Searching for Global Dimming Evidence at SGP and Update of ARM Submissions to BSRN

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Introduction

Global dimming, usually defined as a reduction of incoming solar radiation (insolation) at the surface of the earth, is a topic being discussed with increasing frequency. A recent news article on global dimming in the web-based newspaper the Guardian Unlimited <http://www.guardian.co.uk/> seems to have brought this issue to the forefront with scientists and laypeople alike. In fact, there is a special session devoted to global dimming at the upcoming May 17-21 American Geophysical Union (AGU) meeting in Montreal, Canada. The article quotes Atsumu Ohmura and references his findings on this subject. Ohmura has found evidence that at some locations insolation has been reduced by 10% over a period of 30 years (60’s to the 80’s). Another scientist, Helen Power, quoted in the same Guardian Unlimited article has found that in the 1990’s insolation on average has increased slightly in Germany when compared to prior decades, indicating that for at least the area of study global dimming may be easing (Power 2003). Graham Farquhar is another researcher who has been studying global dimming. His work on the subject has reconciled a paradox in evaporation pan studies; i.e., evaporation has been decreasing with increasing global temperatures (Roderick 2002). Beate Liepert, who is heading the special session at the upcoming AGU meeting, studied surface solar radiation at sites in the United States from 1961 to 1990 (Liepert 2002). He found that insolation declined almost 20 W/m^2 over the thirty years examined in his work. After examining thermopile pyranometer data over the past fifty years, Gerald Stanhill concludes that the globally averaged reduction of insolation has averaged 0.51 ±0.05 W/m^2 per year (Stanhill 2001). In the current work data collected at the Southern Great Plains (SGP) facility are analyzed in an effort to determine if evidence of global dimming (or brightening) can be discerned. The dataset begins in 1993 and continues through 2003, providing just over one decade of data for examination. While most of the previous studies have focused solely on global radiation, global, diffuse, and direct shortwave parameters are investigated here.

Data

The Best Estimate Flux (BEF) dataset is the base dataset used for this analysis. It is a value-added product (VAP) created using an algorithm developed by Shi and Long (Shi 2002). In a nutshell, the BEF data consist of the most accurate data from the three broadband surface radiation measurement sites at SGP (Broadband Radiometer Station (BRS), Extended Facility 13 (E13), and C1 which is often referred to as the radiometer testbed). From Figure 1 we see that the BEF dataset begins midway through 1995, while the first broadband measurements were made in September 1993. Even though the

