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Validation of GLOBE Citizen Science Air Temperature Observations Using Data from the Great American Solar Eclipse

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Abstract. During the Great American Solar Eclipse on August 21, 2017, students and citizen scientists across the United States took weather observations as part of the Global Learning and Observations to Benefit the Environment (GLOBE) Program. They collected air temperature and cloud cover through the GLOBE Observer app and land surface temperature using protocols established by the program. The data will be used to understand the effects an eclipse can have on the weather. Over 80,000 observations were taken before, during and after totality or maximum eclipse. Given the large number of observations, the eclipse was a great opportunity to investigate the accuracy of the GLOBE citizen science data collection. For this study, 700 GLOBE air temperature observations were compared with data from 92 National Weather Service weather stations. Citizen Scientist observations taken within 15 km of a NWS weather station between 15:00 and 20:00 UTC on the day of the eclipse were compared. The results show that there was good correlation with an R^2 of 0.9°C. A t-test showed that the observations were related. Future studies will include further validation of the GLOBE citizen science cloud cover and land surface temperature observations as well as analyses of weather changes during the eclipse.

1. Introduction

The Great American Solar Eclipse on August 21st, 2017 was a unique opportunity for the scientific community to study the effect of solar radiation on Earth's surface. Previous studies have shown that a solar eclipse will impact local weather, specifically air temperature and clouds (Aplin & Harrison 2003; Aplin et al. 2016; Chung et al. 2010; Gandini et al. 2016; Harrison & Giles 2017; Maturilli & Ritter 2016; Portas et al. 2016; Rao et al. 2013). These studies found that air temperature dropped between 1 and 4°C, wind became lighter, and relative humidity increased during eclipses. Also, cold outflow from the umbra was detected in cloudy conditions during 1999 United Kingdom (UK) total eclipse (Aplin & Harrison 2003). Significant reduction in both temperature and wind speed was demonstrated during the 2015 eclipse in the UK (Barnard et al., 2016). The pattern of eclipse related changes in wind, reduction in surface pressure, and reduction in boundary layer height were identified in the 1999 and 2015 eclipses in the UK (Harrison & Gray 2017). Besides obvious reduction in solar radiation and atmospheric cooling, Aplin et al. (2016) reviewed the 44 solar eclipses since 1834 and found that "Gravity waves set up by the eclipse can be detected as atmospheric pressure fluctuations." In addition, solar eclipses have given insights into upper atmospheric ionization.

To successfully observe and draw meaningful conclusions from such an event, a large number of observations are required. Despite the challenges on data quality, sustainability, and legal issues on privacy, citizen science networks have great potential to be a valuable source of data for earth observation (Bonney et al. 2009; Dickinson et al. 2010; Fritz et al. 2017; Semaratne et al. 2017). A bonus is that special weather events, such as eclipses, provide opportunities to engage the public through a citizen science network (Barnard et al. 2012; Illingworth et al. 2014; Portas et al. 2016). During the total solar eclipse in Great Britain in 2015, Harrison and Giles (2017) engaged citizen scientists in taking weather observations. One of their research results was validation of data that citizen scientist takes.

The GLOBE Program makes effort to engage citizens in scientific inquiry and utilize their expertise to collect a large number of data across the world. GLOBE was primarily a K–12 program for teachers and students to be inspired in scientific data collection and experiments since 1994. Now, GLOBE is an international program in 120 countries that engages students and the public as citizen scientists through taking observations of their environment to answer scientific research questions. Thus far, The GLOBE database has over 150 million observations and some research projects have been completed using it (Ault et al. 2006; Rossiter et al. 2015; Ibrahim et al. 2018). However, the validity of the GLOBE observations has been questioned and their accuracy is not known. There is a need to validate the observations and understand their scientific validity. Therefore, the large amount of data collected during this eclipse is very valuable for validation efforts.

This chapter focuses on validating GLOBE air temperature data that was collected by students and citizen scientists during the eclipse. Air temperature was selected over other observations because it was the most abundant dataset that was collected with over 80,000 observations and standard air temperature observations are readily available from the National Weather Service.

