The Meteorological Similarity Comparison Method (MSCM): A new tool for satellite and model testing and development

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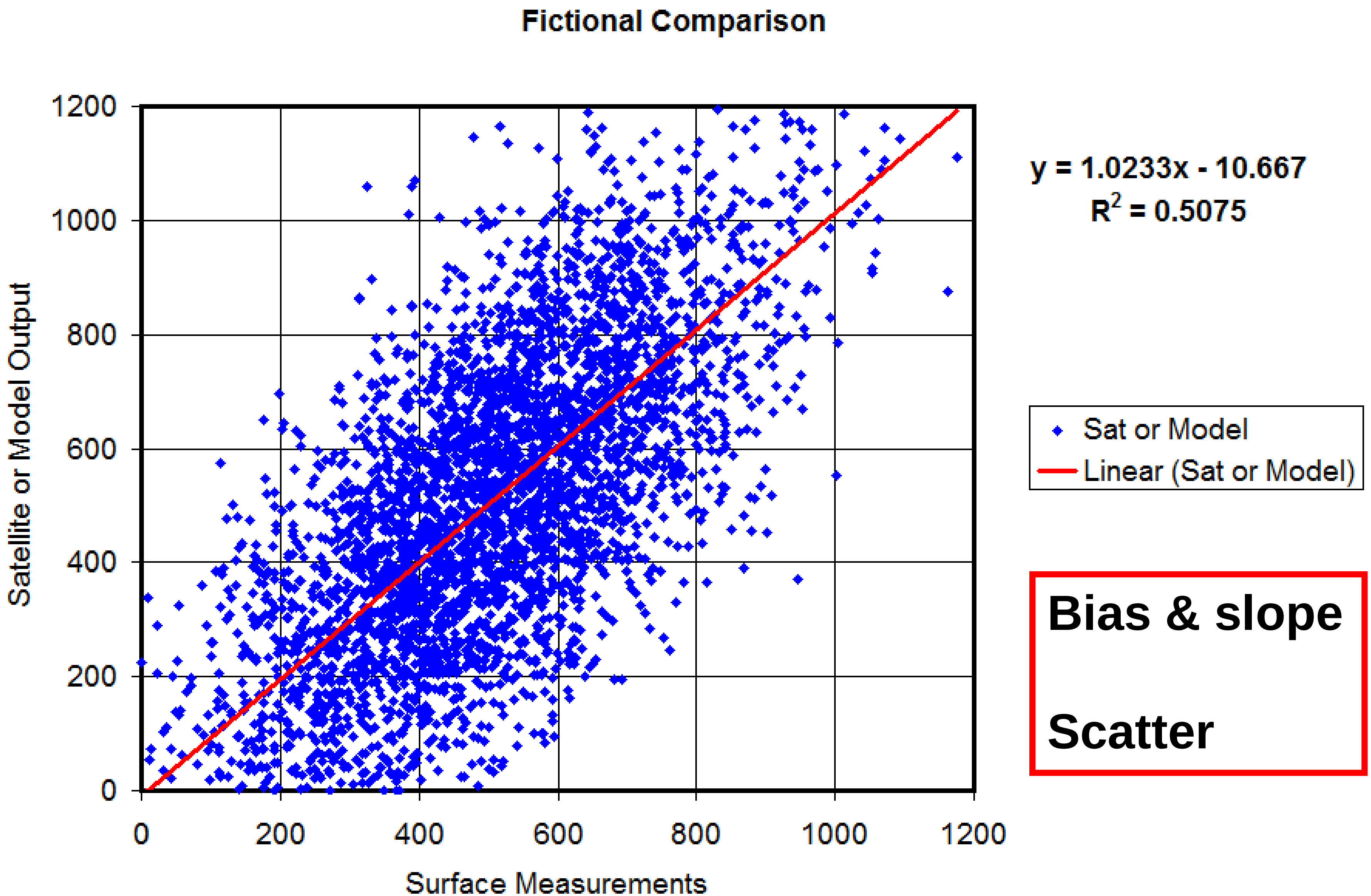
Motivation

- Comparison of cloud and surface radiation parameters from surface “point” measurements to satellite retrievals and model output problematic
  - differences in such aspects as:
    - Spatial/temporal domain
    - for satellite, fields of view and view angles
    - for models, sub-grid representation

Fictional Comparison



Bias & slope

Scatter

Comparison Outcome

- Bias & slope assumed to be an indicator that something is amiss
  - But what?
- Scatter largely assumed to be due to spatial and temporal mis-match
  - But also affects linear fit that produces bias and slope
- Either way, where does one go from here?
  - What part of the model?
    - Parameterizations, assumptions, inputs?
  - What part of the satellite retrieval?

