LITE

C. M. R. Platt

(CSIRO, Division of Atmospheric Research)

LITE

Lidar In-Space Technology Experiment.

9-Day mission on

Space Shuttle DISCOVERY

September 1994.

About 45 hours data

57° Inclined Orbit.

Special Project (One of Several):

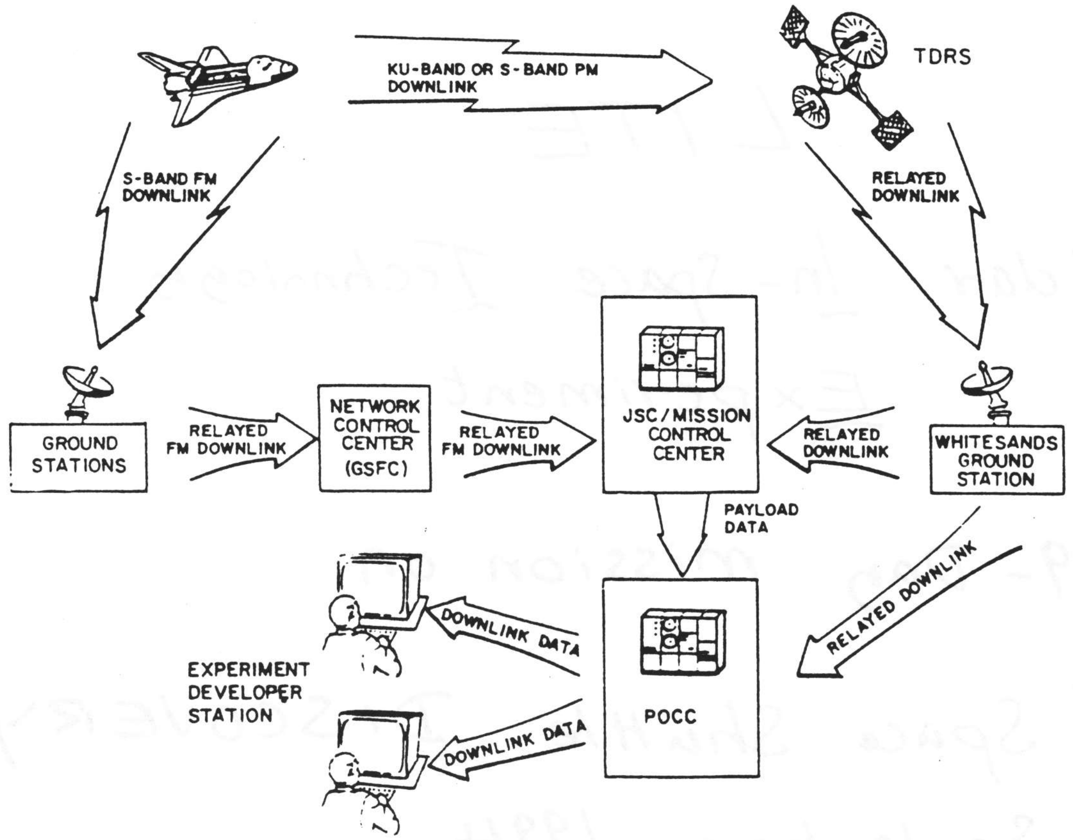
Clouds in the 'WARM POOL',

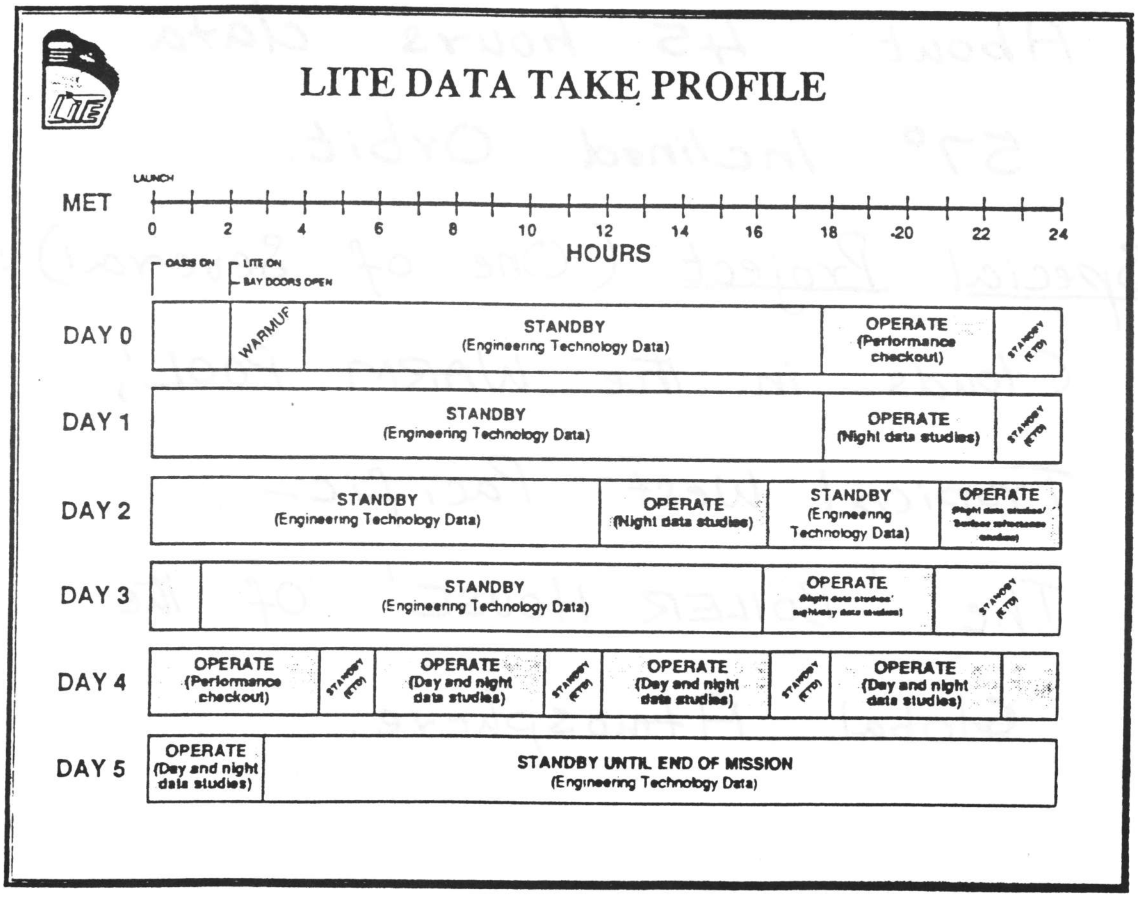
Tropical West Pacific -

The 'BOILER HOUSE' of the

Global Atmosphere.

DOWNLINK DATA FLOW OVERVIEW





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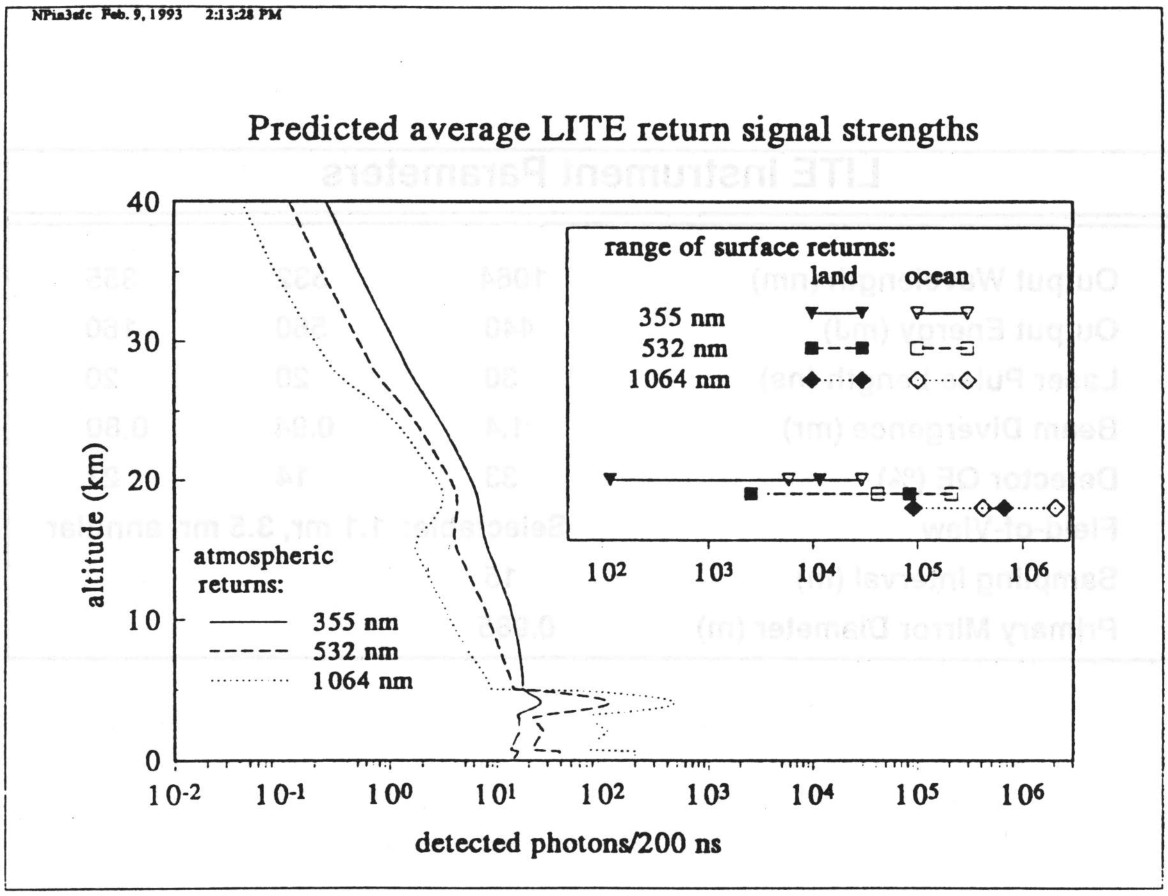


