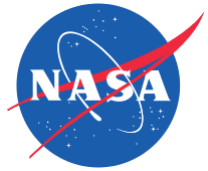


NOAA-20 VIIRS Aerosol Detection Beta Maturity

April 18, 2018

VIIRS Aerosol Team

Shobha Kondragunta (STAR); Pubu Ciren(IMSG); Istvan Laszlo (STAR)

Outline

- Aerosol Cal/Val Team Members
- Product Requirements
- Findings/Issues for Beta maturity
- Documentation (Science Maturity Check List)
- Conclusions
- Path Forward

STAR Aerosol Team

Name	Organization	Major Task
Pubu Ciren	IMSG	Aerosol detection product development and validation
Amy Huff	PSU	Product assessment & User (forecasters) feedback, outreach
Edward J. Hyer	NRL	Product validation, assimilation activities
Shobha Kondragunta	NOAA	Co-lead (detection)
Istvan Laszlo	NOAA	Co-lead (optical depth)
Hongqing Liu	IMSG	Algorithm development, validation, visualization
Lorraine A. Remer	UMBC	Documentation, liaison to Cloud Team
Arthur Russakoff	IMSG	Algorithm integration
Ivan Valerio	IMSG	Data management and monitoring
Hai Zhang	IMSG	Algorithm coding for and maintenance of eIDEA, AerosolWatch websites

Primary VIIRS Bands used in the Aerosol Detection Algorithm

Band Name	Nominal Wavelength Range (µm)	Nominal Central Wavelength (µm)	Horizontal Sample Interval (Km) (Along-Track×Along-Scan)		Algorithm Use
			Nadir	Edge of Scan	
M1	0.402-0.422	0.412	0.742×0.259	1.60×1.58	Dust/Smoke
M2	0.436-0.454	0.445	0.742×0.259	1.60×1.58	Dust/smoke
M3	0.478-0.498	0.488	0.742×0.259	1.60×1.58	Dust/Smoke
M4	0.545-0.565	0.555	0.742×0.259	1.60×1.58	Smoke
M5	0.662-0.682	0.640	0.742×0.259	1.60×1.58	Dust/Smoke
M6	0.739 – 0.754	0.746	0.742×0.776	1.60×1.58	Smoke
M7	0.846-0.885	0.865	0.742×0.259	1.60×1.58	Dust/Smoke
M8	1.230-1.250	1.24	0.742×0.776	1.60×1.58	Dust/Smoke
M9	1.371-1.386	1.378	0.742×0.776	1.60×1.58	Dust
M10	1.580-1.640	1.61	0.742×0.776	1.60×1.58	Smoke
M11	2.225-2.275	2.25	0.742×0.776	1.60×1.58	Dust/Smoke
M12	3.660-3.840	3.70	0.742×0.776	1.60×1.58	Dust/Smoke
M13	3.973-4.128	4.05	0.742×0.259	1.60×1.58	Smoke
M14	8.400-8.700	8.55	0.742×0.776	1.60×1.58	
M15	10.263-11.263	10.763	0.742×0.776	1.60×1.58	Dust/Smoke
M16	11.538-12.488	12.013	0.742×0.776	1.60×1.58	Dust

NDE/STAR VIIRS Aerosol Detection Product Status

Algorithm	Suomi-NPP	NOAA-20
Enterprise Processing System (EPS) v1r2	NDE Operational since July 7, 2017	NDE Currently in I&T March 20, 2018

ADP Requirements

	Proposed Operational Capabilities
Satellite Source (s)	SNPP/NOAA-20 VIIRS
Product Name	Aerosol Detection
Accuracy	Dust: 80% correct detection over land and ocean Smoke: 80% Correct detection over land 70% correct detection over ocean
Latency	30 minutes after granule data is available
Refresh	90 minutes
Timeliness	≤ 3 hours
Coverage	Global
Horizontal Resolution	0.75 km
Other attributes	VIIRS algorithm maintains continuity with MODIS, GOES, and GOES-R algorithms

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

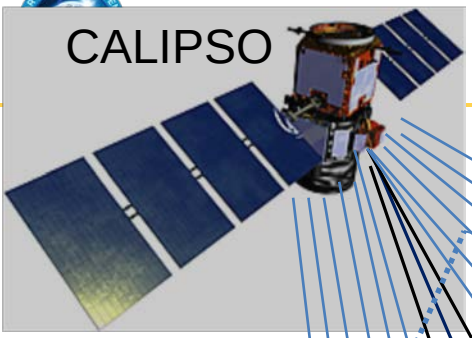
3. Validated

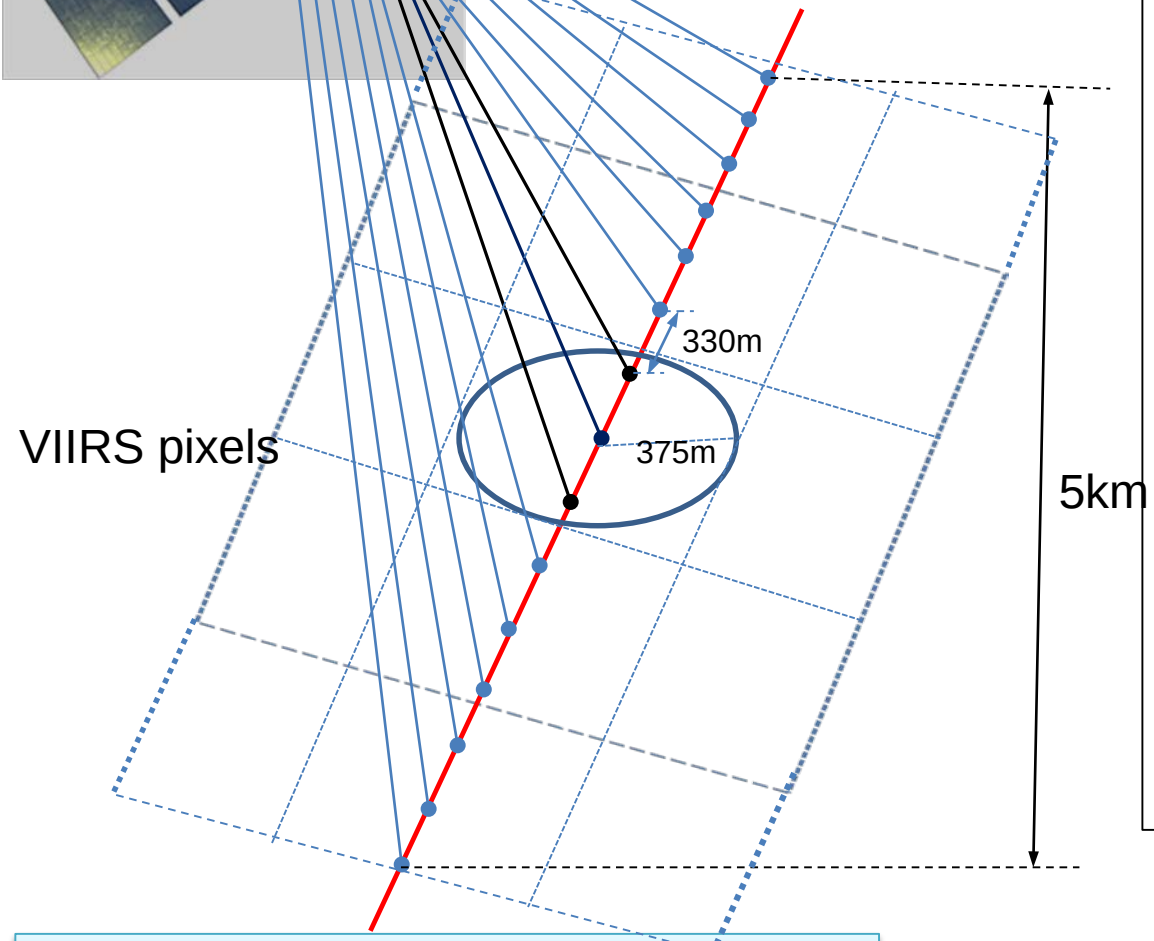
- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

Evaluation methodology

- Visual comparison between Suomi NPP and NOAA-20 ADP product. ADP products for both Suomi NPP and NOAA-20 were generated **off-line** using IDPS VIIRS Cloud Mask
  - Global scale (daily)
  - Global scale (monthly)
  - Correlations
- Time Period
  - January 9 – March 31, 2018
- Comparisons with CALIPSO Vertical Feature Mask (VFM)
  - Matchups in space and time
    - Daily time scale
- Comparisons with AERONET
  - Matchups in space and time
    - Daily time scale

CALIPSO Matchup Criteria



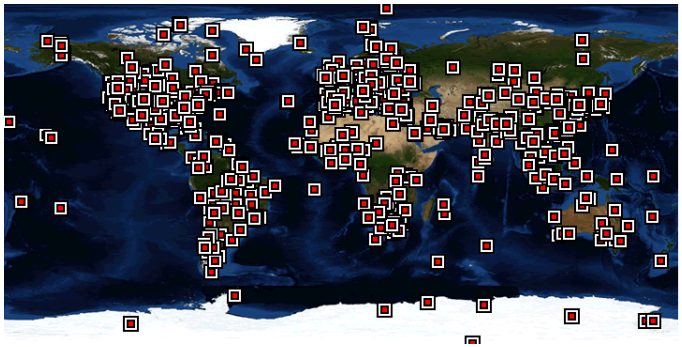


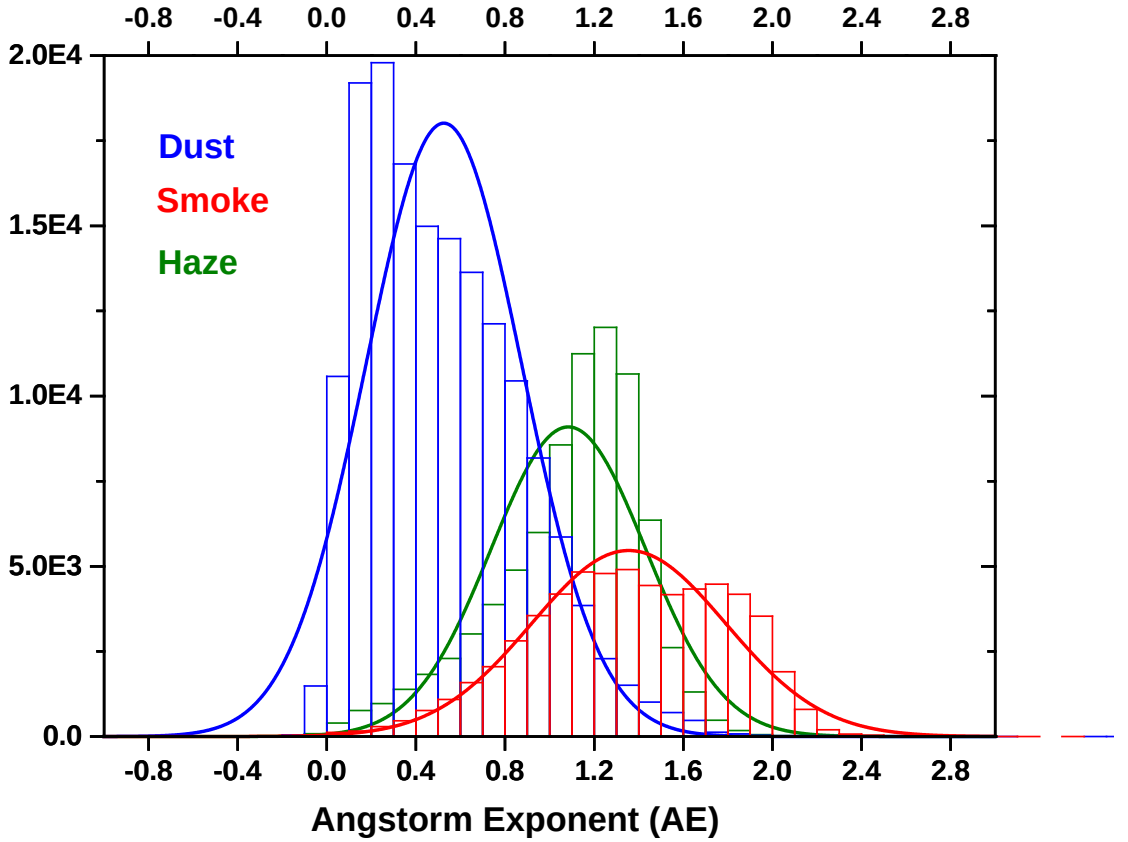
- Time difference: ±2 minutes
- Spatially , VIIRS pixels within ± 375m of the middle CALIPSO profile are selected.
- Middle three profiles are used to determine aerosol type in the column
  - All three profiles need to be cloud-free;
  - Dominant aerosol type is determined through the calculation of dust (or smoke) fraction (i.e., no of dust (or smoke) layers divided by the no. of aerosol layers from surface to 12km.
- VIIRS ADP data are filtered for high quality.