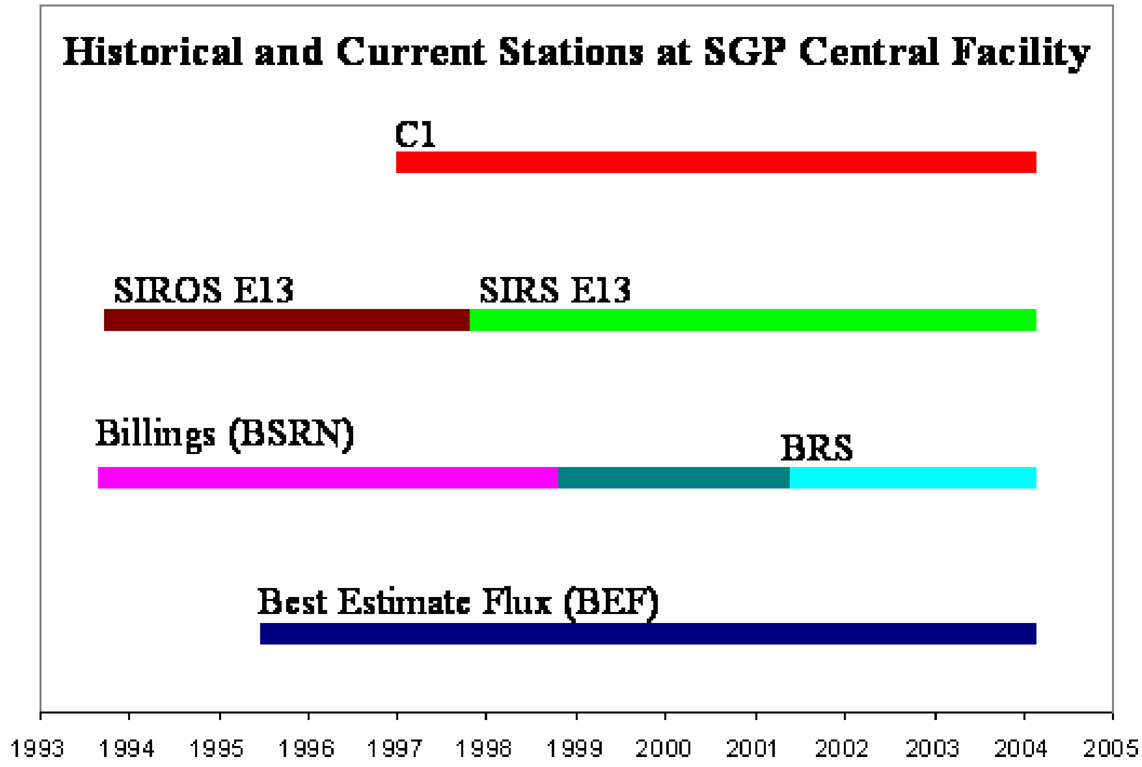

Figure 1. Shows the periods each station was operating. SIROS and SIRS E13 share the same physical location. The site was reconfigured August 1997 when it became SIRS E13. Billings underwent a name change in 2001 becoming BRS. The dark green period of Billings is when that station had intermittent logger problems.

BEF dataset is derived from three stations; there are still sporadic missing data. To fill in the data gaps, data from the original Billings (or Baseline Surface Radiation Network (BSRN)) site, the Solar and Infrared Observing System (SIROS) E13, the Solar Infrared Station (SIRS) E13, BRS, and C1 stations were all used. Without getting too involved in the history of the stations, the instrumentation of each includes radiometers measuring direct, diffuse, and global solar radiation. Data sampling is at one hertz producing one-minute averages with the exception of SIROS E13. This site collected one-minute averages of twenty-second samples. Since the SIROS E13 data are made up of 20-second samples, those data were used to fill gaps only as a last resort. For example, to fill a missing data point an average of the available one-second sampling stations was used, and only if none of those were available, then the SIROS E13 data, if available, were used. Since the BEF dataset uses the summation of the direct and diffuse measurement for the best estimate global data, the direct and diffuse measurements from the other stations were used to fill BEF data gaps of global radiation. As a last resort, the actual global measurement at each station was used if the direct or diffuse measurements were missing. From Table 1 we can see that assembling the data in this fashion produced a robust dataset. Looking at the global column, 102 months have a 100% data rate, fifteen months were between 100% and 95%, and only seven months had more than 5% of data missing. For the analyses presented in Figures 2, 3, and 4, months with more than 5% of the data missing were not considered.

Table 1. The percentage of available data for each of the three parameters under study. Out of 124 months of global data, 102 had 100% available, 15 were between 100% and 95%, and 7 months had less than 95% of data available.

	Global (Summation)	Direct	Diffuse
100%	102	102	101
100% < X ≤ 95%	15	15	16
<95%	7	7	8

