Witnessing a solar eclipse for the first time is an overwhelming experience. Years - at least months - before these magic moments, travel arrangements have to be made, weather statistics and patterns are consulted and discussed, and observation strategies are developed. Decisions on which technical equipment for eclipse photography may become a demanding task, as solar eclipses often occur on the other side of the Earth. Data volumes on eclipse related internet forums start to increase significantly.

Then the big moment has arrived and a long journey seems to have paid off. In a few moments partial phase will begin and everything at our observing site is ready for the great show. We have beautiful weather, as it could be only with a solar eclipse. It is late in the morning and the Sun shines from high in the sky. Tripod, camera, and solar filters are all ready, and notebooks are accessible, either on the ground or on top of the camera bag. One is more and more surrounded by friends and – when far away from home – even locals come to see what is going on. With a friendly smile parents are asked to take their children to the side. The curious scooter driver, who stopped just in front of the camera, could just go a little bit further - out of the telescope’s field of view! „First contact!" This cry comes from the colleague with the most expensive equipment.

It is 24 °C, and in the course of the day the temperature should reach 28 °C. Tears of sweat pearl from the face, and the shirt gets humid, wet and sweaty. Totality is just one hour away. More and more the invisible Moon shifts its silhouette over the Sun’s disk. Not a single cloud can be seen in the sky.

Three minutes before totality! The environment has long been immersed in this sinister, pale light, which now appears darker and darker at every moment. Someone cries: “I’m cold!” I feel chilly, too. On the other hand, I sweat as profusely as if I were in a hot jungle.

Cries of joy - then it is silent: The white corona stands out in front of the dark sky. Perhaps some planets or the brightest stars can be spotted. The back and forth swaying palm tops can be seen only dimly. Everything works perfectly with the planned photo shoots. Again, shouts, then the big moment is over, done! All those who have not traveled half the Earth quickly leave the place. It has only been a minute since the end of the totality, but it seems a normal day has taken over. Only after another hour the last part of the Moon’s silhouette leaves the Sun.

But what about “I’m cold!” at 24 °C under palms? I once heard during a presentation of a temperature drop of 9 °C (16 °F) during a solar eclipse. Someone seems to have been hungry for a record or the German proverb "Wer misst, misst Mist“ ("The one who measures, measures crap") is especially accurate for solar eclipses. Consider the following: During the beginning partial phase of an average solar eclipse (this is about the time interval where the temperature drop occurs), the light and the energy of less than one hour are missing. If, as a result of this, the temperature drops by
9 °C, my question is: “What was the temperature the next morning, after the sun had really disappeared completely below the horizon for twelve hours?”

Whether and how much colder it has become can be determined objectively, of course, only by a measurement, but who is going to drag a weather station (Stevenson screen) with them on holiday?

**Understanding temperature readings and “correct” measurement**

For a meaningful measurement of the air temperature, a lot must be taken into account, that the measured data can be compared with each other world-wide, so that all of us speak about the same thing. Let’s take, as an example, a sunny summer day. For every location there is - of course - only a unique "correct" temperature, which makes sense to tell somebody. We stand barefoot in front of our house and want to measure the temperature. We are equipped with a beautiful thermometer in a decorative metal mount. Soon we begin to sweat. Inside the house we have just read 24 °C. The column of mercury rises and after a short time we have to take the thermometer in the other hand, because the metal has become very hot in the meantime. Our feet are also burning, as we stand on the black tarred forecourt, so we take the few steps on the lawn alongside - refreshment for the feet. We cannot hold the thermometer in our hands anymore, so we go to the shady back side of the house to cool ourselves. We place the thermometer on a garden chair, and soon we notice that the temperature begins to fall. After an hour we read 32 °C and also the metal feels now relatively cool, compared to the moments before. As we are curious about the science, we hang the thermometer on top of the shady north side of our cherry tree and after an additional half hour the thermometer reading is 30 °C.

What exactly do we mean if we talk about the temperature of the air? The Sun radiates energy over a broad energy or frequency spectrum, from the far infrared over the visible region to the ultraviolet and even in traces of x-rays. A part of the energy reaching the Earth's surface is absorbed by the material of the Earth's surface. This heats up the ground. As a consequence, heat radiation is emitted from the ground and absorbed by the ground-near air molecules. Higher air layers are less affected by this heat because the molecules of the lower air layers have already absorbed some of the heat radiation.

