Investigation of the effect of Terra orbit drift with surface observed flux data

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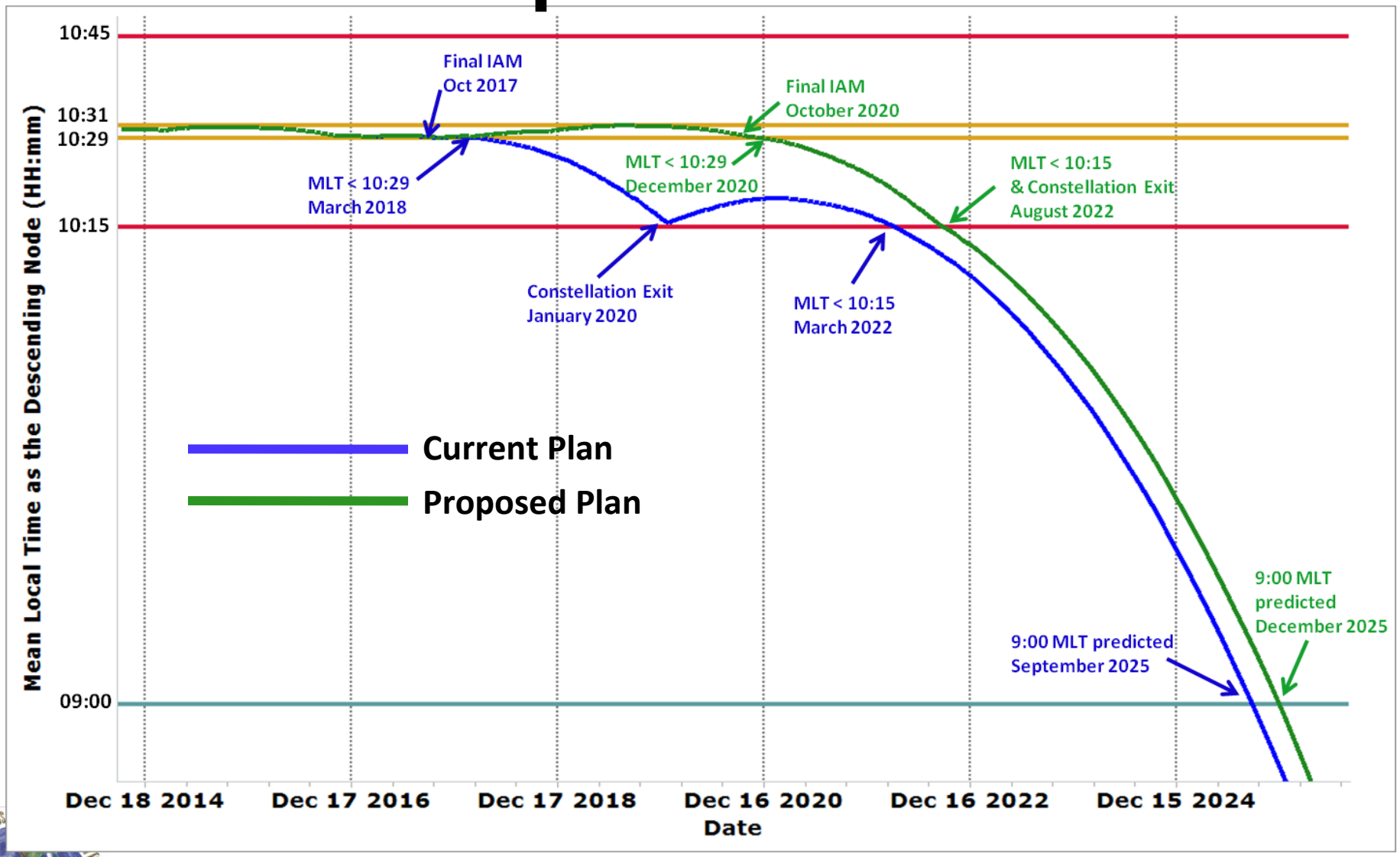
Terra's '5 Year Mission' is now going on 17 Years.

Current & Proposed End of Life Plan



"Proposed" - Problem

Document: "Process For Limiting Orbital Debris" (NASA-STD-8719.14A Revision A with Change 1)

Within protocol for satellite end of life:

- *De-orbit < 25 years after end of operations*
- *"risk of human casualty from surviving debris" < 1:10000.*

Proposed plan:

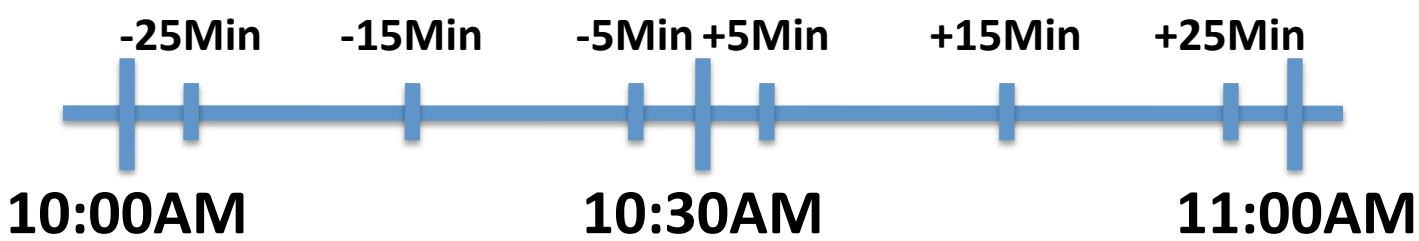
- Pushes re-entry from 2055 to 2077.
- Probability of casualty to 1:1410.

Assess Effect On CERES Downward Flux Calculations

In particular the impact on observing trends in surface irradiance if equator crossing time drifts.

- Use long time records of observed surface downward radiative flux measurements and simulate a drift in MLT. (Requires 1 minute time resolution.)

