2014 STAR JPSS Science Team Annual Meeting

The JPSS Risk Reduction Aerosol Algorithm

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Objectives

- Cross-platform consistency
  - Apply a single algorithm on JPSS and GOES-R
- Extensive internal tests
  - Minimize the dependence on external cloud mask
- Extending the range of aerosol optical thickness
  - Extend the retrievals for episodic aerosol events
- Address known issues in IDPS algorithm
  - Snow/ice contamination
  - Positive bias of Ångström Exponent over water
  - Globally constant land spectral reflectance ratios
  - Degraded or no retrievals over soil-dominated area
  - Negative bias for high AOT over land

Algorithm Comparison (Over Water)

	IDPS	NOAA
Internal Tests	Turbid water; Sun glint; Sea ice	Bright cloud; Cirrus; Sea ice; Spatial homogeneity; Turbid/shallow water; Heavy aerosol
Aerosol Models	MODIS C4	MODIS C5
Surface Reflectance	$R_f+R_u+R_s$	$R_f+(1-R_f)R_u+(1-W)R_s$ [Koepke, 1984]
AOT Range	[0.0, 2.0]	[-0.05, 5.0]
Channel Used	0.67, 0.74(saturation), 0.86, 1.24, 1.61, 2.25 μm	**0.55**, 0.67, 0.74(saturation), 0.86, 1.24, 1.61, 2.25 μm
Residual	$\sum_{\lambda=1}^{n}\left(\rho_\lambda^m-\rho_\lambda^{LUT}\right)^2$	$\sqrt{\sum_{\lambda=1}^{n}\left(\frac{\rho_\lambda^m-\rho_\lambda^{LUT}}{\rho_\lambda^m-\rho_\lambda^{Ray}+0.01}\right)^2}\Big/n$
Ångström Exponent	0.86 vs. 1.61 μm	0.55 vs. 0.86 μm 0.86 vs. 1.61 μm
Inland Lakes	No retrievals	Included

Algorithm Comparison (Over Land)

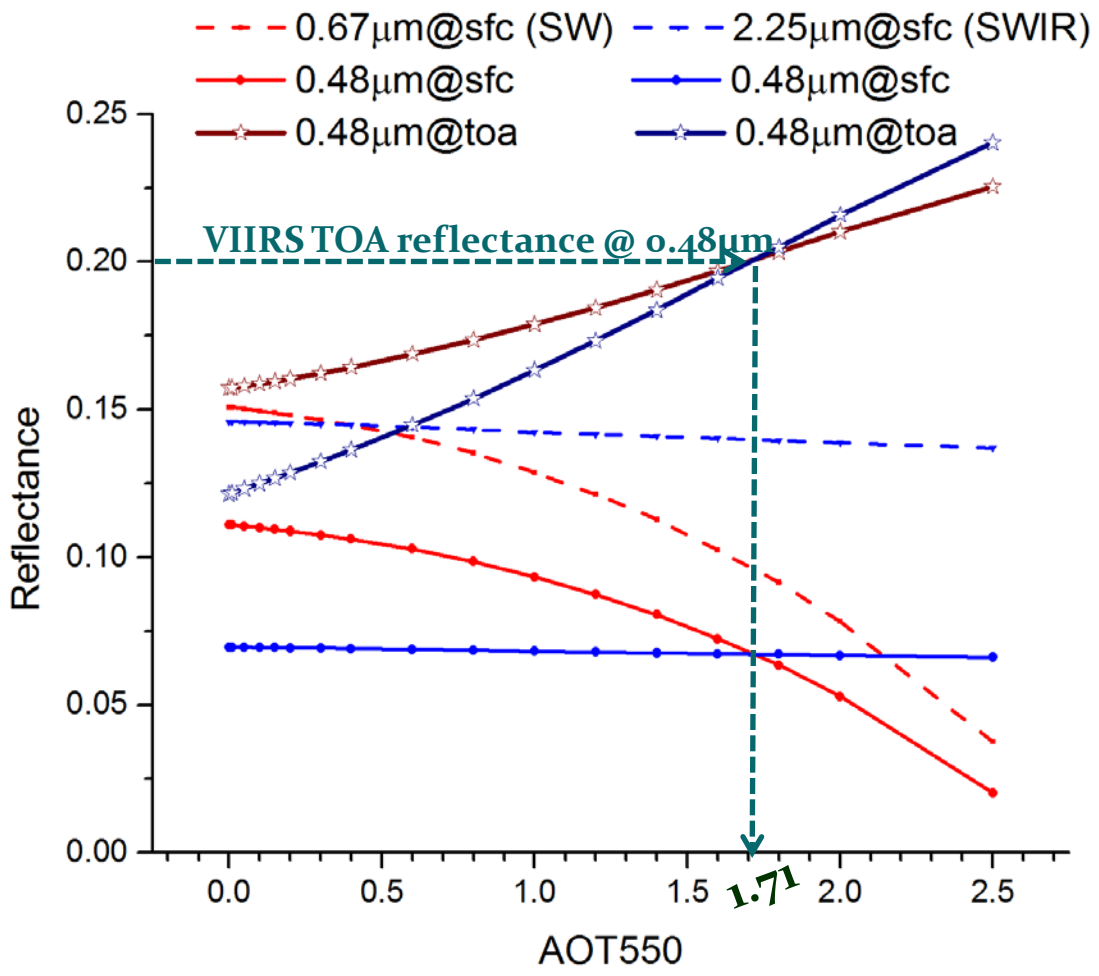
	IDPS	NOAA
Internal Tests	Cirrus; Sunglint; Fire; Snow; Ephemeral water	Cloud; Cirrus; Snow; Spatial homogeneity; Ephemeral water; Heavy aerosol
Aerosol Models	AERONET	MODIS C5
Surface Reflectance Spectral Relationship	Constant ratios	Linear relationship as functions of $NDVI_{SWIR}$ and scene redness
AOT Range	[0.0, 2.0]	[-0.05, 5.0]
Reference Channels	0.48 and 0.67 μm	0.48 and 0.67 μm (SW scheme) 0.48 and 2.25 μm (SWIR scheme)
Residual	$\sum_{\lambda=1}^{n}\left(\alpha_{\lambda}^{corr}-\alpha_{\lambda}^{est}\right)^2$	$\sqrt{\sum_{\lambda=1}^{n}\left(\frac{\rho_{\lambda}^{m}-\rho_{\lambda}^{LUT}}{\rho_{\lambda}^{m}-\rho_{\lambda}^{Ray}+0.01}\right)^2}\Big/n$
Ångström Exponent	Dictated by selected aerosol model	Independent channel retrieval

Land Aerosol Algorithm

- IDPS VIIRS (SW scheme)
  - Surface reflectance at 0.48μm is estimated from 0.67μm
  - Pros: robust spectral surface reflectance relationship
  - Cons: strong atmospheric effect
  - Better performance at low AOTs
- MODIS/ABI (SWIR scheme)
  - Surface reflectance at 0.48μm is estimated from 2.25μm
  - Pros: transparent atmosphere at 2.25μm
  - Cons: uncertain spectral surface reflectance relationship
  - Better performance at high AOTs
- JPSS Risk Reduction Aerosol Algorithm (NOAA VIIRS)
  - SW scheme as the first choice
  - Apply SWIR algorithm if
    - Invalid retrievals from SW scheme
    - Surface reflectance at 0.48μm is out of uncertainty range
  - Surface spectral reflectance relationship are linear functions of redness ratio (TOA M5/M4 reflectance ratio) and $NDVI_{SWIR}$ (TOA M8-M11/M8+M11)

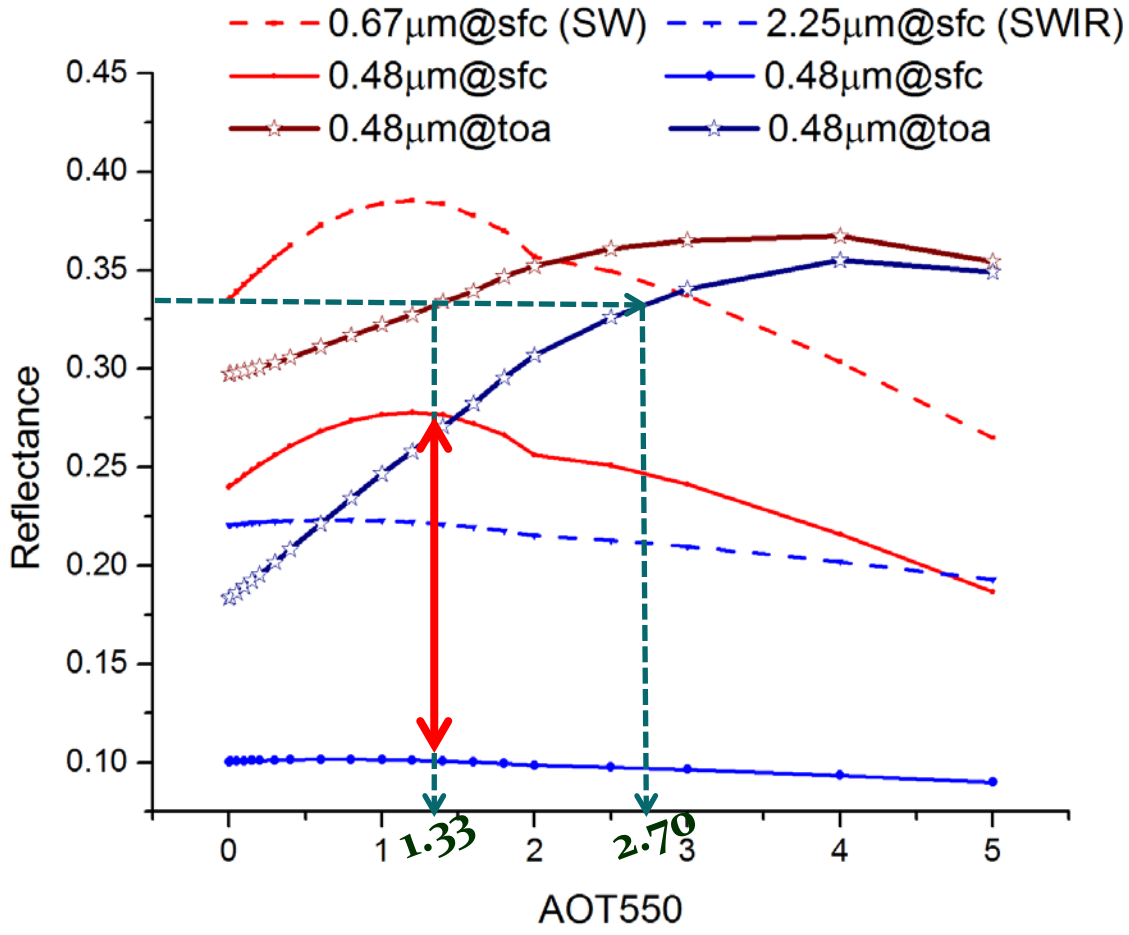
    $Y = (c_1+c_2*\text{Redness}+c_3*NDVI_{SWIR}) + (c_4+c_5*\text{Redness}+c_6*NDVI_{SWIR})*X$

Land Aerosol Algorithm (Cont.)



