

DISPOSITION FORM

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REFERENCE OR OFFICE SYMBOL

SUBJECT

DELNV-VI

NV&EOL G/AP Aerosol Atmospheric Models

TO Director, Visionics

FROM BSIT, VISD

DATE 7 Sep 78

CMT 1

1. In order to adequately model performance of E-0 sensors for use on the realistic battlefield, one element required is a model for the attenuation of visible, 1.06um and IR wavelength energy in fog, hazes, rain and snow. This model should relate to the measure of how far we are capable of seeing, namely the visibility. The model we have chosen has the form of a Beer's Law extinction, with an extinction coefficient which relates to transmission in the following manner:

$$T = e^{-\sigma R}$$

T = Transmission
 σ = Attenuation Coefficient
 R = Range

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The σ_{8-12} , σ_{3-5} or $\sigma_{1.06}$ is normally plotted on log-log graph paper against $\sigma_{.55}$ which directly relates to the visibility.

2. The basic data for the NV&EOL G/AP Atmospheric Model has been collected during tests at Fort A. P. Hill, Virginia, Grafenwoehr and Baumholder, FRG. The data, as collected at AP Hill, has been broken into two groupings; labeled as wet and dry fog. A least square polynomial fit of order two was carried out on this atmospheric data. The fit was carried out in the log-log space relating the scattering attenuation coefficients of the 8-12um or (3-5um) region to that of the visible (.55um) region. The resulting curves are shown in Figures 1 and 2. Figure 1 shows the two curves one for each spectral region with the total data set of over 200 points making up the curve fit. These figures must be considered as preliminary as more data will be included in the curve fit as it becomes available. This fit will be corrected periodically.

3. The data utilized gives fits of the following form:

$$y = a + bx + cx^2$$

where y is $\log \sigma_{3-5}$ or $\log \sigma_{8-12}$ with x being $\log \sigma_{.55}$

Although the data was not marked as wet or dry for Grafenwoehr or Baumholder, it appears through the data plots that it will group in this manner. The Baumholder data being dry and the Grafenwoehr data being wet. This has been plotted in this form and shown as Figures 3 and 4.

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4. The models and fit data for the 3-5 vs. visible curves are the following:

	A	B	C	r ² -linear correlation	Root Mean Error
All Data	-1.000	2.404	-.511	.883	.0147
Dry Data	-1.667	3.398	-.863	.894	.0115
Wet Data	-.917	2.595	-.782	.824	.0238

5. The models and fit data for the 8-12 vs. visible curves are the following:

	A	B	C	r ² -linear correlation	Root Mean Error
All Data	-.980	1.851	-.212	.837	.0207
Dry Data	-1.712	2.565	-.328	.937	.0158
Wet Data	-1.144	2.871	-.895	.735	.0338

Figure 2 shows the region of fit for these curves.

6. The data upon which these fits have been obtained are shown as Table I. The data is shown along with the date on which it was taken. This in turn can be related to the basic experimental data upon which the extinction coefficients have been based.

7. Figure 5 shows how the AP Hill data compares for 3-5 and 8-12 extinction coefficients plotted as functions of one another in two different ways. One case is a least square fit of these data directly and the other is a cross plot using the least square fits with the visible extinction as a parameter. It is shown that the cross plot is valid in the regions where the LSQF is also valid.

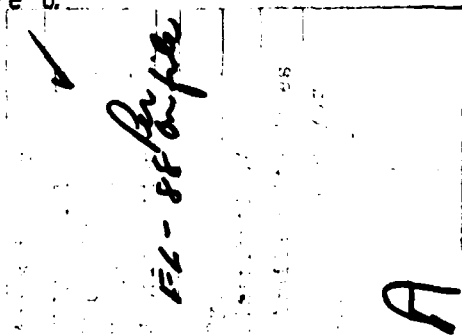
8. Data for the 1.06 micron extinction are found in Table II. These have been curve fit to the form outlined in Section 3 above. In this case

$$y \text{ is } \log \left(\frac{.55}{x} \right)$$

$$x \text{ is } \log \left(\frac{1.06}{.55} \right)$$

	A	B	C	r ² -linear correlation	Root Mean Error
1.06 Data	.239	.751	-.281	.891	.0161

The curve corresponding to this fit is shown in Figure 6.



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9. The following expressions have been obtained as fits to rain and snow data.

Rain

$$\sigma_{8-12} = 10.0^{**}[1.04 * \log_{10}(+^{3.912}/R_{vis})+.037]$$

$$\sigma_{3-5} = 10.0^{**}[1.12 * \log_{10}(+^{3.912}/R_{vis})-.108]$$

Snow

$$\sigma_{8-12} = 10.0^{**} [.993 * \log_{10}(+^{3.912}/R_{vis})+.114]$$

$$\sigma_{3-5} = 10.0^{**}[1.05 * \log_{10}(+^{3.912}/R_{vis})+.021]$$

In these expression Rvis is the visibility range in kilometers.

