

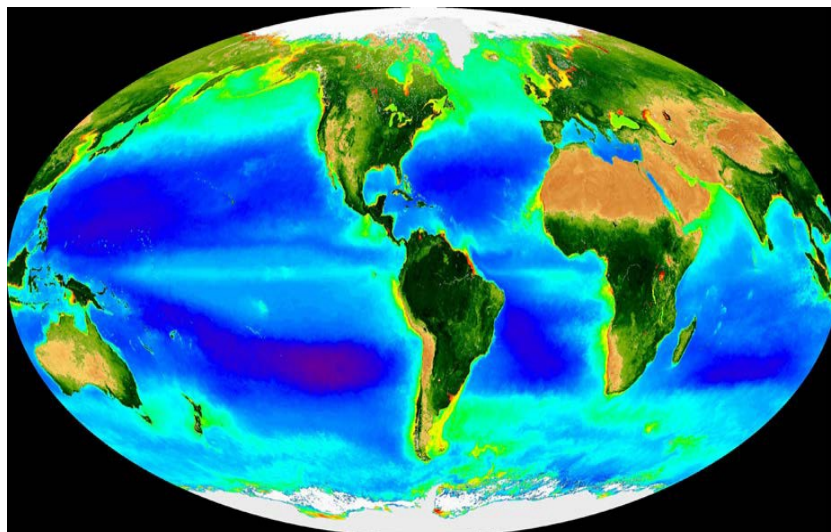
# The Pre-Aerosol Clouds and ocean Ecosystem Mission- PACE:

## Threshold and Goal Requirements for the Ocean Color Instrument

<http://decadal.gsfc.nasa.gov/pace.html>

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**PACE Science Team Workshop (aka: non-meeting meeting)**  
**Greenbelt, MD**  
**January 14, 2015**



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# SDT Operation

- The SDT held three public workshops and ~ weekly teleconferences.
- The SDT was not agnostic about cost – Used NASA engineering team and commissioned IDL and MDL studies to understand science and mission requirements tradeoffs.
- The SDT used findings by other groups (IOCCG, ACE, GEOCAPE, NRC reports, etc...), and the community' s ~37 years of experience operating ocean color sensors.
- The SDT report is based on a whole mission concept.** For an ocean color mission this means:
  - Post launch calibrations including vicarious calibrations.
  - Field campaigns including process studies.
  - Continual algorithm maintenance and re-processings.
- Science Questions->Measurements->Approaches->Instruments Requirements->Mission Requirements
- Science Questions and Instrument and Mission Requirements where prioritized by Thresholds and Goals
  - Threshold = Must have for the success of the mission**
  - Goals = Very nice to have**
  - Achieving goals cannot compromise thresholds.**

