Beta Maturity Science Review For NOAA-21 Aerosol Detection

Presented by Shobha Kondragunta, Pubu Ciren and Amy Huff

Date: 8/24/2023

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.

Maturity Review - Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Beta Maturity Performance Validation
  - On-orbit instrument performance assessment
    - Identify all of the instrument and product characteristics you have verified/validated as individual bullets
    - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
- Users/Downstream-Products feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward (to the next maturity stage)
- Summary

Maturity Review - Exit Criteria

- Beta Maturity Performance is well characterized and meets/exceeds the requirements:
  - On-orbit instrument performance assessment
    - Provide summary for each identified instrument and product characteristic you have validated/verified as part of the entry criteria
    - Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any of them are still a concern that raises any risk.
- Updated Maturity Review Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules
  - Product Requirements
  - Beta Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward (to the next maturity stage)

BETA MATURITY REVIEW MATERIAL

Outline

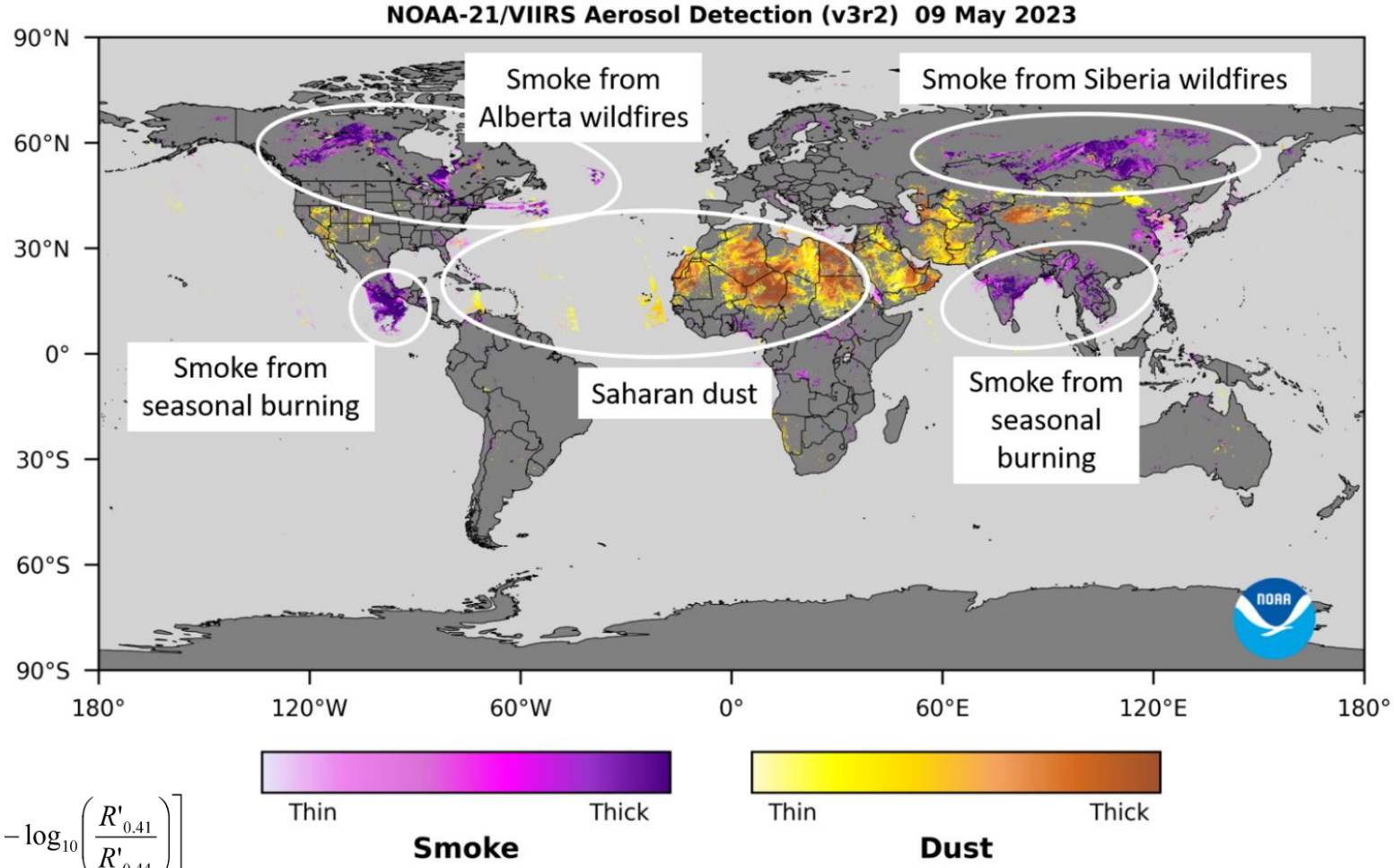
- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

NOAA-21 Aerosol Cal/Val Team Members

Name	Organization	Responsibilities
Amy Huff	IM Systems Group	Aerosol Detection Product validation User outreach and training
Hai Zhang	IM Systems Group	Level 3 product generation Scientific analysis of reprocessed Aerosol Optical Depth product Surface PM2.5 algorithm development and scientific data analysis
Hongqing Liu	IM Systems Group	Aerosol Optical Depth algorithm development and validation Gridded, merged LEO-LEO VIIRS AOD product generation SDR, AOD and ADP product reprocessing in the Cloud (AWS)
Istvan Laszlo	NESDIS/STAR	Co-Lead (AOD)
James Limbacher	IM Systems Group	Aerosol models Aerosol Detection Product algorithm work
Mi Zhou	IM Systems Group	Aerosol Optical Depth algorithm development and validation Gridded, merged LEO-GEO AOD product generation
Michael Cheeseman	IM Systems Group	Applications and assessment of VIIRS AOD and ADP for estimating PM2.5
Pubu Ciren	IM Systems Group	Aerosol Detection Product algorithm development and validation Aerosol Detection Product reprocessing in the cloud (AWS)
Shobha Kondragunta	**NESDIS/STAR**	**Co-Lead (ADP, AOD)**
Zigang Wei	IM Systems Group	Level 3 product generation Scientific analysis of reprocessed Aerosol Optical Depth product
Vaishali Kapoor	NESDIS/OSPO/SPSD/SPB	OSPO PAL for AOD and ADP

Aerosol Detection Product (ADP) Overview

- Detection of **smoke** and **dust** aerosols in the atmosphere for daytime and cloud-free conditions
  - Scaled Absorbing Aerosol Index (SAAI) indicates presence and relative thickness of smoke & dust
    - Deep Blue algorithm path
- ADP algorithm uses spatial and spectral **threshold tests** to separate smoke and dust aerosols from clouds and clear sky over water and land



Index	Threshold (Land)	Threshold (Water)
AAI	> 11.5	> 4
DSDI	> 0	> 10

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

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

SSAI = AAI-Threshold

Aerosol Detection Product Requirements

Attribute	Requirement/Threshold	
Applicable Conditions	Clear sky, daytime only, any altitude; AOD > 0.15	
Horizontal Cell Size	750m at nadir	
Vertical Cell Size	Total column	
Mapping Uncertainty, 3σ	3km	
Measurement Range	Type: smoke, dust	
Accuracy Reported as Probability of Correct Detection (POCD)	**Smoke**	**Dust**
Over Land	80%	80%
Over Water	70%	80%

Source: JPSS L1RD supplement, JPSS-REQ-1002/470-00032, Revision 2.11, February 7, 2019

ADP Processing Environment and Algorithm

	Description	Effective Date
Algorithm version	Version 1.4 (Product version v3r2)	2/11/2023
Version of LUTs	N/A	N/A
Version of PCTs	N/A	N/A

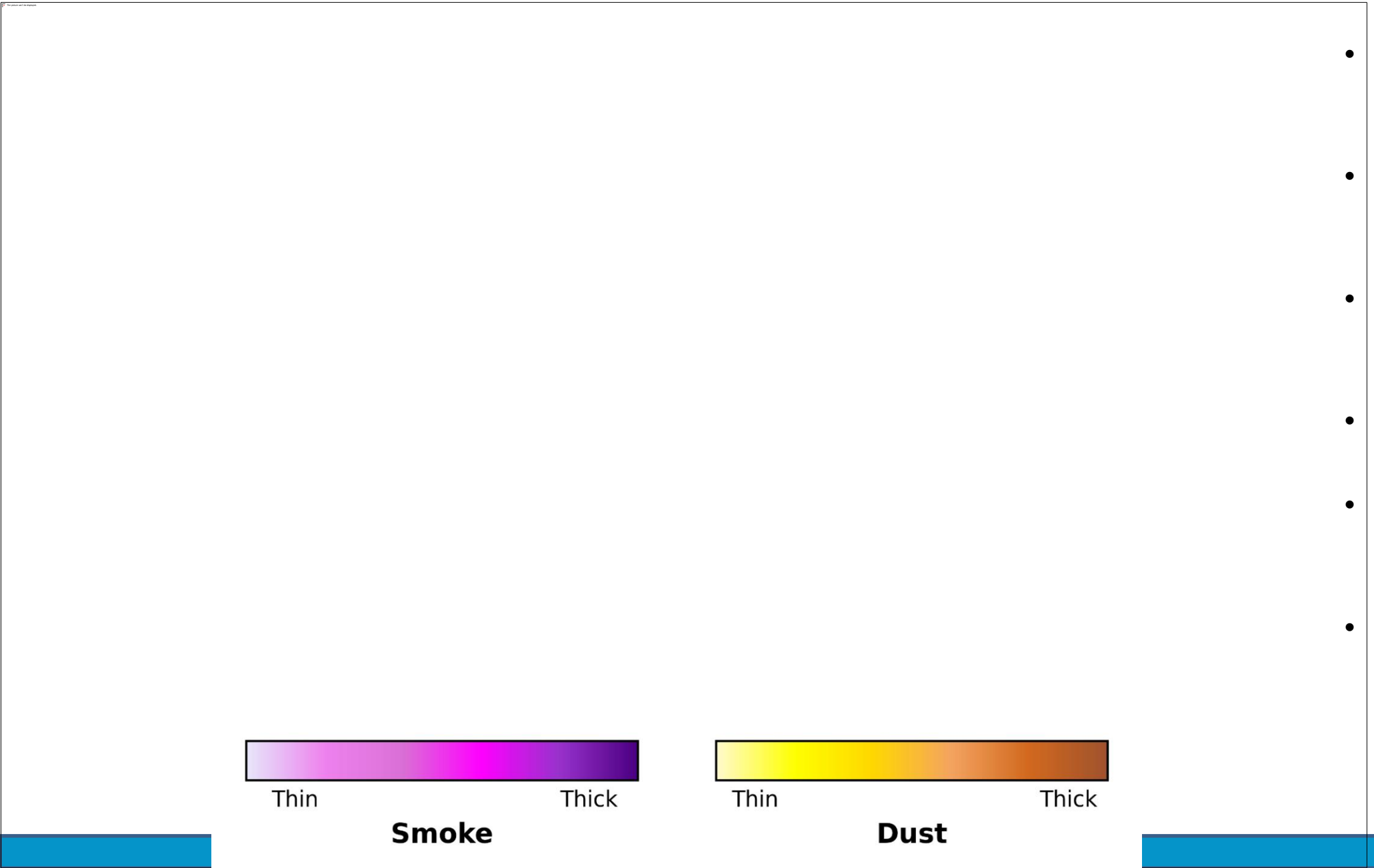
Algorithm Issues/Updates Since Last Product Maturity Review

- **Findings/Issues from NOAA-20 ADP Validated Maturity Review**
  - None
- **Improvements since NOAA-20 ADP Validated Maturity Review**
  - No major changes to the ADP algorithm
  - Minor ADP algorithm changes include:
    - The **bow-tie deletion line mask** is read from the L1b data and added to the algorithm code in order to skip ADP retrievals in bow-tie deletion lines
      - Needed to accommodate changes to the FW L1b input interface (i.e., now the only option is to interpolate at bow-tie deletion lines)
    - An **internal cirrus test** (identical to the cirrus test in the previous version of the Enterprise Cloud Mask, ECM) was added in the algorithm code instead of reading from the ECM
      - Needed to accommodate changes to the bit tests in the ECM “CloudMaskpacked” variable (i.e., the bit tests had a different meaning in previous version of the ECM)

Inter-Sensor Comparison Overview

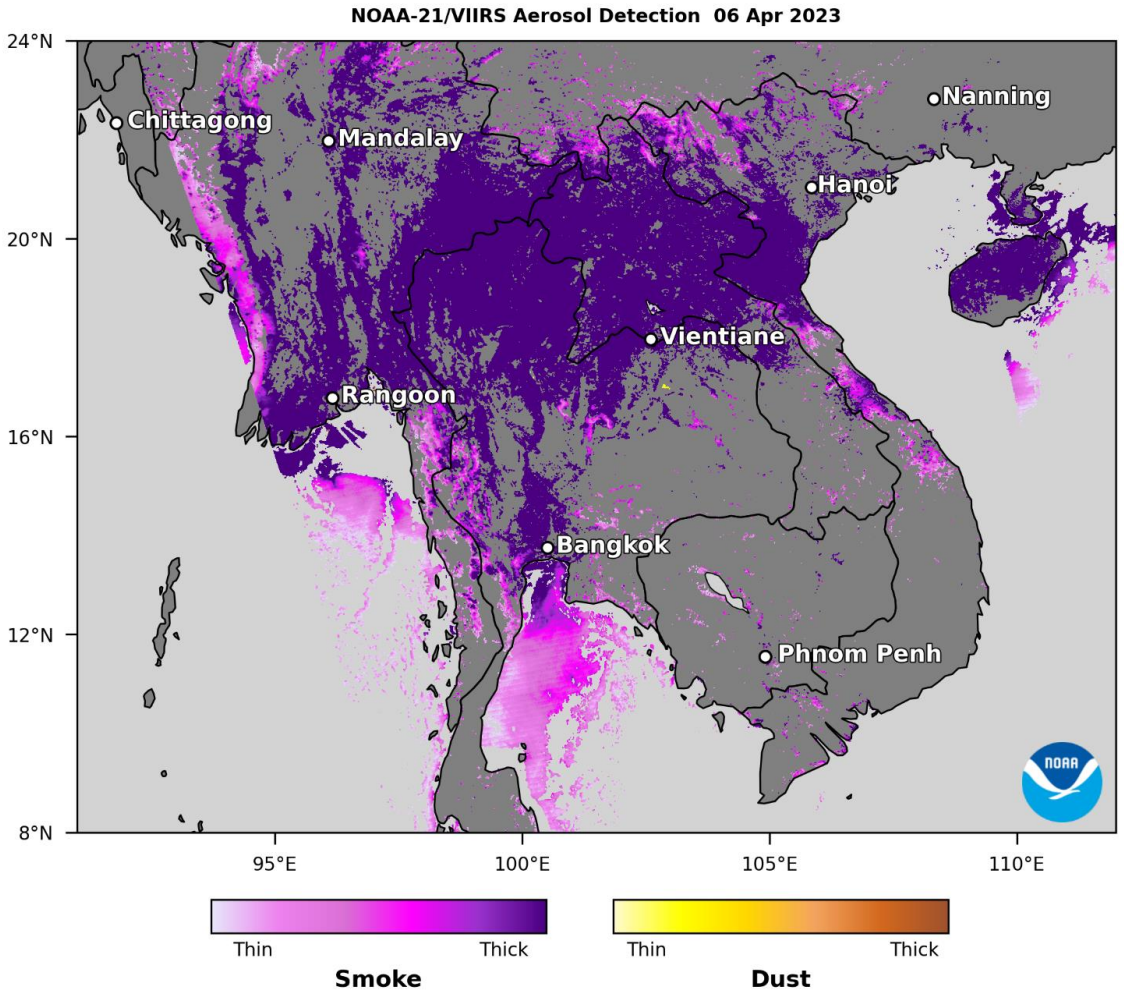
- **Data sets**
  - S-NPP, NOAA-20 and NOAA-21 VIIRS ADP
    - EDR data (750m resolution)
    - Gridded data (0.25° resolution)
  - GOES-18 ABI ADP (2km resolution)
  - S5P TROPOMI total column CO (3.5km x 5.5km resolution)
  - Period: February 11 to July 21, 2023 (~5.5 months)
  - Coverage: global
- **Validation strategies / methods**
  - Visual examination of global distributions, at native resolution and on common grids
  - Visual examination of regional smoke and dust events
  - Analysis of global smoke and dust fraction
  - *Differences are expected due to differences in SDRs and satellite observation times*

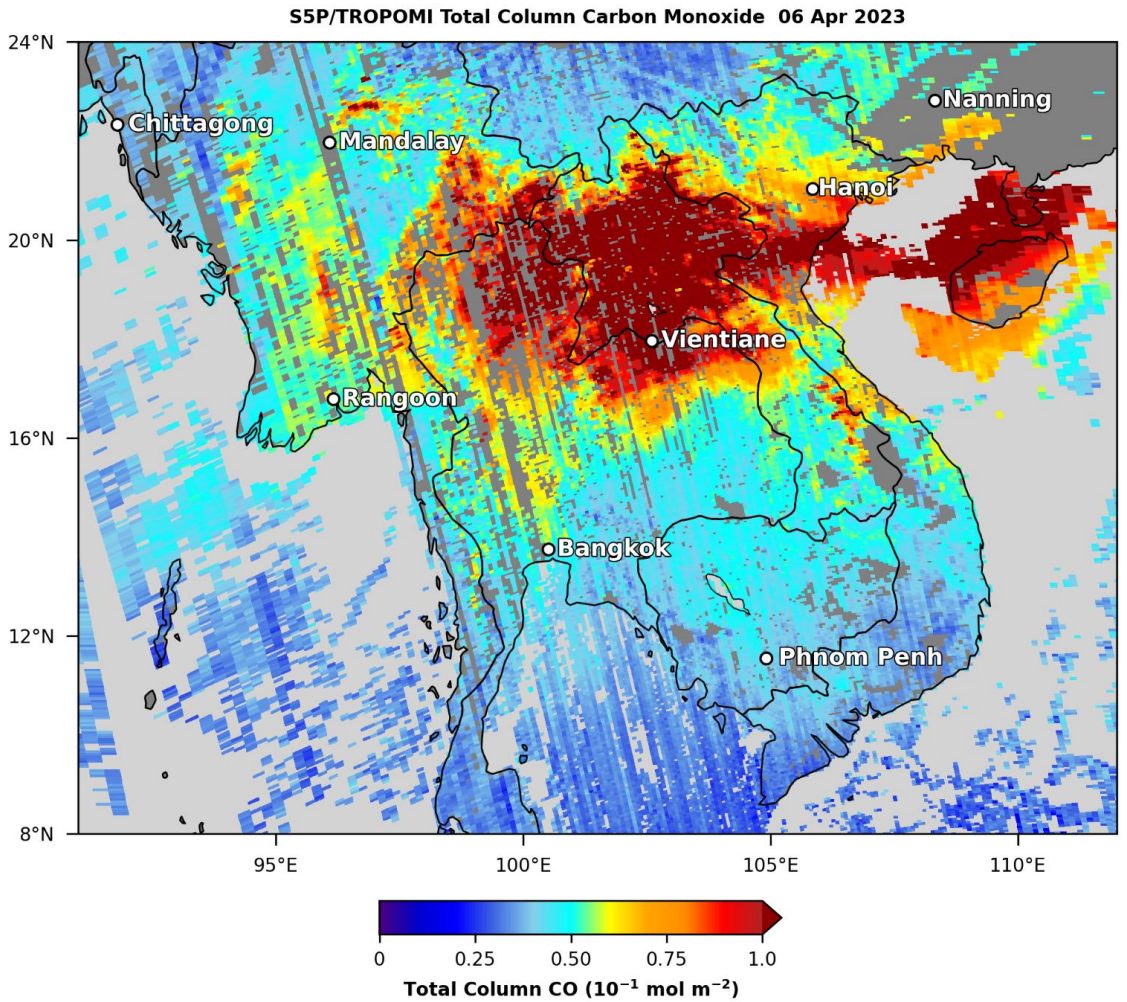
NOAA-21 Global Animation: May 1-31, 2023



- Smoke from Alberta wildfires (transport to Europe & Asia)
- Smoke from seasonal burning in Central America
- Saharan dust transport across Atlantic Ocean
- Blowing dust in central Asia
- Smoke from seasonal burning in South Asia & Southeast Asia
- Smoke from seasonal forest fires in Siberia

Seasonal Fires in Southeast Asia: April 6, 2023

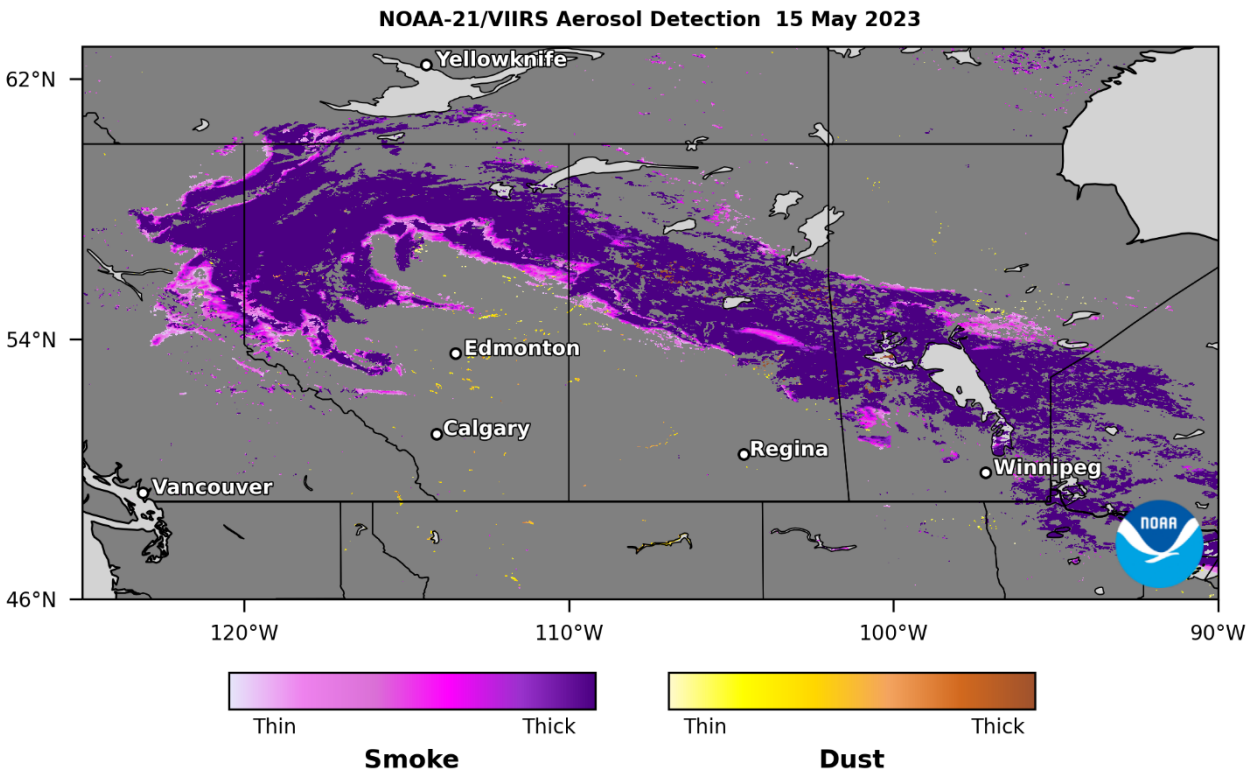


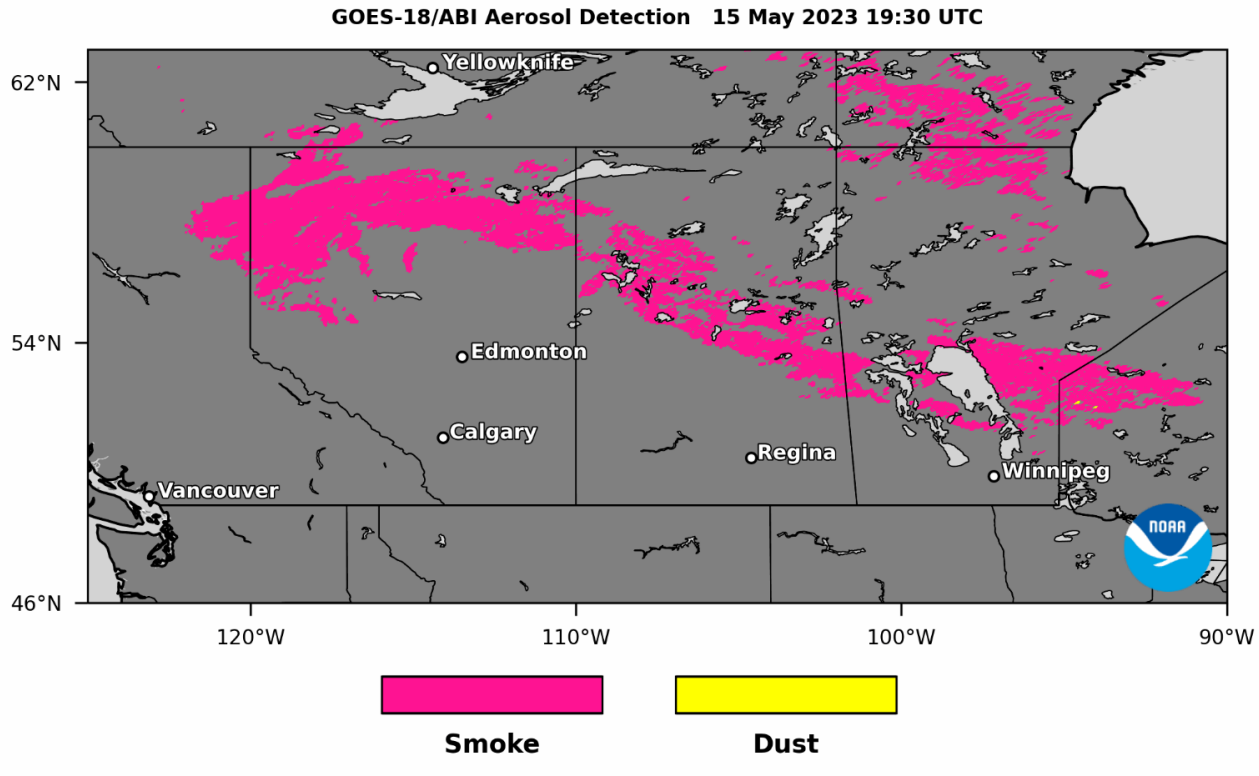


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP
- Spatial coverage and intensity of TROPOMI CO (indicator of biomass burning)

