Revisiting Target Atmospheres for Space-based DWL Concept Comparisons

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Outline

- Background on Target Atmospheres
- Comparison with ESA’s data base
- Comparison with FASCODE/MODTRAN
- Wavelength scaling
- Role in OSSEs
- Areas for enhancement
  - Depolarization
  - Solar background
  - Multiple air-mass classifications

Background on Target Atmospheres

- Developed in 1997 for use in trade studies and comparisons of DWLs operating at differing wavelengths.
- Co-authored by Emmitt, Spinhirne, Menzies, Winker and Bowdle
- Published on www.swa.com
- Underwent several revisions as new data with 2 um, 1.06 um and .532 um observations became available.

TARGET ATMOSPHERES
for use in
DWL CONCEPT STUDIES

Submitted to the
New Millennium Program

by
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March 28, 1997 (1st draft)
May 2, 1997 (2nd draft)
July 23, 1997 (3rd draft)
February 2, 1998 (4th draft with edits by gde)
August 10, 2001(Edits by gde)

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.

Current Target Atmospheres

- The basic backscatter profiles from surface to 25 km were scaled from .532 GLOBE observations. Molecular backscatter, total scatter, attenuation were derived using FASCODE.
- Angstrom exponents used: $\lambda^{-2.5}$ above 3 km and $\lambda^{-1.5}$ at and below 3 km.
- Added some cloud and wind turbulence for use in instrument trade studies.

DESIGN ATMOSPHERES

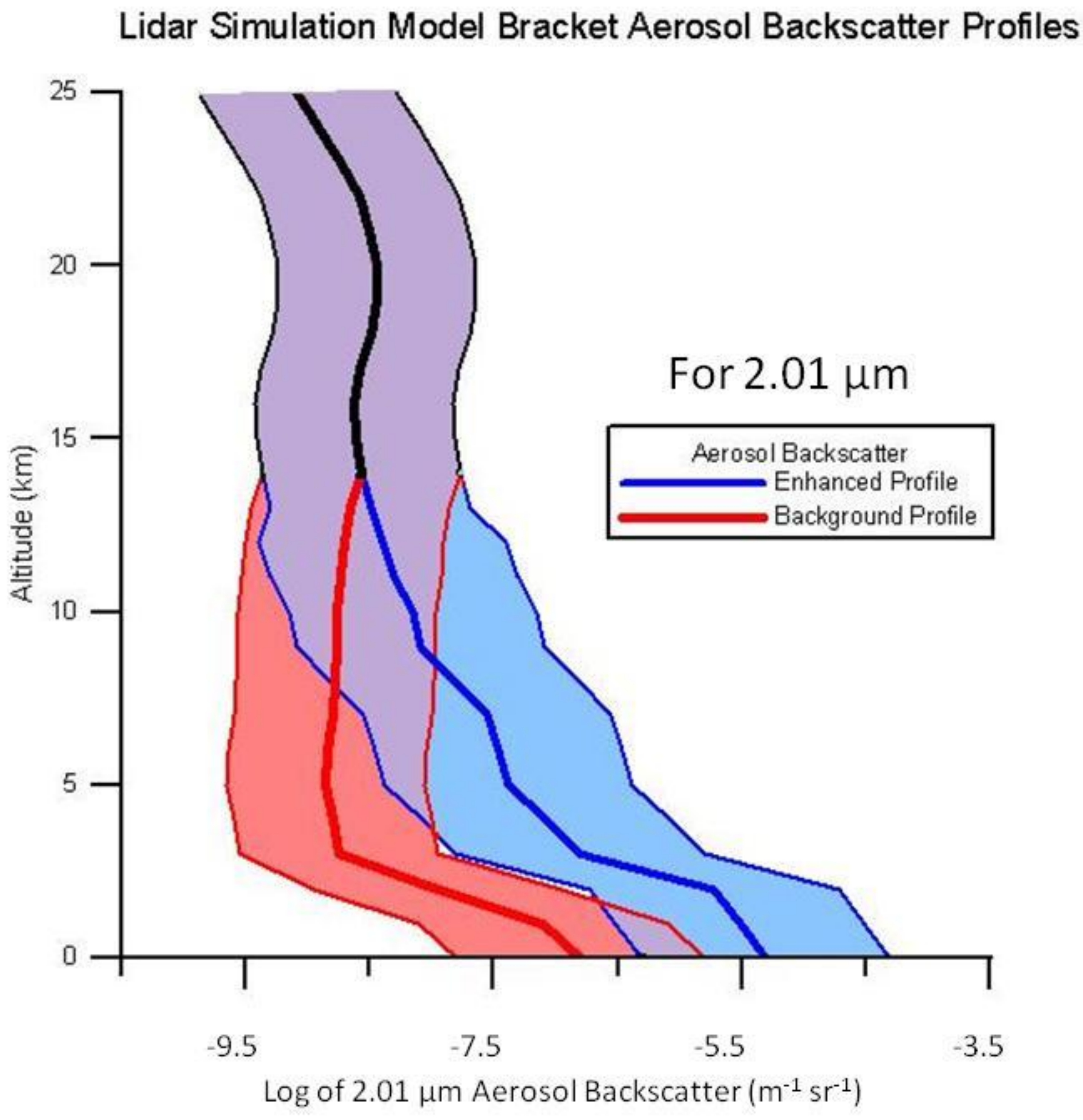
for use in
GTWS CONCEPT STUDIES**

provided by the
Science Definition Team
for the NASA/NOAA
Global Tropospheric Wind Sounder

September 22, 2001

Purpose

Having a common scattering target with internally consistent backscatter wavelength dependence enables meaningful "equal resource/equal target“ comparisons of GTWS concepts that employ Doppler lidars. While the Science Definition Team (SDT) 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 , SABLE/GABLE backscatter surveys, and the AFGL MODTRAN aerosol data bases provide a nearly consistent picture of backscatter climatology.



Lidar Simulation Model Bracket Aerosol Backscatter Profiles
For 2.01 µm
Aerosol Backscatter
Enhanced Profile
Background Profile
Altitude (km)
25
20
15
10
5
0
-9.5
-7.5
-5.5
-3.5
Log of 2.01 µm Aerosol Backscatter (m-1 sr-1)