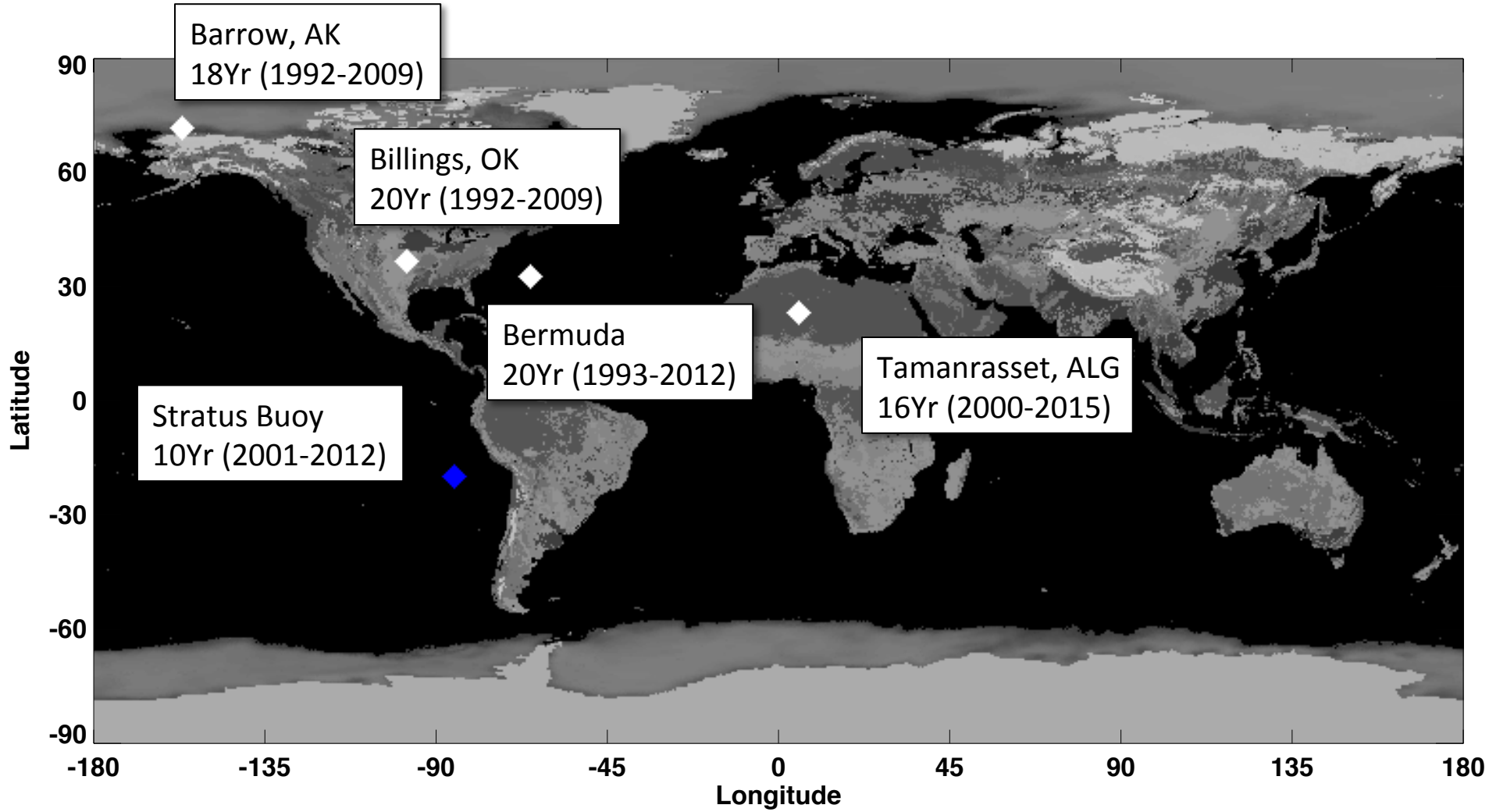
- Construct time series of monthly means at 10:30 AM(PM) local time and at ±5 min, ±15 min, and ±25 min.



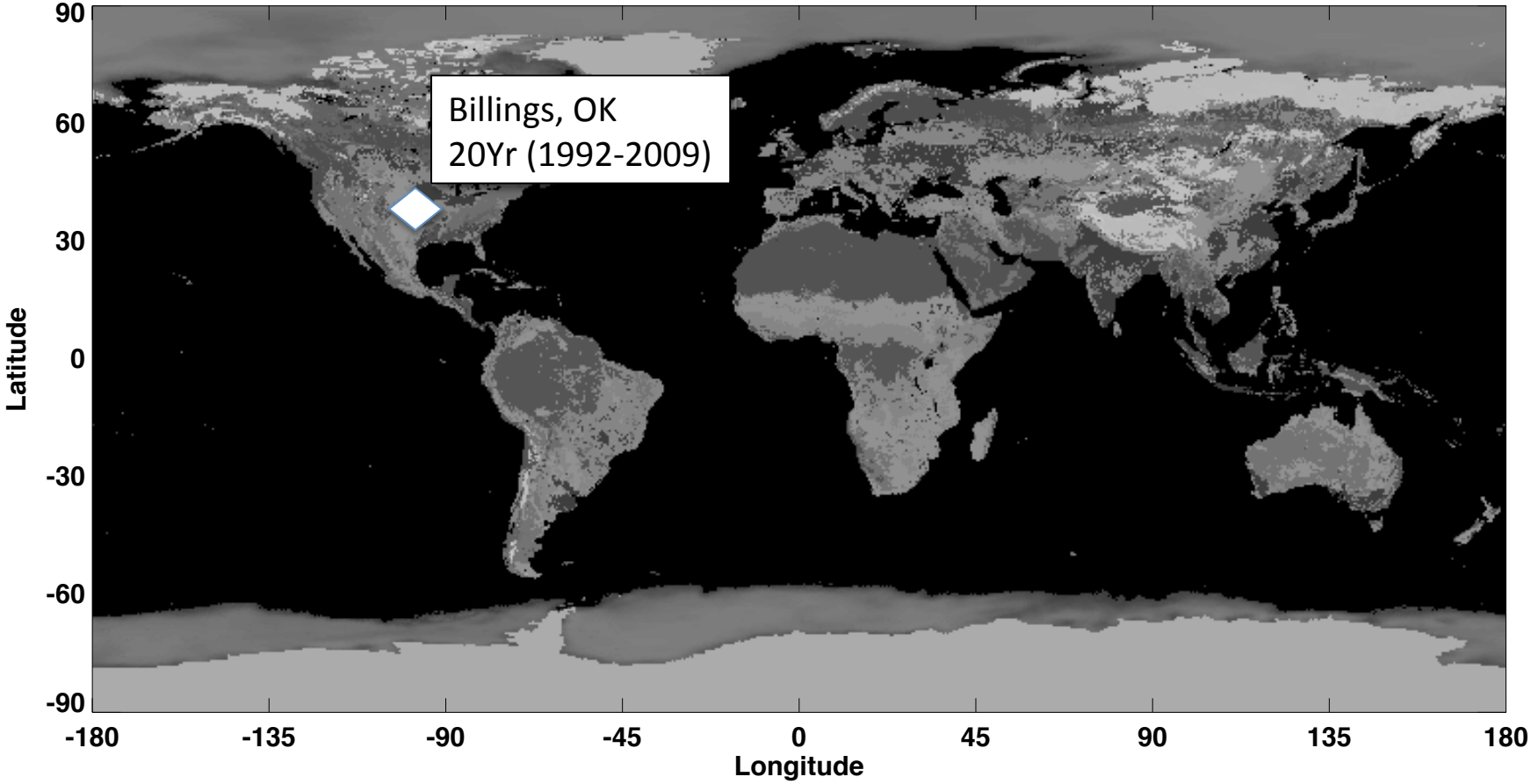
Assess Effect On CERES Downward Flux Calculations

- Within 7 time series, replace last three years of the 10:30 time series with the leading and lagging average flux values.
- Use a first-order cos(SZA) correction for solar irradiance differences between 10:30 AM and other times. Does not account for atmospheric path length differences.
- Deseasonalize the data. (Error propagates back into the record through the canonical monthly mean.)
- Evaluate trend for each time series & compare with that obtained at 10:30 AM or PM over the full time span.