Alberta Wildfires: May 15, 2023

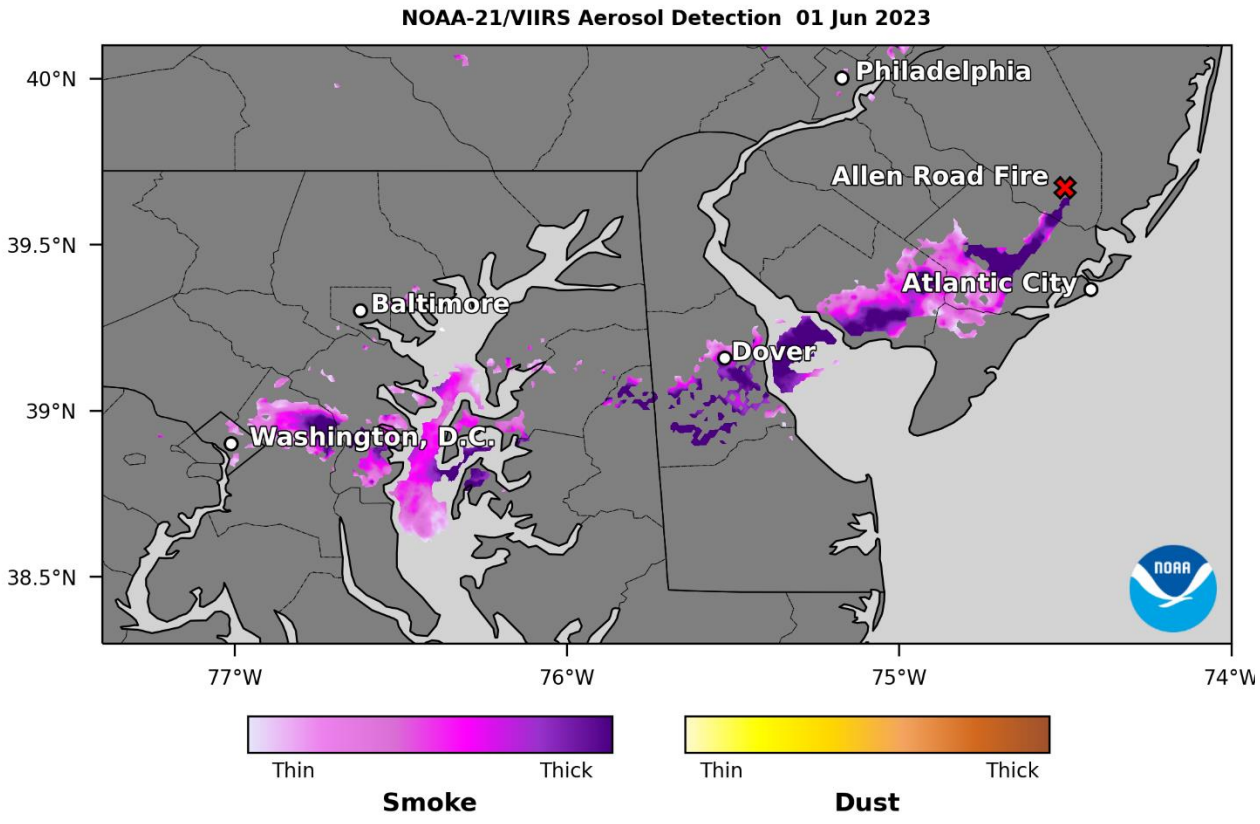


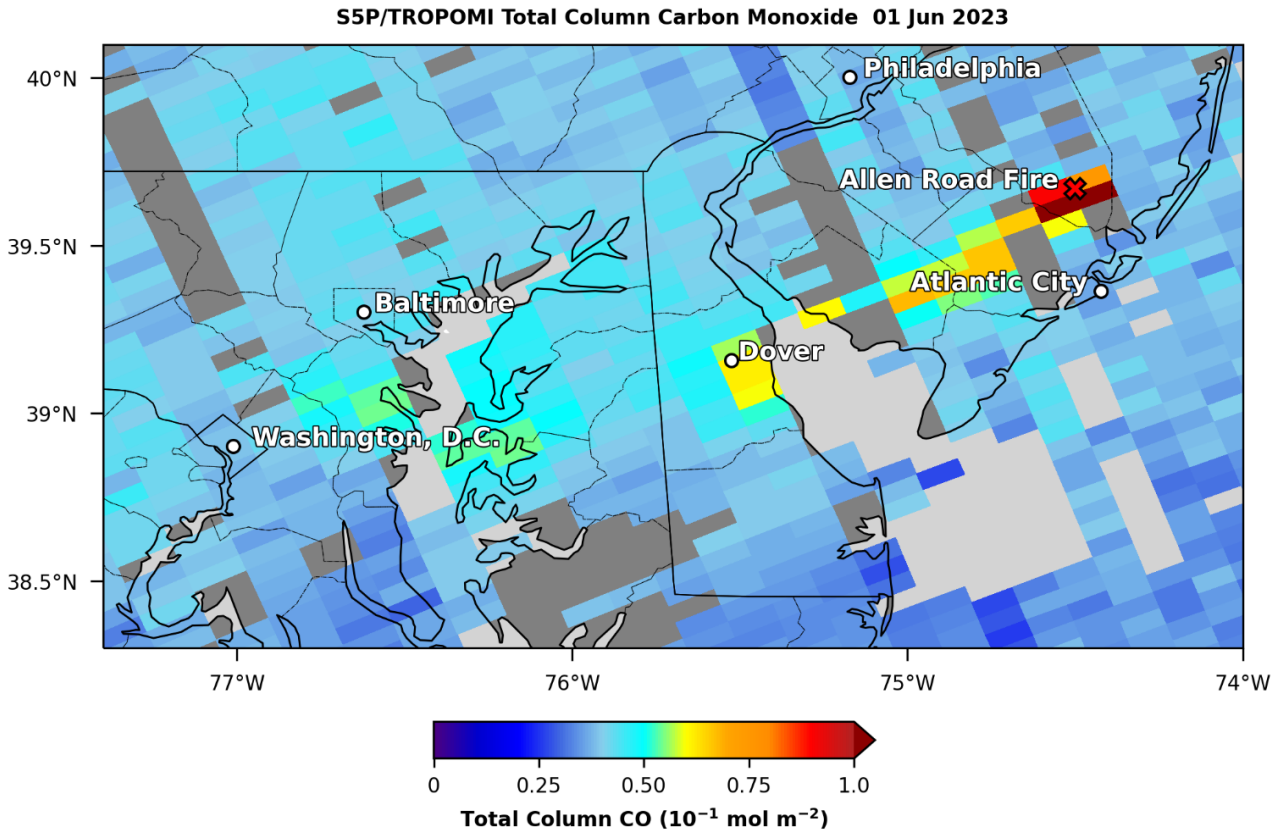


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP (SAAI, Deep-Blue algorithm path)
- Spatial coverage and intensity of TROPOMI CO
- Spatial coverage of GOES-18 ABI ADP
  - Only smoke/dust flags (“yes/no”) retrieved by ABI (IR-Visible algorithm path)

Allen Road Wildfire: June 1, 2023

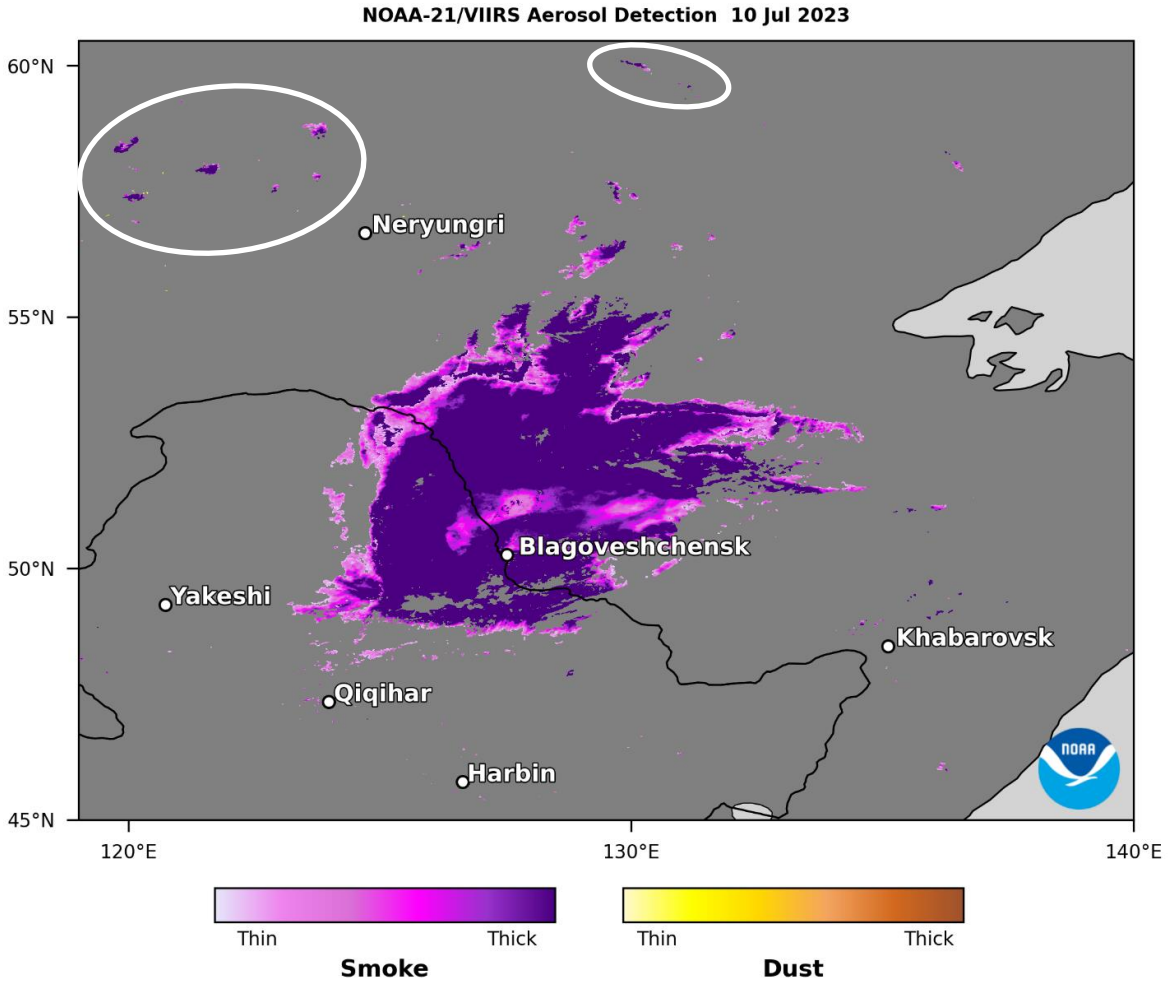


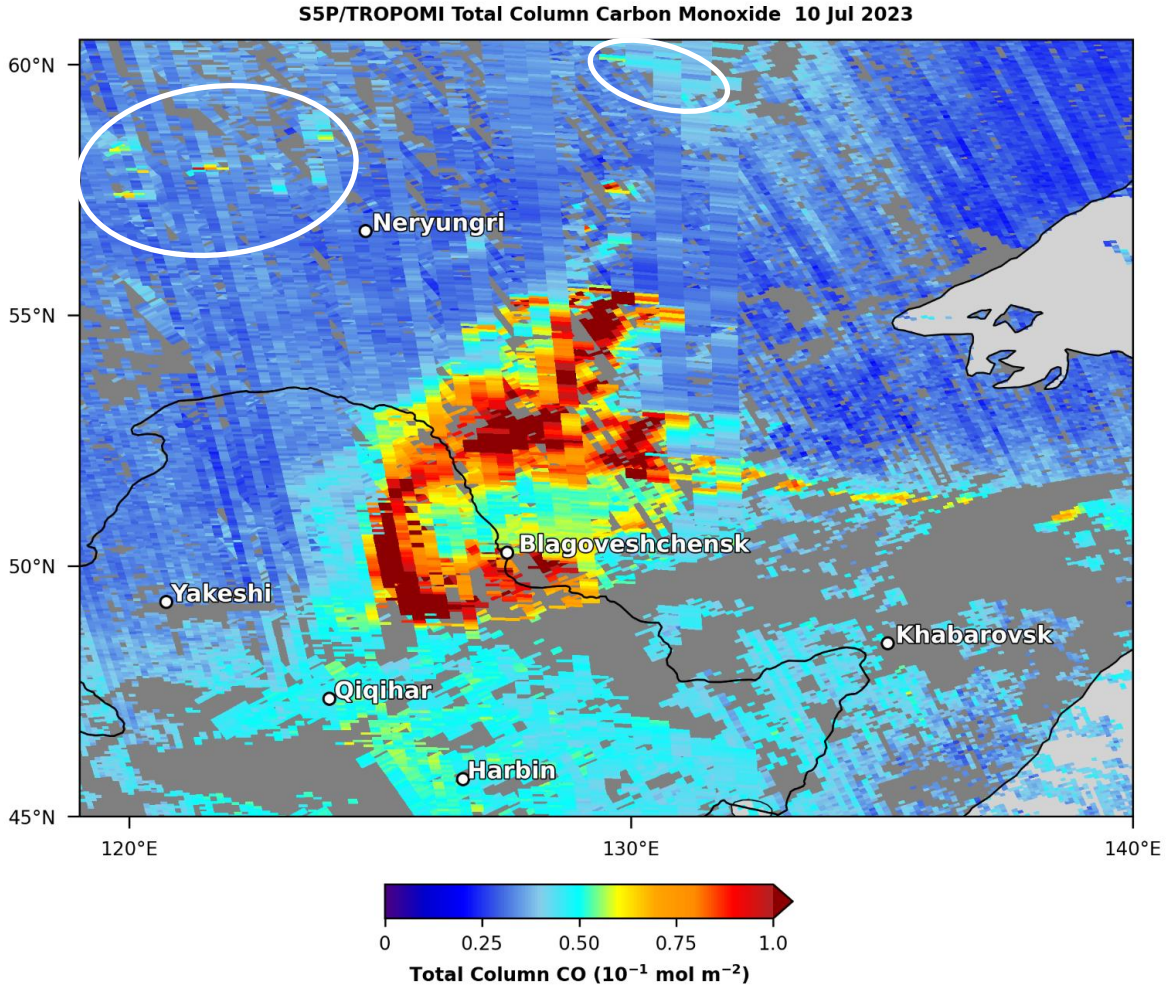


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP
- Spatial coverage and intensity of TROPOMI CO

Seasonal Siberian Wildfires near China/Russia Border: July 10, 2023

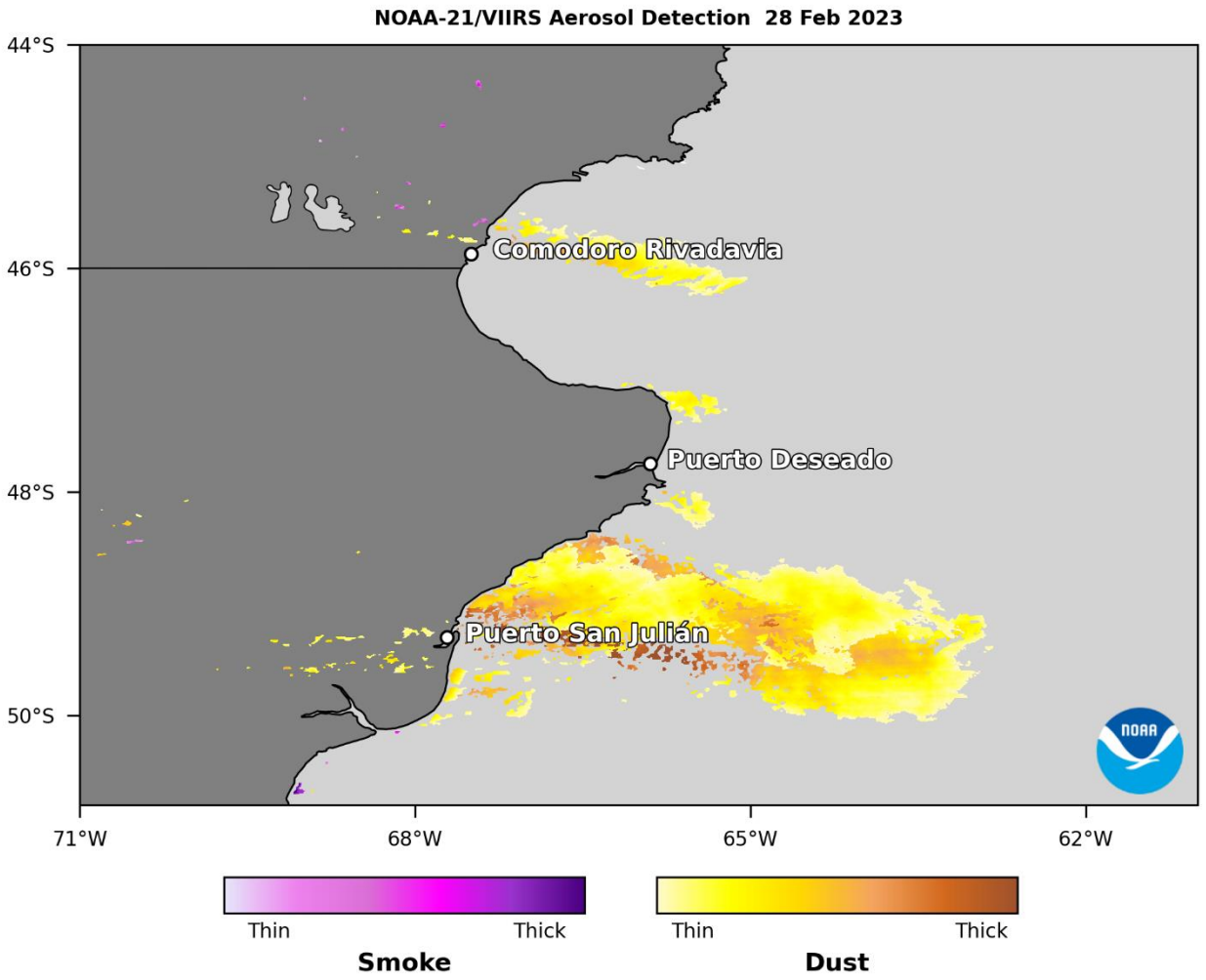


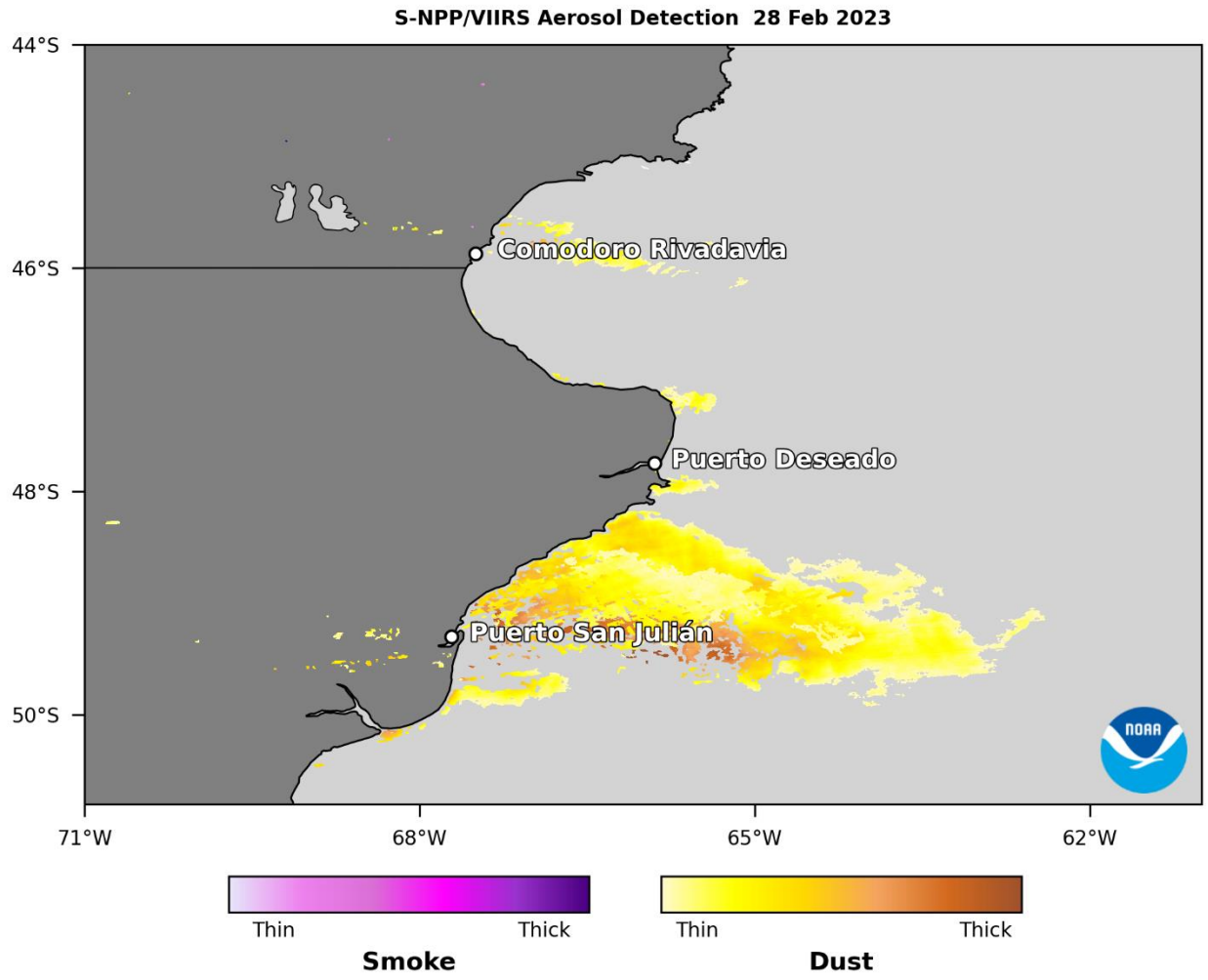


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP
- Spatial coverage and intensity of TROPOMI CO

