



PACE Mission Development

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NASA Goddard

Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Overview



PACE

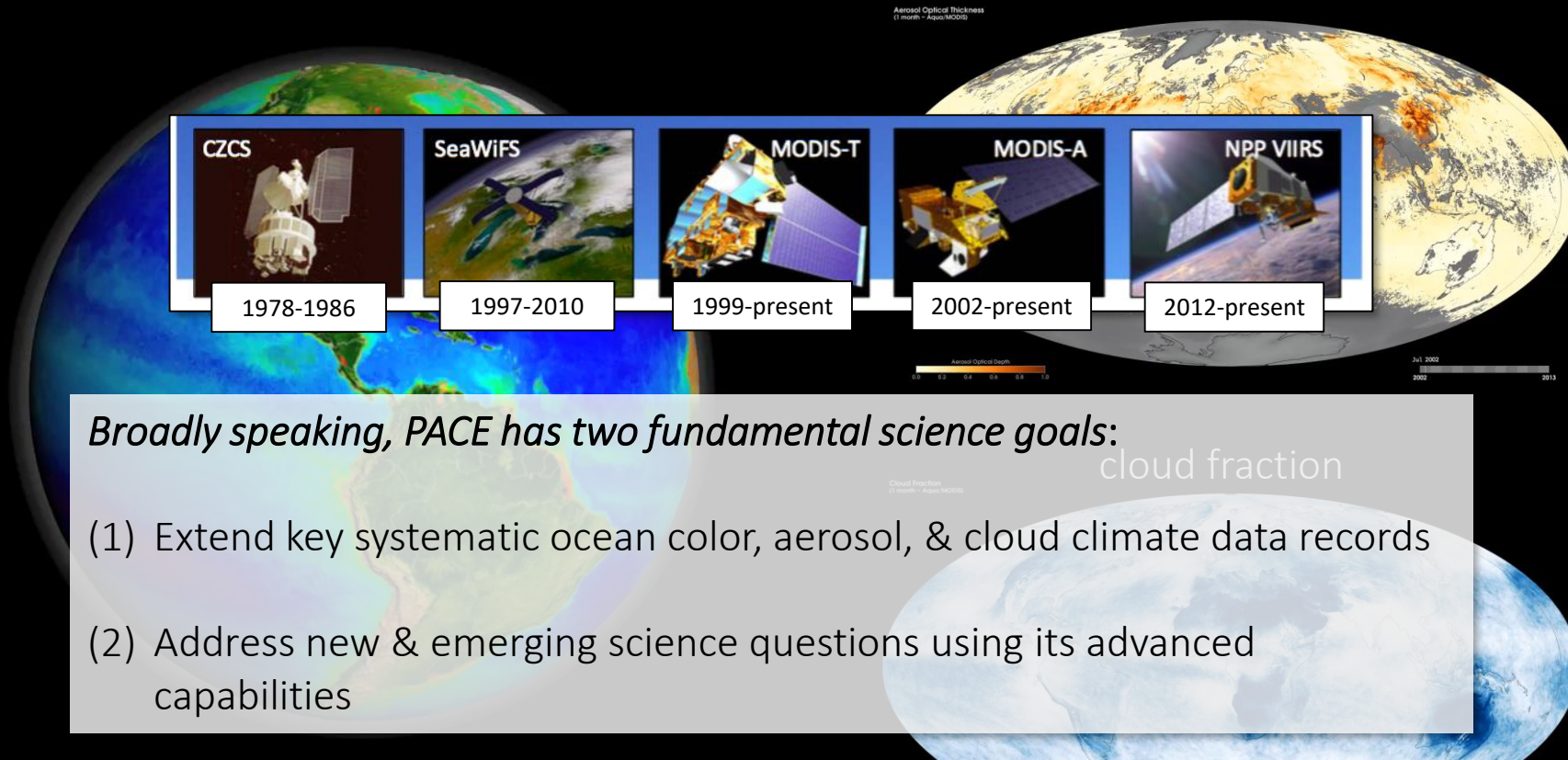
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Jeremy Werdell, Project Scientist

