Geostationary Coastal and Air Pollution Events Mission (GEO-CAPE)

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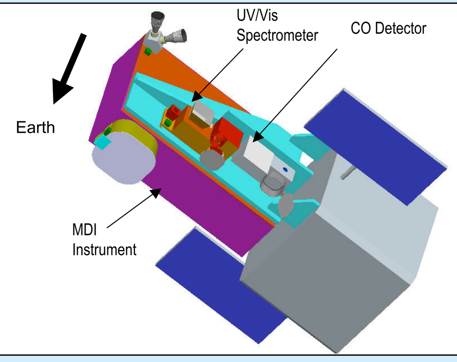
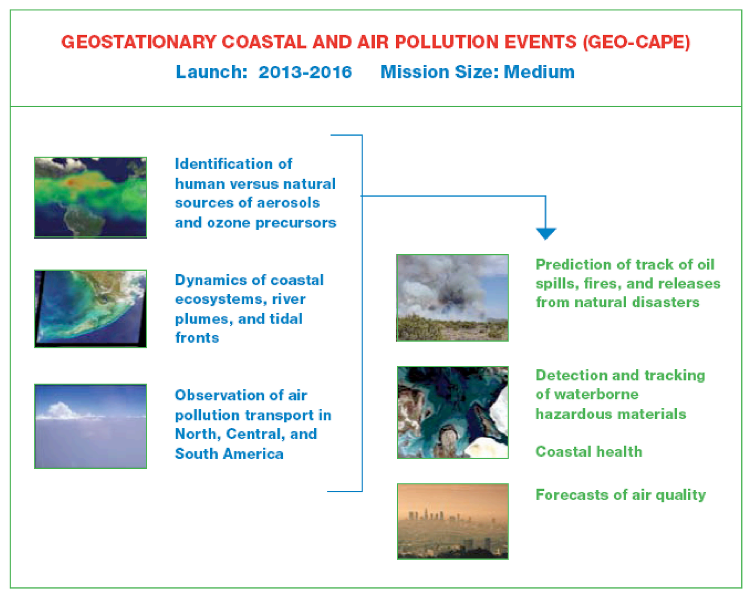


Abstract and Introduction

The U.S. National Research Council's recent decadal survey, Earth Science and Applications from Space, has recommended the Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission for launch in the 2013-2016 time period. GEO-CAPE science objectives include sources, transport, and chemistry of atmospheric pollution as well as coastal ocean dynamics and biophysics. Objectives for the terrestrial biosphere should also be considered.



NASA has conducted preliminary instrument and mission design studies for concepts very similar to GEO-CAPE. Here, we draw from these studies to examine the science measurement requirements for GEO-CAPE, present some possible instrument implementation options, and summarize the overall scope of the mission in terms of technology readiness and size-weight-cost feasibility issues.

OBSERVATORY CONCEPT

Overarching Science Questions

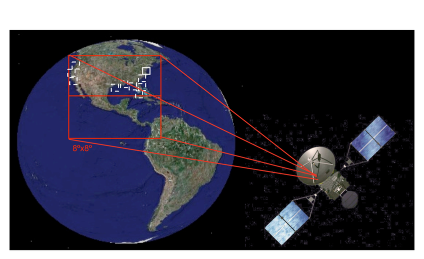
- What are the effects of gaseous and particulate emissions and climate variability and change on global atmospheric composition, and how will future changes in atmospheric composition affect ozone, climate, and regional/global air quality?
- How are coastal ocean ecosystems and the biodiversity they support influenced by climate or environmental variability and change, and how will these changes occur over time?
- What is the current geographical distribution, composition, and health of the terrestrial biosphere around the world, and how are its component ecosystems responding to climate changes?

(from Strategic Plan, Sub-Goal 3A: 3A.1; 3A.3 [NASA 2006])

Mission Concept

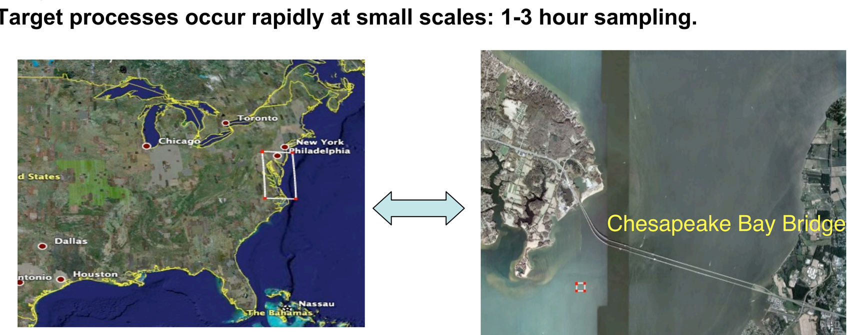
→ Combine instrumentation for atmospheric chemistry with instrument to enable coastal ocean and terrestrial biosphere science as well as enhance atmospheric science.

