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
September 15-17, 2020

Outline of this presentation

- MATCH aerosol transport model
- Surface downward shortwave irradiance anomalies during COVID-19 period (January, February, and March 2020).
- Effect of Australia fire on radiation budget in January 2020
- Level 3 surface radiation data product (SYN1deg) after Terra starts to drift in 2021.
  - Edition 4.1: (Terra+Aqua+GEOs ->) Aqua+GEOs -> NOAA-20(+Aqua)+GEOs
  - Edition 5: TBD
    - Quantify GEO artifacts and diurnal cycle of surface irradiances

Work done after the 2020 spring meeting

- Edition 4.1 EBAF and SYN1deg
- Extended through March 2020
- Fu-liou code k-distribution and CKDMIP
- MATCH aerosol validation
    - Processing (the first day of the month) issue
    - COVID-19
    - January 2020 Australian fires
  - MATCH AOD under partly cloudy conditions
  - Dust aerosols in the no-assimilation run (March 2020).
- Aqua only SYN run
  - A Bug in the MATCH input preparation code leads to a problem in 2004 (July through December).
    - Documented in SYN1deg Data Quality Summary
  - Comparison of 201907 5 cases: Ed4.1. vs. Aqua+GEO vs. Aqua with no GEO vs. Terra with no GEO etc.
- SYN1deg Aqua only (Ed 4.1) versus SYN1deg NOAA-20 (Edition 1)
  - Polar night clouds
  - Thin cirrus over tropics
- MOSAiC data analysis
- GMAO telecon
- Edition 5 SYN (produced the list of variables to be included in TSI)
- C3M revision (Seung-Hee Ham’s presentation)
- CRS (Ryan Scott’s presentation)
- Fingerprinting

MATCH aerosol transport model (Edition 4)

- Climatological aerosol source from the surface.
  - Sea salt and dust might depend on surface wind speed
- Anomalies (deviation from the climatology) of aerosol loading come from MODIS aerosol optical thickness.
- MATCH learns deviations from climatological mean aerosols from MODIS.
- Time to take MATCH to learn aerosol anomalies depends on individual case.
- Wind vectors determine spatial distribution of aerosols
- Precipitation is needed for aerosol sink (scavenging)
- Some chemistry modeling (e.g. oxidize sulfur to produce sulfate)

Aerosol optical thickness sources

Satellites	Retrieval algorithm	Starting periods
Terra	Dark target + Deep blue	March 2000
Aqua	Dark target + Deep blue	July 2002 (begins JD 185)
Terra+Aqua	Dark target + Deep blue	July 2002 (begins JD 185)
NPP	Dark target or Deep blue	February 2012 (begins JD 019)
NOAA-20	Depending on availability of VIIRS aerosol products	February 2018

MATCH assimilation of MODIS aerosol optical depth

Match Modis Assimilation (Modis Preprocessing)

1)Terra and Aqua Deep Blue and Dark Target hourly data are extracted and gridded into 192lon x 94lat daily files.

2) The four AOT fields are merged into a single daily gridded file.

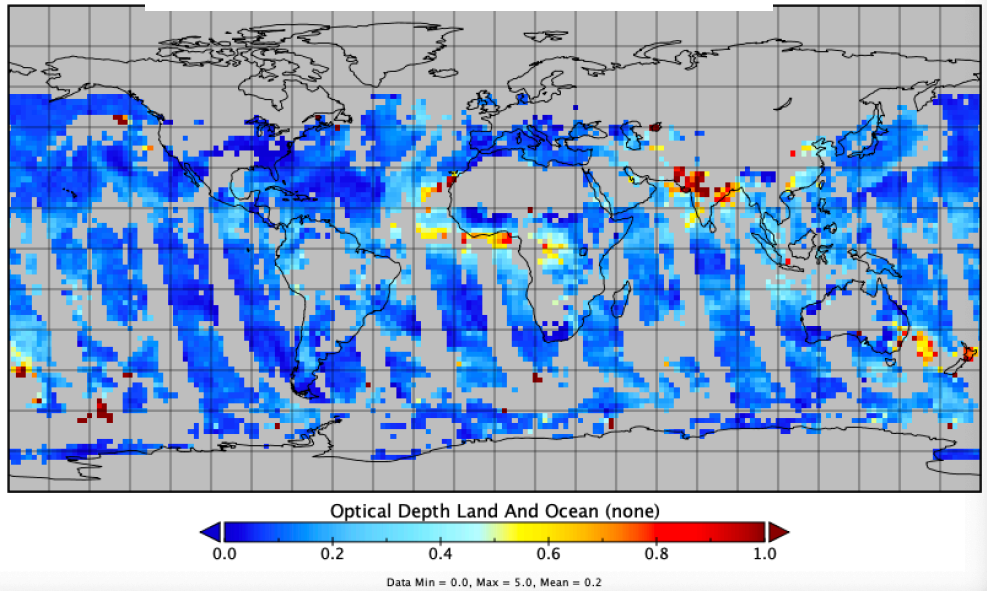
3) The merged daily field is sliced in to hourly 15 degree longitude bands

- Modis data is not directly assimilated at the overpass time
- Instead it is gridded averaged an assimilated at near Local Solar Noon

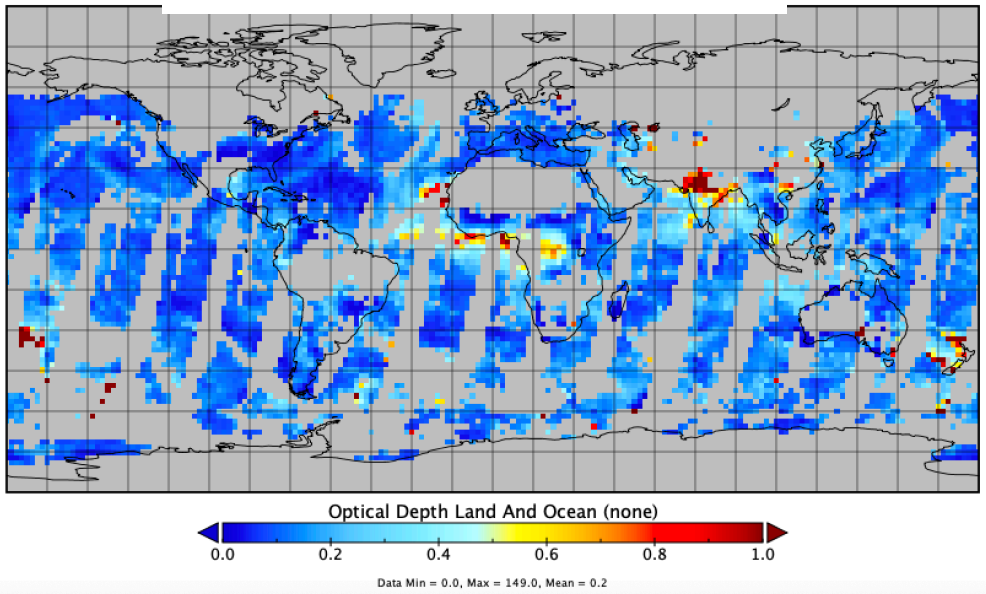
GMT:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
LON0:	180	165	150	135	120	105	90	75	60	45	30	15	0	-15	-30	-45	-60	-75	-90	-105	-120	-135	-150	-165
LON1:	165	150	135	120	105	90	75	60	45	30	15	0	-15	-30	-45	-60	-75	-90	-105	-120	-135	-150	-165	-180

MATCH pre-processed level2 hourly MOD04 into four Daily gridded fields(192x94)

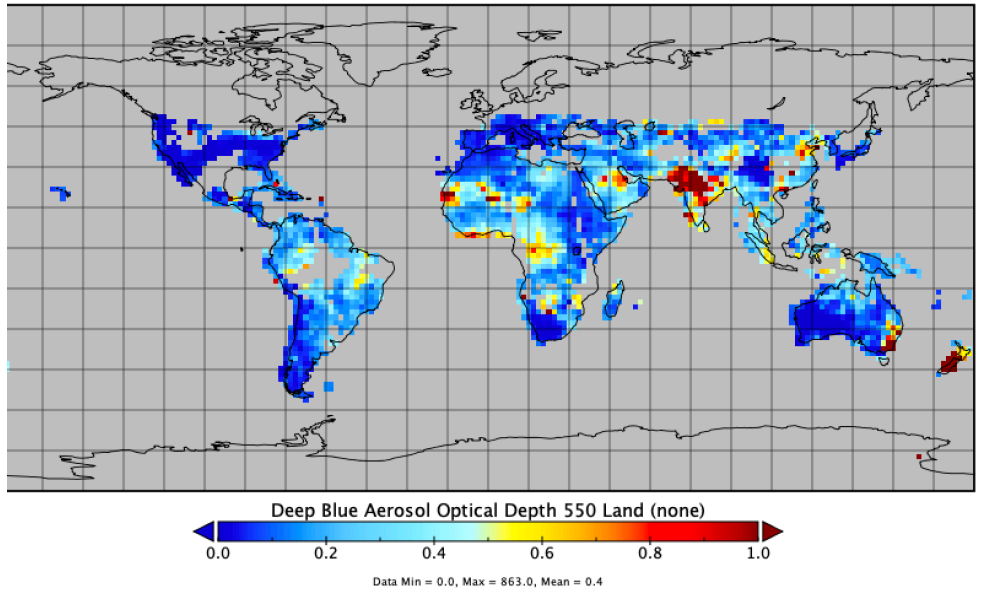
Jan 1 2020 Aqua (Dark Target)



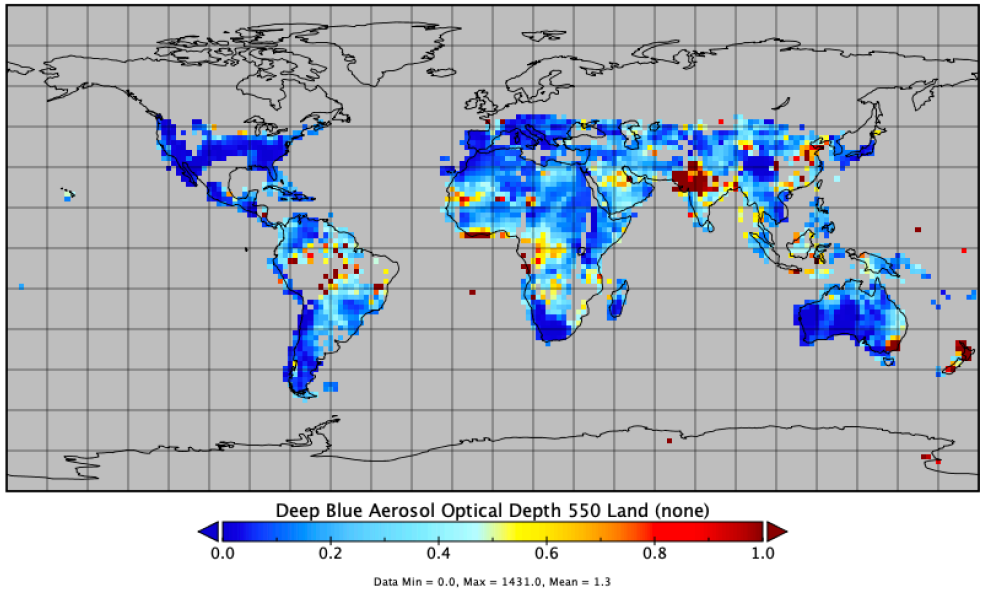
Jan 1 2020 Terra (Dark Target)



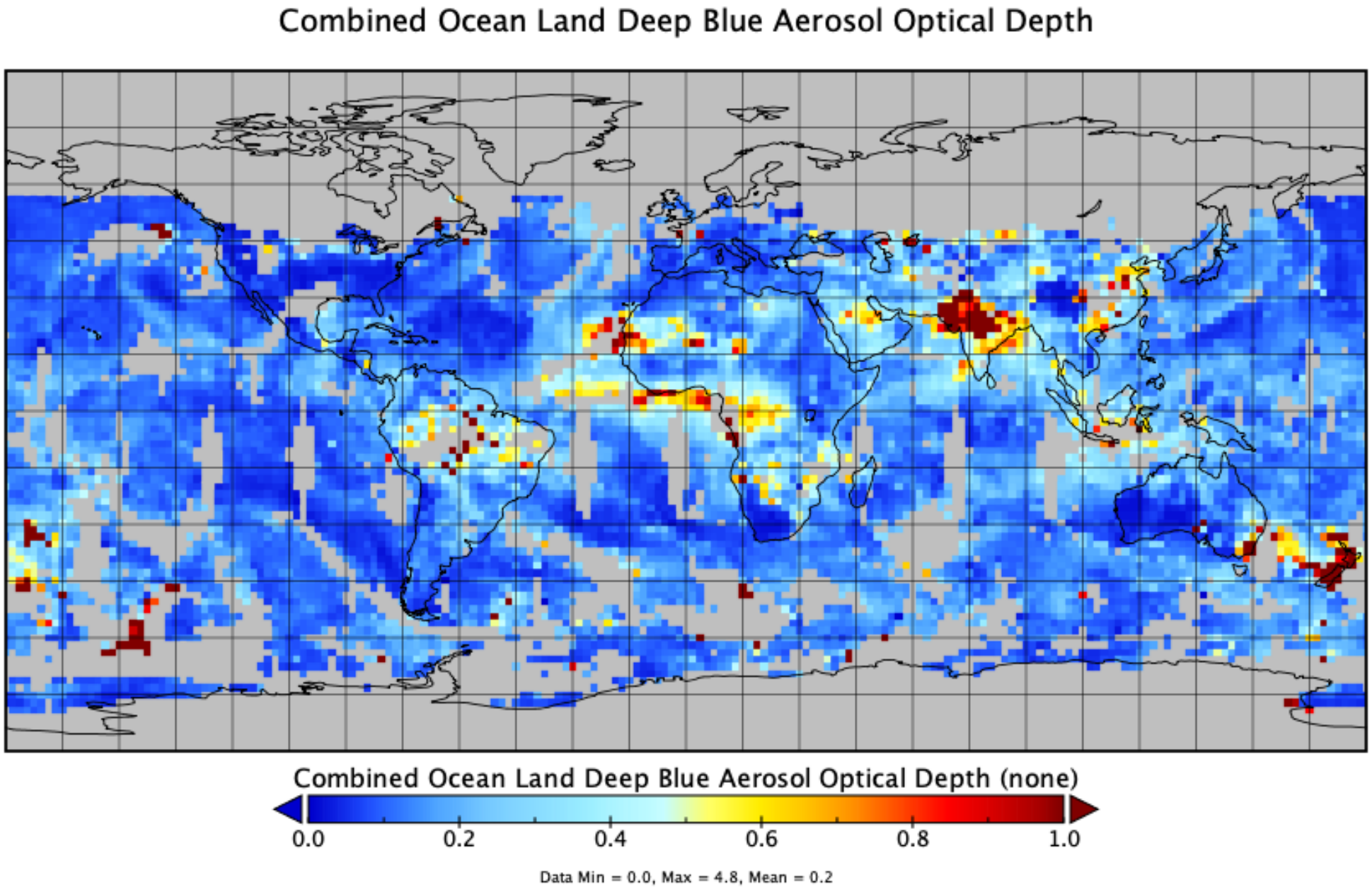
Jan 1 2020 Aqua (Deep Blue)



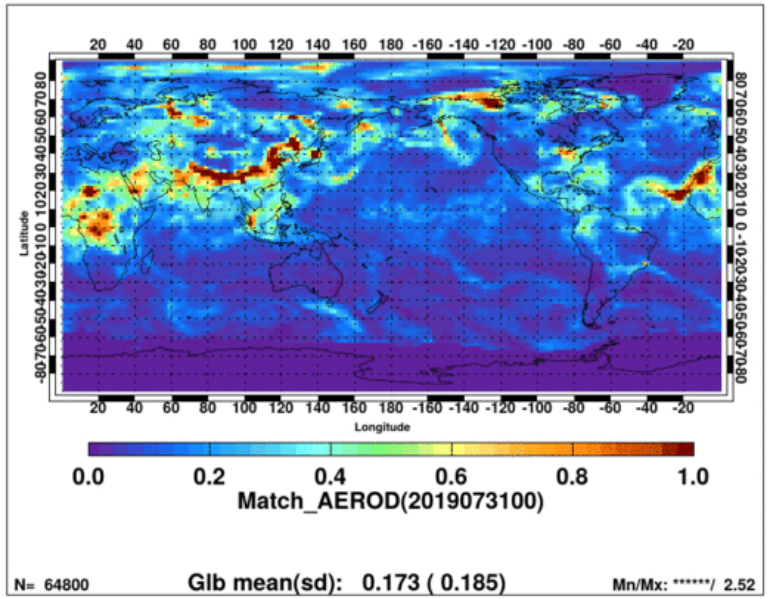
Jan 1 2020 Terra (Deep Blue)

