



NPP Aerosol Products from the VIIRS Instrument

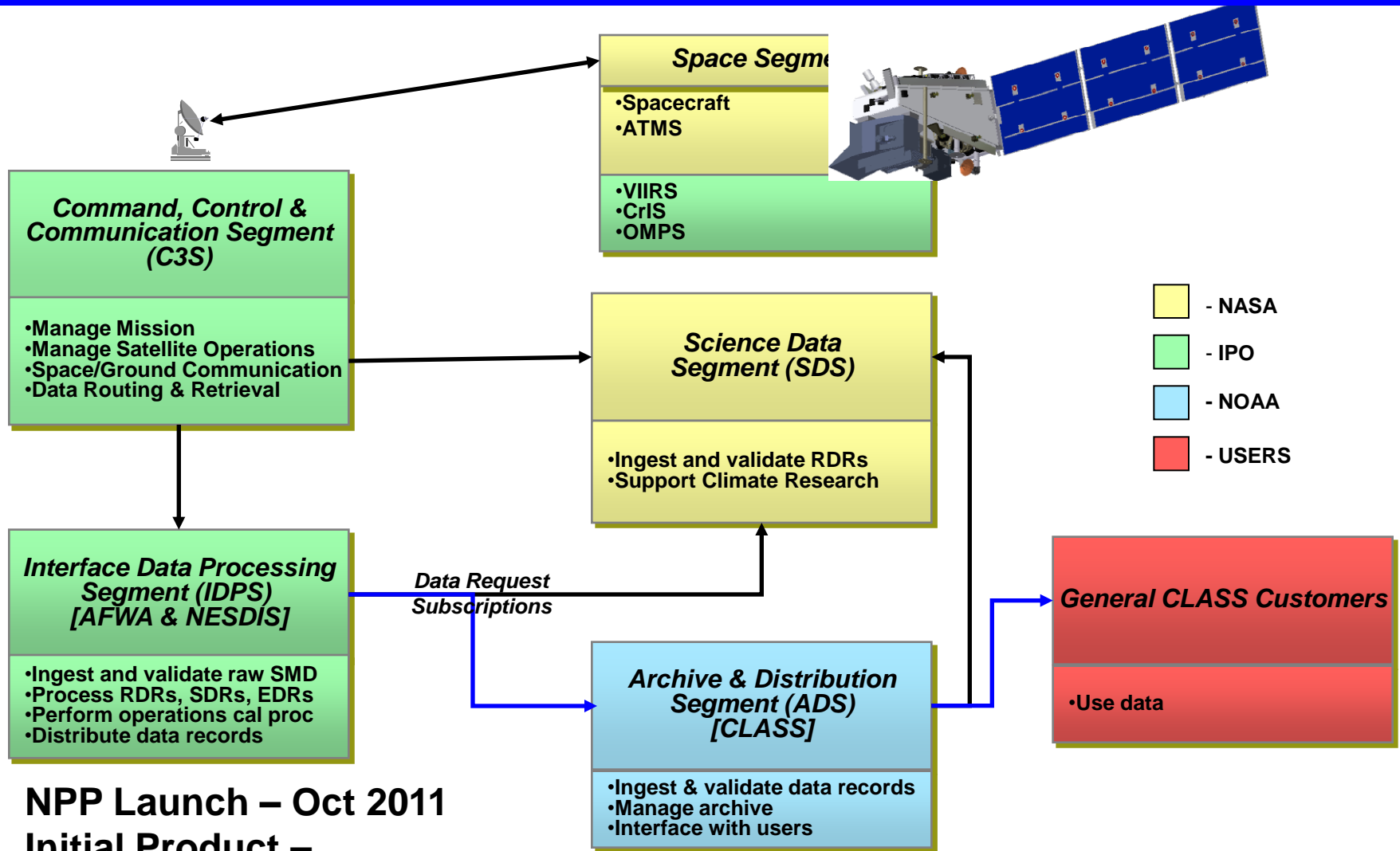
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Working Group: Aerosol Observability
Monterey, CA
April 27-29, 2010

Overview

- NPP Data Products Distribution
- Description of VIIRS Aerosol Products
- VIIRS Aerosol Products are Based on MODIS Heritage
- Impact of VisNIR Optical Crosstalk on the VIIRS Aerosol Products
- VIIRS Cloud Mask (VCM) Algorithm
 - Cloud Detection
 - Differentiation of Heavy Aerosols from Clouds
- Potential Issues for Assimilation of VIIRS Aerosol Products
- Back-up
 - Detailed algorithm description
 - Pre-launch performance predictions

