The EPS Aerosol Detection Product From Multi-Satellite Sensors

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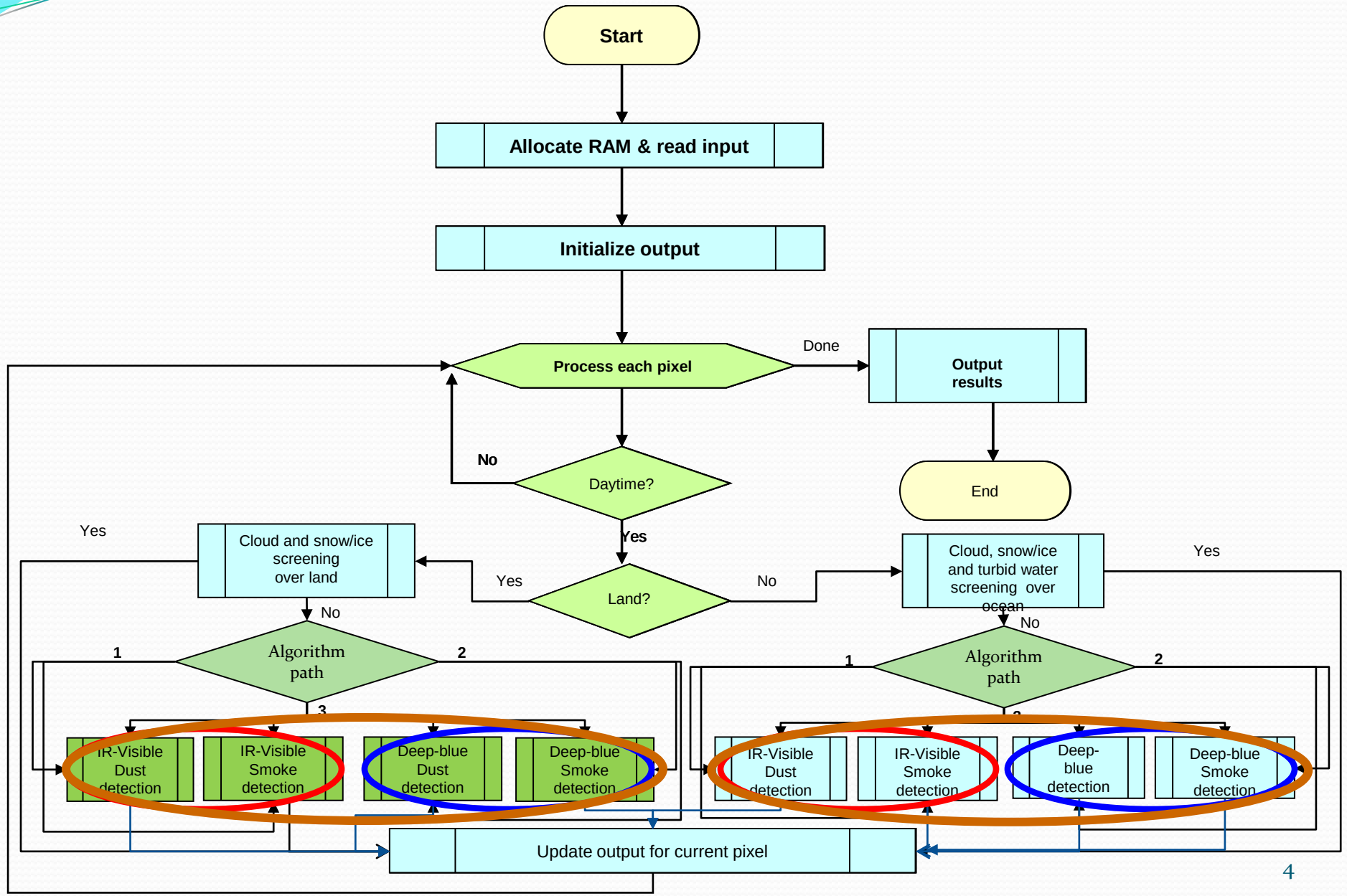
Outline

- Overview of the Enterprise Processing System (EPS) Aerosol Detection Algorithm
- EPS Aerosol Detection Products from Multi-sensors: S-NPP VIIRS, EOS MODIS, Himawari AHI, and future Sensor: TEMPO
- Algorithm improvement
- Summary

What is the EPS Aerosol Detection Algorithm?

- The Enterprise Processing System Aerosol Detection algorithm was designed to have one set of algorithms working on observations from multi-sensors including both GEO and LEO platforms.
- Heritage is the GOES-R AWG and JPSS Risk Reduction aerosol detection algorithms.
- Uniform input and output structure.

EPS Aerosol Detection Algorithm (1)



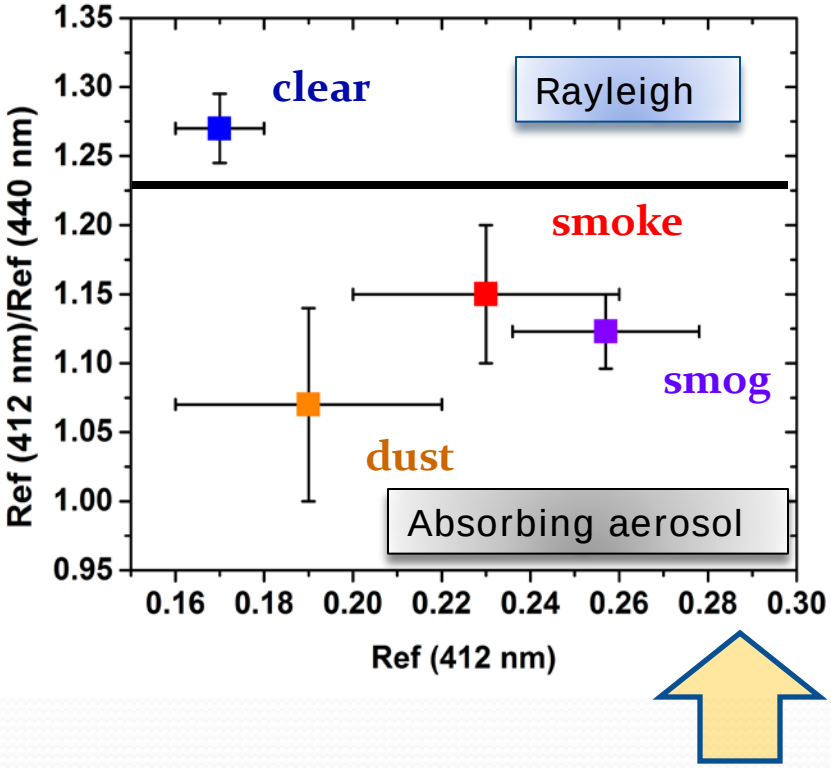
EPS Aerosol Detection Algorithm (2)

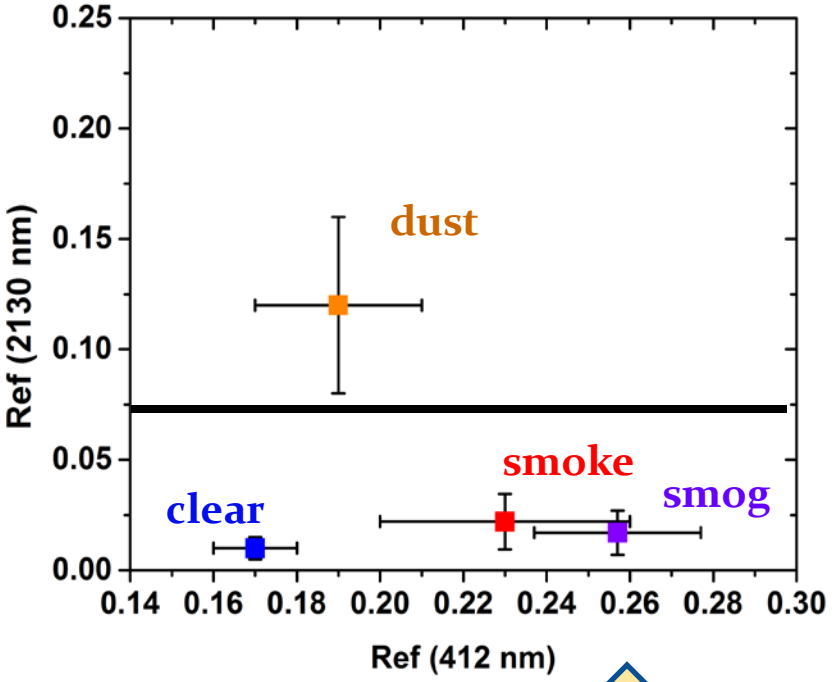
Table 1. Mapping of channels for different sensors to channels used in EPS ADP algorithm

Channel In EPS		Sensors			
		VIIRS	MODIS	ABI	AHI
1	0.412µm	M1	Band 8	X	X
2	0.445 µm	M2	Band 9	X	X
3	0.488 µm	M3	Band 3	Band 1	Band1
4	0.555 µm	M4	Band 4	X	x
5	0.640 µm	M5	Band 1	Band 2	Band3
6	0.746 µm	M6	Band 15	X	X
7	0.865 µm	M7	Band 2	Band 3	Band 4
8	1.24 µm	M8	Band 5	X	X
9	1.38 µm	M9	Band 26	Band 4	X (Band 5)*
10	1.61 µm	M10	Band 6	Band 5	Band 5
11	2.25 µm	M11	Band 7	Band 6	Band 6
12	3.70 µm	M12	Band 20	X(Band 7)*	X(Band 7)*
13	4.05 µm	M13	Band 21	Band 7	Band 7
14	10.7 µm	M15	Band 31	Band 14	Band 14
15	12.01 µm	M16	Band 32	Band 15	Band 15

Green: used by both deep-blue based and IR-visible based detection algorithms
Blue: only used by deep-blue based detection algorithm
Brown: only used by IR-Visible based detection algorithm.
*: band is missing but using the corresponding band in the parentheses instead.
X: channel is missing, but not needed, and filled with "-999.9"

Aerosol Detection Algorithm (path1)





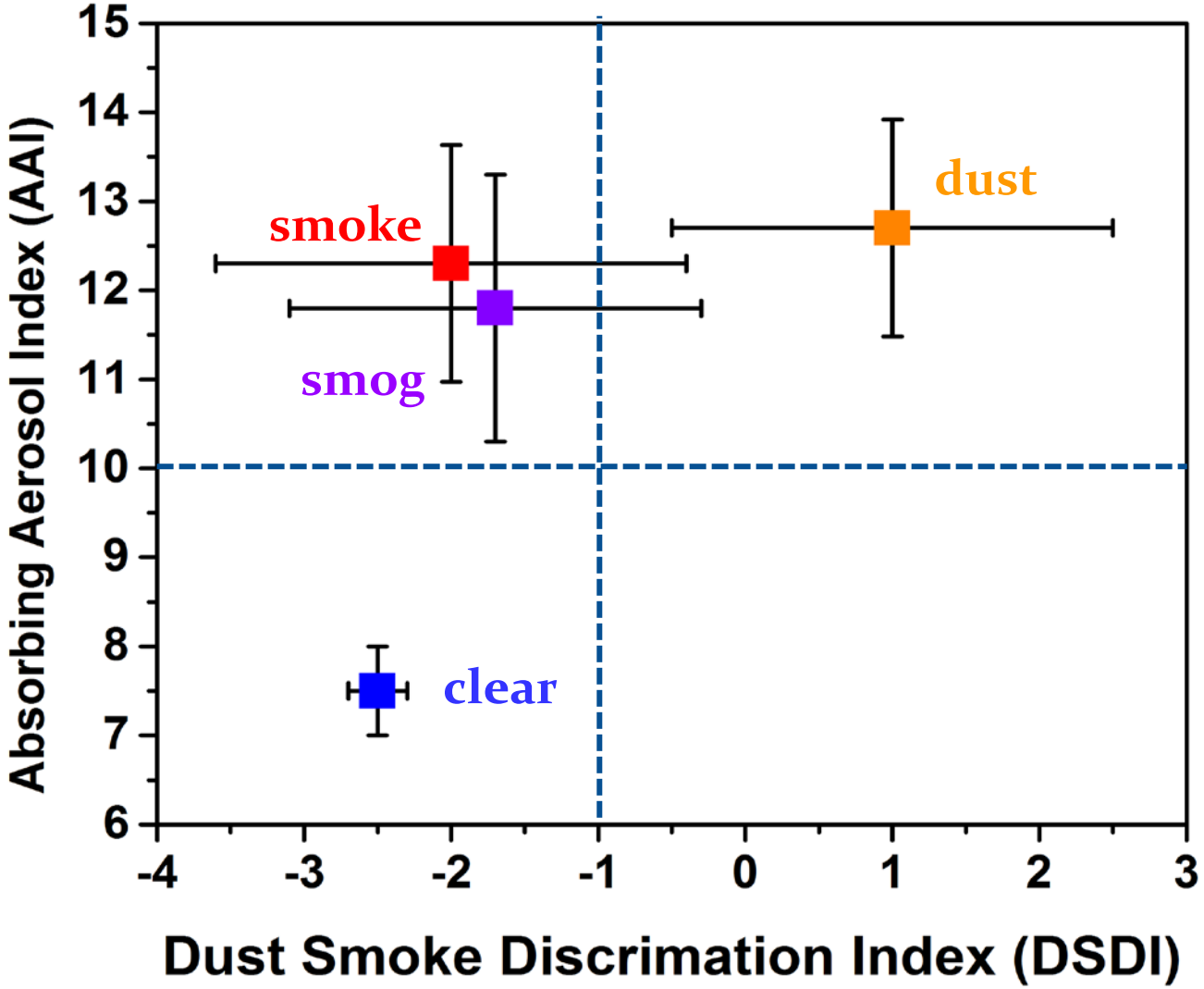
Absorbing Aerosol Index

$AAI = -100[\log_{10}(R_{412}/R_{440}) - \log_{10}(R^{RAY}_{412}/R^{RAY}_{440})]$

