Combined A-Train aerosol observations to constrain direct aerosol radiative effects (DARE) in AeroCom models at different spatial and temporal averaging scales

J. Redemann[1], Y. Shinozuka[2], M. Kacenelenbogen[2], S. LeBlanc[2], M. Segal-Rozenhaimer[2], M. Vaughan[3], P. Stier[4], N. Schutgens[5]

NASA Ames – SRI – BAERI – NASA Langley – Univ of Oxford - VU University Amsterdam

https://earthscience.arc.nasa.gov/sunsat

email: Jens.Redemann-1@nasa.gov

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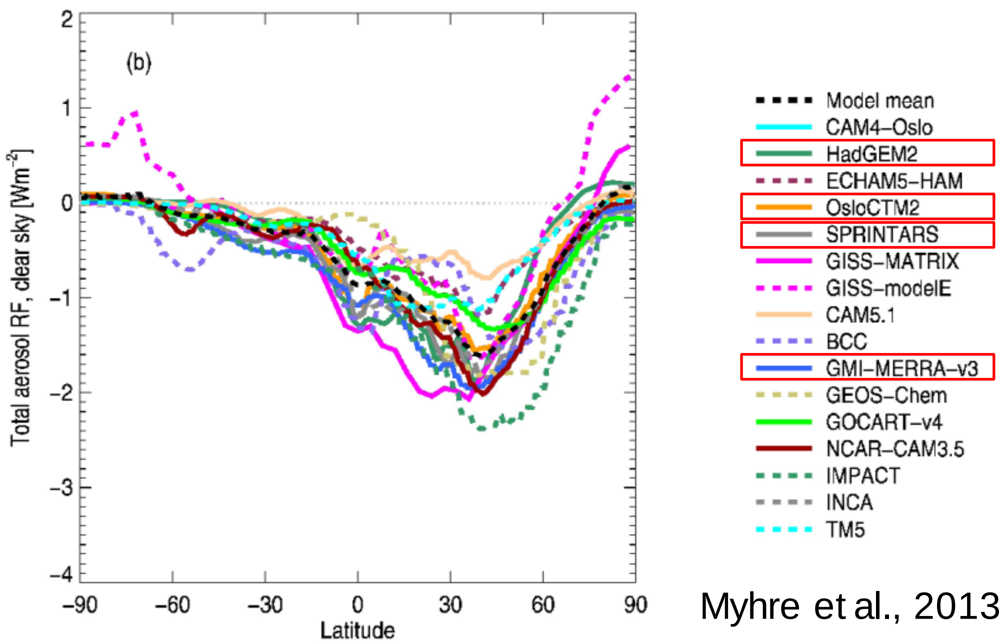
Motivation:

1) Quantifying anthropogenic aerosol radiative forcing (historical or future) of climate requires climate models.
2) Models show large spread in (even) clear-sky direct aerosol radiative forcing of climate.
3) Need to test the models with observations of the most closely related quantity = present-day total (anthropogenic plus natural) Direct Aerosol Radiative Effect (DARE)

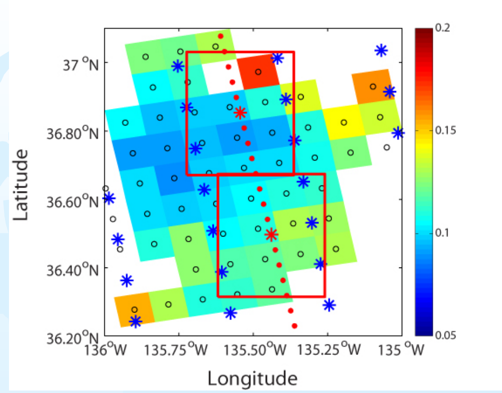
Anthropogenic clear-sky aerosol forcing, AeroCom Phase II



Myhre et al., 2013

* Subset of AeroCom Phase 2 models with SW fluxes and no-aerosol runs stored

Approach: use A-Train aerosol obs to constrain aerosol radiative properties and to calculate observationally-based DARE and its uncertainty



Constraints/Input:

- MODIS AOD (550, 1240 nm) ± (0.03+5%)
- OMI AAOD (388 nm) ± (0.05+30%)
- CALIPSO ext (532, 1064 nm) + δext
- CALIPSO back (532 nm) ±(0.1 $Mm^{-1}sr^{-1}$+30%)

Aerosol models:
7 fine and 3 coarse mode models and refractive indices for bi-modal log-normal size distribution → 100 combinations
Free parameters: N_{fine}, N_{coarse}

Comparison:
AERONET AOD, SSA, g
Airborne test bed data

Retrieval:
ext (λ, z) + δext
SSA (λ, z) + δSSA
g (λ, z) + δg

Rtx code

Target:
$\Delta F_{aerosol}(z) + \delta\, \Delta F_{aerosol}(z)$

Comparison:
CERES F_{clear}
Airborne F_{clear}

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- Results
  - AOD & SSA distributions
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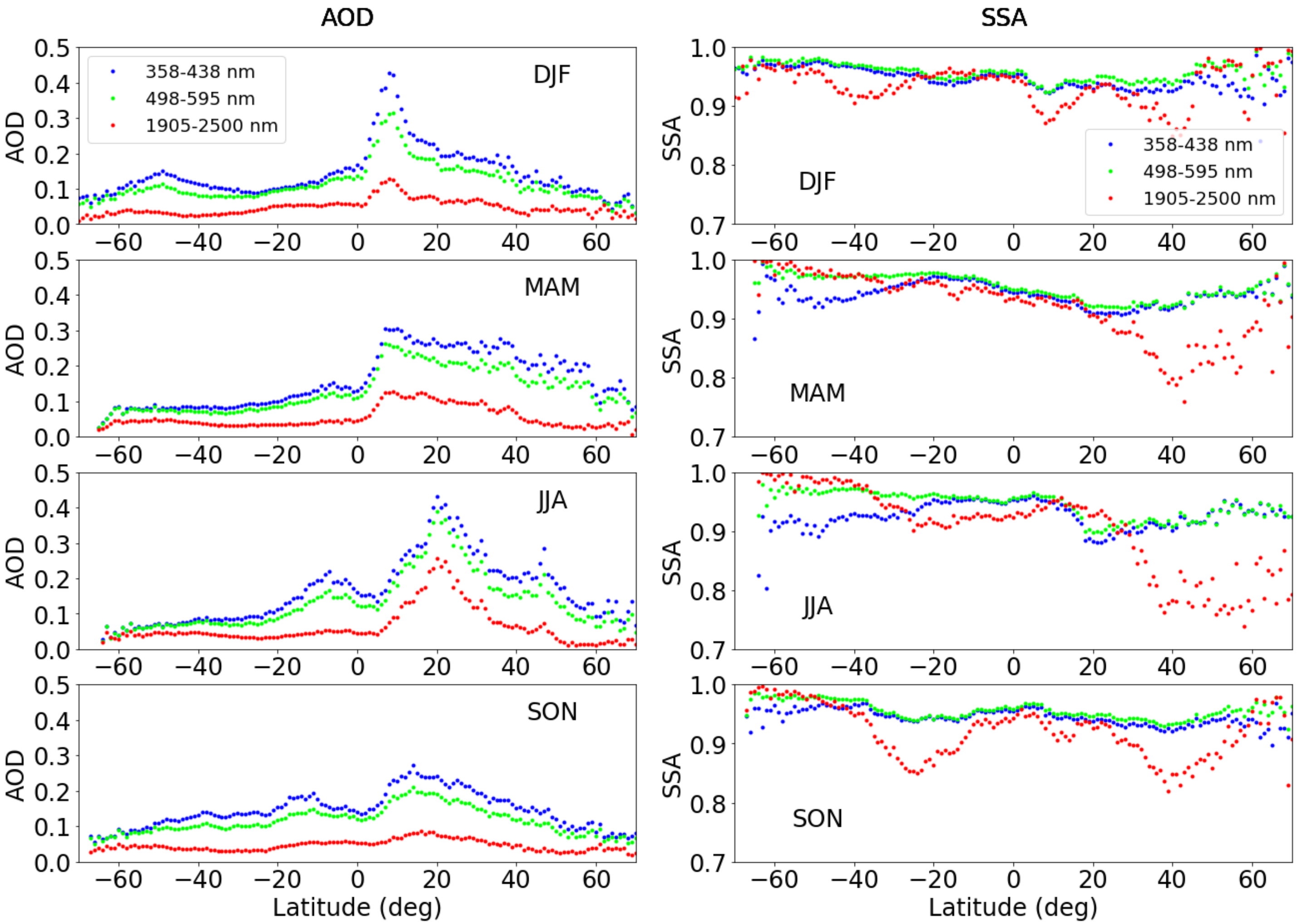
Retrieval choices

