CONSISTENT ALGORITHM SCIENCE ACROSS SATELLITE SENSORS FOR AOD RETRIEVAL

Hongqing Liu, Istvan Laszlo, Shobha Kondragunta, Hai Zhang, and Mi Zhou

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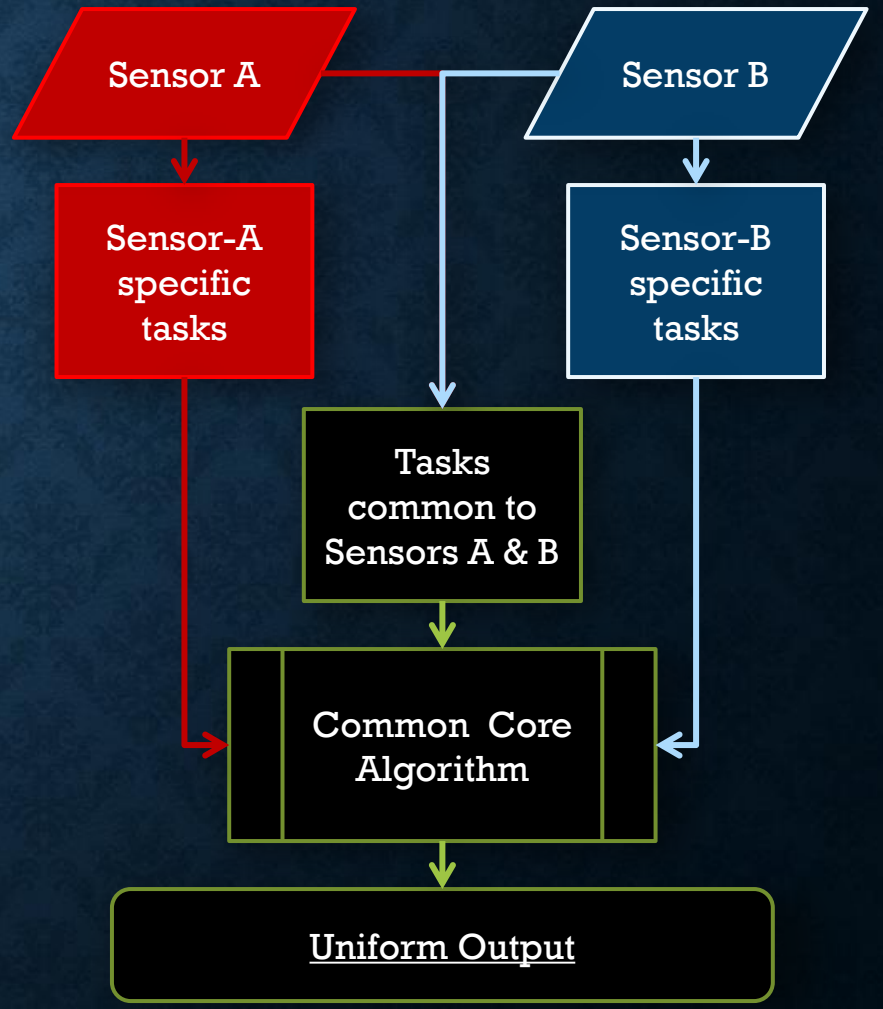
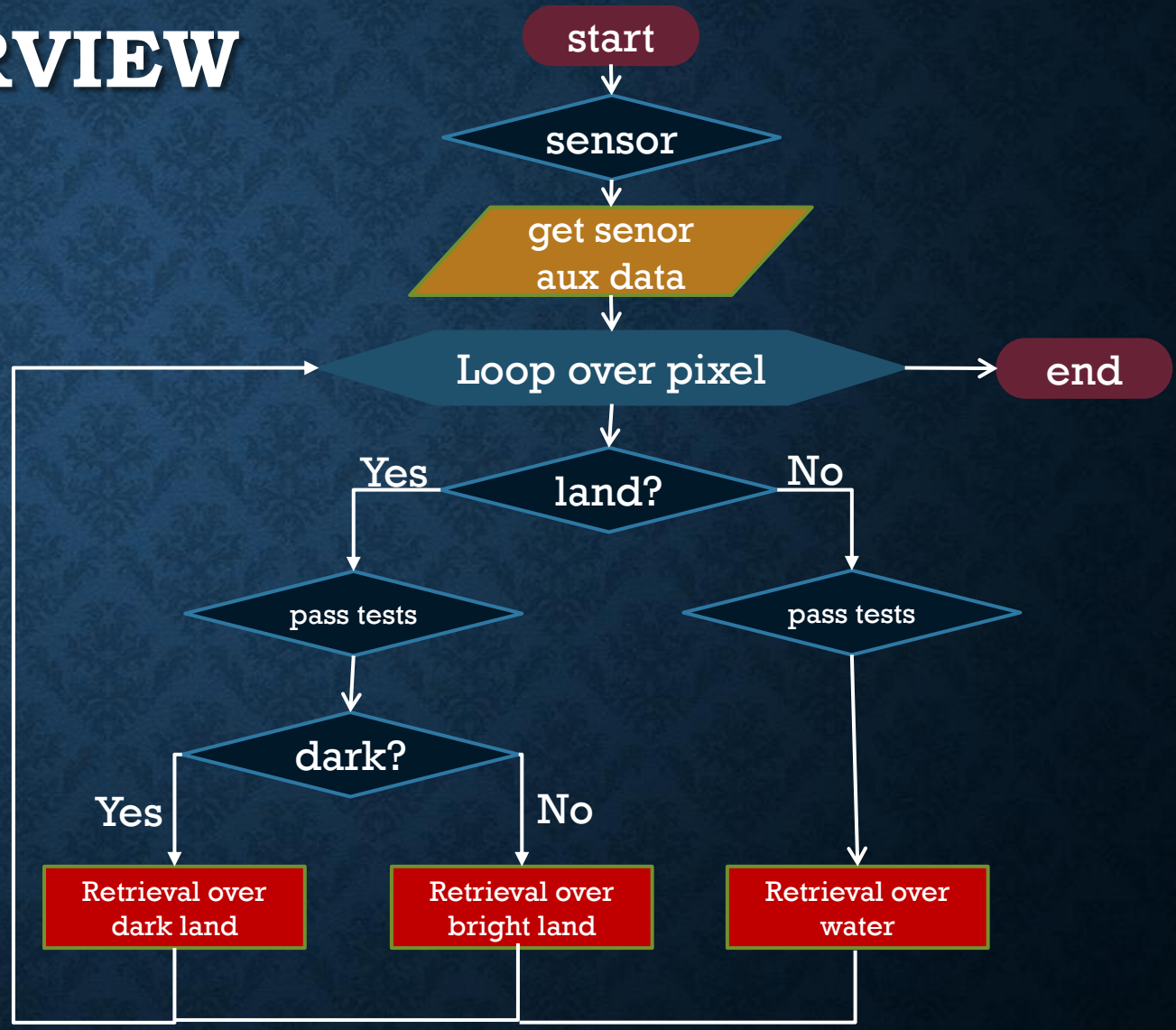
ENTERPRISE APPROACH

- Same **method** (physics and assumptions) and its **realization** (software) are applied to retrieve aerosol optical depth (AOD) regardless of source of satellite input.
- The "enterprise" algorithm is NOT a "proper subset" algorithm (not only algorithm A ∩ algorithm B)
  - does not ignore information available from a more capable sensor;
  - instrument specific tasks are built around a common core.



ALGORITHM OVERVIEW

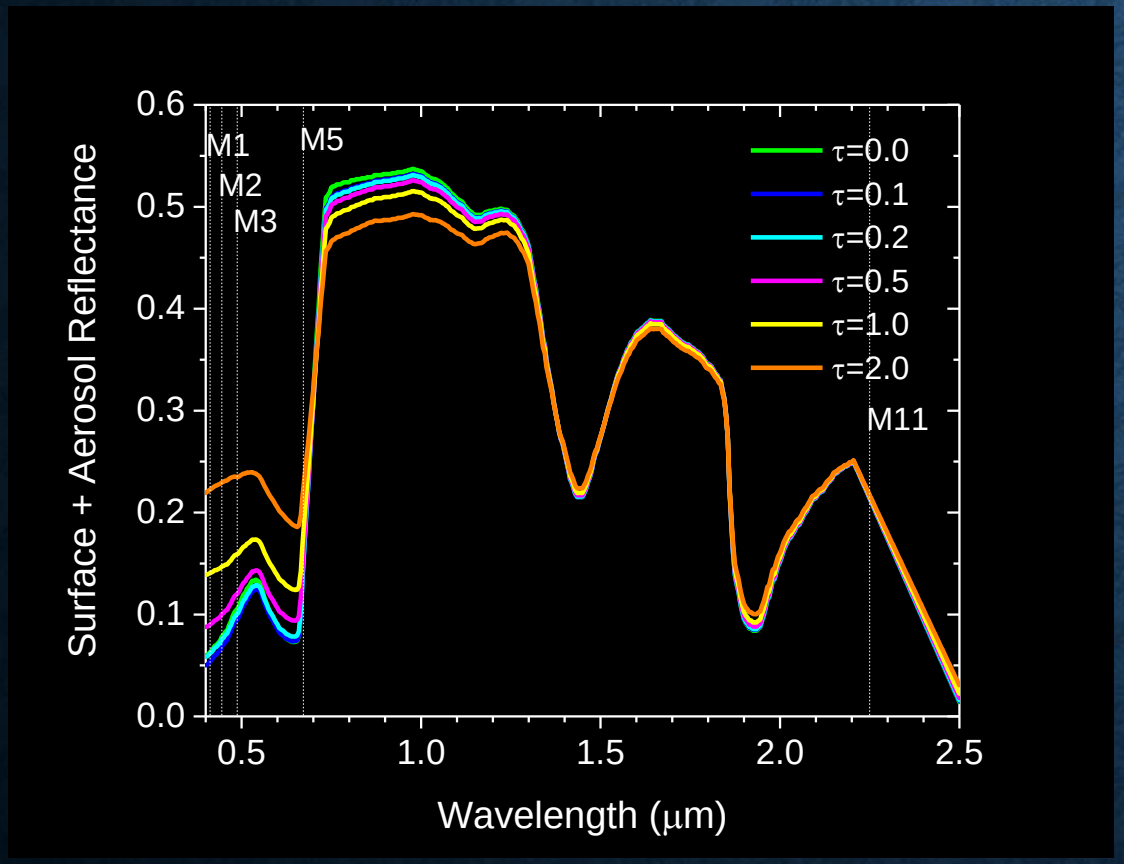
- Retrieve AOD from multispectral, single-look, unpolarized reflectances
- Separate retrievals over land and water
- Separate paths over dark and bright land
- At pixel-level

