NOAA-20 VIIRS AEROSOL OPTICAL DEPTH (AOD) and AEROSOL PARTICLE SIZE (APS) Beta Maturity

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VIIRS Aerosol Team

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Outline

- Aerosol Cal/Val Team Members
- Product Requirements
- Findings/Issues for Beta maturity
- Documentation
- Conclusions
- Path Forward

JPSS Aerosol Cal/Val Team

Name	Organization	Major Task
Pubu Ciren	IMSG	Aerosol detection product development and validation
Amy Huff	PSU	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

Requirements

Attribute	AOD		APS	
Applicable Conditions	Clear sky, daytime only, zenith angles ≤80^{o}			
Vertical Coverage	Total column			
Horizontal Cell Size	0.75 km at nadir, 1.6 km at edge of scan			
Vertical Cell Size	Total column			
Mapping Uncertainty, 3σ	4 km			
Measurement Range	-0.05 to +5		-1 to +3	
Measurement	*Accuracy*	*Precision*	*Accuracy*	*Precision*
Over Ocean	0.08 (AOD< 0.3) 0.15 (AOD≥ 0.3)	0.15 (AOD≤ 0.3) 0.35 (AOD≥ 0.3)	0.3	0.6
Over Land	0.06 (AOD< 0.1); 0.05 (0.1≤AOD≤0.8) 0.20 (AOD>0.8)	0.15 (AOD< 0.1) 0.25 (0.1≤AOD≤0.8) 0.45 (AOD>0.8)	n/a	n/a
Refresh Rate	90 minutes (~100 minutes)			

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.

Data and Evaluation Methodology

Data:

- NOAA-20 AOD:
  - Global data from ASSISTT
  - Global data from NDE I&T
  - Data for selected sites from offline Science Team run
- S-NPP AOD from NDE Ops and I&T
- AERONET Version 3 Level 1.5

Methodology:

- Visual comparison of NOAA-20 and S-NPP global AOD & APS fields and time series of global daily averages
- Quantitative comparison (over selected sites):
  - NOAA-20 vs. AERONET
  - S-NPP vs. AERONET

AOD and APS Production Status

Satellite	DAP	NDE		STAR	
		Ops	I&T	ASSISTT	Sc. Team
S-NPP	v1.1	07/07/2017-			
	v1.2		03/20/2018-		
NOAA-20	v1.1				
	v1.2		03/20/2018*-	02/26/2018-	01/07/2018-04/01/2018[#]

*ECM updated for NOAA-20 on 03/30/2018

[#]Only for selected sites. Ad-hoc global runs. Algorithm is like in DAP v1.2 (but see next slide).

- DAP version numbers are not (necessarily) the same as L2 algorithm versions.
- There is NO difference between AOD codes in DAP versions 1.1 and 1.2 in NDE.
- Lengths of data records vary, common period is short.

NOAA-20 AOD Algorithm "Features"

Platform	LUT + coeffs	Cloud Mask	Ancillary Data
Science Team	NOAA-20(1)	VCM	GFS(2)
ASSISTT	NOAA-20(1)	ECM	GFS(2)
NDE I&T	S-NPP	ECM(3)	GFS (?)

Notes:

(1) Except surface reflectance relationships, which are for S-NPP

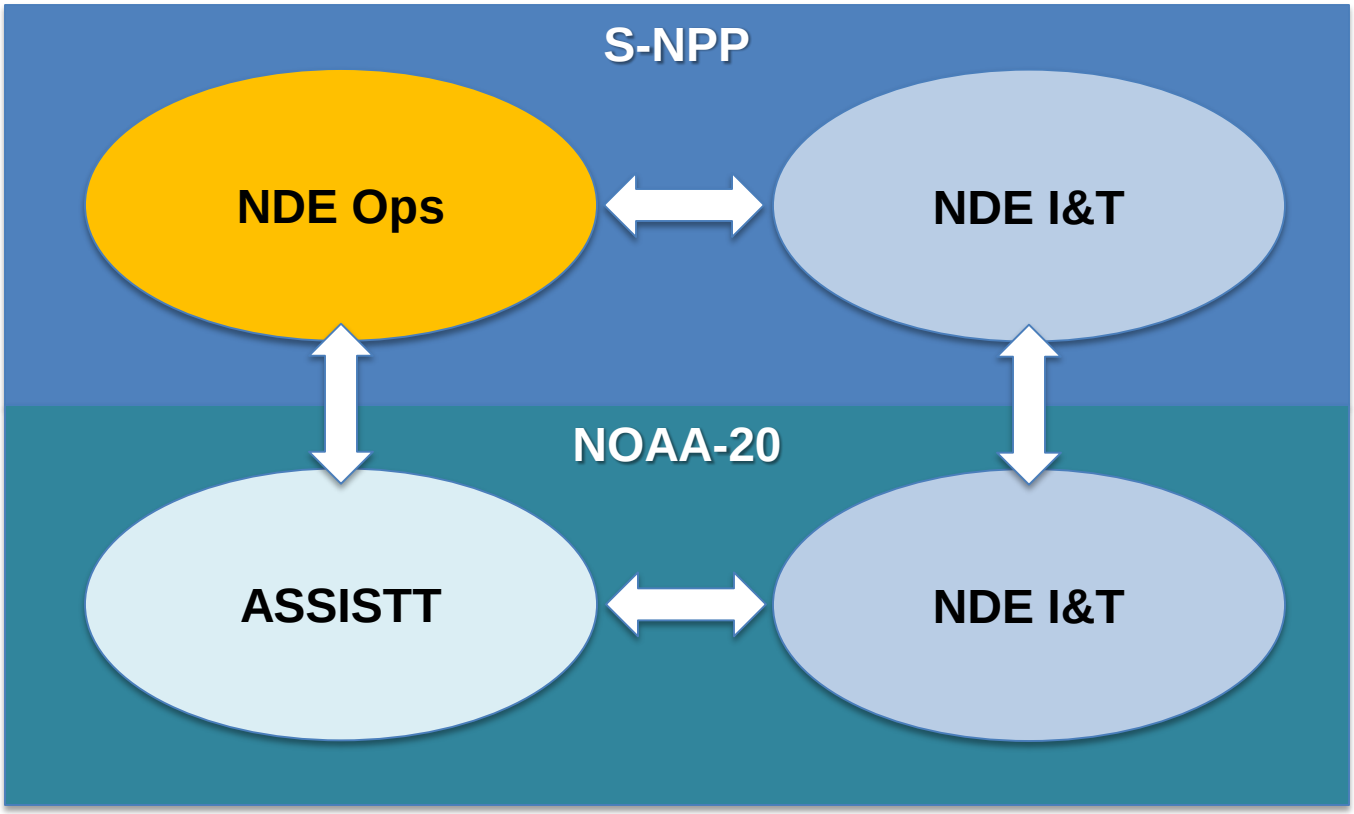
(2) May be somewhat different due to remapping, e.g., nearest neighbor vs. spatial/temporal averaging

(3) ECM was updated for NOAA-20 only on 03/30/2018

- Different "incarnations" of EPS AOD algorithm – comparison is not
- NDE I&T algorithm uses S-NPP LUT and processing coefficients
- ASSIST algorithm uses NOAA-20 LUT and ECM → **ASSISTT run is "best" representation for NOAA-20**

Linking NDE and Offline Retrievals

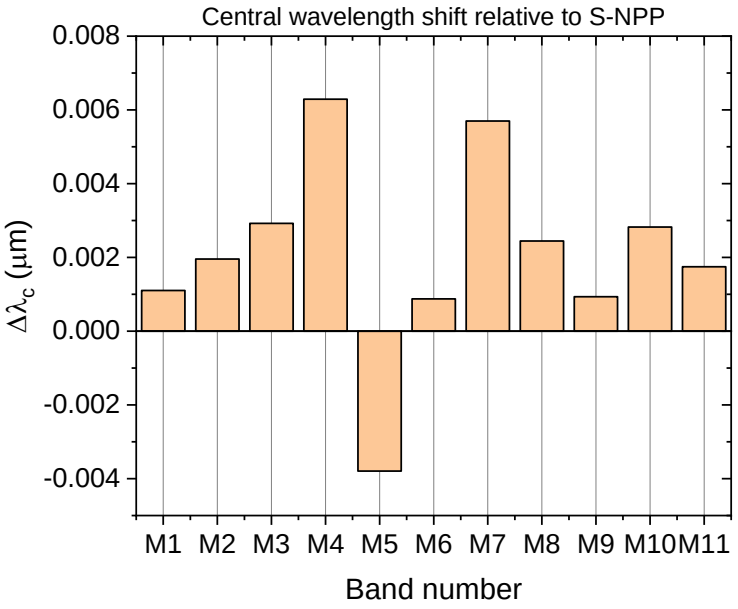
- ASSISTT to NDE I&T and to NDE Ops

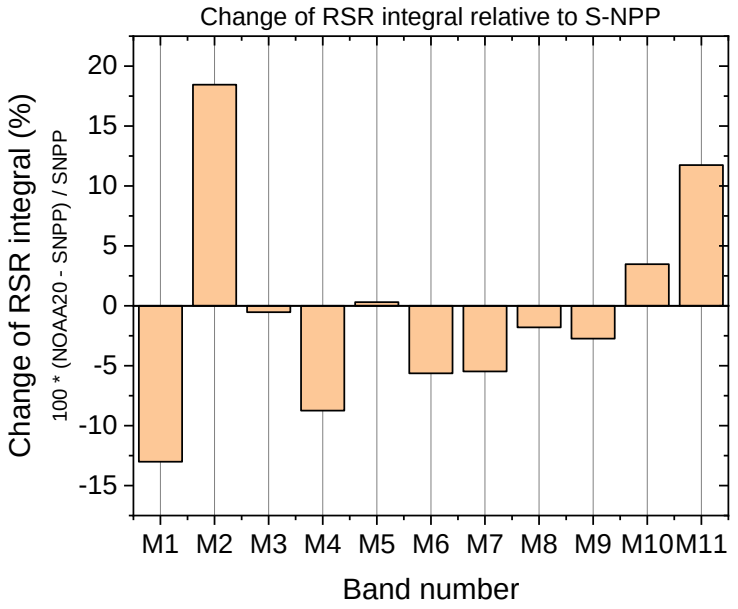


- For global comparison S-NPP data are used.
- What is the impact of RSR (LUT) differences on AOD and APS?

VIIRS RSR: S-NPP vs. NOAA-20

λ_c(μm)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
S-NPP	0.411	0.444	0.486	0.551	0.671	0.745	0.862	1.239	1.375	1.602	2.257
NOAA-20	0.412	0.446	0.489	0.557	0.668	0.746	0.868	1.241	1.376	1.605	2.259





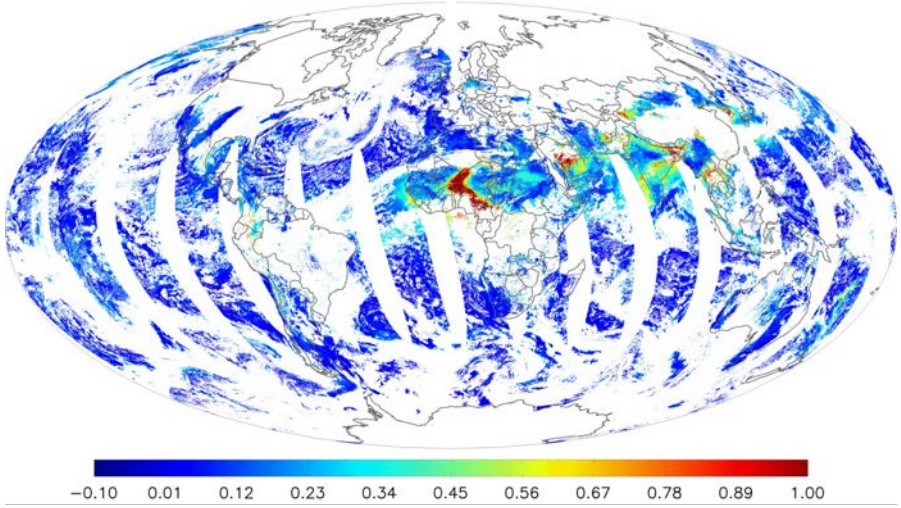
NOAA-20 VIIRS RSR from https://ncc.nesdis.noaa.gov/NOAA-20/docs/J1_VIIRS_RSR_DAWG_At-Launch_Public_Release_V2.1_Nov2016.zip

- Relative to VIIRS on S-NPP the VIIRS reflective bands on NOAA-20
  - shifted to slightly longer wavelengths (exception M5),
  - bands M2, M5, M10 and M11 got wider; other bands got narrower.

