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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**NEPHELOMETER DATA REDUCTION AND VALIDATION (IMPROVE PROTOCOL)**
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REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS

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1.0 PURPOSE AND APPLICABILITY

This technical instruction (TI) describes the reduction and validation of Optec NGN-2 nephelometer and collocated meteorological data according to IMPROVE Protocol.

The Optec NGN-2 nephelometer measures the atmospheric scattering coefficient (b_{scat}) of total atmospheric extinction (b_{ext}). The raw nephelometer output is converted to b_{scat} using instrument and time-specific calibration information.

This TI is a guide to the reduction and validation of nephelometer and collocated meteorological data. Data reduction and validation begin with the daily interrogation of the on-site datalogger and end with Level-1 validated nephelometer and meteorological data. Nephelometer and meteorological data undergo the following reduction and validation steps:

- Daily collection and review
- Daily and weekly Level-A data validation and review
- Seasonal Level-0 data validation
- Seasonal Level-1 data validation and review

This TI describes the validation of the following nephelometer and meteorological parameters:

- Atmospheric scattering coefficient (b_{scat})
- Nephelometer chamber temperature
- Ambient temperature
- Ambient relative humidity

Because most stations are remote, daily review of raw and Level-A validated data are critical to the identification and resolution of problems. Level-1 validated nephelometer data are used for reporting and further analyses.

2.0 RESPONSIBILITIES

2.1 PROGRAM MANAGER

The program manager shall:

- Review Level-1 validated data with the project manager to ensure quality and accurate data validation.
- Coordinate data reduction and validation goals, objectives, and methods with the Contracting Officer's Technical Representative (COTR) to ensure that data validation procedures meet the IMPROVE program requirements.

2.2 PROJECT MANAGER

The project manager shall:

- Review and verify calibration data for each instrument.
- Review Level-1 validated data with the program manager, data coordinator and field specialist.

2.3 DATA COORDINATOR

The data coordinator shall:

- Perform data validation procedures described in this technical instruction.
- Resolve data validation problems with the project manager.
- Identify instrument or data collection and validation problems and initiate corrective actions.

2.4 FIELD SPECIALIST

The field specialist shall review raw and validated data with project manager and data coordinator to resolve instrument problems.

3.0 REQUIRED EQUIPMENT AND MATERIALS

All data reduction and validation occurs on IBM-PC compatible computer systems. The required computer system components include:

- IBM compatible 386/486 computer system with VGA, 80 megabyte hard disk, 8 megabyte RAM
- Microsoft Windows 3.1 and Compatible Printer
- Latest versions of the following software for performing data collection, Level-A validation, and plot review:
  - NGN_PULL.EXE and NGN_PLOT.EXE
- Latest version of software for performing Level-0 and Level-1 validation and Quality Assurance (QA) file summaries:
  - NGN_SEAS.EXE and NGN_QA.EXE
- Latest version of software for generating nephelometer seasonal summary plots:
  - NGN_NSUM.EXE

4.0 METHODS

Data reduction and validation begin with the daily interrogation of the on-site datalogger and end with Level-1 validated nephelometer and associated meteorological data.

This section includes six (6) subsections:

4.1 Daily Collection of Nephelometer and Meteorological Data
4.2 Daily and Weekly Level-A Validation of Nephelometer and Meteorological Data
4.3 Seasonal Update of Quality Assurance (QA) Database (XXXX_C) Files
4.4 Seasonal Update of Quality Assurance (QA) Calibration Files
4.5 Seasonal Level-0 Validation of Nephelometer and Meteorological Data
4.6 Seasonal Level-1 Validation of Nephelometer and Meteorological Data

Figure 4-1 is a flowchart of the data reduction and validation procedures for nephelometer and collocated meteorological data. These procedures are described in the following subsections.

4.1 DAILY COLLECTION OF NEPHELOMETER AND METEOROLOGICAL DATA

Daily collection of raw nephelometer and meteorological data is handled by the NGN_PULL software. NGN_PULL automatically oversees the following tasks relating to daily data collection:

- On-site Campbell Scientific 21XL dataloggers are interrogated daily via telephone modem for all raw nephelometer and meteorological data available since the last download. Raw data collected via telephone modem are saved in daily site-specific ASCII files.

- At sites where telephone access is unavailable, preliminary nephelometer and meteorological data are extracted from satellite-telemetered DCP data. Preliminary DCP data are replaced by data collected via Campbell Scientific data storage module at regular intervals. Preliminary nephelometer and meteorological data collected via DCP are saved in daily ASCII DCP files with other DCP-collected optical data.

Refer to the following documentation for detailed data collection procedures:

- SOP 4300, Collection of Optical Monitoring Data

- TI 4300-4000, Data Collection via DCP

- TI 4300-4002, Nephelometer Data Collection via Telephone Modem

- TI 4300-4004, Nephelometer Daily Compilation and Review of DCP-Collected Data

- TI 4300-4006, Nephelometer Data Collection via Campbell Scientific Data Storage Module

- TI 4100-3300, Troubleshooting and Emergency Maintenance Procedures for Optec NGN-2 Nephelometer Systems

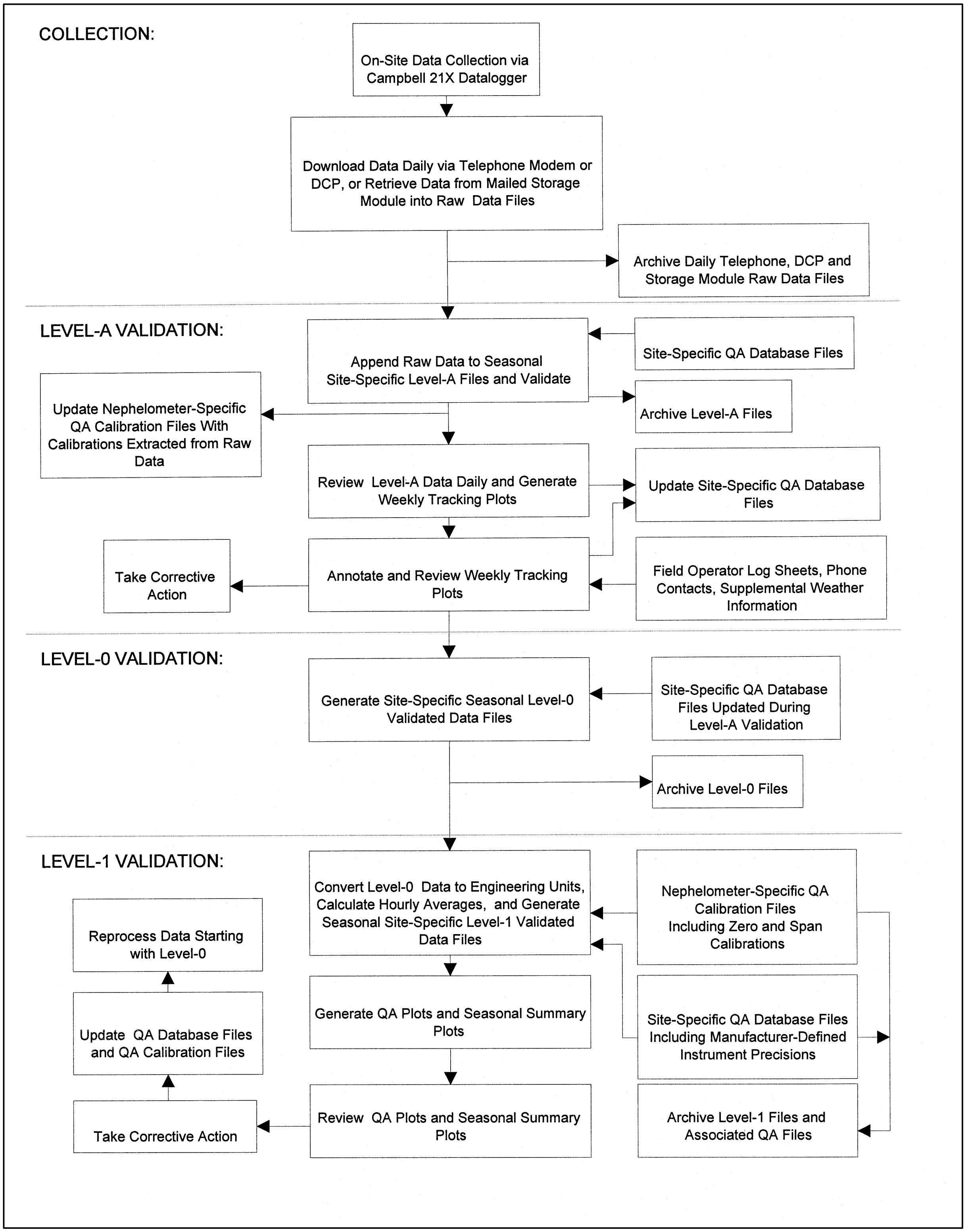


Figure 4-1. Nephelometer and Meteorological Data Reduction and Validation Flowchart.

Figures 4-2 and 4-3 present the file formats of raw data collected via telephone modem and DCP, respectively.

The data coordinator verifies that all data were collected. Any data collection problems are immediately reported to the project manager. Ongoing data collection problems are resolved according to TI 4100-3300, Troubleshooting and Emergency Maintenance Procedures for Optec NGN-2 Nephelometer Systems (IMPROVE Protocol).

4.2 DAILY AND WEEKLY LEVEL-A VALIDATION OF NEPHELOMETER AND METEOROLOGICAL DATA

Level-A validation of raw nephelometer and meteorological data includes:

- Daily automatic reformatting and Level-A validation by the NGN_PULL software
- Daily visual review of raw and Level-A data
- Weekly plotting and review of Level-A data

4.2.1 Daily Automatic Reformatting and Level-A Validation

Daily automatic reformatting and Level-A validation of raw nephelometer and meteorological data by NGN_PULL occurs immediately after collection and is detailed in the documentation listed above. The tasks the NGN_PULL software performs are:

- The following parameters are extracted from the raw telephone-modem or DCP daily data file and appended to site-specific seasonal data files:
  - Serial nephelometer raw scattered light (counts)
  - Serial nephelometer direct light (counts)
  - Serial nephelometer chamber temperature (°C)
  - Serial nephelometer status code (1-9)
  - Analog nephelometer normalized scattered light (1 mVDC = 1 count)
  - Analog status code (1 VDC = code 1)
  - Ambient temperature (°C)
  - Relative Humidity (%)
  - AC and DC power failure information
- Automatic clean air zero calibrations and operator-initiated clean air zero and span calibrations recorded by the datalogger are extracted from the raw data file and appended to nephelometer-specific QA calibration files. Figure 4-4 shows a sample nephelometer-specific QA calibration file.

```
5-Minute Analog Data
01+0163.  02+1993.  03+0059.  04+0755.  05+582.6  06+0999.  07+2.234  08+097.1
```

Element #	Description
01	Datalogger program location identifier (not used)
02	Year
03	Julian date
04	Time (HHMM) at the end of the data period
05	Nephelometer A1 channel (mV x 2.0)
06	Nephelometer A2 channel (mV x 2.0)
07	Ambient air temperature (°C)
08	Ambient relative humidity (%)

```
5-Minute Serial
01+0119.  02+1993.  03+0059.  04+0757.  05+1.000  06+0891.  07+3493.  08+510.0
09+2.000  10+3.510  11+2.000  12+0755.  13+509.3  14+0999.  15+2.456  16+097.1
```

