GOES-R AWG Aerosol, Air Chemistry, and Air Quality (AAA) Team: Aerosol Optical Depth/Suspended Matter and Aerosol Particle Size Algorithm

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AOD/SM/APS (Aerosol Optical Depth/Suspended Matter/Aerosol Particle Size) Team

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Outline

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- Algorithm Description
- ADEB and IV&V Response Summary
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- Summary

Executive Summary

- The ABI SM/AOD and Aerosol Particle Size algorithm generates the Baseline products of aerosol optical depth, suspended matter (mass concentration), and the Option 2 product of aerosol particle size (Ångström Exponent).
- Separate algorithms are developed for over-land and over-water retrievals due to differences in surface properties.
- Collocated AERONET-MODIS database has been prepared for 2000-2009 and used for validation; analyses indicate spec compliance for AOD and for Ångström Exponent for accuracy (but not for precision).
- Version 5 code and ATBD (100%) will be delivered in June 2010.
- In Version 5, over-land retrieval is improved: the algorithm no longer assumes aerosol is transparent at 2.25 µm (similar to MODIS C5).

Requirements

Name	Horiz. Res.	Range	Accuracy	Precision
AOD	2 km	(-1) – (+5) (retain negative retrievals)	Based on AOD ranges: *Over land*: <0.04: 0.06 ; 0.04 – 0.80: 0.04; > 0.80: 0.12 *Over water*: < 0.40: 0.02; > 0.40: 0.10	Based on AOD ranges: *Over land*: <0.04: 0.13; 0.04 – 0.80: 0.25; > 0.80: 0.35 *Over water*: < 0.40: 0.15; > 0.40: 0.23
APS (Ångström exponent)	2 km	-1 to +3	0.3 over ocean and land	0.15
SM*	5 km	TBD	PM2.5, one-hour averaged over column (0-5000 m): 1 μg/m^3	0.5 μg/m^3

*** SM: Recently proposed, not in F&PS; under evaluation**

Product Qualifiers

- total column
- daytime
- clear conditions
- quantitative out to at least 60 degrees LZA and qualitative at larger LZA

Algorithm Description

Algorithm Summary

- Retrieval is from clear-sky reflectances during daytime only.
- The algorithm combines the MODIS and VIIRS methods.
- AOD is retrieved by comparing pre-calculated TOA reflectances with multi-channel observations.
  - » The retrieved AOD and aerosol model are the ones that provide the best agreement of calculated reflectances with observed ones.
  - » Over-land retrieval uses the “dark-dense vegetation” approach.
  - » Over-water retrieval calculates surface reflectance from model.
- Ångström exponent (proxy for APS) is calculated from AODs at two wavelengths
- Suspended matter (mass concentration) is calculated from retrieved AOD and aerosol model and corresponding mass extinction.

ABI AOD/SM & APS Algorithm (1)

- **Builds on the MODIS and VIIRS algorithms**
- **Separate algorithms for over-land and over-water retrievals**
- **Over-land retrieval:**
  - » ABI channels used: three (0.47, 0.64, 2.25 μm)
  - » aerosol models: four (generic, urban, smoke, dust)
  - » surface reflectance at 2.25 μm is retrieved from observed TOA 2.25-μm reflectance accounting for aerosol extinction; surface reflectances at 0.47 and 0.64 μm are retrieved from that at 2.25-µm using the "dark-dense vegetation" relationship
  - » AOD is retrieved from observed TOA 0.47-μm reflectance
  - » aerosol model is estimated from observed TOA 0.64-μm reflectance
  - » Output: AOD in six SW ABI channels (0.47-2.25 µm), aerosol model, SM, and Ångström Exponent

