Merged CERES/GEO Time Sampling
Part I: SRBAVG

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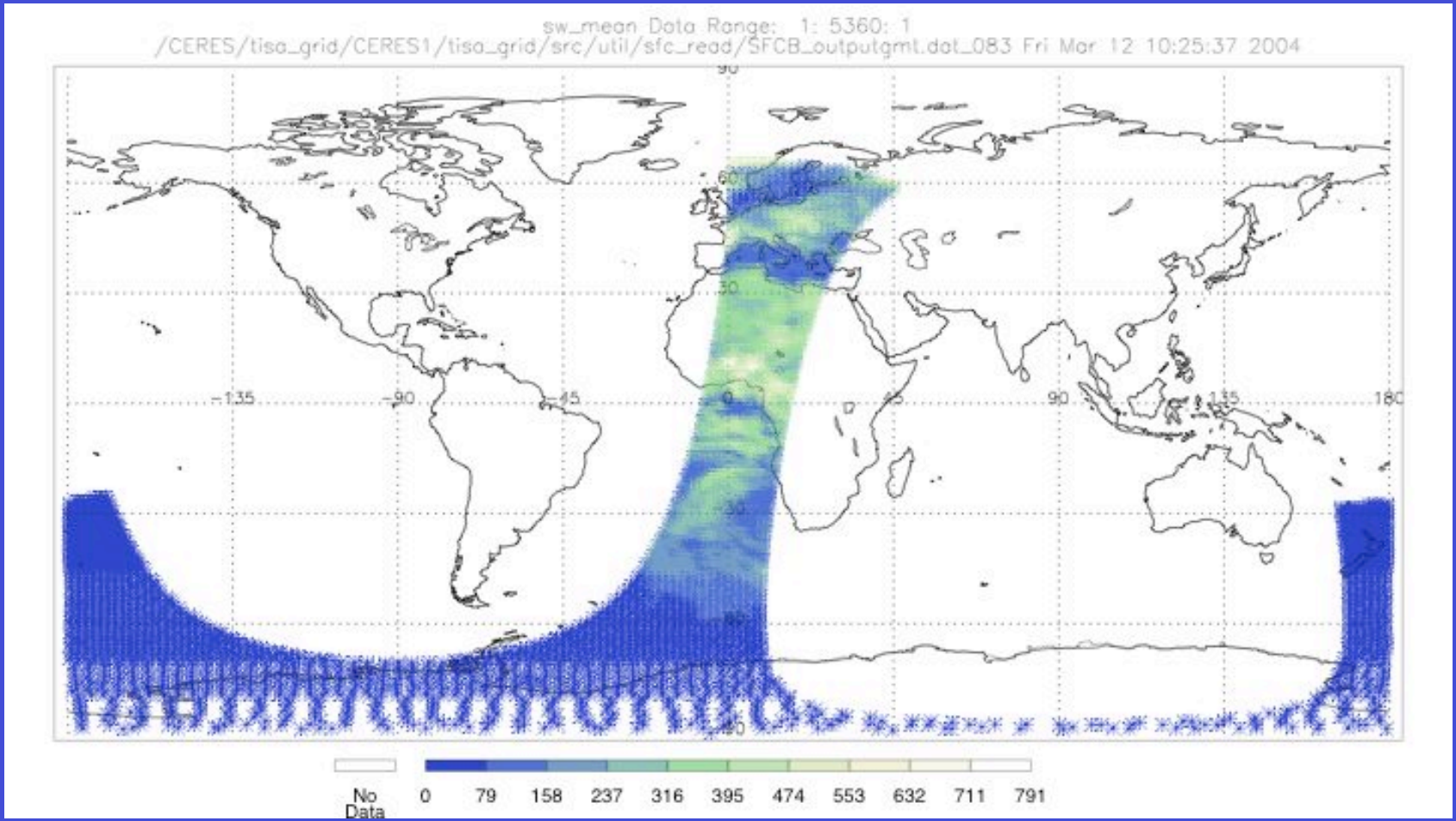
CERES Temporal Interpolation and Spatial Averaging (TISA)

Goals

- Produce climate quality monthly and daily means
  - Must maintain calibration
- Eliminate temporal sampling errors
- Retain consistency among TOA fluxes, cloud properties and surface fluxes
- Produce synoptic maps of TOA, surface, and atmospheric flux

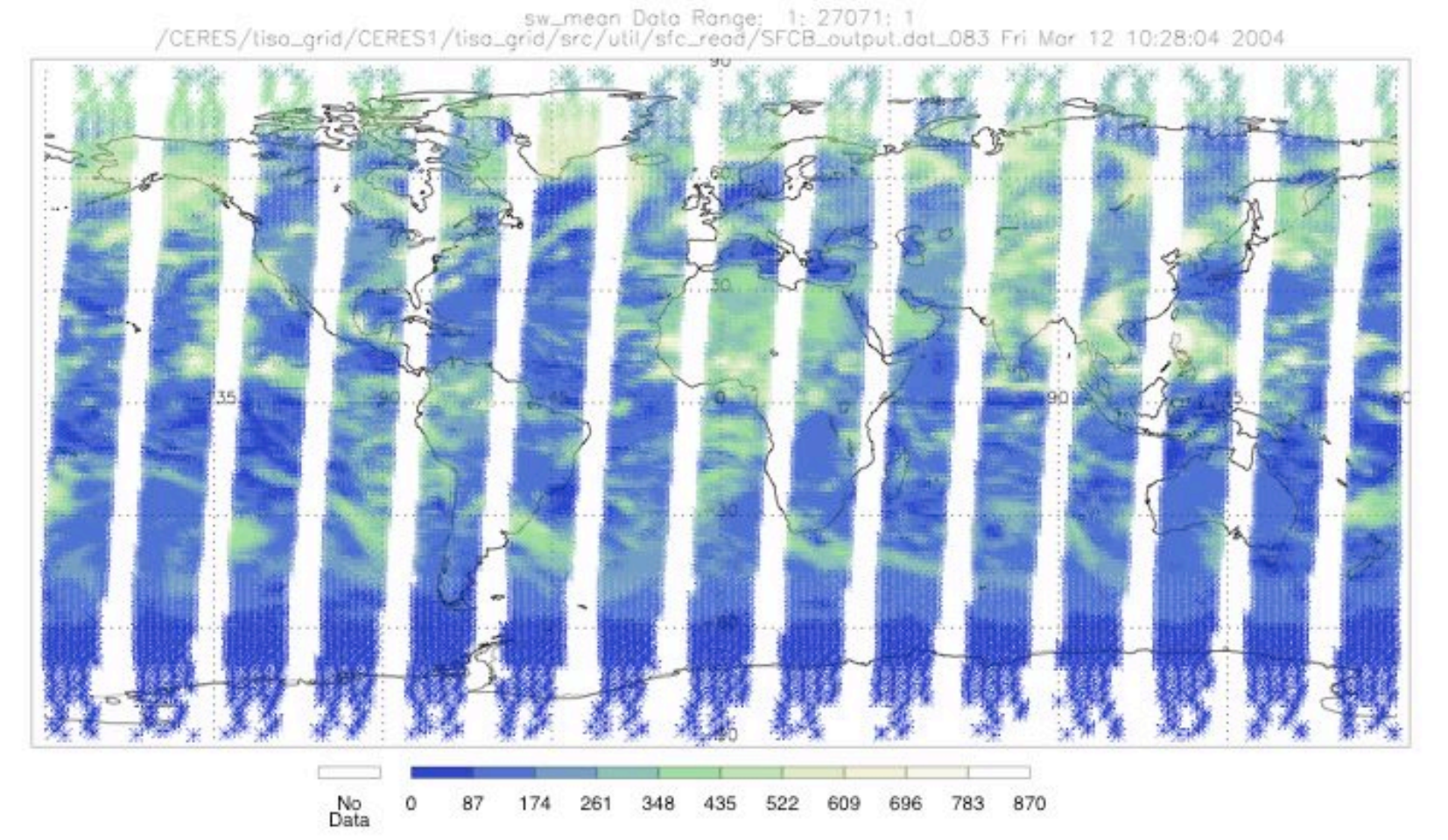
Start with Gridded CERES Observations

One hour of CERES TOA SW Fluxes



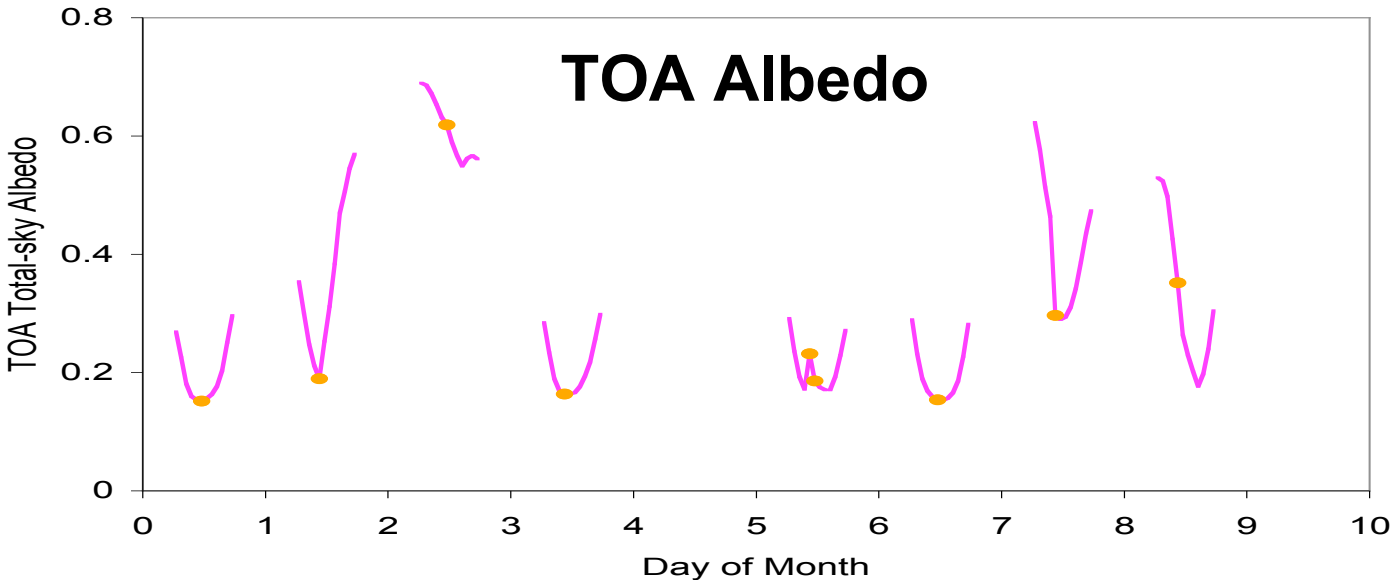
Organize Regional Data by Time

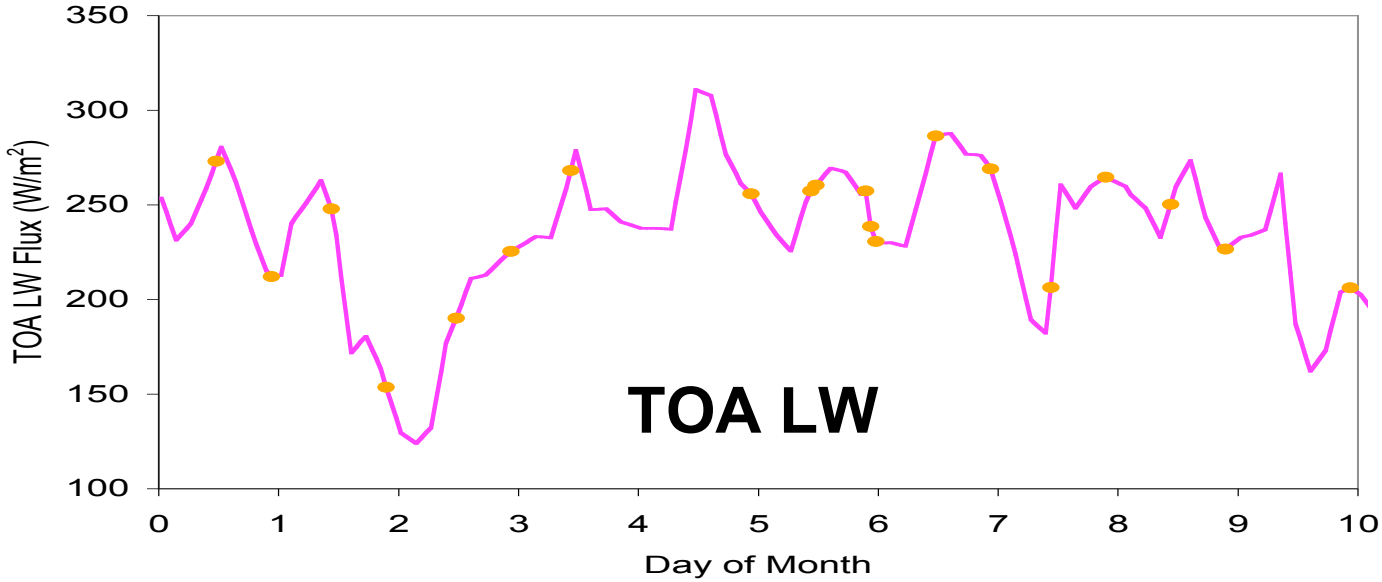
One day of CERES TOA SW Fluxes at 10:30 LT



Interpolate Fluxes and Clouds over Month

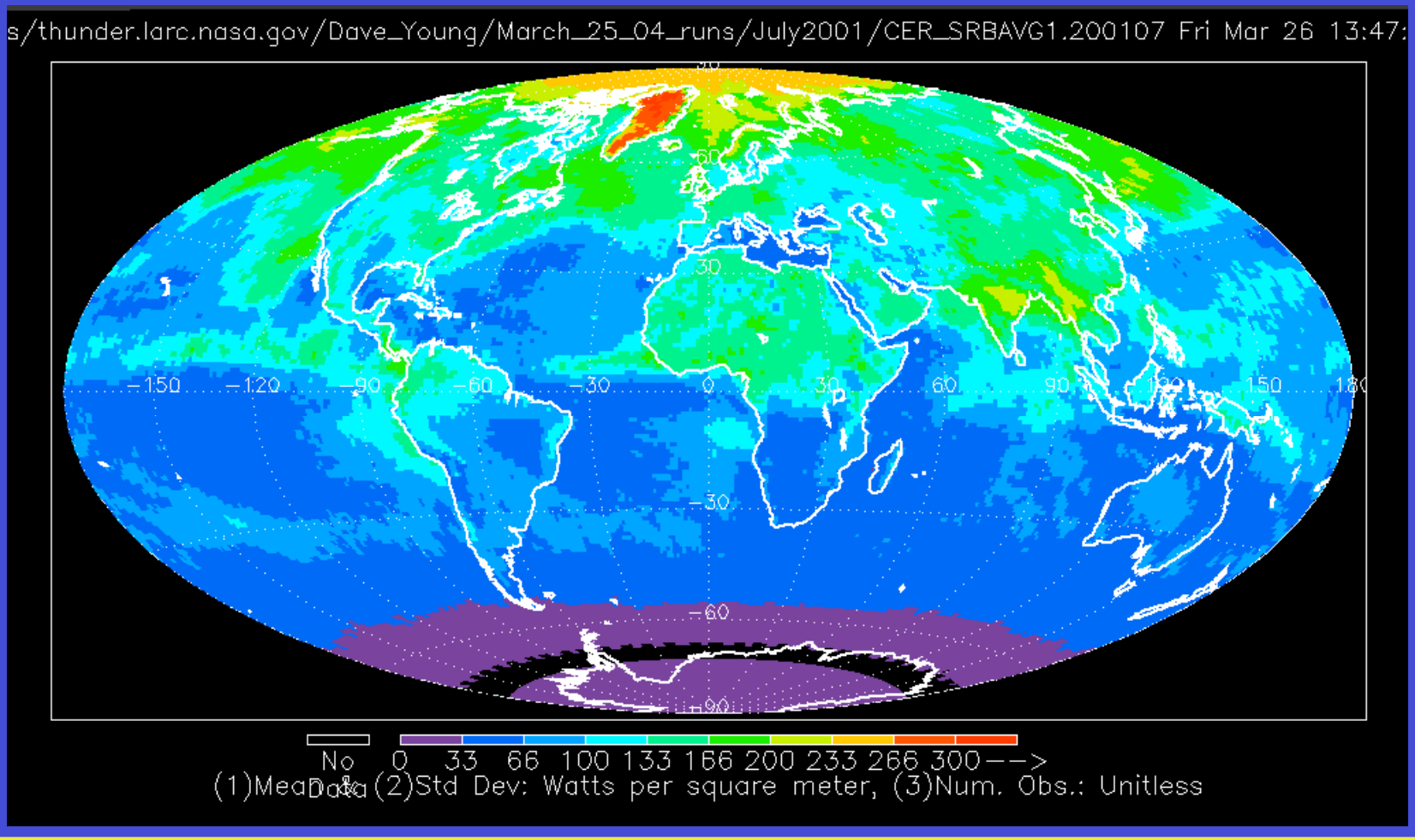
Regional Time Series of Flux from Terra over ARM SGP