Element #	Description
01	Datalogger program location identifier (not used)
02	Year
03	Julian date
04	Time (HHMM) the serial stream was received by the datalogger
05	Nephelometer status code
06	Nephelometer raw scattered light reading (counts)
07	Nephelometer direct light reading (counts)
08	Nephelometer normalized scattered light reading (counts)
09	Nephelometer integration time (minutes)
10	Nephelometer chamber temperature (°C)
11	Not used
12	Nephelometer time (HHMM)
13	Nephelometer A1 channel (mV x 2.0)
14	Nephelometer A2 channel (mV x 2.0)
15	Ambient air temperature (°C)
16	Ambient relative humidity (%)

```
Hourly Code  Summary
01+0104.  02+1993.  03+0059.  04+0800.  05+50.00  06+0.000
```

Element #	Description
01	Datalogger program location identifier (not used)
02	Year
03	Julian date
04	Time (HHMM) at the end of the data period
05	Nephelometer code summary for the past hour
06	Support system code summary for the past hour

The nephelometer code summary is the sum of any or all of the following:

Code	Description
50	Ambient reading
100	Clean air calibration
300	Span calibration
500	Lamp burned out
1000	Precipitation event detected
2000	Chopper motor start-up failure

The support system code summary is the sum of any or all of the following:

Code	Description
300	21X datalogger power low
500	DC power supply voltage low
1000	AC power outage
2000	Blue Earth serial data buffer restarted

Figure 4-2. Raw Telephone-Modem or Campbell Scientific Data Storage Module Data File Format.

```
Example Data                                                     Description
FA40643E93085122318G43-1NN002W4C00432             Identification and quality
# 1  1716
# 2   114   173   210   224   383   407   297   302
# 2   383   140   135   140   125   132   138   128
# 2   141   155
# 3   498   498   498   498   498   498   498   498
# 3   498   498   498   498   498   498   498   498
# 3   498   498
# 4   524   423   324
# 5    50    50    50
# 6    -1    -1    -1
# 7   209   209   209
# 8  1020  1020  1020
# 9    96    92   102
#10   960   954   926
#11  1388
```

Data Group Number	Description
#1	Synergetics DCP operation status
#2	10-minute nephelometer analog A1 readings (mV / 2)
#3	10-minute nephelometer analog A2 readings (mV / 2)
#4	Nephelometer time when 21X datalogger time is xx:30
#5	Hourly nephelometer code summary
#6	Hourly support code summary
#7	Last clean air calibration (counts) (x10)
#8	Last span calibration (counts) (x10)
#9	Ambient temperature at top of hour (°C) (x10)
#10	Ambient relative humidity at top of hour (%) (x10)
#11	DCP battery voltage (VDC) (x100)

Identification and transmission quality:

Characters	Example	Description
1-8	FA40643E	DCP identification
9-10	93	Year of transmission
11-13	085	Julian date of transmission
14-15	12	Hour of transmission
16-17	23	Minute of transmission
18-19	18	Second of transmission
20	G	Failure code
21-22	43	Signal strength
23-24	-1	Modulation frequency deviation from normal
25	N	Modulation quality
26	N	Modulation index
27-29	002	Satellite channel
30	W	Satellite (East or West)
31-32	4C	IFPD (Intermediate Frequency Presence Detector)
33-37	00432	Message length

Figure 4-3. Synergetics DCP Telemetered Data File Format.

```
BOWA                       Site Code
NGN-2-21                   Nephelometer Identification
Number 2                   Nephelometer Operational Cycle Number
37                         Initial Clean Air Calibration
106                        Initial Span Calibration
30,50,50,0,500             Zero Calibration Validation Parameters:
                           - Window size(30 days)
                           - Maximum Distance from Mean (50 counts)
                           -  Maximum  Distance  from  Linear  Regression
Line
                             (50 counts)
                           - Absolute Minimum (20 counts)
                           - Absolute Maximum (500 counts)
----------                 Comment (not used)
----------                 Comment (not used)
----------                 Comment (not used)

01-18-1994 07:15:11        Date and Time of Last Update
93,124,1420,-099.00,0037.05,022.46,023.92,019.78,1,Comment
93,124,1445,-099.00,0106.06,022.37,024.07,021.06,A,Comment
93,124,1500,0037.26,-099.00,022.03,024.16,019.07,I,Comment

                     Field Number
----------------------------------------------------------
1   2   3      4       5      6      7      8    9    10
```

Field #	Description
1	Year
2	Julian Date
3	Time (HHMM)
4	Clean Air Calibration or -99 (Counts)
5	Span Calibration or -99 (Counts)
6	Ambient Temperature (°C)
7	Nephelometer Chamber Temperature (°C)
8	Relative Humidity (%)
9	Validity Code (1= Valid serial , A=Analog, Other = Invalid)
10	Comment (No commas allowed in comment)

Figure 4-4. Example Nephelometer QA Calibration File.

- Three Level-A validity codes, generated by the datalogger and nephelometer, are extracted from the raw data and assigned to nephelometer data during the daily Level-A validation:

    - The ***Power Code***, generated by the datalogger, is an hourly summary of any AC or DC power problems that occurred during the previous hour.

    - The ***Nephelometer Status Code*** is generated by the nephelometer to indicate the type of measurement (ambient, clean air zero or span calibration) or problem (rain, lamp out, chopper motor failure).

    - The ***Data Type Code*** indicates the source of the nephelometer data (serial, analog, DCP).

- Meteorological data are not assigned Level-A validity codes. Meteorological parameter values that exceed the field sizes of the Level-A file are set to -99.

- Data at this point are at Level-A validation. Figure 4-5 shows an example Level-A validated data file and the associated validity codes for the parameters.

4.2.2 Daily Visual Review of Raw and Level-A Data

After Level-A validation by the NGN_PULL software, the data coordinator visually reviews the raw and Level-A data as follows:

- Raw and Level-A data file listings are visually reviewed daily to identify operational problems and initiate corrective procedures as soon as possible.

- Level-A validated data are plotted weekly using the NGN_PLOT software. The plots are posted and visually reviewed by the data coordinator, field specialist, and project manager. Comments regarding the operation of the nephelometer are noted on the plots. An example weekly plot is shown in Figure 4-6. If a new problem is identified beyond those discovered in the daily data review, corrective actions are initiated.

4.3 SEASONAL UPDATE OF QUALITY ASSURANCE (QA) DATABASE (XXXX_C) FILES

The QA database files are site-specific files containing the time-tagged operational history of each site. Specifically, each file includes:

- QA codes entered manually during Level-A validation, that identify periods as invalid

- Precision estimates for nephelometer and meteorological instrumentation

- QA calibration file names

- Rayleigh coefficient

```
NGN_PULL  V1.11:10/07/93  12-02-1993  06:11:47------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------
ACAD 930701 182  000  11   84.52   85.00 -99.00 -99.00   0.059  13.35  13.30  80.70   2850
ACAD 930701 182  100  11   79.13   80.00 -99.00 -99.00   0.055  13.20  13.10  81.80   2795
ACAD 930701 182  200  11   69.22   70.00 -99.00 -99.00   0.047  13.41  13.30  81.00   2815

                                     Column Number
         1         2         3         4         5         6         7         8         9
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Columns	Description
1-3	Site Abbreviation (four characters)
6-7	Year
8-9	Month
10-11	Day
13-15	Julian Date
17-18	Hour
19-20	Minute
22	Power Code (Space = No Power Failure)
23	Nephelometer Status Code (1-9)
24	Nephelometer Data Type Code (0 = Serial 1 = Analog 2 = DCP)
26-32	Nephelometer Serial Calculated Normalized Reading (Counts)
34-40	Nephelometer Analog Reading (1 mVDC = 1 Count)
42-47	Not Used
49-54	Not Used
56-62	Preliminary b_{scat} (km^{-1})
64-69	Nephelometer Chamber Temperature (°C)
71-76	Ambient Temperature (°C)
78-83	Relative Humidity (%)
85-90	Nephelometer Direct Light Intensity (Counts)

Figure 4-5. Level-A Validated Nephelometer Data File Format.

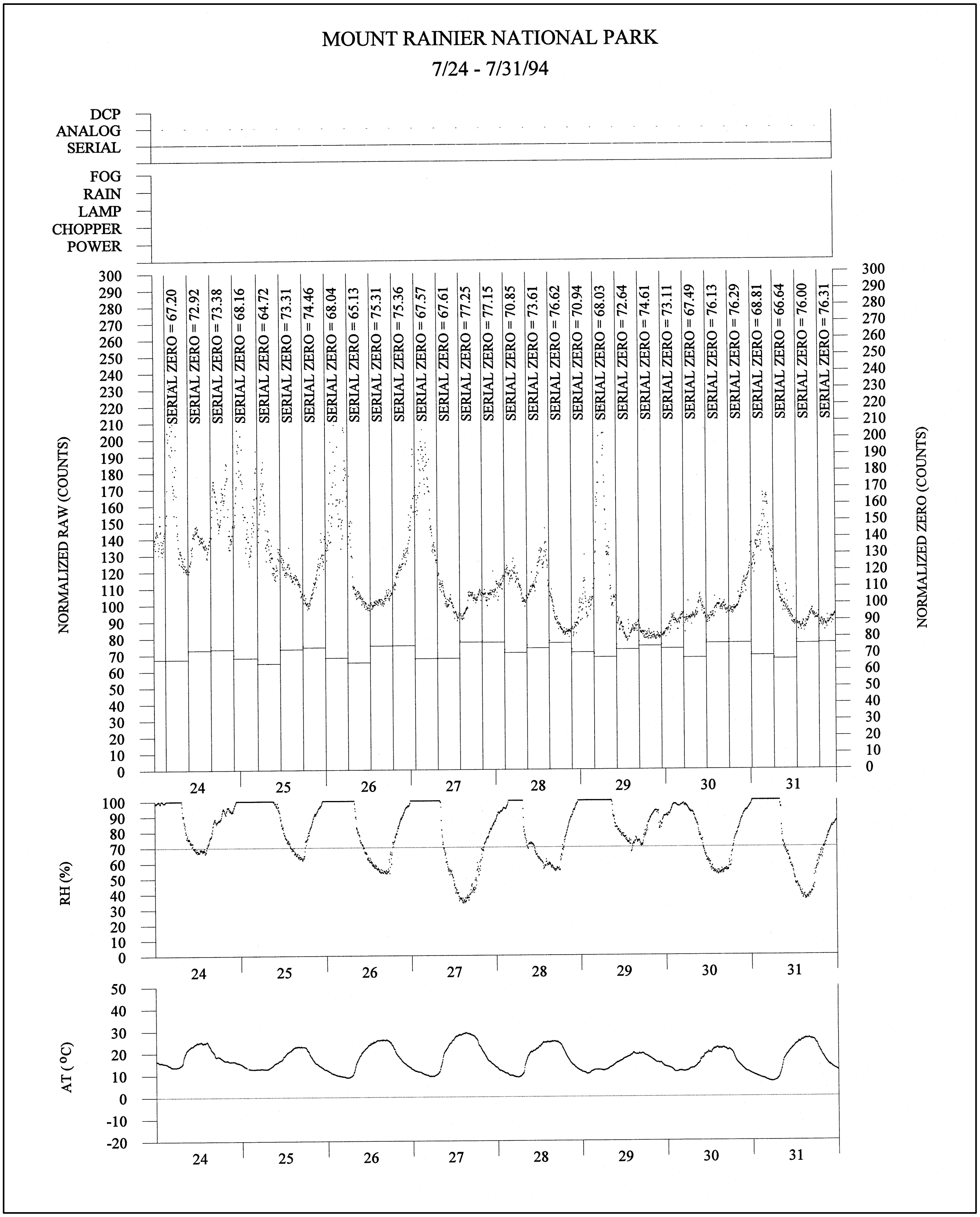


Figure 4-6. Example Weekly Plot of Level-A Validated Nephelometer and Meteorological Data.

Editing the QA database files is the only method of manually invalidating data. Seasonal updating of the QA database files includes:

- Filing log sheets
- Entering Level-A plot review information in the QA database files
- Editing the Rayleigh coefficient

Hardcopy log sheets are chronologically filed by site. Periods identified in the review of Level-A data as invalid are recorded in the site-specific QA database files, XXXX_C (where XXXX is the site code). The following codes are used in the site-specific QA database file:

1: Valid
x: Invalid (x = any other character)

Figure 4-7 shows an example QA Database Code file.

4.4 SEASONAL UPDATE OF QUALITY ASSURANCE (QA) CALIBRATION FILES

The QA calibration files are nephelometer-specific files containing all zero and span calibrations performed on a nephelometer during a specific time period, including the initial zero and span performed during installation. The calibration information in the QA calibration files are used during data reduction to calculate the scattering coefficient based on the nephelometer raw data and to estimate the precision of that data. The files also include parameters used by software to help identify invalid calibrations.

The QA calibration file names are defined in the site-specific QA database files. A new QA calibration file must be defined for the following reasons:

- New nephelometer installed at the site
- Significant change in the operation of the nephelometer as indicated by the raw data

There may be several QA calibration files defined each site-specific QA database file. This usually indicates that the nephelometer (or another nephelometer) has been installed more than once.

The seasonal update of QA calibration files includes the following:

- Update of QA file header information
- Generation of preliminary QA calibration plots and uncertainty estimates
- Review and manual validation of QA file entries
- Generation of final QA calibration plots and uncertainty estimates

