OBB Science Vision

NASA Ocean Biology & Biogeochemistry: ***Science Vision***

Background

- From 2005 - 2007, NASA developed an OBB Advanced Science Plan with a volunteer writing team.
- In 2015, a new volunteer writing team was assembled to update this science plan.
- In 2017, activities stalled in the commenting phase amid OBB program leadership changes.

Recent developments

- In 2021, a new volunteer writing team was convened to build upon the prior Advanced Science Plan and develop a Science Vision for the next decade.
- In 2022, this new Science Vision has undergone targeted review.
- The Executive Summary and first two chapters have been released in draft form on the OBB website, with the remaining chapters expected soon, after a few remaining reviewer comments have been addressed. https://cce.nasa.gov/ocean_biology_biogeochemistry/

Our most sincere thanks to the writing teams

(**current vision**) Michael Behrenfeld, Paula Bontempi, Heidi Dierssen, Stephanie Dutkiewicz, Laura Lorenzoni, Melissa Omand, Joel Scott, Jeremy Werdell

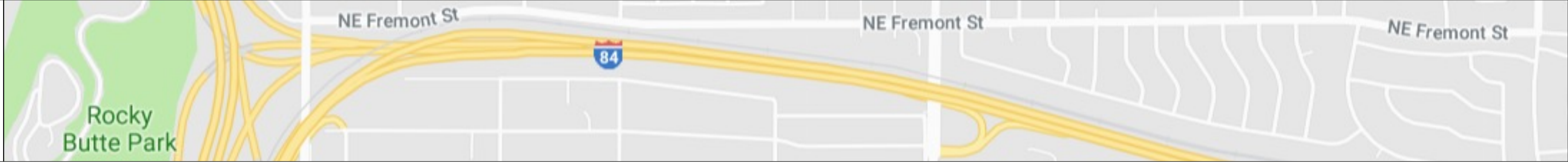
(**2017 plan**) John Dunne, Matthew Long, Antonio Mannino, Patricia Matrai, Frank Muller-Karger, Raymond Najjar, Anastasia Romanou, Cecile Rousseaux, Maria Tzortziou

And thank you to the external reviewers for their valuable insights and comments!

NASA Ocean Biology & Biogeochemistry: ***Science Vision***

- The Science Vision is built around five ***Grand Challenges***, which will link together science questions facing the OBB community over the coming decade.
- Each ***Grand Challenge*** is presented and discussed in the Synthesis within the context of the current state of the science
  - What do we know?
  - What are we capable of presently?
  - What do we need to observe?
  - What are the science questions we want to answer?
  - How do we leverage and maximize the utility of our science?
  - What technologies can we deploy or need to be developed?

Roadmap



Letter to Readers (*Laura Lorenzoni*)

Executive Summary

Introduction (*integrated ‘observing system’ concept*)

1. Grand Challenges and a Sustainable Blue Economy

2. Standing on Shoulders of Giants

3. Grand Challenges: Paths Forward

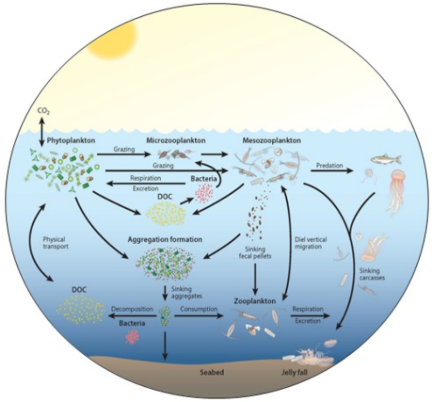
4. Science Vision Synthesis

5. Technical Requirements and Investments

6. Benefits for the Nation and Beyond

1. Grand Challenges and a Sustainable Blue Economy

GLOBAL BIOSPHERE: Characterize how global ocean ecosystems will change in the future in the face of compounding stressors from natural variability, climate warming, and direct human impacts, identify which ecosystems are most vulnerable to these stressors, and quantify how changes in ocean life and biogeochemistry impact our planet as a system of systems.