2. Methodology

2.1. Data Sources

Students and citizen scientists in the GLOBE Program took air temperature, clouds and surface temperature observations during the Great American eclipse. It provides uniform protocols for students and citizen scientists to collect data and investigate the atmosphere, biosphere, hydrosphere, and soil/pedosphere. The data entry, visualization, and retrieving system provide a stable platform for citizen scientists to enter data, for public to view data, and for the scientific community to retrieve data for further research. In 2016, the GLOBE Observer app was released, which allowed citizen scientists to observe clouds using their phone (Hayden 2018). In preparing for the solar eclipse, the GLOBE Program added air temperature observations to the app. During the eclipse, students and citizen scientists took observations every 10 minutes from at least one hour before to one hour after totality or maximum eclipse if they were not on the line of totality. They were encouraged to enjoy the eclipse during totality or maximum eclipse while it was occurring and not take observations during that time. A standard alcohol filled thermometer was used to observe air temperature. Instructions

Figure 1. Tennessee State University professor David Padgett demonstrating to TSU students how to take observations

for taking air temperature were available on the GLOBE Observer app and through the GLOBE website. Over 4000 people participated in GLOBE observations during the solar eclipse collecting over 100,000 observations. Although surface temperature and cloud observations were important observations during the eclipse, that data will not be discussed here.

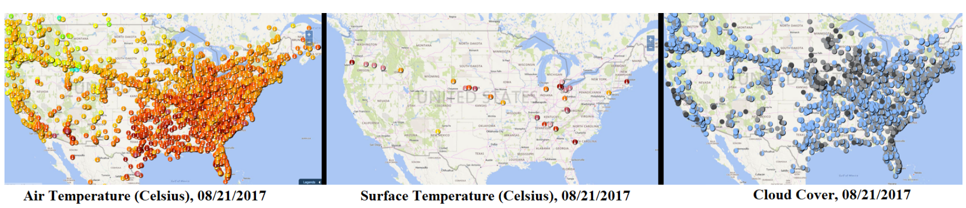

Figure 2. GLOBE Observations taken on August 21, 2017 a) air temperature, b) surface temperature, and c) cloud cover

For this study, GLOBE observations for August 21, 2017 were gathered from the GLOBE data visualization system (https://vis.globe.gov/GLOBE/, accessed on November 20th, 2017) for the day of the eclipse (Figure 2). From the large number of data, only the observations between 15:00 to 20:00 UTC were selected because that was the time-frame within which the eclipse was prominent.

The National Weather Service (NWS) air temperature data was collected from the NOAA National Climatic Data Centers (NCDC) website.[1]

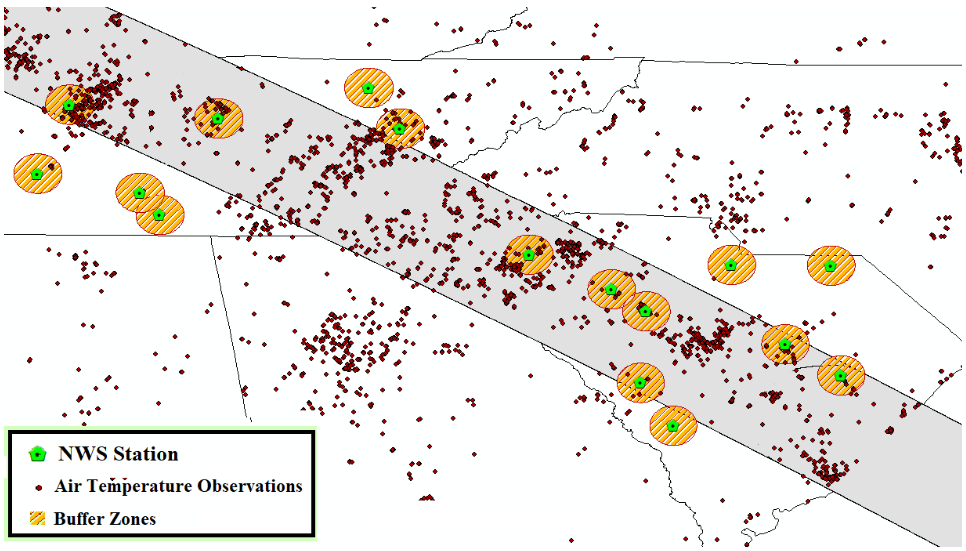

Figure 3. Separating GLOBE observations within 15 km of NWS stations.

