National Aeronautics and Space Administration

GEOS Neural Network Retrieval for AOD Data Assimilation

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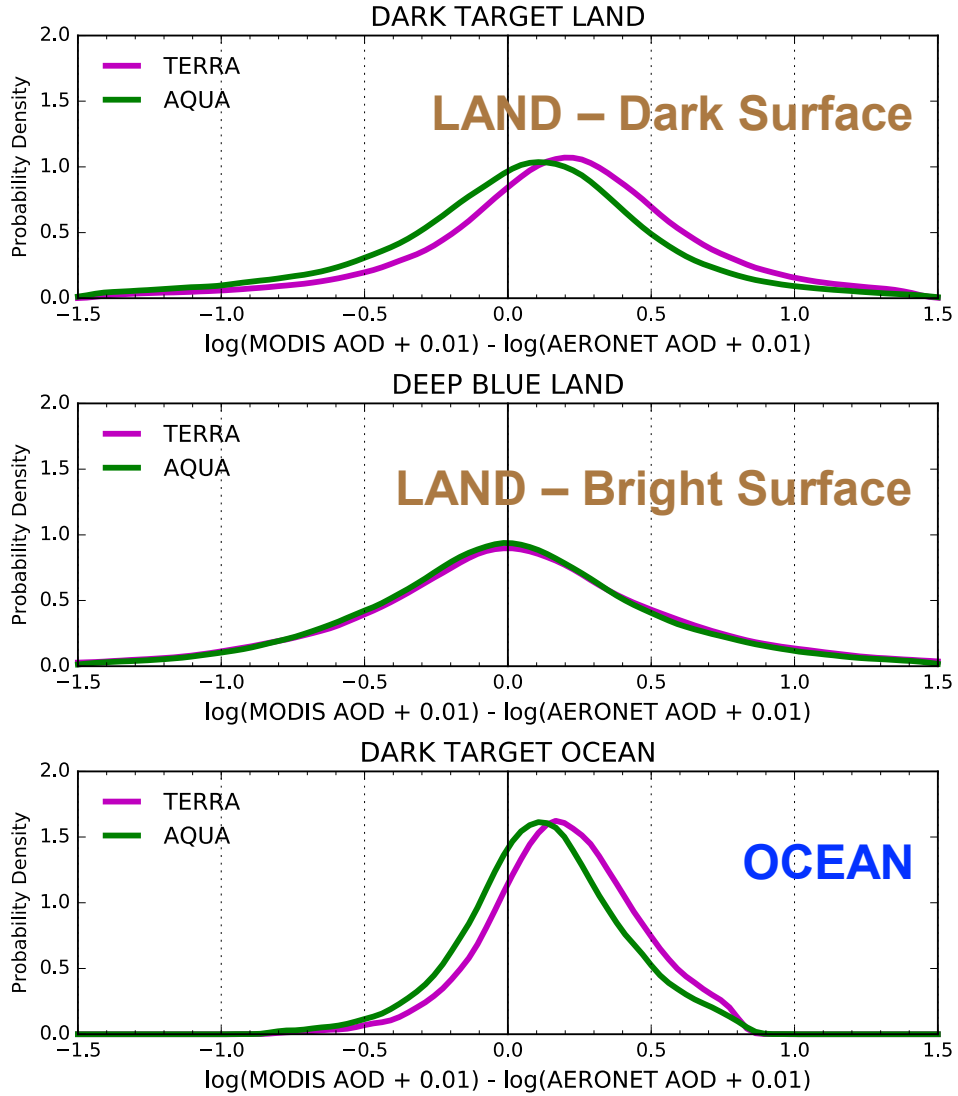
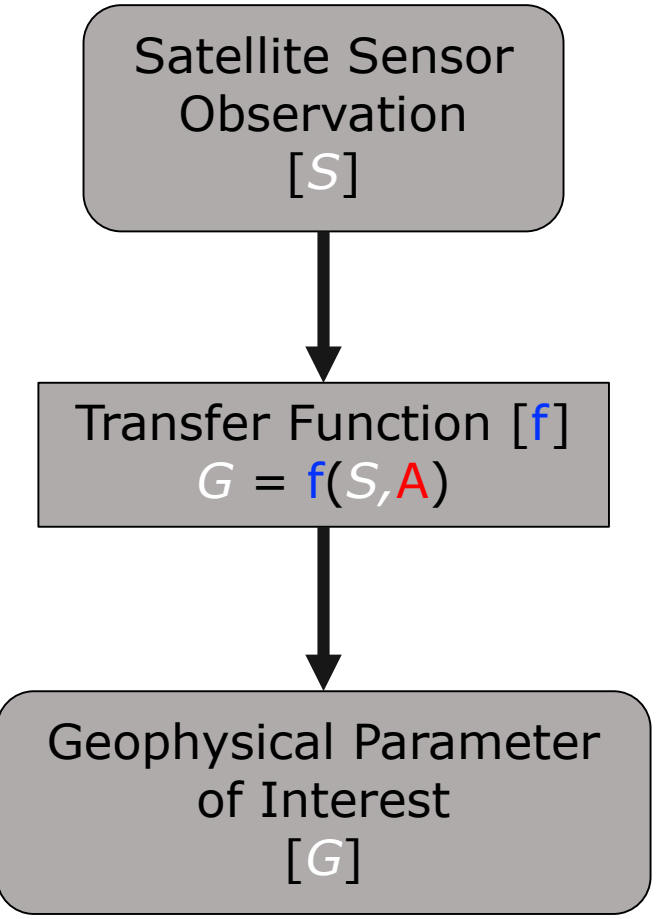
Comparison of MODIS DT & DB AOD Retrievals



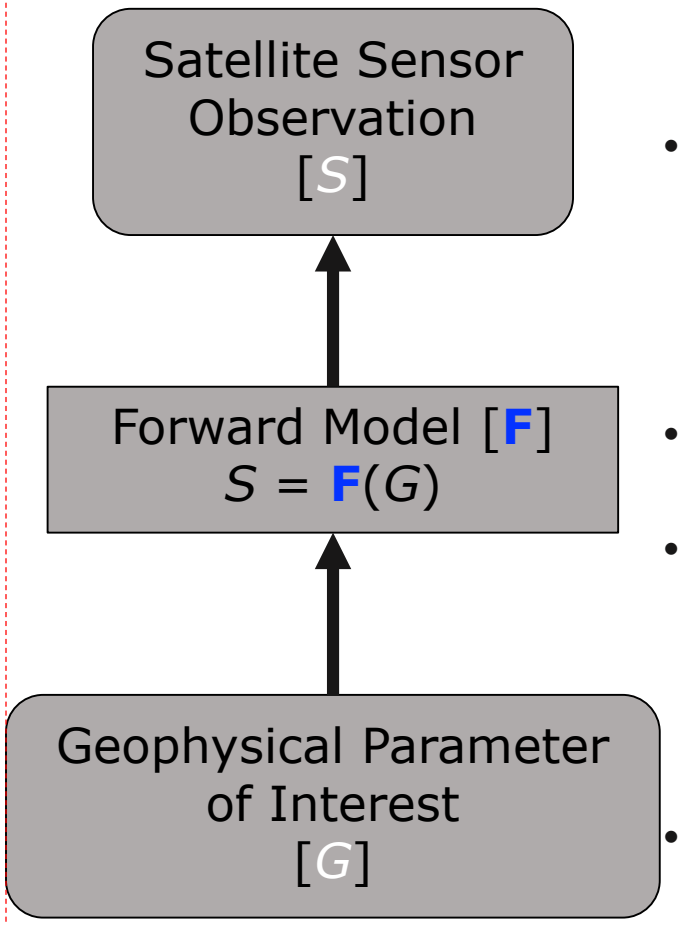
- Biases between datasets can propagate in the model forecast and lead to artificial time variability.
- The AOD data assimilation problem requires a homogenized AOD observing system across different platforms

Empirical Retrievals



- f is a continuous function that maps *S* to *G*
- Represent *f* with a mathematical function that contains a set of empirical parameters, A
- A are determined from a training dataset of pairs of *G* and *S* observations.
- Training empirically captures physical relationships and tunes away calibration issues.

Physically Based Retrievals



- **F** is a physical model derived from first principles (e.g. radiative transfer model)
- **F** is not easily inverted
- The objective of the retrieval algorithm is to search for a G* that minimizes $||S - \mathbf{F}(G)||$
- Product quality affected by calibration issues.

