The scientific utility of GMD surface radiation measurements

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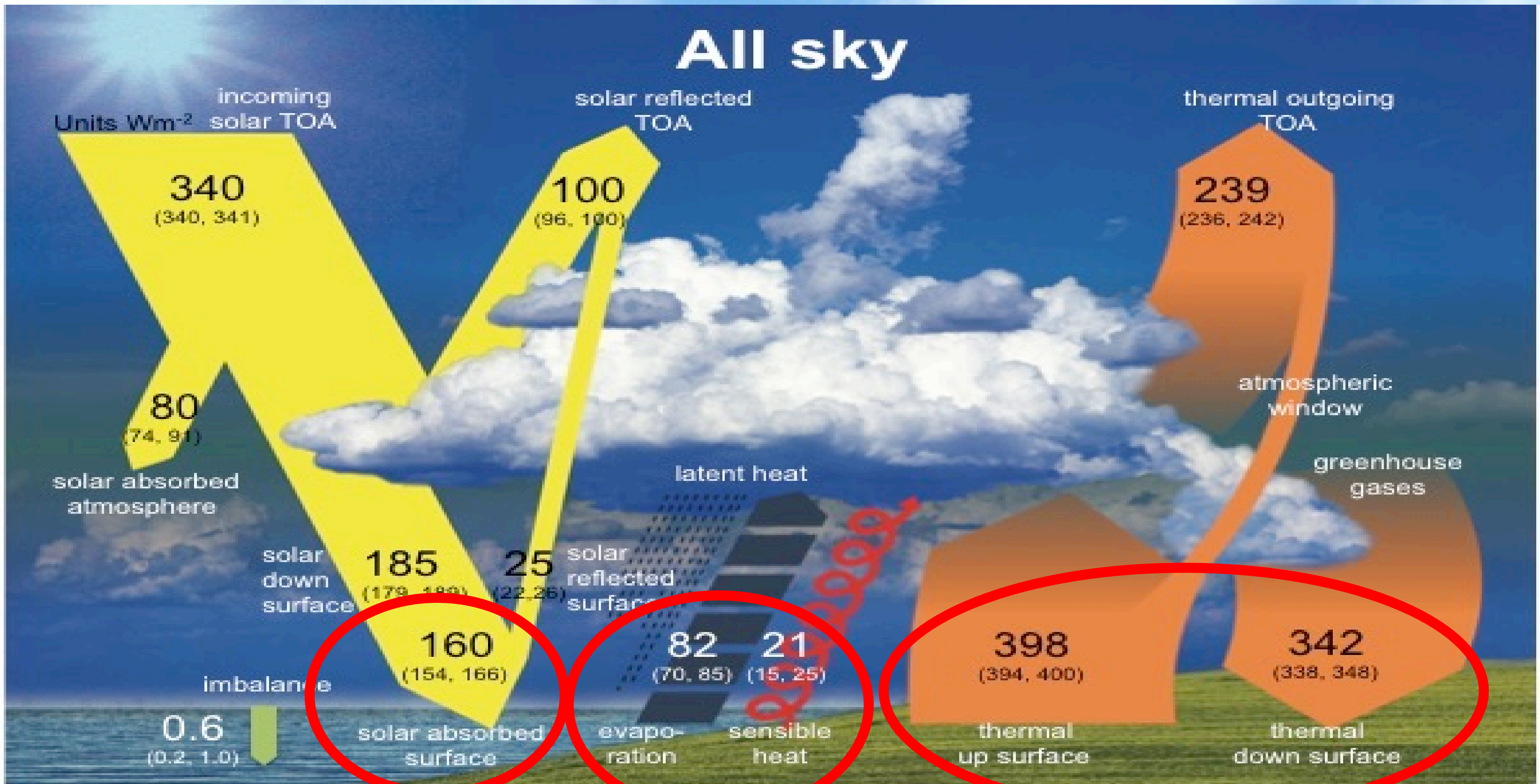
2018 GMAC, Boulder CO