True Positive (TP): VIIRS and CALIPSO say dust
True Negative(TN): VIIRS and CALIPSO say no dust
False Negative(FN): VIIRS says no dust but CALIPSO says dust
False Positive(FP): VIIRS says dust when CALIPSO says no dust

POCD = TP/(TP+FN)
Accuracy = (TP+TN)/(TP+TN+FP+FN)
POFD = FP/(FP+TP)

AERONET Matchup Criteria





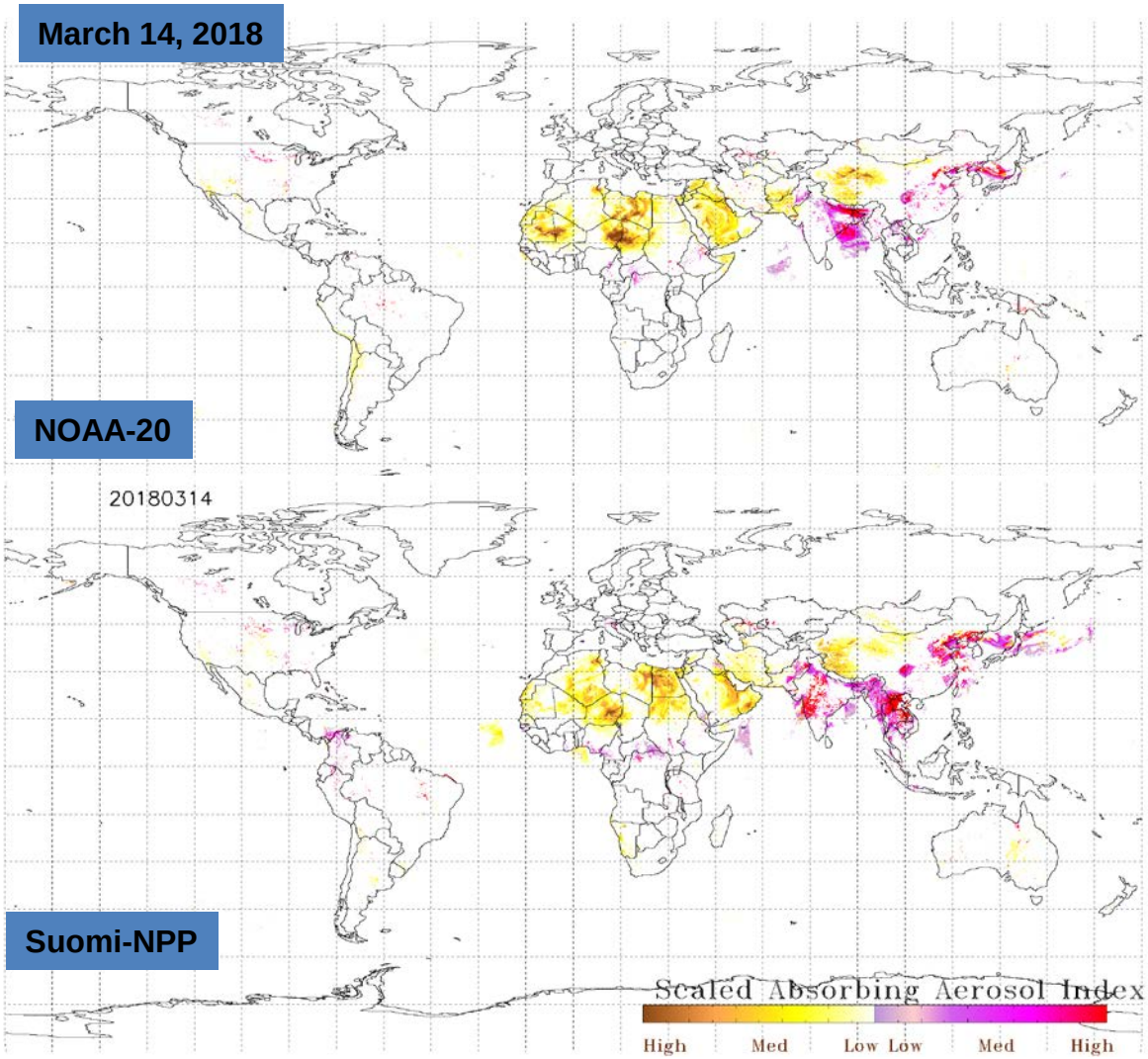
AERONET Smoke: AOD > 0.2 and Angstrom Exponent > 1.0

AERONET Dust: AOD > 0.2 and Angstrom Exponent < 0.5

AERONET and NOAA-20 within ±30 min

NOAA-20 VIIRS > 750 pixels within 27.5 km radius of AERONET

VIIRS ADP: Suomi-NPP vs. NOAA-20

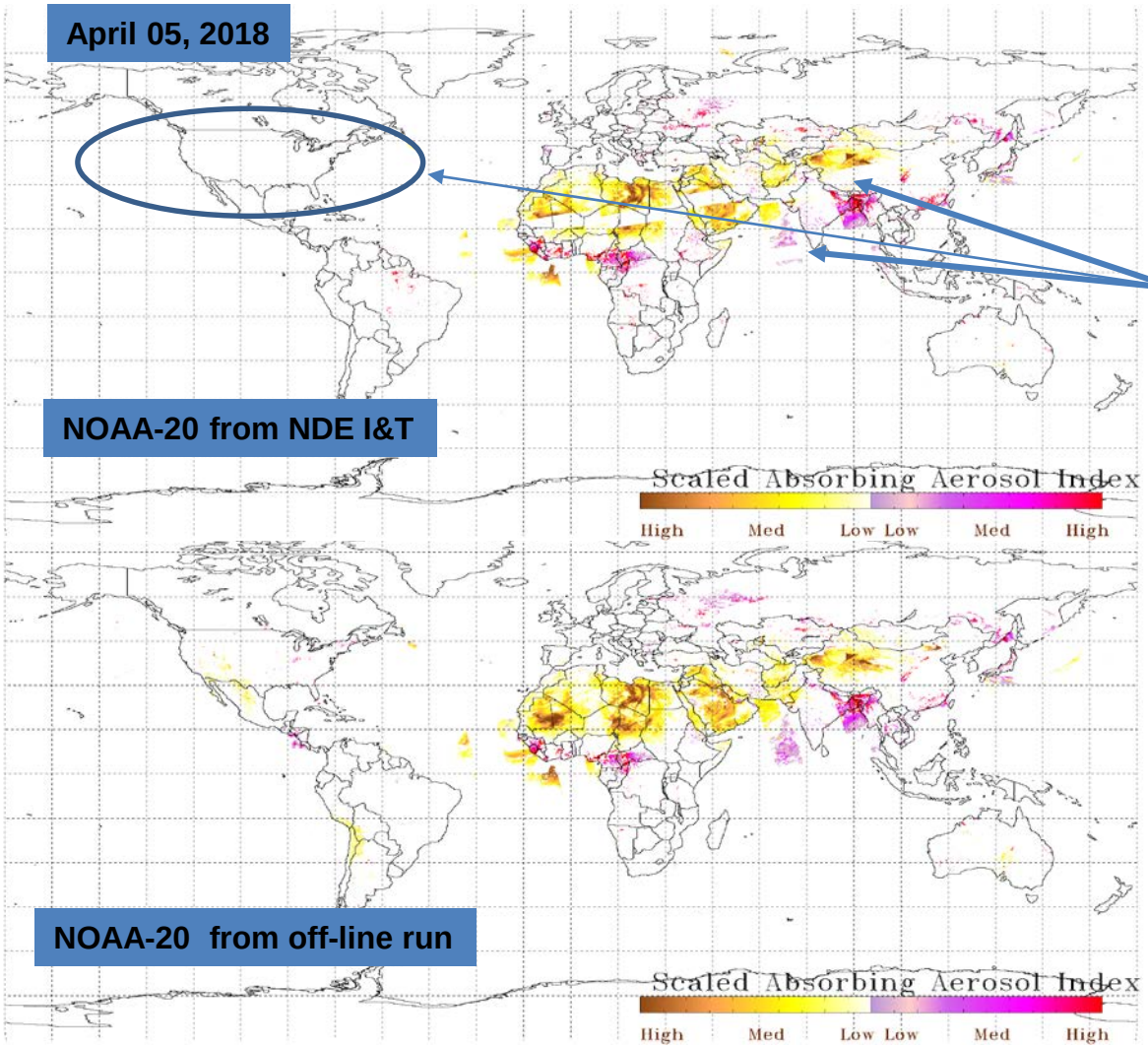


EPS algorithm run off-line on both SNPP and NOAA-20

IDPS Cloud Mask

SDRs downloaded from SCDR

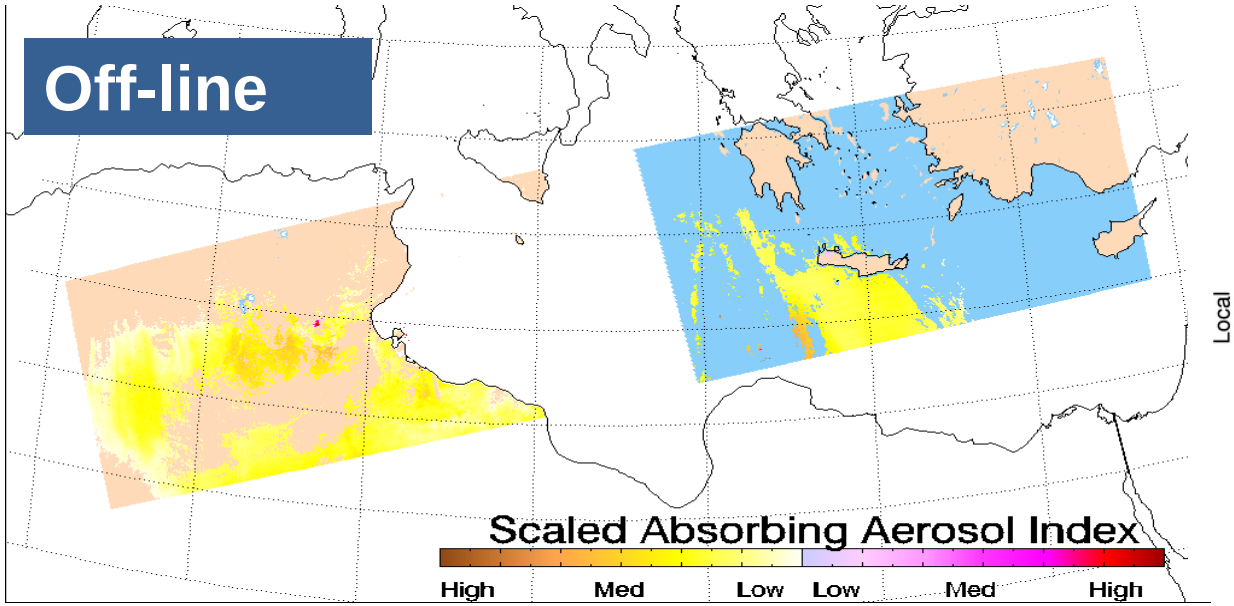
NOAA-20 VIIRS ADP (NDE I&T vs. Off-line)

