Recent Update on MODIS C6 Deep Blue Aerosol Products and Beyond

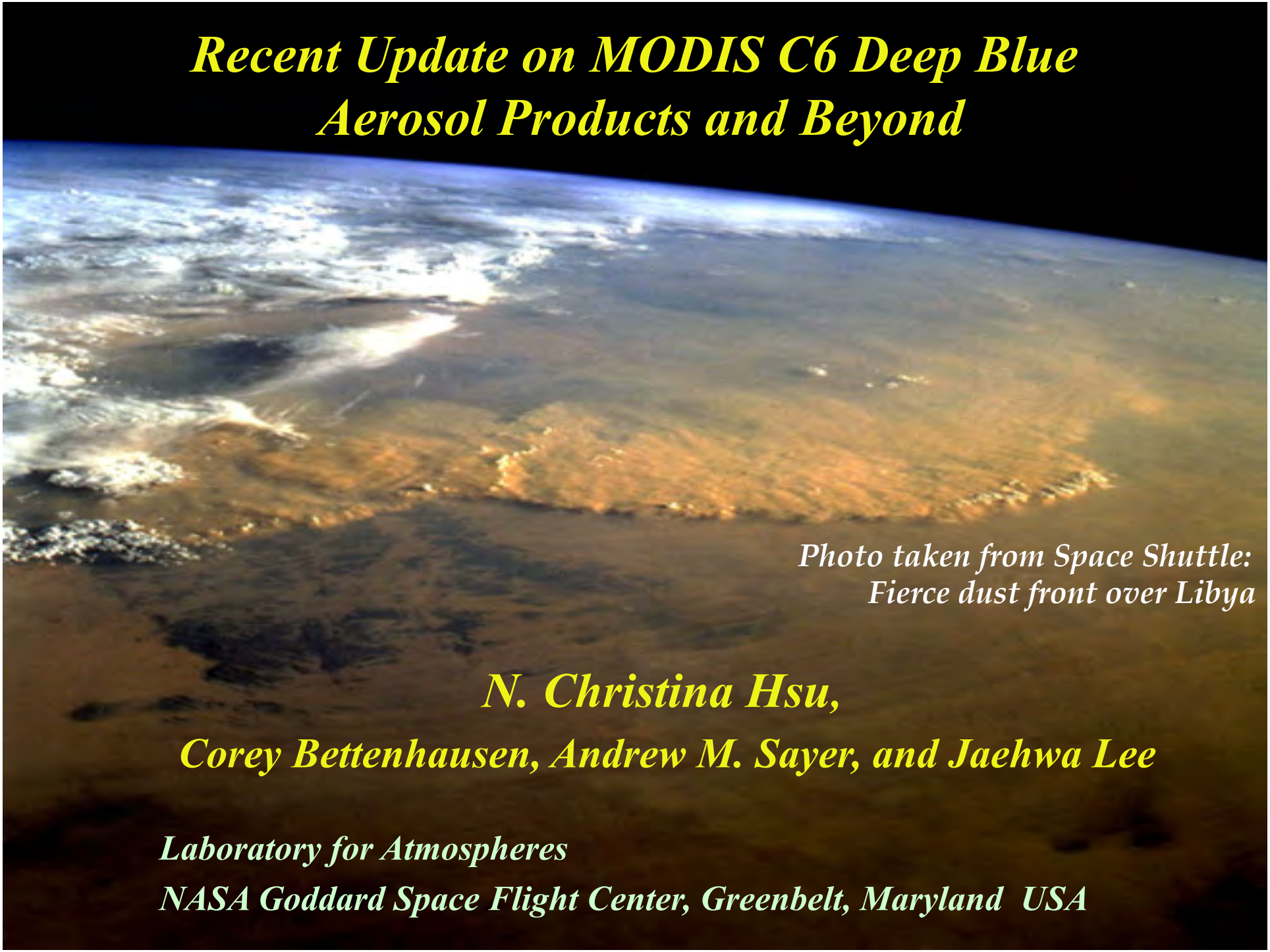


Photo taken from Space Shuttle:
Fierce dust front over Libya

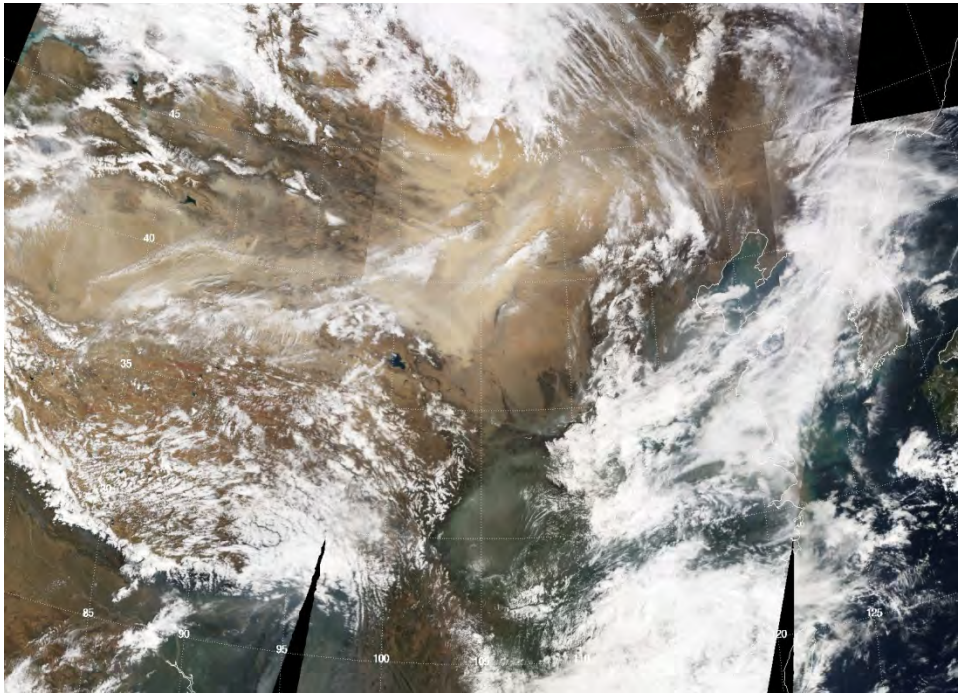
N. Christina Hsu,

Corey Bettenhausen, Andrew M. Sayer, and Jaehwa Lee

Laboratory for Atmospheres

NASA Goddard Space Flight Center, Greenbelt, Maryland USA

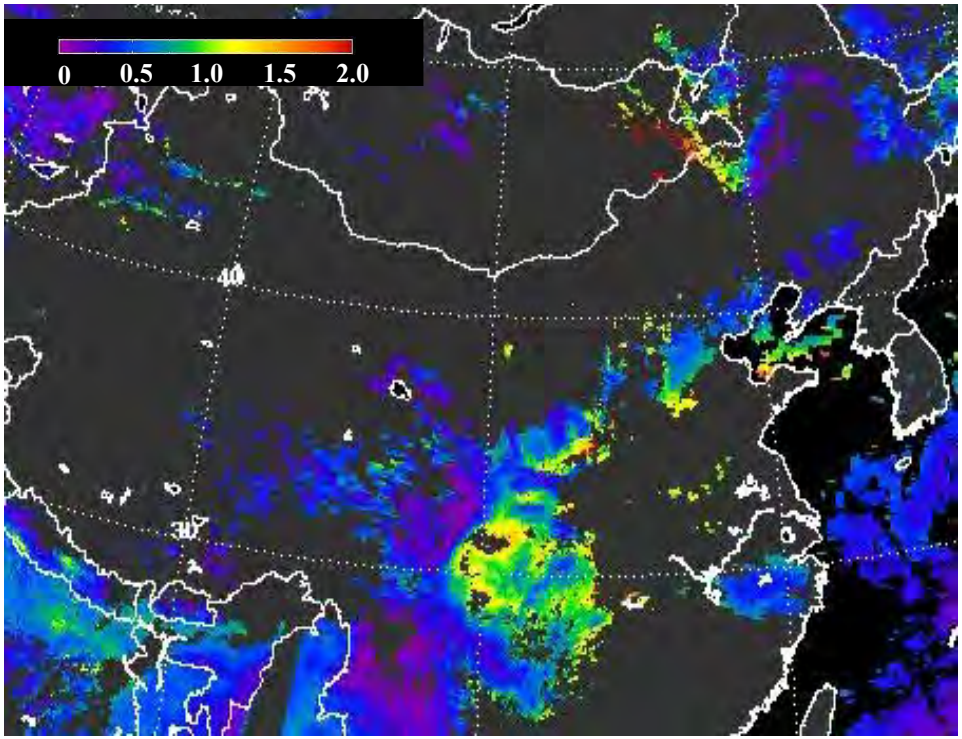
6 April 2001

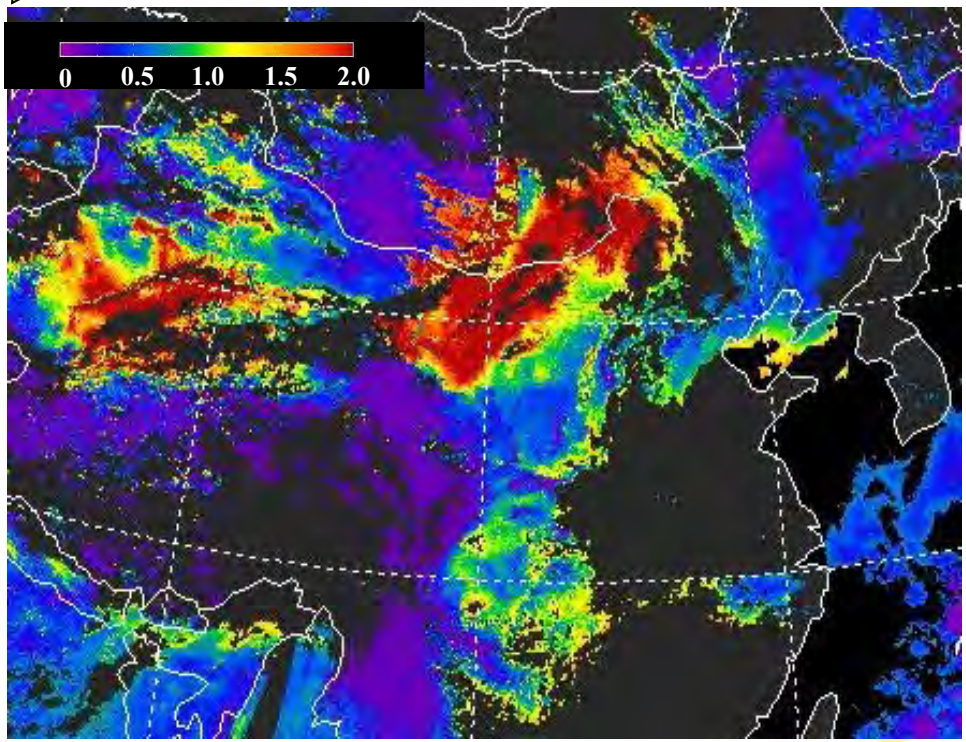


MODIS *Red*-*Green*-*Blue* with Rayleigh scattering removed

Current* MODIS *retrievals:
Aerosol Optical Thickness

New* MODIS *Deep Blue:
Aerosol Optical Thickness

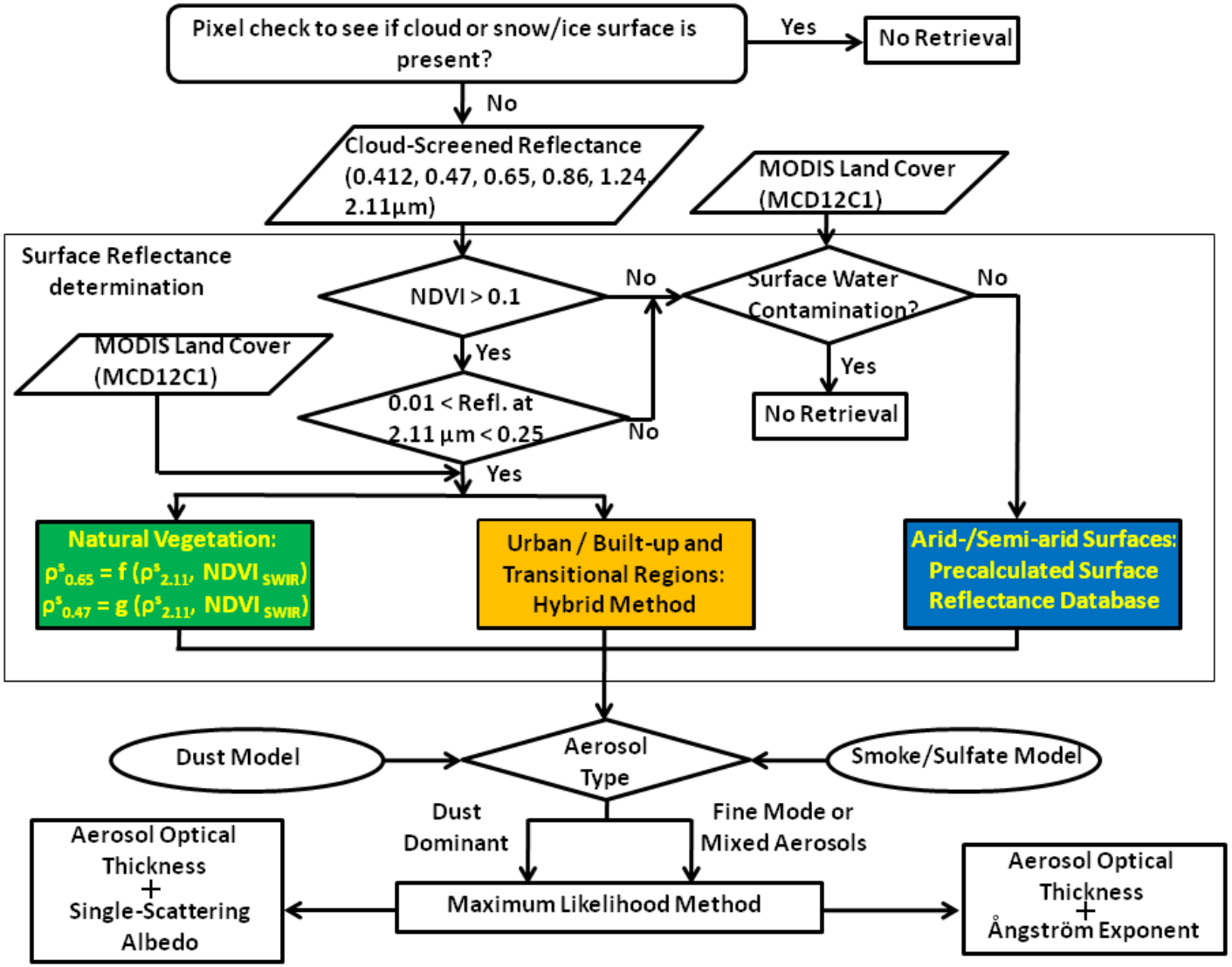




Recent Progress on Deep Blue Aerosol Algorithm in MODIS C6

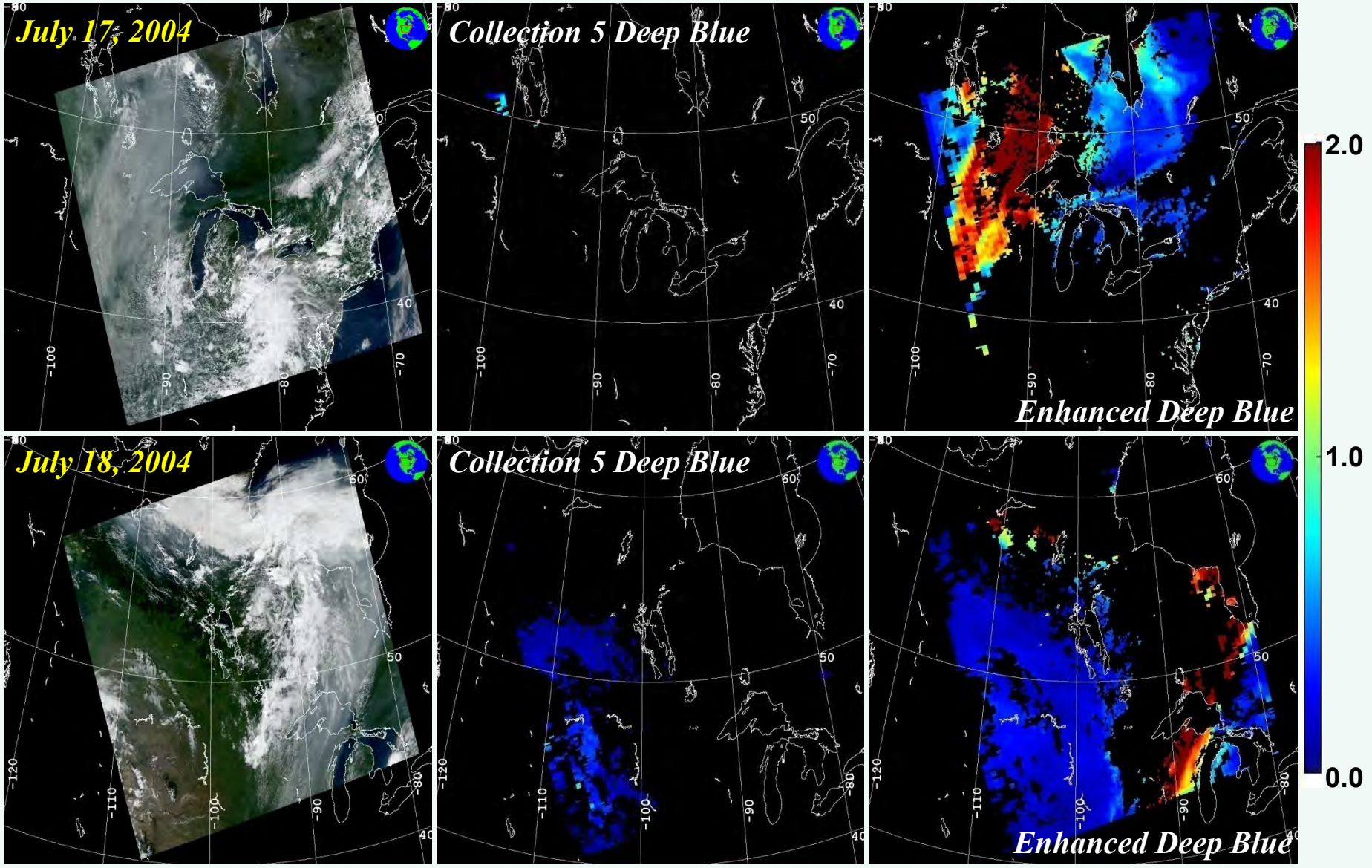
- Expand coverage from arid and semi-arid regions into vegetated (SeaWiFS, MODIS C6, and VIIRS) areas as well as oceans (SeaWiFS and VIIRS only)
- Move away from the static surface reflectance data bases
  - implemented dynamic surface reflectance determination into Deep Blue algorithm;
  - include changes in vegetation using NDVI.
- Improve cloud screening scheme, particularly for the presence of thin cirrus under moist deprived regions