NPP Data Products Distribution



NPP Launch – Oct 2011
Initial Product –
Approximately 3 to 4 months
post launch

VIIRS Aerosol Products

- Aerosol Optical Thickness Environmental Data Record (EDR)
 - AOT is reported at wavelengths from 0.4 to 2.25 microns
 - Quality flags contain information on aerosol model selection including fine mode fraction over ocean
 - Spatial resolution is 6 km at nadir and 9.6 km at EOS (8x8 pixels)
- Aerosol Particle Size Parameter EDR
 - The only VIIRS APSP product is the Angstrom exponent
 - Uses separate wavelength pairs for land and ocean
 - Spatial resolution is 6 km at nadir and 9.6 km at EOS (8x8 pixels)
- Suspended Matter EDR
 - Requires identification and typing of dust, smoke, volcanic ash and sea salt as well as computation of smoke concentration
 - Uses model retrieval from the AOT product and results from volcanic ash tests performed by the VIIRS Cloud Mask
 - Single pixel retrieval (0.75 km resolution at nadir, 1.6 km at EOS)

VIIRS Aerosol Products are Based on MODIS Heritage (Land)



- Aerosol Inversion over Land
 - Based on atmospheric correction used in the MODIS Surface Reflectance algorithm (MOD09 Collection 5)
 - Assumes a constant spectral relationship between 412 nm, 445 nm, 488 nm, 672 nm and 2.25 μm
 - Relationship derived from atmospherically corrected surface reflectance data from global Aeronet sites
 - AOT and aerosol model retrieved at the single pixel level (aggregation to the 8x8 EDR is unique to VIIRS)
 - Five land aerosol models derived from Aeronet size distribution and index of refraction data
 - Model selection is based on best least squares fit to observations
 - VIIRS uses different screening criteria from the MOD09 algorithm
 - Use of the VIIRS Cloud Mask (VCM)
 - Look up Tables used to perform inversion are based on VIIRS F1 test data
 - Effective RSRs used to mitigate impact of VisNIR optical crosstalk

VIIRS Aerosol Products are Based on MODIS Heritage (Ocean)



- Aerosol Inversion over Ocean
 - Based on atmospheric correction used in the MODIS Aerosol algorithm (MOD04 Collection 5)
 - TOA reflectance is modeled as the sum of the TOA reflectances from the fine mode and coarse mode aerosols
 - Uses an approximation from the 6S RTM to model the ocean BRDF to atmosphere coupling (VIIRS specific)
 - Four fine mode and five coarse mode aerosol models derived from Aeronet size distribution and index of refraction data
 - Model selection is based on best least squares fit to observations allowing fine mode fraction to vary from 0 to 1
 - VIIRS uses different screening criteria from the MOD04 algorithm
 - Use of the VIIRS Cloud Mask (VCM)
 - Look up Tables used to perform inversion are based on VIIRS F1 test data
 - Effective RSRs used to mitigate impact of VisNIR optical crosstalk

Baseline Performance and Impact of VisNIR Optical Crosstalk on the VIIRS Aerosol Products