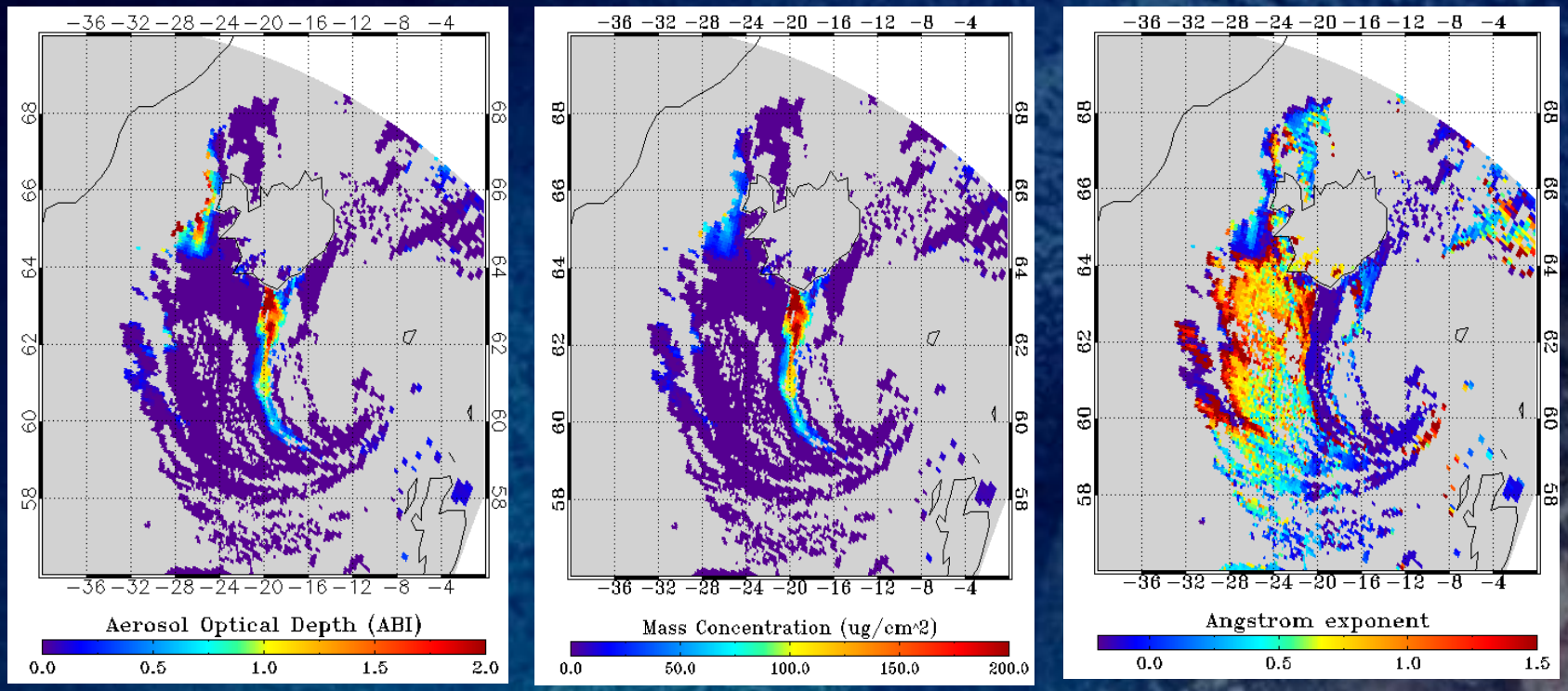
ABI AOD/SM & APS Algorithm (2)

- **Over-water retrieval:**
  - » ABI channels used: four (0.64, 0.86, 1.61, 2.25 μm)
  - » aerosol models: four fine-mode and five coarse-mode models
  - » surface reflectance is calculated from model; accounts for varying wind speed and direction
  - » AOD is retrieved from observed TOA 0.86-μm reflectance
  - » two aerosol models (fine and coarse mode) and fine-mode weight are estimated from observed TOA 0.64--, 1.61, and 2.25-μm reflectances
  - » Output: AOD in six SW ABI channels (0.47-2.25 µm), fine-mode and coarse-mode aerosol models, fine-mode weight, SM, and Ångström Exponent

