



2014 STAR JPSS Science Team Annual Meeting

VIIRS Aerosol EDR

Shobha Kondragunta and Istvan Laszlo

VIIRS Aerosol co-Leads

May 13, 2014





Outline



- Aerosol Cal/Val Team
- VIIRS AOT, APSP and SM
 - IDPS algorithms
 - products
 - requirements
 - data quality
 - future plans
 - alternative algorithms



VIIRS Aerosol Cal/Val Team



Name	Organization	Major Task
Kurt F. Brueske	IIS/Raytheon	Code testing support within IDPS
Bigyani Das	IMSG/NOAA	Algorithm integration
Ashley N. Griffin	PRAXIS, INC/NASA	JAM
Brent Holben	NASA/GSFC	AERONET observations for validation work
Robert Holz	UW/CIMSS	Product validation and science team support
Ho-Chun Huang	UMD/CICS	SM algorithm development and validation
Jingfeng Huang	UMD/CICS	AOT Algorithm development and product validation
Edward J. Hyer	NRL	Product validation, assimilation activities
John M. Jackson	NGAS	VIIRS cal/val activities, liaison to SDR team
Shobha Kondragunta	NOAA/NESDIS	Co-lead
Istvan Laszlo	NOAA/NESDIS	Co-lead
Hongqing Liu	IMSG/NOAA	Visualization, algorithm development, validation
Min M. Oo	UW/CIMSS	Cal/Val with collocated MODIS data
Lorraine A. Remer	UMBC	Algorithm development, ATBD, liason to VCM team
Hai Zhang	IMSG/NOAA	Algorithm coding, validation within IDEA
Stephen Superczynski	IMSG/NOAA	Product evaluation, data management



AEROSOL OPTICAL THICKNESS (AOT) AND AEROSOL PARTICLE SIZE PARAMETER (APSP)



VIIRS AOT Algorithm



- AOT is from cloud-free, daytime VIIRS M-band SRDs over dark surface
- Separate algorithms over land and over ocean

Land

- retrieves AOT and surface reflectances by matching M3/M5 ratio of retrieved surface reflectances with expected ratio
- selects one of five aerosol models that best match retrieved and expected surface reflectances in bands M1, M2, M3, M5, M11

Ocean

- retrieves AOT by matching observed M7 TOA reflectance with calculated reflectance
- selects fine and coarse mode models and their weights out of 2020 combinations of candidate models that best match observed and calculated TOA M5, M6, M7, M8, M10, M11 reflectances

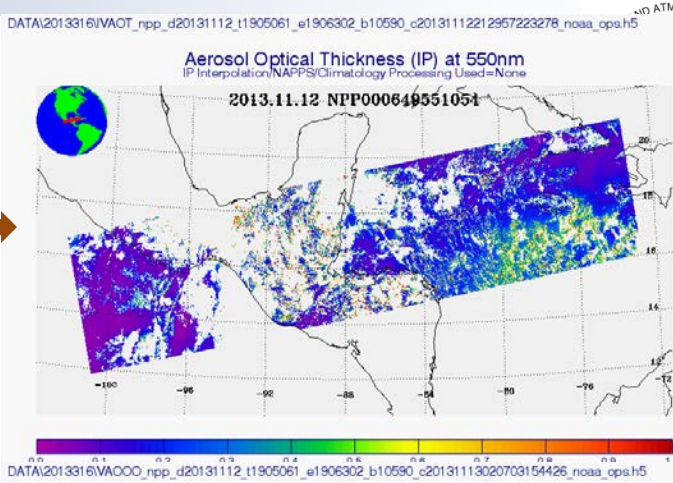
M1: 412, M2: 445, M3: 488, M5: 672, M6: 746, M7: 865, M8: 1,240, M10: 1,610, M11: 2,250 nm



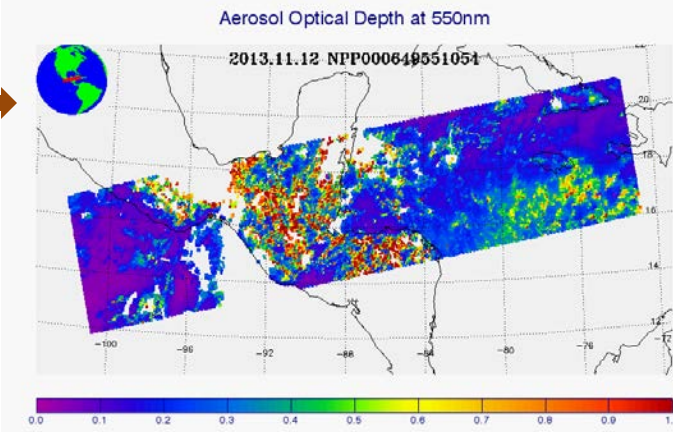
VIIRS Aerosol Products

At NOAA Comprehensive Large Array-data Stewardship System (CLASS):

- **Intermediate Product (IP)**
 - 0.75-km pixel
 - AOT (550 nm); valid range: 0-2
 - APSP from AOTs at M2 (445 nm) and M5 (672 nm) over land, and M7 (865 nm) and M10 (1610 nm) over ocean
 - AMI (Aerosol Model Information)
 - quality flags

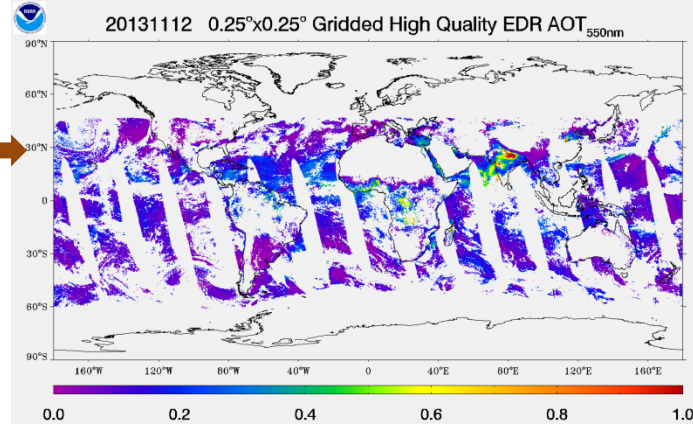


- **Environmental Data Record (EDR)**
 - 6-km cell aggregated from 8x8 IPs filtered by quality flags
 - AOT (10 M bands + 550 nm)
 - APSP (**over-land product is not recommended!**)
 - quality flags
 - 0.75 km
 - SM



At NOAA/NESDIS/STAR

- **Gridded 550-nm AOT EDR**
 - regular equal angle grid: 0.25°x0.25° (~28x28 km)
 - only high quality AOT EDR is used





AOT Product Timeline



Red period: Product is not available to public, or product should not be used.

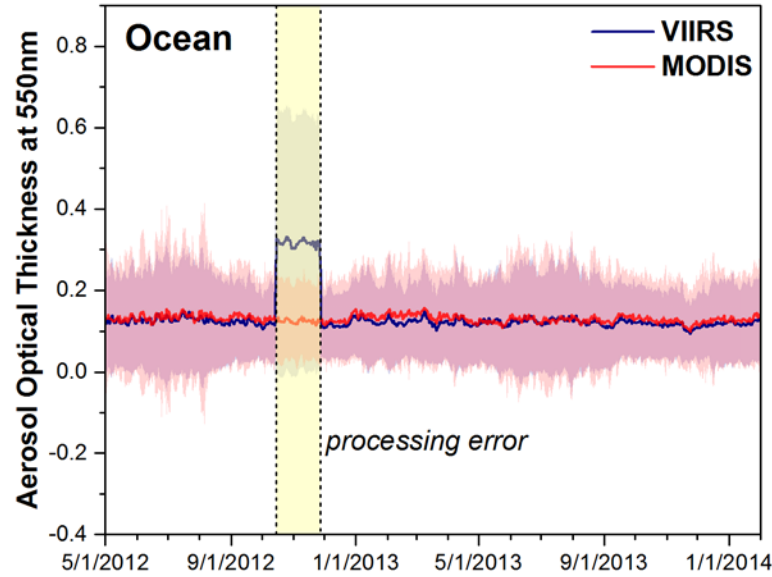
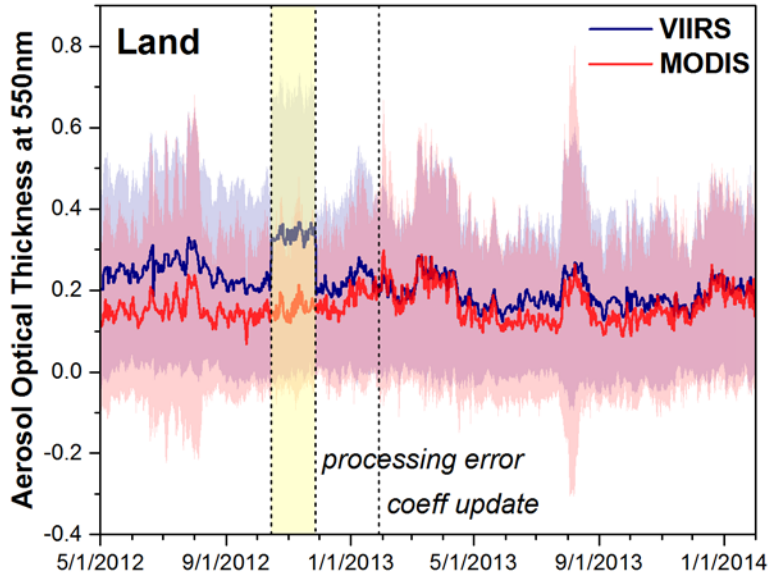
Blue period: Product is available to public, but it should be used with caution, known problems, frequent changes.
(Beta)

Green period: Product is available to public; users are encouraged to evaluate.
(Provisional)

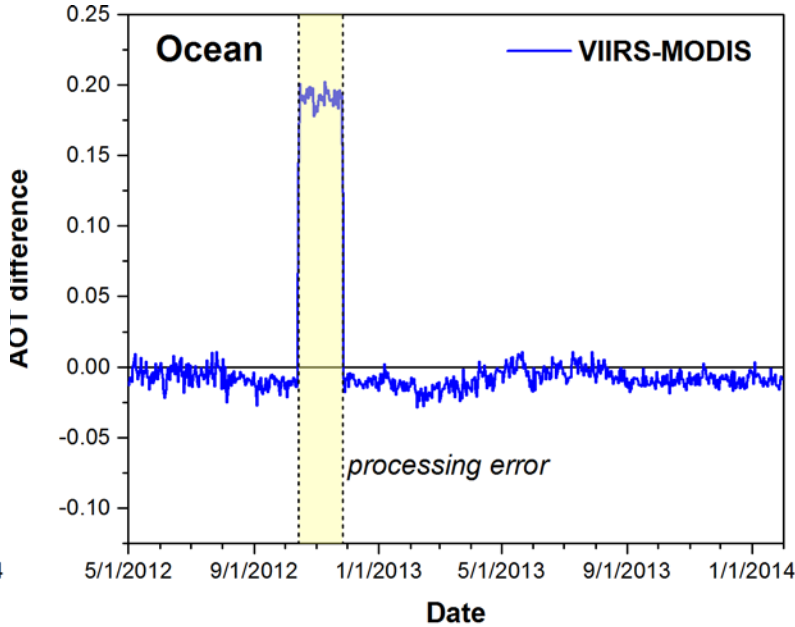
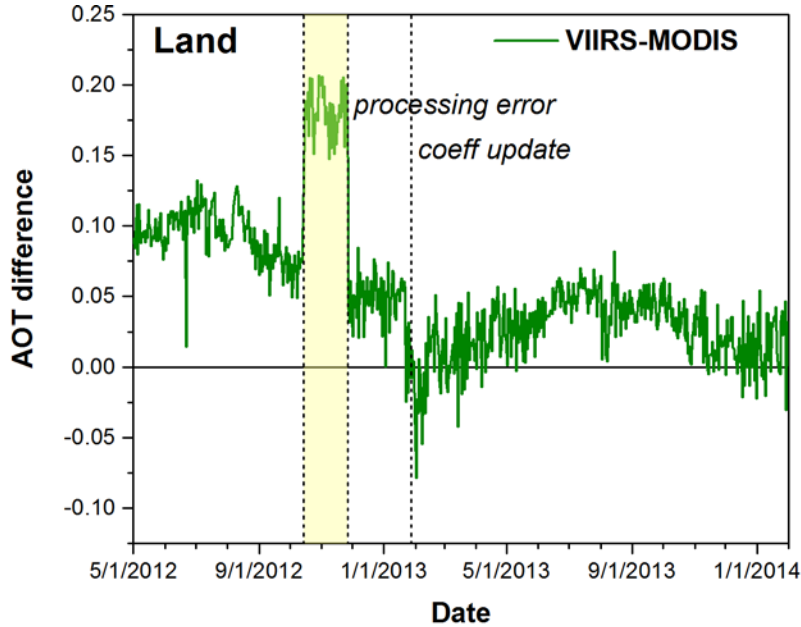
- **No changes to VIIRS aerosol algorithm between Jan 23, 2013 and Feb 20, 2014.**
- **Stable algorithm is needed for evaluation.**