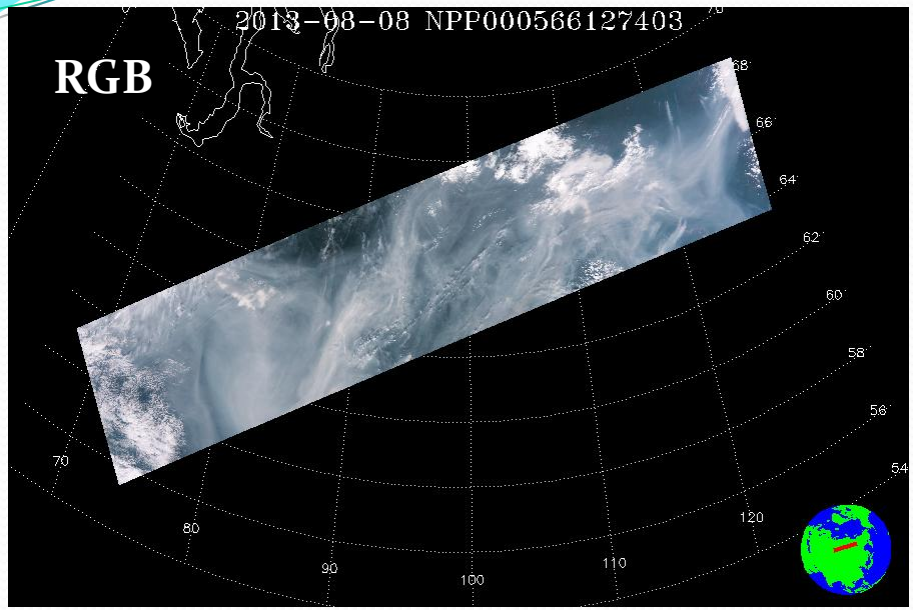
- Measurement
  - AERONET station: Taihu (China)
  - June 9, 2012
  - τ_{550} =1.71
- Retrieval
  - Urban aerosol model
  - τ_{550} =1.71 from both SW and SWIR schemes

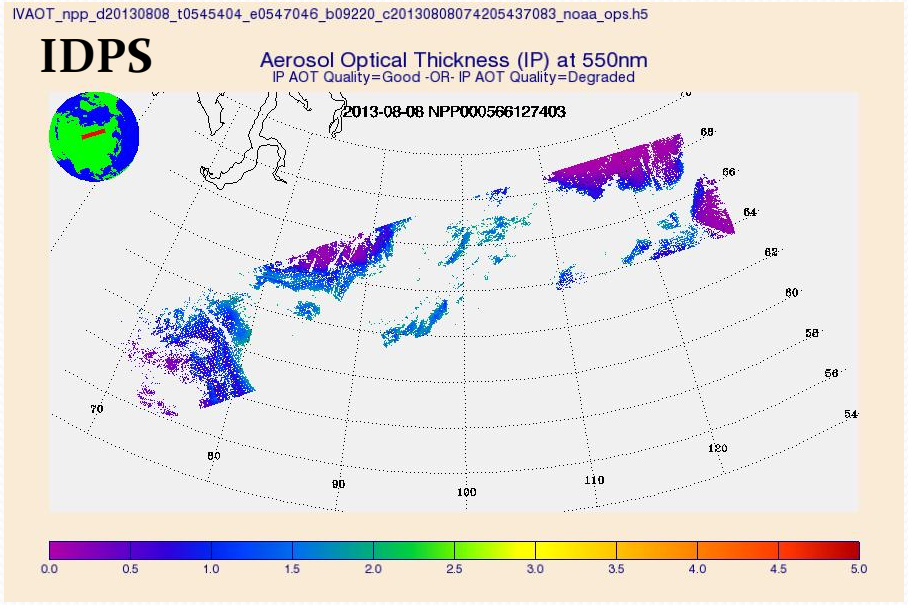
Land Aerosol Algorithm (Cont.)

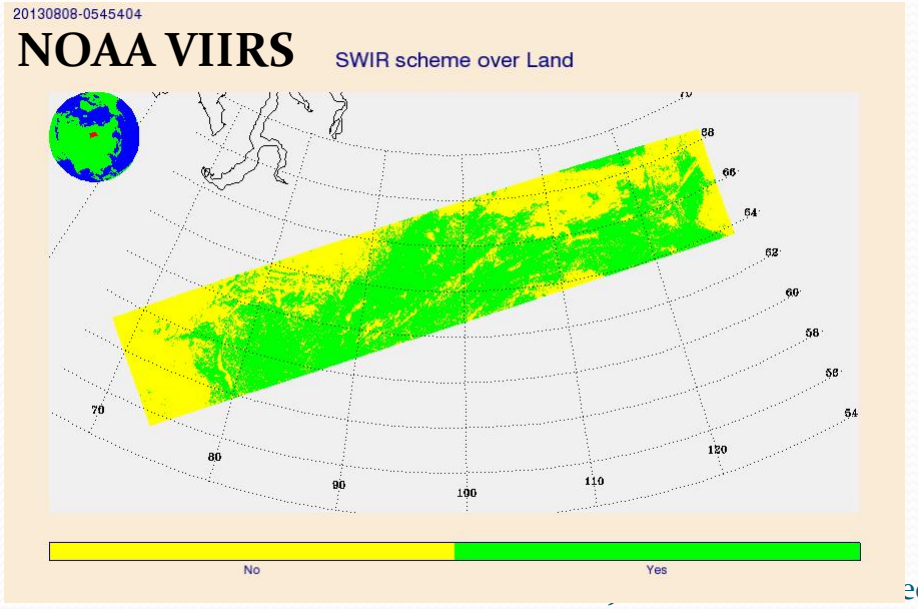


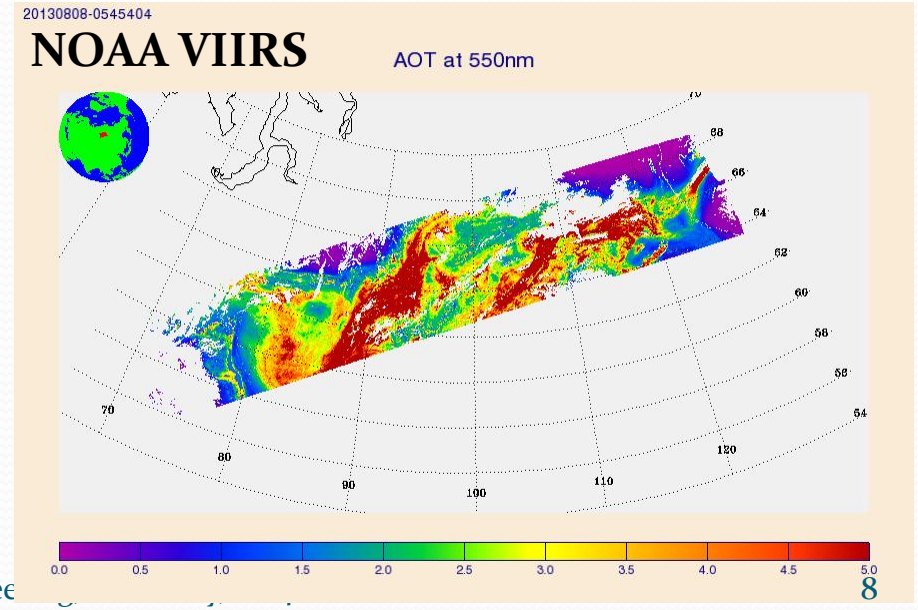
- Measurement
  - AERONET station: Karachi (Pakistan)
  - June 6, 2012
  - τ_{550} =2.70
- Retrieval
  - Generic aerosol model
  - τ_{550} =1.33 from SW scheme
  - τ_{550} =2.70 from SWIR scheme

Land Aerosol Algorithm (Example)









Local Retrievals

- Local retrievals with JPSS Risk Reduction Aerosol Algorithm
  - Global retrievals (74 days)
    - 03/01/2013 – 03/01/2014; every 5 days
    - Wider spatial coverage from RR algorithm

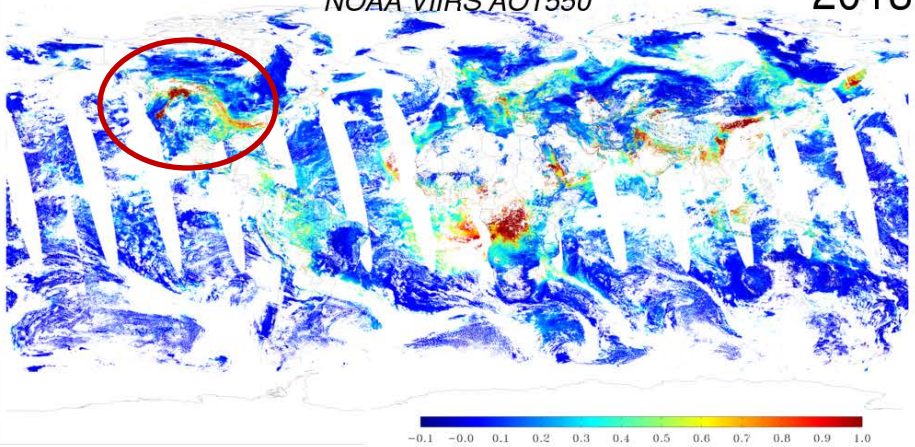
Spatial Coverage	N_{NOAA}/N_{IDPS}	N_{NOAA}/N_{MODIS}
Over Land	1.62±0.13	4.79±0.49
Over Ocean	1.04±0.08	2.73±0.17

Spatial coverage is evaluated by counting the number of 0.1° grids containing retrievals

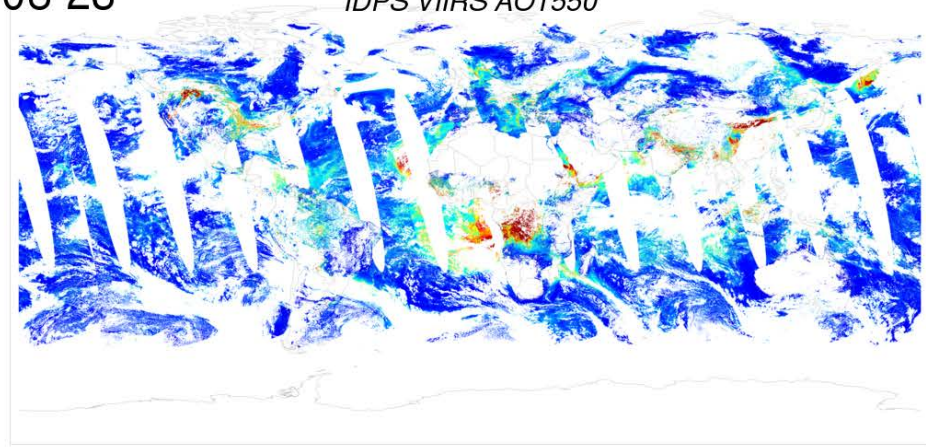
  - Retrievals over AERONET match-ups
    - 05/02/2012 – 03/31/2014
    - Satellite retrievals within 20km-radius circle (centered on stations)
    - AERONET measurements within one-hour window (centered on satellite overpass time)