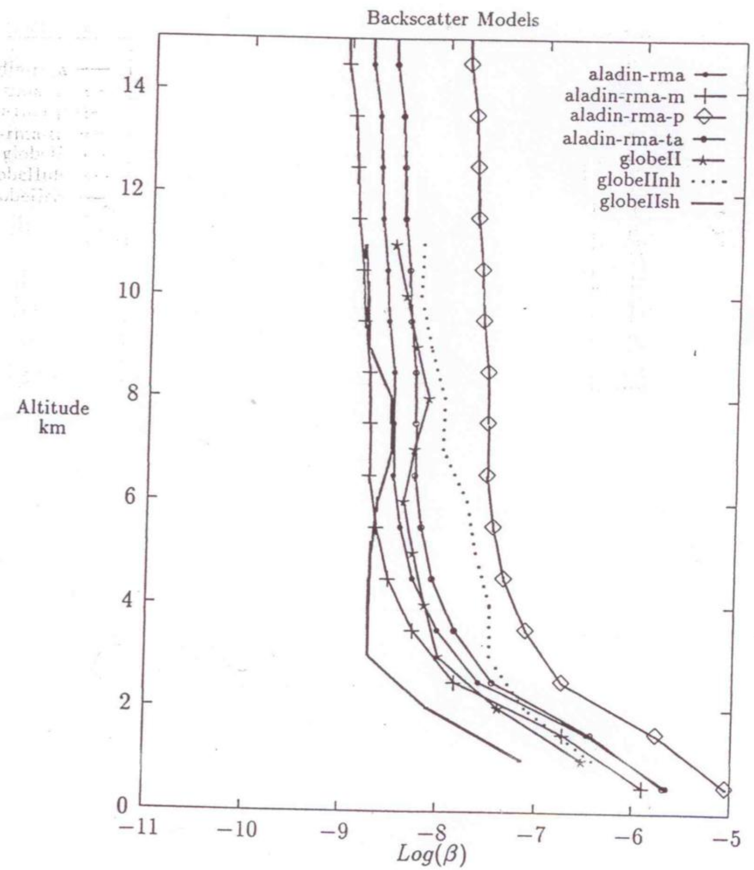
Comparison with ESA's Data Base

Establishment of a backscatter coefficient and atmospheric database

Work performed with funding from ESA to DERA

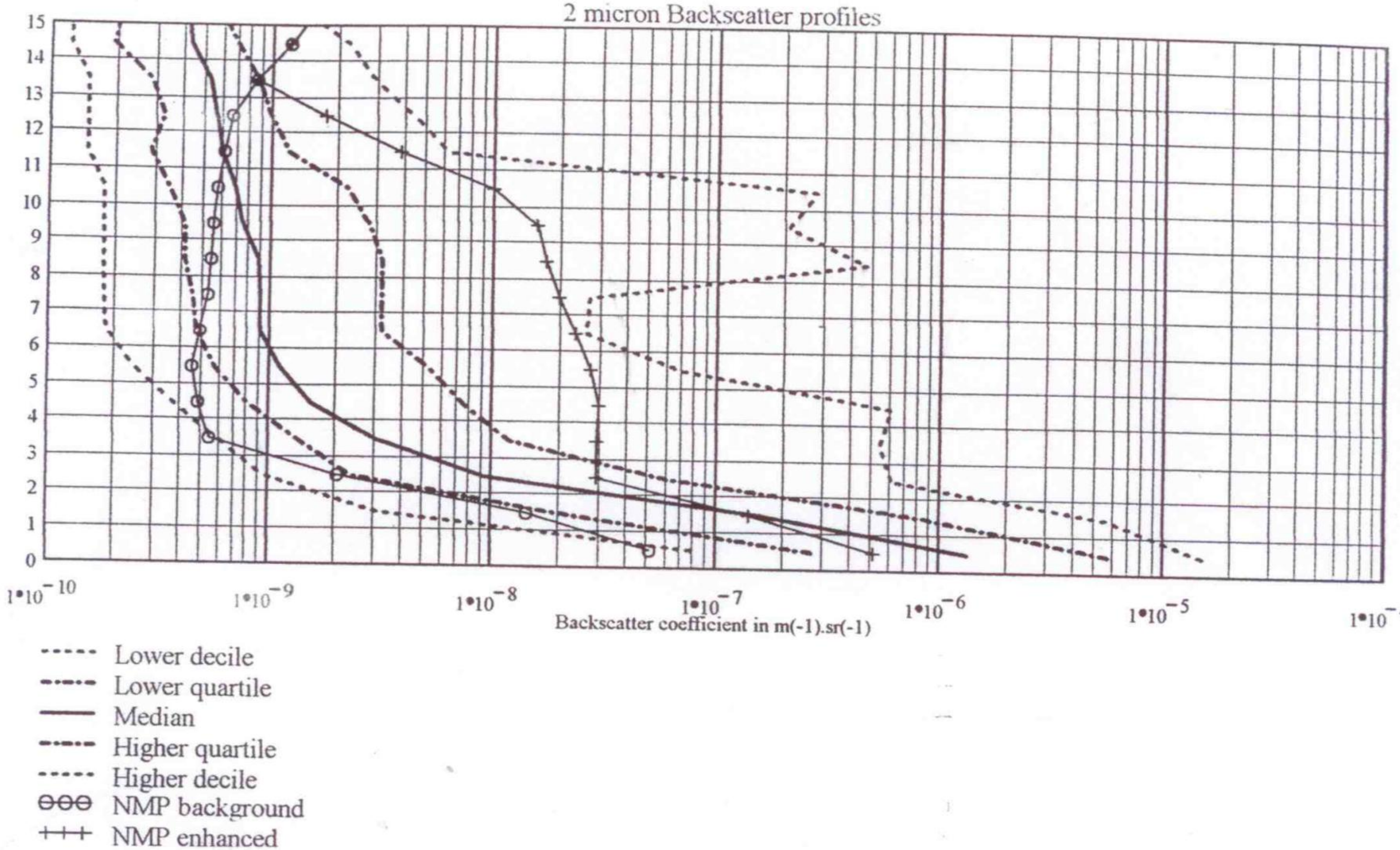
J. M. Vaughan, N. J. Geddes, Pierre H. Flamant and C. Flesia