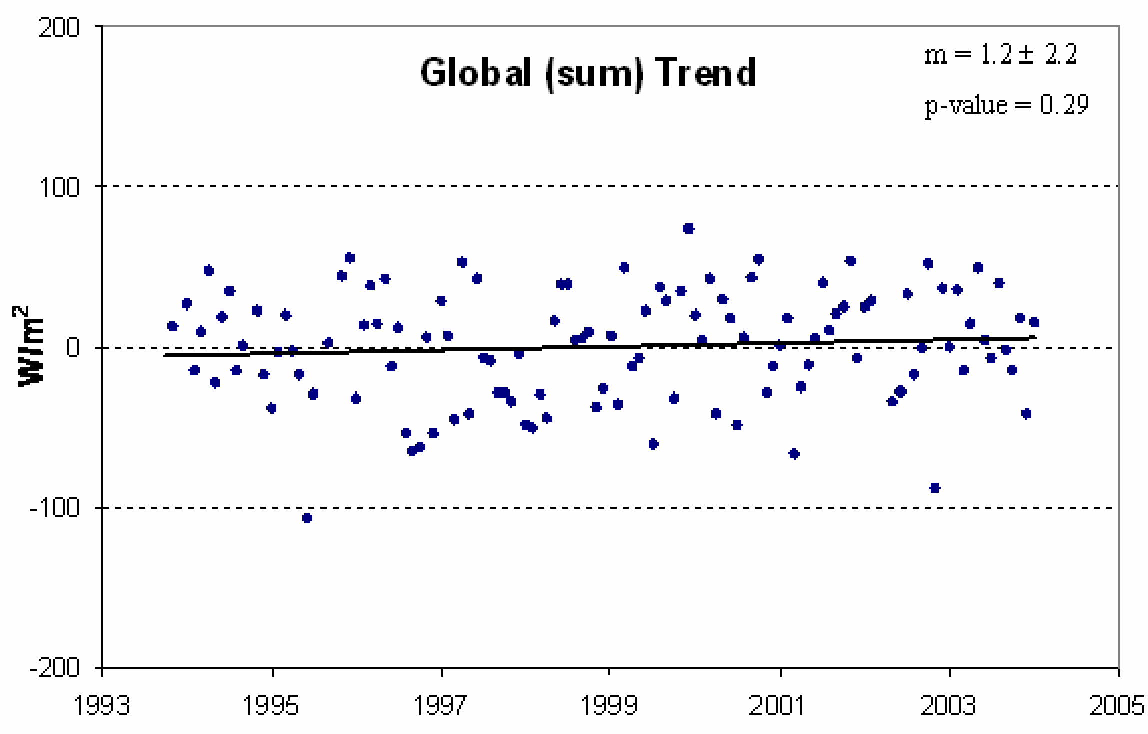

Figure 2. The trend analysis of global (from summation of direct and diffuse) data. Over the 10 year period global radiation was found to have increased at a rate of 1.2 W/m2 per year. This is not, however, statistically significant as the 2σ error overwhelms the calculated trend. The significance level of ~70% is not particularly meaningful when coupled with error in the trend.

Analysis

The first step was to remove the seasonal component in the monthly data since leaving it in can adversely influence trend analysis. To do this the decadal monthly average for each of the twelve months was first calculated for each parameter. That is, for the ten-year dataset a single January average for each component was calculated, and so on. These decadal monthly means were then subtracted from each annual monthly mean, thereby removing the seasonal variation in the dataset. Scatter plots with trend lines were then created and the results of this are seen in Figures 2, 3, and 4. Because only solar

