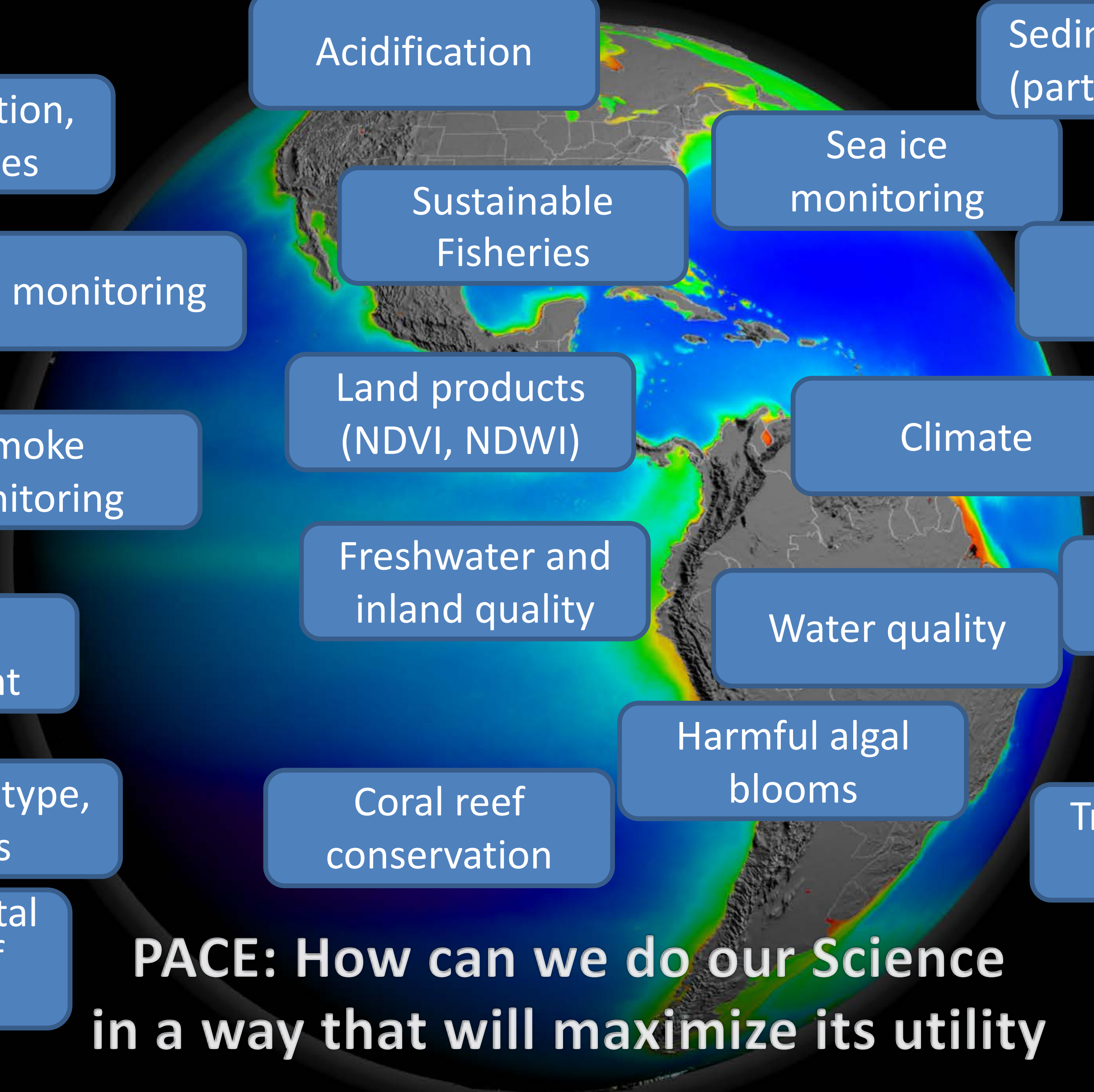


PACE: How can we do our Science in a way that will maximize its utility

- Eutrophication, dead zones
- Acidification
- Sediment products (particle size, type)
- Sustainable Fisheries
- Sea ice monitoring
- Fire monitoring
- Visibility
- Land products (NDVI, NDWI)
- Smoke monitoring
- Climate
- Freshwater and inland quality
- Water quality
- Navigation
- Habitat management
- Harmful algal blooms
- Air quality, type, plumes
- Coral reef conservation
- Trichodesmium blooms
- Intercontinental Transport of Pollution