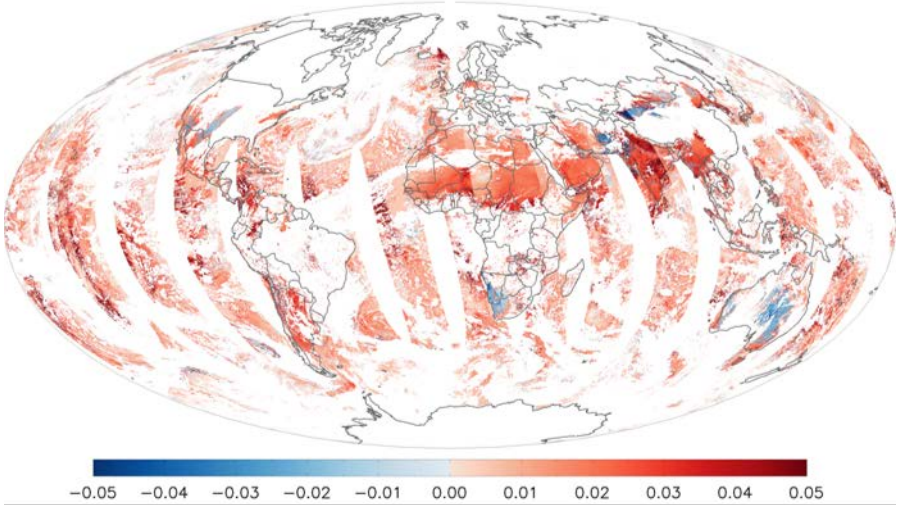
NOAA-20: Impact of LUT on AOD

High-quality 550-nm AOD
02/20/2018

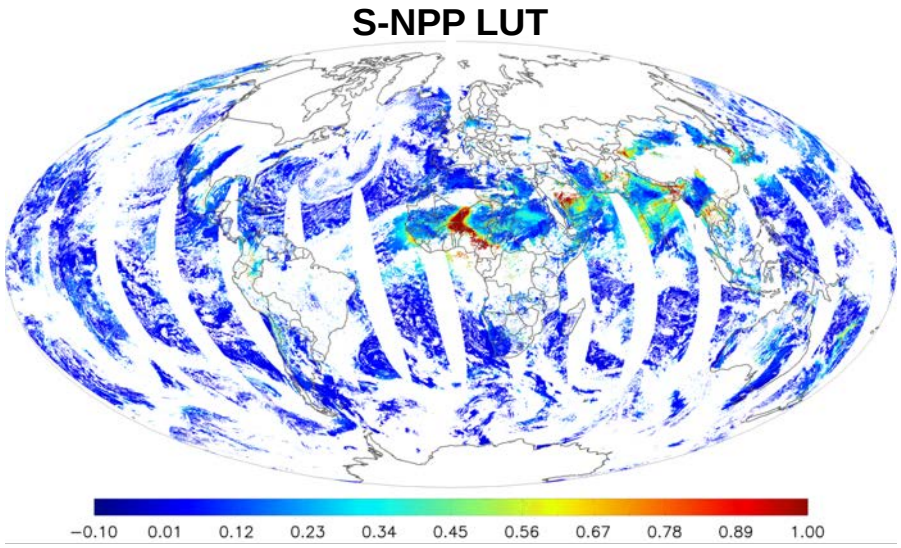
NOAA-20 LUT



NOAA20 – SNPP difference



S-NPP LUT

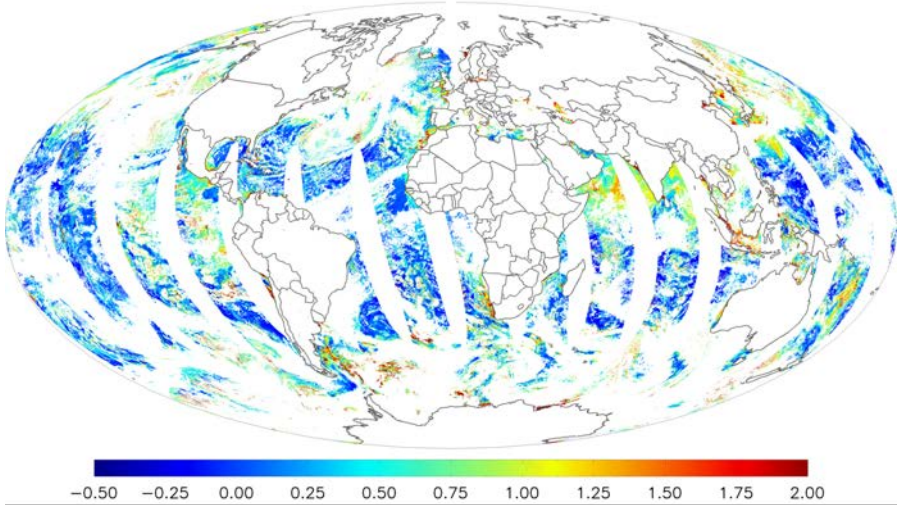


- AOD retrieved by Science Team from NOAA-20 SDR.
- AOD with NOAA-20 LUT (*upper left*) and that with S-NPP LUT (*bottom left*) are visually very similar.
- Using S-NPP LUT with NOAA-20 SDR results in smaller AOD (*upper right*).
  - Global difference = 0.013

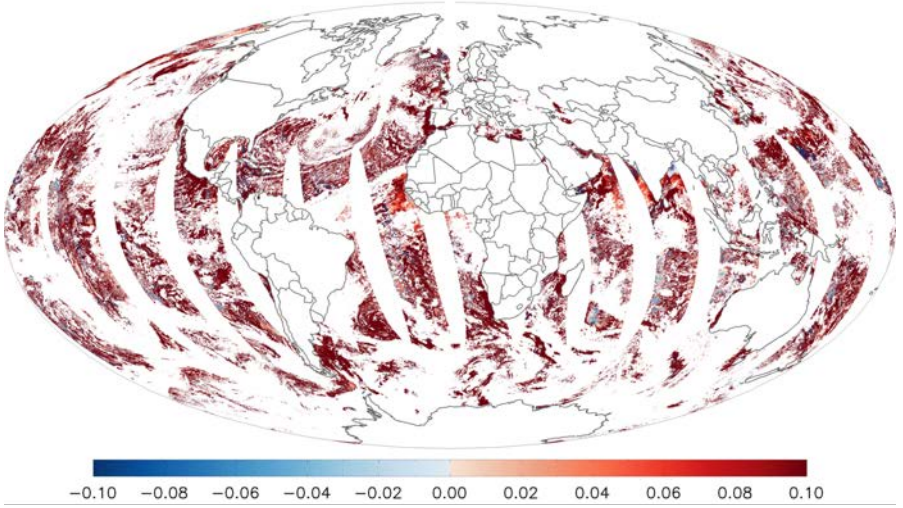
NOAA-20: Impact of LUT on APS

High-quality 550/860-nm Angstrom Exponent (AE)
02/20/2018

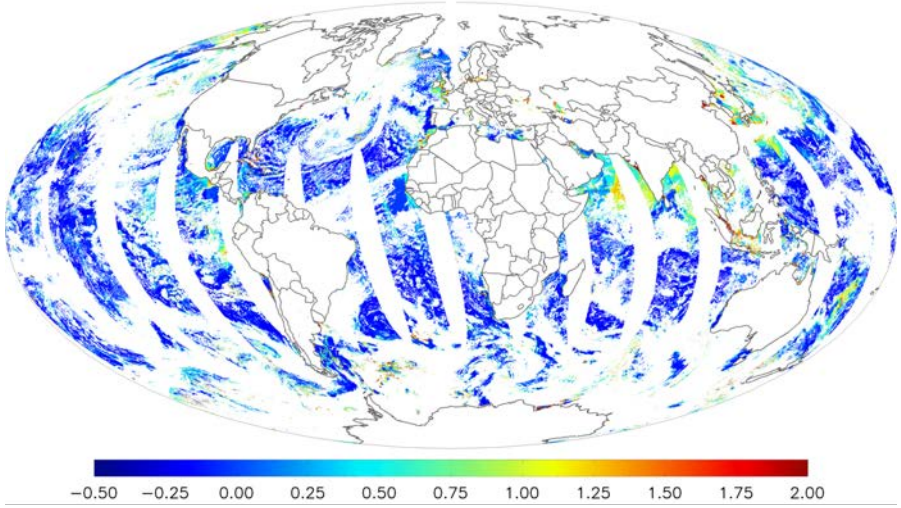
NOAA-20 LUT



NOAA20 – SNPP difference



S-NPP LUT



- APS (AE) retrieved by Science Team from NOAA-20 SDR.
- Differences between APS with NOAA-20 LUT (*upper left*) and that with S-NPP LUT (*bottom left*) are more obvious than those in the 550-nm AOD.
  - Global difference = 0.310;
- Using the S-NPP LUT with NOAA-20 SDR results in smaller AE that suggests larger particles.

S-NPP : NDE I&T and NDE Ops

NOAA-20: NDE I&T and ASSISTT

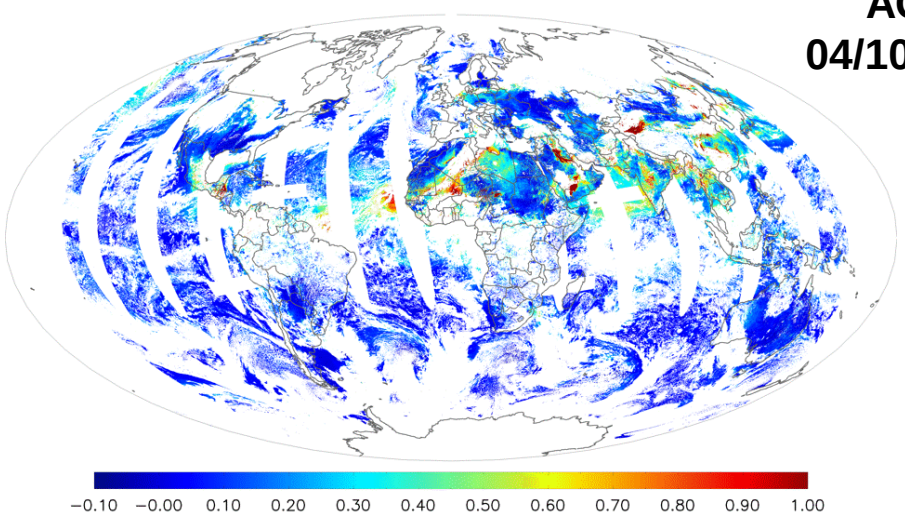
GLOBAL MAPS - AOD

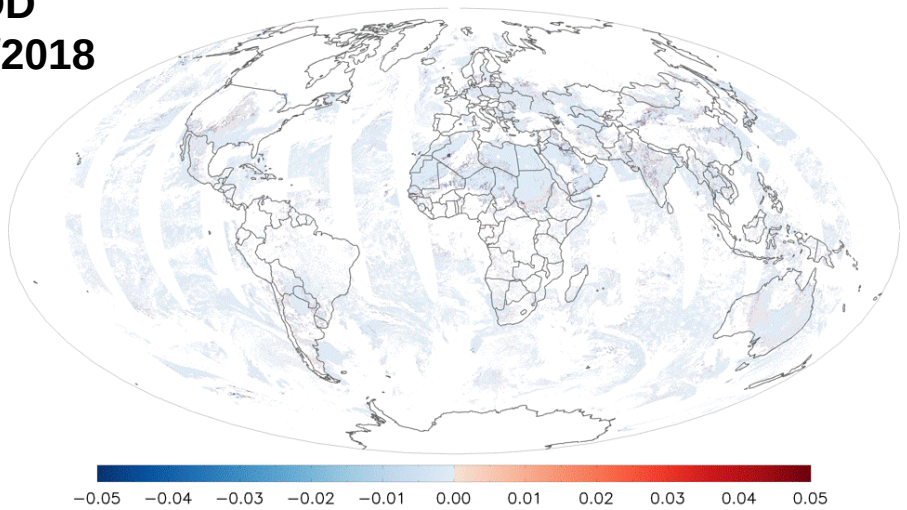
S-NPP AOD: NDE Ops and I&T

NDE I&T (S-NPP)

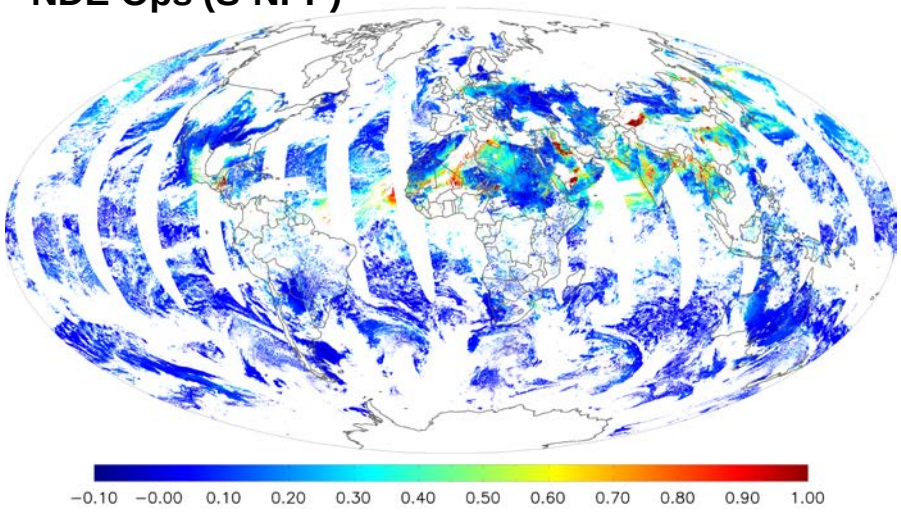
550-nm high-quality AOD 04/10/2018

Ops - I&T difference





NDE Ops (S-NPP)