L1 Reflectances

Read directly from DT & DB Level 2 Files

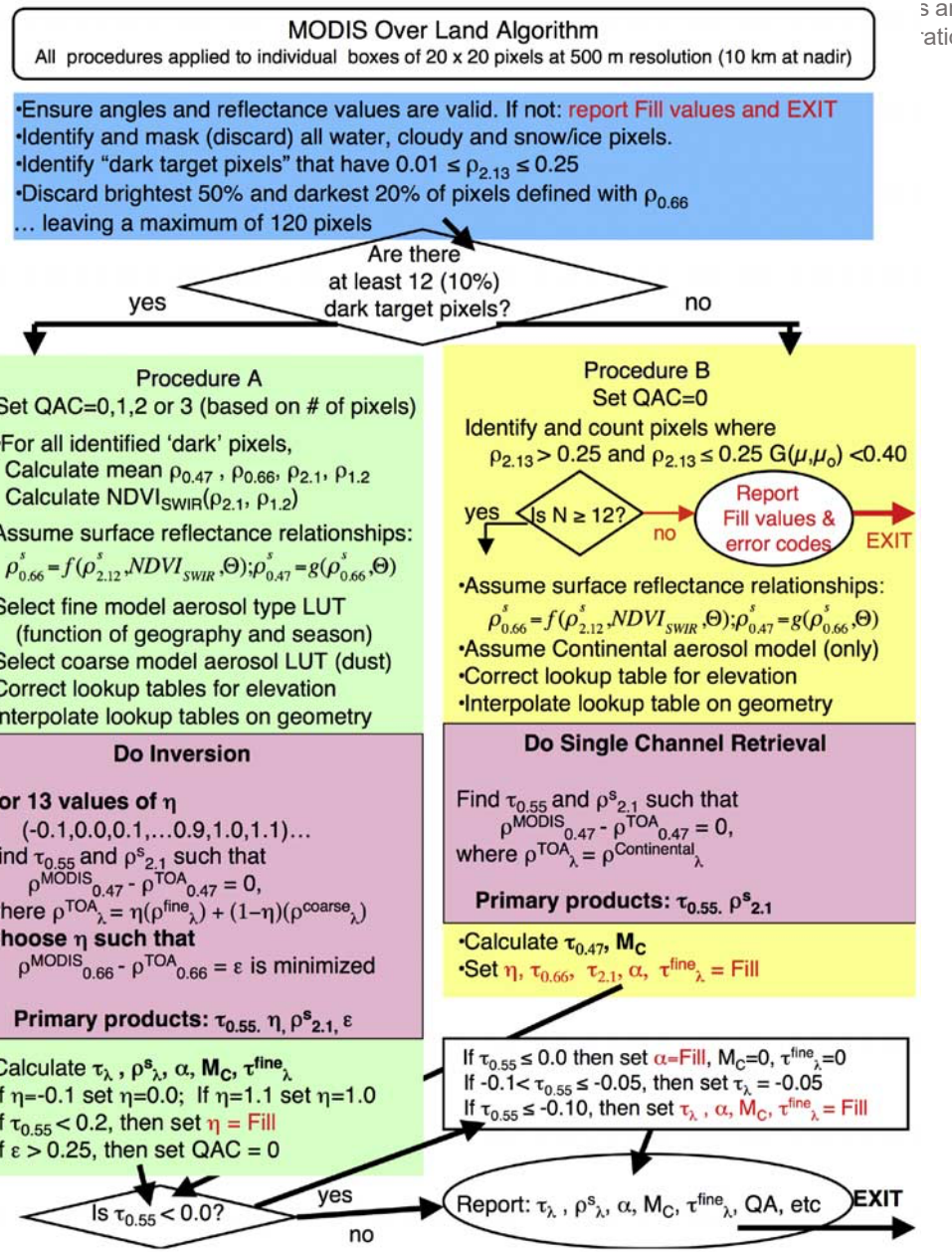
Generate L2 Reflectance
- ❑ Cloud mask
- ❑ Quality control

Collect Relevant Ancillary Data
- ❑ Surface reflectance
- ❑ Aerosol speciation (GEOS forecast)

Machine Learning Algorithm trained with AERONET observations

Do Retrieval

AOD



Observations

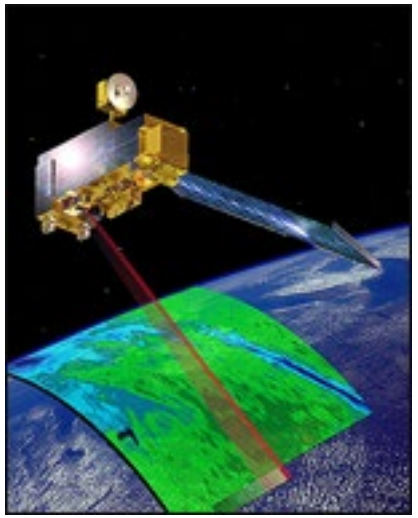
Satellite Sensor Observation:

MODIS MOD04 /MYD04 Level 2 Reflectance

Geophysical Parameter of Interest:

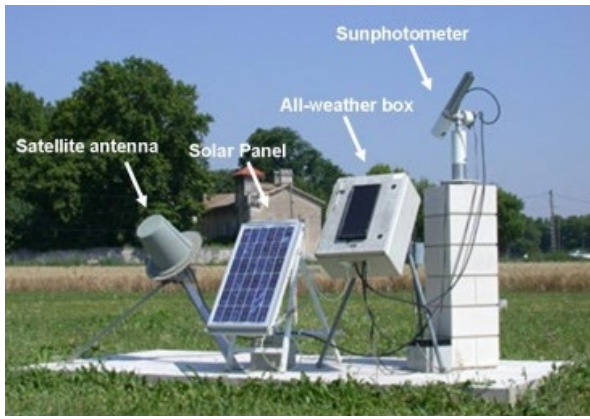
440, 470, 550, 670, 870 nm AOD

- Cloud masked, quality controlled, 10 km data



- Deep Blue Land
  - 3 channels over bright surfaces
  - 412 nm, 470 nm, and 670 nm
- Dark Target Land
  - 9 channels over dark surfaces
  - 412-2100 nm
- Dark Target Ocean
  - 7 channels over ocean
  - 470-2100 nm

- Aerosol Robotic Network (AERONET) observations of AOD
  - Global network of sunphotometers
  - 15 minute sampling
  - Low uncertainty (±0.01)



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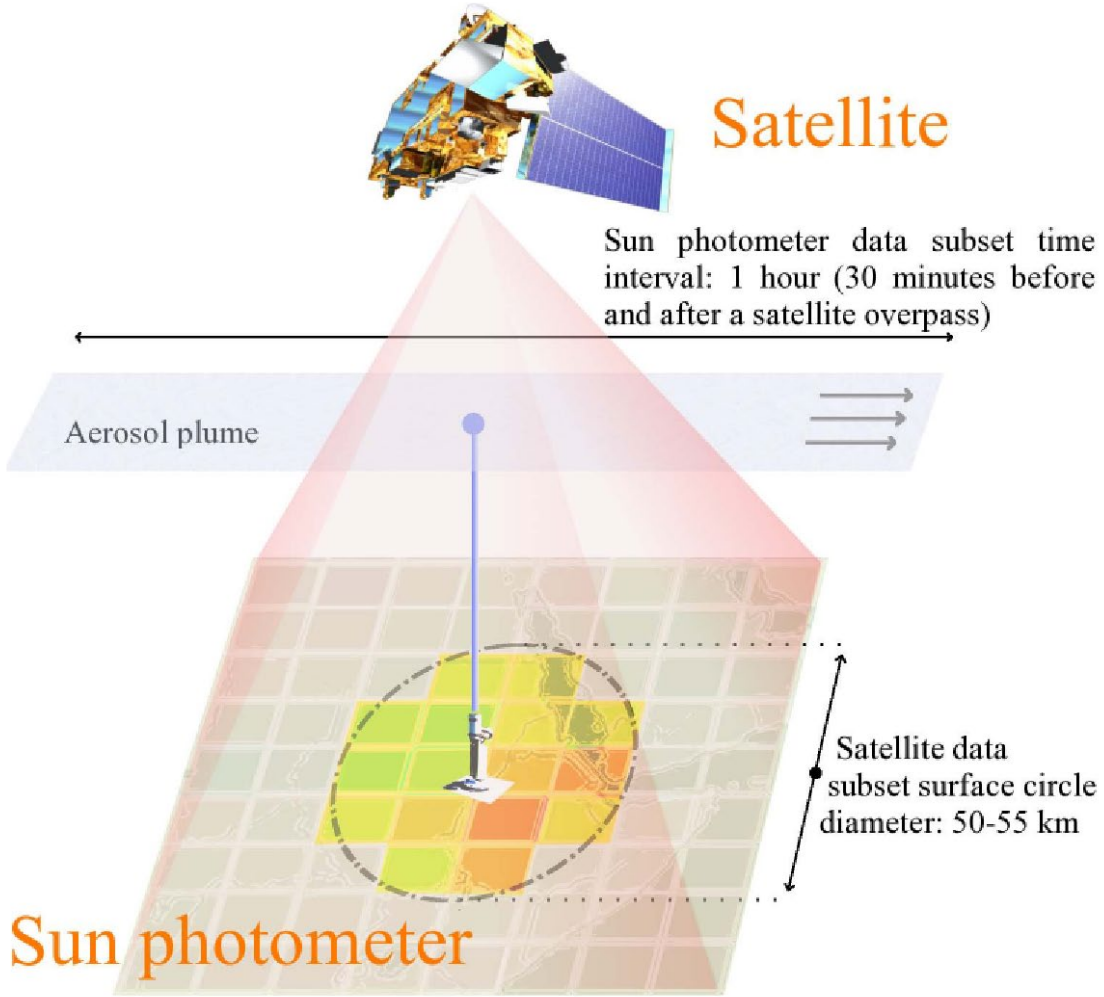
MODIS-AERONET Data Pairs