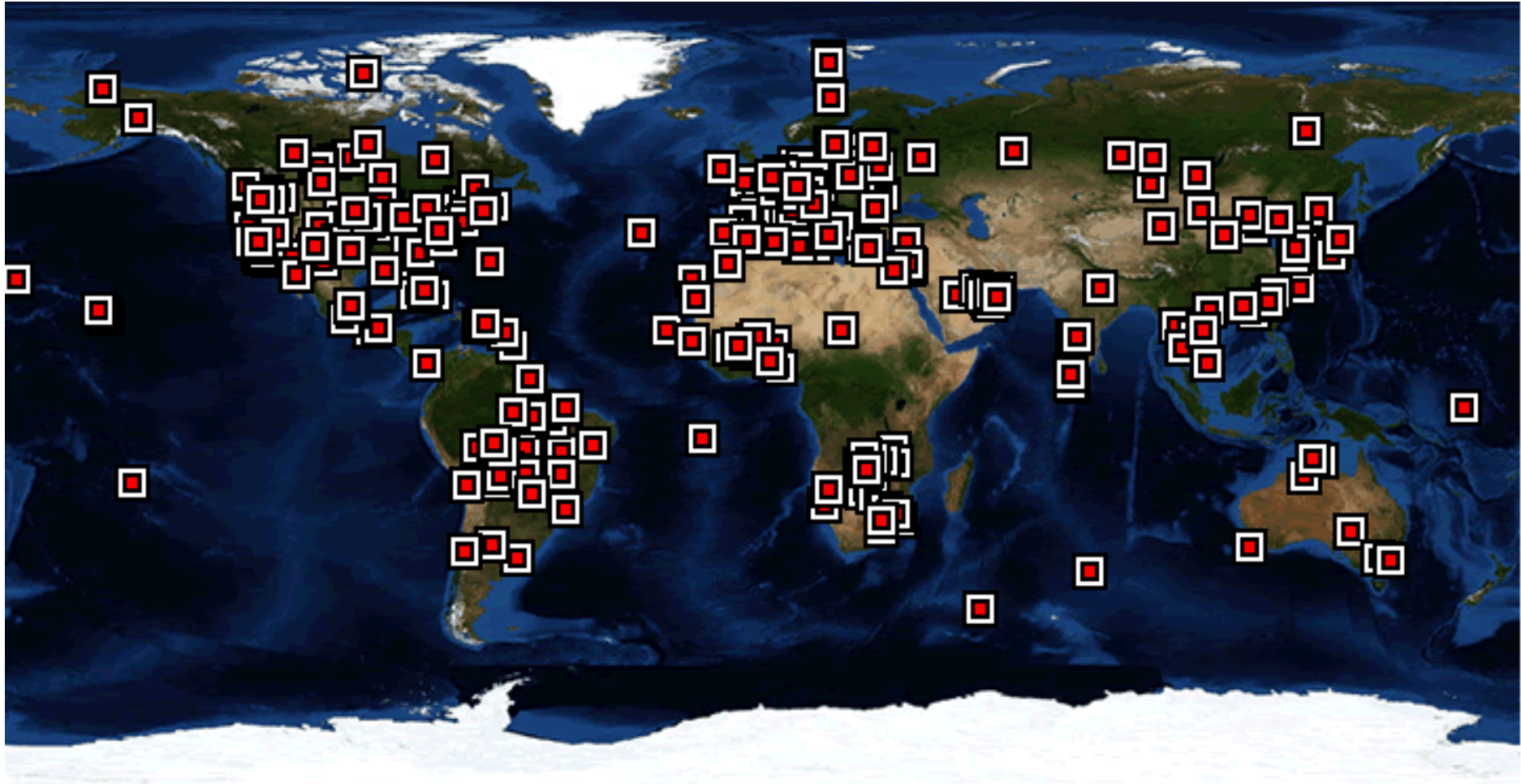
Baseline Performance Evaluated using AERONET Match-up Data



- 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
- Performance results presented
 - 2527 AERONET match-up data point for VIIRS Ocean AOT at 550 nm
 - 455 AERONET match-up data point for VIIRS Ocean Angstrom Exponent ($t > 0.15$)

AERONET Match-up Data

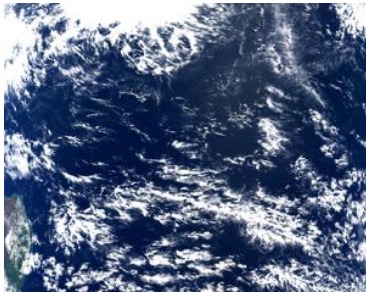
AERONET Locations



Assumptions and Limitations of Crosstalk Analysis

- Aerosol product estimated performance predictions without crosstalk are based on the methodology shown on slide 8
 - Performance of AOT and Angstrom Exponent was computed by comparison of VIIRS algorithm results (using MODIS L1B data as input) with AERONET match-up data
 - Approximately 300 / 5600 match-up data points over land / ocean
 - Used MODIS validation methodology (Remer et. al. 2005)
- Crosstalk induced aerosol product performance degradations are computed using high quality retrievals from eleven MODIS granules
 - Crosstalk map version F1_RO2b_RS1a_RD1
 - Derived from VIIRS TVAC Test Data
 - Impact of both total crosstalk and spatial component of total crosstalk computed
- Crosstalk induced aerosol product performance degradations are computed assuming VIIRS retrievals without added crosstalk are truth
 - Change in results is assumed to be additional error on the algorithm, uncorrelated with other sources of error
 - Final performance reported on the subsequent charts is computed as original performance RSS'd with delta performance
 - Crosstalk is only one component of the final VIIRS Aerosol error budget
 - It is the largest contributor aside from the inherent algorithm error

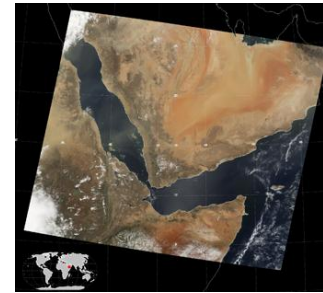
Scenes Run for Crosstalk Analysis



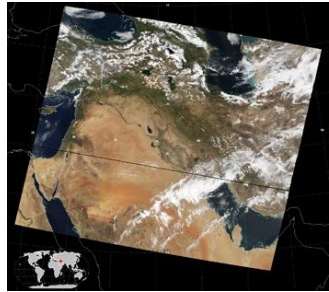
Clouds over Western Atlantic
(2001.213.1220)



Snow over Eastern Siberia
(2002.118.0215)



