JUNE 2006 STATUS
OF
NASA BUILDINGS-RELATED CLIMATE PARAMETERS
FOR THE GLOBE

by

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INTRODUCTION

This report is a continuation of NASA activities described in the January 2006 Status for Buildings-Related Climate Parameters over the Globe Special Report to the ASHRAE Technical Committee 4.2 on Climatic Information. In that earlier report, preliminary buildings climatology maps for the globe have been constructed. The above report also provided very preliminary accuracy information on GEOS-4 reanalysis data that had just been recently received. GEOS-4 has advanced physics as well as higher original spatial resolution.

This status report discusses two items:

1. It describes additional testing of the new GEOS-4 reanalysis data using global NOAA National Climate Data Center (NCDC) site data. GEOS-4 buildings climatology maps are compared to those obtained using the GEOS-1 data.

2. NASA has initiated estimates of surface solar radiation under average clear-sky conditions. Previous SSE data had been limited to monthly all-sky conditions. These new clear-sky estimates are based on new aerosol optical depths, asymmetry factors, and single-scattering albedos as well as Rayleigh scattering and water vapor data. These data are inputs to the NASA/WMO Surface Radiation Budget Quality-Check (SRB(QC)) surface solar radiation algorithm. It is believed that these new clear-sky estimates may be useful to ASHRAE for Design Day estimates in those parts of the globe where clear-sky-only solar radiation data are not available or are unreliable.

NOMENCLATURE

BSRN - Baseline Surface Radiation Network of high-quality, ground-site data stations sponsored by the WMO and several nations.

GEOS-1 - NASA Version 1 Goddard Earth Observation System reanalysis meteorology data (2.5 x 2-deg original spatial resolution – re-gridded to 1 x 1 degree).

GEOS-4 - NASA Version 4 Goddard Earth Observation System reanalysis meteorology data (1.25 x 1-deg original spatial resolution – re-gridded to 1 x 1 degree).

GPCP - NOAA/NASA Global Precipitation Climatology Project merged analysis that combines precipitation estimates from low-orbit microwave data, geosynchronous orbit infrared data, and over 40,000 surface rain gauge observations (2.5 x 2.5-deg original spatial resolution – re-gridded to 1 x 1 degree).

ISCCP - WMO/NASA International Satellite Cloud Climatology Project geostationary satellite cloud and meteorology information (1 x 1-deg spatial resolution used in SRB project).

MATCH - A chemical-transport model created at the National Center for Atmospheric Research (NCAR), the Scripps Institute of Oceanography, and the Max Planck Institute of Meteorology that has been synthesized to the NCAR circulation model as well as both satellite and in-situ observations. MATCH narrow-band aerosol data have been extended to 1 x 1-deg broad-band short wave values by NASA. The broad-band aerosol values are inputs to the NASA short-wave SRB(QC) surface radiation budget algorithm.

SRB - WMO/NASA Surface Radiation Budget (SRB) science data are based primarily on ISCCP data as inputs. Two different algorithms based on different approaches are used for both the short-wave and long-wave calculations as a Quality Check (QC) to insure accuracy of the SRB science products. Primary algorithms were originally selected by WMO after an international competition. QC algorithms were selected by NASA. At this time, the primary SRB algorithm is most accurate for mixed cloudy and clear all-sky conditions (see Appendix). The SRB(QC) algorithm has a slight advantage for clear-sky situations at this time.

COMPARISON OF GEOS-4 REANALYSIS AND GLOBAL NCDC DATA

Figure 1 is a general sketch showing illustrating the spatial relation of the GEOS-4 1-degree cell to a local NCDC measurement site. In the vertical plane, the local site may be either above or below the altitude of 1-deg cell although it is typically below. Horizontally, depending upon the topography within the 1-degree cell, the local data value may represent a small region in comparison to the GEOS-4 cell-average value. Figures 2 and 3 show results presented at the January 2006 ASHRAE meeting. Figure 3 suggests that approximate lapse-rate corrections based upon the elevation difference between the ground site elevation and the average elevation of the GEOS-4 cell may be useful for “correcting” the GOES-4 temperatures at local sites within a cell in the mountains.

Extensive GEOS-4 comparisons with global NCDC ground site data are now in progress. Only those sites which meet an 85 percent selection criterion are used. This means that (1) the site has to have more than 20 hourly observations per day (e.g. ~ 85%) and (2) that observation must be reported for greater than 23, 25 or 26 days per month, depending on the total number of days in the month (~85%). Figure 4 shows those NCDC sites which met the 85 percent data availability criterion in 1998. Some comparisons are now available for 1987, 1991, 1998, and 2004. Figures 5 through 10 summarize some results for 1998. Daily values of average, maximum, minimum, and dew-point temperatures are shown in figures 5 through 8. Specific humidity and surface pressure correlations (figures 9 and 10) show wider variation. All correlations are for uncorrected cell-average values (i.e. without lapse-rate adjustments to specific NCDC locations and heights within the cells). It is anticipated that future lapse-rate correction studies will show improved correlations with the NCDC sites in mountains.

Annual 10-year average temperature differences between GEOS-4 and GEOS-1 are shown in figure 11. In general, 10-year average ocean temperatures are cooler and land values are warmer in the later version. Heating- and cooling-degree-day differences between the two GEOS versions are shown in figures 12 and 13. A key question is which GEOS version provides the most accurate maps of buildings climate zones. Figure 14 shows U.S. climate zone maps based on Briggs et al., GEOS-1, and GEOS-4. The center Briggs et al. map is considered most accurate because it is based on extensive NCDC site data and has been interpolated to political boundaries in fine detail. While both GEOS-based maps are presently limited to a courser 1-deg spatial resolution, the GEOS-4 map appears to be a slightly closer match to the Briggs et al. product. Figure 15 compares global climate-zone maps based on both GEOS-1 and GEOS-4. There is not much difference from an overall view. However, there are some significant differences if one carefully examines each country separately. GEOS-4 is believed to be a superior product compared to GEOS-1 based on the improved physics and ecosystem characterizations included in the model and analysis procedure.

SATELLITE AND GROUND SITE ANALYSIS OF GLOBAL CLEAR-SKY SOLAR RADIATION

The satellite-based estimates of solar radiation are also on a 1-degree global grid and therefore the illustration of the geometry of the 1-degree cell relative to a ground site shown in Figure 1 is also applicable. While the physical parameters impacting the satellite based estimates of temperature and solar radiation are different, the overall impact of the difference in spatial resolution is that the ground observations can be impacted by localized features more than the satellite observations. Figure 16 is a general sketch showing the spatial relation of the SRB(QC)/ISCCP satellite-based 1-deg solar radiation cell to the BSRN network local measurement site geometry. In the vertical plane, the local site may be either above or below the altitude of 1-deg cell. Horizontally, the local BSRN ground site data value may represent a small region in comparison to the satellite-based SRB(QC)/ISCCP 1-deg cell-average value. As noted, cloud-related parameters may differ for instantaneous comparisons because of different view geometries. However, monthly parameters tend to exhibit good agreement because the same types of clouds usually tend to pass over both fields of view over a month-long period. Clear-sky comparisons should also be similar as long as both view areas have a very low and similar cloud fraction.

Figure 17 shows March global patterns of MATCH-based broadband aerosol optical depth, and figure 18 shows the total clear-sky surface short-wave radiation estimated by the SRB(QC) algorithm after including aerosol optical depth, single-scattering albedo, asymmetry factor, precipitable water, and Rayleigh scattering effects. Aerosol plumes can have a significant effect on clear-sky surface solar radiation. For example in March:

Latitude	Location	Color	Total Clear-Sky Radiation (kWh/m^2/day)
30-deg N	Texas	Lt. Pink	6 to 6.5
	N. Africa	Lt. Pink	6 to 6.5
	S. China	Yel. Green	4 to 4.5
40-deg N	Wyoming	Orange	5 to 5.5
	Ctr. Europe	Yel. Green	4 to 4.5
	Ctr. China	Orange	5 to 5.5

It should be noted that the aerosol pollution plume patterns change monthly causing the relative relationship between regions to vary.

Until recently, the historic ground-site data in our possession was for all-sky conditions. Consequently, the accuracy of the SRB(QC)/MATCH-based algorithm had not been tested under clear-sky conditions. Recently, we obtained a special BSRN data set from DOE limited to clear-skies observations. Figure 19 lists the sites and sponsors of each site as well as the organizations that provided quality assessment and synthesis. Figure 20 shows locations and altitudes of the clear-sky sites. Both the clear-sky BSRN and satellite ISCCP data were screened for days when cloud fraction was always less than 5 percent in both systems' area field-of-view. SRB(QC) estimates were then compared with BSRN total clear-sky values as shown in Figure 21. Results are surprisingly good, suggesting that both the SRB(QC)/MATCH clear-sky algorithm and the independent DOE clear-sky analysis of BSRN data are very high quality.

