JANUARY 2007 STATUS OF NASA BUILDINGS-RELATED CLIMATE PARAMETERS FOR THE GLOBE

by

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INTRODUCTION

The NASA Prediction Of World Energy Resources (POWER) project first became aware of long-term needs in the buildings industry at a meeting in Charlottesville, VA in June of 2001. Attending were representatives from William McDonough + Partners (an architectural firm), 2rw Consultants, Inc. (an engineering firm), Old Mill Power Company (a renewable energy firm), and the Assistant Dean of the School of Engineering at the University of Virginia. Their major concern was the time it took to obtain weather and solar radiation data for a foreign country, particularly if the location was in a rural, underdeveloped area. Generally, they had 60 days to submit a preliminary proposal, and it was taking that long to obtain some foreign weather or radiation information. Their need was for a quick look at a complete set of preliminary weather and radiation data in order to design and cost a preliminary building within the proposal time limit.

NASA has received requests for some buildings- and agricultural-related parameters from users of its Surface meteorology and Solar Energy web site (http://eosweb.larc.nasa.gov/sse). The supplied parameters have been defined by the individual requester. It is now clear that some users have requested ASHRAE-type parameters. As a result, NASA is in a position to provide global information on a few of the parameters that ASHRAE uses. This document provides temperature and clear-sky solar radiation parameters that may augment ASHRAE's hottest-month temperature and clear-sky day radiation information. It is hoped that this type of information will help engineer/architect organizations during their preliminary-design proposal activities. It is of interest to some international organizations in other industries.

TECHNICAL CONTENT

Data are presented in charts with conclusions at the bottom of each chart.

Temperature information is presented in figures 1 through 6. Figures 1 and 2 describe validation procedures, and figures 3 through 6 provide global maps of various temperature parameters. The key is that hottest months of each cell are first defined and mapped globally in figure 3. All subsequent temperature maps are for these hottest months. The reader can see the hottest temperatures for each cell on the globe in one map. The hottest-month cooling degree days for Miami, Florida can be approximately compared with those of Acapulco, Mexico in Figure 5, for example. The color bar on each map set to the highest resolution possible to limit the spread of temperature values within a single color. Note that the color bars often change with each panel. These color bars could be set to even finer resolution if maps were made of smaller regions. Color bars with one-degree resolution are possible if map boundaries are carefully chosen.

Clear sky radiation data follows the same format. Figures 7, 8, 9, 10 and 11 describe validation results. Figures 12 and 13 provide clear sky radiation values for the hottest month defined in the top panel of Figure 3.

DEFINITIONS

GEOS-4	NASA Global Modeling and Assimilation Office Goddard Earth Observing System version 4.0.3.
NCDC	NOAA National Climate Data Center
SWDN	Total of direct solar beam and diffuse atmospheric radiation falling on the Earth's horizontal surface.
THMT	Cosine of the Solar zenith angle at the mid-time between sunrise and solar noon for the monthly average day.

Cosine(THMT) = $f + g\,[(g - f)/ 2g]^{1/2}$
where:

f = sin(latitude) sin(solar declination)

g = cos(latitude) cos(solar declination)

If Sunset Hour Angle = 180 deg., set Cosine(THMT) = f.

FUTURE PLANS

Appropriate information is also planned for the coldest months over the globe.

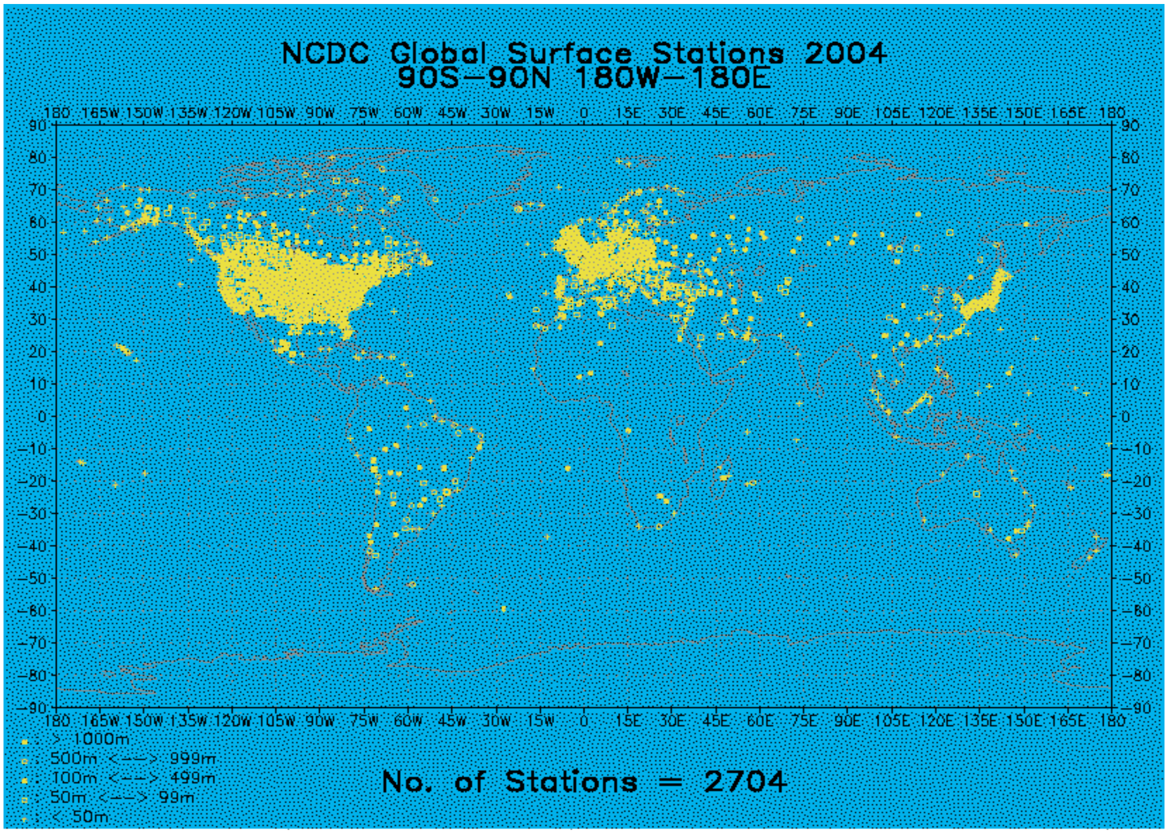
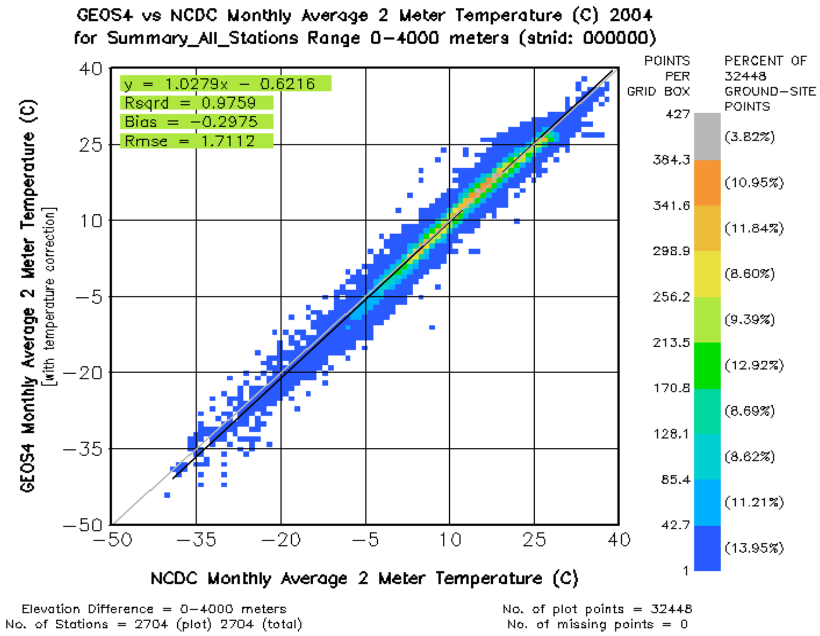


