Comparison of Clouds of Low Optical (Water) Depth Derived using VISST

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Motivation

- CLOWD focus: TOA and SFC SW fluxes very sensitive to small LWP
  - accurate derivation of low LWP is crucial
  - (Sengupta et al, 2003)

- Various sources of LWP do not necessarily compare well
  - up to ~60 g/m^2 differences (Turner et al, 2006 BAMS)

- How do satellite and surface-based retrievals of LWP compare
  - Terra/Aqua MODIS, GOES
  - MWR

- How do the model-derived (Fu-Liou) and observed (CERES) SFC and TOA fluxes, compare as a function of LWP?

NASA Langley Research Center (LaRC) Cloud &Radiation Datasets

- Visible Infrared Solar-infrared Split-Window Technique (VISST)
  - Employs 4 channels (0.65, 3.9, 11 and 12 um)
  - Retrieves cloud and radiative properties at nominal resolution of 4km, e.g.
    - Optical Depth
    - Effective Radius
    - LWP
  - Available from http://www-pm.larc.nasa.gov

Possible Sources of Error in Satellite LWP: Inherent

- Inherent Uncertainty in Satellite-derived retrievals:
  - Visible calibration
  - A priori input:
    - surface albedo
    - Skin temperature
    - Visible Infrared Solar-infrared Split-Window Technique (VISST)

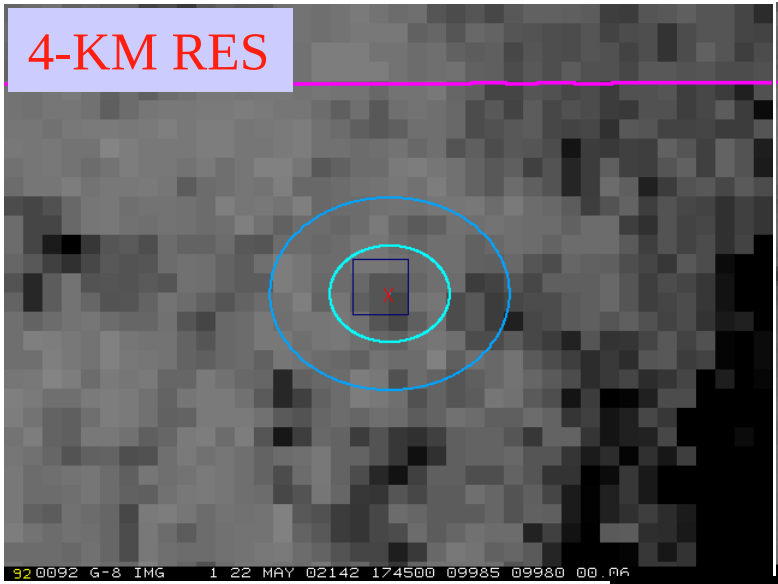
Should only cause biases in our retrievals, not large variations

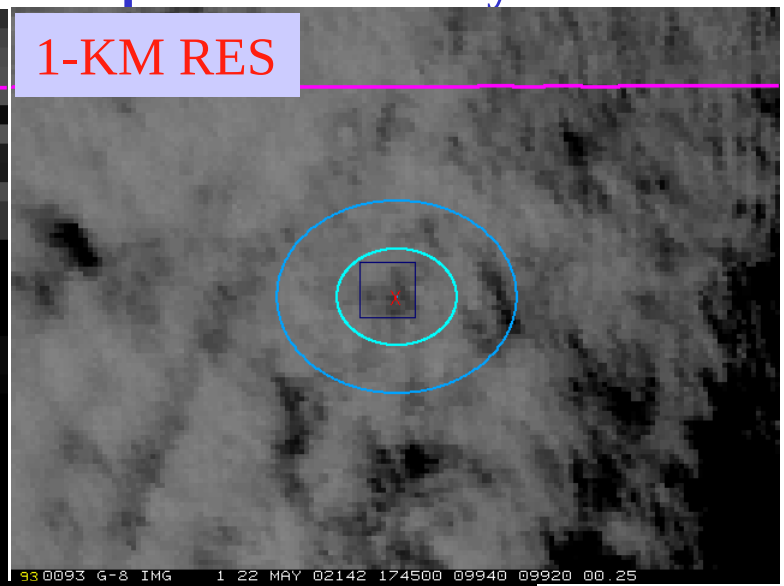
Possible Sources of Error in Satellite LWP: Variability

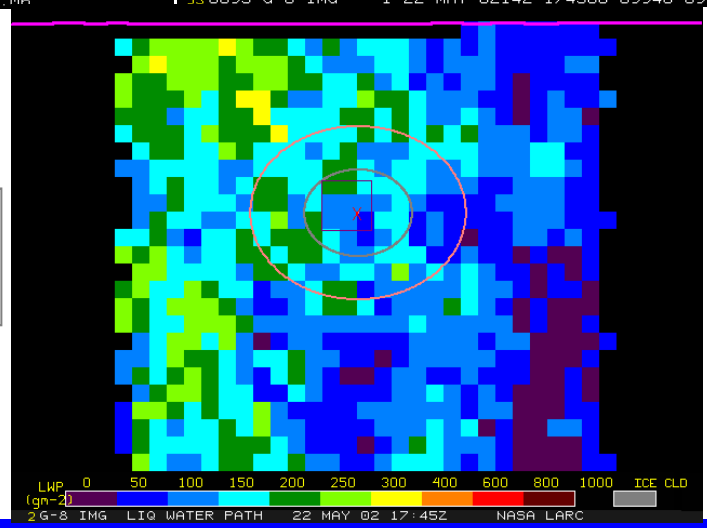
- Satellite Spatial Variability Caused by
  - Navigation
  - Parallax error due to clouds
  - Coarse resolution (nominal 4km)