Maria Tzortziou (CCNY/GSFC, Applied Science lead for PACE-Ocean)

Ali Omar (NASA/LARC, Applied Science lead for PACE-Atmosphere)

Woody Turner (NASA HQs –Applied Science Program Lead for PACE Mission)

The significance of PACE – Ocean Applications

Achieve consensus recommendations within the Science Team on the spectrum of applications we can address with PACE measurements and retrieval approaches (Werdell et al., AGU, 2016)

Ecosystem and Human Health

- Fisheries management
- Detection of harmful algal blooms (HABs)
- Monitoring of sea ice extent and passages
- Mapping of currents /applications to shipping industry, scheduling/fuel economy strategies
- Search And Rescue Satellite Aided Tracking
- Improved models of pathogens, bacteria

Climate System

- Mapping/assessment of C sources/fluxes
- Improvement of climate models skills
- Ecosystem vulnerability assessments
- Support for policy analyses, development of climate change adaptation strategies

Disasters

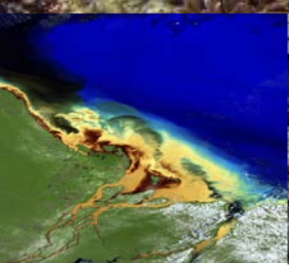
- Impacts of storms and hurricanes
- Major Oil-spills
- Flood disaster response.

Water Resources & Quality

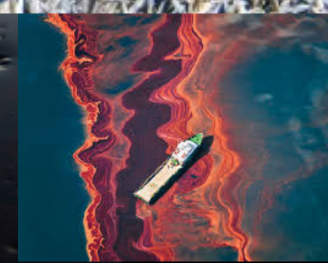
- Observations of eutrophic conditions in coastal offshore waters
- Management of water resources in large lakes, coastal areas, and open oceans

Ecological Forecasting

- Forecasting and early warnings of HABs
- Forecasting of endangered species
- Ecosystem response to future pressures








Applications Envisioned from the PACE Atmosphere Measurements

Achieve consensus recommendations within the Science Team on the spectrum of applications we can address with PACE measurements and retrieval approaches (Werdell et al., AGU, 2016)

PACE Measurement	Instrument	Application for Societal Benefit
AEROSOL PROPERTIES		
Aerosol Optical Depth	OCI/MAP	Air Quality , Visibility, Public Health
Aerosol Size Distribution	OCI/MAP	Air Quality , Public Health
Aerosol type	OCI/MAP	Air Quality , Visibility
Aerosol layer height	OCI (O_2 A Band), MAP	Air Quality, Pollution Transport, Public Health
Aerosol absorption from UV similar to OMI	OCI	Air Quality, Public Health
CLOUD PROPERTIES		
Cloud Optical Depth	OCI	Visibility, Climate
Cloud Effective Particle Size	OCI/MAP	Climate
Effective Variance of Cloud Particle Size Distr.	MAP	Climate
Ice Crystal Shape	MAP	Climate
Cloud Thermodynamic Phase	OCI/MAP	Climate
Cloud Top Height/Pressure	OCI (O_2 A Band)	Climate
Volcanic Ash Images (AOD)	OCI, MAP	Volcanic Ash Advisories/ Disaster Monitoring/Warning
Radiances (Solar)	OCI/MAP	Solar Energy Availabilty/Renewable Energy (Cloud Products)
Stratospheric aerosol concentration	(SWIR, MAP)	Climate
Ash Concentrations from Limb scattering	MAP	Disaster Monitoring/Warning
Assimilation for Weather Forecasting	OCI/MAP	Weather Forecasting (NCEP, NWS, NRL, ECMWF)
Trace gases	Column H_2O	Humidity for aerosol modelling and air quality forecasting, visibility
Imagery	OCI	Disaster Monitoring/Warning
Trace gases – Ozone, NO2 [Column measurements]	OCI	Air Quality, Public Health

Factors that might increase or decrease the applications value of a mission

- Inclusion of a polarimeters (UMBC & SRON) allows for:

    1) **enhanced measurements of atmospheric composition** and pollutants that would increase the value of applications relevant to air-quality & human health

    2) applications to **enhanced ocean color retrievals**

- **Low latency (expected data latency of 6-12 hours)** allows for

    faster satellite data product distribution to end users, near-real time applications, and increased mission applications value.

