

Quantifying the Meteorological Effects of the 2017 Great American Solar Eclipse Using Citizen Scientist Observations



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1. Research Focus

Solar eclipses provide the scientific community with a natural experiment of the processes within the Earth system. Through the rapid reduction and recovery of surface insolation, the short-term interrelationships between surface fluxes, clouds, temperature, and other meteorological components. Past observations of the eclipse-induced temperature perturbation show a wide range of values dependent on multiple factors. One of the primary factors is prevailing cloud cover, which is challenging to quantify.

The large public interest in the 21 August 2017 eclipse provided an opportunity for a study of the eclipse using citizen science. Inspired by past citizen science efforts, the GLOBE Observer (GO) program organized a citizen science campaign for the 2017 eclipse. The large number of observers combined with their ability to travel to meteorologically important areas provided nearly unbroken coverage of the path of totality, and provides a useful complementary view of the eclipse with the automated networks.

Primary questions:

- 1) What is the quantitative relationship between prevailing cloud cover and eclipse-induced temperature perturbation according to citizen scientist observations?
- 2) How well do the results from the citizen scientist observations compare with those from conventional ground observing stations?

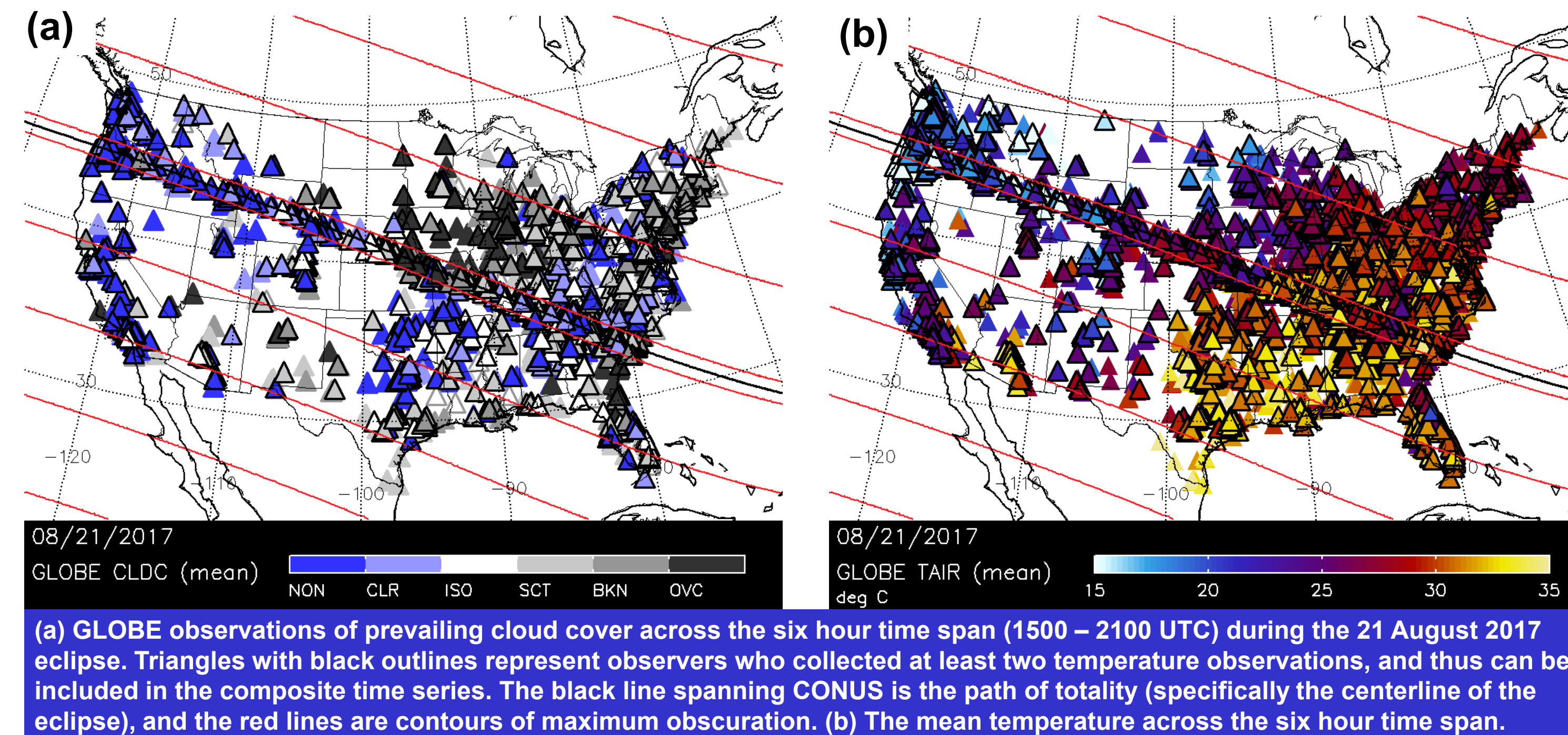