Could cause large variations in retrievals

Satellite-Derived LWP Spatial Variability

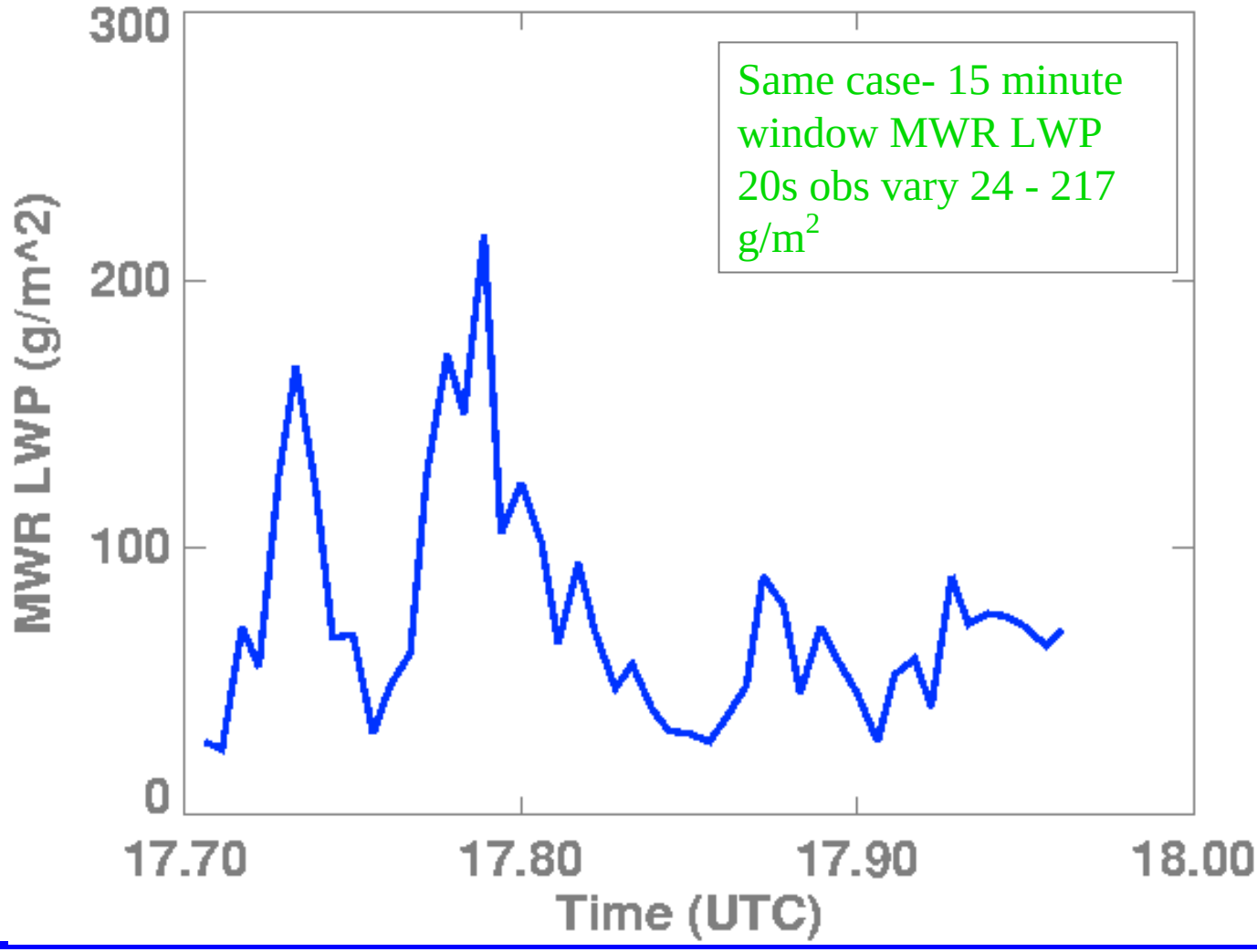






VISST LWP 9pixel box varies ~77 - 223 g/m^2

Microwave Radiometer-derived LWP Temporal Variability



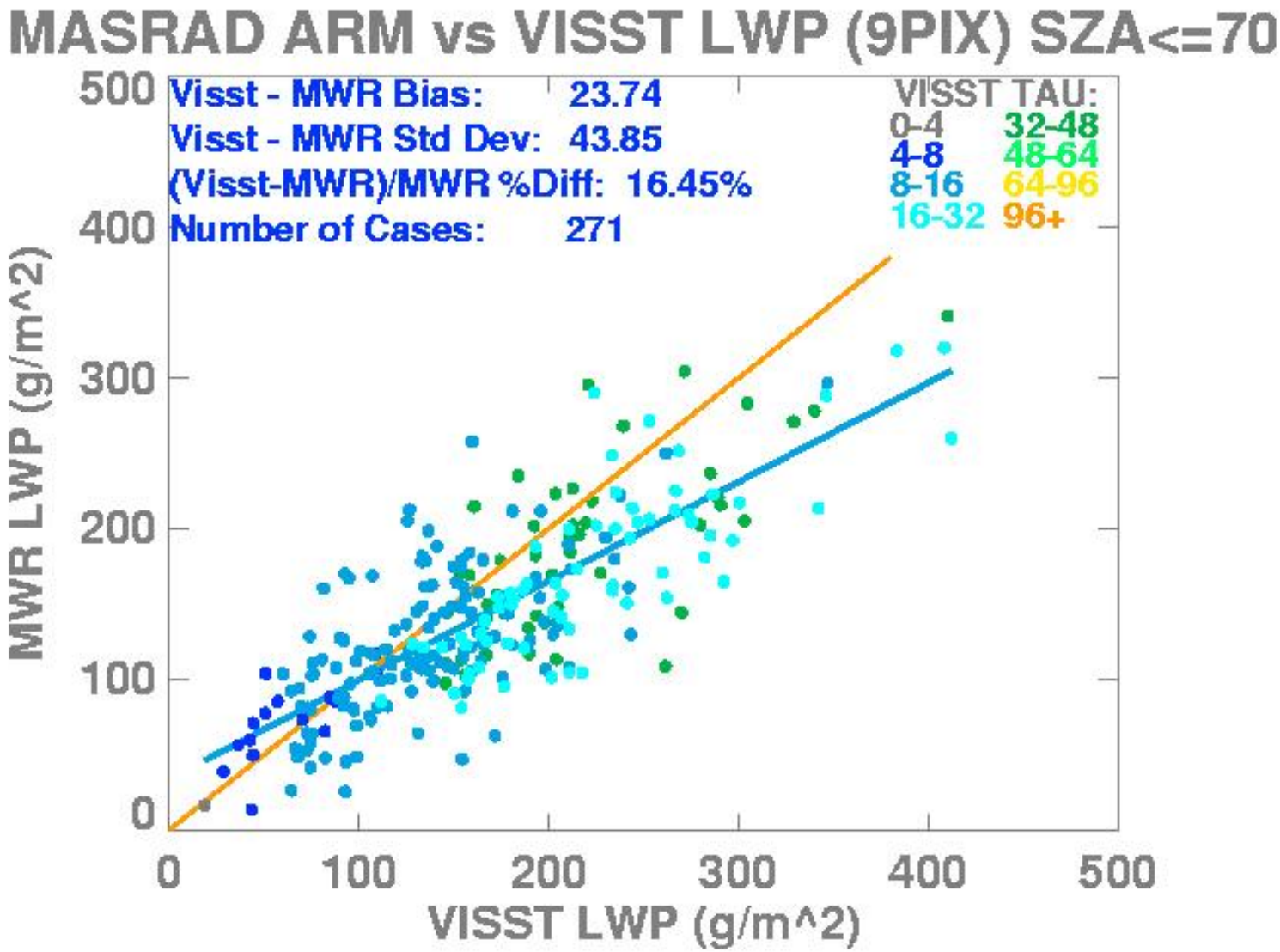
Methodology: GOES VISST vs MWR LWP

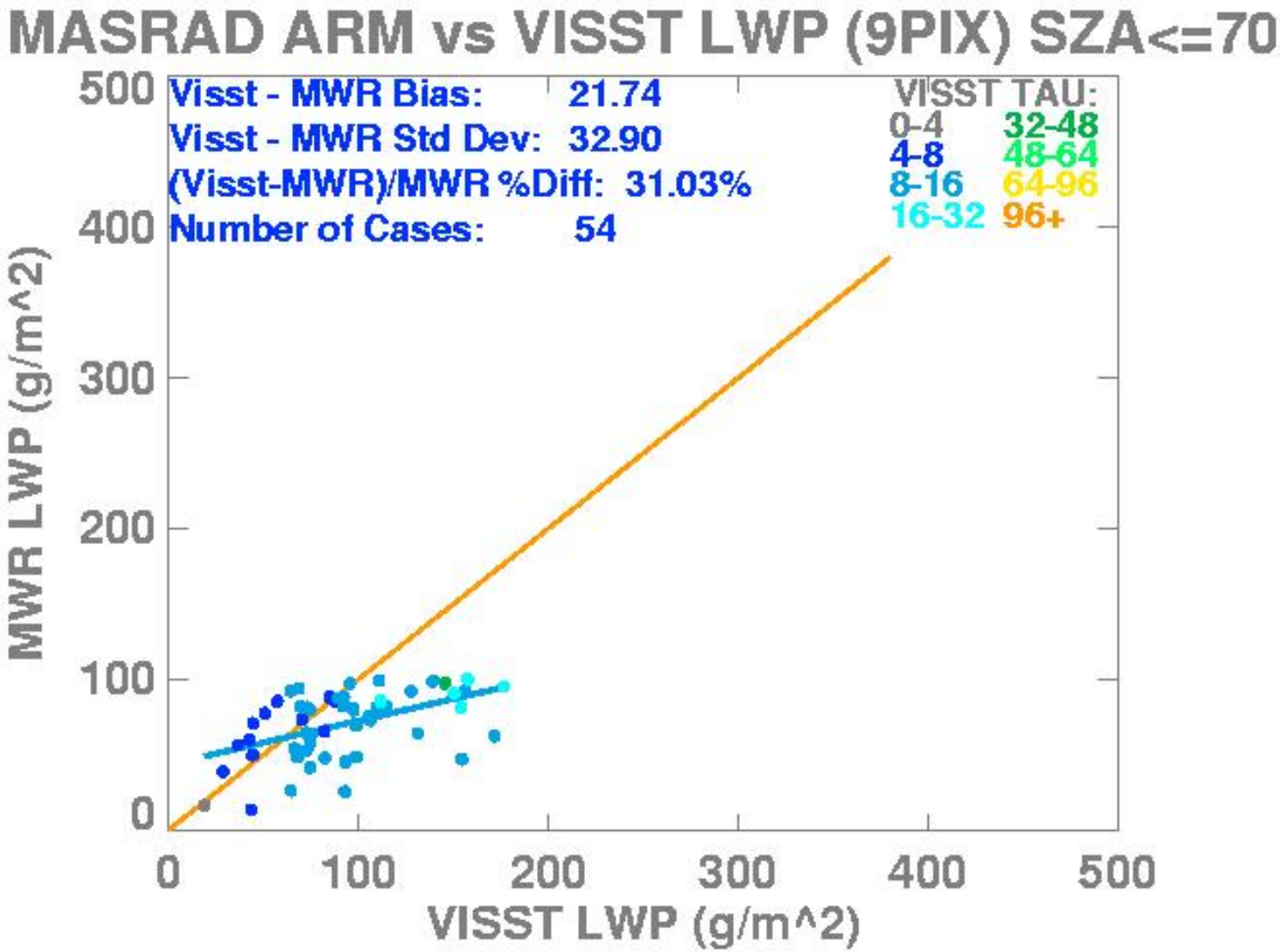
Satellite-derived LWP compared to surface LWP at ARM facilities

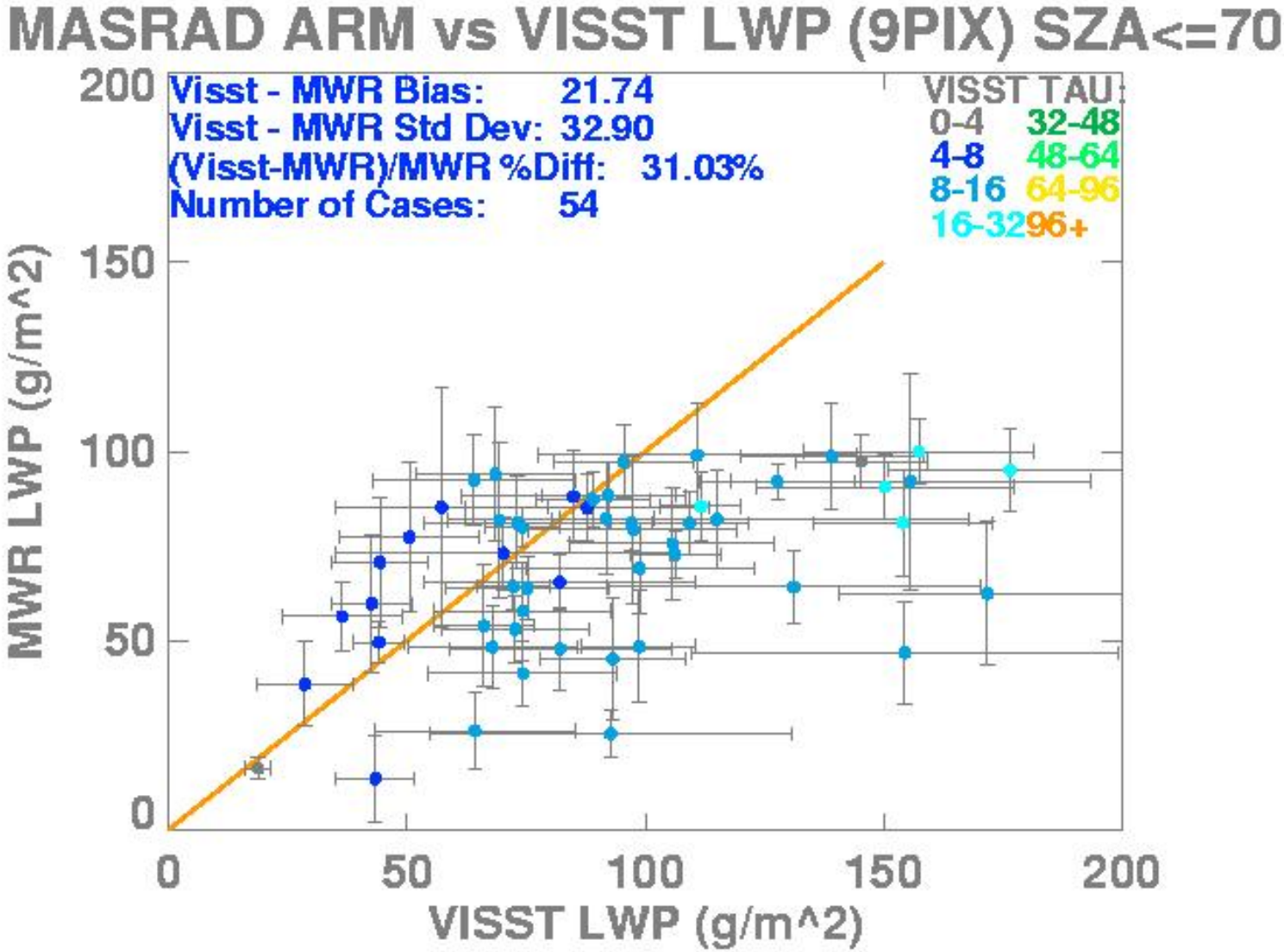
- VISST 9-pixel average
  - 9 pixel average, centered on pixel containing site
  - Parallax-corrected, assuming cloud ht=1.7 km
  - 100% liquid cloud
  - Cloud Temp > 273.15 K
  - SZA <= 70°