Paula Bontempi, Program Scientist

ocean chlorophyll
normalized land vegetation index

aerosol optical thickness

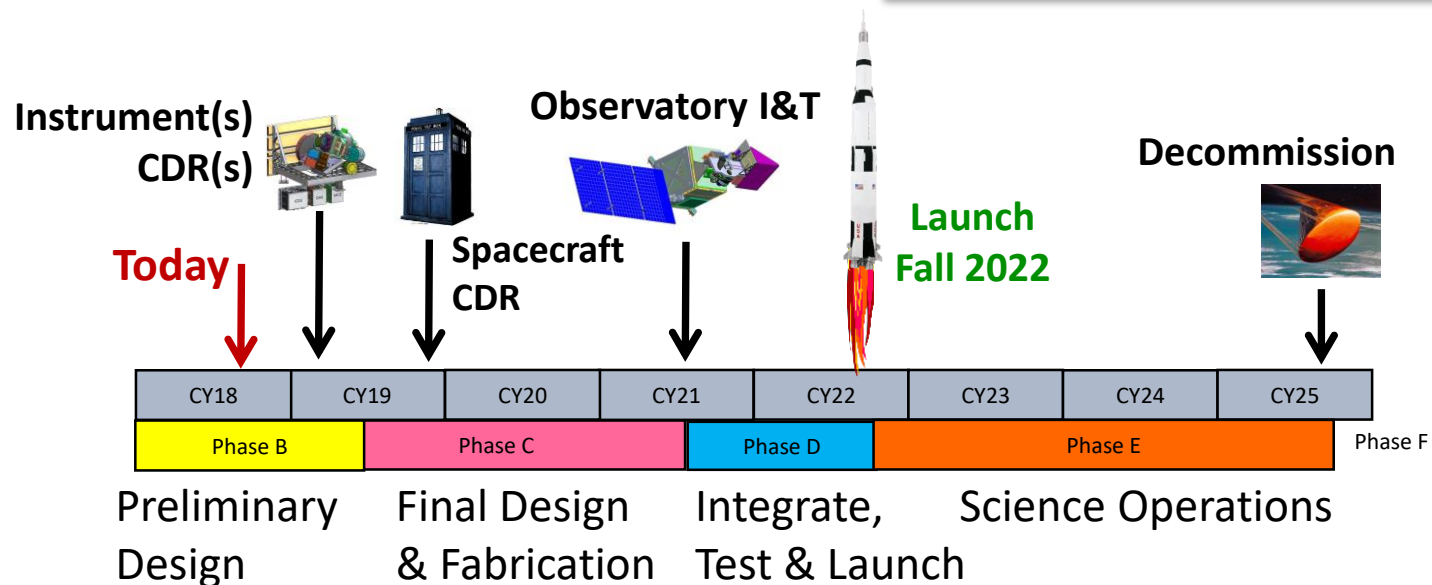


“Majority of Americans say a top priority for NASA should be monitoring key parts of the Earth’s climate system (63%) ...”

Citation: Pew Research Center, June 2018, “Majority of Americans Believe It is Essential That the U.S. Remain a Global Leader in Space.”

PACE Mission characteristics

Key Mission Elements		Key Mission Features	
Mission management	NASA Goddard SFC	Cost	\$805M, DTC
Ocean Color Instrument	NASA Goddard SFC	Life	3-yr, Class C, 10-yr fuel
HARP2 polarimeter	UMBC	Orbit	676.5 km, Sun sync, 1-pm
SPEXone polarimeter	SRON (Netherlands)	Coverage (OCI)	2-day global
Spacecraft/Mission Ops	NASA Goddard SFC	RF Communications	Ka direct to ground 600Mbps
Science data processing	NASA Goddard OBPB		
Competed science teams	NASA Earth Sciences Div.		



Science Goals, Challenges, & Capabilities of OCI

Extend key systematic ocean biological, ecological, & biogeochemical climate data records, as well as **cloud & aerosol climate data records**

Make **new global measurements of ocean color** that are essential for understanding the global carbon cycle & ocean ecosystem responses to a changing climate

Collect **global observations of aerosol & cloud properties**, focusing on reducing the largest uncertainties in climate & radiative forcing models of the Earth system

