Appendix C
Visibility Monitoring

IMPROVE Aerosol Data: Visual Range Values

The following Data Tables correspond to Figures 3.20 and 3.21, respectively.

Standard Visual Range (SVR) [MILES] - Seasonal				
Year	1st Quarter SVR	2nd Quarter SVR	3rd Quarter SVR	4th Quarter SVR
1988		118.52	92.75	133.96
1989	141.66	108.21	103.68	141.71
1990	128.55	103.83	98.93	128.58
1991	127.05	102.73	105.39	122.96
1992	136.77	100.43	107.83	126.14
1993	128.67	120.33	111.32	133.66
1994	144.26	105.86	95.99	129.44
1995	141.85	122.11	114.04	133.12
1996	148.38	102.84	95.60	138.21
1997	138.73	108.11	126.52	128.14
1998	137.16	111.52	95.10	113.66
1999	131.12	105.86	97.79	132.58
2000	148.89	104.62	93.91	140.49
2001	136.63	109.30	98.79	140.65
2002	142.14	113.15	96.32	146.02
2003	154.78	114.92	102.26	146.07
2004	150.61	107.45	118.73	151.27

Standard Visual Range (SVR) [MILES] - Annual Avgs				
Year	Annual SVR	Best 20% SVR	Mid 20% SVR	Worst 20% SVR
1989	123.81	174.23	118.62	79.91
1990	114.97	155.90	112.97	78.79
1991	114.53	163.05	110.91	76.86
1992	117.79	163.05	115.39	77.48
1993	123.50	171.31	120.24	85.56
1994	118.89	162.36	117.31	79.22
1995	127.78	169.26	124.46	91.16
1996	121.26	174.42	118.93	71.21
1997	125.37	163.54	124.27	90.41
1998	114.36	157.52	111.16	77.73
1999	116.84	162.55	114.52	78.73
2000	121.98	169.39	121.91	78.79
2001	121.34	171.31	117.50	78.04
2002	124.41	177.96	121.98	73.14
2003	129.51	186.22	128.75	79.16
2004	132.02	183.24	130.30	84.44

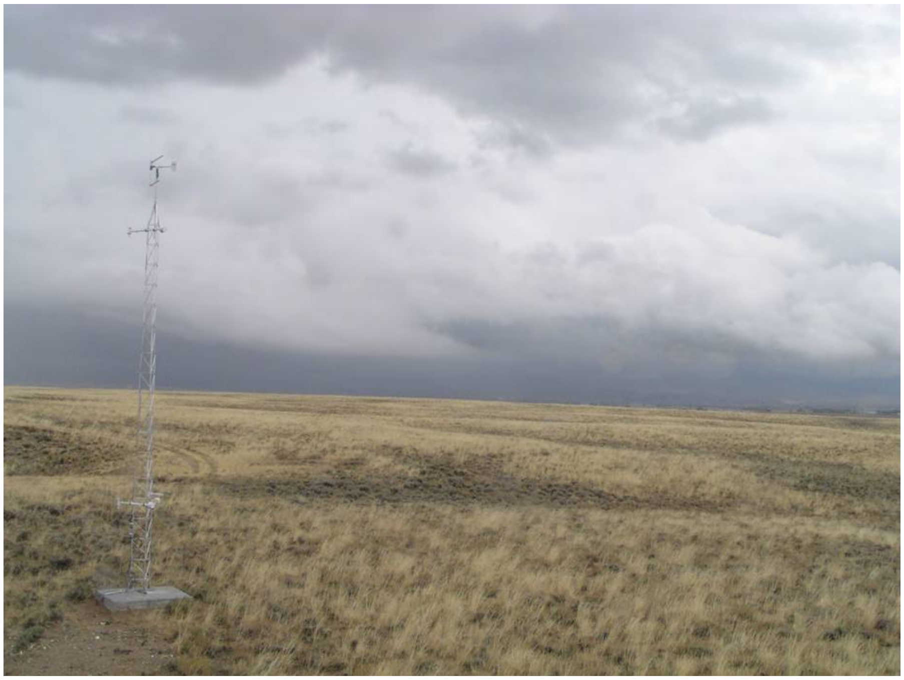
IMAGE CONDITION EXAMPLES

IMAGE CONDITION CODE KEY	
SKY CONDITIONS	CODE DESCRIPTION
0 No clouds	No clouds visible anywhere in the sky.
1 Scattered clouds < half of sky	Less than one-half of the sky has clouds present.
2 Overcast > half of sky	More than one-half of the sky has clouds present.
3 Haze concealing scene	Atmospheric haze conditions are such that determination of the sky value is impossible.
5 Weather concealing scene	Clouds or precipitation are such that determination of the sky value is impossible.
8 Observation cannot be determined	Observation cannot be determined due to extreme exposure inconsistencies, lens (or window) condensation, misalignment, or view obstructed by a foreign object.
9 No observation	No observation taken.
LAYERED HAZE	CODE DESCRIPTION
0 No layered haze	No layered haze boundary (intensity of coloration edge) is perceptible.
1 Ground-based layered haze only	Only a single-layered haze boundary is perceptible with the haze layer extending to the surface.
2 Elevated layered haze only	An elevated layered haze with two boundaries is perceptible (e.g., horizontal plume).
3 Multiple haze layers	More than a single ground-based or elevated haze layer is perceptible. This can be multiple ground-based layers or a combination of both.
5 Weather concealing scene	Clouds or precipitation are such that determination of the presence if layered hazes is impossible.
9 No observation or cannot be determined	Used with sky condition of 9 or if a layered haze value cannot be determined due to reasons other than weather.
UNIFORM HAZE INTENSITY	CODE DESCRIPTION
1 Slight haze intensity	View of Douglas Peak (49.2 km) impaired.
2 Moderate haze intensity	View of Media Mountain (33.8 km) impaired.
3 Considerable haze intensity	View of Half Moon Mountain (21 km) and Lost Mountain (25 km) impaired .
5 Weather concealing scene	Clouds or precipitation are such that determination of the presence if layered hazes is impossible.
9 No observation or cannot be determined	Used with sky condition of 9 or if a layered haze value cannot be determined due to reasons other than weather.

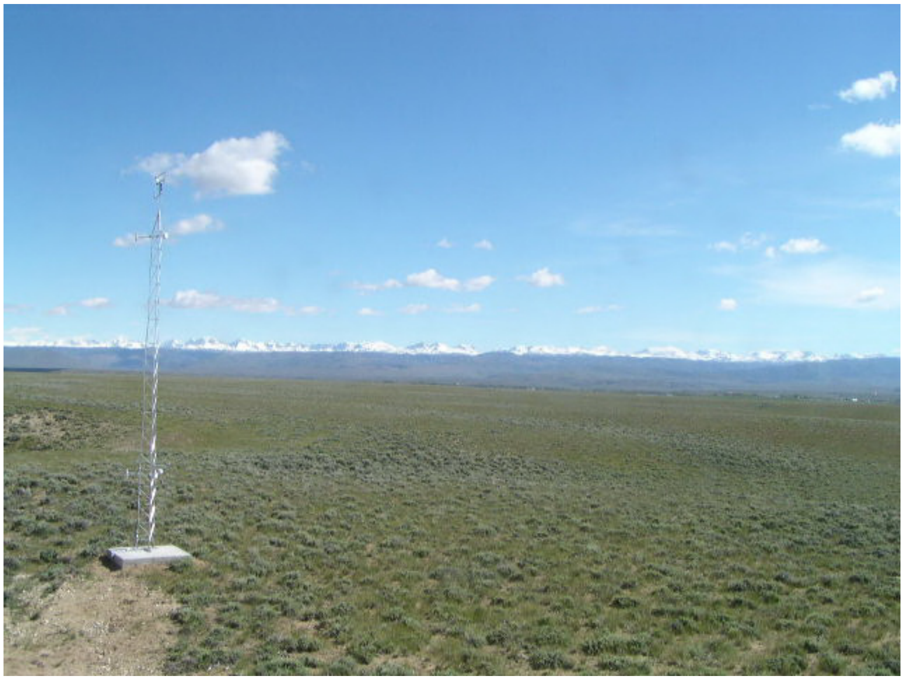
Wyoming Visibility Monitoring Network Digital Image Condition Code Key.

