Variability of the total surface radiation budget and its components over the U.S. from 1996 through 2011

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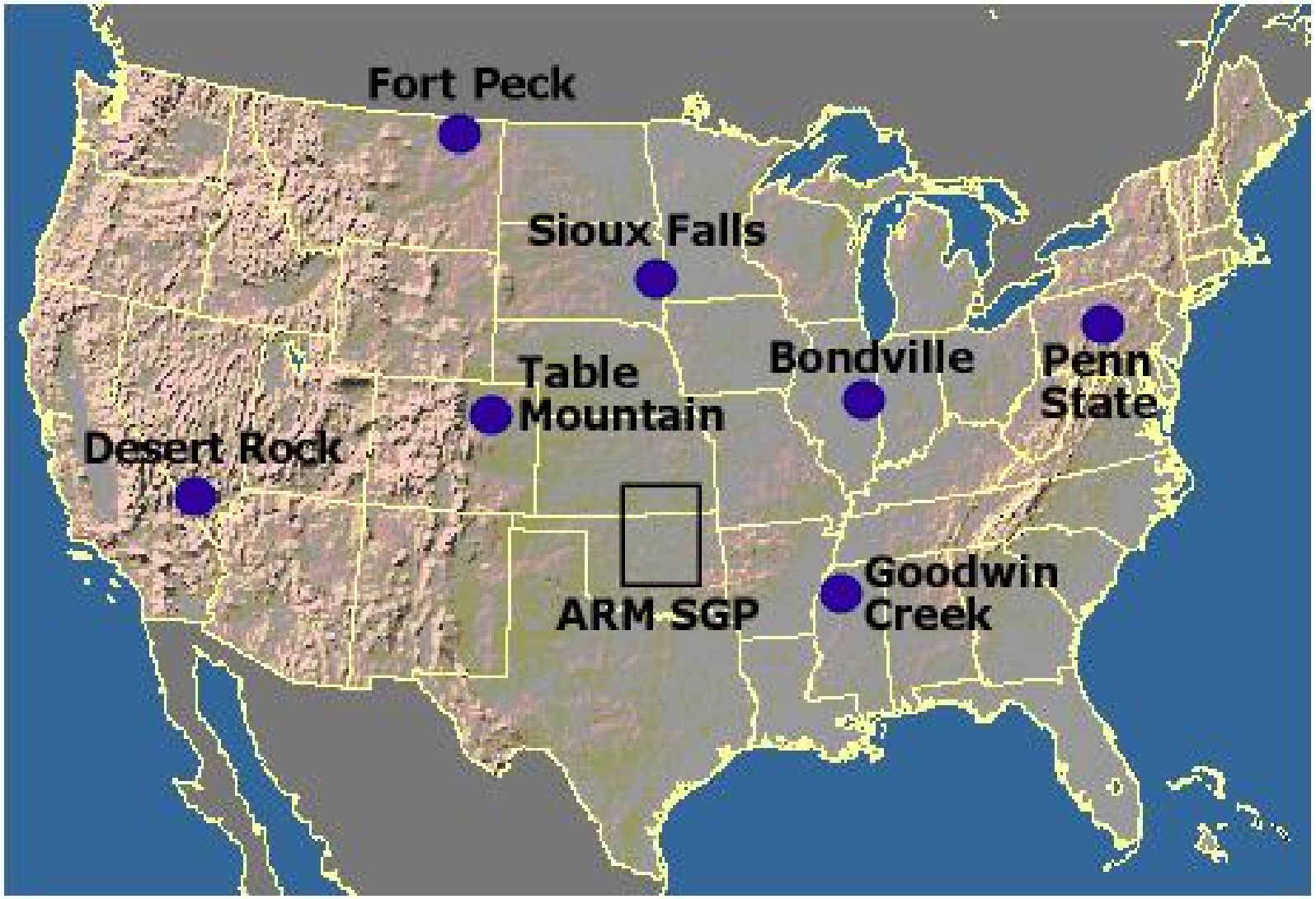
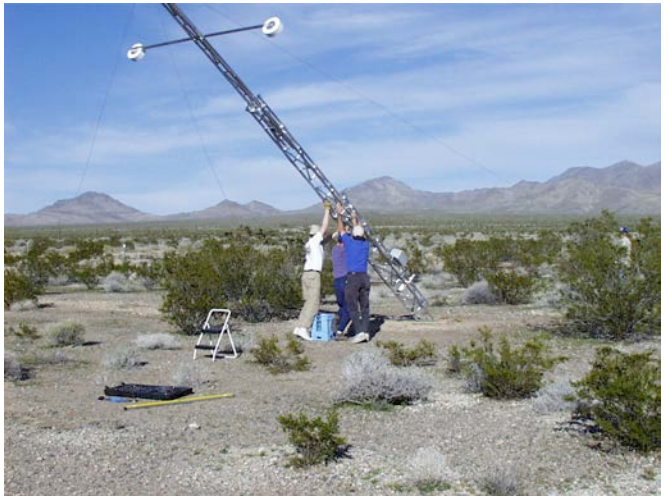
The SURFRAD Network



SURFRAD stations

Sioux Falls, SD



Desert Rock, NV

Fort Peck, MT

Penn State, PA

Analysis

- 16 years of continuous minute-scale Surface Radiation Budget and support data (1996-2011)