2013 08 23

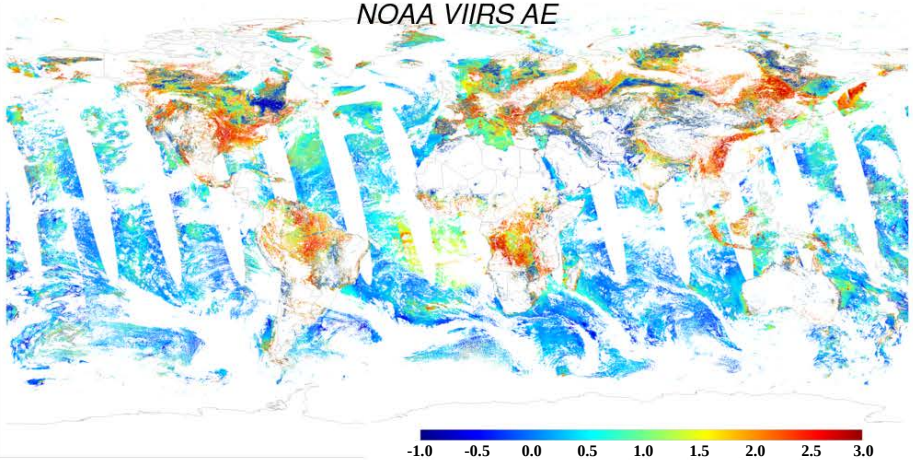
NOAA VIIRS AOT550



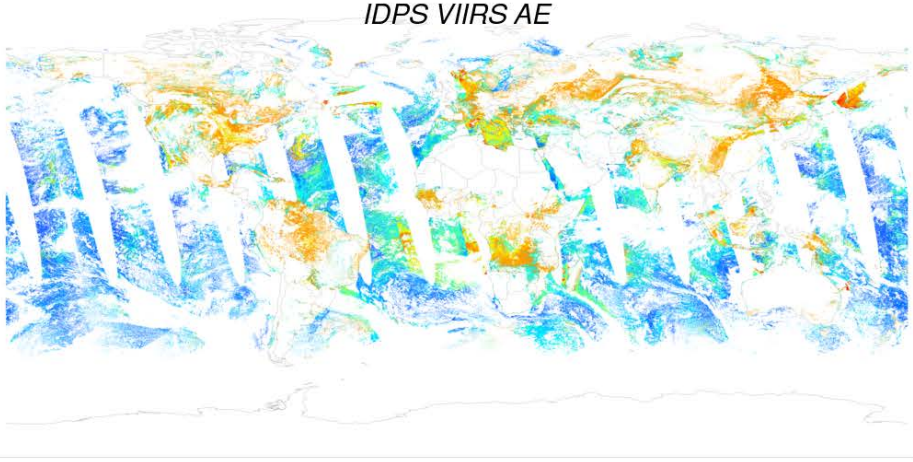
IDPS VIIRS AOT550



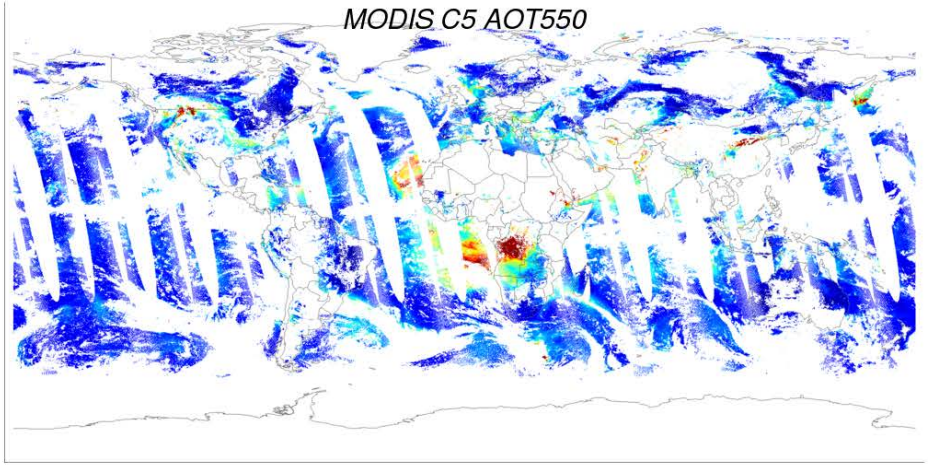
NOAA VIIRS AE



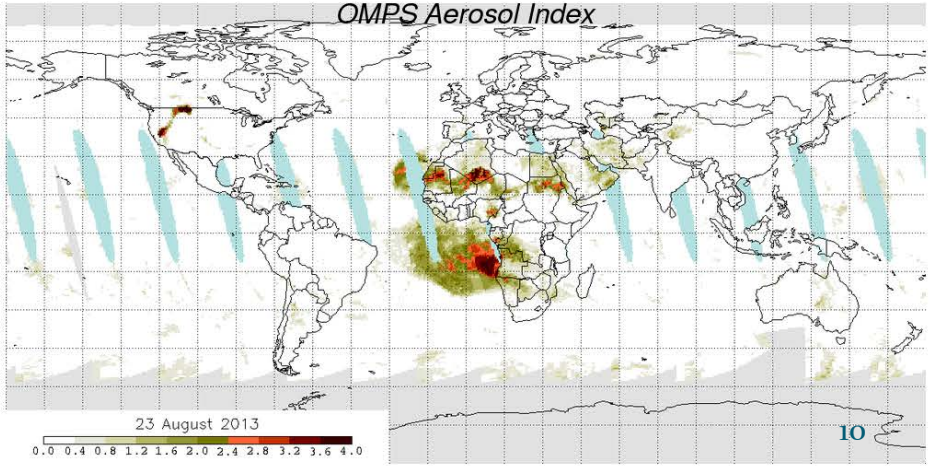
IDPS VIIRS AE



MODIS C5 AOT550



OMPS Aerosol Index



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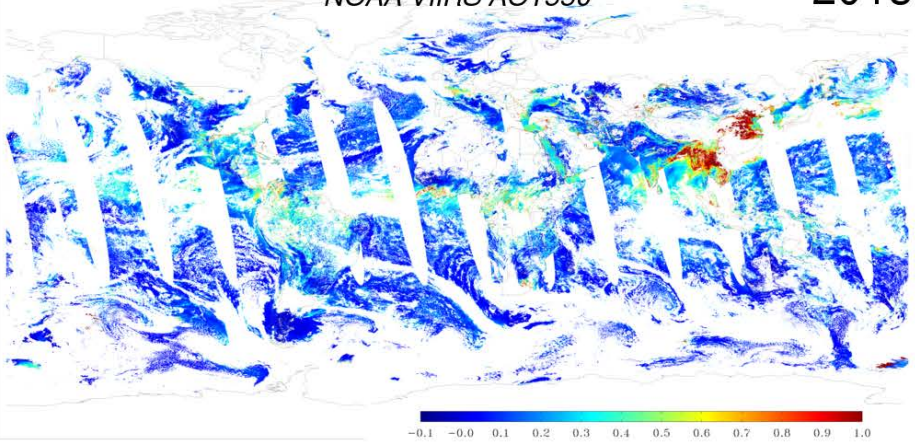
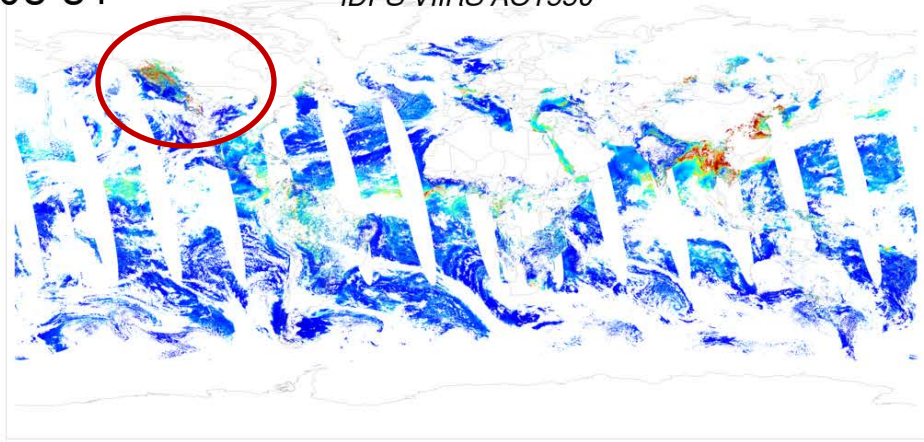
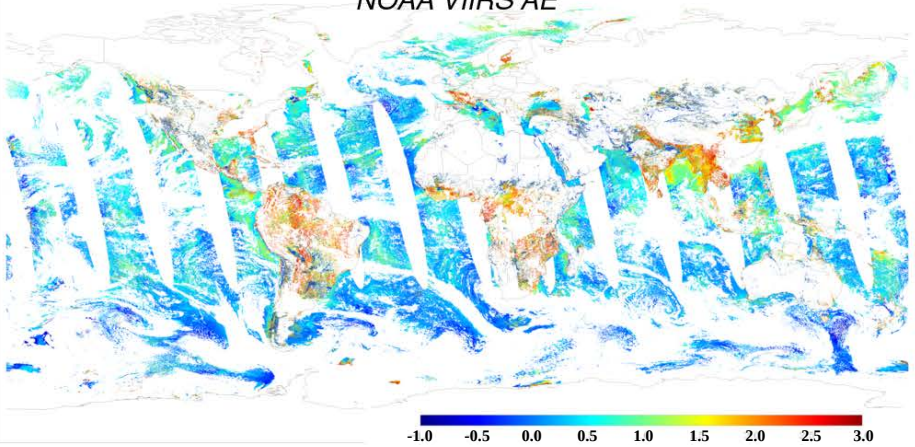
NOAA VIIRS AOT550