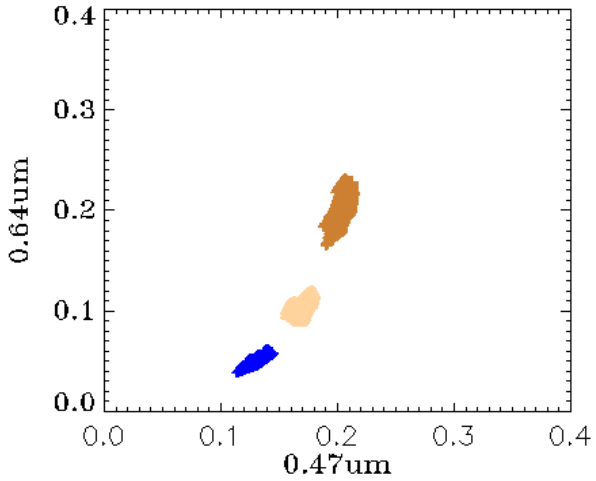
Dust Smoke Discrimination Index

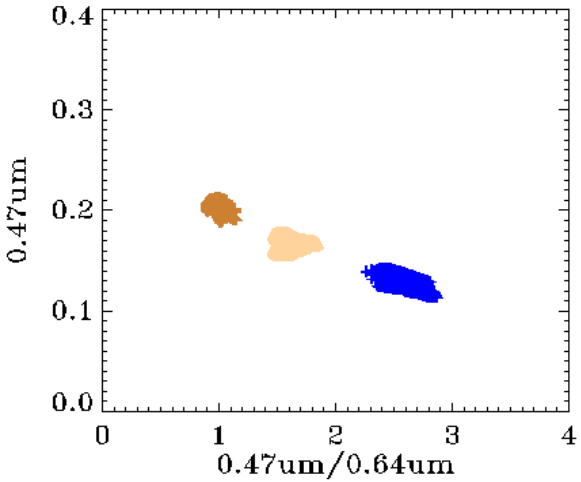
$DSDI = -10[\log_{10}(R_{412}/R_{2250})$

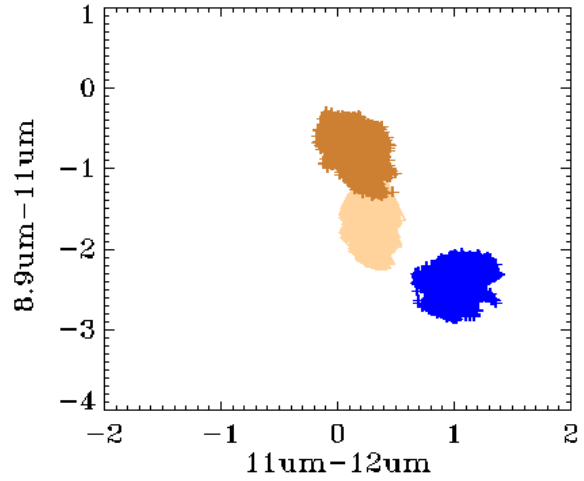
Aerosol Detection Algorithm (path1)

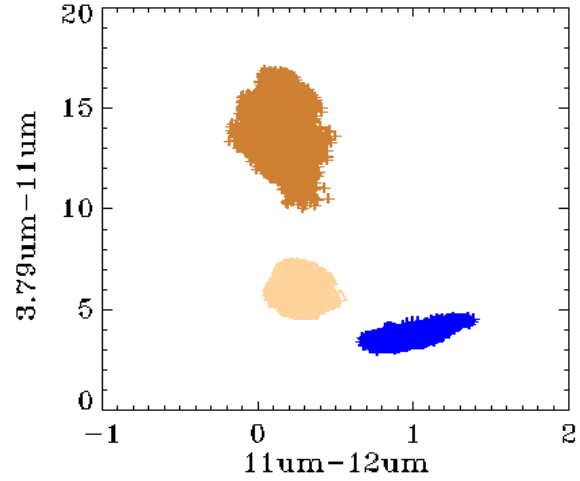


Aerosol Detection Algorithm (path2)









Clear

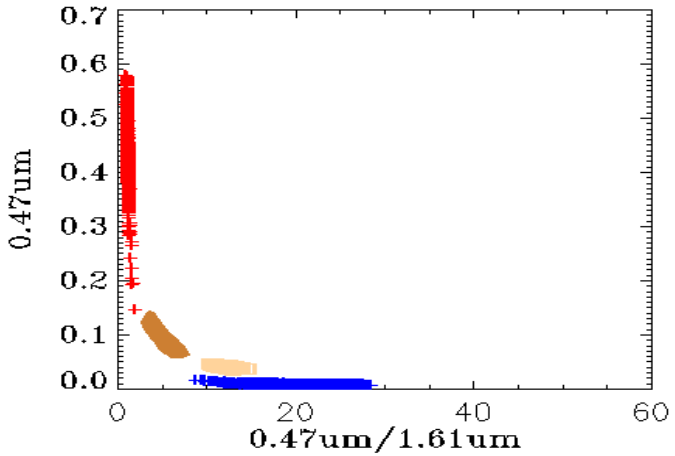
Thin Dust

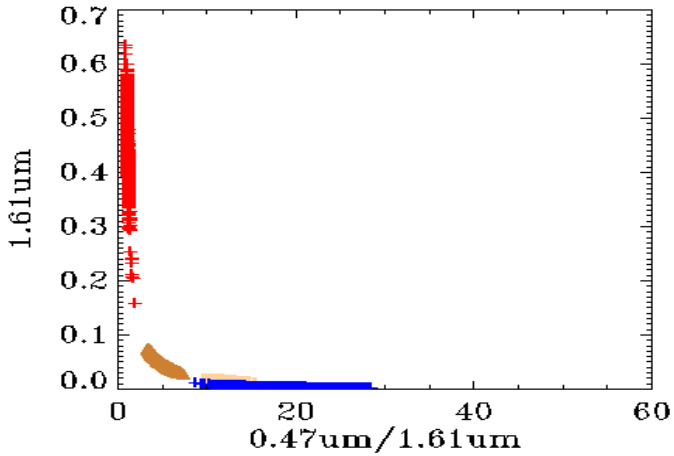
Thick Dust

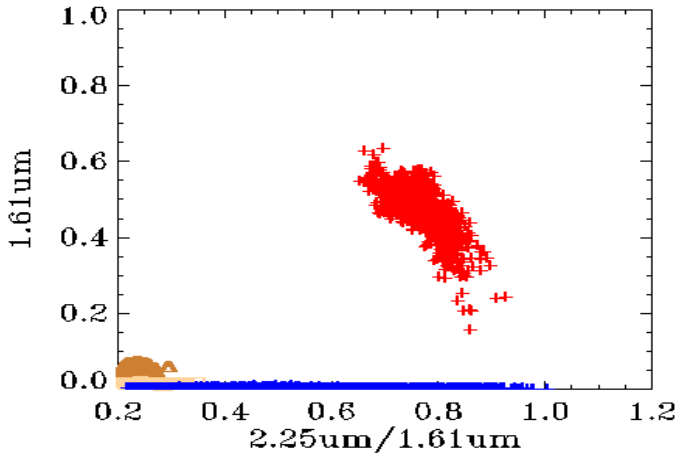
Over water

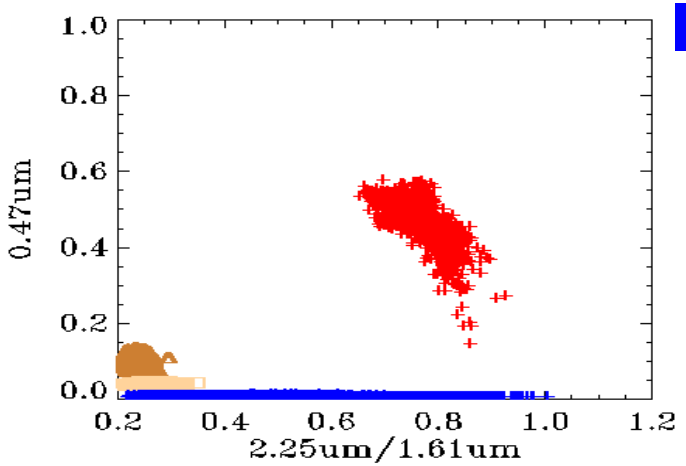
In IR region, dust decreases the brightness temperature difference between 11 and 12 μm, compared to clear sky. In visible region, dust reduces the contrast between two neighboring wavelengths , such as 0.47 μm/0.64 μm.

Aerosol Detection Algorithm (path2)









clouds

Thin Smoke

Thick smoke

clear

Over water

Weak spectral dependence of reflection from clouds and strong wavelength dependent reflection from smoke allows us to use spectral contrast between two visible wavelengths to separate smoke from clouds; and further separate thick smoke from thin smoke .

Outputs from EPS Aerosol Detection(1)

Output flags from EPS ADP product

Type/Byte		Flag Name	Meaning	
			Value: 0 (default)	1
Integer	1	Volcanic Ash	No	yes
	2	Cloud	No	yes
	3	Dust	No	yes
	4	Smoke	No	yes
	5	None/Unknown/Clear	No	yes
	6	Snow/ice	No	yes

Quality flags from EPS ADP product

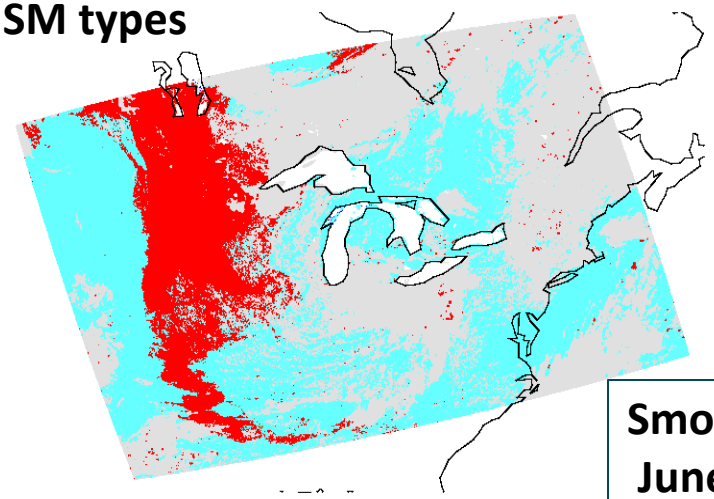
Byte/Bit*		Quality Flag Name	Meaning		
			2bit: 10 (default:00)	01	11
1	0-1	QC_ASH_DETECTION	Low	Medium	High
	2-3	QC_SMOKE_DETECTION	Low	Medium	High
	4-5	QC_DUST_CONFIDENCE	Low	Medium	High
	6-7	QC_NUC_CONFIDENCE	Low	Medium	High

Output from EPS ADP product

Type	Name	Meaning
Float 32	Scaled Absorbing Aerosol Index	Index scaled by the corresponding threshold to illustrate the intensity of smoke/dust event
Float 32	Non-dust aerosol index	an index used to separate smoke from dust

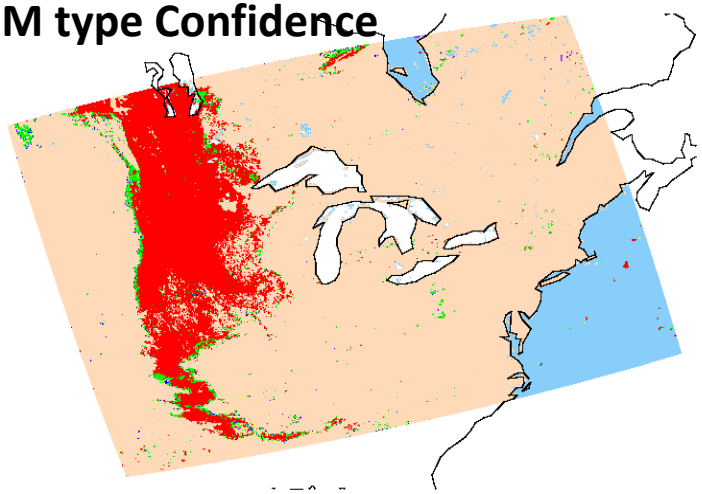
Outputs from EPS Aerosol Detection(2)