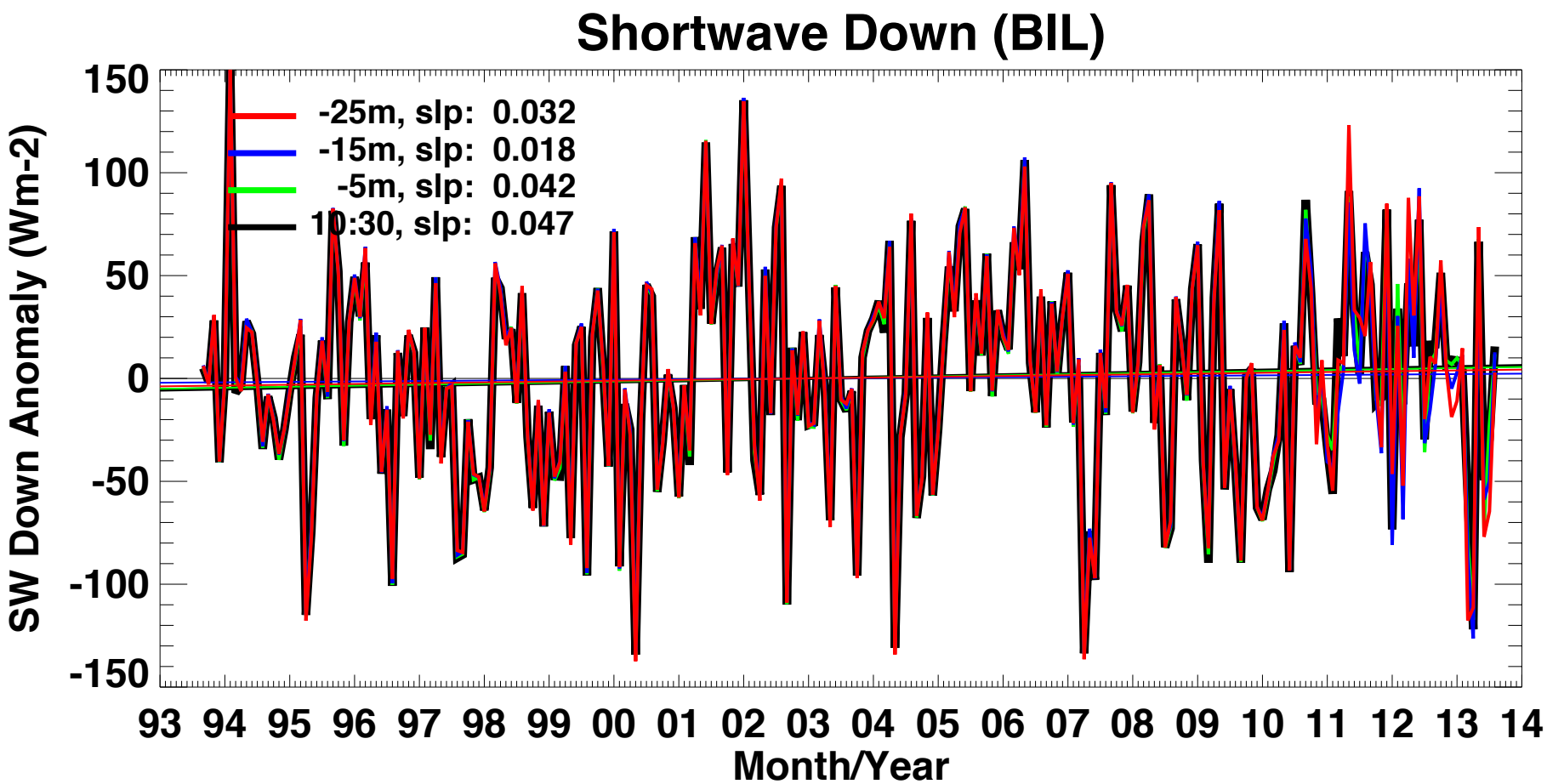
Sites With 16plus Years of Data



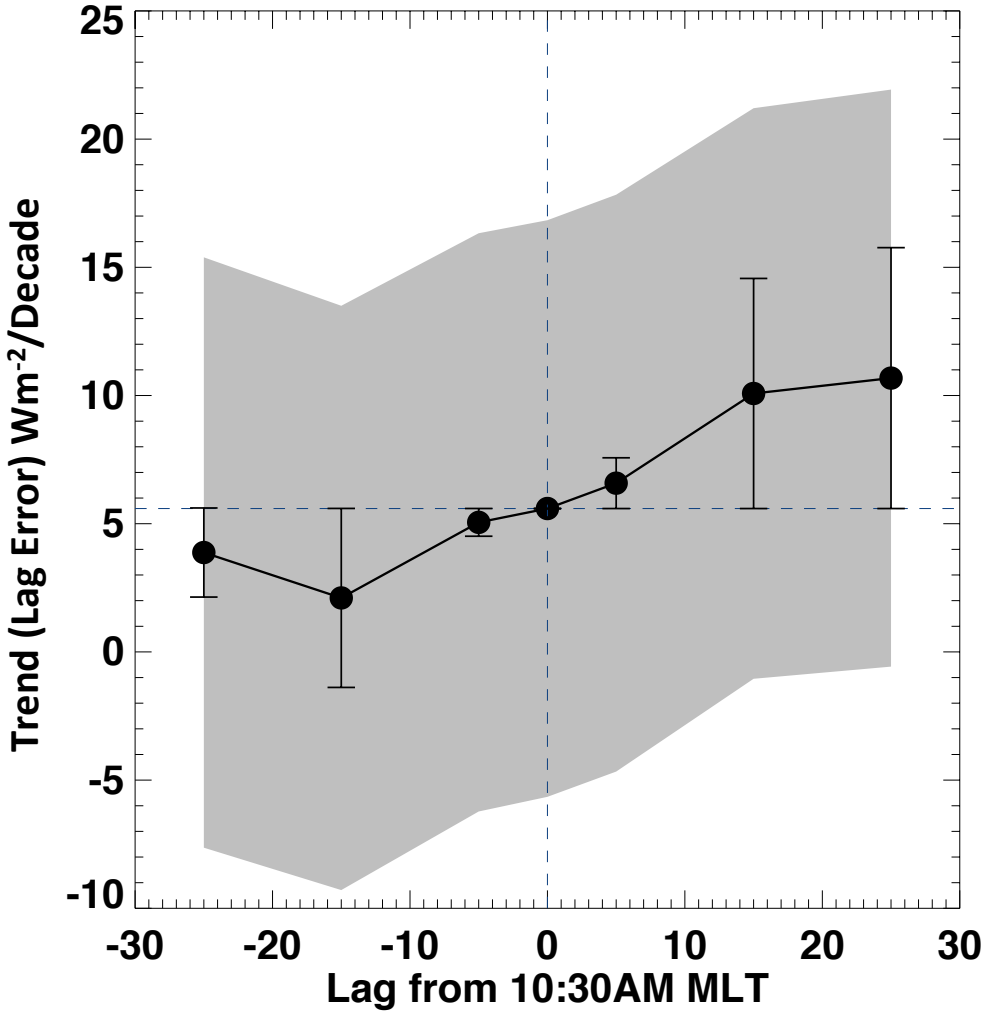
Billings, OK (BIL) (DOE ARM Central Facility) 20 Year Record



Deseasonalized Time Series



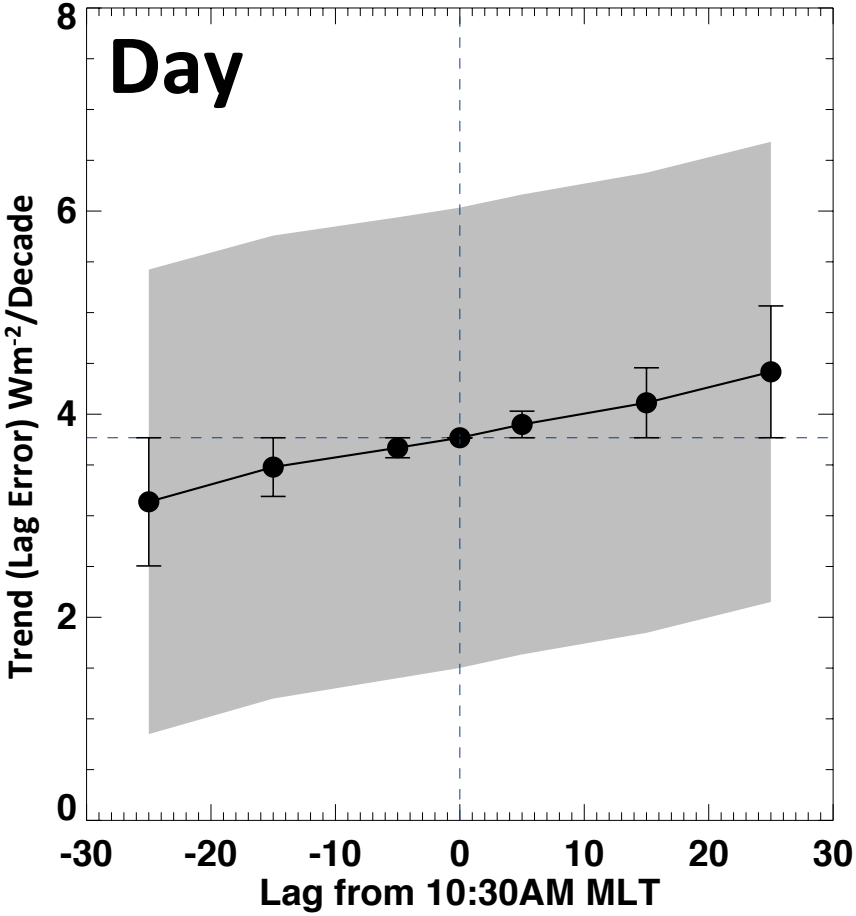
Billings, OK SW Surface Flux Down Trend and Error for Lag/Lead Times w.r.t. 10:30AM