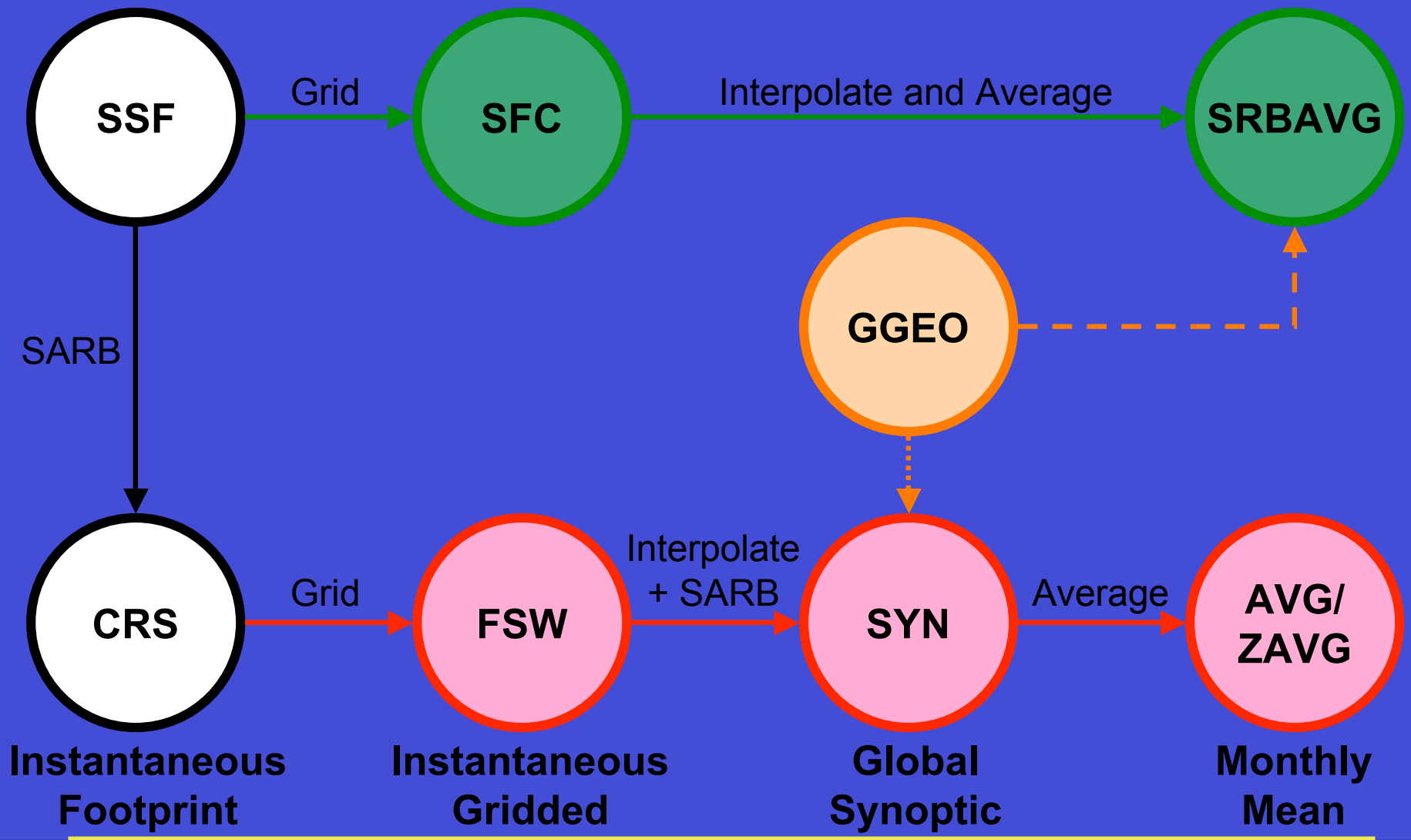


Create Temporally Interpolated and Averaged Data Products

TOA SW Flux Terra FM-1 July 2001



CERES Advanced TISA Processing



CERES Monthly Mean Products

SYN/AVG

- Uses GEO-enhanced interpolation to produce global synoptic flux and cloud fields
- Separate monthly mean produced from hourly fields

SRBAVG

- Takes advantage of improved CERES fluxes
- Uses improved temporal interpolation to remove sampling effects
- 1.0° grid
- TOA and surface fluxes
- Detailed cloud properties
- Product contains GEO and nonGEO monthly means

Time Sampling Challenges

- TRMM
  - Latitudinal coverage limited by 35° inclination
  - 46-day precession cycle causes large hemispheric asymmetries
  - VIRS 48° VZA limit
- Terra / Aqua
  - Sun-synchronous orbits limit diurnal sampling

CERES Interpolation Algorithms

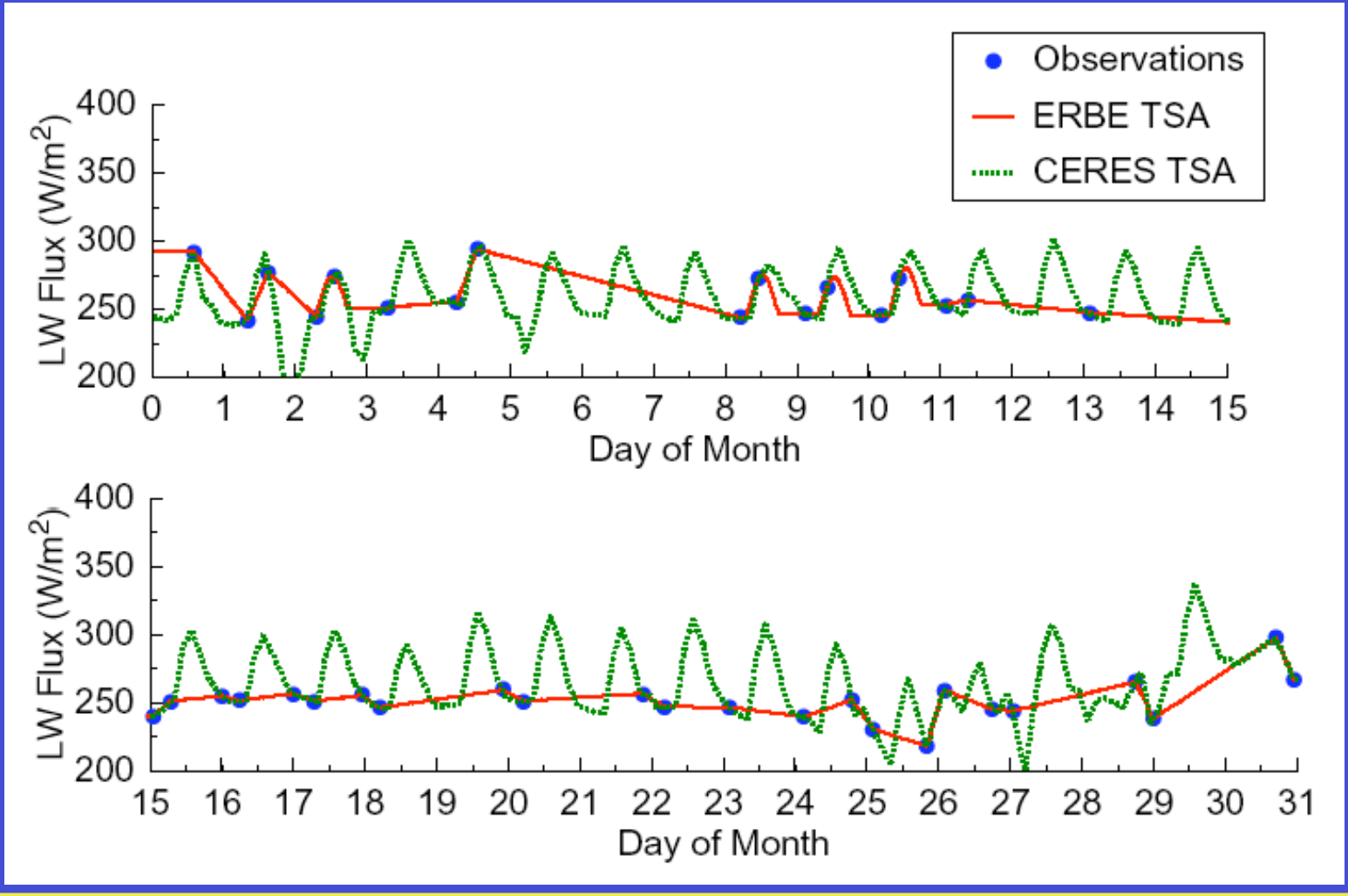
- ERBElike
  - Assumes constant meteorology between observations
  - Uses no ancillary data
  - LW
    - Linear interpolation
    - Simple diurnal modeling over land regions
  - SW
    - Interpolation performed using directional models of albedo
    - Only 12 simple scene types
- CERES nonGEO
  - Same approach as ERBElike
  - Uses new CERES directional models (~200 scene types)

Using Geostationary Data for Temporal Interpolation of TOA Fluxes

- 3-hourly imager data from geostationary satellites is used to define diurnal variations between CERES observations
- Calibration is critical
  - GEO imagers calibration tied to VIRS
- Cloud retrieval is a subset of CERES VIRS algorithm
- Narrowband GEO data converted to flux using NB-BB relationship & CERES TRMM ADMs
- Final fluxes are normalized to CERES observations
  - Normalization applied to total-sky flux and SW clear-sky