Time Series of Daily Mean Aerosol Products (non-collocated) (05/02/2012 – 01/31/2014)

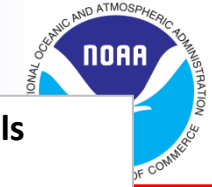


Comparisons with MODIS use MODIS Dark Target Collection 5.1 data





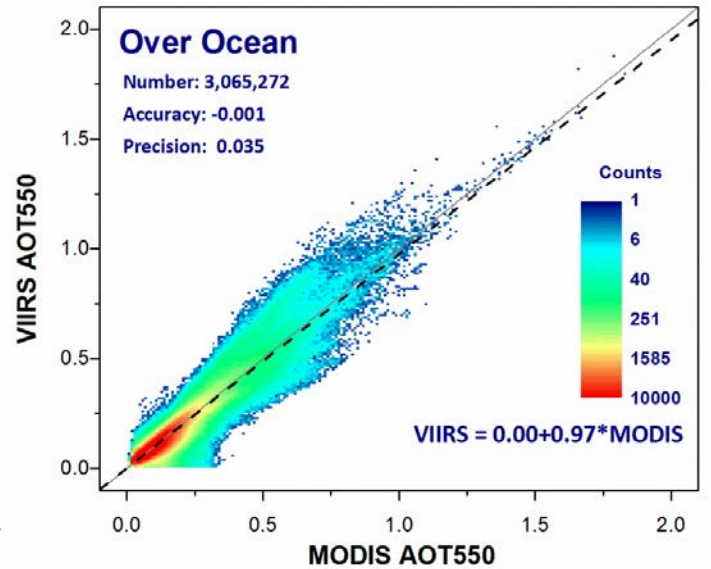
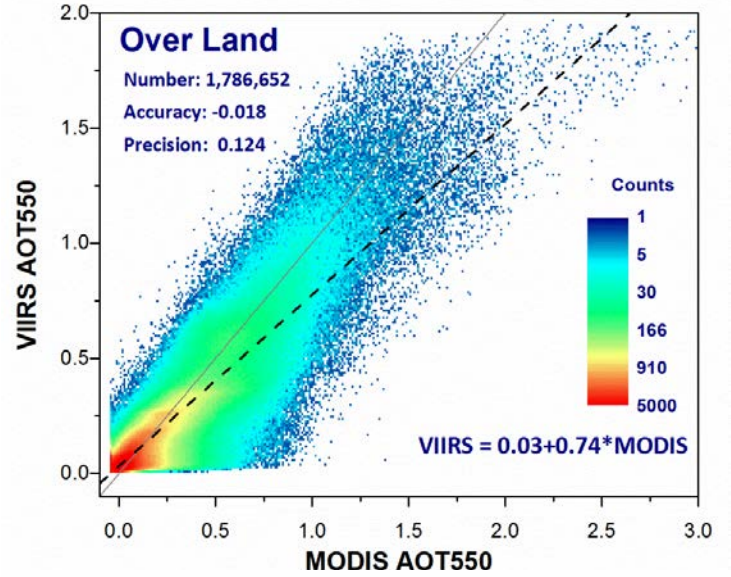
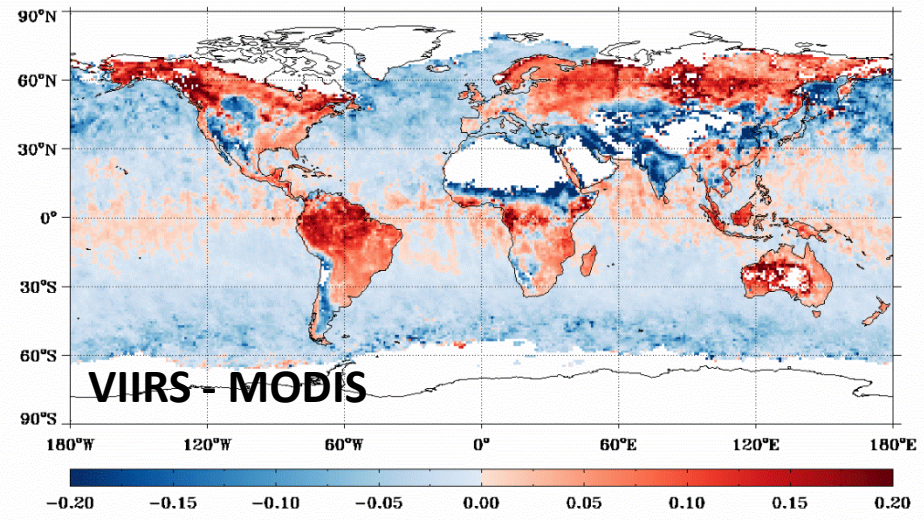
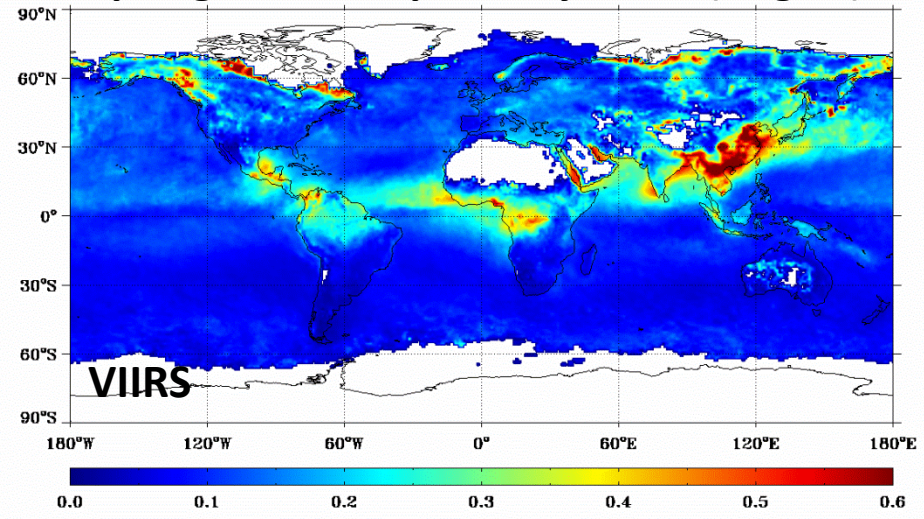
VIIRS vs. MODIS AOT



Comparisons use MODIS Dark Target Collection 5.1 data

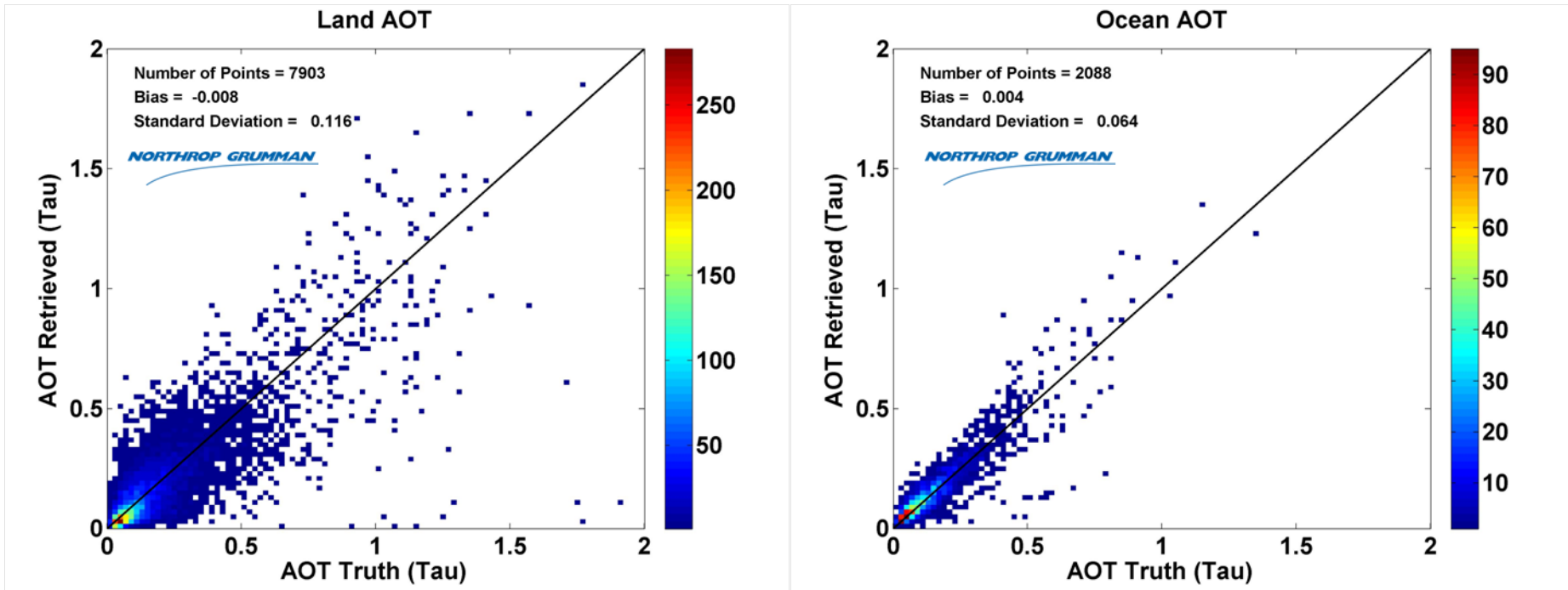
- Collocated VIIRS and MODIS Retrievals
- Over land: 01/23/2013 – 01/31/2014
- Over ocean: 05/02/2012 – 01/31/2014 excluding the processing error period (10/15/2012-11/27/2012)

Spring: March-April-May, 2013 (1° grid)





VIIRS AOT EDR vs. AERONET L1.5 AOT



- Data from the VIIRS Aerosol / AERONET Match-up PGE
- **Period:** May 2, 2012 – December 31, 2013
- **VIIRS: reprocessed using Mx8.2 aerosol code!** (TTO: 02/20/2014)
 - averaged min 25% of high quality AOT in 5x5 EDR cells
- **Truth:** AERONET L1.5 inversion (5/2012–2/2013) + direct sun (from 2/2013)
 - AOT averaged within +/- one hour



VIIRS EDR vs. AERONET L1.5



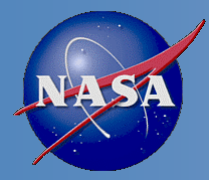
Time period: 05/02/2012 - 12/31/2013; VIIRS data: Mx8.2

LAND	N	ACCURACY		PRECISION	
AOT		Requirement	SNPP/VIIRS	Requirement	SNPP/VIIRS
<0.1	3244	0.060	0.012 ✓	0.150	0.058 ✓
[0.1, 0.8]	4498	0.050	0.016 ✓	0.250	0.117 ✓
>0.8	161	0.200	0.186 ✓	0.450	0.414 ✓
all	7903		-0.008		0.116

OCEAN	N	ACCURACY		PRECISION	
AOT		Requirement	SNPP/VIIRS	Requirement	SNPP/VIIRS
<0.3	1824	0.080	0.007 ✓	0.150	0.041 ✓
≥0.3	264	0.150	0.020 ✓	0.350	0.144 ✓
all	2088		0.004		0.064

OCEAN	N	ACCURACY		PRECISION	
APSP		Requirement	SNPP/VIIRS	Requirement	SNPP/VIIRS
865nm/1610nm	803	0.30	0.02 ✓	0.60	0.37 ✓

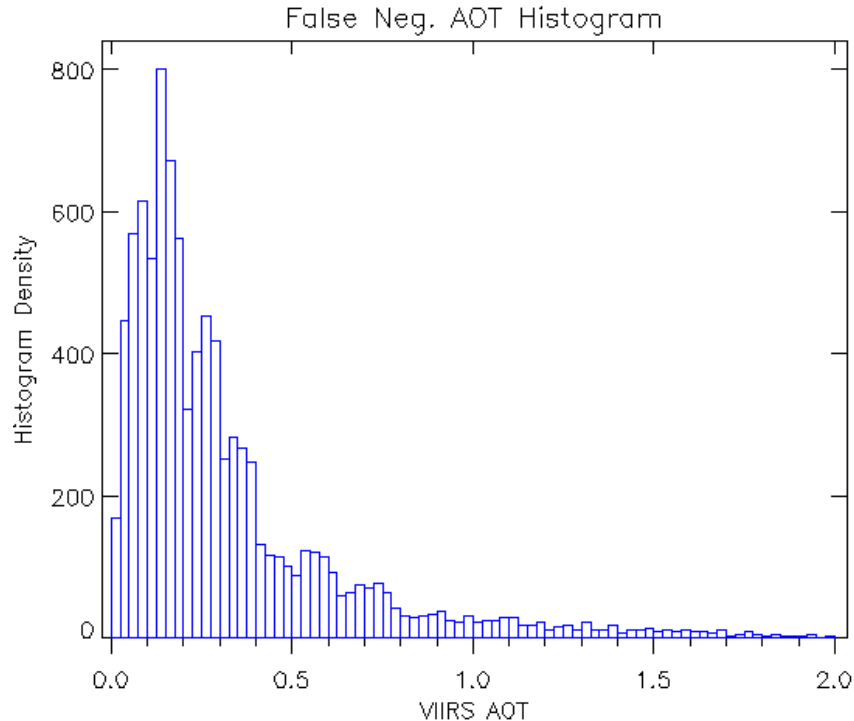
More in posters by Jingfeng Huang et al. and Ho-Chun Huang et al.