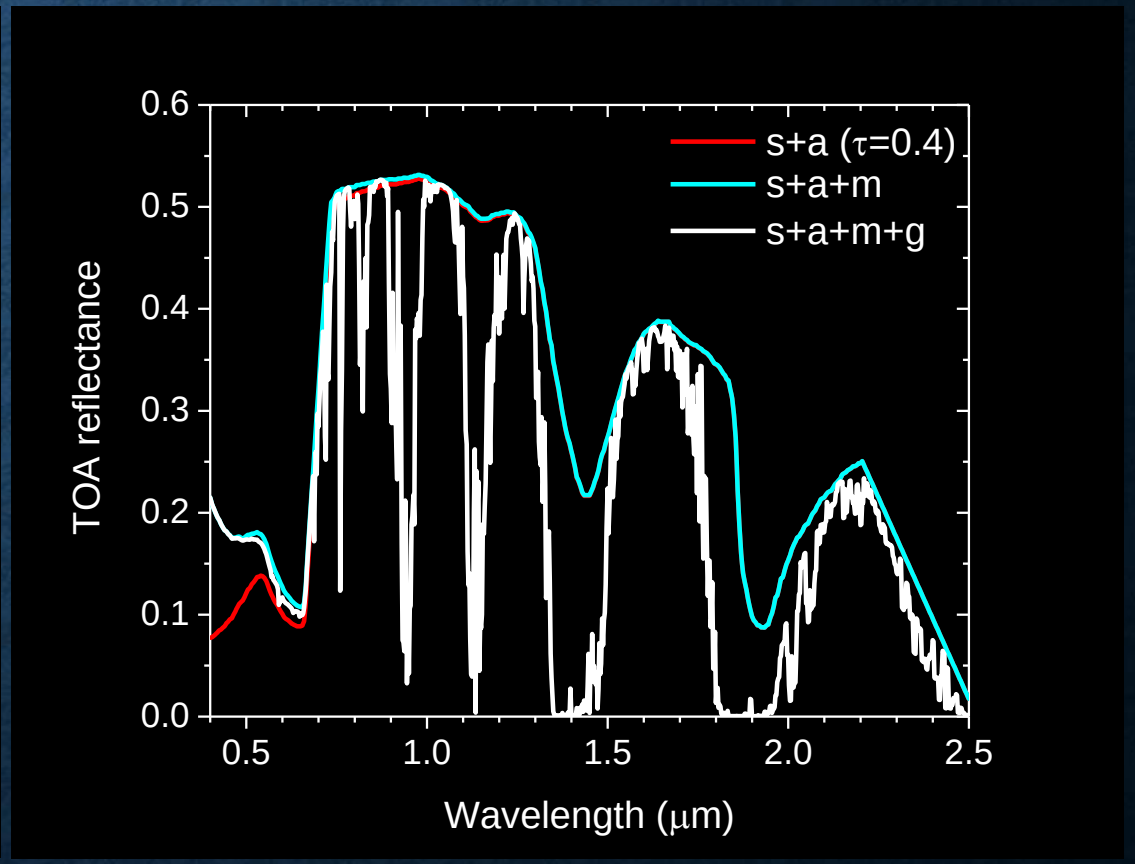


OVER-WATER COMMON CORE ALGORITHM

- MODIS heritage (Tanré et al., 1997; Remer et al., 2005)
- Surface reflectance
  - calculated from model as sum of bidirectional and Lambertian (water-leaving and white foam) reflectances
  - depends on wind speed and direction
  - coupling of atmosphere and surface is calculated outside of lookup table
- Aerosol model:
  - four fine mode and five coarse mode aerosol models (*MODIS C5 models*)
- Assumes aerosol TOA reflectance is fine-mode-weighted average of fine and coarse mode reflectances
- TOA reflectances calculated in selected channels are compared to observed ones to retrieve AOD, pair of fine and coarse mode aerosol models and fraction of fine mode simultaneously.
- Require a reference channel (0.86μm) and at least one residual channel

CHANNELS USED OVER LAND





OVER-LAND COMMON CORE ALGORITHM

- MODIS heritage (Kaufman et al., 1997; Levy et al., 2007; Vermote et al., 2008, Hsu et al., 2013)
- Surface reflectance
  - assumed to be lambertian
  - prescribed spectral relationship as a function of surface type and geometry
- Aerosol model:
  - four aerosol models: dust, generic, urban and smoke (*MODIS C5 models*)
- In general, AOD, aerosol model and surface reflectance are retrieved simultaneously
- Matchup of the calculated and observed TOA reflectances is performed at the blue channel where lower surface reflection and stronger aerosol reflection coexist within the SW spectrum.
- Require the measurements at blue and red/SWIR channels

OVER DARK LAND - SURFACE

For healthy vegetation, blue, red and SWIR (2.2μm) surface reflectances (ρ) are correlated (*Kaufman et al.* , 1997) – Used to decrease number of unknowns.

