Useful aerosol returns from the mid and upper troposphere with OAWL (532)

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Basis for ATHENA-OAWL performance modeling

- Ball provided SWA with the technical detail required for SWA to simulate the performance of OAWL(532) instrument
- SWA built a LOS performance model to serve as the engineering tool for comparing results from Ball's engineering model.
- SWA developed code for simulating ATHENA-OAWL data products using the T511 Nature Run as was done for the 355 nm OAWL OSSE effort.

OAWL Characterization

- The following instrument elements are critical to this aspect of the predicted performance analyses:
  - Minimum range gate (30 meters)
  - Off nadir angle (40 degrees)
  - PRF (150 Hz)
  - EPP (160 mJ)
  - Collector diameter (.7 meters)
  - Shot integration interval (12 seconds; ~ 80km)
  - Vertical layer resolution (1000 m in free trop; 500m in PBL)

Critical Environmental Elements

- The environmental elements that are most critical to the performance modeling are:
  - Solar illumination of the background (land surface, clouds, water,…)
  - Backscatter coefficient as a function of height and media type (cirrus, sulfates, opaque clouds)
  - Variability of the winds on the scales relevant to the sampling distribution within the target layer and along the dwell path (~ 80 km).
  - Molecular scattering (as a noise source and agent for attenuation)

Procedure

- SWA uses a Nature Run (NR) generated by a state-of-the-art (SOTA) global NWP model. We use the T511 NR generated by ECMWF. Before simulating OAWL measurements using the NR, SWA derives optical properties (cloud coverage and aerosol backscatter) of the atmosphere as well as “sub-grid” wind variability on the scale of the illuminated volume of a single OAWL pulse. In the current case, this volume is 30 meters along the LOS and 1 meter in diameter.

Procedure (2)

- The Doppler Lidar Simulation Model (DLSM) is then used to generate an orbit, individual shot locations and accumulated shot LOS data products (velocity, SNR and precision estimate). These products are in very large part dependent on the aerosol backscatter provided though the DLSM. The remainder of this discussion addresses the fidelity of the backscatter distributions used.

Revising the reference atmospheres

What follows is a description of how we have modified the vertical profile of backscatter at 532 nm used in prior DLSM simulations and associated OSSEs. We have decided to make some changes to the Global Tropospheric Wind Sounder (GTWS) standard backscatter profiles proposed in 2001 and published at

http://www.swa.com/ALD/LidarProducts/targetAtm/index_old.html

While these profiles have been in use for more than 10 years, we argue now that they may have been too optimistic over the oceans and within the lower stratosphere. The backscatter profile between the surface and 17 km has been based primarily upon airborne lidar observations during ocean basin campaigns (GLOBE, SABLE, GABLE). A general summary of data from those campaigns can be found in Vaughn, et al, 1998. The characterization of the aerosols above 17 km in the GTWS profiles has been based upon the standard MODTRAN data files provided through FASCODE.

PBL and mid-troposphere

During the course of conducting recent OSSEs involving OAWL (355), SWA proposed an algorithm that used the NR's atmospheric boundary layer (ABL) depths to concentrate the lower tropospheric aerosols within the boundary layer accompanied by a rapid fall off above. This has produced more realistic vertical distributions of velocity retrievals from aerosol DWLs such as WISSCR_Coh and OAWL.

