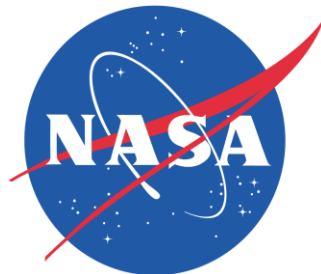# Extending the "Deep Blue" aerosol record from SeaWiFS and MODIS to NPP-VIIRS

**Andrew M. Sayer, N. Christina Hsu (PI)**, Corey Bettenhausen, Jaehwa Lee
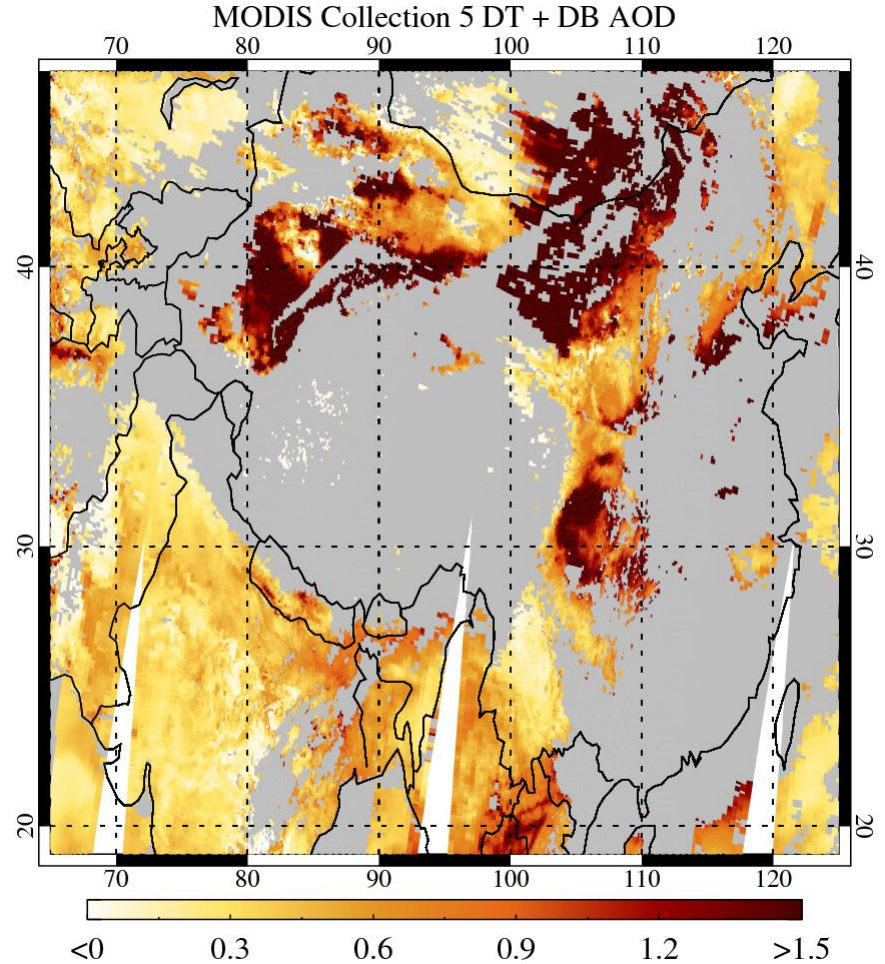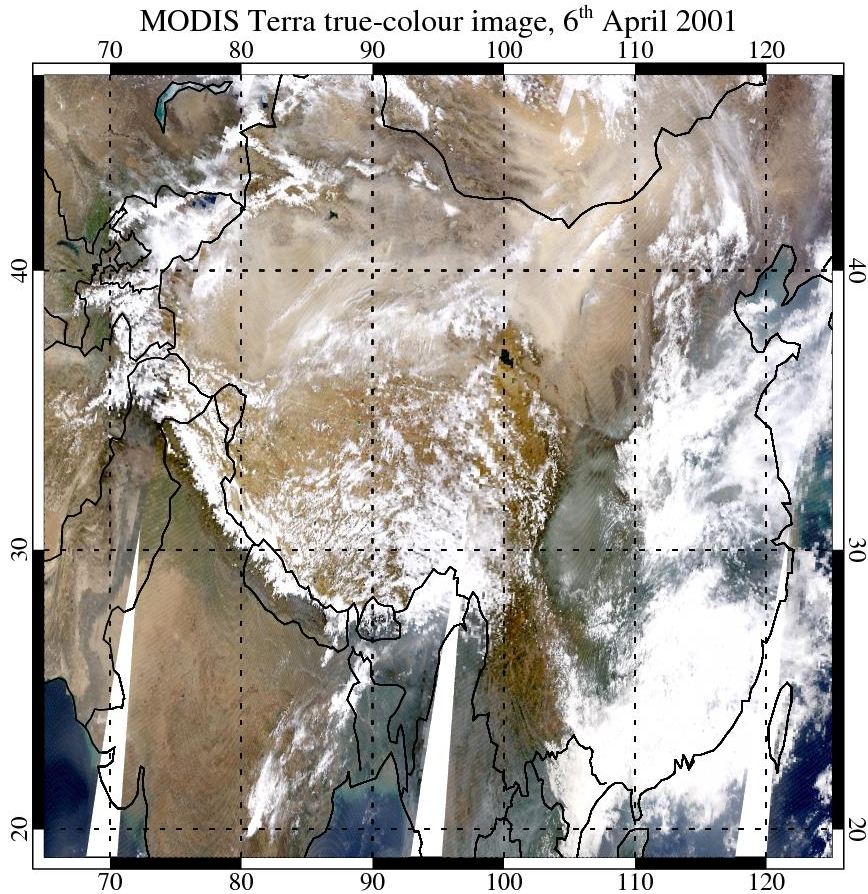
Climate & Radiation Laboratory, NASA Goddard Space Flight Center
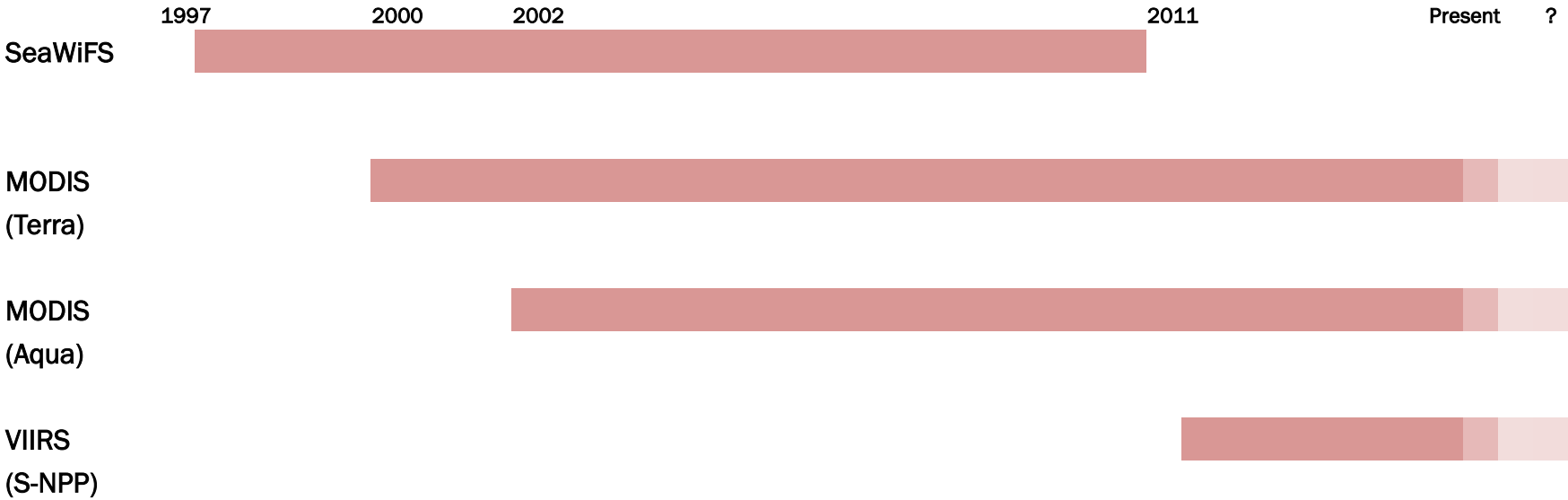
andrew.sayer@nasa.gov