Earth System Energy Balance

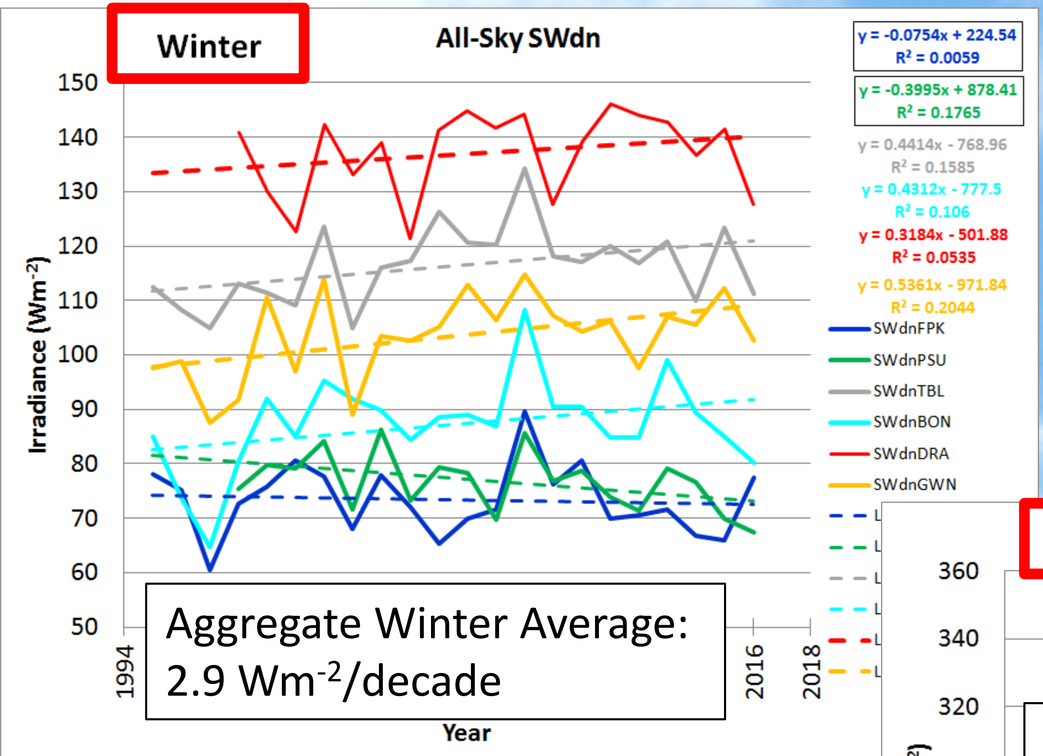


- **About 68% of the solar energy not reflected away is absorbed at the surface (Net SWdn)**
- **Somewhat balanced by the net LW at the surface**
- **The remaining net surface radiative is available for latent and sensible heat fluxes, etc.**

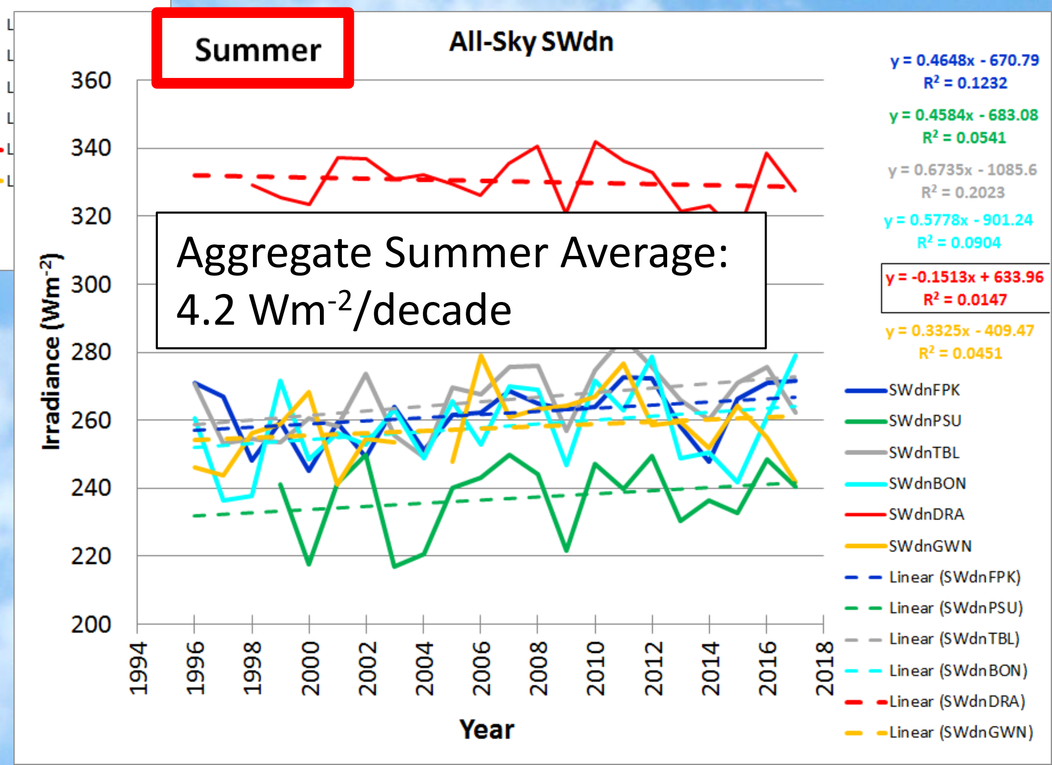
Example Uses for Surface Radiation Observations

- **Observational Studies**
  - Instituted operational Radiative Flux Analysis
    - clear-sky and cloud macrophysical products
  - Magnitude and trends (John Augustine)
- **Comparisons for Diagnosis and Development**
  - Satellite
    - Have global coverage, but issues inferring surface radiation
  - Models
    - Also global coverage, but simplifications and assumptions
    - Weather forecast improvement (Kathy Lantz, Stan Benjamin tomorrow)

SURFRAD Seasonal Trends 1996-2017



Decadal Slope:	Winter	Summer
Fort Peck	-0.8	+4.6
Penn State	-4.0	+4.6
Table Mountain	+4.4	+6.7
Bonneville	+4.3	+5.8
Desert Rock	+3.2	-1.5
Goodwin Creek	+5.4	+3.3



Increasing tendency greater in summer than in winter, regionally dependent.

