Impact of thin and sub-visual cirrus on International Space Station based Doppler Wind Lidar simulations

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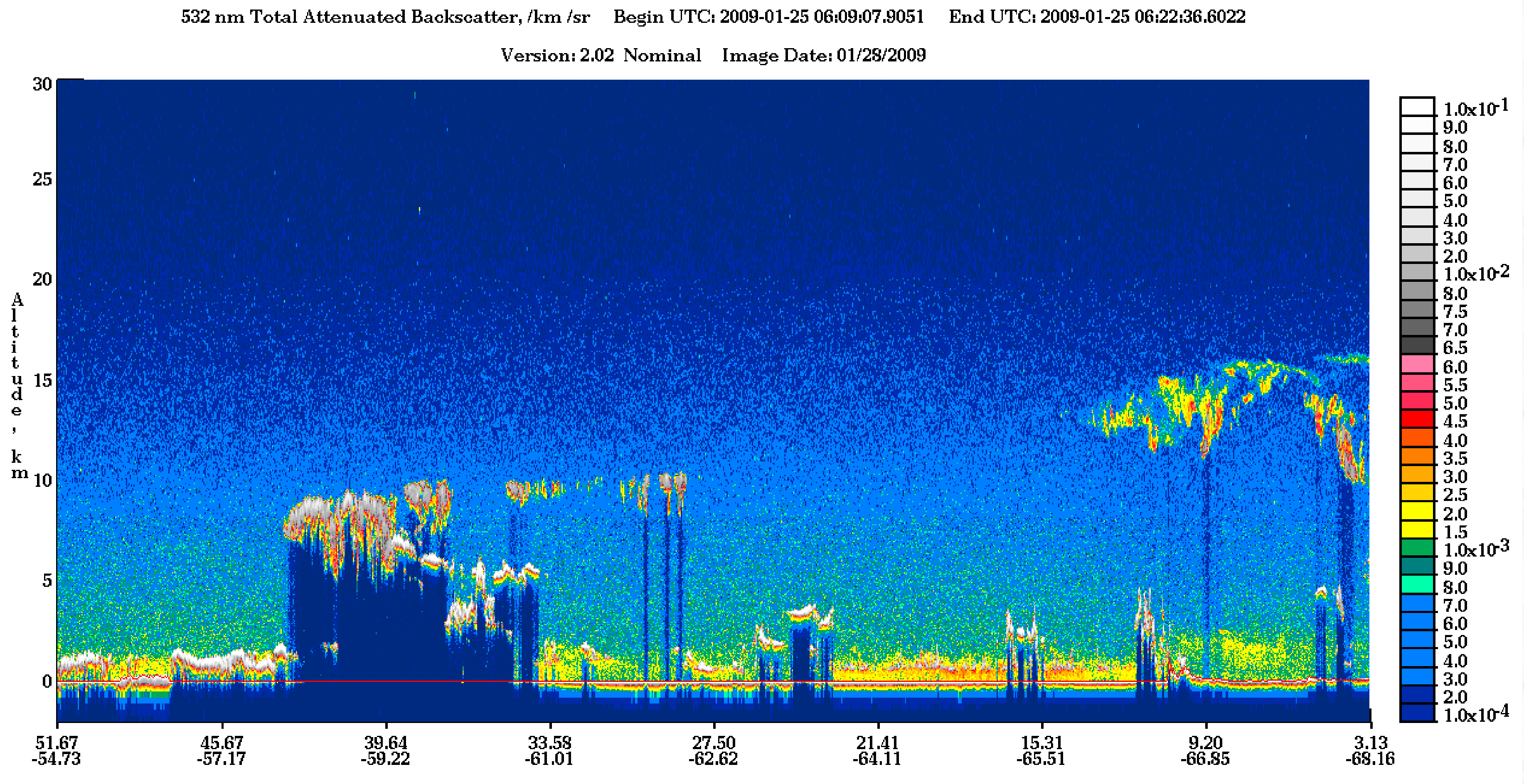
Simpson Weather Associates
Lidar WG meeting
Boulder, 2-4 August, 2011

Overview

- Sub visual cirrus has been understated in DLSM simulations prior to this year; now included in 3 months of T511 simulations for OSSEs.
- CALIPSO and other satellite data regarding sub-visual cirrus
  - Global distribution
- WISCCR/GWOS simulations with and without sub-visual cirrus
  - Focus on equatorial band and the Somalia Current

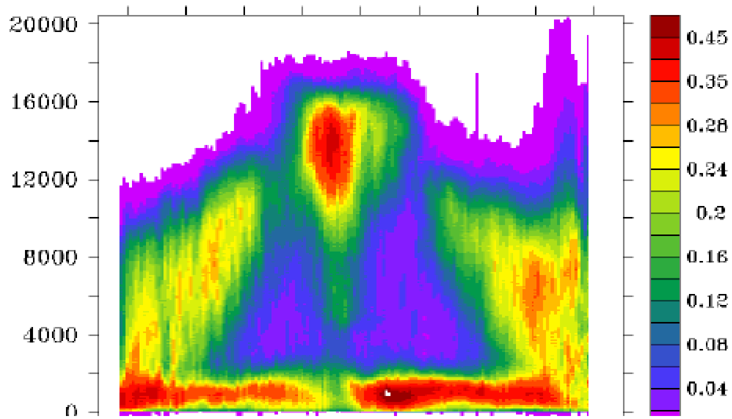
Clouds and Aerosols

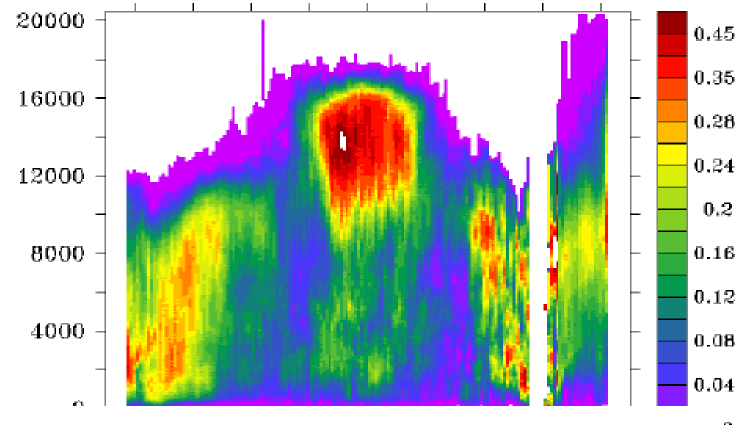
532 nm Total Attenuated Backscatter



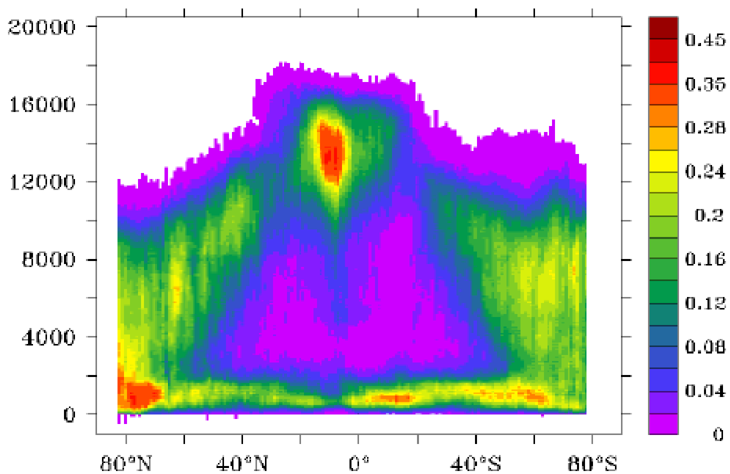
WHAT IS OBTAINED From CALIOP/CALIPSO
October 2006