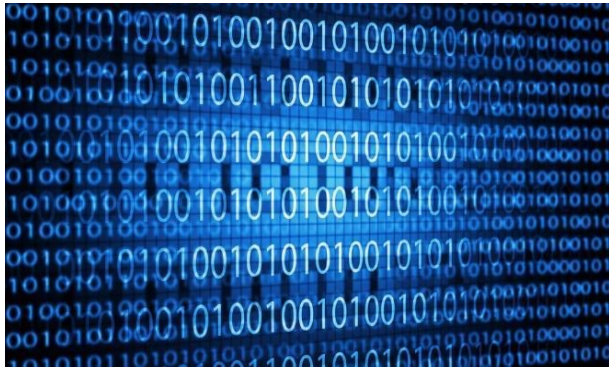


ELEMENTS OF LIFE: Quantify how the role of ocean ecosystems in climate regulation and the biogeochemical cycling of elements will change in the future and what the ramifications of these changes are for the Earth's climate, the diversity of ocean life, resource sustainability, and human welfare.

INTERFACE HABITATS: Establish how natural processes and human activities govern the diversity, function, and resilience of life in interface habitats such that the services and value of these dynamic systems to humanity can be safeguarded and sustained for future generations.

1. Grand Challenges and a Sustainable Blue Economy

Transient Events: Develop the knowledge base and infrastructure to detect, quantify, predict, and understand marine responses to transient events to enable preparation, mitigation, and recovery when these events affect communities.