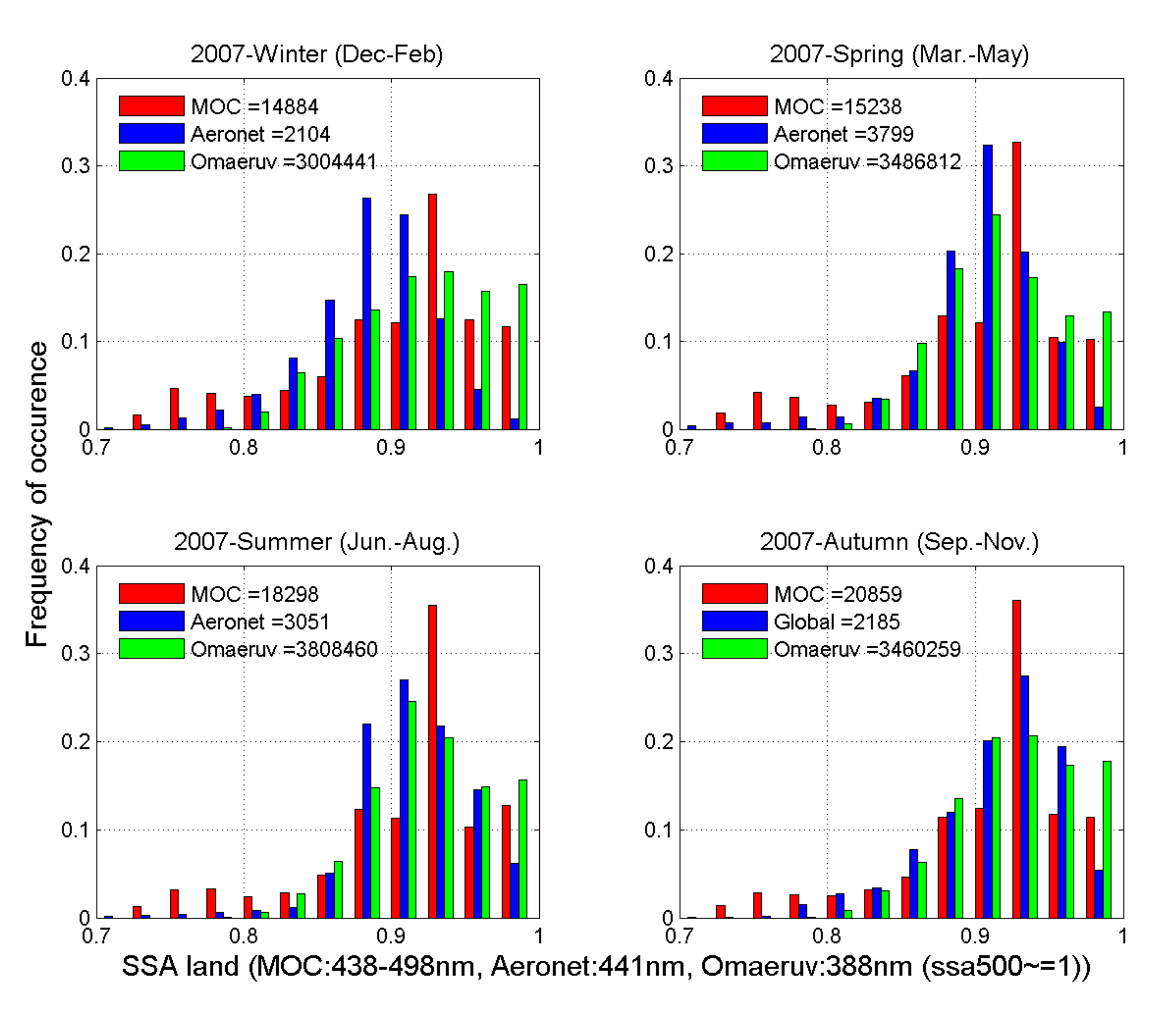
1) Use instantaneously collocated L2 data from MODIS, OMI, CALIOP (MOC)
2) Check whether collocated data from any given sensor is consistent with the pdf of the sensor's global data set
3) Observe satellite data quality flags
4) Use aerosol models that are consistent with in situ data sets from various field campaigns
5) Different choices for different locales:

Locale → Data ↓	Land - Dark target	Land - Enhanced Deep blue	Ocean
MODIS AOD 550nm 1240nm	Corr._O._D._Land (QA_Land=3) 550 nm provided 1240 nm extrapolated from 470, 550, 660 nm	D._B._Spec._A._O._D. _Land (QA_Flag=3) 550 nm provided 1240 nm extrapolated from 412, 470, 660nm	Eff._O._D._Avg_Ocean (QA_Ocean=1,2,3) 550 nm provided 1240 nm provided
OMI *AAOD* 388 nm	OMAERUV A.S.S.A.VsHeight (QA=0) SSA 388 nm provided + MODIS AOD 388 nm extrapolated from 470, 550, 660 nm	OMAERUV A.S.S.A.VsHeight (QA=0) SSA 388 nm provided + MODIS AOD 388 nm extrapolated from 412, 470, 660nm	OMAERO S.S.A.MW (QA=0) SSA 388nm provided + MODIS AOD 388nm extrapolated from seven bands 470- 2120
CALIOP A. backscat 532 nm	CALIOP integrated backscatter screening according to Redemann et al. 2012 (CALIOP zmax-zmin)		

AOD and SSA distribution from A-Train MOC



Comparisons of SSA – MOC vs AERONET vs OMAERUV



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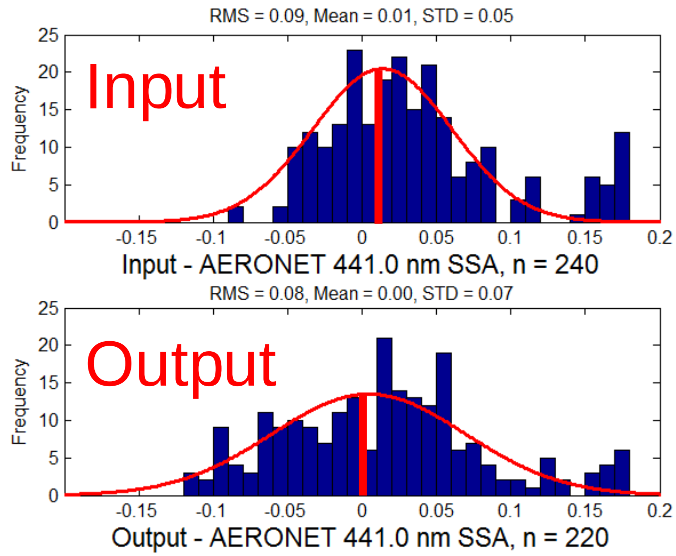
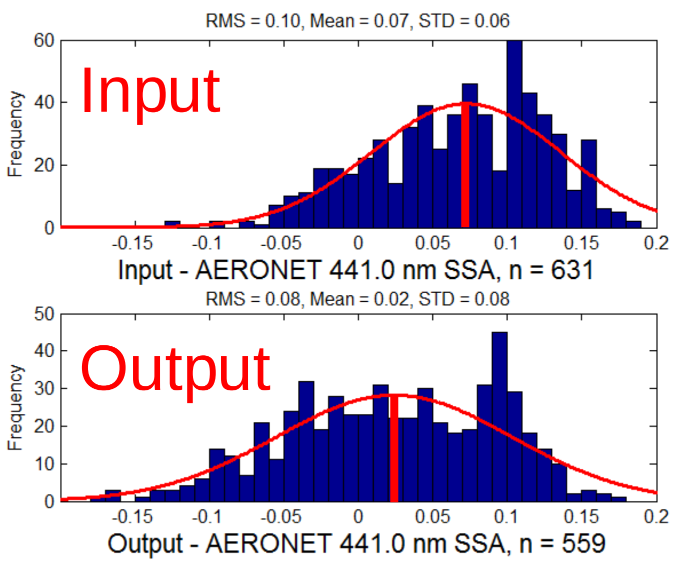
SSA comparisons to AERONET – Ocean & Land