```
Boundary Waters Canoe Area
Nephelometer Calibration File
01/13/94



-----------------------------------------------------------------------------------------------
YR   JD  TIME  LAMP NCODE N-PR CCODE CT-PR ACODE AT-PR RCODE RH-PR QA File  Comment

-----------------------------------------------------------------------------------------------
93, 124,  1630, 1,   1,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA,
93, 229,  0845, 1,   1,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA, new Blue Earth
93, 236,  0750, 2,   1,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA, lamp change
93, 250,  0800, 2,   X,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA, Surge: new modem.
93, 320,  1140, 3,   1,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA, lamp change
93, 327,  0930, 3,   1,   0.20, 1,    1.0,   1,    1.0,   1,    2.0,021_2.QA, new light trap
```

Field	Description
YR	Year
JD	Julian Date
TIME	Time (HHMM)
LAMP	Lamp number
NCODE	Nephelometer validity code (1 = Valid, Other = Invalid)
N-PR	Nephelometer factory-defined precision (%, 0.20 = 20%)
CCODE	Chamber temperature validity code (1 = Valid, Other = Invalid)
CT-PR	Chamber temperature factory-defined precision (°C)
ACODE	Ambient temperature validity code (1 = Valid, Other = Invalid)
AT-PR	Ambient temperature factory-defined precision (°C)
RCODE	Relative humidity validity code (1 = Valid, Other = Invalid)
RH-PR	Relative humidity factory-defined precision (%)
QA FILE	Name of the QA calibration file in use
COMMENT	Comment - No commas allowed

Figure 4-7. Example Nephelometer QA Database File.

4.4.1 Update of QA Calibration File Header Information

Each QA file header must be updated manually to include correct information for the parameters detailed in Figure 4-4, including:

- Site, instrument number
- Initial zero and span calibration
- Zero calibration validation parameters

The QA file header can be edited using the NGN_SEAS software (described below) or using any ASCII text editor.

4.4.2 Generation of Preliminary QA Calibration Plots and Uncertainty Estimates

The data coordinator uses the NGN_QA software to generate preliminary QA calibration plots showing nephelometer zero and span calibrations recorded in the instrument-specific QA calibration files and an estimate of the precision of the nephelometer data based on those calibrations. The following procedures describe the operation of the NGN_QA software:

EXECUTE NGN_QA SOFTWARE	Execute the NGN_QA software from the Windows Program Manager. The NGN_QA display will appear as shown in Figure 4-8.
CHOOSE THE QA FILES TO PLOT	Highlight (click on) the QA files to plot. The QA calibrations will be plotted with at most one year of information per plot. The associated estimate of precision will be printed following the plot(s).
GENERATE THE PLOTS	The highlighted plots can be plotted to the screen or printer attached to the system. An example plot is shown in Figure 4-9 and an example uncertainty analyses is shown in Figure 4-10. The following procedures are used to generate the plots: • Choose the plot destination by clicking **Plot** and then **Screen** or **Printer**. • Generate the plots defined in the submit file by clicking **Plot** and then **GO!**

The NGN_QA software does not change the QA file in any way - it simply identifies which calibrations will be identified as invalid during Level-0 and Level-1 data validation.

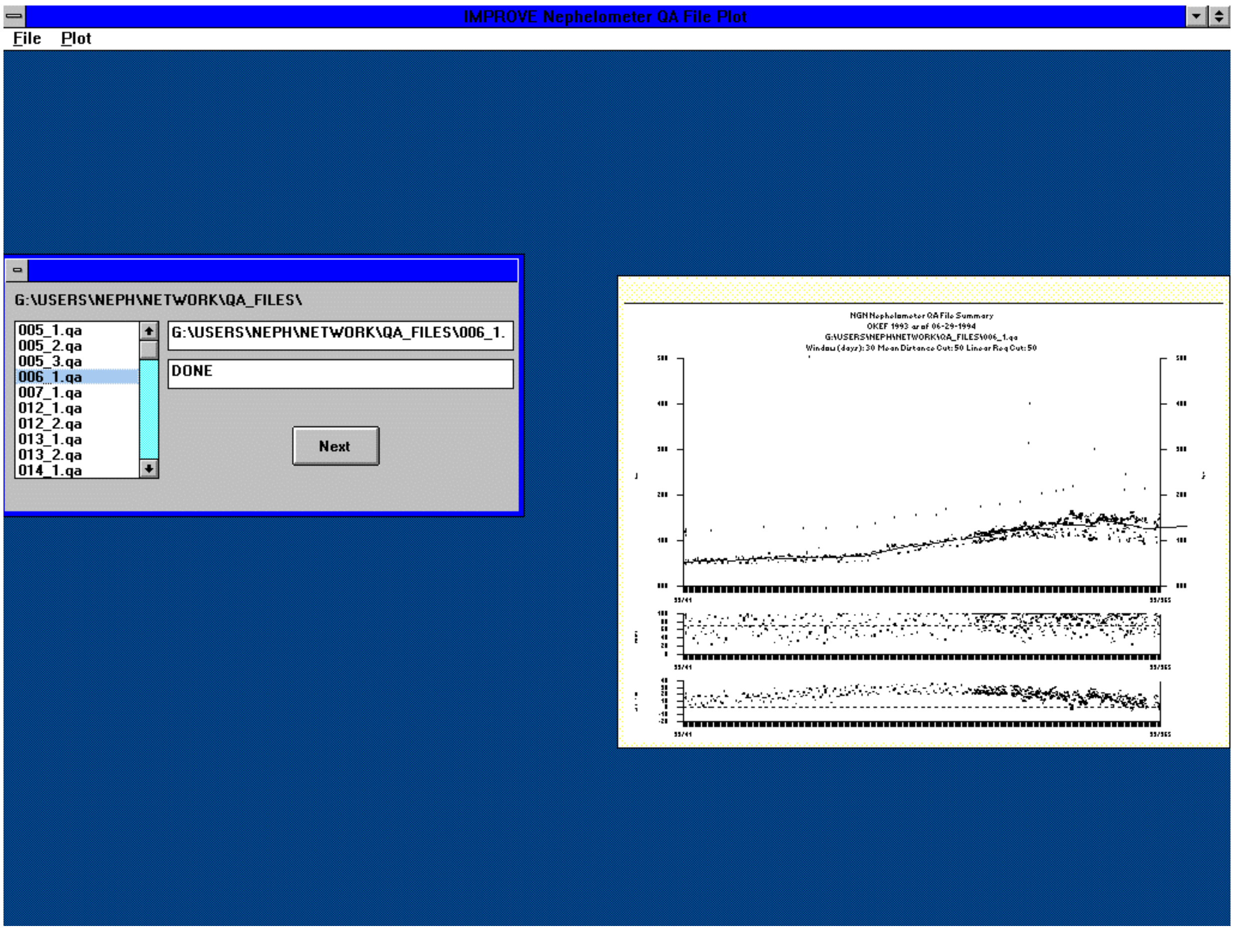


Figure 4-8. NGN_QA Software Display.

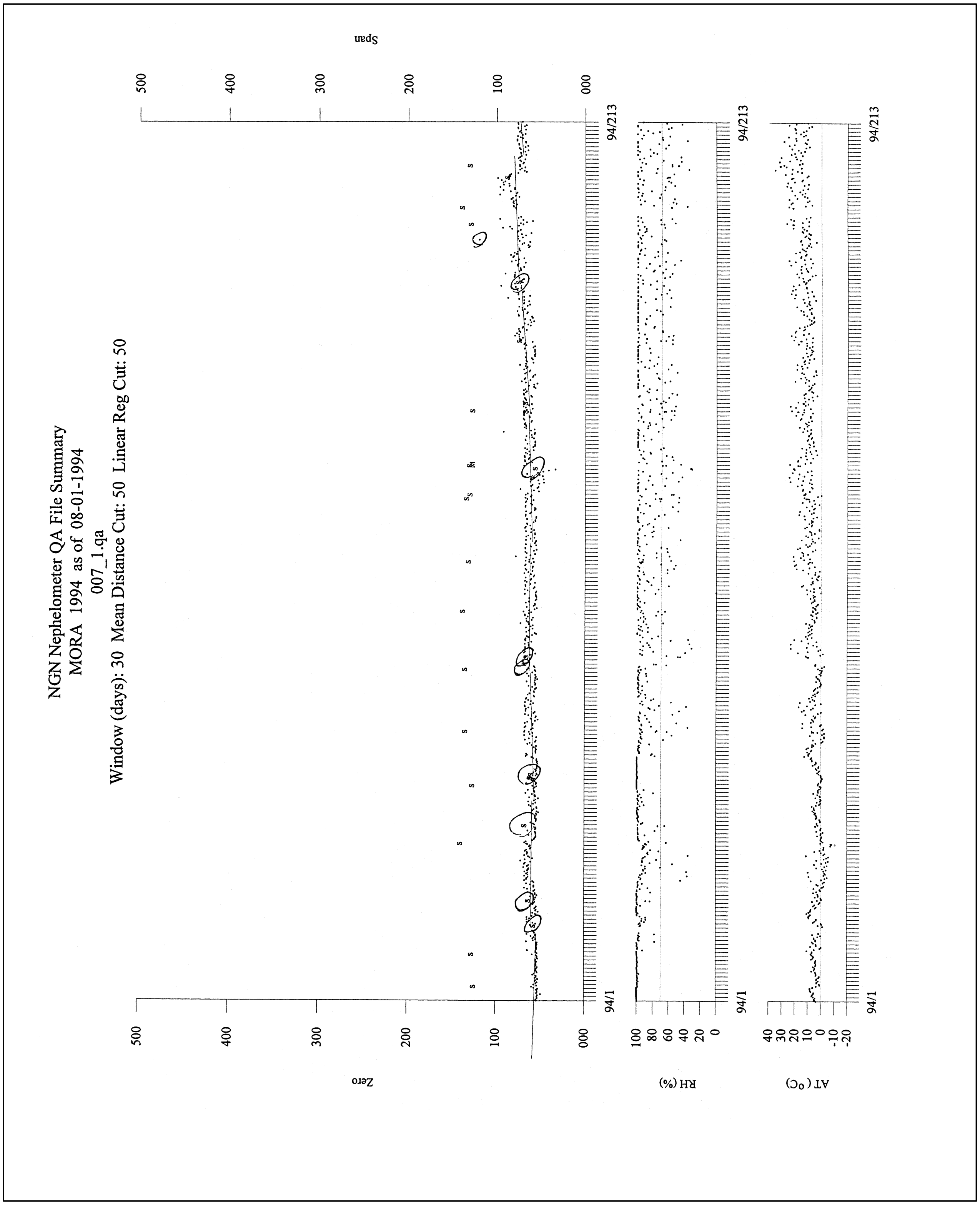


Figure 4-9. Example QA Calibration File Plot.