Figure 1**.** Global distribution of 2004 NCDC stations used for evaluation of GEOS-4 temperature data. These stations were selected based upon an "85% criteria" which required that each station have (a) greater than 20 one-hourly observations per day; and (b) greater than 23, 25, or 26 days per month depending on total days per month. Note that based upon the Federal Meteorological Handbook No. 1, FCM-H1-2005, September, 2005 Washington, D.C., the estimated uncertainty in the surface weather observations is give as:

Parameter	Range	Accuracy
Temperature, deg C	- 62 to - 50	$\pm$ 1.1
	- 50 to +50	$\pm$ 0.6
	+50 to +54	$\pm$ 1.1
Dew Point, deg C	- 34 to - 24	$\pm$ 2.2
	- 24 to - 01	$\pm$ 1.7
	- 01 to +30	$\pm$ 1.1



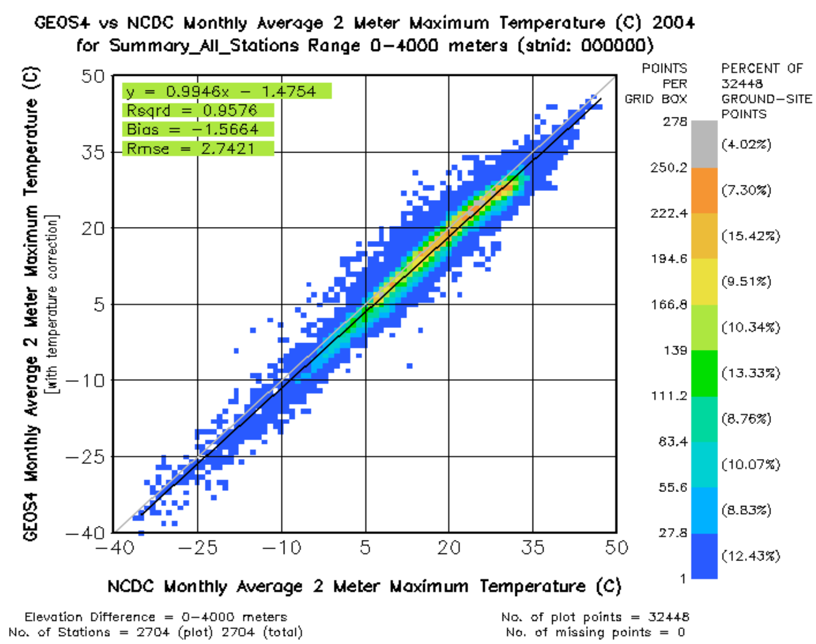


Figure 2. Comparison of GEOS-4 and 2004 NCDC monthly averaged daily maximum (top panel) and daily averaged (bottom panel) temperatures. Note that if the data points plotted as dark blue are discounted then approximately 86 % of GEOS-4 data appear quite accurate.

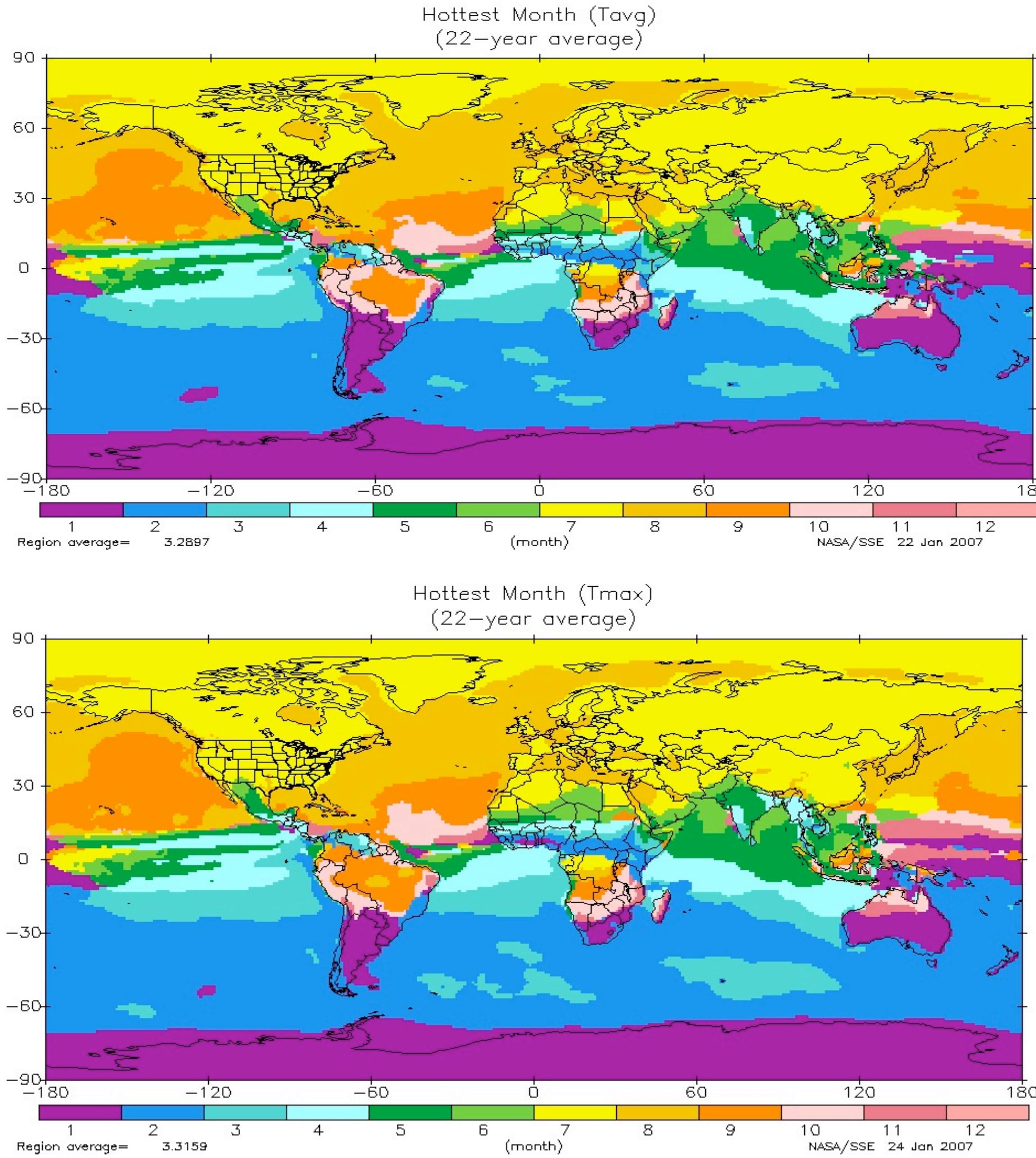
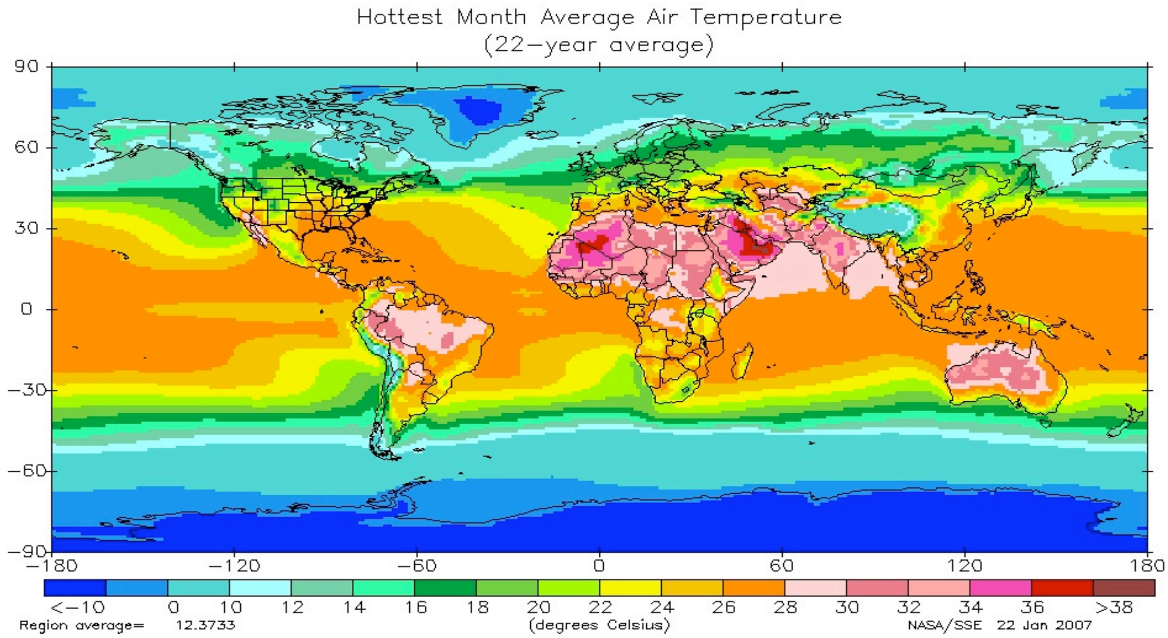


