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**Particle Analysis and Display  
System (PADS):  
Fog Monitor 100  
(FM 100) Extinction  
Module**

**Operator Manual**

**DOC-0217 Rev A-1**

**PADS 2.7.3, FM 100 Extinction  
Module 2.7.0**



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# CONTENTS

<b>1.0 Introduction</b> .....	<b>4</b>
<b>2.0 Configuration</b> .....	<b>4</b>
Configuring the Extinction.....	4
Configuring the Extinction Display .....	7
<b>3.0 The FM 100 Extinction Window</b> .....	<b>9</b>
Chart Display .....	9
Histogram Data Window .....	10
Scaling Options.....	11
<b>Appendix A: Extinction Channels</b> .....	<b>12</b>
<b>Appendix B: Extinction Coefficients and Visibility Calculations</b> .....	<b>14</b>
Extinction Coefficients.....	14
Visibility.....	15

## *List of Figures*

<b>Figure 1: FM 100 Extinction Configuration Editor Window</b> .....	<b>5</b>
<b>Figure 2: FM 100 Extinction Display Editor Window</b> .....	<b>8</b>
<b>Figure 3: Extinction Selectable Chart</b> .....	<b>9</b>
<b>Figure 4: FM 100 Histogram Window</b> .....	<b>10</b>

## 1.0 Introduction

The Particle Analysis and Display System (PADS) is a software package that interfaces with instruments produced by Droplet Measurement Technologies (DMT) and other leading instruments used in the atmospheric sciences. This manual describes the PADS module for the Fog Monitor 100 Extinction Module.

For an explanation of the basic PADS setup and instructions on how to acquire data using PADS, consult the *PADS Operator Manual*. Definitions and calculations used in the Extinction module are also described in the *PADS Operator Manual*.

The Extinction module for PADS is a calculation module that relates specifically to the FM\_100 module. Extinction acquires its data directly from the FM\_100 module and calculates extinction values based on the FM\_100 data. The Extinction module, therefore, is never run in PADS without the FM\_100 module also present. The Extinction module's calculations are stored in a separate Extinction data file.

Note that the FM\_100 and Extinction modules run independently of each other, as do all PADS modules. Thus there will be a slight time delay between when the FM\_100 module acquires data and when the Extinction module calculates extinction values. For this reason, the Extinction module not only time-stamps its data with the computer time associated with when it made the calculations, but it also includes the FM\_100 time-stamp for when the data was actually acquired.

**Note:** The *PADS Operator Manual* and the manuals for most PADS instruments document PADS version 2.5. Since the FM 100 Extinction Module was only introduced in PADS 2.7, however, this manual documents PADS version 2.7.

## 2.0 Configuration

Using PADS, you can configure both the software for the instrument and the instrument's data display in PADS. The following two sections explain how to do this.

### Configuring the Extinction

Your Extinction Module and data system should arrive preconfigured from DMT. In some cases, however, you may want to change the software configuration for the instrument. To do this, follow the steps below. **Note:** *Droplet Measurement Technologies STRONGLY recommends that customers contact our office prior to changing any of the parameters in the instrument*

configuration. Improper changes can result in communication failure and/or changes in PADS computation algorithms, which can compromise data validity.

1. Click on the “Extinction” tab.
2. From the **Configure** menu, select **Configure Instrument**. You will see the following window.