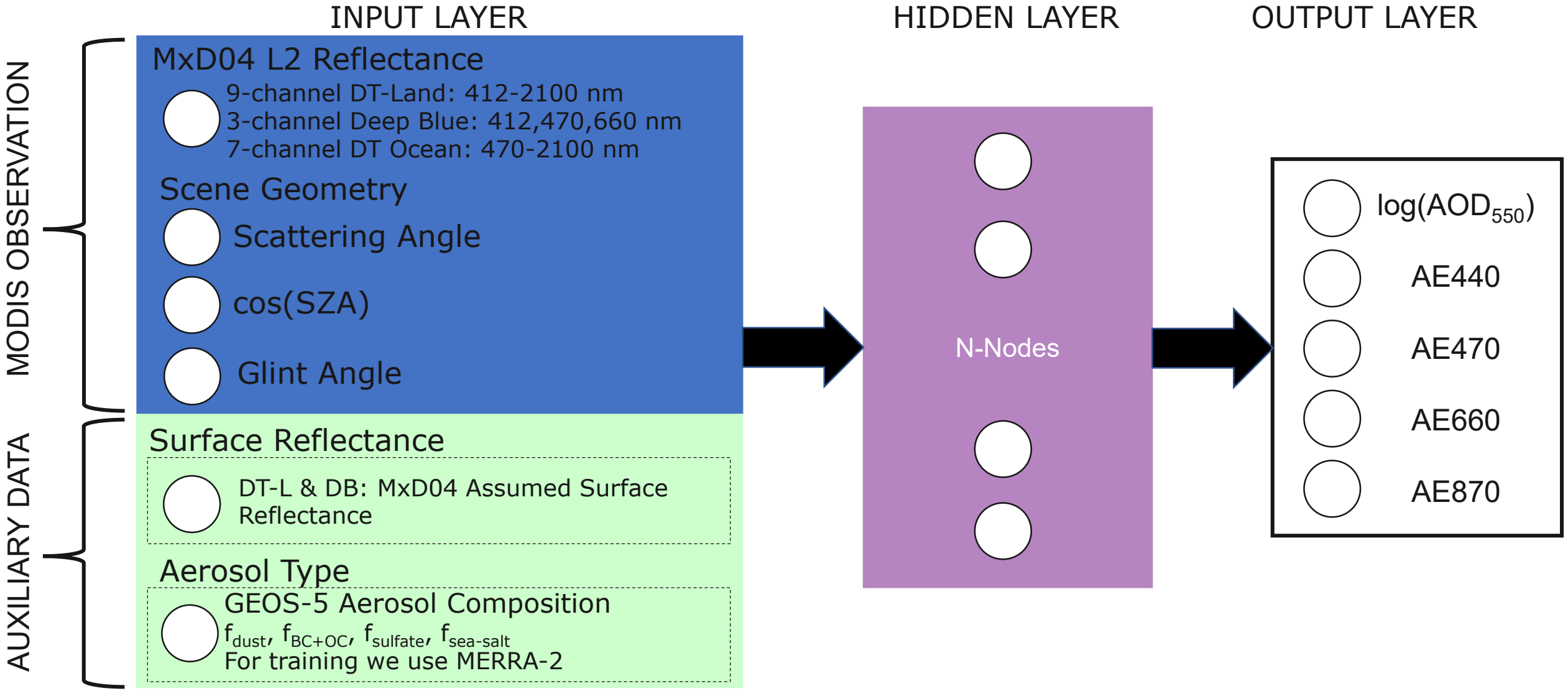
Petrenko, et al. AMT (2012)

- 20 years of data (2000-2021)

Additional Data Screening

- Outlier removal
- Cloud Fraction < 0.7
- Used MERRA-2 to “balance” the dataset by aerosol type
  - Dust
  - Smoke (Black Carbon + Organic Carbon)
  - Sea Salt
  - Sulfate

