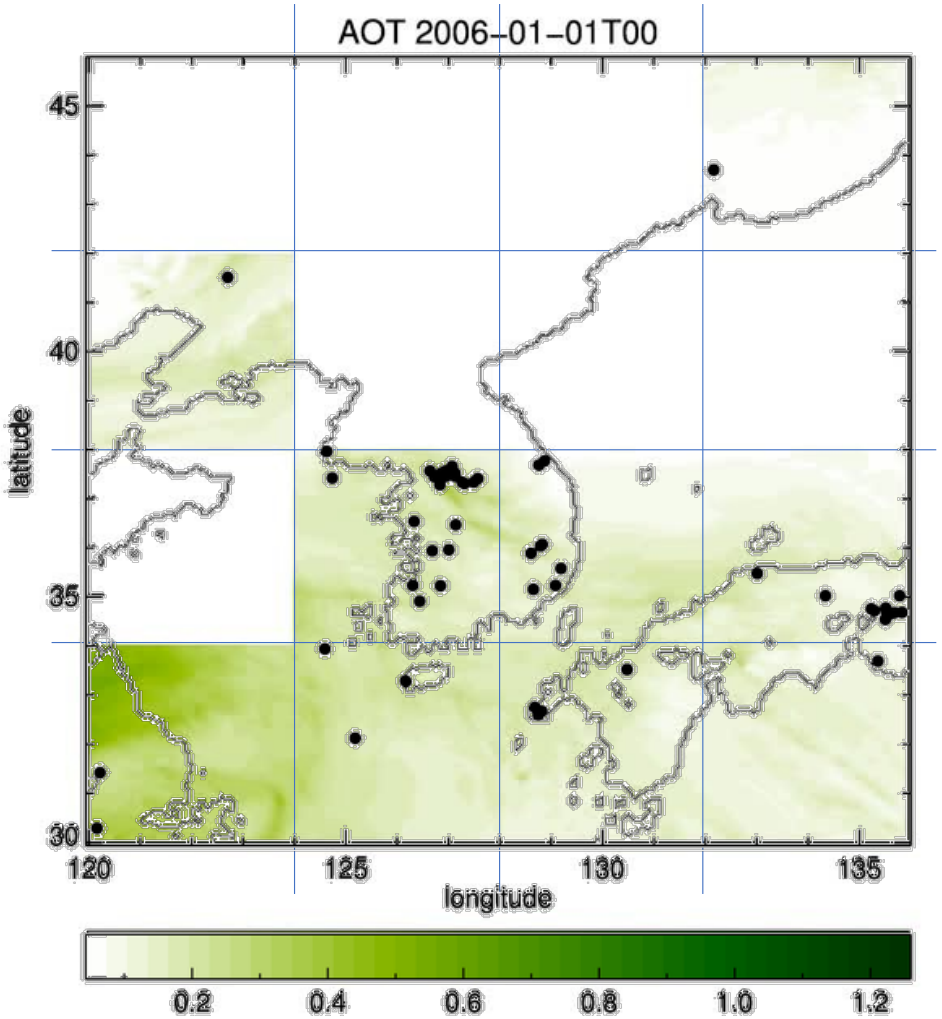
How representative are observations? Spatio-temporal issues when using observations

Nick Schutgens

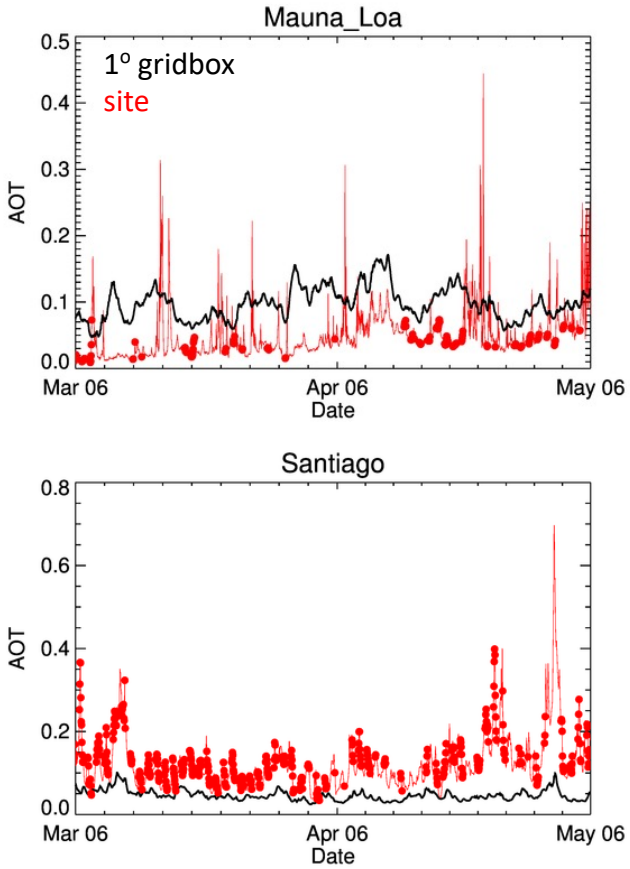
GEOS-5 Nature Run

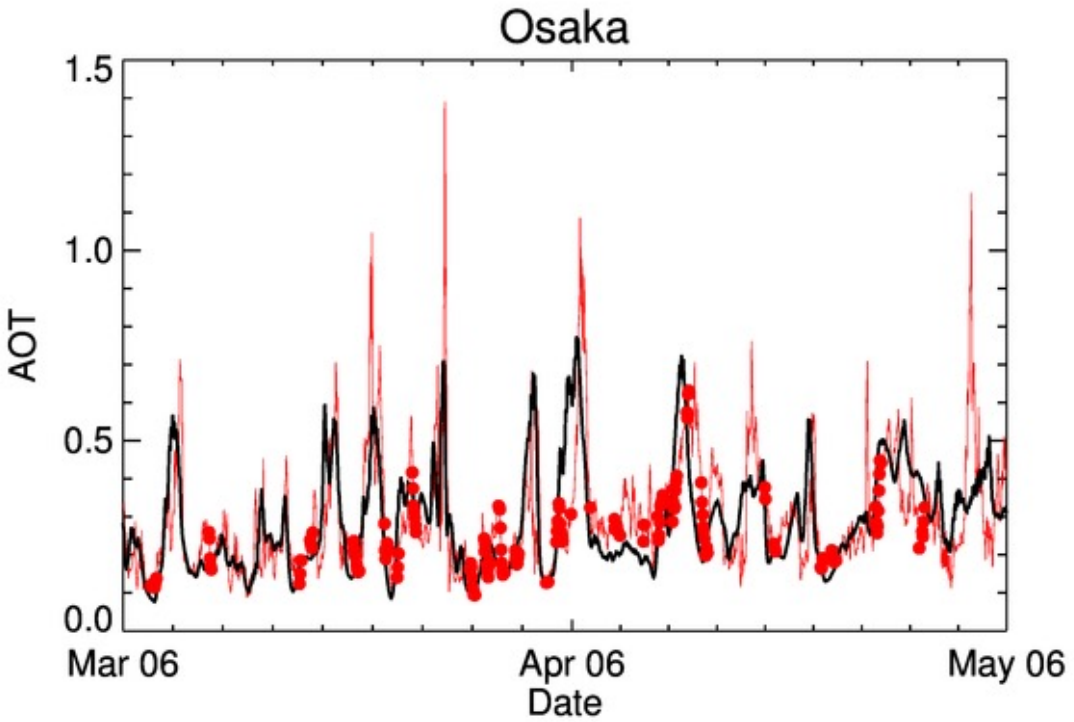
GEOS5 is a two-year global simulation at high resolution: 0.0625° or ~ 7 km near the equator, produced by NASA GMAO and freely available.