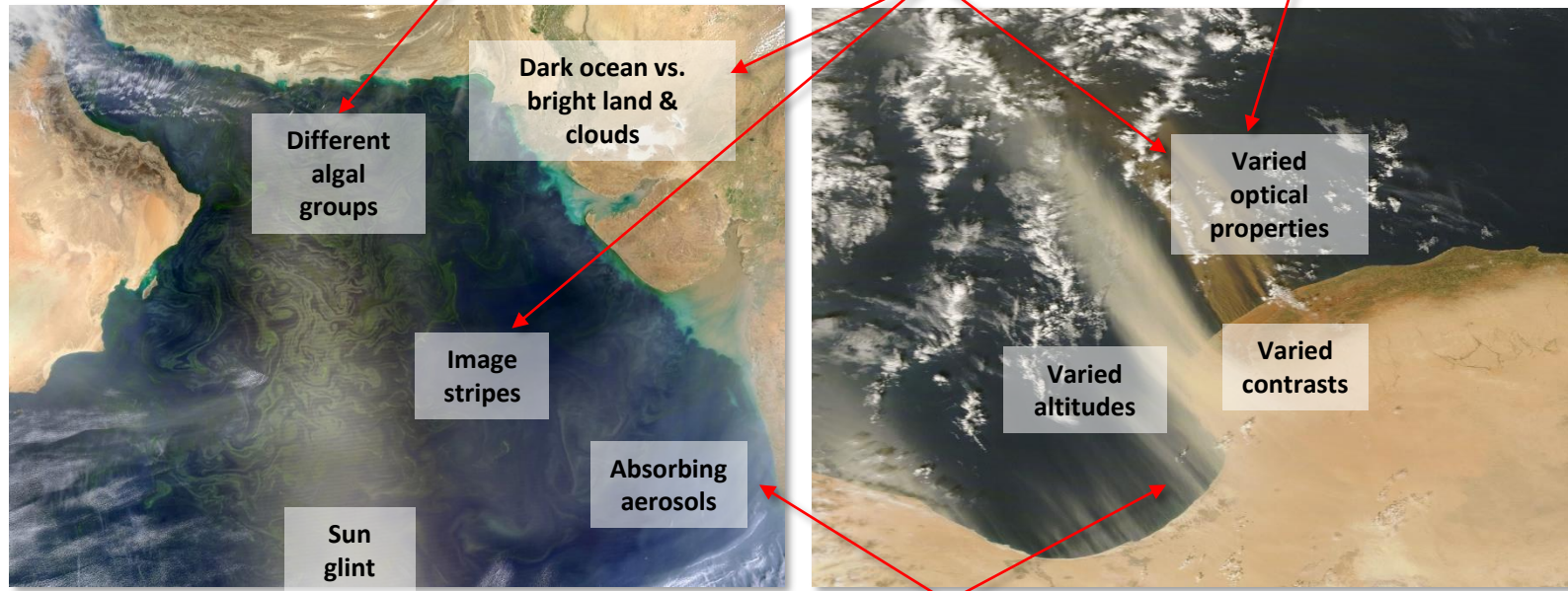
GSD of $1 \pm 0.1 \text{ km}^2$ at nadir

Spectral range from 350-865 @ 5 nm

Lunar calibration & onboard solar calibration (daily, monthly, dim)