2. Citizen Science and Mesonet Data

- Citizen science observations were collected through a special campaign through GO, named *Eclipse Across America*
- Participants were asked to use the GO app for mobile devices to report local cloud cover and temperature (the latter from store-bought instruments)
- 10,500 unique observers collected 75,000 temperature and 20,000 cloud observations from 18,000 observing sites across North America, with most in the contiguous United States (CONUS)
 - about half the sites were in the path of totality
- Citizen science observations have significant advantages over conventional ground observing stations
- However, citizen science also has important limitations
- In addition, observations in the path of totality were collected from the Nebraska Mesonet for comparison with GO results

7. Conclusions

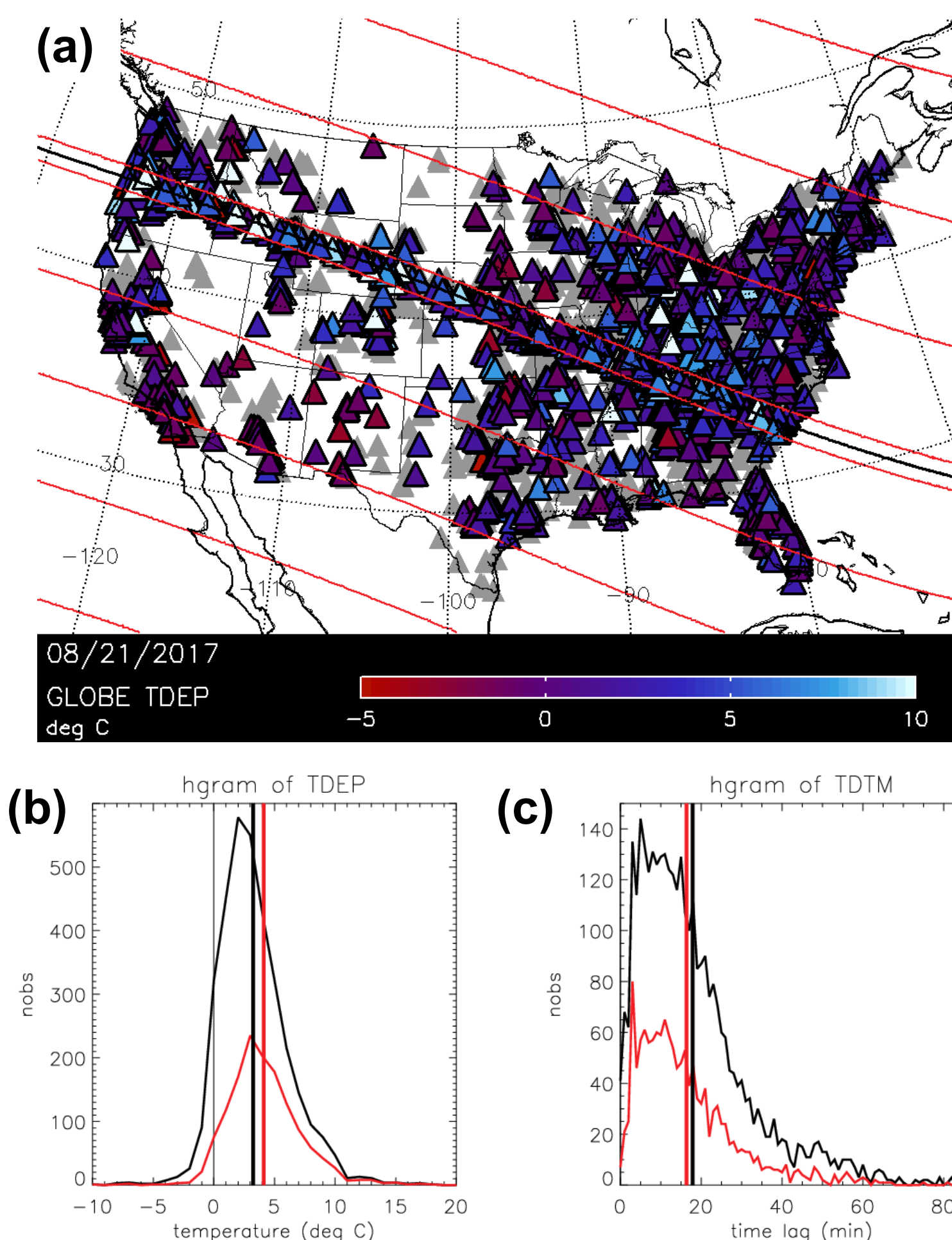
- 1) Cloud cover reduces the temperature perturbation caused by the eclipse. Cloudy regions experience about half the perturbation of clear regions. This conclusion holds for CONUS, the eastern half of CONUS, and the state of Nebraska.
- 2) Observations from the Nebraska Mesonet also show a reduction of the temperature perturbation in cloudy regions of the state compared with clear regions.
- 3) Citizen science observations contribute valuable information about meteorological properties. However, a proper methodology must be applied in order to leverage the strengths of citizen science and reduce the major limitations to producing robust results

