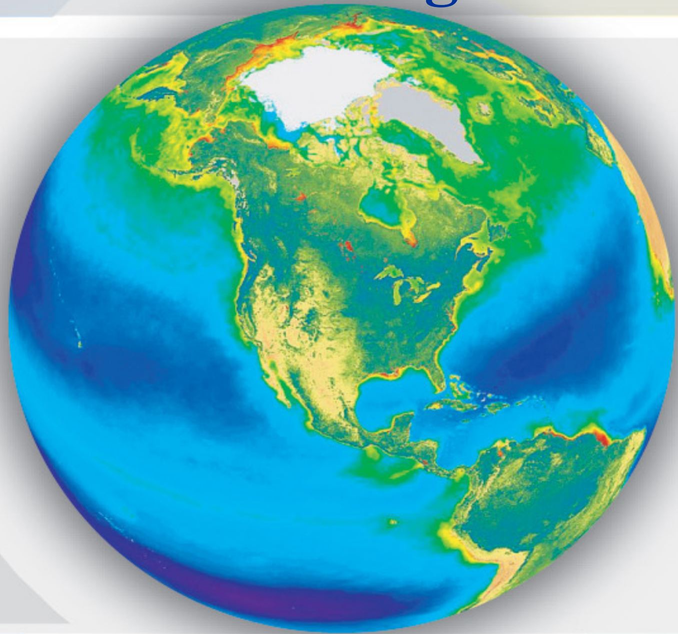
NASA Ocean Biology and Biogeochemistry Advanced Planning



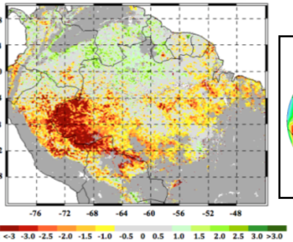
Paula Bontempi
NASA Headquarters

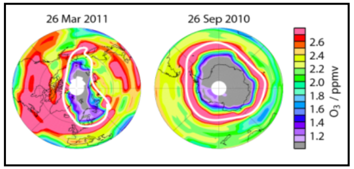
Ocean Carbon and Biogeochemistry Summer Workshop