The ASHRAE Handbook of Fundamentals indicates that both the direct beam and diffuse components of total clear-sky solar radiation are desired. We have attempted to use an unpublished empirical all-sky algorithm on the clear-sky data to estimate both the diffuse and direct components. Figures 22 and 23 show those results. Noisy diffuse-horizontal results in figure 22 are not surprising because we can have thick-aerosol clear skies under high pressure, humid conditions and cleaner clear skies after a cold front with rain has passed. A disturbing problem is the small amount of off-set scatter in the clear-sky direct horizontal (figure 23). We are currently investigating various potential sources of the excessive scatter.

CONCLUDING REMARKS

Significant progress has been made over the past 5 months. Additional work is required for both the reanalysis and clear-sky parameters. These results should allow ASHRAE to begin to assess whether satellite and reanalysis data have a future in their plans. A positive response followed by a list of desired parameters and delivery times would facilitate NASA ability to respond in time for inputs to the 2009 Handbook of Fundamentals or other publications.

APPENDIX

COMPARISON OF MONTHLY-AVERAGE ALL-SKY DIFFUSE AND DIRECT SOLAR RADIATION ON THE EARTH'S SURFACE USING PRESENT NASA SRB AND SRB(QC) SATELLITE-BASED ALGORITHMS

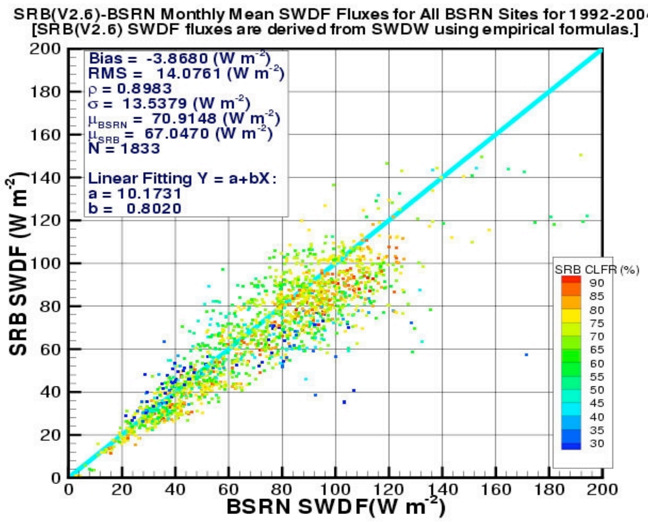


Figure A1. All-sky SRB algorithm horizontal-diffuse comparison.

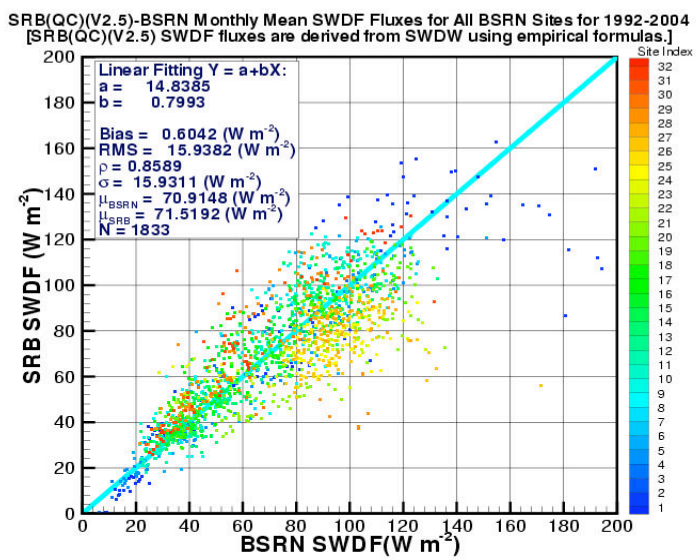


Figure A2. All-sky SRB(QC) algorithm horizontal-diffuse comparison.

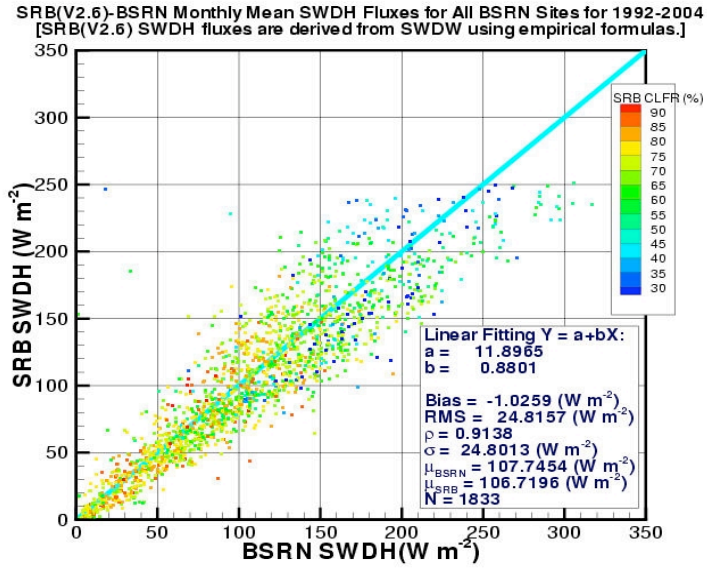


Figure A3. All-sky SRB algorithm horizontal-direct comparison.

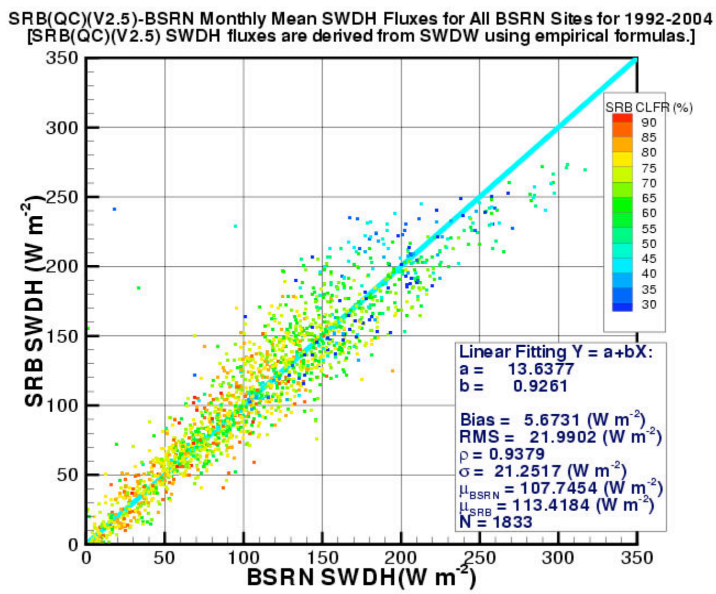


Figure A4. All-sky SRB(QC) algorithm horizontal-direct comparison.

FIGURES

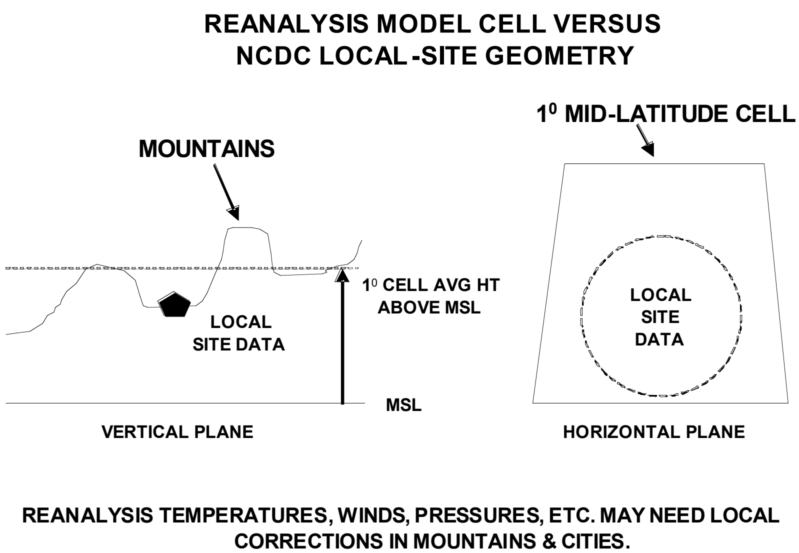


Figure 1. Reanalysis model cell versus NCDC local-site geometry.