- Better identify strongly absorbing mineral dust by using both visible and IR channels simultaneously

Flowchart of MODIS C6 Deep Blue Algorithm

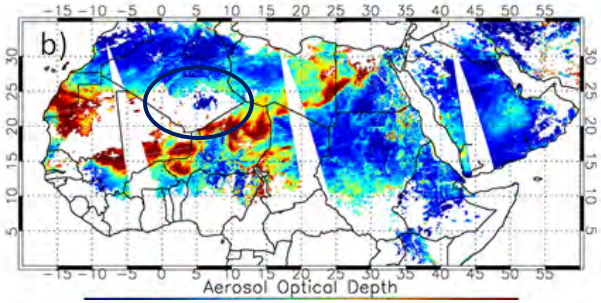


Reference: *Hsu, N. C., M.-J. Jeong, C. Bettenhausen, A. M. Sayer, et al., Enhanced Deep Blue Aerosol Retrieval Algorithm: The Second Generation, J. Geophys. Res. , 118, doi:10.1002/jgrd.50712, 2013.*

Expanding Spatial Coverage of Deep Blue Aerosol Retrieval into Entire Land Surfaces including Vegetated Areas

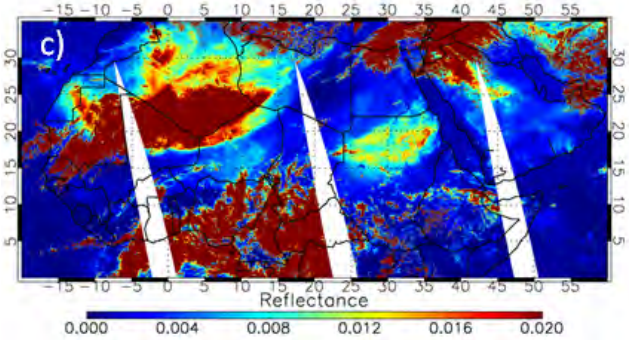


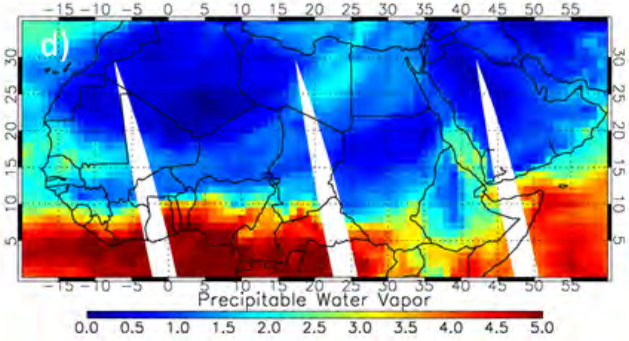
MODIS RGB image over Sahara on March 7, 2006



