TISA Working Group Report

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GEO Image cleaning: ~~M. Nordeen, D. Keyes, K. Khlopenkov, D. Spangenberg, F. Chen, I. Antropov, S. Gibson, R. Arduini~~

Sub-setter: C. Mitrescu, P. Mlynczak, C. Chu, E. Heckert,

Radiation Budget Workshop

18-21 October, 2016, ECMWF, Reading, England

Outline

- Indian Ocean GEO domain processing strategy
- SYN1deg SW terminator flux anomaly and mitigation
- SYN1deg and GERB flux comparisons
- SYN1deg Ed4 and Ed3 mean flux and trend differences
- SW sensitivity studies

- TISA spatially averages the SSF footprint fluxes into 1° x1° nested grid
- TISA temporally interpolates the TOA flux between Terra and Aqua measurements to estimate the daily flux mean

TISA papers

- D.R. Doelling, C.O. Haney, B.R. Scarino, A. Gopalan, R. Bhatt, 2016, Improvements to the geostationary visible imager ray-matching calibration algorithm for CERES Edition 4, J. Atmos. Oceanic Technol., In Press
- K.V. Khlopenkov, D.R. Doelling, 2016, Development of Image Processing Method to Detect Noise in Geostationary Imagery, Proc. SPIE, In Press
- R. Bhatt, A. Angal, D.R. Doelling, X. Xiong, A. Wu, C.O. Haney, B. R. Scarino, A. Gopalan, 2016, Response versus scan-angle corrections for MODIS reflective solar bands using deep convective clouds, *Proc. of SPIE* Vol. 9881, doi: 10.1117/12.2223809
- Q. Mu, A. Wu, T. Chang, A. Angal, D. Link, X. Xiong, D.R. Doelling, R. Bhatt, 2016, Assessment of MODIS On-orbit Calibration using a Deep Convective Cloud Technique, *Proc. of SPIE* Vol. 9972, doi: 10.1117/12.2237047
- X. Xiong, A. Angal, J. Butler, C. Cao, D.R. Doelling, A. Wu, X. Wu, 2016, Global Space-based Inter-Calibration System Reflective Solar Calibration Reference: From Aqua MODIS to S-NPP VIIRS, *Proc. of SPIE* Vol. 9881, doi: 10.1117/12.2224320

CERES PRODUCTS
ED3 TO ED4 IMPROVEMENTS

CERES level 3 Products

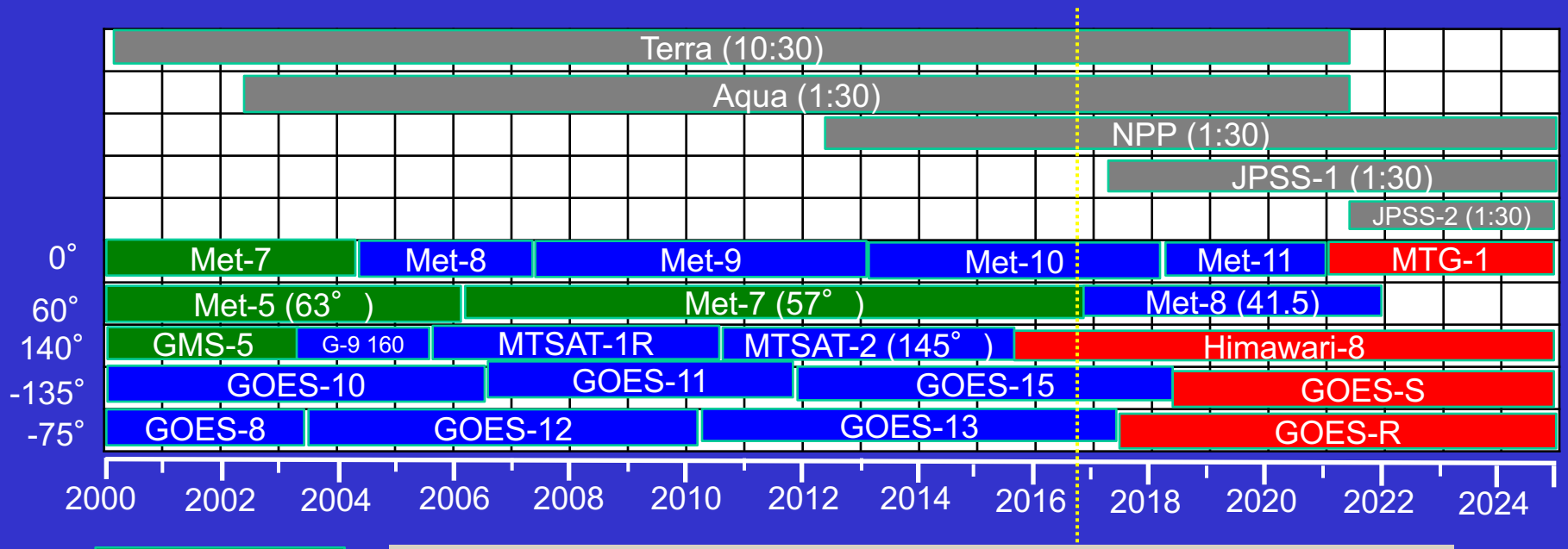
- SSF1deg, single satellite TOA flux and cloud product, CERES/MODIS-only observations, assume constant meteorology in between CERES observations
  - No changes between Ed3 and Ed4, use CERES TRMM directional models
- SYN1deg, TOA flux, cloud, and computed surface and in-atmosphere flux product, Terra (10:30LT)+Aqua (1:30LT)+GEO (1-hourly) observations
  - GEO flux improvements next page
- CldTypHist, MODIS/GEO monthly hourly cloud properties by 3x3 cloud top and optical depth bins
  - Formally known as ISCCP-D2like product
  - 4-channel GEO cloud properties, Ed3 were 2-channel
- FluxByCloudType, Instantaneous gridded CERES fluxes by MODIS 7x6 cloud types
  - New, no Edition 4 product
  - Sub-footprint multi-channel MODIS narrowband to broadband flux conversion. Sub-footprint fluxes normalized to CERES observation

Edition 4 SYN1deg Improvements

	Edition 3	Edition 4
GEO Calibration	• Terra-MODIS Collection 5 reference • GEO/MODIS ray-matching	• Aqua-MODIS Collection 6 • GEO/MODIS ray-matching • Validate with DCC and deserts • SCIAMACHY spectral band adjustment factors (SBAF) • MTSAT-1R point spread function
GEO Clouds	• Visible & 11μm **2-channel cloud code** • Assumed particle sizes • Assume night time emissivity=1	• **4-channel cloud code** • 3.7μm GEO particle sizes • Emissivity based on 3.7, 11, and 12 μm
GEO LW flux	• Column weighted humidity RH and WN radiance to BB global parameterization • Instantaneous Normalization	• WN and WV radiance to BB flux • 5° by 5° LW regional normalization
GEO SW flux	• GEO visible->MODIS 0.65μm-> BB • CERES SW TRMM ADM • 5° by 5° SW regional normalization	• Same as Edition3
Temporal Interpolation	• **GEO 3-hr obs** (linear interpolation) • TRMM SW directional models	• **GEO 1-hr observations** (no interpolation)
Surface Fluxes	• GEOS 4.0/5.2 merged atmosphere • Untuned surface fluxes • 2-channel clouds, MODIS skinT	•GEOS 5.4 atmosphere •Untuned surface fluxes •4-channel clouds MODIS/GEO skinT

INDIAN OCEAN GEO DOMAIN PROCESSING STRATEGY

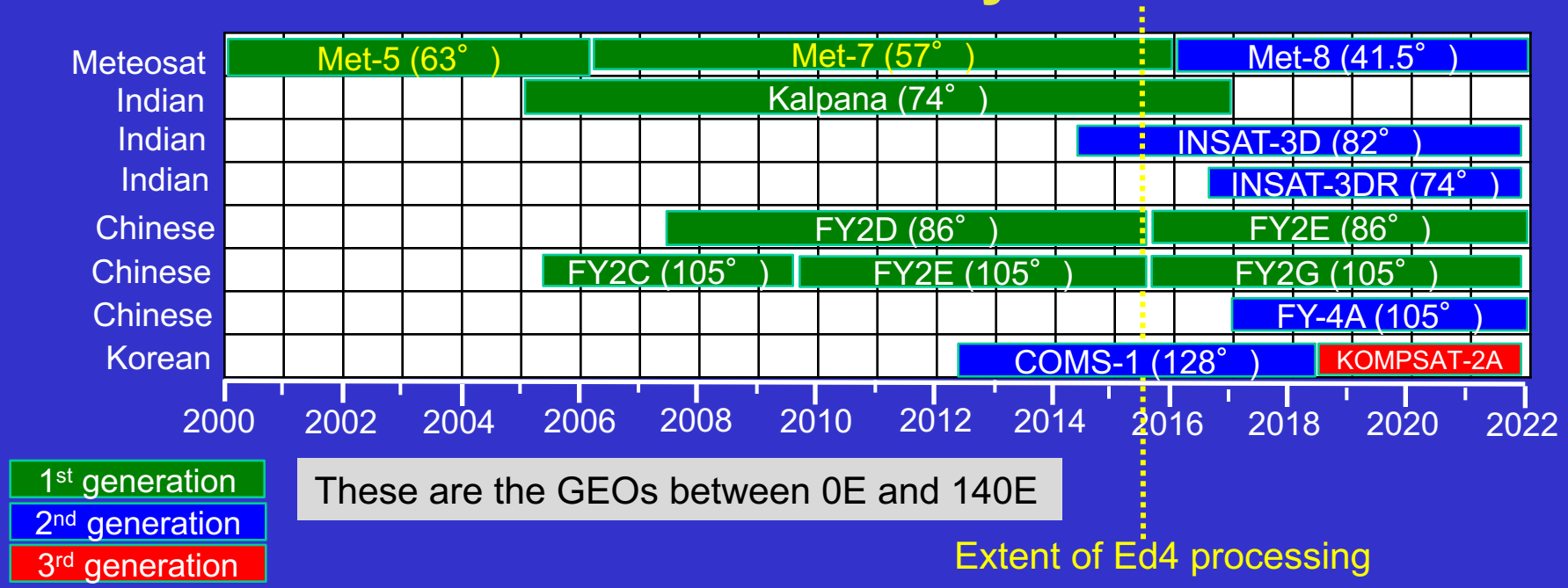
CERES record Geostationary Time Series



1st generation
2nd generation
3rd generation
MODIS/VIIRS

- GOES-R to launch Nov 2016, GOES-S launch in 2018
- Met-11 (0E) to replace Met-10 in March 2018
- Himawari-9 (140E) to launch in Nov 2016
- MTSAT-2 (145E) decommissioned in Dec 4, 2015

Indian Ocean Geostationary Time Series



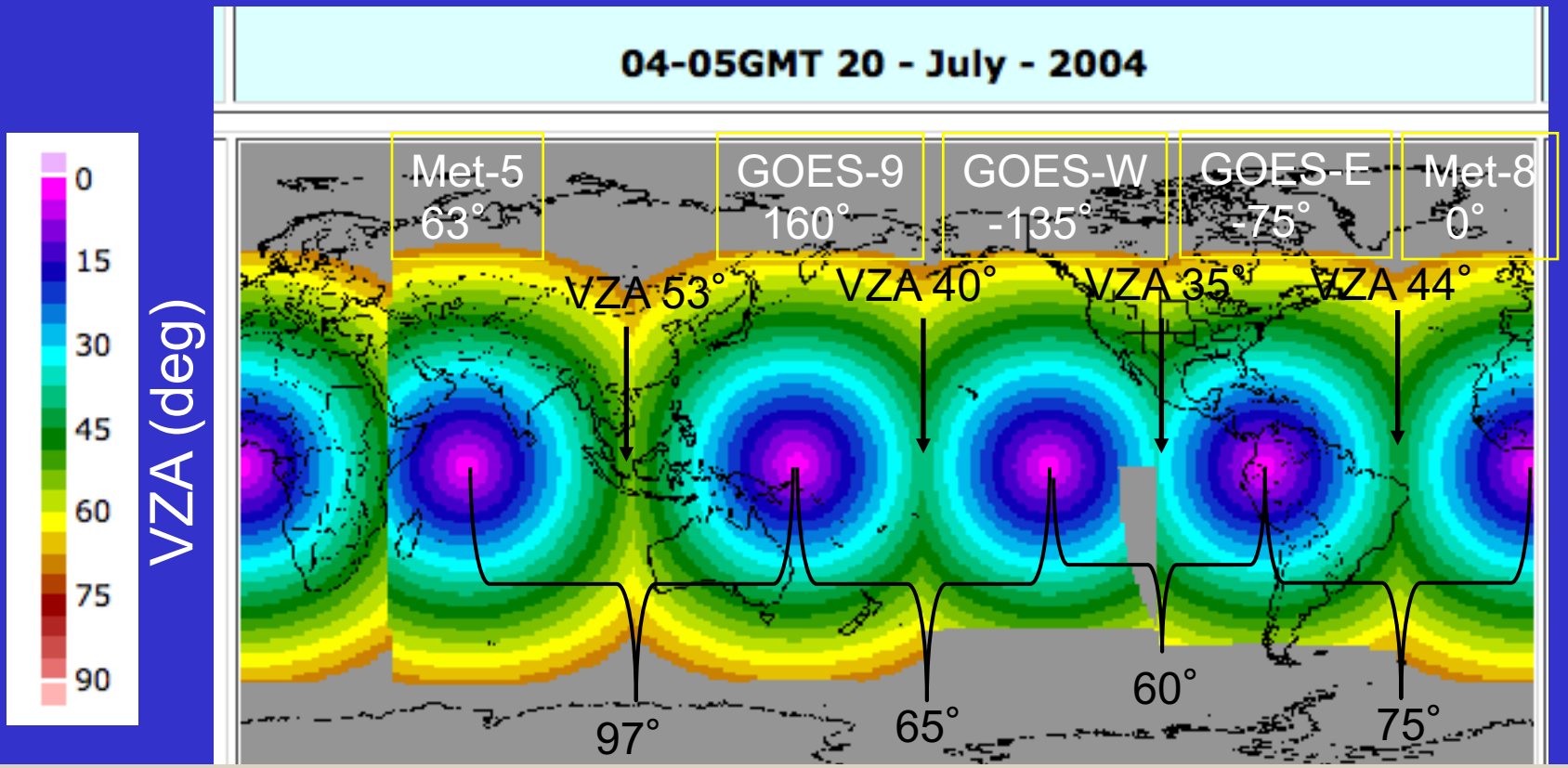
1st generation
2nd generation
3rd generation

These are the GEOs between 0E and 140E

Extent of Ed4 processing

- FY-4A, to launch in Dec. 2016, 3 axis stabilized,
  AGRI imager has 14 channels, 0.5km to 4km resolution, FD every 15 minutes
  GIIRS imager, IR hyperspectral sounder (15km) over China
- KOMPSAT-2A to launch in 2018, imager similar to GOES-R
- Met-8 (41.5E) beginning Sept 21, 2016,
- Met-7 (57E) decommissioned end of 2016
- INSAT-3DR (74E) launched on Sept 8, 2016
- FY-4A to launch in Dec. 2016

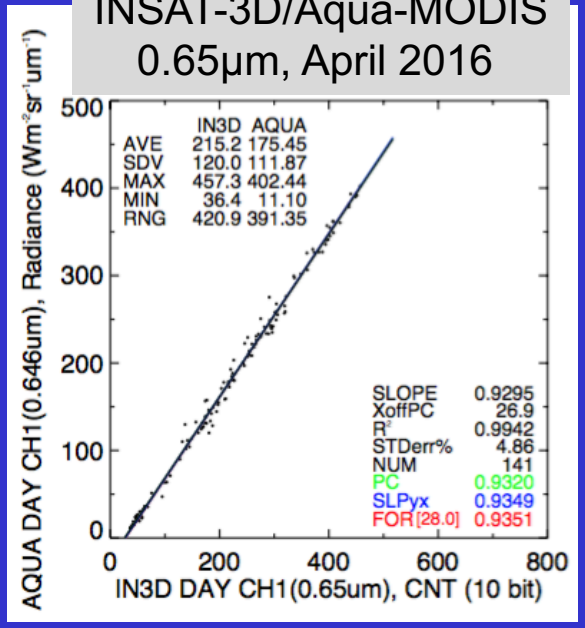
Indian Ocean Met-8 (42E) (current choice)



