MODIS Atmospheres webinar series #4: Collection 6 e-Deep Blue/Dark Target comparison and 'merged' aerosol products

Deep Blue group: N. Christina Hsu (PI), **Andrew M. Sayer,** Corey Bettenhausen, Nick Carletta , M. J. Jeong, Jaehwa Lee
Dark Target group: Rob Levy (PI), Shana Mattoo, Leigh Munchak, Falguni Patadia, Pawan Gupta, Rich Kleidman

(With thanks to previous team members, the MODIS Characterization Support Team, the AERONET group and site PIs/managers, and many others)

Climate & Radiation Laboratory, NASA Goddard Space Flight Center
andrew.sayer@nasa.gov

Images from NASA Earth Observatory, http://earthobservatory.nasa.gov/Features/Aerosols/

Webinar schedule

Topic	Presenter(s)	Date
Overview of Collect 6 update L1 Calibration Overview	Steve Platnick Jack Xiong	25-Jun-14
MODIS Dark Target Global 10 Km Product	Rob Levy	2-Jul-14
MODIS Aerosols Deep Blue	Andy Sayer	9-Jul-14
MODIS Aerosols Merged Dark Target: Deep Blue Product	Rob Levy / Andy Sayer	16-Jul-14
MODIS Dark Target 3 Km Product	Leigh Munchak	23-Jul-14
MOD035 Cloud Mask and Clear Sky Products atmosphere profile and clear sky radiance maps	Steve Ackerman	13-Aug-14
MOD06 Cloud Top Properties Product	Paul Menzel	20-Aug-14
MOD06 Cloud Optical Properties Product	Steve Platnick	27-Aug-14
MOD08 Level 3 Product	Steve Platnick / Bill Ridgway	3-Sep-14
Archives/Data Acquisition: LAADSWEB, MIRADOR, ECHO-Reverb	To Be Determined.	10-Sep-14
MODIS Atmosphere Educational Materials & Resources	Richard Kleidman	17-Sep-14
Giovanni - Aerosols Express	Jim Acker	24-Sep-14
MAIAC 1 Km Aerosol Product	Alexei Lyapustin	01-Oct-14

Motivation

- **Q:** The Collection 6 MODIS atmosphere aerosol products over land have e-Deep Blue (DB), Dark Target (DT), and ‘merged’ data all available a lot of the time. Which should I use, and when?
- **A (short):** It depends.
- **A (longer):** The next ~45 minutes…

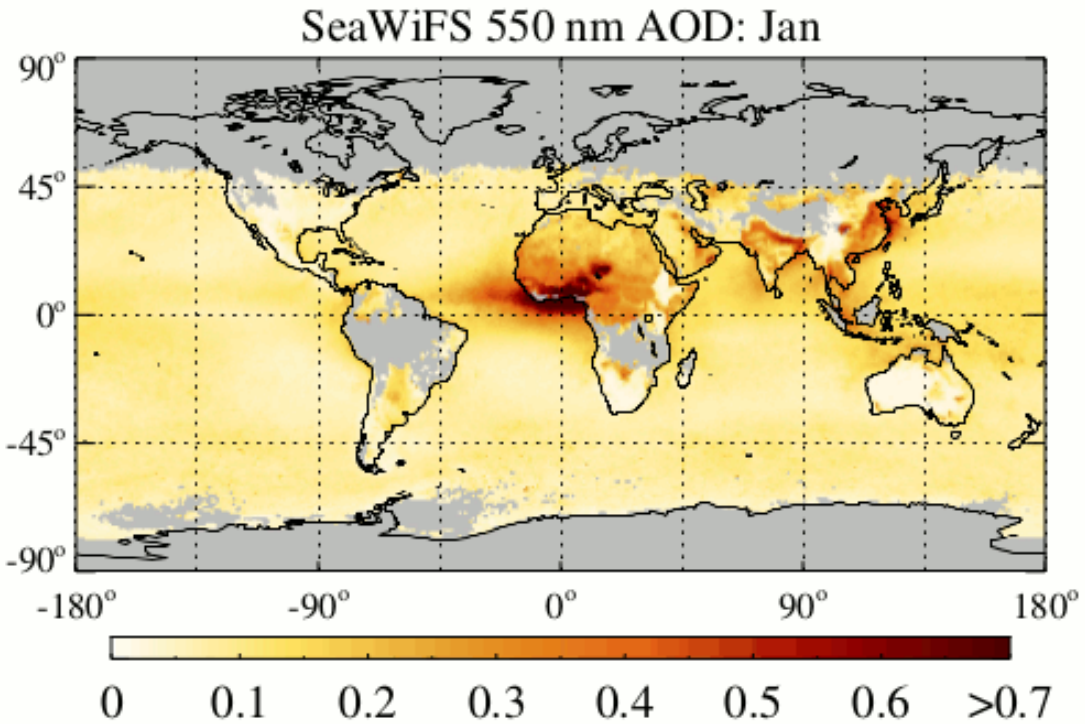
Overview

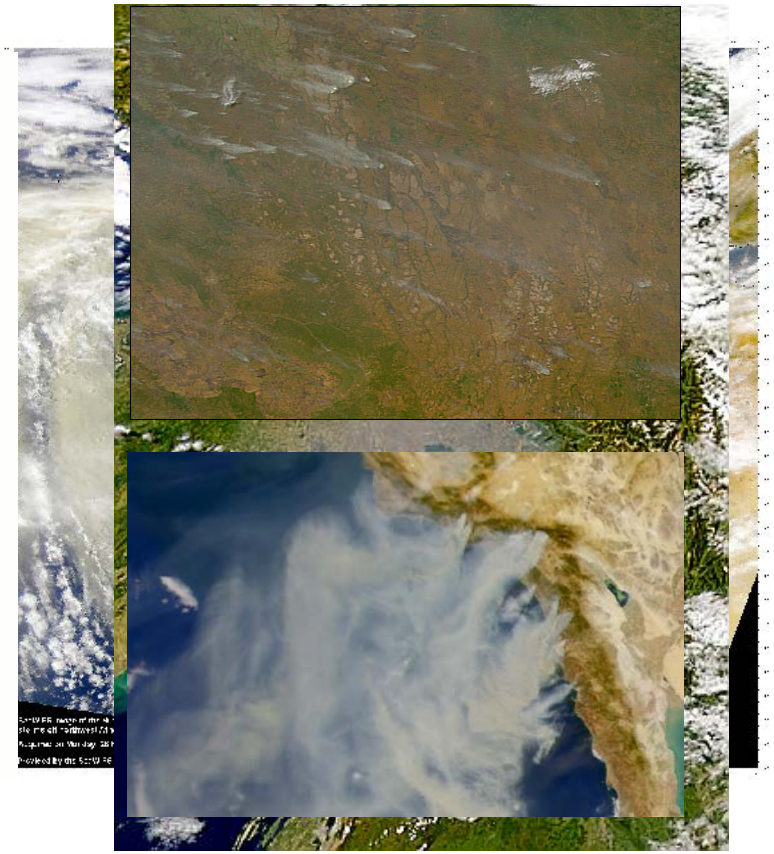
- Aerosols and MODIS overview
- MODIS Deep Blue/Dark Target summary
  - Global/regional comparison of retrievals
- ‘Merging’ algorithm
  - Description
  - Examples
- Evaluation against AERONET

Overview

- **Aerosols and MODIS overview**
- MODIS Deep Blue/Dark Target summary
  - Global/regional comparison of retrievals
- ‘Merging’ algorithm
  - Description
  - Examples
- Evaluation against AERONET

Aerosols and properties of interest: AOD





- Aerosol Optical Depth (AOD): total column optical extinction of aerosol at a given wavelength
  - Most commonly, 550 nm (τ_{550})
  - Related to how much aerosol is in the atmosphere
  - Also termed aerosol optical thickness (AOT)

Moderate Resolution Imaging Spectroradiometer (MODIS) terminology

MxD04_L2.AYYYYDDD.HHMM.CCC.YYYYDDDHHMMSS.hdf

MxD04 = Earth Science Data Type name

x = "O" for Terra or "Y" for Aqua

L2 = Denotes a Level-2 product (or L3 for Level-3, etc.)

A = indicates date/time information follows

YYYYDDD = acquisition year and day-of-year

HHMM = acquisition hour and minute start time

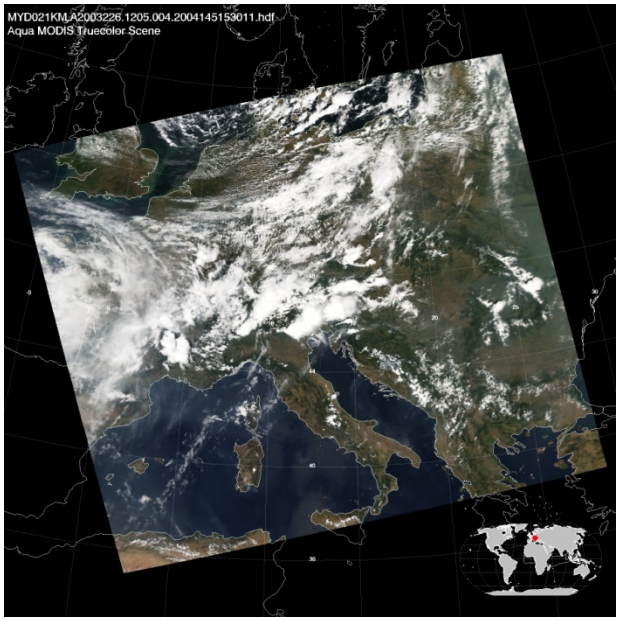
CCC = collection (e.g., '006' for Collection 6)

YYYYDDDHHMMSS = production data and time

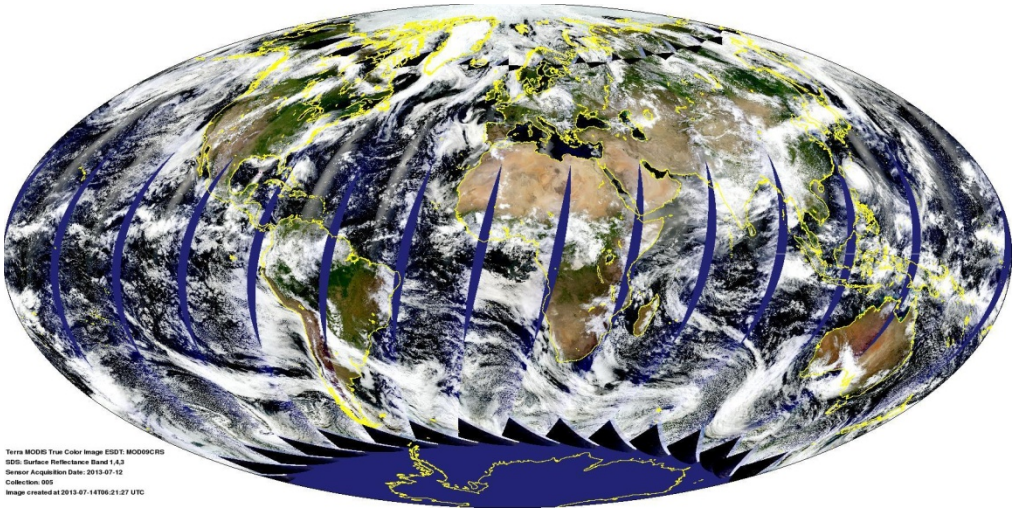
hdf = denotes HDF file format

- A 'Collection' is a MODIS mission (re)processing; Collection 6 is the new version
- Data products relevant to this presentation:
  - **MOD04, MYD04** Level 2 (orbit-level) aerosols
  - **MODATML2, MYDATML2** Level 2 joint atmospheres
  - **MOD08, MYD08** Level 3 (aggregated) joint atmospheres