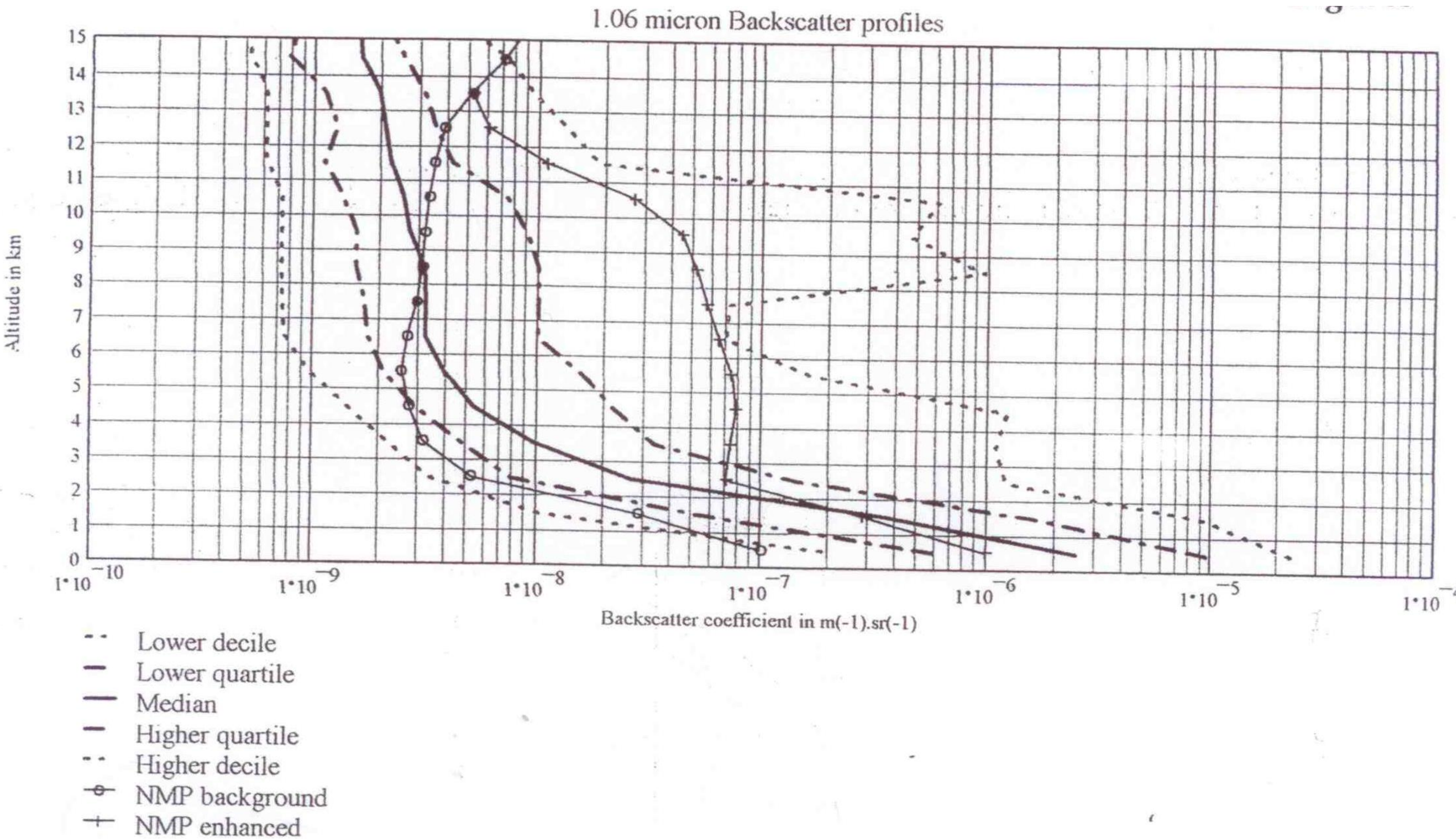
June 1998

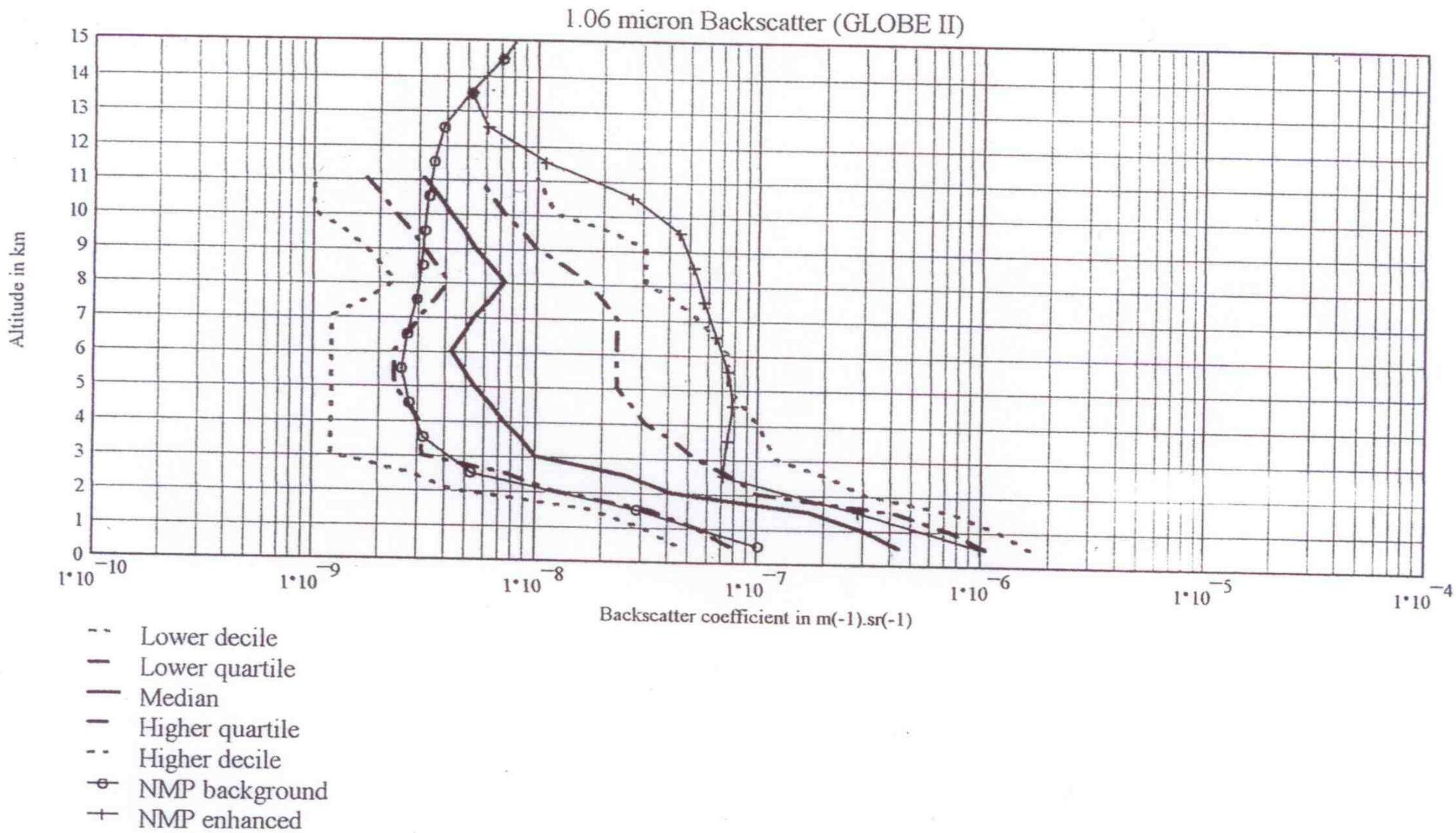


e 3.10: Comparison of aerosol backscatter models at 1.06 μm - profiles of median values:

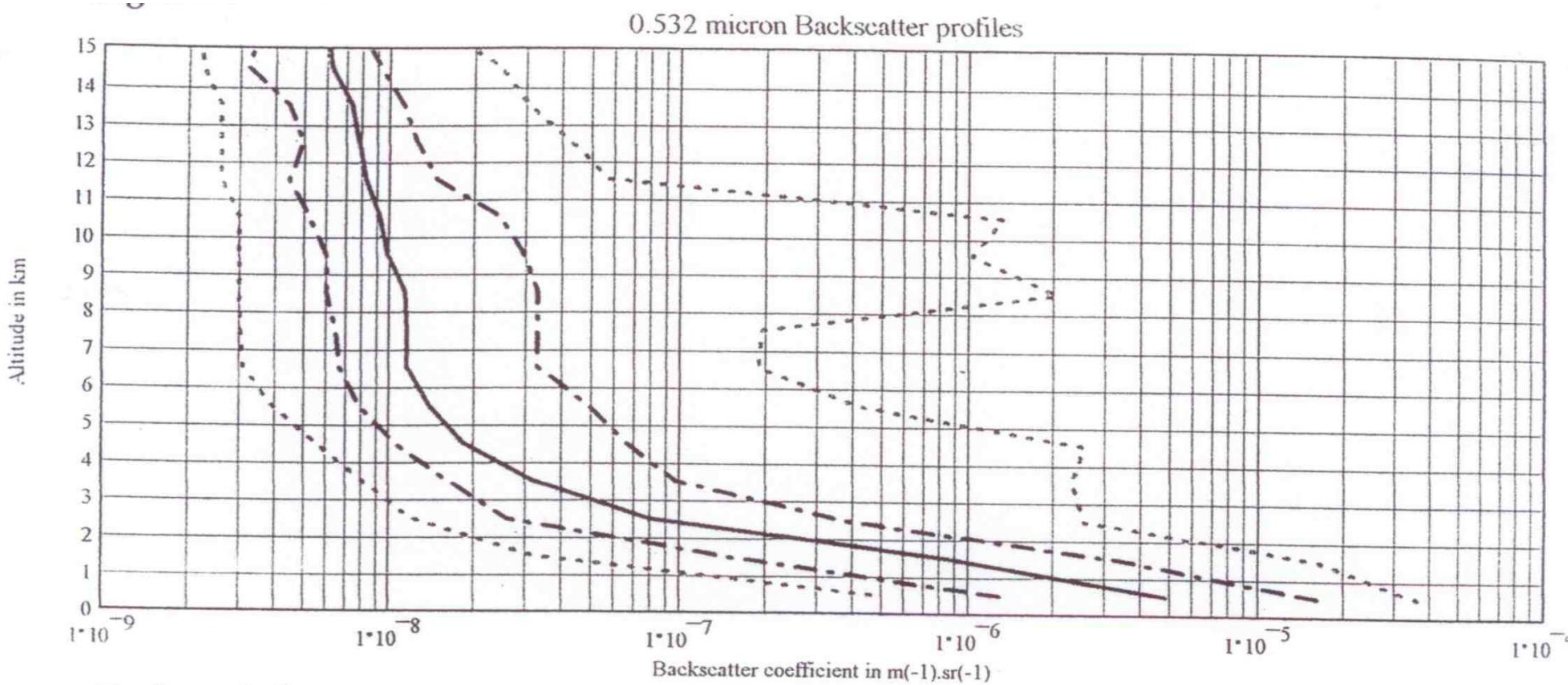
aladin - rma correspond to ALADIN-RMA backscatter
aladin - rma - m to ALADIN-RMA-Minus
aladin - rma - p to ALADIN-RMA-Plus
aladin - rma- ta to ALADIN-RMA-TA
globe II to GLOBE II (May-June 1990)
globe II nh to GLOBE II (Northern Hemisphere)
globe II sh to GLOBE II (Southern Hemisphere).


2 micron Backscatter profiles
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
$1 \cdot 10^{-10}$
$1 \cdot 10^{-9}$
$1 \cdot 10^{-8}$
$1 \cdot 10^{-7}$
$1 \cdot 10^{-6}$
$1 \cdot 10^{-5}$
$1 \cdot 10^{-4}$
Backscatter coefficient in m(-1).sr(-1)
Lower decile
Lower quartile
Median
Higher quartile
Higher decile
NMP background
NMP enhanced


1.06 micron Backscatter profiles
Altitude in km
Backscatter coefficient in m(-1).sr(-1)
Lower decile
Lower quartile
Median
Higher quartile
Higher decile
NMP background
NMP enhanced



1.06 micron Backscatter (GLOBE II)
Altitude in km
Backscatter coefficient in m(-1).sr(-1)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
$1 \cdot 10^{-10}$
$1 \cdot 10^{-9}$
$1 \cdot 10^{-8}$
$1 \cdot 10^{-7}$
$1 \cdot 10^{-6}$
$1 \cdot 10^{-5}$
$1 \cdot 10^{-4}$
Lower decile
Lower quartile
Median
Higher quartile
Higher decile
NMP background
NMP enhanced