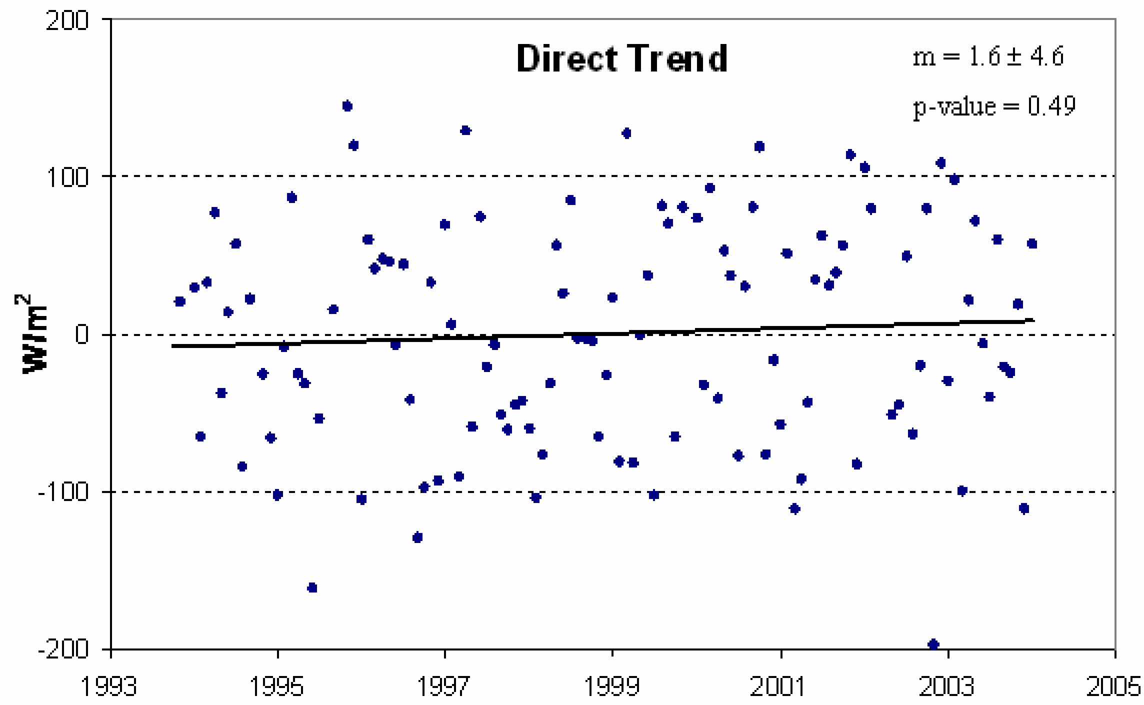

Figure 3. The same as **Figure 1** but for direct component. The calculated trend is less than the 2σ error. The significance level is not particularly insightful.

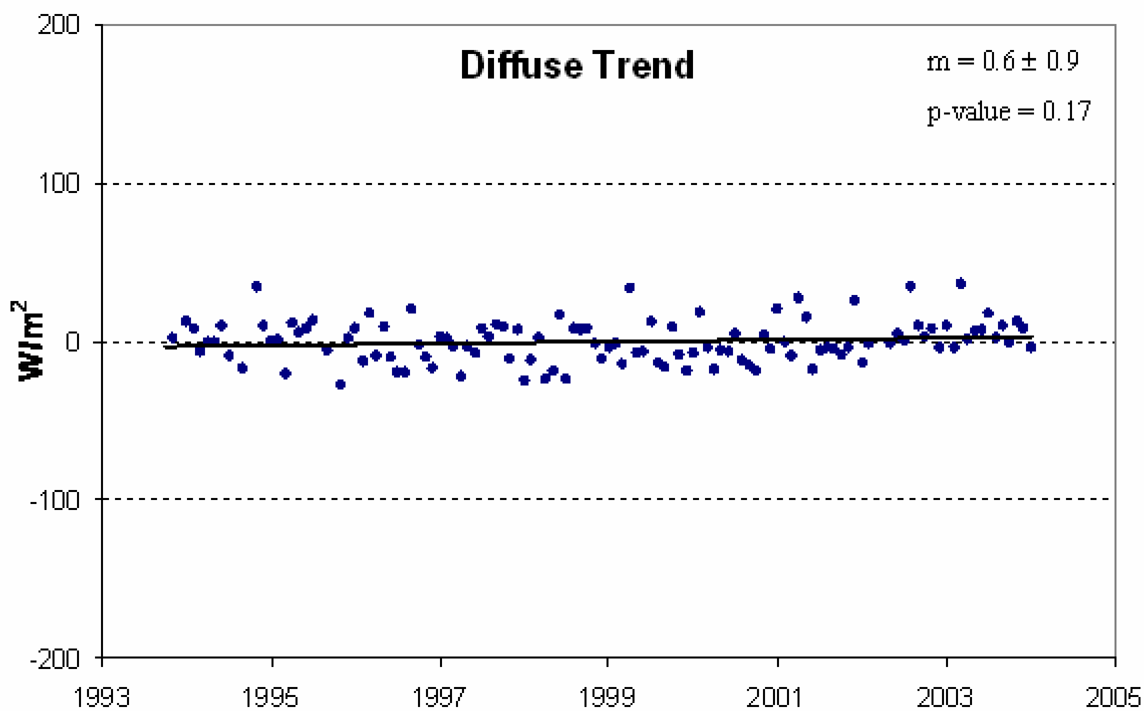

Figure 4. The same as **Figure 1** but for diffuse component. The calculated trend is less than the 2σ error. The significance level is not particularly insightful.