Instrument performance requirements

940, 1038, 1250, 1378, 1615, 2130, 2260 nm

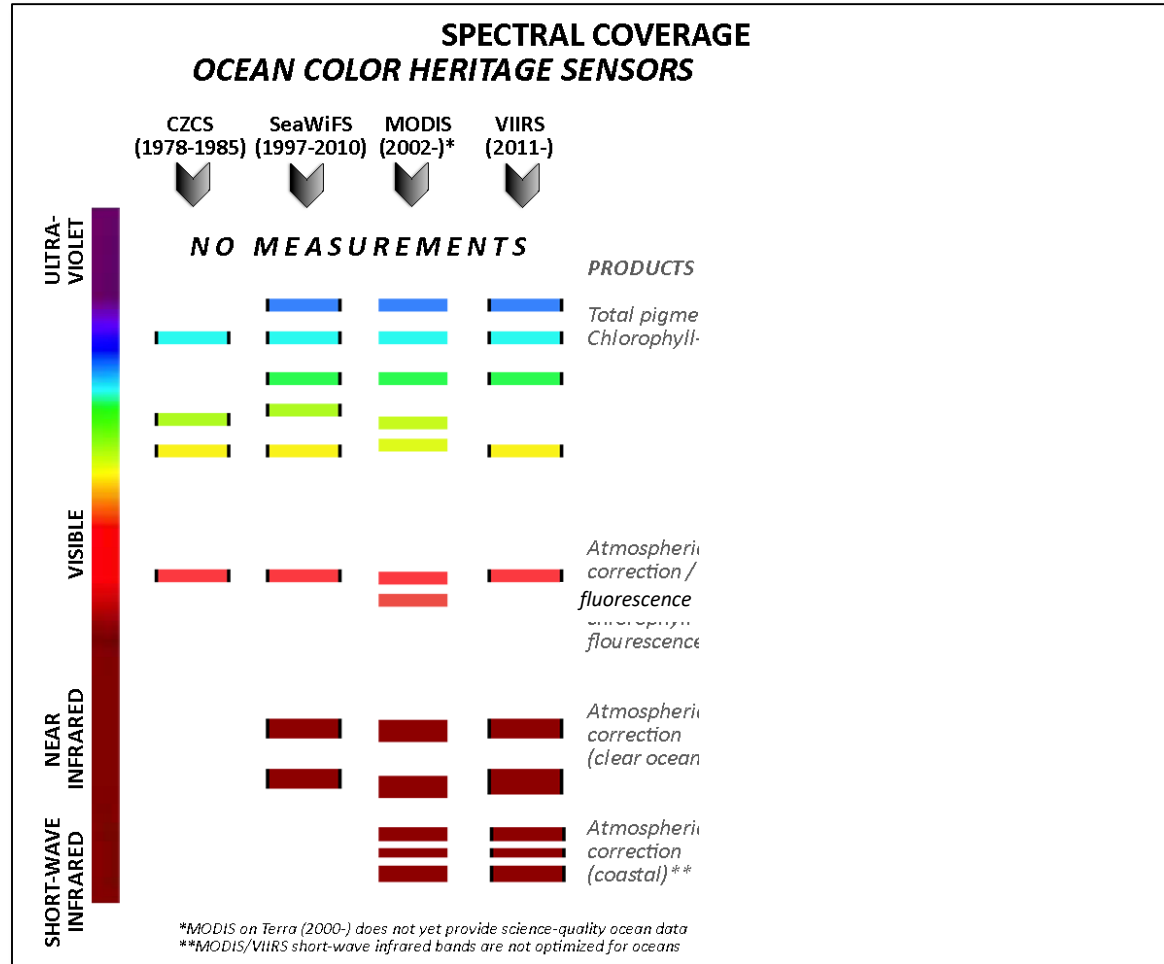


Tilt $\pm 20^\circ$

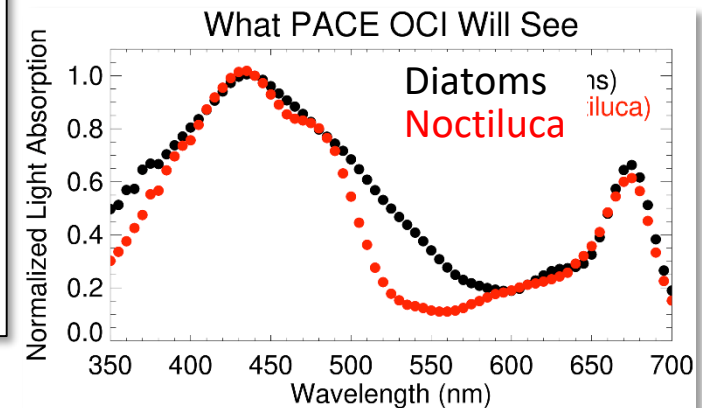
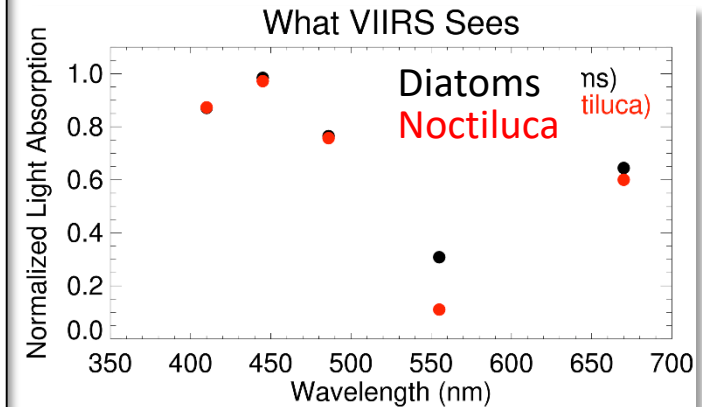
*Spectral range goal of **320**-865 @ 5 nm*

Improve our understanding of how **aerosols influence ocean ecosystems & biogeochemical cycles** and how **ocean biological & photochemical processes affect the atmosphere**

From multi-spectral radiometry to spectroscopy



differentiating between constituents requires additional information relative to what we have today



Multi-Angle Polarimetry on PACE

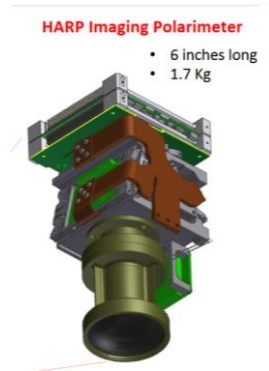
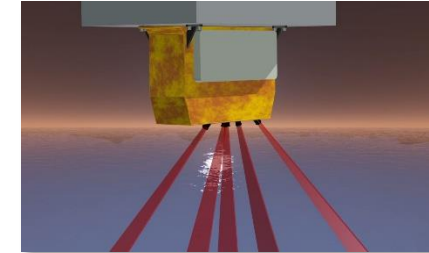
Two cubesat-sized *contributed* instruments