- ARM Microwave Radiometer (MWR) LWP 15 minute average
  - No wet window
  - Obs > - 40 g/m^2
  - QC flag
  - IR Temp > 100 K
  - Threshold > 42 obs per 15 minute

- ARM SGP CF 2002
- MASRAD AMF Deployment at Pt Reyes, CA from March-September 2005


MASRAD ARM vs VISST LWP (9PIX) SZA<=70
Visst - MWR Bias: 23.74
Visst - MWR Std Dev: 43.85
(Visst-MWR)/MWR %Diff: 16.45%
Number of Cases: 271
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
100
200
300
400
500


MASRAD ARM vs VISST LWP (9PIX) SZA<=70
Visst - MWR Bias: 21.74
Visst - MWR Std Dev: 32.90
(Visst-MWR)/MWR %Diff: 31.03%
Number of Cases: 54
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
100
200
300
400
500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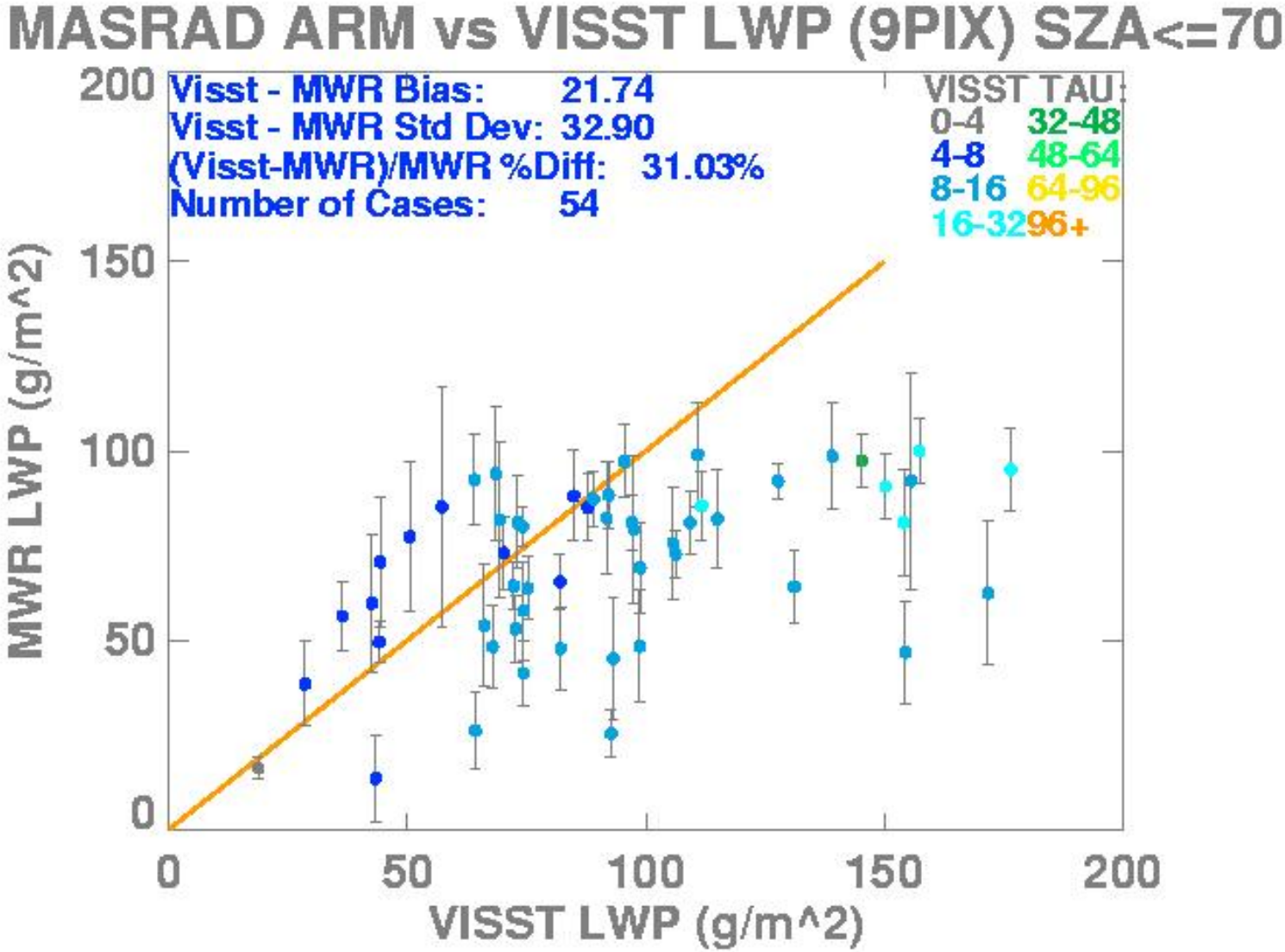
Number of Cases: 54
VISST TAU
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200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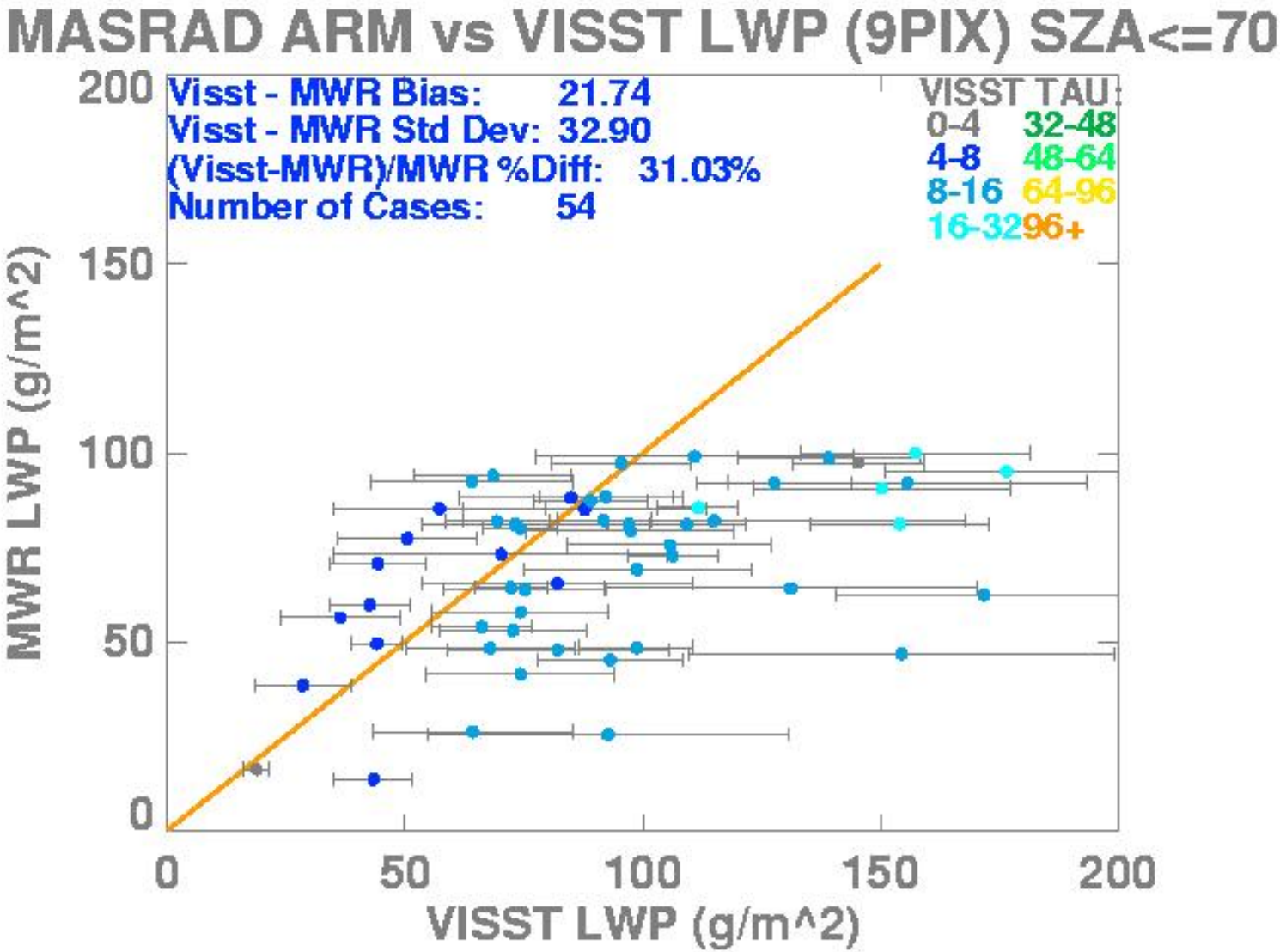
Number of Cases: 54
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200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Visst - MWR Std Dev: 32.90
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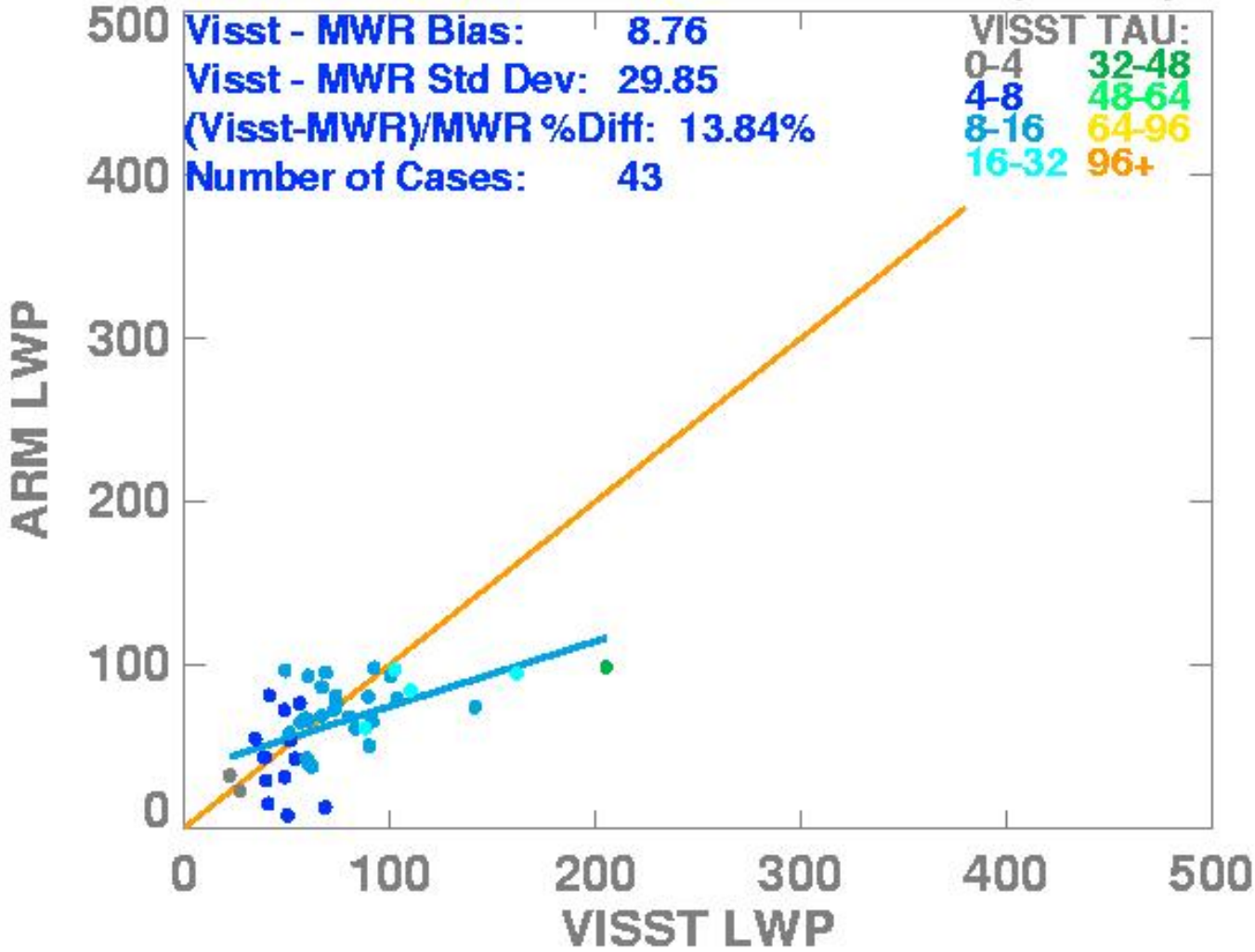
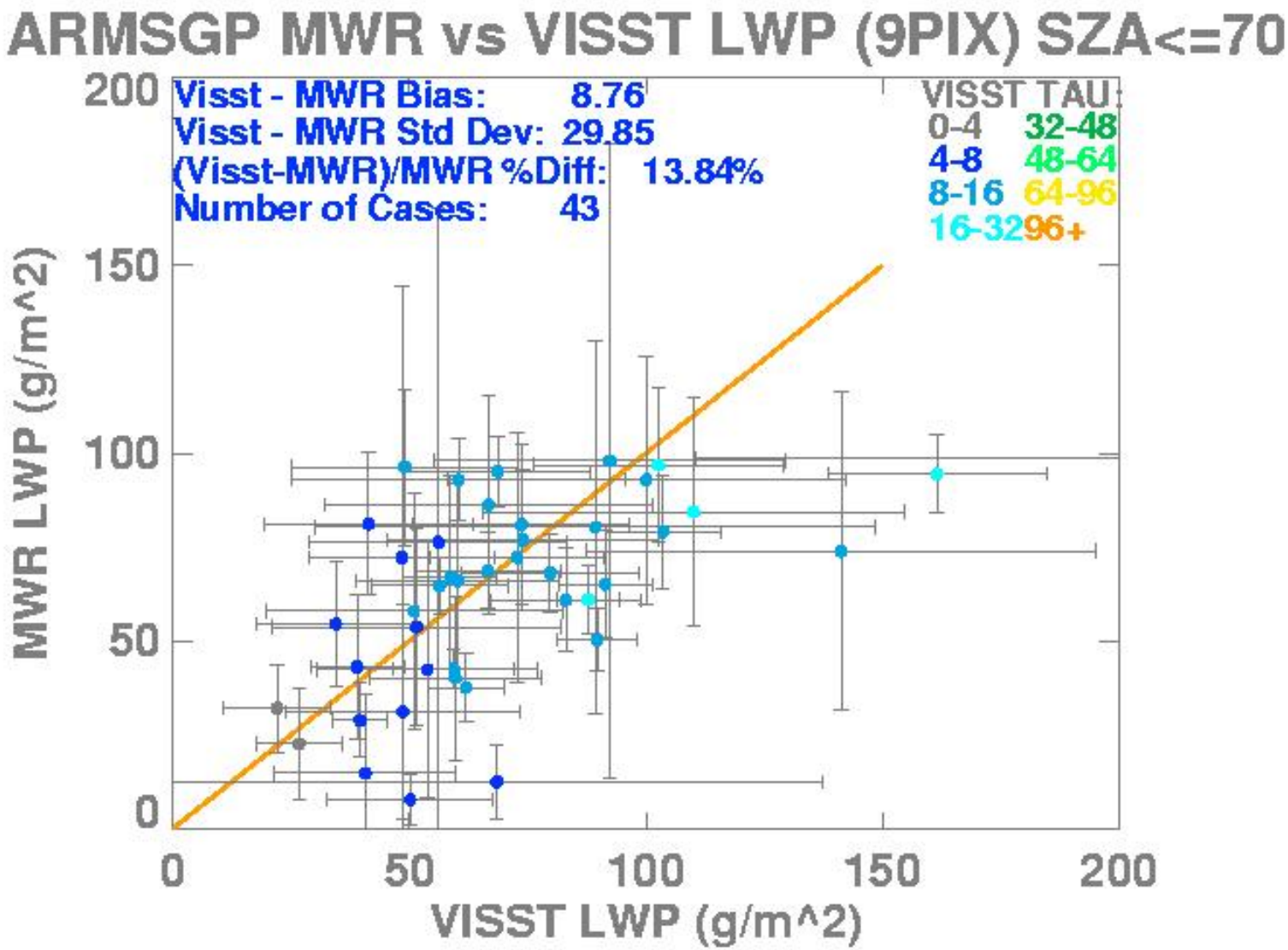
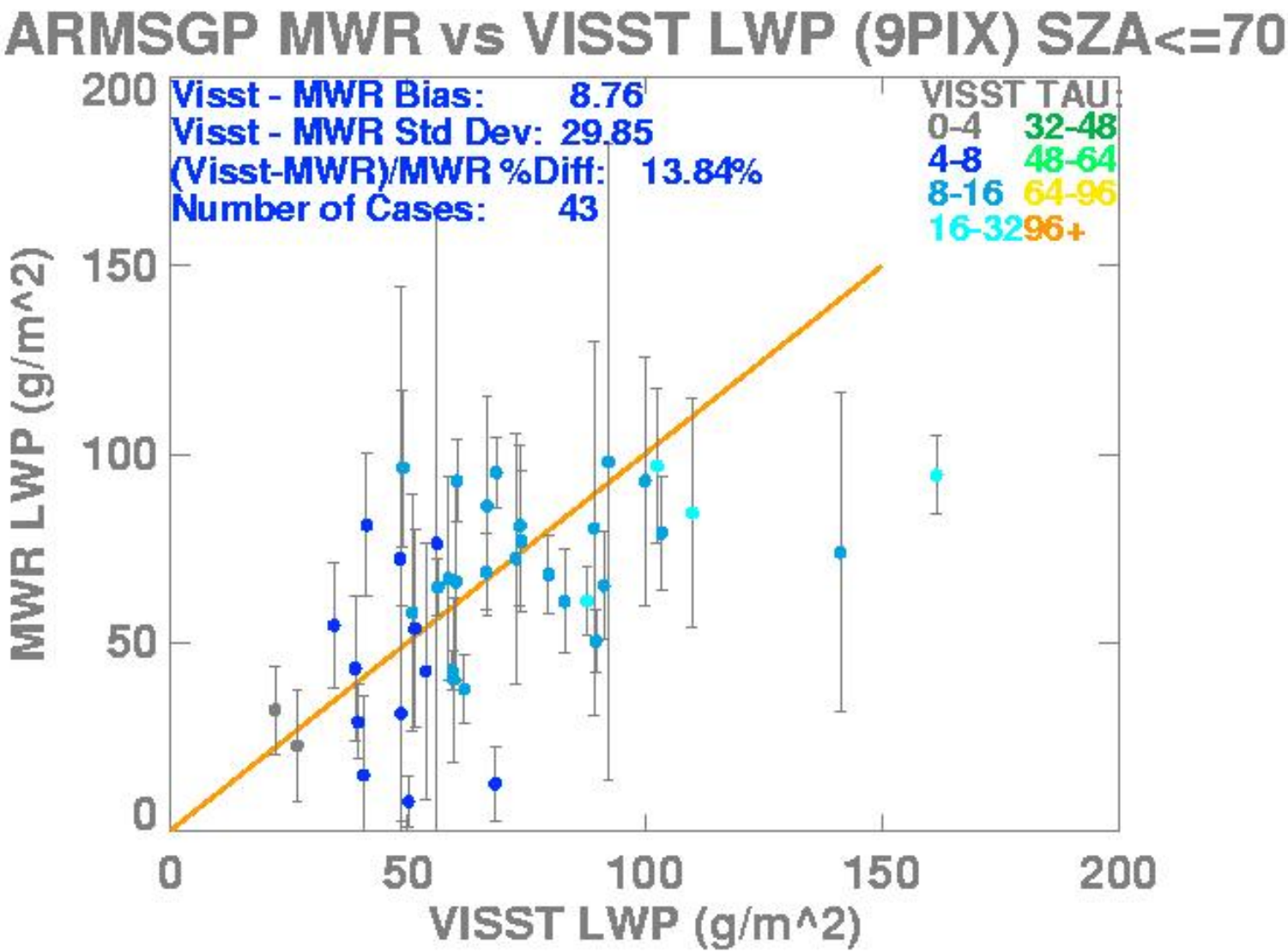
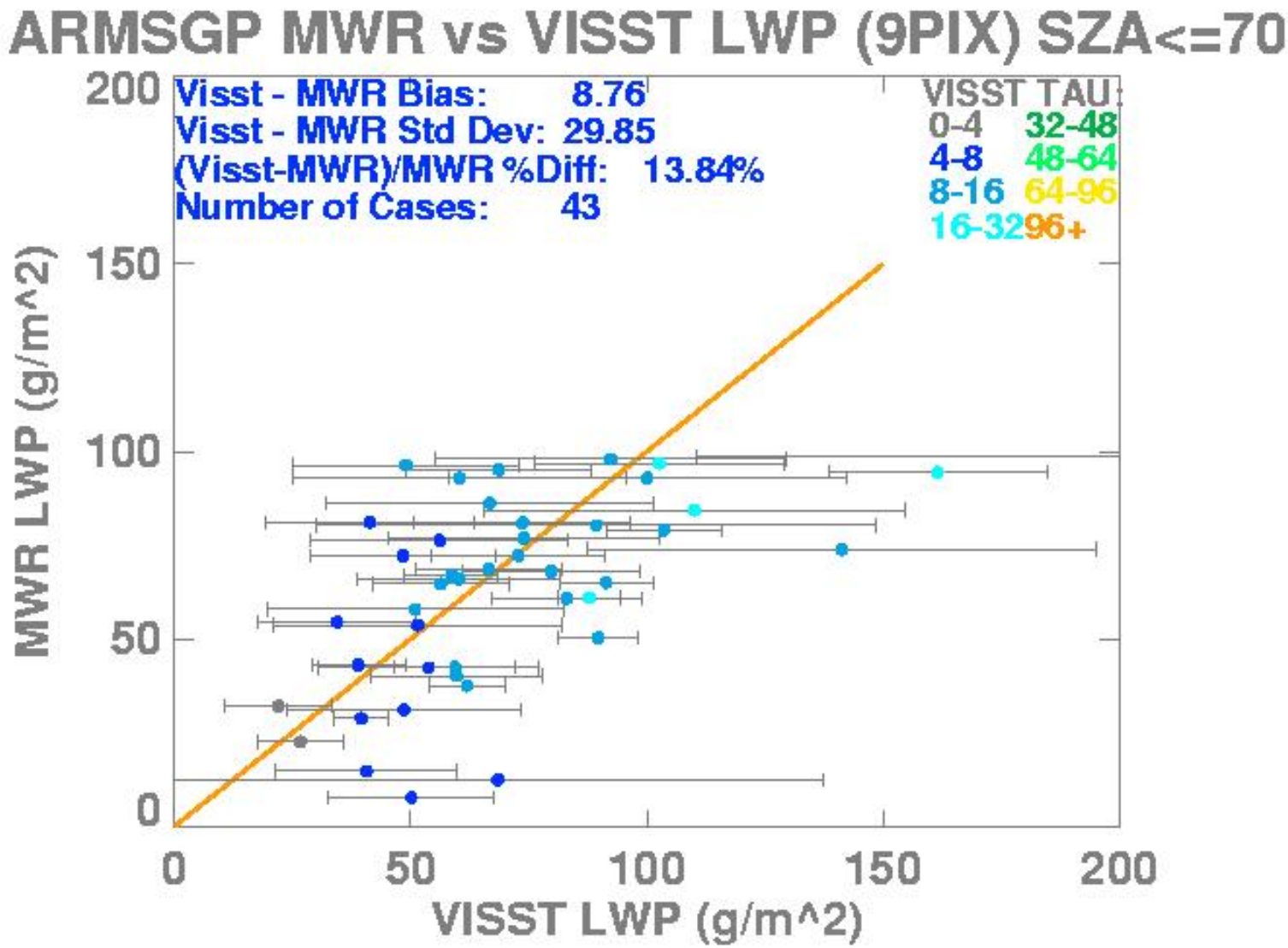
Number of Cases: 54
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200

