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Solar radiation and the incidence and mortality of leading invasive cancers in the United States

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ABSTRACT

Invasive cancer risk is inversely related to ultraviolet light exposure. This study explores relationships between cancer and the satellite-derived sunlight energy. We obtained the North America Land Data Assimilation System (NLDAS) daily average sunlight for the continental United States from 1999–2011. US Cancer Statistics age-adjusted-incidence and mortality was also obtained from the Centers for Disease Control and Prevention (CDC). We found that cancer incidence for all invasive cancers and for 11 of 22 leading cancers significantly decreased with increased solar radiation. Cancer mortality for all invasive cancers was not significantly associated with solar radiation, but for 7 of 22 leading cancers, including cancers of the uterus, leukemias, lung, ovary, and urinary bladder, increased solar radiation predicted decreased mortality. With increasing solar radiation, increased incidence and cancer mortality was observed for liver cancer and increased incidence but not mortality was observed for cervical cancer. The current study confirms studies relating UV radiation to the incidence and mortality of a variety of cancer types. We find associations between solar radiation energy and the incidence and mortality of a number of types of cancers.

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Introduction

There have been many published studies and reviews linking increasing levels of ultraviolet B light or vitamin D levels to decreasing risk of cancers.[1-15] Boscoe and Shymura examined solar UV B as measured by total ozone mapping spectrometry, and the relationship to cancer incidence and mortality, finding distinct relationships. Another solar radiation dataset is available from the United States (US), the NLDAS Daily Sunlight data are available from the CDC.[16] NLDAS is a collaboration project among several groups: the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, Princeton University, the National Weather Service, the University of Washington, and the NCEP Climate Prediction Center.

No articles currently appear in the scientific literature which use the NLDAS as it relates to cancer. Kent et al.[17] examined sunlight data with regards to cognitive decline. Kent's group has also used these data to demonstrate that lower solar energy level is associated with higher stroke rates[18] and with high-density lipoprotein levels.[19] Another published study has examined effects of precipitation and temperature on human disease.[20]

The current study examines the previously reported relationships between UVL and cancer from other data sources using this novel and highly accurate source of solar energy.

Materials and Methods

We used NLDAS Daily Sunlight data, available on CDC Wide-ranging Online Data for Epidemiologic Research (WONDER), for daily sunlight observations from 1999–2011 by State.[21] The primary measure reported is the mean average daily solar radiation, reported in KJ/m^2. Over the same time interval (1999 to 2011), data for US Cancer Statistics were obtained from the CDC WONDER.[22] Incidence data were derived from the CDC National Program of Cancer Registries and the National Cancer Institute's Surveillance, Epidemiology and End Results.[23] Mortality data are provided by the CDC, the National Center for Health Statistics, and the National Vital Statistics System.[24]

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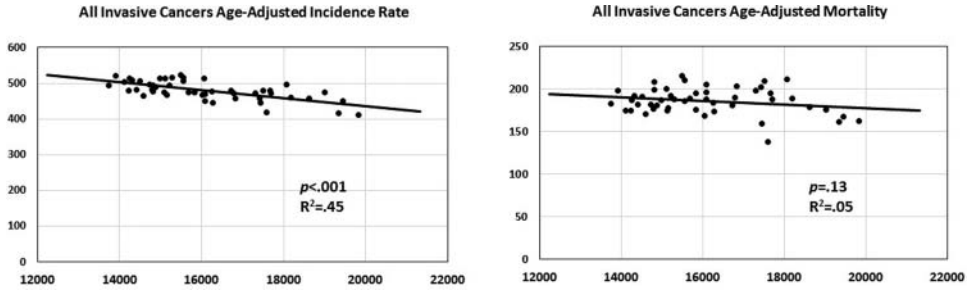

Figure 1. These figures relate solar radiation and all the incidence (left) and the mortality (right) of all invasive cancers between 1999 and 2011. Each point represents an individual US State or the District of Columbia and solar energy is in units of KJ/m^2.