Image Condition Examples for Boulder, Wyoming

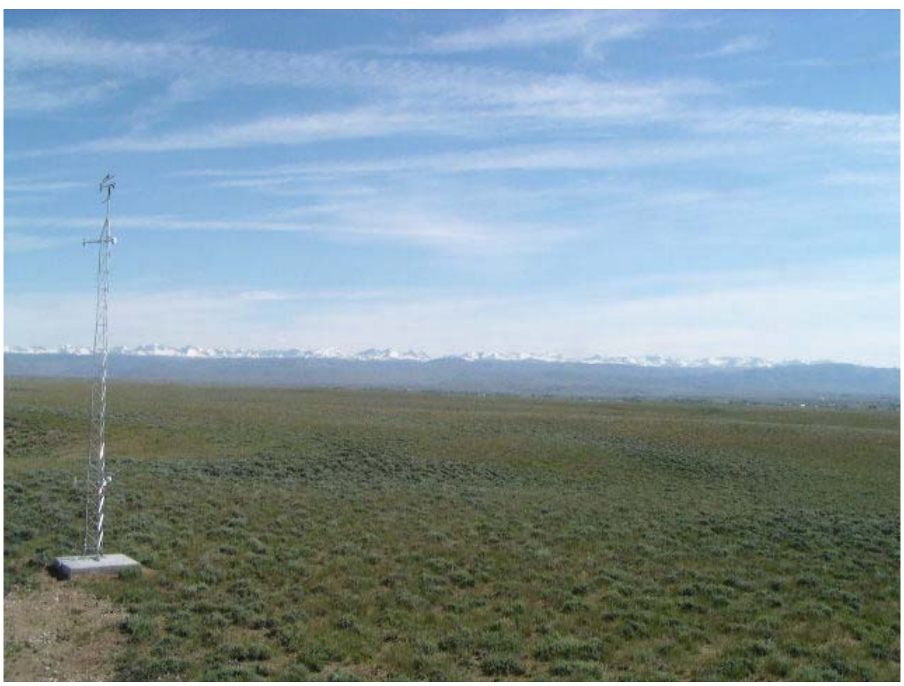
Pristine Conditions
Condition Code = 001
(11/09/2005 @1500)



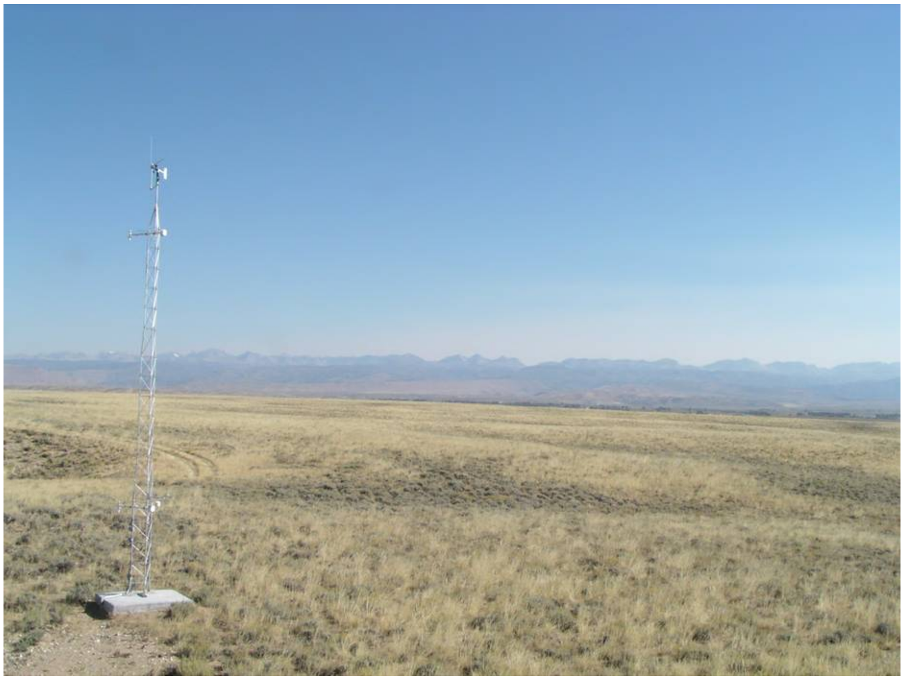
Weather Affected Conditions
Condition Code = 255
(09/12/2005 @0900)



Moderate Haze Conditions
Condition Code = 102
(06/10/2005 @0900)



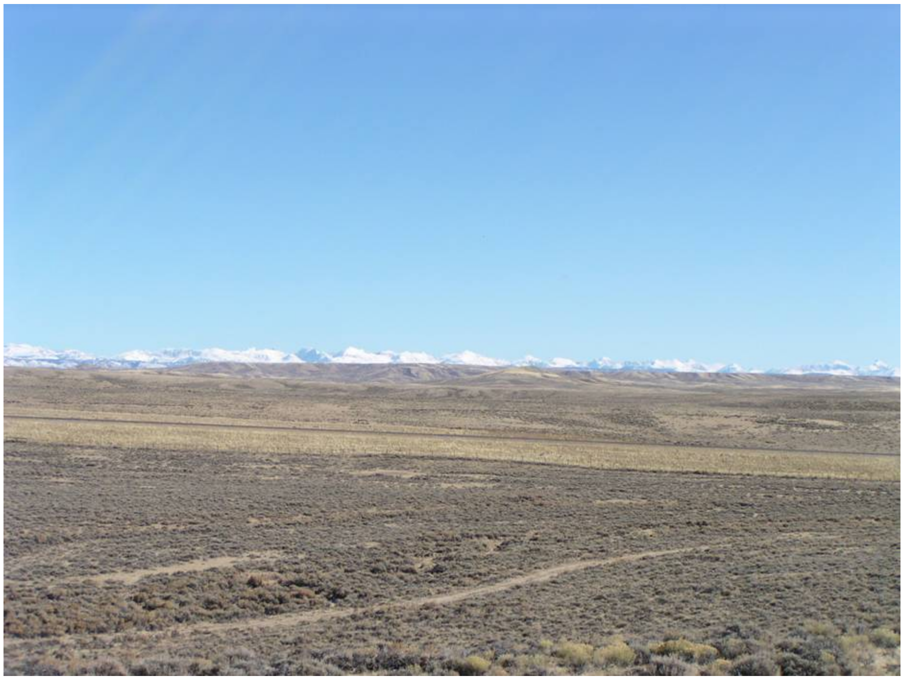
Considerable Haze Conditions
Condition Code = 203
(06/17/2005 @0900)



Ground-based Layered Haze
Condition Code = 012
(08/28/2005 @0900)

Multiple Haze Layers
Condition Code = 233
(03/01/2005 @0900)

Image Condition Examples for Daniel, Wyoming



Pristine Conditions
Condition Code = 001
(11/09/2005 @1200)

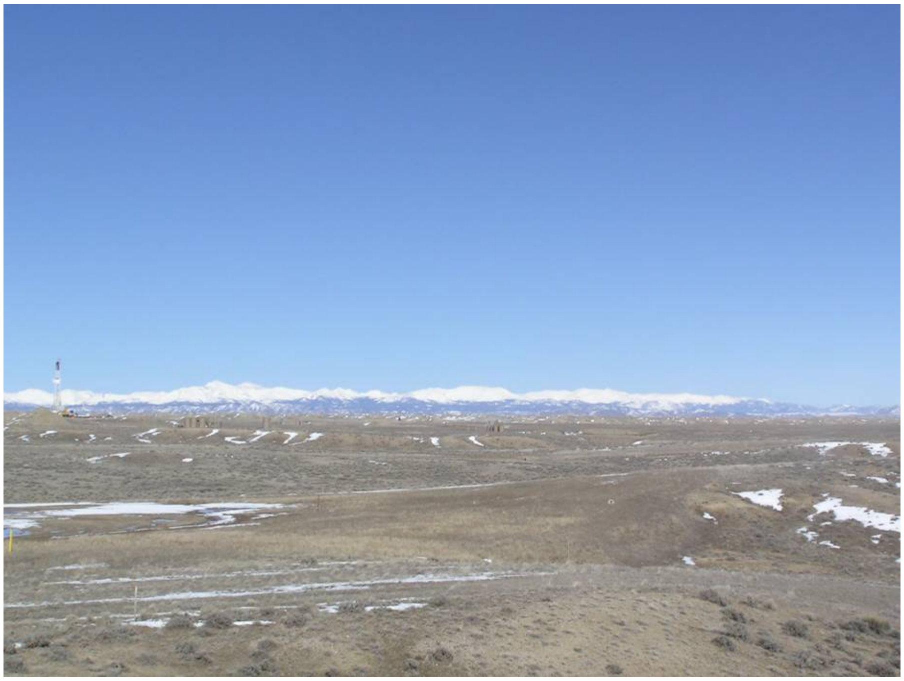
Weather Affected Conditions
Condition Code = 255
(09/09/2005 @1500)

Moderate Haze Conditions
Condition Code = 002
(10/21/2005 @0900)

Ground-based Layered Haze
Condition Code = 012
(09/15/2005 @0900)

Multiple Haze Layers
Condition Code = 132
(10/26/2005 @0900)

Image Condition Examples for Jonah, Wyoming



Pristine Conditions
Condition Code = 001
(03/31/2005 @1500)

Weather Affected Conditions
Condition Code = 255
(04/08/2005 @1500)

Moderate Haze Conditions
Condition Code = 002
(02/04/2005 @1500)

Considerable Haze Conditions
Condition Code = 103
(06/21/2005 @0900)

Ground-based Layered Haze
Condition Code = 012
(01/30/2005 @0900)

Elevated Layered Haze
Condition Code = 223
(03/01/2005 @0900)

Optical Monitoring QA/QC

IMPROVE Optical Monitoring: QA/QC procedures used by the IMPROVE program can be found at http://vista.cira.colostate.edu/views.