Positive bias in input SSA data is removed in MOC retrieval

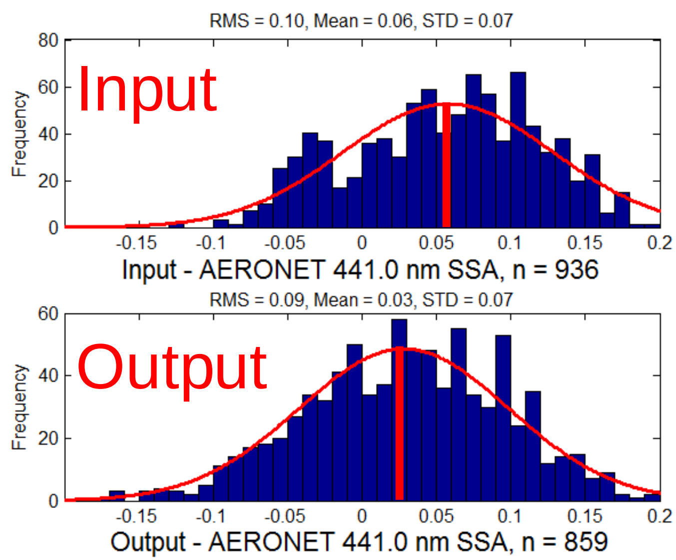
MODIS ocean + OMAERO

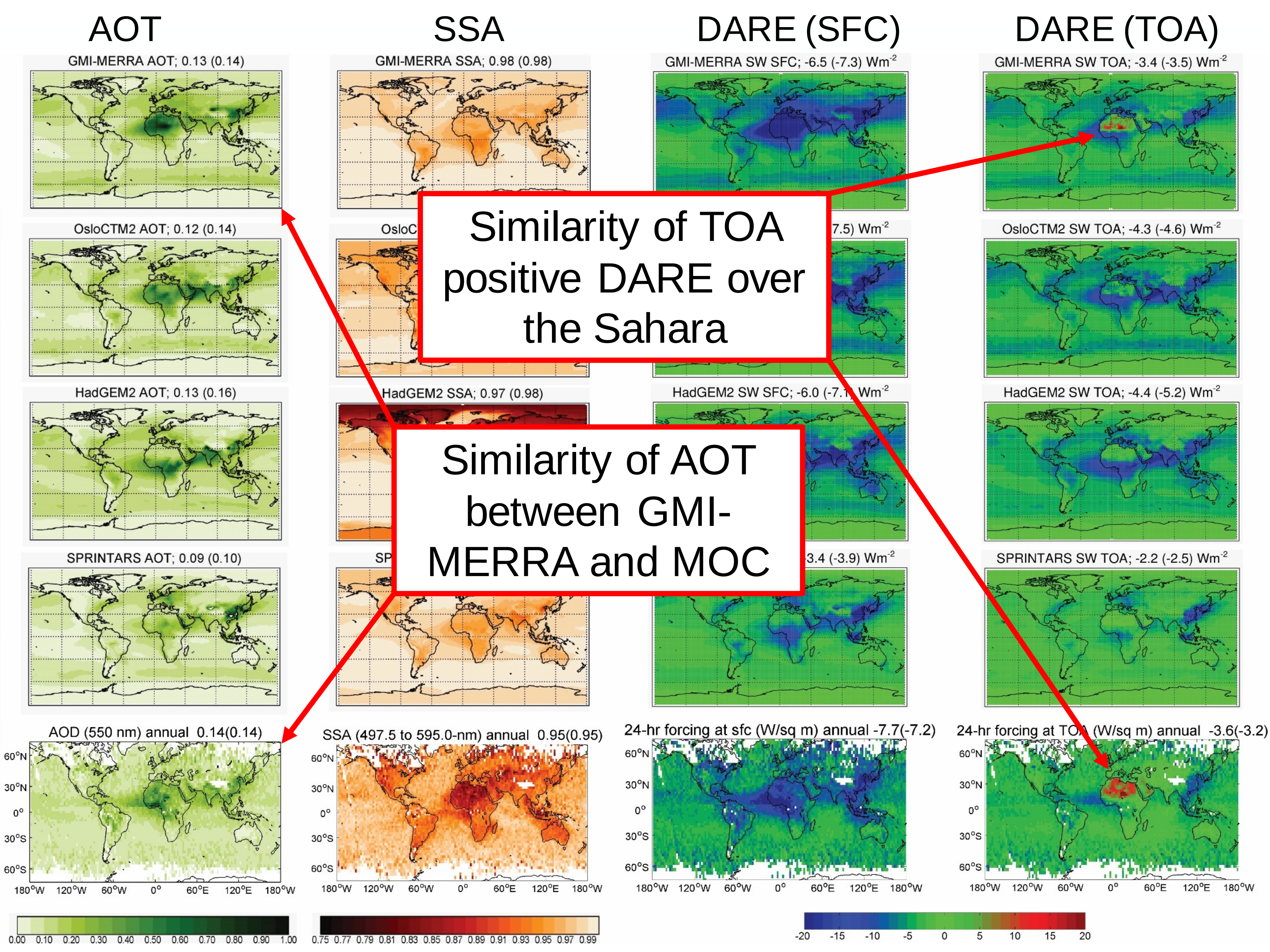


MODIS land DT + OMAERUV



MODIS land DB + OMAERUV



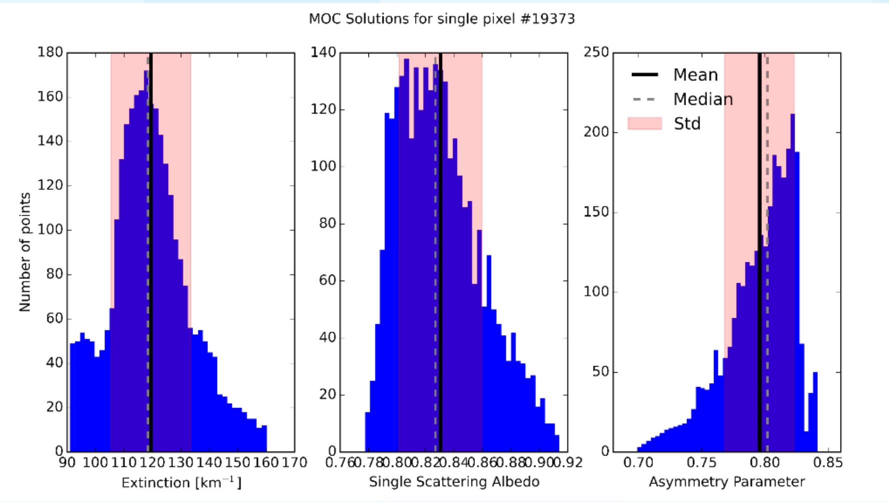


AOT
SSA
DARE (SFC)
DARE (TOA)
GMI-MERRA AOT; 0.13 (0.14)
GMI-MERRA SSA; 0.98 (0.98)
GMI-MERRA SW SFC; -6.5 (-7.3) Wm-2
GMI-MERRA SW TOA; -3.4 (-3.5) Wm-2
OsloCTM2 AOT; 0.12 (0.14)
OsloCTM2 SW TOA; -4.3 (-4.6) Wm-2
HadGEM2 AOT; 0.13 (0.16)
HadGEM2 SSA; 0.97 (0.98)
HadGEM2 SW TOA; -4.4 (-5.2) Wm-2
SPRINTARS AOT; 0.09 (0.10)
SPRINTARS SW TOA; -2.2 (-2.5) Wm-2
Similarity of TOA positive DARE over the Sahara
Similarity of AOT between GMI-MERRA and MOC
AOD (550 nm) annual 0.14(0.14)
SSA (497.5 to 595.0-nm) annual 0.95(0.95)
24-hr forcing at sfc (W/sq m) annual -7.7(-7.2)