LITE RECEIVING TELESCOPE

Telescope: Ritchey- Chretien Cassegrain

Effective Focal Length - 190"

Focal Ratio F / 5.1

Obscuration Ratio - 0.11

Reflecting Surface - Aluminum

Telescope Tube - Aluminum, Titanium

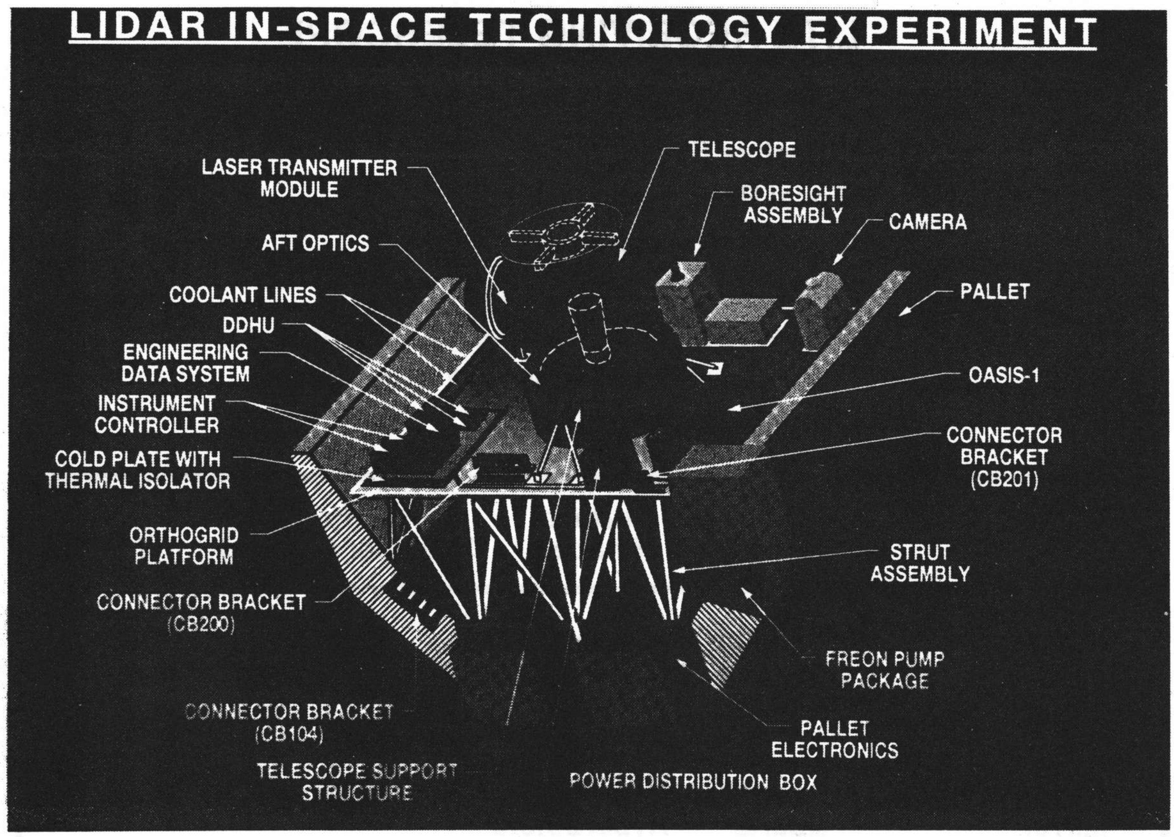
40" Diameter, 66" High (+22" Sun Shield)

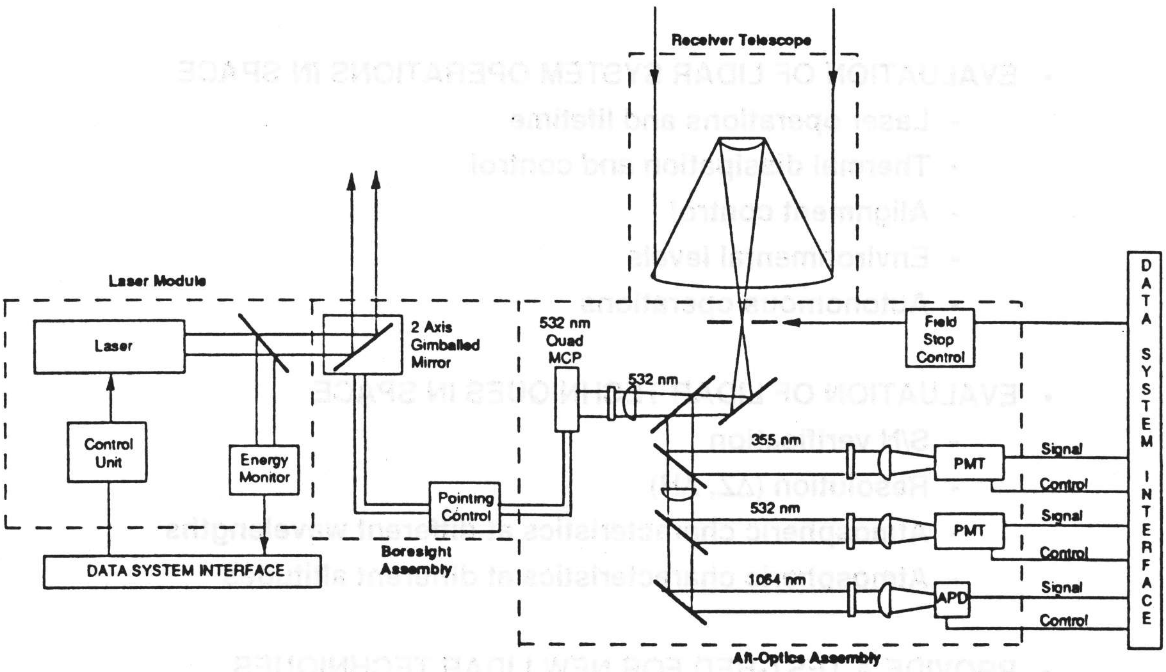
Weight - 520 lbs.

Component	Material	Surface Shape	Clear Aperture Diameter (inches)	Weight (lbs)
Primary Mirror	Beryllium (Kanigen Coated)	Concave Quasi-Hyper-Boloid	37.25	125
Secondary Mirror	Fused Quartz	Convex Hyperboloid	12.25	16

LITE Instrument Parameters

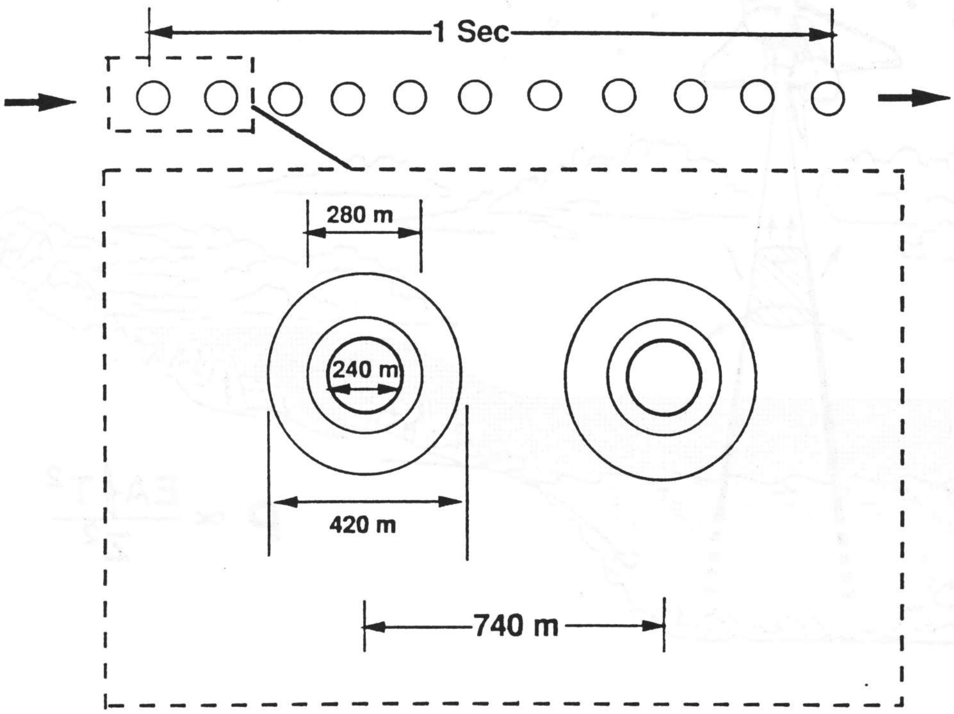
Output Wavelength (nm)	1064	532	355
Output Energy (mJ)	440	560	160
Laser Pulse Length (ns)	30	20	20
Beam Divergence (mr)	1.4	0.94	0.80
Detector QE (%)	33	14	21
Field-of-View	Selectable: 1.1 mr, 3.5 mr, annular		
Sampling Interval (m)	15		
Primary Mirror Diameter (m)	0.985		





