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Photo Credit: NASA

Geostationary Littoral Imaging and Monitoring Radiometer (GLIMR) Instrument Capability and Overview

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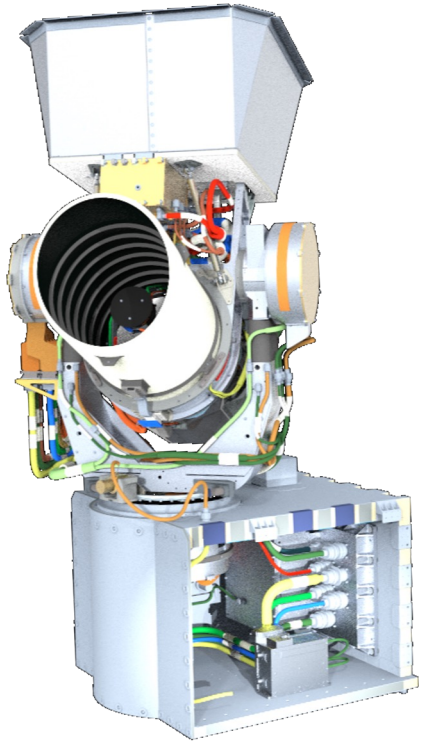
GLIMR is the Pathfinder for GEO HSI Ocean Color

University of New Hampshire | NASA Goddard Space Flight Center | SwRI | Raytheon An RTX Business

GLIMR = Geostationary Littoral Imaging and Monitoring Radiometer

- Mission is to provide unprecedented hyperspectral imaging (HSI) from GEO for ocean color
- NASA EVI-5 project managed by ESSP Program Office at NASA Langley Research Center
- Prime: University of New Hampshire, led by PI Dr. Joseph Salisbury
- Instrument Developer: Raytheon, El Segundo, CA
- Mission support provided by Southwest Research Institute, NASA GSFC, and Kamel Engineering
- Class D instrument, two-year on-orbit life
- Hosted payload (access-to-space being arranged by NASA with support from GLIMR team)
- Pathfinder to prove collection and processing of science data in advance of operational missions

GLIMR



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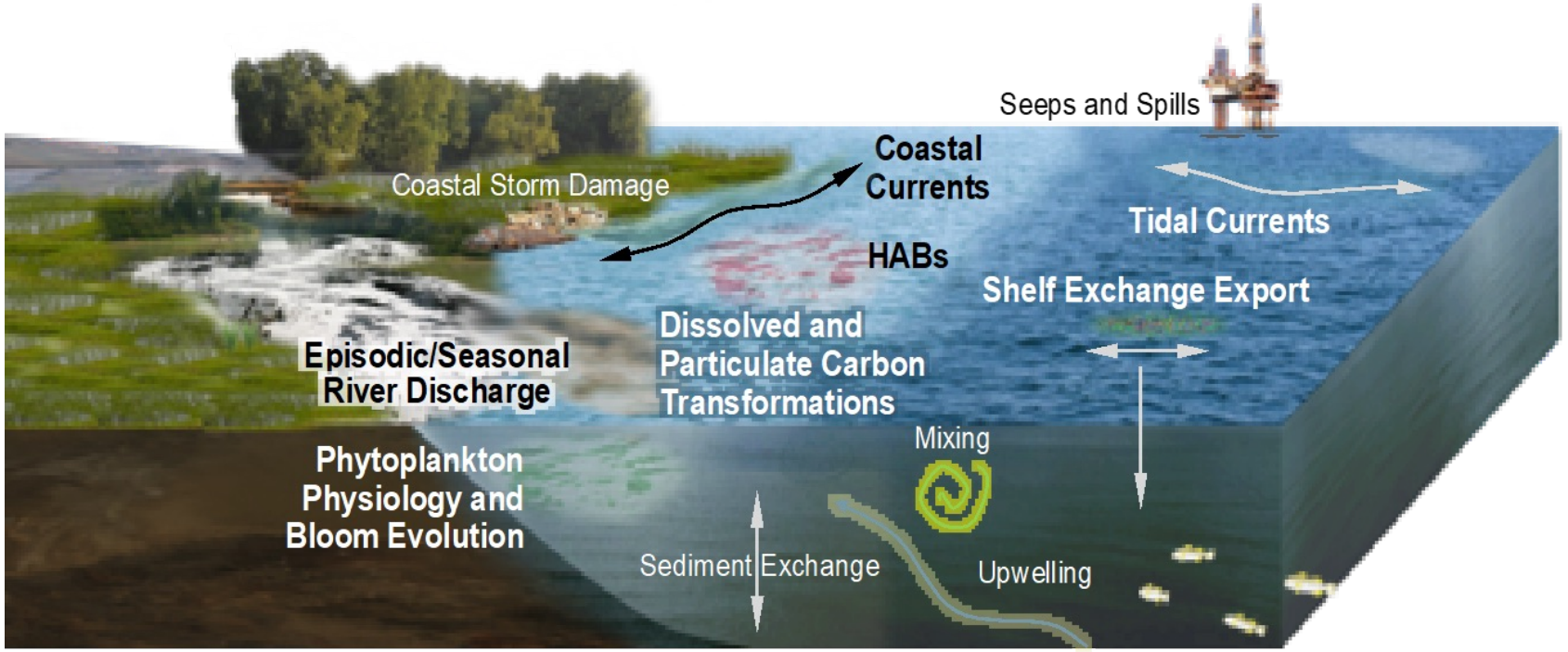
GLIMR Gives Insight into Coastal Ecosystem Dynamics



- GLIMR's unprecedented spectral (340-1040 nm with 252 channels), temporal (~hourly), and spatial (300 m nadir) capabilities significantly advance scientific understanding and management of coastal ecosystems that benefit society
- GLIMR data quantify biological and biogeochemical processes including primary production, track carbon inventories in time and space, and examine impacts of tides, currents, and river discharge on distribution of ocean materials
- GLIMR provides decision-makers at federal, state, and local agencies with vital information on coastal hazards (e.g., oil spills, harmful algal blooms, and water quality) for improved response, containment and public advisories