Frank J. Shields

FRANK J. SHIELDS
A/Ch, Battlefield Systems Integration
VISD, NV&EOL

**NV&E₀L G/AP AEROSOL MODEL
EXTINCTION COEFFICIENTS
LEAST SQUARE 2ND ORDER FIT 222 3-5 DATA PTS, 242 8-12 DATA PTS**

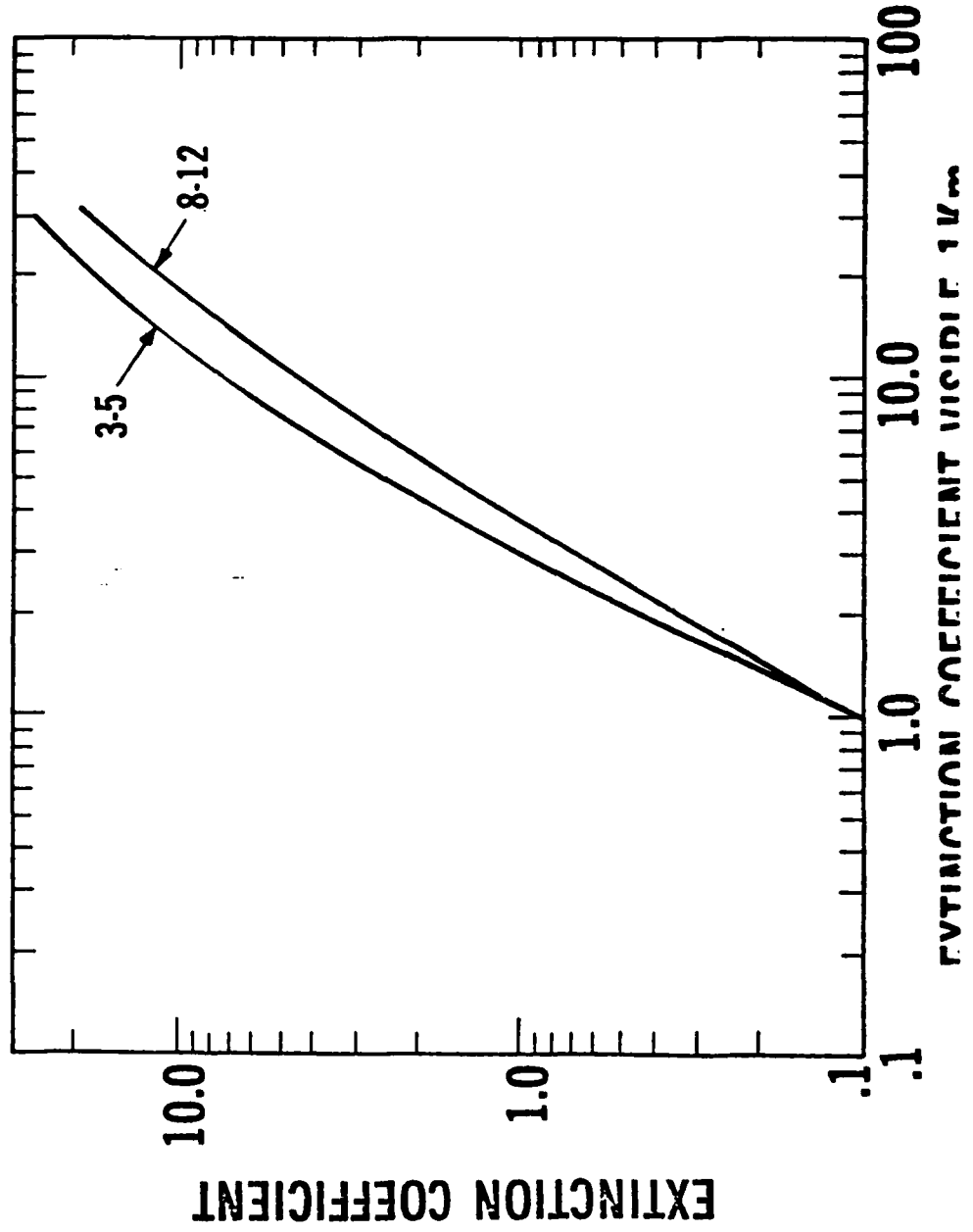


Fig. 1

NV&EOL G/AP AEROSOL MODEL 8-12 μ m MODEL