Blowing Dust in Patagonia: February 28, 2023

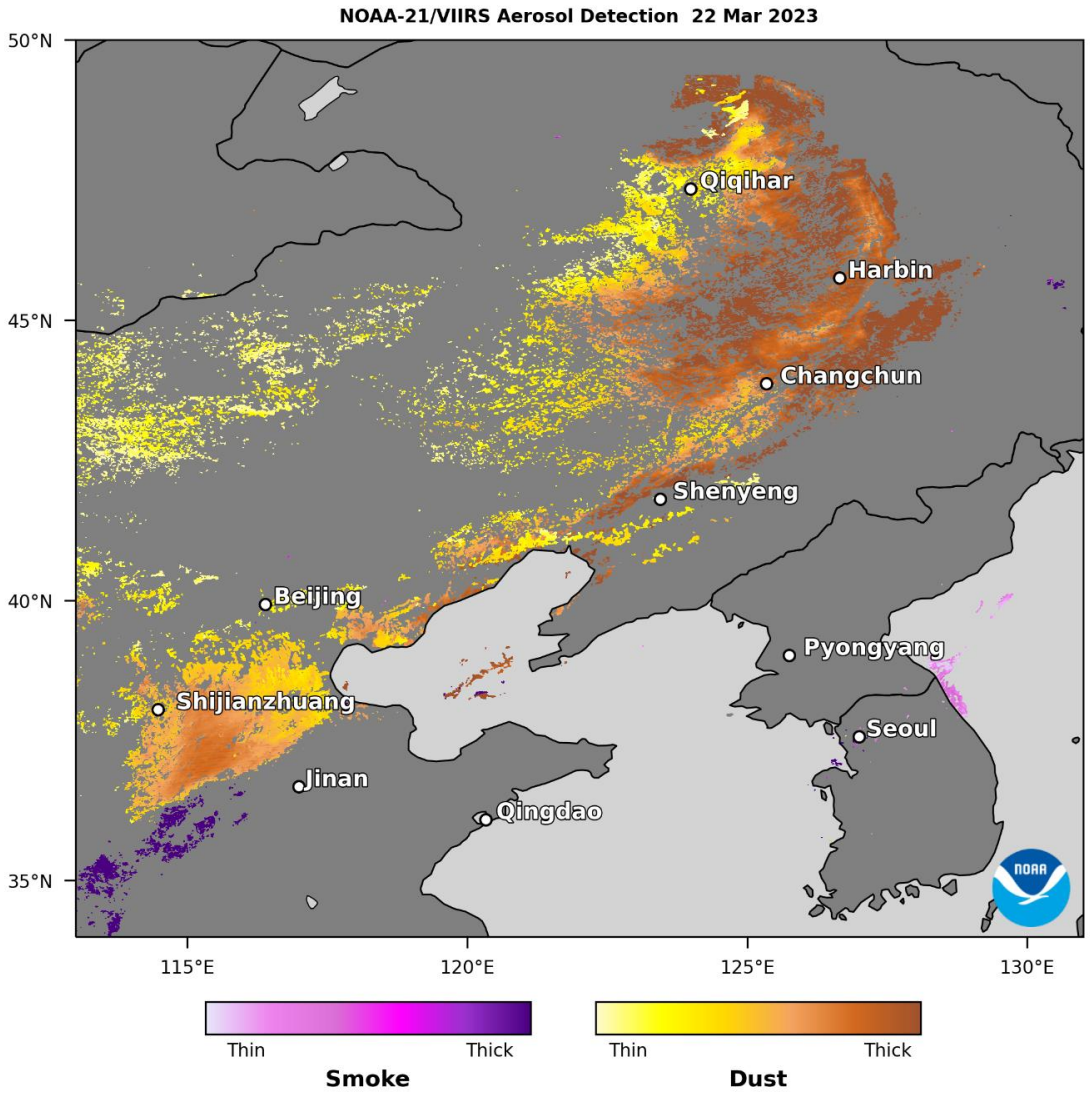


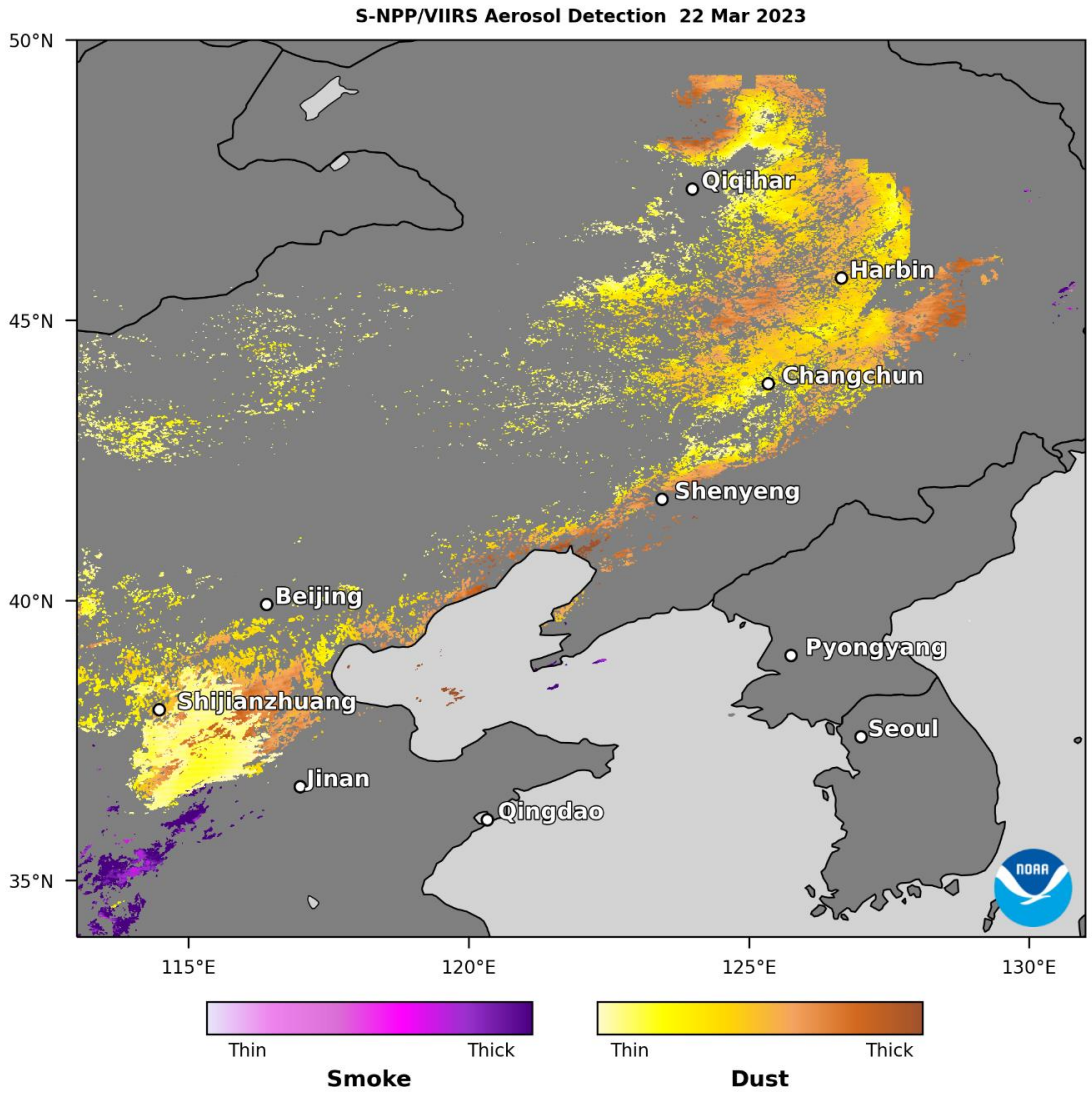


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP

Sandstorm in Northern China: March 22, 2023

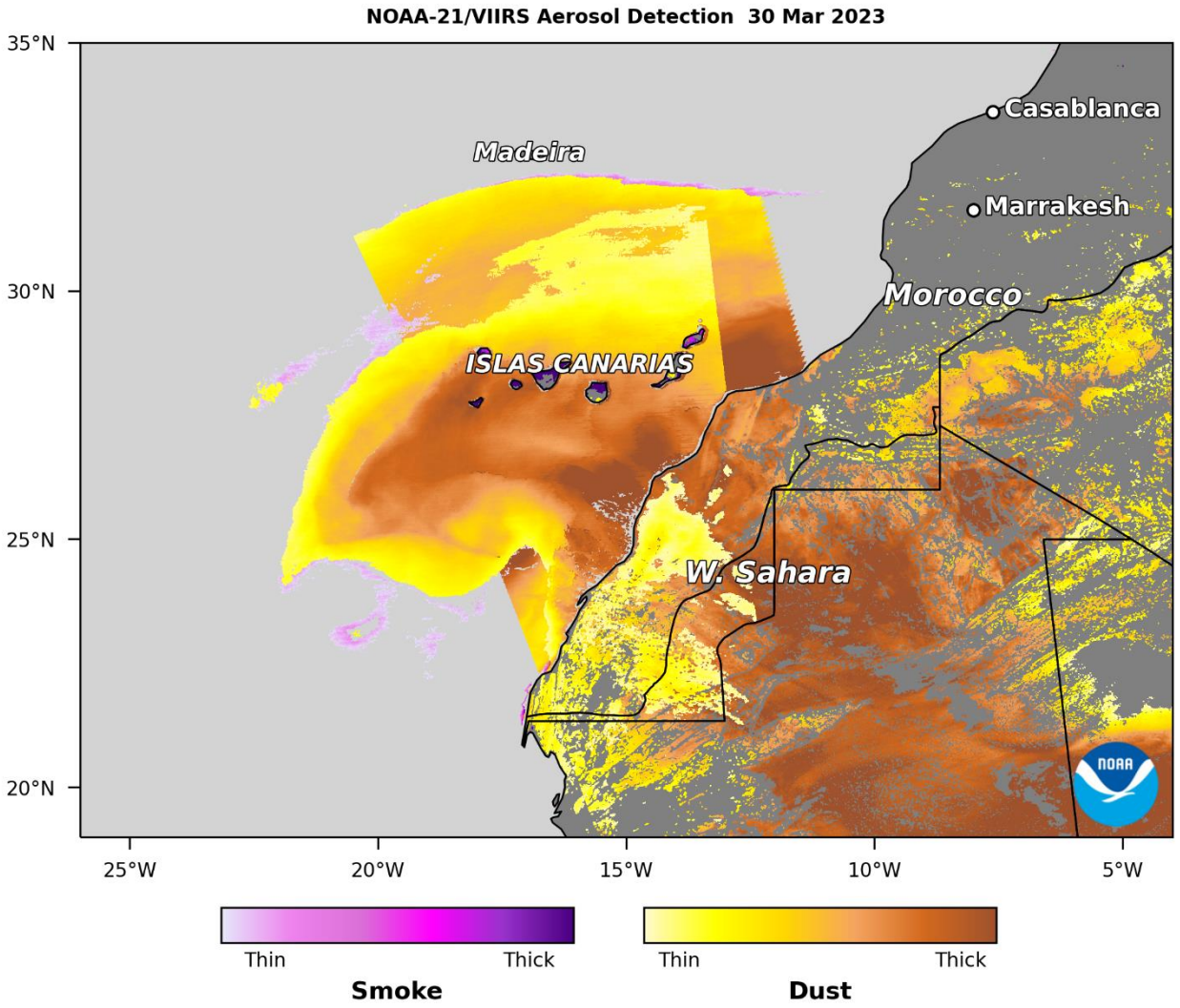


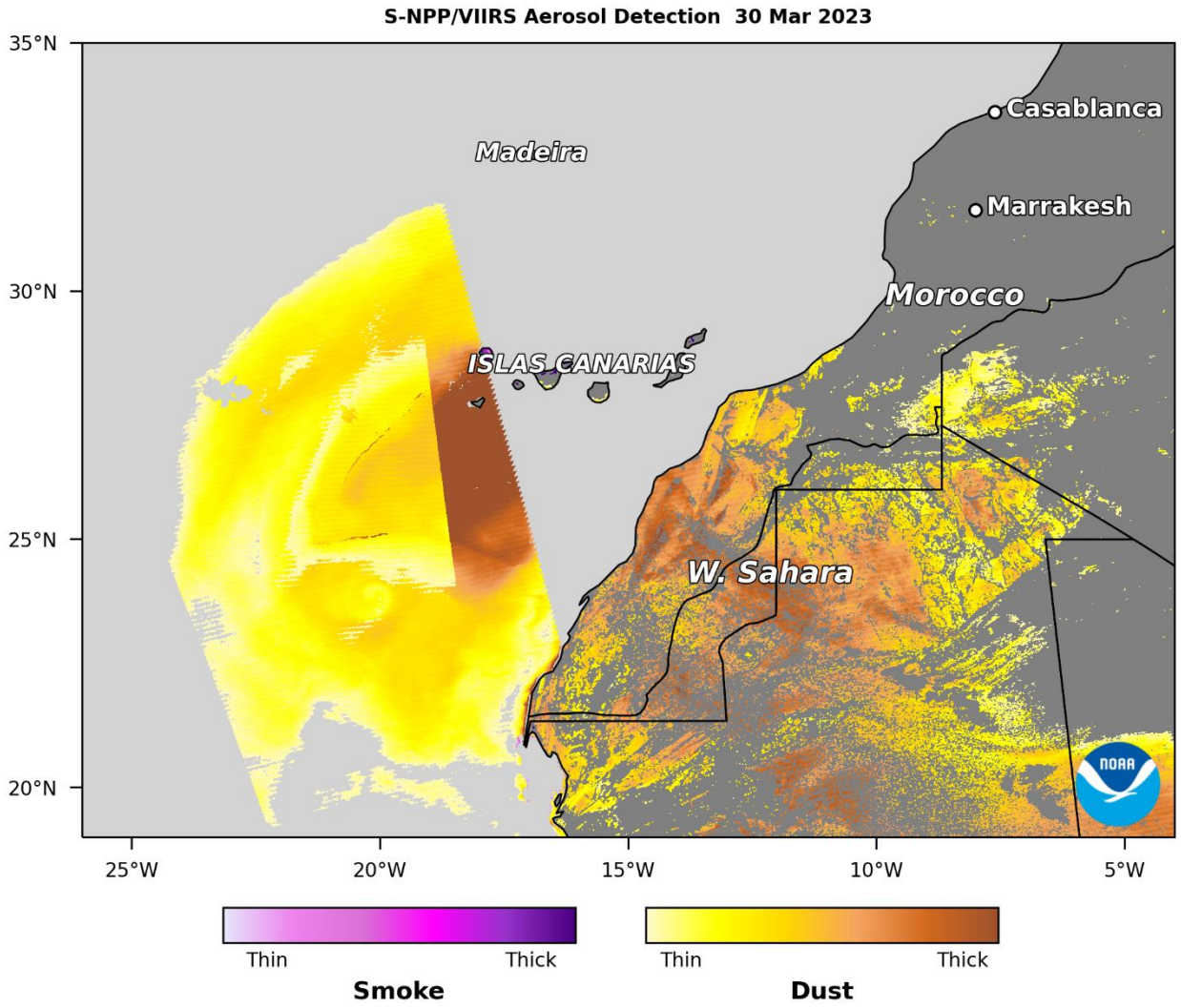


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP

Saharan Dust Engulfs Canary Islands: March 30, 2023

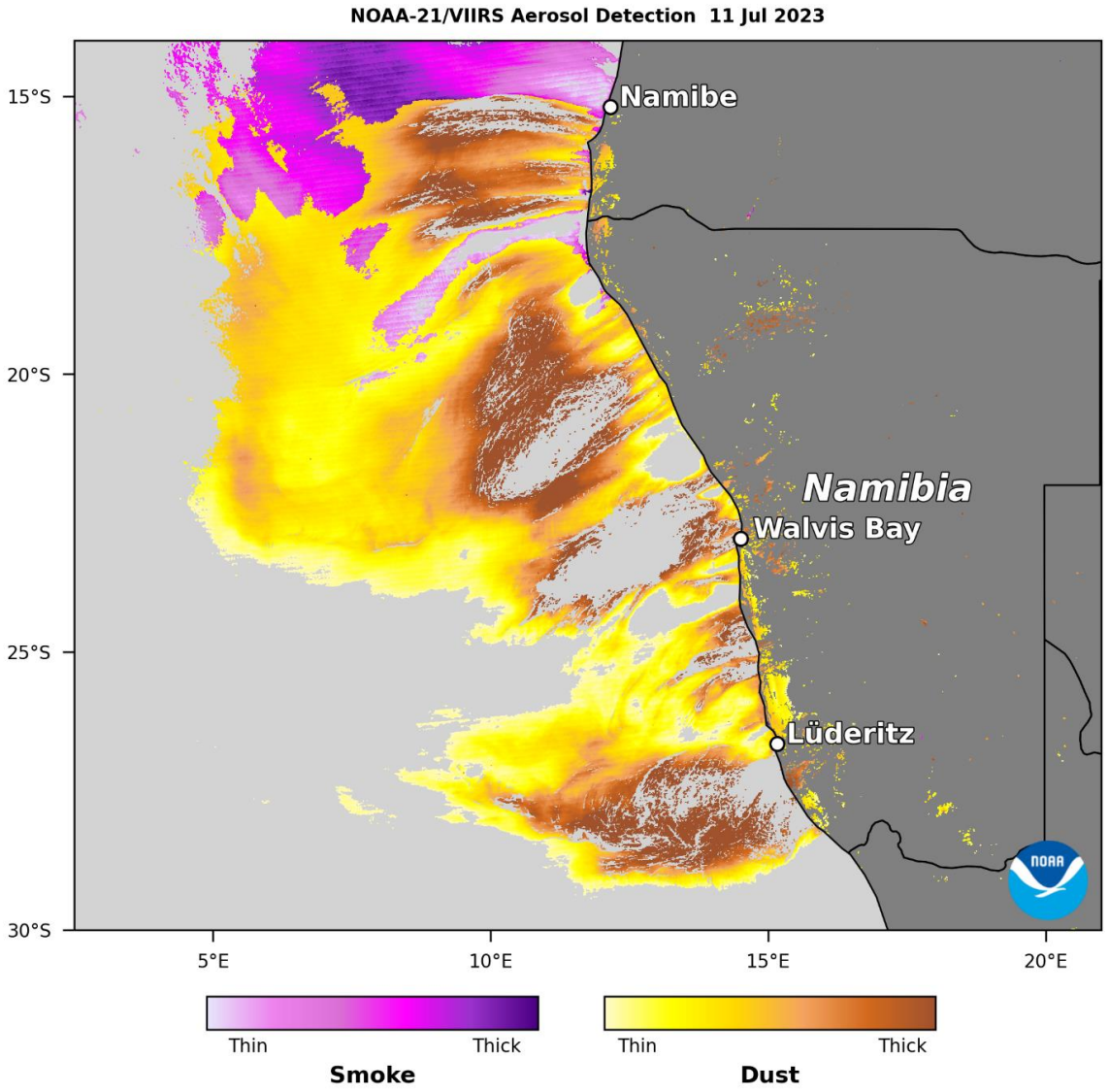


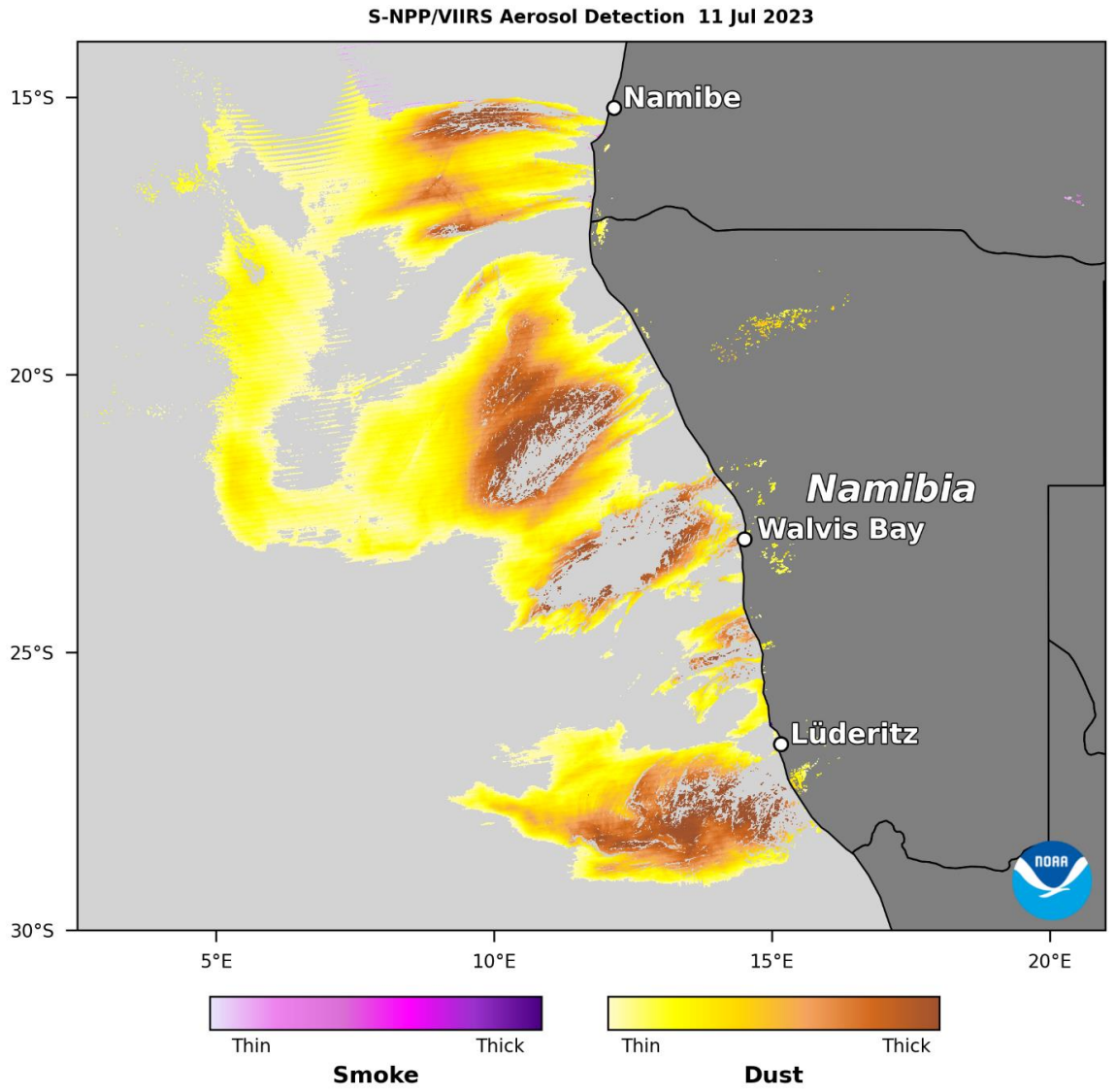


NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP

Dust Blowing off Southwest Africa Coast: July 11, 2023





NOAA-21 VIIRS ADP is consistent with:

- Spatial coverage & relative thickness of NOAA-20 & S-NPP VIIRS ADP

Smoke and Dust Fraction Analysis: February 11 to July 21, 2023

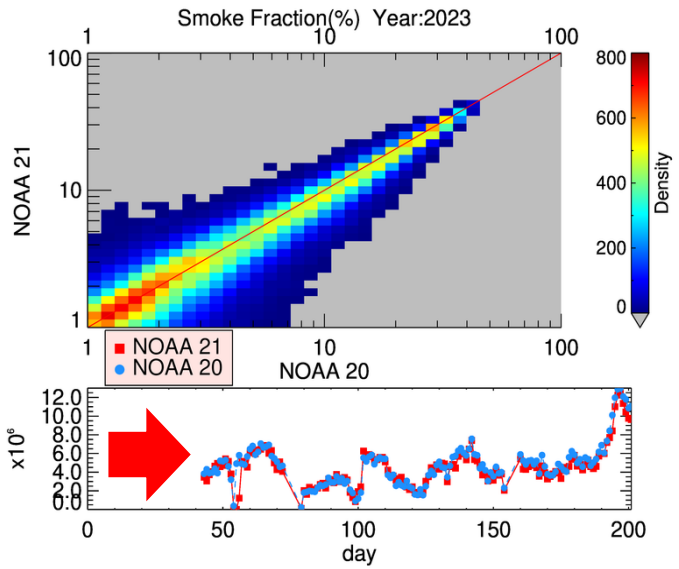
Smoke Fraction =

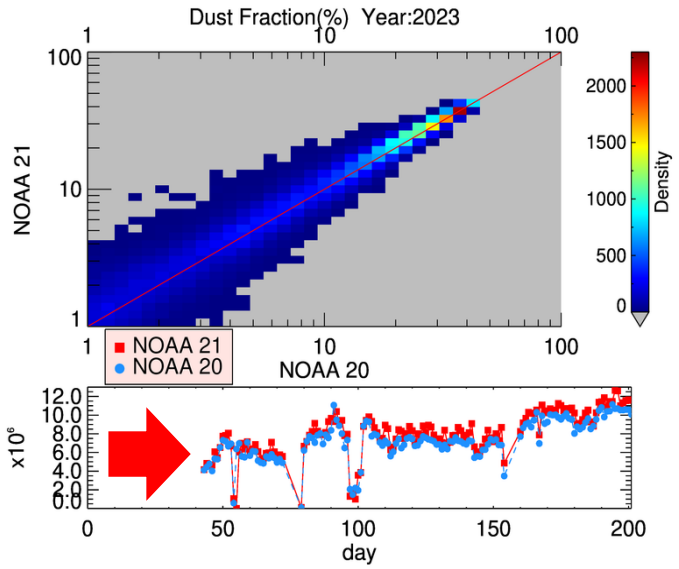
$$\frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

Dust Fraction =

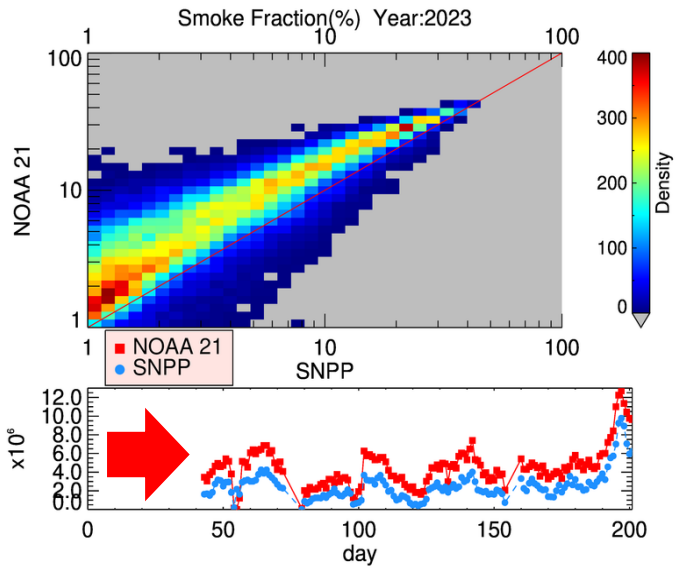
$$\frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

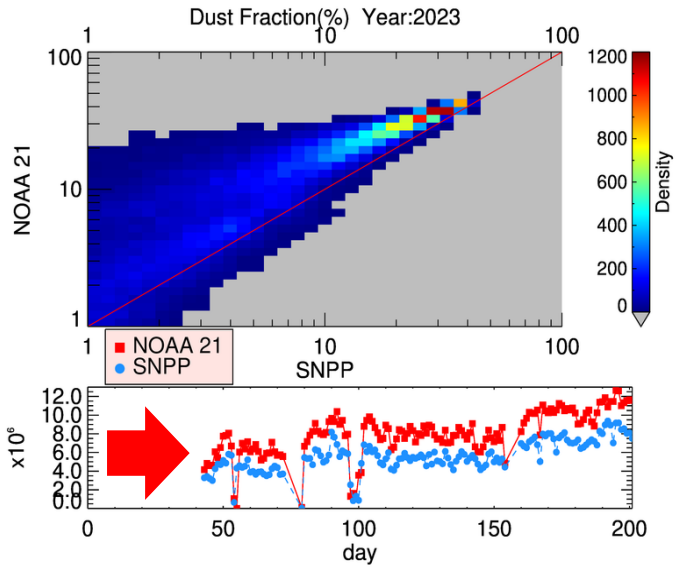
NOAA-21 vs. NOAA-20





NOAA-21 vs. S-NPP

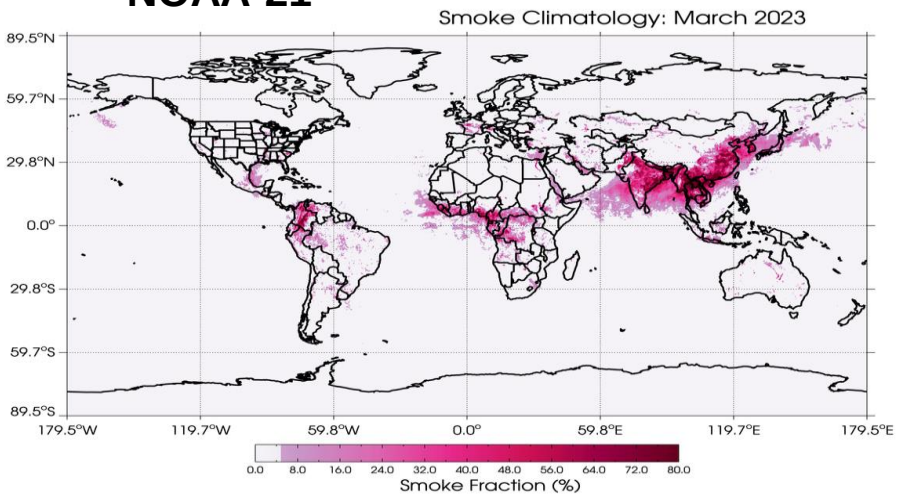




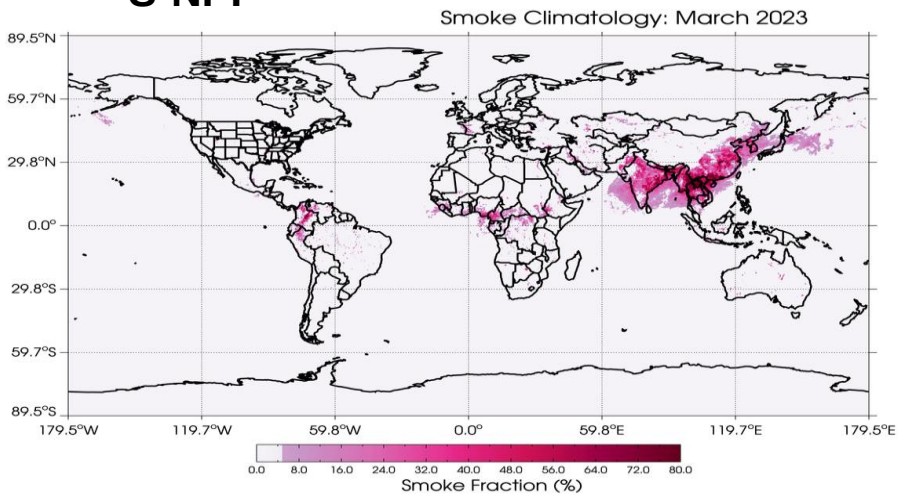
- Large fluctuations in time series plots due to periodic data dropouts
- NOAA-21 smoke & dust fractions are:
  - Very similar to NOAA-20
  - Higher than S-NPP
- Inconsistency w/S-NPP likely caused by SDR M-band calibration differences between S-NPP and NOAA-20
  - Documented during NOAA-20 Validated Maturity Review
  - Illustrated on Slide 45

