Journal of
Emerging Investigators

Is Cloud Cover One of the Effects of Climate Change?

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Summary

The research we conducted attempted to investigate the effects of cloud cover. Our research wanted to see if cloud cover acts as a shield to insolation, allowing less insolation to reach Earth's surface, allowing the Earth to cool. We did this by investigating the relation of cloud cover and sun insolation. We hypothesized that insolation would reduce as the cloud cover increased, which we assessed by calculating insolation and cloud cover using data collected from a pyranometer and a time lapse camera, and then relating them with each other. Our data suggest that our hypothesis was correct. As cloud cover increased, the insolation decreased. It appeared that clouds block out insolation, meaning they might not be a cause of global warming.

Received: June 29, 2013; **Accepted:** Jan 28, 2014; **Published:** March 24, 2014

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Introduction

In general most people acknowledge that the release of greenhouse gases by humans may be a cause of global warming. However, some scientists believe that clouds — which can either warm or cool the earth— may counter the expected temperature rise and/or equalize our climate. Others in the scientific community believe that clouds will most likely have a neutral effect or will even amplify the warming, perhaps strongly, but the lack of proof has created issues within this community. "Clouds really are the biggest uncertainty," said Andrew E. Dessler (1), a climate researcher at Texas A&M. "If you listen to the credible climate skeptics, they've really pushed all their chips onto clouds," states Richard S. Lindzen (2), a professor of meteorology at the Massachusetts Institute of Technology, who is the leading proponent of the view that clouds will "save the day". Dr. Lindzen says "the earth is not especially sensitive to greenhouse gases because clouds will react to counter them," and he believes he has identified a specific mechanism to explain this phenomena. "On a warming planet," he says, "less coverage by high clouds in the tropics will allow more heat to escape to space, countering the temperature increase." The Environmental Defense Fund (3) believes that a major effect of climate change is increased temperature, resulting in a record amount of floods, heat waves, and wildfires over the past few decades. Along with these problems created by the increased temperatures, cloud cover has been affected by the recent change in climate. Climate change appears as changes in weather (increased storms and drought conditions) so it might be assumed that changes in cloud cover might affect the impact of greenhouse gases.

There are numerous cloud types that are found in the Earth's skies. These different cloud types can determine our climate in various ways, making them an important factor of global warming. Clouds can act both as a shield to the radiation attempting to reach the Earth's atmosphere, as well as insulation to keep heat in the Earth's atmosphere (**Figure 1**). More dense clouds can reflect incoming radiation to the Earth's surface (**Figure 1A**), while the thinner clouds trap the insolation in the Earth's atmosphere (**Figure 1B**). On a day with no clouds, the Earth receives about 1000 W/m^2 (watts per meter squared) of radiation. When there is light cloud cover (1-30%), some of the radiation is absorbed or scattered, so the Earth only receives 830

