Ocean color atmospheric correction for operational remote sensing of Chesapeake Bay

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Acknowledgements:
Rick Stumpf & the Gang at the Ocean Biology Processing Group
challenges for remote sensing of estuaries

temporal & spatial variability
  satellite sensor resolution
  satellite repeat frequency
  validity of ancillary data (SST, wind)
  resolution requirements & binning options

straylight contamination (adjacency effects)

non-maritime aerosols (dust, pollution)
  region-specific models required?
  absorbing aerosols

suspended sediments & CDOM
  complicates estimation of $R_{rs}(\text{NIR})$
  complicates BRDF (f/Q) corrections
  saturation of observed radiances

anthropogenic emissions (NO$_2$ absorption)
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NOAA CoastWatch East Coast Node using results for operational processing
the experiment

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run multiple long-term time-series of MODIS-Aqua

Lower Chesapeake Bay, June 2002 - December 2008
processing configuration follows Reprocessing 2010
QC metrics: exclude cloudy days & high sensor zenith angles
final analyses use ~ 13 days per month

generate frequency distributions and monthly time-series
use in situ measurements as reference

consider potential for application in an operational environment
atmospheric correction & the “black pixel” assumption

| ρ_t(λ) | = | ρ_w(λ) | + | ρ_g(λ) | + | ρ_f(λ) | + | ρ_r(λ) | + | ρ_a(λ) |
|--------|---|--------|---|--------|---|--------|---|--------|
| TOA    | water | glint | foam | air    | aerosols |

need ρ_a(λ) to get ρ_w(λ) and vice-versa
atmospheric correction & the “black pixel” assumption

\[ \rho_t(\lambda) = \rho_w(\lambda) + \rho_g(\lambda) + \rho_f(\lambda) + \rho_r(\lambda) + \rho_a(\lambda) \]

TOA water glint foam air aerosols

need \( \rho_a(\lambda) \) to get \( \rho_w(\lambda) \) and vice-versa

the “black pixel” assumption (pre-2000):

\[ \rho_a(\text{NIR}) = \rho_t(\text{NIR}) - \rho_g(\text{NIR}) - \rho_f(\text{NIR}) - \rho_r(\text{NIR}) - \rho_w(\text{NIR}) \]
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calculate aerosol ratios, \( \varepsilon \):

\[ \varepsilon(748,869) \approx \frac{\rho_a(748)}{\rho_a(869)} \]

\[ \varepsilon(\lambda,869) \approx \frac{\rho_a(\lambda)}{\rho_a(869)} \]
are $R_{rs}(\text{NIR})$ really black?
are $\text{Rrs(NIR)}$ really black?
what happens when we don’t account for $R_{rs}(\text{NIR}) > 0$?

use the “black pixel” assumption (e.g., SeaWiFS 1997-2000)
what to do when $\text{R}_{\text{rs}}(\text{NIR}) > 0$?

many approaches exist, here are a few examples:

assign aerosols ($\varepsilon$) and/or water contributions ($\text{R}_{\text{rs}}(\text{NIR})$)
e.g., Hu et al. 2000, Ruddick et al. 2000

use shortwave infrared bands
e.g., Wang & Shi 2007

correct/model the non-negligible $\text{R}_{\text{rs}}(\text{NIR})$
   Siegel et al. 2000 used in SeaWiFS Reprocessing 3 (2000)
   Stumpf et al. 2003 used in SeaWiFS Reprocessing 4 (2002)
   Lavender et al. 2005 MERIS
   Bailey et al. 2010 used in SeaWiFS Reprocessing 6 (2009)

use a coupled ocean-atmosphere optimization
e.g., Chomko & Gordon 2001, Stamnes et al. 2003, Kuchinke et al. 2009
fixed aerosol & water contributions (MUMM)

assign $\varepsilon$ & $\rho_w$(NIR) (via fixed values, a climatology, nearby pixels)
advantages & disadvantages

advantages:

accurate configuration leads to accurate aerosol & $R_{rs}(\text{NIR})$ retrievals
several configuration options: fixed values, climatologies, nearby pixels
method available for all past, present, & future ocean color satellites

disadvantages:

no configuration is valid at all times for all water masses
requires local knowledge of changing aerosol & water properties
implementation can be complicated for operational processing
use of NIR + SWIR bands

in situ: circles & shaded areas

use SWIR bands in “turbid” water, otherwise use NIR bands
use of SWIR bands only

compare NIR & SWIR retrievals when considering only “turbid pixels”
advantages & disadvantages

advantages:

“black pixel” assumption largely satisfied in SWIR region of spectrum straightforward implementation for operational processing

disadvantages:

only available for instruments with SWIR bands
SWIR bands on MODIS have inadequate signal-to-noise (SNR) ratios
difficult to vicariously calibrate the SWIR bands on MODIS
must define conditions for switching from NIR to SWIR
correction of non-negligible $R_{rs}(\text{NIR})$

estimate $R_{rs}(\text{NIR})$ using a bio-optical model
operational SeaWiFS & MODIS processing ~ 2000-present
advantages & disadvantages

advantages:

method available for all past, present, & future ocean color missions
straightforward implementation for operational processing

disadvantages:

bio-optical model not valid at all times for all water masses
summary of the three approaches

defaults as implemented in SeaDAS

in situ: circles & shaded areas
satellite:  NIR (default)  NIR-SWIR (2009, default)  MUMM (default)  Lower Chesapeake Bay
MODIS-Aqua vs. SeaWiFS

default processing ~ OC3 for MODIS-Aqua & OC4 for SeaWiFS
SNR transect for MODIS-Aqua NIR & SWIR bands
MODIS-Aqua Level-2 Chl “match-ups” for NIR & SWIR processing
MODIS-Aqua $\rho_a(443)$
distribution of the turbidity index using in NIR-SWIR switching