Spectro-Polarimeter for Planetary Exploration (SPEXone)

Contribution from the Netherlands (SRON, NSO, Airbus; TNO optics)

POC: Otto Hasekamp

Hyperspectral (UV) + narrow swath



HARP Imaging Polarimeter
 • 6 inches long
 • 1.7 Kg

Hyper Angular Rainbow Polarimeter (HARP-2)

Contribution from University of Maryland Baltimore County

POC: Vanderlei Martins

Hyperangular + wide swath

	SPEXone	HARP-2
Spectral range (resolution)	385-770 nm (hyperspectral 2 nm)	440, 550, 670 nm (10) + 870 nm (40 nm)
# viewing angles	5 (-52°, -20°, 0°, 20°, 52°)	20 for 440, 550, 870 nm + 60 for 670 nm (114°)
Swath width	9° (100 km)	94° (1550 km)
Ground sample distance	2.5 x 2.5 km	3 x 3 km
Heritage	AirSPEX	AirHARP, cubesat HARP for ISS

Required science data products (OCI)

Required data products & additional expected data products:

Level 1 required (~threshold) products

Water-leaving reflectance	Aerosol optical thickness
Chlorophyll-a	Aerosol fine mode fraction
Phytoplankton absorption	Liquid / ice cloud optical thickness
NAP+CDOM absorption	Liquid / ice cloud effective radius
Particulate backscattering	Cloud layer detection ($\tau < 0.3$)
Diffuse attenuation	Cloud top pressure ($\tau > 3$)
Fluorescence line height	Shortwave radiation effect

Building capabilities to produce this full suite of OCI products from proxy data using preliminary/heritage algorithms by the end of 2018

Advanced & evaluation science data products

Required data products & additional expected data products:

Incomplete list of advanced (~baseline) products

Carbon stocks & fluxes	Liquid / ice cloud water path
Phytoplankton pigments	Polarimeter-specific products
Phytoplankton physiology	Applied sciences-specific products
Community structure (PFTs)	Land data products (TBD)
Productivity	Your very favorite data product that
PAR, light attenuation, water quality	we forgot to list

General expectations for future PACE science teams:

- *Novel* methods for required products (exploit spectral capabilities)
- Methods for advanced products + scientific applications

Looking forward: applied sciences


New NASA directive on Applied Sciences within missions

Mission Phase	Applications Activity
Pre-phase A	<ul style="list-style-type: none"> Assessment of the community of practice. Description of potential applications from the PACE data using the requirements established by the Science Definition Team (SDT).
Phase A	<ul style="list-style-type: none"> Applications website establishment. Database of user community individuals begins. Applications Plan written and posted to website. Applications white papers developed and posted to the website. Applications Traceability Matrices developed and posted to the website. Applications Working Group established.
Phase B	<ul style="list-style-type: none"> Workshop conducted with targeted science communities to communicate key model, observation and Applied Sciences opportunities and requirements. Newsletters, articles, posters, and other communications developed to expand the community of potential users. Early Adopters Program initiated.
Phase C/D	<ul style="list-style-type: none"> Annual workshop focus on data quality and user requirements. Description of validation and data quality issues. Conference presentations and community interaction to expand the user community. Data workshops, short courses, and user training. Interaction with NASA Earth Science Data Team.
Phase E	<ul style="list-style-type: none"> Documenting decision on data quality and user requirements. Newsletter, journal articles, conference presentations of applications of data. Community interaction and support of data reprocessing and improvement. Calibration/validation of data quality, format, issues. Conduct Impact Workshop to assess success of Applications implementation. Conduct a Quantitative PACE Data Societal Benefit Value Assessment. Information for Senior Review Submissions.

PACE Applied Sciences program POCs:
Woody Turner, Maria Tzortziou, Ali Omar

A/S Program currently in development


Project Applied Sciences Coordinator: TBD



PACE Applied Sciences Plan

Ali Omar², Woody Turner³, Jeremy Werdell⁴, Antonio
Lafont⁵, and Jeanette de Charon⁵

Applications Lead - Atmosphere, ³NASA HQs PACE Program Applications Lead, ⁴NASA PACE Project Scientist, ⁵NASA PACE Deputy Project Scientist - Oceans, ⁴PACE Project Communications Team.