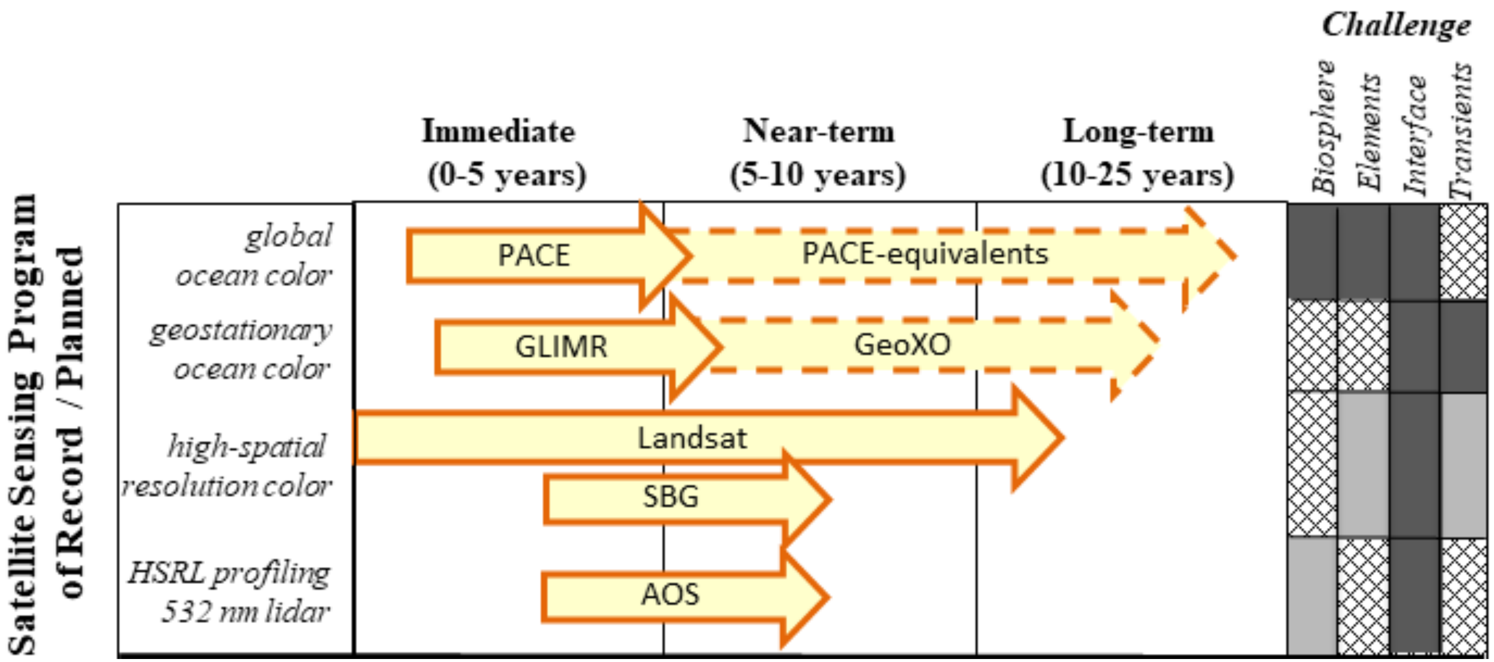


Leveraging Ocean Data and Models: Leverage advanced data harmonization, interoperability, synthesis, integration, and mining strategies and train next-generation scientists to maximize the value of satellite, suborbital, and modeled data streams to facilitate better understanding of life, ocean biogeochemistry, ecosystems, and their dynamic processes.

*"All five of these **Grand Challenges** are intimately linked to climate change, through its impact on ocean life, chemistry, and physics and the need to better predict and respond to future change."*

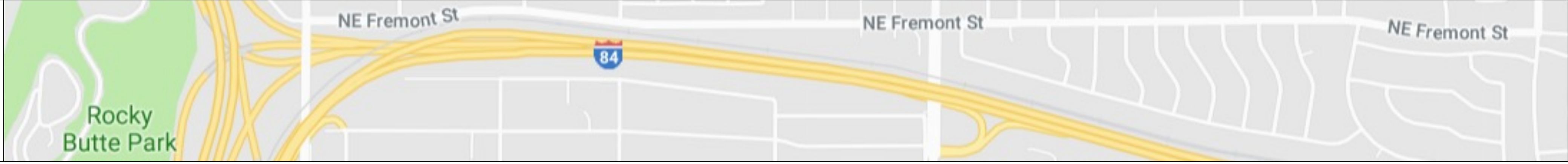
2. Standing on Shoulders of Giants

"The advanced 'observing system' envisioned herein builds upon decades of heritage satellite missions and *it is assumed in the opportunities identified in subsequent sections that currently planned missions in the Program of Record will be successfully completed and that equivalent or improved observing capabilities will be sustained thereafter.*"



(Footnote: In **Sections 5.1**, **5.2**, **5.3**, and **5.5**, details are provided on desired Measurement Specifications and Technology Development needs)

Roadmap

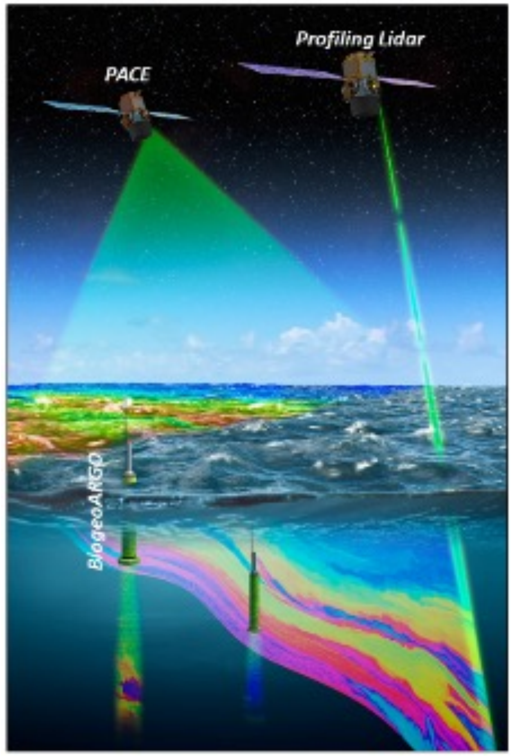


3. Grand Challenges: Paths Forward (*Subsections 3.1-3.5*)

- Restatement of Challenge (*from Section 1*)
- Introductory text outlining the science, technology, and applications scope of the Challenge
- Specific ‘observing system’ elements
- Summary on areas of opportunity [New: immediate (0-5 years)/near-term (5-10 years)/long-term (10-25 years) goals]