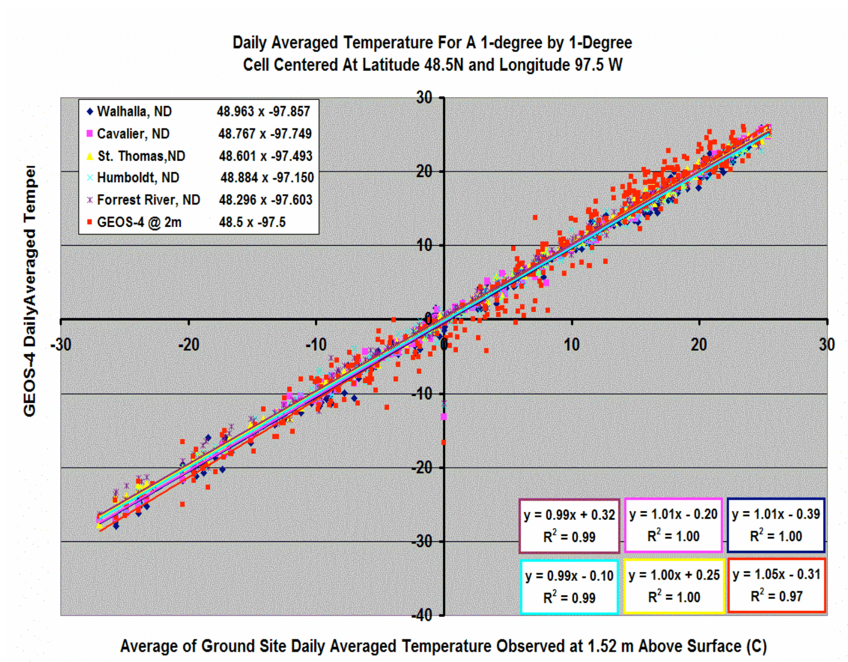


Figure 2. Typical GEOS-4 accuracy in flat terrain regions.

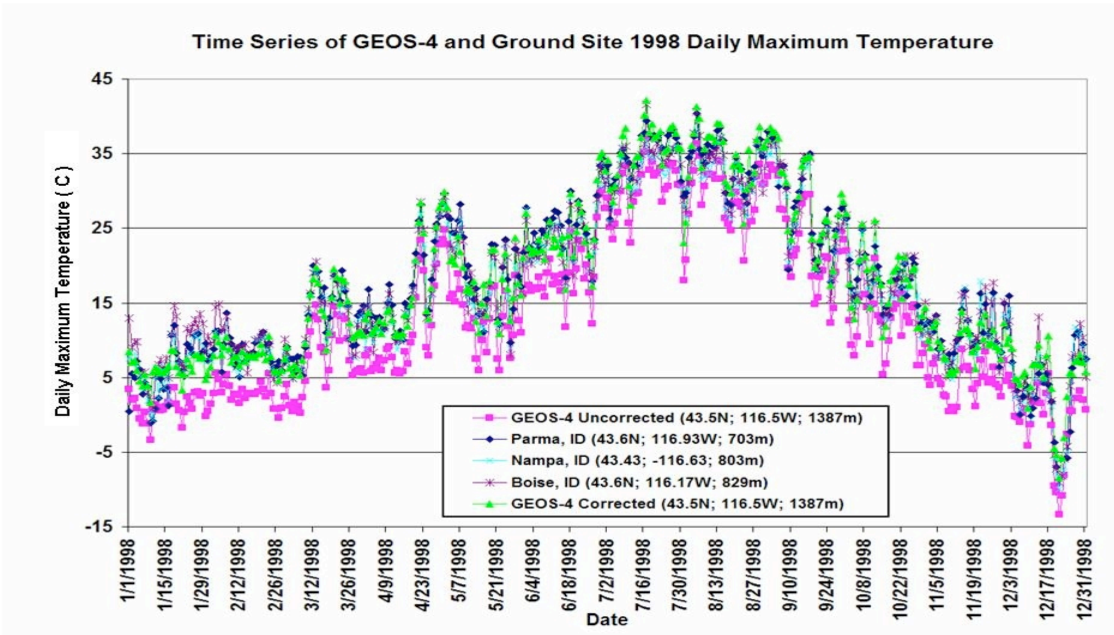


Figure 3. GEOS-4 lapse-rate correction effects in mountain regions.

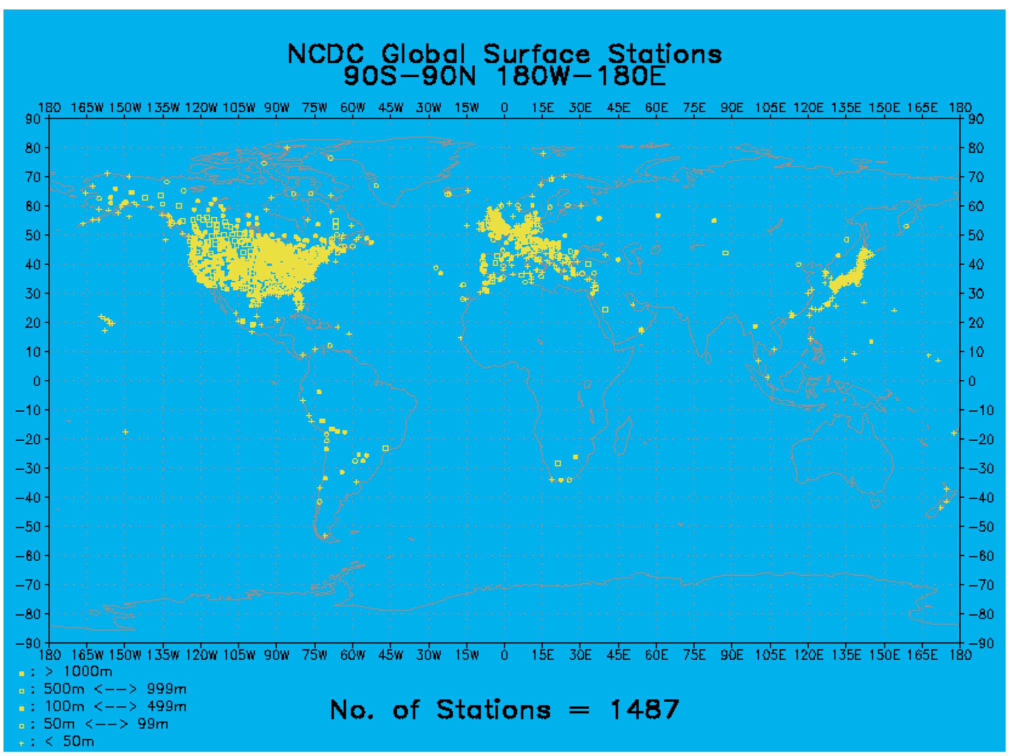


Figure 4. Map of 1998 NCDC sites meeting 85 percent data-availability criteria.

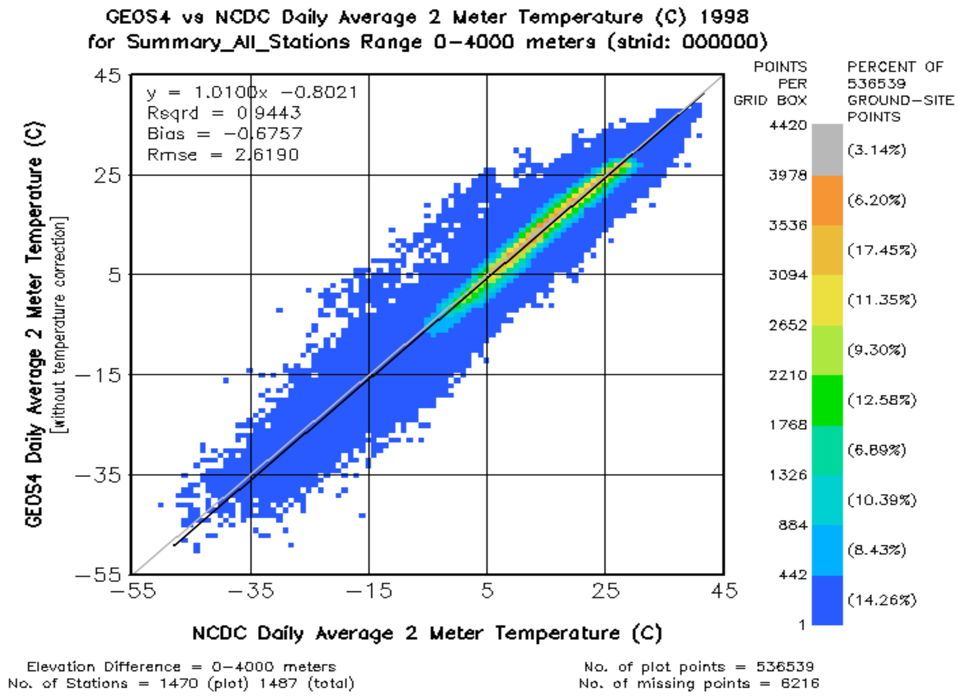


Figure 5. 1998 uncorrected cell-average GEOS-4 average temperatures versus NCDC data. (Includes both flat- and mountain-terrain sites)

