Application of DAI-based smoke/dust detection algorithm to VIIRS observations

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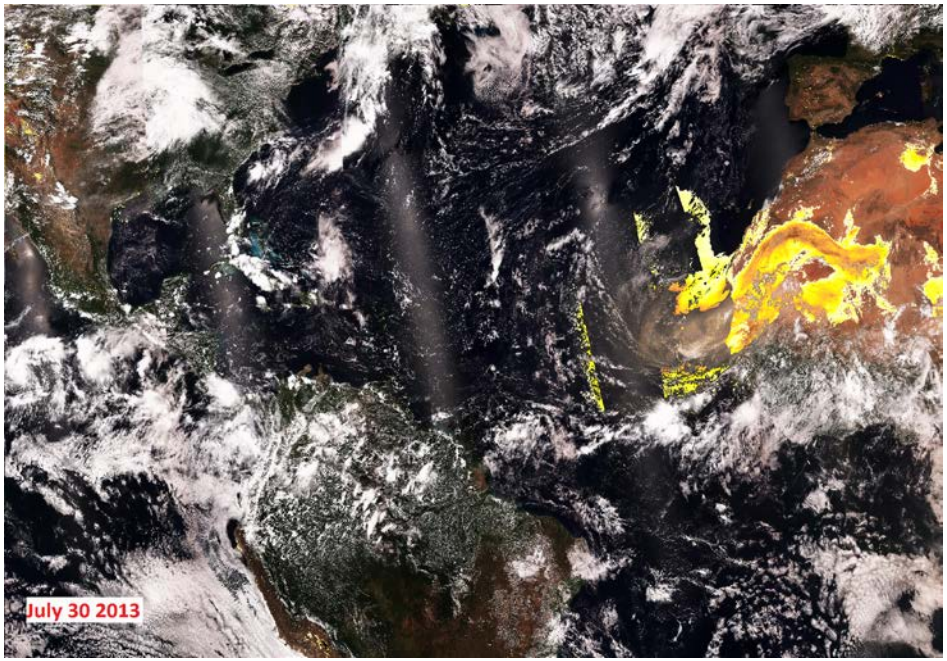

JPSS Risk Reduction Algorithm for VIIRS Dust and Smoke Detection

- Adapt GOES-R Advanced Baseline Imager (ABI) aerosol (dust and smoke) detection algorithm
  - For dust, take advantage of deep-blue channels on VIIRS and adapt MODIS dust detection algorithm developed by STAR*
- Simple, fast, and easy to be implemented operationally
- Detects most plumes with good accuracy

***Dust Aerosol Index (DAI) Algorithm for MODIS**
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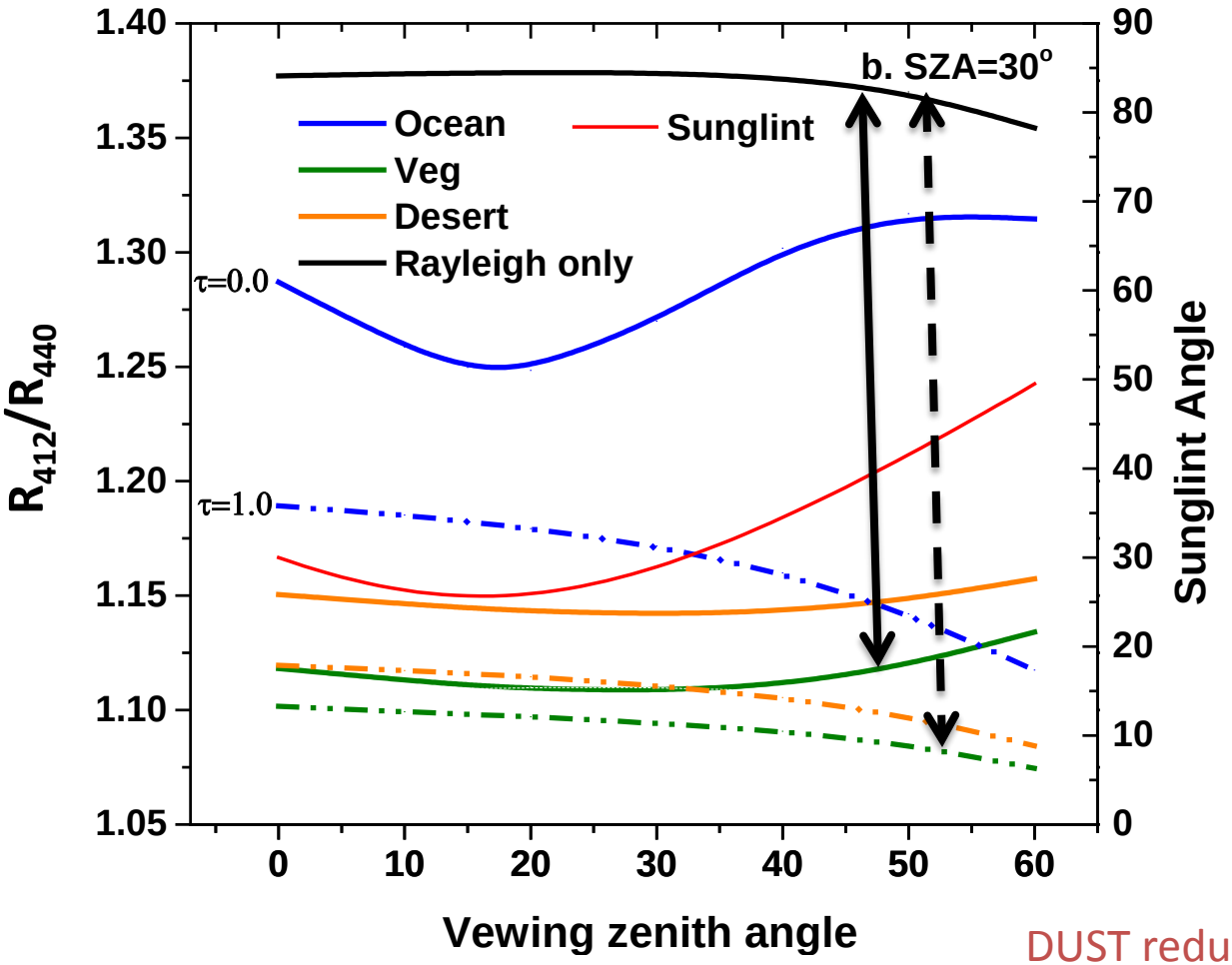
Journal of Geophysical Research: Atmospheres
03/2014 DOI:10.1002/2013JD020855

- Spectral dependence of three processes allows the dust detection
  - Surface reflectance
  - Rayleigh scattering
  - Dust absorption