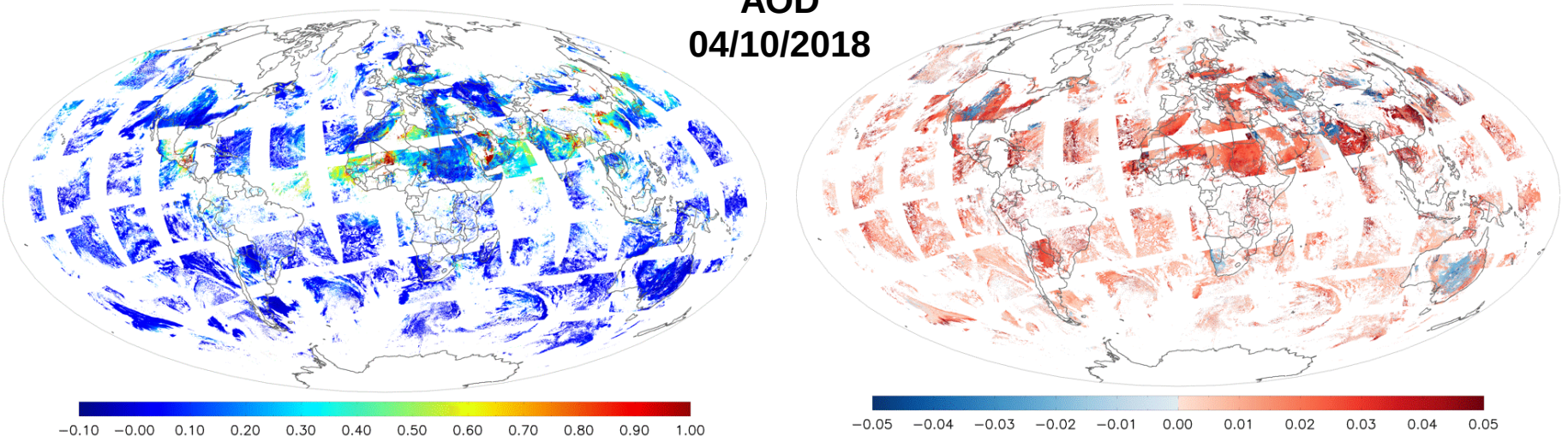
- S-NPP AODs from NDE I&T (*upper left*) and NDE Ops (*bottom left*) are visually identical.
  - Both have missing granules
  - I&T is missing an orbit
- Differences (*top right*) are small as expected
  - Global difference = -6.7×10^{-3}

NOAA-20 AOD: NDE I&T and ASSISTT

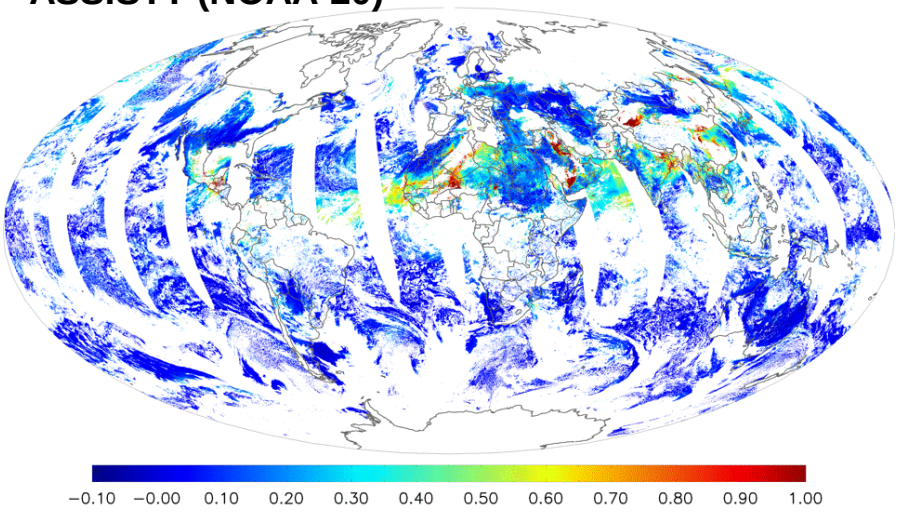
NDE I&T (NOAA-20)

550-nm high-quality AOD 04/10/2018

ASSISTT - NDE I&T difference



ASSISTT (NOAA-20)



- **Large number of granules are missing in NDE I&T AOD product.**
- NOAA-20 AODs from NDE I&T (*upper left*) and ASSISTT (*bottom left*) are visually similar.
- Differences (*top right*) are due to LUT used (NDE I&T: S-NPP LUT, ASSISTT: NOAA-20 LUT), and possible differences in ancillary input, etc.
  - Global difference = 0.012

S-NPP : NDE I&T and NDE Ops

NOAA-20: NDE I&T and ASSISTT

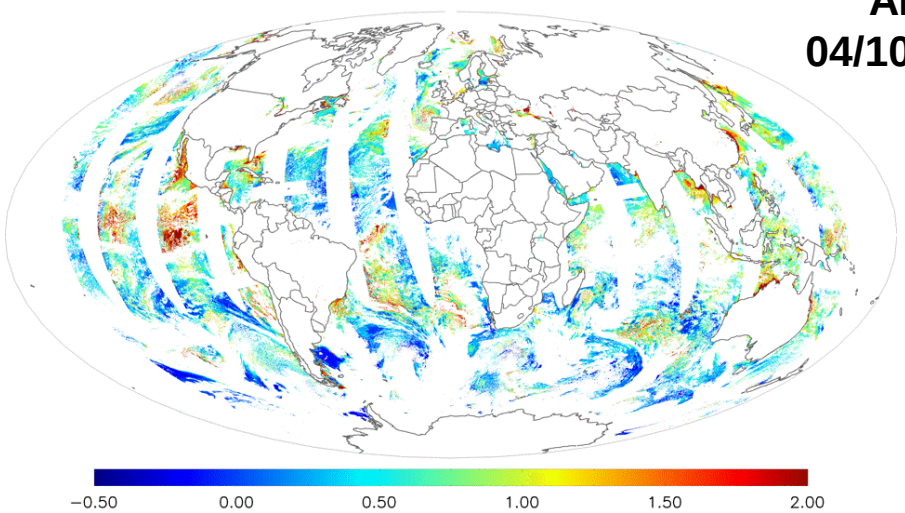
GLOBAL MAPS - APS

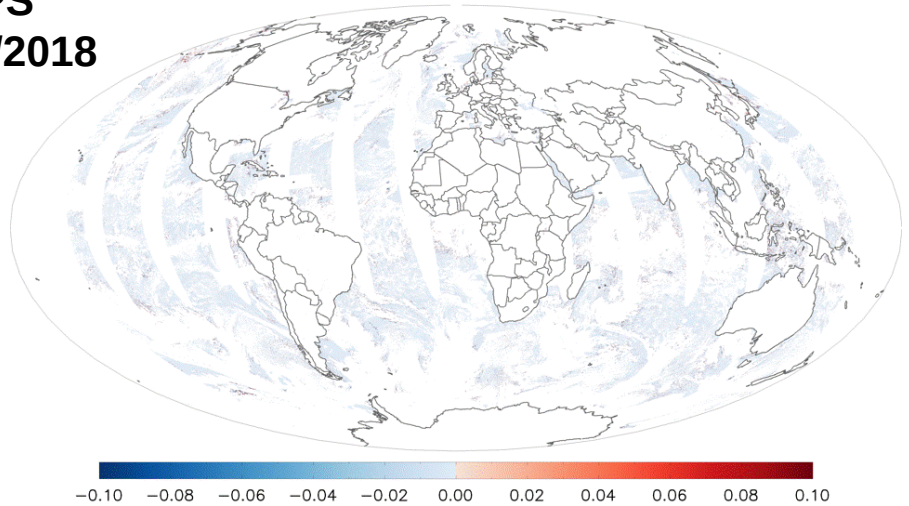
S-NPP APS (SW): NDE Ops and I&T

NDE I&T (S-NPP)

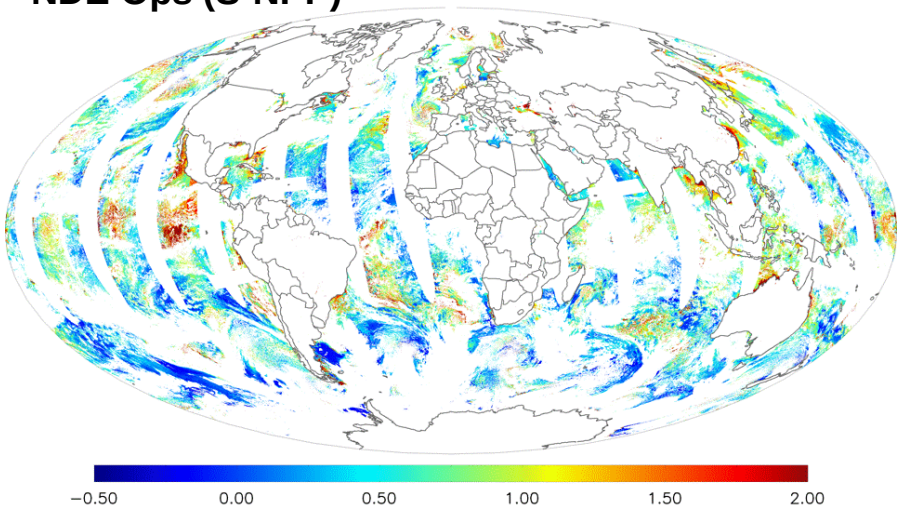
550/860-nm high-quality APS 04/10/2018

Ops - I&T difference





NDE Ops (S-NPP)



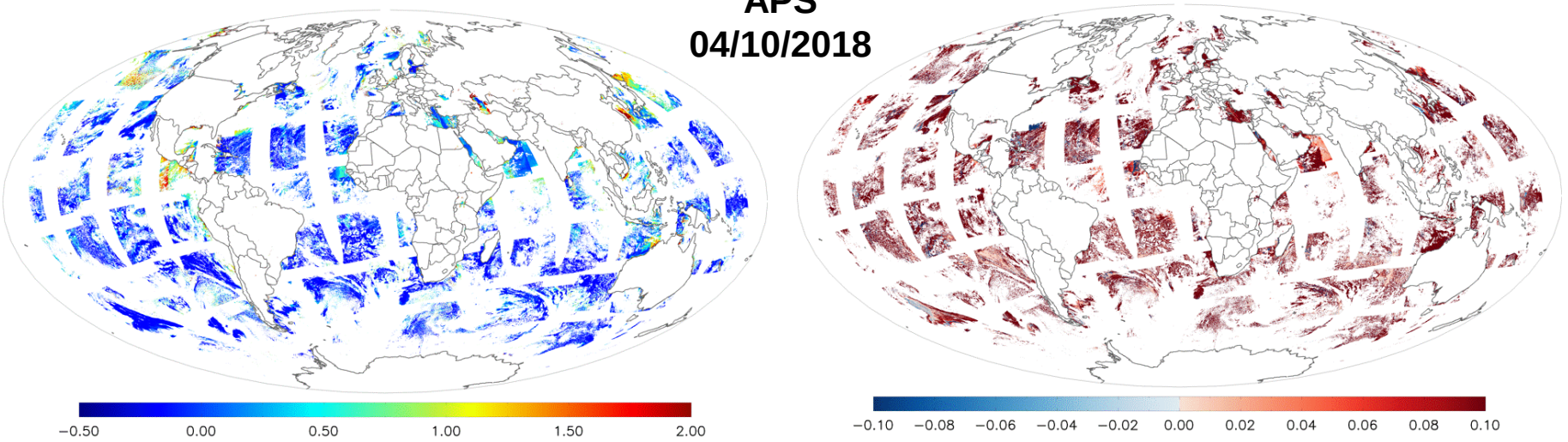
- S-NPP "short-wavelength" APS from NDE I&T (*upper left*) and NDE Ops (*bottom left*) are visually identical.
  - Both have missing granules
  - I&T is missing an orbit
- Differences (*top right*) are small as expected
  - Global difference = 7.6×10^{-4}

NOAA-20 APS (SW): NDE I&T and ASSISTT

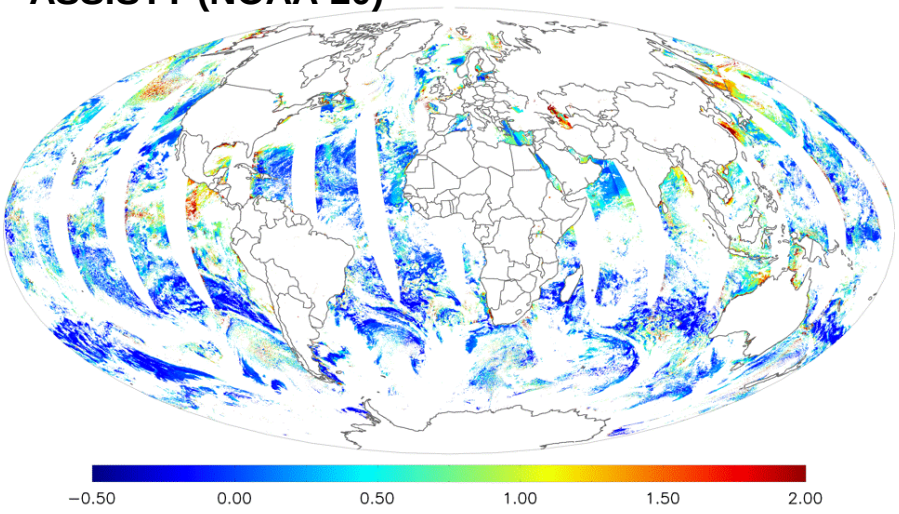
NDE I&T (NOAA-20)

550/860-nm high-quality APS 04/10/2018

ASSISTT - NDE I&T difference



ASSISTT (NOAA-20)



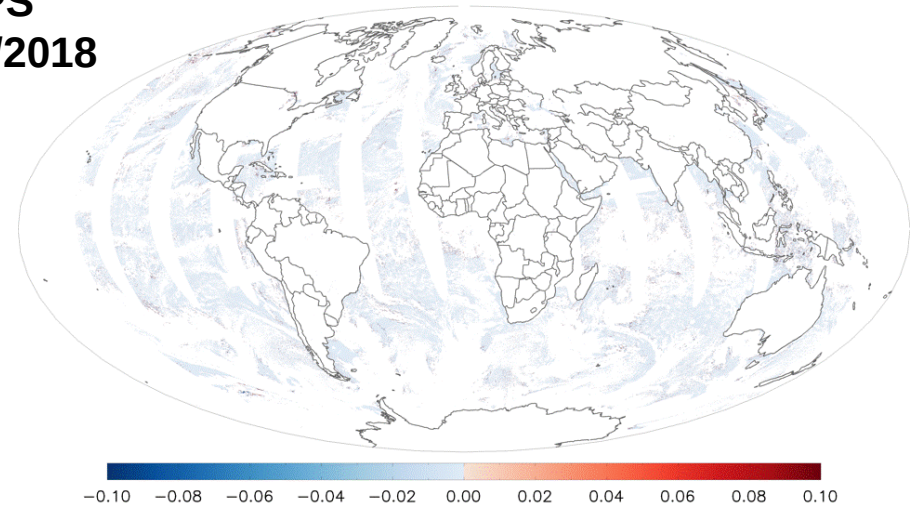
- Large number of granules are missing in NDE I&T APS product.
- NOAA-20 “short-wavelength APS from NDE I&T (*upper left*) is noticeable smaller than that from ASSISTT (*bottom left*)
  - Global difference = 0.248
- Differences (*top right*) are due to LUT used (NDE I&T: S-NPP LUT, ASSISTT: NOAA-20 LUT), and possible differences in ancillary input, etc.