# Deep Blue expands AOD coverage to deserts and other bright surfaces



MODIS Terra true-colour image, 6th April 2001



MODIS Collection 5 DT + DB AOD

# Using multiple similar satellite sensors enables us to obtain a long data record



| 1997 | 2000 | 2002 | 2011 | Present | ? |

SeaWiFS

MODIS (Terra)

MODIS (Aqua)

VIIRS (S-NPP)

# The Deep Blue family consists of three separate aerosol optical depth (AOD) retrieval algorithms

**Bright land**

Surface reflectance database, BRDF correction

AOD retrieved separately at each of 412, 470/490, (650) nm

SSA retrieved for heavy dust events

**Dark land**

Spectral/directional surface reflectance relationship

AOD retrieved separately at 470/490 and 650 nm

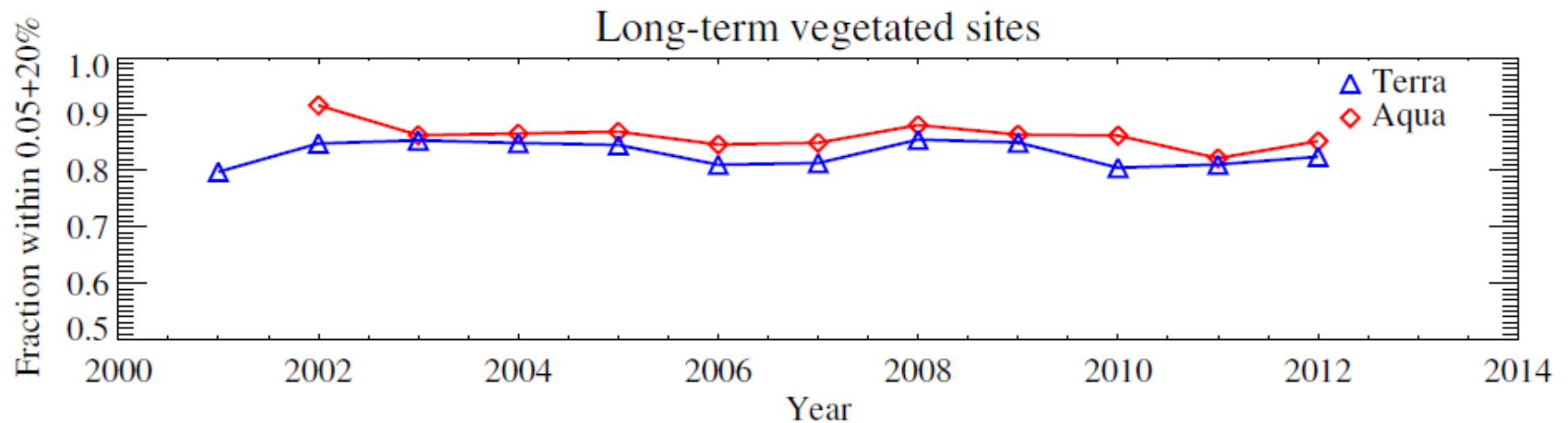**Water**

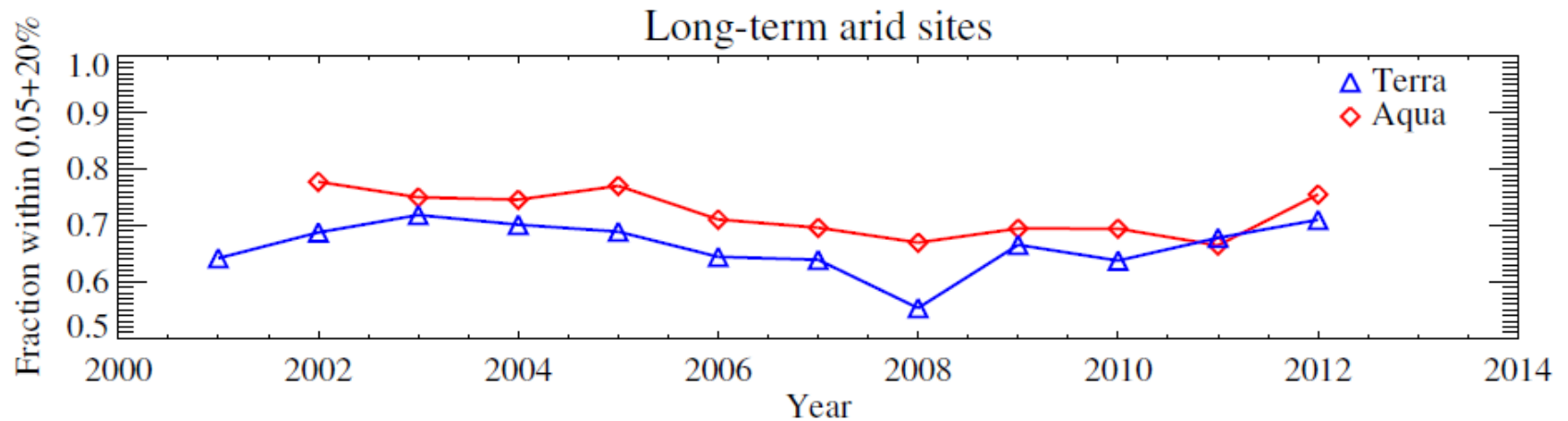Surface BRDF including glint, foam, underlight