6S Radiative Transfer Simulations

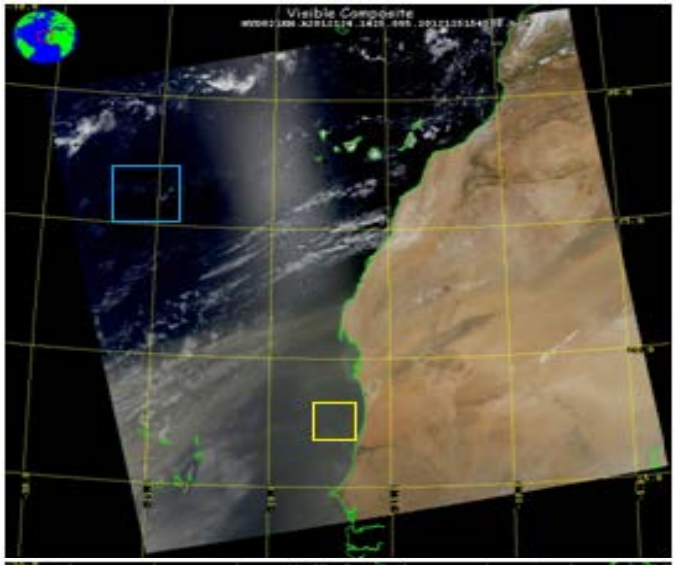


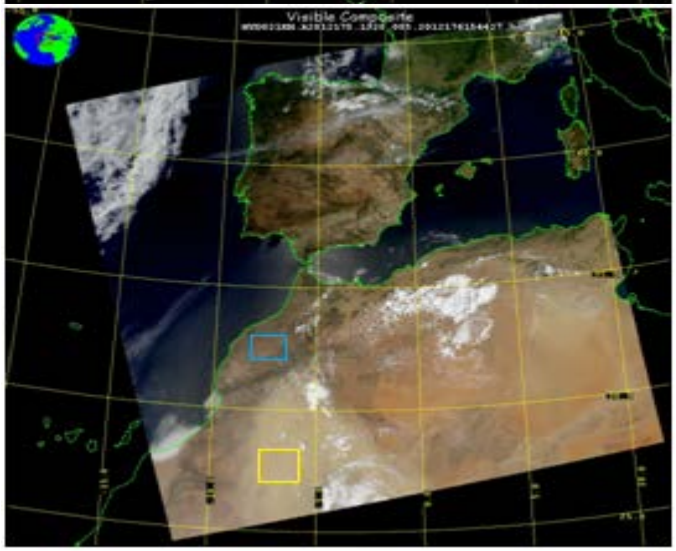
6S Simulations:

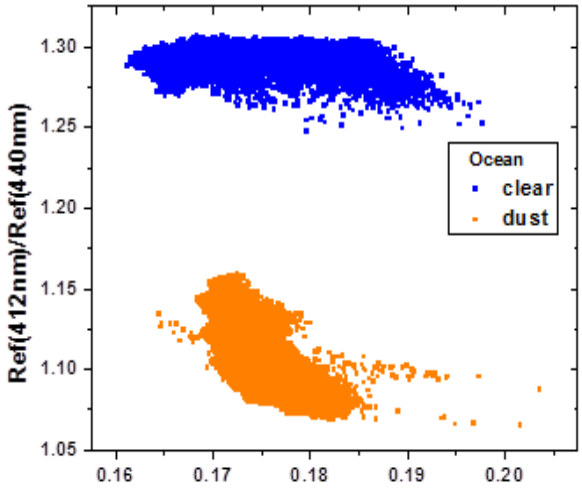
1. MODIS C5 dust aerosol model used
2. Desert, vegetation, ocean BRDF with easterly wind speed of 6 m/s are used to represent surfaces in 6S

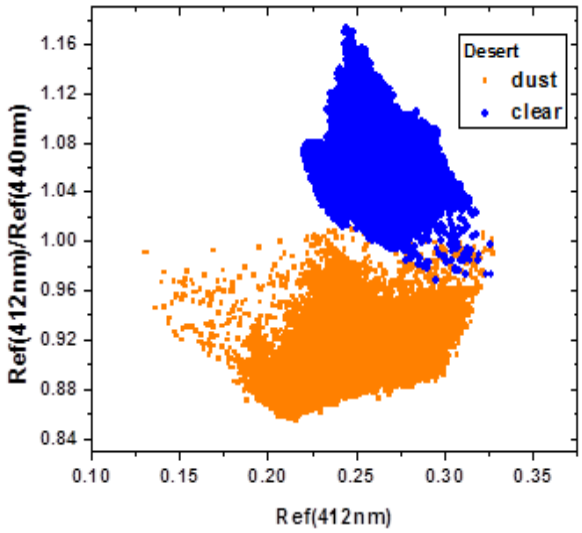
DUST reduces the contrast between 412nm and 440 nm as a result of increasing absorption by dust with decreasing wavelength