Representation error = point value – area average

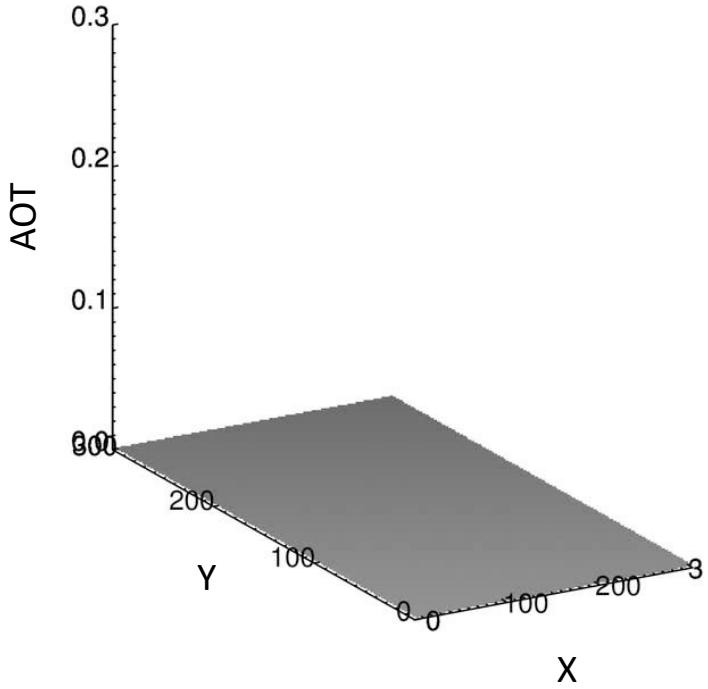


Example time-series

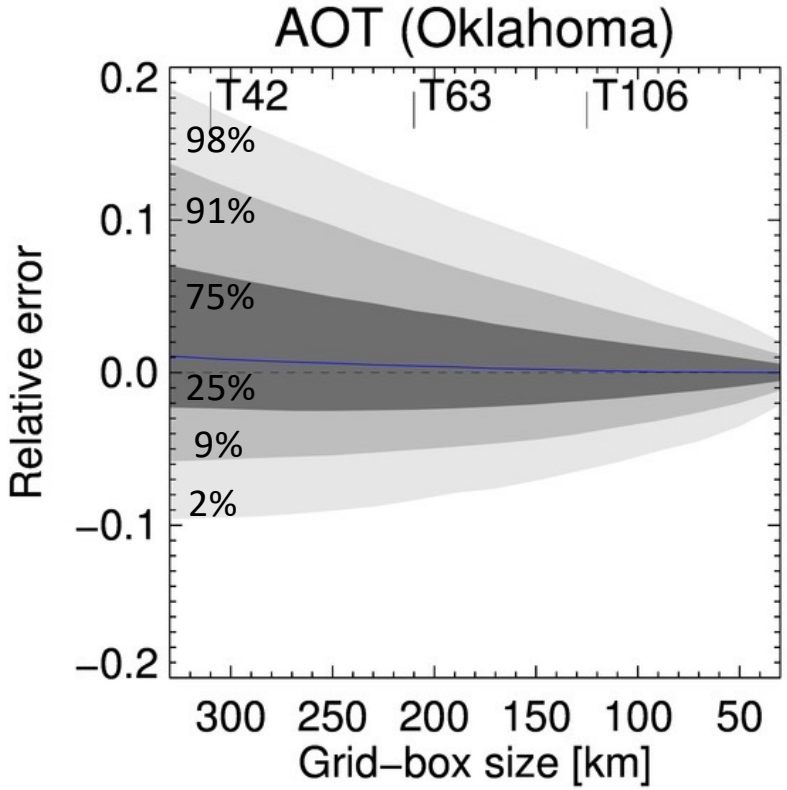




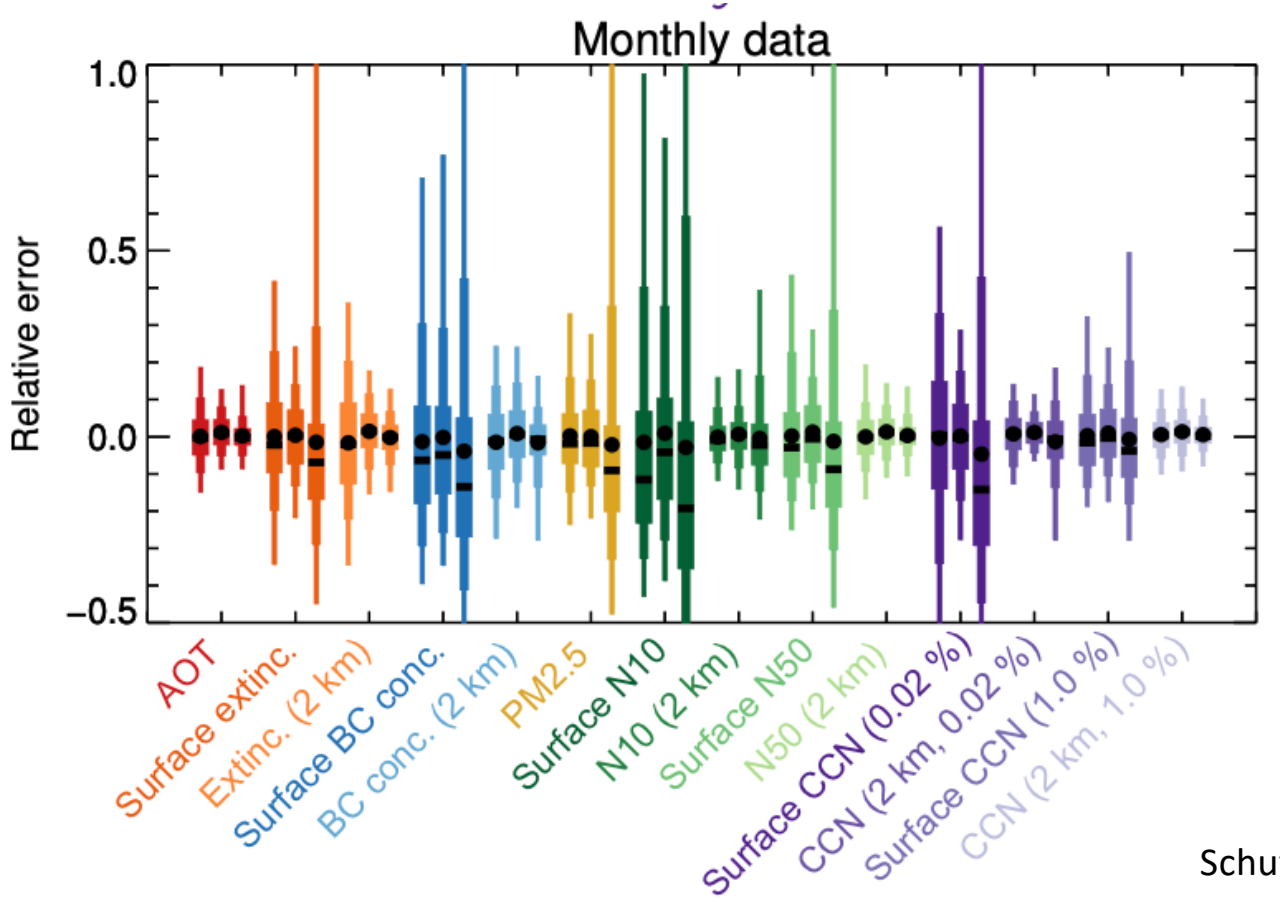
Sub-grid variability



ϵ_r depends on model resolution



ϵ_r depends on parameter

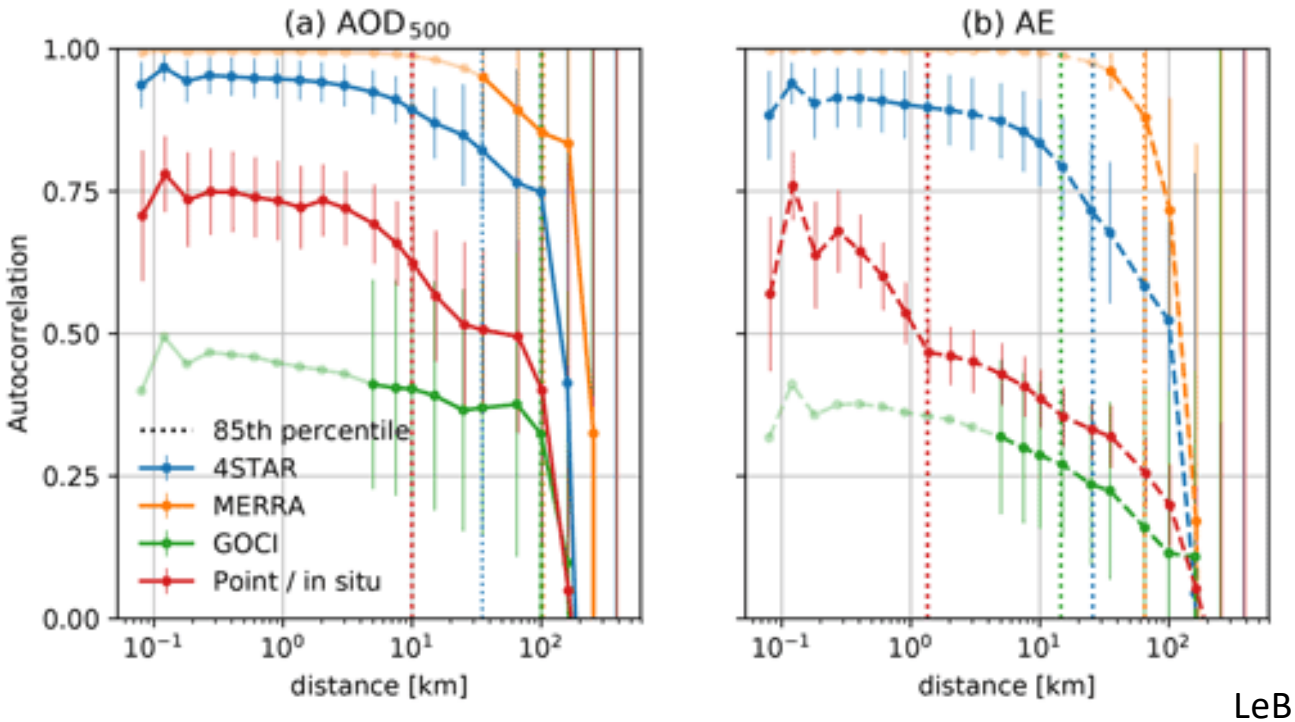


Schutgens et al. *ACP* 2016b

Extensive vs intensive observations

Extensive
Is related to aerosol amount

Intensive
Is related to individual aerosol property



