Use of BSRN data in the validation of NASA's Clouds and the Earth's Radiant Energy System (CERES) EBAF & SYN1deg data products

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- What are CERES and the EBAF & SYN1deg data products?
- How do we validate our products using BSRN data?
- Describe a study determining sensitivity of uncertainty (RMS) to spatial variability of surface sites. (Try to estimate global uncertainties at the surface.)

(All biases are based on Calculation – Observation)

Surface Validation: What are we validating?

Clouds & the Earth's Radiant Energy System (CERES) (https://ceres.larc.nasa.gov/)

Broadband scanning radiometers

- On NASA TRMM, Terra, Aqua, NOAA Suomi NPP and JPSS1
- Radiance in three broad bands

Channel	Wavelengths
Shortwave	0.2 - 5 µm
Total	0.2 – 100 µm
Window	~8 - 12 µm
Longwave	Total - Shortwave

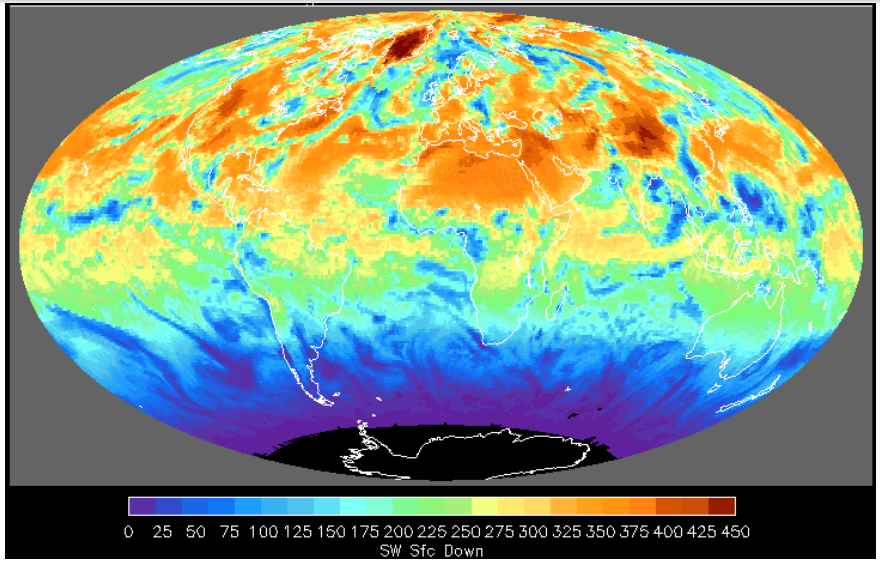
- Radiance is converted to irradiance using scene dependent Anisotropic Directional Models (ADMs)
- A CERES 'footprint' is approximately 30km at the surface for instrument nadir.

SYN1Deg

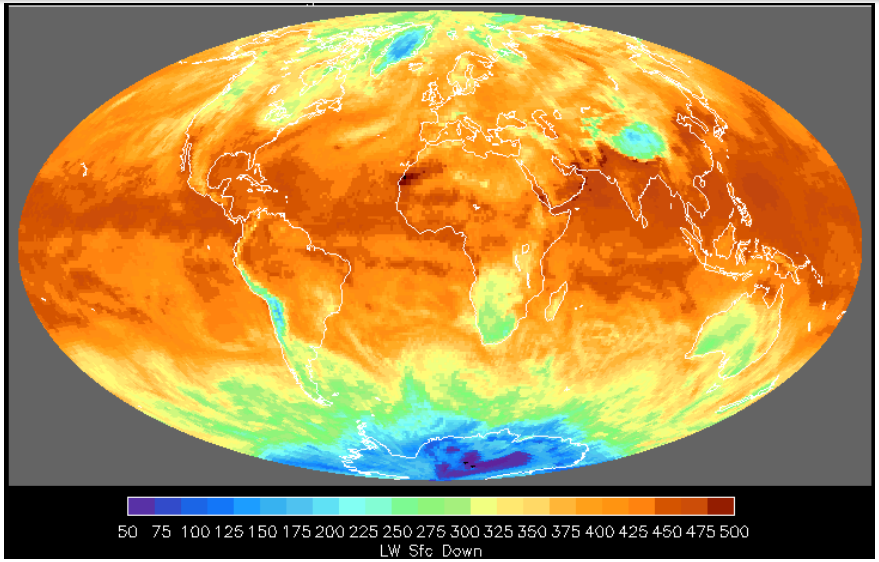
TOA CERES Observations & Column Fluxes from Radiative Transfer Calculations

- Global; Gridded (1˚x1˚); Hourly (Monthly)
- Upward & Downward irradiances provided at:
- 6 Levels (TOA, 70, 200, 500, 850 hPa and Earth's surface)

SW Surface Down (Daily Avg)



LW Surface Down (Daily Avg)



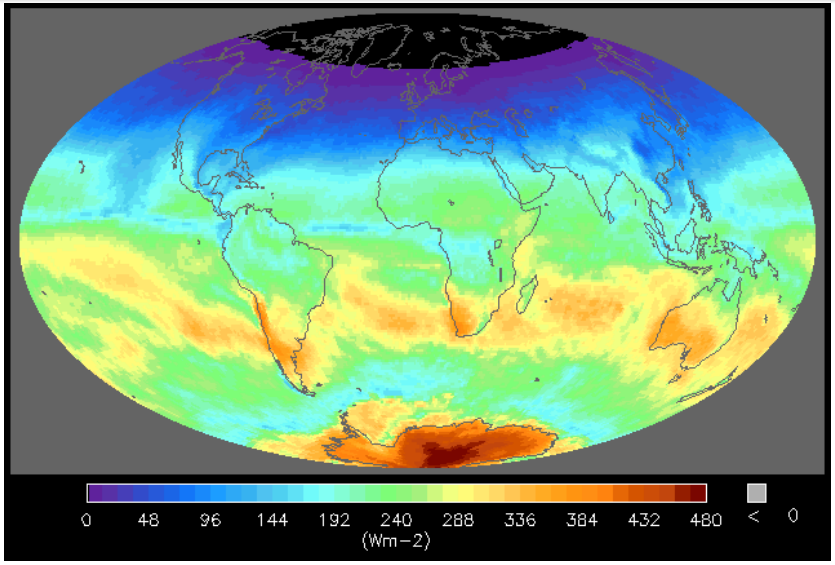
- Clouds: Terra/Aqua MODIS Imagers, Geostationary imagers
- Atmosphere (P, T, q): GMAO GEOS5.4.1
- Aerosol: MODIS AOD assimilated by MATCH Chemical Trans Model
  - Langley Fu & Liou Radiative Transfer Model

EBAF TOA; EBAF-Surface

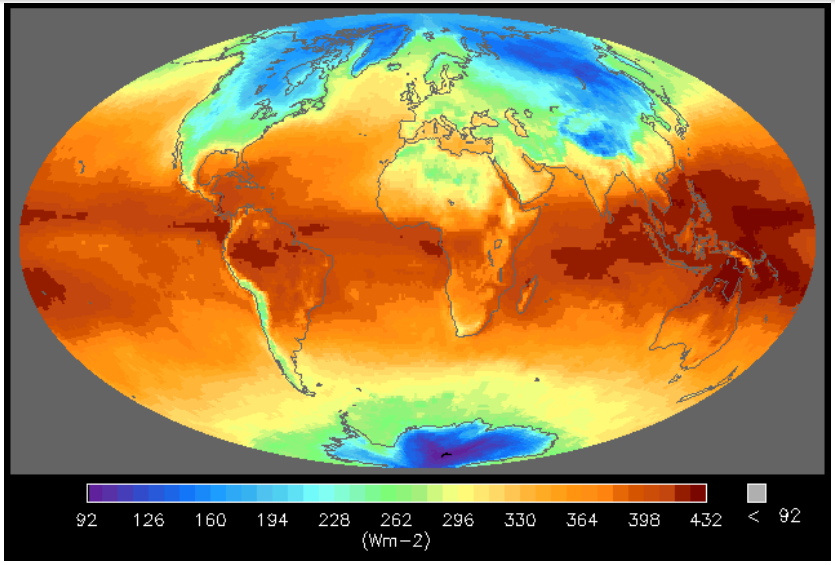
Provides TOA Observations & Surface RT Calculations

- Global; Gridded (1˚x1˚); Monthly Mean
- Upward & Downward irradiances at:
- 2 Levels (TOA, Earth's surface)

SW Surface Down (Monthly Avg)

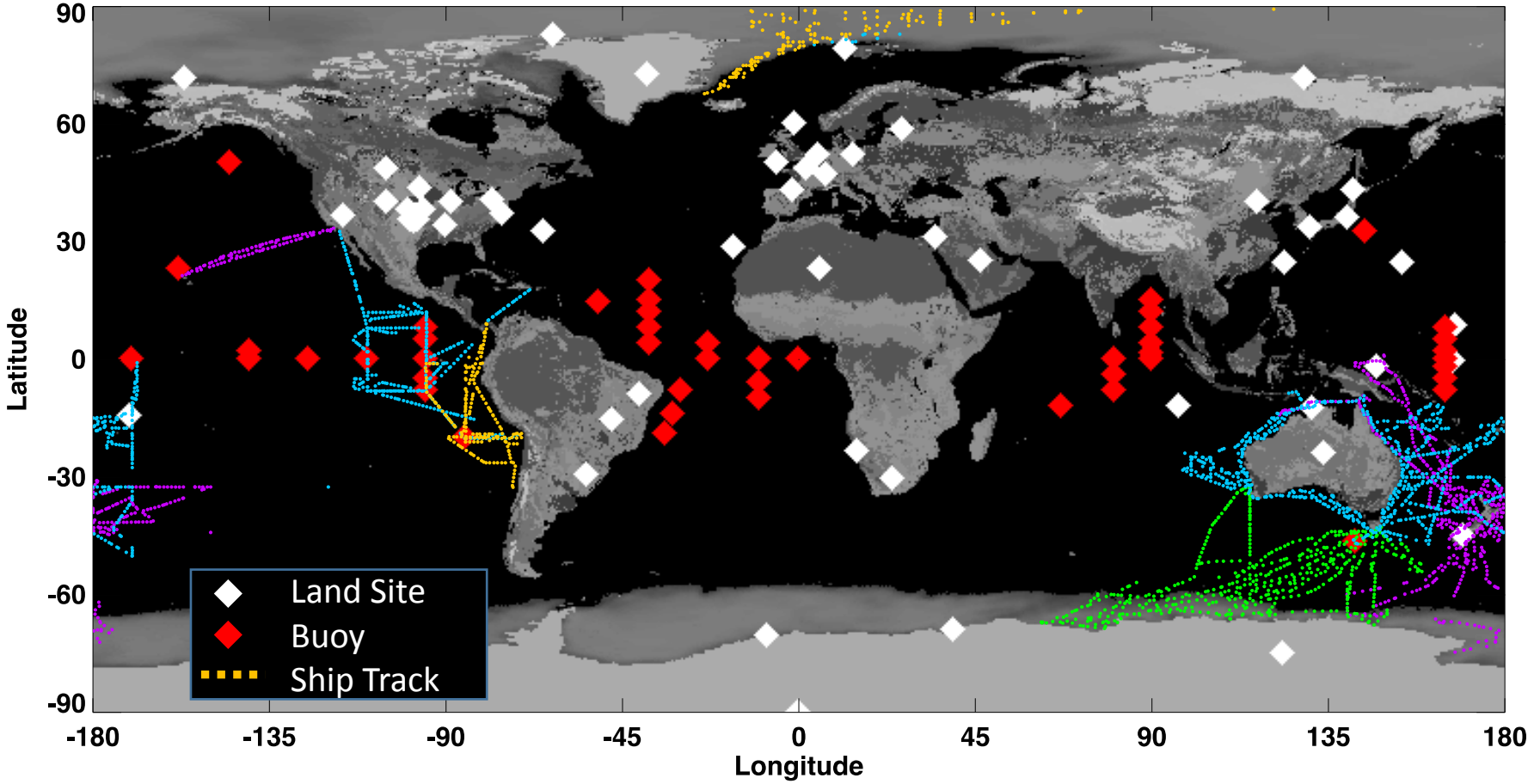


LW Surface Down (Monthly Avg)