- SWIR-scheme: $\rho_{SWIR} \rightarrow \rho_{Red} \rightarrow \rho_{Blue}$

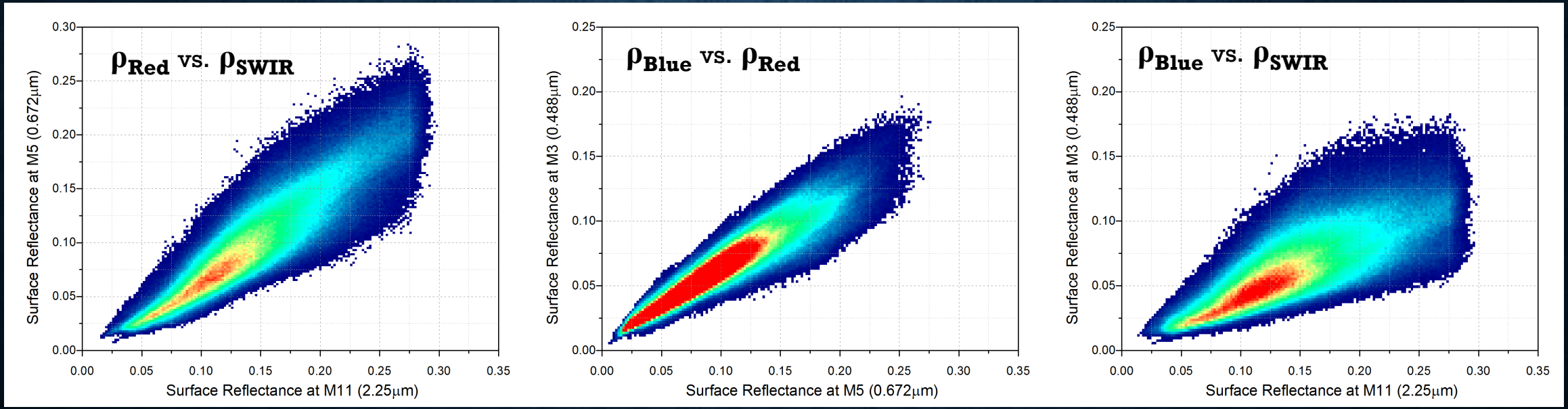
  Pros: transparent at SWIR channel

  Cons: uncertainty of the relationship

- SW-scheme: $\rho_{Red} \rightarrow \rho_{Blue}$

  Pros: less uncertainty of the relationship

  Cons: less transparent at red channel



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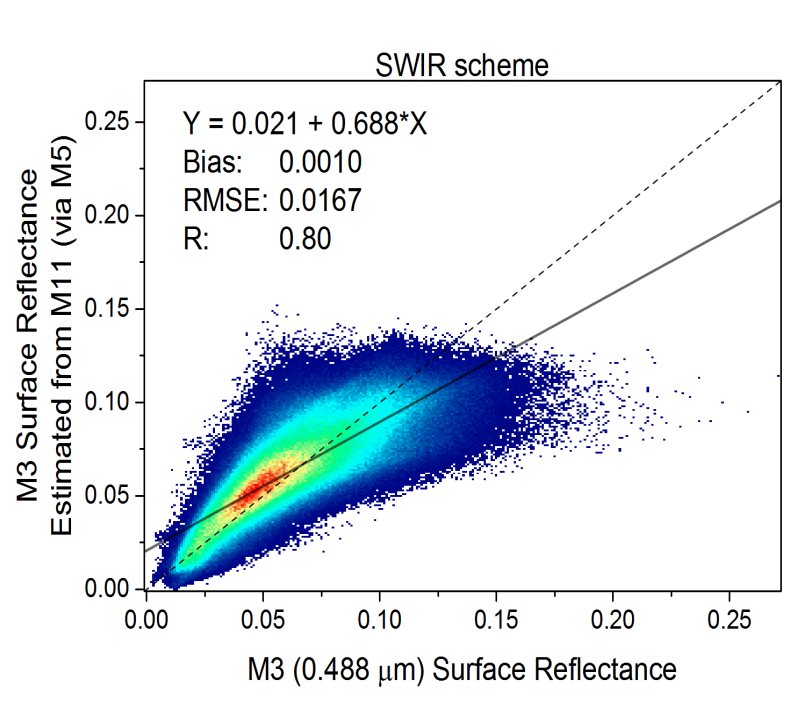
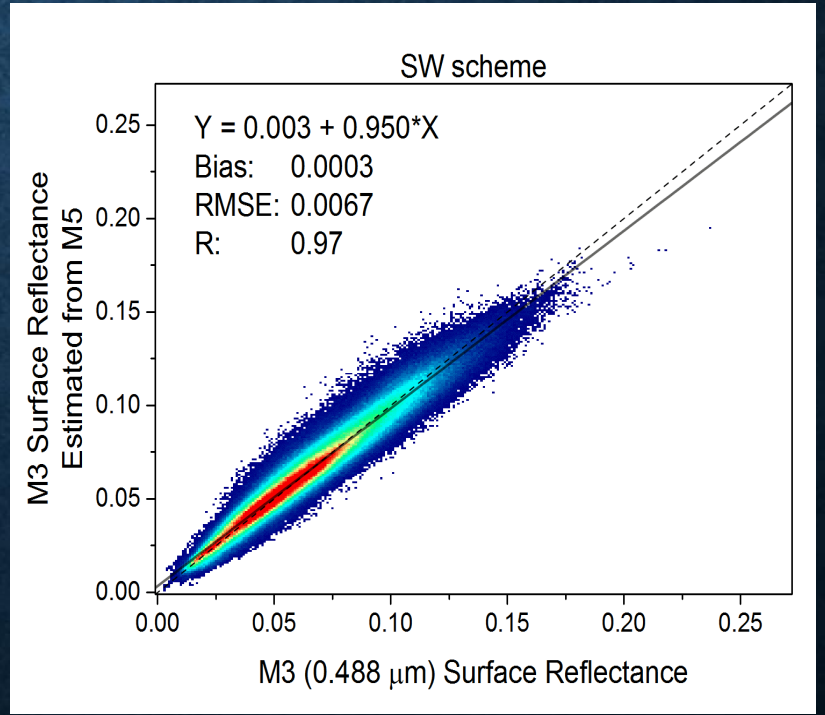
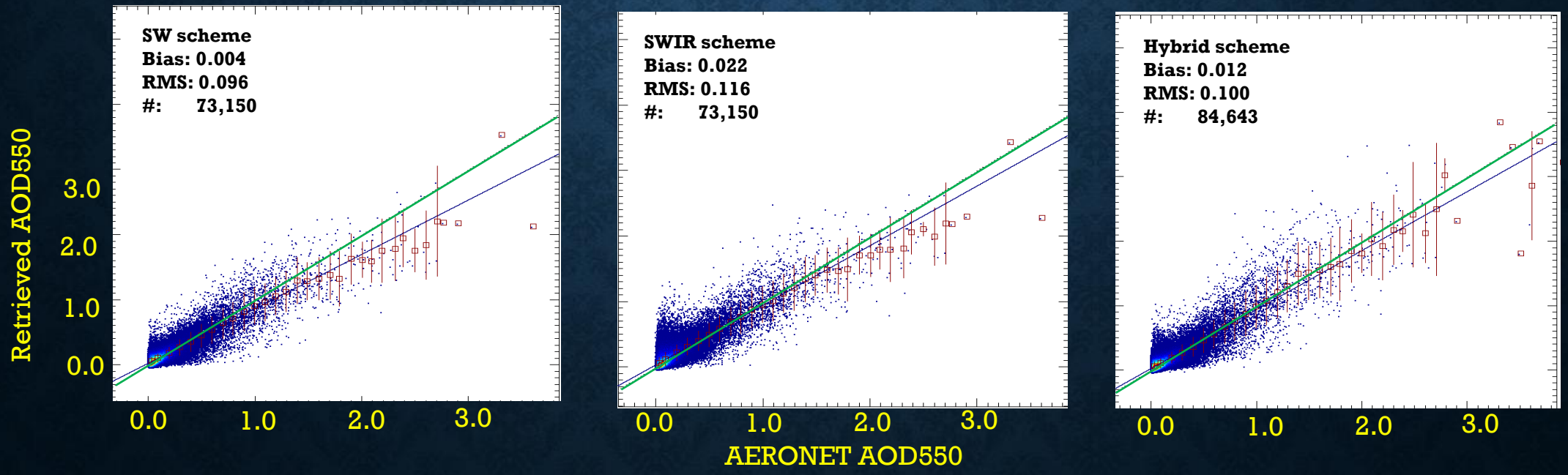




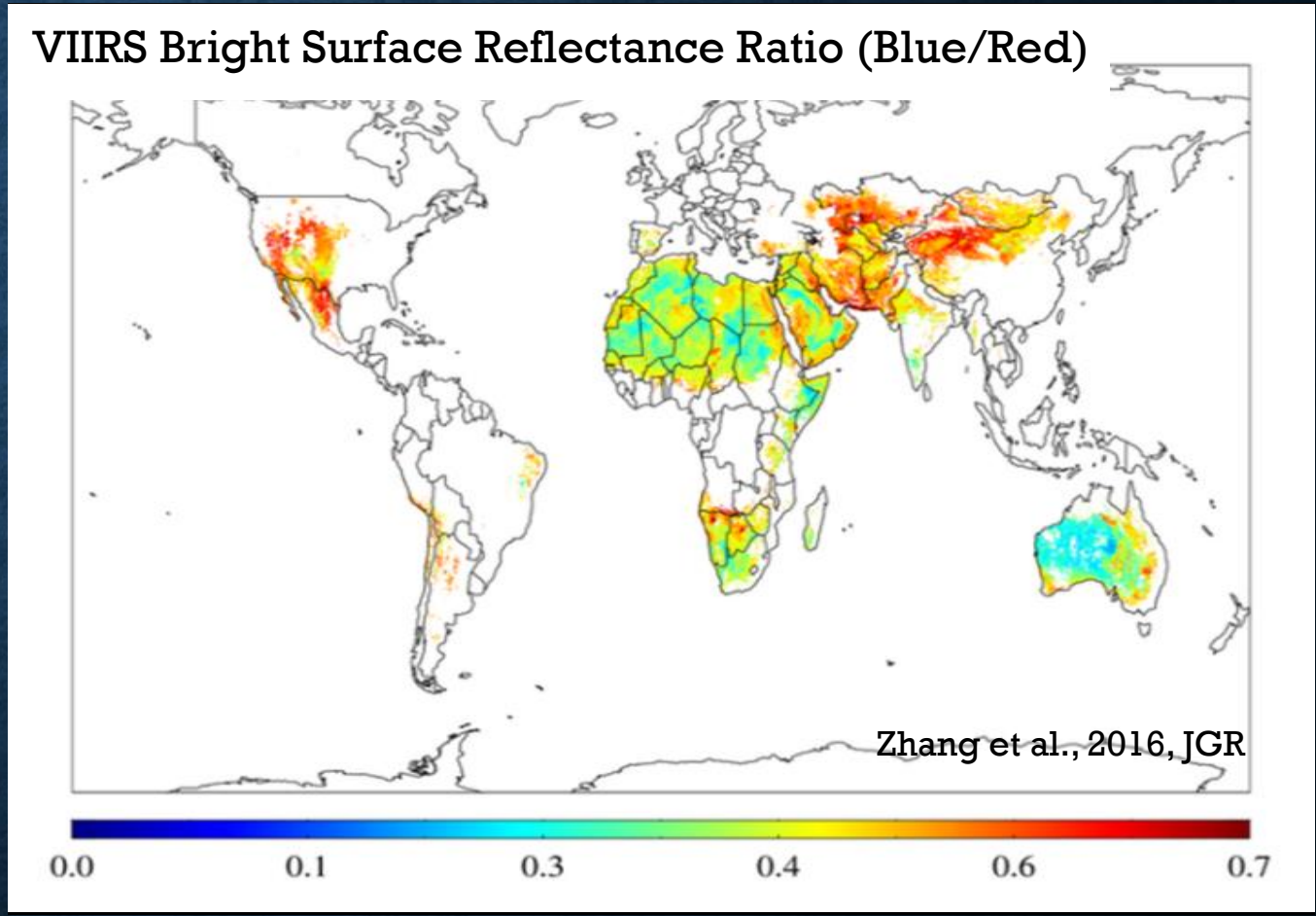
OVER DARK LAND - RETRIEVAL

- Two variants of the dark-target approach:
  - **SW-scheme** : blue and red channels as the reference, preferred for low AOD
  - **SWIR-scheme** : blue and SWIR channels as the reference, preferred for high AOD
- Combination: SW to SWIR switch
  - $|\rho_{M3}(SW)-\rho_{M3}(SWIR)| >$ threshold
- Model selection
  - Select the aerosol model with minimum difference of the calculated and measured reflectance at the residual channels