Multispectral inversion
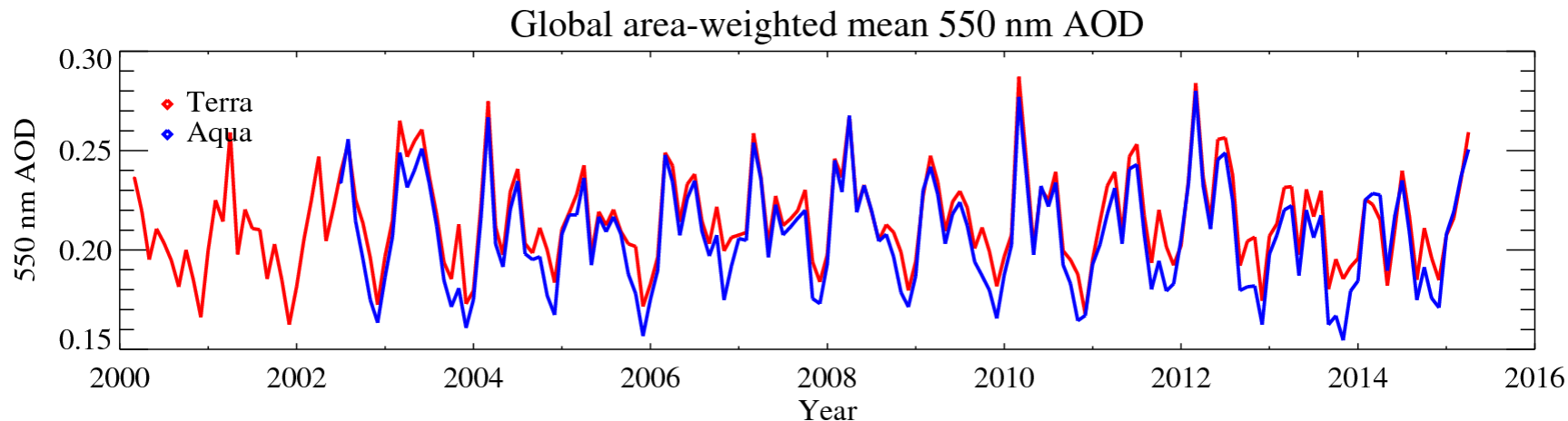
(Not present in MODIS dataset)

All report the AOD at 550 nm, and Ångström exponent (AE)

# MODIS Collection 6 data for Terra and Aqua are now both available, and show good long-term stability
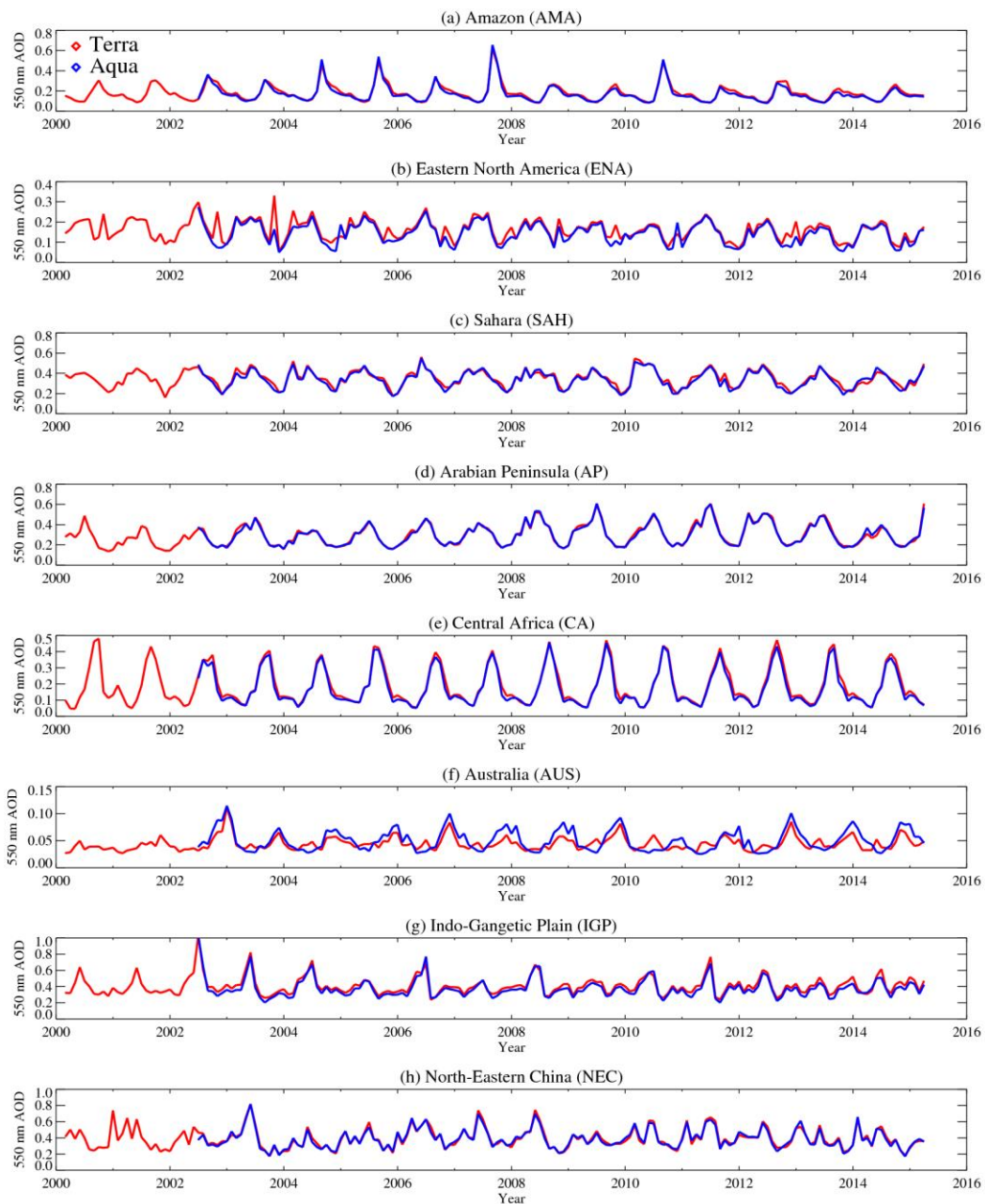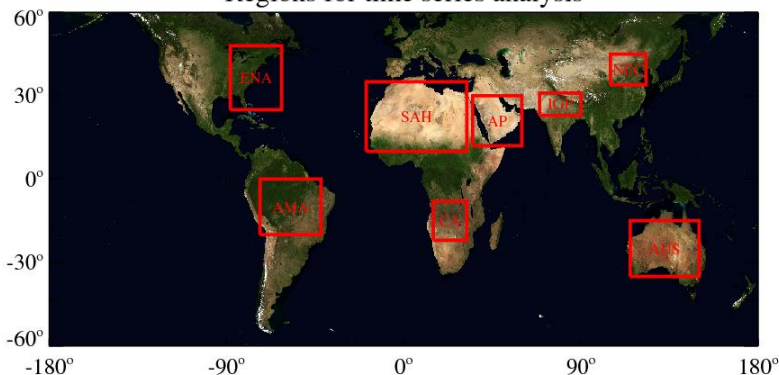
# Terra/Aqua time series track each other closely; Terra has a fairly consistent high AOD offset ~0.005



