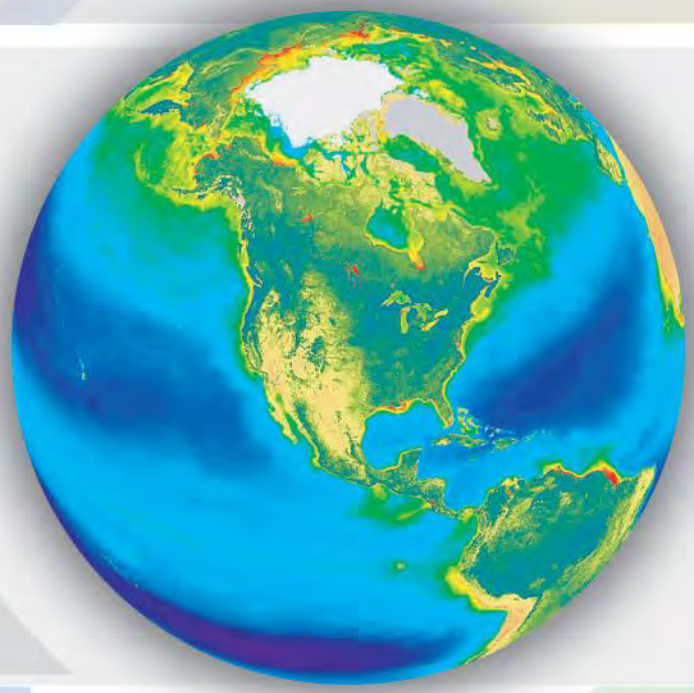
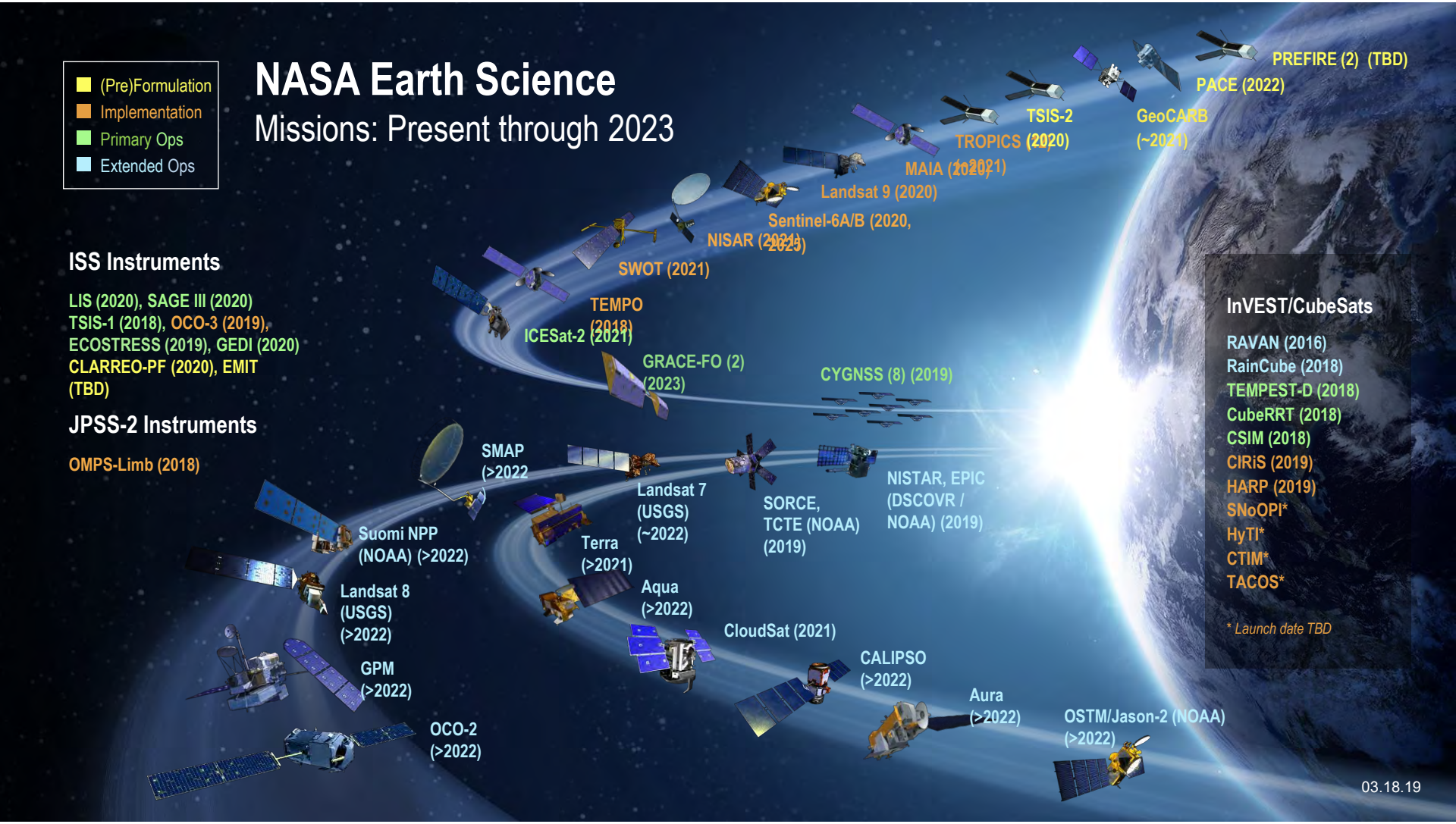
NASA Emerging Applications and Science



Paula Bontempi and Laura Lorenzoni
NASA Headquarters
International Ocean Color Science Meeting
12 April 2019


(Pre)Formulation
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NASA Earth Science
Missions: Present through 2023
ISS Instruments
LIS (2020), SAGE III (2020)
TSIS-1 (2018), OCO-3 (2019),
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(2023)
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(USGS)
(~2022)
SORCE,
TCTE (NOAA)
(2019)
NISTAR, EPIC
(DSCOVR /
NOAA) (2019)
Suomi NPP
(NOAA) (>2022)
Terra
(>2021)
Landsat 8
(USGS)
(>2022)
Aqua
(>2022)
CloudSat (2021)
CALIPSO
(>2022)
GPM
(>2022)
Aura
(>2022)
OSTM/Jason-2 (NOAA)
(>2022)
OCO-2
(>2022)
InVEST/CubeSats
RAVAN (2016)
RainCube (2018)
TEMPEST-D (2018)
CubeRRT (2018)
CSIM (2018)
CIRiS (2019)
HARP (2019)
SNoOPI*
HyTI*
CTIM*
TACOS*
* Launch date TBD
03.18.19

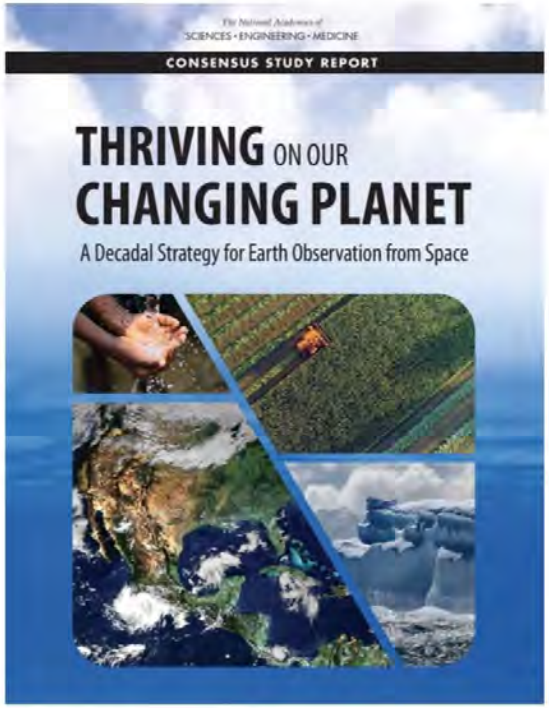
Earth Science Division Budget/Program Overview

- The FY19 Appropriation :
  - **NASA's Earth Science Division - $1,931 billion ($10M increase from FY2018)**
  - **Plankton, Aerosol, Cloud, and Ocean Ecosystem, or PACE, mission fully funded**

- FY20 President's Budget – released in detail on 11 March 2019
  - https://www.whitehouse.gov/omb/budget/
  - **The President's 2020 Budget requests $21.0 billion for NASA, a ($481M decrease from the 2019 annualized CR level).**
  - **Provides $1,779.8 billion for a focused, balanced Earth science portfolio that supports the priorities of the science and applications communities, a reduction of $151.2 million from FY19.**
  - **Consistent with prior budgets, provides no funding for PACE, CLARREO-PF, and the Office of Science, Technology, Engineering, and Mathematics (STEM) Engagement.**
  - **Initiates the Decadal Incubation project to address needs for two targeted observable areas: Planetary Boundary Layer and Surface Topography and Vegetation.**
  - **Begins new Earth Venture Continuity element to focus on specific instruments for continuity of measurements per 2017 Decadal Survey recommendations.**
  - **Invests in CubeSats/SmallSats that can achieve entirely new science at lower cost.**
  - **Moon in the next five years, and Mars after**

NASA/NOAA/USGS Decadal Survey Status

National Academies Decadal Survey News



- The Decadal Survey Final Report was released last week: https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth
- ESD briefed the Committee on NASA's progress on March 26 & 27
- Further briefings on the DO Studies are tentatively scheduled for CESAS Fall meeting.

Look at NASA's DS website for more information:
https://science.nasa.gov/earth-science/decadal-surveys

Recommended NASA Priorities: Designated (Table 3.5)

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		

Recommended NASA Priorities: Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Greenhouse Gases	**CO_2 and methane fluxes and trends,** global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	**Global ice characterization** including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	**Coincident high-accuracy currents and vector winds** to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		X	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & Snow Water Equivalent	**Snow depth and snow water equivalent** including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	**3D structure of terrestrial ecosystem** including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		X	