1. SM types



No data | Volcanic Ash | Snow Ice | Glint | Smoke | Cloud | Dust | None/Undetermined /Clear

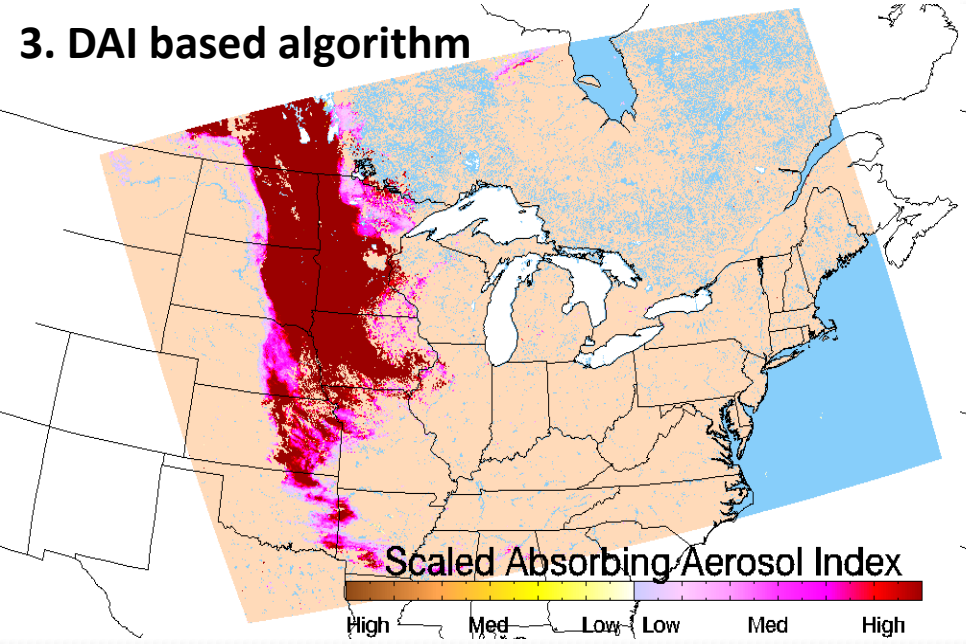
2. SM type Confidence



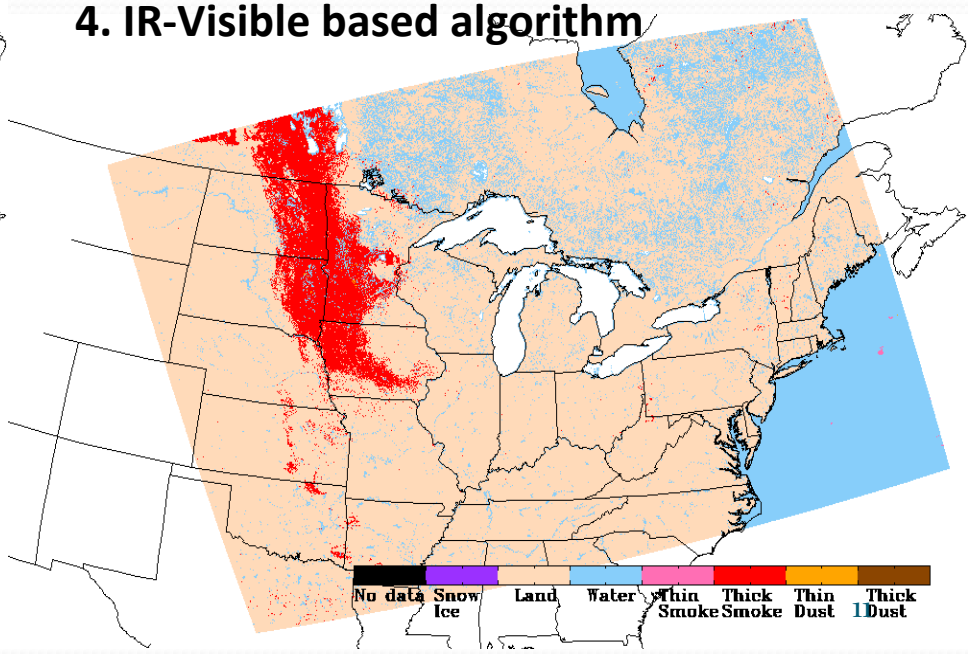
No data | Snow Ice | Land | Water | Smoke low | Smoke med | Smoke high | Dust low | Dust med | Dust high

Smoke over U.S
June 29,2015

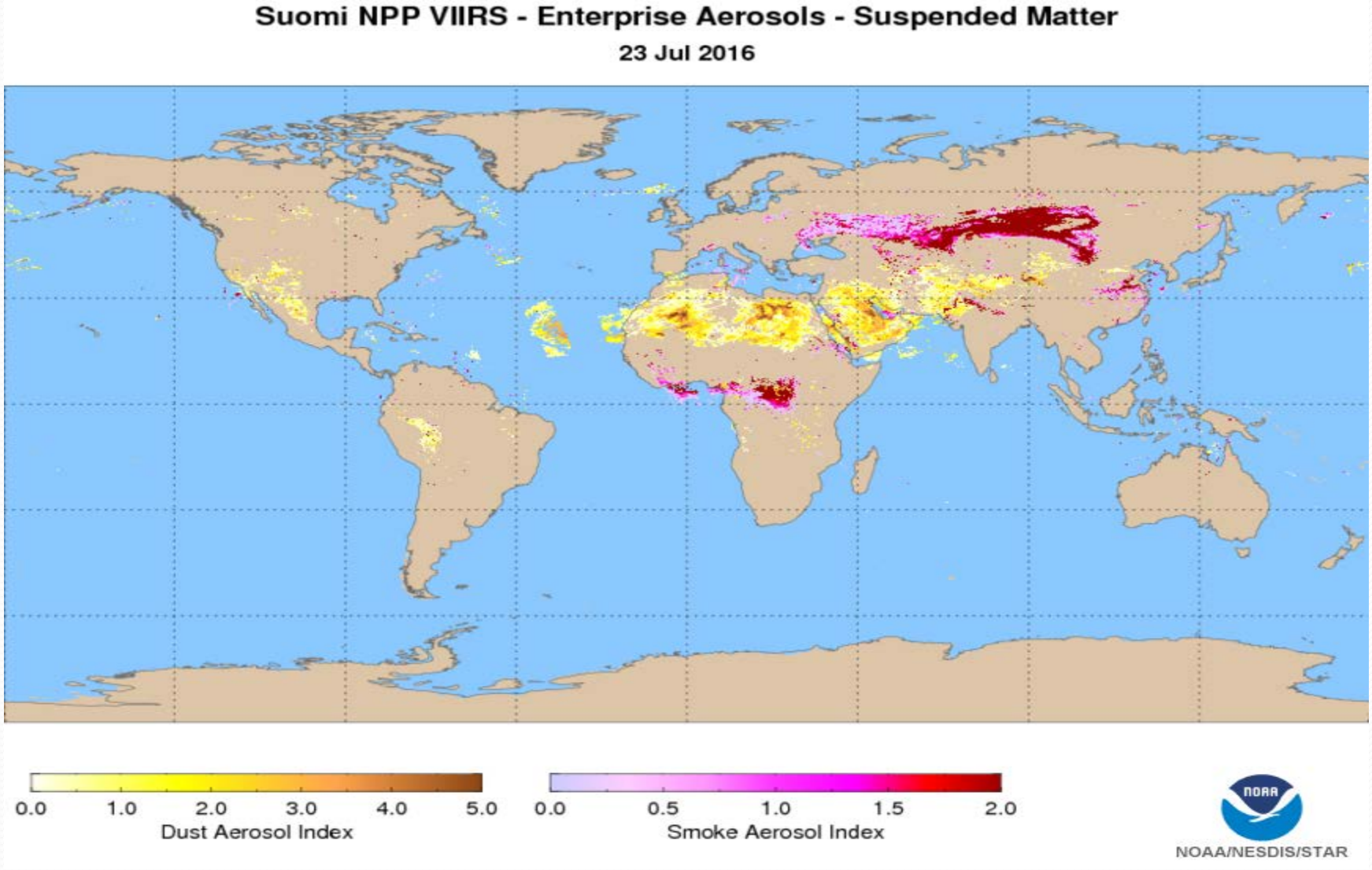
3. DAI based algorithm



4. IR-Visible based algorithm

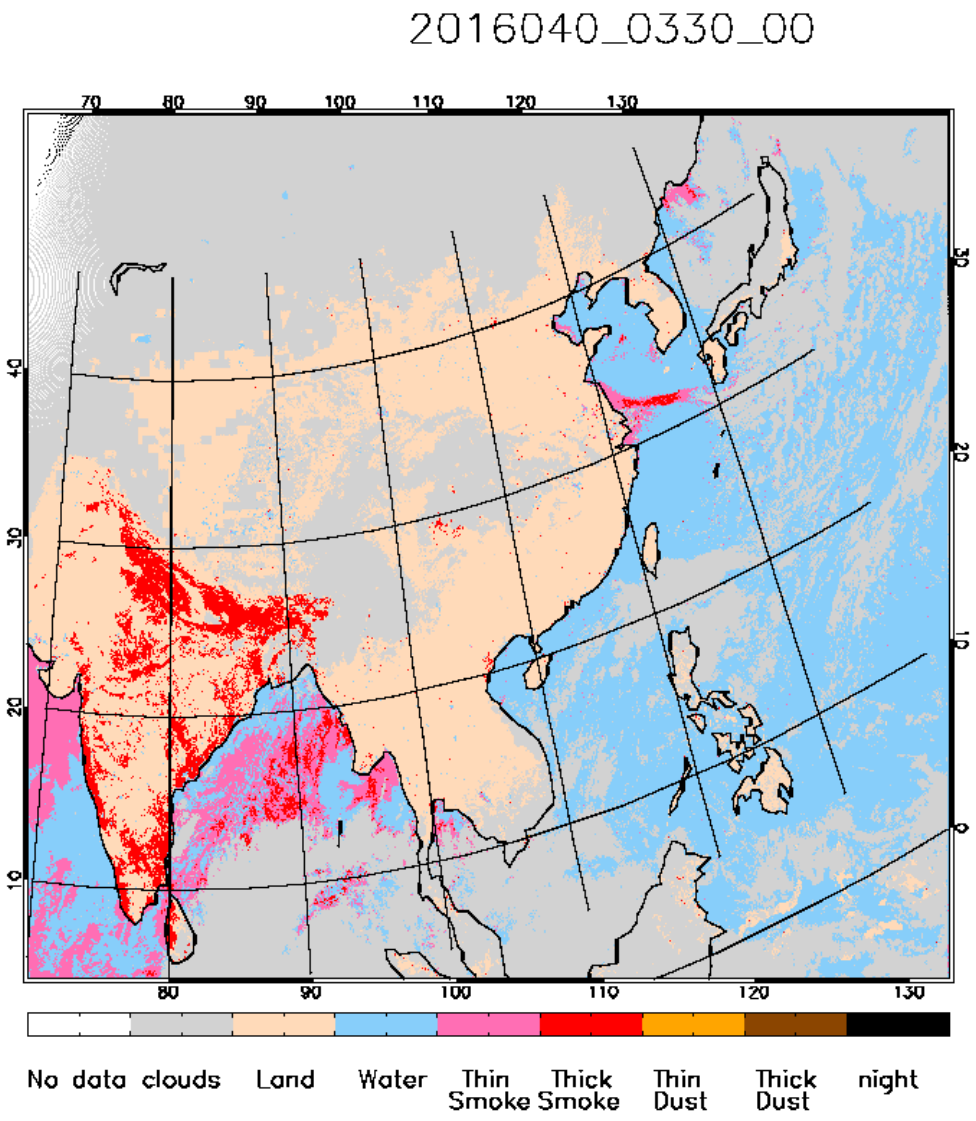


Real-time EPS Aerosol Detection



http://www.star.nesdis.noaa.gov/jpss/EDRs/products_aerosols.php

Enterprise Algorithm Aerosol Detection Product (ADP) generated using AHI for February 9, 2016