Example Output (1) AOD/SM & APS

Eyjafjallajökull, Iceland Volcano, April 19, 2010 – 12:50 UTC

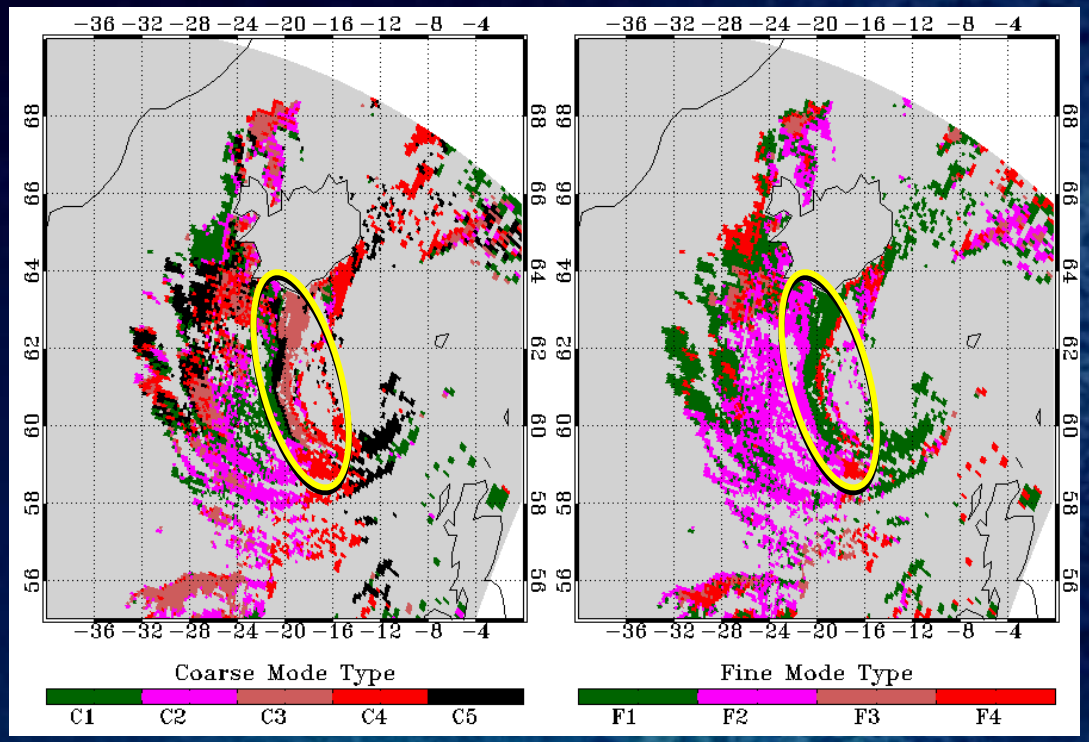
- Aerosol retrieval over water from MODIS/Terra

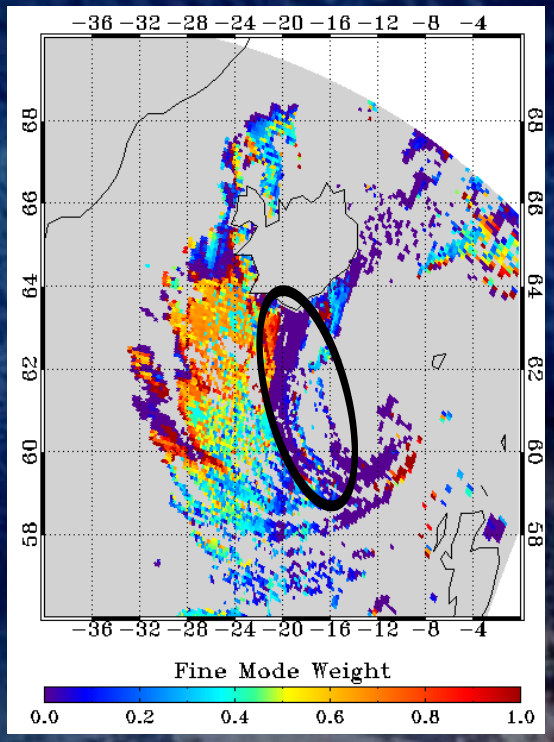


Elevated AOD and mass concentration, and large particles (small Ångström Exponent) in plume

Example Output (2)
Internal Products: model and FMW

Oceanic aerosol models and fine mode weight (FMW)





Algorithm does not have a volcanic ash model; picks coarse mode models C3 (r_{eff}=1.98) and C5 (r_{eff}=2.5) and fine mode models F1 (r_{eff}=0.1) and F4 (r_{eff}=0.25) over ocean

Coarse mode dominates in plume

Algorithm Changes from 80% to 100%

- Improved AOD retrieval over land

  The algorithm no longer assumes that aerosol is transparent at 2.25 µm. Instead, AOD and surface reflectance at this wavelength are retrieved simultaneously