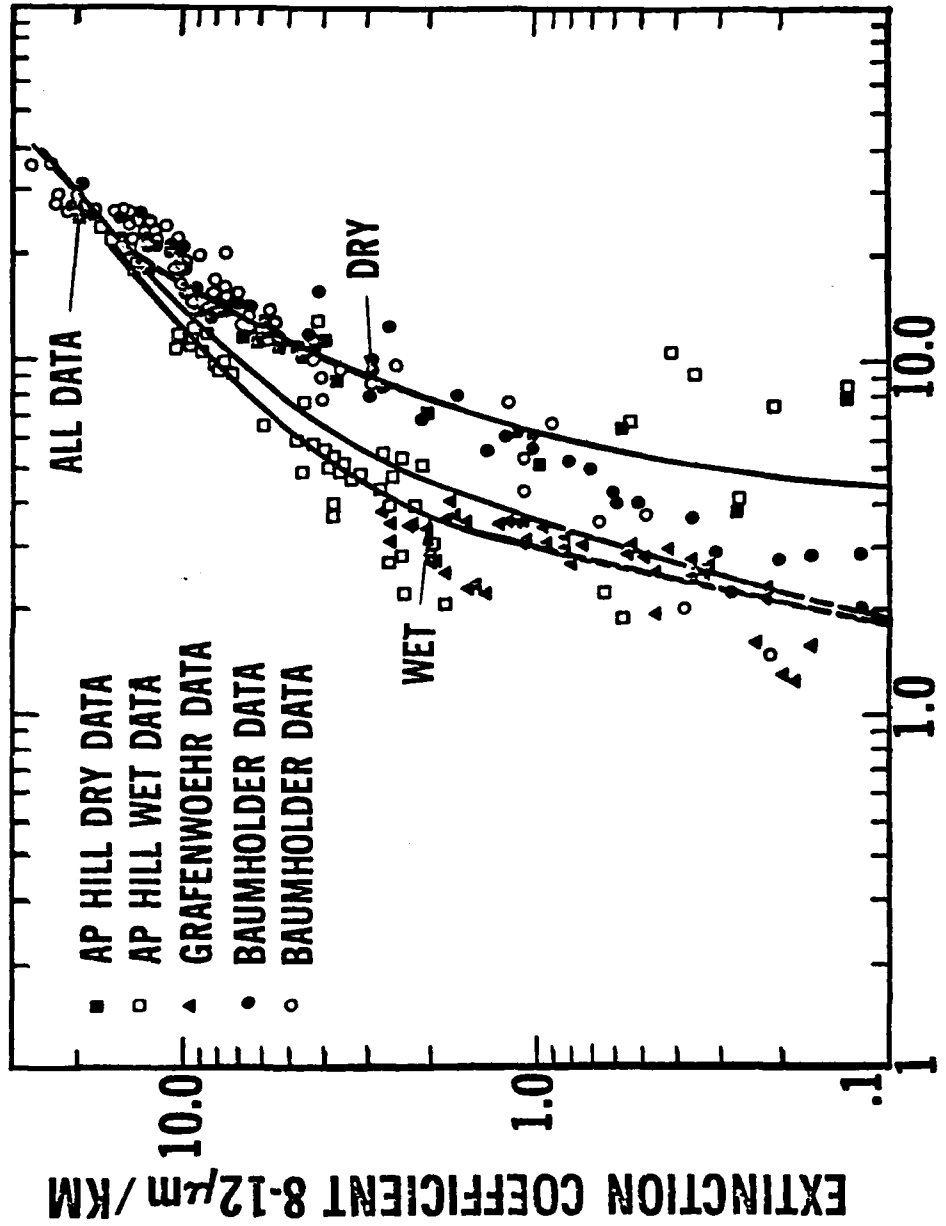
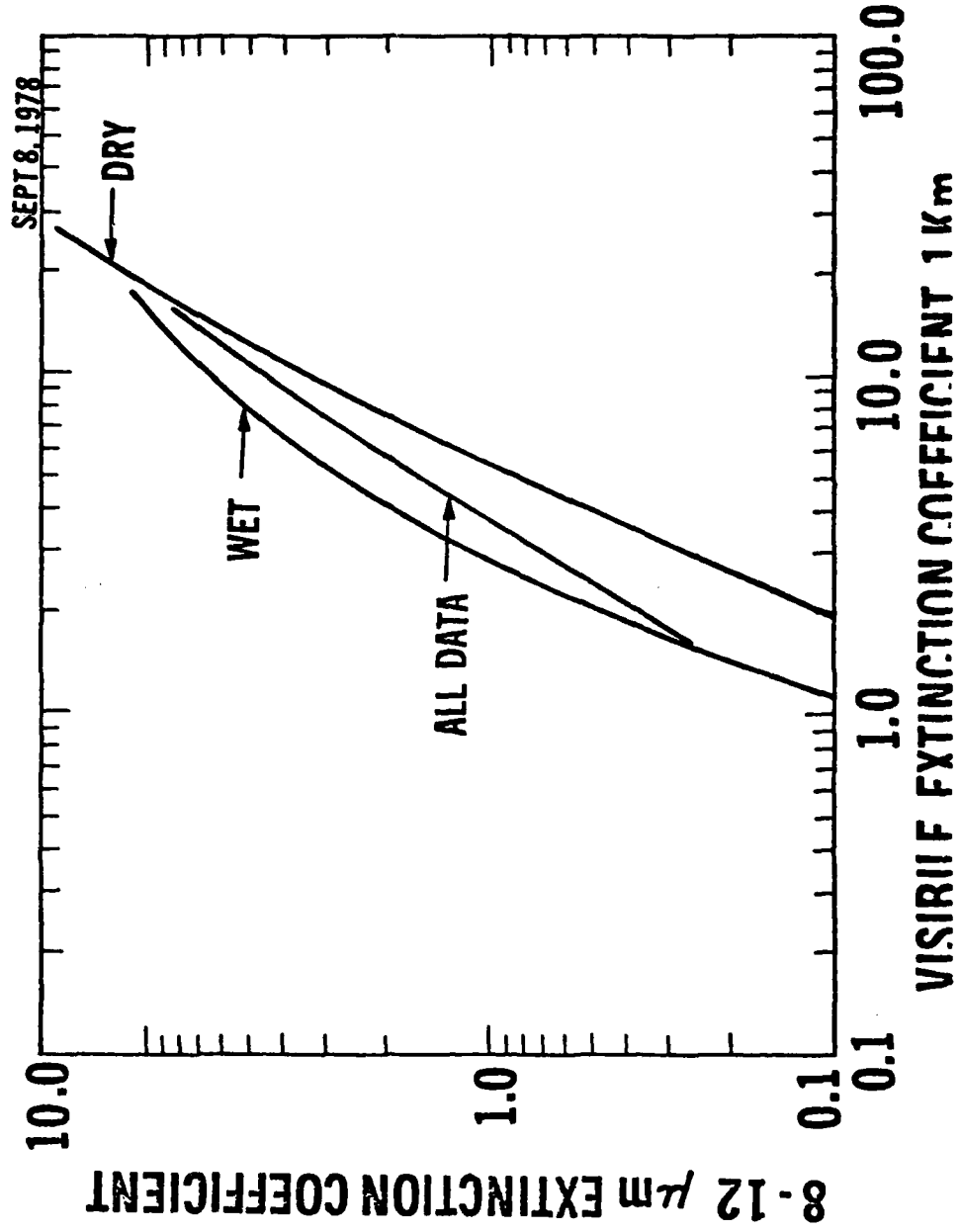
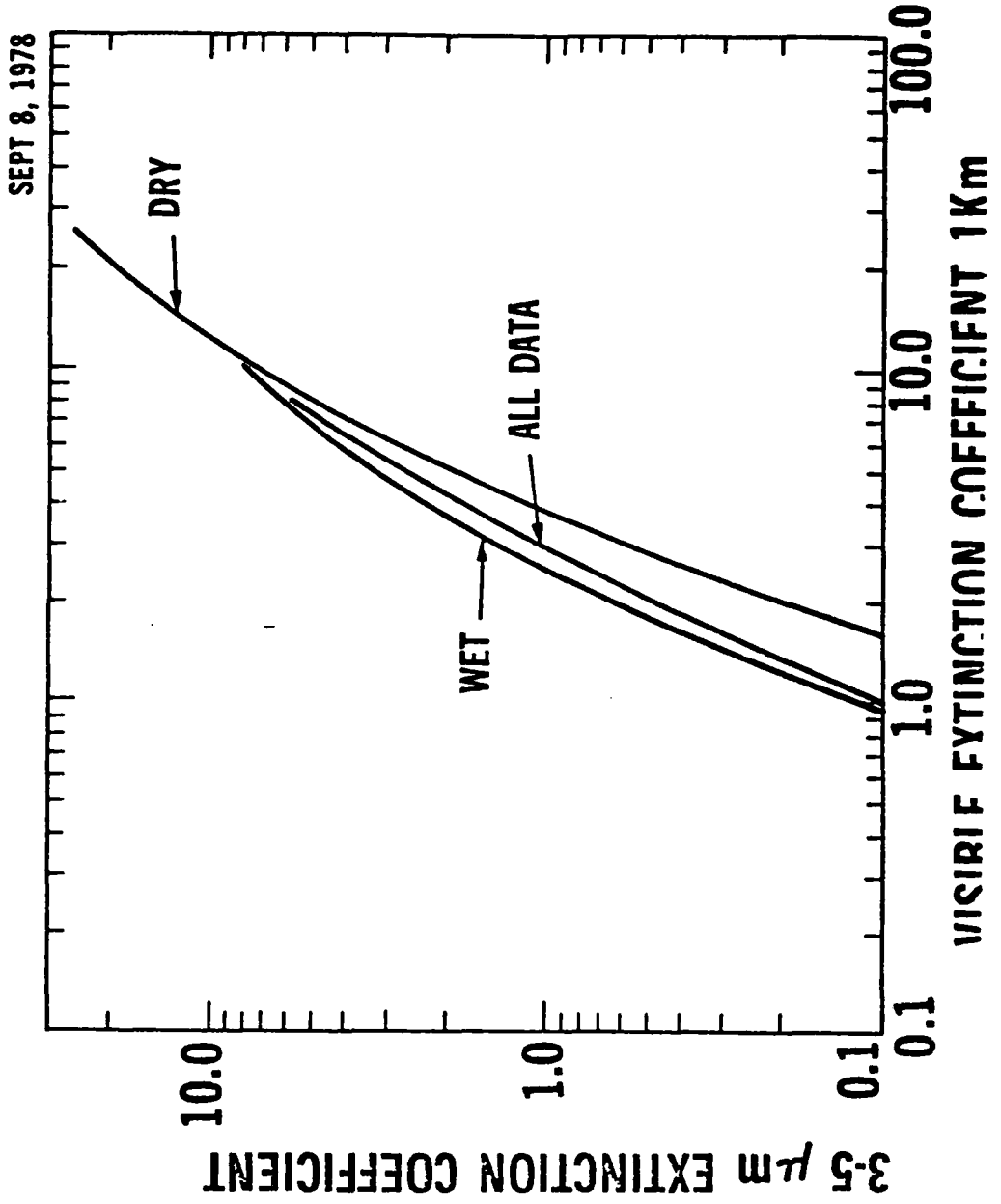