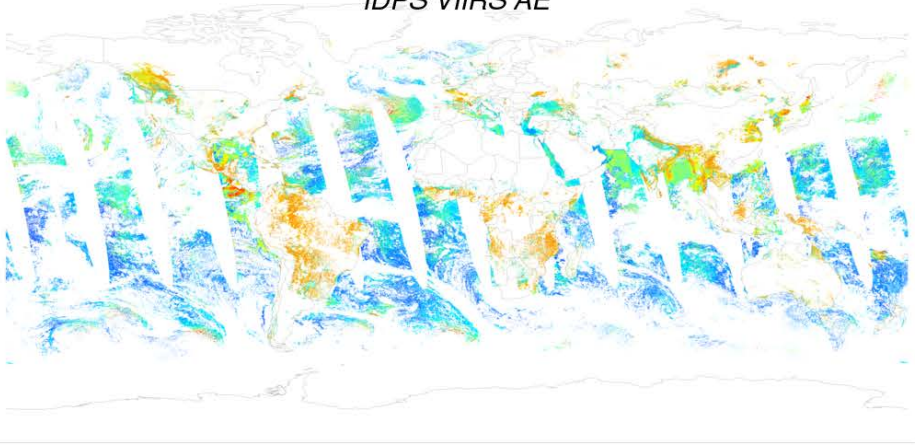
IDPS VIIRS AOT550



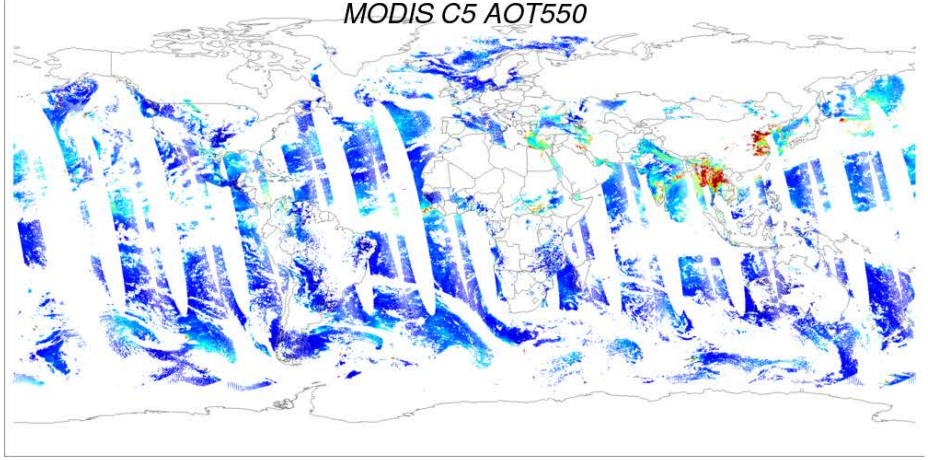
NOAA VIIRS AE



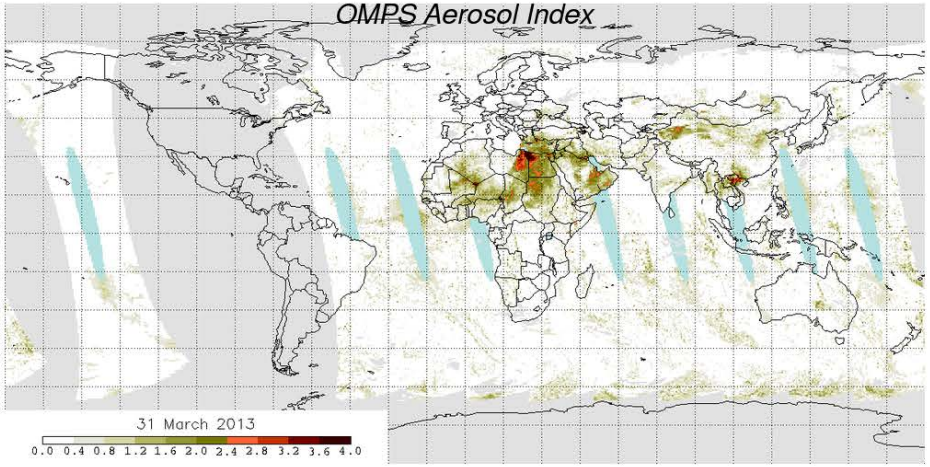
IDPS VIIRS AE



MODIS C5 AOT550

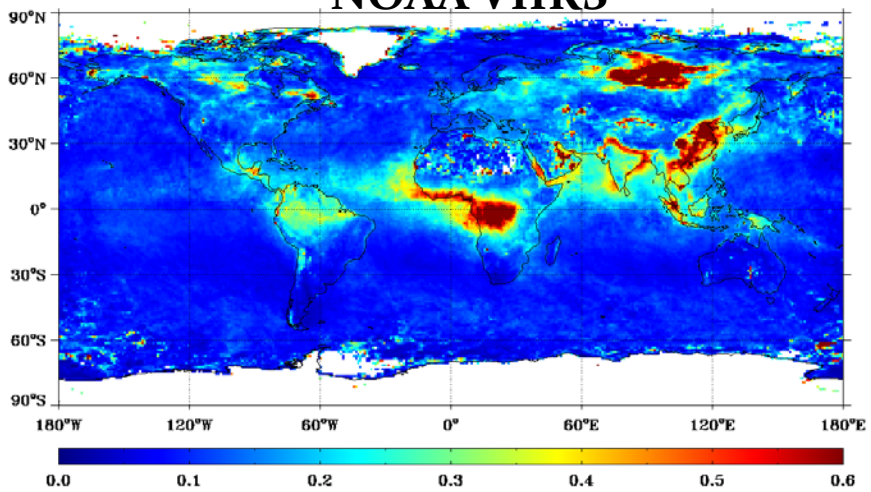


OMPS Aerosol Index

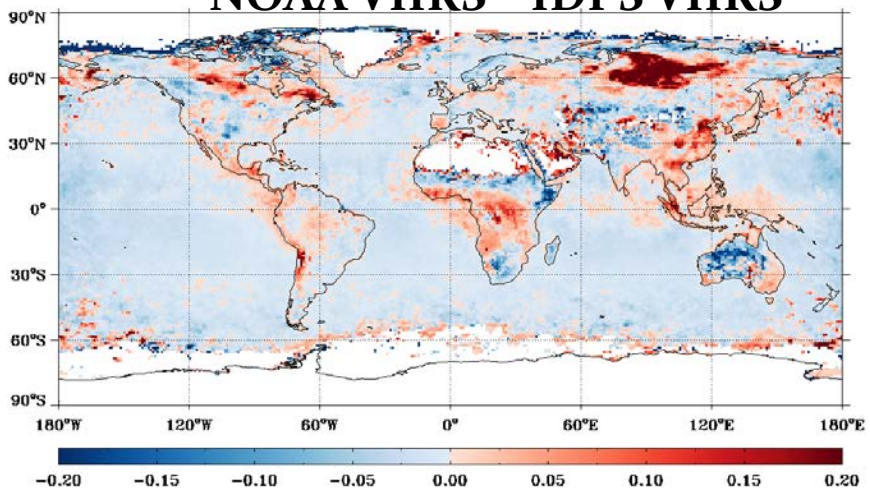


Global 1° Gridded

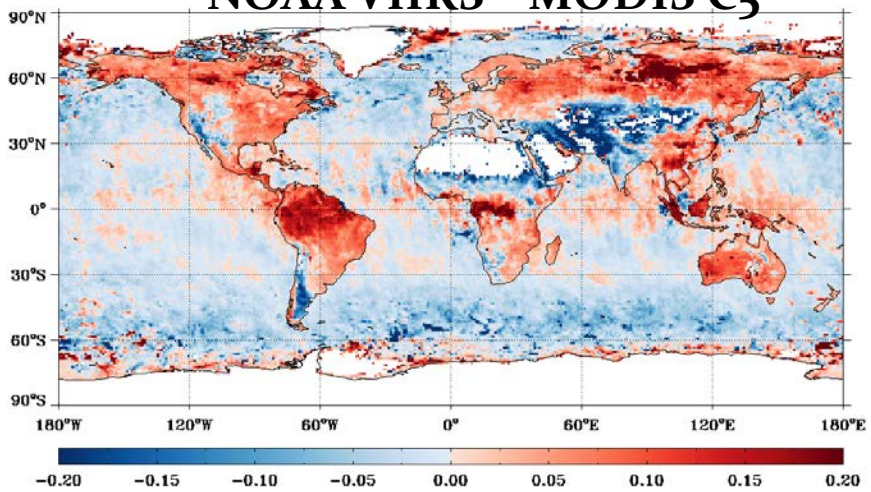
NOAA VIIRS



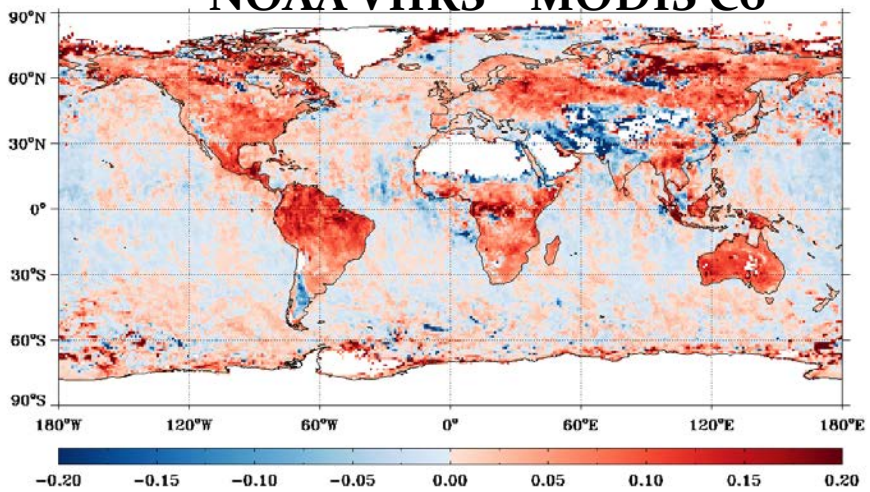
NOAA VIIRS – IDPS VIIRS



NOAA VIIRS – MODIS C5

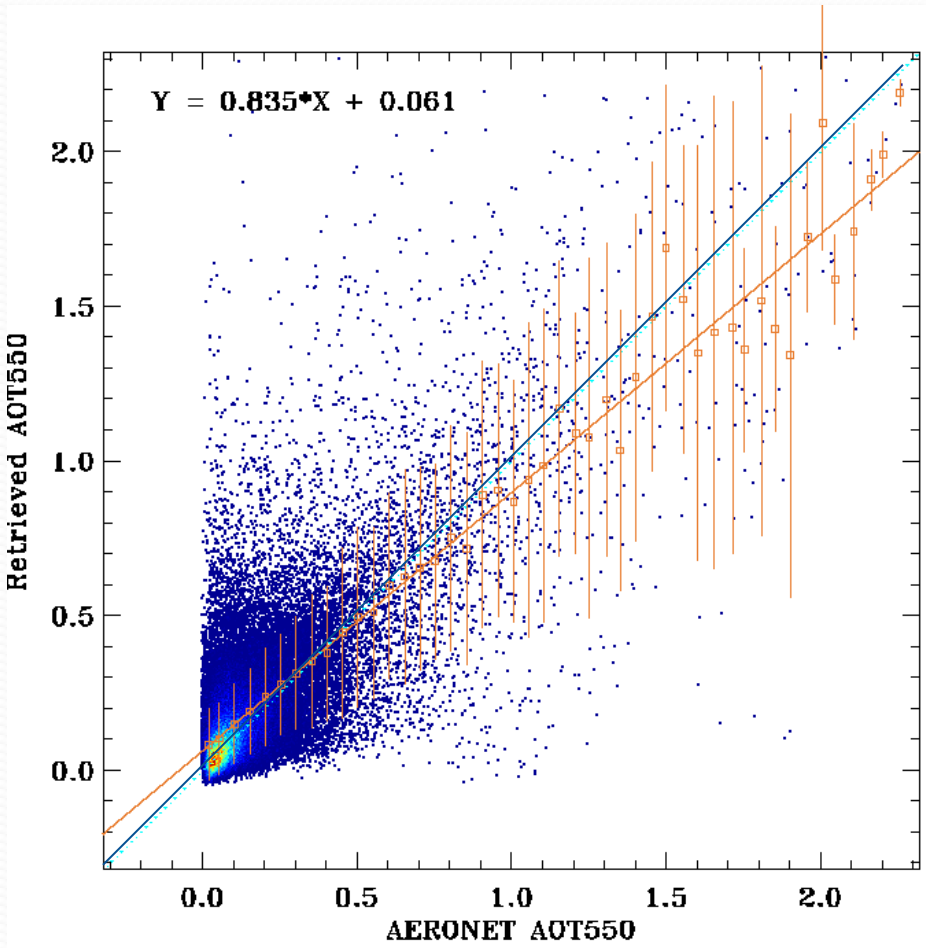


NOAA VIIRS – MODIS C6

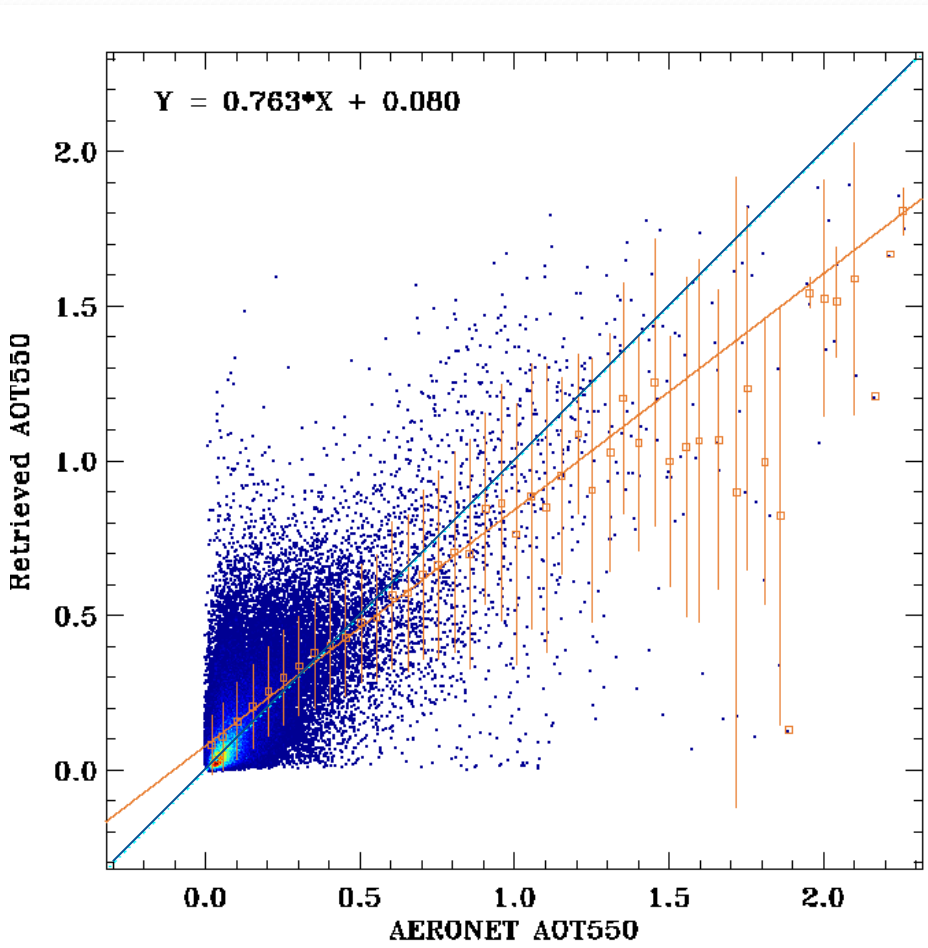


Validation Over Land

NOAA VIIRS



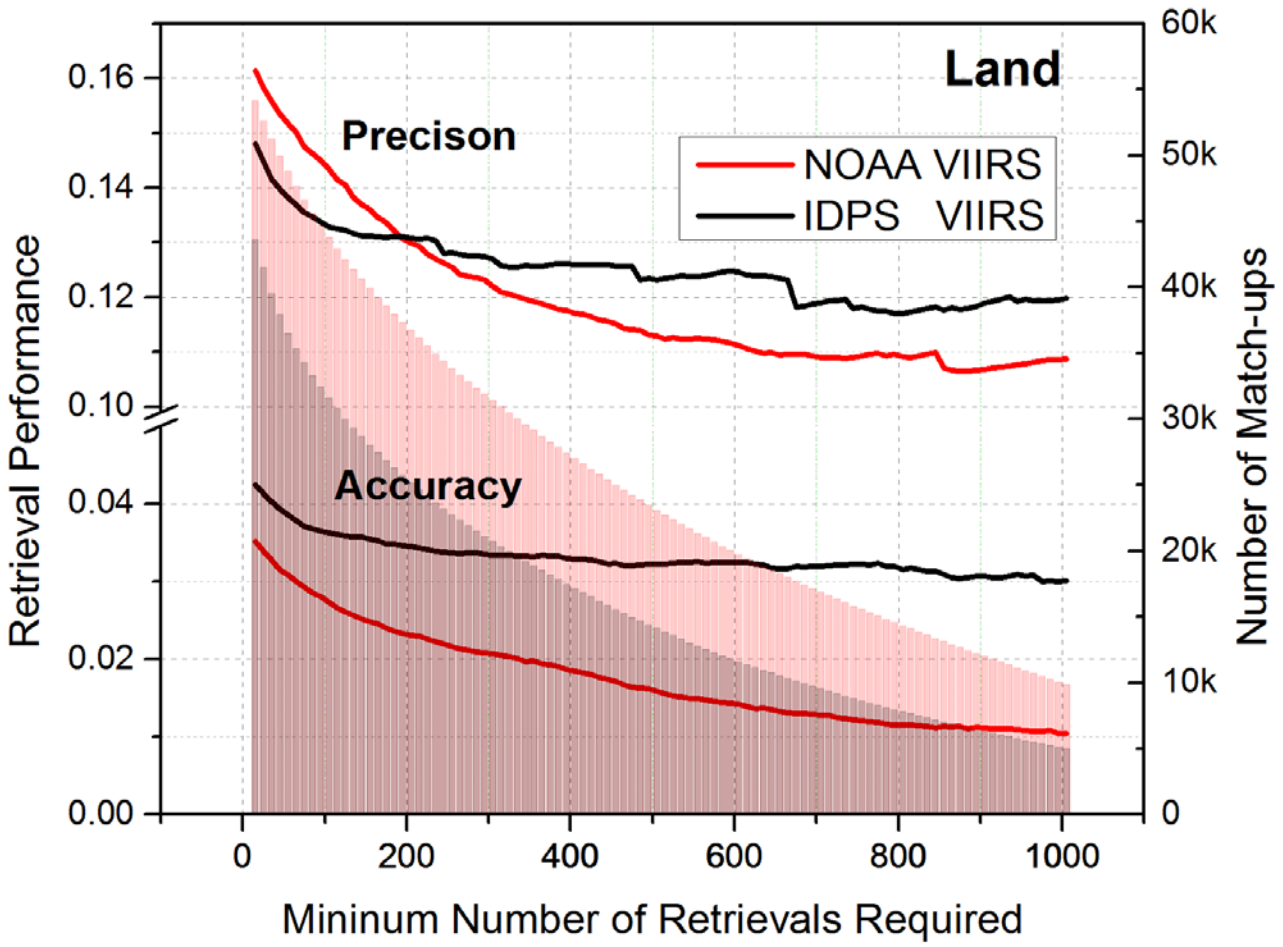
IDPS VIIRS



Statistics

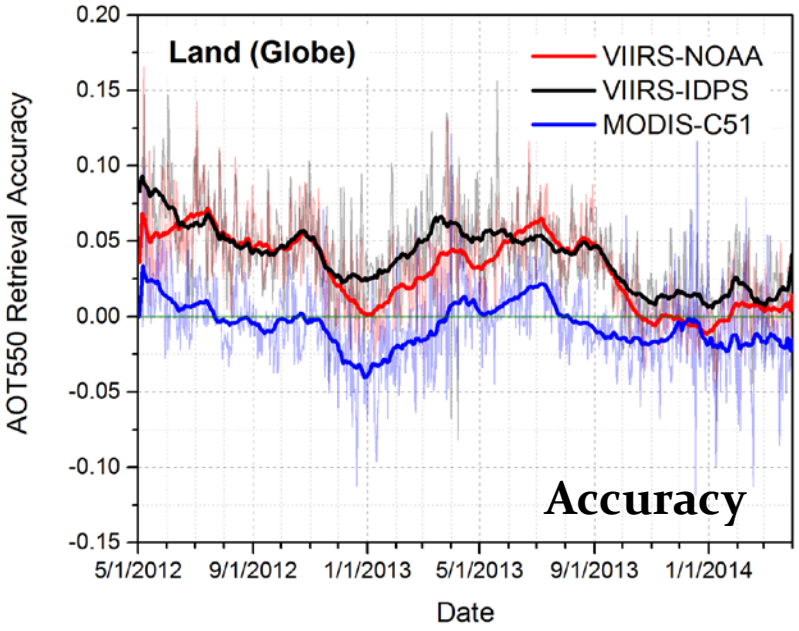
LAND		NOAA-VIIRS	IDPS-VIIRS	Requirement