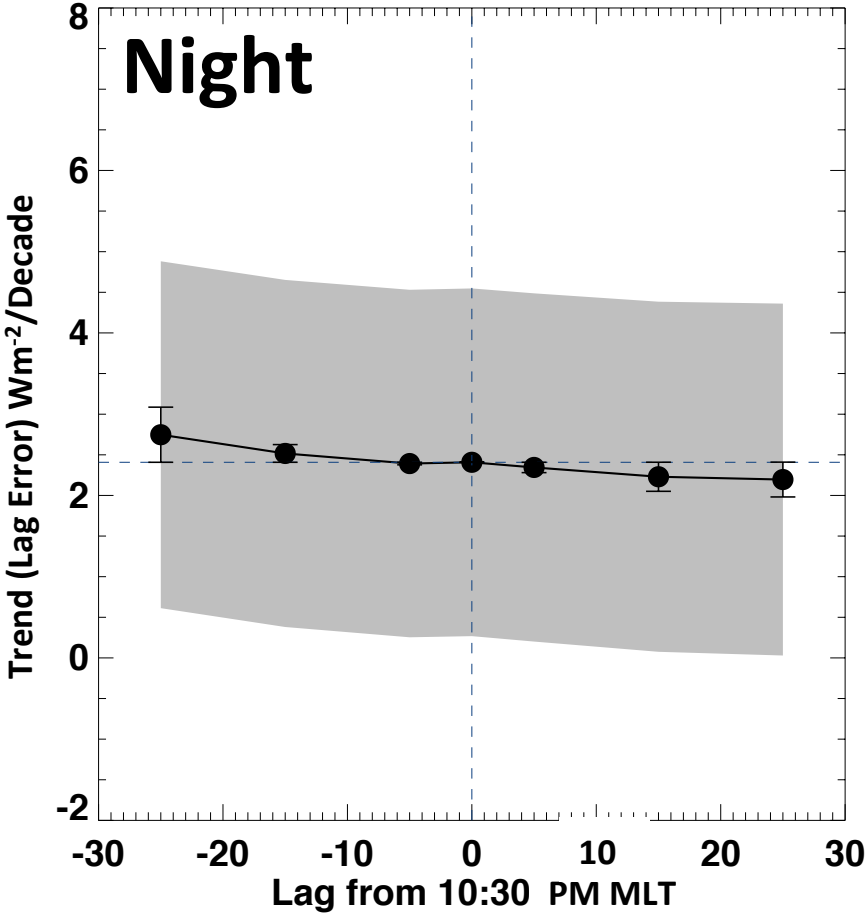


Gray area = 95% confidence interval in trend

Error bars = squared sum of trend error due to MLT change and 95% confidence interval

Billings, OK LW Surface Flux Down Trend and Error for Lag/Lead Times w.r.t. 10:30