Cloud Contamination of VIIRS AOT



VIIRS cloud mask (confidently cloudy/clear) and CALIPSO L2 cloud layer data for Feb-Oct 2013 were matched to within ± 5 minutes.



Feb-Oct 2013		VIIRS	
CALIPSO		Cloudy	Clear
	Cloudy	42055	11422
	Clear	3051	29431

- Mean accuracy of VIIRS cloud mask is 83% but can vary between 79% to 89% depending on the season;
- About 13% of VIIRS pixels reported as “clear” are found to be “cloudy” by CALIPSO;
- VIIRS IP AOT histogram for pixels identified as clear but could be cloudy for February 2013 is shown in the adjacent figure. These retrievals, when included in EDR aggregation, are likely to contaminate EDR AOT; the extent of contamination is under investigation.

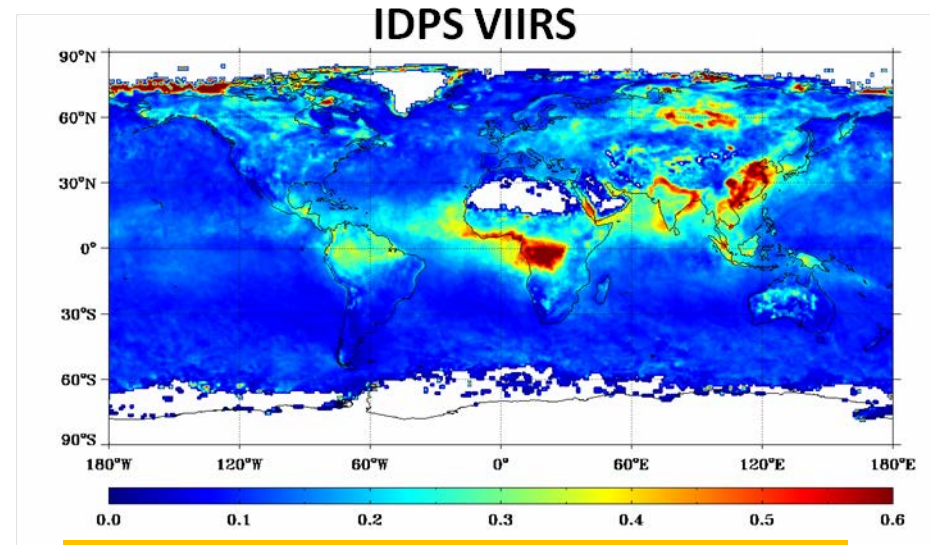
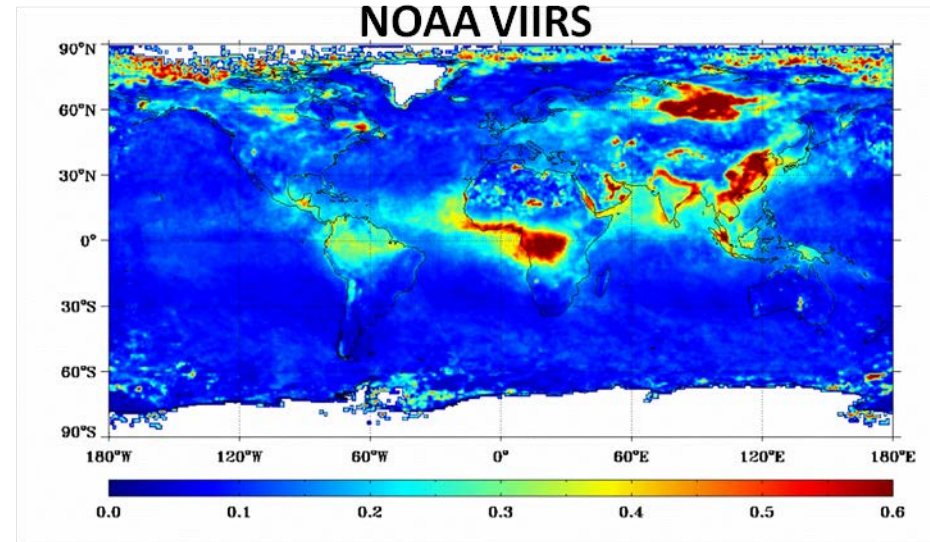


Plans for AOT



- Replace over ocean aerosol models with those more closely matching MODIS models
- Extend AOT range to [-0.05 to 5.00]
- Implement new internal tests to reduce snow/ice and possible residual cloud contamination:
 - Spatial homogeneity filter
 - Spectral filter (e.g., NDSI)
- Continue evaluation of other internal tests (fire, bright pixel, ephemeral water) and update thresholds.
- Develop and test regional, seasonal land surface reflectance ratios (*see poster by Hai Zhang et al.*)
- Extend (in time and scope) evaluation of AOT EDR
- Test/modify NGAS implementation of “deep-blue” retrieval and if needed develop new algorithm, and implement it

- **The JPSS Risk Reduction (RR) (“NOAA VIIRS”) algorithm**
 - *over land*
 - VIIRS-like algorithm; switches to MODIS-like algorithm when VIIRS-like retrieval fails
 - surface reflectance ratios are linear functions of $NDVI_{SWIR}$ and surface redness
 - retrieves over areas where current IDPS algorithm does not retrieve AOT
 - *over ocean*
 - algorithm and aerosol model as in MODIS
 - AOT range [-0.05 to +5.0]
 - AE is from AOTs from independent-channel retrievals
 - **pixel level (750 m) product**



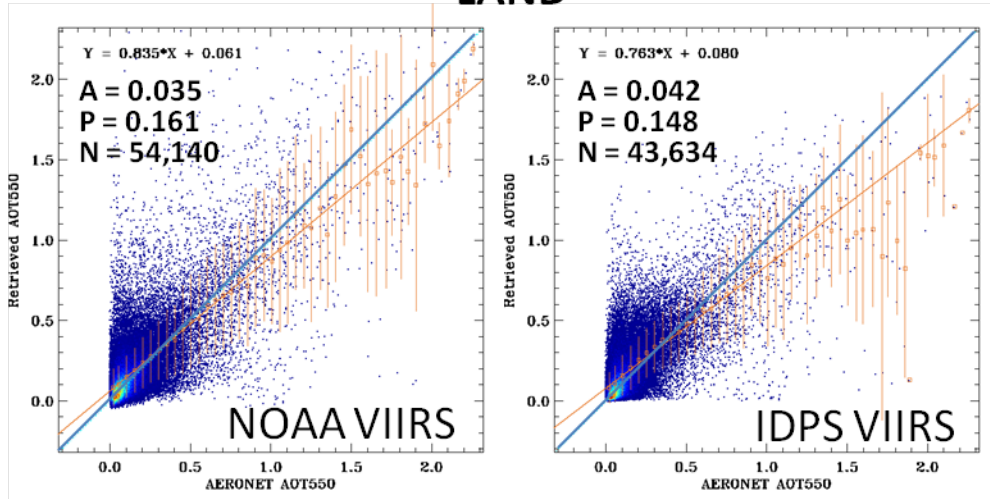
Data: average of every five days between 2013.03.01-2014.03.01; 750-m data



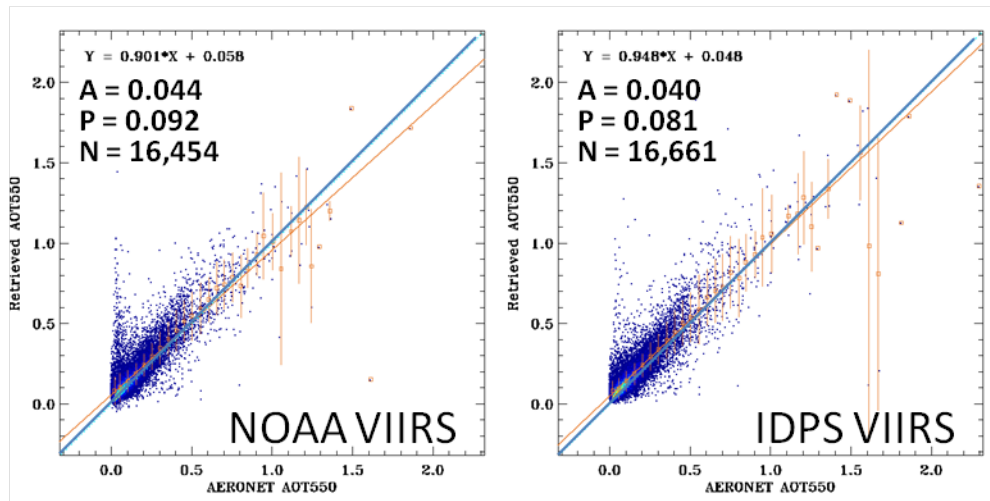
JPSS RR Aerosol Results



LAND



OCEAN



Daily 750-m VIIRS and AERONET
matchup data for
2012.05.02 – 2014.03.31

“First look” results:

- Over land, more retrievals, better overall accuracy, but slightly worse precision.
- Over ocean, comparable accuracy, but slightly worse precision.
- Meets requirements.

Details and more results in talk by
Hongqing Liu in Atmosphere
Breakout on Wednesday at 14:50



Recommendation



- **JPSS RR aerosol algorithm can be an alternative for J1**
- The JPSS RR algorithm already has many updates planned for IDPS aerosol algorithm
 - over land
 - slightly better agreement with AERONET for high AOT values
 - retrievals over areas where current IDPS algorithm does not retrieve AOT
 - over ocean
 - same algorithm and aerosol model as in MODIS
 - meets J1 requirements
 - same algorithm works on VIIRS and ABI
 - **likely needs more adjustments, data filtering; would benefit from more evaluation, and needs consensus from Aerosol Cal/Val Team and users!**



AOT & APSP Summary



- Characterized long term (over a year) record of VIIRS AOT globally and regionally by comparing it similar records from MODIS and AERONET
- VIIRS AOT and APSP (Ångström Exponent) products meet the requirements specified in the Joint Polar Satellite System (JPSS) Program Level 1 Requirements document
- Developed and evaluated new internal tests (for residual cloud, snow/ice) – will be implemented in next version
- **More results and details in Atmosphere Breakout on Wednesday, 14:30-16:10 and in posters!**



SUSPENDED MATTER (SM)



Overview:

Requirements in L1RD Supplement



Product	Threshold	Objective	Notes
SM	Dust, smoke, volcanic ash	Dust, smoke, volcanic ash, sea salt	
Smoke plume	0 to 150 $\mu\text{g}/\text{m}^3$	0 to 200 $\mu\text{g}/\text{m}^3$	
Accuracy			
SM	80%		
Smoke	70%		
Dust	80%		
Ash	60%		Dust can be mis-identified as ash
Mixed Aerosol		80%	Report not only dominant aerosol but other aerosol components as well

Applications

- Exceptional Events (EEs) monitoring (volcanic eruptions, fires, dust storms)
- Assimilation in regional and global aerosol models for daily weather and/or climate predictions
- Operational air quality forecasting