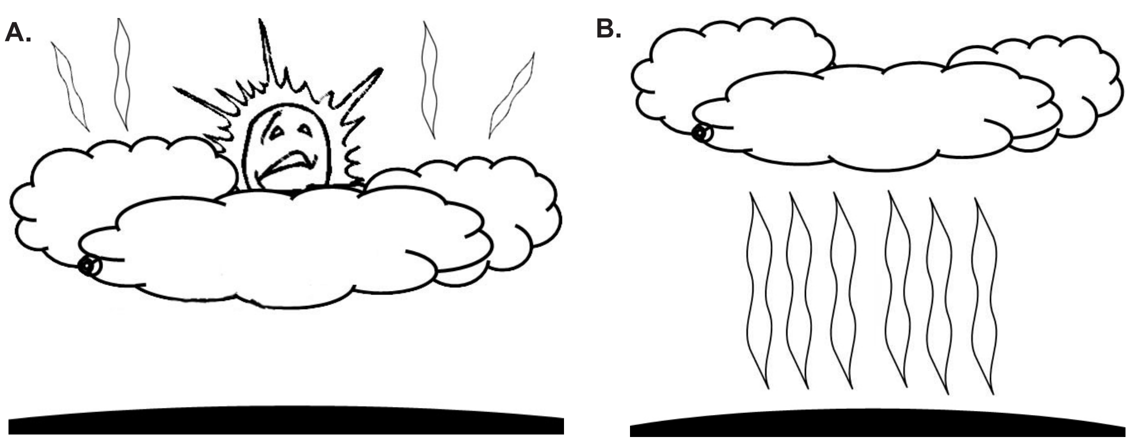

Figure 1: Clouds may have two opposite effects on temperature. A: Clouds may keep the sun's heat from reaching the Earth. **B:** Clouds may retain the heat on the Earth.

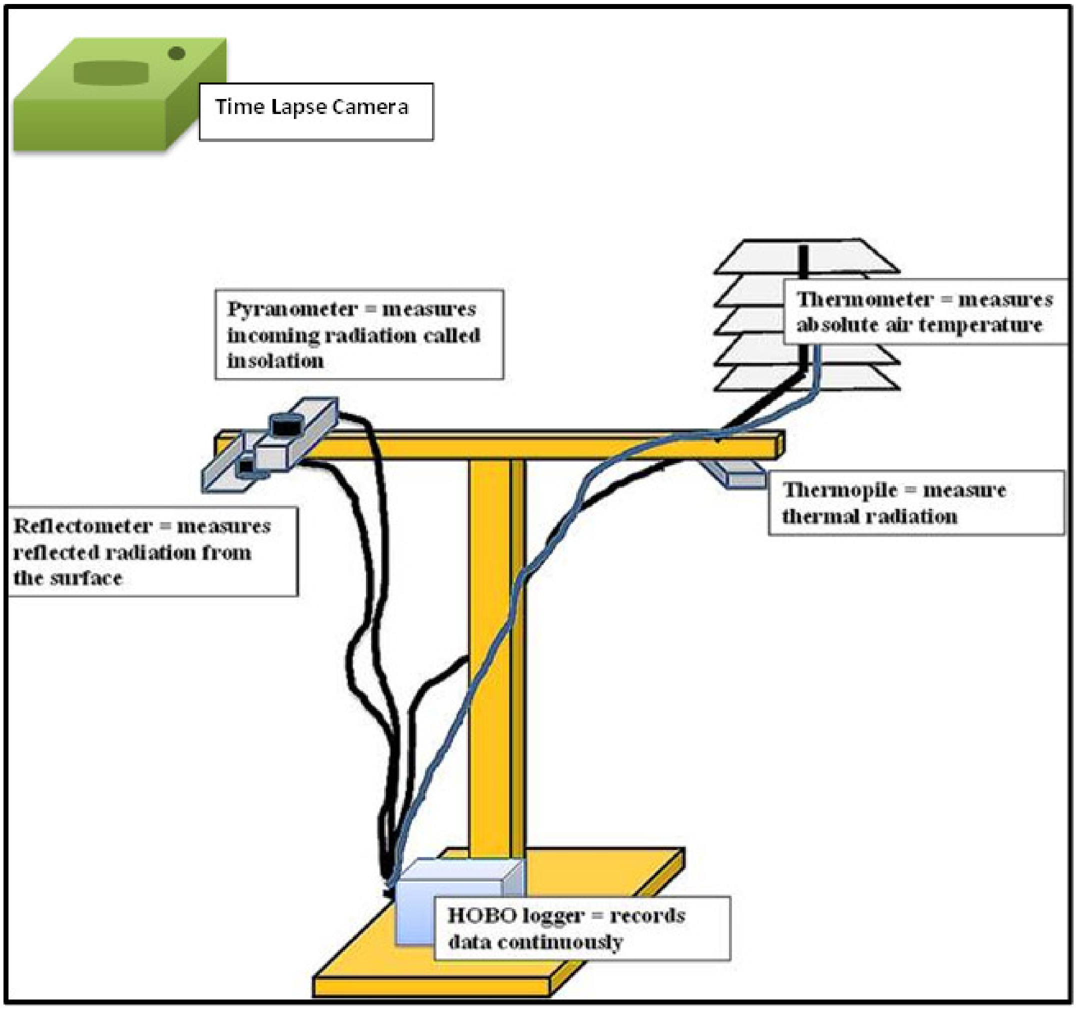

Figure 2: Our experimental setup.