24-hr forcing at TOA (W/sq m) annual -3.6(-3.2)

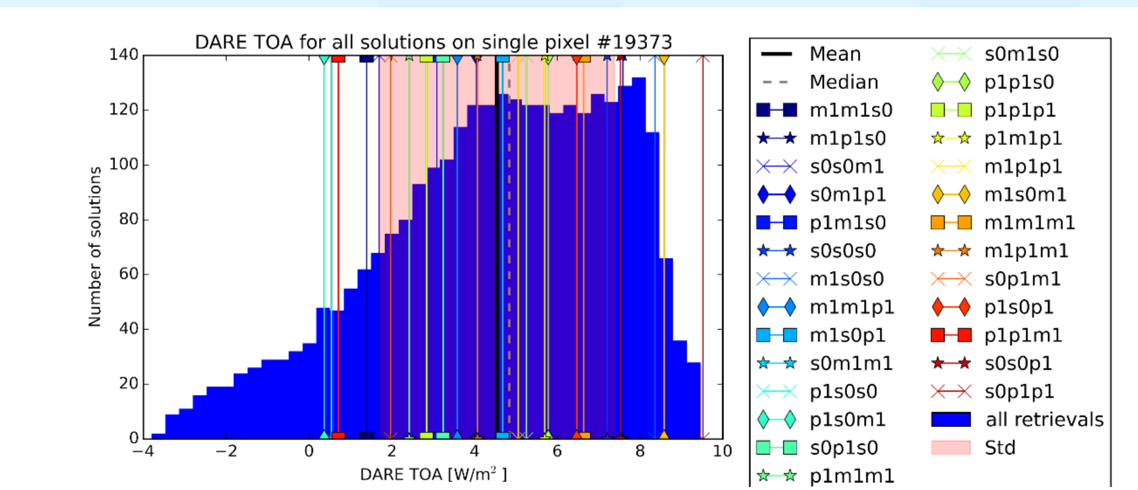
Approach: use A-Train aerosol obs to constrain aerosol radiative properties and to calculate observationally-based DARE and its uncertainty

Two main sources of uncertainty in calculating DARE from observations/retrievals:

1) $\langle DARE \rangle \neq DARE(\langle \tau_{AAC}, \omega_{AAC}, g_{AAC} \rangle, \langle A_{surface} \rangle)$



Global assessment of this uncertainty for MOC aerosol retrievals is still ongoing!



etrievals:

) + δext

) + δSSA

) + δg

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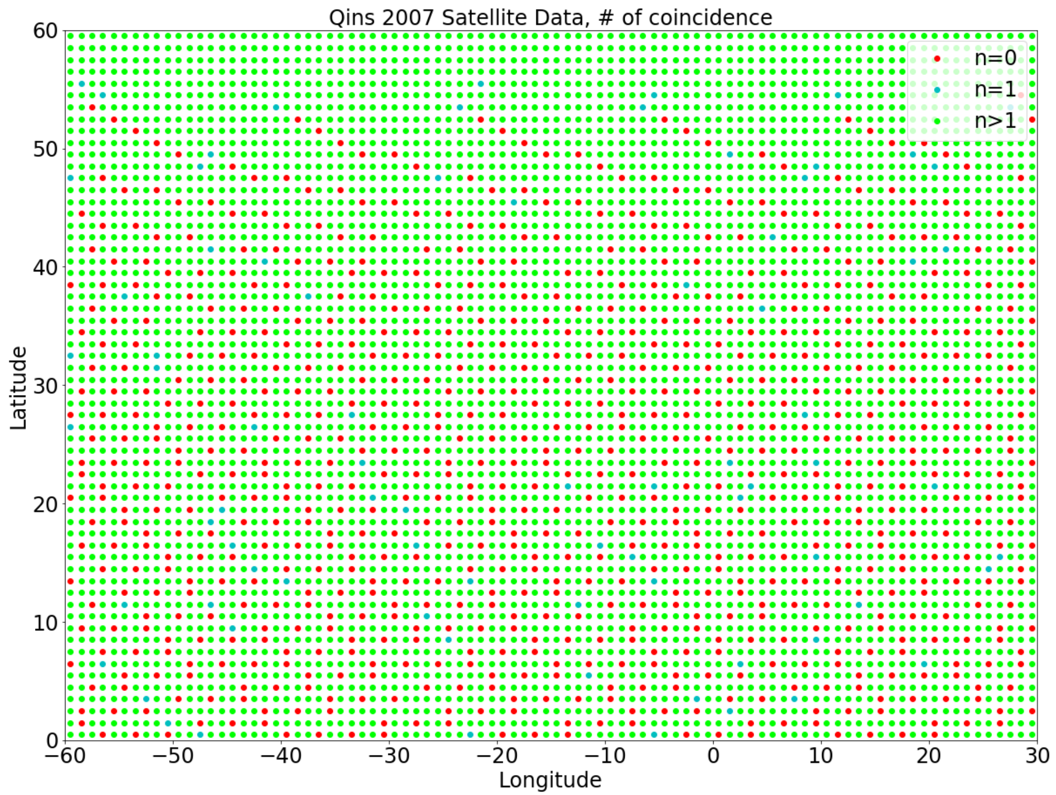
Two main sources of uncertainty in calculating DARE from observations/retrievals:

2) Is observational sampling (x,t) sufficient to calculate DARE?