MODIS C5 Deep Blue AOT

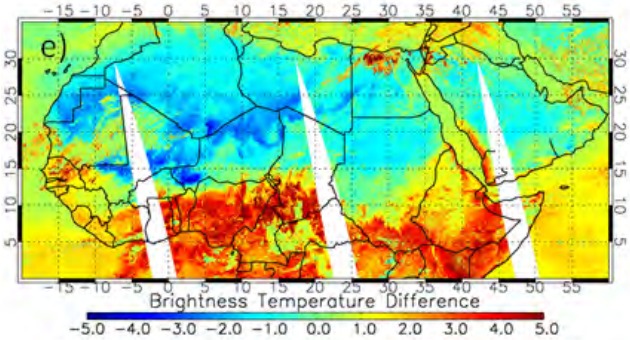
TOA Reflectance at 1.38 μm

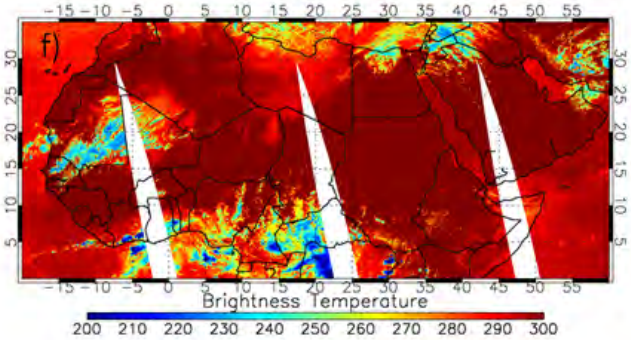




Precipitable water vapor

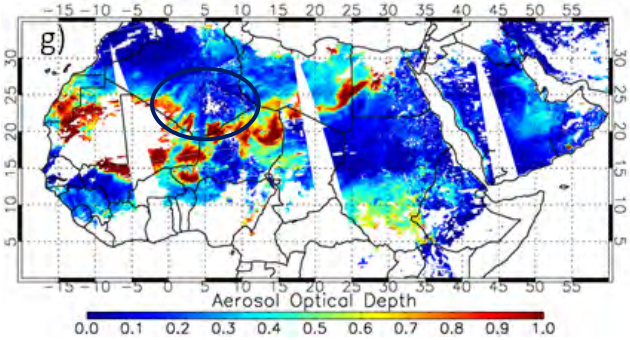
BTD11-12





Brightness temperature at 11 μm

MODIS C6 Deep Blue AOT

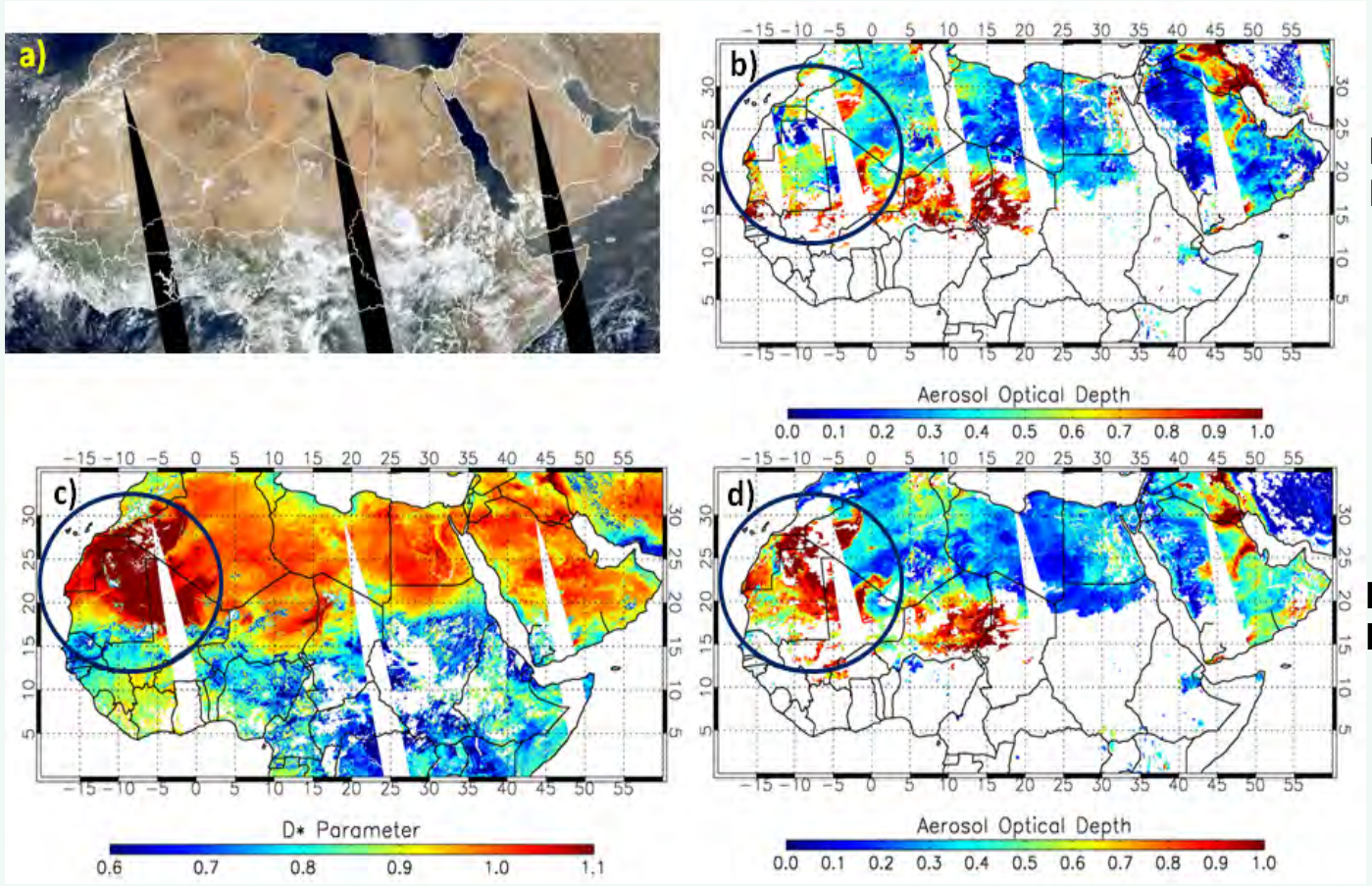


Improving Thin Cirrus Over-Screening over Moist Deprived Regions

Identifying Strongly Absorbing Dust using Brightness Temperature Differences from Thermal Infrared Channels

MODIS RGB image over Sahara on July 9, 2007

D* values

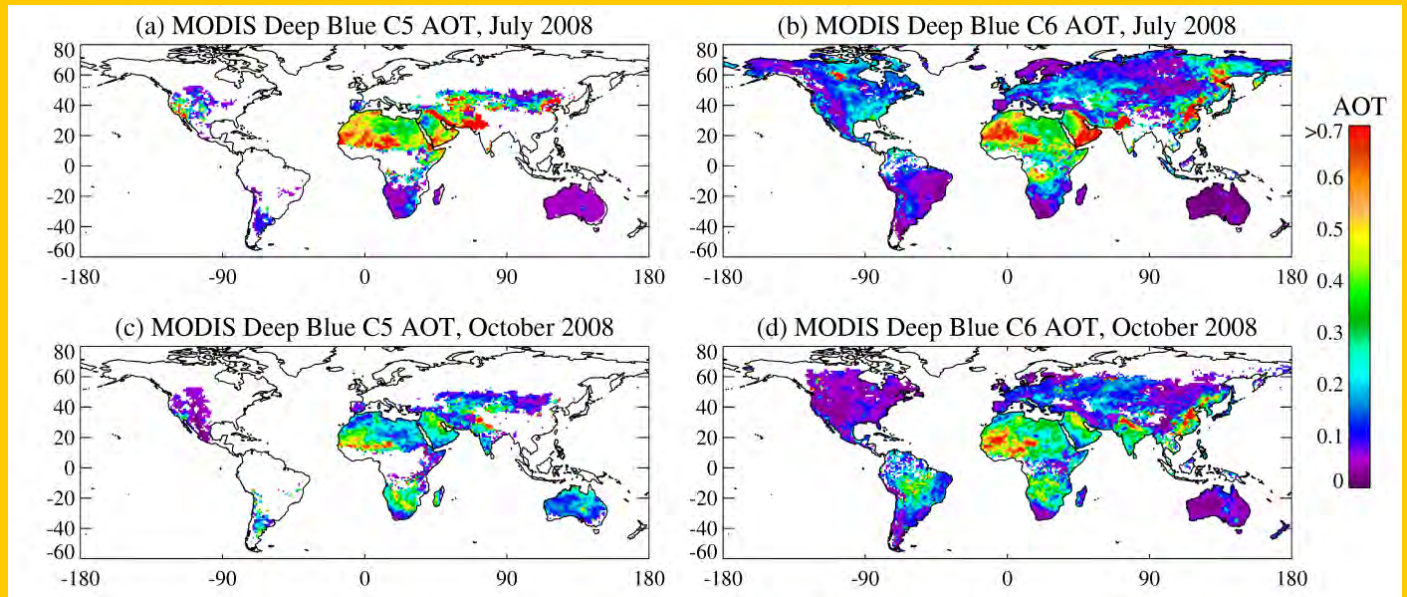


MODIS C5 Deep Blue AOT

MODIS C6 Deep Blue AOT

When D* >1.1, a Heavy Dust Flag will be triggered and then different retrieval path will be performed in the Deep Blue algorithm, where D* = *exp*{[(BTD11-12) + 0.05] / [(BTD8-11) – 10.0)]}.

