Increasing Intensity of Solar Radiation in the Continental United States 1979 to 2011: Implications for Skin Cancer

A B Fleischer, Jr.

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Abstract

Importance: Skin cancer rates continue to escalate in the United States, yet little is known about changes in climatologic contributors to this epidemic.

Objectives: To assess whether there has been a change in solar radiation over time.

Methods: This manuscript analyzes extant climatologic data on measured solar radiation from the North America Land Data Assimilation System Daily Sunlight available from the Centers for Disease Control and Prevention. Data for the Continental United States was analyzed from 1979 to 2011. In addition to descriptive statistics, to test the hypothesis that sunlight energy is changing, a series of regressions was performed on data on National, Regional, and Divisional levels. Also, the relationship between total sunlight energy and ultraviolet B radiation was explored.

Results: The average daily sunlight was 16,432MJ/m2 across the Continental United States. Over the 32 year study period, the Continental United States experienced a 2.4% increase in average daily radiation, which translates to a 0.076% per year increase. Although all 9 United States Census Bureau Geographic Divisions saw an increase in their average daily radiation over the study period, for two of these Divisions, Pacific and West North Central, the change was not significant. The Geographic Division with the greatest numeric increase in daily sunlight energy, New England, experienced a 6% increase, translating to a 0.19% increase per year. Daily sunlight energy was an excellent predictor for UVB energy (p=.0001, R2=.97)

Conclusions: Solar radiation demonstrates increases over time, which may have profound implications for a continuously increasing risk of nonmelanoma skin cancer.

INTRODUCTION

Nonmelanoma skin cancer and melanoma continue to increase in frequency in the United States.1,2 Health behaviors certainly may modify an individual's or group's risk of skin cancer,3 but environmental factors may also play a role in this trend. Ultraviolet light exposure remains the most important contributor to the pathogenesis of nonmelanoma skin cancer,4,5 but its effect on melanoma is not as clear.6 Most human diseases are multifactorial, and understanding all of the factors contributing to a condition helps guide public health efforts aimed at prevention and control.

Around the world, climatologic data are being accumulated on an ongoing basis, and there are now large amounts of these data available for investigators to perform hypothesis testing. Specifically, The North America Land Data Assimilation System (NLDAS) Daily Sunlight data are available from the Centers for Disease Control and Prevention.7 NLDAS is an impressive collaboration project among several groups: the National Oceanic and Atmospheric Administration National Centers for Environmental Prediction Environmental Modeling Center, the National Aeronautics and Space Administration Goddard Space Flight Center, Princeton University, the National Weather Service Office of Hydrological Development, the University of Washington, and the NCEP Climate Prediction Center. The NLDAS data are archived and distributed by the Goddard Earth Sciences Data and Information Services Center. Detailed information about the NLDAS project can be found online.8

The current study examines the question as to whether there has been a change in the amount of sunlight reaching the United States and to characterize any observed changes.

METHODS

The NLDAS Daily Sunlight data available on CDC WONDER are daily sunlight (insolation or solar radiation) observations over the years 1979 to 2011.7 Reported measures include but are not limited to the average daily solar radiation, reported in kilojoules per square meter (KJ/m2). Sunlight data are available by location and can be assessed at the county, State, geographic division, geographic region, or combined 48 contiguous (continental) states plus the District of Columbia as defined by the United States Census Bureau are presented in Table 1.9

To relate total solar radiation to ultraviolet B radiation (UVB), comparisons were made between 3 separate surface radiation (SURFRAD)10 sensing sites were chosen for data extraction. SURFRAD does not have available data over the entire study period from 1979 to 2011. From 1995 to 2011, monthly average UVB was obtained from Bondville, IL, Fort Peck, MT and Goodwin Creek, MS11 and compared with NLDAS sunlight energy data over the same period for these three US States.

Data were extracted from the CDC WONDER system, and then analyzed by Microsoft Excel 2013 or by SAS 9.3.

All regressions reported are linear and significance was achieved when $p<.05$. There were no human nor animal subjects so this study was not subject to IRB review.

RESULTS

Figure 1 presents the average daily sunlight energy to each State in the Continental United States over the 32 year study period from 1979 to 2011. Note that the readings refers to all light energy and is not strictly limited to light in the ultraviolet light spectrum. Table 2 presents the average solar radiation over the entire study period for the Continental United States, as well as each Geographic Region and Division. In terms of extremes, the West Region has 23% more average daily sunshine intensity than the Northeast Region. Similarly, the West South Central Division experienced 28.5% more average solar radiation than New England. The lowest recorded observation was 849 KJ/m2 whereas the highest recorded observation was 37,714 KJ/m2.