The MODIS sensor



MODIS Aqua granule RGB composite for August 14th, 2003, 12:05 UTC



MODIS Terra daytime RGB composite for July 12th, 2013

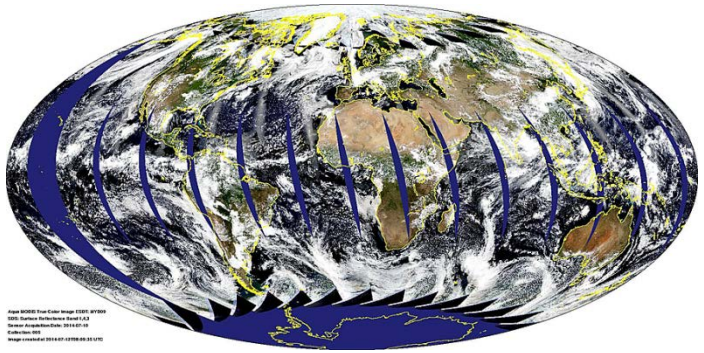
Images available online at http://modis-atmos.gsfc.nasa.gov

- 36 spectral bands from visible to thermal IR
- Spatial resolutions (level 1b) 250 m to 1 km at nadir
  - 'Bowtie effect' leads to pixel enlargement and distortion near swath edges
- Swath width 2,300 km, giving near-global daily coverage
- Flying on polar-orbiting platforms
  - Near-constant local solar time of observation ~10:30 am (Terra, descending), ~1:30 pm (Aqua, ascending)
  - 14-15 orbits per day, 16-day orbital repeat cycle
  - Data organised into 5-minute 'granules'

Overview

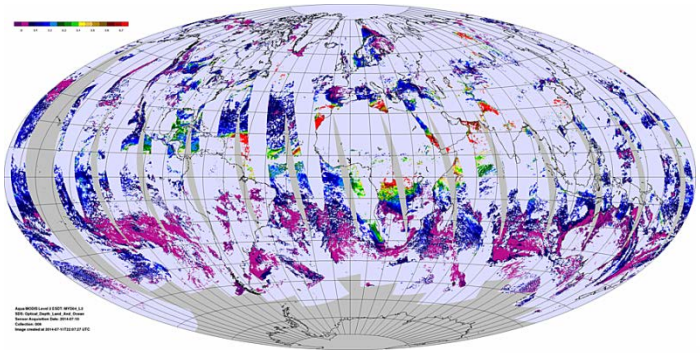
- Aerosols and MODIS overview
- **MODIS Deep Blue/Dark Target summary**
  - Global/regional comparison of retrievals
- ‘Merging’ algorithm
  - Description
  - Examples
- Evaluation against AERONET

MODIS Atmospheres aerosol products basics

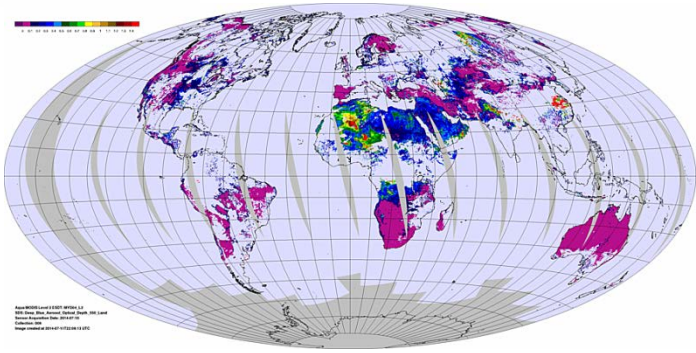


RGB

Browse images from http://modis-atmos.gsfc.nasa.gov/IMAGES/index.html



DT/ocean



DB

Three aerosol algorithms in MxD04:

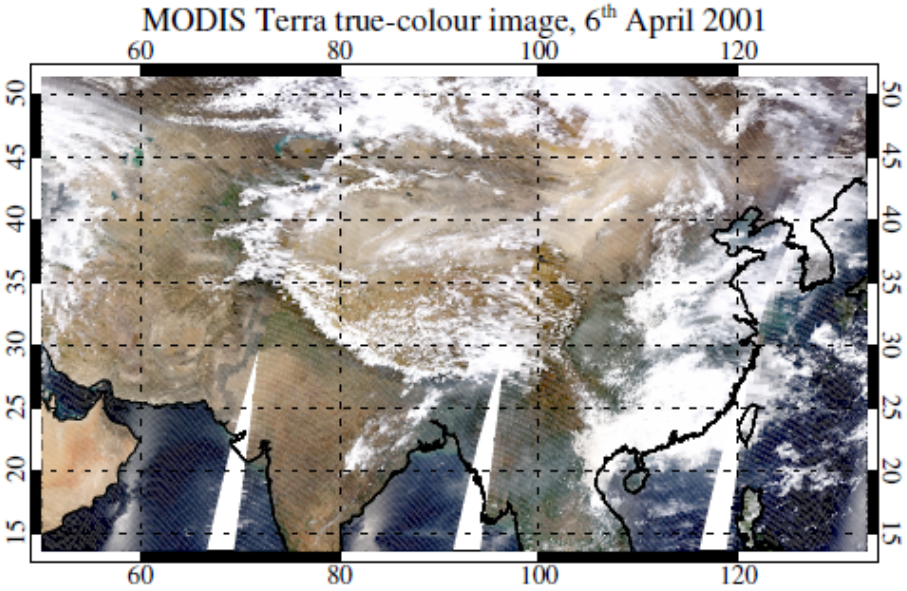
Enhanced Deep Blue (DB/eDB, land only)

Dark Target (DT, dark land only)

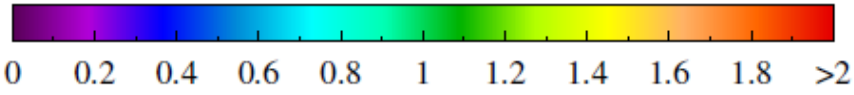
Ocean (water only)

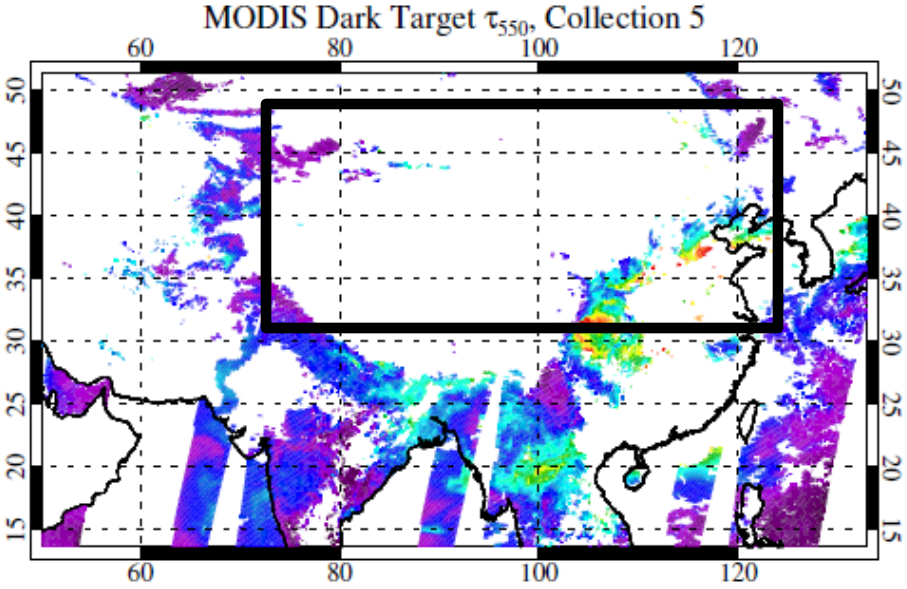
- Level 2 (MxD04) nominal pixel resolution10x10 km at nadir
- Other aerosol algorithms (not discussed here) exist, e.g. :
  - MODIS: MAIAC, land/ocean surface ‘atmospheric correction, regional algorithms
  - Non-MODIS sensors too (e.g. MISR, SeaWiFS, VIIRS, AVHRR, POLDER, ATSR, MERIS, geostationary, etc…)

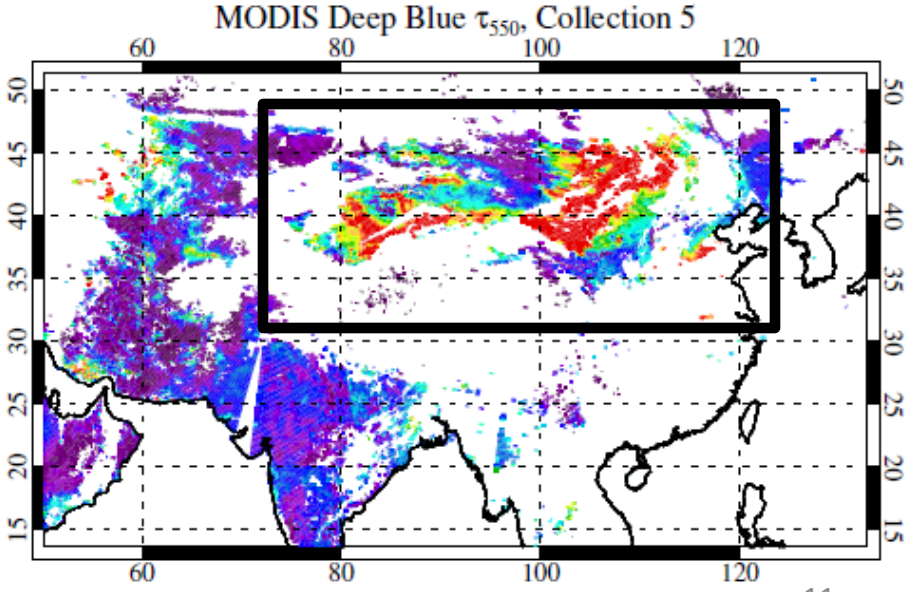
MODIS aerosols as of Collection 5



- Ocean: one algorithm
- Land: two algorithms, minimal spatial overlap
  - Dark Target algorithm over (mainly) vegetated surfaces
  - Deep Blue algorithm over bright surfaces (e.g. deserts)
    - In C6, it does more than that
  - This provided the initial rationale for the merge