MODIS Observations: Dust vs. Clear Sky

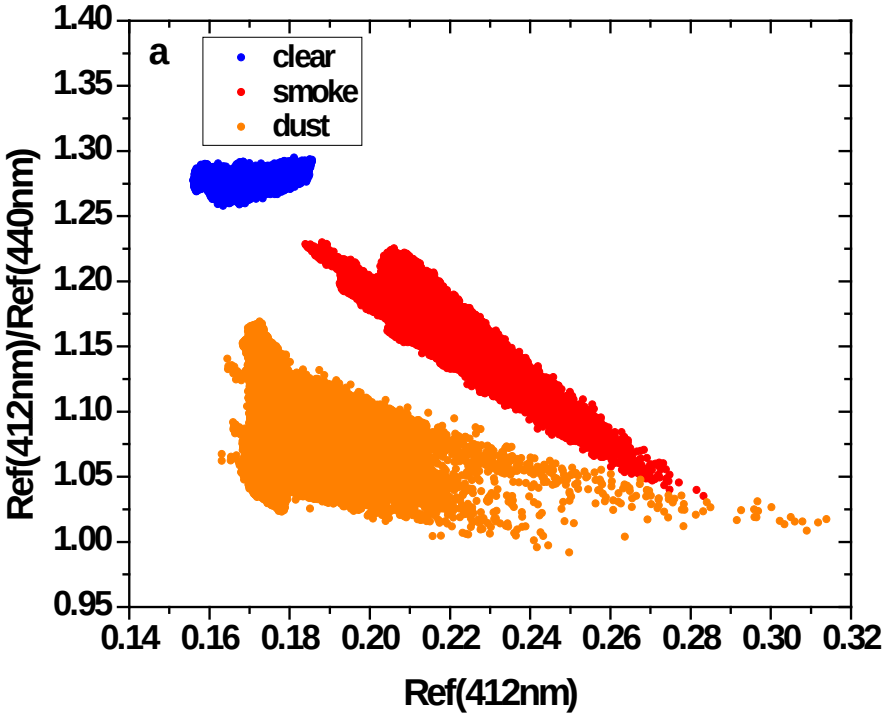


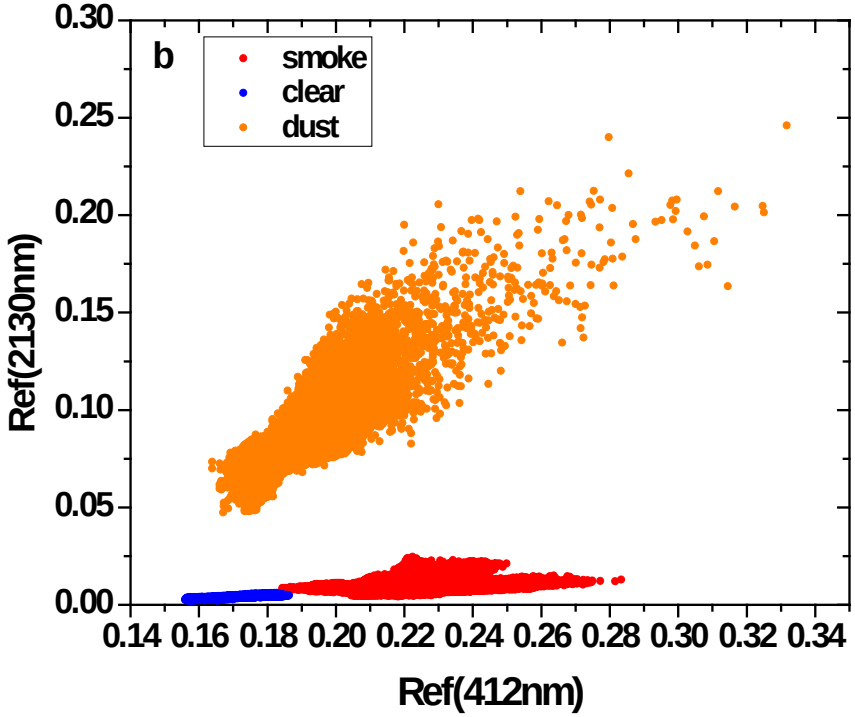






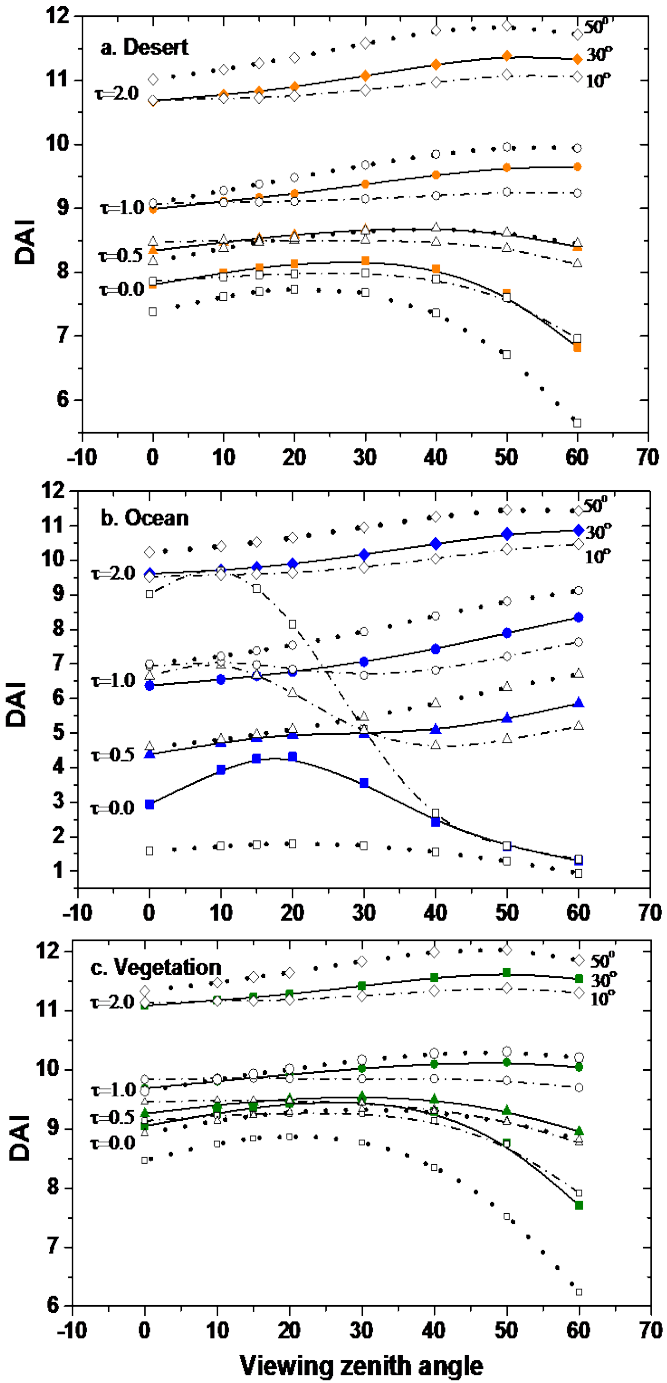
Smoke and dust vs. Clear Sky





Smoke:

- Has the same effect as dust in terms of reduction of the contrast between 412nm to 440nm
- Difference in particle size enables us to pick-out the smoke by introducing short-wave IR channel (2.13 µm)



Dust Aerosol Index

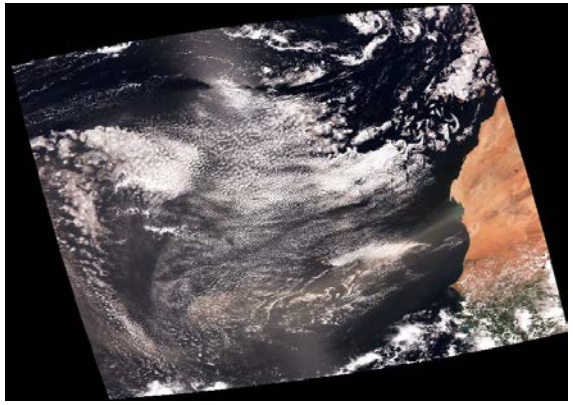
$$DAI = 100*[\log_{10}(R_{412nm}/R_{445nm})-\log10(R'_{412nm}/R'_{445nm})]$$

$$NDAI = -10*[\log_{10}(R_{412nm}/R_{2.25um})]$$

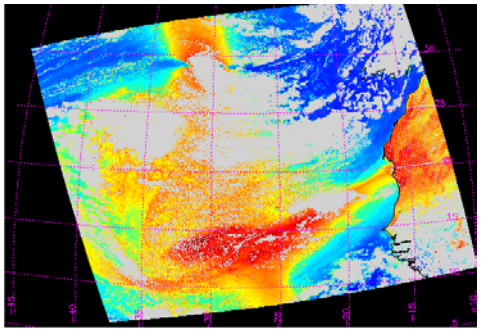
R' -- reflectance from Rayleigh scattering

- **Clouds are first screened by using $R_{0.42um}$**
- **Residual Clouds over water are screened using 0.86 μm spatial variability test. Over land, residual clouds are screened by 412 nm spatial variability test. Cirrus clouds are screened using 1.38 μm test.**
- **Bright desert surfaces are screened for by bright pixel index (normalized difference of 1.24 μm and 2.25 μm).**
- **Turbid water test based on Shi and Wang, 2007 uses 0.746 um and 1.24 μm measurements.**
- **Sunglint, snow/ice, fire hot spots are also screened based on different tests (geometry, spectral etc.)**
- **DAI and NDAI are computed for pixels that pass these tests:**
  - **Water: DAI ≥ 4 and NDAI ≥ -10**
  - **Land: DAI ≥ 11.5 and NDAI ≥ 0**