Upper troposphere and lower stratosphere

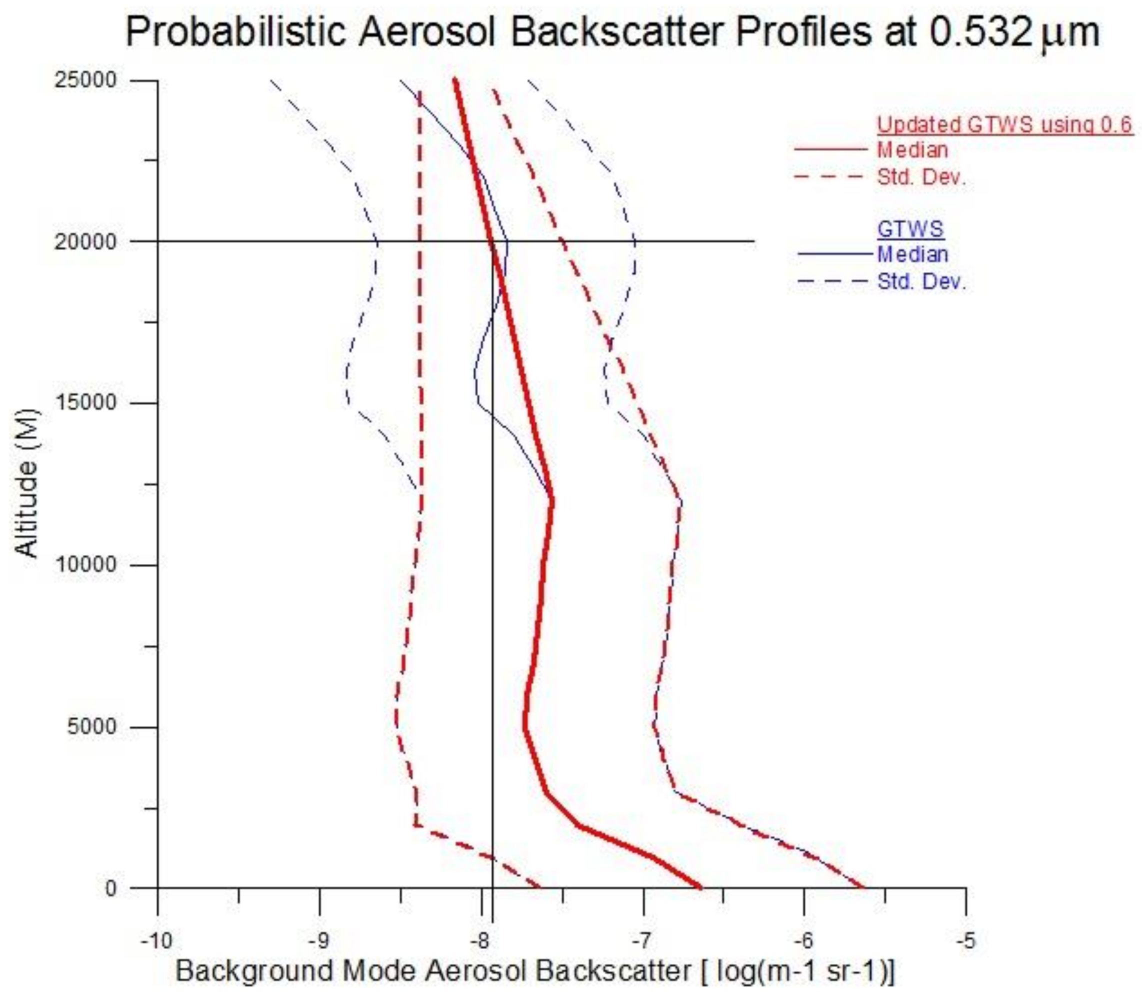
- Until recently, the GTWS aerosol profiles have been used primarily for conducting trade studies and comparing various DWL concepts in terms of vertical coverage and measurement precision/representativeness. In the case of SOTA coherent detection lidars, there was little chance of obtaining useful results much above 12 km or the top of the troposphere. Thus no exaggeration of performance has resulted in past studies. However, in the case of OAWL, the primary advantage of this technique (performance scaled to the backscatter ratio) enables useful returns well into the lower stratosphere. Thus, the GTWS profile above 12 km has been reviewed with reference to several stratospheric aerosol studies and climatologies at 532nm.

Modifications to aerosol model above 12km

- SWA has recommended two basic changes to the GTWS profiles above 12 km:
- The median logarithmic backscatter declines above 12 km at a rate of - .04 $sr^{-1}m^{-1}$/km.
- The width of the aerosol log-normal distribution of variability is set to .2 at 25 km and scaled up to the value of .8 used below 12 km.

Explanation

- Next slide provides a comparison between the GTWS profiles for the background mode at 532 nm with the new GRABOP (Global Reference Atmospheric Backscatter Opportunity Profile). These profiles (for several wavelengths) should be considered as ensembles constructed from histograms of backscatter measured at various altitudes under a variety of atmospheric conditions. Understanding this point is critical for using these profiles within NR based OSSEs. When the DLSM simulates DWL performance using the NR provided PBL heights, the lower tropospheric backscatter opportunities are now represented as a layer of well mixed aerosols capped by rapidly diminishing concentrations approaching the nominal values associated with the mid troposphere..



New GRABOP profile (red) for 532 background aerosol backscatter compared to the original GTWS profile (blue). The key feature is the diminishing width of the log-normal distribution.