ISCCP FD - SURFRAD Comparison: MSCM

ISCCP-FD 280 km equal-area global grid

Meteorological Similarity Comparison Method

Comparing a 280 km X 280 km box to a point measurement somewhere in the box

If the box has 30% cloud cover and the point is experiencing 60% cloud cover, it does not make sense to compare them

Throw that comparison pair out!

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, JGR, 115, D15105, doi:10.1029/2009JD012743.

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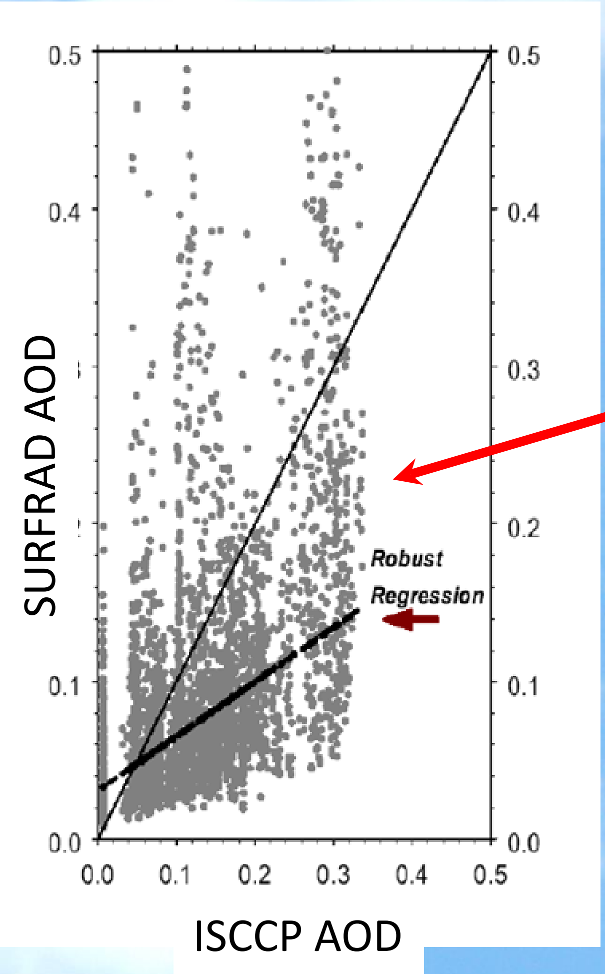
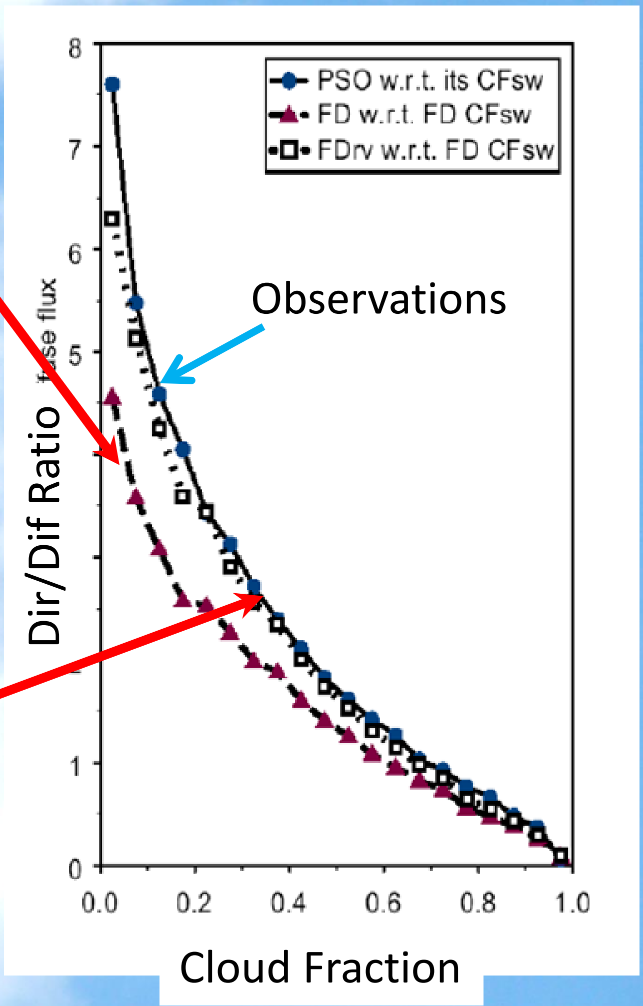


Comparisons of ratio of direct over diffuse SW versus cloud fraction shows ISCCP low bias

SURFRAD AOD shows ISCCP input AOD off by factor of 2

Comparisons show much better agreement using half the original aerosol AOD as input to ISCCP retrievals.