Global area-weighted mean 550 nm AOD



AOD difference histograms
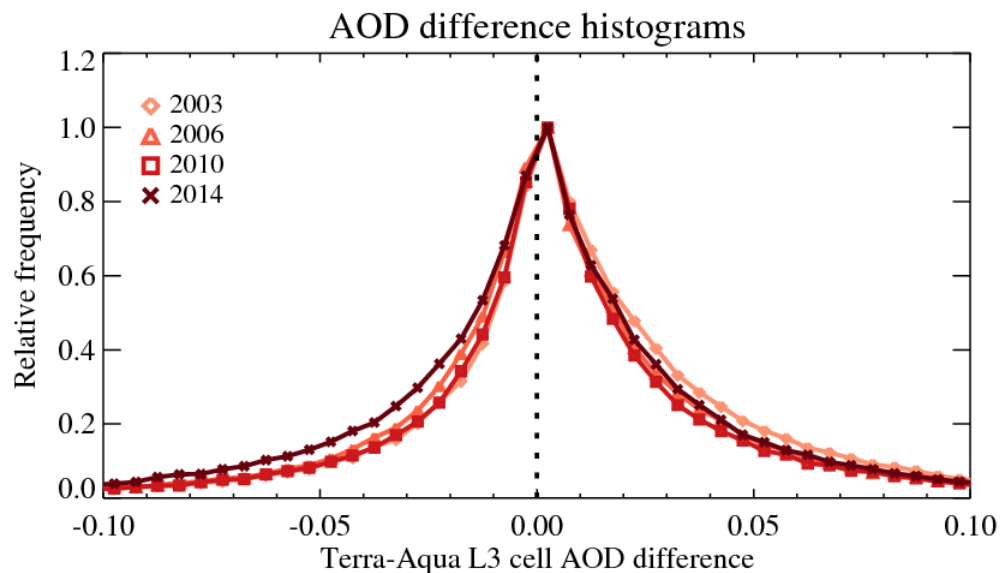
# Regionally, the two sensors show consistent seasonal and interannual variability



Regions for time series analysis



(a) Amazon (AMA)
◇ Terra
◇ Aqua

(b) Eastern North America (ENA)

(c) Sahara (SAH)

(d) Arabian Peninsula (AP)

(e) Central Africa (CA)

(f) Australia (AUS)

(g) Indo-Gangetic Plain (IGP)

(h) North-Eastern China (NEC)

# The Visible Infrared Imaging Radiometer Suite (VIIRS) was launched on S-NPP at the end of 2011, and is similar* to SeaWiFS and MODIS

- Spectral range 412 nm – 12 μm
- Swath width ~3000 km
- M-band resolution ~0.75 km
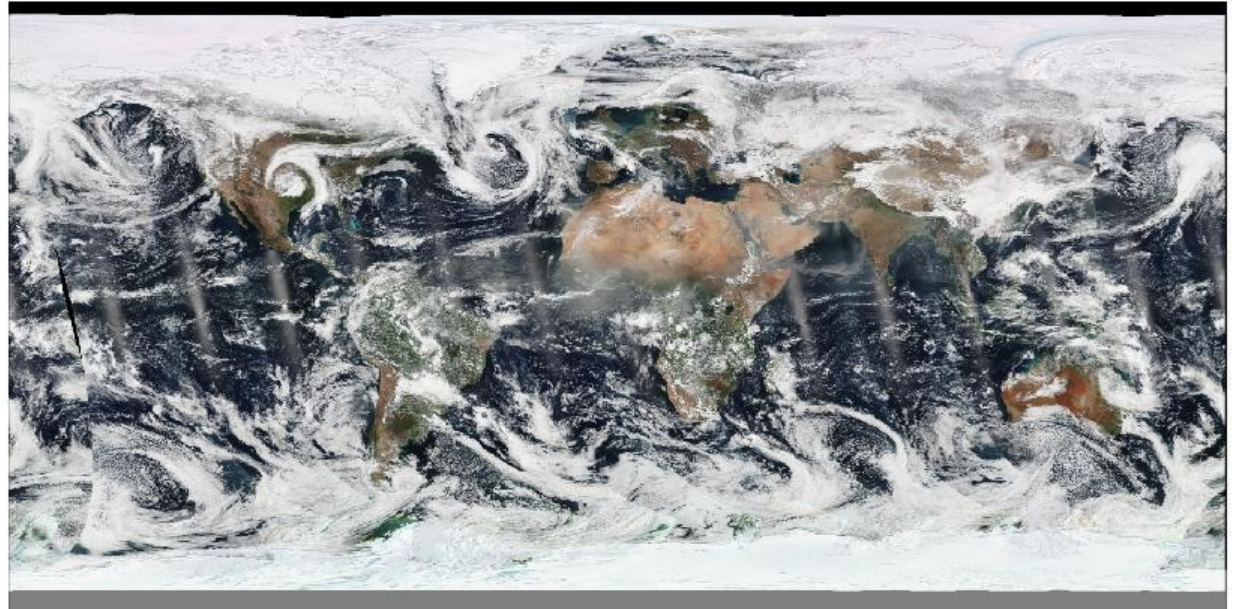


VIIRS RGB (True Color) 2012-03-22

R : M05 (0.672 $\mu$m); G : M04 (0.555 $\mu$m); B : M03 (0.488 $\mu$m)