Learn more about PACE



PACE

<https://pace.gsfc.nasa.gov>
@NASAOcean (Twitter)
@NASA.Ocean (Facebook)
Technical Memo. series



PACE Plankton, Aerosol, Cloud, ocean Ecosystem

HOME ABOUT MISSION SCIENCE APPLICATIONS CAMPAIGNS NEWS GALLERY

PACE Plankton, Aerosol, Cloud, ocean Ecosystem

NASA Sets the PACE for Advanced Studies of Earth's Ocean and Atmosphere

PACE's advanced technologies will provide unprecedented insight into Earth's ocean and atmosphere, which impact our everyday lives by regulating climate and making our planet habitable. Our oceans teem with life, supporting many of Earth's economies. New discoveries in Earth's living ocean will be revealed with PACE's global observations, such as the diversity of organisms fueling marine food webs and how ecosystems respond to environmental change. PACE will observe our atmosphere to study clouds along with the tiny airborne particles known as aerosols. Looking at the ocean, clouds, and aerosols together will improve our knowledge of the roles each plays in our changing planet.

PACE's data will reveal interactions between the ocean and atmosphere, including how they exchange carbon dioxide and how atmospheric aerosols might fuel phytoplankton growth in the surface ocean. Novel uses of PACE data—from identifying the extent and duration of harmful algal blooms to improving our understanding of air quality—will result in direct economic and societal benefits. By extending and expanding NASA's long record of satellite observations of our living planet, we will take Earth's pulse in new ways for decades to come.

NASA's long-term chlorophyll record is unparalleled



PACE will show all chlorophyll is not created equal

Why Do We Need PACE?

Ocean Ecology Aerosols & Clouds Carbon Applied Sciences Economy & Society Science Questions

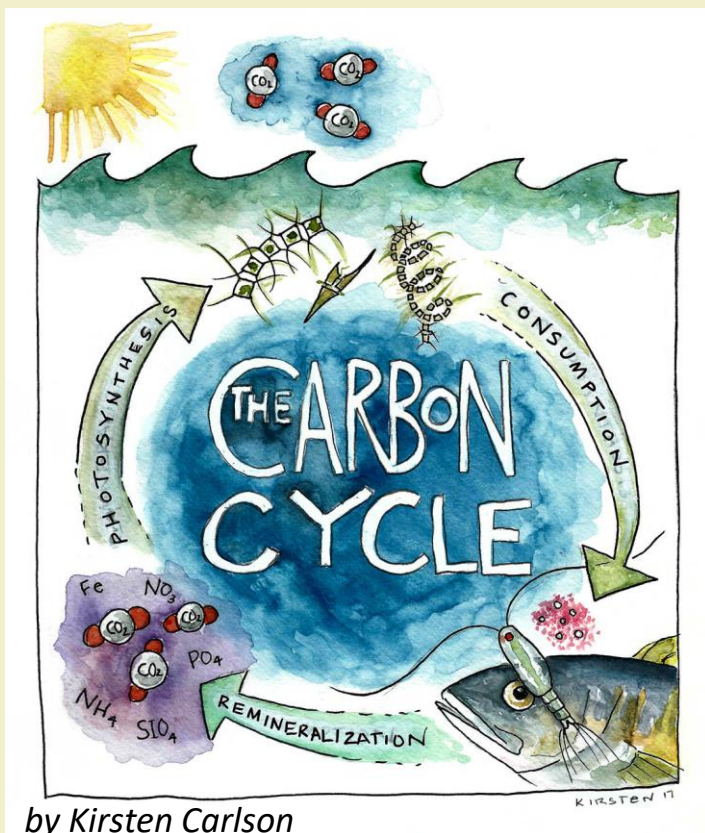
Our ocean teems with life and many of its most vital species are invisible to us. Like on land, the ocean has deserts, forests, meadows, and jungles, providing habitats for many forms of life. The types of life in these habitats is determined by microscopic algae that float in our ocean. Known as "phytoplankton," these tiny organisms come in many different shapes, sizes, and colors. The diversity of phytoplankton types determines the roles they play in ocean habitats. It also determines how well they capture energy from the sun and carbon from the atmosphere.

[Read More](#)