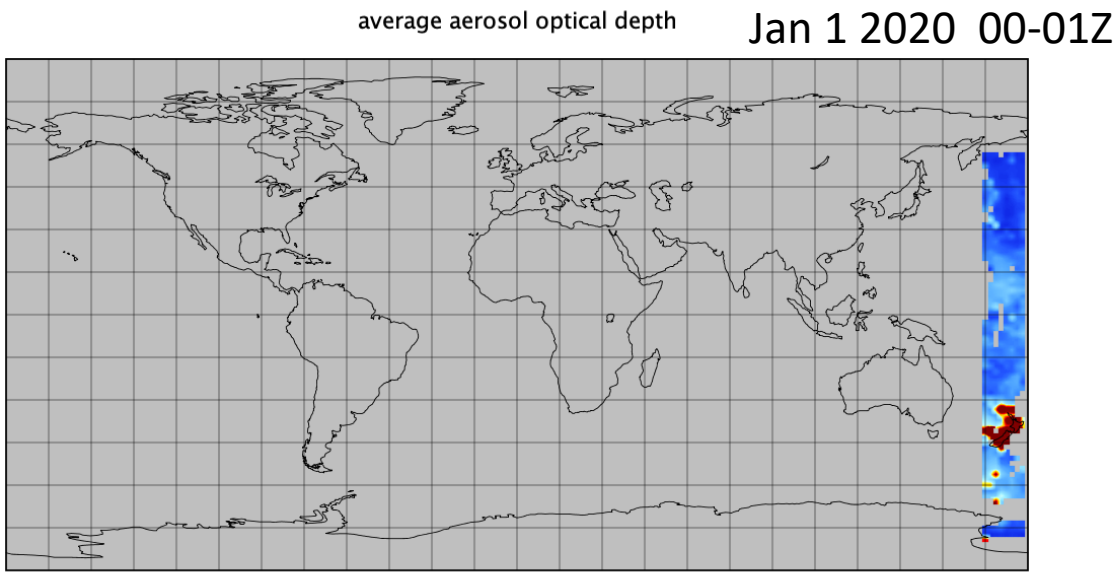


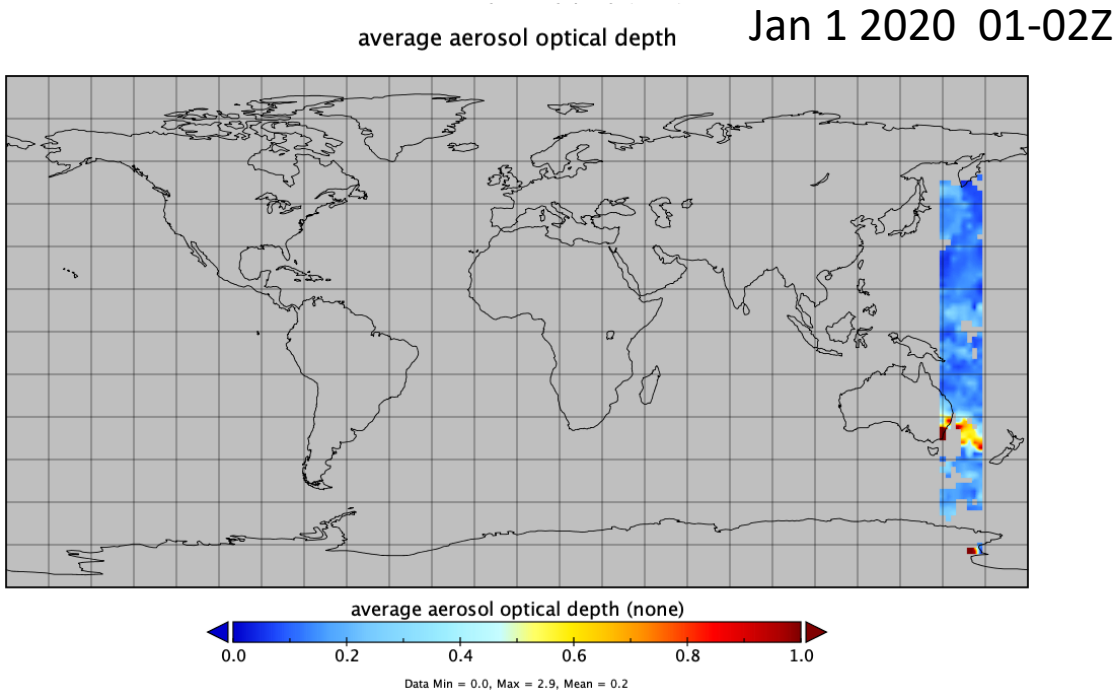
MATCH merges these 4 fields into a single Daily gridded AOT field (192x94)



The daily field is then sliced up by longitude band into hourly AOT fields (192x94)
That are the input for the hourly Match assimilation

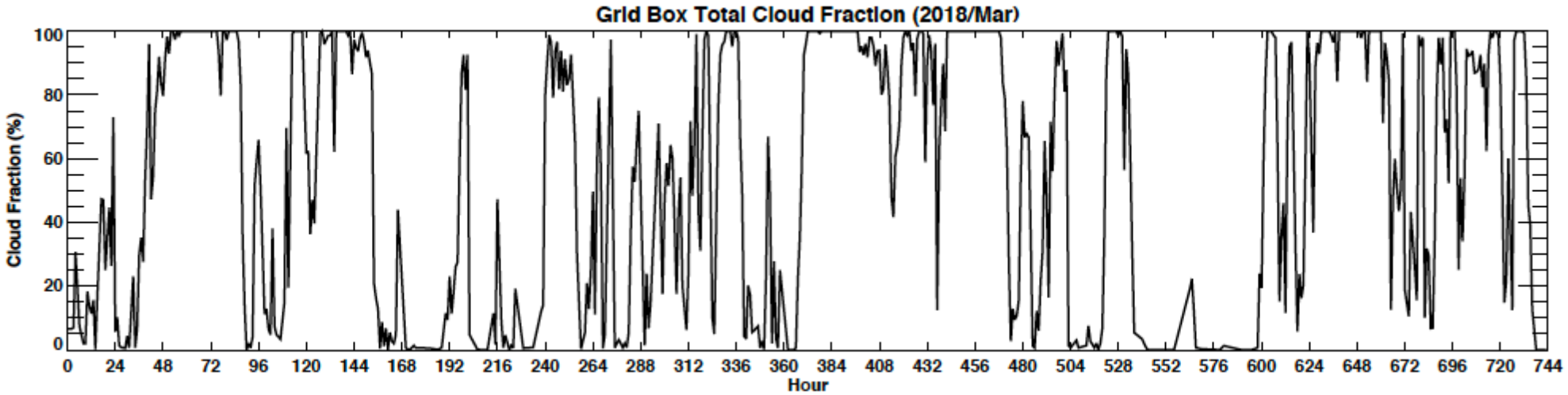


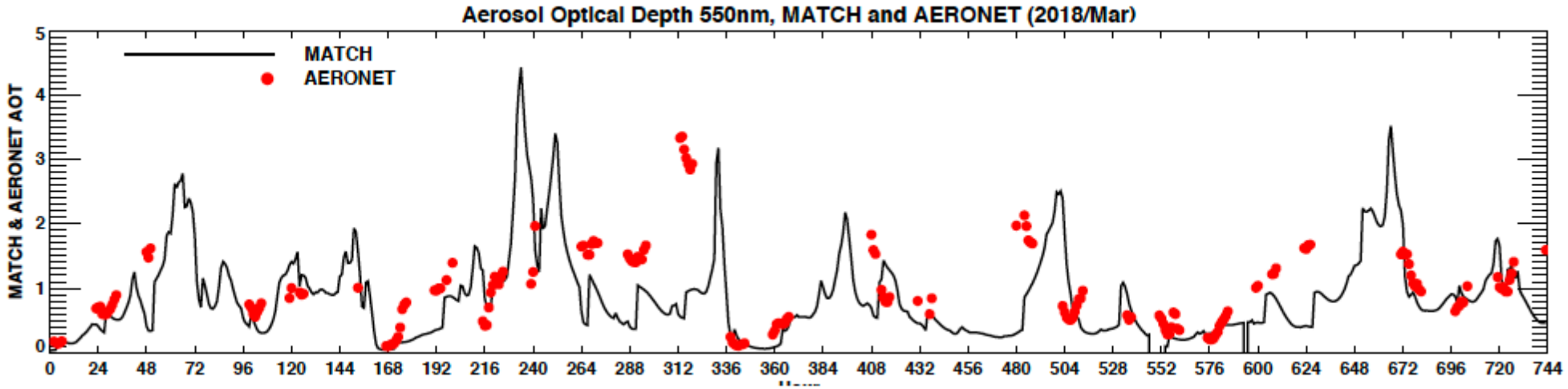




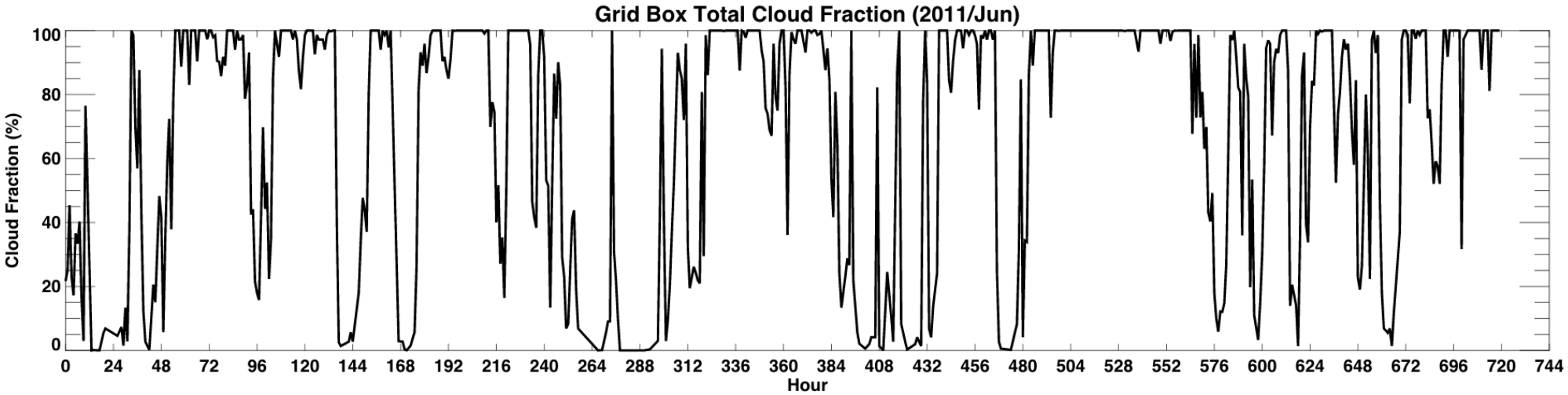
Note: Animation is for July 31 2019
This is just to illustrate the assimilation
Hourly bands moving across the globe.

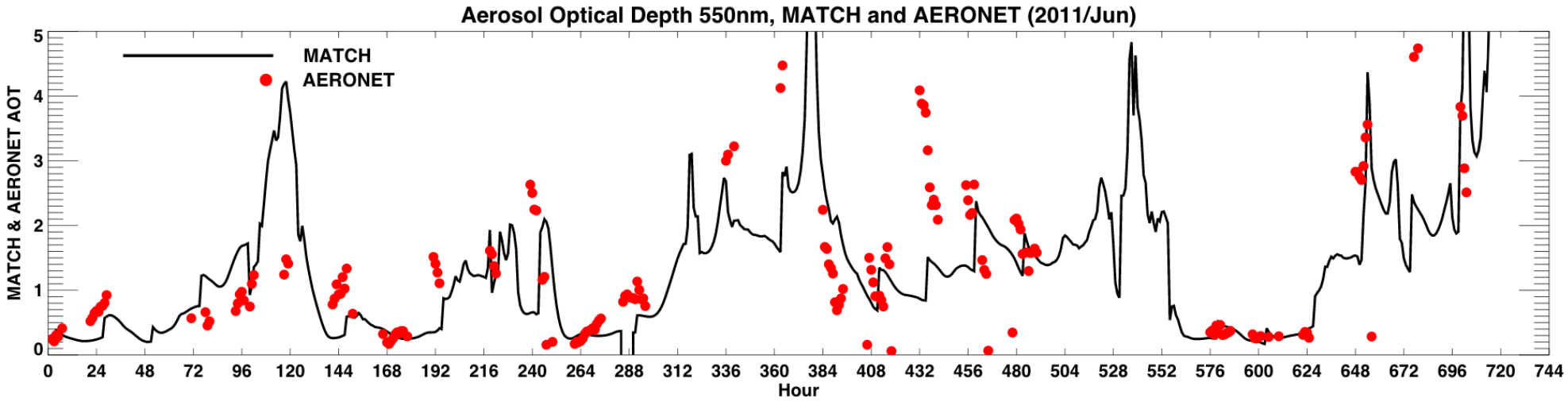
Comparison with AERONET: Beijing China, March 2018



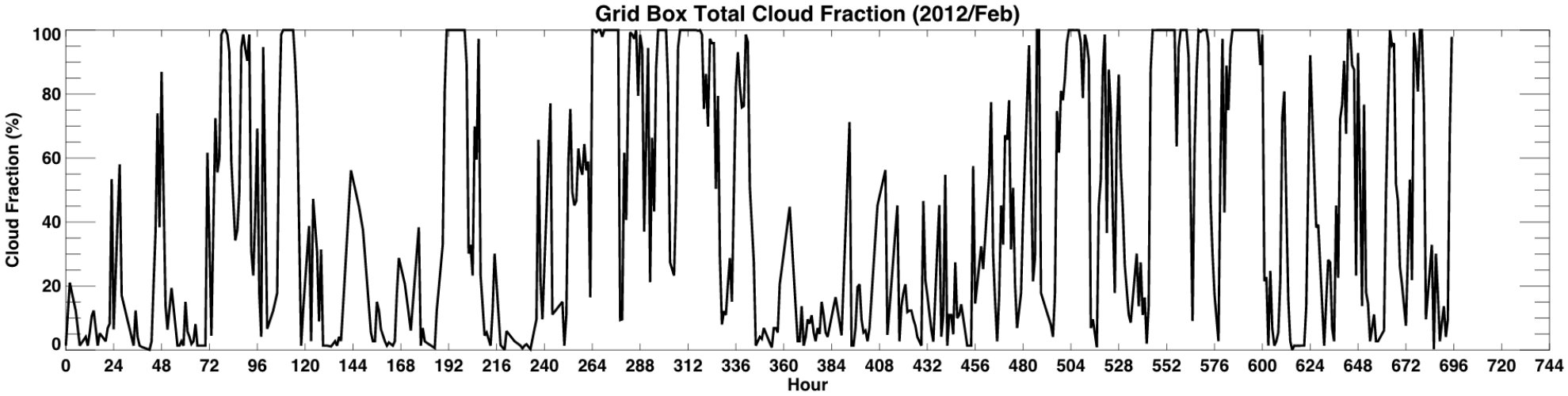


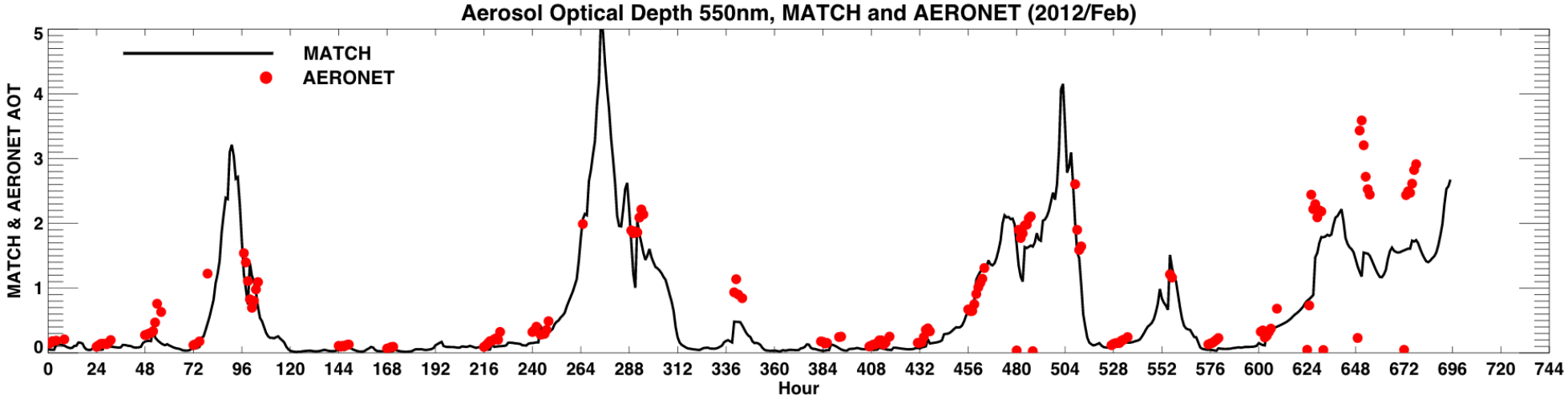
Comparison with AERONET: Beijing China, June 2011