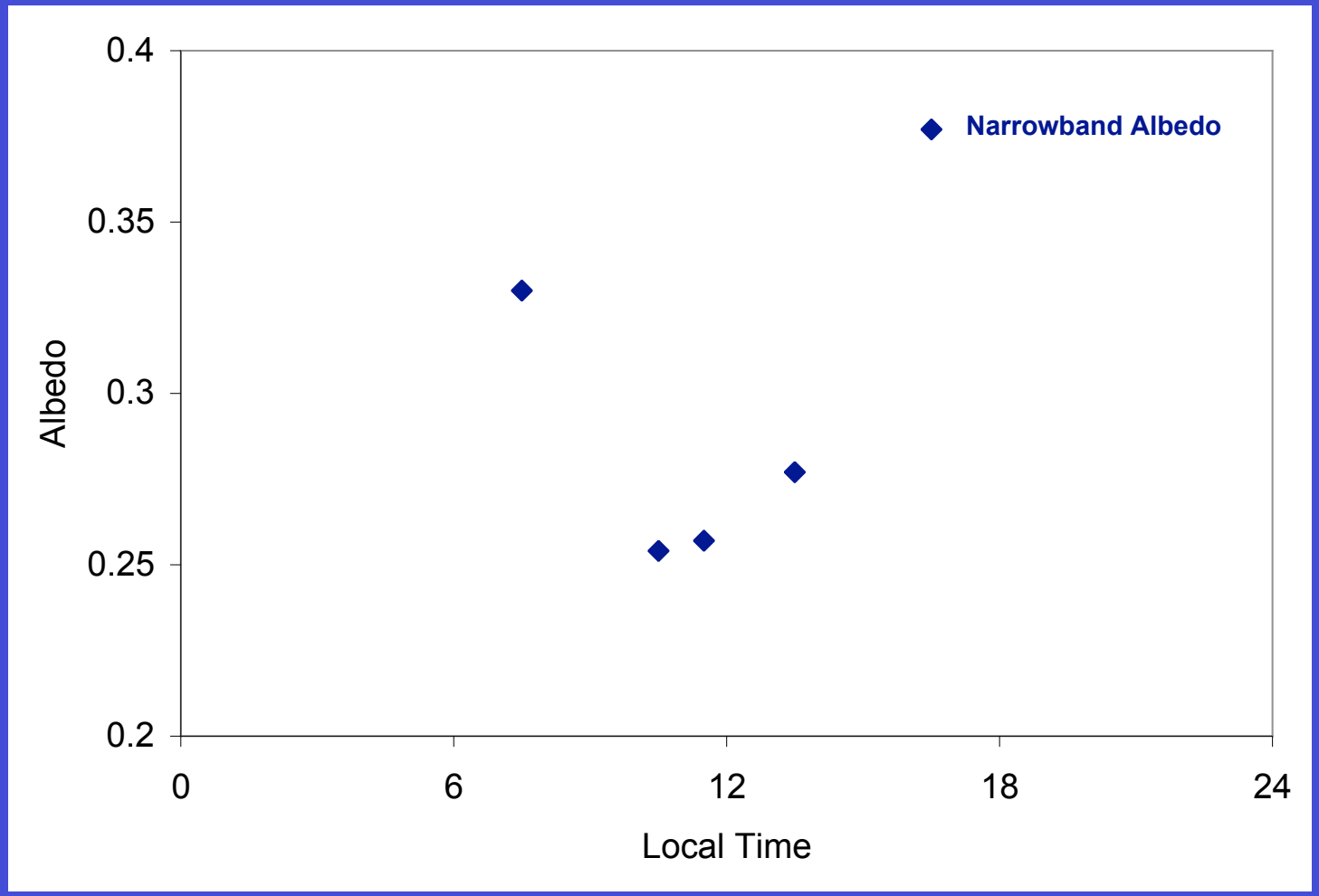
Temporal Interpolation of TOA LW Flux

January 1998 E. Sahara 24.5N 20.5E



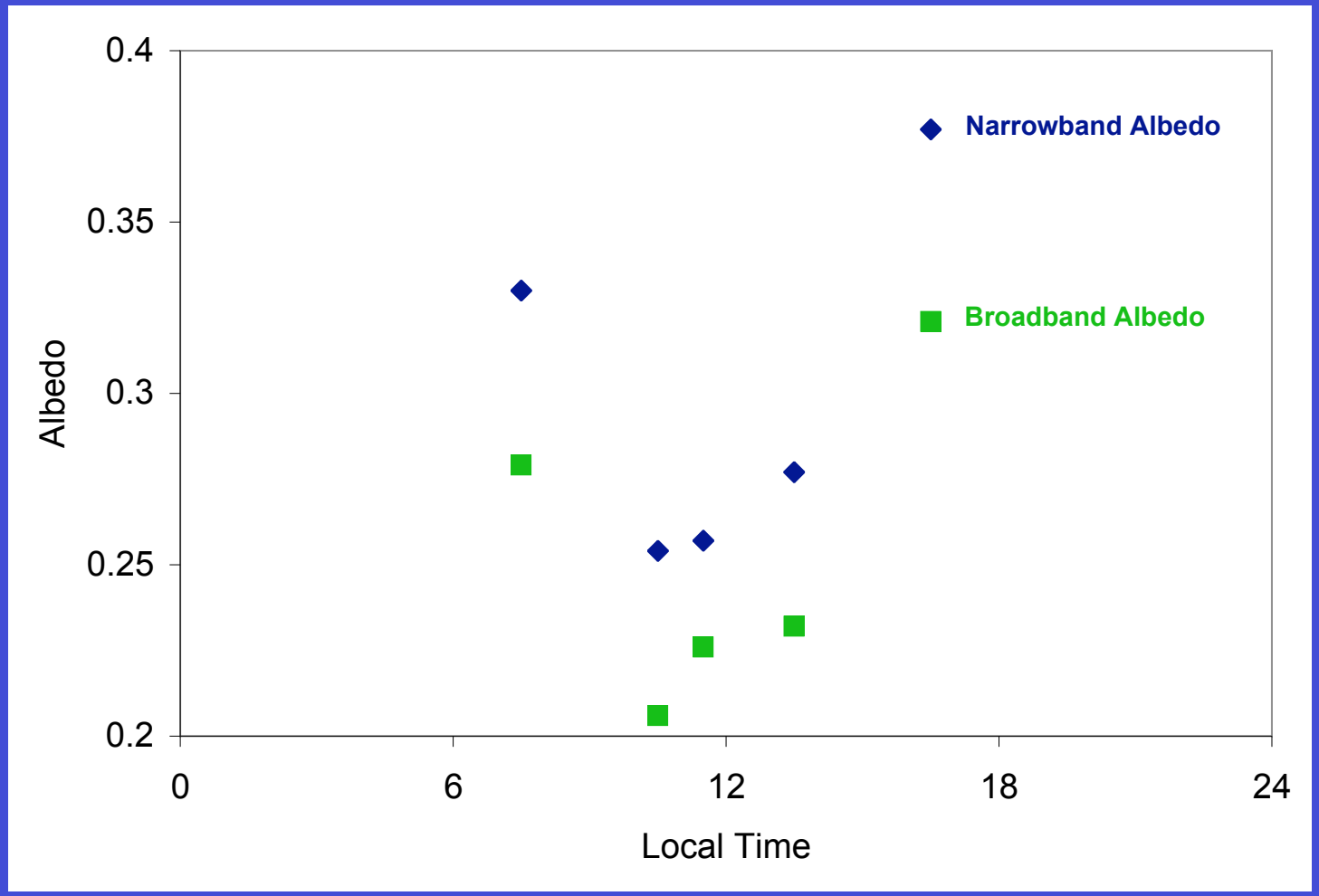
Temporal Interpolation of TOA SW Flux

Step #1 NB Observations



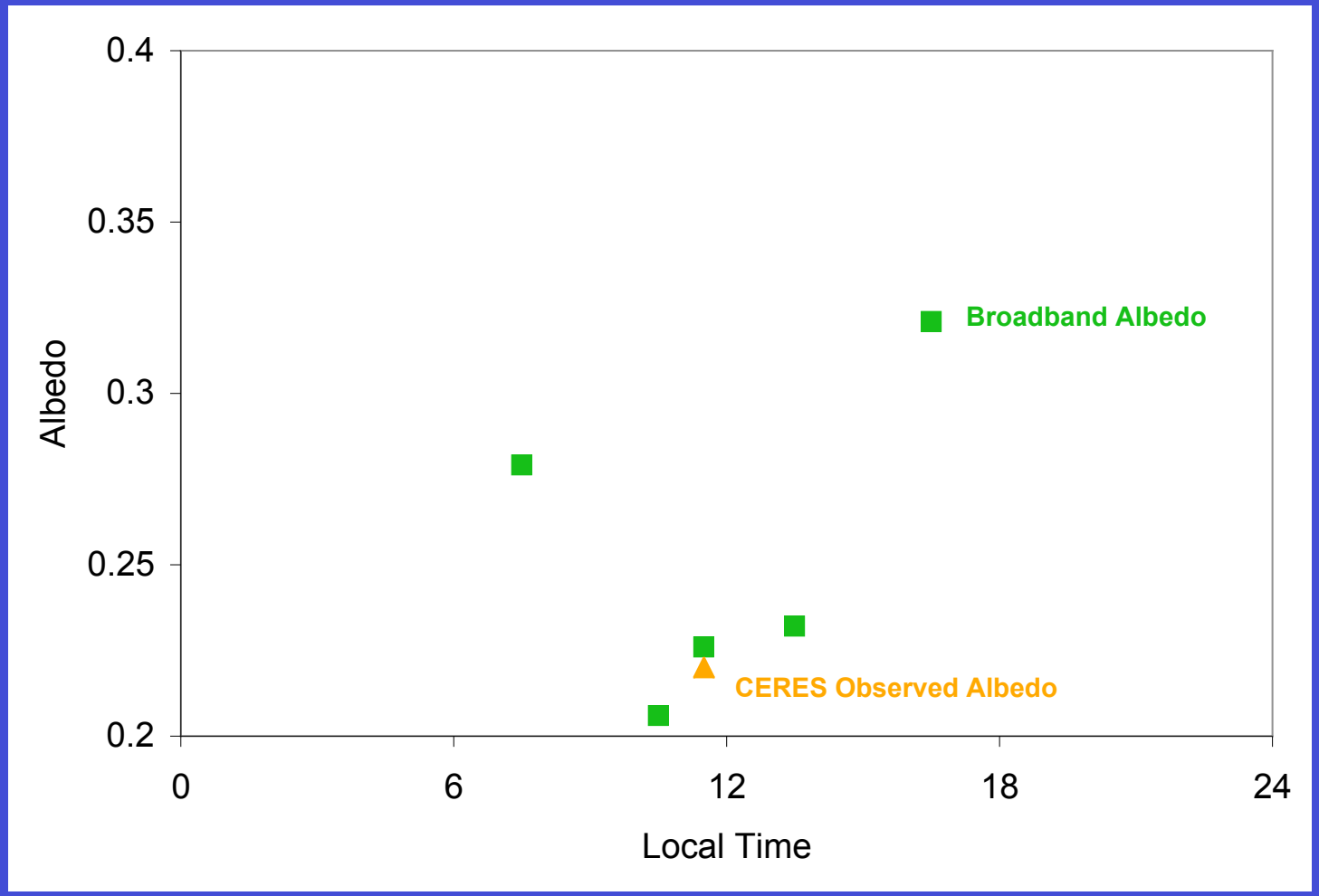
Temporal Interpolation of TOA SW Flux

Step #2 Estimate BB Albedo



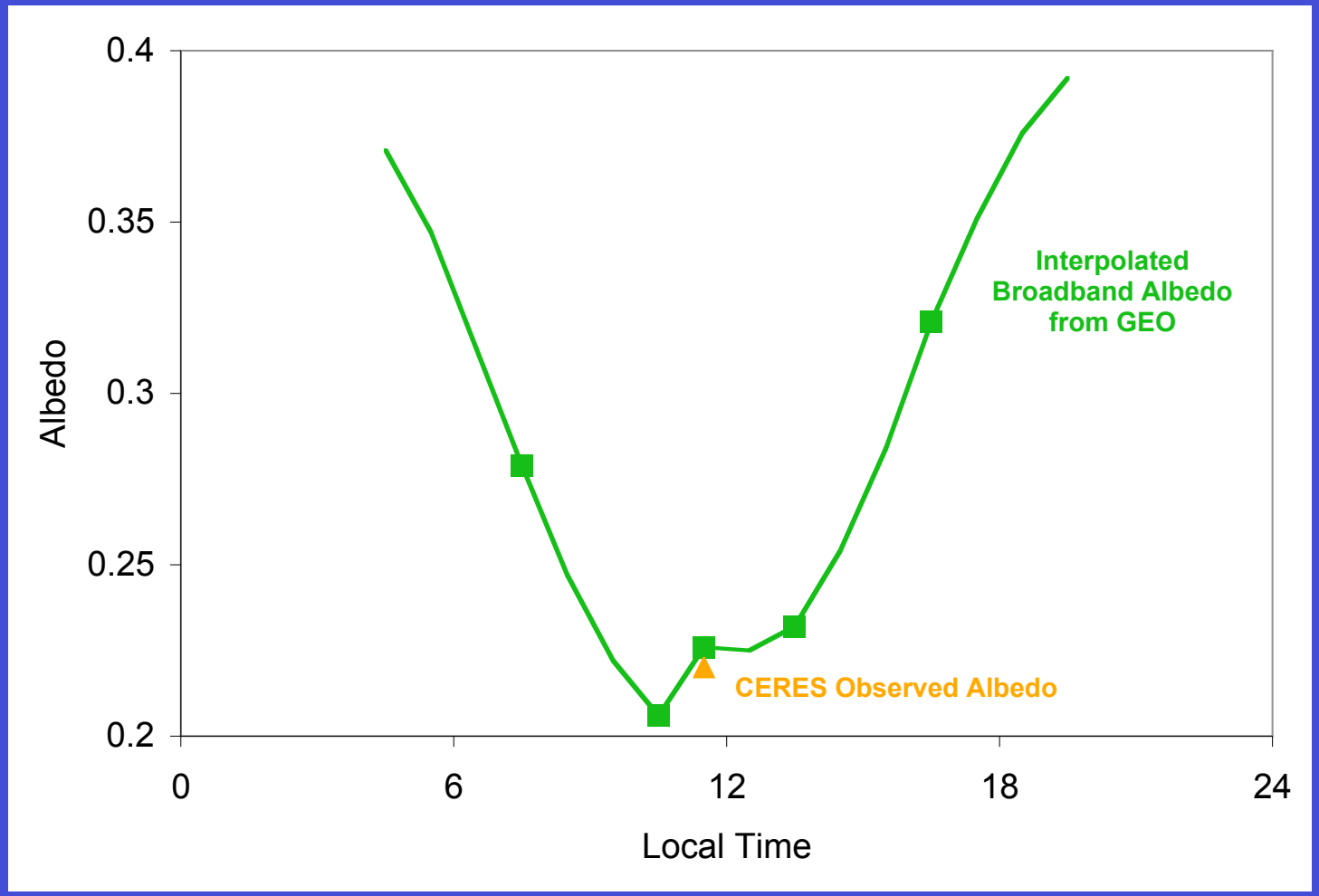
Temporal Interpolation of TOA SW Flux

Step #3 Use only days with CERES observations



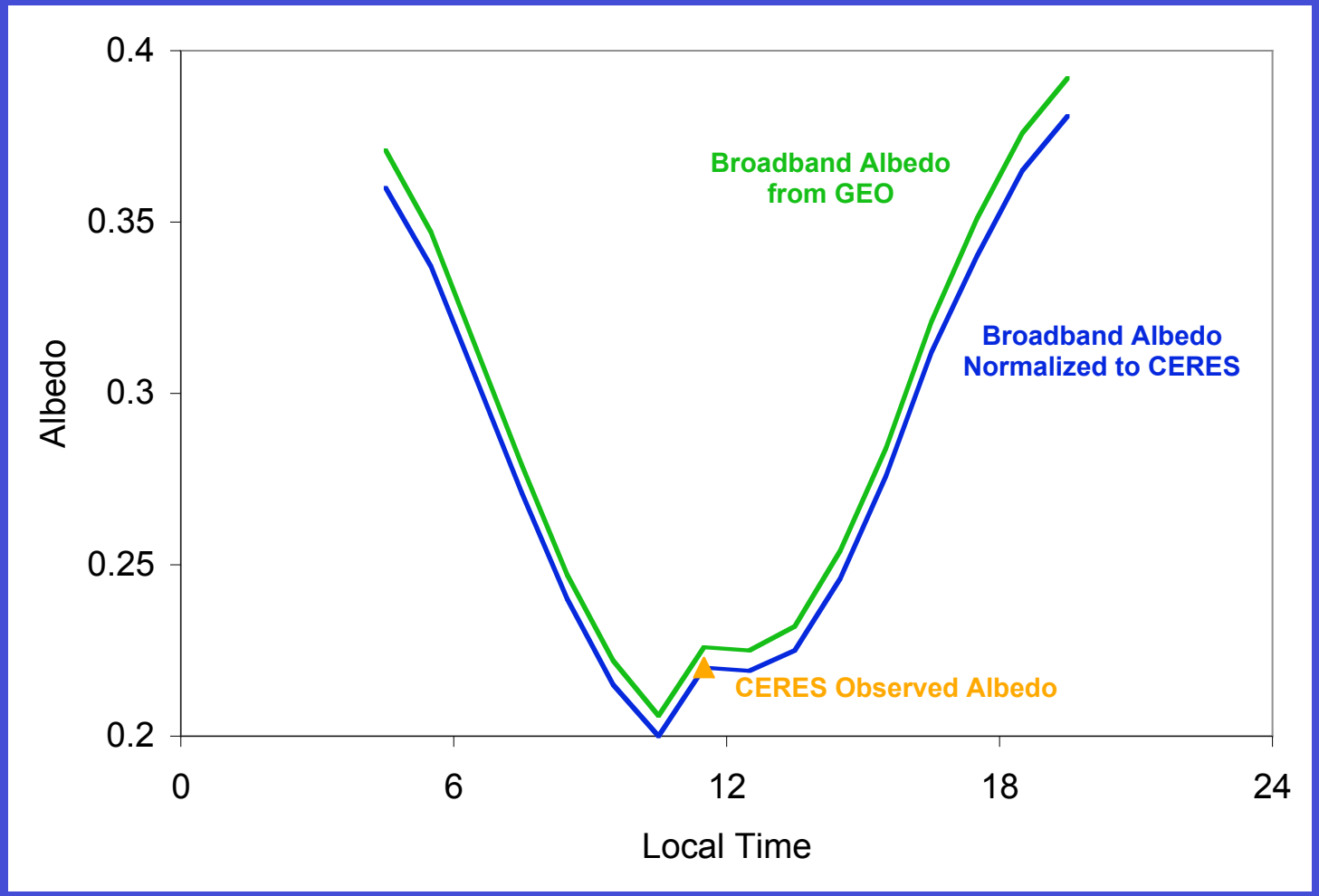
Temporal Interpolation of TOA SW Flux

Step #4 Interpolate to all daylight hours



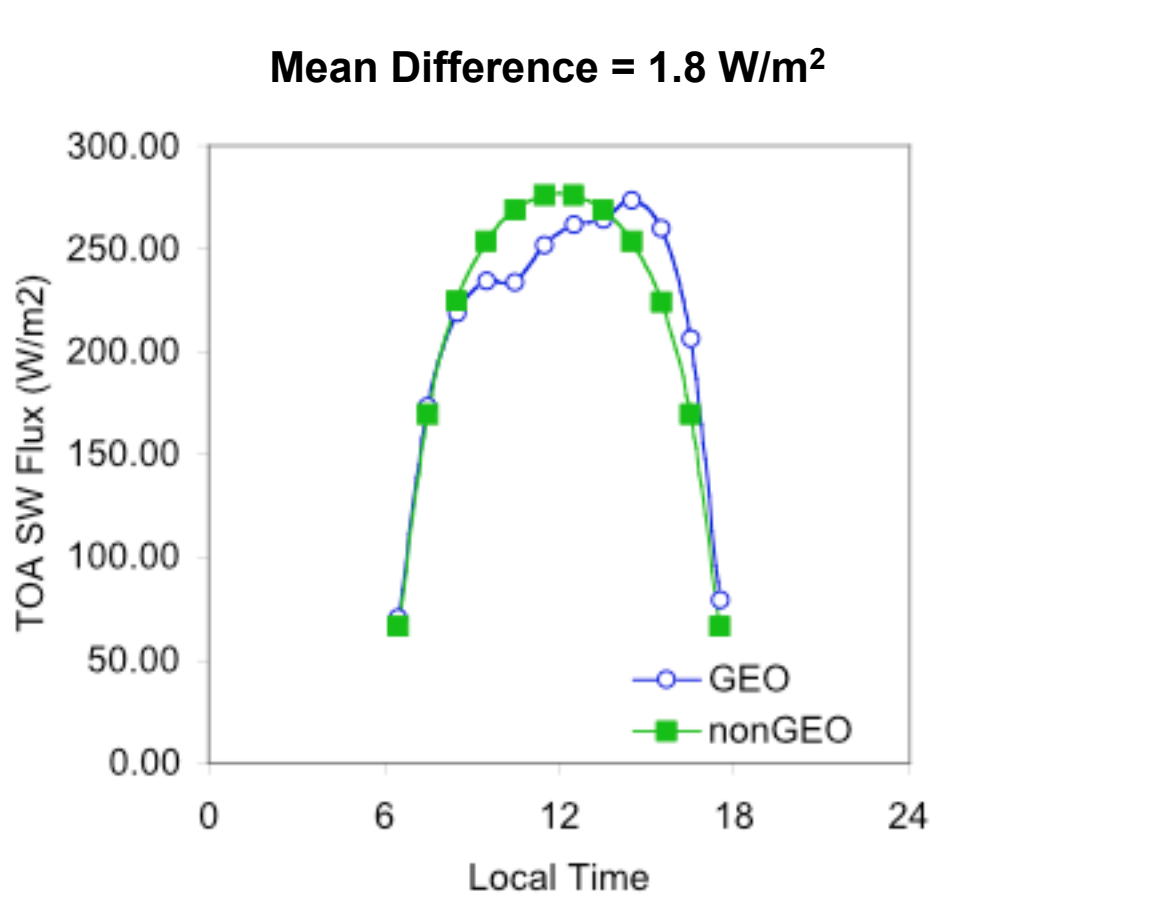
Temporal Interpolation of TOA SW Flux

Step #5 Normalize time series to CERES



GEO vs. nonGEO Monthly Mean Diurnal SW Flux

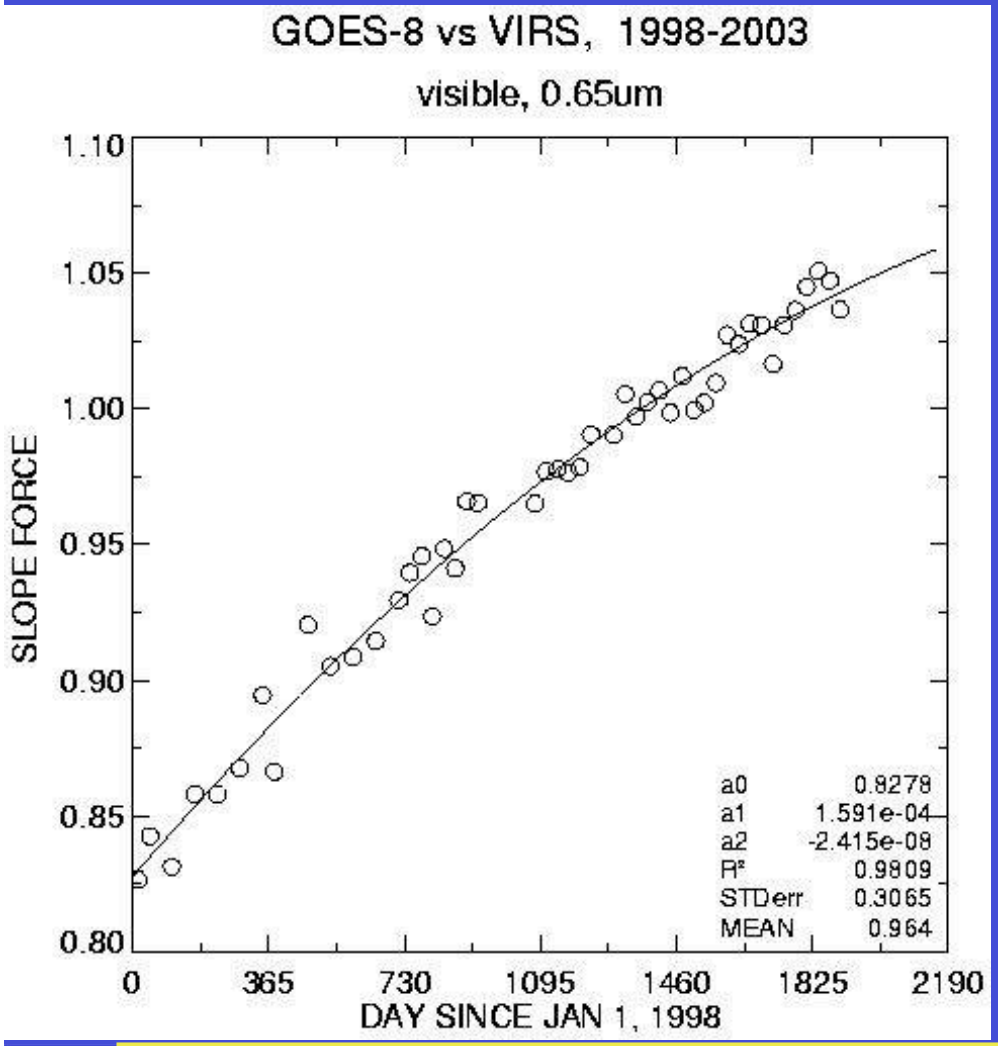
Equatorial Pacific Region CERES DRM

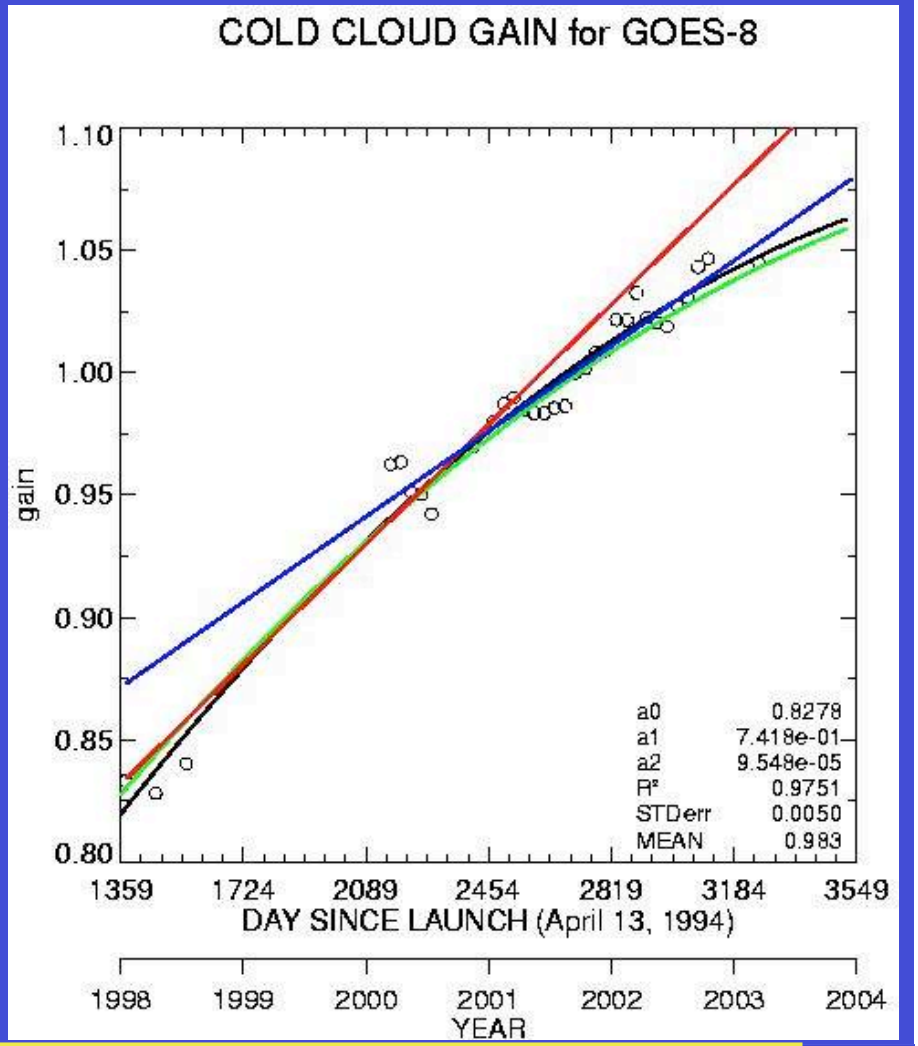


GGEO Calibration Techniques

- Ray-matched MODIS vs GEO radiance data
  - Ties calibration to well-calibrated MODIS data
  - Limited geographic coverage
- Deep convective cloud albedo
  - Used to get trends (not absolute calibration)
- Noon matching of GEO data at central longitudes
  - Used to transfer calibration across all GEO satellites