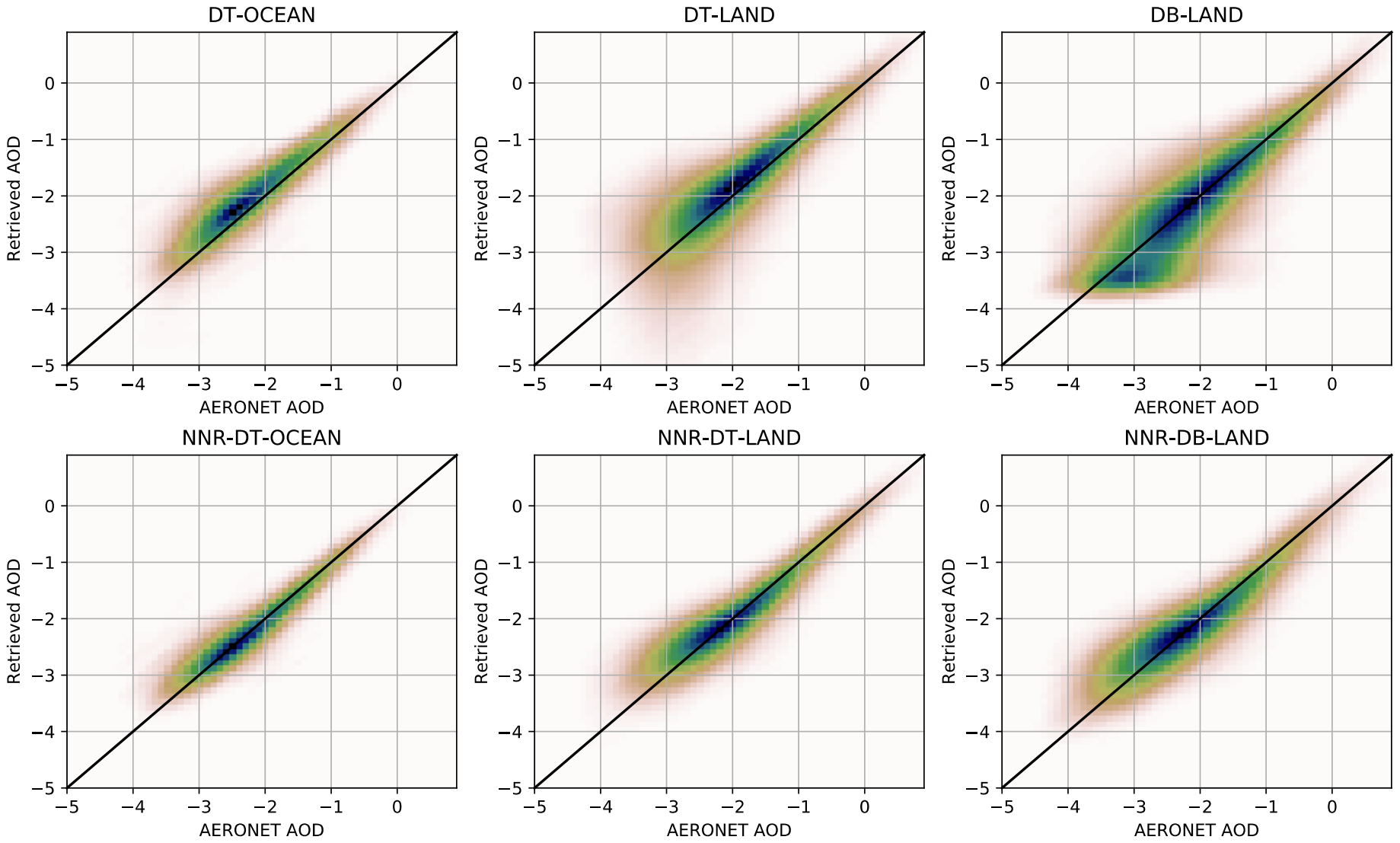
GEOS NNR for AOD



550 nm AOD

DT & DB →

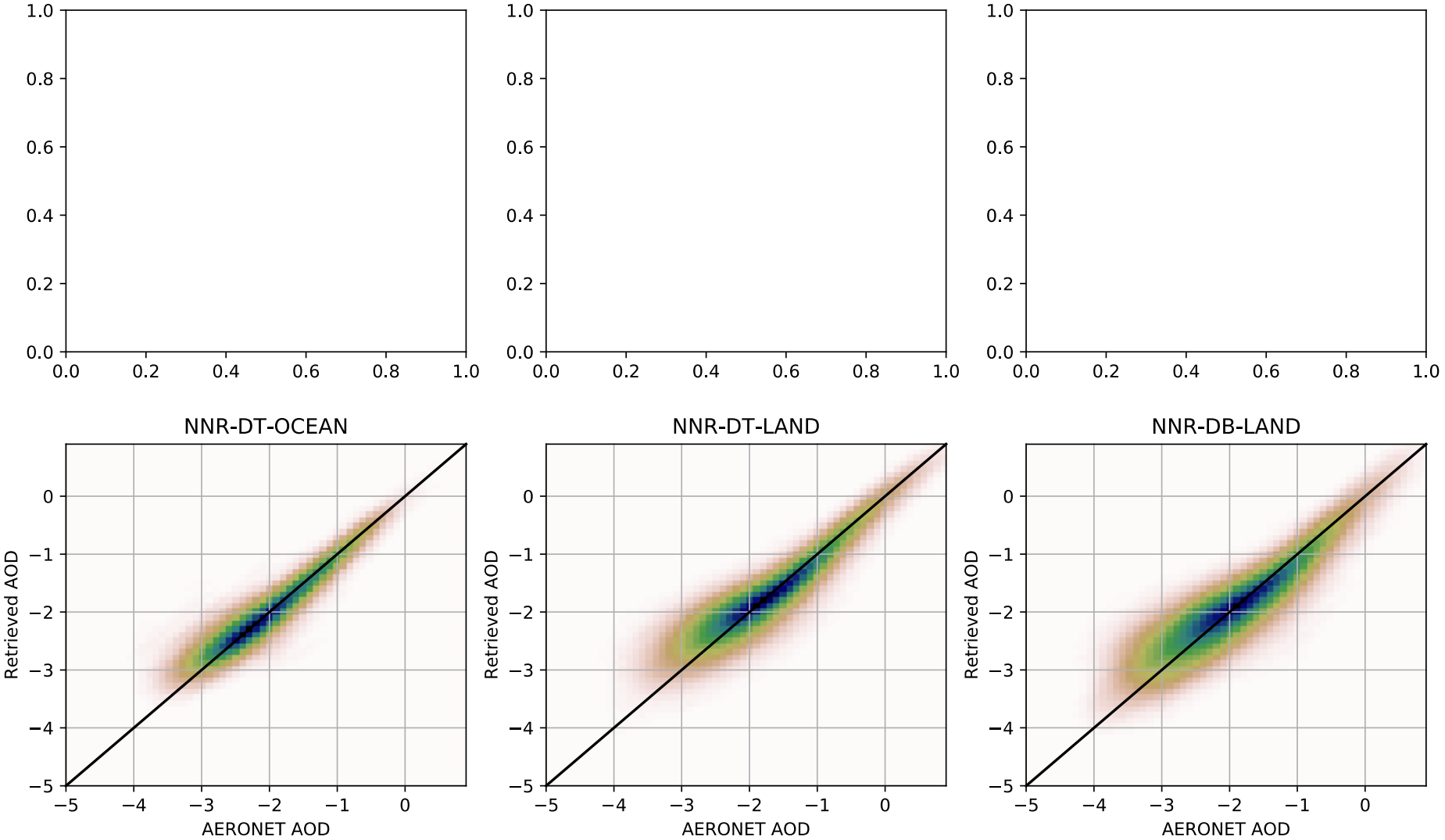
NNR →



440 nm AOD

DT & DB →

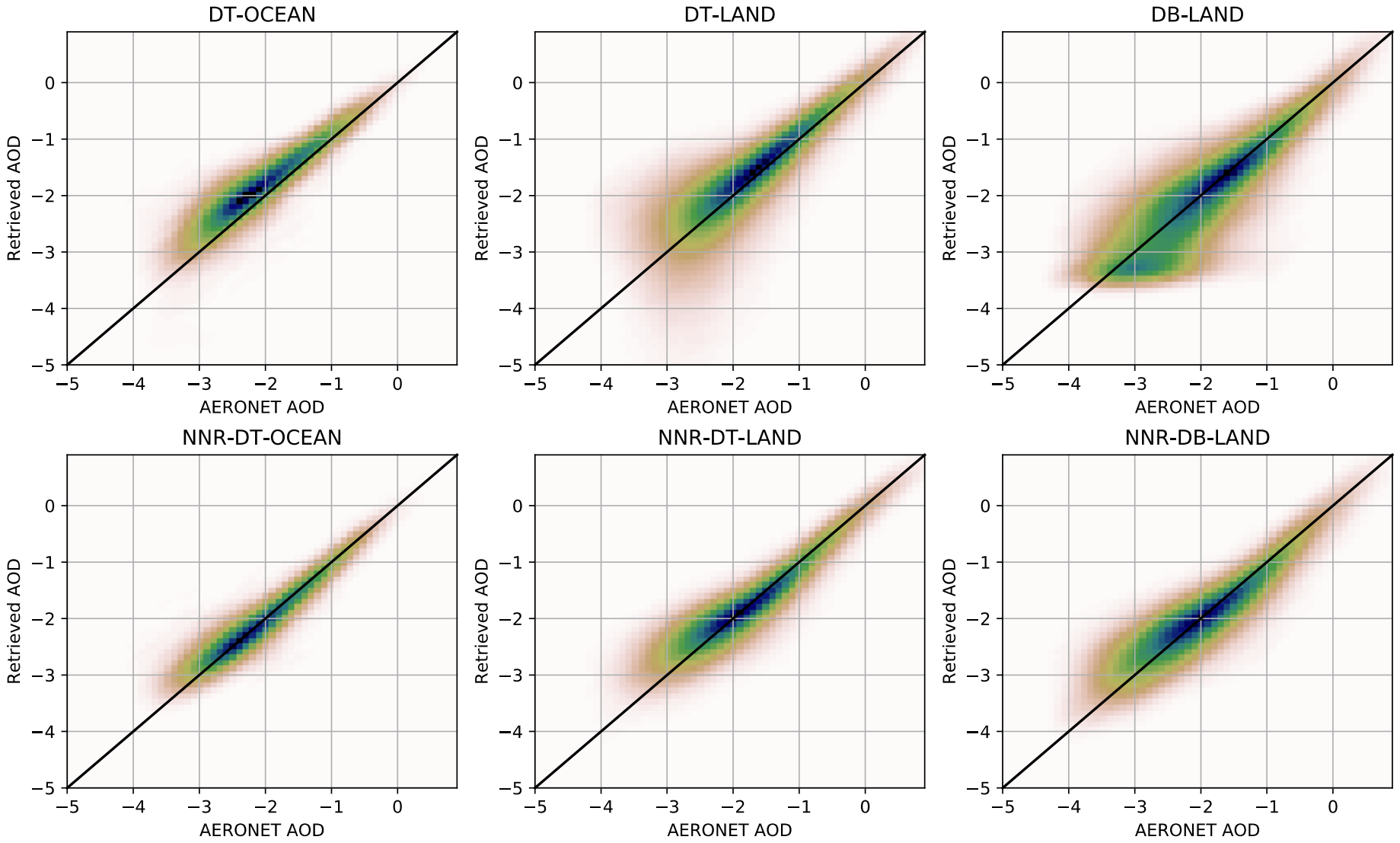
NNR →



470 nm AOD

DT & DB →

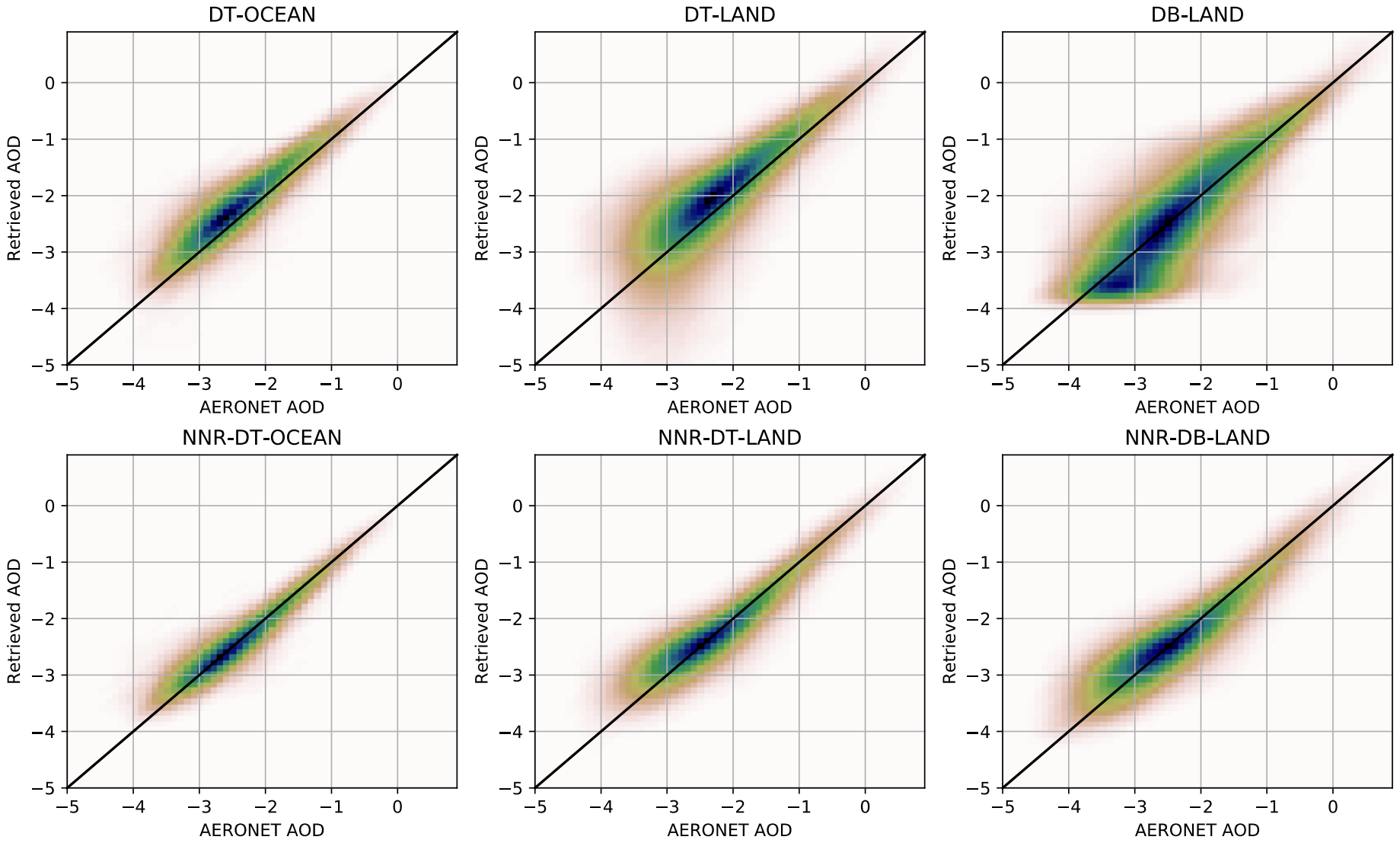
NNR →



660 nm AOD

DT & DB →

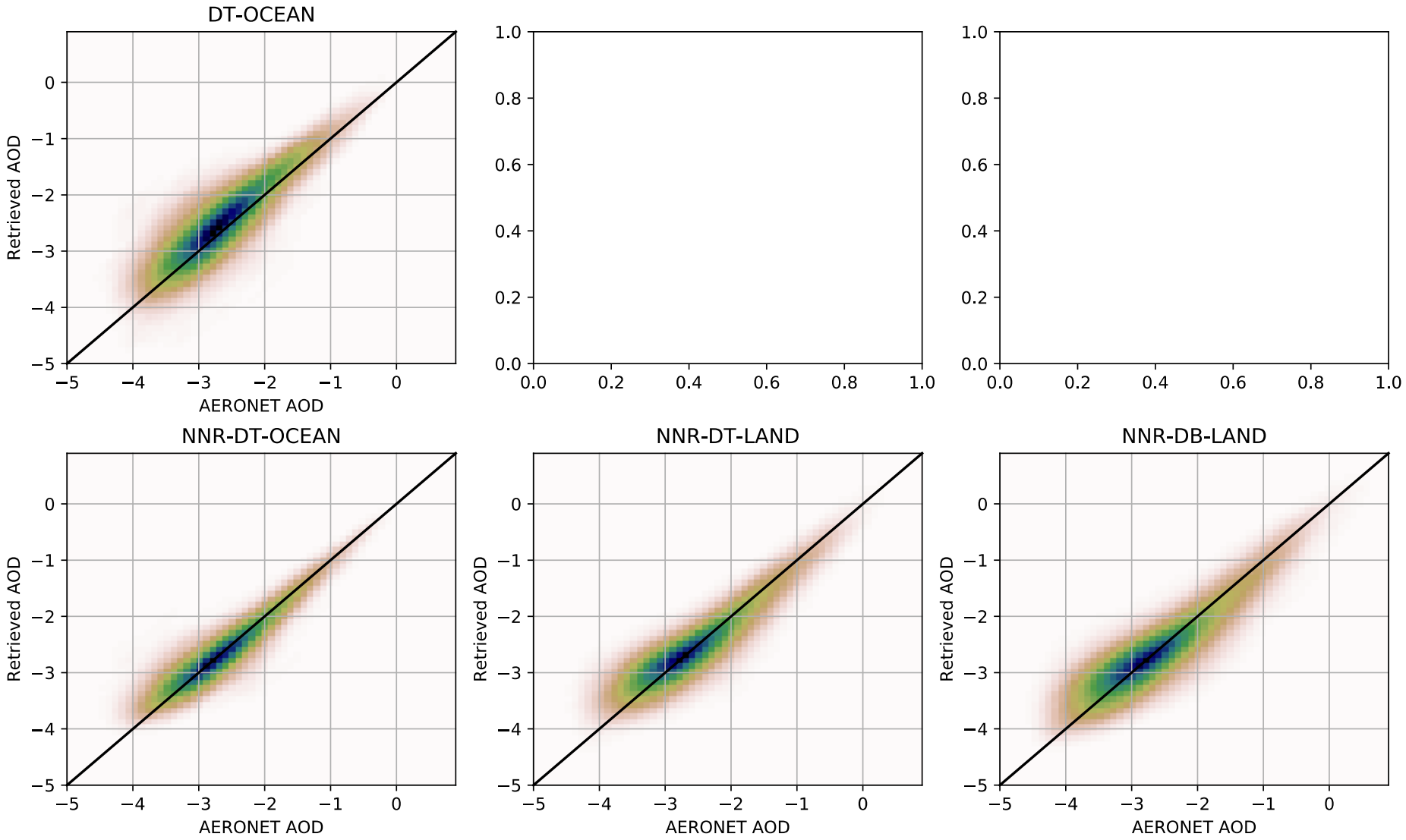
NNR →



870 nm AOD

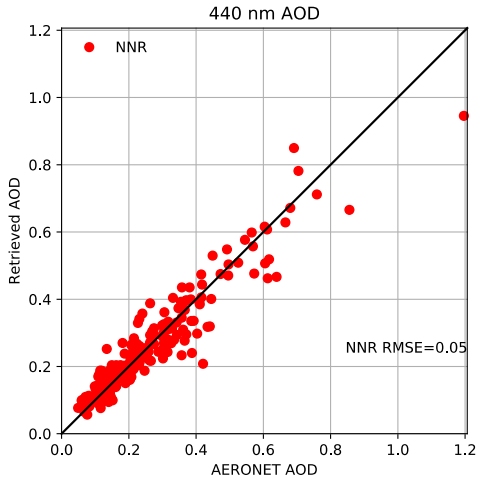
DT & DB →

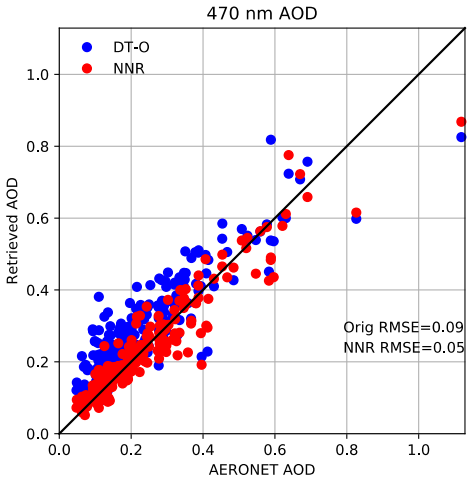