We used age-adjusted incidence and age-adjusted mortality rates from the combined 48 contiguous (continental) states plus the District of Columbia, excluding Alaska and Hawaii to parallel the NLDAS data. Separate analyses were performed for each invasive cancer sites and for all of the leading cancer sites as identified by the CDC. Data analysis was analyzed by Microsoft Excel 2013. All regressions reported are linear and significance was achieved when $p < .05$. No adjustments were performed for multiple testing due to the difficulty in interpreting the results from this exploratory, ecological study.[25] Note that cancer data were deidentified and were accessed on a Statewide basis, so these procedures in this manuscript were in agreement with the Helsinki Declaration of 1975.

Results

Cancer Incidence. We found associations between increasing solar energy and decreasing cancer incidence for: all invasive cancers (Fig. 1, $p < .001$),

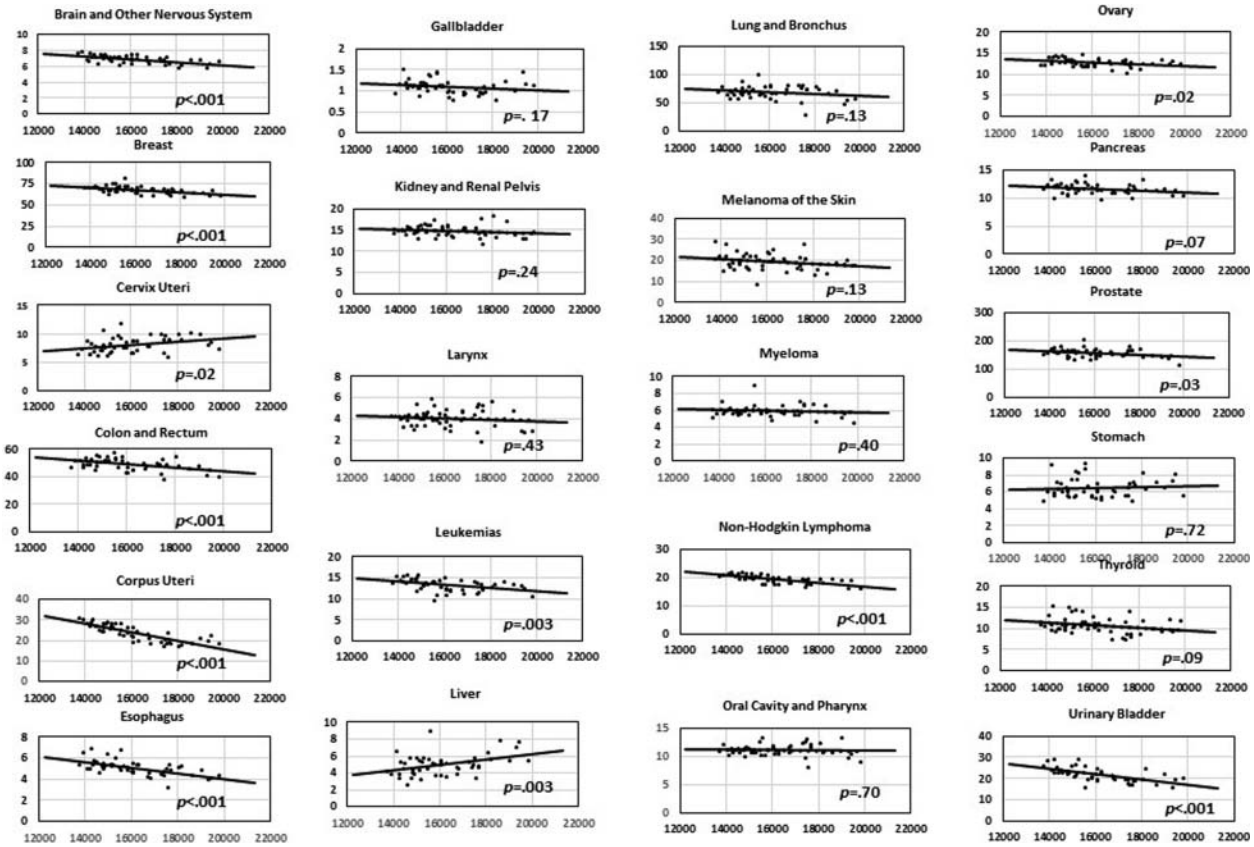

Figure 2. These 22 figures relate the relationships between average daily solar radiation and the incidence from the leading types of cancer between 1999 and 2011. Each point represents an individual US State or the District of Columbia and solar energy is in units of KJ/m^2.

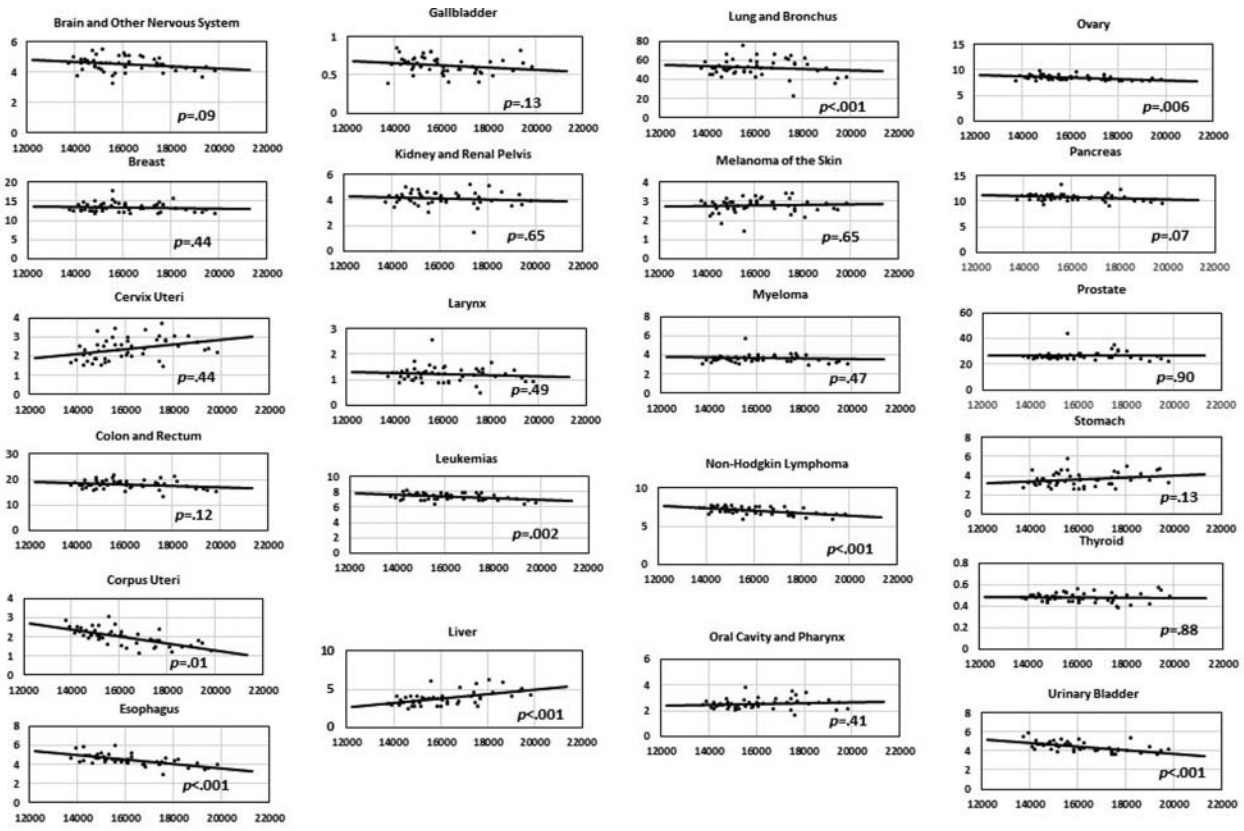

Figure 3. These 22 figures relate the relationships between average daily solar radiation and the mortality from the leading types of cancer between 1999 and 2011. Each data point represents an individual US State or the District of Columbia and solar energy is in units of KJ/m^2.

