed preliminary estimates of the error in remotely-sensed ocean color caused by uncertainties and approximate knowledge of the amount of NO_2 in the satellite's field of view.

New measurements and regional air-quality model simulations were used to determine spatial and temporal variability in NO_2 and other trace gases at urban sites close to coastal regions.

Results were assessed in terms of the proposed GEOCAPE OC sensor characteristics and recommendations were made to meet OC retrieval requirements.

- **Results to date**

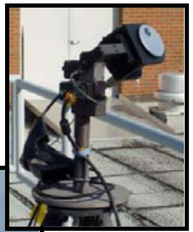
→ Measurements at near-coastal land sites show that the temporal variability of NO_2 can easily exceed 0.5 DU over a period of an hour.

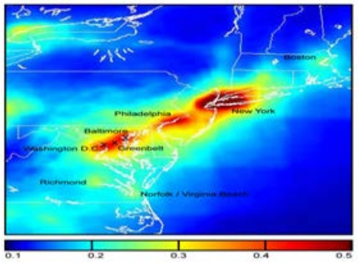
→ Considerable temporal variability was also observed in total column O_3 amounts, as high as 40-50 DU at coastal urban sites.

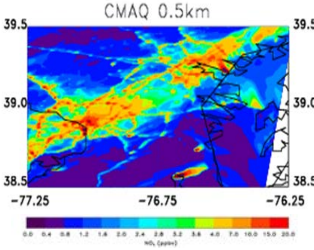
→ The observed short-term temporal changes in NO_2 and O_3 amounts cannot be captured by OMI or other satellite instruments in sun-synchronous orbits with at most 1-3 daily overpasses

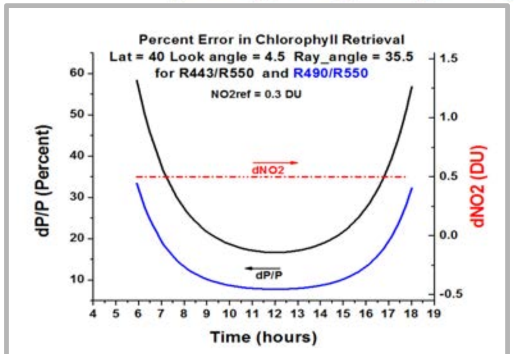
→ Preliminary results suggest that each 0.5 DU change in NO_2 results in 5-7% error in water leaving radiances at 410 nm, low solar zenith angle (< 40^o) and low look angle. The error becomes larger (reaching 15-20%) for larger solar zenith and look angles (expected with GEOCAPE), and when NO_2 is distributed at higher altitude.

→ If not sufficiently corrected, such variability in NO_2 could result in a false temporal variability in chlorophyll-a, with retrievals errors over 50% depending on solar zenith angle.









Error in chl-a from 0.5 DU error in NO_2

- **Impacts & recommendations for GEO-CAPE**

-If uncorrected, atmospheric variability will lead to a false estimate of time-dependent coastal ocean processes.

-The resulting error in Rrs and nLw is spectrally dependant (with maximum at 400-450 nm), so it does not cancel out when using band-ratios for retrievals of ocean biogeochemical variables.

- Based on these preliminary results, a 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 accurate atmospheric NO2 correction of coastal ocean color measurements from GEO-CAPE.

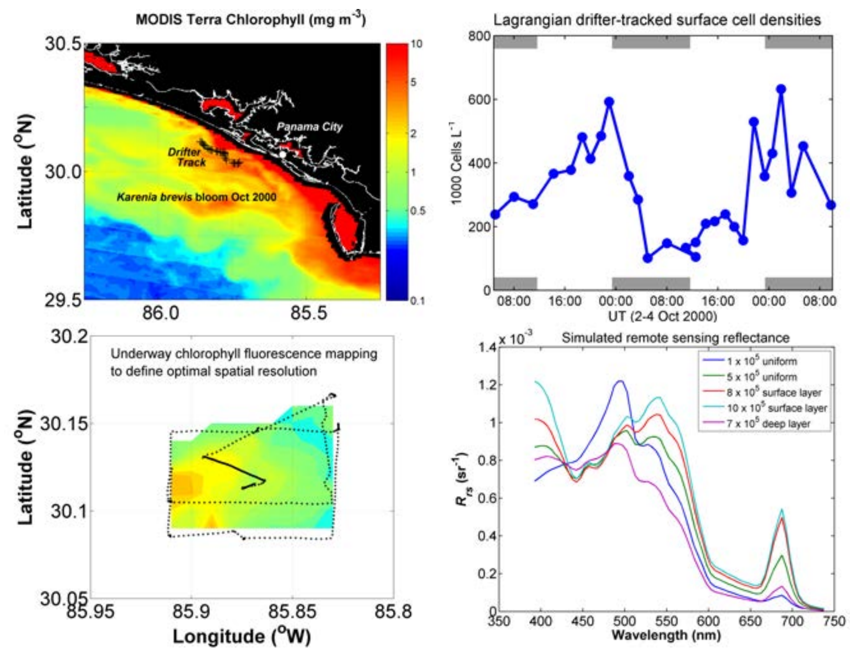
- Additional work, using measurements of atmospheric variability over estuarine and coastal waters and a vector RT code, will provide improved estimates that will be used to assess results in terms of the GEO-CAPE mission objectives and measurement and instrument requirements

Consideration of Temporal and Spatial Dynamics of Vertically Migrating Harmful Algal Blooms in Support of Developing GEO-CAPE Science and Mission Requirements

Steven E. Lohrenz - University of Massachusetts Dartmouth

- **Summary:** Systematic analysis of in situ observations to define temporal and spatial scales needed to resolve dynamics and provide diagnostic criteria for discrimination of vertically migrating harmful algal blooms (HABs)