LeBlanc et al. *ACP* 2022
See also Anderson et al. 2003

ϵ_r comparable or larger than measurement/retrieval errors

Observable	Observation	Representation (monthly)
AOD	0.04 ± 10% (O) 0.05 ± 15% (L)	11-16%
PM2.5	15% (d)	21-46%
BC conc.	bias ± 15%	40-57%

Representation errors for model resolution of 200 km. Most CMIP6 models use ~100 km, most AEROCOM models use ~ 200 km.

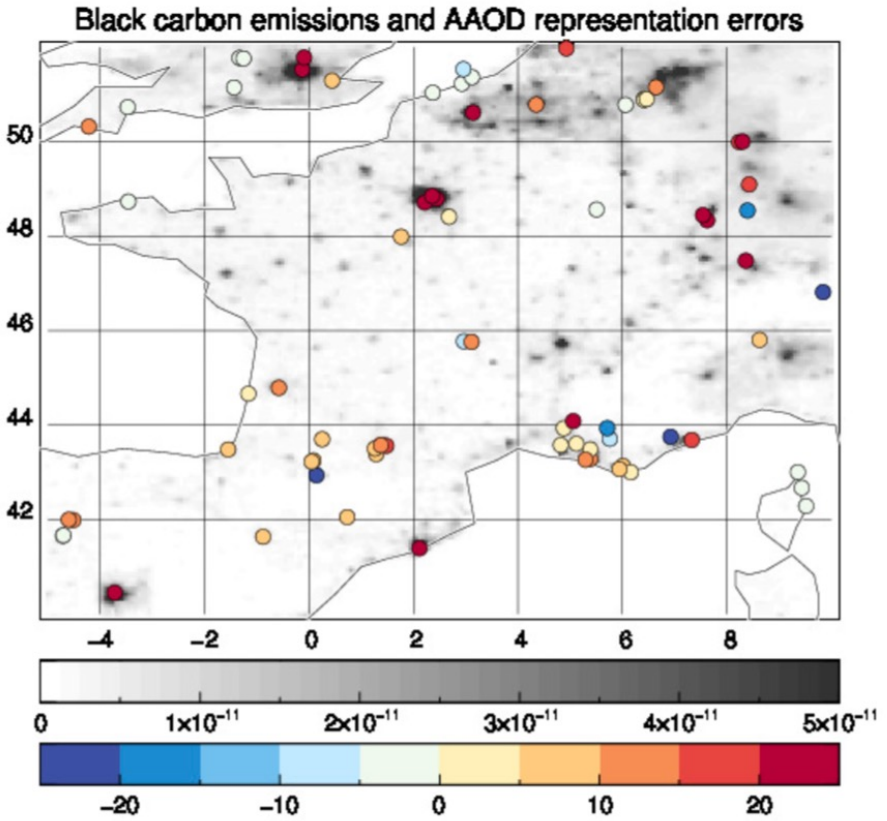
Temporal sampling not included.