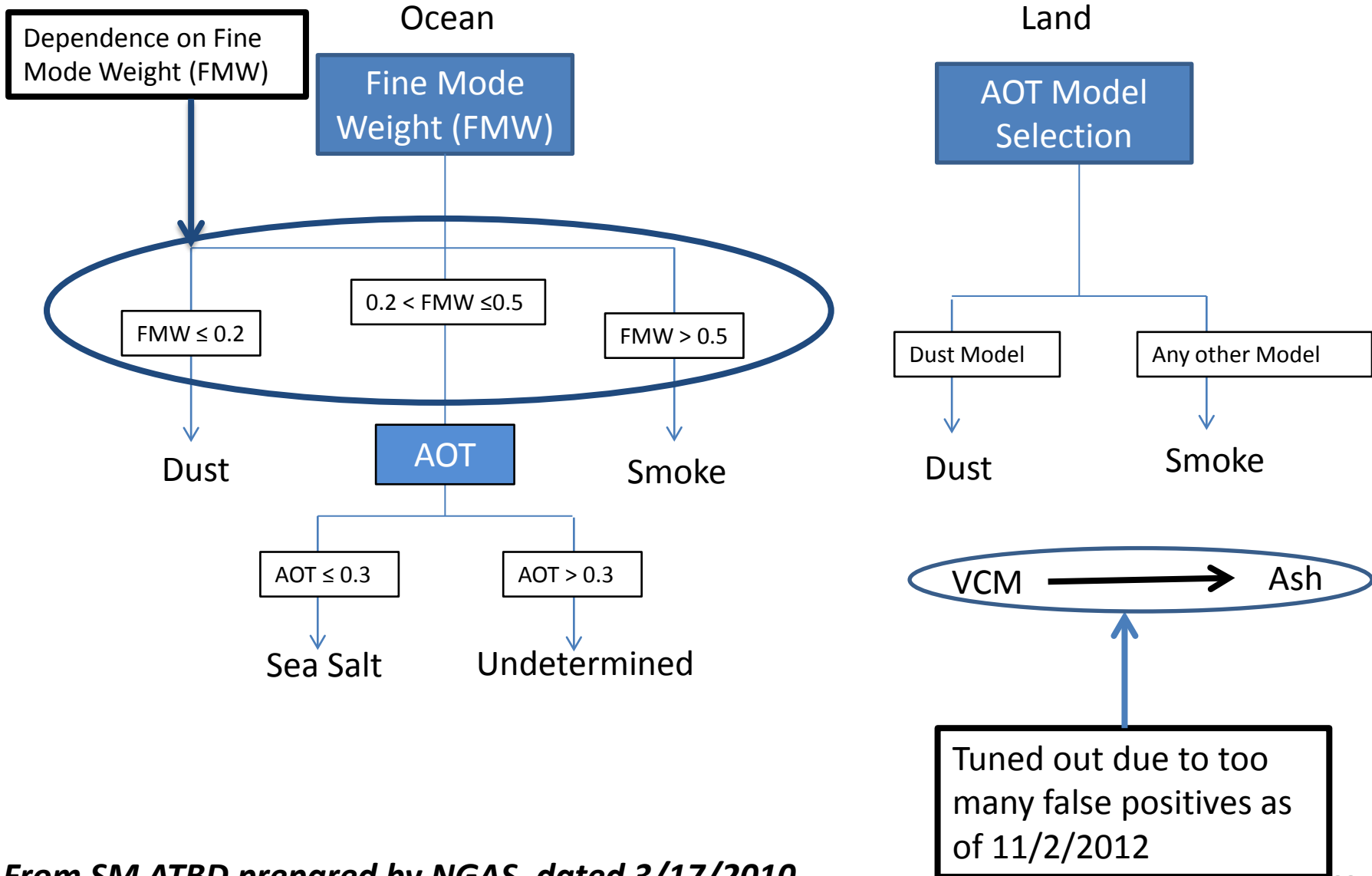
Users

- National Weather Service, Environmental Protection Agency, State and local environmental agencies

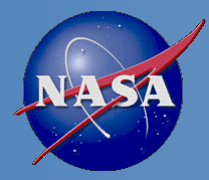


Overview:

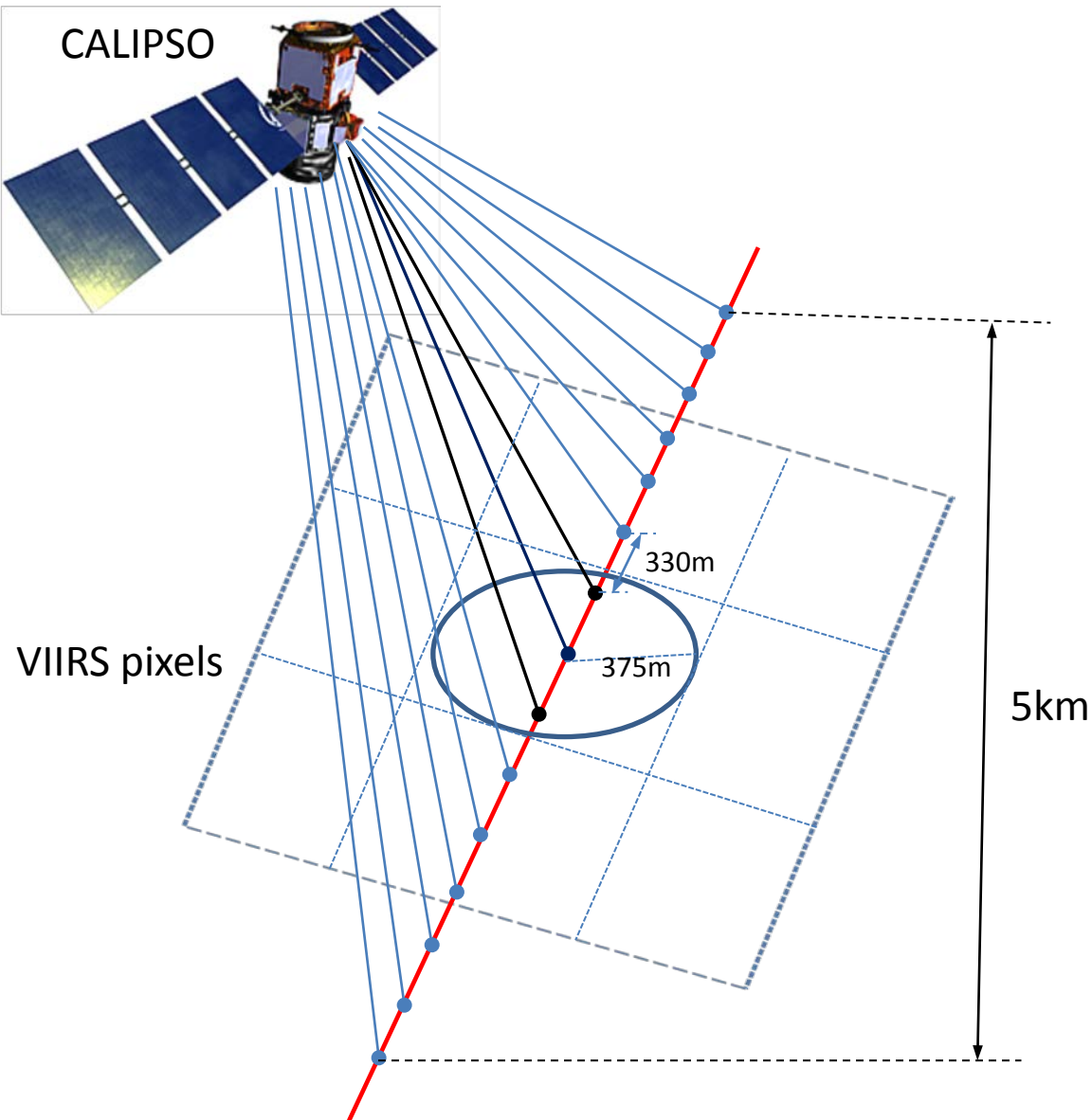
IDPS Suspended Matter Algorithm



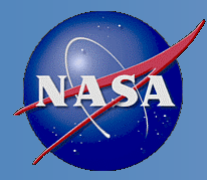
From SM ATBD prepared by NGAS, dated 3/17/2010



SNPP SM Algorithm Evaluation: Validation Approach



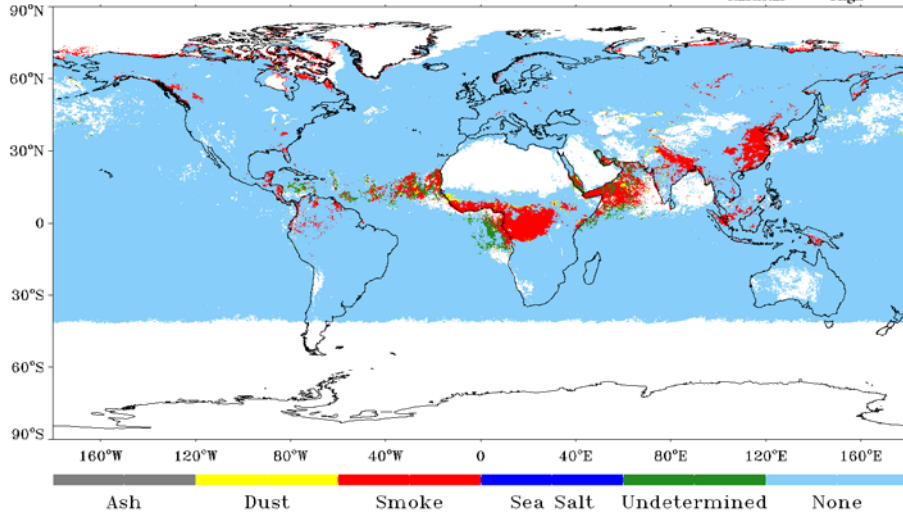
- Qualitative comparison of monthly global maps of VIIRS SM (dominant aerosol type), dust fraction, and smoke fraction to other correlative measurements (CALIPSO, MISR)
- Direct matchups of CALIPSO and VIIRS SM to compute accuracy, probability of detection, and false alarm ratio



SNPP SM Algorithm Evaluation: VIIRS vs. MISR

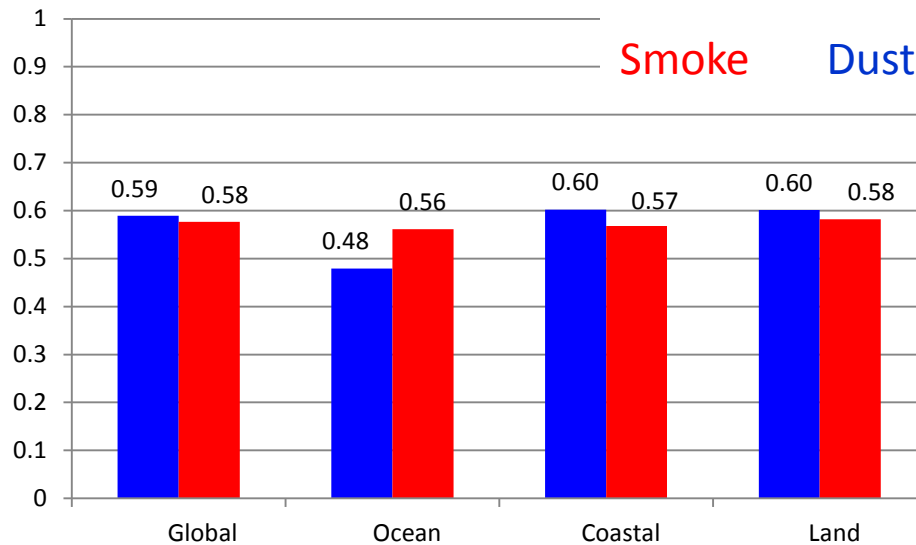


20130601-20130630 VIIRS Dominant SusMatter Type Resol_{0.25x0.25} QF_{High}

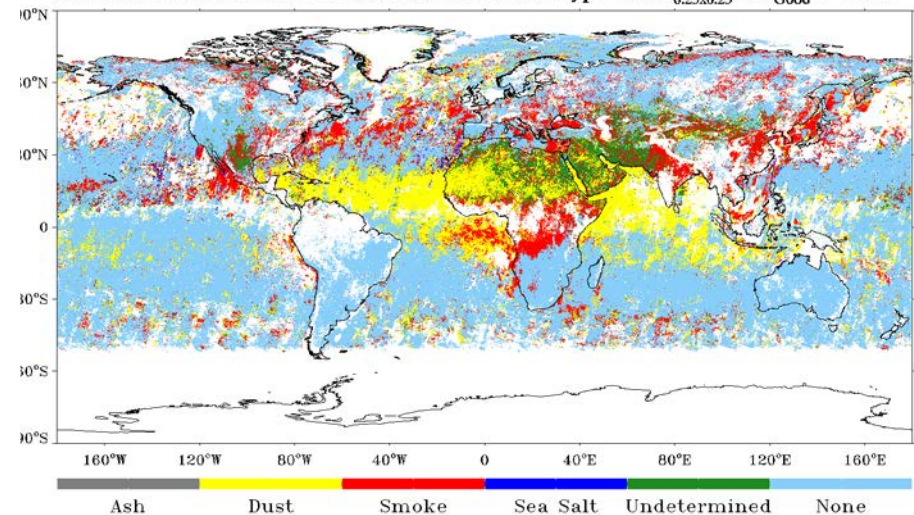


- SM is not a legacy NASA MODIS product
- VIIRS SM algorithm relies on AOT and other internal parameters (**not validated**) to identify and type SM.
- SM product very difficult to evaluate and validate due to non-availability of “truth” dataset. Comparisons with MISR show that VIIRS SM doesn’t identify dust near the source and dust outflow regions (Sahara and Atlantic Ocean)..
- **The VIIRS SM product is not recommended for use in any applications. An alternate algorithm has been developed and is being tested.**