It is important to note that the following "warning" accompanies the transmissometer data section on the IMPROVE website (John Molenar, Air Resource Specialists, 2002): http://vista.cira.colostate.edu/improve/Publications/GrayLit/TransDataUseWarning/TransDataUseWarning.htm

"The IMPROVE monitoring network currently operates 17 transmissometers at 15 Class I areas collecting estimates of light extinction. Most of these sites contain more than 10 years of data and it is tempting to use these data to examine the long term trends of haze. However, transmissometers are subject to varying biases that can obscure or worse, create false trends. In addition, the transmissometer data released on the IMPROVE website are at Level 1 of the quality control process and should be considered as preliminary data. These data should only be used after careful scrutiny and reconciliation with concurrent aerosol and nephelometer data. Due to the uncertainties in the transmissometer data, they have not been used historically for trend analysis, but as an adjunct data set to be used in an attempt to come to "closure" with aerosol and other optical measurements

Following [this text on the web] are the main, but not all, issues related to the use of transmissometer extinction data. The misleading interpretations in the trends of haze that these transmissometer data can cause are then illustrated using data from Big Bend and Guadalupe Mountains National Parks (John Molenar, Air Resource Specialists, 2002)."

Transmissometer Data Quality Issues

First: Transmissometers DO NOT directly measure the atmospheric extinction coefficient. A transmissometer measures the irradiance (I_r) of a light at some distance (r) from the source. The average extinction (b_{ext}) of the path is calculated as:

$$b_{ext} = \ln (I_O / I_r) / r \qquad (1)$$

where: I_O is the estimated irradiance of the light source that would be measured at the distance (r) in the complete absence of any atmosphere (gases or aerosols).

Anything that modulates the measured irradiance (I_r) will affect the estimated extinction coefficient. Besides aerosols and absorbing gases along the path, this can include (but is not limited to): snow, rain, fog, clouds, airborne insect swarms, birds, fogged or dirty optical surfaces, misalignment of the detector or light source, optical blooming or turbulence, non-uniform light beam, or varying I_O.

Second: Transmissometers CANNOT be directly calibrated. Various methods have been used to indirectly estimate I_O but they all include major uncertainties and are not always self-consistent. In addition to the uncertainties associated with the initial estimate of I_O, current transmissometers occasionally suffer from step changes in the initial I_O when lamps are replaced in the field and all experience an increase in I_O as the lamp ages. It must be noted that any % change in I_O results in an absolute incremental offset in calculated b_{ext} that is independent of b_{ext}. For example: a transmissometer operating along a 5km path that has an unaccounted for 5% change in I_O will have an absolute offset of 10 Mm^{-1} in calculated b_{ext} for all b_{ext}.

Third: "Validity" codes are assigned for every hourly b_{ext} measurement using standard defined criteria in an initial systematic effort to identify possible "interferences" and apply standard corrections to account for

I_O drifts that may be biasing the data. These procedures are very global and at best should only be considered the first task of a series of increasingly more comprehensive data validation methodology.

Fourth: Primarily due to the above concerns, relying on transmissometer data without examining concurrent co-located nephelometer and/or speciated aerosol data is dangerous often leading to misleading conclusions. Each specific site must be critically examined using all concurrent nephelometer and aerosol data before any confidence can be placed in the transmissometer data."

[The example referenced in the first paragraph can be read on the website at the link provided above].

- -

The following figures are provided for additional reference to discussions in the main document and to further represent the preceding discussion regarding the uncertainty associated with the transmissometer data. Additionally, tables including the data used in the figures in the main document are included in this section.

The following table includes seasonal (quarterly) and annual transmissometer-based visual ranges based on data sets including > 50% valid data. Note that the averages are not representative if all four seasons do not include data. Only the seasonal data from this table are presented in the main document.

Transmissometer Data - SVR (miles)					
Above 50% Valid Data					
Year	Winter	Spring	Summer	Fall	Annual
1989		102.7	74.9	122.0	99.9
1990	142.8	88.9			115.9
1991		106.7	94.1	129.4	110.1
1992	122.5	125.7			124.1
1993		98.1	78.0	88.9	88.3
1994	92.1	76.7	89.1	126.8	96.2
1995		98.1	90.5	120.0	102.9
1996	156.3	111.8	73.2		113.8
1997		81.5	83.5	104.8	89.9
1998		78.4	85.0	145.6	103.0
1999	126.3	110.2	94.4	116.9	111.9
2000	103.8		78.6		91.2
2001	115.8	96.9	118.4	154.1	121.3
2002		110.0	109.2	136.4	118.5
2003		127.4	116.9		122.2
2004	129.2	112.7	78.4	83.6	101.0

The following table includes the seasonal and annual transmissometer-based visual ranges based on all data sets, whether > 50% of the data met the validity criteria or not. All data from this table are illustrated in figures in the main text. Data are also used in the following figures to compare visual ranges calculated from transmissometer data to those calculated from IMPROVE aerosol data collected at the IMPROVE BRID site. The BRID site does not include a nephelometer.

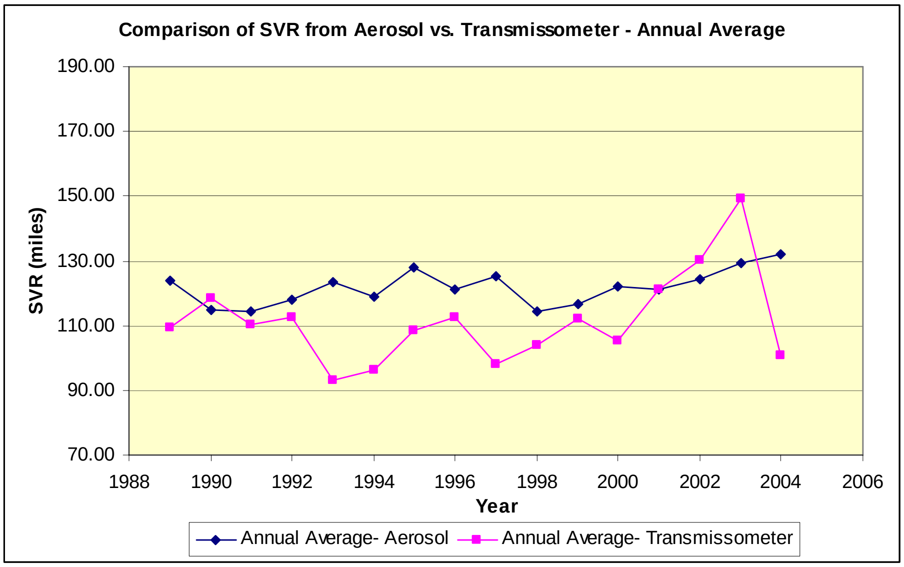
Transmissometer Data - SVR (miles)					
All Data					
Year	Winter	Spring	Summer	Fall	Annual
1989	137.3	102.7	74.9	122.0	109.2
1990	142.8	88.9		124.1	118.6
1991	111.2	106.7	94.1	129.4	110.4
1992	122.5	125.7	93.1	109.5	112.7
1993	106.7	98.1	78.0	88.9	92.9
1994	92.1	76.7	89.1	126.8	96.2
1995	125.2	98.1	90.5	120.0	108.5
1996	156.3	111.8	73.2	108.6	112.5
1997	123.0	81.5	83.5	104.8	98.2
1998	107.4	78.4	85.0	145.6	104.1
1999	126.3	110.2	94.4	116.9	111.9
2000	103.8	96.6	78.6	141.9	105.2
2001	115.8	96.9	118.4	154.1	121.3
2002	165.8	110.0	109.2	136.4	130.4
2003	181.8	127.4	116.9	171.0	149.3
2004	129.2	112.7	78.4	83.6	101.0

The table below includes the aerosol data used in the following comparisons for easy reference:

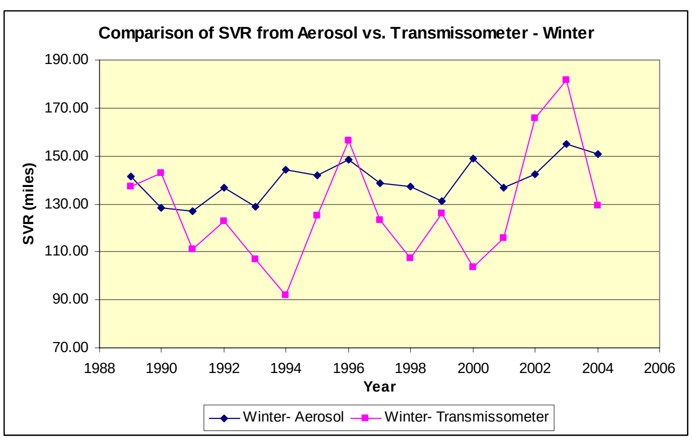
Aerosol Data					
Standard Visual Range (SVR) [MILES]					
Year	Winter	Spring	Summer	Fall	Annual
1989	141.66	108.21	103.68	141.71	123.81
1990	128.55	103.83	98.93	128.58	114.97
1991	127.05	102.73	105.39	122.96	114.53
1992	136.77	100.43	107.83	126.14	117.79
1993	128.67	120.33	111.32	133.66	123.50
1994	144.26	105.86	95.99	129.44	118.89
1995	141.85	122.11	114.04	133.12	127.78
1996	148.38	102.84	95.60	138.21	121.26
1997	138.73	108.11	126.52	128.14	125.37
1998	137.16	111.52	95.10	113.66	114.36
1999	131.12	105.86	97.79	132.58	116.84
2000	148.89	104.62	93.91	140.49	121.98
2001	136.63	109.30	98.79	140.65	121.34
2002	142.14	113.15	96.32	146.02	124.41