S-NPP APS (LW): NDE Ops and I&T

NDE I&T (S-NPP)

860/1610-nm high-quality APS 04/10/2018

Ops - I&T difference



NDE Ops (S-NPP)

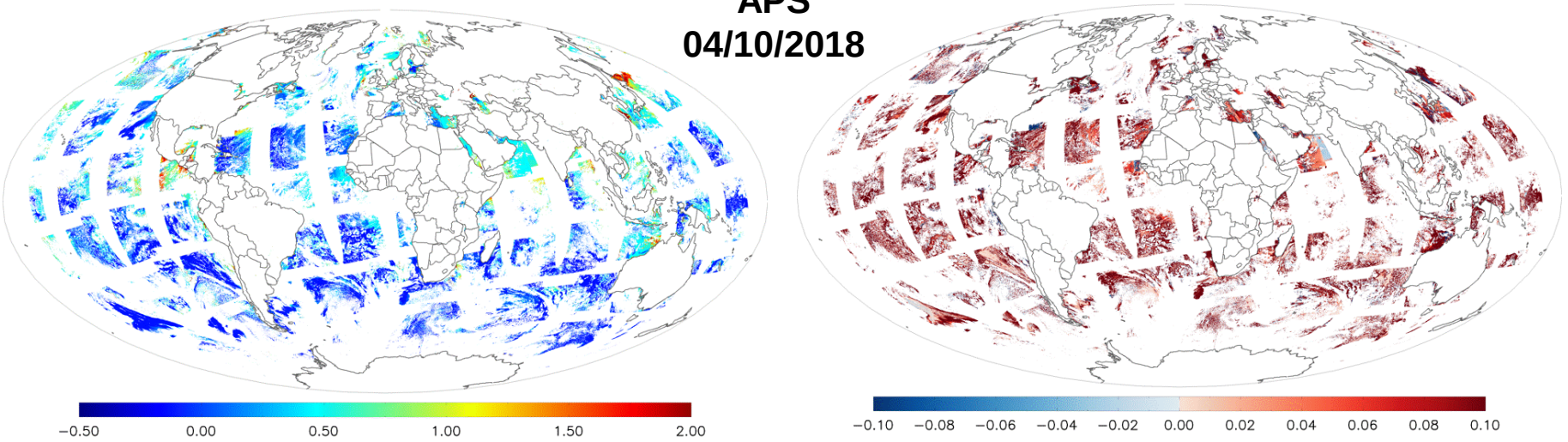
- S-NPP “long-wavelength” APS from NDE I&T (*upper left*) and NDE Ops (*bottom left*) are visually identical.
  - Both have missing granules
  - I&T is missing an orbit
- Differences (*top right*) are small as expected
  - Global difference = 8.2×10^{-4}

NOAA-20 APS (LW): NDE I&T and ASSISTT

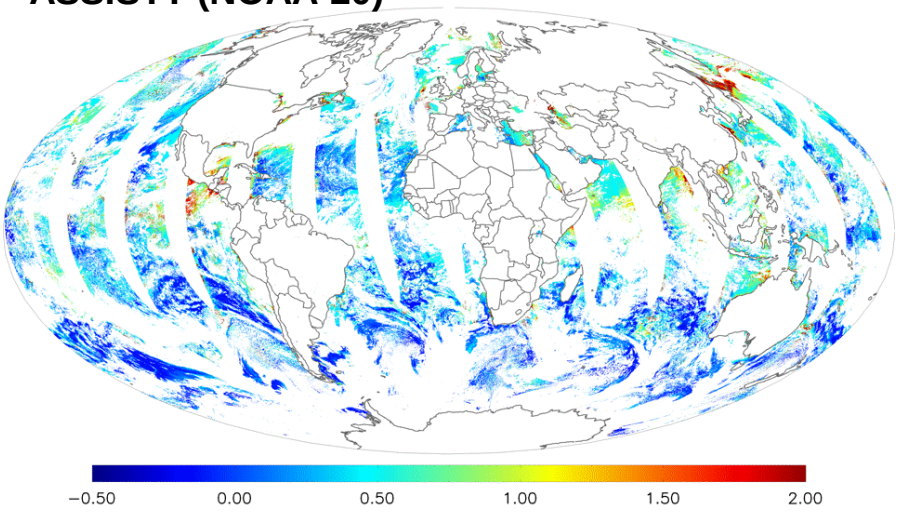
NDE I&T (NOAA-20)

860/1610-nm high-quality APS 04/10/2018

ASSISTT - NDE I&T difference



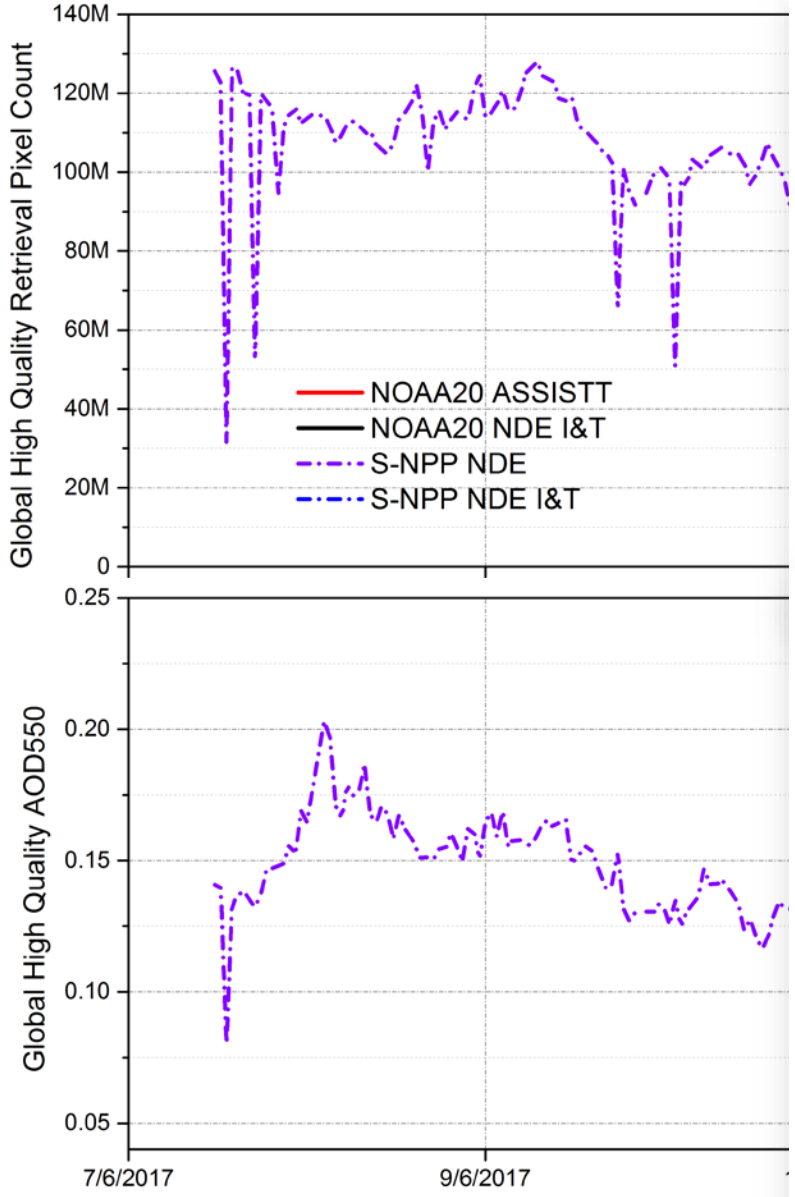
ASSISTT (NOAA-20)

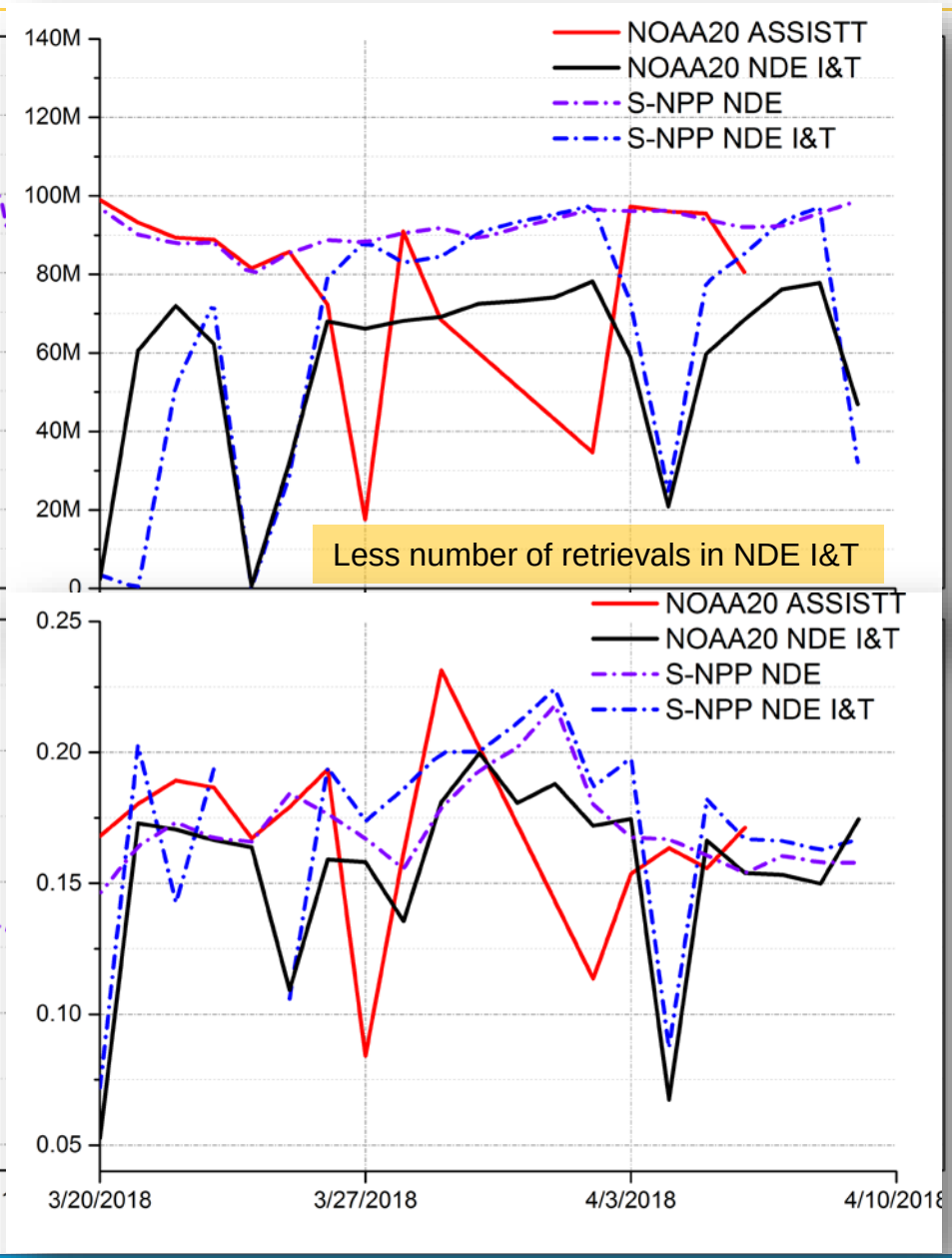


- NOAA-20 "long-wavelength APS from NDE I&T (*upper left*) is noticeable smaller than that from ASSISTT (*bottom left*)
  - Global difference = 0.167
  - Difference is smaller than that for SW APS (0.248)
- Differences (*top right*) are due to LUT used (NDE I&T: S-NPP LUT, ASSISTT: NOAA-20 LUT), and possible differences in ancillary input, etc.