LITE System Functional Diagram

For Shuttle at 160 Nautical Miles (296 km) Traveling at 7.4 km/sec

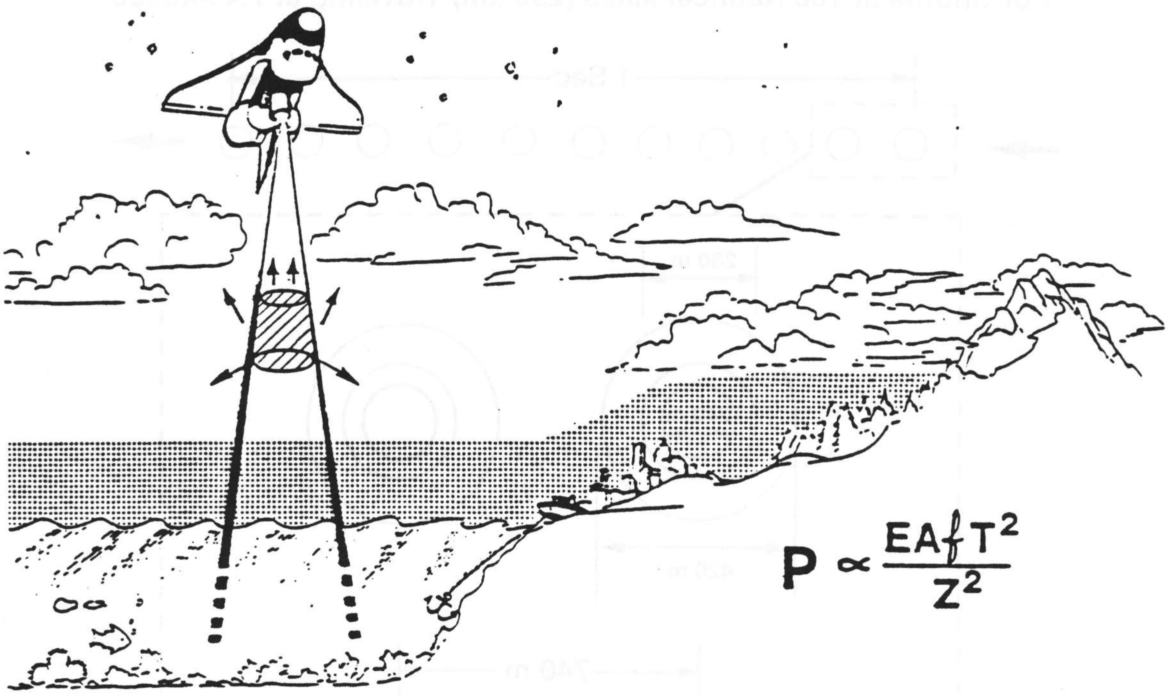


LITE TECHNOLOGY OBJECTIVES

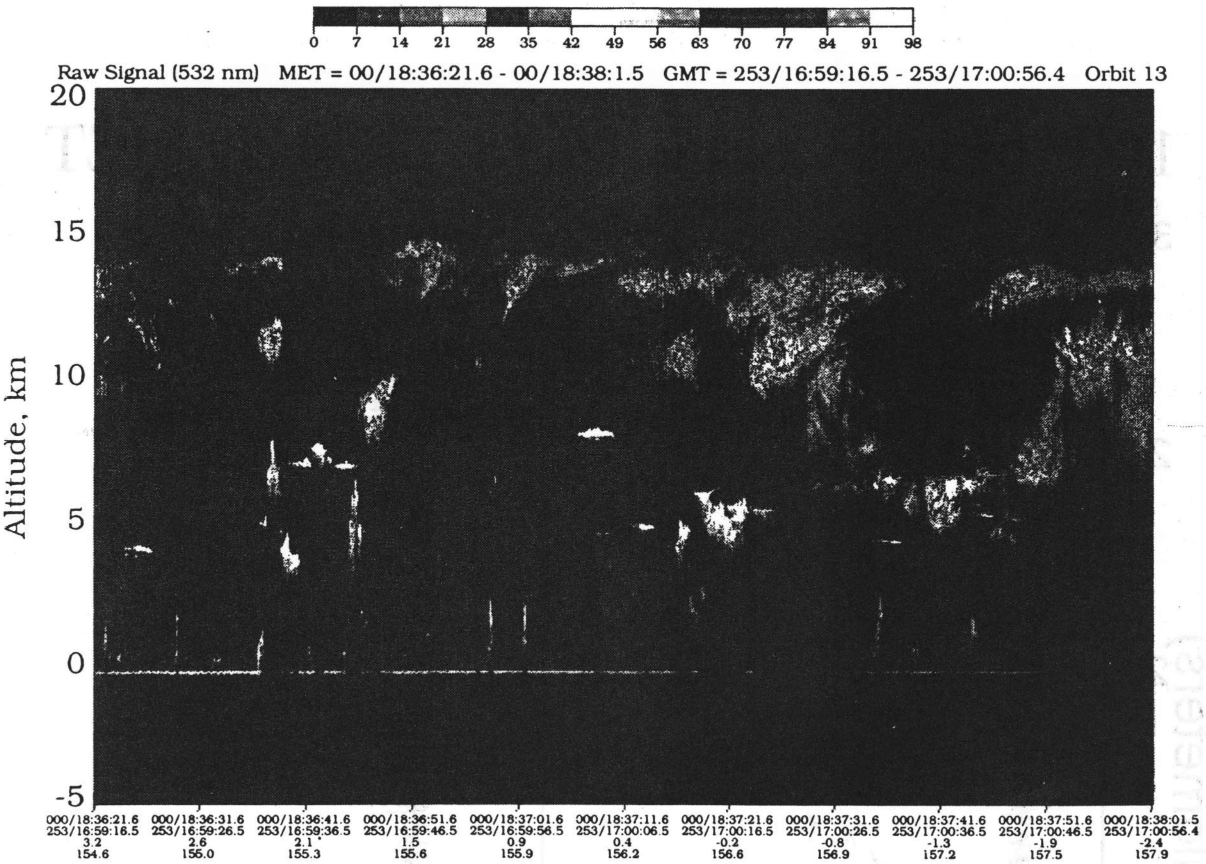
- EVALUATION OF LIDAR SYSTEM OPERATIONS IN SPACE
  - Laser operations and lifetime
  - Thermal dissipation and control
  - Alignment control
  - Environmental levels
  - Autonomous operations