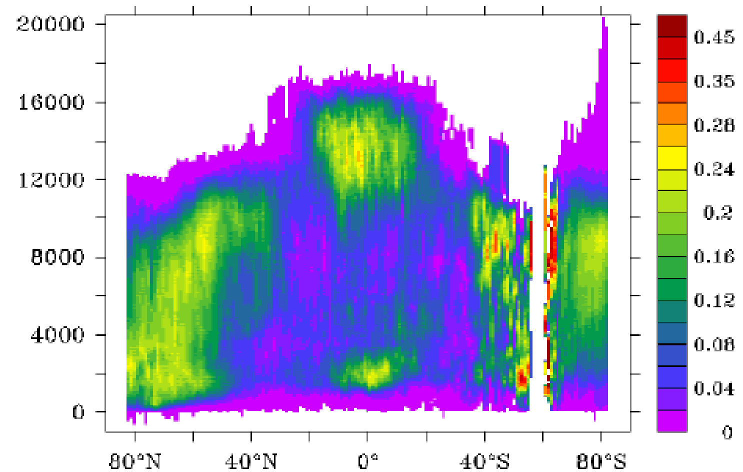
Night Ocean Land





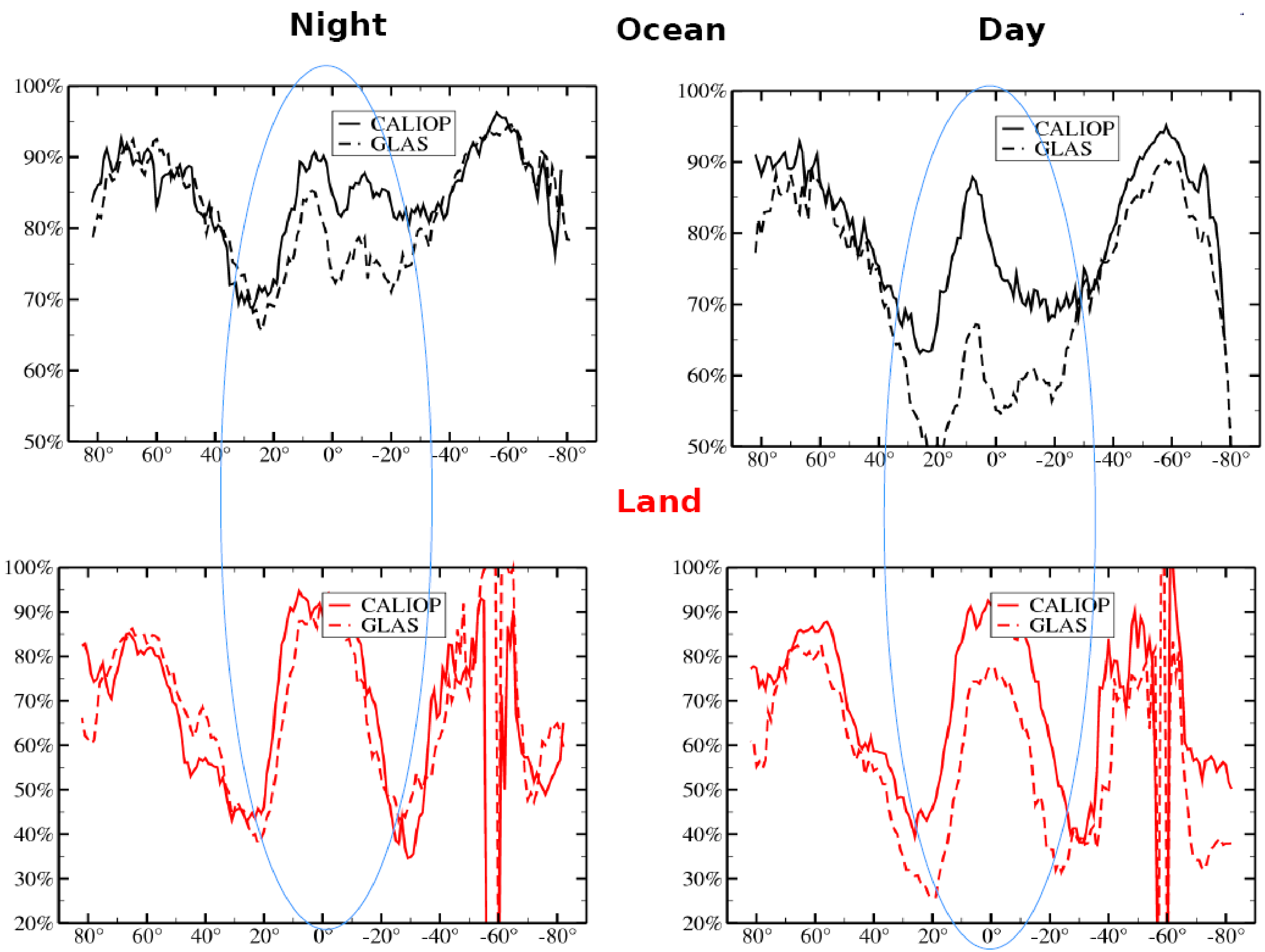
Day Calipso data v1.10





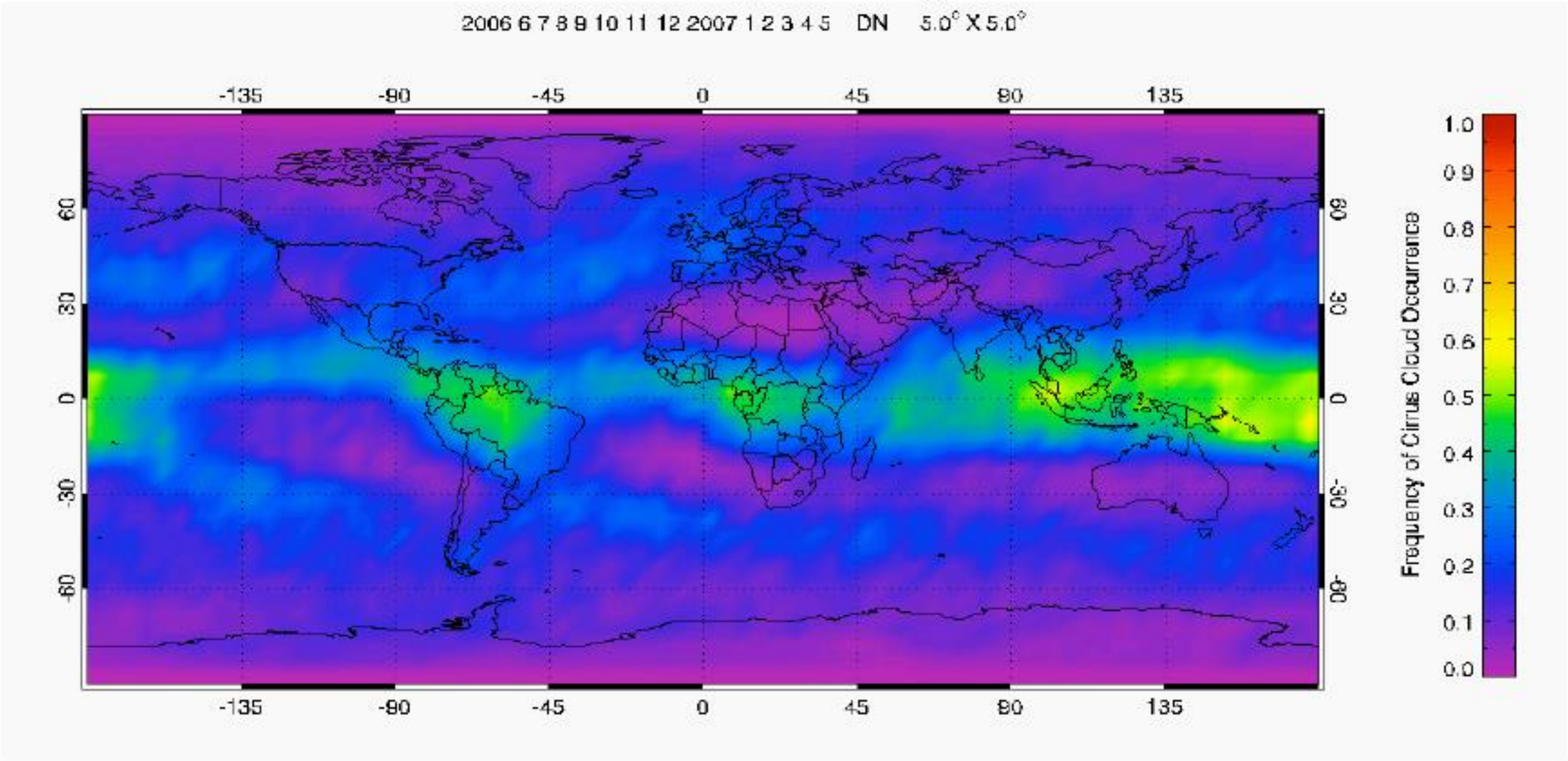
Earthcare workshop, ESTEC, 8 May 2007

Seze, Pelon, Flamant, Vaughn, Trepte and Winker



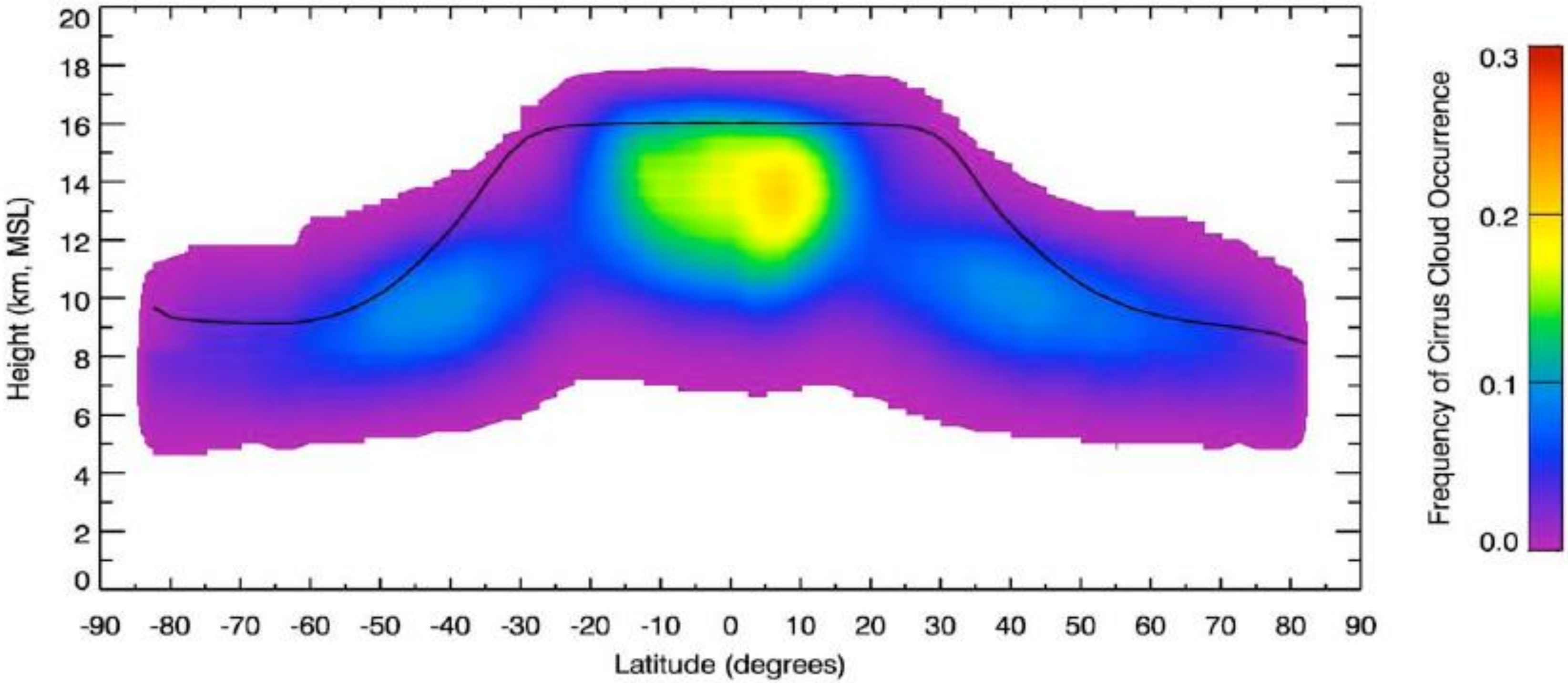
GLAS october 2003 – CALIOP october 2006

Average 1-Y Global Cirrus Frequency



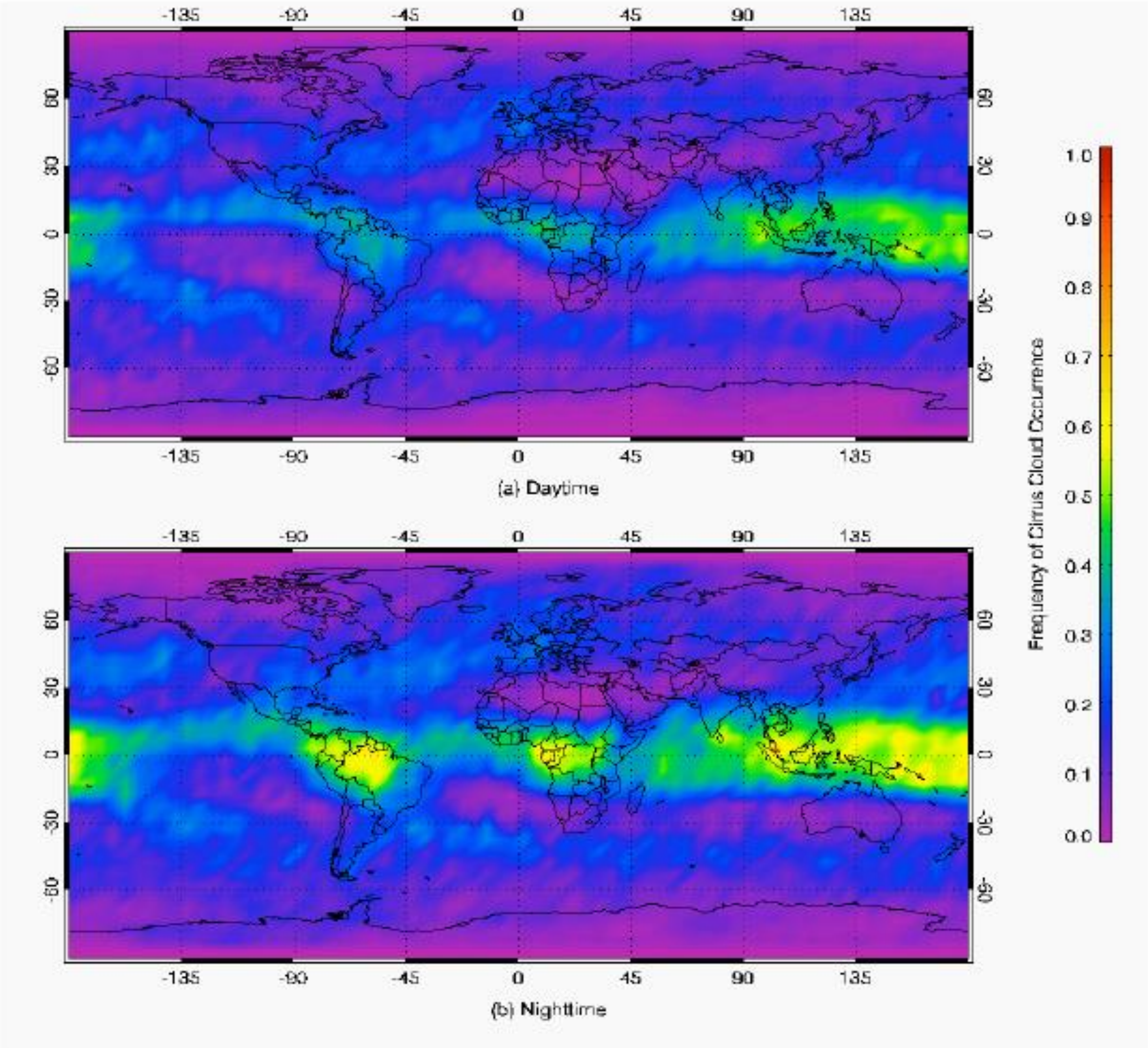
Sassen et al., (2008)

Latitudinal Average Cirrus Heights

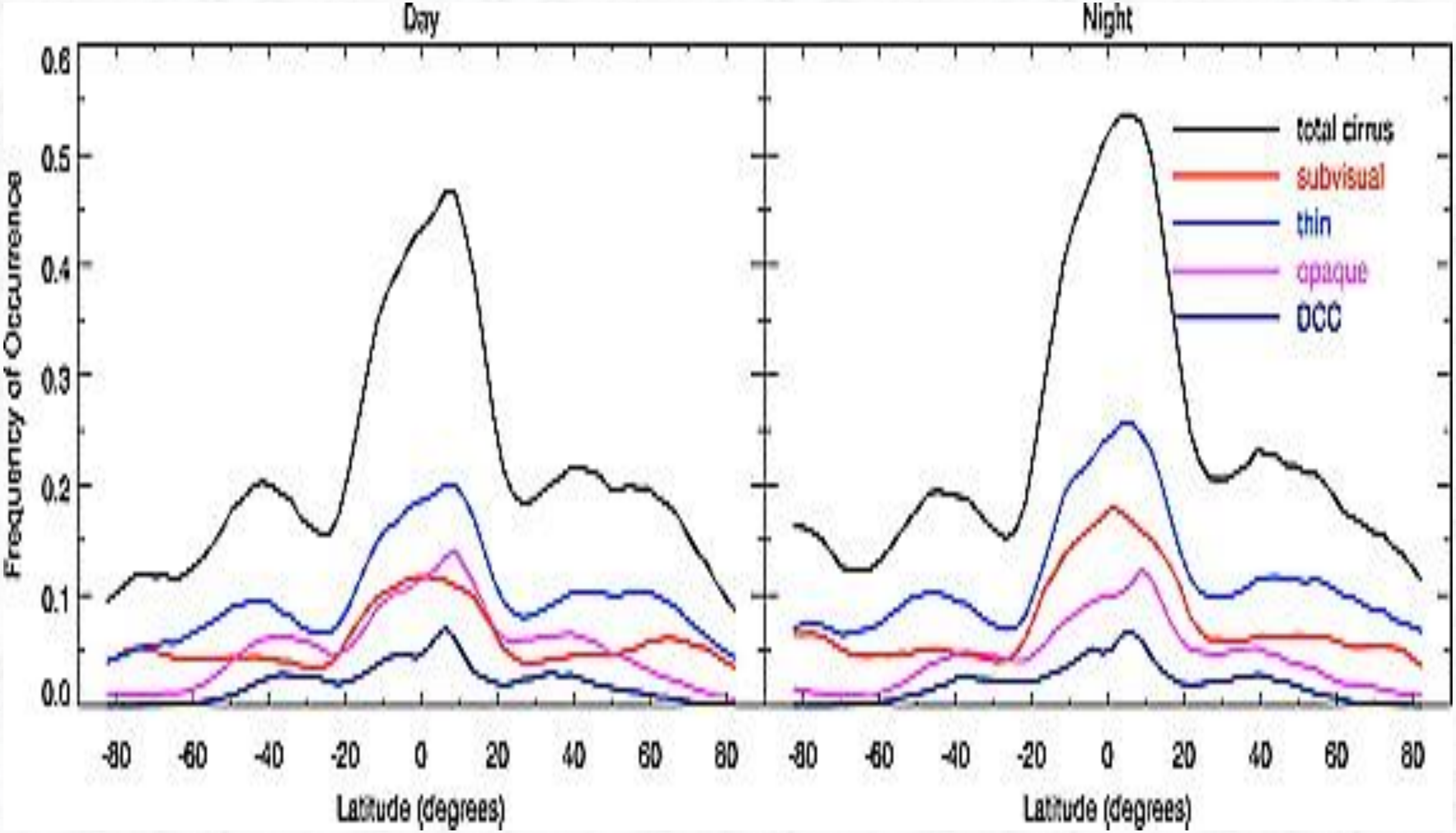


Sassen et al., (2008)

Global Cirrus Day Vs. Night



Sassen et al., (2008)

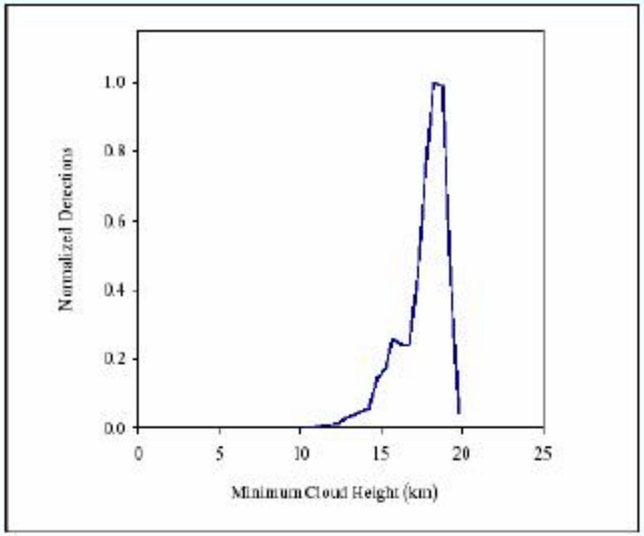


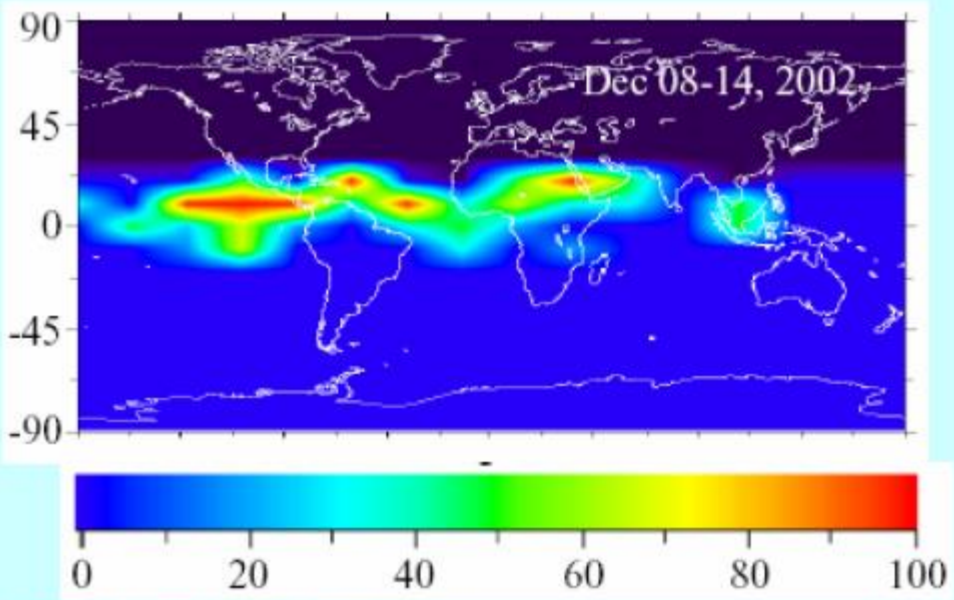
Sassen et al., (2009): Total, SUBVISUAL Cirrus, Thin Cirrus, Opaque Cirrus

Satellite Retrievals of Sub-visible Cirrus

The Limb Scatter Detection of High Altitude Subvisible Cirrus by the OSIRIS Infrared Imager

Adam E. Bourassa,[1] Douglas A. Degenstein,[1] Edward J. Llewellyn,[1] Nicholas D.Lloyd,[1] and Kevin Noone[2]

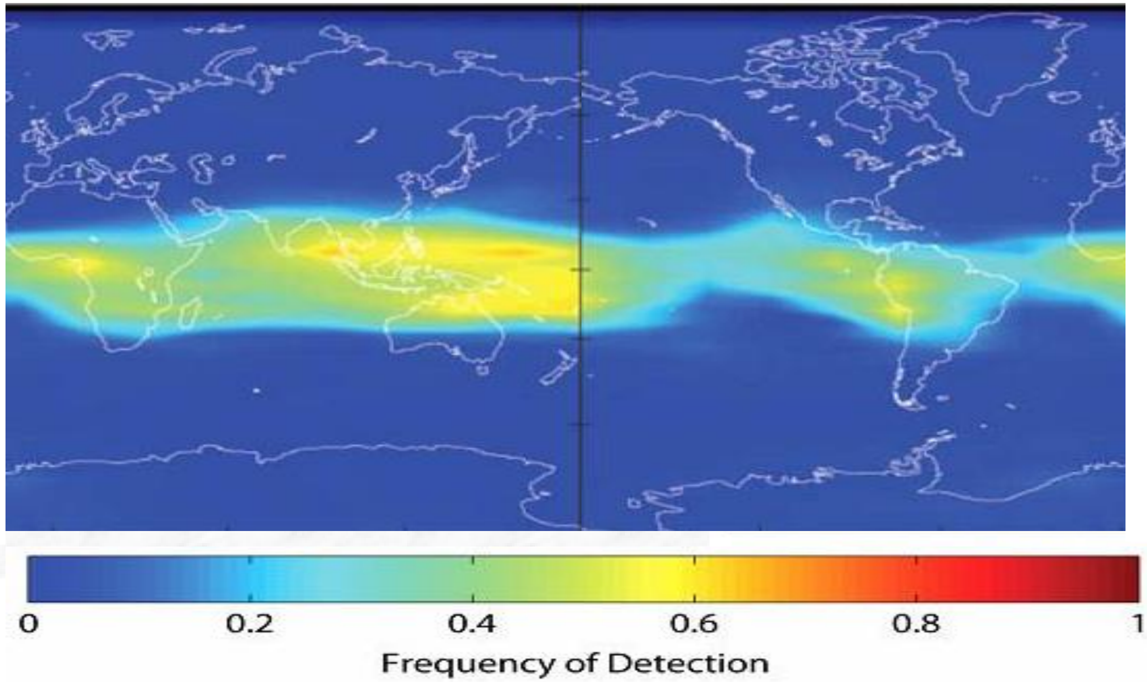




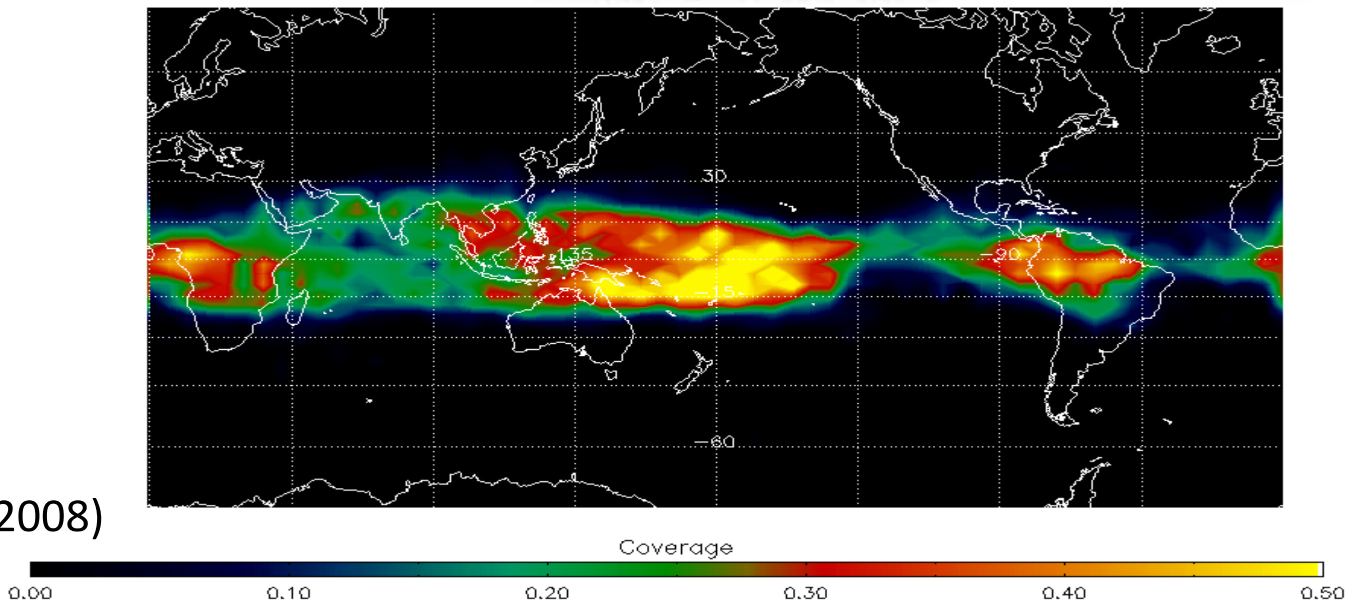
Comparison of annual average OSIRIS sub visual cirrus with CLD/CAL cirrus

