Predicted Performance of NPOESS Aerosol Products

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Introduction

Abstract:
The National Polar-orbiting Operational Environmental Satellite System [NPOESS] is being developed to replace the current NOAA Polar Orbiting Environmental Satellite (POES) and the DoD Defense Meteorological Satellite Program (DMSP) systems. The instruments represent significant improvements over the current operational sensors. The Visible-IR Imager Radiometer Suite [VIIRS] with 22 channels will be replacing the 6-channel Advanced Very High Resolution [AVHRR] on the POES system and the 2-channel Operational Linescan System [OLS] on the DMSP system. Measurements of the atmospheric aerosols from NPOESS, will come from the VIIRS instrument. The 22 VIIRS spectral bands include 16 radiometric bands plus 5 imaging bands and a day-night band. The aerosol related Environmental Data Records (EDRs) will be derived primarily from the radiometric channels covering the visible through the short-wave infrared spectral regions (412 to 2250 nm). The primary aerosol products will be the aerosol optical thickness, aerosol particle size parameter, and the identification and typing of suspended matter. These aerosol products and their derivation will be described including recent updates to the retrieval algorithms due to improved performance demonstrated by the MODIS collection 5 aerosol algorithm modifications. Pre-launch estimations of on orbit performance have been derived using both proxy and synthetic data. The proxy data technique uses MODIS level 1B data to simulate the radiances which will be measured by VIIRS and compares the retrieved aerosol properties with AERONET match-up data used for MODIS aerosol product validation. The synthetic data technique uses a radiative transfer model to simulate VIIRS radiance data from a global data set and compares the retrieved aerosol properties with predefined truth.

The VIIRS Instrument

Aerosol Optical Thickness Requirements:

Aerosol optical thickness (AOT), for this EDR, is defined as the extinction (scattering + absorption) optical thickness of the vertical column above the geolocation of the horizontal cell in a narrow band about the specified wavelength.

•Horizontal Cell Size	Nadir 6 km	EOS 12.8 km
•Measurement Range	0 to 2	
	Ocean	Land
•Precision	0.02+0.03τ	0.04+0.1τ
•Uncertainty	0.03+0.05τ	0.05+0.15τ

Angstrom Exponent Requirements:

Aerosol particle size may be characterized by two different parameters, the Ångström wavelength exponent and the effective radius. The Ångström wavelength exponent "alpha" (α) is defined by:

$$\alpha = -(\ln\tau(\lambda 1) - \ln\tau(\lambda 2))/(\ln\lambda 1 - \ln\lambda 2)$$

where: λ1 and λ2 are wavelengths, in micrometers, of the band centers of two narrow bands, and τ(λ1) and τ(λ2) are the extinction (scattering + absorption) at those wavelengths due to the vertical optical thickness of the atmospheric aerosols.

•Horizontal Cell Size	Nadir 6 km	EOS 12.8 km
•Measurement Range	-1 to 3	
	Ocean	Land
•Accuracy	0.3	0.6
•Precision	0.3	0.6

Suspended Matter Requirements:

The required content of this EDR is to report the presence of suspended matter such as dust, sand, volcanic ash, SO2, or smoke at any altitude.

•Horizontal Cell Size	Nadir .75 km EOS 1.6 km
•Probability of Detection	85%
•Probability of Correct Typing	80%
•Smoke Concentration	
➢Measurement Range	0 – 1000 μg/m³
➢Uncertainty	50%

Conclusions

The VIIRS Aerosol products present an improvement over existing remote sensing aerosol products. The VIIRS products will be available operationally at improved latency, will have improved spatial resolution and be of similar science quality to the current MODIS products and have substantially better performance than the current AVHRR products. However, the state of the science algorithms implemented for NPP are unlikely to initially satisfy all of the aggressive NPOESS system requirements on a global basis. Improvements in the science of remote sensing retrievals of aerosol properties are under continued development by the remote sensing science community and it is expected that future developments will be leveraged for performance improvements in the NPOESS era.

Background Image from MODIS Aqua provided by NASA Visible Earth Catalog

Core Land AOT Inversion:

Following the MODIS surface reflectance (MOD09 collection 5) approach for retrieval of aerosol over land, the surface reflectance in the red (672 nm) and blue (488 nm) bands is calculated for each value of AOT and each aerosol model by solving the Lambertian TOA reflectance equation:

$$\rho_{toa}(\tau_A) = Tg_{og}Tg_{O_3}\left[\begin{array}{l}(\rho_{R+A}(\tau_A) - \rho_R(P_0))Tg_{H_2O}(U_{H_2O}/2) + \rho_R(P) \\ + Tg_{H_2O}(U_{H_2O})T_{R+A}(\tau_A,\theta_s)T_{R+A}(\tau_A,\theta_v)\dfrac{\rho_{surf}}{1-S_{R+A}\rho_{surf}}\end{array}\right]$$

The best AOT value for each model is the value which satisfies the expected surface reflectance ratio between the blue and red bands for vegetated surfaces. Then, for each aerosol model, solve for the reflectance at 412 nm, 445 nm and 2.25 μm using the AOT value for that model. Compute a residual based on the expected 412 nm, 445 nm and 2.25 mm to 672 nm ratios. Select the model with the lowest residual.