W/m^2 of radiation. Medium cloud coverage (31-59%) could reduce the Earth's radiation to 300 W/m^2, and a high amount of low-hanging clouds (60-80%) could bring down the amount of radiation to 230 W/m^2. If it is overcast due to a large amount of cloud cover, the Earth may receive less than 150 W/m^2 of radiation, even in the middle of the day (4). For example, if 342 W/m^2 of incoming insolation comes in contact with the Earth's surface and atmosphere, 77 W/m^2 is directly reflected by clouds, aerosols, and atmospheric gases back into space, and 67 W/m^2 is absorbed by the atmosphere. Of the rest, 30 W/m^2 is reflected by the Earth's surface and 168 W/m^2 is absorbed by the Earth's surface.

Our experiment tested if the amount of cloud cover over an area affects that area's amount of solar insolation. Insolation is defined as solar irradiance on a horizontal surface at Earth's surface. It is controlled primarily by the seasons and the weather. Maximum daily total insolation is greatest during the summer when the sun is highest in the sky. Even under clear sky conditions, the atmosphere reduces the amount of sunlight that reaches Earth's surface. Gas molecules (including water vapor) and aerosols (small particles suspended in the atmosphere) scatter sunlight, some of which is returned to space. Gases (including water vapor) and aerosols also absorb sunlight and some of this energy is re-radiated back to space. Of course, clouds have a major effect on insolation because they reflect a great deal of sunlight back to space (5). We have noticed that in South Florida that if there was 100% cloud cover in the sky then the amount of incoming solar radiation appears to be high. The data from this study might assist in determination if clouds are a factor of climate change.

Results

Data was collected using sensors measuring incoming and reflected solar insolation, thermal radiation and air temperature (**Figure 2**). The data was compared to images taken of cloud cover (**Figure 3**). The comparisons showed that when there was a large amount of cloud cover, such as 50% or more, there was less insolation, and the more clouds, the less radiation. Inversely, when there was less than 50% cloud cover, there was more solar radiation, and the insolation continued to rise if there was even less cloud cover. On August 5, 2012, a storm occurred, and the cloud cover reached one hundred

Figure 3: Photographs of cloud cover taken by our time-lapse camera.

percent. The insolation reached as low as 0.00977 W/m^2, which is particularly low since most of the values were between 0.01 and 0.1 W/m^2 (**Figure 4**). Another stormy day was August 15, 2012, and just like on August 5, the insolation was less than most days. On a day with clear skies, like July 30, the radiation received ranged from 0.01099 to 0.11722. Although some days were not as consistent, overall our hypothesis was consistent with the data collected. If there are more clouds over an area, that area will receive less radiation than if there were no clouds at all.

Discussion

The purpose of our project was to find out if the amount of cloud cover has an effect on the amount of insolation. We expected that cloud cover would affect the amount of insolation. Our data showed that our assumptions that clouds would reduce incoming solar radiation all the time were not always true. We found anomalies such as when the sky was mostly covered by clouds, there was still increasing solar radiation, thus increasing the temperature of our area.