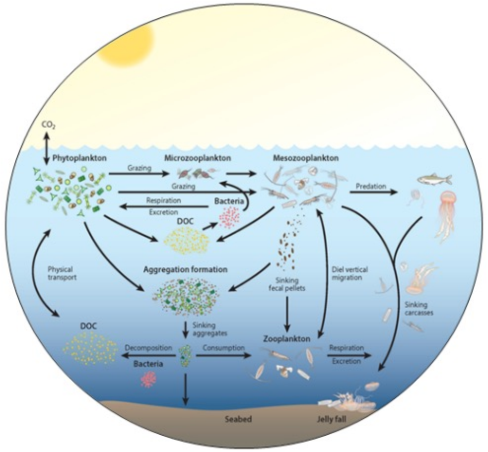
Reiterating: *These paths forward build on the current Program of Record and the continuation of these foundational measurements into the future*

3.1. Global Biosphere



- 'Observing system' elements
  - ➢ Plankton Communities in '4-D'
    Temporally-resolved 3-dimensional reconstruction of global plankton communities
  - ➢ Observations in Challenging Regions
    Ecologically-important, rapidly-changing ocean regions (e.g., polar and upwelling systems) where observing conditions (e.g., persistent clouds, solar angle) compromise traditional ocean color measurements
  - ➢ Mixing and Stratification
    Satellite technology coupled with physical ocean models - seasonal plankton dynamics, exchanges of heat and momentum, carbon biogeochemistry, materials exchange, etc.
  - ➢ Integrated Global Biosphere Observing System
    Field survey measurements, processes studies, and advanced modeling - interpret and synthesize remote sensing and autonomous data for global system level understanding

3.2. Elements of Life



- ‘Observing system’ elements
  - ➢ Surface Ocean Properties and Rates

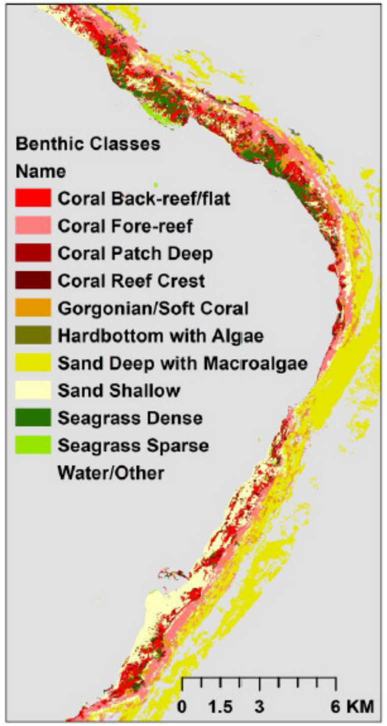
    Quantifying living and dissolved pools of elements (e.g., C, N, Fe) and their transformation rates (e.g., NPP, remineralization) in the upper ocean
  - ➢ Subsurface Ocean Properties and Rates

    Linking above to mesopelagic and deeper
  - ➢ Plankton Rates
  - ➢ Remotely-detectable properties linked to key plankton rates (e.g., phytoplankton division, zooplankton/mixotrophic grazing, viral lysis, migration)
  - ➢ Ocean-Atmosphere Processes

    Biogenic emissions to the atmosphere / Atmospheric inputs to ocean ecosystems
  - ➢ Carbon Dioxide Reduction (CDR)

    While this Science Vision does not advocate ocean-based CDR activities, NASA’s ocean remote sensing assets have obvious value here

