Spatial and Temporal Distributions of Absorbing Aerosols along the U.S. Coastal Regions

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Abstract

The current atmospheric correction (AC) algorithm for ocean color products uses non- or weakly-absorbing aerosol models to derive aerosol contributions to the top-of-atmosphere (TOA) radiances. Therefore, the atmospheric correction algorithm tends to significantly over-estimate aerosol radiance contributions and under-estimate satellite-derived normalized water-leaving radiances at blue bands 412 and 443 nm when strongly absorbing aerosols are present. This will often result in negative normalized water-leaving radiance values at those bands. To address this problem, the first step is to correctly identify the pixels under the influence of strongly absorbing aerosols. Eight years of MODIS-Aqua L1B images located along the U.S. east coastal region have been analyzed, and the absorbing aerosol index developed by Shi and Wang (2007) was calculated. The results show strong seasonal and interannual variations in the appearance of strongly absorbing aerosols along the U.S. East Coast. Also, the spatial and temporal patterns for the pixels that are identified as contaminated by strongly absorbing aerosols are consistent with those of pixels for which values of MODIS-derived normalized water-leaving radiance at 412 nm are negative.

Atmospheric Correction and Absorbing Aerosols

$$\rho_t(\lambda)=\rho_r(\lambda)+\rho_a(\lambda)+T(\lambda)\rho_g(\lambda)+t(\lambda)\rho_{wc}(\lambda)+t(\lambda)\rho_w(\lambda)$$

Measured by sensor (known):

$\rho_t(\lambda)$ - TOA radiance

Theoretically calculated (known):

$\rho_r(\lambda)$ - radiance contributed by molecule scattering (Rayleigh scattering)

$\rho_g(\lambda)$ - radiance contributed by specular reflection of sun-glint

$\rho_{wc}(\lambda)$- radiance contributed by white-cap (sea surface bubbles and foams)

$T(\lambda)$ - direct transmittance from the ocean surface to the sensor

$t(\lambda)$ - diffuse transmittance from the ocean surface to the sensor

Major component to be estimated in AC:

$\rho_a(\lambda)$ - radiance contributed by aerosol scattering (including multi-scattering)

Target (unkown for visible bands, assumed 0 for NIR or SWIR bands):

$\rho_w(\lambda)$ - water-leaving radiance

Define: $\rho_{tc}(\lambda)=\rho_t(\lambda)-\rho_r(\lambda)-T(\lambda)\rho_g(\lambda)-t(\lambda)\rho_{wc}(\lambda)$

$$\Rightarrow \rho_a(\lambda)=\rho_{tc}(\lambda)-t(\lambda)\rho_w(\lambda)$$

The major task of AC is to estimate $\rho_a(\lambda)$ for all λ, given ρ_a at two NIR (for NIR AC) or two SWIR bands (for SWIR AC) for which ρ_w are assumed 0. This is accomplished by correctly selecting two aerosol models from dozens of candidates which are all non- or weakly-absorbing aerosol models (Gordon and Wang, 1994). Therefore, for absorbing aerosols, the ρ_a at short wavelengths (blue bands) will be over-estimated by AC due to the non- or weakly-absorbing nature of the aerosol models. The consequence is the underestimated ρ_w at short wavelengths, and the erroneous estimation of chlorophyll-a concentration.

Identification of Absorbing Aerosols

For this purpose, Shi and Wang (2007) defined two indices for MODIS bands - turbid water index and absorbing aerosol index which can be calculated before the deriving of $\rho_a(\lambda)$:

$$Tur_{ind}=\varepsilon_M(748,1240)/\tilde{\varepsilon}_M^{SWIR}(748,1240); \quad Abs_{ind}=\rho_{tc}(412)/\tilde{\rho}_a(412)$$

where ("^" indicates exponent):

$$\varepsilon_M(\lambda_1,\lambda_2)=\rho_{tc}(\lambda_1)/\rho_{tc}(\lambda_2);\ \tilde{\varepsilon}_M^{SWIR}(\lambda_1,\lambda_2)=\varepsilon_M(\lambda_{SWIR1},\lambda_{SWIR2})\wedge[(\lambda_2-\lambda_1)/(\lambda_{SWIR2}-\lambda_{SWIR1})]$$

$$\tilde{\rho}_a(\lambda)=\rho_{tc}(869)\tilde{\varepsilon}_M^{NIR}(\lambda,869); \quad \tilde{\varepsilon}_M^{NIR}(\lambda_1,\lambda_2)=\varepsilon_M(\lambda_{NIR1},\lambda_{NIR2})\wedge[(\lambda_2-\lambda_1)/(\lambda_{NIR2}-\lambda_{NIR1})]$$