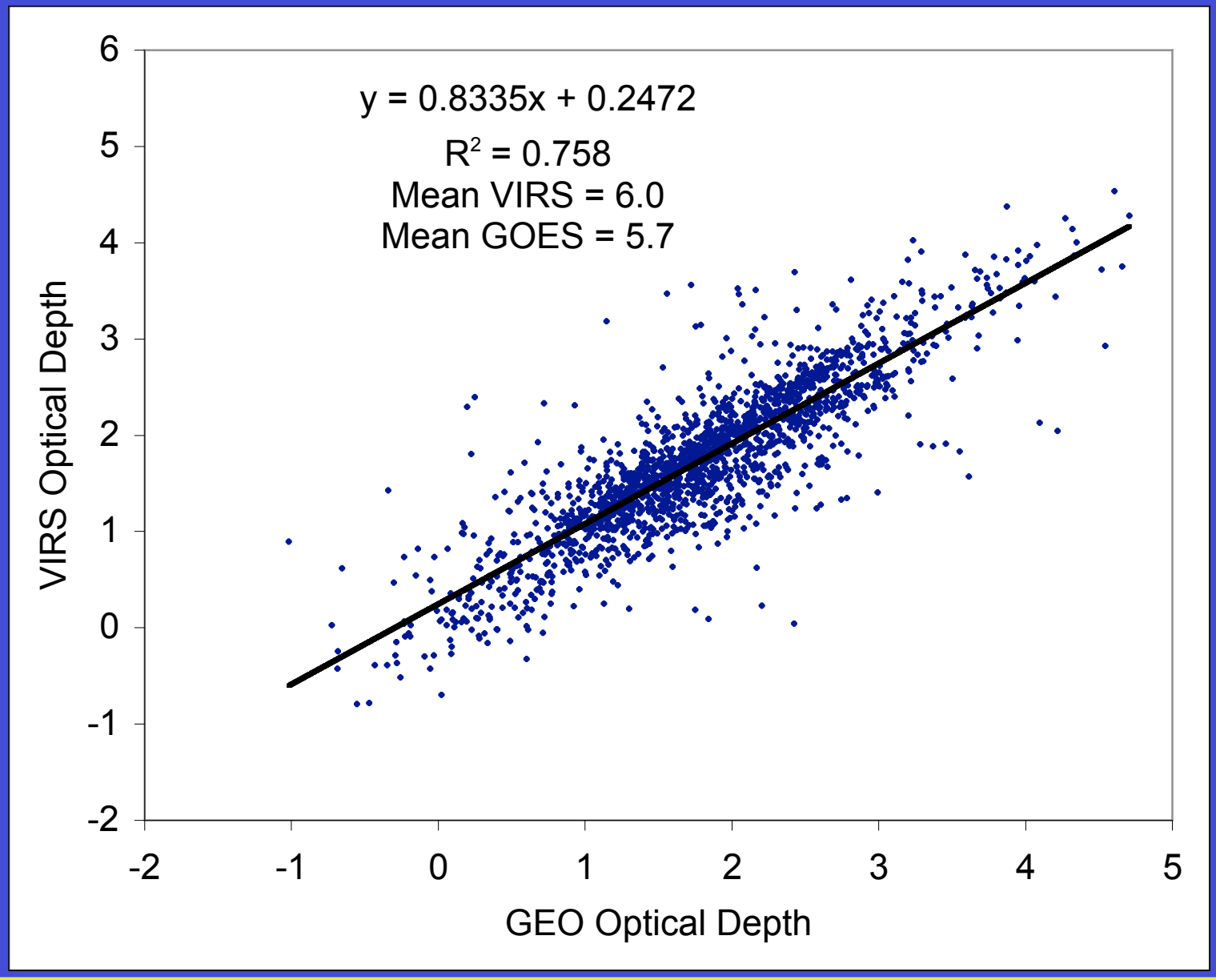
Consistency of Calibration Methods

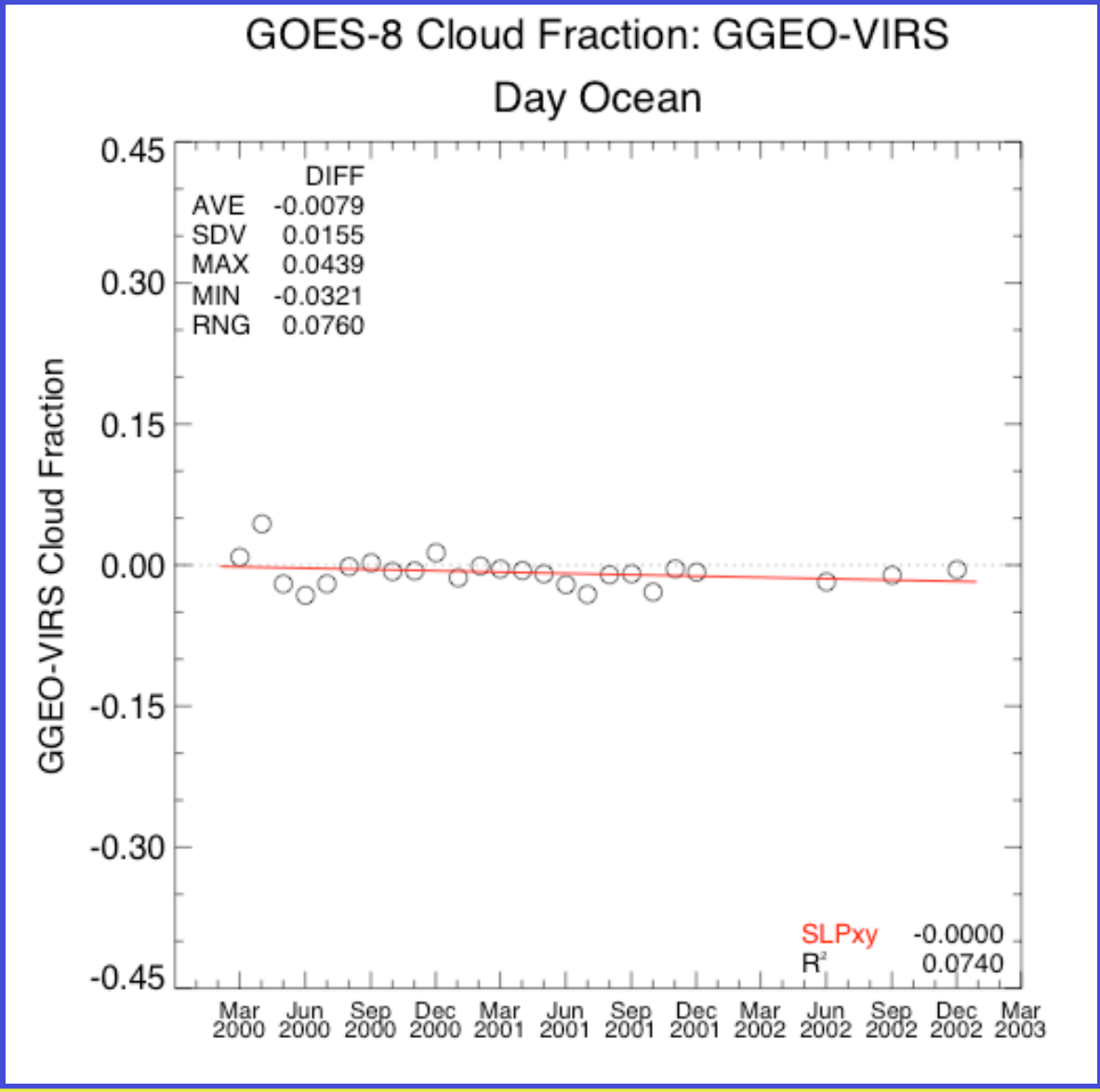


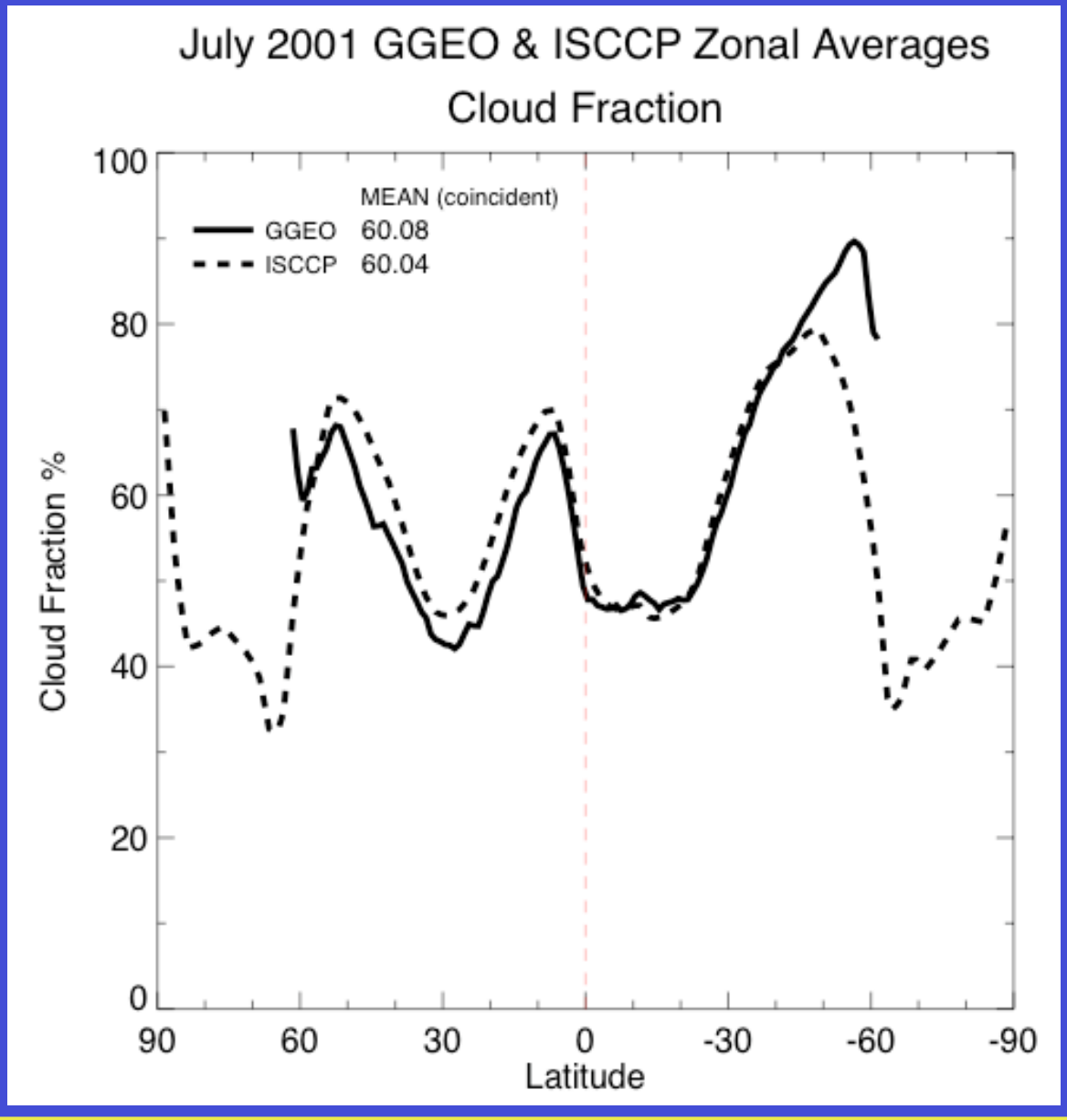


GGEO Cloud Property Retrievals

- Needed for SW interpolation & for monthly clouds
  - Necessary for ADM selection
- Uses IR/Vis retrievals (run as subset of CERES cloud algorithm)
- Uses CERES surface property maps and MOA soundings
- Properties
  - Cloud Amount
  - Cloud Temperature
  - Cloud Height (using standard 4 CERES layers)
  - Optical Depth/Emittance (Daytime Only)


y = 0.8335x + 0.2472
R² = 0.758
Mean VIRS = 6.0
Mean GOES = 5.7
VIRS Optical Depth
GEO Optical Depth
6
5
4
3
2
1
0
-1
-2
-2
-1
0
1
2
3
4
5


GOES-8 Cloud Fraction: GGEO-VIRS
Day Ocean
DIFF
AVE -0.0079
SDV 0.0155
MAX 0.0439
MIN -0.0321
RNG 0.0760
SLPxy -0.0000
R² 0.0740
GGEO-VIRS Cloud Fraction
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
Mar 2000
Jun 2000
Sep 2000
Dec 2000
Mar 2001
Jun 2001
Sep 2001
Dec 2001
Mar 2002
Jun 2002
Sep 2002
Dec 2002
Mar 2003


July 2001 GGEO & ISCCP Zonal Averages
Cloud Fraction
MEAN (coincident)
GGEO 60.08
ISCCP 60.04
Cloud Fraction %
100
80
60
40
20
0
90
60
30
0
-30
-60
-90
Latitude

GEO Calibration Sensitivity Tests

- Goal: Test effect of imager calibration on monthly mean fluxes
- Test by varying imager gain by ±5%
- Calibration affects both radiances and cloud retrievals
  - Cloud properties affect selection of DRMs
  - Cloud mask affects selection of clear-sky radiances

Calibration Sensitivity Summary (TRMM)

(Change in monthly mean flux due to a ±5% imager calibration error)

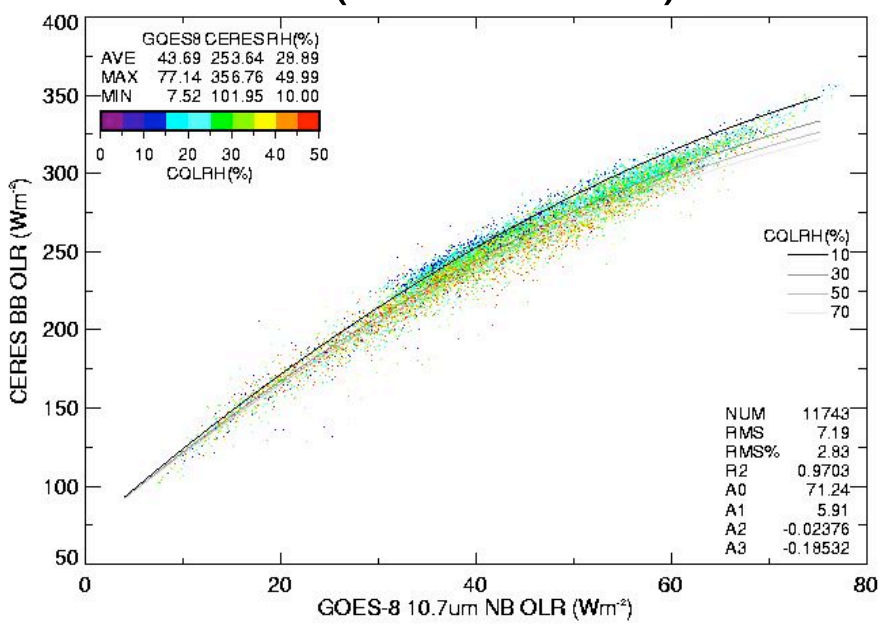
	Mean Flux	Mean & rms Flux Difference (W/m^2)			
		IR + 5%	IR - 5%	Vis + 5%	Vis - 5%
Total-sky LW	257.6	0.01 (0.08)	-0.01 (0.08)	0.00 (0.00)	0.00 (0.00)
Total-sky SW	99.3	-0.04 (1.35)	0.54 (3.10)	0.94 (1.31)	-0.94 (1.31)
Clear-sky LW	284.7	-0.29 (0.69)	0.30 (0.92)	0.01 (0.27)	-0.02 (0.26)

Narrowband-to-Broadband Conversion

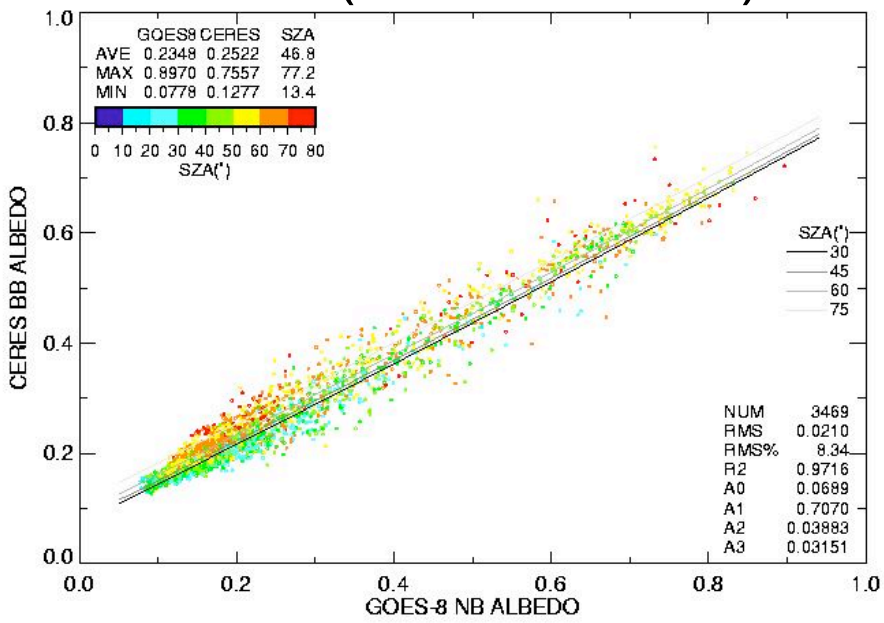
- Removing spectral differences key to accurately incorporating GEO data

- TRMM processing used global NB-BB fits
  - Separate relationships for land, ocean, and desert regions
  - LW relationship includes RH dependence
  - SW relationship includes SZA dependence

LW (rms ~3-5%)



SW (rms ~10-15%)



Improved Narrowband-to-Broadband Conversion

- Goal: Develop SW narrowband to broadband relationships to account for
  - Viewing geometry
  - Scene type (geo-type, cloud optical depth and phase)
  - Individual satellite spectral response functions

- Implement as visible to broadband radiance based conversion
  - Apply conversion before applying broadband ADM
  - Use gain and offset approach rather than a ratio
    - Not strictly tied to cloud property results to take into account misidentified scenes and differences between geostationary satellite derived cloud properties

Data

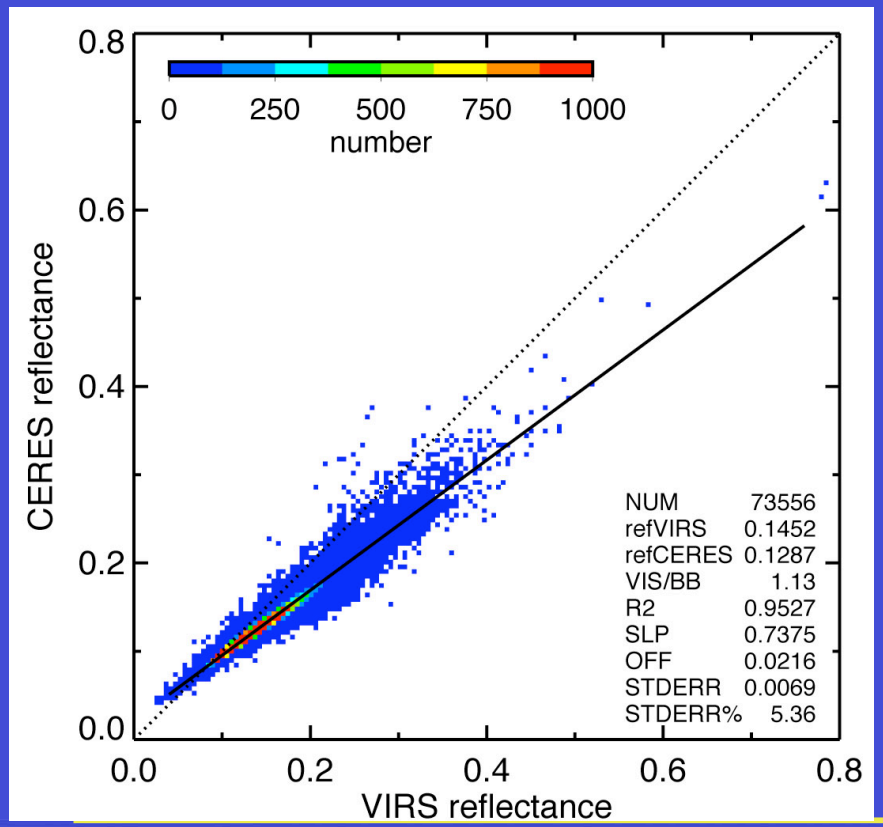
- TRMM CERES SSF broadband cross-track footprints provide coincident, collocated and co-angled visible (VIS 0.65µm) and broadband (BB 0.3-5µm) radiances at 10 km resolution.
  - The precessionary TRMM orbit provides good angular sampling in cross-track mode.
  - VIRS sampling limited to 47° view angle.