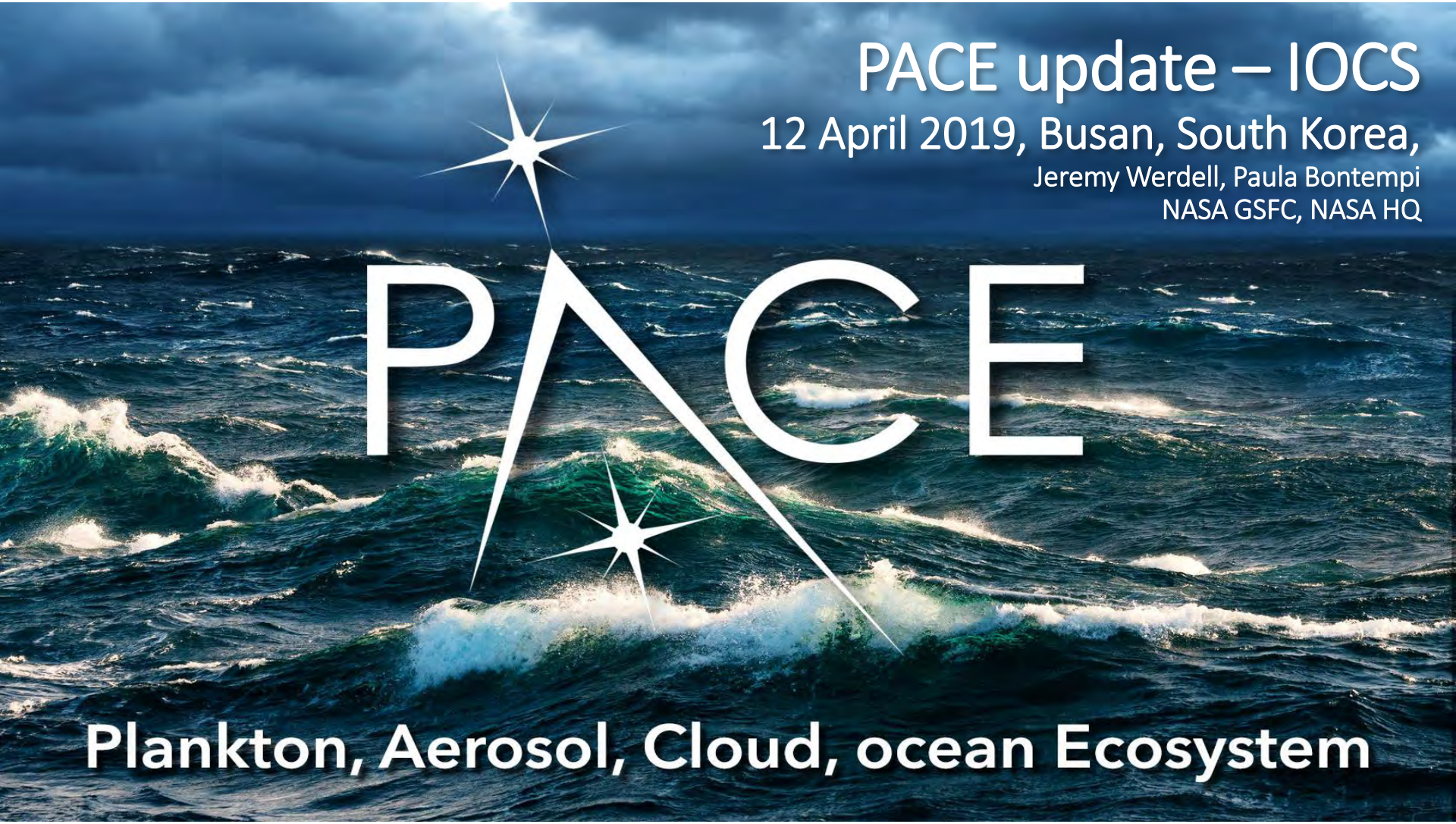
Recommended NASA Priorities: Incubation/Other

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	**Diurnal 3D PBL thermodynamic properties and 2D PBL structure** to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	**High-resolution global topography** including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X

** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables

Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element

Aquatic Biogeochemistry	**Radiance Intercalibration**
Magnetic Field Changes	**Sea Surface Salinity**
Ocean Ecosystem Structure	**Soil Moisture**


PACE update – IOCS
12 April 2019, Busan, South Korea,
Jeremy Werdell, Paula Bontempi
NASA GSFC, NASA HQ
PACE
Plankton, Aerosol, Cloud, ocean Ecosystem

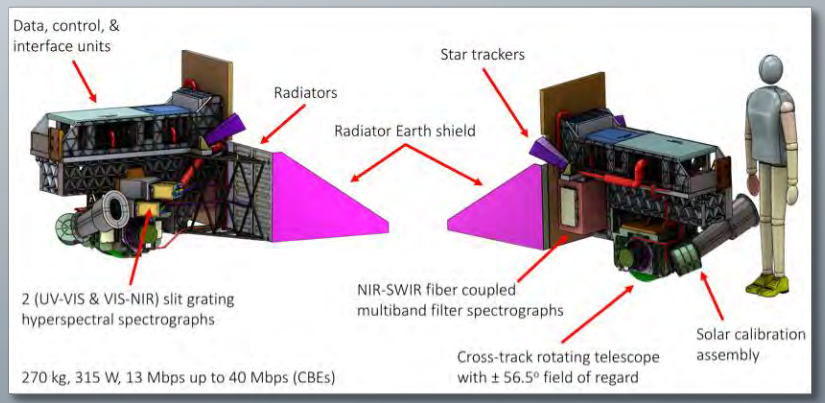
Cost, Schedule, Lifespan

- $805M Design-to-Cost
- Category 2, Class C
- ~Dec 2022 launch
- 3-year design life
- 10-years of propellant

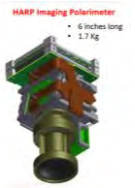
Orbit

- 675.5 km altitude
- Polar, ascending orbit
- Sun synchronous
- 98^{o} inclination
- 13:00 local Equatorial crossing

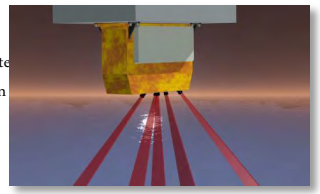
- 340 – 890 nm at 5 nm resolution
- Plus, 940, 1038, 1250, 1378, 1615, 2130, and 2250 nm
- 1 – 2 day global coverage
- Ground pixel size of 1 km^2 at nadir
- ± 20° fore/aft tilt to avoid Sun glint
- Twice monthly lunar calibration
- Daily on-board solar calibration
- Performance that meets or exceeds heritage
- Built at NASA Goddard Space Flight Center



UMBC Hyper Angular Rainbow Polarimeter (HARP-2)



SRON Spectro-polarimeter for Planetary Exploration (SPEXone)



PACE polarimeters *NOT* in 2017 Decadal Survey Program of Record

	HARP-2	SPEXone
UV-NIR range	440, 550, 670, 870 nm	Continuous from 385-770 nm in 5 nm steps
SWIR range	None	None
Polarized bands	All	Continuous from 385-770 nm in 15-45 nm steps
Number of viewing angles [degrees]	10 for 440, 550, 870 nm; 60 for 670 nm [spaced over 114°]	5 [-57°, -20°, 0°, 20°, 57°]
Swath width	±47° [1556 km at nadir]	±4.5° [106 km at nadir]
Global coverage	2 days	30+ days
Ground pixel	3 km	2.5 km
Heritage	AirHARP, Cubesat	AirSPEX

Looking Forward: PACE Science Team pre- & post-launch schedule

Pre-launch Science Teams

- FY15 – 17: ROSES 2013 A.25
  - Pursued consensus and community-endorsed paths forward for IOPs & atmospheric correction
  - Final reports are being submitted and will be compiled into a NASA Technical Memo.
- **FY20 – 22: ROSES 2019 A.38 (3 years)**
  - Allow lead time for pre-launch scientific algorithm & applications development prior to launch
  - Initiates interface between algorithm developers and OBPG/OB.DAAC
- FY23 – 25: ROSES 2022 [TBD] (~3 years)
  - At-launch algorithms and post-launch competed science/applications for OCI's aerosol, cloud, & ocean science, plus aerosol & clouds (& oceans?) from SPEXone & HARP-2

Post-launch competed sciences teams (TBD)

- Most likely competed through ROSES 2025
- To continue during mission extension(s)

Looking forward: vicarious calibration

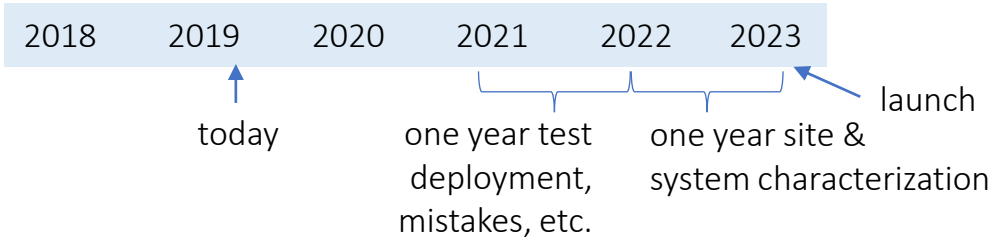
ROSES 2014 A.3 OBB (FY15-17) - written and competed before PACE was a real mission

- Issued under OBB, managed jointly between OBB and ESTO
- Allowed lead time for concepts to mature prior to launch & Identified technical development needs/risks for the approaches selected
- Three projects funded that have completed analysis and tests of hardware

ROSES 2018 A.49 (amendment 22 Feb 2019)

- Select best approach and hardware for further risk reduction on instrumentation for OCI ocean color vicarious calibration
- Two selections with a down-select after 12 months
- 4 year horizon
- NOIs were due 26 March, proposals 23 May
- Completely open competition (US-based PI's); international collaborators welcome

options: systems in development, expected external assets (BOUSSOLE, MOBY), FRM4SOC (Copernicus/EUM), other *in situ* sources, models



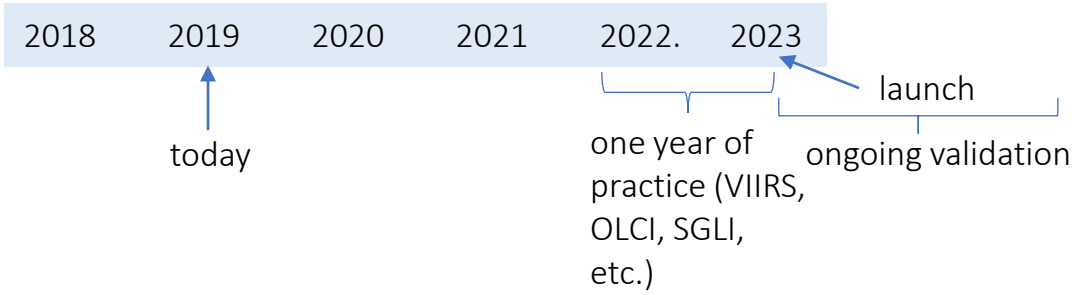
Looking forward: a validation program

FY22 – FY25 (TBD): ROSES 2021 &

FY26 – FY28 (TBD): ROSES 2025

- Perform validation experiments during mission ops for all data products (aerosol, cloud, ocean color), including validation of polarimetry data products as possible
- Include airborne (as possible) and *in situ* measurements

International community (e.g., ESA, EUMETSAT, and the Copernicus Program) are investing in Fiducial Reference Measurements for Sentinel and **coordination is critical**



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

Uncertainty requirements accompany all L1 req'd data products (i.e., we need quantitative validation of all of these products)

PACE will provide insight into systems that affect our everyday lives

With advanced global remote sensing capabilities, PACE will provide a combination of **atmosphere and ocean observations** to benefit society in the areas of water resources, disaster impacts, ecological forecasting, human health, and air qualit

Users at local, state, federal and international agencies as well as the general public will be able to apply data from PACE to make more informed and robust decisions about their activities.

