The Effect of Solar Eclipses on Temperature and Sunshine at the Blue Hill Meteorological Observatory

Jonathan O'Brien[1,2], Lizzy Suzedell[3], Don McCasland[1], Kaitlin Geagan[1], and Michael Iacono[1,4]

[1] Blue Hill Observatory, Milton, MA, [2] Plymouth State University, Plymouth, NH, [3] State University of New York, Oswego, NY, [4] Atmospheric and Environmental Research, Lexington, MA

Background

- Blue Hill Meteorological Observatory in Milton, Massachusetts is located on the summit of Great Blue Hill about 10 miles SSW of Boston at an elevation of 635 feet (194 meters) above mean sea level.
- Founded on **February 1, 1885** by Abbot Lawrence Rotch, Blue Hill is home to the longest continuous climate record in North America. Extensive weather records exist for every day since its founding.
- **This project investigates past total or partial solar eclipses and how their influence has affected the weather data as recorded at Blue Hill.**

Motivation: American Eclipse of 2017

- On August 21, 2017, a partial solar eclipse occurred at Blue Hill.
- A narrow northwest to southeast path across the country from Oregon to South Carolina experienced a total eclipse this day, earning this event the moniker of "The Great American Eclipse of 2017".
- This occurrence inspired research on how solar eclipses have impacted weather at Blue Hill.
- The goals of this project are to determine which past solar eclipses were the most impactful at Blue Hill, to develop an "eclipse climatology" for the Observatory, and to study the specific effects of the 2017 eclipse.

Methods: Weather Observing at Blue Hill

- Traditional methods and instruments are used for official records at Blue Hill to ensure long-term consistency.
- Two such instruments are particularly relevant to recording eclipses:
  The **Campbell-Stokes sunshine recorder** measures sunshine duration by focusing direct solar light through a magnifying glass ball onto a special card. "Bright sunshine" is recorded when the focused sunlight is sufficiently strong (more than ~120 W/m2) to burn the card.
  The **hygro-thermograph** records a continuous trace of both temperature and relative humidity, where the temperature is especially responsive to the change in solar energy during eclipses. Its accuracy is verified by comparison to the traditional thermometers, which are read several times per day, to ensure the chart reflects official observations.

Campbell-Stokes sunshine recorder at Blue Hill

Hazen instrument shelter at Blue Hill with hygro-thermograph and thermometers.

Historical Solar Eclipses at BHO

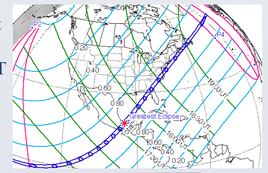
- Since 1885, **37 partial or total solar eclipses** have occurred at the Blue Hill Observatory, including the most recent on August 21, 2017.
- 17 of these eclipses occurred during good viewing conditions, another 17 were in poor conditions (little to no chance of viewing) and 3 were marginally viewable.
- The odds of actually seeing a solar eclipse at BHO are consistent with the Observatory's annual mean sunshine percentage of 52%.
- Only one total solar eclipse has occurred at the Observatory, near sunrise on October 2, 1959, but it was obscured due to rain.
- At least five previous partial solar eclipses had a noticeable impact on the weather at Blue Hill (see table below).

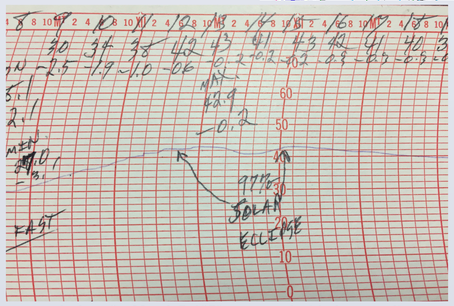
Solar Eclipses with noticeable impact on weather at BHO