- TOA Observed CERES: "Balanced" by Ocean Heat storage
- "Filled" Clear sky by converting MODIS narrowband to broadband
  - Surface irradiance is matched to TOA to balance over time

BSRN provides the backbone of our results.



- Key - established calibration requirements.

Surface Validation: Web-Tool

SYN1Deg

https://ceres-tool.larc.nasa.gov/cave/jsp/CAVE4Selection.jsp

EBAF-Surface

https://ceres-tool.larc.nasa.gov/cave/jsp/CAVEEBAF4Selection.jsp

Site Selection

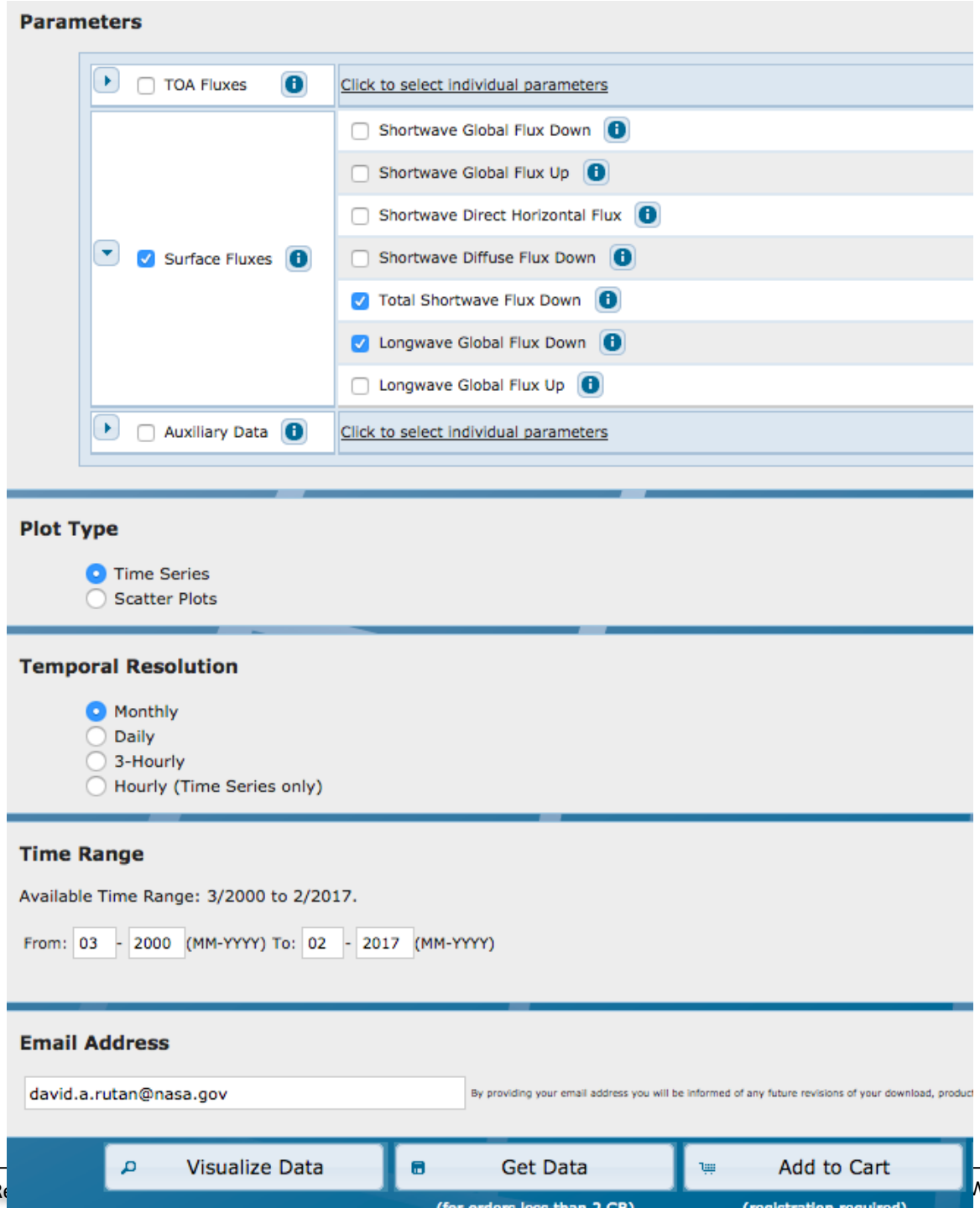
Surface Site Description Page

Surface Sites:

- PSU - Penn State, PA, USA (40.72, 282.07)
- BOS - Boulder, CO USA (SURFRAD) (40.13, 254.76)
- BOU - Boulder Tower, CO, USA (BSRN) (40.05, 254.99)
- BON - Bondville, IL, USA (40.05, 271.63)
- XIA - Xianghe, China (39.98, 116.38)
- E09 - Ashton, Kansas, USA (37.13, 262.73)
- CLH - Chesapeake Lighthouse, VA, USA (36.90, 284.29)
- E11 - Byron, Oklahoma, USA (36.88, 261.72)
- E12 - Pawhuska, Oklahoma, USA (36.84, 263.57)

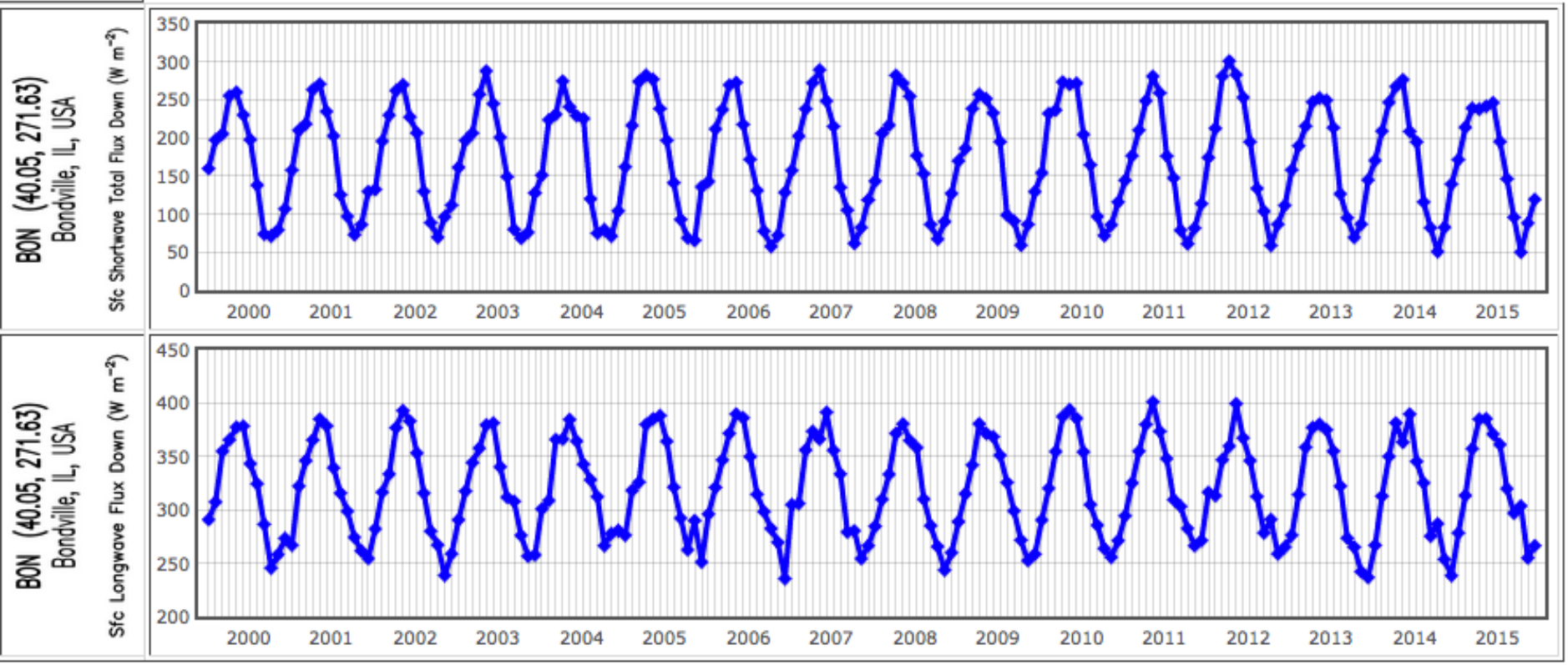
Click icons on map to select/unselect individual stations or select ranges below