Measurement Availability

- Only a few sites with many measured quantities to assess causes
- These few sites have limited representation of climate regimes and situations
  - If you "fix" the problems for these, how sure are we that they are fixed for situations not represented?
- Many "BSRN-type" surface radiation sites covering many various climates and situations
  - Plus far more cases, more robust statistics

MSCM

- **Meteorological Similarity Comparison Method**
- **A methodology for proceeding beyond comparison with only measurements at BSRN-type sites**
- **Zhang, Y., C. N. Long, W. B. Rossow, and E. G.Dutton (2010): *Exploiting Diurnal Variations to Evaluate the ISCCP-FD Flux Calculations and Radiative-Flux-Analysis-Processed Surface Observations from BSRN, ARM and SURFRAD*, <u>JGR</u>, 115, D15105, doi:10.1029/2009JD012743.**

Radiative Flux Analysis

- All data tested for quality (QCRad code)
  - Long and Shi, 2008, TOASJ
- Flux Analysis methodology
  - Time series analyses of surface broadband radiation and meteorological measurements
  - Use detected clear sky data to fit functions
  - Interpolate coefficients to produce continuous estimate of clear-sky irradiances
  - Use results to infer cloud properties

RFA Outputs

Parameter	Meas./Retr.	Comments
Downwelling Total SW	Measured	Unshaded Pyranometer
Clear-sky Total SW	Retrieved	Long and Ackerman, 2000, JGR
Diffuse SW	Measured	Shaded Pyranometer
Clear-sky diffuse SW	Retrieved	Long and Ackerman, 2000, JGR
Direct SW	Measured	Sun Tracking Perheliometer
Clear-sky direct SW	Retrieved	Long and Ackerman, 2000, JGR
Upwelling SW	Measured	Pyranometer
Clear-sky Upwelling SW	Retrieved	Long, 2005, ARM
Downwelling LW	Measured	Pyrgeometer
Clear-sky Downwelling LW	Retrieved	Long and Turner, 2008, JGR
Upwelling LW	Measured	Pyrgeometer
Clear-sky Upwelling LW	Retrieved	Long, 2005, ARM
Clear-sky periods	Retrieved	Long and Ackerman, 2000, JGR [daylight only]
Air Temperature	Measured	Temperature sensor
Relative Humidity	Measured	Humidity sensor
Total Sky Cover	Retrieved	Long et al., 2006, JGR [daylight only]
LW Effective Sky Cover	Retrieved	Long and Turner, 2008, JGR; Durr and Philipona, 2004, JGR [low/mid cloud only]
Cloud Vis optical depth	Retrieved	Barnard and Long, 2004, JAM; Barnard et al., 2008, TOASJ [Skycover>90% only]
Cloud SW transmissivity	Retrieved	Long and Ackerman, 2000, JGR [daylight only]
sky brightness temperature	Retrieved	Long, 2004, ARM
cloud radiating temperature	Retrieved	Long, 2004, ARM [LW Scv>50% only]
clear-sky LW emissivity	Retrieved	Marty and Philipona, 2000, GRL; Long, 2004, ARM

Complete Net surface radiative cloud forcing and cloud macrophysical properties without using any measurements typically used as input for model calculations

