Surface Atmosphere Radiation Budget (SARB) working group update

Seiji Kato[1], Fred G. Rose[2], David A. Rutan[2],

Alexander Radkevich[2], Seung Hee Ham[2], Tyler J. Thorsen[1]

Thomas E. Caldwell[2], Antonio Viudez-Mora[2], Ryan C. Scott[2],

David Fillmore[3], and Xianglei Huang[4]

[1]NASA Langley Research Center

[2]Science System & Applications Inc.

[3]NCAR

[4]University of Michigan

CERES Science Team Meeting
May 11-13, 2020

Work done after the fall 2020 meeting

- Edition 4.1 SYN was extended through February 2021
- Edition 4.1 EBAF was extended through November 2020 (December 2020 to February 2021 were produced but not released)
- MATCH aerosol latency was shortened from more than a month to 7 days from the end of the month
- Edition 4 MATCH aerosol AODs and clear-sky surface shortwave irradiances were evaluated with surface observations
  - SYN vs. CRS validation
  - Direct and diffuse irradiance validation
- CCCM algorithms were revised (D1 version) with Edition 4 CERES flux, Edition 4+ CERES-MODIS clouds, Version 4 CALIPSO and R05 CloudSat data (need to process)
- GEOS, MERRA2, AIRS, and CrIS temperature and humidity (in collaboration with GMAO and Xianglei Huang) were compared and analyzed
- Continued developing temperature and humidity bias correction using AIRS spectral data.
- Surface flux validation code upgrade (ongoing)
  - Combine current surface observation binary files into single NETCDF-4 for each site/month for ease of access and use.
  - 2. Update older FORTRAN code that creates current binary files from (ARM/NOAA/BSRN) and write directly into new NETCDF-4 files. (This is the bigger more complex job.)

Outline of this presentation

- EBAF Edition 4.1
  - Clear-sky sampling correction (cloud removed versus observed clear-sky sampling) to produce total area clear-sky irradiances.
- MATCH
  - AODs and clears-sky shortwave surface irradiance evaluation.
  - TOA albedo bias due to aerosol type errors
  - Edition 5 plan
- Aqua-NOAA20 transition
  - Comparison of AIRS and CrIS derived temperature and specific humidity (summary)
- CCCM revision (D1 version) summary

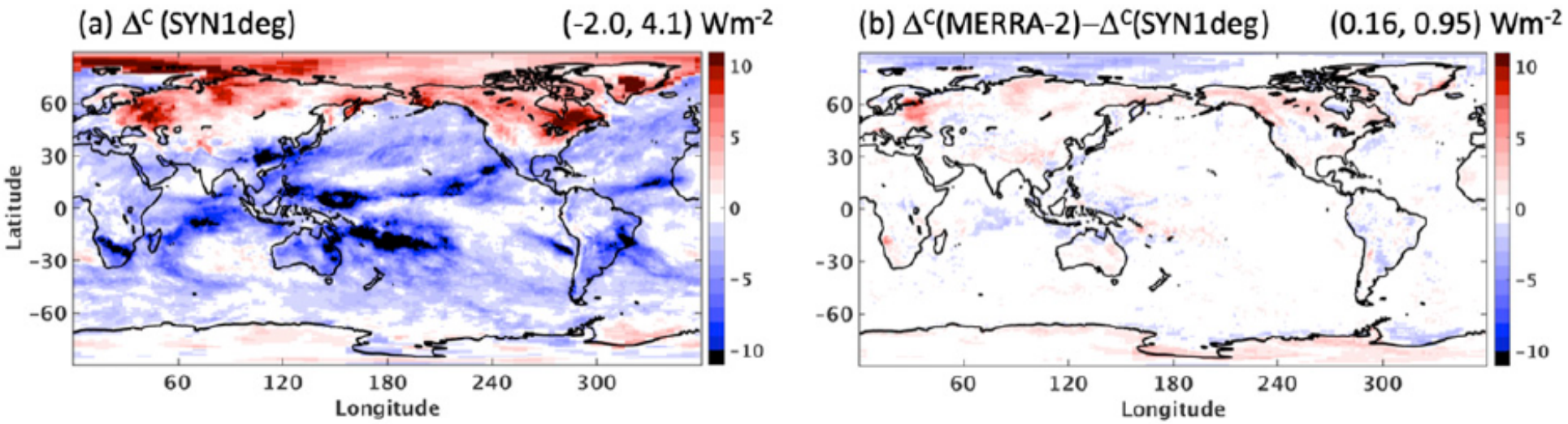
Edition 4.1 SYN and EBAF

- SYN1deg-Month through February 2021 is available
- EBAB (surface and total area clear-sky irradiances) through November 2020 is available.
  - NOAA-20 cloud data are used from August 16 through August 31.
  - S-NPP aerosols are used from August 16 through September 3rd
- Because of upper tropospheric humidity drift in GEOS-5.4.1 started in November 2019 (Ham's presentation) due to a loss of a microwave humidity sensor (MHS), an additional correction will be applied, starting from December 2020 data.
  - November 2019 to November 2020 data are affected by the moisture drift but not corrected.

Edition 4.1 SYN and EBAF (and surface and clear-sky sampling correction)

- Total area clear-sky TOA and surface are produced by adding the correction (Loeb et al. 2020),

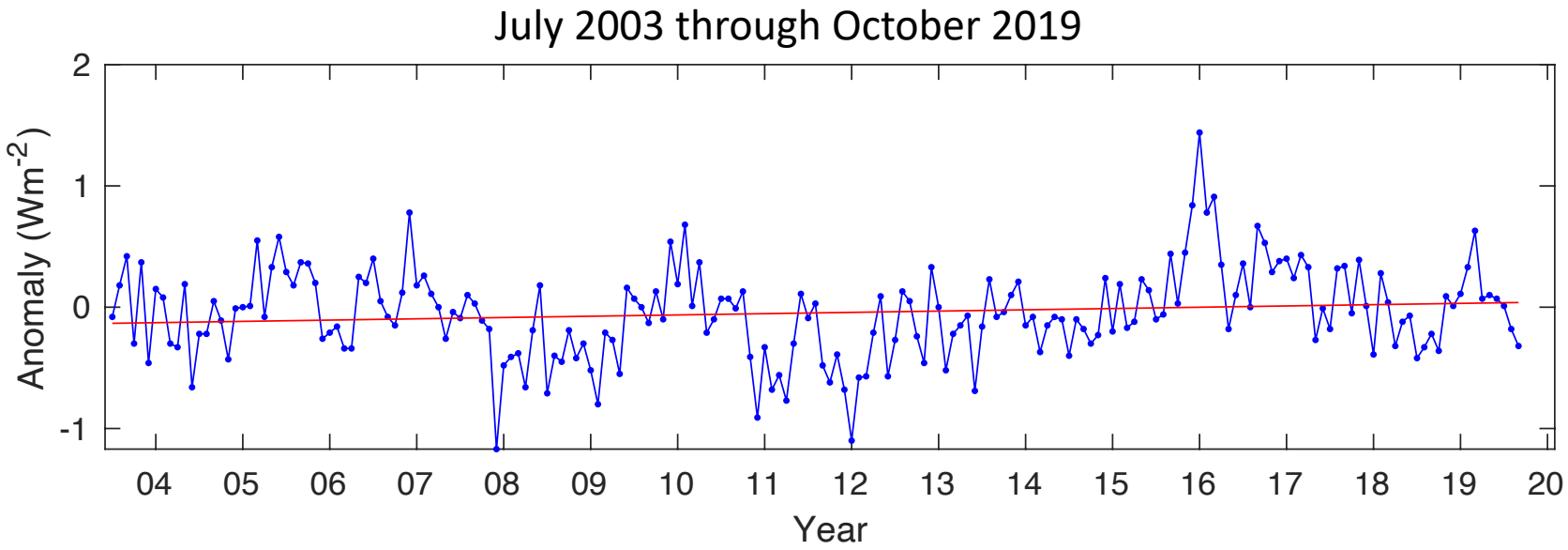
$$\Delta^c = F_{cs}^C(cloud\ removed) - F_{cs}^c(observed\ clear - sky\ weight)$$



Differences of Δ^c from those computed with ERA-Interim and ERA-5 are similar

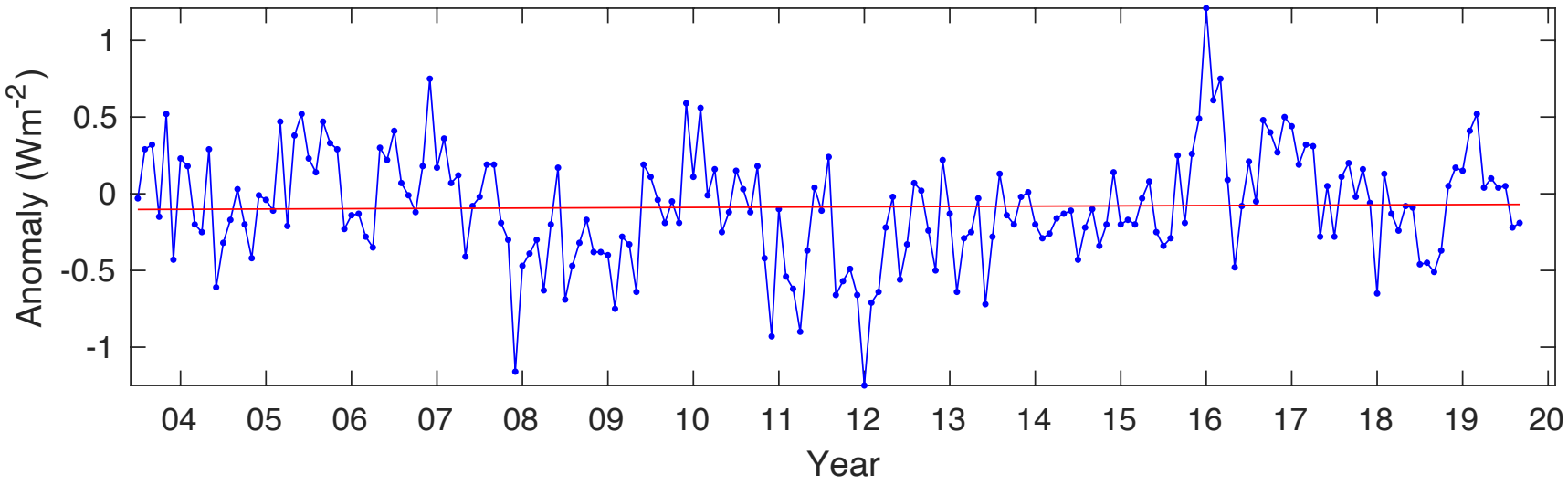
Global monthly Clear-sky OLR (observed and total area)

Cloud free
Observed OLR



0.11±0.2Wm^{-2} dec^{-1}

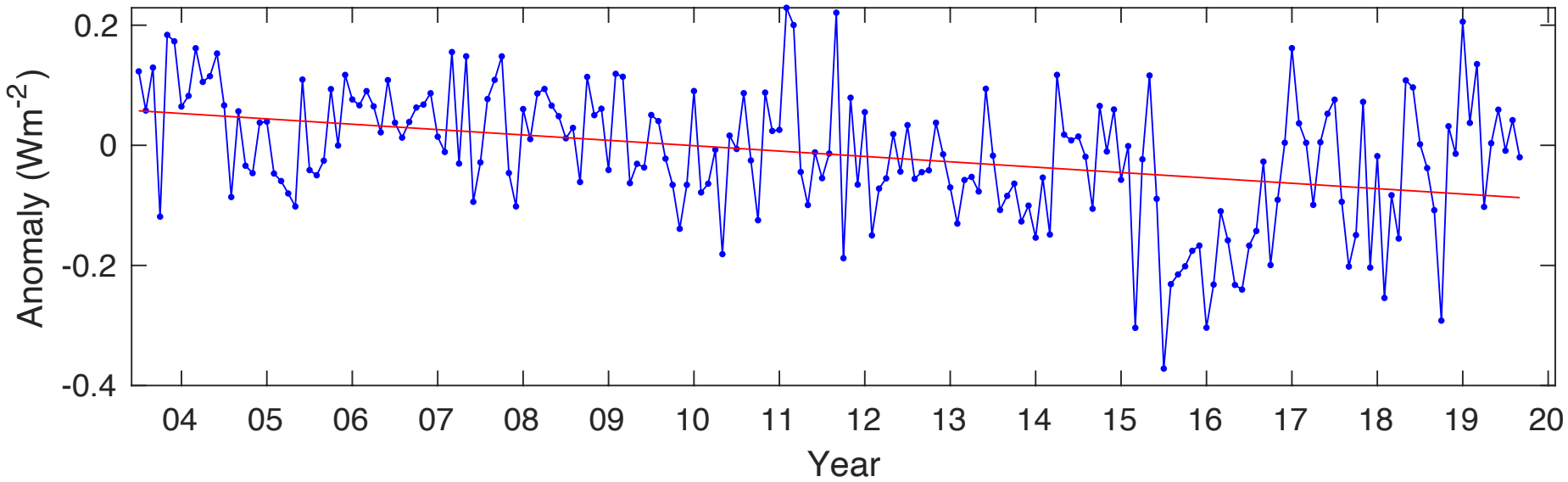
Total area (i.e. cloud removed) with clear-sky sampling correction



0.02±0.19Wm^{-2} dec^{-1}

Clear-sky correction (total area – cloud free)

July 2003 through October 2019



-0.09±0.05 Wm^{-2} dec^{-1}

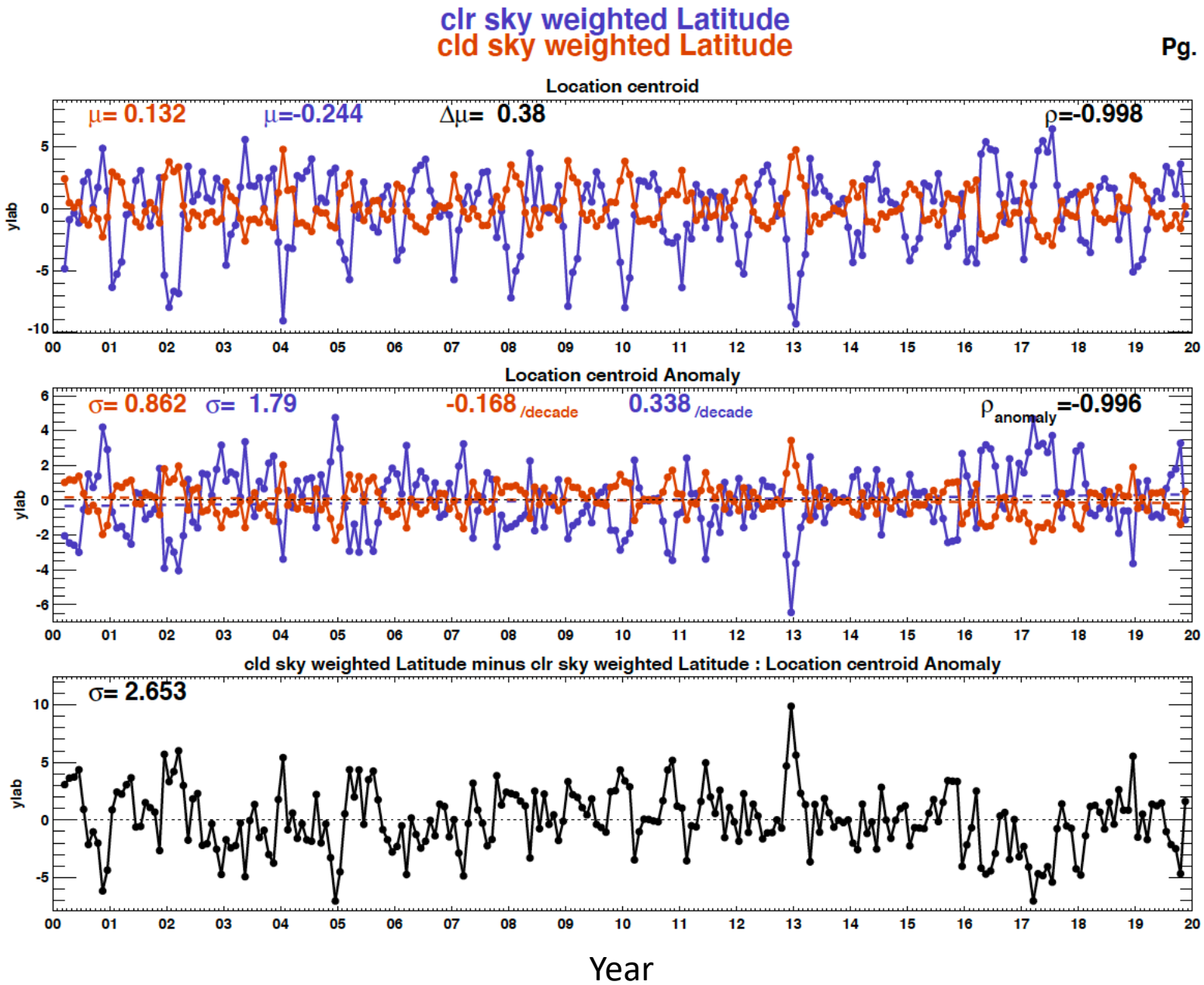
Global observed clear-sky and total area clear-sky OLR trend difference is not large, but the correction adds a negative trend

$$\frac{d\ total\ area\ OLR}{dt} < \frac{d\ clear\ area\ OLR}{dt}$$

A possible reason is that variables that affect clear-sky OLR for clear-sky area and total area (or cloudy area) change at different rates.