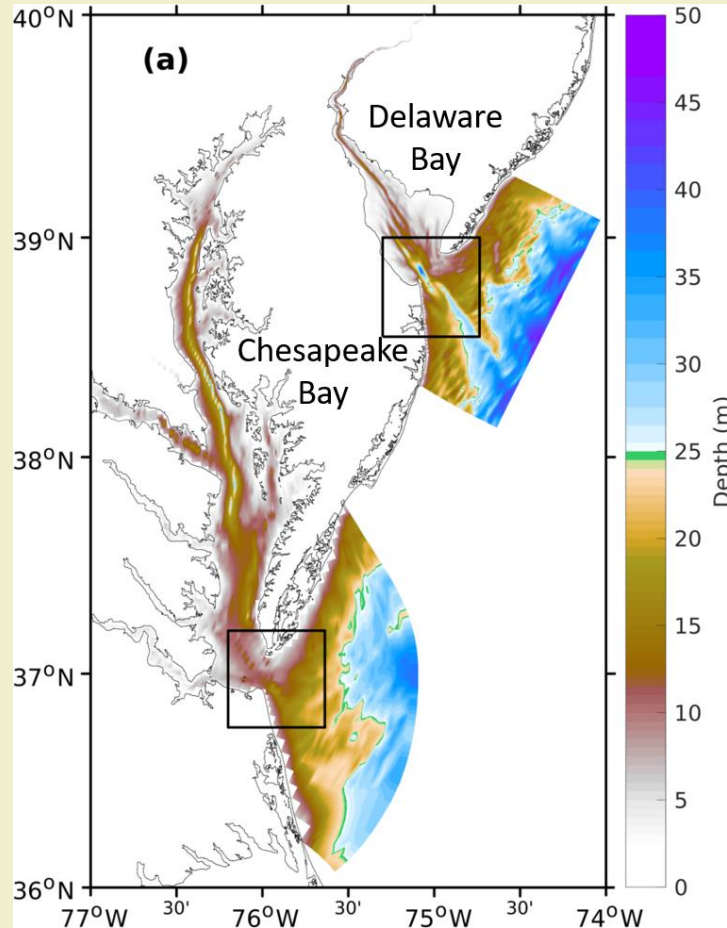
Chesapeake Bay Research Activities

abridged version

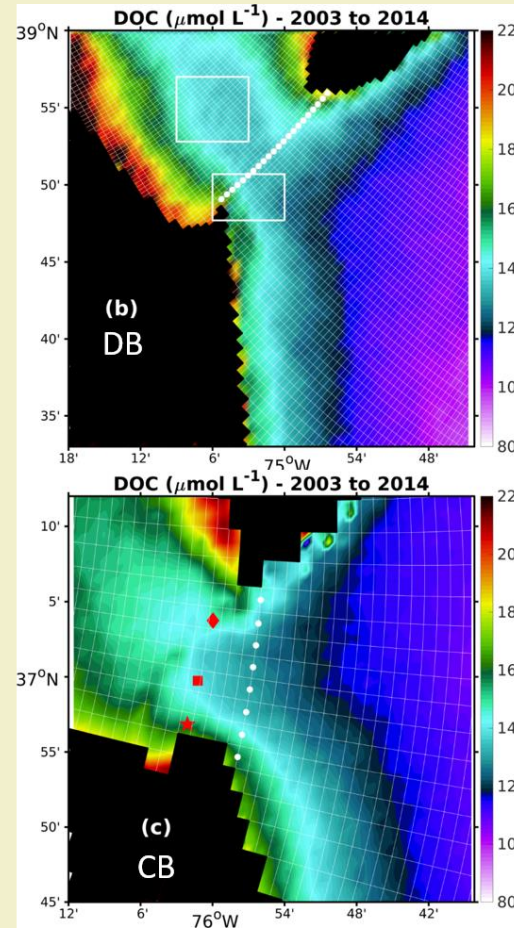
Antonio Mannino, NASA GSFC
and many others



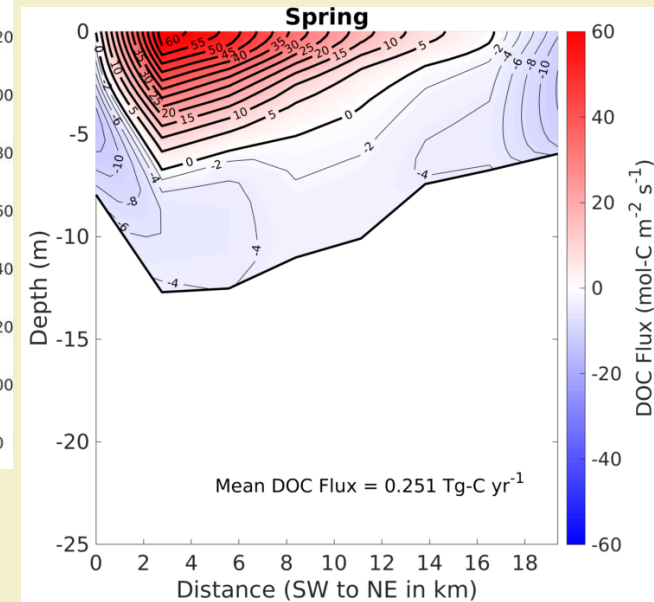
DOC Fluxes from Chesapeake Bay and Delaware Bay from Satellite DOC and Estuarine Model Physics