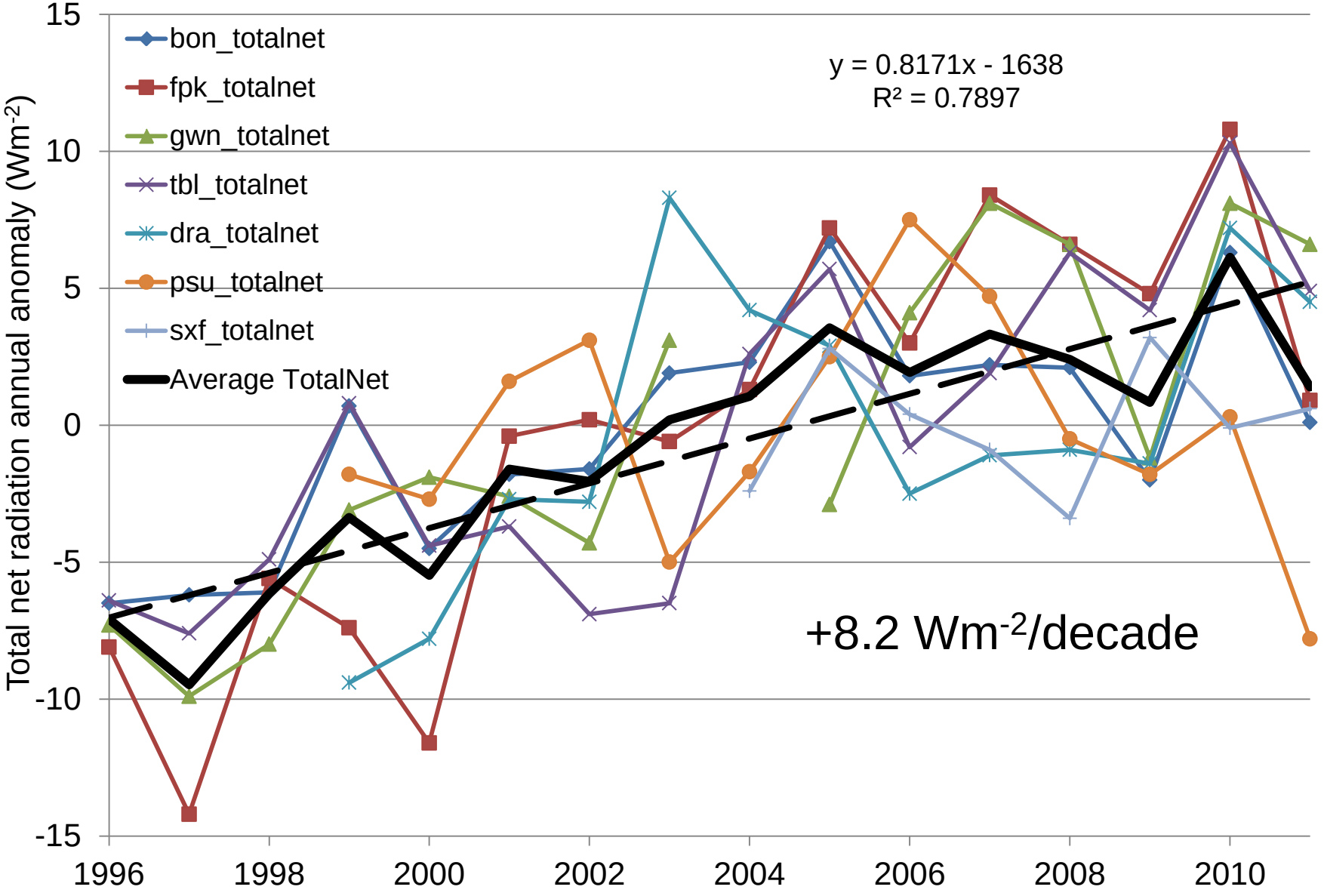
- Monthly averages were computed for all measured and derived quantities for each station

- Annual averages computed from monthly means

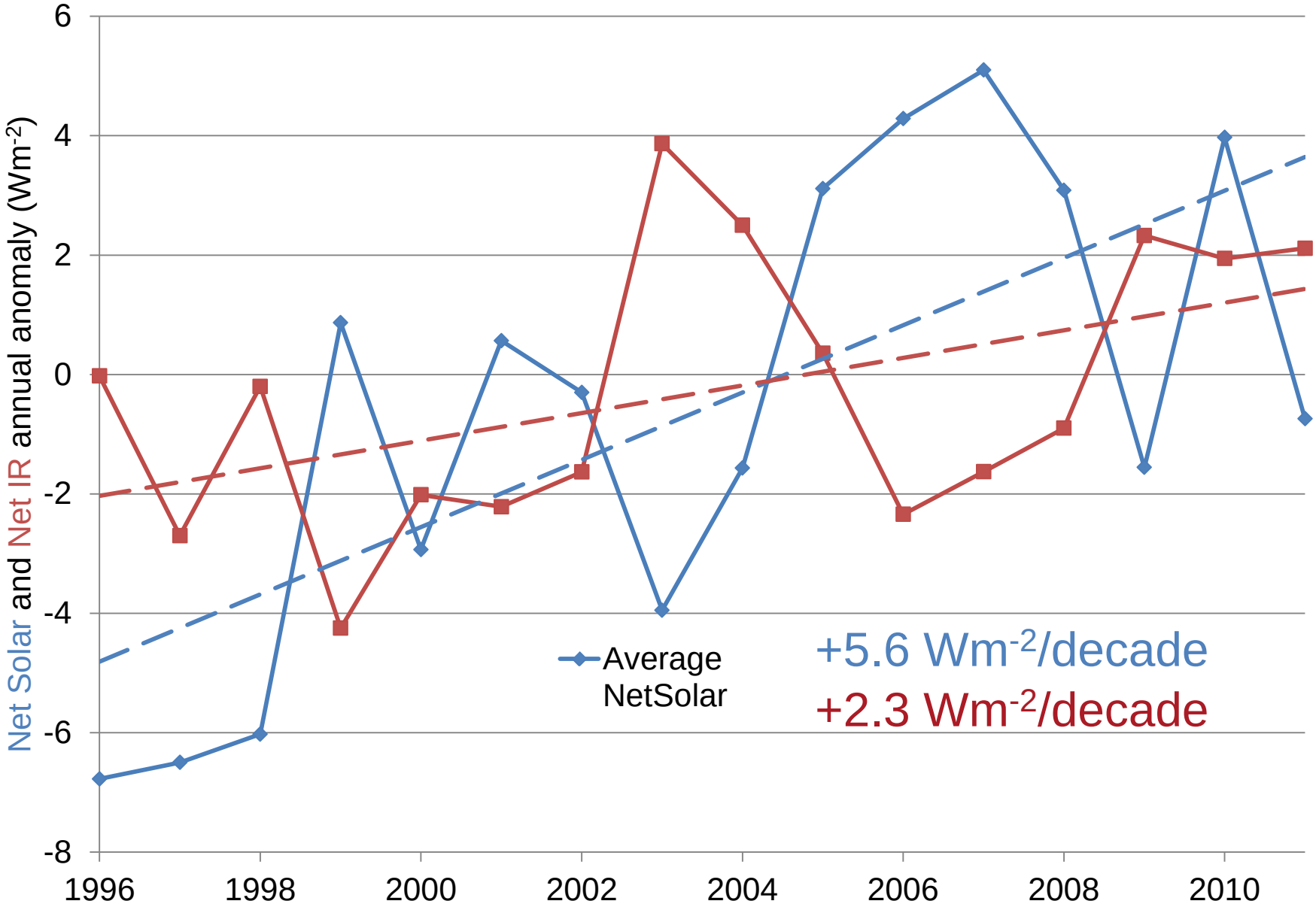
- We normalized the annual averages by computing anomalies from the long-term means