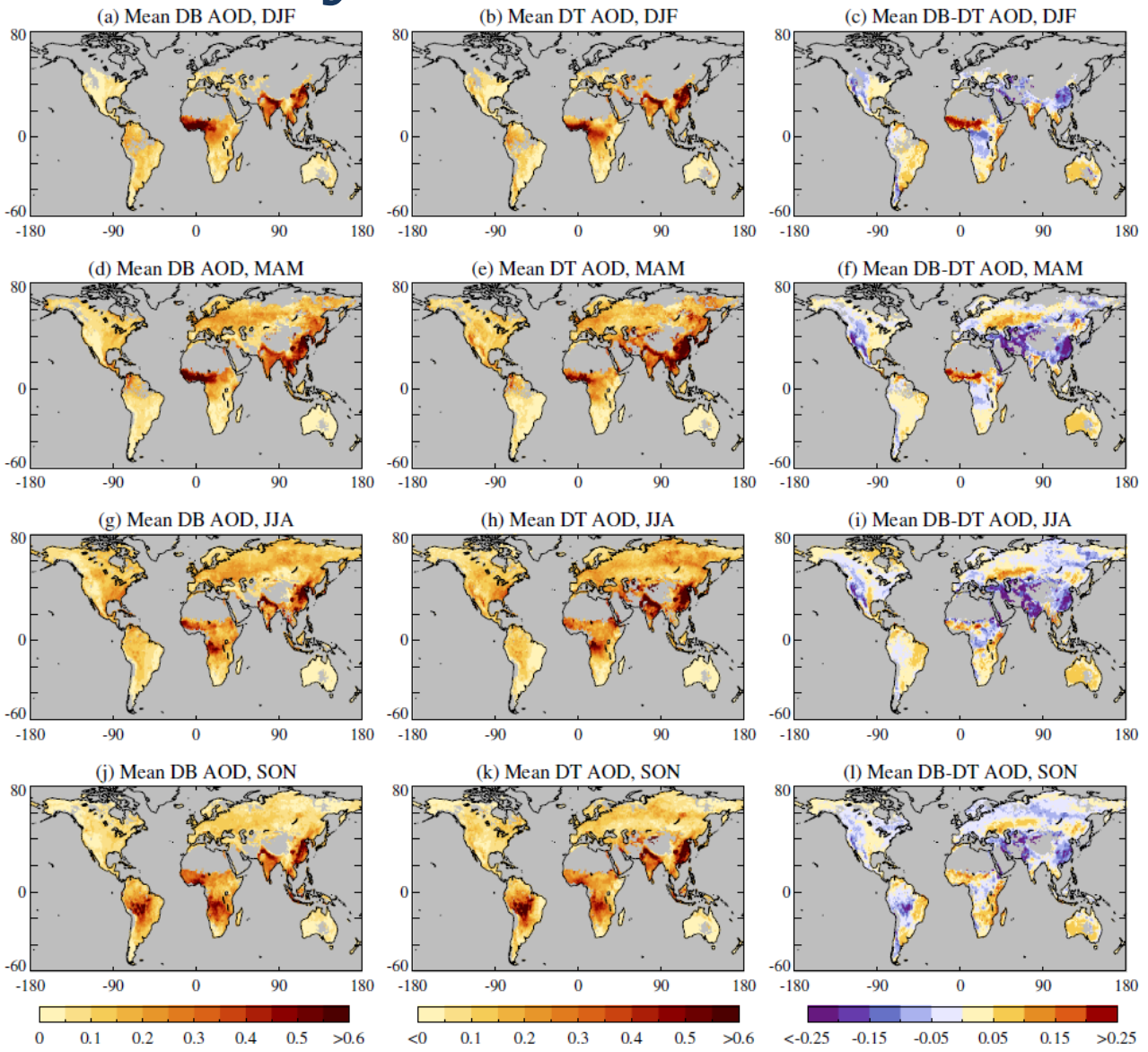
Algorithm summaries

Characteristic	e-Deep Blue (DB)	Dark Target (DT)	Ocean
Domain	Land	'Dark' (i.e. partly/fully vegetated) land	Dark (i.e. non-turbid/shallow) water
Averaging method	Retrieve then average	Average then retrieve	Average then retrieve
Aerosol optical model	Prescribed regionally/seasonally Sometimes retrieved	Fine model prescribed regionally/seasonally Coarse (dust analogue) model mixed in	Combination of 4 fine and 5 coarse modes 'Best' and 'average' solutions reported
Surface properties prescribed	Database or type-dependent dynamic, pseudo-Lambertian	Global dynamic relationship, pseudo-Lambertian	BRDF model incorporating glint, whitecaps, and fixed underlight
550 nm AOD uncertainty confidence envelope	~+/-(0.03+0.2*AOD_{MODIS}) (depends on geometric air mass)	+/-(0.05+0.15*$AOD_{AERONET}$)	+(0.04+0.1*$AOD_{AERONET}$) to -(0.02+0.1*$AOD_{AERONET}$)

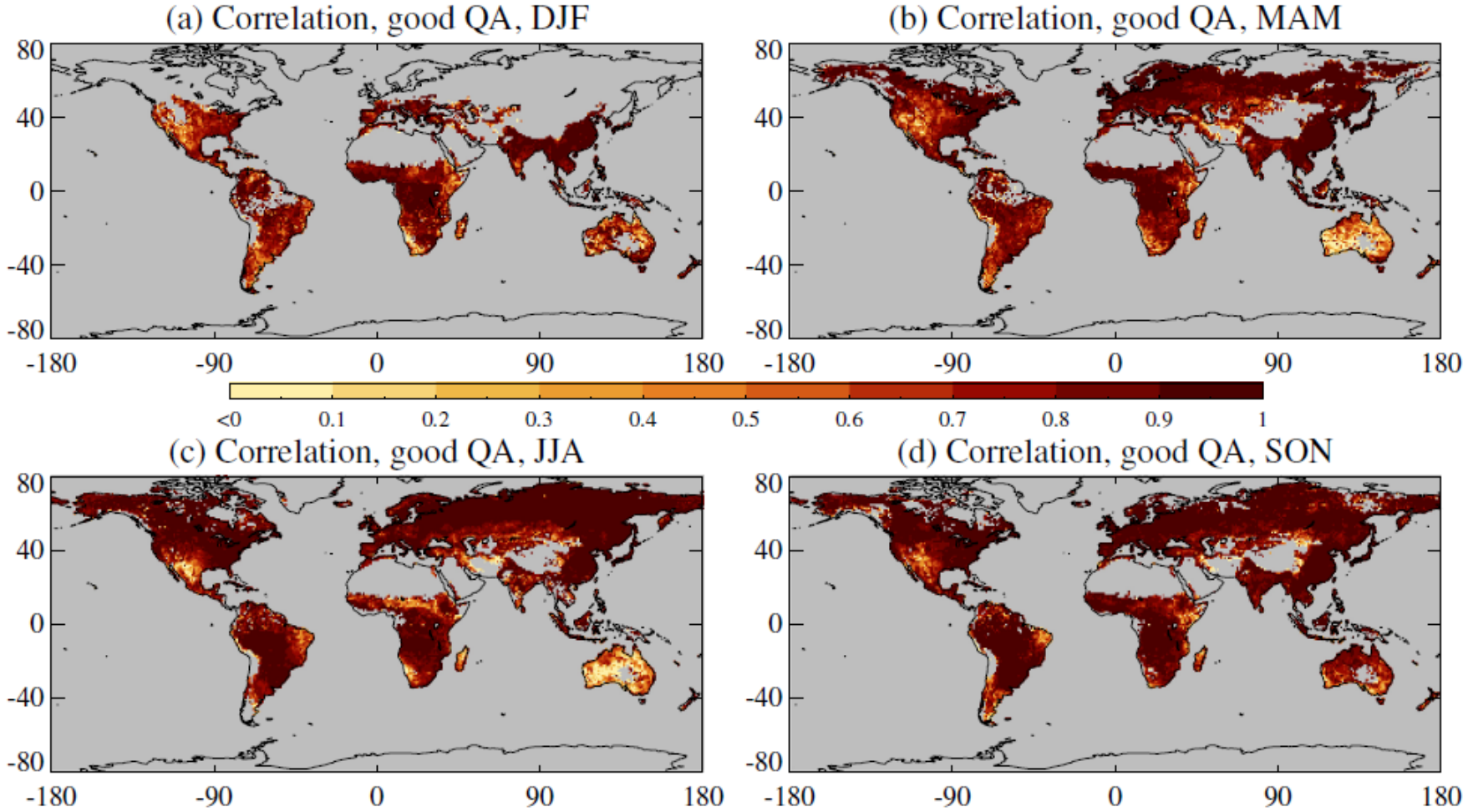
- All algorithms are only applied over daytime, cloud-free, snow/ice-free pixels
- All results shown hereafter, unless noted otherwise, are:
  - Only for retrievals passing each algorithm's quality assurance (QA) checks
  - For Aqua data
  - For AOD at 550 nm

Seasonality of AOD

- Seasonal mean AOD:
  - Left column: DB
  - Middle column: DT
  - Right column: DB-DT difference
  - Maps use only colocated retrievals
- Similar global AOD patterns and seasonal cycles
- Regional/seasonal offsets, often within retrieval uncertainty