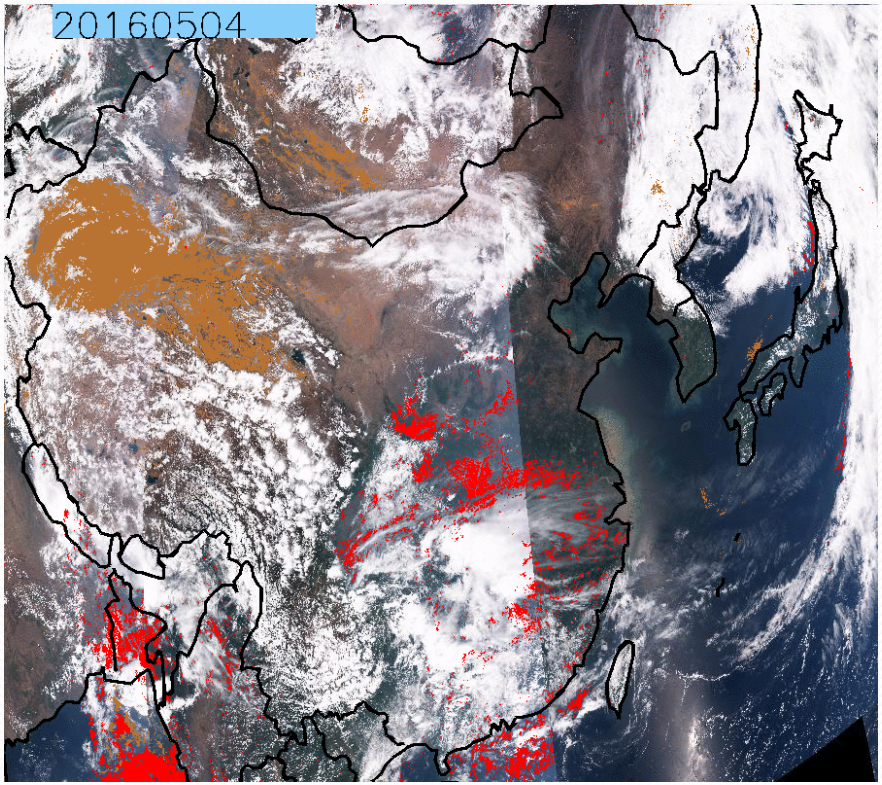


Winter-time smog (mainly sulfate and highly absorbing brown carbon) is a big concern in Asia with high concentrations of aerosols in the boundary layer impacting air quality and visibility.

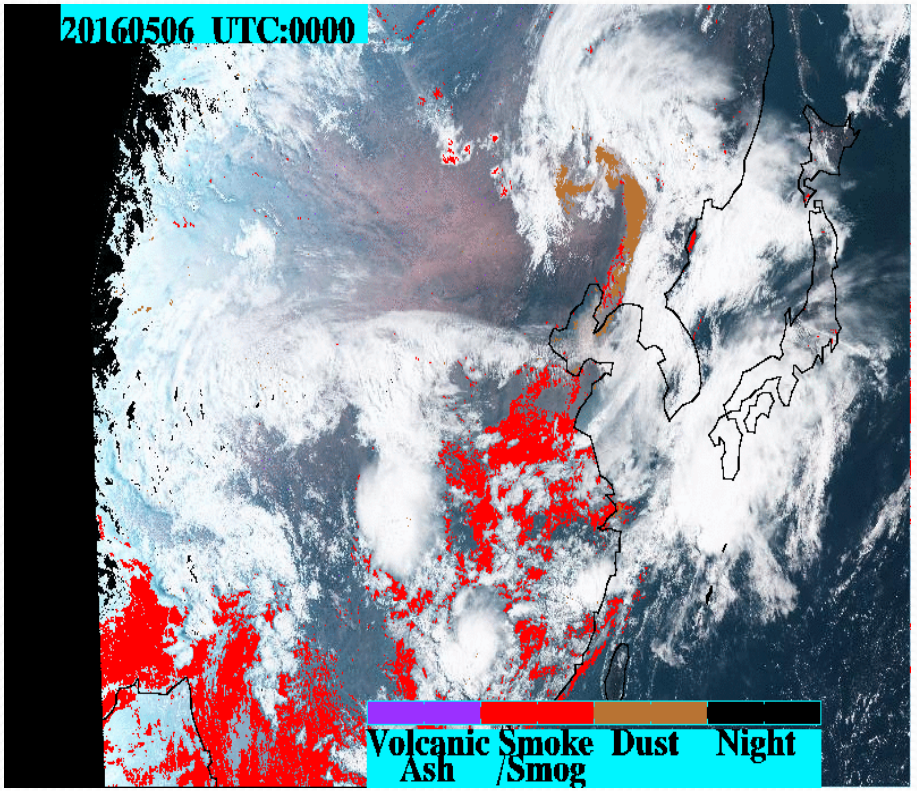
30-minute AHI aerosol imagery loop

Enterprise Aerosol Detection Products: GEO v.s. LEO

SNPP VIIRS



AHI

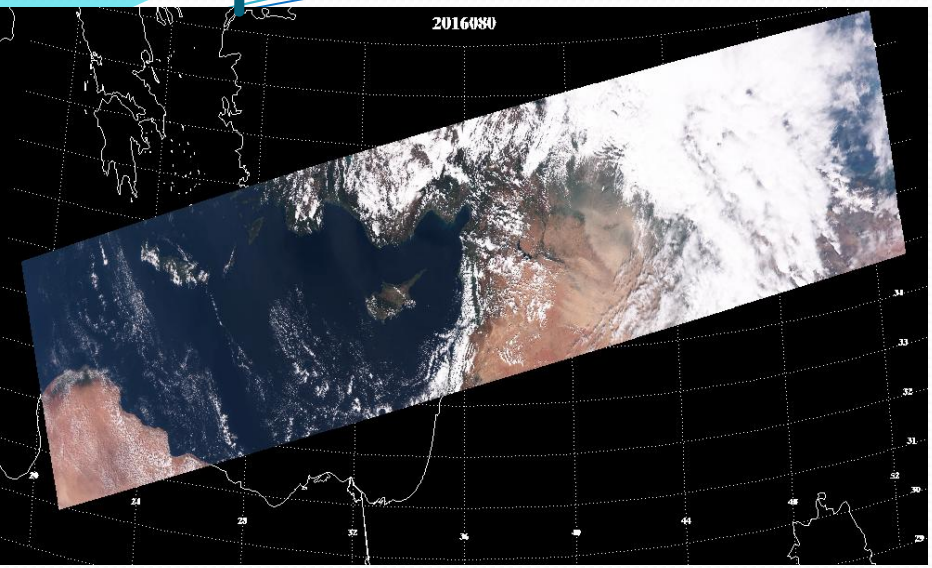


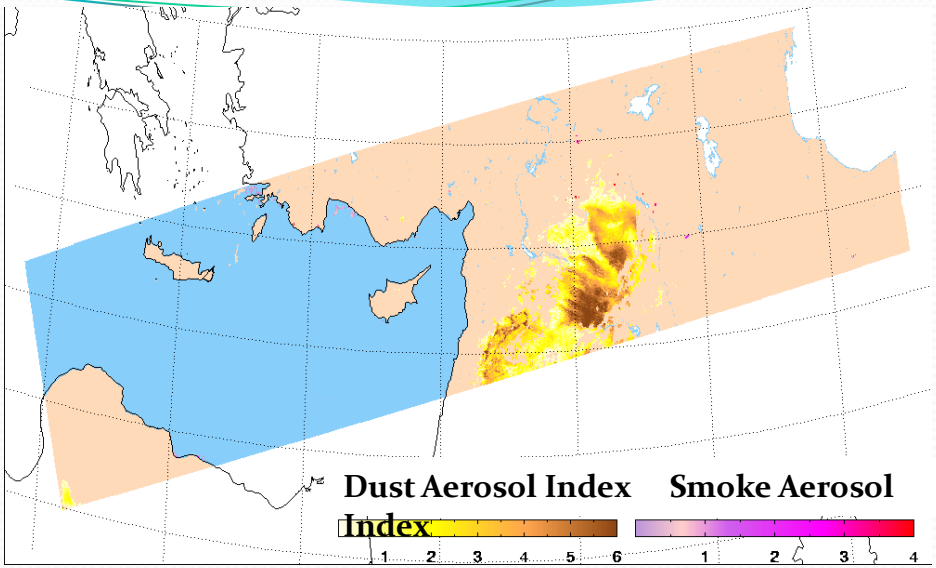
Smoke/Smog

Dust

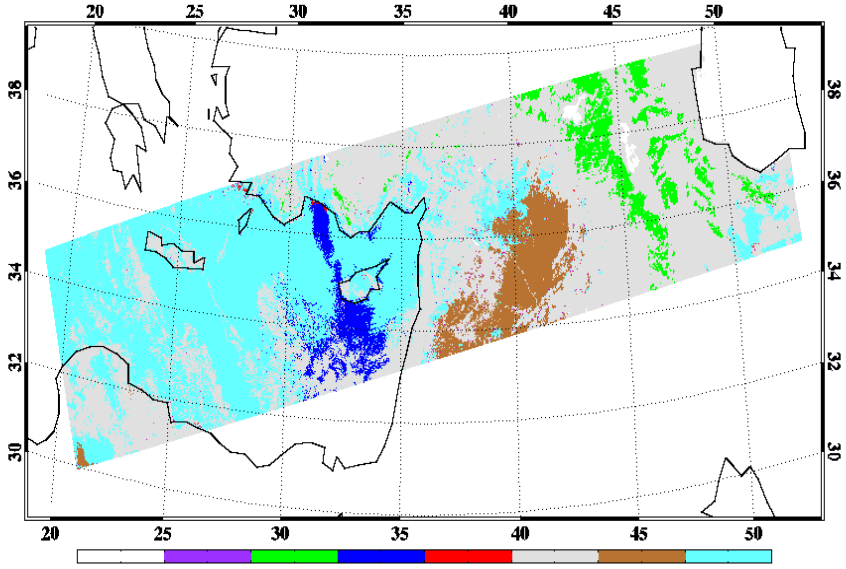
Asian dust captured in EPS ADP from both VIIRS (*left*) and Himawari AHI (*right*).