OSIRIS cirrus

> 12 km



CloudSat/
Calipso
cirrus
>15 km



Evans et al. (2008)

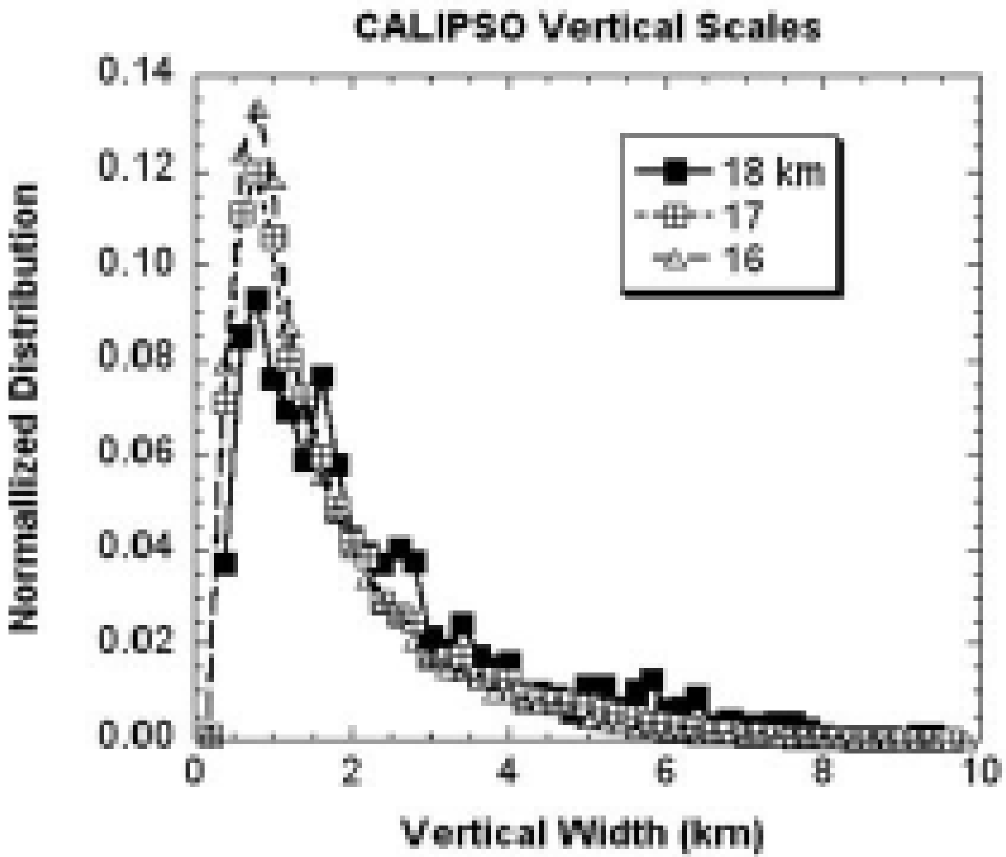


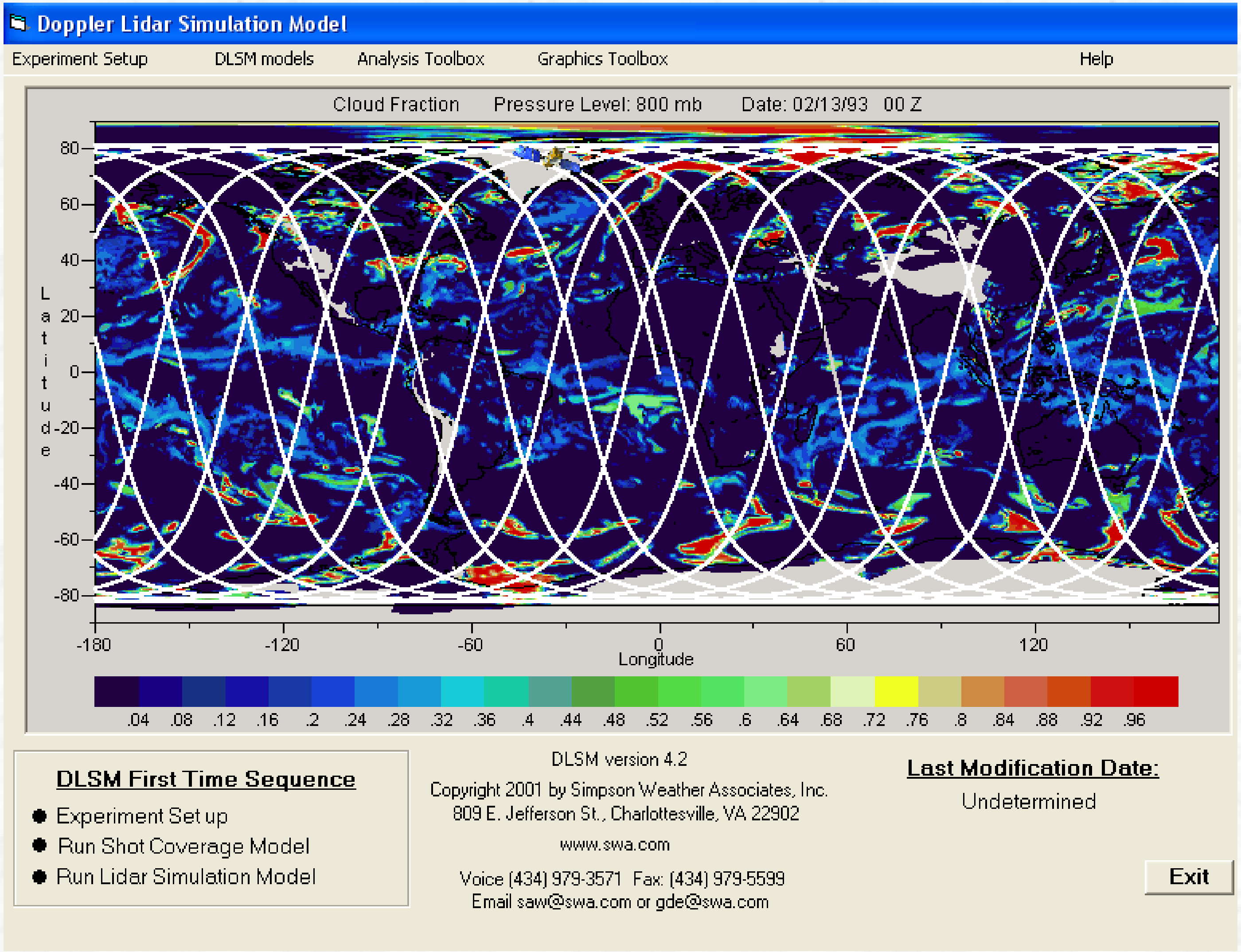
Figure 12. Vertical scales of cirrus as observed by CALIPSO at 17 km (~90 hPa) in the tropics. The pdfs peak between 0.8 and 1.0 km.

The DLSM

(Doppler Lidar Simulation Model)

- Used since 1988 to simulate DWL performance for OSSEs using inputs from Nature Runs.
  - Clouds
  - Subgrid scale wind variability
  - Aerosol distributions
- Simulate both direct and coherent detection
- Stress realistic characterization of random and systematic errors.

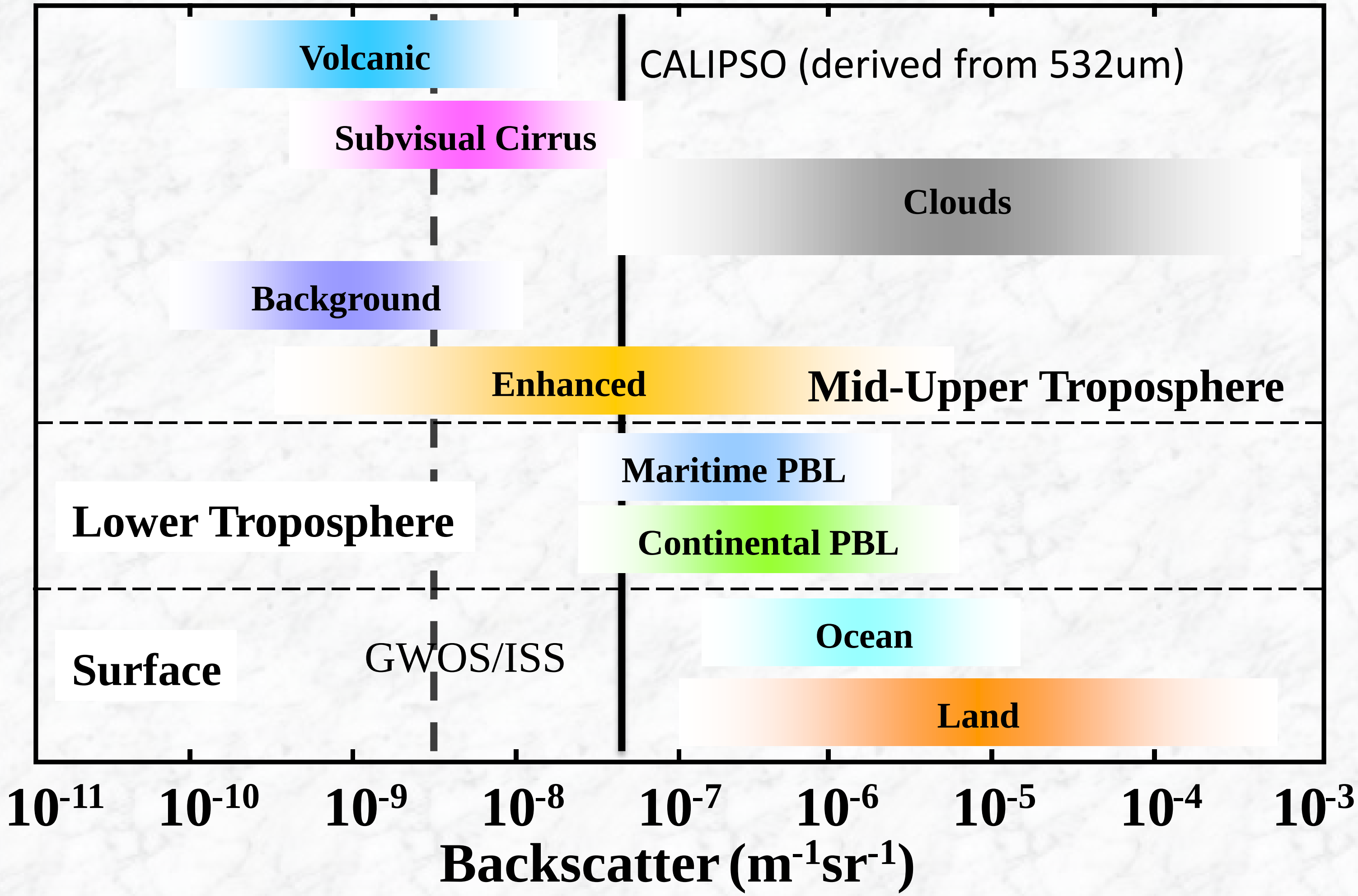
Doppler Lidar Simulation Model



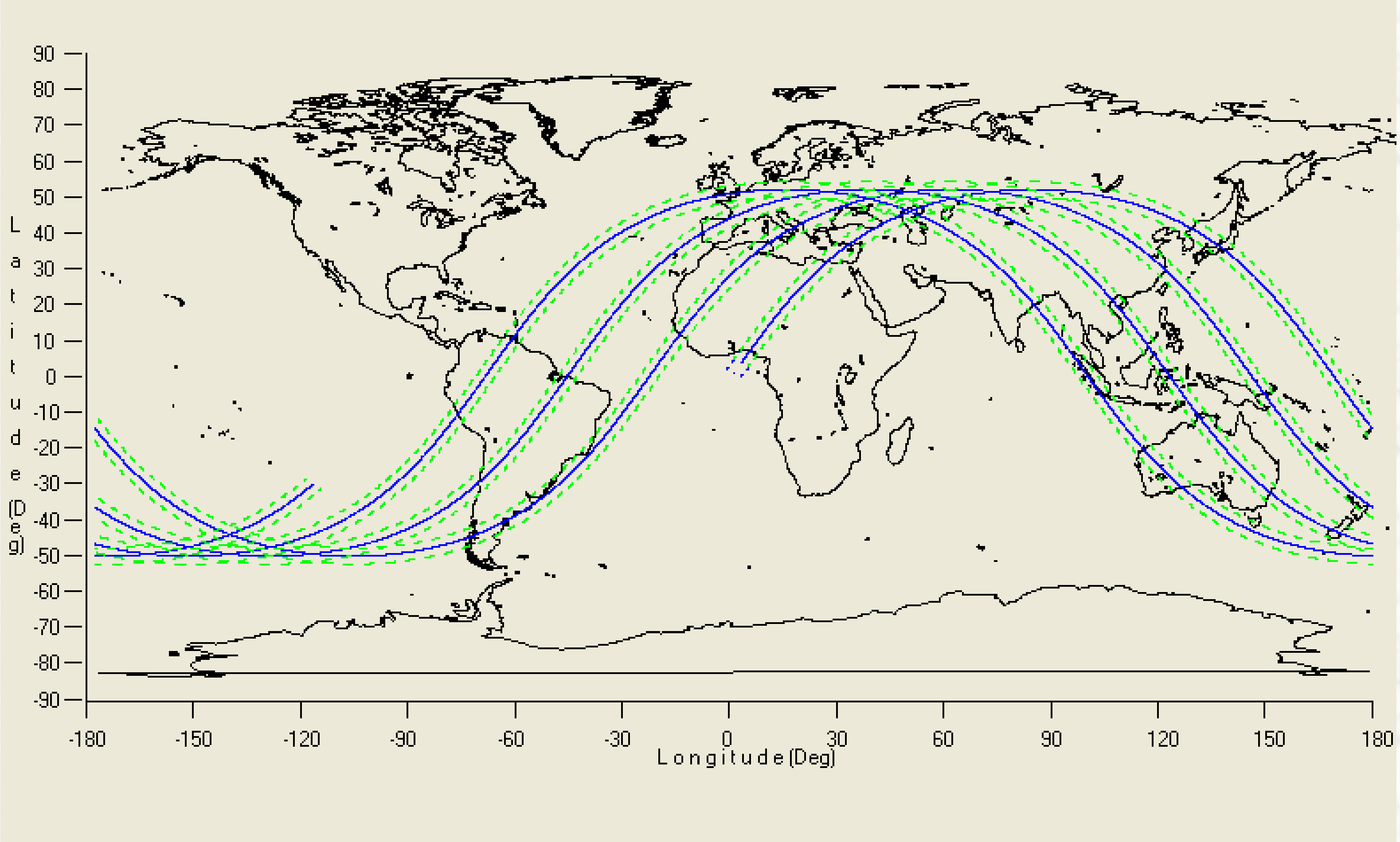
Recent DLSM simulations for use in OSSEs

- Emphasis on the tropics.
- Scaling GWOS down to 350km for ISS
- Clouds in T511 Nature Run modified to conform to ISCCP coverage statistics; added subvisual cirrus
- Have been understating very thin to subvisual cirrus effects which would be very positive for coherent detection coverage yet only slightly negative for direct detection accuracies.

