

Second Draft Review of BSII Transmissometer Data
September 10, 2010

1.0 Transmissometry

Transmissometers measure the irradiance of a light source over a specified path length. If the initial irradiance is known (calibration), the path transmittance is directly calculated:

$$T_r = I_r/I_0$$

Where:

- T_r = path transmittance of path length r
- I_r = irradiance measured at end of path
- I_0 = irradiance that would be measured at end of path if it was a perfect vacuum (i.e. no extinction along path length)

The Optec LPV-3 (figure 1) transmissometer was designed to make such a measurement.

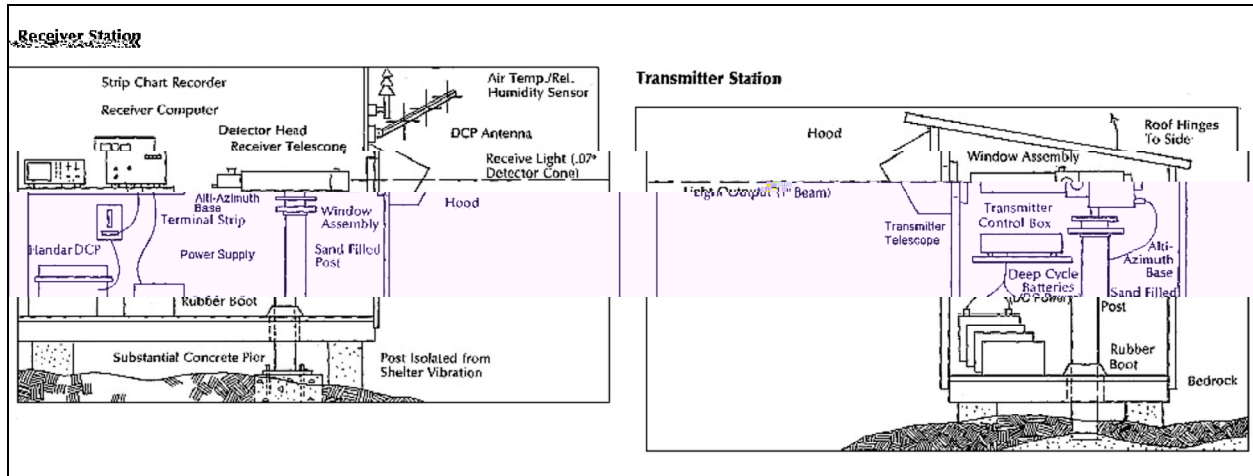


Figure 1: Optec transmissometer installation schematic.

The major issues with transmissometers are:

1. The light source must be kept at constant output irradiance (I_0), or the functional variability of I_0 with time and/or ambient conditions must be known.
2. The transmitter of the LPV-3 is designed to project a spherical wave, thus turbulence effects are mitigated by using long integration times to make an accurate measurement of I_r . This is the same process used in stellar radiometry from the earth's surface. Integration times are a function of how strong the turbulence is.
3. Path transmittance is a function of ALL material along the path that reduces the irradiance. This includes: gases, aerosols, rain, snow, fog, optical surfaces (windows and lens), insects, birds, turbulence, etc. Calibration takes into account the transmittance of the optical surfaces, however, ANY change in window transmittance due to dust, smudging, rain, condensation, etc. causes the path transmittance to be underestimated.