Figure 2 shows that over this study period, sunlight energy in the United States triples in Summer compared with Winter. Figure 3 depicts the monthly average daily solar radiation by geographic region. Note that the West Region Consistently produces the highest amounts of solar radiation in April through September, whereas the South Region produces the highest amounts of solar radiation in October through March.

To test the hypothesis that sunlight energy is changing from 1979 to 2011, a series of regressions was performed on data on a National, Regional, and Divisional levels. Table 2 presents the change in average daily sunlight energy obtained with linear regression from 1979 to 2011. Note that the number of KJ/m2 significantly increased on a National basis and for all of the Geographic Regions. Although all 9 Geographic Divisions saw an increase in their energy over the study period, for two of these Divisions, Pacific and West North Central, the change was not significant. For both of these Divisions, the regression coefficient of determination (R-Squared) was lower than for any other of the Divisions. Graphic presentations of the change in energy over these study periods is presented for the Nation (Figure 4), Geographic Regions (Figure 5), and Geographic Divisions (Figure 6). Linear regression estimates are depicted for these figures.

To verify that the NLDAS total solar energy levels represent UVB levels, a regression was performed for the monthly averages of total solar energy from 3 US States compared with ground-based UVB recordings from SURFRAD. Although the SURFRAD recordings were from a single site and the NLDAS was from entire States, there was a highly significant relationship between total solar energy and UVB ($p<.001$, $R2=.97$). Thus, the observations about total solar energy relate closely to UVB (Figure 7).

Figure 1

A 32 year average of the average daily solar radiation by State in the Continental United States. The West and South display the highest daily radiation whereas New England displays the lowest.

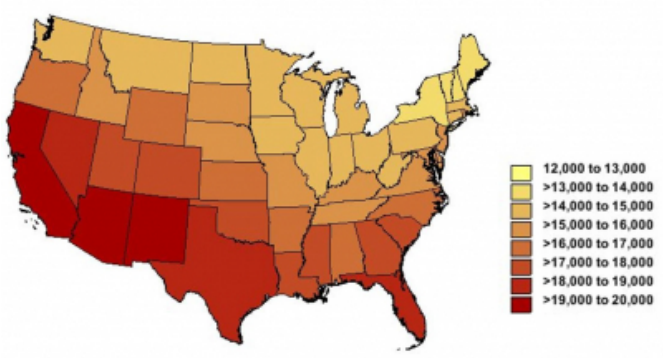

Figure 2

A 32 year average of the average daily solar radiation by day of the year in the Continental United States. The solar radiation on the peak Summer days is more than three-fold higher than the lowest Winter days.

Figure 3

The intensity of daily solar radiation by Month and Geographic region for the Continental United States.

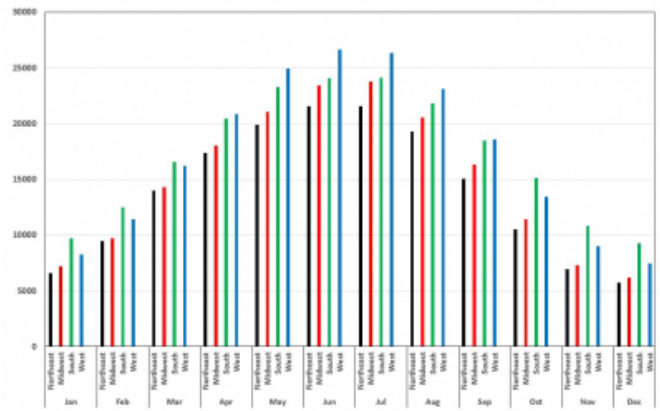

Figure 4

The change in the average daily solar radiation by year for the Continental United States with linear regression line. The mean daily increased solar radiation over the study period was 393 KJ/m2.