LUTs:

Aerosol LUT:

•Transmission	T_{R+A}
•Spherical Albedo	S_{R+A}
•Atmospheric Path Radiance	ρ_{R+A}
•Ratio of AOT at band center to AOT at 550 nm	

Core Ocean AOT Inversion:

Following the MODIS approach, TOA reflectance is modeled as the sum of the TOA reflectances from the fine mode and coarse mode aerosols:

$$\rho^c_{toa}(\tau_a) = \eta\rho^s_{toa}(\tau_a) + (1-\eta)\rho^l_{toa}(\tau_a)$$

Solve the bi-directional TOA reflectance equation for AOT (6S approximation) using the observed TOA reflectance in the 0.865 mm band for each model combination

$$\rho_{toa} = Tg_{og}Tg_{O_3}\left[\begin{array}{l}(\rho_{R+A} - \rho_R(P_0))Tg_{H_2O}(U_{H_2O}/2) + \rho_R(P) \\ + Tg_{H_2O}(U_{H_2O})\left[\begin{array}{l}T_{R+A}(\theta_s)T_{R+A}(\theta_v)\dfrac{\rho_{w+wc}}{1-S_{R+A}\rho_{w+wc}} + e^{-\tau_{R+A}m}\rho_G \\ + t^d_{R+A}(\theta_s)e^{-\tau_{R+A}/\cos(\theta_v)}\overline{\rho_G} + t^d_{R+A}(\theta_v)e^{-\tau_{R+A}/\cos(\theta_s)}\overline{\rho_G}' \\ + t^d_{R+A}(\theta_s)t^d_{R+A}(\theta_v)\overline{\overline{\rho_G}} + \dfrac{T_{R+A}(\theta_s)T_{R+A}(\theta_v)S_{R+A}\overline{\overline{\rho_G}}^2}{1-S_{R+A}\overline{\overline{\rho_G}}}\end{array}\right]\end{array}\right]$$

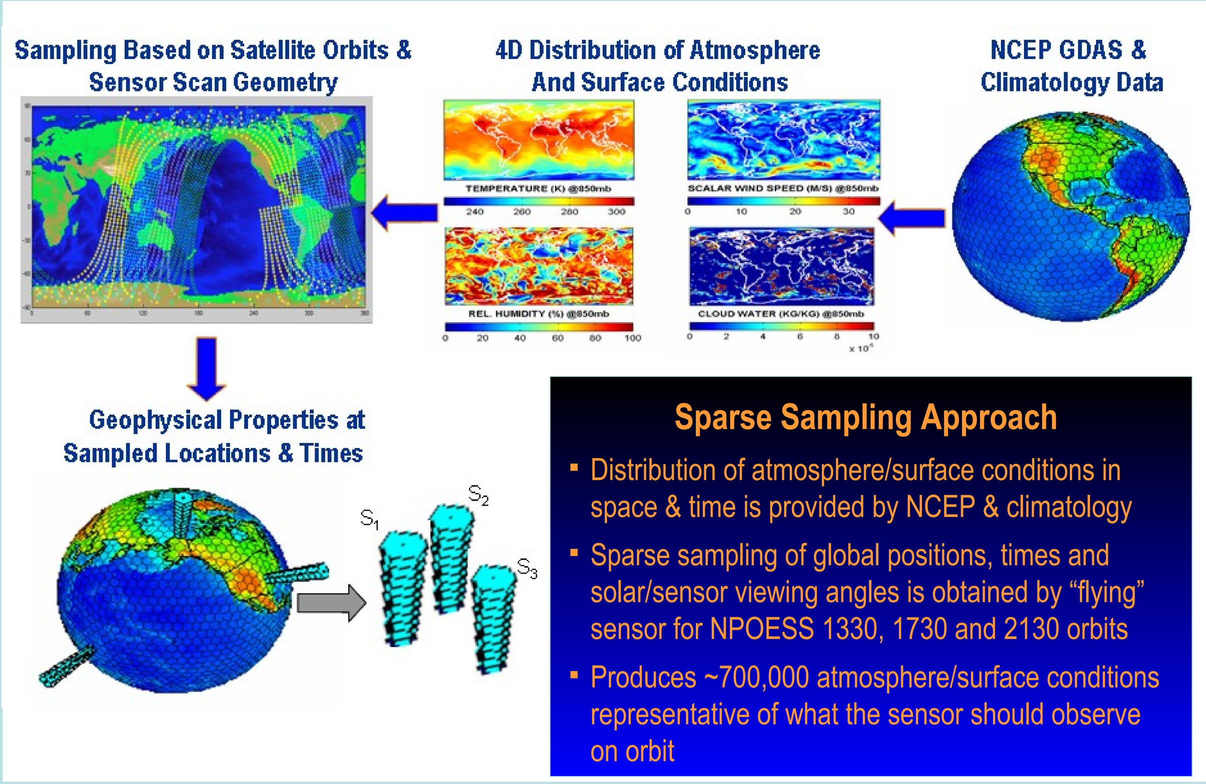
For each ocean model combination solve for the TOA reflectances in the 0.672, 0.746, 1.61 and 2.25 mm bands using the AOT derived from the 0.865 mm band and compute the residual:

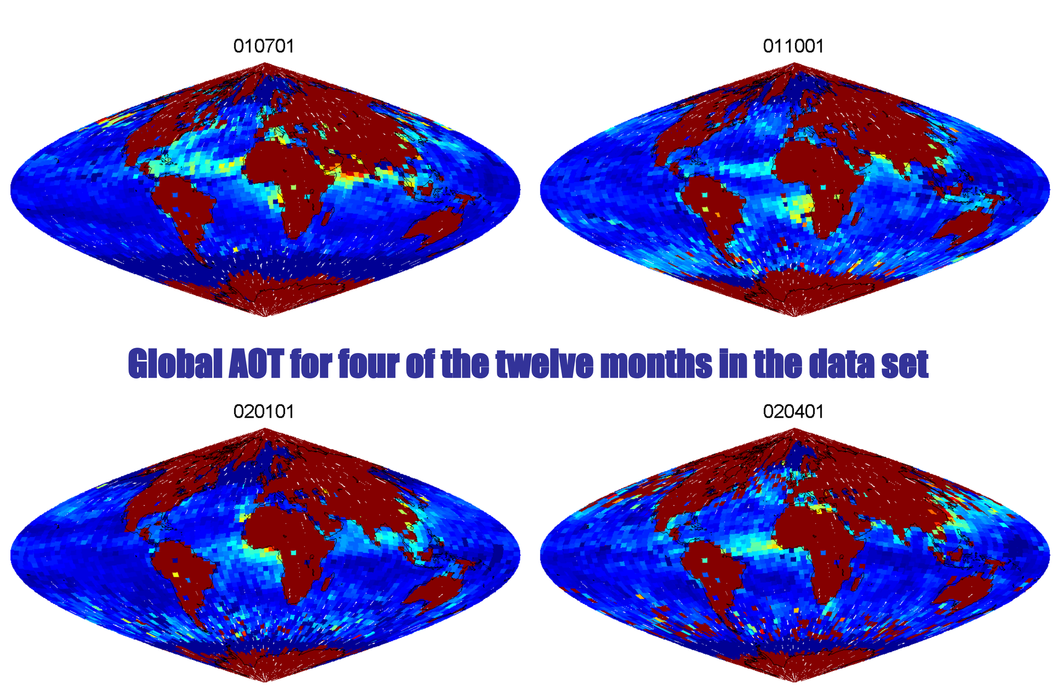
$$\mathrm{Residual}^c = \sum_{i=1}^{n}\left(\rho^c_{toa}(\tau^{inv}_a)^i - \rho^i_{obs}\right)^2$$

Select ocean model combination with the lowest residual

Sun Glint LUT:

Normalized integral of down welling sky shine with ocean surface BRDF ρ_G





Global AOT for four of the twelve months in the data set

Testing with AERONET Match-up Data

MODIS / AERONET match-up data and analysis methodology taken from:
- ➢http://modis-atmos.gsfc.nasa.gov/MOD04_L2/validation.html

MODIS L1B data is run through VIIRS Aerosol algorithm
- ➢LUTs and band dependent constants in code tailored for MODIS band passes

QCed AERONET retrievals averaged from ±30 minutes from MODIS overpass

AERONET retrievals at 440 nm and 870 nm interpolated linearly in log space to the MODIS band wavelengths
- ➢470 nm, 550 nm, 660 and 870 nm over ocean

High quality VIIRS AOT EDR retrievals are aggregated in a 5x5 cell surrounding the AERONET site
- ➢5 out of 25 valid retrievals required for match-up

AERONET Locations