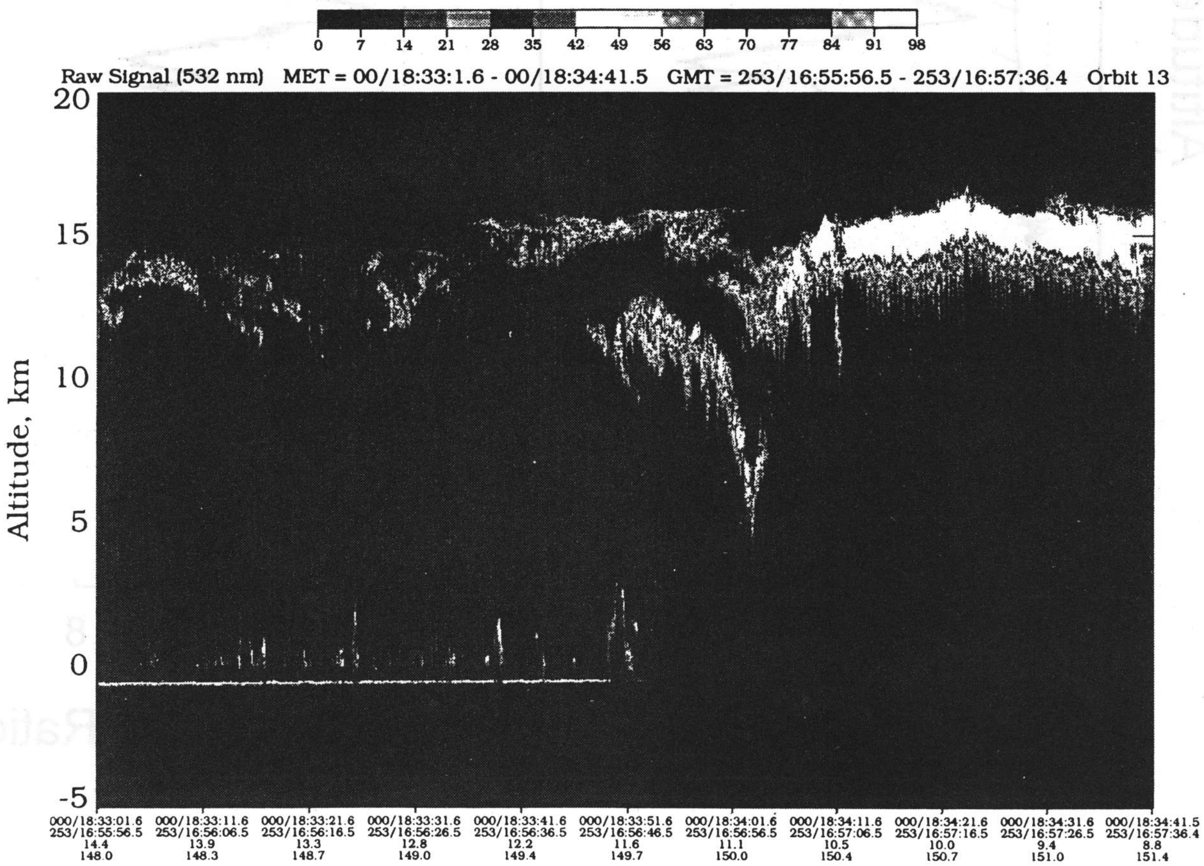
- EVALUATION OF LIDAR TECHNIQUES IN SPACE
  - S/N verification
  - Resolution (ΔZ, ΔH)
  - Atmospheric characteristics at different wavelengths
  - Atmospheric characteristics at different altitudes

- PROVIDE A TEST-BED FOR NEW LIDAR TECHNIQUES
  - Different LIDAR techniques
  - Emerging laser technologies
  - Wavelength control

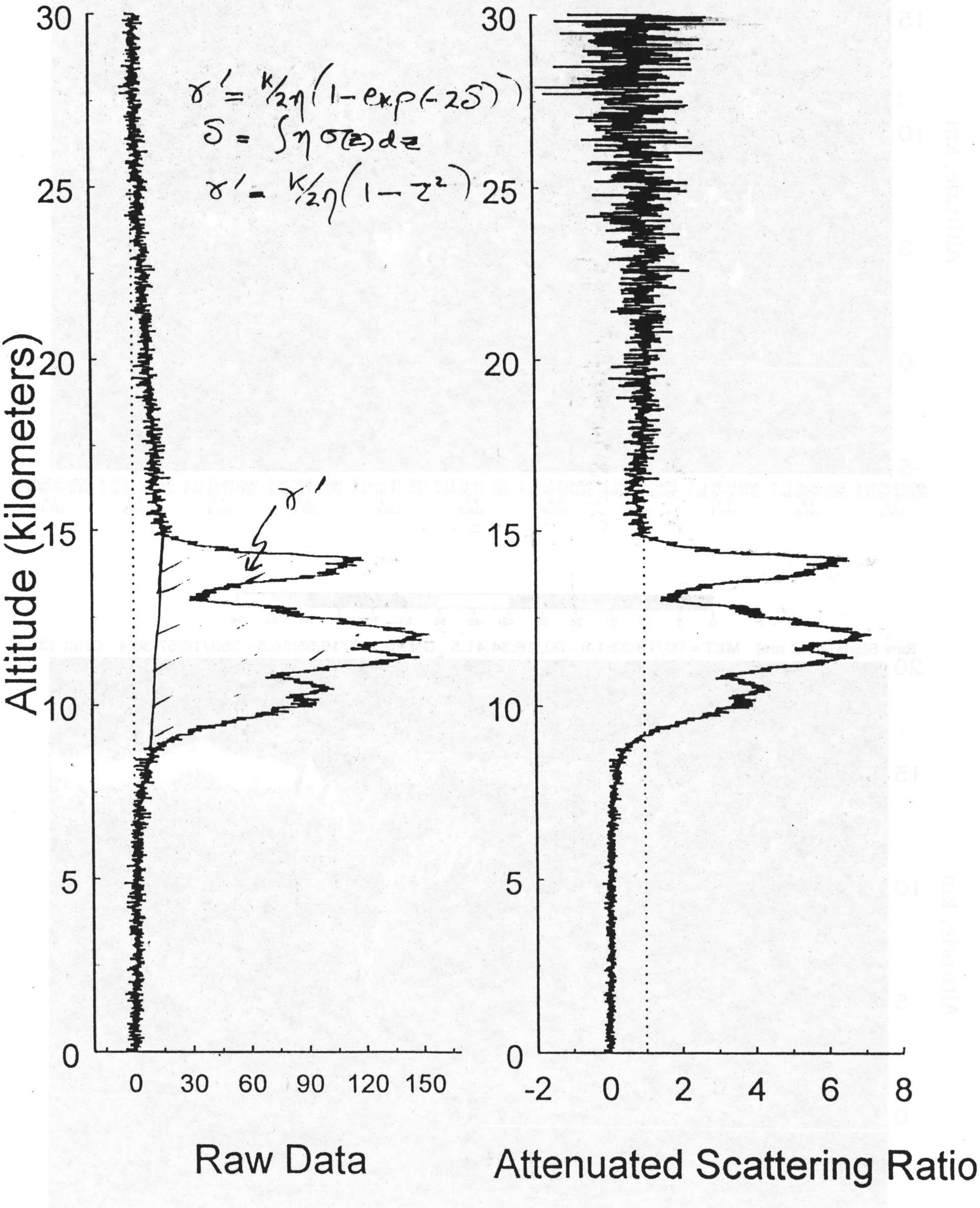


$$P \propto \frac{EA\beta T^2}{Z^2}$$


0 7 14 21 28 35 42 49 56 63 70 77 84 91 98
Raw Signal (532 nm) MET = 00/18:36:21.6 - 00/18:38:1.5 GMT = 253/16:59:16.5 - 253/17:00:56.4 Orbit 13
Altitude, km
20
15
10
5
0
-5
000/18:36:21.6 253/16:59:16.5 3.2 154.6
000/18:36:31.6 253/16:59:26.5 2.6 155.0
000/18:36:41.6 253/16:59:36.5 2.1 155.3
000/18:36:51.6 253/16:59:46.5 1.5 155.6
000/18:37:01.6 253/16:59:56.5 0.9 155.9
000/18:37:11.6 253/17:00:06.5 0.4 156.2
000/18:37:21.6 253/17:00:16.5 -0.2 156.6
000/18:37:31.6 253/17:00:26.5 -0.8 156.9
000/18:37:41.6 253/17:00:36.5 -1.3 157.2
000/18:37:51.6 253/17:00:46.5 -1.9 157.5
000/18:38:01.5 253/17:00:56.4 -2.4 157.9


0 7 14 21 28 35 42 49 56 63 70 77 84 91 98
Raw Signal (532 nm) MET = 00/18:33:1.6 - 00/18:34:41.5 GMT = 253/16:55:56.5 - 253/16:57:36.4 Orbit 13
Altitude, km
20
15
10
5
0
-5
000/18:33:01.6 253/16:55:56.5 14.4 148.0
000/18:33:11.6 253/16:56:06.5 13.9 148.3
000/18:33:21.6 253/16:56:16.5 13.3 148.7
000/18:33:31.6 253/16:56:26.5 12.8 149.0
000/18:33:41.6 253/16:56:36.5 12.2 149.4
000/18:33:51.6 253/16:56:46.5 11.6 149.7
000/18:34:01.6 253/16:56:56.5 11.1 150.0
000/18:34:11.6 253/16:57:06.5 10.5 150.4
000/18:34:21.6 253/16:57:16.5 10.0 150.7
000/18:34:31.6 253/16:57:26.5 9.4 151.0
000/18:34:41.5 253/16:57:36.4 8.8 151.4