Date	Peak Solar Coverage	Summary
5/28/1900	90 percent	Despite poor viewing conditions, only one glimpse of the Sun was observed. Many detailed observations were made, and a temperature drop of 1.5 degrees was attributed to the eclipse.
3/7/1970	97 percent	This near total eclipse occurred in the mid-afternoon, peaking around 2 PM local time. Viewing conditions at BHO were good. The temperature fell from 43°F to at least 41°F during the peak of the eclipse, before rebounding back to 43°F afterwards.
7/10/1972	86 percent	A partial eclipse that occurred during mid-afternoon with good viewing conditions. The temperature fell from 77°F at 2 PM to 70°F at 4 PM, likely due at least in part to the eclipse.
5/10/1994	88 percent	Peaking from 1-2 PM this annular partial eclipse caused the temperature to fall by 8 °F from onset to peak, the largest temperature drop that could be attributed to an eclipse at BHO.
12/25/2000	60 percent	Another early afternoon partial eclipse during which the temperature fell just one degree from 18°F to 17°F during the peak of the event despite clear skies. This may have been partly due to the eclipse, but an association is harder to establish due to the weakness of the Sun in late December.

Weather impacts from the March 7, 1970 solar eclipse

- Path of totality near U.S. East Coast
- **97% totality** at Blue Hill
- Peak solar coverage at 1:46 PM EST
- Thermograph and sunshine records for this date (below) show drop in temperature and loss of sunshine





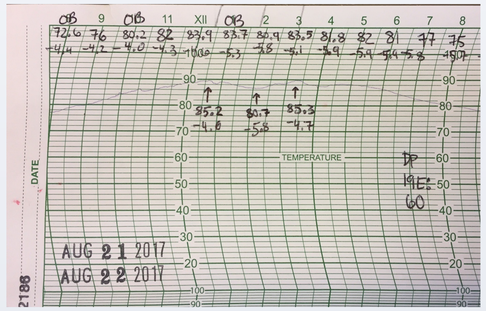
Thermograph chart for March 7, 1970, annotated with the pre-eclipse maximum temperature and hourly temperatures from 8 AM to 6 PM that day.

Part of the Campbell-Stokes sun card record for March 7, 1970, with the peak of the eclipse labeled. Sunshine on the card was recorded in Solar Time, which was four minutes later than Eastern Standard Time on this day.

Impacts: August 21, 2017 Partial Eclipse

Temperature

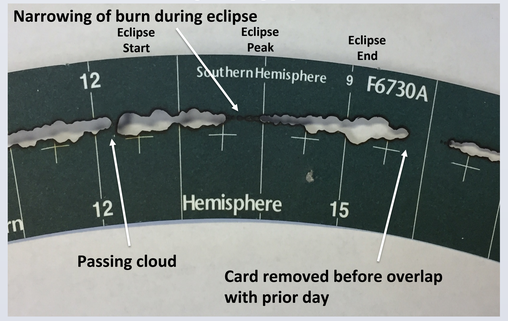
- The August 21, 2017 eclipse, with a peak solar coverage of **63 percent** at 1:45 P.M. EST at BHO, fortuitously fell on a day with good viewing conditions. The sun was also partly filtered by thin cirrus and a few altocumulus clouds.
- The temperature fell 4.5°F between approximately 12:30 P.M. and 2:00 P.M. EST, from a high of 85.2°F to an intra-event low of 80.7°F.
- Following the minimum of 80.7°F, the temperature increased again to a high for the day of 85.3°F near 3:20 P.M. EST, just one tenth of a degree higher than the maximum value before the eclipse began.



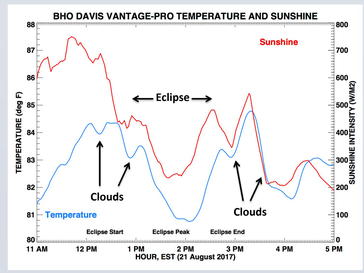
Thermograph chart for August 21, 2017, annotated with pre-eclipse maximum, eclipse minimum, and post-eclipse maximum temperatures as well as hourly temperatures from 8 AM to 8 PM that day.