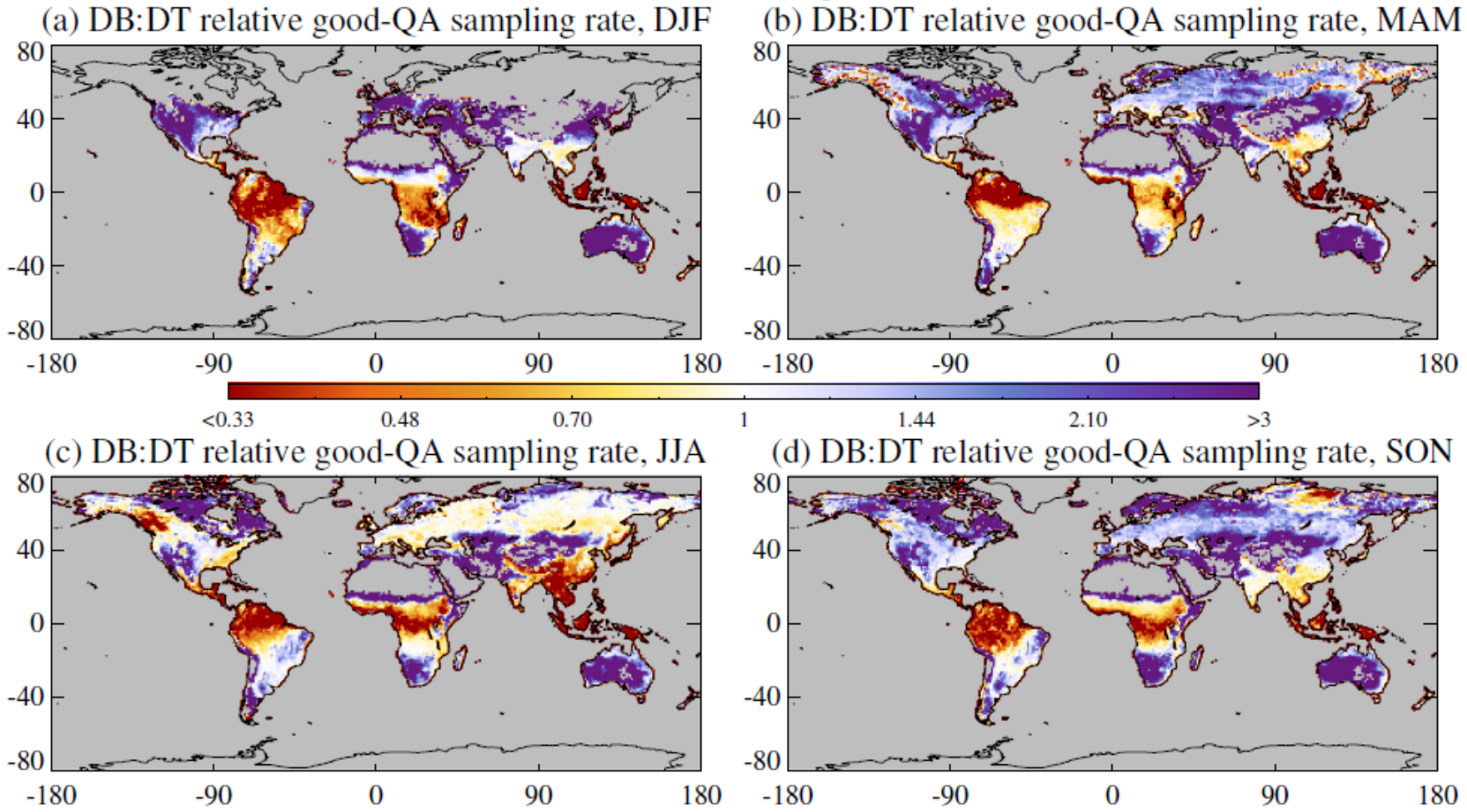


Correlation between DB and DT



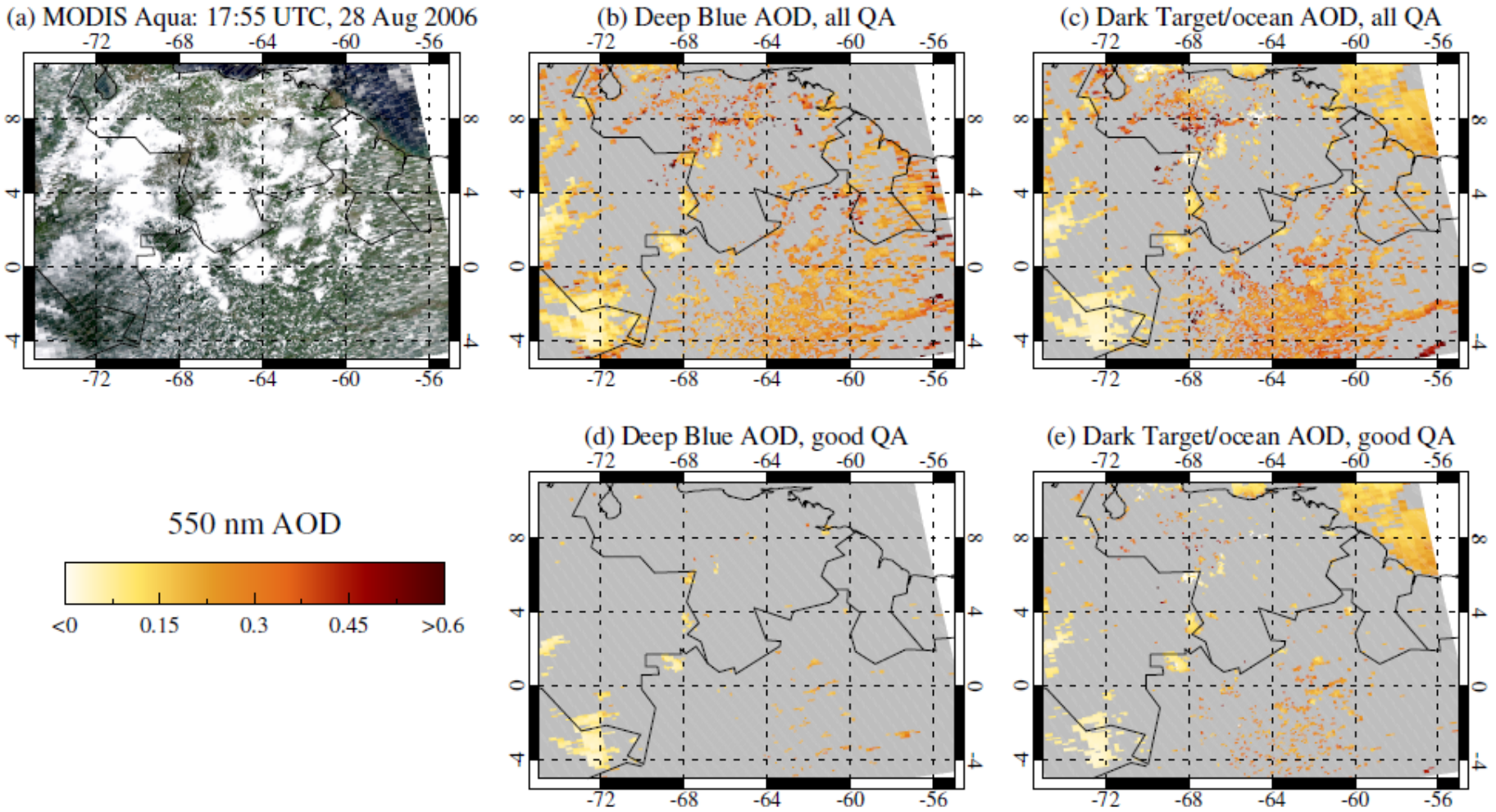
- Over much of the world, DB and DT AOD are highly correlated (r>0.9) within a season
  - That does not imply that they are correct
- Lower correlations where AOD is persistently low, and/or surface conditions tricky for one/both algorithms
  - Australia, Sertão area of Brazil, mountains

Sampling rate



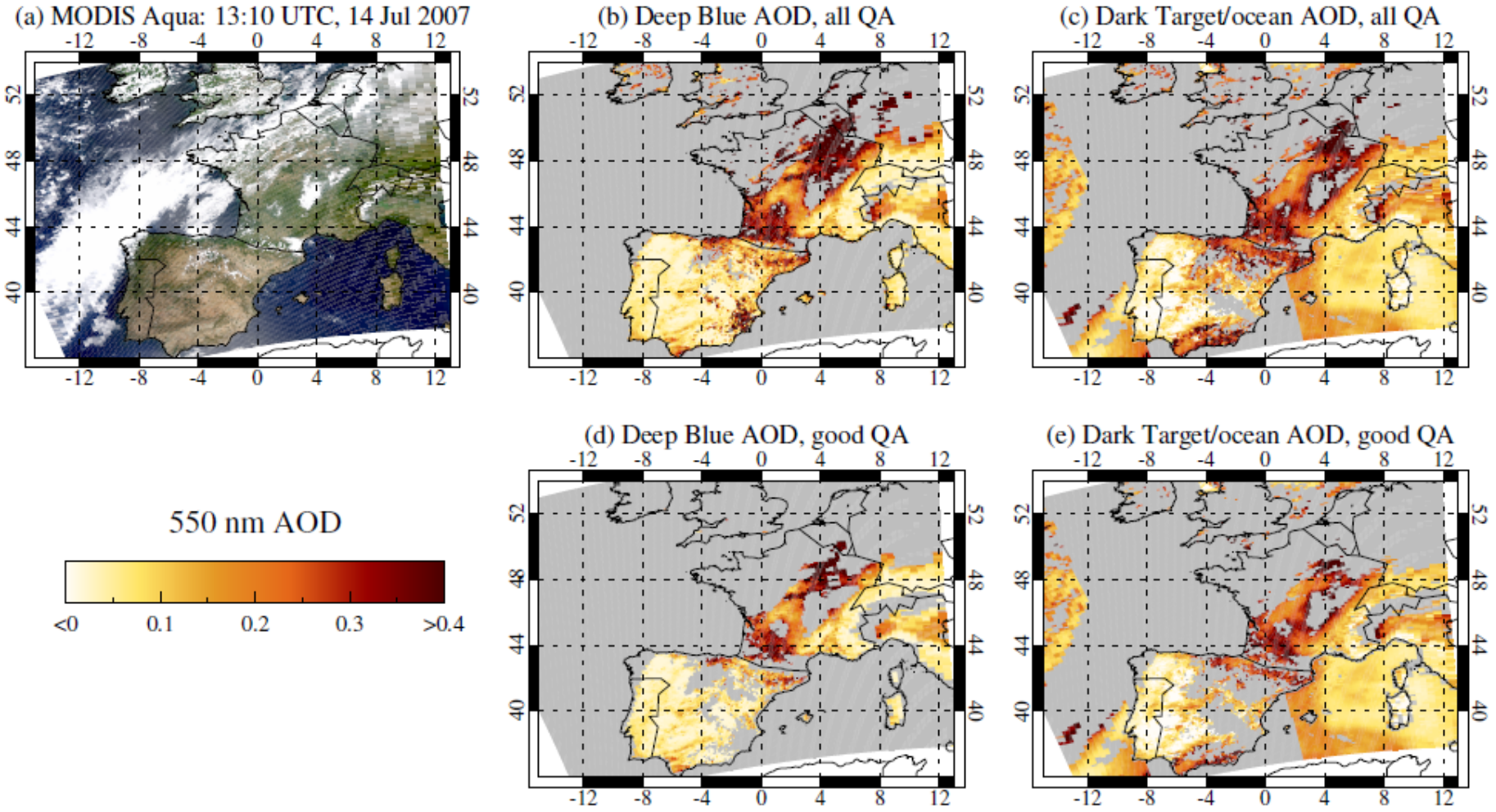
- Ratio of number of retrievals passing QA checks, for regions where both algorithms provide retrievals
  - DB tends to provide retrievals more frequently at mid/high-latitudes **(purple)**
  - DT tends to provide retrievals more frequently in the tropics **(red)**
  - In North America, Europe and India, often similar data volume

Granule-level comparisons



- Sampling frequency in tropical reasons determined in part by occurrence of small cumulus clouds
  - DB discards more data than DT near cloud edges