Fig. 2

NV&EOL G/AP AEROSOL MODEL 8 - 12 μ m MODEL



NV&EOL G/AP AEROSOL MODEL 3-5 μm MODEL



— LEAST SQUARE FIT 3-5 μm vs 8-12 μm DATA
- - - CROSS PLOT USING VISIBILITY AS MAPPING COORDINATE

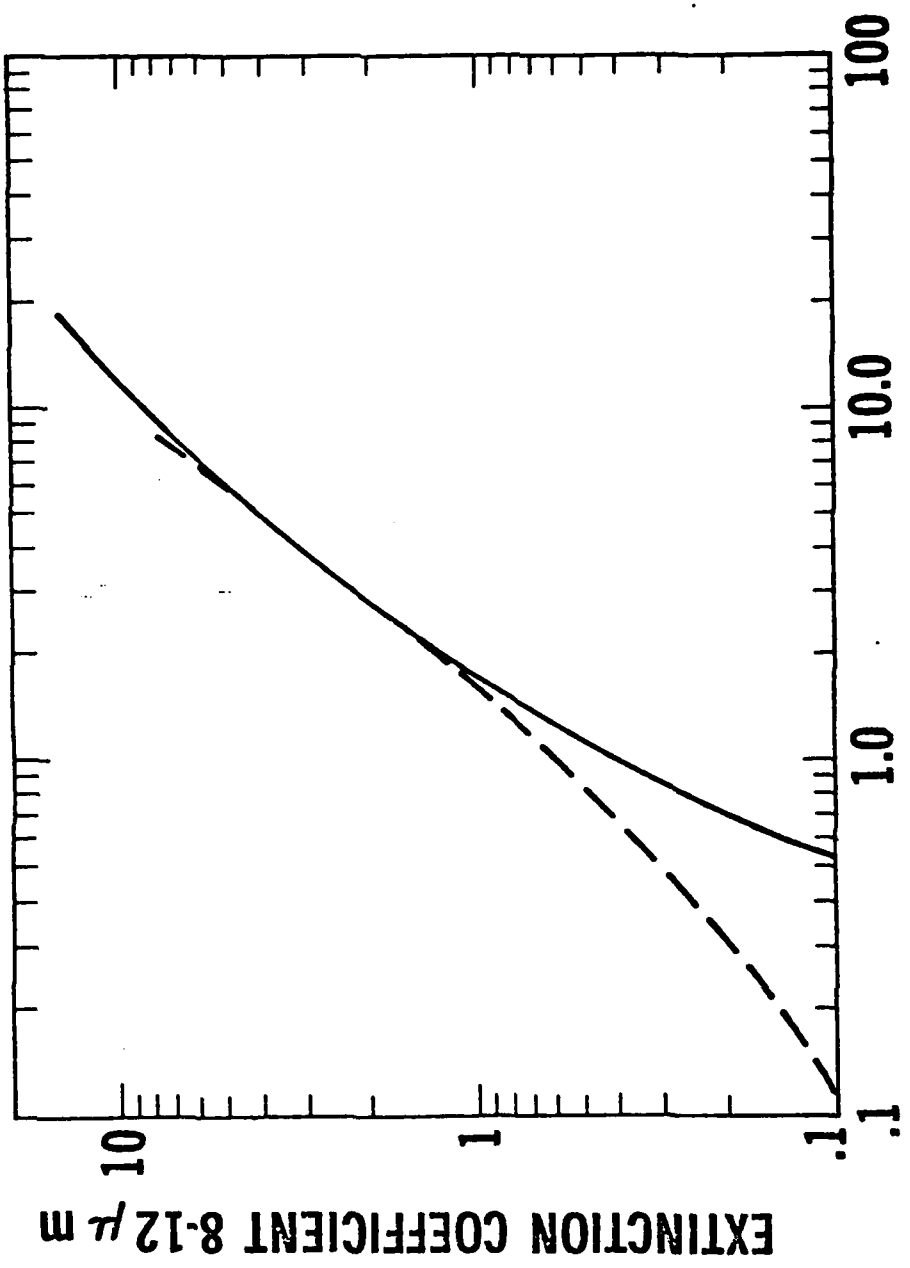


FIG. 5.