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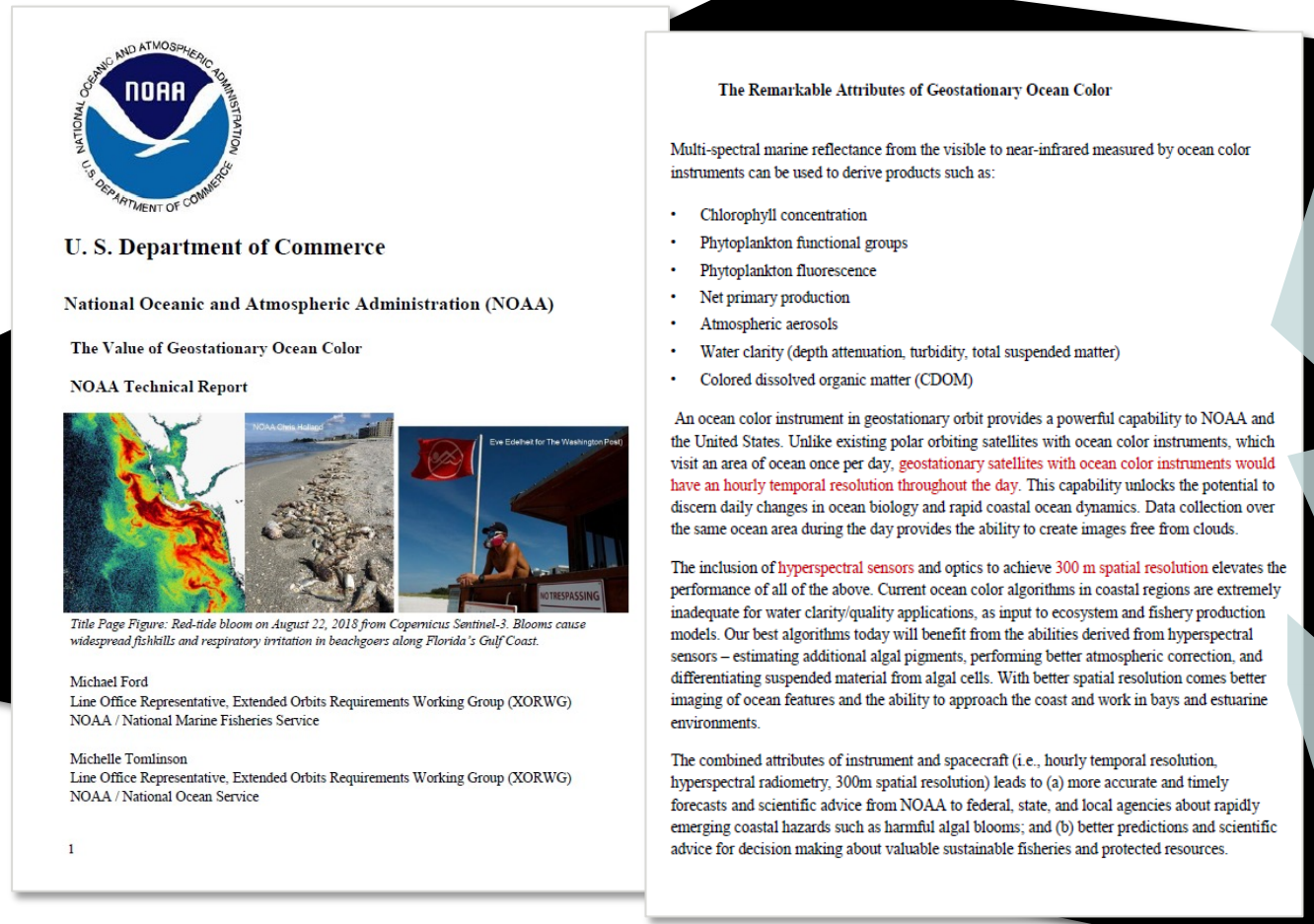
Excellent 2021 NOAA Report Articulates "The Value of Geostationary Ocean Color"



U. S. Department of Commerce

National Oceanic and Atmospheric Administration (NOAA)

The Value of Geostationary Ocean Color

NOAA Technical Report

Title Page Figure: Red-tide bloom on August 22, 2018 from Copernicus Sentinel-3. Blooms cause widespread fishkills and respiratory irritation in beachgoers along Florida's Gulf Coast.

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The Remarkable Attributes of Geostationary Ocean Color

Multi-spectral marine reflectance from the visible to near-infrared measured by ocean color instruments can be used to derive products such as:

- Chlorophyll concentration
- Phytoplankton functional groups
- Phytoplankton fluorescence
- Net primary production
- Atmospheric aerosols
- Water clarity (depth attenuation, turbidity, total suspended matter)
- Colored dissolved organic matter (CDOM)

An ocean color instrument in geostationary orbit provides a powerful capability to NOAA and the United States. Unlike existing polar orbiting satellites with ocean color instruments, which visit an area of ocean once per day, geostationary satellites with ocean color instruments would have an hourly temporal resolution throughout the day. This capability unlocks the potential to discern daily changes in ocean biology and rapid coastal ocean dynamics. Data collection over the same ocean area during the day provides the ability to create images free from clouds.

The inclusion of hyperspectral sensors and optics to achieve 300 m spatial resolution elevates the performance of all of the above. Current ocean color algorithms in coastal regions are extremely inadequate for water clarity/quality applications, as input to ecosystem and fishery production models. Our best algorithms today will benefit from the abilities derived from hyperspectral sensors – estimating additional algal pigments, performing better atmospheric correction, and differentiating suspended material from algal cells. With better spatial resolution comes better imaging of ocean features and the ability to approach the coast and work in bays and estuarine environments.