AOD: Levy et al., AMT 6, 2013 (MODIS C6 vs AERONET)
PM2.5: Hains et al., AE 41, 2007 (instrument intercomparison at sub-urban site, daily data)
BC conc: Slowik et al., AST 41, 2007 (laboratory intercomparison of instruments)

ϵ_r has bias (& random component)

In yearly averages of continuous point measurements, representation *biases* exist for sites near sources (duh!)

But more in general, yearly recurring situations (emissions, meteorology) give rise to biases.

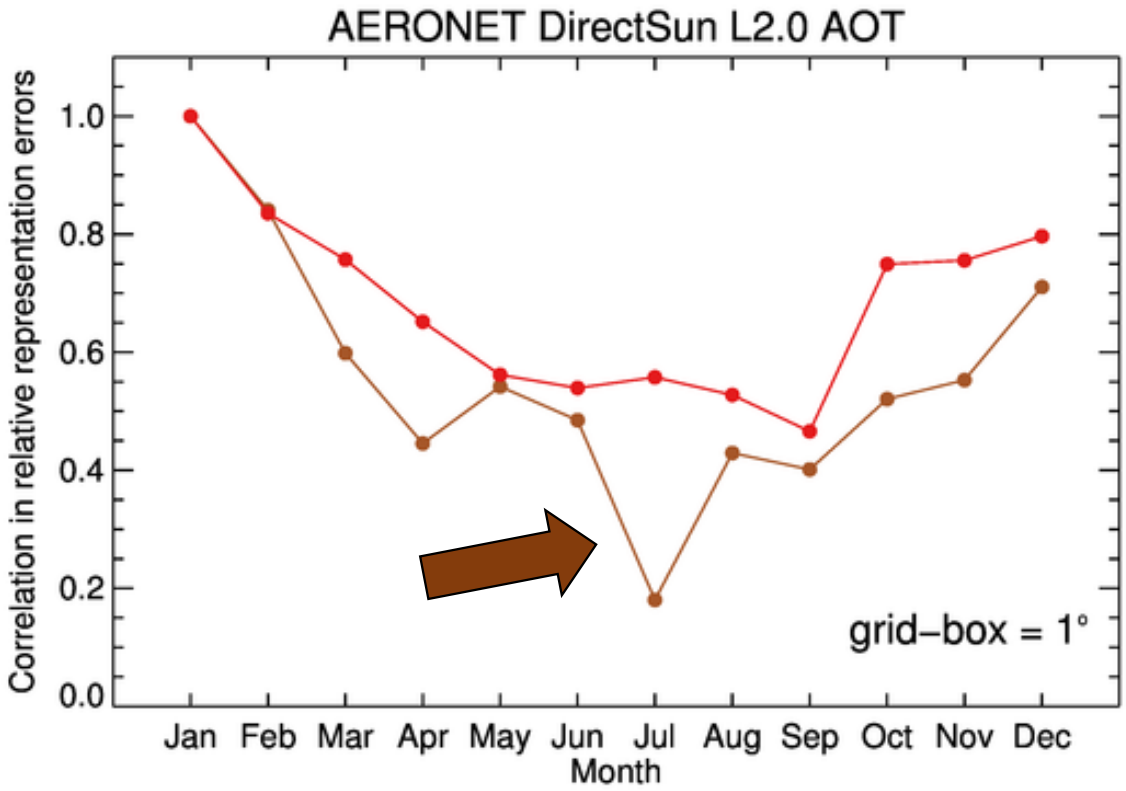


BC emissions [kg/m^{2}s]

ϵ_r [%]