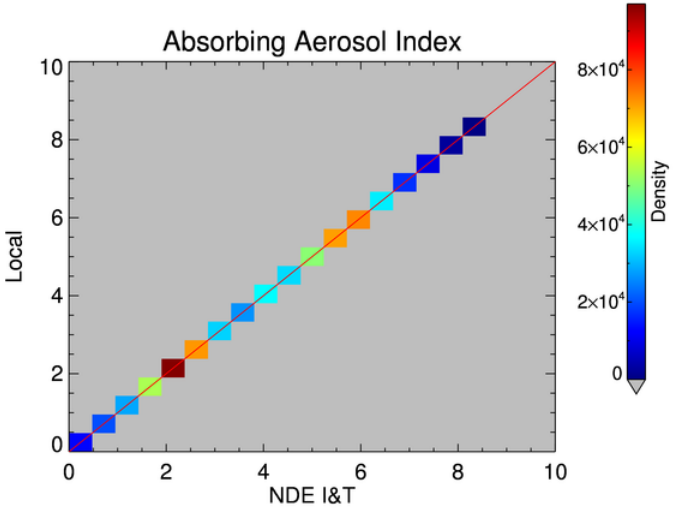


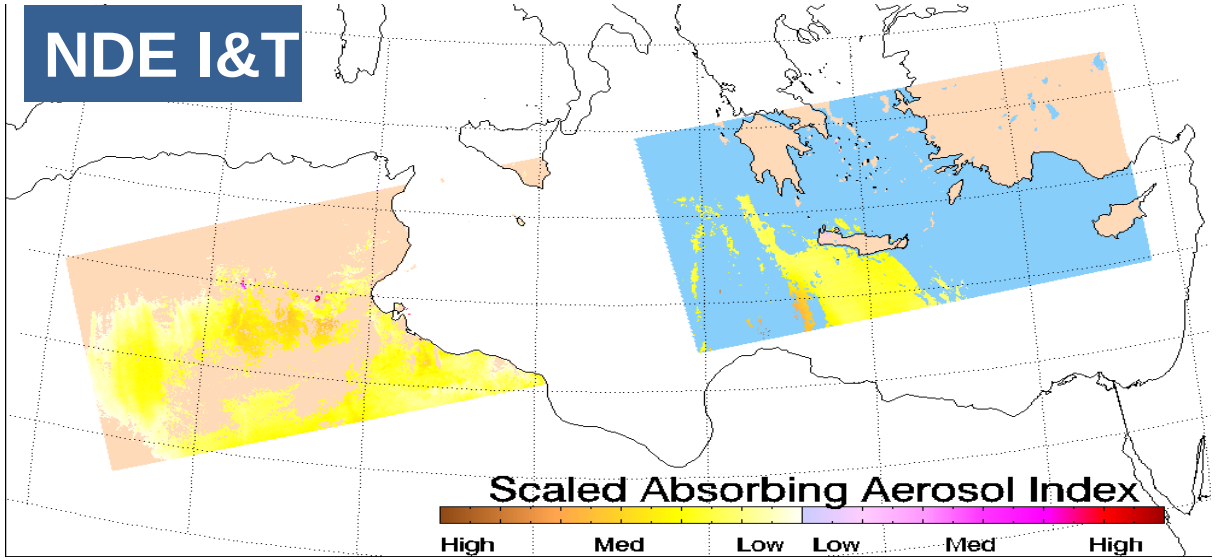
Missing granules in I&T

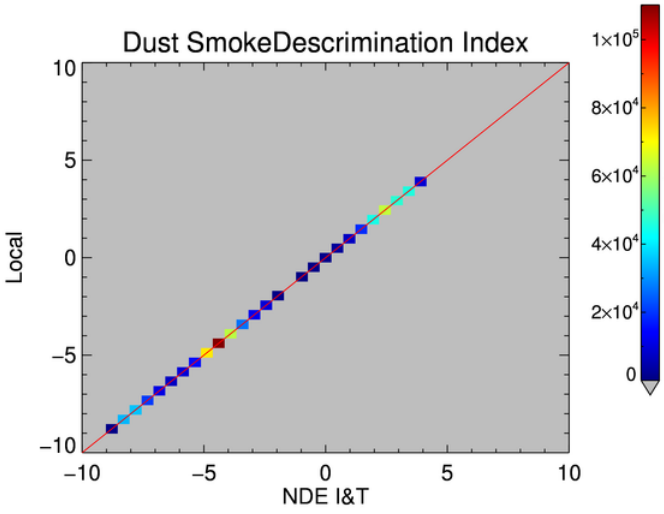
Input SDRs same. NDE I&T ADP generated using Enterprise Cloud Mask (ECM). Off-line ADP generated using IDPS Cloud Mask (old VCM).

NOAA-20 VIIRS: NDE I&T vs. Off-line Run



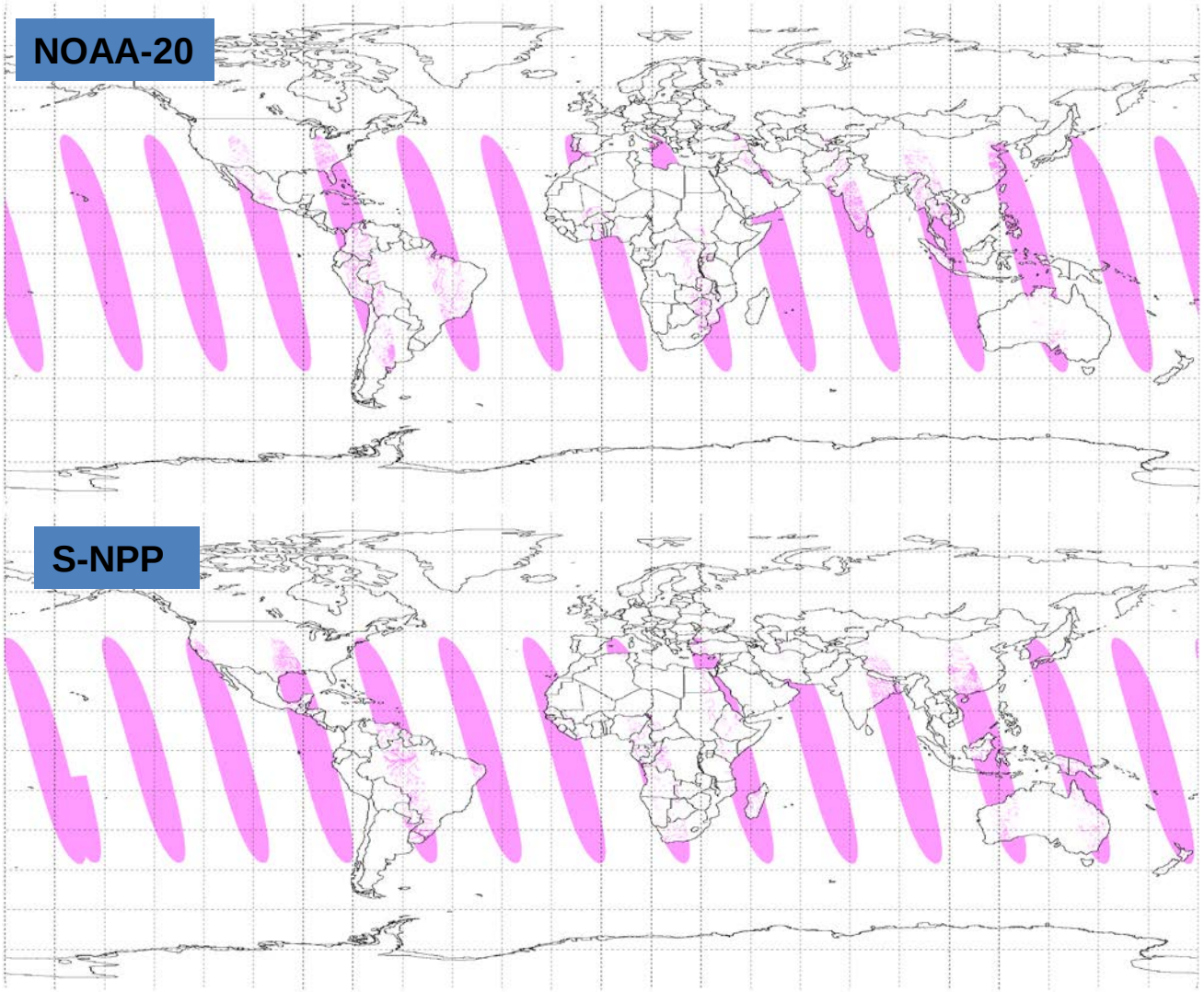






Sunglint

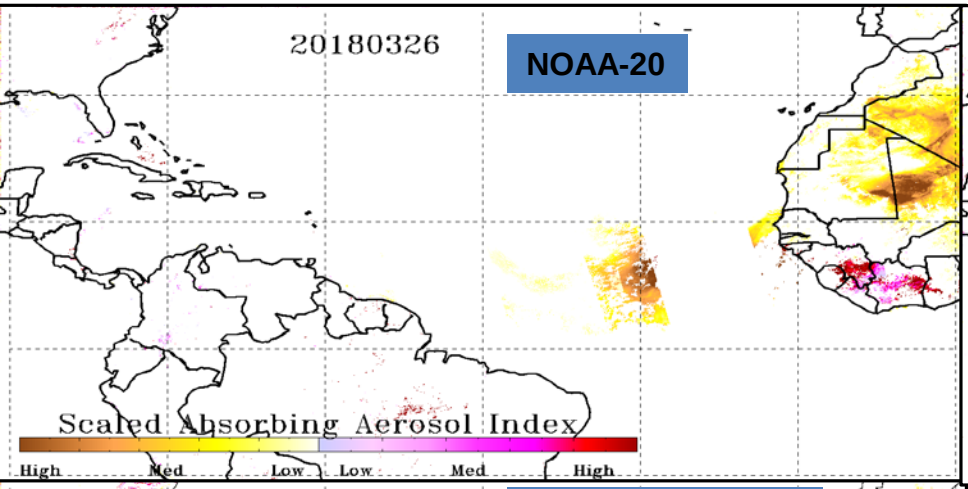
$0 < \eta < 40^0$

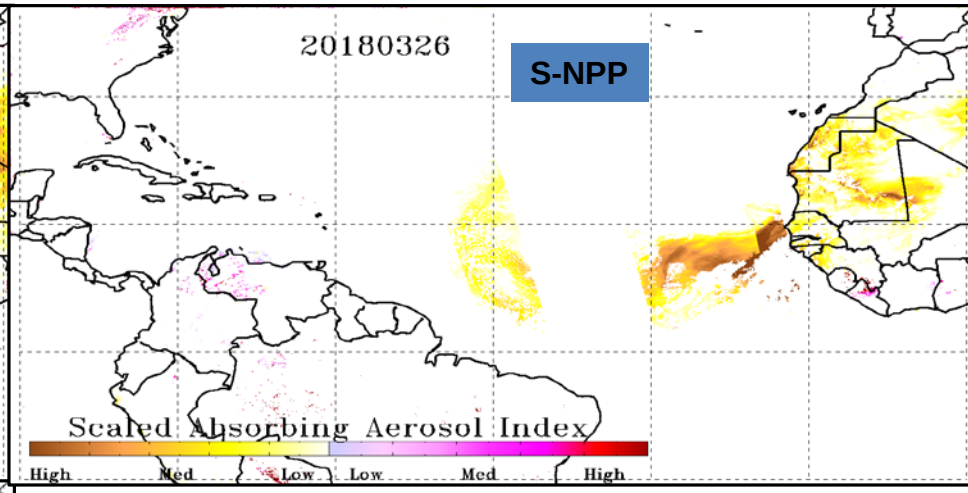


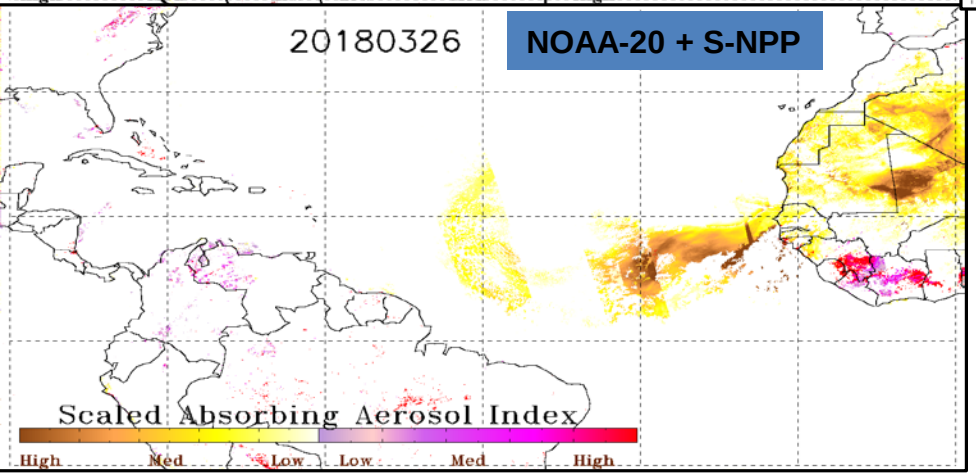
$$\mathbf{Cos(\eta) = Cos(\theta_0)*Cos(\theta)+Sin(\theta_0)*Sin(\theta)*Cos(180-\varphi)}$$

η is the sunglint angle; θ_0 is the solar zenith angle
θ is the satellite zenith angle; φ is the relative azimuth angle