- CERES and VIRS visible (VIS) radiances are binned as follows:
  - Are nearly the same as the CERES bidirectional model bins

VIRS and CERES Reflectance for Selected Angular Bins

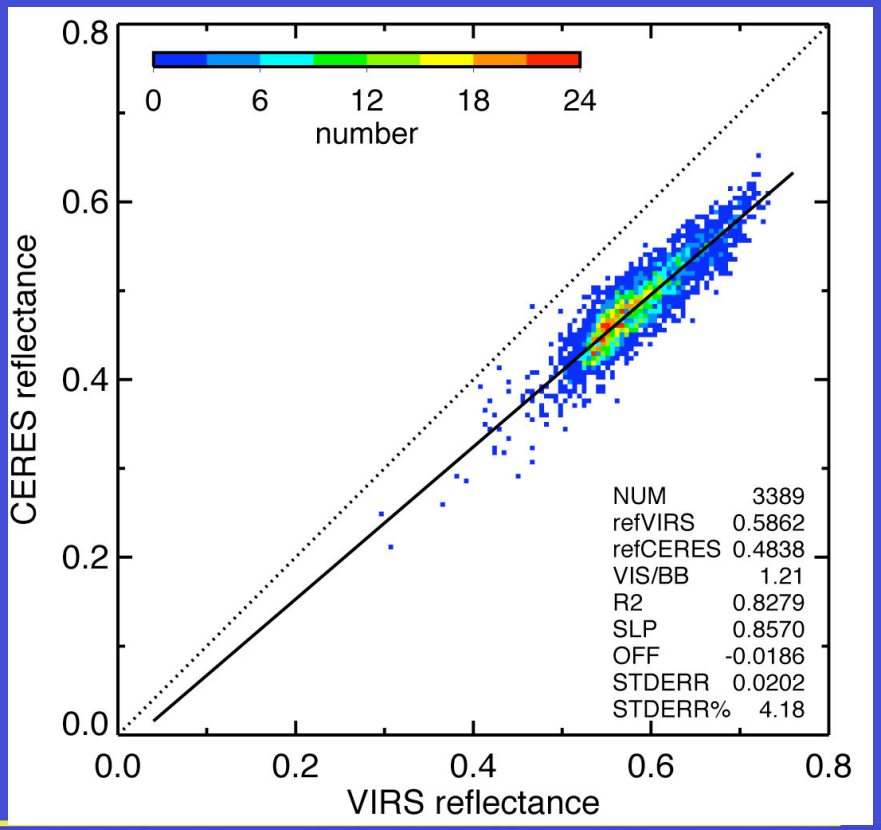
CLEAR OCEAN GLINT BIN

VZA=35° AZA=20° SZA=35°



OVERCAST OCEAN BIN

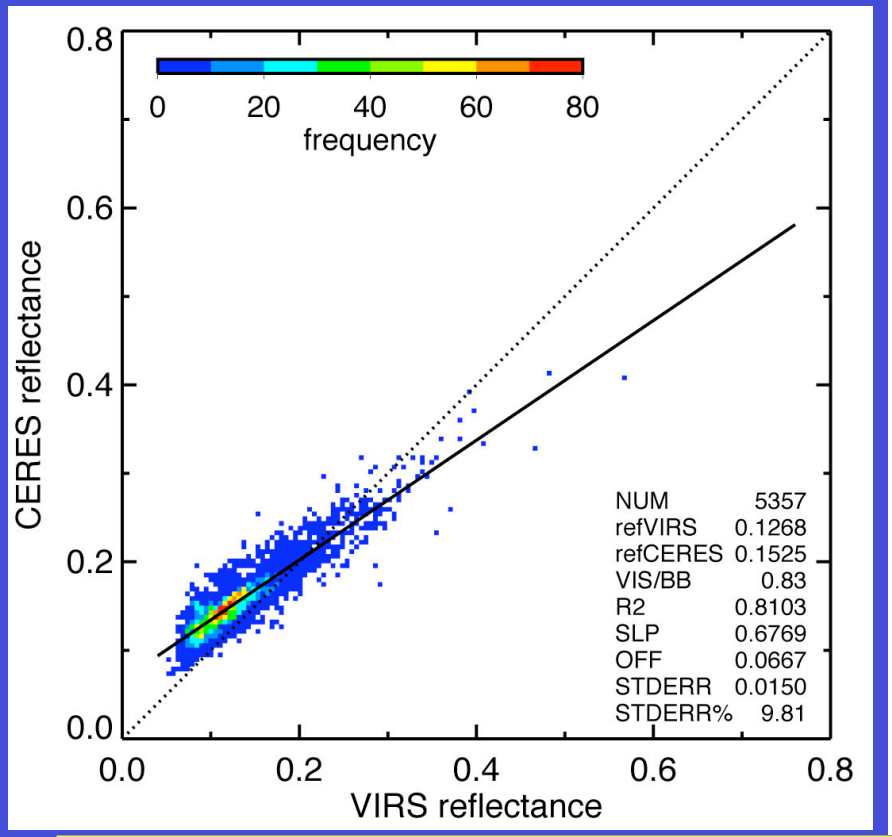
VZA=25° AZA=60° SZA=45° 18<τ<40 liquid



VIRS and CERES Reflectance for Selected Angular Bins

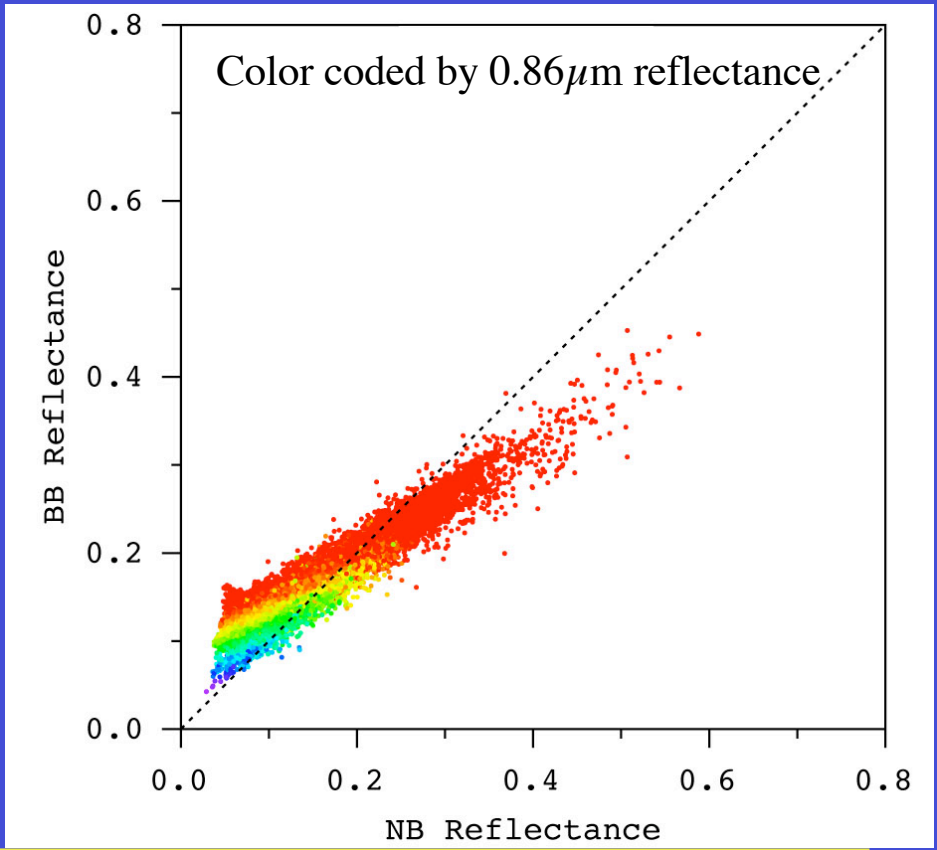
TRMM GRASS BIN

VZA=45° AZA=5° SZA=55°



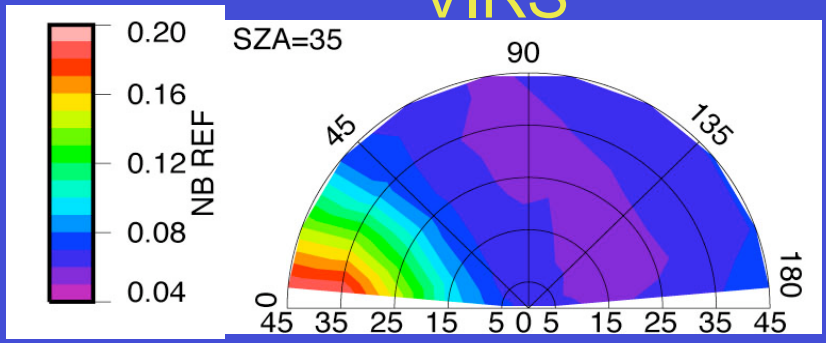
TERRA GRASS BIN

VZA=55° AZA=40° SZA=25°

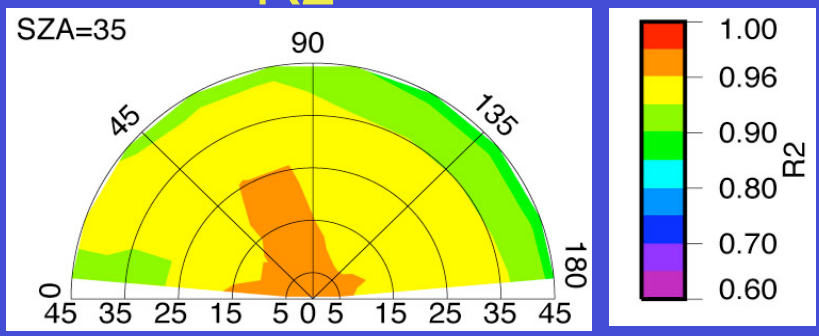


Clear OCEAN, SZA=35°

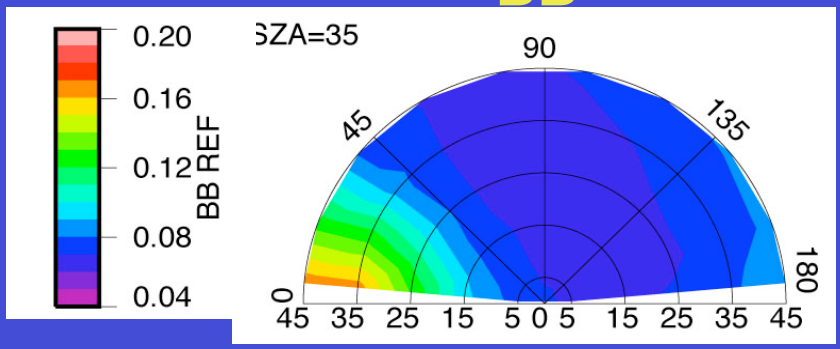
VIRS



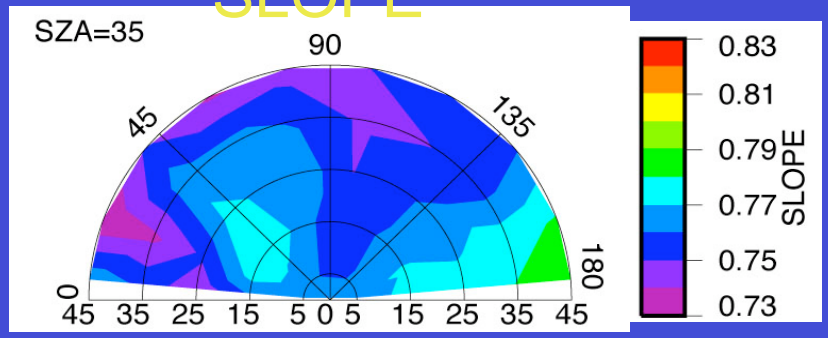
R2



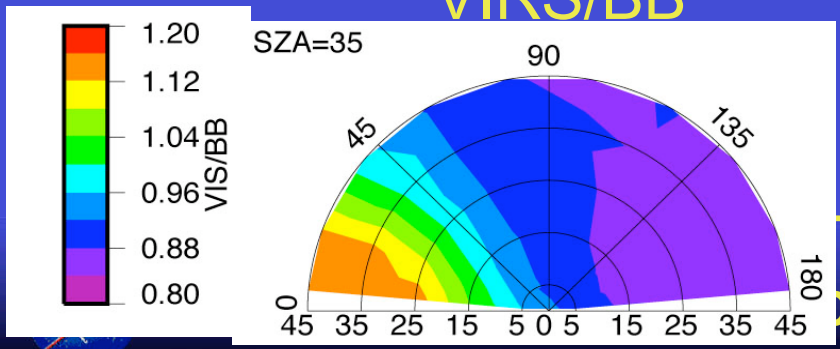
BB



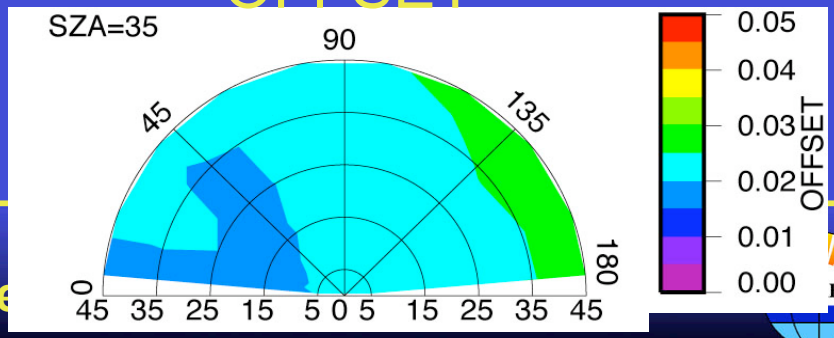
SLOPE



VIRS/BB



OFFSET



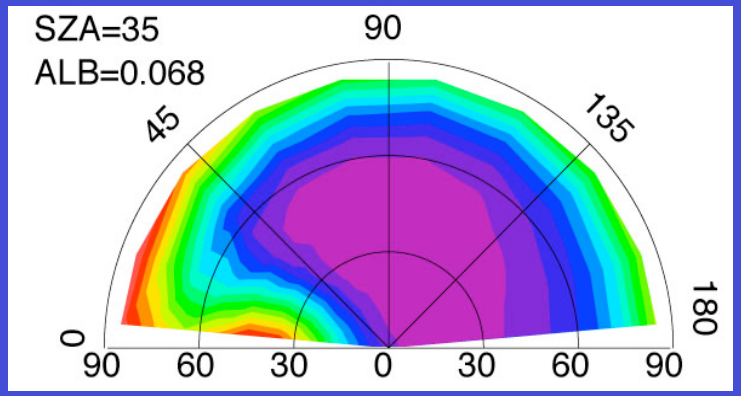
Fill Unsampled bins

- Estimate the slope and offset for bins that are unsampled by generating footprint level reflectances using filled VIRS bins and theory
- Use DISORT to compute VIRS and BB reflectances for the given bins
  - Only 3 geo-types used, ocean, prairie and desert
- Use the following equation
  - where (j) is the unsampled bin and (i) is the sampled bin

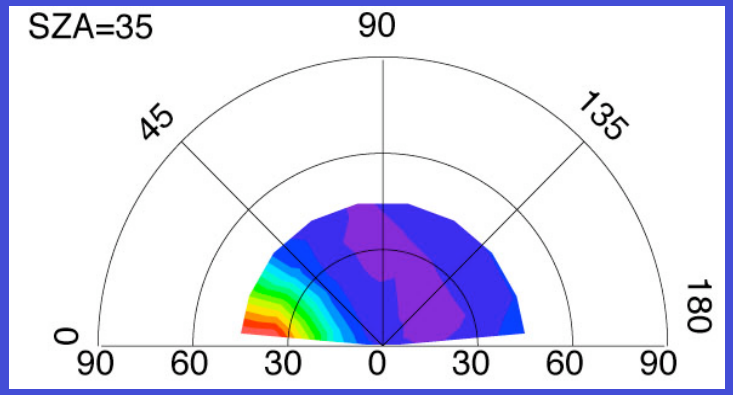
$$\rho_{j,k} = \sum_{i}^{N_{\text{VIRS bins}}} \sum_{k}^{N_{\text{bin footprints}}} \rho^{\text{VIRS}}_{i,k} \frac{\rho^{\text{mod}}_{j}}{\rho^{\text{mod}}_{i}}$$