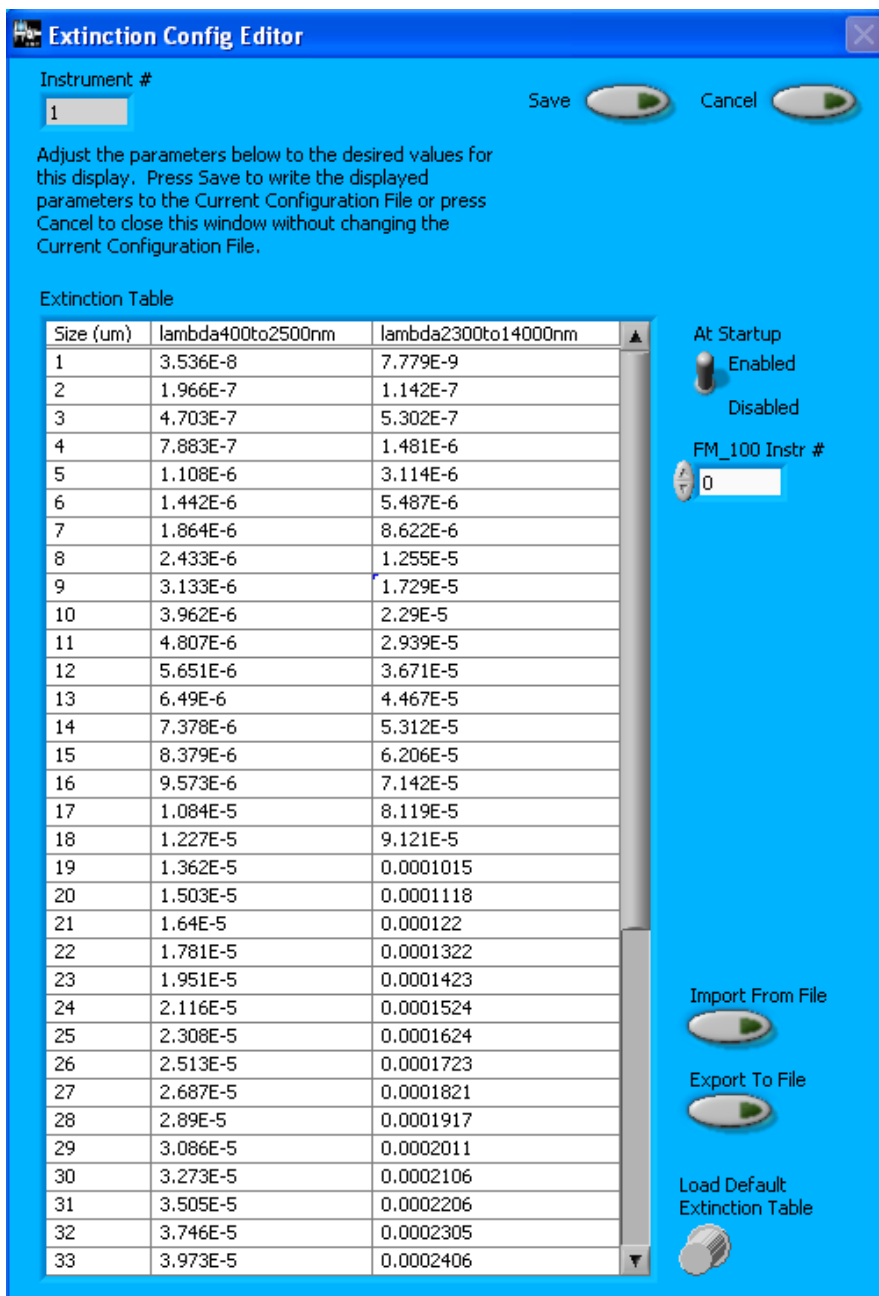


Figure 1: FM 100 Extinction Configuration Editor Window

3. Now you can configure the instrument parameters to your desired specifications. You will find a list of the parameters you may want to reconfigure in the two sections below, “Occasionally Reconfigured Extinction Parameters” and “Rarely Reconfigured Extinction Parameters.” If at any time you would like to revert to the previously saved values for the Extinction parameters, press **Cancel** to exit the window without saving changes.
4. When you are done configuring the Extinction parameters, press **Save** at the top of the Config editor window. (If you would instead like to revert to the previously saved values, click **Cancel**.) Then press the green **Reset Program** button for the new configuration to take effect. Note that pressing the **Reset Program** button will clear any data currently being displayed.

### ***Occasionally Reconfigured Extinction Parameters***

**At Startup Enabled / Disabled:** If you want the Extinction Module to acquire data when PADS begins sampling, make sure this parameter is in the “Enabled” mode. In some cases, such as if the FM 100 is inoperative, you may want to use this control to disable the Extinction Module. Disabling the module allows data to transmit from other instruments without interference.

**Extinction Table:** This table lists factors used in calculating extinction coefficients for the different spectral bands. You can modify the values in the table by typing in new numbers directly, by importing a new file, or by pressing the **Load Default Extinction Table** button to revert to the table’s original default values. The factors listed in the table are the extinction efficiencies for different particle sizes multiplied by the cross sectional area of the particle  $\text{cm}^2$ . For more information, see *Appendix B*.

**Import from File:** This button allows you to import an external file into the Extinction Table. The file must be in comma-delimited .csv format.