Applications Community Building Activities

Mission Applications Plan

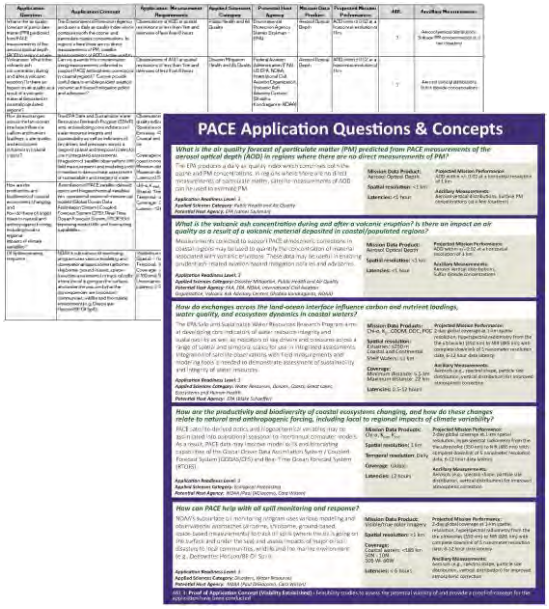
Describes the elements of the applications program for the project, its management, and deliverables from all Phases of the mission

PACE applications by development phase

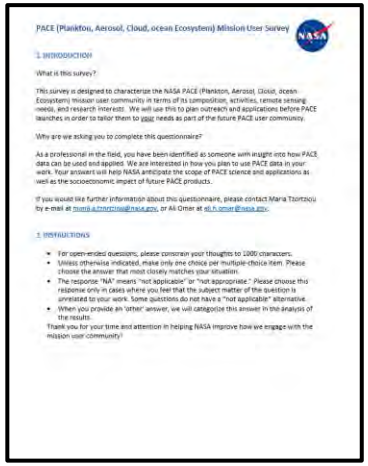
Mission Phase	Applications Activity
Pre-phase A	Assessment of the community of practice. Description of potential applications from the PACE data using the requirements established by the Science Definition Team (SDT).
Phase A	Applications website establishment. Database of user community individuals 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	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. Early Adopters Program established.
Phase C/D	Annual workshop focused on results from Early Adopters. Description of validation datasets to the community of practice. Conference presentations and papers, newsletters and journal articles on user interaction to expand the community of potential. Data workshops, short courses, focus sessions, tutorials. Interaction with NASA HQ Applied Sciences to prepare funding opportunities.
Phase E	Documenting decision support provided by mission data. 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.

Applications Traceability Matrix

developed with input from the user



PACE Community Survey



Applications White Papers

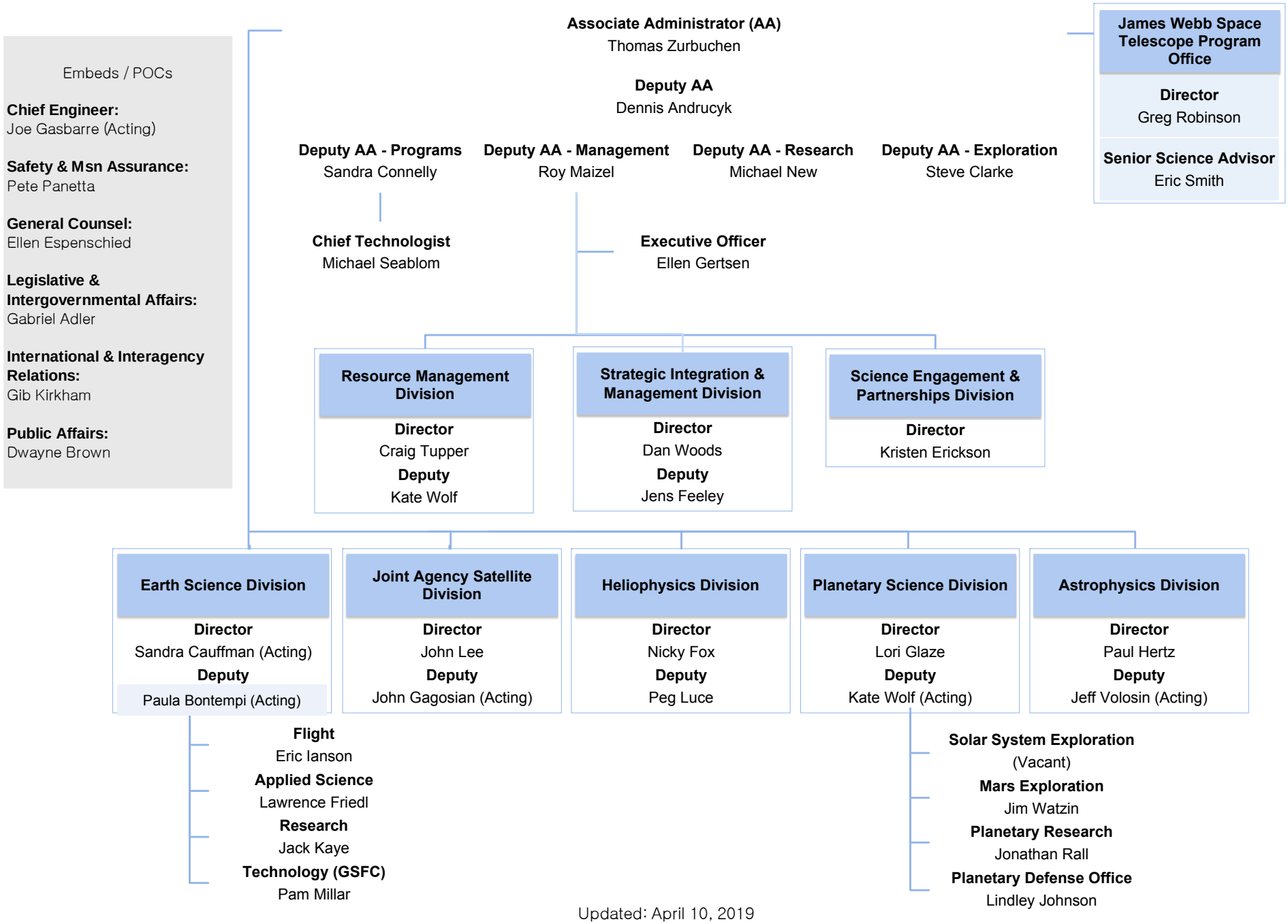
PACE Mission Applications - Contact Us:

Maria Tzortziou
maria.a.tzortziou@nasa.gov
212-650-5769

Ali Omar
ali.h.omar@nasa.gov
757-864-5128

Woody Turner
woody.turner@nasa.gov
202-358-1662

@NASAOcean https://pace.gsfc.nasa.gov/ @NASAOcean


Embeds / POCs
Chief Engineer:
Joe Gasbarre (Acting)
Safety & Msn Assurance:
Pete Panetta
General Counsel:
Ellen Espenschied
Legislative & Intergovernmental Affairs:
Gabriel Adler
International & Interagency Relations:
Gib Kirkham
Public Affairs:
Dwayne Brown
Associate Administrator (AA)
Thomas Zurbuchen
Deputy AA
Dennis Andrucyk
James Webb Space Telescope Program Office
Director
Greg Robinson
Senior Science Advisor
Eric Smith
Deputy AA - Programs
Sandra Connelly
Deputy AA - Management
Roy Maizel
Deputy AA - Research
Michael New
Deputy AA - Exploration
Steve Clarke
Chief Technologist
Michael Seablom
Executive Officer
Ellen Gertsen
Resource Management Division
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Craig Tupper
Deputy
Kate Wolf
Strategic Integration & Management Division
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Dan Woods
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Jens Feeley
Science Engagement & Partnerships Division
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Earth Science Division
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Paula Bontempi (Acting)
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John Lee
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Applied Science
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Research
Jack Kaye
Technology (GSFC)
Pam Millar
Solar System Exploration
(Vacant)
Mars Exploration
Jim Watzin
Planetary Research
Jonathan Rall
Planetary Defense Office
Lindley Johnson
Updated: April 10, 2019

Evolution over the last two decades…

Then:

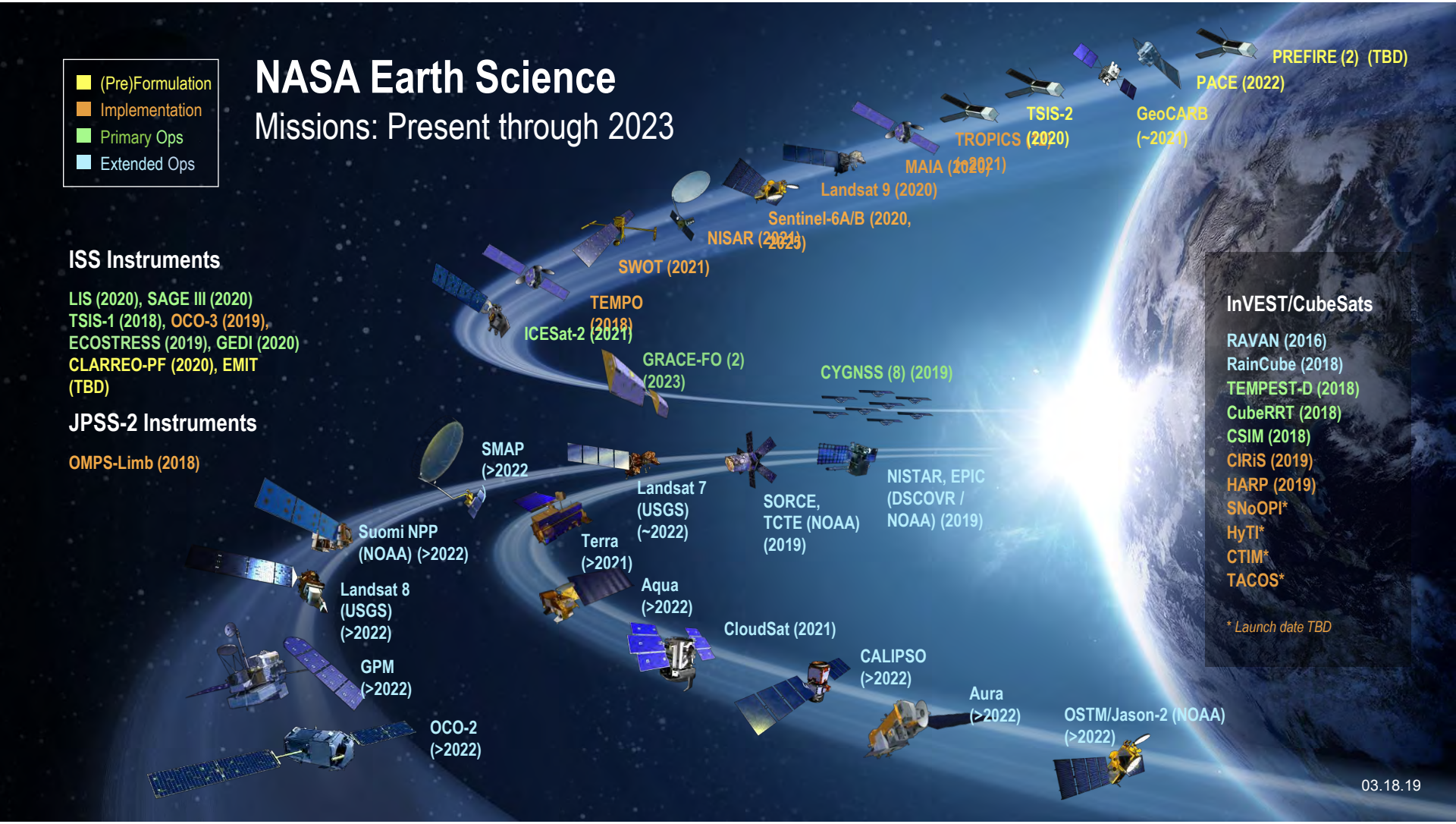
- **IOCCG circa 2003 – ESA, JAXA, ISRO, CNES, SOA, NOAA, NASA**
- **Solar constant, atmospheric correction, assimilation OC data in to numerical models**
- **Algorithm and data product focus, data processing focus, instrument issues**
- **Exploration → Discovery → Research**