- - Lower decile
— Lower quartile
— Median
— Higher quartile
- - Higher decile

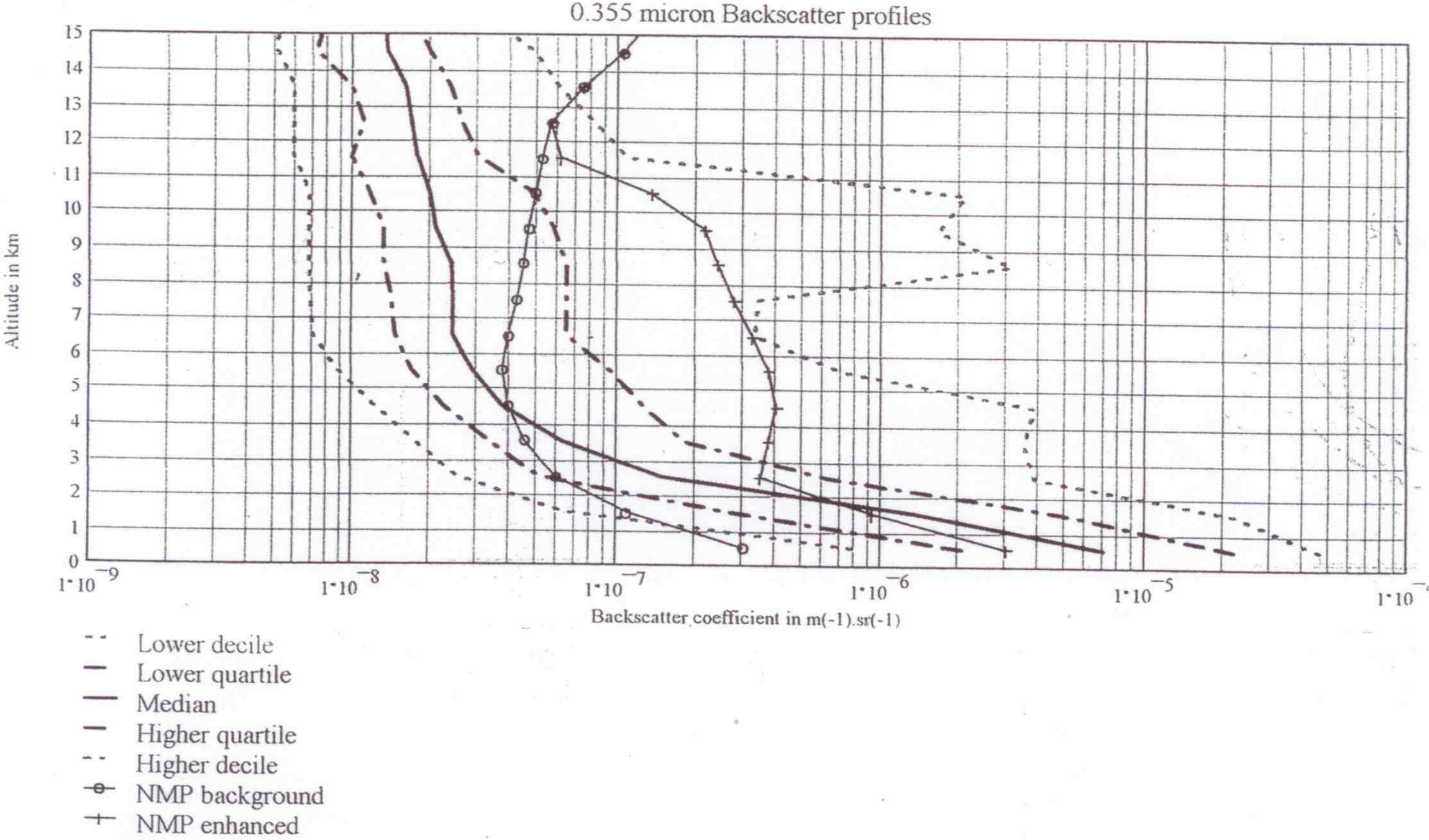


Figure 3.7: (A) Upper: 0.53 μm backscatter profiles derived from the 10.6 μm data of Table 3.1 and Equation 3.5 - see also Table 3.10.

(B) Lower: 035 μm backscatter profiles derived from the 10.6 μm data of Table 3.1 and equation 3.5 - see also Table 3.11 The NMP enhanced and background profiles are also shown for comparison at 0.35 μm [Emmit et al 1998]

2.5.8 The conversion factor of backscatter at 10.6 μm from backscatter measurements at 1.06 μm (Nd-YAG lidar) and 0.69 μm (Ruby lidar), or extinction at 1.0 μm has been studied numerically for different volcanic aerosols i.e. background prevolcanic, post-St. Helens, early post-El Chichon, late post-El Chichon [Kent and Yue, 1991]. The results are presented in Table 2.2.

Table 2.2

Aerosols type	References	$\beta_{10.6}/\beta_{0.69}$ x10^{-2}	$\beta_{10.6}/\beta_{1.06}$ x10^{-2}	$\beta_{10.6}/\alpha_{1.0}$ x10^{-4} sr^{-1}
Background prevolcanic	[Gras and Michael, 1979]	0.33	0.66	0.94
Post-St. Helens	[Hofmann and Rosen,1982]	0.91	1.73	3.12
Early post-El Chichon	[Hofman and Rosen, 1983]	1.60	2.86	5.11
Late post-El Chichon	[Osborn et al, 1989]	0.49	1.00	1.49
Late post- El Chichon	[Oberbeck et al, 1989]	0.38	0.77	0.97

Comparison with FASCODE

- Many engineers use MODTRAN/FASCODE in assessing performance of DWL concepts.
- With a focus on the aerosol returns from the lower troposphere, we find that FASCODE/MODTRAN provides backscatter values ~ 10 – 30 times higher than those in our Target Atmospheres' "background mode".

Comparisons at 1 km and .355um

	NMP(back)	NMP(enh)	MODTRAN (Maritime 23km)	ESA
Beta (a)	1.5E-7	1.5E-6	5.5E-6	1.5E-6

Scaling Issues

- Scaling expressed using an Angstrom Exponent or a Color Ratio.
- Much of ESA's backscatter database derived from 10.6 um observations in SABLE and GABLE in the Atlantic in 1988-1990 using a simple expression for the Angstrom Exponent.
- NMP's Target Atmospheres derived from 1.06 um and .532um observations made in GLOBE 1990 over the Pacific using two differing Angstrom Exponents.
- The following few slides are based upon modeling done with NASA/ROSES funding for the analyses of CALIPSO data. Modeling done by Kirk Fuller (UAH)

General Format for Color Ratios

Channel	1	2	3	4
1	1.0	β_{12}	β_{13}	β_{14}
2	$1/\beta_{12}$	1.0	β_{23}	β_{24}
3	$1/\beta_{13}$	$1/\beta_{23}$	1.0	β_{34}
4	$1/\beta_{14}$	$1/\beta_{24}$	$1/\beta_{34}$	1.0

1 .355um
2 .532
3 1.06
4 2.06

For reference: using $\lambda^{-2.5}$; β_{14} = 81.1
using $\lambda^{-1.5}$;β_{14} =13.9