2002 ARMSGP MWR vs VISST LWP (9PIX) SZA<=70




ARMSGP MWR vs VISST LWP (9PIX) SZA<=70
Visst - MWR Bias: 8.76
Visst - MWR Std Dev: 29.85
(Visst-MWR)/MWR %Diff: 13.84%
Number of Cases: 43
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200

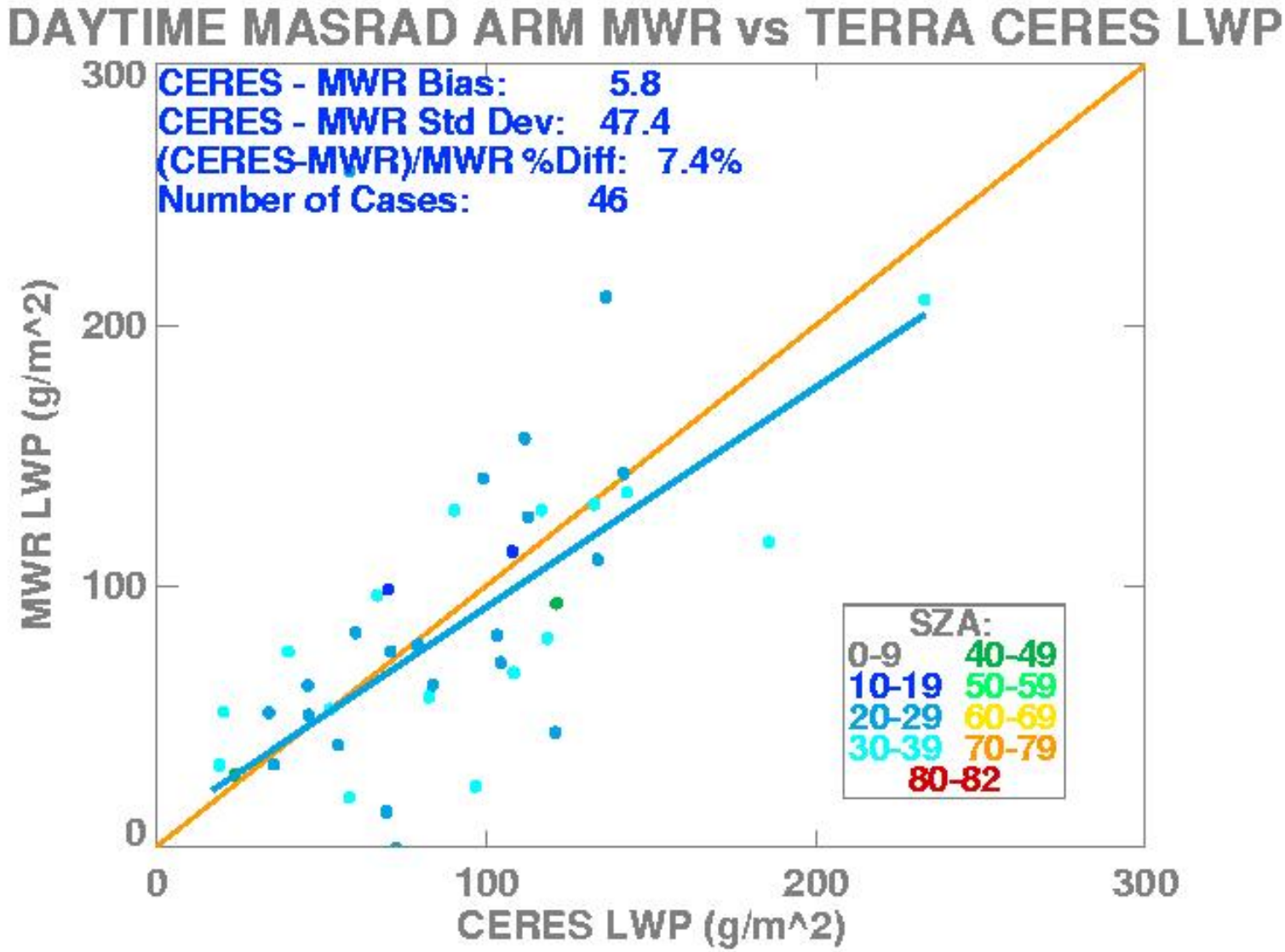

ARMSGP MWR vs VISST LWP (9PIX) SZA<=70
Visst - MWR Bias: 8.76
Visst - MWR Std Dev: 29.85
(Visst-MWR)/MWR %Diff: 13.84%
Number of Cases: 43
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200