MOC2007updated2014Oct_2007locations.png, YS, 2017-06-26 15:50:02

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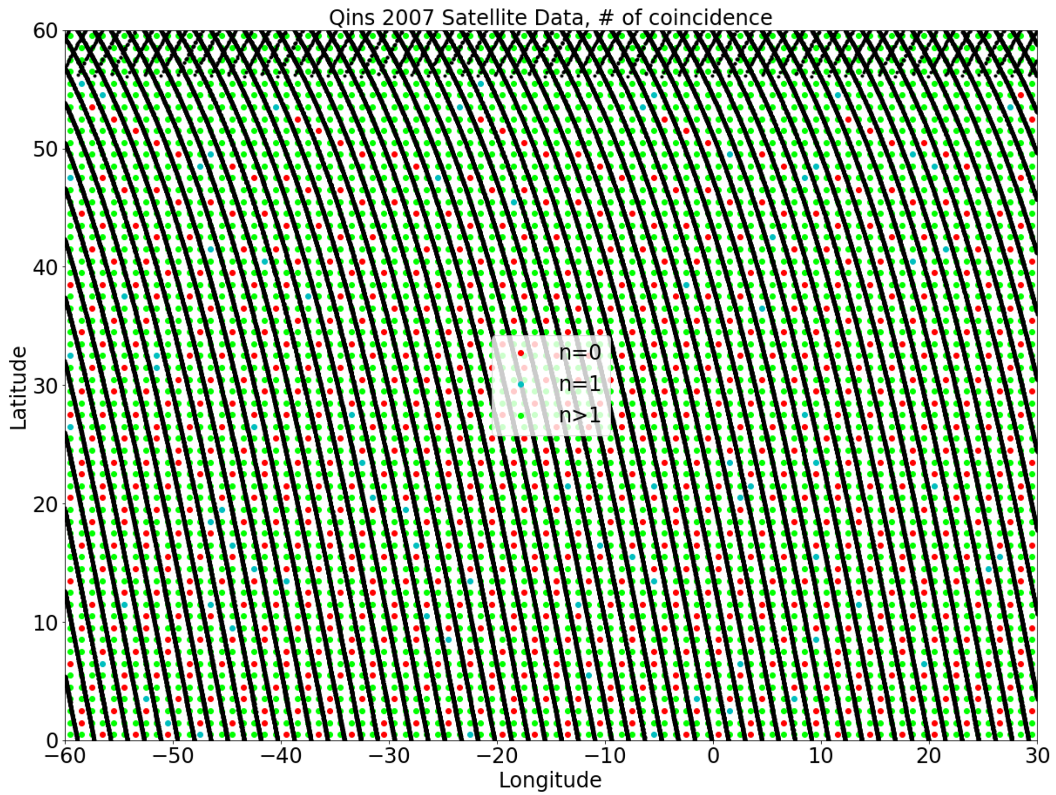

See also: Colarco et al., AMT, 2014; , Schutgens et al., ACP, 2016

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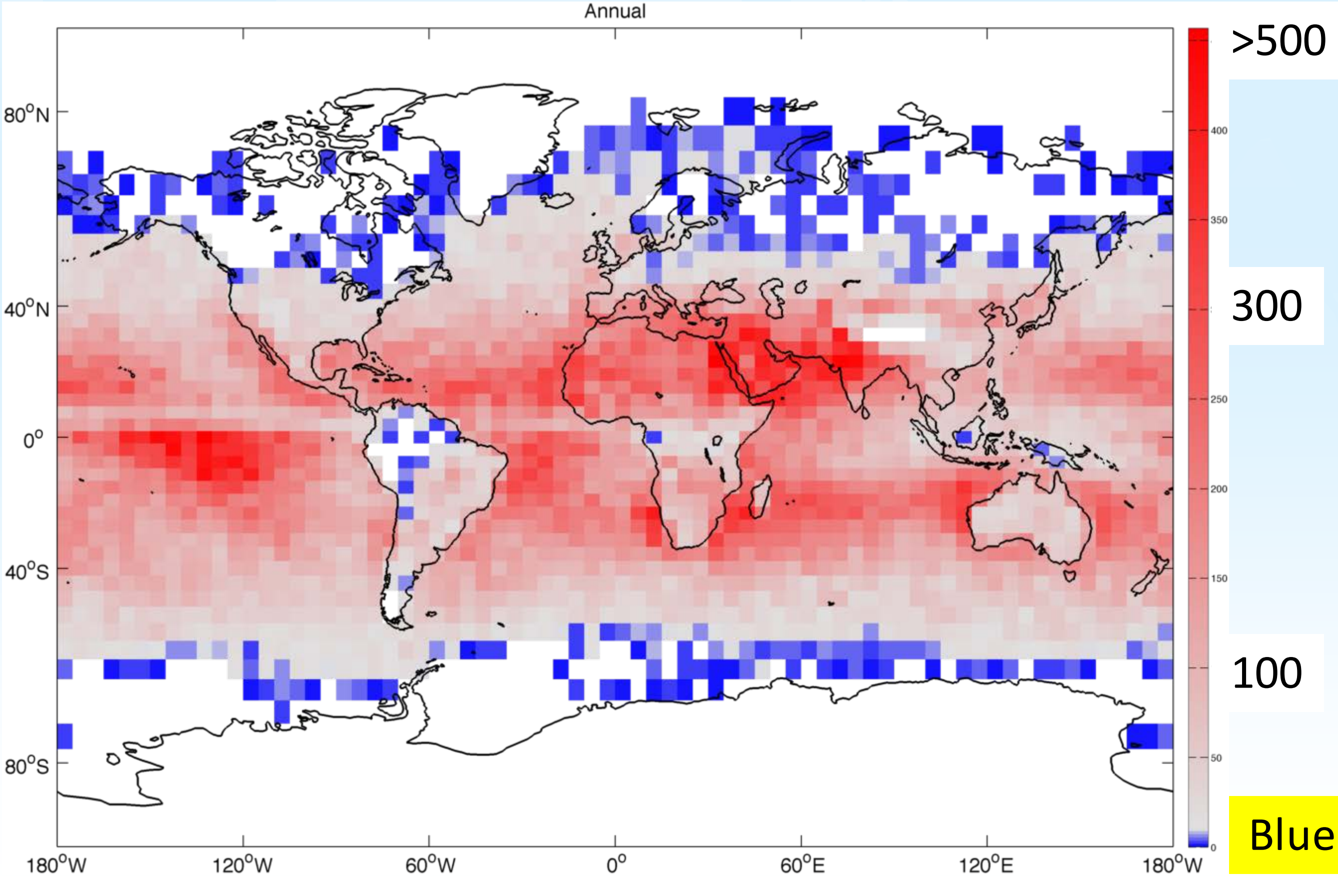

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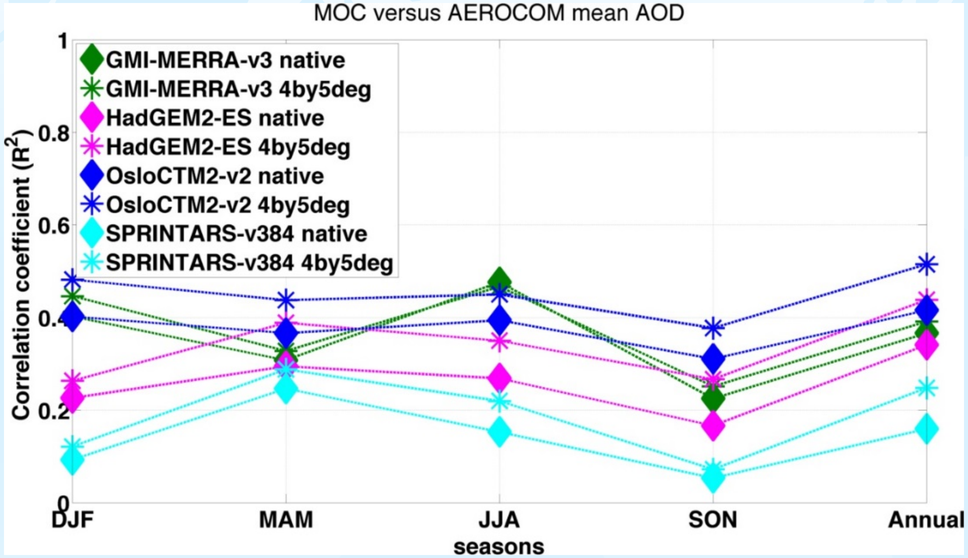
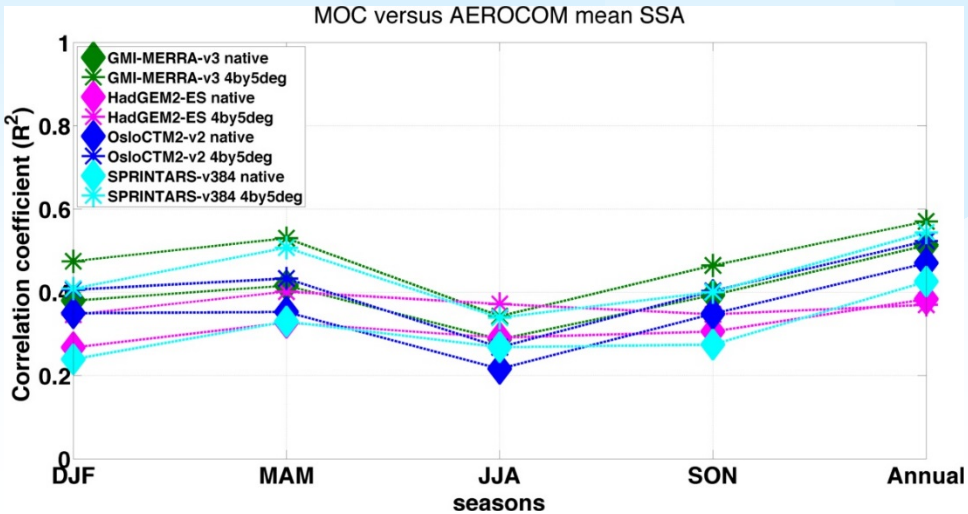


AOD:
Some improvement in model-obs comparison in going from native to 4x5 deg resolution!