Then and Now:

- **Validation**
- **Vicarious Calibration**
- **Remote Sensing of Optically Complex and Shallow waters**
- **Research to operations**
- **Atmospheric Correction**
- **PFTs**

Now:

- **Shift to societal benefits, management, policy, and economics**
- **Investment relative to outcome**
- **What can we do - science questions/frontiers in oceanography and Earth science**
- **Money to support research**
- **Better coordination among agencies, internally and internationally**
- **Balance between biology/ecology/biogeochemistry and physics**
- **Explore what we have**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NOAA) (2019)
Suomi NPP
(NOAA) (>2022)
Terra
(>2021)
Landsat 8
(USGS)
(>2022)
Aqua
(>2022)
CloudSat (2021)
CALIPSO
(>2022)
GPM
(>2022)
Aura
(>2022)
OSTM/Jason-2 (NOAA)
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RAVAN (2016)
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CubeRRT (2018)
CSIM (2018)
CIRiS (2019)
HARP (2019)
SNoOPI*
HyTI*
CTIM*
TACOS*
* Launch date TBD
03.18.19

Issues (still) and ideas

- Validation
  - Challenges (and solutions)?
    - Data collection/data limited, data sharing/submission
    - Robust instruments but in a fixed location, or vice versa (ship or autonomous sampling)
    - Biofouling
    - Long deployments
    - Tilt effects/self-shading/wave focusing
    - Characterize instruments
    - Publish protocols
    - Status of a data product (optically complex waters such as POC, open ocean DOC)
    - A NOMAD-like database for an R_{rs} match-up data set which is regularly updated (sat v. *in situ*; IOPs)
    - Time Series
    - Blue or optically clear waters - still a solved or still a challenge?
    - Can we learn approaches from the terrestrial or atmospheric fields?

Issues (still) and ideas

- Technology development (in situ or remote)
  - New instrument incentive/path to commercialization
  - Role of cubesats
  - Bio-Argo
  - $2K Profiler challenge – a possibility?

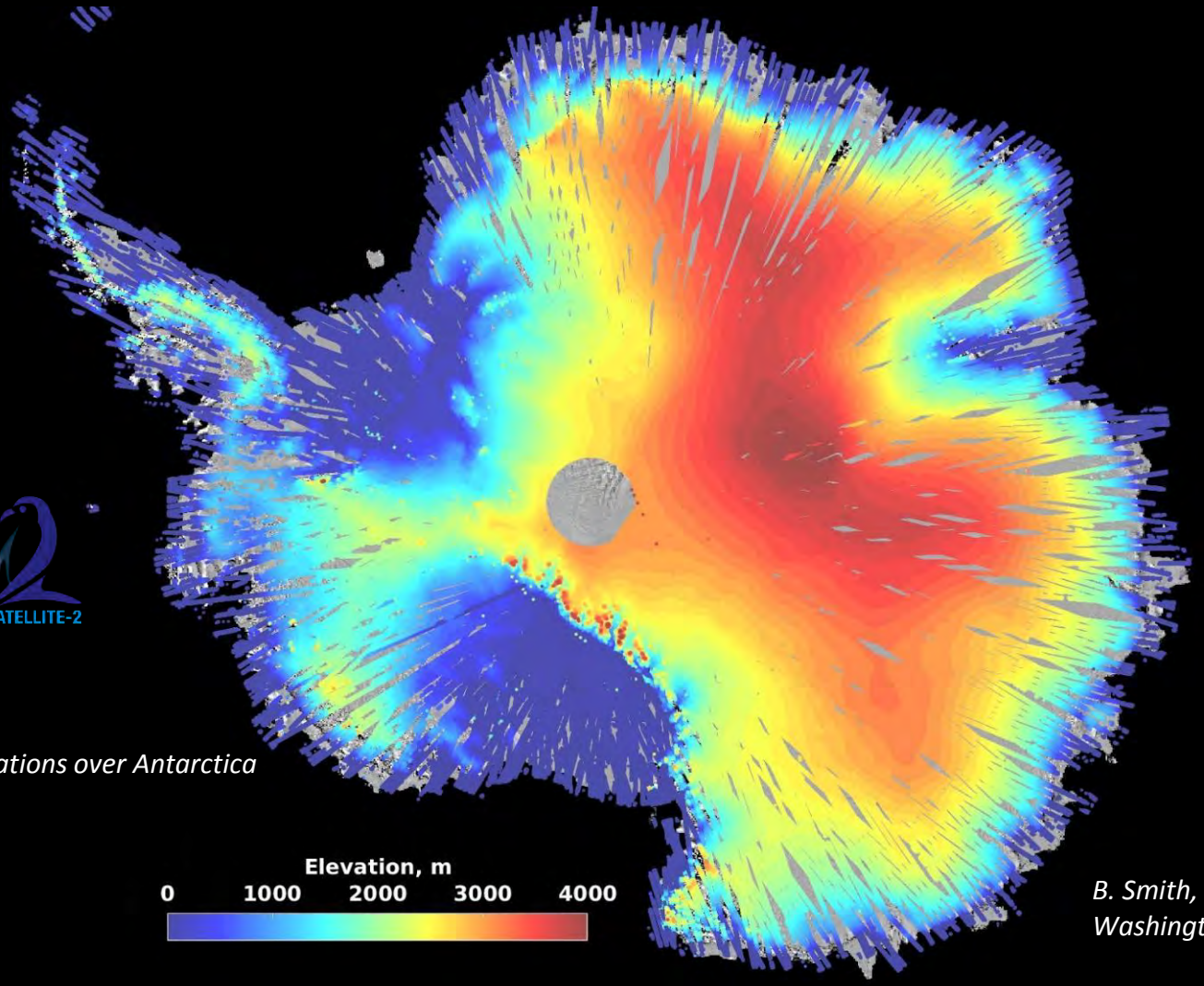
- Numerical Modeling
  - Model applications – promotion of OCR as a necessary input to NWP models (heat exchange etc.) and, as more standard, ecosystem models
    - We are somewhat advancing on the second but not as much on the first. How could we gain more impact?
  - Regional (nested) to global
  - Disconnect between modeler needs and research products - scale? (one degree to 1/12 degree)
  - Uncertainties in data products
  - Data assimilation challenges

Issues (still) and ideas

- Science (Observations, approaches, technology, models, etc.)
  - Address oceanography/Earth system science from space
  - Vertical structure of the ocean – role of new technologies (lidar, tie to Bio-Argo to resolve physical properties (MLD, PAR, Zeu) to get at sources, sinks, stocks and fluxes (Aquatic Carbon from Space)
  - Scales of motion – merge in situ and remote data in a seamless linkage
  - Quantification and sampling for a carbon inventory
    - POC, DOC, C-based productivity, contribution by non-algal particles?
  - Heat content in the global ocean
  - Plastics
  - Sub-mesoscale – not just the temporal resolution, but the spatial
  - Temporal processes and patterns
  - Data fusion - models/sat/in situ to distinguish drivers of geophysical patterns in the ocean - natural vs. anthropogenic
  - High latitude/ice related studies

  - Data rich
  - One portal for all data to meet the range of users' needs

  - Utility of non-traditional OCR approaches, what can radar or lidar do, for example?



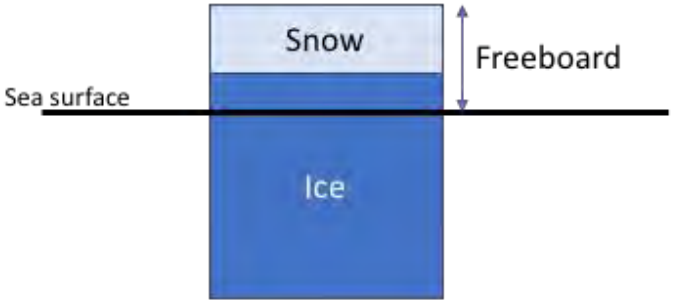
First three weeks of observations over Antarctica