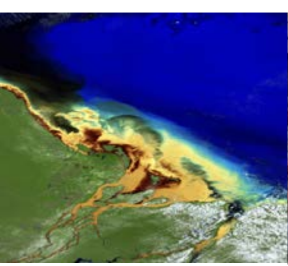
PACE: A Climate Initiative Mission with Enhanced Capabilities

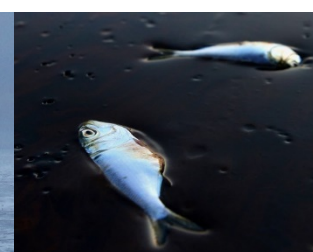
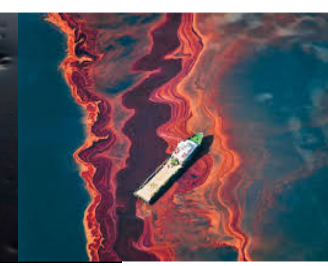
Guidance from Decadal Survey

"Thriving on Our Changing Planet: A Decadal Strategy for Earth" (excerpts):

Observation from Space Ocean color.
For the open ocean, the *Program of Record* includes a number of sensors (MODIS, Landsat, VIIRS, PACE) that will help to meet ocean color objectives. **In the coming decade, the hyperspectral radiometer on PACE is likely to provide more advanced ocean color capabilities for addressing key science priorities addressed in this survey's SATM including marine ecosystem fluxes and structure, function and biodiversity.** The global ocean ecosystem data from PACE complements the near-shore coastal, aquatic inland, and terrestrial ecosystem information that would be derived from the *Surface Biology and Geology Targeted Observable*. *High spatial/temporal resolution coastal and inland aquatic ocean color also has been identified as a variable of interest (see Aquatic Biogeochemistry Targeted Observable, Ecosystem Panel, Appendix C), and the NASA/Moore Foundation Proof of Concept mission (the HawkEye Ocean Color Sensor on a CubeSat) will help to address this.*

High spectral resolution measurements from PACE and from a future high spatial resolution imaging spectrometer for coastal and inland waters will determine signatures of phytoplankton taxonomic diversity and particle size distributions, enabling us for the first time to quantify global ocean ecosystem structure and biodiversity metrics from space. Space-based high-resolution imaging spectroscopy will also enable for the first time global characterization of the nearshore coastal zone and shallow aquatic ecosystems.




PACE: A Climate Initiative Mission with Enhanced Capabilities

Decadal Survey for Earth Science and Applications from Space (ESAS 2017)

"Thriving on Our Changing Planet: A Decadal Strategy for Earth":

Under its 'Designated' measurements, the Aerosol Targeted Observable 1, TO-1, the ESAS 2017 considered a candidate measurement approach that includes a **lidar and a polarimeter**. The polarimeter provides column integrated information on aerosols that could be used to constrain lidar extinction profile estimates as well as cloud size in the upper one to two optical depths of clouds as well as total cloud optical depth. The polarimeter can also provide aerosol particle size, optical depth, and some information on speciation. Depending on implementation specifics, a lidar may also contribute to **aquatic ecosystem structure, ocean mixed layer depth**, ice sheet topography, land topography, and PBL height

PACE Applications website

National Aeronautics and Space Administration

Search

HOME MISSION ▾ SCIENCE ▾ APPLICATIONS ▾ CAMPAIGNS GALLERY ▾

Applications

Societal Benefit & Relevance to Applied Sciences

The PACE mission will provide a combination of high-quality global atmospheric and oceanic observations that provide direct benefits to society in areas such as water resources monitoring, fisheries management, air quality forecasting, and disaster monitoring. For example, in regions of the country where there are no ground measurements, PACE data will fill critical gaps to provide public health notices of poor water and air quality. Understanding and protecting our ecosystems is key to sustaining Earth's economy. Thus, PACE data will benefit the public from data users to policy makers to industry.

The NASA Applied Sciences Program promotes and funds activities to discover and demonstrate innovative uses and practical benefits of NASA Earth science data, scientific knowledge, and technology. Some key outputs for PACE include white papers and Applications Traceability Matrices. We have also initiated an Early Adopters Program. Check out our Applications E-Brochure.