On a stormy day, with high cloud cover, there was relatively low insolation compared to a day with no clouds at all. We conclude that if there are more clouds over an area, that area will receive less radiation than if there were no clouds at all. Between 1978 and 2012, solar radiation was measured over the Mediterranean Sea and compared to the data estimated using Reed's formula (6). The results showed that the insolation estimated using the formula was too high when there was a clear sky and too low when there was a highly cloudy sky. The clear sky estimate was too high was due to high amount of water vapor in the air. The reason the formula was too low is when a high amount of clouds were present could be the imperfection of the cloud cover index. Either way, the average difference between the observational data and the data from the formula is insignificant, and demonstrates that this formula can be used to predict average insolation over long periods of time over the Mediterranean Sea (6).

Our process was limited because we had to use different sites for the camera and the pyranometer. Due to various issues we only were able to collect one week of data that had both sensor information and cloud cover. Our equipment could have been tampered with, either accidentally or on purpose. We found evidence of animals chewing on the case enclosing the Hobo logger and some of the sensors were lose. Another time we found all the sensors removed from another site and we would not have known until the next time we collected the data. To obtain more accurate results, we also could have checked on the equipment more often.

This experiment demonstrates a small example of an area affected by insolation and cloud cover and the effects on temperature of a small representation of a typical suburban area in South Florida. The most clear mesoscale indicator of climate changes due to urbanization is a well-known urban/rural convective circulation known as urban heat islands (UHI, 7). One of the main causes of UHI formation is the progressive replacement of natural surfaces by built surfaces, through urbanization. Natural surfaces use large proportions of the absorbed radiation in the evapotranspiration process and release water vapor that cools the air. In contrast, built surfaces tend to absorb a lot of the incident radiation, which is released as heat. Therefore it appears that human activity in urban environments has some impact (on the regional scale) such as changing the atmospheric composition, affecting the water cycle, and changing some ecosystems.

Methods

Our field study was conducted in a grassy residential area in Miami, FL. Although Miami is an urban area, there are many areas that have vegetation, approximately 45% is vegetated as calculated by using Google Earth satellite image. Our field site included low volume vegetation (grass and low trees), buildings and infrastructure (houses, roads, sidewalks) to provide a representative sample of the Miami area. The field was situated in South Miami Middle Community School to provide security for the equipment. The independent variable in our experiment was the amount of cloud cover, while the dependent variable was the amount of incoming solar radiation coming through the atmosphere.