2.0 BSII Transmissometer Installation

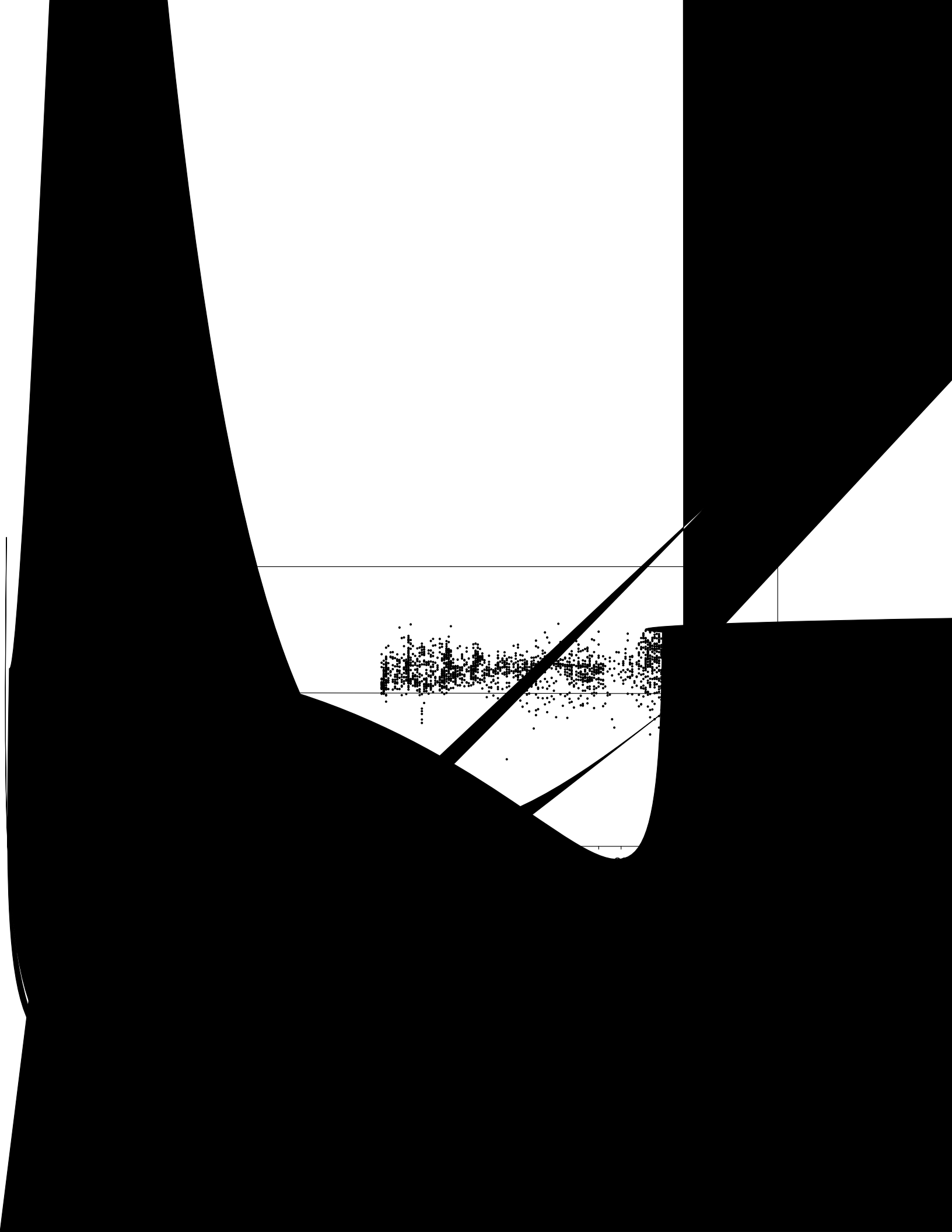


4.0 Temperature Correction of Transmissometer Data

The LPV-3 transmissometer operates under ambient conditions in non-temperature controlled shelters and enclosures. This allows the system to operate with low power consumption and be located in almost any possible place. However, the system does have a response that is linear with temperature and must be accounted for. The vast majority of this response is associated with the transmitter due to temperature effects on the feedback circuit that keeps the transmitter at a constant output as the incandescent lamp ages. This response must be accounted for in the calculation of path transmittance. Figure 6 (upper plot) displays the 10 minute rolling average of one-minute measured raw transmissometer readings as a function of the temperature measured in the transmitter enclosure. As expected the response is very linear (0.26%/deg C) and thus can be accounted for with a simple temperature function.

Corrected Raw = Raw * 0.0026 (Calibration Temperature - Transmitter Enclosure temperature)

The lower plot in figure 6 has the raw measurements corrected for transmitter shelter temperature using the above equation. The calibration temperature is the temperature measured when the system was calibrated in Ft. Collins prior to installation at Sloan, NV. The regression line of this plot now has a slope of 0.0.