In meteorology, standardized conditions to measure the air temperature can be described as follows:

- **Standard measuring height is 2 meters** above the ground (because the higher you go, the cooler it gets in general)
- **The ground on which measurements are to be made should be as representative as possible for the surrounding area** (and not the black tarred parking area from the above example)
- **The thermometer must be in the shade** (so that it does not heat up by direct solar irradiation, as in the example)
- **The air around the thermometer should be able to circulate freely** (to prevent heat build-up).
- **Keep away from buildings** (so that the temperature is not falsified by heat radiation)

The well-known weather houses (Stevenson screens), which are found all over the world, meet these conditions as much as possible: These huts stand in a (relatively) free field and offer shade within their interior. They are painted in white color in order not to heat up in an uncontrolled way. They have all-round slats for air circulation. There is a gap between the four walls and the roof to prevent heat build-up. The doors, through which one gets to the devices inside, are located on the shady side, so that during the reading process no solar radiation can fall into the interior. For most of us in the northern hemisphere, this is on the north side.

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1 In some countries, standard heights range from **1.25 m** to **2 m**.
Temperature measurements far from home

This sounds very complicated, but fortunately this is not really true, at all. A weather station is designed to provide consistent measurements over many years, but solar eclipses last only for a few hours. Therefore it may be sufficient to fix a thermometer on a tree. If there is a ladder around, the 2-meter rule can be fulfilled. However, hardly anyone wants to climb on a ladder every few minutes during a solar eclipse and try to read and write down a temperature under weaker getting conditions. Digital thermometers with a large display can be very helpful in this case.

Perfectly, of course, are so-called data loggers, which are programmed in advance, and which can store many measurement points. So the only problem is finding the best possible location for setting up the instruments during the solar eclipse. This can be difficult, for example, on a passenger ship or in the middle of nowhere (deserts, outback…) Nevertheless, I would like to encourage interested people to carry out temperature measurements. It is then very important to describe the circumstances of the measurements, so that something can be learned from them and measurements can be compared.

My temperature sensor

The measurements that are described here were done with programmable temperature and humidity loggers with a storage capacity of up to 55'000 data points.

Image 1

Temperature and humidity logger Model testostor 171-3 from Testo AG, Switzerland. Measuring interval and measuring time have to be programmed in advance (of the travel) on a PC connected via USB cable. Temperatures are stored with one decimal digit. Beginning in 2001, only this type of instrument was used. Typically two of them were used simultaneously.
**Total solar eclipse of June 21, 2001**
(Zambia)

Observing site: 14°11′51″S; 24°58′43″E near the village Lalafuta, Zambia.

Participants: Travelling group of the Swiss Astronomical Association SAG guided by Walter Staub (†).

In this first automatic temperature measuring experiment during the adventurous journey through Zambia we used two data loggers (Image 1). They were programmed for measurements every eleven seconds.

The devices were placed at about little less than two meters high on the roof of a white Toyota Hi-Lux, but under the wooden construction for the sleeping tents, thus quite ideal.

We arrived at our eclipse observing site near the village of Lalafuta in western Zambia two days before the eclipse day. Therefore it was possible to compare the temperature in the course of a “normal” day (June 20, 2001; Image 2a) with the temperature during the eclipse day (June 21, 2001; Image 2b).
To show how perfect the temperatures were measured, the values of one logger are increased by 1 °C in the above curves, while those of the other logger are reduced by 1 °C (gray curves). The averaged values are shown as the black curve. The temperature fluctuations some minutes after totality occurred because the doors of the car, on which the loggers were positioned, were opened several times and closed again.

**Discussion**: On both days we had fantastic clear skies. The typical temperature fluctuations due to the thermals were much more pronounced - as expected - before the highest daily temperatures were reached on both days. It is also easy to see how quickly these loggers can react to temperature differences. The blue curves are polynomials of the fourth degree through the measuring points outside the eclipse time interval. Thus, a temperature drop of about 4 to 5 °C and a delay of about ten minutes can be estimated.