## Threshold Requirements

<b>Orbit</b>	<ul style="list-style-type: none"> <li>• sun-synchronous polar orbit</li> <li>• equatorial crossing time between 11:00 and 1:00</li> <li>• orbit maintenance to <math>\pm 10</math> minutes over mission lifetime</li> </ul>
<b>Global Coverage</b>	<ul style="list-style-type: none"> <li>• 2-day global coverage to solar zenith angle of <math>75^\circ</math></li> <li>• sun glint avoidance</li> <li>• multiple daily observations at high latitudes</li> <li>• solar view zenith angles not exceeding <math>\pm 60^\circ</math></li> </ul>
<b>Instrument Performance Tracking</b>	<ul style="list-style-type: none"> <li>• characterization of all detectors and optical components through monthly observations through Earth-viewing port of stable, external illuminated source</li> <li>• characterization of instrument performance changes to <math>\pm 0.2\%</math> within the first 3 years and maintenance of this accuracy thereafter for the duration of the mission</li> <li>• monthly characterization of instrument spectral drift to an accuracy of 0.3 nm</li> <li>• daily measurement of dark current and observations of a calibration target/source, with knowledge of daily calibration source degradation to <math>\sim 0.2\%</math></li> </ul>
<b>Instrument Artifacts</b>	<ul style="list-style-type: none"> <li>• Prelaunch characterization of linearity, RVVA, polarization sensitivity, radiometric and spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric and band-to-band stability, bidirectional reflectance distribution, and relative spectral response</li> <li>• overall instrument artifact contribution to TOA radiance of <math>&lt; 0.5\%</math></li> <li>• no image striping at sensor spectral radiance</li> <li>• crosstalk contribution to radiance uncertainties 0.1% at <math>L_{typ}</math></li> <li>• polarization sensitivity of <math>\leq 1\%</math> and knowledge of polarization sensitivity to <math>\leq 0.2\%</math></li> <li>• no detector saturation for any science measurement bands at <math>L_{max}</math></li> <li>• RVVA of <math>&lt; 5\%</math> for the entire view angle range and by <math>&lt; 0.5\%</math> for view angles that differ by less than <math>1^\circ</math></li> <li>• Stray light contamination <math>&lt; 0.2\%</math> of <math>L_{typ}</math> 3km away from a cloud</li> <li>• out-of-band contamination of <math>&lt; 0.01</math> for all multispectral channels</li> <li>• radiance-to-counts relationship characterized to 0.1% over full dynamic range</li> </ul>
<b>Spatial Resolution</b>	<ul style="list-style-type: none"> <li>• Global spatial coverage of 1 km x 1 km (<math>\pm 0.1</math> km) along-track</li> </ul>
<b>Atmospheric Corrections</b>	<ul style="list-style-type: none"> <li>• retrieval of <math>[\rho_w(\lambda)]_N</math> for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 5% or 0.001 over the wavelength range 400 – 700 nm</li> <li>• two NIR atmospheric correction bands comparable to heritage</li> <li>• NUV band centered near 350</li> </ul>
<b>Science Spectral Bands</b>	<ul style="list-style-type: none"> <li>• 5 nm spectral resolution from 355 to 800 nm</li> <li>• complete ground station downlink and archival of 5 nm data.</li> </ul>
<b>Signal-to-noise</b>	<ul style="list-style-type: none"> <li>• spectral instrument SNR at <math>L_{typ}</math> as defined in Table 1 and Appendix I for all science measurement bands</li> </ul>
<b>Data Processing, Reprocessing, Distribution</b>	<ul style="list-style-type: none"> <li>• full reprocessing capability of all PACE data at a minimum frequency of 1 – 2 times annually.</li> </ul>

In some cases, the SDT is very prescriptive in technical requirements and instrumental approaches. This is based on the experience that the OC community has accumulated from CZCS through present.

However, the SDT is mindful of not overprescribing in areas where technical innovation may offer novel approaches.

# Ocean Science Measurement Goals (not ranked)

- Accuracy: Retrieval of normalized  $[r_w(l)]N$  for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 10% or 0.002 over the wavelength range of 350 – 395 nm
- Aerosol heights: Identified approach or measurement capacity for evaluating/measuring aerosol vertical distributions and type for improved atmospheric corrections.
- Atmospheric correction: SWIR atmospheric correction band at 2130 nm with a SNR of 100.
- Coverage: 1-day global coverage
- Coverage: Coverage to a solar zenith angle  $>75^\circ$
- Crossing time: Noon equatorial crossing time ( $\pm 10$  min)
- Instrument artifact: Overall instrument artifact contribution to TOA radiance retrievals of  $<0.2\%$ .
- Navigation and Registration: pointing knowledge of 0.05 IFOV; band-to-band registration of 90% of one IFOV; simultaneity of 0.01 second
- Nitrogen dioxide: Identified approach for characterizing NO<sub>2</sub> and ozone concentrations at sufficient accuracy for improving atmospheric corrections
- Mission lifetime: 10 years
- Performance changes: Characterization of instrument performance changes to  $\pm 0.1\%$  within 3 years and maintenance of this accuracy thereafter
- Saturation: No detector saturation for any science measurement bands up to  $1.2 \times L_{\max}$
- Signal-to-noise: SNR for bio-optical science bands and/or atmospheric correction bands greater than those shown Appendix II
- Spatial resolution: Spatial resolution of 1 km<sup>2</sup> ( $\pm 10\%$ ) at all scan angles
- **Spatial resolution: Along-track spatial resolution of 250 m x 250 m to  $<1$  km<sup>2</sup> for inland, estuarine, coastal, and shelf area retrievals for all bands or a subset of bands – OCI-C**
- Spectral coverage: 5 nm spectral coverage from 800 to 900 nm
- Spectral sub-sampling: Spectral sub-sampling at  $\sim 1$ -2 nm resolution from 655 to 710 nm for refined characterization of the chlorophyll fluorescence spectrum
- Water vapor: Spectral measurement band centered at 820 nm or 940 nm to determine water vapor content