TIME SERIES OF GLOBAL DAILY MEAN AOD

Global Daily Pixel Count and Mean AOD





EVALUATION WITH AERONET

Evaluation with AERONET

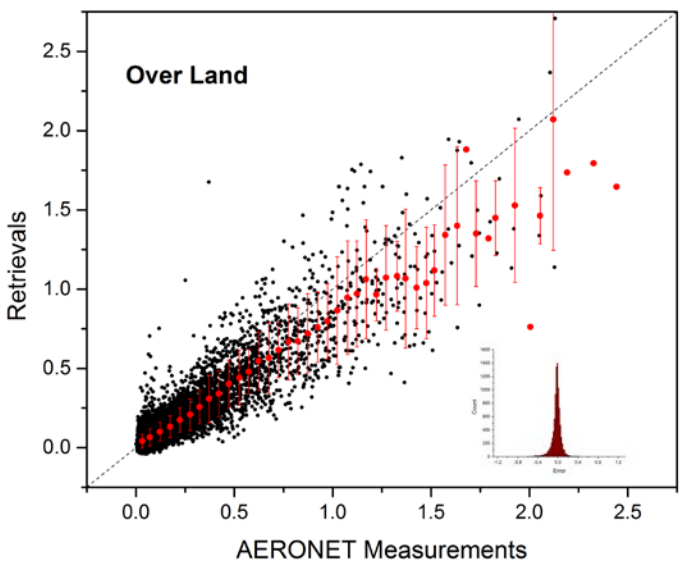
- Characteristics of match-ups from satellite retrievals and AERONET V3 L1.5 Direct-sun measurements:
  - Spatial domain: circle of 27.5km-radius centered on AERONET stations
  - Temporal domain: one-hour centered on satellite overpass time
  - At least 2 AERONET measurements within temporal domain
  - At least 750 pixel retrievals within spatial domain
  - Angstrom Exponents are evaluated only if 550-nm AOD is larger than 0.15

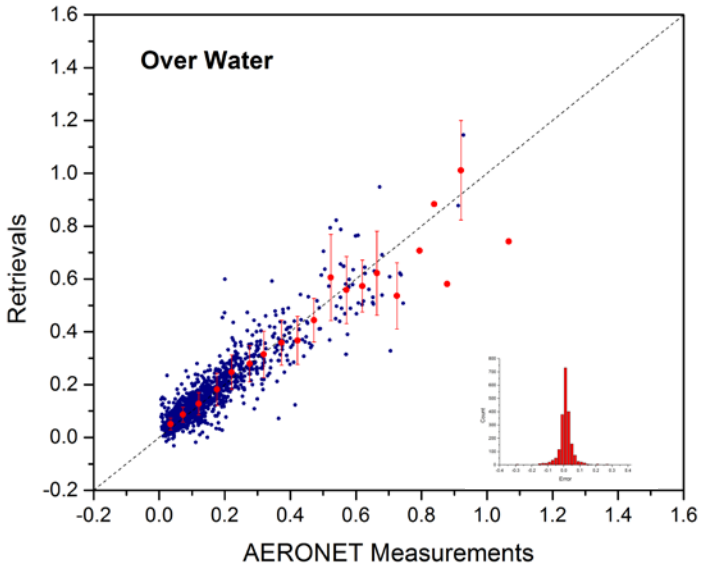
S-NPP	
NDE Ops	10/17/2017 – 04/05/2018
NOAA-20	
NDE I&T	03/20/2018 – 04/05/2018
STAR ASSISTT	02/26/2018 – 04/05/2018
STAR Science Team	01/07/2018 – 04/01/2018

No attempt is made to constrain comparison to common time period

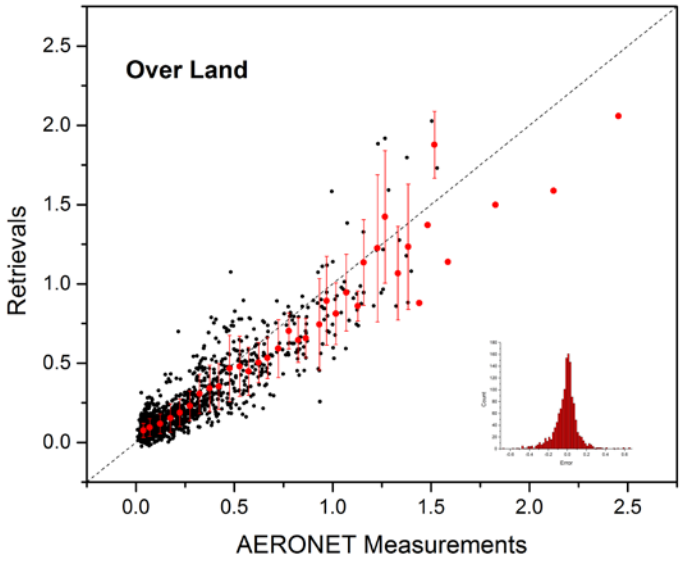
AOD Scatter Diagrams and Histograms

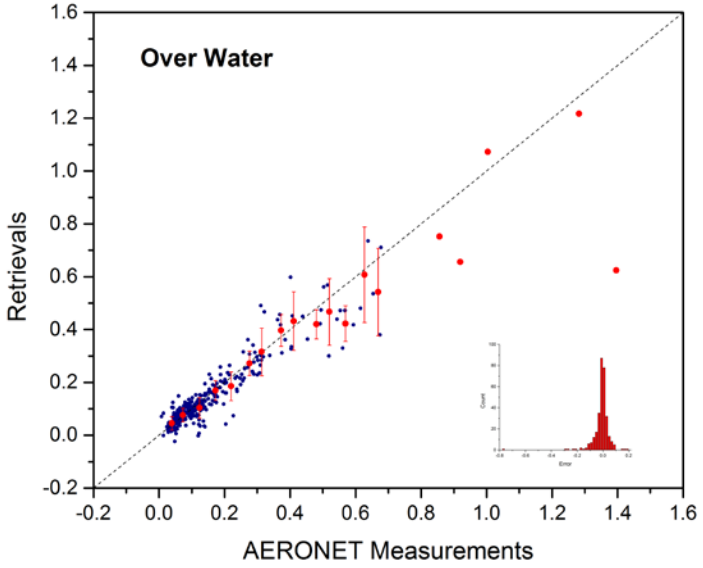
NDE Ops (S-NPP)



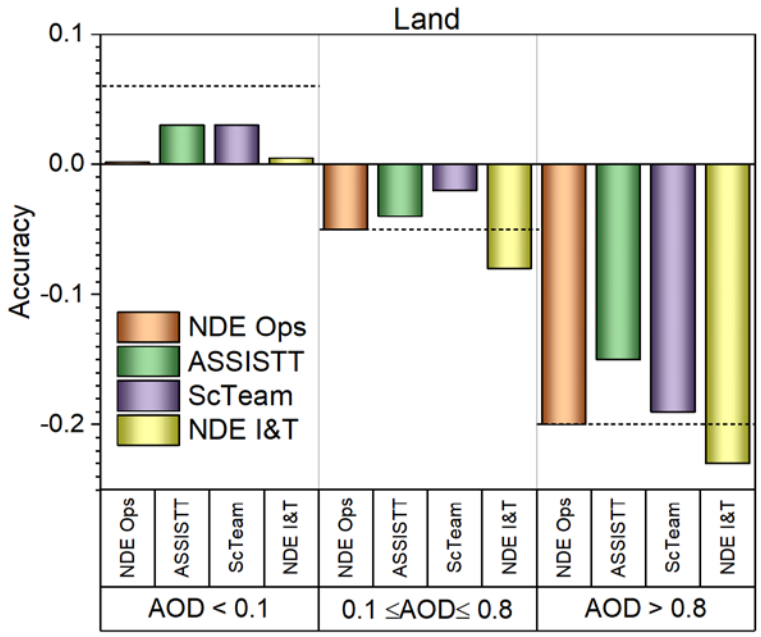


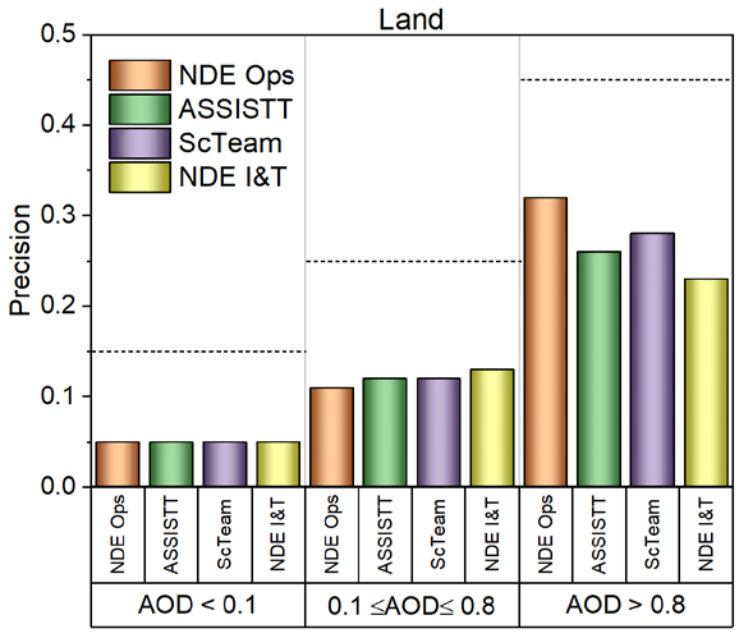
ASSISTT (NOAA-20)