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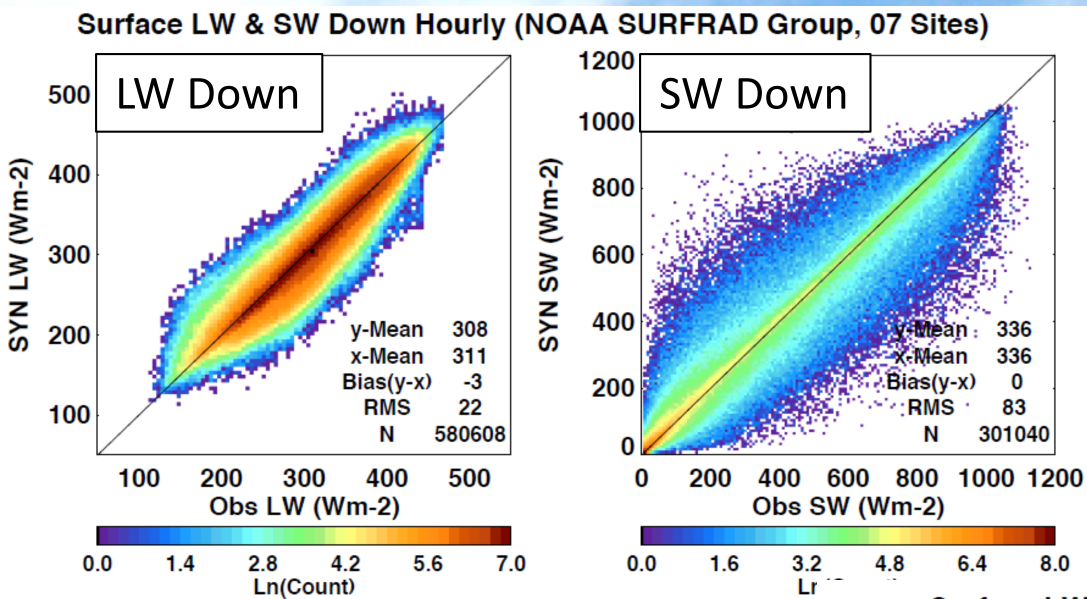
CERES SYN 1-deg surface irradiance

- From polar orbiting satellites from NASA only
- MODIS and MATCH for cloud and aerosol information
- Gridded Surface albedo, snow (land), and ice (water)
  - Snow surfaces still problematic
- Gridded ozone information used for absorption correction
- Reanalysis for atmospheric profiles and other meteorological information
- Most importantly – uses 3-hour cloud information from GOES to better account for diurnal cloud variations

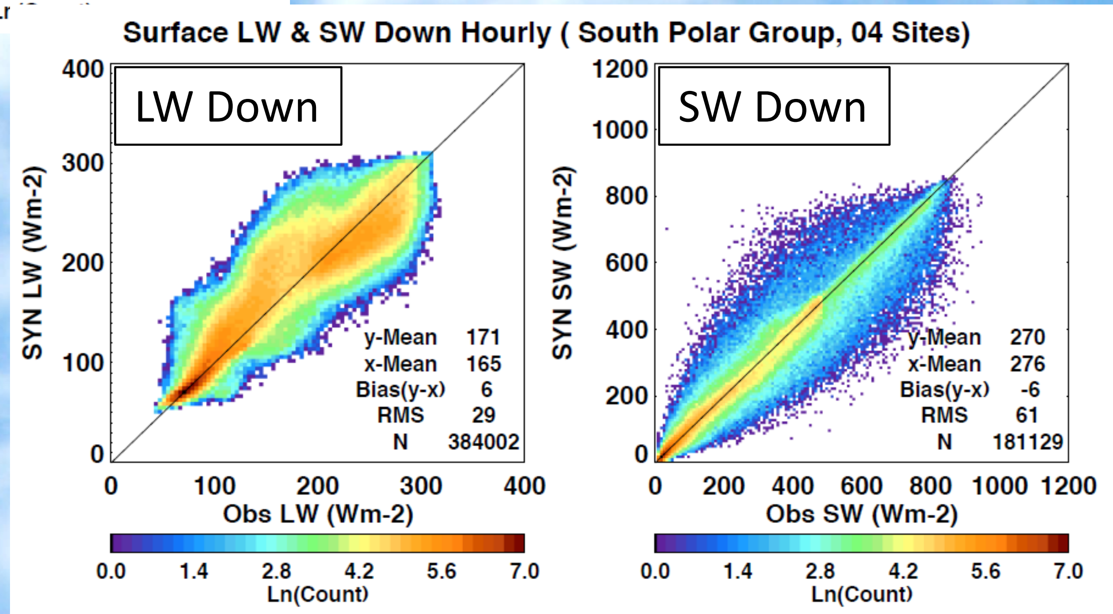
CERES SYN 1-deg. vs 7 U.S. SURFRAD and 4 Antarctic Sites (2003 – 2014)



Continental US:
Mean does well, (-3 LW, 0 SW) but still considerable point-by-point uncertainties.