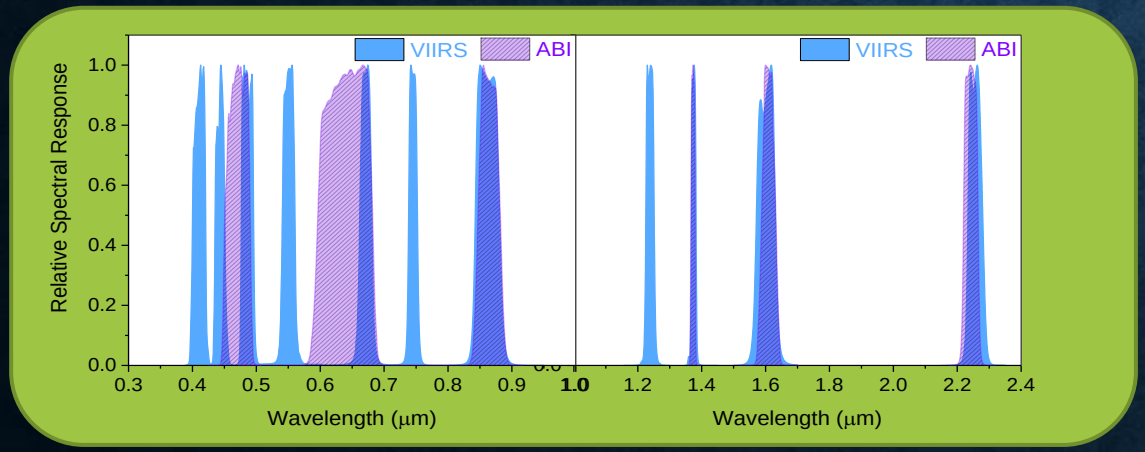
OVER BRIGHT LAND

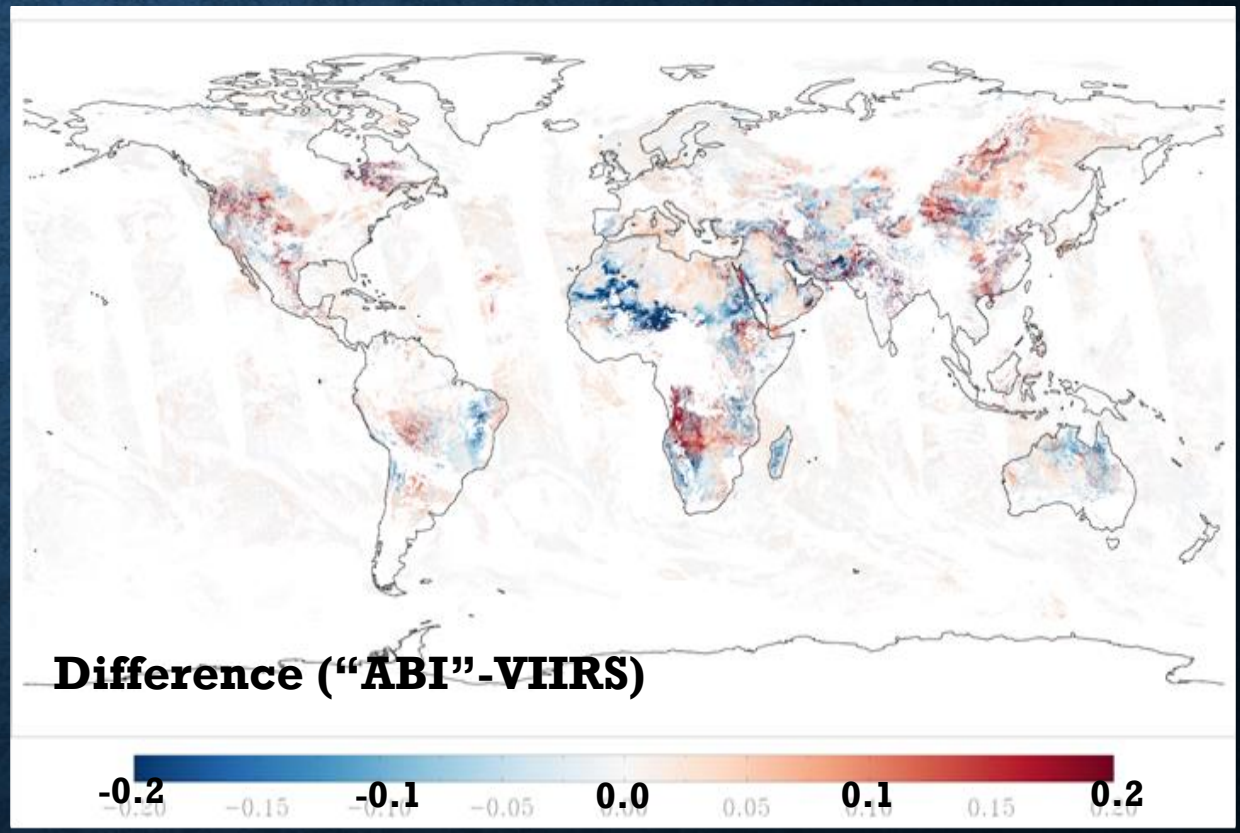
- Derive regional (0.1°x0.1°) database of bright surface spectral reflectance relationship
  - Ratios tend to be less variable than albedos
  - Function of geometry
- Retrieval uses blue/deep-blue and red channels



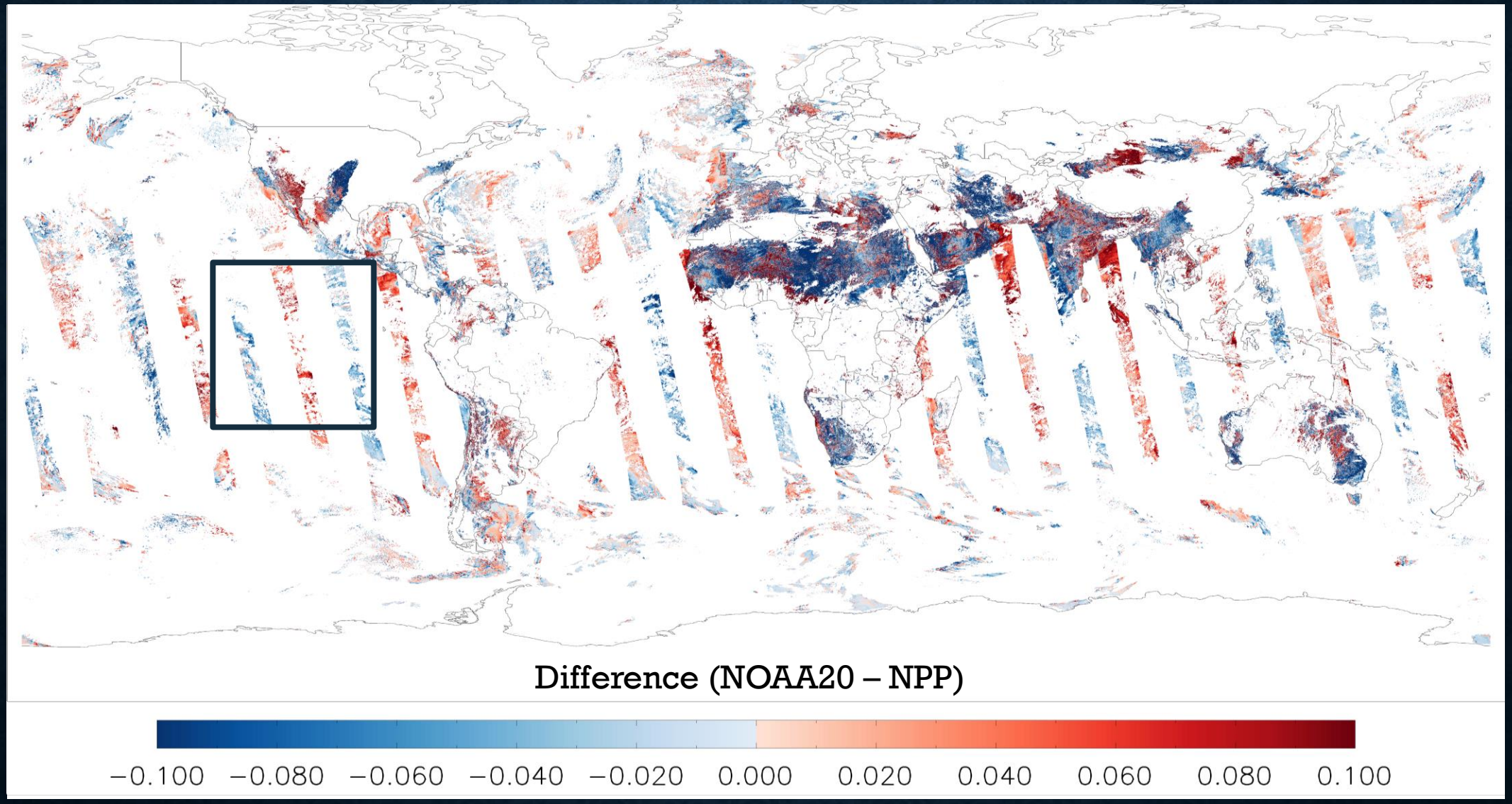
ACROSS SENSORS – CHANNEL DIFFERENCE

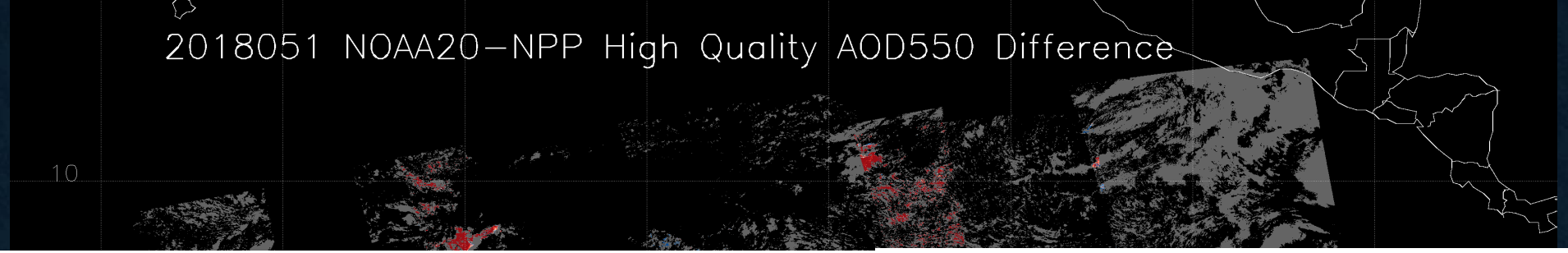
- Lookup tables, coefficients and land surface reflectance relationship need to be generated for each sensor.
- Selection of aerosol model is impacted due to different residual channels used.