Figure 3. Top panel shows the global distribution of hottest months based upon the daily averaged 10-meter air temperature (Tave). Bottom panel shows the global distribution of the hottest months based upon the daily maximum 10-meter temperature (Tmax). The hottest Tave and the hottest Tmax months were computed from the 22-year GEOS-4 archive available from the POWER web site. Note that maximum temperatures usually occur in the same month as the highest average temperatures. Note also that the GEOS-4 data captures the advective influence of the persistent trade winds on the oceanic and terrestrial temperature patterns at the southern tip of South America; similarly, at the southern coast of South Africa and Australia.



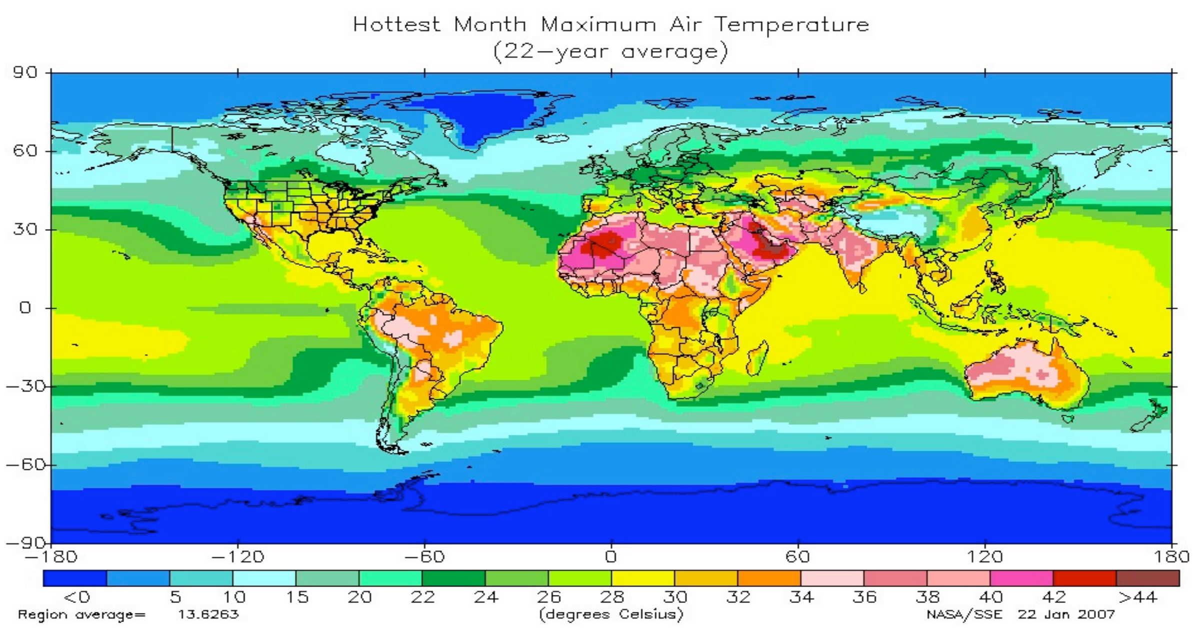


Figure 4. Top panel shows the global distribution of the monthly averaged 10-meter air temperatures (Tave) corresponding to distribution of the hottest months shown in the top panel of figure 3. The bottom panel shows the global distribution of the monthly averaged maximum temperatures (Tmax) corresponding to distribution of the hottest months shown in the bottom panel of Figure 3. The Tave values and the Tmax values were computed from the 22-year GEOS-4 archive available from the POWER web site. Note: Color bars use different temperature scales. Maximum temperatures (22-yr average of daily maximum values) may be much higher than the 22-yr average of daily average values at some locations.