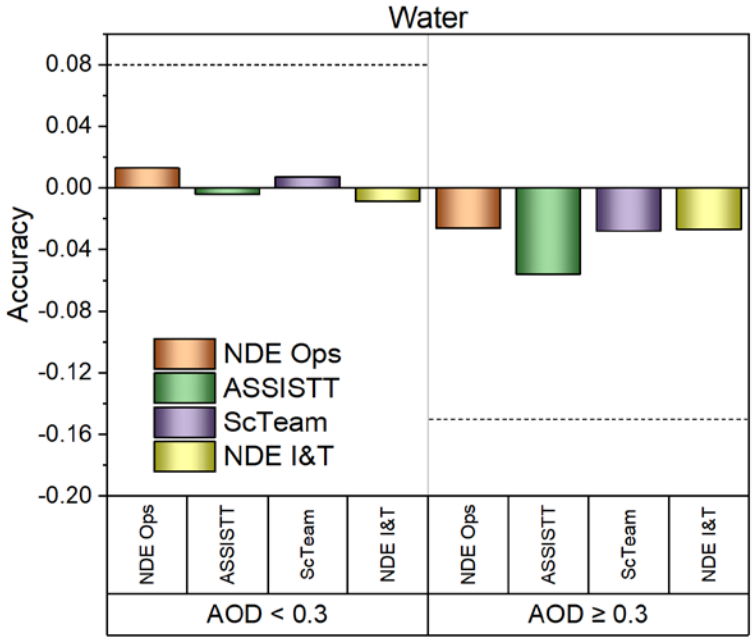


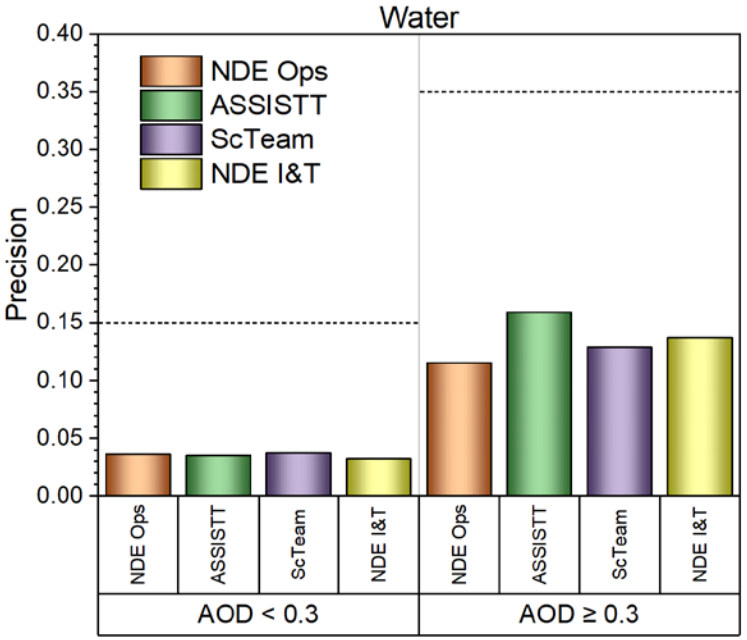


AOD Accuracy and Precision

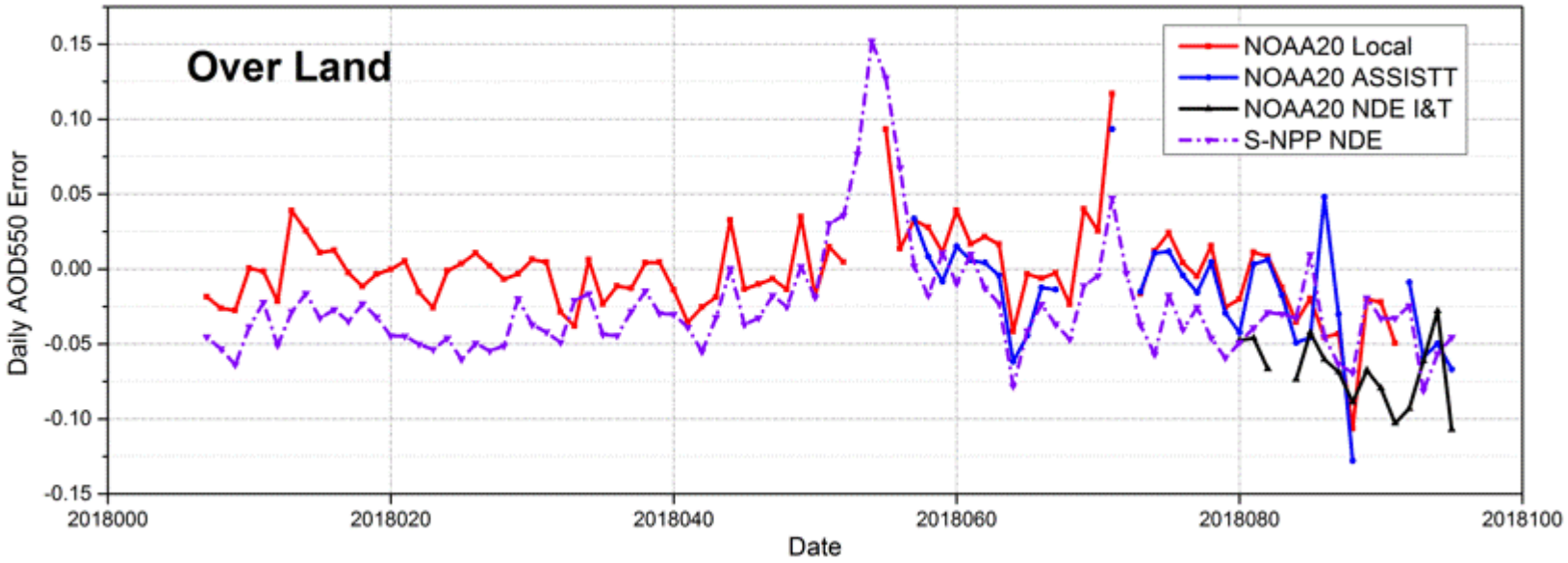






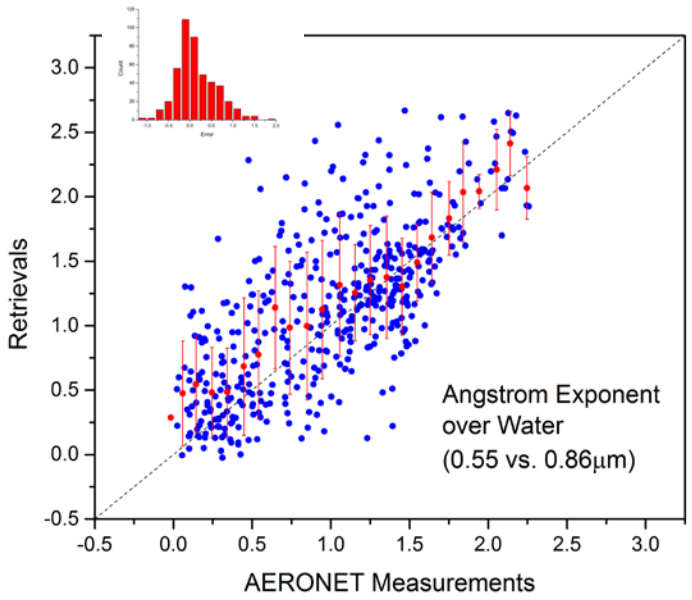


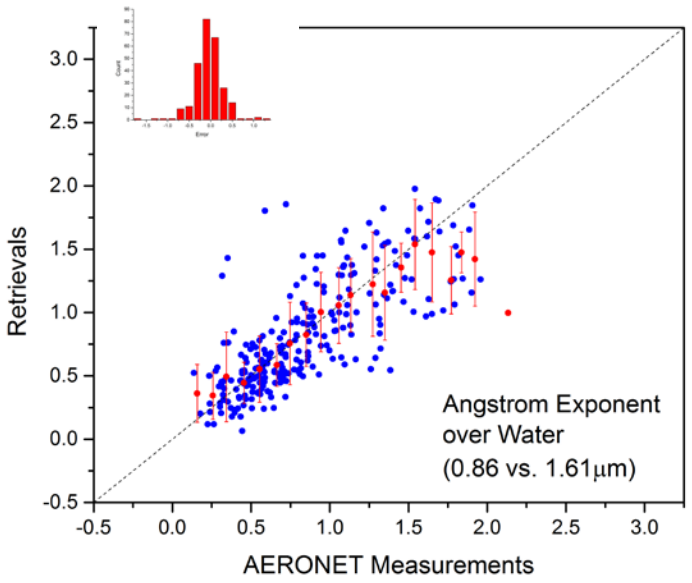
Time Series of Daily Mean AOD



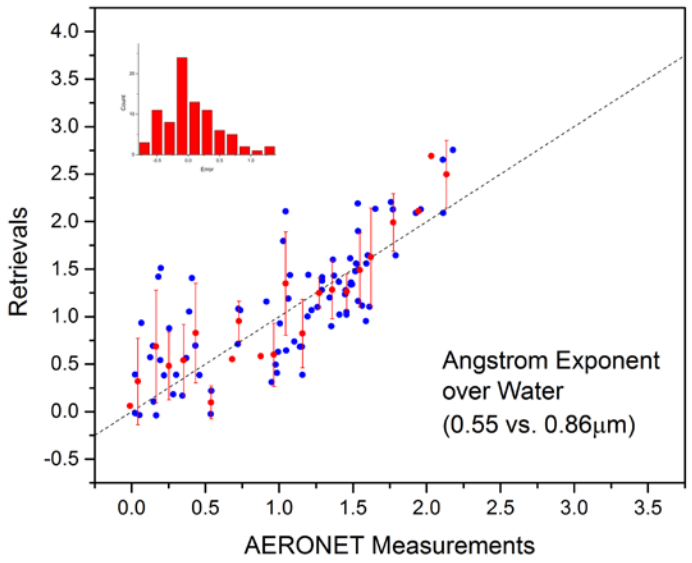
APS Scatter Diagrams and Histograms

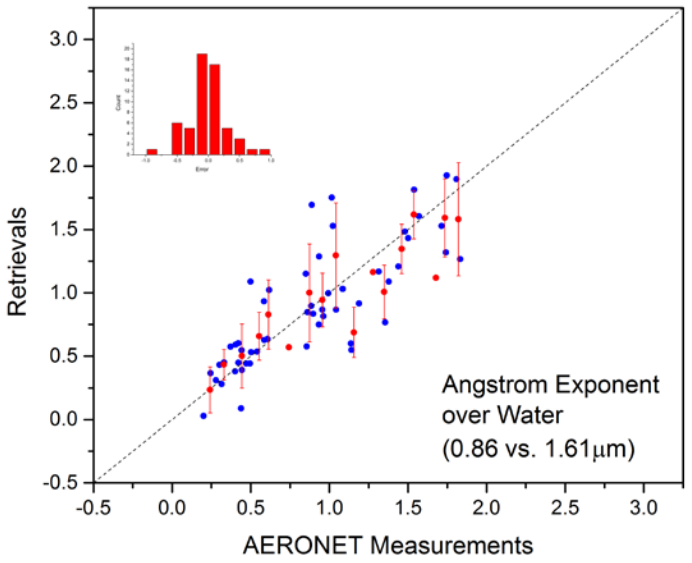
NDE Ops (S-NPP)



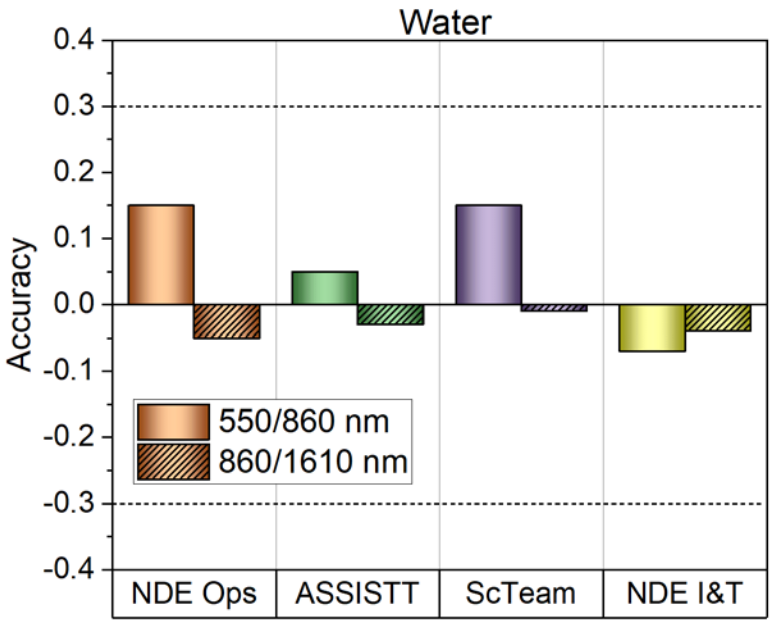


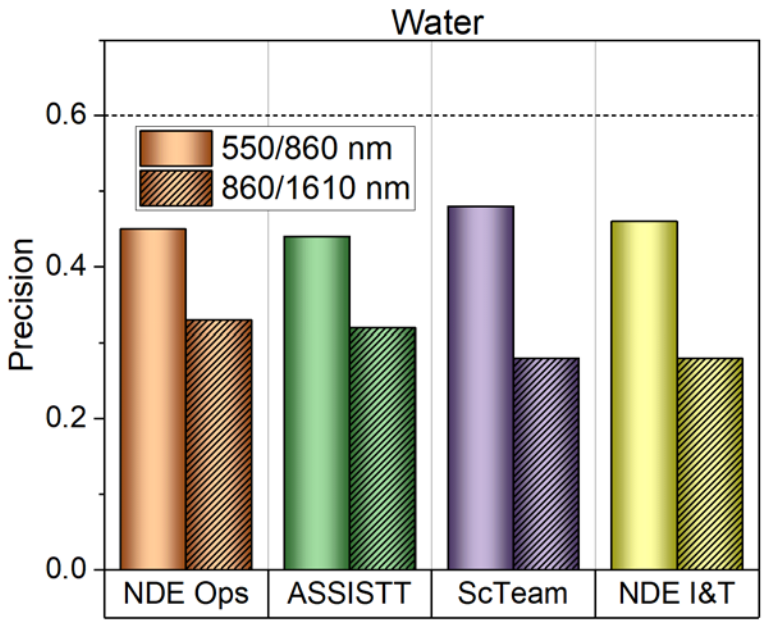
ASSISTT (NOAA-20)