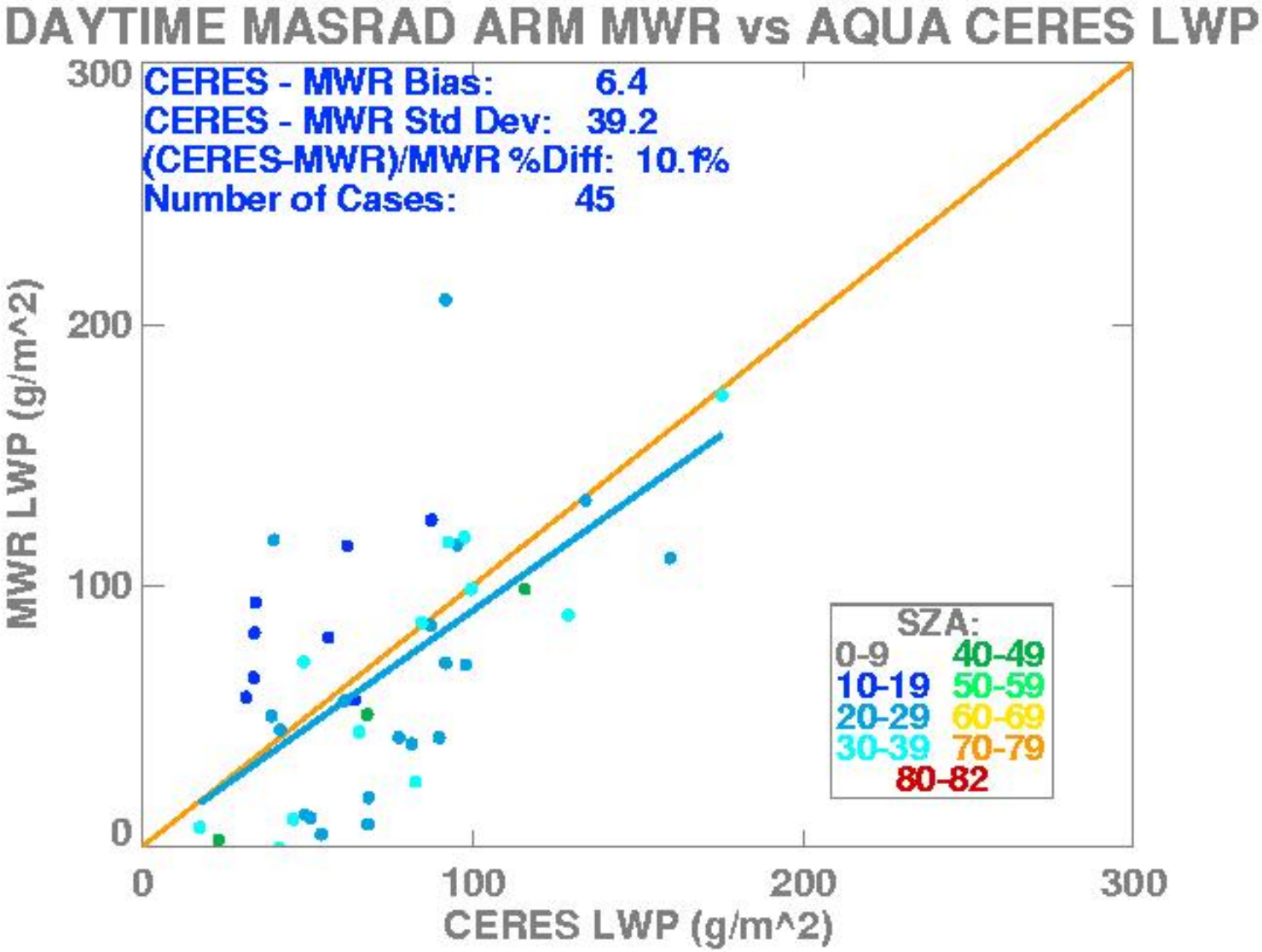

ARMSGP MWR vs VISST LWP (9PIX) SZA<=70
Visst - MWR Bias: 8.76
Visst - MWR Std Dev: 29.85
(Visst-MWR)/MWR %Diff: 13.84%
Number of Cases: 43
VISST TAU:
0-4
4-8
8-16
16-32
32-48
48-64
64-96
96+
MWR LWP (g/m^2)
VISST LWP (g/m^2)
0
50
100
150
200

Methodology: Pt Reyes CERES vs MWR LWP

- AMF Deployment at Pt Reyes, CA from March-September 2005
  - CERES Terra/Aqua SSF (Single Scanner Footprint; Geier et al, 1999)
  - LWP derived from MODIS using VISST
  - Closest footprint (20-km res nadir) to the site
  - Cloud Amount > 60%
  - VZA < 60°
  - Cloud Temp > 273.15 K

- ARM MWR LWP 15 minute average
  - No wet window
  - Obs > - 40 g/m^2
  - QC flag
  - Threshold > 30 obs (CERES comparison) per 15 minute


DAYTIME MASRAD ARM MWR vs TERRA CERES LWP
CERES - MWR Bias: 5.8
CERES - MWR Std Dev: 47.4
(CERES-MWR)/MWR %Diff: 7.4%
Number of Cases: 46
MWR LWP (g/m^2)
CERES LWP (g/m^2)
0
100
200
300
SZA:
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-82


DAYTIME MASRAD ARM MWR vs AQUA CERES LWP
CERES - MWR Bias: 6.4
CERES - MWR Std Dev: 39.2
(CERES-MWR)/MWR %Diff: 10.1%
Number of Cases: 45
MWR LWP (g/m^2)
CERES LWP (g/m^2)
0
100
200
300
SZA:
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-82

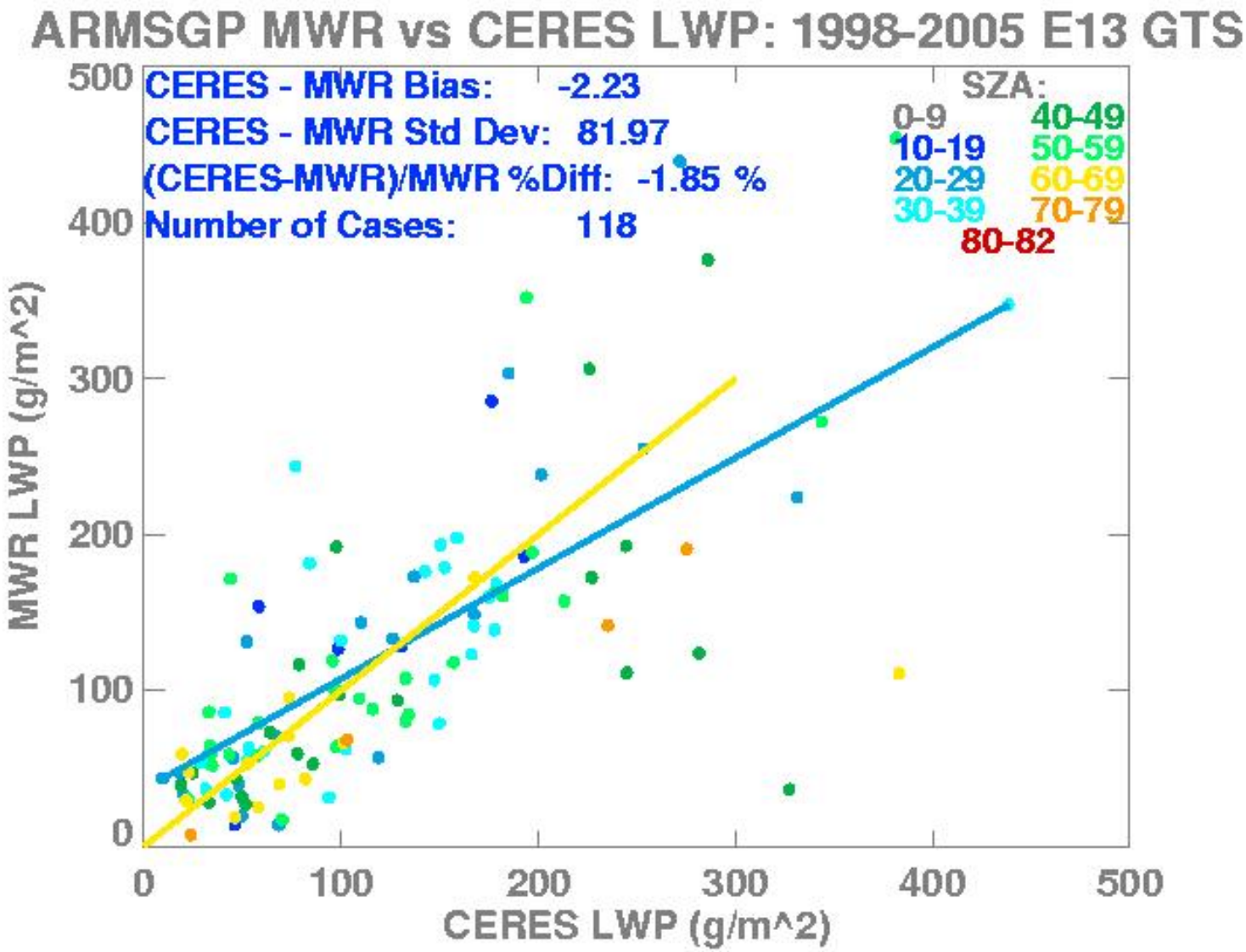
Methodology: SGP CERES vs MWR LWP

Used Data from GTS

- Grand Time Series (GTS) merged products
  - contains footprints within 25km of site:
    - CERES SSF footprint fluxes (include MODIS cloud retrievals)
    - CERES CRS (Clouds and Radiative Swath) Fu-Liou radiative transfer model results using GEOS4 profiles
    - ARM surface-based fluxes, MWR LWP, Sfc cloud fraction, etc
    - Available from ftp://snowdog.larc.nasa.gov/pub/cave_stats/gts/ARM

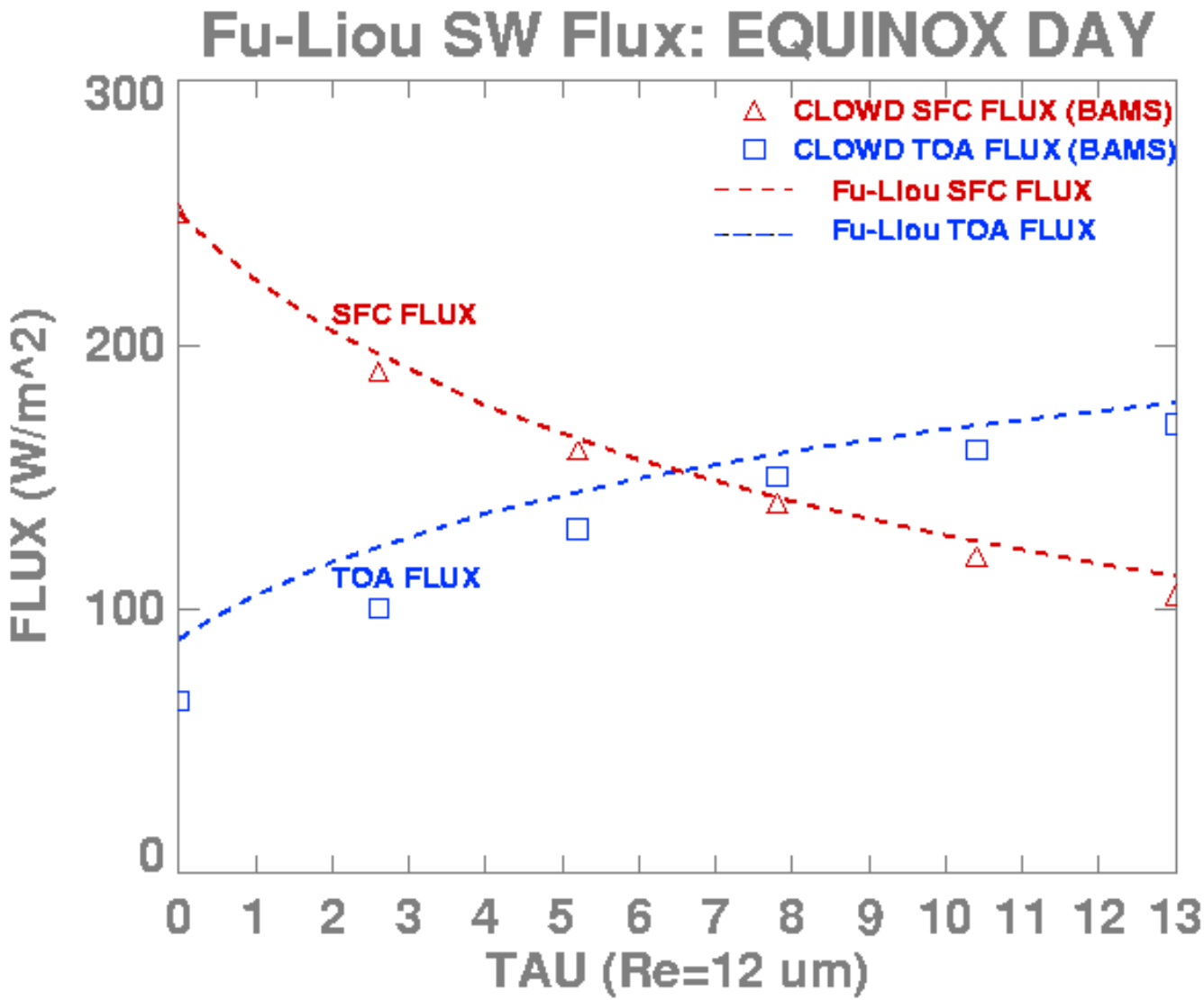
- ARM SGP CF 1998-2005
  - CERES TRMM and Terra LWP, derived from MODIS using VISST
  - Closest footprint (20-km res nadir) to the site
  - Cloud Amount > 95%
  - > 90% Liquid Water Cloud