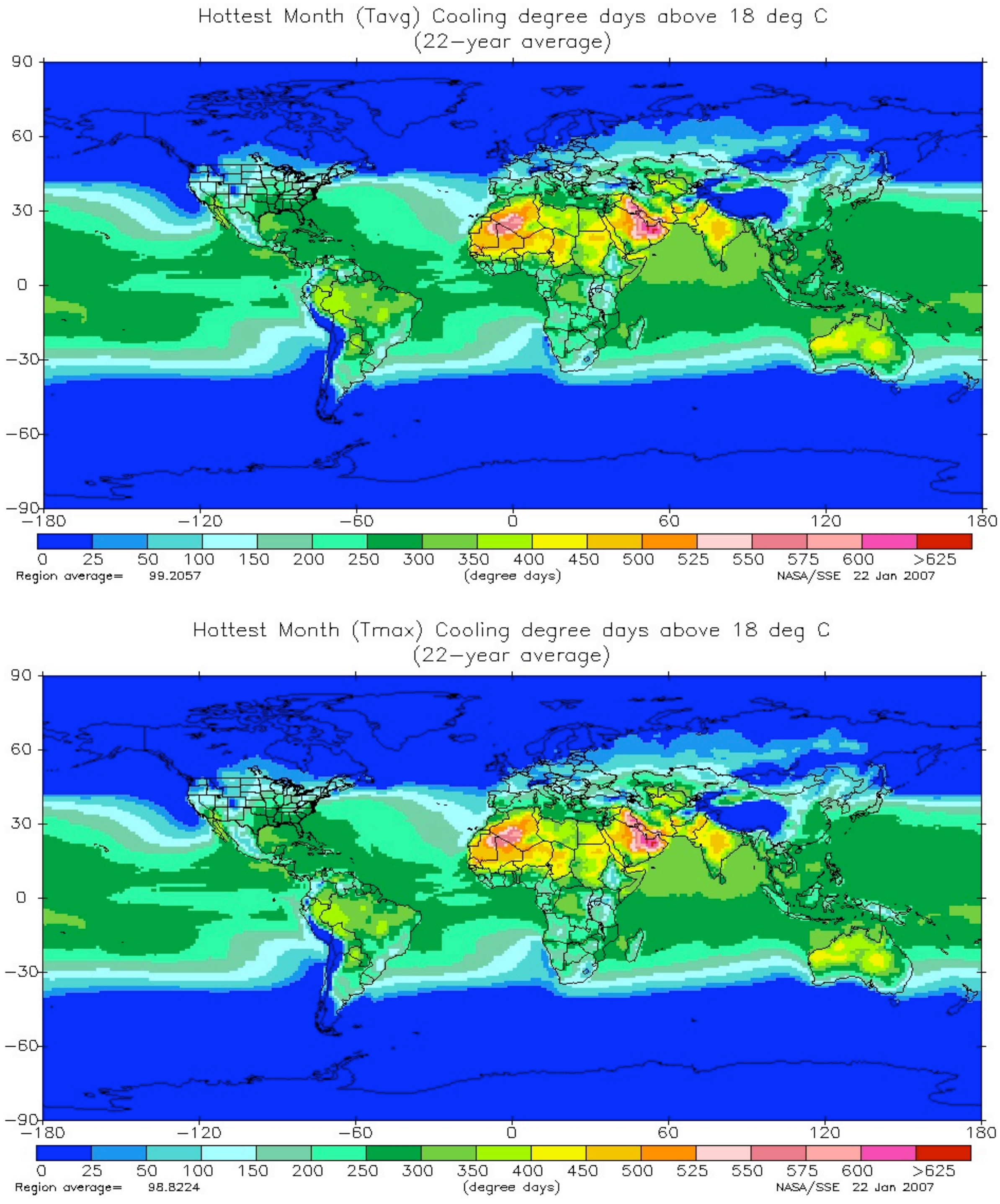


Figure 5. Top panel shows the global distribution of the cooling degree days above 18 deg C based upon the Tave values given in the top panel of Figure 4. The bottom panel shows the global distribution of cooling degree days above 18 deg C based on the Tmax values given in the bottom panel of Figure 4. <u>Note:</u> Cooling degree days are similar for most locations.

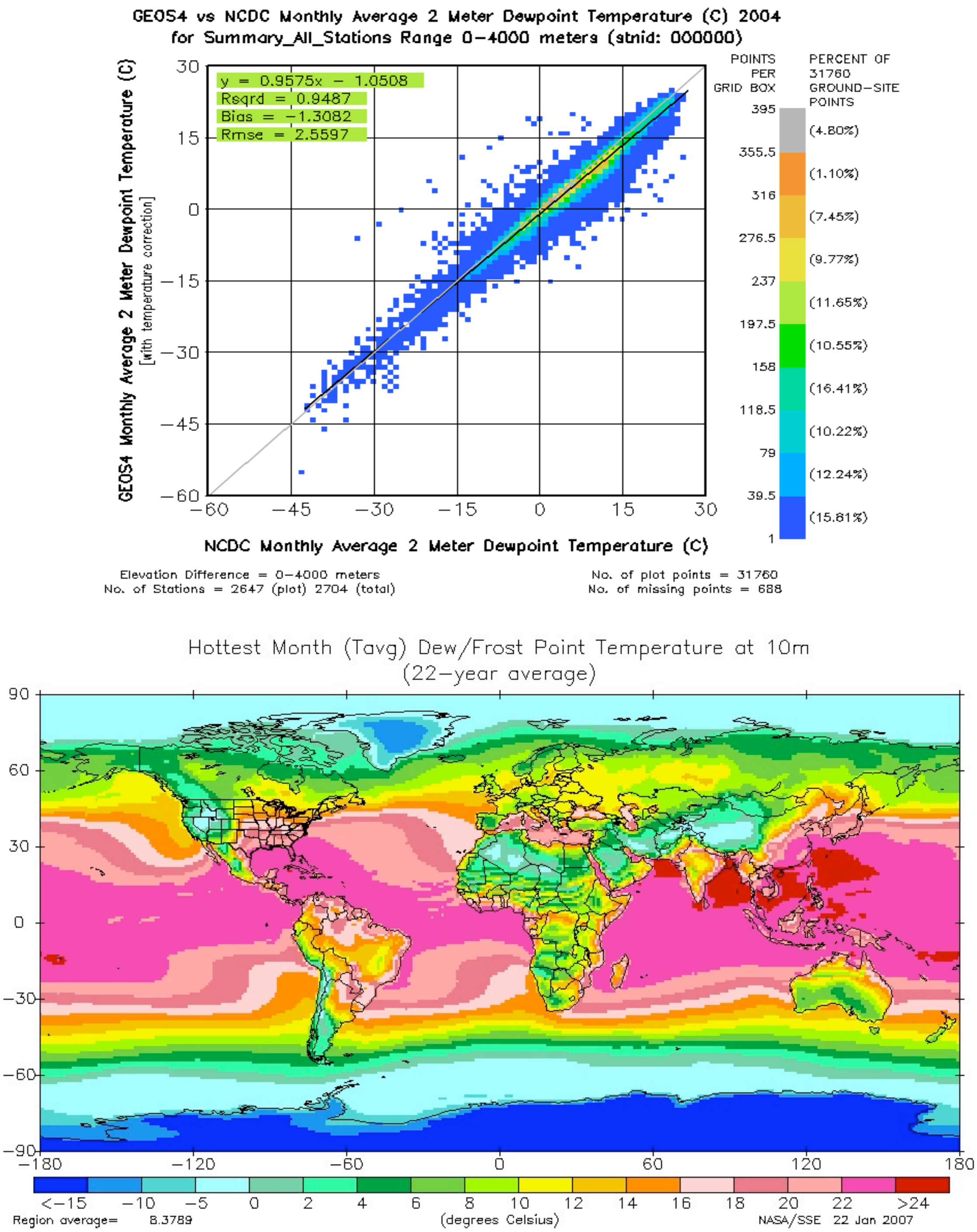
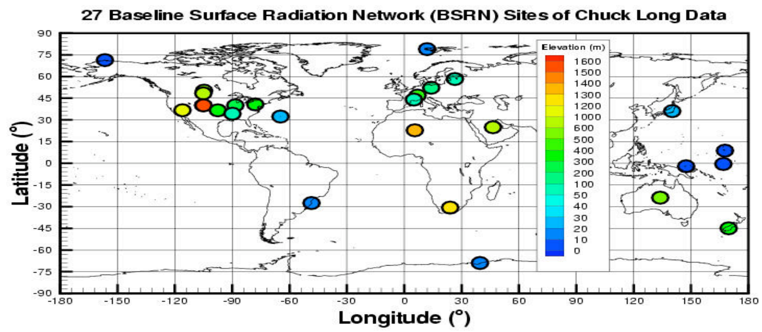