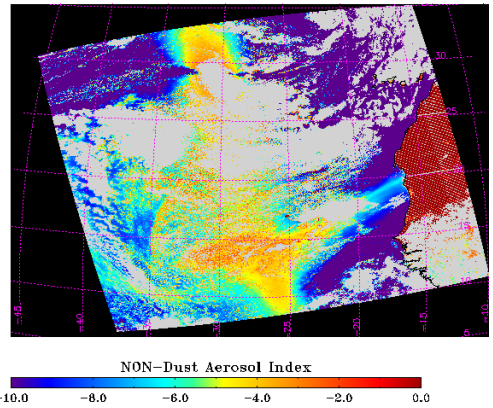
JPSS RR dust/Smoke Detection



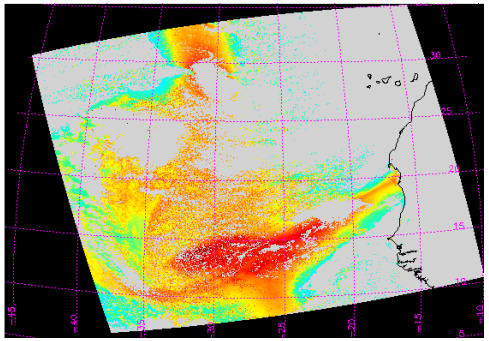
DAI after cloud screening



NDAI after cloud screening

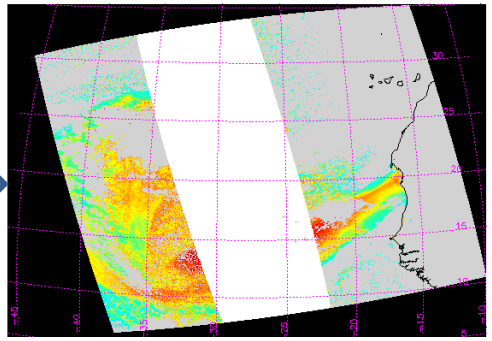


Dust flag



Sunglint flag

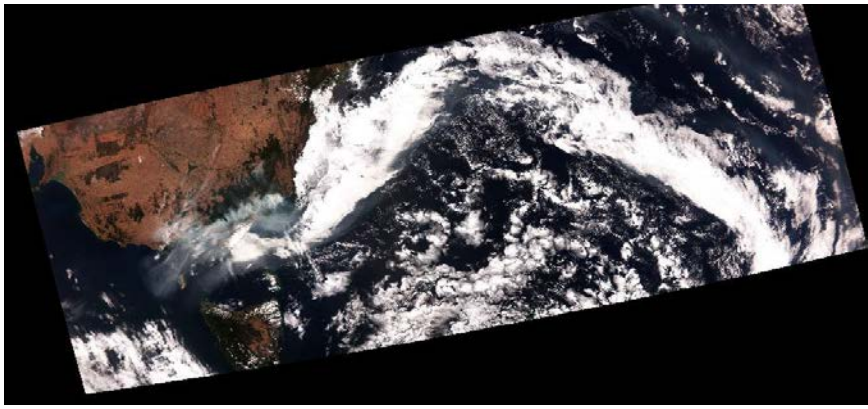
Final dust flag

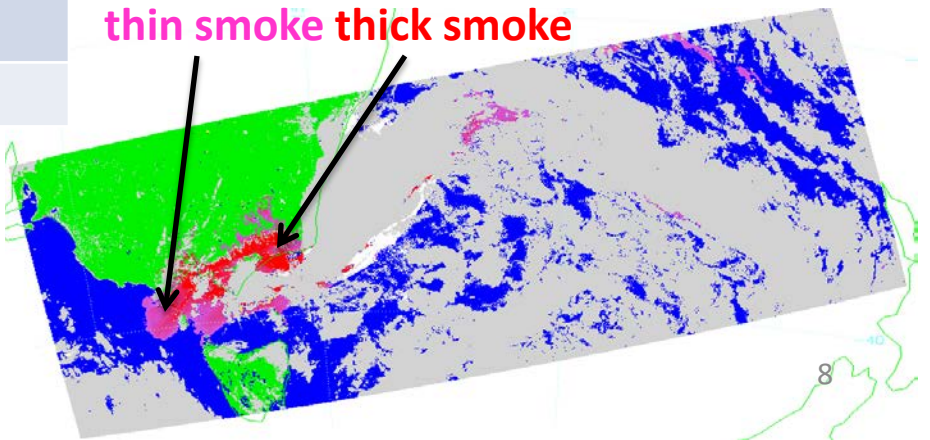


VIIRS Smoke Detection

- The NDAI in the dust algorithm can also indicate the presence of smoke and/or haze mixed in with smoke

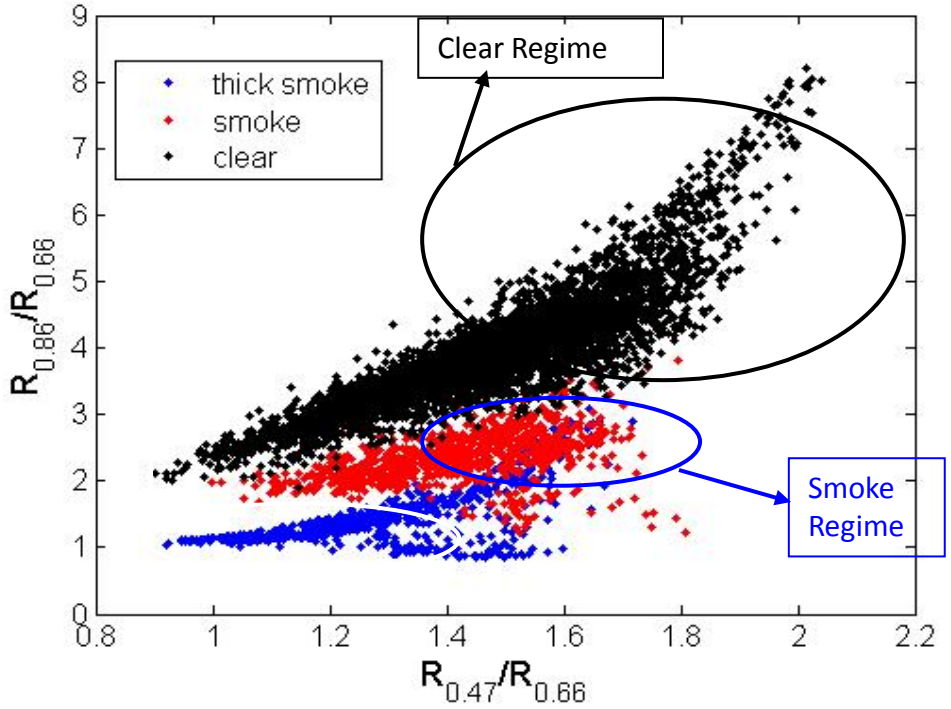
Surface	Condition	Smoke Detection
Land	DAI ≥ 5.0 and NDAI ≤ -2.0	Thin Smoke
	DAI ≥ 9.0 and NDAI ≤ -2.0	Thick Smoke
Water	DAI ≥ 4.0 and NDAI ≤ -10.0 $R_{410} < 0.1$	Thin Smoke
	DAI ≥ 9.0 and NDAI ≤ -4.0	Thick Smoke

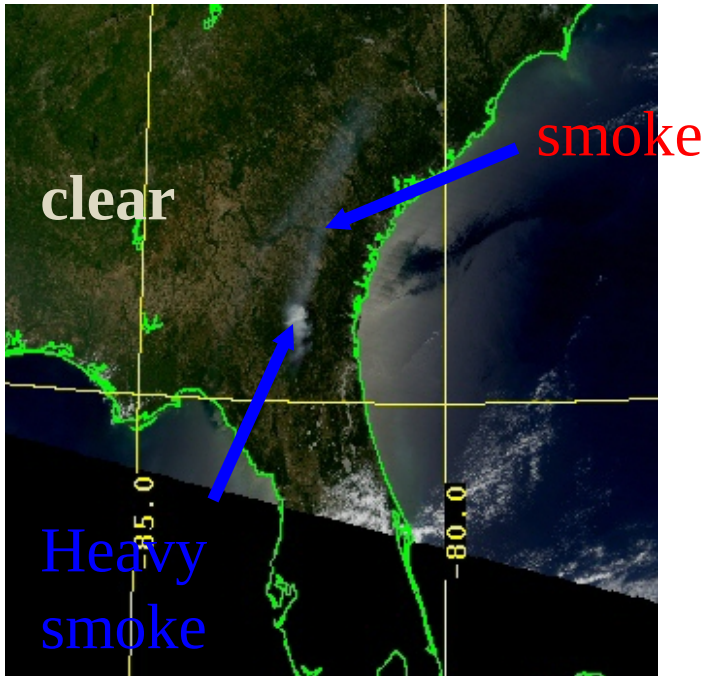




JPSS RR Algorithm for Smoke Detection

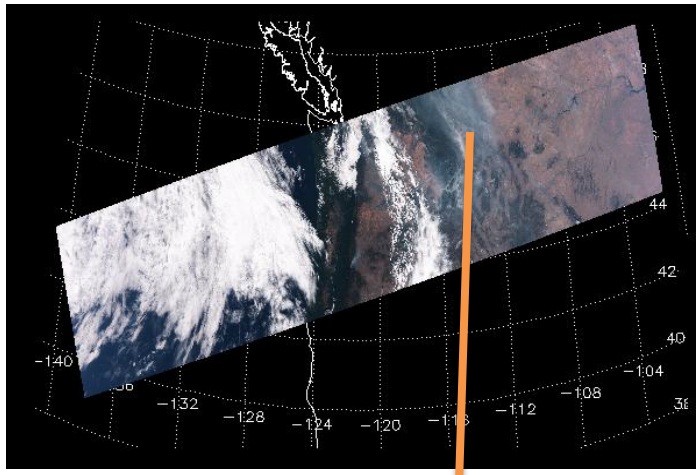
- **Spectral (wavelength dependent) thresholds can separate thick smoke, light smoke, and clear sky conditions**