2.2. Analysis

The first step in the analysis was to identify the GLOBE observations that match the time and location of NWS observations. About 2800 observations from more than 250 weather stations were collected between the time-frame of 15:00 to 20:00 UTC, August 21, 2017. A buffer of 15 km was placed around the NWS stations, and if GLOBE observations were taken within the buffer, that weather station was kept for this analysis. Of the 250 weather stations, 92 stations had GLOBE observations within 15 km. From the 80,000 available air temperature observations, the data was narrowed down to 63,082 observations by limiting the observation time to between 15:00 to 20:00 UTC. Next, a 15 km buffer was placed around the NWS weather stations and GLOBE observations within the buffer were separated out (Figure 3). Lastly, only GLOBE observations that occurred within ±6 minutes from a NWS observation were used narrowing the dataset down to 676 observations for the comparison.

The NWS observations were spaced every 20 minutes so the dataset had observations for 15:15, 15:35, 15:55, 16:15, 16:35 . . . 19:55. The GLOBE observations that occurred ±6 minutes from these times were selected. The GLOBE observations were subtracted from the NWS observations. Basic statistics including the average difference, standard deviation of difference, R^2, and t-test were performed.

[1] `https://www7.ncdc.noaa.gov/CDO/cdopoemain.cmd?datasetabbv=DS3505&countryabbv=&georegionabbv=&resolution=40`, accessed on November 20th, 2017.

3. Results

An example of the comparison between the GLOBE observations and NWS data is shown in Table 1. It is evident for this location that the peak temperature was at 17:15 UTC for both GLOBE and NWS and then the temperature fell for both. For this location, the maximum difference in air temperature was 1.9° C for the 15:37 UTC GLOBE observation. The maximum difference in time of measurement was four minutes for the GLOBE observation of 15:51 UTC. In this manner, comparison for all 92 station observations were done.

Table 1. Validation for the Station: RICKENBACKER INTL AIRPORT, 724285

Time NWS (UTC)	Temp NWS (C°)	Temp GLOBE (C°)	Time GLOBE (UTC)	Temp Difference (C°)	Time Difference (min)
15:35	28.4	30.3	15:37	1.9	0:02
15:55	28.8	28.9	15:51	0.1	0:04
16:15	29.2	28.8	16:16	0.4	0:01
16:35	29.7	28.9	16:37	0.8	0:02
16:55	30.3	31.7	16:53	1.4	0:02
17:15	30.6	30.9	17:14	0.3	0:01
17:35	30.1	29.6	17:33	0.5	0:02
17:55	30.5	31	17:55	0.5	0:00
18:15	29.8	29.6	18:15	0.2	0:00
18:35	28.8	29.3	18:36	0.5	0:01
18:55	28.3	29.5	18:53	1.2	0:02
19:15	28.7	29.1	19:13	0.4	0:02
19:35	29.8	29.3	19:34	0.5	0:01
			Average:	0.89	0:02

The comparison of GLOBE observations with NWS observations are summarized in Figure 4. The r-squared value of this match is 0.9°C, which indicates that the two datasets are quite similar. The trend-line matches the one-to-one line showing that there is no influence from the temperature on accuracy of the observations. For this analysis, this means that the GLOBE observations match well with the NWS dataset.

In Figure 5, 241 out of the 676 total observations (35.6%) show a temperature difference of 0 to 0.5°C between the datasets. For another 145 observations, the difference was between 0.5 to 1°C. That means that 83.8% of the data have a temperature difference between 0 to 2°C. Only 14 observations have a temperature difference of over 4° C with a a maximum difference of 4.6° C for one particular GLOBE observation. Figure 5 shows that most of the differences were less than 2 degrees Celsius, and the maximum difference was below 4.6°C. The largest discrepancies appear to be in Illinois and Indiana while the lowest seem to be along the line of totality.

In Figure 7 the average difference in temperature binned by time every 20 minutes is shown. The dot is the average difference in air temperature while the black bar shows the error range based on standard deviation. To complete the validation, a t-test was run on both datasets and the resulting P-value was 0.32, which indicates that the two