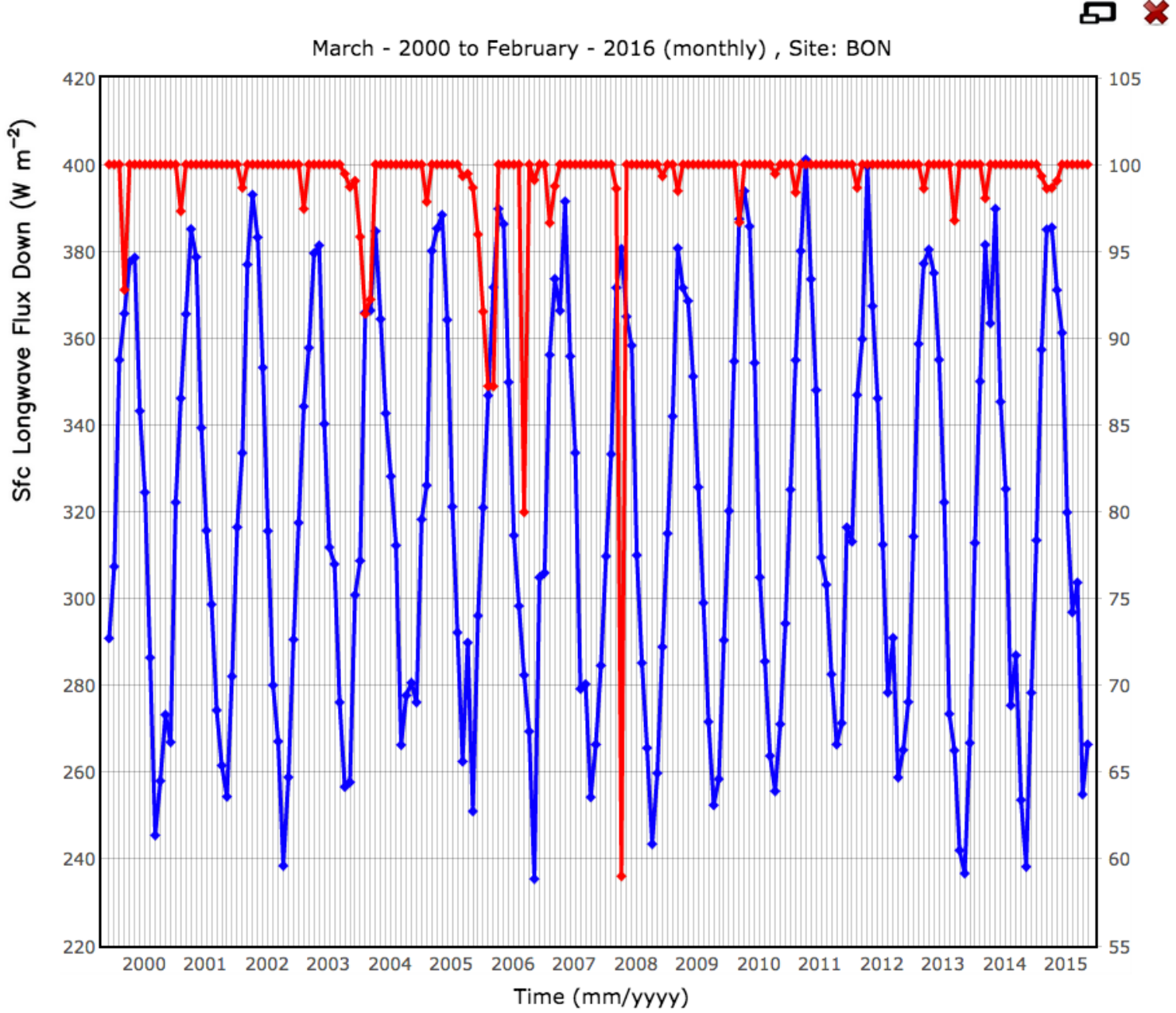
North


Parameters
TOA Fluxes
Click to select individual parameters
Shortwave Global Flux Down
Shortwave Global Flux Up
Shortwave Direct Horizontal Flux
Surface Fluxes
Shortwave Diffuse Flux Down
Total Shortwave Flux Down
Longwave Global Flux Down
Longwave Global Flux Up
Auxiliary Data
Click to select individual parameters
Plot Type
Time Series
Scatter Plots
Temporal Resolution
Monthly
Daily
3-Hourly
Hourly (Time Series only)
Time Range
Available Time Range: 3/2000 to 2/2017.
From: 03 - 2000 (MM-YYYY) To: 02 - 2017 (MM-YYYY)
Email Address
david.a.rutan@nasa.gov
By providing your email address you will be informed of any future revisions of your download, product
Visualize Data
Get Data
Add to Cart

CERES Validation

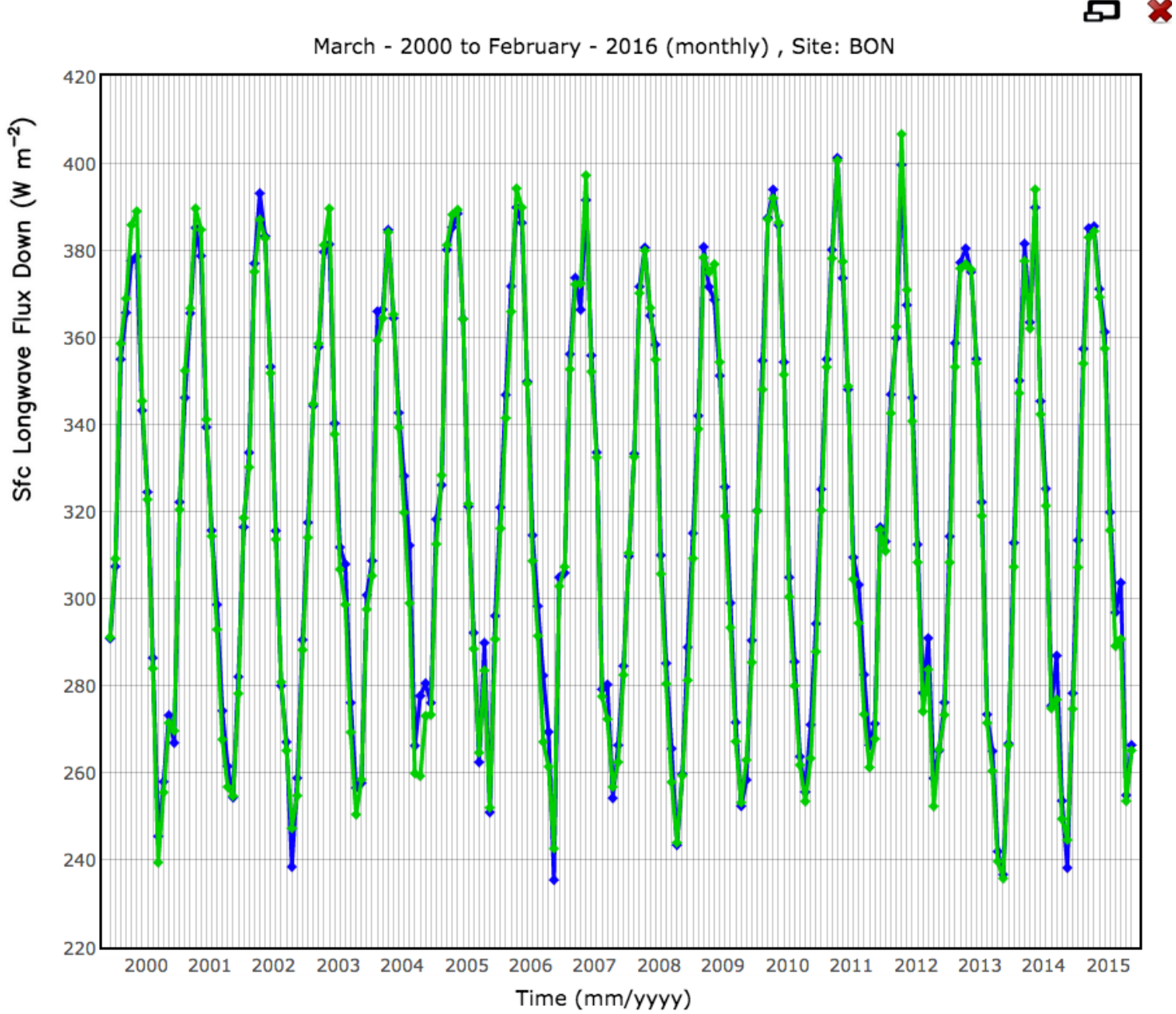
Parameter	March - 2000 to February - 2016 (monthly)

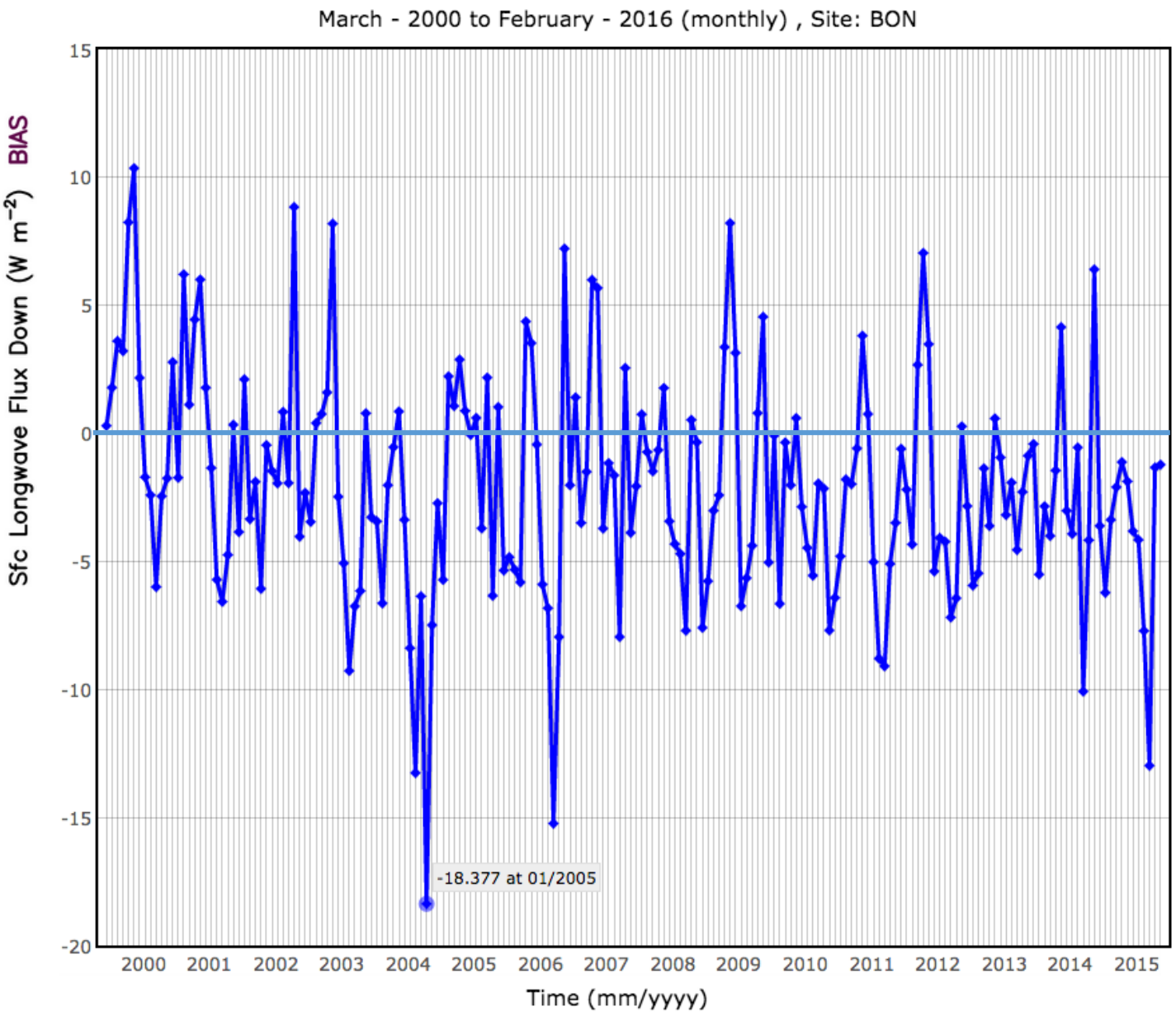




Save Data as ASCII File | Hide Count Values | Show CERES Values | Show Bias Values