The combined attributes of instrument and spacecraft (i.e., hourly temporal resolution, hyperspectral radiometry, 300m spatial resolution) leads to (a) more accurate and timely forecasts and scientific advice from NOAA to federal, state, and local agencies about rapidly emerging coastal hazards such as harmful algal blooms; and (b) better predictions and scientific advice for decision making about valuable sustainable fisheries and protected resources.

https://repository.library.noaa.gov/view/noaa/33278/noaa_33278_DS1.pdf

Why ocean color?

To derive products with **scientific and socio-economic benefit** such as:

- Chlorophyl concentration
- Phytoplankton functional groups
- Phytoplankton fluorescence
- Net primary production
- Atmospheric aerosols
- Water clarity
- Colored dissolved organic matter (CDOM)

Why GEO?

"Hourly temporal resolution" gives:

- Higher chance of cloud-free collection
- Capture of diurnal dynamics

Why hyperspectral imaging?

HSI "elevates the performance" of the above products over multispectral

- Improved atmospheric correction
- Algal pigment determination and distinction between algal cells from suspended material

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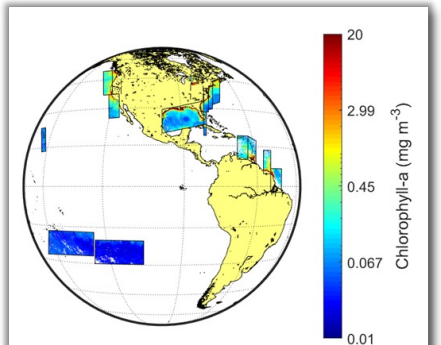
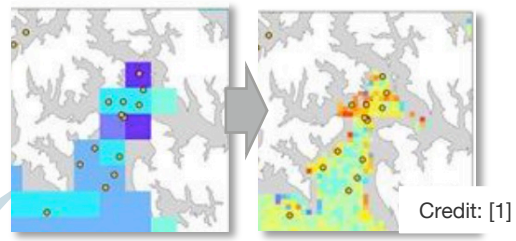
GLIMR is a Proving Ground for Future Operational Ocean Color

- Specific aspects of GLIMR are relevant to future operational missions such as GeoXO OCX, independent of specific hardware implementation

GLIMR Aspect	Relevance as Pathfinder for Operational Ocean Color
GEO station	Develop daily Region-of-Interest revisit and calibration CONOPS to maximize temporal science content, e.g., techniques for adjusting collection / processing to maximize amount of cloud-free data
Hyperspectral data for ocean color	Develop data flow and processing algorithms for high spectral resolution imagery user adoption
Image Quality	Advance understanding of utility of 300 m GSD to hyperspectral ocean data color products
“Landmark Imager”	Demonstrate use of co-boresighted context imager and algorithms to provide exquisite geolocation knowledge
Stabilized scanning	Prove scheme for precision LOS control for very slow (~10 μrad/sec) science scans; applicable to gimbaled or alternative systems

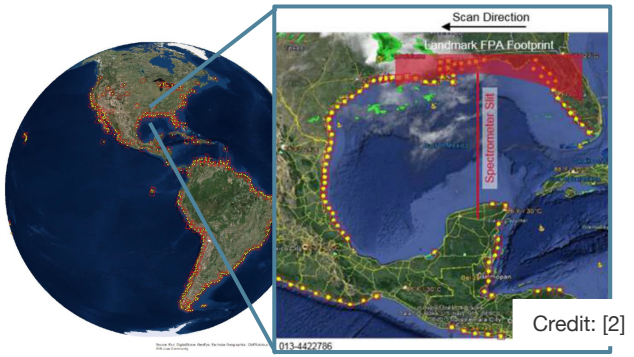


Optimize GEO CONOPS



Credit: [1]

Learn value of high-res HSI to science



Credit: [2]

Develop landmark imaging methodology, expanding on GOES IPATS

[1] NOAA Technical Report: The Value of Geostationary Ocean Color

[2] De Luccia et al. Proc. SPIE 9881, Earth Observing Missions and Sensors: Development, Implementation, and Characterization IV, 988119 (May 2, 2016)

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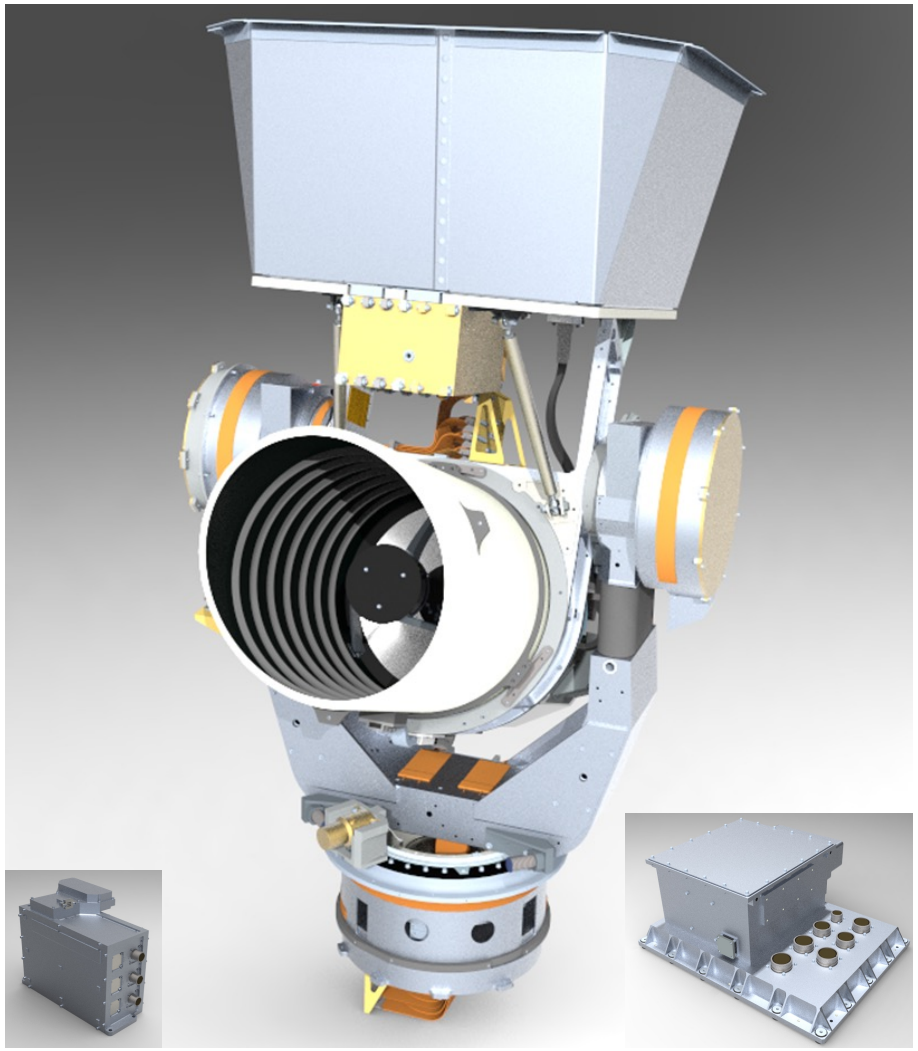
GLIMR Architected to Support Mission Needs