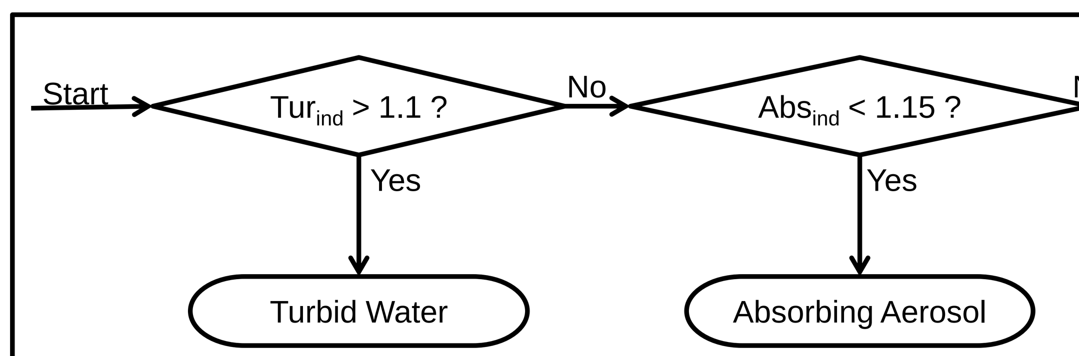

Diagram 1. Flow chart for turbid water and absorbing aerosol pixel identification procedure

MODIS-Aqua-derived 8-year Statistics of Absorbing Aerosol Occurrence off the U.S. East Coast