Min Availability Filter (%): 0 replot

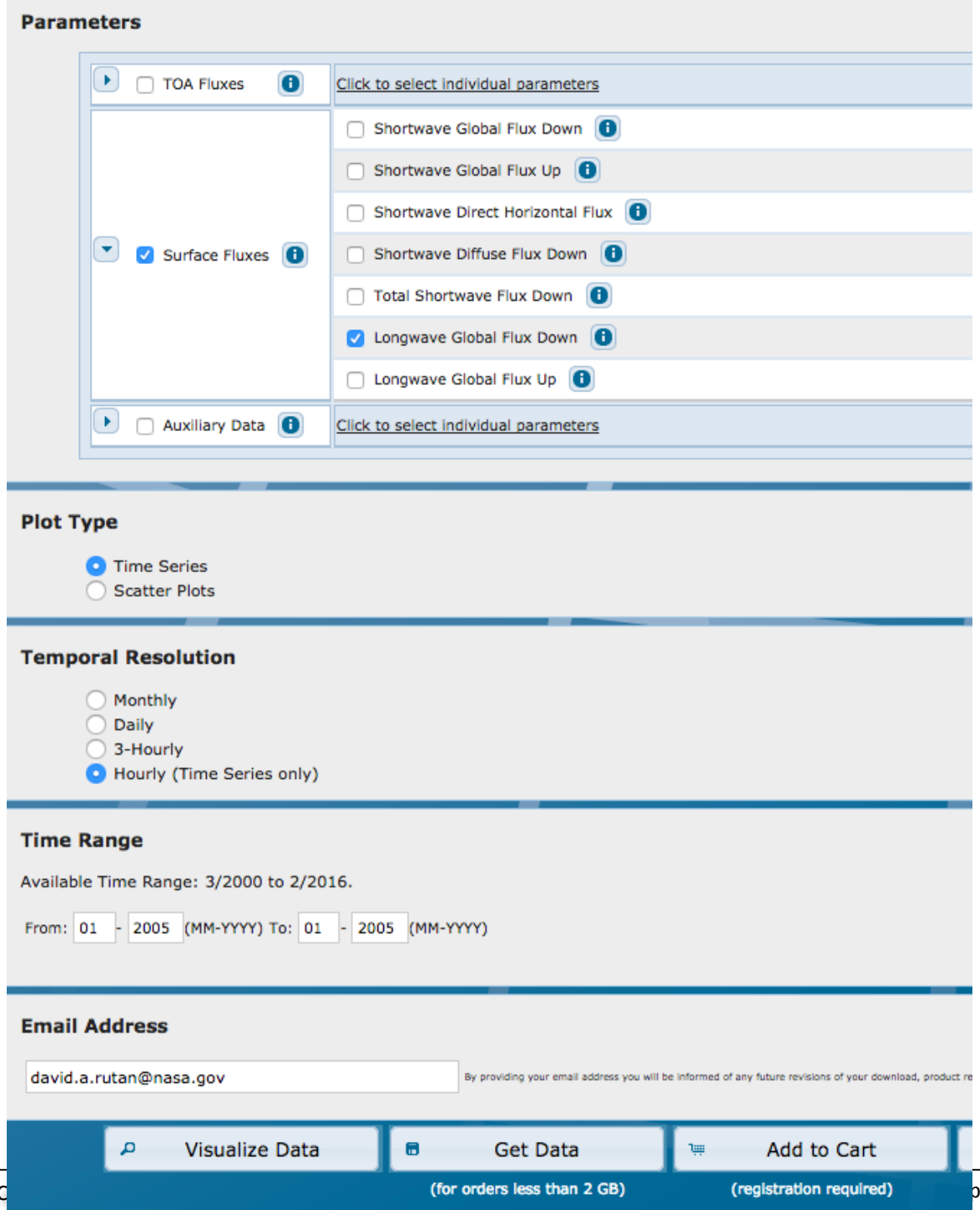

March - 2000 to February - 2016 (monthly) , Site: BON
Sfc Longwave Flux Down (W m^{-2})
420
400
380
360
340
320
300
280
260
240
220
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Time (mm/yyyy)
Save Data as ASCII File
Show Count Values
Hide CERES Values
Show Bias Values
Min Availability Filter (%):
0
replot



Save Data as ASCII File | Show Values | Show PDF Bias

Min Availability Filter (%): 0

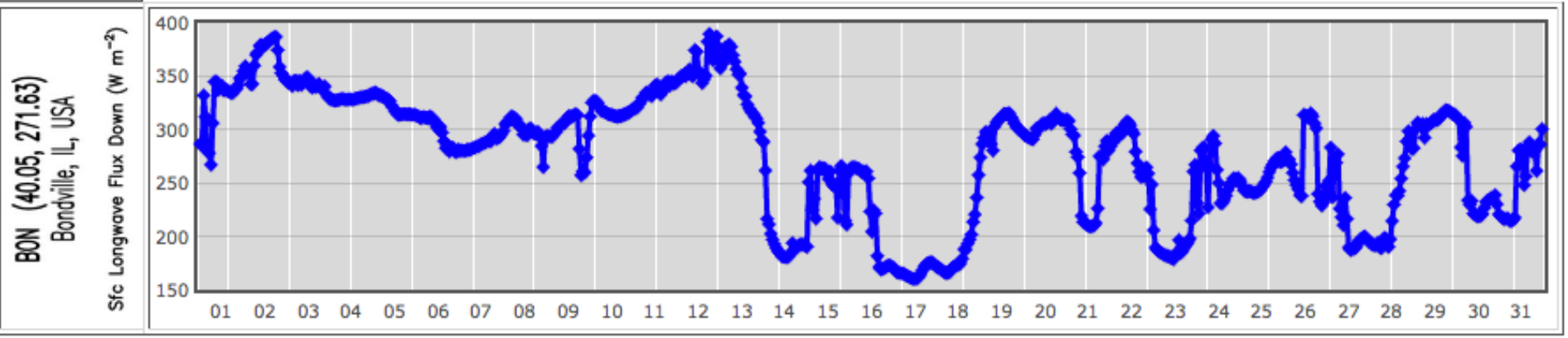
Statistics: Npoints: 192, SYN-mean: 317.705, OBS-mean: 319.778, SYN-OBS Bias: -2.073, StdDev: 4.387

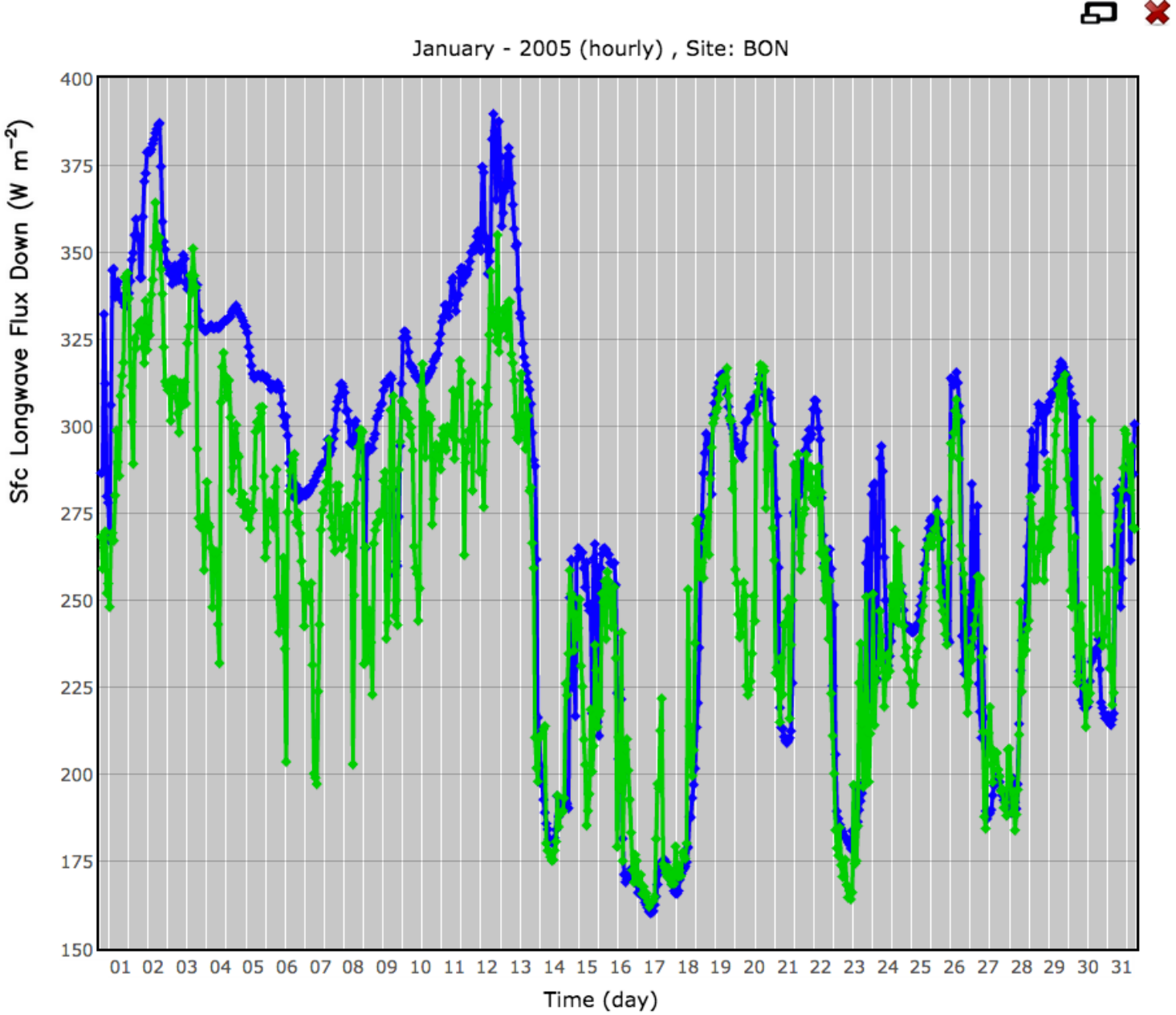

Parameters
TOA Fluxes
Click to select individual parameters
Surface Fluxes
Shortwave Global Flux Down
Shortwave Global Flux Up
Shortwave Direct Horizontal Flux
Shortwave Diffuse Flux Down
Total Shortwave Flux Down
Longwave Global Flux Down
Longwave Global Flux Up
Auxiliary Data
Click to select individual parameters
Plot Type
Time Series
Scatter Plots
Temporal Resolution
Monthly
Daily
3-Hourly
Hourly (Time Series only)
Time Range
Available Time Range: 3/2000 to 2/2016.
From: 01 - 2005 (MM-YYYY) To: 01 - 2005 (MM-YYYY)
Email Address
david.a.rutan@nasa.gov
By providing your email address you will be informed of any future revisions of your download, product re
Visualize Data
Get Data
(for orders less than 2 GB)
Add to Cart
(registration required)