14-month Mean Accuracy



20130601-20130630 MISR Dominant SusMatter Type Resol_{0.25x0.25} QF_{Good} > 50%



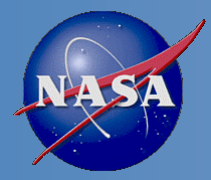


JPSS Risk Reduction Algorithm Development



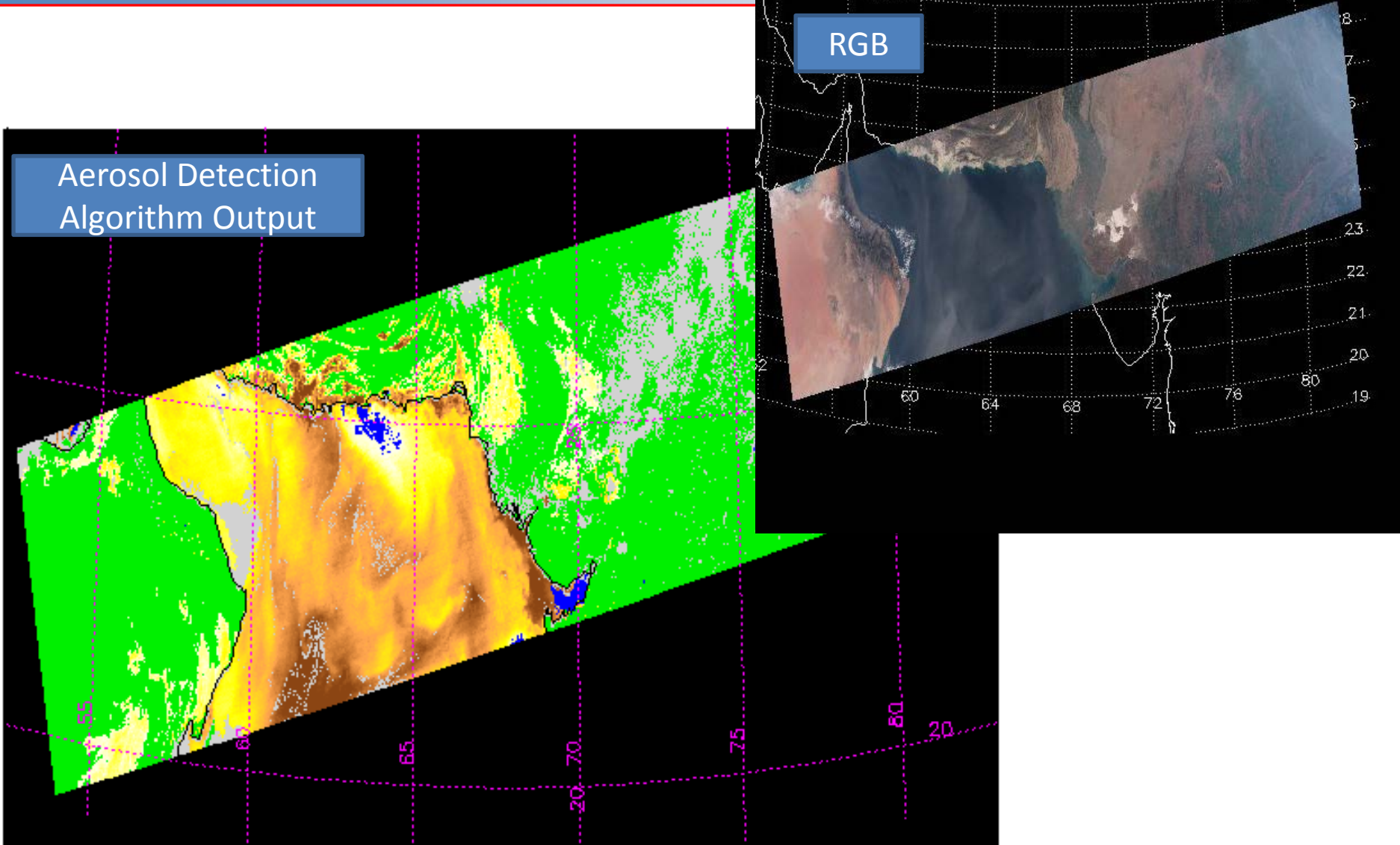
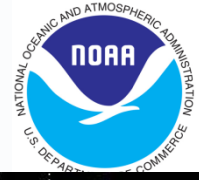
Algorithm details to be presented in tomorrow's
"atmosphere" breakout session by Pubu Ciren

- **Adapt GOES-R ABI aerosol detection (dust and smoke) algorithm to VIIRS**
 - For dust, a slightly different algorithm than the one developed for GOES-R was used to take the advantage of deep blue (412 nm) channel present on VIIRS but will not be present on ABI.
- **Advantages:**
 - Algorithm uses spectral threshold methods and some texture tests for uniformity to separate dust, smoke, and clouds.
 - Algorithm is fast and designed to run in near real-time.
 - Algorithm uses VIIRS blue channels (412 nm and 445nm) that GOES-R ABI will not have.
- **Disadvantages:**
 - Like any algorithm based on thresholds, tuning of thresholds will be needed for changes associated with calibration etc.



JPSS RR Algorithm:

Dust Storm in the Arabian Sea on January 13, 2013



Dust Aerosol Index

Smoke Aerosol Index

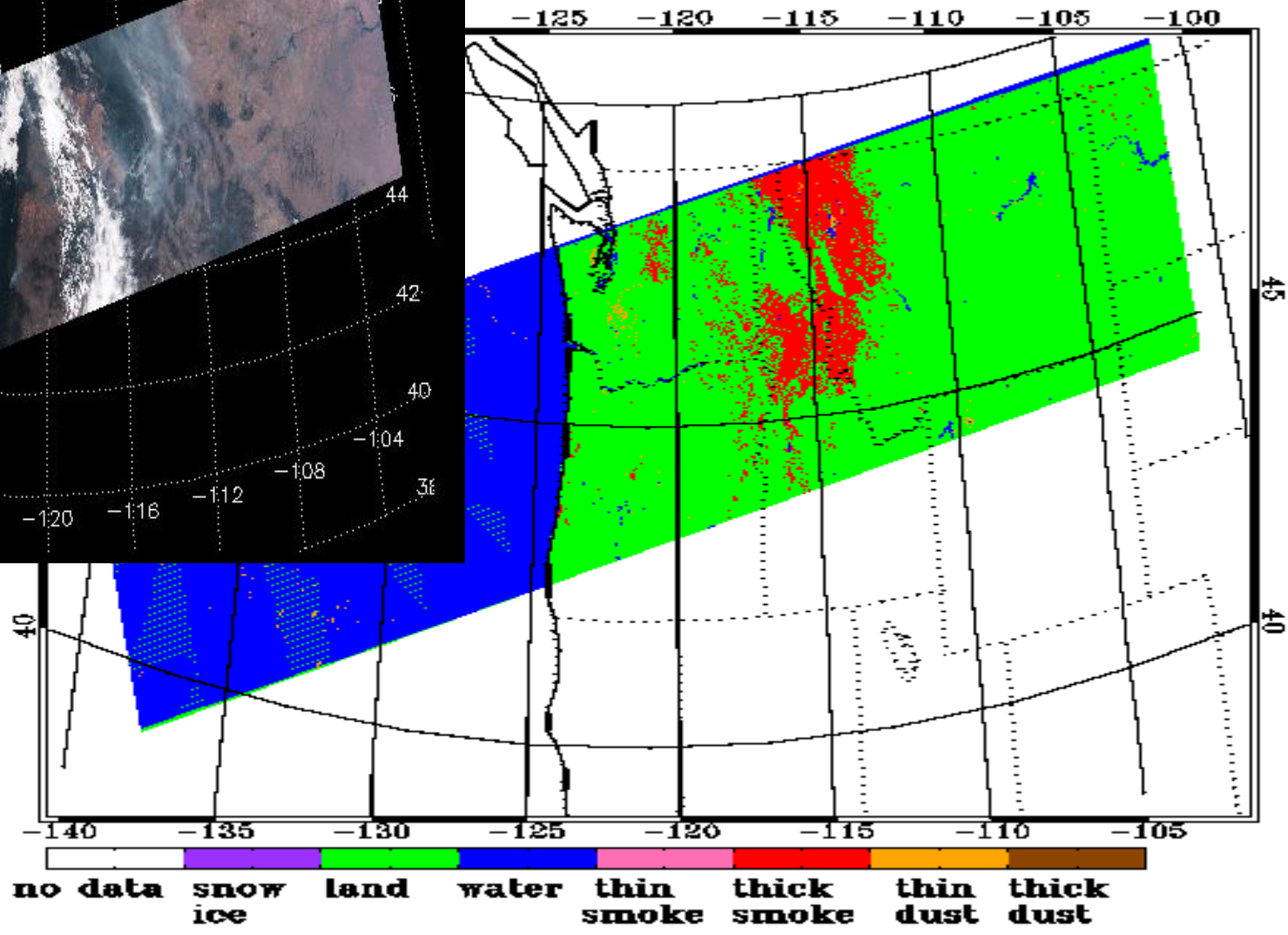
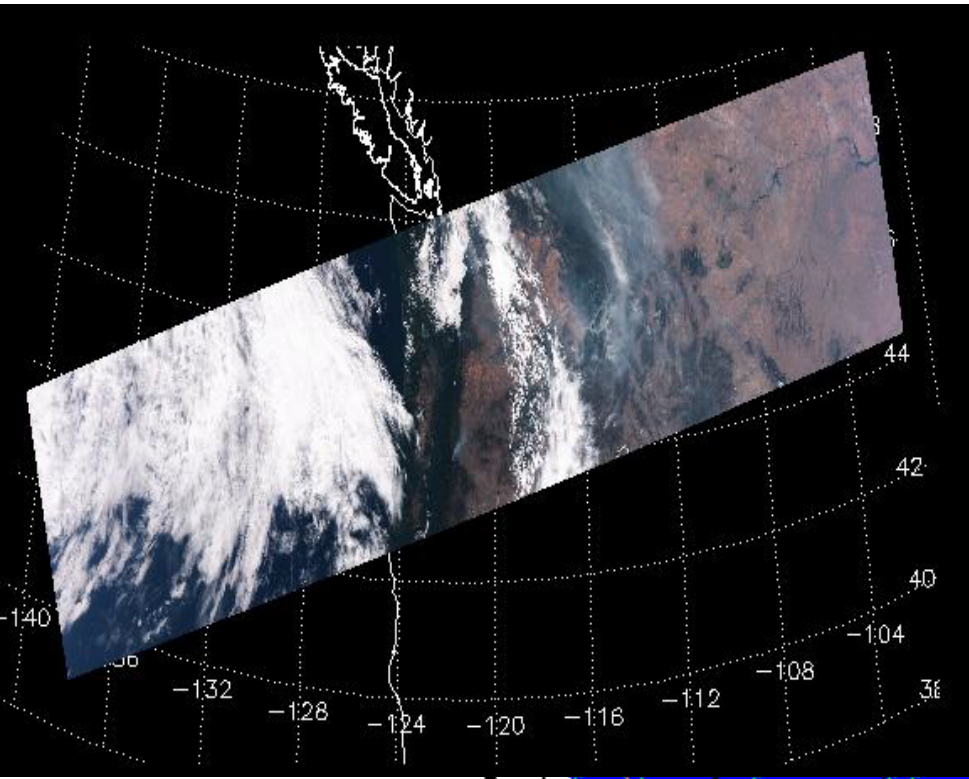
water land clouds



JPSS RR Algorithm:

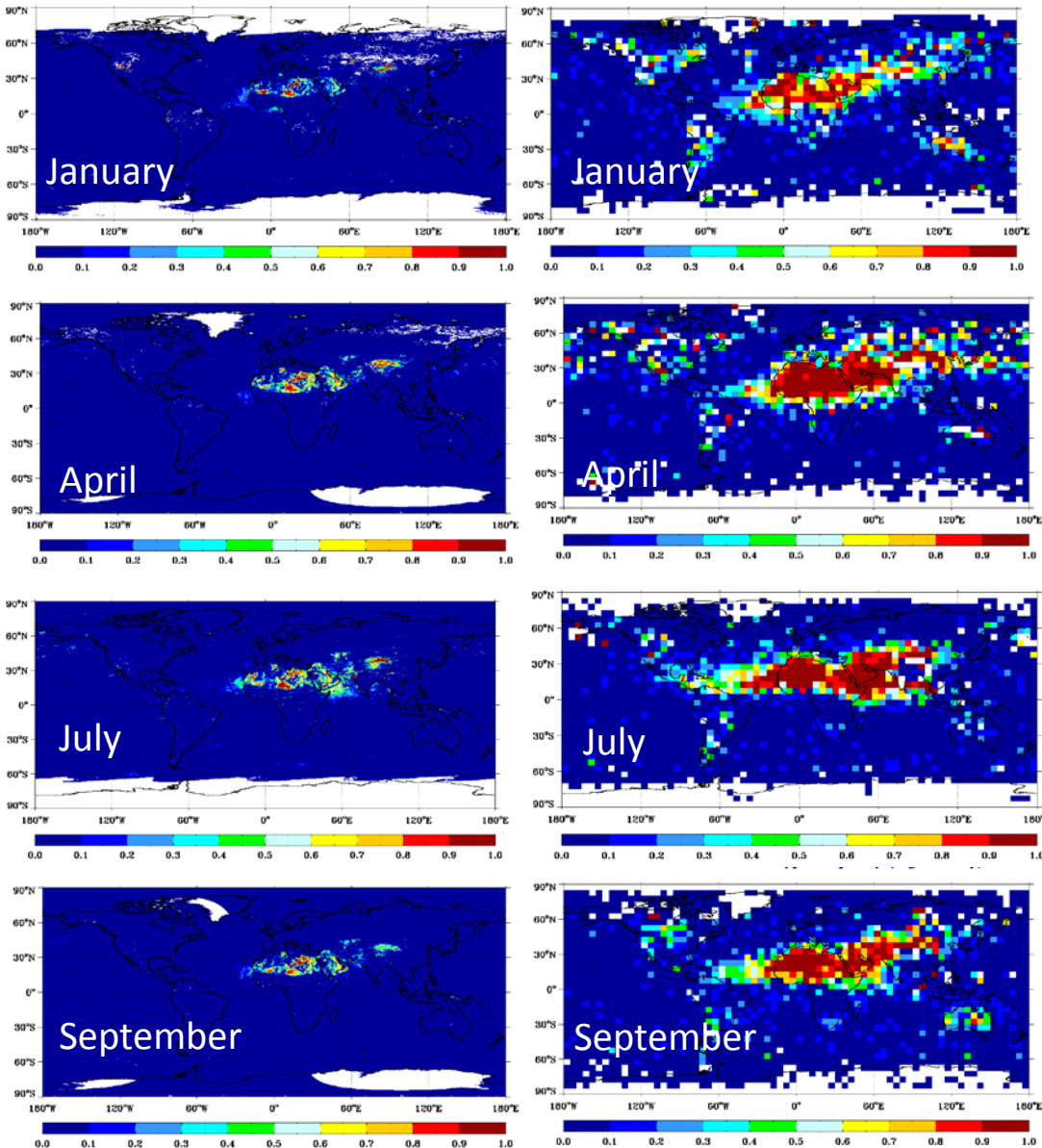


Smoke from Fires in the Western US on September 22, 2013



VIIRS Dust Fraction

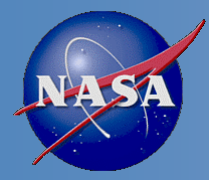
CALIPSO Dust Fraction



JPSS RR Algorithm: VIIRS vs. CALIPSO Global Maps

- CALIPSO data at a coarser grid resolution ($5^\circ \times 5^\circ$). Due to narrow swath of CALIPSO, coarser resolution is needed to get a good sample size;
- VIIRS data at a finer grid resolution ($0.25^\circ \times 0.25^\circ$);
- CALIPSO dust detection is also based on a classification/typing algorithm and not a physical retrieval. Dust accuracy is 91%.

VIIRS is detecting dust only near the dust source and outflow regions whereas CALIPSO dust is detecting it more widely (e.g., Australia). Some but *not very distinct* seasonal pattern in VIIRS.

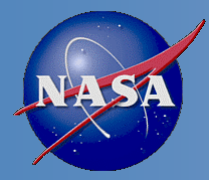


JPSS RR SM Algorithm Evaluation: VIIRS vs. CALIPSO Matchups for Dust



	Land											
Month	1	2	3	4	5	6	7	8	9	10	11*	12
Accuracy	100.0	99.4	99.9	99.9	98.4	99.4	99.6	98.7	100.0	100.0	-	100.0
POCD	N/A	71.4	77.8	80.0	75.3	73.4	97.9	76.5	N/A	N/A	-	N/A
POFD	N/A	50.0	8.7	42.8	13.5	53.4	39.4	35.3	N/A	N/A	-	N/A
	Water											
Month	1	2	3	4	5	6	7	8	9	10	11	12
Accuracy	99.8	99.8	99.9	99.9	99.8	99.6	99.7	99.8	100.0	100.0	-	100.0
POCD	54.2	N/A	N/A	N/A	N/A	80.0	94.8	91.8	N/A	N/A	-	N/A
POFD	56.6	N/A	N/A	N/A	N/A	46.1	49.5	47.6	N/A	N/A	-	N/A

* CALIPSO data not available



JPSS RR SM Algorithm Evaluation: VIIRS vs. AERONET Dust Matchups



Stations							
	True positive	False positive	True negative	False negative	Accuracy	POCD	POFD
Banizoumbou	10	1	65	12	85.2	45.4	9.0
Darkar	1	0	25	1	96.3	50.0	0.0
IER_Cinzana	2	0	23	1	96.2	66.6	0.0
Solar_Village	6	5	29	4	79.5	60.0	45.4
Capo_Verde	2	1	9	0	91.6	100.0	33.3
Cape_San_Juan	1	2	18	0	90.4	100.0	66.6

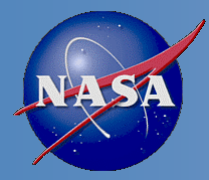
401 AERONET stations	Accuracy	POCD	POFD
Year of 2013	99.8	86.9	39.3



Conclusions



- The JPSS RR SM algorithm for dust and smoke is performing better than operational (IDPS) SM algorithm
 - Meets requirements for dust and smoke.
 - Dust detection evaluated using results from algorithm run on one year (2013) of data
 - Smoke detection evaluated on limited set of granules (22). Full one year run is forthcoming
 - Volcanic ash product will be passed on from VCM (**when JPSS RR volcanic ash product is ready**)
 - No sea salt will be detected
 - No smoke concentration will be reported. There is a user need for this and this information will come from a different algorithm (Automated Smoke Detection and Tracking Algorithm) that was developed using VIIRS fire hot spot and AOT products.
- Future work
 - Extensive evaluation of smoke product will be conducted
 - ATBD and other user documentation will be prepared
 - The dust algorithm is running in near real time on DB data and case studies will be selected and presented to NWS for discussion on transitioning from MODIS to VIIRS. Already had a conversation with NWS air quality program manager
 - Similar approach will be taken with other users.



BACKUP SLIDES



Over Land AOT Retrieval



- Atmospheric correction of reflectances [*Vermote and Kotchenova, 2008*]
 - Basis: aerosols change the ratios of spectral reflectances (spectral contrast) from those of the surface values
 - Dark target algorithm, conceptually similar to MODIS over-land alg.
- Lambertian surface reflection is assumed
- 5 aerosol models [*Dubovik et al. 2002*]:
 - dust, smoke (*high and low absorption*), urban (*clean & polluted*)
 - bimodal lognormal size distribution, function of AOT, spherical particles
- Surface reflectances in selected M bands are retrieved for varying AOT and their ratios are compared to expected values
- AOT and aerosol model that provide the best match between ratios of surface reflectances retrieved in multiple channels and their expected values are reported as solution



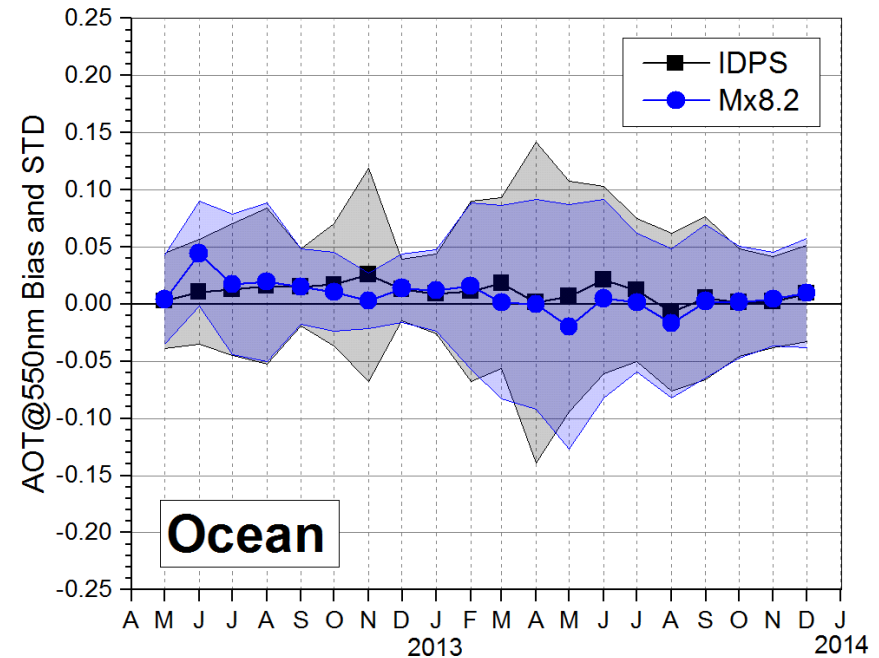
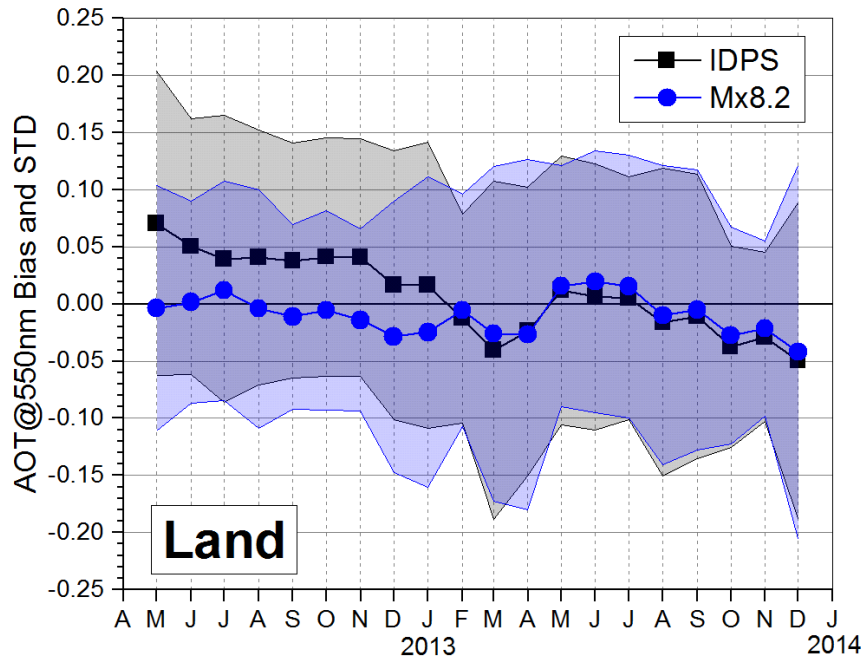
Over Ocean AOT Retrieval



- Close adaptation of the MODIS approach [*Tanré et al.*, 1997]
 - wind-dependent (speed and direction) ocean surface reflectance is calculated analytically
 - combines 4 fine mode and 5 coarse mode models with 0.01 increments in fine mode fraction (2020 models)
 - TOA reflectances in selected M bands are calculated and compared to observed ones to retrieve AOT aerosol models and their weights simultaneously
 - AOT and aerosol model that most closely reproduces the VIIRS-measured TOA reflectance in multiple bands are reported as solution



VIIRS AOT EDR vs. AERONET L1.5 AOT



- Time series of monthly average VIIRS-AERONET AOT difference and standard deviation of differences
- Mx8.2 bias < 0.04 over land and < 0.025 over ocean for almost all months examined.
- Mx8.2 std < 0.20 over land and < 0.10 over ocean.