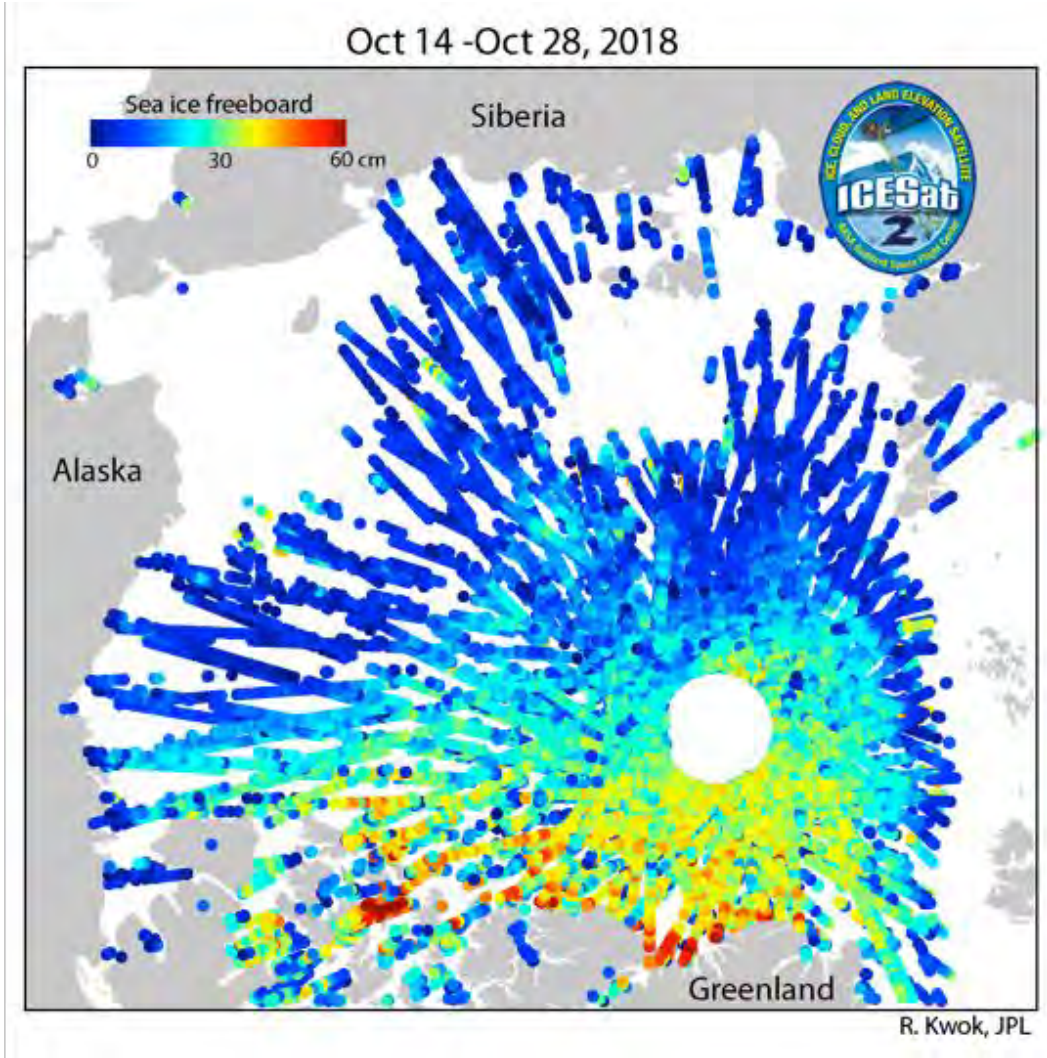
B. Smith, U. Washington

Sea Ice

Arctic Sea Ice Freeboard from 14-days of ICESat-2 data

Thin ice (low freeboard in dark blue) at the beginning of growth season

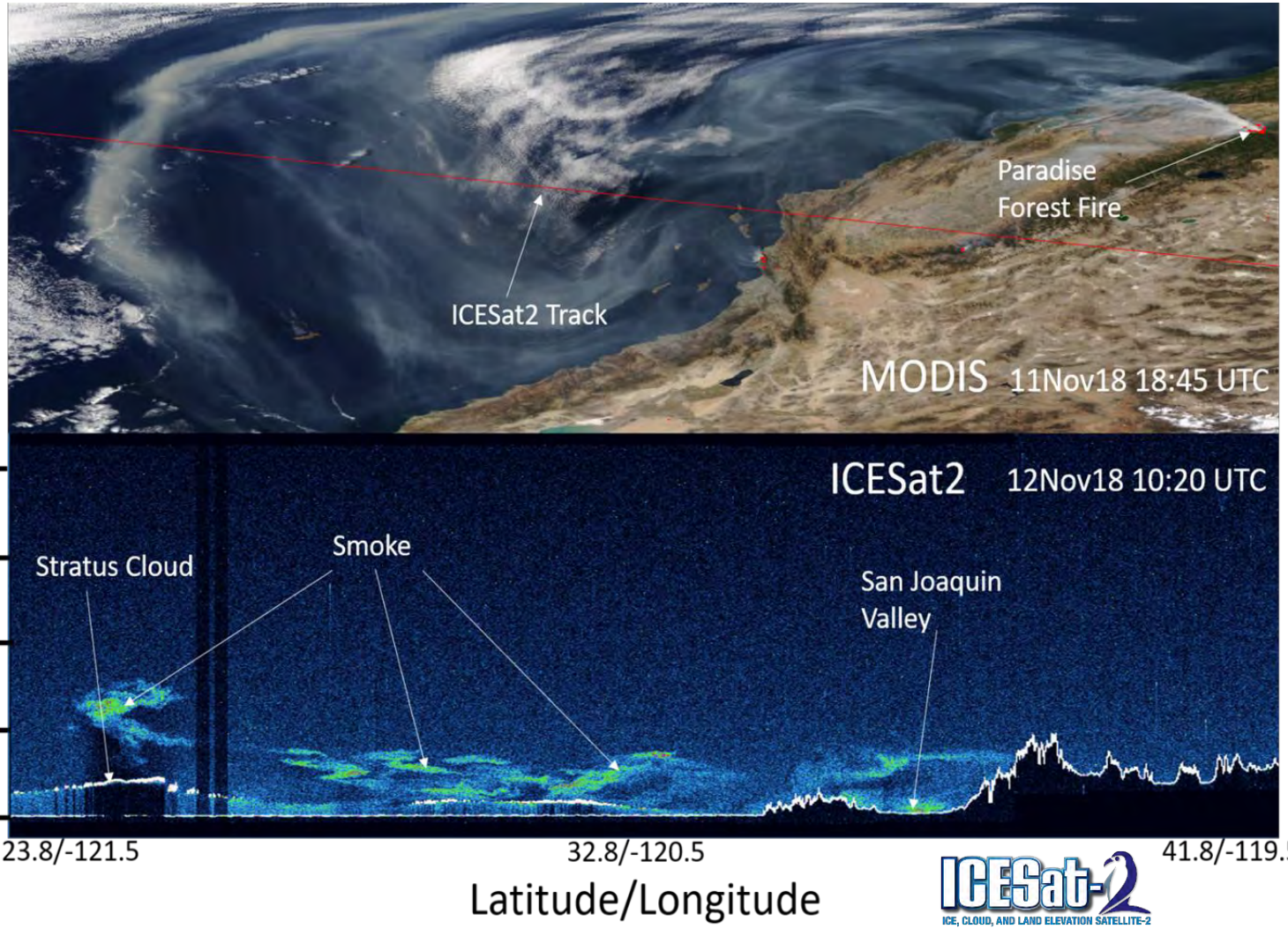




Smoke

California Fires

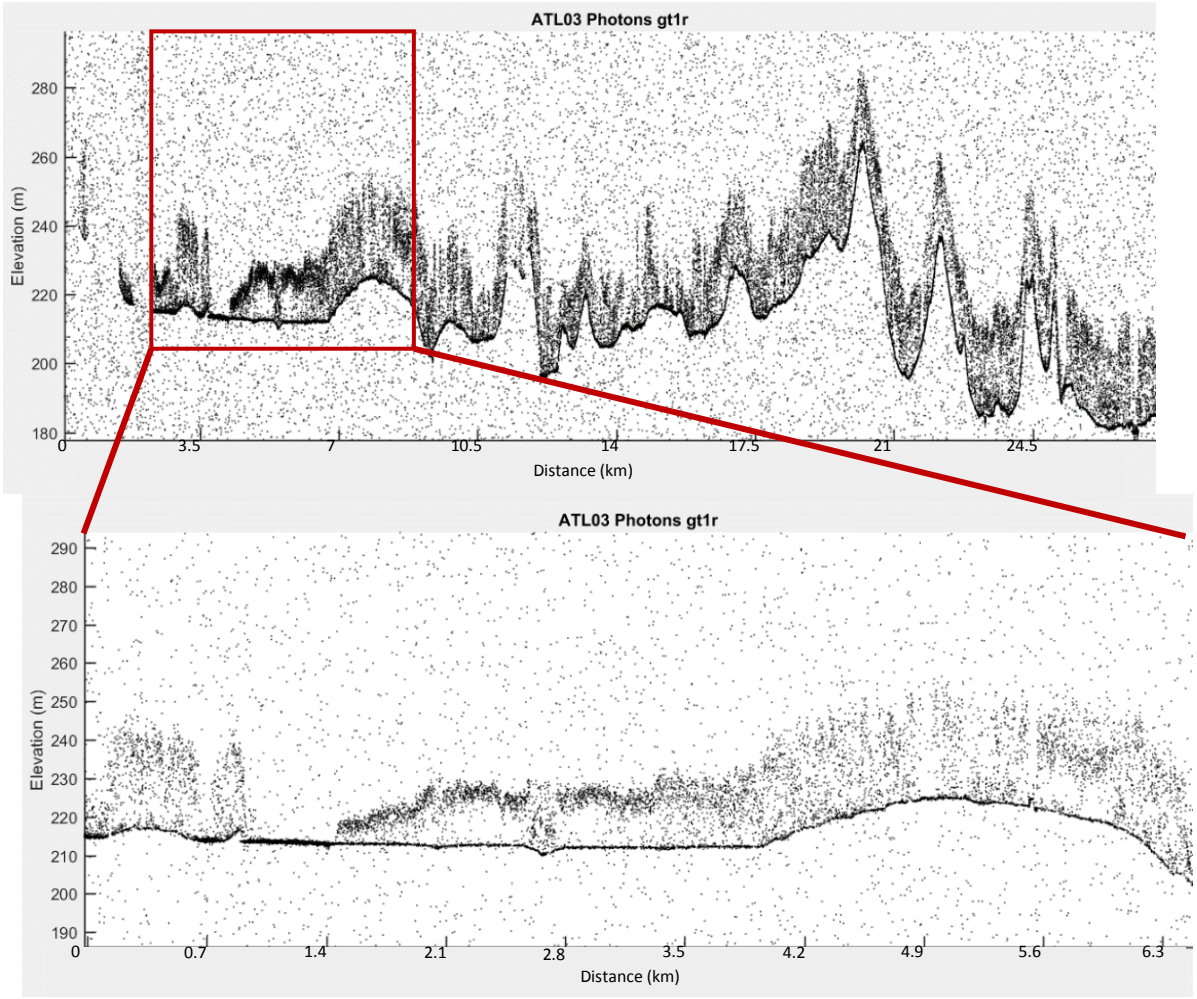
November-2018



Steve Palm SSAI/GSFC
Yuekui Yang GSFC

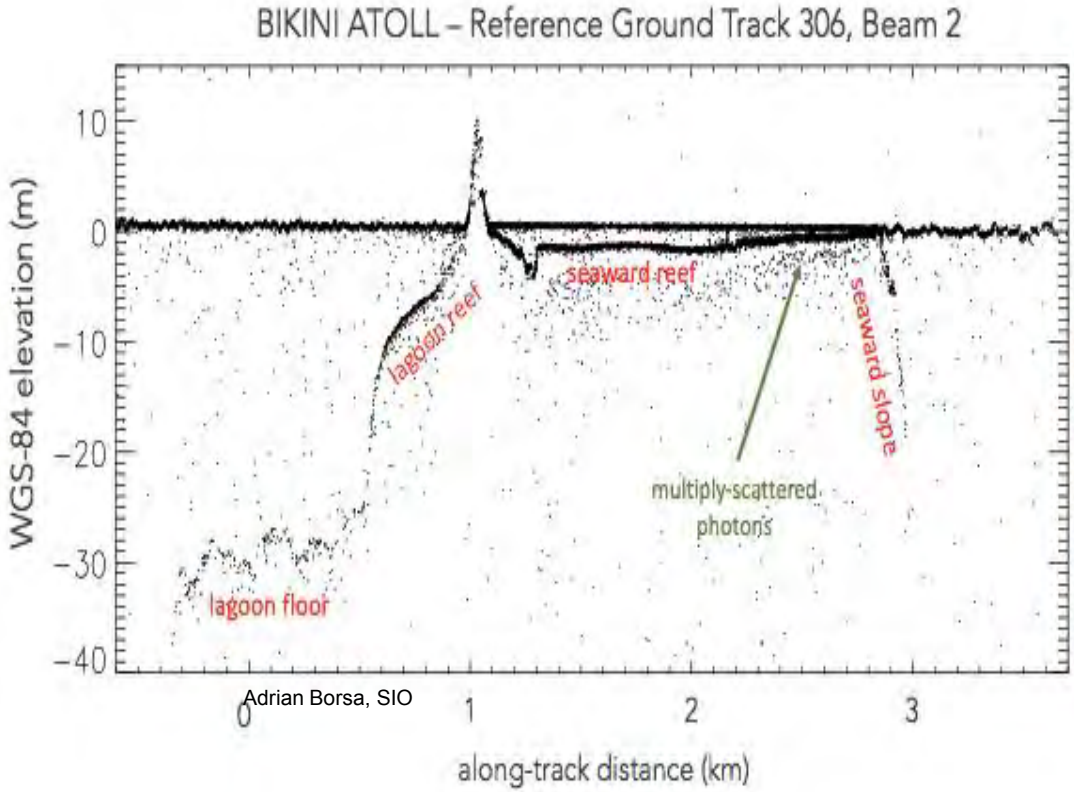
ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