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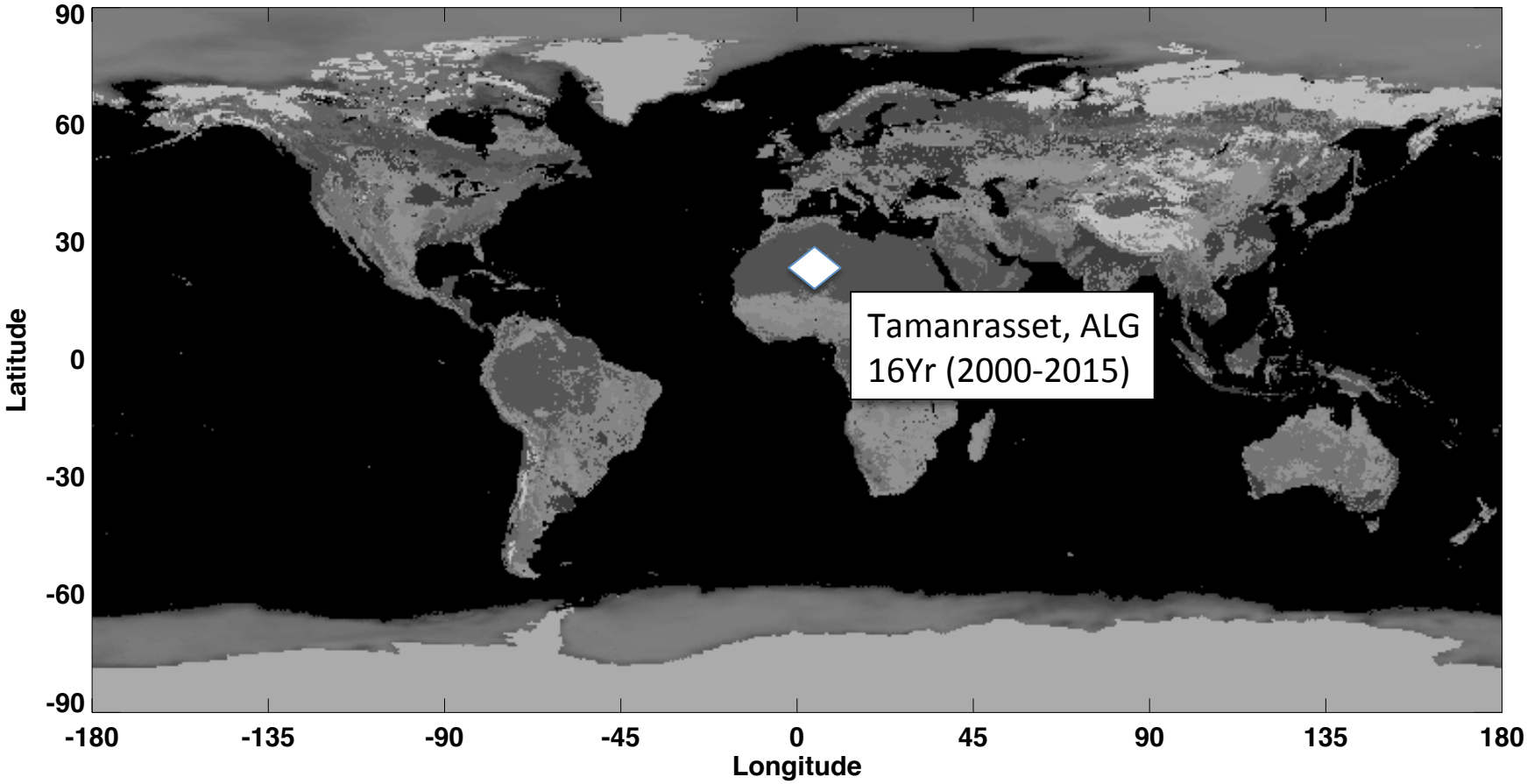
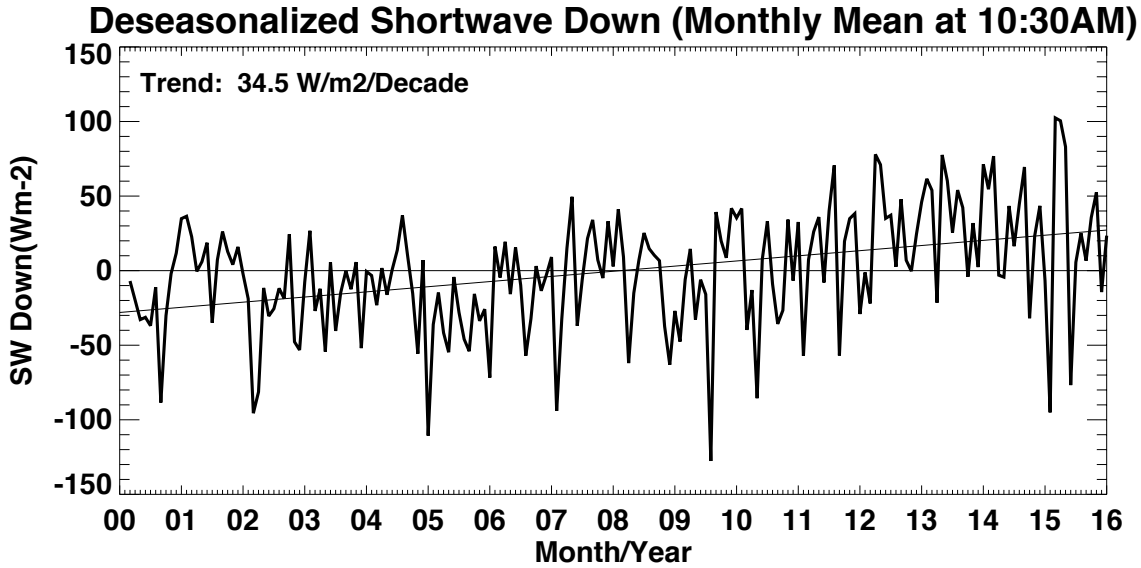
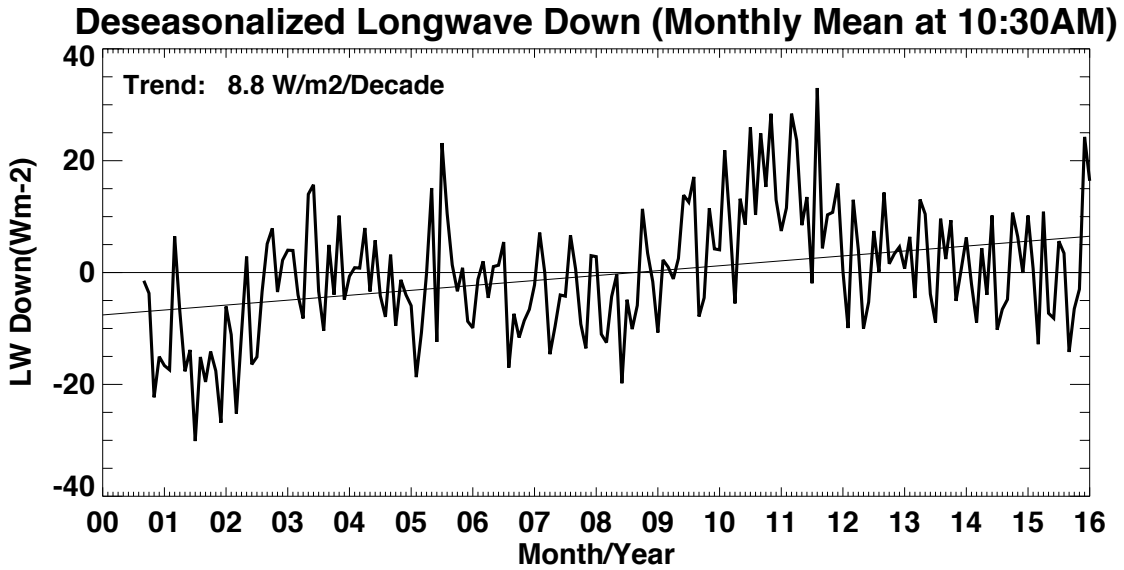
Tamanrasset, Algeria (TAM) (BSRN Facility)
16 Year Record

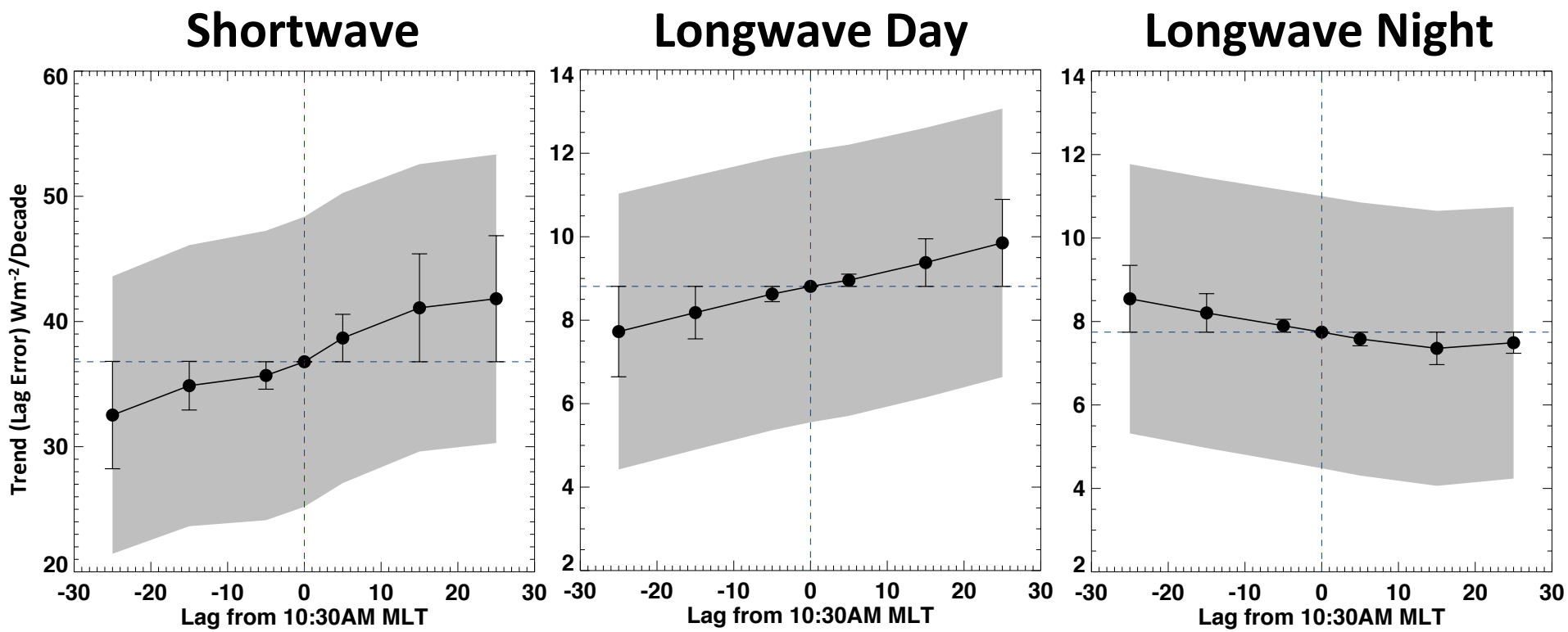


Trends at Tamanrasset, Alg





Tamanrasset, ALG Surface Flux Down Trend and Error for Lag/Lead Times w.r.t. 10:30AM