Main objectives for PACE Applications are to:

- Achieve the right balance between maximizing the applications value of the mission and minimizing the risks associated with any increases to mission cost
- Assess and achieve consensus recommendations with the PACE Science Team on the spectrum of applications that can be addressed with PACE measurements and retrieval approaches
- Facilitate collaboration between the science team members and the applications user community
- Identify key stakeholders and engage them in discussions about PACE-derived products, product characteristics, data availability, and formatting within the parameters of mission capabilities
- Assess and interpret the impact of applications on PACE measurement requirements, retrievals, and instrument characteristics (spatial resolution, spectral resolution, latency and accuracy)
- Quantify the uncertainties of the data that will be used for applications bearing in mind that the uncertainty thresholds for scientific investigations may be different from those for societal benefit applications
- Provide simulated data produced for science studies to the early adopter communities to test their applications prior to the launch of PACE
- Develop communication plans and tools for PACE applications, including the PACE Applications Traceability Matrix (ATM), applications workshops, and White-Papers on current PACE Mission Applications areas

PACE's advanced capabilities will benefit society in these areas:

Improved monitoring of water quality (e.g., low oxygen conditions) and water resources. Enhanced management of water resources, fisheries, and ecosystems. Refined detection of Harmful Algal Blooms. Improved knowledge of toxic matter abundances (e.g., pollutants, pathogens, bacteria). Refined monitoring of sea ice extent and ocean currents.

Click here for an overview of PACE Mission Applications - Harmful Algal Blooms.

Support improved models for forecasting and early warning detection of Harmful Algal Blooms, identification of endangered species, and assessment of biodiversity. Refined data assimilation into ocean models to improve model skill and forecasting capabilities.

Click here for an overview of PACE Mission Applications - Fisheries.

PACE will enable refined detection, tracking, and assessment of the effects of hurricanes, oil spills and seeps, volcanic ash plumes, and fires. It will improve evaluation of the impact of these disasters on marine and terrestrial ecosystems and human health.

Click here for an overview of PACE Mission Applications - Hazards & Aviation Safety.

PACE will support improved air quality monitoring, forecasting, and management. It will also allow refined assessment of climate change impacts on air quality and public health.

Click here for an overview of PACE Mission Applications - Air Quality.

Improved mapping, assessment and understanding of climate-relevant biogeochemical concentrations and fluxes. Enhanced climate model skill and forecasting capabilities. Better support for policy analyses and assessments. Refined design of planning adaptation and response approaches to impacts of climate change.

For more information, access these PACE Applications materials: Questions & Concepts | Traceability Matrix

PACE Applications Team

PACE Early Adopters e-brochure

View "PACE Application Questions & Concepts"

Consider joining the PACE Early Adopter Program!

- Engage in pre-launch research that will enable integration of PACE data into your application after launch
- Participate in discussions of PACE data products related to application needs
- Take a lead role in PACE applications research, meetings, workshops, and related activities
- Receive simulated PACE data products & calibration/validation data from PACE field campaigns, modeling, [illegible]rgistic studies

PACE Applications Plan

PACE

Applications Plan

Ver. 1.0

October 2017

Edited by:

Maria Tzortziou [1], Ali Omar [2], Woody Turner [3], Jeremy Werdell [4], Antonio Mannino [4], and Annette de Charon [5]

[1] NASA HQs PACE Deputy Program Applications Lead - Oceans, [2] NASA HQs PACE Deputy Program Applications Lead - Atmosphere, [3] NASA HQs PACE Program Applications Lead, [4] NASA PACE Project Scientist, [5] NASA PACE Deputy Project Scientist - Oceans, [4] PACE Project Communications Team.