Similar results with simulated GOES-R Series retrievals.

South Polar Sites (snow):
Mean bias of 6 Wm^{-2}, and considerable point-by-point uncertainties.



Surface Radiation Data Use: Models
Estimating clear-sky climatologies Using BSRN sites

High resolution <u>BSRN records</u> (minute data)

*** GMD associated with 1/3 of the BSRN sites that have contributed data to the BSRN Archive, operates 13 sites**

RadFlux

<u>SW clear sky algorithm</u>

Long and Ackerman (2002) JGR

Takes into account magnitude and temporal variability of diffuse and total downward solar radiation

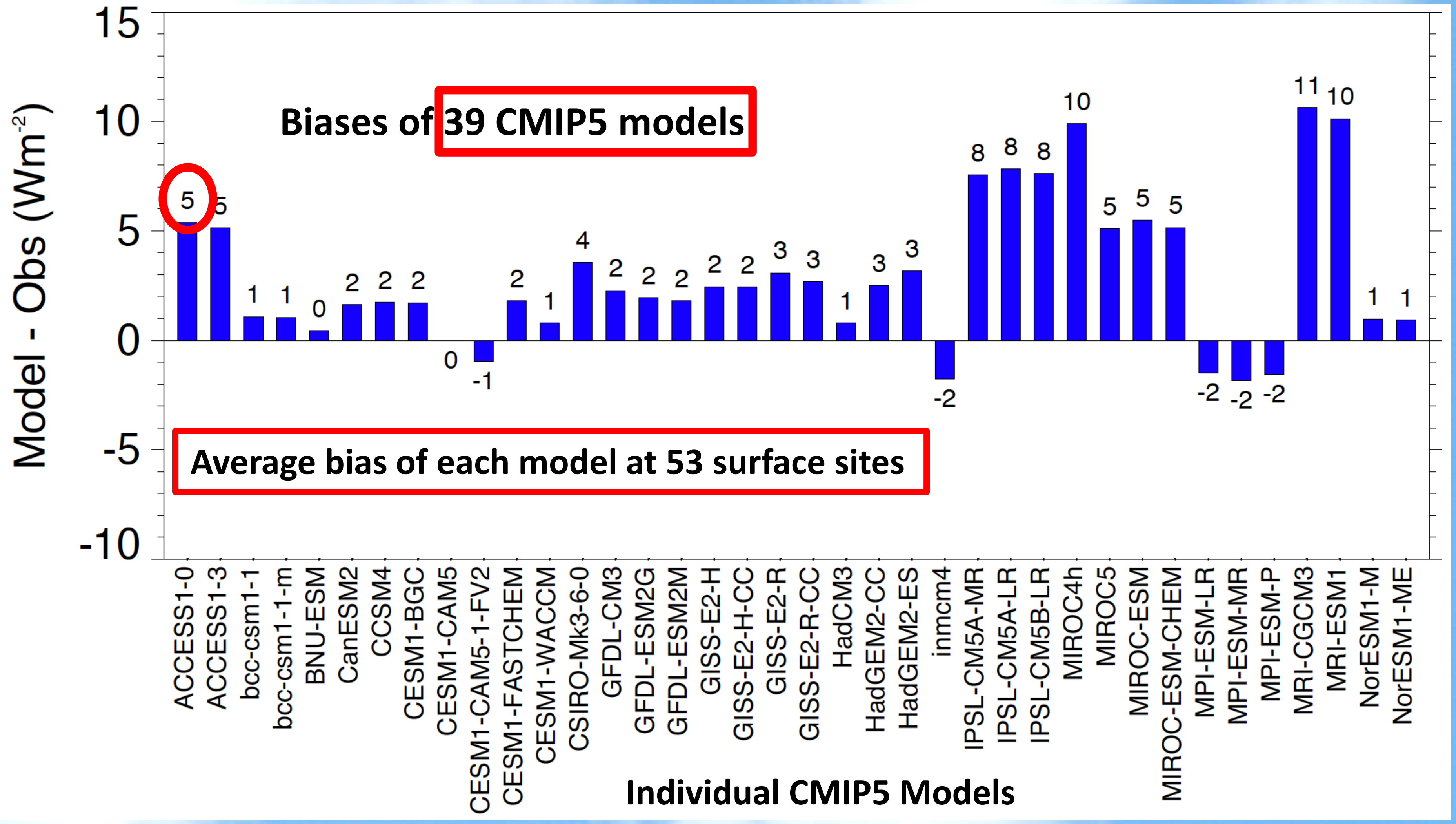
<u>LW clear sky algorithm</u>

Long and Turner (2008) JGR

Makes use of clear episodes detected by the SW algorithm and takes into account variability of downward longwave radiation, measured ambient air temperature and effective sky brightness temperature.