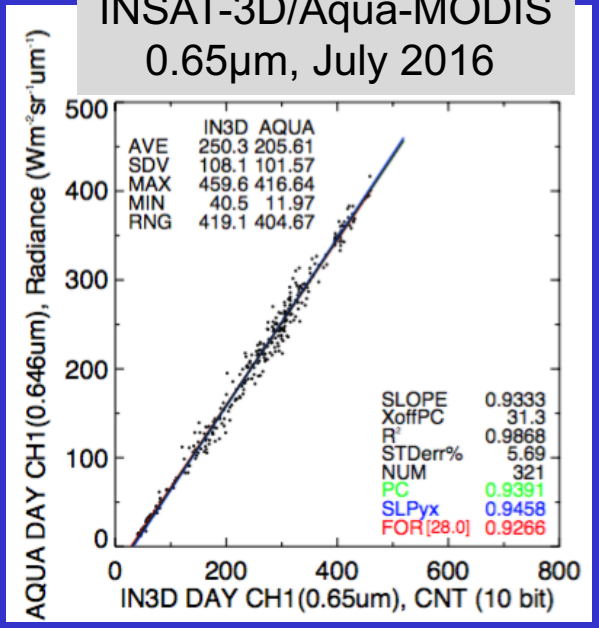
- What to do beginning in 2017, when Met-7 is decommissioned
- There would be 98° longitude separation between Met-8 (42E) and Him-8 (140E), Similar to time between 2003 and 2005, using Met-5 (63E) and GOES-9 (160E)
- Prefer to only process 5 GEOs over the CERES record
- Met-8 is a well behaved imager, and is well-calibrated when referenced to MODIS
- Data not yet available beginning in November on McIDAS servers

Indian Ocean INSAT-3D (82E) visible

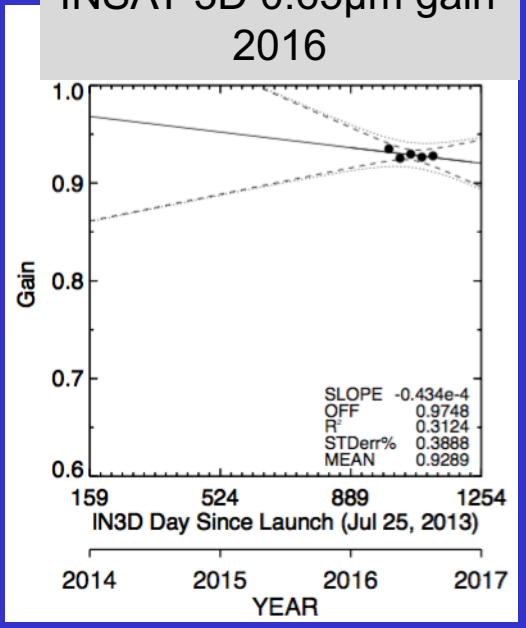
INSAT-3D/Aqua-MODIS 0.65μm, April 2016



INSAT-3D/Aqua-MODIS 0.65μm, July 2016



INSAT-3D 0.65μm gain 2016

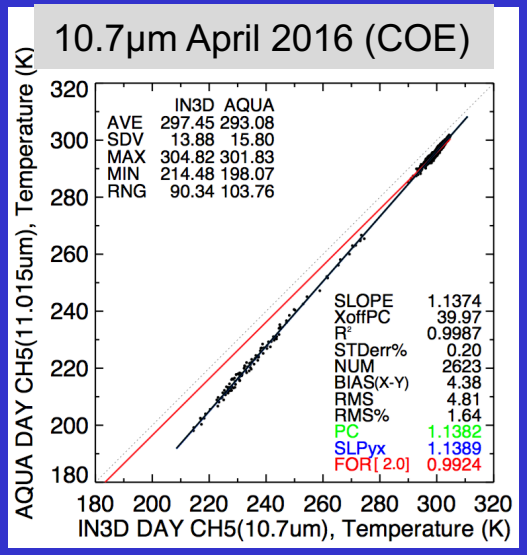


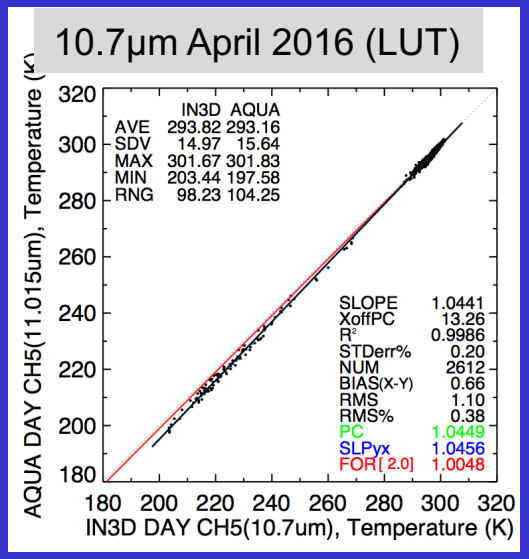
- The INSAT-3D visible channel has a linear response and well-behaved
- Cloud working group has real-time cloud properties for INSAT-3D

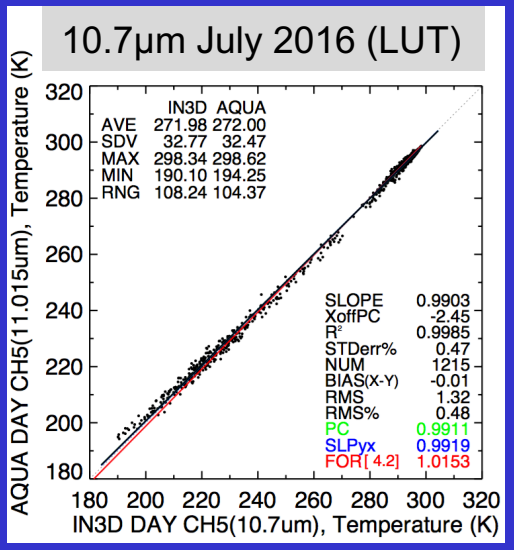
Scans FD half-hourly

Indian Ocean INSAT-3D (82E) IR

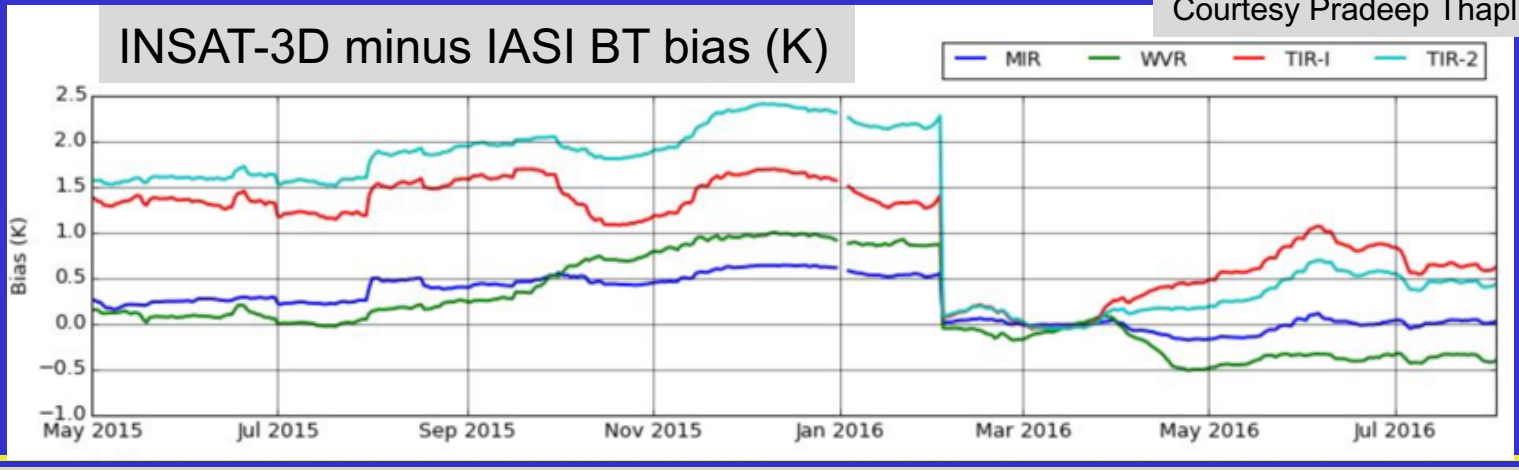
INSAT-3D/Aqua-MODIS







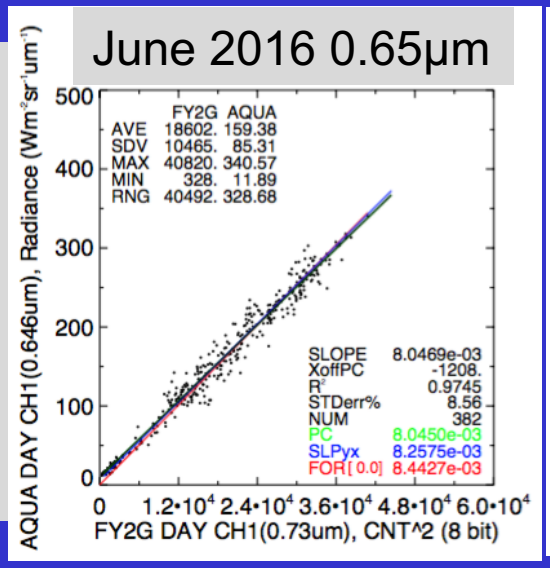
Courtesy Pradeep Thapliyal ISRO

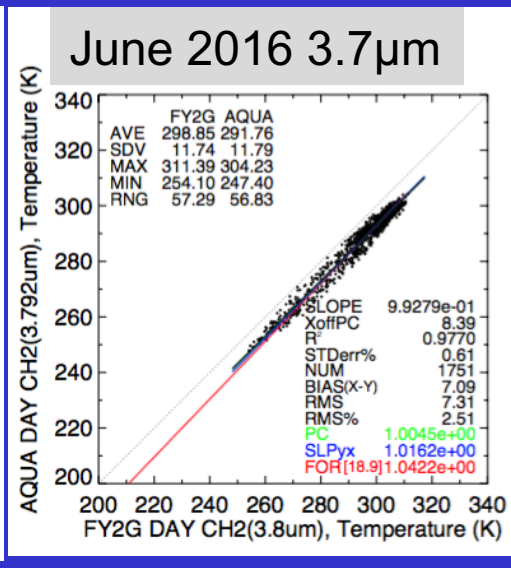


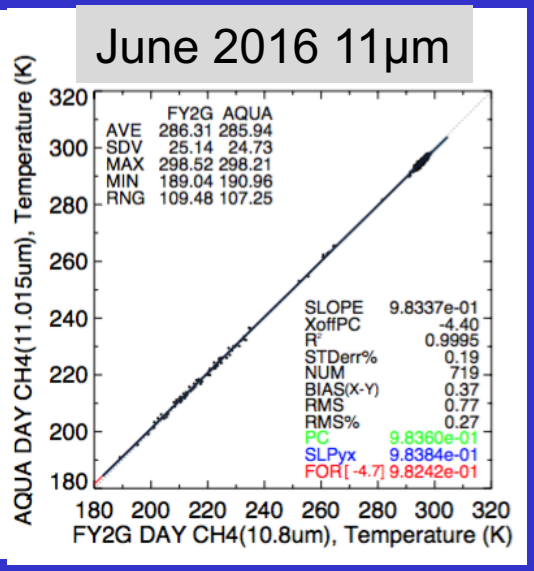
- Have worked with McIDAS and ISRO to implement new IR (LUT) coefficients and compared them to the old coefficients (COE).

Indian Ocean FY-2E(86E)/-2G(105E)

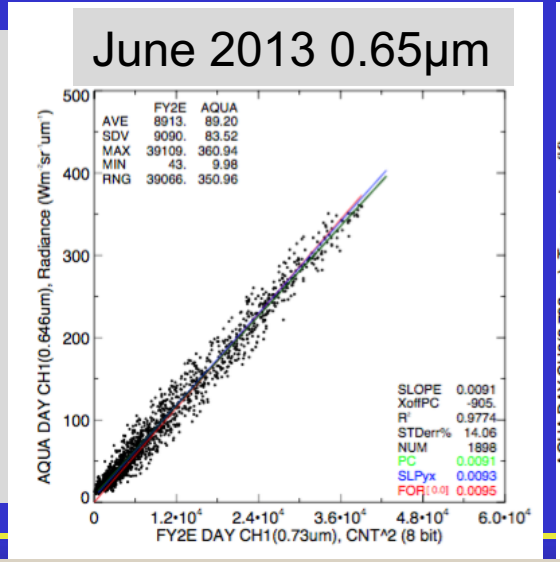
FY-2G/Aqua-MODIS

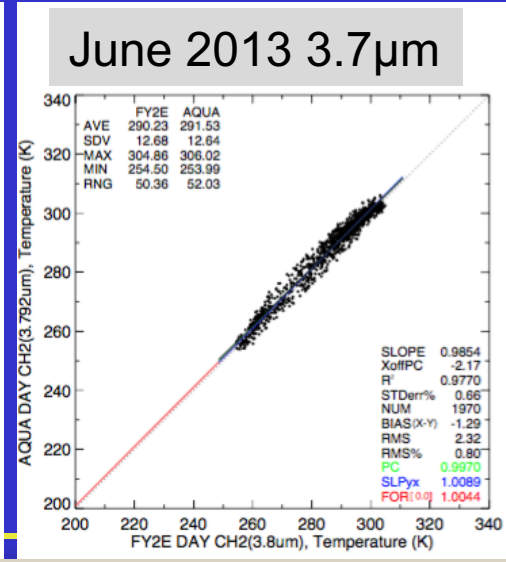


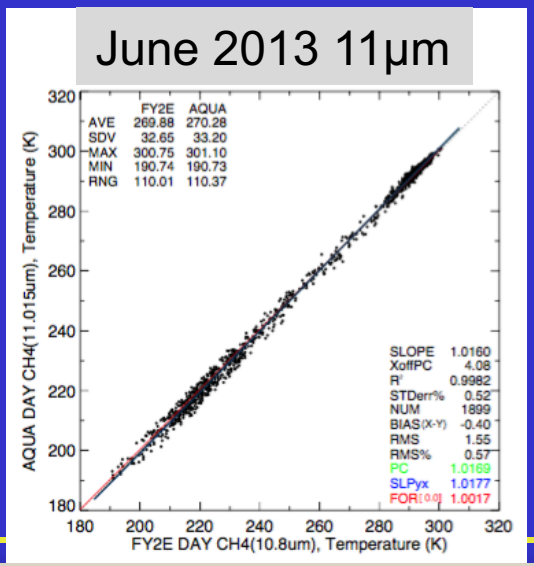




FY-2E/Aqua-MODIS





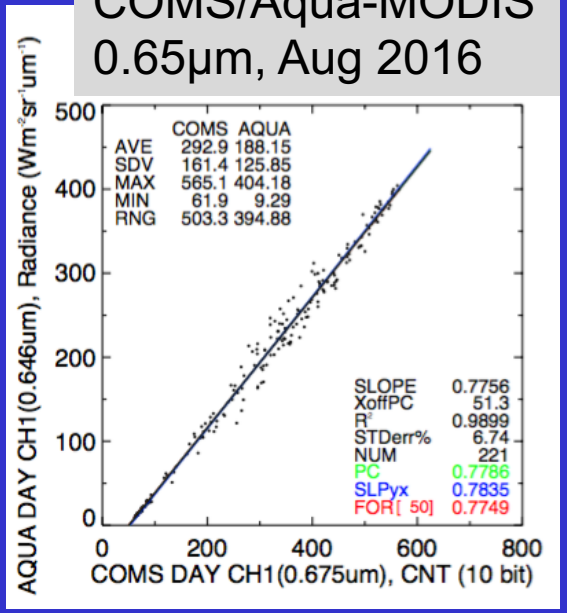


- The FY-2E/G visible sensor is noisy, the IR is noisy also but linear

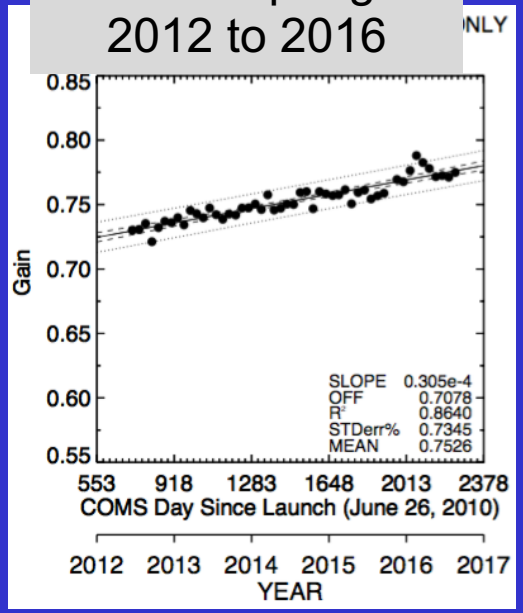
Scans FD hourly

COMS-1 (128E)