3. Meteorological Conditions during Eclipse



- The mean temperature across CONUS varied by 20°C across path of totality, reflecting variety of meteorological conditions along path
- Cloudiness varied greatly over nation, including path of totality
 - western CONUS was largely cloud-free
 - eastern CONUS had large cloud cover in Kansas/Nebraska/Missouri, but lower cloud cover in Kentucky/Tennessee/the Carolinas
- Large variability in cloud cover allows investigation of cloud effect on temperature perturbation

4. GLOBE Observations of temperature perturbation

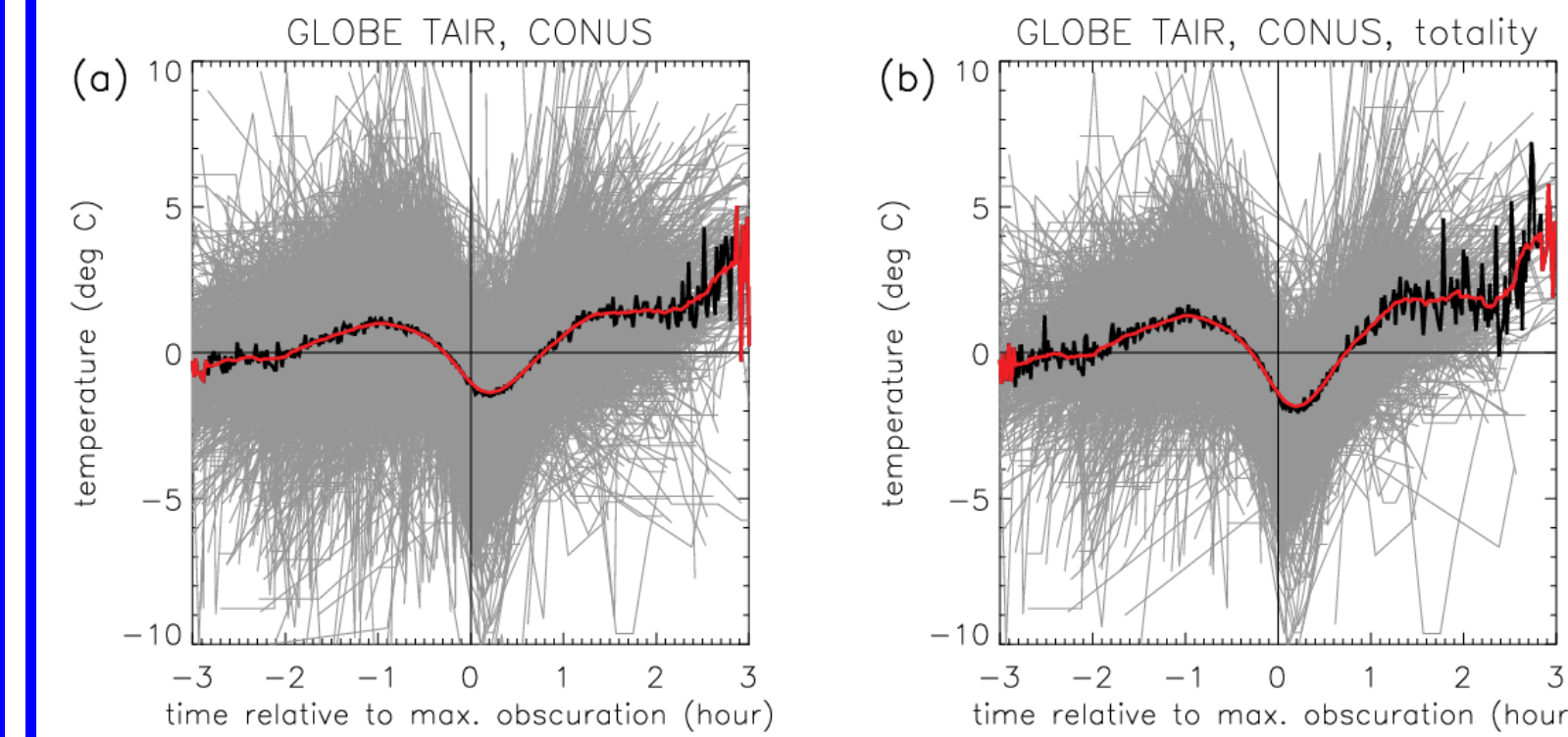


- Temperature perturbation from individual observing sites is calculated as difference between maximum temperature before totality (or maximum partiality) and minimum temperature immediately after
 - sites with only one observation cannot be used to estimate temperature perturbation
- Temperature perturbations vary by 15°C between sites, including sites within 100 km
 - negative temperature perturbations (i.e. temperature rise) are meteorologically possible, but more likely to be measurement artifacts
- The mean temperature perturbation for sites in path of totality were 0.9°C higher than all sites
- The time of maximum temperature perturbation occurred 1.5 min later for sites in totality than for all sites
- Results from individual stations are affected by the number and timing of observations collected from each site, which creates a spread of perturbation values significantly greater than the natural variability associated with the eclipse

Selected References

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- Stephens, G. L., et al. (2002), THE CLOUDSAT MISSION AND THE A-TRAIN, *Bull. Amer. Meteor. Soc.*, **83**, 1771–1790.