- Added calculation of suspended matter
- Gas parameterization is now based on line-by-line radiative transfer model calculations
- Added quality flags

ADEB and IV&V Response Summary

- All ATBD comments have been addressed
  - » more details on theory, assumptions and retrieval steps are provided (including that of SM)
  - » effect of SN ratio was analyzed
  - » version 5 no longer assumes aerosol is transparent at 2.25 μm
  - » use of SEVIRI with the current ABI algorithm is limited due to the fewer number of SW channels on SEVIRI
- No feedback required substantive modifications to the approach

Validation Strategy

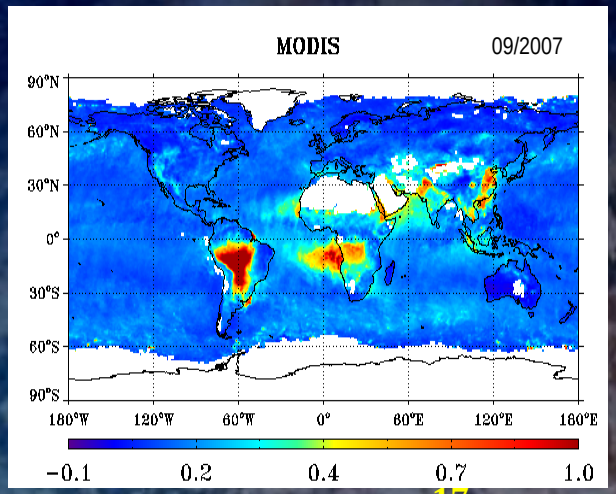
Validation Strategy

- **Use MODIS reflectances as proxy for ABI and retrieve AOD and APS**
  - » Many MODIS channels are similar to those of ABI
  - » Clear-sky TOA gas-absorption-corrected reflectances from MODIS collection 5 aerosol product are used
    - – avoids MODIS vs. ABI cloud screening and gas absorption differences
    - – provides a wide range of realistic atmospheric and surface conditions
  - » NCEP data used for surface pressure, ocean surface wind speed/direction
- **Retrievals are matched up with reference data in space and time**
  - » Co-location follows MODIS strategy
    - – ground data are temporally averaged within 1-hour window around the MODIS overpass time and the MODIS data are spatially averaged in a 50x50 km box centered on the ground station
- **Appropriate statistics are calculated and compared to F&PS**
  - » bias, precision (and pdf)

Validation Strategy- Reference Data

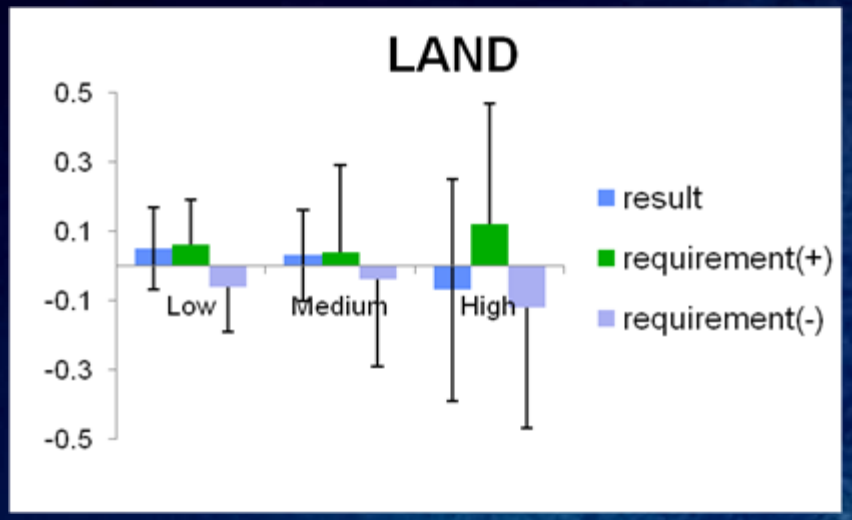
- **AERONET aerosol product (primary reference data)**
  - » The ground-based AERONET remote sensing network provides a comprehensive dataset of aerosol properties and has been widely used for evaluating satellite retrievals and model simulations in the aerosol community.
  - » AERONET version 2 level 2.0 data are collected as ground "truth" for years 2000-2009.