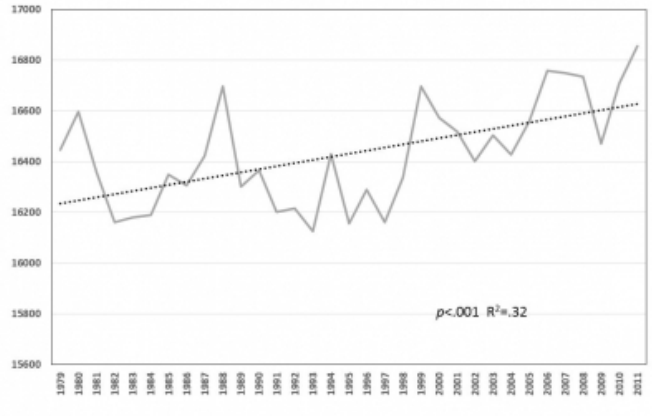

Figure 5

The change in the average daily solar radiation by year for the Continental United States by Geographic Region with linear regression lines. All Regions demonstrate significant increases in average daily solar radiation, with the greatest increases in the South.

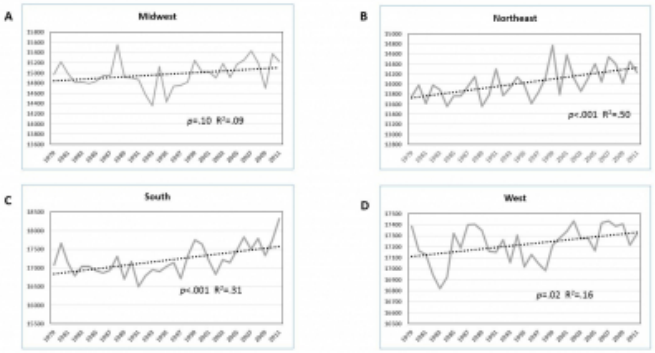

Figure 6

The change in the average daily solar radiation by year for the Continental United States by Geographic Division with linear regression lines.

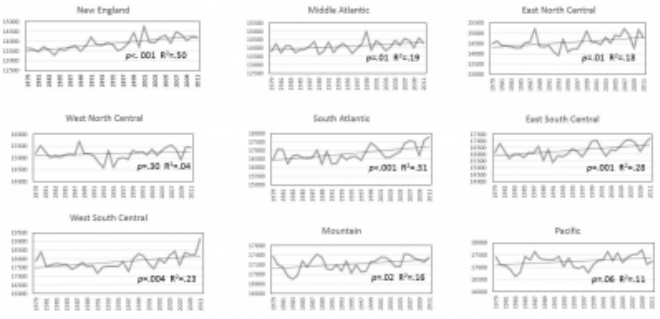

Figure 7

The relationship between NLDAS-derived average daily total solar energy and the SURFRAD-derived total UVB with linear regression and 95% confidence interval lines.

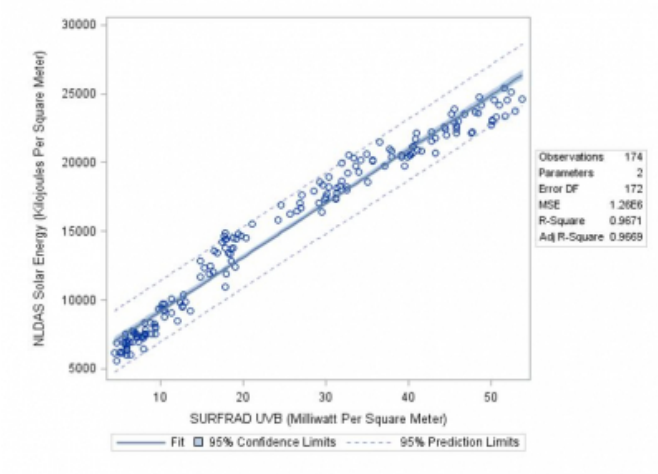

Table 1

Classification of US States Into Geographic Regions and Divisions

Geographic Regions	Northeast	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont
	Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
	South	Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia
	West	Alaska*, Arizona, California, Colorado, Hawaii*, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming_
Geographic Divisions	New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
	Middle Atlantic	New Jersey, New York
	East North Central	Illinois, Indiana, Michigan, Ohio, Wisconsin
	West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
	South Atlantic	Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia
	East South Central	Alabama, Kentucky, Mississippi, Tennessee
	West South Central	Arkansas, Louisiana, Oklahoma, Texas
	Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
	Pacific	Alaska*, California, Hawaii*, Oregon, Washington