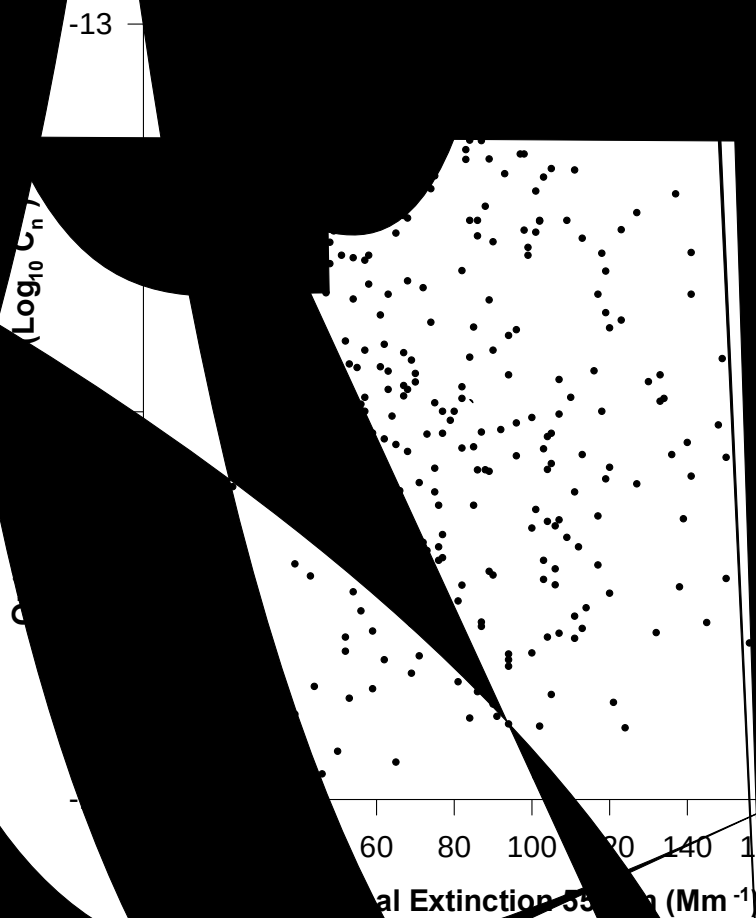
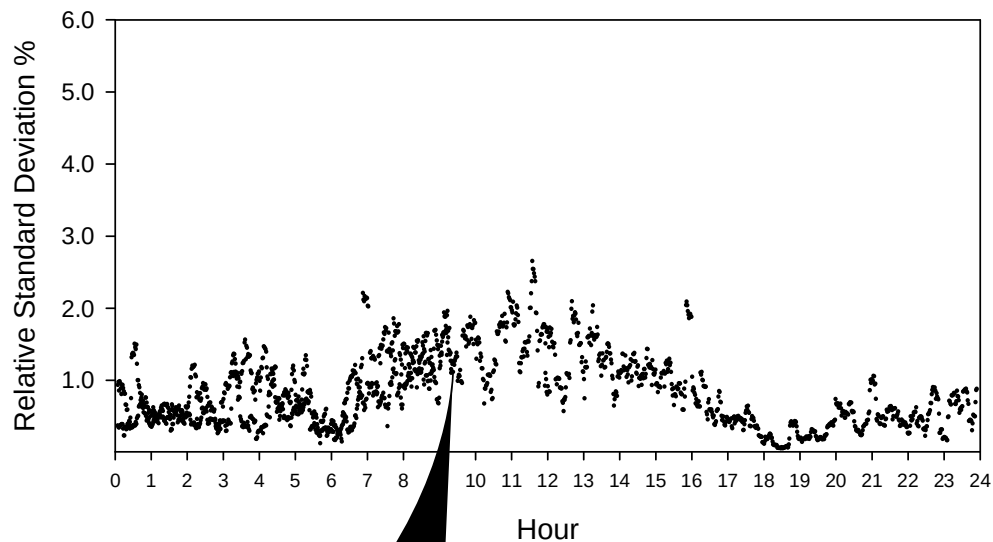