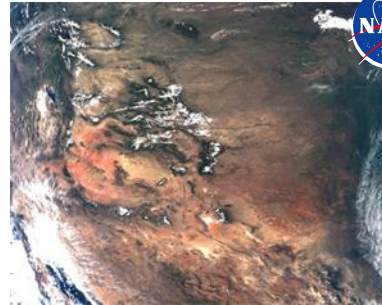
Smoke Over Southern Africa
(2003.151.0735)



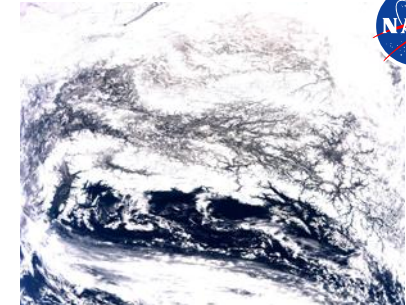
Dust over Red Sea
(2002.121.0750)



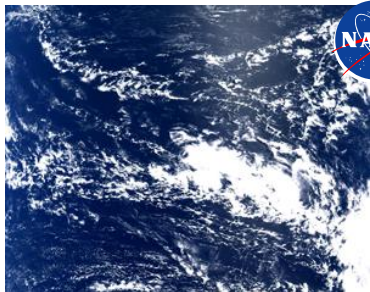
Amazon Basin
(2002.148.1420)



Intermountain – West US
(2002.151.1755)



Gulf of Alaska
(2003..094.2040)



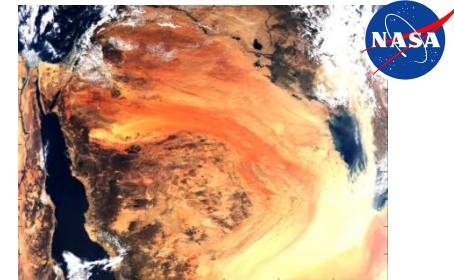
Eastern Pacific
(2003.094.2100)



Eastern Pacific – Hawaii
(2003.033.2355)



Southeastern Africa
(2000.258.0830)



Middle East Dust Storm
(2007.061.1025)

Summary Results: Total Crosstalk over Land

EDR	Parameter	Attribute	Estimated Performance No Crosstalk	Crosstalk F1	VIIRS Spec	IODR Spec	Heritage Performance
AOT	Range		0 to 2 Tau	0 to 2 Tau	0-2 Tau	0-2 Tau	0-1.5 Tau (validated)
AOT	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
AOT	Land AOT at 470 nm	Accuracy	0.054	0.054	N/A	N/A	N/A
AOT	Land AOT at 550 nm	Accuracy	0.055	0.055	N/A	N/A	N/A (0.074)
AOT	Land AOT at 660 nm	Accuracy	0.062	0.062	N/A	N/A	N/A
AOT	Land AOT at 470 nm	Precision	0.139	0.140	0.04+0.1 τ	0.03	N/A
AOT	Land AOT at 550 nm	Precision	0.125	0.127	0.04+0.1 τ (0.064)	0.03	N/A (0.095)
AOT	Land AOT at 660 nm	Precision	0.117	0.119	0.04+0.1 τ	0.03	N/A
AOT	Land AOT at 470 nm	Uncertainty	0.149	0.151	0.05+0.15 τ	N/A	0.05-0.35
AOT	Land AOT at 550 nm	Uncertainty	0.137	0.138	0.05+0.15 τ (0.086)	N/A	0.05-0.35 (0.120)
AOT	Land AOT at 660 nm	Uncertainty	0.132	0.134	0.05+0.15 τ	N/A	0.05-0.35
APSP	Range		"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"
APSP	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
APSP	Land Angstrom Exponent	Accuracy	0.288	0.289	0.6	N/A	N/A
APSP	Land Angstrom Exponent	Precision	0.563	0.572	0.6	0.3	N/A
APSP	Land Angstrom Exponent	Uncertainty	0.632	0.641	N/A	N/A	N/A

The total crosstalk has a minor impact on the land AOT and on the land angstrom exponent.