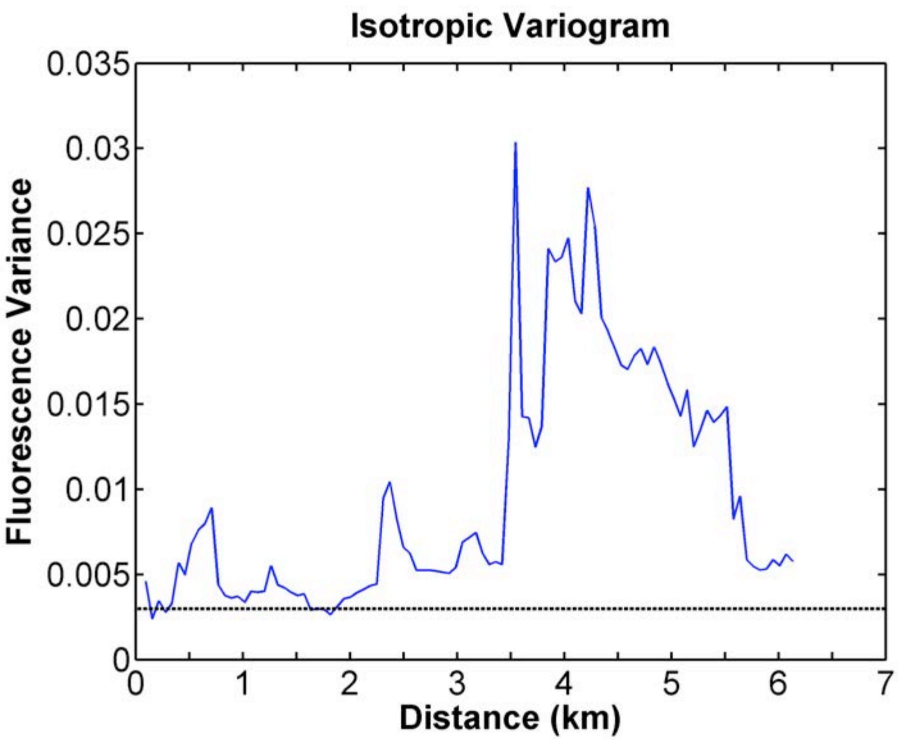
- Objectives:
  - Examine temporal variations in upper water column population distributions and associated inherent optical properties (IOPs) to identify critical temporal sampling scales needed to resolve variations
  - Use radiative transfer modeling in conjunction with measured and modeled IOPs to develop simulated datasets of water leaving radiance in relation to bloom dynamics
  - Examine length scales of bloom features in relation to sensor spatial resolution

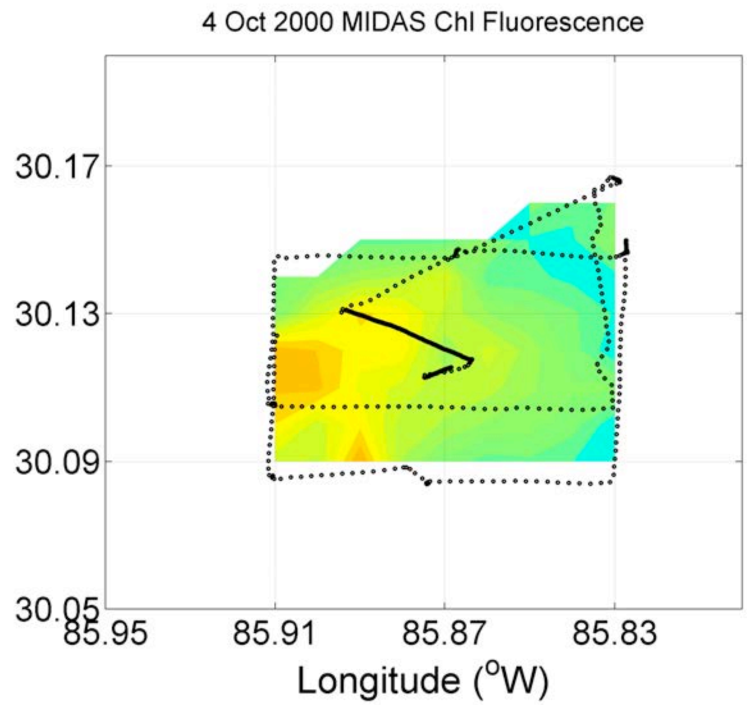


- Results to date
  - Temporal variations in HAB vertical migration necessitates acquisition of multiple daily images to resolve and detect
  - Radiative transfer simulations of remote sensing reflectance (*Rrs*) for different vertical distributions showed distinct spectral patterns
  - Length scales for underway mapped fluorescence were less than 0.5 km in the vicinity of bloom features

- Recommendations for GEO-CAPE
  - Three to four daily images required to characterize temporal variability in surface bloom dynamics
  - Simulations of *Rrs* will provide a means to characterize effectiveness of discrimination for different spectral resolutions and vertical bloom distributions
  - **Spatial resolution of <0.5 km is needed to adequately resolve bloom features**

Spatial Variability Underway Chl-a Fluorescence





Variogram of the residual fluorescence (blue line) compared to the noise threshold (dashed line). Where variance exceeds the noise threshold, this is attributed to real variation in observable patterns.

- Variance in the residuals exceeded the noise level for features having spatial scales on the order of 0.5 km or less.
- Moline et al. (2005) reported minimum length scales of 50-300 m based on spatial scales of optical properties from an autonomous underwater vehicle.
- Bissett e al. (2004) also reported optimal ground sampling scales for inner shelf waters of 50-200 m for locations 1-10 km from shore.

Spatial Resolution Requirements for GEO-CAPE

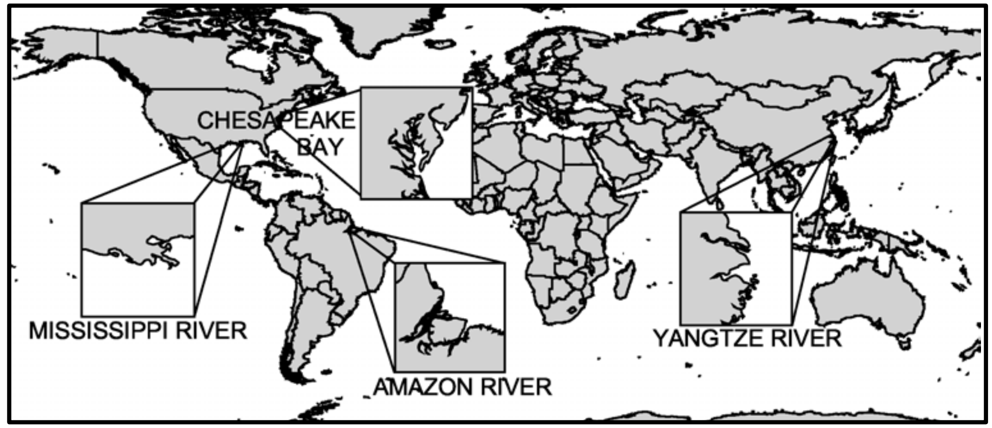
Dirk Aurin & Antonio Mannino – NASA GSFC

Summary

What resolution best captures spatial structure and dispersion of remotely sensed total suspended materials in coastal and near-shore environments?