Total solar eclipse of March 29, 2006 (Libya)

Observing site: 28°14'02"N; 21°30'04"E, 90 km south of Jalu, Libya.
Participants: Travelling group managed and guided by Fritz Arm (Vista-Reisen.ch).
Unfortunately the measurements during the annular solar eclipse of October 3, 2005 in Spain were lost, but six months later we got another great chance. In this temperature measurement experiment on the eastern region of the Sahara desert in Libya, we used two loggers (Image 1) that were programmed for a fifteen seconds measuring interval. The devices were placed at a height of about two meters on the north side of a kitchen tent in "Eclipse City". Again, this was a relatively ideal place.

In order to show how the temperatures have been measured, the values of the one logger are increased by 1 °C in the above curves, while those of the other logger are reduced by 1 °C (gray curves in Image 3). The mean value is again the black curve.

Discussion: On the eclipse day the sky was practically cloudless.
As we were in an almost infinite and shallow desert, there was not a very great thermic.
The blue curves are fifth-degree polynomials through the measurement points outside the eclipse time range.
Thus, a temperature drop of about 3 to 4 °C and a delay of about six minutes can be estimated from the data.

"Eclipse wind": This expression is circulating in many places. It is attributed to the fact that the cooling of the air during a solar eclipse produces a “falling wind”, the so-called eclipse wind.
Personally, this effect has never been noticed, but the opposite, as especially is shown in this measurement and in the experiment before.
The more the Sun is eclipsed by the Moon, the less any thermal and air movements are.
Perhaps the expression “Eclipse calm" would rather be appropriate.

A travelling report (German) with this experiment can be downloaded from the author’s website RobertNufer.ch as pdf: http://robertnufer.ch/02_finsternisse/2006_libyen/2006_libyen_tagebuch.pdf.
Total solar eclipse of August 1, 2008 (Mongolia)

Observing site: 45°57′32″N; 91°48′16″E, 23 km south-east of Bulgan, Mongolia.
Participants: Travelling group managed and guided by Fritz Arm (Vista-Reisen.ch).
In this temperature measurement experiment in western Mongolia, we used two loggers (Image 1), which were programmed to fifteen seconds measuring intervals.
Since in this treeless desert landscape, apart from the cooking and dining yurts, there was no way to place the equipment optimally and shielded from direct sunlight, we decided to place one sensor – enrolled into a white paper tube - at a height of two meters. The other one, also enrolled into a white paper tube, was placed on the ground. The probe was about then 5 cm above ground.
For the first time, we wanted to document the influence to the temperature readings at different measuring heights.
Since we were at our observing site more than one day before the eclipse, the temperature of a "normal" day (July 31, 2008; Image 4a) could be compared with the temperature of the eclipse day (August 1, 2008; Image 4b).

**Discussion:** The two graphics look almost as if an eclipse had taken place on both days, but the temperature drop on July 31, 2008 was the result of a violent storm that rose at the same time of day as the solar eclipse the following day.

The example shows that meteorological long-term predictions or statistics are not very helpful, because "climate is what you expect, weather is what you get".

The ground at the observing site was relatively dark and was therefore heated by the sunshine.

So the ground temperatures were much higher than the two-meter temperatures as long as the sun was high in the sky. The influence of the thermal was also very strong with strong wind blows, which came to a standstill towards evening.

Also, the temperature amplitudes caused by the thermals were much smaller on the ground than on a height of two meters. This was the case, because at or near the ground the temperature storage capacity of the soil is measured rather than the temperature of the atmosphere.

During the eclipse the heavens were mostly cloudless.

As we were in the mountainous region of the Altai Mountains, there were great thermals.

A part of the temperature fluctuations was caused by the yurt itself, in which heat accumulated and then escaped when the door was opened for an extended period of time.

The blue curve is a polynomial of the fifth degree by some manually placed points, which is to roughly approximate the presumed course without eclipse.

This can be used for a crude estimation of a temperature drop of just less than 4 °C and a delay of perhaps ten minutes for this eclipse.