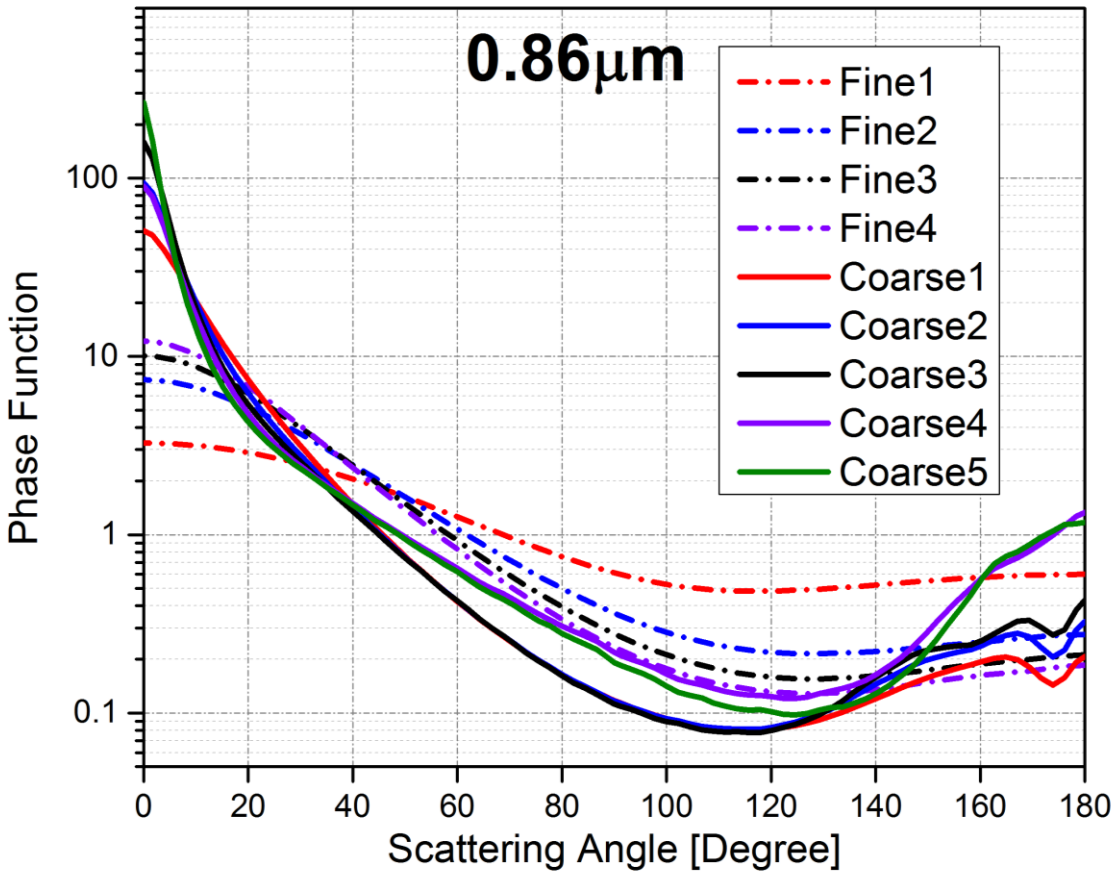


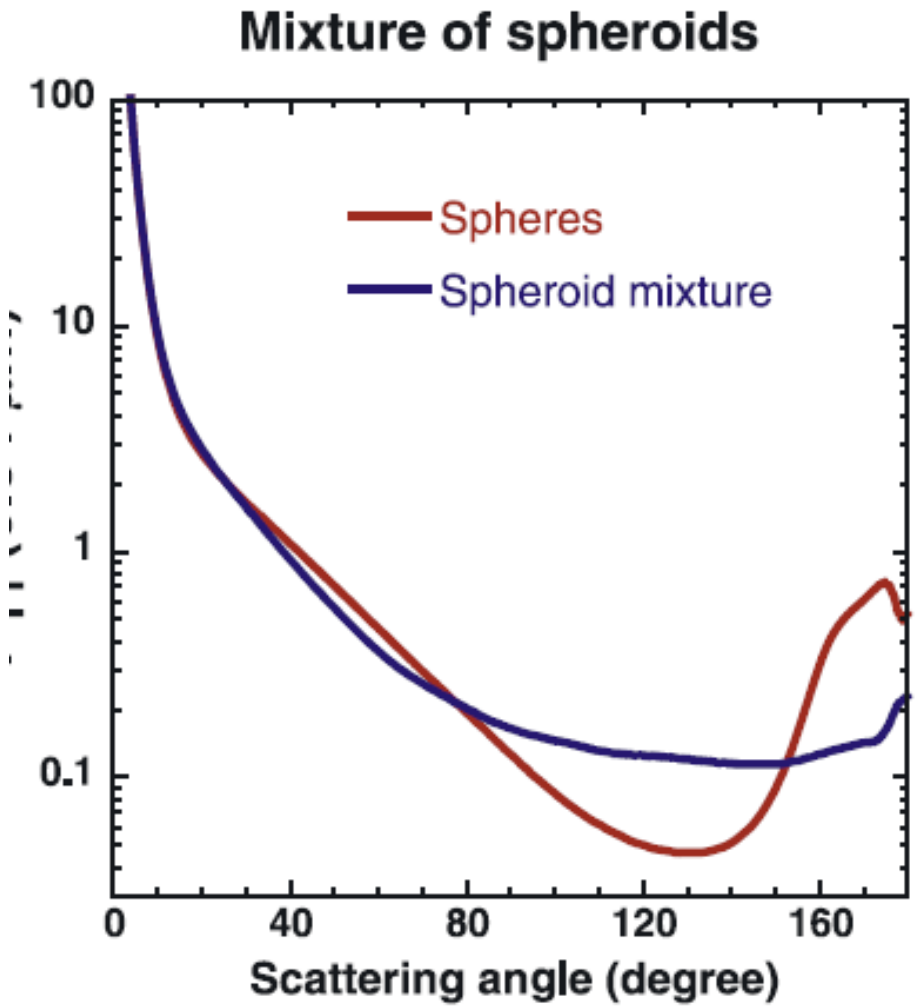


ACROSS SENSORS – GEOMETRY DIFFERENCE

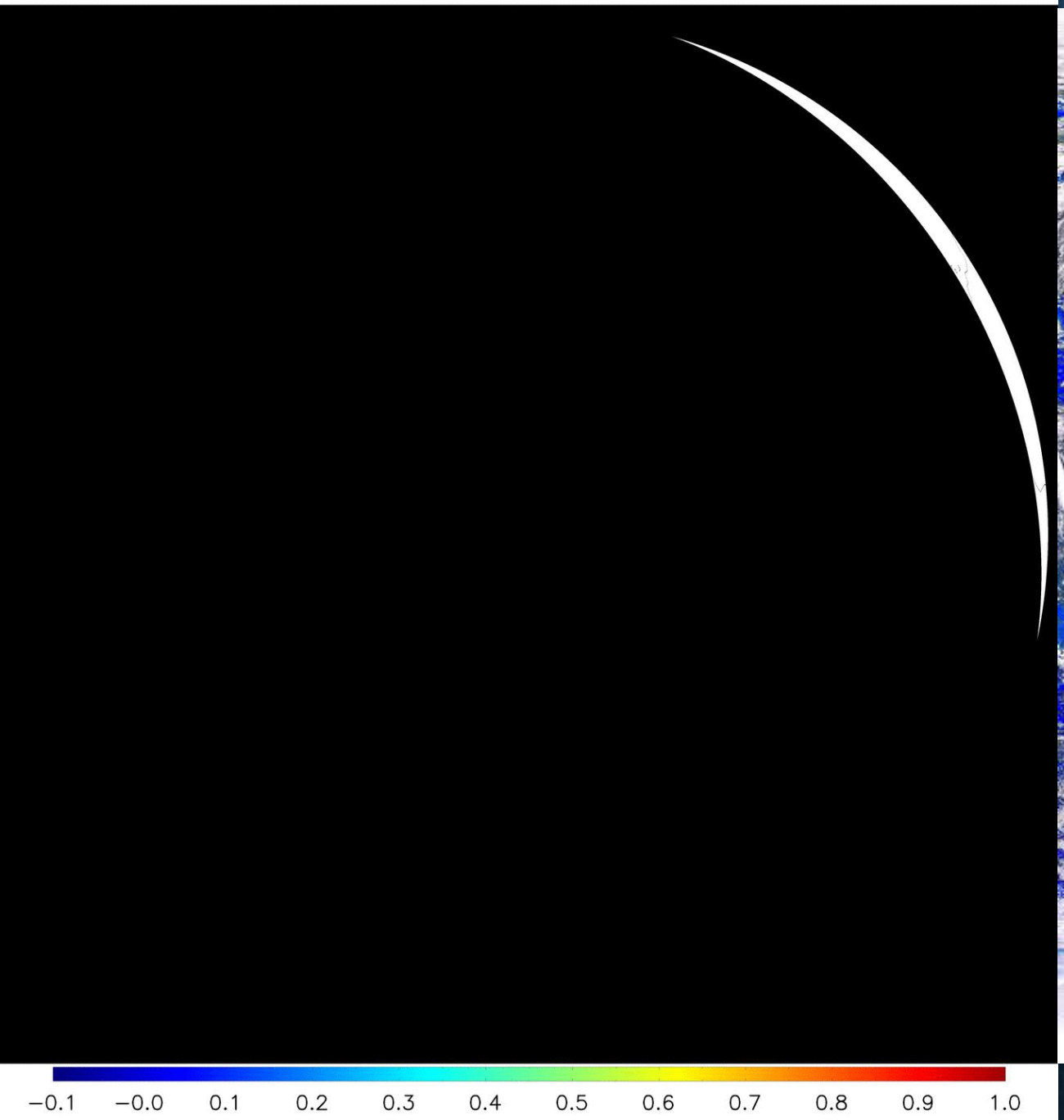



2018051 NOAA20−NPP High Quality AOD550 Difference

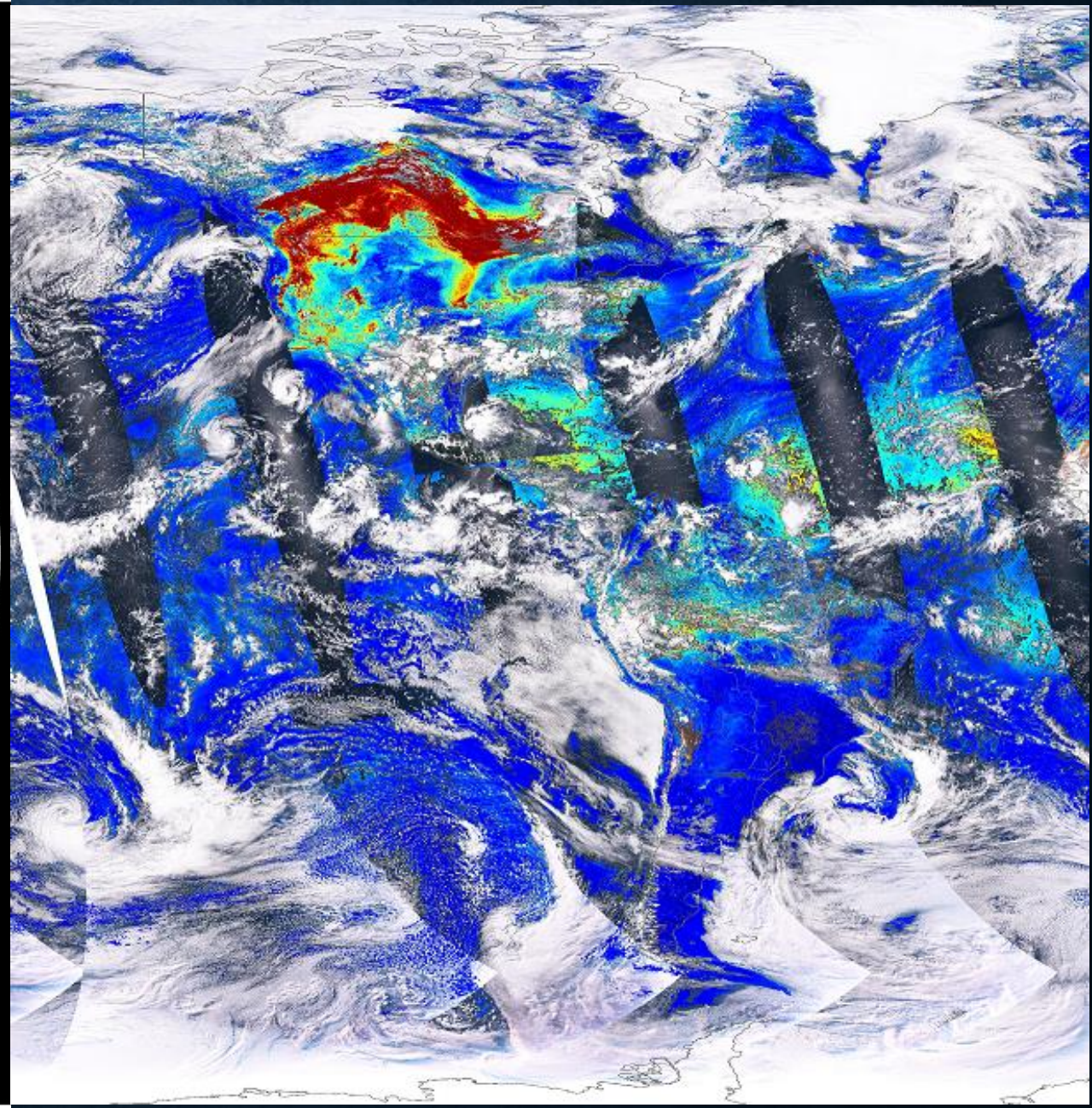

0.86μm
Fine1
Fine2
Fine3
Fine4
Coarse1
Coarse2
Coarse3
Coarse4
Coarse5
Phase Function
100
10
1
0.1
0
20
40
60
80
100
120
140
160
180
Scattering Angle [Degree]


Mixture of spheroids
Spheres
Spheroid mixture
100
10
1
0.1
0
40
80
120
160
Scattering angle (degree)