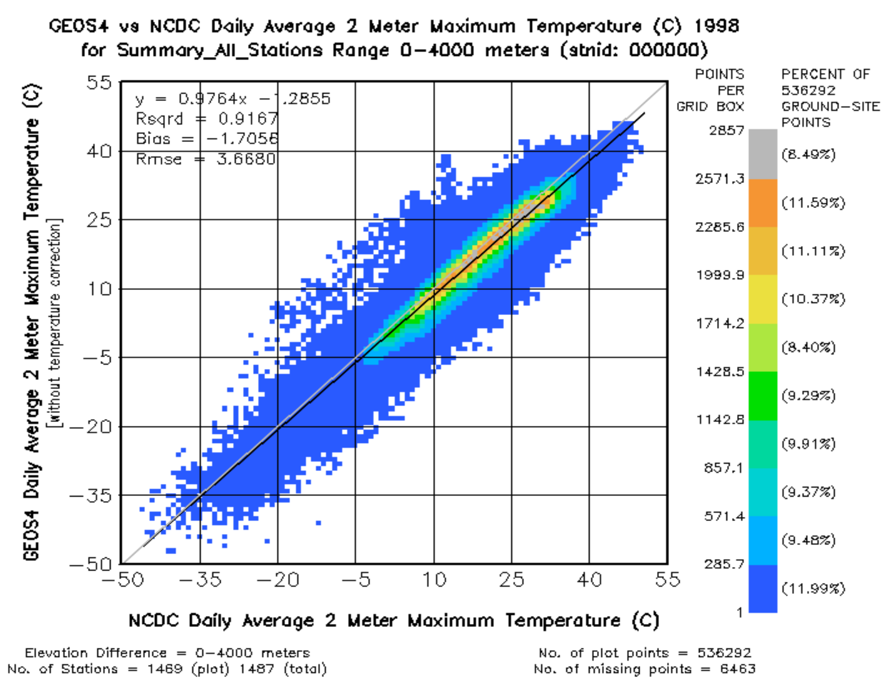


Figure 6. 1998 uncorrected cell-average GEOS-4 maximum temperatures versus NCDC data. (Includes both flat- and mountain-terrain sites)

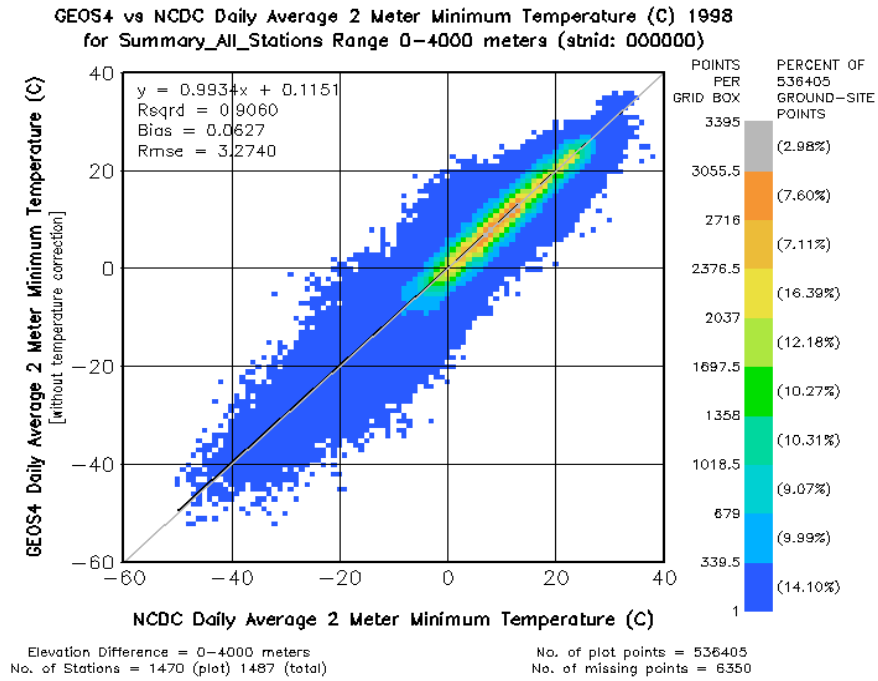


Figure 7. 1998 uncorrected cell-average GEOS-4 minimum temperatures versus NCDC data. (Includes both flat- and mountain-terrain sites)

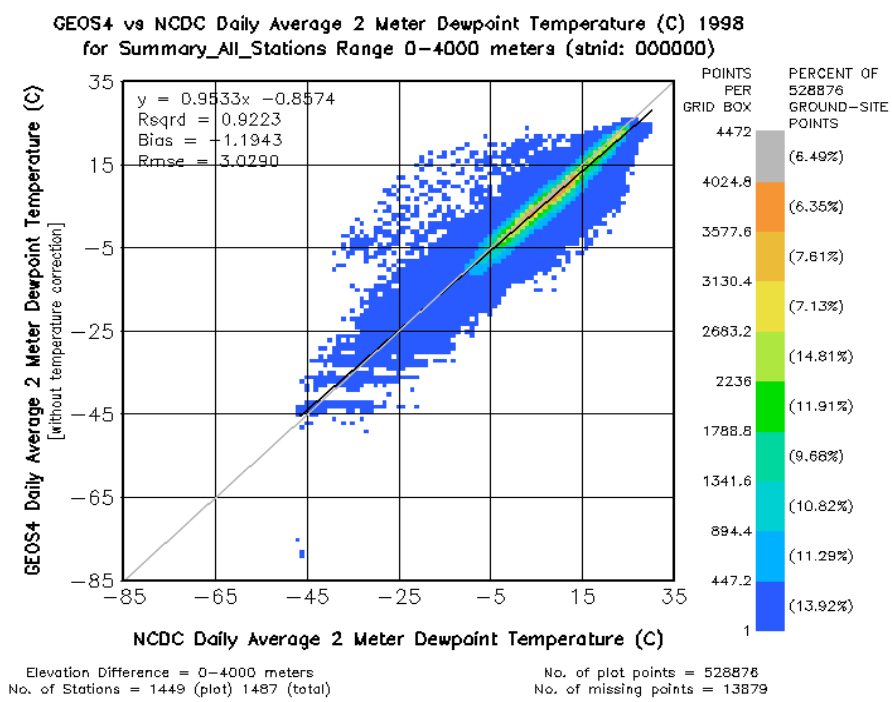


Figure 8. 1998 uncorrected cell-average dewpoint temperatures versus NCDC data.

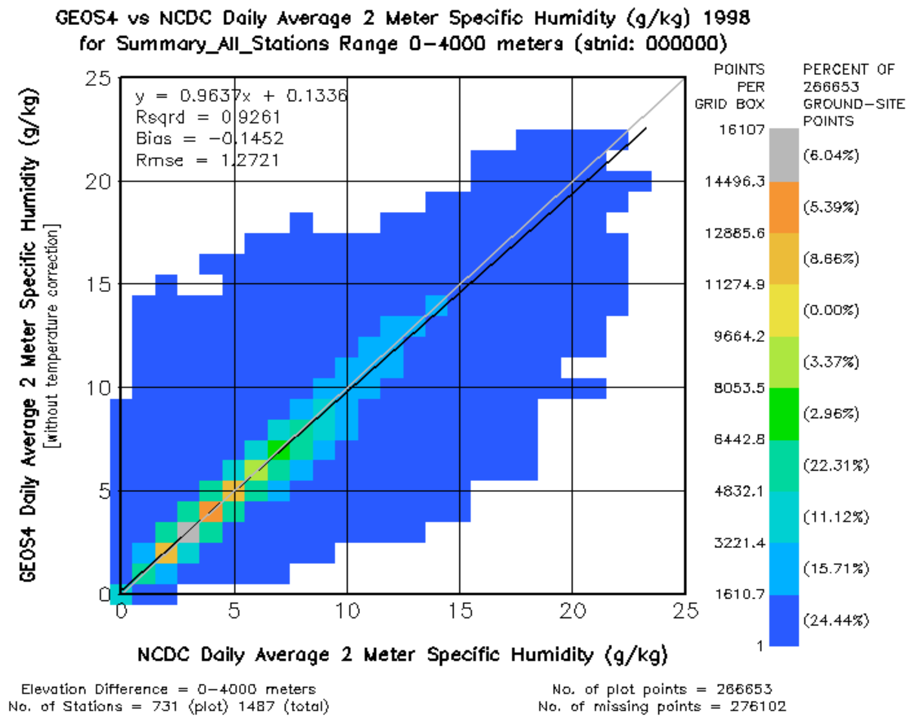


Figure 9. 1998 uncorrected cell-average specific humidity versus NCDC data.