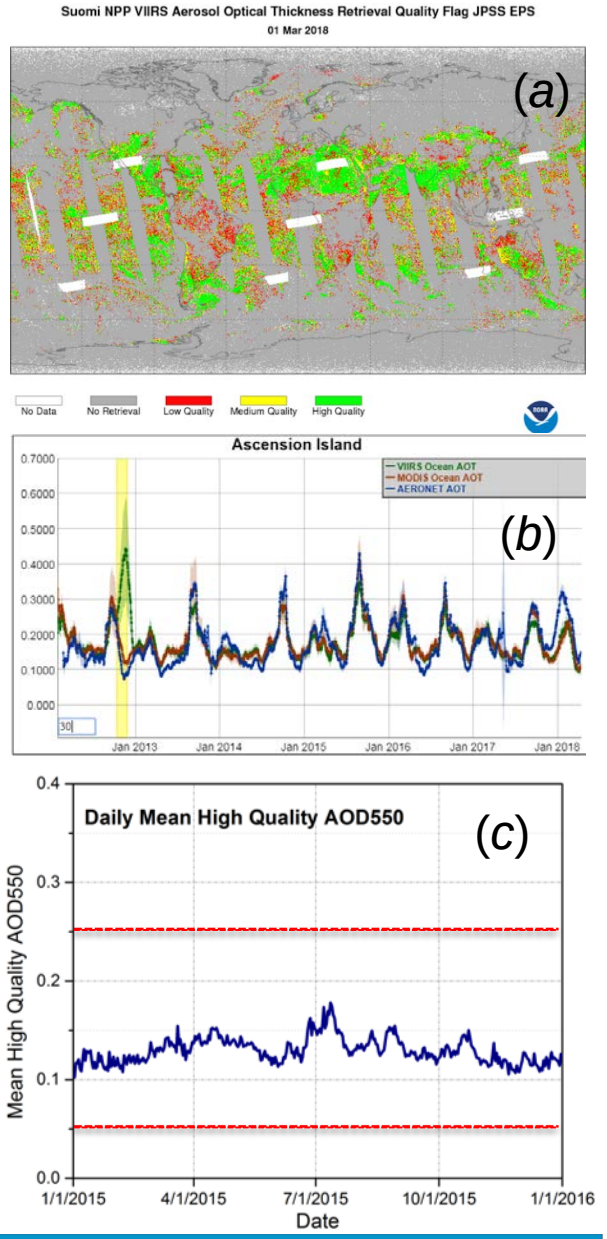
APS Accuracy and Precision





NOAA-20 Long-Term Monitoring

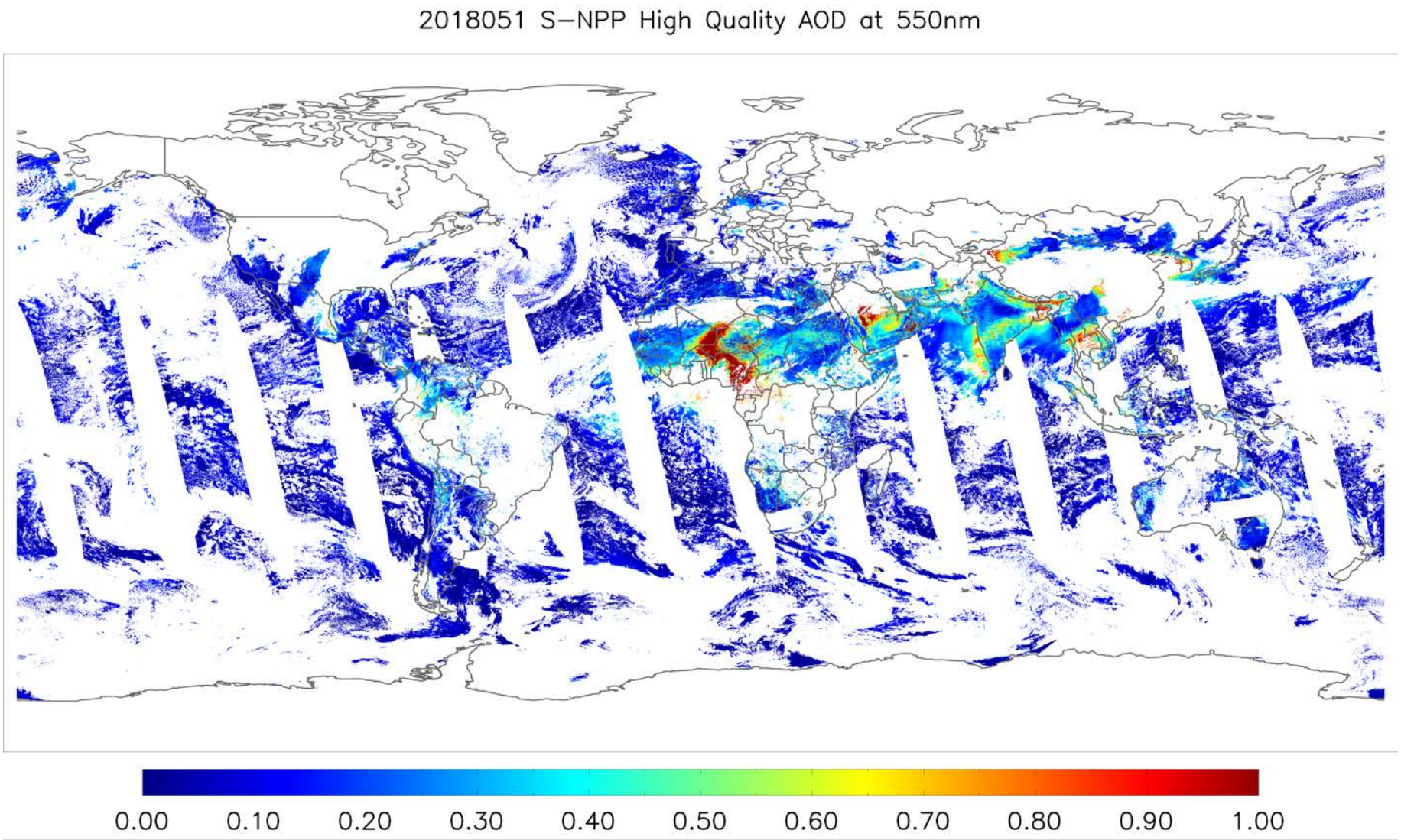
- ***STAR LTM (a):***
  - parameters plotted:
    - AOD
    - Aerosol model (under development)
    - Retrieval quality (under development)
  - currently for VIIRS/NPP; will do same for NOAA-20
- ***STAR Science Team (b):***
  - Interactively displays VIIRS, MODIS and AERONET AOD, AE, geometry, cloud fraction, reflectance and bias for six global sites.
  - Currently for S-NPP VIIRS in IDPS. Working on adapting it for S-NPP and NOAA-20 EPS AOD in NDE.
- ***OSPO (c):***
  - Used reprocessed (Science Team) 2015 NPP VIIRS EPS AOD retrievals to estimate preliminary thresholds for daily (weekly, monthly) monitoring of
    - Mean all- and high-quality AOD
    - Mean percentage of all and high-quality retrievals
  - *NOTE: Metadata of current NDE product is not correct !*



Documents (Check List)

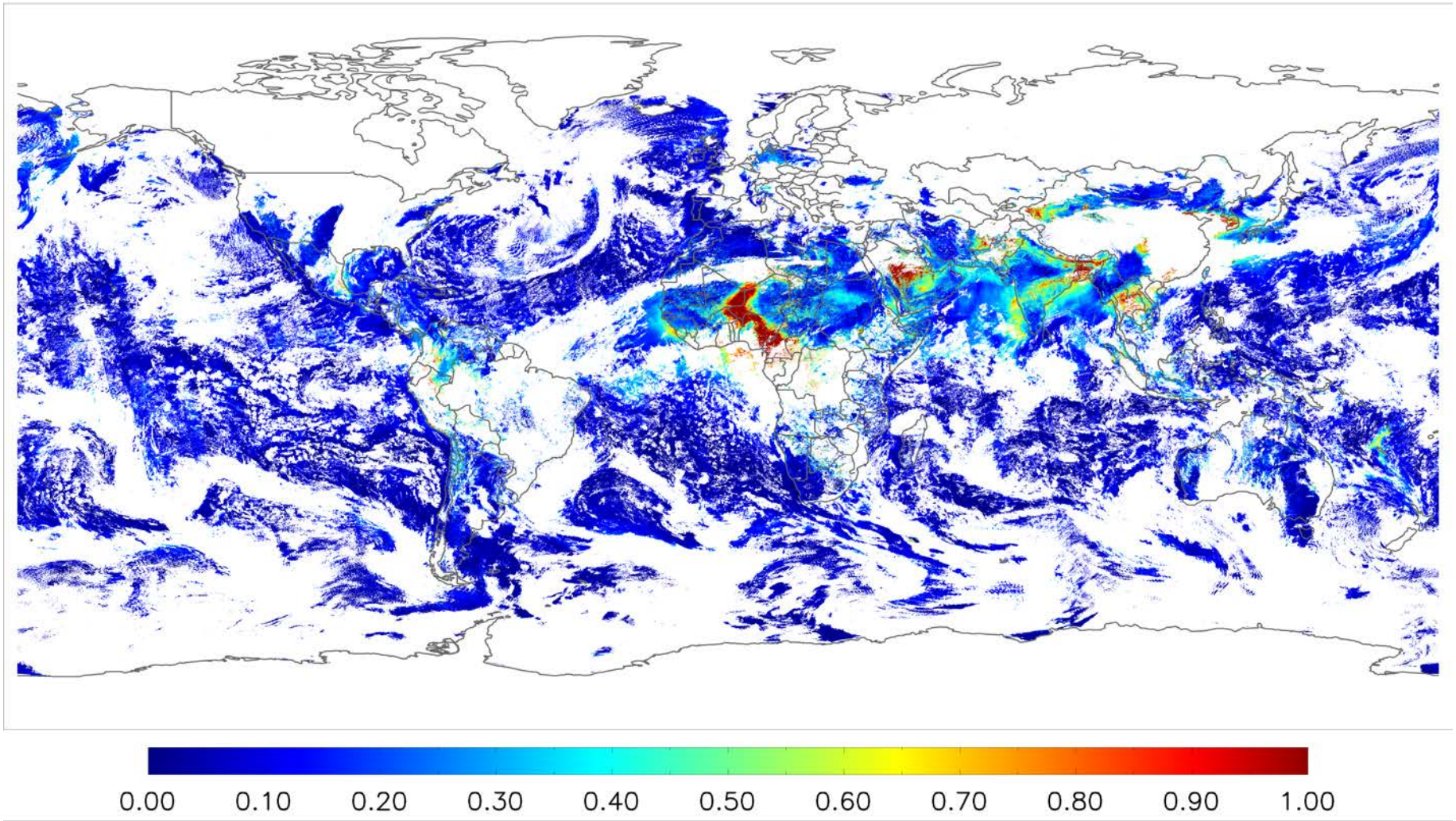
Science Maturity Check List	Exist
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes (S-NPP)
Regular Validation Reports (Demonstrates long-term performance of the algorithm)	JPSS Annual Meeting (S-NPP)

S-NPP and NOAA-20 synergy (1)



S-NPP AOD on 02/20/2018

S-NPP and NOAA-20 synergy (2)



NOAA-20 AOD overlaid on S-NPP AOD on 02/20/2018 (~50 min time difference)

Summary

- Used NOAA-20 retrievals from ASSISTT and S-NPP retrievals from NDE Ops.
- Global fields of AOD from NOAA-20 and S-NPP for days examined are very similar. Somewhat larger differences are present in APS.
- Limited evaluation with ground-based AERONET data indicates AOD and APS retrieved from NOAA-20 reflectances meet requirements. NOAA-20 Accuracy and Precision are similar to those from S-NPP.
- **The quality of the NOAA-20 VIIRS aerosol optical depth (AOD) and aerosol particle size (APS) products indicates that the products have reached Beta maturity.** (Upstream Cloud Mask Product must be at least Beta.)
- Known issues:
  - Metadata of averages are incorrect in NDE
  - Many missing granules in NDE I&T
  - NDE I&T (likely) does not yet use NOAA-20 LUTs and processing coefficients
  - Saturation of channels (e.g., M6) may not be properly indicated in input to the aerosol algorithm.

Path Forward to Provisional Maturity

- Processing of NOAA-20 AOD and APS in NDE I&T must stabilize; preferred source is NDE Ops.
- Evaluation of longer record of NOAA-20 AOD from **NDE Ops** by comparing it to
  - S-NPP AOD and APS product,
  - AERONET AOD and APS.
- Update spectral land-surface reflectance relationships derived from NOAA-20 VIIRS observations.
- Update thresholds for internal tests.
- Saturation of channels is properly indicated in input to aerosol code.
- Algorithm Science updates (beyond Provisional/Validated Maturity):
  - Attempt to improve regional performance by expanding/revising candidate aerosol models and surface reflectance relationships.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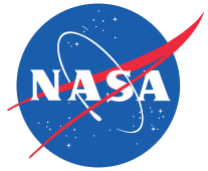

NASA

APPENDIX

Appendix A-1

- AOD: NDE Ops (S-NPP) vs. AERONET **AOD**; 10/17/2017 – 04/05/2018

Land	Require.	NOAA20	Dark	Bright
AOD550 < 0.1				
Accuracy	0.06	0.002	0.0005	0.01
Precision	0.15	0.05	0.05	0.06
Number	/	5,003	4,170	671
0.1 ≤ AOD550 ≤ 0.8				
Accuracy	0.05	-0.05	-0.05	-0.06
Precision	0.25	0.11	0.11	0.10
Number	/	3,701	2,876	743
AOD550 > 0.8				
Accuracy	0.20	-0.20	-0.22	-0.05
Precision	0.45	0.32	0.31	0.37
Number	/	343	319	27
All				
Accuracy	N/A	-0.03	-0.03	-0.03
Precision	N/A	0.11	0.11	0.10
Number	/	9,047	7,365	1,441

Water	Requirement	NOAA20
AOT550 < 0.3		
Accuracy	0.08	0.013
Precision	0.15	0.036
Number	/	1,948
AOT550 >= 0.3		
Accuracy	0.15	-0.026
Precision	0.35	0.115
Number	/	145
All		
Accuracy	N/A	0.010
Precision	N/A	0.047
Number	/	2,093

Appendix A-2

- ASSISTT (NOAA-20) vs. AERONET **AOD**; 02/26/2018 – 04/05/2018

Land	Require.	NOAA20	Dark	Bright
AOD550 < 0.1				
Accuracy	0.06	0.03	0.02	0.08
Precision	0.15	0.05	0.05	0.06
Number	/	582	485	73
0.1 ≤ AOD550 ≤ 0.8				
Accuracy	0.05	-0.04	-0.04	-0.02
Precision	0.25	0.12	0.12	0.14
Number	/	689	533	146
AOD550 > 0.8				
Accuracy	0.20	-0.15	-0.15	-0.32
Precision	0.45	0.26	0.26	0.15
Number	/	93	89	4
All				
Accuracy	N/A	-0.02	-0.02	0.01
Precision	N/A	0.12	0.12	0.14
Number	/	1,364	1,107	223

Water	Requirement	NOAA20
AOT550 < 0.3		
Accuracy	0.08	-0.004
Precision	0.15	0.035
Number	/	272
AOT550 >= 0.3		
Accuracy	0.15	-0.056
Precision	0.35	0.159
Number	/	41
All		
Accuracy	N/A	-0.011
Precision	N/A	0.068
Number	/	313

Appendix A-3

- NDE I&T (NOAA-20) vs. AERONET **AOD**; 03/20/2018 – 04/05/2018

Land	Require.	NOAA20	Dark	Bright
AOD550 < 0.1				
Accuracy	0.06	0.005	0.00	0.02
Precision	0.15	0.05	0.05	0.03
Number	/	154	120	21
0.1 ≤ AOD550 ≤ 0.8				
Accuracy	0.05	-0.08	-0.08	-0.07
Precision	0.25	0.13	0.13	0.14
Number	/	208	171	34
AOD550 > 0.8				
Accuracy	0.20	-0.23	-0.23	-0.31
Precision	0.45	0.23	0.25	0.19
Number	/	47	41	7
All				
Accuracy	N/A	-0.07	-0.07	-0.07
Precision	N/A	0.15	0.15	0.16
Number	/	409	332	62

Water	Requirement	NOAA20
AOT550 < 0.3		
Accuracy	0.08	-0.004
Precision	0.15	0.035
Number	/	272
AOT550 >= 0.3		
Accuracy	0.15	-0.056
Precision	0.35	0.159
Number	/	41
All		
Accuracy	N/A	-0.011
Precision	N/A	0.068
Number	/	313