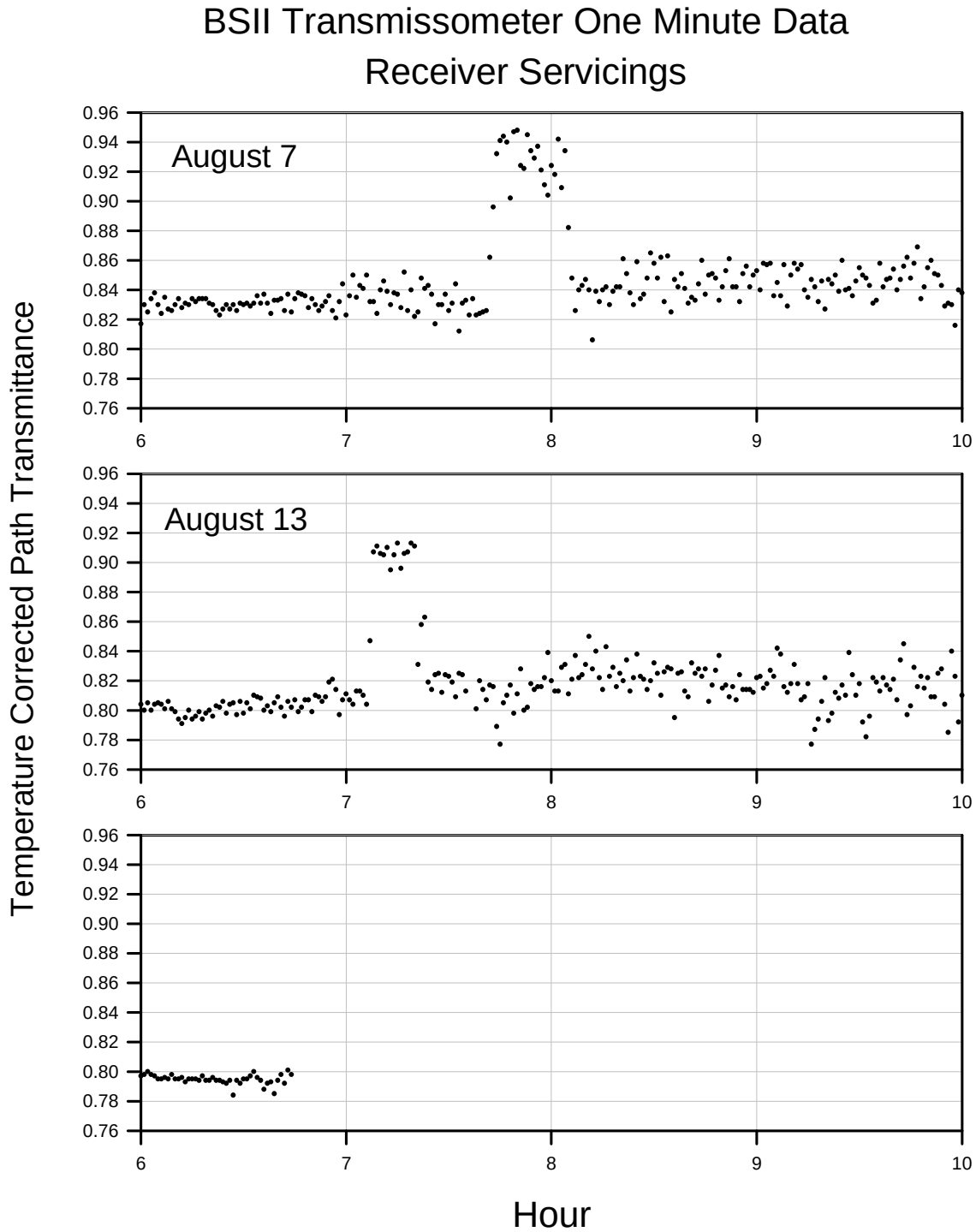