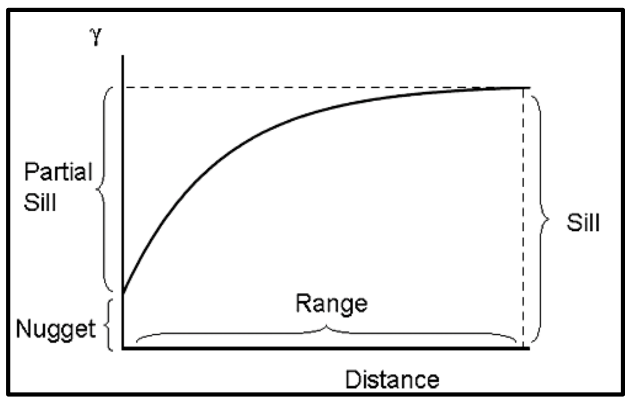
Approach

- 434 MODIS 250 m resolution images processed to TSM at turbid, optically complex river plumes during peak and nadir flow.
- Interpixel variability, σ, calculated at virtual stations along a transect exiting the plume toward offshore. If σ of an array around each station (i.e. 2x2, 3x3, 4x4 pixels, etc.) exceeds background noise, then heterogeneity in TSM would be missed with coarser resolution.
- Semivariogram analysis to establish degree of variability captured with the plume.



$$\sigma = STD/\bar{p} \qquad STD = \left(\frac{1}{n-1}\sum_{i=1}^{n}(p_i - \bar{p})^2\right)^{1/2}$$

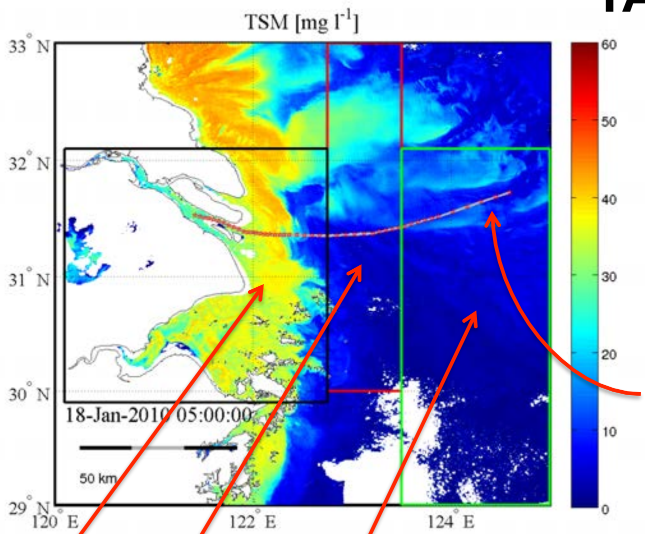
Where p_i is the property value of the ith pixel, and $\bar{p}$ is the average of an array of adjacent pixels



Idealized semivariance γ(h) increases to range as more distant observations diverge, then plateaus at sill. "Nugget" denotes proportion of variance resolved. Slope of γ (h) indicates intermediate scale patchiness.

Spatial Resolution to Capture TSM Variability in River Plume & Ocean

YANGTZE RIVER



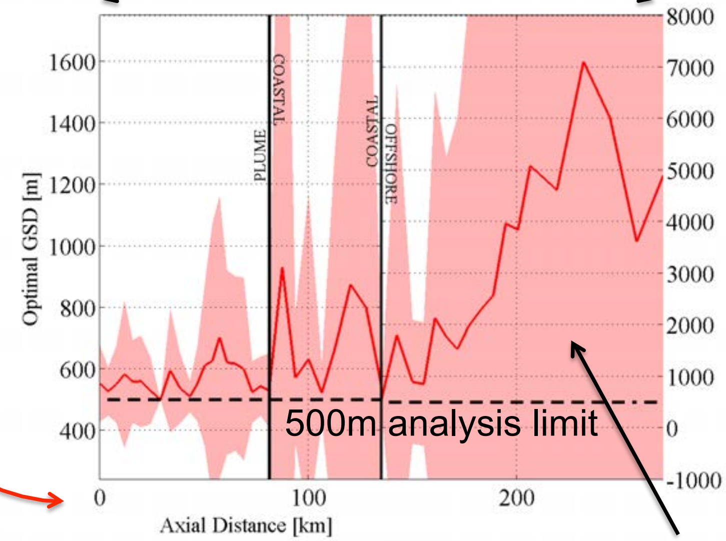
Virtual Transect

Plume

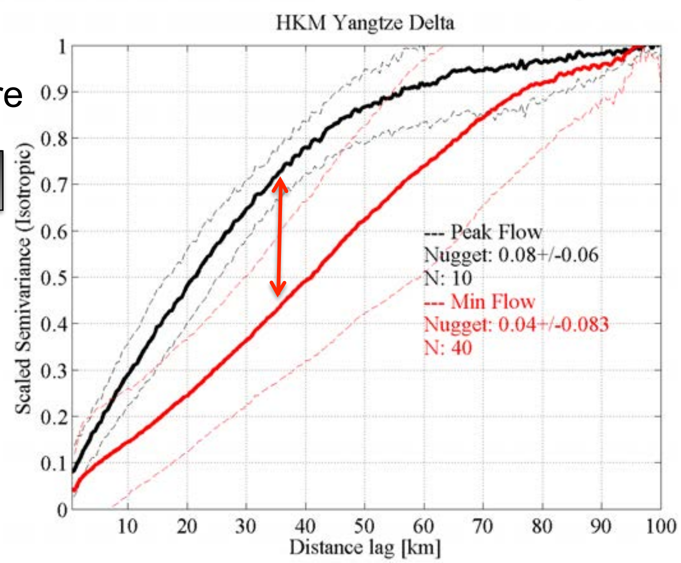
Coastal

Offshore

note change in scales



Standard error (shaded) among 84 images



Conclusion

- 92% ± 6% variability captured
- Patchiness increases at 20 – 40 km scales during peak flow

Conclusion

- ~500m – 600m required in Plume
- ~600m – 800m required Coastal
- ~1km – 6km required Offshore