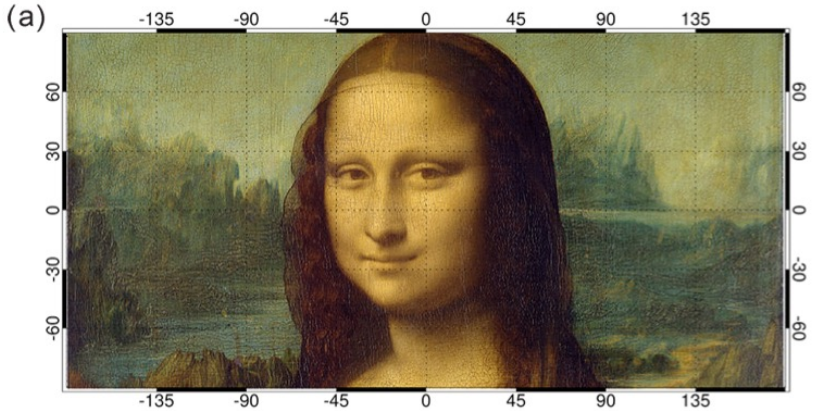
Schutgens *ACP* 2021

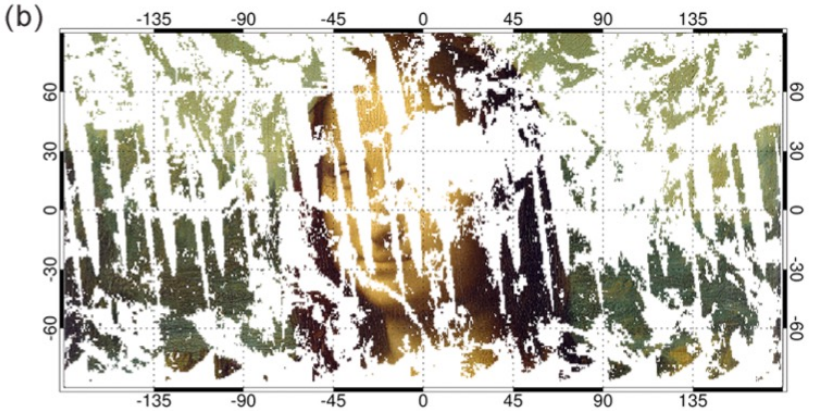
ϵ_r shows temporal correlations



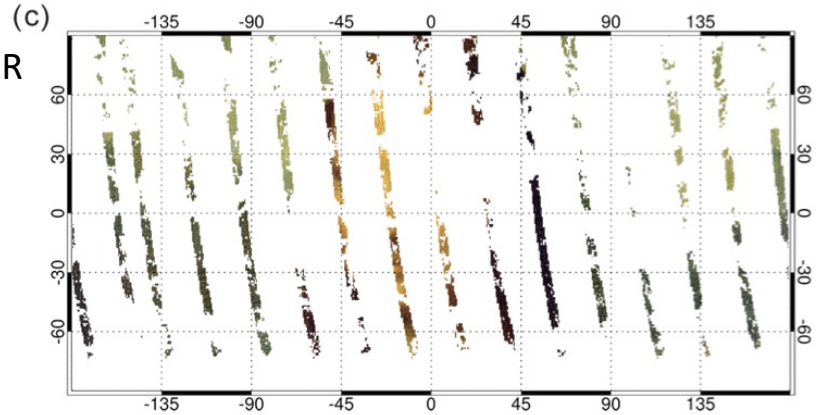
Schutgens *ACP* 2021

It is not much better for satellites…

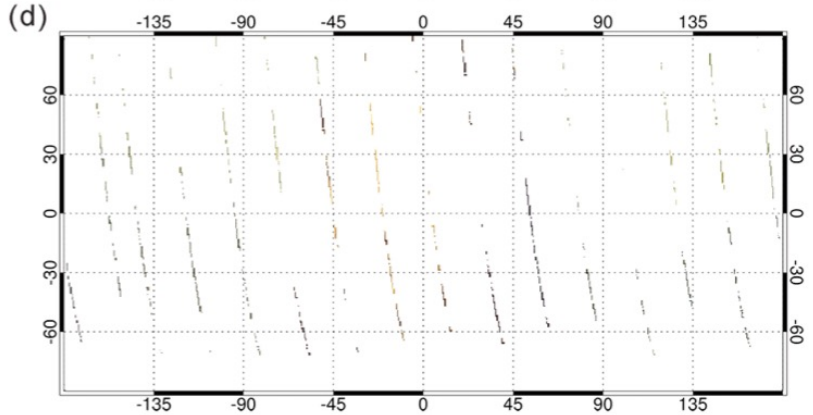




MODIS Aqua

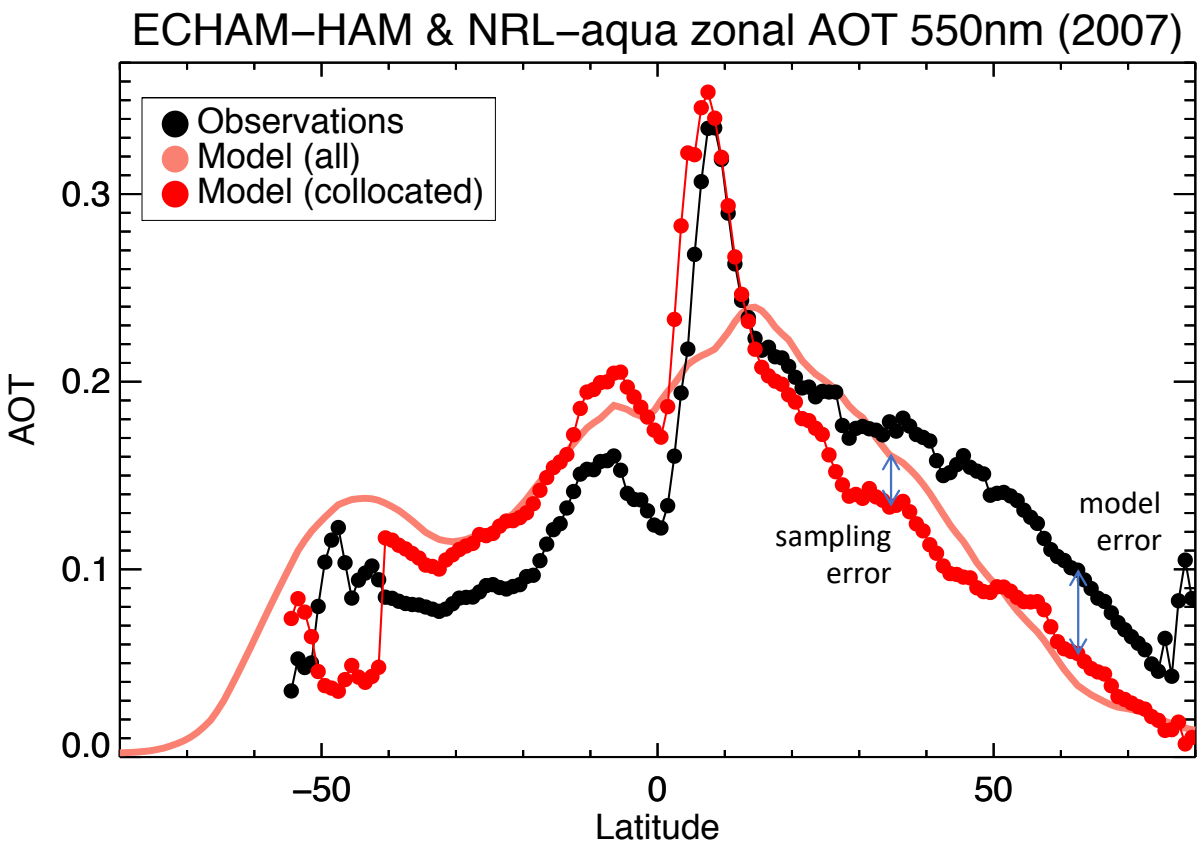


MISR