```
Nephelometer QA File Uncertainty Analysis - 07-31-1994
FILE: 007_1.qa

QA file header contents:
---------------------------------------------------------
MORA
NGN-2-07
Number 1
55.0
117.0
30,50,20
-----------
-----------
07-31-1994 05:34:57
YR  JD HHMM ZERO    SPAN    AT     CT     RH     C   COMMENT
---------------------------------------------------------

---------------------------------------------------------
Rayleigh (1/km)  (b,spo):  .01
Span (1/km) (b,spf):      0.071000
Initial Slope (m):        0.000984
---------------------------------------------------------

The following calibration checks were made:
YR/MM/DD  JD ZERO     SPAN     DIFF     SLOPE m(t)
---------------------------------------------------
93/02/08 039 0055.180 0117.550 0062.370 0000.000978
93/02/10 041 0051.130 0112.430 0061.300 0000.000995
93/02/10 041 0055.280 0116.880 0061.600 0000.000990
93/02/10 041 0055.310 0118.630 0063.320 0000.000963
93/02/11 042 0055.510 0119.540 0064.030 0000.000953
93/02/11 042 0053.950 0119.560 0065.610 0000.000930
93/02/11 042 0055.500 0114.350 0058.850 0000.001037
93/03/09 068 0057.820 0121.440 0063.620 0000.000959
93/04/06 096 0057.040 0123.600 0066.560 0000.000916
93/05/05 125 0060.240 0118.210 0057.970 0000.001052
93/05/19 139 0059.510 0110.430 0050.920 0000.001198
93/06/02 153 0060.710 0124.690 0063.980 0000.000953
etc.....
---------------------------------------------------------
Mean Span-Zero Difference:      62.965
Std. Dev. Span-Zero Difference: 6.001
---------------------------------------------------------

Mean of the slopes:      0.000978
Std. Dev. of the slopes: 0.000097
Number of samples:        42
Degrees of freedom:       41
T value:                  2.021
Uncertainty: 0.2002  (20.0217%)
```

Figure 4-10. Example Uncertainty Analysis.

4.4.3 Review and Manual Validation of QA File Entries

The data coordinator reviews the preliminary QA calibration plots to identify invalid zero and span calibrations caused by incorrect nephelometer operation. The NGN_QA software generates plots showing the following:

- Zero calibrations that pass all software validation tests [**.**]
- Span calibrations coded as valid [**s**]
- Zero calibrations that fail at least one software validation test [**m**, **r**, >, <] (see below)
- Manually invalidated zero or span calibrations [**I**]
- Ambient temperature and relative humidity [**.**]

Zero calibrations are identified by the NGN_QA software as invalid (code r, m, >, <) for the following reasons:

- Mean Test (**m**) — In a given window of time (usually 30 days), the zero calibration exceeds the mean of all valid zeros in the window by a defined number of counts (usually 50).
- Linear Regression (**r**) — In a given window of time (usually 30 days) the zero calibration exceeds the linear b_{ext} fit value through the valid zeros in the Test window by a defined number of counts (usually 50).
- Absolute Minimum (<) or Maximum (>) — The zero calibration raw counts are less than the defined absolute minimum (usually 0) or greater than the defined absolute maximum (usually 500).

The window size, mean threshold, linear regression threshold, minimum, and maximum are defined in each QA file as is detailed in Figure 4-4.

Invalid calibrations *not identified by the software* must be invalidated manually by the data coordinator. The NGN_SEAS software or any ASCII text editor can be used to edit the QA files. The following codes are used in the QA calibration file:

1	:	Valid serial zero or span
A	:	Valid analog zero or span
I:	:	Invalid zero or span

Any code other than 1 is considered invalid by the NGN_SEAS software during Level-0 and Level-1 data reduction. Analog calibrations are recorded in the QA calibration files for backup purposes only - they are not used for data reduction. If serial data logging fails, analog calibrations can be coded with a 1 and used in place of serial data.

4.4.4 Generation of Final QA Calibration Plots and Uncertainty Estimates

The data coordinator generates final QA calibration plots after validating the zero and span calibrations based on the preliminary plots. Any invalid calibrations shown on the final plots as valid must be edited manually as described above. Uncertainty estimates generated during QA calibration plot review are entered manually in the QA database files by the data coordinator. The uncertainty estimates appear in the Level-1 data file for reference.

4.5 SEASONAL LEVEL-0 VALIDATION OF NEPHELOMETER AND METEOROLOGICAL DATA

Level-0 validation of nephelometer and meteorological data is performed seasonally and serves as an intermediate data reduction step. Level-0 data validation includes:

- Review of Level-A data
- Updating the NPROCESS.CON constants file
- Level-0 validation processing procedures

4.5.1 Review of Level-A Data

The data coordinator and project manager further review the Level-A nephelometer data and plots to identify periods of invalid nephelometer data caused by the following:

- Burned out lamp
- Power failures
- Water contamination
- Other problems

Level-A meteorological data are also reviewed to identify invalid periods caused by sensor failures.

4.5.2 Updating the NPROCESS.CON Constants File

The nephelometer data validation constants file (NPROCESS.CON) contains the following information:

Level-0 Validation Constants
Raw nephelometer underrange and overrange
Raw nephelometer rate-of-change
Ambient temperature underrange and overrange
Relative humidity underrange and overrange

Level-1 Validation Constants
Nephelometer raw std. dev. / mean filter
Nephelometer b_{scat} rate-of-change filter
Nephelometer b_{scat} RH filter
Nephelometer b_{scat} maximum filter

The NPROCESS.CON file must be updated as described in the following section with the correct data validation constants before Level-0 and Level-1 data validation can proceed. Figure 4-11 is an example nephelometer constants (NPROCESS.CON) file.

4.5.3 Level-0 Validation Processing Procedures

Level-0 validated nephelometer data are generated from Level-A data by the NGN_SEAS software using the following validation criteria:

- Nephelometer data with a Level-A nephelometer status code not equal to 1 are invalid at Level-0.
- Meteorological data with parameter values of -99 are invalid at Level-0.
- Nephelometer and meteorological data identified as invalid in the site-specific QA database files are considered invalid at Level-0.
- Out of range data and data whose rate of change between 5-minute values exceeds the specified criteria specified in the nephelometer constants (NPROCESS.CON) file is invalid at Level-0. Table 4-1 lists the range and rate-of-change criteria for IMPROVE nephelometer and meteorological data.

Table 4-1

Nephelometer and Meteorological Level-0 Validation Range Criteria

Parameter	Underrange	Overrange	Rate of Change
Nephelometer Raw Reading (counts)	0	9999	200
Ambient Temperature (°C)	-50	70	10
Relative Humidity (%)	0	100	25
Nephelometer Chamber Temperature (°C)	-50	50	10

Nephelometer data can be of any type (serial, analog, or DCP) to be valid at Level-0 validation. The Level-0 data file format and validity code summary is shown in Figure 4-12.

The following are the Level-0 data validation procedures:

EXECUTE NGN_SEAS SOFTWARE	Execute the NGN_SEAS software from the Windows Program Manager. The NGN_SEAS display will appear as shown in Figure 4-13.

```
NPROCESS.CON
Optec NGN-2 Nephelometer Data Processing Constants File
Last Updated: 4/22/94 (TRPA sites)

Last Update by: Scott
------------------------------------------------------------------------------------------------------------
     |   Min   |   Max   | Delta  |SD/MEAN|Delta |Max    |  RH  |   AT (C)      |     RH (%)   |   CT (C)     |
     |   raw   |   raw   |  raw   | bscat |bscat |bscat  | bscat| Range Limits  | Range Limits | Range Limits |
Site | (counts)| (counts)|(counts)|  (%)  |(1/km)|(1/km)|  (%) | Min Max  Delta| Min Max Delta| Min Max Delta|
------------------------------------------------------------------------------------------------------------
ACAD,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
BOWA,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
CORG,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -30, 70,   5,   1,  105,   5,  -50, 50,   5
DOSO,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
EBFO,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
GRSM,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
JARB,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
LOPE,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
LYBR,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
MACA,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
MORA,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
MOZI,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -30, 50,   5,   1,  105,   5,  -50, 50,   5
OKEF,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
SNPA,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -30, 50,   5,   1,  105,   5,  -50, 50,   5
THSI,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
UPBU,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
ARE,     0,      5000.0,    200,      10,  0.05,     5.0,   95,  -50, 50,  10,   1,  105,  25,  -99,-99, -99
CTH,     0,      5000.0,    200,      10,  0.05,     5.0,   95,  -50, 50,  10,   1,  105,  25,  -99,-99, -99
QAK,     0,      5000.0,    200,      10,  0.05,     5.0,   95,  -50, 50,  10,   1,  105,  25,  -99,-99, -99
SIK,     0,      5000.0,    200,      10,  0.05,     5.0,   95,  -50, 50,  10,   1,  105,  25,  -99,-99, -99
AFTC,    0,      9999.0,    100,      10,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
DALA,    0,      9999.0,    100,      10,  0.05,     5.0,   95,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
LTBV, -500,      9999.0,    300,      25,  0.10,     5.0,  -99,  -30, 40,   5,   1,  105,   5,  -30, 40,   5
BLIS, -500,      9999.0,    300,      25,  0.10,     5.0,  -99,  -30, 40,   5,   1,  105,   5,  -30, 40,   5
T13T,    0,      9999.0,    100,      10,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
T24T,    0,      9999.0,    100,      10,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
T38T,    0,      9999.0,    100,      10,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
TBEL, -500,      9999.0,    100,      50,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
RAYR, -500,      9999.0,    100,      10,  0.05,     5.0,  -99,  -50, 50,   5,   1,  105,   5,  -50, 50,   5
```

Figure 4-11. Nephelometer Constants (NPROCESS.CON) File.