Transatlantic Dust Transport
March 26, 2018

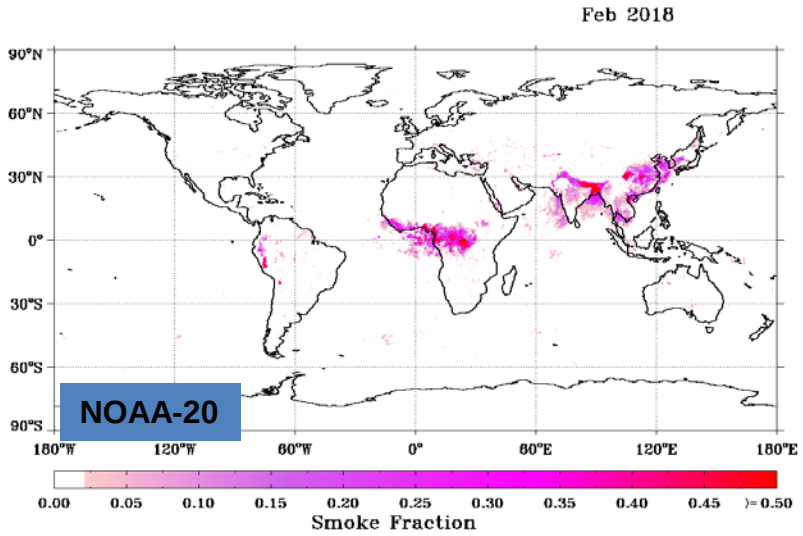


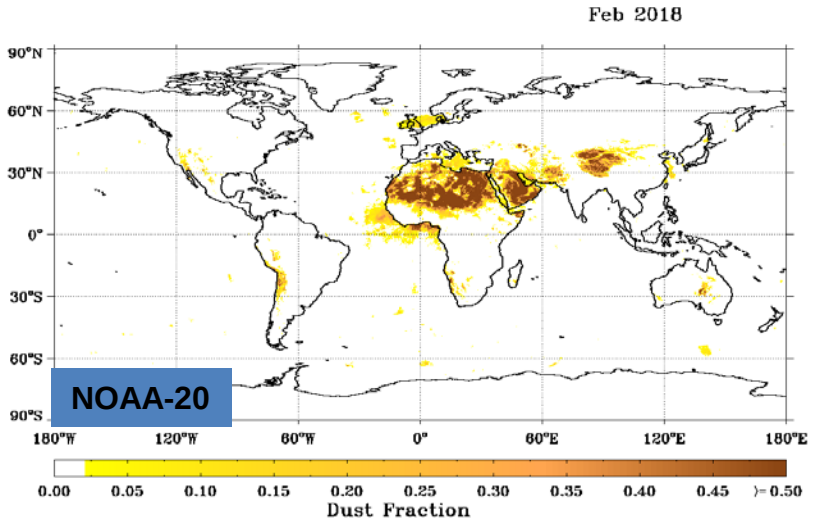


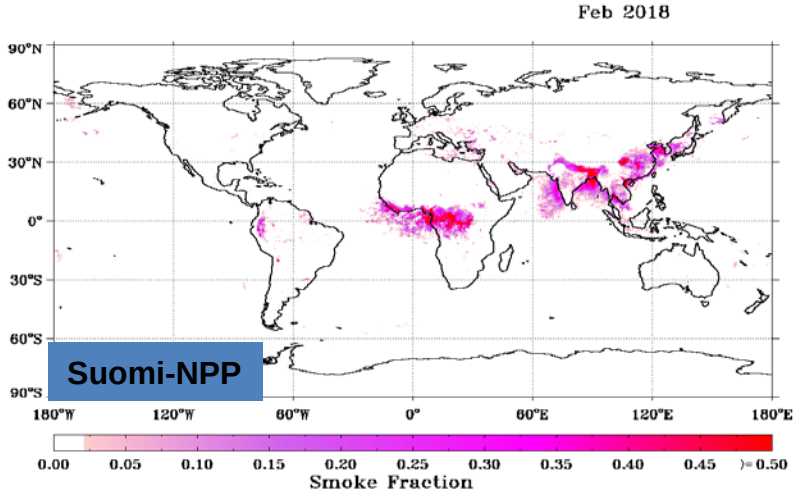


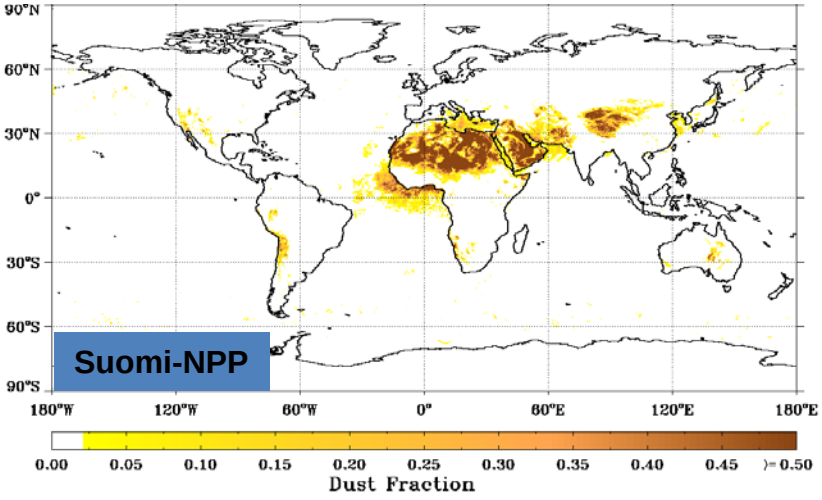
By combining ADP from NOAA-20 with ADP from S-NPP will increase the coverage

VIIRS Smoke and Dust Fractions for February 2018 (0.25° x 0.25°)

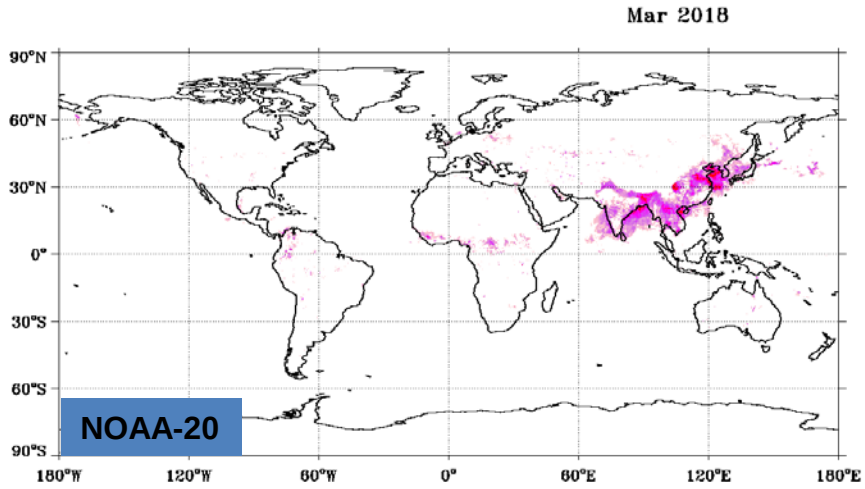


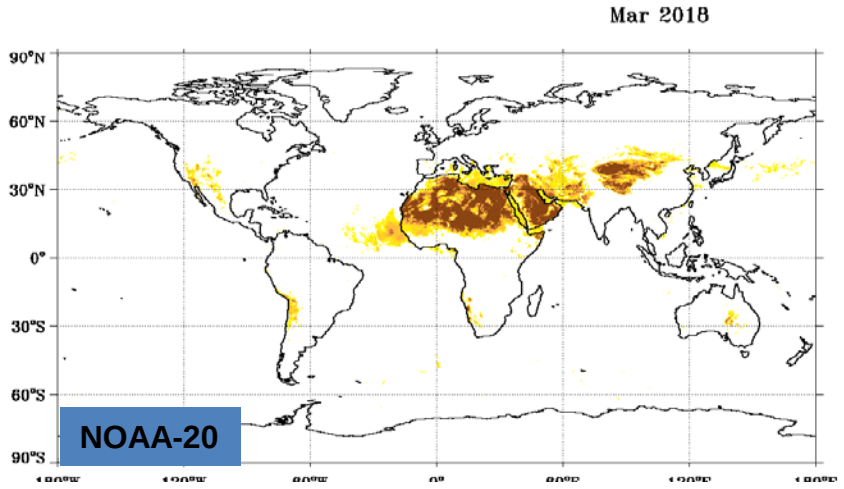


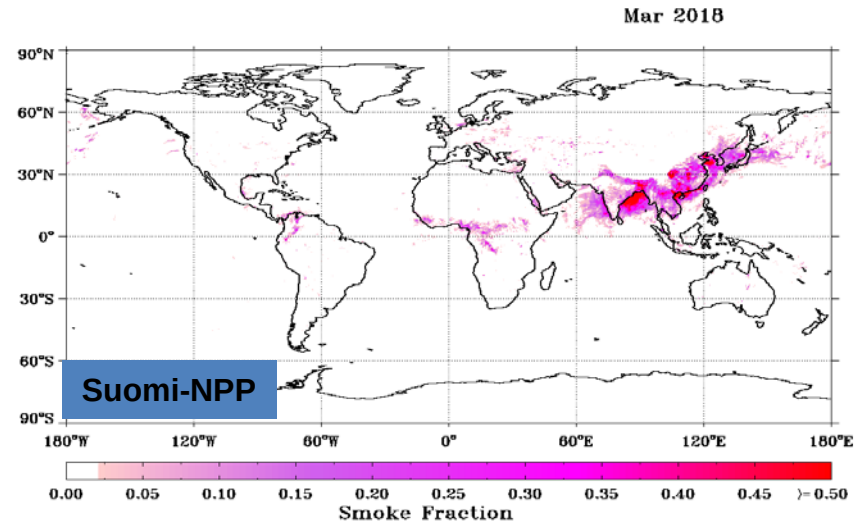


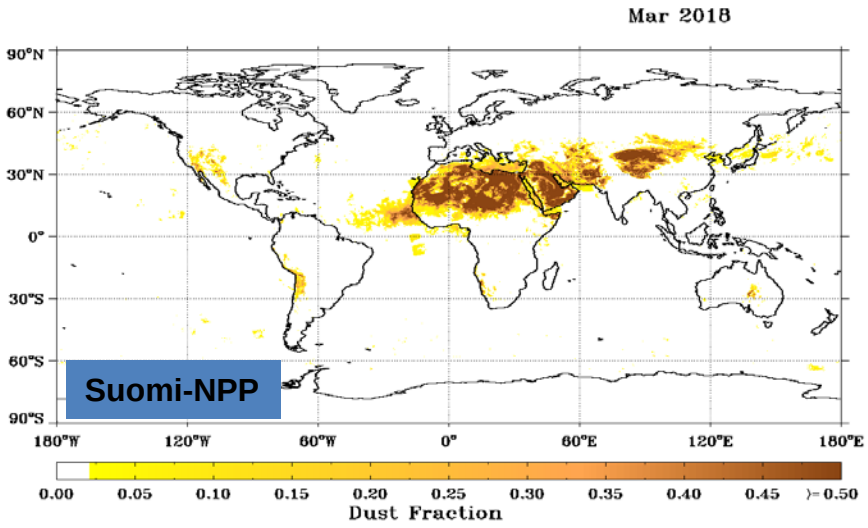


VIIRS Smoke and Dust Fractions for March 2018 (0.25° x 0.25°)



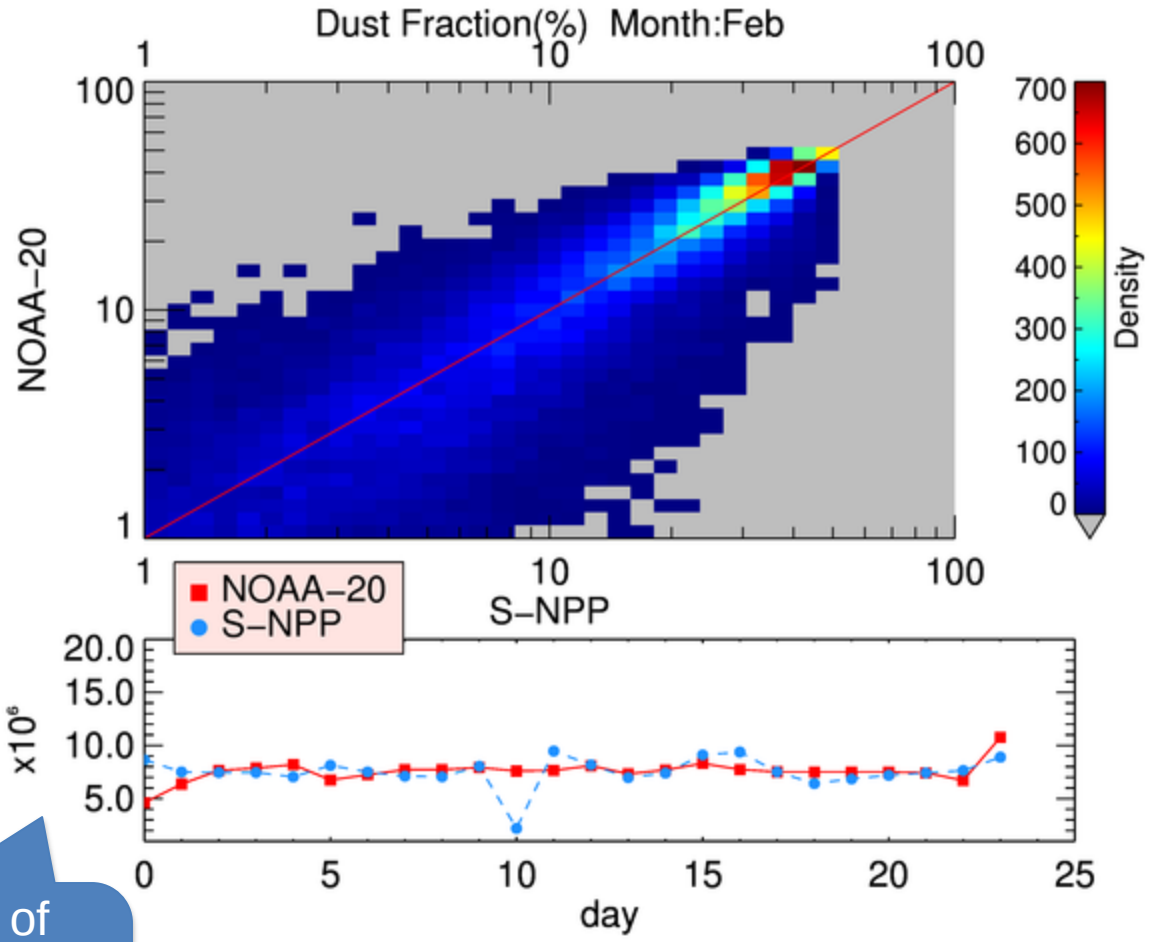






VIIRS Dust Fraction (NOAA-20 vs. S-NPP)