Figure 6. The scatter plot in top panel illustrates the agreement between 2-meter dew point temperature observations at NCDC stations and GEOS-4 data. The bottom panel shows the global distribution of the GEOS-4 10-meter monthly averaged dew point or frost point for temperatures below freezing for the hottest Tave months shown in the top panel of Figure 3.

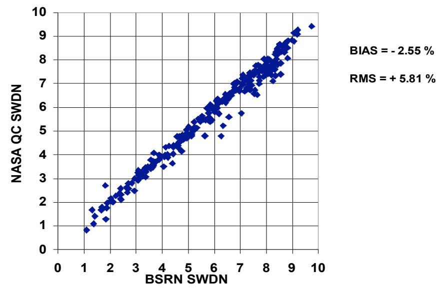


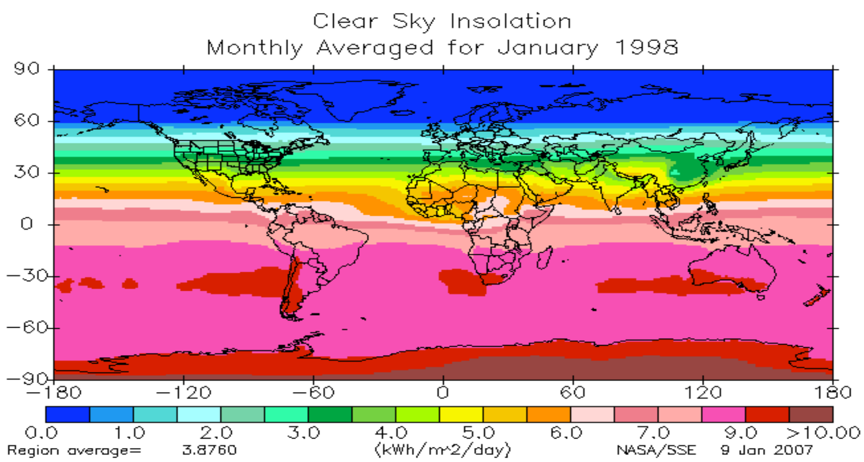
SYMBOL	LAT-deg	LON-deg	SITE LOCATION	SPONSOR
NYA	78.9333	11.9500	Ny Alesund, Spitsbergen (N)	Germany/Norway
BAR	71.3167	-156.6000	Barrow, Alaska	USA
TOR	58.2667	26.4667	Toravere	Estonia
LIN	52.2167	14.1167	Lindenberg	Germany
REG	50.2000	-104.7167	Regina	Canada
PSU	40.7167	-77.9333	Rock Springs, Pennsylvania	USA
FPE	48.3167	-105.1000	Fort Peck, Montana	USA
PAY	46.8167	6.9500	Payerne	Switzerland
CAR	44.0500	5.0333	Carpentras	France
BOS	40.1333	-105.2333	Boulder, Colorado	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	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,	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

Figure 7. Site locations of the WMO Baseline Surface Radiation Network (BSRN).

Notes: 1. BSRN data were quality-checked and synthesized at different stages by the Swiss Federal Institute of Technology, DOE/PNNL, and NASA/LaRC.

2. In 1989, WMO estimated that site-measured total solar radiation data uncertainties range from 6 % at research stations to as high as 12 % at some operational sites. Solar diffuse uncertainties could be as high as 25%.





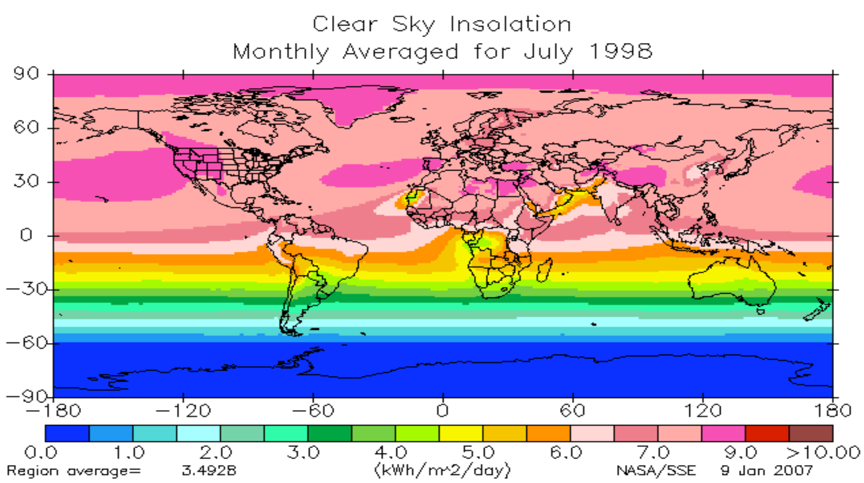


Figure 8. Estimated uncertainty (top panel) and Winter (middle panel), and Summer (bottom panel) maps of the NASA-estimated clear-sky total shortwave radiation on a horizontal surface. The NASA QC SWDN estimate is a satellite data analysis procedure that is used on both the NASA Surface Radiation Budget (SRB) and the Clouds and the Earth's Radiant Energy System (CERES) projects.