10 Profile Average 00/18:38:54.59 MET



Lidar integrated Backscatter

The integrated backscatter $\gamma'(\pi)$ through a cloud can be written as:

$$\gamma'(\pi) = \frac{k}{2\eta}(1-\exp(-2\eta\int_{z_0}^{z'}\sigma_c(z')dz'),$$

k is the isotropic (radar) backscatter to extinction ratio,

η is a multiple scattering factor. Also

$$\gamma'(\pi) = \frac{k}{2\eta}(1-\tau^2)$$

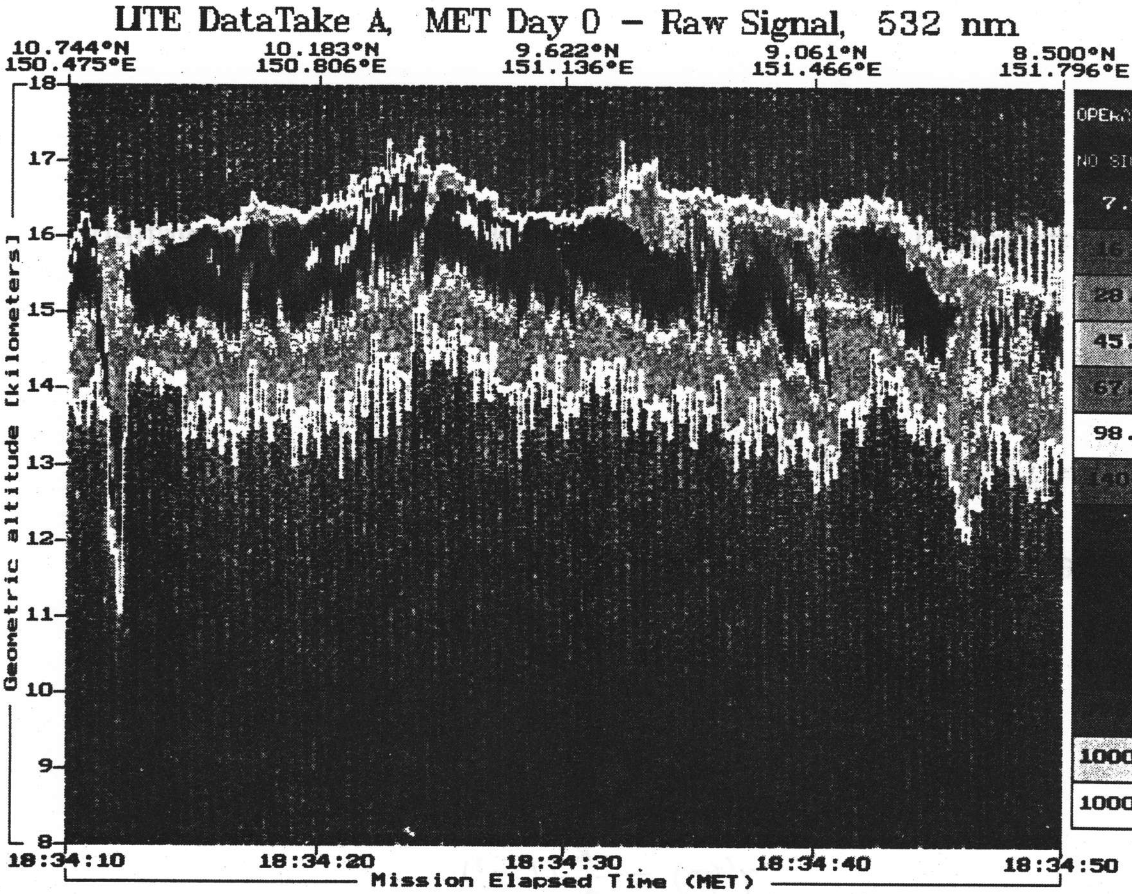
σ is the cloud volume extinction coefficient.

τ is the single path transmittance through the cloud.