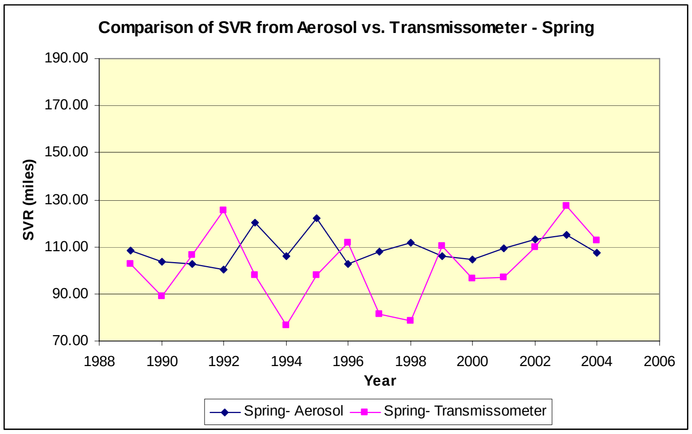
2003	154.78	114.92	102.26	146.07	129.51
2004	150.61	107.45	118.73	151.27	132.02

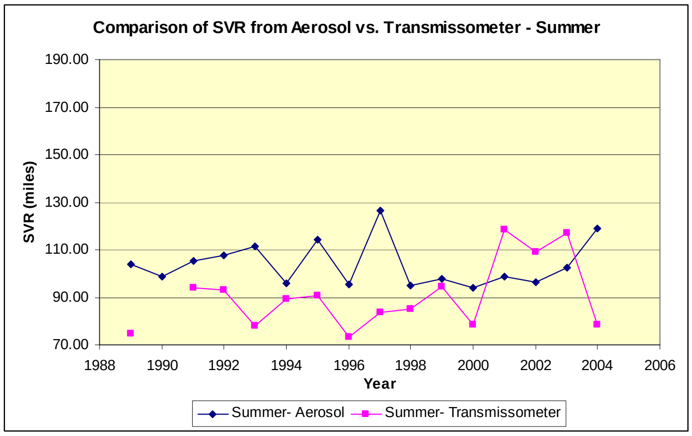
The following graph illustrates the comparison between annual averages calculated from aerosol- versus transmissometer-based visual ranges. The transmissometer averages are based on "all data." Note that the following five graphs begin at the 70 mile visual range point in order to allow more detail to be seen.

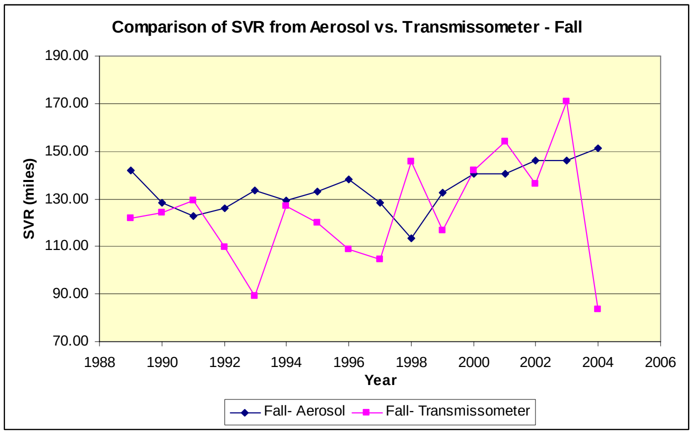


The following graphs show the seasonal comparisons of average visual ranges between these two types of data. The "all data" dataset from the transmissometer is used for these comparisons.









These graphs clearly show that caution must be taken when evaluating the transmissometer data.

NEPHELOMETER MONITORING SYSTEM

A nephelometer collected continuous measurements of the ambient atmospheric particle scattering coefficient (b_{sp}) at the Boulder monitoring station. An aspirated temperature/relative humidity (AT/RH) sensor was collocated with the nephelometer for data validation and interpretation purposes. Data were collected with a Campbell 23X datalogger and downloaded daily using a StarBand Satellite modem. The data were then validated in three stages according to IMPROVE protocol (Level-A, Level-0, and Level-1) as described below. Standard operating procedures (SOPs) and technical instructions (TIs) that fully describe the applied acquisition and reduction procedures include:

- SOP 4300 Collection of Optical Monitoring Data (IMPROVE Protocol)
- TI 4300-4002 Nephelometer Data Collection via Telephone Modem (IMPROVE Protocol)
- TI 4300-4006 Nephelometer Data Collection via Campbell Scientific Data Storage Module (IMPROVE Protocol)
- TI 4400-5010 Nephelometer Data Reduction and Validation (IMPROVE Protocol)

The nephelometer system was configured with the following instrumentation:

- Optec NGN-2 ambient nephelometer
- Rotronics MP-101A air temperature/relative humidity (AT/RH) sensor with aspirated air radiation shield
- Serial/analog data acquisition system, including:
  - Campbell Scientific 23X datalogger
  - Serial data interface
  - Solid state storage module (SM 192)
- Manual span gas system (SUVA 134a span gas, gas regulator, and supply hoses)
- Mounting tower and hardware

ON-SITE DATALOGGING

The 23X datalogger collected and time-tagged the following data:

Nephelometer RS232 serial data, including:

- Status (ambient, clean air, span, lamp out, rain, chopper failure)
- Raw scattered light value (counts)
- Raw lamp brightness value (counts)
- Normalized scattered light value (counts)

- Integration time (minutes)
- Chamber temperature (ºC)
- Date: year - month - day
- Time: hour - minute (MST)

Nephelometer analog data, including:

- Analog line 1: normalized scattered light value (mV)
  - Analog line 2: status (mV)

Ambient temperature (°C) - 5-minute averages of 10-second samples

Relative humidity (%) - 5-minute averages of 10-second samples

The nephelometer was operated on Mountain Standard Time in a 5-minute cycled mode. Clean air calibrations were automatically performed at approximately 6-hour intervals. Manual clean air and span gas calibrations were performed by the site operator or ARS at approximately 7-14 day intervals.

NEPHELOMETER DATA COLLECTION AND VALIDATION

The three levels of IMPROVE protocol data validation are described in the following subsections.

Level-A Nephelometer Data Validation

Raw nephelometer data collected daily from the station were reformatted and underwent Level-A validation. The procedure includes:

- Nephelometer, ambient temperature, and relative humidity data are extracted from the raw data and appended to site-specific Level-A validated data files. Nephelometer and datalogger-generated status codes are appended along with the data. Data too large or too small to occupy the data fields in the Level-A data files are set to -99.

- Zero and span calibrations recorded by the datalogger are extracted from the raw data and entered into the QA calibration database. Calibration information is used during Level-1 validation.

Data at this point are at Level-A validation. Level-A data are visually reviewed daily to identify operational problems and initiate corrective procedures as soon as possible. Level-A validated data are plotted weekly, and comments regarding the operation of the nephelometer are noted on the plots. Data and comments from operator log sheets are checked against data collected by satellite modem to identify inconsistencies and errors. Data from the log sheets are entered into the Quality Assurance (QA) Database.

Level-0 Nephelometer Data Validation

Level-0 validation of nephelometer data is performed quarterly. During Level-0 validation ARS staff scientists review Level-A data to identify periods of invalid data caused by the following:

- Burned out lamp
- Power failures
- Water contamination in nephelometer chamber
- Meteorological sensor failures (out of range values)
- Other problems

Periods identified as invalid are entered into the QA database.

Level-1 Nephelometer Data Validation

Level-1 validated nephelometer data are generated from Level-0 data, and include:

- Conversion of raw nephelometer and meteorological data to engineering units
- Checks for out of range values
- Identification of nephelometer b_{sp} data affected by meteorology
- Estimation of uncertainty

Each of these steps is detailed below:

Conversion of Raw Nephelometer and Meteorological Data to Engineering Units

- Meteorological data (ambient temperature, relative humidity, and chamber temperature) are already in engineering units.

- The nephelometer scattering coefficient (b_{sp}) is calculated by determining a calibration line for each data point, based on the interpolated current zero value and the difference between the original span and zero.

Level-1 Range Checks

Level-1 nephelometer 5-minute and hourly average data are checked as follows:

- Data invalid at Level-0 is invalid at Level-1.

- Calculated b_{scat} data (b_{sp} plus Rayleigh scattering) less than 80% Rayleigh scattering are invalid at Level-1 (Rayleigh scattering of 10.3 Mm^{-1}, based on elevation, was used for the Boulder station).

- Meteorological data valid at Level-0 are valid at Level-1.