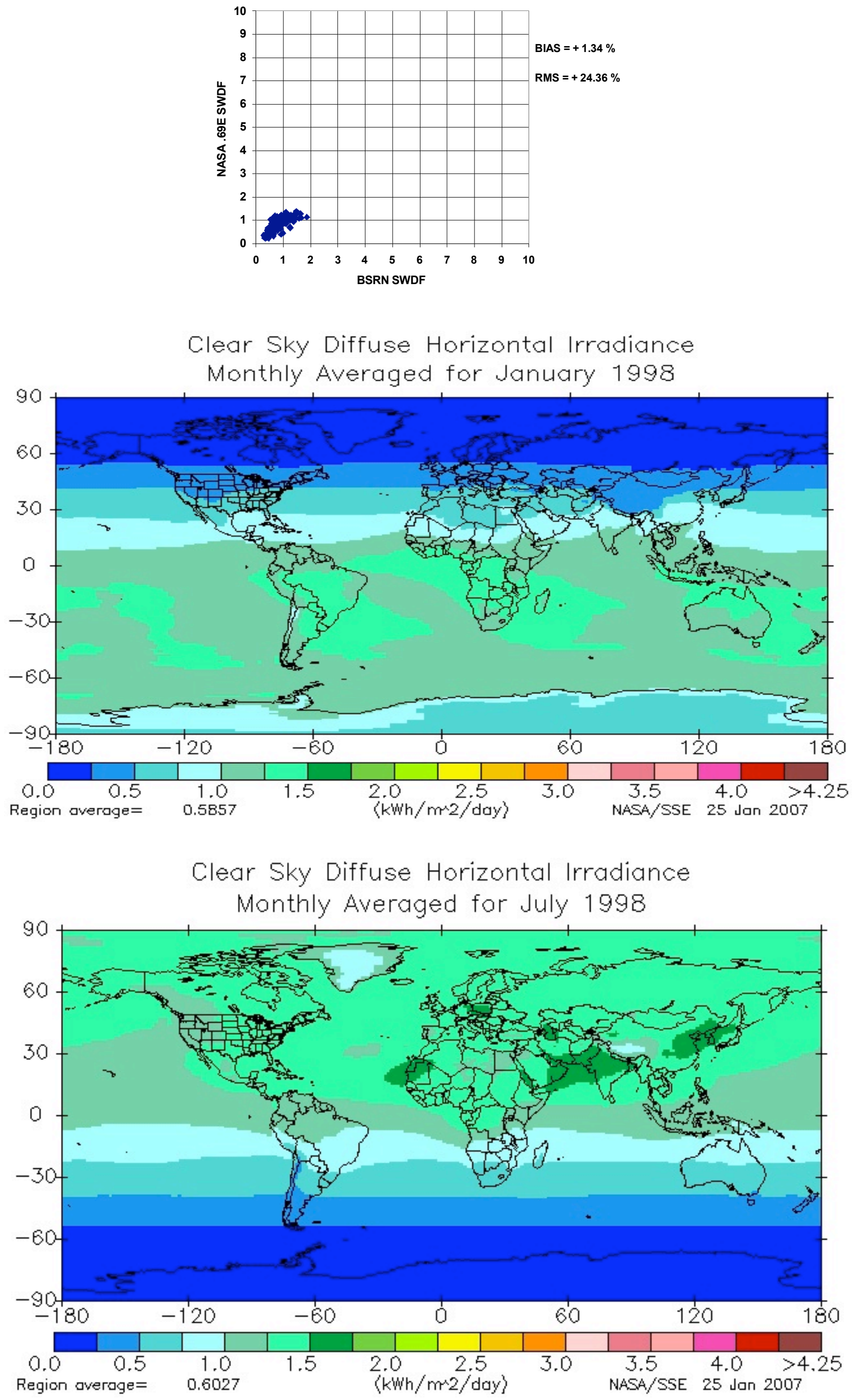


Figure. 9. Estimated uncertainty (top panel) and Winter (middle panel), and Summer Bottom Panel) maps of NASA clear-sky diffuse shortwave irradiance on a horizontal surface. The NASA estimate of SWDF radiation is based on SWDF = 0.69 * Erbs equation (10) in (Erbs et al., Solar Energy, Vol. 28, No.4, pp.293-302, 1982) = 0.69(1.317-(3.023*KT)+(3.372*(KT^2))-(1.769*(KT^3)))*SWDN where KT = surface SWDN/top-of-atmosphere SWDN.

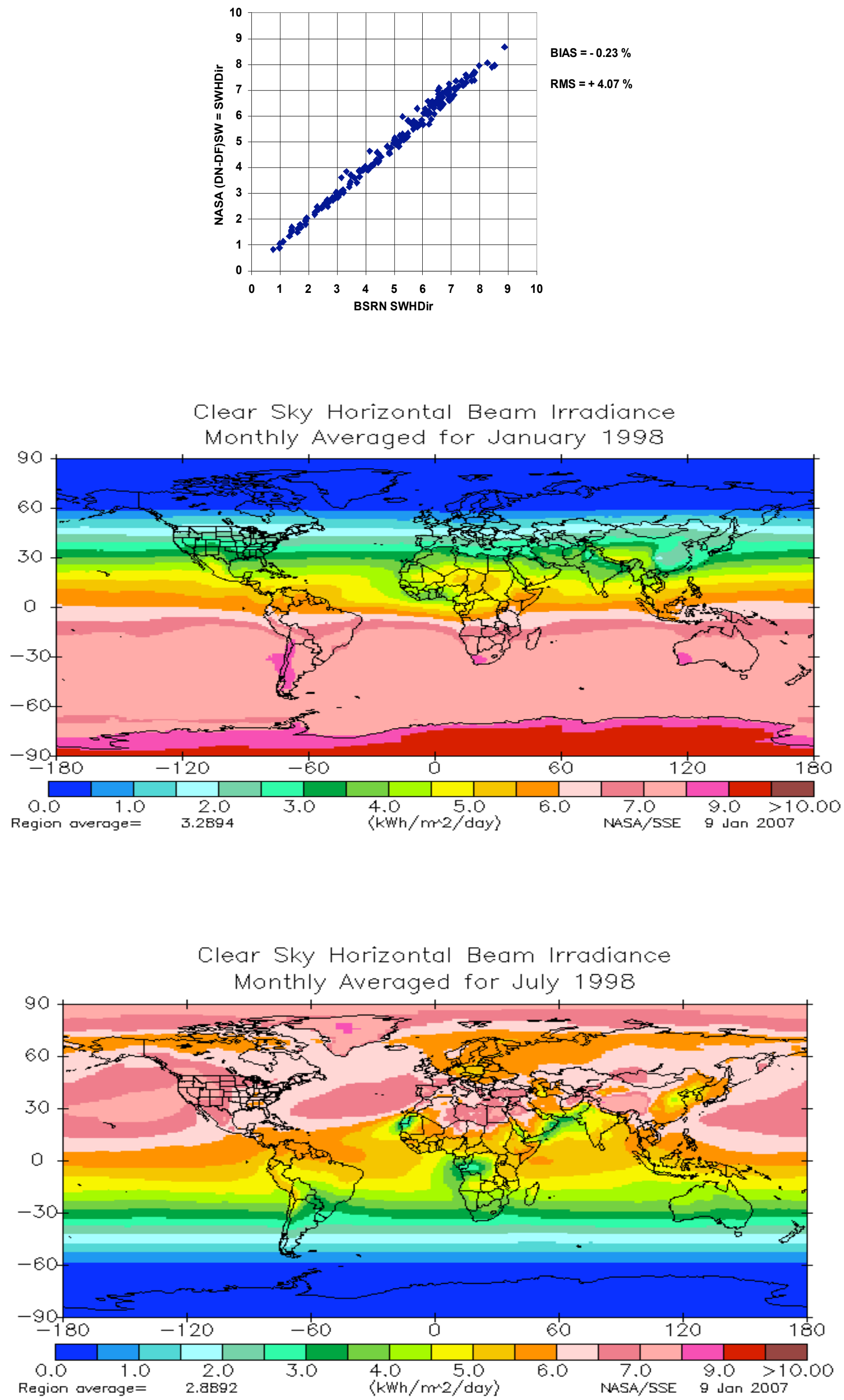
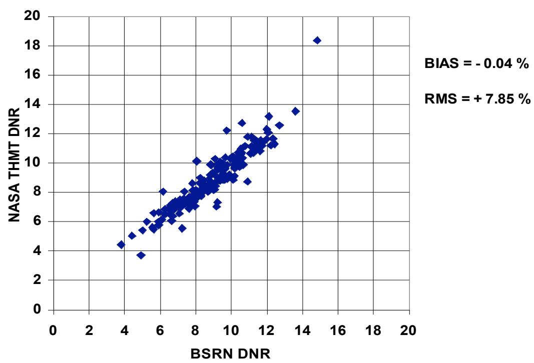
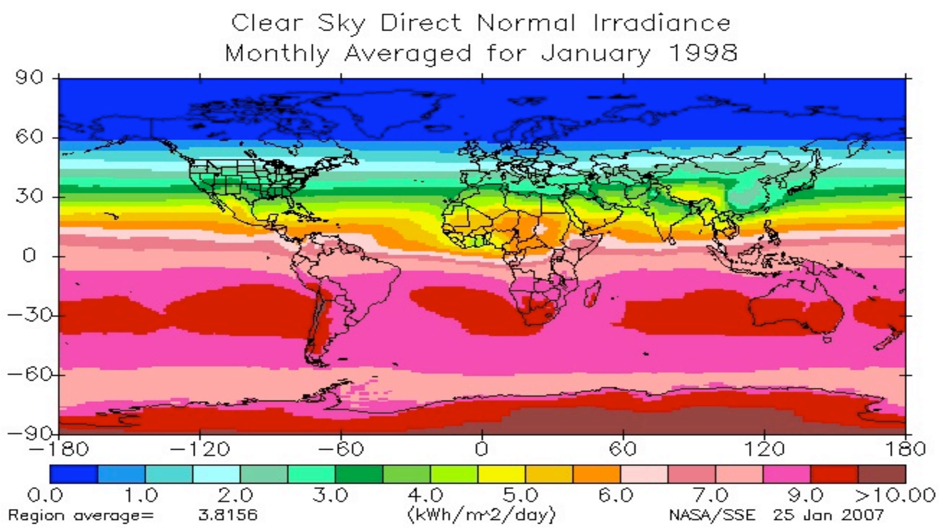