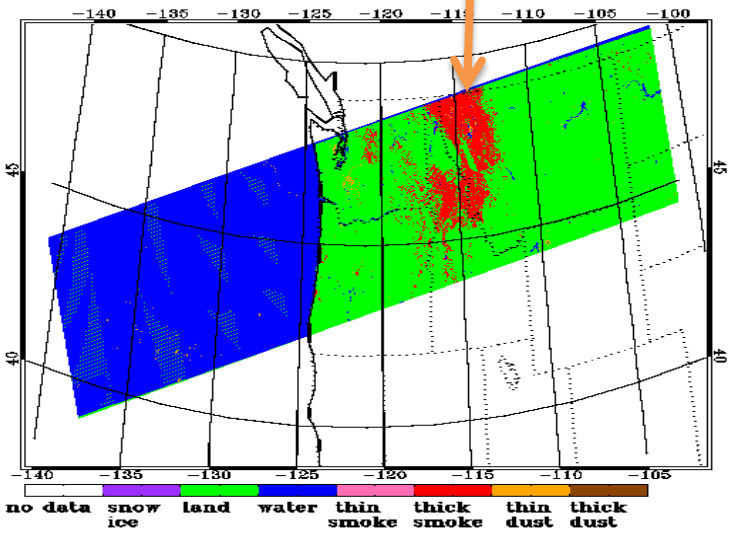




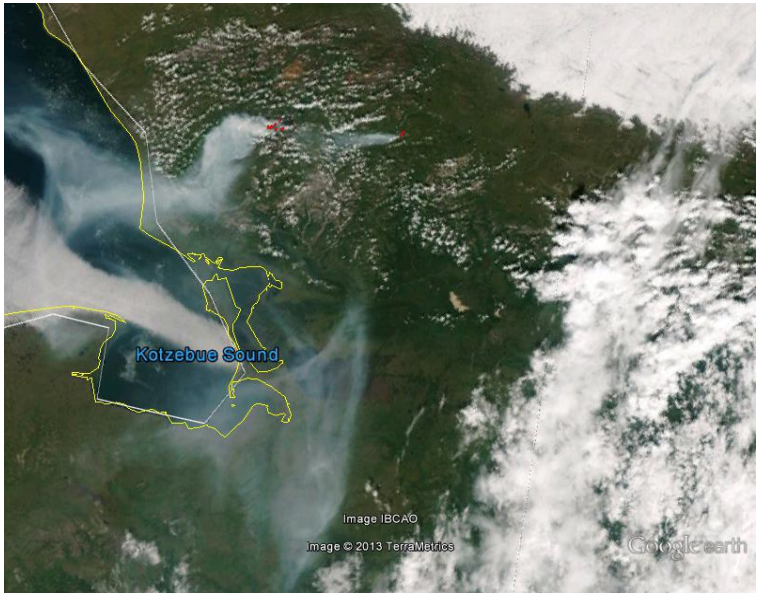
JPSS RR Dust and Smoke Detection Examples

Smoke over West Coast of United States on September 22, 2012

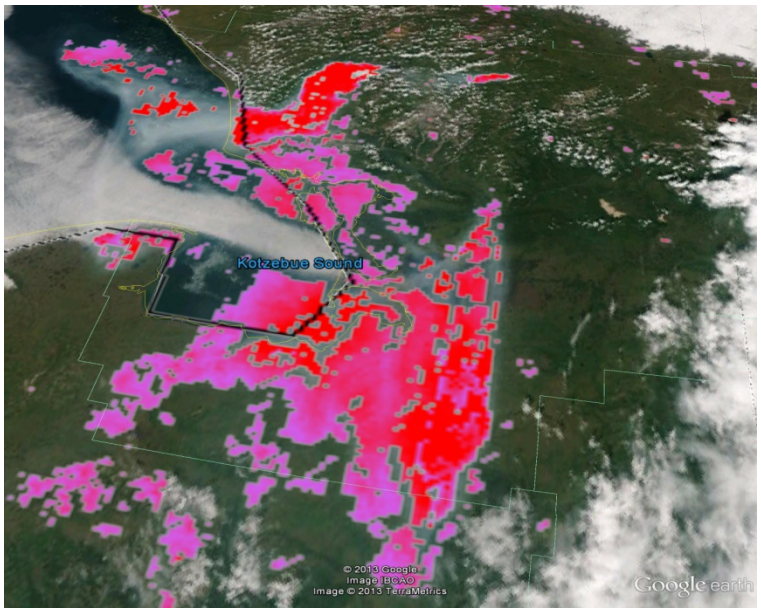




JPSS RR Dust and Smoke Detection Examples



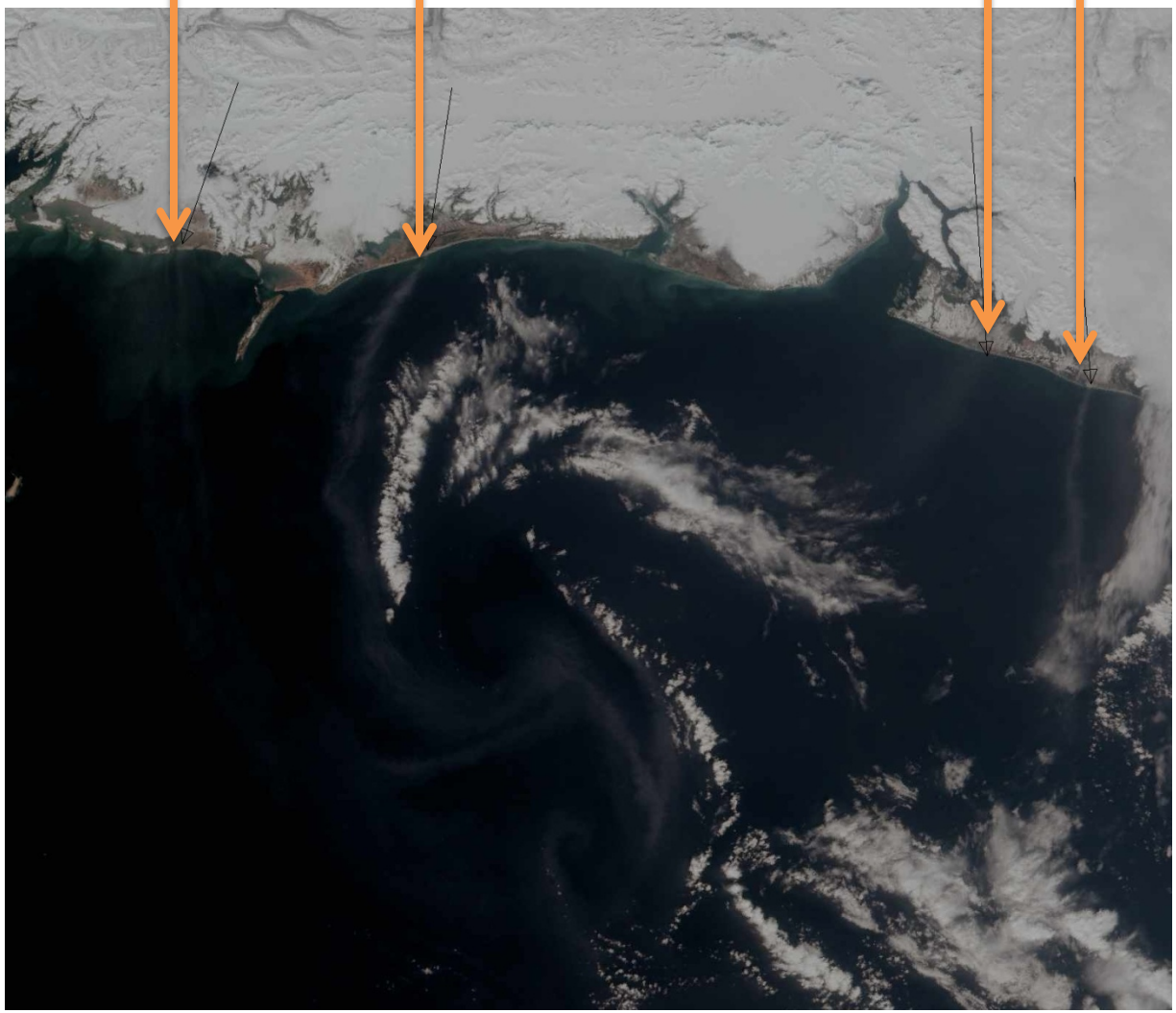
VIIRS fire hot spots and visible smoke in the RGB image on July 8, 2012