Figure 8 shows the effect of turbulence on the BSII transmissometer raw data. The top plot is the 10 minute moving average of the temperature corrected raw reading versus time of day. (The peaks seen are when the receiver shelter was serviced on the mornings of August 6 and August 13 and the window was removed for cleaning). The lower plot is the relative standard deviation (RSD) of the average in percent. The period August 1-20 was used because the transmitter window transmittance decreased very slowly during this period (between storms). The minimums in RSD occur near sunrise and sunset when optical and mechanical turbulence is at daily minimums, thus the standard deviation of the 10 minute average is very small i less than 1% of the mean. During the day turbulence follows the solar driven temperature profile, thus RSD increase to a maximum at mid-day. At night turbulence is not driven by solar radiation but by large scale eddies that are blobs of differing temperature air moving through the boundary layer, thus RSD is higher at night that at sunrise and sunset.



6.0 Degradation of Receiver Shelter Window

The receiver was serviced three times during this initial period: the mornings of August 6, 13, and 27. Figure 9 plots the one-minute temperature corrected path transmittance during these servicings.



The large increase in one-minute data is when the window is removed for cleaning. If the air quality remains the same during the 30 minutes it takes to service the receiver shelter, then window cleaning can have possible three outcomes:

1. Path transmittance increases after cleaning: The window was dirty and cleaning removes dirt and smudges.
2. Path transmittance remains the same after window cleaning: The window was not dirty and cleaning had no effect.
3. Path transmittance decreases after window cleaning: The window was clean but a poor cleaning effort made the window dirty (i.e. smudges)

Table 1 indicates that the first two window cleanings resulted in an increase in path transmittance of 1.0 to 1.3%, the window was dirty, #1 above. The third resulted in essentially no change in path transmittance, thus is an example of #2 above.

Table 1: Receiver window cleaning	August 6	August 13	August 27
Path transmittance before window cleaning	0.831	0.803	0.784
Path Transmittance with window removed	0.929	0.907	0.869
Path transmittance after window cleaning	0.844	0.813	0.781
Difference in window transmittance after cleaning	0.013 (1.3%)	0.010 (1.0%)	-0.003 -0.3%)

8.0 Degradation of Transmitter Enclosure Window

Figure 10 plots the one-minute data for the August 27th transmitter servicing.