Total net surface radiation

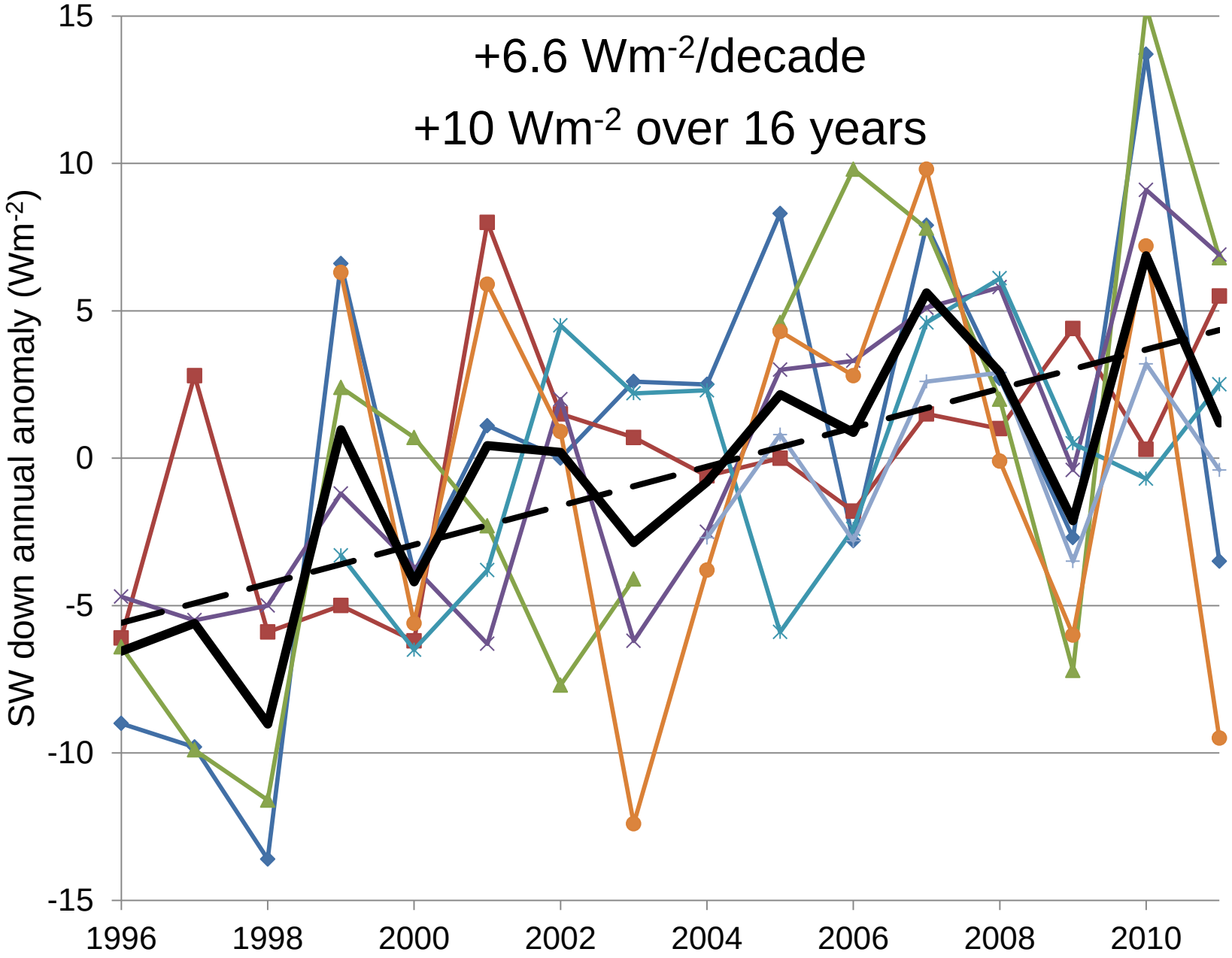
SW↓ - SW↑ + LW↓ - LW↑



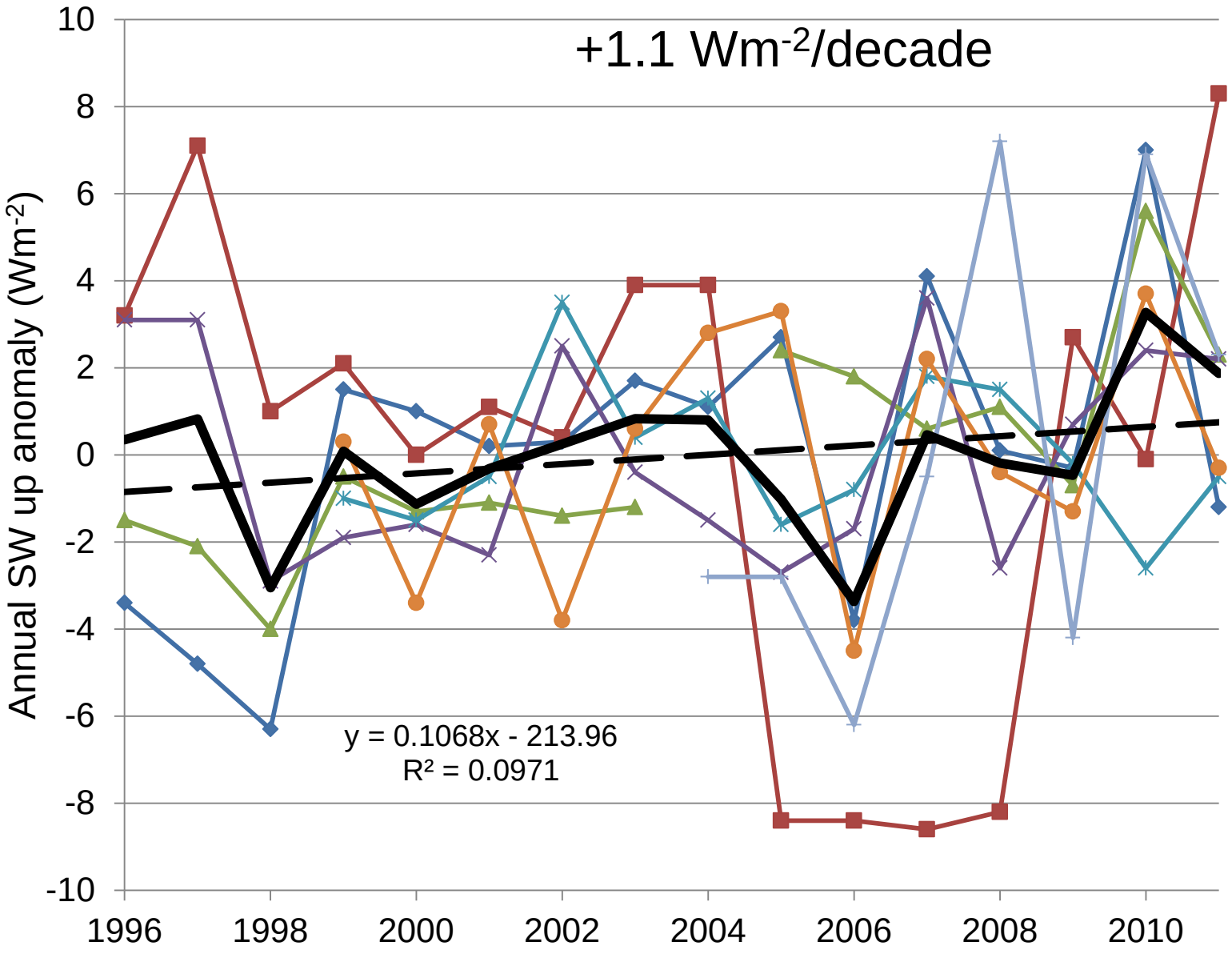