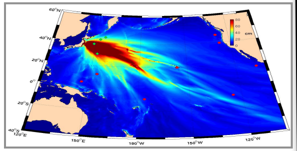
23 July 2015

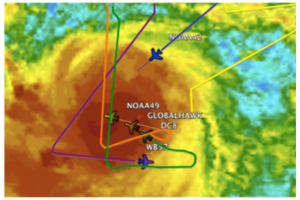
NASA's Earth Science Division

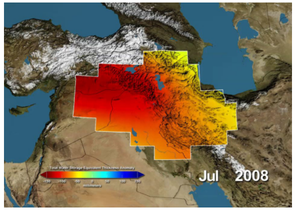
Research

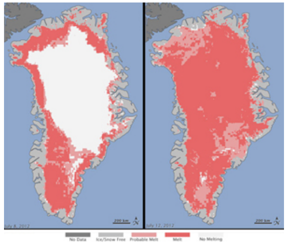




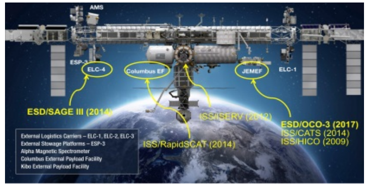




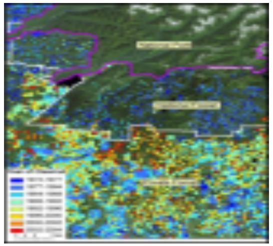


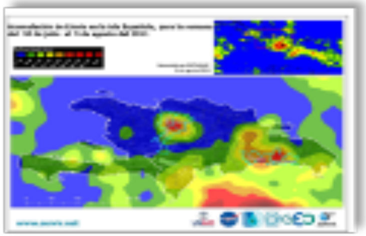


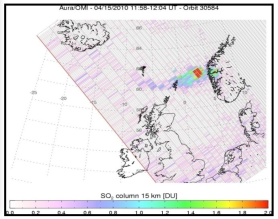
Flight

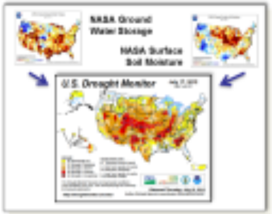


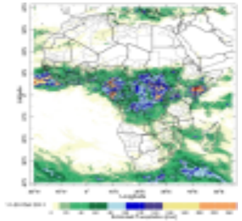
Applied Sciences



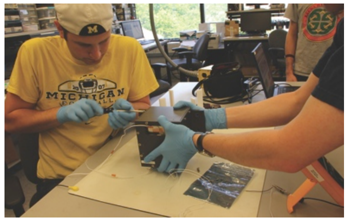


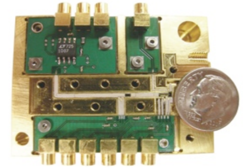


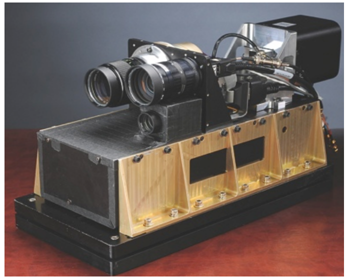




Technology







3 ESD-developed EO missions launched since 2/2014
2 ISS-developed EO instruments launched (2014, 2015)
11+ more ESD EO launches before 2022

Formulation
Implementation
Primary Ops
Extended Ops
SLI-TBD
Formulation in 2015
JPSS-2 (NOAA)
RBI
OMPS-Limb
[[TSIS-2]]
[[Future Altimetry]]
NI-SAR
PACE
SWOT
TEMPO
GRACE-FO (2)
ICESat-2
CYGNSS
RapidScat, CATS,
LIS, SAGE III (on ISS)
SMAP
SORCE
TRMM
QuikSCAT
[[TCTE]]
EO-1
Landsat-7
(USGS)
Terra
Suomi NPP
(NOAA)
Aqua
Landsat-8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

Advanced Planning – Why?

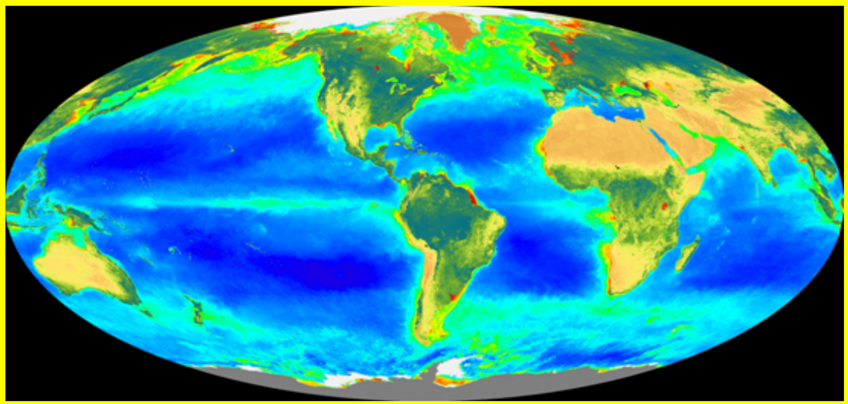
- What have we accomplished since the last plan (2008)?
  - Are the existing questions still valid or do they need to evolve?
- What's next scientifically?
- Systematic Observations – Suomi NPP to JPSS (?)
- New observations
- Science Questions -> Measurements -> Instrument concepts -> Mission Concepts
  - Modeling, Technology, Applied Science, Data management, Cal/Val