Image courtesy Wisconsin Atmospheres PEATE/SIPS

*for our purposes

# VIIRS Deep Blue will extend and improve on MODIS heritage products

- Spatial resolution 6 km
  - Reduced scan-edge pixel growth compared to MODIS
- Pixel-level AOD uncertainty estimates (eventually)
- Pixel-level quality assurance (QA) flags
  - Files will include additional QA-filtered datasets
- Levels 2 (swath-level) and 3 (daily/monthly aggregate) products
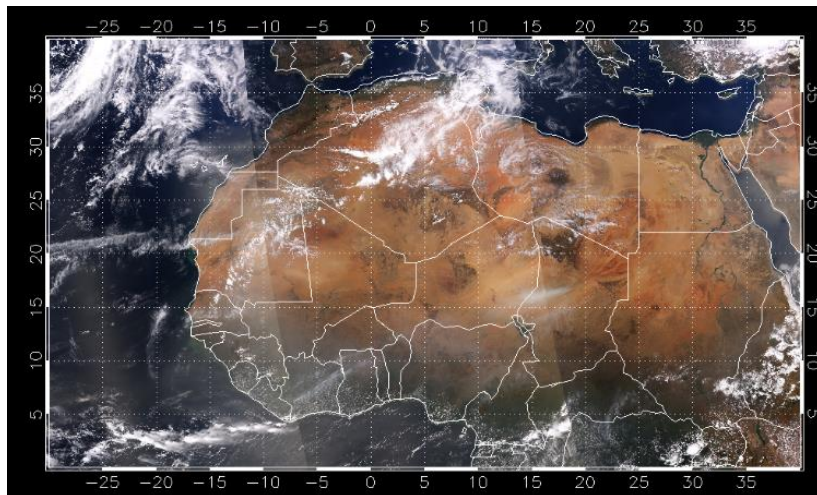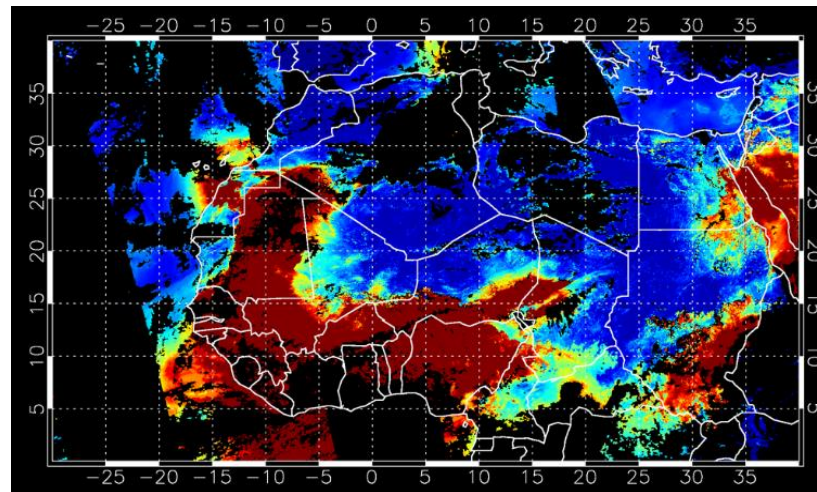- Full mission (re)processing(s) with consistent algorithm and calibration



160 km grid
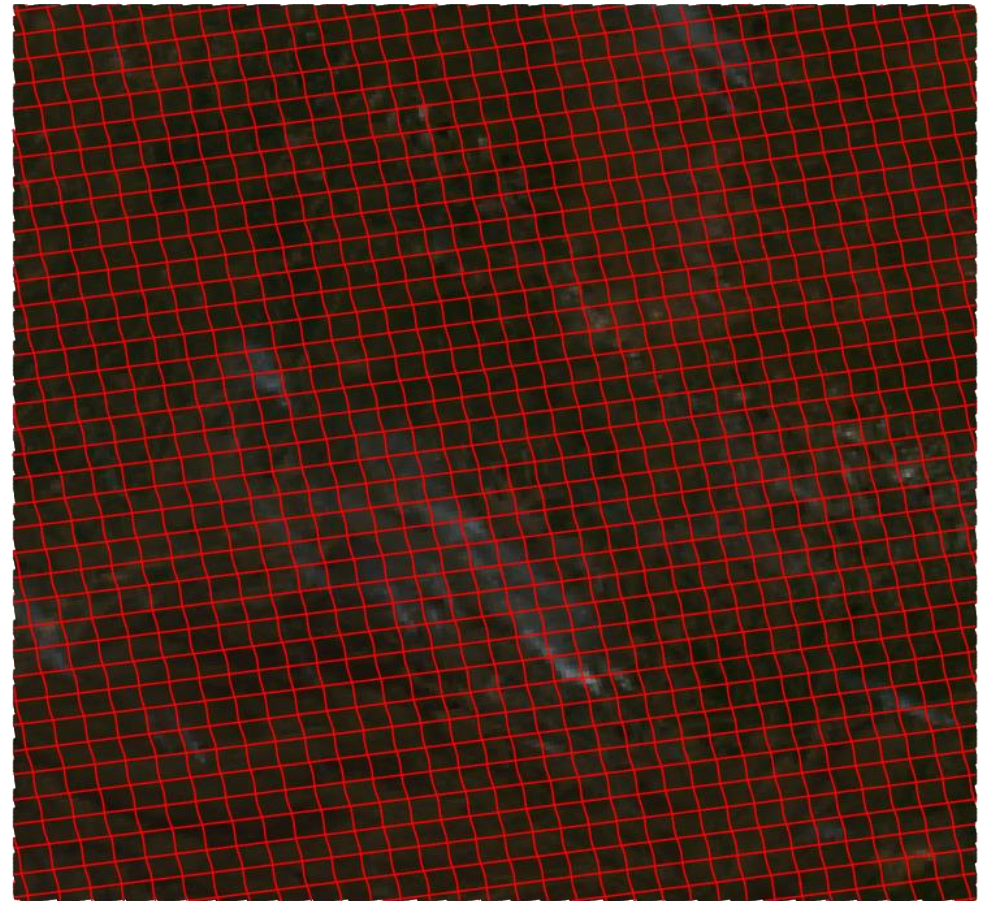
Fires in Africa: 10-12 °S, 21-23 °E
MODIS Aqua, June 1 2006, 12:05 UTC

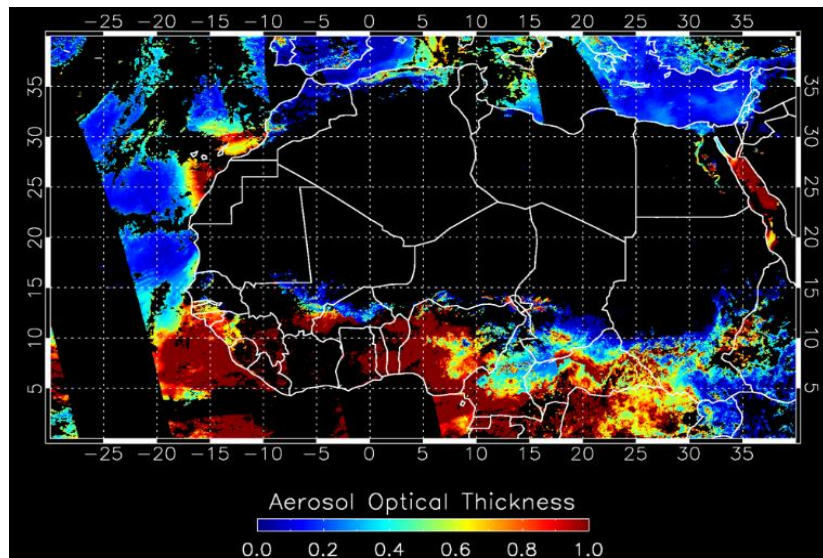# NASA VIIRS Deep Blue covers more surface types than NOAA VIIRS, without the inter-orbit gaps of MODIS