**Export from File:** This button allows you to save the current Extinction Table to a location of your choice. The file is exported in comma-delimited .csv format, which can be opened in Excel or other spreadsheet programs.

**Load Default Extinction Table:** This button reverts the data in the Extinction Table to their original values.

You will notice that there are other parameters listed on the **Extinction Config Editor** window. You should not need to change these, and changing them may compromise your data. If you are curious about these parameters or think you do need to modify them, see the section titled “Rarely Reconfigured Extinction Parameters” below or consult with a DMT technical representative.

### ***Rarely Reconfigured Extinction Parameters***

The Extinction configuration editor displays several parameters that you will rarely need to modify. The following is a list of these parameters and an explanation of what they do.

**Instrument #:** This lists the number corresponding to the instrument you are viewing, in this case the Extinction Module. (Although the module is not technically an instrument, PADS considers it one.) If your Extinction Module has been assigned instrument number one, you will see “1” in this field. You should not need to modify the instrument number, and in fact you are unable to do so from within PADS.

**FM\_100 Instr #:** This is the number PADS has assigned to the FM 100 instrument. This number should not need to be modified.

After making changes in the instrument configuration window, you will need to press the **Save** button and then click the green **Reset Program** to activate these changes. Clicking **Reset Program** will clear any data PADS is currently displaying.

## **Configuring the Extinction Display**

To configure the Extinction display, click on the Extinction tab if you have not already done so. Then select **Configure** from the menu bar and click on **Configure Display**. This will bring up the following window.

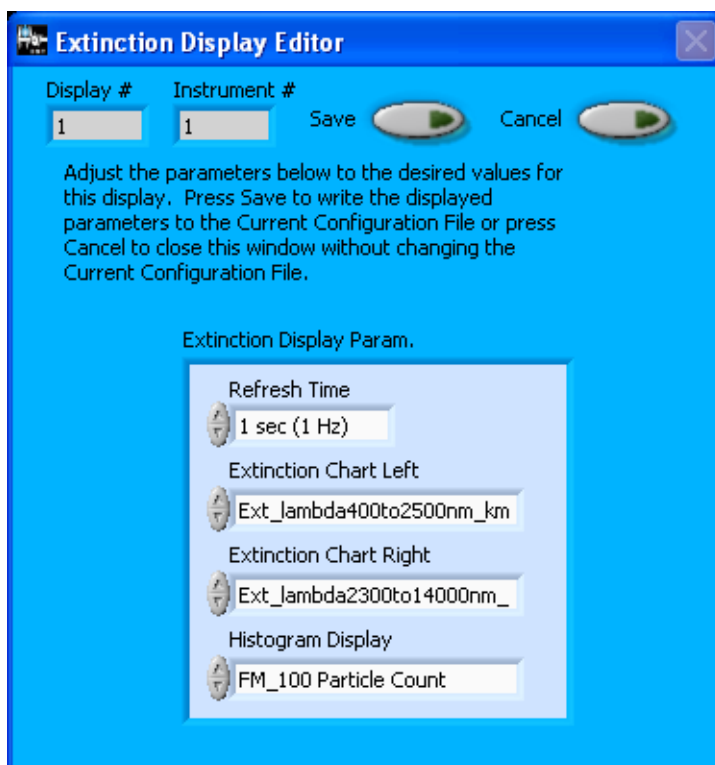


Figure 2: FM 100 Extinction Display Editor Window

You do not need to modify the **Display #** or **Instrument #**. Changing the **Refresh Time** allows you to set the time intervals for data display during acquisition mode; you can choose any time that is equal to or greater than the sample time. (Choosing a time less than the sample time is not useful, since the same data will be displayed multiple times.)

**Extinction Chart Left** and **Extinction Chart Right** allow you to select channels to be displayed in the Extinction Module's top graph. These channels are displayed with respect to time. The channel names are displayed in the top left and right corners of the graph. The channel on the left is graphed in white, while the one on the right is in red.

**Histogram Display** determines the channel displayed in the histogram at the bottom of the Extinction Window. You can use the histogram to display particle counts or extinction coefficients. (See *Appendix B* for information about how PADS calculates extinction coefficients.)

**Note:** You can also change the chart and histogram channels from the Extinction Window, which changes them for the current session only. Changing these channels in the Display Editor changes the defaults used on start-up.