Comparison with AERONET: Beijing China, February 2012

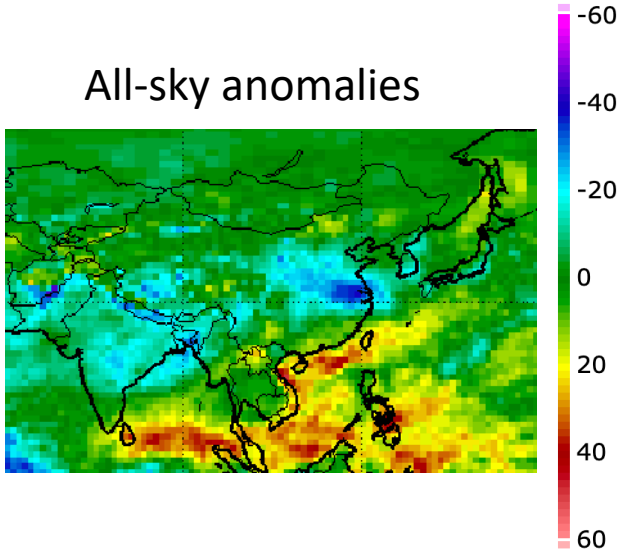




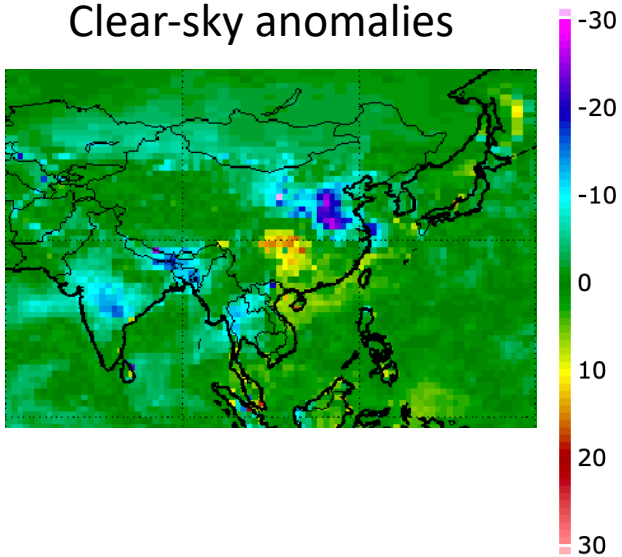
Surface downward shortwave clear-sky irradiance anomalies (Jan. Feb. March 2020)

EBAF surface downward shortwave irradiance anomalies January 2020 Clear-sky total region

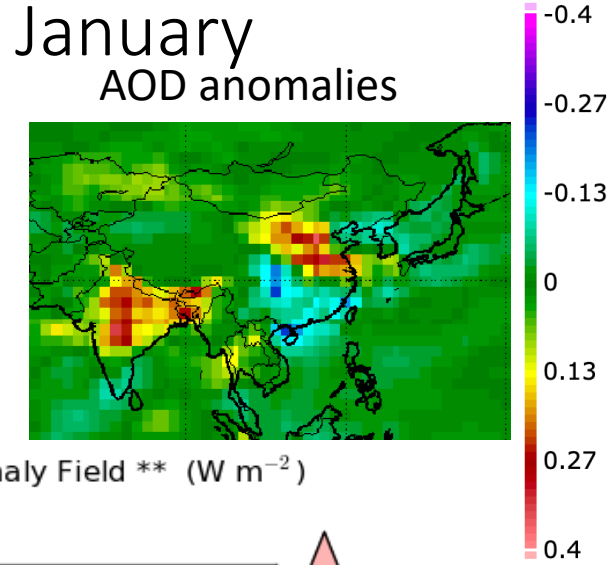
All-sky anomalies

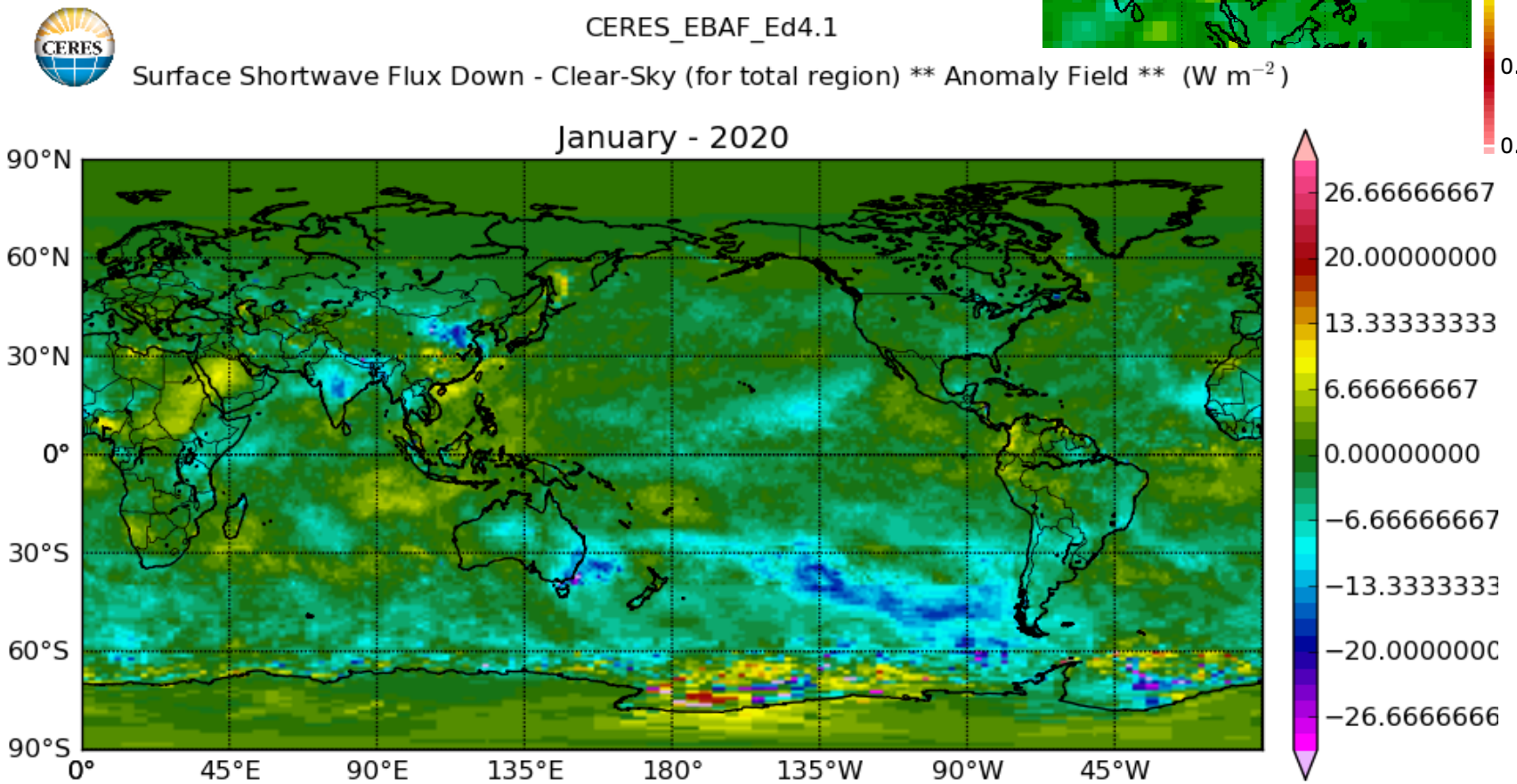


Clear-sky anomalies



AOD anomalies

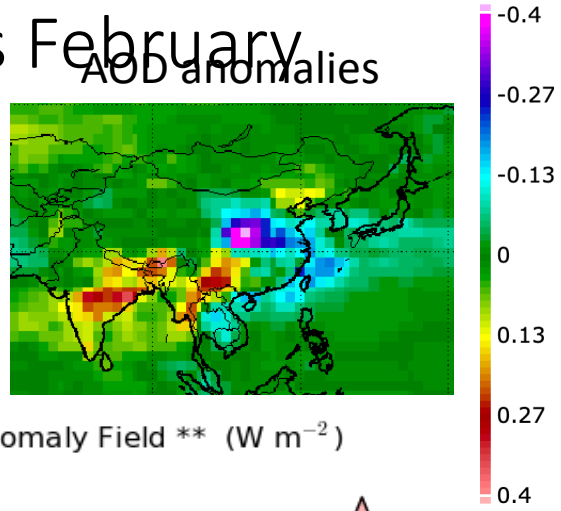




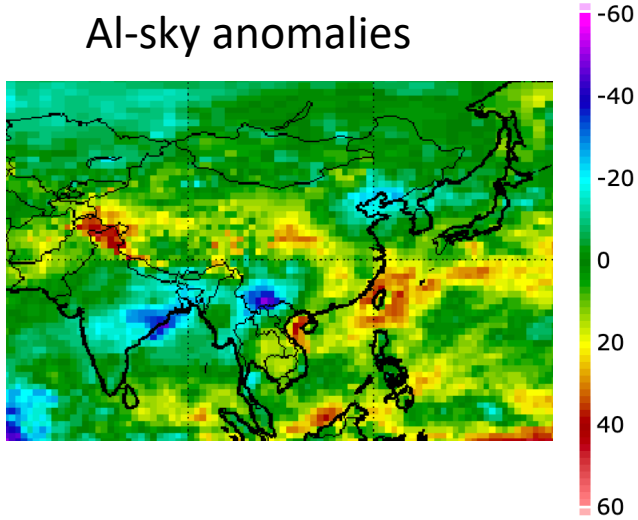
Generated at https://ceres.larc.nasa.gov

EBAF surface downward shortwave irradiance anomalies February 2020 Clear-sky total region

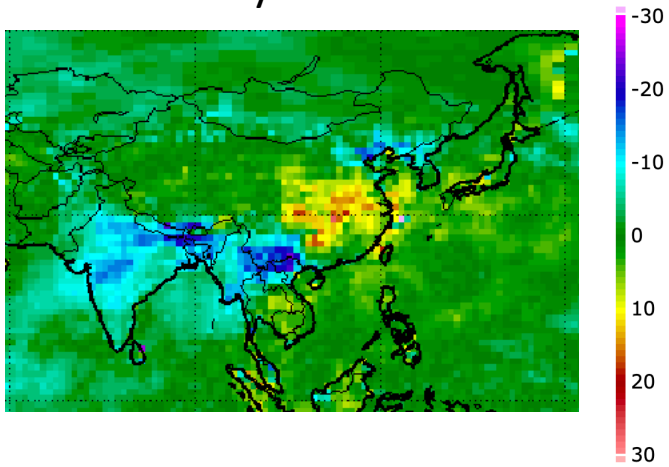
AOD anomalies

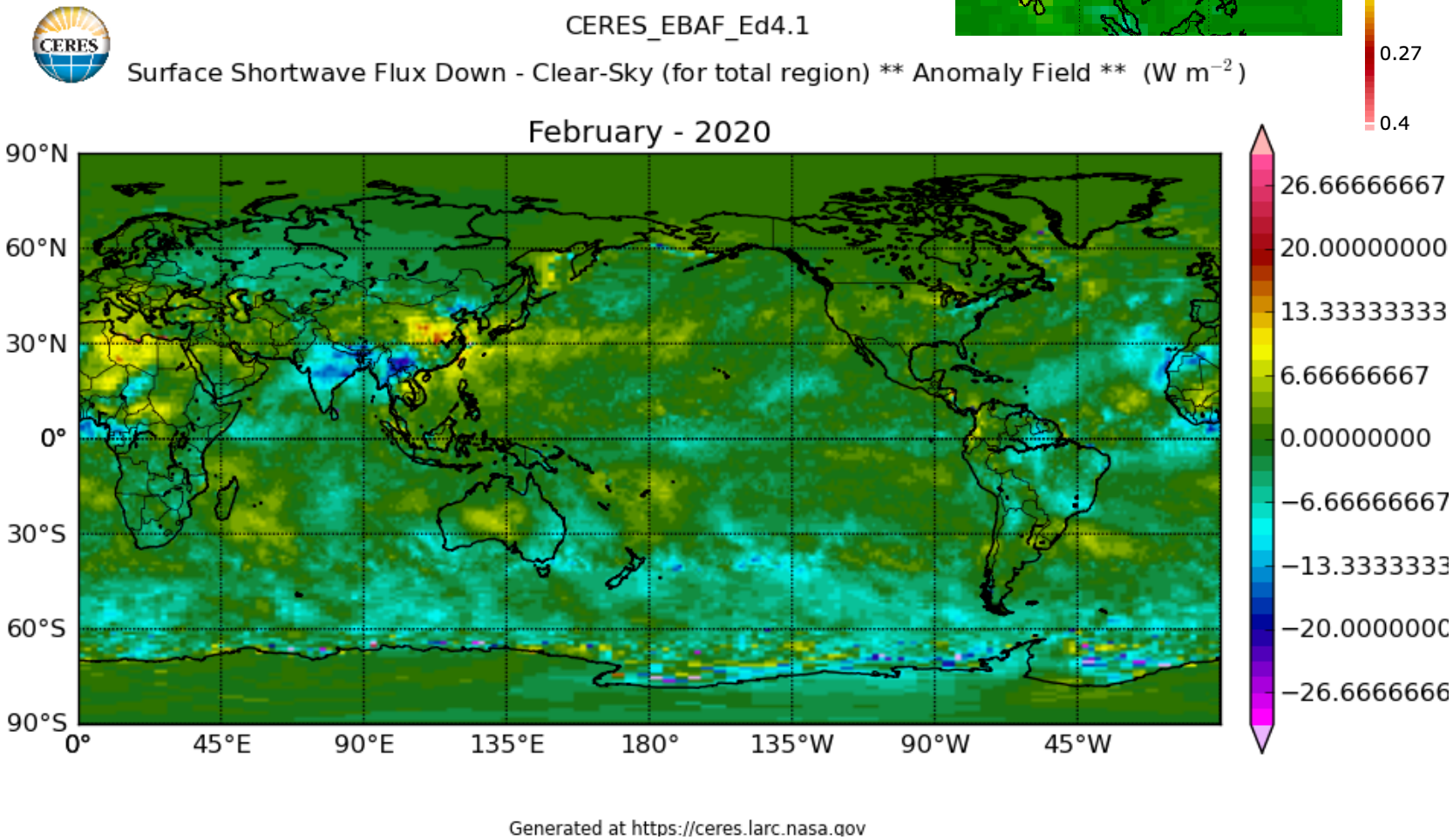


Al-sky anomalies



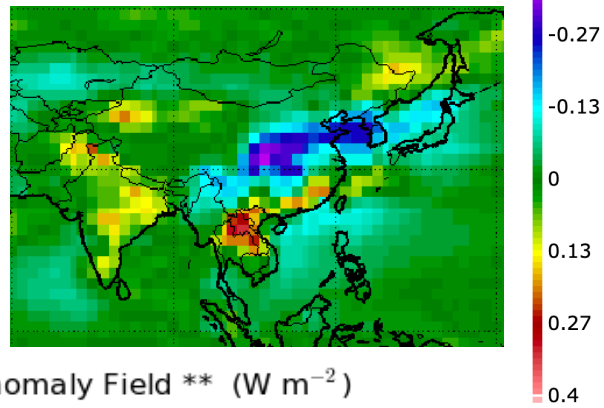
Clear-sky anomalies



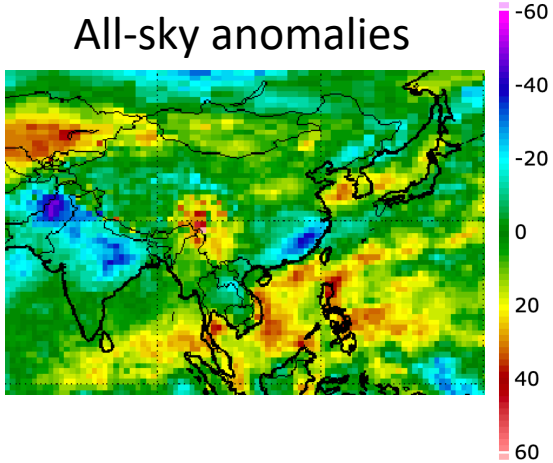


EBAF surface downward shortwave irradiance anomalies March 2020 clear-sky total region