Smoke and Dust Fraction Comparison: March 2023

NOAA-21

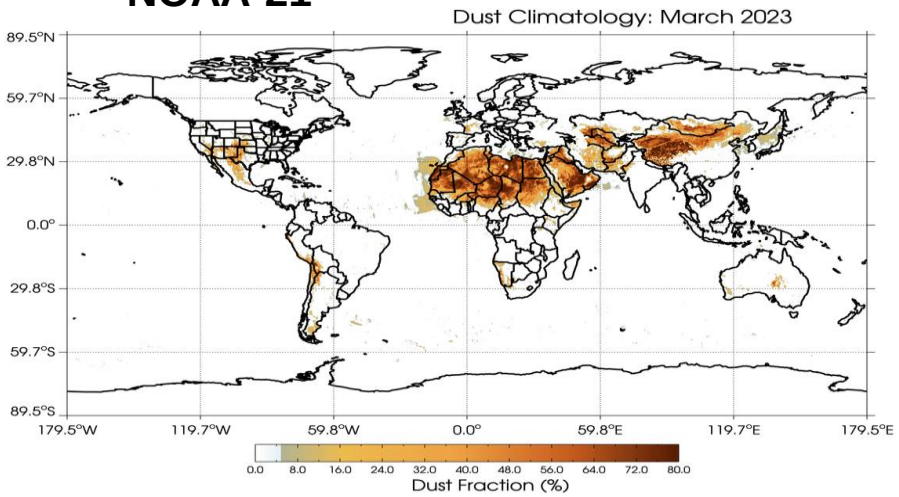


S-NPP

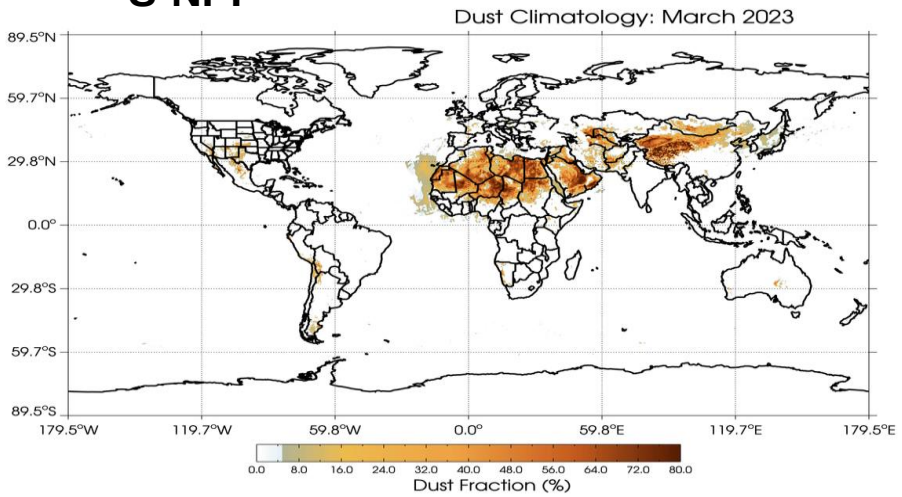


$$\textbf{Smoke Fraction} = \frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

NOAA-21



S-NPP



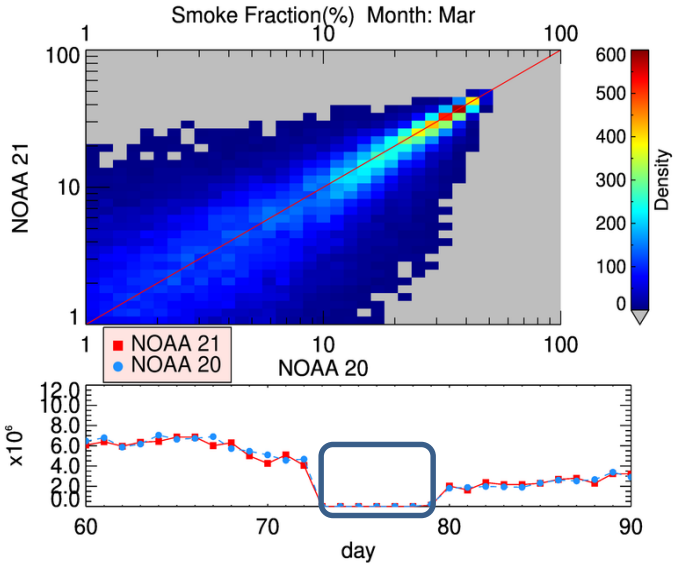
$$\textbf{Dust Fraction} = \frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

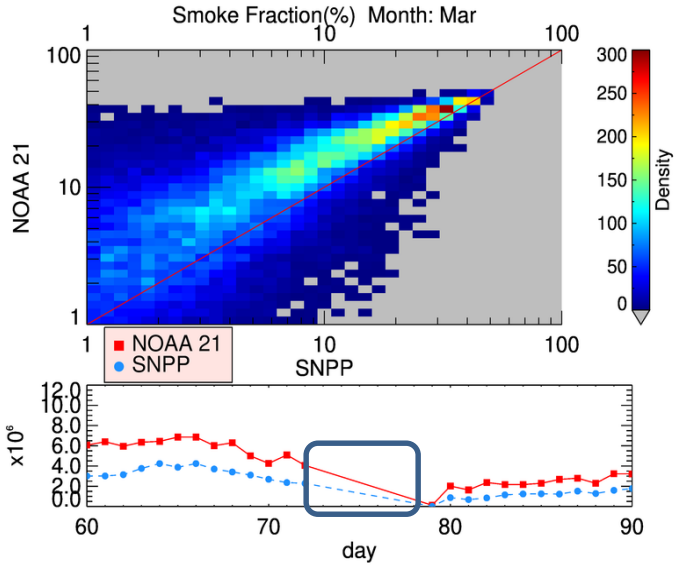
Smoke and Dust Fraction Analysis: March 2023

NOAA-21 vs. NOAA-20

NOAA-21 vs. S-NPP

Smoke



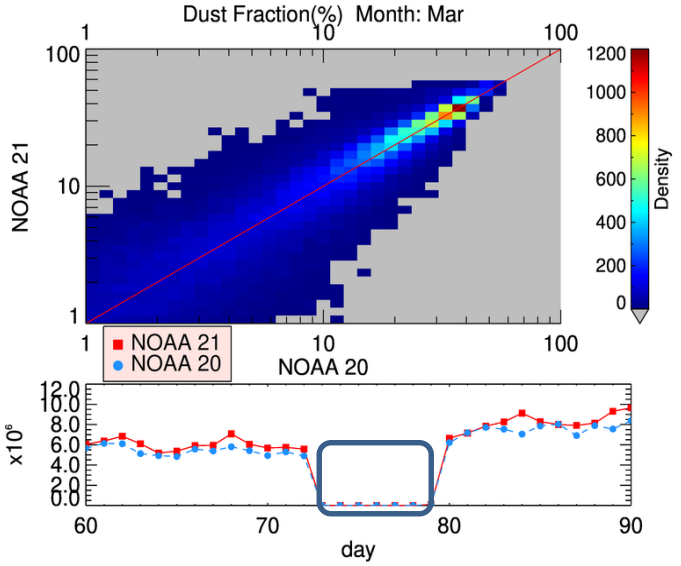


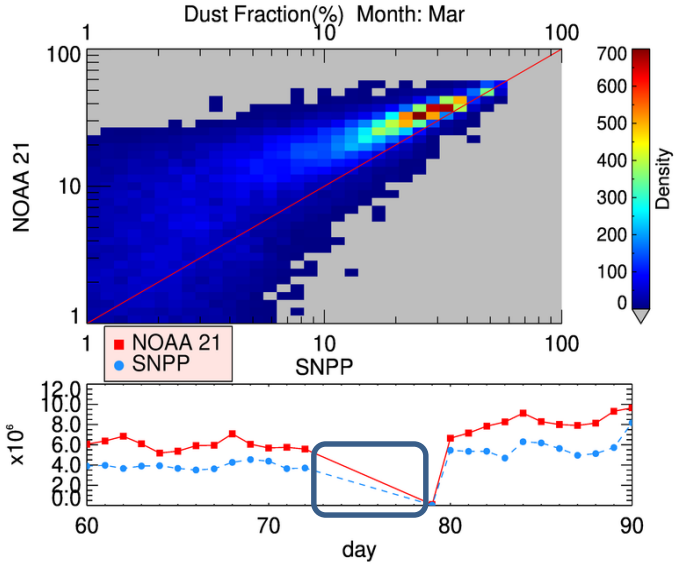
Smoke Fraction =

$$\frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

Data flow to I&T directories stopped March 13-20 due to configuration file error

Dust



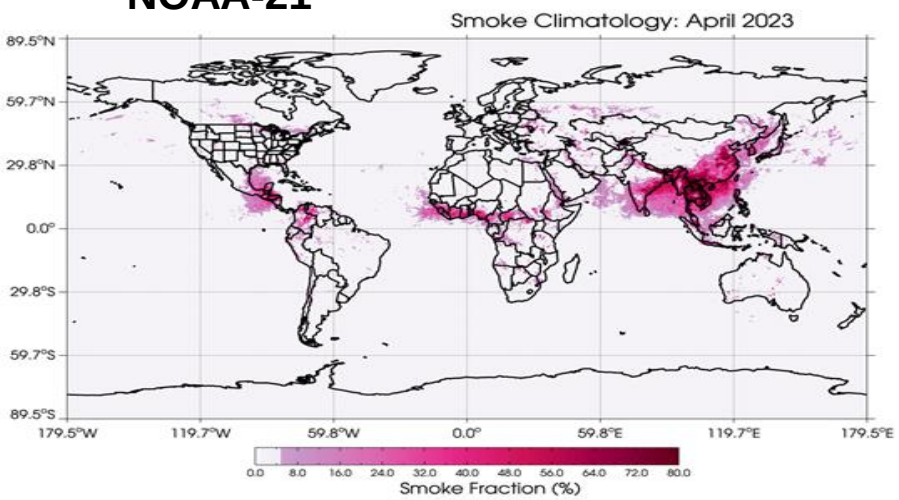


Dust Fraction =

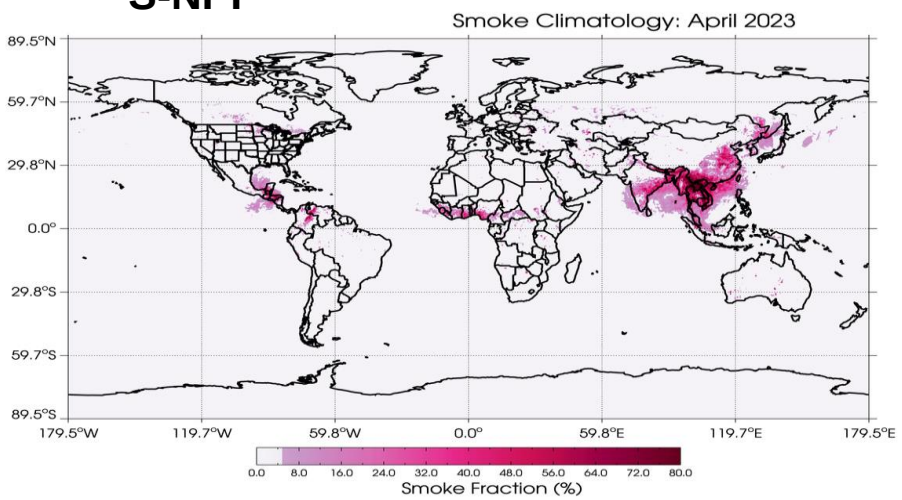
$$\frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

Smoke and Dust Fraction Comparison: April 2023

NOAA-21



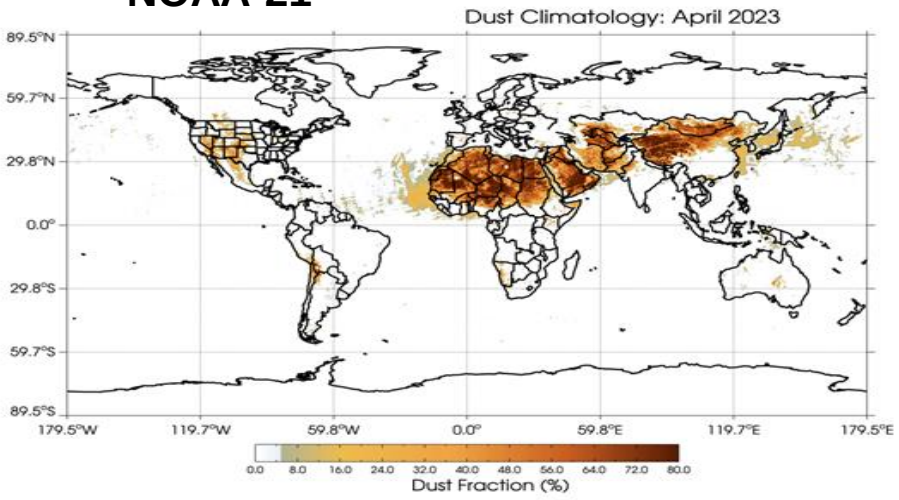
S-NPP



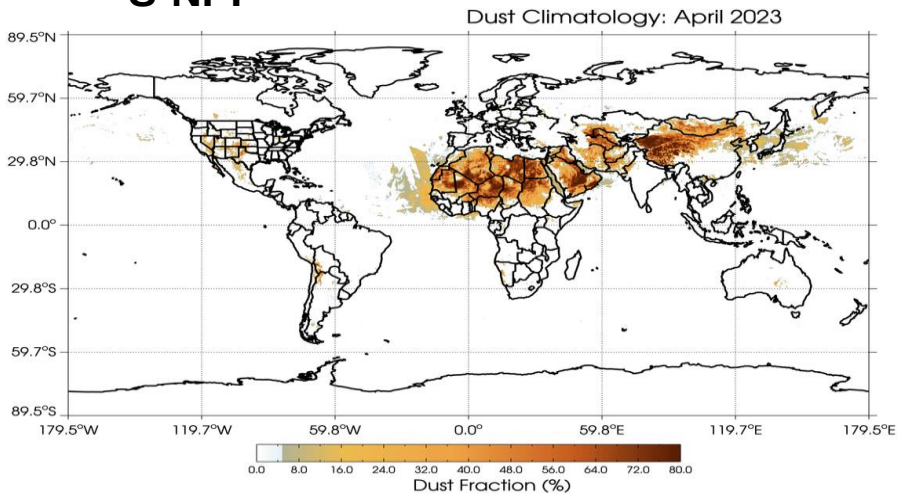
Smoke Fraction =

$$\frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

NOAA-21



S-NPP



Dust Fraction =

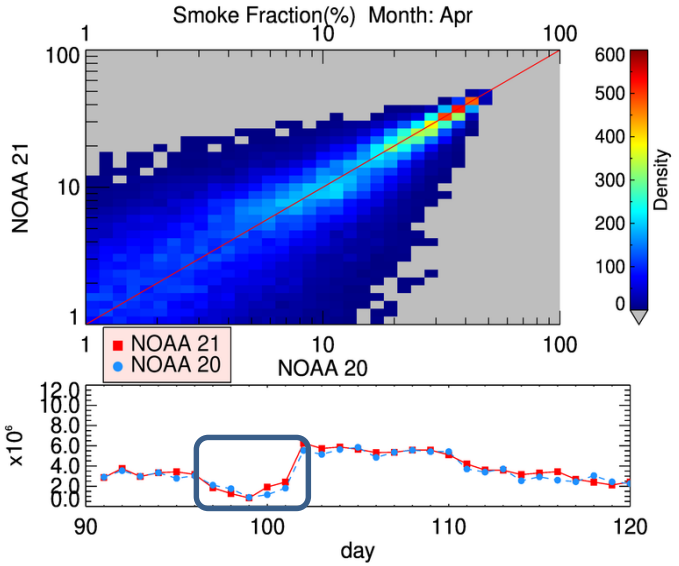
$$\frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

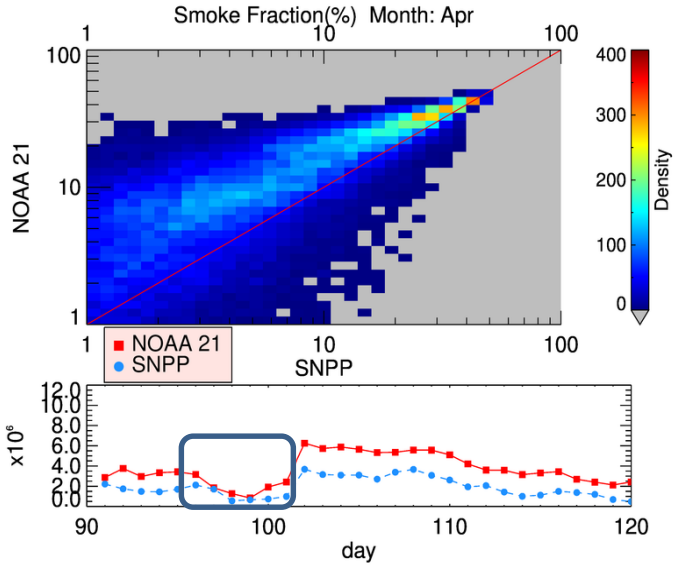
Analysis of Smoke and Dust Fraction: April 2023

NOAA-21 vs. NOAA-20

NOAA-21 vs. S-NPP

Smoke



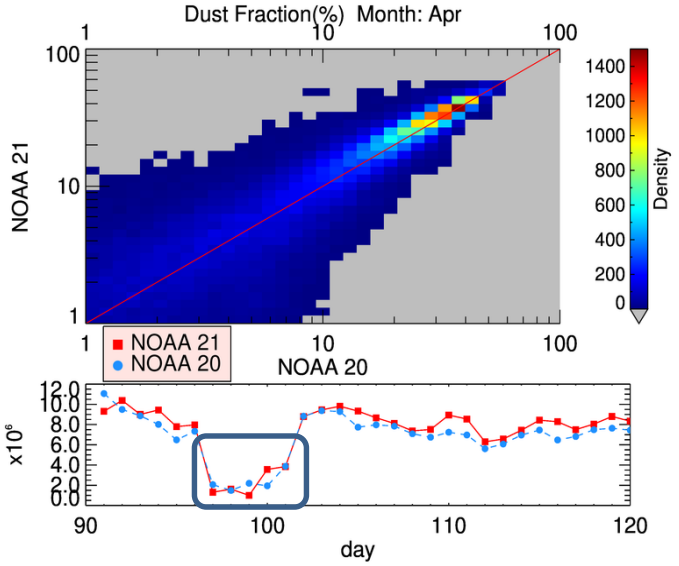


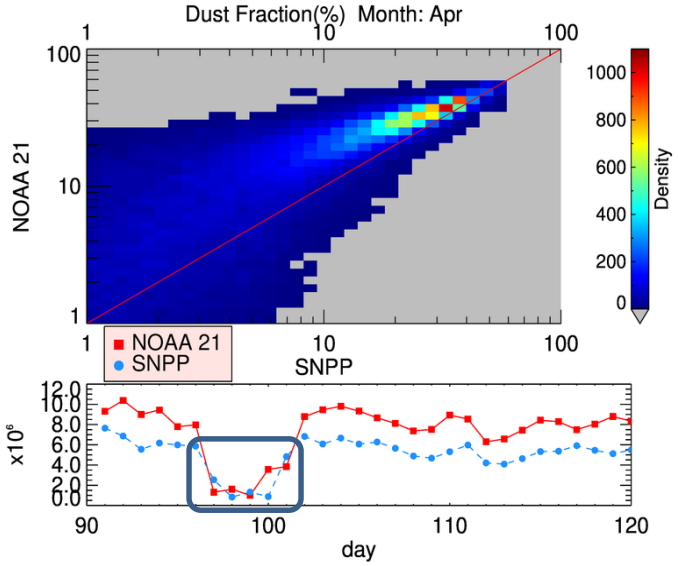
Smoke Fraction =

$$\frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

Gaps in data flow to I&T directories April 7-12 due to unknown issue

Dust



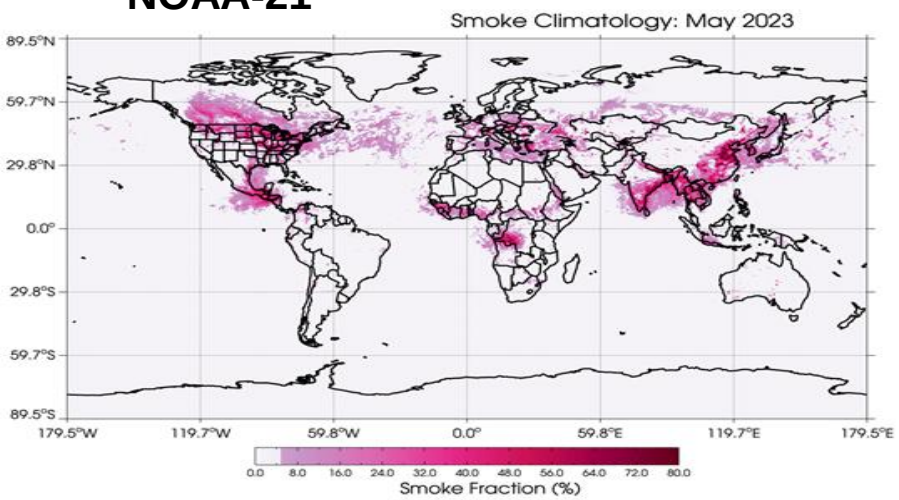


Dust Fraction =

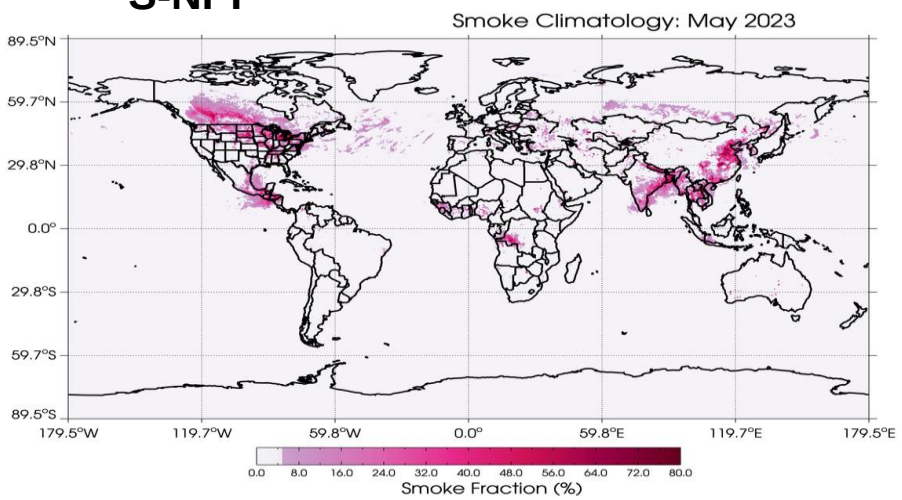
$$\frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