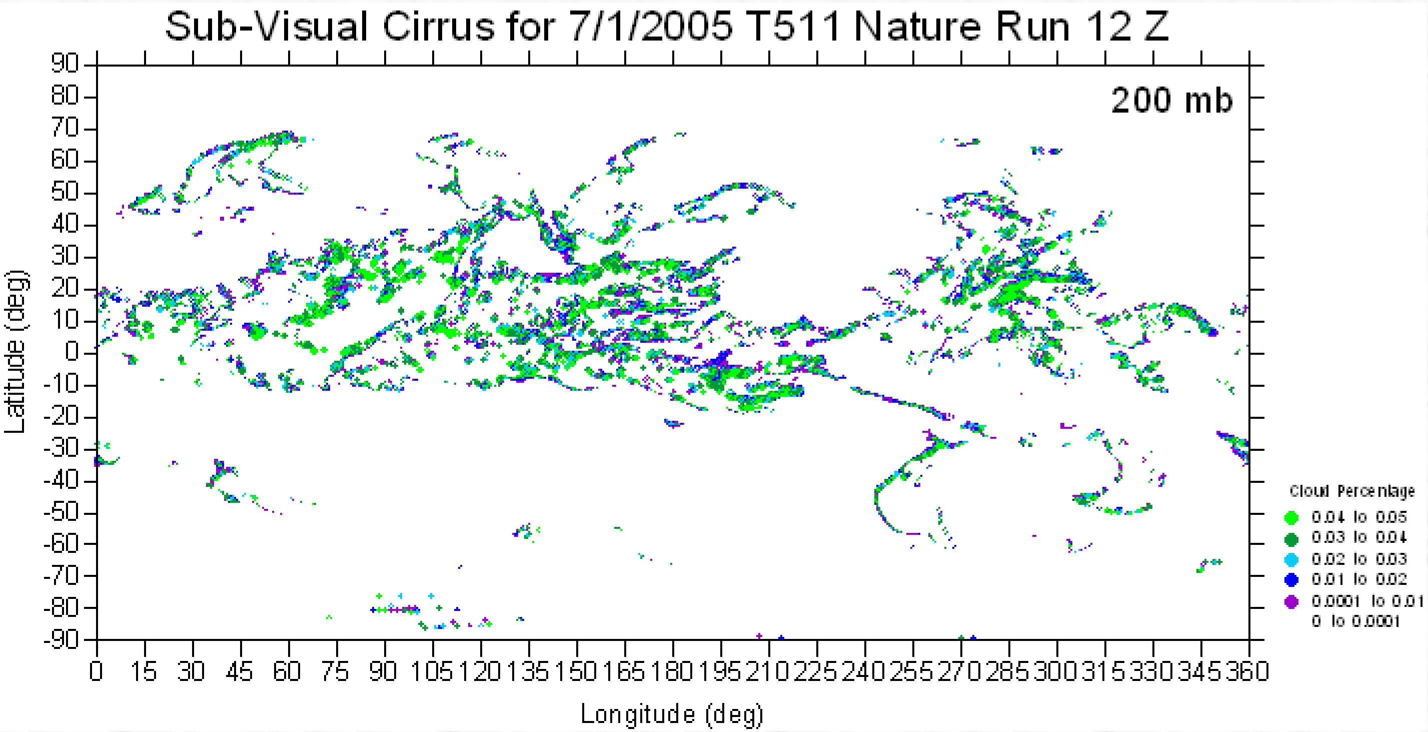
Natural Variability of 2 μm Backscatter

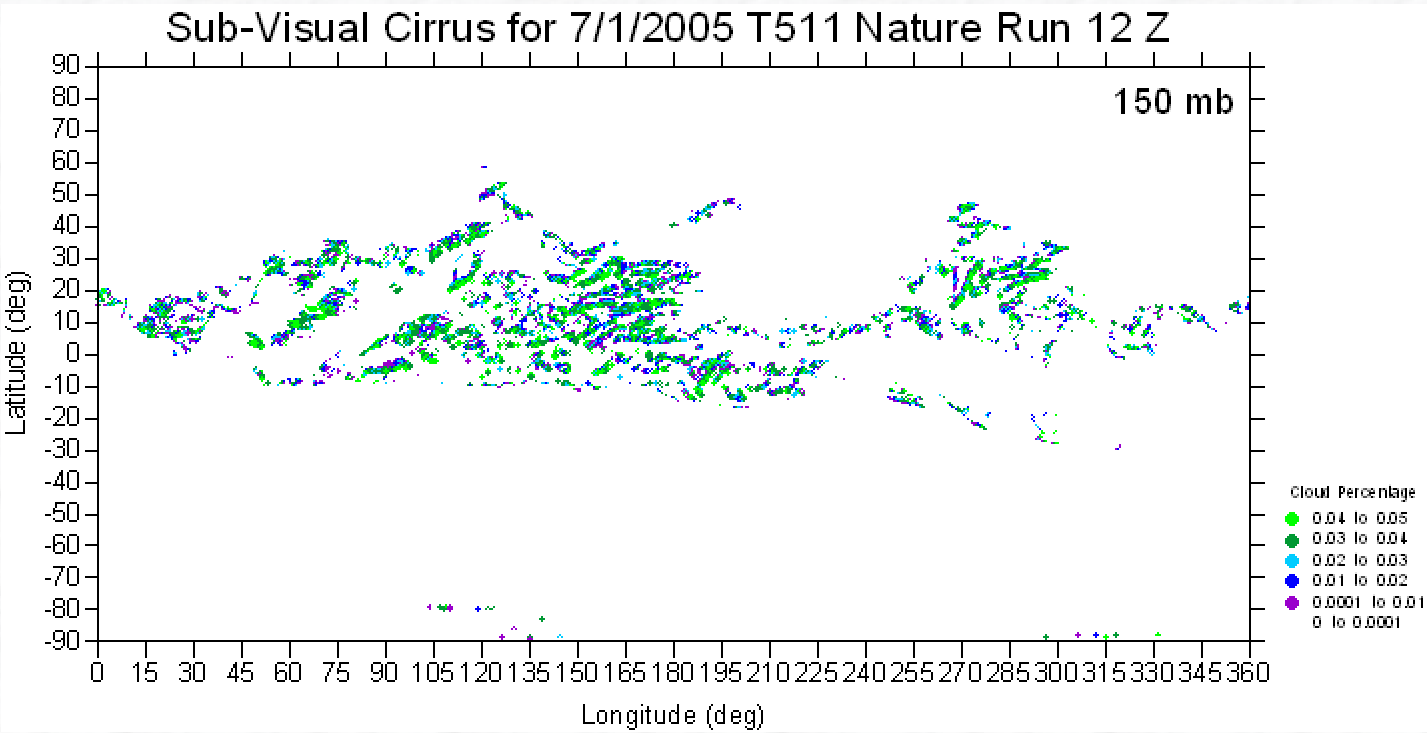


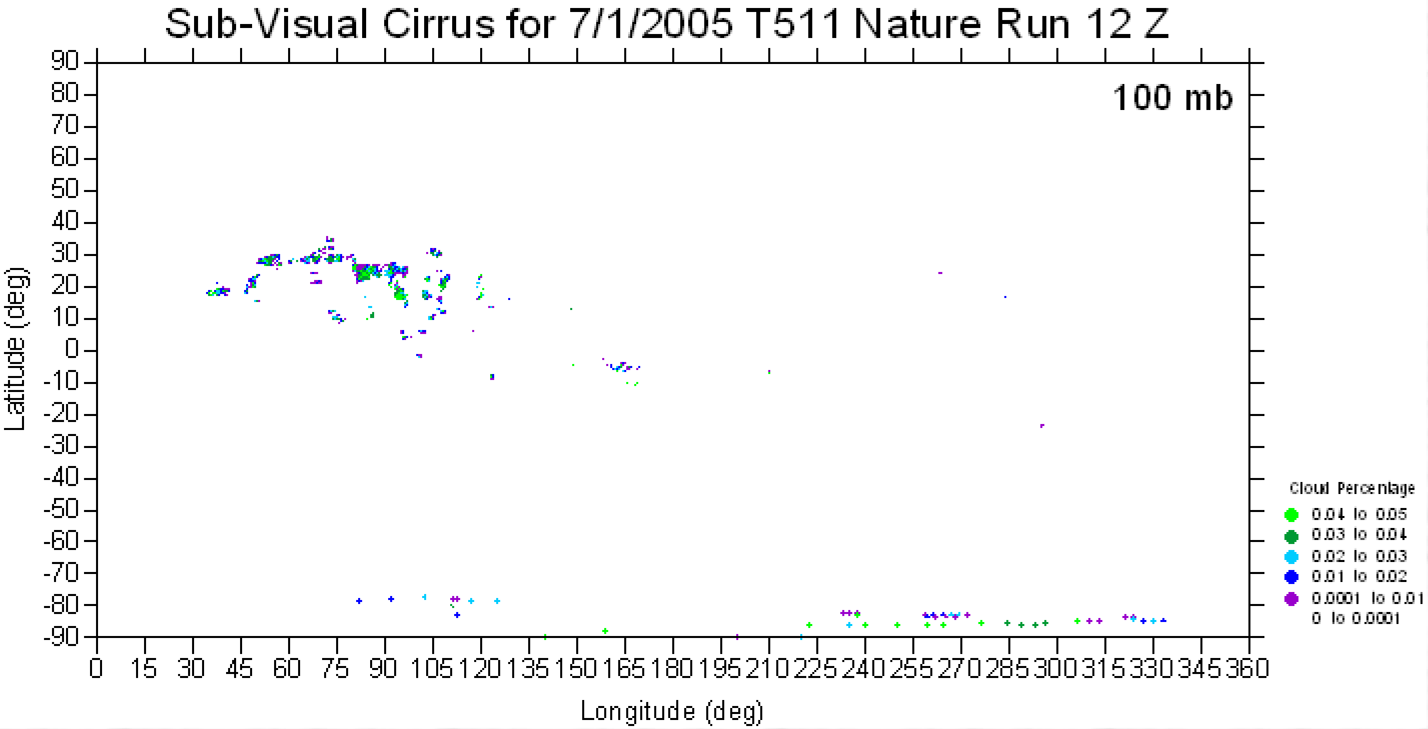
ISS Wind Lidar Coverage for three orbits



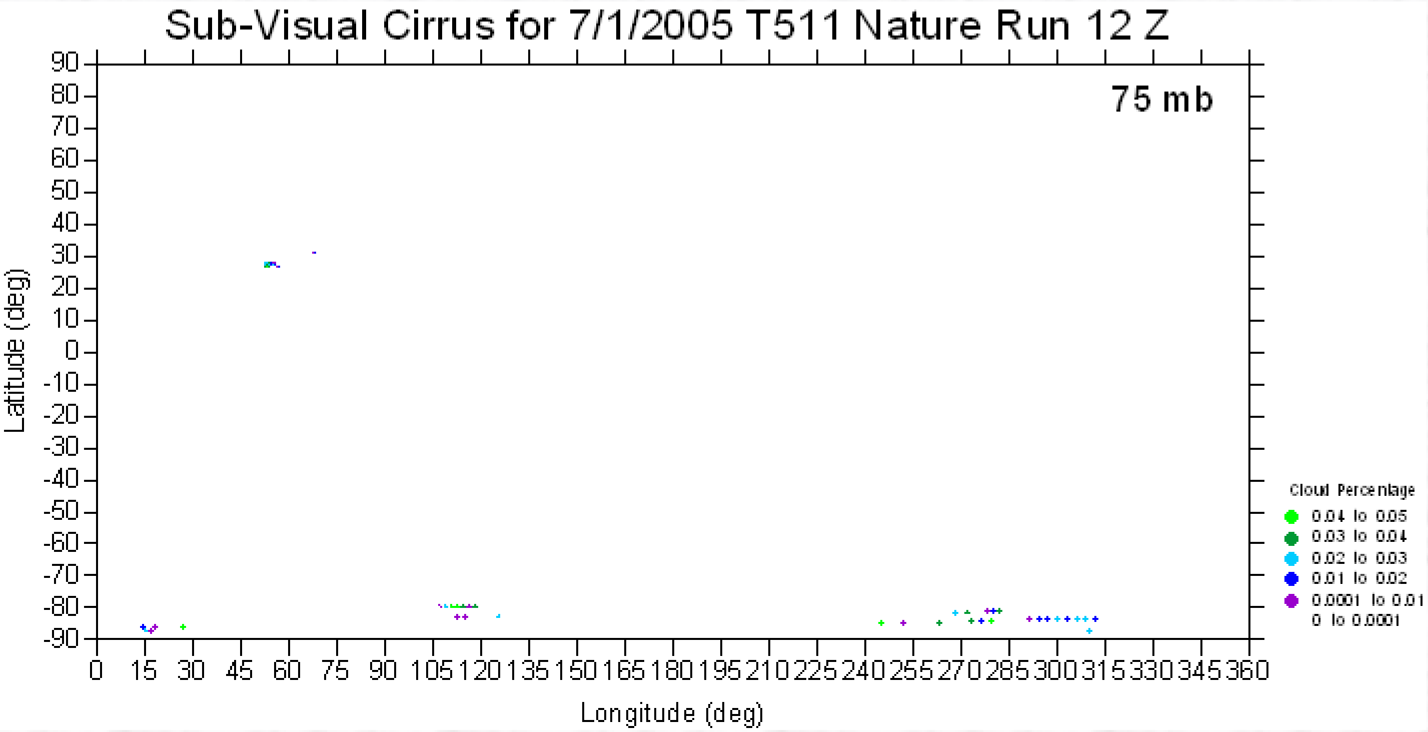
Simulated thin and sub-visual cirrus


Sub-Visual Cirrus for 7/1/2005 T511 Nature Run 12 Z
200 mb
Latitude (deg)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
Longitude (deg)
Cloud Percentage
0.04 to 0.05
0.03 to 0.04
0.02 to 0.03
0.01 to 0.02
0.0001 to 0.01
0 to 0.0001


Sub-Visual Cirrus for 7/1/2005 T511 Nature Run 12 Z
150 mb
Latitude (deg)
Longitude (deg)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
Cloud Percentage
0.04 to 0.05
0.03 to 0.04
0.02 to 0.03
0.01 to 0.02
0.0001 to 0.01
0 to 0.0001



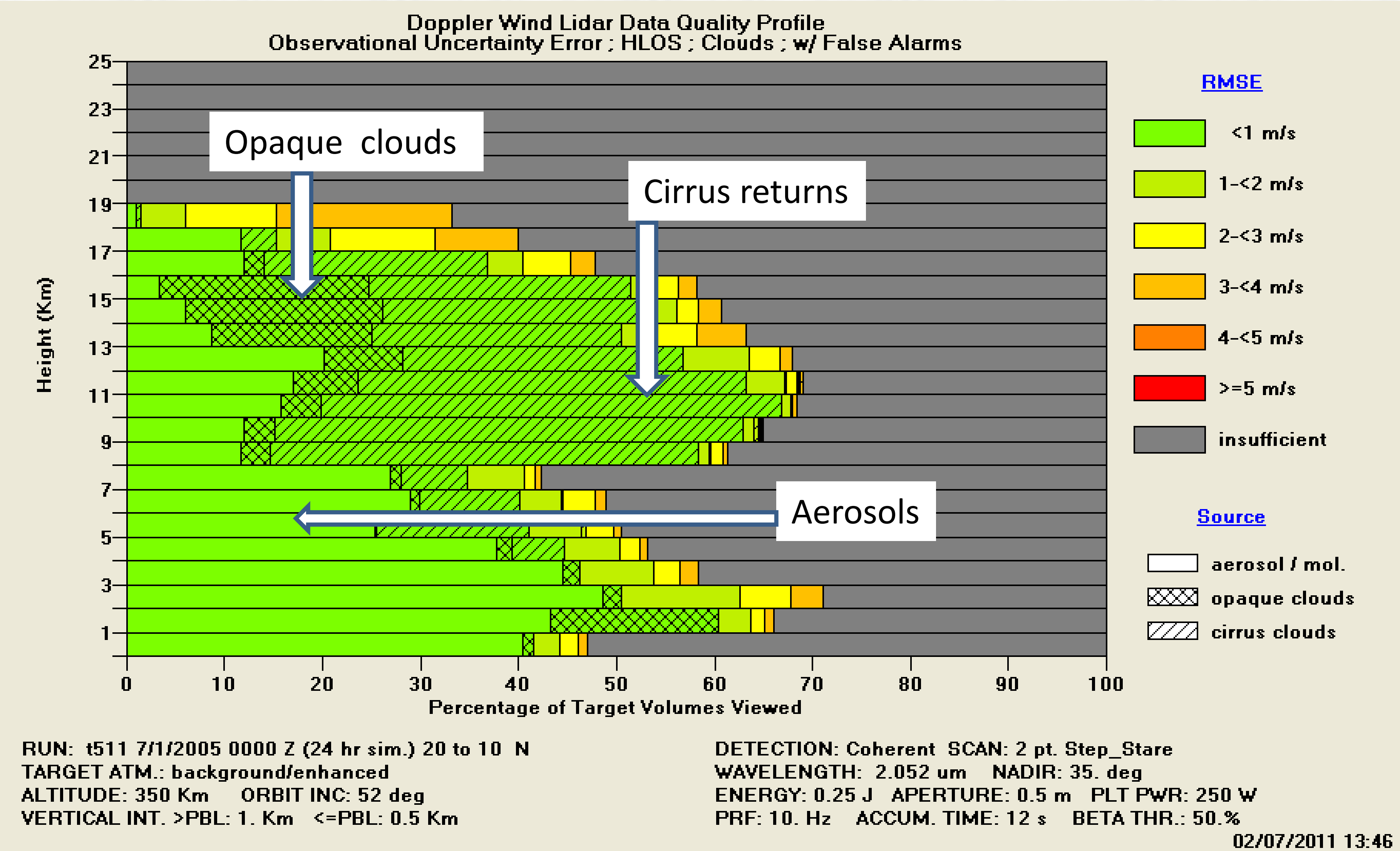
Sub-Visual Cirrus for 7/1/2005 T511 Nature Run 12 Z
100 mb
Latitude (deg)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
Longitude (deg)
Cloud Percentage
0.04 to 0.05
0.03 to 0.04
0.02 to 0.03
0.01 to 0.02
0.0001 to 0.01
0 to 0.0001