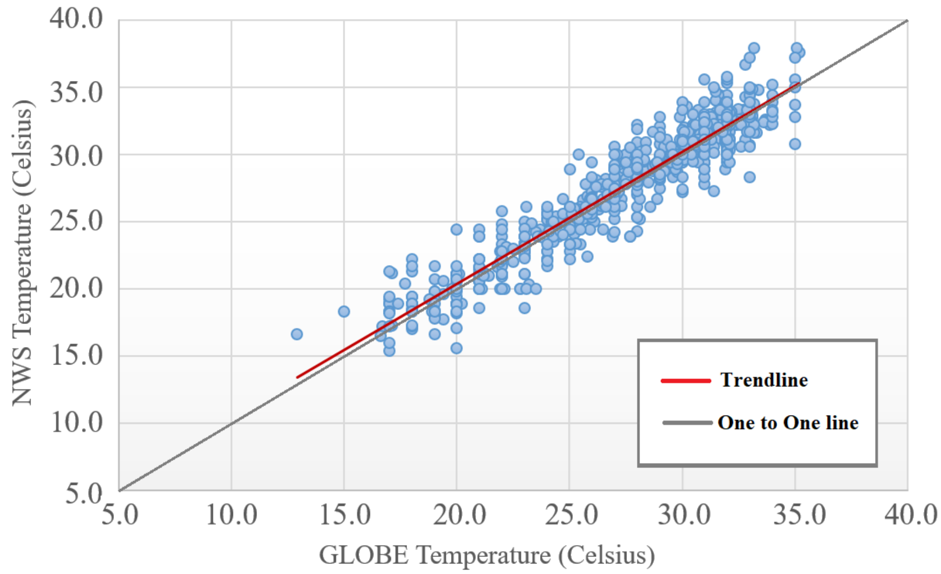

Figure 4. Comparison between NWS and GLOBE air temperature observations (between 15:00 to 20:00 UTC, 21 Aug 2017).

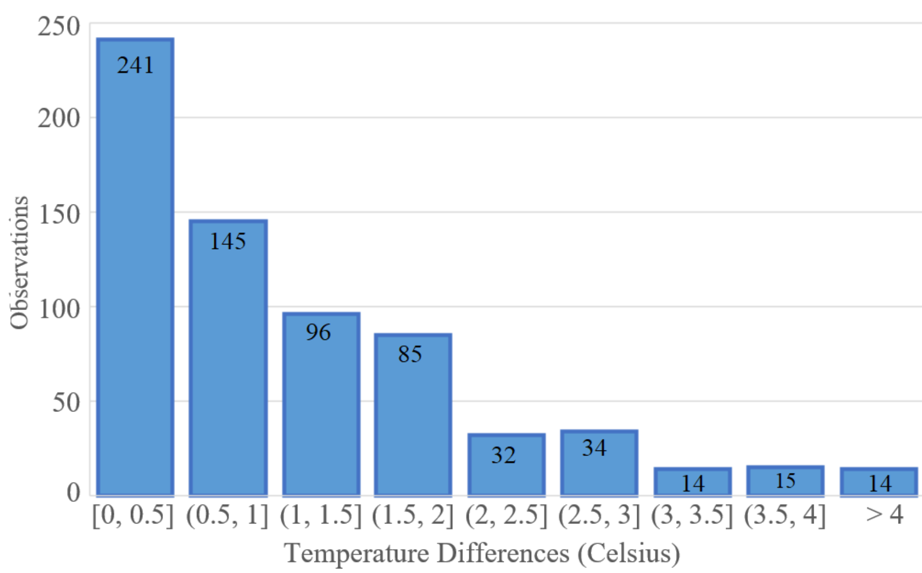

Figure 5. Binned errors of GLOBE versus NWS Observations at 17:55 UTC, 21 Aug 2017. The bins are in 0.5° C intervals and represent the number of observations that fall within that range.

datasets, though collected independently from each other, do not have any significant differences between them.

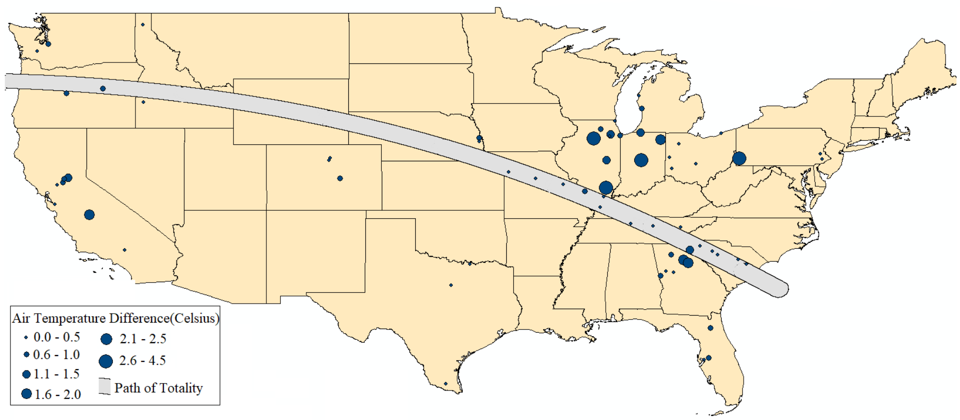

Figure 6. Difference in air temperature reported between GLOBE and NWS observations of 17:55 UTC.