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Characteristic	Value
Spectral range	340 nm to 1040 nm
Number of spectral bands	252
Ground Sample Distance	300 m nadir, ~ 330 m in Gulf of Mexico center
Cross-scan (N-S) FOV	1.47 deg
Sensitivity	SNR > 500 across visible band (up to ~ 1300) (see later slide)
Instrument Polarization	< 2%
Radiometric Stability	< 0.5%
Image Navigation and Registration	“Landmark Imager” with 133 m nadir GSD
Mass (with contingency)	156 kg
Power (with contingency)	237 W
Output data rate	~ 50 Mbps

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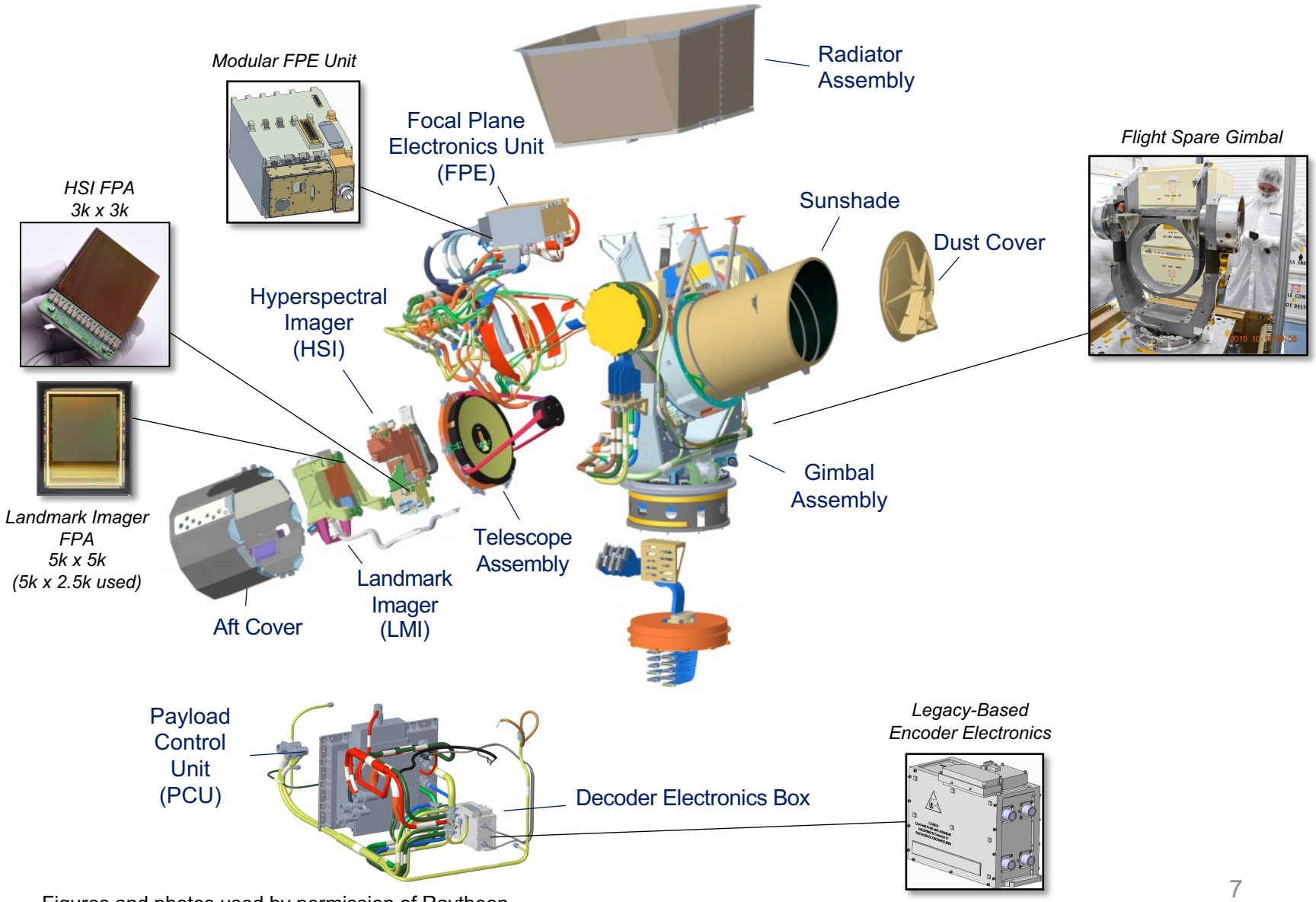
GLIMR Leverages Existing Hardware and Designs