Appendix A-4

- Science Team (NOAA-20) vs. AERONET **AOD**; 01/07/2018 – 04/01/2018

Land	Require.	NOAA20	Dark	Bright
AOD550 < 0.1				
Accuracy	0.06	0.03	0.03	0.05
Precision	0.15	0.05	0.05	0.06
Number	/	2,255	1,886	298
0.1 ≤ AOD550 ≤ 0.8				
Accuracy	0.05	-0.02	-0.02	-0.01
Precision	0.25	0.12	0.13	0.11
Number	/	1,984	1,576	381
AOD550 > 0.8				
Accuracy	0.20	-0.19	-0.17	-0.28
Precision	0.45	0.28	0.28	0.17
Number	/	202	191	11
All				
Accuracy	N/A	-0.001	-0.004	0.011
Precision	N/A	0.117	0.119	0.105
Number	/	4,441	3,653	690

Water	Requirement	NOAA20
AOT550 < 0.3		
Accuracy	0.08	0.007
Precision	0.15	0.037
Number	/	745
AOT550 >= 0.3		
Accuracy	0.15	-0.028
Precision	0.35	0.129
Number	/	86
All		
Accuracy	N/A	0.003
Precision	N/A	0.055
Number	/	831

Appendix A-5

- AOD: NDE Ops (S-NPP) vs. AERONET **APS**; 10/17/2017 – 04/05/2018

AE over Water	Require.	NOAA20 (0.55 vs 0.86 µm)	NOAA20 (0.86 vs 1.61 µm)
Accuracy	0.3	0.15	-0.05
Precision	0.6	0.45	0.33
Number		458	264

- ASSISTT (NOAA-20) vs. AERONET **APS**; 02/26/2018 – 04/05/2018

AE over Water	Require.	NOAA20 (0.55 vs 0.86 µm)	NOAA20 (0.86 vs 1.61 µm)
Accuracy	0.3	0.05	-0.03
Precision	0.6	0.44	0.32
Number		86	58

Appendix A-6

- NDE I&T (NOAA-20) vs. AERONET **APS**; 03/20/2018 – 04/05/2018

AE over Water	Require.	NOAA20 (0.55 vs 0.86 µm)	NOAA20 (0.86 vs 1.61 µm)
Accuracy	0.3	-0.07	-0.04
Precision	0.6	0.46	0.28
Number		30	23

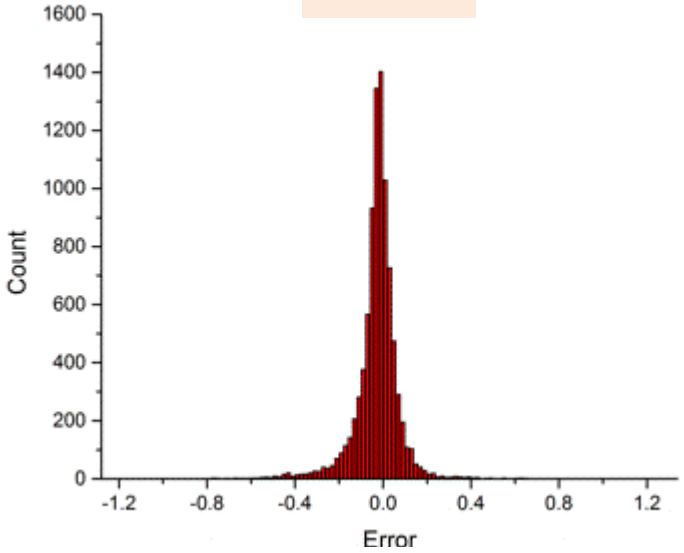
- Science Team (NOAA-20) vs. AERONET **APS**; 01/07/2018 – 04/01/2018

AE over Water	Require.	NOAA20 (0.55 vs 0.86 µm)	NOAA20 (0.86 vs 1.61 µm)
Accuracy	0.3	0.15	-0.01
Precision	0.6	0.48	0.28
Number		209	128

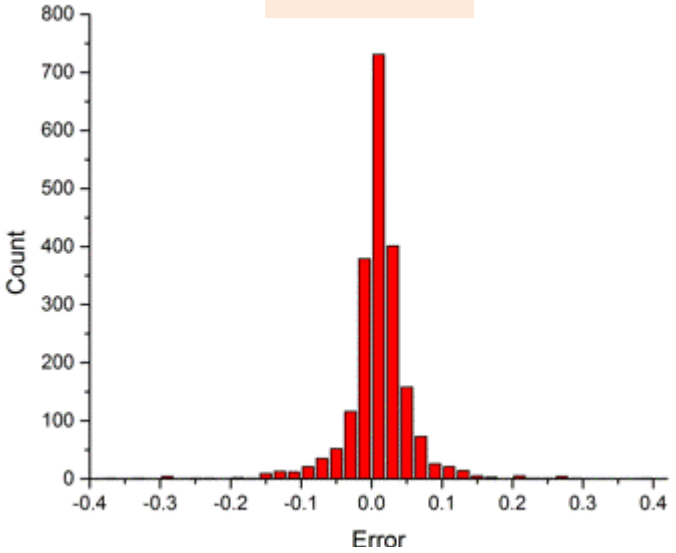
Appendix B-1: AOD Bias Histograms

NDE Ops (S-NPP)

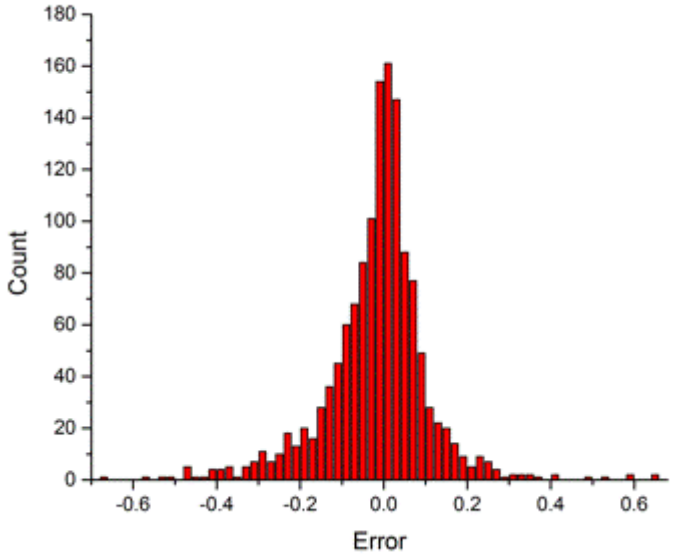
LAND

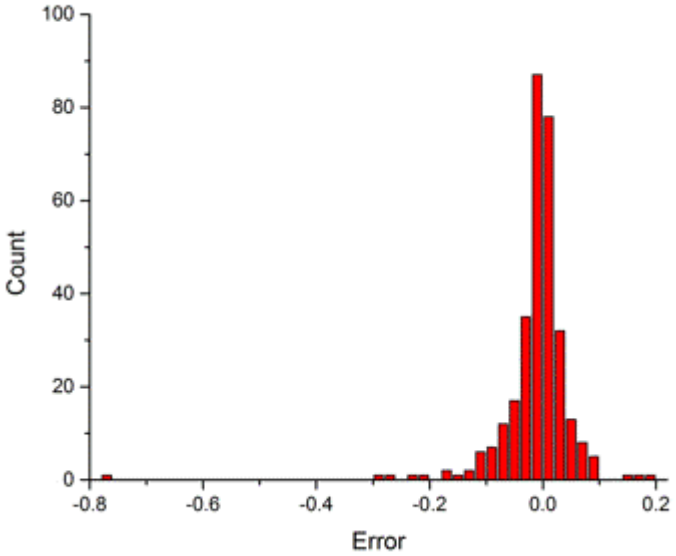


WATER



ASSISTT (NOAA-20)



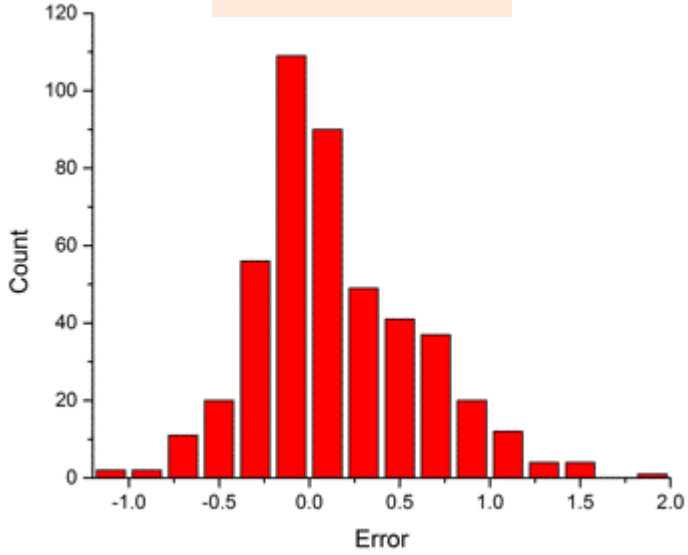


Appendix B-2: APS Error Histograms

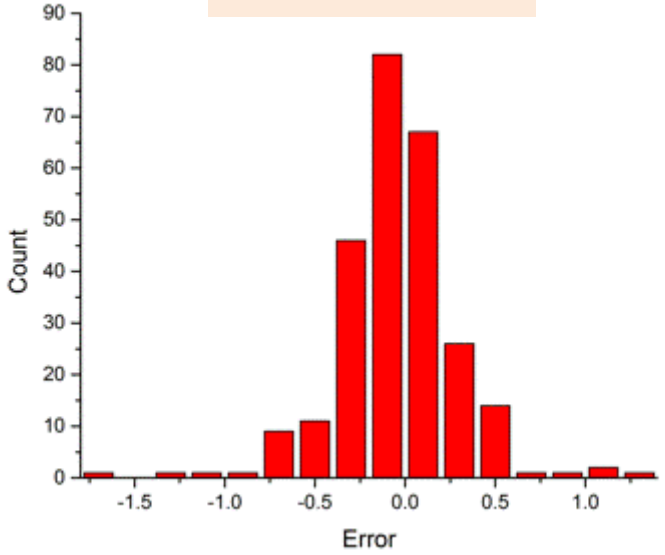
NDE Ops (S-NPP)

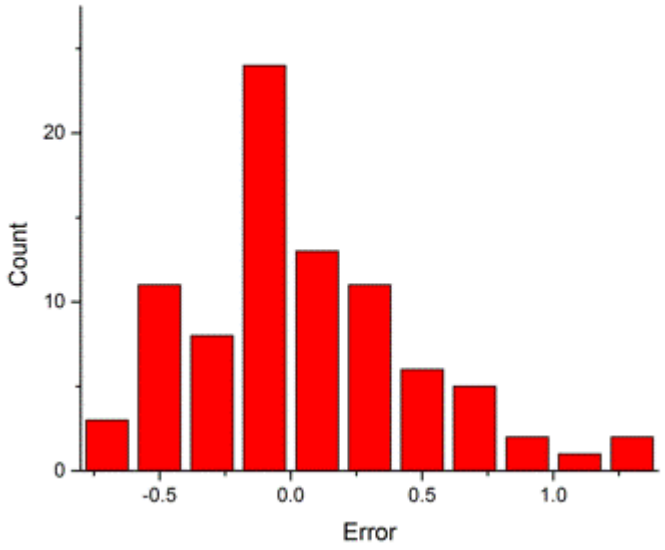
ASSISTT (NOAA-20)

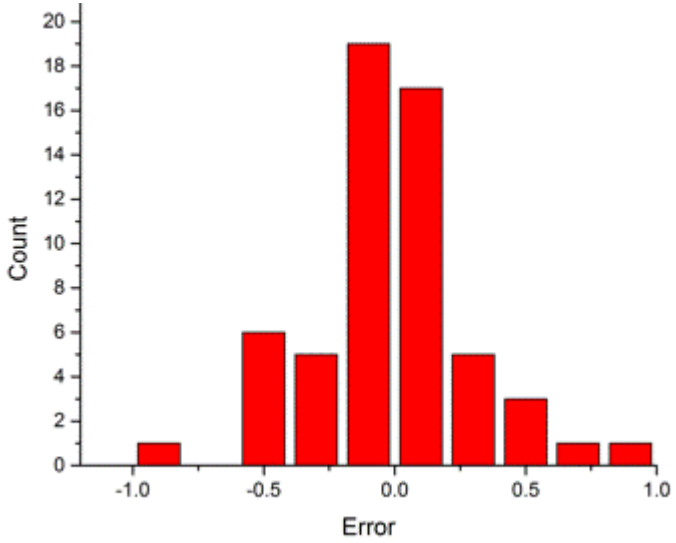
550/860 nm



860/1610 nm







Appendix C: Science Team NOAA-20 Retrieval Inputs

	Data	Comment
SDRs	Reflectance (M1-M11)	From NDE (via SCDR) Saturated reflectance at M6 is not used
	Brightness Temperature (M15, M16)	
Geo	Longitude, Latitude	From VIIRS terrain-corrected geolocation for M-bands (GMTCO)
	Solar/satellite Zenith/azimuth Angles	
Masks	Cloud	From VCM (VIMCO)
	Land/water	
	Snow/ice	
	Sunglint	
	Fire	
	Cloud Shadow	
	Heavy Aerosol	
Model	Total Precipitable Water	From GFS with spatial and temporal interpolation. Surface pressure is corrected to local elevation for each pixel.
	Column Ozone	
	Surface Pressure	
	Wind Speed/direction (10 meter above surface)	