data were examined, all nighttime data were rejected using a zenith angle of 90° as all those data would do is dilute the results. The stated purpose of this project was to determine if any evidence of global dimming could be discerned from broadband data collected at the ARM SGP location. We can see in Figure 2 that the trend line is increasing for the global parameter at a rate of 1.2 W/m^2 per year. While this is interesting and contradicts the general trend found by other researchers in prior decades, the results are not statistically significant as the 2σ error of 2.2 W/m^2 overwhelms the calculated trend. Similar results are found for both the direct and diffuse parameters (Figures 3 and 4) where the trends are 1.6 ± 4.6 W/m^2 and 0.6 ± 0.9 W/m^2 respectively. When performing trend analysis it is customary to examine the p-value, or significance level, as a confidence measure of a calculated trend. Typically a p-value ≤ 0.5, or significance level of 95%, is the cutoff for considering a trend significant. Looking at Figures 2, 3, and 4, we see that the confidence levels are approximately 70%, 50%, and 80% for global, direct and diffuse respectively. So, while these results hint at the possibility that insolation has actually increased over the past ten years, the results are not strong enough to rule out random variability in the data as the cause of the calculated upward trends.

To ascertain if a seasonal trend was evident, the data were averaged according to the seasons (Figure 5). That is, March, April, and May were averaged as spring, June through August as summer, and so on. For this analysis the required percent of available data was relaxed slightly. Since a number of averaging periods were coming in at just under 95% of data available, the threshold was set at 94%. Looking at Table 2 we can that with the threshold set at 94%, only two data points were rejected over the decade of seasonal averages for the summation data. As with the analyses of the monthly data though, the 2σ error and poor confidence levels overwhelm the results of the seasonal analysis. It is interesting to note, however, that while fall and winter trends are essentially flat-lined, spring has a slight upward trend of ~1 W/m^2 per year, and summer has a calculated upward trend of 2.5 W/m^2 per year. It should be kept in mind that some of the months that were rejected in the monthly analyses due to a low percentage of available data are included in the seasonal analysis. It seems unlikely, however, that even with a 100% decadal dataset, statistically significant results would be found.

Summary and Conclusions

In recent years some researchers have been finding evidence of global dimming, or a reduction in incoming solar radiation, in various regions around the world. The bulk of the current studies examine data prior to the 1990's. In this work we examine ten years of data collected at the Southern Great Plains (SGP) research facility beginning with September 1993 in an effort to see if evidence of global dimming can be discerned. The Best Estimate Flux (BEF) Value Added Product dataset is used. To fill gaps in the BEF dataset, data collected at several SGP broadband sites, e.g., C1 and SIRS E13 are used. Monthly and seasonal averages of global, direct, and diffuse parameters were calculated from the ten-year dataset, and trend analyses were performed. In the monthly data small increasing trends are found in all the parameters. For the seasonal data, summer shows a moderate upward trend, while spring, fall, and winter are nearly flat. In all the results, however, the 2σ error and low confidence levels found do not lead one to be confident of the results. So, while there are hints of a general increase in insolation (maybe more pronounced in the summer months), the results are not statistically significant.

