

TARGET ATMOSPHERES for use in DWL CONCEPT STUDIES

Submitted to the
New Millennium Program

by
An Ad Hoc Committee:

[G.D. Emmitt](#), Lead
Simpson Weather Associates, Charlottesville, VA

J. Spinhirne
NASA/GSFC, Greenbelt, MD

R. Menzies
NASA/JPL, Pasadena, CA

D. Winker
NASA/LaRC, Hampton, VA

D. Bowdle
NASA/GHCC, Huntsville, AL

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The following material was put together in its original form at the request of the participants of the March 1997 NMP Lidar Workshop held in Washington, D.C. Subsequently, revisions have been made, in part, in response to request for more complete representation of the attenuation coefficients.

Having a common scattering target with internally consistent backscatter wavelength dependence would allow more meaningful "equal resource/equal target" comparisons of DWL concepts. While the Ad Hoc group realizes that aerosol backscatter from the

atmosphere will vary over several orders of magnitude, will vary over altitude, latitude and season and will also vary over space/time scales that are not readily modeled, the GLOBE and SABLE/GABLE backscatter surveys have yielded a somewhat consistent picture of backscatter climatology. To meet the request for a set of bounding profiles, we have chosen (1) the "background" distribution of $b(p)$ that appears in most stacked histograms of the GLOBE/SABLE/GABLE data sets and (2) the distribution of "enhanced" backscatter opportunities that are most apparent during the summer seasons and more common in the northern hemisphere. The background mode value should not be interpreted as representing the minimum value of the aerosol cross section to be found. Rather, it represents a low cross section modal peak for aerosols in tropospheric air that does not have loading enhancement due to identifiable aerosol transport. There is a distribution of values and measurements indicating that the lowest aerosol cross sections can be an order of magnitude lower than the mode in some cases. The actual distribution of cross sections in the background mode are not well known. Measurements indicate that the background aerosol mode is present in large regions of the globe, mostly in the upper troposphere but can also be found in the boundary layer. The global distribution of these modes is not known, nor is the correlation of these modes with regions of ageostrophy. Therefore, these profiles should only be used to develop system point designs for concept evaluation and comparisons.

It is expected that these profiles will be used to simulate the performance of a DWL concept at each altitude. For example, for an altitude of 8 km, the simulation of a $.355 \mu\text{m}$ system scanned at 45° nadir should produce two distributions of velocity errors as a function of $b(p)$ with a 2-way transmission of .489, a mean velocity of $25 \text{ m}^{-1} \text{ s}^{-1}$, a layer mean shear of 32.0 E-3 s^{-1} , and a "shot scale" turbulence with a standard deviation of 2 m s^{-1} . The first distribution would be for the "background" aerosol mode that has a geometric mean of $4.4 \text{ E-8 m}^{-1} \text{ sr}^{-1}$ and a width of $\ln(s) = .8$. The second distribution would be for the "enhanced" aerosol mode with a geometric mean of 2.5 E-7 and a width of $\ln(s) =$

1.0. A complete description of the point design including the energy/pulse, prf, integration time, mirror diameter, etc. should accompany any presentation of the simulated results.

This effort to provide some common reference atmospheres is on-going. Any suggestion for improving these profiles and/or their application should be communicated to the NMP or gde@swa.com

TARGET ATMOSPHERES $\lambda = 1.06 \mu\text{m}$ (9433.96 cm^{-1})