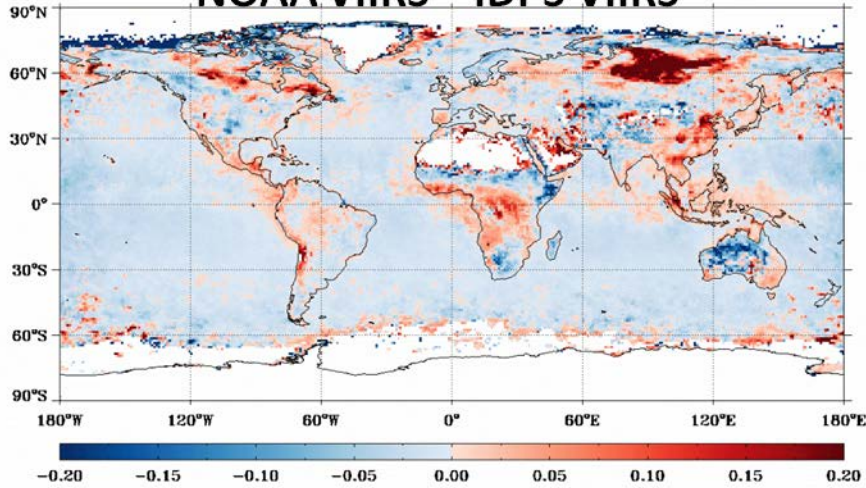
More in posters by Jingfeng Huang et al. and Ho-Chun Huang et al.



JPSS RR Aerosol Results



NOAA VIIRS – IDPS VIIRS



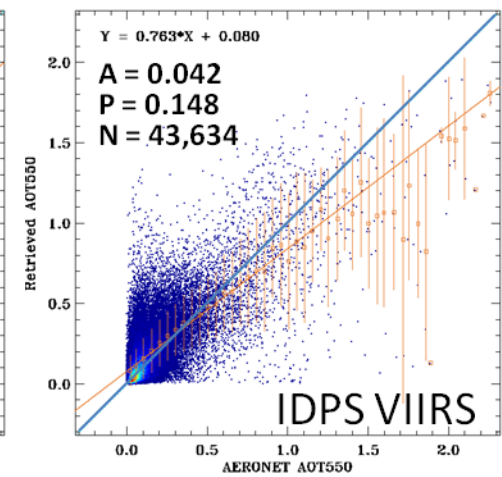
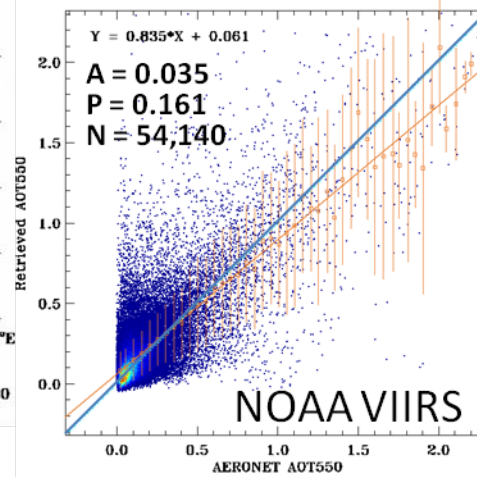
Data: average of every five days between 2013.03.01-2014.03.01, 750-m data

- Over land, better overall accuracy, but slightly worse precision.
- Over ocean, comparable accuracy, but slightly worse precision.
- Meets requirements.

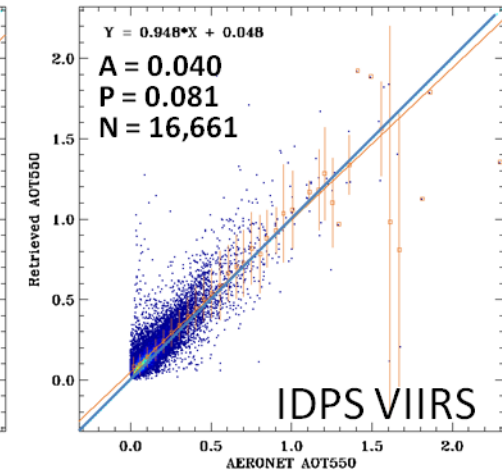
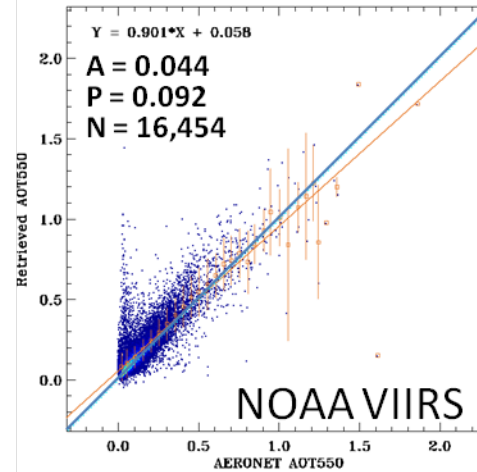
Details and more results in talk by H. Liu in Atmosphere Breakout on Wednesday at 14:50

daily 750-m data for 2012.05.02 – 2014.03.31

LAND

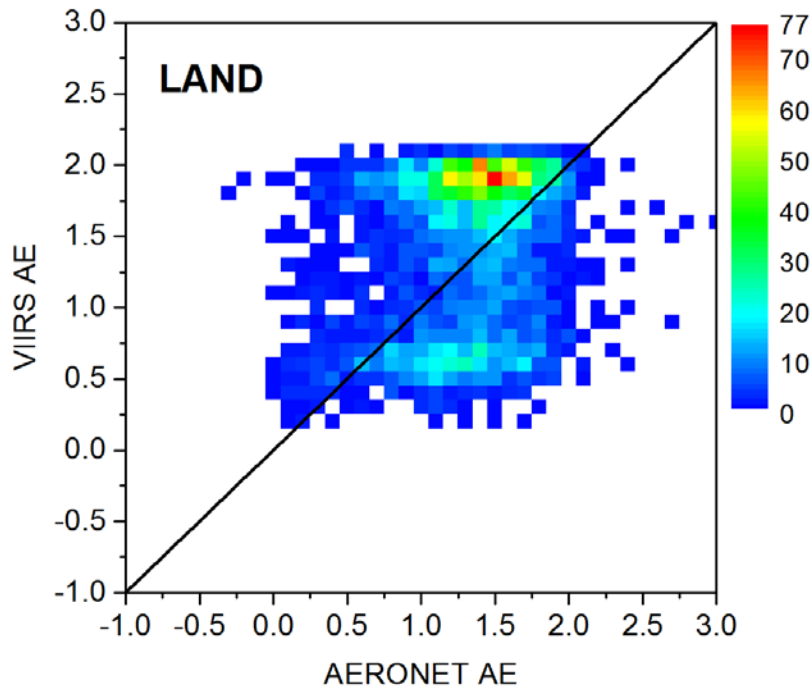


OCEAN

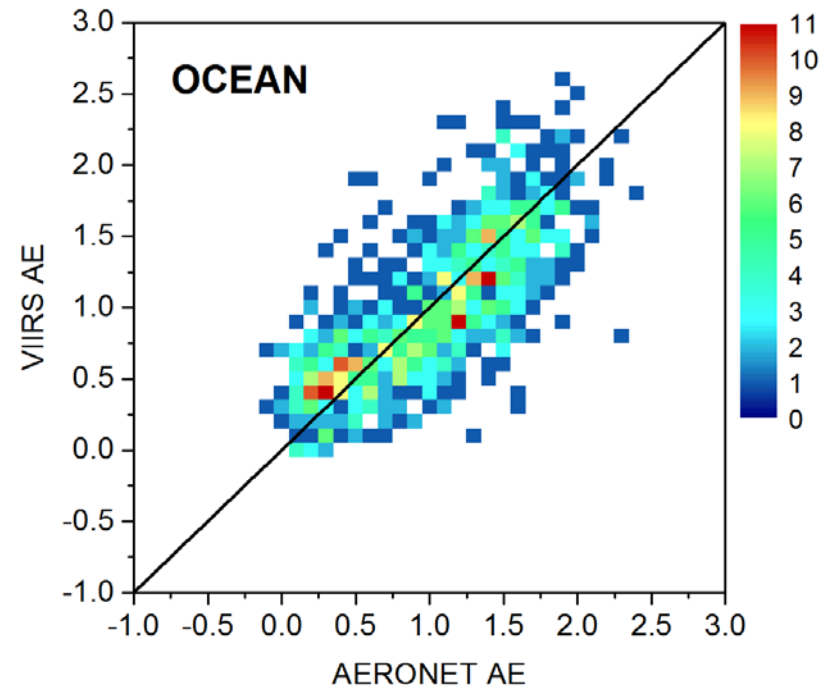




VIIRS AE EDR vs. AERONET L1.5 AE



No skill over land



Some skill over ocean

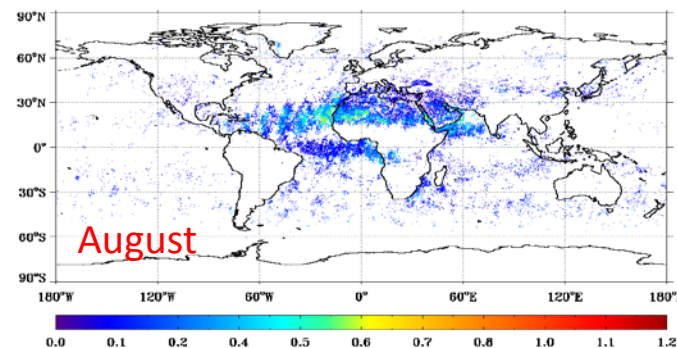
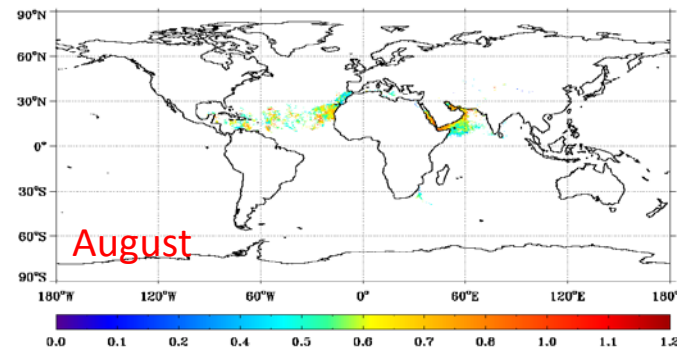
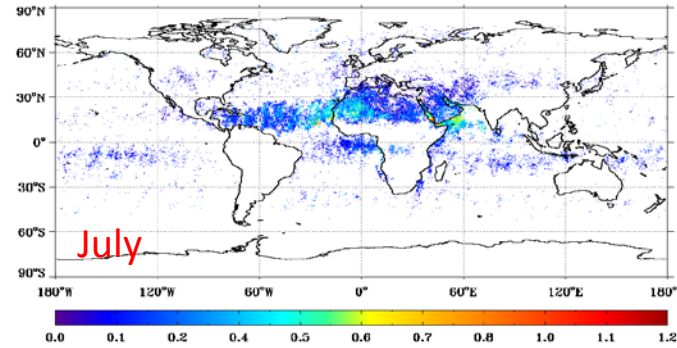
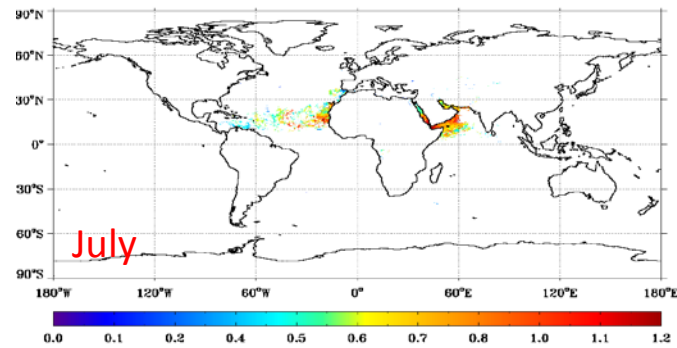
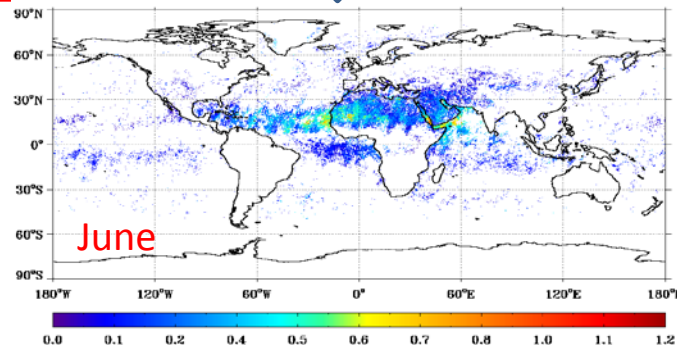
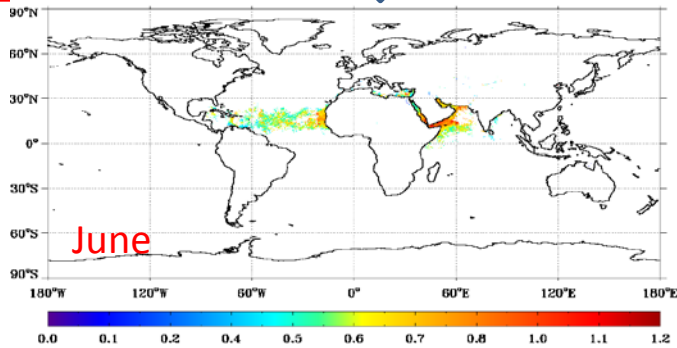
Time period: 05/02/2012 - 12/31/2013; Data: Mx8.2