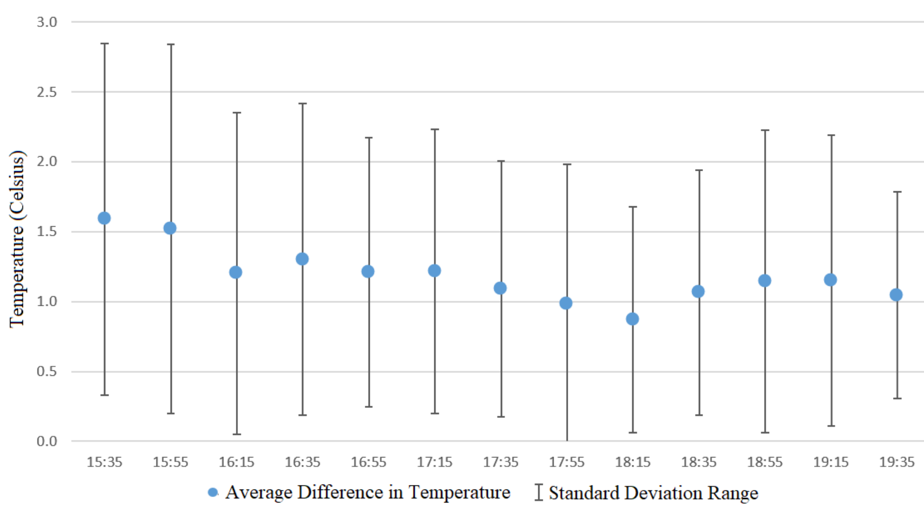

Figure 7. Average difference between GLOBE observations and NWS air temperature over time during the eclipse across the United States. The average difference is represented by the dot and the standard deviation by the bars.

4. Conclusions and Discussion

This study compared the citizen scientists collected air temperatures with NWS air temperatures within 15 km distance during 2017 US eclipse event. The results showed that air temperature, as observed by students and citizen scientists through the GLOBE Program, is reasonably accurate. Differences between the NWS observations and GLOBE citizen science observations were mainly within 2°C. Also, the observations entered by the citizen scientists was not exactly the values reported by the NWS stations. This indicates that the observers used thermometers and did not just take air temperature observations that are recorded on the internet at airports.

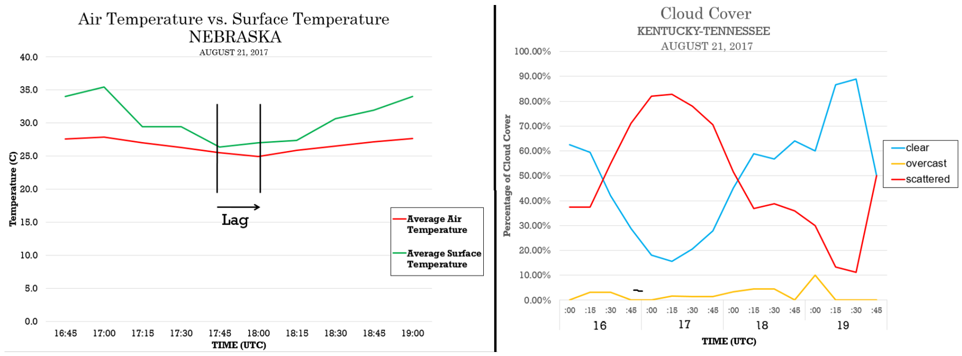

Figure 8. Examples of station observations comparing, a) surface temperature to air temperature and b) cloud cover (clear, scattered and overcast).

Future studies will look at the changes in air temperature, clouds and surface temperature over time during the eclipse. Figure 8 is an example of the type of data that is available within the GLOBE database. Figure 8a, focused on the observations taken in Nebraska, shows the decrease in both air and surface temperature with during the eclipse. There is a lag shown where the surface temperature reaches its minimum about 15 minutes before the air temperature reaches its minimum. Figure 8b shows the change in cloud cover with time which again coincides with the time of the eclipse of that region. Note that skies became clearer in general as totality approached and then skies became cloudier again once the sun came out from behind the moon. This data is rich for further study.

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