Comparisons of Monthly AOT at 550 nm and Angstrom Exponent for July and October 2008 (MODIS Aqua C5 vs. C6)



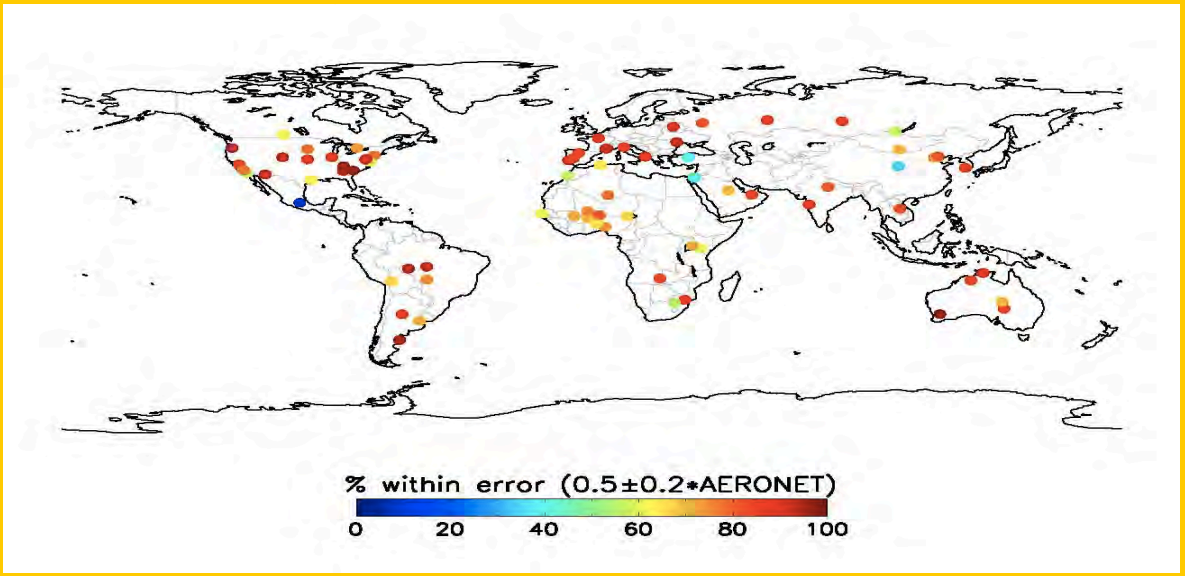
AOT

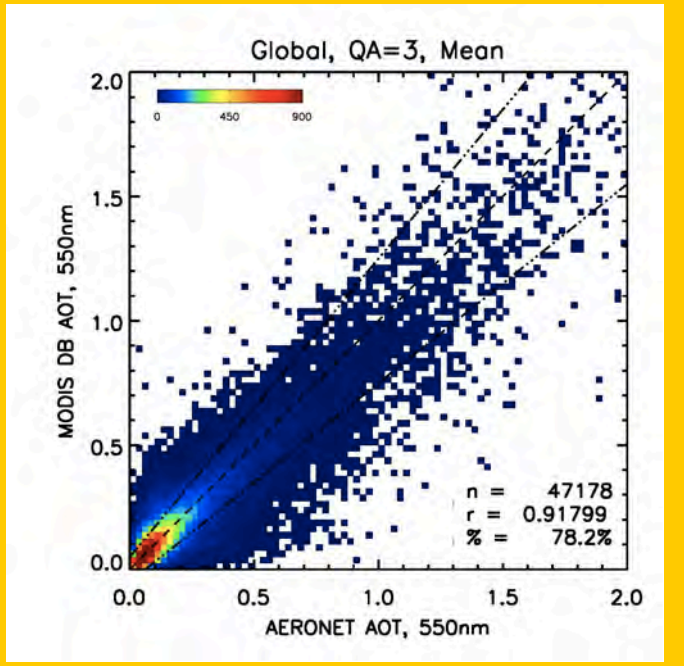
AE

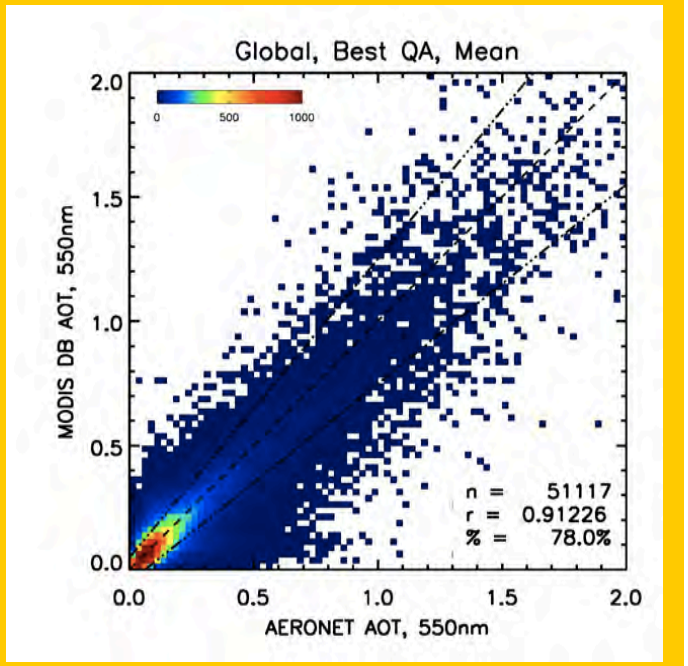
Only data with better QA (2 or 3) flag are included in the analysis

MODIS C6 Deep Blue Aerosol Retrieval Validation

Global Statistics of the Comparisons of MODIS-Aqua with AERONET AOT







- Over land, the expected error is **±0.05±0.20*AOT.**
- Among the land only data, **78.2%** of the QA=3 data and **78.0%** of the QA=2,3 fall into the expected error range.

Reference: *Sayer et al, Validation and uncertainty estimates for MODIS Collection 6 "Deep Blue" aerosol data, JGR, 2013.*

Applying Polarization Correction to Terra L1B data for *Deep Blue* Aerosol Retrieval

(PC algorithm developed by ocean color team)

$$I_m/M_{11} = I_t + m_{12}\,(Q_t \cos 2\alpha + U_t \sin 2\alpha) + m_{13}\,(-Q_t \sin 2\alpha + U_t \cos 2\alpha)$$

I_m : TOA MODIS measured radiance

I_t : TOA MODIS expected radiance

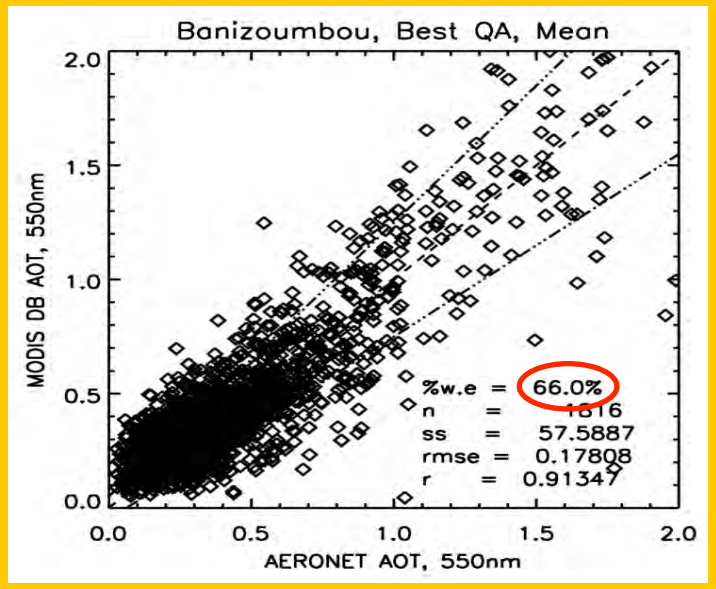
Q_t, U_t : linear Stokes vector components, modeled from Rayleigh and glint

