Pre-flight testing of an Ocean Radiometer for Carbon Assessment (ORCA) prototype with a realistic scene from a Hyperspectral Image Projector (HIP)

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HIP Projection of MODIS Satellite Image Into ORCA Prototype in the Lab

- ORCA (Ocean Radiometer for Carbon Assessment) is a proposed ocean color sensor for the NASA PACE (Pre- Aerosol Cloud Ecosystems) mission.
- Clouds provide stray light that interferes with the ability to measure ocean color and bio-chemistry to quantify carbon processes.
- HIP difference images potentially allow measurement of stray light effects with realistic scenes before ORCA flies.

Typical Cloud Pixel

Typical Ocean Pixel

Original Image

HIP Image Measured by ORCA

Difference Image (at 645 nm)
Hyperspectral Image Projector (HIP)

- SWIR Spectral Engine
- VNIR Spectral Engine
- Super-continuum Source
- Spatial Engine
- 500 mm Collimator For Projection to ORCA
ORCA at the HIP lab at NIST

NIST Reference Instruments:
• Enable measurements of HIP output radiance (ground truth)
• Includes an ASD spectrometer and a CCD camera with tunable filters

Liquid Light Guide:
• Couples HIP Spectral Engine to HIP Spatial Engine

Translation stage moves HIP between Reference Instruments and ORCA
HIP simulating Solar-Illuminated Earth Spectra

- Red data points show HIP output matched to some typical Earth-reflected target spectra
- Target spectra: Top-of-Atmosphere (TOA) Solar: Blue; Soil: Black; Vegetation: Green
- Shows that the HIP has enough light to simulate a bright sunny day outside
- Spectral resolution of the HIP is 2 nm
Monochromatic Band Projection

• Using the HIP, we projected six MODIS monochromatic band images into ORCA at the following band center wavelengths:

<table>
<thead>
<tr>
<th>“Eigenspectrum #”</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>645</td>
</tr>
<tr>
<td>2</td>
<td>667</td>
</tr>
<tr>
<td>3</td>
<td>678</td>
</tr>
<tr>
<td>4</td>
<td>748</td>
</tr>
<tr>
<td>5</td>
<td>859</td>
</tr>
<tr>
<td>6</td>
<td>869</td>
</tr>
</tbody>
</table>

• All six images were projected sequentially, but all within the integration time of ORCA
• The radiance levels at each wavelength had been adjusted prior to the test, using a calibrated detector at the output, so that they would have equal radiance levels for a spatially uniform scene

• Measurement of radiance levels of the 6 monochromatic bands from the HIP as made using an ASD spectrometer:
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ORCA Raw Images Relative to HIP Displayed Images

- Image Displayed On HIP
- ORCA Slit
- ORCA Raw Image of HIP Scene

X-direction

Y-direction

Wavelength
Subtracted the ORCA Image of the HIP Continuum from the ORCA Raw Images

Below the brightness level of the HIP continuum image is greatly enhanced so it can be seen – in reality it is less than a percent or so and cannot be easily seen in the ORCA raw scene image if HIP scene illumination duty cycle is a large fraction of ORCA integration time.
Alignment of ORCA Slit Image Relative to HIP Displayed Image

Image Displayed On HIP

ORCA Slit
Fiducials were added to a test scene to verify HIP spectral/spatial sync and to provide coordinates for alignment of HIP to ORCA images.

- **Eigenfiducials** provide means to verify HIP spectral/spatial sync: These are verified to be in order.
- **Chevron fiducial** provides coordinates for alignment of HIP Images to ORCA Images.
To simulate ORCA scan motion along Y-direction, we scrolled the HIP image along Y-direction in 10 different frames.

The ORCA slit (shown in red here) stayed fixed.
Analysis at 645 nm – Assembled 10 frames into a 2D ORCA Image and compared to HIP Image
Analysis at 667 nm
Analysis at 859 nm
Analysis at 869 nm
Summary

• MODIS Satellite Imagery was projected by the HIP into the NASA ORCA IIP Prototype
• Raw imagery as collected by the ORCA IIP Prototype was assembled into spatial images
• Difference images are largest near cloud edges, but analysis could be improved still
• Served as a prototype test
• Lessons learned:
  • Add fiducials to provide alignment of ORCA to HIP
  • Consider increasing the spatial resolution of the original spatial imagery
• Future work:
  • Incorporate ORCA point spread response into analysis
  • Incorporate flat-fielding of HIP spatial images into analysis
  • Use broadband spectra interpolated from MODIS
  • Compare broadband spectra projection results to monochromatic band projection results presented here
  • Improve automation of ORCA and of HIP to enable rapid collection of more data
Result of ENVI/SMAAC: 5 Eigenimages (EI) and corresponding Eigenspectra (ES)

This prepares the image cube for HIP projection. EI1 through EI5 will be displayed on the HIP spatial engine in sync with the production of the corresponding ES1 through ES5 on the HIP spectral engine.

Note: the eigenimages here have been enhanced with a square root contrast stretch so that they all show up on the monitor you are viewing this with. On the HIP, they are projected without this enhancement.