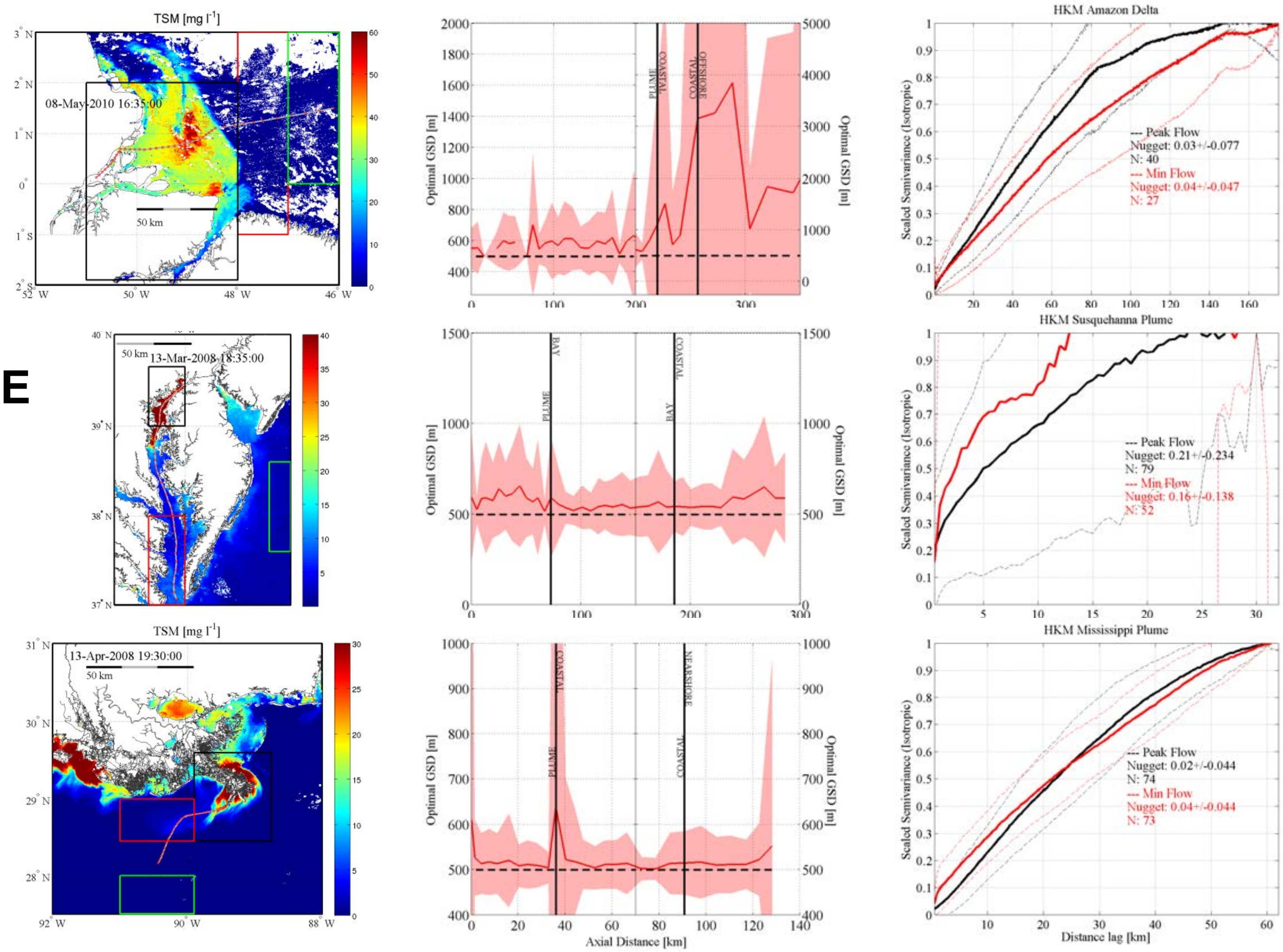
Dirk Aurin & Antonio Mannino

Spatial Resolution to Capture TSM Variability in River Plume & Ocean

AMAZON RIVER

CHESAPEAKE BAY

MISSISSIPPI RIVER



500 – 600 m resolution required in all plume and most nearshore regions

Tidal exchanges across the land-ocean interface
Time and space scales of biological, biogeochemical and optical variability

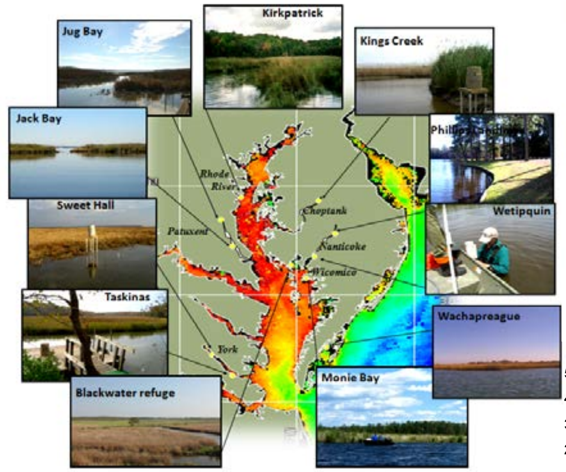
Maria Tzortziou (University of Maryland, NASA/GSFC) and Antonio Mannino (NASA/GSFC)

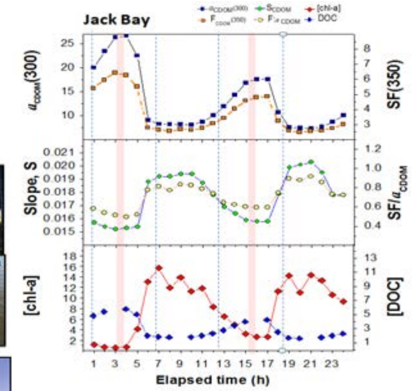
• Summary of Activity

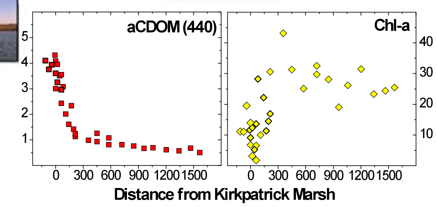
Coastal marshes are hot spots of biogeochemical transformation and exchange. ***The time and space scales of these biogeochemical exchanges however, are poorly constrained.***

We conducted high-frequency (hourly), high-resolution (25-100m) field observations to characterize temporal variability in water bio-optical characteristics and spatial gradients in dissolved carbon due to tidal marsh outwelling in the Chesapeake Bay.

Results were applied to make recommendations on the temporal frequency and spatial resolution required on GEO-CAPE to resolve carbon fluxes, near-shore processes, and exchanges of carbon, nutrients and pollutants at the land -ocean interface.







• Results to date

<u>Temporal Variability - Summary:</u>

→ Strong temporal variability in biogeochemical variables associated with tidal patterns, ***as strong as by a factor of 15 in chlorophyll, and a factor of 5 in CDOM absorption*** within 6-hour periods (low to high tide).

<u>Spatial Variability - Summary:</u>

→***Strong spatial gradients in DOC, CDOM, DIC, pCO2 and chl-a , with changes by a factor of 2 to 10 within a distance of 0.5 to 1 km.***

→ Tidal outwelling of dissolved carbon from wetlands and marshes, and trapping of algae and other suspended particulate matter in marsh systems.

→Attention is needed when extrapolating observations closer to the "source", because of non-conservative mixing.

• Impacts & recommendations for GEO-CAPE

<u>Temporal Variability - Resolution:</u>

→ ***3-hour resolution is needed*** *to resolve observed patterns.*

→*Additional information regarding the exact time of low and high tide would improve interpolation and estimates of carbon dynamics and fluxes in estuarine and coastal waters.*

<u>Spatial Variability - Resolution:</u>

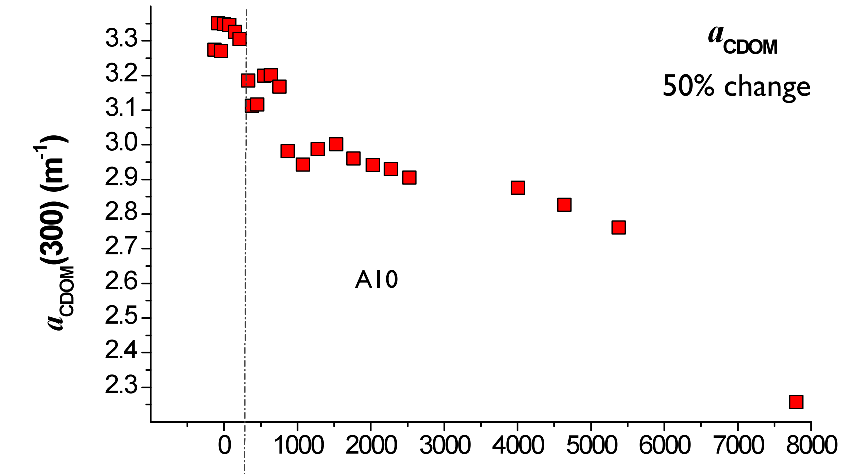
→***250-500 m resolution*** *would allow resolving spatial gradients associated with land-ocean exchanges.*