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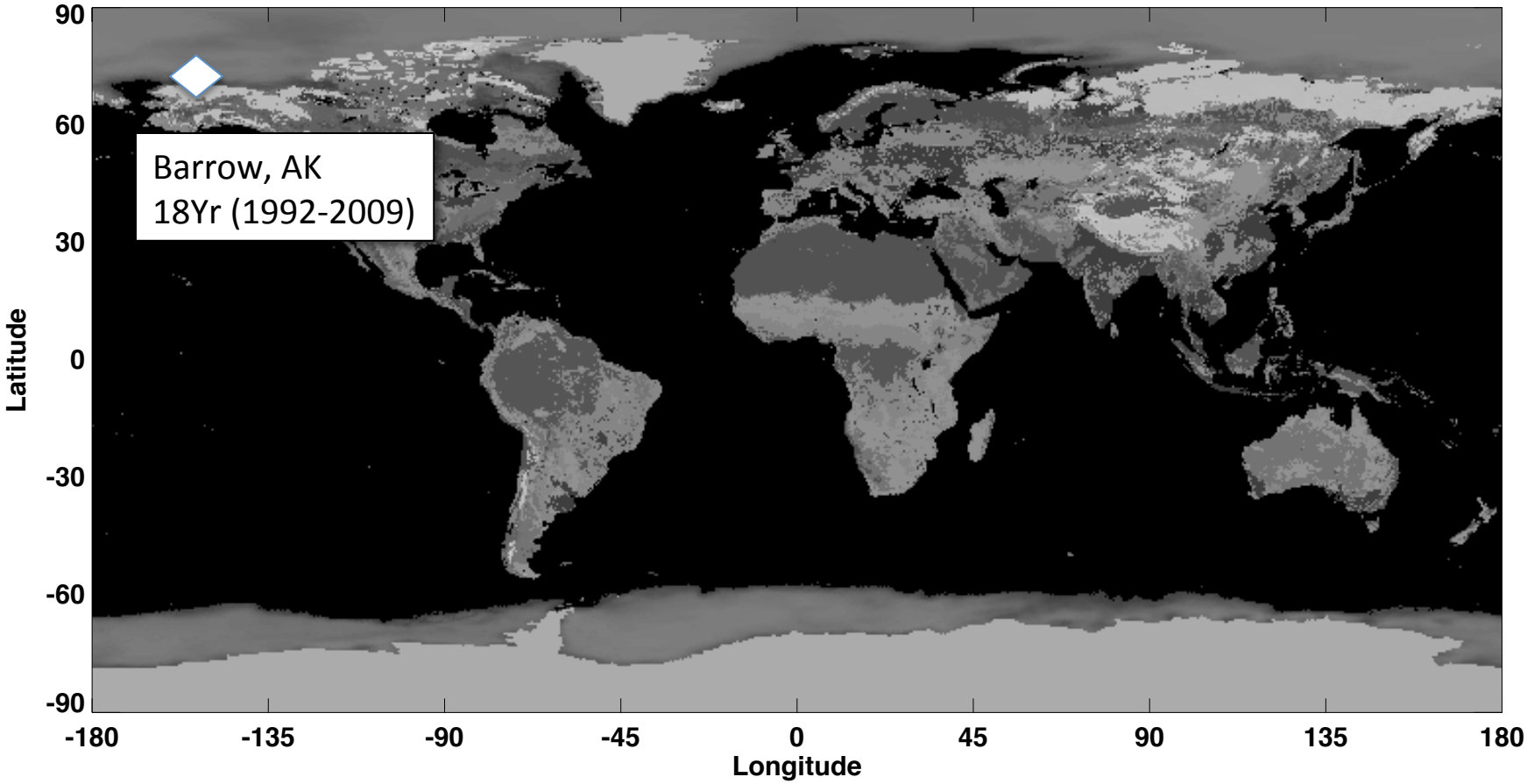
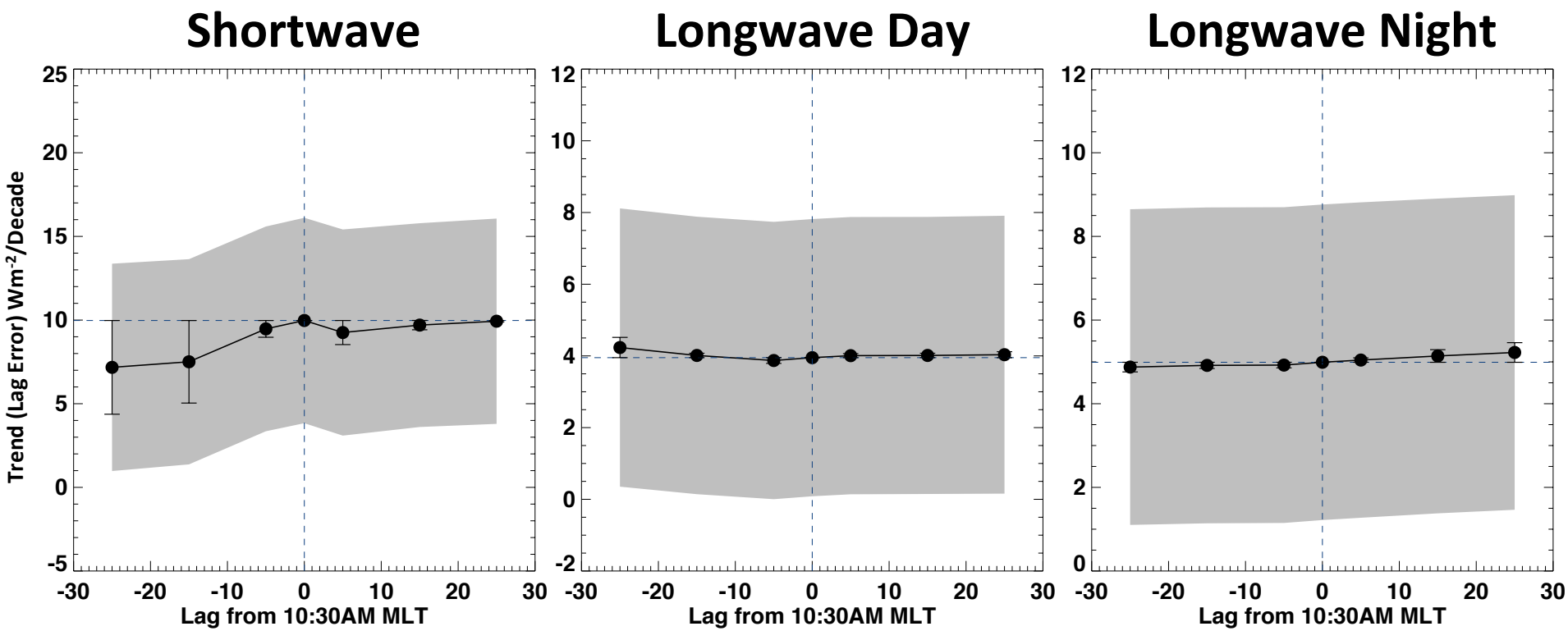
Barrow, Alaska (BAR) (BSRN Facility)
18 Year Record