Identification of Nephelometer b_{sp} Data Affected by Meteorology

Nephelometer measurements can be greatly influenced during periods of:

- Fog
- Heavy rain
- High relative humidity (> 90%)
- Blowing snow
- Other extreme meteorological conditions

Under these conditions nephelometer readings will no longer correspond to the optical properties of particulates in the atmosphere. Periods of meteorological interference identified during Level-1 are labeled "Weather Affected." Data not so labeled are called "Filtered." The following filters were used to identify these periods:

- Maximum: hourly b_{sp} data exceeding 5000 Mm^{-1} was coded as weather-affected.

- Relative Humidity: hourly b_{sp} data when the relative humidity exceeded 90% was coded as weather-affected.

- Rate of change: hourly b_{sp} data when the rate of change between consecutive hourly scattering values exceeded 50 Mm^{-1}, both values were coded as weather-affected.

- Standard deviation divided by the mean: hourly b_{sp} data when the standard deviation divided by the mean of the valid 5-minute scattering readings exceeded 10% was coded as weather-affected.

Nephelometer Measurement Uncertainty

The measurement uncertainty of the Optec NGN-2 ambient nephelometer is calculated from the distribution of calibration slopes determined during manual span/zero calibrations. The reported uncertainty is the 95% confidence limit of a two-tailed t-distribution.

Important elements of Optec NGN-2 nephelometer calibration are:

- The nephelometer output consists of unitless values (counts).

- The nephelometer has no adjustable parameters.

- The unitless clean air (zero) and SUVA 134a (span) calibration values correspond to nephelometer-detector response to scattering by Rayleigh air and SUVA 134a, respectively.

- After a period of time, the nephelometer chamber will tend to accumulate dust and other matter, increasing the background scattering. The value (in counts) of clean air and SUVA 134a calibrations, therefore, will increase over time.

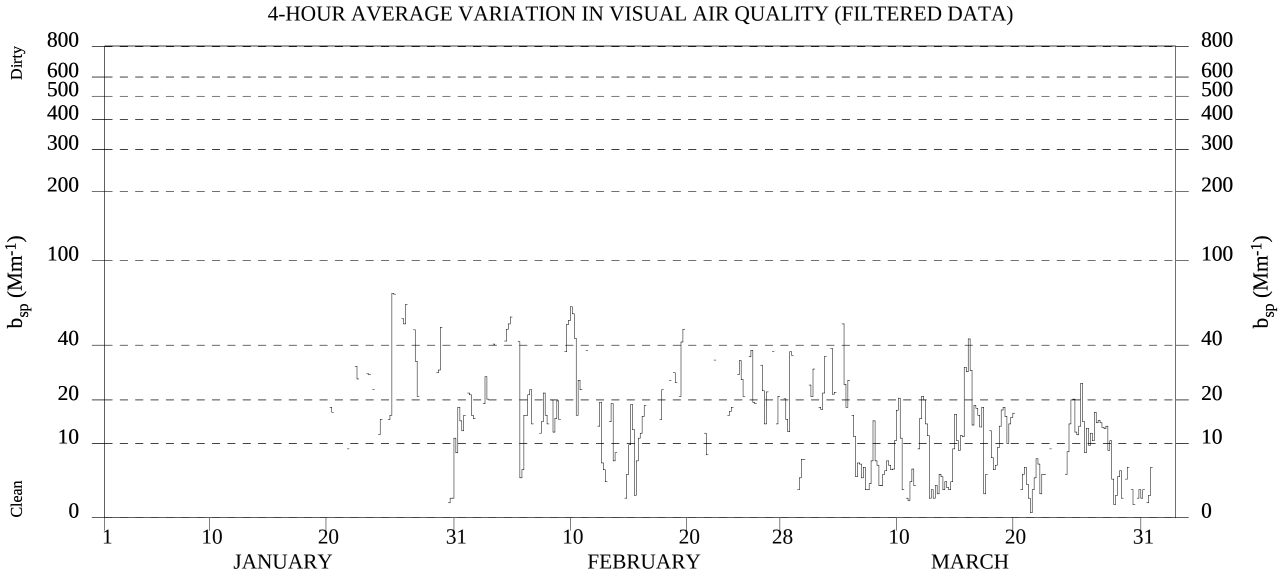
- Rayleigh scattering of air is a function of temperature and pressure, but can be reasonable approximated based on site altitude.

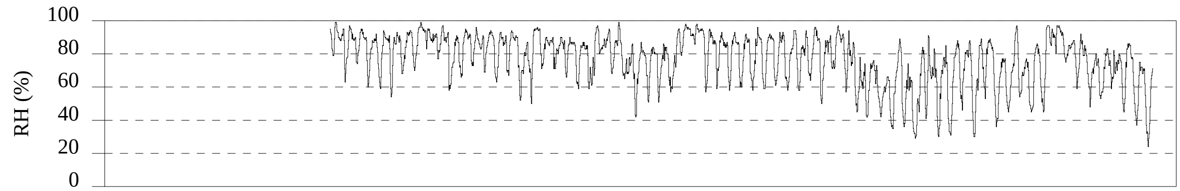
- The scattering for SUVA 134a is assumed to be equal to 7.25 times that of Rayleigh air.

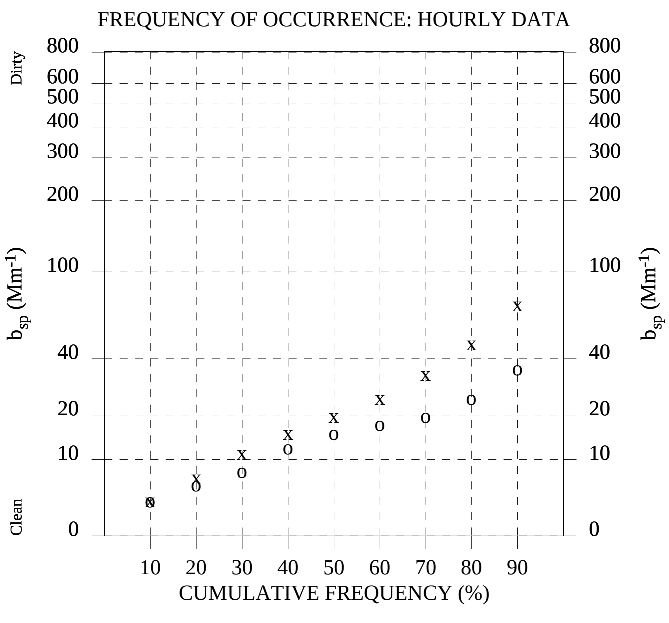
The following diagrams show quarterly and annual scattering data from the Boulder site.

BOULDER, WYOMING

Partial First Quarter: January 20, 2005 - March 31, 2005







CUMULATIVE FREQUENCY SUMMARY

%	Unfiltered Data [x] b_{sp}	Filtered Data [o] b_{sp}
10	3.0	3.0
20	6.0	5.0
30	10.0	7.0
40	14.0	11.0
50	18.0	14.0
60	23.0	16.0
70	31.0	18.0
80	44.0	23.0
90	67.0	33.0

VISIBILITY METRIC (FILTERED DATA)

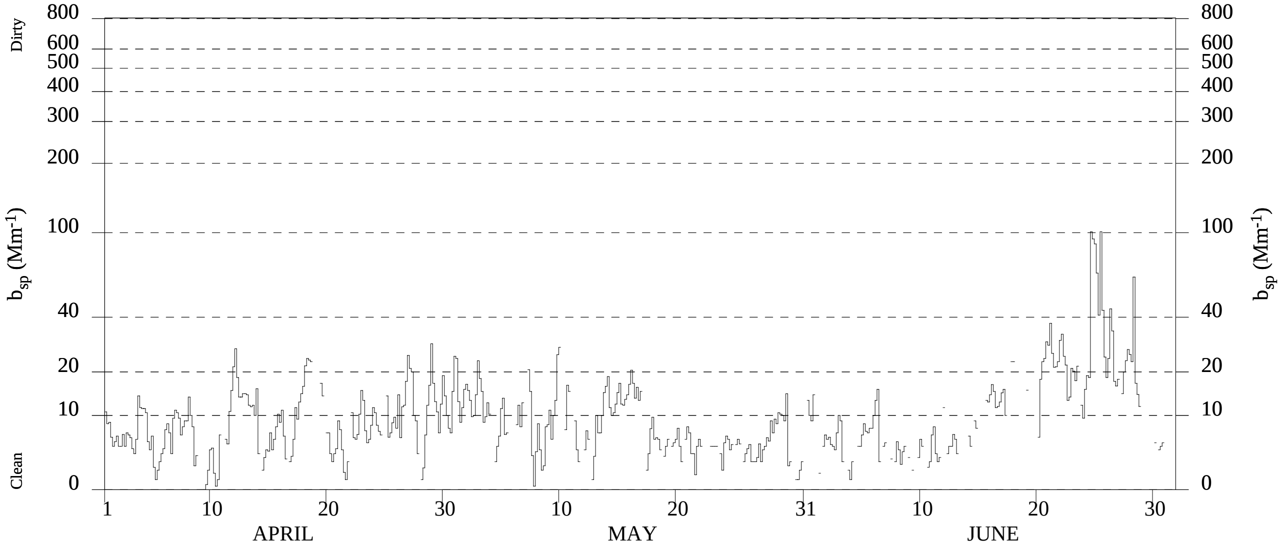
	b_{sp}
Mean of cleanest 20%	2.9
Mean of all data	15.9
Mean of dirtiest 20%	36.9