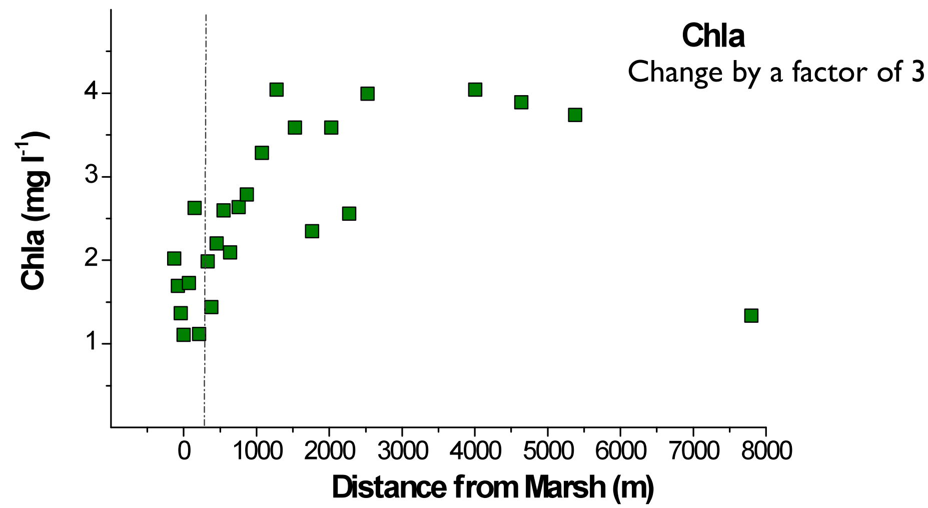
→ *1km too coarse to resolve observed biogeochemical gradients.*

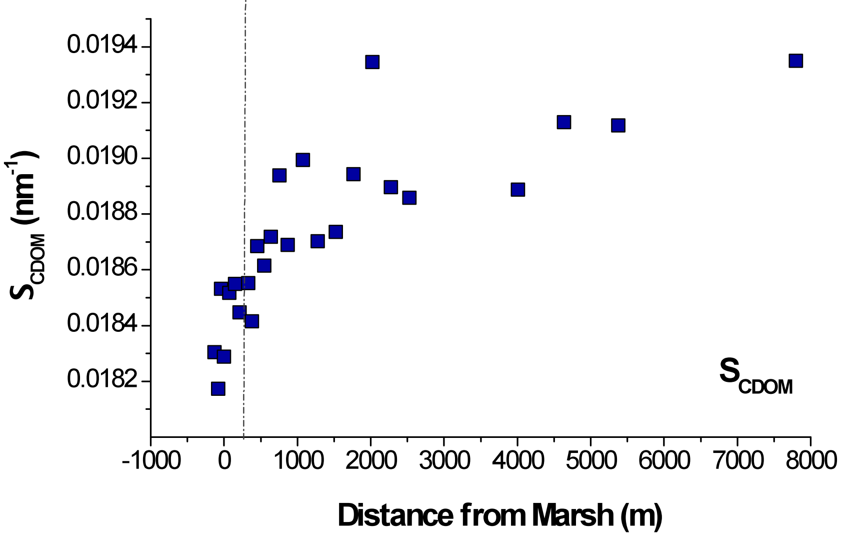
→ *GEO-CAPE observations will need to be combined with new, advanced estuarine biogeochemical models for assessing the relative importance of different processes at the land-ocean interface.*

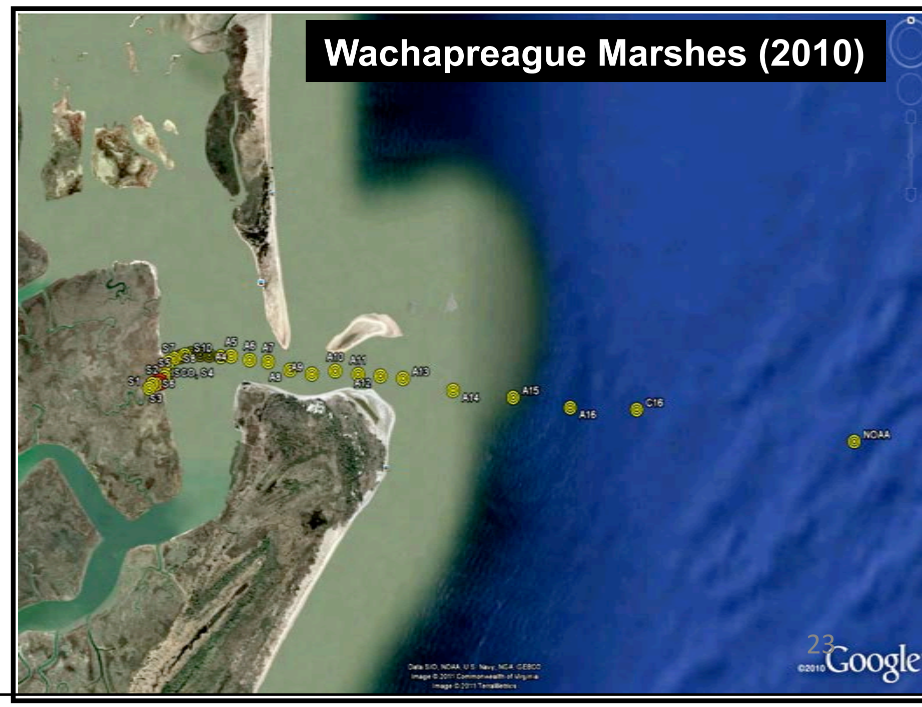
Resolution	Needed	Desirable
Temporal	3-hour	1-2 hours
Spatial	500 m	250 m