CERES Validation

Select a Date: Jan 2005 LOAD DATA

Parameter	January - 2005 (hourly)

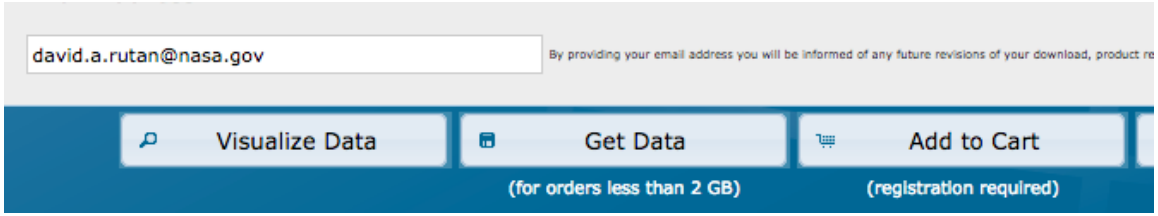




Save Data as ASCII File | Show Count Values | Hide CERES Values | Show Bias Values | Show Diurnal Values

Min Availability Filter (%): 0 replot

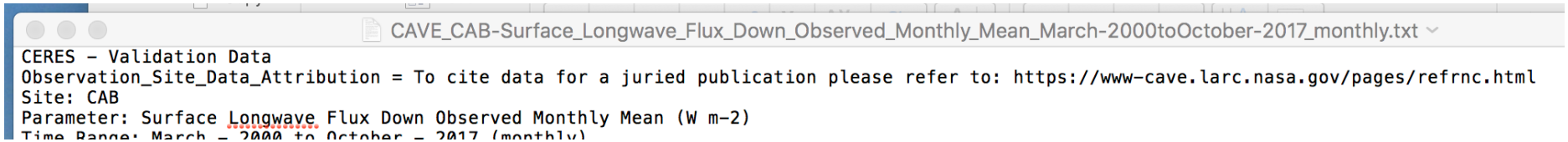
A Note on Data Citation:



Surface Observed Fluxes

Surface observations from around the globe are collected here and made available as 1 hourly, 3 hourly, daily, and monthly averages. Original data sources and some site specific information, along with links to original data providers, can be found at the CAVE web site.

Product Attribution:
Many scientists around the globe work hard to provide reliable time series of observed surface fluxes. For a complete description of how to cite these data if used in a juried publication go to the CAVE Reference page.



Data contained in CAVE are there because of the hard labor of people maintaining instruments in difficult locations throughout the world. Therefore, if you use data contained in the CAVE data base in refereed journal articles *please* reference all original data sources used according to the following list.

Full policies of each agency are listed at the bottom of this page. One need only reference those data sets used:

- **DOE ARM Data: (Acknowledgement)**

  ARM data is made available through the U.S. Department of Energy as part of the Atmospheric Radiation Measurement Program.

- **NOAA Global Monitoring Division, SURFRAD, and Global Baseline Sites (GMD): (Acknowledgement)**

  These data are made available through the NOAA's Earth System Research Laboratory/Global Monitoring Divisioin - Radiation (G-RAD)

  Include for NOAA SURFRAD Data (Reference):

  - Augustine, J. A., J. J. DeLuisi, and C. N. Long, 2000: SURFRAD-A National Surface Radiation Budget Network for Atmospheric Research, Bull. of Amer. Met. Soc. Vol. 81, No. 10, pp. 2341-2358.

- **BSRN Data: (Reference)**

  Ohmura A., E. Dutton, B. Forgan, C. Frohlich, H. Gilgen, H. Hegne, A., Heimo, G., Konig-Langlo, B. McArthur, G. Muller, R. Philipona, C. Whitlock, K. Dehne, and M. Wild, 1998: Baseline Surface Radiation Network (BSRN/WCRP): New precision radiometery for climate change research. Bull. Amer. Meteor. Soc., Vol. 79, No. 10, 2115-2136.

- **NREL SSV Data: (Reference)**

  Myers, D. R., S. Wilcox, M. Anderberg, S. H. Alawaji, N. M. Al Abbadi, M. Y. bin Mahfoodh, 1999: Saudi Arabian solar radiation network of data for validating satellite remote-sensing systems, Earth Obs. Sys. IV SPIE Vol 3750, 18-20 July, Denver CO.

- **LaRC COVE Data: (Reference)**

  Jin, Z., T. P. Charlock, and K. Rutledge, 2002: Analysis of the Broadband Solar Radiation and Albedo Over the Ocean Surface at COVE. J. Atmos. & Ocean Tech. 19, pp. 1585-1601.

- **WHOI PACS Data: (Reference)**

  Anderson, S. P., K. Huang, N. J. Brink, M. F. Baumgartner, and R. A. Weller, 2000: Pan American Climate Study (PACS) Data Report, Woods Hole Oceanographic Institution Technical Report, WHOI-2000-03.

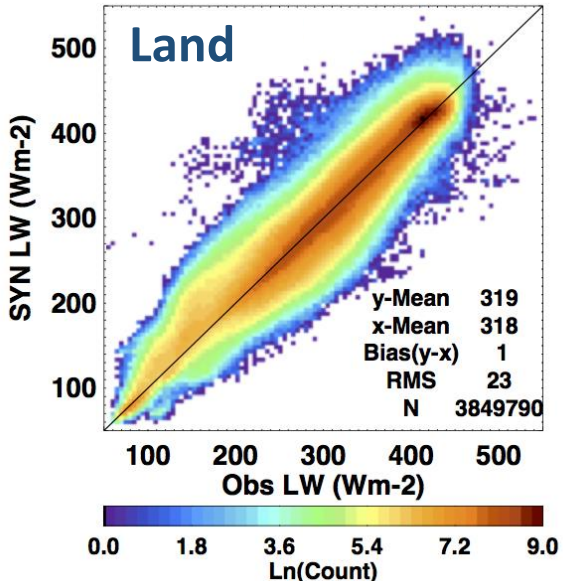
- **CERES SYN1Deg: (Reference)**

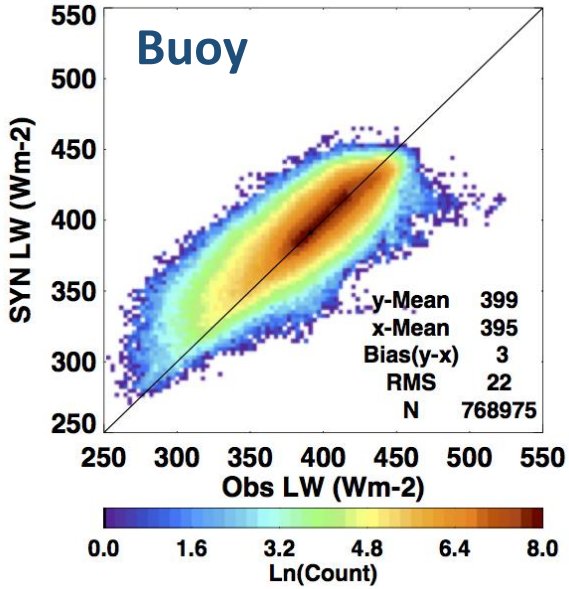
  Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment, Bull. Amer. Meteor. Soc., Vol. 77, 853-868.

Surface Validation: Results

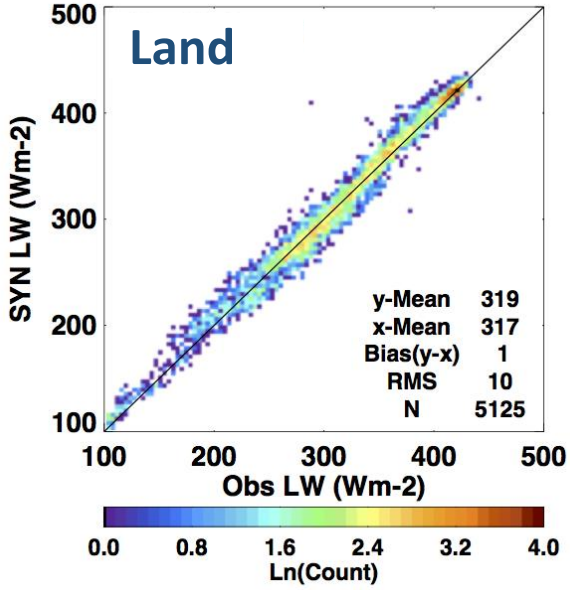
Longwave Surface Irradiance Down (SYN1Deg Ed4)
(2000/02 - 2016/12)