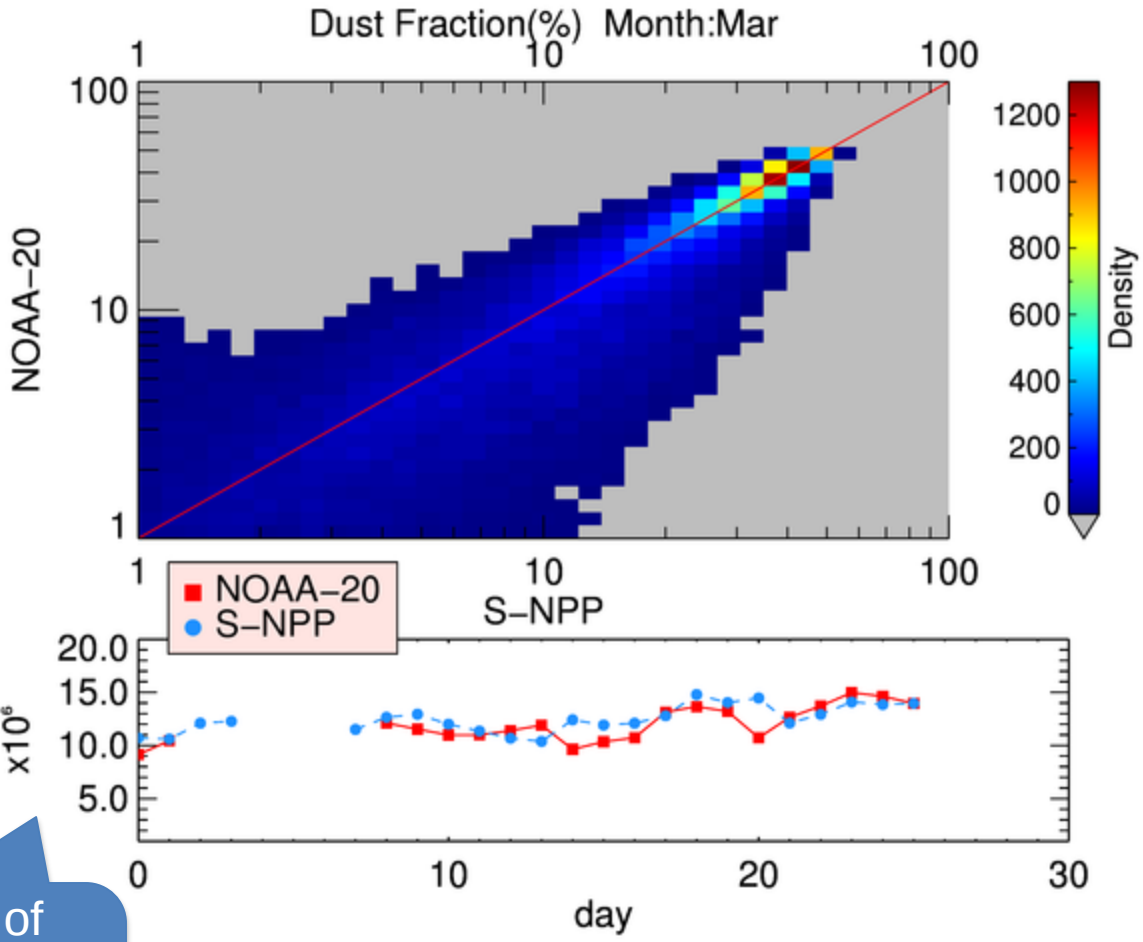
Dust Fraction (0.25° x 0.25°)



Time series of total number of global daily dust pixels

VIIRS Dust Fraction (NOAA-20 vs. S-NPP)

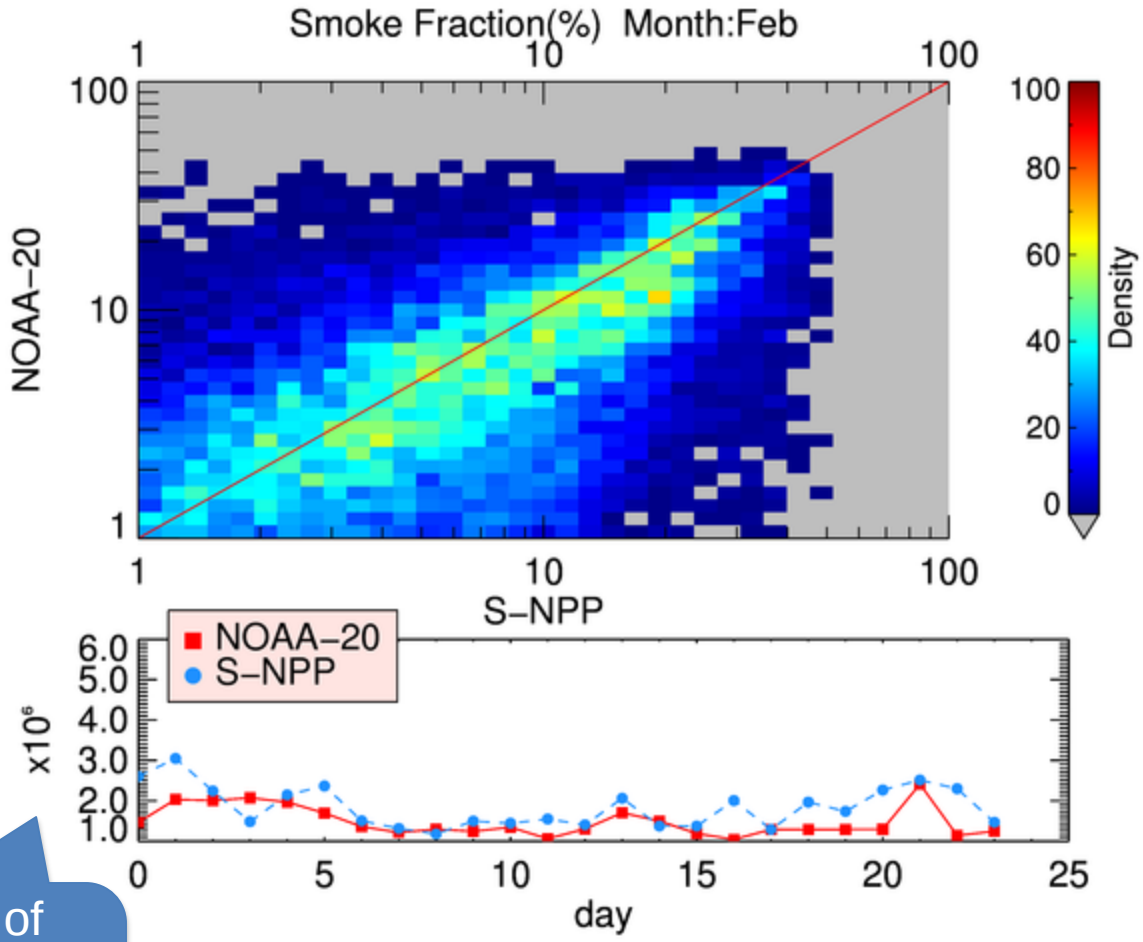
Dust Fraction (0.25° x 0.25°)



Time series of total number of global daily dust pixels

VIIRS Smoke Fraction (NOAA-20 vs. S-NPP)

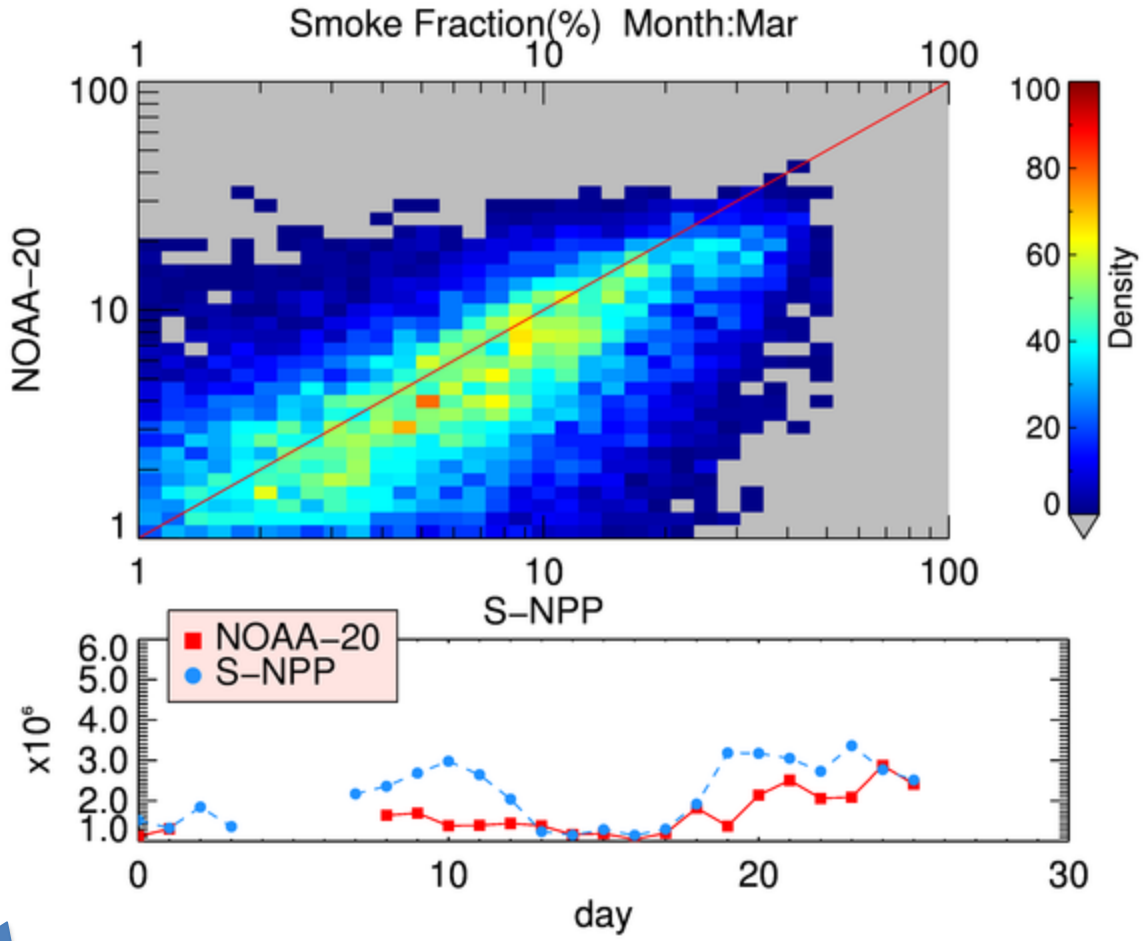
Smoke Fraction (0.25° x 0.25°)