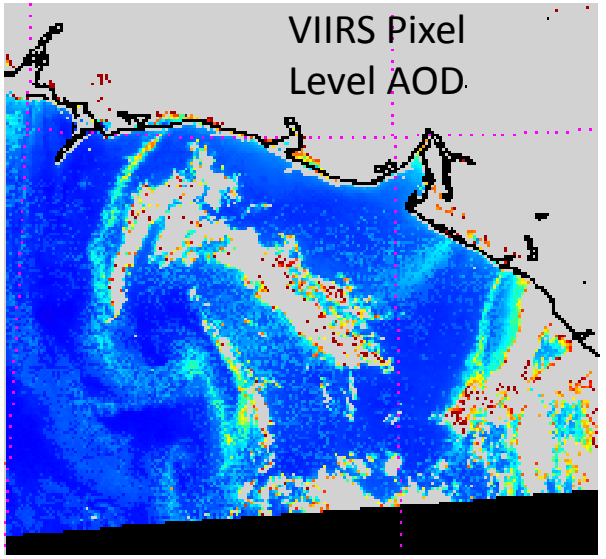


JPSS RR smoke detection algorithm identifies the smoke plumes including the one removed from fire hot spots

JPSS RR Dust and Smoke Detection Examples

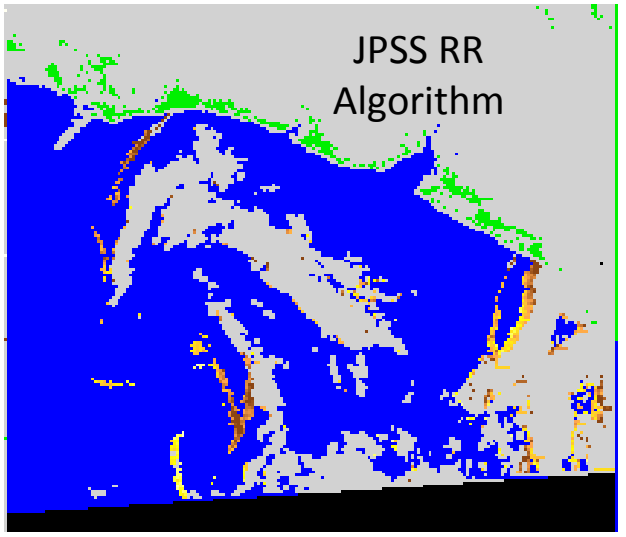
VIIRS true color image of blowing dust from different sources in Alaska on April 28, 2013





Aerosol Optical Depth

0.1 0.2 0.3 0.4 0.5



Validation

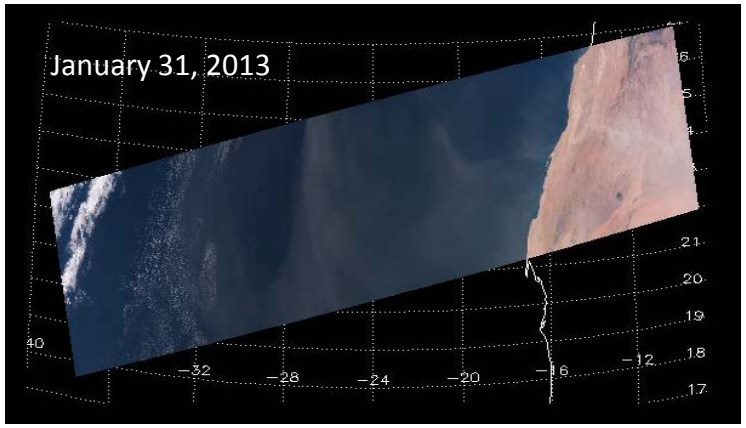
- JPSS RR dust detection algorithm run on VIIRS observation for the entire year of 2013.
  - VIIRS smoke/dust frequency vs. CALIPSO and MISR
  - VIIRS smoke and dust detection matchups with CALIPSO and AERONET
- Derive performance metrics
  - Accuracy
  - Probability of Correct Detection (POCD)
  - Probability of False Detection (POFD)

		TRUTH DATA: Yes	TRUTH DATA: No
VIIRS	Yes	A	B
	No	C	D

POCD = A/(A+C)

POFD = B/(A+B)