When you are done, click on **Save** to update the configurations or **Cancel** to revert to the previous configuration. After you reset PADS, you will be able to see any changes you

have made to Refresh Time. Note that clicking **Reset Program** will clear out any data currently being displayed.

### 3.0 The FM 100 Extinction Window

The following sections describe the chart display and histogram in the Extinction Window. For explanations of the **Enable** button and **Fault/No Fault** button, see the “Instrument Tabs” section of the *PADS Operator Manual*.

#### Chart Display

The chart on the top half of the Extinction Window allows you to display two Extinction Module channels with respect to time. Figure 3 shows this chart.

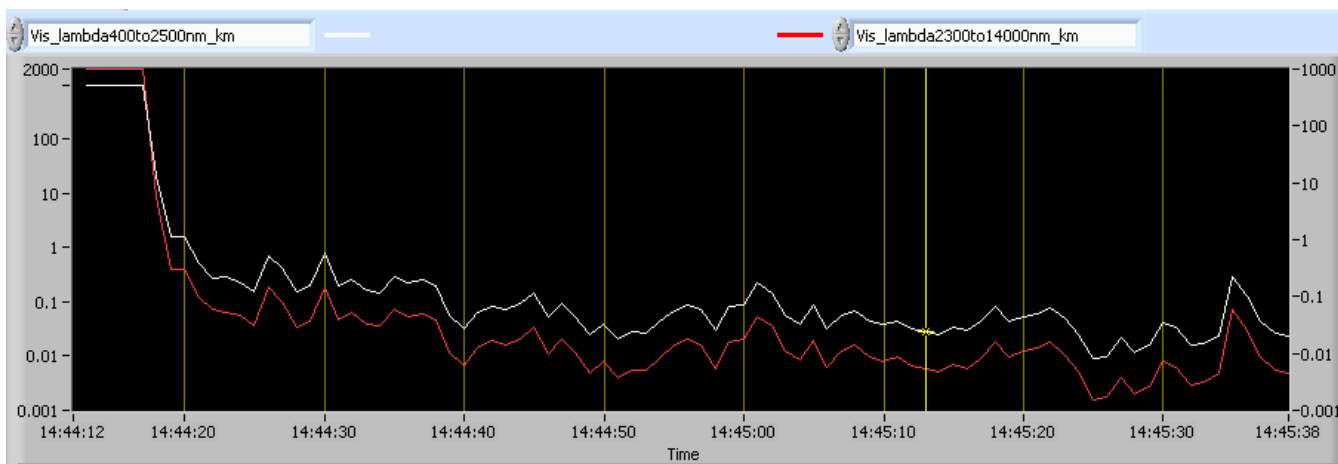


Figure 3: Extinction Selectable Chart

To change these channels, click on the fields to the above left of the graph (for the channel in white) or to the above right (for the channel in red). Clicking on these fields will bring up a list of all the available Extinction Module channels, from which you can choose the one you want. Selecting a new channel changes it for the current session only. To change the default channels displayed upon start-up, go to the Configure menu, select Configure Display, and select the desired defaults.

For information on specific channels, their definitions, and their acceptable ranges, consult *Appendix A: Extinction Channels* and the *PADS Operator Manual's Appendix A: Definitions*. For information on how PADS calculates extinction efficiency and visibility, see *Appendix B: Extinction Coefficients and Visibility Calculations*.

You can change the scaling for each channel display using the buttons to the left of the chart. See the **Scaling Options** section of this document for more information.

Note that the two channels displayed in the chart have their own y-axis scale. The scale for the white channel appears to the left of the graph, and that for the red channel to the right. In Figure 3, for instance, the red channel and white channel are both approximately 1,000 at the start of the sampling session, although the red line appears above the white line.

## Histogram Data Window

On the bottom of the Extinction Window is a histogram display (Figure 4). The histogram shows data for the current moment in time. It can display various channels by size bin, including particle counts and extinction coefficients.