Smoke and Dust Fraction Comparison: May 2023

NOAA-21

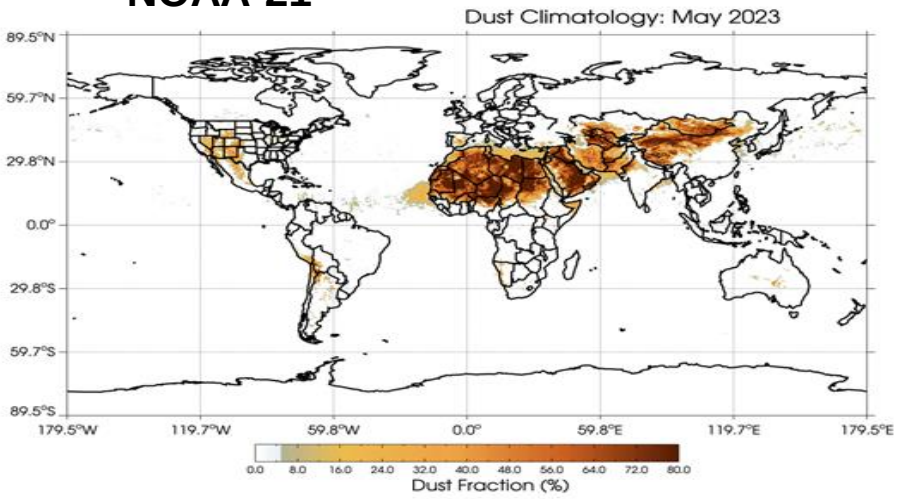


S-NPP

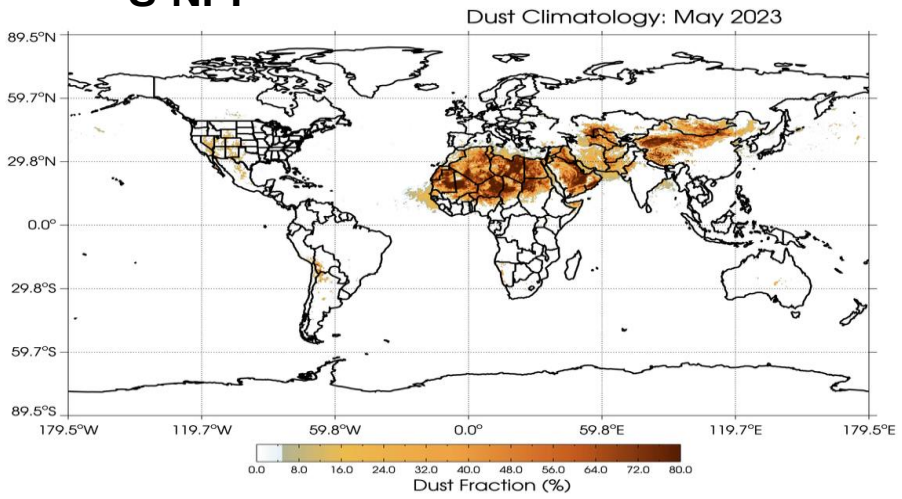


Smoke Fraction $= \frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$

NOAA-21



S-NPP



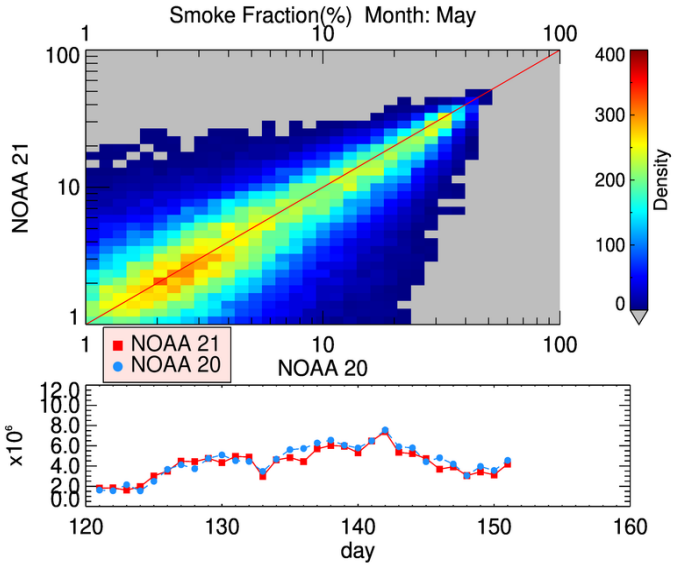
Dust Fraction $= \frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$

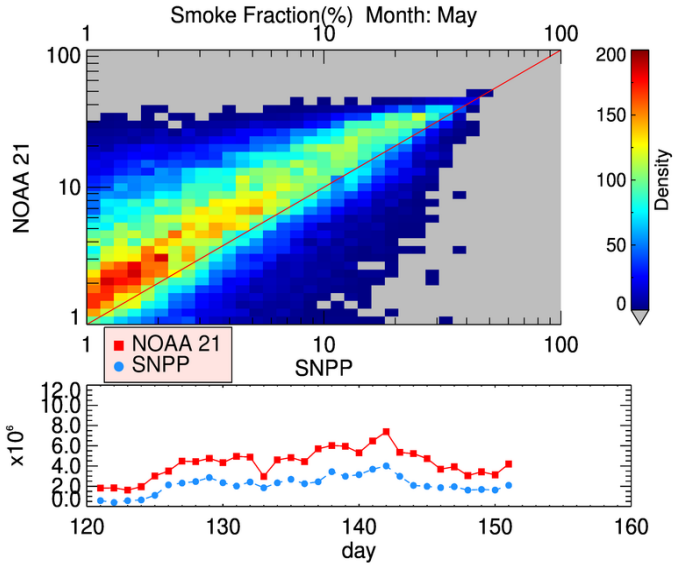
Analysis of Smoke and Dust Fraction: May 2023

NOAA-21 vs. NOAA-20

NOAA-21 vs. S-NPP

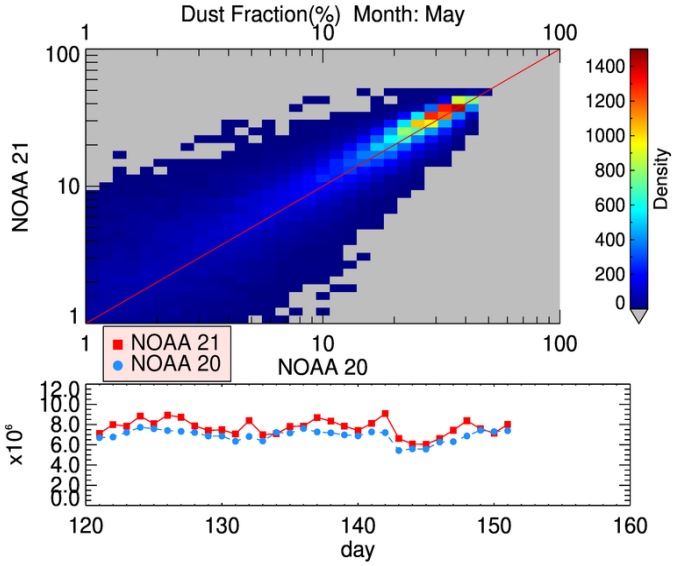
Smoke

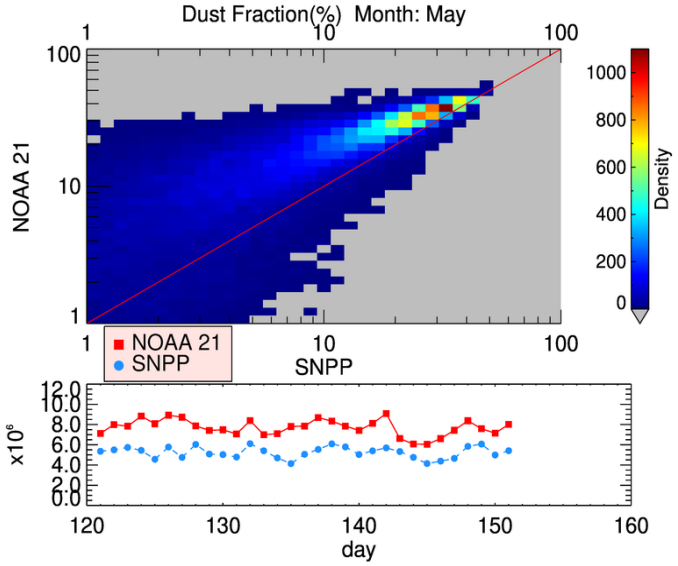




$$\text{Smoke Fraction} = \frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

Dust

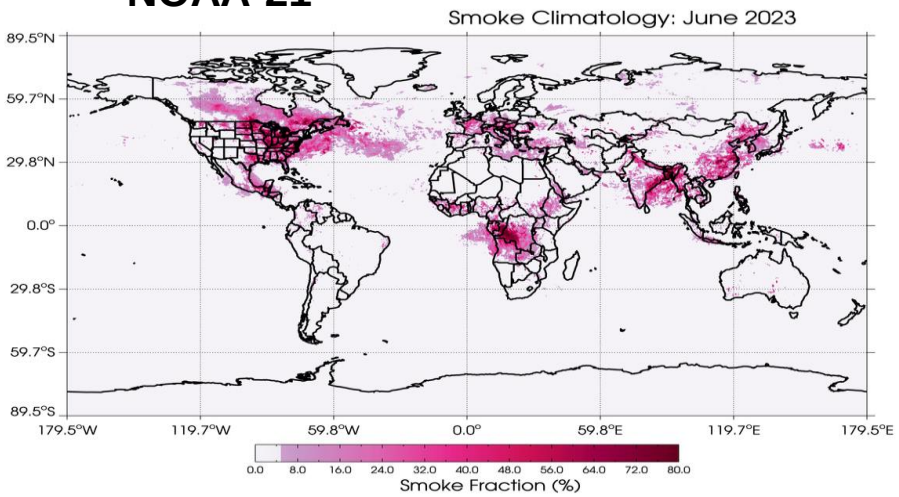




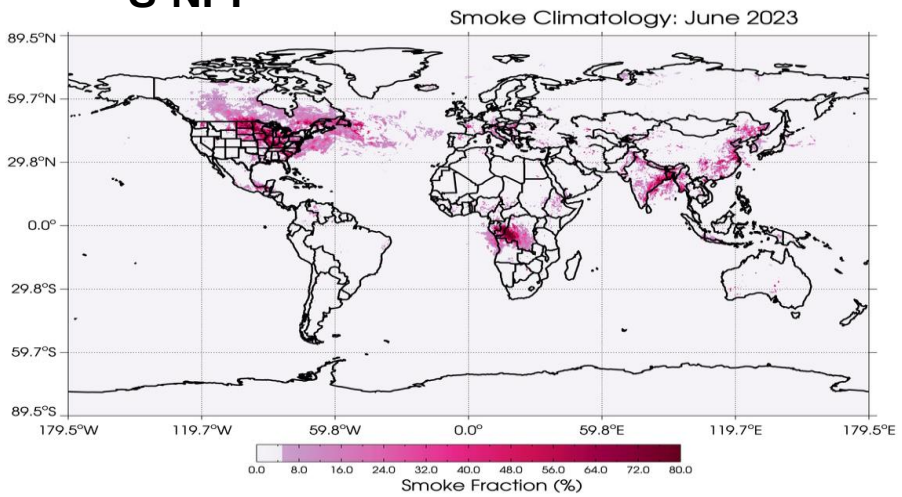
$$\text{Dust Fraction} = \frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

Smoke and Dust Fraction Comparison: June 2023

NOAA-21

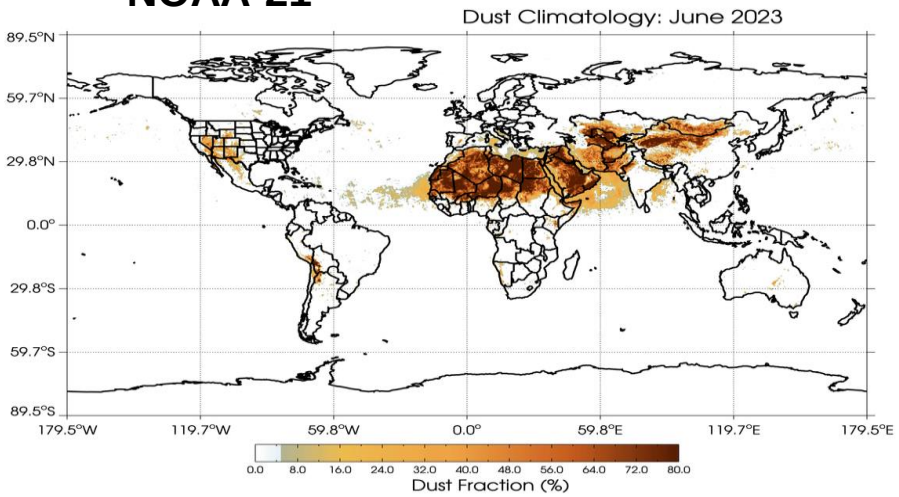


S-NPP

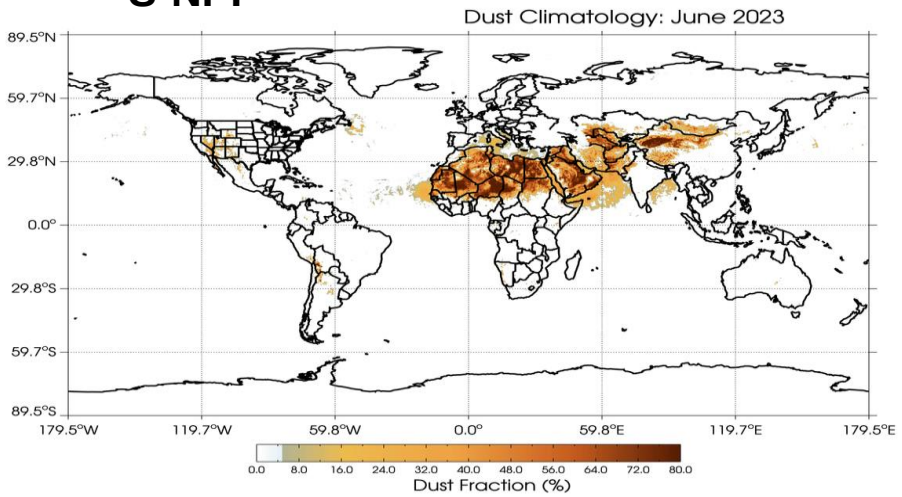


$$\textbf{Smoke Fraction} = \frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

NOAA-21



S-NPP



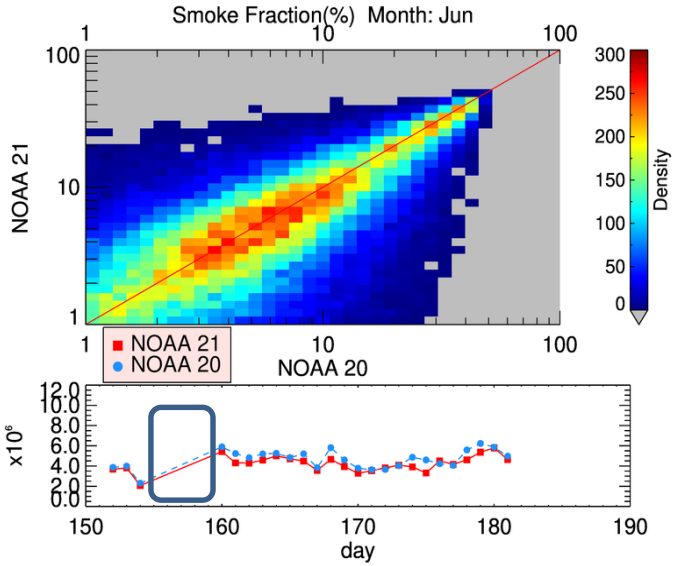
$$\textbf{Dust Fraction} = \frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

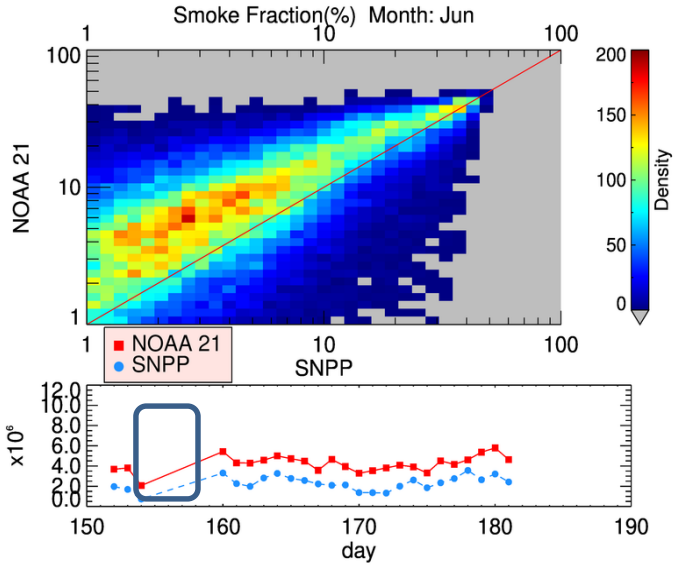
Analysis of Smoke and Dust Fraction: June 2023

NOAA-21 vs. NOAA-20

NOAA-21 vs. S-NPP

Smoke



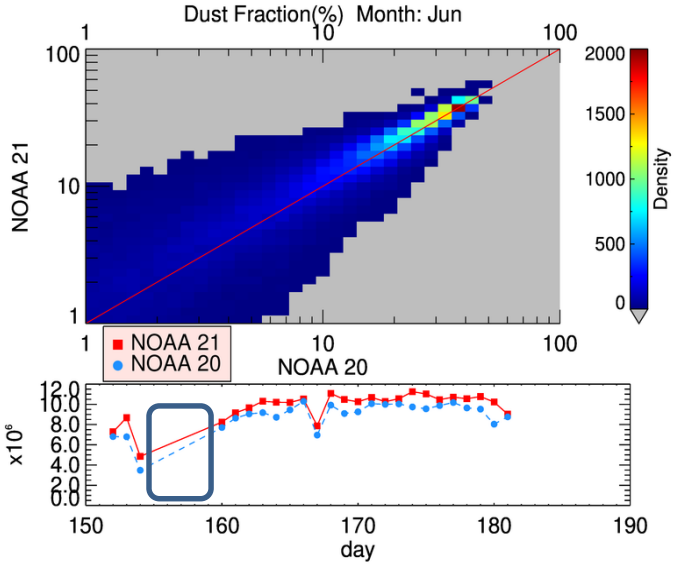


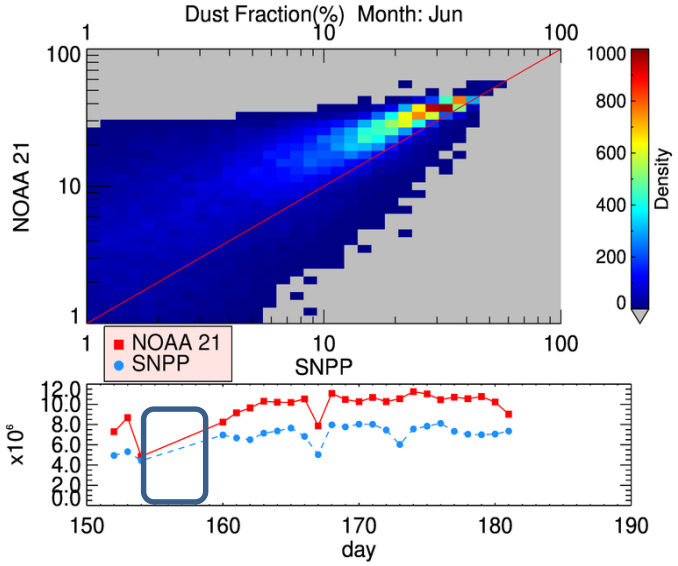
Smoke Fraction =

$$\frac{\text{smoke}}{\text{smoke} + \text{dust} + \text{none}}$$

Data flow to I&T directories stopped June 4-7 due to IDPS software updates

Dust





Dust Fraction =

$$\frac{\text{dust}}{\text{smoke} + \text{dust} + \text{none}}$$

Summary of Inter-Satellite Comparisons

- NOAA-21 VIIRS ADP spatial coverage/intensity is consistent with:
  - NOAA-20 & S-NPP VIIRS ADP (LEO/LEO)
  - TROPOMI CO (LEO/LEO)
  - GOES-18 ABI ADP (LEO/GEO)
- NOAA-21 VIIRS ADP detects smoke and dust plumes:
  - Over land and water
  - From mesoscale to planetary scale
  - At low, middle, and high latitudes
- NOAA-21 smoke and dust fractions are consistently higher than those for S-NPP
  - Likely due to calibration differences observed between S-NPP and NOAA-20
    - Documented during NOAA-20 Maturity Review
    - Illustrated in more detail on Slide 45

ADP Algorithm Performance Evaluation Overview

- **Data sets**
  - S-NPP, NOAA-20 and NOAA-21 VIIRS ADP EDR data (750m resolution)
  - "Truth" data:
    - AERONET, in situ "truth"
      - Coverage: global station locations
      - Period: February 11 to July 21, 2023 (~5.5 months)
    - CALIPSO/CALIOP vertical feature mask (VFM), satellite "truth"
      - Coverage: global satellite tracks
      - Period: February 11 to June 21, 2023 (~4.5 months)
- **Validation strategies / methods**
  - Probability of Correct Detection (POCD) calculated using 2x2 contingency table
  - VIIRS ADP must meet **specific POCD requirements** for detection of smoke & dust

2x2 Contingency Table

VIIRS ADP	Truth Data: Yes	Truth Data: No
Yes	A	B
No	C	D

A = true positive (correct detection)

B = false positive (false detection)

C = false negative (missed detection)

D = true negative (null detection)

VIIRS ADP Requirements		
Detection Type		**POCD (%)**
Smoke	Over Land	**80**
	Over Water	**70**
Dust	Over Land	**80**
	Over Water	

Probability of Correct Detection (POCD) $= \frac{A}{A+C}$

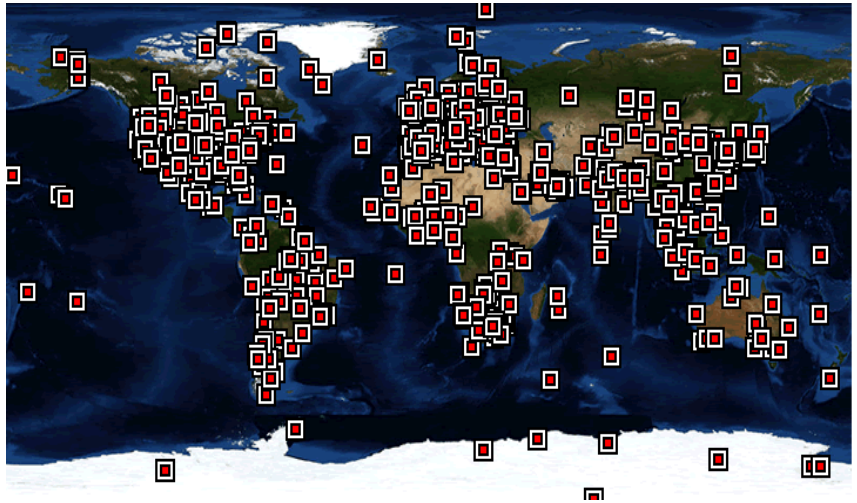
Probability of False Detection (POFD) $= \frac{B}{A+B}$

Accuracy $= \frac{A+D}{A+B+C+D}$

AERONET Matchups Criteria

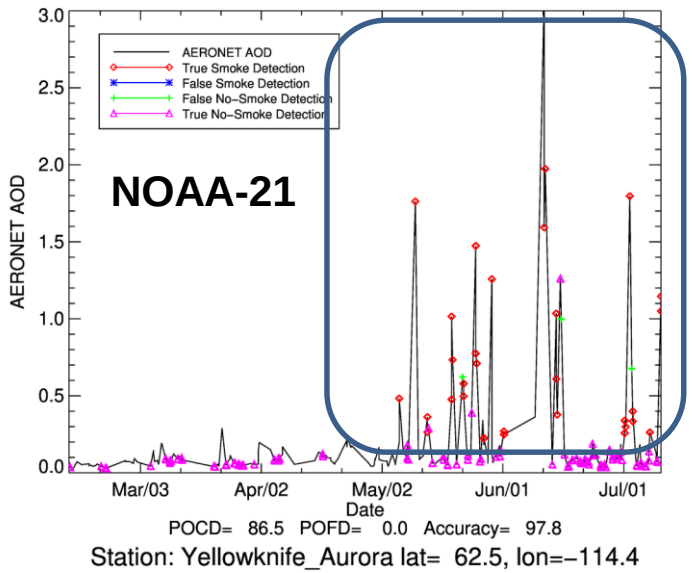
- AERONET/VIIRS observations ±30 min
- > 750 VIIRS pixels within 27.5km radius of AERONET station
- Level 1.5 AERONET data
- Aerosol type (smoke, dust) based on:
  - AERONET AOD interpolated to 550nm
  - AERONET Ångström exponent at 440nm/870nm

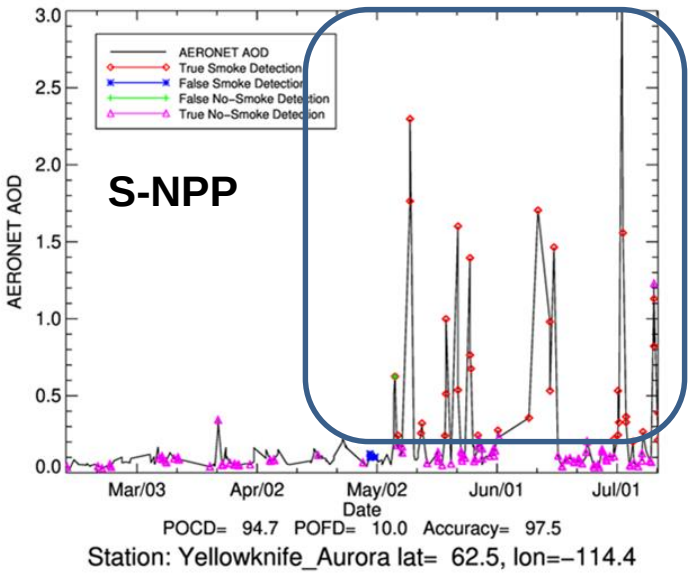
AERONET Detections		AOD @550nm	Ångström Exponent (440nm/870nm)
	No		< 0.5
Dust	**Yes**	> 0.2	< 0.5



VIIRS ADP	AERONET		
		Yes	**No**
	Yes	A	B
	No	C	D

Example of VIIRS ADP/AERONET Matchups for Smoke

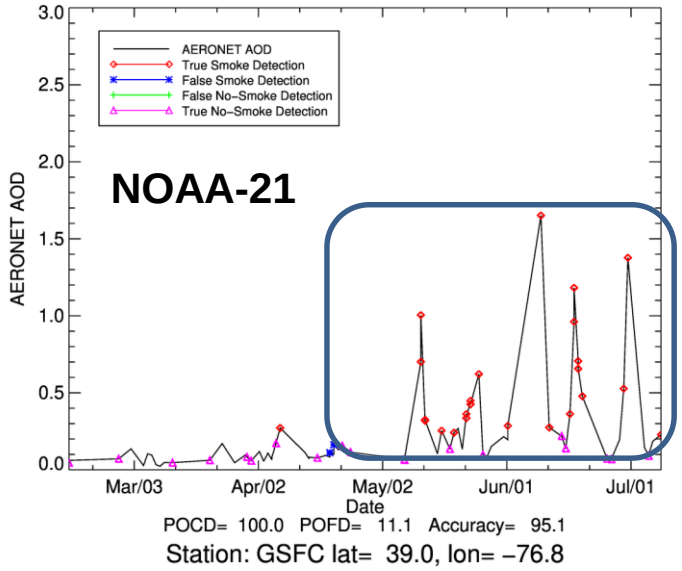


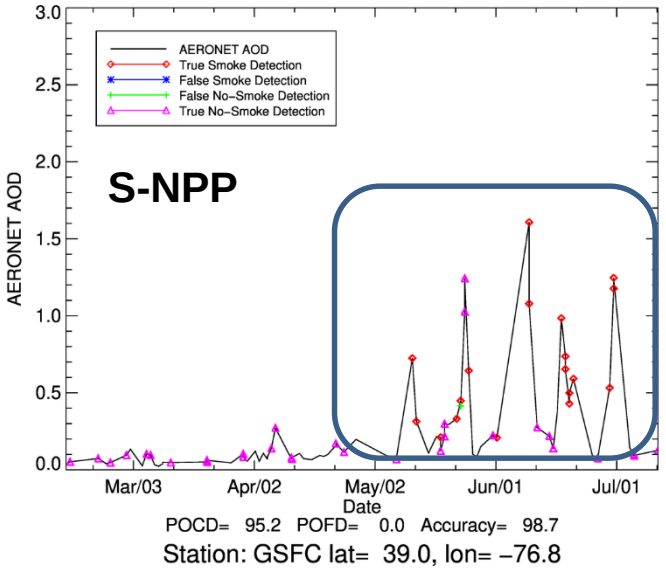


Yellowknife, Canada

- Station near wildfires
- Near-source smoke

Red Diamond = Correct Smoke Detection (“A”)