brain/nervous system cancer (Fig. 2, $p < .001$), breast cancer ($p < .001$), colon/rectum cancer ($p < .001$), corpus uteri cancer ($p < .001$), esophageal cancer ($p < .001$), larynx cancers ($p < .001$), leukemias ($p = .002$), non-Hodgkins lymphoma ($p < .001$), ovarian cancer ($p = .02$), prostate cancer ($p = .03$), and urinary bladder cancer ($p < .001$).

We found associations between increasing solar energy and increasing cancer incidence for: cervix uteri cancer ($p = .02$) and liver cancer ($p = .003$).

We found no associations between solar energy and cancer incidence for: gallbladder cancer ($p = .2$), kidney/renal pelvis cancer ($p = .2$), lung and bronchus cancers ($p = .1$), melanoma ($p = .1$), myeloma ($p = .4$), oral cavity and pharynx cancer ($p = .7$), cancer of the pancreas ($p = .07$), stomach cancer ($p = .7$), and thyroid cancer ($p = .09$).

Cancer Mortality. We found no association between increasing solar energy and decreasing cancer incidence for all invasive cancers (Fig. 1, $p = .12$). Associations were demonstrated between increasing solar energy and decreasing cancer incidence for: uterine cancer (Fig. 3, $p = .01$), esophageal cancer ($p < .001$), leukemias ($p = .002$), lung cancer ($p < .001$), non-Hodgkins lymphoma ($p < .001$), ovarian cancer ($p = .006$), and urinary bladder ($p < .001$).

We found that increasing solar energy increased liver cancer cancer mortality ($p < .001$).

No associations were demonstrated between solar energy and cancer mortality for: brain/nervous system cancer ($p = .09$), breast cancer ($p = .4$), cancer of the cervix uteri ($p = .4$), colon/rectum cancer ($p = .12$), gallbladder cancer ($p = .13$), kidney/renal pelvis cancer ($p = .65$), cancer of the larynx ($p = .5$), melanoma of the skin ($p = .6$), myeloma ($p = .5$), oral cavity and pharynx ($p = .4$), cancer of the pancreas ($p = .07$), prostate cancer ($p = .9$), stomach cancer ($p = .13$), and thyroid cancers ($p = .9$).

Discussion

This study examines the relationship between satellite-derived total sunlight exposure measurements from

the NLDAS and cancer incidence and mortality. These findings support published work relating the inverse relationship between UVL and cancer rates. Although the current study does not look specifically at UVL, the amount of solar energy striking each square meter of Earth is likely closely related to the magnitude of UVL. The availability of solar energy and cancer data on a State-by-State basis allowed each State to act as independent data points in our analyses. This is a refinement over studies that use latitude to predict solar energy. Engelsen reviews the many environmental factors beyond latitude that influence the quantity of ultraviolet light affecting human health, which includes cloud cover, ozone levels, and altitude.[26] The NLDAS takes much of this into account.

As stated above, we found associations between increasing solar energy and decreasing cancer incidence and mortality for: corpus uteri cancers, esophageal cancer, leukemias, non-Hodgkins lymphoma, ovarian cancer, and urinary bladder cancer. Using somewhat different methods, Boscoe and Schymura found generally similar results, but for instance they found that there was also an effect on prostate cancer incidence and mortality, not demonstrated herein. Although this latter study used different satellite measurements and a different, more detailed method of analysis, the similarity of the results suggest that using different methods outcomes are quite similar.