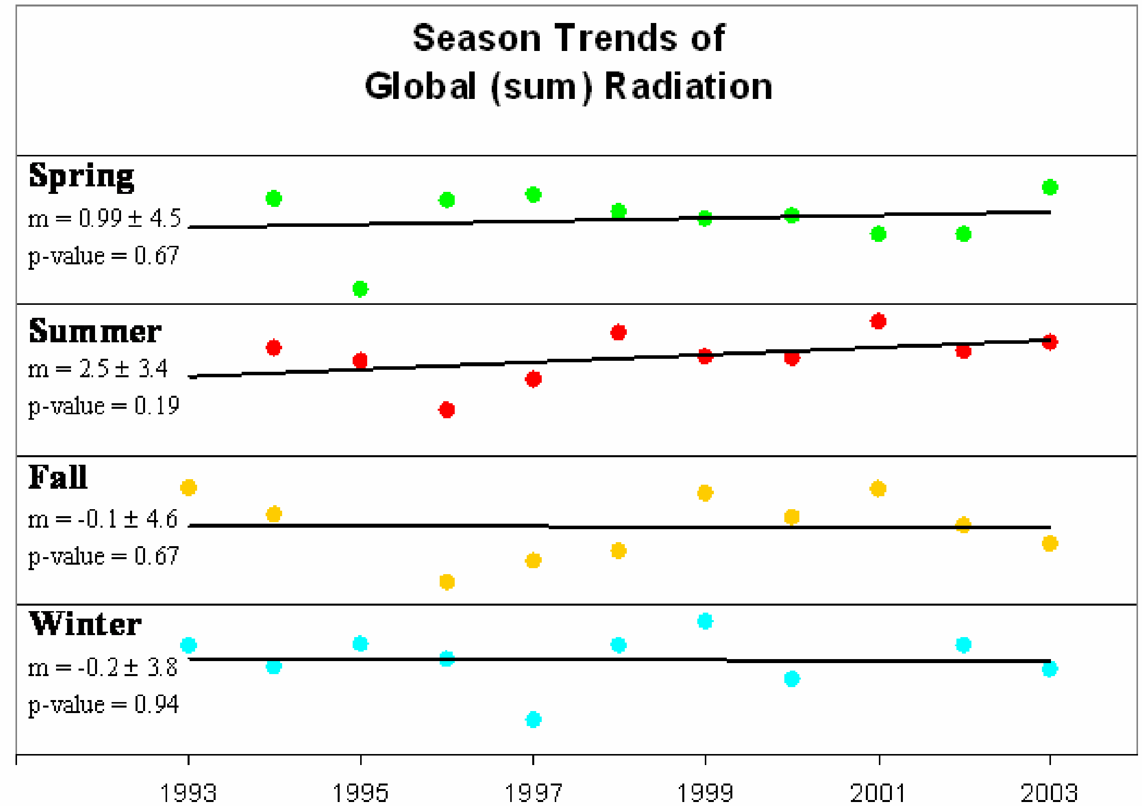

Figure 5. The seasonal trends for spring, summer, fall, and winter are shown. Fall and winter have no appreciable trend. The spring trend is slightly upward, and summer shows the most pronounced seasonal trend. None of these results are statistically significant, however, as the errors and low significance levels cannot exclude random variability in the data.

Table 2. The percentage of available data for each of the four seasons. For example, over the ten years a spring average could be calculated, seven of those years had 100% of the data available and three had between 100% and 94% of available data.

	Spring	Summer	Fall	Winter
100%	7	6	4	9
100% < X ≤94%	3	4	6	1
<94%	0	0	1	1

Appendix: ARM Submissions to the BSRN Database

Data from the four ARM sites included in the Baseline Surface Radiation Network (BSRN) archive (Figure 6), BRS (Billings), E13, Manus and Nauru, have been submitted through December 2003 (Figure 7). Earlier this year all the diffuse data corrected according to the Dutton et al. method have now been submitted for each site when Eppley PSP's were employed for the diffuse measurement.

There were some delays over the past year or so with the submission process, but those problems seem to have been resolved. In the past the delay in getting data from the TWP sites has prevented a timely submission process to the archive, but the TWP data transfer has improved so this shouldn't be problem in the future. As always, if ARM is interested in submitting other stations to the BSRN archive, we are happy to do so.