Enterprise Aerosol Detection Products : DUST

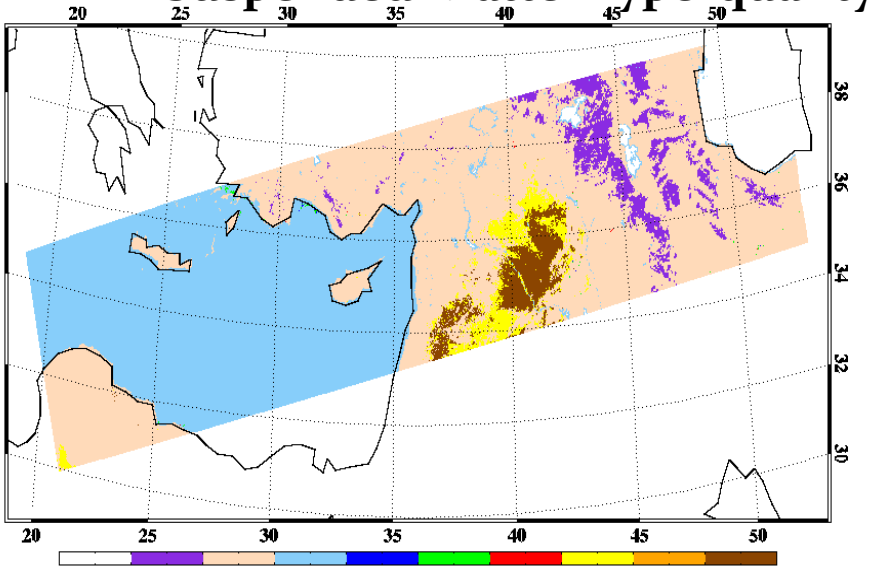




Suspended-Matter Type



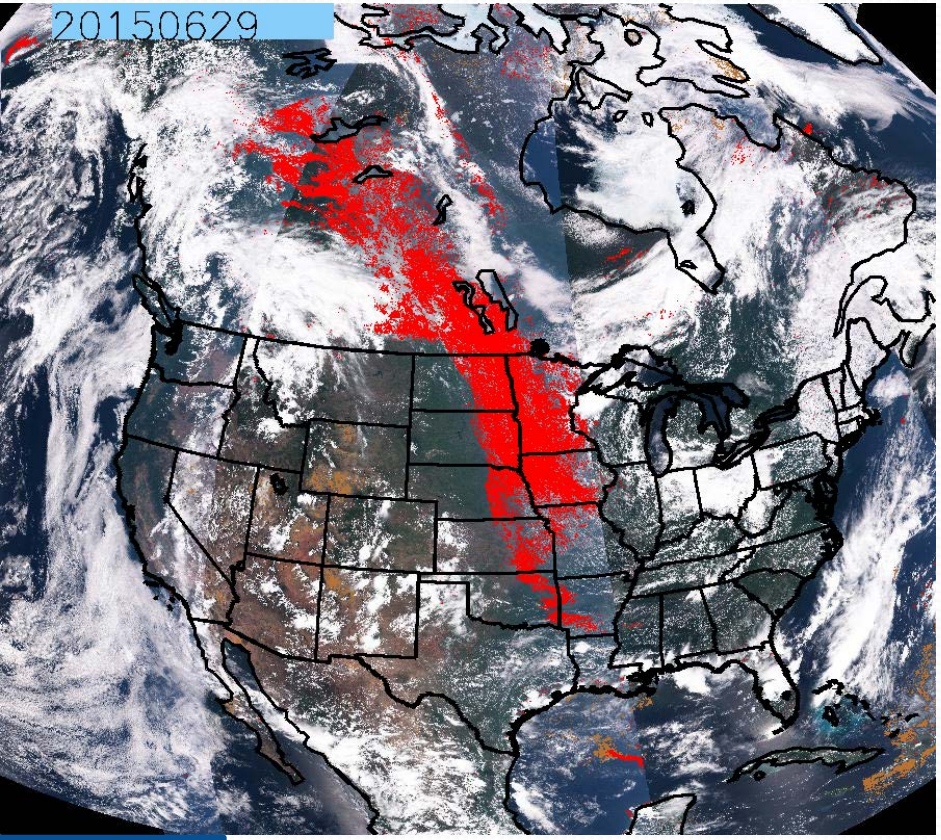
Suspended-Matter Type quality



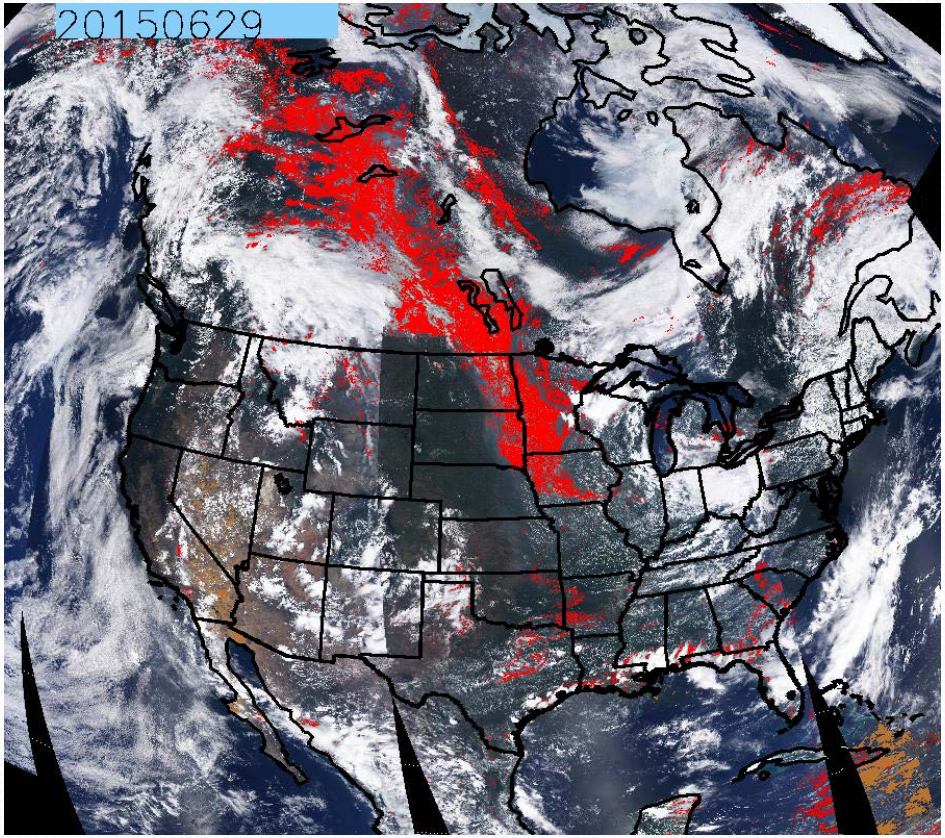
Enterprise Aerosol Detection Products : MODIS

Smoke plume from forest fire originated from Canada on 06/29/2015

S-NPP VIIRS



MODIS Aqua

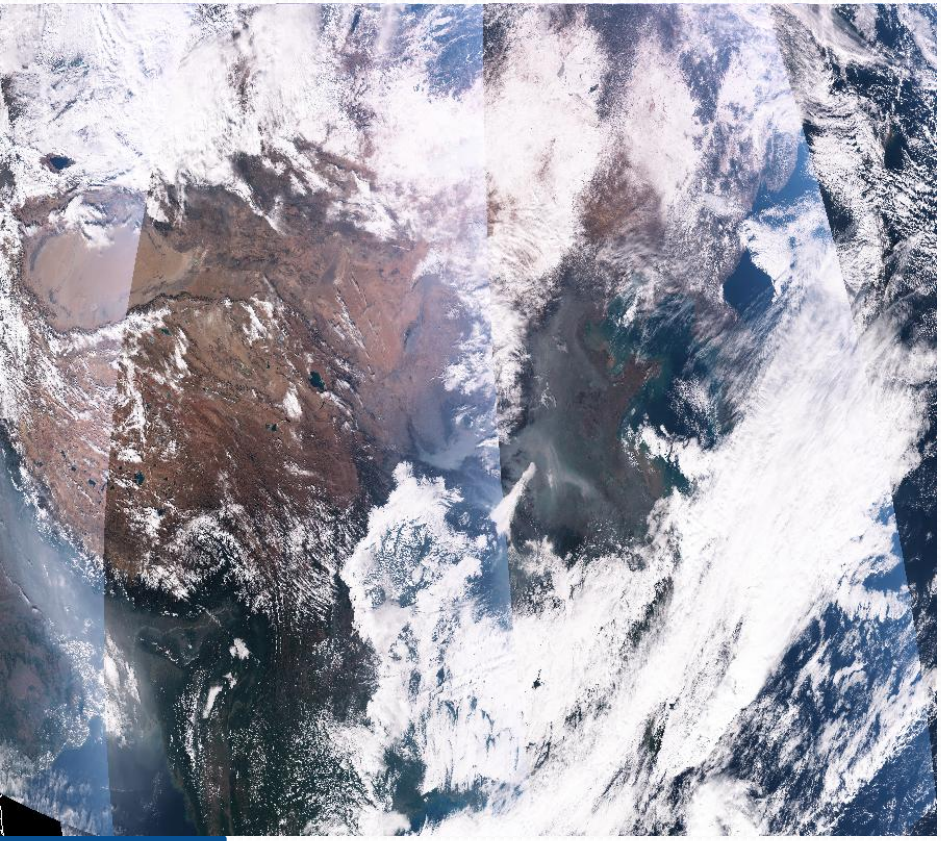


Smoke/Smog

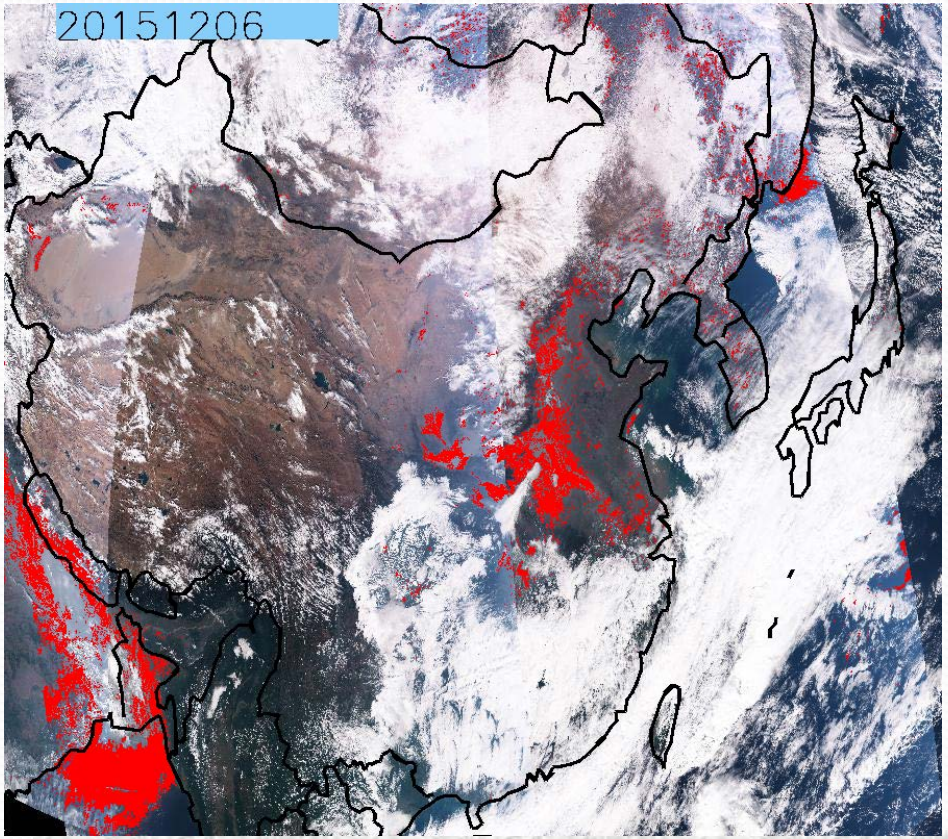
Dust

Enterprise Aerosol Detection Products : Asian Smog

S-NPP VIIRS RGB



EPS ADP on S-NPP VIIRS



Smoke/Smog

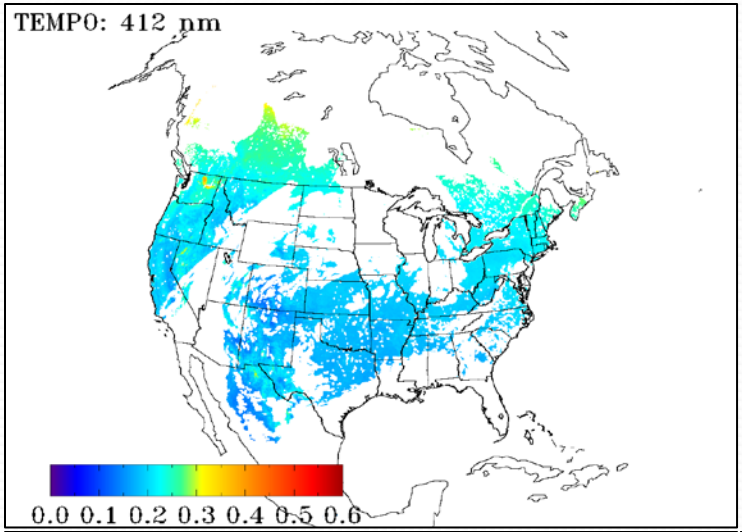
Dust

Asian Smog lingering over China and India on 12/06/2015 detected by EPS ADP

Enterprise Aerosol Detection algorithm applied to future sensor: TEMPO

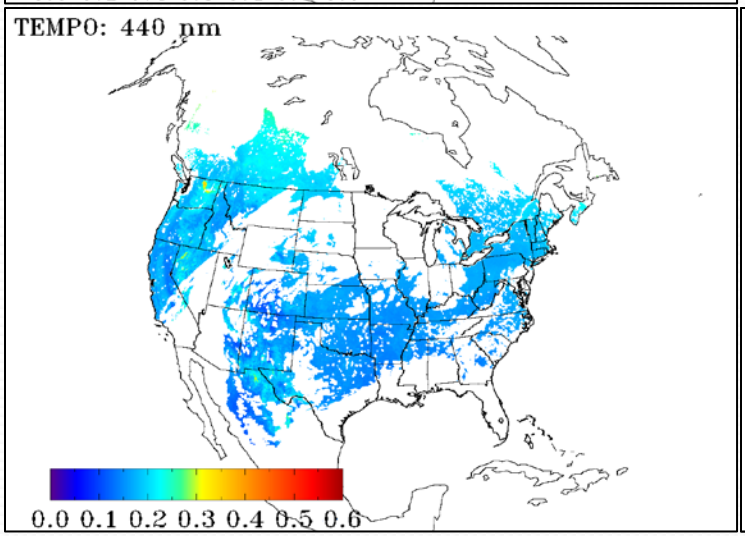
- TEMPO (Tropospheric Emissions: Monitoring of Pollution), a NASA Earth Venture Instrument , is a UV-Visible (290-740nm) spectrometer on GEO orbit.
- First GEO-satellite with measurements in the “deep-blue” spectral region.
- Will be on-orbit about the same time as GOES-R.
- NASA generated synthetic radiances for a smoke case
  - Hourly, 7-km nature run for 22 cases; smoke case for August 7, 2006 used in this study
  - Simulated radiances for GOES-R and TEMPO footprints using VLIDORT
  - Aerosol optical properties from OPAC data base