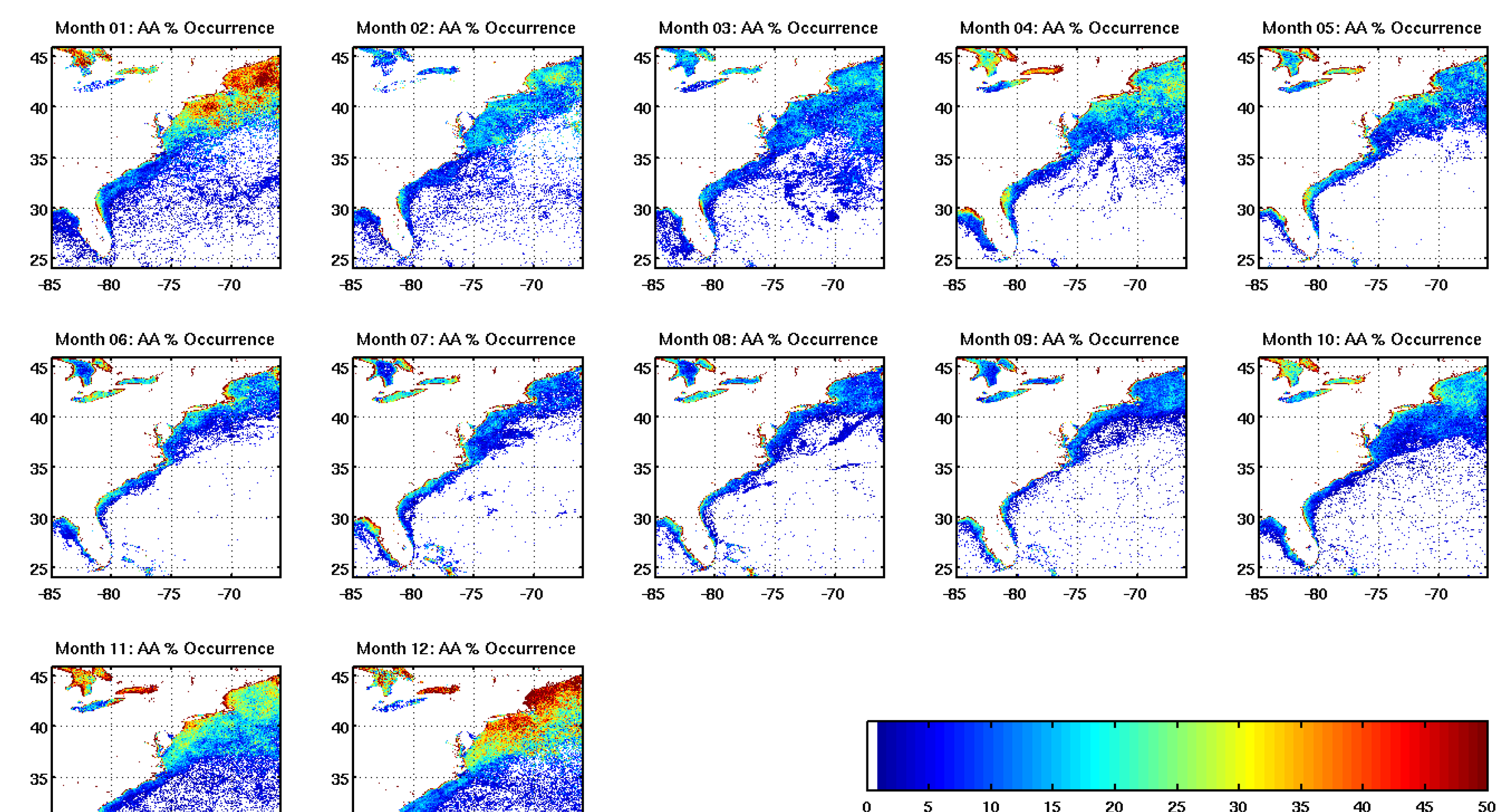

Figure 1. Monthly climatology of MODIS-Aqua-derived absorbing aerosol percentage occurrence off U.S. East Coast