S-NPP/VIIRS RGB March 22, 2012



VIIRS Deep Blue AOD



NOAA VIIRS (IDPS) AOD



Aerosol Optical Thickness

MODIS C6 AOD



Aerosol Optical Thickness
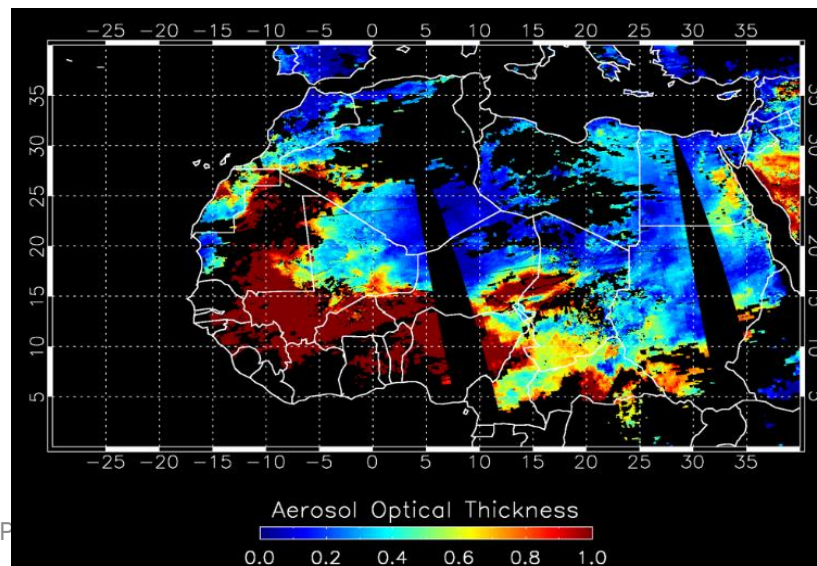
# Retrieval quality seems comparable to MODIS...
## ... over vegetated/suburban land
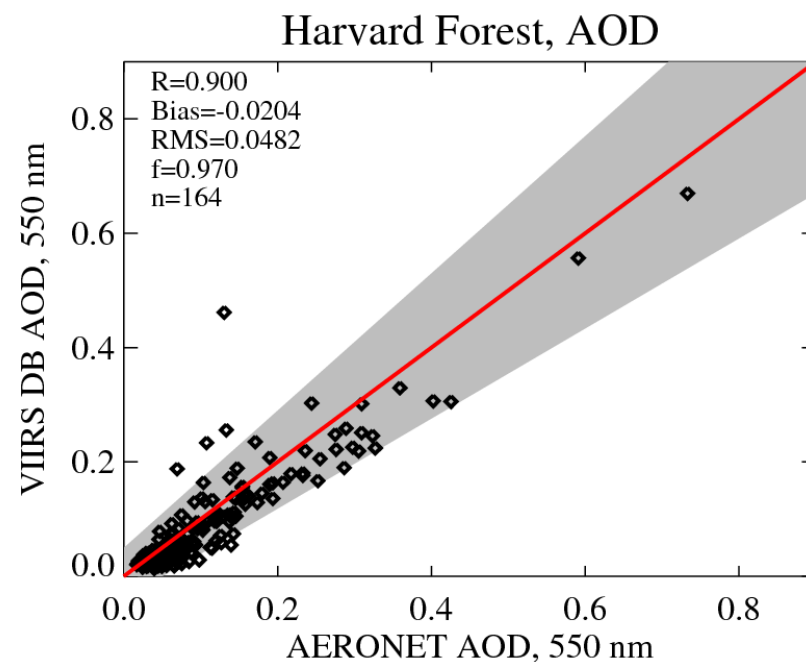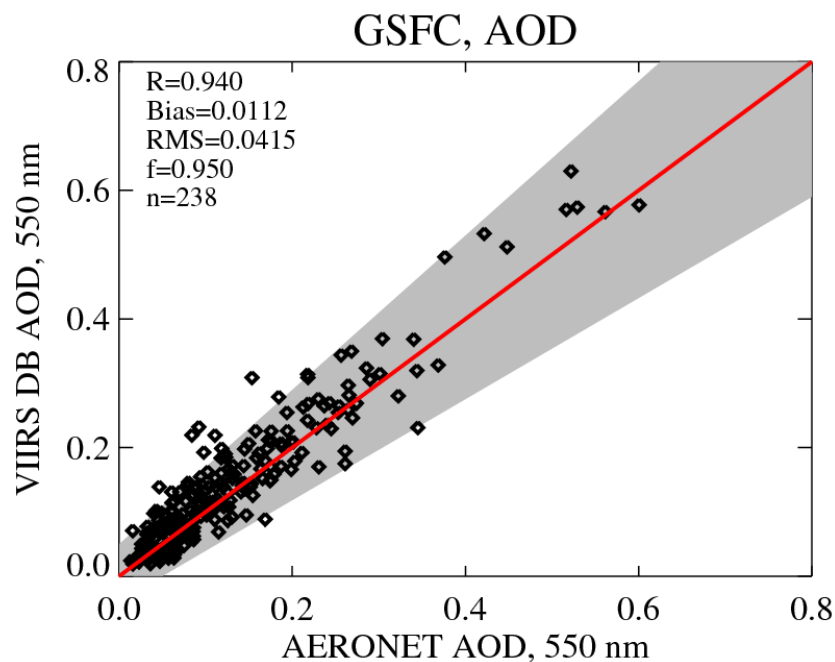


GSFC, AOD

R=0.940
Bias=0.0112
RMS=0.0415
f=0.950
n=238

Harvard Forest, AOD

R=0.900
Bias=-0.0204
RMS=0.0482
f=0.970
n=164

- Shaded 'expected error' confidence interval of ±(0.05+20%)