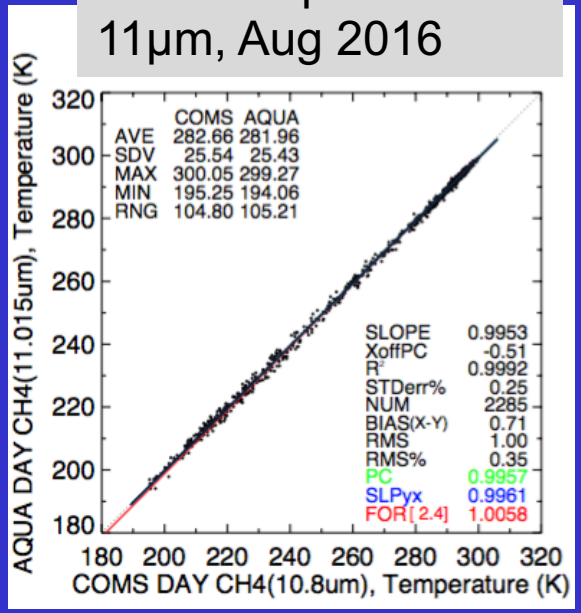
COMS/Aqua-MODIS 0.65μm, Aug 2016



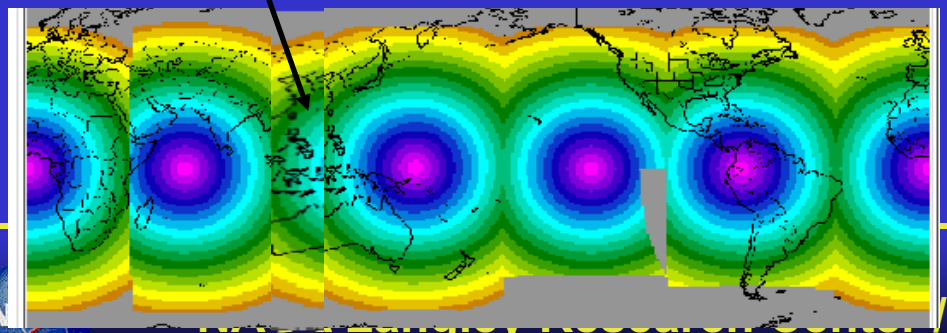
COM 0.65μm gain 2012 to 2016



COMS/Aqua-MODIS 11μm, Aug 2016



- COMS-1 is similar to GOES 8-12 and is well-calibrated
- Maybe fill in the small rectangle gap, but scan FD only every 3-hours



Scans FD 3-hourly, NH 15 minutes

Edition 4 GEO processing

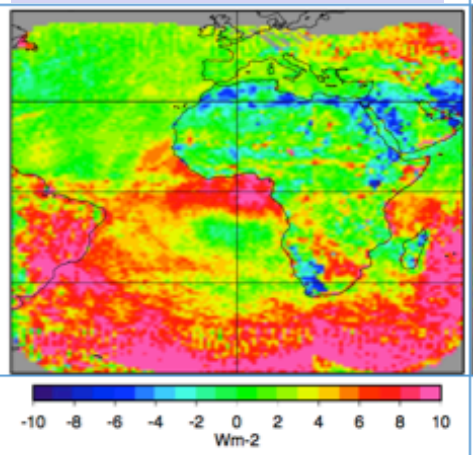
- GEO 1-hourly imager and cloud retrievals processed through June 2015
- When Himawari-8 cloud retrievals have been validated with the cloud and SARB working groups continue processing through December 2016
  - Himawari-8 has replaced MTSAT-2 beginning in July 2015
  - Continue to use Met-7 until December 2016
- Beginning January 2017 use Met-8 over Indian Ocean
  - Met-7 will be decommissioned in Jan 2017

SW TERMINATOR FLUX ANOMALY

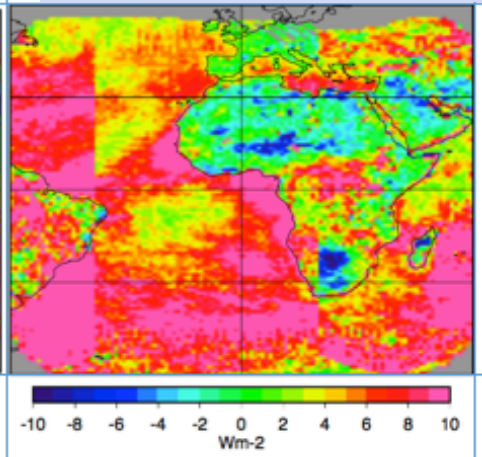
Validate the GEO SW ED4 fluxes with GERB

Dataset minus GERB monthly SW, Jan 2010

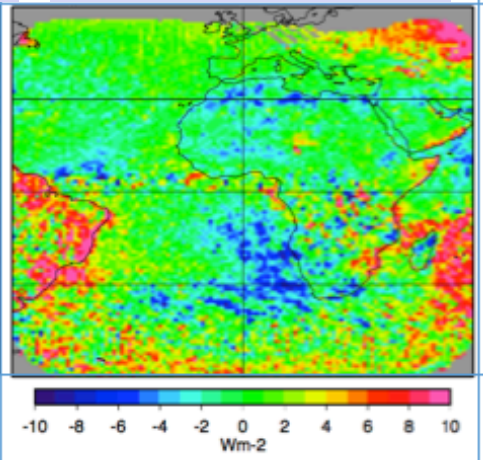
SYN1deg Ed4 GEO BB



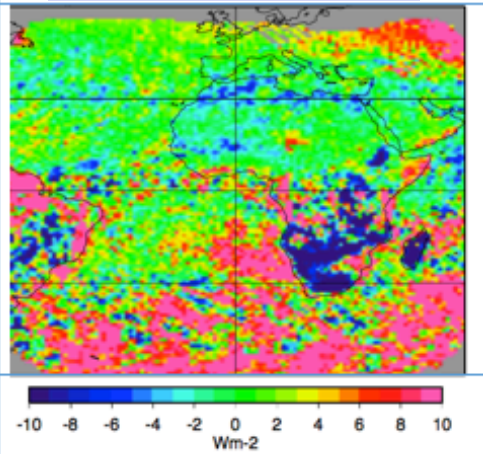
SYN1deg Ed4 computed



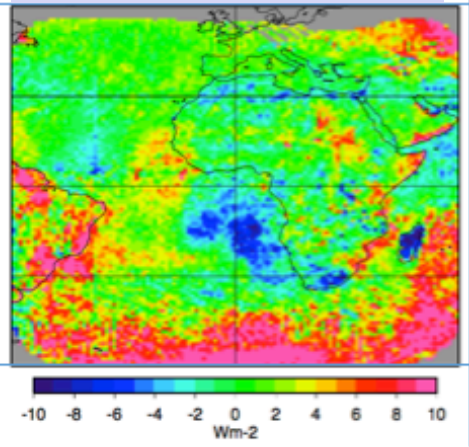
SSF1deg Terra+Aqua



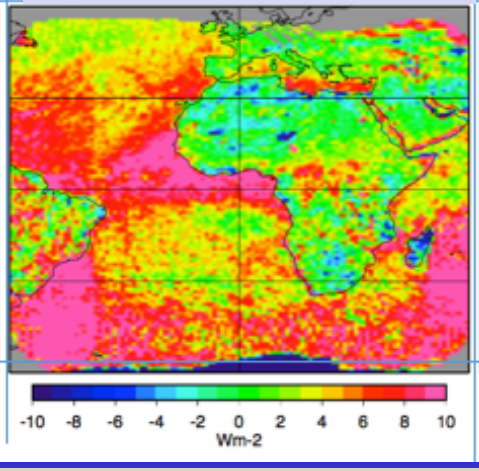
SSF1deg Terra-only



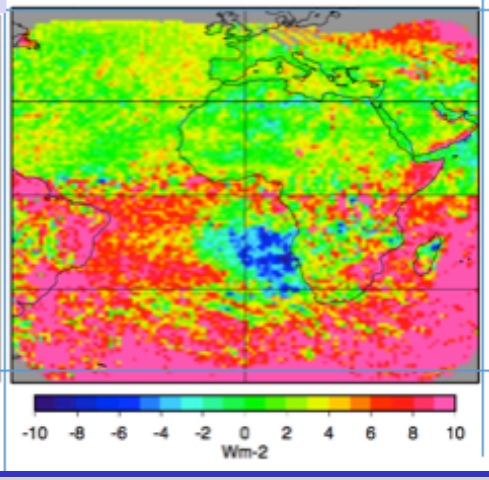
SYN1deg Ed3 GEO BB



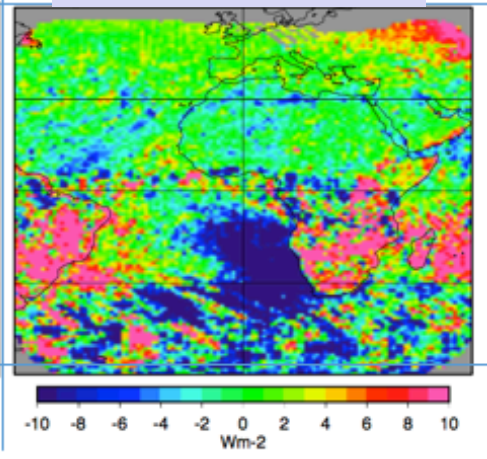
SYN1deg Ed3 computed



EBAF Ed2.8



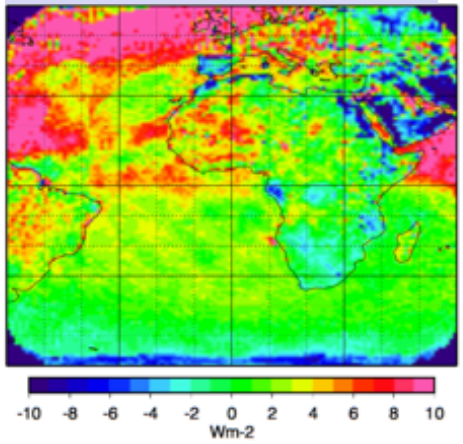
SSF1deg Aqua-only



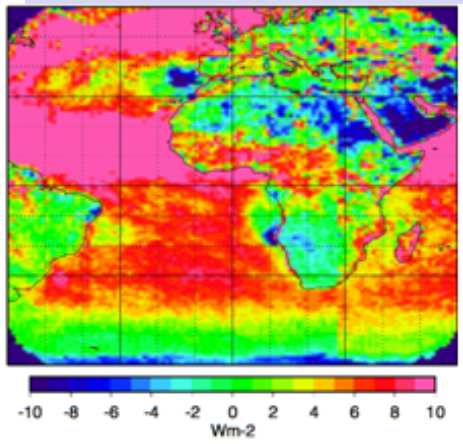
- SYN1deg GEO Ed4 overestimates the monthly SW flux w/r GERB, more then Ed3
- SSF1deg-Terra&Aqua is more similar to GERB

Dataset minus GERB monthly SW, July 2010

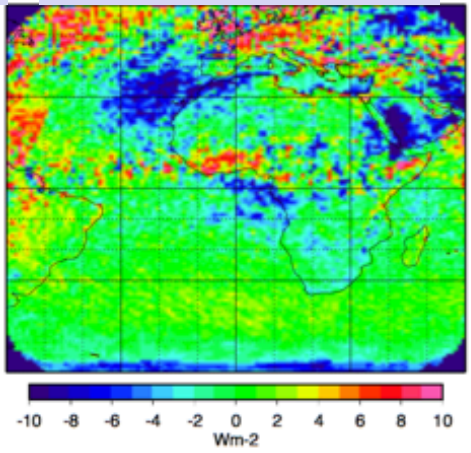
SYN1deg Ed4 GEO BB



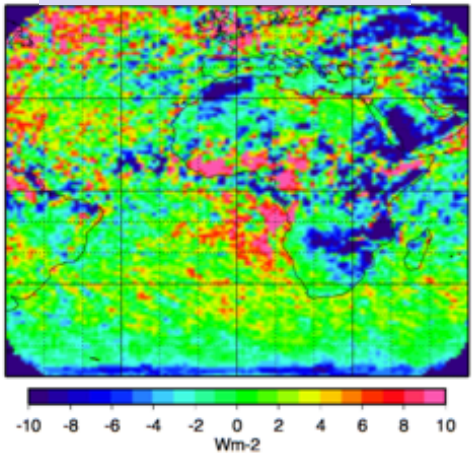
SYN1deg Ed4 computed



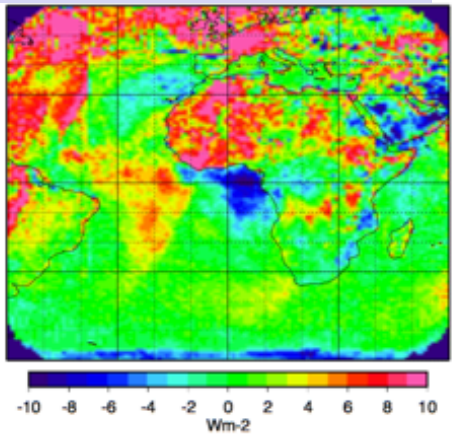
SSF1deg Terra+Aqua



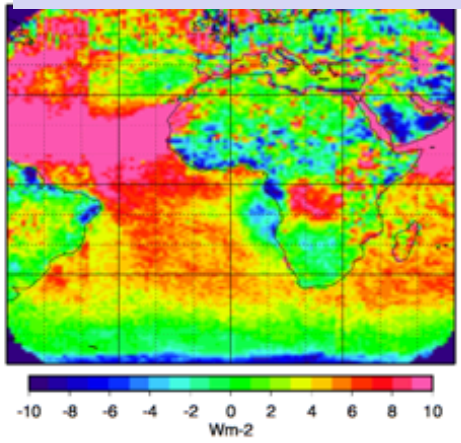
SSF1deg Terra-only



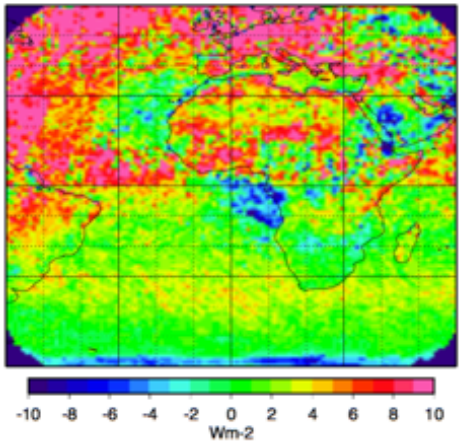
SYN1deg Ed3 GEO BB



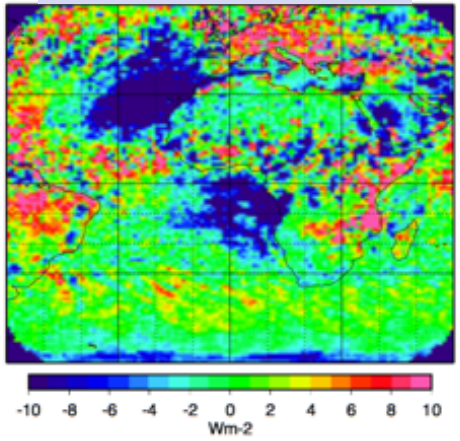
SYN1deg Ed3 computed



EBAF Ed2.8



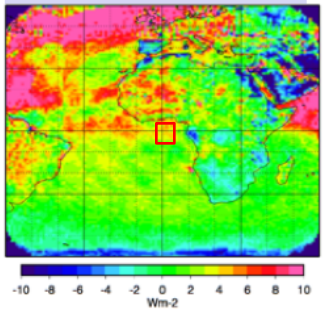
SSF1deg Aqua-only



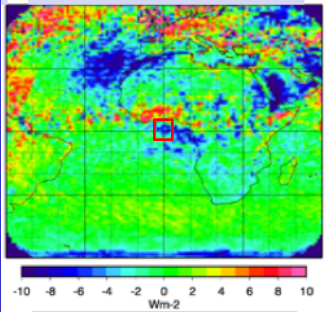
- In SH the Terra (10:30) and Aqua (1:30) are further apart to better capture diurnal
- In NH Terra and Aqua are overpasses are closer in time than in SH