Time series of total number of global daily smoke pixels

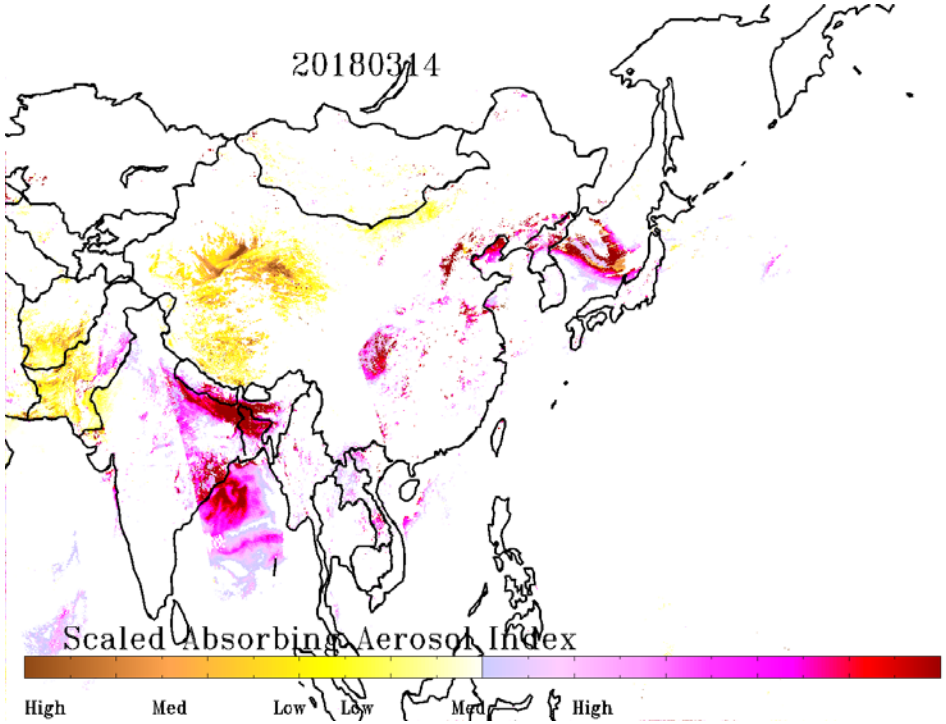
VIIRS Smoke Fraction (NOAA-20 vs. S-NPP)

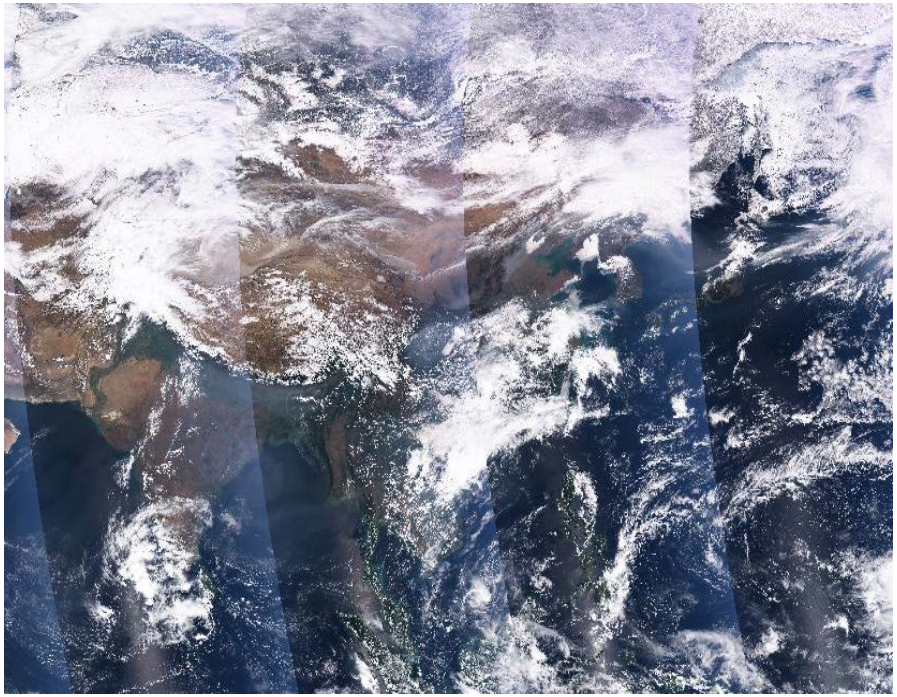
Smoke Fraction (0.25° x 0.25°)



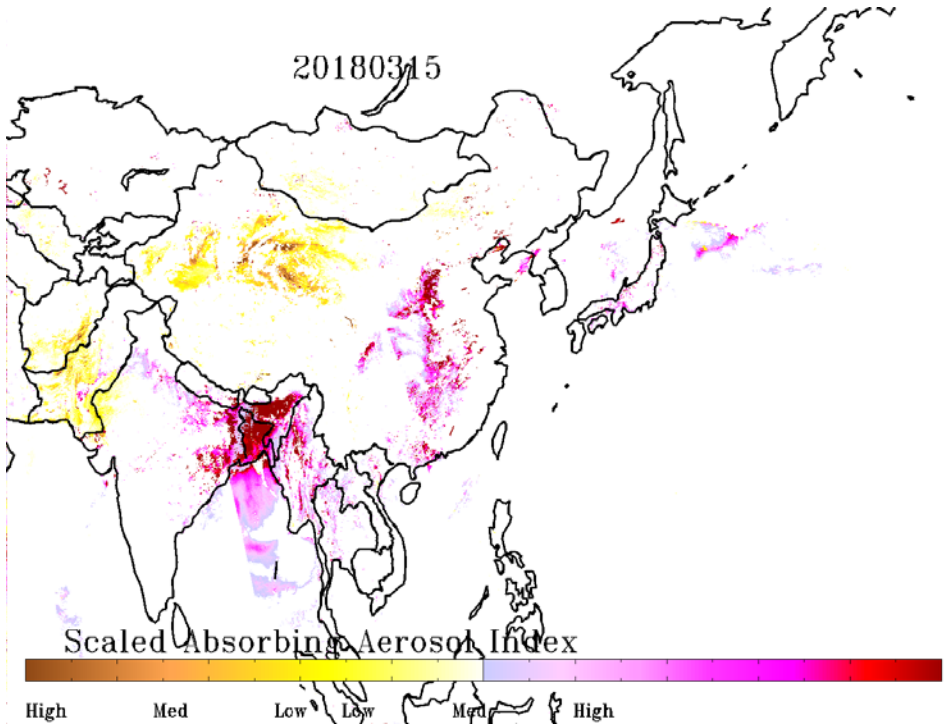
Time series of total number of global daily smoke