Ocean VIS reflectance, sza=35°

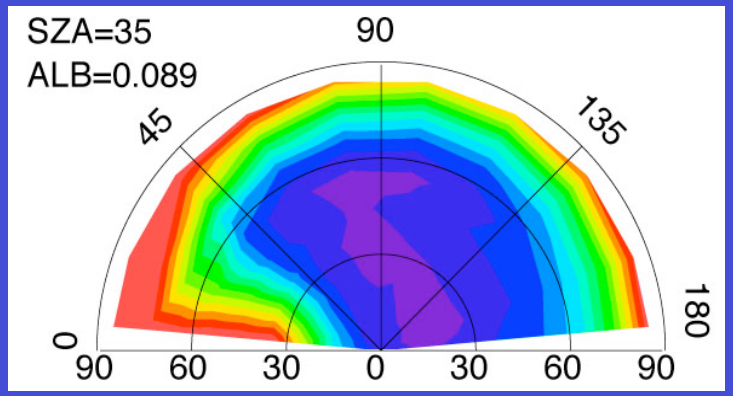
DISORT

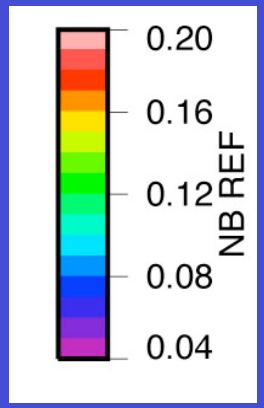


VIRS



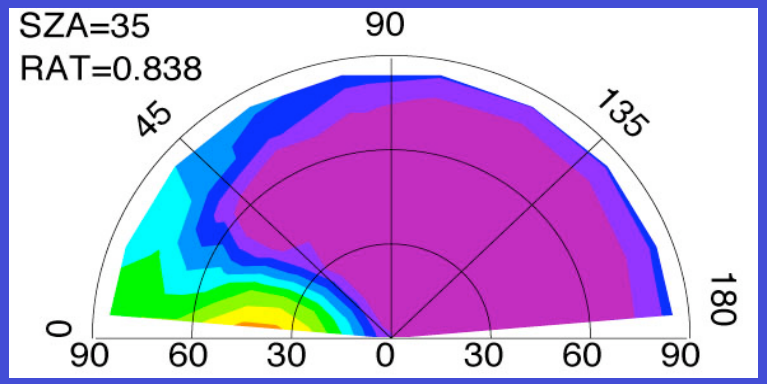
DISORT+VIRS



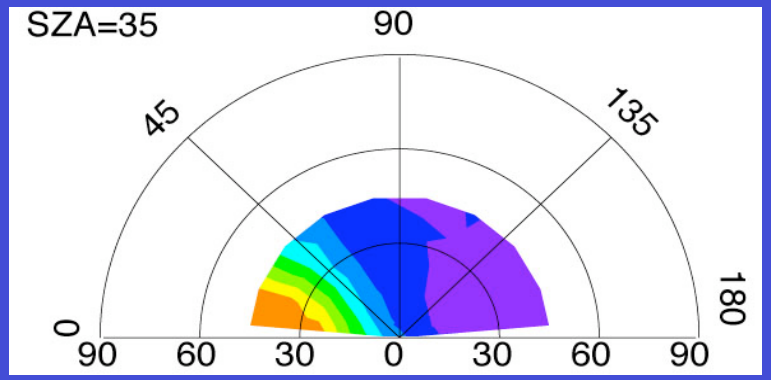


Ocean VIS/BB ratio, sza=35°

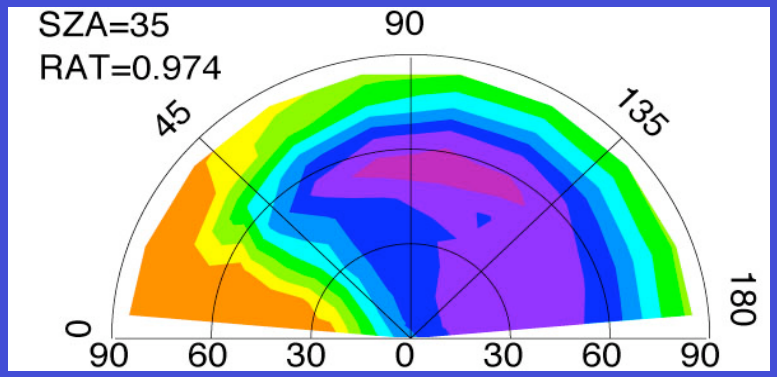
DISORT

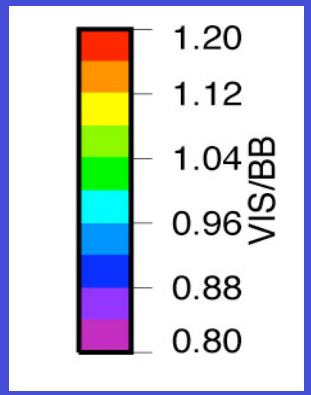


VIRS

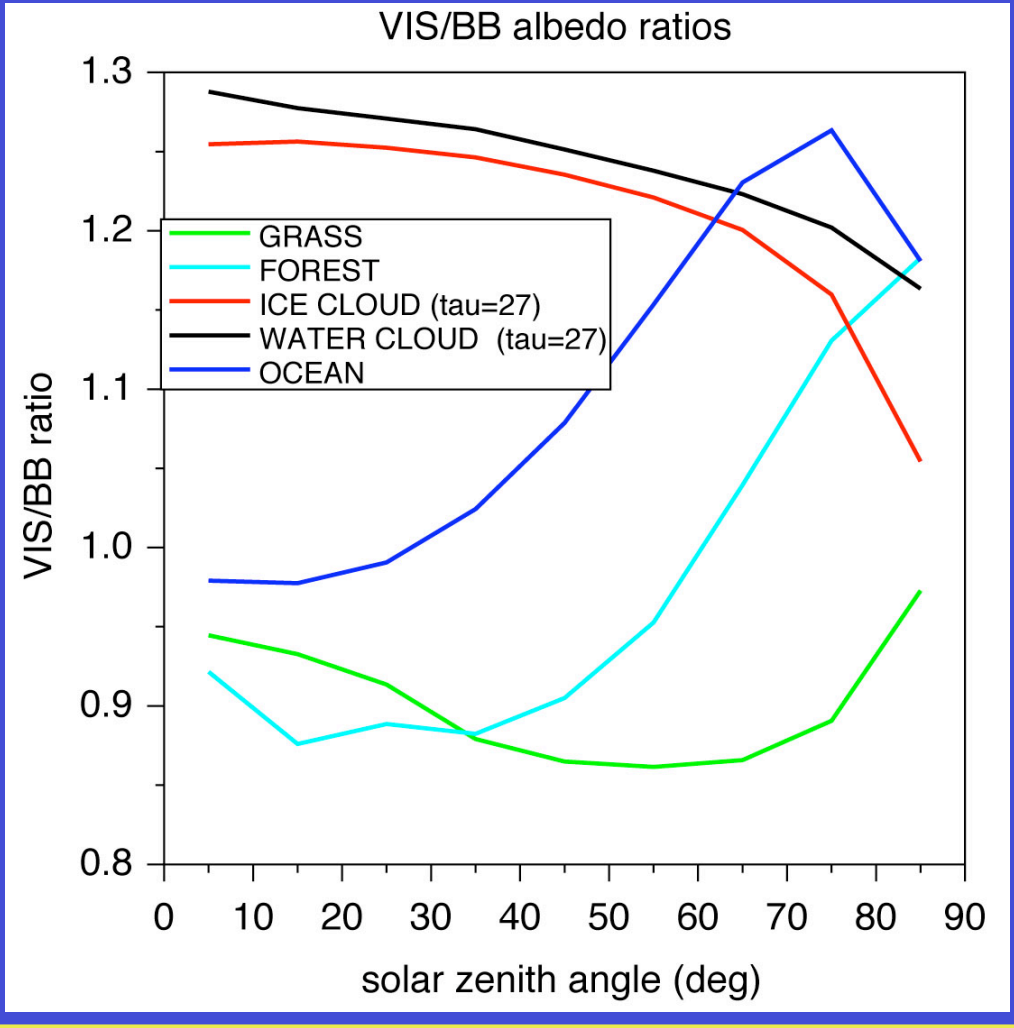


DISORT+VIRS





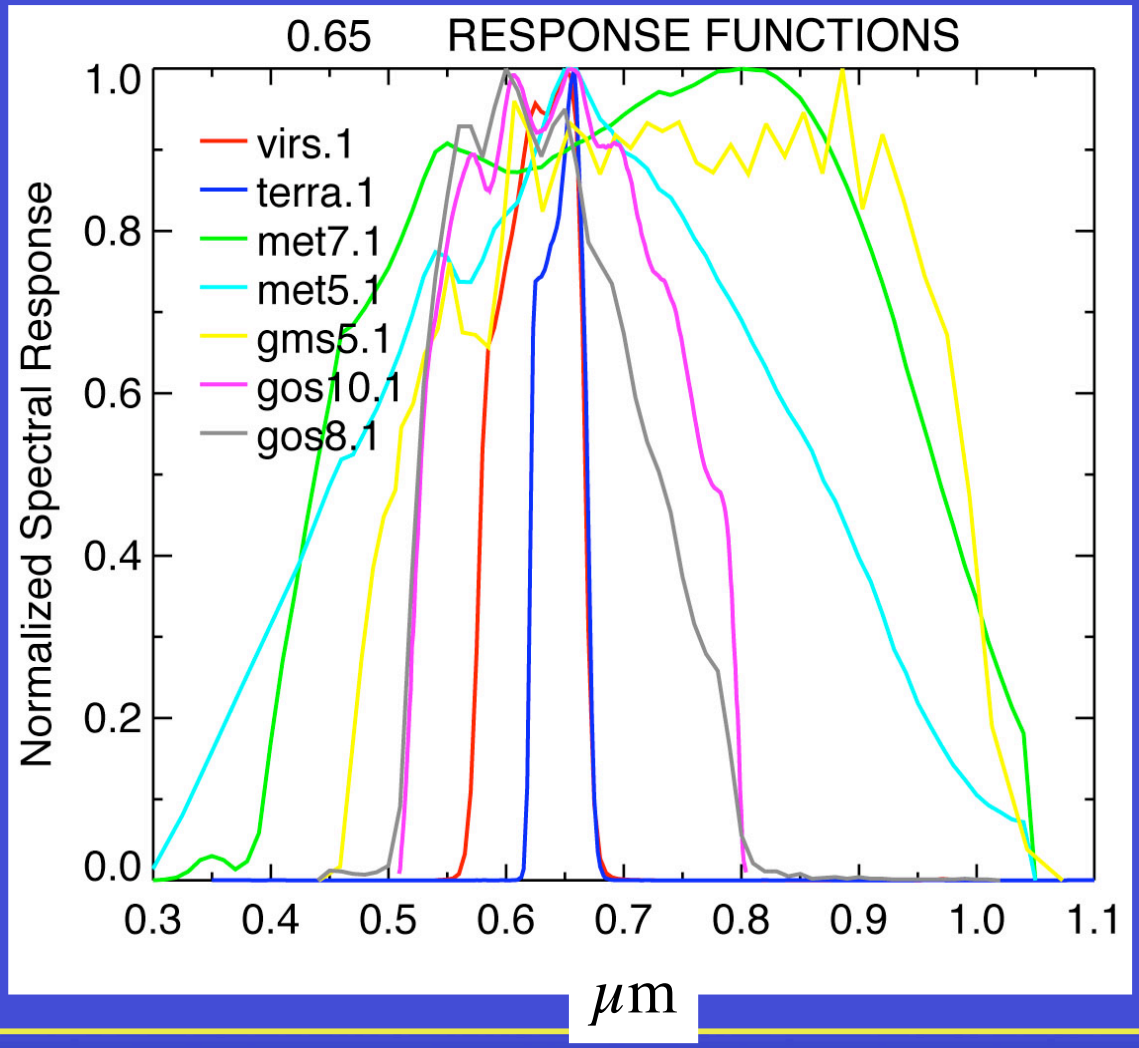
VIS/BB albedo ratios



VIRS/GEO model

- To account for surface and satellite spectral differences
- Use DISORT to compute GGEO visible bin reflectances
  - VIRS, MODIS, Meteosat-7, Meteosat-5, GMS-5, GOES-10, GOES-8
  - Only 3 geo-types used, ocean, prairie and desert
- For each angular bin, geo-type and phase compute a least squares regression between VIRS and the given GGEO reflectances as a function of optical depth

GGEO spectral response functions

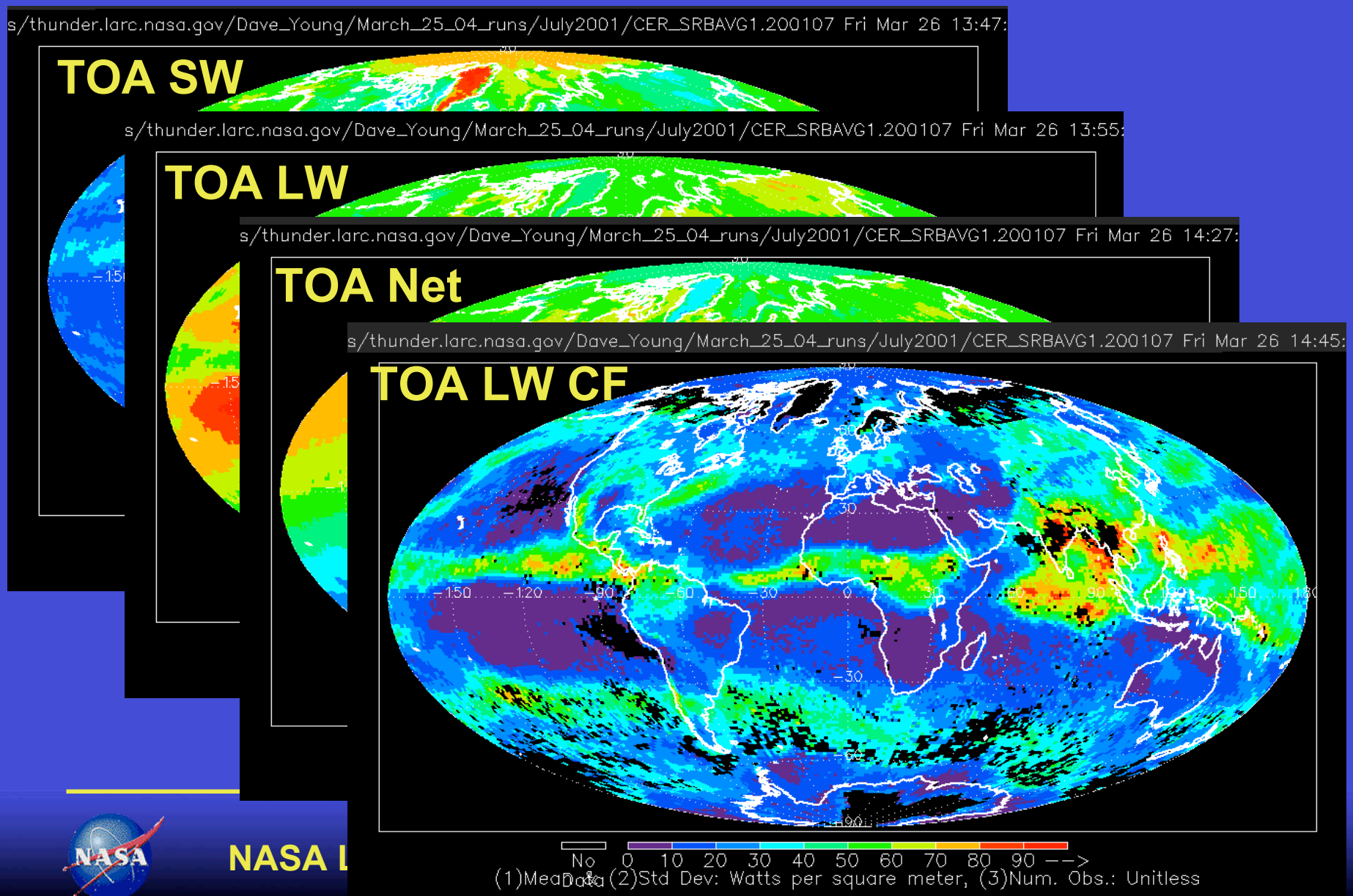


Comparison of Coincident CERES and GEO-derived Broadband Fluxes

CERES - GEO mean and (rms)
SW flux Difference (W/m^2)