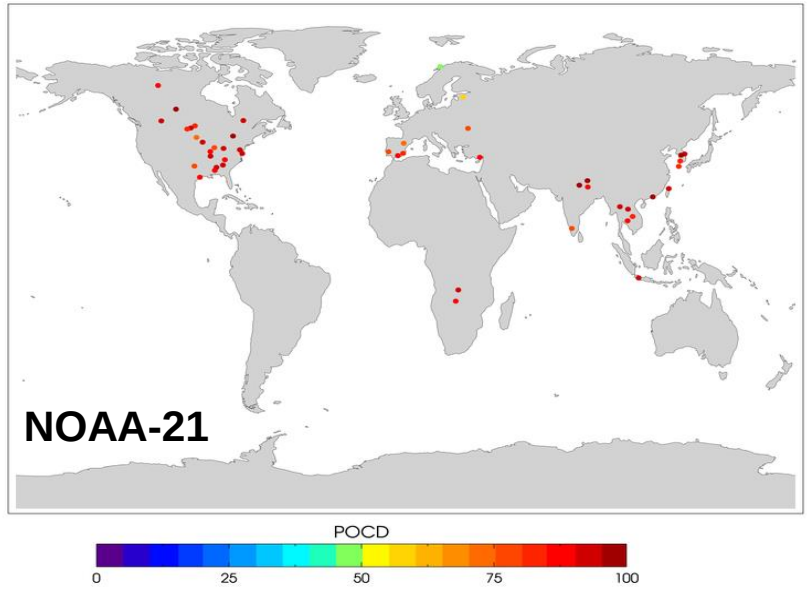


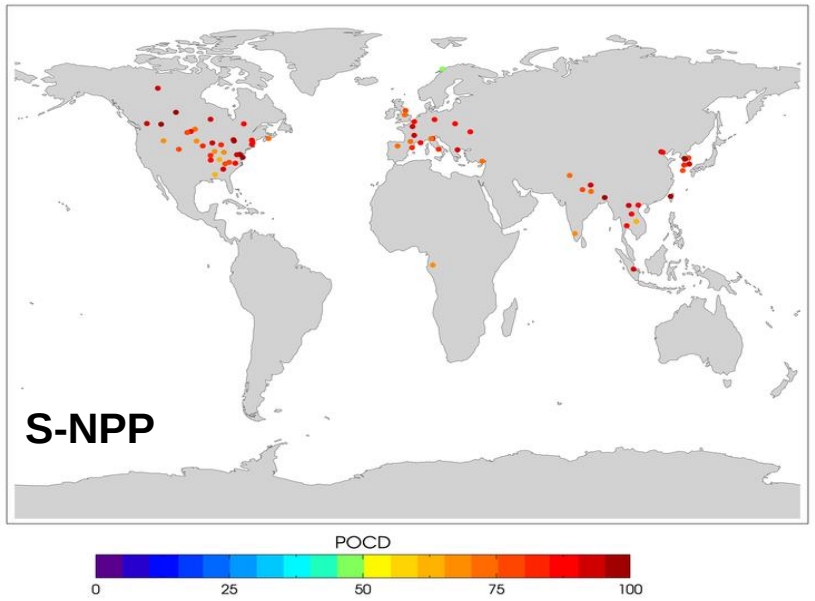


GSFC, Maryland

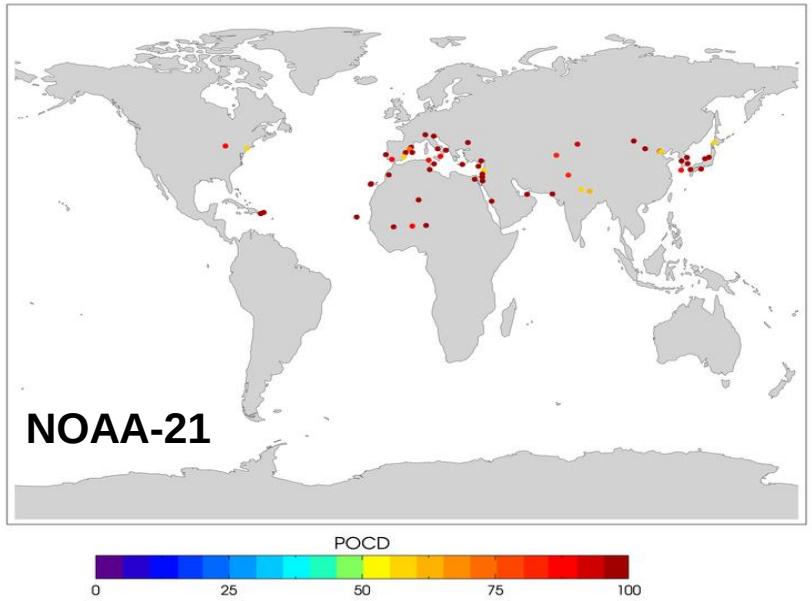
- Station far away from wildfires
- Transported smoke

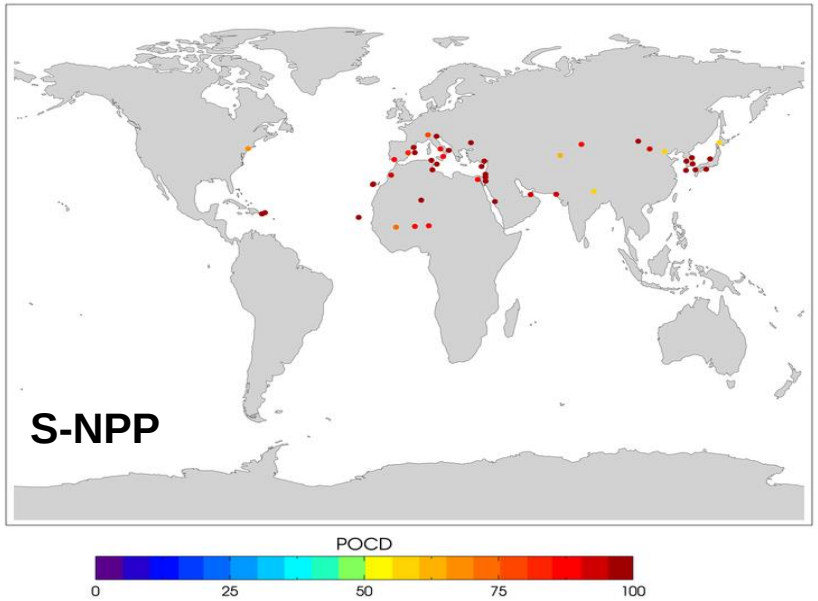
Global VIIRS ADP POCD by AERONET Station





Smoke

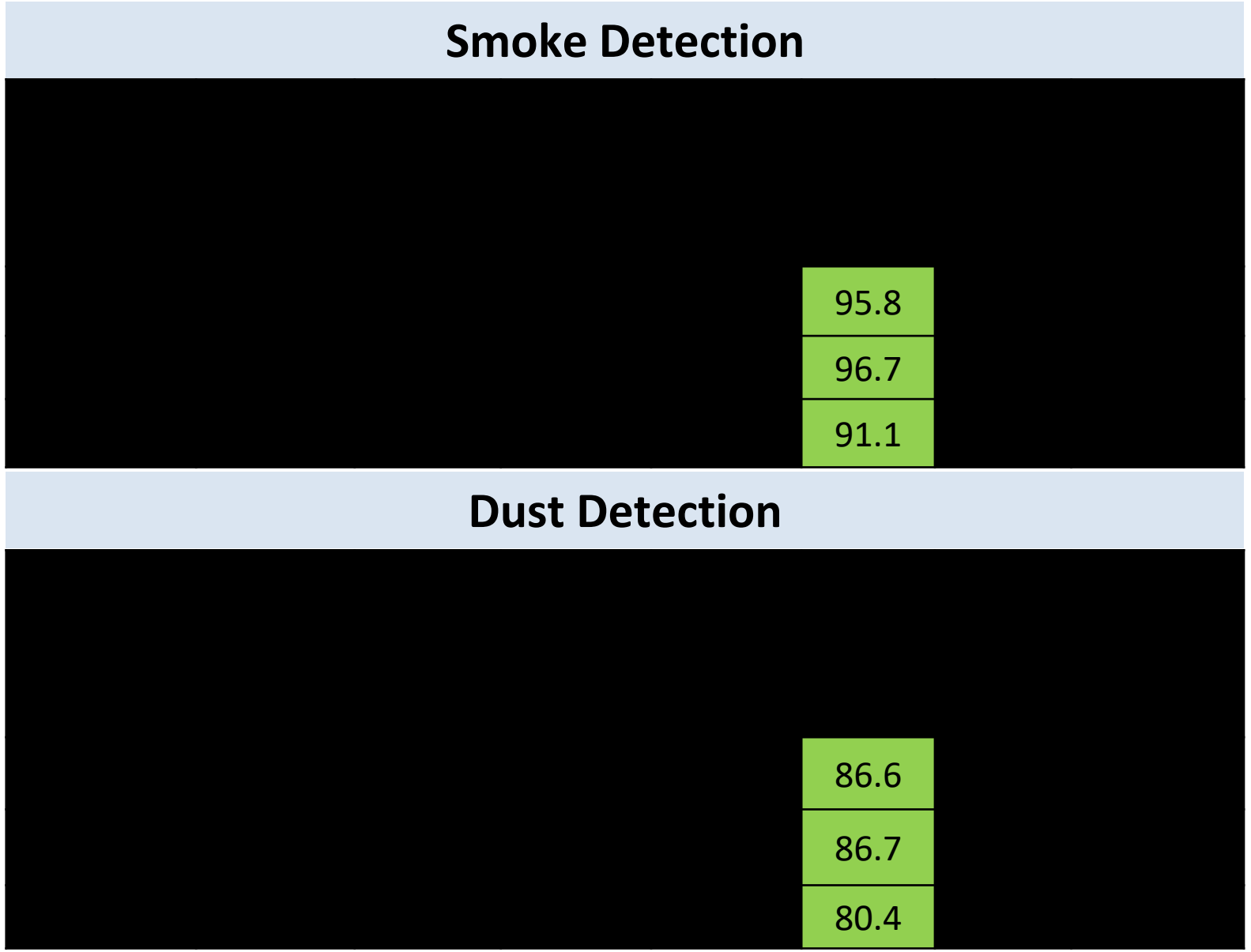




Dust

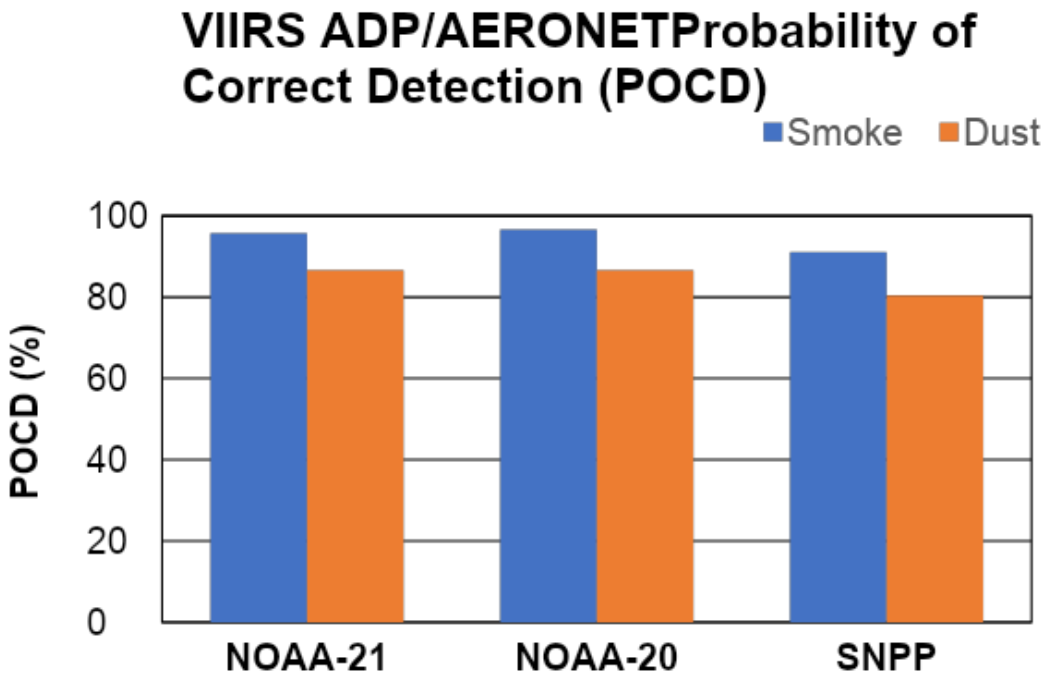
VIIRS ADP/AERONET Validation Statistics

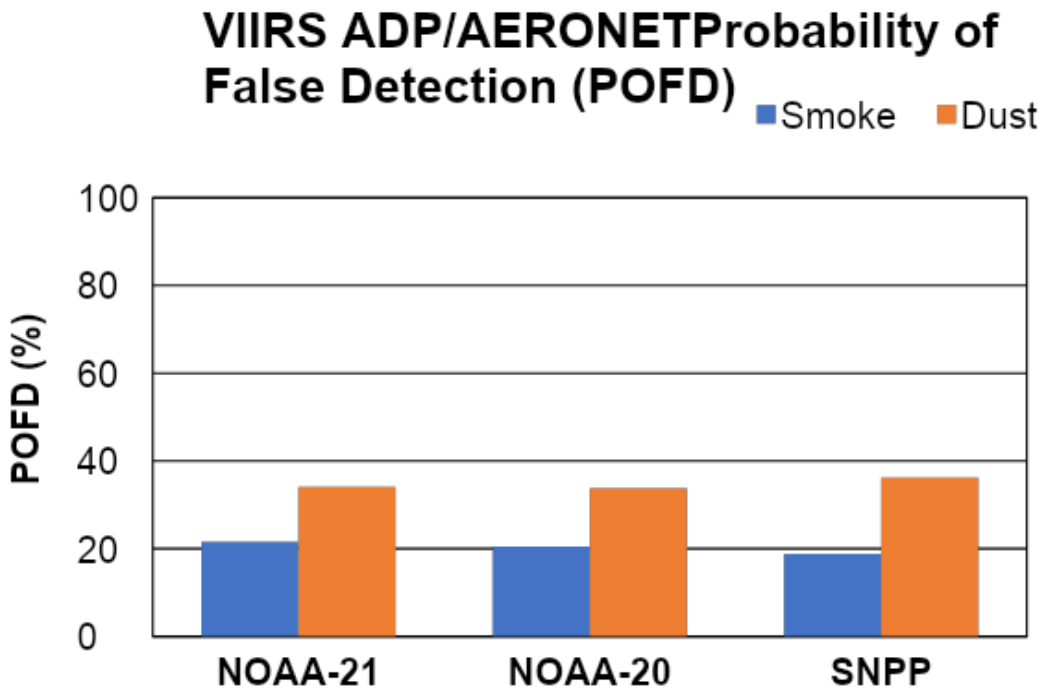
- Statistics were not calculated separately for matchups over land and water because most AERONET stations are over land
- Many smoke matchups (~3,300) due to intense Canadian wildfires and seasonal burning in Asia
- Fewer but sufficient number of dust matchups (~900)
- **VIIRS ADP meets POCD requirements:**
  - Smoke: 80% over land, 70% over water
  - Dust: 80% over land & water
- NOAA-21 POCD values very close to those for NOAA-20



Summary of VIIRS ADP Validation with AERONET

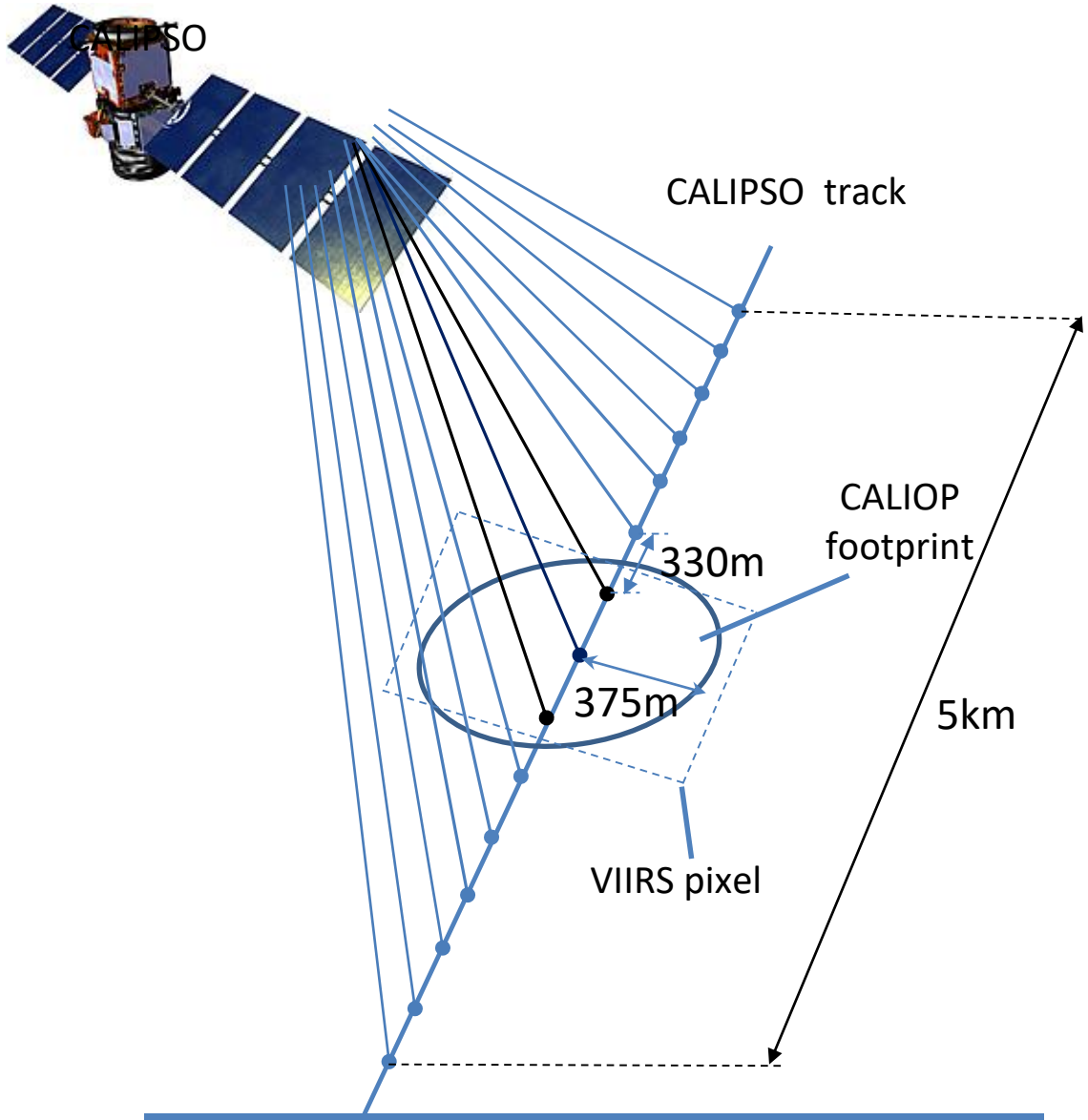
- NOAA-21 POCD values very close to those for NOAA-20, slightly higher than S-NPP
  - Smoke more likely to be correctly identified than dust
- POFD similar for all three satellites
  - False alarms for dust are more likely than for smoke





CALIPSO/CALIOP Vertical Feature Mask (VFM) Matchups Criteria

- CALIPSO/VIIRS observations ±30 min
- VIIRS pixels within ±375m of CALIPSO track
- 3 CALIPSO profiles in middle of VIIRS pixel used to determine aerosol type
  - All must be cloud-free
- VFM aerosol types: smoke, dust, cloud, other
- VIIRS ADP types: smoke, dust, cloud, not retrieved
  - Only high quality retrievals used
- **CALIPSO is at the end of its lifetime**
  - **Decommission scheduled for September 2023**
  - **In Safe Hold Mode since July 1, 2023**
  - **Satellite orbit has drifted substantially**
    - **Equatorial crossing originally 13:30 UTC, now 15:15 UTC**
  - **Fewer matchups with NOAA-21 VIIRS ADP**
  - **Most matchups occurred over high latitudes**