Granule-level comparisons



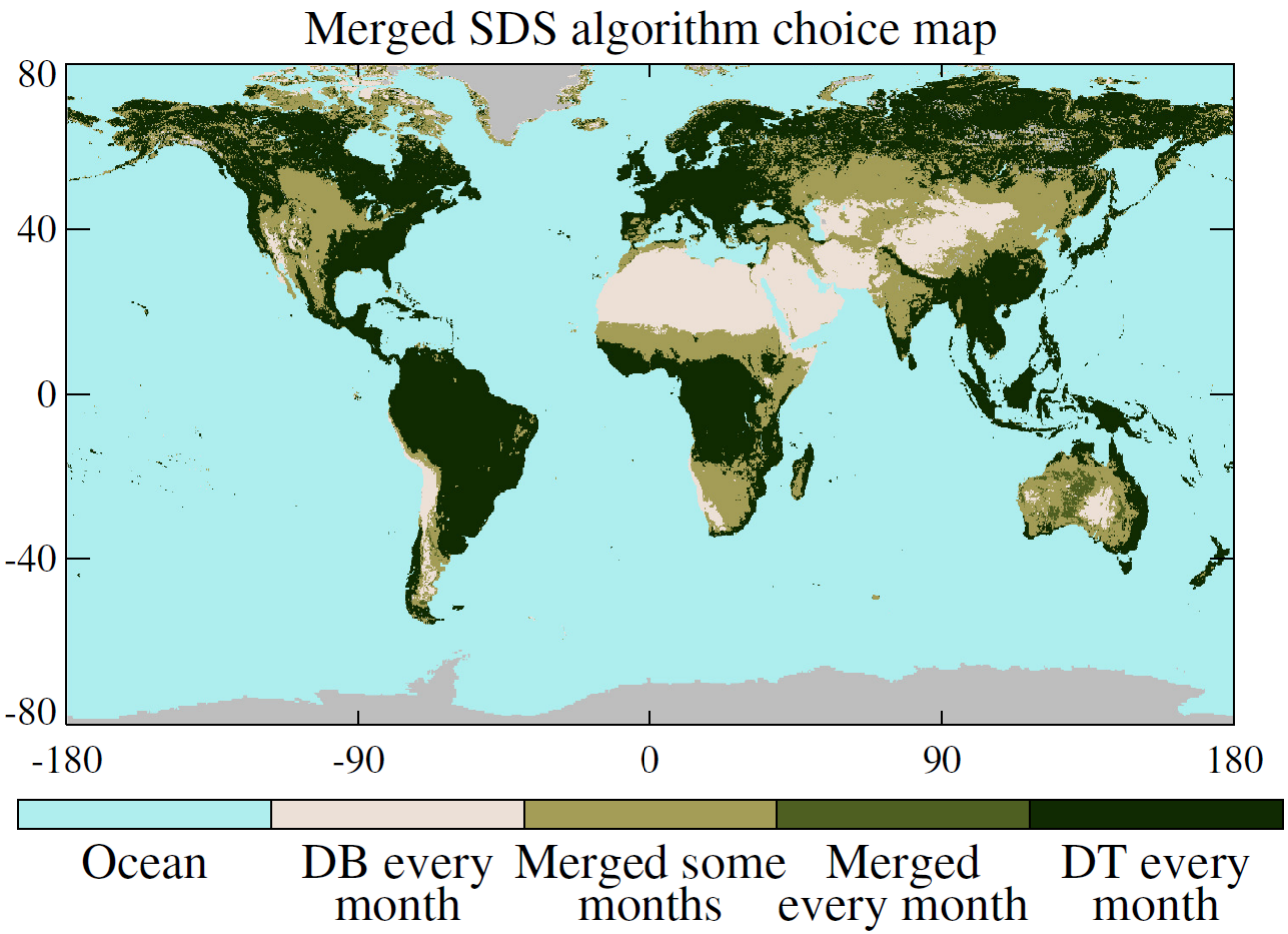
- Where other cloud types dominate, extent of near-cloud spatial coverage tends to be more similar

Overview

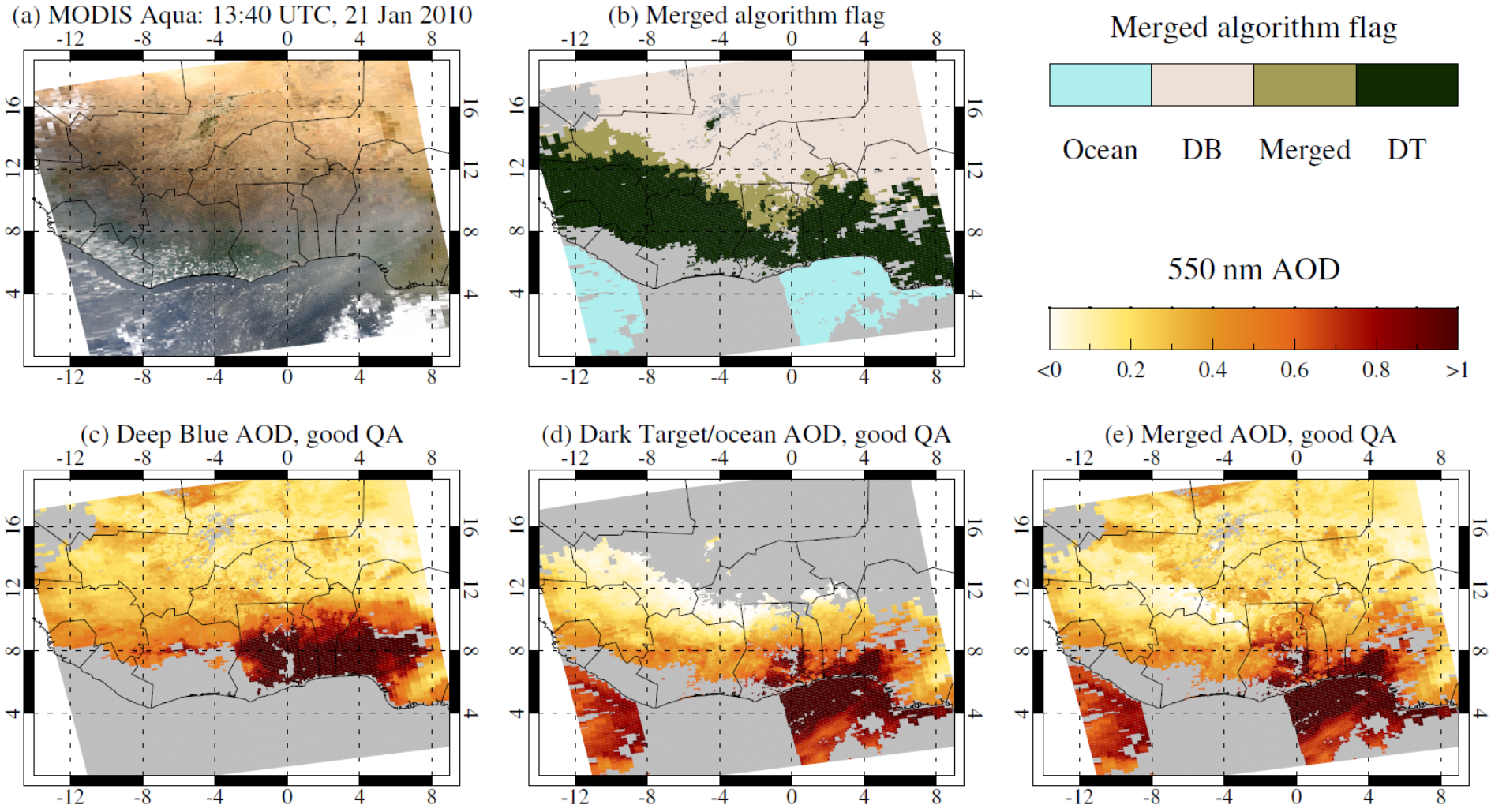
- Aerosols and MODIS overview
- MODIS Deep Blue/Dark Target summary
  - Global/regional comparison of retrievals
- **‘Merging’ algorithm**
  - Description
  - Examples
- Evaluation against AERONET

What is the ‘merged’ MODIS dataset?

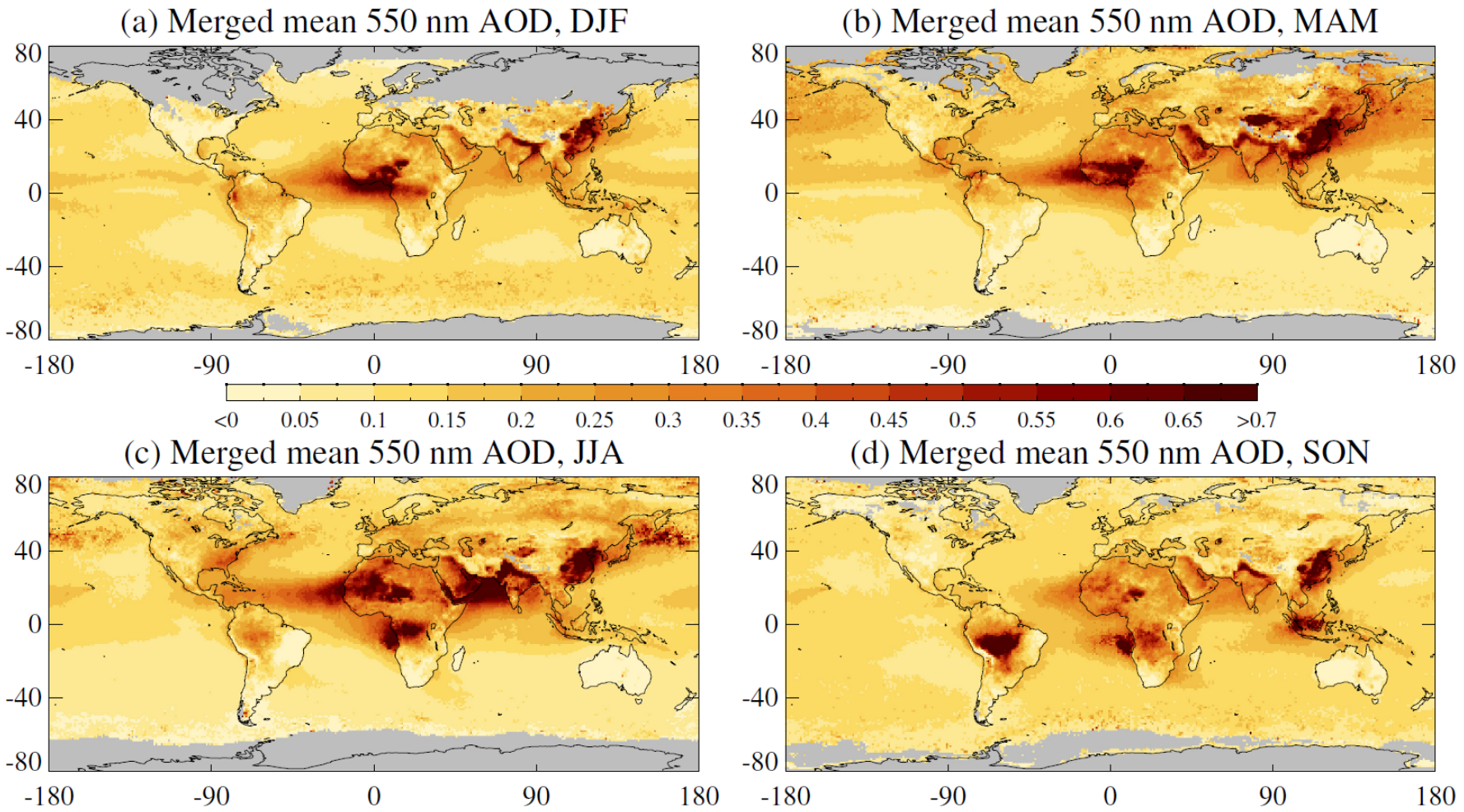
- This first attempt largely mimics Collection 5 user habits: use Deep Blue to fill in gaps in the Dark Target/ocean dataset
  - Only contains retrievals passing QA checks
- 12 monthly climatologies of NDVI used to assign retrievals over land:
  - NDVI < 0.2: Deep Blue
  - NDVI > 0.3: Dark Target
  - Otherwise: pick the algorithm with higher QA value, else average if both QA=3
- Ocean algorithm used over water