RFA Outputs Uncertainty

Variable	Est. 95% Uncertainty	Information Source
Downwelling Total SW	6% or 10 Wm^{-2}	Stoffel, 2005, ARM-TR
Downwelling Diffuse SW	3% or 4 Wm^{-2}	Stoffel, 2005, ARM-TR
Downwelling Direct SW	6%or 20 Wm^{-2}	Stoffel, 2005, ARM-TR
Clear-skyTotal, Diffuse, Direct SW	RMSE(2X Meas. Uncert.)	Long and Ackerman, 2000
Upwelling SW	6% or 10 Wm^{-2}	Stoffel, 2005, ARM-TR
Clear-sky Upwelling SW	RMSE(2X Meas. Uncert.)	Long, 2005
Downwelling LW	2.5% or 4 Wm^{-2}	Stoffel, 2005, ARM-TR
Clear-sky Downwelling LW	4-5 Wm^{-2}	Long and Turner, 2008
Upwelling LW	2.5% or 4 Wm^{-2}	Stoffel, 2005, ARM-TR
Clear-sky Upwelling LW	Unknown	
Daylight Fractional Sky Cover	10%	Long et al., 2006
LW Effective Sky Cover	1-2 Oktas	Durr and Philipona, 2004
Cloud Visible Optical Depth	10%	Barnard & Long, 2004; Barnard et al., 2008
Effective Cloud Transmissivity	10%	Estimated from above Total and Clear-sky SW
Cloud Radiating Temperature	Unknown	
Cloud Radiating Height	Unknown	

Processed RFA data

- Available as PI Product at ARM Archive
  - For all fixed sites and several AMF deployments
- Plans to upgrade current ARM SW Flux Analysis VAP to Full RFA
- Most BSRN and SURFRAD sites
  - 2004 & 2005 contributed as part of the GEWEX/NASA Radiative Flux Assessment Archive
  - These data used for the MSCM paper

MSCM: Basis of the approach

- Use the data to screen for similar conditions
  - Ex: only comparing radiation values and radiative forcing for times with matching cloud amounts between the data sets
- Eliminates much of the spatial mismatches affecting previous comparisons
- Thus affords a more detailed analysis of the ensuing differences
- Leads to better understanding of the underlying causes of the differences

Examples

- Compare clear-sky parameters to test treatment of atmospheric state
  – This resulted in finding that ISCCP-FD had double the aerosol loading it should
- Use overcast conditions to compare cloud optical depth
- Compare all-sky cloud transmissivity for comparable cloud amounts

ISCCP Study

Station Acronym	Station Name [Owner][2]	Quality Rate-Network[3]	Station Lat/Lon	FD Cell[4] Lat/Lon
NYA	Ny Alesund, Spitsbergen [GM/NY]	B-BSRN	78.9N/ 11.9E	78.8N/ 6.4E
FPE	Fort Peck, MT [USA]	A-SURFRAD	48.5N/254.8E	48.8N/255.8E
PAY	Payerne, [Switzerland]	A-BSRN	46.8N/ 6.9E	46.2N/ 5.4E
PSU	Rock Springs, PA [USA]	A-SURFRAD	40.7N/282.1E	41.2N/281.7E
BOS	Boulder, CO [USA]	A-SURFRAD	40.2N/254.6E	41.2N/255.0E
BON	Bondville, IL [USA]	A-SURFRAD	40.1N/271.4E	41.2N/271.7E
DRA	Desert Rock, NV [USA]	A-SURFRAD	36.6N/243.9E	36.2N/243.6E
BIL	Billings, OK [USA]	B-ARM	36.6N/262.5E	36.2N/262.2E
TAT	Tateno [Japan]	B-BSRN	36.0N/140.1E	36.2N/141.2E
GCR	Goodwin Creek, Mississippi [USA]	A-SURFRAD	34.2N/270.1E	33.8N/271.5E
NAU	Nauru Island [USA]	B-ARM	0.5S/166.9E	1.2S/166.2E
MAN	Momote, Manus Is., Papua New Guinea [USA]	B-ARM	2.1S/147.7E	1.2S/148.8E
DAR	Darwin [Australia]	B-ARM	12.5S/130.9E	13.8S/129.9E
GVN	George von Neumayer, Ant. [GM]	B-BSRN	70.7S/351.8E	71.2S/348.3E
SPO[6]	South Pole, Antarctica [USA]	B-BSRN	89.8S/258.0E	88.8S/300.0E