The x-axis labels indicate the upper boundary of each size bin, which PADS reads from the `FM_100_p.csv` threshold table. A bin's lower boundary is the upper boundary of the previous bin, except for the first bin, which has a lower boundary of 2  $\mu\text{m}$ . *Note: This size limit may not exactly match the actual size of the smallest particles in bin 1, which is determined by your ADC Threshold setting. However, the discrepancy is minor and does not significantly affect calculations such as concentration, ED, LWC, and MVD.*

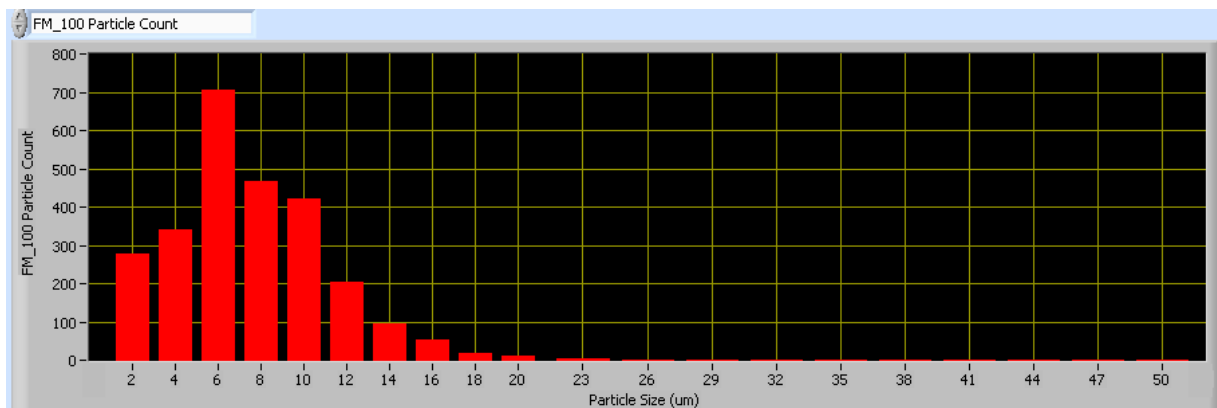


Figure 4: FM 100 Histogram Window

The histogram's scale can be changed by typing new values into the labels on the end of the y-axis. (The x-axis scale cannot be changed this way.) You can also change the histogram's scaling using the buttons to the left of the display. See the following section for more details.

## Scaling Options

The buttons to the left of the chart display and histogram allow you to scale the data in different ways. More information about these buttons is provided below.

### Autoscale Button

The Autoscale controls let you control how the y scale is set. If you enable autoscaling, PADS will automatically select an appropriate scale with which to display the current data. For instance, if the histogram is displaying particle counts and the probe is not currently detecting many particles, the y-axis range will decrease. On the other hand, if you disable autoscaling, the scale of the axis will remain constant. In this case, the range will always be the same as it was when autoscaling was disabled. The minimum and maximum Y values can then be changed manually by typing new numbers into these fields. *In playback mode, autoscaling will not take effect until you change the time using the time controls.*

Note that the Autoscale Y button overrides the Autoscale Y option in the drop-down menu that appears when you right-click on the chart.

### Log-Scale Button

When you turn on the Log-Scale button, PADS scales the y-axis logarithmically rather than linearly. Autoscaling can be enabled or disabled with this option.

### Normalized Button

If you enable normalization, PADS will scale the particle data so that each bin of data is divided by the width of that bin in  $\mu\text{m}$ . Normalization is useful when the widths of the size bins are not constant, as is often the case when an optical spectrometer has to cover a large size range or if some size bins are made larger to decrease uncertainty due to operational limitations. Without normalization, the concentrations from one size bin cannot be compared quantitatively from those in another size bin of different width. For example, if 8 particles are counted in a size bin that is 2  $\mu\text{m}$  wide and 8 particles are counted in the next larger channel that is 4  $\mu\text{m}$  wide, the size distribution would appear flat and we would assume that it was equally probable to measure particles of either size. This is a biased sample, however, since the larger size bin is twice as wide as the smaller. If we normalize by the width, however, we find that the smaller size category has 4 particles per  $\mu\text{m}$  and the larger size bin only has 2 particles per  $\mu\text{m}$ . This is now an unbiased sample.

## Appendix A: Extinction Channels

Below is a list of Extinction channels for a module used under the following conditions: the FM 100 has 20 bins, and extinction and visibility are calculated for 400-2500 nm and 2300-14000 nm. The Extinction channels output file will contain data values for each channel for each sampling instance. You can also plot each of these channels as a function of time using the Extinction Window chart display. For definitions of the channels, consult *Appendix A: Definitions* in the *PADS Operator Manual*.