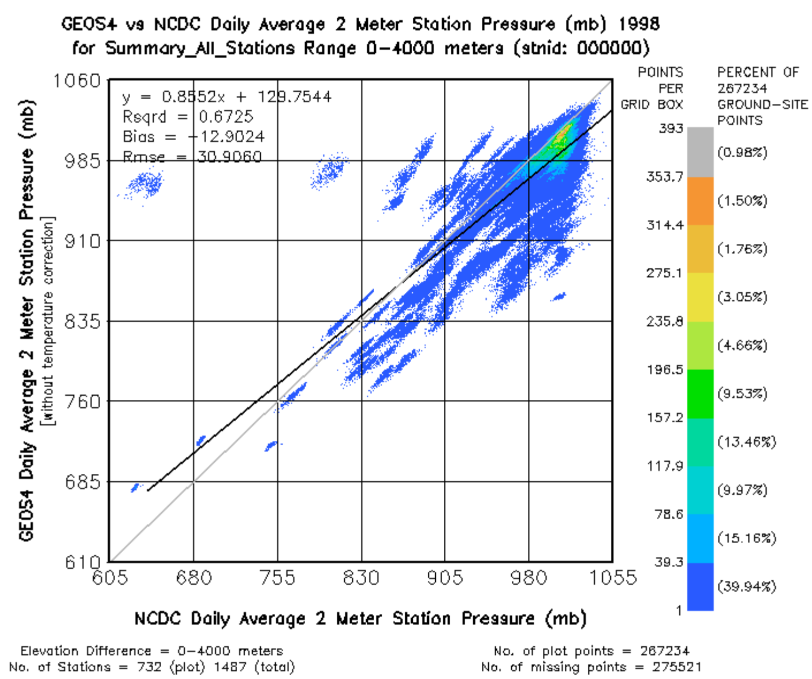


Figure 10. 1998 uncorrected cell-average surface pressure versus NCDC data.

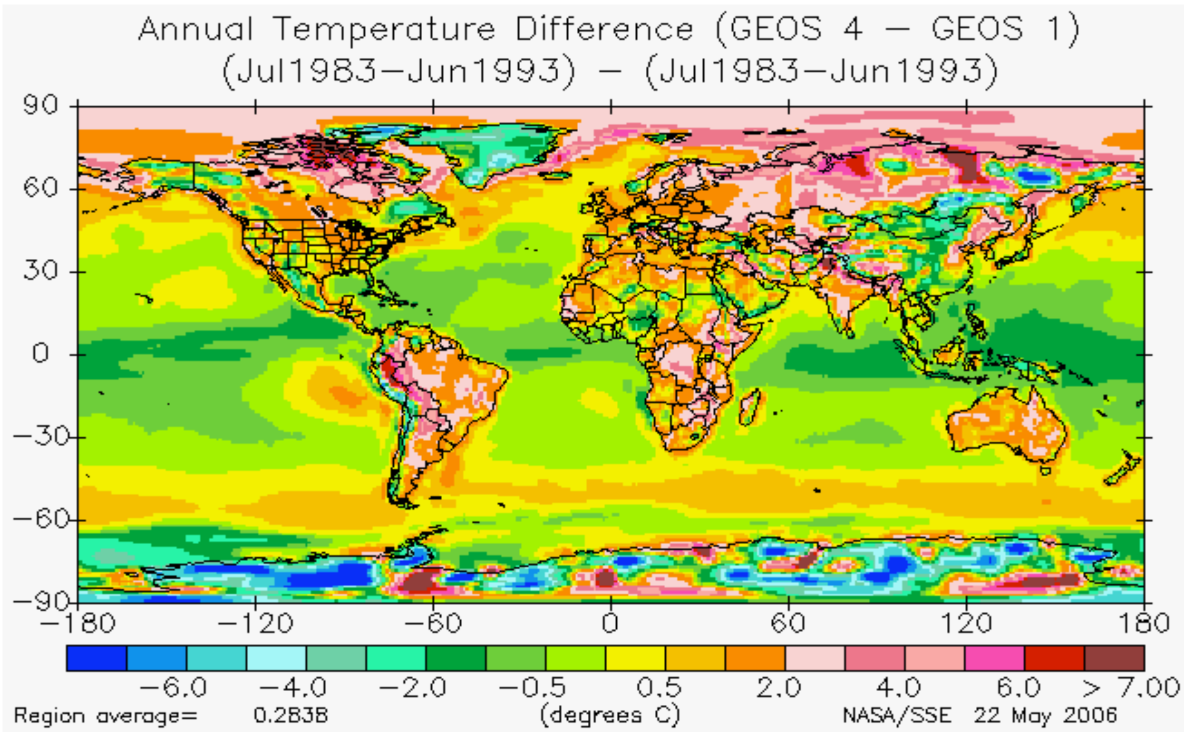


Figure 11. 10-year cell-average GEOS 4 minus GEOS-1 temperature differences.

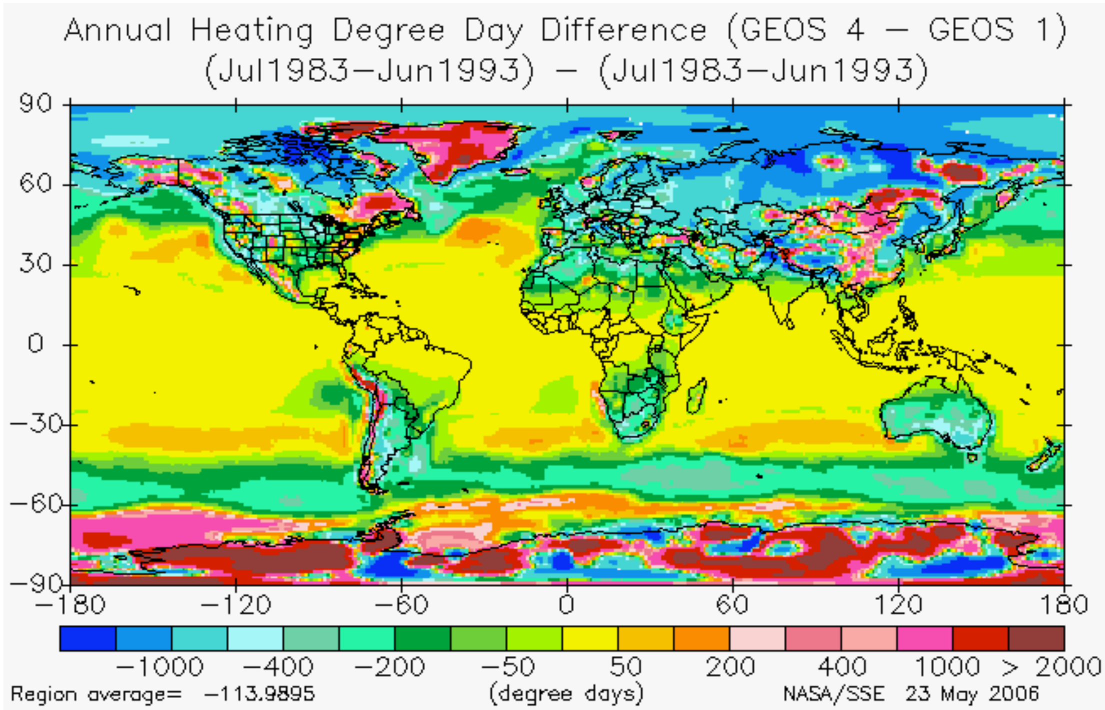


Figure 12. 10-year cell-average GEOS 4 minus GEOS-1 heating degree day difference.