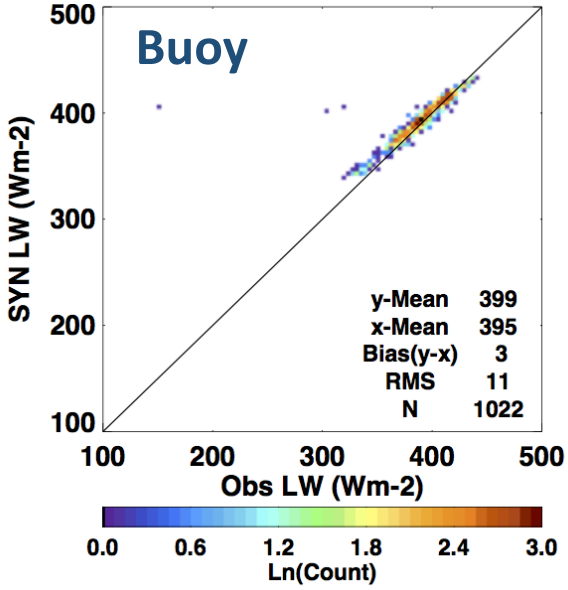
Hourly





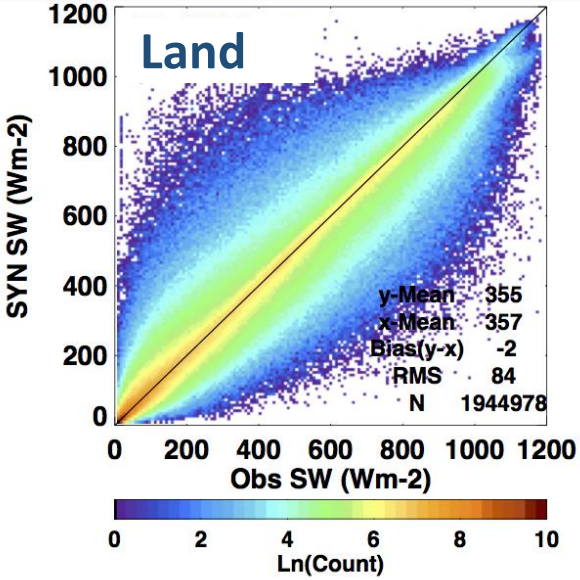
Monthly

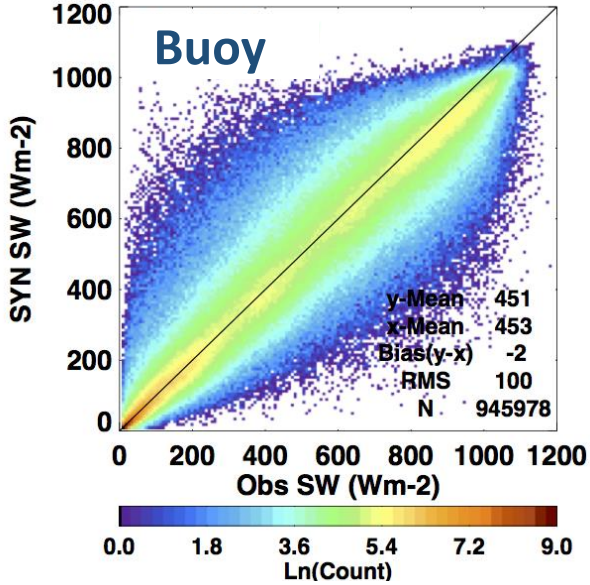




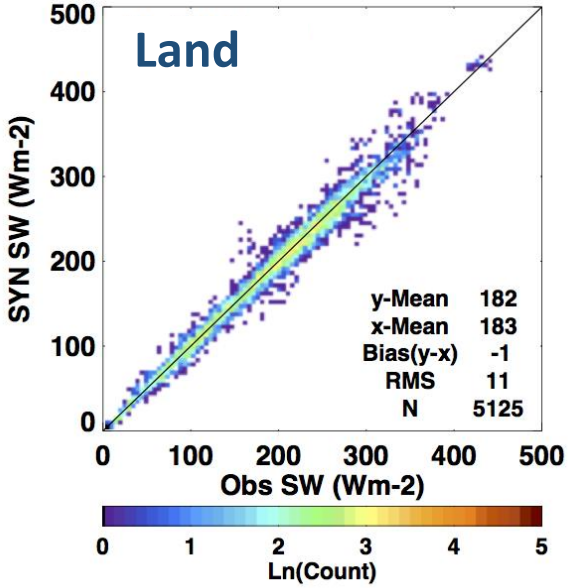
Shortwave Surface Irradiance Down (SYN1Deg Ed4)
(2000/02 - 2016/12)

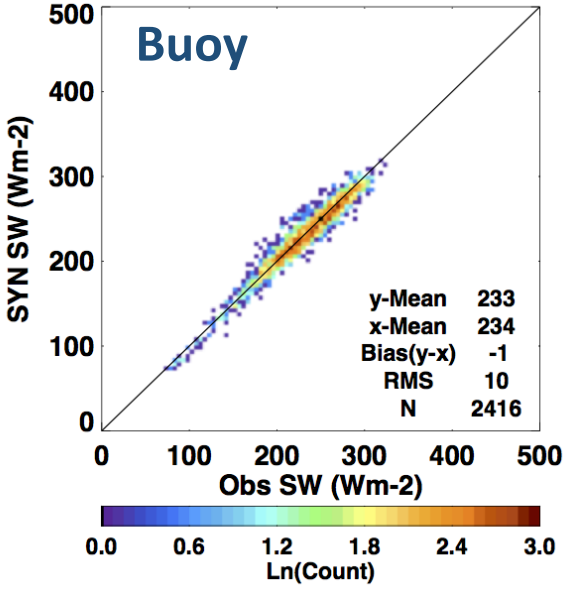
Hourly





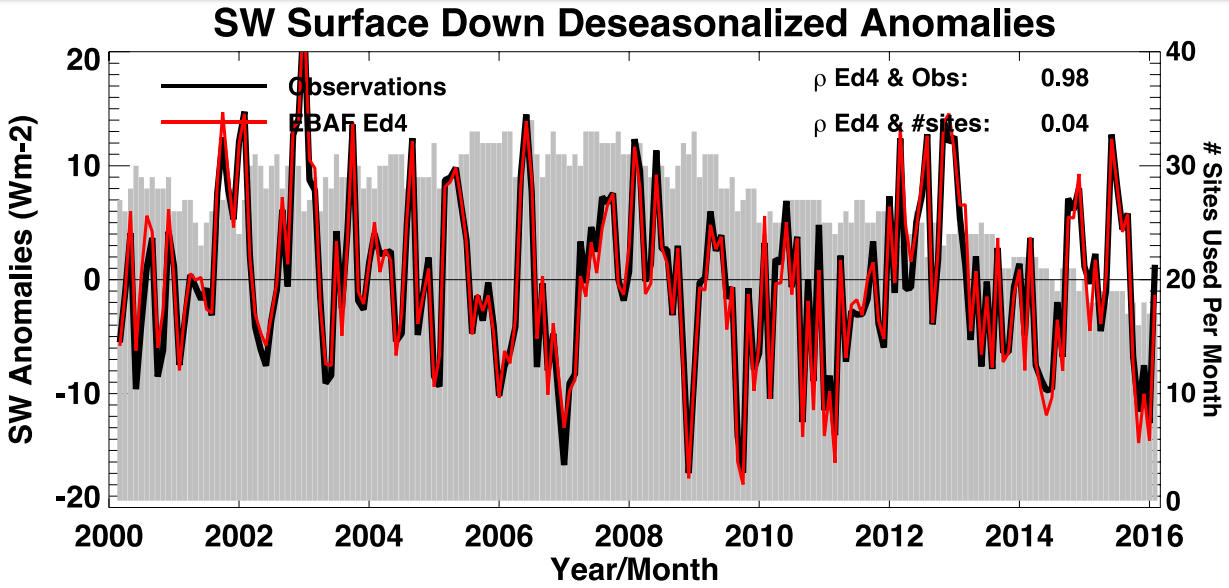
Monthly

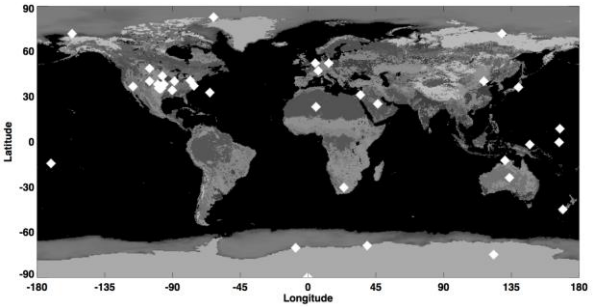


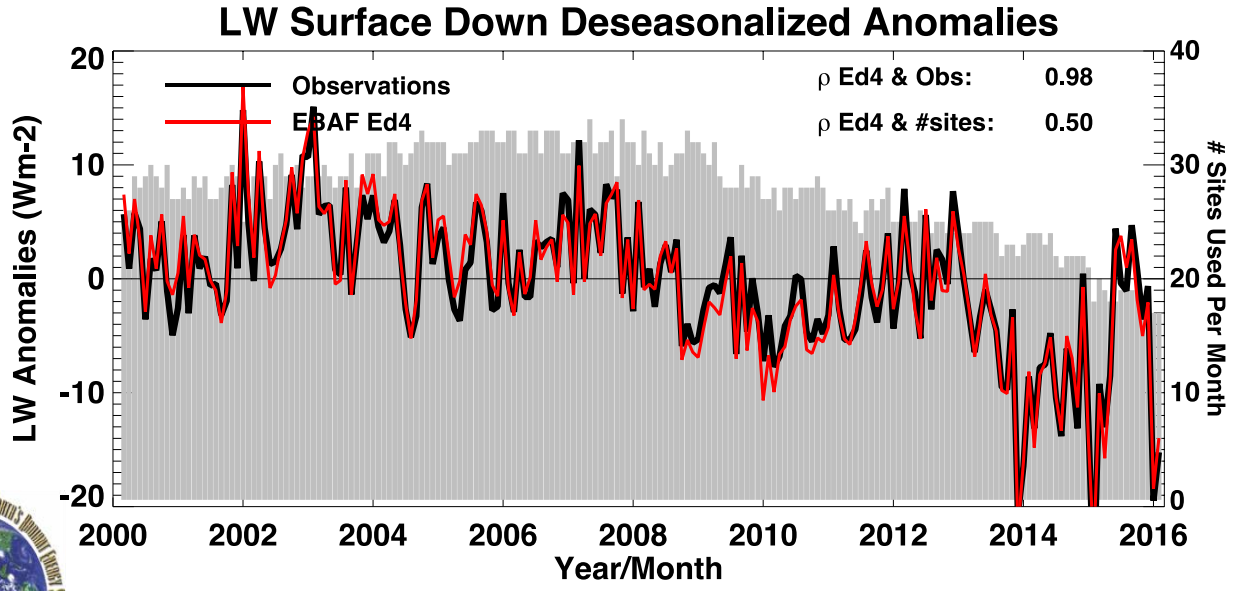


Surface Irradiance Down (EBAF-Surface Ed4)

Land Sites (2000/02 - 2016/12)