β_i / β_j for Fine Dust

Channel	1	2	3	4
1	1.0	2.60	7.81	56.40
2		1.0	3.00	21.66
3			1.0	7.22
4				1.0

β_i / β_j for Coarse Dust

Channel	1	2	3	4
1	1.0	1.02	1.21	1.19
2		1.0	1.18	1.16
3			1.0	0.98
4				1.0

β_i / β_j for Bimodal Dust

Channel	1	2	3	4
1	1.0	2.36	5.70	13.54
2		1.0	2.42	5.74
3			1.0	2.37
4				1.0

β_i / β_j for Fine Polluted Dust

Channel	1	2	3	4
1	1.0	2.23	7.35	42.23
2		1.0	3.29	18.91
3			1.0	5.74
4				1.0

β_i / β_j for Coarse Polluted Dust

Channel	1	2	3	4
1	1.0	0.70	0.49	0.37
2		1.0	0.70	0.53
3			1.0	0.76
4				1.0

β_i / β_j for Bimodal Polluted Dust

Channel	1	2	3	4
1	1.0	2.19	6.59	21.84
2		1.0	3.00	10.00
3			1.0	3.32
4				1.0

β_i / β_j for Fine Clean Marine

Channel	1	2	3	4
1	1.0	2.26	10.00	42.71
2		1.0	4.42	18.87
3			1.0	4.27
4				1.0

β_i / β_j for Coarse Clean Marine

Channel	1	2	3	4
1	1.0	1.05	2.03	5.81
2		1.0	1.93	5.53
3			1.0	2.87
4				1.0

β_i / β_j for Bimodal Clean Marine

Channel	1	2	3	4
1	1.0	1.13	2.26	6.56
2		1.0	2.00	5.81
3			1.0	2.90
4				1.0

β_i / β_j for Fine Clean Continental

Channel	1	2	3	4
1	1.0	2.21	9.99	38.74
2		1.0	4.50	17.50
3			1.0	3.89
4				1.0

β_i / β_j for Coarse Clean Continental

Channel	1	2	3	4
1	1.0	1.45	2.88	6.26
2		1.0	1.99	4.32
3			1.0	2.17
4				1.0

β_i / β_j for Bimodal Clean Continental

Channel	1	2	3	4
1	1.0	1.58	3.45	7.78
2		1.0	2.19	4.93
3			1.0	2.25
4				1.0

β_i / β_j for Fine Polluted Continental

Channel	1	2	3	4
1	1.0	2.10	7.85	34.11
2		1.0	3.73	16.21
3			1.0	4.35
4				1.0

β_i / β_j for Coarse Polluted Continental

Channel	1	2	3	4
1	1.0	0.39	0.55	0.57
2		1.0	1.41	1.44
3			1.0	1.02
4				1.0

β_i / β_j for Bimodal Polluted Continental

Channel	1	2	3	4
1	1.0	2.09	7.58	29.53
2		1.0	3.63	14.14
3			1.0	3.89
4				1.0

β_i / β_j for Fine Dry Smoke

Channel	1	2	3	4
1	1.0	1.90	7.60	31.84
2		1.0	4.00	16.76
3			1.0	4.19
4				1.0

β_i / β_j for Coarse Dry Smoke

Channel	1	2	3	4
1	1.0	1.19	1.50	1.04
2		1.0	1.26	0.87
3			1.0	0.69
4				1.0

β_i / β_j for Bimodal Dry Smoke

Channel	1	2	3	4
1	1.0	1.90	7.49	28.73
2		1.0	3.95	15.15
3			1.0	3.84
4				1.0

Three primary classes of aerosols

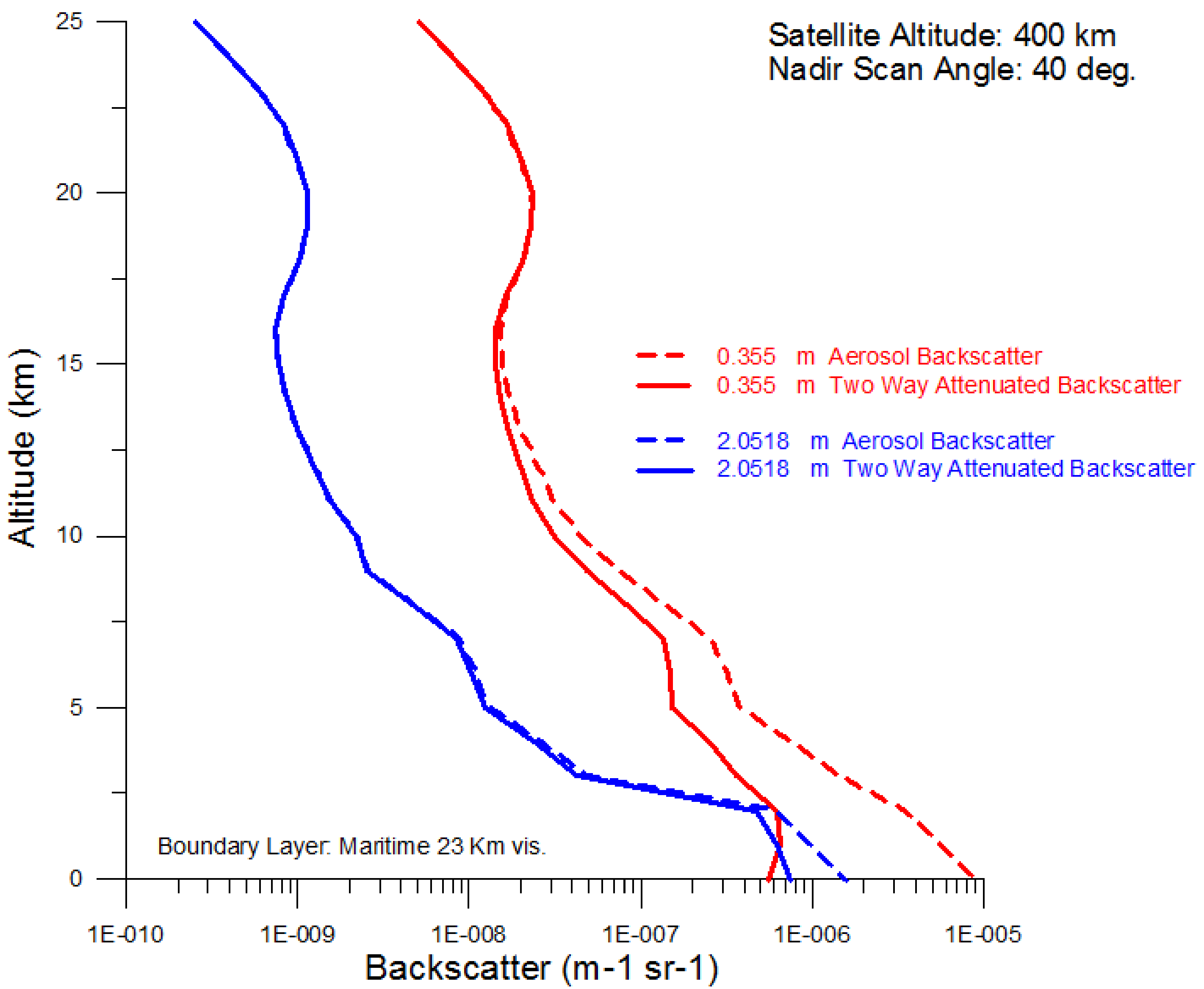
Particle Size Class	**Angstrom Exponent**	**Color Ratio (2.01/.355)**
Fine (dust, marine, dry smoke)	-2.18	.022 (45.5)
Coarse natural (marine, continental)	-1.32	.098 (1.02)
Coarse polluted (smoke, etc.)	-1.0	.17 (5.8)

General derivations of backscatter at 2.01 um from observations at .355 um
Example: Beta 2.01 = (2.01/.355)^-2.18 *Beta .355 = .022 *Beta .355