Spatial Scales of biological, biogeochemical and optical variability









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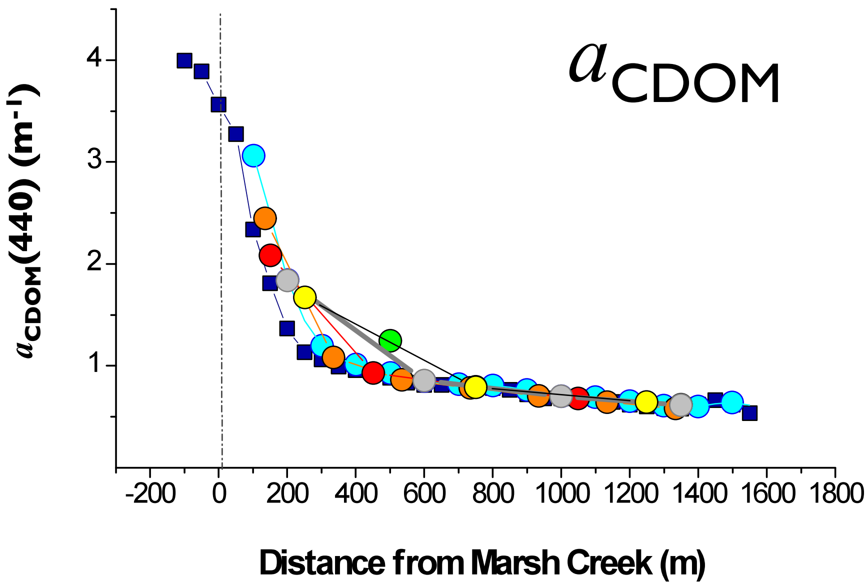
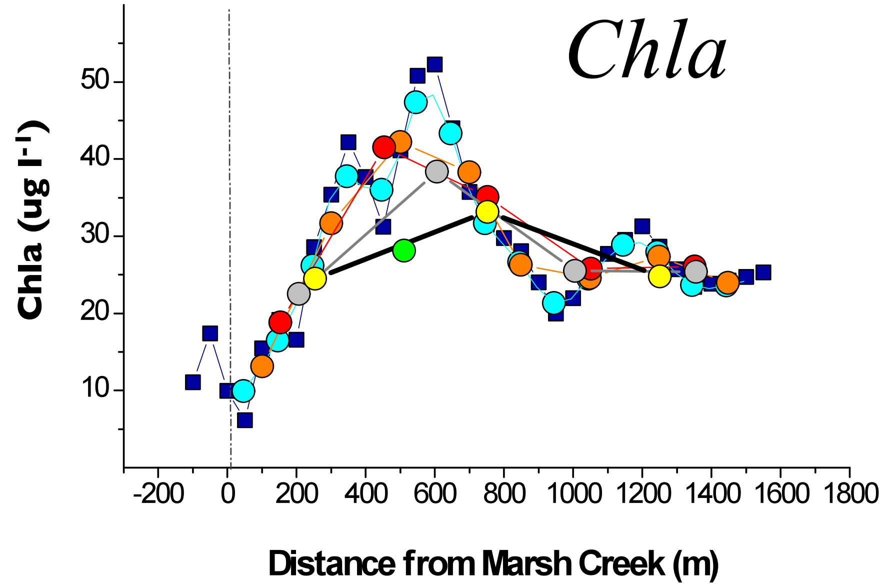
Spatial Scales of biological, biogeochemical and optical variability

Kirkpatrick Marsh





	CDOM	chl-a
100m	± 7%	-10% to 25%
200m	up to 13%	-20% to 40%
300m	up to 25%	-20% to 40%
400m	up to 36%	-25% to 40%
500m	> 40%	-25% to 40%
1 km	> 40%	-40% to 55%

M. Tzortziou, A. Mannino, P. Neale, P. Megonigal, M. Butterworth

Spatial Scales of biological, biogeochemical and optical variability

Spatial Variability - Summary:

• We found strong spatial gradients in DOC, CDOM, DIC, pCO_2 associated with tidal export of dissolved carbon from marshes

• Marshes seem to trap algae and other suspended particulate matter

Spatial Variability / Resolution:

• 1km too coarse to resolve these gradients

• 250-500 m resolution would allow resolving spatial gradients associated with land-ocean exchanges

• High resolution is needed to start exploring processes in sub-estuaries & tributaries

• Attention is needed when extrapolating to the "source", because of non-conservative mixing

• Need combination of satellite observations with field observations and advanced estuarine biogeochemical models to study the land-ocean interface.

Temporal Variability / Resolution:

• Strong temporal variability in biogeochemical variables associated with tidal patterns, ***factor of 15 in chlorophyll, and 5 in CDOM absorption*** within 6-hour periods (low to high tide).

Resolution	Needed	Desirable
Temporal	3-hour	1-2 hours
Spatial	500 m	250 m

M. Tzortziou, A. Mannino, P. Neale, P. Megonigal, M. Butterworth

Synthesis of Science Study Recommendations on Requirements

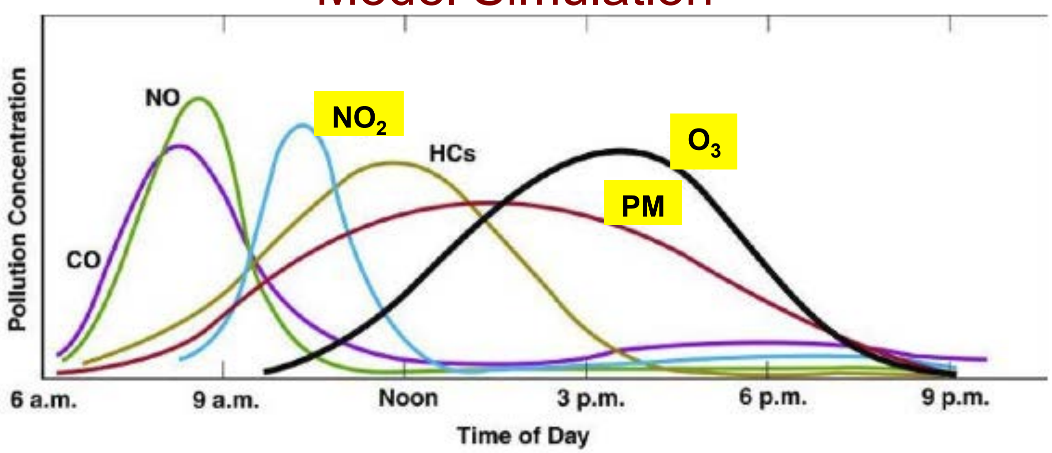
• **Temporal resolution:** <3 hour frequency needed; <1-2 hour desirable

• **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.

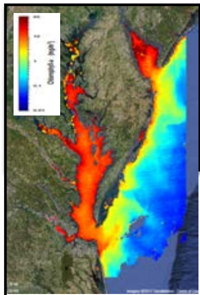
Model Simulation



Tropospheric chemistry evolves rapidly during the day

Potential Synergies of PACE & GEO-CAPE

- Infrastructure: vicarious calibration sites, ground station resources, *in situ* sensor technology development, augmenting AERONET sites, airborne sensors, etc.
- Joint field campaigns – pre- and post-launch
  - Algorithm development (UV, hyperspectral, etc.)
  - Atmospheric corrections
- Use PACE for data at high latitudes beyond GEO-CAPE FOR
- Use PACE as proxy data to learn how to handle hyperspectral data sets
- cal/val plan: vicarious calibration site within GEO-CAPE OC FOR but not too steep sensor angle.
- Cross-calibration/validation of satellite sensors
- GEO-CAPE support for open ocean experiments