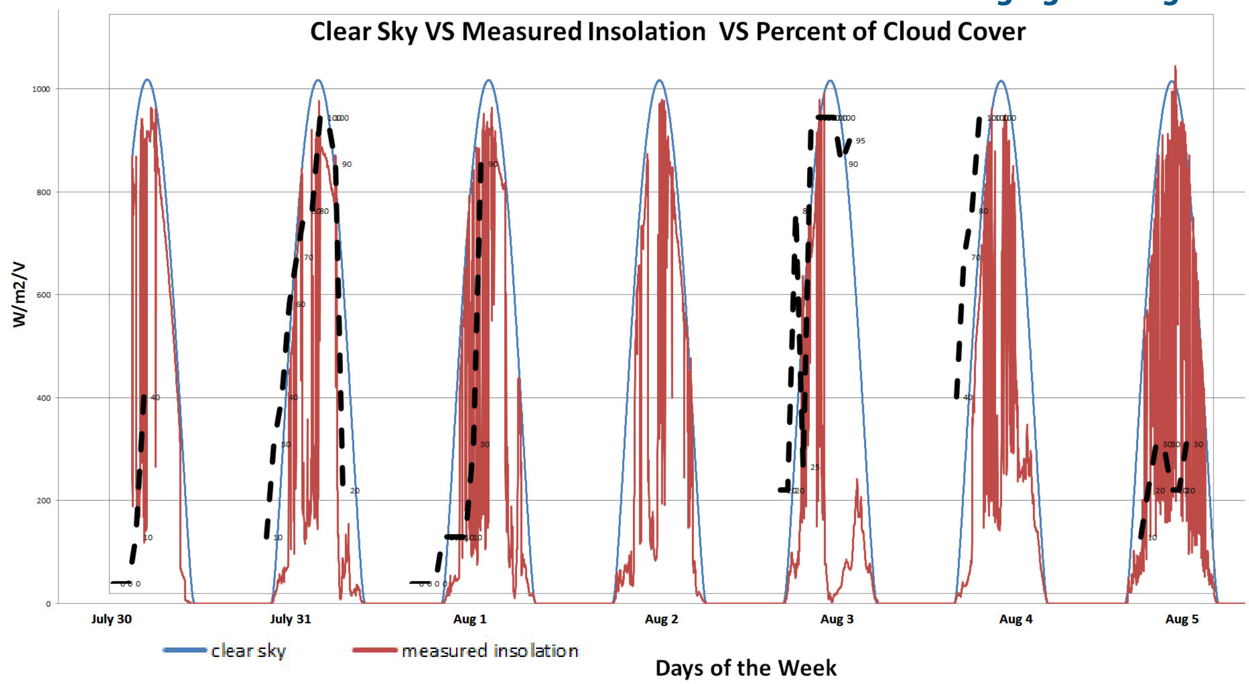

Figure 4: Clear Sky vs. Insolation vs. Percent Cloud Cover. The clear sky data is a calculation of a very clean sky without particulates or clouds. Insolation is a measure of solar radiation energy received on a given surface area and recorded during a given time. Cloud cover was calculated as a percent of the visible sky covered by clouds.

All the equipment was on a stand one meter above the ground (Figure 2). We used four sensors (a thermopile, a thermometer, and two pyranometers – one measuring up and one measuring down) connected to a four-channel HOBO logger plus a time- lapse camera (Plant Cam-Wingscapes). We set the HOBO logger to collect at one minute intervals. While these data were collected, we placed the time- lapse camera and recorded the cloud cover for twelve hours (8:00 am-8:00 pm) using thirty- minute intervals. Data was imported to the computer each week. Due to various issues we only were able to collect one week of data that had both sensor information and cloud cover. We associated the times of the time-lapse camera images with the times of the pyranometer data and compared. Cloud cover was calculated by using a 10-part grid and measuring the percent covered. All sensor data was collected in volts. The pyranometers were all calibrated to each pair and constants were known for each pair. This information was used in the Excel calculation to convert the data into W/m^2/V. The following equation was used to convert the thermopile to temperature in Excel: (=-0.002603*(V*2)^6 +0.04082*(V*2)^5 -0.38431*(V*2)^4 +1.8498*(V*2)^3 -6.835*(V*2)^2 +32.71*(V*2) -26.75). Clear Sky data was calculated using a number of variables. 1) Total precipitable water vapor (PW) in the atmosphere, in units of cm of water. The higher the value, the less the insolation; 4 cm appears to be reasonable value for Miami in the summer. PW is approximately related to the dewpoint temperature, which is calculated from air temperature and relative humidity. 2) Aerosol optical thickness. This is a value for a very clean sky, again a reasonable low value for Miami in the summer. 3) Barometric pressure in millibars (mbar). Standard pressure, 1013.25 mbar at an elevation of 10 m for our site. 4) The solar zenith is when the sun is directly overhead. Since we use the geodetic latitude we say "up" is at its highest point is 0 degrees. 5) We use a clear sky model uses a modified cosine curve symmetrical around the solar noon so that we were able to estimate the clear-sky insolation. With this model were are able to control the various percentages of cloud cover data for "clear-sky" to see if varying amounts of cloud cover is a factor.

Acknowledgments

We want to thank our science teacher Dr. Suzanne Banas for her vision and support throughout this process. Without her we would not have been able to complete these experiments. Dr. Kathleen Sealey, Department of Biology, University of Miami, provided us with classroom space and assisted us on this journey to becoming scientists. Special thanks to David Brooks, PhD, Director: Climate Science Research for Educators and Students (CSRES), for providing us with the necessary equipment, training in real world research, and his unflagging support in every aspect.

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