<0.1	Accuracy	0.05	0.05	0.06
	Precision	0.12	0.11	0.15
	Number	27,174	21,107	
[0.1, 0.8]	Accuracy	0.03	0.04	0.05
	Precision	0.17	0.15	0.25
	Number	26,079	21,861	
>0.8	Accuracy	-0.12	***-0.22***	0.20
	Precision	***0.49***	***0.46***	0.45
	Number	887	666	
All	Accuracy	0.04	0.04	
	Precision	0.16	0.15	
	Number	54,140	43,634	

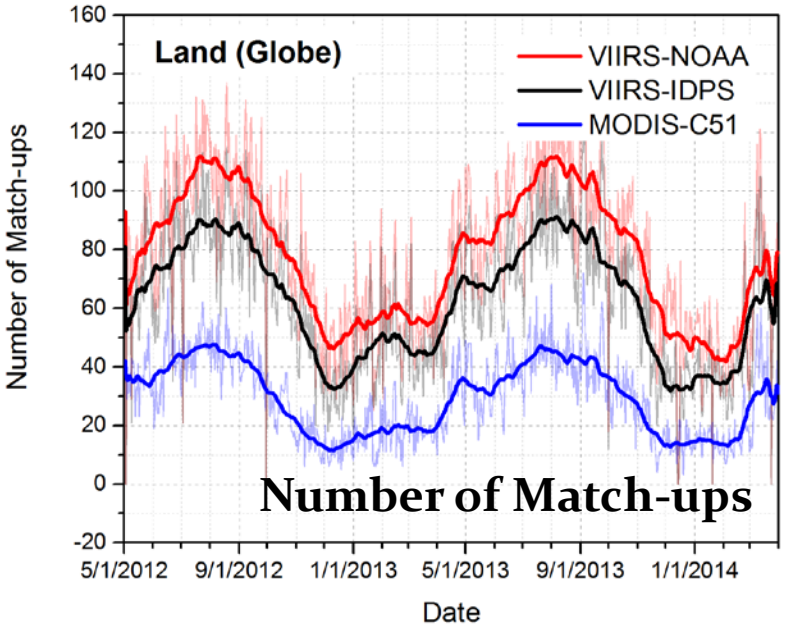
Sampling Issue in Validation

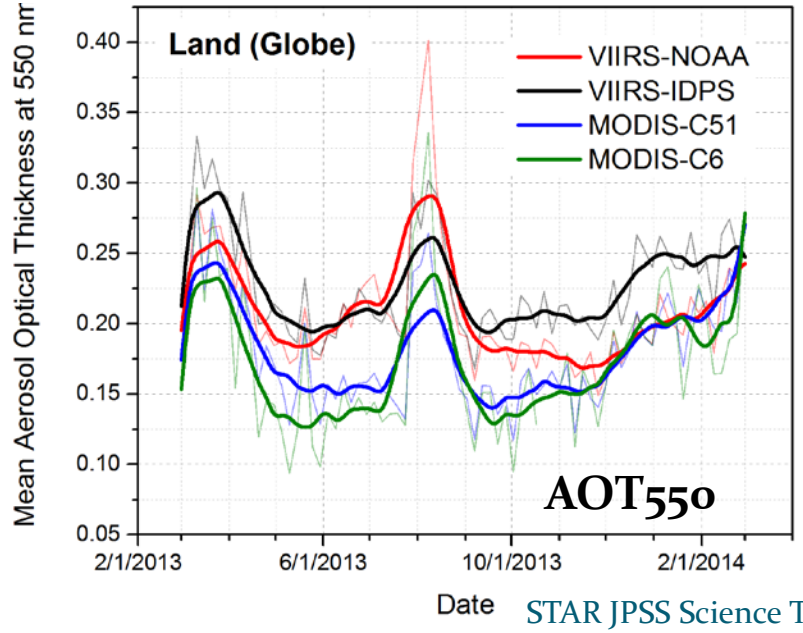


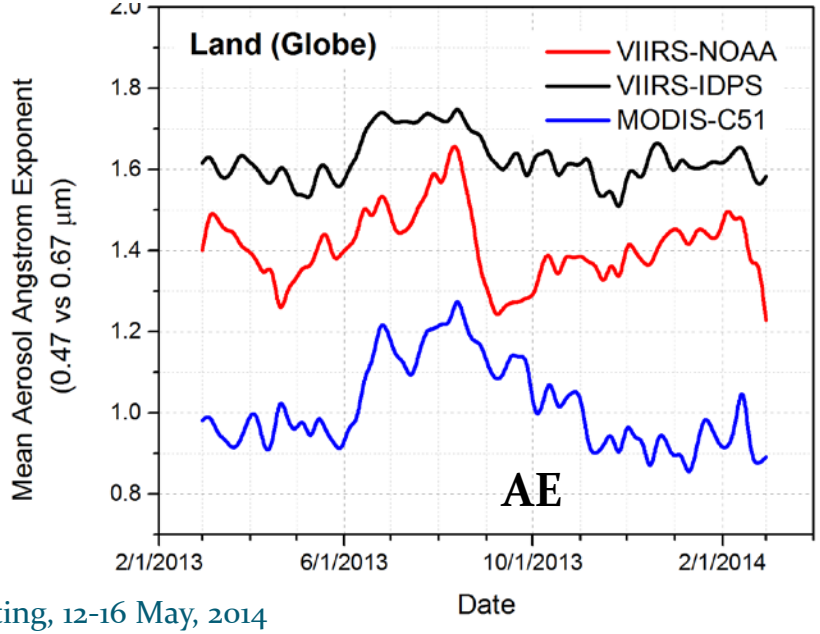
- As many as ~2100 pixels within the 20km-radius-circle matching domain.
- Validation requires at least **15** satellite retrievals (<1%).
- Statistics improve as the required minimum number of retrieval increases.
- RR algorithm outperforms the IDPS if minimum number of retrievals is higher than 200.