2018222_0700 **GOES-16 ABI**

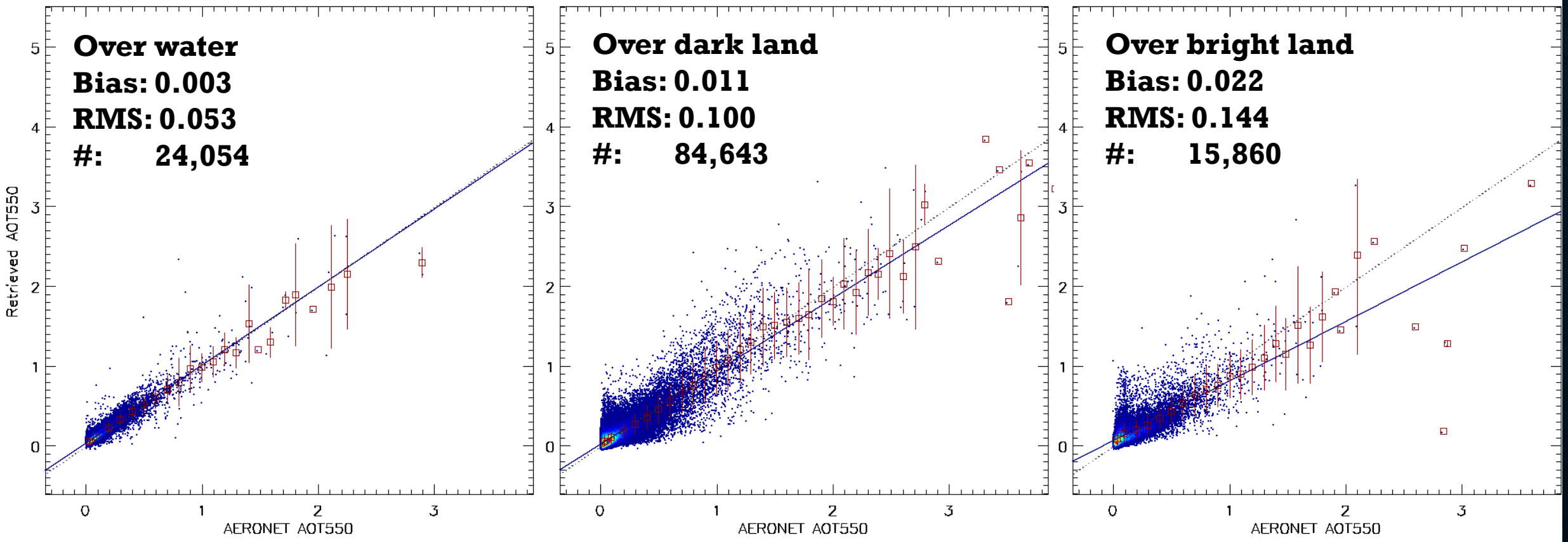


2018-08-10 NPP VIIRS



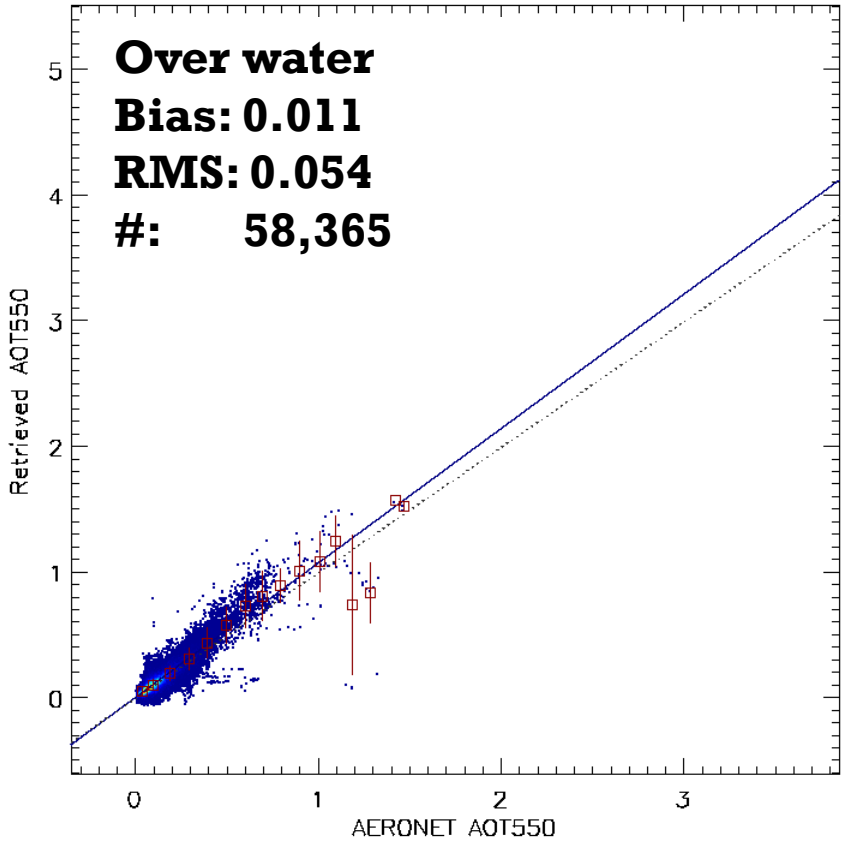
NPP VIIRS AOD VALIDATION

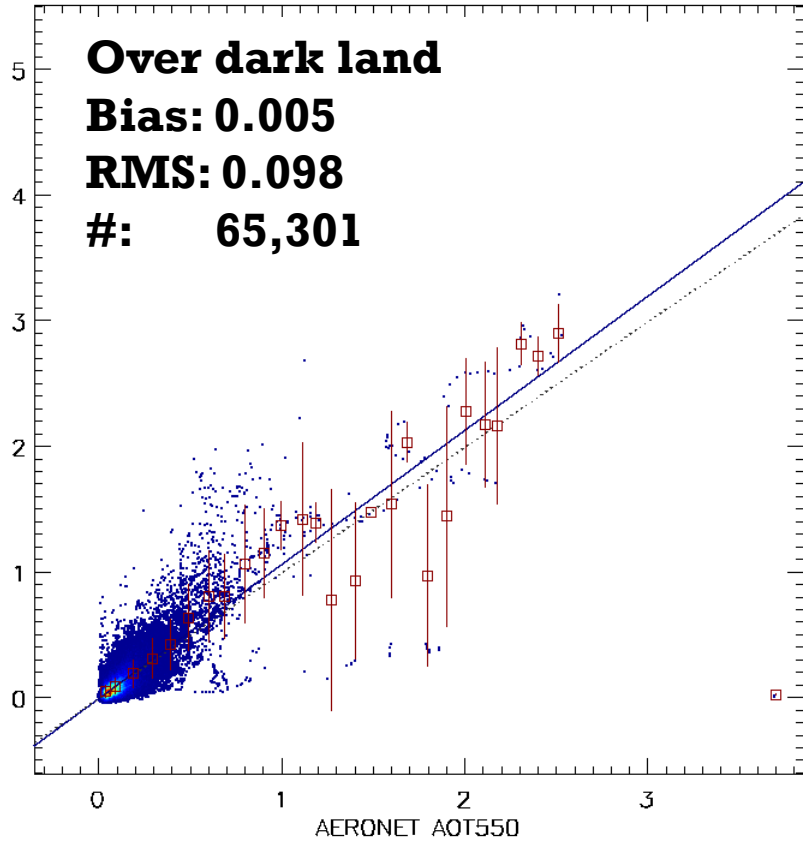
NOV. 2012 – DEC. 2017

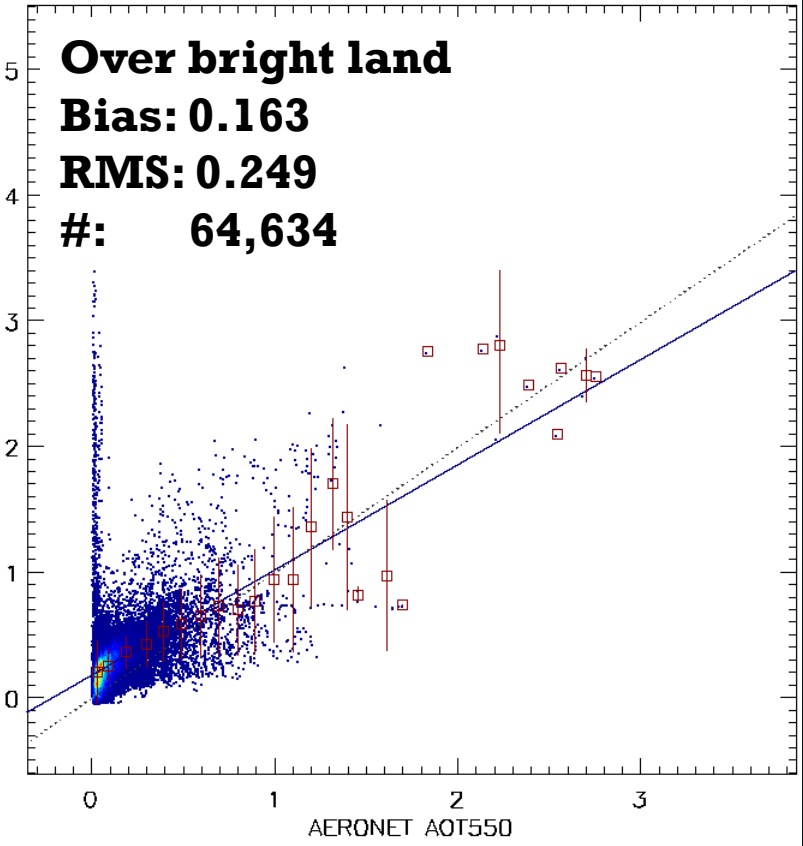


GOES16 EPS AOD VALIDATION

DEC. 14, 2017 – OCT. 6, 2018

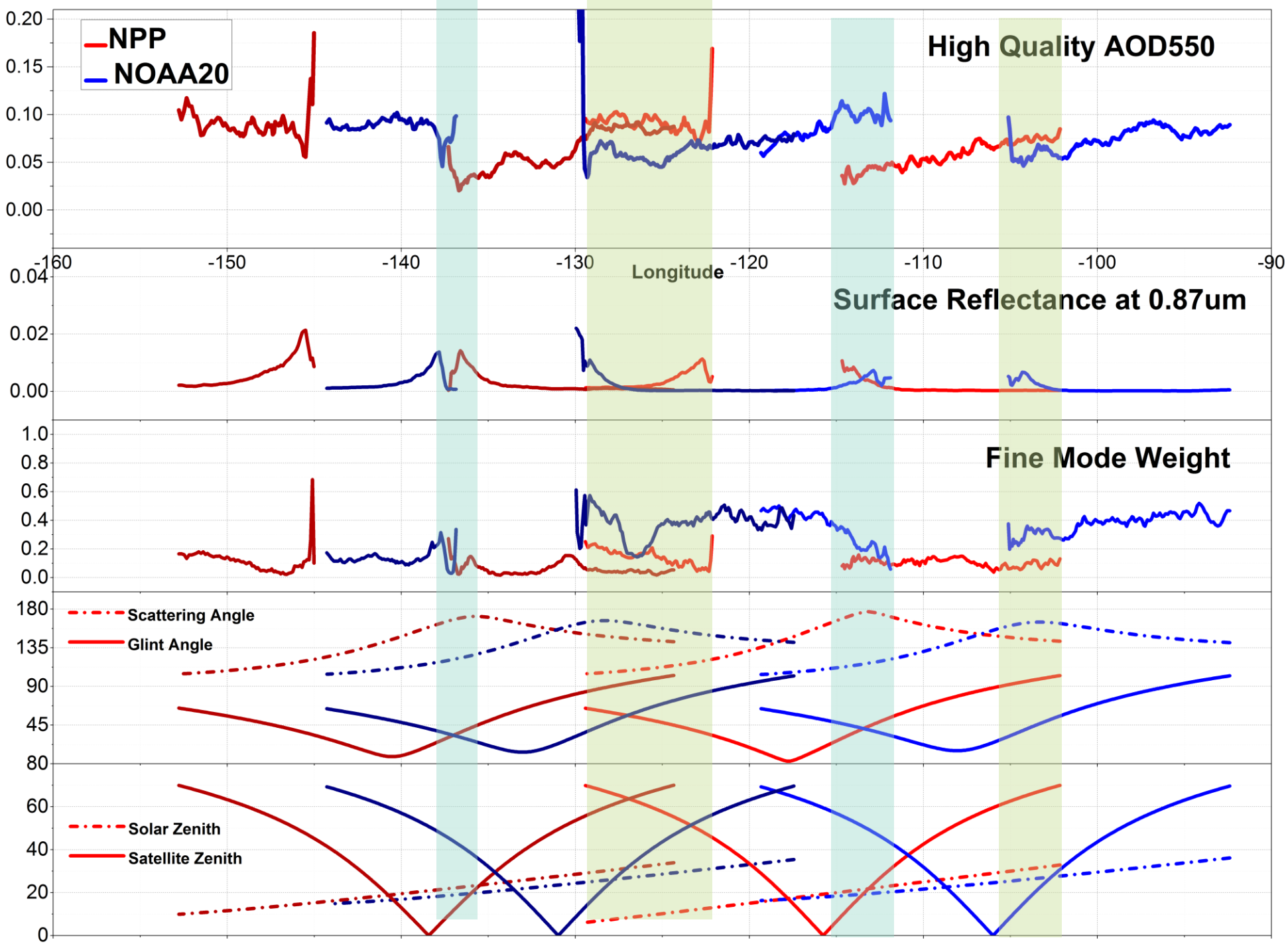


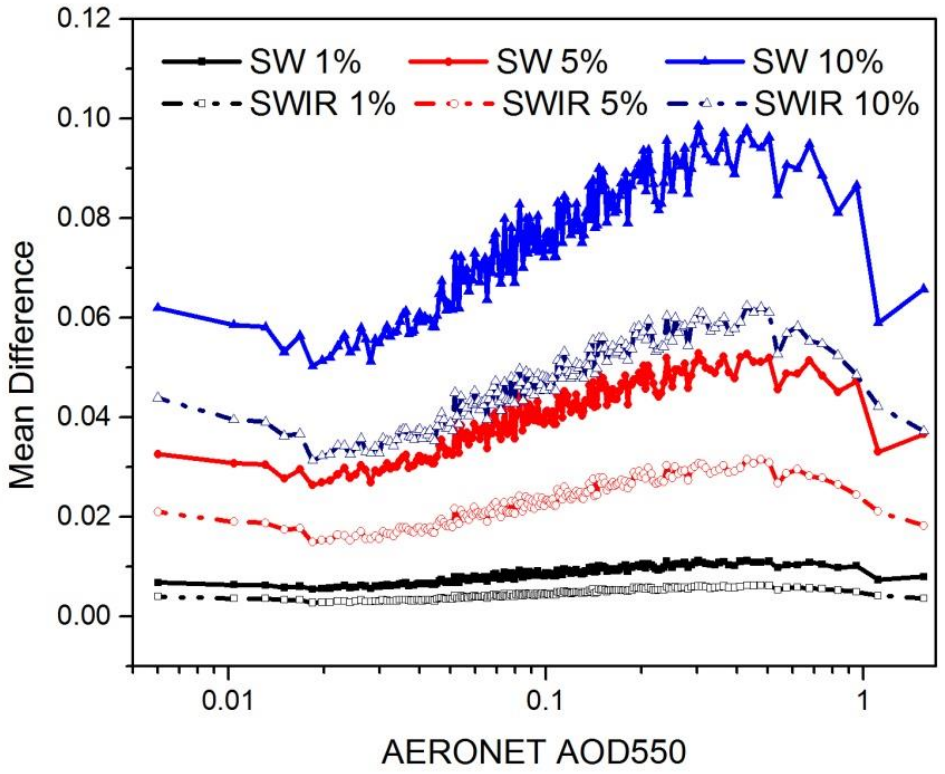


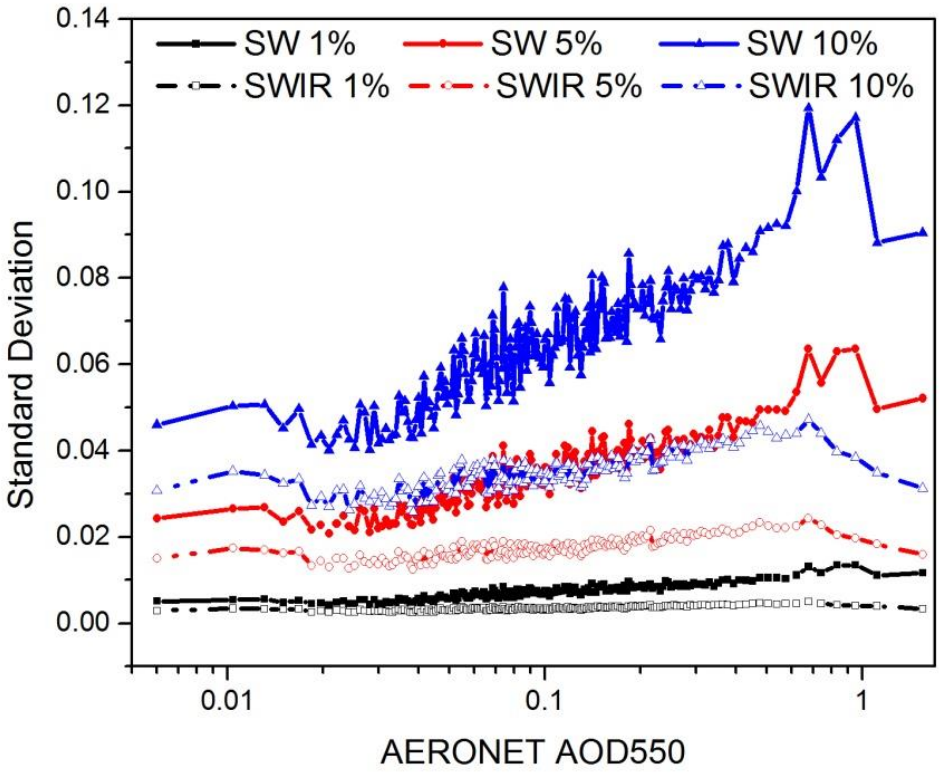


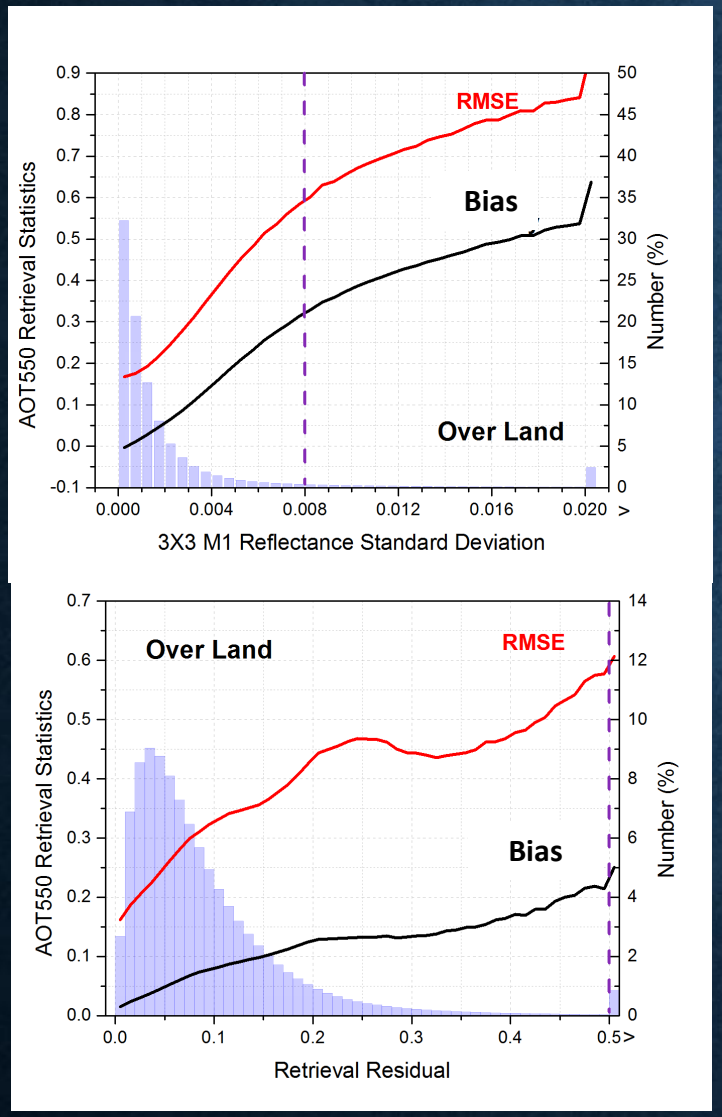
CHALLENGES

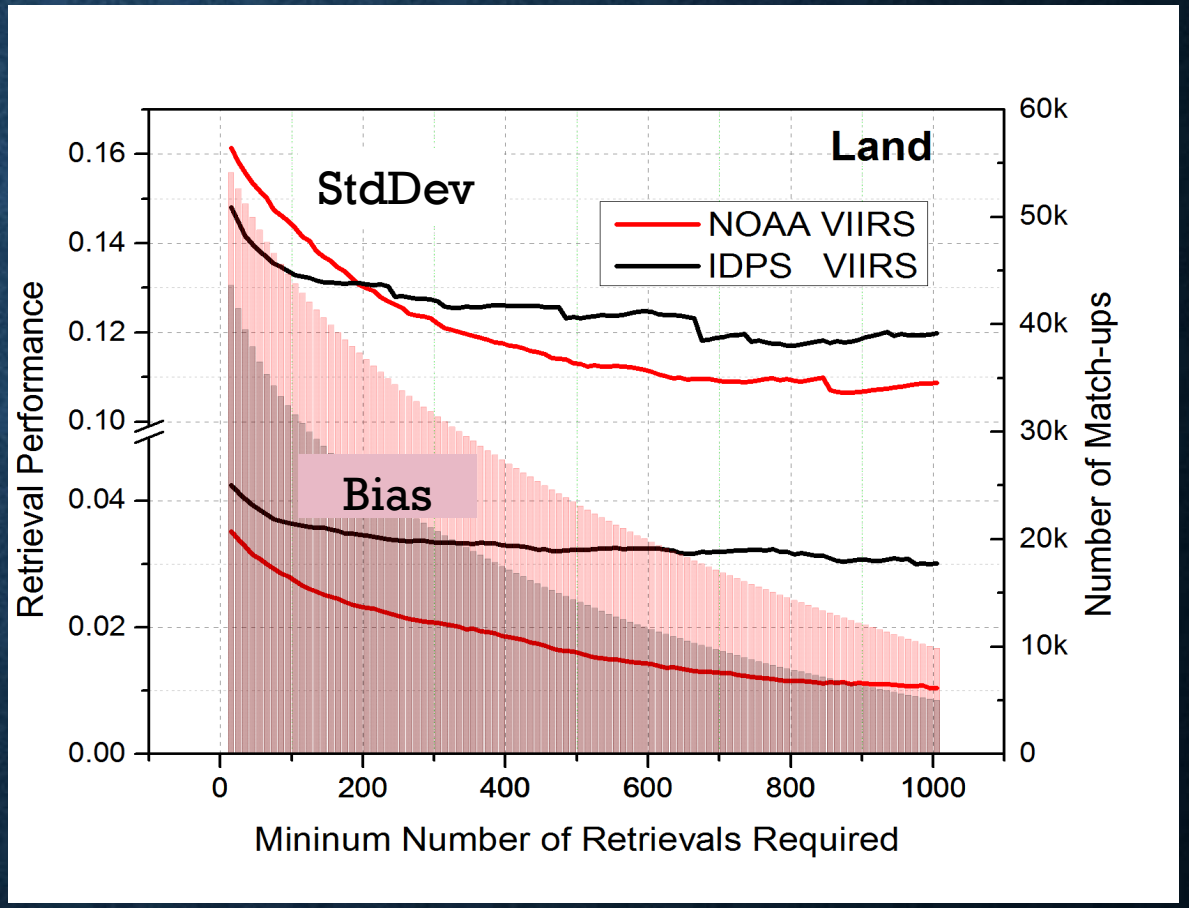