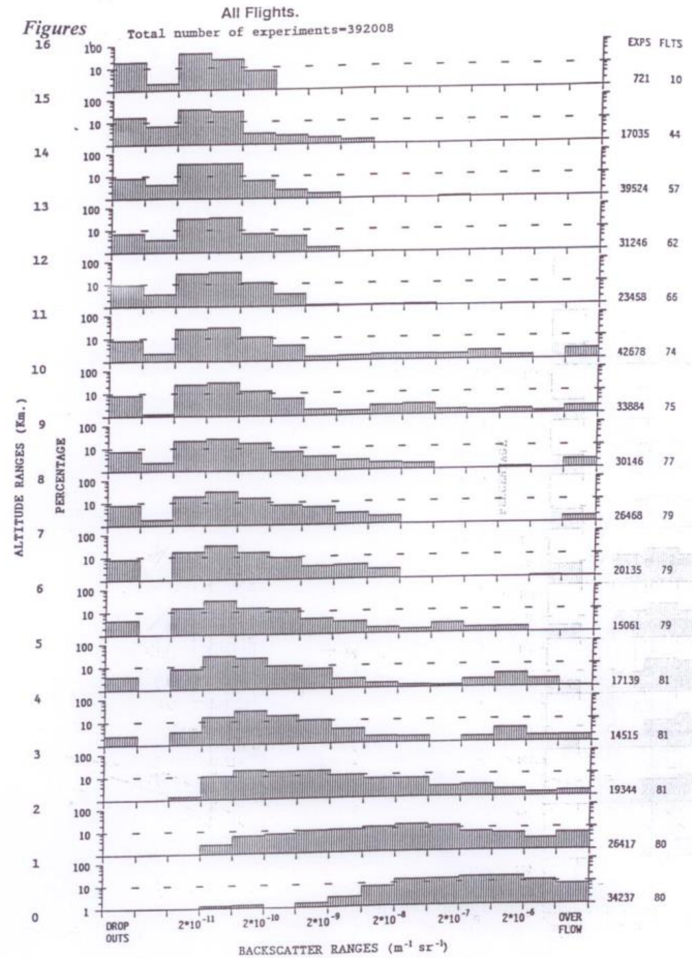
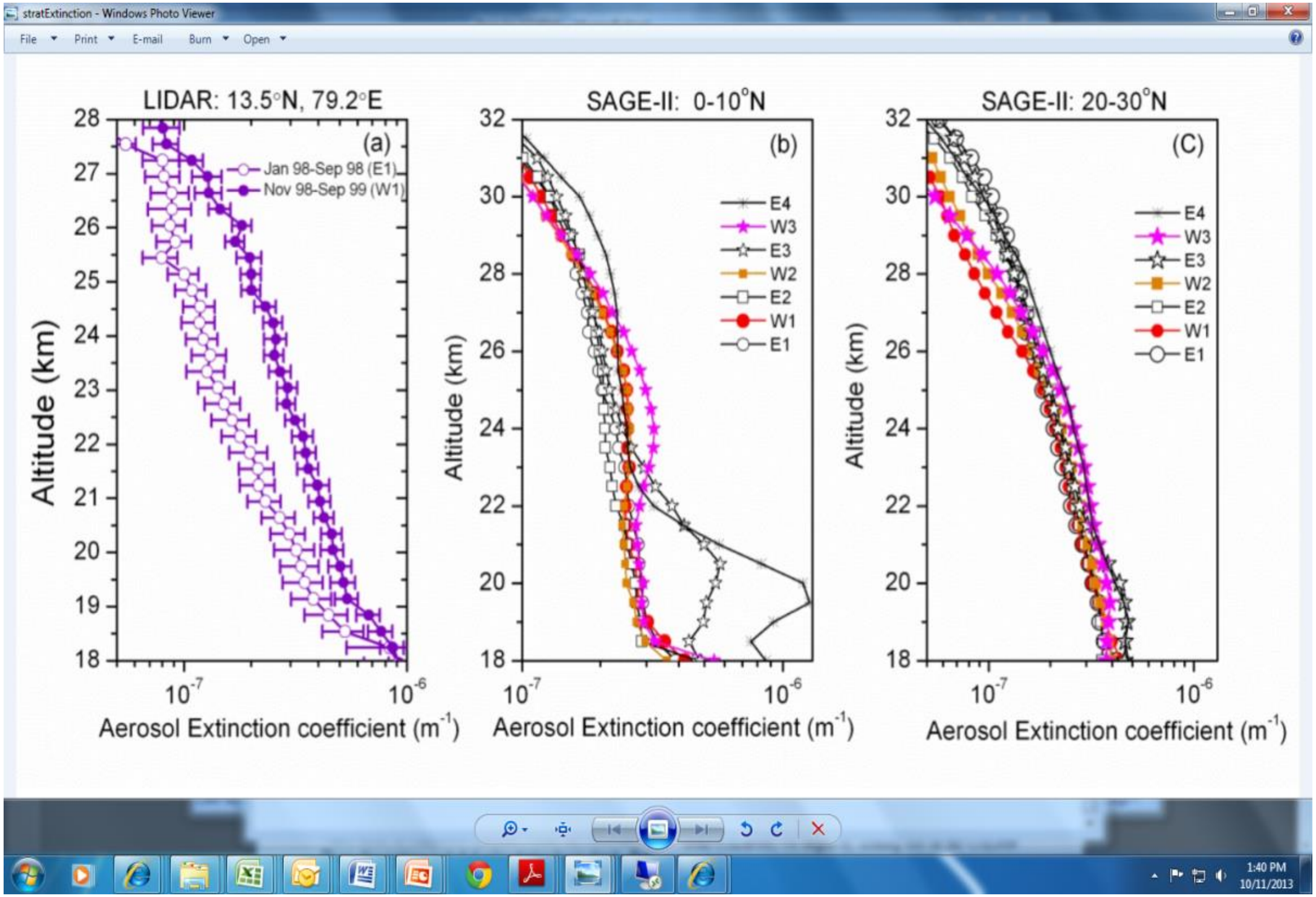