Used 15 ARM, BSRN, and SURFRAD sites

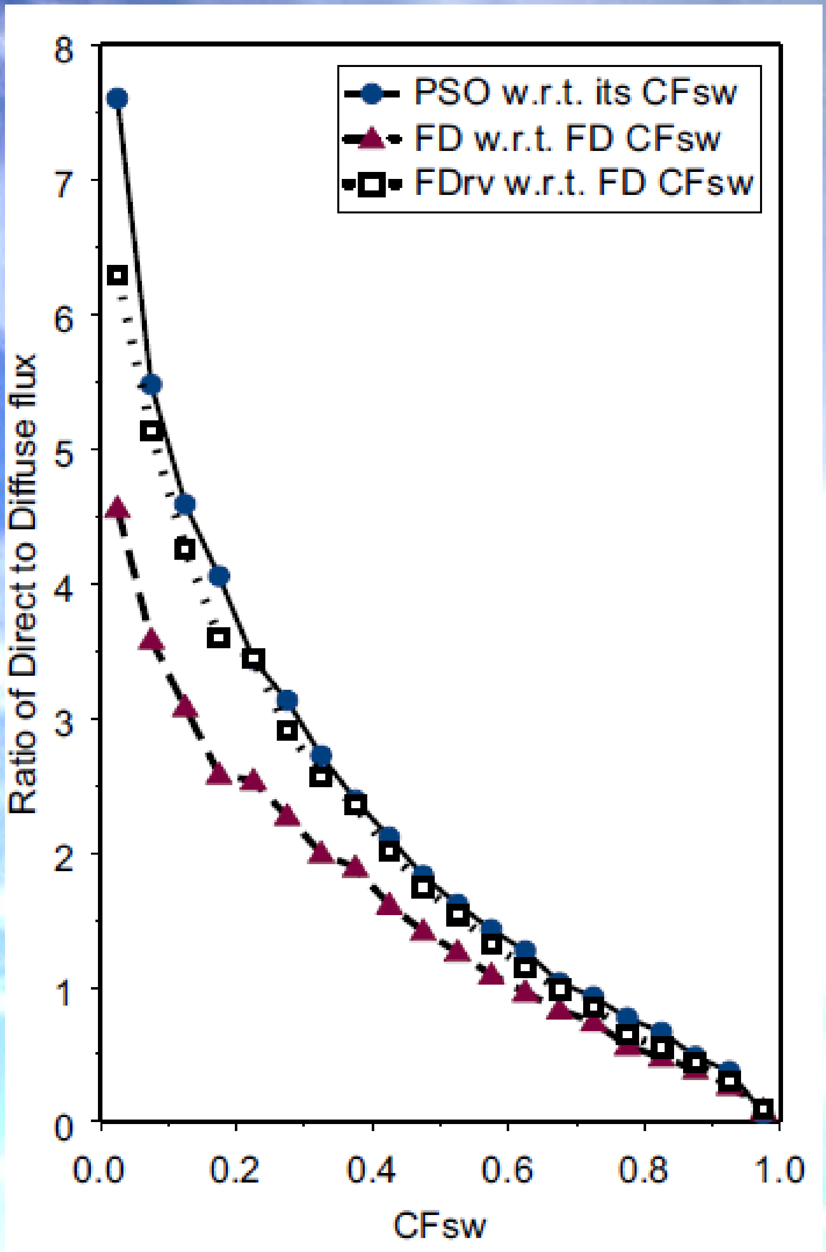
79N – 90S

Year 2004

ISCCP-FD

3-hour averages

Samples



- **Dir/Dif by Cloud Fraction**
- **Shows bias in original ISCCP data compared to RFA**
  - **Increasing difference for decreasing CF**
- **Agreement after adjusting aerosol loading by ½**