Key Enablers for Affordable High-Performance System:

- Existing two-axis gimbal
  - Flight spare with proven pedigree
  - Donated to program by Raytheon
  - Provides agile access to regions-of-interest across whole earth
- Existing HSI focal plane
  - GFE large format array from NASA NEODaC program
  - Provides high sensitivity, low noise performance
- Legacy-based electronics
  - Units directly adapted from designs proven on flight programs



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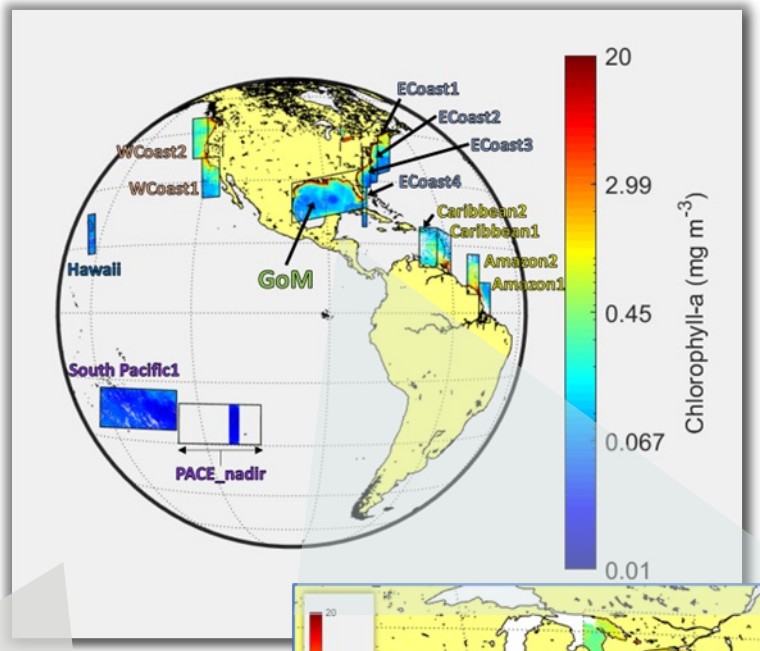
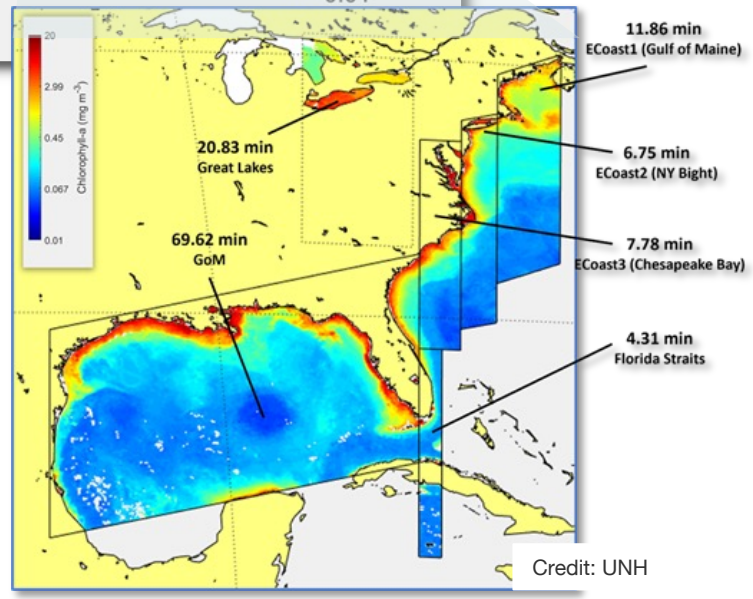
Nominal Daily Operations

- GLIMR will be operated for ~ 15 hours each day, from early morning in the eastern part of its field of regard to late afternoon in the western part
- GLIMR will slew back and forth between Science and “Cal/Val” areas of interest (AOIs) and brief star / space looks
  - Scientific scans of AOIs scheduled based on scientific priority and local solar zenith angle
  - AOIs observed repeatedly throughout the day
  - Star / space looks require only ~ 30 sec including slew

Baseline Science Scan AOI	Frequency
Gulf of Mexico from Gulf states to 21°N	6x/ day
Coastal waters for East & West CONUS	2x/ day
Amazon River Plume region	2x/ day
Caribbean Sea region of interest	2x/ day
Hawaii region of interest	2x/day
Other HAB target sites	3x/ day

Science and Cal/Val Areas of Interest (AOI)

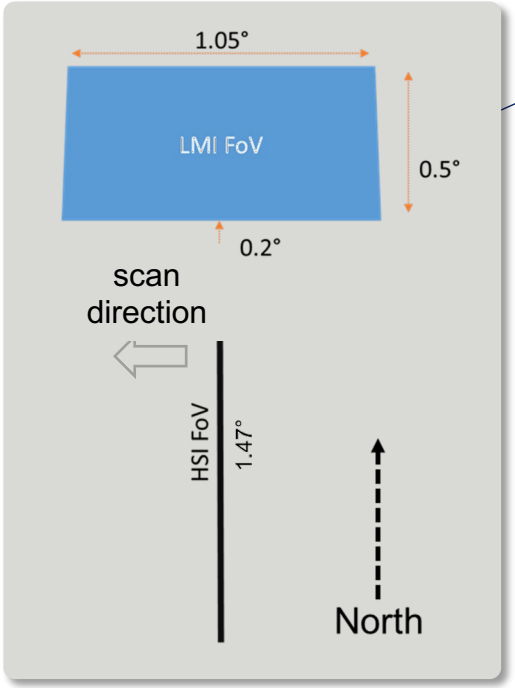




Nominal GoM and East Coast Scans

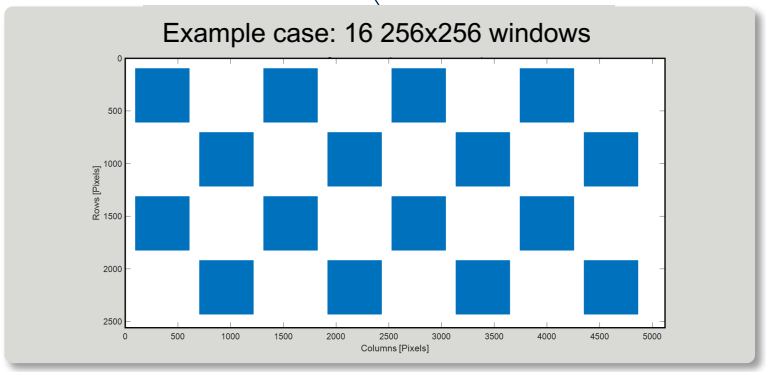
GLIMR is Testbed for Optimizing Science and Landmark Collection Operations