*Not included in this analysis

Table 2

Change in Average Daily Sunlight Energy from 1979 to 2011

Geographic Area		Average Daily Sunlight Over Study Period 1979-2011 (KJ/m²)	Observed Increase in Average Daily Sunlight (KJ/m²/year)	*p* Value	Coefficient of Determination (R Squared)
Continental United States		16,432	12.3	<.001	.32
Geographic Regions	Northeast	14,023	8.08	.1	.09
	Midwest	14,970	18.7	<.001	.50
	South	17,204	23.1	<.001	.31
	West	17,220	6.79	.02	.16
Geographic Divisions	New England	13,877	25.1	<.001	.50
	Middle Atlantic	14,121	14.3	.01	.19
	East North Central	14,544	14.8	.01	.18
	West North Central	15,173	4.87	.30	.04
	South Atlantic	15,173	24.8	<.001	.31
	East South Central	16,312	26.5	.001	.28
	West South Central	17,831	20.5	.004	.23
	Mountain	17,213	5.86	.02	.16
	Pacific	17,241	9.23	.06	.11

DISCUSSION

For the Continental US as measured by the NLDAS Daily Sunlight data, this paper finds that solar radiation reaching the Earth's surface significantly increases over the 32 year study period. It should be emphasized that the measures contained within this dataset are not exclusively ultraviolet radiation. Rather these measures portray all wavelengths of sunlight, only a fraction of which are the oncogenic UVA and UVB wavelengths. Nevertheless, since NLDAS solar energy levels are closely aligned with UVB levels, it is likely that UVB radiation is increasing over the past three decades.

Readers should note that over the entire study period, the magnitude of increase on a National basis is only estimated to be 2.4% in units of KJ/m2, which translates to a 0.076% per year increase in KJ/m2. In the Geographic Division with the greatest numeric increase in daily sunlight energy, New England, there was a 6% increase, translating to a 0.19% increase per year. In the West North Central Division, the area with the smallest numeric (and statistically nonsignificant) increase, the increase over 1979 to 2011 was 1.0% translating to 0.032% change in KJ/m2 per year. The increase in the rate of nonmelanoma skin cancer has been far

greater than this increase,12 so the radiation change may not be the primary driver of change.

Those people residing in higher solar radiation areas such as the South or West Regions experience a larger dose of potentially harmful radiation than those in other areas. Hypothetically, if the increase in New England Division continues at 6% every 32 years, we would need to wait 132 years for New England to achieve the current average daily solar radiation of the Pacific Division.

There also appears to be marked year to year variations nationally and on a more local basis that contribute to the observed variability in the data. Just as some climate variability makes some seasons display more extreme temperatures than others,13,14 solar irradiation may display similar variability. This observation is likely the reason that, although all measures indicate that the average daily solar radiation is rising, the various observed coefficients of determination are all less than or equal to 0.50.

The implications of this study regarding increasing health risks from yearly increasing solar radiation are patently apparent. Nonmelanoma skin cancer rates continue to inexorably rise in the US and most such skin cancer has ultraviolet radiation as a cause.5,15,16 Any increase in ambient ultraviolet levels poses incremental increased risk over time. Threshold effects have been observed in at least one animal model suggesting that further radiation, around the oncogenesis threshold, increases risk.17 Recent evaluation and recommendations by the United States Surgeon General appear prudent.18 Clearly, since the data depicted in Figure 1 are typical of UV Index data published on a continuous basis, prudent solar protection approaches are required. With respect to the skin, further vigilance is required as ambient radiation rates increase over time.

At the same time, the issue of sunlight and health remains a complex one. Ultraviolet radiation increases could result in decreased vitamin D deficiency, with the possibility of decreased systemic risks of many conditions linked to hypovitiminosis D states. The literature on the benefits of ultraviolet radiation is extensive19 and beyond the scope of this discussion.

This author is not able to comment upon the methodologic limitations inherent in the measurements and estimations and algorithms employed by governmental climatologic and space agencies that generated this data. It is also beyond the scope of this author to speculate upon mechanisms such as ozone depletion and other factors noted to contribute to increasing solar radiation. It is certainly possible that despite an increase in overall radiation, that there may not be as large of a magnitude in change in ultraviolet radiation. There is no a priori reason to assume that the ultraviolet light proportion in the total radiant flux has changed, but this author could find no evidence scholarly activity related to this topic in the United States.