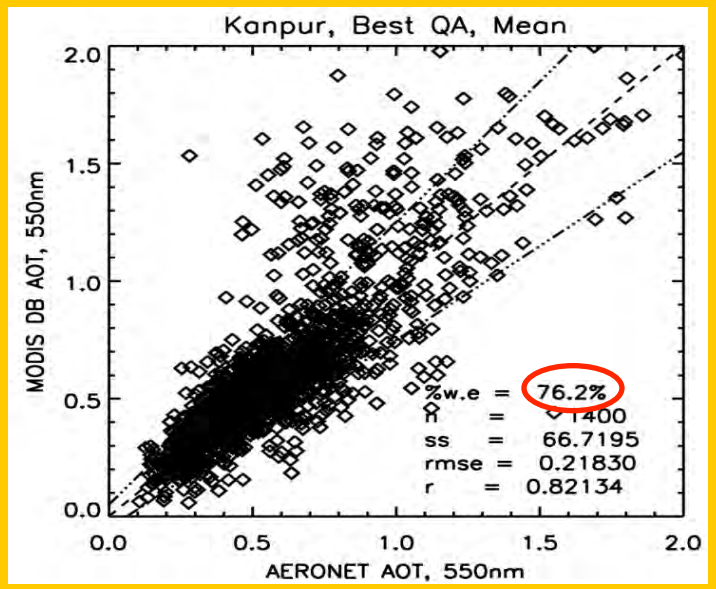
α : angle between the incident light and sensor reference plane

M11, m12, m13 : fitted instrument characterization parameter (depend on band, mirror side, detector, scan angle)

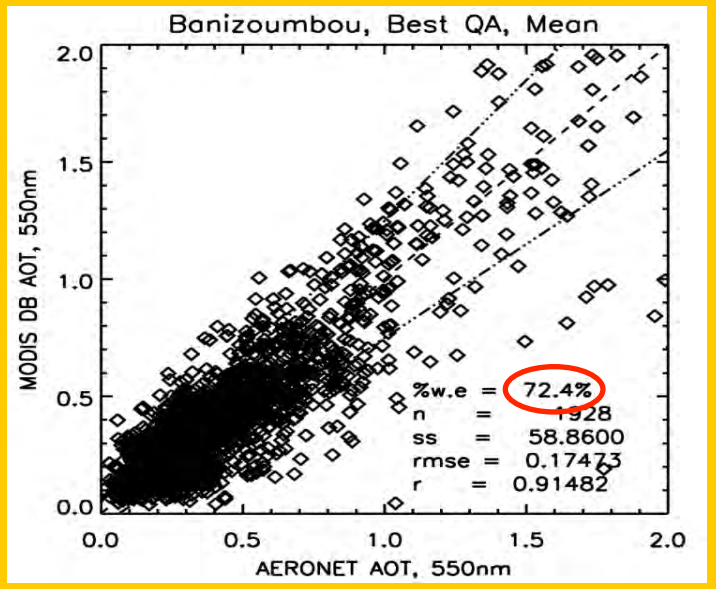
(Meister et al., 2005, Appl. Opt.)

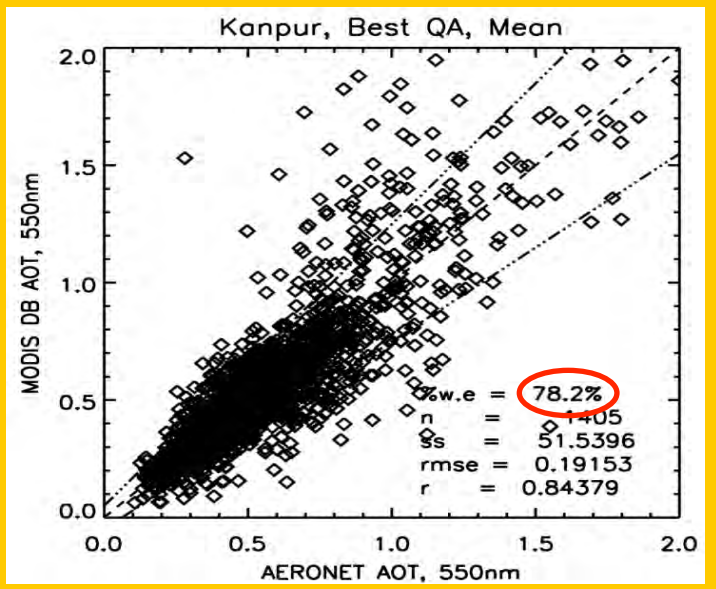
Before Polarization Correction





After Polarization Correction



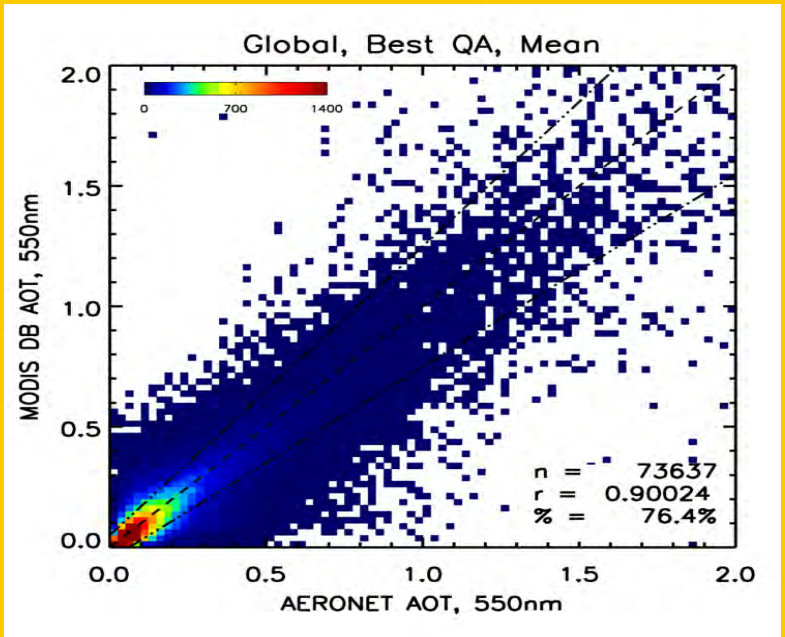


★ **The percentages of Terra/MODIS retrieved AOT that fall into the expected error have improved after applying the polarization correction provided by ocean color group at GSFC.**

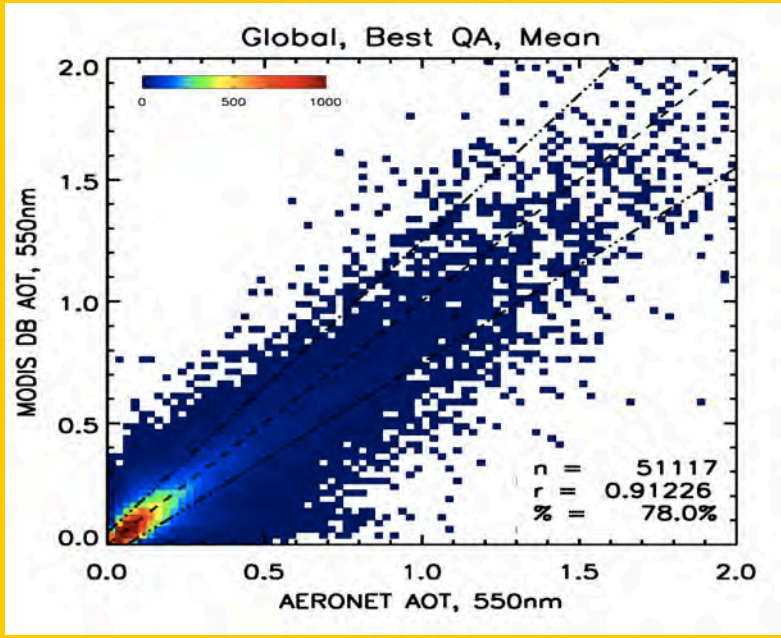
MODIS C6 Deep Blue Aerosol Retrieval Validation