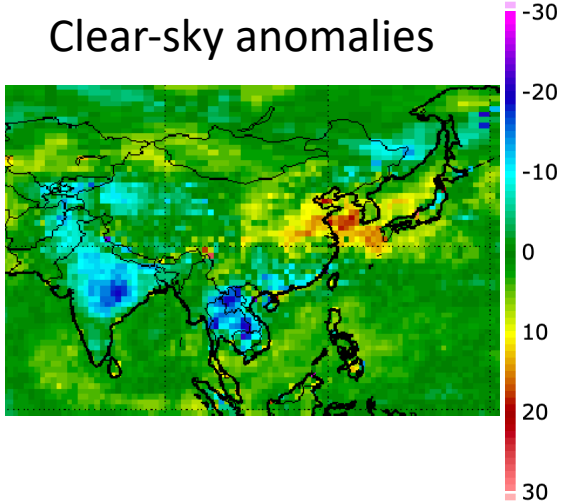
AOD anomalies

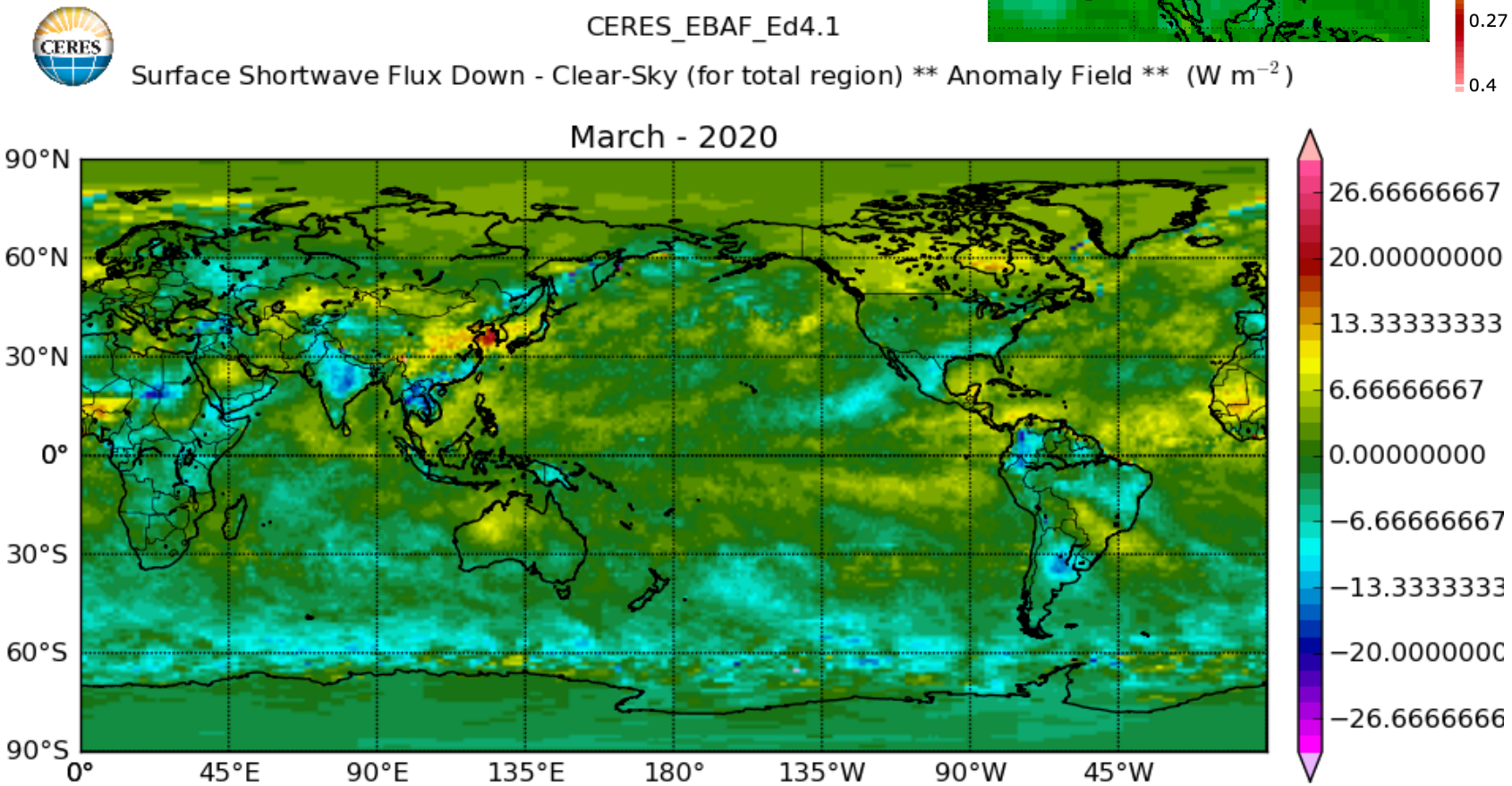


All-sky anomalies



Clear-sky anomalies

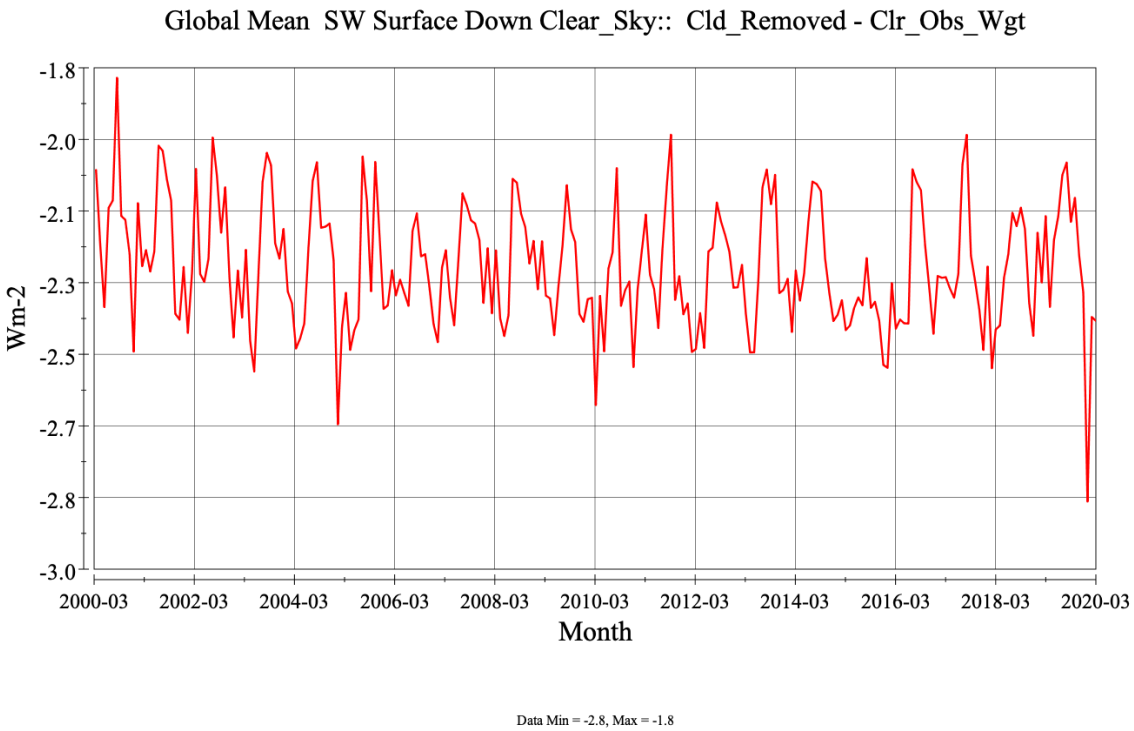


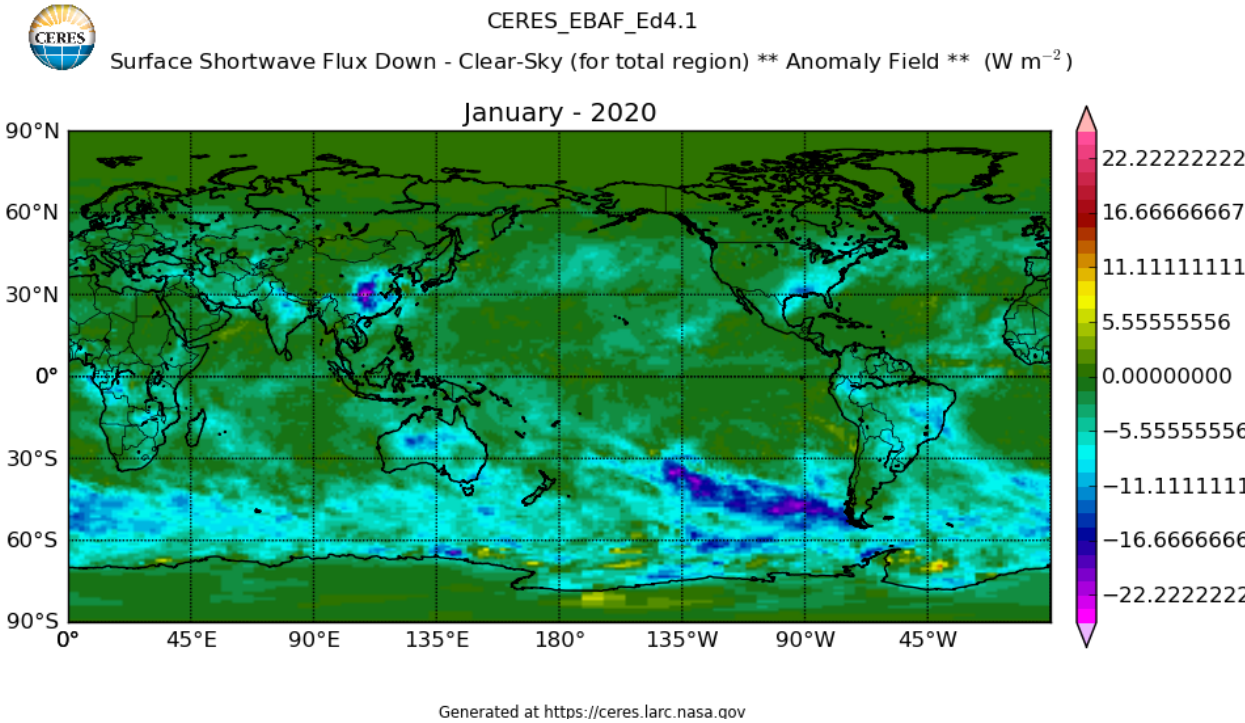


Anomaly is ~10Wm-2 over land but water vapor anomalies affect the downward shortwave irradiance

Aerosol optical thickness anomalies in 2020

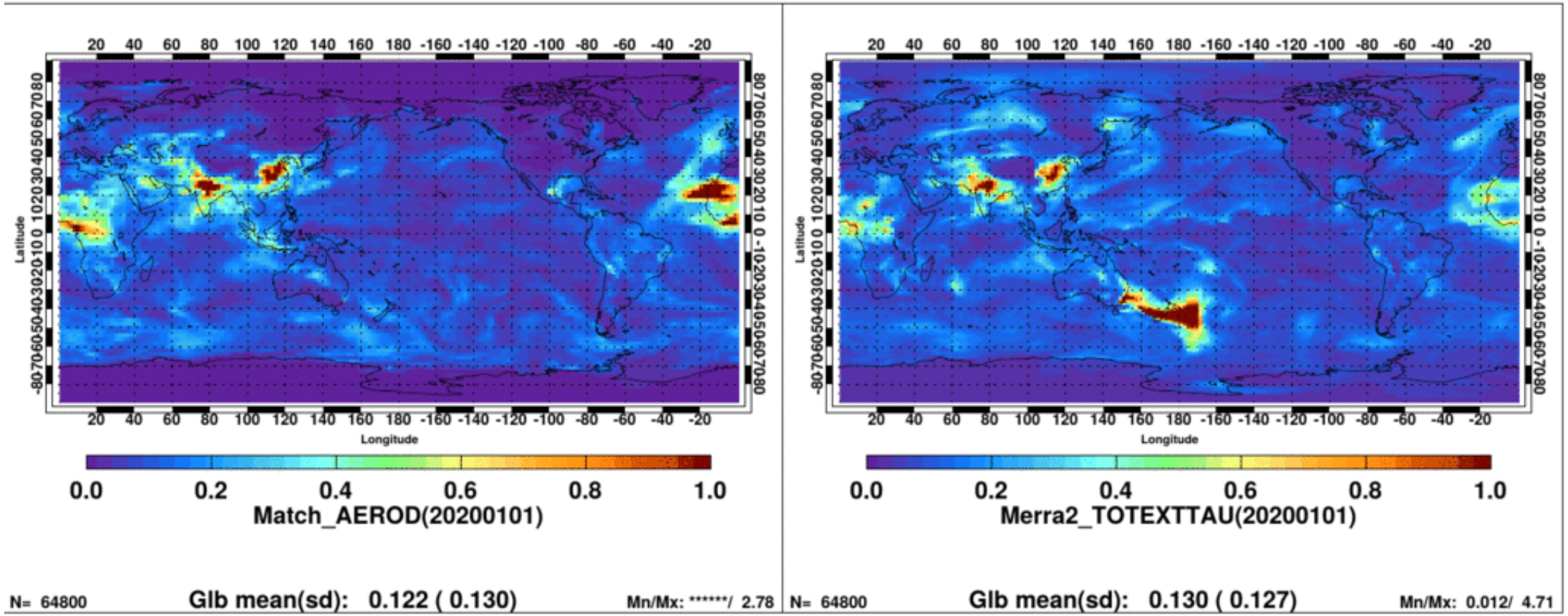
Aerosol anomalies in January 2020





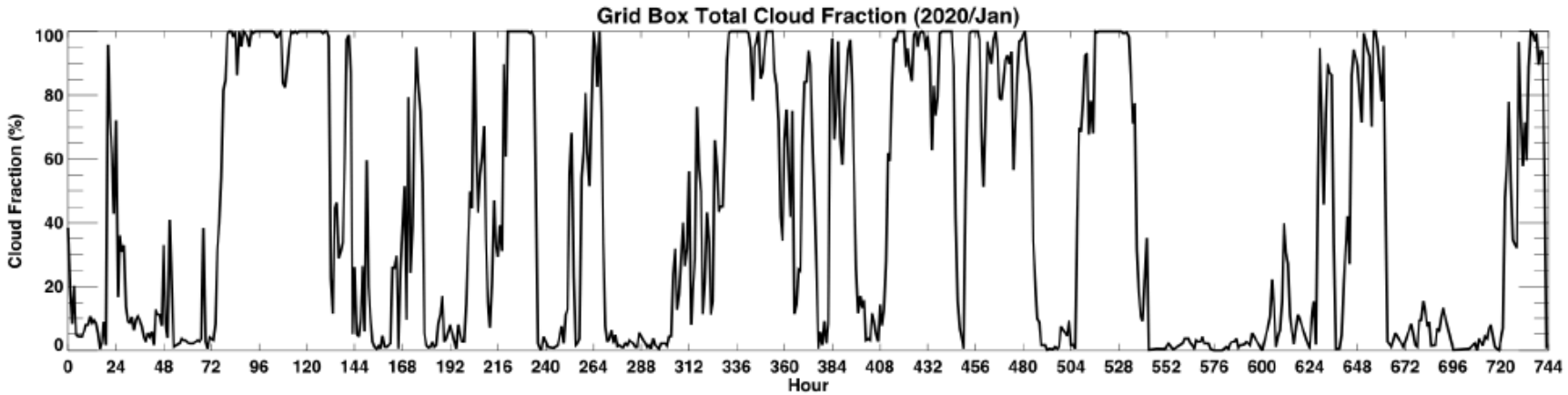
Clear-sky correction applied to clear-sly downward shortwave with observed sampling is ~20% larger than a mean correction
Aerosol under cloudy conditions largely come from MATCH model
i.e. need validation by surface aerosol optical depth observations