- Surface reflectance
  - Better parameterization
  - Globally general or regionally specific ?
- Aerosol model
  - Continuous vs. discrete
  - Specified vs. selection
- Algorithm design
  - Consistency vs. variation
  - Constraint vs. independence


NPP
NOAA20
High Quality AOD550
0.20
0.15
0.10
0.05
0.00
-160
-150
-140
-130
-120
-110
-100
-90
Longitude
Surface Reflectance at 0.87um
0.04
0.02
0.00
Fine Mode Weight
1.0
0.8
0.6
0.4
0.2
0.0
Scattering Angle
Glint Angle
180
135
90
45
80
Solar Zenith
Satellite Zenith
60
40
20
0


SW 1%
SW 5%
SW 10%
SWIR 1%
SWIR 5%
SWIR 10%
Mean Difference
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.01
0.1
1
AERONET AOD550


SW 1%
SW 5%
SW 10%
SWIR 1%
SWIR 5%
SWIR 10%
Standard Deviation
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.01
0.1
1
AERONET AOD550


RMSE
Bias
Over Land
AOT550 Retrieval Statistics
Number (%)
3X3 M1 Reflectance Standard Deviation
Over Land
RMSE
Bias
AOT550 Retrieval Statistics
Number (%)
Retrieval Residual


Land
StdDev
NOAA VIIRS
IDPS VIIRS
Bias
Retrieval Performance
Number of Match-ups
Mininum Number of Retrievals Required