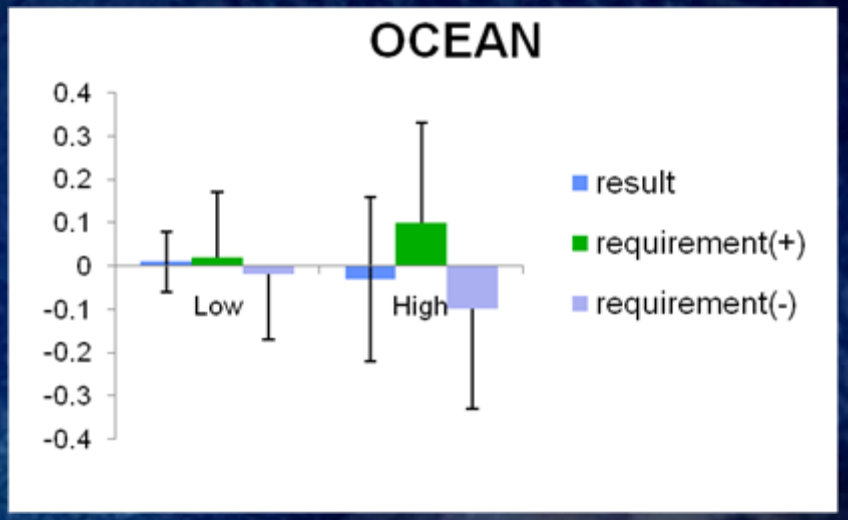
- **MODIS aerosol product**
  - » AOD from MODIS collection 5 aerosol product are collected as independent satellite-based reference data for the years 2000-2009 for Terra (MOD04) and 2002-2008 for Aqua (MYD04).
  - » Current state of the art, extensively validated product.
  - » Large variety of atmospheric and surface conditions.



Validation Results

Offline Validation - AOD





Range	Land				Water			
	AOD	Accuracy	Precision	# of points	AOD	Accuracy	Precision	# of points
Low	<0.04	0.05 (0.06)	0.12 (0.13)	18,100				
Medium	0.04 - 0.8	0.03 (0.04)	0.13 (0.25)	109,308	<0.4	0.01 (0.02)	0.07 (0.15)	27,975
High	> 0.8	-0.07 (0.12)	0.32 (0.35)	3,225	>0.4	-0.03 (0.10)	0.19 (0.23)	2592

- numbers in parenthesis are F&PS requirements
- the AOD product meets the requirements

Offline AOD Validation Comparison with MODIS Statistics

Land

	Accuracy	Precision	RMSE	Correlation	MinErr	MaxErr
ABI	0.028	0.137	0.140	83.3%	-2.179	1.982
MODIS	0.027	0.124	0.127	87.2%	-1.889	3.330

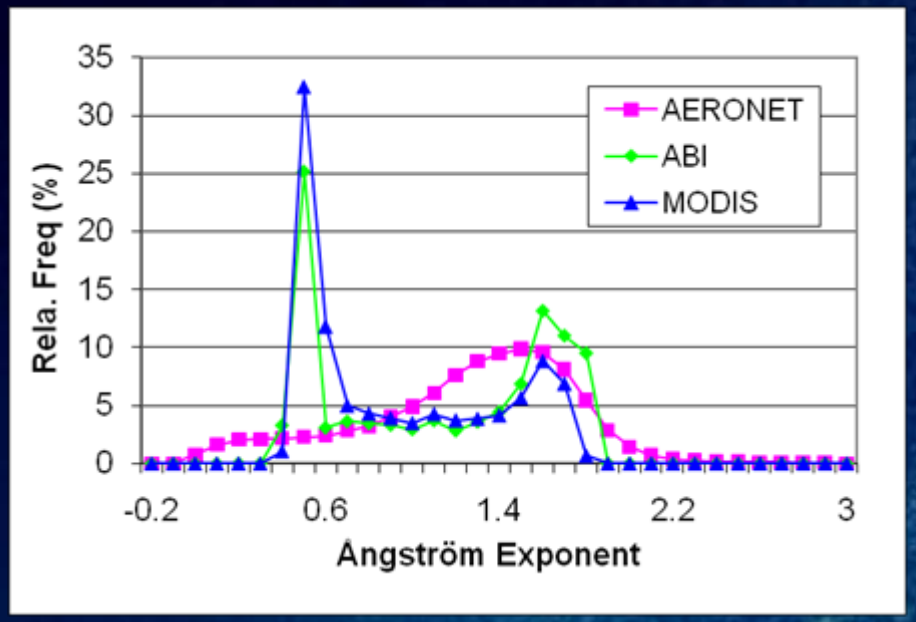
Ocean

	Accuracy	Precision	RMSE	Correlation	MinErr	MaxErr
ABI	0.008	0.091	0.091	87.0%	-1.014	2.546
MODIS	0.017	0.100	0.102	84.8%	-0.976	2.668