```
NGN_PULL  V1.11:10/07/93  12-02-1993  06:11:47------------------
LEVEL-0: NGN_SEAS 1.0A 12/03/93 12-14-1993 16:56:34-------------
----------------------------------------------------------------
----------------------------------------------------------------
----------------------------------------------------------------
----------------------------------------------------------------
---------------------------------------------------------------
----------------------------------------------------------------
----------------------------------------------------------------
----------------------------------------------------------------
ACAD 930701 182 0000   85.00  1111   0.00 X1  13.30 11  80.70 11
ACAD 930701 182 0100   80.00  1111   0.00 X1  13.10 11  81.80 11
ACAD 930701 182 0200   70.00  1111   0.00 X1  13.30 11  81.00 11

                 Column Number
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234
```

Columns	Description
1-3	Site Abbreviation
6-7	Year
8-9	Month
10-11	Day
13-15	Julian Date
17-18	Hour
19-20	Minute
21-28	Raw Nephelometer Scattering Data (Counts)
31-34	Level-0 Nephelometer Validity Codes:
30	Power (Space = No Power Failure)
31	Nephelometer Status Code from Level-A (1-9)
32	Data Type (0 = Serial 1 = Analog 2 = DCP)
33	Validity Code from QA Database (1 = Valid, Any other = Invalid)
34	Level-0 Range Check Code (1 = Valid, Any other = Invalid)
35-41	Chamber Temperature (°C)
43-44	Chamber Temperature Validity Codes:
43	Validity Code from QA Database (1 = Valid, Any other = Invalid)
44	Level-0 Range Check Code (1 = Valid, Any other = Invalid))
45-51	Ambient Temperature (°C)
53-54	Ambient Temperature Validity Codes:
53	Validity Code from QA Database (1 = Valid, Any other = Invalid)
54	Level-0 Range Check Code (1 = Valid, Any other = Invalid))
55-61	Relative Humidity (%)
63-64	Relative Humidity Validity Codes:
63	Validity Code from QA Database (1 = Valid, Any other = Invalid)
64	Level-0 Range Check Code (1 = Valid, Any other = Invalid)

Note: The first ten lines are for data reduction information.

Figure 4-12. Level-0 Validated Nephelometer Data File Format.

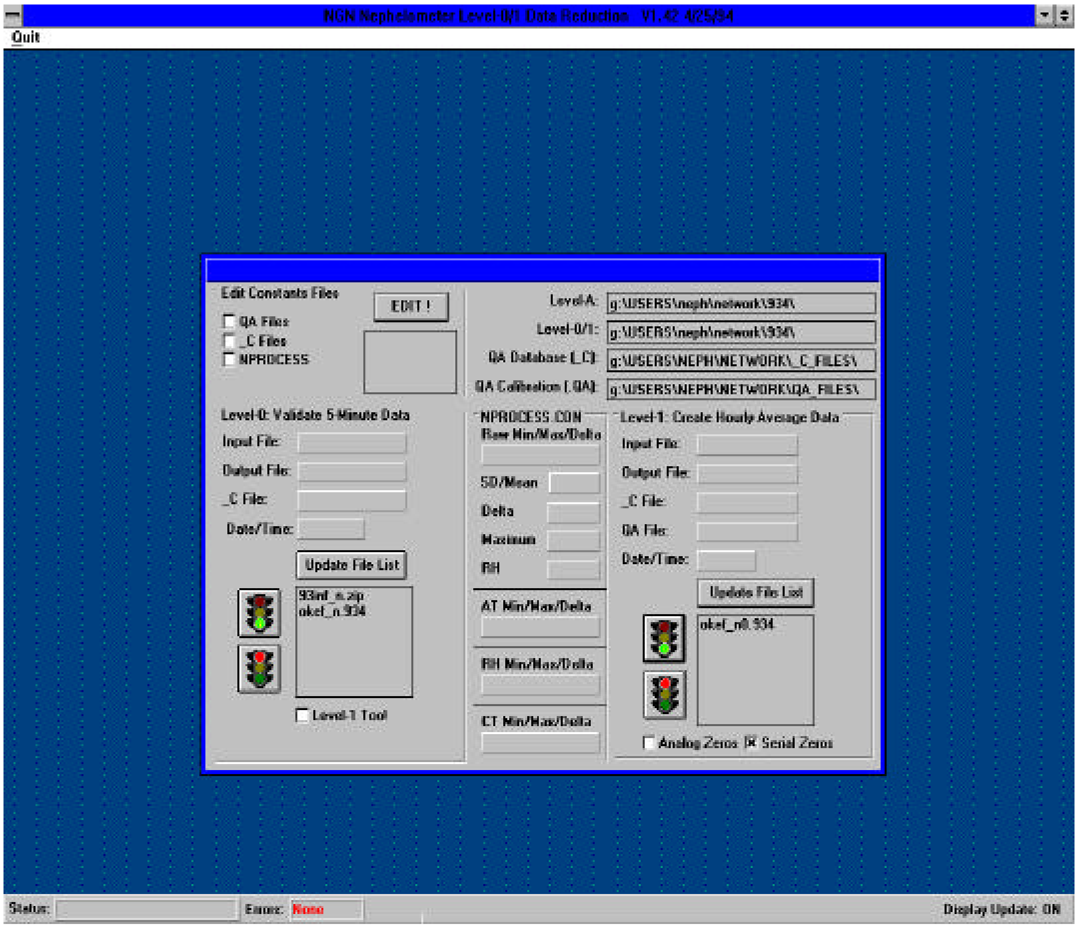


Figure 4-13. NGN_SEAS Software Display.

SET DATA DIRECTORIES

The directories for all files used by NGN_SEAS are shown on the NGN_SEAS display. Set the Level-A directory to the location where the Level-A data files exist by clicking the Level-A directory box. A dialog box will appear which allows the user to change the directory. Set the correct directory for the Level-0/1, QA database, and QA calibration code files the same way.

CHECK QA DATABASE CODE (XXXX_C) FILES

Verify that the QA database code (XXXX_C) files have been updated correctly as follows:

- Click the **_C Files** box in the **Edit Constants Files** frame.
- Highlight the file to edit in the **File to Edit** box.
- Click the **EDIT!** button to load the file into the Windows Notepad editor.
- Verify that the file is correct. Save any changes and exit Notepad.
- Check all the files that will be required for Level-0 validation.

CHECK QA CALIBRATION (XXX_N.QA) FILES

Verify that the QA calibration (XXX_N.QA) files have been updated correctly as follows:

- Click the **QA Files** box in the **Edit Constants Files** frame.
- Highlight the file to edit in the **File to Edit** box.
- Click the **EDIT!** button to load the file into the Windows Notepad editor.

  The following validity codes are used to manually edit the QA calibration files:

  1: Valid Serial Calibration
  I: Invalid
  A: Valid Analog Calibration

- Verify that the file is correct. Save any changes and exit Notepad.
- Check all the files that will be required for Level-1 validation.

CHECK CONSTANTS (NPROCESS.CON) FILE

Verify the Level-0 and Level-1 data validation constants in the are correct as follows:

- Click the **NPROCESS.CON** box in the **Edit Constants Files** frame.
- Highlight the file to edit in the **File to Edit** box.

- Click the **EDIT!** button to load the file into the Windows Notepad editor.

  Edit the constants as required in the NPROCESS.CON file.

- Verify that the file is correct. Save any changes and exit Notepad.

- Check all the files that will be required for Level-1 validation.

START LEVEL-0 VALIDATION

Start the Level-0 validation processing as follows:

- Click the **Update** button to update the list of available Level-A validated files to process.

- Highlight the Level-A validated file(s) to process.

- Click the **GREEN LIGHT** icon to start the Level-0 validation process.

- Click the **RED LIGHT** icon to stop any processing in progress.

- Each highlighted level-A file will be processed in order. The Level-0 validated data will be output to the file shown in the **Output File** box.

- The **Status** box will show the current processing status. When all the highlighted files have been processed the status box will show **DONE**.

The input, output, QA database, and QA calibration file names being used for processing are updated on the NGN_SEAS display. The file naming conventions are detailed in Table 4-2.

CHECK ERRORS

Any errors encountered by NGN_SEAS during data validation are recorded in the file NGN_SEAS.ERR. The number of errors will be displayed at the bottom of the NGN_SEAS display.

To check the errors click on the **Errors** at the bottom of the display. The Notepad program will be invoked to view the error file. Correct any errors by updating the following files:

- QA database files

- QA calibration files

- Nephelometer constants (NPROCESS.CON) file

Table 4-2

Nephelometer and Meteorological Data File Naming Conventions

Validation Level	File Naming Convention	Example
Daily Raw	SSSSYYDX.JJJ, where SSSS = site code YY = year X = A,1,2....9 JJJ = Julian date	ACAD93DA.321 Acadia daily raw file for Julian date 321 of 1993.
Seasonal Site-Specific Level-A	SSSS_N.YYN, where SSSS = site code YY = year N = season	ACAD_N.933 Acadia Level-A Summer season 1993
Seasonal Site-Specific Level-0	SSSS_N0.YYN, where SSSS = site code YY = year N = season	ACAD_N0.933 Acadia Level-0 Summer season 1993
Seasonal Site-Specific Level-1	SSSS_N1P.YYN, where SSSS = site code P = averaging period (hours) YY = year N = season	ACAD_N11.933 Acadia Level-1 hourly average Summer season 1993

4.6 SEASONAL LEVEL-1 VALIDATION OF NEPHELOMETER AND METEOROLOGICAL DATA

Level-1 validation of nephelometer and meteorological data is performed seasonally following Level-0 validation. Level-1 validation of nephelometer and meteorological data is handled by the NGN_SEAS software. NGN_SEAS handles the following tasks:

- Computation of hourly averages from Level-0 data
- Automatic validation of QA calibration file entries
- Conversion of hourly average data to engineering units
- Overrange/underrange checks
- Identification of nephelometer b_{scat} data affected by meteorological interference
- Estimation of precision

Level-1 is typically the final validation level for IMPROVE nephelometer data. The following subsections detail the Level-1 validation of nephelometer and meteorological data in the order NGN_SEAS performs the above listed operations:

- Level-1 validation processing procedures
- Level-1 seasonal summary plots
- Review of Level-1 seasonal summary plots

4.6.1 <u>Computation of Hourly Averages from Level-0 Data</u>

Level-1 hourly averages are computed from Level-0 validated data for nephelometer and meteorological parameters. The data in an hourly average period includes the data following the hour. For example, the hourly average for 11:00 includes data from 11:00 through 11:59.

4.6.2 <u>Automatic Validation of QA Calibration File Entries</u>

The zero calibration information in the QA calibration files is used to calculate a calibration line for each nephelometer data point. Validation of QA zeros is detailed in Section 4.4.

4.6.3 <u>Conversion of Hourly Average Data to Engineering Units</u>

- Meteorological data (ambient and chamber temperatures and relative humidity) are already in engineering units.
- The nephelometer scattering coefficient (b_{scat}) of total extinction (b_{ext}) is calculated by determining a calibration line for each raw nephelometer scattering data point as follows:

- The ***Zero*** is determined by interpolating (in time) between the valid clean air calibrations prior to, and following the data point.

- The ***Initial Span*** is determined from the initial calibration of the instrument upon installation.

  Initial Span = Initial Upscale Span Gas Calibration - Initial Clean Air Calibration

- The ***Rayleigh*** coefficient is the site-specific altitude-dependent scattering of particle-free air.

- The ***Designated Span*** is determined by the span gas used during the initial calibration, and the Rayleigh coefficient. The span gas SUVA (HFC-134a) (Dupont) has been shown to scatter 7.1 times that of particle-free (Rayleigh) air.

  Designated Span = 7.1 x ***Rayleigh***

- The slope and intercept of the calibration line are:

  Slope = (***Designated Span*** - ***Rayleigh***) / ***Initial Span***
  Intercept = ***Rayleigh*** - (***Slope*** x ***Zero***)

- Nephelometer data and calibrations are in unitless counts. If the units for the Rayleigh coefficient are km^{-1}, the units for b_{scat} will also be km^{-1}. Nephelometer scattering (b_{scat}) is calculated from the calibration line as follows:

  b_{scat} = (***Slope*** x Raw Nephelometer Value) + ***Intercept***

4.6.4 Level-1 Range Checks

The following additional validation checks are performed to complete the Level-1 validation process:

- Data invalid at Level-0 is invalid at Level-1
- Calculated b_{scat} data less than Rayleigh scattering is invalid
- Meteorological data is not validated beyond Level-0

The file format for Level-1 validated data is provided in Figure 4-14.