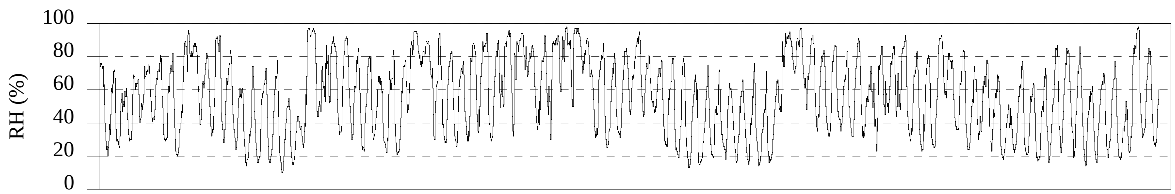
NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	1704	100
Valid Hourly Averages (Filtered and Unfiltered)	1695	99
Valid Hourly Averages (Filtered)	767	45
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		45

BOULDER, WYOMING

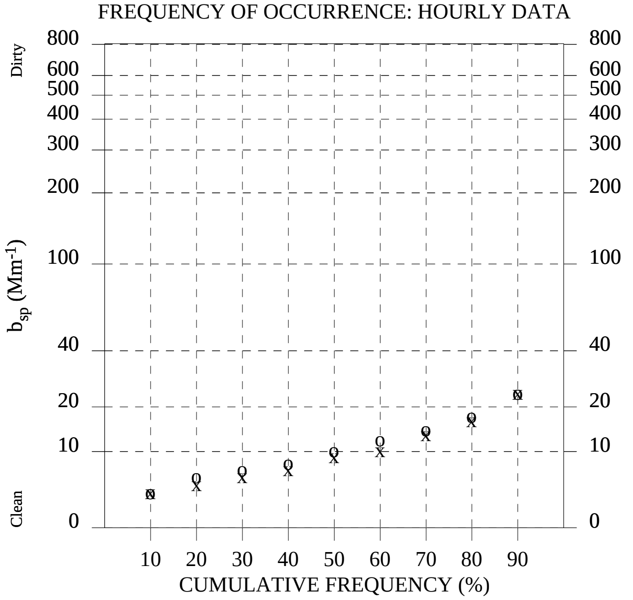
Second Quarter: April 1, 2005 - June 30, 2005

4-HOUR AVERAGE VARIATION IN VISUAL AIR QUALITY (FILTERED DATA)





FREQUENCY OF OCCURRENCE: HOURLY DATA



CUMULATIVE FREQUENCY SUMMARY

%	Unfiltered Data [x] b_{sp}	Filtered Data [o] b_{sp}
10	3.0	3.0
20	4.0	5.0
30	5.0	6.0
40	6.0	7.0
50	8.0	9.0
60	9.0	11.0
70	12.0	13.0
80	15.0	16.0
90	22.0	22.0

VISIBILITY METRIC (FILTERED DATA)

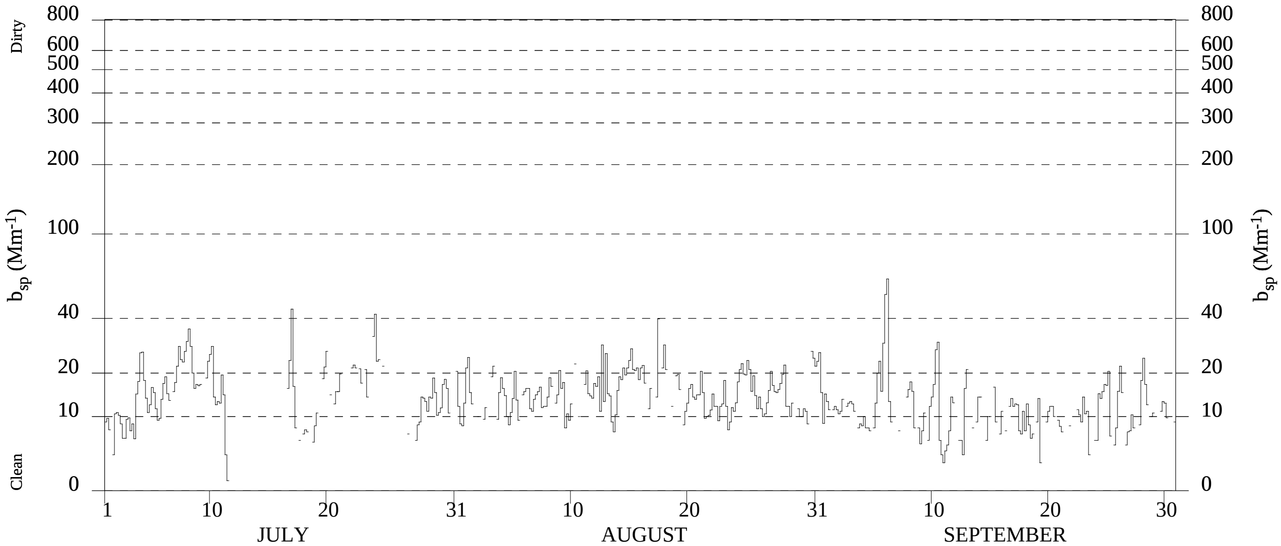
	b_{sp}
Mean of cleanest 20%	3.0
Mean of all data	11.8
Mean of dirtiest 20%	27.4

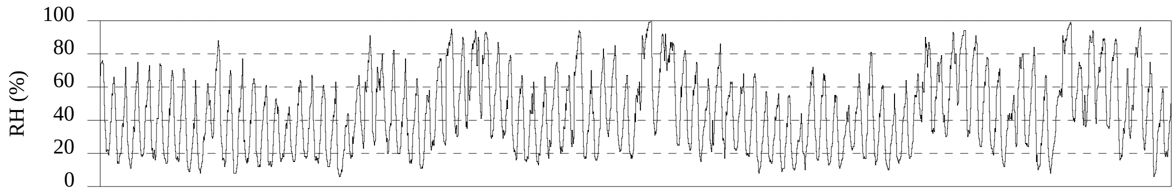
NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	2184	100
Valid Hourly Averages (Filtered and Unfiltered)	2183	100
Valid Hourly Averages (Filtered)	1296	59
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		59

BOULDER, WYOMING

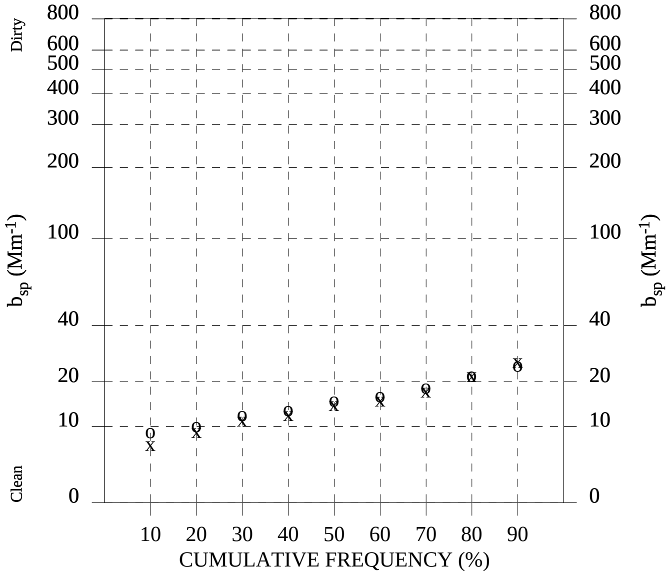
Third Quarter: July 1, 2005 - September 30, 2005

4-HOUR AVERAGE VARIATION IN VISUAL AIR QUALITY (FILTERED DATA)





FREQUENCY OF OCCURRENCE: HOURLY DATA



CUMULATIVE FREQUENCY SUMMARY

%	Unfiltered Data [x] b_{sp}	Filtered Data [o] b_{sp}
10	6.0	8.0
20	8.0	9.0
30	10.0	11.0
40	11.0	12.0
50	13.0	14.0
60	14.0	15.0
70	16.0	17.0
80	20.0	20.0
90	24.0	23.0