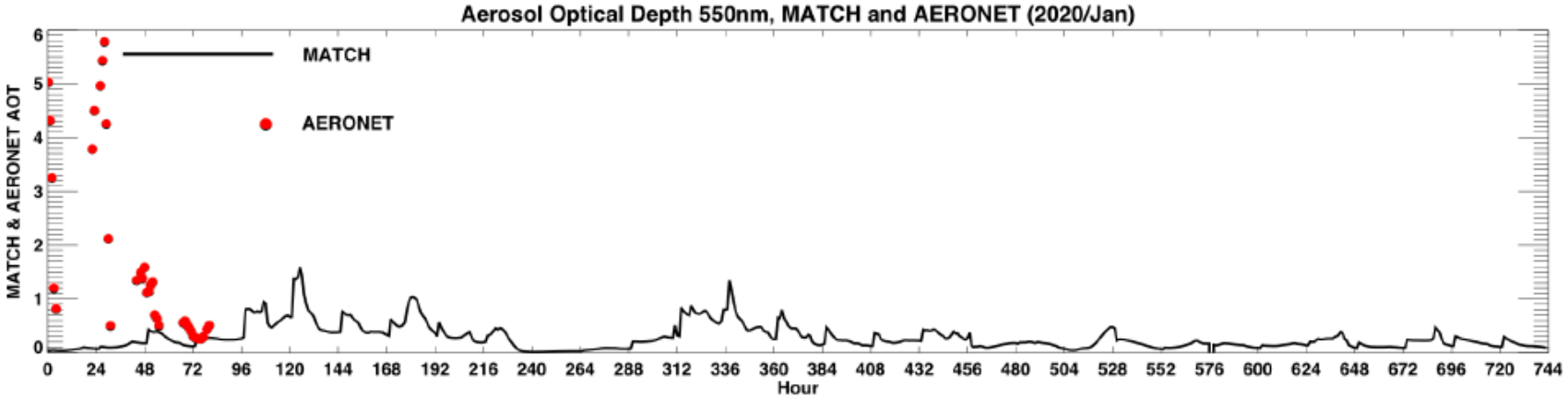
January 2020 Australian fires



Comparison with AERONET AOD: January 2020

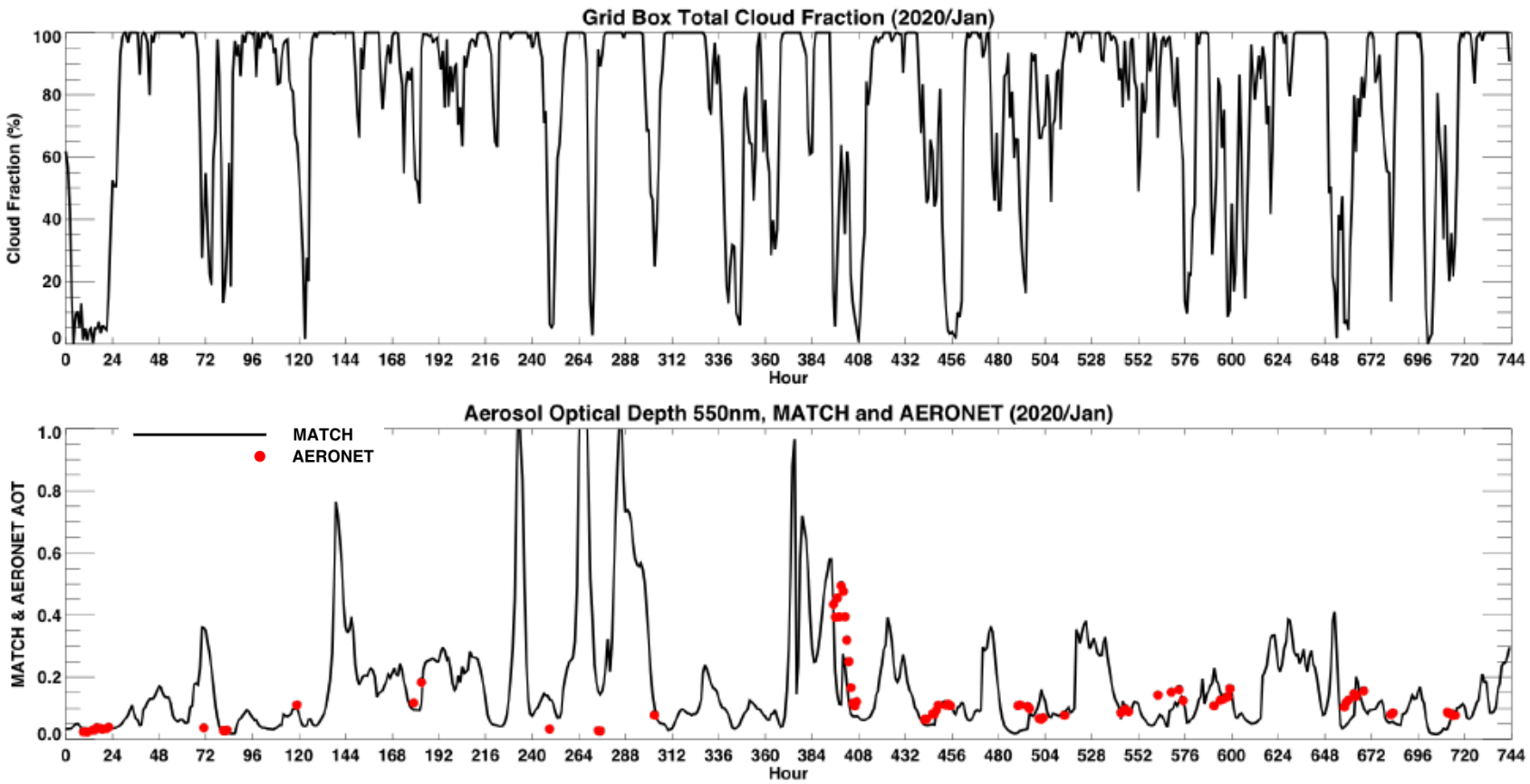
Tumbarumba, Australia

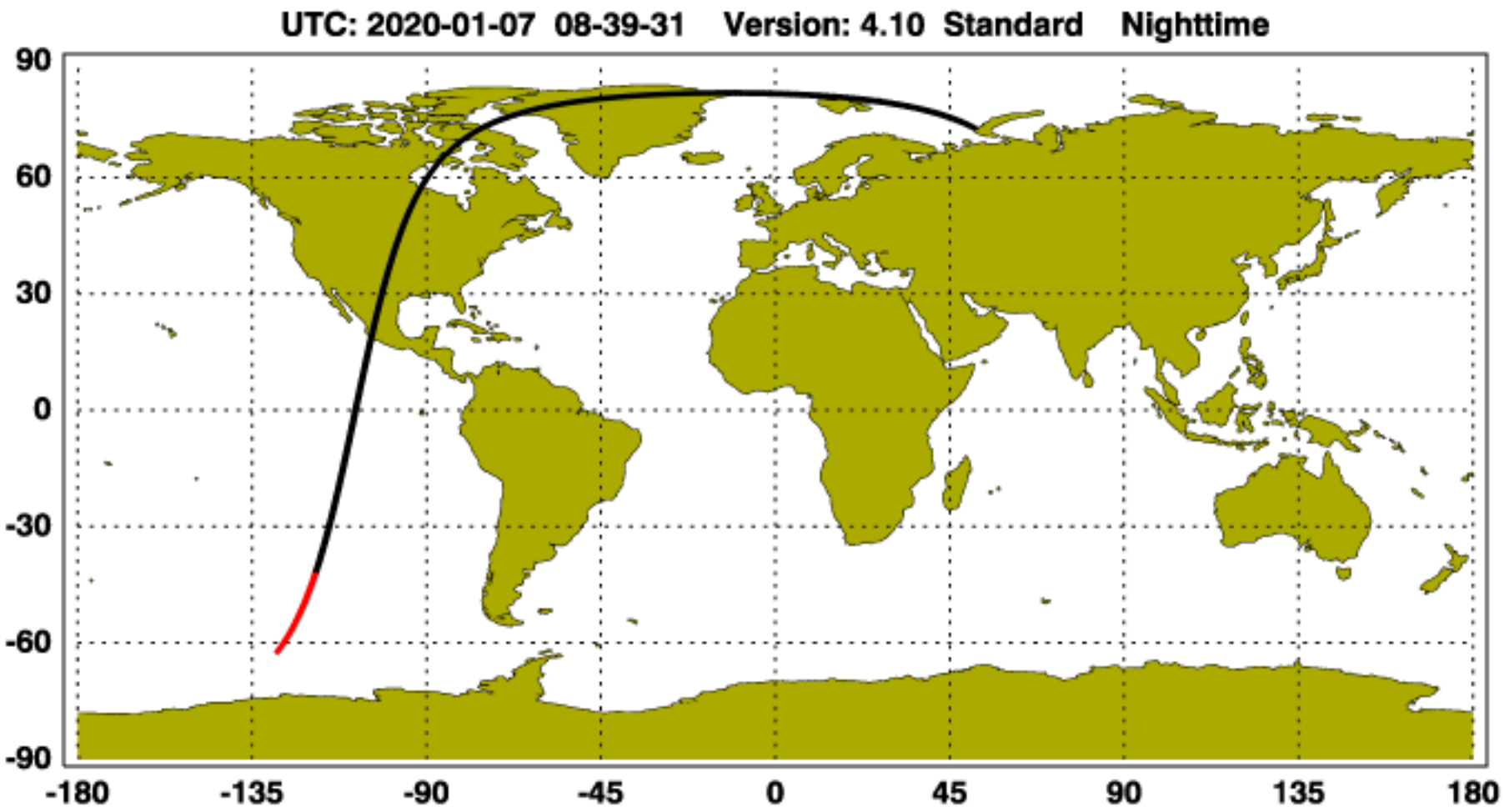


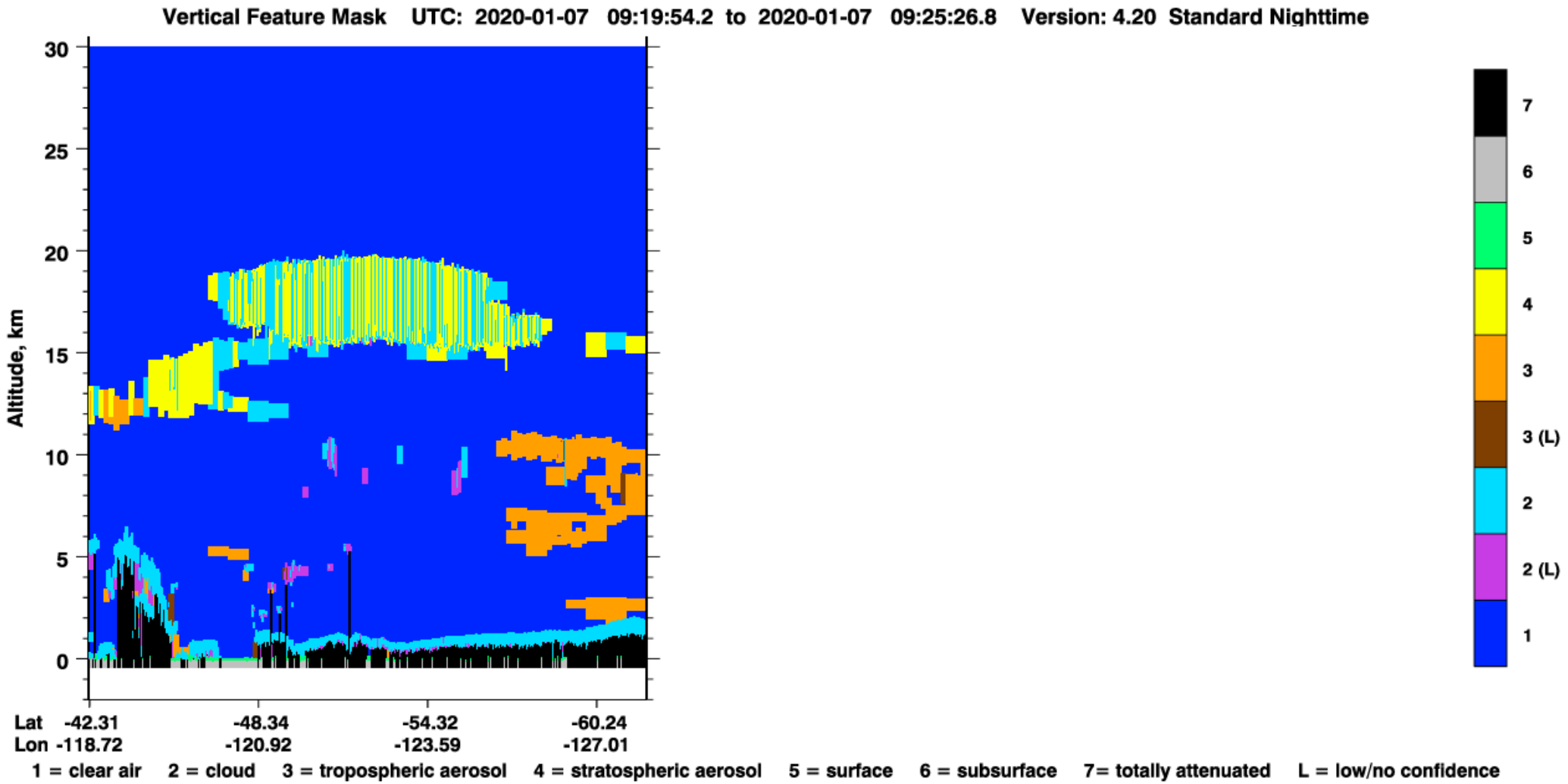


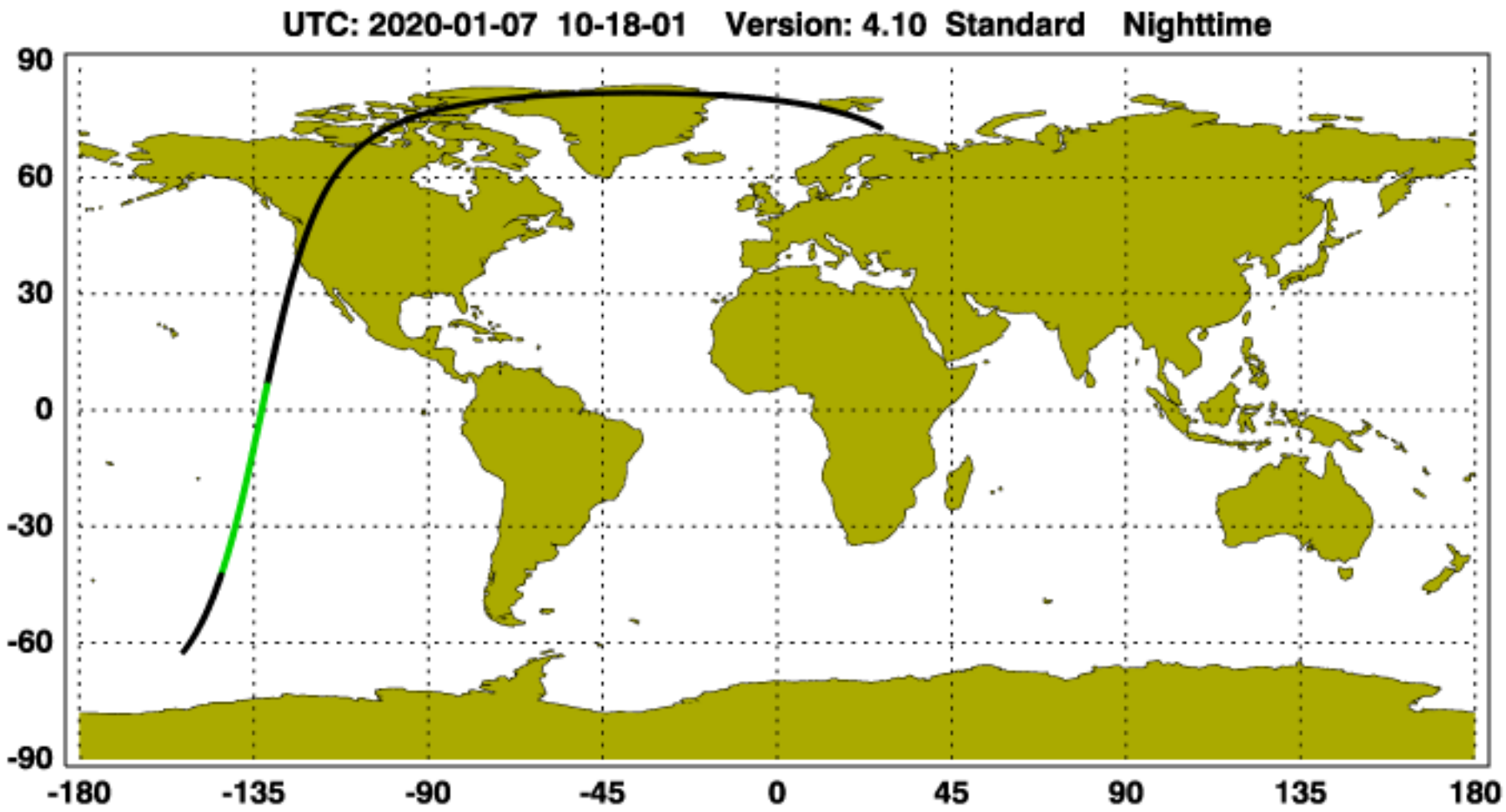
Comparison with AERONET AOD: January 2020