NASA Goddard SPACE FLIGHT CENTER

Preface

This document is under Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission configuration control. Changes to this document require prior approval of the PACE Configuration Control Board (CCB) Chairperson or designee. Submit proposed changes to the PACE Configuration Management Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

We will be discussing this in detail at the ST meeting Tuesday, 16 January 4-5 pm

NASA Earth Science Division Directive for Project Applications

Missions in Formulation and Development	Person	Phase	Launch	Community Assessment	Project Studies	Application Plan	Application Traceability Matrix	Project Applications Workshops	Focus Sessions	Tutorials	Event Reports	Community Contact List (working Group)	Early Adopter Program	Use Cases/ Case Studies	Project Application Posters	Si Pr
Systematic Missions																
GEO CARB	John Haynes	Coming!	2022													
CLARREO-PF	Bruce Wielicki	Pre-A	2020													
PACE/ACE	Maria Tzortziou & Ali Omar	A	2022	X		X	X	X				X			X	
LANDSAT 9		A	2020													
GRACE FO	Mike Jasinski	D	2017	X	X	X	X	X	X	X	X	X		X	X	
ICESAT-II	Vanessa Escobar	C	2018	X		X	X	X	X	X	X	X	X		X	
Sentinel-6		B	2020													
NISAR	Sue Owen	B	2020			X										
OMPS-Limb		B	2017													
RBI		C	2019													
SWOT	Margaret Srinivasan	C	2020	X		X	X	X		X	X	X	X	X	X	
HyspIRI	Jeff Luvall	Pre-A	TBD		X	X	X	X				X				
GEO-CAPE	Maria Tzortziou	Pre-A	TBD	X			X	X				X		X	X	
SAGE-III on ISS*	Richard Eckman	D	2016													
Earth System Pathfinder																
CYGNSS	John Murray	D	2016													
GEDI on ISS		C	2019													
OCO-3 on ISS	Karen Yuen	C	2018													
ECOSTRESS on ISS	Christine Lee	C	2017			X				X	X	X		X	X	
TEMPO	John Haynes	C	2017													
TROPICS	Brad Zovodsky	A	TBD													
MAIA	John Haynes	A	2020													
LIST	David Harding															
ASCENDS	Bing Lin	Pre-A	2023			X	X		X	X			X	X		
Missions in Operations																
GPM	Dalia Kirschbaum	Extended Mission	2015													
SMAP	Vanessa Escobar	Phase E	2015	X	X	X	X	X	X	X	X	X	X	X	X	X

Deliverables:

- Community Assessment
- Project Studies
- Application Plan
- Application Traceability Matrix
- Project Applications Workshops
- Focus Sessions
- Tutorials
- Event Reports
- Community Contact List (working Group)
- Early Adopter Program
- Use Cases/ Case Studies
- Project Application Posters/White Papers
- Simulated Products
- Early Adopter Workshop
- Early Adopter Benchmark Meeting
- Data Workshops
- Short Courses
- Post-Launch EA program
- Impact Workshop

PACE Applied Science: Next Steps

Applications activities will be planned and conducted during the different development phases of the PACE mission based on the maturity of mission products with respect to the project objectives for product applications, and in accordance with the ESD Directive on Project Applications Program (Table 1).

Table 1: PACE Applications products 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.

PACE Applications relevant publications

Publications: PACE Applications Science Plan

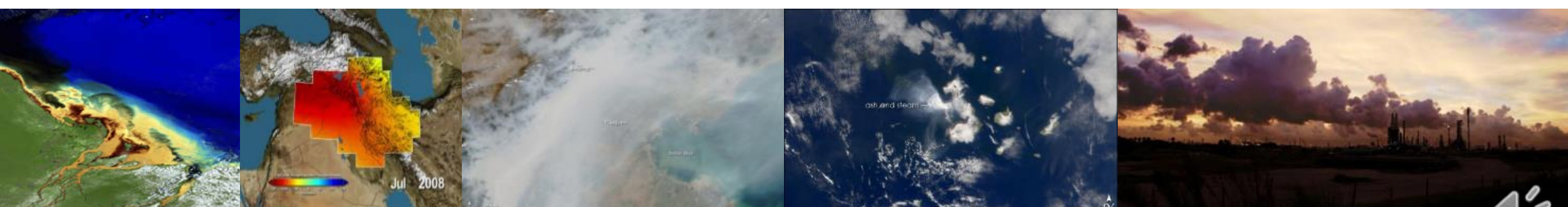
- The PACE Applications Science Plan was developed, following the guidelines outlined in the recently published Earth Science Division Directive for implementing a Project Applications Program within the Earth Science Division (ESD).