Land and Vegetation: Broadleaf Trees in Russia

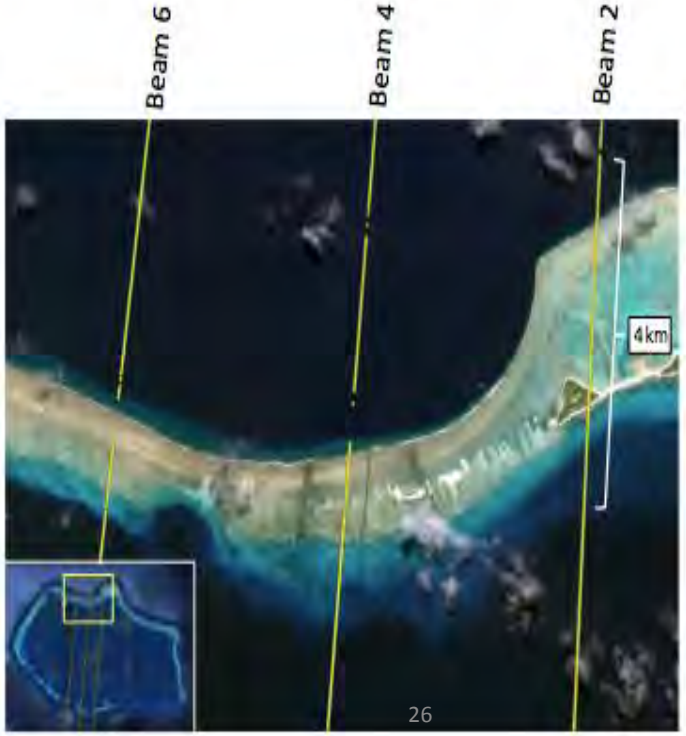


Amy Neuenschwander, U Texas

Bathymetry - Bikini Atoll

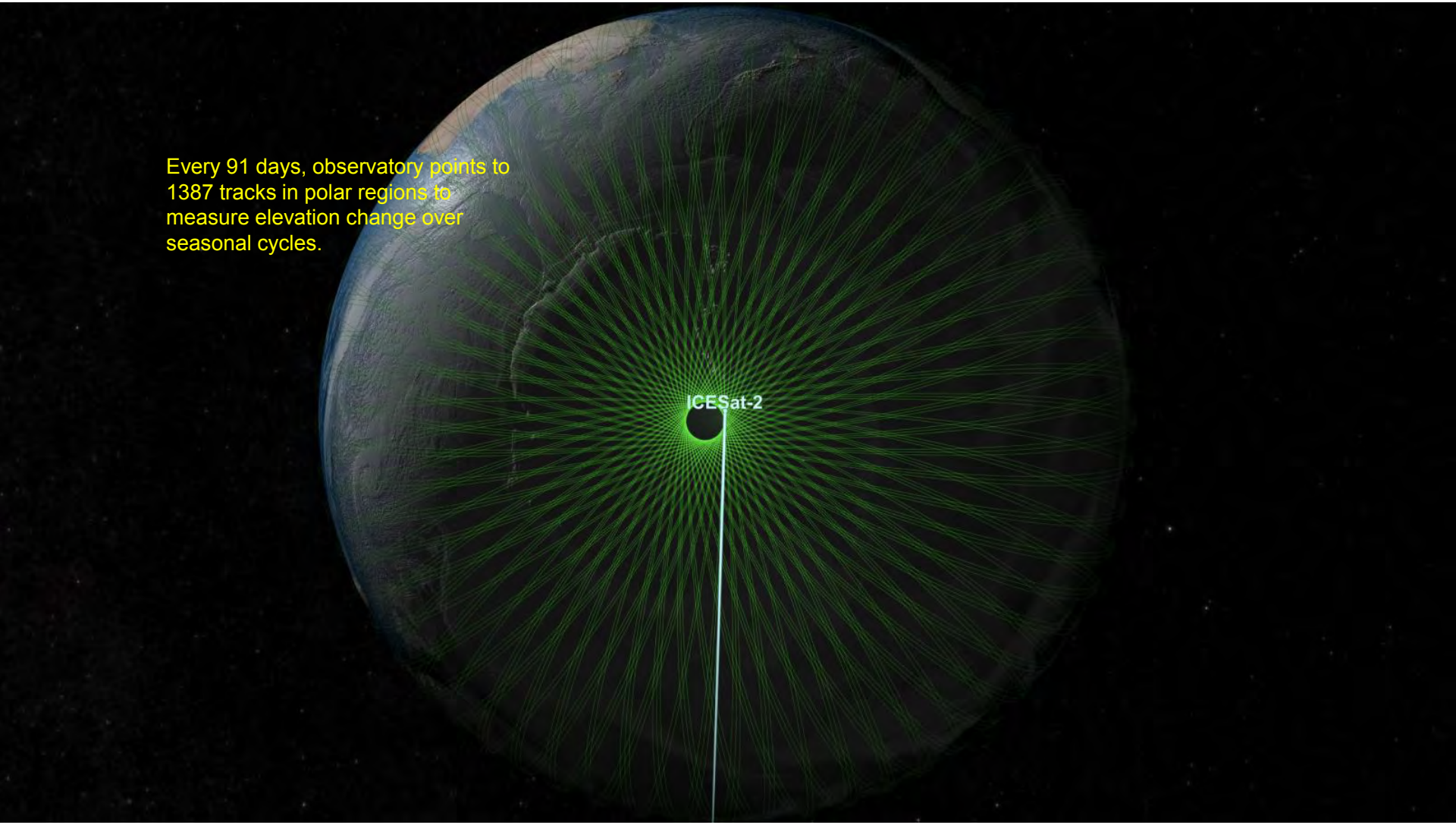


Adrian Borsa, SIO



Adrian Borsa, UCSD-Scripps

ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

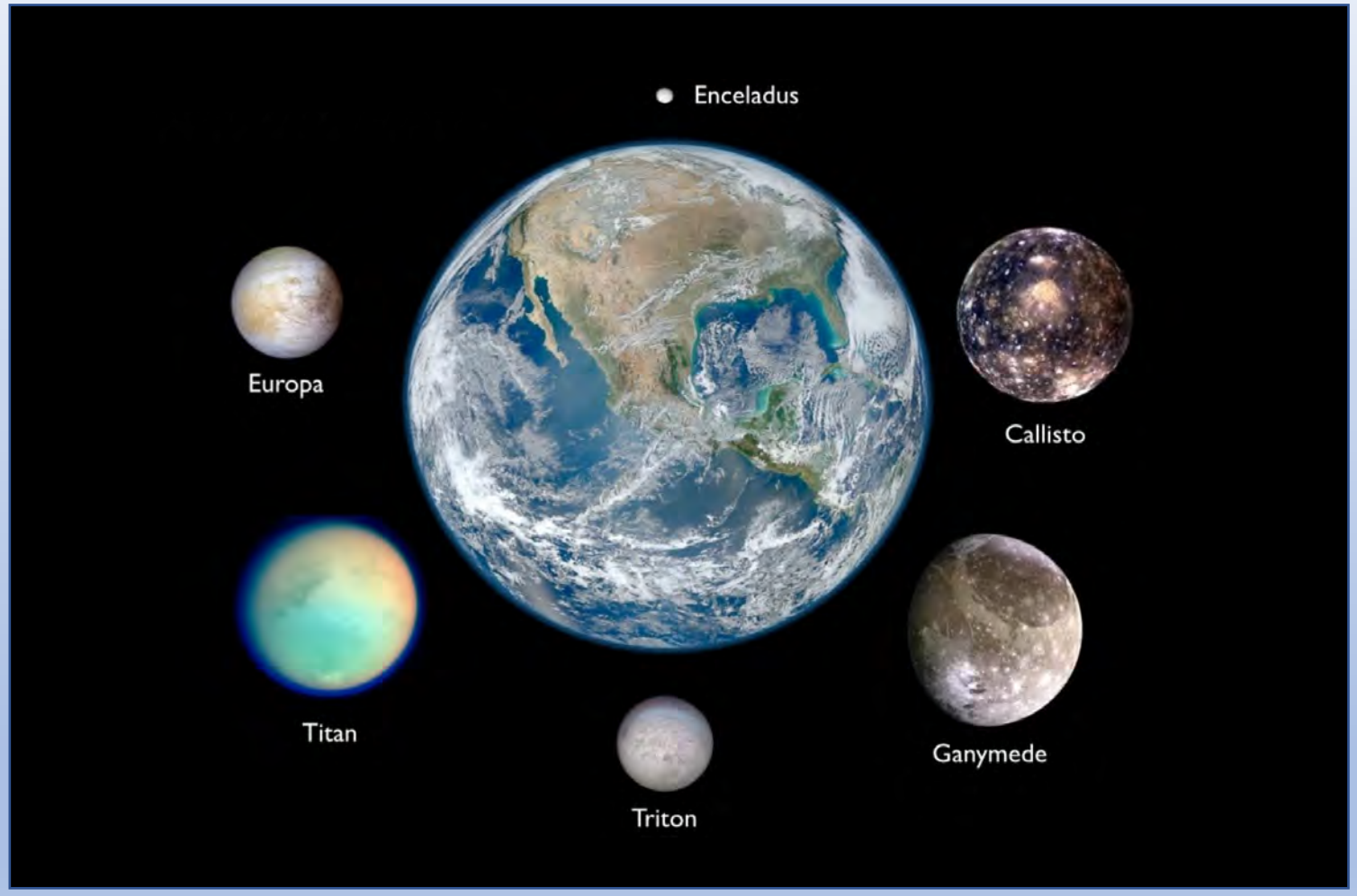

Every 91 days, observatory points to 1387 tracks in polar regions to measure elevation change over seasonal cycles.
ICESat-2

The Future of Ocean Color - Opportunities

- Minimum requirements report from IOCCG
- Gaps in our oceanographic scientific knowledge?
- Beyond passive radiometry
  - Measurements beyond the polar passive multi-band radiometry – CEOS can be the right forum to express and gain support towards requirements associated with inter-agency mission development and coordination.
  - Support and promotion of geostationary OCR capabilities
  - Advantages of other measurements for aquatic biological / biogeochemical / ecological retrievals:
    - Hyperspectral spectroscopy – e.g. NASA PACE, Surface Biology and Geology
    - Lidar – demonstrated with CALIPSO
    - Polarimetry – demonstrated with POLDER
- Discovr, ICESat-2, potential with SAR/Sentinel/commercial combinations
- True global coverage? Fusion of data products possible, harmonization of time series
- Multi-platform and sensor data fusion for Earth Science
- Original IOCCG agenda to focus over time

- Oceans in Other Worlds

Overarching Goal



Advancing comparative studies to characterize Earth and other ocean worlds across their interiors, oceans, and cryospheres, to investigate their habitability, to search for biosignatures, and to understand life - in relevant ocean world analogues and beyond.