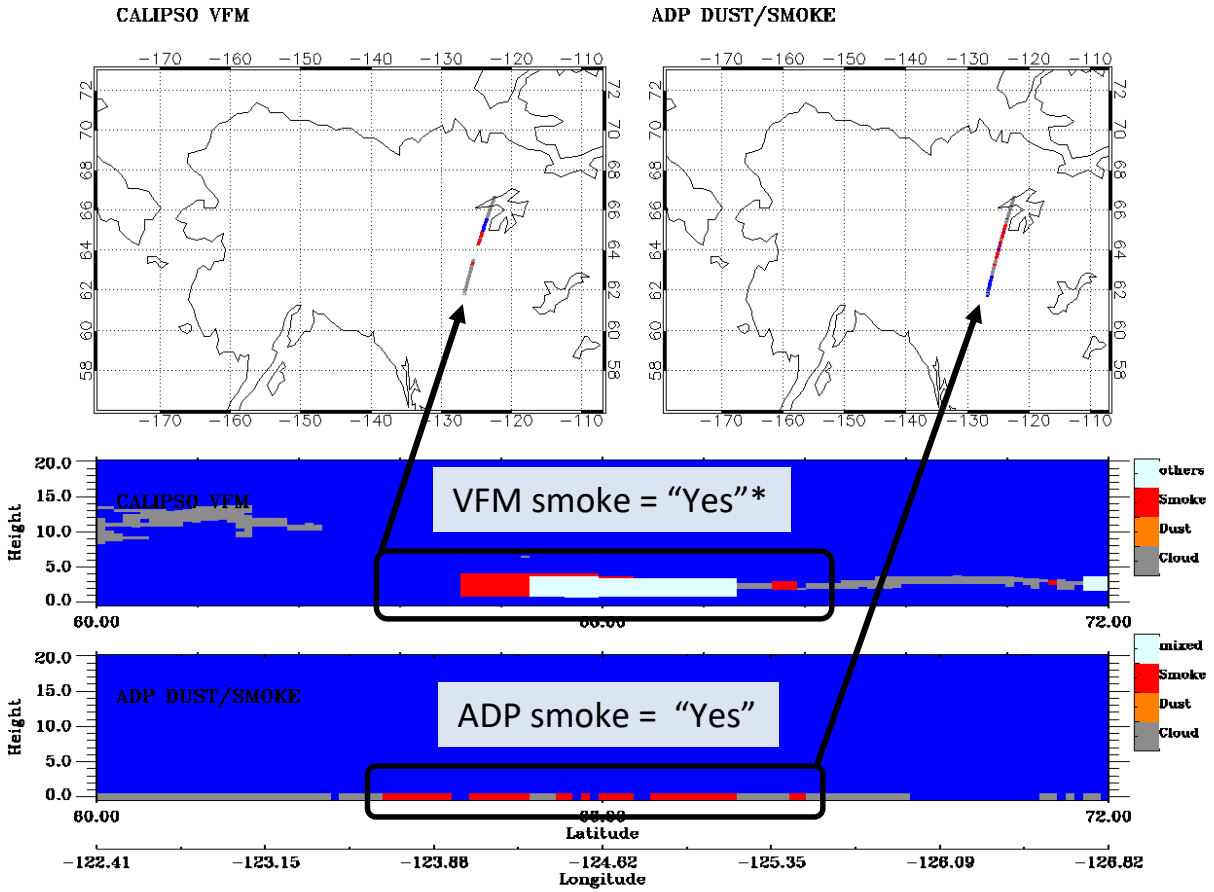


Examples of VIIRS ADP/VFM Matchups

VIIRS ADP	VFM: Yes	VFM: No
Yes	A	B
No	C	D

Smoke Detection: May 18, 2023 12:08-12:09 UTC

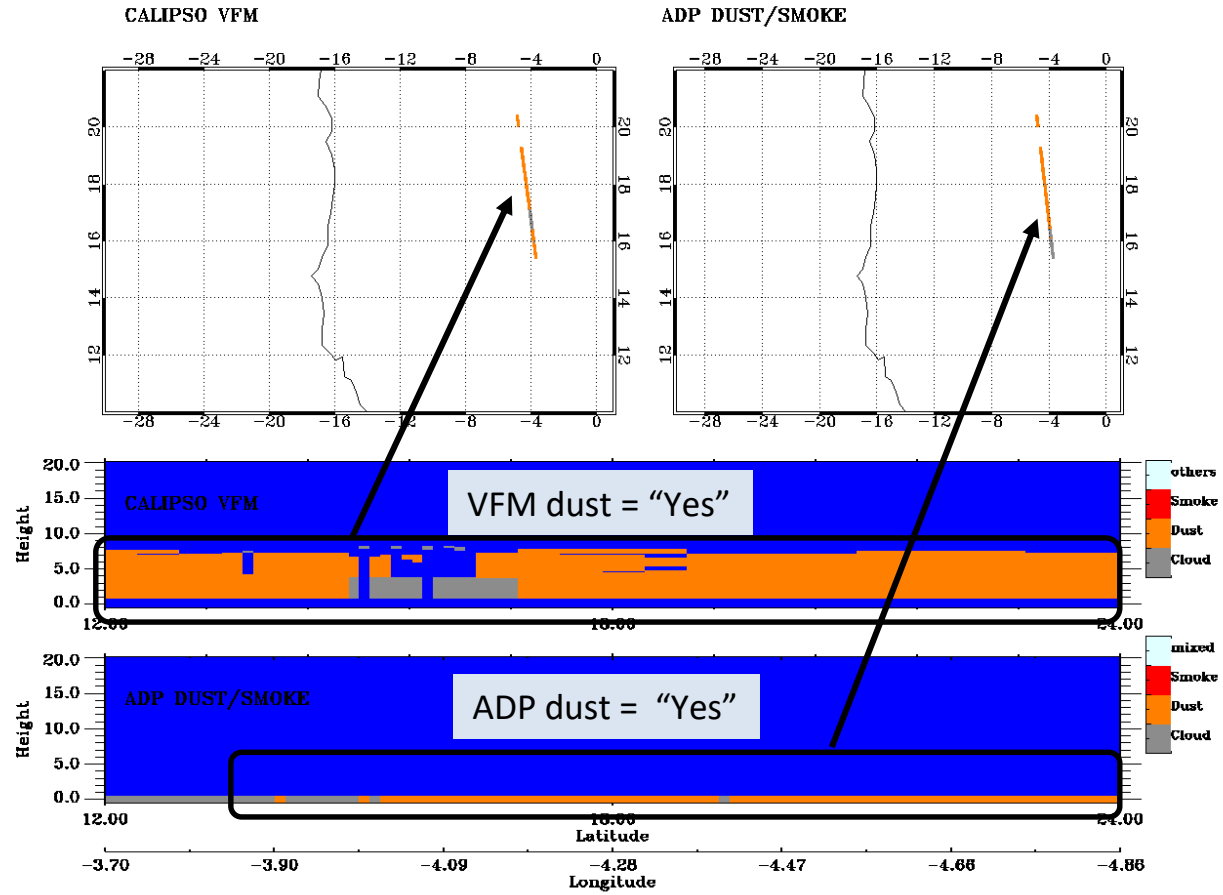
POCD = 92% POFD = 19% Accuracy = 96%



*Smoke plume partially identified as polluted smoke (cyan) by VFM

Dust Detection: March 27, 2023 14:11-15:44 UTC

POCD = 83% POFD = 18% Accuracy = 98%

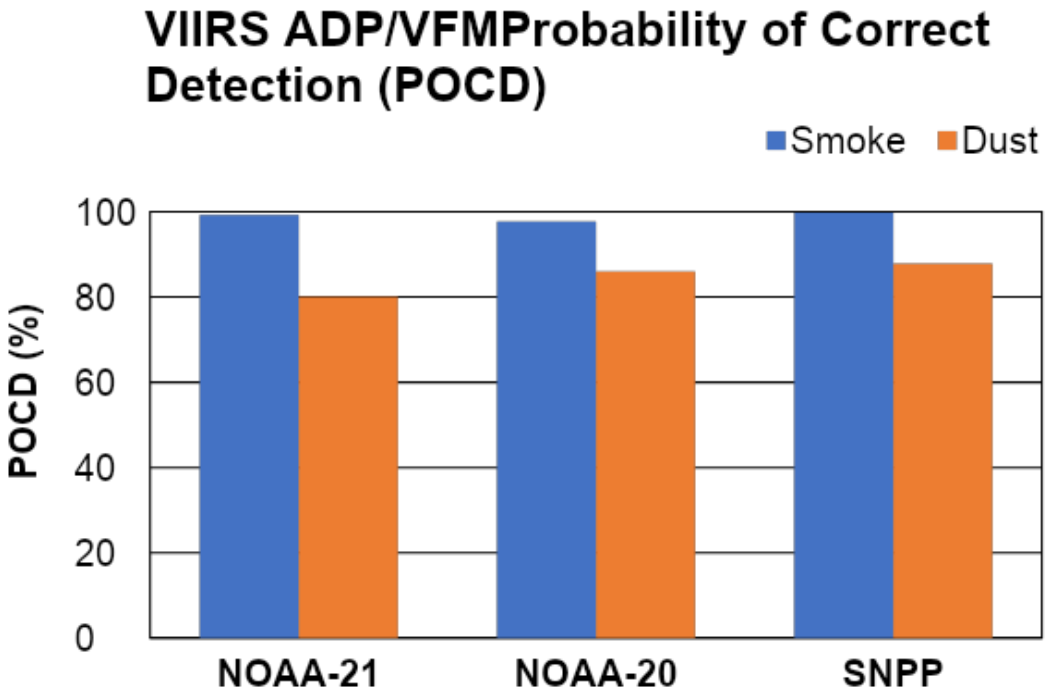


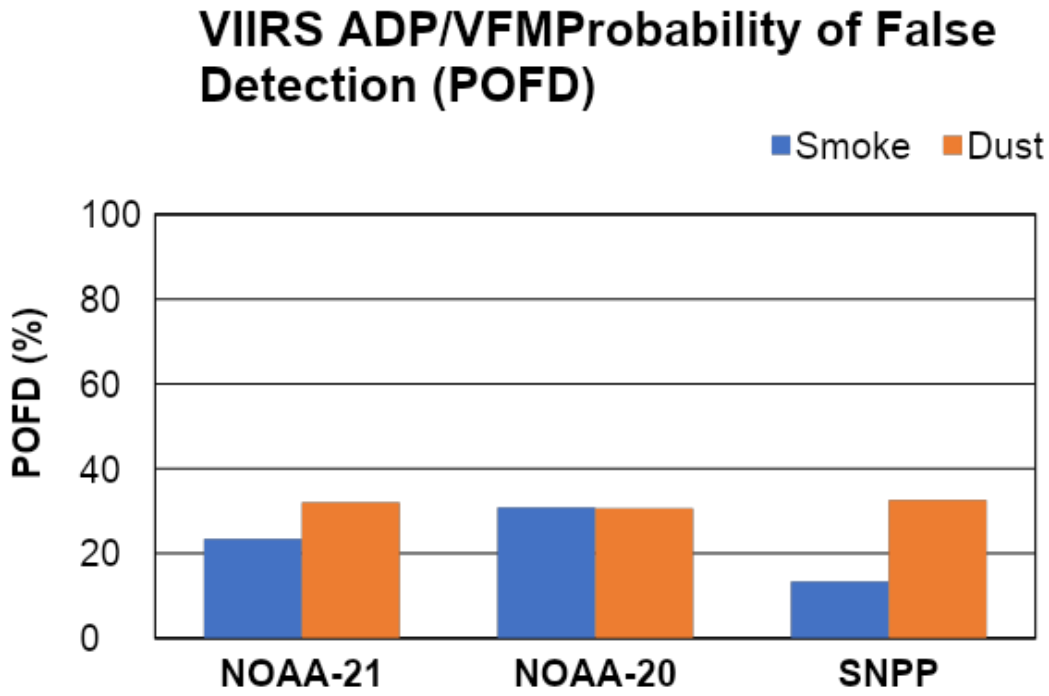
VIIRS ADP/VFM Validation Statistics

- Fewer matchups compared to AERONET validation, especially for dust
  - Caused by drifting CALIPSO orbit
  - Validation statistics were not calculated separately for matchups over land and water
- **VIIRS ADP meets POCD requirements:**
  - Smoke: 80% over land, 70% over water
  - Dust: 80% over land & water

Summary of VIIRS ADP Validation with CALIPSO VFM

- NOAA-21 POCD values similar to those for NOAA-20 and S-NPP
  - Smoke more likely to be correctly identified than dust (similar to AERONET results)
- Dust POFD very similar for all three satellites
  - False alarms for dust are more likely than for smoke (similar to AERONET results)
- NOAA-21 smoke POFD < NOAA-20 but > S-NPP
  - Difficult to draw substantive conclusions due to relatively low number of matchups

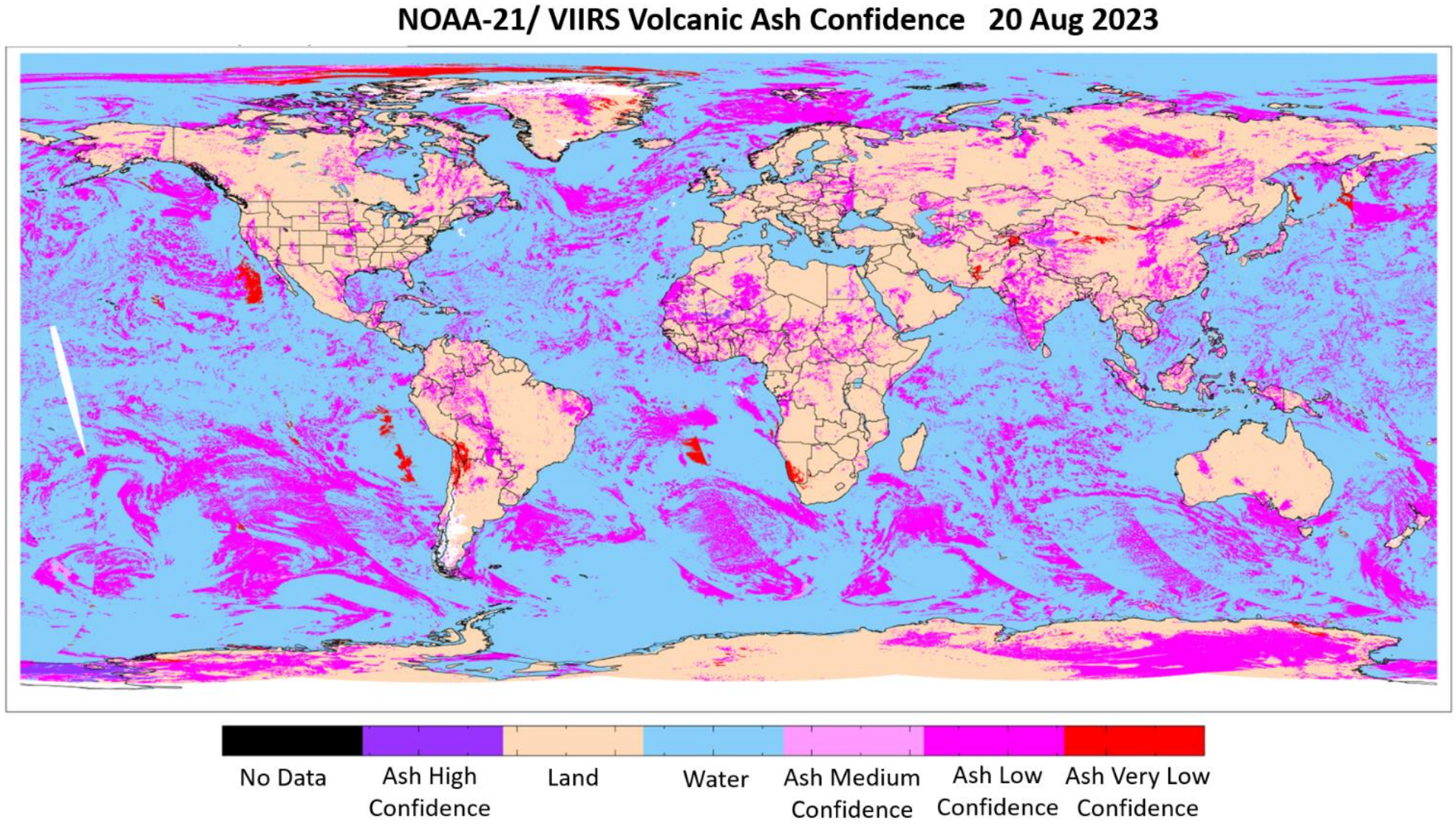




Required ADP Algorithm Inputs

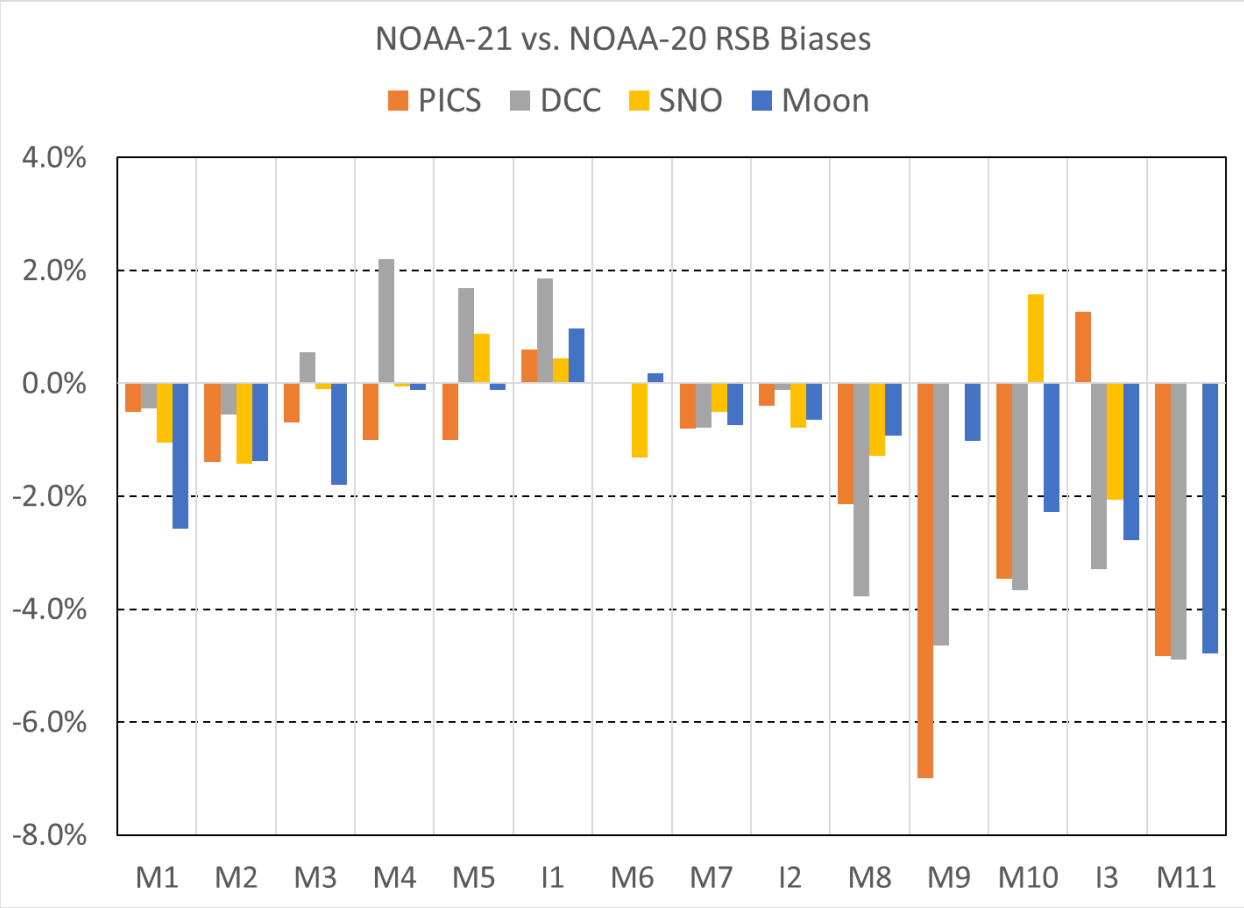
- Primary Sensor Data
  - NOAA-21 VIIRS M-band SDR (M1-M13, M15-M16) and GEO
- Ancillary Data
  - Land/water mask and snow/ice mask
- Upstream Algorithms
  - Cloud Mask and Snow Cover are inputs to the ADP algorithm
    - NOAA-21 products checked, no issues
  - Volcanic Ash is passed through and reported as the “Ash” variable in ADP output; not used in the ADP algorithm
    - No issues reading in Volcanic Ash
    - Missing Volcanic Ash granules have no impact on ADP (no crashes)
      - Reported as “Ash” variable missing in ADP output
  - Example plots on Slide 43
- LUTs / PCTs
  - None

Examples of Upstream Algorithm Products



- No issues with the NOAA-21 upstream products!
- VIIRS ADP algorithm uses only the **thin cirrus mask** from the Cloud Mask product
- The ADP algorithm passes through the **Volcanic Ash** product and reports it in the ADP EDR files as the “Ash” variable

Evaluation of Required ADP Algorithm Inputs: SDRs



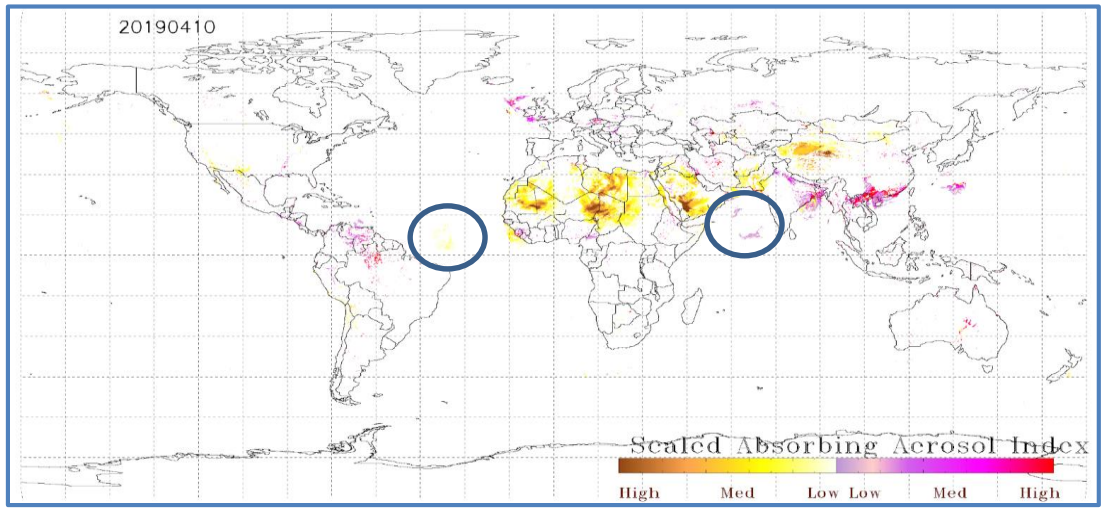
- Good agreement for VNIR bands
- Larger differences and variability for SWIR bands

From Provisional Maturity Science Review For NOAA-21 VIIRS SDR 3/30/2023

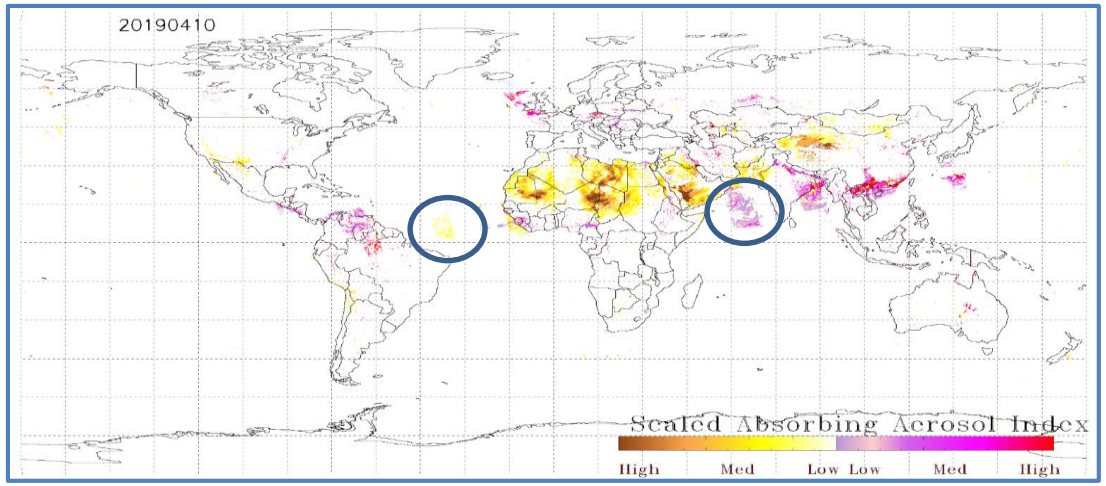
- NOAA-21 VIIRS SDR Provisional Maturity Review indicated variability in NOAA-21 SWIR bands relative to NOAA-20 (figure)
- **No impact from the SWIR bands variability was observed on NOAA-21 ADP!**
- The fix implemented by the SDR team also did not impact ADP

Impact of S-NPP/NOAA-20 Calibration Differences on NOAA-21

S-NPP



Bias Corrected S-NPP



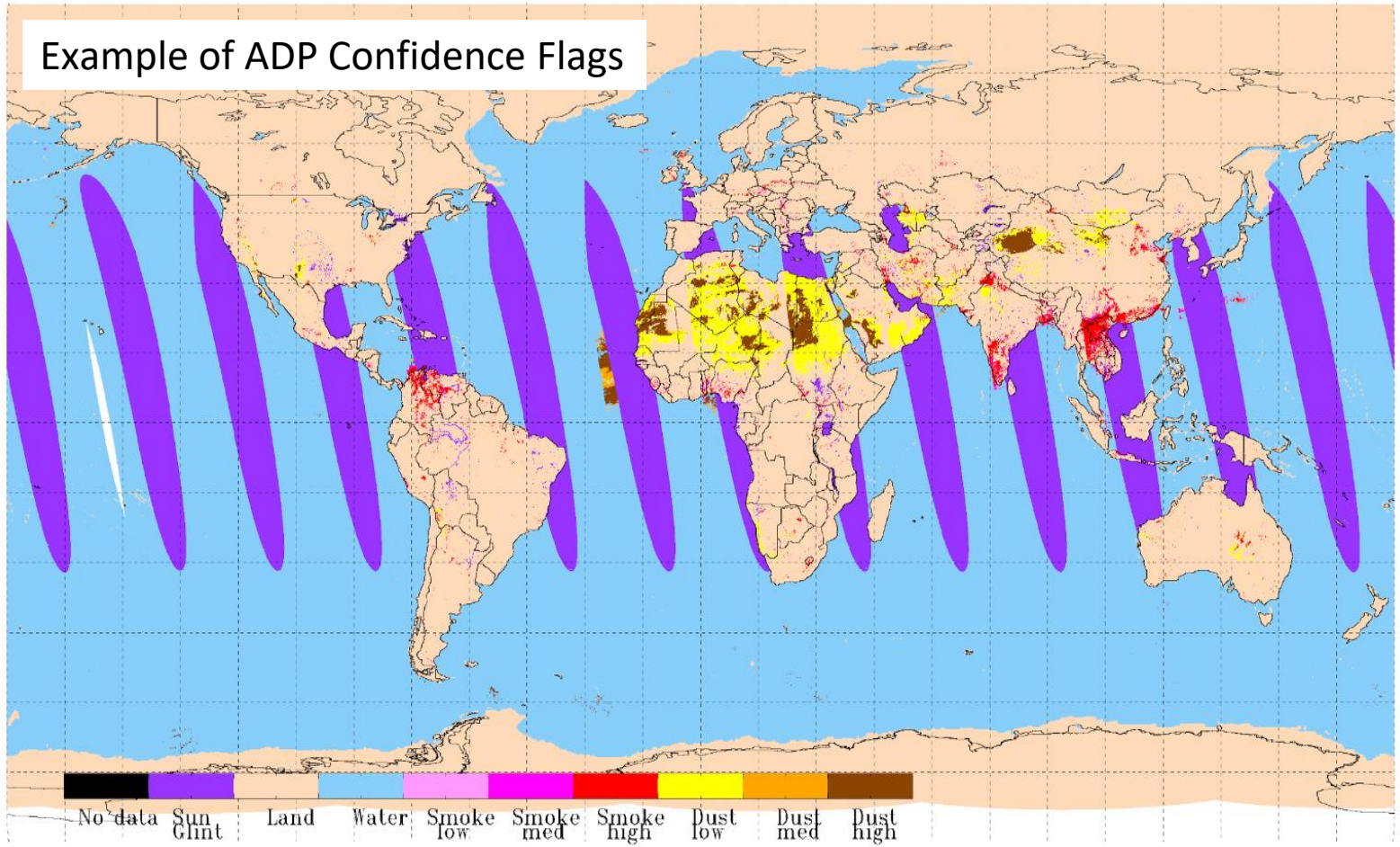
- NOAA-20 Maturity Review found that NOAA-20 detected more smoke than S-NPP due to SDR M-band calibration differences
- Bias corrected S-NPP ADP reduces differences in smoke detection compared to NOAA-20:
  - 5% increase in smoke pixels, mainly over ocean
  - <1% increase in dust pixels, mainly over ocean
  - Changes due to cloud mask were not considered
- **NOAA-21 & NOAA-20 ADP have similar performance**
- **Variations between NOAA-21/S-NPP ADP are likely caused by the same calibration differences observed for NOAA-20**

NOAA-20 = SNPP * (1+bias)

VIIRS Band	% Change in Reflectance	VIIRS Band	% Change in Reflectance
M1	-3	M7	-3.8
M3	-2.6	M9	-1.2
M5	-5	M11	-2.2

Definitions of ADP Confidence Flags

- No screening for large solar or satellite view zenith angles
  - Values are provided in output file for end users
- Internal screening for clouds and snow/ice