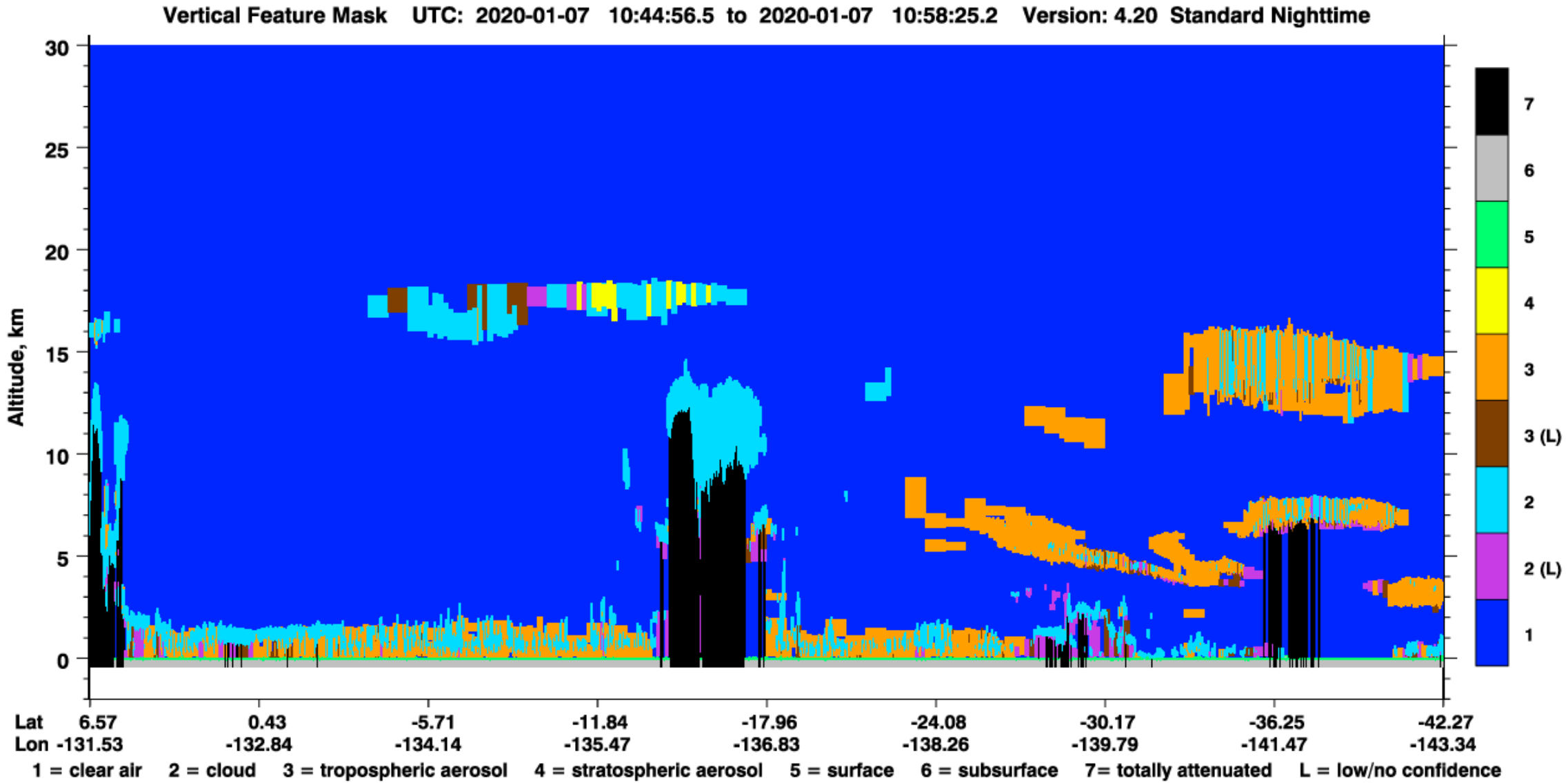
CEILAP Rio Gallegos, Argentina




UTC: 2020-01-07 08-39-31 Version: 4.10 Standard Nighttime
90
60
30
0
-30
-60
-90
-180
-135
-90
-45
0
45
90
135
180


Vertical Feature Mask UTC: 2020-01-07 09:19:54.2 to 2020-01-07 09:25:26.8 Version: 4.20 Standard Nighttime
Altitude, km
30
25
20
15
10
5
0
Lat -42.31 -48.34 -54.32 -60.24
Lon -118.72 -120.92 -123.59 -127.01
7
6
5
4
3
3 (L)
2
2 (L)
1
1 = clear air 2 = cloud 3 = tropospheric aerosol 4 = stratospheric aerosol 5 = surface 6 = subsurface 7= totally attenuated L = low/no confidence

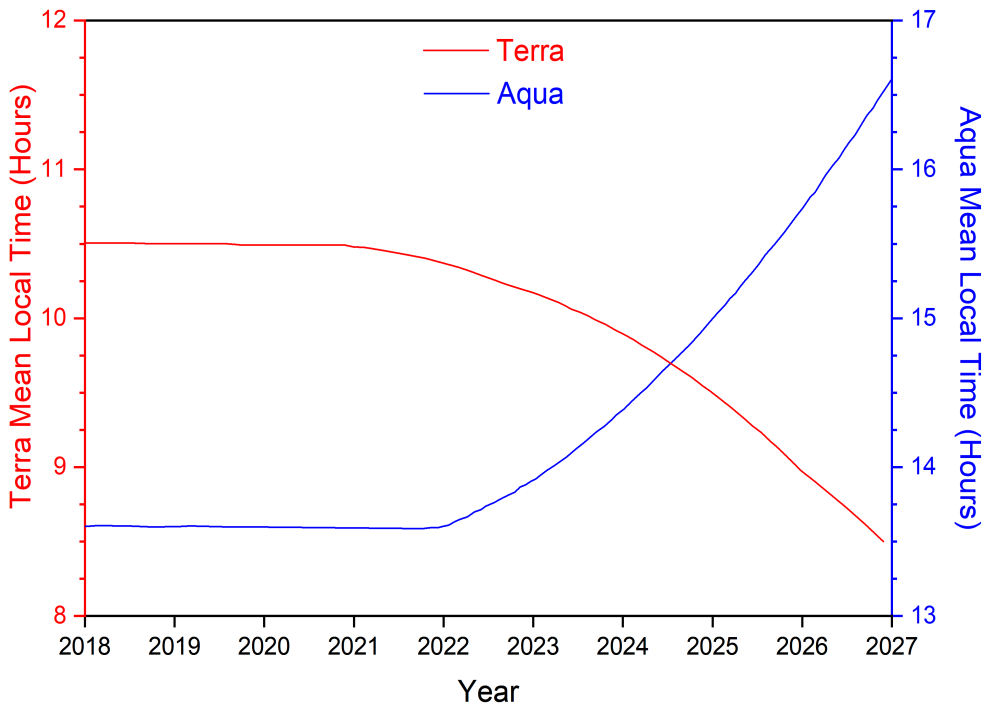

UTC: 2020-01-07 10-18-01 Version: 4.10 Standard Nighttime
90
60
30
0
-30
-60
-90
-180
-135
-90
-45
0
45
90
135
180


Vertical Feature Mask UTC: 2020-01-07 10:44:56.5 to 2020-01-07 10:58:25.2 Version: 4.20 Standard Nighttime
Altitude, km
30
25
20
15
10
5
0
Lat 6.57 0.43 -5.71 -11.84 -17.96 -24.08 -30.17 -36.25 -42.27
Lon -131.53 -132.84 -134.14 -135.47 -136.83 -138.26 -139.79 -141.47 -143.34
7
6
5
4
3
3 (L)
2
2 (L)
1
1 = clear air 2 = cloud 3 = tropospheric aerosol 4 = stratospheric aerosol 5 = surface 6 = subsurface 7= totally attenuated L = low/no confidence

SYN processing plans after Terra starts to drift

Testing Aqua+ GEO (no Terra) SYN (to form radiation budget timeseries with NOAA-20 + GEO)

Mean local time for equator crossing
(Loeb and Doelling 2020)



Global mean TOA reflected shortwave
Aqua only climatological mean is within 0.01 Wm^{-2} of Terra+Aqua with a standard deviation of 0.13 Wm^{-2}

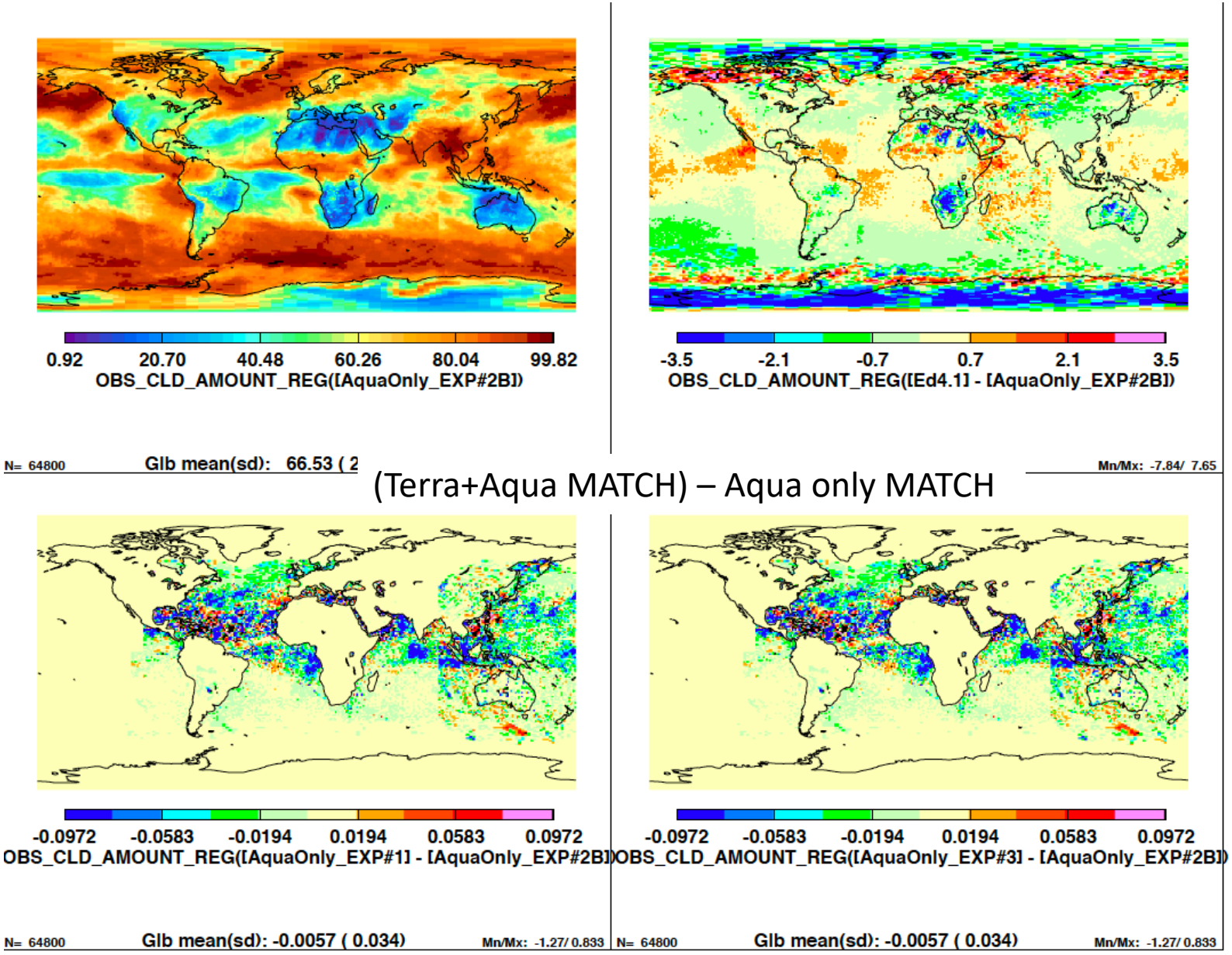
Regional mean TOA reflected shortwave
Aqua only climatological mean is within 1.0 to 1.5Wm^{-2} and local differences can reach 5 Wm^{-2}.

Whether Aqua only Edition 4 SYN needs to be produced depends on the schedule of MODIS Collection 7 and new GMAO reanalysis product.

Aqua only SYN1deg (July 2019)

- **SYN1deg-Aqua EXP#1**
  - TSI-Aqua only with current code
  - GGEO where cloud code used MATCH Terra+Aqua
  - Surface Albedo History map, Aqua-only
  - MATCH Aqua-only
- **SYN1deg-Aqua EXP#2**
  - TSI-Aqua only with current code but with different GGEO
  - GGEO where cloud code uses MATCH Aqua-only (rerun GEO netCDFs)
  - Surface Albedo History map, Aqua-only
  - MATCH Aqua-only
- **SYN1deg-Aqua EXP#3**
  - TSI-Aqua only with new x86b code (TISA bugs fixed, snow models chosen correctly, for NOAA20 too)
  - GGEO where cloud code used MATCH Terra+Aqua
  - Surface Albedo History map, Aqua-only
  - MATCH Aqua-only
- **SYN1deg-NOAA20 EXP#4**
  - TSI-NOAA20 only with new x86b code (bugs fixed, snow models chosen correctly, for NOAA20 too)
  - GGEO where cloud code used MATCH Terra+Aqua
  - Surface Albedo History map, NOAA20-only (Tom has delivered)
  - MATCH Aqua-only
- **SYN1deg-Aqua** Exp#5 :
  - Aqua Only constant meteorology extraction/extension from Ed4.1 production TAG(TSIB)

Cloud amount test with Aqua only MATCH (Case 2)



(Terra+Aqua+GEO) – Aqua+GEO
Both with Terra+Aqua MATCH

(Terra+Aqua MATCH) – Aqua only MATCH

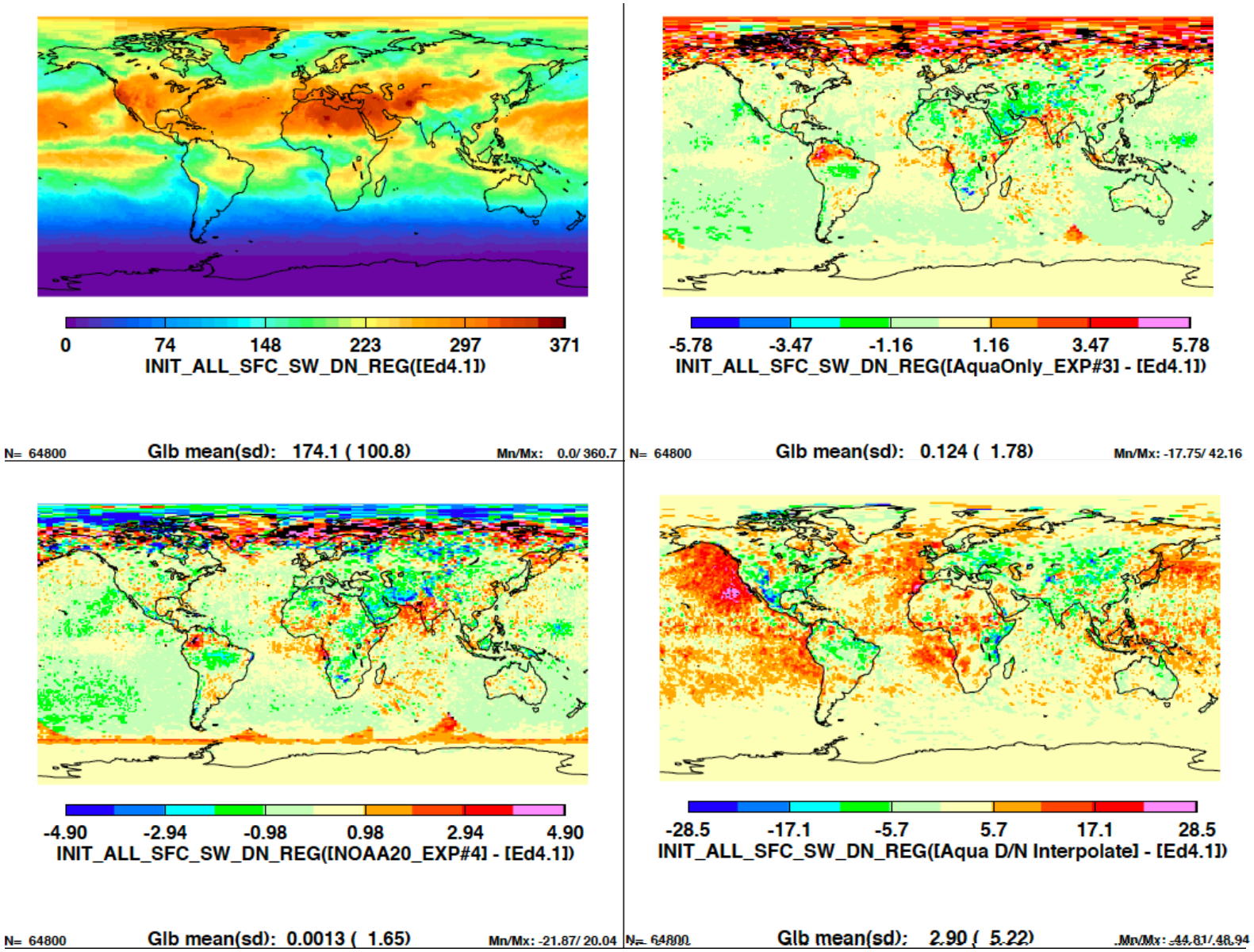
GEO code runs with Tera+Aqua.

Difference of GEO cloud amount with Aqua only and Terra+Aqua is over ocean only and small.