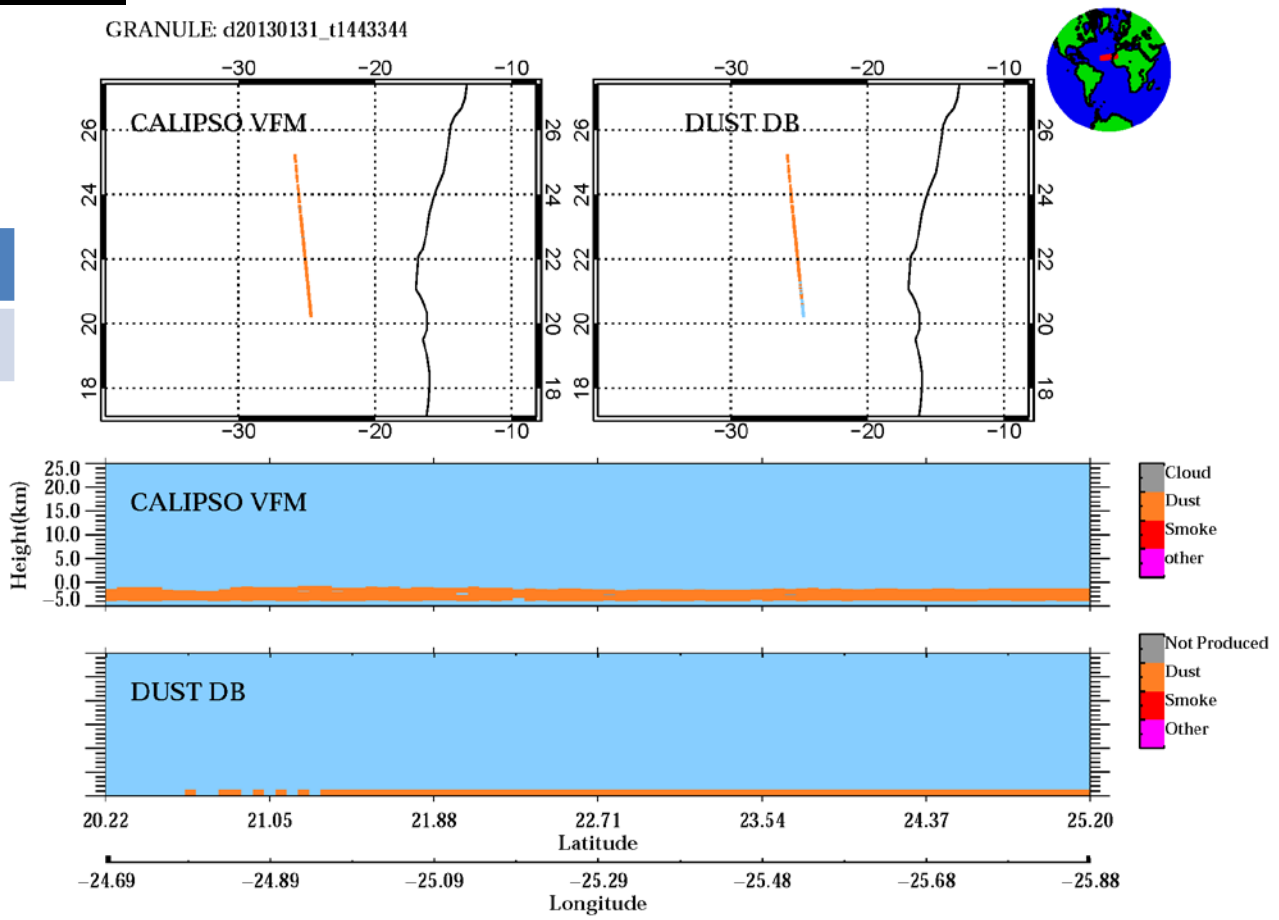
Accuracy* = (A+D)/(A+B+C+D)