```
NGN_PULL     V1.91:2/15/94     02-15-1994     14:12:39------------------------------------------------------------------------------------------------------------------------------
LEVEL-0:  NGN_SEAS  1.3  3/2/94  03-02-1994  15:01:19------------------------------------------------------------------------------------------------------------------------------
LEVEL-1:  NGN_SEAS  1.3  3/2/94  03-02-1994  17:43:10------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

SITE YYMMDD  JD HHMM INS  BSCAT  PREC    VA  RAW-M   RAW-SD  #  N/A   SD/M  DEL   MAX     RH 0123456789MPM0T  YINTER   SLOPE     AT  AT-SD  #  AT-PR    CT  CT-SD  #   CT-PR    RH  RH-SD  #   RH-PR N/A
LOPE 931130 334 1900 014  0.057  0.000   XL  122.68  25.49  12 -99.0  10.0  0.10  5.00   -99 0C0000000000000 -0.0450 0.00083  -0.97  0.20  12   1.00   0.22   0.20 12   1.00  88.01   1.18 12   2.00XXXX
LOPE 931130 334 2000 014  0.080  0.000   V   151.25   8.71  12 -99.0  10.0  0.10  5.00   -99 0C0000000000000 -0.0457 0.00083  -1.47  0.11  12   1.00  -0.25   0.10 12   1.00  90.46   0.88 12   2.00XXXX
LOPE 931130 334 2100 014  0.087  0.000   V   160.71   8.58  12 -99.0  10.0  0.10  5.00   -99 0C0000000000000 -0.0465 0.00083  -1.78  0.28  12   1.00  -0.44   0.19 12   1.00  90.71   0.96 12   2.00XXXX
LOPE 931130 334 2200 014  0.072  0.000   XD  143.10  22.18  12 -99.0  10.0  0.10  5.00   -99 0C0000000000000 -0.0472 0.00083  -2.65  0.21  12   1.00  -1.16   0.19 12   1.00  92.16   0.32 12   2.00XXXX
LOPE 931130 334 2300 014  0.070  0.000   XD  142.32  21.74  12 -99.0  10.0  0.10  5.00   -99 0C0000000000000 -0.0479 0.00083  -3.17  0.15  12   1.00  -1.65   0.11 12   1.00  91.63   0.51 12   2.00XXXX

                                                                                                     Column Number

         1         2         3         4         5         6         7         8         9        10        11        12        13        14        15        16        17        18        19        20
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Column	Data
1-4	Site Abbreviation
6-7	Year
8-9	Month
10-11	Day
13-15	Julian Day
17-18	Hour
19-20	Minute
22-24	Nephelometer Serial Number
26-32	b_{scat} (km^{-1})
34-40	b_{scat} Estimated Precision (%/100)
42-43	b_{scat} Validity/Interference Code
45-51	Raw Nephelometer Hourly Average (Counts)
53-59	Standard Deviation of Raw Nephelometer Average (Counts)
61-62	Number of Data Points in Hourly Nephelometer Average
64-68	(Not Used)
70-74	Standard Deviation/Mean Interference Threshold
76-81	b_{scat} Rate of Change Interference Threshold
83-88	Maximum b_{scat} Interference Threshold
90-92	Relative Humidity Interference Threshold
94-108	Composite Nephelometer Code Summary
110-116	Y-intercept of Calibration Line Used to Calculate b_{scat}
118-124	Slope of Calibration Line Used to Calculate b_{scat}
126-131	Average Ambient Temperature (°C)
133-138	Standard Deviation of Hourly AT Average
140-141	Number of Data Points in Hourly AT Average
143-148	Estimated Precision of Ambient Temperature
150-155	Average Nephelometer Chamber Temperature (°C)
157-162	Standard Deviation of Hourly CT Average
164-165	Number of Data Points in Hourly CT Average
167-172	Estimated Precision of Chamber Temperature
174-179	Average Relative Humidity (%)
181-186	Standard Deviation of Hourly RH Average
188-189	Number of Data Points in Hourly RH Average
191-196	Estimated Precision of Relative Humidity
197-200	(Not Used)

b_{scat} Validity/Interference Code (columns 42-43):

V = Valid
I = Invalid
< = b_{scat} less than Rayleigh scattering
XZ = Data point immediately preceded and followed by interference
X? = Interference of type ?

Type (?) of Interference	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
RH > max. threshold	x		x		x		x		x		x		x		x
b_{scat} > max. threshold	x	x			x	x			x	x			x	x	
St. Dev./Mean>threshold				x	x	x						x	x	x	x
b_{scat} rate of change > threshold								x	x	x	x	x	x	x	x

Composite Nephelometer Code Summary (columns 94-108):

Column	Data
94-103	Nephelometer diagnostic code (internal use)
104	Number of missing data points
105	Number of power failure codes
106	Number of manual QA invalidation codes
107	Number of Level-0 invalidated data points
108	Number of times non-serial data were used

Note: The first 10 lines are for data reduction information.

Figure 4-14. Level-1 Validated Nephelometer Data File Format.

4.6.5 Identification of Nephelometer b_{scat} Data Affected by Meteorological Interference

Nephelometer data is filtered to identify periods likely affected by meteorological interference. The following filter criteria (defined in the nephelometer constants file, NPROCESS.CON) are used to identify these periods:

- Rate of Change: If the rate of change between nephelometer hourly b_{scat} data exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} rate-of-change threshold: 0.05 km^{-1}

- Maximum: If the nephelometer b_{scat} data exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} maximum threshold: 5.0 km^{-1}

- Relative Humidity: If the relative humidity corresponding to the nephelometer b_{scat} value exceeds the following threshold, the b_{scat} value is coded as filtered:

  Nephelometer b_{scat} RH threshold: 95%

- σ/μ: If the standard deviation of the hourly raw nephelometer data divided by the mean of the hourly raw nephelometer data exceeds the following threshold, the value is coded as filtered:

  Raw nephelometer σ/μ threshold: 10%

Nephelometer data identified as affected by meteorological interference is still considered valid. An additional validity code is assigned to the hourly average data point in the Level-1 file as shown in Figure 4-14.

4.6.6 Estimation of Precision

The following methods are used to estimate the precision of Level-1 validated data.

- The precision of meteorological data are defined by the factory specified precision for the sensors. These precision are recorded in the site-specific QA database files. Typical precisions of meteorological sensors are detailed in Table 4-3.

Table 4-3

Typical Factory-Defined Precisions of Meteorological Sensors

Sensor	Precision
Rotronics Ambient Temperature	± 0.5 °C
Rotronics Relative Humidity	± 2 %
Optec NGN-2 Nephelometer Chamber Temperature	± 2 °C

- The estimated precision of nephelometer data for a given time period is based on calibrations performed during that time period. The precision estimates for are recorded in the site-specific QA database files and are automatically placed in the Level-1 data files. The relative error (uncertainty) in scattering due to drift of the slope of the calibration line is evaluated based on the instrument specific zero and span checks performed. The following statistical analysis was applied to calculate potential uncertainty:

$V(t)$	=	Normalized nephelometer reading at time t
$V_o(t)$	=	Normalized clean air reading at time t
$V_s(t)$	=	Normalized SUVA 134a reading at time t
$b_{scat,o}$	=	Scattering coefficient for clean air
$b_{scat,s}$	=	Scattering coefficient for SUVA 134a
V_o	=	average normalized clean air reading
V_f	=	average normalized SUVA 134a reading
$b_{scat}(t)$	=	theoretical scattering coefficient at time t
m	=	slope of the calibration line used to calculate the theoretical scattering coefficient $b_{scat}(t)$

$$m = \frac{(b_{scat,s} - b_{scat,o})}{(V_s(t) - V_o(t))}$$

Given a normalized nephelometer reading *V(t)*, the theoretical b_{scat} at time *t* is:

$$b_{scat}(t) = b_{scat,o} + m(V(t) - V_o(t))$$

assuming that $V_o(t)$ and $V(t)$ are known without error.

The slope of the calibration line is not constant as defined above, but changes (drifts) with time. Figure 4-15 illustrates the drift in the clean air and span values with time. Figure 4-16 illustrates how these drifting values cause the slope of the calibration line to drift.

The actual slope of the calibration line at time *t* is:

$$m(t) = (b_{scat,s} - b_{scat,o}) / (V_s(t) - V_o(t))$$

The actual b_{scat} (denoted b'_{scat}), given a nephelometer reading *V(t)*, is:

$$b'_{scat}(t) = b_{scat,o} + m(t)\ (V(t) - Vo(t))$$

The relative error between the theoretical b_{scat} and actual $b¢_{scat}$ is:

$$= ((m - m(t))\ (V(t) - V_o(t))) / (b_{scat,o} + m(V(t) - V_o(t)))$$

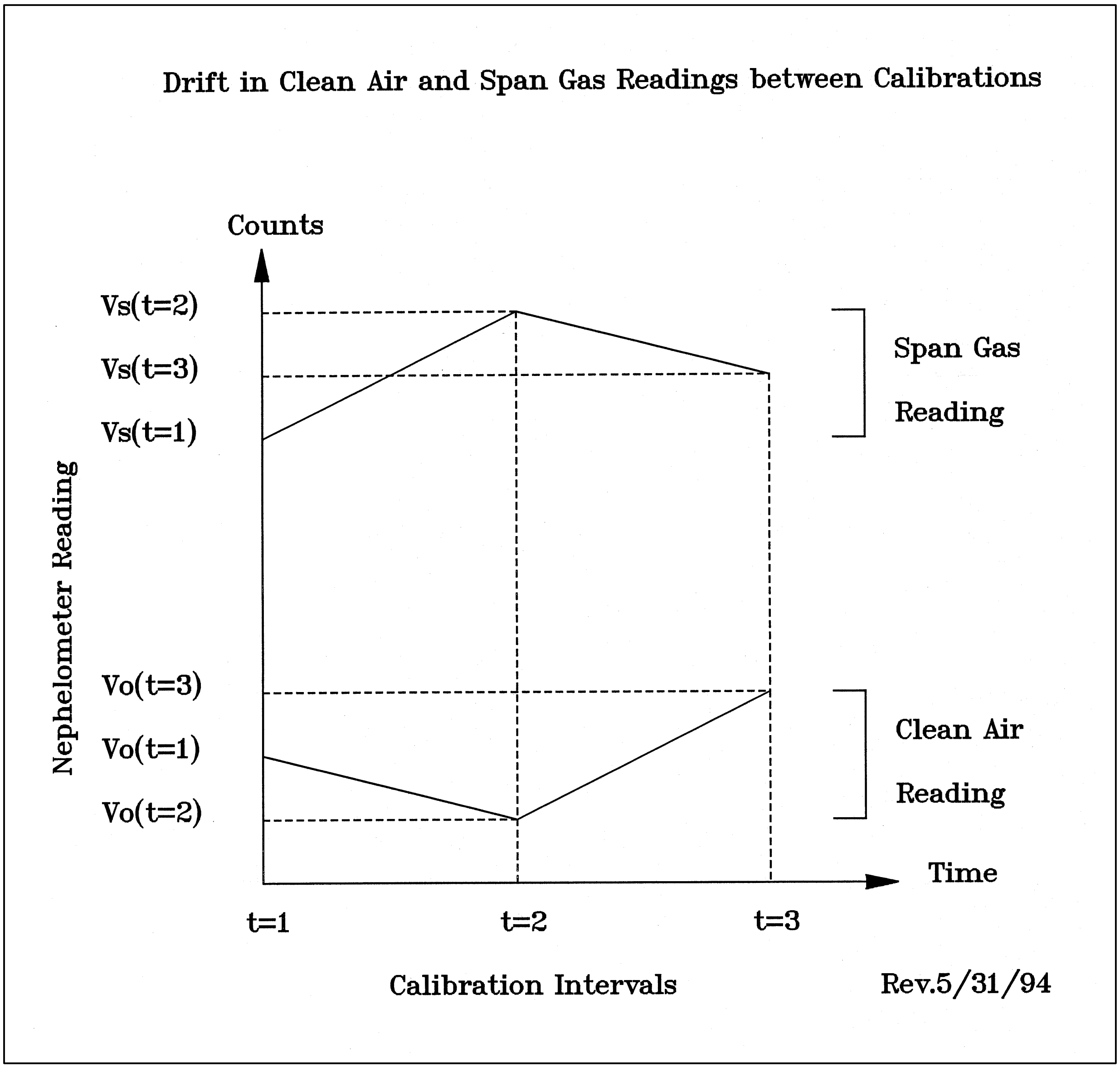


Figure 4-15. Drift in the Clean Air and SUVA 134a Values With Time.

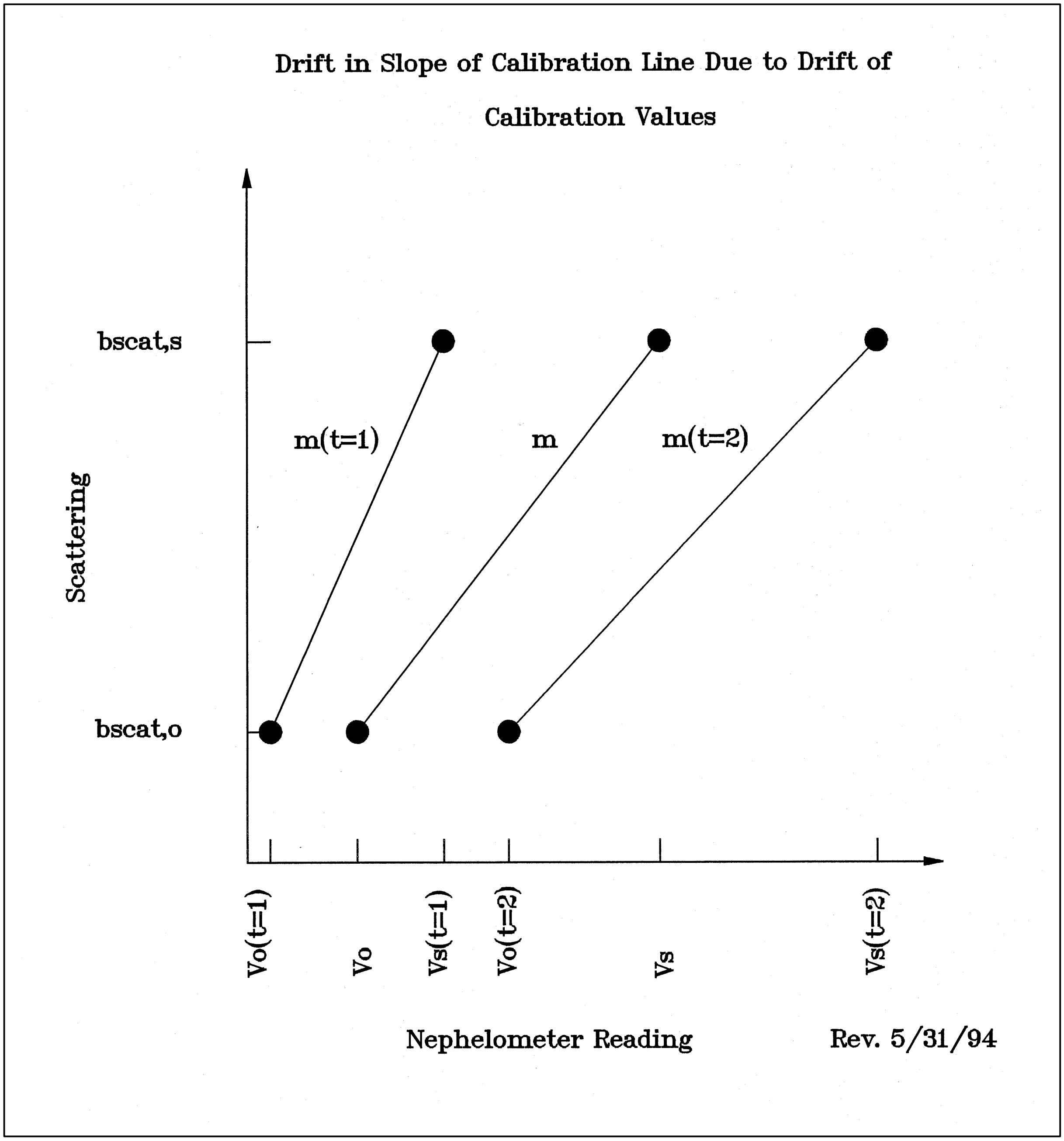


Figure 4-16. Drift in Slope of Calibration Line Due to Drift of Calibration Values.

$$relative \quad error = (b_{scat}(t) - b'_{scat}(t)) \,/\, b_{scat}(t)$$

$$= (m - m(t)) \,/\, (b_{scat,o} \,/\, (V(t) - V_o(t)) \; m$$

$$= \left| (m - m(t)) \,/\, (b_{scat,o} \,/\, (V(t) - Vo(t)) + m) \right|$$

The magnitude of the relative error is:

$$\left| relative \quad error \right| = \left| (b_{scat}(t) - b'_{scat}(t)) \,/\, b_{scat}(t) \right|$$

The magnitude of the relative error is bounded by the slopes such that:

$$\left| relative \quad error \right| \leq \left| (m - m(t)) \,/\, m \right|$$

Assuming that the calculated slopes, *m(t)*, of the calibration lines are normally distributed about the average slope *m* with a standard deviation *s*, then for a probability (confidence level) of 95%:

$$\left| m - m(t) \right| \leq 2s$$

so that

$$\left| (b_{scat}(t) - b'_{scat}(t)) \,/\, b_{scat}(t) \right| \leq \left| 2s \,/\, m \right|$$

Assuming that *s* is estimated by s_m with k degrees of freedom, based on k+1 sample values of *m(t)*, and using the two-tailed *t* distribution, the relative error at a 95% confidence level (which for a two-tailed *t* distribution is read from the 97.5 column of the *t* table) is:

$$\left| relative \quad error \right| \leq t_{k,0.025} \times s_m \,/\, m$$

4.6.7 Level-1 Validation Processing Procedures

Level-1 validation of nephelometer data, detailed above, is handled by the NGN_SEAS software.

Level-1 nephelometer and meteorological data reduction, detailed above, is handled by the NGN_SEAS software. The procedures for validating data to Level-1 are as follows:

EXECUTE NGN_SEAS SOFTWARE	Execute the NGN_SEAS software from the Windows Program Manager. The NGN_SEAS display will appear as shown in Figure 4-13.

CHECK QA DATABASE (XXXX_C) FILES

Verify that the QA database files (XXXX_C) are correct as is described in the Level-0 validation section of this TI.

CHECK QA CALIBRATION (XXX_N.QA) FILES

The QA calibration files are nephelometer-specific files containing the automatic the automatic and manual clean air zero and span calibrations performed on the instrument. The clean air calibrations are used to calculate the calibration line for each nephelometer data point. Invalid calibrations must be coded as invalid in the QA calibration files as described in the Level-0 validation section of this TI.

CHECK NPROCESS FILE

The nephelometer constants (NPROCESS.CON) file contains the data validation constants used for Level-0 and Level-1 validation. Verify the constants in the file as described in the Level-0 validation section of this TI.

START LEVEL-1 VALIDATION

Start the Level-1 validation processing as follows:

- Click the **Update** button to update the list of available Level-0 validated files.
- Highlight the Level-0 validated file(s) to process.
- Click the **GREEN LIGHT** icon to start the Level-1 validation process.
- Click the **RED LIGHT** icon to stop any processing in progress.
- Each highlighted Level-0 file will be processed in order. The Level-1 validated data will be output to the file shown in the **Output File** box.
- The **Status** box will show the current processing status. When all the highlighted files have been processed the status box will show **DONE**.

CHECK ERRORS

Any errors encountered by NGN_SEAS during data validation are recorded in the file NGN_SEAS.ERR. The number of errors will be displayed at the bottom of the NGN_SEAS display.

To check the errors click on the **Errors** at the bottom of the display. The Notepad program will be invoked to view the error file. Correct any errors by updating the following files:

- QA database files
- QA calibration files
- Nephelometer constants file (NPROCESS.CON)

After updating the listed files, start Level-0 and Level-1 validation again.

4.6.8 Level-1 Seasonal Summary Plots

Level-1 validated nephelometer and relative humidity data are summarized in seasonal summary plots. Figure 4-17 shows an example seasonal summary plot. The plots are described in detail below:

4-Hour Average Variation in Visual Air Quality (Filtered Data)
Timeline of 4-hour average scattering data filtered to remove data affected by meteorological interference. The data are plotted as b_{scat} (km^{-1}).

Relative Humidity
Timeline of hourly relative humidity. Note that periods of high scattering are often associated with periods of high relative humidity.

Frequency of Occurrence and Cumulative Frequency Summary
Frequency of occurrence distribution of hourly scattering data, both unfiltered and filtered for meteorological interference. The 10% to 90% values are plotted in 10% increments and are summarized in the table next to the plot. The 50% value represents the median of the valid hourly averages.