Barrow, AK Surface Flux Down
Trend and Error for Lag/Lead Times w.r.t. 10:30AM



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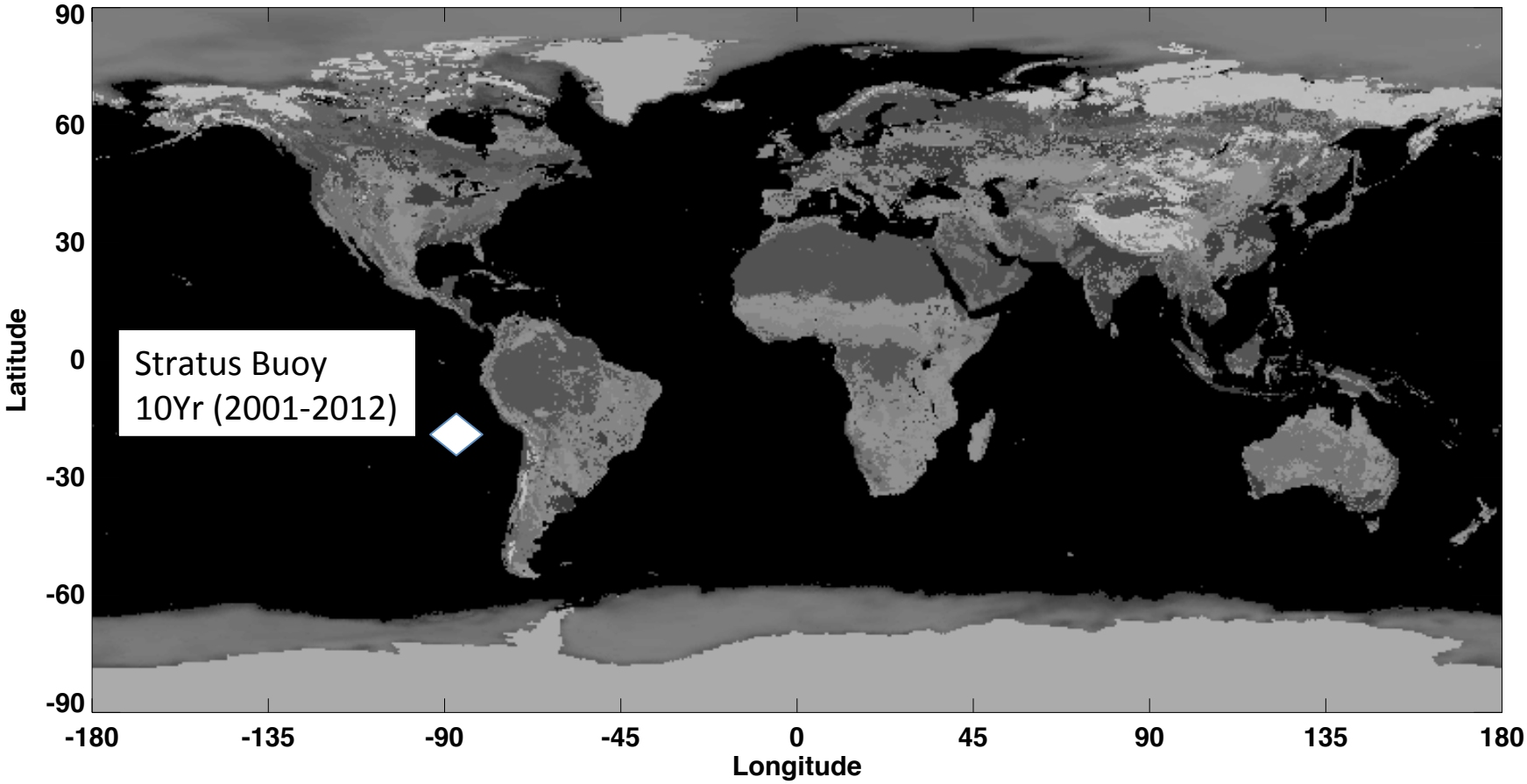
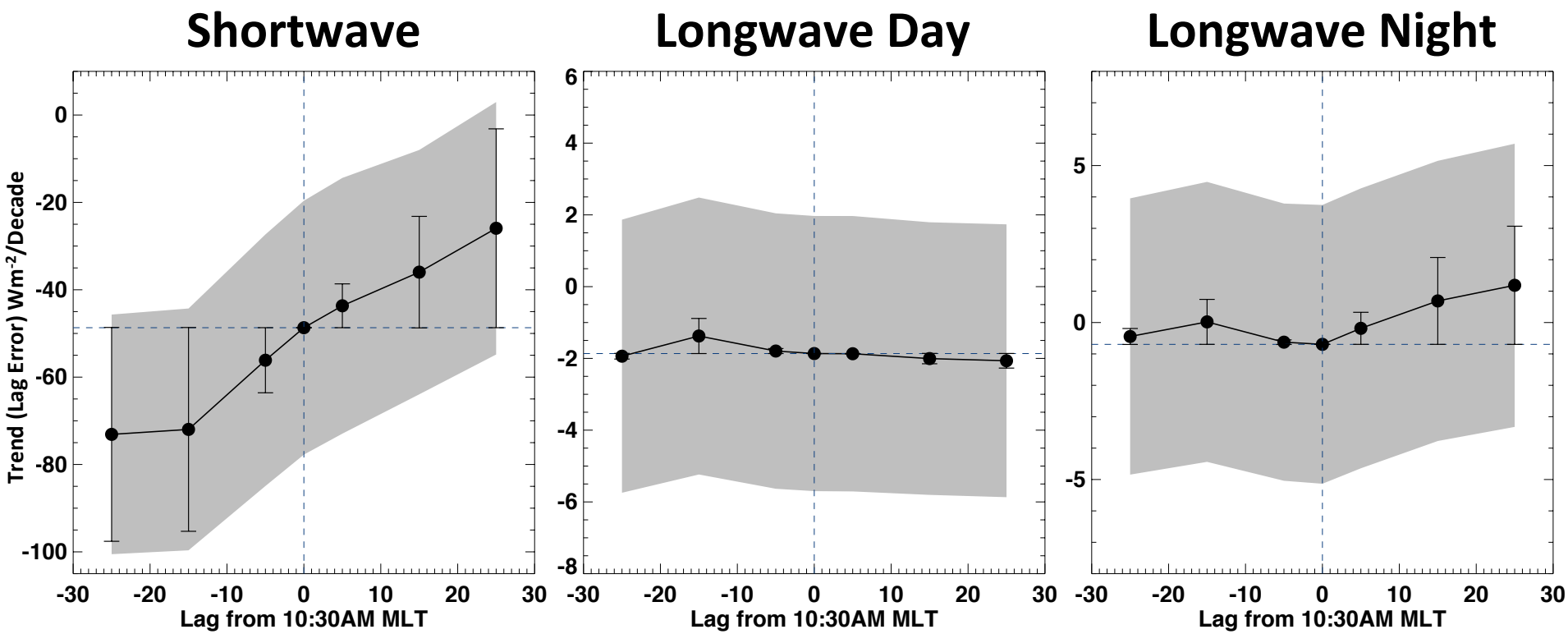
Stratus Buoy (STR) (Woods Hole Ocean. Inst.) 10 Year Record



