11.2 COMPARING THE EXPECTED DATA PRODUCTS OF A HYBRID SPACE-BASED DWL WITH THOSE CURRENTLY AVAILABLE TO GLOBAL FORECAST MODELS

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1. Introduction

Given that the NASA/NOAA Global Tropospheric Wind Sounder (GTWS) reference designs for both direct and coherent detection Doppler Wind Lidars (DWL) were large, expensive, and would require significant technology advances over the state-of-the-art, interest has increased in a hybrid DWL instrument that uses both direct and coherent detection. This may be the optimum solution, reducing cost, time-to-data impact, and risk. The hybrid technology roadmap is consistent with the combined roadmaps for direct and coherent, with the addition of developing shared technology, shared scanner, a shared spacecraft, and launch.

Hybrid DWL addresses the key technology challenges of lasers, detectors, telescopes and pointing by using coherent and direct lidars for different parts of the atmospheric depth of regard, for regions where they individually perform best. Coherent technologies perform better in those parts of the atmosphere where the direct detection lidar is weakest and vice versa. For either direct or coherent lidar alone to meet GTWS requirements (Emmitt (2001)), laser power, optics, and pointing are driven by conditions in the most challenging parts of the altitude range. Hybrid DWL promises to reduce technology demands on both. While the use of two lidars instead of one adds some complexity, it also changes and lowers the most serious technology challenges. The hope is that this will reduce mission risk, cost, and time to launch date.

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2. Hybrid DWL Concept

Hybrid DWL was first proposed in 1995 as Wind Observing Satellite/Hybrid (WOS/H) (Emmitt (1995)). It capitalizes on the strengths of both direct and coherent technologies. It uses coherent DWL for probing the lower troposphere with highly accurate wind velocity measurement at and below clouds and in regions of enhanced aerosols throughout the troposphere. In and through partly cloudy scenes, the coherent DWL is most likely to make a useful observation since the backscatter tends to increase towards the earth's surface and a single shot may be sufficient to make an accurate observation. Direct DWL (molecular reflection) is used for broad coverage of the mid/upper cloud free troposphere and lower stratosphere with modest accuracy. For the hybrid DWL, lower cost is expected from reducing the investment in "very large" individual DWLs (direct or coherent detection alone); sharing a launch; sharing a platform; sharing pointing control, data collection, mission management, science team, and other resources.

Several of the data and mission synergisms realized by the hybrid DWL concept are:

- The hybrid approach will provide full tropospheric wind observations **sooner**, with much of the accuracy, resolution and coverage needed by tomorrow's global and regional models
- The molecular DWL sub-system would, in its first mission, provide useful wind observations in cloud free regions of the mid/upper troposphere and lower stratosphere
- The coherent DWL sub-system would immediately meet the science and operational requirements throughout the troposphere in regions of high

aerosol backscatter (dust layers, clouds, PBL aerosols)

- The molecular system may provide good first guesses in the coherent system's weak signal regime, enabling the coherent system to provide a more accurate wind observation than either system alone could make.
- The coherent system could be optimized explicitly for resolving the ageostrophic features (moisture jets, Tropical circulations) of the lower troposphere, while the molecular system could be optimized to produce fewer, but still accurate, observations of the larger divergent features of the mid and upper troposphere
- The more dynamically interesting regions of the troposphere usually involve clouds. The coherent system is best suited to sampling through and below clouds. The molecular system, which is compromised by clouds, would provide the winds above and around the generally cloudy areas

3. The Hybrid DWL

In Table 1, two hybrid operational class DWLs are defined. One uses the larger direct detection subsystem that meets the data requirements and the other uses a smaller system that assumes at least a factor of two improvement in throughput/detection efficiency over that demonstrated to date within the NASA laboratory.

As has been the case for the individual technology DWL concepts, there is a funded effort to evaluate the potential data impacts of the hybrid DWL on operational weather forecasting (Emmitt (2000)). This is done using Observing System Simulation Experiments (OSSEs) where simulated DWL winds must compete with all other sources of wind data used by today's operational and research global forecast models. OSSEs are on-going at both NOAA/NCEP and at NASA/GSFC. A Doppler Lidar Simulation Model (DLSM) is used with a high resolution global model 30-90 day run to provide truth for simulating the observations (effects of clouds, wind variability, aerosol distributions, etc. included) which are then used with a different global forecasting model to assess impacts. The following "performance profiles" were developed along with the DLSM to summarize the vertical coverage of a specific DWL concept using specific assumptions of aerosol concentrations and realistic atmospheric situations as provided by the "nature runs" mentioned above.