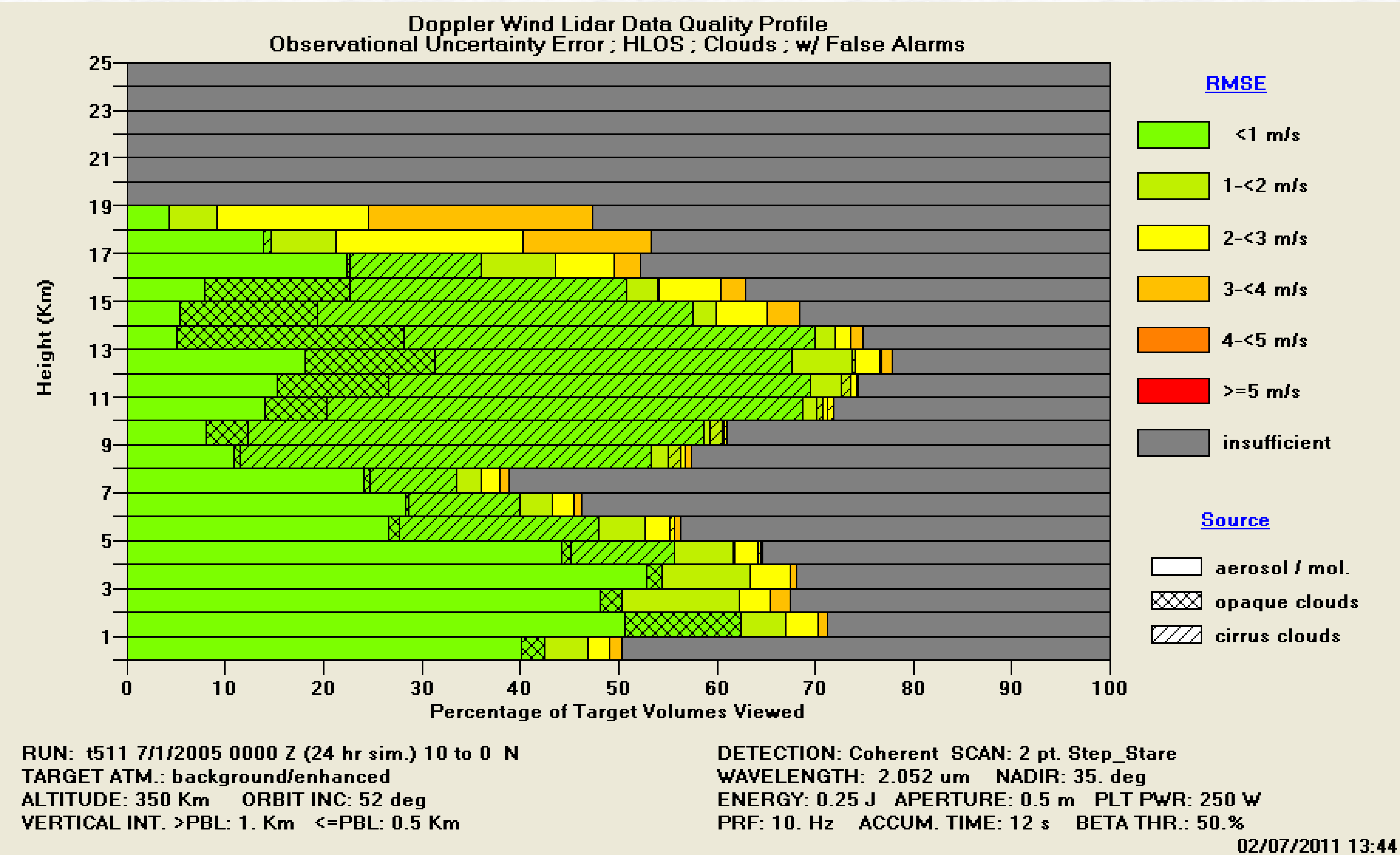
Sub-Visual Cirrus for 7/1/2005 T511 Nature Run 12 Z
75 mb
Latitude (deg)
Longitude (deg)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
Cloud Percentage
0.04 to 0.05
0.03 to 0.04
0.02 to 0.03
0.01 to 0.02
0.0001 to 0.01
0 to 0.0001

Simulated WISSCR's performance using the DLSM with the T511 ECMWF Nature Run

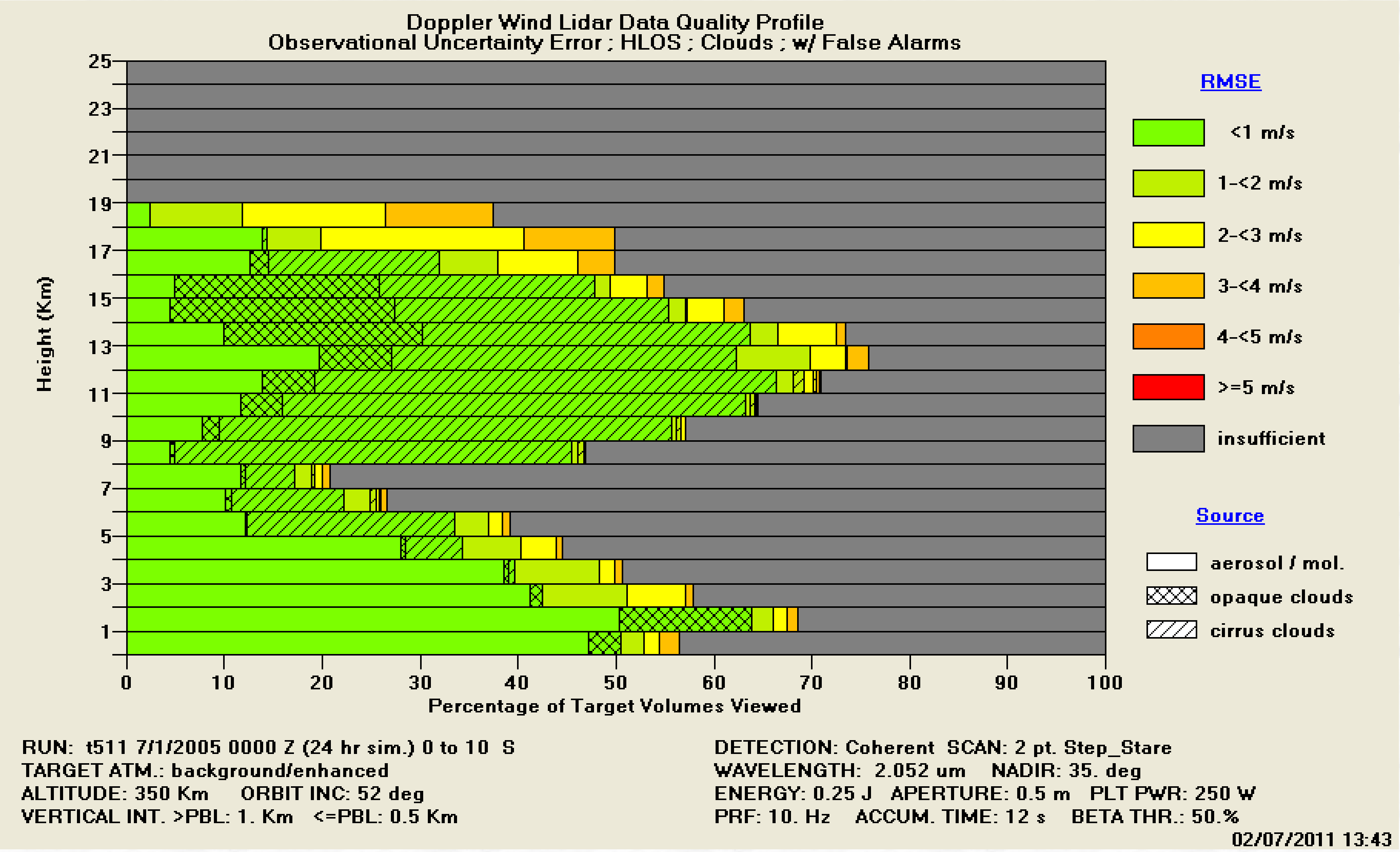
Aerosol/cloud subsystem of the Wind Lidar on ISS
20 – 10 N



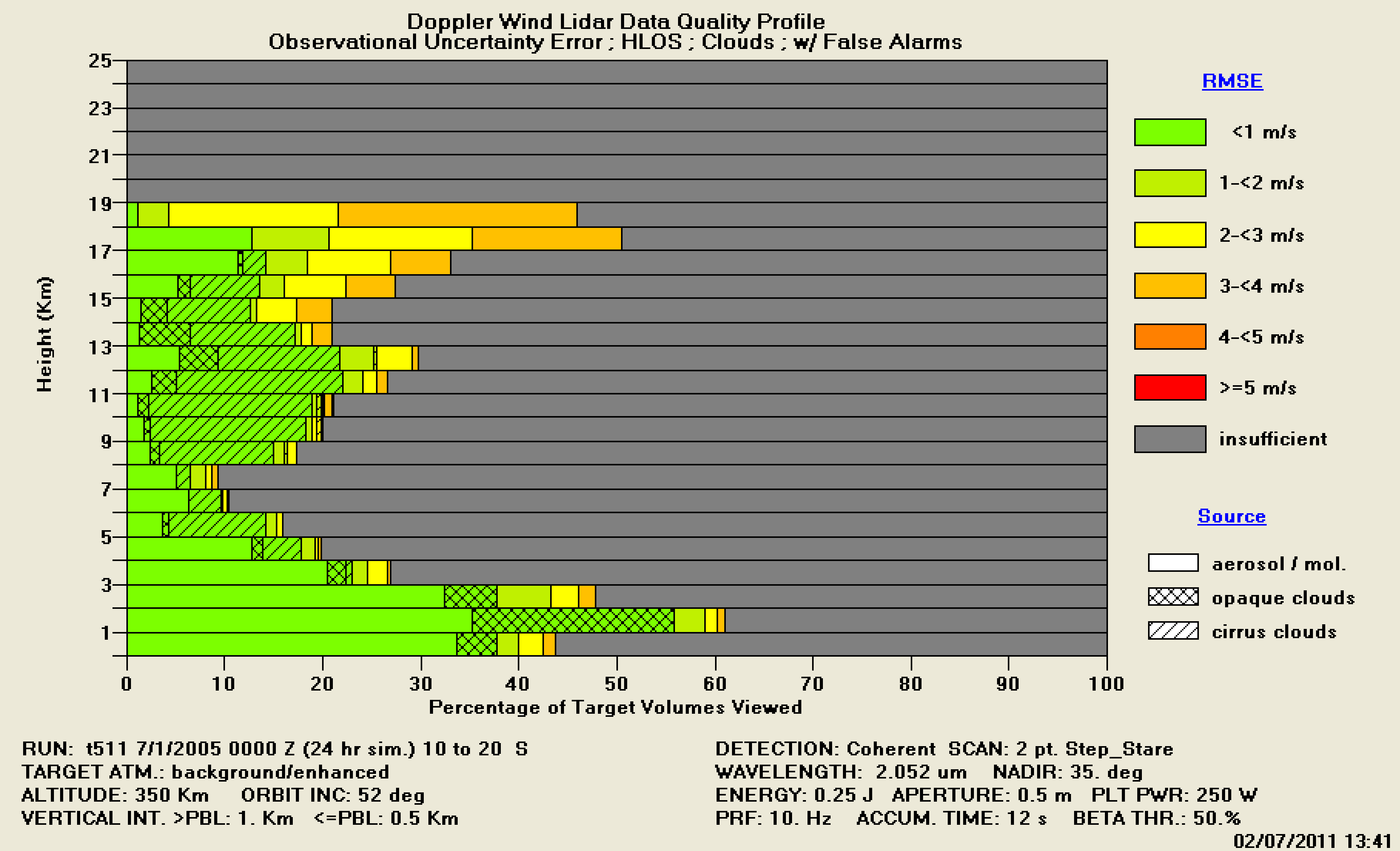
Aerosol/cloud subsystem of the Wind Lidar on ISS
10 -0 N



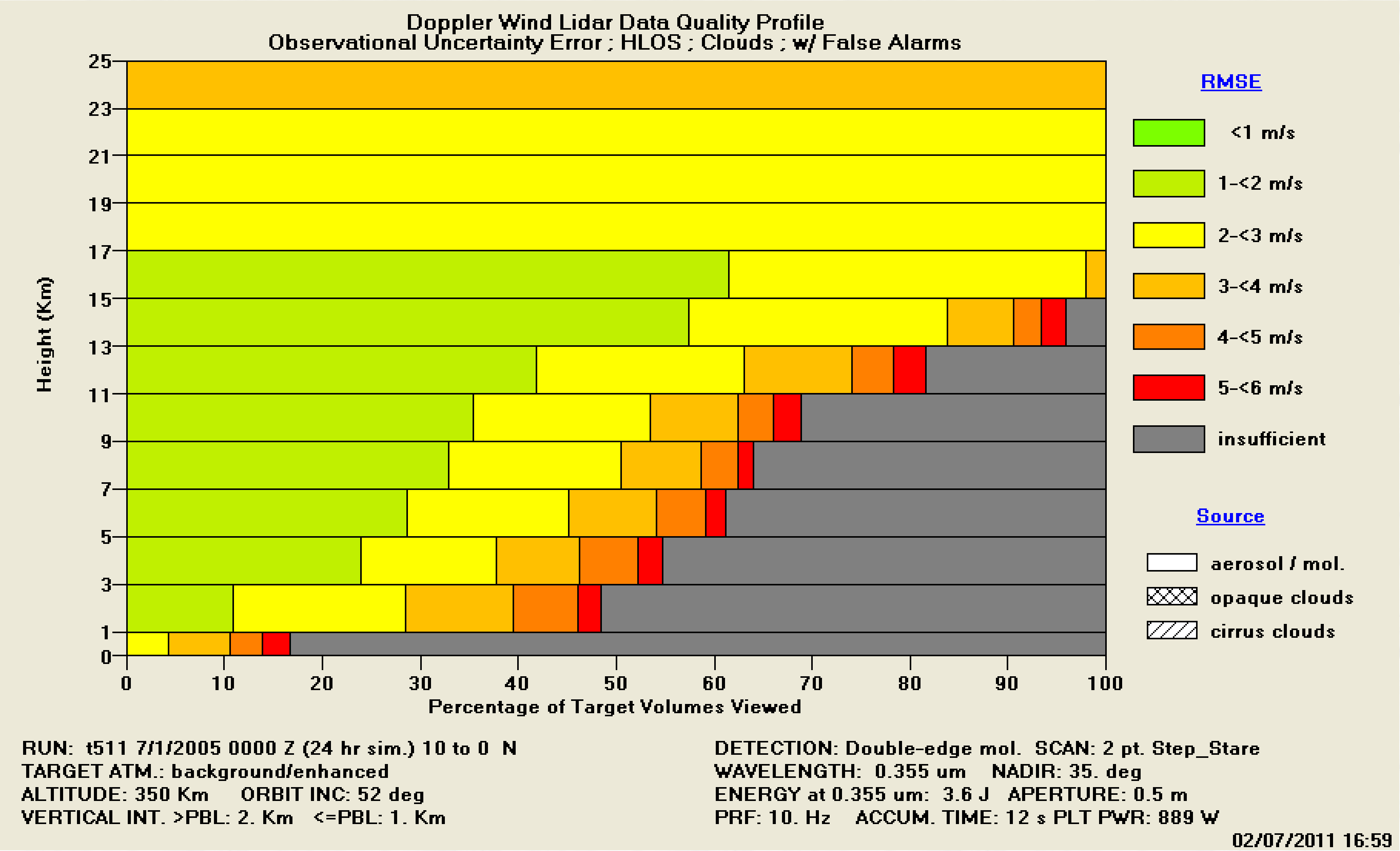
Aerosol/cloud subsystem of the Wind Lidar on ISS
0 – 10 S