Example granule showing the merging procedure



Seasonal average ‘merged’ AOD

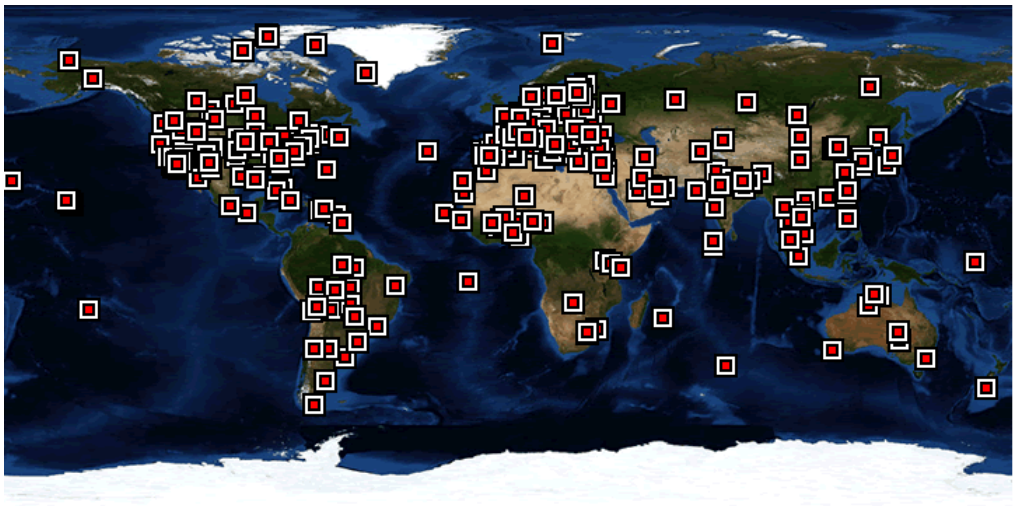


- Seasonal mean of daily mean AOD from the ‘merged’ SDS, 2006-2008

Overview

- Aerosols and MODIS overview
- MODIS Deep Blue/Dark Target summary
  - Global/regional comparison of retrievals
- ‘Merging’ algorithm
  - Description
  - Examples
- **Evaluation against AERONET**

Evaluation against AERONET



Images from NASA AERONET page, http://aeronet.gsfc.nasa.gov/

- Aerosol Robotic Network (AERONET): A standard resource for satellite AOD validation
  - Global network with consistent protocols, reference calibration
  - Several hundred sites with at least 1 year of observations
  - Also have a ship-borne Maritime Aerosol Network for over-ocean coverage (not shown)

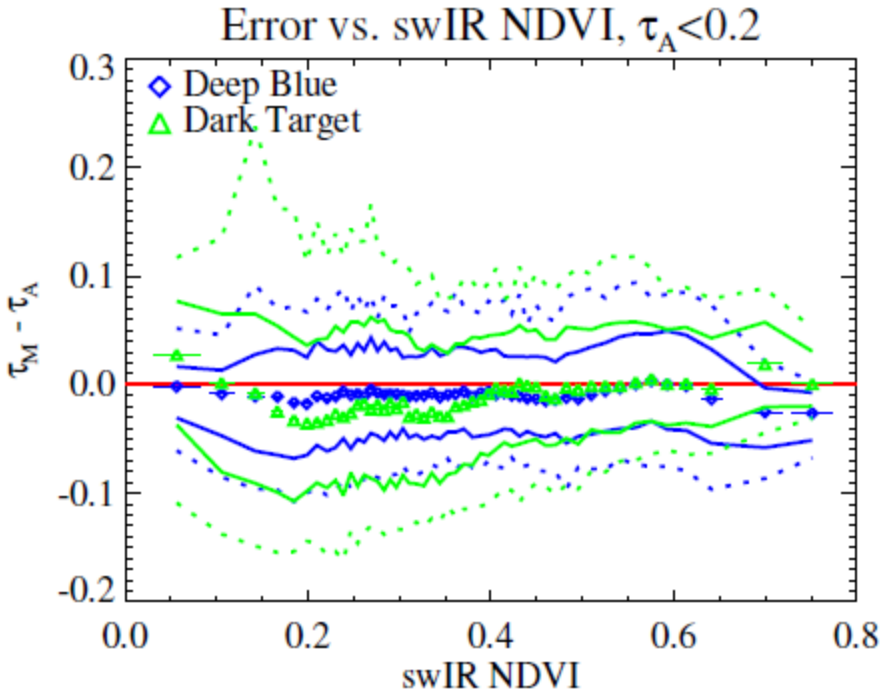
Comparison methodology:

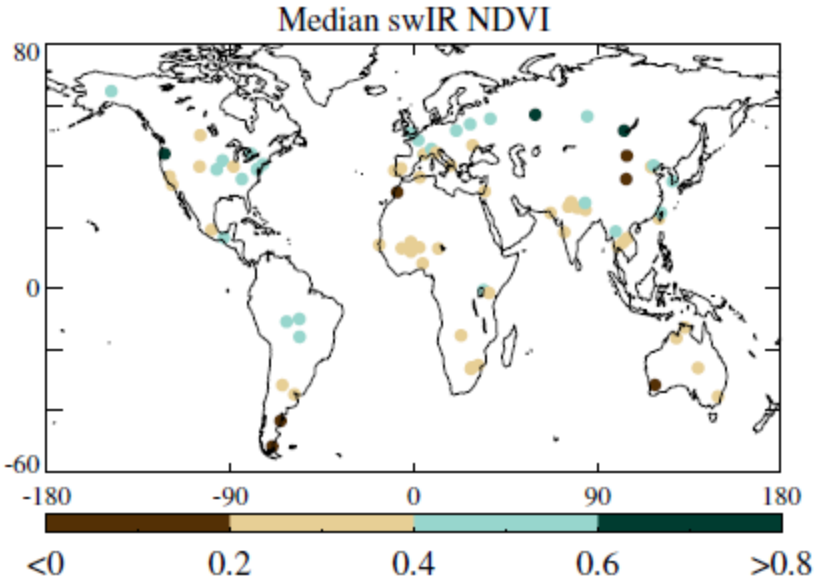
Average AERONET AOD within 30 minutes of satellite overpass

Average MODIS AOD within 25 km of AERONET site

Compare AOD at 550 nm

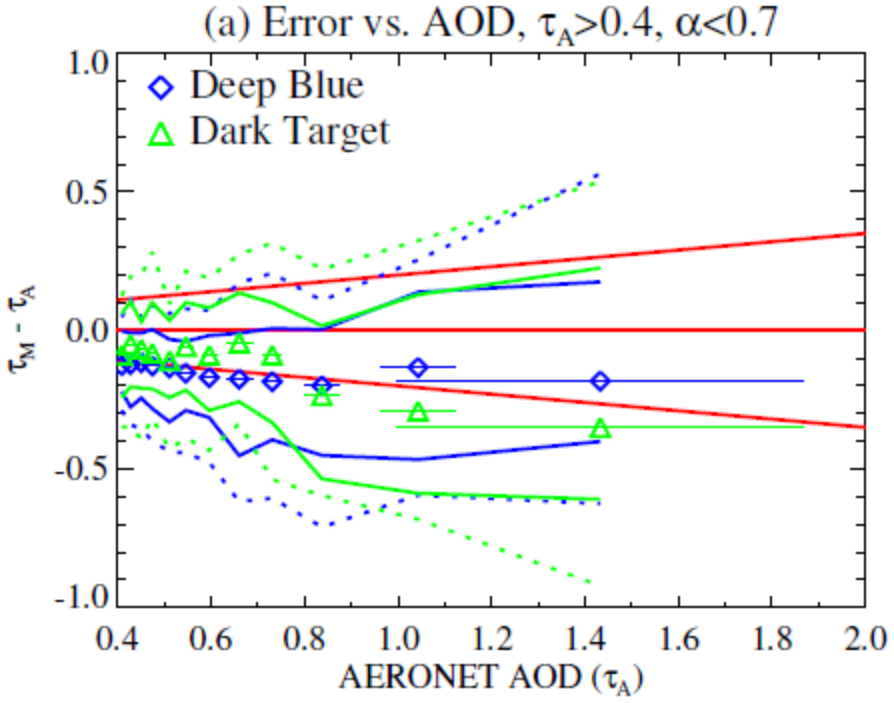
DB vs. DT: surface-related biases

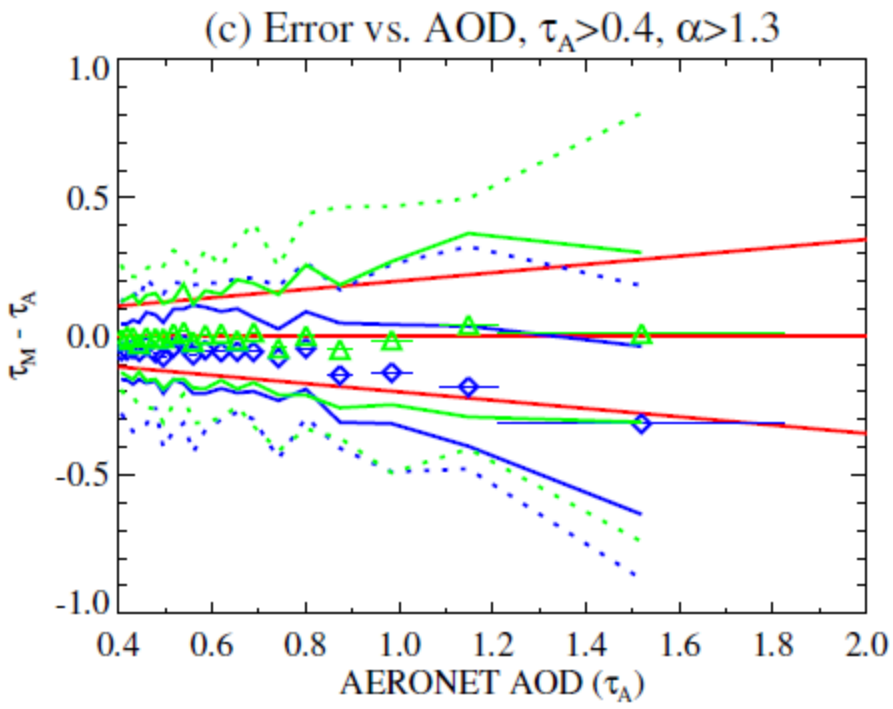




- Median (symbols) and confidence envelopes (68%, 90%) of DB and DT AOD bias vs. AERONET with respect to swIR NDVI, for low-AOD cases
- Higher swIR NDVI for (generally) a more densely-vegetated surface
- Shows similar (small) biases in both datasets, DT has more scatter at less-vegetated surfaces
- These low AOD cases are a majority (~80% of points)