Clear sky BSRN data processed at ETH Zurich by Maria Hakuba with support from Chuck Long

SW down clear-sky evaluation: Biases from Observations

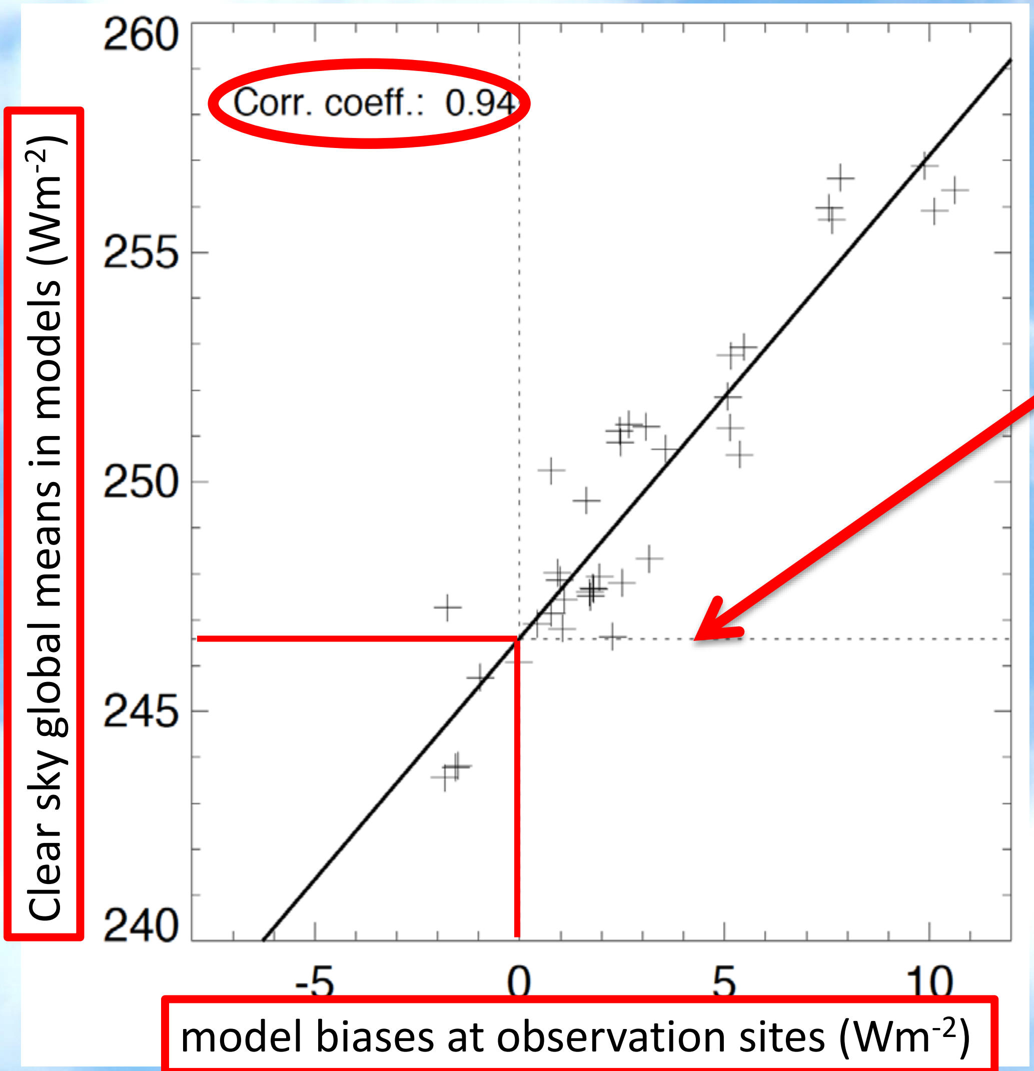


Individual CMIP5 model biases averaged over **53 BSRN sites**

Best estimates for global mean clear sky fluxes

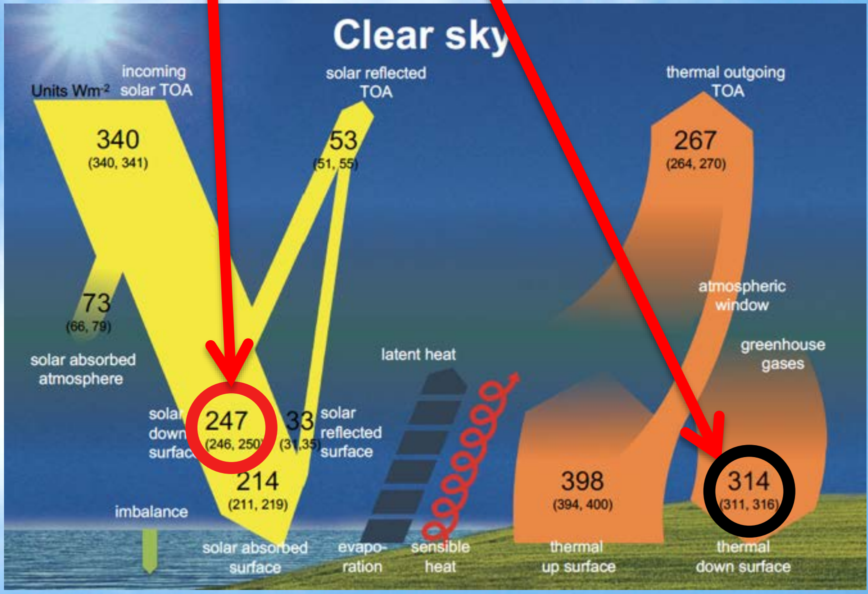