In using the "performance profiles" it should be understood that the horizontal axis expresses the percentage of all DWL lidar sampling attempts within the specified simulation time period (usually 24 hours) that meet the criteria of accuracy noted in the color key on the right. Most of the information need to interpret the charts is provided within the chart itself. It is important to note that the accuracies are those realized after the Line-of-sight uncertainties are projected onto the horizontal plane and are thus larger than those reported as unprojected LOS errors. The black areas to the right of the chart represent the percentage of time that the lidar can not provide any useful (errors < 3 m/s) information due to obscuration by clouds or insufficient signal to obtain a useful observation.

In Figure 1, a performance profile for the Hybrid DWL described in Table 4 is shown for the case where the entire globe is covered by the "background" mode of aerosol distribution. The background mode has been defined by both airborne field studies and models and is meant to represent the most demanding (lowest concentrations) conditions in which an aerosol DWL system must perform to meet the GTWS data requirements. In this case the direct molecular subsystem provides most of the useful (RMSE < 3 m/s) wind observations in the cloud free regions above the boundary layer.

In the case (Figure 2) where the vertical distribution of aerosols is enhanced (by convection, dust layers, aerosol pollution, etc.) the coherent system provides very accurate (~1 m/s or better) observations throughout most of the troposphere. These enhanced conditions are expected frequently over much of the continental northern hemisphere in the summer. It is likely and desirable to conduct a pre-operational space-based mission with more modest lidar systems than those needed to achieve full operational status. The performance profile in Figures 3 and 4 are based upon the argument that the demo mission should 1) retire the risks associated with all necessary DWL components (transceivers, detectors, scanners, etc) and 2) provide data products of the anticipated accuracy for the full system (better to have fewer excellent measurements than many marginally useful measurements).

4. Summary

Any new observing system must compete with the existing systems and the model's first guess errors. Currently operational forecast models have wind data available from surface stations, rawinsondes, ACARS, cloud motion vectors, water vapor motion vectors and scatterometers. The most obvious gap in wind observations (in particular vertical profiles) above the surface is over the oceans and sparsely populated areas. An orbiting Doppler wind lidar could provide significant coverage of these areas. In addition, the DWL could compete with rawinsonde wind observations over land areas as well if the DWL data is more accurate and more representative. In this paper we argue that a DWL utilizing both direct and coherent detection techniques (hybrid DWL) could compete very well with existing systems. The direct detection subsystem would provide competitive wind observations from the upper portions of the troposphere and lower stratosphere where cloud coverage is minimal. The coherent subsystem would provide very accurate wind observations in the lower troposphere and in/below broken cloud layers. The hybrid DWL would use fewer platform resources and carry a significant technology margin of risk reduction.

5. Acknowledgements

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6. References

Emmitt, G. D. ,2001: Global wind observational requirements and the hybrid observing system approach, AMS Fifth Symp. Integrated Observing Systems, Albuquerque, NM, January.

Emmitt, G. D. ,2000: Hybrid technology Doppler wind lidar: assessment of simulated data products for a space-based system concept, SPIE Lidar Remote Sensing for Industry and Environment Monitoring, Sendai, Japan, October.

Emmitt, G. D. , 1995: Initial concept for a wind observing satellite- hybrid (WOS/H). Working Group for Space-based Lidar Winds, Clearwater, FL, January 1995.

Instrument Parameters **For** **Combined IPO Hybrid**	**IPO1 H(DD,CD)***	**IPO2 H(DD,CD)**
Average Laser Power (Watts)	750+300=1050	375+300=675
Effective Telescope Area (m^2)	0.78 0.2	0.5 0.2
Data Rate (bits/hour)	26 E09	26 E09
Mass of Instrument (kg)	TBD	TBD
Total Average Instrument Power (Watts)	1050+600=1650	675+600=1275