This manuscript finds evidence of a consistent and sustained increase in solar radiation over the past three decades. Whether the magnitude of this increase is sufficient to be a major factor in our current skin cancer epidemic is unclear.

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FINANCIAL DISCLOSURE:

Dr. Fleischer serves as a consultant to Kikuka America International. He was formerly an investigator for Galderma, Regeneron, AbbVie, and Eli Lilly. He was formerly an Employee of Merz North America. He has no other potential conflicts including Honoraria, Speakers bureau, Stock ownership or options, Expert testimony, Grants, Patents filed, received, pending, or in preparation, Royalties, or Donation of medical equipment

References

1. Guy GP, Jr., Machlin SR, Ekwueme DU, Yabroff KR. Prevalence and costs of skin cancer treatment in the U.S., 2002-2006 and 2007-2011. American journal of preventive medicine. 2015;48(2):183-187.
2. Jemal A, Saraiya M, Patel P, et al. Recent trends in cutaneous melanoma incidence and death rates in the United States, 1992-2006. Journal of the American Academy of Dermatology. 2011;65(5 Suppl 1):S17-25.e11-13.
3. Saraiya M, Glanz K, Briss PA, et al. Interventions to prevent skin cancer by reducing exposure to ultraviolet radiation: a systematic review. American journal of preventive medicine. 2004;27(5):422-466.
4. El Ghissassi F, Baan R, Straif K, et al. A review of human carcinogens--part D: radiation. The Lancet. Oncology. 2009;10(8):751-752.
5. Rass K, Reichrath J. UV damage and DNA repair in malignant melanoma and nonmelanoma skin cancer. Advances in experimental medicine and biology. 2008;624:162-178.
6. Berwick M, Buller DB, Cust A, et al. Melanoma Epidemiology and Prevention. Cancer treatment and research. 2016;167:17-49.
7. CDC. North America Land Data Assimilation System (NLDAS) Daily Sunlight (KJ/m²) (1979-2011) Request. http://wonder.cdc.gov/nasa-insolar.html. Accessed January 19, 2016.

8. Rui H MD. README Document for North America Land Data Assimilation System Phase 2 (NLDAS-2) Products. 2014; ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/NLDAS/README.NLDAS2.pdf. Accessed January 15, 2016.
9. US Census Bureau. Census Regions and Divisions of the United States. http://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf. Accessed January 20, 2016.
10. National Oceanic & Atmospheric Administration. SURFRAD (Surface Radiation) Network. http://www.esrl.noaa.gov/gmd/grad/surfrad/index.html. Accessed January 20, 2016.
11. National Oceanic & Atmospheric Administration. Index of /data/radiation/surfrad/averages. Index of /data/radiation/surfrad/averages. Accessed January 20, 2016.
12. Wu S, Han J, Li WQ, Li T, Qureshi AA. Basal-cell carcinoma incidence and associated risk factors in U.S. women and men. American journal of epidemiology. 2013;178(6):890-897.
13. Karl TR, Knight RW, Plummer N. Trends in high-frequency climate variability in the twentieth century. Nature. 1995;377(6546):217-220.
14. Woodhouse CA OJ. 2000 Years of Drought Variability in the Central United States. Bulletin of the American Meteorological Society. 1998;79(January 20, 2016):2693-2714.
15. Kricker A, Armstrong BK, Goumas C, et al. Ambient UV, personal sun exposure and risk of multiple primary melanomas. Cancer causes & control : CCC. 2007;18(3):295-304.
16. Lucas RM, McMichael AJ, Armstrong BK, Smith WT. Estimating the global disease burden due to ultraviolet radiation exposure. International journal of epidemiology. 2008;37(3):654-667.
17. Tanooka H, Ootsuyama A. Radiation carcinogenesis in mouse skin and its threshold-like response. Journal of radiation research. 1991;32 Suppl 2:195-201.
18. Surgeon General. The Surgeon General's Call to Action to Prevent Skin Cancer. 2014. Accessed January 20, 2016.
19. Baggerly CA, Cuomo RE, French CB, et al. Sunlight and Vitamin D: Necessary for Public Health. Journal of the American College of Nutrition. 2015;34(4):359-365.

Author Information

Alan B. Fleischer, Jr., MD
Division of Dermatology, Department of Surgery, University of Kentucky, College of Medicine
Lexington, KY, USA
alan.fleischer@uky.edu