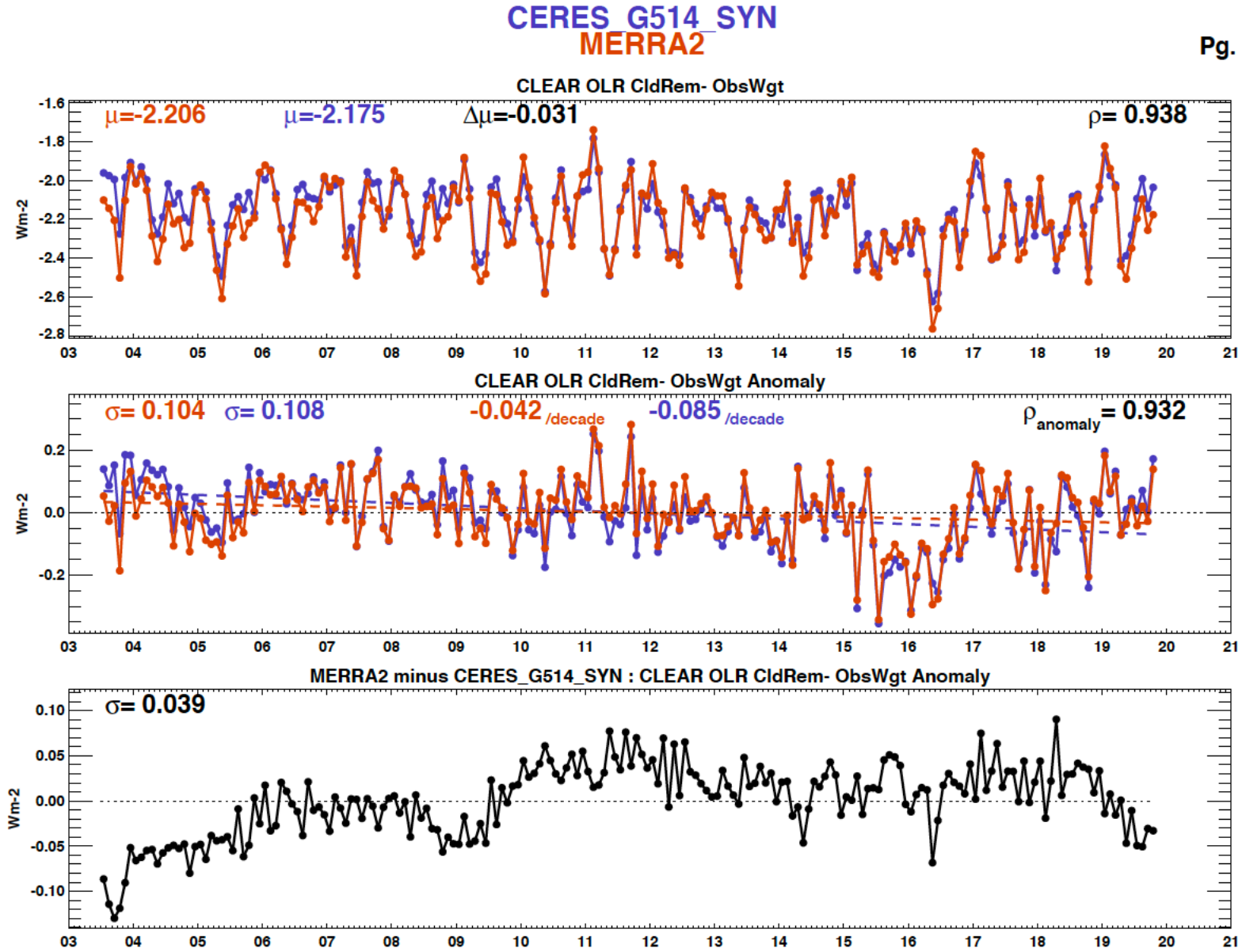
For example, water vapor amount over cloudy area increases faster than water vapor amount over clear area.

Clear-sky sampling change



A similar analysis of longitude and hour leads to no significant trend in where and when clear-sky scenes are occurring.

Cloud removed – observed clear-sky weighted Clear-sky OLR Comparison with MERRA-2

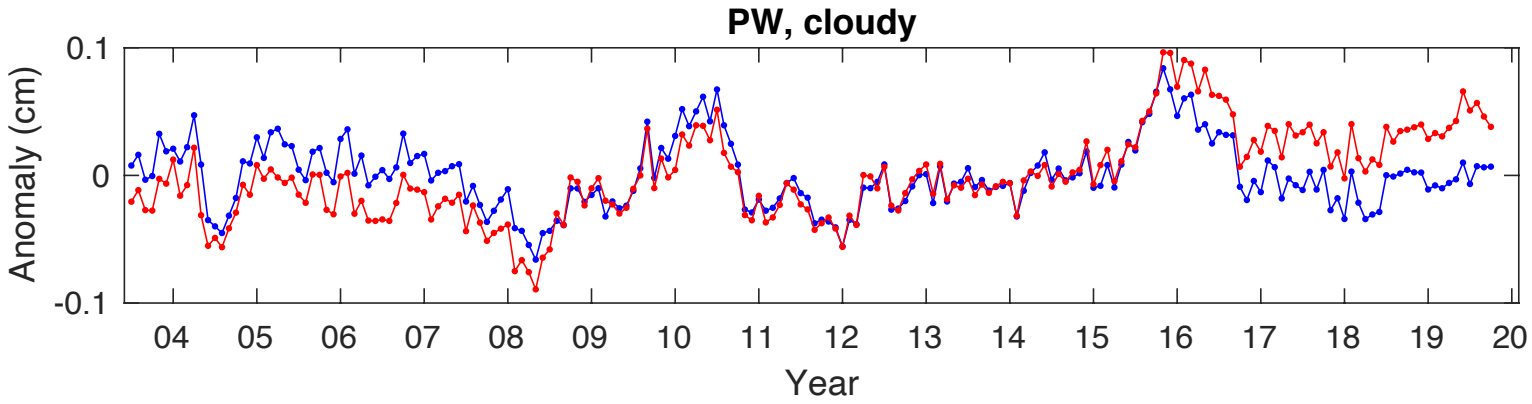


GEOS-5.4.1 OLR is from Edition 4.1 SYN1deg

MERRA-2 OLR is taken from the MERRA-2 product.

Both have a decreasing trend, but the MERRA-2 slope is ~50% of the slope computed with GEOS-5.4.1

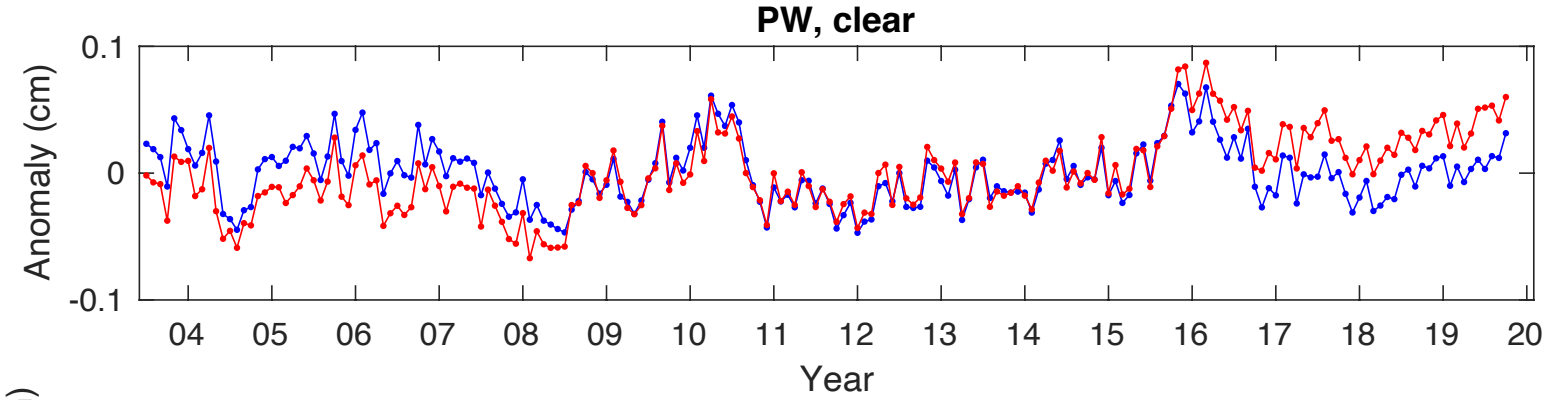
Precipitable water, cloudy part versus clear part



GEOS-5.4.1
0.0007 cm dec^{-1}

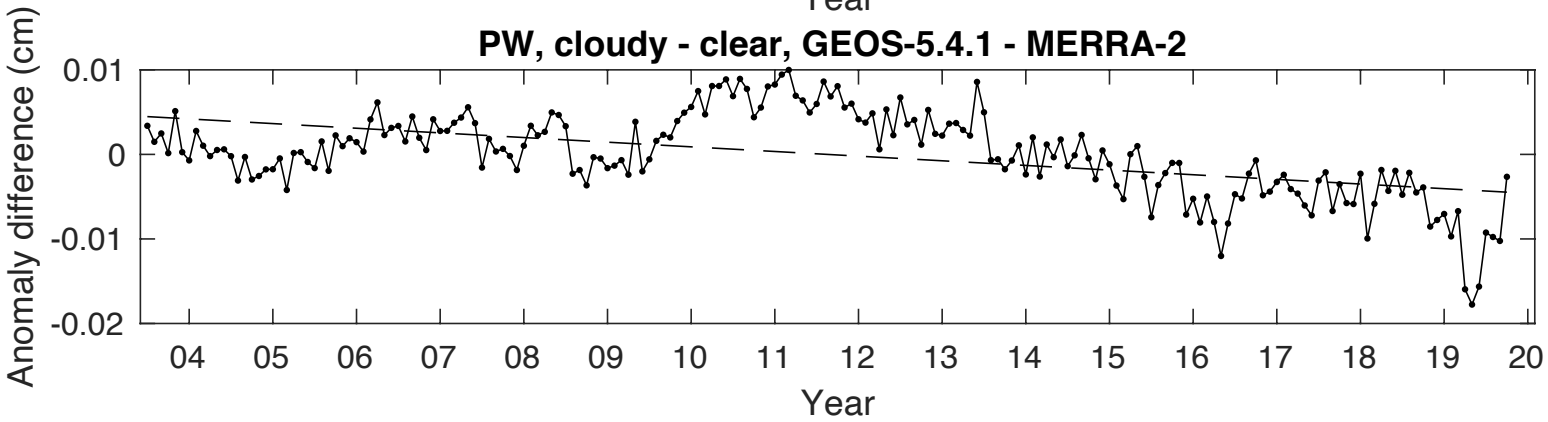
MERRA-2
0.0453 cm dec^{-1}

GEOS-5.4.1
An increasing trend over cloudy area and a decreasing trend over clear-area, but he difference is too small