- **Combination of medium-resolution (5 km) continental scanning instruments (designed for atmospheric chemistry) with high-resolution (300-m) regional scanning event imaging spectrometer.**



➢ Very high spatial resolution imager is a programmable geosynchronous multi-disciplinary observatory.

- **Shared resource for regular observations, special observing studies, and emergencies**
- **Target processes occur rapidly at small scales: 1-3 hour sampling.**



250 x 500 km scan/15 min

Scan coastal waters at 300-m resolution

➢ Meet or exceed science measurement requirements for atmospheric composition, coastal oceans, and terrestrial biosphere.

➢ Precursor designs in ESEI, COCOA, GEOCarb.

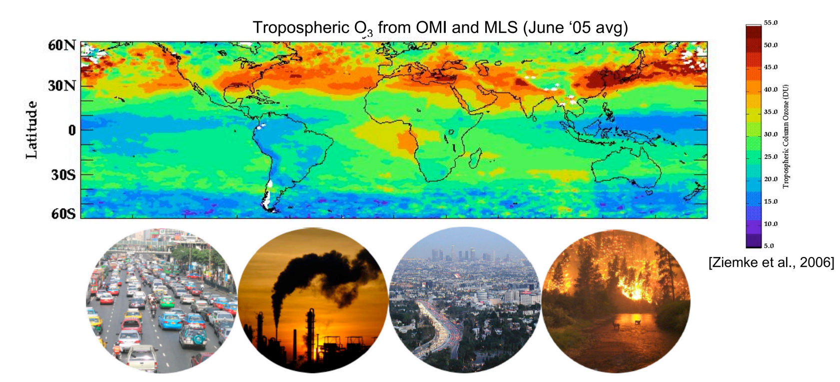
➢ Potential ground-breaking new science in each discipline plus synergies.

ATMOSPHERIC POLLUTION

Science Objectives

The air-quality objective is to satisfy basic research and operational needs related to: air-quality assessment and forecasting to support air-program management and public health; emission of O_3 and aerosol precursors, including human and natural sources; pollutant transport into, across, and out of North, Central, and South America; and large puff releases from environmental disasters. Measurements of aerosols from the air-quality instrument can be used to correct aerosol contamination of the high-resolution coastal ocean imager.

➢ **Local and regional emissions impact ozone and aerosol on local to global scales.**

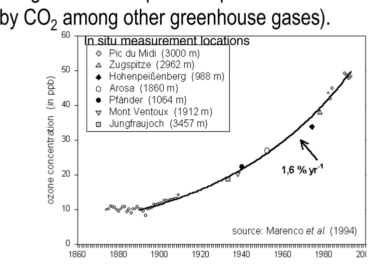


➢ **Better understanding of the key processes that connect global and local scales is required to accurately simulate, assess, and project these effects in the future.**

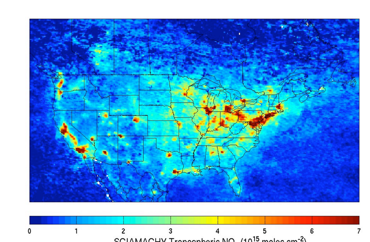
Climate and Air Quality

➢ **Changes in ozone, aerosol, and other pollutant species impact climate change and affect local air quality.**

Tropospheric O_3 is an important greenhouse gas. Background concentrations have increased 100-200% over the past century producing a climatic impact comparable to that of CH_4 (exceeded only by CO_2 among other greenhouse gases).