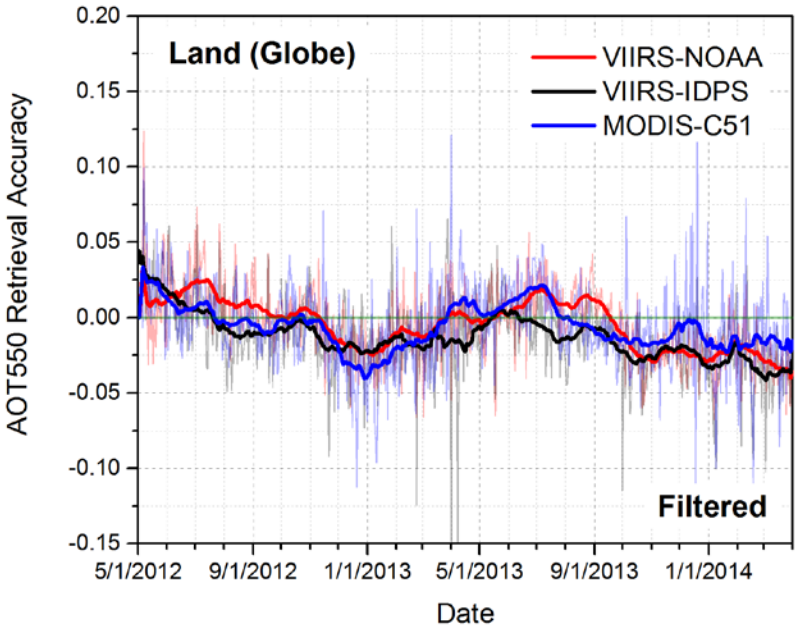
Time Series

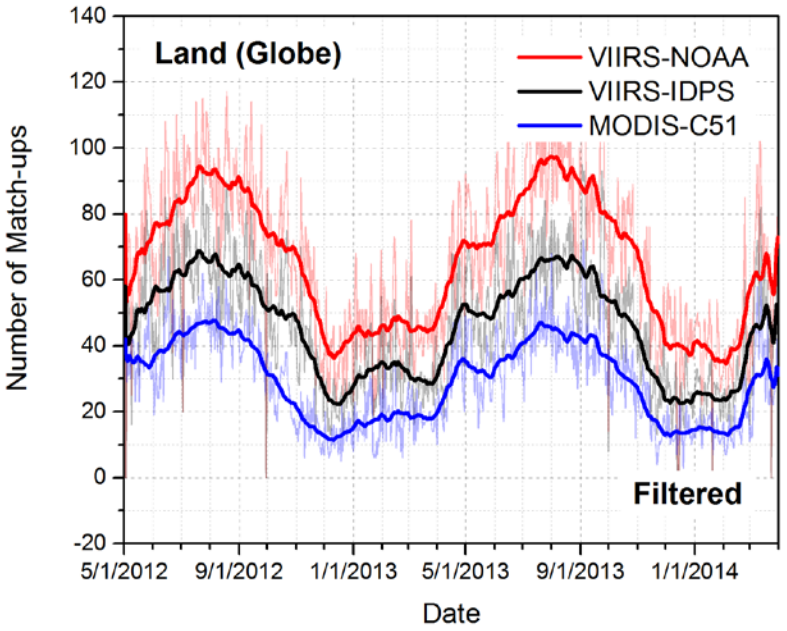

Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
AOT550 Retrieval Accuracy
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date
Accuracy


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Number of Match-ups
160
140
120
100
80
60
40
20
0
-20
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date
Number of Match-ups


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
Mean Aerosol Optical Thickness at 550 nm
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AOT550


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Mean Aerosol Angstrom Exponent
(0.47 vs 0.67 μm)
1.8
1.6
1.4
1.2
1.0
0.8
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AE





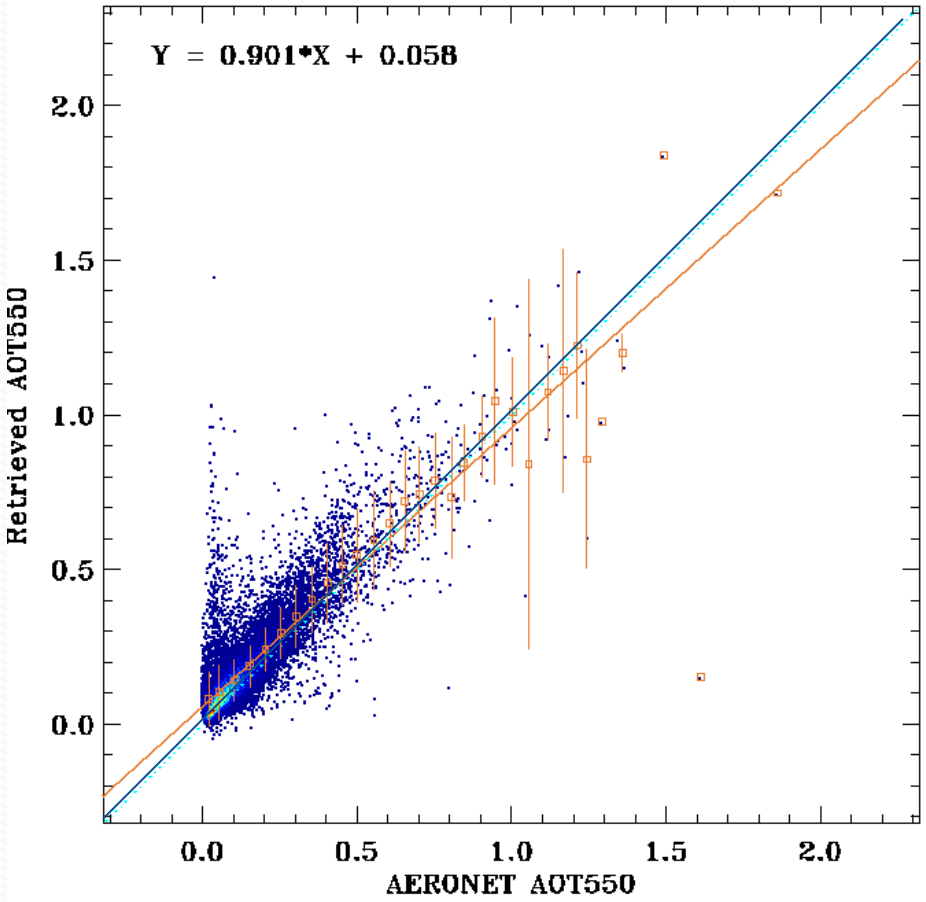
VIIRS pixel level retrievals are filtered before averaging in order to be comparable with MODIS products:

- Requiring at least 100 pixel retrievals within 20km-radius-circle matching domain.
- Discarding the highest 40% and lowest 20% AOTs in spatial averaging.
- Number of match-ups:

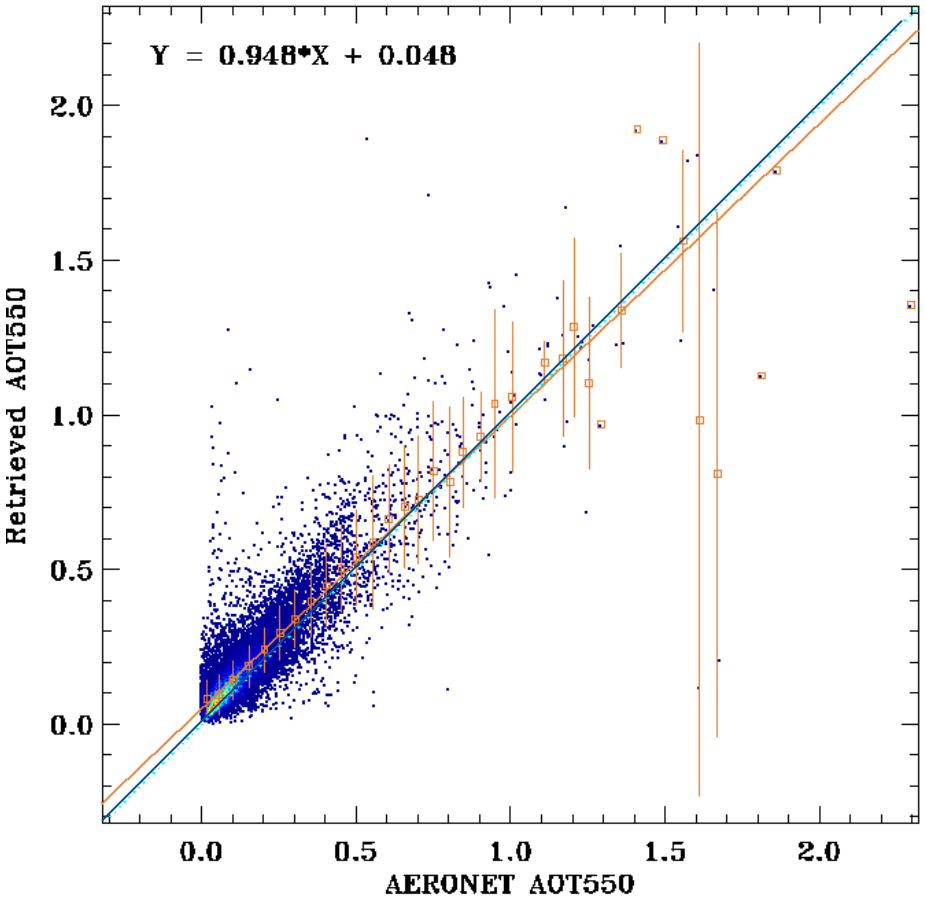
  VIIRS-NOAA: 45,855
  VIIRS-IDPS: 31,889
  MODIS-C51: 20,422