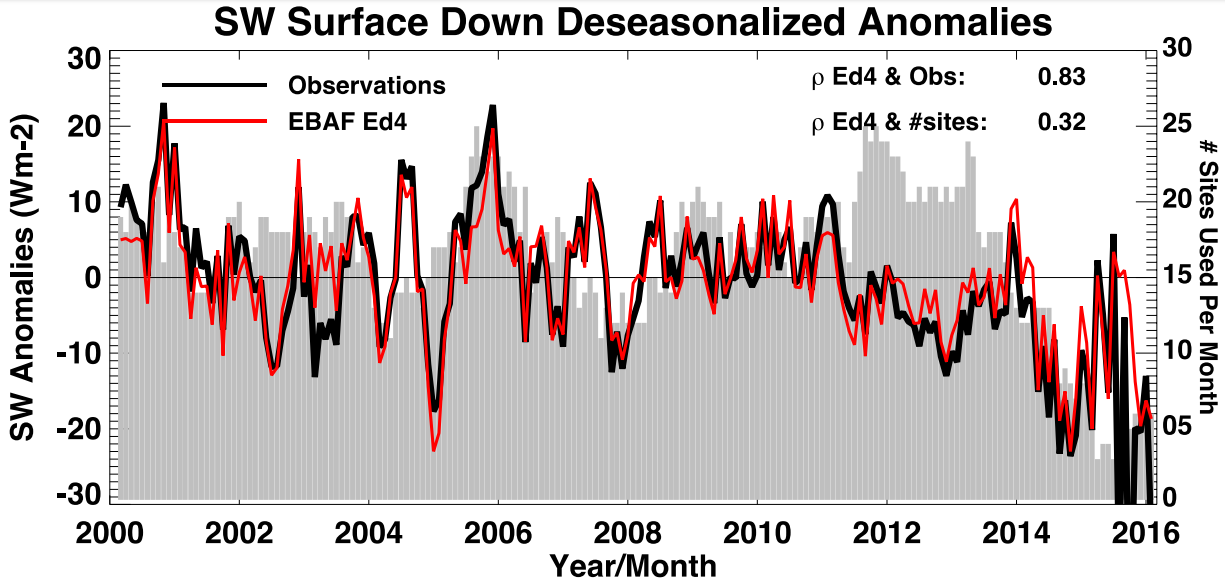


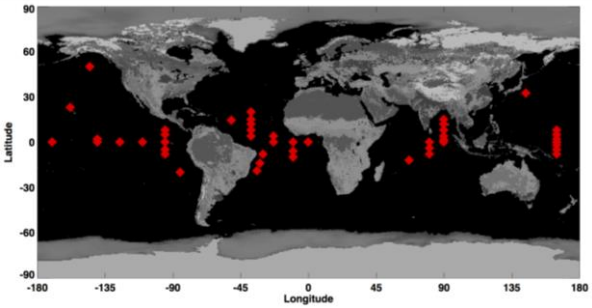


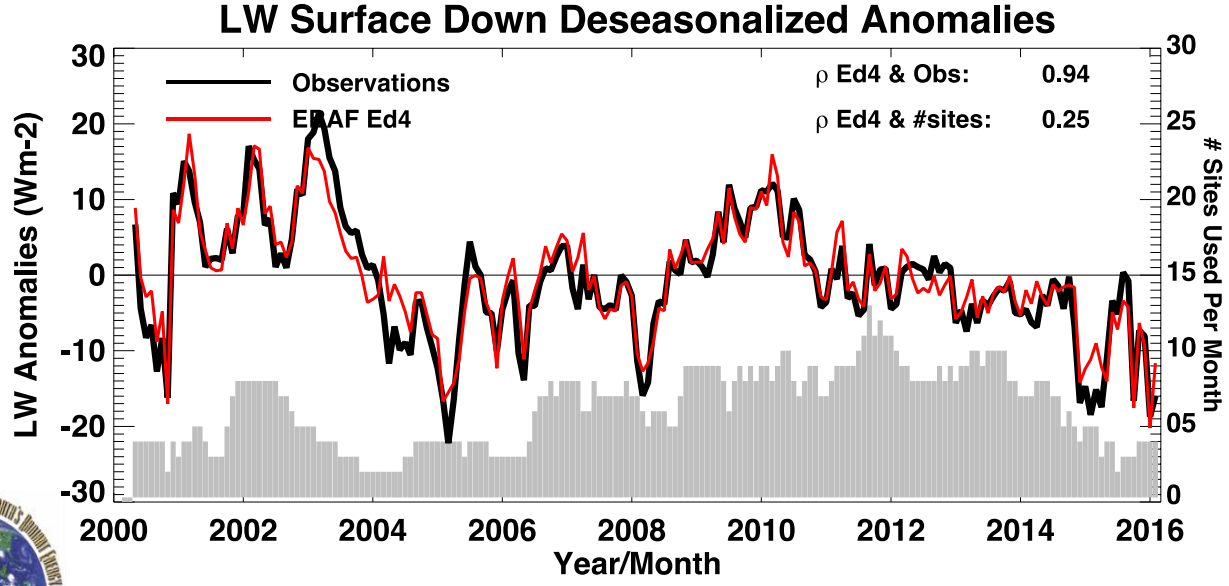


Surface Irradiance Down EBAF-Surface Ed4

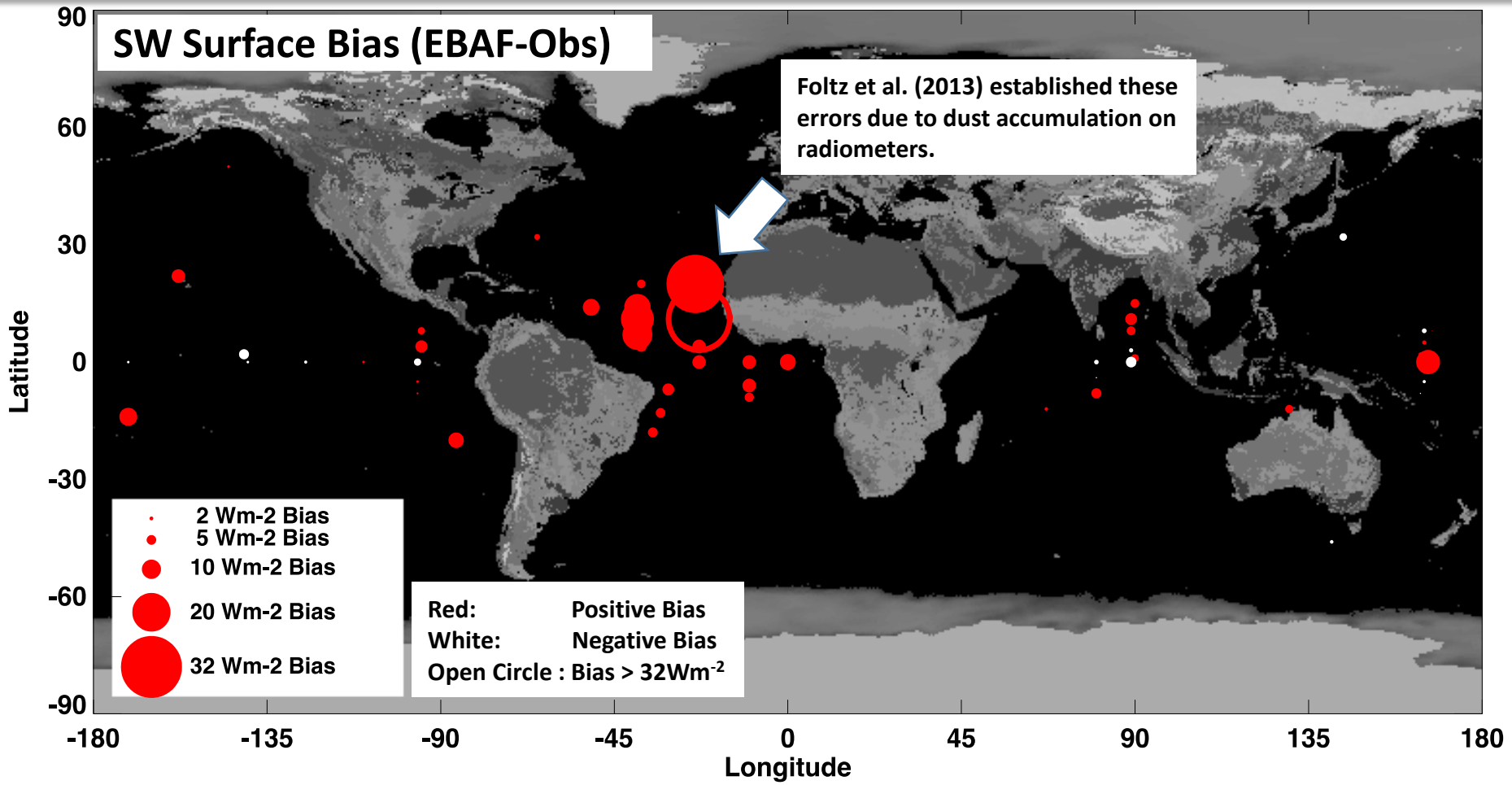
Buoys (2000/02 - 2016/12)







A Word (?) About Buoys



"B" in BSRN is:

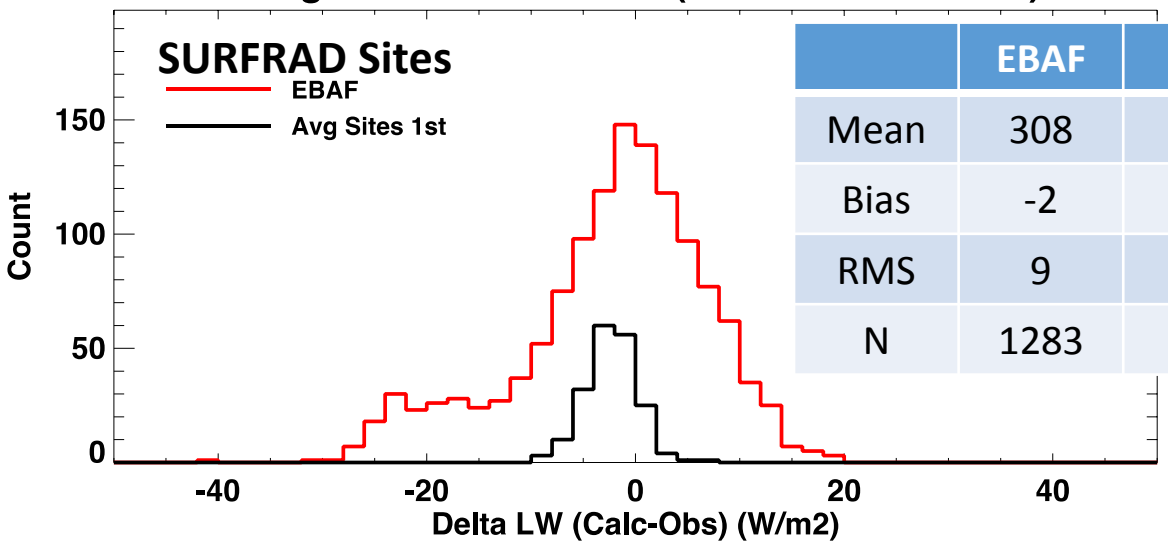
Baseline: a specific value or values that can serve as a comparison or control.

Can BSRN establish a quality baseline for buoys?