3.3. Interface Habitats



- 'Observing system' elements
  - ➢ Temporally-resolved interface observations

    High spatial, spectral, and temporal resolution satellite measurements

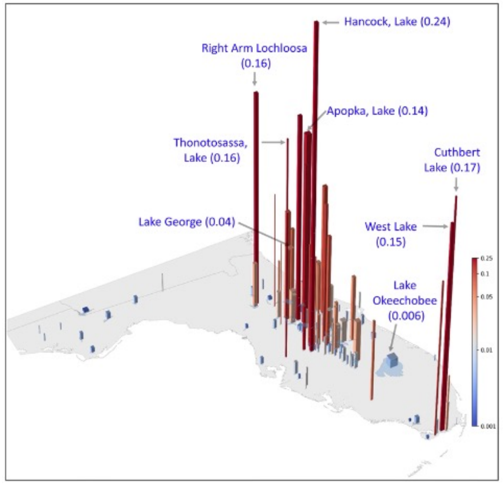
  - ➢ Suborbital surveys

    Active and passive suborbital measurements (e.g., airplanes, drones, etc.) to characterize specific systems in detail

  - ➢ Synthesizing observational data

    Data processing capabilities, atmospheric correction and subsurface retrieval algorithm improvements, training of next-generation scientists in merging and using diverse new data streams (e.g., geostationary, CubeSat, autonomous sensor, etc.)

3.4. Transient Events



- ‘Observing system’ elements
  - ➢ Satellite support system

    High spatial and spectral resolution satellite observations with sub-daily repeat coverage as foundation for additional suborbital assets

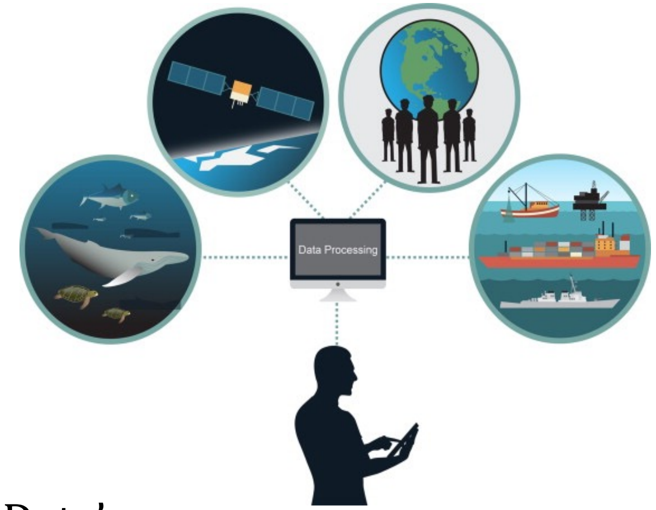
  - ➢ Suborbital assets

    Airborne passive and active sensors, in-water autonomous systems, integrated modeling and data assimilation – rapid results for event tracking and informed responses.

  - ➢ Disturbance Responses: Improving the Odds

    Effective approaches for developing mechanistic understanding of short-term ecosystem responses – this may entail purposeful manipulations or a ‘stand-by’ deployment scheme (sort of a ‘*tornado chaser*’ approach)