Validation Over Ocean

NOAA VIIRS



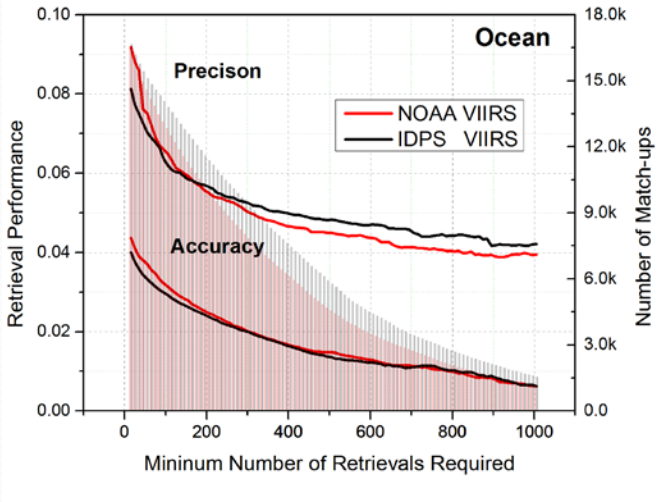
IDPS VIIRS



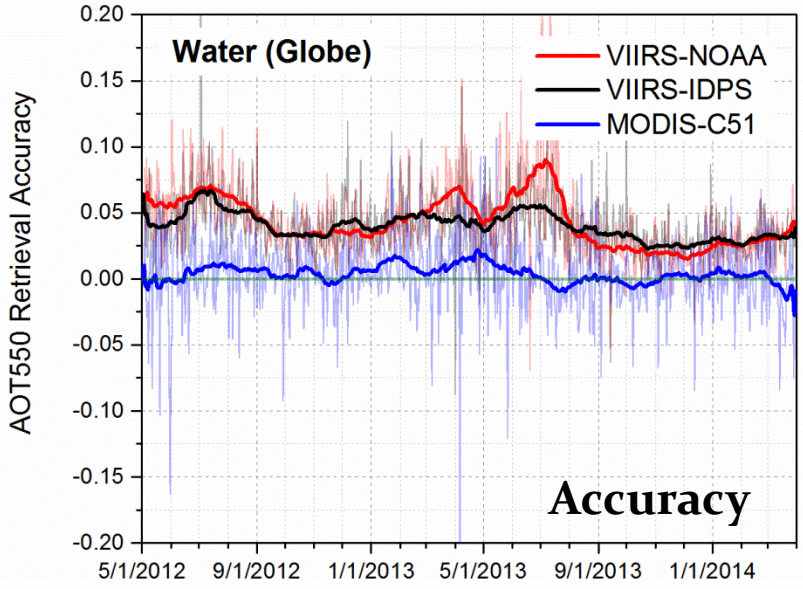
Statistics

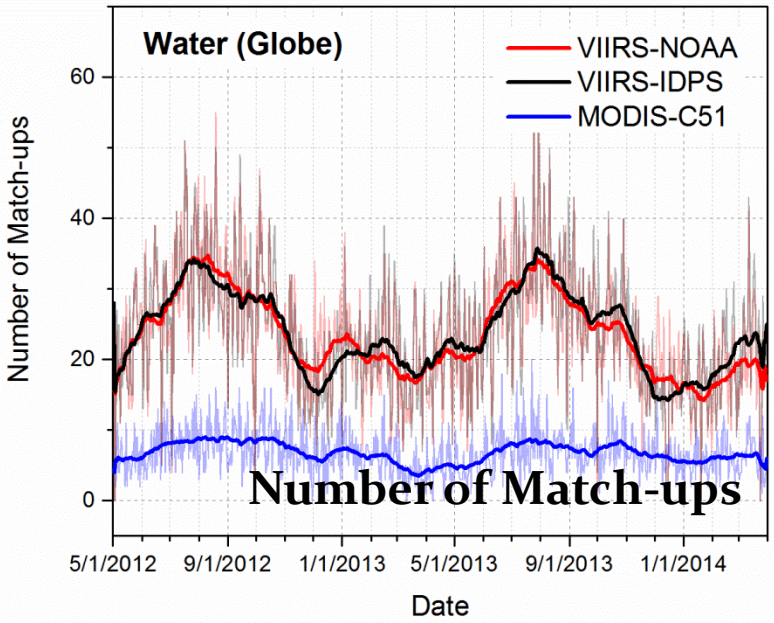
Ocean		NOAA-VIIRS	IDPS-VIIRS	Requirement
<0.3	Accuracy	0.04	0.04	0.08
	Precision	0.08	0.07	0.15
	Number	14,851	14,939	
>=0.3	Accuracy	0.04	0.04	0.15
	Precision	0.18	0.16	0.35
	Number	1,603	1,722	
All	Accuracy	0.04	0.04	
	Precision	0.09	0.08	
	Number	16,454	16,661	

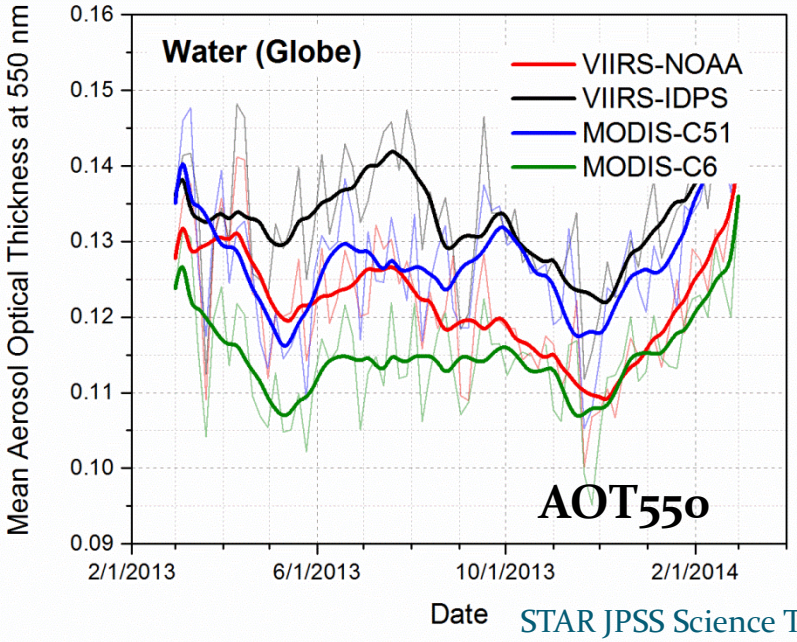
- Statistics can be a function of minimum number of retrievals (MN) required for matching.
- RR algorithm has a slightly higher precision if MN>200

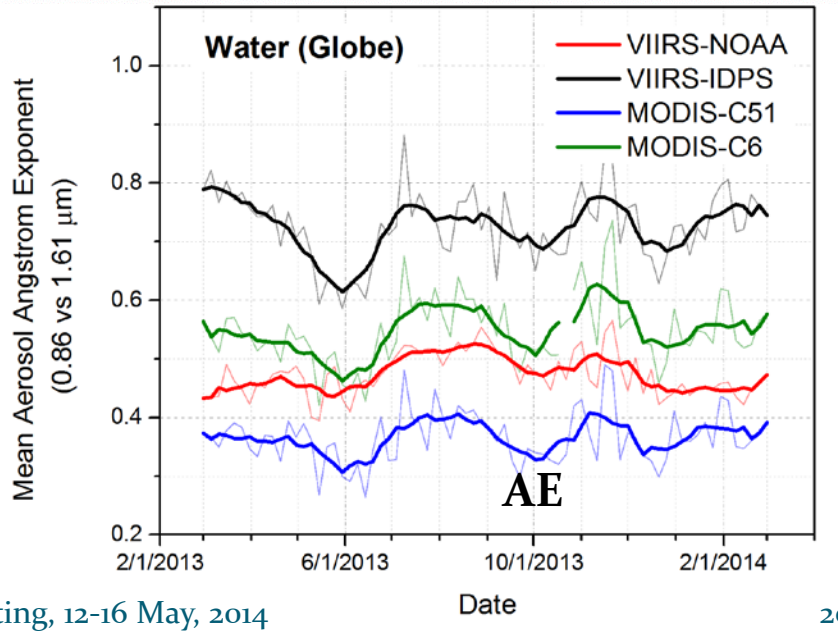


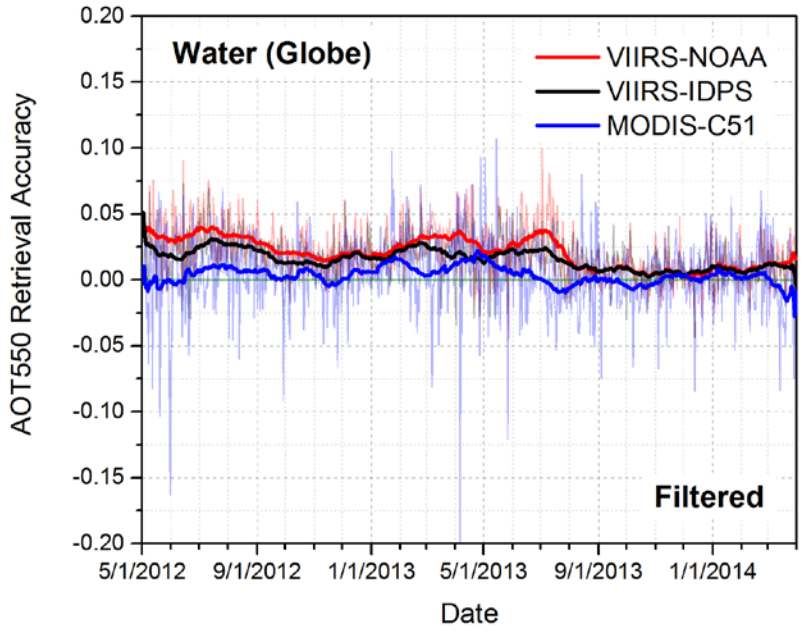
Time Series

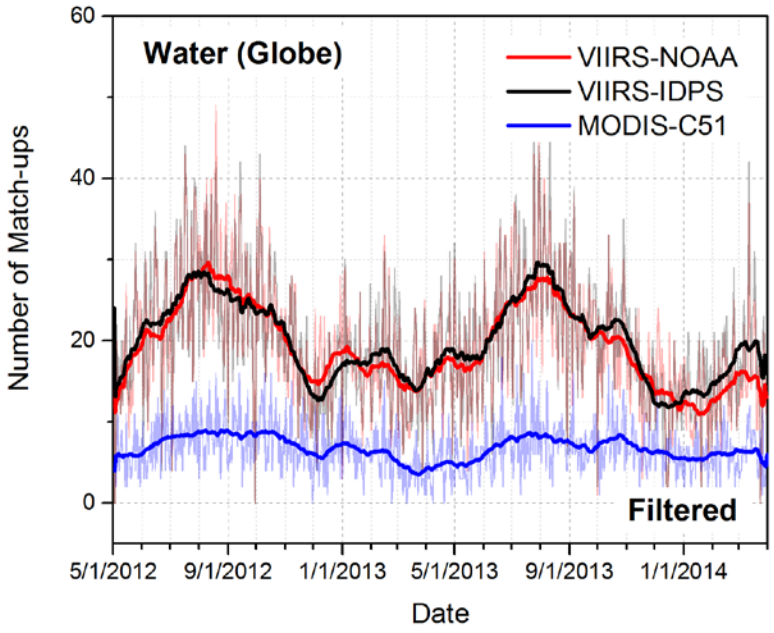

Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
AOT550 Retrieval Accuracy
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Accuracy


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Number of Match-ups
60
40
20
0
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date
Number of Match-ups


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
Mean Aerosol Optical Thickness at 550 nm
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AOT550


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
Mean Aerosol Angstrom Exponent
(0.86 vs 1.61 μm)
1.0
0.8
0.6
0.4
0.2
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AE