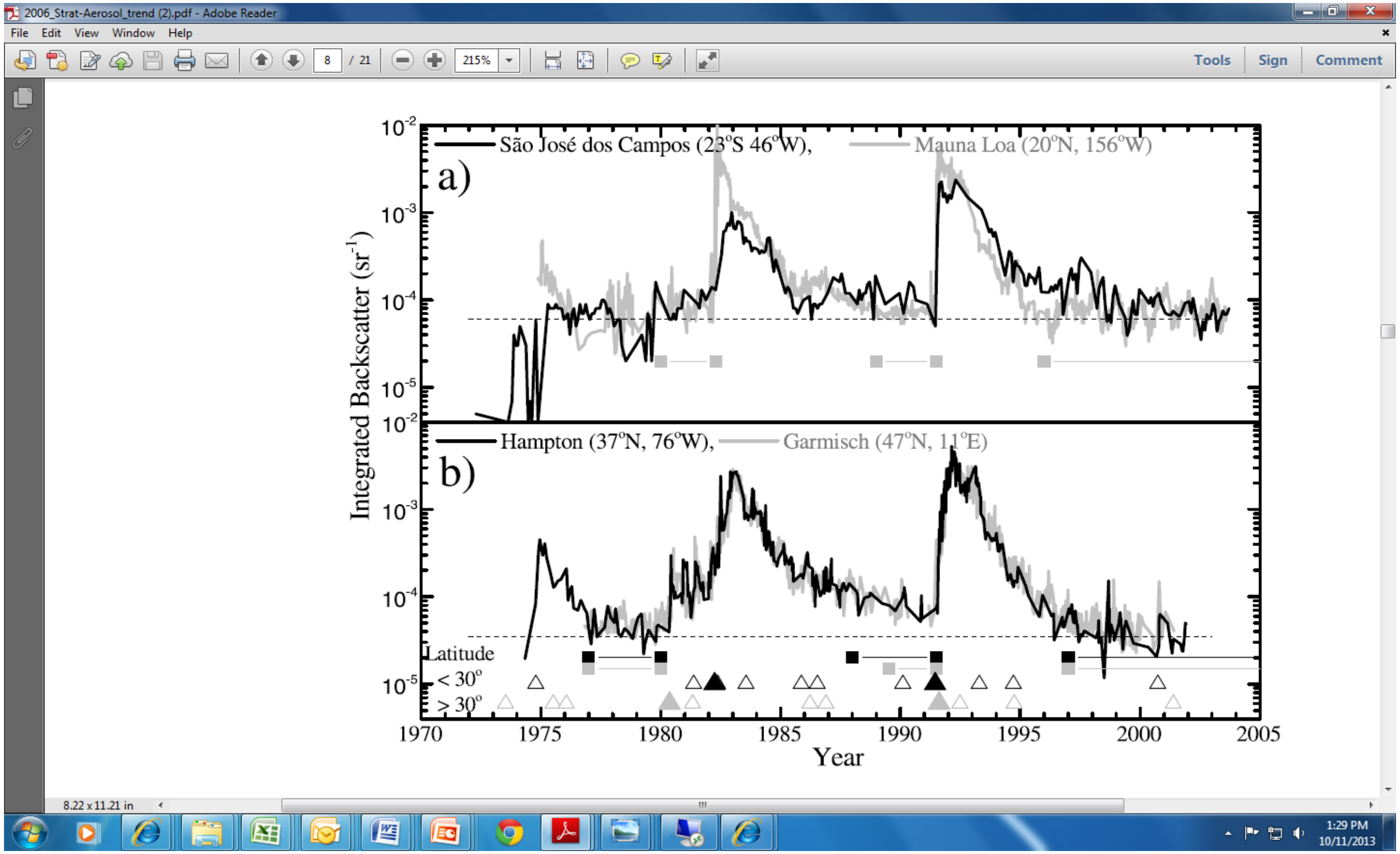
Figure 3.1: Histogram of back scatter distributions over the Atlantic 1988-90 as a summary of 80 individual recordings. [See Alejandro et al 1990, 1995, Vaughan et al 1991, 1995]

Stacked histograms of backscatter measured at various levels in the atmosphere during SABLE and GABLE. This figure taken from the ESA document authored by Vaughn et al, 1998.