Monthly Hourly SW flux, (0N 0E) July 2010

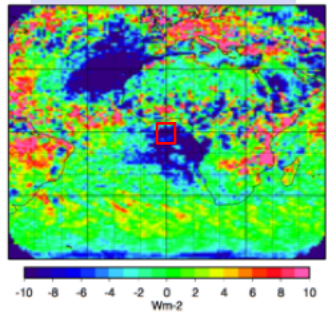
SYN1deg Ed4 GEO BB



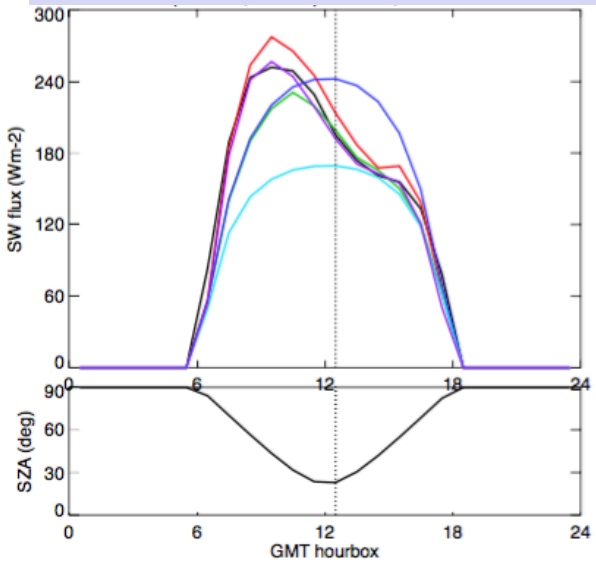
SSF1deg Terra+Aqua



SSF1deg Aqua-only

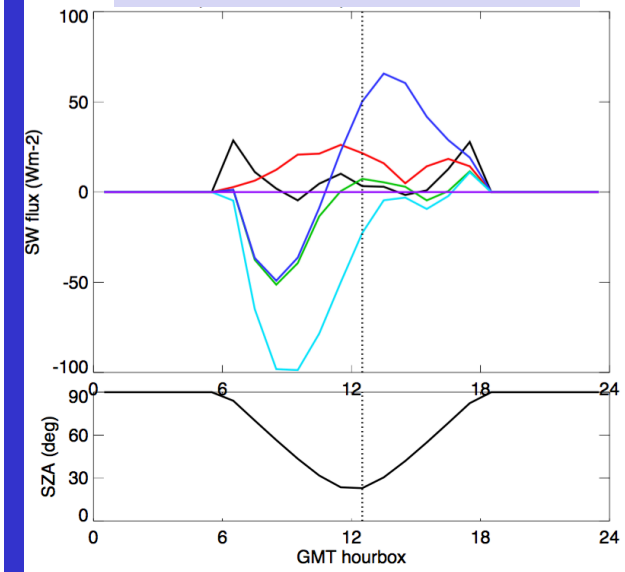


Dataset Monthly Hourly SW flux



DATASET	Month	Asym	MHstd
SYN_GEO	89.3	378.5	10.7
SYN_Comp	92.7	373.4	7.3
SSF_T+A	80.4	208.3	21.1
SSF_Terra	91.9	5.1	39.3
SSF_Aqua	67.5	4.9	40.3
GERB	85.2	369.5	0.0

Dataset minus GERB flux



DATASET	Month	Asym	MHstd
SYN_GEO-G	4.1	378.5	10.7
SYN_Comp-G	7.5	373.4	7.3
SSF_T+A-G	-4.9	208.3	21.1
SSF_Terra-G	6.6	5.1	39.3
SSF_Aqua-G	-17.7	4.9	40.3
GERB-G	85.2	369.5	0.0

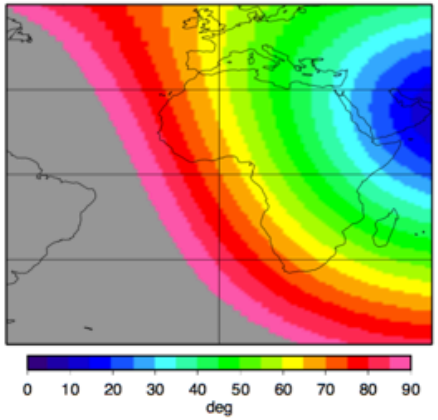
Asym = morning – afternoon flux
MHstd = Dataset – GERB
Monthly hourly RMS error

- SSF_Terra overestimates monthly SW flux by +7 Wm-2 of GERB
- SSF_Aqua underestimates monthly SW flux -18 Wm-2 of GERB
- SSF_Terra&Aqua underestimates monthly SW flux by -5 Wm-2 and only has half of the asymetric flux of GERB
- SYN has same asymetric flux, small MH RMS error, but monthly SW flux +4 Wm-2 of GERB, due to near terminator flux anomaly

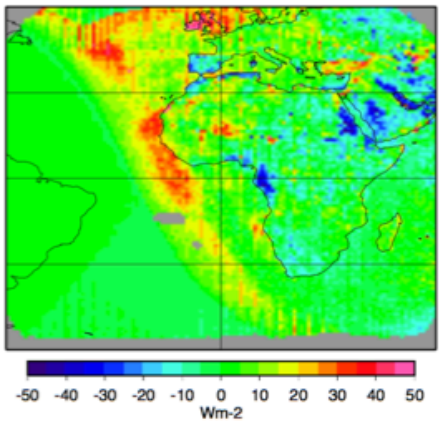
NA

Dataset minus GERB MH SW flux, July 2002

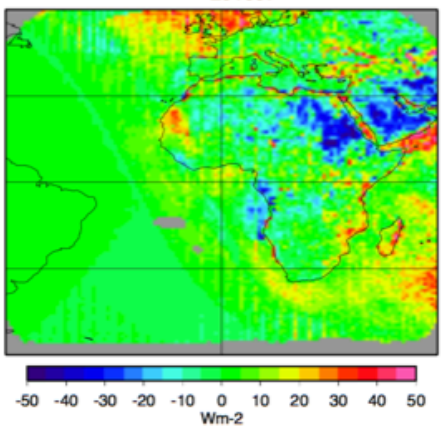
SZA, GMT=7



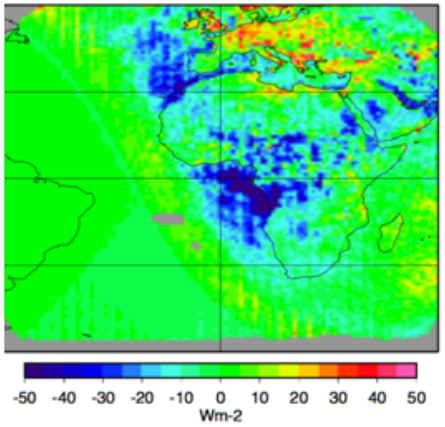
SYN-GEO, GMT=7



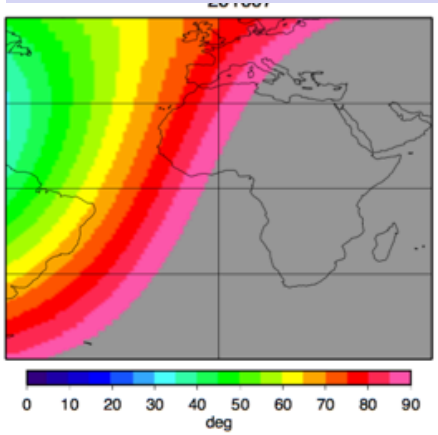
SYN-COMP, GMT=7



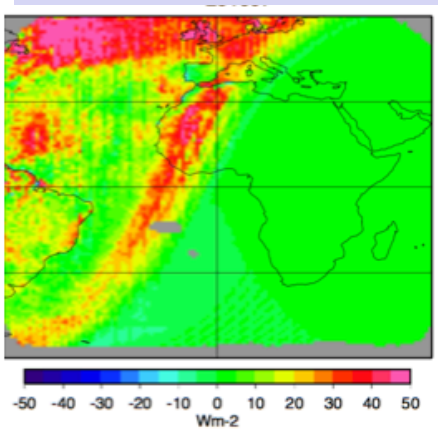
SSF-Terra&Aqua, GMT=7



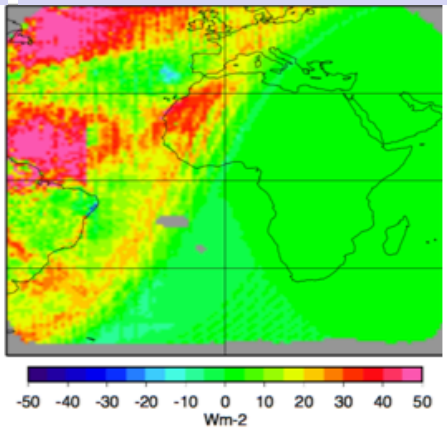
SZA, GMT=7



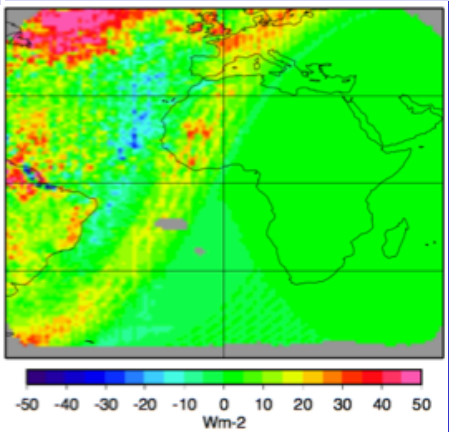
SYN-GEO, GMT=18



SYN-COMP, GMT=18

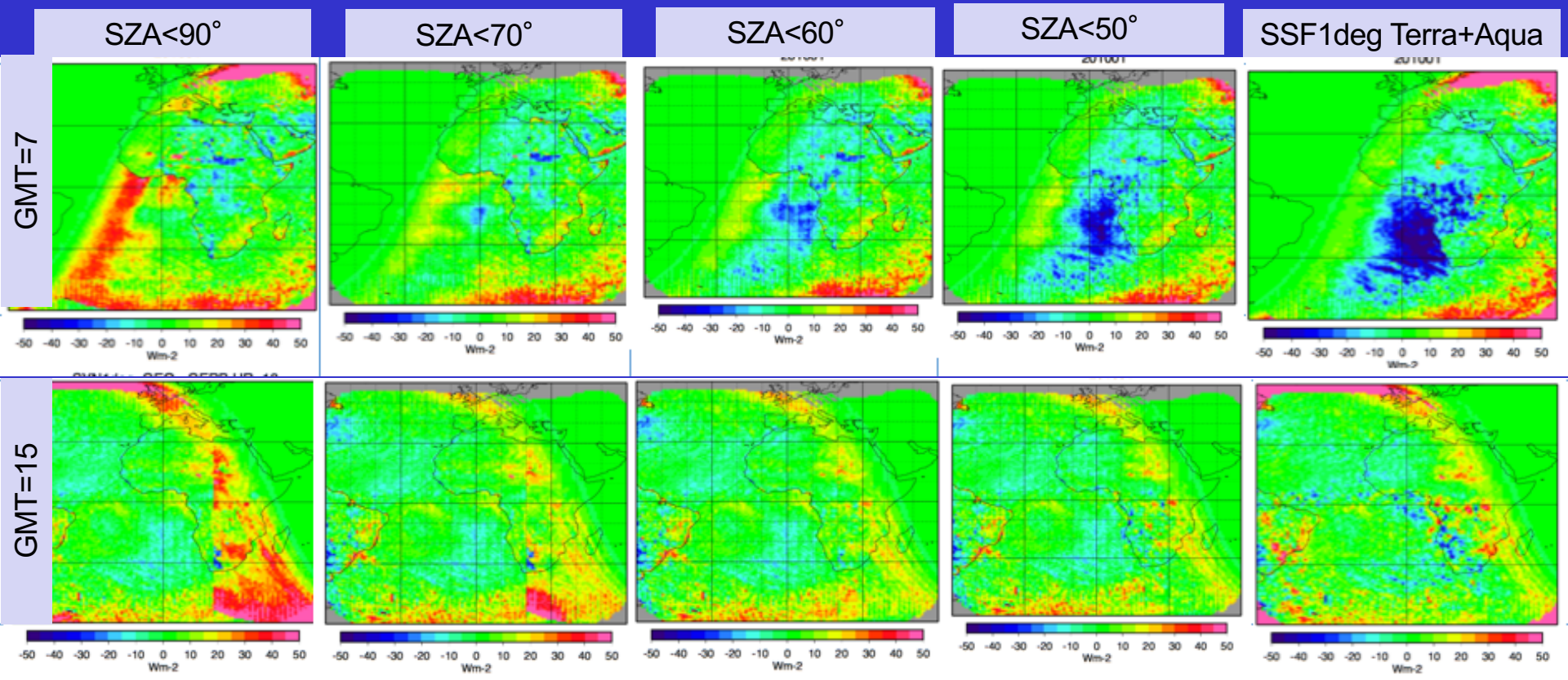


SSF-Terra&Aqua, GMT=18



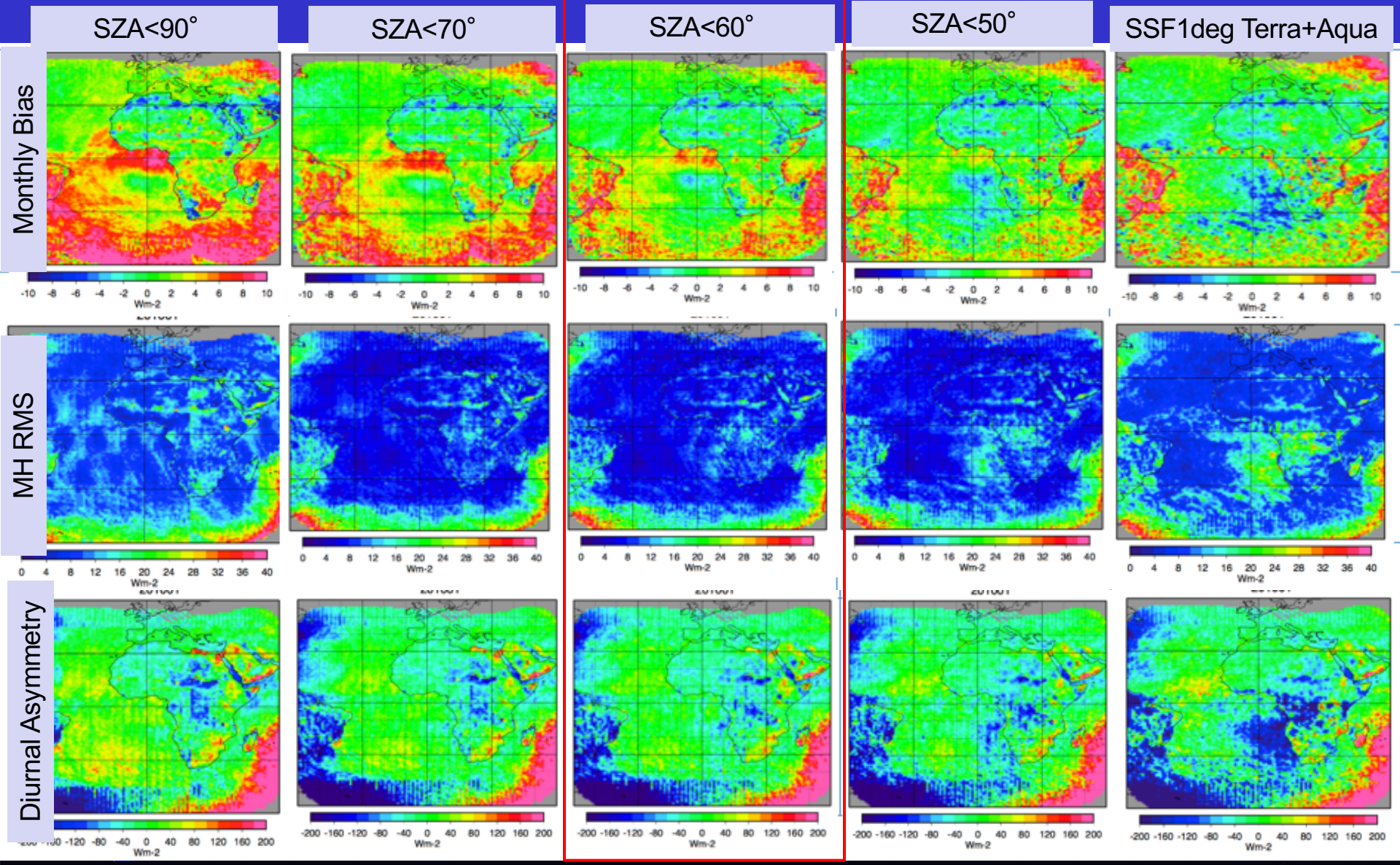
- Clearly the SYN-GEO has a near terminator flux anomaly
- Do not use GEO fluxes for SZA>threshold, and rely on directional models

Dataset minus GERB MH SW flux, Jan 2002



• The SZA threshold is a delicate balance between removing the GEO diurnal signal or the near terminator flux anomaly