Asian Smog and Dust Events in Asia
March 14, 2018



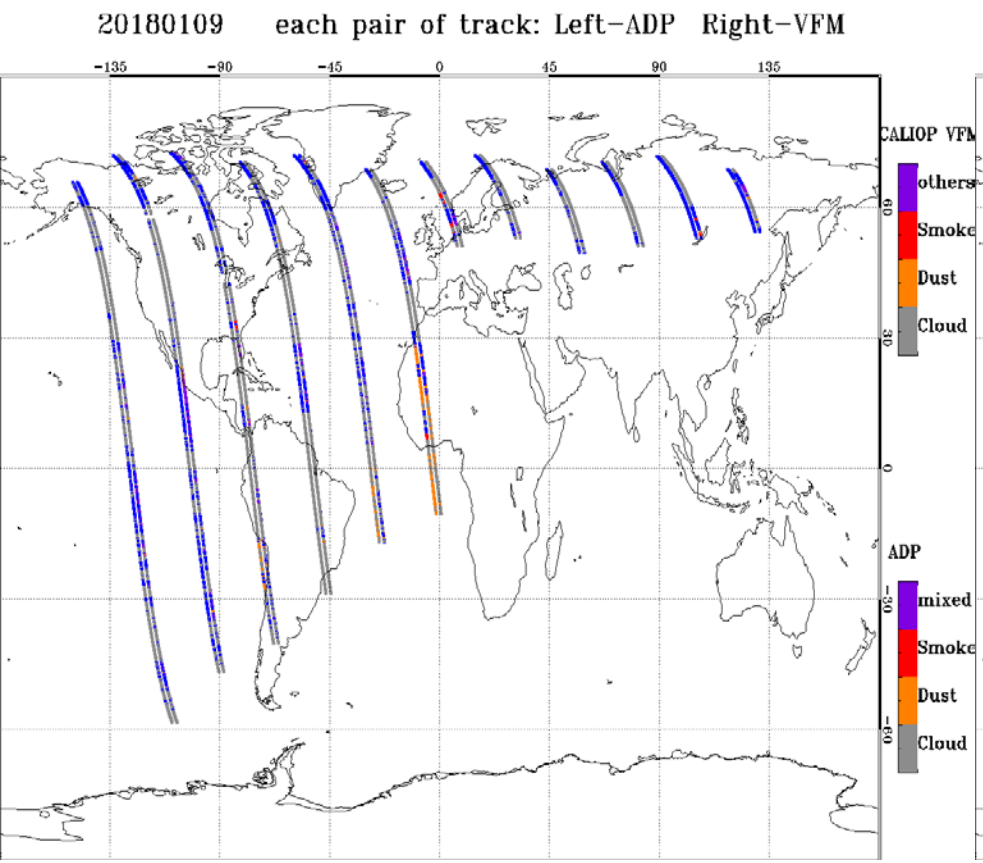


Asian Smog and Dust Events in Asia
March 15, 2018

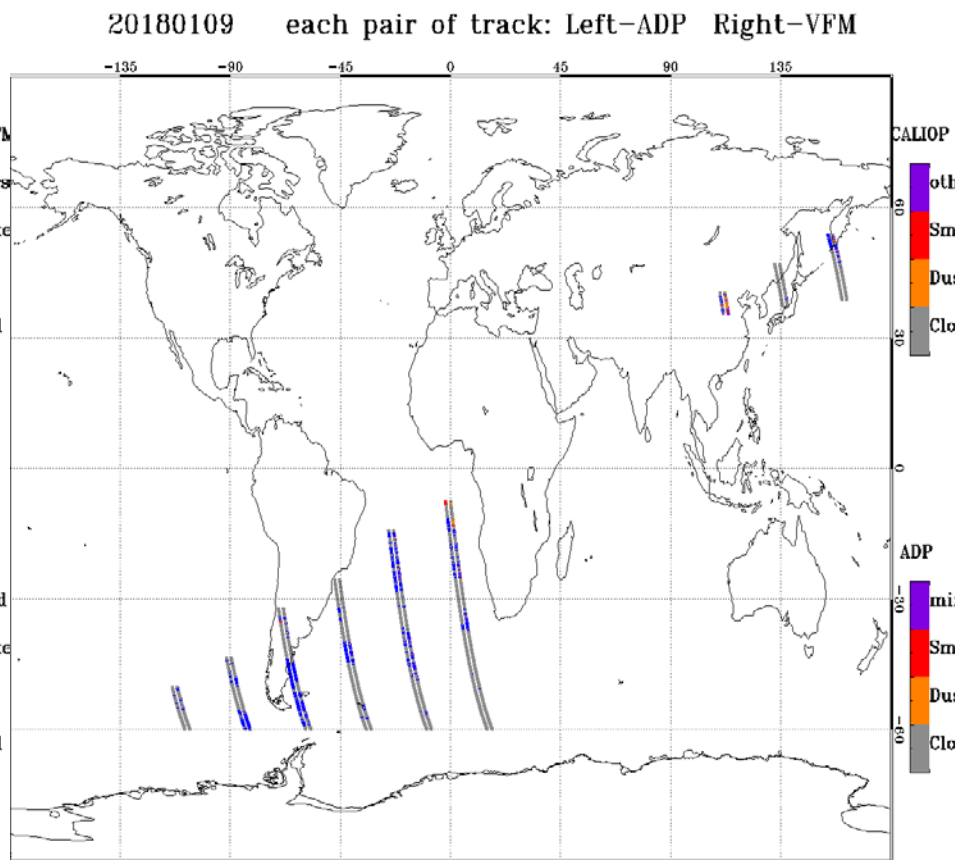


Matchup tracks between ADP and CALIPSO VFM

NOAA-20 vs. CALIPSO VFM

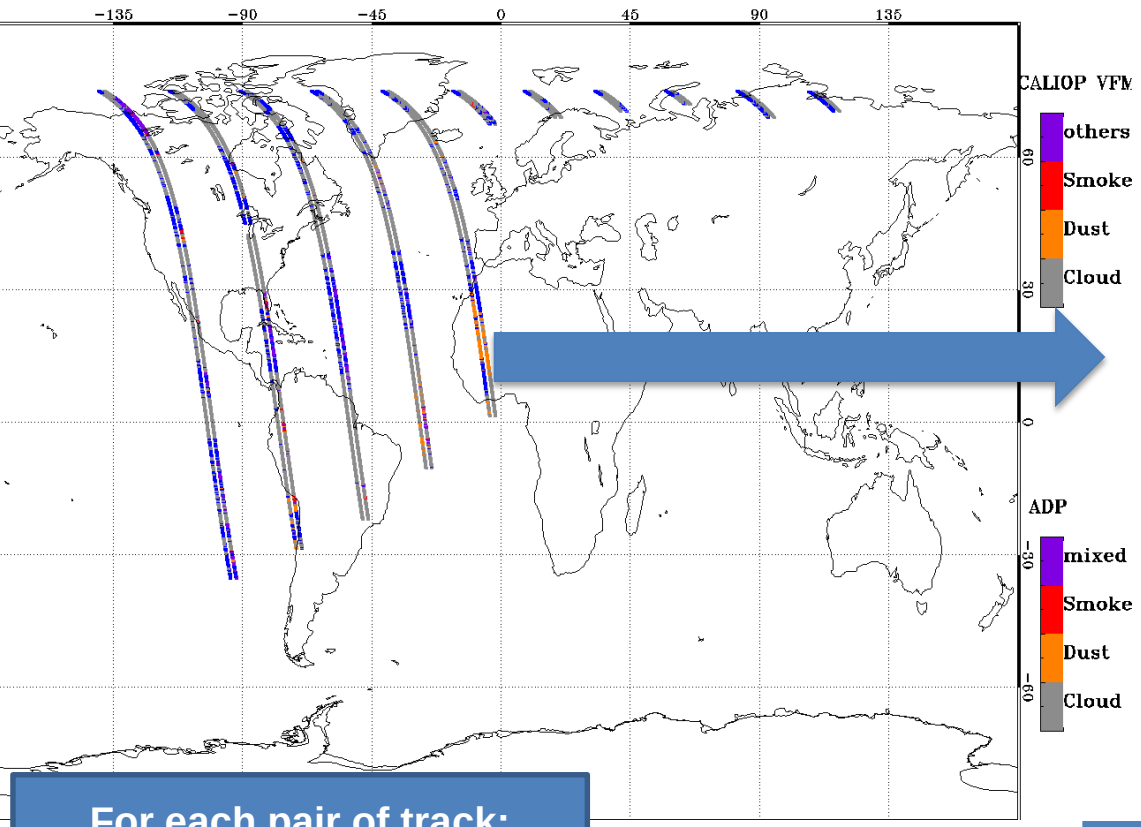


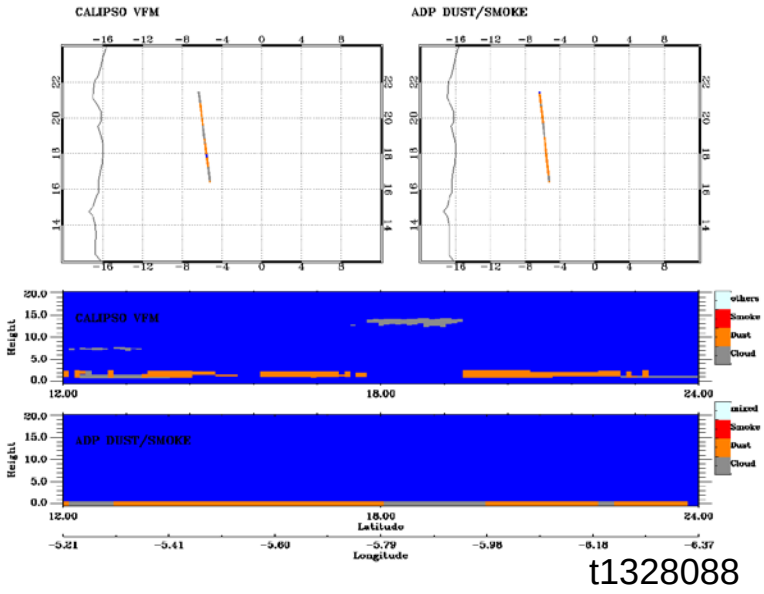
S-NPP vs. CALIPSO VFM



NOAA-20 VIIRS vs. CALIPSO

Feb 10, 2018



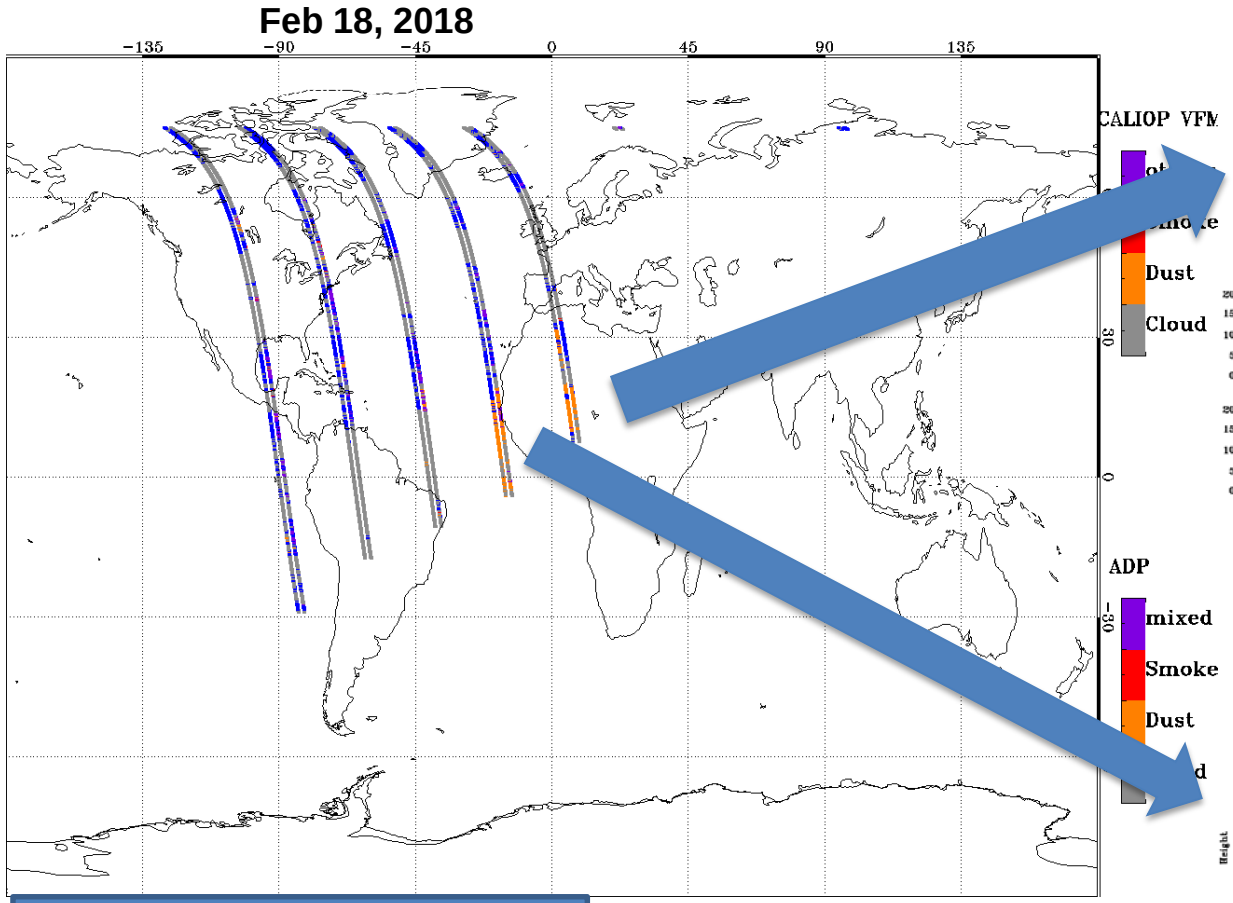


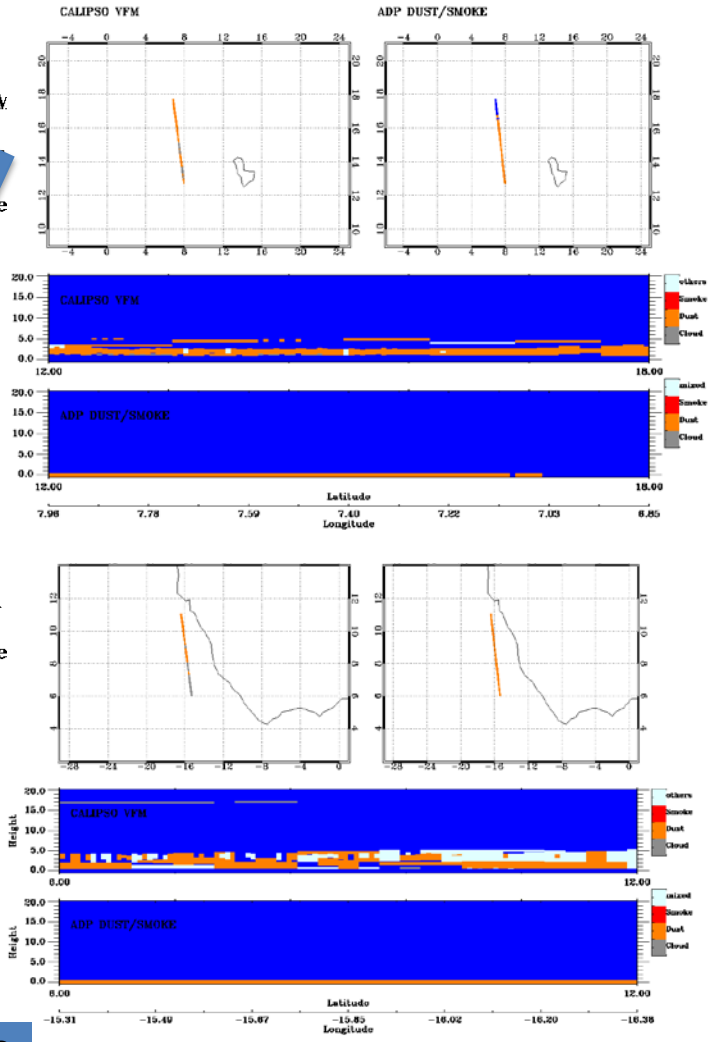
t1328088

For each pair of track: Left: ADP right: CALISPO VFM

Accuracy	93%
POCD	89%

NOAA-20 VIIRS vs. CALIPSO





For each pair of tracks:
Left: ADP right: CALISPO VFM

	t1415547	t1236263
Accuracy	95%	78%
POCD	100%	100%

NOAA-20 VIIRS vs. CALIPSO Summary

January 9 – March 31, 2018

Smoke

Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
NOAA-20	103	39	21	2750	97.9	83.1	27.4
S-NPP	167	23	30	3804	98.6	84.7	12.1

Dust

Time Period	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
NOAA-20	7586	5202	603	22057	83.6	92.6	40.1
S-NPP	11312	7895	901	31229	82.9	92.6	41.1

Requirement of Correct Detection

Dust 80% over land; 80% over ocean

Smoke 80% over land; 70% over ocean

SNPP VIIRS vs. CALIPSO Summary (NDE EPS July 21, 2017 – March 31, 2018)

Smoke

Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
S-NPP (NDE)	1589	316	64	25758	98.6	96.1	16.6

Dust

Time Period	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
S-NPP	34051	21418	2666	86947	83.4	92.7	38.6

Requirement of Correct Detection

Dust 80% over land; 80% over ocean

Smoke 80% over land; 70% over ocean

NOAA-20 VIIRS vs. AERONET Summary

January 9 – March 31, 2018

Smoke

Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
NOAA-20	604	63	375	399	69.6	61.7	9.4
S-NPP	690	53	380	360	70.4	63.9	7.1

Dust

Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
NOAA-20	129	44	88	186	70.4	59.4	25.4
S-NPP	174	72	121	330	72.3	58.9	29.2

Requirement of Correct Detection

Dust 80% over land; 80% over ocean

Smoke 80% over land; 70% over ocean

SNPP VIIRS vs. AERONET Summary (NDE EPS July 21, 2017 – March 31 2018)

Smoke

Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
S-NPP (NDE)	4074	941	1230	9236	85.9	76.8	18.7