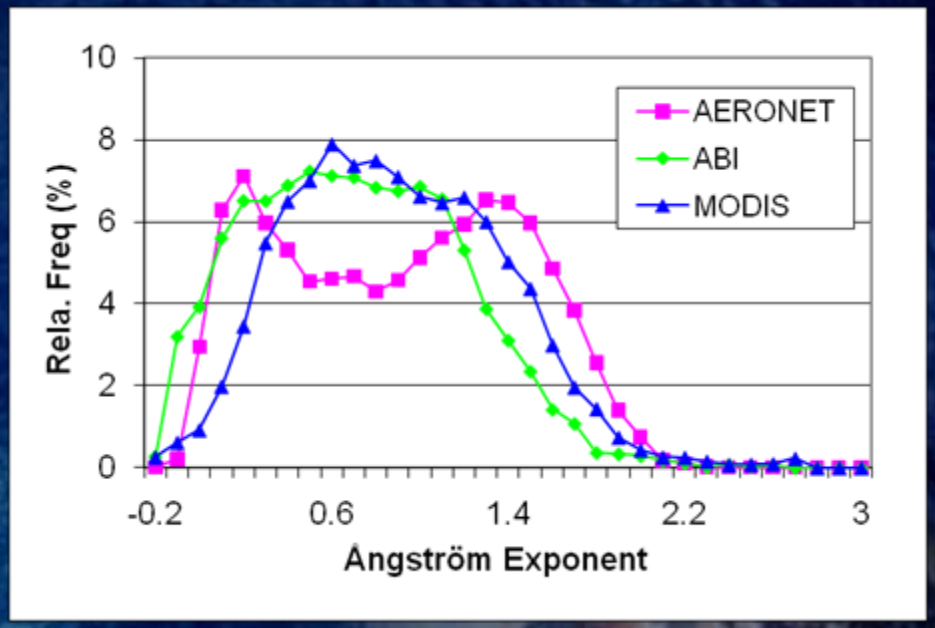
- ABI and MODIS statistics are comparable over land
- ABI bias is smaller over ocean

Offline Validation - APS

LAND



OCEAN



Accuracy
ABI = -0.13 (0.30)
MODIS = -0.33

Precision
ABI =0.57 (0.15)
MODIS =0.53

Accuracy
ABI = -0.20 (0.30)
MODIS = -0.01

Precision
ABI = 0.40 (0.15)
MODIS = 0.36

- **Ångström Exponent retrieval meets the F&PS requirement for accuracy but NOT for precision – Precision is too tight – MODIS product does not meet it either**
- **NWS SME now asks for actual particle size (not Ångström Exponent)**

Validation Results Summary

	Land			Water		
	Range	Accuracy	Precision	Range	Accuracy	Precision
AOD	<0.04	0.05 (0.06)	0.12 (0.13)	<0.4	0.01 (0.02)	0.07 (0.15)
	0.04 - 0.8	0.03 (0.04)	0.13 (0.25)			
	> 0.8	-0.07 (0.12)	0.32 (0.35)	>0.4	-0.03 (0.10)	0.19 (0.23)
APS* (Ångström Exponent)	-1 to 3	-0.13 (0.30)	0.57 (0.15)	-1 to 3	-0.20 (0.30)	0.40 (0.15)

spec is in parenthesis
*Option 2 product

Summary

- The ABI SM/AOD and APS Algorithm provides current state-of-the-art multi-channel retrievals that utilizes the new capabilities offered by ABI.
- Version 5 code and the 100% ATBD will be delivered soon.
- The AOD and (with the exception of precision) the APS products meet specifications.
- Need to revisit requirements for APS – it is unlikely that algorithm can be improved to meet precision requirements for Ångström Exponent.