Figure 10. Estimated uncertainty (top panel) and Winter (middle panel), and Summer (bottom panel) maps of NASA clear-sky direct-beam shortwave irradiance on a horizontal surface.





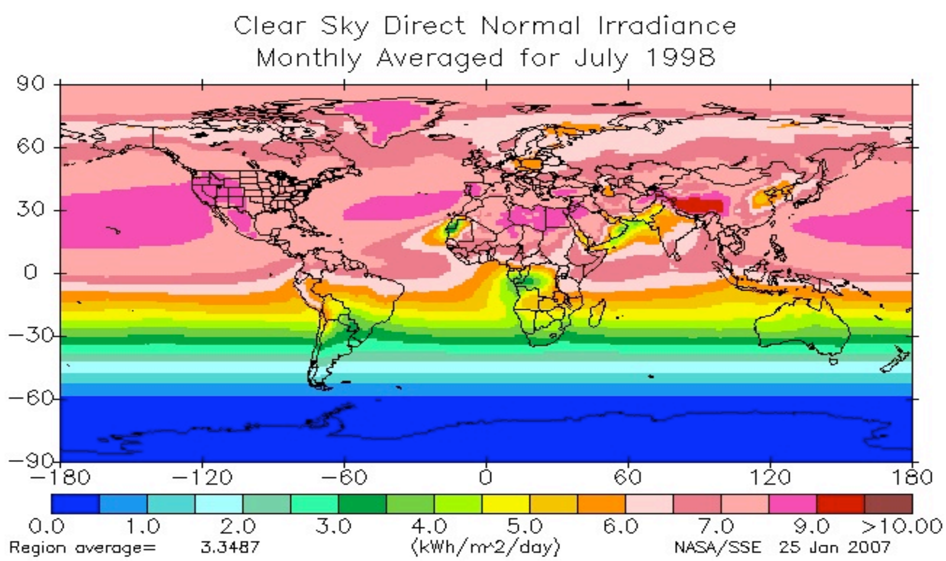


Figure 11. Estimated uncertainty and Winter/Summer maps of NASA clear-sky direct normal shortwave irradiance on a horizontal surface. The NASA THMT is a method to estimate the direct normal irradiance.