Ocean Biology STM

Category	Focused Questions*	Approach	Maps to Science Question	Measurement Requirements	Instrument Requirements	Platform Requir'ts	Other Needs
Ocean Biology	1 What are the standing stocks, composition, & productivity of ocean ecosystems? How and why are they changing? [OBB1] 2 How and why are ocean biogeochemical cycles changing? How do they influence the Earth system? [OBB2] 3 What are the material exchanges between land & ocean? How do they influence coastal ecosystems, biogeochemistry & habitats? How are they changing? [OBB1,2,3] 4 How do aerosols & clouds influence ocean ecosystems & biogeochemical cycles? How do ocean biological & photochemical processes affect the atmosphere and Earth system? [OBB2] 5 How do physical ocean processes affect ocean ecosystems & biogeochemistry? How do ocean biological processes influence ocean physics? [OBB1,2] 6 What is the distribution of algal blooms and their relation to harmful algal and eutrophication events? How are these events changing? [OBB1,4]	Quantify phytoplankton biomass, pigments, optical properties, key (functional) phytoplankton groups, and productivity using bio-optical models and chlorophyll fluorescence	1, 2, 6	Water-leaving radiances in near-ultraviolet, visible, & near-infrared for separation of absorbing & scattering constituents and calculation of chlorophyll fluorescence Total radiances in UV, NIR, and SWIR for atmospheric corrections Cloud radiances for assessing instrument stray light	**Ocean Radiometer** • 5 nm resolution 350 to 750 nm • 1000 – 1500 SNR for 20 nm aggregate bands UV & visible • 750 – 1000 SNR for 10 nm fluorescence bands (667, 678, 748 nm band centers) • 30 to 40 nm bandwidth atmospheric correction bands at 765, 865, 1245, 1640 nm with 180 – 750 SNR • 0.5% radiometric accuracy • 0.1% radiometric stability • 58.3o cross track scanning • Sensor tilt (20o) for glint avoidance • Polarization insensitive	Orbit permitting 2-day global coverage of ocean radiometer measurements Sun-synchronous orbit with crossing time between 10:30 a.m. & 2:30 p.m.	Global data sets from missions, models, or field observations: *Measurement Requirements* (1) Ozone (2) Water vapor (3) Wind *Science Requirements* (1) SST (2) SSH (3) PAR (4) UV (5) MLD (6) CO_2 (7) pH (8) Ocean circulation (9) Aerosol deposition (10) run-off loading in coastal zone (11) **other….**
		Measure particulate and dissolved carbon species, their characteristics and optical properties	2, 3				
		Assess ocean photobiochemical processes	2, 4				
		Estimate particle abundance, size distribution, & characteristics	1, 3, 2				
		Assimilate ACE observations in ocean biogeochemical model fields of key properties (cf., air-sea CO_2 fluxes, export, pH, etc.)	2				
		Compare ACE observations with ground-based and model data of biological properties, land-ocean exchange in the coastal zone, physical properties (e.g., winds, SST, SSH, etc), and circulation (ML dynamics, horizontal divergence, etc)	3, 4, 5, 6	High vertical resolution aerosol heights, optical thickness, & composition for atmospheric corrections Subsurface particle scattering & depth profile	**Lidar** • **Yong** – we need specifications for the lidar here, to do both aerosols and ocean particles – follow format above for ocean readiometer		
		Combine ACE ocean & atmosphere observations with models to evaluate (1) air-sea exchange of particulates, dissolved materials, and gases and (2) impacts on aerosol & cloud properties	4				
		Assess ocean radiant heating and feedbacks	5	Broad spatial coverage aerosol heights for atmospheric correction Subsurface polarized return for typing oceanic particles	**Polarimeter** **Emmanuel** – we need specification for the polarimeter here, to do both aerosols and particle polarization – follow format above for ocean radiometer		
		Conduct field sea-truth measurements and modeling to validate retrievals from the pelagic to near-shore environments	1, 4, 2, 5, 3, 6				

* ACE focused questions are traceable to the four overarching science questions of NASA's Ocean Biology and Biogeochemistry Program [OBB1 to OBB4] as defined in the document: *Earth's Living Ocean: A Strategic Vision for the NASA Ocean Biological and Biogeochemistry Program* (under NRC review)

Advance Plan:
Earth's Living Ocean: The Unseen World



NASA Ocean Biology and Biogeochemistry Program

Team from April 2005: Michael Behrenfeld, Heidi Dierssen, Paul DiGiacomo, Steve Lohrenz, Chuck McClain, Frank Muller-Karger, Dave Siegel, (Paula Coble)

May 2006-October 2006: Posted for Public Comment

Reviewers: Tony Freeman, Norm Nelson, Jim Yoder

March 2007: Briefed to NRC OSB

April 2007: Negotiations with NRC for review (OSB and SSB)

September 2007: Public comments incorporated

April 2008: Briefed to NRC SSB

April 2008: Letter drafted for NASA SMAC review

December 2008: plan to have joint SSB/OSB (NASA-NOAA) sponsored review

April 2009: Statement of Task for OSB, SSB finalized (NASA, NOAA, NSF, ONR)