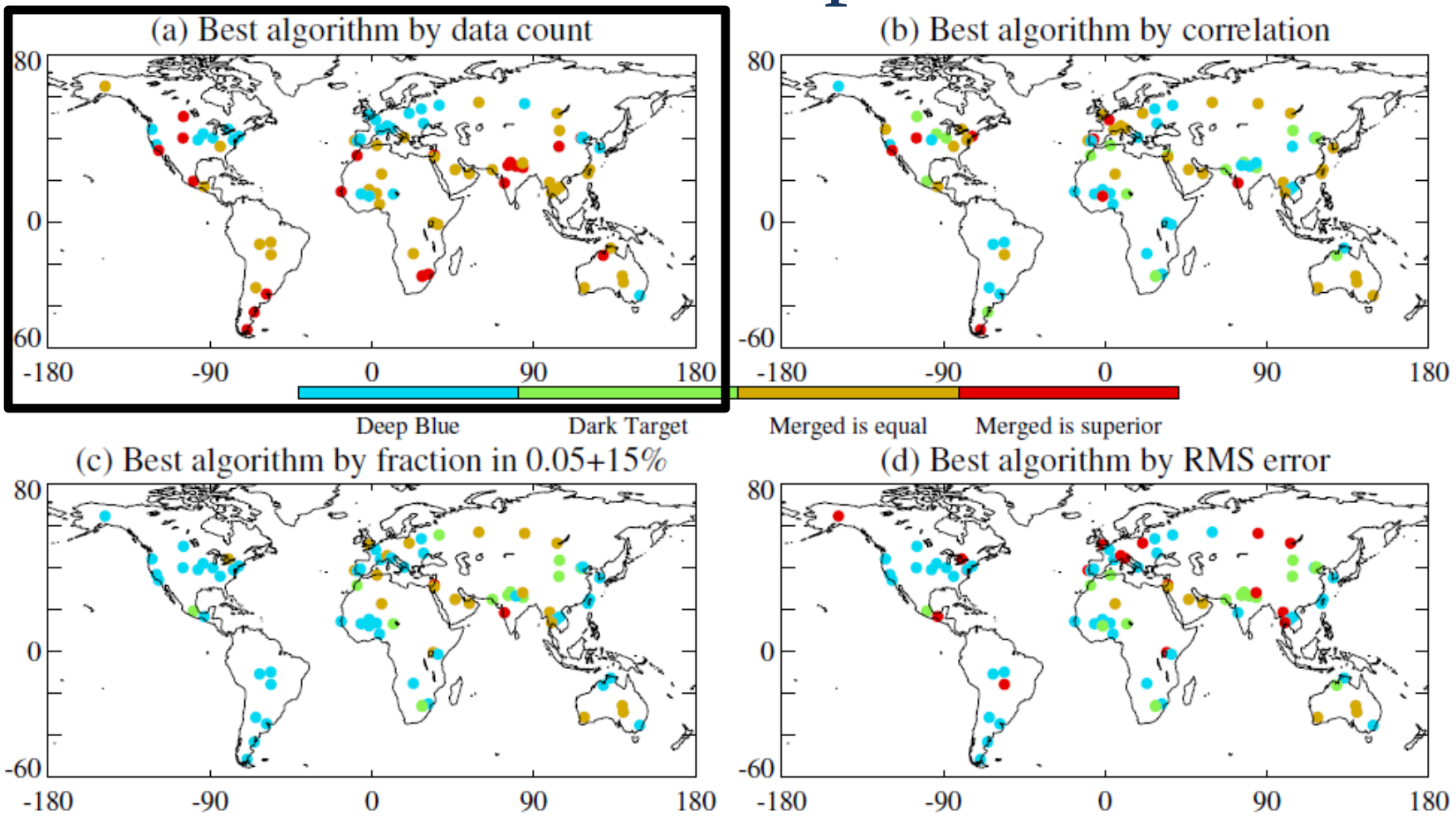
DB vs. DT: aerosol-related biases





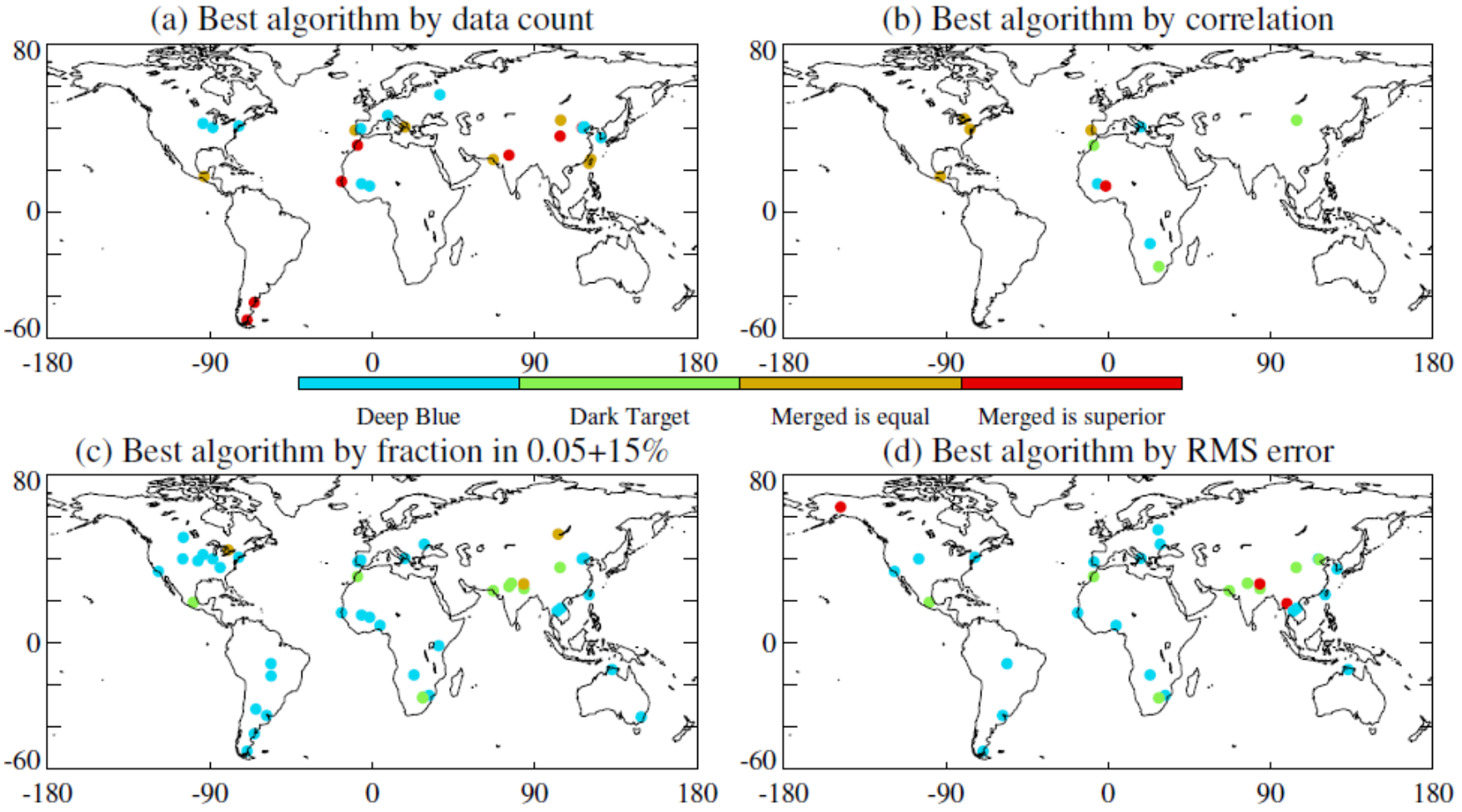
- Median (symbols) and confidence envelopes (68%, 90%) of DB and DT AOD bias vs. AERONET AOD, split by AERONET Ångström exponent (AE)
- Left plot: low AE (e.g. dust)
  - DB has slight low bias, DT has bias becoming more negative with increasing AOD
- Right plot: high AE (e.g. smoke, urban pollution)
  - DT has little bias, DB has bias becoming more negative with increasing AOD
- Width of error distributions similar
- These high AOD cases are a minority (<10%) of points

Global comparison



- Maps show 'best' algorithm, by different metrics, at each AERONET site
  - Gold: merged SDS takes only DB or DT retrievals; Red: merged mixes DB and DT, and does better than both
- Which is best depends on what statistical metric you're interested in
  - The merged dataset tends to have a higher data volume
  - However, DB or DT outperform by other metrics at some sites
  - Thus, usage choices may depend on whether analyses are regional or global

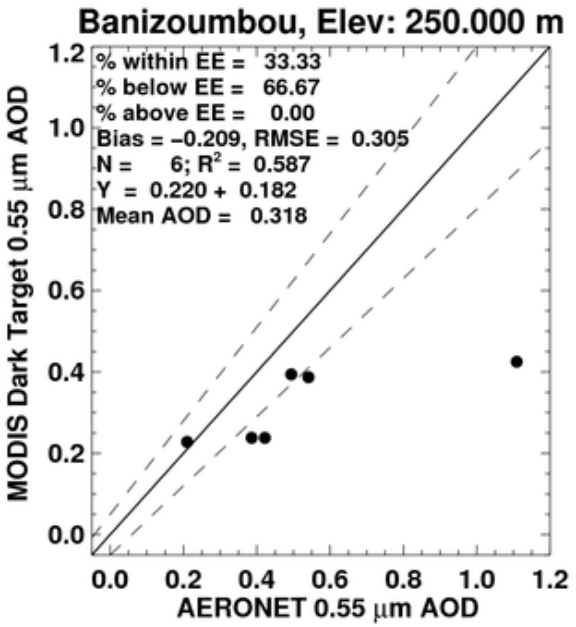
Where does performance quality differ?



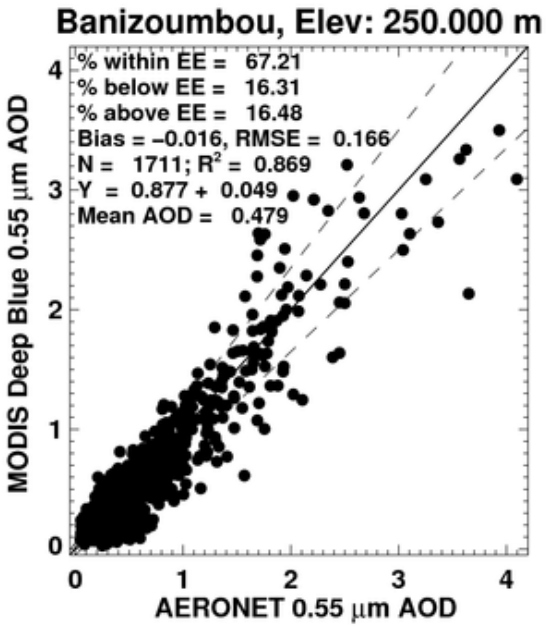
- As before, but only where different in algorithm quality is large
- Fewer sites plotted, i.e. level of performance is similar at many sites

Example: Banizoumbou (Niger)