Summary Results: Spatial Crosstalk over Land

EDR	Parameter	Attribute	Estimated Performance No Crosstalk	Crosstalk F1	VIIRS Spec	IODR Spec	Heritage Performance
AOT	Range		0 to 2 Tau	0 to 2 Tau	0-2 Tau	0-2 Tau	0-1.5 Tau (validated)
AOT	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
AOT	Land AOT at 470 nm	Accuracy	0.054	0.054	N/A	N/A	N/A
AOT	Land AOT at 550 nm	Accuracy	0.055	0.055	N/A	N/A	N/A (0.074)
AOT	Land AOT at 660 nm	Accuracy	0.062	0.062	N/A	N/A	N/A
AOT	Land AOT at 470 nm	Precision	0.139	0.140	0.04+0.1 τ	0.03	N/A
AOT	Land AOT at 550 nm	Precision	0.125	0.126	0.04+0.1 τ (0.064)	0.03	N/A (0.095)
AOT	Land AOT at 660 nm	Precision	0.117	0.118	0.04+0.1 τ	0.03	N/A
AOT	Land AOT at 470 nm	Uncertainty	0.149	0.150	0.05+0.15 τ	N/A	0.05-0.35
AOT	Land AOT at 550 nm	Uncertainty	0.137	0.137	0.05+0.15 τ (0.086)	N/A	0.05-0.35 (0.120)
AOT	Land AOT at 660 nm	Uncertainty	0.132	0.133	0.05+0.15 τ	N/A	0.05-0.35
APSP	Range		"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"
APSP	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
APSP	Land Angstrom Exponent	Accuracy	0.288	0.288	0.6	N/A	N/A
APSP	Land Angstrom Exponent	Precision	0.563	0.568	0.6	0.3	N/A
APSP	Land Angstrom Exponent	Uncertainty	0.632	0.637	N/A	N/A	N/A

The spatial component of crosstalk has a minor impact on the land AOT and on the land angstrom exponent.

Summary Results: Total Crosstalk over Ocean

EDR	Parameter	Attribute	Estimated Performance No Crosstalk	Crosstalk F1	VIIRS Spec	IORD Spec	Heritage Performance
AOT	Range		0 to 2 Tau	0 to 2 Tau	0-2 Tau	0-2 Tau	0-1.5 Tau (validated)
AOT	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
AOT	Ocean AOT at 550 nm	Accuracy	0.008	0.009	N/A	0.03	N/A (0.011)
AOT	Ocean AOT at 660 nm	Accuracy	0.008	0.008	N/A	0.03	N/A
AOT	Ocean AOT at 870 nm	Accuracy	0.008	0.008	N/A	0.03	N/A
AOT	Ocean AOT at 550 nm	Precision	0.055	0.055	0.02+0.03 τ (0.025)	0.03	N/A (0.056)
AOT	Ocean AOT at 660 nm	Precision	0.055	0.055	0.02+0.03 τ	0.03	N/A
AOT	Ocean AOT at 870 nm	Precision	0.055	0.055	0.02+0.03 τ	0.03	N/A
AOT	Ocean AOT at 550 nm	Uncertainty	0.056	0.056	0.03+0.05 τ (0.038)	0.04	0.03-0.13 (0.062)
AOT	Ocean AOT at 660 nm	Uncertainty	0.056	0.056	0.03+0.05 τ	0.04	0.03-0.13
AOT	Ocean AOT at 870 nm	Uncertainty	0.056	0.056	0.03+0.05 τ	0.04	0.03-0.13
APSP	Range		"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"
APSP	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
APSP	Ocean Angstrom Exponent	Accuracy	0.090	0.090	0.3	0.3	N/A
APSP	Ocean Angstrom Exponent	Precision	0.330	0.338	0.3	0.3	N/A
APSP	Ocean Angstrom Exponent	Uncertainty	0.342	0.349	N/A	N/A	0.11 (effective radius)

The total crosstalk has a negligible impact on the ocean AOT and a minor impact on the ocean angstrom exponent.

Summary Results: Spatial Crosstalk over Ocean

EDR	Parameter	Attribute	Estimated Performance No Crosstalk	Crosstalk F1	VIIRS Spec	IORC Spec	Heritage Performance
AOT	Range		0 to 2 Tau	0 to 2 Tau	0-2 Tau	0-2 Tau	0-1.5 Tau (validated)
AOT	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
AOT	Ocean AOT at 550 nm	Accuracy	0.008	0.008	N/A	0.03	N/A (0.011)
AOT	Ocean AOT at 660 nm	Accuracy	0.008	0.008	N/A	0.03	N/A
AOT	Ocean AOT at 870 nm	Accuracy	0.008	0.008	N/A	0.03	N/A
AOT	Ocean AOT at 550 nm	Precision	0.055	0.055	0.02+0.03 τ (0.025)	0.03	N/A (0.056)
AOT	Ocean AOT at 660 nm	Precision	0.055	0.055	0.02+0.03 τ	0.03	N/A
AOT	Ocean AOT at 870 nm	Precision	0.055	0.055	0.02+0.03 τ	0.03	N/A
AOT	Ocean AOT at 550 nm	Uncertainty	0.056	0.056	0.03+0.05 τ (0.038)	0.04	0.03-0.13 (0.062)
AOT	Ocean AOT at 660 nm	Uncertainty	0.056	0.056	0.03+0.05 τ	0.04	0.03-0.13
AOT	Ocean AOT at 870 nm	Uncertainty	0.056	0.056	0.03+0.05 τ	0.04	0.03-0.13
APSP	Range		"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"	"-1 to 3 Alpha"
APSP	HCS		6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	6 km (Nadir) 12.8 km (EOS)	10 km (Nadir)	10 km (Nadir) 40 km (EOS)
APSP	Ocean Angstrom Exponent	Accuracy	0.090	0.090	0.3	0.3	N/A
APSP	Ocean Angstrom Exponent	Precision	0.330	0.332	0.3	0.3	N/A
APSP	Ocean Angstrom Exponent	Uncertainty	0.342	0.344	N/A	N/A	0.11 (effective radius)