Timeline / Mission Themes	Immediate (1 – 5 Years)	Near-Term (5 - 10 Years)	Long-Term (10 - 25 Years)	Ecosystems	Biogeochemistry	Habitats	Hazards
Global Separation of In-water Constituents & Advanced Atmospheric correction	**Advanced radiometer & scattering lidar** • 5nm resolution from UV through visible • Ozone & extended NIR atmosphere bands • Atmosphere & subsurface particle scattering profiles	**Ocean radiance and atmosphere aerosols** • Advanced radiometer • Scattering lidar for aerosol speciation • Polarimeter for global aerosol coverage •500 m passive resolution	**Radiometry, aerosols, and physiology lidar** • Global radiometry system • Aerosol height & species • Midnight/noon obs of variable stimulated fluorescence				
High Spatial & Temporal Resolution Coastal	**Coastal carbon – GEO** **Support analysis of current satellite data** **Landsat DCM partnership** **Development of suborbital sensor systems**	**High-res coastal imager** • 20 bands from UV - NIR • 10 m res – 100 km swath **GEO carbon mission** **Deployment of suborbital systems**	**Constellation of imaging spectrometers** • High temporal res • LEO, MEO or GEO • Include SAR **Continued deployment of suborbital systems**				
Plant Physiology & Functional Composition	**Support analysis of global passive data** • Assess functional groups using hyperspectral data • Estimate algal carbon & chlorophyll to characterize physiology	**Support analysis of global & GEO data**	**Variable fluorescence lidar constellation** •Map physiological provinces at different times of day • Dawn/dusk variable fluorescence lidar • Noon/midnight lidar				
Mixed Layer Depth	**Synthesis/analysis of observational forecast fields & on orbit remote sensing** **Mixed layer model development**	**Prototype mixed layer sensor development** • field testing of novel approaches for remote detection of mixed layer depth & light availability	**Mixed layer depth mission** •Space-borne proof-of-concept mission for global mixed layer depth mapping				

Bold Green Text Represents Satellite Missions

Bold Blue Text Represents Development Activities leading to Missions

Cross-hatch indicates secondary contribution to Mission Theme

Top Priority Science Question	Color Code	Example of Benefits to Society
How are ocean ecosystems and the biodiversity they support influenced by climate or environmental variability and change, and how will these changes occur over time?		Improved management of ecosystem goods and services
How do carbon and other elements transition between ocean pools and pass through the Earth System, and how do biogeochemical fluxes impact the ocean and Earth's climate over time?		Information based policy on greenhouse gas emissions and nutrient loading
How (and why) is the diversity and geographical distribution of coastal marine habitats changing, and what are the implications for the well-being of human society?		Mapping and assessment of coastal habitats for future development plans and tourism
How do hazards and pollutants impact the hydrography and biology of the coastal zone? How do they affect us, and can we mitigate their effects?		National security and improved forecasting of natural and human-induced hazards

Science Questions

- How are ocean ecosystems and the biodiversity they support influenced by climate and environmental variability and change, and how will these changes occur over time?
- How do carbon and other elements transition between ocean pools and pass through the Earth System, and how do biogeochemical fluxes impact the ocean and Earth's climate over time?
- How (and why) is the diversity and geographical distribution of coastal marine habitats changing, and what are the implications for the well-being of human society?
- How do hazards and pollutants impact the hydrography and biology of the coastal zone? How do they affect us, and can we mitigate their effects?

Mission Themes/Science Requirements

- Global separation of in-water constituents and advanced atmospheric corrections
- High temporal and spatial resolution coastal measurements
- Active assessments of plant physiology and functional composition
- Mixed layer depth

Science Requirements Lead to Observational Strategies

- Global Hyperspectral Imaging Radiometer
- Geostationary Hyperspectral Imaging Radiometer(s)
- Multi-Spectral High Spatial Resolution Imager
- Portable Sensors from Suborbital Platforms
- Variable Fluorescence Lidar
- Mixed Layer Depth and Illumination Sensor
- Ocean Particle Profiler and Aerosol Column Distributions

Science Requirements Lead to Observational Strategies

- Global Hyperspectral Imaging Radiometer
  - Aerosol-Ocean-Cloud (polarimeter, lidar, ocean radiometer, radar)
- Geostationary Hyperspectral Imaging Radiometer(s)
- Multi-Spectral High Spatial Resolution Imager
  - Plant Physiology and Functional Types
- Portable Sensors from Suborbital Platforms
- Variable Fluorescence Lidar
- Mixed Layer Depth and Illumination Sensor
- Ocean Particle Profiler and Aerosol Column Distributions

the missions are given in Part II, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	\$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	\$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	\$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	\$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	\$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	\$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	\$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	\$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	\$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	\$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	\$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	\$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	\$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	\$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	\$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational

Earth's Living Ocean: The Unseen World

- NASA seeks to advance understanding of the Earth's living ocean through global research, observations and predictive models

- Cal/Val

- Plan – Living Document

- Next Decadal Survey (2015-2017)