- ARM MWR LWP 15 minute average


ARMSGP MWR vs CERES LWP: 1998-2005 E13 GTS
CERES - MWR Bias: -2.23
CERES - MWR Std Dev: 81.97
(CERES-MWR)/MWR %Diff: -1.85 %
Number of Cases: 118
SZA:
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-82
MWR LWP (g/m^2)
CERES LWP (g/m^2)
0
100
200
300
400
500

Comparison of Fu-Liou Flux with Model Fluxes (BAMS)

- Focus on Shortwave only
- Modified Fu-Liou (delta 2 stream radiative transfer model)
  - Latest Version FU0602
  - Available online: http://srbsun.larc.nasa.gov/flp0599
- Compare Fu-Liou to fluxes from BAMS Sidebar 1
  - 100% cloud amount
  - Based on cloud height ~900-1300 m
  - Equinox Day
  - Midlatitude summer profile
  - Used mean SZA for day at Continental site (~37 N)
    - approximate diurnal average used by BAMS
  - Effective radius 12 um, for optical depth 1-13
    - approximate LWP 0-100 g/m^2


Fu-Liou SW Flux: EQUINOX DAY
CLOWD SFC FLUX (BAMS)
CLOWD TOA FLUX (BAMS)
Fu-Liou SFC FLUX
Fu-Liou TOA FLUX
SFC FLUX
TOA FLUX
FLUX (W/m^2)
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13
TAU (Re=12 um)

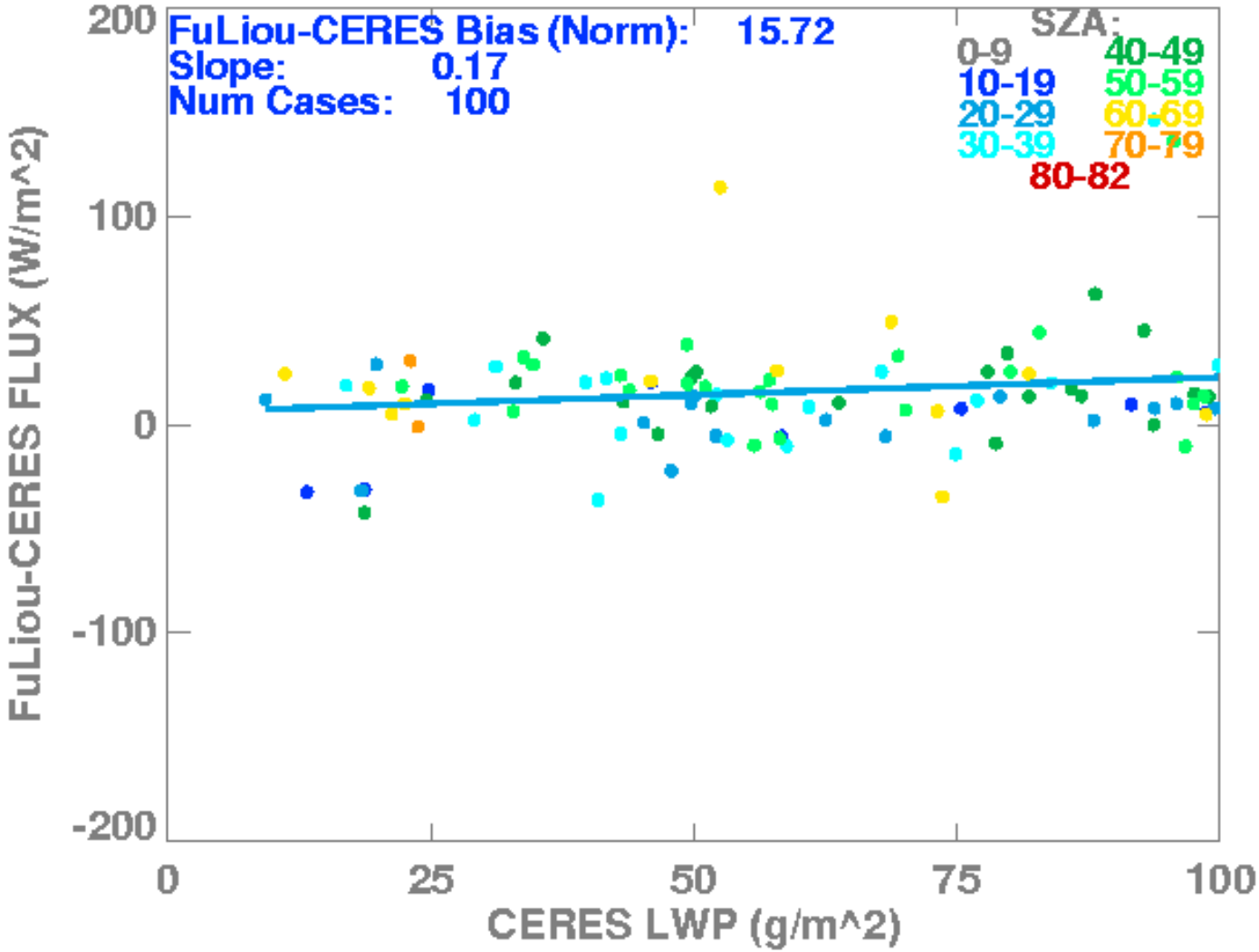
TOA SW Upwelling Flux Comparisons with LWP: Observed and Model

- OBSERVED: CERES SSF TRMM and TERRA footprint data
  - Contains Cloud and Radiation data (20-km res at nadir)
  - Used footprint closest to site
  - Limited dataset to footprints with
    - 0-100 g/m^2 LWP
    - TOA cld amt > 95%
    - > 90% Liquid Clouds
  - 1809 (100) points for SGP (CF only) sites between 1998-2005
  - Normalized flux differences to mean SZA
  - Available from http://eosweb.larc.nasa.gov

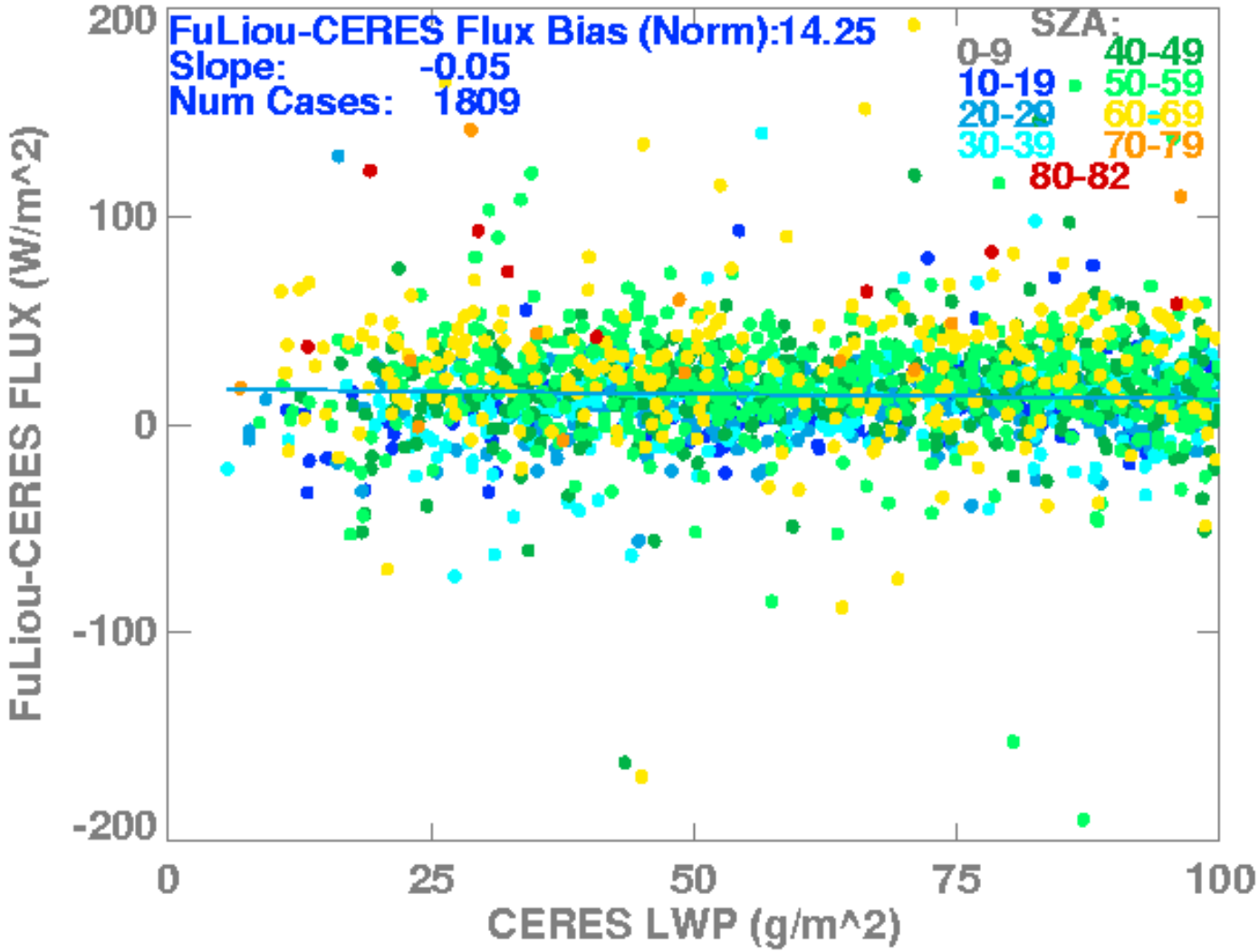
- MODEL: CRS (Clouds and Radiative Swath) product Fu-Liou model-derived fluxes