3.5. Leveraging Ocean Data and Models

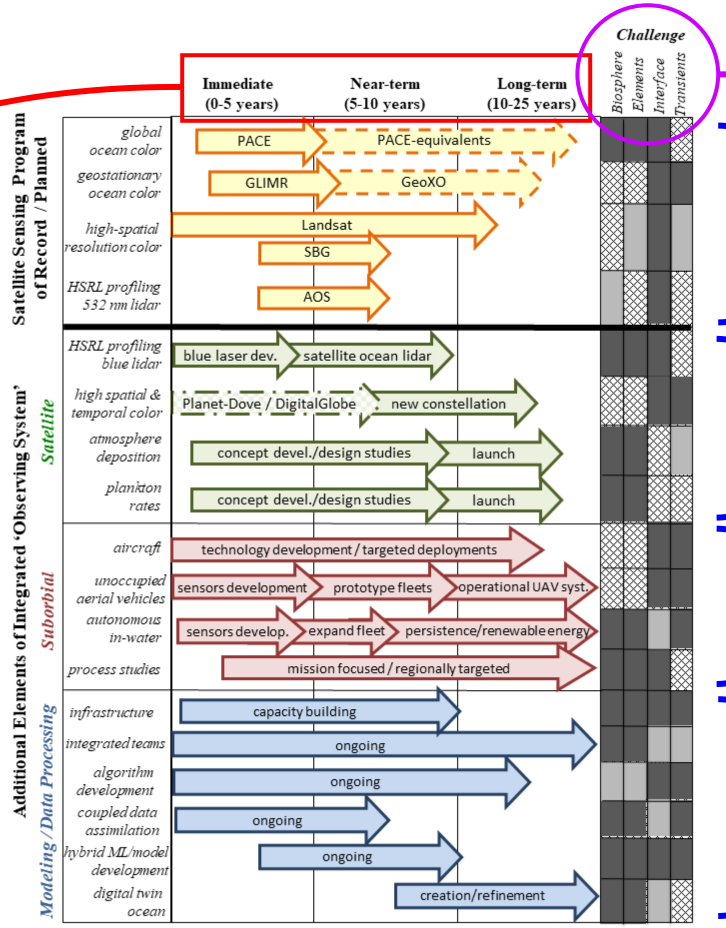


- ‘Observing system’ elements
  - ➢ Access and Utility of Ocean Observational Data
    - *Data Access*: Accessibility of different data streams through a hierarchy of networked computational and data facilities
    - *Skills*: Tools and training for researchers and others to work with ‘Big Data’
    - *Syntheses*: Syntheses and common currencies for diverse and multi-dimensional data
    - *Machine Learning*: Integrate machine learning specialists and statisticians within ocean biology and biogeochemical research groups.
  - ➢ Numerical Models and Data Assimilation
    - *Model Development*: Coordination between modeling groups, improved representation of physics, lights fields, and non-linear interactions
    - *Data Stream Uncertainties*: Better constraining and articulating uncertainties
    - *Coupled Data Assimilation*: Combined physical - biogeochemical data assimilation
    - *Hybrid Modeling and Machine Learning*: Mathematical equations for well understood processes / machine learning for processes less well understood or captured
    - *Ocean Color Satellite Mission Emulators*: Models explicitly resolving inherent and apparent optical properties and radiative transfer
    - *Ocean Digital Twin*: Ocean version of ‘Earth Digital Twin’

4. Science Vision Synthesis

"The five **Grand Challenges** are unified under the single goal of *creating an integrated and accessible 'observing' system that encompasses elements of measurements, modeling, and workforce* to advance understanding of aquatic systems that enables improved assessments, responses, adaptations, and management in the face of Earth system change ... [and requires] meaningful coordination, cooperation, and communication between NASA's OBB, physical oceanography, cryospheric sciences, biodiversity, terrestrial ecosystems, astronomy, and atmospheric science programs, as well as other national and international partnerships."

Timeframe for objective



Grand Challenges addressed

Sustained Program of Record Measurements

New satellite observations

New suborbital capabilities

New and continued modeling and data processing capabilities and capacities

Science Vision
(cont'd)

- ***Science Vision Synthesis*: chapter also includes subsection on 'Education and Engagement.'**
- ***Technical Requirements and Investments***: Chapter includes description of measurement relevance to Grand Challenges, details on measurement specifications, and required technology development.
- ***Benefits for the Nation and Beyond:*** Benefits from this OBB Science Vision extend far beyond the direct advances made to scientific knowledge.

CC&E Joint Science Workshop

Who: 5 NASA Programs & Communities

Where: The Hotel, College Park, Maryland (in person)

When: 8-12 May 2023 (Mon-Fri)

Agenda:

Mon-Tue: OCRT meeting

Wed-Thu: Joint Science Plenary sessions on

1) Human Influence on Global Ecosystems
2) Climate Change Impacts
3) Disturbance, Resilience, Mitigation, Adaptation
4) Research to Applications
5) Future Research Directions

Fri: DAAC trainings

More: https://cce.nasa.gov/meeting_2023/index.html