Surface clear-sky SW down

GCM global means versus their biases averaged over BSRN sites



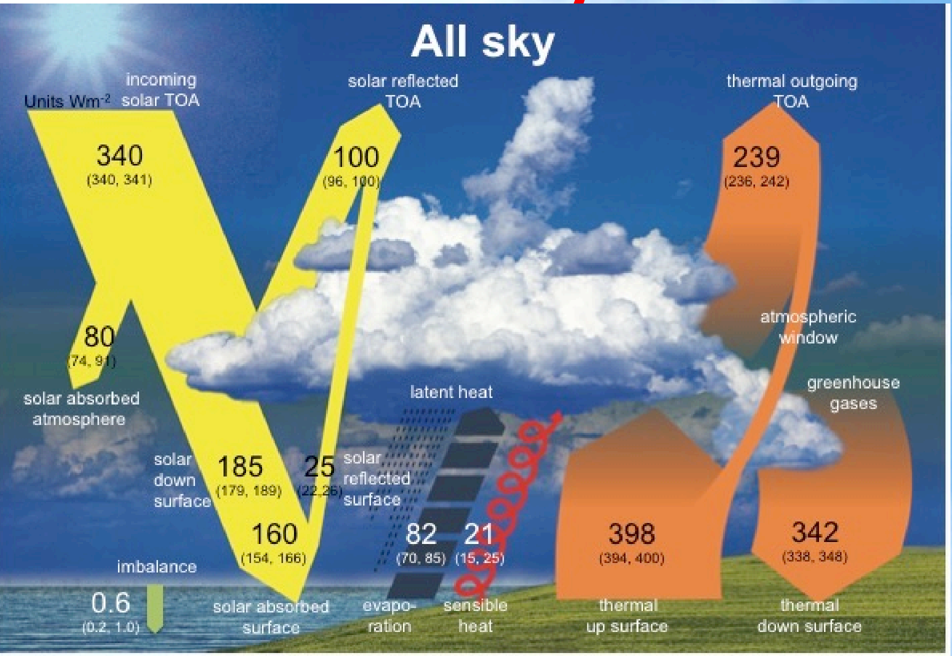
Best estimate surface clear-sky SW down:
247 Wm^{-2}

Clear-sky LW down:
314 Wm^{-2}



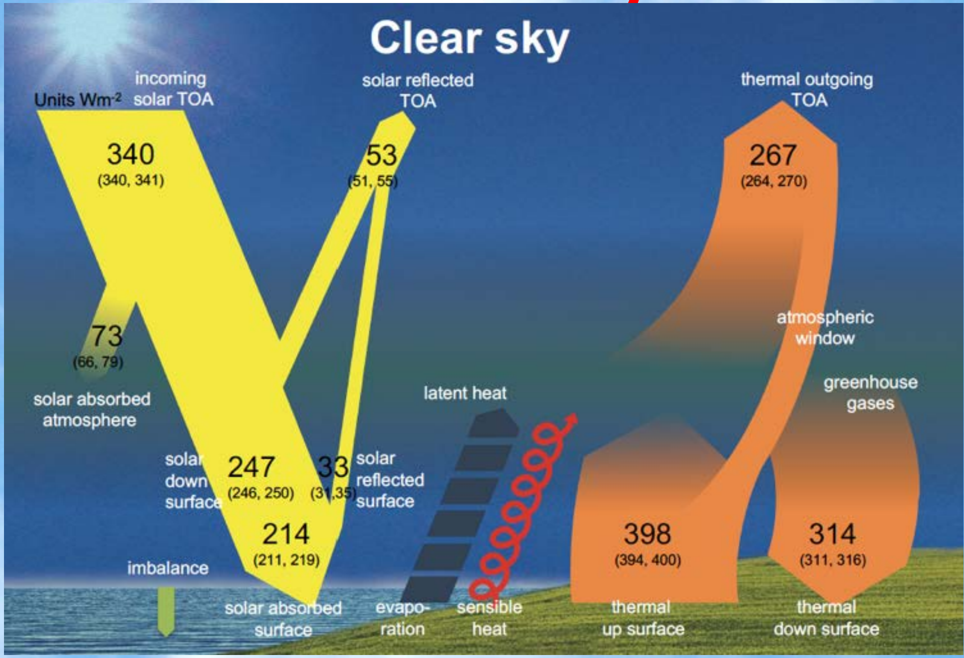
Global All- and Clear-sky Estimates using Observations and Models

All sky



Wild et al 2015 Clim. Dyn.