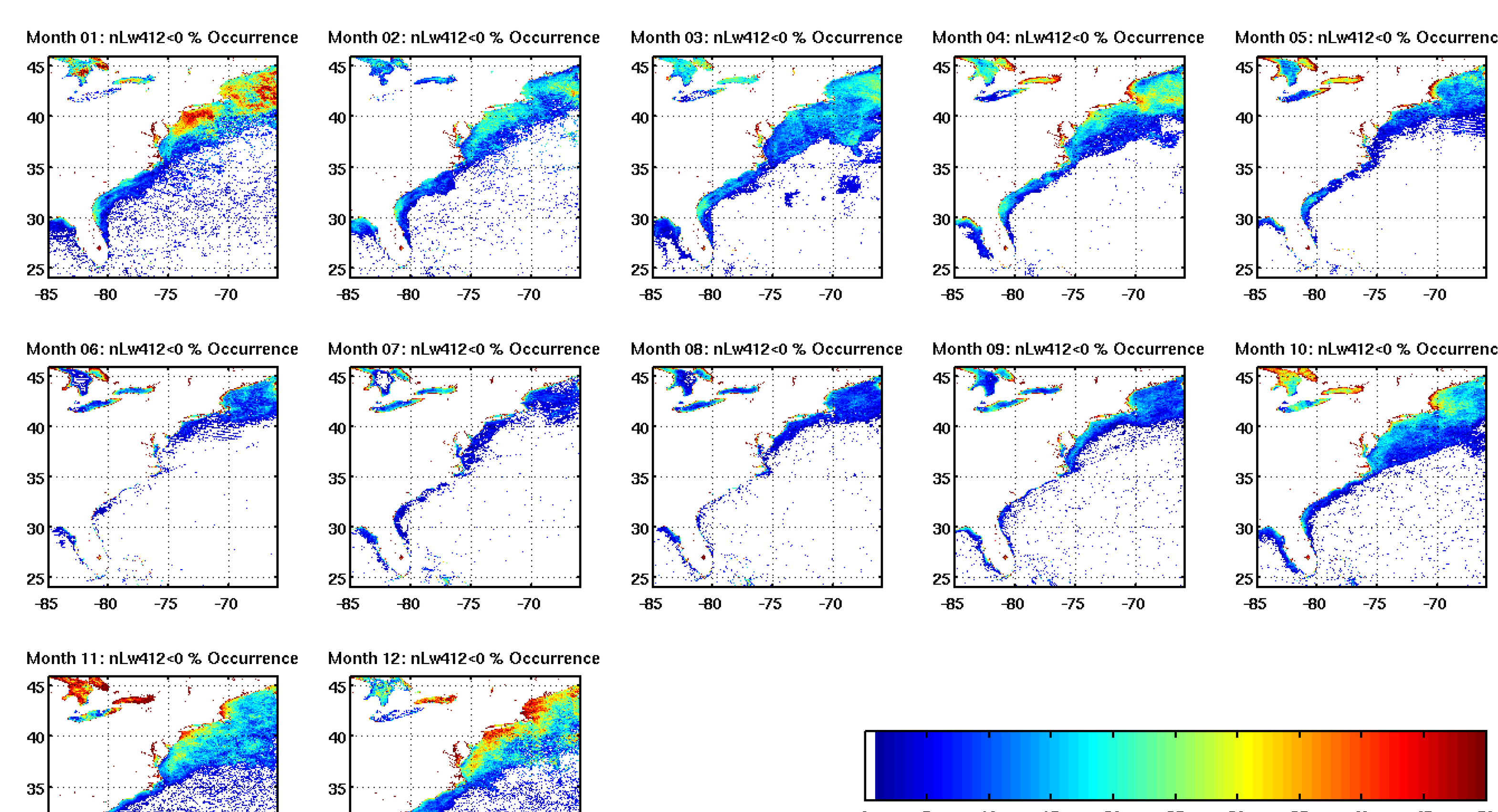

Figure 2. Monthly climatology of MODIS-Aqua-derived negative nLw(412) percentage occurrence off U.S. East Coast