# Summary of the PACE SDT Recommendations

1-To address **threshold** PACE science questions dealing with global Ocean Biogeochemistry and Ecology the PACE mission must include:

- A well-characterized ocean color instrument covering the spectral range between 350 and 900 nm at ~5 nm resolution, plus three SWIR bands at a spatial resolution of 1 km<sup>2</sup> (nadir). This instrument option is called **OCI**.

- A mission architecture that includes continual post launch calibration (including lunar and vicarious calibration), algorithms development and maintenance, field validation and process studies.

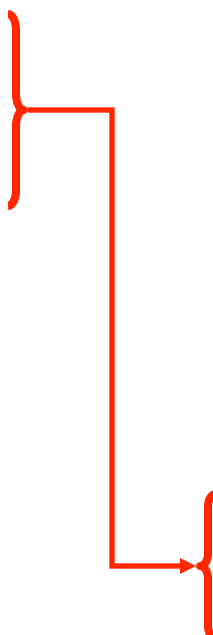
$\lambda$	Band Width (nm)	Spatial Resolution (km <sup>2</sup> )	L <sub>typ</sub>	L <sub>max</sub>	SNR-Spec
350	15	1	7.46	35.6	300
360	15	1	7.22	37.6	1000
385	15	1	6.11	38.1	1000
412	15	1	7.86	60.2	1000
425	15	1	6.95	58.5	1000
443	15	1	7.02	66.4	1000
460	15	1	6.83	72.4	1000
475	15	1	6.19	72.2	1000
490	15	1	5.31	68.6	1000
510	15	1	4.58	66.3	1000
532	15	1	3.92	65.1	1000
555	15	1	3.39	64.3	1000
583	15	1	2.81	62.4	1000
617	15	1	2.19	58.2	1000
640	10	1	1.9	56.4	1000
655	15	1	1.67	53.5	1000
665	10	1	1.6	53.6	1000
678	10	4	1.45	51.9	2000
710	15	1	1.19	48.9	1000
748	10	1	0.93	44.7	600
820	15	1	0.59	39.3	600
865	40	1	0.45	33.3	600
1240	20	1	0.088	15.8	250
1640	40	1	0.029	8.2	180
2130	50	1	0.008	2.2	50

# ...Summary of the PACE SDT Recommendations

2- To continue legacy imager-based aerosol and cloud data records initiated during the EOS era with MODIS, the **OCI** must be augmented to include:

- Three additional SWIR bands at 1 km<sup>2</sup> spatial resolution. This instrument options is called **OCI+**

$\lambda$	Band Width (nm)	Spatial Resolution (km <sup>2</sup> )	$L_{typ}$ (w/m <sup>2</sup> -sr- $\mu$ m)	$L_{max}$ (w/m <sup>2</sup> -sr- $\mu$ m)	SNR-Spec
350	15	1	7.46	35.6	300
360	15	1	7.22	37.6	1000
385	15	1	6.11	38.1	1000
412	15	1	7.86	60.2	1000
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820	15	1	0.59	39.3	600
865	40	1	0.45	33.3	600
1240	20	1	0.088	15.8	250
1640	40	1	0.029	8.2	180
2130	50	1	0.008	2.2	50
<b>940</b>	<b>25</b>	<b>1</b>	<b>7.8</b>	<b>210</b>	<b>150</b>
<b>1378</b>	<b>10</b>	<b>1</b>	<b>3.5</b>	<b>95</b>	<b>100</b>
<b>2250</b>	<b>50</b>	<b>1</b>	<b>0.7</b>	<b>24</b>	<b>150</b>



# ...Summary of the PACE SDT Recommendations

3-To address goal science questions and applications regarding global coastal and estuarine environments as well as inland water bodies, the PaCE mission, in addition to threshold requirements, should have:

- A goal of hyperspectral (5 nm) observations at a spatial resolution better than 500 x 500 m. This instrument option is called **OCI coastal (OCI-C)**

$\lambda$	Band Width (nm)	Spatial Resolution (m)	SNR-Spec
350	?	< 500x500	?
355	?	< 500x500	?
360	?	< 500x500	?
365	?	< 500x500	?
390	?	< 500x500	?
395	?	< 500x500	?
400	?	< 500x500	?
.	?	< 500x500	?
.	?	< 500x500	?
.	?	< 500x500	?
900	?	< 500x500	?
1240	20	1	250
1640	40	1	180
2130	50	1	50

$\lambda$	Band Width (nm)	Spatial Resolution (km <sup>2</sup> )	$L_{typ}$ (w/m <sup>2</sup> -sr- $\mu$ m)	$L_{max}$ (w/m <sup>2</sup> -sr- $\mu$ m)	SNR-Spec
350	15	1	7.46	35.6	300
360	15	1	7.22	37.6	1000
385	15	1	6.11	38.1	1000
412	15	1	7.86	60.2	1000
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820	15	1	0.59	39.3	600
865	40	1	0.45	33.3	600
1240	20	1	0.088	15.8	250
1640	40	1	0.029	8.2	180
2130	50	1	0.008	2.2	50

*Achieving OCI-C cannot compromise OCI performance thresholds.*



# ...Summary of the PACE SDT Recommendations

4- To address **goal** science questions regarding the effect of aerosols on ocean productivity, the PACE mission should have:

A multi-angle polarimeter (3M) in addition to ocean threshold requirements. This option is called **OCI-3M**.

5- To address **goal** science questions regarding how aerosols affect cloud properties, the PACE mission should include the **OCI+** option and:

A multi-angle polarimeter (3M) and select atmospheric bands at 250m spatial resolution. I call this option **"The whole enchilada"**.

$\lambda$	Band Width (nm)	Spatial Resolution (km <sup>2</sup> )	L <sub>typ</sub> (w/m <sup>2</sup> -sr- $\mu$ m)	L <sub>max</sub> (w/m <sup>2</sup> -sr- $\mu$ m)	SNR-Spec
350	15	1	7.46	35.6	300
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640	10	1	1.9	56.4	1000
655	15	1	1.67	53.5	1000
665	10	1	1.6	53.6	1000
<b><u>665</u></b>	<b><u>2.5</u></b>	<b><u>250x250m</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>
678	10	4	1.45	51.9	2000
710	15	1	1.19	48.9	1000
748	10	1	0.93	44.7	600
<b><u>763</u></b>	<b><u>2.5</u></b>	<b><u>250x250m</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>
820	15	1	0.59	39.3	600
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<b><u>865</u></b>	<b><u>2.5</u></b>	<b><u>250x250m</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>
<b><u>940</u></b>	<b><u>25</u></b>	<b><u>1</u></b>	<b><u>7.8</u></b>	<b><u>210</u></b>	<b><u>150</u></b>
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<b><u>1640</u></b>	<b><u>2.5</u></b>	<b><u>250x250m</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>	<b><u>MODIS</u></b>
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<b><u>2250</u></b>	<b><u>50</u></b>	<b><u>1</u></b>	<b><u>0.7</u></b>	<b><u>24</u></b>	<b><u>150</u></b>

## ...Summary of the PACE SDT Recommendations

Science Questions	Mission Options	Brief Description
Threshold Ocean Science Questions	OCI	Hyperspectral imager ~5nm resolution from 350-900 nm + 3 SWIR bands. 1 km <sup>2</sup> spatial resolution.
Legacy Atmospheric Science Questions	OCI+	OCI instrument plus 3 additional SWIR bands at 1 km <sup>2</sup> spatial resolution.
Goal Science Questions-Coastal Oceans	OCI-C	OCI with spatial resolution better than 500x500 m.
Goal Science Questions Aerosols	OCI-3M	OCI and a 3M
Goal Science Questions Aerosols and Clouds	OCI-TWE	OCI+ sensor, selected atmospheric bands at 250 m x 250 m spatial resolution, and a 3M.