Focus on variability above tropopause



Comparisons between SAGEII and a 532 lidar at Gadanki, India.
Figures from Sunikumar, et al 2011.



History of integrated backscatter from two tropical sites (Sa˜o Jose´ dos Campos and Mauna Loa) and two midlatitude sites (Hampton and Garmisch).

The wavelengths for all measurements are between 589 and 694 nm.

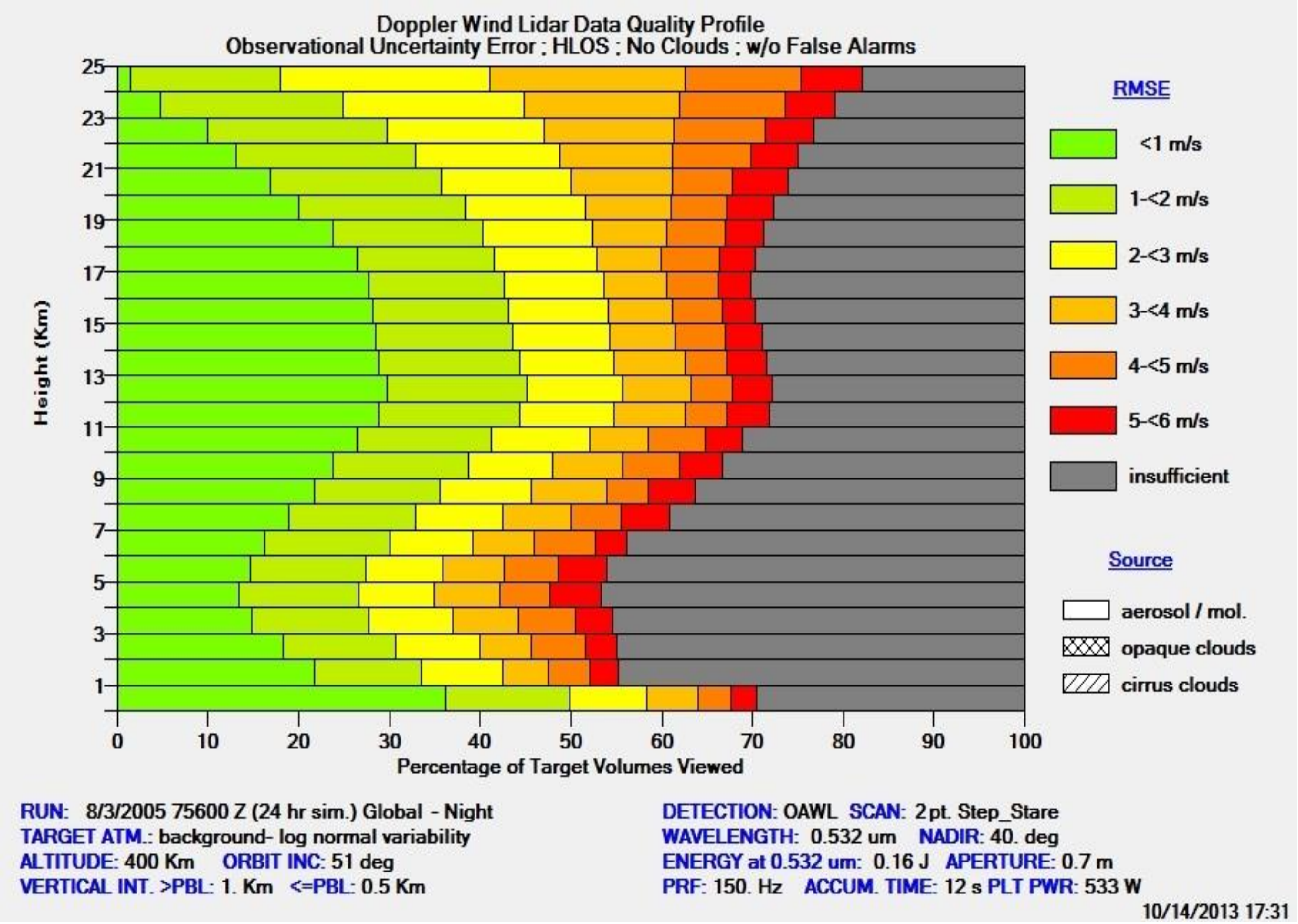
(a) Sa˜o Jose´ dos Campos, Brazil, integration from 17– 35 km, and Mauna Loa, Hawaii, United States, integration from 15.8–33 km.