SSA:
Significant improvement in model-obs comparison in going from native to 4x5 deg resolution!

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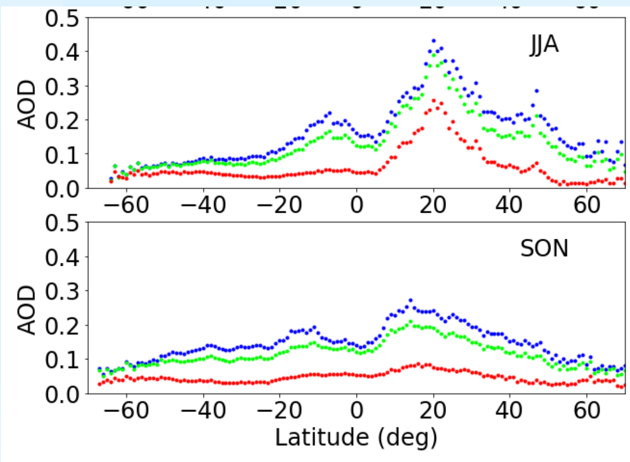


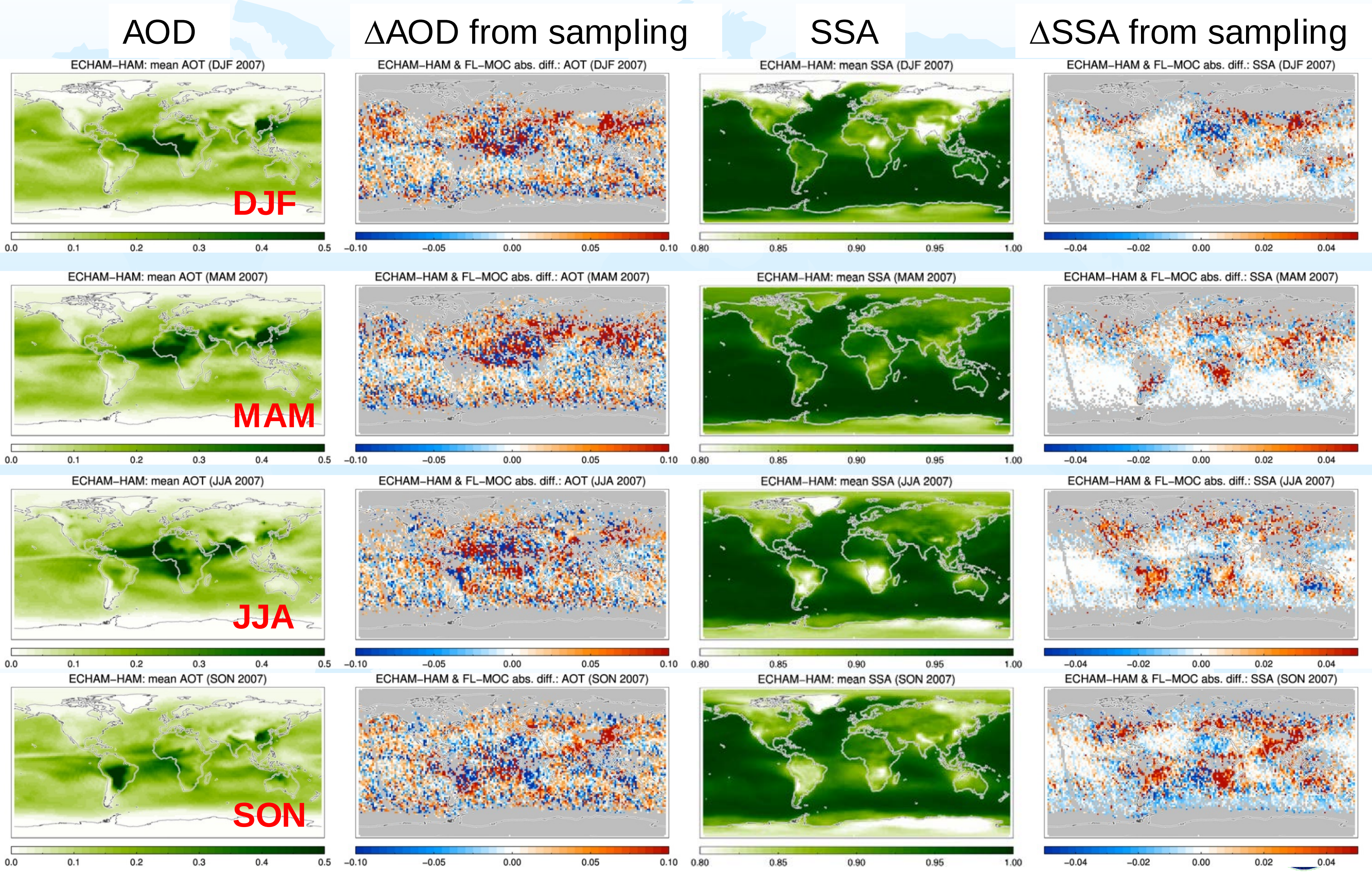
Idea: Use models to assess uncertainty in aerosol properties from sampling, i.e., **compare models at full resolution to models at MOC sampling**!
See also Schutgens et al., 2016 ACP