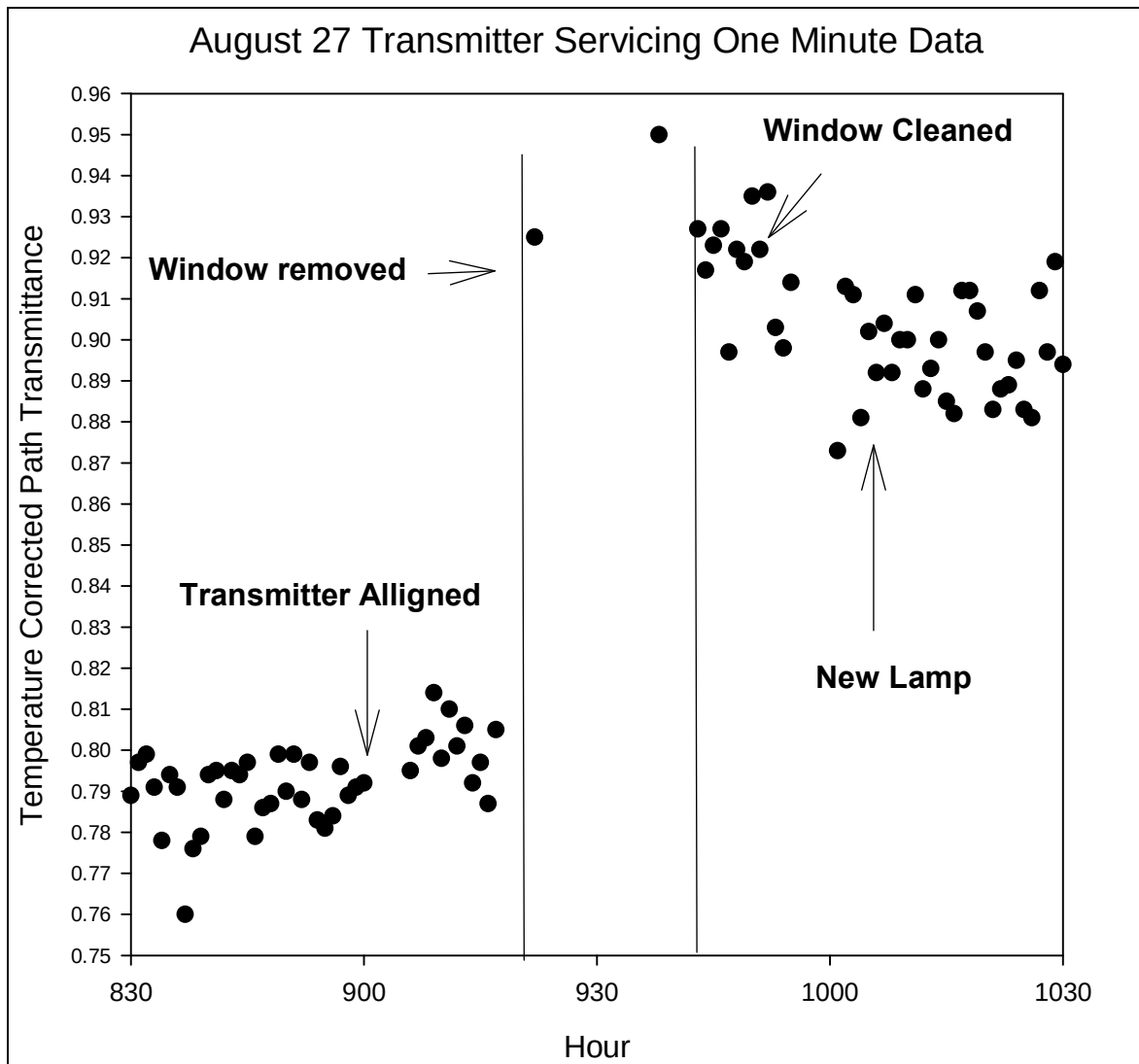


Figure 10: August 27 transmitter servicing.

At this servicing it was noticed that the transmitter was mis-aligned. This was probably due to strong winds catching the sun shade and moving the transmitter enclosure on the pier. After alignment path transmittance increased by +1.3%. After window cleaning path transmittance increased by 11.8%, making a total change in path transmittance of + 13.1% from July 25 to August 27. This is a combination of misalignment of the transmitter and dirt on the window caused by the strong storms that occurred from July 27- August 27.

After the new lamp was installed the measured path transmittance dropped by 2%. Since the air quality probably did not change over these 30 minutes, this means that either the original lamp brightened by 2% during the 850 hrs of operation, the calibration of the new lamp is 2% to high, or a combination of the two.

9.0 Use of DustTrak Data to Reconcile Transmissometer Measured Path Transmittance

The DustTrak was installed during the initial transmissometer installation trip. Unfortunately the DustTrak failed due to high temperatures. It was sent back to the manufacture and upgraded with a new EPROM to handle temperatures up to 50°C. It was reinstalled during the August 27th site servicing. The DustTrak measures aerosol mass continuously. It is not meant to be used as an absolute value but rather as an indication of low aerosol (clean periods) and varying concentrations as a check on the transmissometer data. When the aerosol concentrations are low ($< 10 \mu\text{g}/\text{m}^3$) it can be seen from figure 5 that the path transmittance should be greater than 0.92.

Figure 11 plots DustTrak aerosol mass concentration, transmissometer path transmittance, calculated path transmittance using Rayleigh and aerosol extinction, and the difference between the two from 1800 on August 27th to 1800 on the 28th. The 24hr period immediately following the major system servicing discussed in section 9.

From 1800 to 1930 on the 27th (when turbulence is at a minimum) figure 11 shows that the estimated path transmittance from aerosol data is very close to that measured by the transmissometer (within 0-2%). After 1930 on the 27th, the aerosol mass and measured path transmittance both vary relatively rapidly with a cycle of about 2 hrs. The calculated and measured path transmittance track but begin to diverge and by 1200 on the 28th are up to 10% different. A major rain/dust storm occurred during these hours. This indicates that the windows of the receiver shelter and/or transmitter enclosure were very probably covered in dust and rain smears. There is also a possibility that the transmitter became misaligned due to high winds.

Figure 12 indicates that this offset continued through September 6th.

10.0 Transmitter Misalignment Solution

It appears that the transmitter enclosure can be misaligned due to high southwest winds that occur at this site. The solution will be to remove the sun shade from the enclosure. As shown in figure 13, the sun shade does reduce transmitter enclosure temperature. However, the misalignment issue must be addressed and it is expected that removing the sun shade will not increase enclosure temperatures above the operating range.