(b) Hampton, Virginia, United States, integration from tropopause to 30 km, and Garmisch-Partenkirchen, Germany, integration from tropopause+1 km to layer top.

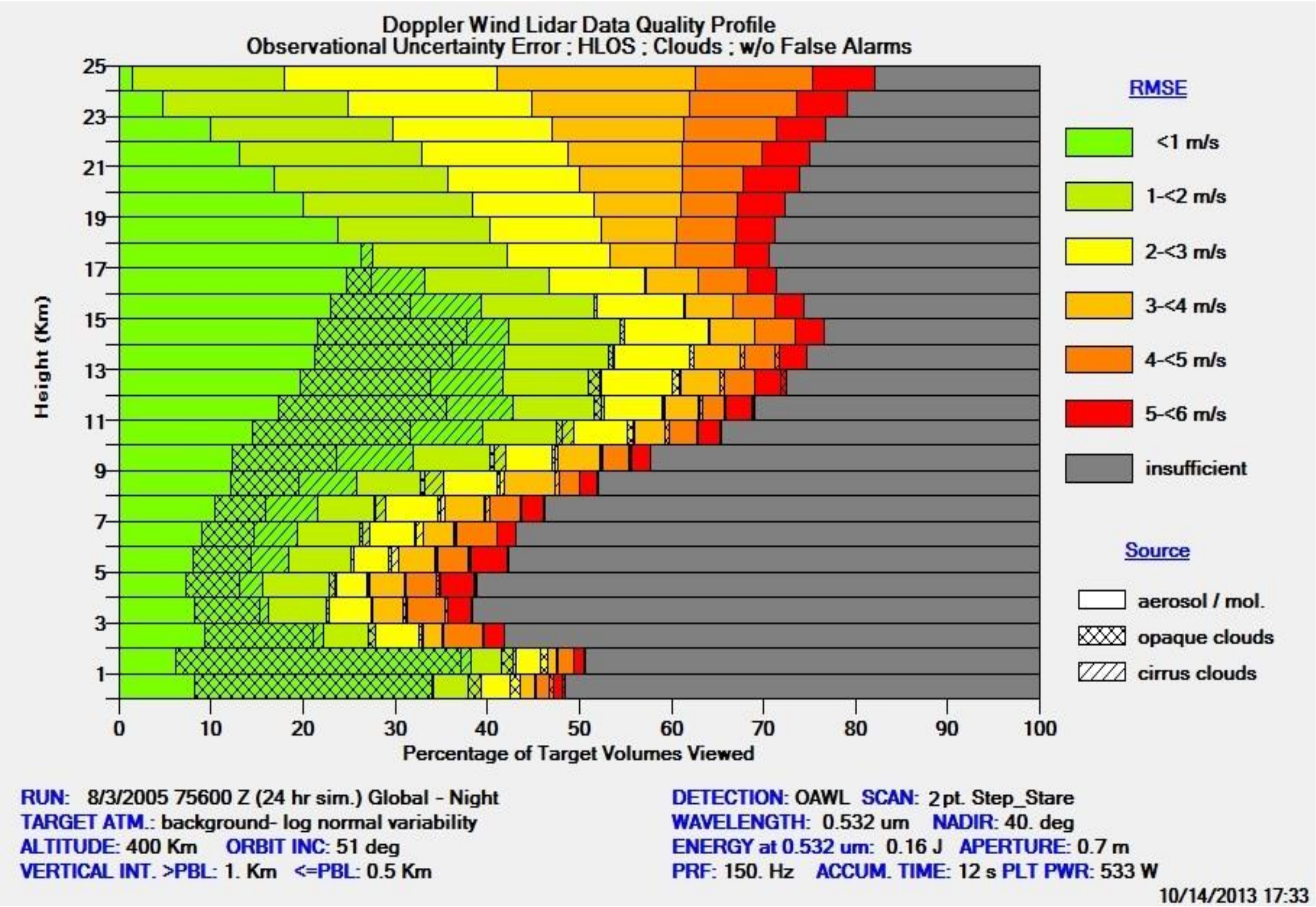
Performance Profiles

- The following slides express the vertical profile of HLOS data products from OAWL (532) using the GABROP within the T511 NR for August 5, 2005. The predicted nighttime performance above 12 km needs some discussion. The median backscatter falls off log-linearly compared with the "S" shaped GTWS profiles. However, we now ensure that backscatter variability is considerably smaller between 12 and 25km. Thus the loss of opportunities on the clean side of the median are much more limited now as are the up-side opportunities for very good (precise) measurements. Since the OAWL nighttime sensitivity is near the median then the percentage of time a useful (sigma<6m/s) is provided is higher at (say, 20km) than at 12 km where there is greater variability of backscatter near the tropopause.