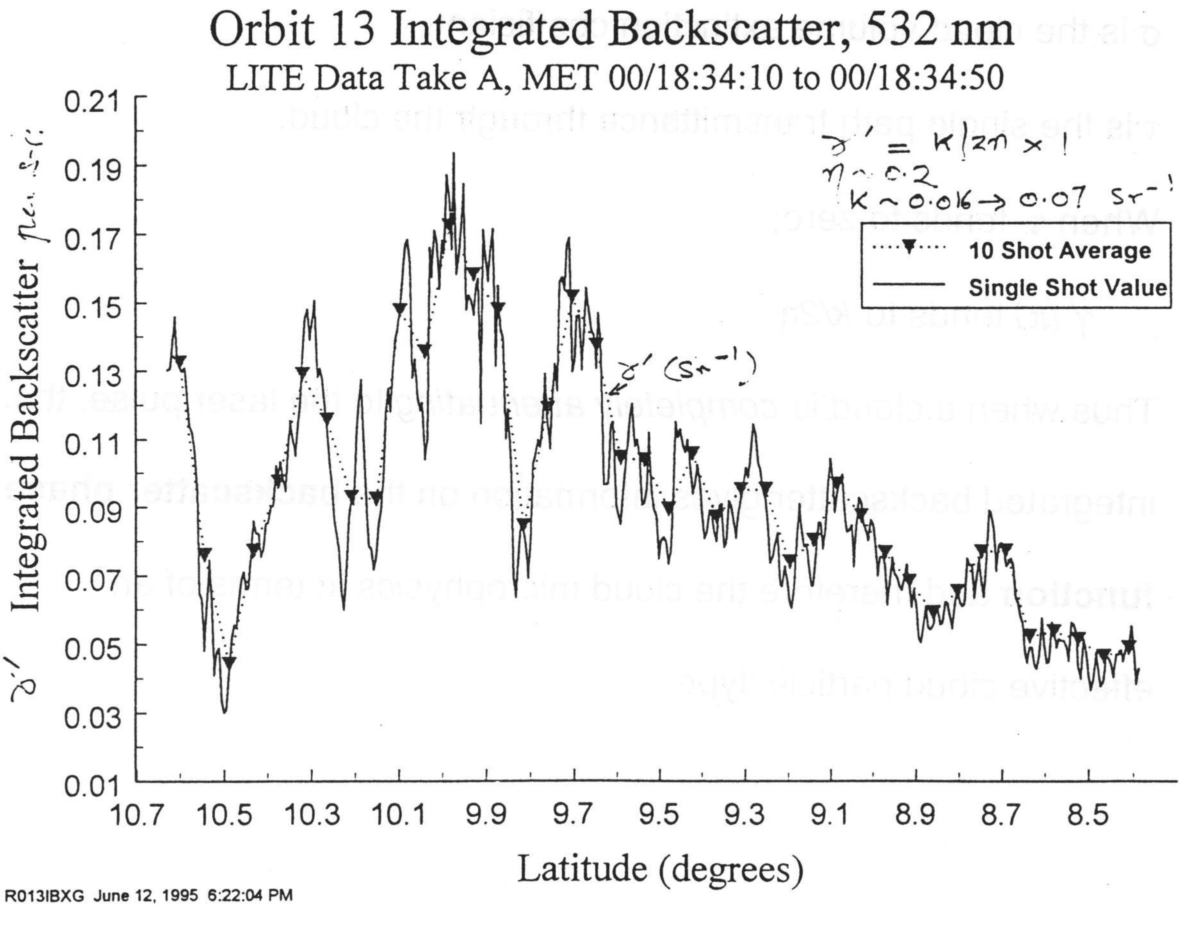
When τ tends to zero,

$\gamma'(\pi)$ tends to $k/2\eta$

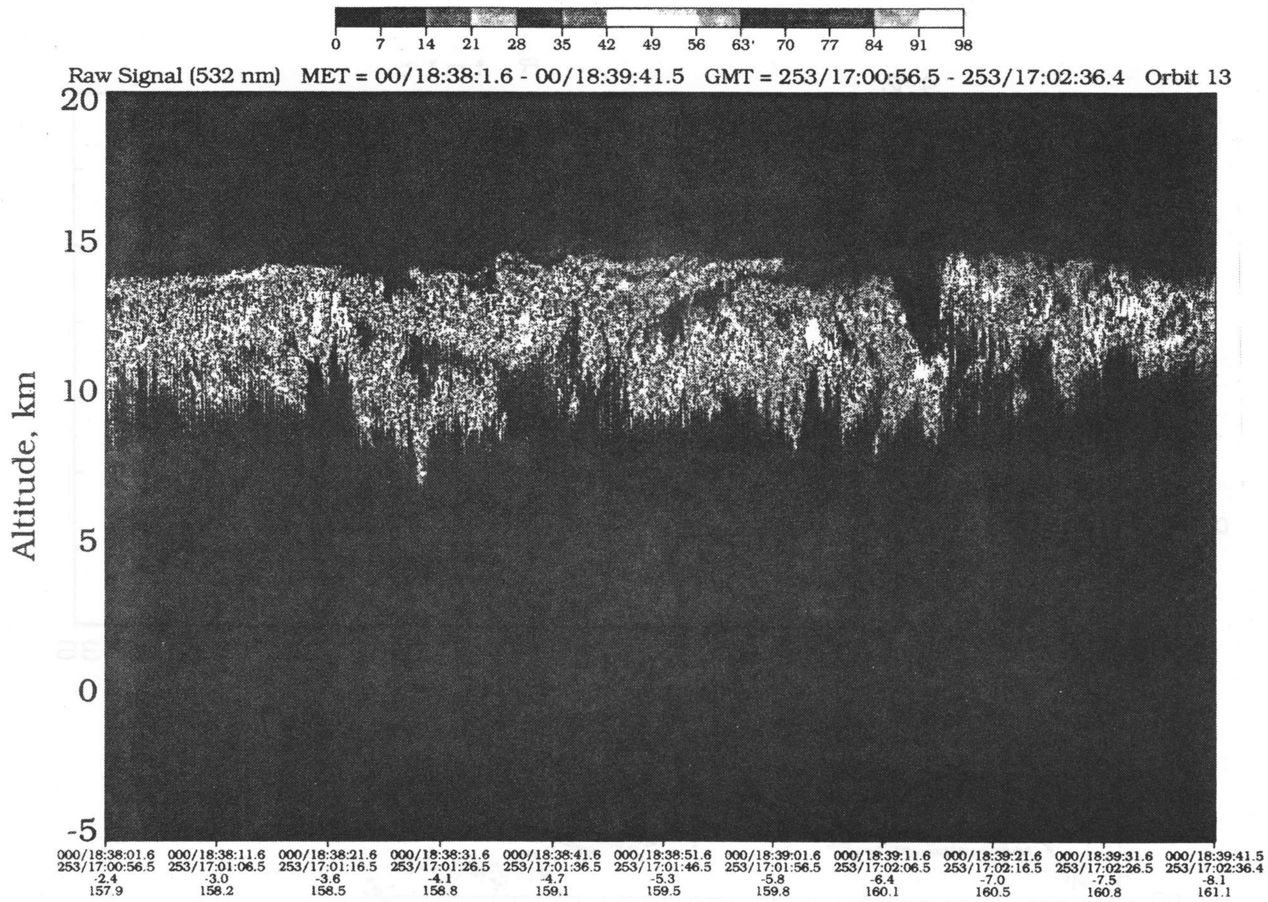
Thus when a cloud is *completely attenuating* to the laser pulse, the integrated backscatter gives information on the **backscatter phase function** and therefore the cloud microphysics in terms of an effective cloud particle 'type'.

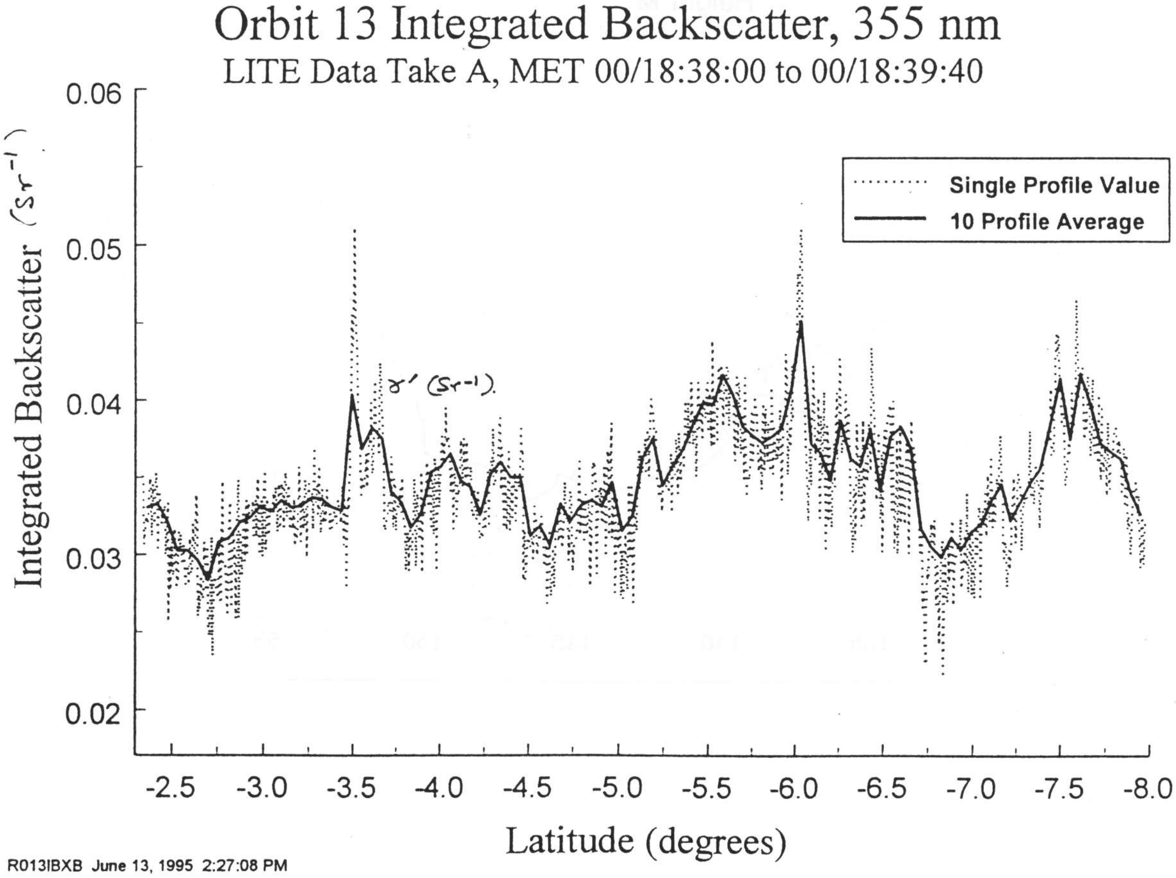


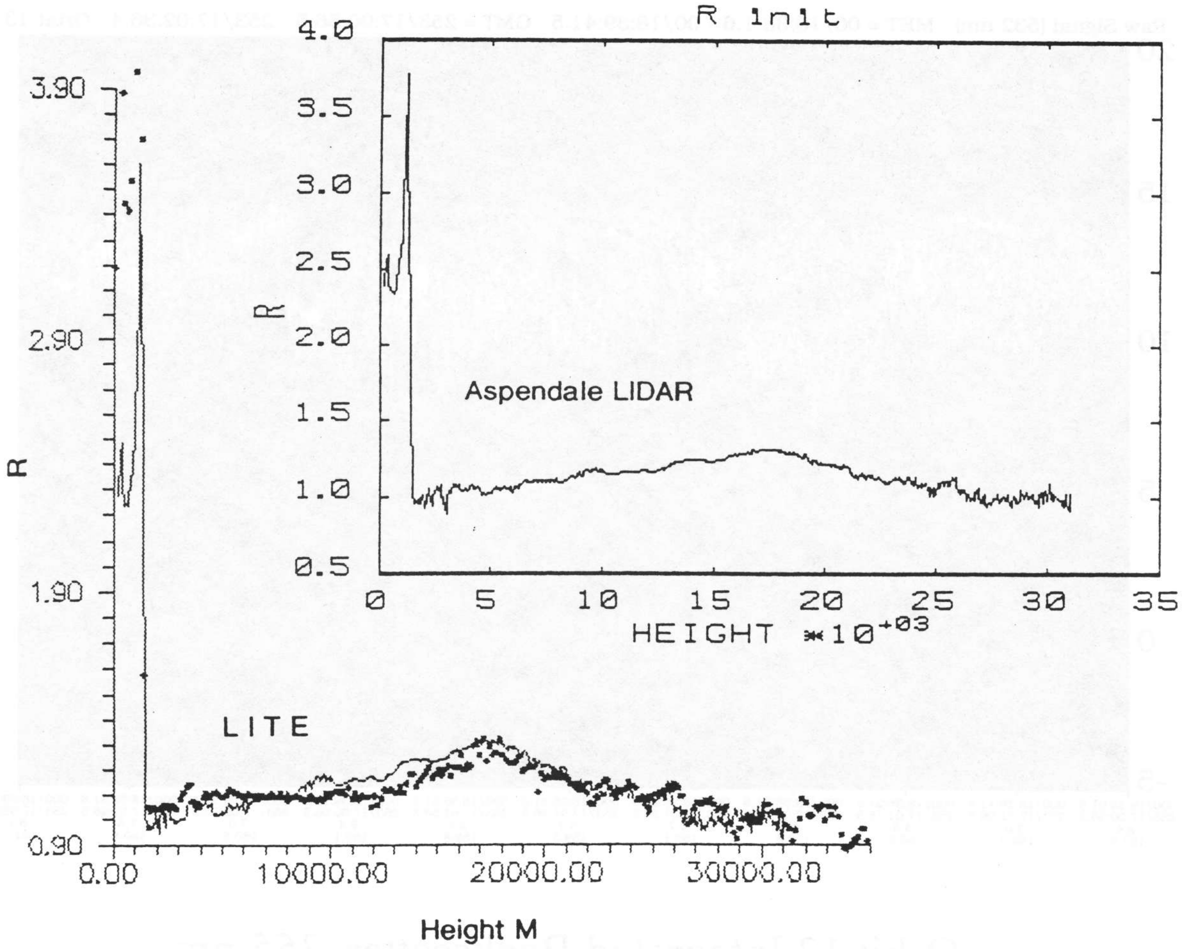
LITE DataTake A, MET Day 0 - Raw Signal, 532 nm
10.744°N 150.475°E
10.183°N 150.806°E
9.622°N 151.136°E
9.061°N 151.466°E
8.500°N 151.796°E
Geometric altitude [kilometers]
18
17
16
15
14
13
12
11
10
9
8
7.5
28.5
45.1
67.7
98.5
140.6
1000.0
1000++
18:34:10
18:34:20
18:34:30
18:34:40
18:34:50
Mission Elapsed Time (MET)