* DD is Direct Detection, CD is Coherent Detection

Table 1. Parameters for combined IPO Hybrid DWL

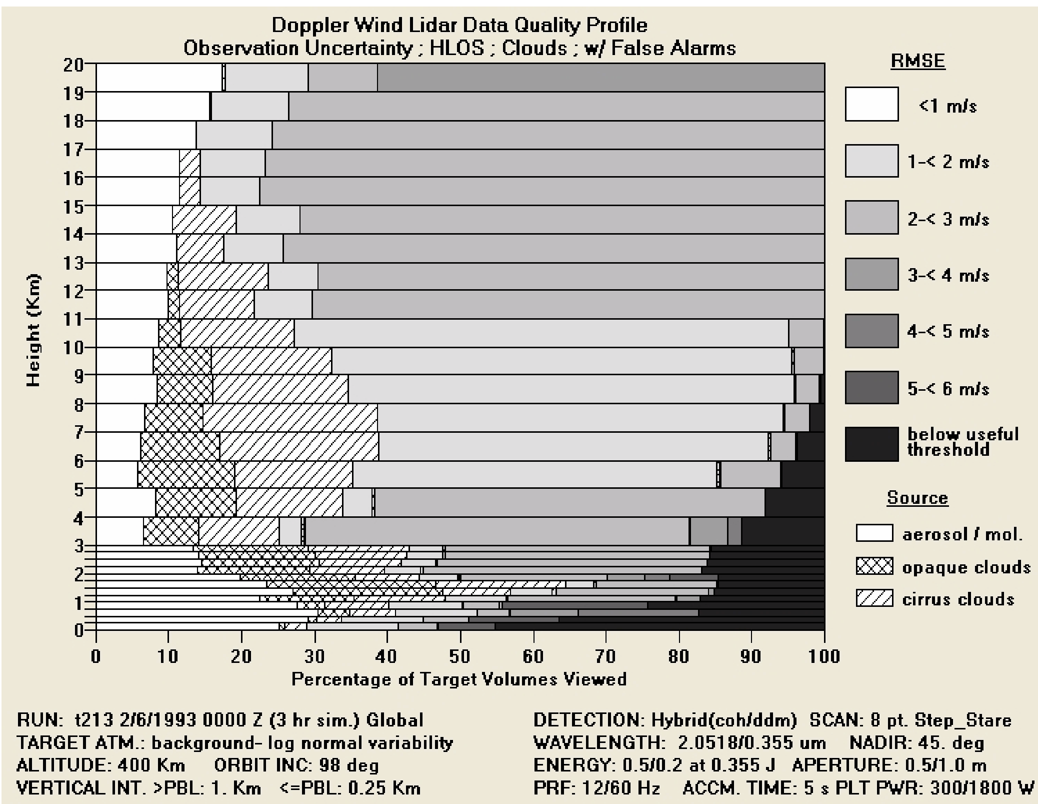

Figure 1. Performance profile for the hybrid DWL that would meet the NASA/NOAA global wind observation requirements in regions where the aerosols are concentrated in the lower troposphere (background mode).

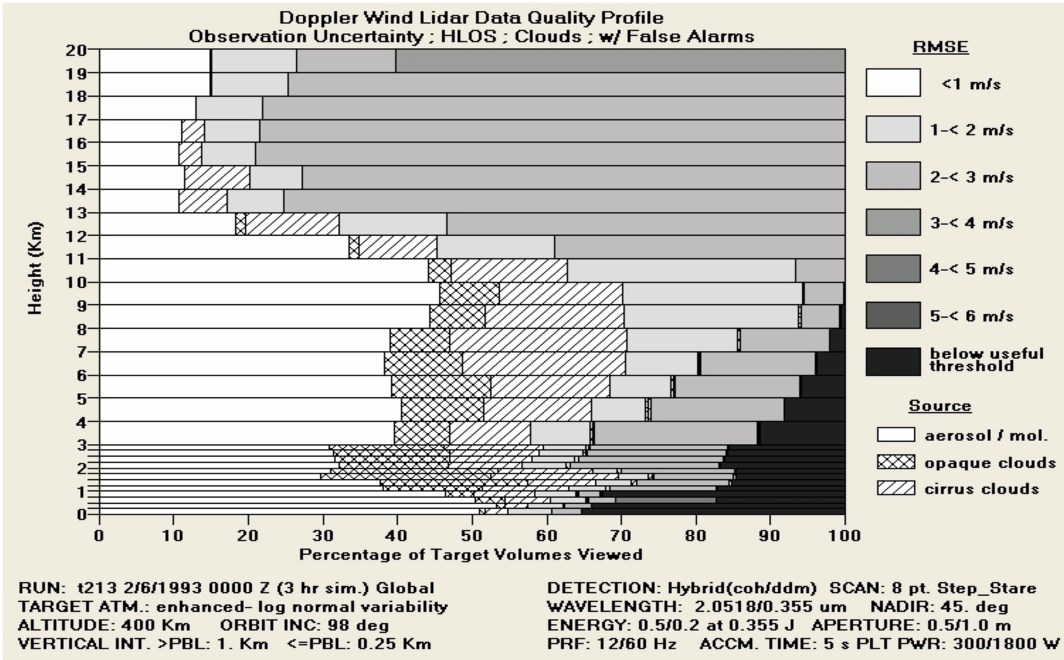

Figure 2. Performance profile for the same system used in Figure 1, except that the aerosol distribution was that expected for regions of the globe where there is significant vertical pumping of lower tropospheric aerosols (enhanced mode)