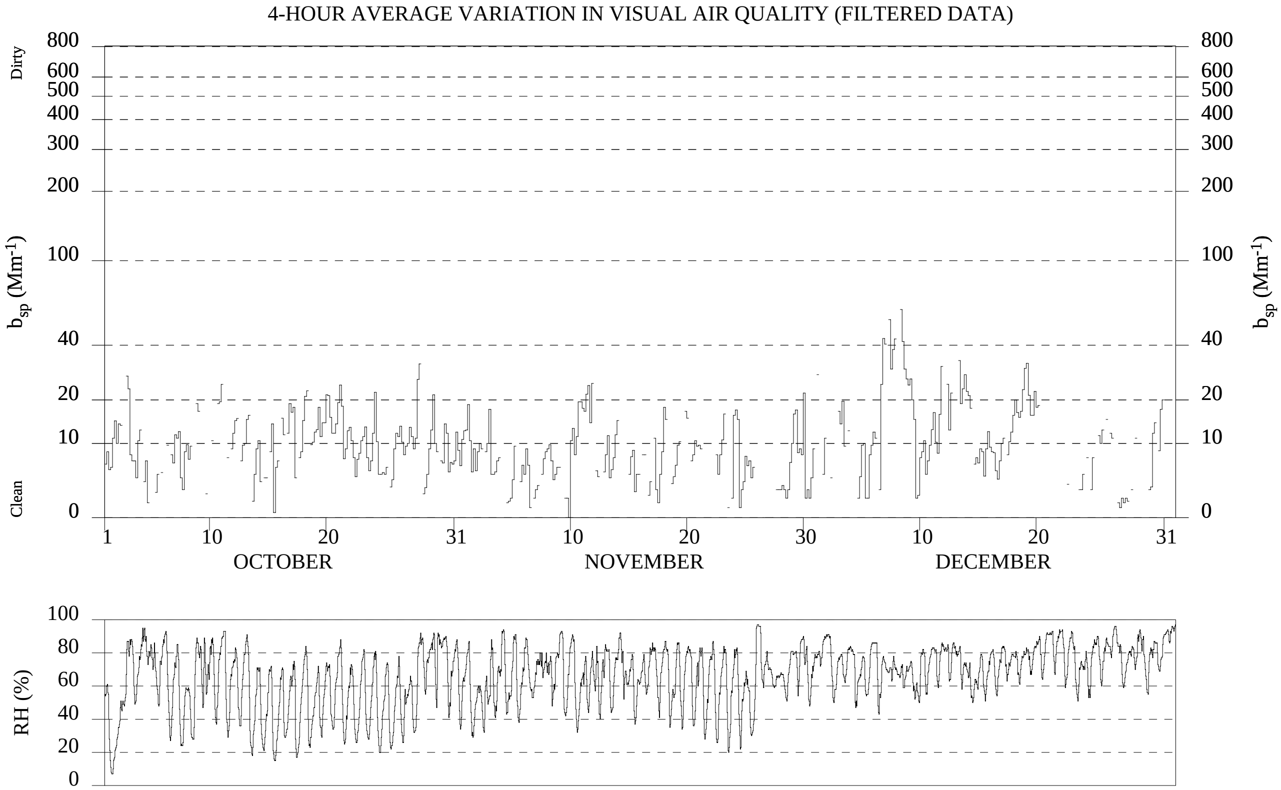
VISIBILITY METRIC (FILTERED DATA)

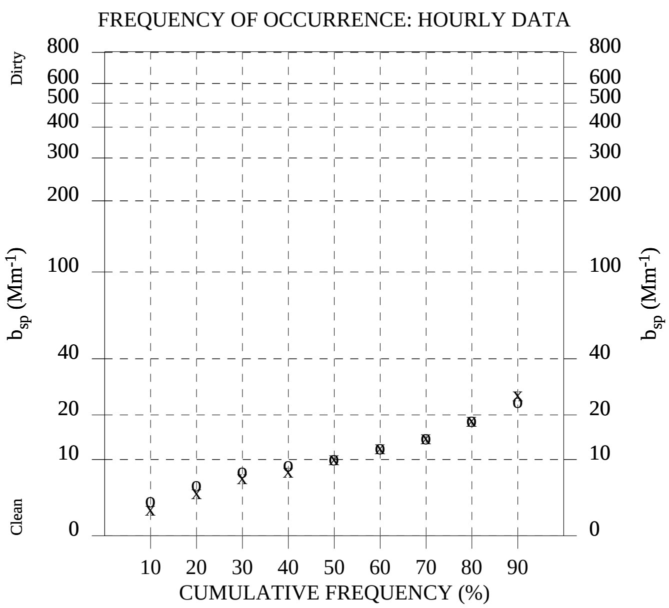
	b_{sp}
Mean of cleanest 20%	7.2
Mean of all data	15.0
Mean of dirtiest 20%	26.0

NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	2208	100
Valid Hourly Averages (Filtered and Unfiltered)	2085	94
Valid Hourly Averages (Filtered)	1210	55
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		58

BOULDER, WYOMING

Fourth Quarter: October 1, 2005 - December 31, 2005





CUMULATIVE FREQUENCY SUMMARY

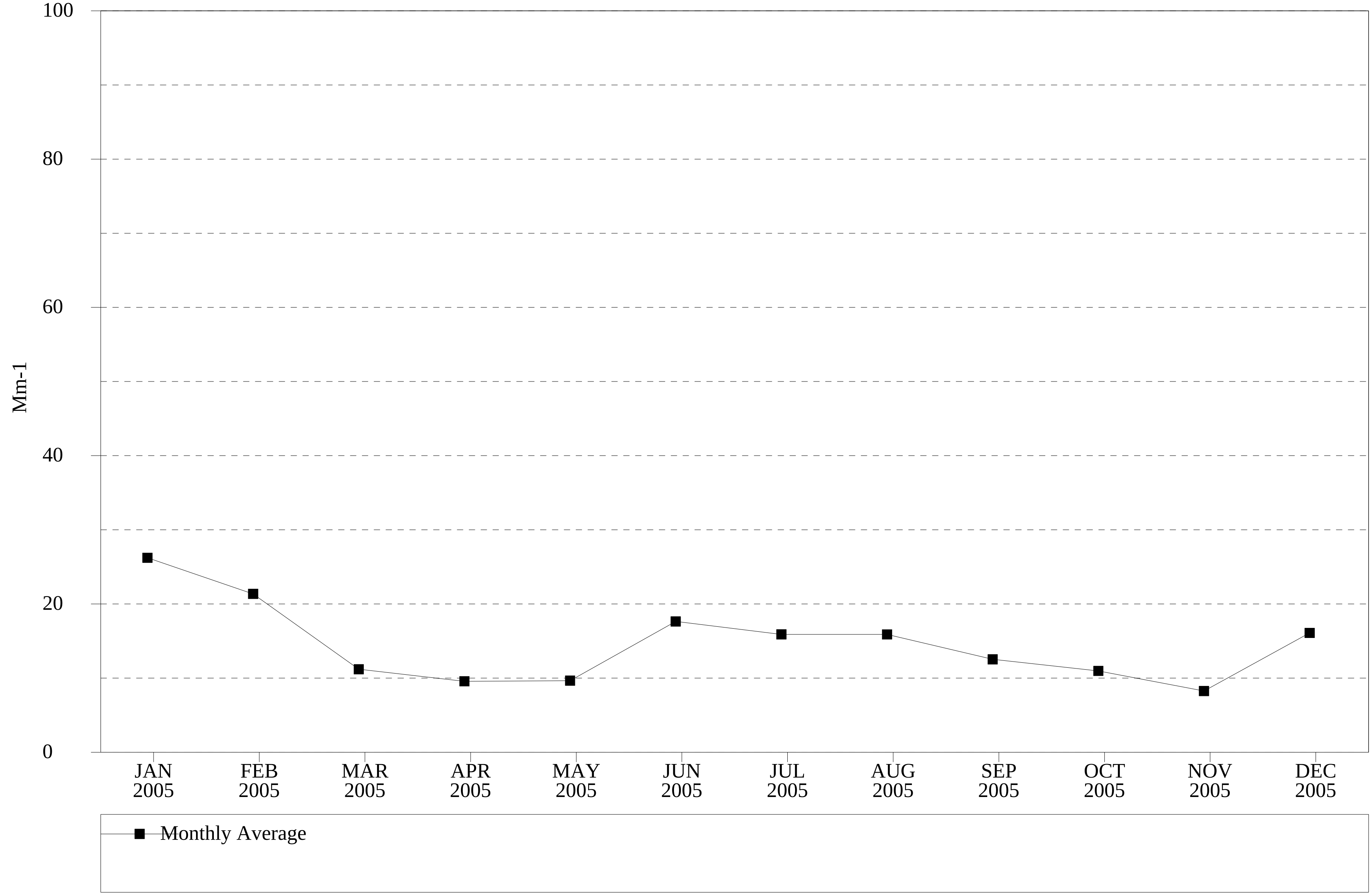
%	Unfiltered Data [x] b_{sp}	Filtered Data [o] b_{sp}
10	2.0	3.0
20	4.0	5.0
30	6.0	7.0
40	7.0	8.0
50	9.0	9.0
60	11.0	11.0
70	13.0	13.0
80	17.0	17.0
90	24.0	22.0