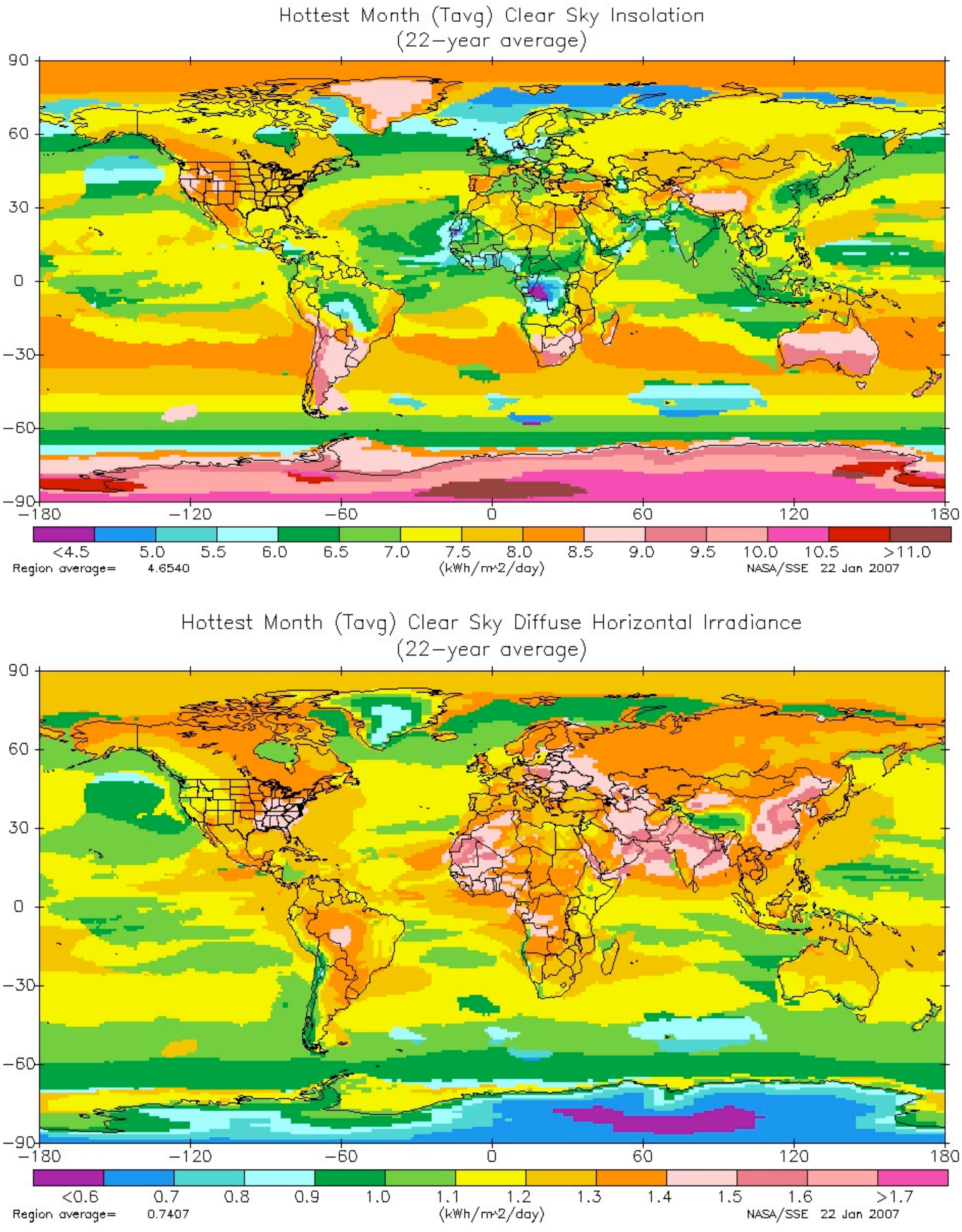
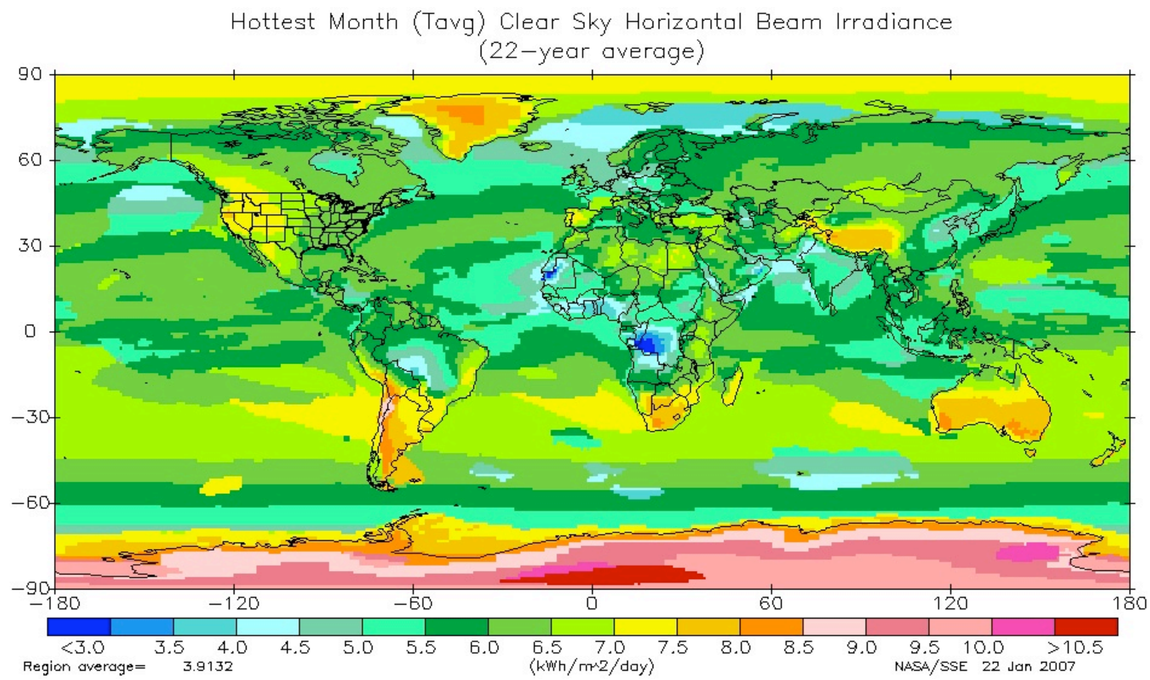


Figure 12. Top panel shows the global distribution of the clear sky total radiation corresponding to the hottest average months shown in Figure 3. Bottom panel shows corresponding global distribution of the clear sky horizontal diffuse radiation for the hottest average months. Note: Color bars are different.



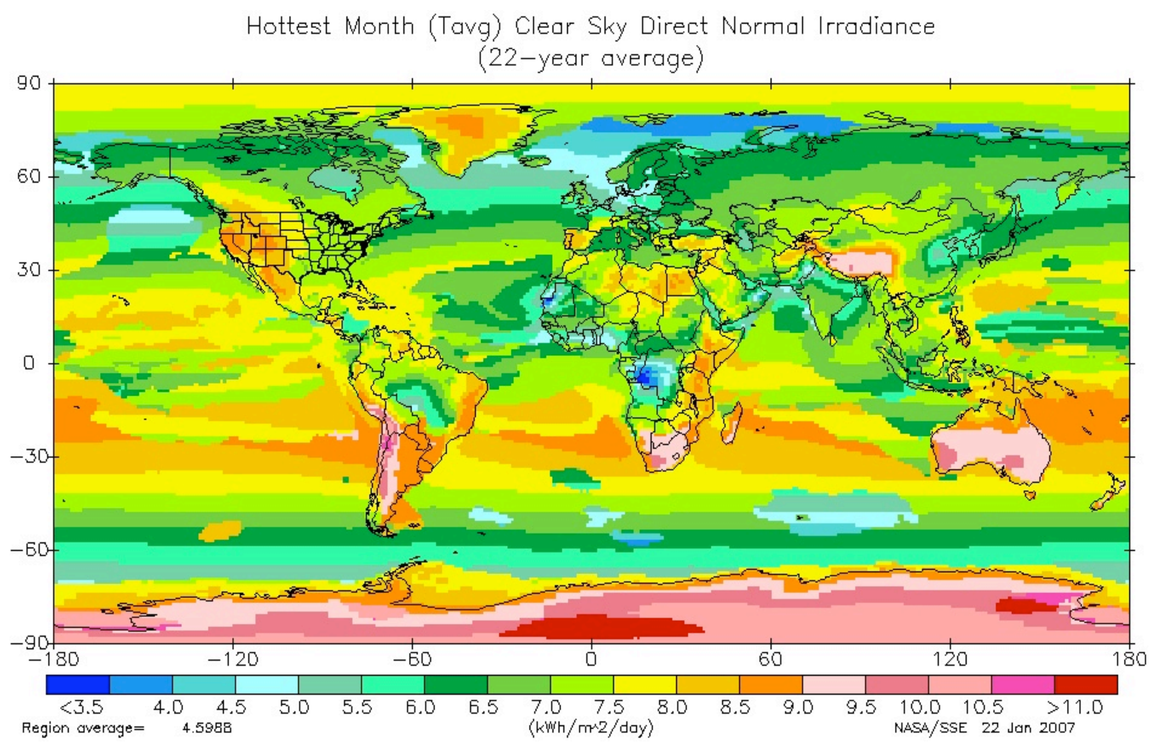


Figure 13. Top panel shows the global distribution of the clear sky horizontal beam radiation corresponding to the hottest average months shown in the top panel of Figure 3. Bottom panel shows corresponding global distribution of the clear sky direct normal radiation for the hottest average months. Note: Color bars are different.