We conclude that Terra+Aqua MATCH can be used for Aqua+GEO test

Bottom two plots are essentially the same

CASE 3, 4, and 5 surface downward shortwave regional differences from Edition 4 Terra+Aqua+GEO



Aqua+GEOs

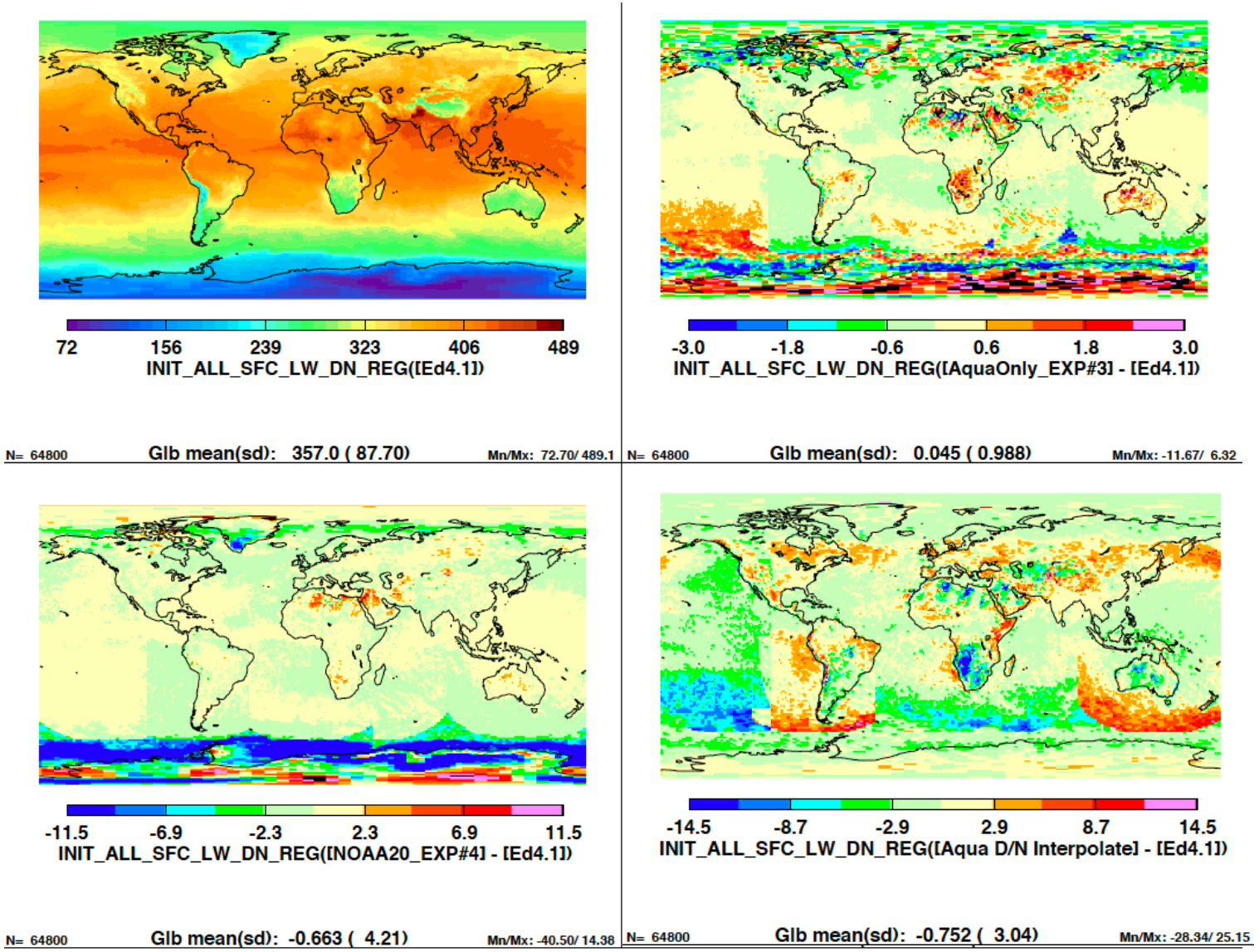
Differences are due to Terra Aqua sampling and cloud diurnal cycle

NOAA-20+GEOs

Aqua only no GEOs

Differences are due to cloud diurnal cycle and GEO artifacts

CASE 3, 4, and 5 surface downward longwave regional differences from Edition 4 Terra+Aqua+GEOs



Aqua+GEOs

NOAA-20+GEOs

Aqua only

GEO artifacts more apparent because temperature diurnal cycle is included in Aqua only longwave computations

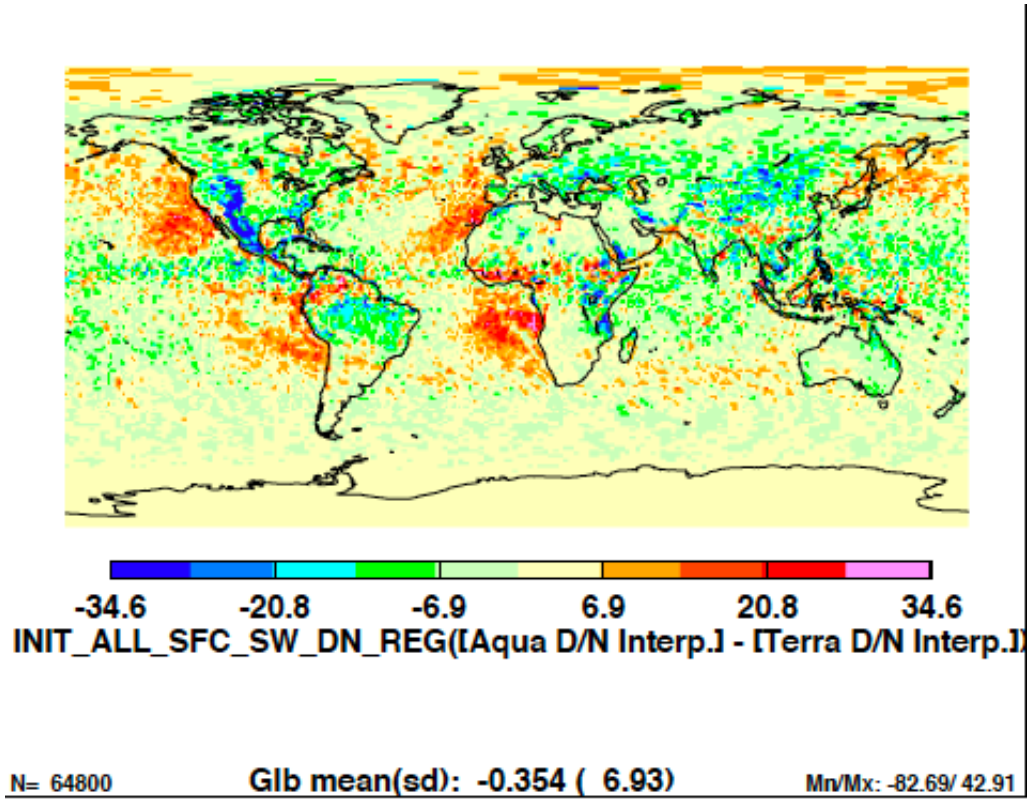
Edition 4.1 SYN

- When Terra starts to drift in 2021, switching to Aqua+GEOs introduces up to ~5 Wm^{-2} regional discontinuity in downward shortwave and longwave irradiances between 60°N to 60°S.
- When Aqua starts to drift in ~2022, switch to NOAA-20 for daytime and keeping Aqua for nighttime globally. This minimizes cloud change (clouds during polar night and cirrus in the tropics).
  - The cloud working group is working to minimize cloud property differences between those derived from VIIRS NOAA-20 and MODIS Aqua. The result of this may change the plan.

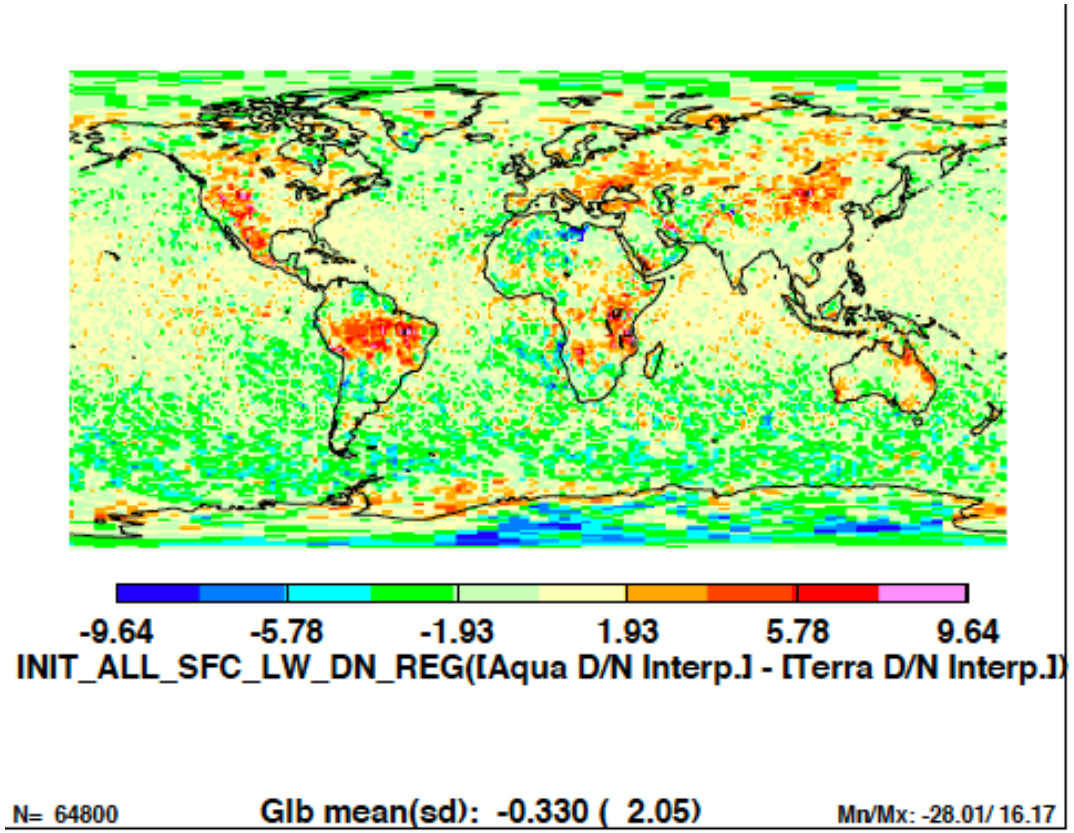
Diurnal variability of surface irradiance due to diurnal variability of cloud properties

Diurnal surface irradiance variability
Aqua only – Terra only (no GEOs)

Downward shortwave irradiance difference



Downward longwave irradiance difference



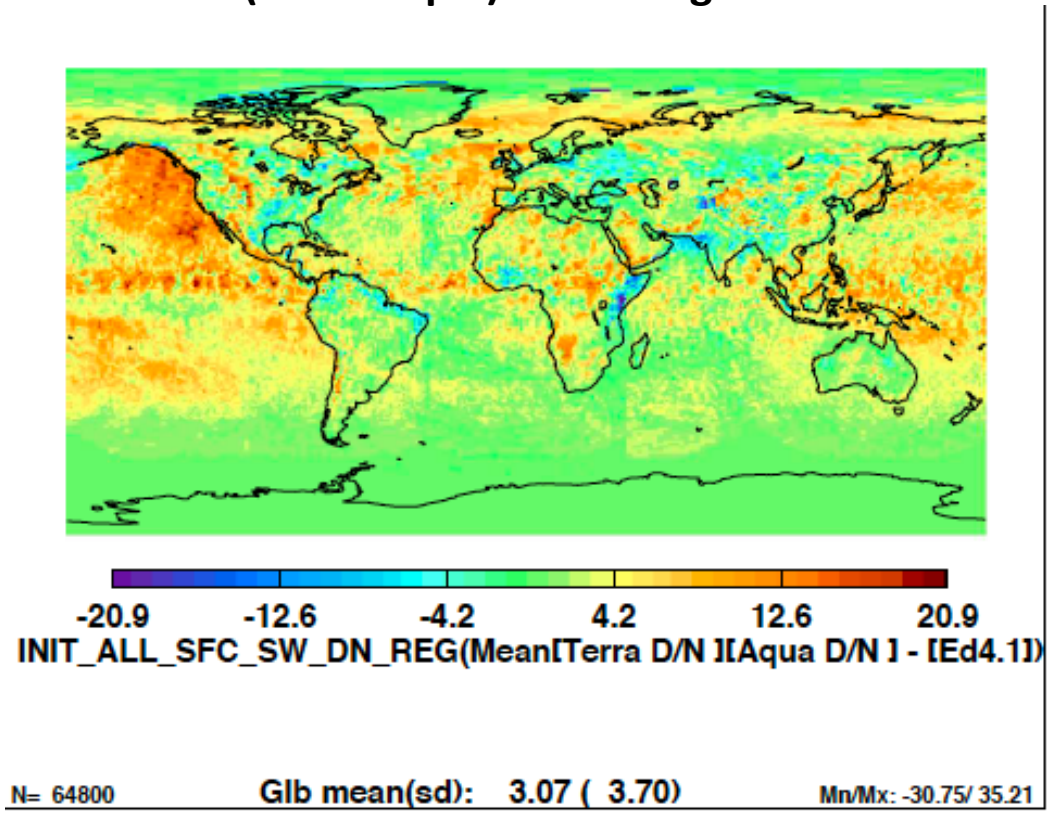
Generally, less clouds over marine stratocumulus regions and more convective clouds over lands in the afternoon

GEO artifacts– needs to be corrected in the EBAF process

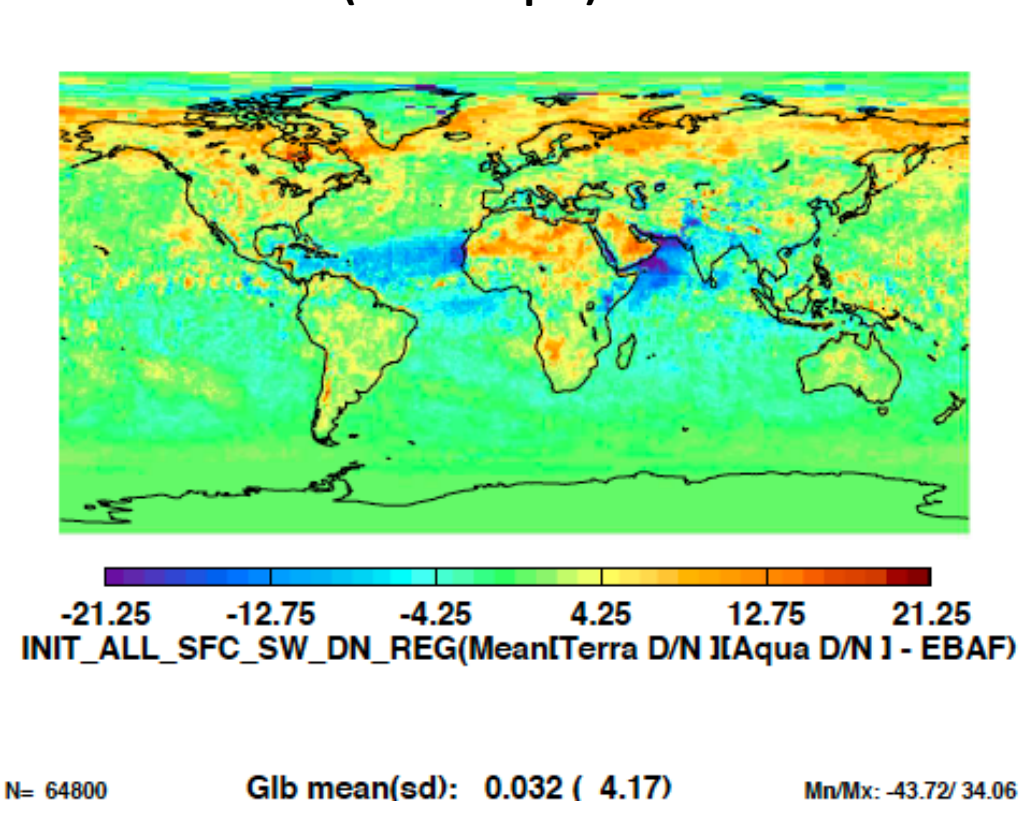
- Using the mean surface irradiances computed with Terra and Aqua clouds, we analyze the effect of GEO artifacts on surface irradiances using July 2019 SYN.
  - Effects of GEO artifacts on surface downward shortwave irradiance are mostly taken out by the EBAF process.
  - The largest effects of GEO artifacts on surface downward longwave irradiance come from nighttime cloud optical thickness (and depend on GEO).
  - GEOs used in July 2019 are, MET-11, MET-8, Himawari-8, GOES-15, and GOES-16.