GEOS-5.4.1
-0.0012 cm dec^{-1}

MERRA-2
0.0379 cm dec^{-1}

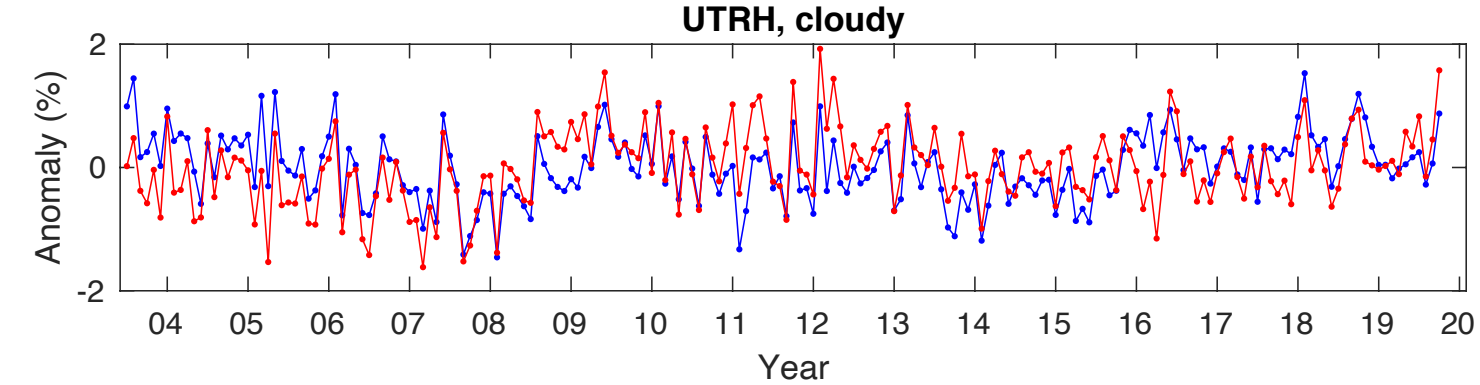


GEOS-5.4.1
0.0082 cm dec^{-1}

MERRA-2
0.0075 cm dec^{-1}

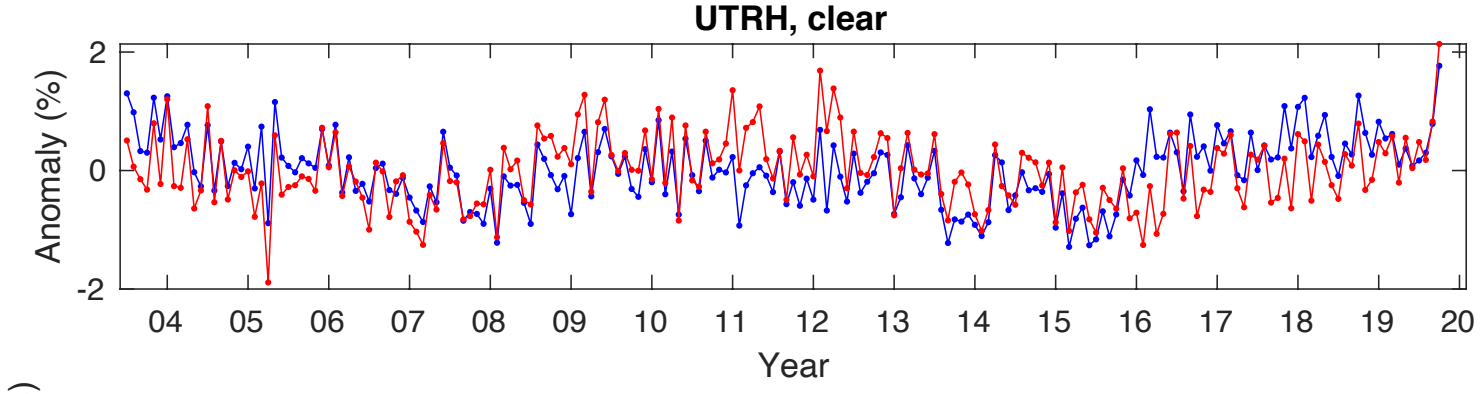
Upper tropospheric relative humidity

GEOS-5.4.1
A larger increasing trend over clear-sky



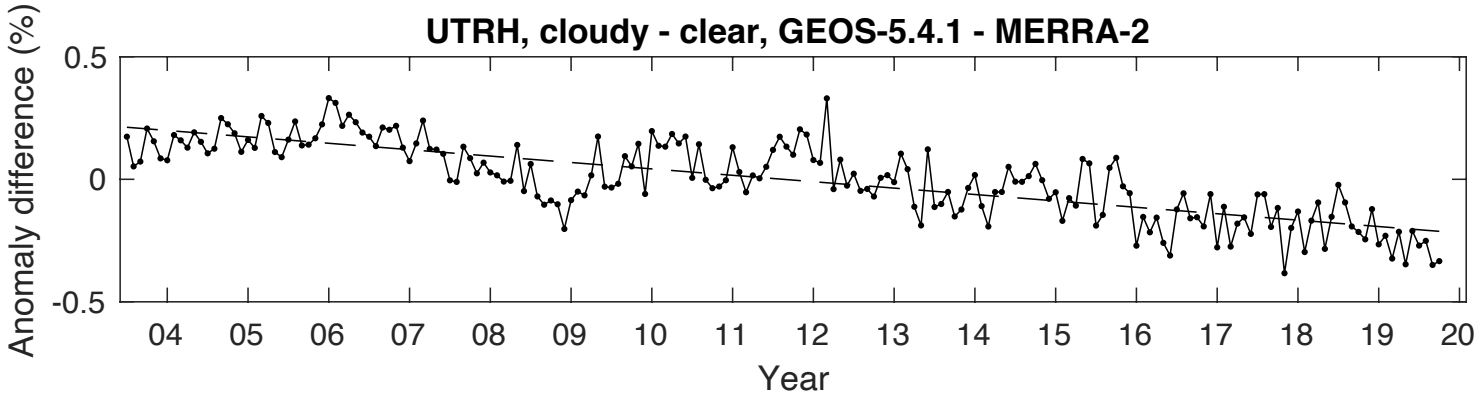
GEOS-5.4.1
0.053 % dec^{-1}

MERRA-2
0.30 % dec^{-1}



GEOS-5.4.1
0.083 % dec^{-1}

MERRA-2
0.067 % dec^{-1}

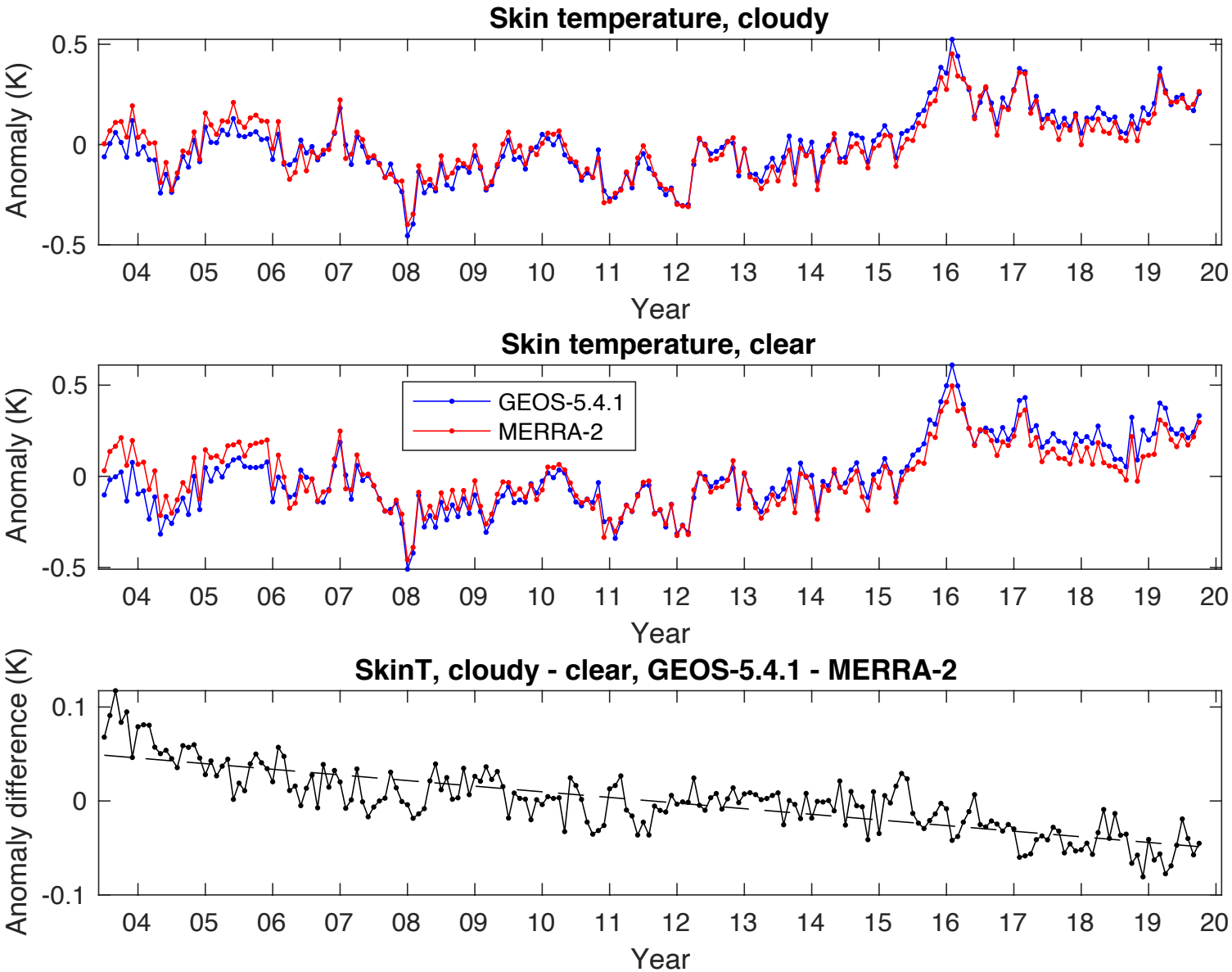


GEOS-5.4.1
-0.03 % dec^{-1}

MERRA-2
0.23 % dec^{-1}

Surface skin temperature

GEOS-5.4.1
A larger increasing trend over clear-area



GEOS-5.4.1
0.19 K dec^{-1}

MERRA-2
0.12 K dec^{-1}

GEOS-5.4.1
0.25 K dec^{-1}

MERRA-2
0.12 K dec^{-1}

GEOS-5.4.1
-0.08 K dec^{-1}

MERRA-2
0.00 K dec^{-1}

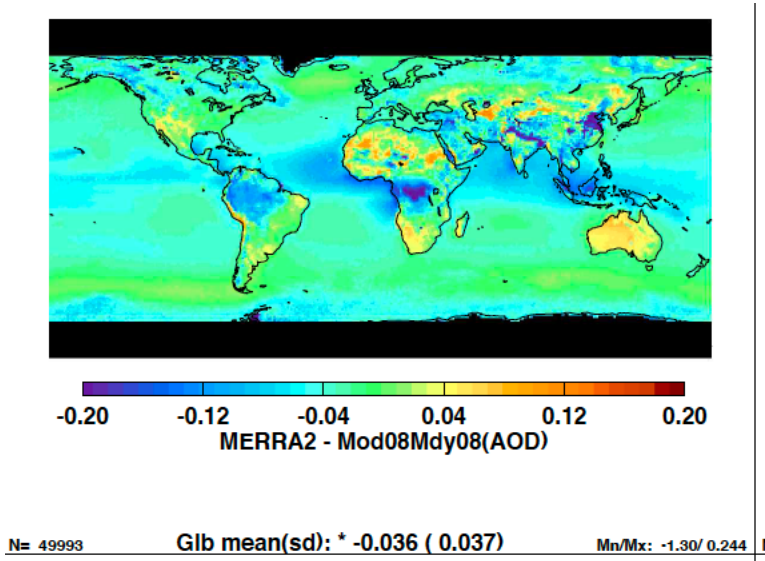
Clear-sky OLR correction summary

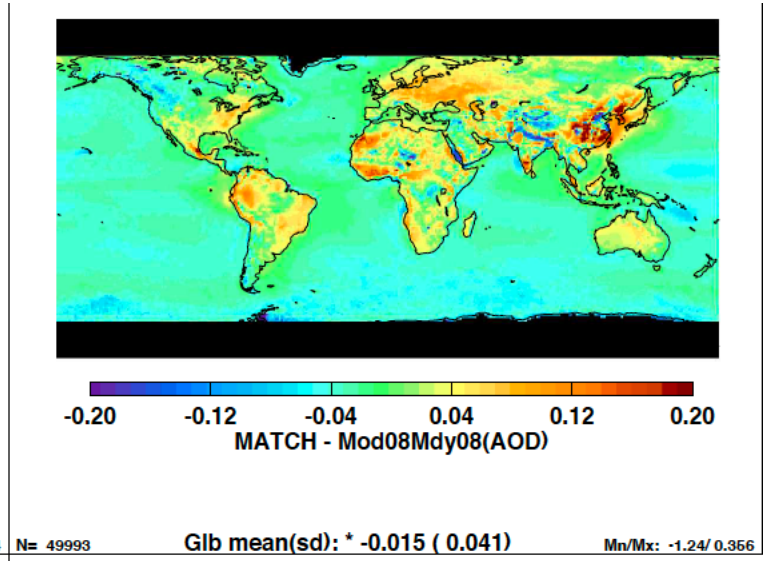
- Anomalies of clear-sky sampling correction to observed clear-sky OLR have a negative trend (total sky OLR – clear-sky OLR)
- Correction is based on GEOS-5.4.1
- The largest GEOS-5.4.1 and MERRA-2 trend difference of total-sky – clear-sky caused by precipitable water, upper tropospheric relative humidity, and skin temperature is due to upper tropospheric relative humidity.
- GEOS-5.4.1 upper tropospheric relative humidity trend is opposite to the OLR correction trend, if the trend were driving the OLR correction trend.
- A part of the decreasing trend is due to surface skin temperature trend that differs from MERRA-2 skin temperature trend. (MERRA-2 has a larger contribution from UTRH).
- The decreasing trend is not caused by water vapor amount over cloudy area increases faster than water vapor amount over clear area.

Edition 4.1 MATCH aerosol and clear-sky and partly cloudy surface downward shortwave irradiance validation

MATCH aerosol optical thickness comparison with MODIS aerosol optical thickness (March 2000 – Feb. 2020 mean bias)

MERRA-2 - MODIS

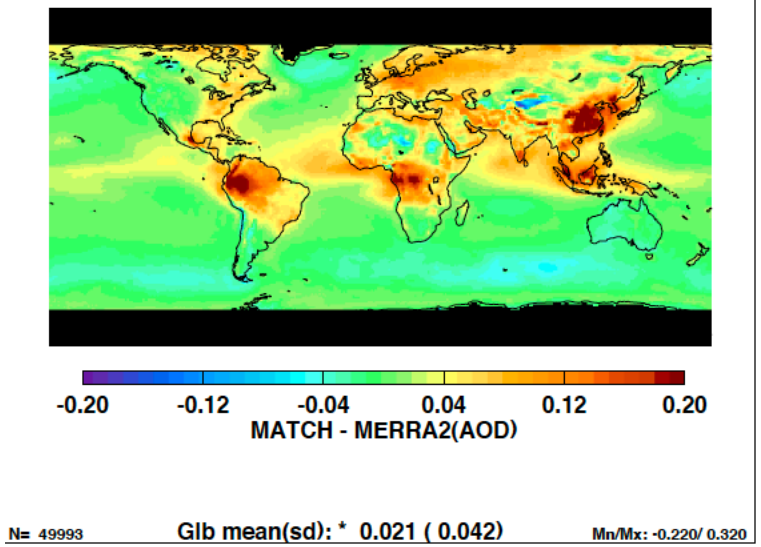




MATCH - MODIS

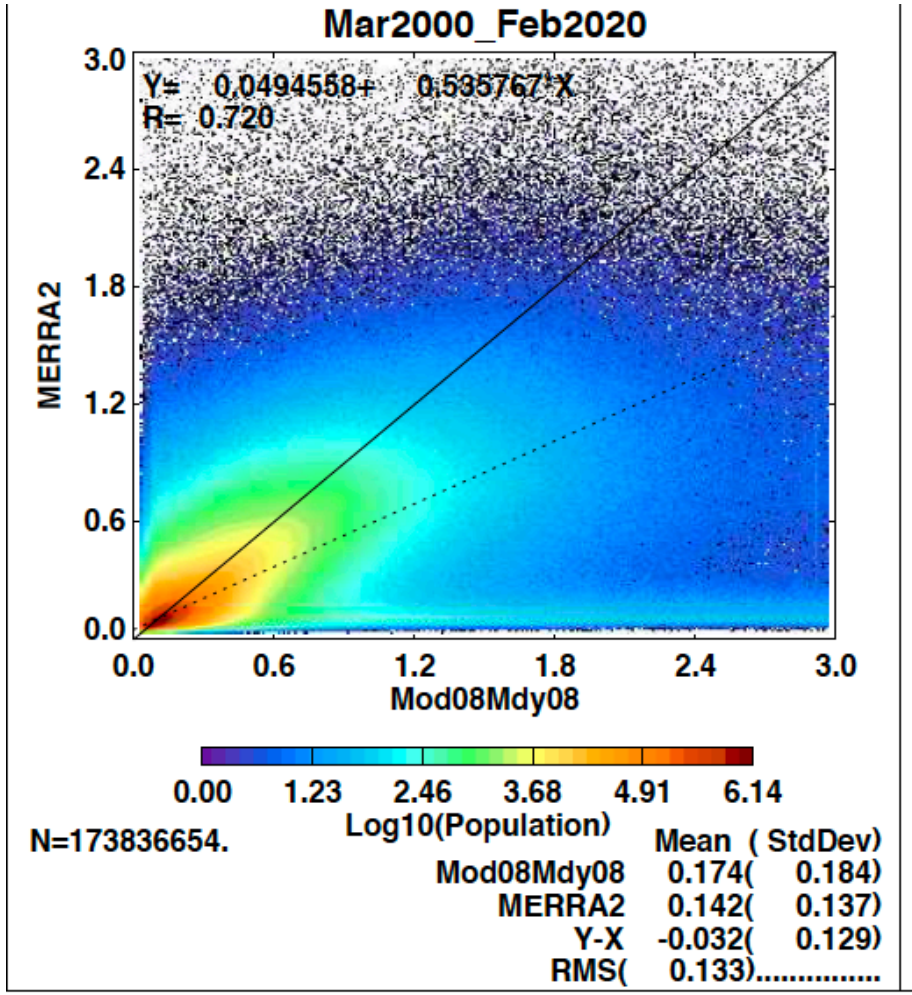
MATCH AOT is larger over land

MATCH – MERRA-2

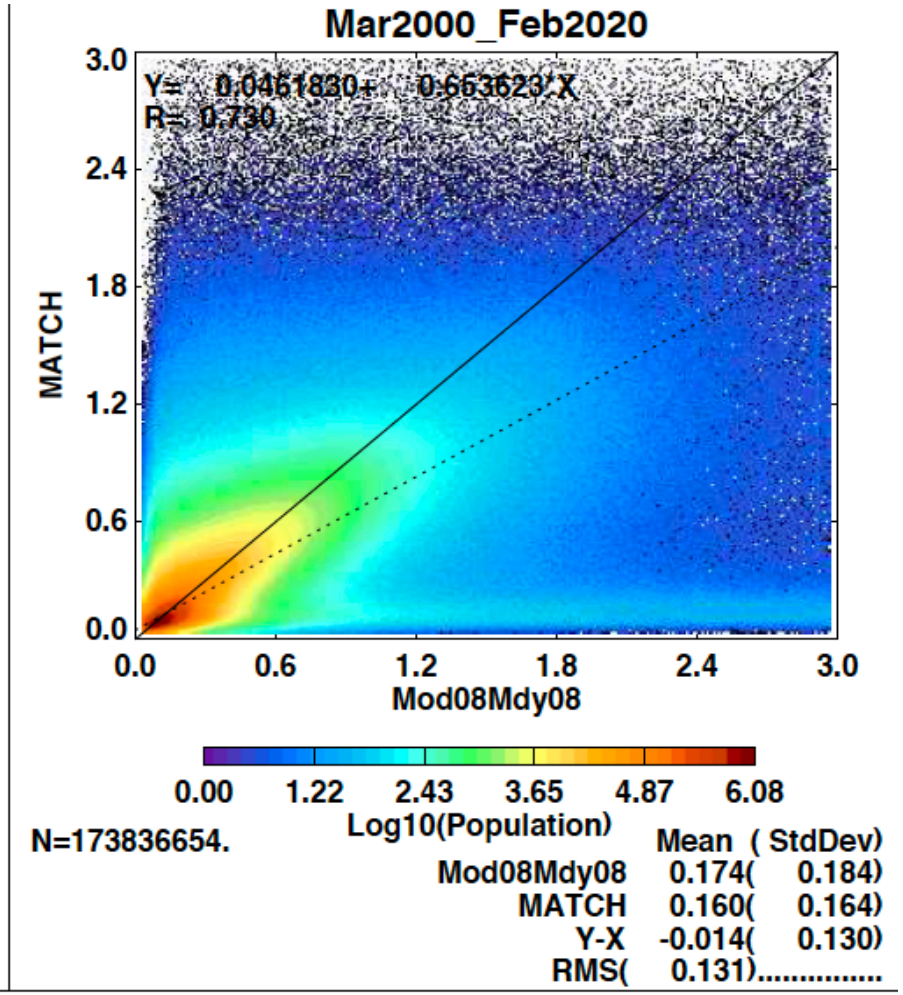


Comparison of 20 years of AOT

MERRA-2 vs. MODIS



MATCH vs. MODIS



MATCH aerosol optical thickness under clear-sky conditions are closer to MODIS-derived aerosol optical thickness

The mean difference of -0.014 compared to -0.032.

Comparison with AERONET: Clear-sky

Table 2. Hourly AERONET station statistics for MATCH and MERRA-2.
Continental Groups, Clear Sky conditions[1]

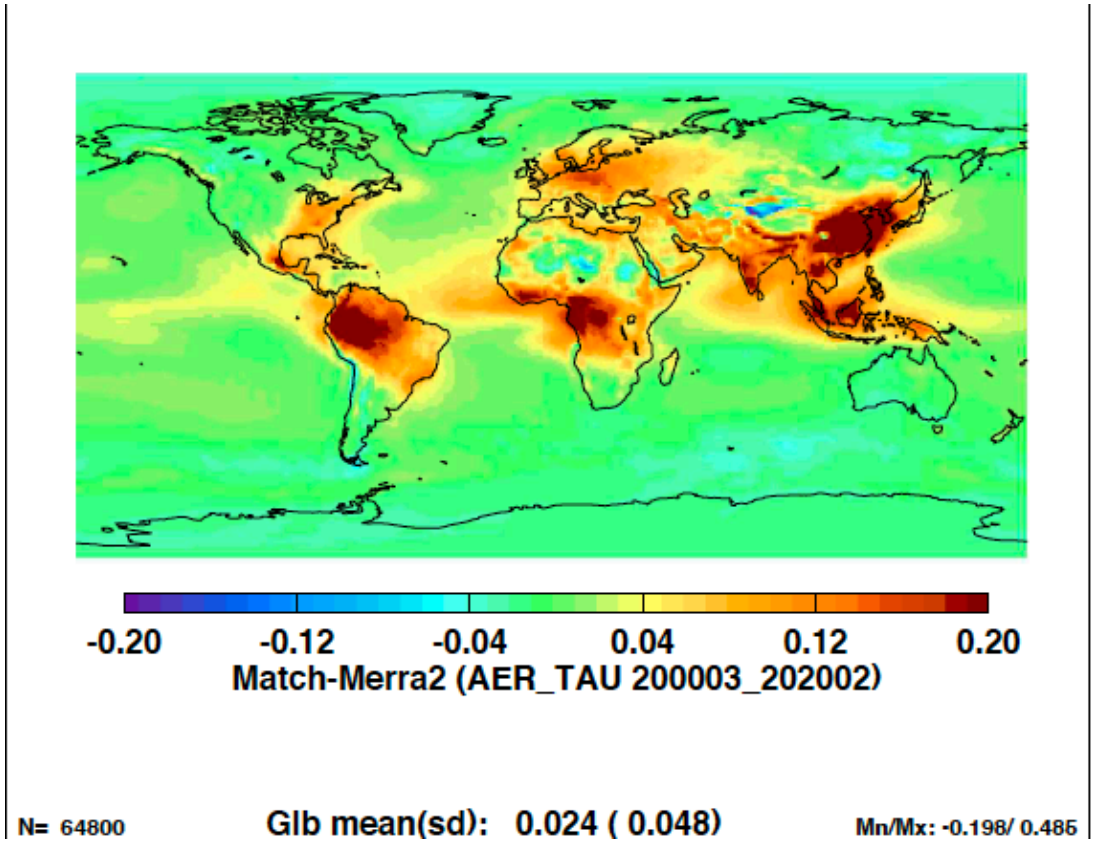
				MATCH			MERRA-2		
Site	Predominant Aerosol Type	Number	Observed Average	Bias	RMS	R^2	Bias	RMS	R^2
Australia (5 Sites)	Dust Smoke	20925	0.06	0.01	0.06	0.4	0.03	0.05	0.7
Brazil (7 Sites)	Smoke Polluted	6554	0.14	0.02	0.10	0.8	-0.02	0.08	0.9
Central Africa (5 Sites)	Smoke	2139	0.70	-0.10	0.24	0.9	-0.10	0.24	0.9
North Africa (5 Sites)	Dust	10047	0.17	0.07	0.15	0.7	0.02	0.10	0.8
China SE Asia (8 Sites)	Polluted	2827	0.26	-0.00	0.18	0.7	-0.03	0.15	0.8
India/Bangledesh (6 Sites)	Smoke Polluted	3010	0.51	-0.09	0.28	0.6	-0.10	0.24	0.8
North America (9 SItes)	Continental Polluted	21429	0.10	-0.00	0.07	0.7	0.00	0.06	0.8
Europe (10 Sites)	Continental Polluted	10211	0.13	0.01	0.07	0.7	-0.02	0.05	0.8

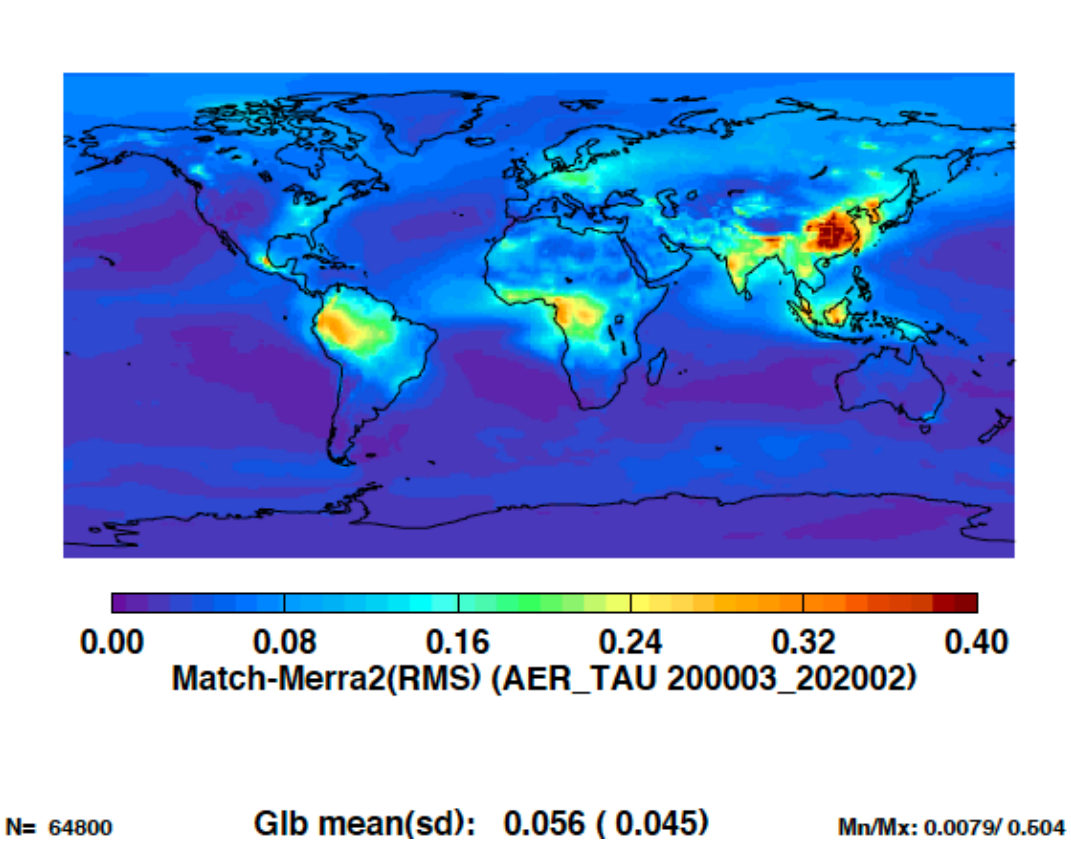
[1]The time period used is from Mar 2000 through Apr 2020. Actual period varies by site depending on AERONET data availability. Clear Sky is identified by MODIS and geostationary satellites and the cloud fraction is less than 1% over a SYN1deg grid box.