Dataset minus GERB, Jan 2002



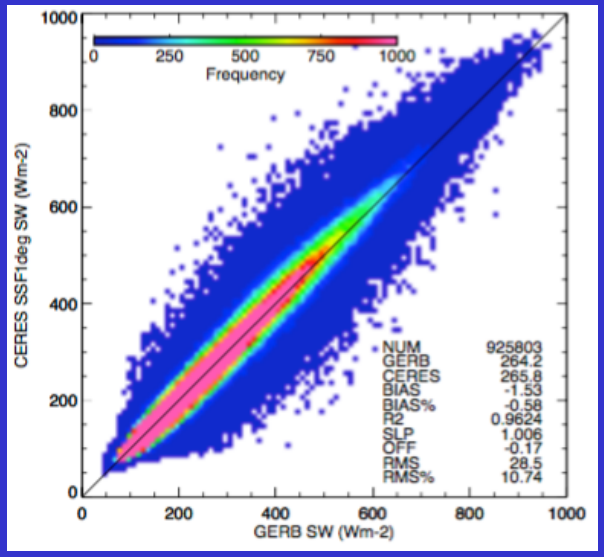
Near Terminator SW Flux Anomaly

- As a quick fix to release the SYN1deg Ed4 dataset, only use GEO BB fluxes where the SZA <60˚
  - Rely on directional model
  - Do not need to rerun SYNI, since the untuned relies on the cloud properties only
  - Deliver the new TSI code, and rerun 15 years at DAAC
  - Rerun the SYN1deg code using existing SYNI and new TSI
- The Ed4 SW derived BB flux code is the same Ed3
  - However, the hourly GEO observations have reduced the time difference from 90 to 30 minutes when linearly regressing the CERES and GEO fluxes to normalize the GEO measurements to CERES
- TISA greatest priority will be to improve the GEO SW flux code
  - Evaluate the ADM, SW NB to BB, GEO/MODIS clouds, etc

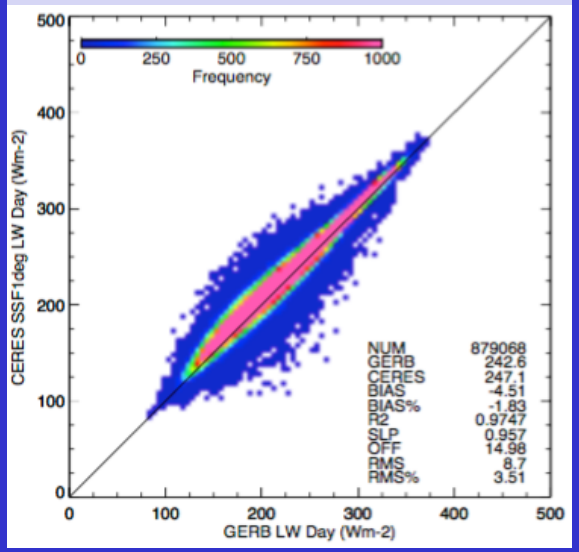
CERES/GERB COMPARISONS

GERB and CERES coincident flux

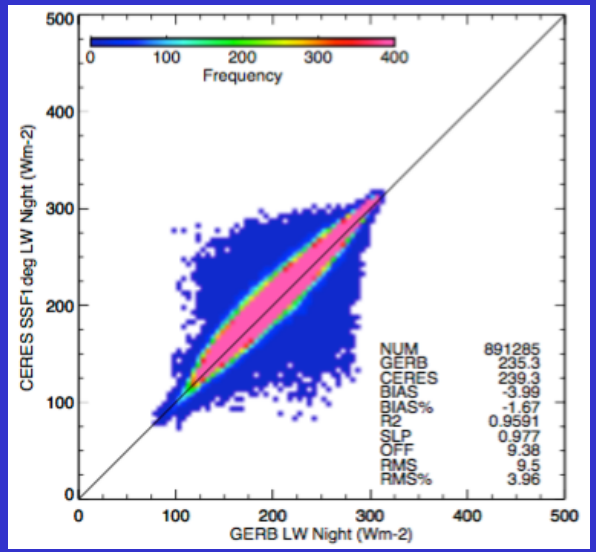
SW, Jan 2010



LW day, Jan 2010



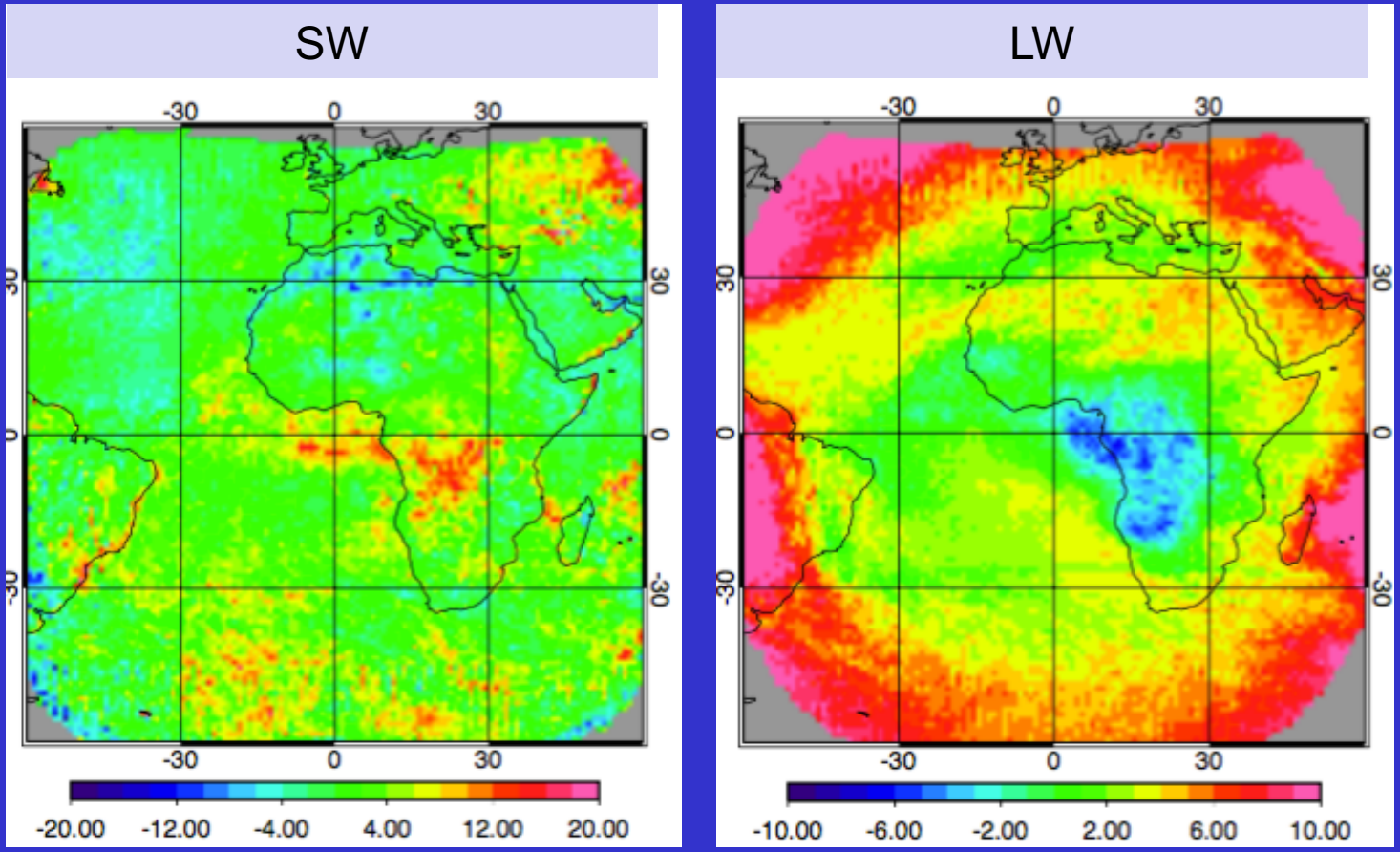
LW night, Jan 2010



CERES-GERB (%)	SW day	LW day	LW night
July 2004	+8.3	-2.3	-2.2
Jan 2005	+7.3	-2.6	-2.3
Jan 2010	-0.6	-1.8	-1.7
July 2010	-0.2	-1.7	-1.6
Jan 2012	-2.6	-1.8	-1.7
July 2012	-2.3	-1.6	-1.6
Jan 2016	+6.9	-2.0	-2.0

GERB 1&2: BARG Ed2
GERB3: BARG Ver999
CERES: Ed4

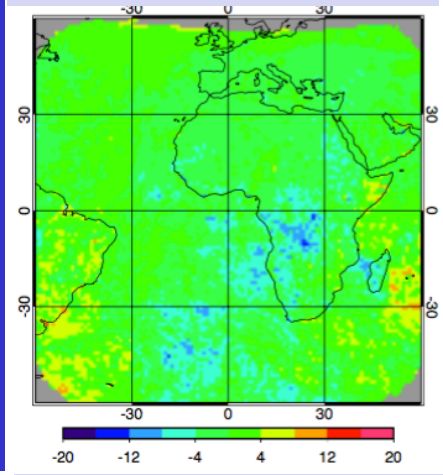
CERES – GERB regional bias, Jan 2005



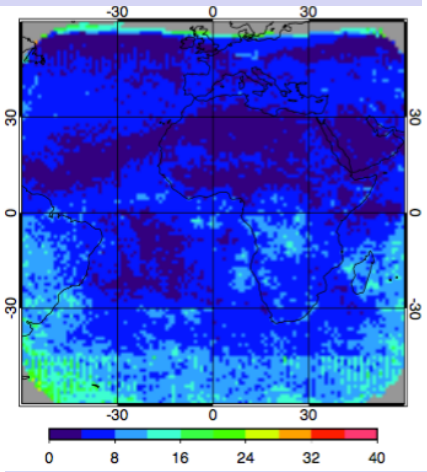
- Use mean CERES/GERB regional monthly ratio to normalize GERB to CERES
- Use CERES/GERB regional monthly linear regression to normalize