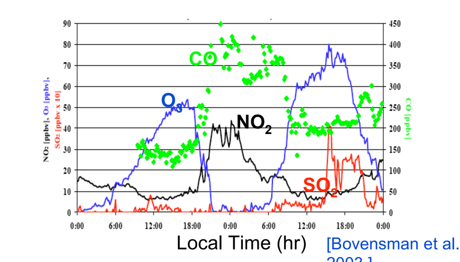
Aerosol increases generally have the opposite direct climate impact, diminishing greenhouse warming by reflecting more sunlight back to space. Aerosol also affect cloud processes, an indirect climate effect that is unquantifiable today.



Satellite NO_2 information uniquely validates NOx (an O_3 precursor) emission inventories. High-resolution, continuous NO_2 measurements will provide a much more comprehensive quantification of source strengths and variations.

Changes in the large-scale atmospheric composition contribute to worsening local air quality in many regions.

Declining air quality in the US costs the public $ billions in health care and lost productivity, produces several thousand premature fatalities annually [Bell et al., 2004], damages our environment, and decreases our standard of living.

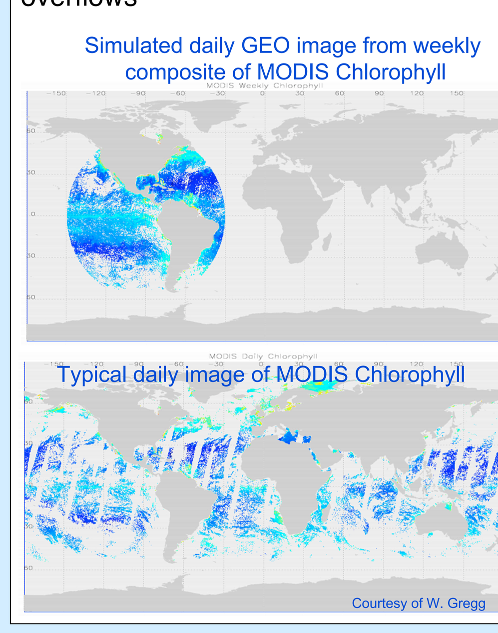


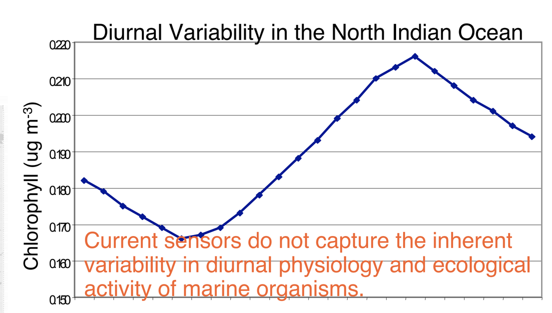
High temporal resolution measurements (e.g., hourly) are required to capture critical diurnal variability in photochemical and boundary layer processes necessary for understanding regional pollution formation.

COASTAL OCEAN

Science Objectives

The ocean objectives are to quantify the response of marine ecosystems to short-term physical events, such as the passage of storms and tidal mixing; to assess the importance of high temporal variability in coupled biological-physical coastal-ecosystem models; to monitor biotic and abiotic material in transient surface features, such as river plumes and tidal fronts; to detect, track, and predict the location of sources of hazardous materials, such as oil spills, waste disposal, and harmful algal blooms; and to detect floods from various sources, including river overflows





Limitations of Current Sensors

- Spectral resolution: No UV (and SWIR) bands for aerosol detection and atmospheric corrections; No UV and too few VIS bands for spectral deconvolution
- Temporal coverage: Only every 1 or 2 days
- Spatial resolution: Unable to resolve heterogeneity in coastal waters
- Radiometric accuracy & precision: Inadequate for application of new inversion bio-optical models - exceptional accuracy and precision required particularly in bio-optically complex coastal waters.