MERRA-2 assimilates AERONET AOT (Randles et al. 2017)

Fillmore et al. (2021)

MATCH vs. MERRA-2 aerosol optical thickness All-sky conditions





The spatial patter on the difference between MATCH and MERA-2 AOT is similar to the spatial patter of the difference under clear-sky conditions

Comparison with AERONET: All-sky

Table 3. Hourly AERONET station statistics for MATCH and MERRA-2.
Continental Groups, All Sky Conditions[1]

Site	Predominant Aerosol Type	Number	Observed Average	MATCH Bias	MATCH RMS	MATCH R^2	MERRA-2 Bias	MERRA-2 RMS	MERRA-2 R^2
Australia (5 Sites)	Dust Smoke	110523	0.09	0.00	0.09	0.5	0.02	0.07	0.8
Brazil (7 Sites)	Smoke Polluted	72656	0.25	0.03	0.23	0.8	-0.04	0.18	0.9
Central Africa (5 Sites)	Smoke	41193	0.55	-0.07	0.26	0.8	-0.10	0.26	0.9
North Africa (5 Sites)	Dust	43205	0.23	0.08	0.20	0.7	0.01	0.14	0.8
China SE Asia (8 Sites)	Polluted	52287	0.45	0.01	0.31	0.7	-0.08	0.27	0.8
India/Bangladesh (6 Sites)	Smoke Polluted	44534	0.61	-0.06	0.32	0.6	-0.10	0.32	0.7
North America (9 SIte)	Continental Polluted	160356	0.13	0.02	0.13	0.6	0.00	0.09	0.7
Europe (10 Sites)	Continental Polluted	175010	0.18	0.04	0.14	0.6	-0.02	0.08	0.8

[1] The time period used for the statistics is from March 2000 through April 2020. The actual period varies by site depending on AERONET data availability.
[2] Correlation coefficient.

Fillmore et al. (2021)

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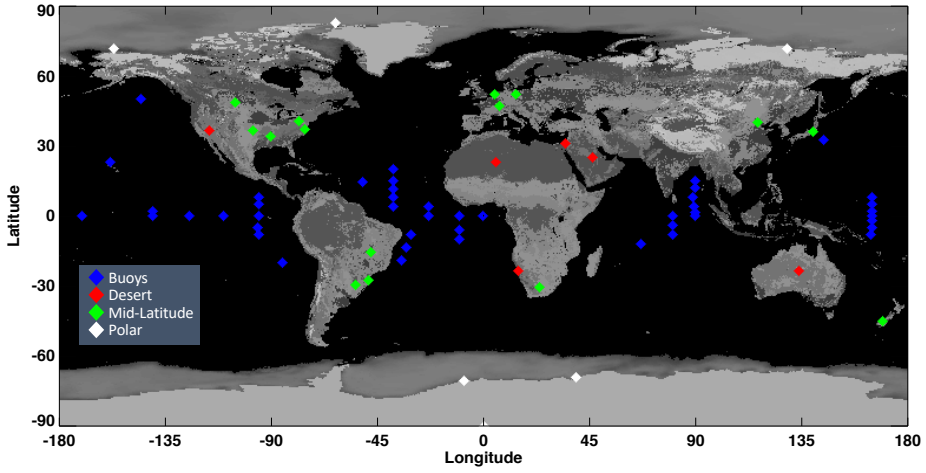
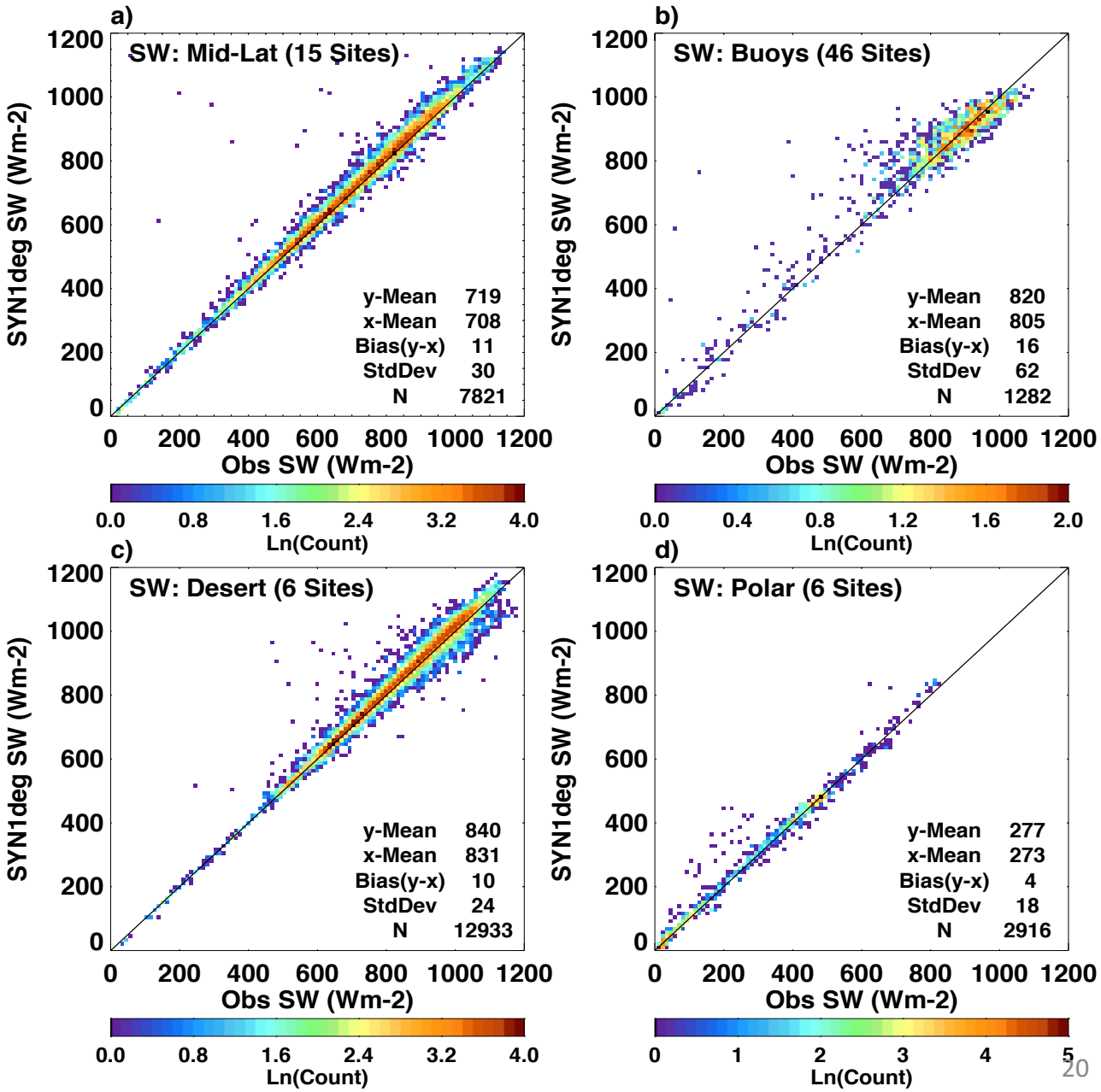
Surface downward shortwave hourly irradiance validation (Ed. 4.1 SYN1deg-Hour)

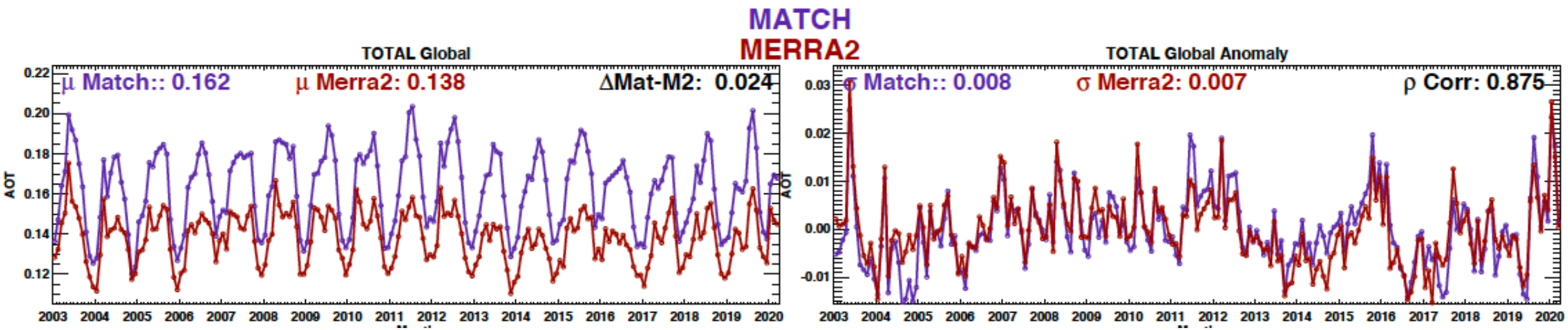
Select hour boxes with 100% clear based on MODIS and GEO



Clear-sky SYN1deg hourly irradiances tend to be larger when the solar zenith angle is small



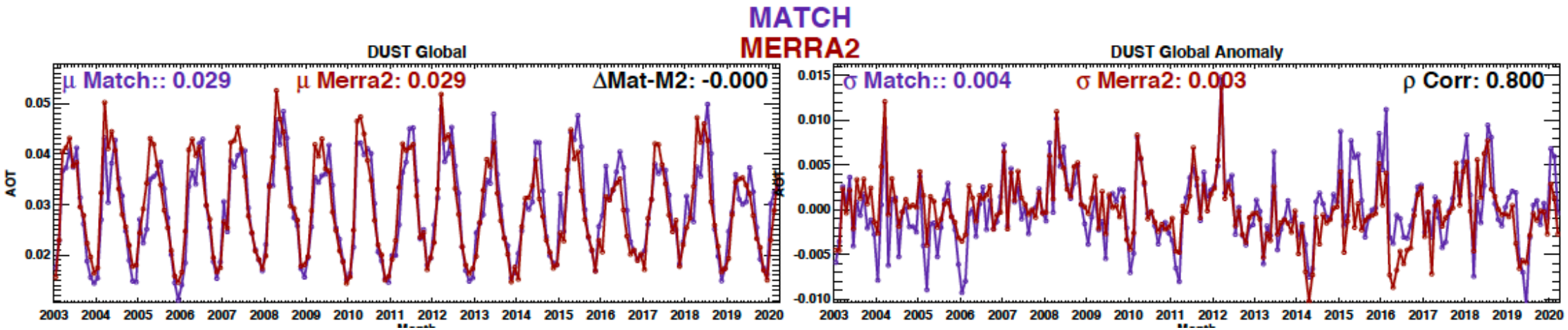
Aerosol optical thickness variability



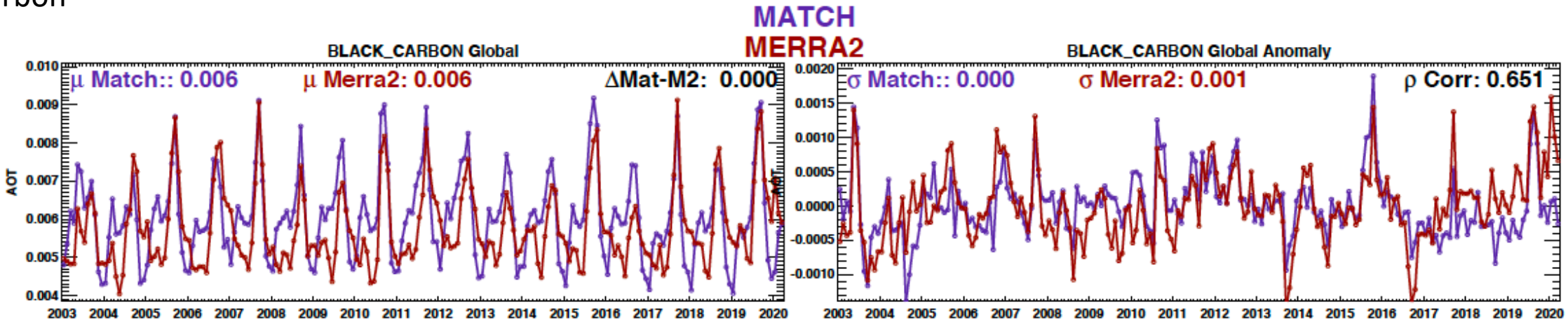
Although seasonal variabilities are different, MATCH and MERRA-2 AOT global monthly anomalies agree.

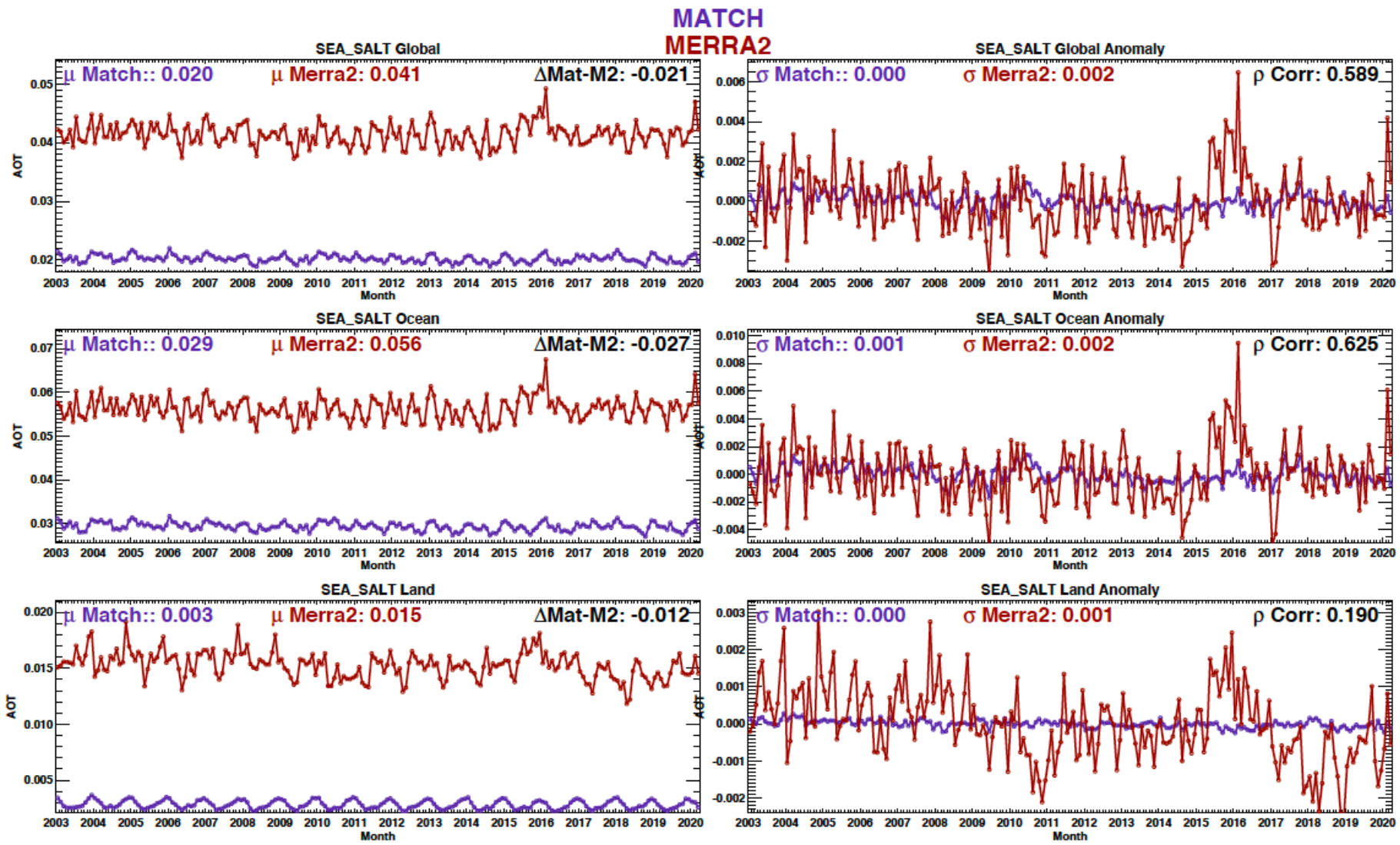
Variability by aerosol type

Dust



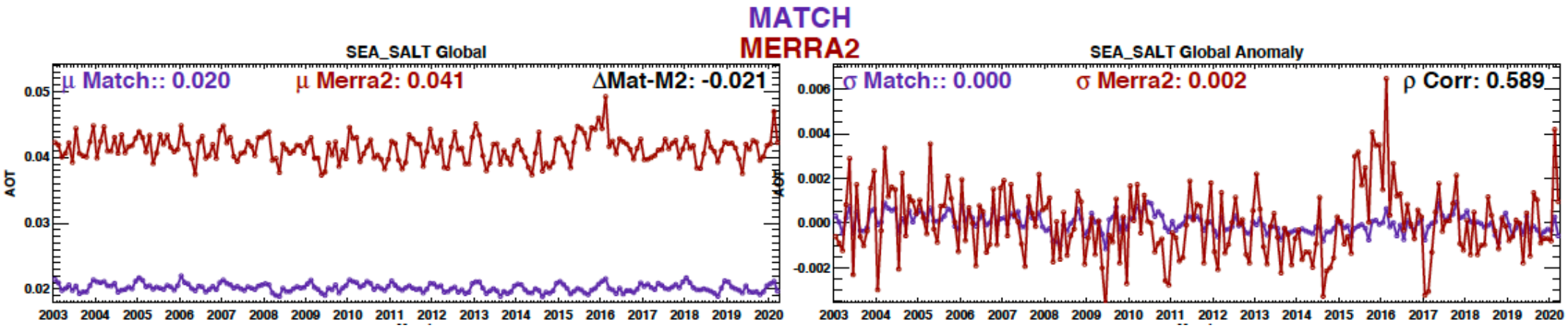
Black carbon



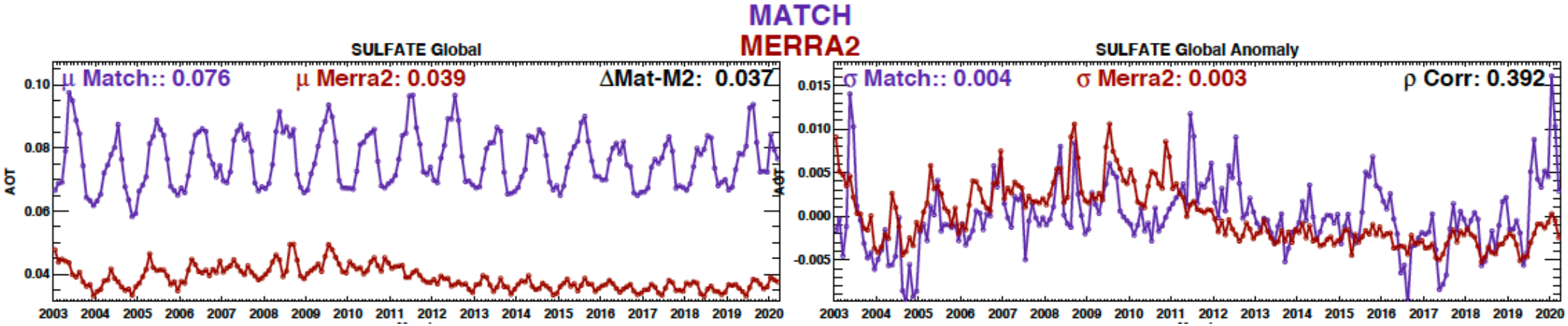

MATCH
MERRA2
SEA_SALT Global
μ Match:: 0.020
μ Merra2: 0.041
ΔMat-M2: -0.021
SEA_SALT Global Anomaly
σ Match:: 0.000
σ Merra2: 0.002
ρ Corr: 0.589
SEA_SALT Ocean
μ Match:: 0.029
μ Merra2: 0.056
ΔMat-M2: -0.027
SEA_SALT Ocean Anomaly
σ Match:: 0.001
σ Merra2: 0.002
ρ Corr: 0.625
SEA_SALT Land
μ Match:: 0.003
μ Merra2: 0.015
ΔMat-M2: -0.012
SEA_SALT Land Anomaly
σ Match:: 0.000
σ Merra2: 0.001
ρ Corr: 0.190
AOT
Month