(Terra+Aqua) – SYN and (Terra+Aqua) – EBAF downward shortwave irradiance

(Terra+Aqua) - SYN1deg-Month



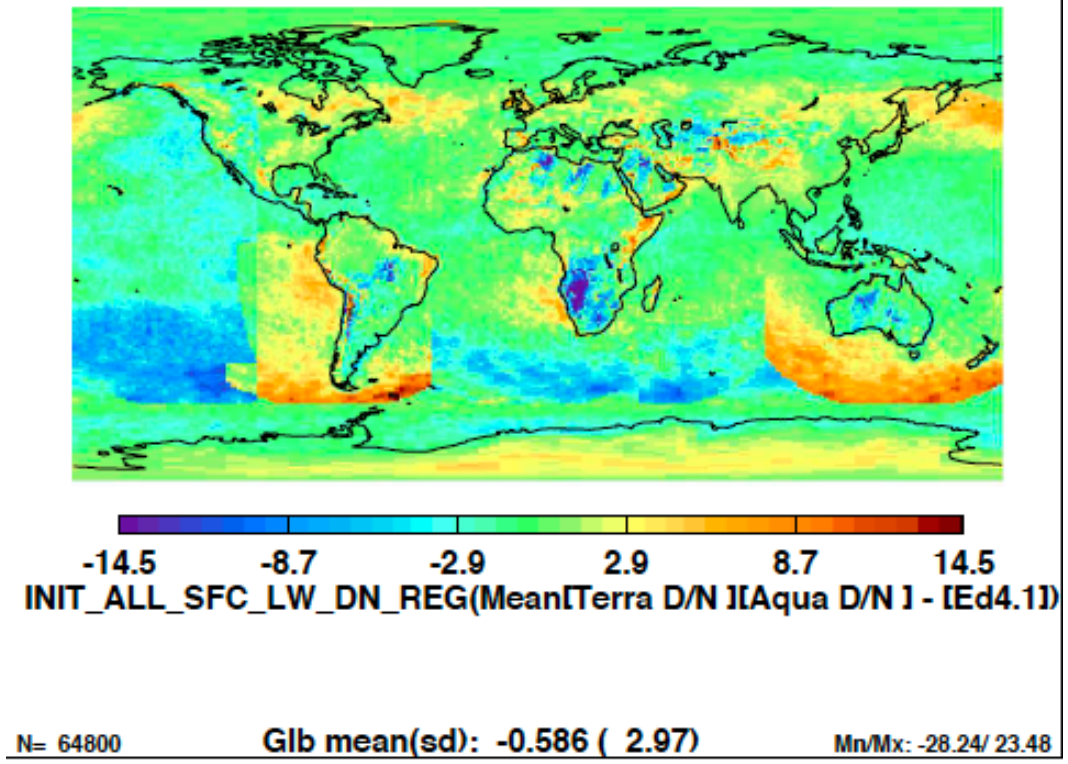
(Terra+Aqua) - EBAF



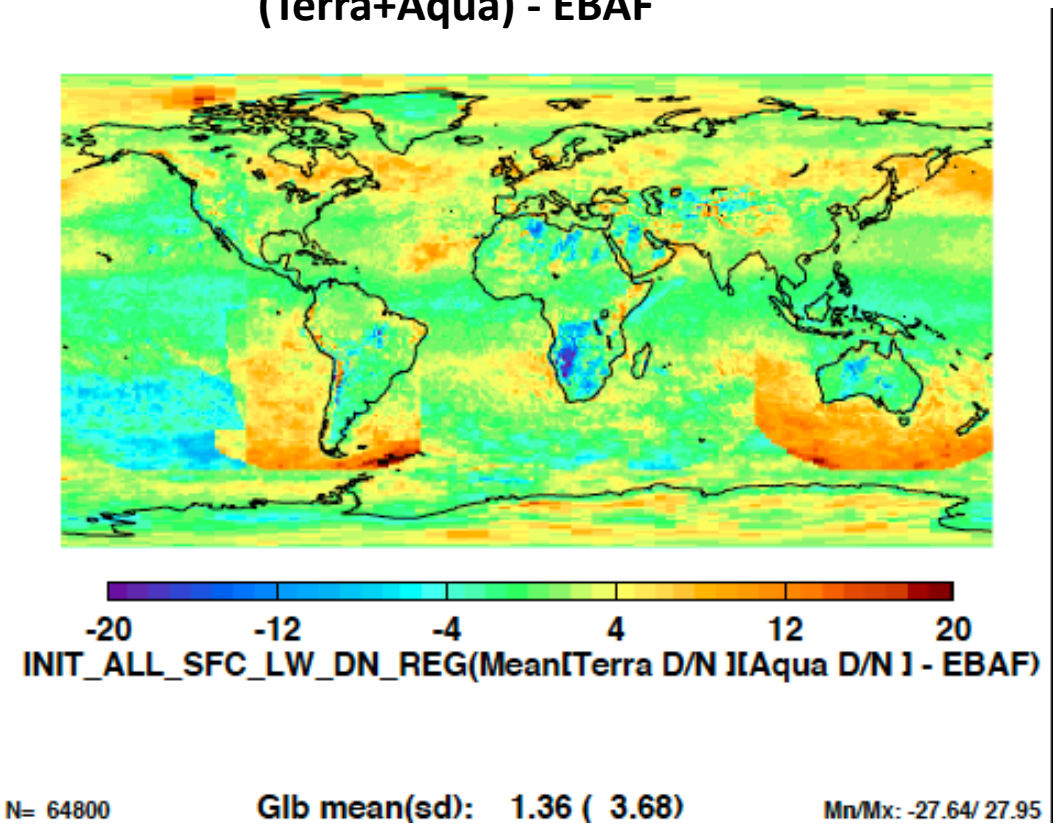
GEO artifacts are largely taken out by the EBAF process

(Terra+Aqua) – SYN and (Terra+Aqua) – EBAF downward longwave irradiance

(Terra+Aqua) - SYN1deg-Month

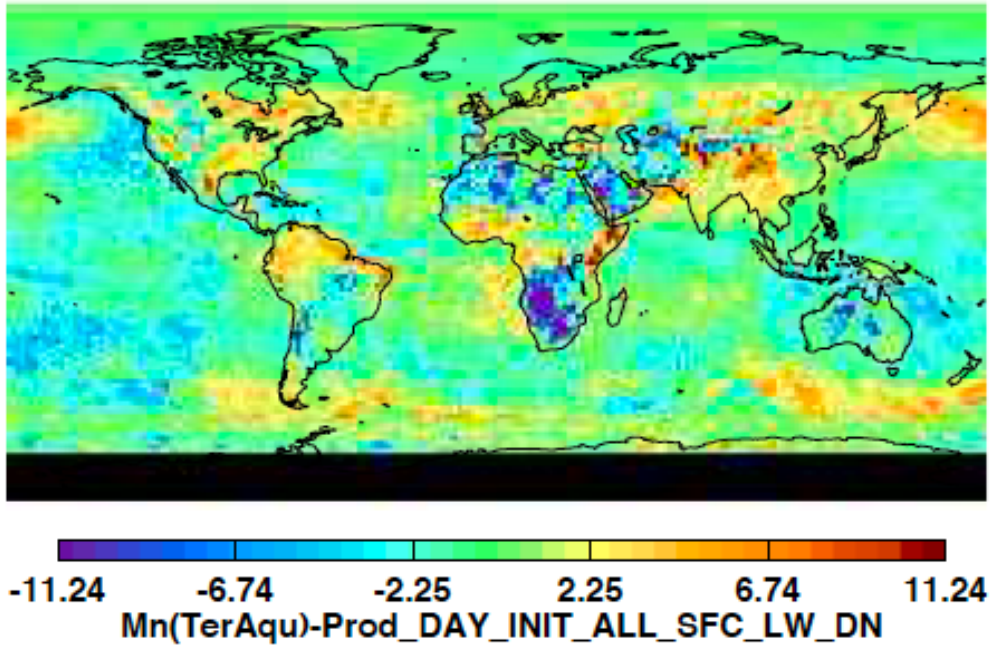


(Terra+Aqua) - EBAF



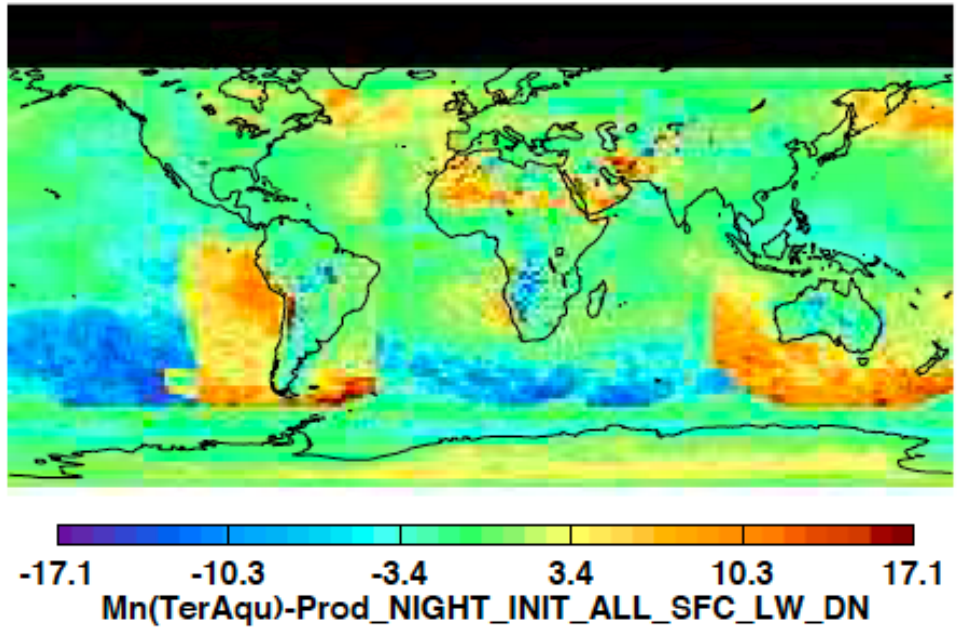
(Terra+Aqua) – SYN daytime and nighttime downward longwave irradiance

Daytime



N= 58320 Glb mean(sd): * -0.696 (2.81) Mn/Mx: -35.19/ 34.78

Nighttime

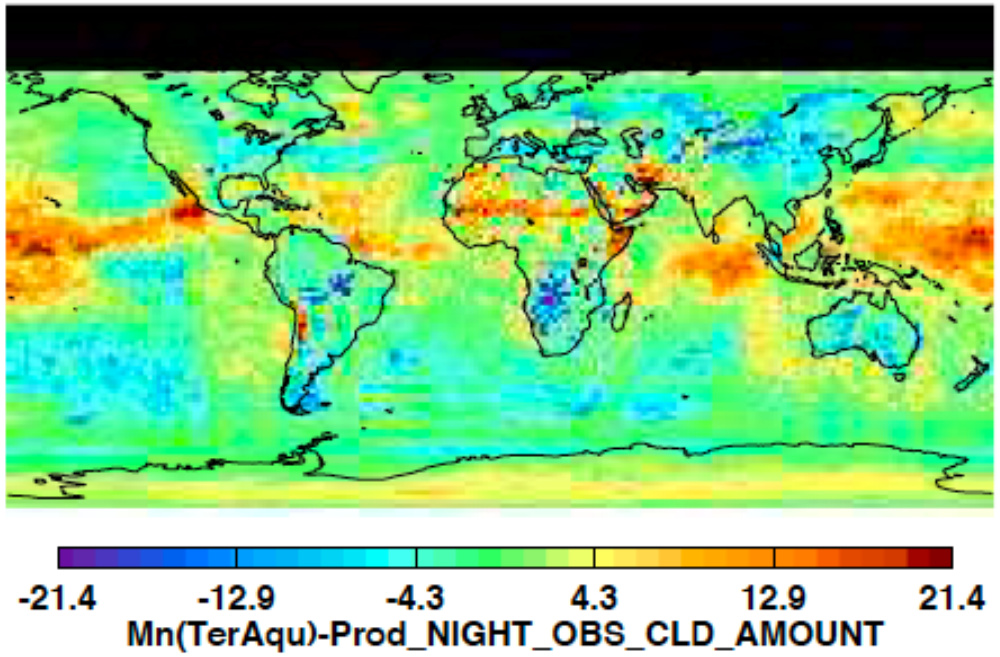


N= 56520 Glb mean(sd): * -0.408 (4.28) Mn/Mx: -39.96/ 41.40

New generation GEOs (Himawari-8 and GOES-16): Positive difference at large viewing zenith angle at nighttime
Other GEOs: Negative difference.

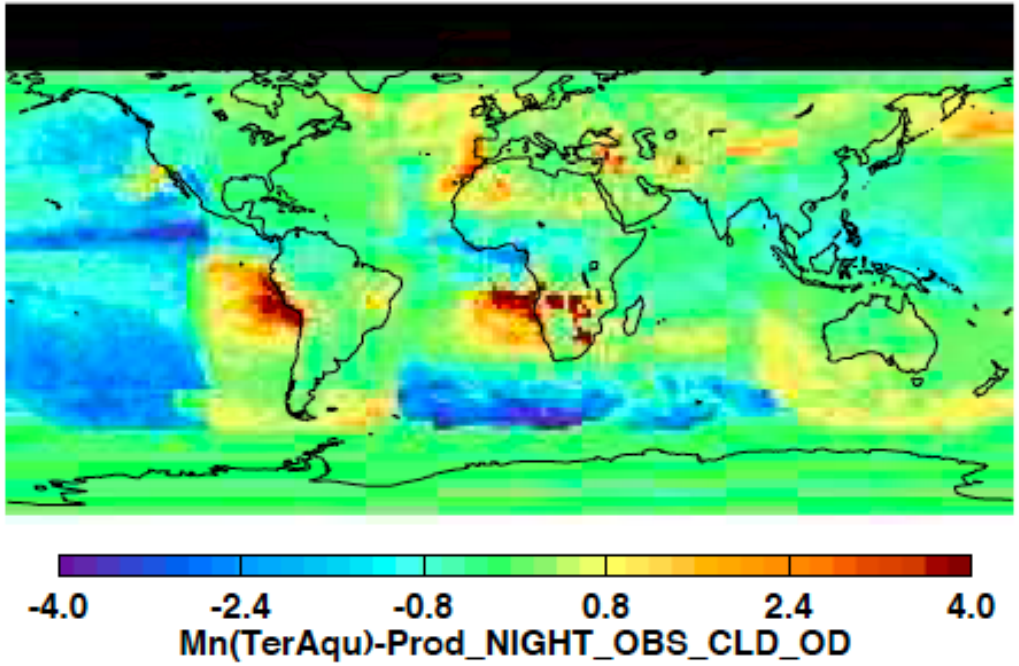
Nighttime cloud amount and optical thickness differences

Cloud amount
(Terra+Aqua) – (Terra+Aqua+GEOs)



N= 56520 Glb mean(sd): * 0.672 (5.36) Mn/Mx: -55.94/ 42.17

Optical thickness
(Terra+Aqua) – (Terra+Aqua+GEOs)



N= 56520 Glb mean(sd): * -0.302 (0.991) Mn/Mx: -5.49/ 9.78

Nighttime optical thickness inconsistency between GEOs and Terra/Aqua and among GEOs is the largest problem
For new generation GEOs, both cloud amount and optical thickness differences are probably due to viewing zenith angle differences.

Summary

- The effect of a smaller aerosol optical thickness over china in March 2020 on the monthly regional mean surface downward shortwave irradiance is ~10Wm^{-2}.
- Clear-sky sampling correction to the downward shortwave irradiance increased by 20% in January 2020 due to Australia fires.
- Regional discontinuity of surface downward shortwave and longwave irradiance caused by switching Terra+Aqua+GEOs to Aqua+GEOs or NOAA-20+GEOs can be as large as 5 Wm^{-2}.
- The largest GEO artifact affecting downward longwave irradiances in July 2019 is nighttime cloud optical thickness artifacts.

Publications

- Thorsen, T. J., R. A. Ferrare, S. Kato, and D. M. Winker, 2020: Aerosol direct radiative effect sensitivity analysis, J. Climate, in press.
- Di Biagio C., J. Pelon, Y. Blanchard, L. Loyer, S. R. Hudson, V. P. Walden, J.–C. Raut, S. Kato, V. Mariage, and M. A. Granskog, 2020: Towards a better surface radiation budget analysis over sea ice in the high Arctic Ocean: a comparative study between satellite, reanalysis, and local–scale observations, submitted to J. Geophys. Res.
- Kato, S., D. A. Rutan, F. G. Rose, T. E. Caldwell, S.-H. Ham., A. Radkevich, T. J. Thorsen, A. Viudez-Mora, D. Follmore, and X. Huang, 2020: Uncertainty in satellite-derived surface irradiances and challenges in producing surface radiation budget climate data record, Remote Sens. 2020, 12, 1950; doi:10.3390/rs12121950.
- Pan, F., S. Kato, F. G. Rose, A. Radkevich, and X. Liu, 2020: An algorithm to derive temperature and humidity profile changes using spatially and temporally averaged spectral radiance differences, J. Atmos. Ocean. Technol., 37, 1173-1187, DOI: 10.1175/JTECH-D-19-0143.1.
- Kato, S., N. G. Loeb, D. A. Rutan, and F. G. Rose, 2020: Effects of electromagnetic wave interference on observations of Earth radiation budget, submitted to J. Quant. Spec. Radiant. Trans., 253, DOI:10.1016/jjqsrt.2020.107157.
- Kato, S., F. G. Rose, D. A. Rutan, N. G. Loeb, J. T. Fasullo, and K. E. Trenberth, and M. Satoh, 2020: Regional energy and water budget of the atmosphere over ocean, submitted to *J. Climate*.
- Assia Arouf, M., H. Chepfer, M. Chiriaco, R. Guzman, T. Vaillant de Guélis, T. S. L'Ecuyer, S. Kato, M. D. Shupe, M. R. Gallagher, 2020: The Surface Longwave Cloud Radiative Effect from Space Lidar Observations, submitted to *J. Climate*.