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Cancer Mortality. We found no association between increasing solar energy and decreasing cancer incidence for all invasive cancers ($p = .12$). Associations were demonstrated between increasing solar energy and decreasing cancer incidence for: uterine cancer ($p = .01$), esophageal cancer ($p < .001$), leukemias ($p = .002$), lung cancer ($p < .001$), non-Hodgkins lymphoma ($p < .001$), ovarian cancer ($p = .006$), and urinary bladder ($p < .001$).

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No associations were demonstrated between solar energy and cancer mortality for: brain/nervous system cancer ($p = .09$), breast cancer ($p = .4$), cancer of the cervix uteri ($p = .4$), colon/rectum cancer ($p = .12$), gallbladder cancer ($p = .13$), kidney/renal pelvis cancer ($p = .65$), cancer of the larynx ($p = .5$), melanoma of the skin ($p = .6$), myeloma ($p = .5$), oral cavity and pharynx ($p = .4$), cancer of the pancreas ($p = .07$), prostate cancer ($p = .9$), stomach cancer ($p = .13$), and thyroid cancers ($p = .9$).

The current study helps provide independent validation of other studies that have used other measures of solar intensity as they relate to cancer. UVL is oncogenic for nonmelanoma skin cancer.[27] Although melanoma of the skin is a light-related cancer, there is a complex relationship between this cancer and UVL and vitamin D.[28,29] By contrast, the cancer protective effects of sunlight are demonstrated in this study and many others. The findings of the current study add to the body of knowledge by their unique ecological approach, examining each US State Individually and examining both the incidence and mortality of a broad range of cancer types. The mechanism by which this effect occurs is unclear but much evidence for the role of vitamin D.[30-35] As Grant and Garland[11] succinctly stated, "Vitamin D metabolites increase cell differentiation, suppress growth-stimulatory signals, potentiate growth-inhibitory signals and reduce cell proliferation, metastasis and angiogenesis." Individual groups of investigators have added tremendously to this understanding.[31,34-39]

We found that light energy was more strongly related to cancer incidence than to mortality. Mortality rates are dependent upon the accuracy of the death certificate with known error rates.[40] Also, the factors that create cancer may be markedly different from those promoting biologically aggressive behavior.

Increased incidence of cervical and liver cancer, and increased liver cancer mortality were observed with increasing solar energy. Chen reported in China that increasing UVB was associated with decreases in many cancers including liver cancer, but increased mortality from cervical cancer.[8] The relationship between cancer and light energy is complex, and is modulated by many other environmental and genetic factors.

There are limitations of the current study. The cancer data used for the measurement of the incidence and mortality of cancers may be subject to measurement biases that could influence the results. A variety of sources have noted potential errors in reporting cancer-related information.[40,42] The complex modeling and details of the NLDAS are beyond the scope of this manuscript. Validation work on various aspects of the NLDAS have been performed. Luo and colleagues demonstrated that NLDAS measurements of solar radiation seem generally reliable,[43] and in an

unpublished manuscript one of us (ABF) demonstrated that NLDAS closely predicts ground-based UV light B readings. Most noteworthy validation is the finding that solar radiation predicts health outcomes.[17-19,44]

Every study has the potential of raising more questions and provoking more questions that can be studied. For instance, the study period of 1999 to 2011 could be divided into intervals to assess time-related changes. Alternatively, subset analysis by race and ethnicity could help elucidate more information from this type of ecological study. However, these were beyond the scope of the current study, but point to excellent future work that can be done.

A more important limitation is that this study does not address movement of individuals or groups between US States. Cancer in our study is assessed by State and not according to any demographic variables related to individuals. Cohn and Morin reported that 57% of adult Americans have not lived outside of their current State whereas 43% have moved between States.[45] Oncogenesis is complex, and the effect of solar radiation is more likely to be long-term rather than short-term. In this regards, the present study examines incidence and mortality over the same time periods with solar radiation. By contrast, because solar radiation may have many long-term effects, further studies may help to elucidate the temporal association between exposure and oncogenesis.

In summary, the current study confirms other ecological studies relating solar radiation to the incidence and mortality of a variety of cancer types.

Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

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