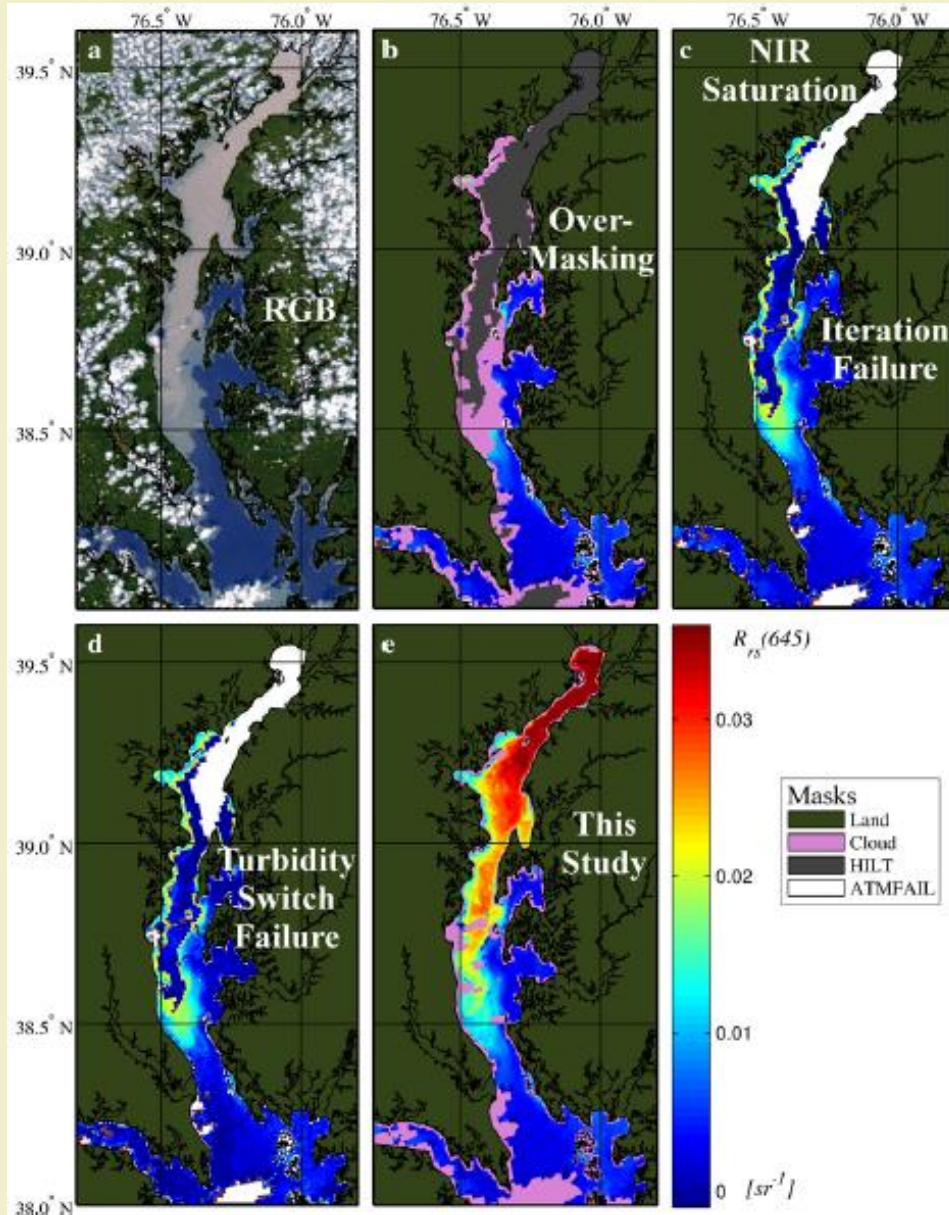
ROMS with ECB & DB grids



2007-2011 Mean Annual Flux from CB mouth to MAB = $0.21 \text{ Tg C yr}^{-1}$



Improved Coverage and Data Quality for Turbid Waters



- Improved masking in high turbidity waters
- Applied SWIR bands to enable turbid water retrievals

MODIS image from Sept. 11, 2011 following Hurricane Irene and Tropical Storm Lee

Future Plans

- Satellite- and ROMS-based Carbon budget for lower Chesapeake Bay and Middle Atlantic Bight
 - POC, DOC and DIC
 - fluxes, standing stocks and Net Community Production
 - Terrestrial DOM fluxes
- Satellite-derived Phytoplankton community composition for Chesapeake Bay (lower) and Middle Atlantic Bight
- Potentially Satellite-derived water quality parameters
- Improvements in data products with PACE (2024)