Stratus Buoy Surface Flux Down
Trend and Error for Lag/Lead Times w.r.t. 10:30AM



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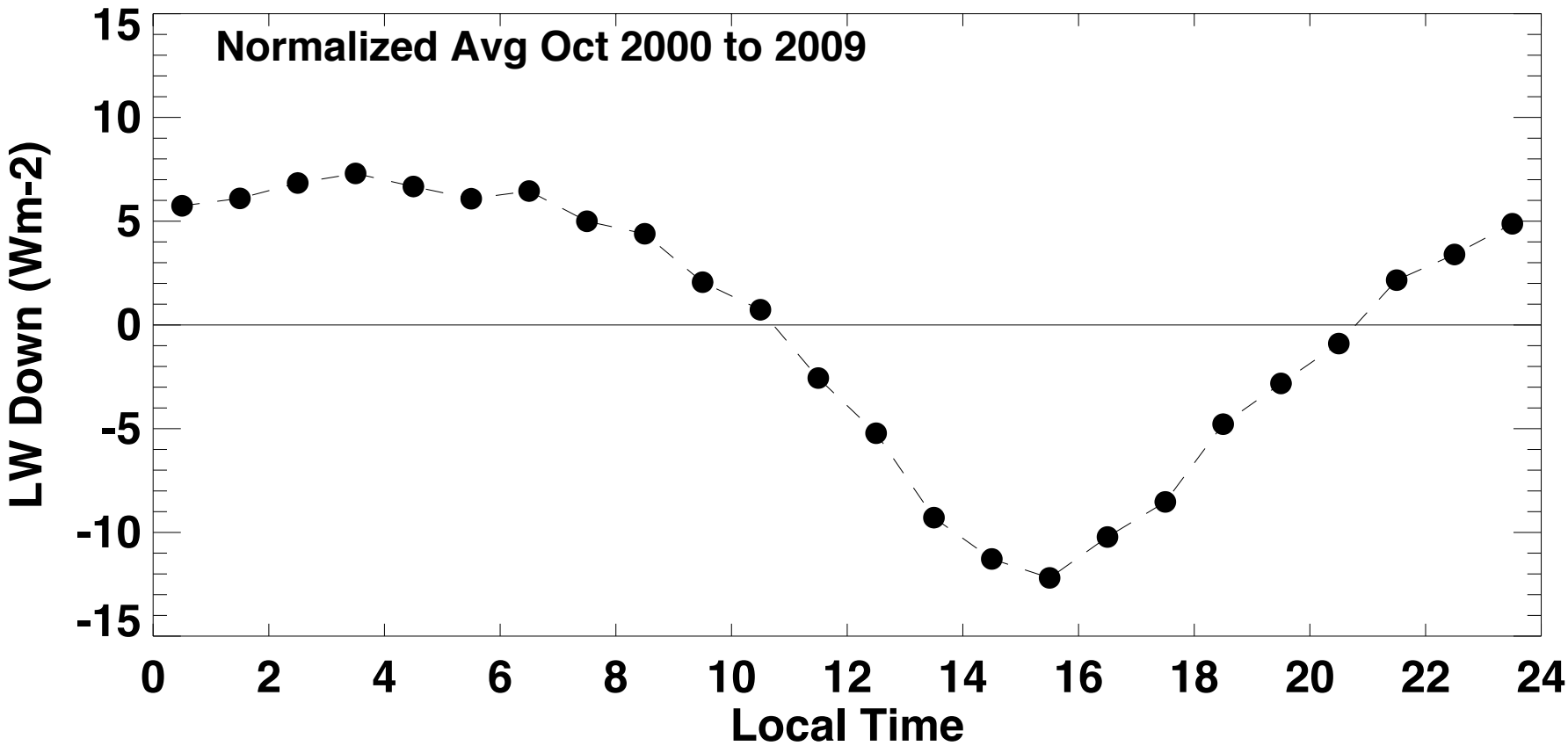
LW Diurnal Cycle STRATUS Buoy



SW Down Trend (Err) Wm^{-2}/Decade

Site		-25min	-15min	-5min	10:30AM	+5min	+15min	+25min
	+95%Conf	15.4	13.5	16.3	16.8	17.8	21.2	21.9
BIL	Trend (Err)	3.9 (1.7)	2.1 (3.5)	5.1 (0.5)	5.6 (0.0)	6.6 (1.0)	10.1 (4.5)	10.7 (5.1)
	-95%Conf	-7.6	-9.3	-6.2	-5.7	-4.7	-1.0	-0.6
	+95%Conf	43.6	46.1	47.2	48.4	50.3	52.6	53.3
TAM	Trend (Err)	32.5 (4.3)	34.9 (1.9)	35.7 (1.1)	36.8 (0.0)	38.7 (1.9)	41.1 (4.3)	41.8 (5.0)
	-95%Conf	21.4	23.6	24.1	25.2	27.1	29.6	30.3
	+95%Conf	13.4	13.6	15.6	16.1	15.4	15.8	16.1
BAR	Trend (Err)	7.2 (2.8)	7.5 (2.5)	9.5 (0.5)	10.0 (0.0)	9.3 (0.7)	9.7 (0.3)	9.9 (0.0)
	-95%Conf	1.0	1.4	3.4	3.8	3.1	3.6	3.8
	+95%Conf	15.0	13.5	16.0	16.6	17.1	19.6	19.8
BER	Trend (Err)	4.2 (2.4)	2.7 (3.9)	5.9 (0.6)	6.5 (0.0)	7.0 (0.5)	9.1 (2.7)	9.5 (3.0)
	-95%Conf	-6.7	-8.2	-4.3	-3.6	-3.1	-1.4	-0.7
	+95%Conf	-45.7	-44.3	-27.3	-19.6	-14.4	-8.0	3.0
STR	Trend (Err)	-73.1 (24.5)	-72.0 (23.3)	-56.1 (7.5)	-48.7 (0.0)	-43.7 (5.0)	-36.0 (12.8)	-25.9 (22.8)
	-95%Conf	-100.5	-99.6	-84.9	-77.7	-72.9	-63.9	-54.8

BIL: Billings OK (Mid-Latitude)
TAM: Tamanrasset Alg. (Desert)
BAR: Barrow AK (N Polar)
BER: Bermuda (Island)
STR: Stratus Buoy (Tropical Marine StCu)

LW Down Trend (Err) Wm^{-2}/Decade (10:30AM)

Site		-25min	-15min	-5min	10:30AM	+5min	+15min	+25min
	+95%Conf	5.4	5.8	5.9	6.0	6.2	6.4	6.7
BIL	Trend (Err)	3.1 (0.6)	3.5 (0.3)	3.7 (0.1)	3.8 (0.0)	3.9 (0.1)	4.1 (0.3)	4.4 (0.7)
	-95%Conf	0.9	1.2	1.4	1.5	1.6	1.8	2.2
	+95%Conf	11.0	11.5	11.9	12.1	12.2	12.6	13.1
TAM	Trend (Err)	7.7 (1.1)	8.2 (0.6)	8.6 (0.2)	8.8 (0.0)	9.0 (0.1)	9.4 (0.6)	9.9 (1.0)
	-95%Conf	4.4	4.9	5.4	5.6	5.7	6.2	6.6
	+95%Conf	8.1	7.9	7.7	7.8	7.9	7.9	7.9
BAR	Trend (Err)	4.2 (0.3)	4.0 (0.1)	3.9 (0.1)	4.0 (0.0)	4.0 (0.1)	4.0 (0.1)	4.0 (0.1)
	-95%Conf	0.4	0.1	0.0	0.1	0.1	0.1	0.2
	+95%Conf	0.6	0.7	0.8	0.8	0.9	1.1	1.3
BER	Trend (Err)	-1.0 (0.2)	-0.9 (0.1)	-0.8 (0.0)	-0.8 (0.0)	-0.7 (0.1)	-0.4 (0.3)	-0.2 (0.5)
	-95%Conf	-2.5	-2.4	-2.3	-2.3	-2.2	-2.0	-1.8
	+95%Conf	1.9	2.5	2.0	2.0	2.0	1.8	1.7
STR	Trend (Err)	-1.9 (0.1)	-1.4 (0.5)	-1.8 (0.1)	-1.9 (0.0)	-1.9 (0.0)	-2.0 (0.1)	-2.1 (0.2)
	-95%Conf	-5.7	-5.2	-5.6	-5.7	-5.7	-5.8	-5.9

BIL: Billings OK (Mid-Latitude)
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Summary

*Whether changed or not appears that it will remain within +/- 15mins of 10:30 MLT through 2020.

*Resultant error is largely a function of climatology of the site.

*More pronounced with stronger diurnal cycles.

*Worst case scenario (Where clouds change rapidly around 10:30, eg. at Stratus buoy with marine StCu) the error is approaching the 95% confidence band at 15 minutes lag.