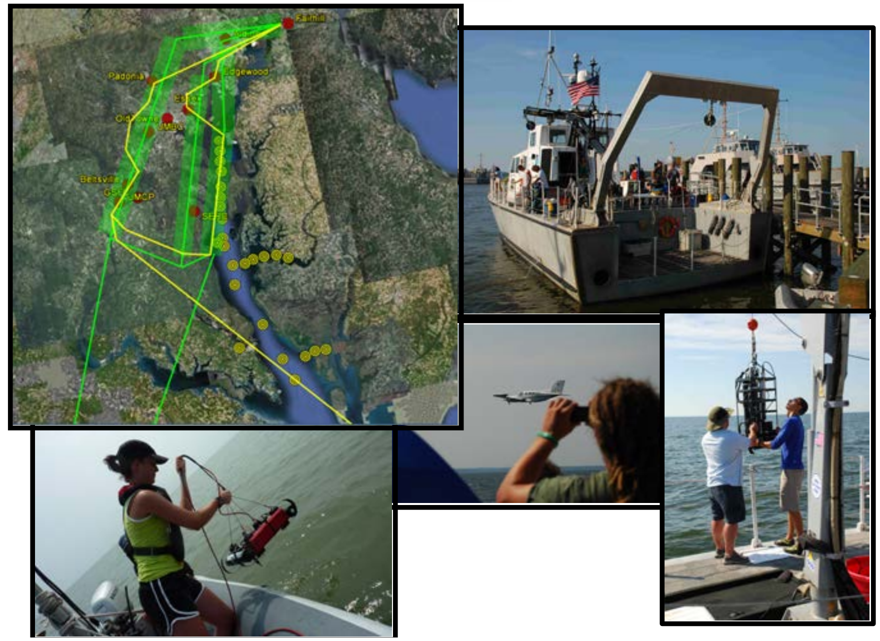


GEO-CAPE July 2011 field campaign in Chesapeake Bay (CBODAQ)

Summary of Activity

Goal was to obtain detailed atmospheric & oceanographic observations for characterizing short-term dynamics and spatio-temporal variability in atmospheric and coastal ecosystem processes.

1) **Transects** – sampling along a gradient (north to south, river tributary to open waters of the bay, salt marsh creek to open waters of bay),
2) **Sampling a water mass** throughout a day by following a surface drifter, and
3) **Sampling same location** throughout a day



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

Measurements

- High resolution (spatial, temporal and spectral) UV-Vis-NIR multi-/hyperspectral AOPs, IOPs, POC/PN, DOC, SPM, nutrients, primary production, CTD, aerosol spectral properties & composition, column & surface trace gases (ozone, NO_2), boundary layer height, meteorological data.
- Measurements coordinated with DISCOVER-AQ aircraft flights over Chesapeake Bay.

Results will lead to recommendations on

- measurement requirements,
- instrument requirements,
- atmospheric correction,
- interdisciplinary science,
- algorithm development for coastal products.

Mannino & Tzortziou, Chief Scientists

Constellation of Ocean Color Science Missions

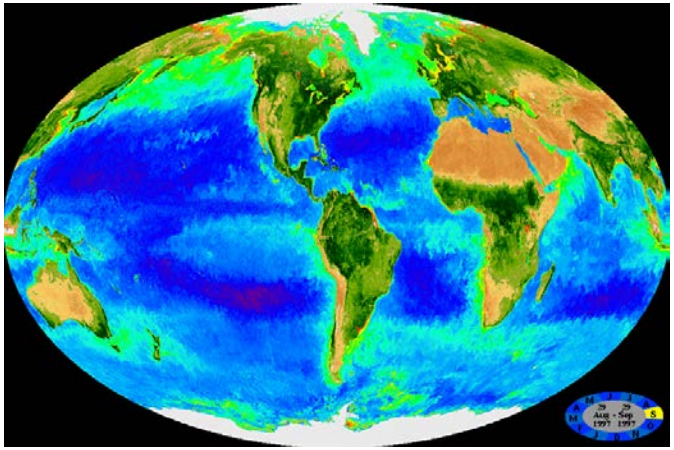
Global ocean color missions:

- *JAXA S-GLI; ESA OLCI; etc.*
- *NASA PACE (2019);* ACE (>2020)

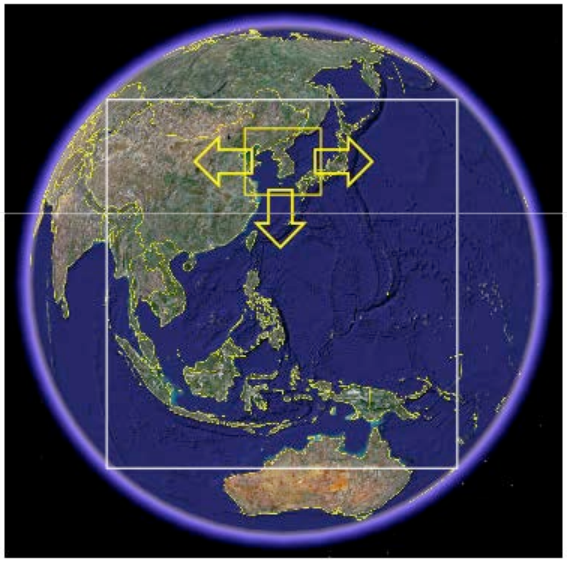
Geo ocean color missions:

- *Korea's GOCI-II*
- *NASA's GEO-CAPE*
- *ESA's HOCI or OCAPI*
- *ISRO's HR-Geo*

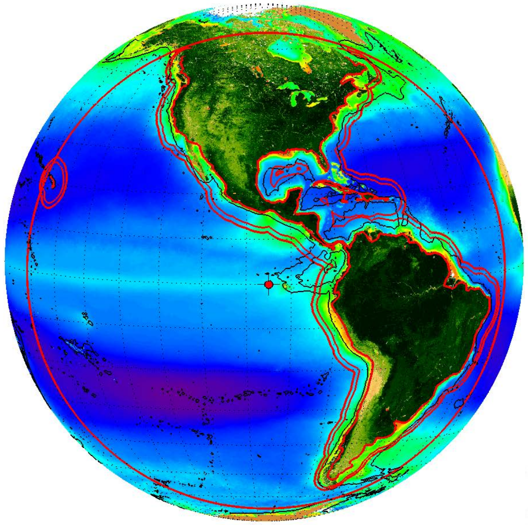
PACE-OES, OLCI, S-GLI, etc.