Clear sky



Submitted to Clim. Dyn. 2018

- **New estimates for global mean radiation budget without cloud effects** based to the extent possible on information contained in the direct observations from surface and space.
- Combined with all sky budgets allows for **estimation of global mean surface, atmosphere and TOA cloud radiative effects.**

Summary

- Knowledge of the surface radiative energy budget is essential to understanding the Earth-Atmosphere system
- GMD is associated with over 1/3 of the sites that have submitted data to the BSRN Archive
- These data are being used:
  - not only for climatological and trend studies
  - also in conjunction with model and satellite products for evaluation and diagnoses
  - and combined scientific studies

Thank You

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Following are Extra

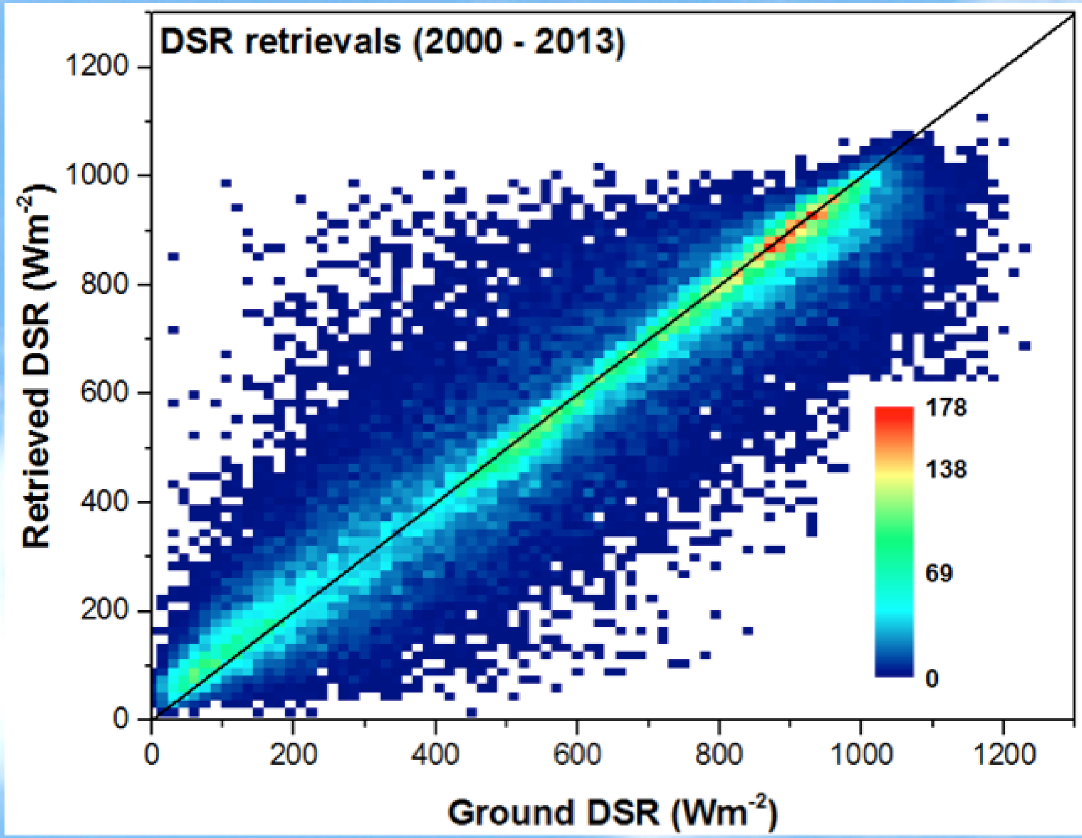
RadFlux Output

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]
LW Effective Clear-sky periods	Retrieved	Long and Turner, 2008, JGR [24-hour, may be high clouds present that do not affect LW]
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 or satellite retrievals

New GOES-R surface irradiance

- **6 shortwave channels on the new Advanced Baseline Imager (ABI) – improves inference of surface and atmospheric properties**
- **Onboard calibration to check calibration drift**
- **ABI algorithm for surface SW more sophisticated than current GOES**
- **4 km, 5-min. resolution over CONUS, 15-min full disk**



GOES-R ABI surface SW algorithm tested with10 years of MODIS data

Less bias in cloudy conditions