Rtx code

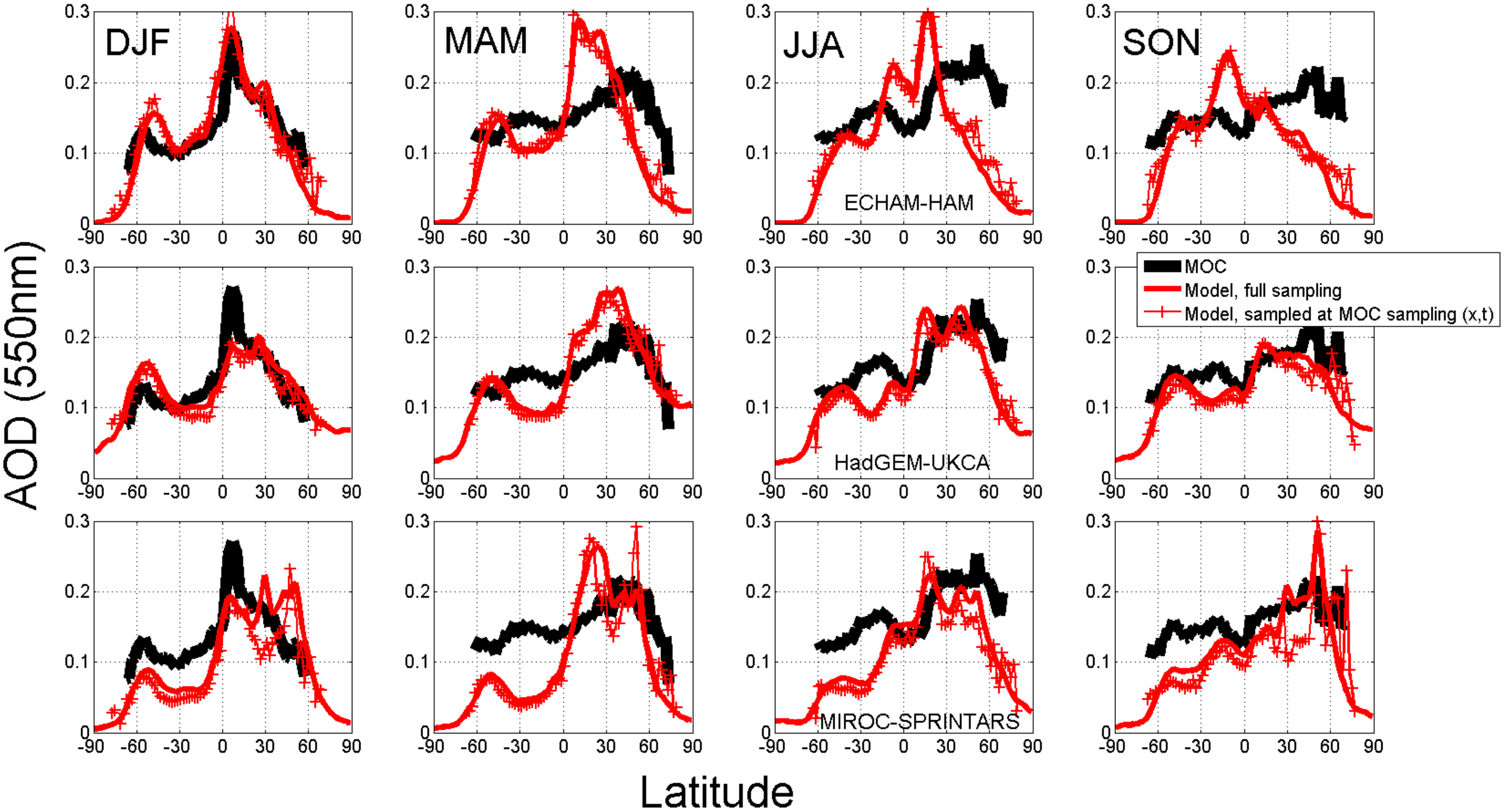
Aerosol Retrievals:
ext (λ, z) + δext
SSA (λ, z) + δSSA
g (λ, z) + δg

Target:
$\Delta F_{aerosol}(z) + \delta\, \Delta F_{aerosol}(z)$

Sampling biases in MOC aerosol properties assessed using ECHAM-HAM model – AOD & SSA