Colarco et al. *AMT* 2014

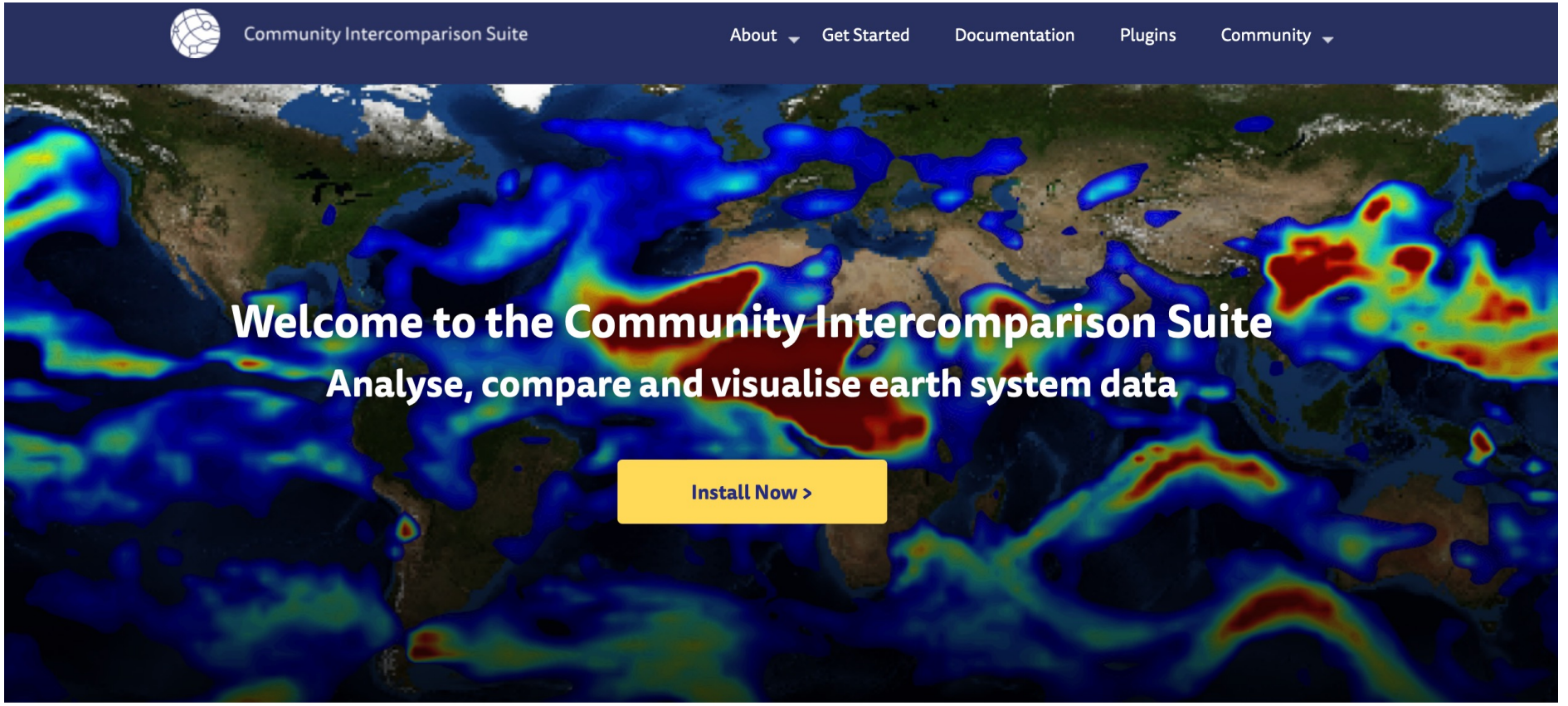
Temporal sampling & model evaluation



Based on MODIS Aqua DarkTarget retrievals

Schutgens et al. *ACP* 2016b

www.cistools.net

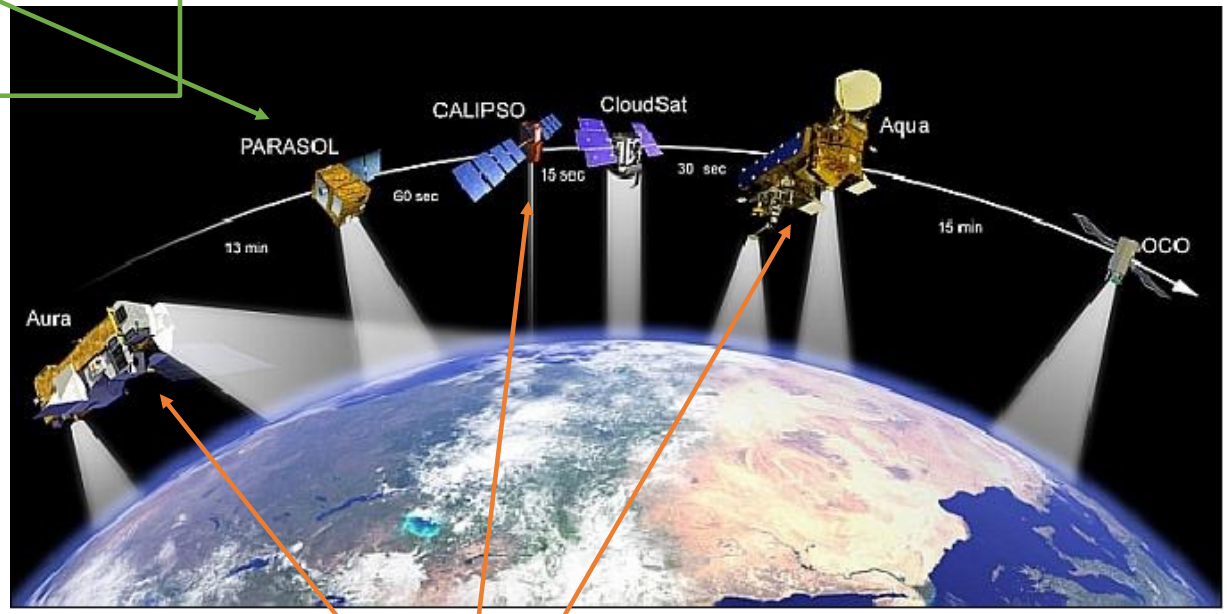


Watson-Parris et al. *GMD* 2016

Satellites

POLDER:
(POLarization and Directionality of the Earth's Reflectances)