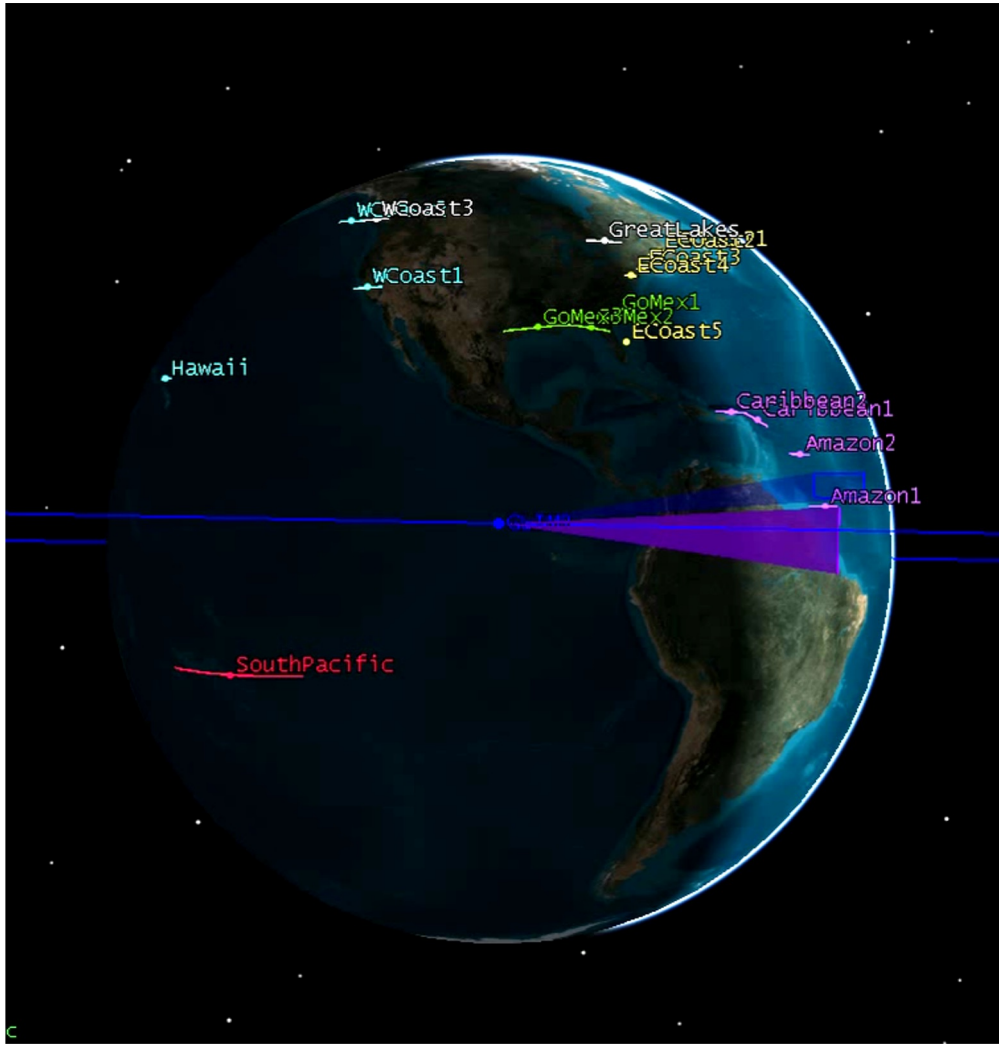
- With GLIMR we can experiment and optimize:
  - different daily AOI revisit patterns
  - different landmark collection patterns
  - optimal interleaving of star / space looks



GLIMR LMI (half of array is used) is field-offset to north of slit; good for GoM, but future system likely will have multiple LMI FOV regions