CERES – GERB SW, Jan 2010

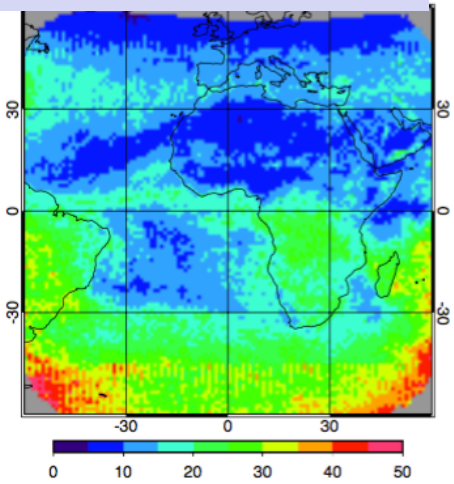
SYN monthly,
RMS=2.9%



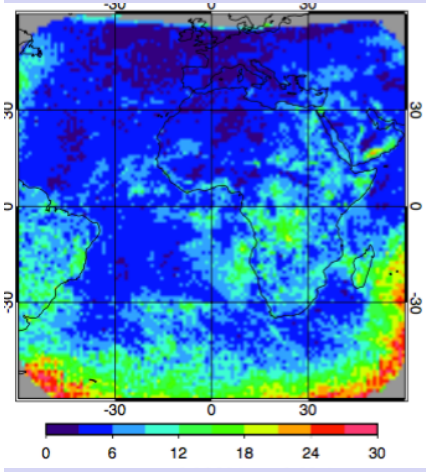
SYN daily
RMS=6.1%



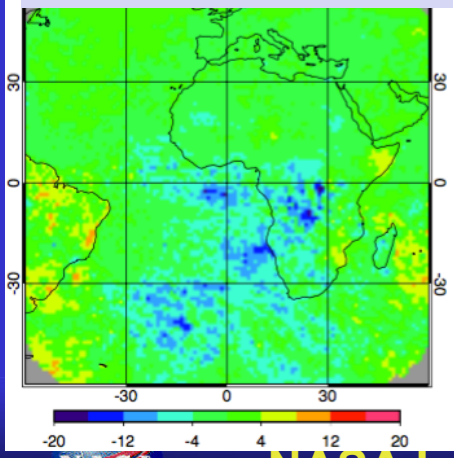
SYN hourly
RMS=17.0%



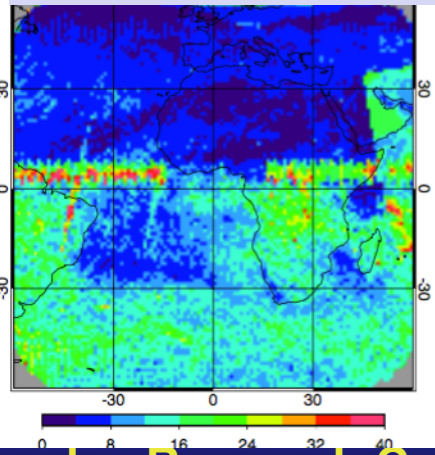
SYN Mhour
RMS=6.9%



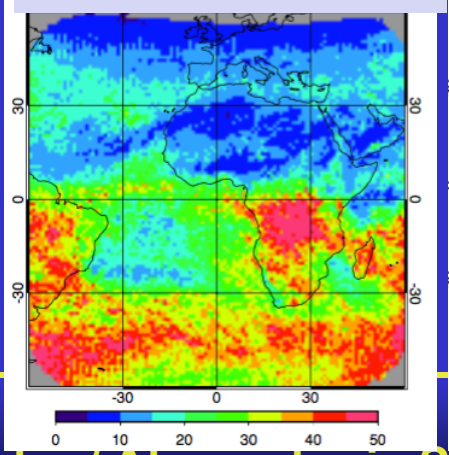
SSF-T&A monthly
RMS=3.7%



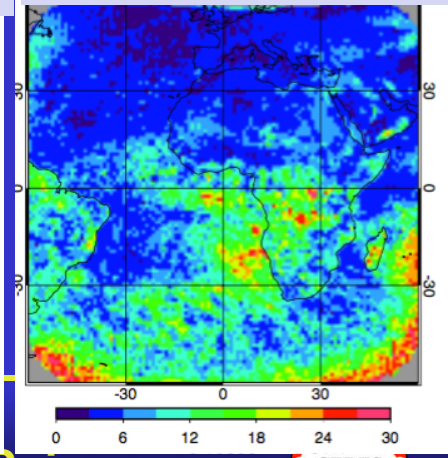
SSF-T&A daily
RMS=11.5%



SSF-T&A hourly
RMS=23.2%

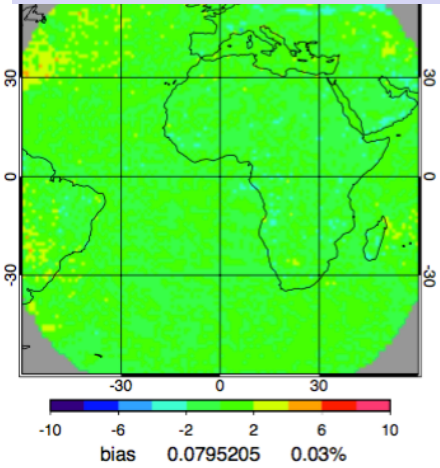


SSF-T&A Mhour
RMS=9.0%

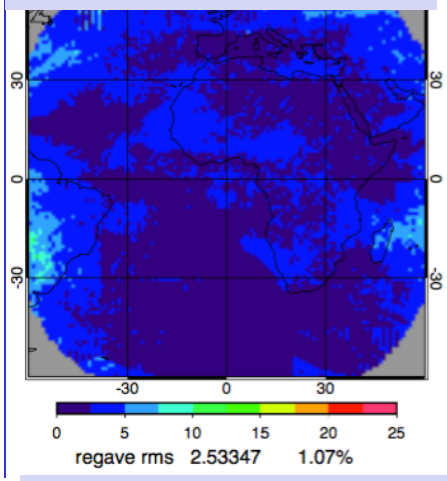


CERES – GERB LW, Jan 2010

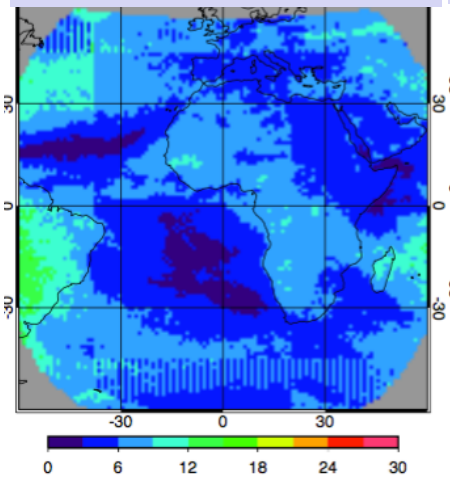
SYN monthly,
RMS=0.4%



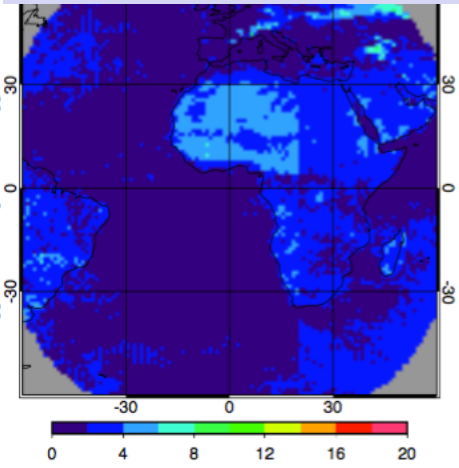
SYN daily
RMS=1.1%



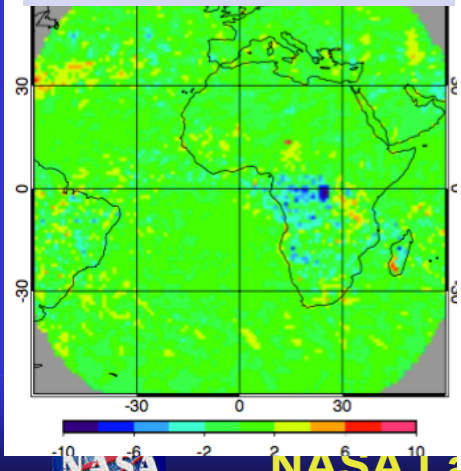
SYN hourly
RMS=2.5%



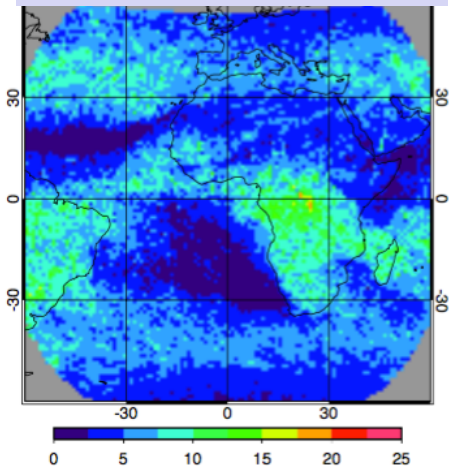
SYN Mhour
RMS=0.8%



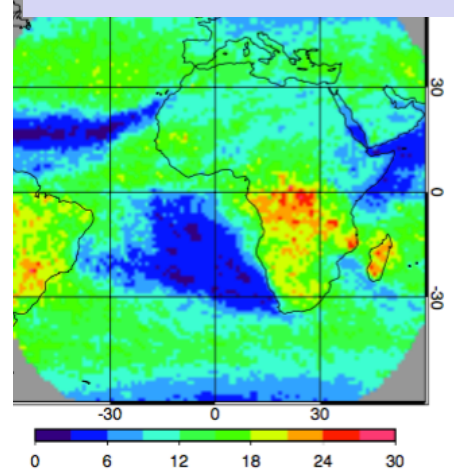
SSF-T&A monthly
RMS=0.6%



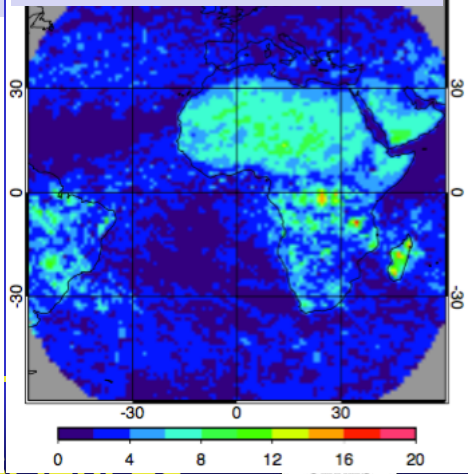
SSF-T&A daily
RMS=2.2%



SSF-T&A hourly
RMS=4.8%



SSF-T&A Mhour
RMS=1.3%



CERES – GERB SW Comparisons SYN/SSF_TA

RMS %	Bias	Monthly	Daily	1hour	M1hour
Jul 2004	-0.6/-1.8	3.5/4.5	6.3/11.3	17.0/23.1	7.6/9.1
Jan 2005	-0.8/-1.6	3.5/4.2	6.3/10.2	17.4/23.2	7.5/8.7
Jan 2010	-0.5/-1.3	2.9/3.7	5.9/10.4	17.0/23.2	6.9/8.2
Jul 2010	-1.5/-2.6	4.4/5.0	6.7/11.4	17.3/23.4	8.2/9.6
Jan 2012	1.1/0.2	2.9/3.0	6.6/10.4	18.0/23.5	6.8/7.7
Jul 2012	1.5/0.4	4.7/4.7	6.8/11.4	17.4/23.1	8.0/9.1
Jan 2016	-0.8/-1.3	2.9/3.3	6.0/9.5	17.0/22.7	6.9/8.1

- The SYN product is an improvement over using SSF Terra+Aqua, especially for higher spatial resolutions
- Daily, hourly, and M1hour RMS errors reduced by 40%, 25% and 15% compared to SSF_TA %, respectively.

CERES – GERB SW Comparisons SYN/SYN_terminator_flux

RMS %	Bias	Monthly	Daily	1hour	M1hour
Jul 2004	-0.6/1.1	3.5/4.2	6.3/6.0	17.0/17.5	7.4/9.4
Jan 2005	-0.8/1.1	3.5/3.9	6.3/5.9	17.4/17.6	7.5/9.3
Jan 2010	-0.5/1.4	2.9/3.5	5.9/5.6	17.0/17.4	6.9/9.2
Jul 2010	-1.5/0.2	4.4/4.5	6.7/6.2	17.3/17.4	8.2/10.0
Jan 2012	1.1/3.1	2.9/4.6	6.6/6.9	18.0/18.7	6.8/9.4
Jul 2012	1.5/3.3	4.7/6.0	6.8/7.0	17.4/18.1	8.0/10.3
Jan 2016	-0.8/1.3	2.9/3.4	6.0/5.6	17.0/17.1	6.9/8.6

• The SYN terminator flux increased the regional monthly flux bias and the monthly hourly flux RMS, which was even greater than the SSF Terra+Aqua

CERES – GERB LW Comparisons SYN/SSF_TA

RMS%	Bias	Monthly	Daily	1hour	M1hour
Jul 2004	-0.0/0.1	0.4/0.6	1.0/1.8	2.2/3.8	0.7/1.1
Jan 2005	-0.0/0.1	1.1/1.1	1.2/2.3	2.6/4.8	0.8/1.3
Jan 2010	0.0/0.1	0.4/0.6	1.1/2.2	2.5/4.8	0.8/1.3
Jul 2010	-0.0/0.1	0.3/0.5	1.0/1.8	2.9/3.9	0.7/1.1
Jan 2012	0.0/0.1	0.4/0.5	1.3/2.2	2.8/4.5	0.9/1.2
Jul 2012	-0.0/0.1	0.3/0.5	1.0/1.8	2.2/3.8	0.7/1.1
Jan 2016	-0.2/0.1	1.2/1.2	1.2/2.2	2.7/4.8	1.0/1.2

- The SYN product is an improvement over using SSF Terra+Aqua, especially for higher spatial resolutions
- Monthly, Daily, hourly and M1hour RMS errors reduced by 30%, 45%, 45% and 15%, respectively, compared to SSF_TA
- The GEO LW is based on IR and WV NB2BB and not dependent on clouds

GERB and CERES Comparison Conclusions

Ed3 from Doelling et al. 2013

RMS %	SW month	SW daily	LW month	LW daily
Ed3	3.5	7.8	0.5	1.9
Ed4	3.5	6.3	0.4	1.1

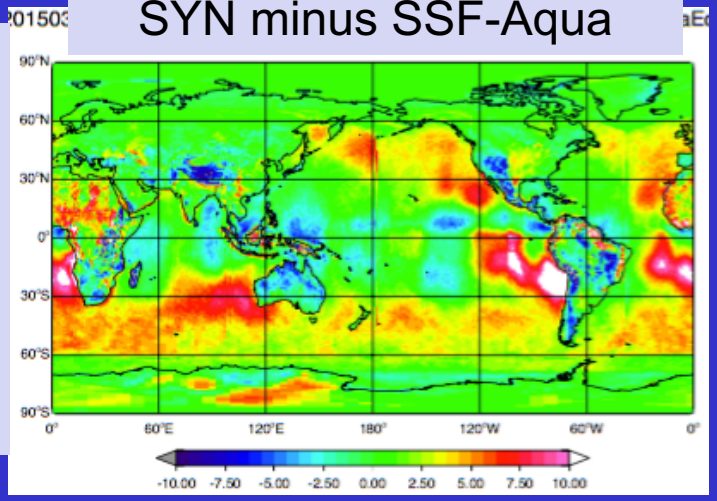
- SYN Ed4 is an improvement over Ed3, especially for LW
- The LW is now includes the GEO WV channel and does not use GEO clouds, does not use TRMM ADM
- SW improvements due to hourly GEO rather than 3-hourly and 4-channel clouds, algorithms remained the same