Visibility Metric
Visibility statistics for data filtered for meteorological interference, including:

- Mean of the cleanest 20% of valid data
- Mean of all valid data
- Mean of the dirtiest 20% of valid data

Nephelometer Data Recovery
Data collection statistics, including:

- Total number of hourly averages possible in the period
- Number of valid hourly averages including filtered and unfiltered data
- Number of valid hourly averages including filtered data only
- Filtered data as percent of unfiltered and filtered data

Seasonal summary plots are generated using the NGN_NSUM software. The following procedures describe the operation of the NGN_NSUM software:

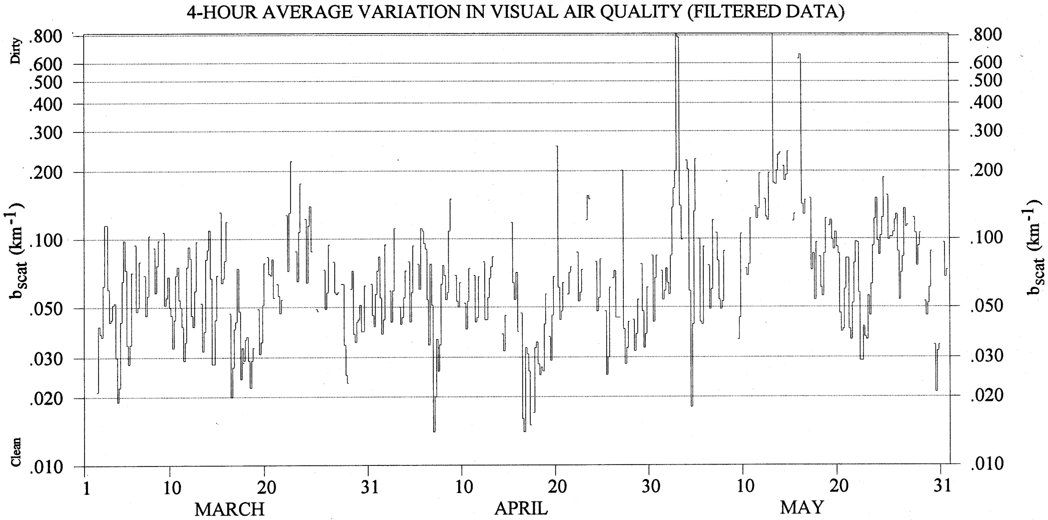
EXECUTE NGN_NSUM SOFTWARE — Execute the NGN_NSUM software from the Windows Program Manager. The NGN_NSUM display will appear as shown in Figure 4-18.

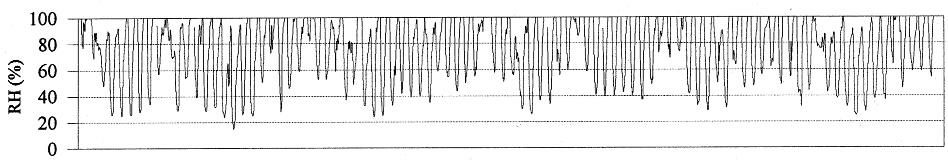
EDIT THE SUBMIT FILE — The submit file defines the Level-1 validated data files and associated parameters used to generate the plots. Figure 4-19 details the format of the submit file. The following procedures are used to edit the submit file:

- Click on **File**. Click on **Edit Submit File**. The Windows Notepad program will be launched.
- Open an existing submit file or create a new one in Notepad.
- Save the submit file and exit Notepad.

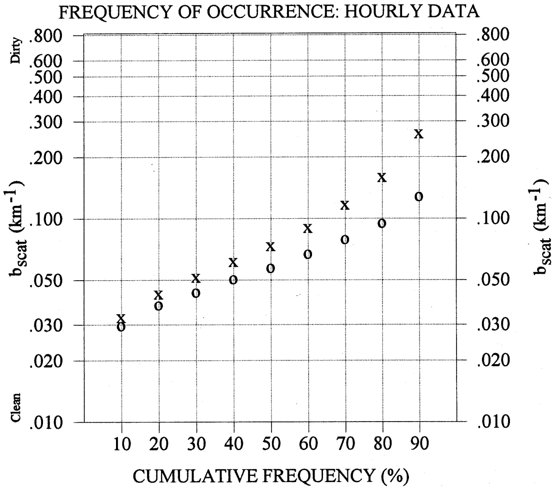
OKEFENOKEE NATIONAL WILDLIFE REFUGE, GEORGIA
IMPROVE Nephelometer Data Summary
Spring Season: March 1, 1994 - May 31, 1994

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





FREQUENCY OF OCCURRENCE: HOURLY DATA



CUMULATIVE FREQUENCY SUMMARY

%	Unfiltered Data [x] b_{scat}	Filtered Data [o] b_{scat}
10	0.033	0.030
20	0.043	0.038
30	0.052	0.044
40	0.062	0.051
50	0.074	0.058
60	0.091	0.068
70	0.118	0.080
80	0.161	0.096
90	0.264	0.130

VISIBILITY METRIC (FILTERED DATA)

	b_{scat}
Mean of cleanest 20%	0.029
Mean of all data	0.075
Mean of dirtiest 20%	0.162

NEPHELOMETER DATA RECOVERY	NUM	%
Total Possible Hourly Averages In The Time Period	2208	100
Valid Hourly Averages (Filtered and Unfiltered)	2108	95
Valid Hourly Averages (Filtered)	1461	66
Filtered Data Percent Of Filtered and Unfiltered Hourly Averages		69

N11:08/21/94 11:16 a P:08/24/94[-99] V1.44:8/18/94

Figure 4-17. Example Level-1 Seasonal Summary Plot.

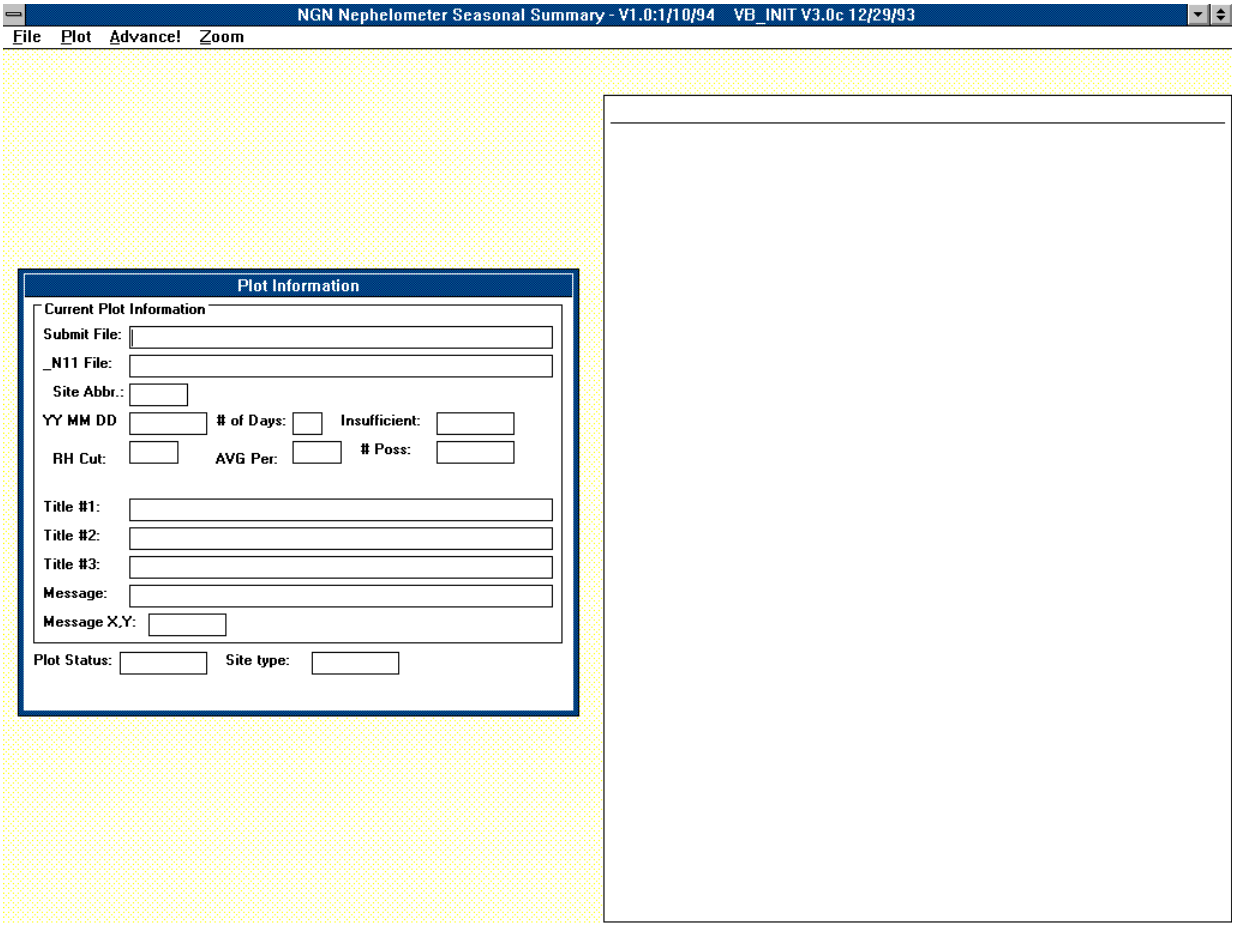


Figure 4-18. NGN_NSUM Software Display.

```
ACAD_N11.933                              Level-1 validated file name
ACAD                                      Site abbreviation
93,7,1                                    Year, month, and day of start of plot
92                                        Number of days to read from file
0                                         Number possible hours, 0=ALL
1                                         Plot scale (0=WEST  1=EAST)
-99                                       RH filter threshold (%)
                                          (-99 for IMPROVE)
4                                         Averaging period for timeline plot (hours)
0                                         Draw timeline daily lines? ( 0=NO 1=YES)
ACADIA NATIONAL PARK, MAINE               Main title
IMPROVE Nephelometer Data Summary         Second title
July 1, 1993 - September 30, 1993         Third title
Lightning Surge 8/28/93                   Timeline plot comment
3.5,1.5                                   Location of comment (" from upper left)
MORA_N11.933                              Next site.....
MORA
93,7,1
92
0
1
-99
4
0
MOUNT RAINIER NATIONAL PARK, WASHINGTON
IMPROVE Nephelometer Data Summary
July 1, 1993 - September 30, 1993

-99,-99
```

Figure 4-19. NGN_NSUM Software Submit File Format.

GENERATE THE PLOTS

The plots defined in the submit file can be plotted to the screen or to any Windows-compatible printer attached to the system. The following procedures are used to generate the plots:

- Choose the submit file to use by clicking **File** and then **Choose Submit File**. Select the submit file to use from the file selection box.

- Generate the plots defined in the submit file by clicking **Plot** and then **Plot All Plots** (printer) or **Plot To Screen** (screen).

- The plots defined in the submit file will be sent to the printer selected by the user after clicking **Plot All Plots**.

4.6.9 Review of Level-1 Seasonal Summary Plots

Seasonal summary plots of Level-1 validated data are reviewed by the data coordinator and project manager to identify the following:

- Data reduction and validation errors
- Instrument operational problems
- Calibration problems

Problems identified in the Level-1 seasonal summary plot review are resolved by editing the QA database code and/or calibration files to identify additional data as valid or invalid and performing the Level-0 and Level-1 validation procedures again.

When the Level-1 seasonal summary plots have passed the review process, the raw through Level-1 validated data and associated QA files are archived as described in TI 4600-5000, Nephelometer Data Archiving.