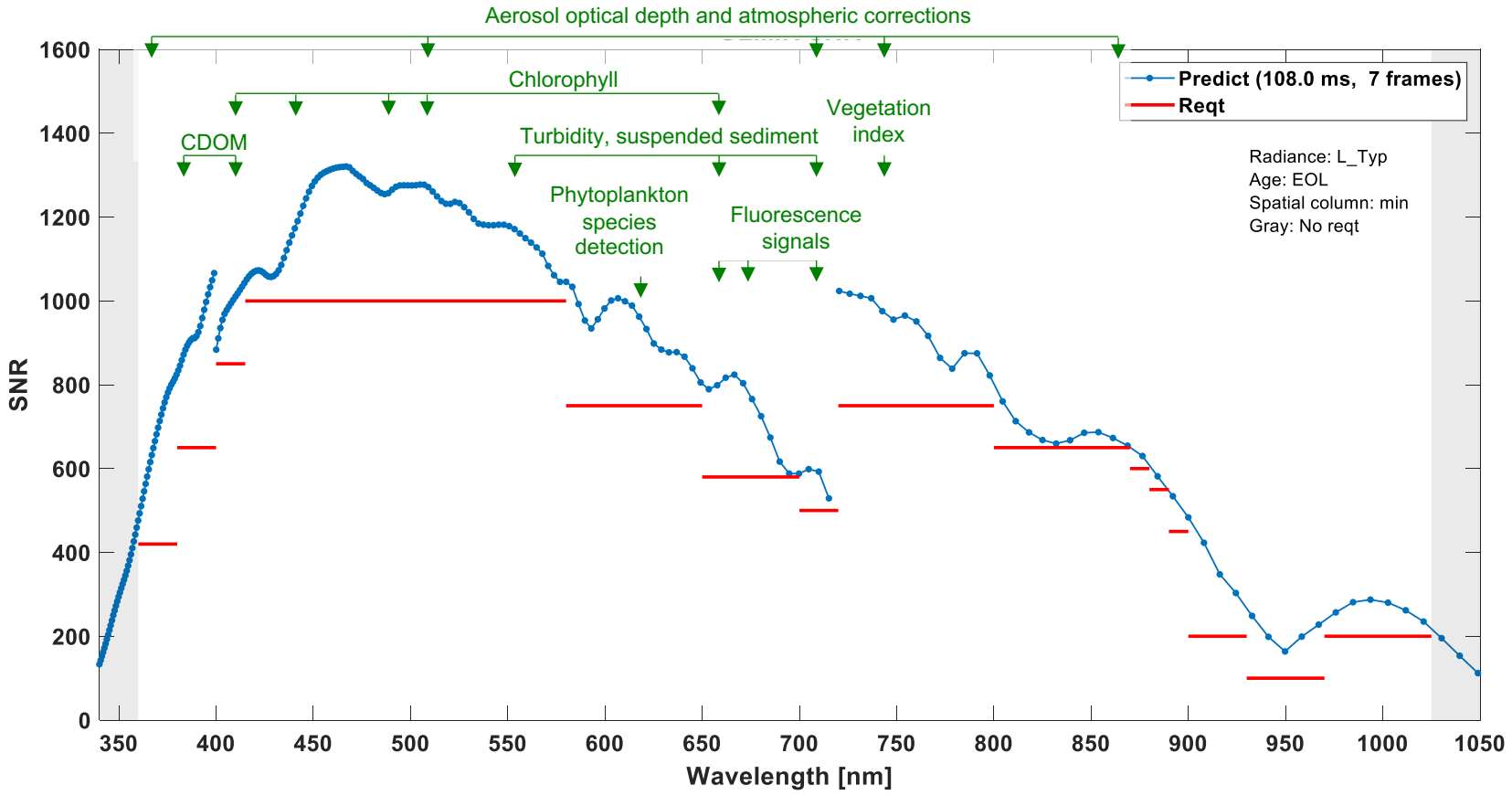
LMI can use up to 32 windows within FOV; configurations can be optimized per AOI, e.g., to increase chances of cloud-free landmark collection





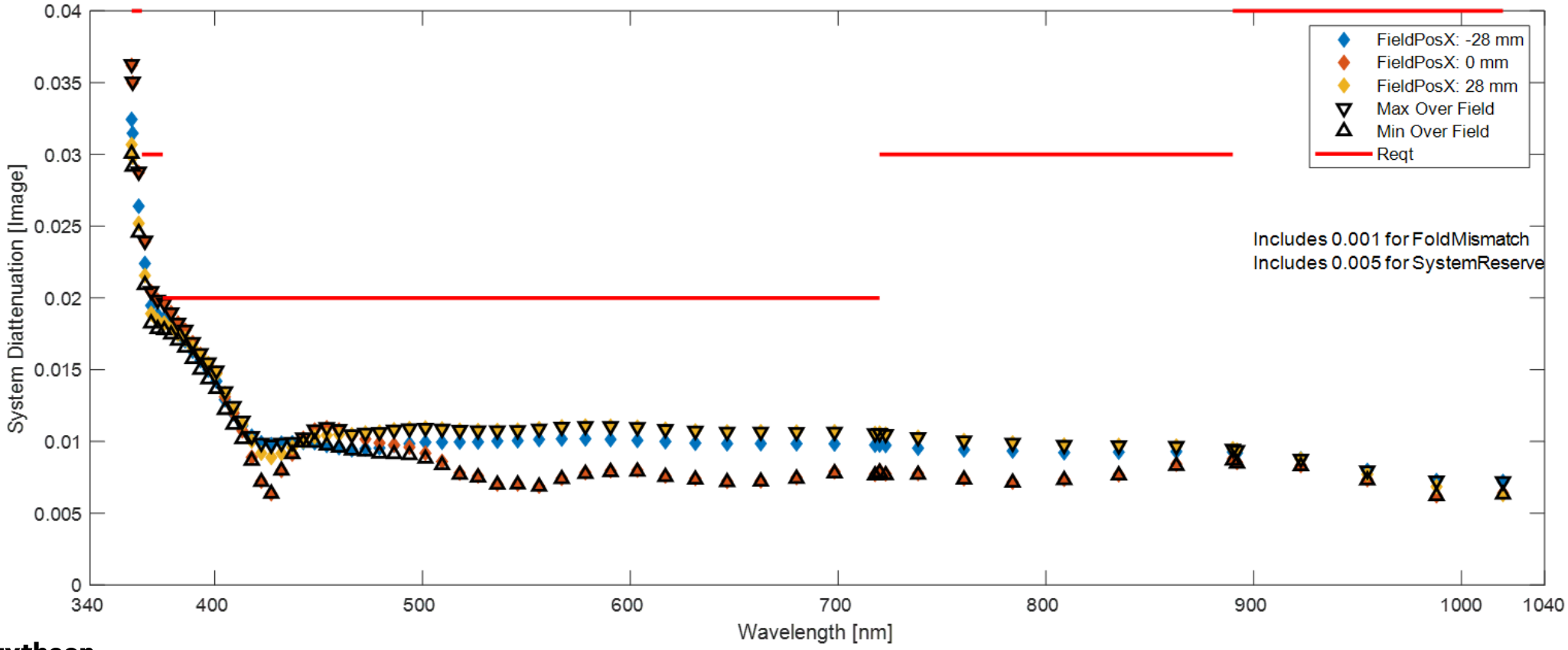
GLIMR Provides Excellent Signal-to-Noise Ratio