Net Solar and Net Longwave



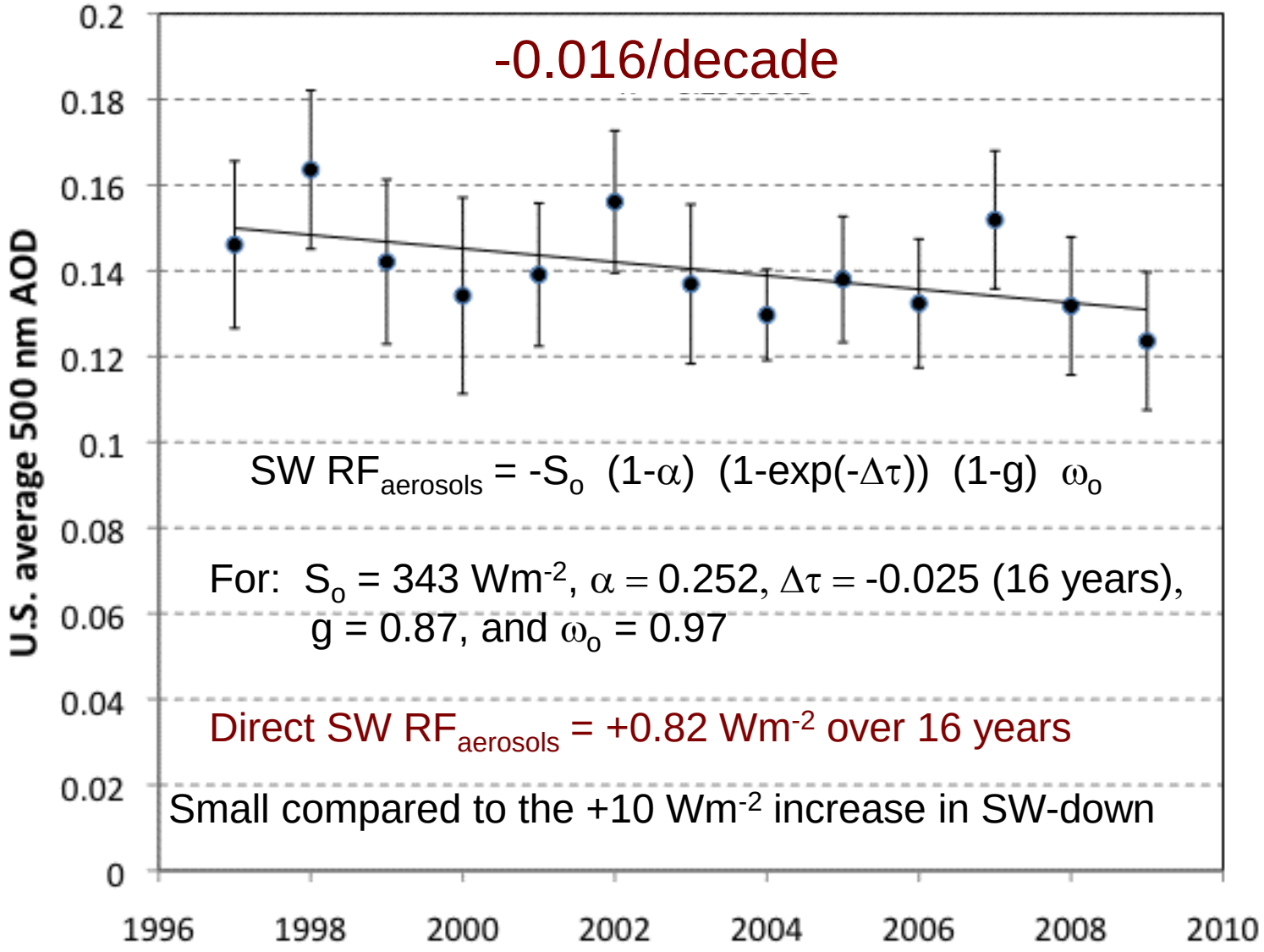
Shortwave–down (SW↓)



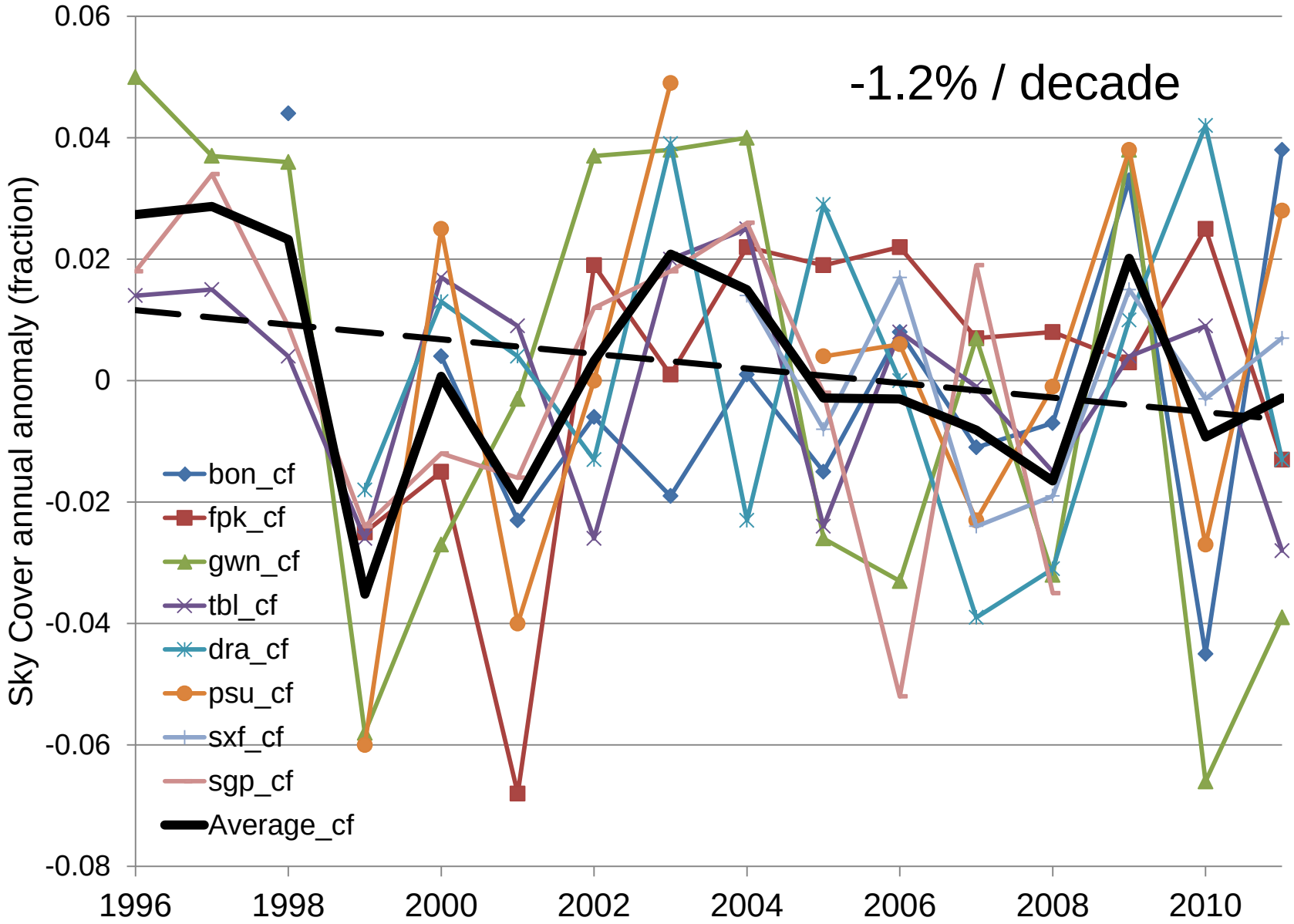
Shortwave–up (SW↑)