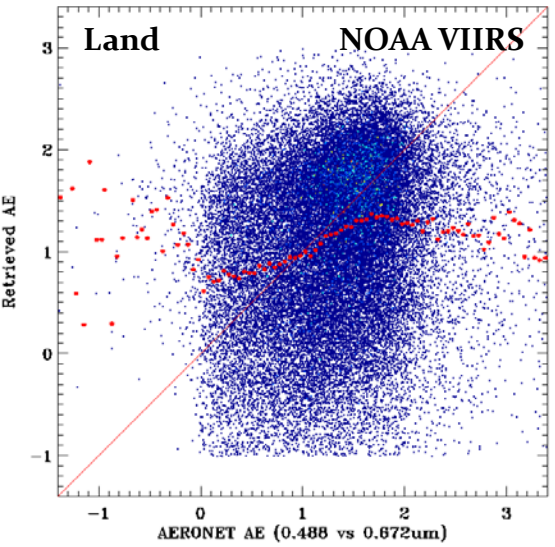
- Requiring at least 100 pixel retrievals with 20km-radius-circle matching domain.
- Discarding the highest 40% and lowest 20% AOTs in spatial averaging.
- Number of match-ups:

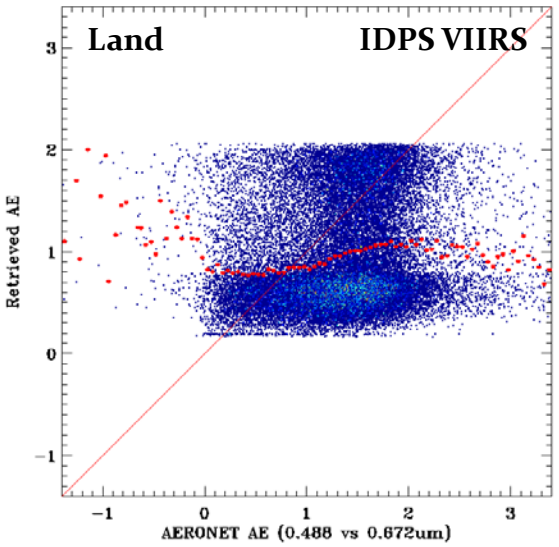
  VIIRS-NOAA: 13496
  VIIRS-IDPS: 13905
  MODIS-C51: 4745

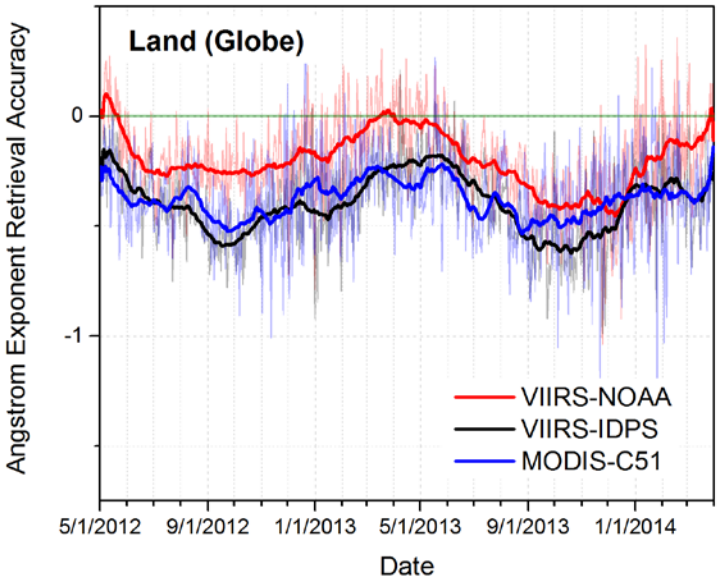
Aerosol Ångström Exponent

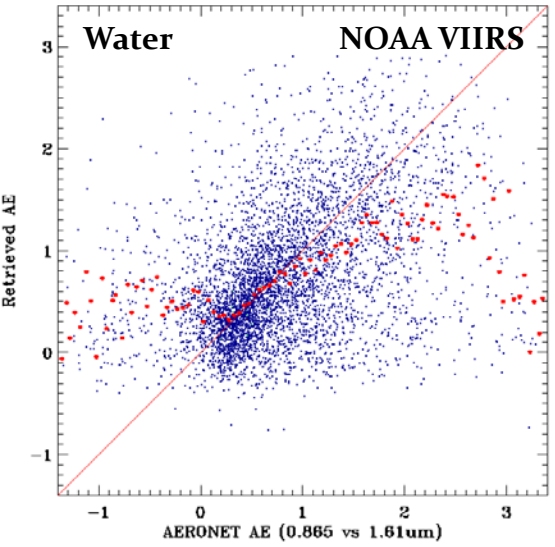
- Independent channel retrieval
  - Spectral AOTs are retrieved from corresponding channels
  - Assign aerosol model as the one selected from the AOT550 retrieval

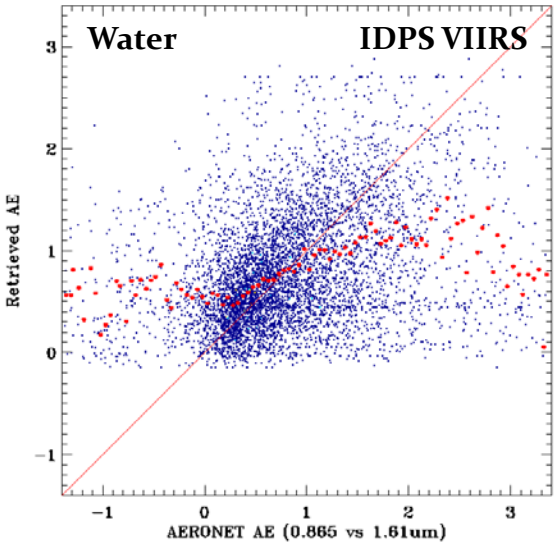
- Output the spectral AOTs at VIIRS channels calculated from the retrieved AOT550 and selected aerosol model
  - Can be used to calculate Ångström Exponent

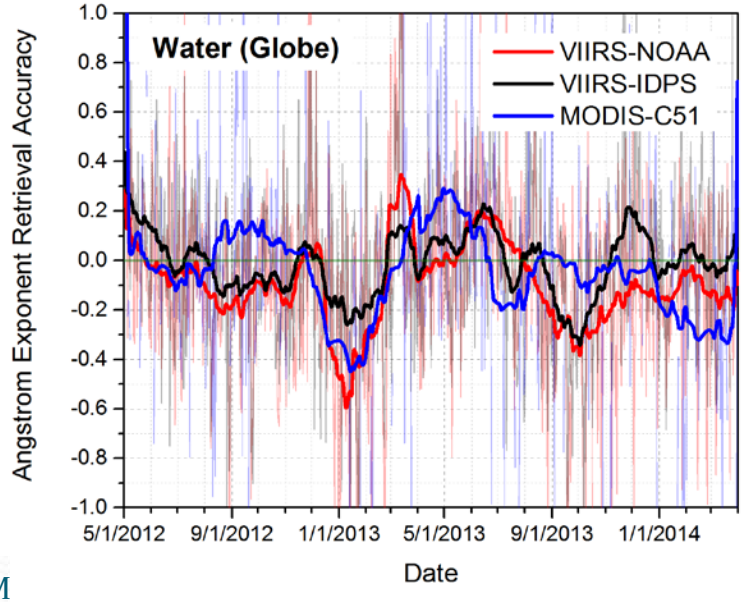

Land
NOAA VIIRS
Retrieved AE
AERONET AE (0.488 vs 0.672um)


Land
IDPS VIIRS
Retrieved AE
AERONET AE (0.488 vs 0.672um)


Land (Globe)
Angstrom Exponent Retrieval Accuracy
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date


Water
NOAA VIIRS
Retrieved AE
AERONET AE (0.865 vs 1.61um)

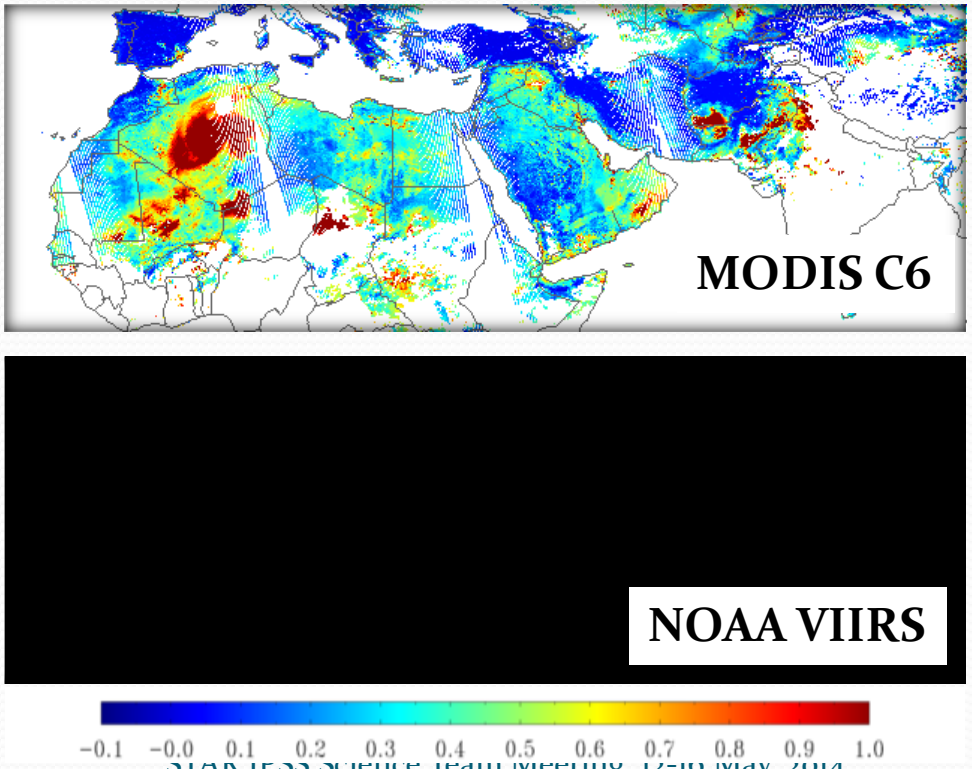

Water
IDPS VIIRS
Retrieved AE
AERONET AE (0.865 vs 1.61um)


Water (Globe)
Angstrom Exponent Retrieval Accuracy
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date

Retrieval over Bright Surface

- Attempting to retrieve aerosol over bright surface with deep-blue channels (M1 and M2)
- Establish spectral surface reflectance relationship between M1 and M2
- Assign aerosol model (generic or dust/smoke)

AOT550 over North Africa and Middle East (06/24/2013)



Summary

- JPSS Risk Reduction Aerosol Algorithm was developed.
  - Single algorithm applied to both VIIRS and ABI
  - More functionalities with less number of line of code than the IDPS algorithm (~3500 vs. ~5600)
- RR algorithm is tested with global retrievals
  - Wider spatial coverage than IDPS
  - More retrievals over significant aerosol events
  - Wider AOT range [-0.05, 5.0]
- Evaluation with AERONET shows slight improvement over IDPS for cases dominated by clear-sky.
- Evaluation with MODIS shows better consistency of retrievals over water.

Summary (Cont.)

- Some IDPS retrieval issues have been addressed:
  - Snow/ice contamination in the Spring season is reduced
  - Ångström Exponent over water is decreased
  - Land spectral reflectance relationship depends on $NDVI_{SWIR}$ and redness
  - More retrievals over arid area
  - Alternative scheme is available for high AOT cases
- Experiment with independent-channel AE retrieval and retrieval over bright land surface using deep-blue channels.
- Future plans
  - Evaluate and improve internal tests
  - Deep-dive evaluation
  - Improve the surface reflectance estimation