NV&EOL G/AP AEROSOL MODEL
1.06 μm MODEL

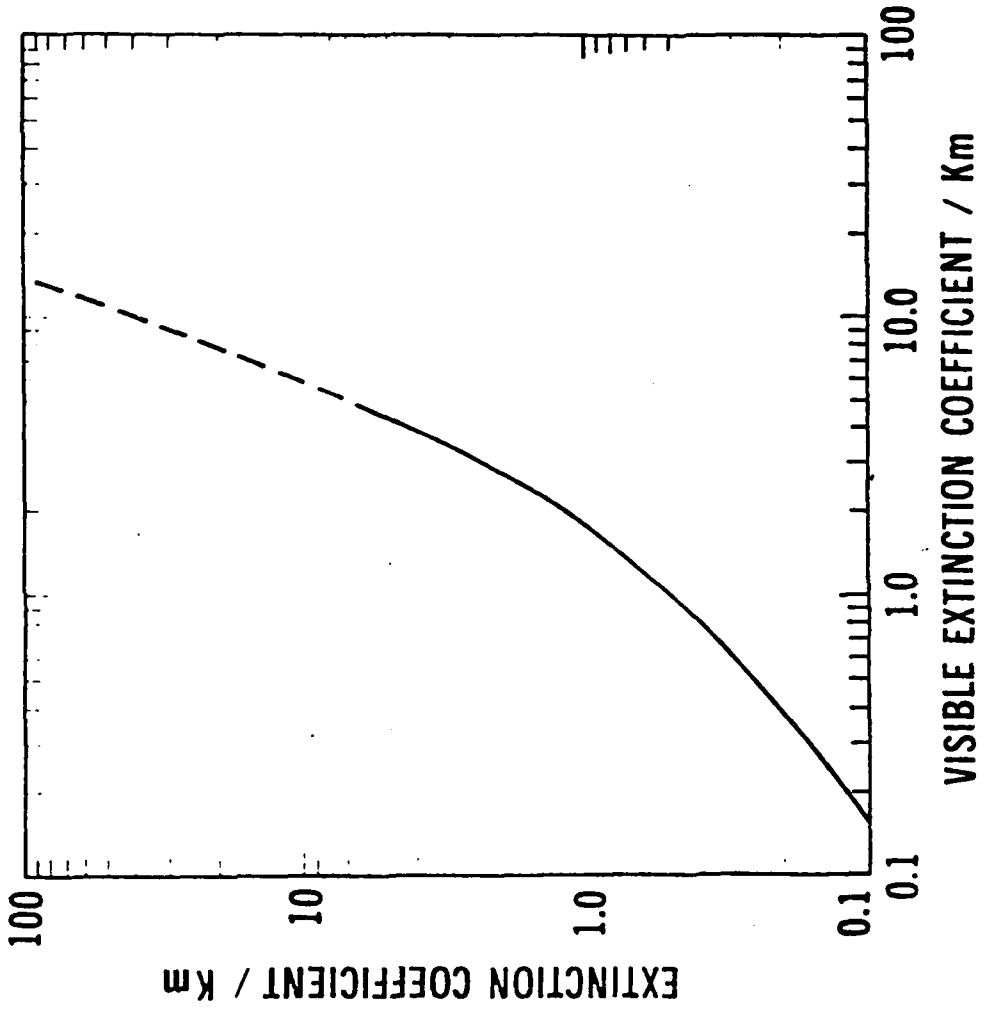


FIG. 6

EXTINCT .55 UM	EXTINCT 3-5 UM	EXTINCT 8-12UM.	DATE	FOG TYP
25.679993	0.0	13.200000	228	w
21.199997	0.0	10.099999	228	w
25.529999	0.0	21.709991	228	w
32.187957	0.0	17.159988	228	w
25.279990	17.309998	18.959991	228	w
22.079987	24.309998	15.070000	228	w
25.509995	26.609985	15.070000	228	w
21.759995	21.929993	12.700000	228	w
22.079987	22.619995	10.660000	228	w
21.099991	22.369995	12.790000	228	w
20.299988	19.649994	10.980000	228	w
16.609983	16.539999	9.330000	228	w
16.959991	17.009995	9.970000	228	w
15.270000	14.520000	8.129999	228	w
12.690000	11.710999	5.940000	228	w
10.450000	9.560000	4.639999	228	w
14.020000	12.780000	5.709999	228	w
19.589995	19.959991	10.360000	228	w
18.209991	17.709991	10.030000	228	w
20.649994	19.979996	11.080000	228	w
21.199997	18.599991	13.400000	228	w
11.910000	11.929999	5.790000	228	w
8.000000	7.429999	3.080000	228	w
6.480000	6.349999	1.169999	228	w
6.139999	4.450000	1.049999	228	w
8.049999	5.980000	1.690000	228	w
6.200000	5.009999	1.230000	228	w
5.099999	3.759999	0.820000	228	w
5.000000	2.929999	0.710000	228	w
3.580000	1.040000	0.360000	228	w
5.339999	4.690000	1.419999	228	w
9.610000	9.009999	2.940000	228	w
9.910000	10.320000	2.929999	228	w
11.870000	13.059999	4.339999	228	w
13.919999	16.919998	6.559999	228	w
14.719999	16.399994	7.009999	228	w
13.139999	12.389999	2.599999	228	w
16.369999	17.019999	4.100000	228	w
8.650000	7.440000	2.790000	228	w
7.290000	5.349999	2.009999	228	w
3.980000	1.770000	0.510000	228	w
2.219999	0.310000	0.280000	228	w
5.439999	4.049999	1.030000	228	w
4.040000	1.580000	0.610000	228	w
2.680000	0.400000	0.310000	228	w
4.259999	1.799999	0.610000	228	w
2.759999	0.310000	0.210000	228	w
1.919999	0.130000	0.120000	228	w
2.809999	0.300000	0.120000	228	w
2.809999	0.490000	0.170000	228	w
2.129999	0.220000	0.036000	228	w
1.030000	0.220000	0.036000	228	w
24.849999	24.000000	20.409999	301	w
25.639987	0.0	22.249995	301	w

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28.109935	0.0	24.149957	301	W
26.439957	0.0	21.119955	301	W
25.019957	0.0	17.759991	301	W
24.429950	0.0	25.959986	301	W
33.339946	0.0	27.429993	301	W
33.339946	0.0	24.439987	301	W
29.109985	0.0	20.750000	301	W
24.109935	0.0	17.319992	301	W
28.439990	0.0	13.299988	301	W
27.459951	0.0	14.879990	301	W
25.000000	0.0	16.379970	301	W
24.839946	23.609955	14.719999	301	W
22.109985	21.259995	13.290000	301	W
21.039993	21.159992	12.400000	301	W
24.199997	25.859995	14.150000	301	W
23.009995	25.799983	14.059999	301	W
25.849994	33.979996	15.710000	301	W
23.359985	25.369995	13.270000	301	W
23.469986	29.099991	12.540000	301	W
21.919995	22.000000	11.540000	301	W
20.259998	20.349991	10.570000	301	W
14.019935	20.199997	10.459999	301	W
17.519989	16.389999	10.250000	301	W
17.709991	16.569992	10.360000	301	W
16.609985	14.570000	10.259999	301	W
14.740000	12.400000	9.679999	301	W
13.339999	10.379999	8.360000	301	W
15.160000	12.310000	9.290000	301	W
13.919999	11.209999	8.660000	301	W
15.009999	11.759999	8.490000	301	W
14.360000	11.559999	8.790000	301	W
16.599991	15.540000	7.370000	301	W
17.069992	15.070000	7.900000	301	W
15.809999	13.509999	7.179999	301	W
20.089995	18.799988	7.799999	301	W
19.430000	13.919999	7.099999	301	W
14.740000	14.419999	7.520000	301	W
13.520000	12.099999	7.259999	301	W
13.469999	15.070000	7.339999	301	W
12.919999	9.570000	6.339999	301	W
12.780000	12.610000	6.679999	301	W
12.110000	5.430000	5.529999	301	W
11.469999	9.030000	5.730000	301	W
12.490000	10.150000	5.629999	301	W
11.040999	7.770000	5.059999	301	W
10.129999	5.959999	4.589999	301	W
10.669999	7.190000	4.320000	301	W
9.530000	5.959999	3.560000	301	W
9.110000	5.530000	4.120000	301	W
7.949999	5.129999	4.219999	301	W
10.569999	6.620000	3.290000	301	W
8.250000	5.410000	2.990000	301	W
9.320000	4.270000	2.509999	301	W
7.740000	3.200000	1.200000	301	W
5.759999	3.240000	0.900000	301	W
5.240000	2.190000	1.110000	301	W
4.350000	1.820000	1.110000	301	W
3.500000	1.120000	0.637000	301	W
3.730000	0.734000	0.431000	301	W
2.020000	0.300000	0.343000	301	W

