Challenges of Absorbing Aerosols

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PACE opens new vistas in aquatic biology…

Blue and near-UV spectra from the OCI will measure accessory (non-chlorophyll) pigments, separate chlorophyll and colored dissolved organic matter, and characterize phytoplankton taxonomy.

…but atmospheric interference might make this challenging

B. Mitchell, UCSB: Retrieving UV-absorbing mycosporine amino acids, algal proteins, and particle size distributions is needed to specify phytoplankton functional groups and plankton ecosystem structure.

S. Maritorena, UCSB: Dissolved organic matter and absorbing aerosols both absorb in the UV, which may limit the ability to differentiate them.

Devred et al. [2013]
Aerosol is transported over many ocean regions

SeaWiFS mission cumulative climatology of chlorophyll-a concentration ($C_a$). White shows locations where $C_a > 0.3$ mg m$^{-3}$, and the assumption of a black surface in the NIR is likely to be violated [Bailey et al., 2010]

MISR April aerosol optical depth (AOD) climatology 2000-2012, [Kalashnikova et al., 2013]
Aerosol is transported over many ocean regions

OMI absorbing aerosol climatology, [Courtesy of Omar Torres]
The goal of atmospheric correction (AC) is to convert observed top-of-atmosphere spectral radiance to water-leaving reflectance (Rrs) over the NUV-VIS spectral regime.

TOA reflectance computed from old (M70) and new (Rh80M06) aerosol models

Current NASA atmospheric correction approach

- Obtain AOD and Aerosol Type from Red-NIR bands
- Extrapolate to Blue, UV (for next-generation instrument)
- Correlate with surface reflectivity at (MOBY) surface buoy

Ahmad et al. [2010] works well for spectrally flat aerosols
“Complicated” aerosols

Dust and brown carbon strongly absorb toward UV

Courtesy of Rajan Chakrabarty

Wagner et al. [2012]
Dust and BC absorption features might be misinterpreted as CDOM absorption.
Remote sensing reflectance for various water types

Case1: Chl=0.2
Case1: Chl=10
Case2: Chl=1, High CDOM

Remote Sensing Reflectance (sr-1)

Wavelength (nm)

Courtesy of Curt Mobley
Theoretical sensitivity to absorption

- **Compared atmospheres with Ahmad dustlike fine mode particles with same particle with hematite $n_i$**
  - Dry particles ($r_v = 0.149$, $r_n = 0.084$)
  - Ahmad = “dustlike”
  - Adjusted = “dustnihem”
- **“Two-stage atmospheric correction”**
  - $L_{u,\lambda} - x_{\lambda} = L_{w,\lambda}/E_{d,\lambda} = R_{rs,\lambda}$
  - Scaling at to $R_{rs}$ at 555

- SOS vector model
- AOD =0.3
- Rayleigh atmosphere + aerosol
- Nadir view
- Ocean albedo was adjusted to match ECOLIGHT
Retrieved and scaled Rrs vs. “true” Rrs

- SOS vector model
- AOD = 0.3
- Rayleigh atmosphere + aerosol
- Nadir view
- Ocean albedo was adjusted to match ECOLIGHT
Neglecting hematite dust aerosols leads to errors outside of the PACE Rrs retrieval requirement.
Using AirMSPI to explore the value of a polarimeter


Flight altitude: 20 km

Multiangle viewing: Between ±67° using single-axis gimbal

AirMSPI data were acquired over the USC SeaPRISM AERONET-OC site on the Eureka platform on February 6, 2013
AERONET observations vs. AirMSPI optimized coupled aerosol-surface retrieval (no look up tables)
Aerosol optical depth retrieval sensitivity to measurement information content

- Colored dots: Mean AirMSPI retrieval results based on 8 initial guesses at 19:43 UTC.
- Colored error bars: Spread of these 8 results.
- Blue and green lines: SeaPRISM observation at 19:08 and 20:08 UTC.
Normalized water-leaving radiance sensitivity to measurement information content

- Colored symbols: Mean and spread of AirMSPI retrieval results based on 8 initial guesses.
- Blacks symbols: SeaPRISM observations with error bars denoting PACE SDT uncertainty target.
Since standard Chl-a retrievals use band ratios of blue to green, retrievals were normalized by the 555 nm value.

- The band-ratio approach works well for spectrally flat, absorbing aerosols.
- Coupled atmosphere-ocean retrievals from a multi-angle polarimeter would help in cases of “complicated” aerosols, and in the case where the surface spectrum is not simply modeled by a chlorophyll concentration only.
Dust and Brown Carbon strongly absorb in the UV, similar to CDOM absorption

Unaccounted aerosol absorption at near-UV and blue can lead to Rrs biases beyond PACE defined threshold of maximum of 20% or 0.004 over the λ of 350 – 395 nm, and the maximum of 5% or 0.001 over the λ of 400 – 600 nm

Aerosol absorption features vary significantly depending on aerosol internal and external mixing, and cannot be approximated by a simple spectral model at UV and blue wavelengths

Multiangle polarimetry distinguishes atmosphere and surface absorption in the UV-VNIR

We expect a polarimeter to provide a risk reduction for PACE's Rrs retrievals at short wavelengths and for coastal waters
Feedback is welcome

Thank you!
Dust aerosols are composed of *internal and external mixtures* of different minerals. Iron oxides dominate dust short VIS-UV absorption spectra.
Atmospheric dust spectra cannot be easily approximated

Iron Oxide content of the atmospheric mineral dust varies globally from 1 to 10%

Perlwitz et al., [2015]