Global Statistics of the Comparisons of MODIS with AERONET AOT: Terra vs. Aqua

Terra

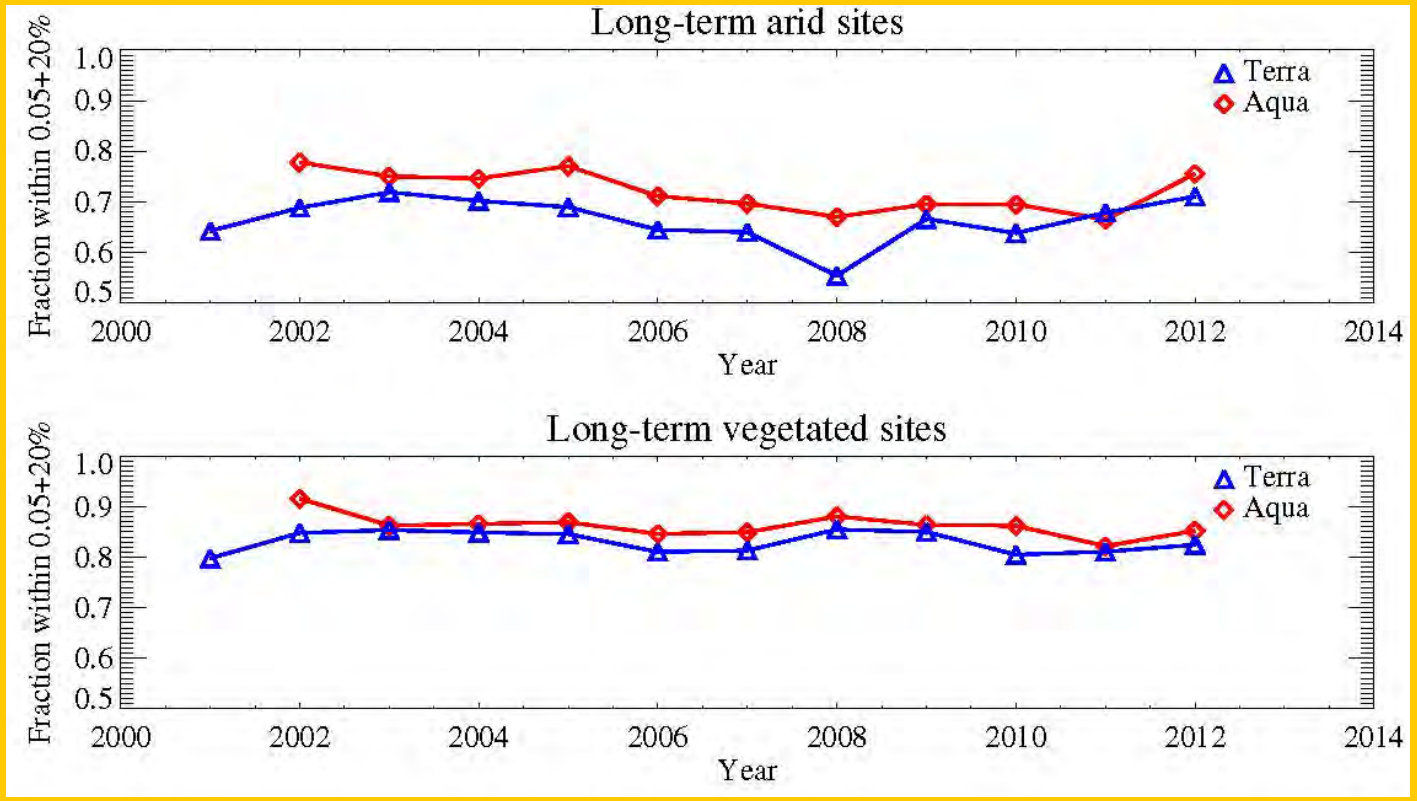


Aqua



- Over land, the expected error is ±0.05±0.20*AOT.
- Overall, the performance for Aqua is better than for Terra. Among the land only data, 78.0% of the Aqua and 76.4% of the Terra data fall into the expected error range.

MODIS C6 Deep Blue Aerosol Retrieval Performance as Function of Year: Terra vs. Aqua



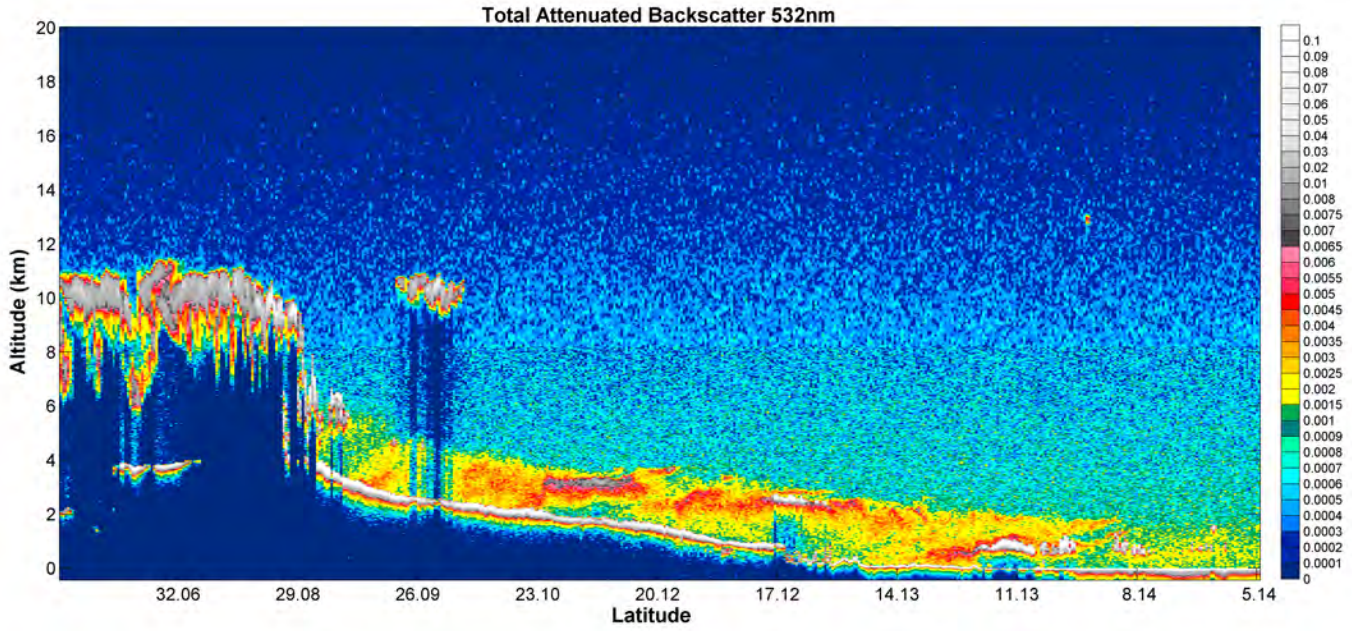
- **In general, no obvious changes in the long-term stability of the AOT retrieval performance for both C6 Terra and Aqua;**
- **As expected, the performance of DB aerosol retrieval is better over vegetated region compared to the arid regions. Overall, performance for Aqua is better than that for Terra.**

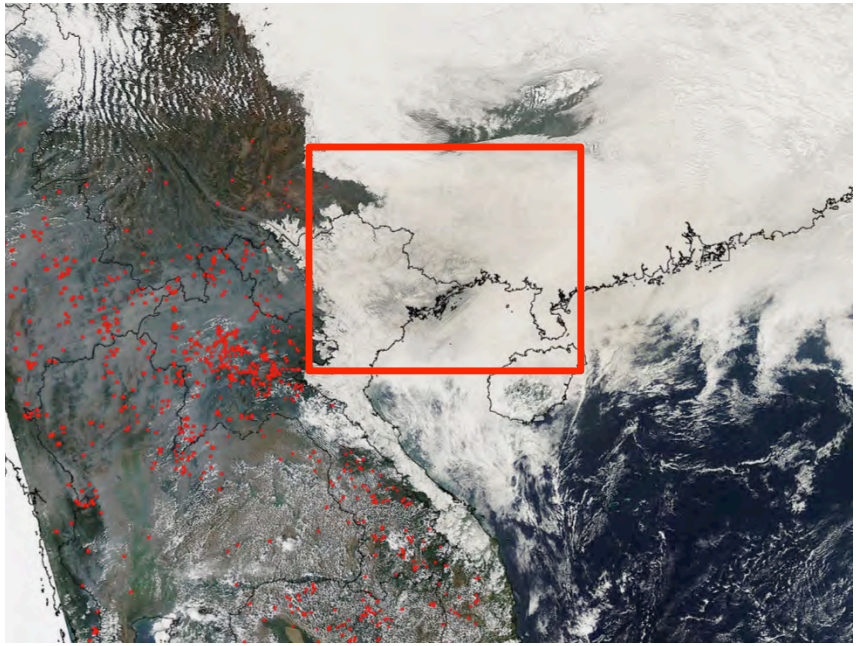
Planning for MODIS Collection 7:

Extending Deep Blue Aerosol Products from Cloud free to Cloudy regions

Aerosol above cloud
Vertical distribution

Southeast Asia



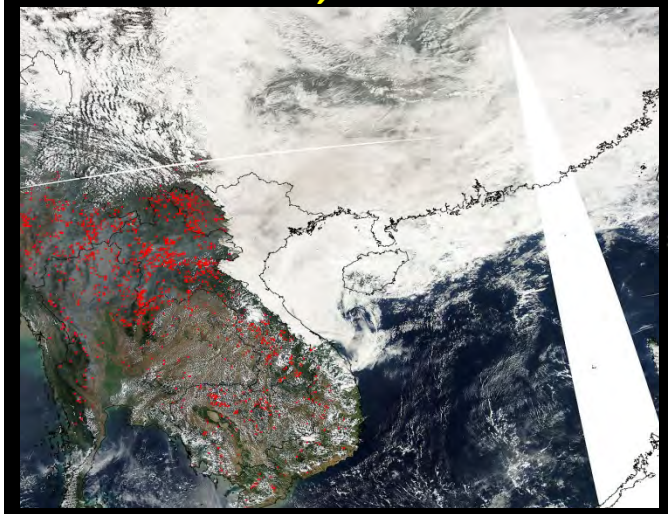


Smoke plumes are frequently observed above stratus clouds during spring over SE Asia.

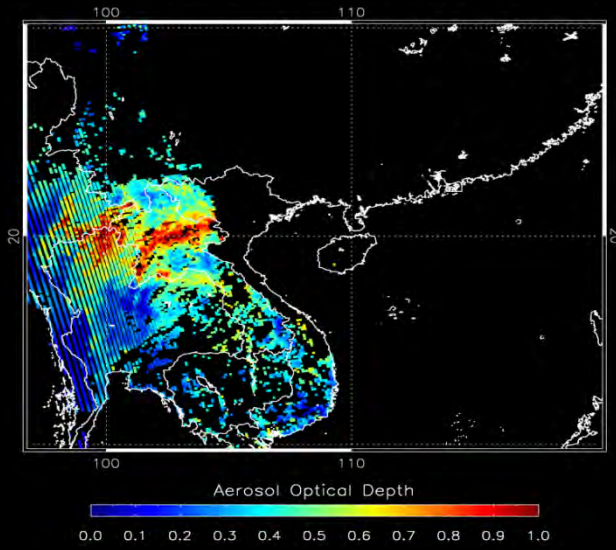
(Top) CALIPSO image of aerosol and cloud vertical profiles; (Bottom) MODIS true color image superimposed with fire count data (red dots).

New Deep Blue Aerosol Products for MODIS C7: AOD and Aerosol Forcing above Clouds

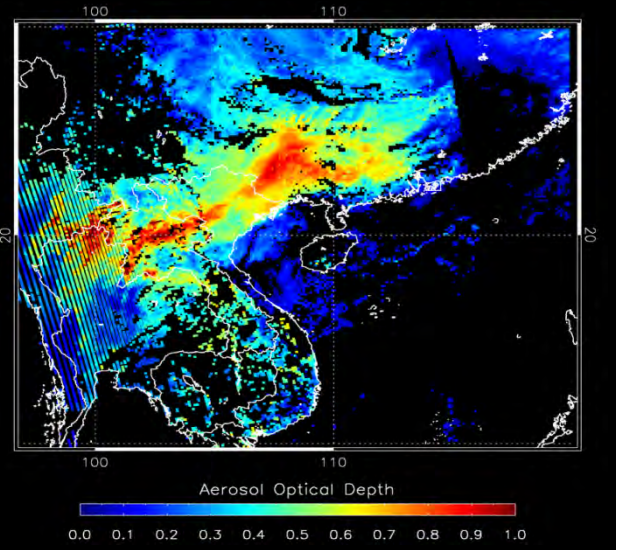
Aqua/MODIS RGB March 6, 2009



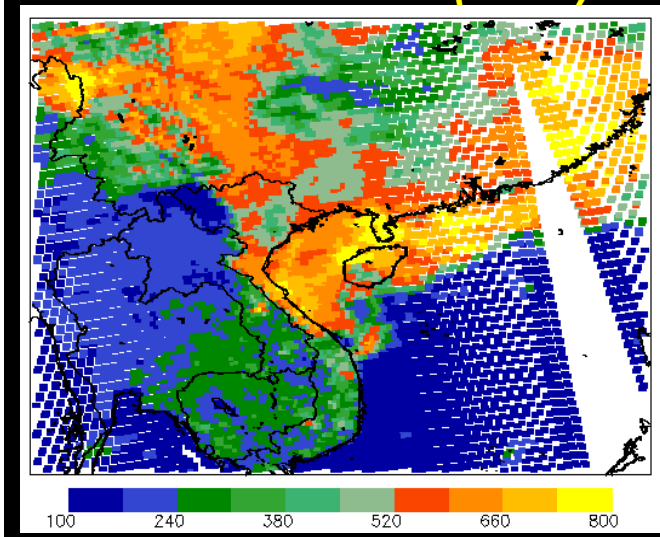
MODIS C6 Deep Blue AOD



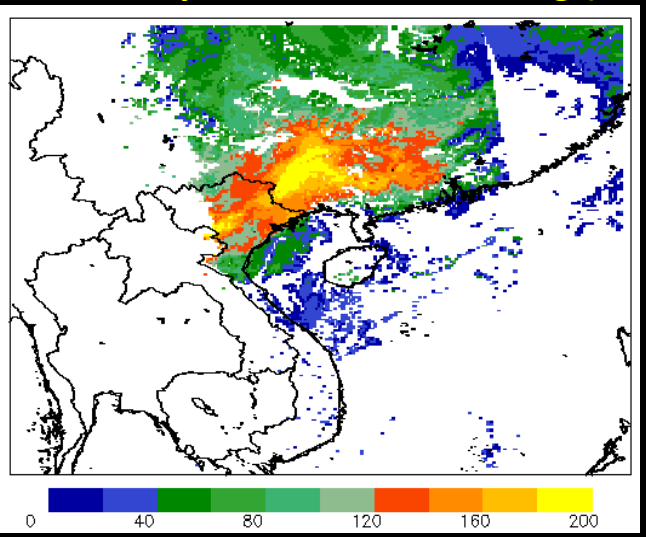
MODIS C6 Deep Blue + new AOD above clouds



CERES TOA SW Flux (Wm^{-2})



MODIS Deep Blue Aerosol Forcing (Wm^{-2})



Aerosol retrieval above cloud algorithm is based upon *Hsu et al. 2003.*

Summary

- **Both the spatial coverage and retrieval accuracy have been substantially improved in the MODIS C6 Deep Blue aerosol products compared to C5, as a result of the enhancement made in surface reflectance determination scheme and cloud screening as well as the utilization of thermal IR bands.**
- **Based upon the comparisons with AERONET AOD global observations, the expected error for Aqua/MODIS C6 DB is 0.05±20% over land. The performance for Terra is a little bit worse compared to that for Aqua, due to sensor degradation issue of Terra.**
- **We have started planning for the MODIS C7 reprocessing to implement the AOD and aerosol forcing above cloud retrievals into the Deep Blue algorithm.**

For more details, See our posters:

1. Sayer et al., MODIS Collection 6 Aerosol Products: Comparing "Deep Blue" and "Dark Target" Data

2. Lee et al., Retrieval of Aerosol Optical Properties under Thin Cirrus from MODIS

3. Bettenhausen et al., Validation of MODIS Collection 6 Deep Blue Aerosols