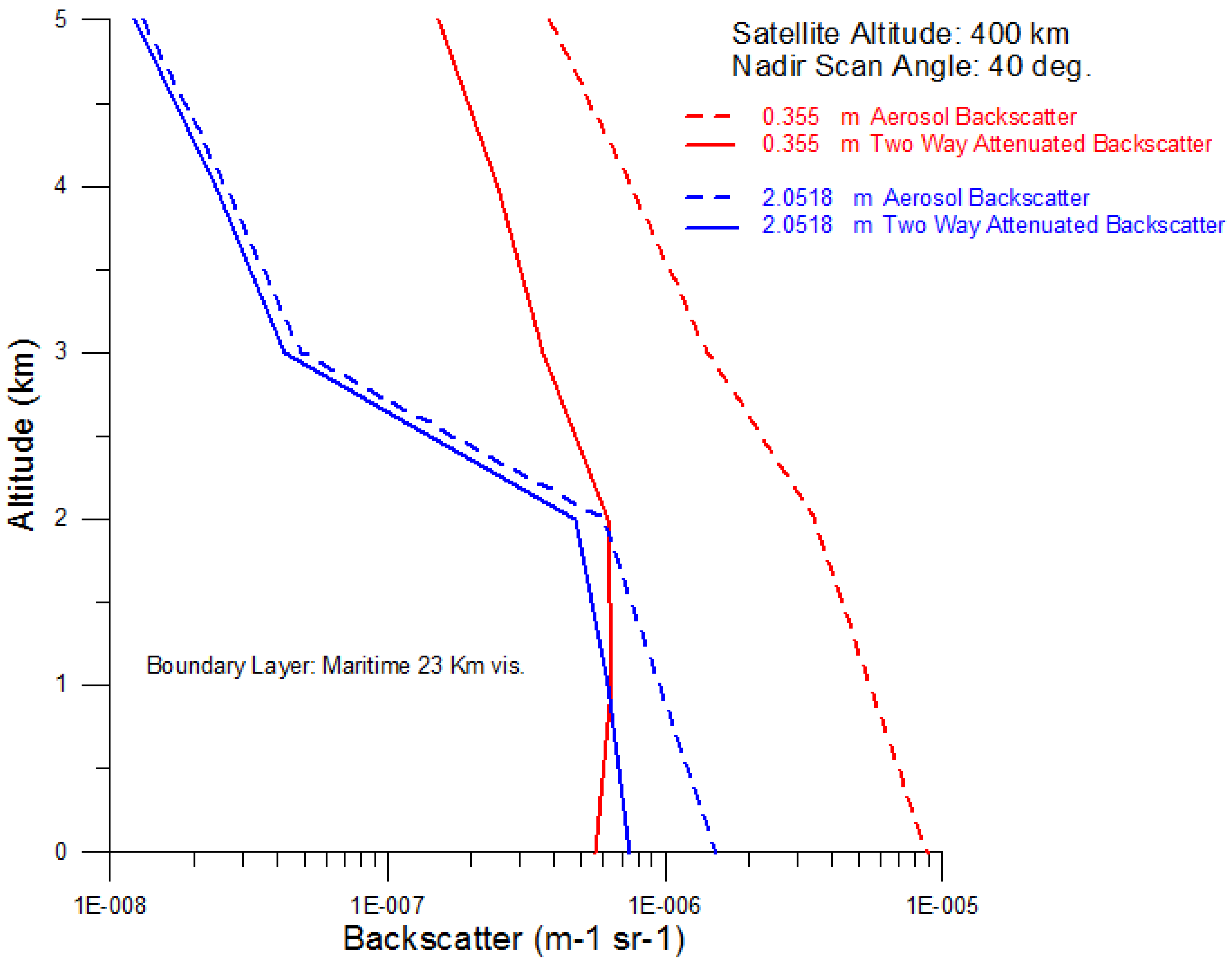
Issues for OSSEs

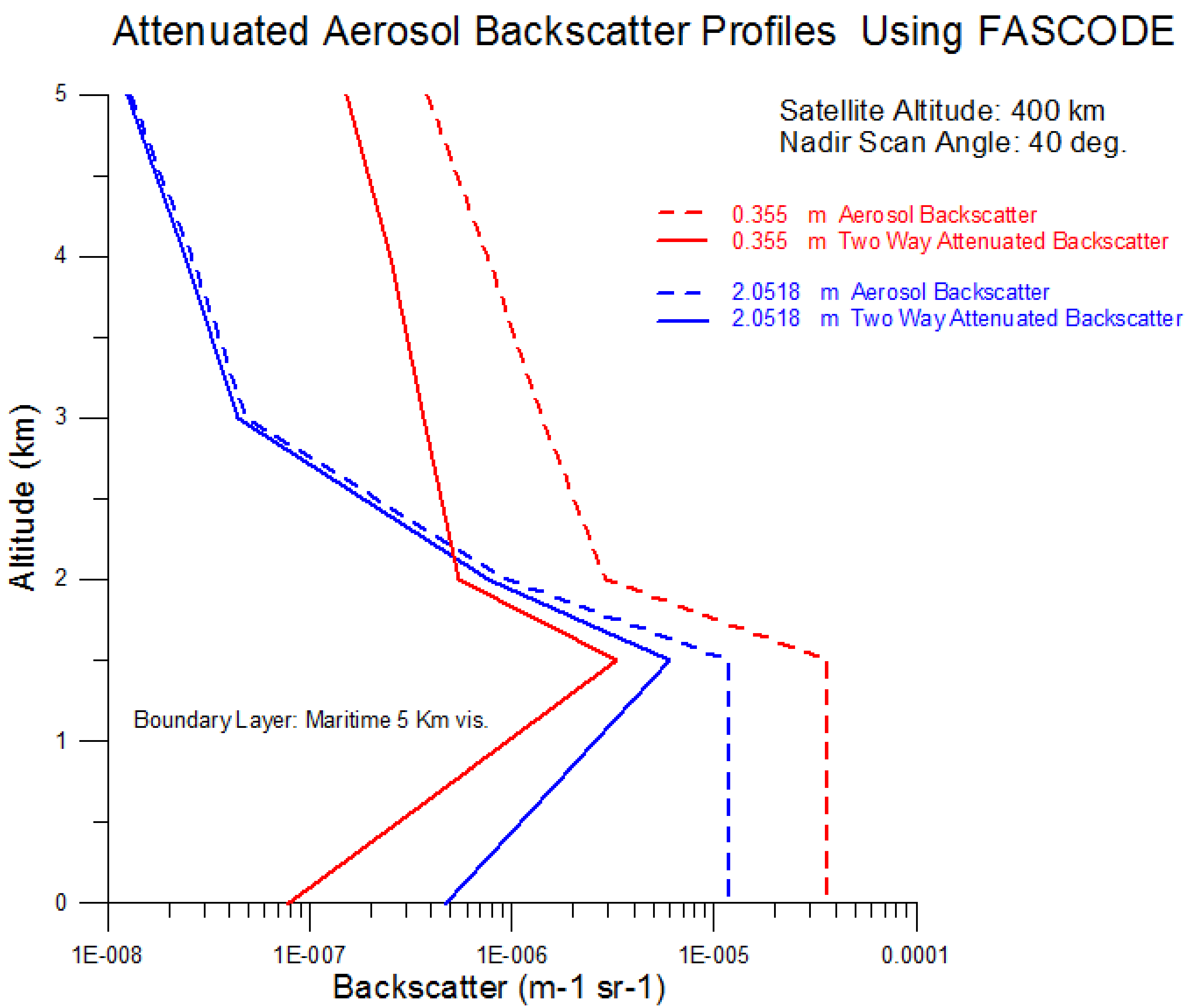
- Strategy is to keep the optical property modeling as simple as possible and consistent with the information provided by the Nature Run.
- Currently we add sub-grid scale turbulence based upon model wind variability on its grid scale.
- We derive cloud optical properties (optical depth) from model provided cloud and water phase information.
- We run the experiments with three options for aerosol distribution:
  - Entire globe in background
  - Entire globe in enhanced mode
  - Backscatter (background through enhanced) organized by model RH fields