Sea salt and sulfate

Sea salt



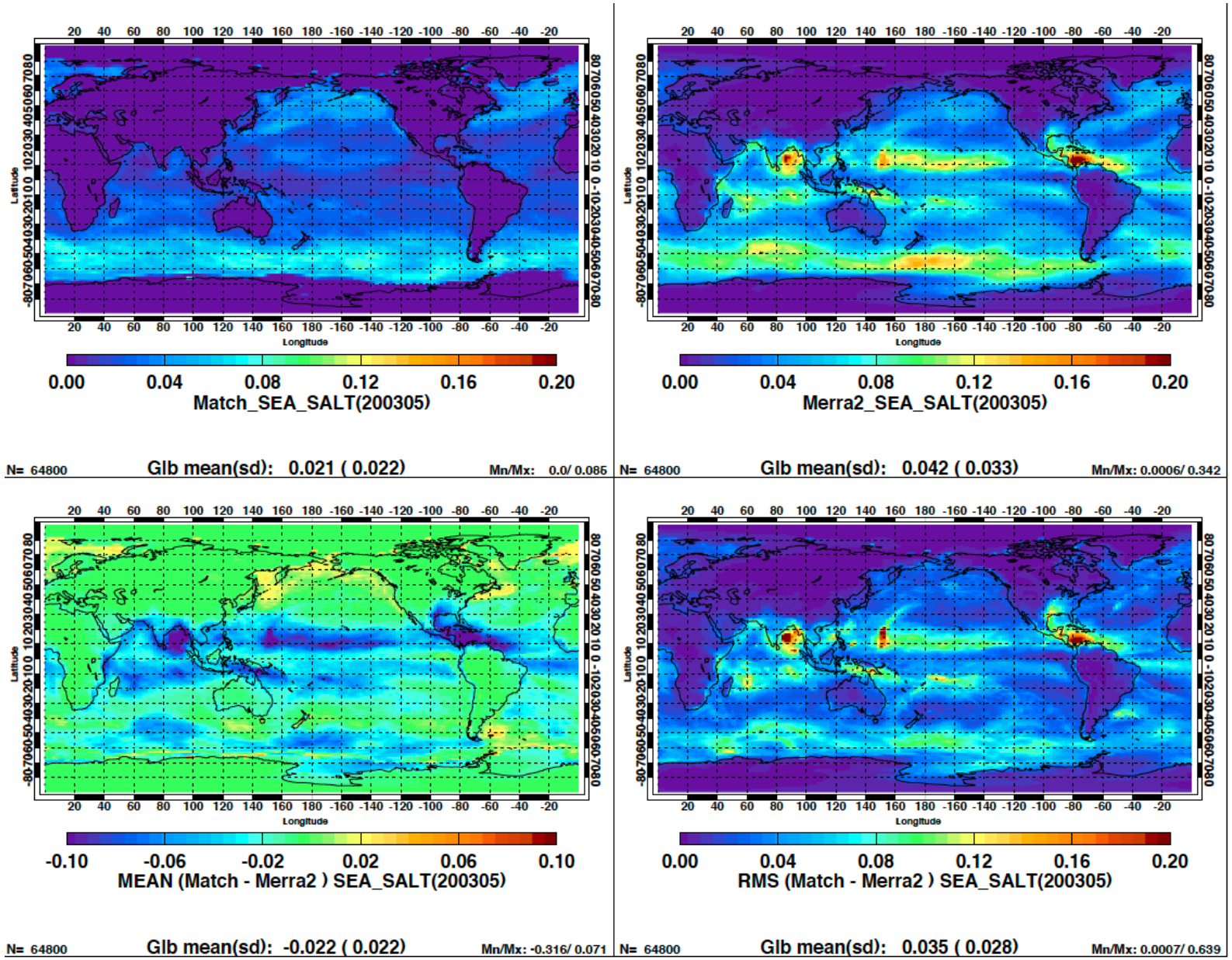
Salfate



Sea salt regional differences

MATCH

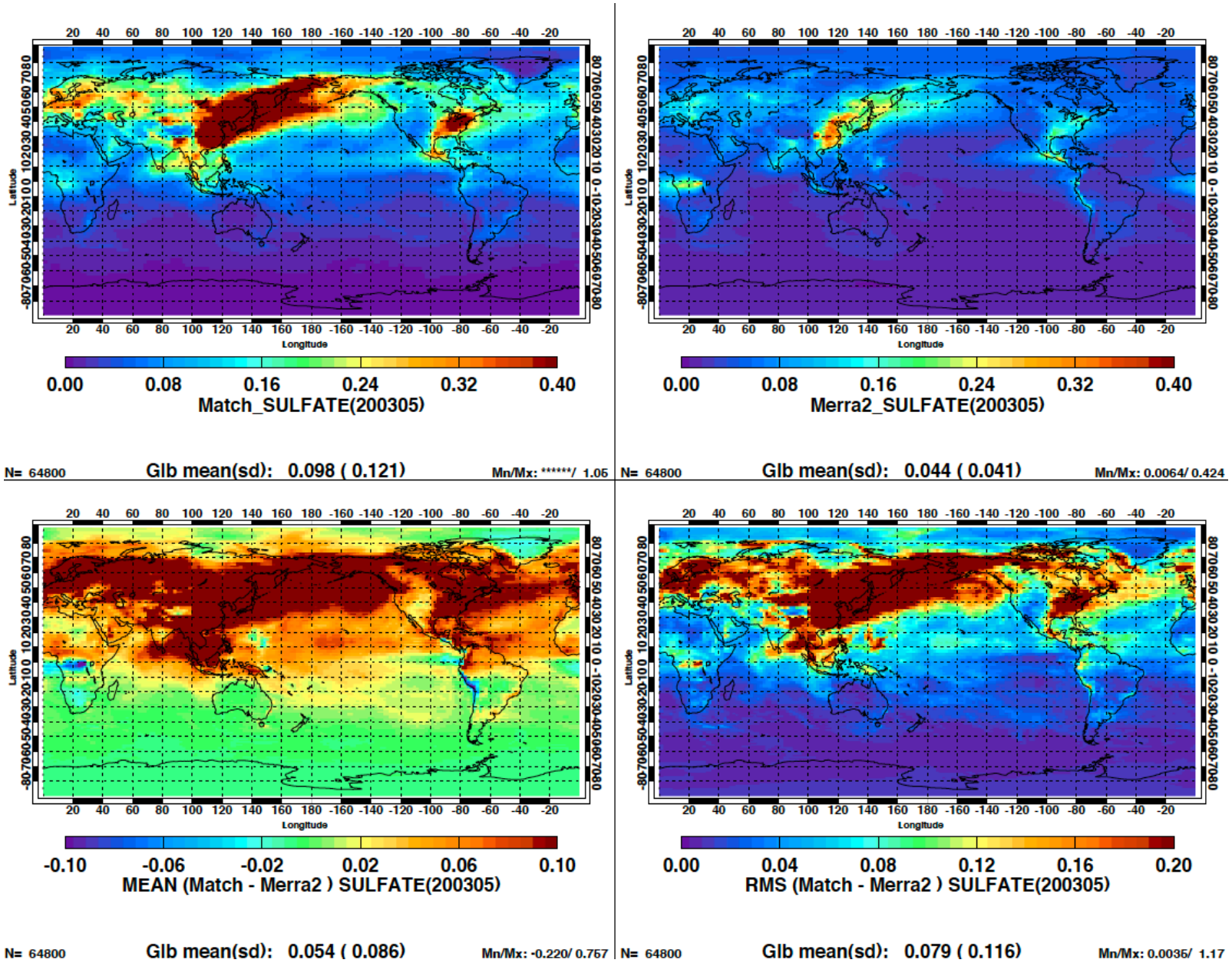
MERRA-2



Sulfate regional differences

MATCH

MERRA-2



Understand the Impact of using a large fraction of sulfate for maritime clean aerosol

TABLE 4. Composition of aerosol types. Mass values are given for a relative humidity of 50% and for a cutoff radius of 7.5 μm.

Aerosol types	Components	N_i (cm^{-3})	M_i ($\mu g\ m^{-3}$)	Number mixing ratios (n_j)	Mass mixing ratios (m_j)
Continental clean	total	2600	8.8		
	water soluble	2600	5.2	1.0	0.591
	insoluble	0.15	3.6	0.577E–4	0.409
Continental average	total	15 300	24.0		
	water soluble	7000	14.0	0.458	0.583
	insoluble	0.4	9.5	0.261E–4	0.396
	soot	8300	0.5	0.542	0.021
Continental polluted	total	50 000	47.7		
	water soluble	15 700	31.4	0.314	0.658
	insoluble	0.6	14.2	0.12E–4	0.298
	soot	34 300	2.1	0.686	0.044
Urban	total	158 000	99.4		
	water soluble	28 000	56.0	0.177	0.563
	insoluble	1.5	35.6	0.949e–05	0.358
	soot	130 000	7.8	0.823	0.079
Desert	total	2300	225.8		
	water soluble	2000	4.0	0.87	0.018
	mineral (nuc.)	269.5	7.5	0.117	0.033
	mineral (acc.)	30.5	168.7	0.133E–1	0.747
	mineral (coa.)	0.142	45.6	0.617–4	0.202
Maritime clean	total	1520	42.5		
	water soluble	1500	3.0	0.987	0.071
	sea salt (acc.)	20	38.6	0.132E–1	0.908
	sea salt (coa.)	3.2E–3	0.9	0.211E–5	0.021
Maritime polluted	total	9000	47.4		
	water soluble	3800	7.6	0.422	0.160
	sea salt (acc.)	20	38.6	0.222E–2	0.814
	sea salt (coa.)	3.2E–3	0.9	0.356E–6	0.019
	soot	5180	0.3	0.576	0.006
Maritime tropical	total	600	20.8		
	water soluble	590	1.2	0.983	0.058
	sea salt (acc.)	10	19.3	0.167E–1	0.928
	sea salt (coa.)	1.3E–3	0.3	0.217E–5	0.014

Changes the mass mixing ratio from 0.1 to 100.

Combine optical properties from MOPSMAP

Number concentration scaling factor of i-th constituent,

$$r_i = \frac{n_i}{n_0}$$

Extinction coefficient

$$\alpha_{ext} = \sum_{i=1}^{N} r_i \alpha_{ext,i}$$

Scattering coefficient

$$\alpha_{scat} = \sum_{i=1}^{N} r_i \omega_{0,i} \alpha_{ext,i}$$

Single scattering albedo

$$\omega_0 = \sum_{i=1}^{N} \frac{r_i \alpha_{scat.i}}{\alpha_{ext}}$$

Asymmetry parameter

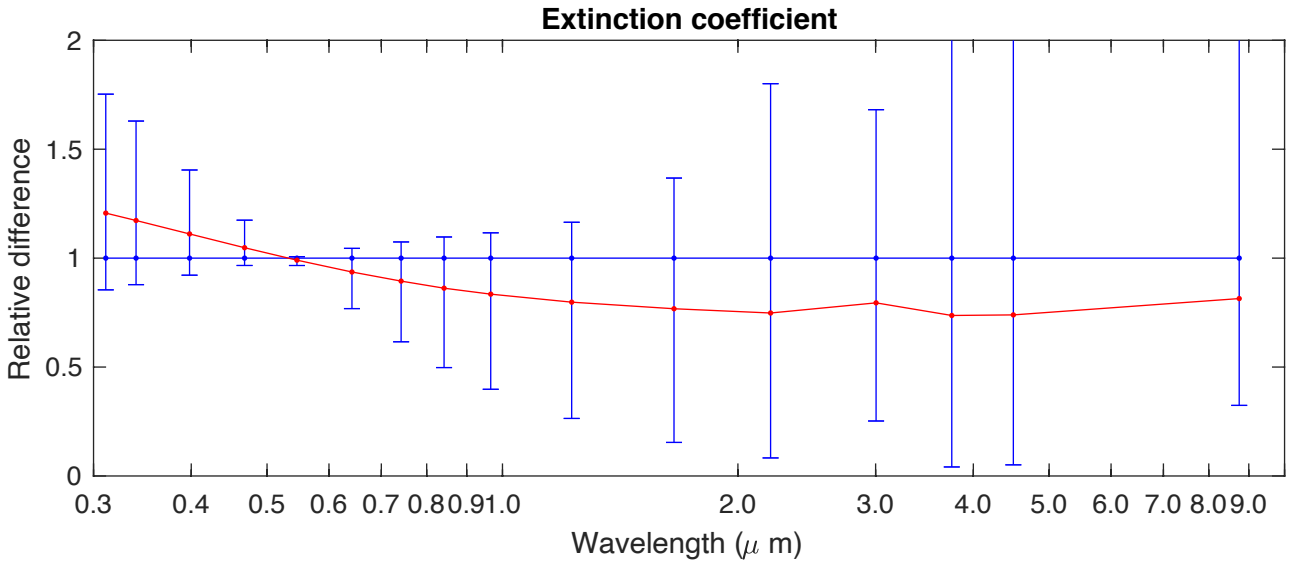
$$g = \sum_{i=1}^{N} \frac{r_i g_i \alpha_{scat,i}}{\alpha_{scat}}$$

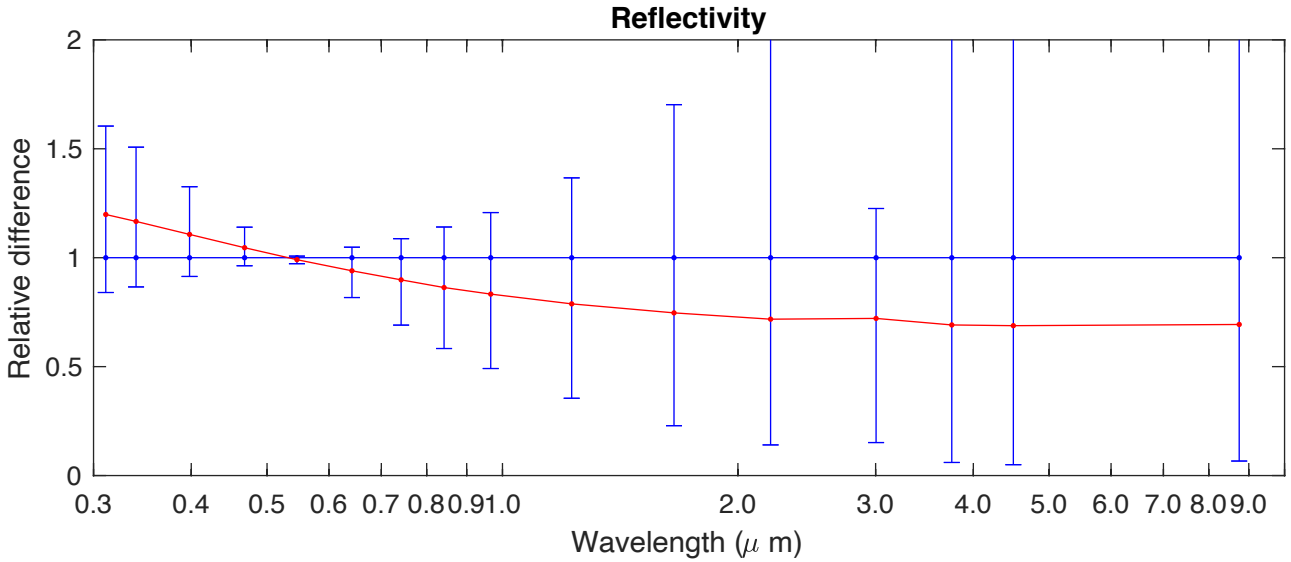
An assumption is the number concentration changes.

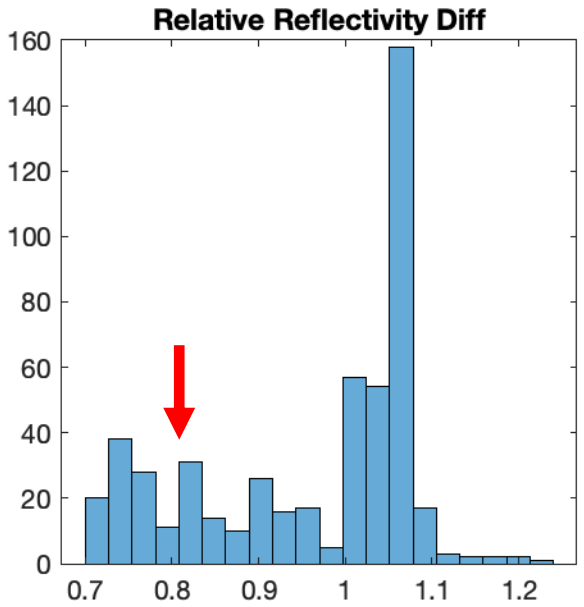
Size changes of sea salt particles are handled by the ratio of accumulation and coarse mode number concentrations.