GRASP & SRON:
Use multi-angle polarization measurements



OMI:
(Ozone Monitoring Instrument)
High spectral resolution spectrometer

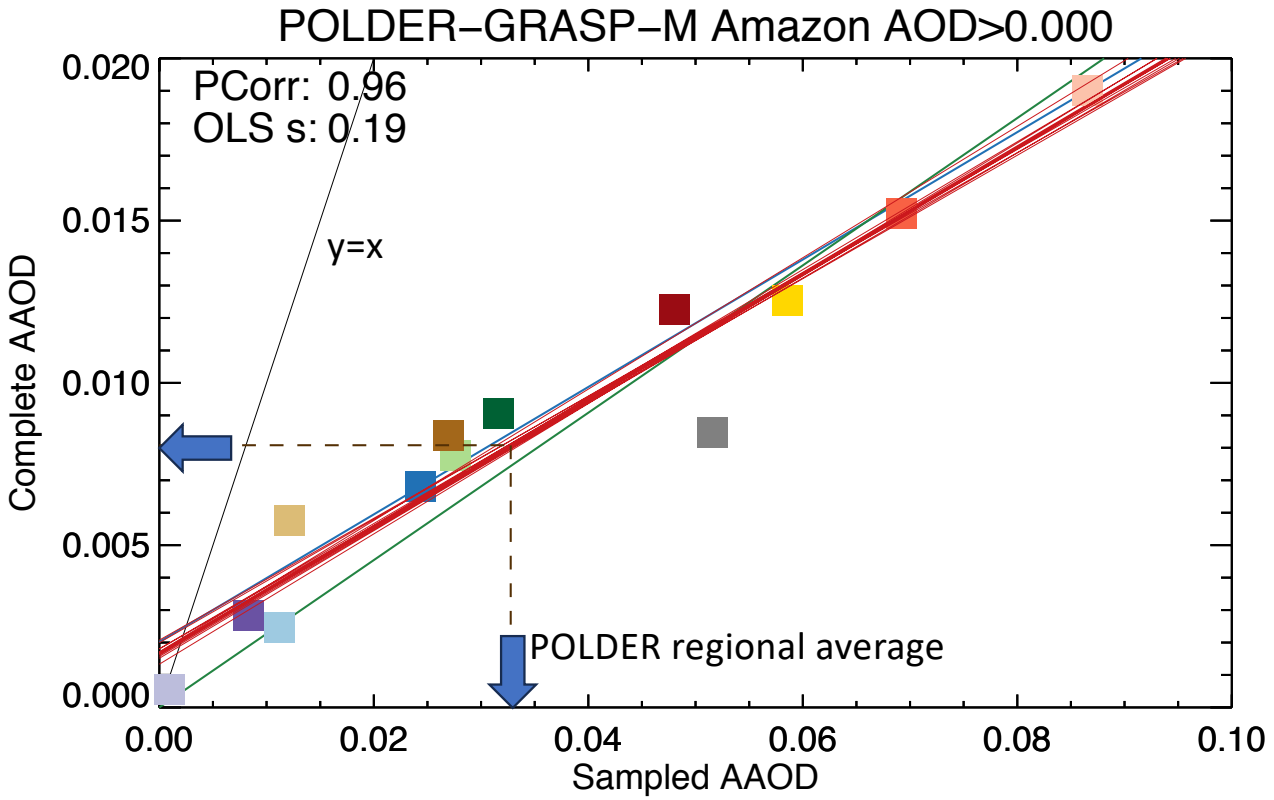
OMAERUV:
Uses UV wavelengths

MODIS-OMI-CALIOP:

FL-MOC:
Reinterprets existing measurements

Schutgens et al. *ACP* 2021
Schutgens et al. *ACP* 2020

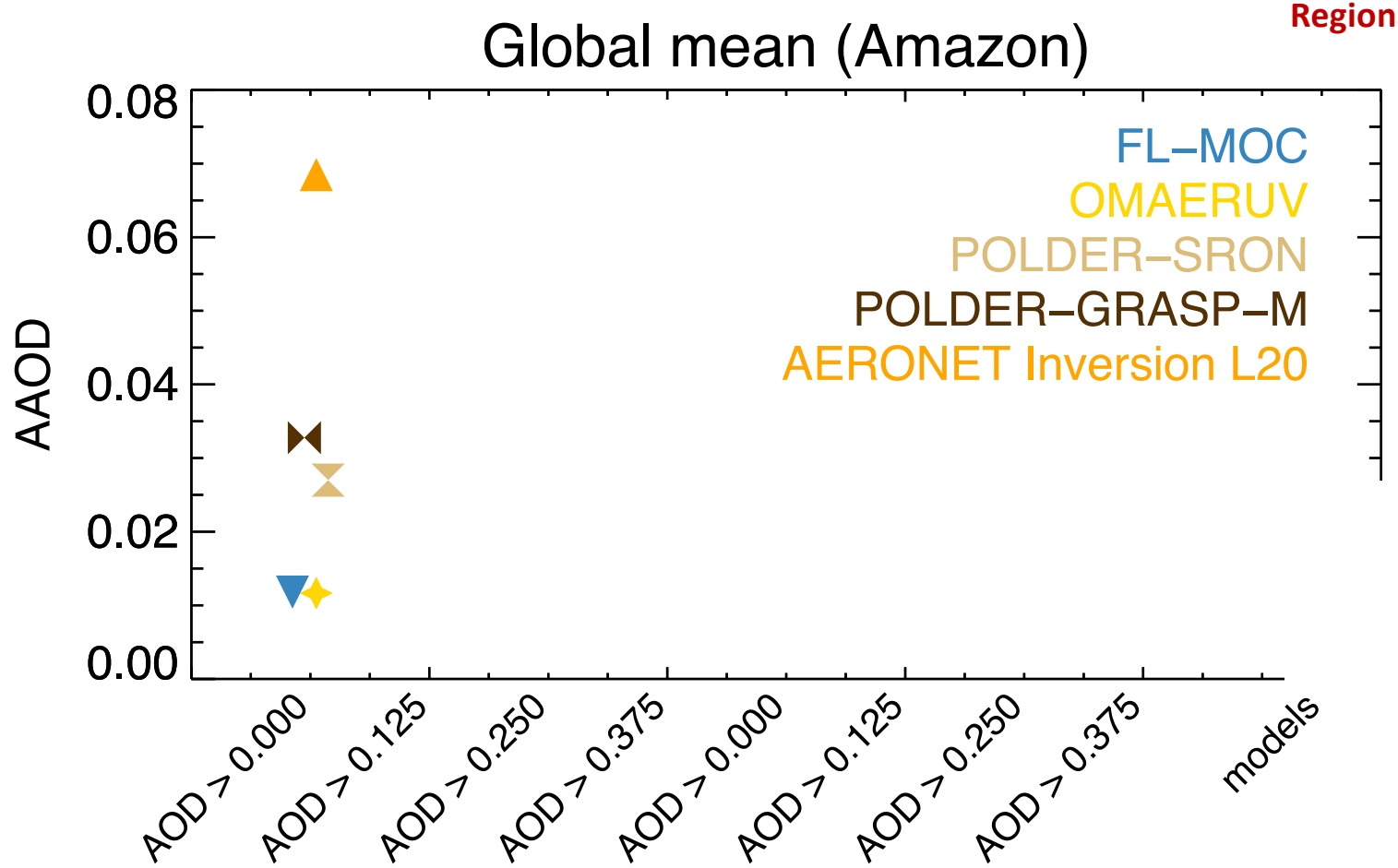
Homogenizing observations (using model data)