NNR →

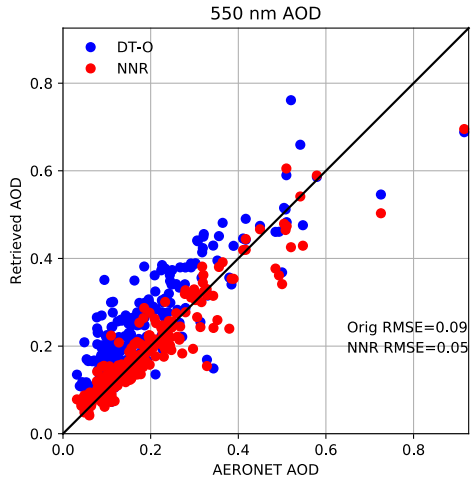


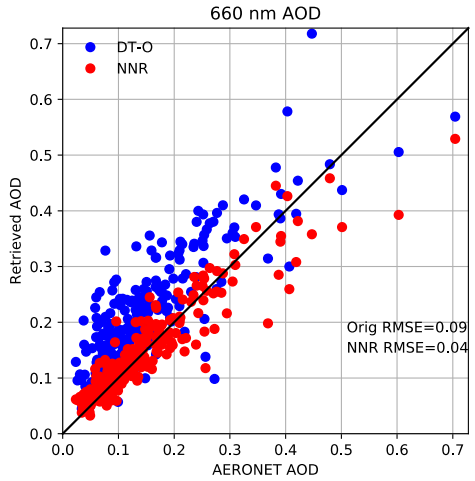
Testing at Specific Sites

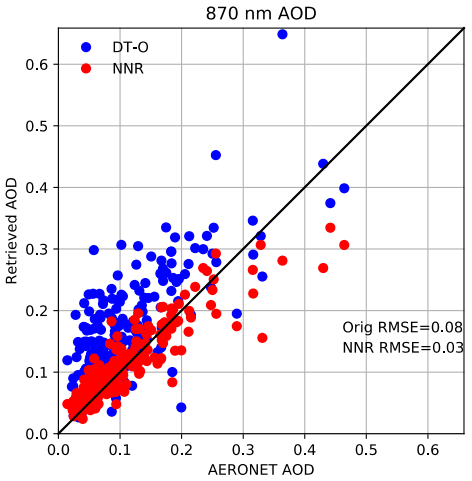
Terra DT-OCEAN Shirahama



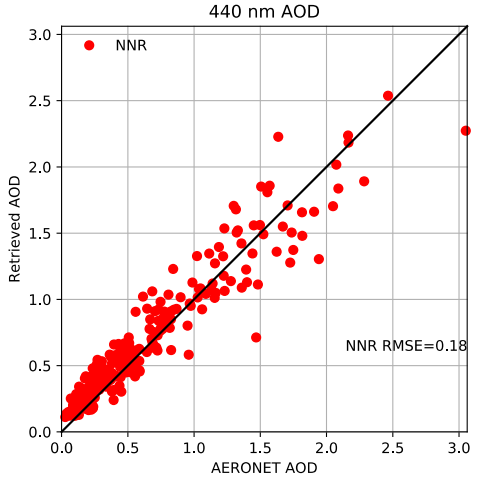


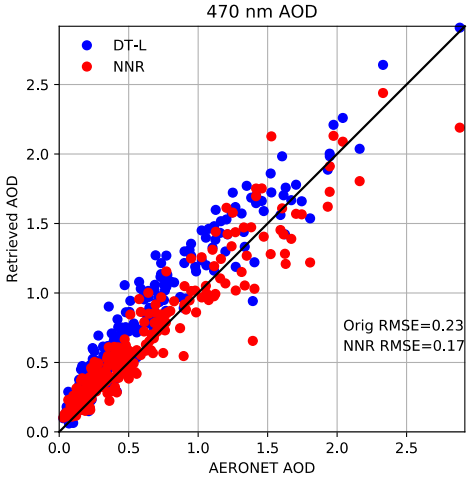


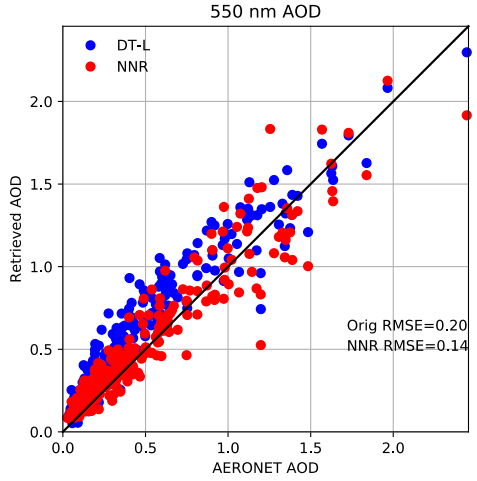


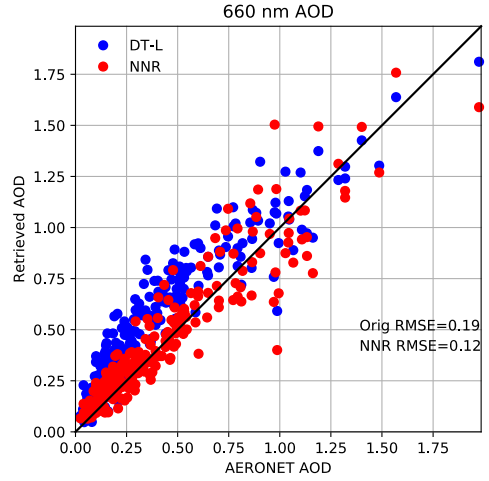


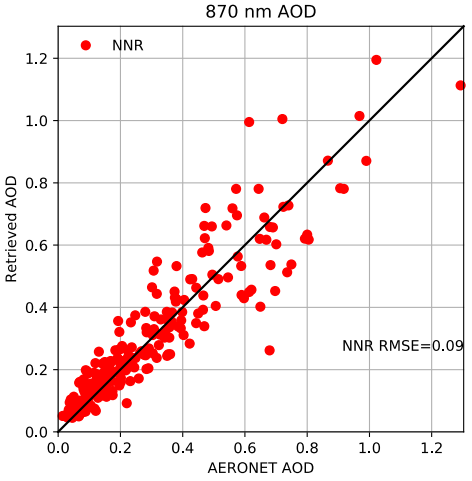
Terra DT-LAND Beijing-CAMS