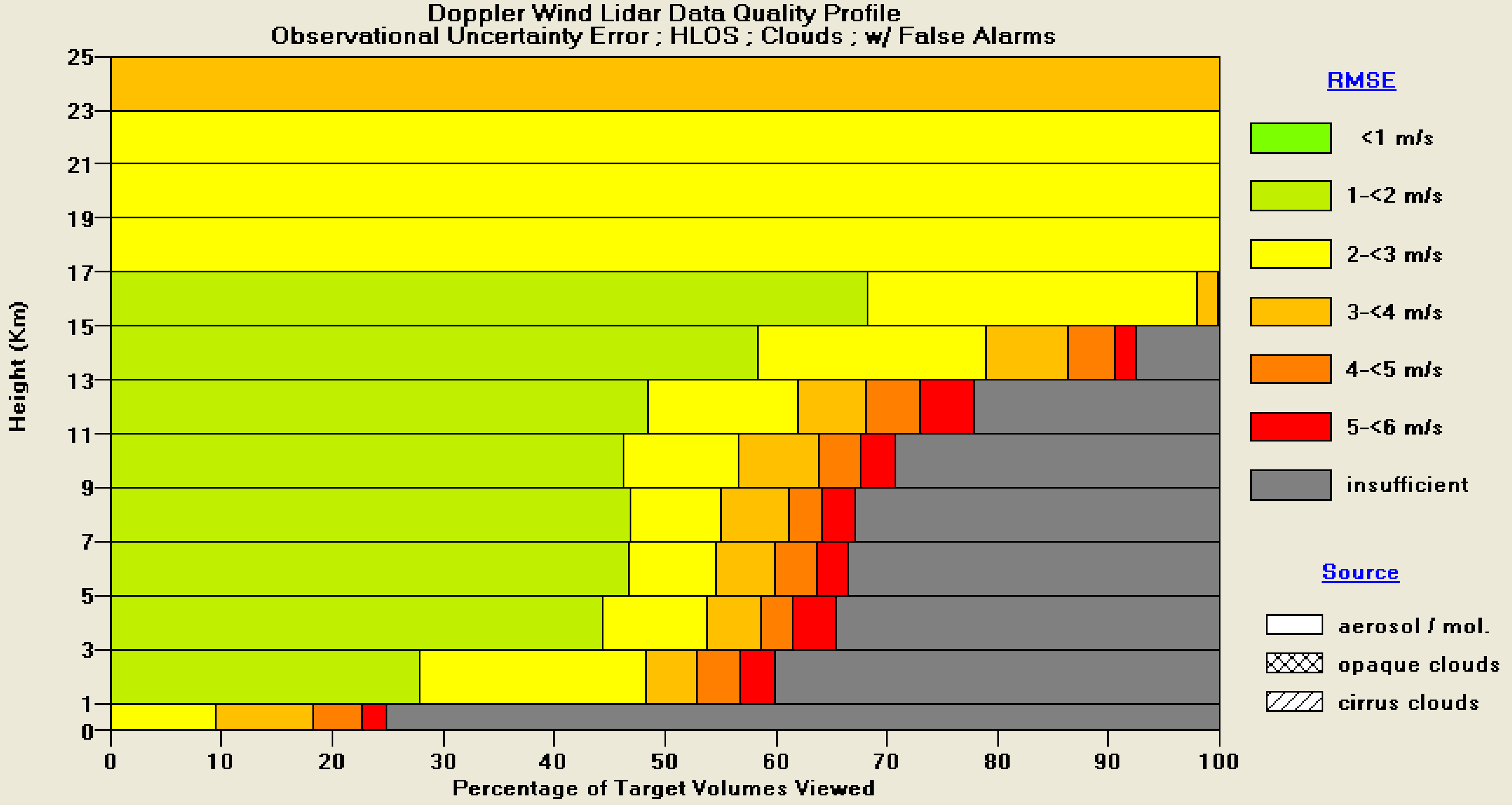
Aerosol/cloud subsystem of the Wind Lidar on ISS
10 -20 S



Molecular subsystem of the Wind Lidar on ISS
10 – 0 N



Molecular subsystem of the Wind Lidar on ISS
0 - 10 S

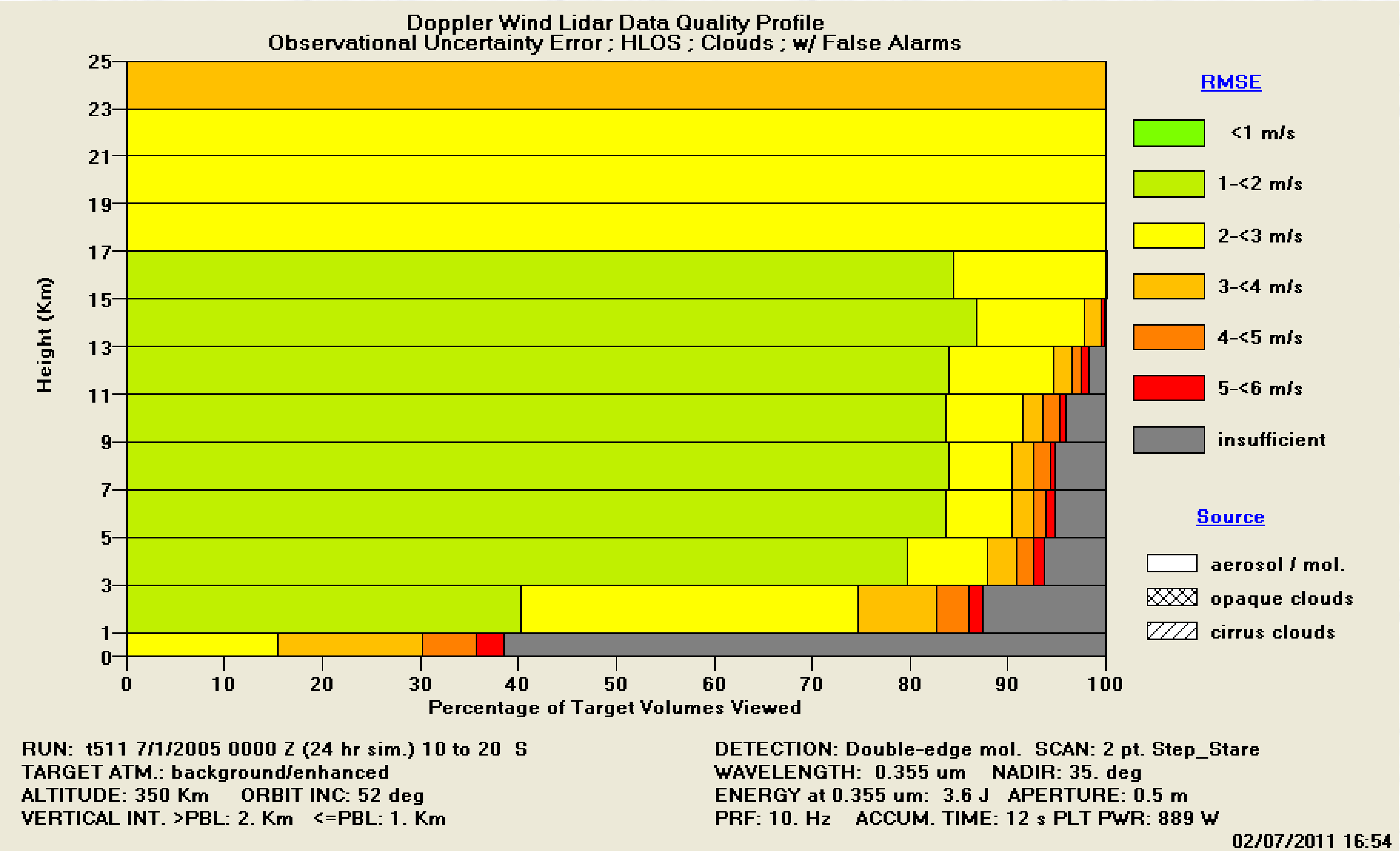


RUN: t511 7/1/2005 0000 Z (24 hr sim.) 0 to 10 S
TARGET ATM.: background/enhanced
ALTITUDE: 350 Km ORBIT INC: 52 deg
VERTICAL INT. >PBL: 2. Km <=PBL: 1. Km

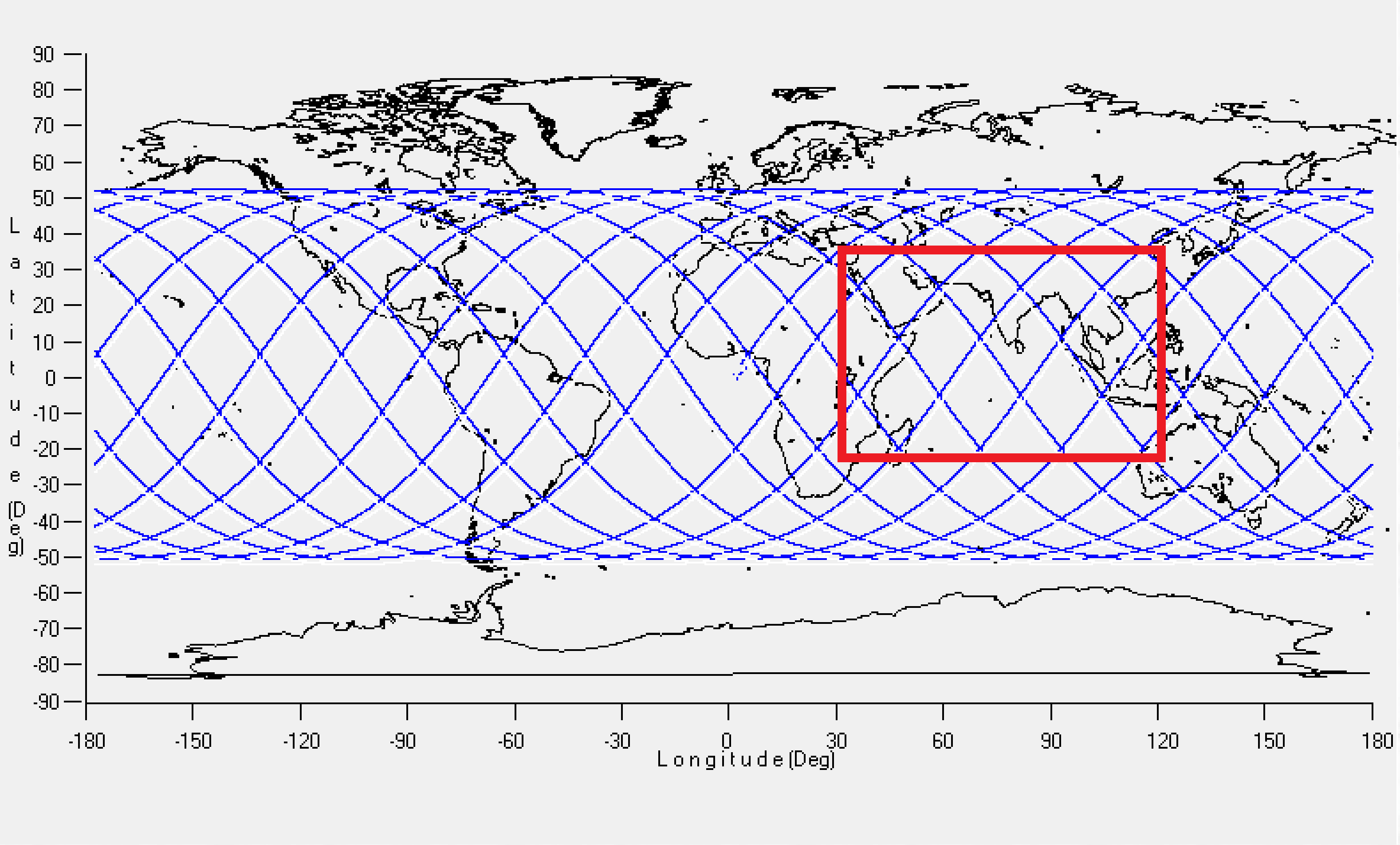
DETECTION: Double-edge mol. SCAN: 2 pt. Step_Stare
WAVELENGTH: 0.355 um NADIR: 35. deg
ENERGY at 0.355 um: 3.6 J APERTURE: 0.5 m
PRF: 10. Hz ACCUM. TIME: 12 s PLT PWR: 889 W

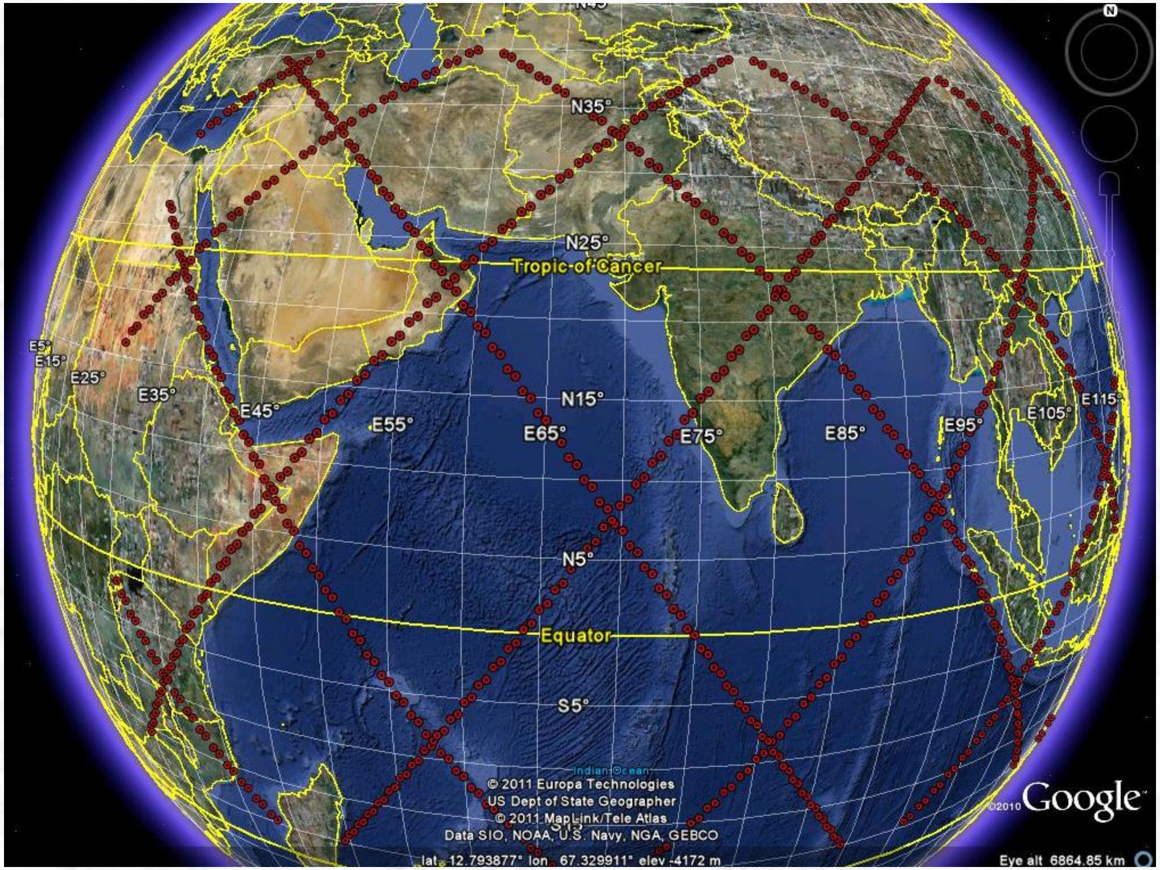
02/07/2011 16:54

Molecular subsystem of the Wind Lidar on ISS 10 -20 S



Global coverage of WISSCR for 24 hours





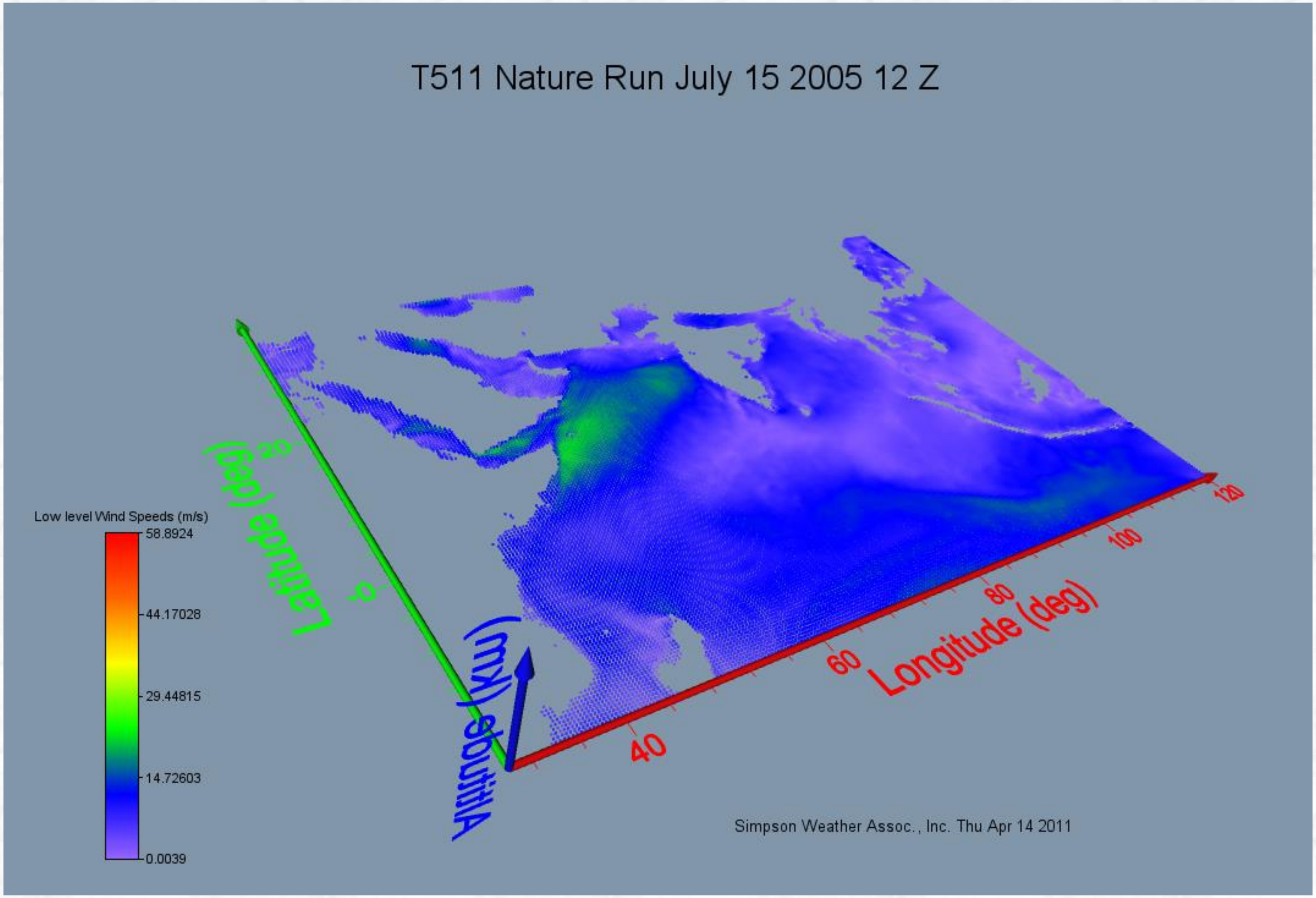
WISSCR Sampling Coverage

WISSCR sounding locations over 24 hours within the Monsoon Region. There are 720 LOS products, each the result of averaging 120 individual laser pulses with 1 km vertical resolution above 2km and 250m resolution within the lowest 2km.