Clear-sky Direct and Diffuse

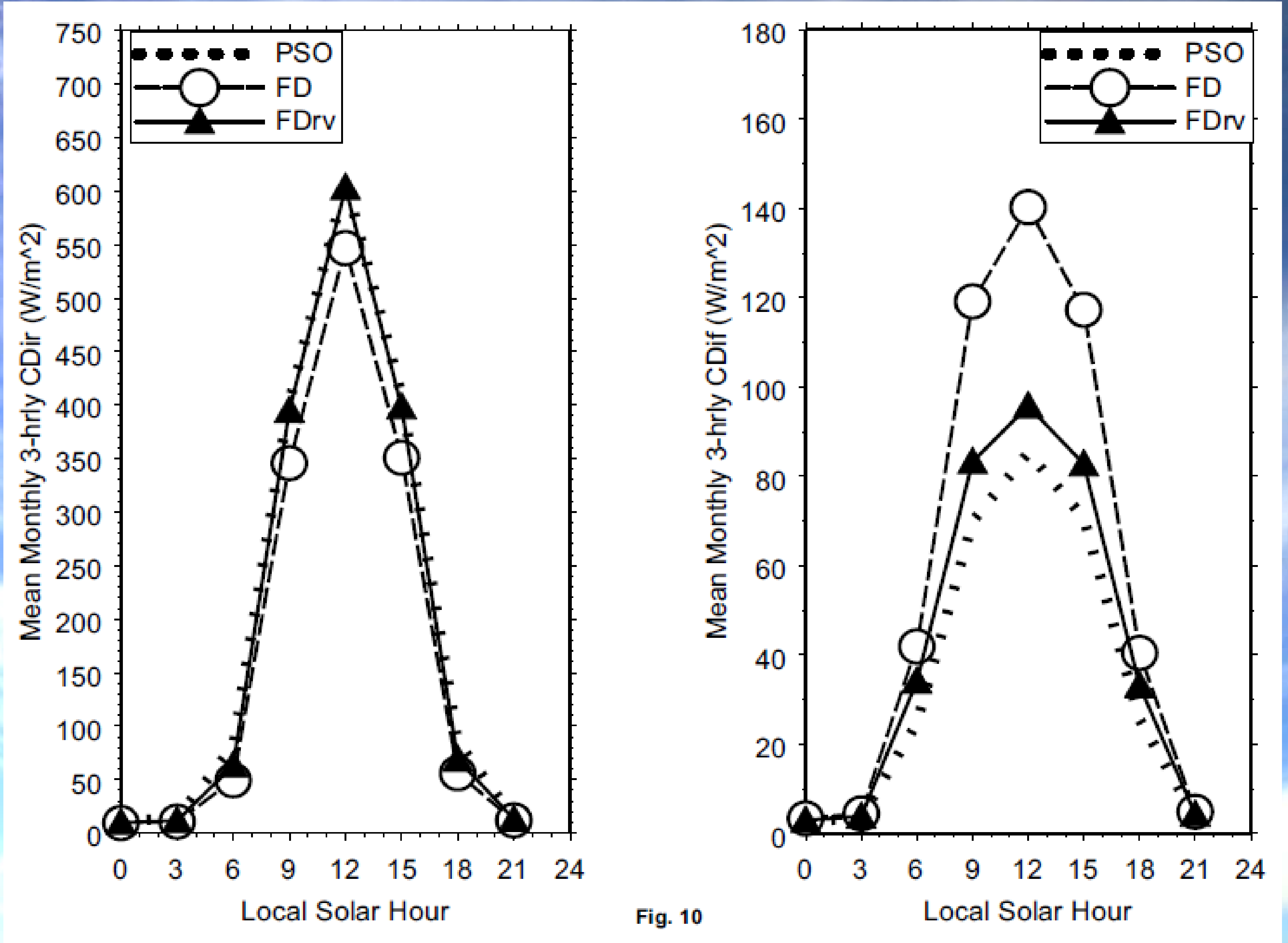