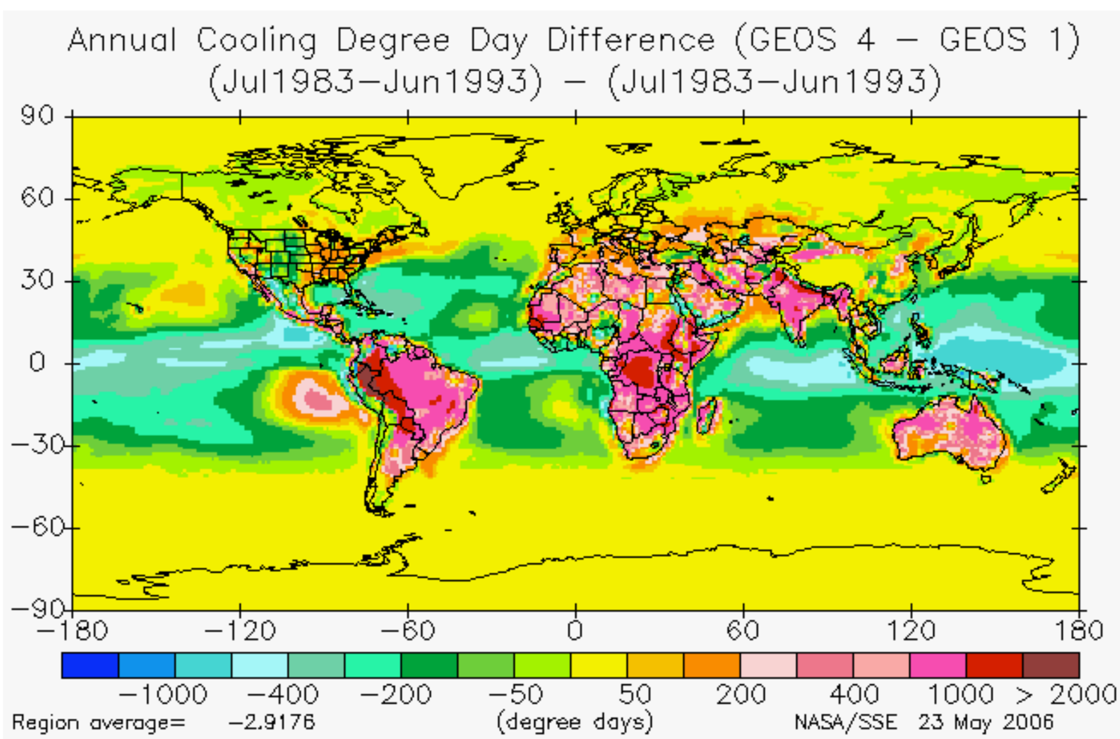
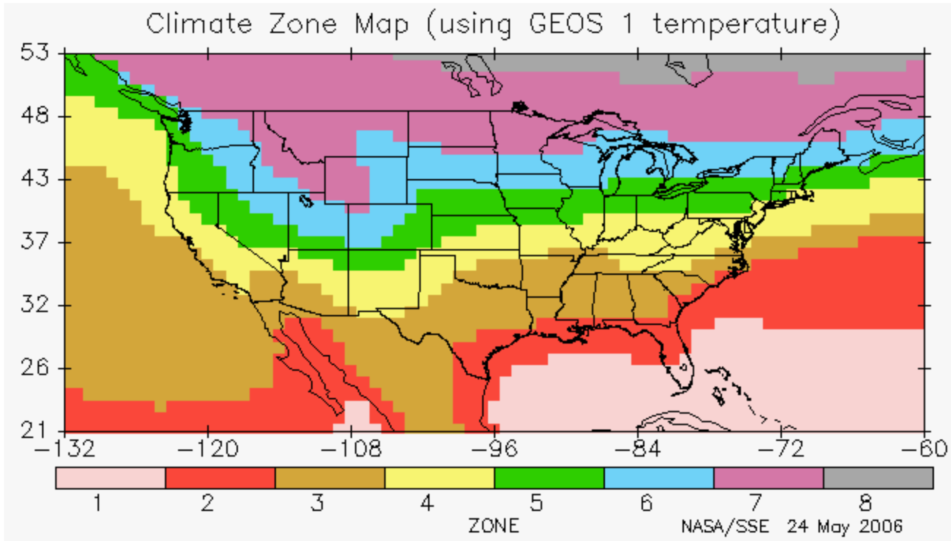
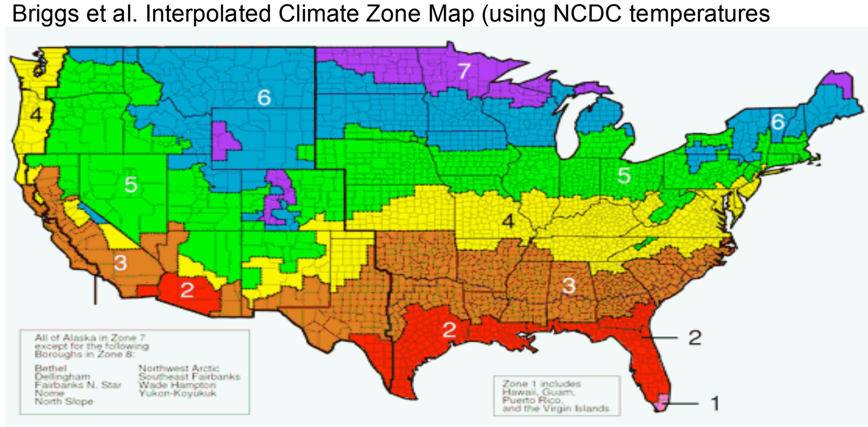


Figure 13. 10-year cell average GEOS 4 minus GEOS-1 cooling degree day difference



Briggs et al. Interpolated Climate Zone Map (using NCDC temperatures



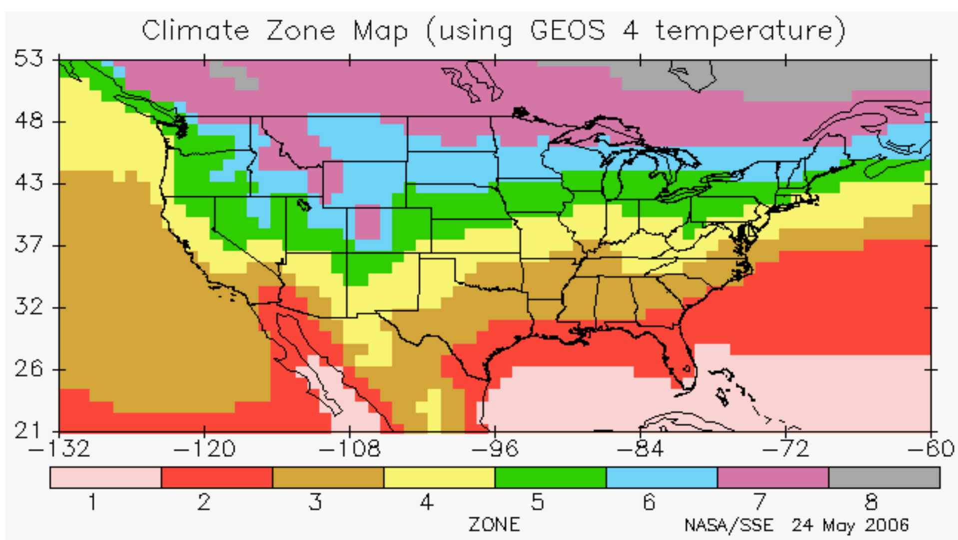
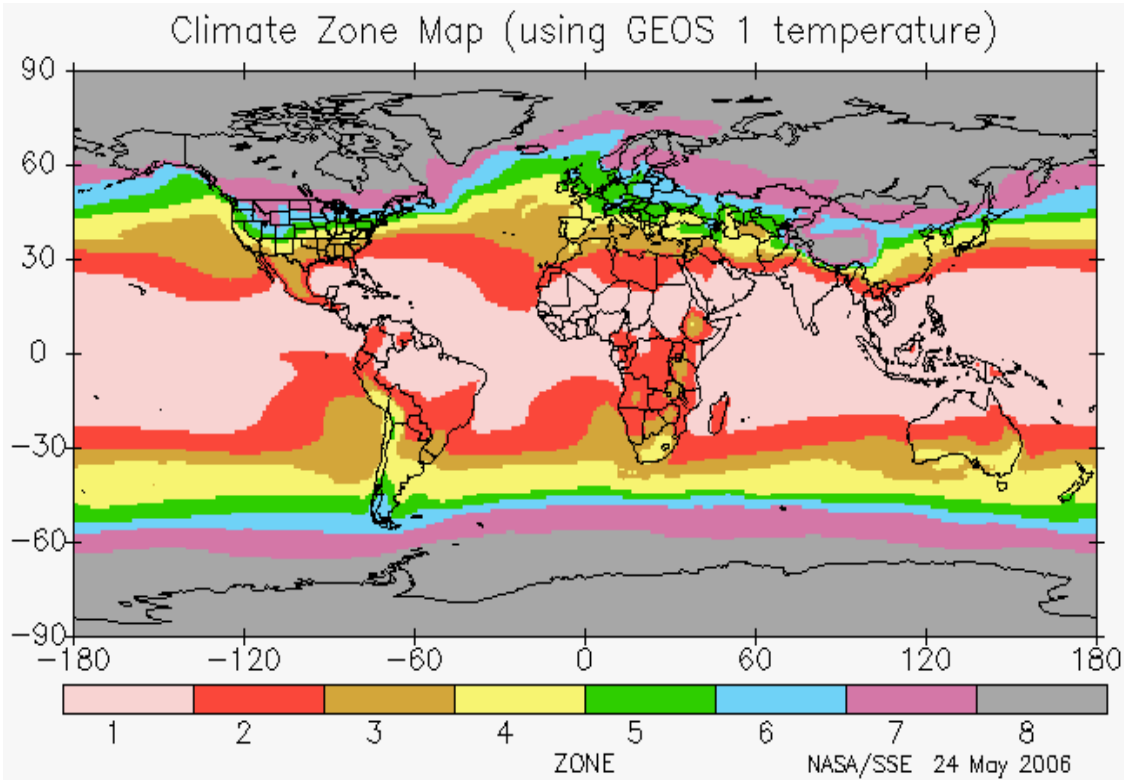


Figure 14. Cell average versus interpolated U.S. buildings climate zone differences.