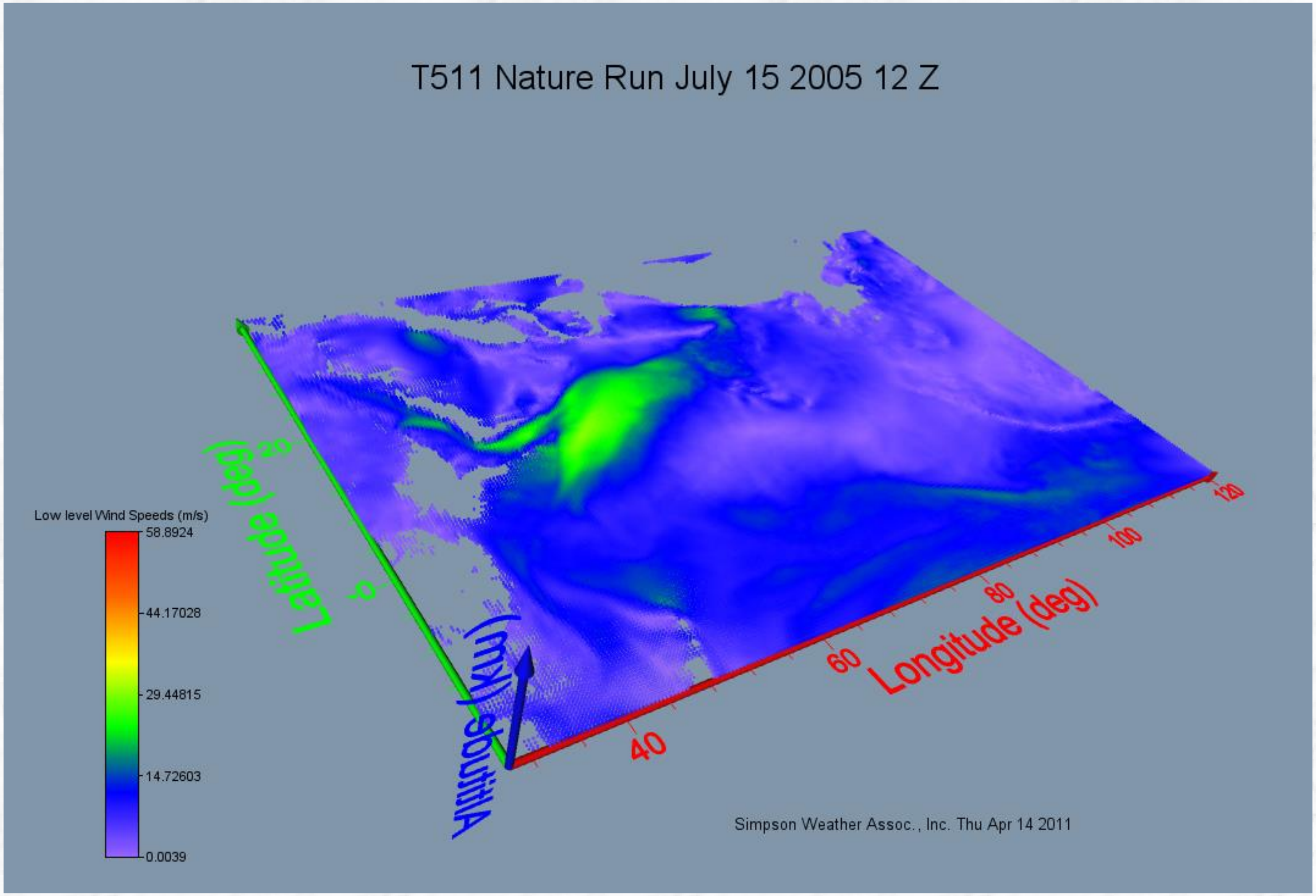
Simulation of WISSCR over Monsoon Region

- Use the Doppler Lidar Simulation Model (DLSM) developed for instrument concept evaluations and potential Numerical Weather Prediction model impact studies.
- Simulate WISSCR observations using ECMWF Nature Run (T511).
- Select days in July and August with Somalia Low Level Jets with varying intensities and locations.

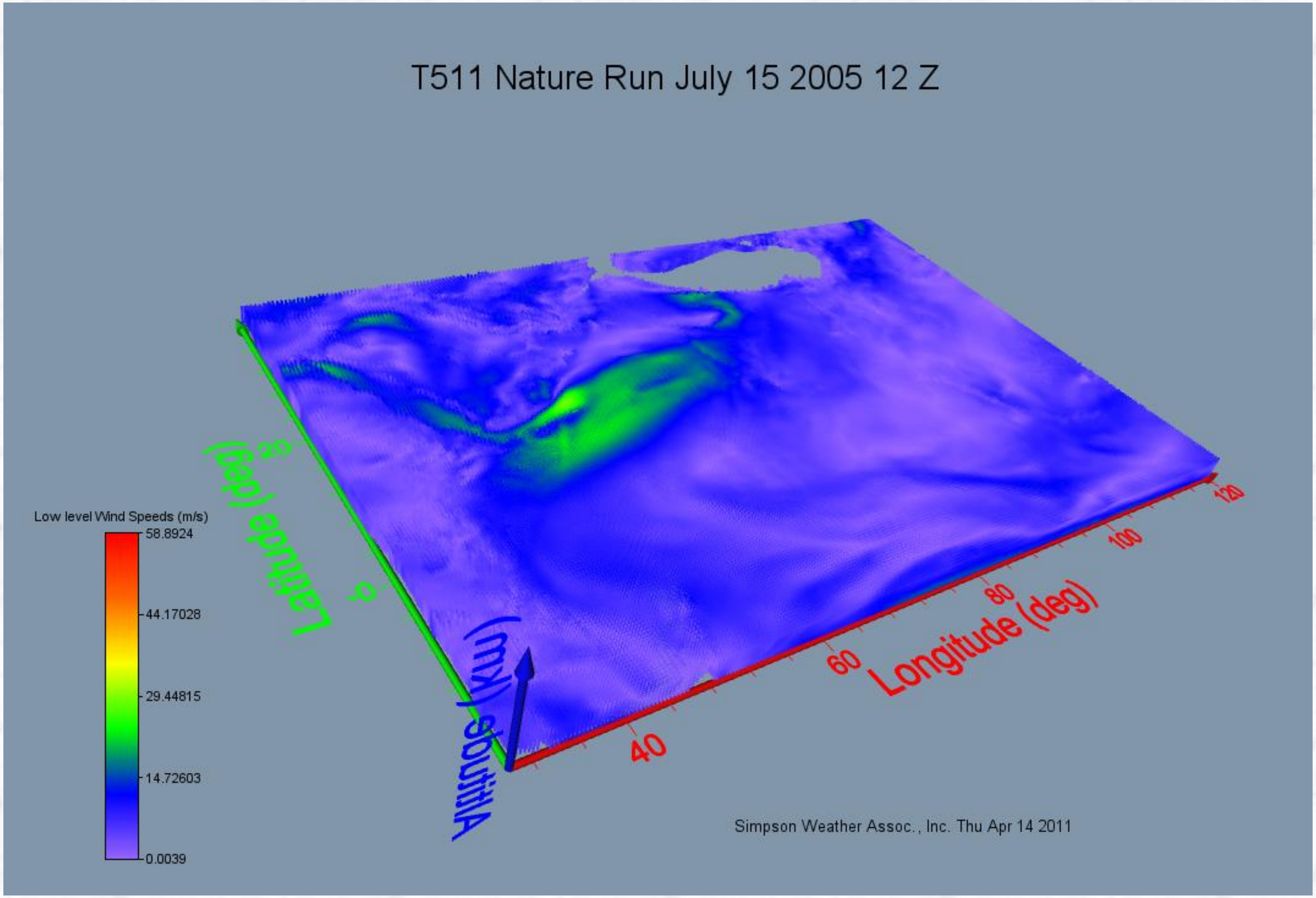
Somalia LLJ within 250 meters MSL



Somalia LLJ at 1000 meters MSL



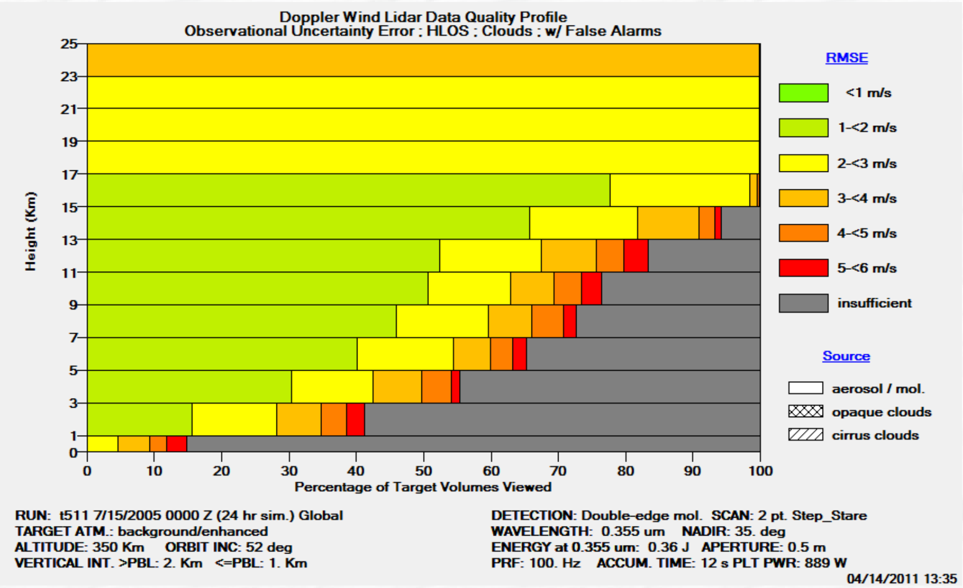
Somalia LLJ at 1500 meters MSL

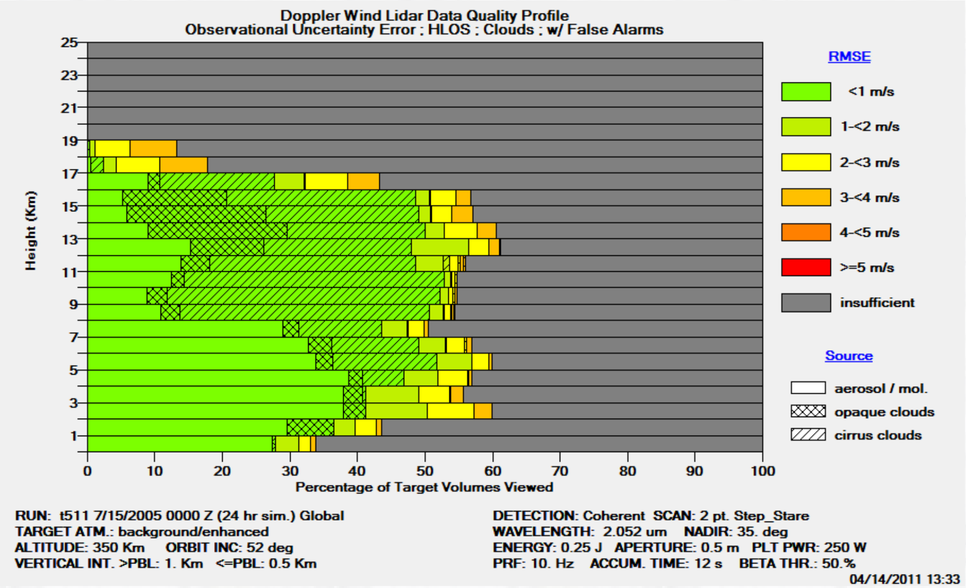


Summary of WISSCR data products for 24 hours over Monsoon Region

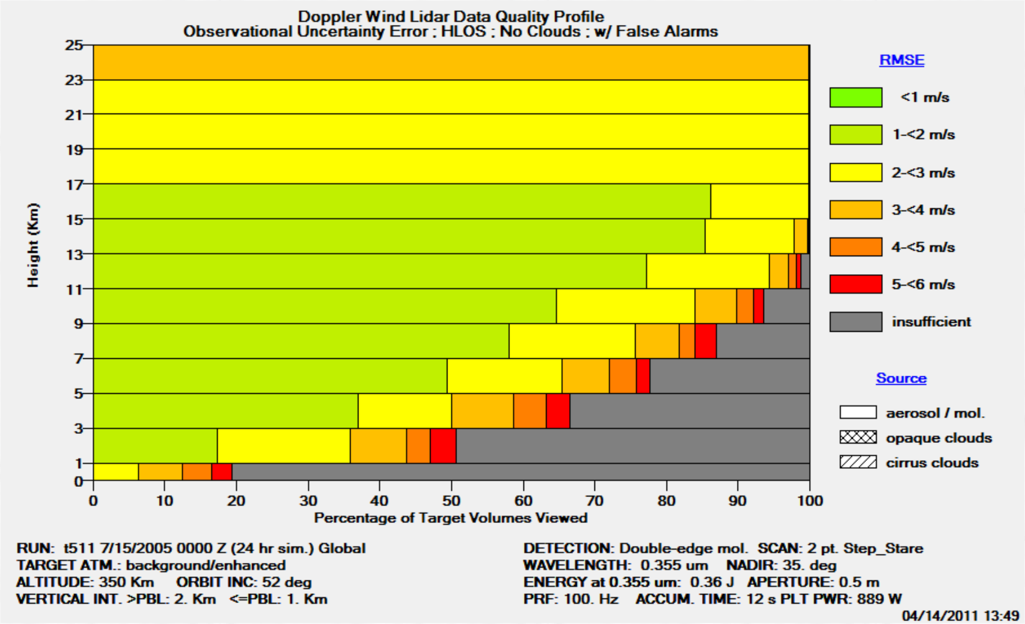
The charts show the percentage of the attempts to make a wind observation at each level below 25km during a 24 hour period over the Monsoon Region. The colors denote accuracy (m/s) and the hatching in the lower figure denote returns from clouds, including those that are penetrated by the laser beam. The top figure represent the performance of the direct detection subsystem of the hybrid technology WISSCR. Note the 2 km vertical resolution and the best accuracy of

1-2 m/s RMSE. The lower figure represents the performance of the coherent subsystem. Note the vertical resolution of 1 km and the returns from clouds (cirrus, subvisual cirrus and opaque. The accuracies are mostly in the < 1 m/s level.