Publications: Reports

- *PACE Applications For Societal Benefit: Atmosphere Measurements* in the Report "The Atmospheric Component of NASA's Plankton, Aerosol, Cloud, ocean Ecosystems (PACE) mission", A. Omar

Publications:

- Earth's Living Ocean. The 2017-2027 Advanced Science Plan for NASA's Ocean Biology and Biogeochemistry Research. Working Group (co-authors in alphabetical order): Mike Behrenfeld, Heidi Dierssen, John Dunne, Matthew Long, Antonio Mannino, Paty Matrai, Frank Muller-Karger, Raymond Najjar, Anastasia Romanou, Cecile S. Rousseaux, Maria Tzortziou
- The science and applications value of PACE measurements is explicitly discussed in this new NASA Ocean Biology and Biogeochemical Program Advanced Science Plan for the next decade (2017-2027).



PACE Applications relevant publications

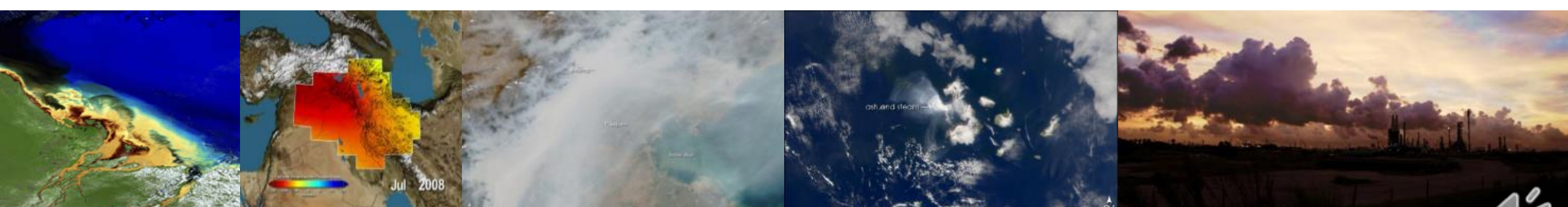
Publications: Manuscripts relevant to the PACE mission

- P. Jeremy Werdell, Lachlan I.W. McKinna, Emmanuel Boss, Steven G. Ackleson, Susanne E. Craig, Watson W. Gregg, Zhongping Lee, Stéphane Maritorena, Collin S. Roesler, Cécile S. Rousseaux, Dariusz Stramski, James M. Sullivan, Michael S. Twardowski, Maria Tzortziou, Xiaodong Zhang. *Progress in Oceanography.*

  Manuscript written by the PACE IOPs Science Team members. It presents a synopsis of the current state of the art in the retrieval of a core suite of properties used in studying ocean biogeochemistry, namely spectral marine inherent optical properties, and discusses a number of applications relevant to the PACE mission.

- Duncan B.N., (in alphabetical order) J. B. Abshire, L. Brucker, J. S. Carton, J. C. Comiso, E. P. Dinnat, B. C. Forbes, W. W. Gregg, D. K. Hall, I. Ialango, R. Jandt, R. A. Kahn, S. R. Kawa, T. Kumpula, T. V. Loboda1, R. Nassar, L. E. Ott, C. L. Parkinson, J. Pulliainen, K. Rautiainen, C. S. Rousseaux, A. J. Soja, J. Tamminen, M. A. Tzortziou, J. S. Wang, D. M. Winker, D. L. Wu (In Review). Space -Based Observations for Understanding Changes in the Arctic-Boreal System: The Foundation for Coordinated Scientific Research and Informed Decision-Making on Human Welfare, Environmental Health, Economic Development, Adaptation, and Geostrategy. Submitted to Review of Geophysics.

- DPA Omar has been invited to submit *PACE Applications For Societal Benefit: Atmosphere Measurements*, for Journal of Applied Remote Sensing (JARS) Special Issue "Advances in Remote Sensing for Air Quality Management"



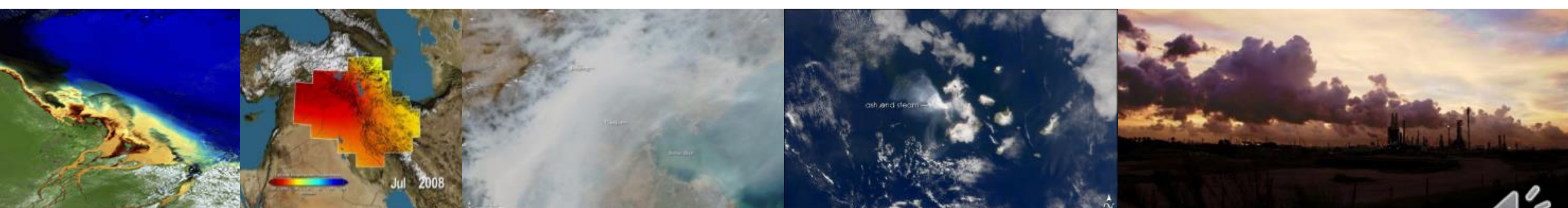
PACE Applications relevant workshops

- Co-organized and participated in end-user-centered water quality workshop: *“Towards a satellite-based near real time monitoring system for water quality”.*