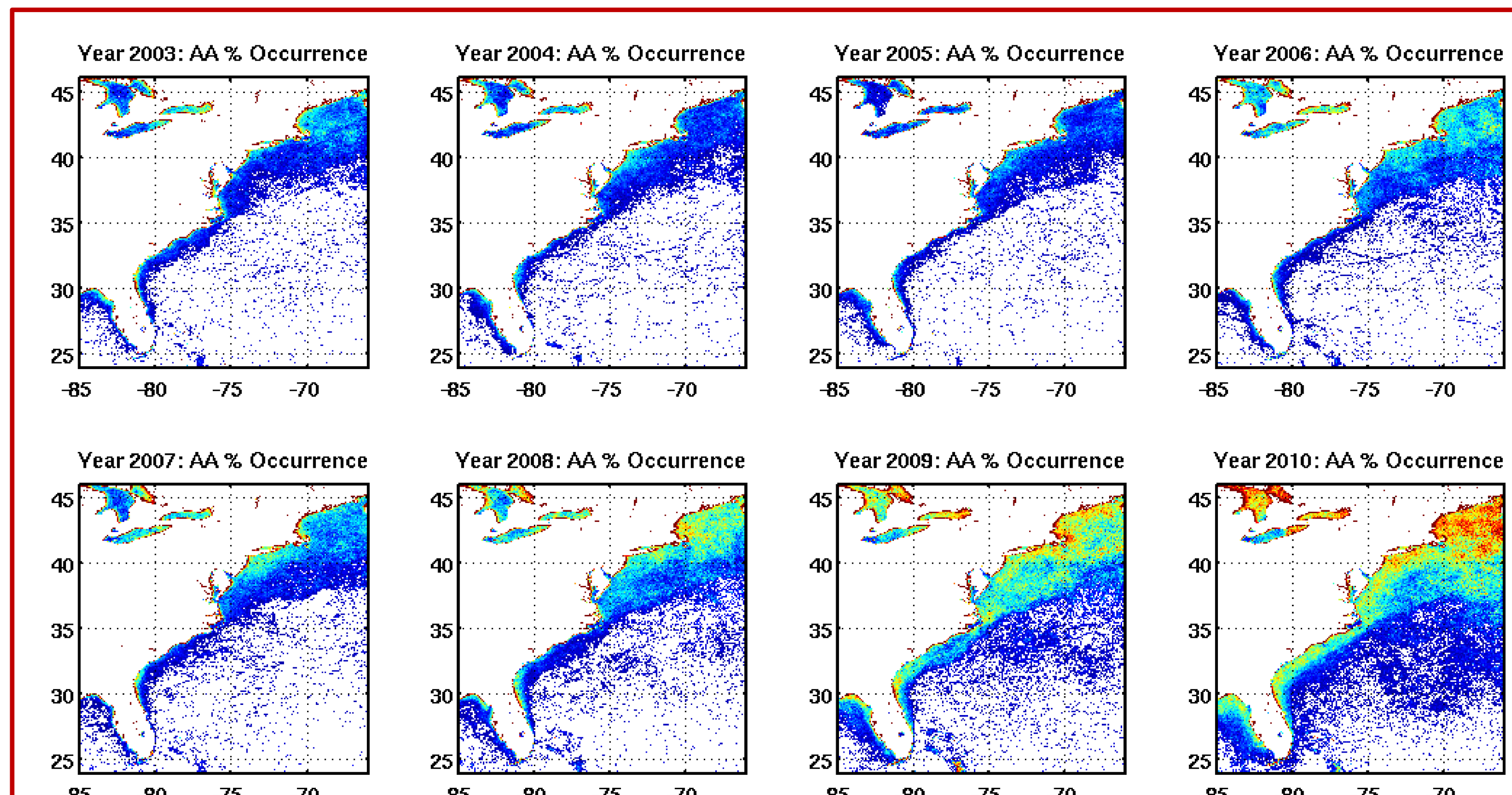

Figure 3. Annual percentage occurrence of MODIS-Aqua-derived absorbing aerosols off U.S. East Coast

Validation: Comparison with OMI Products

- There are two aerosol products from OMI: OMAERUV and OMAERO.
- OMAERUV is mainly used for land while OMAERO is mainly used for ocean.
- Both algorithms pre-specify only a couple of aerosol models for a given location.
- Single Scattering Albedo (SSA) is derived after aerosol model is determined.
- Both algorithms calculate UV-absorbing Aerosol Index (UVAI).
- Cloud usually have larger UVAI (higher absorption) for both algorithms.
- Discrepancies in UVAI exist between OMAERUV and OMAERO.

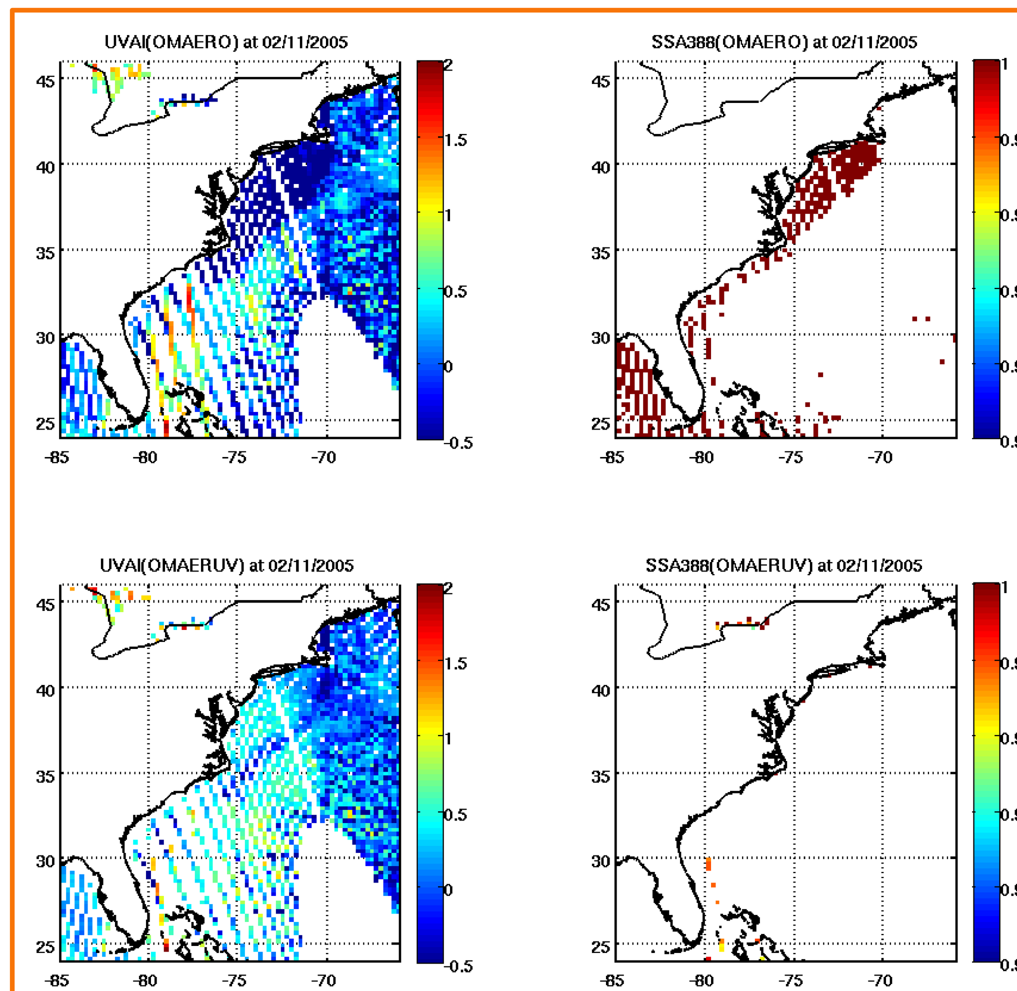

Figure 4. Comparisons between the absorbing indices from OMAERO, OMAERUV, and MODIS-Aqua on Feb.11, 2005 off U.S. East Coast