A travelling report (German) with this experiment can be downloaded from the author’s website [RobertNufer.ch](http://RobertNufer.ch) as pdf:

Total solar eclipse of July 22, 2009 (China)

Air temperature during the total solar eclipse of July 22, 2009 (in Wuhan, China)

Observing site: 30°46'54"N; 114°28'54"E, Lake Wuhu, Wuhan, China.
Participants: Three travelling groups managed by Ralf Wittmann (Wittmann-Travel, Hamburg, Germany)
In this temperature measurement experiment on a small lake at the northern edge of the industrial metropolis of Wuhan, we used two loggers (Image 1) that were programmed for a four seconds measuring interval.
The devices were mounted on the shady western side of a power pole made of concrete, one at two meters high, the other on the ground, so that the sensor was five centimeters above ground.

Discussion: This eclipse shows very nicely the "bed cover effect" in cloudy sky.
Before and during most of the time during the eclipse, the sky was largely covered with a thin layer of clouds, which caused difficulties for eclipse photographers.
The Sun was never completely covered by this cloud layer, but it was never completely free.
As a result, the decrease in the solar radiation caused by the eclipse was much smaller than in the case of a cloudless sky. In addition, less heat could be radiated into the space through the cloud cover.
It was only towards the end of the eclipse that the cloud layer began to clear and thermal come into effect.
The blue curve is a polynomial of the fifth degree by some manually placed points, which is to roughly approximate the presumed course without eclipse.
For this eclipse, a cooling of 2 °C and a delay of perhaps 10 minutes can be estimated.
The fine red curve of the measurement in only 5 cm above the ground shows how the temperature course at the ground is decoupled from the atmosphere. The probe is irradiated directly from the ground in this arrangement and heated accordingly.

A travelling report (German) with this experiment can be downloaded from the author’s website RobertNufer.ch as pdf: http://robertnufer.ch/02_finsternisse/2009_china/china_2009_rn.pdf.
Total solar eclipse of July 11, 2010 (French Polynesia)

Air temperature on July 2, 2010 (cruising toward Nuku Hiva, Marquesas Islands, French Polynesia)

Air temperature during the total solar eclipse of July 11, 2010 (near Hikueru, French Polynesia)

Observing site: 17°55'55"S; 142°26'05"W, on Board of the passenger freighter Aranui 3, between the atolls Hikueru and Marokau, Tuamotu Archipelago, French Polynesia.

Participants: Passengers of the Aranui 3.

To find optimal places for the two data loggers (Image 1) was tricky aboard of the dual-purpose passenger/freighter Aranui 3. Airstreams (draft) and salt water sprays during test measurements made the results completely unusable. Fortunately we had about ten day for finding an optimal place for the sensors.

The most favorable position was found by putting the sensors into shady, horizontal U-shaped steel profiles next to the suites, one at the left side, the other at the right side of the vessel, at about ten meters above the water line. Of course it was impossible to fulfill the “2 meters above ground” rule.
Discussion: The Pacific is a gigantic heat reservoir. Surface temperature changes in this region in the course of a year at most by 0.4 °C PER MONTH. A solar eclipse can therefore hardly have a measurable influence on the open sea!

Image 6a confirms this assumption.

As long as the ship moved in north-east direction on July 2, 2010, the temperature on the left and right of the ship hardly changed, even not hours after sunrise.

The change of about 1 °C can probably be attributed to a slight warming of the ship.

After arrival in the port of Taiohae the sunny side of the ship (red curve in Image 6a) heated more than the shady side (black curve in Image 6a).

In the morning of the eclipse day on 11 July 2010, the bow of the Aranui 3 pointed to the south-west to the west and the cruising speed of the vessel was very slow. (Just fast enough for keeping the cruise direction stable). The passengers could stay at the stern of the ship, where watching the eclipse was very comfortable and the view to the Sun was optimal.

The "correct" black curve (Image 6b) was measured on the left shaded side of the ship. There was almost no change in temperature during and even after the eclipse.

On the right sunny side of the ship the temperature was always one degree higher, and the temperature started to increase, the higher the Sun was in the sky.

After the eclipse, the ship took a course toward Tahiti (274°), which made the Sun even more shining to the right side of the ship.