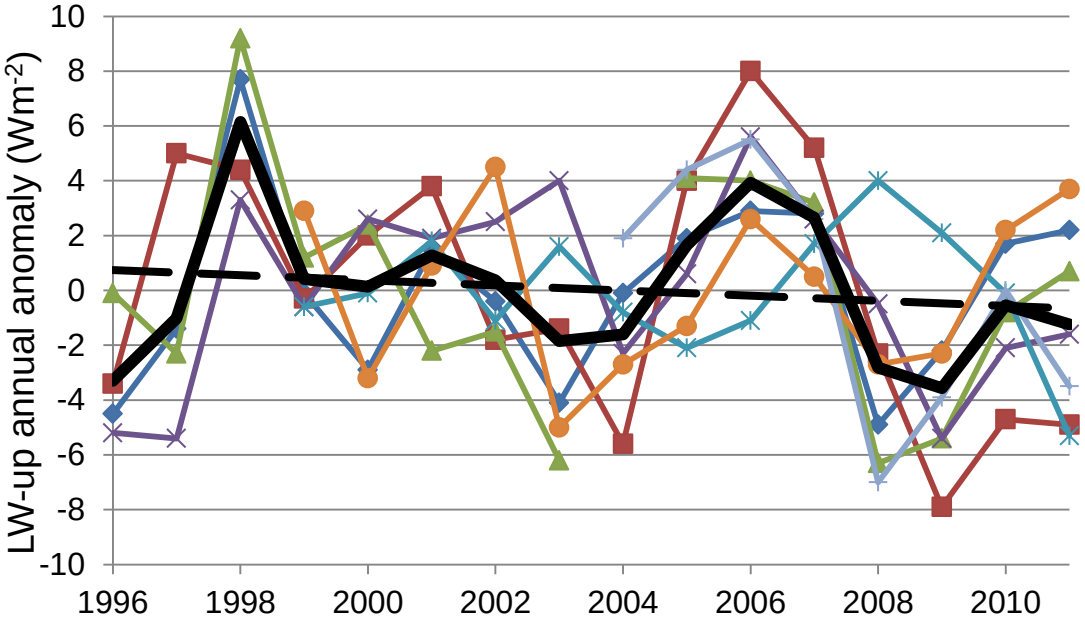
500 nm Aerosol optical depth



Fractional sky cover

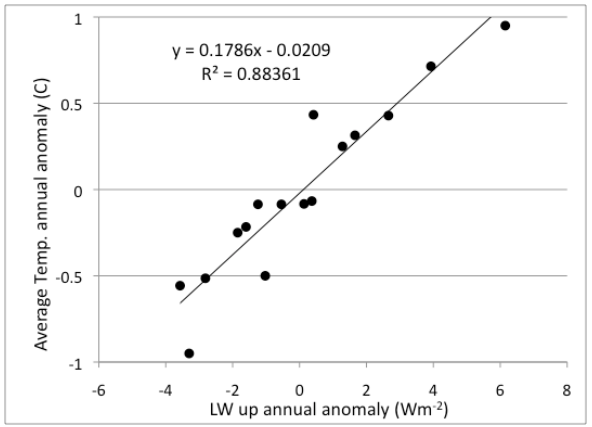


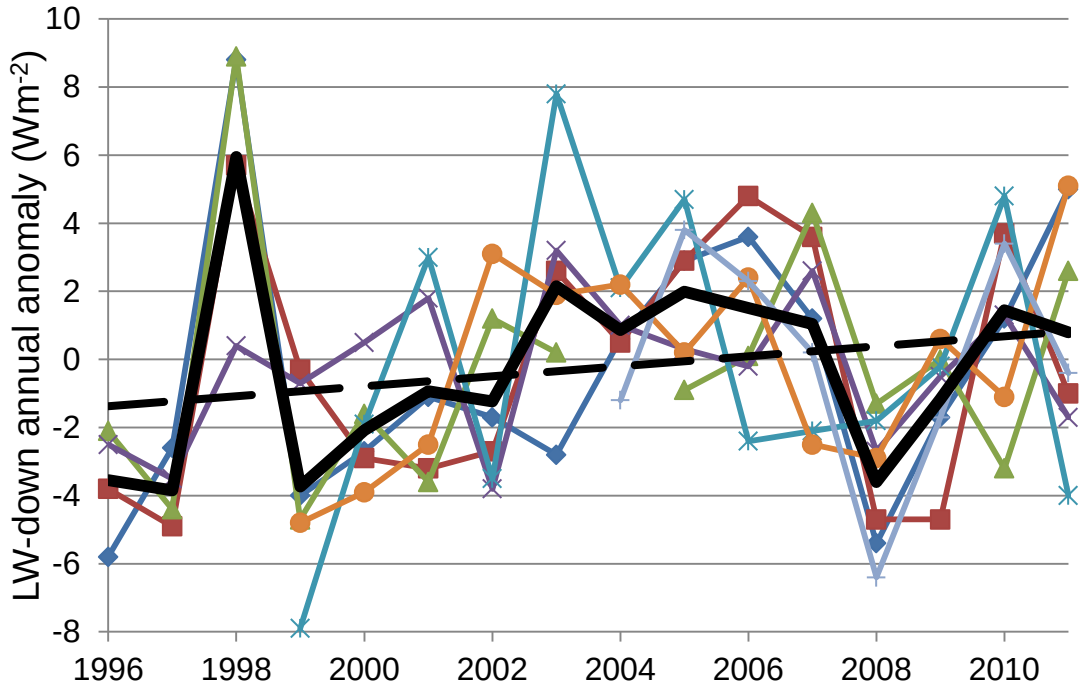
Net LW +2.3 Wm^{-2}/decade



LW↑

-0.9 Wm^{-2}/decade

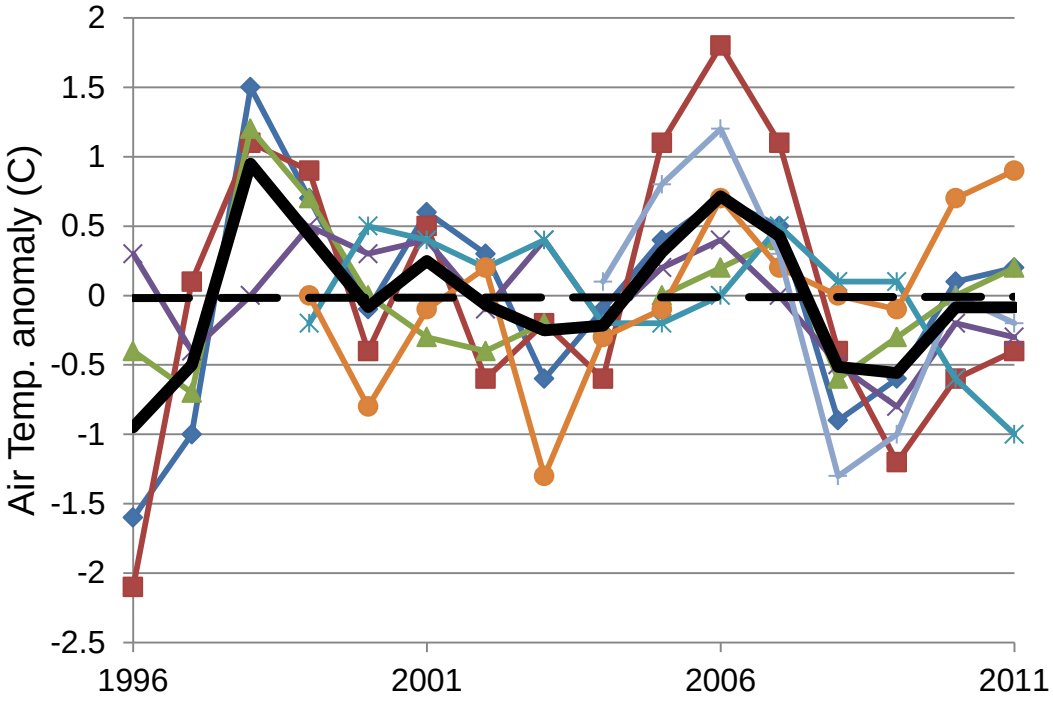




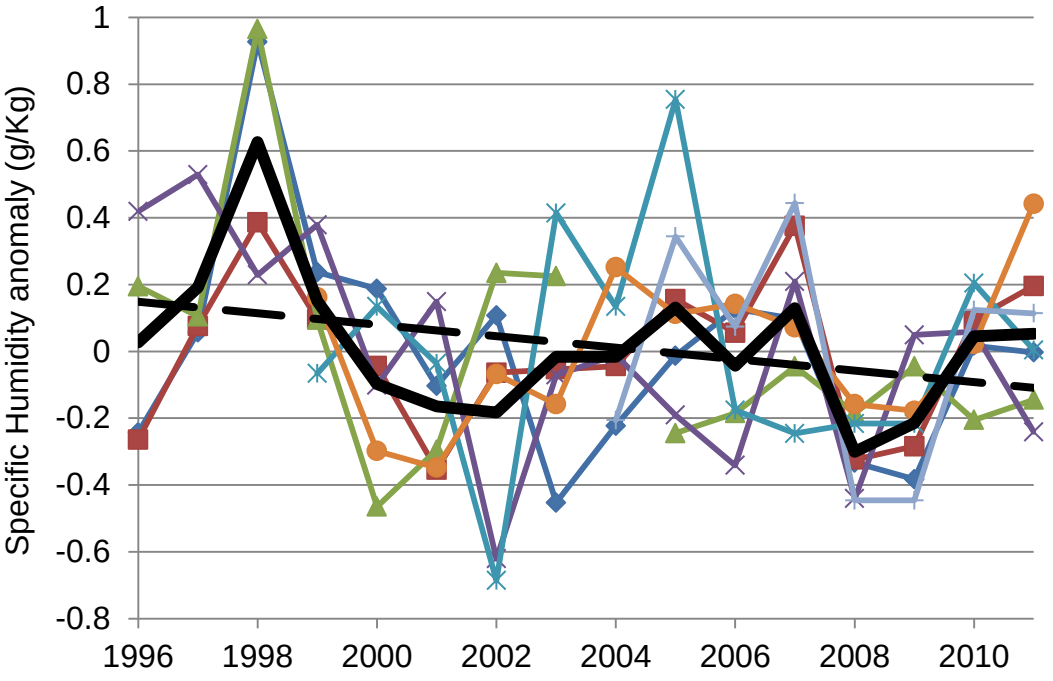
LW↓

+1.5 Wm^{-2}/decade

30 ppm increase in CO_2 (1996-2011) explains only+0.09 Wm^{-2}/decade

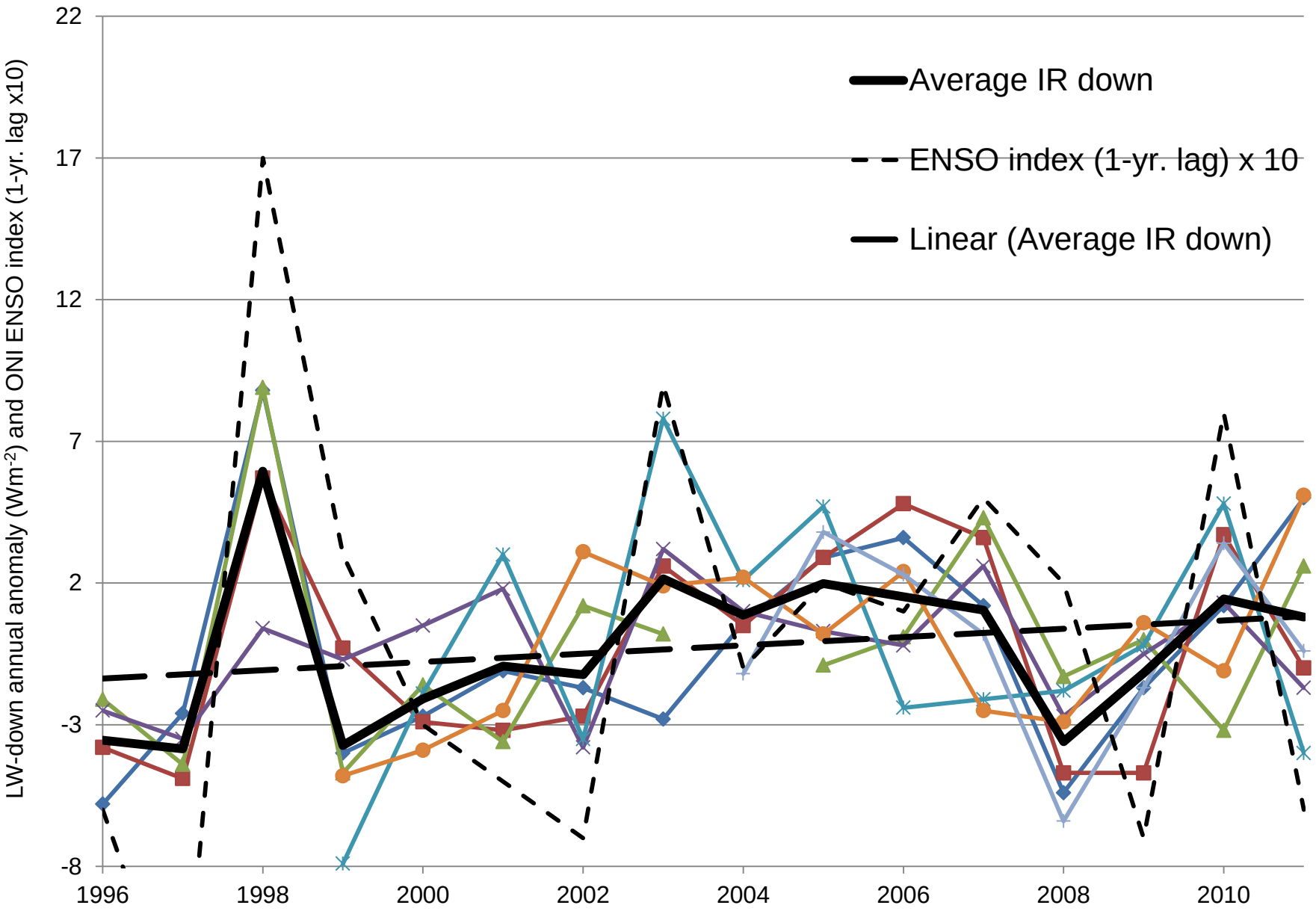


No trend in
Air Temperature