# Retrieval quality seems comparable to MODIS...
## ... over arid land
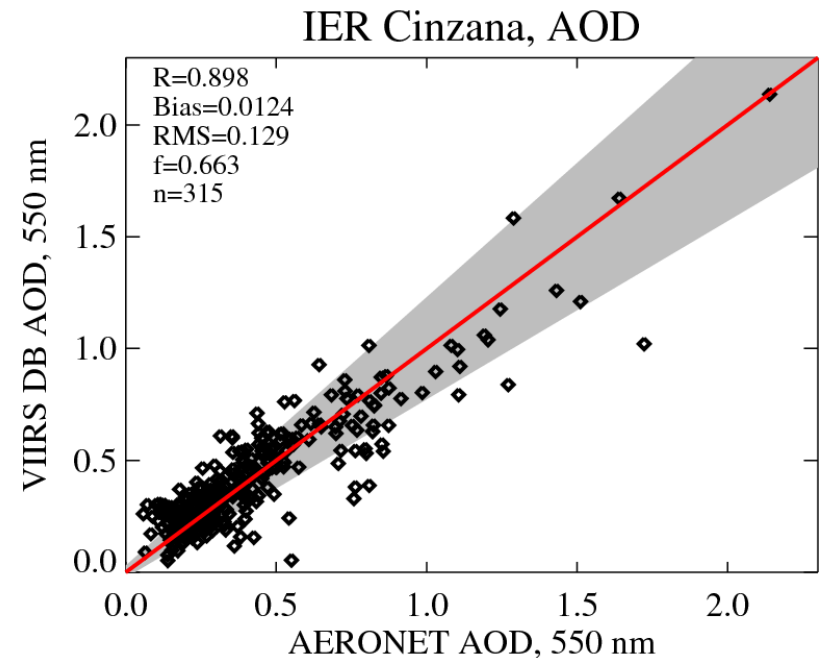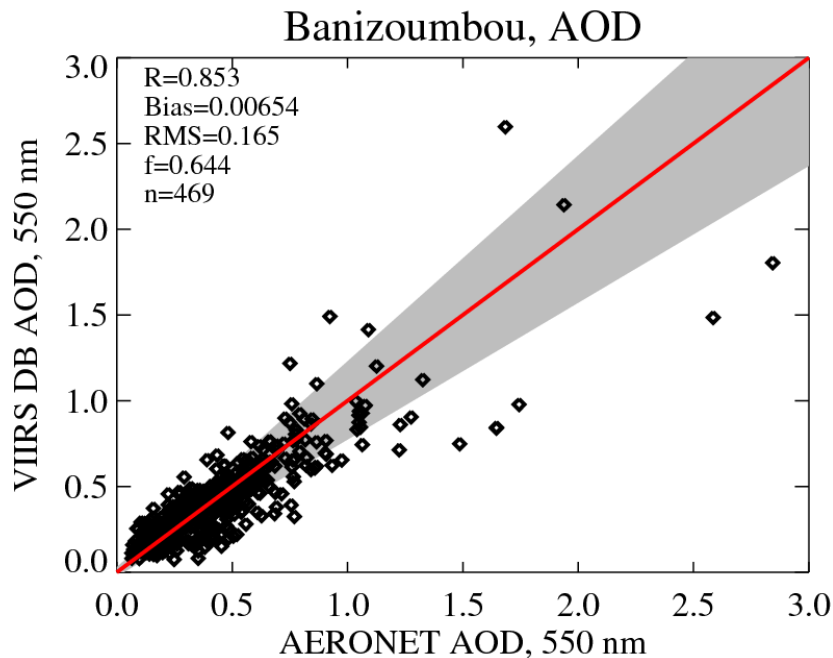


Banizoumbou, AOD
R=0.853
Bias=0.00654
RMS=0.165
f=0.644
n=469

IER Cinzana, AOD
R=0.898
Bias=0.0124
RMS=0.129
f=0.663
n=315

- Shaded 'expected error' confidence interval of ±(0.05+20%)

# Retrieval quality seems comparable to MODIS...
## ... over water



(a) Ascension Island, ocean, AOD

R=0.846
Bias=0.00655
RMS=0.0379
f=0.854
n=205

(b) Ascension Island, ocean, AE

R=0.675
Bias=0.145
RMS=0.361
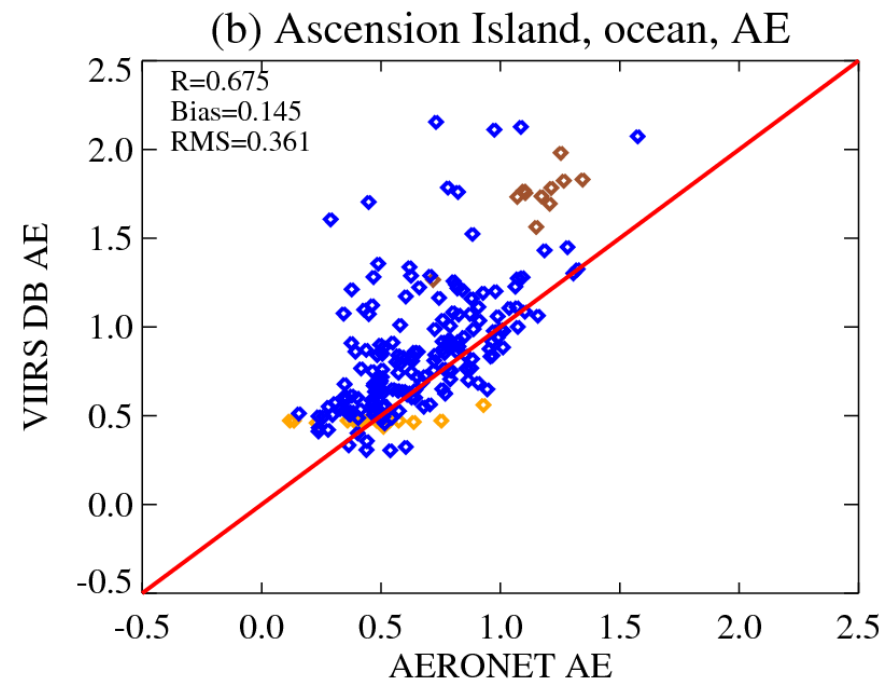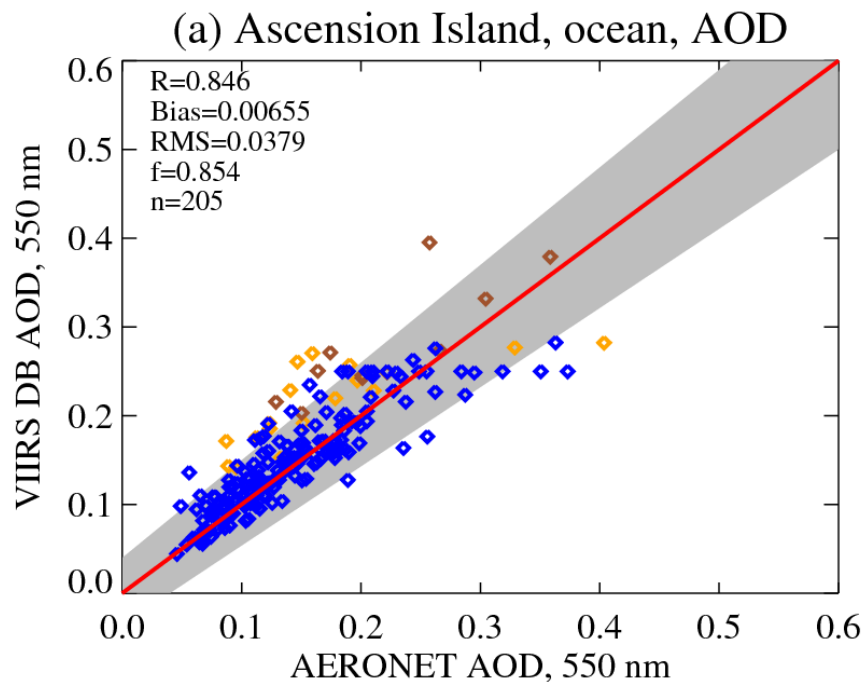
- Shaded 'expected error' confidence interval of ±(0.04+10%)
- Colours indicate aerosol optical model (retrieved, not prescribed):
  maritime, dust, fine-mode dominated