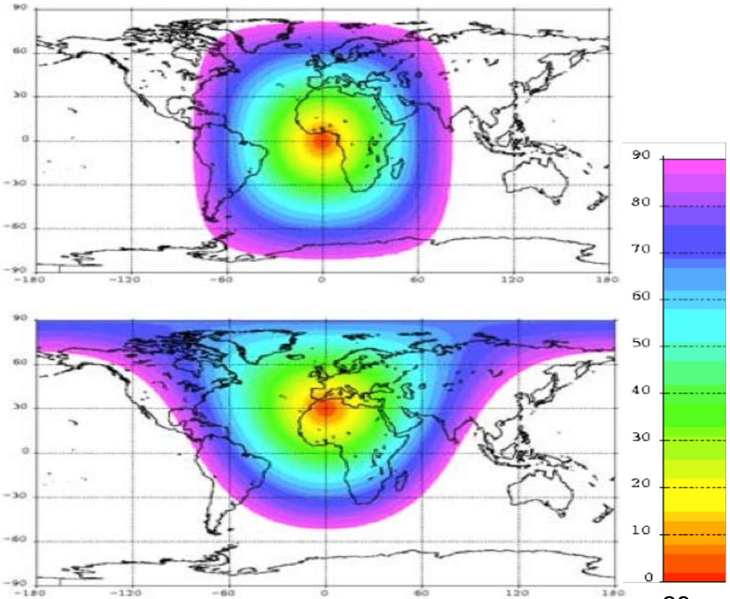
GOCI-II: 2018



GEO-CAPE: >2020



OCAPI: ?



Backup

GEO-CAPE Oceans STM

Draft v.4.0 - Dec. 8, 2011

Science Focus

- Short-Term Processes
- Land-Ocean Exchange
- Impacts of Climate Change & Human Activity
- Impacts of Airborne-Derived Fluxes
- Episodic Events & Hazards

Science Questions

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)

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)

4 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? (OBB 1 & 2)

5 How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone? (OBB 4)

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 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 [Maps to Science Question: 1 2 3 4]

(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. [Maps to Science Question: 1 2 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 5]

(d) Estimate upper ocean particle characteristics including particle abundance and particle size distribution. [1 2 3]

(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]

Measurement Requirements

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:
- Threshold: ≥4 times/yr
- Baseline: ≤3 hours

Spatial Resol. (nadir):
- #Descope: ≤500 x 500 m
- #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

RSI examples: Amazon & Orinoco River plumes, Peruvian upwelling, Cariaco Basin, Bay of Fundy, Rio Plata, etc. TBD)

Instrument Requirements

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 (NO_2)#; 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: ≥1000:1 for 10 nm FWHM (350-800 nm); ≥600:1 for 40 nm FWHM in NIR; ≥250:1, ≥180:1 and ≥100:1 for the 1245 & 1640 nm (20 & 40 nm FWHM); ≥500:1 NO_2 band.
- #Baseline: ≥1500:1 for 10 nm (350-800 nm); NIR, SWIR and NO_2 bands same as threshold; ≥100:1 for the 2135nm (50nm FWHM)

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

#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%

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

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

Pre-launch characterization: to achieve radiometric precision above on orbit

Solar Zenith Angle Sensitivity: Threshold: ≤70°; Baseline: ≤75

Platform Requirem.

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 and download of full spatial data and spectral data.

Ancillary Data Requirem.

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 & dust 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.

GEO-CAPE Science Questions are traceable to NASA's OBB Advanced Planning Document ....

* Coastal coverage within field-of-view (FOV) includes major estuaries and rivers such as Chesapeake Bay & Lake Pontchartrain/Mississippi River delta, 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).

 # Requirements under review for further discussion

Ocean Color Products

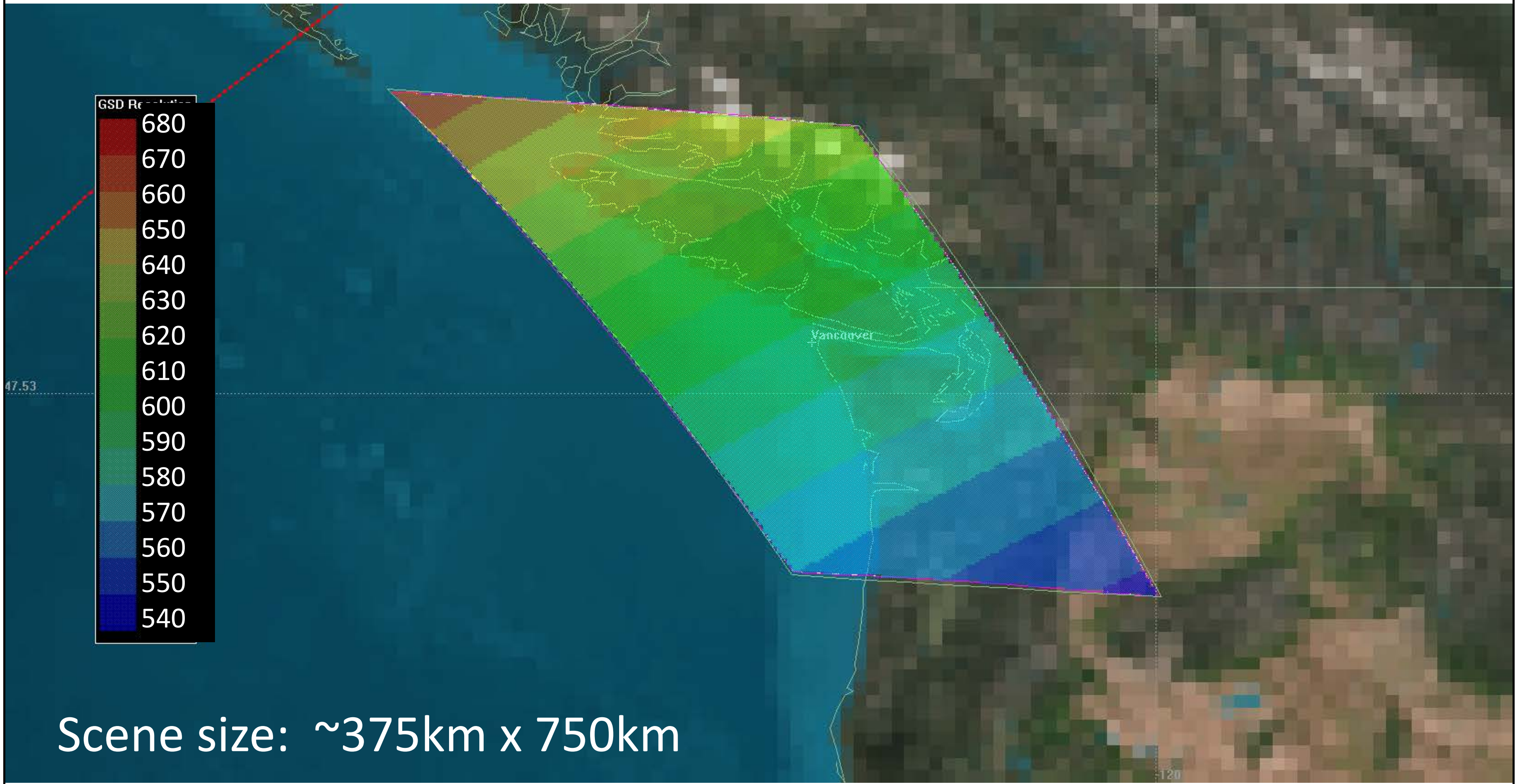
Mission Critical Products (drive requirements; heritage algorithms)

- 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

GSD Resolution = 375m (nadir – 95W) near Vancouver (25km^2 averages)



Jay Smith