Time	Ext_lambda400to2500nm_km-1_ch12
FM_100 Time	Ext_lambda400to2500nm_km-1_ch13
FM_100 OPC_ch0	Ext_lambda400to2500nm_km-1_ch14
FM_100 OPC_ch1	Ext_lambda400to2500nm_km-1_ch15
FM_100 OPC_ch2	Ext_lambda400to2500nm_km-1_ch16
FM_100 OPC_ch3	Ext_lambda400to2500nm_km-1_ch17
FM_100 OPC_ch4	Ext_lambda400to2500nm_km-1_ch18
FM_100 OPC_ch5	Ext_lambda400to2500nm_km-1_ch19
FM_100 OPC_ch6	Ext_lambda2300to14000nm_km-1_ch0
FM_100 OPC_ch7	Ext_lambda2300to14000nm_km-1_ch1
FM_100 OPC_ch8	Ext_lambda2300to14000nm_km-1_ch2
FM_100 OPC_ch9	Ext_lambda2300to14000nm_km-1_ch3
FM_100 OPC_ch10	Ext_lambda2300to14000nm_km-1_ch4
FM_100 OPC_ch11	Ext_lambda2300to14000nm_km-1_ch5
FM_100 OPC_ch12	Ext_lambda2300to14000nm_km-1_ch6
FM_100 OPC_ch13	Ext_lambda2300to14000nm_km-1_ch7
FM_100 OPC_ch14	Ext_lambda2300to14000nm_km-1_ch8
FM_100 OPC_ch15	Ext_lambda2300to14000nm_km-1_ch9
FM_100 OPC_ch16	Ext_lambda2300to14000nm_km-1_ch10
FM_100 OPC_ch17	Ext_lambda2300to14000nm_km-1_ch11
FM_100 OPC_ch18	Ext_lambda2300to14000nm_km-1_ch12
FM_100 OPC_ch19	Ext_lambda2300to14000nm_km-1_ch13
Ext_lambda400to2500nm_km-1_ch0	Ext_lambda2300to14000nm_km-1_ch14
Ext_lambda400to2500nm_km-1_ch1	Ext_lambda2300to14000nm_km-1_ch15
Ext_lambda400to2500nm_km-1_ch2	Ext_lambda2300to14000nm_km-1_ch16
Ext_lambda400to2500nm_km-1_ch3	Ext_lambda2300to14000nm_km-1_ch17
Ext_lambda400to2500nm_km-1_ch4	Ext_lambda2300to14000nm_km-1_ch18
Ext_lambda400to2500nm_km-1_ch5	Ext_lambda2300to14000nm_km-1_ch19
Ext_lambda400to2500nm_km-1_ch6	Ext_lambda400to2500nm_km-1
Ext_lambda400to2500nm_km-1_ch7	Ext_lambda2300to14000nm_km-1
Ext_lambda400to2500nm_km-1_ch8	Vis_lambda400to2500nm_km
Ext_lambda400to2500nm_km-1_ch9	Vis_lambda2300to14000nm_km
Ext_lambda400to2500nm_km-1_ch10	Status
Ext_lambda400to2500nm_km-1_ch11	GPS Time

Extinction channels fall into several broad categories:

*Time Channels:* The time channels store time data. Time is generated by the PADS computer clock and is the time when the Extinction Module receives the data from FM 100. FM\_100 Time is also generated by the PADS clock, and it is the time at which the FM 100 received the data. Typically, Time and FM\_100 Time will be close, but Time will lag slightly behind FM\_100 Time. Both Time and FM\_100 Time are given in seconds after midnight on the day the program was started. GPS Time is included in every instrument's list of channels whenever a GPS is included as one of the PADS instruments. GPS Time will be collected from an instrument other than the Extinction Module, even though it appears as a channel in the Extinction output file.

*Size Bin Channels:* Channels labeled FM\_100\_OPC\_ch[i] store data on the number of particles of different sizes that the FM 100 has detected. These data can be displayed in the histogram.

*Extinction and Visibility Channels:* The Extinction module has several types of extinction and visibility channels:

- Ext\_lambda[AAA]to[BBB]nm\_km-1\_ch[i] stores data on the extinction coefficients for particles of size i at spectral band AAA-BBB nm.
- Ext\_lambda[AAA]to[BBB]nm\_km-1 stores the extinction coefficients for *all* particle sizes at spectral band AAA-BBB nm.
- Vis\_lambda[AAA]to[BBB]nm\_km stores the visibility for all particle sizes at spectral band AAA-BBB nm.