  The workshop was held at NASA Goddard on 27 September 2017. The goal of the workshop was to hold an open discussion about how NASA might be able to work with State, Local, and other organizations to develop a near real time, web-based, water-quality warning system using NASA (and other) remote sensing data. The science and applications value of the PACE mission was highlighted at the workshop.

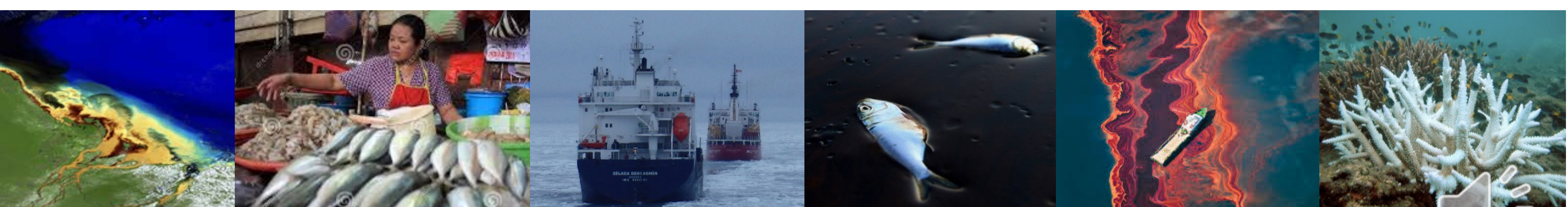
  Meeting Report (In Preparation), to be submitted to *EOS Transactions*

- Participated in the NASA-sponsored *KORUS OC Post Field Campaign Operational Meeting* (Portland Oregon, April 19-21, 2017) to discuss and synthesize preliminary results from the 2016 KORUS OC / KORUS AQ field campaigns. The goal of the oceanographic field campaign was to perform ocean and atmospheric measurements for risk reduction of PACE and GEO-CAPE missions.



PACE Applications Group - Action Items

- **Update/revise the PACE Applications Science Plan as needed**.
- Work towards the development of an **Early Adopters Program** to demonstrate societally relevant applications to proposed data products.
- Improve and update the **“Applications" PACE website** with input from NASA, the users community, and the PACE Science Team.
- Develop new **White-Papers on current PACE Mission Application areas**: Climate System, Oceans/Coasts/Lakes Ecosystem and Human Health, Ecological Forecasting, Water Resources, Disasters, Air Quality and Human Health. We have already developed white papers relevant to “Harmful Algal Blooms”, “Fisheries” and "Inland/Lake Water Quality, Air Quality from Satellite Measurements, and Volcanic Ash Advisories.
- Continue activities to further identify **key stakeholders and user communities** for the PACE missions, and work with potential users to identify, develop and promote activities that will engage them in decisions about data, availability, and formatting within the parameters of mission capabilities.
- Continue developing **communication strategies and organizing outreach activities** that foster interactions between the PACE Science Team, operational users, managers, policy makers and other relevant stakeholders.



PACE Applications Working Group

PACE Science Team Applications Sub-Group:

Steve Ackleson (CASE II waters)

Emmanuel Boss (global datasets)

Heidi Dierssen (cyanobacteria, suspended sediments, floating vegetation, floating plastics etc)

Deric Gray (NRL, military applications, diver visibility, etc)

Olga Kalashnikova (polarization, atmosphere)

Robert Levy (Air Quality, Atmospheric composition)

Dave Miller (NRL, military applications etc)

Ali Omar (Air Quality, Volcanic Ash)

Mike Ondrusek (NOAA, operational, water quality, fisheries)

Steve Platnick (clouds, climate)

Lorraine Remer (aerosols, air-quality)

Mike Twardowski (WETLabs, wide range of users)

Maria Tzortziou (Coastal systems)