	BACKGROUND ¹		ENHANCED ²		WINDS		Molecular	Clouds
Altitude ³	$b_a^{4,4}$	a^5	$b_a^{6,6}$	a^7	u^8	$S_u^{9,9}$	b_m^{10}	$t, \%^{11}$
25	8.0 E-9	.42 E-3	8.0 E-9	.42 E-3	15	1	.33 E-8	
24	8.0 E-9	.89 E-3	8.0 E-9	.48 E-3	15	1	.39 E-8	
23	8.0 E-9	.44 E-3	8.0 E-9	.44 E-3	15	1	.46 E-8	
22	8.0 E-9	.45 E-3	8.0 E-9	.45 E-3	15	1	.53 E-8	
21	8.0 E-9	.46 E-3	8.0 E-9	.46 E-3	15	1	.63 E-8	
20	8.0 E-9	.47 E-3	8.0 E-9	.47 E-3	15	1	.73 E-8	
19	8.0 E-9	.49 E-3	8.0 E-9	.49 E-3	15	1	.86 E-8	
18	8.0 E-9	.52 E-3	8.0 E-9	.52 E-3	15	1	1.0 E-8	
17	8.0 E-9	.54 E-3	8.0 E-9	.54 E-3	15	1	1.2 E-8	
16	8.0 E-9	.55 E-3	8.0 E-9	.55 E-3	15	1	1.4 E-8	
15	8.0 E-9	.56 E-3	8.0 E-9	.56 E-3	18	1	1.6 E-8	
14	6.0 E-9	.47 E-3	6.0 E-9	.47 E-3	22	1	1.9 E-8	
13	4.0 E-9	.38 E-3	4.0 E-9	.38 E-3	26	1	2.2 E-8	
12	3.6 E-9	.38 E-3	8.0 E-9	.60 E-3	28	2	2.5 E-8	
11	3.3 E-9	.38 E-3	1.4 E-8	.95 E-3	35	5	2.8 E-8	
10	3.2 E-9	.42 E-3	4.0 E-8	.24 E-2	50	10	3.2 E-8	.14,100
9	3.1 E-9	.36 E-3	4.8 E-8	.24 E-2	40	5	3.5 E-8	
8	3.0 E-9	.27 E-3	5.4 E-8	.27 E-2	25	2	4.0 E-8	
7	2.8 E-9	.13 E-3	6.0 E-8	.27 E-2	18	1	4.5 E-8	
6	2.5 E-9	.49 E-3	7.0 E-8	.35 E-2	16	1	5.0 E-8	
5	2.5 E-9	.57 E-3	7.8 E-8	.39 E-2	14	1	5.5 E-8	

4	2.9 E-9	.13 E-3	7.6 E-8	.33 E-2	13	1	6.2 E-8	
3	3.4 E-9	.15 E-3	7.0 E-8	.31 E-2	12	1	6.8 E-8	5,50
2	7.0 E-9	.23 E-3	7.0 E-8	.23 E-2	11	1	7.4 E-8	
1	5.0 E-8	.16 E-2	5.0 E-7	.16 E-1	10	2	8.3 E-8	
Surface	1.0 E-7	.32 E-2	1.0 E-6	.32 E-2	2	1	9.1 E-8	

TARGET ATMOSPHERES $\lambda = 2.0518 \mu\text{m}$ (4873.77cm⁻¹)

	BACKGROUND ¹		ENHANCED ²		WINDS		Molecular	Clouds
Altitude ³	b _a ^{4 4}	a ⁵	b _a ^{6 6}	a ⁷	u ⁸	S _u ⁹⁹	b _m ¹⁰	t, % ¹¹
25	1.4 E-9	.15 E-3	1.4 E-9	.15 E-3	15	1	.23 E-9	
24	1.4 E-9	.28 E-4	1.4 E-9	.28 E-4	15	1	.28 E-9	
23	1.4 E-9	.66 E-4	1.4 E-9	.66 E-4	15	1	.32 E-9	
22	1.4 E-9	.38 E-4	1.4 E-9	.38 E-4	15	1	.38 E-9	
21	1.4 E-9	.33 E-4	1.4 E-9	.33 E-4	15	1	.44 E-9	
20	1.4 E-9	.77 E-4	1.4 E-9	.77 E-4	15	1	.52 E-9	
19	1.4 E-9	.15 E-4	1.4 E-9	.15 E-4	15	1	.61 E-9	
18	1.4 E-9	.89 E-4	1.4 E-9	.89 E-4	15	1	.71 E-9	
17	1.4 E-9	.13 E-4	1.4 E-9	.13 E-4	15	1	.84 E-9	
16	1.4 E-9	.30 E-3	1.4 E-9	.30 E-3	15	1	.98 E-9	
15	1.4 E-9	.11 E-3	1.4 E-9	.11 E-3	18	1	1.1 E-9	
14	1.0 E-9	.11 E-2	1.0 E-9	.11 E-2	22	1	1.3 E-9	
13	7.0 E-10	.31 E-3	7.0 E-10	.31 E-3	26	1	1.6 E-9	
12	6.2 E-10	.73 E-4	2.8 E-9	.12 E-3	28	2	1.8 E-9	
11	5.9 E-10	.91 E-3	4.8 E-9	.99 E-3	35	5	2.0 E-9	
10	5.5 E-10	.11 E-2	1.5 E-8	.14 E-2	50	10	2.3 E-9	.14,100
9	5.4 E-10	.19 E-2	1.6 E-8	.24 E-2	40	5	2.6 E-9	
8	5.3 E-10	.33 E-2	1.8 E-8	.39 E-2	25	2	2.9 E-9	
7	5.1 E-10	.33 E-2	2.1 E-8	.39 E-2	18	1	3.2 E-9	
6	4.5 E-10	.40 E-2	2.5 E-8	.48 E-2	16	1	3.5 E-9	
5	4.4 E-10	.63 E-2	2.9 E-8	.72 E-2	14	1	4.0 E-9	
4	5.1 E-10	.74 E-2	3.0 E-8	.83 E-2	13	1	4.4 E-9	
3	5.6 E-10	.10 E-1	2.8 E-8	.11 E-1	12	1	4.9 E-9	5,50

