Contribution of Ultraviolet and Shortwave Infrared Observations to Atmospheric Correction of PACE Ocean-Color Imagery

We have evaluated, using simulations with a coupled radiation transfer code, the gain in marine reflectance accuracy expected by including observations in the UV and SWIR compared with just using observations in the visible to NIR.

The study has been performed for the PACE threshold aggregate bands with respect to the standard MODIS set of bands used to generate ocean color products.

Atmospheric correction methodology

TOA reflectance (after correction for molecular scattering or not) is decomposed in principal components.

Components sensitive to the ocean signal are combined to retrieve the principal components of marine reflectance, allowing reconstruction of the marine reflectance.

\[
\rho = \rho_{TOA} - \rho_m = f(\rho_w)
\]

\[
\rho = \sum_i c_{pi} e_{pi}
\]

\[
\rho_w = \sum_j c_{wj} e_{wj}
\]

\[
c_{wj} = g_j(c_{pi})
\]
Figure 1: Left: The first 5 eigenvectors of the TOA reflectance. Right: the first 5 eigenvectors of the marine reflectance. They were computed for an ensemble of simulations that included a wide range of angular geometries and geophysical conditions (absorbing and non-absorbing aerosols, Case 1 and Case 2 waters --Z. Lee), with no noise. Prior distributions are uniform. Spectral bands are centered on 412, 443, 490, 510, 555, 665, 748, 865, 1245, 1640, and 2135 nm. The first 3 eigenvectors of the TOA reflectance are smooth spectrally and are mostly related to atmospheric/surface processes.
**Figure 2:** Top: Correlation coefficients (%) between the principal components of $\rho$, $c_{pi}$, and the principal components of $\rho_w$, $c_{wj}$ for standard and PACE bands; Bottom: Empirical functions based on linear correlation matrix. The mapping is accomplished using neural network modeling. Higher order $c_{wj}$ are fixed at their mean values, estimated on the simulated data ensemble.

$$c_{w1, 2} = g_1, 2(c_{p4}, c_{p5}, c_{p6}, c_{p7})$$
$$c_{w3, 4, 5, 6} = g_3, 4, 5, 6(c_{p5}, c_{p6}, c_{p7})$$

$$c_{w4} = g_4(c_{p5}, c_{p6}, c_{p7}, c_{p8}, c_{p9}, c_{p10}, c_{p11})$$
$$c_{w5} = g_5(c_{p6}, c_{p7}, c_{p8}, c_{p9}, c_{p10}, c_{p11})$$
$$c_{w6} = g_6(c_{p7}, c_{p8}, c_{p9}, c_{p10}, c_{p11})$$
$$c_{w7} = g_7(c_{p9}, c_{p10}, c_{p11})$$
$$c_{w8} = g_8(c_{p10}, c_{p11})$$
Figure 3: Theoretical performance of the PCA-based atmospheric correction algorithm. Left: Standard bands; Right: PACE bands. Errors are significantly reduced using the PACE bands.
Figure 4: Error on retrieved $\rho_w(443)$ as a function of various angular and aerosol parameters. The inversion is performed using the PCA-based algorithm applied to the PACE bands (UV-SWIR).
Figure 5: Examples of retrieved and prescribed water reflectance spectra. Left: Using the standard bands; Right: Using the PACE bands. Retrievals are generally more accurate using the extended spectral range.

Summary

- Extending the spectral range of TOA observations to UV and SWIR, retrieval accuracy on $\rho_w$ is improved from 0.037 to 0.24 at 412 nm, from 0.0013 to 0.0007 at 665 nm, and from 0.0010 to 0.0004 at 865 nm (Case 2 waters are better handled).

- Performance of the PCA-based algorithm is degraded at large viewing zenith angles and aerosol optical thickness, is better at scattering angles around 120-130 deg., and exhibits little dependence on single scattering albedo and aerosol scale height.
RT Comparisons (plane-parallel versus spherical atmosphere)

AOS-I*: Atmosphere : Rayleigh scattering with AOT=0.5, no depolarization factor, it gives $\lambda = 369.86$ nm with AFGL MS and lat.=0., No gaseous absorption. 120 1-km layers. $\mu_0 = 0.6$; $\mu = [0.02, 0.10, 0.16, 0.20, 0.28, 0.32, 0.40, 0.52, 0.64, 0.72, 0.84, 0.92, 1.00]$. Monte Carlo, Local Estimation Method, 1 billion photons.

Plane-parallel atmosphere without Sun glint

Figure 6: Comparison of Stokes parameters computed using the GISS RT code (ref.) and the Monte Carlo code (plane-parallel atmosphere) as a function of view zenith angle for relative azimuth angles of 0, 60, 120, and 180 deg. (red an green curves). Absolute differences are <0.00004 for I, Q, and U, and relative differences are generally <0.02% for DoLP.
Spherical shell atmosphere without Sun glint

Figure 7: Same as Figure 6, but spherical shell atmosphere for Monte Carlo code. The typical effect of sphericity is to lower intensity $I$ by 0.3-0.5% for viewing zenith angles <50 deg. and up to 2% at larger viewing angles, and polarization ratio DoLP by 0.3-0.4%.

Summary

- Good agreement between results of GISS RT code and Monte Carlo code for AOS-I*. Better agreement can be obtained using more photons.

- Sphericity needs to be taken into account in the calculation of Rayleigh look-up tables for accurate ocean-color remote sensing (as well as temperature profile, index of refraction, depolarization factor of the phase function).