MOPSMAP: Gasteiger and Wiegner, 2018, mopsmat.net

Difference relative to OPAC maritime clean







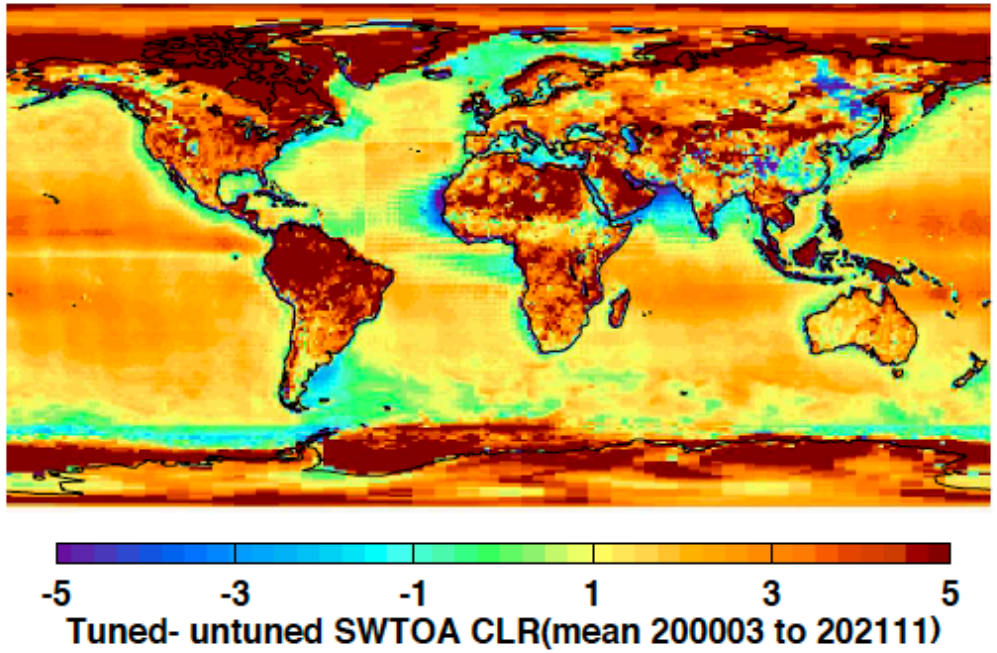
[Water soluble * 3
Sea salt (Accum) * 0.3
Sea salt (coarse) * 0.3] / OPAC maritime clean

Albedo of [Water soluble * 3
Sea salt (Accum) * 0.3
Sea salt (coarse) * 0.3]
Is 19 % lower than albedo of OPAC maritime clean

This is taken out by the EBAF adjustment

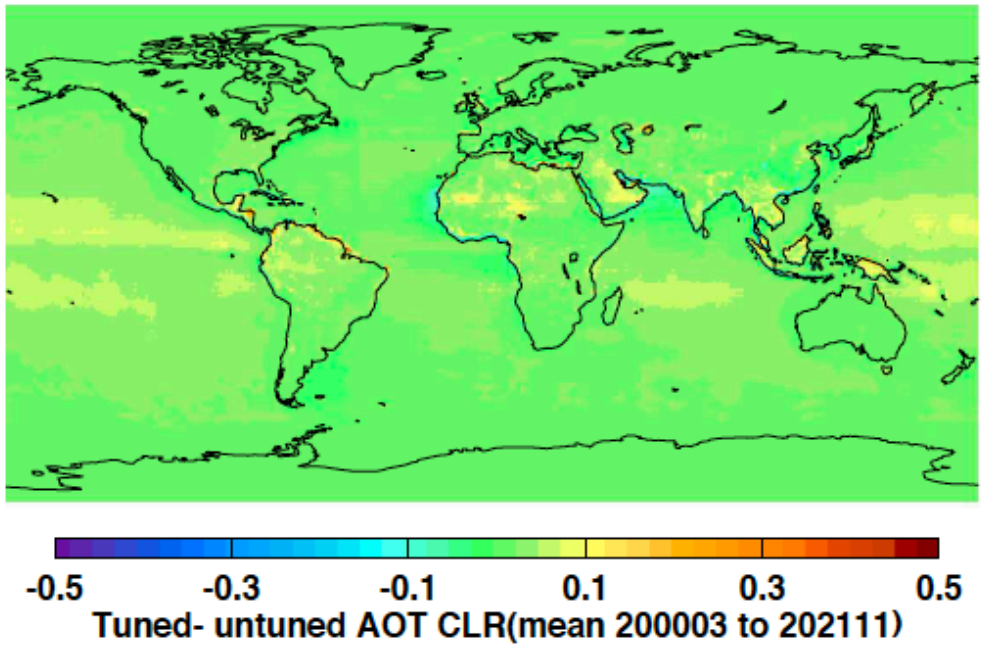
EBAF clear-sky adjustment

TOA reflected shortwave irradiance (Wm-2)



N= 64800 Glb mean(sd): 2.24 (3.58) Mn/Mx: -36.86/ 75.94

Aerosol optical thickness

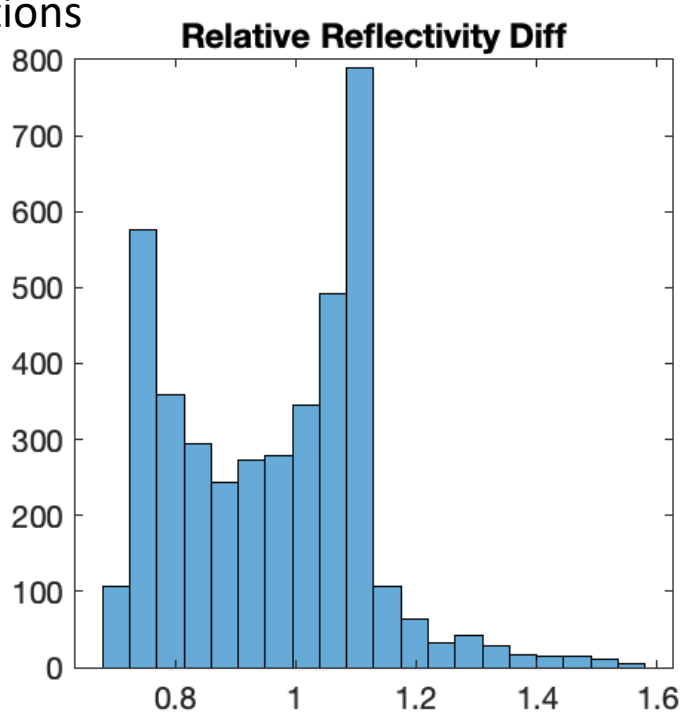


N= 64800 Glb mean(sd): 0.020 (0.024) Mn/Mx: -0.260/ 0.792

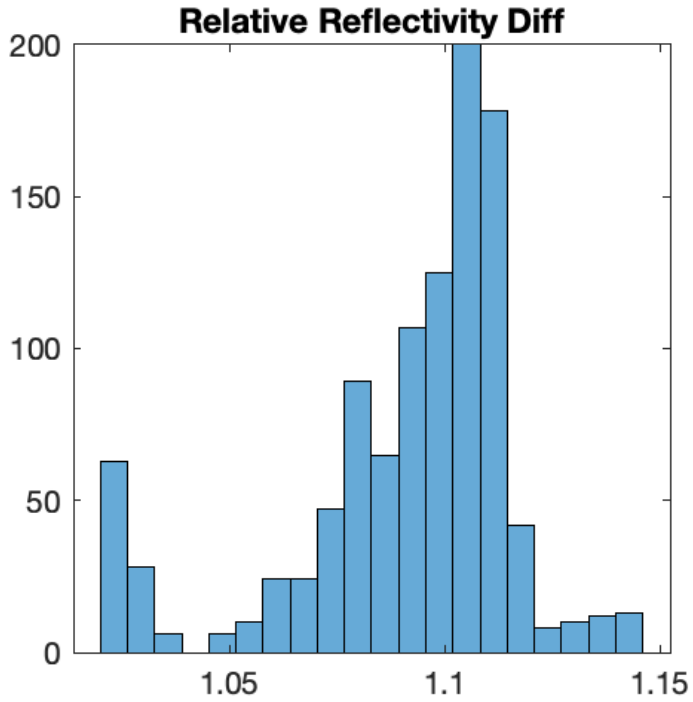
Irradiance changes are not due to aerosol optical thickness only
Aerosol optical thickness adjustment qualitatively agree with the result

Desert aerosol

All combinations



Relative to OPAC Desert aerosol



Screen some combinations using depolarization ratio and lidar ratio

Uncertainty in albedo is ±10%

Table 1. Ranges of the measured aerosol intensive parameters are given for all HSRL-1 classified measurements from 2006–2012. Ranges are given as first and last quartile, with 5th and 95th percentiles in parenthesis.

Aerosol Type	Aerosol Depolarization (%)	Lidar Ratio (sr)	Backscatter color ratio (532 nm : 1064 nm)	Depolarization Spectral Ratio (1064 nm : 532 nm)
Ice	23–32 (17–42)	18–33 (8–45)	1.3–2.3 (0.7–3.0)	0.7–1.1 (0.4–1.3)
Pure Dust	31–33 (30–35)	45–51 (41–57)	1.4–1.6 (1.0–1.7)	0.9–1.0 (0.8–1.1)
Dusty Mix	13–20 (10–28)	29–49 (14–63)	1.3–1.8 (1.1–2.3)	1.1–1.7 (0.8–2.1)
Marine	4–9 (2–13)	17–27 (9–33)	1.3–1.6 (1.2–1.8)	0.5–1.1 (0.2–1.5)
Polluted Marine	3–5 (1–6)	36–45 (27–50)	1.5–1.7 (1.3–1.8)	1.1–2.0 (0.4–2.8)
Urban	3–7 (2–10)	53–70 (43–81)	1.7–2.1 (1.4–2.5)	1.5–2.3 (1.1–3.1)
Smoke	4–9 (2–16)	55–73 (46–87)	1.9–2.5 (1.4–3.0)	0.4–0.9 (0.2–1.2)
Fresh Smoke	3–6 (2–8)	33–46 (24–52)	2.1–2.5 (1.9–2.8)	0.9–1.7 (0.3–2.3)

Burton et al. (2013)

Summary of aerosol and surface downward shortwave irradiance validation

- MATCH clear-sky aerosol optical thicknesses agree with MODIS aerosol optical thickness better than MERRA-2 aerosol optical thickness
- MATCH all-sky aerosol optical thicknesses are larger than MERRA-2 aerosol optical thickness especially over land (global mean difference is 0.024). Based on AERONET, there is no indication that MATCH aerosol optical thickness is biased high, except over dust regions.
- Computed downward shortwave irradiances under clear-sky conditions at small solar zenith angles tend to be positively biased but the reason for the bias is unknown.
- MATCH deseasonalized anomalies of aerosol optical thickness agree with MERRA-2 deseasonalized anomalies.
- MATCH produces too much sulfate and too little sea salt. This gives about 20% less direct aerosol radiative effect at TOA over a maritime clean environment (20% of ~ 5 Wm-2 direct aerosol radiative effect).
- Uncertainty in aerosol direct aerosol effect due to aerosol type is about 10%.

Edition 5 MATCH optical properties

- Aerosol optical properties used to compute mass extinction coefficients and those used in radiative transfer computations in CERES data products need to be consistent.
- Proposed 14 aerosol types
  - Sulfate, sulfuric acid, Sea Salt (4 size bins), Dust (4 size bins), hydrophobic organic carbon, hydrophilic organic carbon, hydrophobic black carbon, hydrophilic black carbon.
  - No ash (TBD).
  - (Edition 4: Sulfate (suso), OPAC water soluble, insoluble (organic), black carbon, sea salt, small dust and large dust.

Edition 5 MATCH

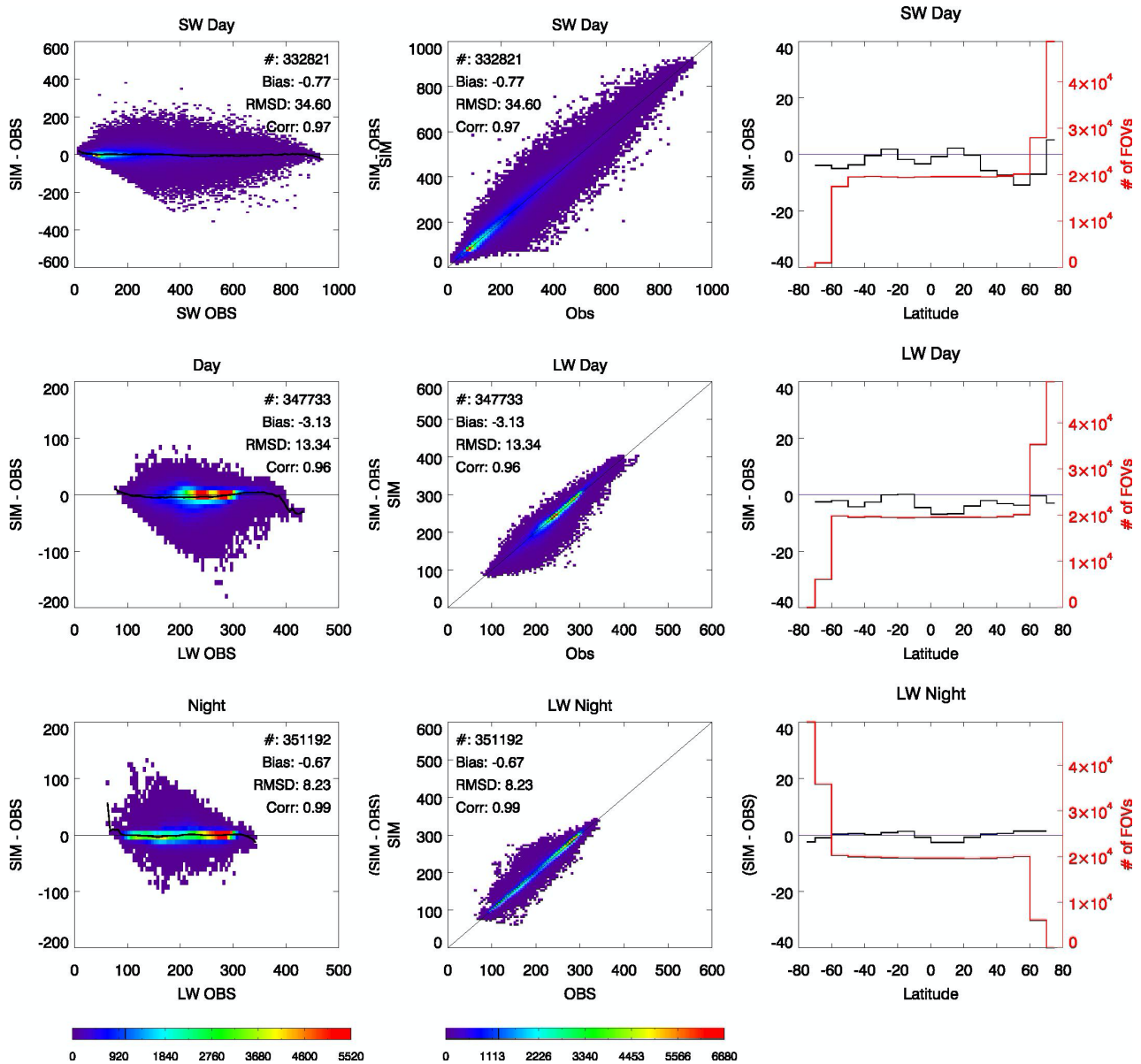
- Incorporate CAM 6.3 Bulk Aerosol Module physics module and aerosol package into existing MATCH MODIS/VIIRS AOD assimilation framework.
- Increase spatial resolution, ~ x 2 in horizontal (1 degree) and vertical (40 levels), temporal output to remain hourly.
- Aerosol and chemical source inventories are to be determined, static emissions versus time dependent emission (need to considerlatency issue).

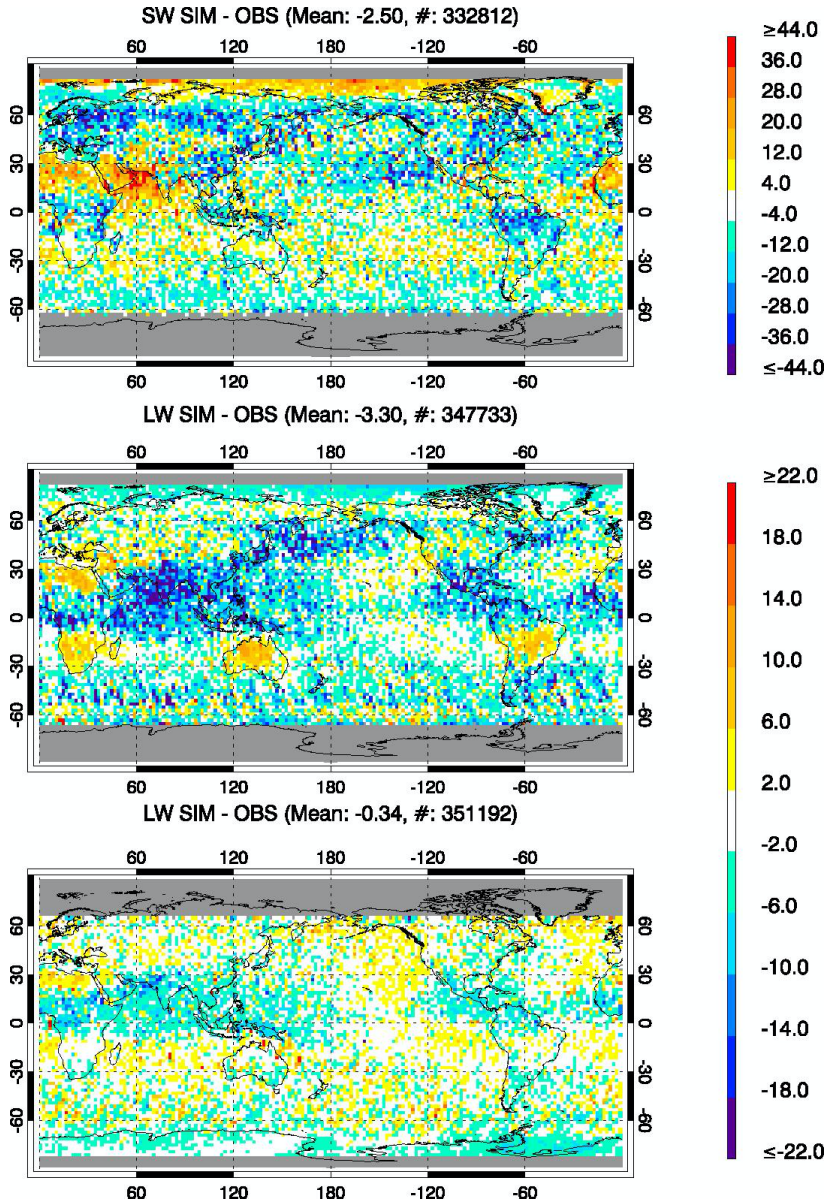
AIRS vs. CrIS comparison summary

- Prepare for the Aqua – NOAA-20 transition.
- AIRS CrIS difference was largely due to cloud cleaning (i.e. sampling)
- CLIMCAPS AIRS and CrIS temperature and humidity are similar (level 3 products).
- Qing Yue of JPL will produce CLIMCAPS-Aqua.

RelD-beta3/ v7_vgrp_tarea_calip_top_PSCrvd_CAL_aer4_ir11_pts1_THM_ee2_wo_2BCWC_Liq_if_liqprcp_rmv_80km_Tw_Top_P850_ssf4_omee_ocn

ENH





No CALIPSO feature properties (dust fraction used, AOD) are used

CCCM revision summary

- Edition 4 clouds combined with Edition 4 ADM improve computed irradiance agreement with CERES.
- Enhanced cloud algorithm (one layer cloud cases only) improves the agreement (especially for daytime longwave).
- Aerosols. When MODIS AOD is available, CALIPSO AOD is not used. Aerosol layer heights and dust aerosol ID come from CALIPSO. Over land, the use of Deep-blue AODs gives a better agreement with CERES than the use of dark-target AODs (consistent with the MODIS team's merged product)

Publications

- Fillmore, D. W., D. A. Rutan, S. Kato, F. G. Rose, and T. E. Caldwell, 2021: Evaluation of aerosol optical depths and clear-sky radiative fluxes of the CERES Edition 4.1 SYN1deg data product, submitted to *Atmospheric Chemistry and Physics*.
- Ghiz, M. L., R. C. Scott, A. M. Vogelmann, J. T. M. Lenaerts, M. Lazzara, and D. Lubin, 2020: Energetics of surface melt in West Antarctica, the Cryosphere, DOI:10.5194/tc-2020-311.
- Ham, S.-H., S. Kato, F. G. Rose, N. G. Loeb, K.-M. Xu, T. J. Thorsen, M. G. Bosilovich, S. Sun-Mack, Y. Chen, and W. F. Miller, 2021: Examining cloud macrophysical changes over the Pacific for 2007-2017 using CALIPSO, CloudSat, and MODIS observations, submitted to *Journal of Applied Meteorology and Climatology.*
- Painemal, D., Corral, A. F., Sorooshian, A., Brunke, M. A., Chellappan, S., Gorooh, V. A., S.-H. Ham, L. O'Neill, W. L. Smith Jr., G. Telioudis, H. Wang, X. Zeng, and P. Zuidema, 2021: An overview of atmospheric features over the Western North Atlantic Ocean and North American East Coast—Part 2: Circulation, boundary layer, and clouds. Journal of Geophysical Research: Atmospheres, 126, e2020JD033423
- Kato, S., F. G. Rose, D. A. Rutan, N. G. Loeb, J. T. Fasullo, and K. E. Trenberth, and M. Satoh, 2021: Regional energy and water budget of the atmosphere over ocean, *J. Climate*, 34(11), DOI: 10.1175/JCLI-D-20-0175.1.
- Kato, S., and F. G. Rose, 2021: Reply to "Comments on 'Global and Regional Entropy Production by Radiation Estimated from Satellite Observations'", *Journal of Climate*, *34*(9), 3729-3731.
- Kato, S., F. G. Rose, F..-L. Chang, D. Painemal, and W. L. Smith, 2021: Evaluation of regional surface energy budget over ocean derived from satellites, submitted to *Frontiers in Marine Science*.
- Loeb. N. G., G. C. Johnson, T. J, Thorsen, J. M. Lyman, F. G. Rose, and S. Kato, 2021: Satellite and ocean data reveal marked increase in Earth's heating rate, submitted to *Geophysical Research Letter*.