2	3.5 E-9	.20 E-2	3.0 E-8	.34 E-2	11	1	5.4 E-9	
1	2.5 E-8	.16 E-1	2.5 E-7	.28 E-1	10	2	5.9 E-9	
Surface	5.0 E-8	.23 E-1	5.0 E-7	.48 E-1	2	1	6.6 E-9	

TARGET ATMOSPHERES $\lambda = .355 \mu\text{m}$ (28169 cm^{-1})

	BACKGROUND ¹		ENHANCED ²		WINDS		Molecular	Clouds
Altitude ³	b _a ⁴	a ⁵	b _a ⁶	a ⁷	u ⁸	s _u ⁹	b _m ¹⁰	t, % ¹¹
25	1.2 E-7	.21 E-1	1.2 E-7	.21 E-1	15	1	.29 E-6	
24	1.2 E-7	.69 E-2	1.2 E-7	.69 E-2	15	1	.33 E-6	
23	1.2 E-7	.73 E-2	1.2 E-7	.73 E-2	15	1	.40 E-6	
22	1.2 E-7	.79 E-2	1.2 E-7	.79 E-2	15	1	.46 E-6	
21	1.2 E-7	.86 E-2	1.2 E-7	.86 E-2	15	1	.54 E-6	
20	1.2 E-7	.94 E-2	1.2 E-7	.94 E-2	15	1	.64 E-6	
19	1.2 E-7	.11 E-1	1.2 E-7	.11 E-1	15	1	.75 E-6	
18	1.2 E-7	.12 E-1	1.2 E-7	.12 E-1	15	1	.88 E-6	
17	1.2 E-7	.13 E-1	1.2 E-7	.13 E-1	15	1	1.0 E-6	
16	1.2 E-7	.15 E-1	1.2 E-7	.15 E-1	15	1	1.2 E-6	
15	1.2 E-7	.17 E-1	1.2 E-7	.17 E-1	18	1	1.4 E-6	
14	9.0 E-8	.17 E-1	9.0 E-8	.17 E-1	22	1	1.7 E-6	
13	6.0 E-8	.18 E-1	6.0 E-8	.18 E-1	26	1	1.9 E-6	
12	5.4 E-8	.20 E-1	5.4 E-8	.20 E-1	28	2	2.2 E-6	
11	5.2 E-8	.22 E-1	7.0 E-8	.23 E-1	35	5	2.5 E-6	
10	4.8 E-8	.24 E-1	2.0 E-7	.30 E-1	50	10	2.8 E-6	.14,100
9	4.6 E-8	.27 E-1	2.3 E-7	.34 E-1	40	5	3.2 E-6	
8	4.4 E-8	.29 E-1	2.5 E-7	.37 E-1	25	2	3.5 E-6	
7	4.1 E-8	.31 E-1	3.0 E-7	.42 E-1	18	1	3.9 E-6	
6	3.8 E-8	.36 E-1	3.5 E-7	.48 E-1	16	1	4.4 E-6	
5	3.7 E-8	.40 E-1	4.0 E-7	.54 E-1	14	1	4.9 E-6	
4	4.2 E-8	.38 E-1	4.0 E-7	.52 E-1	13	1	5.4 E-6	
3	4.9 E-8	.38 E-1	3.5 E-7	.49 E-1	12	1	5.9 E-6	5,50
2	7.0 E-8	.46 E-1	3.5 E-7	.52 E-1	11	1	6.6 E-6	
1	1.5 E-7	.37 E-1	1.5 E-6	.67 E-1	10	2	7.2 E-6	