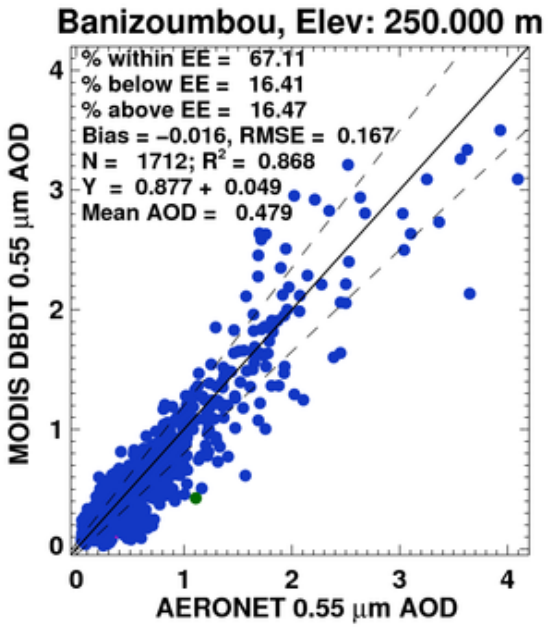
Dark Target



Deep Blue



Merge

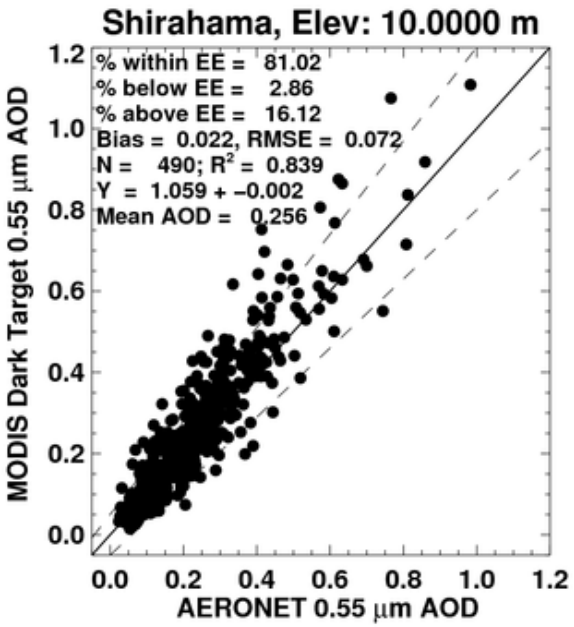


Map from Google Earth

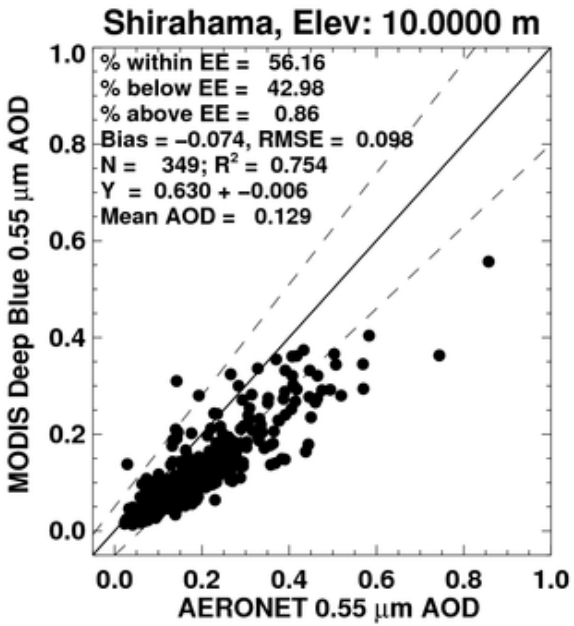
- DB performs well
- DT has few retrievals
- Merge mostly draws from DB (blue)

Example: Shirahama (Japan)

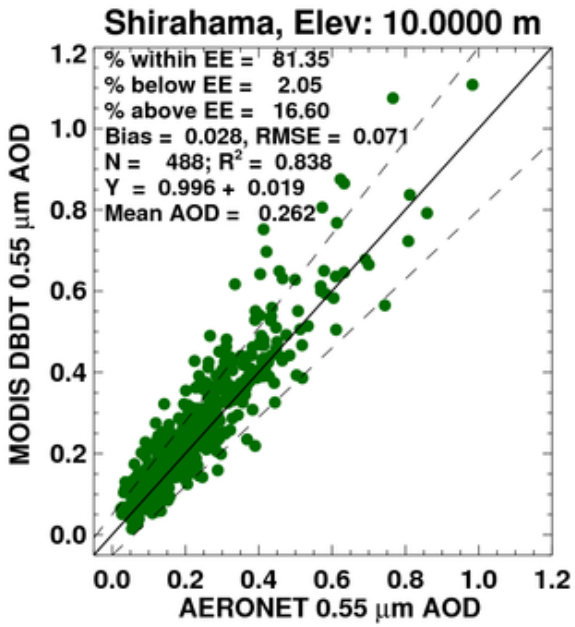
Dark Target

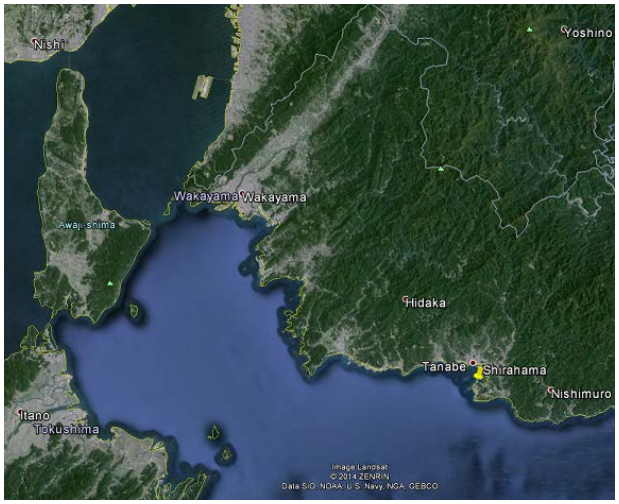


Deep Blue



Merge



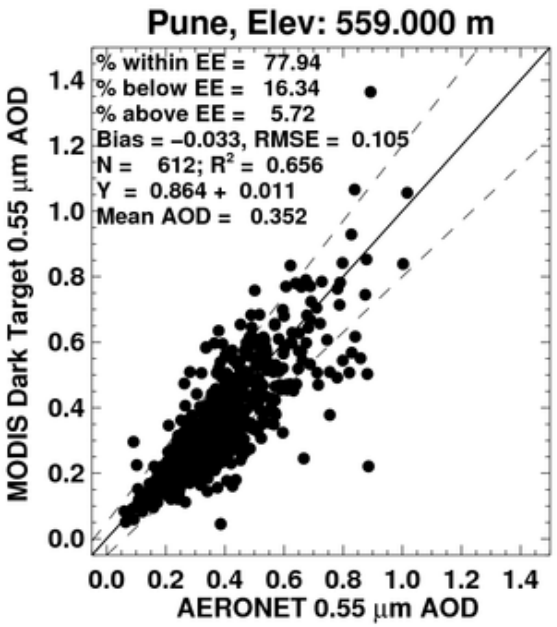


Map from Google Earth

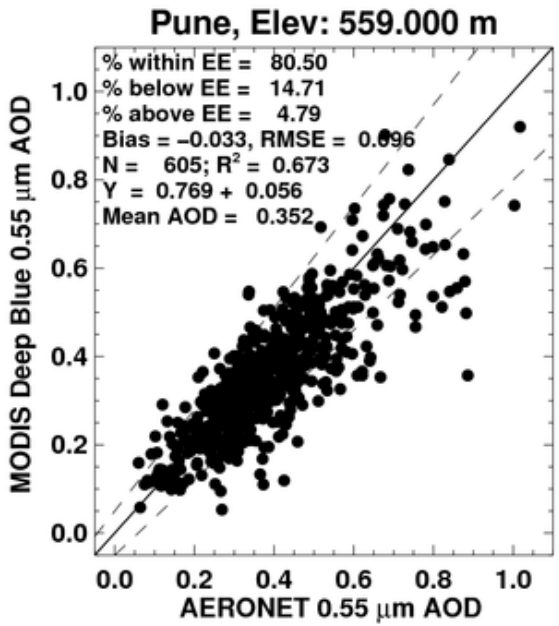
- DT performs well, slight high bias
- DB has fewer retrievals, and low bias
- Merge mostly draws from DT (green)

Example: Pune (India)

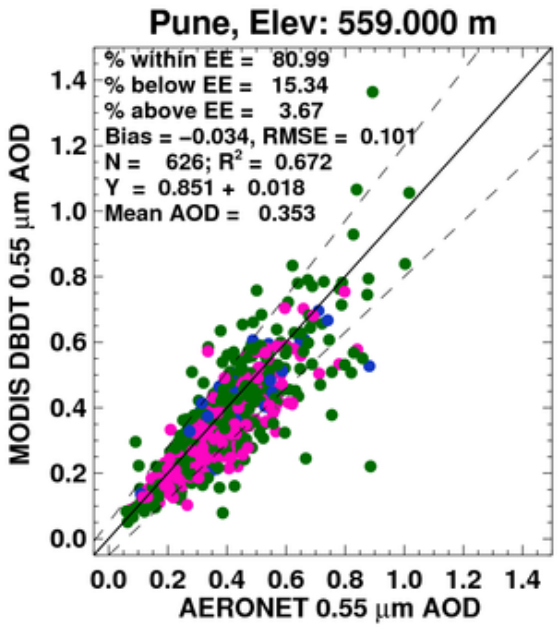
Dark Target

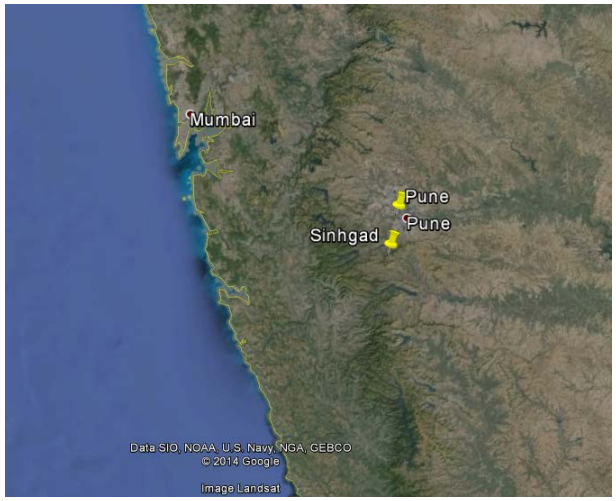


Deep Blue



Merge





Map from Google Earth

- Both DB and DT perform well
- Merge sometimes draws from DT (green), sometimes DB (blue), sometimes merges (red)
- Slightly better performance overall from the merge than either DB or DT

Summary

- Deep Blue (DB) and Dark Target (DT) provide similar views of the global aerosol system from MODIS
  - Often agree closely, but this doesn't imply both are correct, and should not be considered as independent datasets
- Neither algorithm, or their merge, is consistently better than the others
- Quality of performance is often very similar between algorithms
  - In many areas, it will likely not matter much which algorithm is used
  - Usage recommendations are more complicated than can be presented concisely
  - DB is still the only option over deserts, and there is only one ocean algorithm, so for global analyses use of the merge may be simplest
  - Encourage users to do analyses with both DB and DT data, where practical
  - We expect results for Terra will be quantitatively similar
- Please contact us with questions, comments, interesting results

Links:

MODIS Atmospheres website: *modis-atmos.gsfc.nasa.gov*

NASA LAADS (data distribution) website: *ladsweb.nascom.nasa.gov*

MODIS Collection 6 on the NASA LAADS ftp server: *ladsweb.nascom.nasa.gov/allData/6/<product name>*