Coastal Ocean Ecological Products

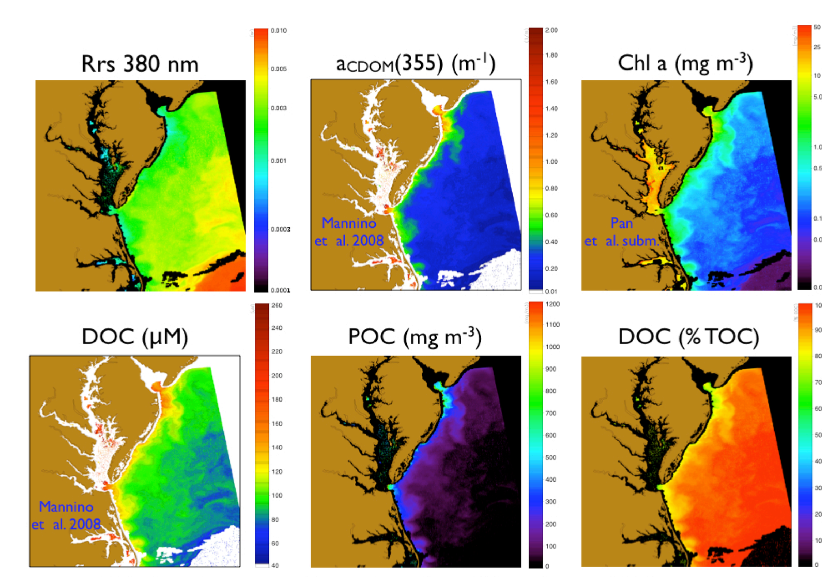


Figure AM3: Coastal ocean satellite products from high resolution MODIS-Aqua processing for August 5, 2005. Chl a - Chlorophyll a; DOC - Dissolved Organic Carbon; POC - Particulate OC; TOC - Total OC.

- GEO-CAPE will enable coastal ocean ecological products at high spatial and temporal resolution.
- Coastal ocean spatial scales are the main driver for the very high resolution events imager (MDI).

TERRESTRIAL BIOSPHERE

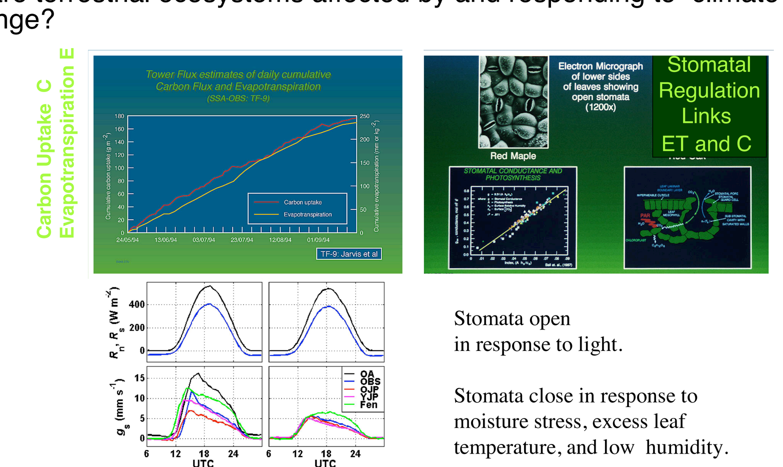
Science Questions

➢ What is the current distribution and species or functional type composition of the major forest and grassland ecosystems and agricultural systems?

➢ What is the status of disturbance and fragmentation in these systems?

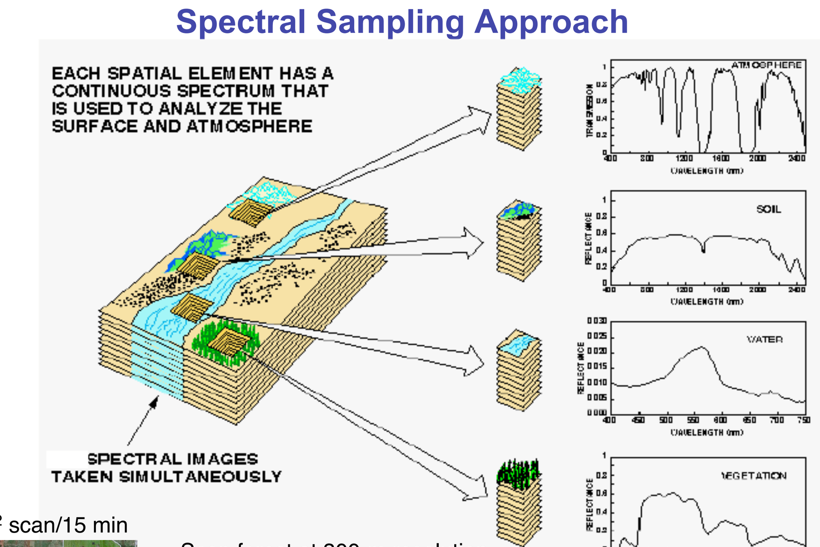
➢ What is the temporal variation in biogeochemical processes (e.g., transpiration, light use efficiency, nutrient uptake) that affect productivity in these ecosystems?