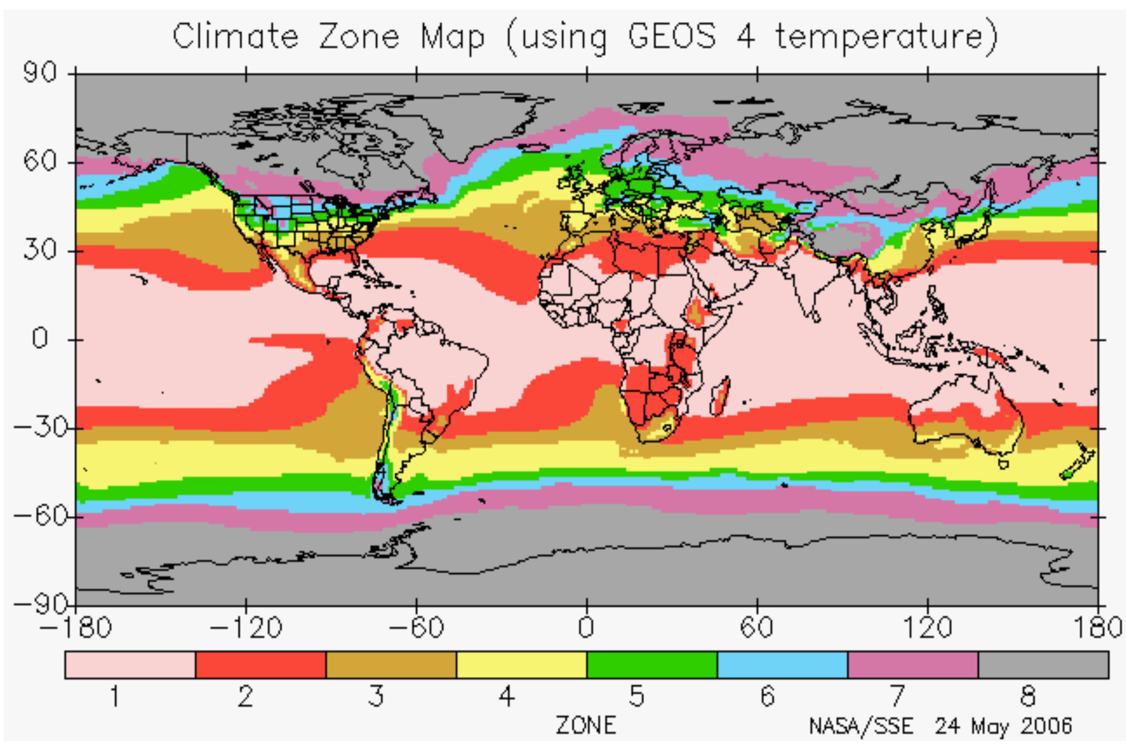


Figure 15. Global buildings climate zone differences.

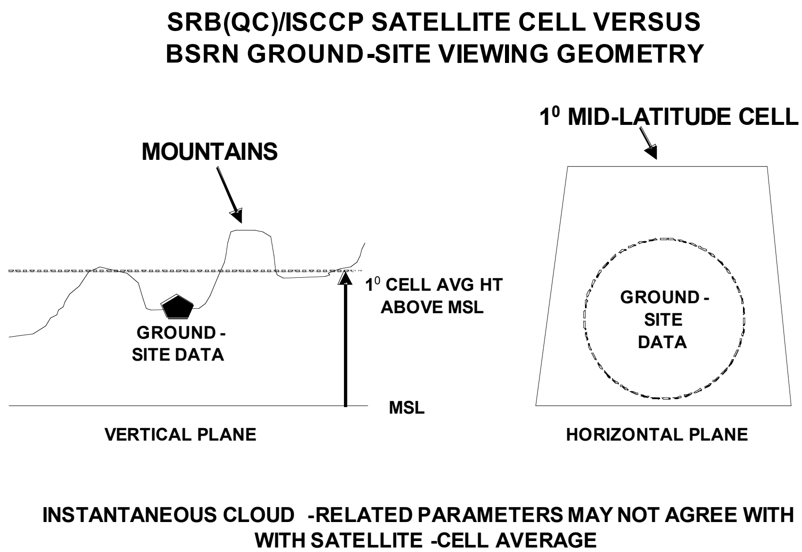


Figure 16. Satellite cell geometry versus BSRN ground-site geometry.

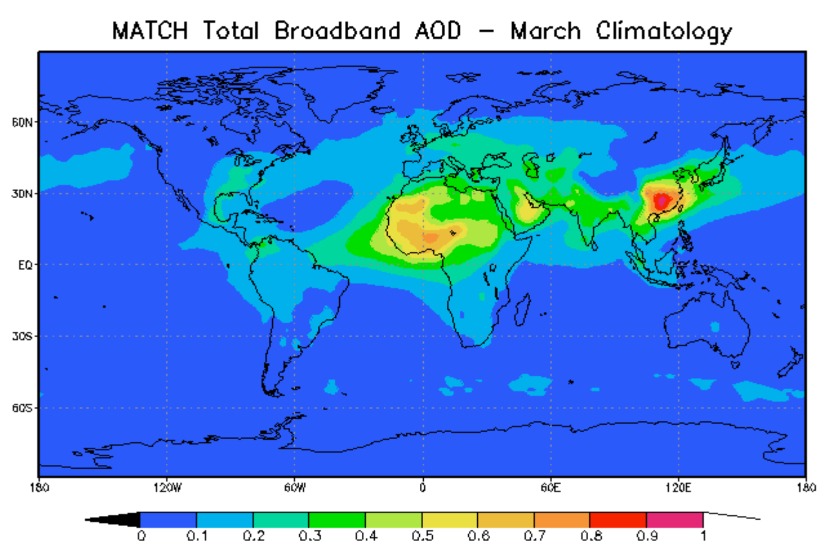


Figure 17. Sample of new multi-organization global aerosol climatology.

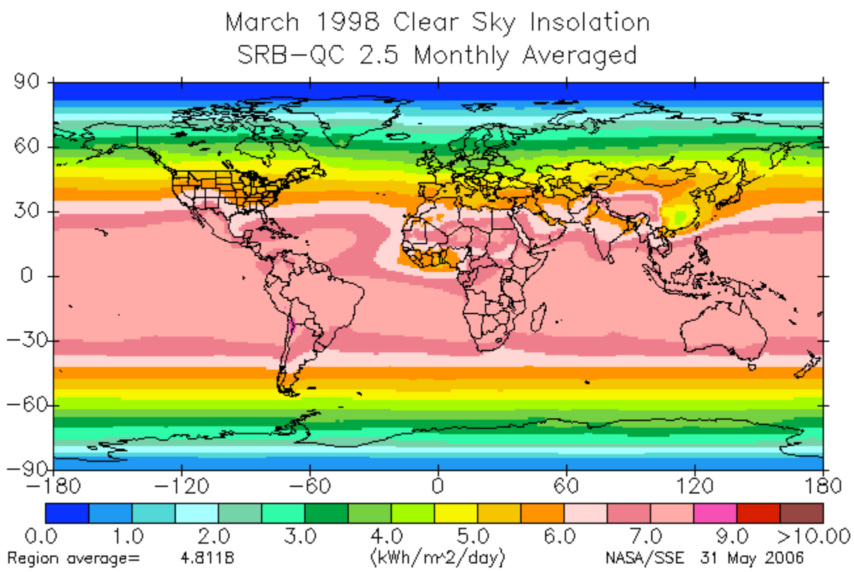


Figure 18. Sample of clear sky total insolation using new aerosol data.