OCEAN	N	ACCURACY		PRECISION	
		Requirement	SNPP/VIIRS	Requirement	SNPP/VIIRS
865nm/1610nm	803	0.30	0.02 ✓	0.60	0.37 ✓

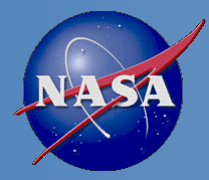


VIIRS "Dust AOT"

MISR "Dust AOT"

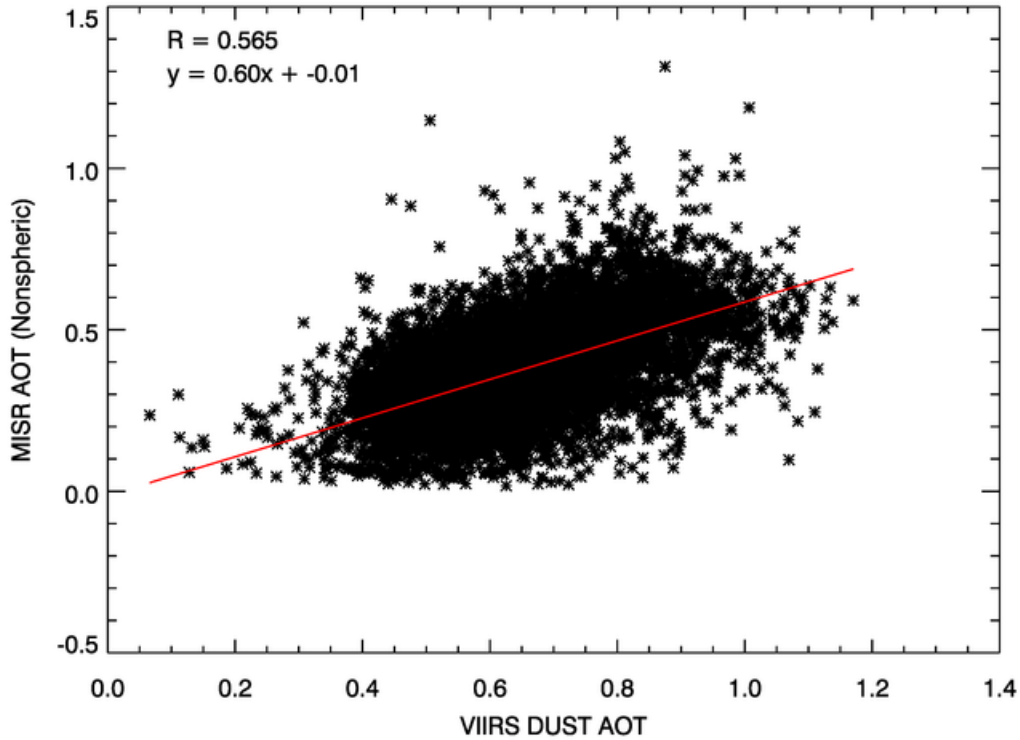


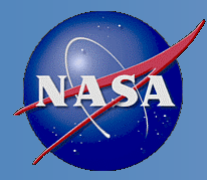
- VIIRS dust flag and best quality AOT are combined to generate "dust AOT". MISR non-spherical AOT is assumed to be "dust AOT".
- MISR dust AOT observed over the biomass burning region is likely coarse mode smoke aerosol?
- VIIRS dust AOT biased high compared to MISR.
- VIIRS high AOT observed year round in the Red Sea, Persian Gulf, and Arabian Sea.



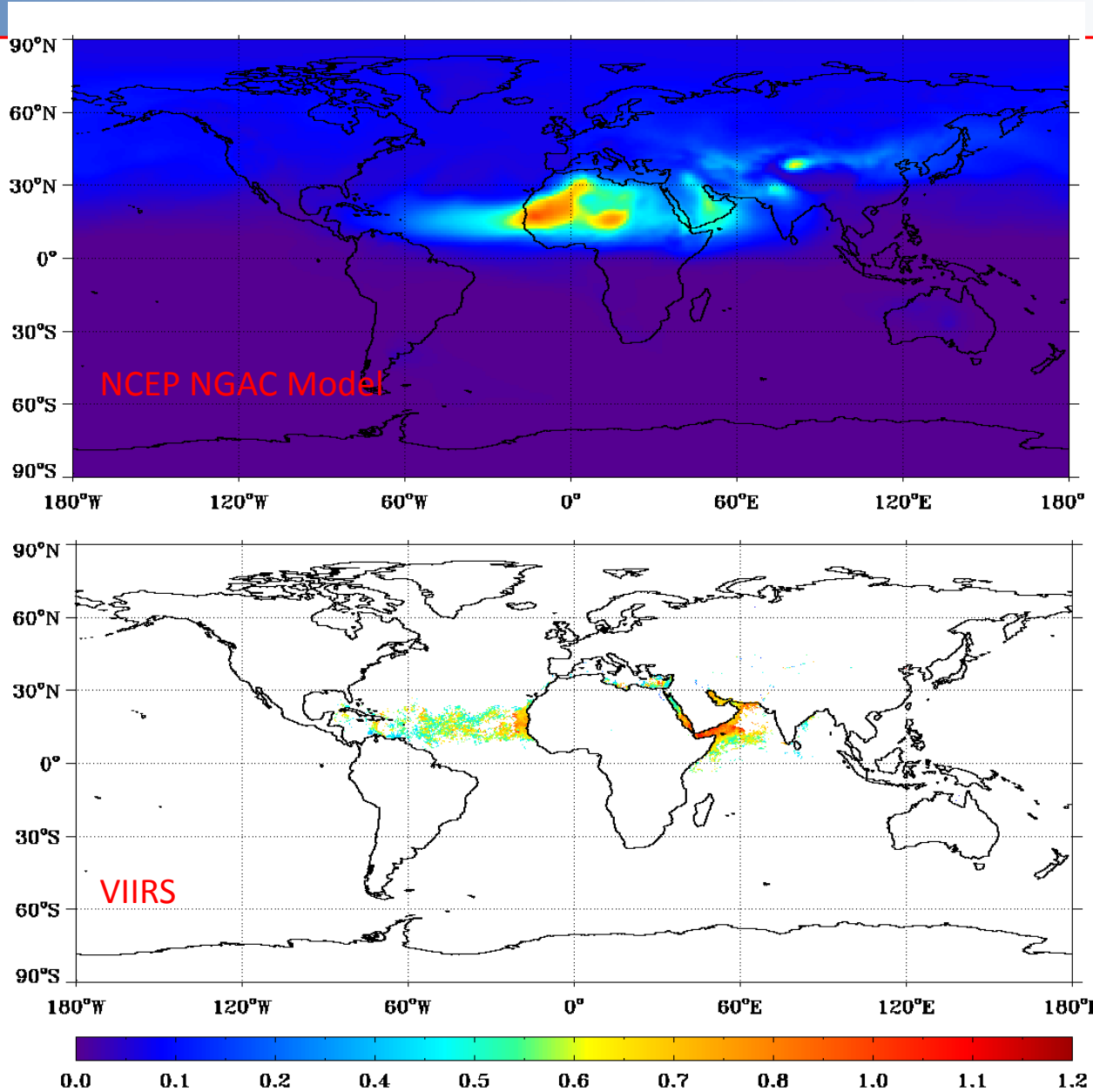
VIIRS vs. MISR Dust AOT Correlation

June 2013



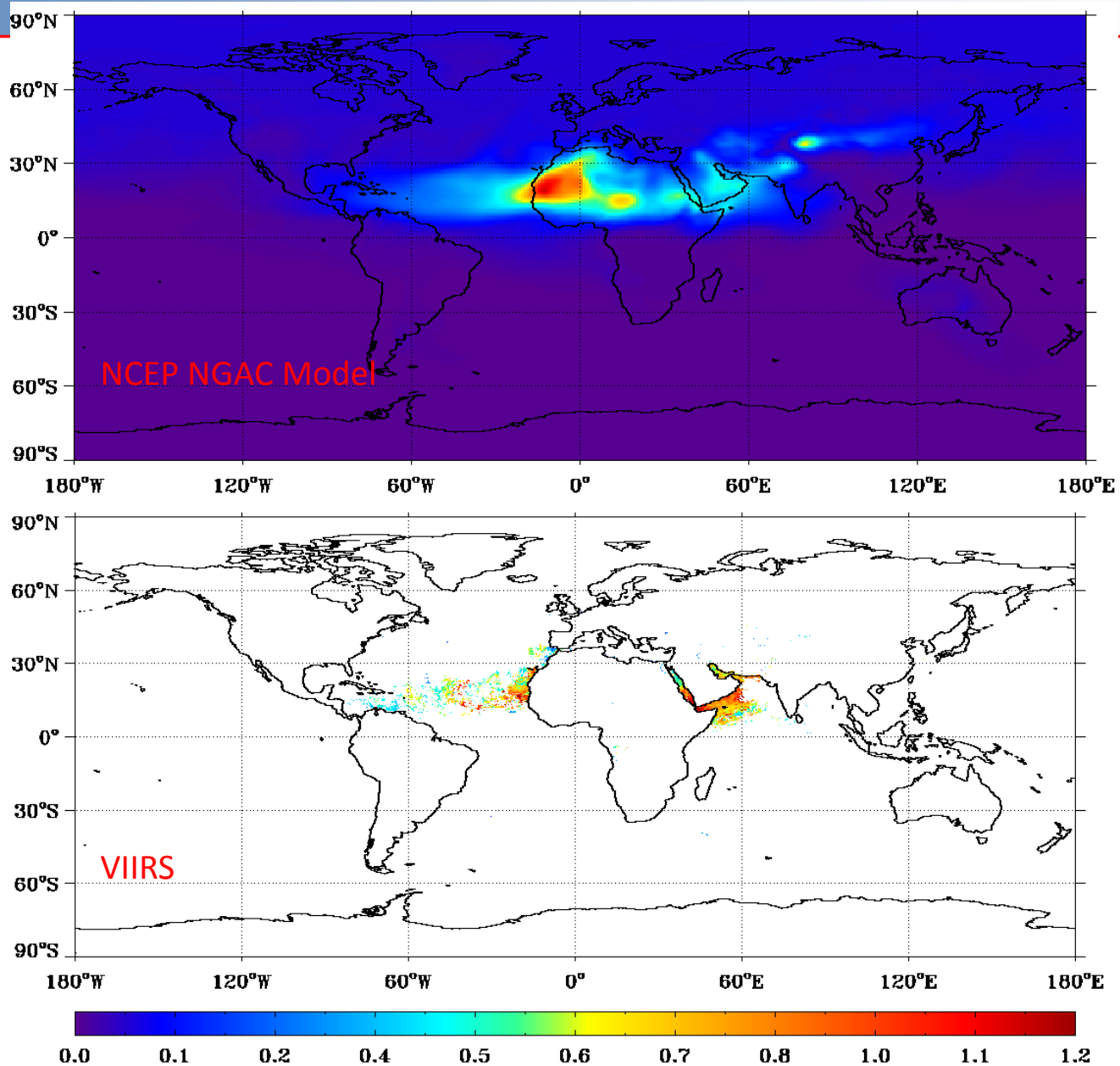


June 2013 Dust AOT





July 2013 Dust AOT





August 2013 Dust AOT