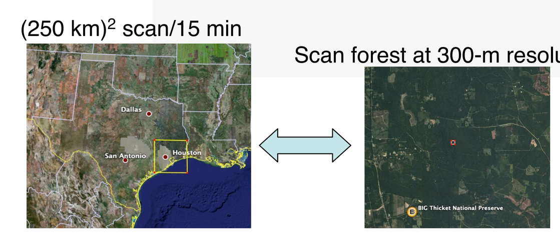
➢ How are terrestrial ecosystems affected by and responding to climate variability and change?



- **Diurnal variation in atmosphere-surface mass/energy exchange is a key process in carbon and water cycling.**

Spectral Sampling Approach





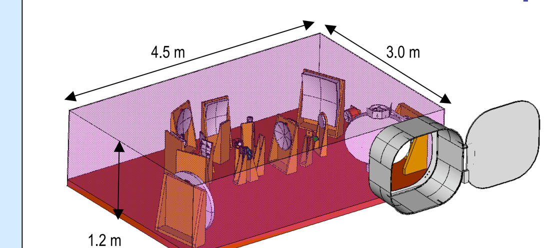
- **Although terrestrial biosphere objectives are not explicitly addressed in the GEO-CAPE discussion, the spectral and temporal data sought by GEO-CAPE conform closely to those needed for plant physiological function studies. The utility of GEO-CAPE data for terrestrial ecosystems should be considered at least through mission formulation studies.**

NOMINAL PAYLOAD

Instrument Requirements

	Coastal Ocean	Atmosphere	Biosphere
Spectral Bands (nm)	340-1100, 1240, 1640	300-480, 400-600, 2300, 4600	400-1300, 2000-2300
SNR	>1000 in UV-VIS	1000	>800
Spectral Resolution	1-5 nm	<1 nm UV 1-2 nm Vis	5-10 nm
Spatial Resolution	100-300 m	>1 km	<250 m
Temporal Resolution	3-6 / day	~ hourly	3-6 / day
Spatial Coverage	~320 km Ocean adjacent to coast; estuaries, bays, rivers, large lakes	200 km Polluted urban areas	200 km Ecosystem area
Radiometric Stability	<0.1% band-to-band 0-10 hours	<0.1% band-to-band 0-10 hours	<0.1% band-to-band 0-10 hours

Multi Discipline Imager (MDI)



MDI Instrument Concept

- Enables scientific objectives of coastal ocean, atmosphere, and biosphere.
- Capable of pointing anywhere on visible Earth hemisphere.
- Measurement parameters adjustable: dependent on science objective.
- Employs three focal planes/bands
  - Two Si: 1k (spectral) x 2k (spatial) Rockwell hybrid focal plane
  - One HgCdTe: 256 x 2k Rockwell hybrid focal plane

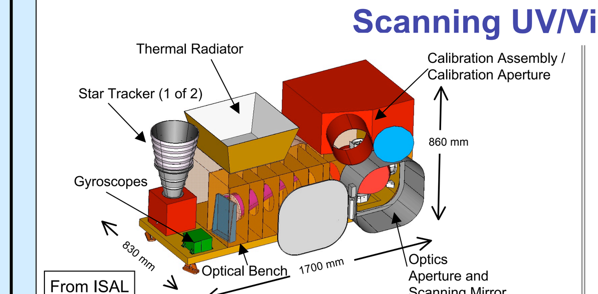
MDI Instrument Performance Data

Spectral Bands: 300-556, 340-1139, 1240, 1640 nm
Spectral Resolution: 0.75 (3x sample), 0.8, 40, 40 nm
SNR: > 1000 (bands 1, 2); > 500 (bands 3, 4)
Spatial Resolution: 300 m pixels, Coverage: 500 km
Temporal Resolution: < 1 hour

Technology Assessment / Development Needs

- Mirror stabilization system for image generation will require further development to meet the required precision.
- Large size drives cost, risk; need to optimize for science and feasibility.