ED4 AND ED3 SYN1DEG TREND ANOMALIES

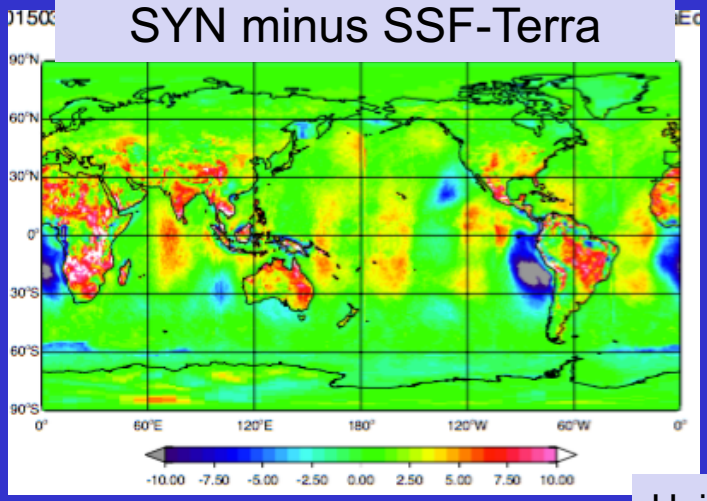
SYN – SSF 12-year SW flux difference

Edition 3

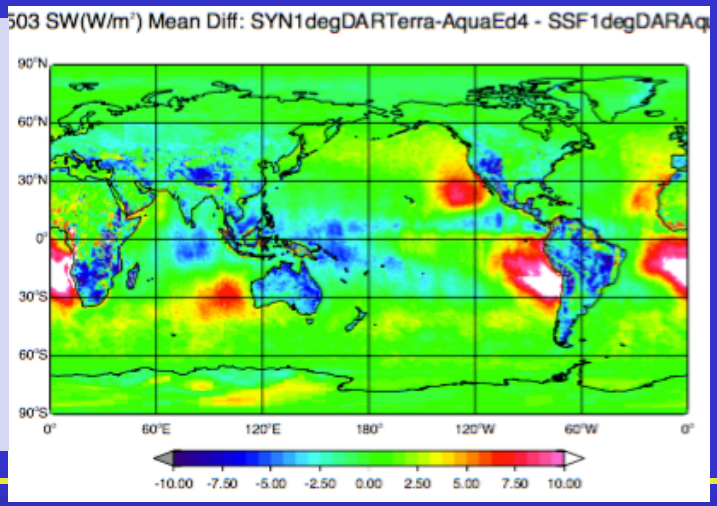
SYN minus SSF-Aqua

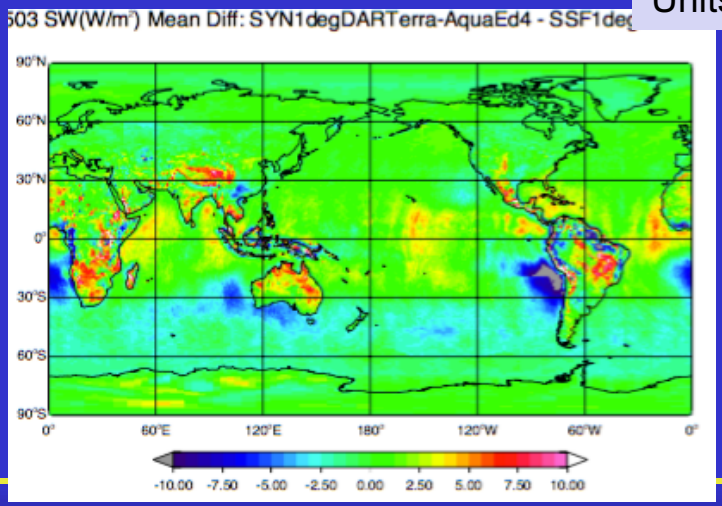


SYN minus SSF-Terra



Edition 4





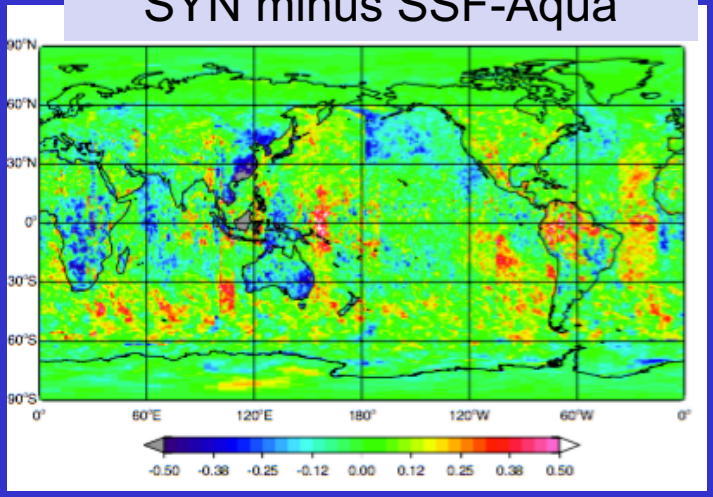
Units: Wm^{-2}

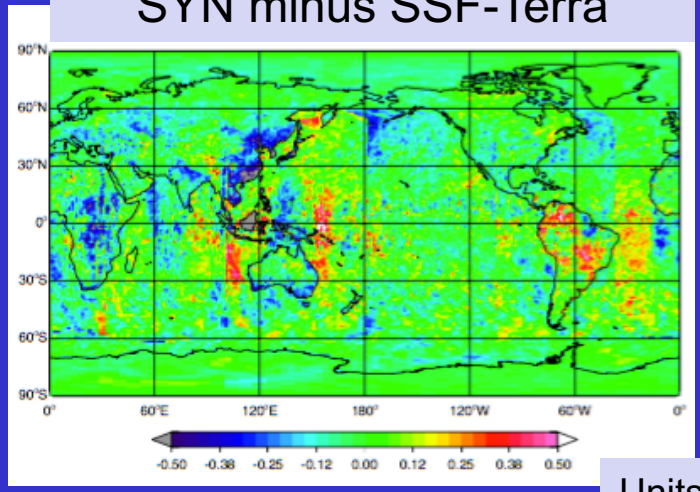
SYN – SSF SW regional trend anomalies

SYN minus SSF-Aqua

SYN minus SSF-Terra

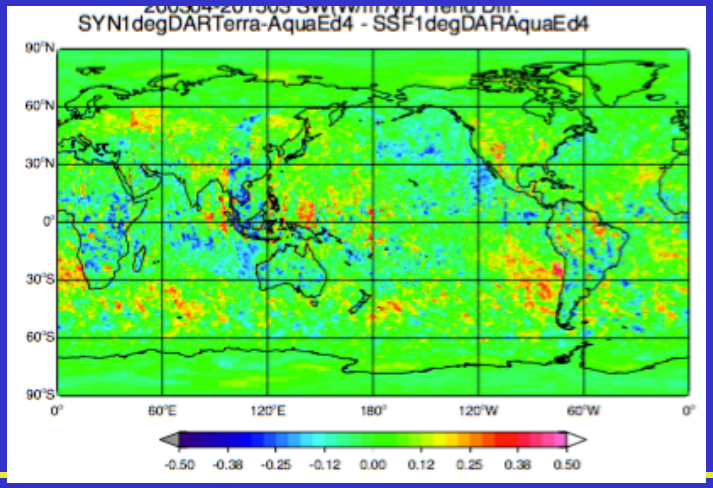
Edition 3

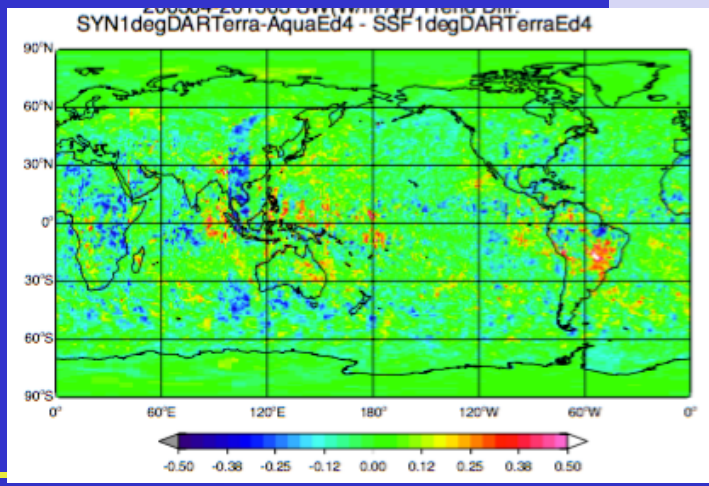




Units: $Wm^{-2}yr^{-1}$

Edition 4

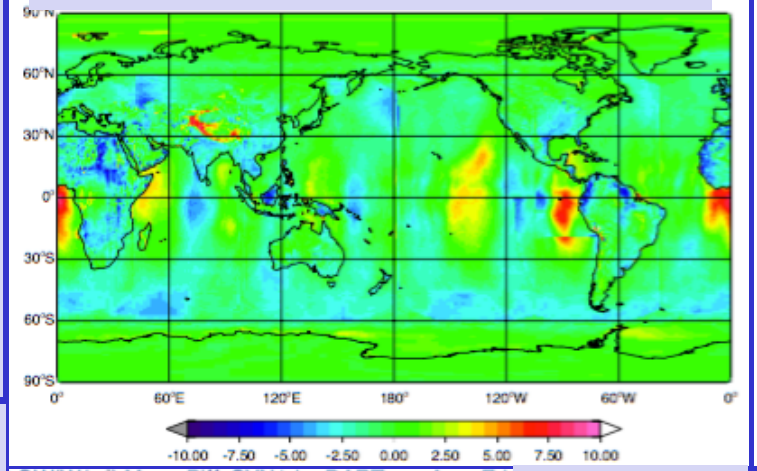




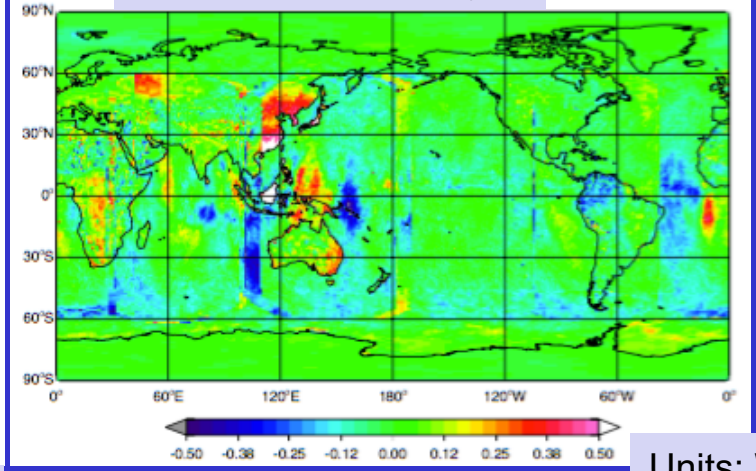
SYN Ed4 SW flux comparisons

SYN Ed4 minus Ed3

Mean difference



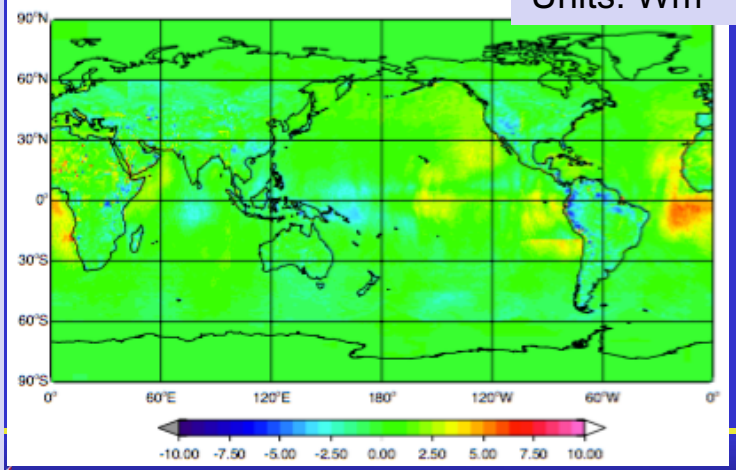
Trend anomaly

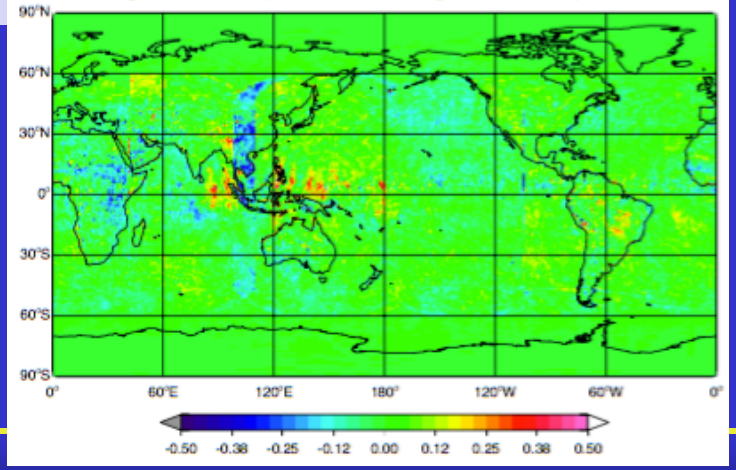


Units: $Wm^{-2}yr^{-1}$

SYN Ed4 minus SSF-Terra+Aqua

Units: Wm^{-2}



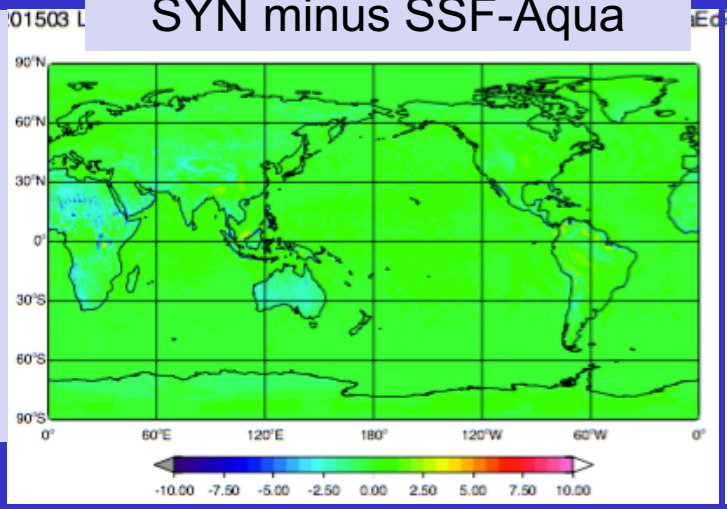


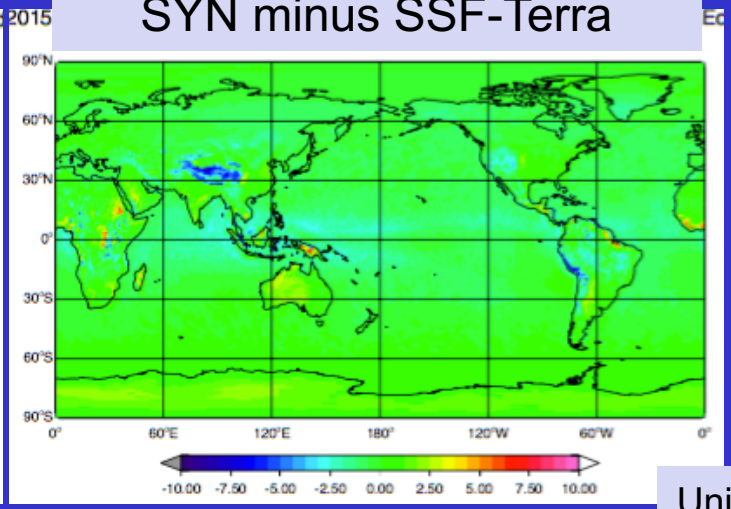
SYN – SSF 12-year LW flux difference

SYN minus SSF-Aqua

SYN minus SSF-Terra

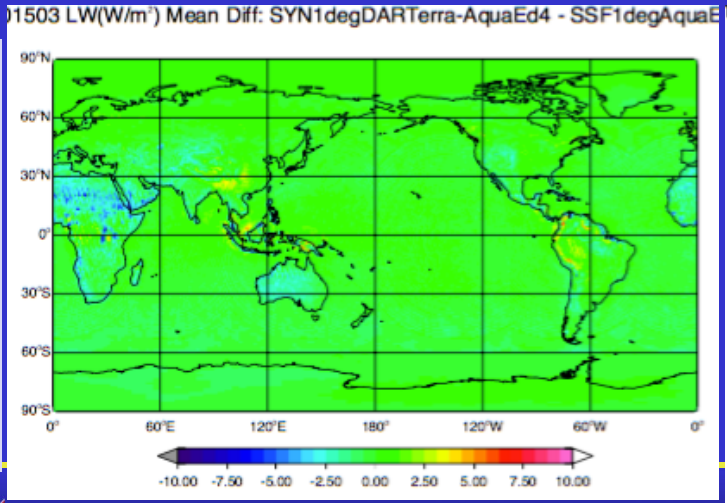
Edition 3

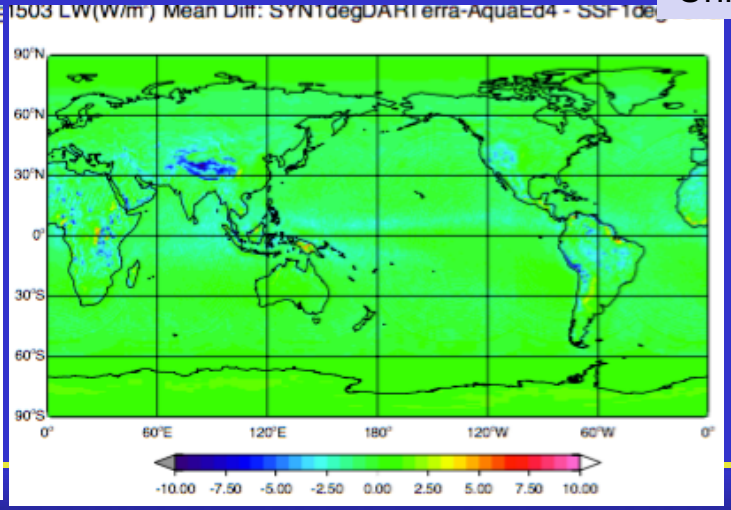




Units: Wm^{-2}

Edition 4

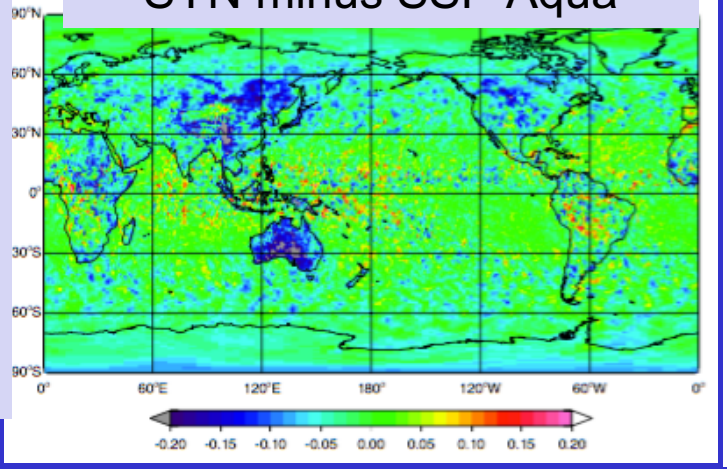




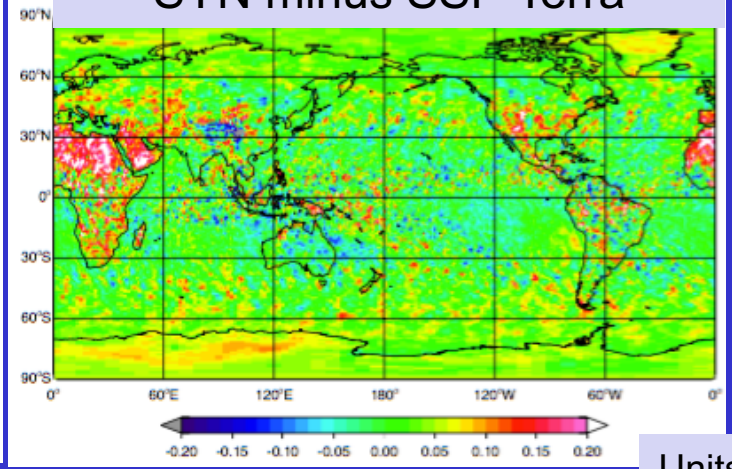
SYN – SSF LW regional trend anomalies

Edition 3

SYN minus SSF-Aqua



SYN minus SSF-Terra



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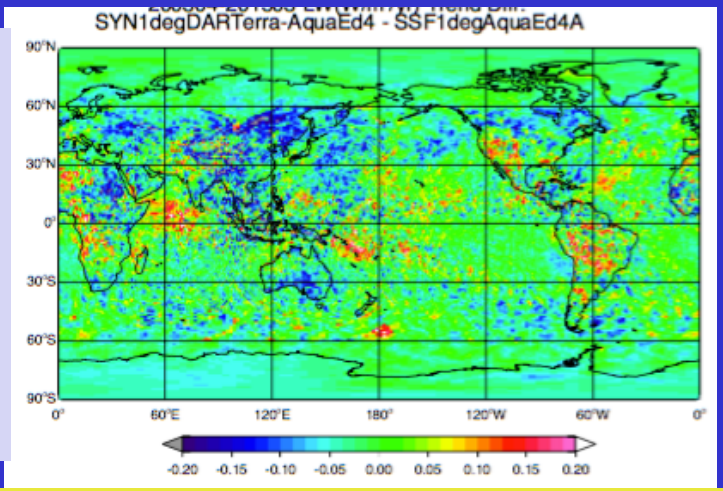
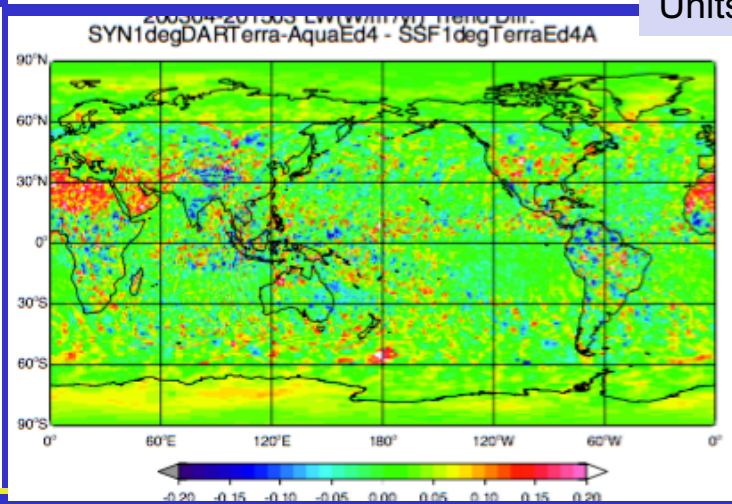