Surface	3.0 E-7	.32 E-1	3.0 E-6	.90 E-1	2	1	8.1 E-6	
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CAVEATS

1. These atmospheres are meant only for the purpose of enabling "equal target" comparisons of different DWL concepts and their potential LOS data products. Emphasis is on measurement accuracy and not representativeness or coverage. Furthermore, there is no claim to the frequency of occurrence of the two backscatter modes.
2. The wavelength dependency of the backscatter coefficient across the 1-2 orders of magnitude width of the background mode is thought to vary from I^{-3} on the left side (lower on the left side (lower b) to $I^{-1.5}$ on the right side (higher on the right side (higher b)). A $I^{-2.5}$ was used in these tables going from 1.06 μm data to 2.0518 and .355 μm at and above 3 km. Since a different was used in these tables going from 1.06 μm data to 2.0518 and .355 μm at and above 3 km. Since a different I coefficient was used below 3 km, some smoothing of the resulting profiles has been done to make the transition more realistic.
3. Issues related to sampling and averaging (or co-processing) within regions of realistic wind variability are not addressed with these reference atmospheres. Significant differences will result from different scanning patterns and laser shot densities.

Superscripts in Target Atmosphere Tables

¹based upon GLOBE data representing the "background" aerosol mode found in both northern and southern hemisphere data sets.

²based upon GLOBE data taken during periods when aerosol backscatter was clearly enhanced over the background cases. Enhancement includes effects of elevated dust layers, convective pumping, biomass burning, etc.

³number is taken to be the midpoint of the layer; data is at midpoint of layer except for surface wind which is taken to be at 10 m (units: km).

⁴assumed to be the geometric mean of a lognormal distribution of GLOBE "background" aerosol mode data with $\ln(s) = .8$ (units: $\text{m}^{-1} \text{sr}^{-1}$).

⁵total attenuation coefficient (aerosol scattering, aerosol absorption, molecular scattering, molecular absorption) based on MODTRAN (units: km^{-1}). Specific molecular line absorption may be somewhat different for a precise wavelength.

⁶geometric mean of the backscatter events that are in excess of the "background" aerosol mode of backscatter, sometimes referred to as the convective mode. $\ln(s)$ is assumed to be 1.0

⁷same explanation as in 5 above

⁸based upon global averages from ECMWF T106 Nature Run; exception is the jet superimposed at 10 km (units: m s^{-1})

⁹"reasonable" values of s_v (horizontal) on scales less than 10 km

¹⁰molecular backscatter $b(p)$ taken from MODTRAN (units: $\text{m}^{-1} \text{sr}^{-1}$)

¹¹Clouds are expressed in terms of their optical depth (t) and the percent coverage of the Target Sample Volume(TSV). The physical thickness is assumed to be 1 km (eg. cloud listed at 10km is located between 9 and 10km). The cloud between 2 and 3km is assumed to be composed of scattered small clouds that have horizontal dimensions equal to the spacing between individual lidar shots. Thus each shot has the same probability of being terminated by a cloud.

General: all b_a 's are derived from the 1.06 GLOBE data in the following way:

"BACKGROUND (CLEAN)"

1.06 @ 2.06 $b(2.06)/b(1.06) = .18$ above 2 km; .5 at and below 2 km

1.06 @ .355 $b(.355)/b(1.06) = 15.0$ above 2 km; 3.0 at and below 2 km

"ENHANCED"

1.06 @ 2.06 $b(2.06)/b(1.06) = .18$ (13-15 km); .35 (3-12 km); .5 at and below 2 km

1.06 @ .355 $b(.355)/b(1.06) = 1.5$ (13-15 km); 5.0 (3-12 km); 3.0 at and below 2 km

SUGGESTED OPTIONS FOR BASELINE ASSUMPTIONS

FOR CONCEPT COMPARISONS

1. Orbit altitudes:

300 km (shuttle)

450 km (free flyer)

833 km (operations platform)

2. Nadir viewing angles:

30 deg

45 deg

3. Optical output:

1 watt

10 watts

50 watts

4. Mirror diameter:

.5 meter

1 meter

2 meters

5. Step-stare scanning (no angular change in perspective between co-processed shots)

6. Target volumes:

.25 x 100 x 100 km below 3 km

1 x 100 x 100 km at and above 3 km