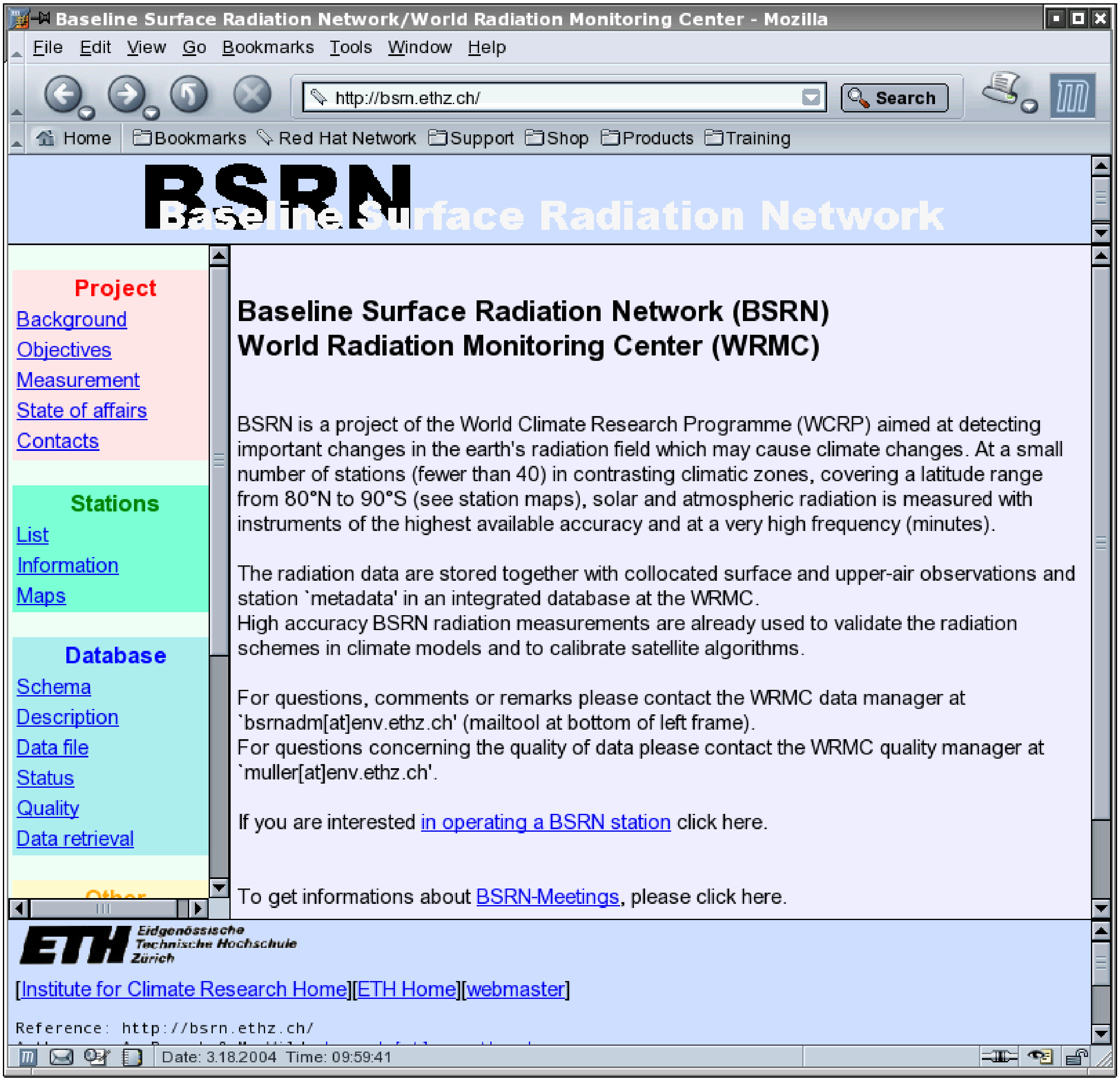

Figure 6. Screen shots of the BSRN home page <http://bsrn.ethz.ch> above and the status page to the right. Note that the status page does not reflect all the files that have been submitted. Currently all ARM sites have been submitted through December 2003. The ARM sites are E13, BIL, MAN, and NAU.