For information on how PADS calculates these values, see *Appendix B*.

*Channel for Other Statistical Data:* Status is currently non-functional, but in the future it will store statistical data on the communications between PADS and the FM 100 probe.

## Appendix B: Extinction Coefficients and Visibility Calculations

### Extinction Coefficients

Assume the FM 100 has  $n$  sizing bins defined by the bin boundaries  $b_1, b_2, b_3, \dots, b_n, b_{n+1}$  (in  $\mu\text{m}$ ) so that bin 1 is from  $b_1$  to  $b_2$ , bin 2 is from  $b_2$  to  $b_3$ , ..., bin  $n$  is from  $b_n$  to  $b_{n+1}$ . The bin droplet concentrations for the sample interval have been determined to be  $c_i$  droplets per  $\text{cm}^3$  for  $i = 1, \dots, n$ .

Let  $m_i$  be the midpoint of the  $i$ th bin,  $i = 1, 2, \dots, n$ .

Meanwhile, assume the PADS extinction table provides data in the following form:

- 1.)  $n'$  sizing bins are defined by the bin size  $b'_1, b'_2, b'_3, \dots, b'_n$  (in  $\mu\text{m}$ )
- 2.)  $m'$  spectral bands are defined by the frequency ranges  $\lambda_1-\lambda_2, \lambda_3-\lambda_4, \dots, \lambda_{2m'-1}-\lambda_{2m'}$  (in  $\text{nm}$ )<sup>1</sup>
- 3.)  $n' \cdot m'$  extinction factors are defined by the values  $e_{i',j'}$  for particles of size  $i'$  in spectral bandwidth  $j'$ . The extinction factor listed in the table is equal to

$$\text{extinction efficiency } (i', j') \bullet (\pi/4) [ [\text{diameter in cm } (i')]^2$$

where particles are assumed to have a refractive index of 1.33.

Note that the number of FM 100 sizing bins may not match the number of extinction table sizing bins, i.e.  $n \neq n'$ . Moreover, the extinction table may not provide exact  $e_{m(i),j'}$  values for all possible values of  $m_i$ . As a result, PADS must interpolate the extinction table data to obtain best estimates of  $e_{m(i),j'}$  for a given  $m_i$  and  $j'$ . It does so using a linear interpolation. First, the program determines  $i^*$ , where  $i^*$  is the smallest value in the extinction-table array  $[1, 2, 3, \dots, n']$  such that  $m_i \geq b'_{i^*}$ . Next, PADS computes a fractional size index,  $s_i$ , as follows:

$$s_i = \frac{m_i - b'_{i^*}}{b'_{i^*+1} - b'_{i^*}}$$

Then PADS approximates the extinction factor  $e_{m(i),j'}$ :

<sup>1</sup> Currently, the FM 100 Extinction Module uses two spectral bandwidths: 400 - 2500 nm and 2300 - 14000 nm.

$$e_{m(i),j'} = e_{i^*,j'} + s_i \bullet (e_{i^*+1,j'} - e_{i^*,j'})$$

Using this factor, PADS then calculates  $ext_{i,j'}$ , the extinction coefficient in  $km^{-1}$  for spectral band  $j'$  for all particles in bin  $i$ :

$$ext_{i,j'} = e_{m(i),j'} \bullet c_i \bullet 10^5$$

with  $10^5$  being a unit conversion factor to convert cm to km.

Finally, PADS computes the extinction coefficient in  $km^{-1}$  for spectral band  $j'$  for *all* particles sized by the FM 100 during the sampling interval:

$$total\ ext_{j'} = \sum_{i=1}^n ext_{i,j'}$$

## Visibility

Once PADS has calculated extinction coefficient as described above, it calculates the visibility in km,  $v_{j'}$ , for a spectral band  $j'$  using the Koschmeider relationship:

$$v_{j'} = \frac{3.92}{total\ ext_{j'}}$$

Note that PADS forces  $v_{j'}$  to be between zero and a maximum visibility threshold that is typically set to 1,000. The maximum exists because as particle counts go to zero, extinction coefficients will also go to zero, which means that if visibility is unconstrained it will approach infinity. Since visibility is in fact limited by factors other than particles in the atmosphere, it makes sense to limit visibility. Contact DMT for assistance if you would like to change the maximum visibility threshold.