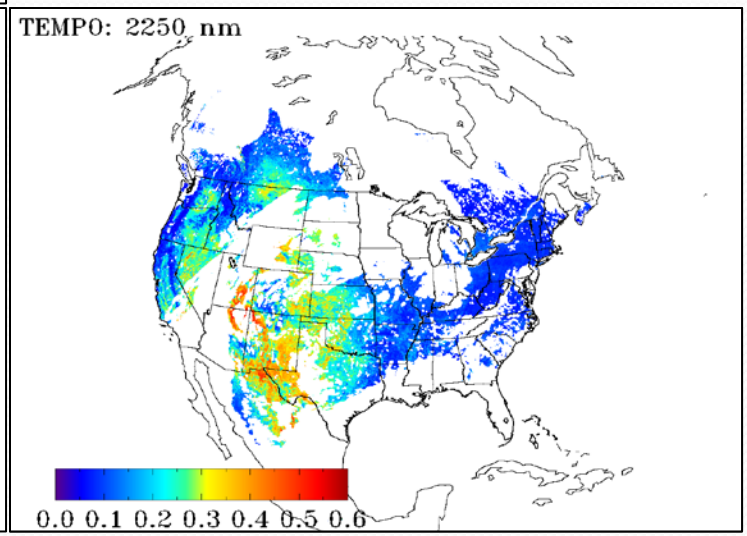
Enterprise Aerosol Detection algorithm applied to future sensor: TEMPO



Exp	412 nm	440 nm	2.25 µm
1	TEMPO	TEMPO	GOES-R
2	TEMPO	TEMPO	TEMPO

Input data for EPS aerosol detection algorithm

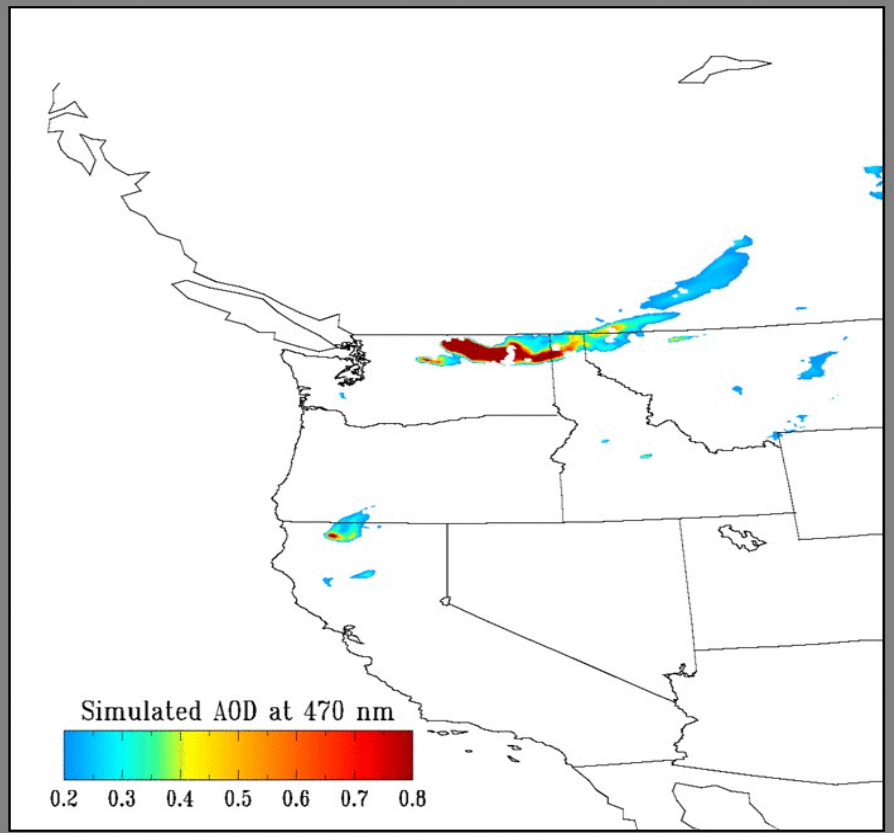


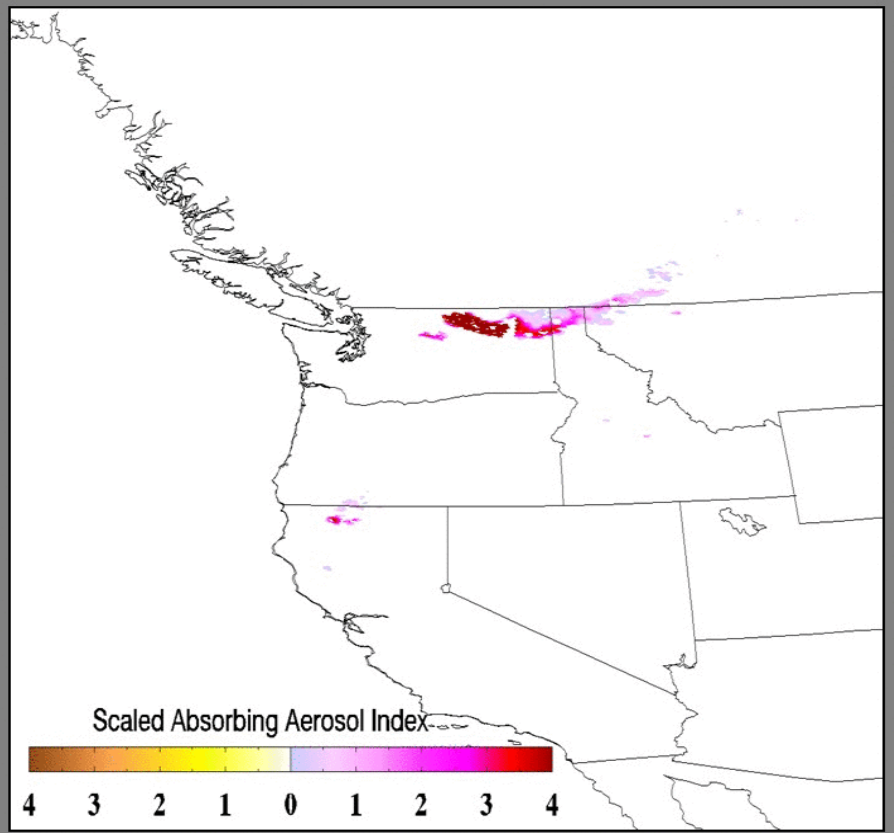


Exp 2

Enterprise Aerosol Detection algorithm applied to future sensor: TEMPO

UTC: 00:00

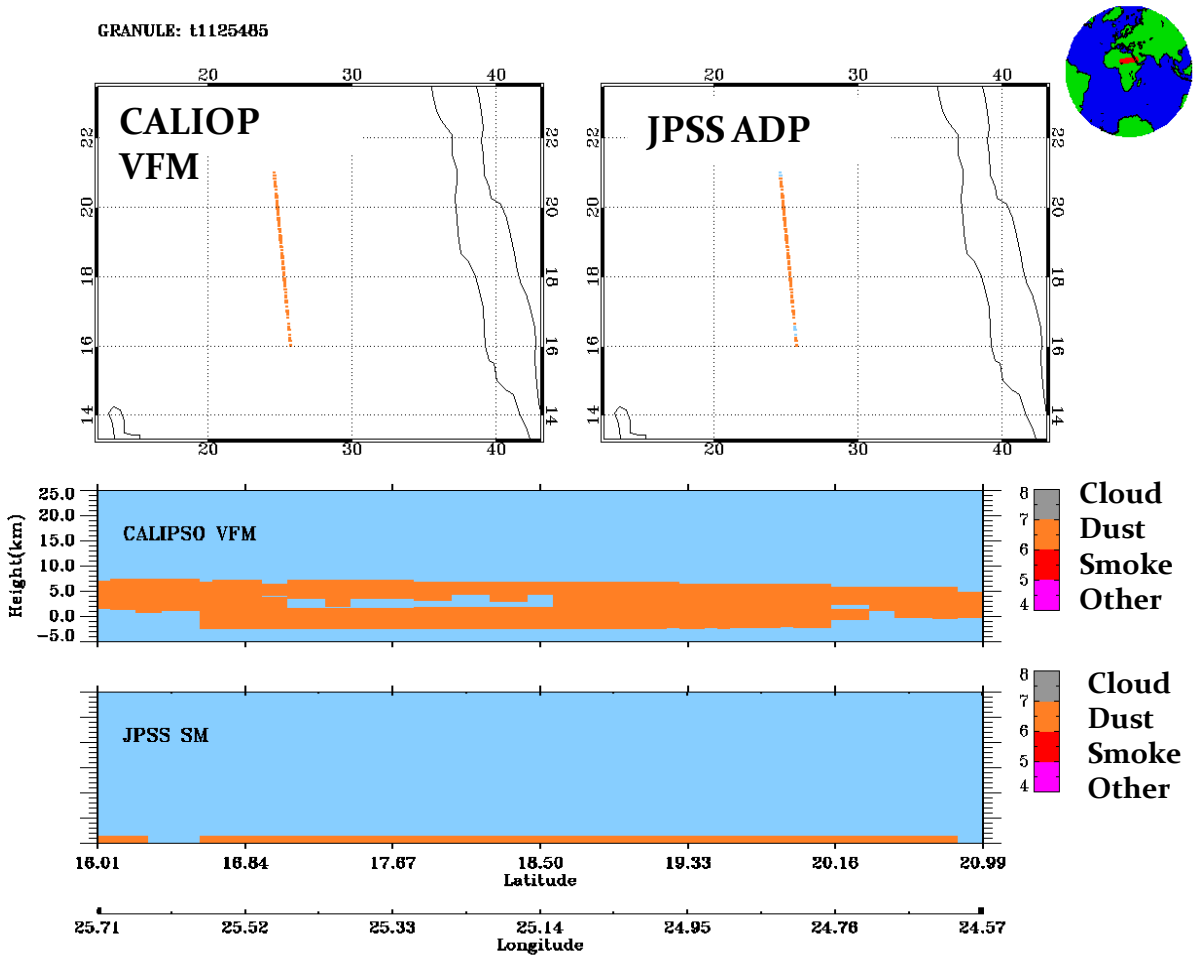




EPS ADP (on VIIRS) vs. CALIPSO

Land	Accuracy (%)	POCD (%)	POF D (%)
DUST	84.4	85.3	3.1
SMOKE	98.4	96.7	34.1

Water	Accuracy (%)	POCD (%)	POF D (%)
DUST	95.4	96.4	3.3
SMOKE	94.0	97.2	45.7



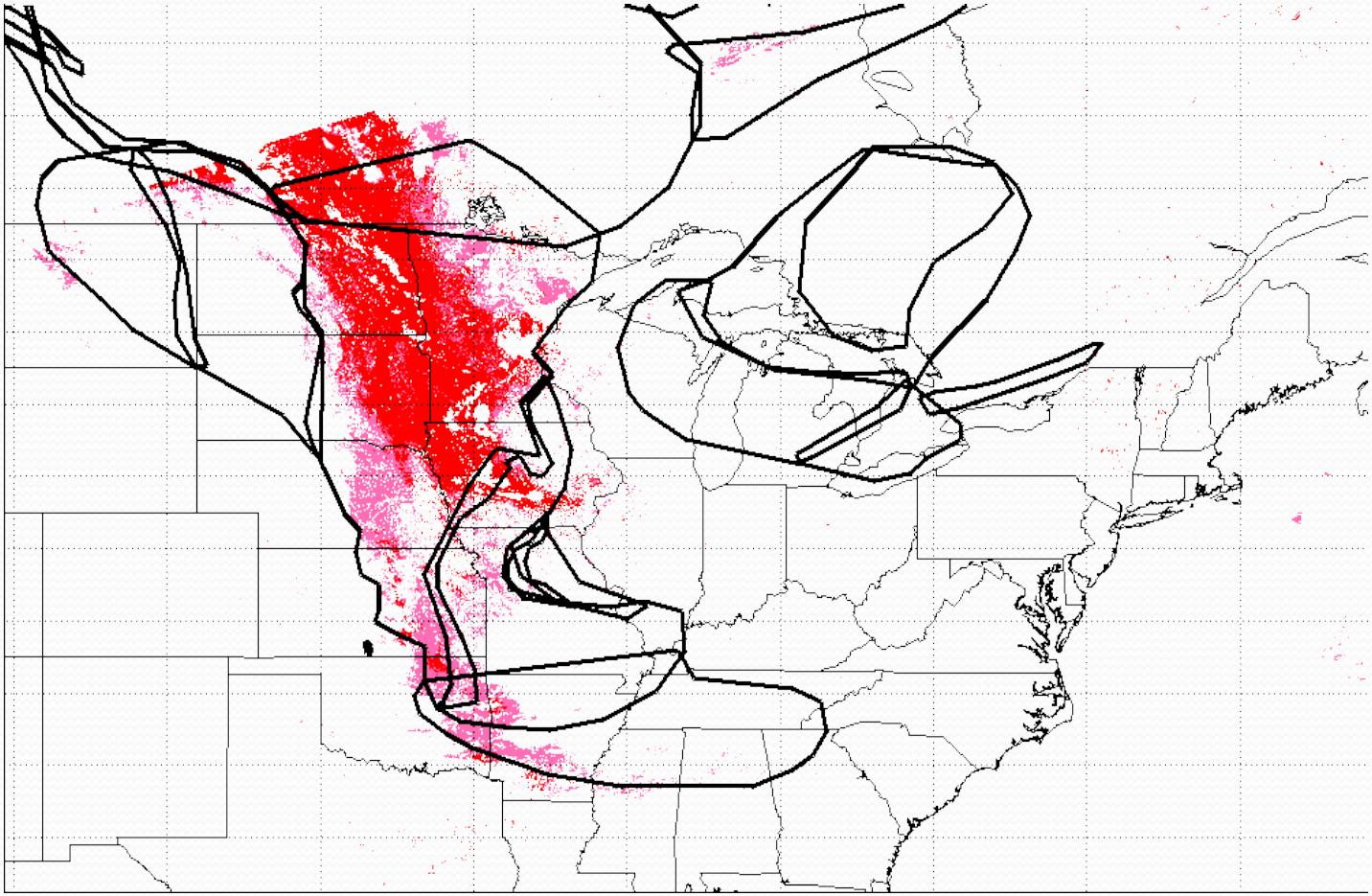
TRUTH DATA

JPSS ADP

	Yes	No
Yes	A	B
No	C	D

POCD = A/(A+C)
POFD = B/(A+B)
Accuracy = (A+D)/(A+B+C+D)