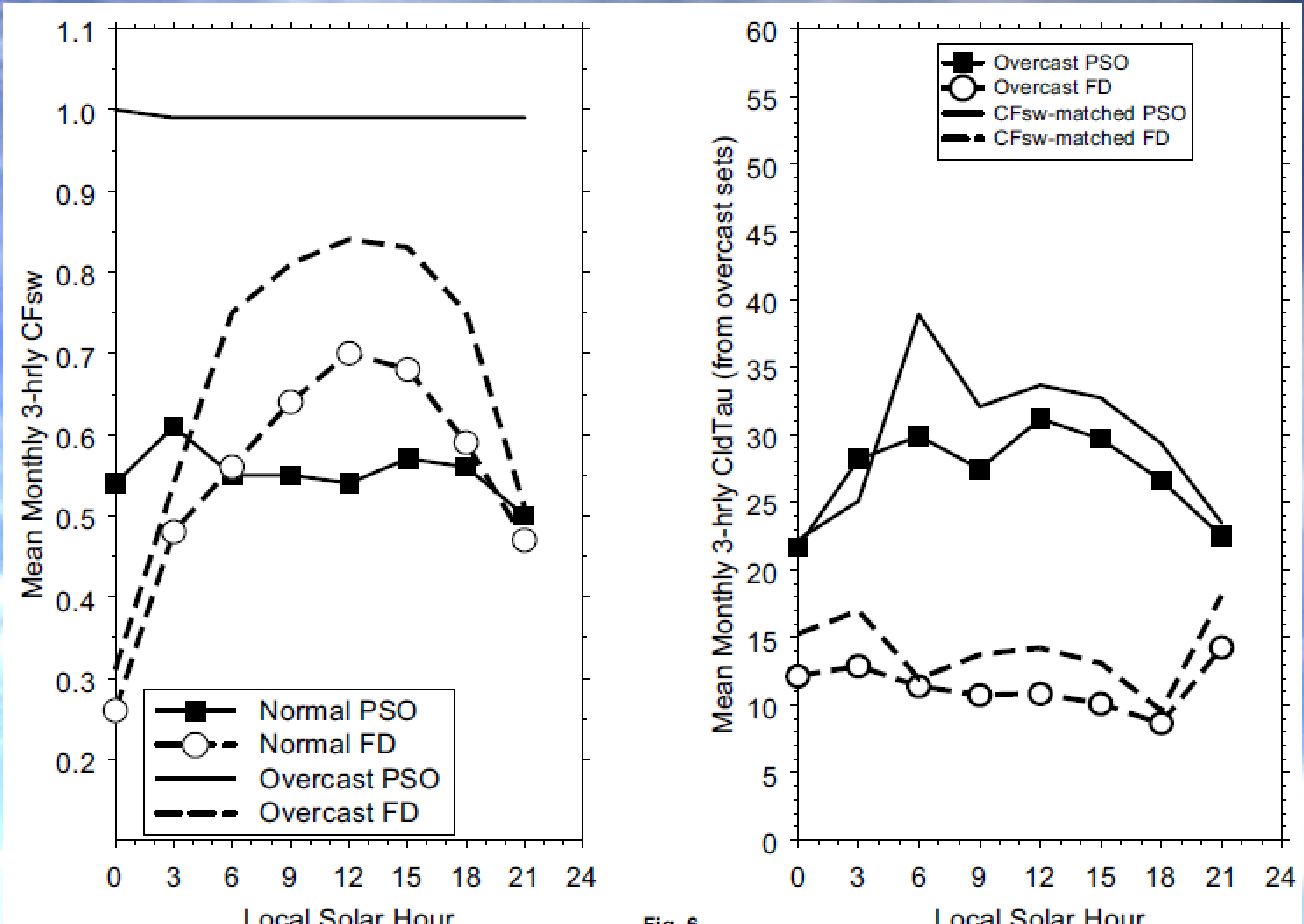