Sunshine Duration

- The effect of the eclipse was also noted on the BHO sunshine recorder, though clouds were in the vicinity during the eclipse.
- The width of the burn mark narrowed dramatically during the eclipse, from a robust burn typical of a sunny summer day to a thin line when the Sun was just strong enough to burn the card at the event's peak.
- While the change is remarkable, any burn on the card is considered official "bright" sunshine. Thus, the BHO sunshine record will show continuous sunshine during the eclipse period.



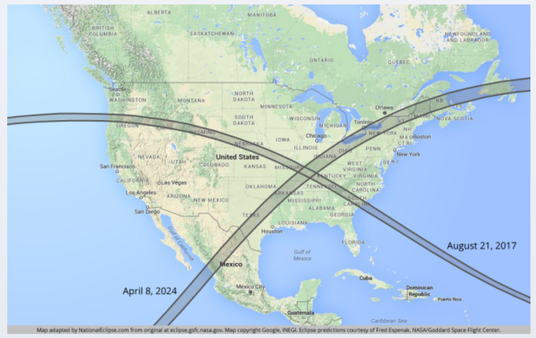
Part of the Campbell-Stokes sun card record for August 21, 2017, with significant features labeled. Sunshine on the card was recorded in Solar Time, which was 12 minutes later than Eastern Standard Time on this day.



- Smoothed 1-minute data from the Davis Vantage-Pro radiometer at BHO show the reduction in total (direct and diffuse) sunshine and the delayed drop in temperature due to both the eclipse and passing clouds on 21 August, 2017.

What's Next

- The next solar eclipse visible from Blue Hill will be on **April 8, 2024**.
- The path of totality in this partial eclipse will pass much closer to Blue Hill, with a solar coverage of 92 percent at the Observatory, and the peak of the eclipse will occur near 3:30 P.M. local time.
- Because of this timing, and the greatly increased degree of solar blockage, this eclipse has the potential to have an even larger impact on temperature and sunshine at Blue Hill, especially if viewing conditions are favorable.
- The next **total solar eclipse** at Blue Hill will be on **May 1, 2079**. This will be a "sunrise" eclipse, very similar to the rained-out total eclipse on October 2, 1959.



The path of totality for the 2024 solar eclipse, overlaid with that of the 2017 eclipse.

Solar Eclipse Fun Facts

- The high temperature of 85°F makes August 21, 2017 the warmest day to feature a solar eclipse at BHO, though historically most solar eclipses have occurred on cool days.
- The coldest solar eclipse day (January 24, 1925) had a morning low temperature of -5°F and a high temperature of only 15°F.
- A partial eclipse on February 3, 1916 was obscured by the tail end of a snowstorm that brought 12 inches of snow.
- There were 9 solar eclipses from 1900-1920 and 6 during the 1970s, while only 3 will have occurred from 2000-2020.

Conclusions

- 37 partial or total solar eclipses have occurred at the location of BHO since 1885, but only 17 were observable due to the weather.
- In generally cloud-free conditions, even a partial solar eclipse can have a significant, but brief, impact on local temperature and sunshine.
- By far, the most important factor in determining whether an eclipse will have a large meteorological impact is simply the maximum percentage of the sun that is blocked. Other factors include the time of day and the season in which the eclipse occurs.
- Solar eclipses of more than 80% coverage can reduce the temperature at BHO by up to 4 to 8°F in warm months and by 1 to 2°F in cold months.
- The temperature minimum typically occurs 10-15 minutes after the minimum in solar intensity once the sun is blocked.
- Had the 2017 eclipse not occurred, it is conceivable that August 21 would have had a high temperature in the upper 80s, as opposed to the actual high of 85°F.
- The August 21 eclipse came close to stopping the burning of the card in the Campbell-Stokes sunshine recorder (along with thin clouds that day) by reducing the direct solar intensity to less than 200 W/m2.

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