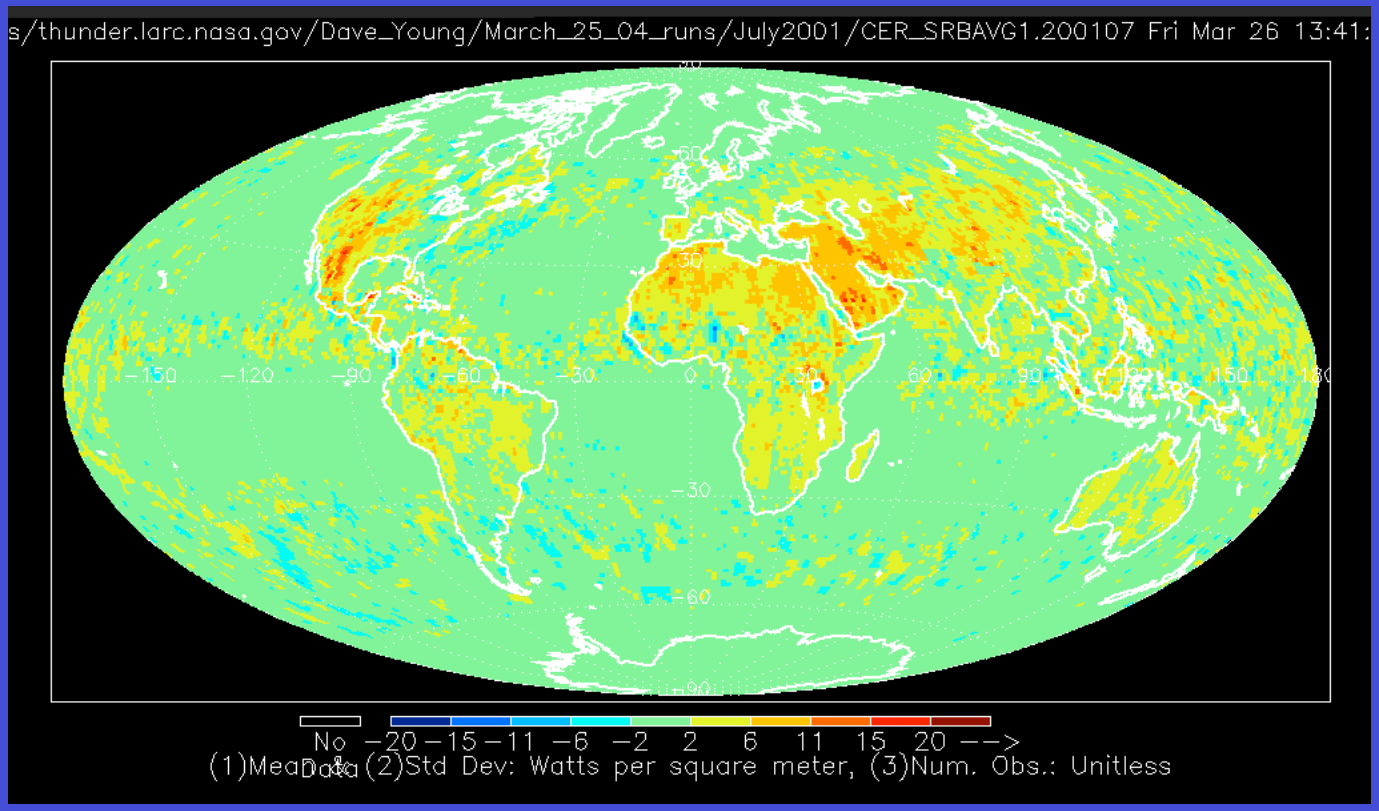
July 2001	Mean SW	GEO Data	MODIS Data
Ocean	210.8	2.7 (28.5)	-1.2 (18.2)
Land	302.0	-12.0 (34.3)	-9.6 (24.1)
Desert	310.3	1.6 (27.4)	2.9 (20.4)

July SRBAVG Monthly Means



NASA L

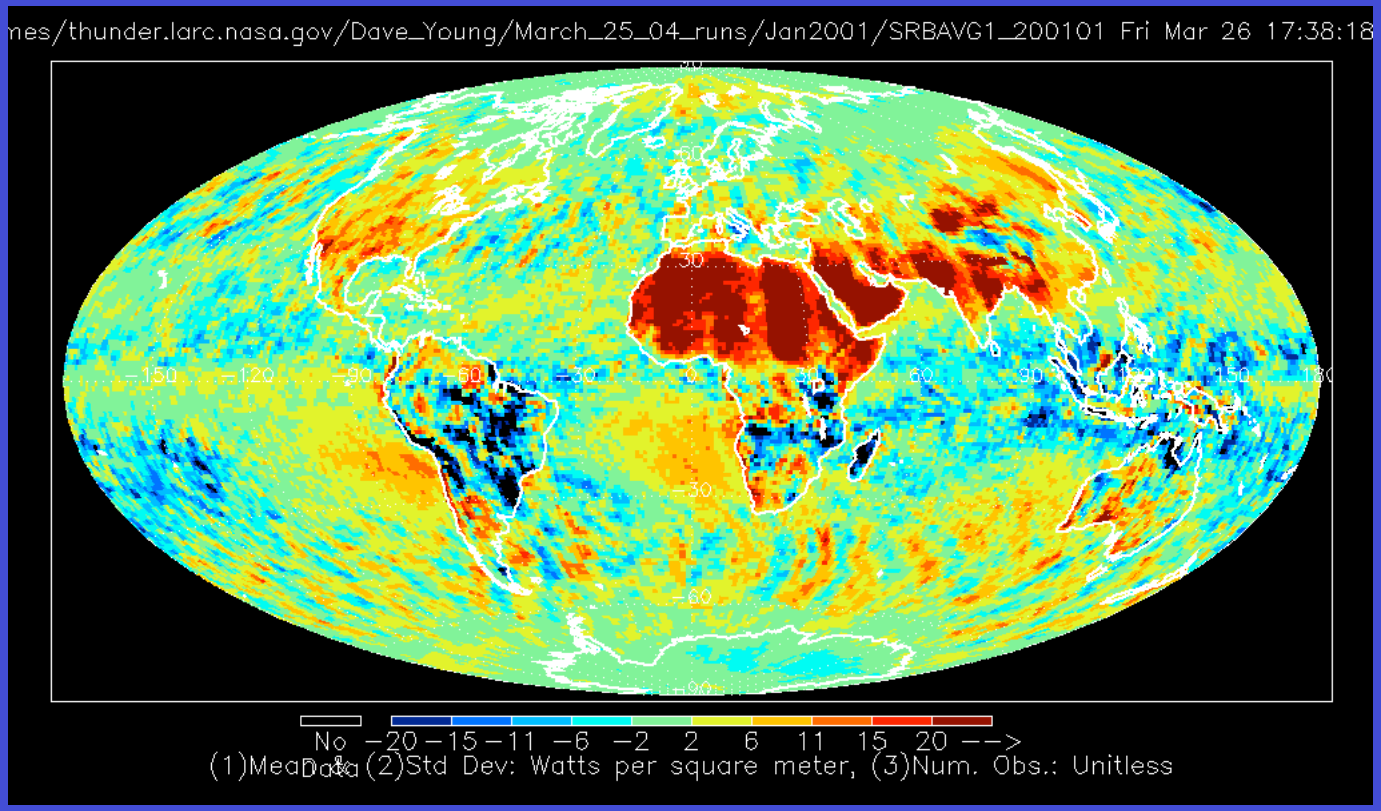
Adding GEO Data Decreases Temporal Sampling Errors
TOA LW Flux Change Terra FM-1 July 2001



Decrease:
Yellow-red

Increase:
Blue

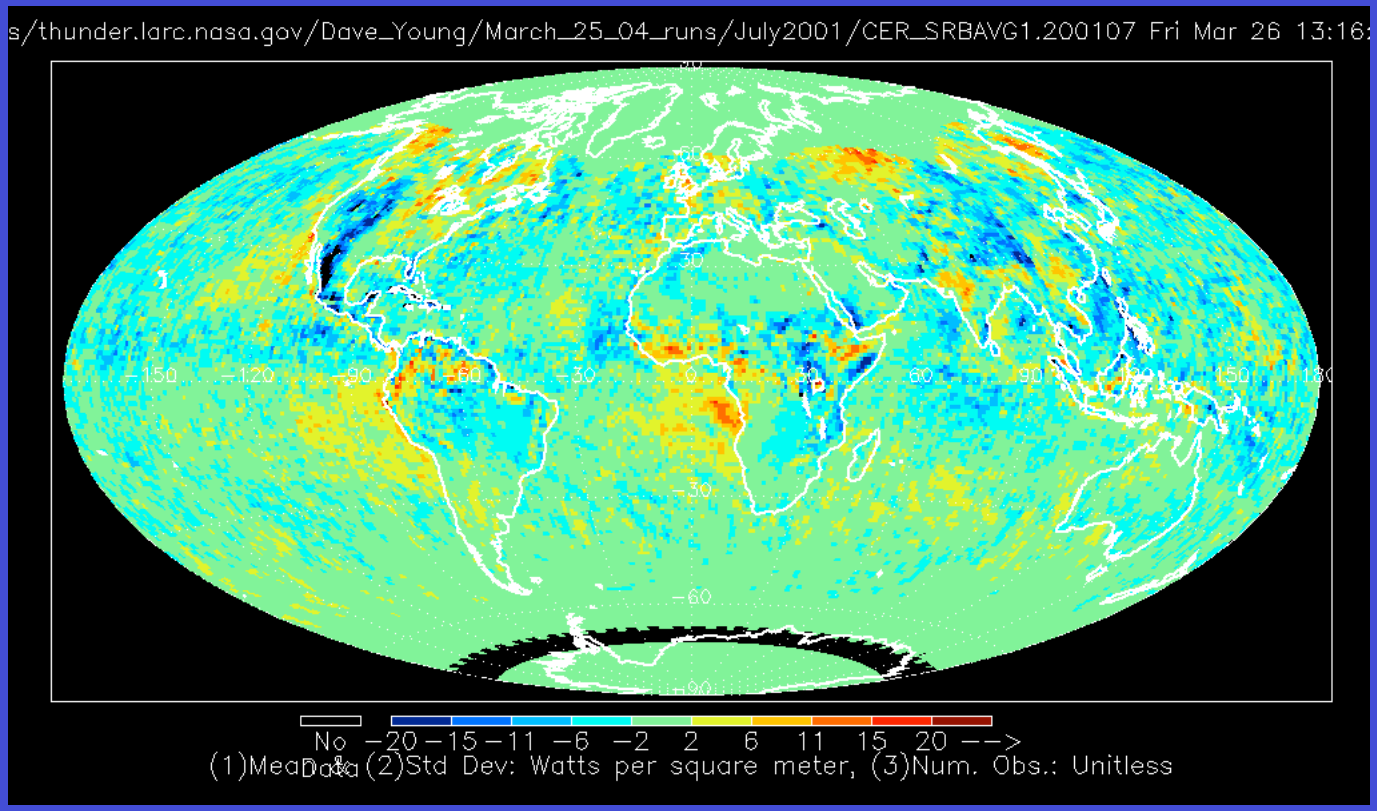
Adding GEO Data Decreases Temporal Sampling Errors
2:30 - 9:30 LT LW FLUX Terra FM-1 July 2001



PM Higher:
Yellow-red

AM Higher:
Blue

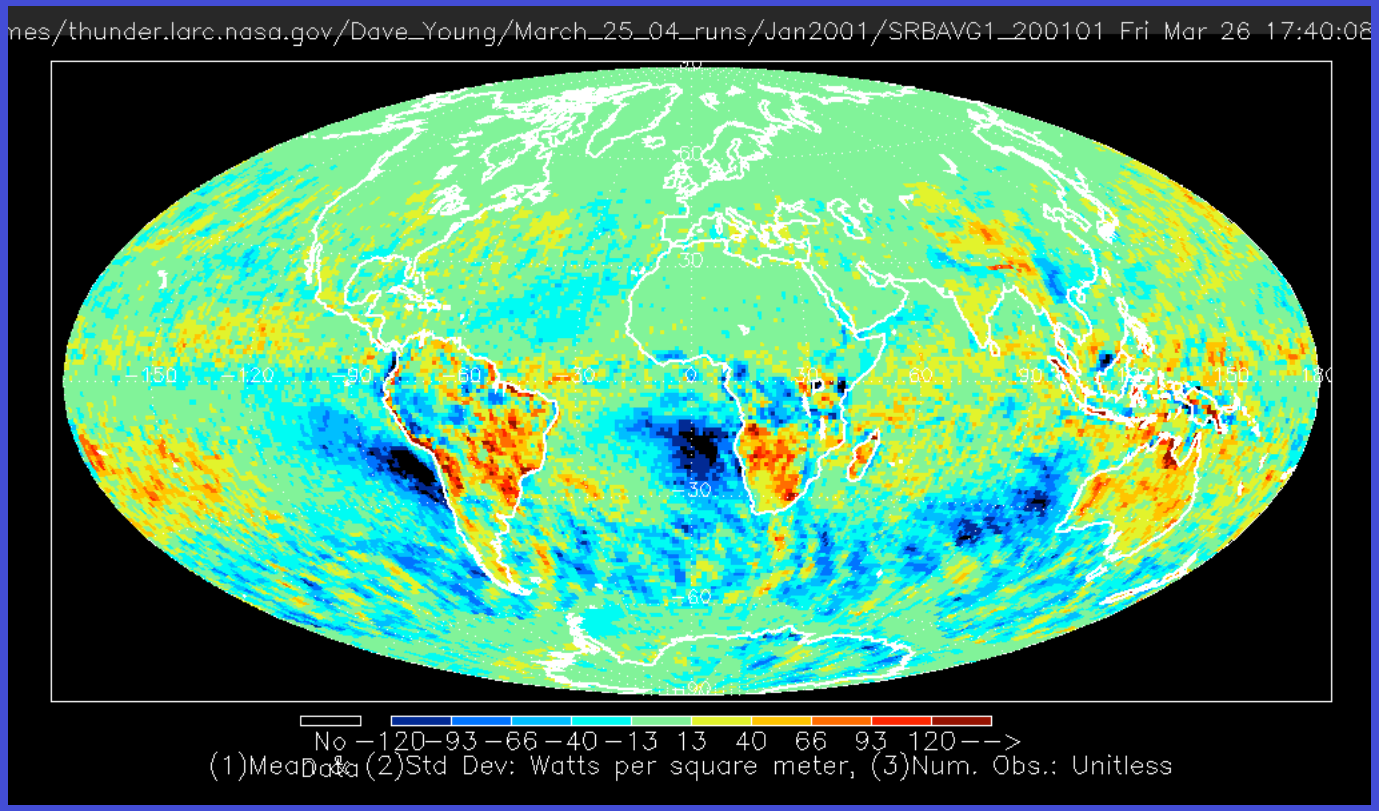
Adding GEO Data Decreases Temporal Sampling Errors
TOA SW Flux Change Terra FM-1 July 2001



Decrease:
Yellow-red

Increase:
Blue

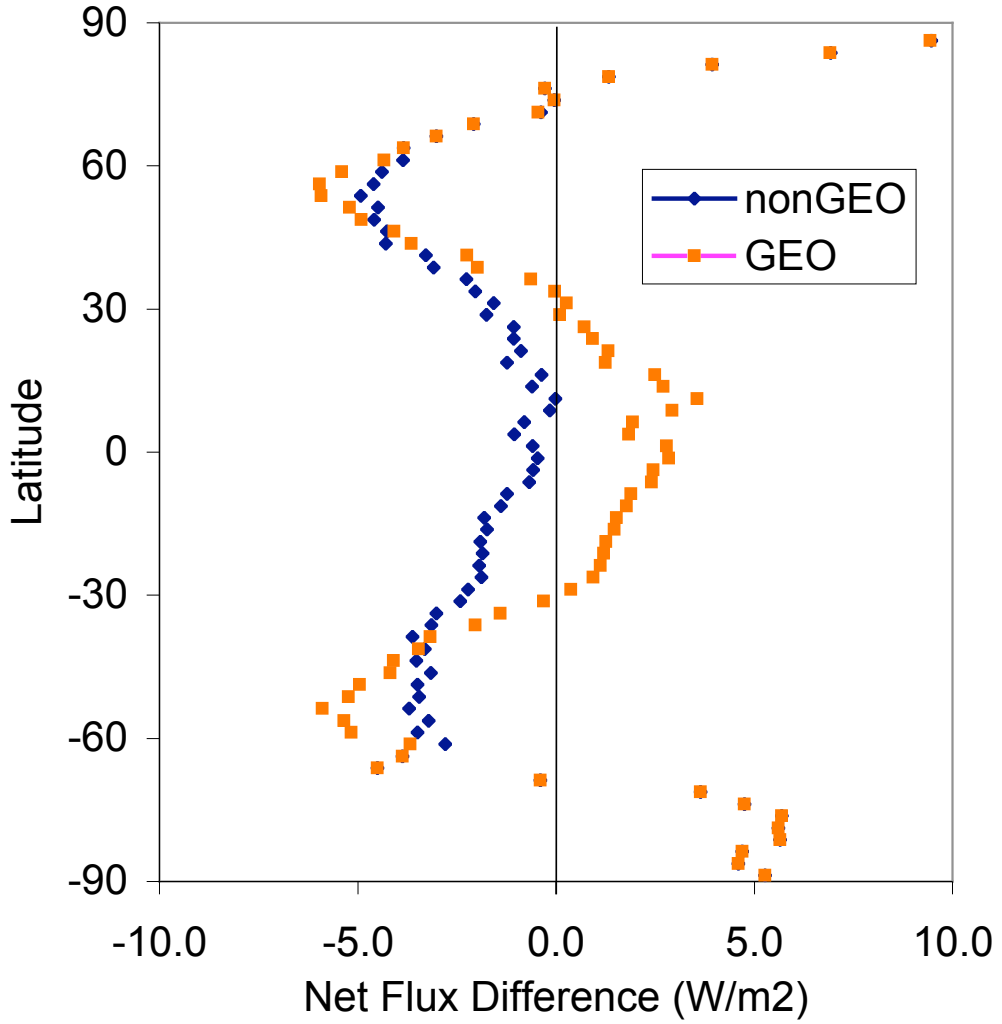
Adding GEO Data Decreases Temporal Sampling Errors
2:30 - 9:30 LT SW FLUX Terra FM-1 July 2001