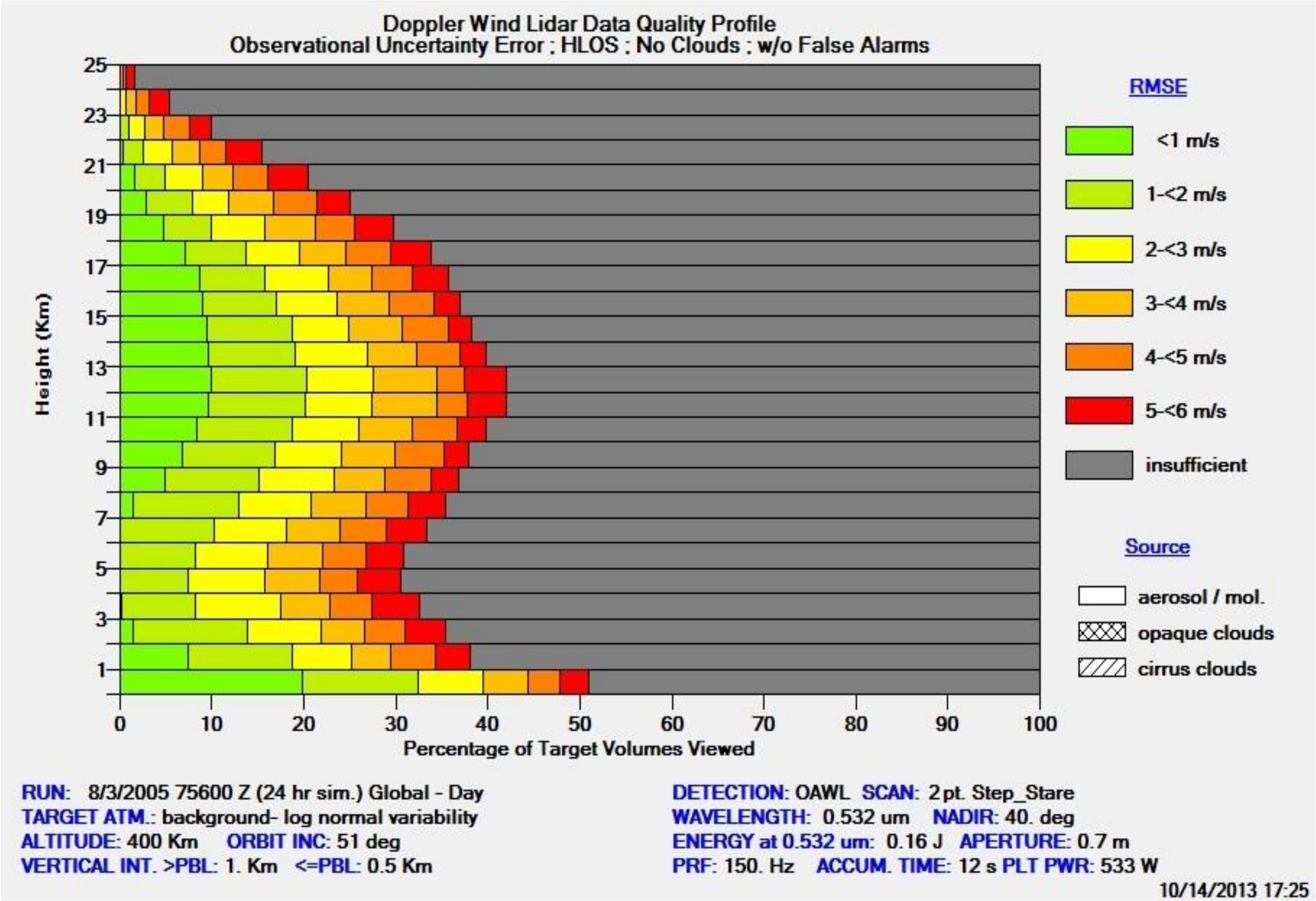
Night no clouds



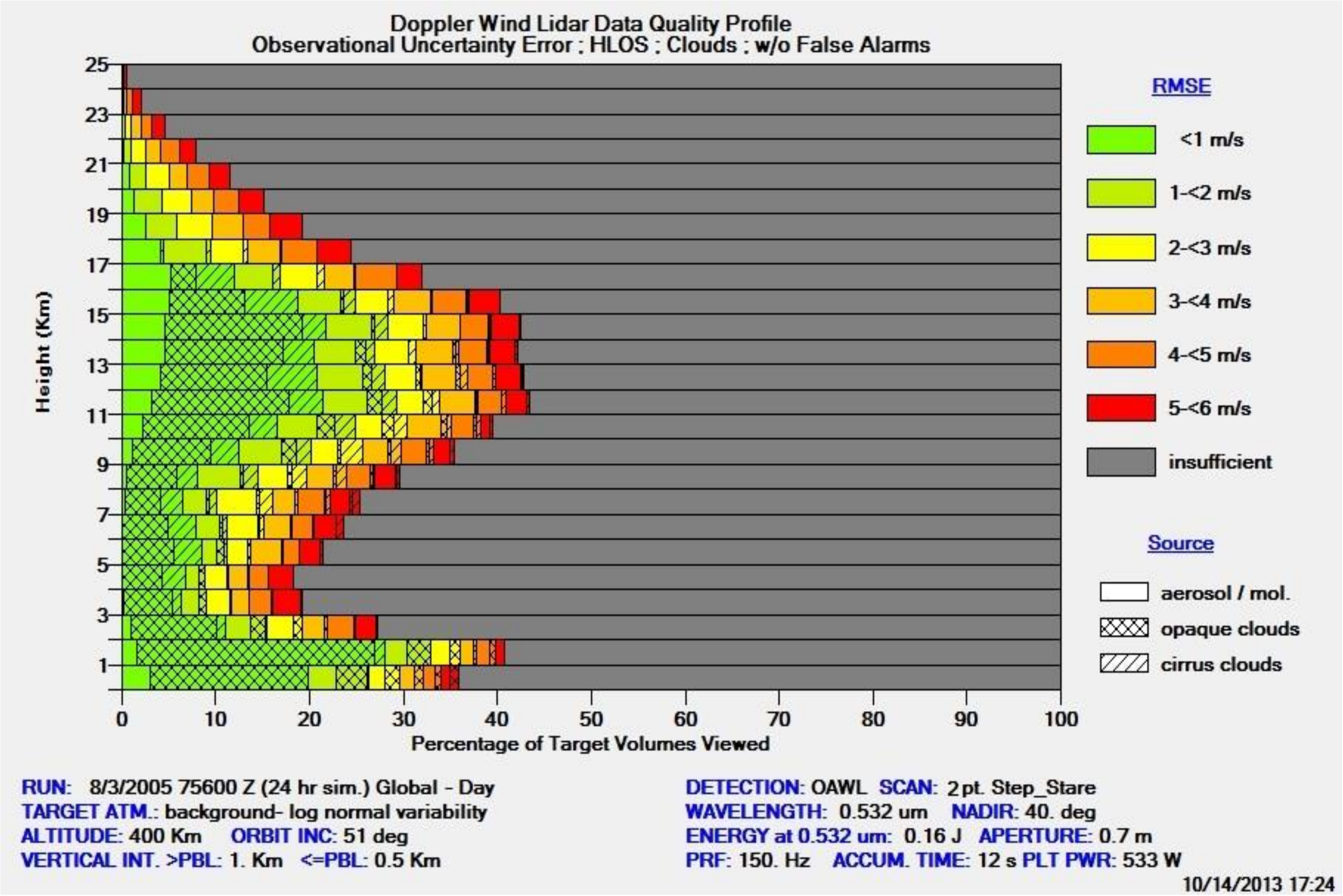
Night with clouds



Day with no clouds



Day with clouds



Conclusions

The obvious conclusion is that ATHENA-OAWL operating at 532 nm will deliver significant vertical coverage in the nighttime but will be limited primarily to measurements from cloud returns during the daytime.

Additional explanation

- The rationale for the changes to the lower stratospheric representation of backscatter opportunities is based upon lidar (Trickl, et al, 2013; Antuna, et al, 2002; Estavan, et al ,2000), in situ (Deshler, et al, 2006;Jager and Deshler, 2002) and space –based measurements (Sunilkumar, et al , 2011;Antuna, 2002). The near log-linear fall off of the backscatter coefficient with altitude above 12 km is supported by the published results from Sunilkumar, et al , 2011 (Figure 3). The narrow width of the variability of the lower stratospheric backscatter (during non-volcanic enhancements) is also supported by Sunilkumar, et al , 2011. The 5 degree latitude by 1km backscatter estimates from CALIPSO (Figure 4 from Thomason, et al, 2007)) suggest a value of 1.3E-8 m^{-1} sr^{-1}at 20 km which can be compared to the GRABOP value of 1.2E-8 m^{-1} sr^{-1}. Another supporting set of analyses comes from a summary paper by Deshler, et al, 2006 for the non-volcanic periods between 1971 and 2004. From Figure 5 we estimate the average backscatter in the layer 15 -25 to be ~ 1.0E-8 with most of the aerosol loading below the midpoint at 20km.