- Grand Time Series (GTS) merged products
  - contains footprints within 25km of site:
    - CERES SSF footprint fluxes (include MODIS cloud retrievals)
    - CERES CRS Fu-Liou radiative transfer model results using GEOS4 profiles
    - ARM surface-based fluxes, MWR LWP, Sfc cloud fraction, etc
    - Available from ftp://snowdog.larc.nasa.gov/pub/cave_stats/gts/ARM

FuLiou-CERES TOA FLUX vs CERES LWP: 1998-2005 CF



FuLiou-CERES TOA FLUX vs MWR LWP: 1998-2005 SGP

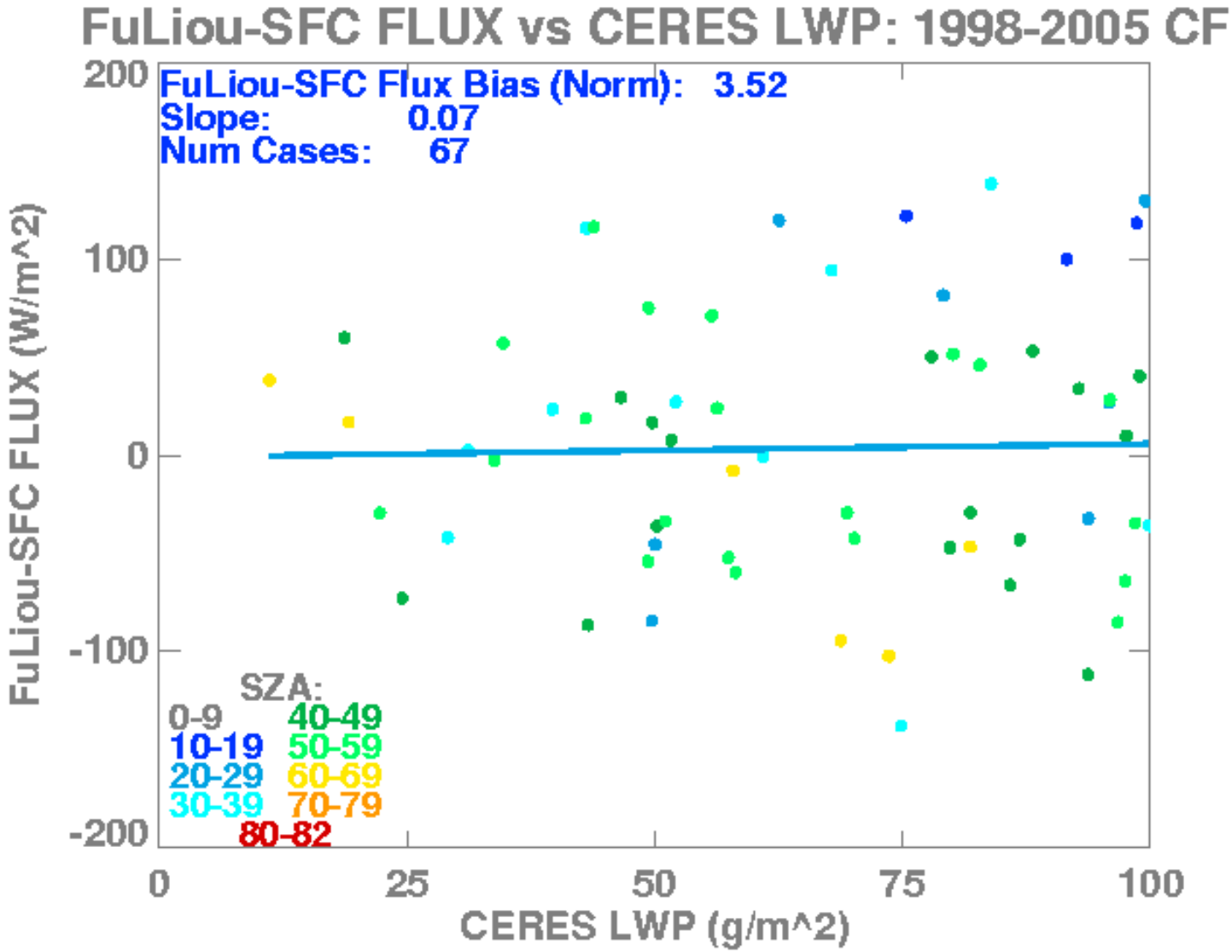


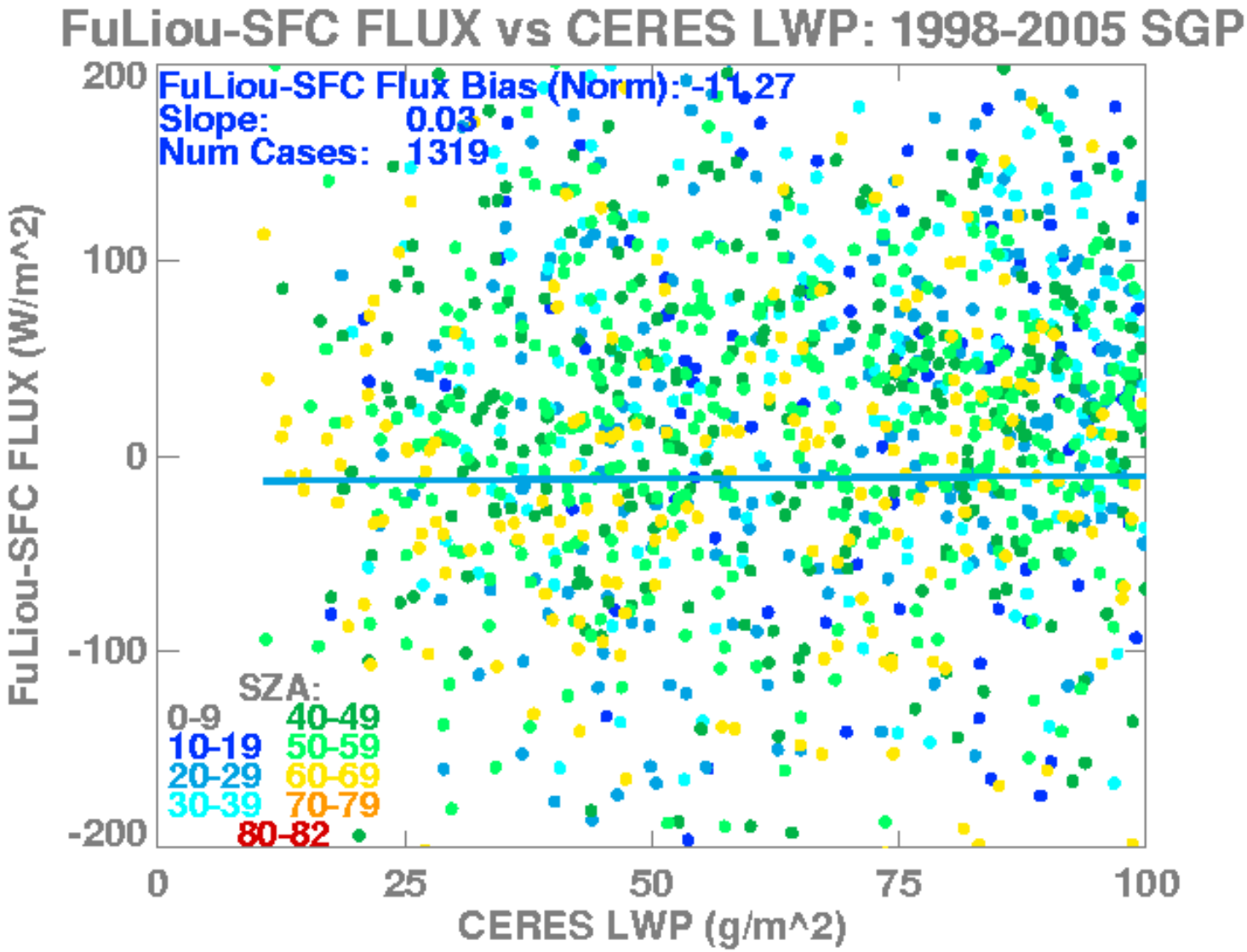
SFC SW Downwelling Flux Comparisons with LWP: Observed & Model

- OBSERVED: SFC fluxes from SIRS (Solar and Infrared Radiation Station) radiometers
  - NOT observed from CERES

- MODEL: CRS (Clouds and Radiative Swath) Fu-Liou model-derived fluxes
  - Used footprint closest to site
  - Limited dataset to footprints with SSF data
    - 0-100 g/m^2 LWP
    - TOA cld amt > 95%
    - > 90% Liquid Clouds
    - Sfc cloud amt > 95% (based on Long and Ackerman pyranometer method)

  - 1319 (67) points for SGP (CF only) sites between 1998-2005
  - Normalized flux differences to mean SZA


FuLiou-SFC FLUX vs CERES LWP: 1998-2005 CF
FuLiou-SFC Flux Bias (Norm): 3.52
Slope: 0.07
Num Cases: 67
SZA:
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-82
200
100
0
-100
-200
0
25
50
75
100
FuLiou-SFC FLUX (W/m^2)
CERES LWP (g/m^2)


FuLiou-SFC FLUX vs CERES LWP: 1998-2005 SGP
FuLiou-SFC Flux Bias (Norm): -11.27
Slope: 0.03
Num Cases: 1319
SZA:
0-9
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-82
200
100
0
-100
-200
0
25
50
75
100
FuLiou-SFC FLUX (W/m^2)
CERES LWP (g/m^2)

SUMMARY

- Overall, satellite-derived LWP consistent with MWR
  - Challenge- comparing spatially varying, coarse-resolution satellite LWP with temporally varying, narrow field of view MWR LWP
  - Standard deviations of satellite LWP at least approach 1-1 agreement with MWR

- BB TOA Upwelling SW Flux: Fu-Liou modeled TOA SW fluxes appear to be doing a good job, no obvious LWP-dependent biases at low LWP.

- BB SFC Downwelling SW FLUX: Modeled BB SFC SW downwelling fluxes, for all SGP sites shown, seem to show no obvious LWP-dependent bias in CLOWD range. Variability due to other factors such as spatial sampling noise.

Future Work

- Repeat analysis for GOES-derived BB fluxes for both TOA and SFC, compare to Fu-Liou model
- Examine LWP dependencies with respect to GOES-derived BB fluxes