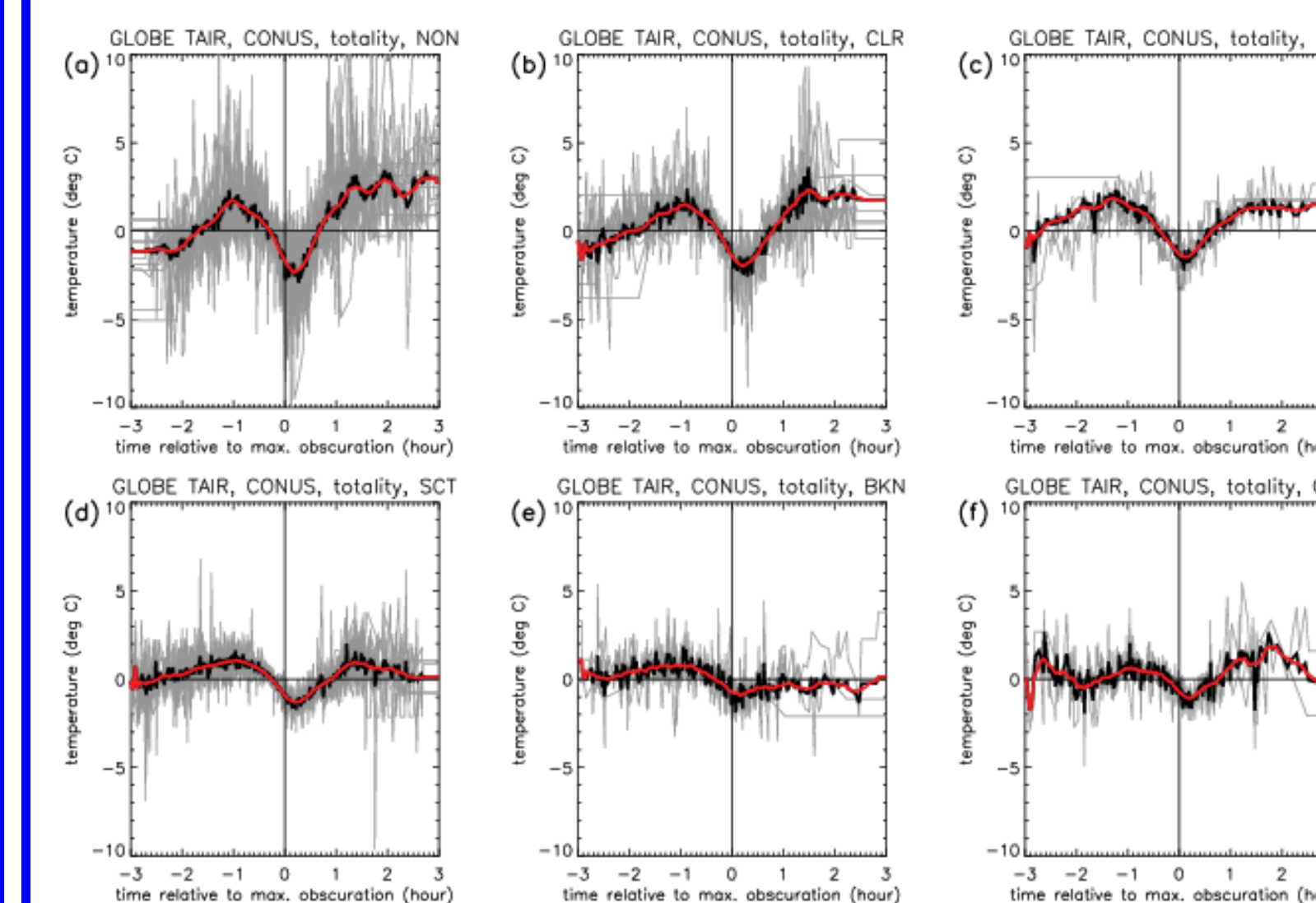
5. Composite Time Series of Temperature Perturbation



The composite time series of temperature change from GLOBE data from three hours before to three hours after the time of maximum obscuration. Gray lines are the time series from individual observers, the black line is the unsmoothed composite time series, and the red line is the smoothed time series. (a) shows time series for all observers, and (b) shows only observations from the path of totality.