BASELINE SURFACE RADIATION NETWORK (BSRN) CLEAR-SKY SITES

WMO AND NOAA/CMDL PROVIDE LEADERSHIP TO THE BSRN

SYMBOL	LAT -deg	LON -deg	SITE LOCATION	SPONSOR
NYA	78.9333	11.9500	Ny Alesund, Spitsbergen (N)	Germany/Norwa
BAR	71.3167	-156.6000	Barrow, Alaska	USA
TOR	58.2667	26.4667	Toravere	Estonia
LIN	52.2167	14.1167	Lindenberg	Germany
REG	50.2000	-104.7167	Regina	Canada
PSU	40.7167	-77.9333	Rock Springs, Pennsylvania SURFRAD	USA
FPE	48.3167	-105.1000	Fort Peck, SURFRAD, Montana	USA
PAY	46.8167	6.9500	Payerne	Switzerland
CAR	44.0500	5.0333	Carpentras	France
BOS	40.1333	-105.2333	Boulder, Colorado, SURFRAD	USA
BON	40.0667	-88.3667	Bondville, Illinois	USA
BOU	40.0500	-105.0000	Boulder, Colorado	USA
DRA	36.6500	-116.0167	Desert Rock, Nevada, SURFRAD	USA
BIL	36.6000	-97.5167	Billings, Oklahoma, ARM/CART	USA
TAT	36.0500	140.1333	Tateno	Japan
GCR	34.2500	-89.8667	Goodwin Creek, Mississippi	USA
BER	32.3000	-64.7667	Bermuda	USA
SOV	24.9167	46.4167	Solar Village, Riyadh	Saudi Arabia
TAM	22.7833	5.5167	Tamanrasset	Algerie
KWA	8.7167	167.7333	Kwajalein, Marshall Islands	USA
NAU	-0.5167	166.9167	Nauru Island, ARM	USA
MAN	-2.0500	147.4333	Momote, Manus Is., Papua New Guinea, ARM	USA
ASP	-23.7900	133.8833	Alice Springs	Australia
FLO	-27.5333	-48.5167	Florianopolis	Brazil
DAA	-30.6667	24.0000	De Aar	South Africa
LAU	-45.0000	169.6833	Lauder	New Zealand

1. **ALL-SKY DATA WERE SYNTHESIZED AND QUALITY TESTED AT THE SWISS FEDERAL INSTITUTE OF TECHNOLOGY.**

2. **CLEAR-SKY DATA WERE SYNTHESIZED AT THE DOE/PNNL.**

Figure 19. Sponsors of BSRN clear-sky site data.

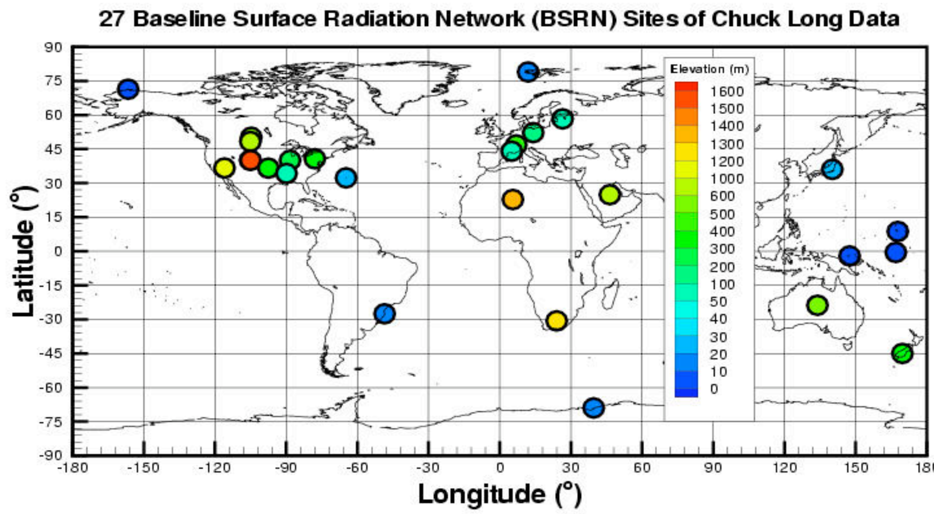


Figure 20. Map of 27 BSRN clear-sky sites.

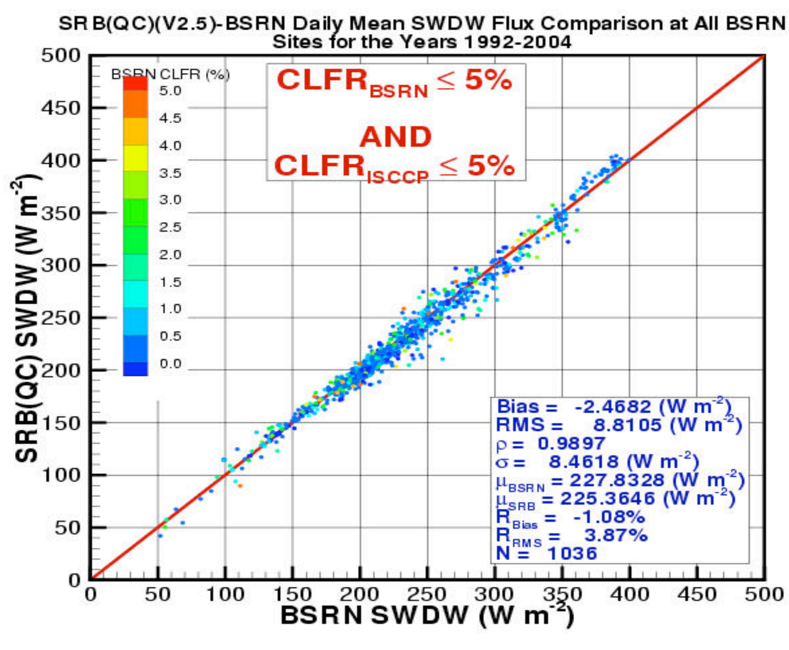


Figure 21. Comparison of satellite (SRB(QC)/ISCCP) and ground-site (BSRN) clear-sky horizontal-total irradiance for 5 per cent or less clouds in both systems viewing area.

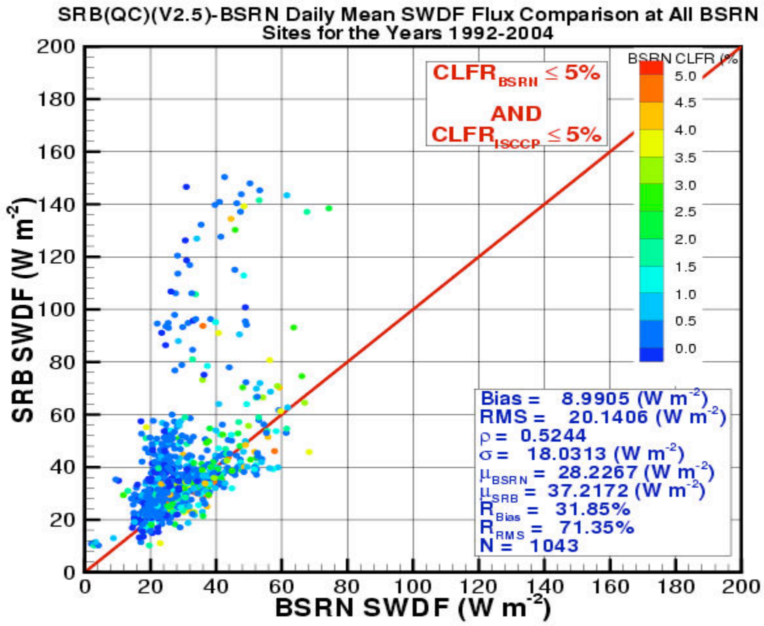


Figure 22. Comparison of satellite (SRB(QC)/ISCCP) and ground-site (BSRN) clear-sky horizontal-diffuse irradiance for 5 per cent or less clouds in both systems viewing area.

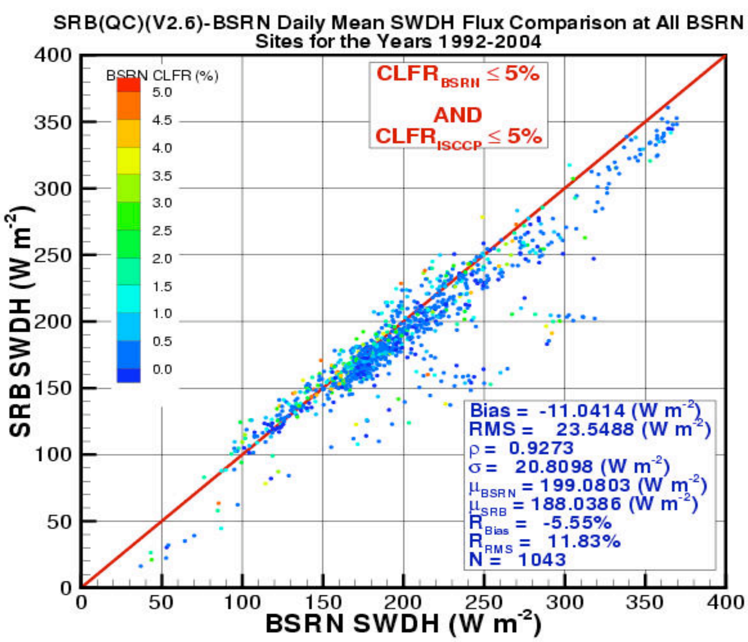


Figure 23. Comparison of satellite (SRB(QC)/ISCCP) and ground-site (BSRN) clear-sky horizontal-direct irradiance for 5 per cent or less clouds in both systems viewing area.