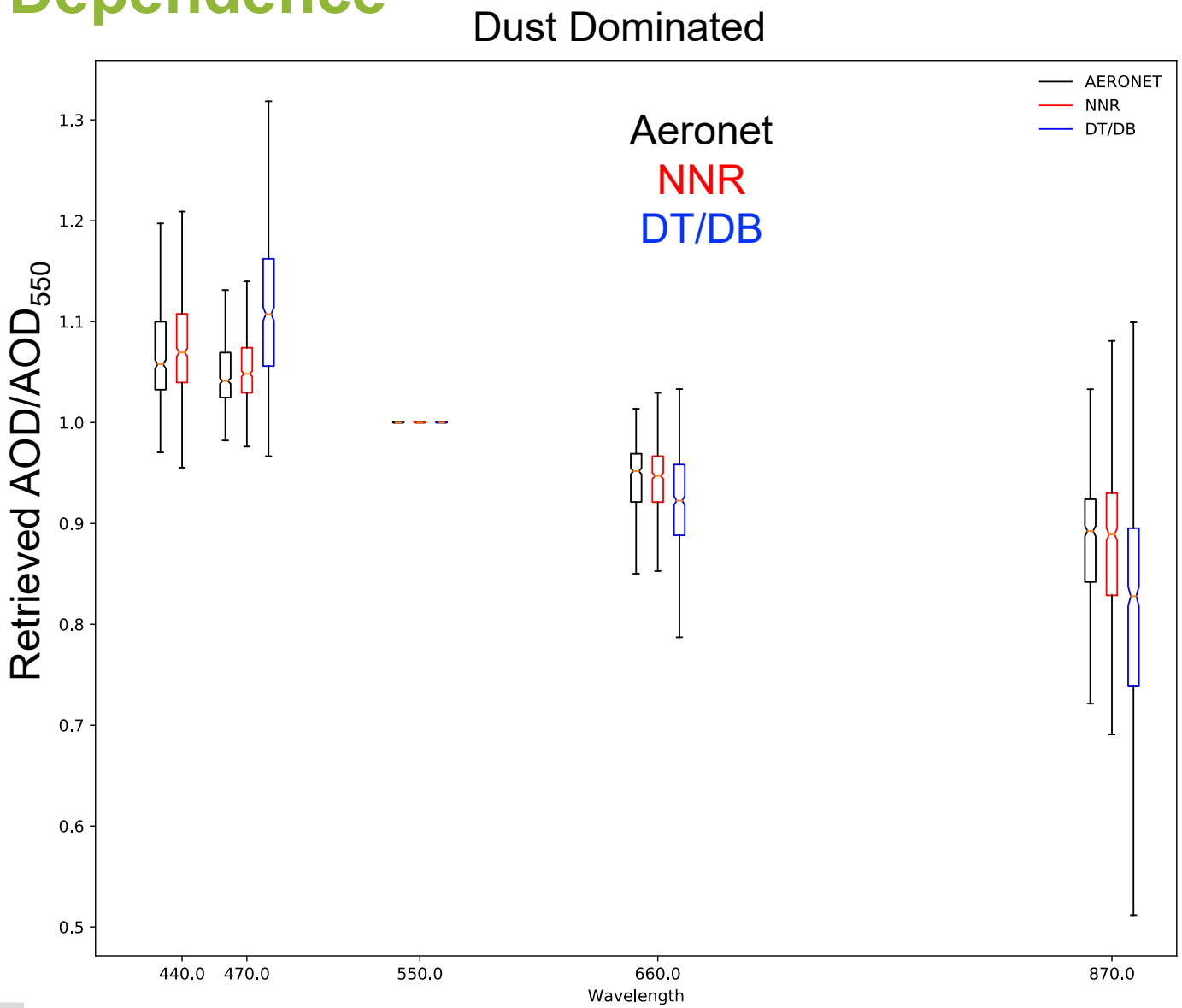




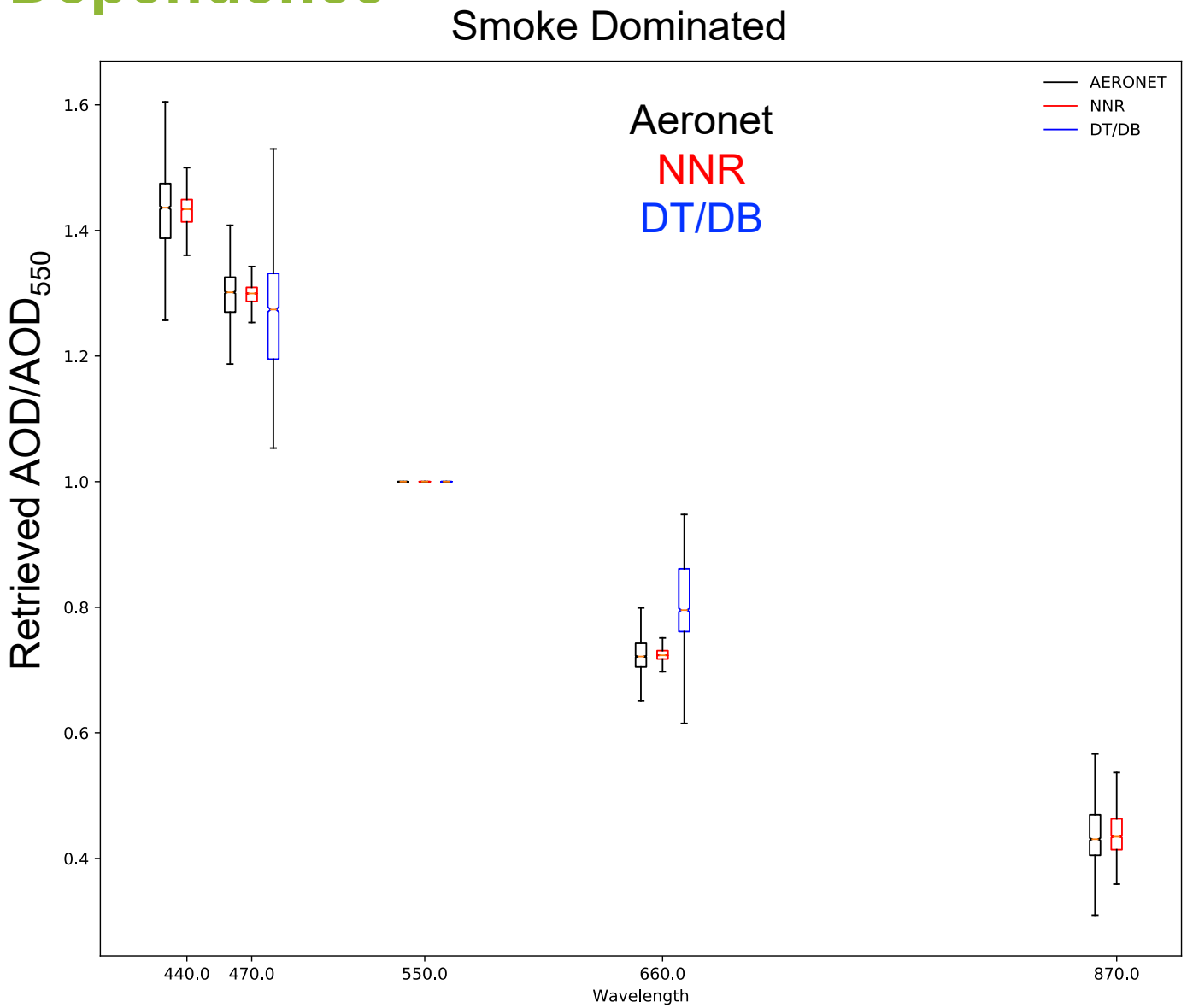




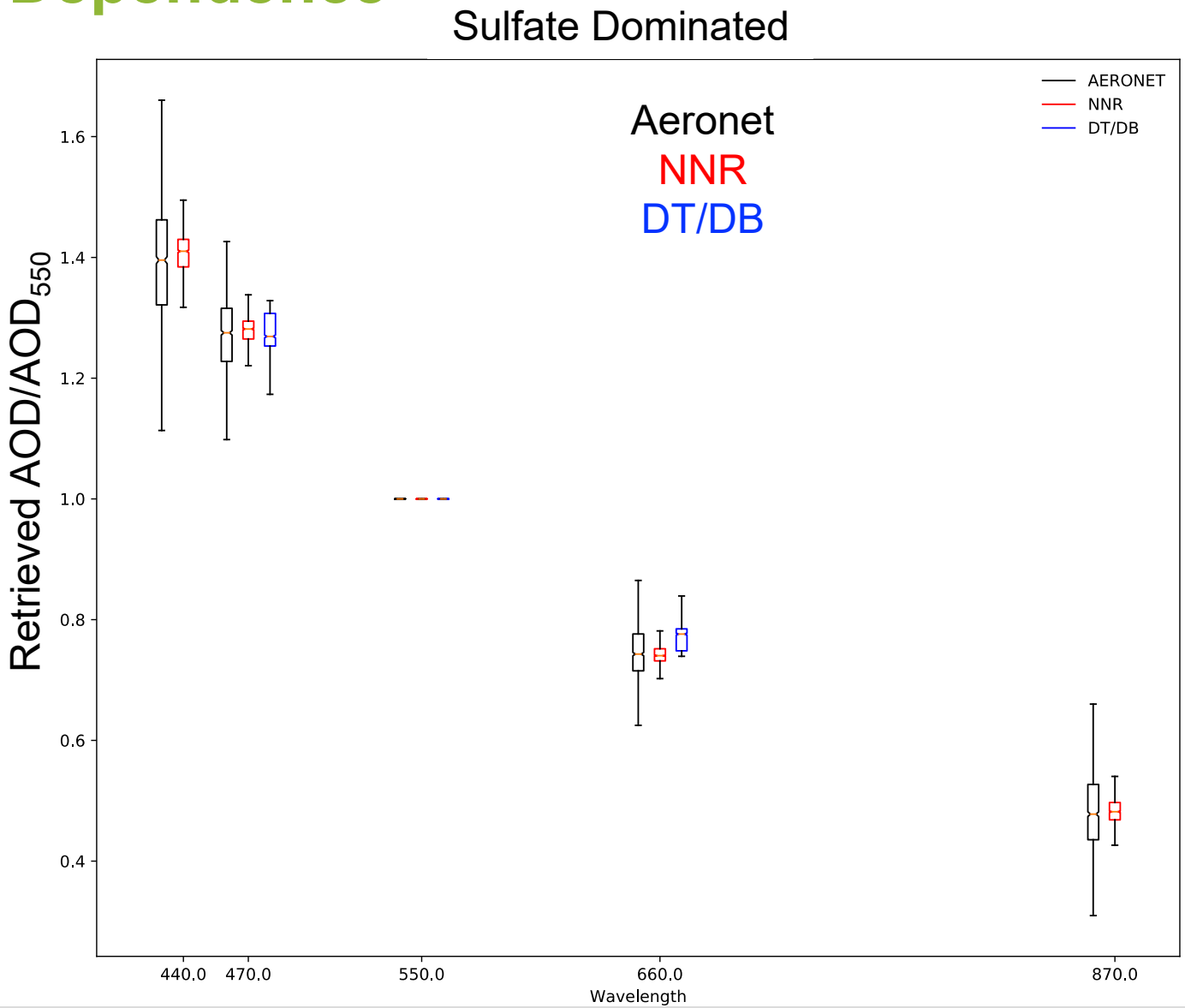
AOD Spectral Dependence



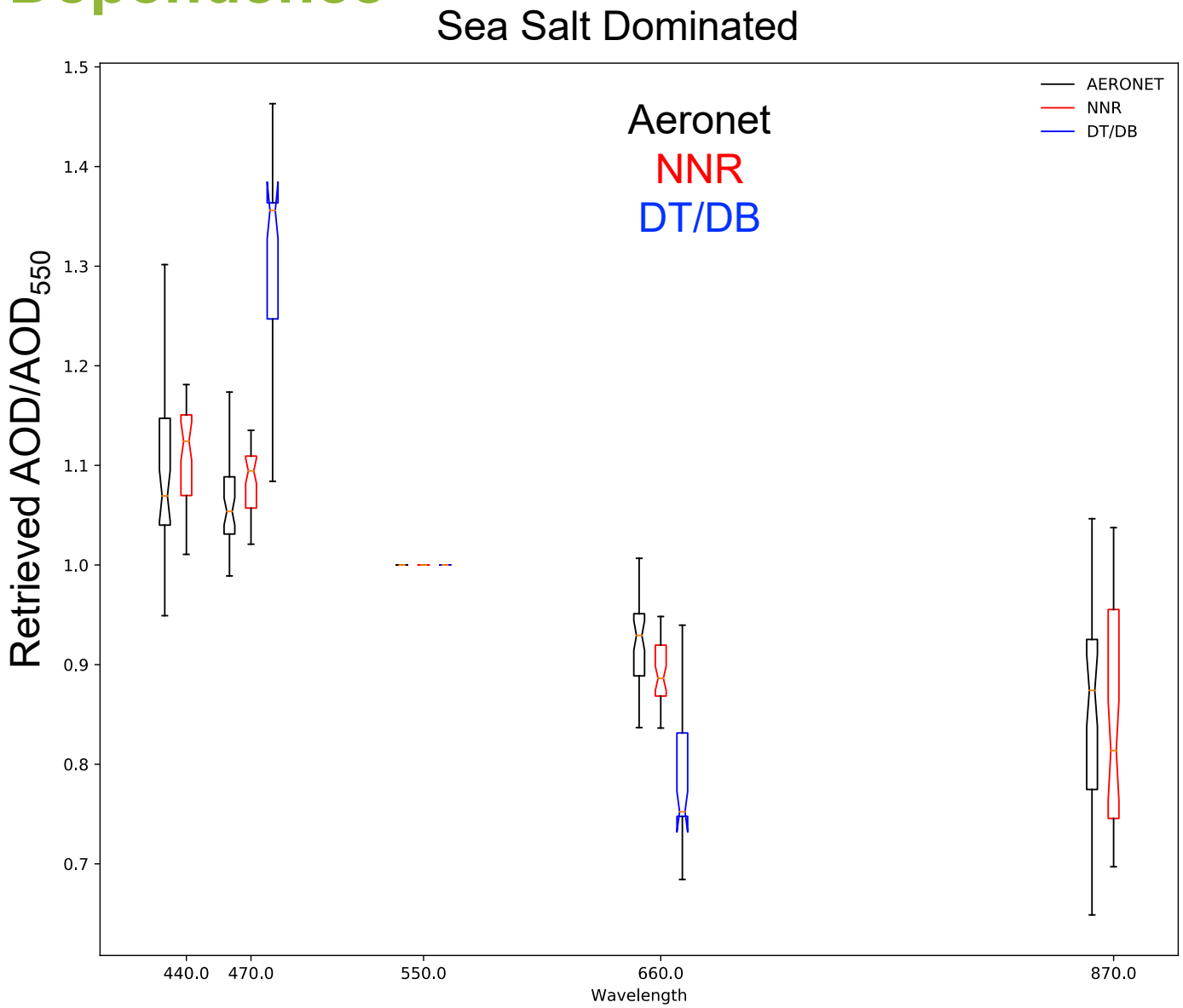
AOD Spectral Dependence



AOD Spectral Dependence

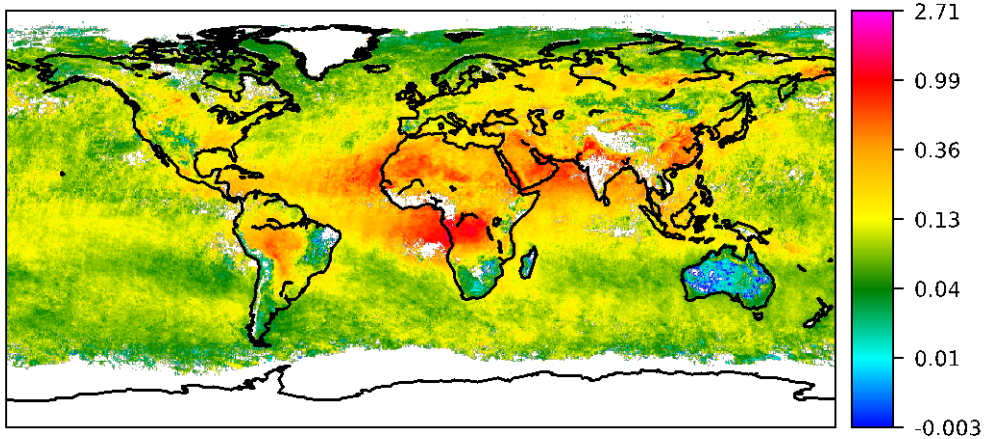


AOD Spectral Dependence

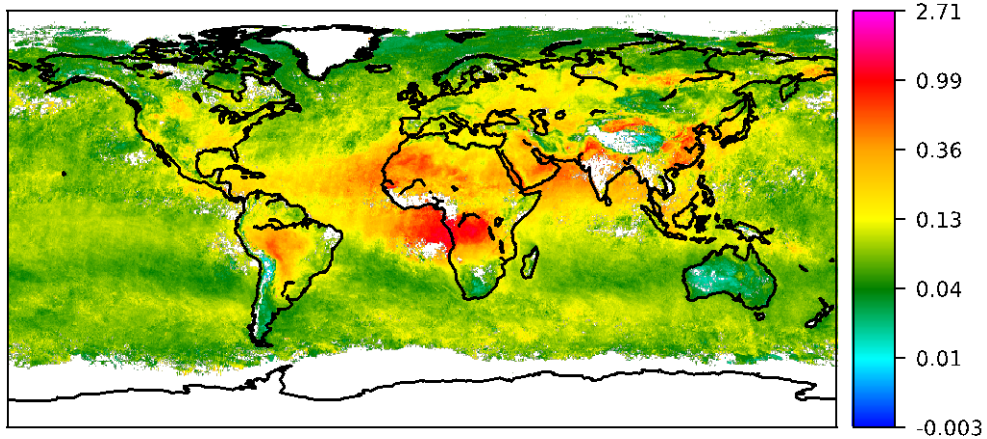


Monthly Means of AOD550

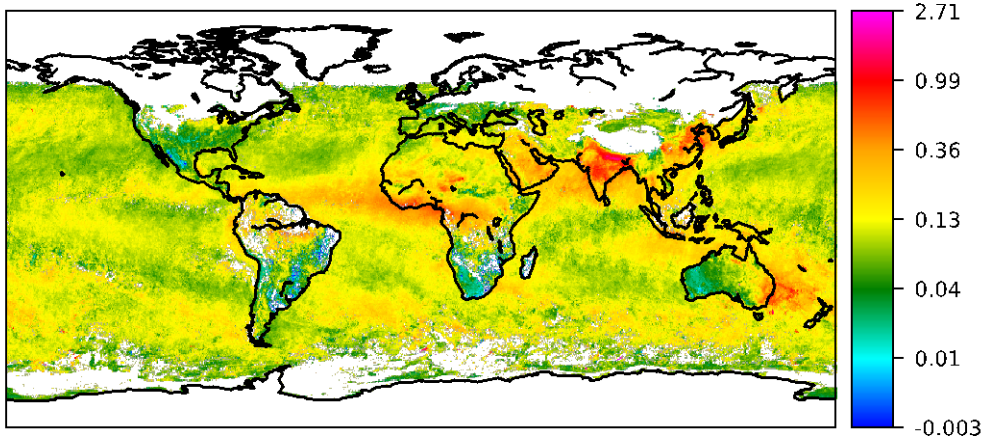
MOD04 ALL AOD 20160801