Therefore, the measured temperature at the end of the measurement was 6 °C higher there compared to the more shady (left) side of the ship.

A travelling report (German) with this experiment can be downloaded from the author’s website RobertNufer.ch as pdf:
**Total solar eclipse of November 14, 2012 (Australia)**

Observing site: 16°43'38"S; 145°38'53"E, Campground „Ellis Beach“ north of Cairns, Queensland, Australia.

Participants: Robert and Susanne Nufer, Patrick Gfeller.

In this temperature measurement experiment, we used two loggers (Image 1). One of them was optimally mounted at two meters above the ground on the shaded side of a very large tree, just a few meters from the sandy beach of the “Ellis Beach” camp ground. The measuring interval was set to two seconds. The readouts are shown as black curve in Image 7.

The other instrument hung on the outer wall of the showers and toilets building at a height of about two meters, too. Those measurements are shown as the red curve in Image 7.

**Discussion:** The temperature measured at the shower building was only slightly higher, independent of all other influences, which may be explained by the heat capacity of the building material. The effect of the solar eclipse was in this case simply the one-hour delayed rise in the daytime temperature.

If the rising curve is shifted one hour to the left from the time of the totality in thought, an effect of about 1 °C can be estimated around the totality time.

A travelling report (German) with this experiment can be downloaded from the author's website RobertNufer.ch as pdf:
Observing site: 2°44'35"S; 107°37'28"E, am Strand von Tanjung Pandan, Belitung, Indonesia.

Participants: Robert Nufer und Patrick Gfeller.

In this temperature measuring experiment, we used two loggers (Image 1). The measuring interval was programmed to twenty seconds for both instruments. With this “slow” measuring interval it was possible to measure the temperature in the morning before the eclipse day, the eclipse day, and even the following day. The units were mounted at a height of about two meters on the shady northern side of the hotel building where we stayed for three days. Unfortunately the only “two meter mounting location” was found on two heat exchangers boxes from the hotel’s air conditions. Indeed, not the optimal place for temperature measurements. The loggers were about three meters apart. A third logger was mounted between those loggers and set to a much shorter measuring interval, but unfortunately the data went lost during the readout procedure.
In order to show how identical the two temperatures were measured, the values of the one logger are increased by 1 °C in the above curves, while those of the other logger are reduced by 1 °C (gray curves). The mean value is the black curve. (Images 8a and 8b)

Belitung is a small island between Sumatra and Borneo, covering only three times the size of the Swiss canton of Lucerne (4500 km²).

During the nights and also during the days the sky was covered partially by clouds. This is the reason for the why the temperature was constant during the nights and the slow temperature increase after sunrise.

Discussion: Image 8a shows the "normal" temperature progression on a partly cloudy morning. A virtually identical curve (not shown) was measured on March 10, 2016, the day after the solar eclipse.

About thirty minutes after sunrise the temperature began to rise linearly. The daily high temperature was about 31 °C. At nine o'clock the thermodynamic amplitudes increased slightly.

During the eclipse, one of the sensors (upper gray curve in Image 8b) showed virtually no temperature drop. The other sensor measures a drop of one degree.

Outside the eclipse time interval, however, the measured values from both loggers were virtually identical to one tenth of a degree. For this discrepancy we have not found an explanation so far, except for the heat exchangers in the immediate vicinity of the sensors.

Using only the lower gray curve would be a spoiling of the data. Even then, an explanation should be found of why it should have been cooler after sunrise, but the temperature before sunrise over hours was very constant.

A travelling report (German) with this experiment can be downloaded from the author’s website RobertNufer.ch as pdf:

**Conclusion**

In my opinion these temperature measurements show astonishingly many interesting aspects, which in any case justify further measurements, although - of course - temperature measurements are not the main reason to follow solar eclipses.

If possible, several independent measuring devices should be used at the same observation site. For the upcoming eclipse in the United States, I plan to measure the temperature at different heights, for example 5 cm, 1 m, 2 m, and 5 m, if possible.

Several of the shown examples exhibit the reduction of thermal during the eclipses (“Eclipse calm”). Therefore measuring wind speed and wind direction could deliver supplementary information on the atmospheric effect of solar eclipses.

**References**

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