Dust

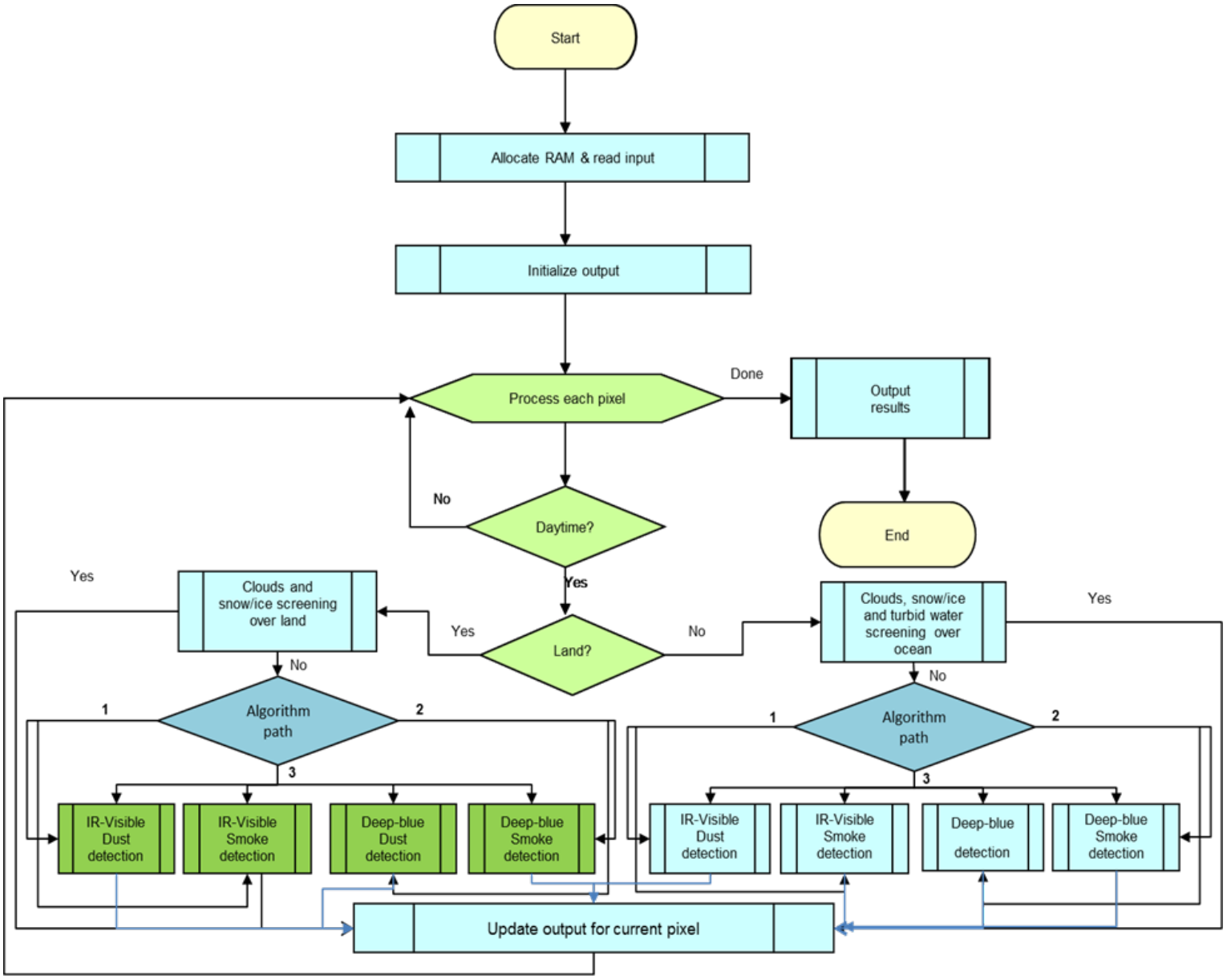
Satellite	True positive	False positive	False negative	True negative	Accuracy	POCD	POFD
S-NPP(NDE)	557	446	166	1872	79.8	77.0	44.0

Requirement of Correct Detection

Dust 80% over land; 80% over ocean

Smoke 80% over land; 70% over ocean

EPS Algorithm



Confidence/Quality Flags

Confidence Flag	Criteria
High	Confidence Value > 0.5
Medium	0.25 < Confidence Value < 0.5
Low	Confidence Value < 0.25 Pixel adjacent to cloud Turbid water Bright pixel Pixel adjacent to snow/ice Cloud shadow Glint
No Retrieval	Cloud Snow/ice

No screening for large solar/satellite zenith angles (values are provided in output for users). We are revising the way we do quality flags for the next algorithm update

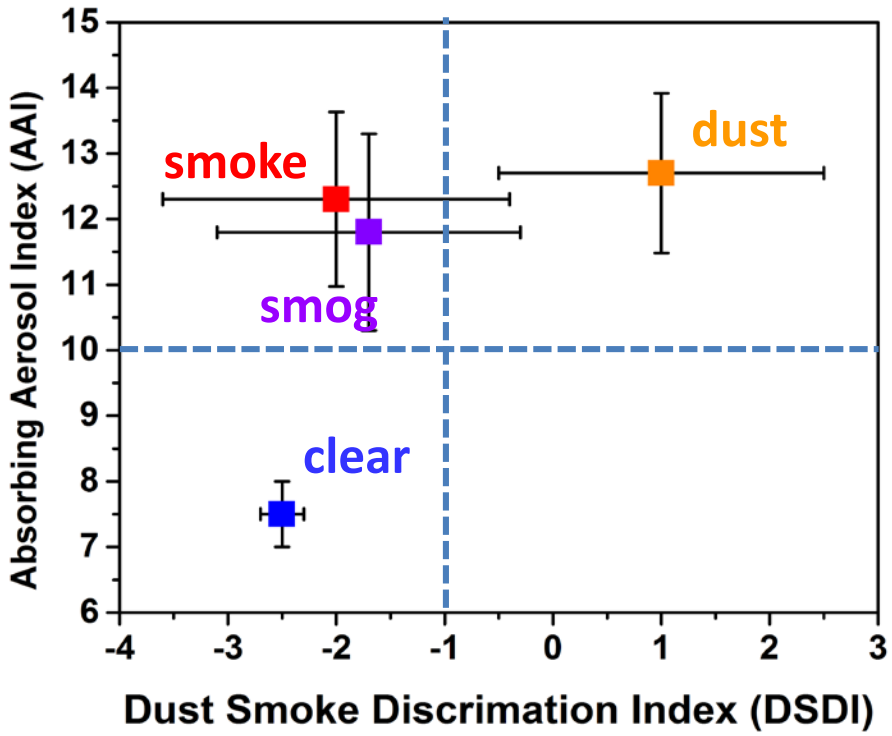
Documents (Check List)

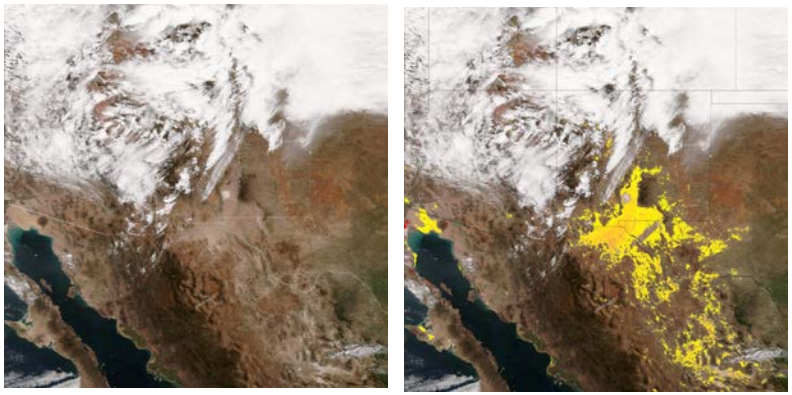
Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes (NOAA-20)
Algorithm Theoretical Basis Document (ATBD)	Yes (Suomi NPP)
Algorithm Calibration/Validation Plan	Yes (Suomi NPP)
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes (MODIS)
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	JPSS Annual Meeting presentations

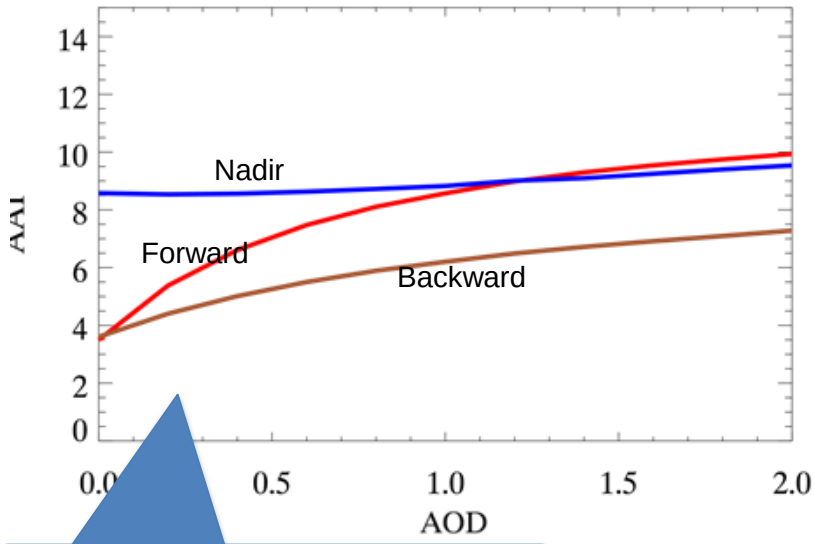
Summary and path forward

- Disclaimer: NOAA-20 ADP product evaluation is based on off-line runs using IDPS Cloud Mask
- NOAA-20 ADP product meets requirements for dust and smoke, based on CALIPSO comparisons
- NOAA-20 ADP product does not meet requirements (NOT EXPECTED) based on AERONET comparisons. Reasons: (1) AERONET dust/smoke identification is also based on classification and thus not as accurate as CALIPSO, (2) Number of matchups with AERONET are limited, (3) matchup criteria too strict
- False dust detections have been identified over bright surfaces when satellite observes the Earth in nadir view
  - Algorithm updates to minimize false detections are forthcoming
  - Updates will be implemented for both SNPP and NOAA-20
- AerosolWatch website will incorporate NOAA-20 active fires, ADP, and AOD products as soon as they become provisional.

False Dust Detections







$$AAI = -100\left[\log_{10}\left(\frac{R_{0.41}}{R_{0.44}}\right) - \log_{10}\left(\frac{R'_{0.41}}{R'_{0.44}}\right)\right]$$

$$DSDI = -10\log_{10}\left(\frac{R_{0.41}}{R_{2.2}}\right)$$

Theoretical calculations of AAI for three scenes corresponding to nadir, forward, backward scattering geometries

Zhang, Ciren, Kondragunta, Laszlo, Liu, An Evaluation of VIIRS Dust Detection Algorithm over Land, in preparation for JGR

Path Forward/Algorithm Updates

- Further analysis of the data by stratifying the product over land and over water
- Thresholds for various tests specific to NOAA-20 VIIRS as it is in a different orbit (different geometry) and some minor differences in SRFs (*see Laszlo presentation*)
  - Requires several months/at least a year worth of data to do the analysis
- Algorithm changes to IR-Visible part of the algorithm
  - Based on GOES-R (IR-Visible) experience, mainly the way confidence values are estimated
    - If multiple tests are needed to determine dust/smoke and only one test passes, report confidence based on that test. This change will increase the detections
    - Equal weight given to all spectral tests. Use only the most important test in determining confidence value
- Combine solar/satellite zenith angle criteria with confidence flags
- In nadir view geometry, rely on IR-Visible part of the algorithm to minimize false positives

Backup Slide

Example for Calculation of Confidence Level of Dust detection

Deep Blue path

Test1: AAI ≥ threshold1
Test2: DSDI ≥ threshold2
Confidence values:

$$\text{con\_value}_{\text{db}} = \frac{\text{con\_value(Test1)} + \text{con\_value(Test2)}}{2}$$

For each test, con_value is determined as following:
If $(value - threshold) < value_1$ then Con_value = 0.0
If $value_1 \leq (value - threshold) < value_2$ then Con_value = 0.5
If $(value - threhsold) \geq value_2$ then Con_value = 1.0

$value_1$ is 5% of threshold, $value_2$ is 30% of threshold

IR- Visible path

Test 1: $\text{BT}_{\text{M15}} - \text{BT}_{\text{M16}} \leq -0.2K$
Test 2: $\text{BT}_{\text{M12}} - \text{BT}_{\text{M15}} \geq 15K$

Confidence values:

$$\text{con\_value}_{\text{IR\_vis}} = \frac{\text{con\_value(Test1)} + \text{con\_value(Test2)}}{2}$$

For each test, con_value is determined as following:
If $(value - threshold) < value_1$ then Con_value = 0.0
If $value_1 \leq (value - threshold) < value_2$ then Con_value = 0.5
If $(value - threhsold) \geq value_2$ then Con_value = 1.0

$value_1$ is 5% threshold, $value_2$ 30% of threshold

Ensemble confidence values:
$\text{con\_value}_{\text{db}} + \text{con\_value}_{\text{IR\_Vis}}$

high confidence
confidence value>0.5

Medium confidence
0.25<confidence value<=0.5

low confidence
confidence value<=0.25

1. Cloud adjacency
2. Turbid water
3. Bright pixel
4. Adjacent to snow/ice pixels
5. within sunglint
6. Cloud shadow