The spatial component of crosstalk has a negligible impact on the ocean AOT and a minor impact on the ocean angstrom exponent.

Conclusions

- Minimal impact to the Aerosol Optical Thickness over land
- Minimal impact to the Angstrom Exponent over land
- Negligible impact to the Aerosol Optical Thickness over ocean
- Minimal impact to the Angstrom Exponent over ocean
- Use of effective RSR will reduce impact slightly

VIIRS Cloud Mask (VCM) Algorithm

VIIRS Cloud Mask IP Overview



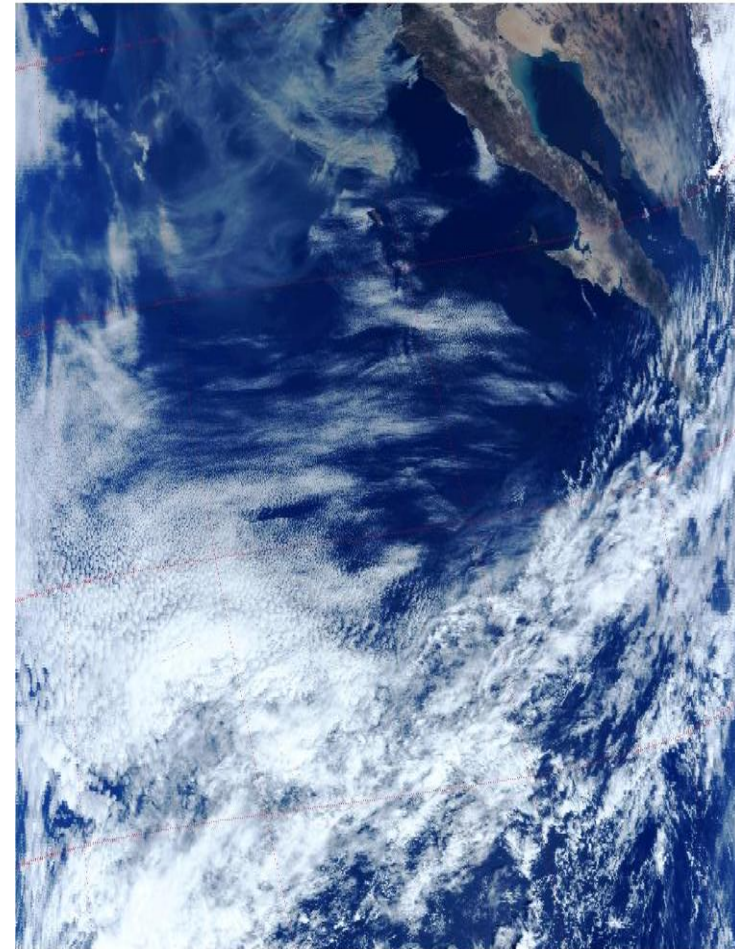
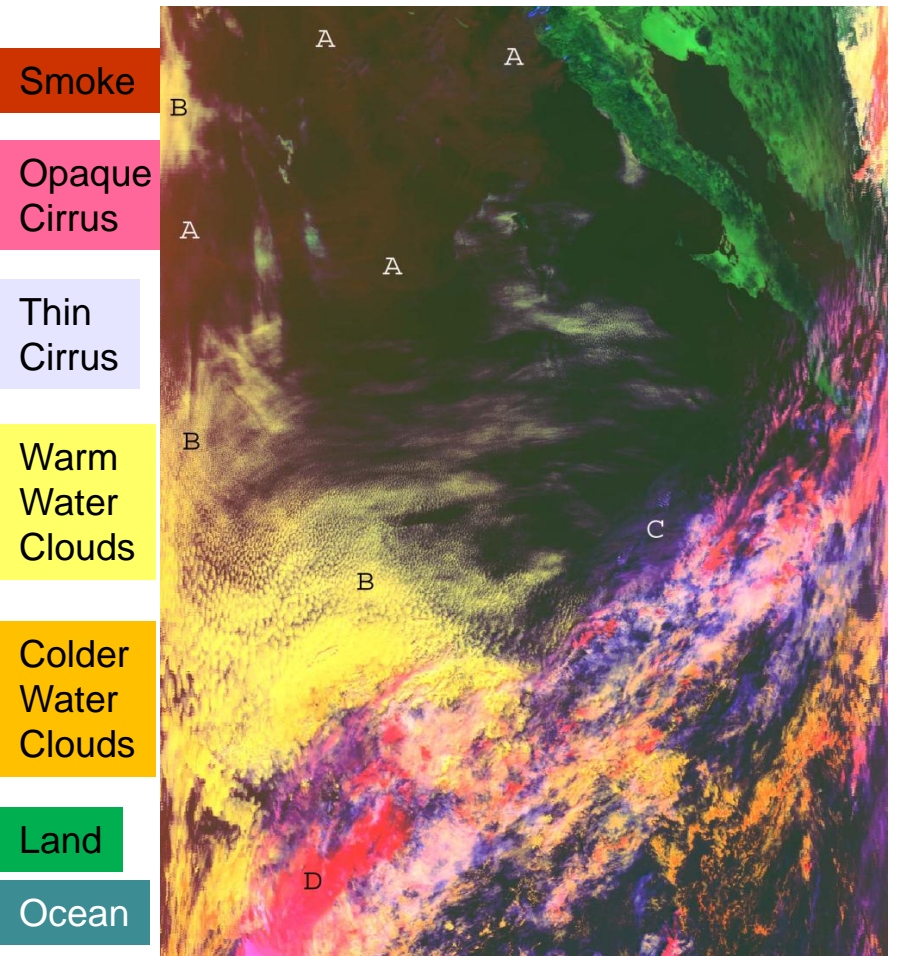
- EDR Definition - NPP System Specification, Appendix D Sec. 40.4.2
 - “A VIIRS Cloud Mask (VCM) is produced and used in the processing of many EDRs, which classifies pixels as Confidently Clear, Confidently Cloudy, Probably Clear, and Probably Cloudy. A Binary Cloud Map is included as a subset of the VCM, comprising only those pixels that are Confidently Cloudy or Confidently Clear.”
- EDR Highlights
 - Forms the beginning of the NPP VIIRS algorithm processing chain, after Active Fire Mask
 - Used in production of all remaining VIIRS EDRs
 - Uses a majority of VIIRS M-bands and I-bands
 - Applies a series of multi-spectral tests tailored to detect different types of clouds
 - Strong MODIS (MOD35) heritage – but with many enhancements