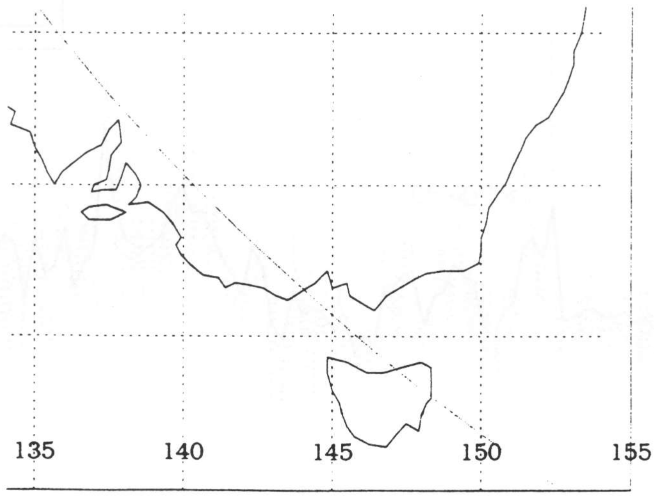


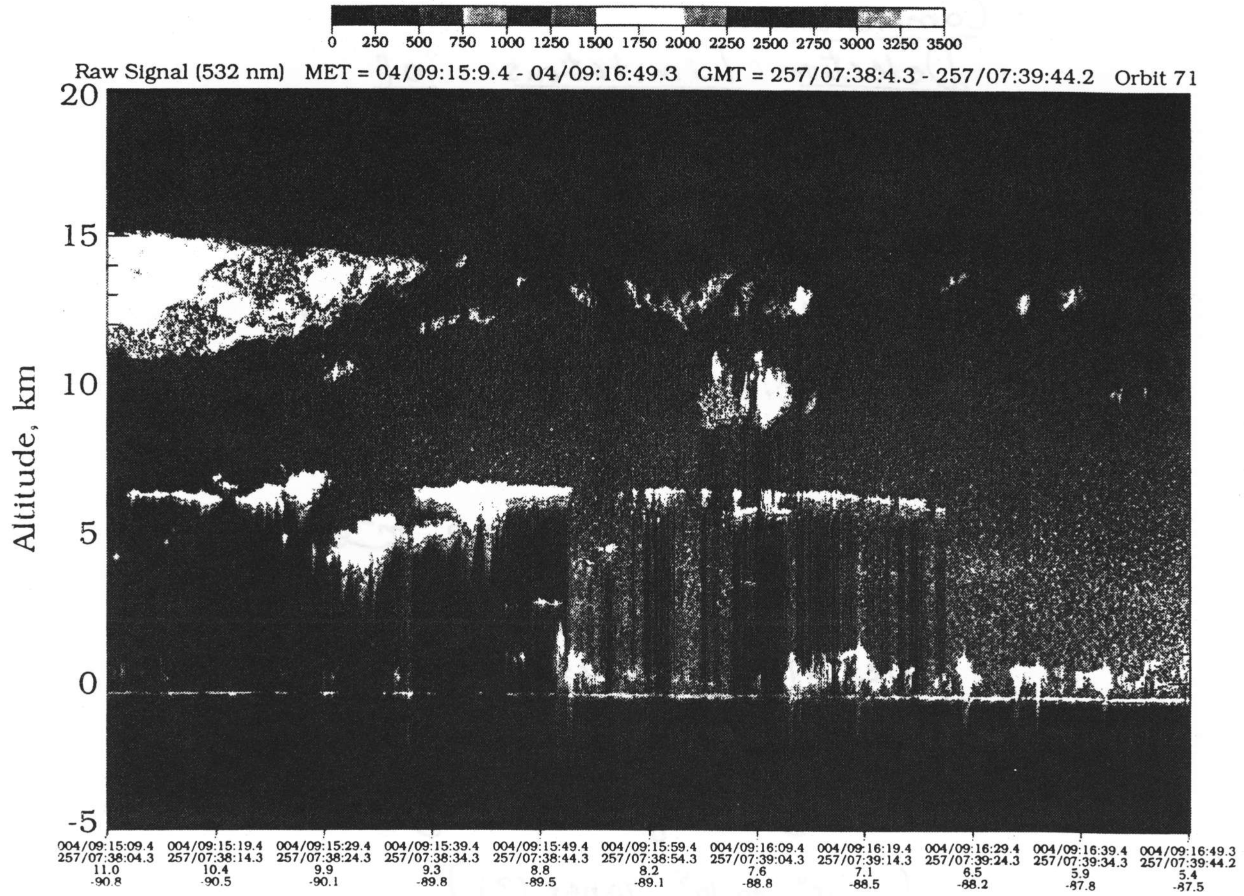
Orbit 13 Integrated Backscatter, 532 nm
LITE Data Take A, MET 00/18:34:10 to 00/18:34:50
Integrated Backscatter
0.21
0.19
0.17
0.15
0.13
0.11
0.09
0.07
0.05
0.03
0.01
10.7
10.5
10.3
10.1
9.9
9.7
9.5
9.3
9.1
8.9
8.7
8.5
Latitude (degrees)
10 Shot Average
Single Shot Value
γ' = k/2η × 1
η ~ 0.2
k ~ 0.016 → 0.07 sr⁻¹
γ' (sr⁻¹)
γ'
R013IBXG June 12, 1995 6:22:04 PM