- High signal-to-noise ratio (SNR) is essential to support accurate atmospheric correction and estimation of water leaving reflectance for science product signatures across spectrum



GLIMR Minimizes Polarization Effects on Science Data

- Instrument polarization is a key contributor to water leaving reflectance uncertainty
- The GLIMR design achieves significantly less than 2% over nearly the entire spectral range for all field angles



GLIMR is Multidimensional Capability Advancement

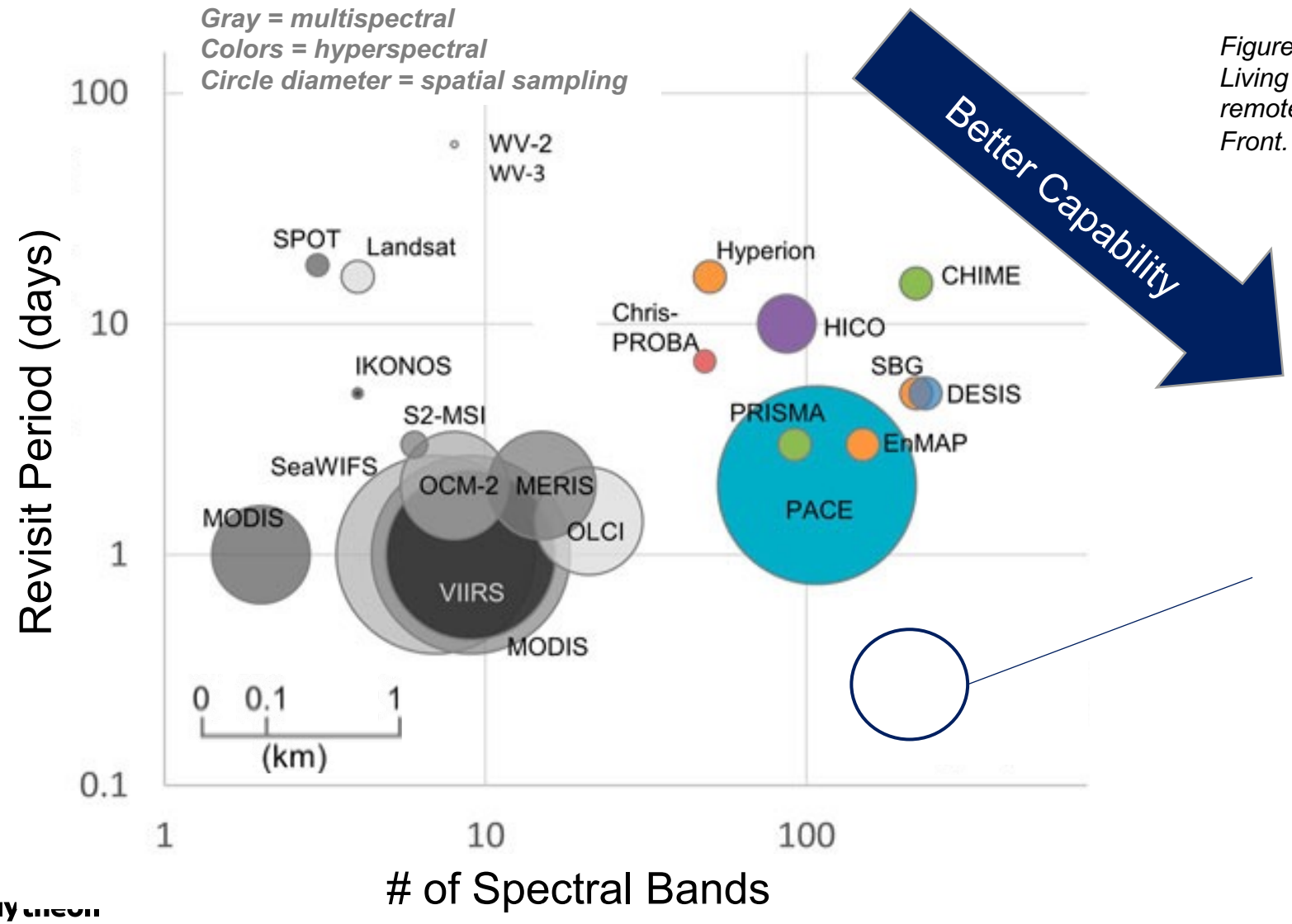
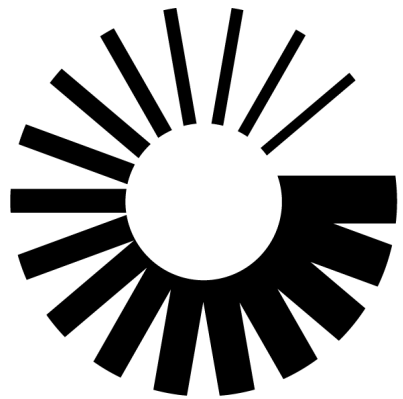


Figure modified from Dierssen, H. M., et al. (2021). Living up to the hype of hyperspectral aquatic remote sensing: science, resources and outlook. Front. Environ. Sci. 9:134.

GLIMR
- 252 bands
- 2-6x daily revisits
- 300 m GSD nadir

Summary

- GLIMR will provide unprecedented hyperspectral ocean color data with the temporal frequency achievable from geostationary orbit
- Extensive use of legacy hardware and designs allows cost-effective execution
- Instrument hardware is progressing through build and test
- Nominal collection operations are defined with built-in flexibility to adapt as we learn how best to use GEO HSI capability to benefit science
- GLIMR plays an important role in preparing the ocean color community for future operational GEO HSI capability such as GeoXO OCX



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