VIIRS Cloud Mask IP Overview - Enhancements



- Exploits VIIRS Unique Sensor Data;
 - Uses I-bands to detect sub-pixel clouds pixels that would impact Ocean (SST and OCC) EDRs
 - Spatial tests applied to all confidently/probably clear pixels
 - Daytime: I2 (water cloud edges) and I5 (ice cloud edges)
 - Nighttime: I4 (water cloud edges) and I5
 - Exploits 412-nm band (M1) to detect clouds over deserts and to discriminate between clouds and heavy aerosols
- Applies Variable Cloud Detection Thresholds over Land
- Allows Surface Conditions to Vary with Season, e.g. TOC NDVI
- Enhances in Cloud Top Phase Classifications, i.e. Including Three Types of Ice Clouds: Thin, Opaque, and Overlap Cirrus
- Projects Shadows using a Geometrically-Based Algorithm
- Identifies Ephemeral Water for Aerosols using I1 and I2 bands

VCM Cloud Confidence and Heavy Aerosol Image



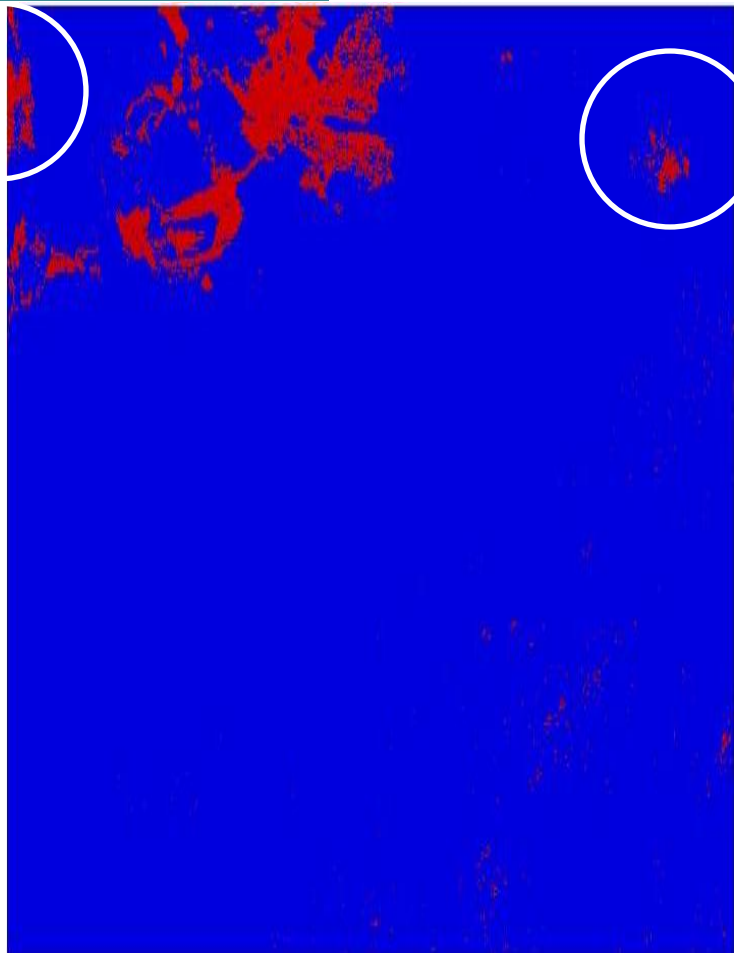
MODIS MOD.2003.299.1840

RGB (0.41- μm ; 1.6- μm ; 11.0- μm - 12.0- μm)

True Color

Quantitative Cloud Confidence & Qualitative Aerosol Flag

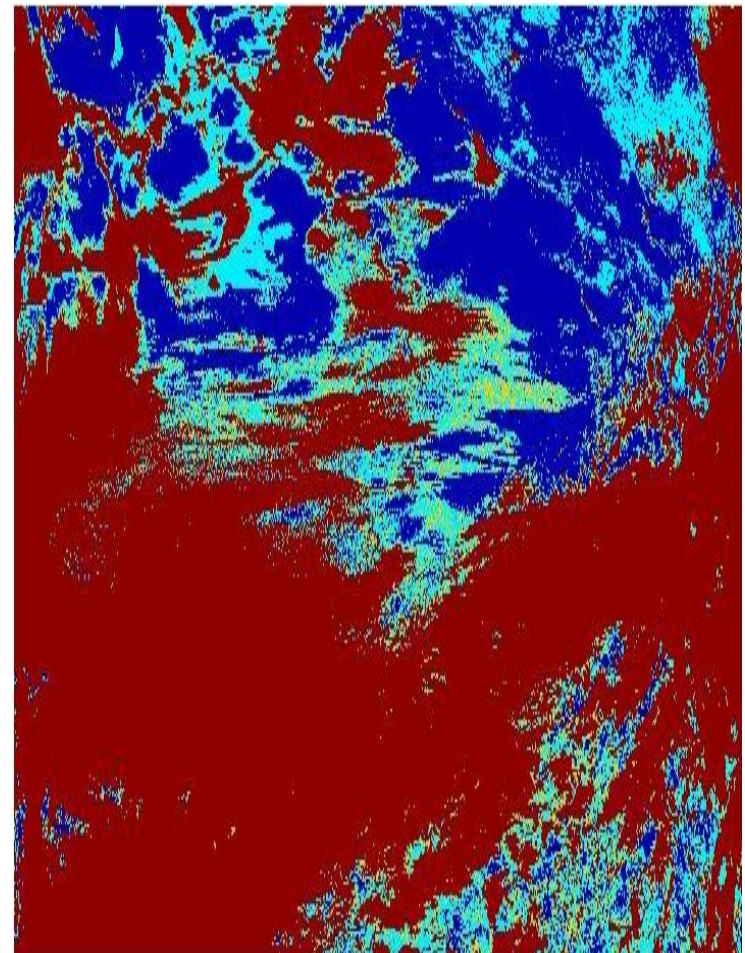
Smoke over clouds



Land

Heavy Aerosol Flag

Only applied to confidently cloudy pixels



VCM Cloud Confidence

- Confidently Cloud
- Confidently Clear

Potential Issues for Assimilation of VIIRS Aerosol Products



- VIIRS products can be assimilated similar to MODIS
 - Similar coverage (no Deep Blue)
 - Different data format, fields and quality flags
 - VIIRS product is at a higher spatial resolution
- Ocean aerosol products should have fewer issues than land
 - Small levels of residual cloud contamination
 - Three dimensional cloud effects (scattered light)
 - Currently no land based fine mode models over ocean (advected smoke and pollution)
 - Aerosols over clouds may have artificially high optical depths
- Land aerosol products will have issues similar to the current MODIS product but there will be differences
 - Different underlying assumptions about the surface reflectance will mean different regional biases
 - Residual cloud contamination will be larger over land than over ocean even after final VCM tuning
 - Surface feature artifacts are inevitable
- Pay attention to quality flags
 - Medium quality is statistically almost as good as high quality but is more likely to contain artifacts