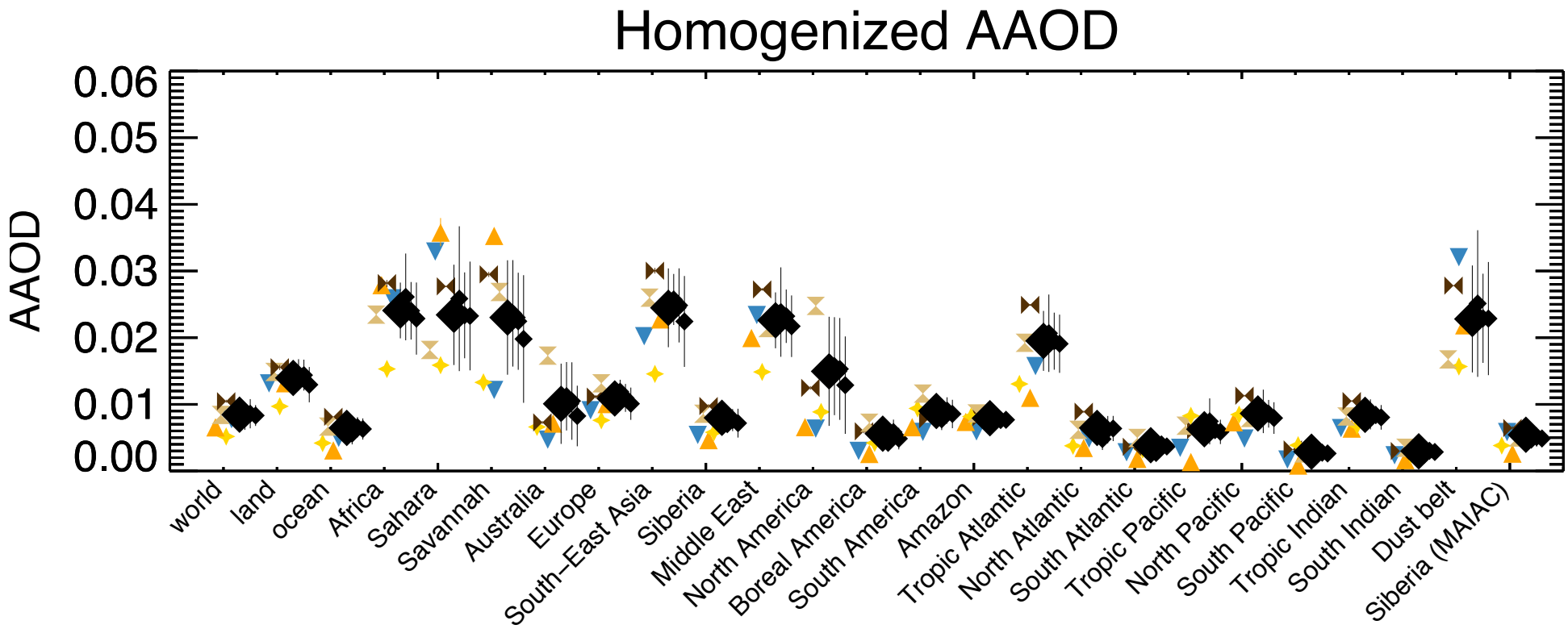
Based on 3 years of data over the Amazon

Using real AAOD observations

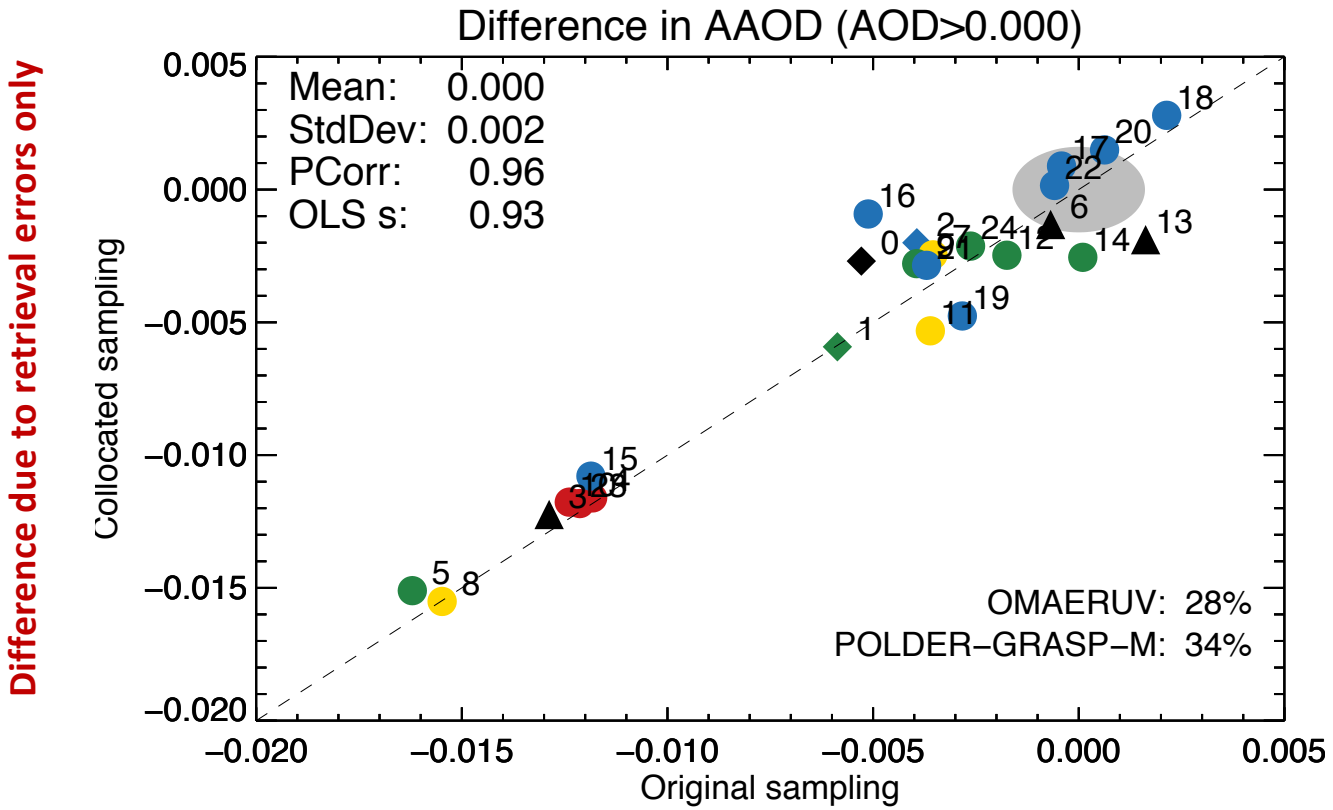
Regional, 3 year estimates



For different regions



Impact of retrieval biases



Difference due to retrieval errors only

Difference due to homogenization and retrieval errors

Global AOD & AAOD & SSA

Region	AOD
world	0.153 ± 0.008

AAOD	Region
0.0085 ± 0.0017	world

Region	SSA
world	0.944 ± 0.011

For use of homogenized observations to study model process errors, see Zhong et al. *Nature Comm*. 2022 (also Zhong et al. *in review)*

Summary

- Representation errors cannot be ignored
  - Comparable to measurement/retrieval errors
  - Comparable to model errors
- Temporal sampling can & should be mitigated through temporal collocation
  - How to interpret results, e.g. model resolution?
- Homogenization of observations seem possible
  - At least on large spatio-temporal scales