Sampling biases in MOC aerosol properties assessed using models - AOD



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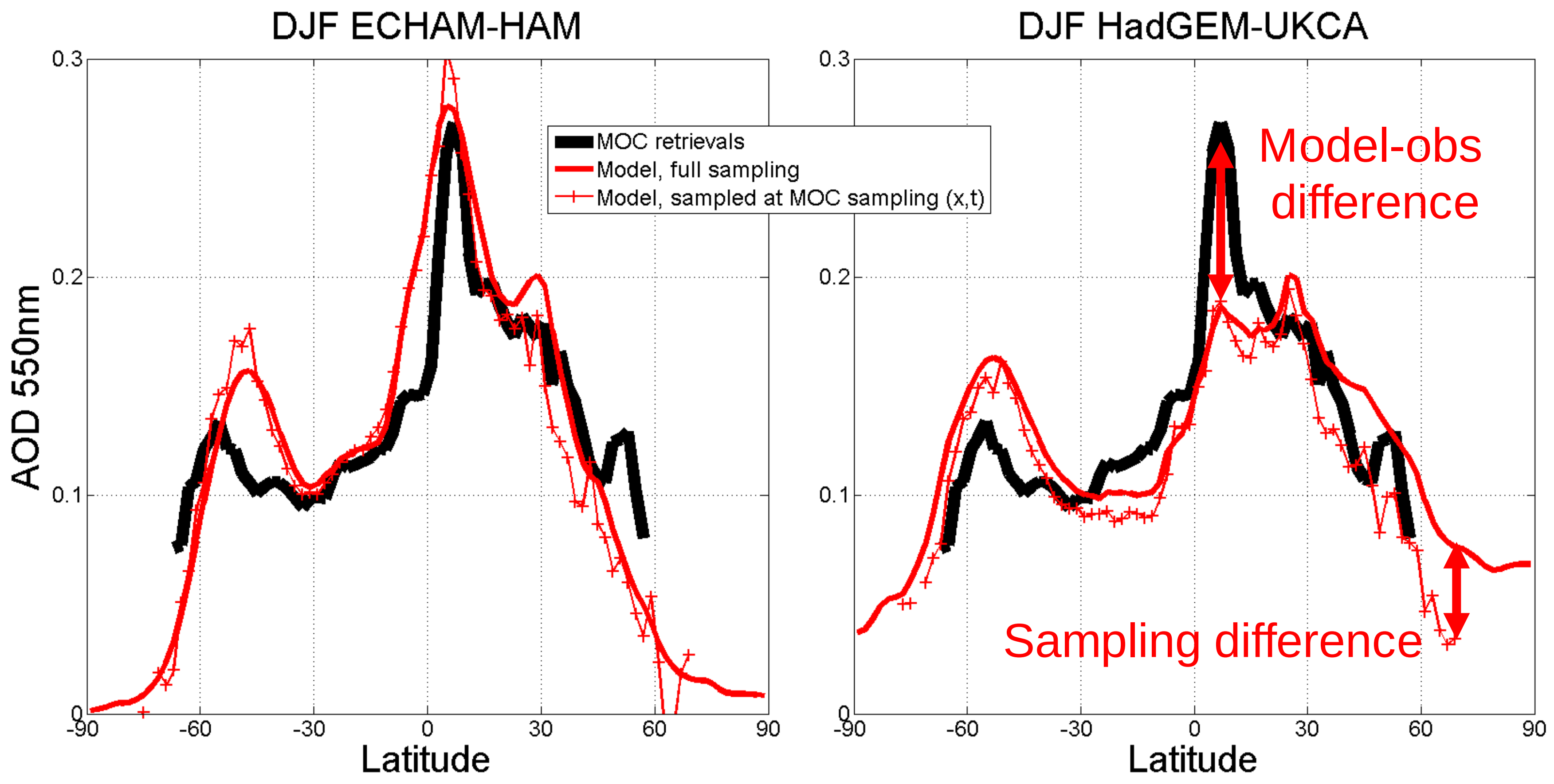
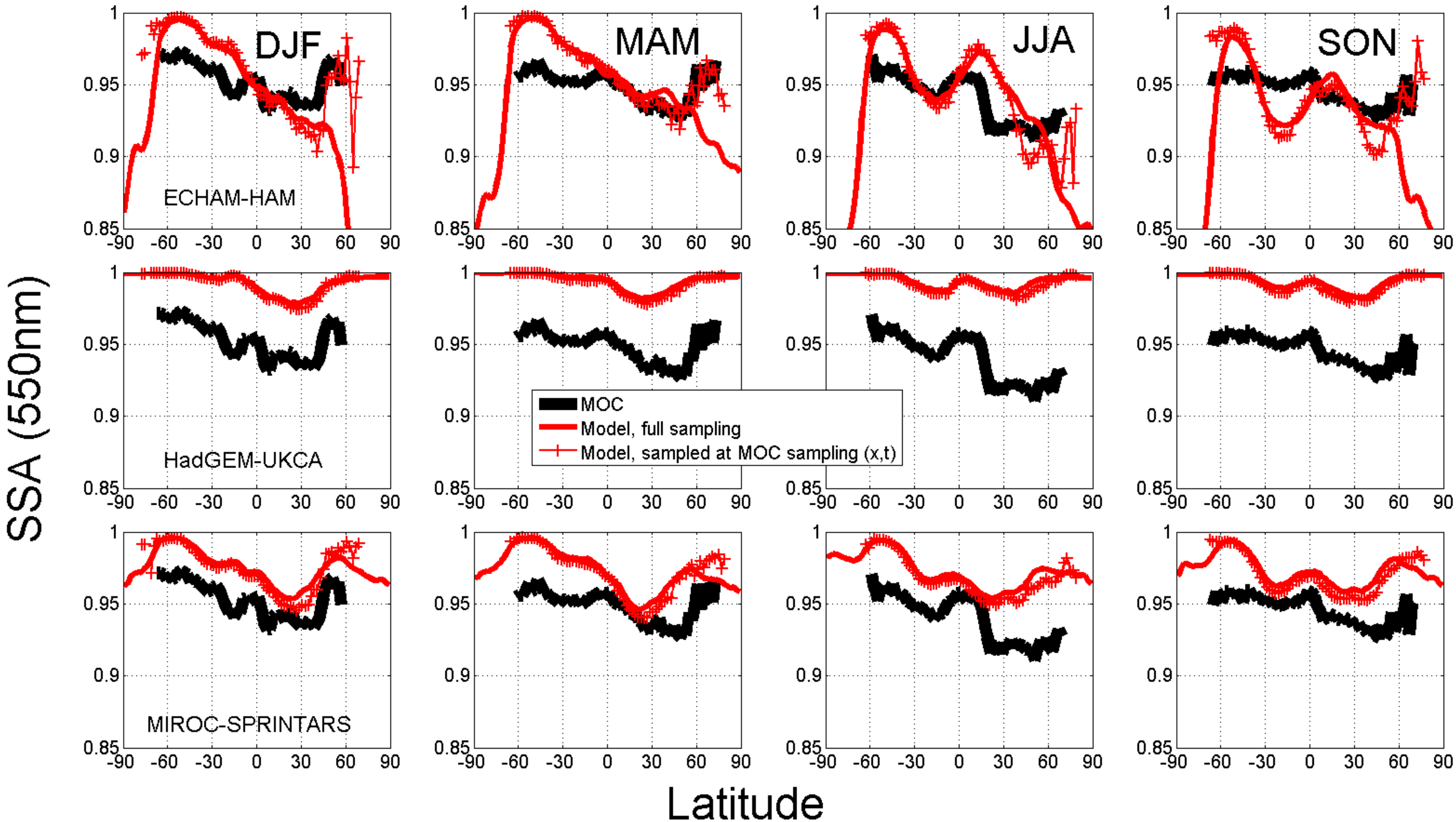
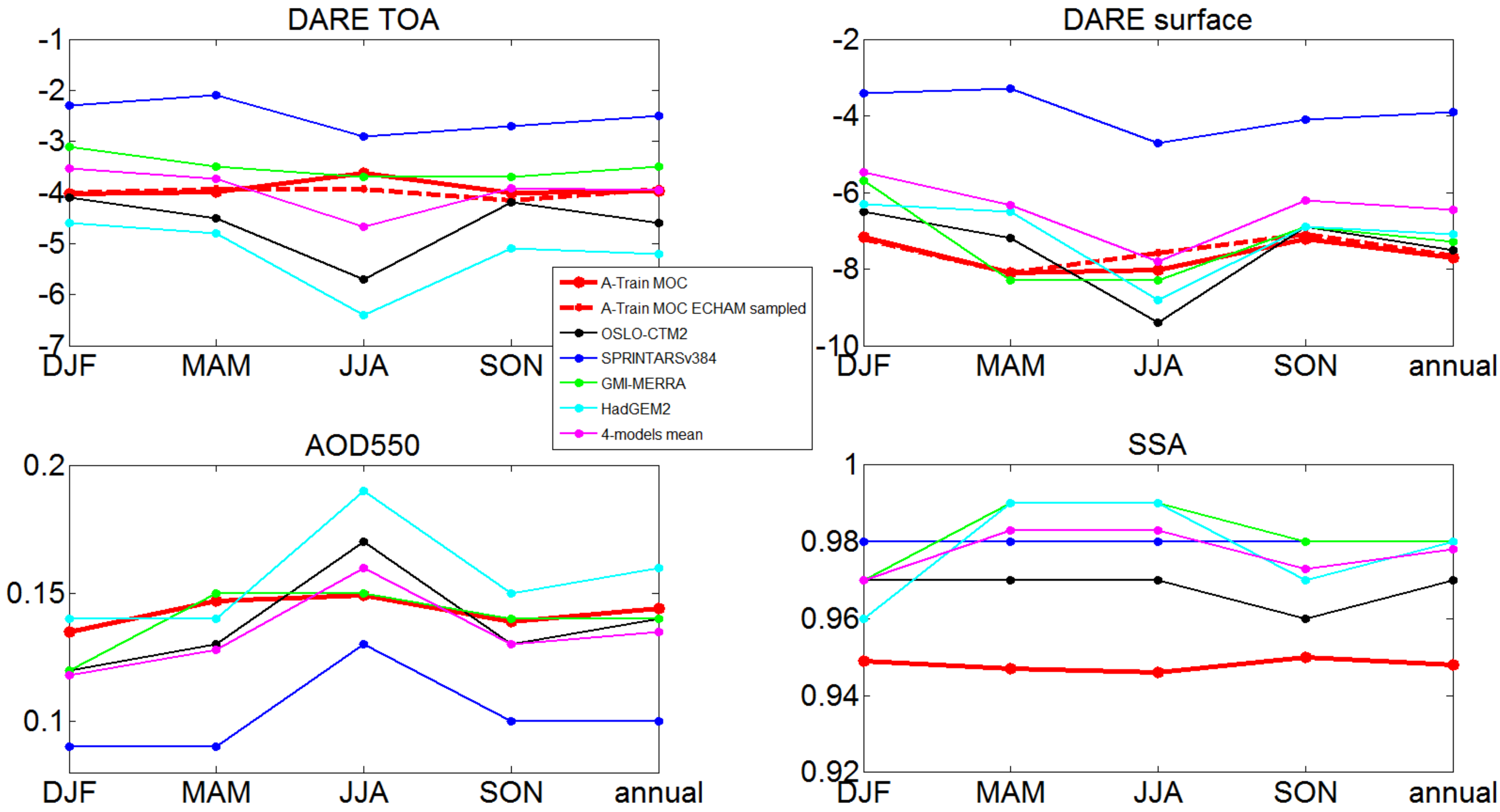


Sampling biases in MOC aerosol properties assessed using models - SSA



Comparison of A-Train MOC to 4 climate models:

Seasonal AOD, SSA, DARE-TOA, DARE-surface



Conclusions

1. Combined A-Train (MODIS, OMI and CALIOP L2 - MOC) retrievals yield aerosol properties that agree better with AERONET in terms of SSA(441nm) than input OMI+MODIS data.
2. Assessments of clear-sky Direct Aerosol Radiative Effects (DARE) from observations have uncertainties
   A. from translating the mean and range of aerosol properties into a mean and range of DARE, and
   B. from spatial/temporal sampling.
3. Using three climate models we find **the impact of temporal sampling** for seasonal
   A. zonal mean AOD was less than 0.05 at all latitudes, and
   B. zonal mean SSA was generally less than 0.03 at all latitudes except N of 50N in ECHAM-HAM, and
   C. DARE (clear-sky) is affected by ~10% in JJA season when MOC sampling is sparse in NH (>30°N).
4. Do models produce proper temporal variation in aerosol properties?
5. A-Train MOC derived clear-sky seasonal DARE @TOA and @SFC agree best with GMI-MERRA. Neither show the clear seasonal cycle in AOD, SSA and DARE, which was prevalent in most models to date.