Developing science and technology research for exploring ocean worlds

Ocean worlds research is at the forefront of Astrobiology, guiding the search for life beyond Earth, particularly in three key areas:

- Geophysics: The icy satellites of the outer solar system are geophysically distinct from the terrestrial planets. But as we explore their geophysical evolution, and processes occurring at their ice-ocean and ocean-rock interfaces, important insights can be gained from comparative studies of Earth's cryosphere, especially in the Arctic and Antarctica.

- Ocean Systems: Ocean worlds provide a first opportunity for comparative oceanography between Earth and other planets, including ice-ocean interactions. Such studies are not only important in terms of understanding habitability beyond Earth but also to better understand Earth's ability to sustain life through time.

- Life: Ocean worlds provide the nearest planetary opportunities to search for extant Earth-like life. They are predicted to host the essential ingredients for habitability (water, energy and essential elements). Analog and theoretical studies of resource exchange, the generation of life-supporting energy, especially at rock-water and ice-ocean interfaces, and detecting signs of life in Earth's cryosphere and ocean will further understanding of life, both on Earth and on ocean worlds.

The Future of Ocean Color - Opportunities

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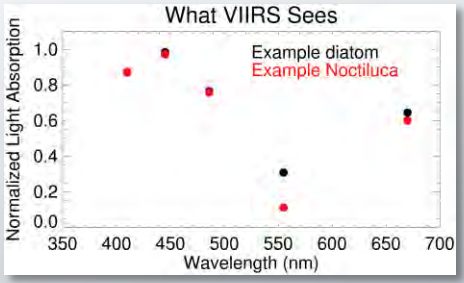
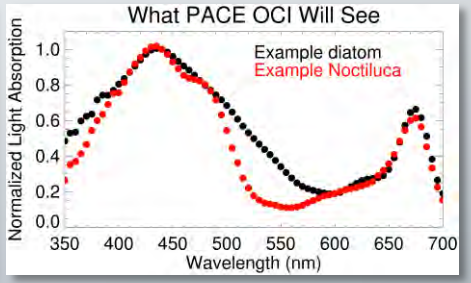
- Oceans in Other Worlds

Back Up





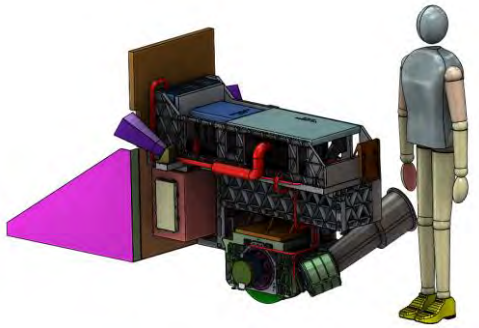
PACE OCI in 2017 Decadal Survey Program of Record

Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) Instruments

(Primary) Ocean Color Instrument (OCI)

Wide swath, UV-VIS imaging spectrometer with SWIR channels designed for ocean color applications, useful for aerosols and clouds

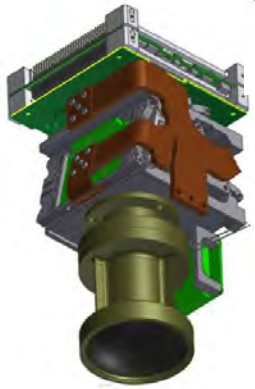
- Preliminary design review (PDR): Mar 2018
- Critical design review (CDR): Dec 2019



Hyper Angular Rainbow Polarimeter 2 (HARP2)

wide-swath multi-angle polarimeter, hyper-angle capability

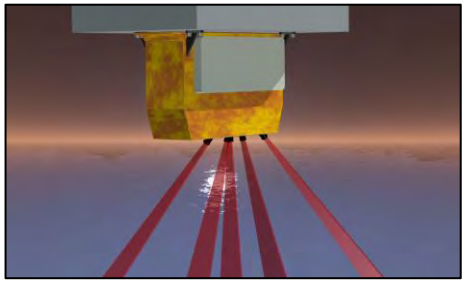
- PDR: Aug 2018
- CDR: Apr 2019



Spectro-Polarimeter for Planetary Exploration (SPEXone)

narrow-swath multi-angle polarimetric spectrometer

- PDR: Jul 2018
- CDR: Feb 2019



Polarimetry on PACE

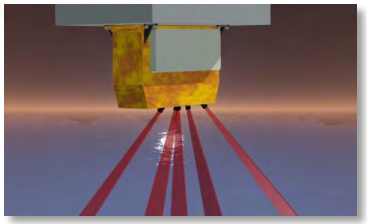
Two cubesat-sized *contributed* instruments

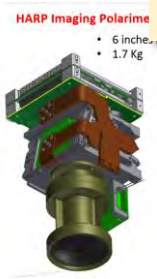
Spectro-Polarimeter for Planetary Exploration (SPEXone)

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

POC: Otto Hasekamp

Hyperspectral (UV) + narrow swath + high accuracy





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 (continuous @ 5 nm)	440, 550, 670 nm (10) + 870 nm (40 nm)
Polarized bands	385-770 nm (continuous @ 15-45 nm)	All
Polarimetric accuracy (DoLP)	0.002	< 0.01
# viewing angles	5 (-57°, -20°, 0°, 20°, 57°)	10 for 440, 550, 870 nm + 60 for 670 nm (114°)
Swath width	9° (106 km at nadir); 30+ day global cov.	94° (1556 km at nadir); 2 day global coverage
Ground sample distance	2.5 km^2	3.0 km^2
Heritage	AirSPEX, SPEX/ASPIM	AirHARP, cubesat HARP for ISS

Aerosols + Clouds, Convection, Precipitation

A-CCP Monthly Highlight:

Science Goals & Traceability To Decadal Survey

- A-CCP Goals are directly traceable to the 2017 DS *Most Important* and *Very Important* Goals
- SATM which has been released for input and consultation with Academia, International Community, and Industry.
- Face to face discussions planned at the Community Workshop on 1-5 April 2019

Overarching A-CCP Goal	A+CCP	A	CCP	2017 DS Most Important Very Important	Goals
Understand the processing of water and aerosol through the atmosphere and develop the societal applications enabled from this understanding.				C-2a, C-2g, W-1a, W-2a	**G1** Cloud Feedbacks Reduce the uncertainty in low- and high-cloud climate feedbacks by advancing our ability to predict the properties of low and high clouds.
				C-2g, C-5c, H-1b, W-1a, W-2a, W-4a	**G2** Storm Dynamics Improve our physical understanding and model representations of cloud, precipitation *and dynamical* processes within storms.
				H-1b, W-1a, W-3a, S-4a	**G3** Falling Snow Quantify the rate of falling snow at middle to high latitudes to advance understanding of its role in cryosphere-climate feedbacks.
				W-1a, W-5a, C-5a	**G4** Aerosol Processes Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.
		D I		C-2h, C-5c	**G5** Aerosol Radiative Forcing Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.

Goal only fully realizable via combined mission

A or CCP makes meaningful contribution to goal

Aerosols + Clouds, Convection, Precipitation

A-CCP: **Study Status and Current Timeline**

2018	Oct	Study Plan / Start
2019	4 Mar	SATM (RevB) released to International Community/Industry & SCC for Input
2019	19 Mar	Request for Information (RFI) Released for Observables
2019	**2- 4 Apr**	**Community Workshop** in Pasadena (2 month delay due to shutdown)
2019	**19 Apr**	**Final SATM & RFI Deadline**
2019	May – Aug	Architecture Construction Workshops I-III & Architecture Refinement
2019	**Mid Aug**	**Qualitative Ranking of Science Value & Programmatics**
2019	Fall	Suborbital Workshop
2019	Fall	3+ Architecture Studies + Value Framework Assessments
2020	Summer	
2021	Sept	Demonstrate **Mission Concept Review (MCR) readiness** and delivery of final report to HQ

SATM = Science / Applications Traceability Matrix

Surface Biology and Geology

Surface Biology and Geology (SBG) Recent Events

- **November-December 2018** – Four Research and Applications (R&A) Working Groups established for *Algorithms, Applications, Cal-Val,* and *Modeling* with these WG co-leads meeting together as the R&A Steering Committee; in parallel with R&A activities, Architecture studies get underway at Centers
- **Ongoing** – Regular calls by SBG Leadership, R&A Steering Committee, and R&A Working Groups
- **January 17, 2019** – SBG Partnerships Study Session at JPL
- **February 8, 2019** – SBG JPL Leadership Stock-taking Meeting with HQ SBG Program Leads, NASA Headquarters
- **February 27-28, 2019** – A-Team Architecture Session at JPL with inputs, including latest Science and Applications Traceability Matrix, from R&A Working Groups
- **March 13-14, 2019** – R&A Co-Leads Meeting in DC
- **March-April 2019** – Development of public website to share SBG information
- **June 12-14, 2019** – **SBG All Hands Meeting**, hosted by GSFC in DC
- **January 2019 to September 2021** – Finalize SATM, Assessment of candidate architectures, Design of SBG observing system concept
- **December 2021** – Final Report, Mission Concept Review

Surface Biology and Geology

SBG Update

- Research and Applications WG activities (Algorithms, Applications, Cal/Val, Modeling) are currently running in parallel with Architecture activities—at this point in the SBG Study (year 1 of 3 years), both activities are *casting as wide a net as possible* in order to consider as many options as possible.
- Plans are to begin narrowing these Research and Applications foci and architectural design options in year 2 through a Value Framework process, likely ending up with 3 mission architecture options for NASA to consider in the third and final year of the SBG study
- All potential domestic and international partnerships are currently on the table

Surface Biology and Geology

Surface Biology and Geology (SBG) Study

K. Turpie
kturpie@umbc.edu

Decadal Survey (DS) – The US National Research Counsel Committee on Earth Science and Applications from Space advised NASA regarding the development of remote sensing assets into the coming decade.

Designated Observables – The **DS** pointed to the development of assets for five broad areas of observation, one of which was referred to as Surface Biology and Geology (**SBG**).

SBG Objectives – Combined visible to shortwave infrared imaging spectroscopy and multispectral or hyperspectral thermal infrared imagery to study terrestrial and aquatic ecosystems and biodiversity, geology, volcanoes, the water cycle, and applied sciences topics relevant to many societal benefit areas. **SBG** will look at global and event-driven processes and change.

SBG Architecture Study – NASA has initiated a 3-year mission architecture study, which has three teams to look at **Candidate Architecture Formulations**, **Research and Applications (R&A)**, and **Cost Analysis**. A **Mission Concept Review (MCR)** is targeted for late 2021.