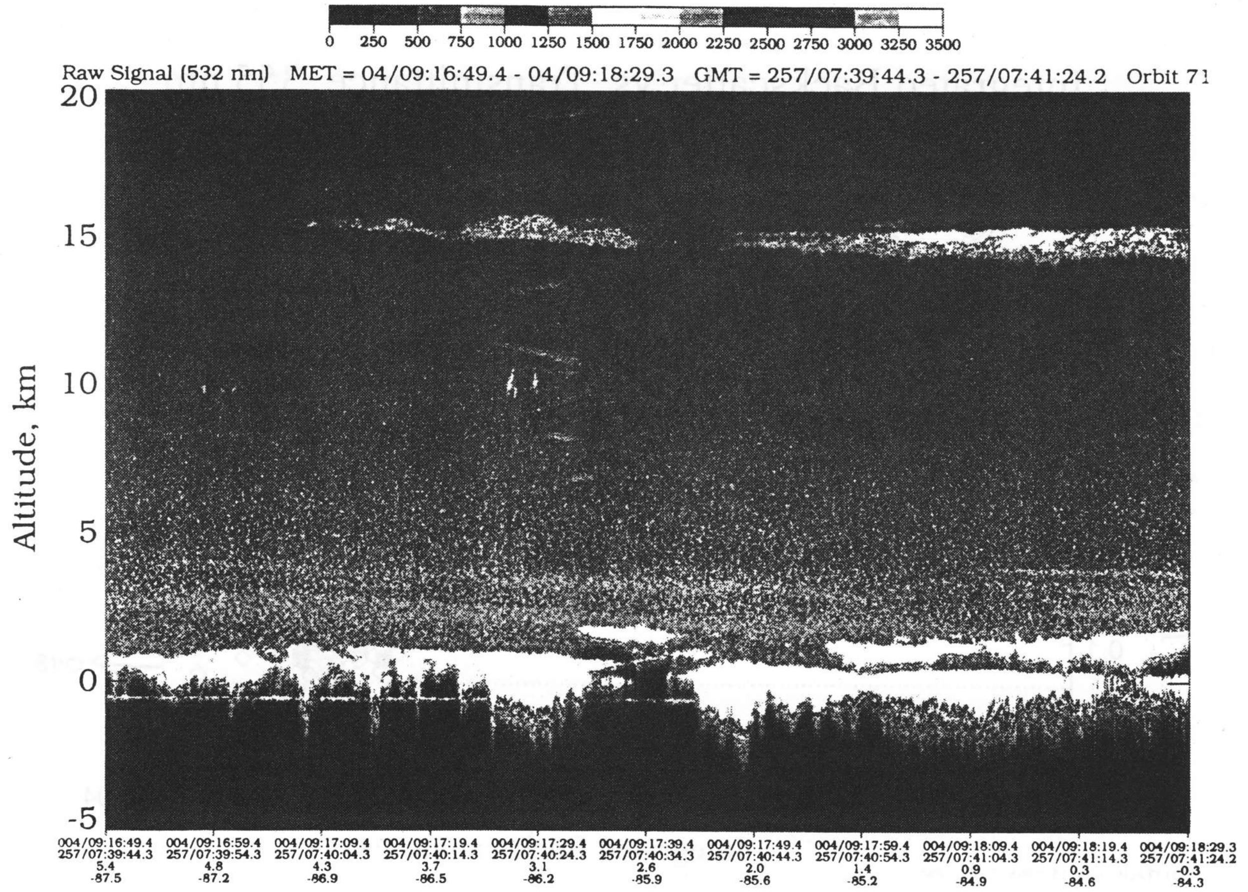

0 7 14 21 28 35 42 49 56 63 70 77 84 91 98
Raw Signal (532 nm) MET = 00/18:38:1.6 - 00/18:39:41.5 GMT = 253/17:00:56.5 - 253/17:02:36.4 Orbit 13
Altitude, km
20
15
10
5
0
-5
000/18:38:01.6 253/17:00:56.5 -2.4 157.9
000/18:38:11.6 253/17:01:06.5 -3.0 158.2
000/18:38:21.6 253/17:01:16.5 -3.6 158.5
000/18:38:31.6 253/17:01:26.5 -4.1 158.8
000/18:38:41.6 253/17:01:36.5 -4.7 159.1
000/18:38:51.6 253/17:01:46.5 -5.3 159.5
000/18:39:01.6 253/17:01:56.5 -5.8 159.8
000/18:39:11.6 253/17:02:06.5 -6.4 160.1
000/18:39:21.6 253/17:02:16.5 -7.0 160.5
000/18:39:31.6 253/17:02:26.5 -7.5 160.8
000/18:39:41.5 253/17:02:36.4 -8.1 161.1


Orbit 13 Integrated Backscatter, 355 nm
LITE Data Take A, MET 00/18:38:00 to 00/18:39:40
Integrated Backscatter (sr⁻¹)
0.06
0.05
0.04
0.03
0.02
Single Profile Value
10 Profile Average
γ' (sr⁻¹)
-2.5 -3.0 -3.5 -4.0 -4.5 -5.0 -5.5 -6.0 -6.5 -7.0 -7.5 -8.0
Latitude (degrees)
R013IBXB June 13, 1995 2:27:08 PM


R init
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
R
Aspendale LIDAR
0
5
10
15
20
25
30
35
HEIGHT *10+03
3.90
2.90
1.90
0.90
R
LITE
0.00
10000.00
20000.00
30000.00
Height M


135
140
145
150
155

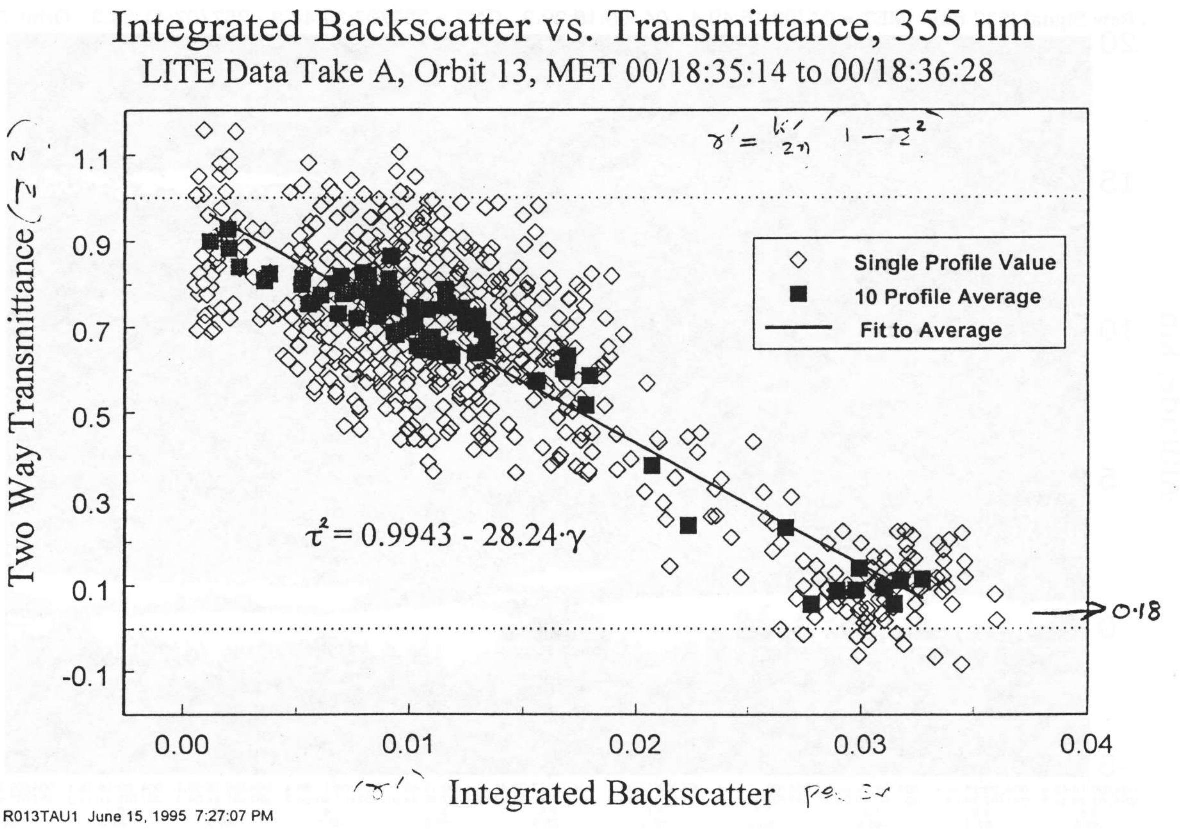

0 250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000 3250 3500
Raw Signal (532 nm) MET = 04/09:15:9.4 - 04/09:16:49.3 GMT = 257/07:38:4.3 - 257/07:39:44.2 Orbit 71
Altitude, km
20
15
10
5
0
-5
004/09:15:09.4 257/07:38:04.3 11.0 -90.8
004/09:15:19.4 257/07:38:14.3 10.4 -90.5
004/09:15:29.4 257/07:38:24.3 9.9 -90.1
004/09:15:39.4 257/07:38:34.3 9.3 -89.8
004/09:15:49.4 257/07:38:44.3 8.8 -89.5
004/09:15:59.4 257/07:38:54.3 8.2 -89.1
004/09:16:09.4 257/07:39:04.3 7.6 -88.8
004/09:16:19.4 257/07:39:14.3 7.1 -88.5
004/09:16:29.4 257/07:39:24.3 6.5 -88.2
004/09:16:39.4 257/07:39:34.3 5.9 -87.8
004/09:16:49.3 257/07:39:44.2 5.4 -87.5


0 250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000 3250 3500
Raw Signal (532 nm) MET = 04/09:16:49.4 - 04/09:18:29.3 GMT = 257/07:39:44.3 - 257/07:41:24.2 Orbit 71
Altitude, km
20
15
10
5
0
-5
004/09:16:49.4 257/07:39:44.3 5.4 -87.5
004/09:16:59.4 257/07:39:54.3 4.8 -87.2
004/09:17:09.4 257/07:40:04.3 4.3 -86.9
004/09:17:19.4 257/07:40:14.3 3.7 -86.5
004/09:17:29.4 257/07:40:24.3 3.1 -86.2
004/09:17:39.4 257/07:40:34.3 2.6 -85.9
004/09:17:49.4 257/07:40:44.3 2.0 -85.6
004/09:17:59.4 257/07:40:54.3 1.4 -85.2
004/09:18:09.4 257/07:41:04.3 0.9 -84.9
004/09:18:19.4 257/07:41:14.3 0.3 -84.6
004/09:18:29.3 257/07:41:24.2 -0.3 -84.3

Comment:

Detection Limitations of Space Lidar

There is a large range in atmospheric backscatter coefficient. This varies from ~10^{-7} $m^{-1}sr^{-1}$ for Rayleigh and aerosol to ~5×10^{-3} $m^{-1}sr^{-1}$ for dense (water) clouds. We need detectors with large dynamic range — or suitable 'in-flight' adjustable systems. (~ 10^4 to 10^5 range (?)).



R013TAU1 June 15, 1995 7:27:07 PM

Conclusions

- LITE can give excellent vertical definition of cloud boundaries and structure.
- LITE can detect layers of thin cirrus and aerosol.
- Large variations in lidar integrated attenuated backscatter have been detected in the tops of opaque tropical mesoscale convective systems, including a tropical cyclone.
- The fluctuations in integrated backscatter are interpreted as variations in cloud microphysics.
- The integrated backscatter in semitransparent clouds can be correlated with the cloud two-way transmittance.
- Cloud transmittance can be measured very easily employing the attenuated molecular backscatter in the 532 nm or 355 nm lidar channels.
- Multiple scattering effects in the lidar return can be dominant at times. Low water clouds exhibit considerable pulse stretching, whereas cirrus cloud do not.

TROPICAL WEST PACIFIC