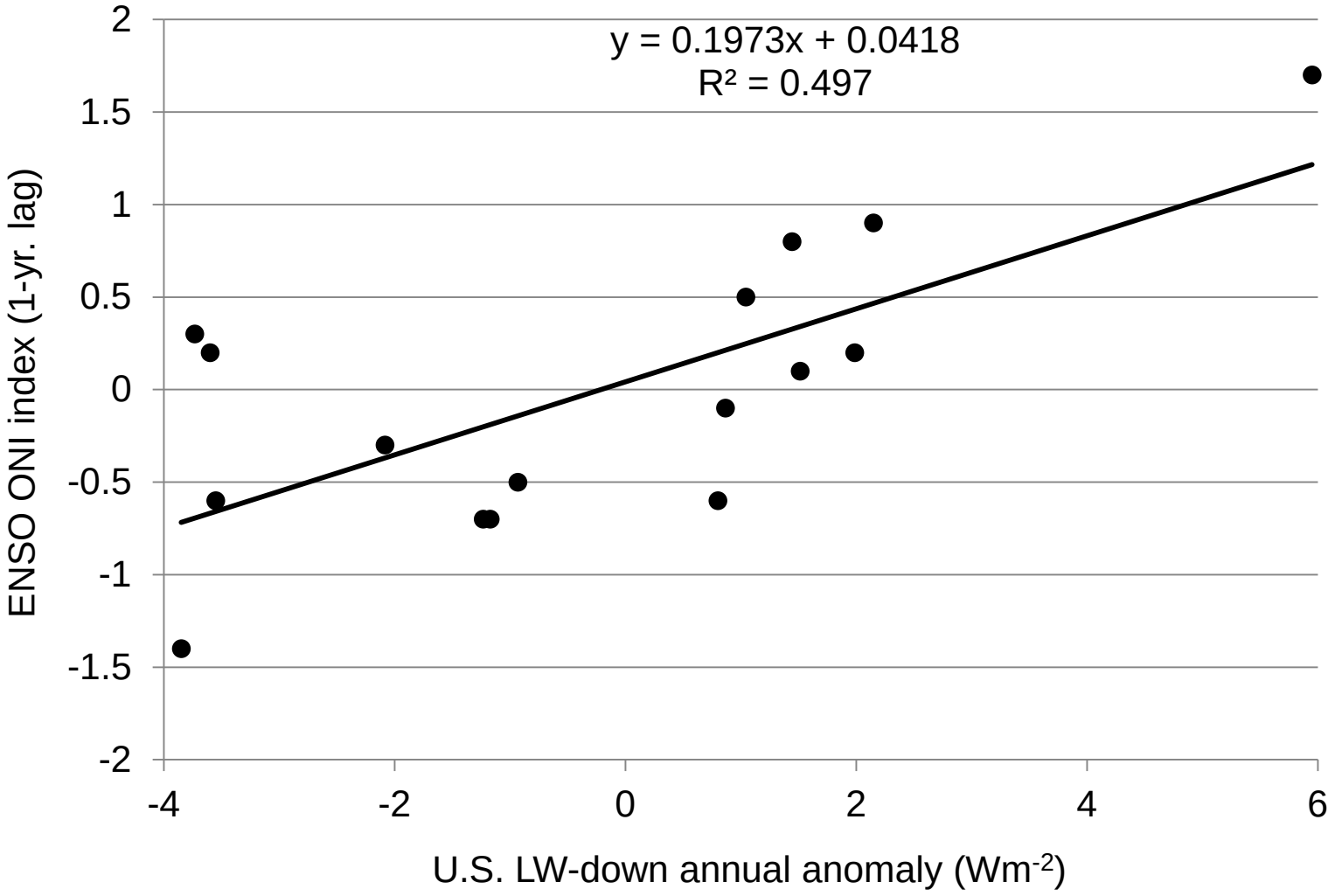


Specific humidity
-0.17g/Kg / decade

LW-down and ENSO



ENSO index vs. U.S. LW-down



Summary

✓ Detected a +8.2 Wm^{-2}/decade trend in U.S. total net radiation from 1996 to 2011

✓ Solar brightening of is the dominant contributor to the SRB increase

✓ Decreasing cloud cover was mostly responsible for the observed brightening; decreasing aerosols had only a minor effect

✓ Net LW shows a +2.3 Wm^{-2}/decade increase, but with high interannual variability – not statistically significant

✓ Variability of $LW\uparrow$ well explained by the surface air temperature variability

✓ The small increase in $LW\downarrow$, if real, is not consistent with the flat trend in surface air temperature, decreasing specific humidity, or decreasing cloud cover

✓ The variability in $LW\downarrow$ does appear to be modulated by ENSO

✓ Coincident surface heat flux measurements would have been useful to help explain how the surplus surface net radiation of 12 Wm^{-2} was utilized