Scanning UV/Vis Spectrometer



Measurement Concept

- Measure atmospheric pollutants O_3, aerosols, and precursors NO_2, SO_2, HCHO.
- Field of regard: Western Hemisphere with emphasis on continental United State
- Measurements complement capabilities of MDI and CO detector instruments respectively.
- Sample revisit time of 1 hour, during sun illumination.
- Mission Design Life: 2 years, goal 5 years (consumables sized for 5 years), launch Sept. 2014.

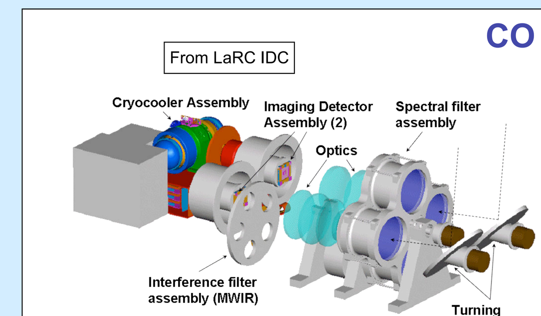
Performance Data

- Single focal plane, continuous band from 300 nm to 480 nm.
- Spectral resolution: 0.8 nm.
- Signal-to-noise ratio of 720 at 320 nm and 1500 at 430 nm.
- Typical scanned field-of-view: 8° N/S (5000km) x 8° E/W (5000 km). Can point anywhere on visible hemisphere.
- Pointing stability maintained through active jitter compensation.
- Sample spatial resolution 1.25 km N/S x 5.0 km E/W.

Technology Assessment / Development Needs

- Measurement demonstration and technical feasibility completed under NASA Instrument Incubator Program at GSFC.
- No technical hurdles to instrument or spacecraft.
- Pointing requirements are commensurate with GOES; need additional design study for steering mirror control feedback.
- Detector optimization, single crystal silicon mirror testing, and aircraft demo recommended for technology readiness level 6.

CO Detector



Carbon Monoxide Measurement Concept

- Gas correlation filter radiometer measures CO in near-IR reflected sunlight and thermal IR emission.
- Spectral combination approach identifies CO boundary layer distribution from space.
- Measures CO, an atmospheric pollutant precursor of O_3 and primary indicator of combustion.
- Continue outstanding performance of MOPITT; scientific findings based on MOPITT data demonstrate the measurement maturity and technical feasibility for geostationary orbit.

Instrument Performance Data

- Detector: Use of large format 2-D arrays in space (no scanning)
- Data array: 1024 x 1024 pixels for each SWIR & MWIR
- Spatial resolution: 5 x 5 km^2; spectral resolution better than 0.1 cm^{-1} provided by gas filter.
- Each spatial pixel requires frame averages to achieve SNR.
- Onboard calibration: blackbody targets, deep space and solar views

Technology Assessment / Development Needs

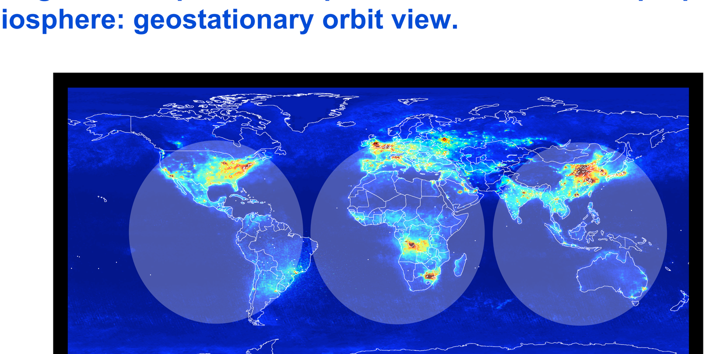
- Technology for this instrument is at high readiness level.
- Measurement Heritage: MOPITT, HALOE
- Beneficial investments:
  - Radiation hard high performance electronics (ADC, FPGAs,solid state storage, etc)
  - Light weight thermal control and structural materials

Summary

- **Strategic Plan: GEO-CAPE as an Earth-viewing, Hubble-like programmable observatory facility.**

➢ **Geostationary orbit enables unprecedented continuous, frequent, high spatial-resolution observations that are required to provide the scientific foundation for quantitatively connecting local and global scales of pollution, coastal ocean, and land carbon.**

➢ **The GEO-CAPE mission concept presents a new and unique approach to satellite remote sensing of atmospheric composition, coastal ocean properties, and the terrestrial biosphere: geostationary orbit view.**



Option to Reposition Geo Longitude

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