Approach – The **SBG Study** will look at many observing architectures, utilizing concepts from the **HyspIRI** precursor study and new ideas and advances with instrument technologies. Candidate architectures will include small-sat and medium class concepts, and industry and foreign partnerships.

Working Groups – The **R&A team** has 4 working groups (**Algorithms**, **Calibration and Validation**, **Applications**, and **Modeling**) leveraging community input. The **Aquatic Study Group** (**ASG**, formerly of **HyspIRI**) also continues to provide input.

Workshop – NASA is also holding an invitation-only, **SBG Community Workshop** (11-14 June 2019) to update user communities on the current **SBG** study plan and to get community feedback.

Current Distillation of Desired SBG Capabilities

VSWIR	
Spectral Range	0.4 to 2.5 µm
Spectral Resolution	10 nm
SNR	VNIR: 400 SWIR: 250
GSD	30-45 m
Revisit	16 days
Coverage	Global
Local time for acquisition	From 10:30 am to 1:30 pm

TIR	
Spectral Range	8 to 12 µm; 3-5 µm for Fires
Spectral Bands	Multiple (>2)
SNR	>200
GSD	60-100 m
Revisit	Weekly
Coverage	Global
Local time for acquisition	Can vary

What's Next?

ESD Leadership Team continues to address additional DS topics

Next Center Forum (monthly) – **April 25, 2018**, 1:00pm – 3:00pm EDT, in person and Webex
See https://inside.nasa.gov/2017ESAS

Check the ESD Decadal Survey web page and Inside NASA page to:

- Find meeting schedules and details
- Ask questions and see answers as they become available
- Review information in previous sets of charts
- https://science.nasa.gov/earth-science/decadal-surveys

Community forums are quarterly. Look at DS website for more information.

Field Campaign Planning/Field Project Updates

- **EXport Processes in the Ocean from Remote Sensing (EXPORTS) – Data Mining and OSSEs (2015-2018) Field Campaign (2017-2020)**
  - **http://oceanexports.org**
  - **US NSF is key domestic partner**
  - **Galway Statement and the Atlantic Ocean Research Alliance**
  - **Line P program**
  - **Dave Siegel (UCSB) is the Science Team Leader, Ivona Cetinić (NASA GSFC) is the NASA Project Scientist**
  - **11 NASA teams funded, six NSF teams funded (more may be added)**
  - **International participation welcome**

- **EXPORTS Program Goal: to develop a predictive understanding of the export and fate of global ocean primary production and its implications for the Earth's carbon cycle in present and future climates (link to satellite observations)**

- **NASA Open competition for the program made selections in July 2017, completed field season in the NE Pacific 6 August – 13/14 September (one process and one survey ship)**
  - **Second field season (North Atlantic) is TBD, pending budget, would be spring 2020**
  - **Two ships currently being planned plus discussions with WHOI's Audacious project and BIARRITZ in the UK.**

- **All data will be publicly available in SeaBASS**

Field Campaign Planning/Field Project Updates

- Two field campaign scoping proposals selected in ROSES 2013 A.3 OBB:
  - Arctic COastal Land Ocean InteRactions Scoping Study (Arctic-COLORS) – A. Mannino/NASA Goddard Space Flight Center – draft Science Plan through review and near final – expected spring 2019 to be complete, planning for next phase of possible implementation team competition

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- Competitions in 2017-2018-2019 (https://nspires.nasaprs.com/):
  - The Science of Terra, Aqua, and Suomi National Polar-orbiting Partnership (NPP) Science Team (68/230 proposals selected January 2018)
    - Terra and Aqua Data include: MODIS (T, A), ASTER (T), MOPITT (T), MISR (T), CERES (T, A), AIRS/AMSU-A (A), AMSR-E (A), and EOS Direct Broadcast sites
    - Suomi NPP - ATMS, VIIRS, CrIS, OMPS, CERES
    - Science Data Analysis + Multiplatform and sensor data fusion
    - Algorithms – New Data Products
    - Real- or Near-Real-Time Data Algorithms
    - NASA Suomi NPP Science Team Leader & Terra/Aqua/Suomi NPP Disc. Leads
    - MODIS-VIIRS Science Team Meeting in the US - October 2018

- Competitions in ROSES 2018-2019 (https://nspires.nasaprs.com/):
  - PACE System Vicarious Calibration – ROSES 2018 A.48 amendment (22 Feb 2019) [23 May 2019] - $5-8M/ over four years
    - Ocean color vicarious calibration approach and instrumentation competition – six months development and three years of testing
    - Two selections with a downselect to one after 12 months.
  - PACE Science Team – ROSES 2019 A.38 [17 July 2019] - $3.2M/yr for three years
    - Pre-launch algorithm selection, OCI, polarimeters

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- Competitions in ROSES 2018-2019 (https://nspires.nasaprs.com/):
  - Carbon Monitoring System – ROSES 2018 A.49 - $3.9M/yr [23 May 2019]
  - Continuing Oceans a part of this one but read carefully - Not Carbon Cycle Science Research!
  - Development towards a Carbon Monitoring System (CMS). CMS initiative directed by Congress in 2010, NASA initiated pre-Phase A, pilot studies, a scoping effort for a CMS (http://carbon.nasa.gov/index.html).

  - Studies to produce and evaluate prototype monitoring, reporting and verification system approaches and/or calibration and validation data sets for future NASA missions, including, but not limited to, MRV work in support of REDD, REDD+, or SilvaCarbon projects.

  - Studies that address research needs to advance remote sensing-based approaches to monitoring, reporting, and verification (e.g., quantification of forest degradation; independent assessment of the accuracy of airborne remote sensing observations of biomass and carbon stocks; use of airborne flux observations and satellite remote sensing, as alternative methods for quantifying net carbon emissions/storage).

  - Studies that build upon, extend, and/or improve the existing CMS products for biomass and flux resulting from NASA's first phases of CMS pilot studies; such studies may include, for example, product improvements, refined characterization and quantification of errors and uncertainties, and/or preparation and delivery of a mature product for long- term archive at an established NASA DAAC or equivalent data center.

  - Studies that can evaluate and enhance national reported carbon emissions inventories from bottom-up estimates from various sectors of emissions within the United States, and have the potential to be applied to reported national inventories from other nations.

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- Competitions in ROSES 2019 (https://nspires.nasaprs.com/):
  - Interdisciplinary Science – five topics – ROSES 2019 A.32 – $11.5M/yr for 3 yrs - [15 November 2019]
    - Volcanoes in the Earth System
    - Interactions Between Sea Ice and the Atmosphere
    - Polar Ocean/Biology/Biogeochemical Coupling
    - The Life Cycle of Snow
    - Impacts of urbanization on local and regional hydrometeorology
    - Space Archaeology: Using the Past to Inform the Present and Future
    - Exploring the Microbial Biodiversity of the Atmosphere.

- Competitions anticipated in 2020 (https://nspires.nasaprs.com/):
  - Ocean Biology and Biogeochemistry
    - OBB open
    - EXPORTS synthesis (maybe 2021 to allow for cruise synthesis)
  - Carbon Cycle Science – anticipated 2020 – possible USDA, NASA collaborations
  - Remote Sensing of Water Quality – (Terrestrial Hydrology and OBB programs) – anticipated ROSES 2021

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- ROSES (2020?) - http://nspires.nasaprs.com/
  - New (Early Career) Investigator Program In Earth Science (NIP) – 2015 was A.35 - ~$1.0M/yr for three years [every 1-2 yrs]
    - Outstanding scientific research and career development of scientists and engineers at the early stage of their professional careers (no longer an E/PO requirement)
    - In ROSES 2015, 115 proposals received, 22 selected
    - Anticipated 2020 – three year cycle with six years of eligibility

- ROSES 2016 & 2017 - http://nspires.nasaprs.com/
  - NASA EARTH AND SPACE SCIENCE FELLOWSHIP (NESSF) PROGRAM 2016 ACADEMIC YEAR NOW FINESST (Future Investigators in NASA Earth and Space Science and Technology (FINESST)*– each fellowship ~$30K/yr, raised to $45K/yr in 2017 [try to do annually – selection target for May 2019]
    - accredited U.S. Universities - Masters or Doctoral degrees in Earth and space sciences
    - Financial support from the Science Mission Directorate's divisions: Earth Science, Heliophysics, Planetary Science, Astrophysics.
    - Students admitted to, or already enrolled in, a full-time Masters and/or Ph.D. program at accredited U.S. universities eligible (non-US citizens welcome)
    - Students may enter the fellowship program at any time during their graduate work

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- ROSES 2019 - http://nspires.nasaprs.com/ - Released 22 March 2019
  - Rapid Response and Novel Research in Earth Science – A.29 – (Laura Lorenzoni, POC)

[rolling deadline] - No budget for this –funded out of core

Caveat to Proposers:

- Read solicitation in its entirety. It has a number of specific requirements. Failure to meet them will result in a proposal being returned without review.
  - Rapid Response to Earth System Events
  - Novel Ideas in Earth Remote Sensing
- Understand that NASA reserves the right to return or decline proposals to this solicitation based on internal review with limited feedback to the proposers.
- Prior to proposal submission, contact the most relevant NASA program officer (http://science.nasa.gov/researchers/sara/program-officers-list/#earth) and the current RRNES program officer. Proposers that forego this step run an increased risk of having their proposals declined or returned without review.
- Proposals should normally be for support of one year or less, under the assumption that further work will be proposed to another program.
- This solicitation is not intended to support mitigation of active disasters or immediate hazards. Contact the Disasters Program Manager in NASA's Applied Sciences Division and/or the other most relevant NASA program manager directly to discuss expedited options (http://science.nasa.gov/researchers/sara/program-officers-list/#earth).
- No longer support for "limited duration opportunity for an unanticipated research collaboration"

NASA OB&B Research – Research Opportunities in Space and Earth Sciences

- ROSES 2019 - http://nspires.nasaprs.com/ - Released 22 March 2019
  - Topical Workshops, Symposia, Conferences – E.2 – (Max Bernstein, POC) – [rolling]
  - Topical workshops, symposia, conferences, other scientific/technical meetings that advance goals of Earth Science, Heliophysics, and Planetary Science.
  - Not limited to traditional in-person meetings of scientists, may include bringing together members of the scientific communities relevant to NASA - online discussion forums and web-based collaboration portals, especially in support of a traditional event. Proposals for multiple related events should be well justified.
  - Scientific/technical events of interest to SMD, not education, public outreach, admin.
  - Where other ROSES program elements specifically solicit for events, proposals must be submitted in response to those solicitations.
  - Must demonstrate relevance of event to SMD - how the scientific/technical area(s) will advance high-level SMD goals and objectives, and specific (existing or anticipated) outcomes identified in ROSES program elements, SMD roadmaps, other SMD program documents, the NASA Science Plan, findings in decadal surveys, or the reports of NASA advisory bodies or groups relevant to NASA. Targeted science, data analysis that leads to science, technologies, methods, and capabilities that enable the attainment of relevant goals. Must explicitly state from what source (e.g., ROSES program element, roadmap, or decadal survey) relevance derives.
  - Additional Earth Science Requirements