EPS ADP vs. NOAA HMS smoke product

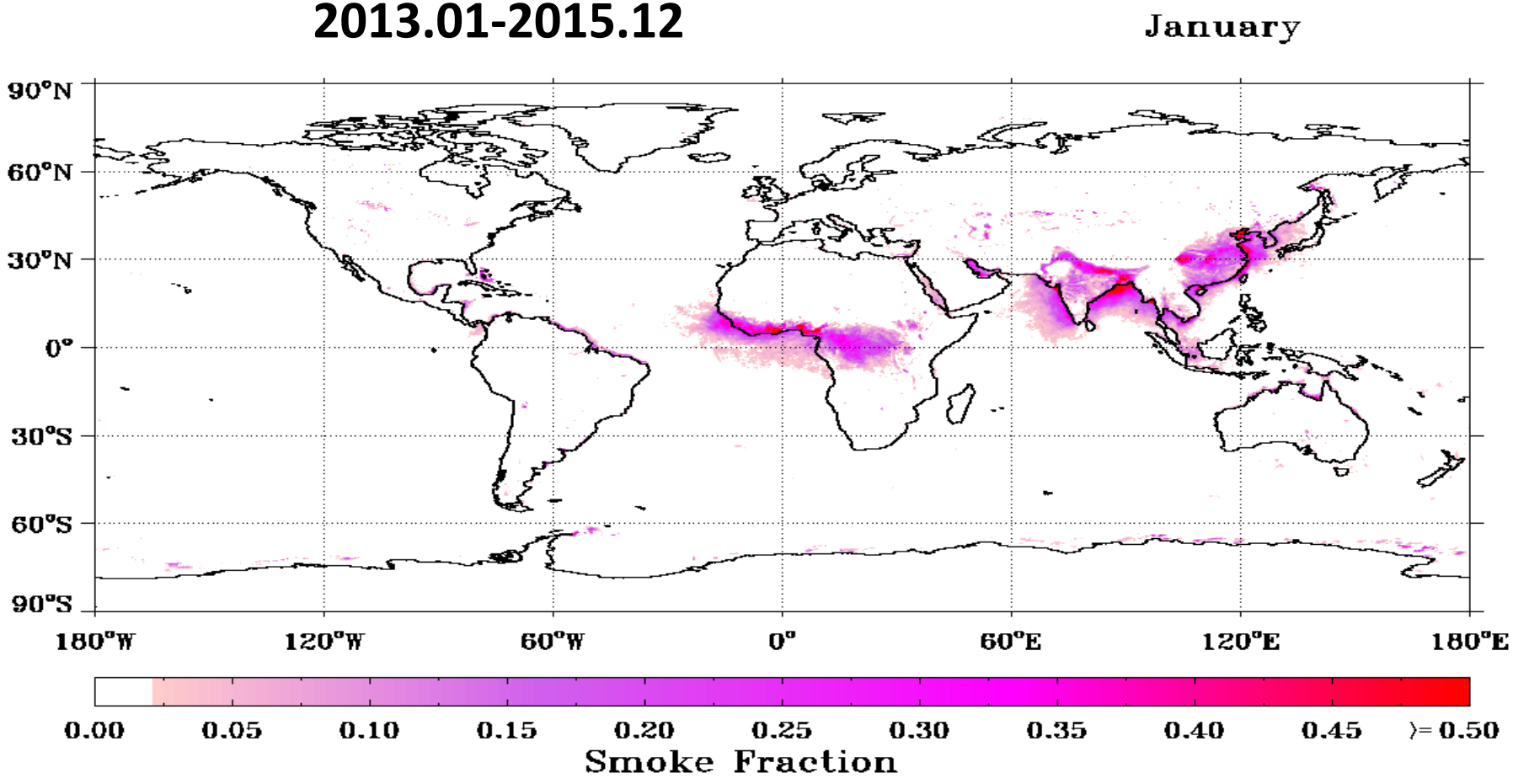


Example of smoke plume on 06/29/2015. Polygons of smoke plume from NOAA HMS (black-thick line) overlap smoke mask from EPS ADP on VIIRS

Global Monthly Smoke Fraction

0.25 x 0.25 degree

2013.01-2015.12

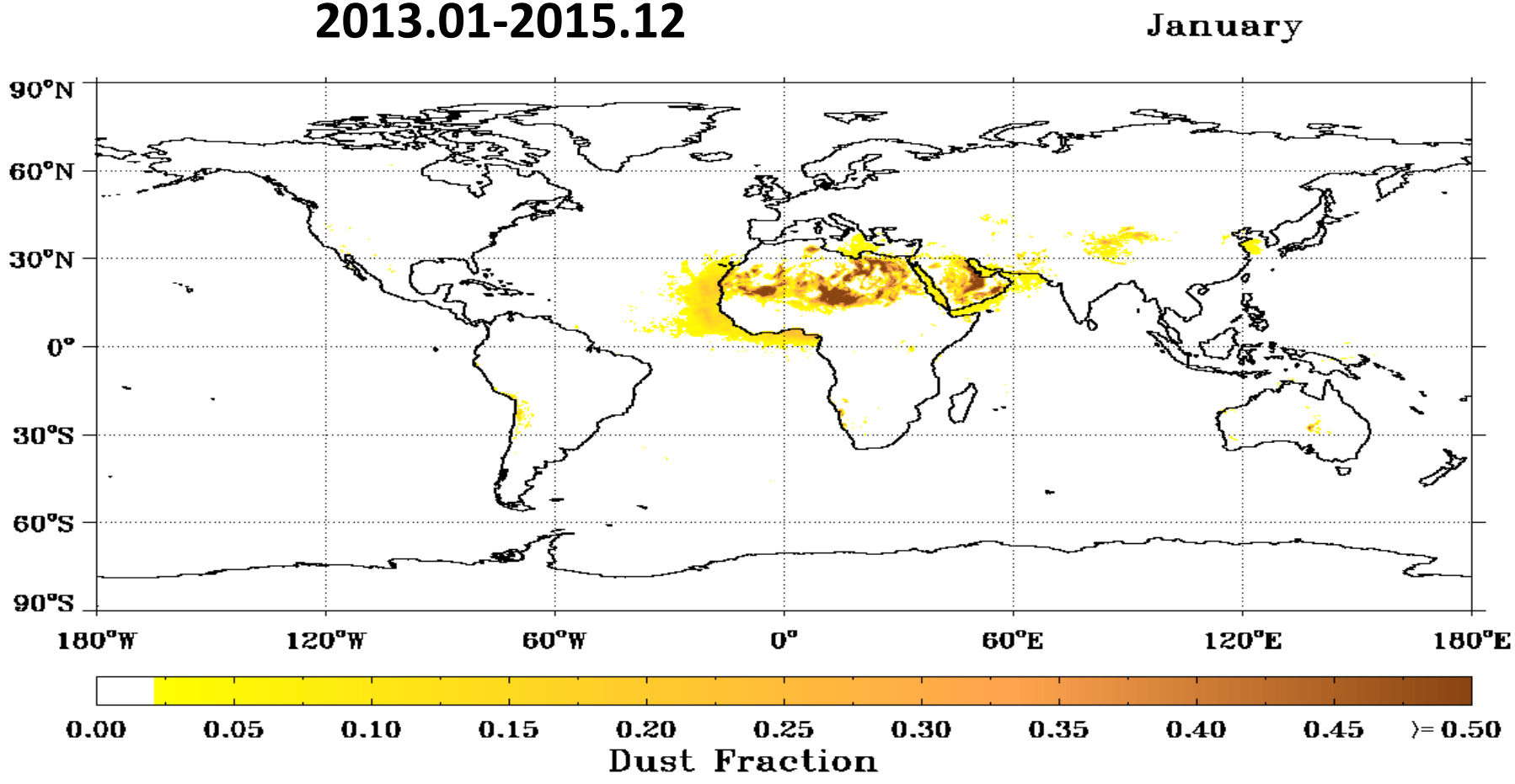


Smoke(dust) fraction is defined as the Number of smoke (dust) detected divided by the total number of detections in each grid.