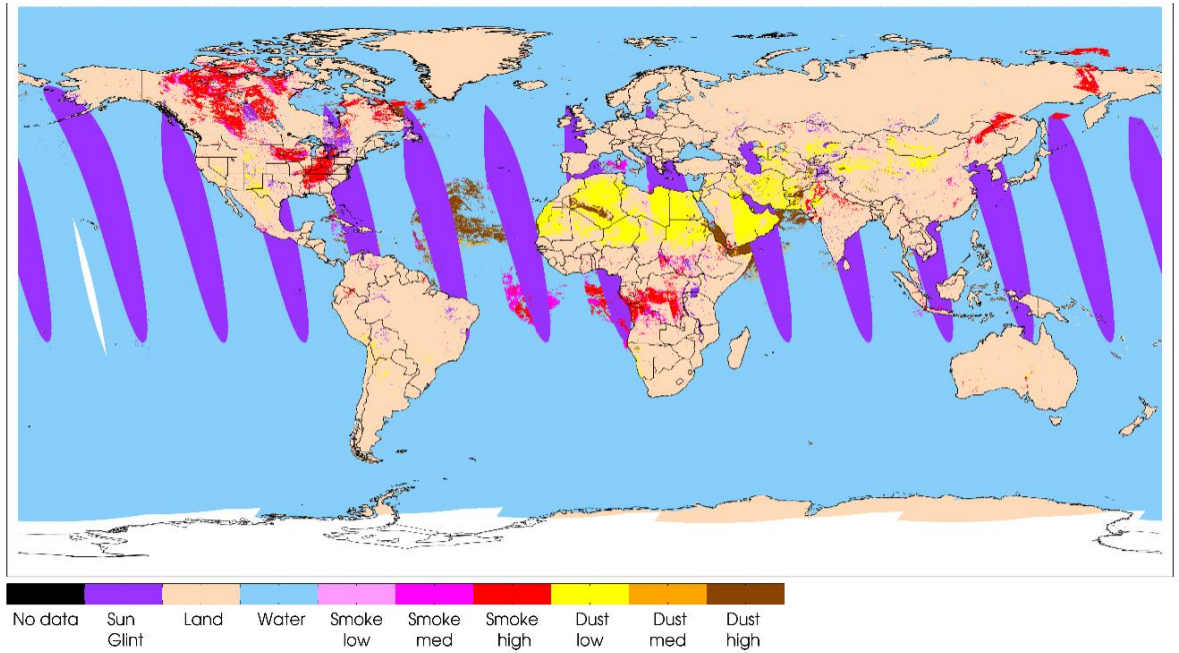


The Confidence Value (CV) is determined by how close the spectral difference is to the threshold criteria

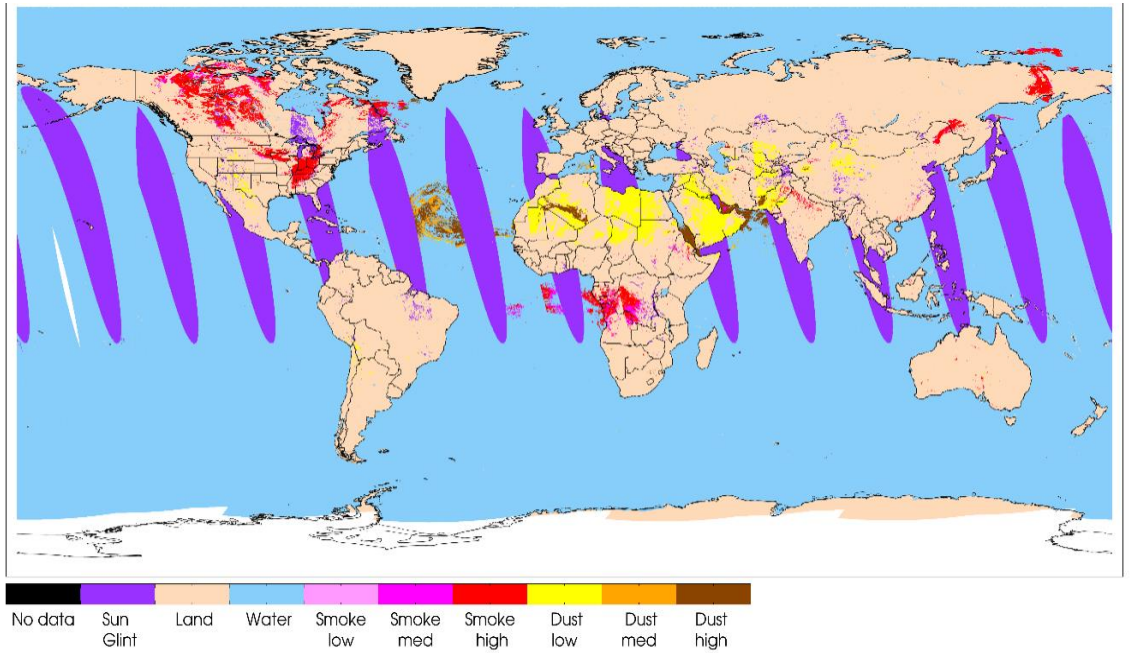
Confidence Flag	Threshold Criteria
High	
Low	CV < 0.25 • Pixel adjacent to cloud • Turbid water • Bright pixel • Pixel adjacent to snow/ice • Cloud shadow • Sun glint

Example of ADP Confidence Flags for July 16, 2023

NOAA-21



NOAA-20



- Confidence flags for all three satellites are very similar
  - Differences are expected due to variations in satellite observation times
  - Dust confidence flags over ocean are slightly different for S-NPP compared to NOAA-21 & NOAA-20
    - Likely due to calibration differences (Slide 45)
  - Note that ADP is a threshold-based algorithm

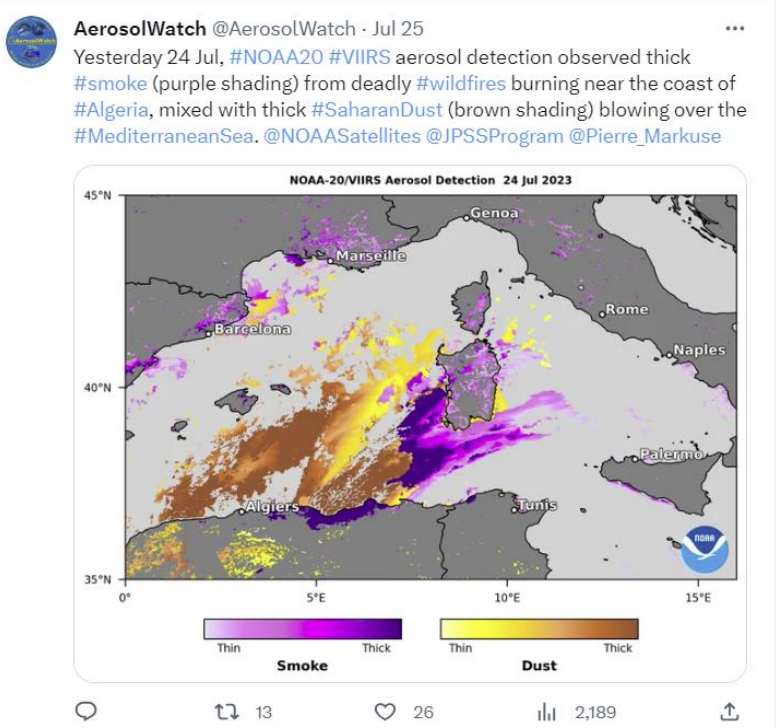
Error Budget

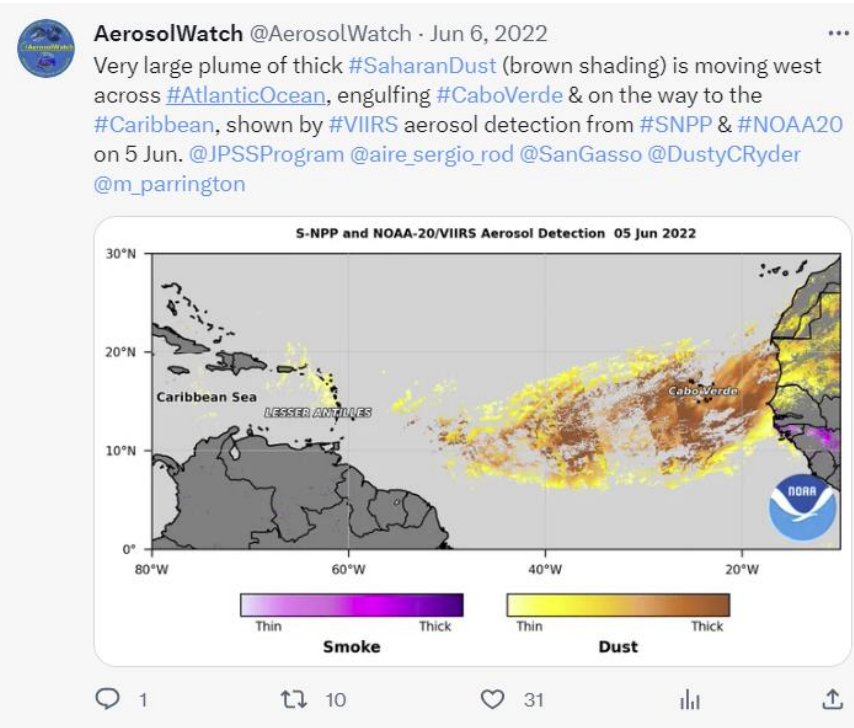
Attribute Analyzed	Required POCD (%)	On-orbit Performance POCD (%)				Meet Requirement?	Additional Comments
		Validation Dataset	NOAA-21	NOAA-20	S-NPP		
Dust over land	80	AERONET	86.6	86.7	80.4	Yes	Statistics not calculated separately over land & water
		VFM	80.0	86.0	87.8		
Dust over water	80	AERONET	86.6	86.7	80.4	Yes	Statistics not calculated separately over land & water
		VFM	80.0	86.0	87.8		
Smoke over land	80	AERONET	95.8	96.7	91.1	Yes	Statistics not calculated separately over land & water
		VFM	99.1	97.7	99.8		
Smoke over water	70	AERONET	95.8	96.7	91.1	Yes	Statistics not calculated separately over land & water
		VFM	99.1	97.7	99.8		

User Feedback

- NOAA-21 VIIRS ADP data are pre-Beta maturity; no user feedback yet

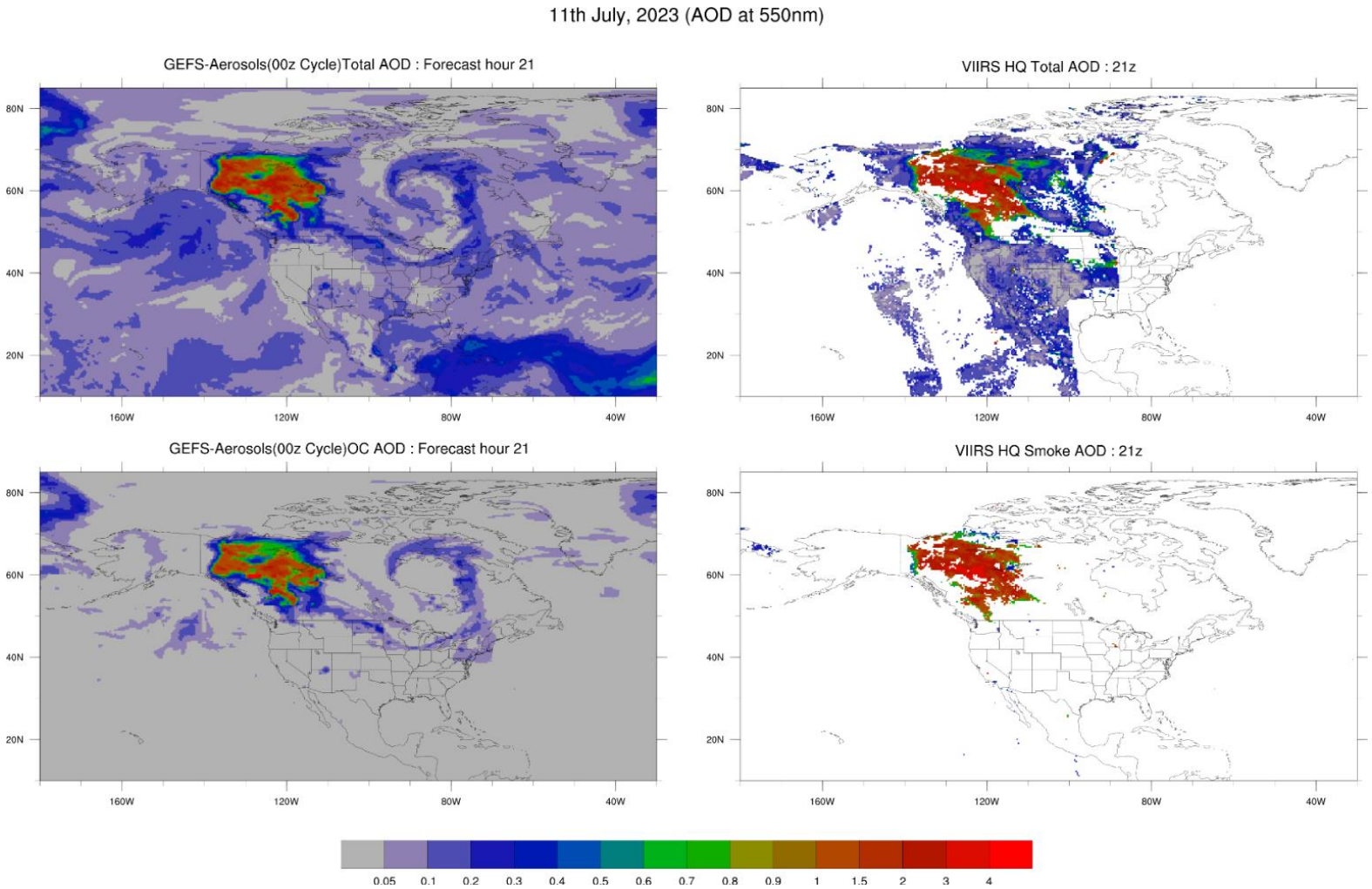
Name	Organization	Application	Feedback on S-NPP & NOAA-20 VIIRS ADP
Joel Dreesen & James Boyle	Maryland Department of the Environment (MDE)	Operational air quality forecasting & event analysis	• In times of operational ambiguity, the dust and smoke mask is another tool to properly identify aerosols. • It's very useful for post-analysis. Given the number of smoky days this summer, I check Aerosolwatch and use the VIIRS ADP imagery for our post-exceedance write ups and analysis.
Partha Bhattacharjee	NOAA NWS	Global aerosol model (GEFS-Aerosols) verification	• The masks are particularly useful to identify events like dust plumes over the Atlantic and smoke events over North America when we are evaluating model predicted AOD.





User Feedback

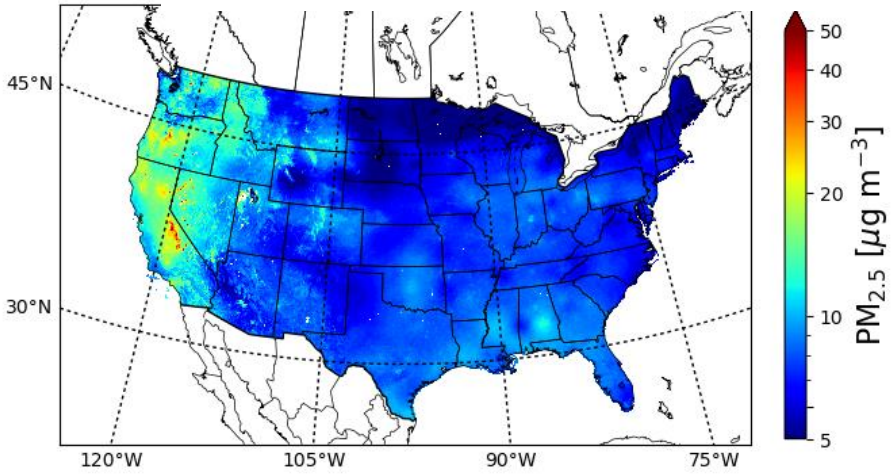
- NOAA-21 VIIRS ADP data are pre-Beta maturity; no user feedback yet



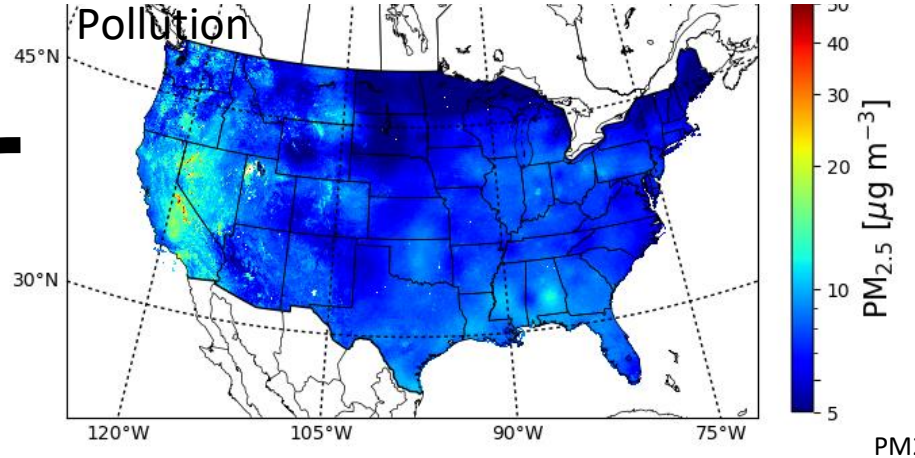
"The masks are particularly useful to identify events like dust plumes over the Atlantic and smoke events over North America when we are evaluating model predicted AOD."
-- Partha Bhattacharjee

Science Studies using ADP

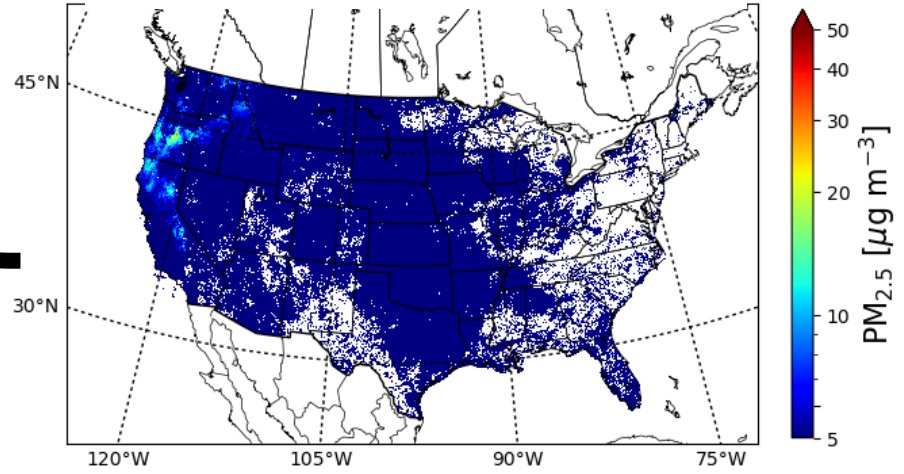
Total PM2.5: All Sources



PM2.5: Anthropogenic + Dust Pollution



PM2.5: Smoke Pollution



PM2.5 represents particulate pollution in units of mass ($\mu g/m^3$) for particles smaller than 2.5 um in median diameter

- Developed a methodology to scale VIIRS aerosol optical depth to daily average surface PM2.5 using a geographically weighted regression algorithm and then separate total PM2.5 into smoke and non-smoke (anthropogenic+dust) pollution.
- The smoke/non-smoke partition algorithm relies on an independent qualitative indication of smoke from VIIRS aerosol detection product.

S. Kondragunta (NOAA), M. Cheeseman, H. Zhang, P. Ciren (IMSG)

Science Studies using ADP

ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

Markers of economic activity in satellite aerosol optical depth data

Shobha Kondragunta[4,1], Zigang Wei[2], Hai Zhang[2], Hongqing Liu[2], Istvan Laszlo[1], Bin Zhang[3], Changyong Cao[1] and Pubu Ciren[2]

Published 20 July 2023 • © 2023 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 18, Number 8

Citation Shobha Kondragunta *et al* 2023 *Environ. Res. Lett.* **18** 084013

DOI 10.1088/1748-9326/ace466

Article PDF Article ePub

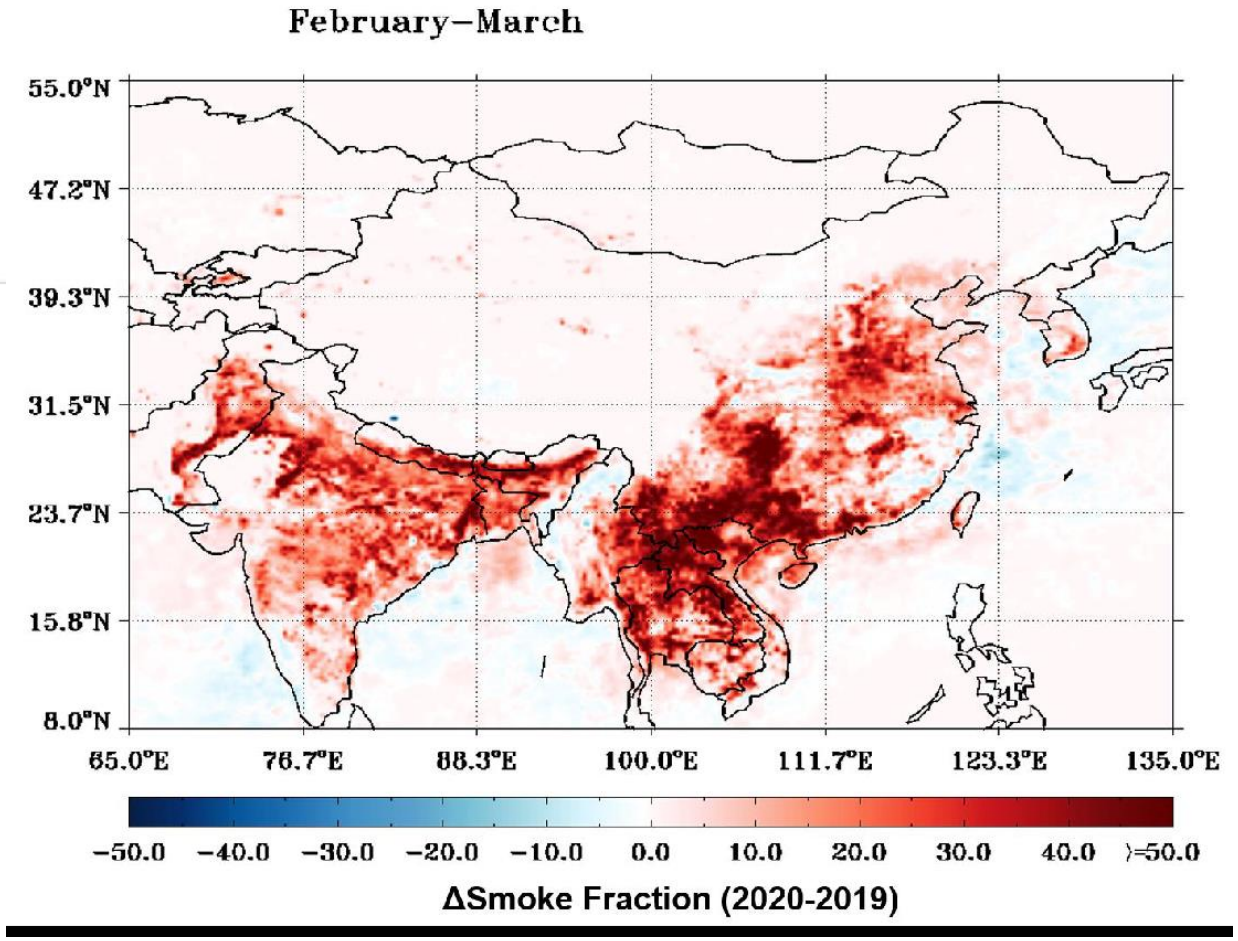


Figure S2. Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite (VIIRS) smoke fraction difference between 2020 and 2019, indicating significant smoke was present in the atmosphere over Asia in 2020.

Downstream Product Feedback

- NOAA-21 VIIRS ADP does not have downstream products

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
SDR calibration	Differences in calibration of NOAA-20 and S-NPP VIIRS M-band SDRs	Product quality	• Reprocessed entire record (through 2021) of S-NPP & NOAA-20 ADP EDR data on AWS cloud using reprocessed SDR data
CALIPSO satellite decommissioning	CALIPSO is at end of its scientific lifetime; decommission scheduled for September 2023	No satellite "truth" data for validation	• Rely on AERONET validation • Explore use of ground-based LIDAR networks • Explore data from atmospheric lidar (ATLID) on the ESA/JAXA EarthCARE mission, launch expected in 2024

NOAA-21 VIIRS ADP Documentation

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes for NOAA-20 & S-NPP ADP
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	At team meetings ~quarterly

Check List - Beta Maturity

Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	**Yes with a note that we do not really have significant unidentified or identified errors**
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	**Yes with a note that product is quite good for quantitative applications**
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	**Yes. We have false positives for dust in high latitudes**

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
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 select locations, periods, and associated ground truth or field campaign efforts.	**Yes**
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	**Yes**
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	**Yes**
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	**Yes**

Conclusion

- Cal/Val results summary
  - ~5 months of global NOAA-21 VIIRS ADP data were evaluated
    - Late winter, spring, and early summer
  - Inter-satellite comparisons to NOAA-20 & S-NPP VIIRS ADP, TROPOMI CO, and GOES-18 ABI ADP
  - Algorithm performance evaluated using ground-based AERONET measurements and satellite CALIPSO VFM
  - **Evaluation results indicate NOAA-21 VIIRS EPS ADP meets requirements**
    - NOAA-21 performance is in general:
      - Very similar to NOAA-20
      - Slightly different than S-NPP
      - Observed variations between NOAA-21/S-NPP VIIRS ADP are likely caused by the same SDR M-band calibration differences observed for NOAA-20
        - Documented during NOAA-20 Validated Maturity Review
- **Performance exceeds algorithm Beta maturity**
- **Team recommends algorithm Provisional maturity**

Path Forward: Future Cal/Val Activities

- Upcoming NOAA-21 VIIRS ADP Validation Milestones:
  - Provisional Maturity Review: December 2023
  - Declared Ready for Operations: February 2024
  - Validated Maturity Review: June 2024
- Continue routine validation and “deep-dive” analyses of smoke and dust events using AERONET data
- Explore alternative validation datasets to mitigate the loss of CALIPSO data
  - Ground-based LIDAR networks
  - Upcoming ESA/JAXA EarthCARE satellite’s atmospheric lidar (ATLID); launch expected in 2024
- Make corrections and updates to ADP algorithm as needed

Path Forward: Planned Improvements to ADP Algorithm

1. Callback for thick brown-colored smoke plumes (mis-classified as thick dust)
   - Analysis is ongoing to develop a method to callback these smoke plumes satellite CO (e.g., TROPOMI CO)
2. Removal of false dust detections at high latitudes
   - Some thin clouds are mis-classified as dust at high latitudes
   - Analysis is ongoing to improve the Rayleigh scattering calculation at large viewing/illumination angles & improve cloud identification