Fig. 10

CF and Cloud Tau Comparisons



Samples

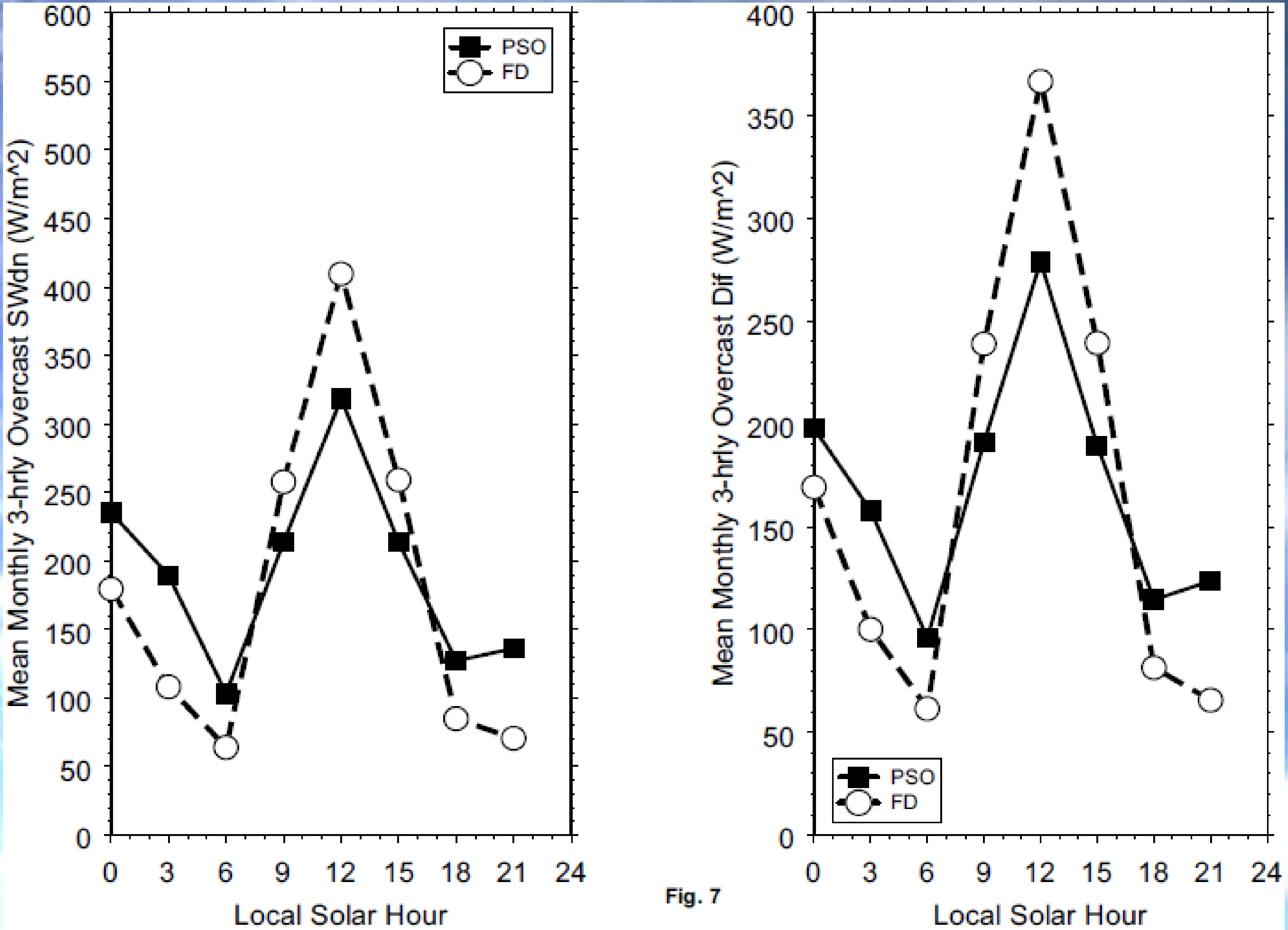


Fig. 7

Some Paper Highlights

- For downward total SW, Dif, Dir
  - matching CF reduces the flux difference by up to a factor of 2
  - Reducing AOD by ½ accounts for most of remaining differences
  - Still some differences in diurnal cycle
  - Best agreement/analysis when matching CF and cloud optical depth jointly

Some Paper Highlights

- For downward LW
  - Matching either Tair or CF reduces differences to nearly zero
  - But diurnal differences due to differing sensitivities to cirrus and low clouds
- These results confirm that the primary source of the FD surface flux uncertainty of about 10–15 Wm^{-2} is the input quantities and not the radiative transfer model.

MSCM Summary

- The paper includes a "blueprint" describing the MSCM
  - Serves as a set of instructions for future use of the Radiative Flux Analysis in satellite and model comparison studies
  - Techniques significantly increase the value of surface radiation and meteorological measurements beyond that of the individual measurements themselves