Units: $Wm^{-2}yr^{-1}$

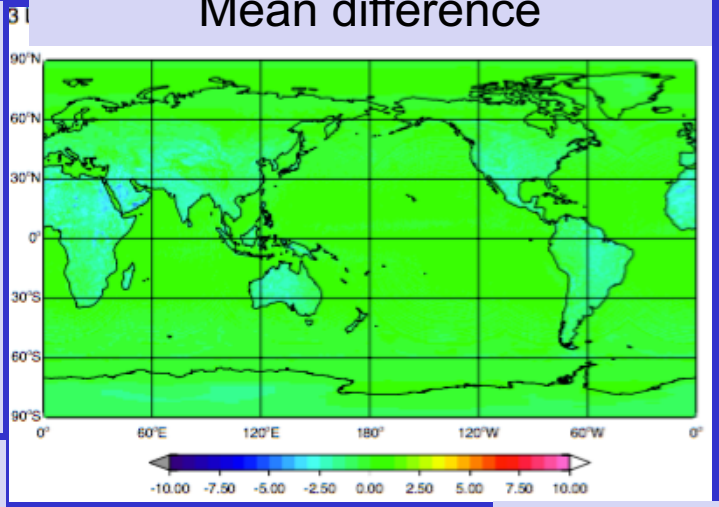
SYN Ed4 LW flux comparisons

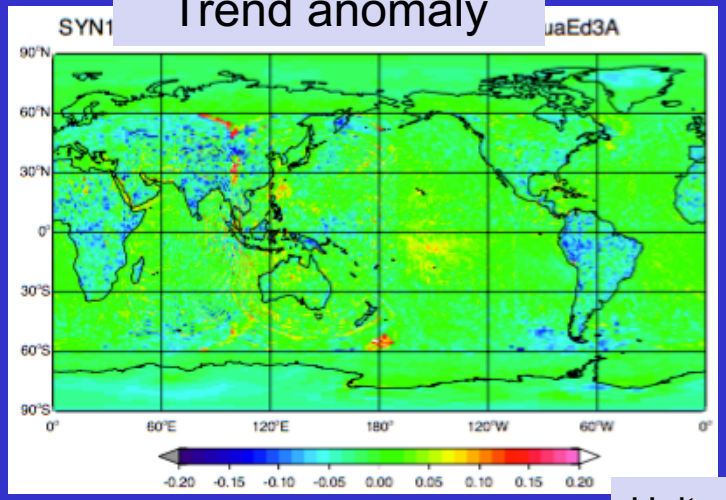
SYN Ed4 minus Ed3

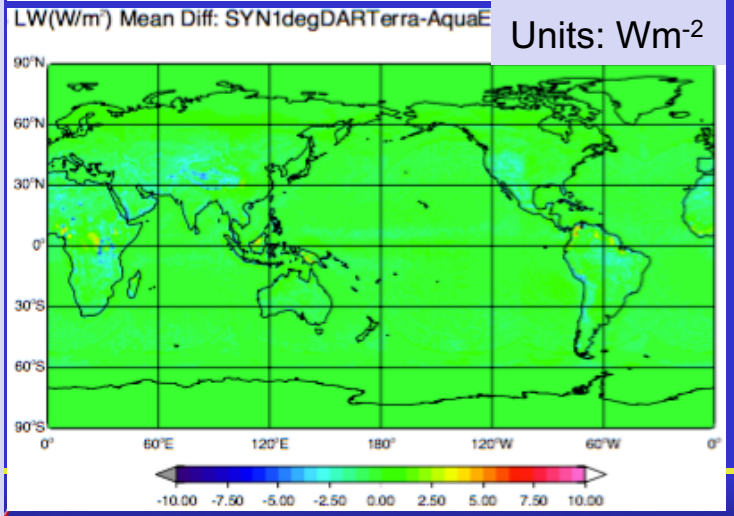
SYN Ed4 minus SSF-Terra+Aqua

Mean difference

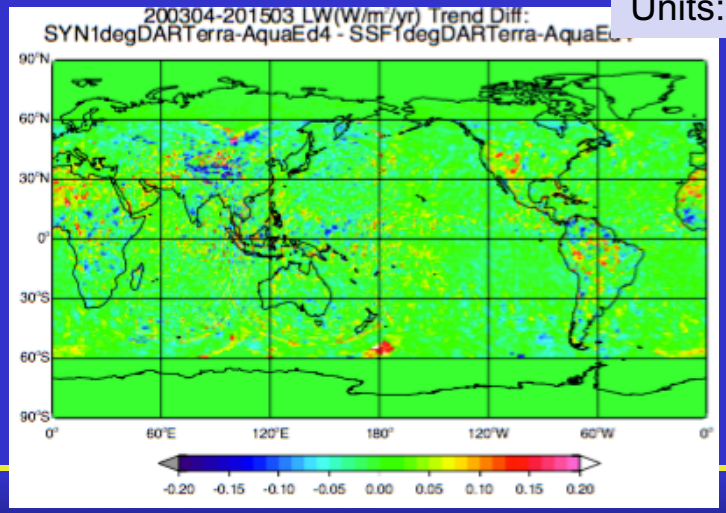
Trend anomaly







Units: Wm^{-2}



Units: $Wm^{-2}yr^{-1}$

SYN Ed4 trend anomaly conclusion

	Ed3 SW	Ed3 LW	Ed4 SW	Ed4 LW
SSF-Terra	96.27	239.21	96.79	239.21
SSF-Aqua	96.06	238.96	96.60	238.79
SYN	97.56	238.79	96.87	238.57

- The SYN Ed4 minus SSF1deg-Terra&Aqua have smaller regional SW and LW flux differences than Ed3
- The relative SYN Ed4 regional SW and LW flux trends are smaller compared to SSF1deg than Ed3
- The SYN1deg Ed4 global mean SW flux is 0.77 Wm^{-2} less than Ed3, for LW -0.22 Wm^{-2}
  - SSF1deg Ed4 – Ed3 SW ~0.5 Wm^{-2}

SW SENSITIVITY STUDIES

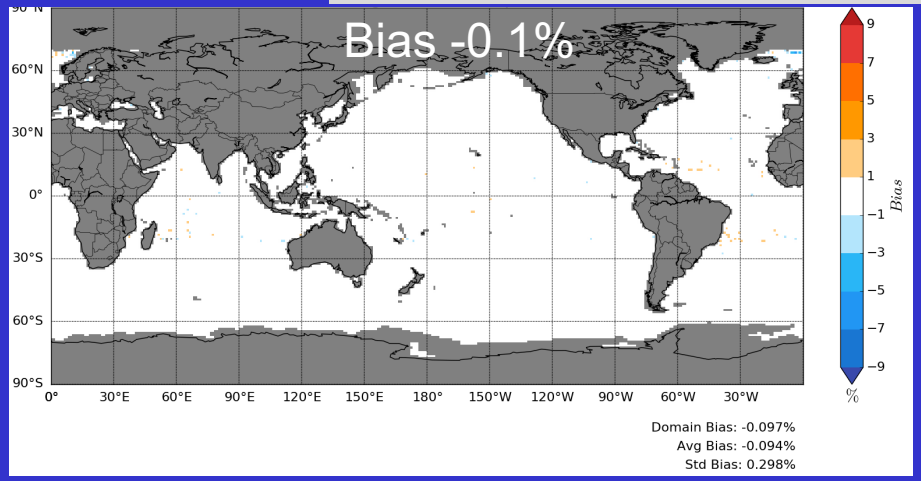
Planned GEO visible to SW flux studies

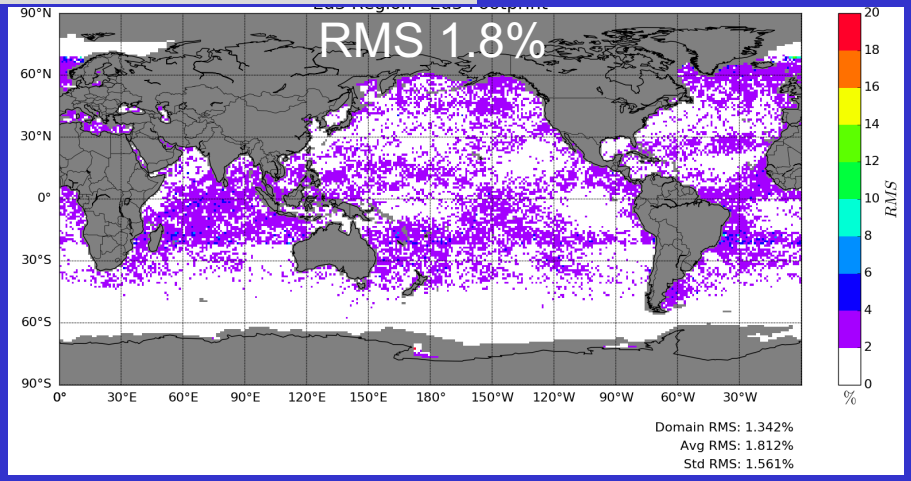
- GEO derived SW flux
  - Calibrate GEO visible channels with MODIS C6
  - Theoretical GEO visible to MODIS band 1 (0.65μm) radiance conversion
  - Empirical (SSF) GEO-MODISlike to BB radiance conversion
  - Convert BB radiance to flux using CERES TRMM ADMs
  - Normalize GEO fluxes with CERES using coincident data
- 1-hourly GEO from 3-hour reduced the Aqua-based GEO minus Terra observed fluxes RMS error from 13.6 to 9.0 Wm^{-2}
- ADM studies
  - Footprint vs regional, MODIS vs GEO clouds, TRMM vs Ed4 ADM
- SSF and Himawari-8 multiple visible channel to BB radiance studies
  - Adding 11μm improves SSF based NB2BB from 10.3 Wm^{-2} to 8.6 Wm^{-2}
  - Use SSF derived multi-channel NB to BB coefficients with Him-8
- Test theoretical GEO NB to BB radiance models designed for each GEO
  - Use ScaRaB BB radiance to evaluate improvement
  - Use Aqua based models and compare with Terra observations

ADM sensitivity studies

Regional (110km) minus Footprint (20km) TRMM SW ADM application

CERES radiances and MODIS clouds, Jan 2010

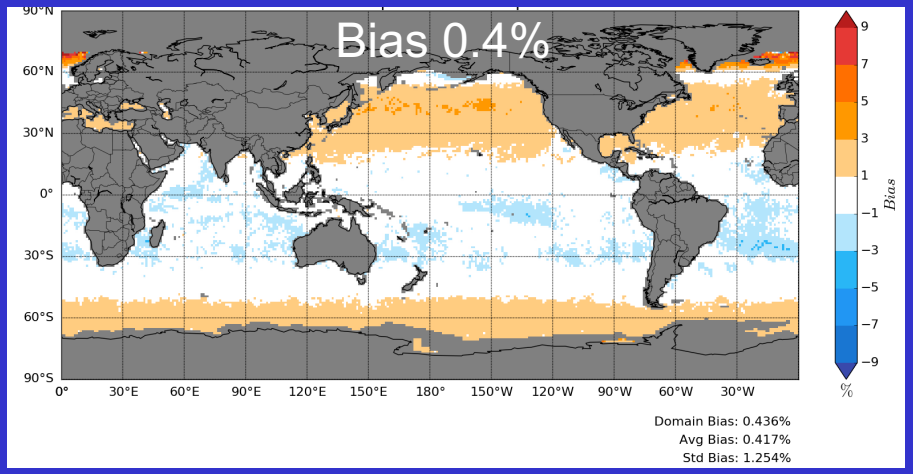


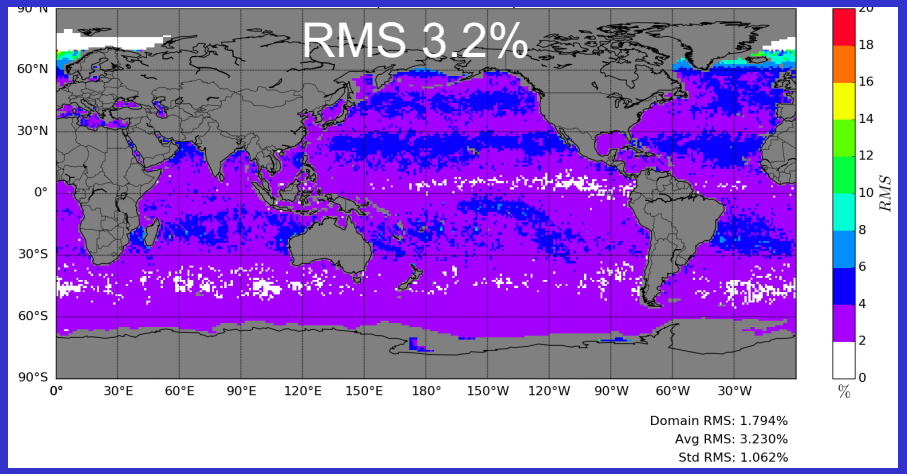


- Little dependence of footprint size when applying TRMM SW ADM

TRMM minus Ed4 SW ADM

Using CERES footprint radiances and MODIS clouds, Jan 2010

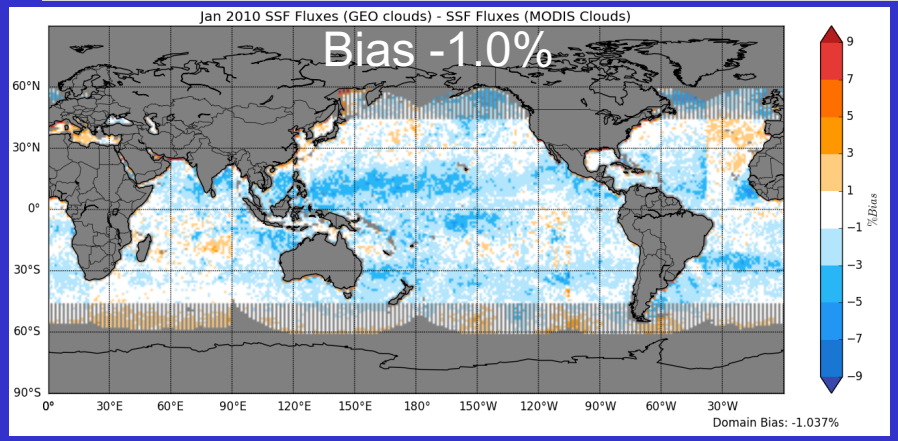


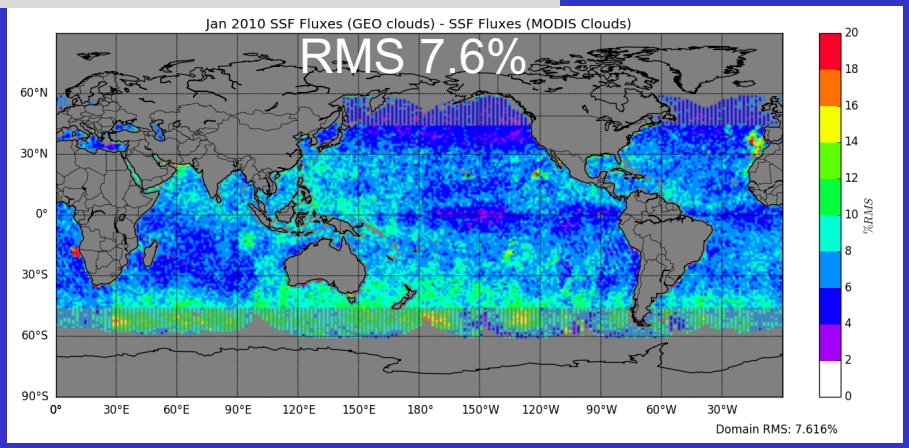


- SZA (zonal) dependent TRMM vs Ed4 SW ADM difference
- TRMM orbit within ±35° latitude

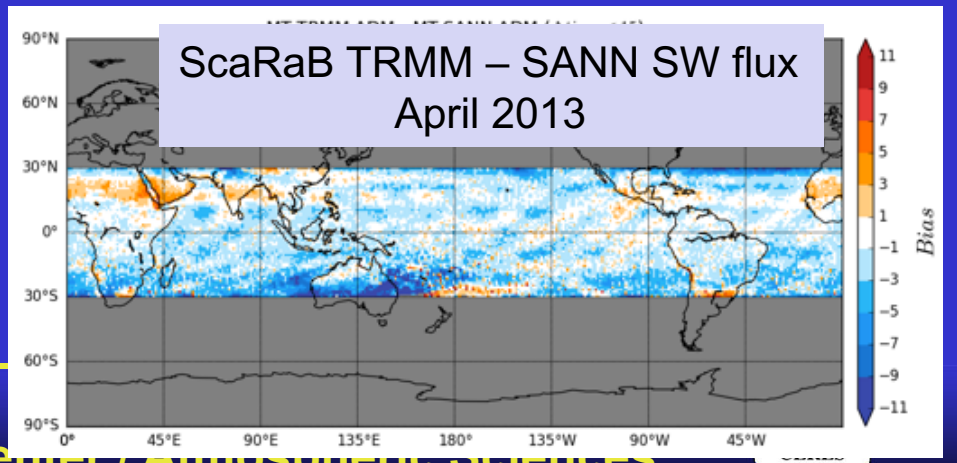
GEO minus MODIS clouds ADM fluxes

Using CERES footprint radiances and TRMM SW ADM, Jan 2010





- Cloud property quality the largest factor in application of the TRMM SW ADM

Conclusions

- The TRMM ADM greatest limitation is that the GEO cloud properties should be MODIS-like
  - Cloud group working to retrieve GEO clouds similar to MODIS, great potential for Him-8 and other 3rd generation GEOs
- Ed4 GEO MODIS-like to BB radiance conversion also based on MODIS clouds, based on SSF
  - Use theoretical direct GEO to BB radiance in Ed5
  - Test using ScaRaB fluxes