# Retrieval quality seems comparable to MODIS...
## ... over water
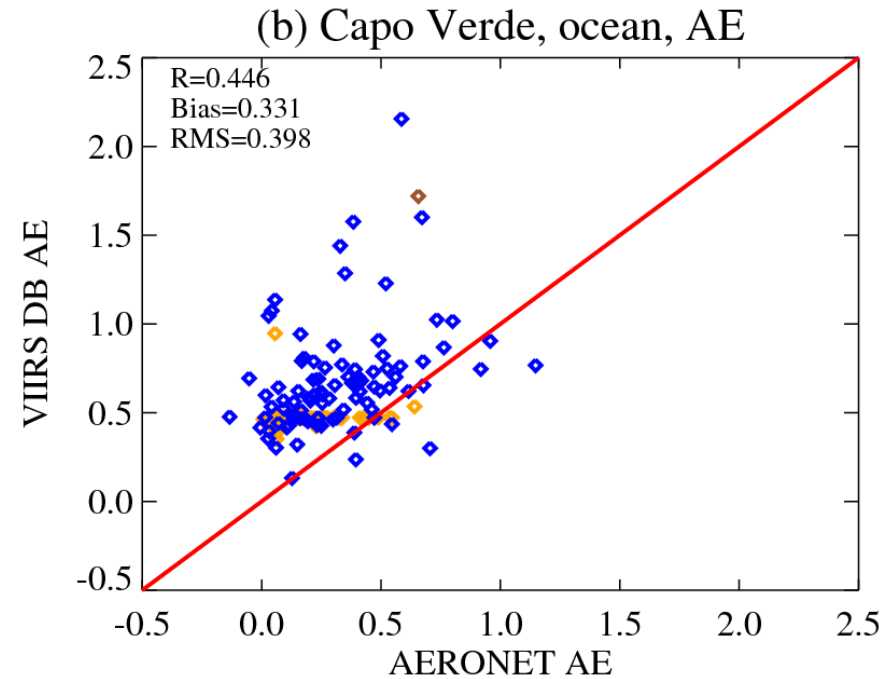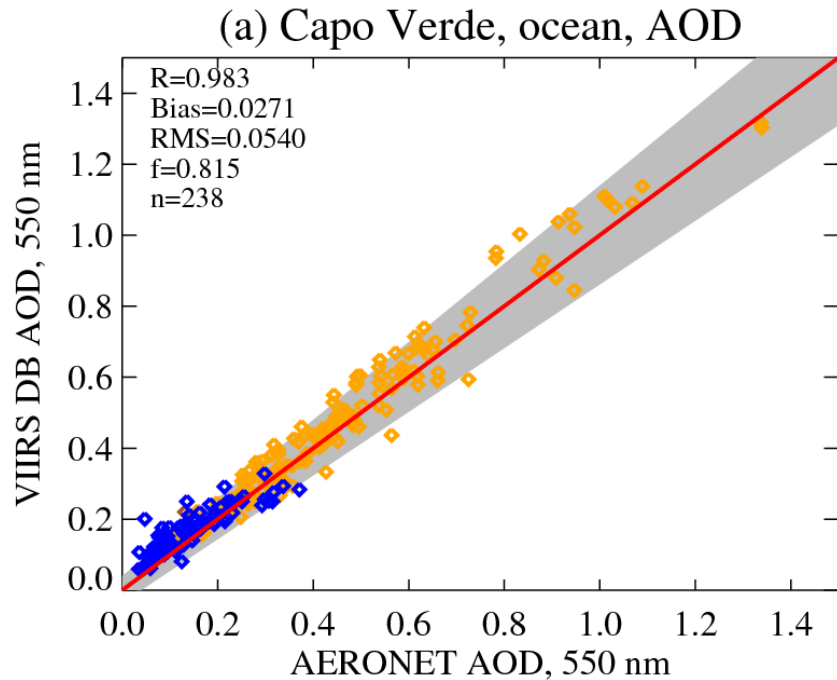


(a) Capo Verde, ocean, AOD

R=0.983
Bias=0.0271
RMS=0.0540
f=0.815
n=238

(b) Capo Verde, ocean, AE

R=0.446
Bias=0.331
RMS=0.398

- Shaded 'expected error' confidence interval of ±(0.04+10%)
- Colours indicate aerosol optical model (retrieved, not prescribed): maritime, dust, fine-mode dominated

# We like hearing from data users

- Centralised Deep Blue website coming soon! Meanwhile:
  - SeaWiFS version 4 – http://disc.gsfc.nasa.gov
  - MODIS Collection 6 – http://modis-atmos.gsfc.nasa.gov/
  - VIIRS first release later this year
    - Will be archived at http://ladsweb.nascom.nasa.gov/data/, alongside MODIS data
    - Near real-time (NRT) data will also be available via LANCE: https://earthdata.nasa.gov/data/near-real-time-data

- Hsu *et al.* (2004), Aerosol properties over bright-reflecting source regions, *IEEE TGRS*, 42 (3), 557-569, doi:10.1109/TGRS.2004.824067

- Hsu *et al.* (2006), Deep Blue retrievals of Asian aerosol properties during ACE-Asia, *IEEE TGRS*, 44, 3180–3195, doi:10.1109/TGRS.2006.879540

- Hsu *et al.* (2013), Enhanced Deep Blue aerosol retrieval algorithm: The second generation, *J. Geophys. Res.*, 118, 9296–9315, doi:10.1002/jgrd.50712

- Sayer *et al.* (2012), SeaWiFS Ocean Aerosol Retrieval (SOAR): Algorithm, validation, and comparison with other data sets, *J. Geophys. Res.*, 117, D03206, doi:10.1029/2011JD016599

- Sayer *et al.* (2013), Validation and uncertainty estimates for MODIS Collection 6 "Deep Blue" aerosol data, *J. Geophys. Res.*, 118, 7864–7872, doi:10.1002/jgrd.50600

- Sayer *et al.* (2014), MODIS Collection 6 aerosol products: comparison between Aqua's e-Deep Blue, Dark Target, and `merged' datasets, and usage recommendations, *J. Geophys. Res.,* 119, 13,965–13,989, doi:10.1002/2014JD022453