Attenuated Aerosol Backscatter Profiles Using FASCODE

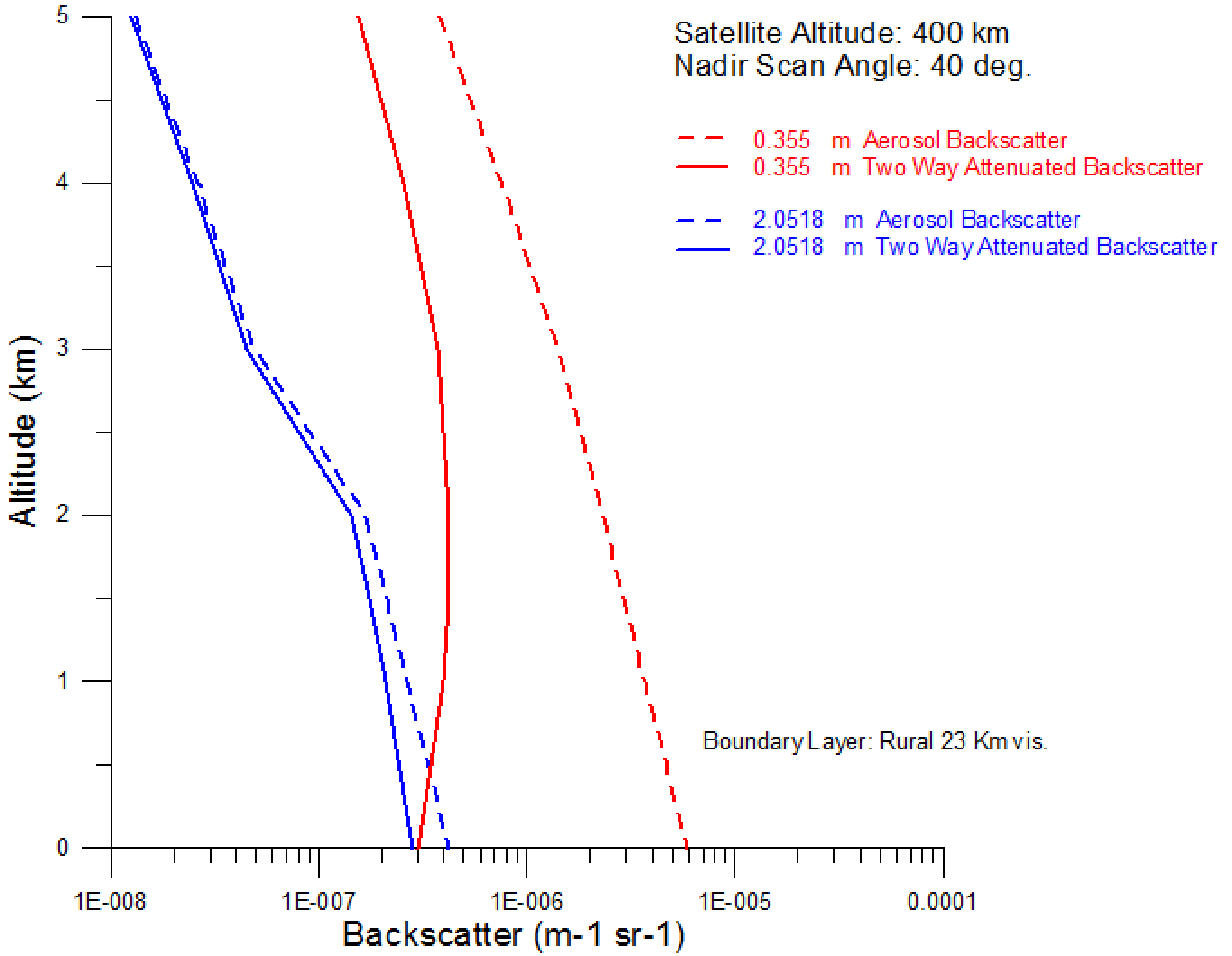


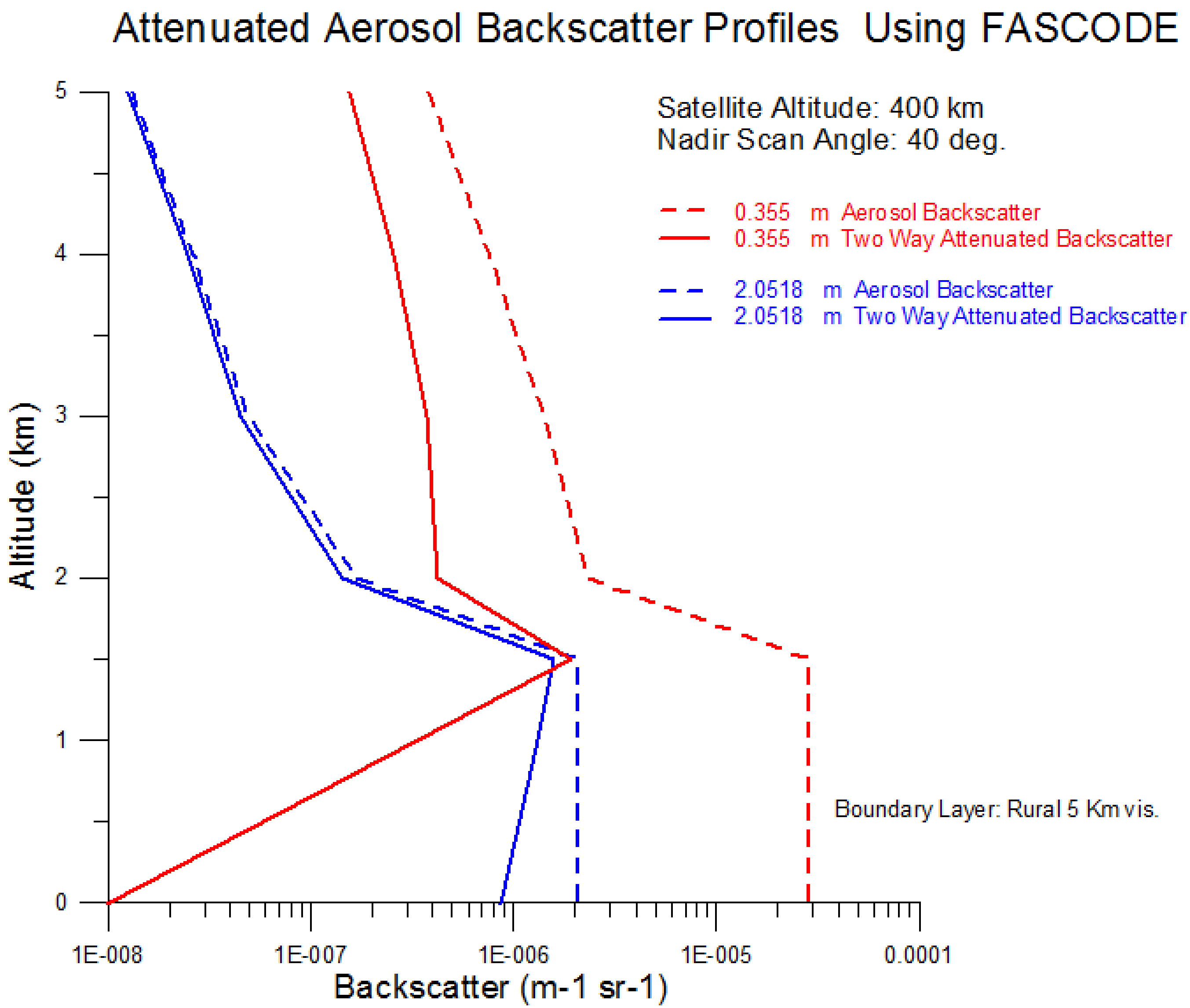
Attenuated Aerosol Backscatter Profiles Using FASCODE




Attenuated Aerosol Backscatter Profiles Using FASCODE
Satellite Altitude: 400 km
Nadir Scan Angle: 40 deg.
0.355 m Aerosol Backscatter
0.355 m Two Way Attenuated Backscatter
2.0518 m Aerosol Backscatter
2.0518 m Two Way Attenuated Backscatter
Boundary Layer: Maritime 5 Km vis.
Altitude (km)
0
1
2
3
4
5
1E-008
1E-007
1E-006
1E-005
0.0001
Backscatter (m-1 sr-1)

Attenuated Aerosol Backscatter Profiles Using FASCODE




Attenuated Aerosol Backscatter Profiles Using FASCODE
Satellite Altitude: 400 km
Nadir Scan Angle: 40 deg.
0.355 m Aerosol Backscatter
0.355 m Two Way Attenuated Backscatter
2.0518 m Aerosol Backscatter
2.0518 m Two Way Attenuated Backscatter
Boundary Layer: Rural 5 Km vis.
Altitude (km)
0
1
2
3
4
5
1E-008
1E-007
1E-006
1E-005
0.0001
Backscatter (m-1 sr-1)

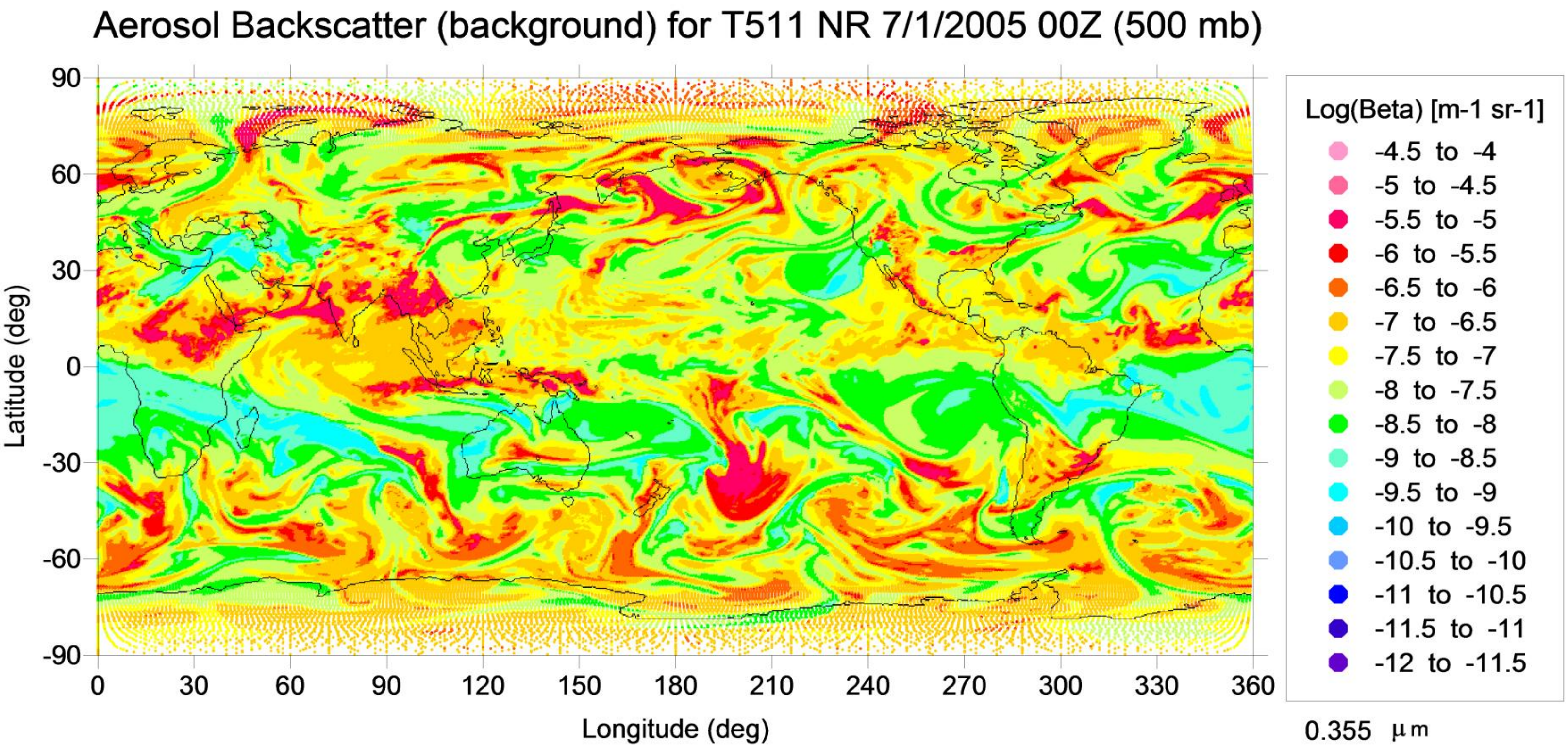
Areas for Enhancement

- Employ a first order, source anchored set of air-mass types with differing backscatter (this was done in some of the first DWL simulations for OSSEs in the early 1990's)
- Add depolarization effects by clouds (especially thin cirrus)
- Add solar background in a more advanced fashion (ground and clouds). Not just day/night adjustments to SNR.