END

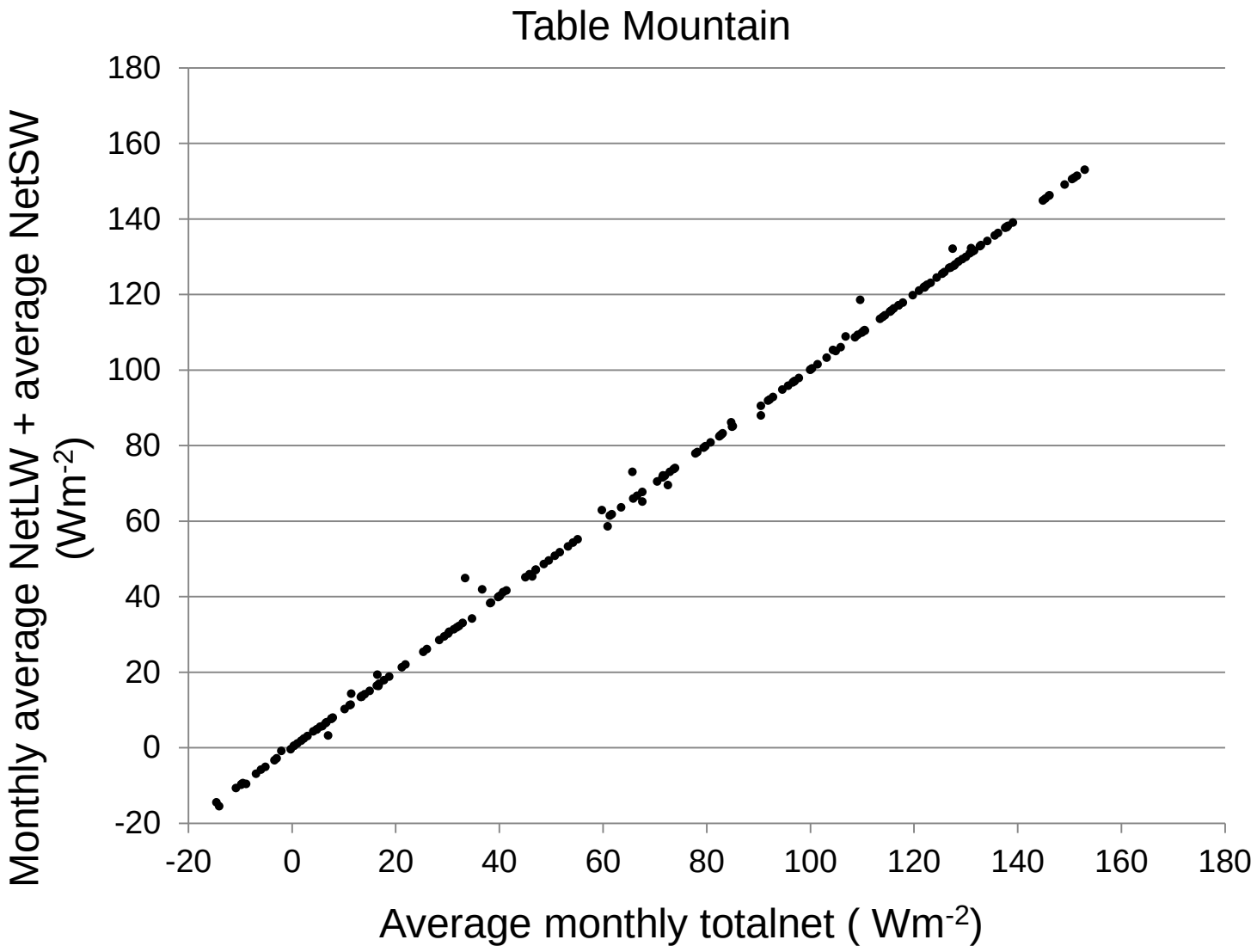
Monthly coverage of radiation measurements

Station	quantity	100% coverage	≥95% coverage	70-94% coverage	<70% coverage
Bondville	NetSW	83.8%	96.4%	2.1%	1.6%
1996-2011	NetIR	76.6%	93.8%	5.2%	1.0%
192 months	TotalNet	75.0%	93.8%	4.2%	2.1%
Fort Peck	NetSW	77.6%	94.3%	1.6%	4.2%
1996-2011	NetIR	72.9%	90.1%	6.3%	3.6%
192 months	TotalNet	67.2%	88.5%	6.8%	4.7%
Goodwin Cr.	NetSW	76.1%	92.2%	5.6%	2.2%
1996-2011	NetIR	73.9%	91.7%	5.0%	3.3%
180 months	TotalNet	70.6%	88.9%	7.8%	3.3%
Table. Mt.	NetSW	71.9%	97.9%	2.1%	0.0%
1996-2011	NetIR	64.6%	93.2%	4.7%	2.1%
192 months	TotalNet	56.3%	92.7%	5.2%	2.1%
Desert Rock	NetSW	75.6%	93.0%	6.4%	0.6%
1999-2011	NetIR	67.3%	89.2%	5.1%	5.8%
156 months	TotalNet	65.4%	87.2%	6.4%	6.4%
Penn State	NetSW	78.9%	97.4%	1.3%	1.3%
1999-2011	NetIR	82.1%	96.2%	1.3%	2.6%
156 months	TotalNet	94.9%	94.9%	2.6%	2.6%
Sioux Falls	NetSW	83.3%	99.0%	1.0%	0.0%
2004-2011	NetIR	56.3%	97.9%	2.1%	0.0%
96 months	TotalNet	55.2%	96.9%	3.1%	0.0%

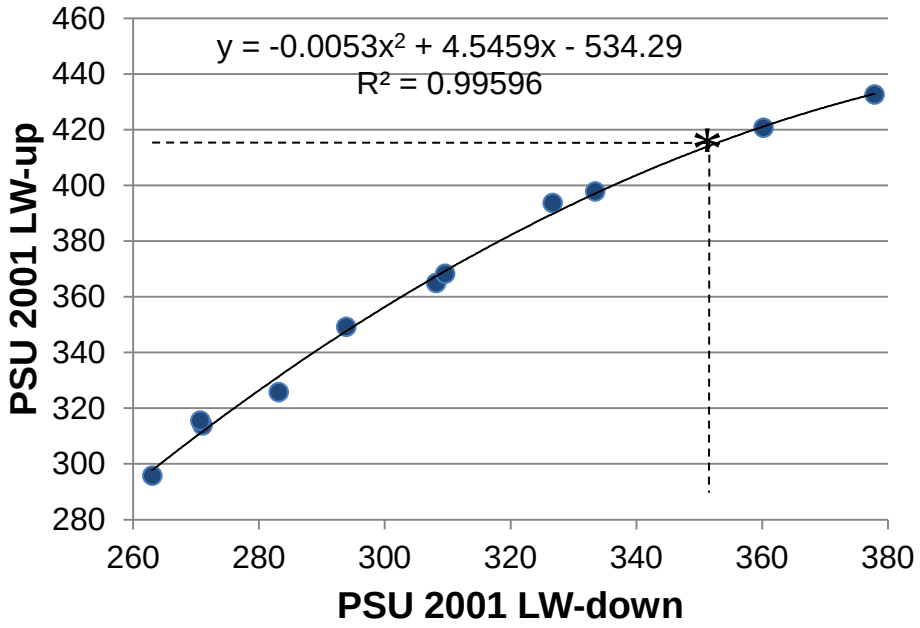
Mann Kendall results for trend significance (95% level)

Parameter	MK median trend	95% lower limit trend	95% upper limit trend	MK significance
Total surface net	+0.86	+0.57	+1.08	significant
Net SW	+0.53	+0.27	+1.08	significant
Net LW	+0.20	-0.05	+0.49	not significant
SW-down	+0.72	+0.26	+1.11	significant
SW-up	+0.07	-0.09	+0.29	not significant
LW-down	+0.26	-0.13	+0.52	not significant
LW-up	-0.08	-0.43	+0.30	not significant
Temperature	-0.001	-0.07	0.07	not significant
Specific humidity	-0.01	-0.03	0.01	not significant
Sky cover	-0.002	-0.004	0.0009	not significant

Consistency among SRB variables



Monthly gap filling



1. Empirical methods
2. Physical relationships
   e.g., SW-down = SW-up / albedo
3. Collocated data
4. Other sources (e.g.,http://weather-warehouse.com)
5. NCEP Reanalysis (Temp., RH)