Backups

Contribution to clear-sky OLR correction trend

(Thorsen's and Loeb's presentations for the method)

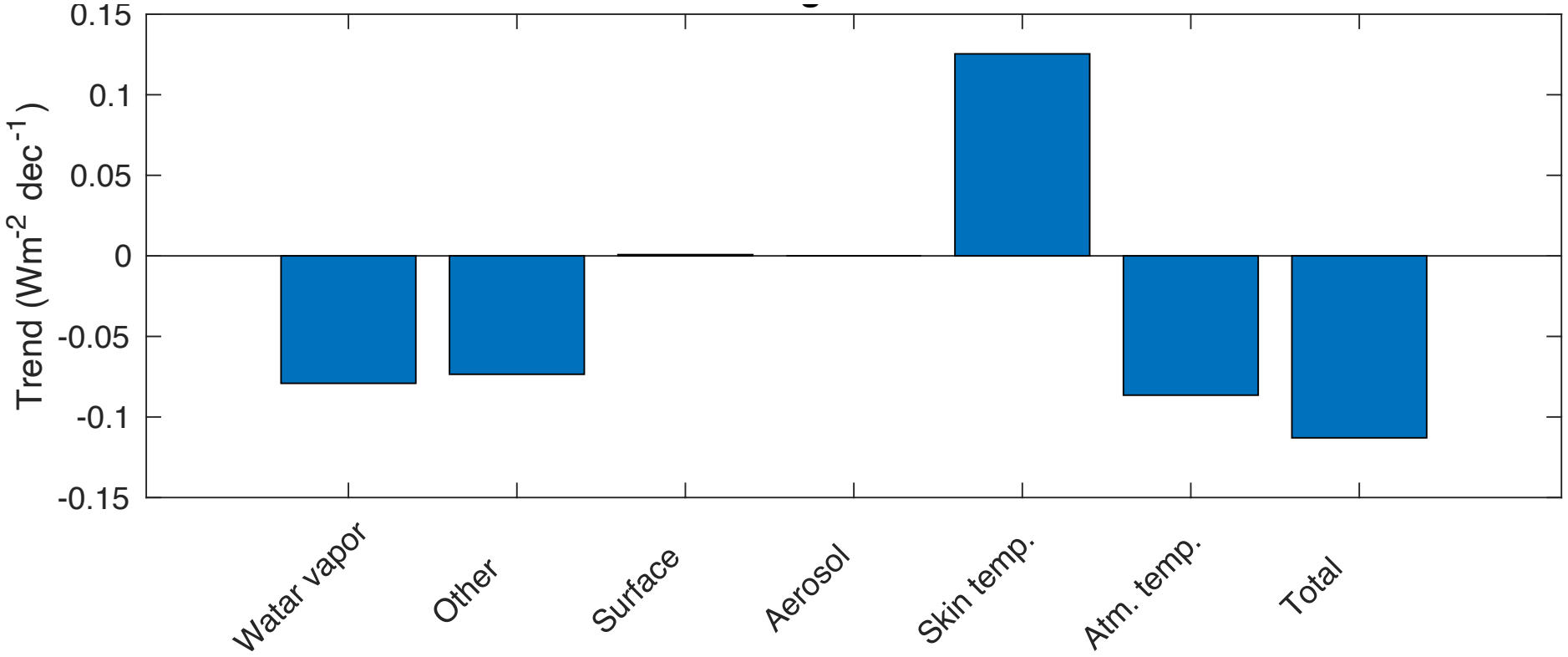
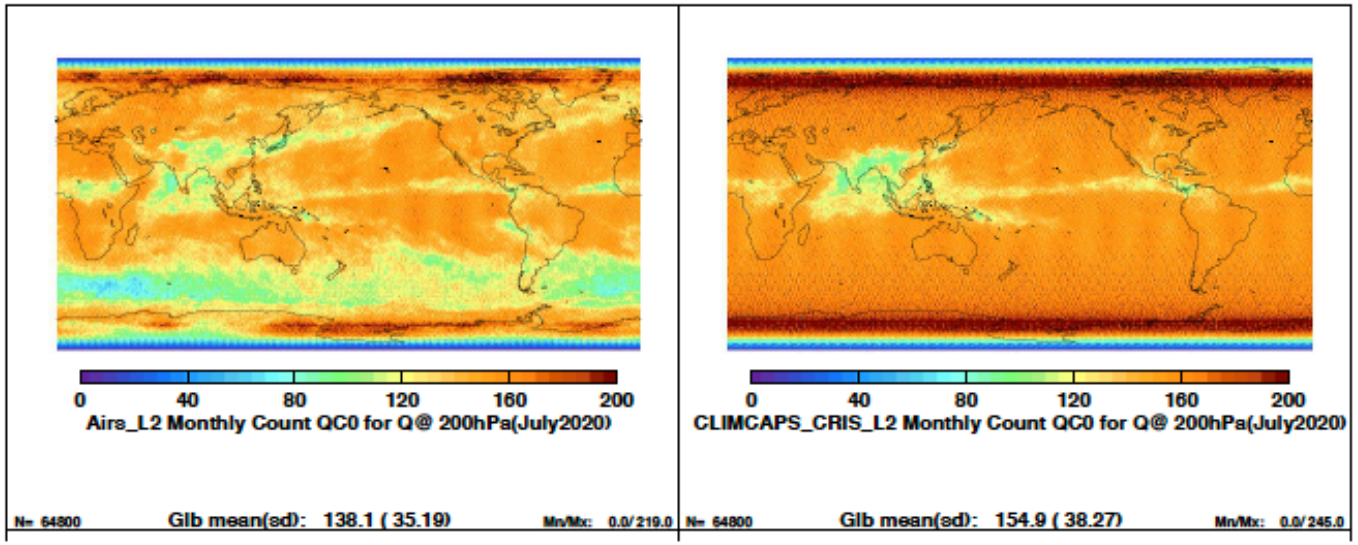


TABLE 1c. Microphysical properties of aerosol components in dry state. Here, σ, r_{modN}, r_{modV}, r_{min}, and r_{max} are parameters of the lognormal size distributions (see section 3c). The term ρ is the density of the aerosol particles and M^* is the aerosol mass per cubic meter air, integrated over the size distribution and normalized to 1 particle per cubic centimeter of air. The term M^* [(μg m^{-3}) (particles cm^{-3})$^{-1}$] is calculated with a cutoff radius of 7.5 μm.

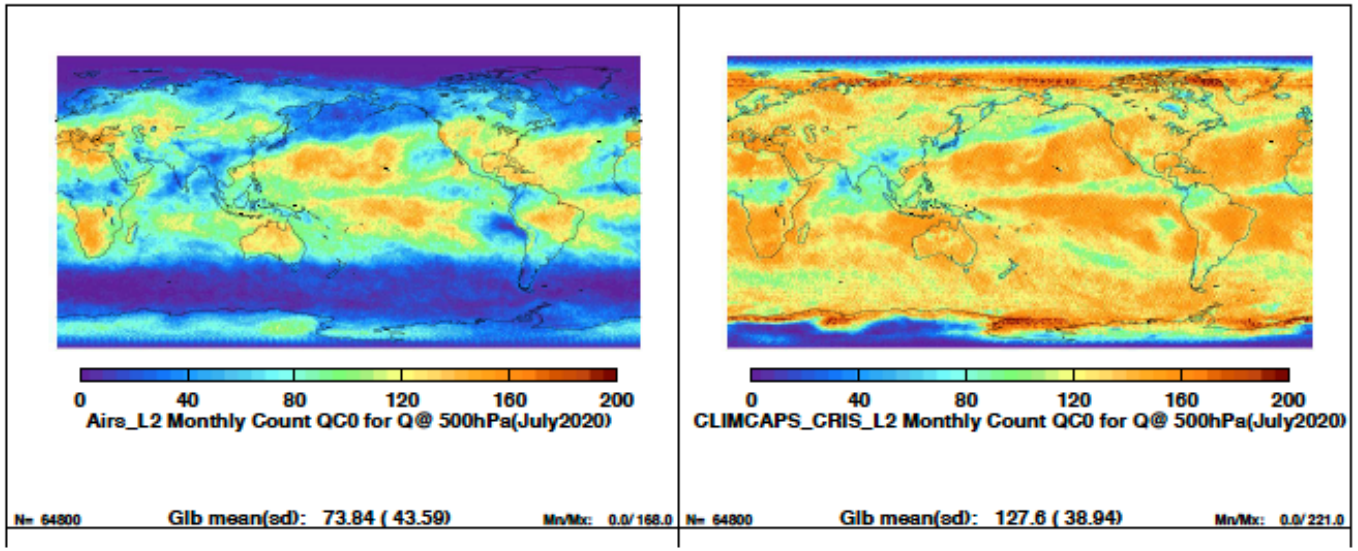
Component	File name	σ	r_{modN} (μm)	r_{modV} (μm)	r_{min} (μm)	r_{max} (μm)	ρ (g cm^{-3})	M^* (μg m^{-3})/ (part. cm^{-3})
Insoluble	INSO	2.51	0.471	6.00	0.005	20.0	2.0	2.37E1
Water-soluble	WASO	2.24	0.0212	0.15	0.005	20.0	1.8	1.34E–3
Soot	SOOT	2.00	0.0118	0.05	0.005	20.0	1.0	5.99E–5
Sea salt (acc. mode)	SSAM	2.03	0.209	0.94	0.005	20.0	2.2	8.02E–1
Sea salt (coa. mode)	SSCM	2.03	1.75	7.90	0.005	60.0	2.2	2.24E2
Mineral (nuc. mode)	MINM	1.95	0.07	0.27	0.005	20.0	2.6	2.78E–2
Mineral (acc. mode)	MIAM	2.00	0.39	1.60	0.005	20.0	2.6	5.53E0
Mineral (coa. mode)	MICM	2.15	1.90	11.00	0.005	60.0	2.6	3.24E2
Mineral-transported	MITR	2.20	0.50	3.00	0.02	5.0	2.6	1.59E1
Sulfate droplets	SUSO	2.03	0.0695	0.31	0.005	20.0	1.7	2.28E–2

Number of Retrievals Grid box per Month using QC=0(Best)

AIRS | CLIMCAPS CrIS



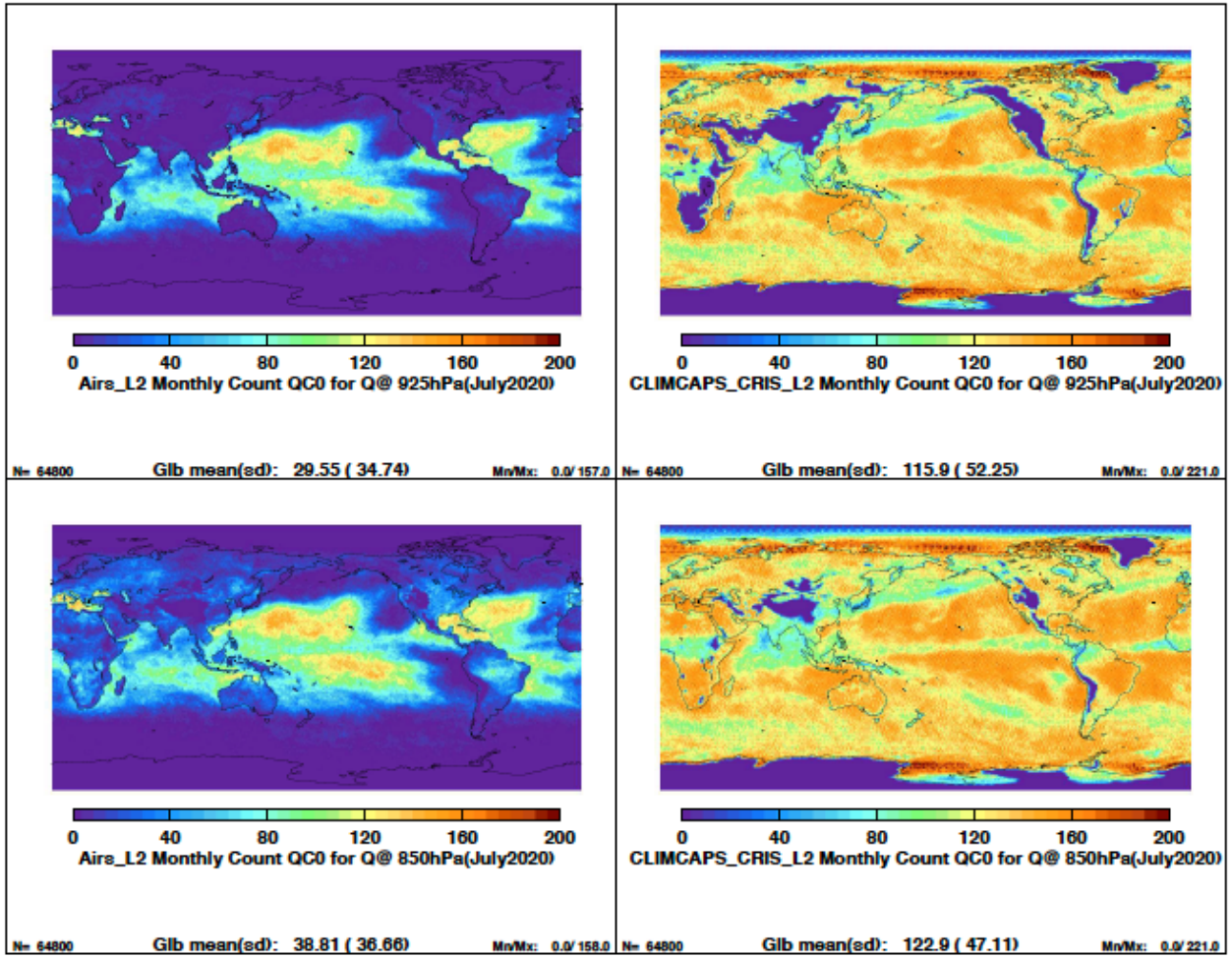
200 Hpa



500 Hpa

Number of Retrievals Grid box per Month using QC=0(Best)