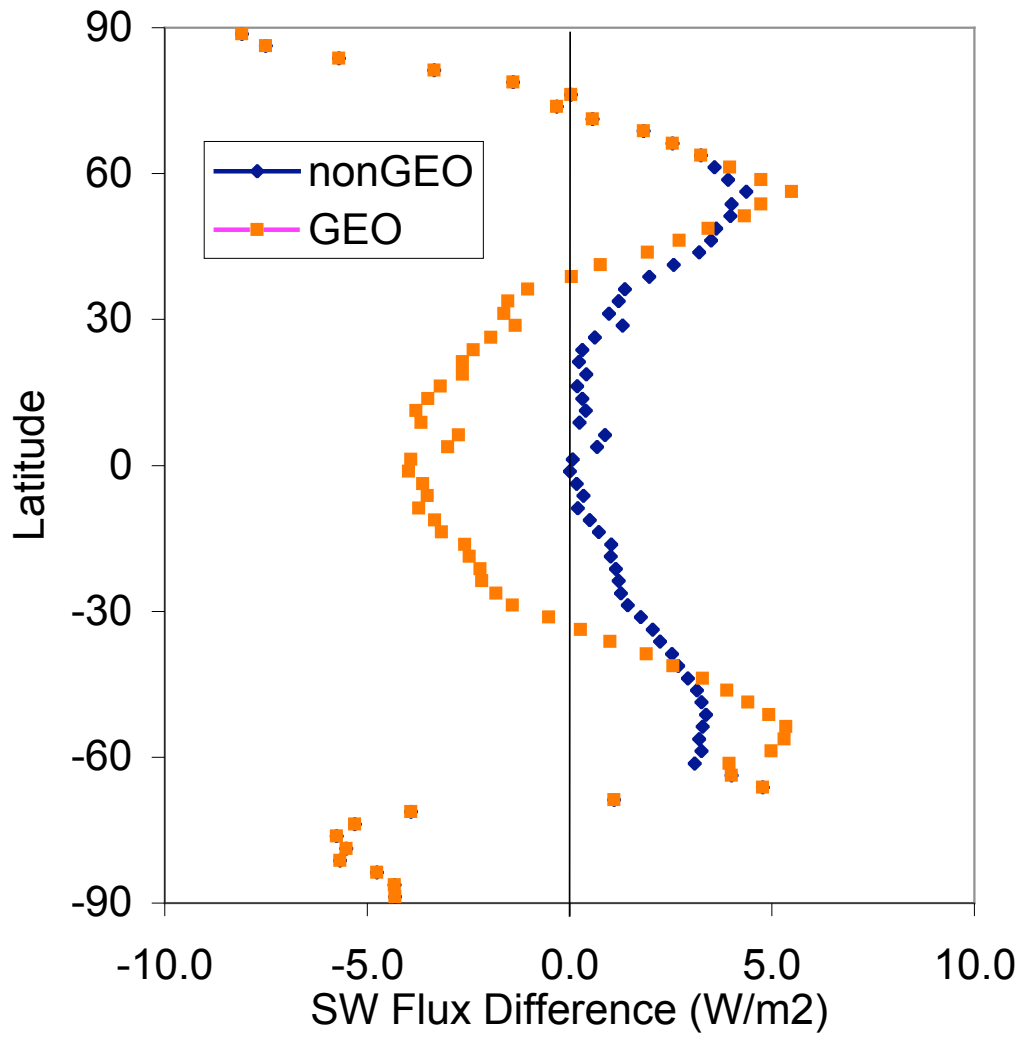
PM Brighter: Yellow-red

AM Brighter: Blue

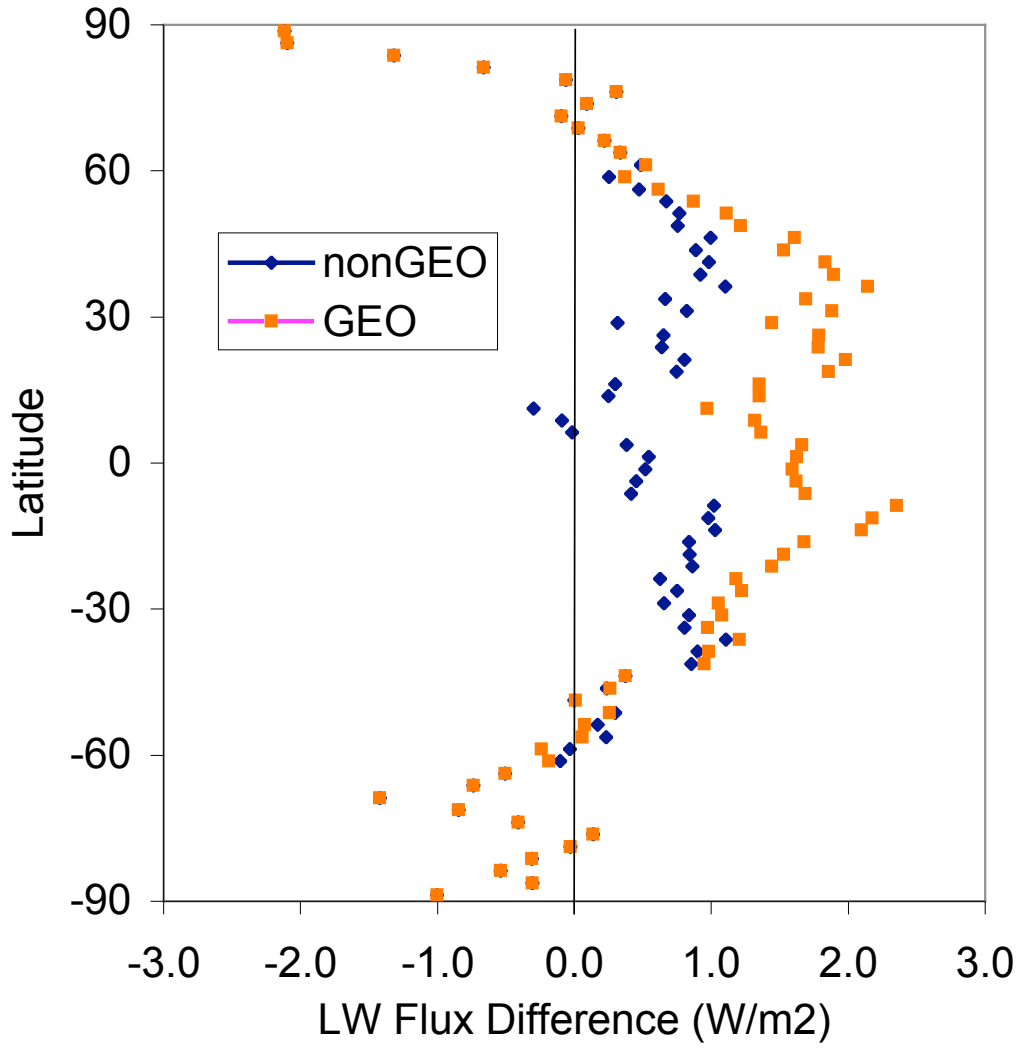
ERBElike - SRBAVG Annual Net TOA Flux



ERBElike - SRBAVG Annual SW TOA Flux

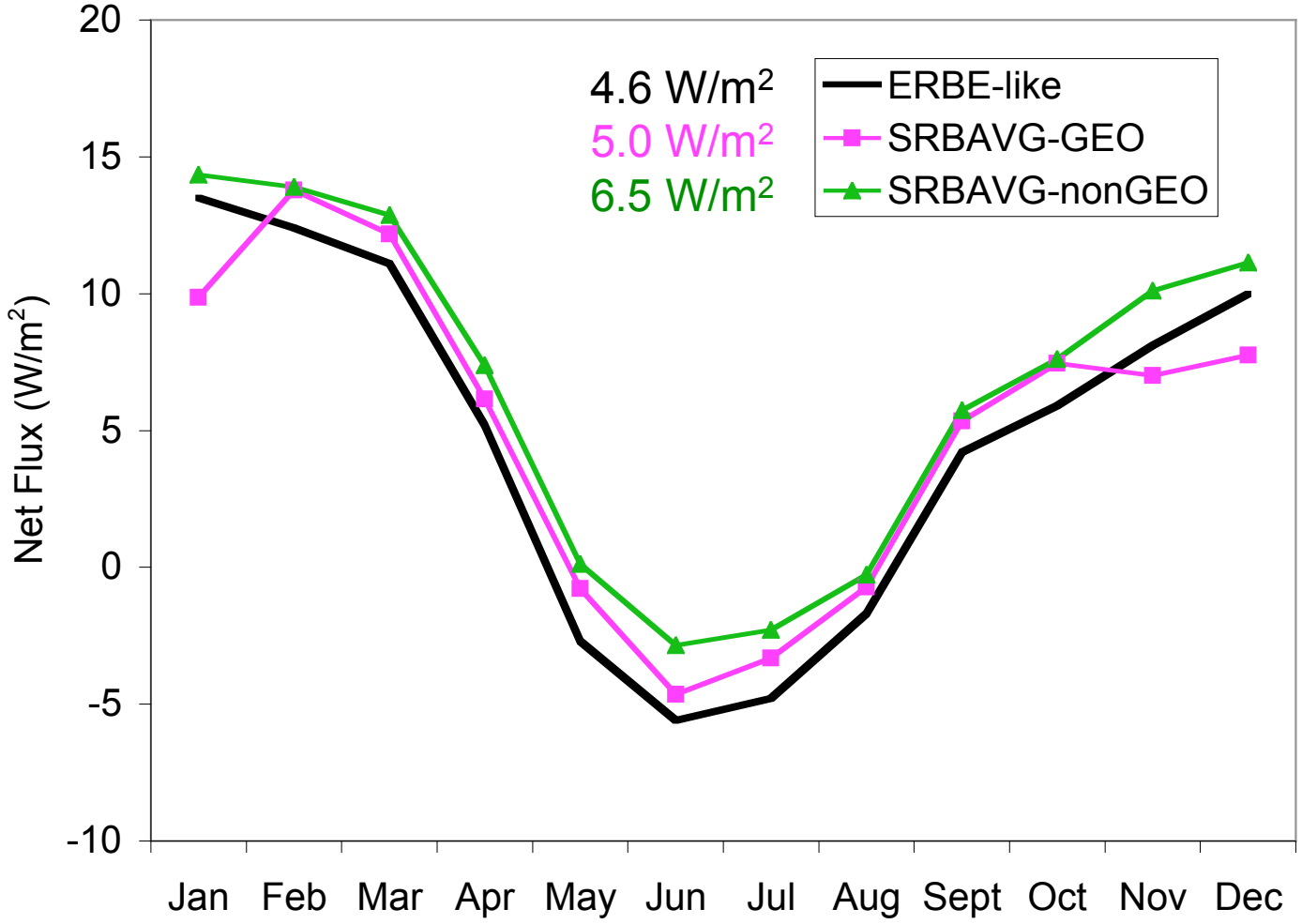


ERBElike - SRBAVG Annual LW TOA Flux



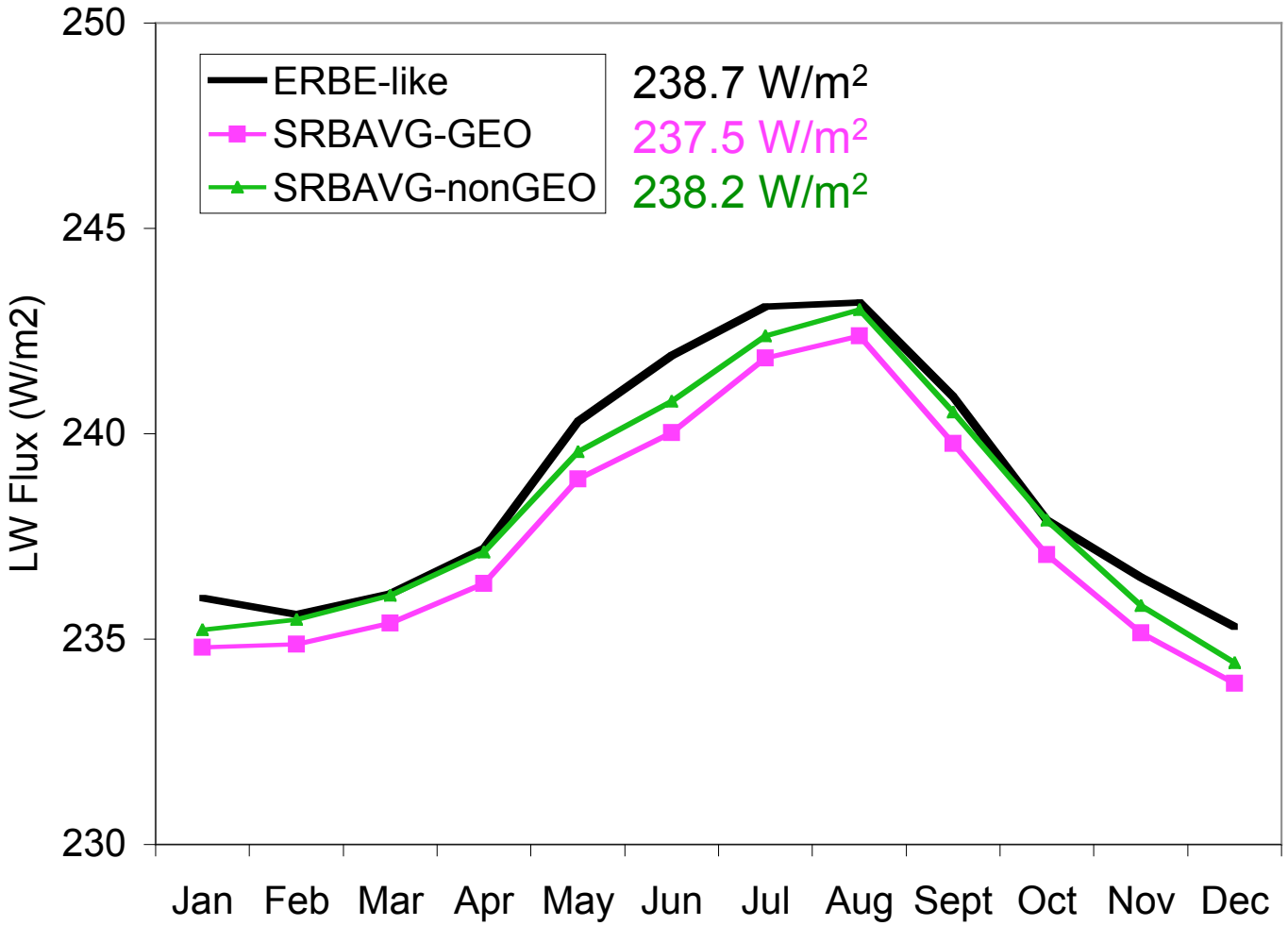
Global TOA Net Flux Comparison

Beta 2 SRBAVG January-December 2001



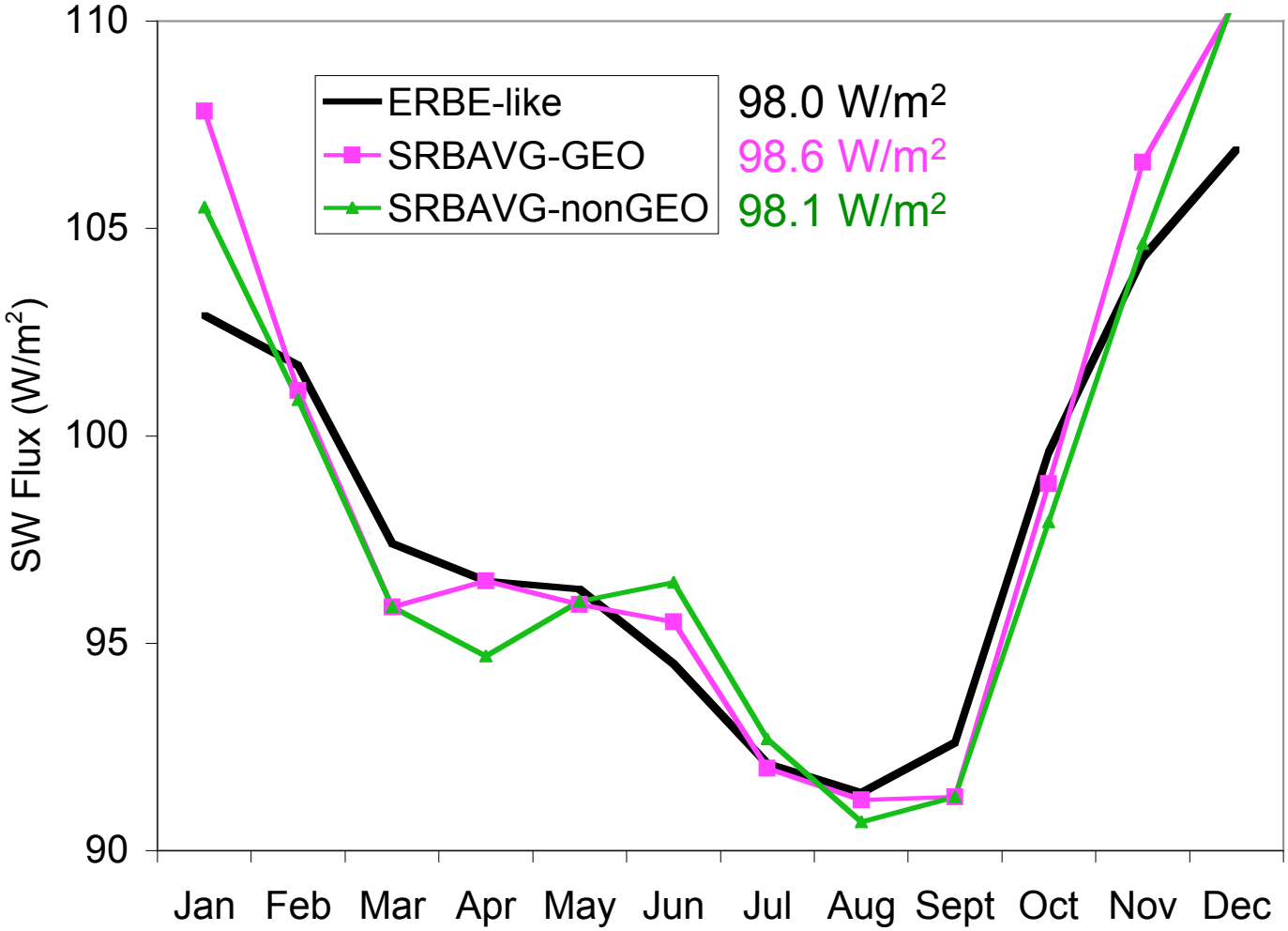
Global TOA LW Flux Comparison

Beta 2 SRBAVG January-December 2001



Global TOA SW Flux Comparison

Beta 2 SRBAVG January-December 2001



Global Mean TOA All-sky Fluxes

July 2001	ERBElike	Ed2 nonGEO	Beta GEO	Ed2 GEO
LW	243.1	242.4	241.8	241.4
SW	92.1	90.9	92.0	91.5
Net	-4.8	-2.8	-3.3	-2.4

January 2001	ERBElike	Ed2 nonGEO	Beta GEO	Ed2 GEO
LW	236.0	235.5	234.8	234.3
SW	102.9	101.8	107.8	102.5
Net	13.5	15.3	9.9	15.8

Validation

- Surface flux comparisons
  - Monthly mean downwelling fluxes at BSRN sites
  - Instantaneous comparisons at ARM SGP
- Direct Integration
  - Similar to ADM test
  - Only possible for TRMM, but errors masked by compensation
- TRMM/Terra and Terra/Aqua comparisons
  - TRMM/Terra from March 2000 only
  - Terra Aqua in initial phase (Beta Aqua just becoming available)
- Waiting breathlessly for GERB

Summary

- Major improvements have been made in NB-BB conversion
- Large regional temporal sampling errors corrected using GEO data, but…..
- Global imbalance remains unchanged
- What next?
  - Product scheduled for release in July 2004
  - Testing of GGEO data will continue
    - CERES-to-CERES comparison
    - Tests for normalization flatness
  - Surface flux comparisons for Terra
  - Flux imbalance
    - Twilight
    - Directional models