Global Monthly Dust Fraction

0.25 x 0.25 degree

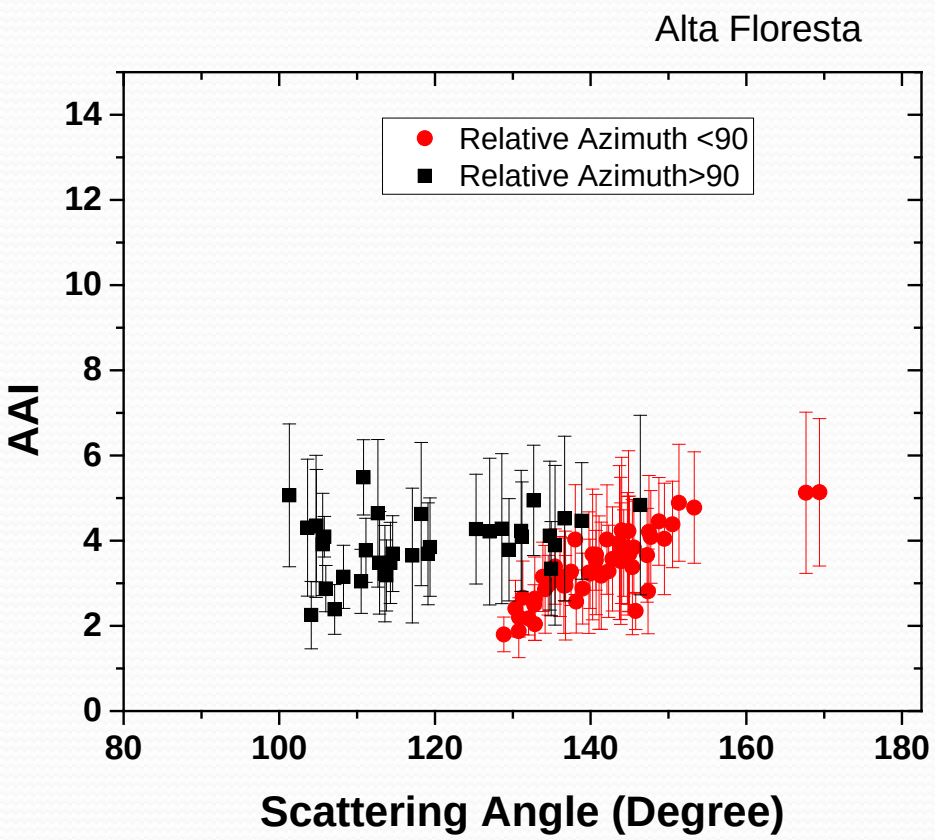
2013.01-2015.12

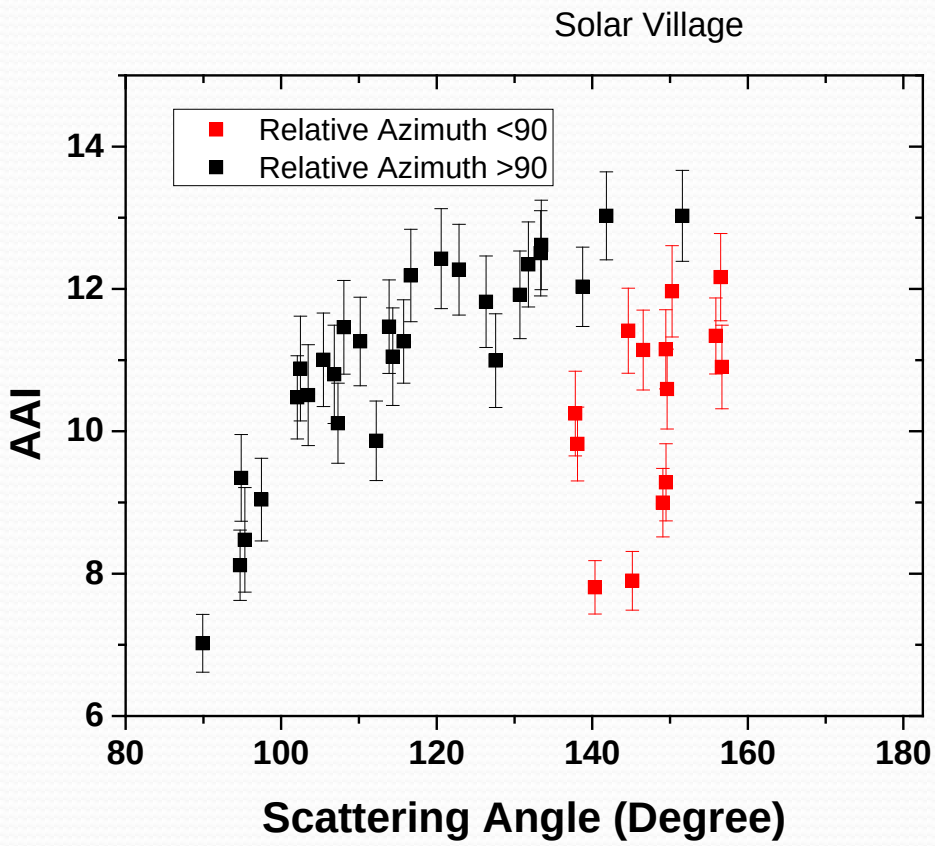


Smoke(dust) fraction is defined as the Number of smoke (dust) detected divided by the total number of detections in each grid.

Algorithm improvements (1)

AOD<0.2, 2012.05 to 2014.05



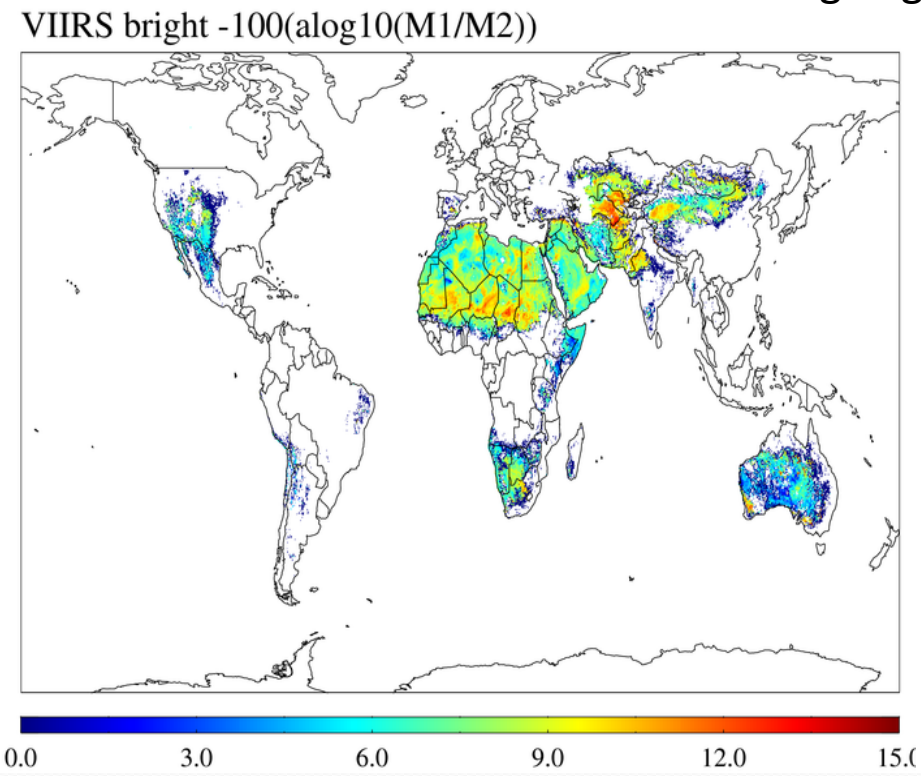


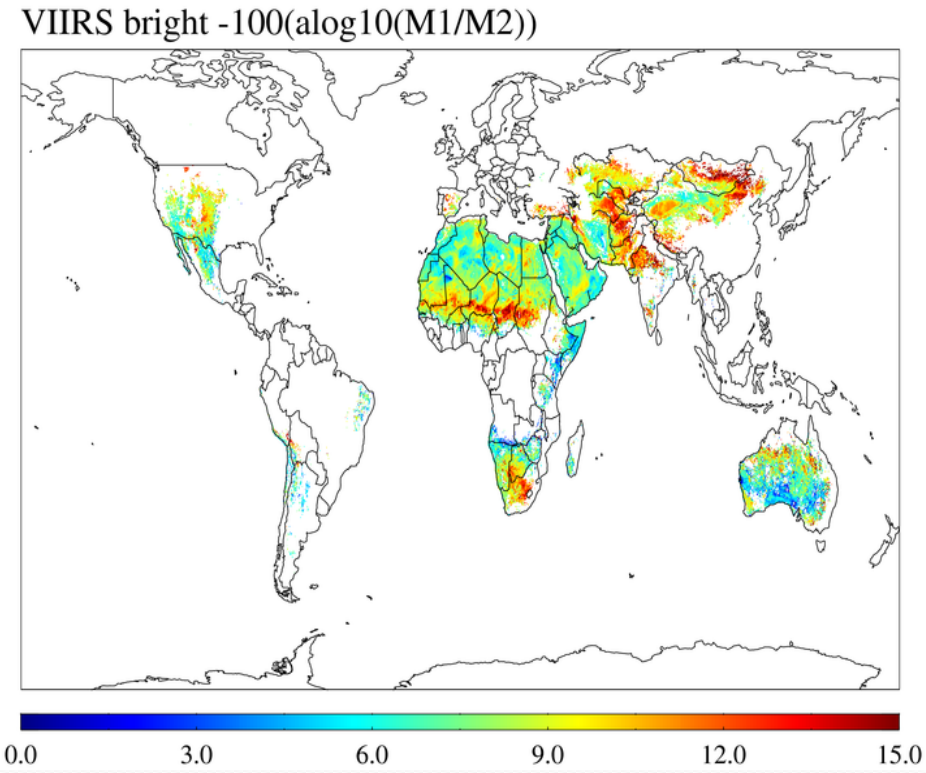
Background AAI is a function for scattering angle and different between backward (Relative azimuth<90) and forward (Relative azimuth>90) direction.

Algorithm improvements (2)

Relative azimuth >90.0 **Relative azimuth <90.0 Bright surface**

Scattering angle=140



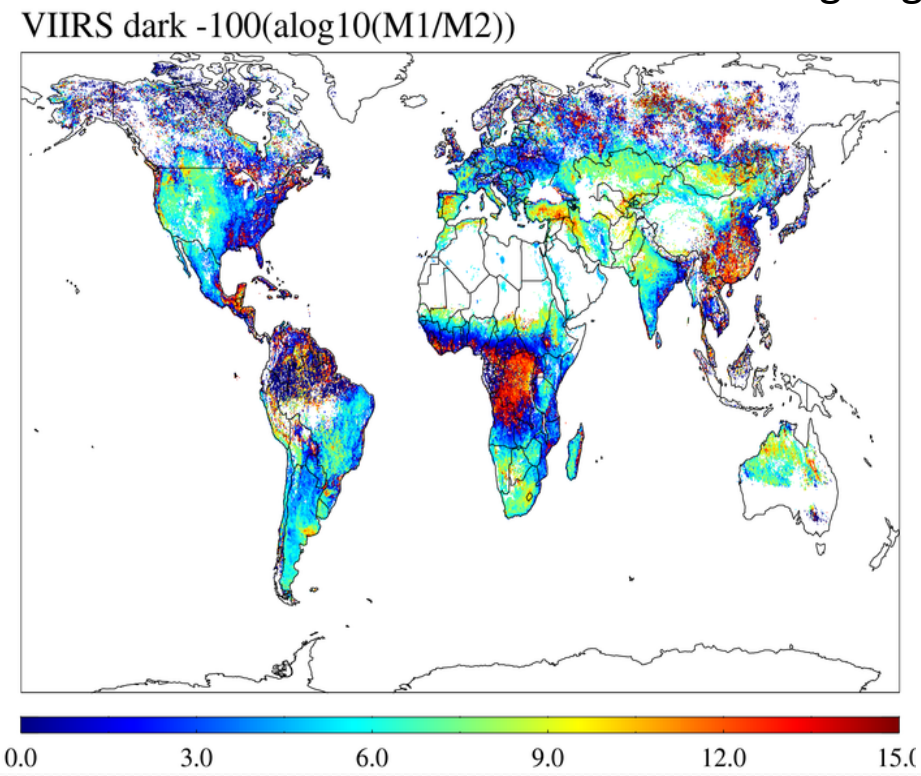


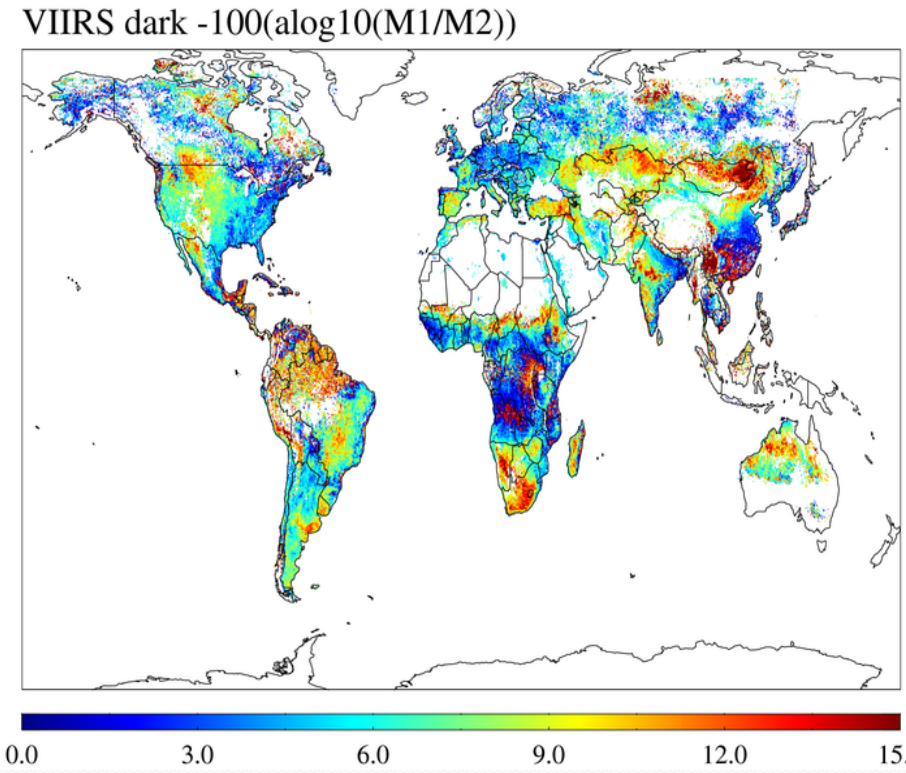
The derived climatology of surface reflectance ratio between M1 and M2, indicates that AAI threshold may vary with geo-location, as a result of surface type changes.

Algorithm improvements (3)

Relative azimuth >90.0 **Relative azimuth <90.0 Dark surface**

Scattering angle=140





The derived climatology of surface reflectance ratio between M1 and M2, indicates that AAI threshold may vary with geo-location, as a result of surface type changes.

Summary

- EPS Aerosol detection algorithm combines IR-visible based and DAI-based algorithms to work on observations from multi-sensors.
- The concept, function and results of EPS ADP algorithm have been demonstrated by applying EPS aerosol detection algorithm to observations from multi-sensors, including MODIS, S-NPP VIIRS, AHI and future sensor (TEMPO)
- Validations against CALIOP VFM product indicated that EPS aerosol detection algorithm meets requirements with an accuracy of around 80%.
- Future improvements on EPS aerosol detection algorithm is undergoing by creating geometry and geo-location dependent thresholds to reduce false alarm rate.