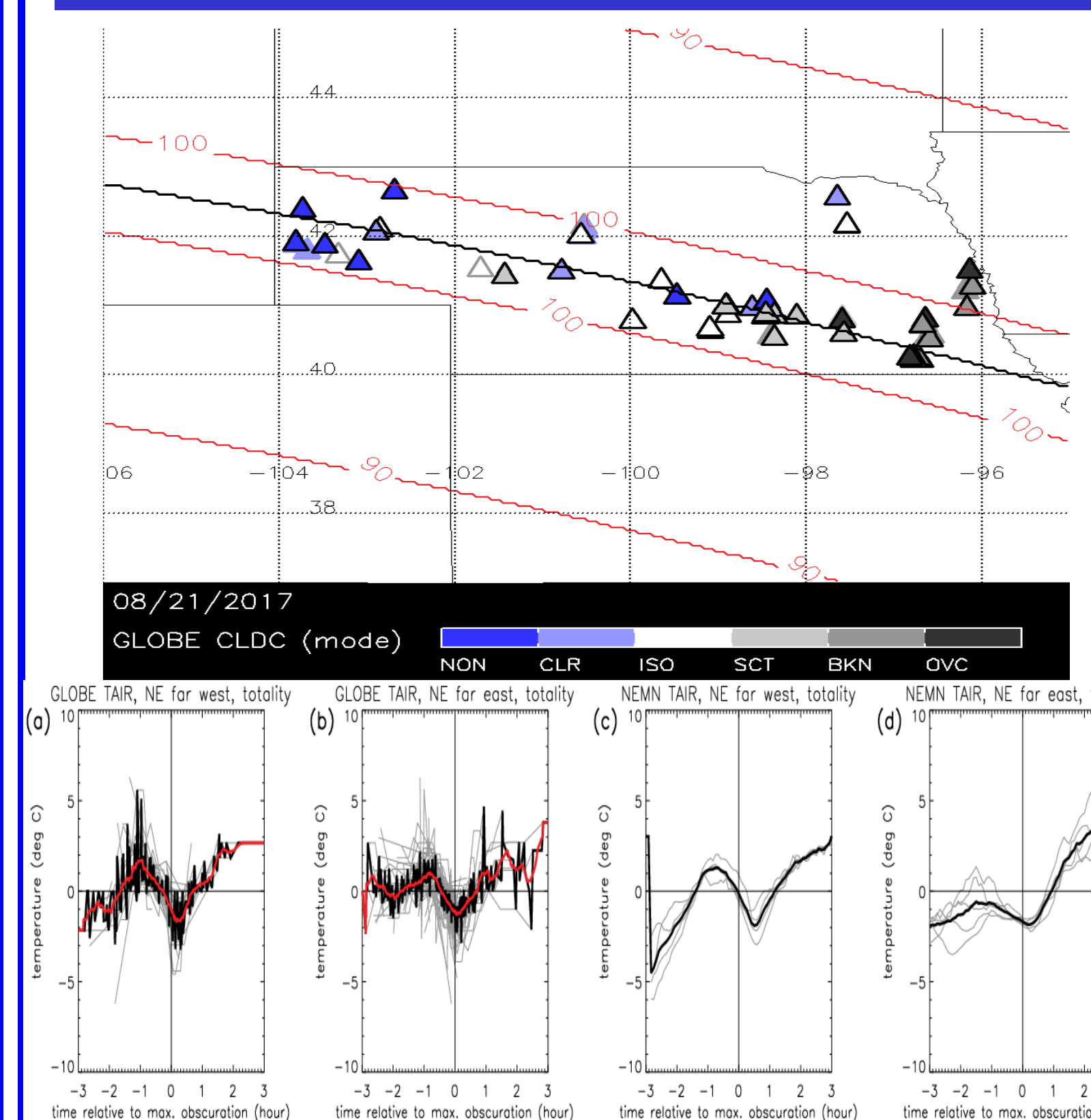
- Composite time series of temperature are constructed from individual time series by removing the mean of each series and aligning each time series by the time of totality (or maximum partiality)
 - a box-average smoothing with 20 min window is applied to reduce the minute-to-minute noise in the composite time series
- Both versions produce reflectivity values above 5 km more than 10 dBZ lower than observed
- The composite time series depict obvious temperature perturbations during the eclipse, with sites in totality experiencing a mean perturbation of 3.12°C
- Perturbations fall within the low range of observations from previous eclipses

6. Sensitivity of temperature perturbation to cloud cover



The composite time series of temperature change from GLOBE observations for the CONUS data subdivided into 1° longitudinal bins along the path of totality, then grouped by prevailing cloud type. Gray lines are the composite time series from the 1° longitudinal bins, and black (red) lines are the unsmoothed (smoothed) composite time series of the composites. The cloud categories are (a) none, (b) clear, (c) isolated, (d) scattered, (e) broken, and (f) overcast.

- Sites along the path of totality are grouped into 1° longitude bins, and a composite time series for each bin is calculated
- Also, each 1° bin is assigned a predominant cloud cover value according to the most common value reported from all sites in each bin
 - in effect, the sites in each bin “borrow” cloud observations from their neighbors
- The bins are then grouped by cloud cover value, and a composite time series for each value is calculated, a “composite of the composites”



Mean vertical profiles of simulated DCC (a) snow water content (SWC) and (b) graupel water content (GWC) in SPV5 sorted by maximum updraft velocity.

- There is a clear relationship between prevailing cloud cover and eclipse-induced temperature perturbation, where cloudy conditions reduce the perturbation by 2.34°C (57%) relative to clear conditions
- Limiting the data to eastern CONUS (to avoid spurious results from the climatologically drier west) reveals the same relationship
- Nebraska
 - Nebraska had clear (cloudy) conditions in the western (eastern) half of the state
 - The sites in the path of totality are grouped into 2° longitude bins, and composite time series are calculated as with the CONUS data
 - The sites furthest to the east show a temperature perturbation 1.12°C (33%) smaller than the sites furthest west
- Observations from the Nebraska Mesonet depict a similar relationship, though with a larger temperature perturbation difference of 1.96°C (61%)

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