Surface Validation:
Spatial Uncertainty Analysis

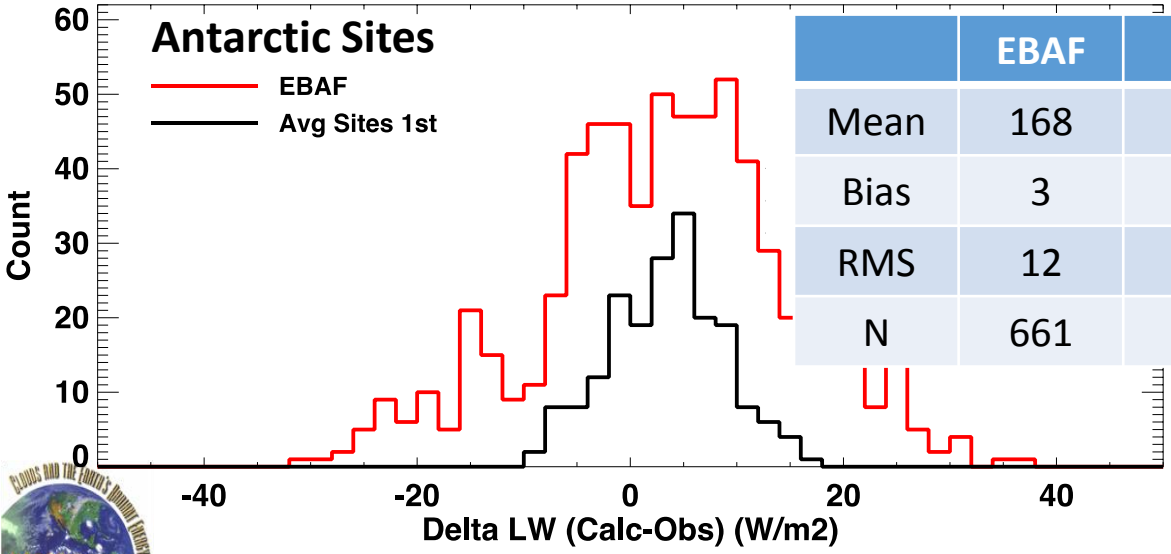
**(Not spatial representativeness in a grid box;
but how does uncertainty change as we aggregate groups of sites over large areas?)**

Longwave Surface Bias (EBAF-Observation)

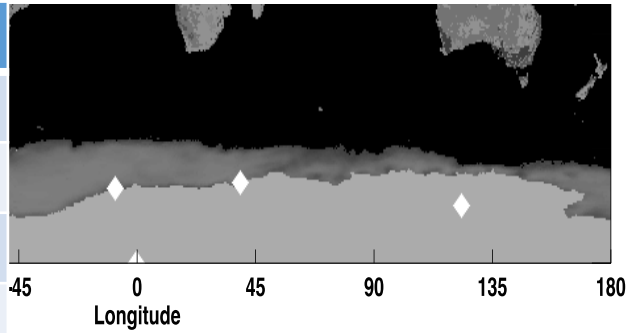


	EBAF	Avg
Mean	308	309
Bias	-2	-2
RMS	9	3
N	1283	192

Longwave Surface Bias (EBAF-Observation)

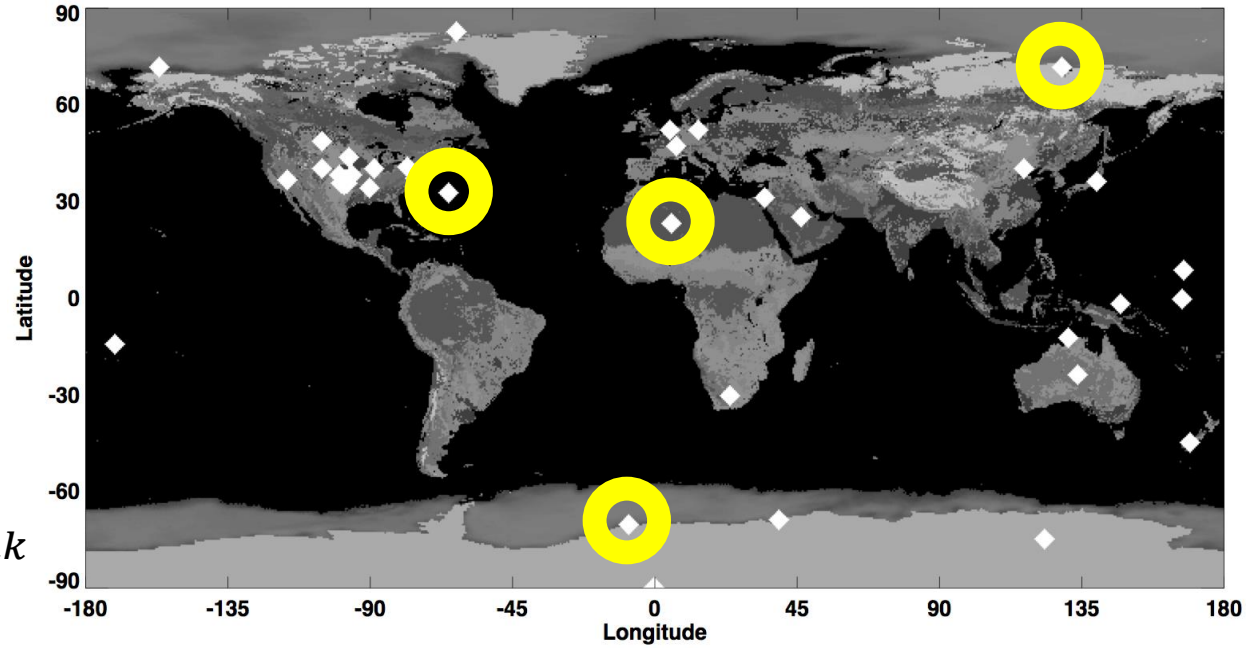


	EBAF	Avg
Mean	168	169
Bias	3	3
RMS	12	4
N	661	192



Calculate RMS over larger and larger groups of sites; randomly selecting groups 100 times.

Do land and buoy sites separately.



$$\overline{F_{il(comp;obs)}(K)} = \frac{1}{K}\sum_{1}^{K} F_{ilk}$$

$$\overline{\Delta F_{il}(K)} = \overline{\Delta F_{il(calc)}(K)} - \overline{\Delta F_{il(obs)}(K)}$$

$$\overline{F_{x,RMS}(K)} = \left[\frac{1}{N}\sum_{i}^{N}\frac{1}{L}\sum_{l}^{L}\left[\overline{\Delta F_{il}(K)}\right]^2\right]^{\frac{1}{2}}$$

$$(x = 100\ realizations)$$

Total Sites = 36

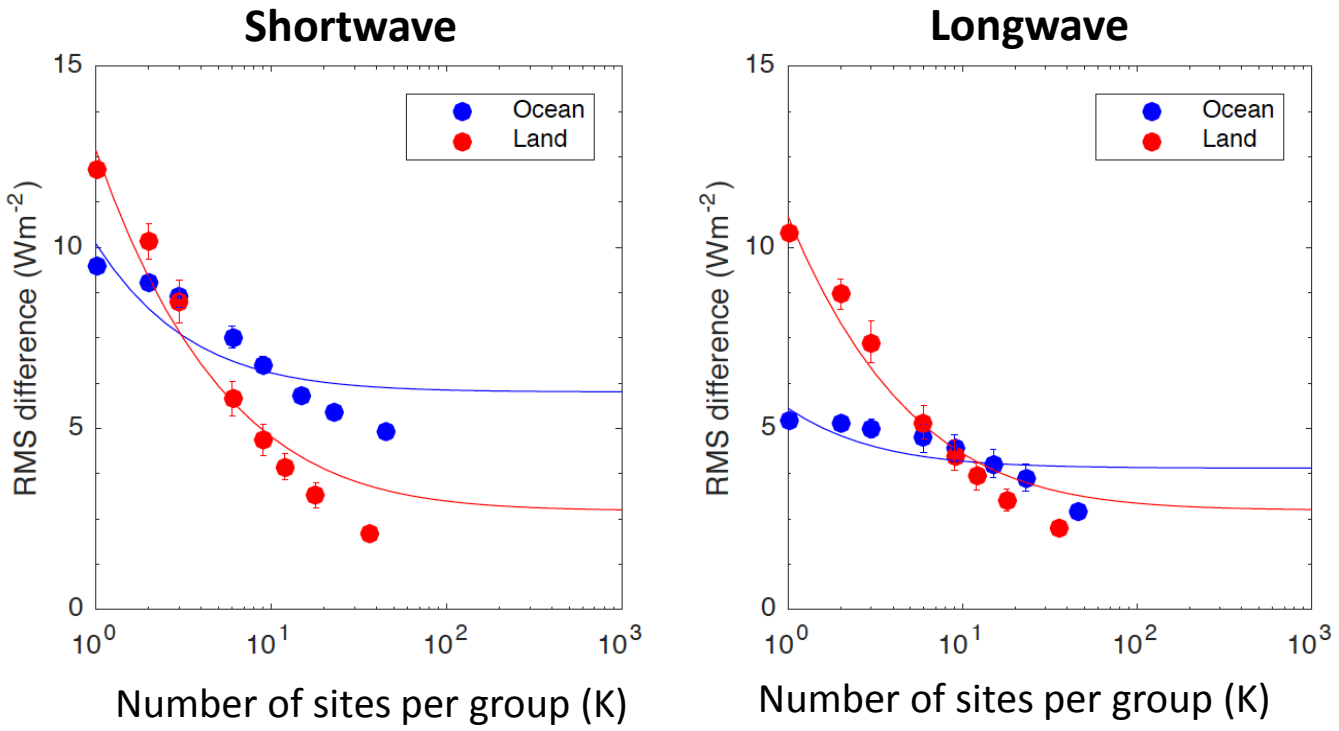
When K = 4 (# of sites per group)

Then L = 9 (# of groups)

N = # of months

Replicate 100 Times (no Duplication)

Plot RMS as a function of increasing group size.



$$\overline{F_{x,RMS}(K)}^2 = \Delta F_{x,bias}^2 + \frac{\Delta F_{x,random}^2}{K}$$

	Land (Wm^{-2})		Buoy (Wm^{-2})	
	Shortwave	Longwave	Shortwave	Longwave
$\Delta F_{x,bias}^2$	3.2	3.1	7.3	4.2
$\Delta F_{x,random}^2$	9.6	7.9	5.4	2.0

Summary

- CERES EBAF & SYN1Deg along with surface observation can still be accessed at:

https://ceres-tool.larc.nasa.gov/ord-tool

- BSRN data serves as the base upon which most of our validation and uncertainty analysis rests.
- It would be beneficial to have a baseline criteria for use of buoy data in validation processes.
- Uncertainty due to spatial variability in our surface validation sites shows:
  - Decrease is rapid for the land indicates higher spatial variability for these sites
  - Slower over ocean buoys:
    - Sites are primarily in tropics, less spatial variability in general
    - Fewer site with continuous time series adds to less reliable relationship.

Publications Using BSRN data

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