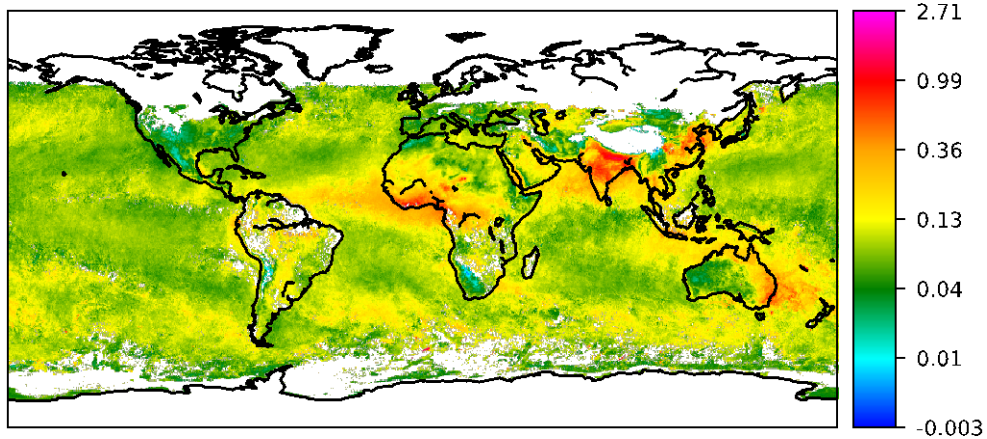
NNR ALL AOD 20160801



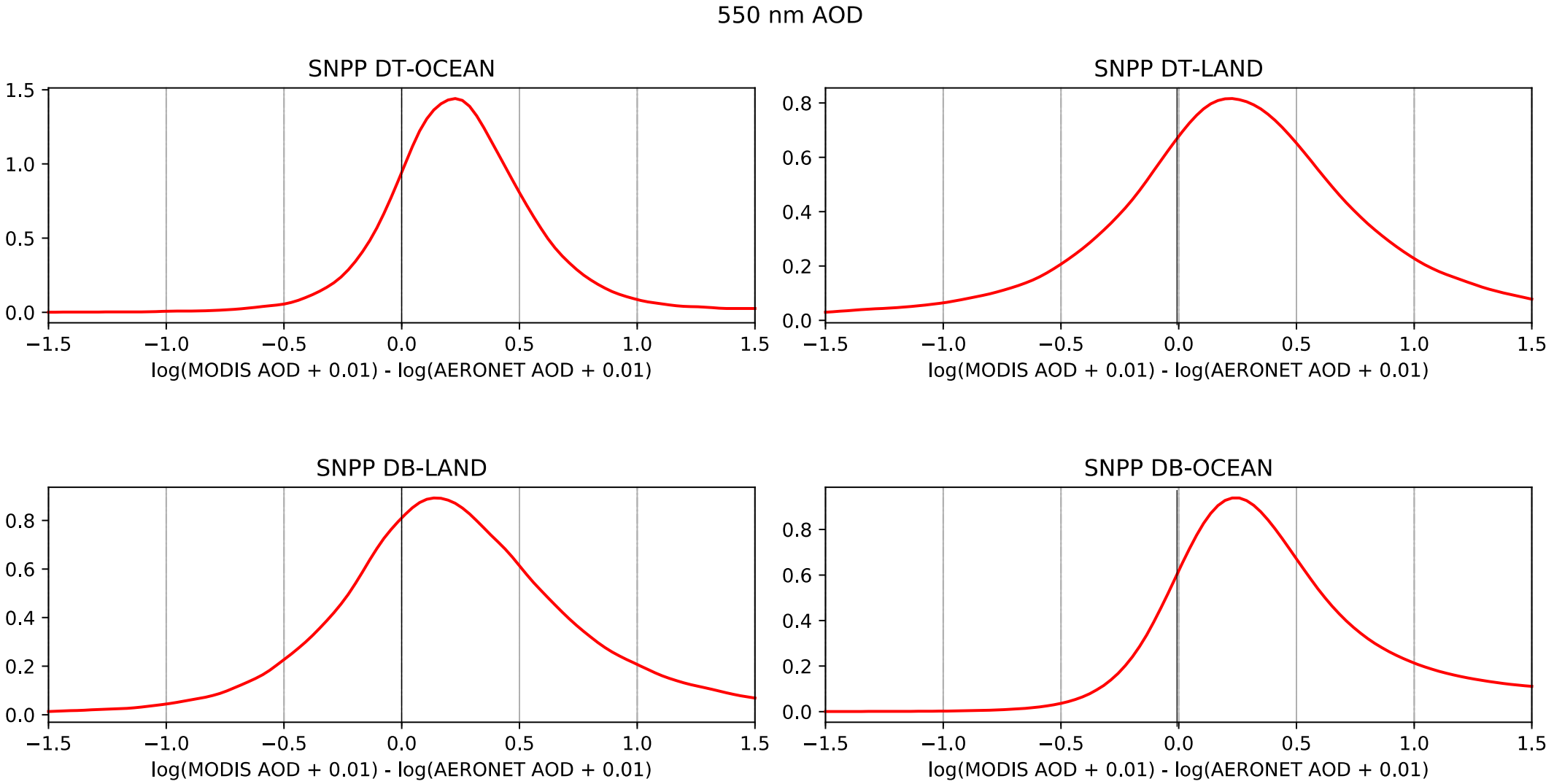
MOD04 ALL AOD 20191201



NNR ALL AOD 20191201



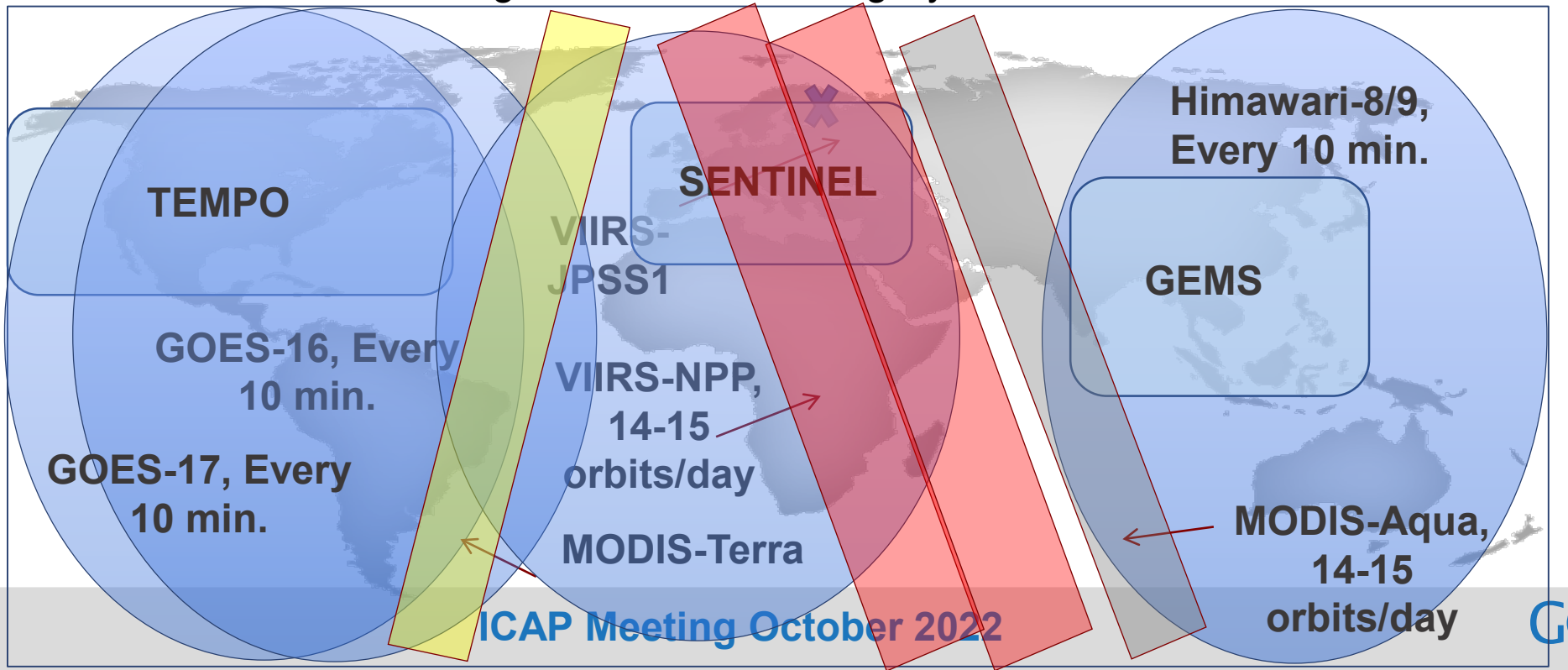
Transition to DB & DT Applied to VIIRS



Summary and Outlook

- The NNR provides a way to homogenize the AOD observing system for data assimilation
- A NNR for VIIRS, GOES-16 and AHI-8 will be developed using the same methodology as the MODIS-NNR
- JEDI-based aerosol analysis system supports new multi-wavelength NNR AOD
  - may expand wavelength range to 340–1020

Target Aerosol Observing System in GEOS



Summary and Outlook

- Innovate the training methodology to give probabilistic predictions
  - e.g. ensemble learning, gaussian process learning, deep evidential regression
  - Benefits: provides quantitative uncertainties of the predictions that can be used in the aerosol assimilation