1.520000	0.000000	0.021000	301	W
1.500000	0.000000	0.549000	3112	W
2.900000	0.600000	0.421000	3112	W
2.750000	0.500000	0.357000	3112	W
2.750000	0.500000	0.400000	3112	W
2.700000	0.300000	0.323000	3112	W
2.700000	0.500000	0.462000	3112	W
2.500000	0.200000	0.335000	3112	W
2.400000	0.300000	0.164000	3112	W
2.799999	0.700000	0.547000	3112	W
3.500000	1.400000	1.169000	3112	W
3.299999	1.200000	0.975000	3112	W
3.500000	1.350000	1.198999	3112	W
3.200000	1.000000	0.834000	3112	W
3.000000	0.850000	0.716000	3112	W
3.099999	1.000000	0.924000	3112	W
3.200000	1.100000	1.047000	3112	W
3.000000	1.200000	0.844000	3112	W
3.299999	1.000000	1.108000	3112	W
3.599999	2.200000	1.034999	3112	W
3.700000	1.900000	1.716000	3112	W
3.599999	2.050000	2.728999	3112	W
3.500000	1.800000	2.558999	3112	W
3.500000	2.100000	2.292000	3112	W
3.500000	1.900000	2.202999	3112	W
3.500000	1.400000	1.266999	3112	W
3.400000	1.400000	1.292999	3112	W
3.700000	2.000000	1.505000	3112	W
2.750000	2.200000	2.021000	3112	W
2.200000	1.700000	1.433999	3112	W
2.299999	1.800000	1.559999	3112	W
2.700000	2.200000	1.933999	3112	W
2.750000	2.000000	2.011000	3112	W
2.500000	2.300000	1.790000	3112	W
2.299999	2.100000	1.514000	3112	W
3.099999	3.200000	2.591999	3112	W
2.799999	1.800000	2.101000	3112	W
2.750000	2.100000	2.004999	3112	W
2.700000	1.700000	1.927999	3112	W
1.700000	0.100000	0.039000	3012	W
2.100000	0.300000	0.222000	3012	W
1.500000	0.200000	0.063000	3012	W
2.299999	0.380000	0.222000	3012	W
2.099999	0.200000	0.076000	3012	W
2.500000	0.600000	0.349000	3012	W
1.200000	0.0	0.184000	2912	W
1.200000	0.0	0.195000	2912	W
1.500000	0.0	0.235000	2912	W
1.900000	0.0	0.458000	2912	W
2.700000	0.0	0.403000	2912	W
4.000000	0.0	1.740000	2912	W
3.200000	0.400000	0.270000	1606	D
3.999999	4.000000	3.610000	1606	D
10.000000	6.700000	4.230000	1606	D
7.000000	3.500000	2.009999	1606	D
6.500000	2.700000	0.570000	1606	D
7.999999	0.000000	0.130000	1606	D
2.700000	0.100000	0.0	1606	D
3.100000	0.300000	0.070000	1606	D
10.000000	7.500000	4.370000	1606	D

15.109999	14.179999	3.740000	1606	D
13.200000	8.980000	5.839999	2810	D
15.209999	13.370000	3.339999	2810	D
11.320000	9.070000	4.879999	2810	D
5.059999	1.770000	0.930000	2810	D
11.650000	5.469999	3.900000	2810	D
11.370000	8.980000	5.379999	2311	D
11.079999	9.330000	6.190000	2810	D
12.410000	10.549999	6.570000	2311	D
18.069999	17.379999	13.200000	2311	D
13.590000	14.709999	9.009999	2311	D
13.110000	13.230000	7.730000	2311	D
13.590000	12.559999	8.809999	2311	D
12.020000	10.169999	6.230000	2311	D
11.520000	10.760000	5.770000	2311	D
2.109999	2.700000	2.379999	2710	W
2.059999	1.719999	1.799999	2710	W
4.309999	2.410000	2.379999	2710	W
5.079999	5.900000	5.990000	2710	W
5.990000	4.910000	4.349999	2710	W
2.730000	1.339999	2.440000	2710	W
6.759999	2.740000	0.570000	3005	W
5.240000	0.0	2.690000	211	W
4.620000	0.0	2.570000	211	W
5.280000	0.0	2.429999	211	W
4.959999	0.0	2.110000	211	W
2.259999	0.0	0.420000	211	W
1.549999	0.340000	0.0	211	W
1.419999	0.340000	0.0	211	W
7.799999	4.599999	4.500000	305	W
3.900000	2.200000	2.200000	305	W
1.159999	0.800000	0.590000	305	W
4.139999	0.420000	0.270000	305	W
3.049999	4.099999	3.610000	305	W
10.900000	6.770000	4.230000	305	W
7.679999	3.570000	2.009999	305	W
8.520000	0.910000	0.130000	305	W
11.709999	7.599999	4.370000	305	W
13.700000	14.179999	8.040000	305	W
10.920000	8.490000	7.340000	404	W
11.270000	9.969999	9.790000	404	W
12.030000	9.969999	9.500000	404	W
12.170000	10.719999	10.080000	404	W
12.470000	10.259999	8.449999	404	W
10.549999	10.690000	10.790000	404	W
11.379999	11.200000	10.860000	404	W
10.679999	9.830000	9.000000	404	W
0.240000	8.429999	7.959999	404	W
4.369999	9.570000	8.129999	404	W
9.039999	8.379999	7.700000	404	W
0.089999	9.160000	6.020000	404	W
0.360000	5.120000	4.490000	404	W
5.970000	4.669999	4.400000	404	W
5.559999	4.469999	4.399999	404	W
5.000000	4.059999	3.819999	404	W
4.730000	3.629999	3.270000	404	W
3.750000	2.860000	2.740000	404	W
5.000000	4.000000	3.730000	404	W
5.000000	3.879999	3.639999	404	W
5.000000	4.120000	3.790000	404	W