VIIRS vs. CALIPSO

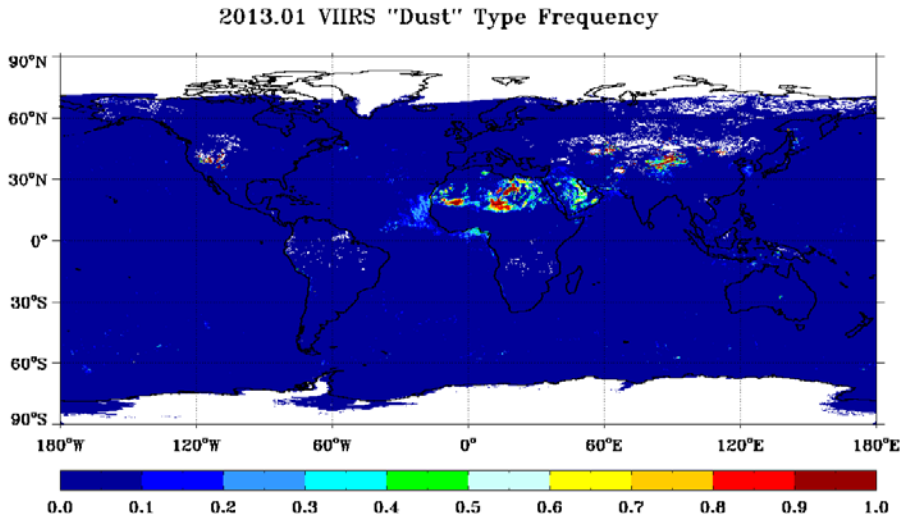
SM DAI

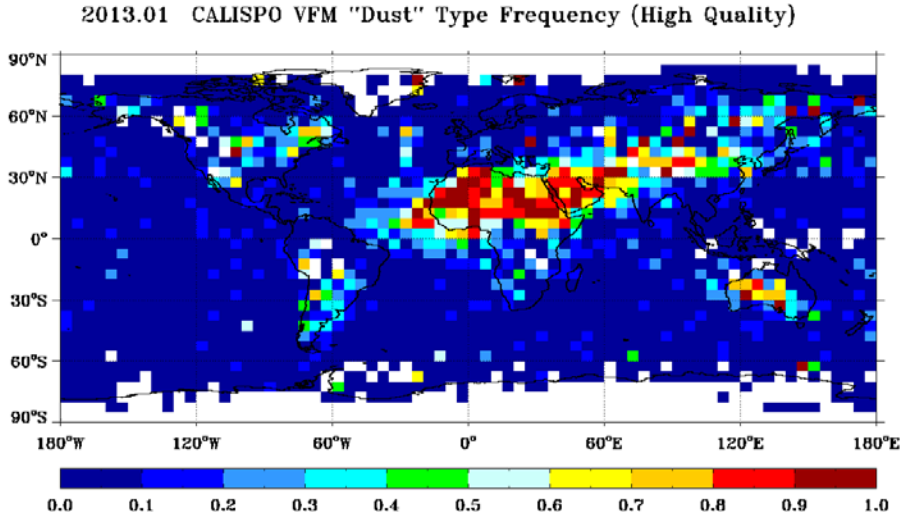
Accuracy	83%
POCD	85%



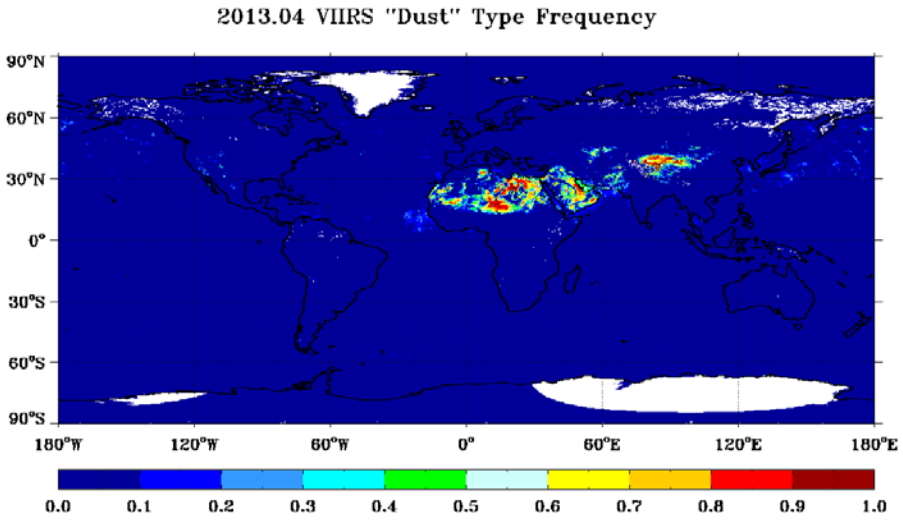
DUST

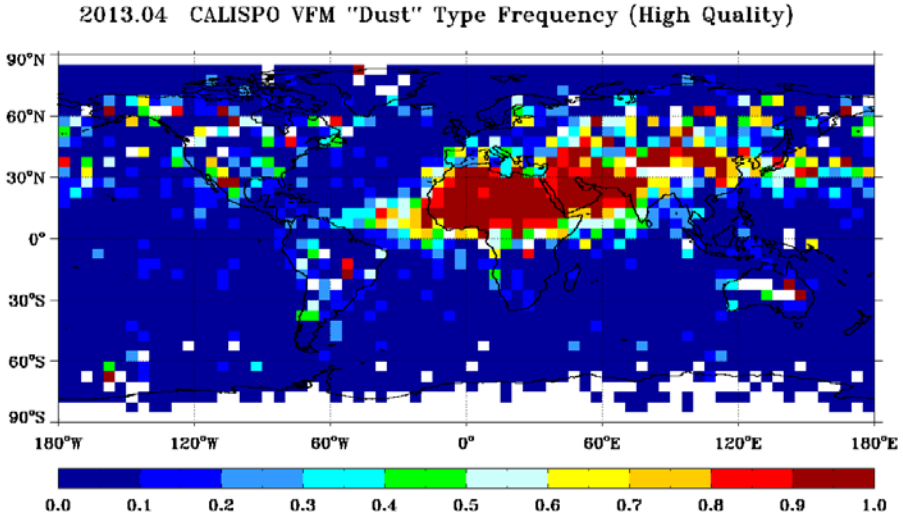
January





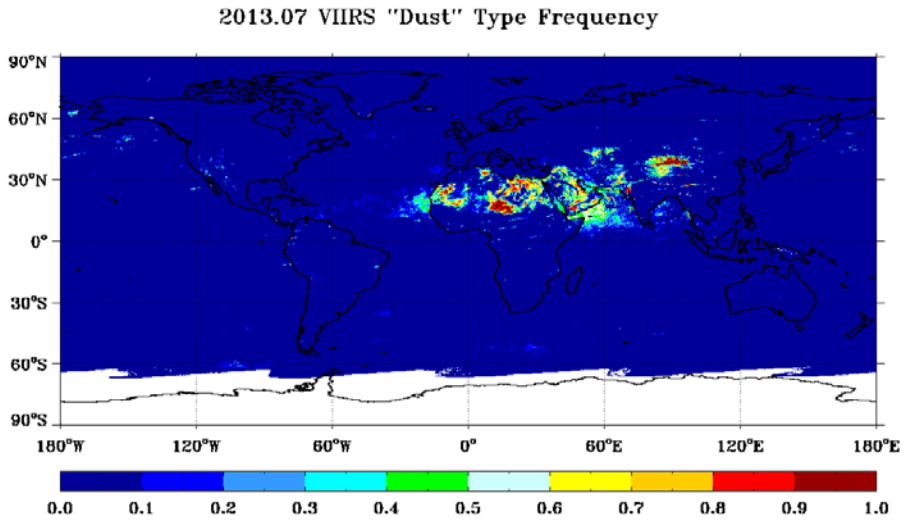
April

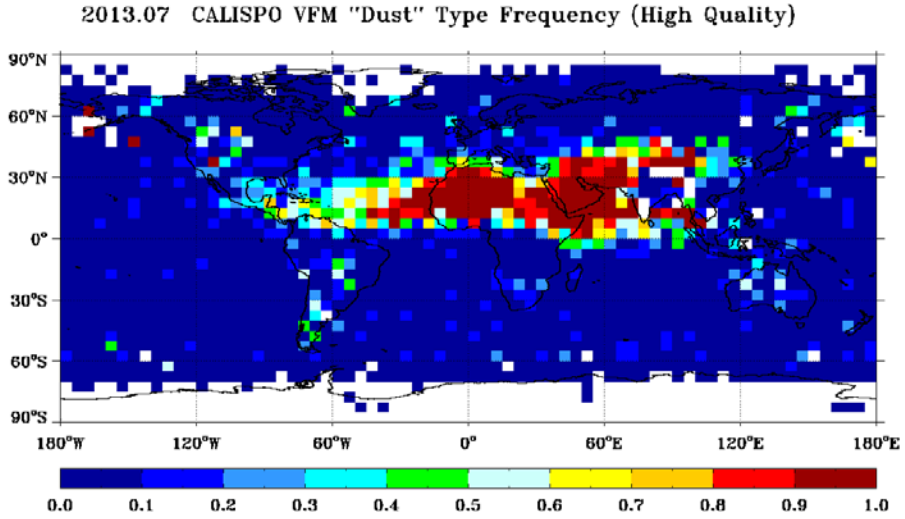




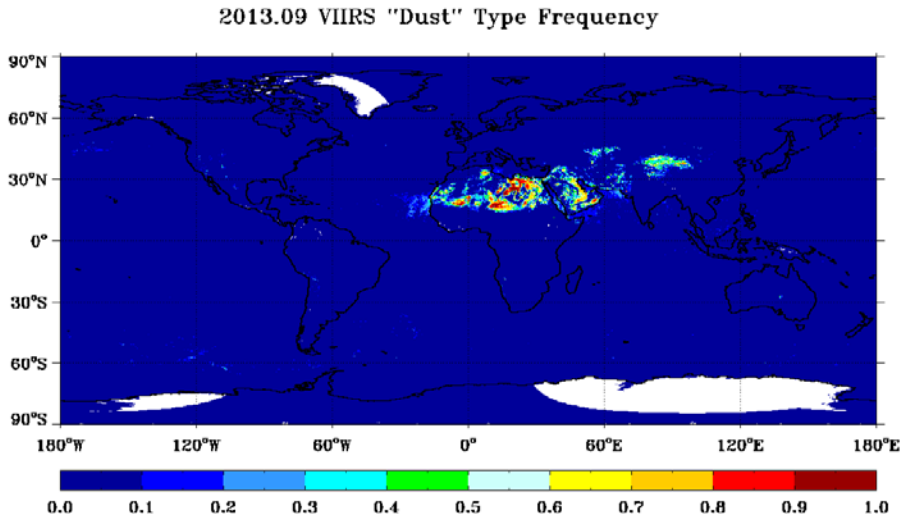
DUST

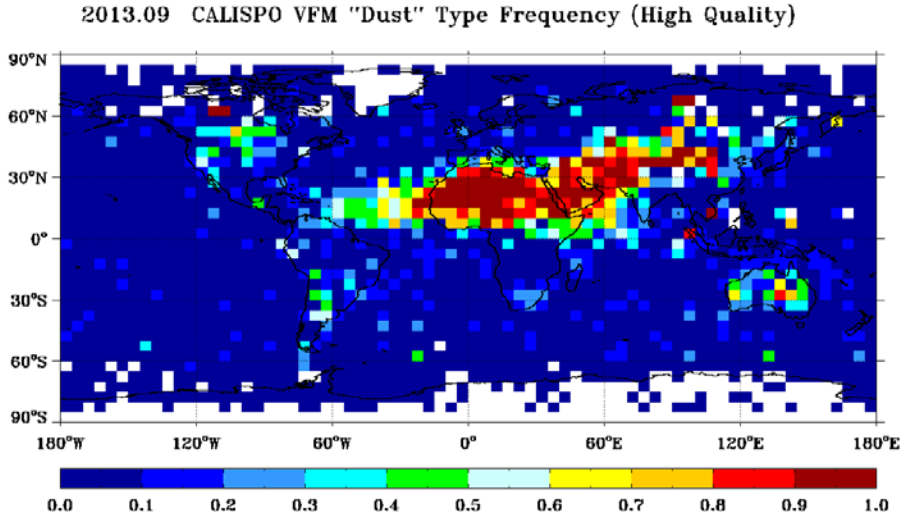
July





September





JPSS RR Dust Detection Over Land: VIIRS vs. CALIPSO

	Month (2013)											
	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

* CALIPSO data not available

JPSS RR Dust Detection Over Water: VIIRS vs. CALIPSO

	Month (2013)											
	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 Dust Detection : VIIRS vs. AERONET

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

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

Summary

- An algorithm based on observations from deep-blue and shortwave-IR developed for MODIS has been adapted for VIIRS.
  - Algorithm is simple, fast, and easy to be implemented operationally.
- Dust and smoke detections meet L1RD requirements
- Additional validation on smoke detection is needed
- Additional investigation of data artifacts (false detections) is required to enhance product accuracy