AIRS CLIMCAPS CrIS

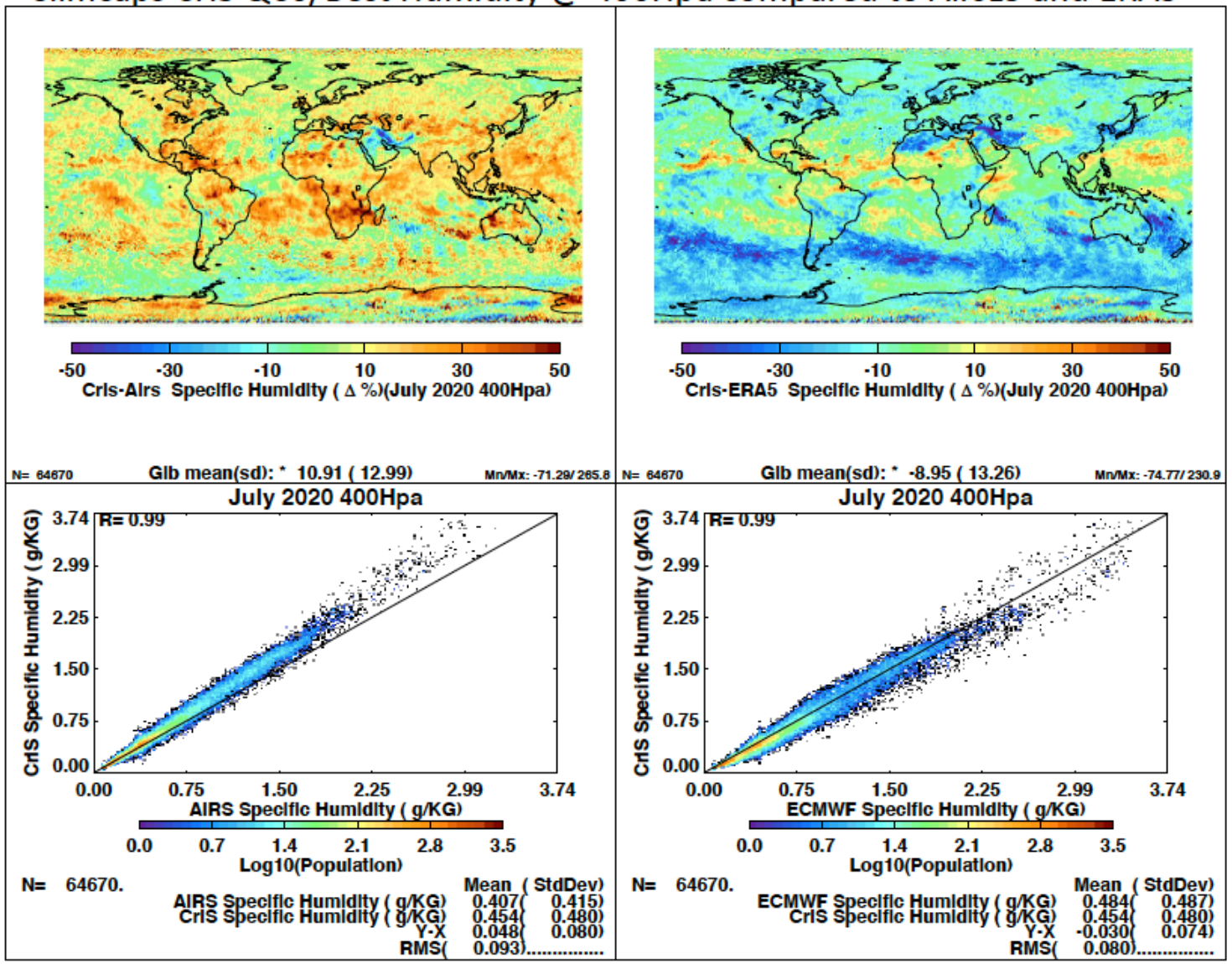


925 Hpa

850 Hpa

Monthly Mean July 2020

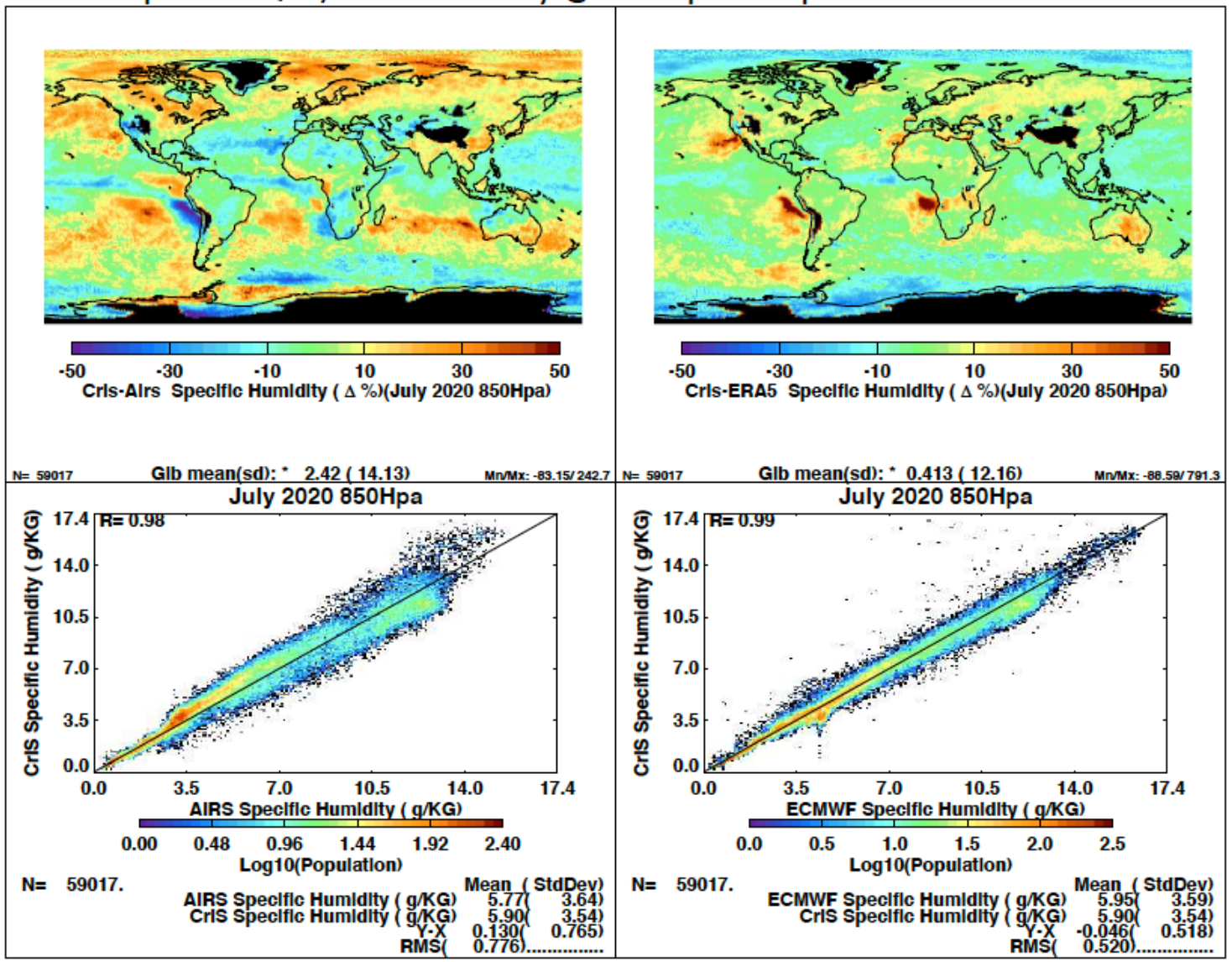
Climcaps CrIS QC0/Best Humidity @ 400Hpa compared to AirsL3 and ERA5



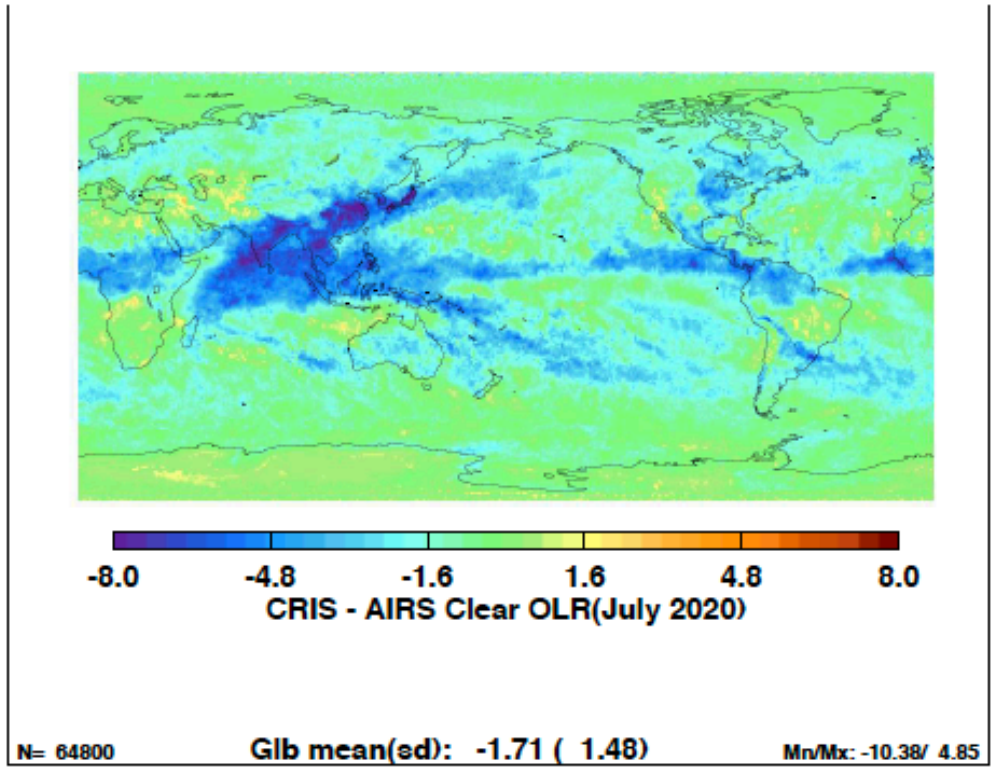
AIRS is dryer Because AIRS is more conservative to clear clouds

Monthly Mean July 2020

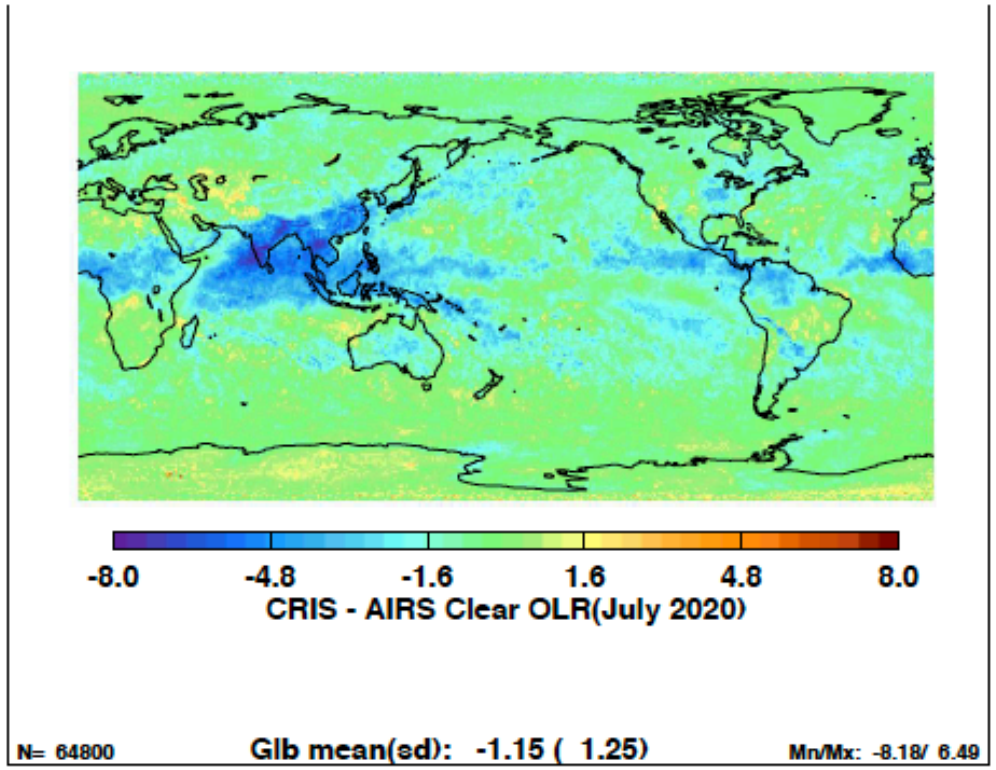
Climcaps CrIS QC0/Best Humidity @ 850Hpa compared to AirsL3 and ERA5



No QC filtering of CrIS Climcaps
Fuliou Monthly Cris-AirsL3



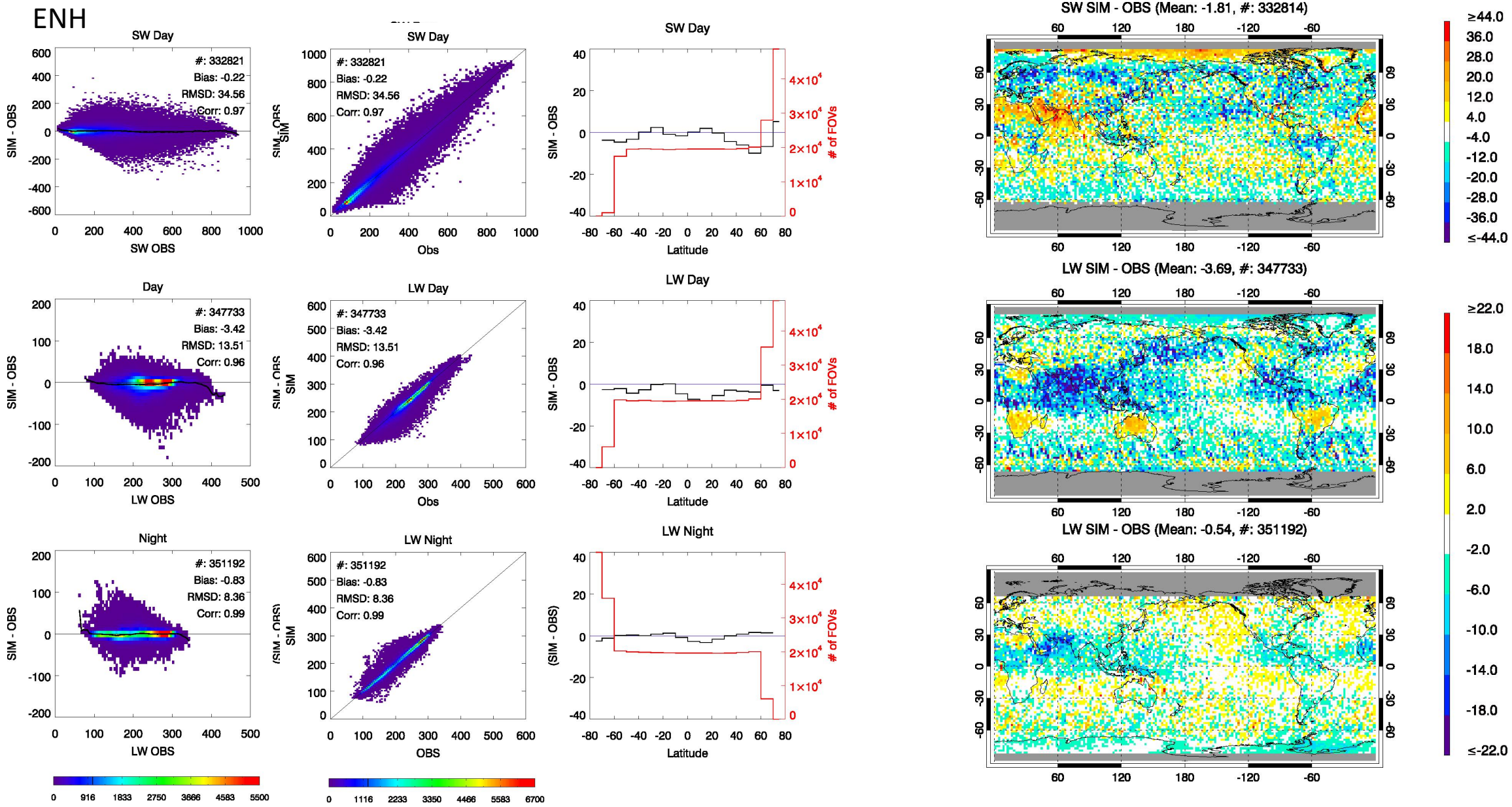
QC=0 (best only) filtering of CrIS Climcaps
Fuliou Monthly Cris-AirsL3



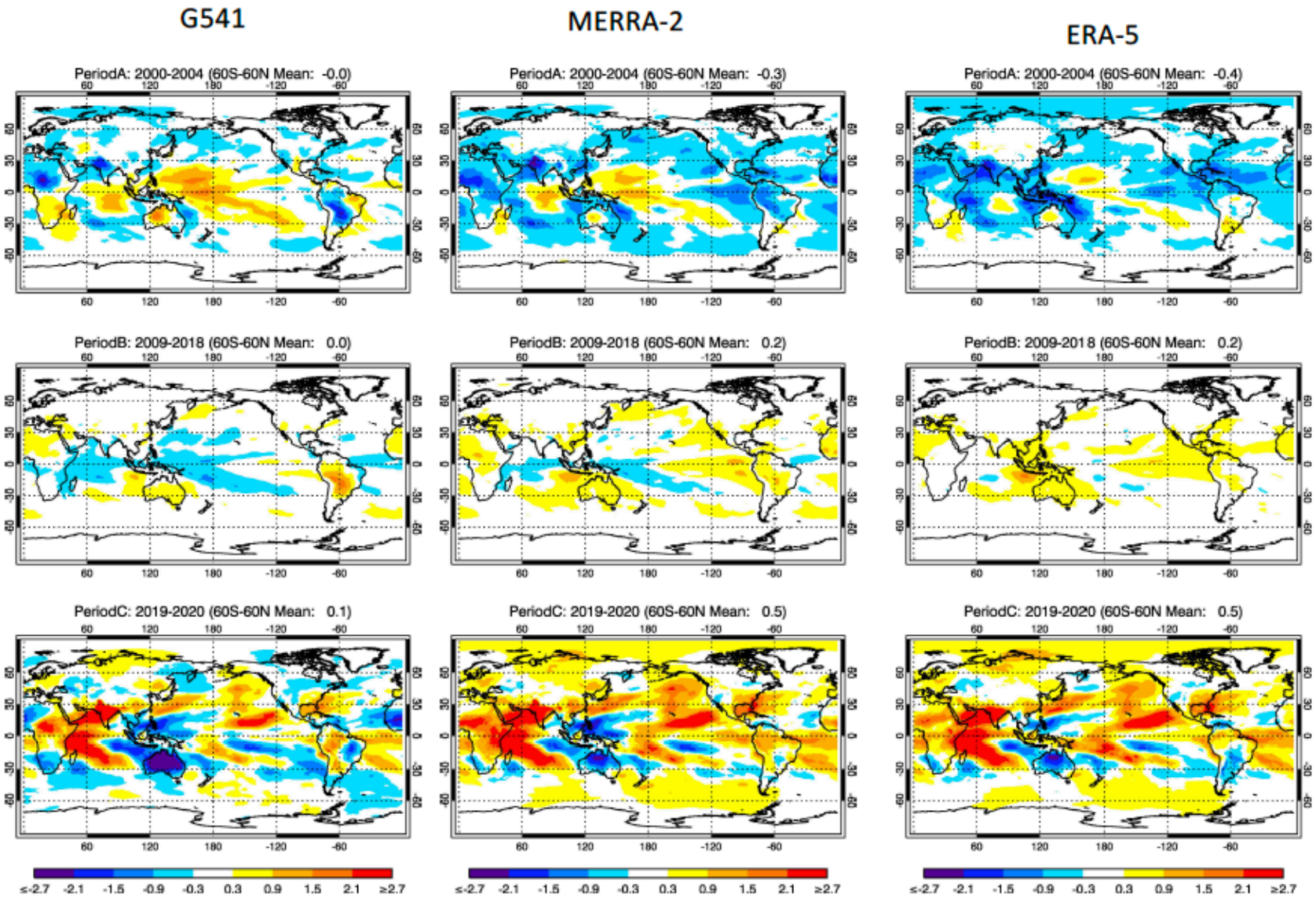
MATCH: No MODIS nor CALIPSO aerosols are used.
Aer1 : The original method used in RelB.
Aer3: CALIPSO AOD is not used anymore when MODIS AOD is available. Deep—blue MODIS AOD is used.
Aer4: CALIPSO feature properties are not used since the averaging requires some assumptions.

	MATCH Only	Aer1	Aer3	Aer4
MATCH Aerosol as default	Y	Y	Y	Y
MODIS Land Dark-Target updates MATCH AOD (Clear Daytime)	N	Y	Y	Y
MODIS Land Deep-blue AOD overwrites MATCH or Land Dark-target AOD if it is available (Clear Daytime)	N	N	Y	Y
MODIS Ocean Dark-Target AOD updates MATCH AOD (Daytime)	N	Y	Y	Y
CALIPSO dust fraction (obtained from feature AODs) modifies MATCH aerosol type fractions when MODIS AOD is not available	N	Y	Y	N
CALIPSO dust fraction (obtained from feature AODs) modifies MATCH aerosol type fractions when MODIS AOD is available	N	N	Y	N
CALIPSO COLUMN AOD updates MATCH AOD when MODIS AOD is not available	N	Y	Y	Y
CALIPSO Feature AOD updates MATCH AOD when CALIPSO COLUMN and MODIS AOD is not available	N	Y	Y	N
CALIPSO COLUMN AOD is used to scale MODIS AODs at multiple wavelengths	N	Y	N	N
CALIPSO Feature AOD (Backup of COLUMN AOD) is used to scale MODIS AODs at multiple wavelengths	N	Y	N	N
CALIPSO aerosol profiles A (obtained from VFM aerosol boundaries) updates MATCH aerosol profile shapes regardless of dust/nondust types	N	Y	Y	Y
If CALIPSO aerosol profile A is not available, CALIPSO aerosol profiles B (obtained from feature aerosol boundaries) updates MATCH aerosol profile shapes for dust and non-dust types.	N	Y	Y	N
Consistent weights for averaging CALIPSO feature aerosol properties (e.g., Area, Horavg, etc)	NA	N	Y	Y

RelD-beta3/ v7_vgrp_tarea_calip_top_PSCrvd_CAL_aer3_ir11_pts1_THM_ee2_wo_2BCWC_Liq_if_liqprcp_rmv_80km_Tw_Top_P850_ssf4_omee_ocn



Once MODIS AOD is available, CALIPSO AOD is not used. Deep-blue Land is preferred to dark-target algorithm.

PW TOA-SFC

- In period A (2000-2004), PW anomaly is negative, explaining positive anomalies of [EBAF_t]-[EBAF_c].
- In periodi C, WV decreased over deep convection region, even with global increase, partly explaining positive anomalies of [EBAF_t]-[EBAF_c].