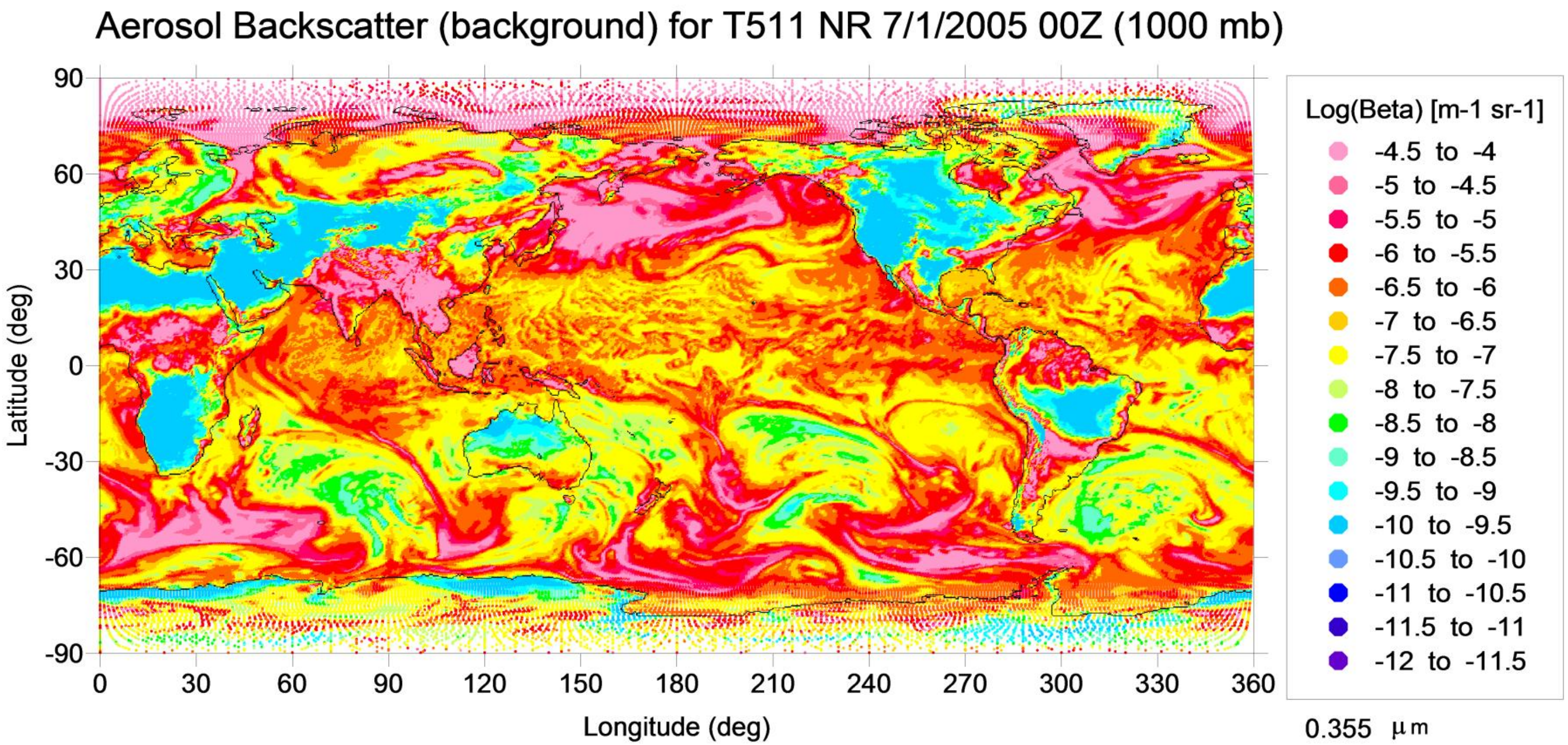
Discussion

- Given the constraints associated with OSSEs, how should we upgrade the Target Atmospheres, if at all?
- What process should we use to vet changes?

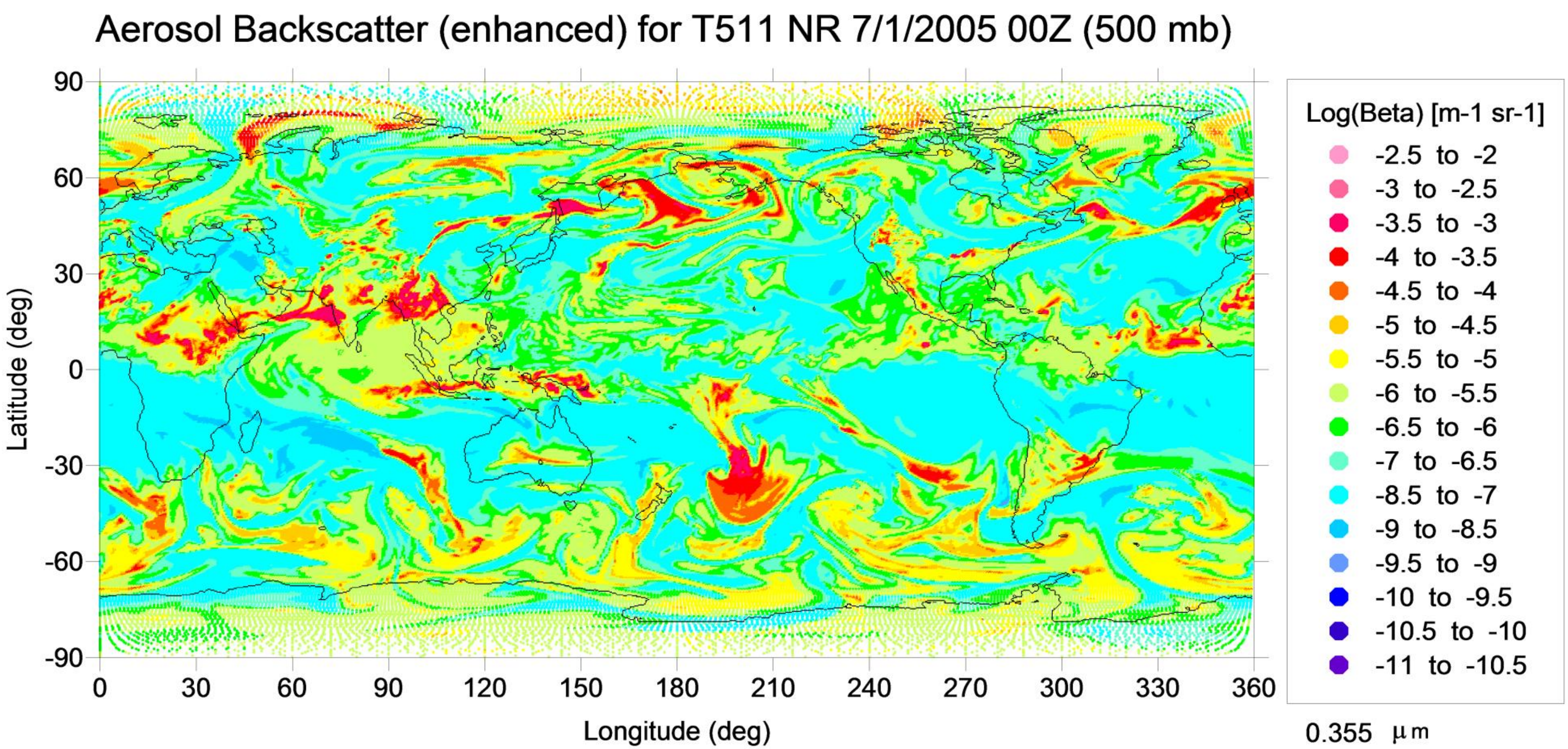
.355um Aerosol backscatter (RH organized)



.355um Aerosol backscatter (RH organized)



.355um Aerosol backscatter (RH organized)



.355um Aerosol backscatter (RH organized)