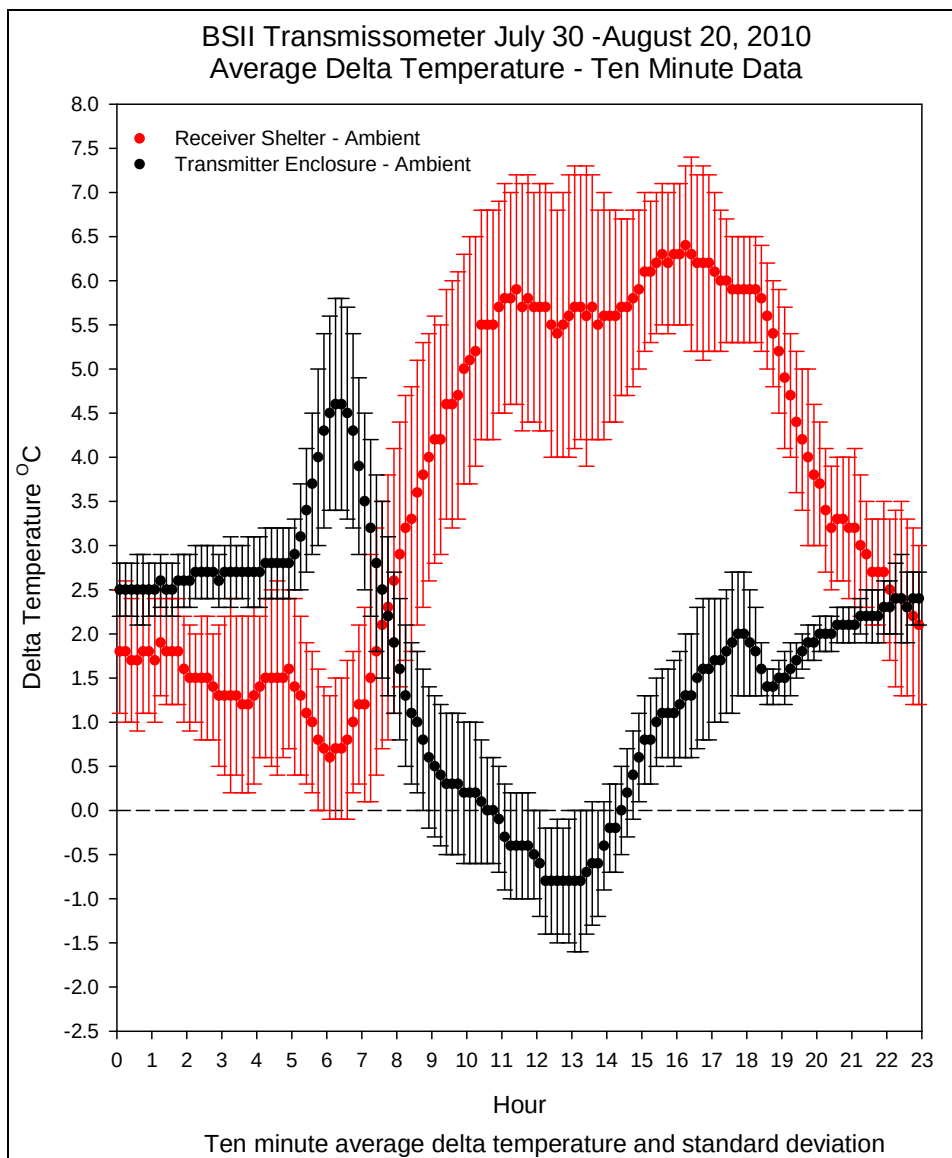


Figure 13: Ten minute moving average of delta temperature: receiver shelter - ambient and transmitter enclosure - ambient.

12.0 Conclusions

The system is operating within expected parameters. Temperature and lamp brightening corrections are stable and in the expected range. These corrections will be applied in real time to path transmittance data.

In order minimize the possibility of transmitter misalignment the sun shade on the transmitter enclosure will be removed. This will result in increased transmitter enclosure temperatures, but they are not expected to rise above the operating range of the transmitter.

DustTrak data will allow for further fine tuning of the temperature correction and lamp brightening functions. In addition verify probable changes in the conditions of the receiver shelter and transmitter shelter windows.

IT WILL require much more frequent servicing of the receiver shelter and transmitter enclosure windows to generate accurate path transmittance data. It is recommended that the receiver and transmitter be serviced every 2-3 days and **immediately** after **ANY** rain/dust storm.