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Other
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News
Links
Sitemap
BSRN file system
FAQ
Mailbox

STATION	YEAR													TOTAL
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	
ASP	-	-	-	12	12	12	12	12	12	12	12	1	-	97
FLO	-	-	6	12	12	12	12	12	-	-	-	-	-	66
REG	-	-	-	12	12	12	12	12	-	-	-	-	-	60
TOR	-	-	-	-	-	-	-	12	4	-	-	-	-	16
CAR	-	-	-	-	4	12	12	12	5	-	-	-	-	45
NYA	5	12	12	12	12	12	12	12	12	12	-	-	-	113
LIN	-	-	3	12	12	12	12	12	12	12	4	-	-	91
GVN	9	12	12	12	12	12	12	12	12	12	-	-	-	117
TAT	-	-	-	-	11	12	12	12	12	12	12	9	-	92
SYO	-	-	12	12	12	12	12	12	12	12	-	-	-	96
PAY	3	12	12	12	12	12	12	12	12	12	12	-	-	123
BAR	12	12	12	12	12	12	12	12	12	12	12	-	-	132
BOU	12	12	12	12	12	12	12	12	12	12	12	-	-	132
BER	12	12	12	12	12	12	12	12	12	12	12	-	-	132
KWA	9	12	12	12	12	12	12	12	12	12	12	-	-	129
SPO	12	12	12	12	12	12	12	12	12	12	12	-	-	132
E13	-	-	-	-	-	4	12	12	12	12	12	6	-	70
BIL	-	6	12	12	12	12	12	12	12	12	12	7	-	121
MAN	-	-	-	-	3	12	12	12	12	12	12	6	-	81
NAU	-	-	-	-	-	-	2	12	12	12	12	6	-	56
FPE	-	-	-	12	12	12	12	12	12	12	12	1	-	97
BON	-	-	-	12	12	12	12	12	12	12	12	1	-	97
GCR	-	-	-	12	12	12	12	12	12	12	12	1	-	97
BOS	-	-	-	5	12	12	12	12	12	12	12	1	-	90
DRA	-	-	-	-	-	-	10	12	12	12	12	1	-	59
PSU	-	-	-	-	-	-	7	12	12	12	12	1	-	56
CAN	-	-	-	-	-	-	-	-	-	-	-	-	-	0
ILO	4	12	12	7	-	-	-	-	-	-	-	-	-	35
CLH	-	-	-	-	-	-	-	-	6	12	12	12	-	42
DAA	-	-	-	-	-	-	-	-	7	12	12	10	-	41
SOV	-	-	-	-	-	-	4	12	12	12	12	-	-	52
TAM	-	-	-	-	-	-	-	-	10	11	-	-	-	21
SBO	-	-	-	-	-	-	-	-	-	-	-	2	-	2
CAM	-	-	-	-	-	-	-	-	-	8	-	-	-	8
LER	-	-	-	-	-	-	-	-	-	7	-	-	-	7
ALB	-	-	-	-	-	-	-	-	-	-	-	-	-	0
LAU	-	-	-	-	-	-	-	5	12	12	12	1	-	42
PAL	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Total	78	114	141	216	234	256	287	329	320	338	268	66	0	2647

Figure 7. Same as Figure 6.

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References

Dutton, E. G., J. J. Michalsky, T. Stoffel, B. W. Forgen, J. Hickey, D. W. Nelson, T. L. Alberta, and I. Reda, 2001: Measurement of broadband diffuse solar irradiance using current commercial instrumentation with a correction for thermal offset errors. *J. Atmos. and Ocean. Tech.*, **18**, 297–314.

Liepert, B. G., 2002: Observed reductions of surface solar radiation at sites in the United States and worldwide from 1961 to 1990. *Geophys. Res. Lett.*, **21**, 10, 61-1–61-4.

Power, H. C., 2003: Trends in solar radiation over Germany and an assessment of the role of aerosols and sunshine duration. *Theor. Appl. Climatol.*, **76**, 47–63.

Roderick, M. L., and G. D. Farquhar, 2002: The cause of decreased pan evaporation over the past 50 years. *Science*, **298**, 1410–1411.

Shi, Y., and C. N. Long, 2002: Techniques and methods used to determine the best estimate of radiation fluxes at SGP Central Facility. In *Proceedings of the Twelfth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, ARM-CONF-2002. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/publications/proceedings/conf12/extended_abs/shi-y.pdf

Stanhill, G., and S. Cohen, 2001: Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. *Agric. for. Meteorol*, **107**, 255–278.