4.690000	3.770000	3.469999	404	W
2.579999	2.460000	2.570000	2505 ✓	W
3.910000	3.759999	3.959999	2505	W
4.090000	4.520000	4.330000	2505	W
3.220000	4.160000	3.960000	2505	W
3.300000	2.610000	2.059999	2505	W
22.699997	15.500000	17.099991	2605 ✓	W
19.099991	15.500000	14.099999	2605	W
19.099997	14.900000	13.599999	2605	W
20.000000	16.000000	14.599999	2605	W
21.799983	7.200000	10.199997	2605	W
15.000000	12.599999	0.0	2605	W
15.599999	11.500000	0.0	2605	W
15.900000	11.200000	0.0	2605	W
7.000000	12.000000	0.0	2605	W

N = 242

27 = 0.0

7 = 0.0

VISIBLE EXTINCTION	I.C.G. EXTINCTION		DATE OF EXPERIMENT
0.200000	0.120000	0.0	2106
0.280000	0.150000	0.0	1706
0.310000	0.190000	0.0	1706
0.330000	0.190000	0.0	1706
0.370000	0.190000	0.0	1706
0.350000	0.260000	0.0	2406
0.520000	0.190000	0.0	2306
0.520000	0.230000	0.0	2206
0.690000	0.280000	0.0	2206
0.690000	0.220000	0.0	2206
0.400000	0.330000	0.0	2106
0.410000	0.390000	0.0	2206
0.710000	0.330000	0.0	1706
0.420000	0.330000	0.0	1706
0.950000	0.300000	0.0	1706
1.500000	0.375000	0.0	1706
0.570000	0.420000	0.0	1606
0.615000	0.490000	0.0	2406
0.770000	0.440000	0.0	2206
0.820000	0.470000	0.0	1606
0.850000	0.470000	0.0	2106
1.099999	0.460000	0.0	2106
0.780000	0.560000	0.0	1506
0.890000	0.560000	0.0	2106
0.980000	0.520000	0.0	2406
1.000000	0.560000	0.0	1506
1.200000	0.520000	0.0	2406
1.540000	0.550000	0.0	2506
1.299999	0.620000	0.0	2806
1.400000	0.620000	0.0	2406
1.099999	0.650000	0.0	1606
1.290000	0.720000	0.0	1506
1.400000	0.780000	0.0	2406
1.299999	0.830000	0.0	1606
1.749999	0.725000	0.0	2406
2.200000	0.800000	0.0	2406
2.500000	0.820000	0.0	2406
1.900000	1.090000	0.0	1606
2.000000	1.099999	0.0	2106
1.560000	1.299999	0.0	2106
1.089999	1.400000	0.0	1506
2.299999	1.400000	0.0	1606
2.400000	1.500000	0.0	2106
2.299999	1.599999	0.0	2106
2.500000	1.700000	0.0	1506
2.900000	1.700000	0.0	1506
3.440000	1.700000	0.0	1506
1.000000	1.299999	0.0	1606
1.200000	1.299999	0.0	1606
1.200000	1.400000	0.0	1606
2.400000	1.099999	0.0	1706
1.000000	2.099999	0.0	1606
1.749999	2.400000	0.0	1506
4.000000	2.599999	0.0	1506
1.400000	2.900000	0.0	2106
1.500000	2.599999	0.0	1506
4.000000	3.200000	0.0	1606
3.750000	3.249999	0.0	1506
5.739999	6.450000	0.0	1606
7.000000	7.450000	0.0	1506

TABLE II

1.900000	1.200000	0.0	2706
1.200000	1.000000	0.0	2706
1.500000	1.000000	0.0	2706
1.900000	1.500000	0.0	2706
1.900000	1.500000	0.0	2706
2.500000	2.000000	0.0	2706
1.500000	0.850000	0.0	1606
1.500000	0.850000	0.0	2706
1.700000	0.940000	0.0	2706
5.000000	3.700000	0.0	2706
2.200000	0.740000	0.0	2706
1.500000	0.700000	0.0	2706
1.700000	0.700000	0.0	2706
2.700000	2.000000	0.0	2706
2.900000	1.950000	0.0	2706
2.799000	2.049000	0.0	2706
3.000000	2.200000	0.0	2706
3.400000	2.450000	0.0	2706
3.700000	2.549000	0.0	1306
3.900000	2.799000	0.0	1306
4.000000	3.000000	0.0	1306
5.000000	3.700000	0.0	1306
5.200000	4.000000	0.0	1306
7.200000	6.500000	0.0	1306

N = 85 POINTS.

TABLE II

1.06 μm vs VISIBLE

EXTINCTION DATA