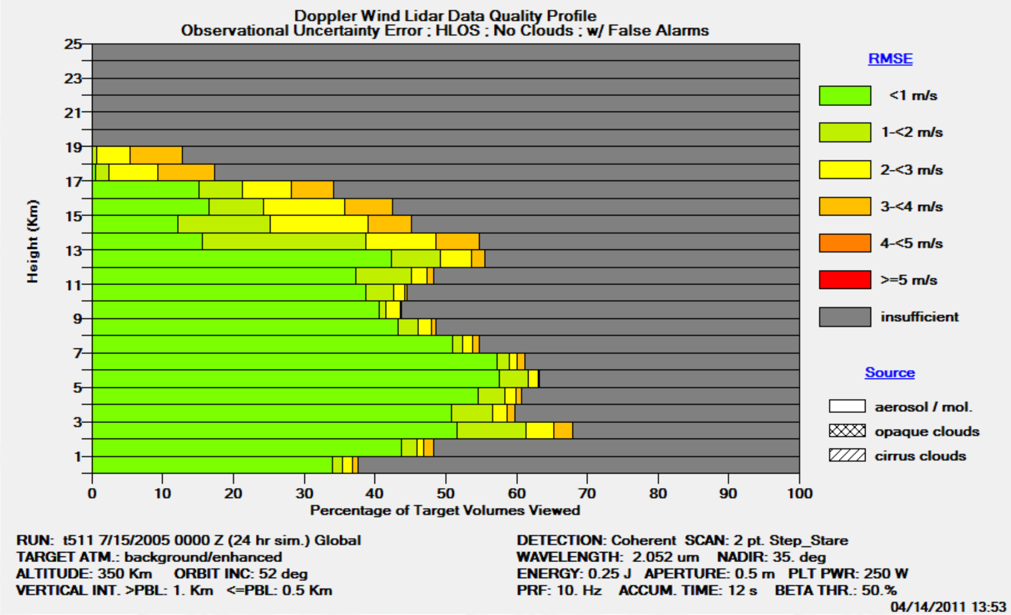




Summary of WISSCR data products for 24 hours over Monsoon Region

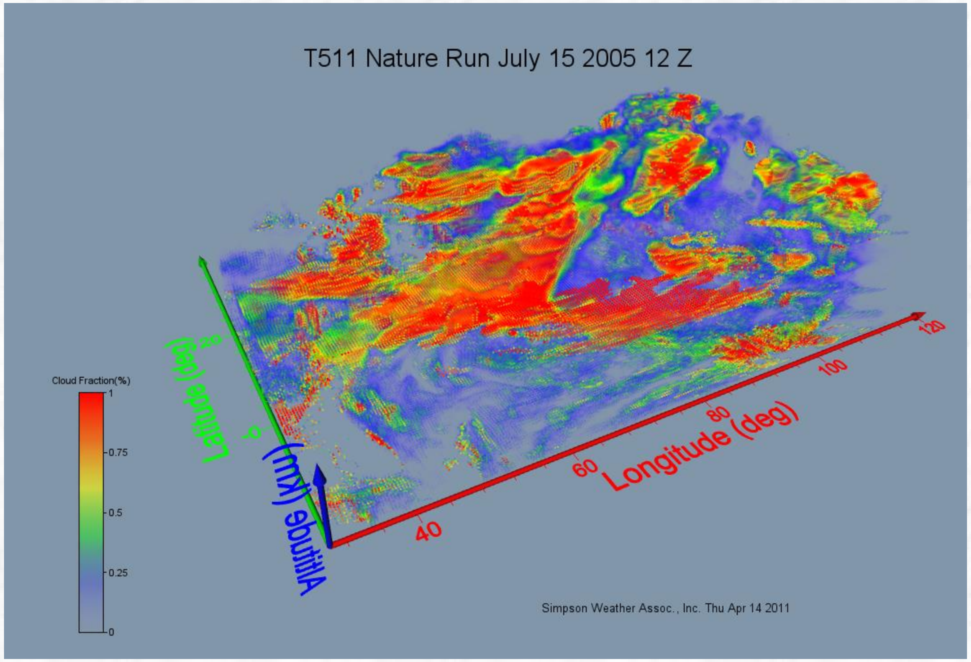


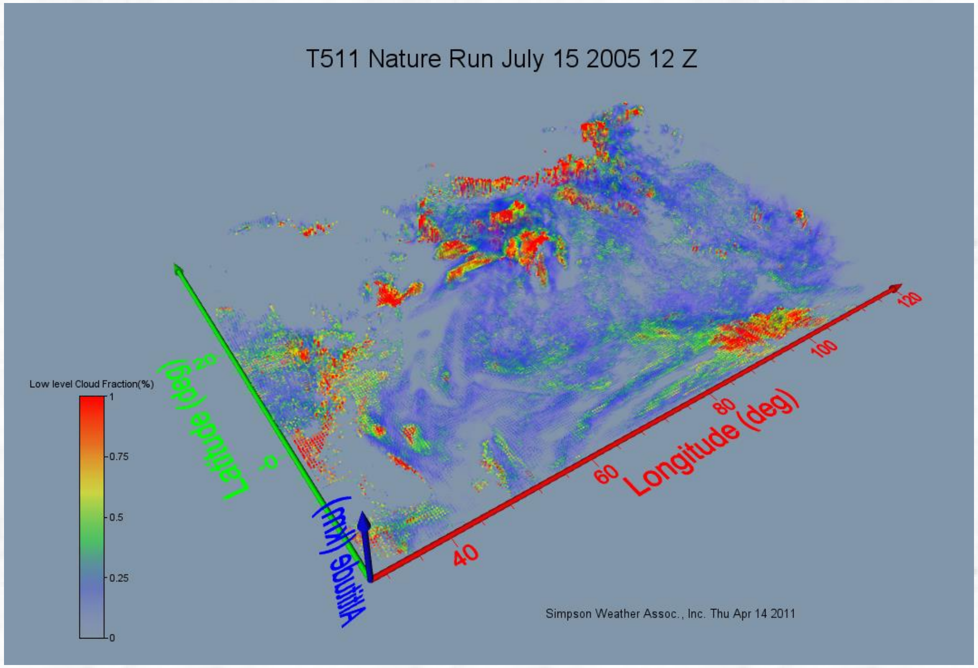
This is a similar presentation as that in the previous slide except that the simulation was done with no clouds were used from the T511 Nature Run. Note that there is actually more useful wind measurements available from the coherent system when clouds are present.



Cloud Coverage as represented in T511 Nature Run

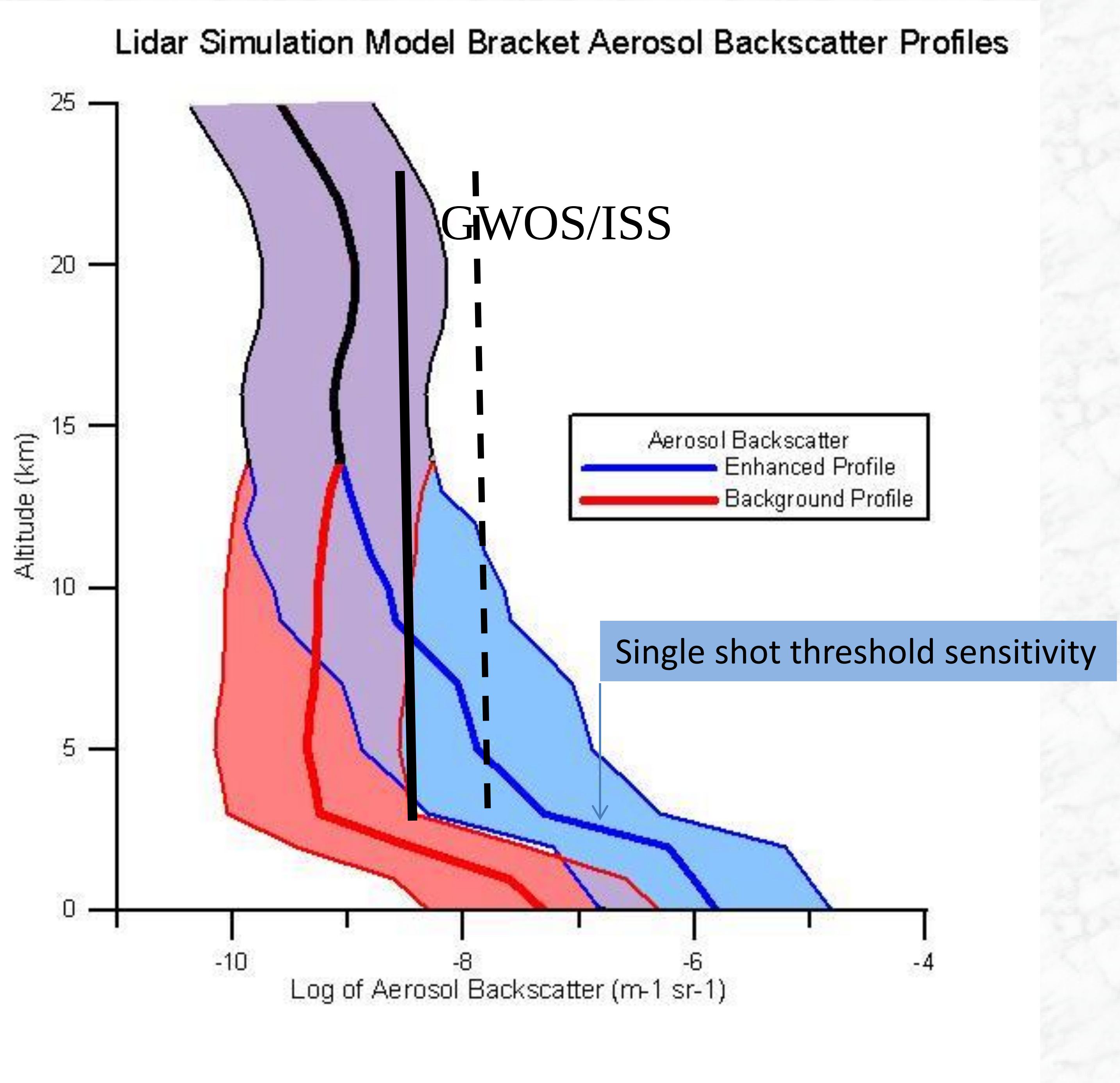
The top figure illustrates the cloud coverage provided by the T511 Nature Run for all levels within the troposphere. The lower figure represents only those clouds below 5000 meters. Note that much of the upper level cloud is of sufficiently low optical depth that the coherent subsystem can obtain a good wind measurement within the cloud layer and also penetrate to aerosol and cloud layers below.





Summary

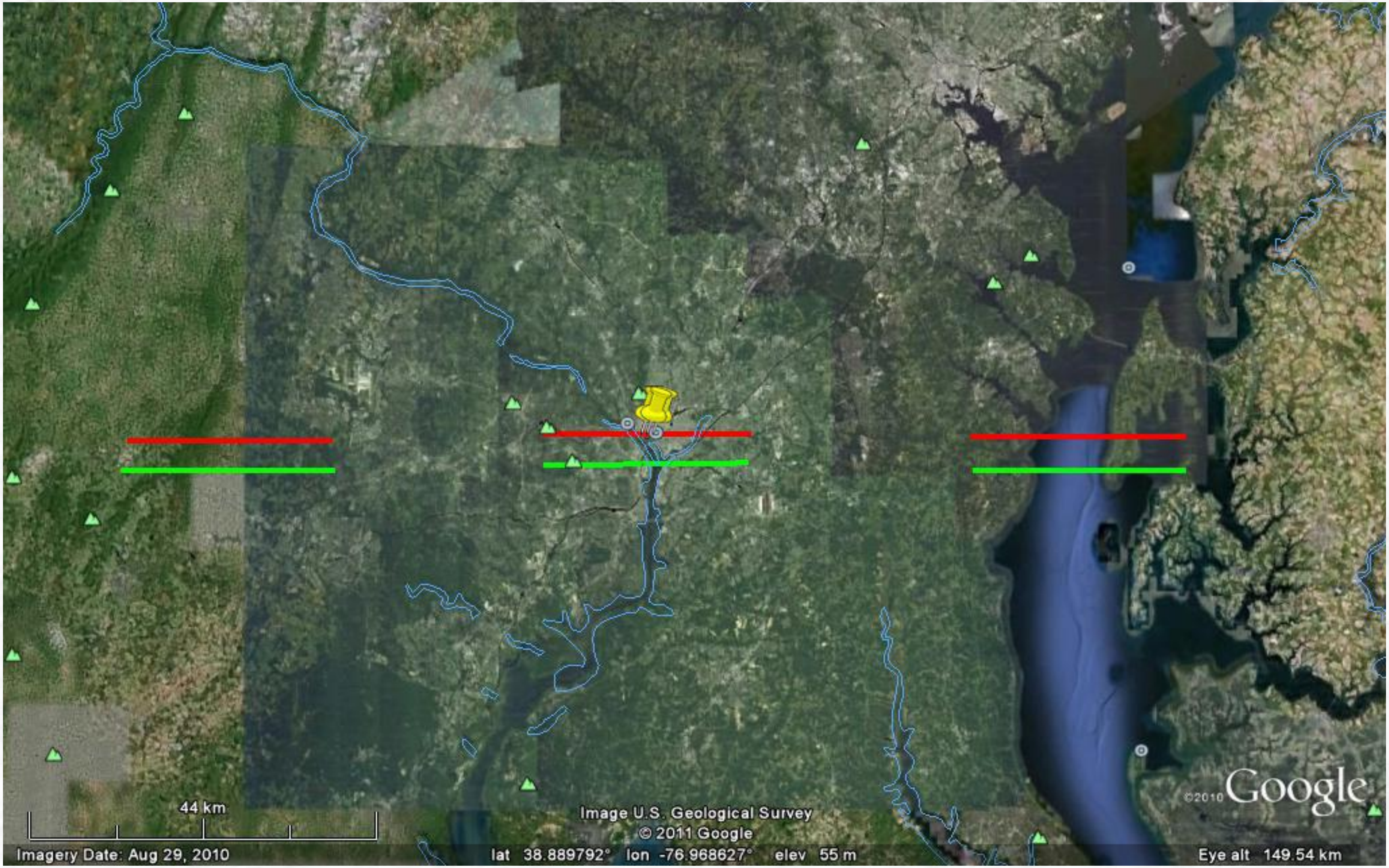
- Clouds will be a major factor in DWL coverage of significant weather features
  - A molecular system will be negatively effected by the high clouds in the tropics.
  - An aerosol system will provide winds within most of the high level clouds and within the lower troposphere below.
- The hybrid technology approach provides the best vertical coverage for science investigations in the tropics
  - A molecular subsystem is critical to tropospheric/stratospheric exchange investigations
  - The coherent subsystem is critical for accurate, high spatial resolution measurements in cloudy scenes and in the lower troposphere.


Lidar Simulation Model Bracket Aerosol Backscatter Profiles
GWOS/ISS
Aerosol Backscatter
Enhanced Profile
Background Profile
Single shot threshold sensitivity
Altitude (km)
25
20
15
10
5
0
-10
-8
-6
-4
Log of Aerosol Backscatter (m-1 sr-1)

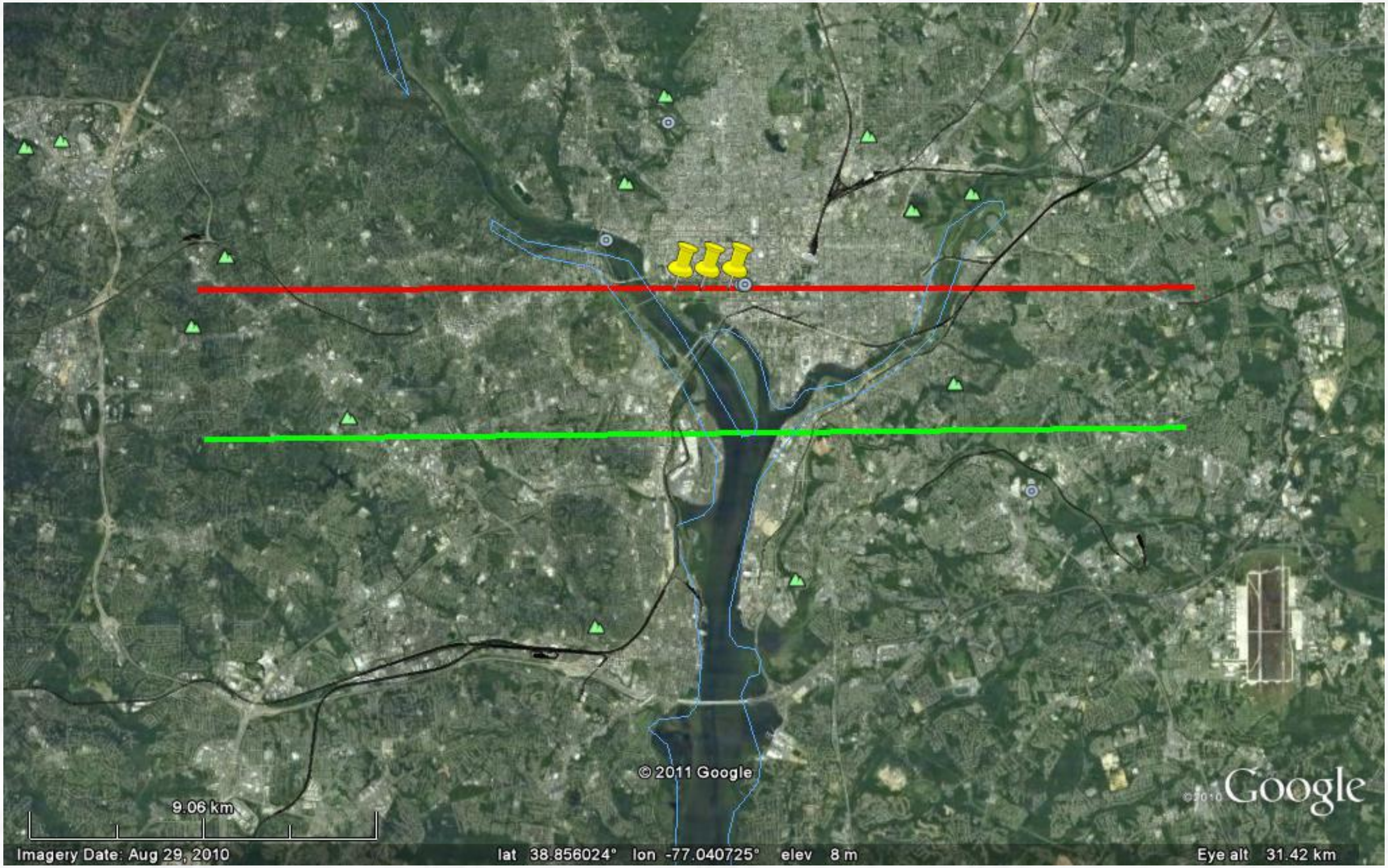
The Sampling Pattern

- Illuminated volume
  - Coherent (250m long cylinder, ~ 2m diameter footprint)
    - Spectral domain processing provides information on turbulence intensity, BL depth, precipitation fall velocities
  - Direct (2000m long, ~ 50m diameter)
    - Accuracy a function of intensity of return, presence of clouds/aerosols could be derived.
- Sampling pattern, a ground perspective
- Pattern over a hurricane

4 second dwell pattern for both direct and coherent (fore and aft perspectives)



4 second dwell pattern (fore and aft sampling)



Single shot coherent samples (~ 700meter intervals)