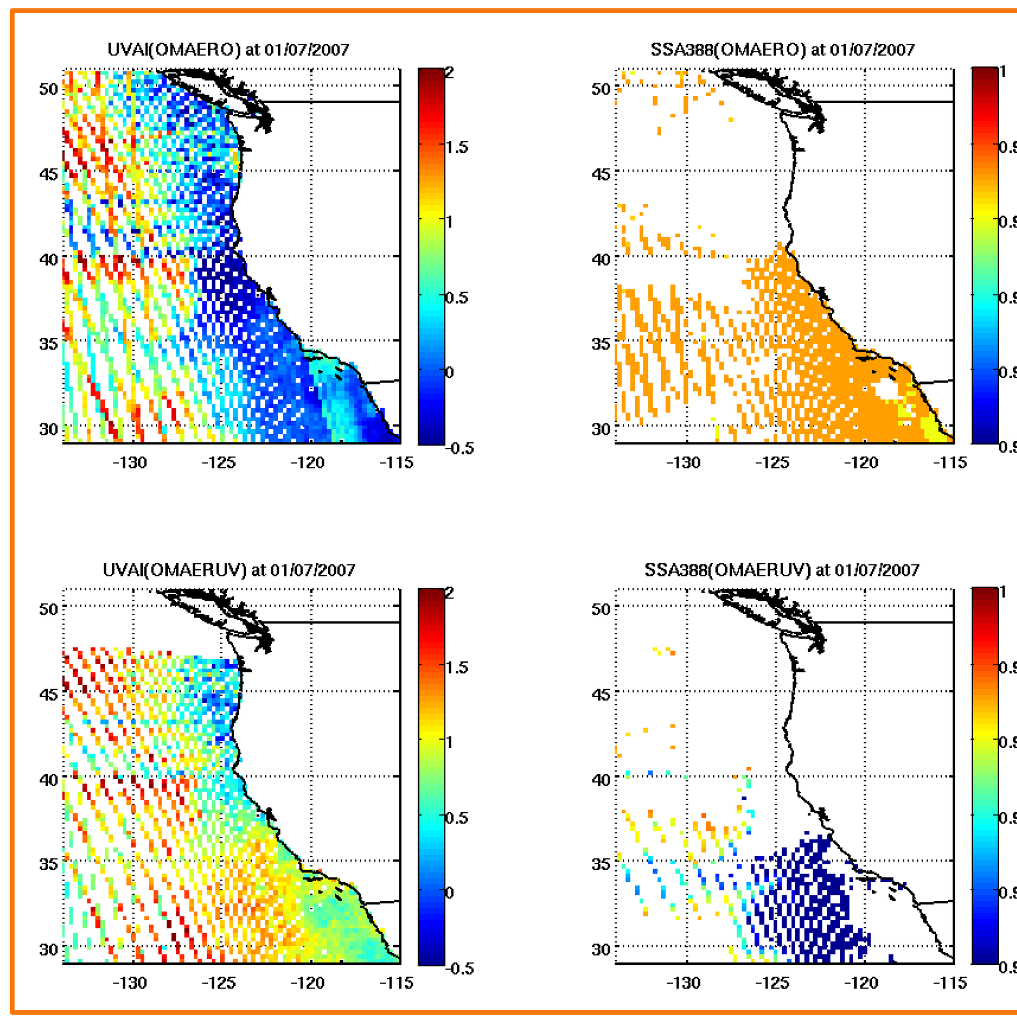

Figure 5. Comparisons between the absorbing indices from OMAERO, OMAERUV, and MODIS-Aqua on Jan.07, 2007 off U.S. West Coast

References:

Gordon, H.R. and Wang, M. (1994). Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: A preliminary algorithm. *Applied Optics, 33,* 443-452.

Shi, W. and Wang, M. (2007). Detection of turbid waters and absorbing aerosols for the MODIS ocean color data processing. *Remote Sensing of Environment, 110,* 149-161.

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