VISIBILITY METRIC (FILTERED DATA)

	b_{sp}
Mean of cleanest 20%	3.1
Mean of all data	11.6
Mean of dirtiest 20%	25.3

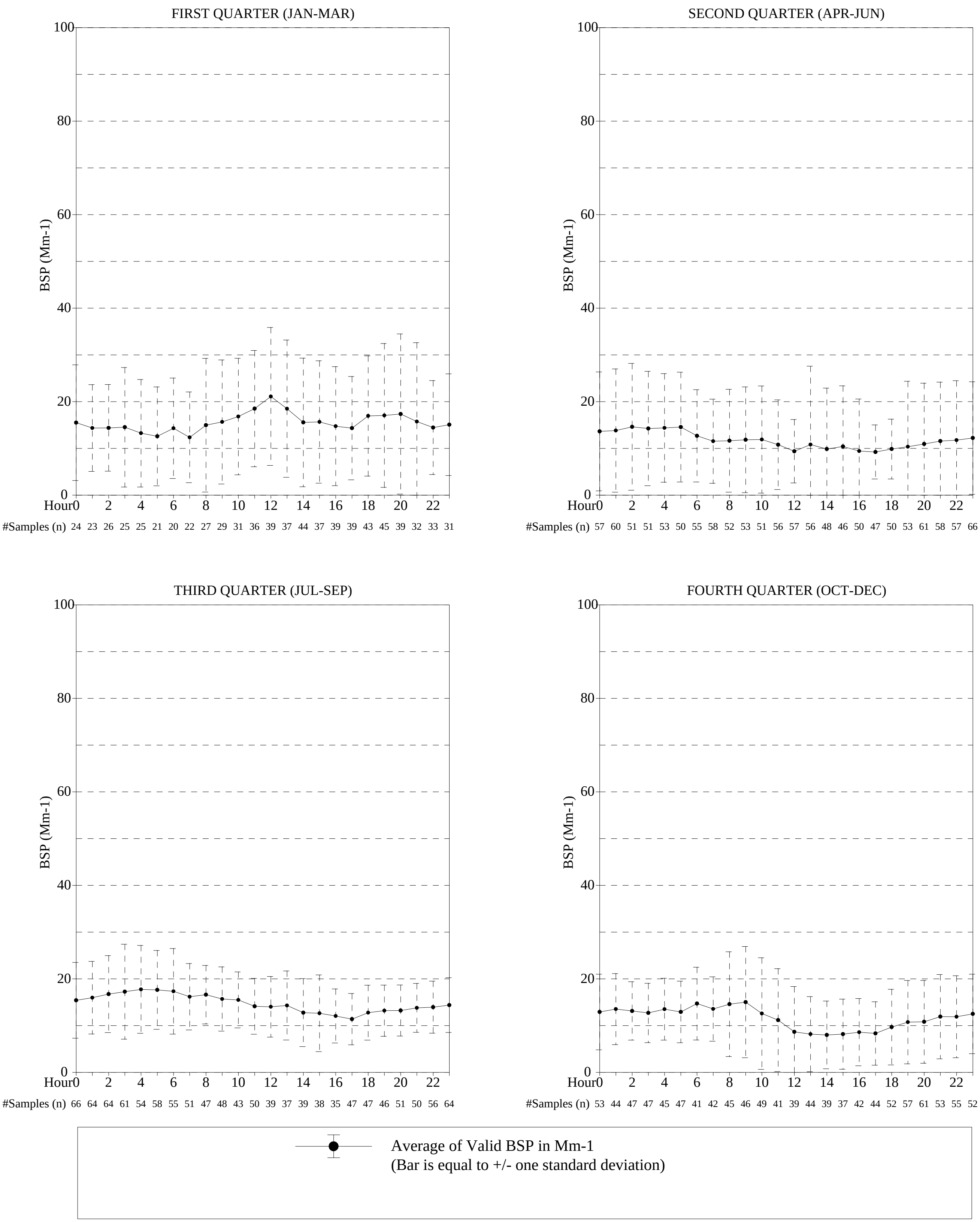
NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	2208	100
Valid Hourly Averages (Filtered and Unfiltered)	2201	100
Valid Hourly Averages (Filtered)	1122	51
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		51

Boulder | Filtered bsp Data Summary by Month
January 2005 to December 2005 | 01/01/2005 - 12/31/2005

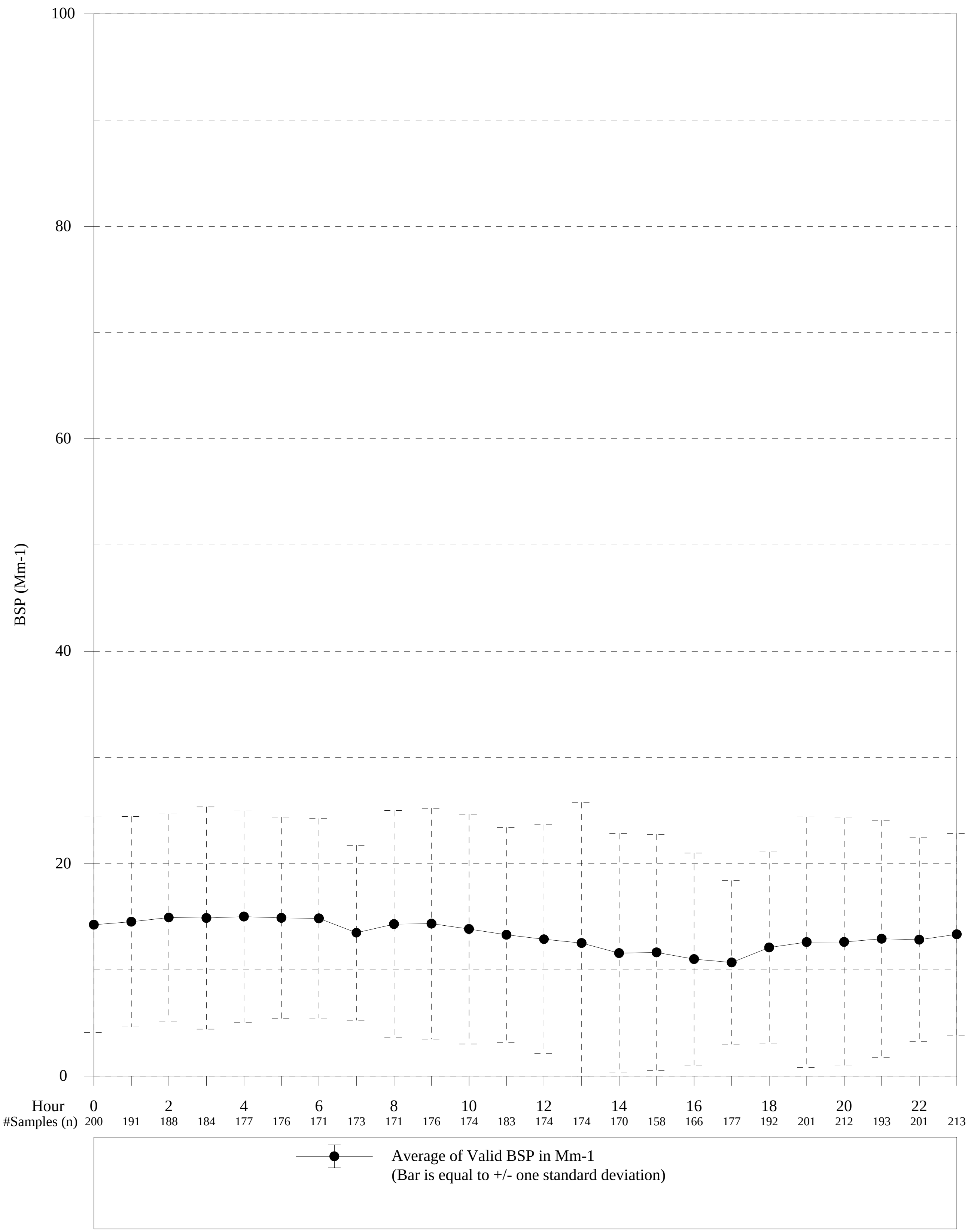


 Preliminary Validation BSPF-1 04-24-2006

Filtered bsp Plots



Boulder | Annual Diurnal Filtered bsp Plot | 2005



Final Validation

03-13-2006

NGN-2 Ambient Nephelometer and
AT/RH Sensor and Sampling Specifications
Boulder, Wyoming

Parameter	Sensor	Units	Sample Frequency	Notes
Nephelometer Raw readings	Optec NGN-2 Nephelometer	mVDC and Counts	2-minute average samples every 5 minutes	Optec NGN-2 serial output logged
Nephelometer clean air calibration readings	Optec NGN-2 Nephelometer	mVDC and Counts	10-minute average at approximately 6-hour intervals	Start time drifts as controlled by Optec NGN-2 software
Nephelometer span calibrations (SUVA 134a)	Optec NGN-2 Nephelometer	mVDC and Counts	10-minute average performed manually at approximately 7-14 day intervals	Operator initiated during site visits
Nephelometer operating mode code	Optec NGN-2 Nephelometer	Unitless	1 code per nephelometer raw reading	Optec NGN-2 serial output logged
Chamber temperature	Solid State Sensor	°C	Concurrent with nephelometer reading	Available on serial data stream only
Ambient temperature	Rotronic MP-101A solid-state AT/RH	°C (-30° to +50°C)	Concurrent with nephelometer reading (5-minute averages of 10-second samples)	Sensor in passive air radiation shield
Ambient relative humidity	Rotronic MP-101A solid-state AT/RH	%RH (0% to 100%)	Concurrent with nephelometer reading (5-minute averages of 10-second samples)	Sensor in aspirated air radiation shield