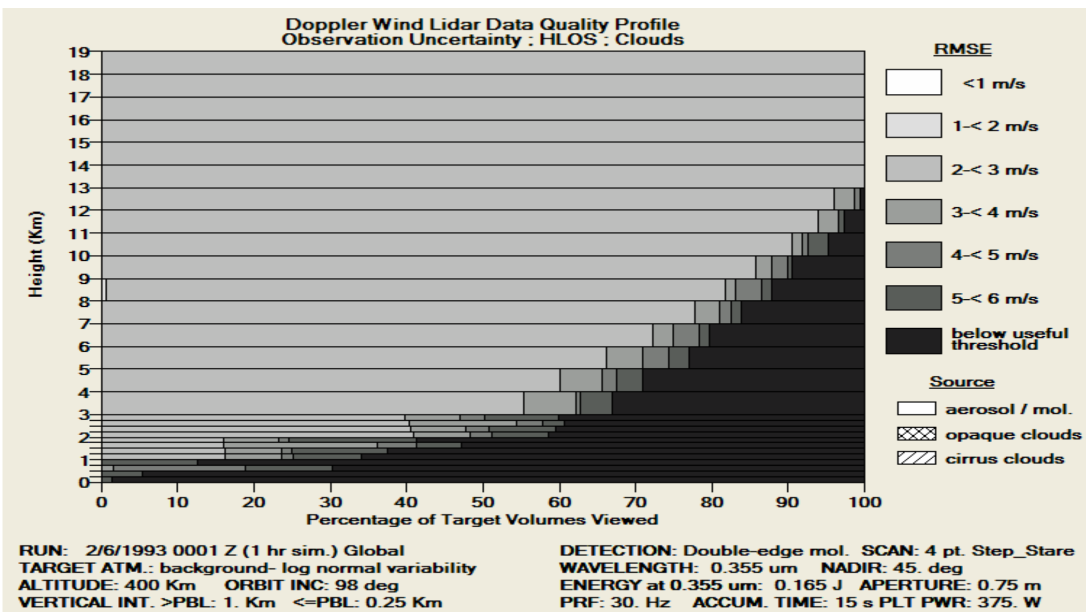

Figure 3. Performance profile for the direct detection sub-system of a "demo-class" hybrid DWL

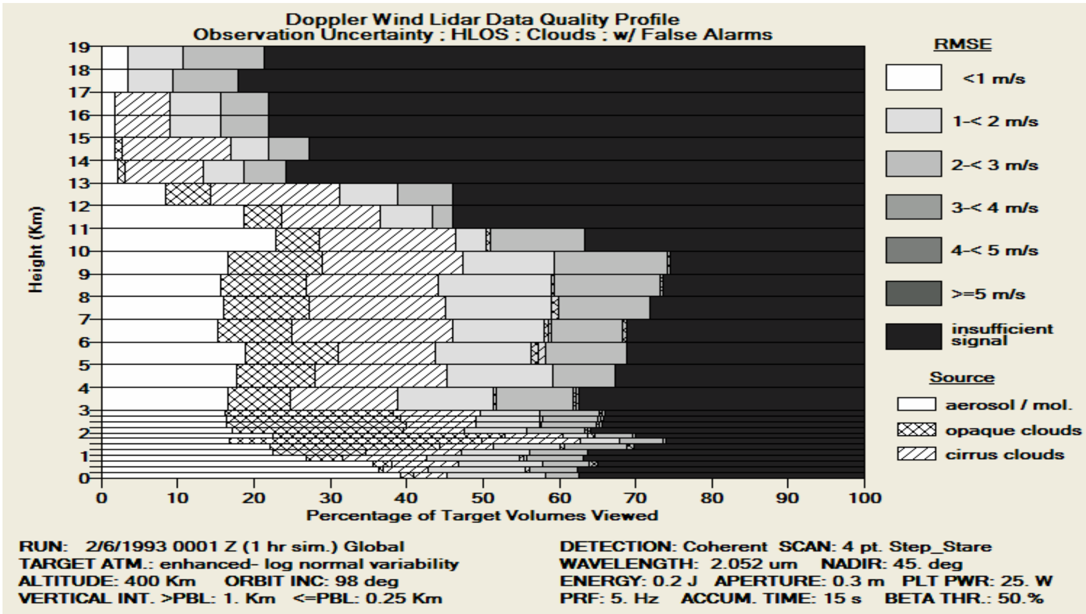

Figure 4. Performance profile for the coherent detection sub-system of a "demo-class" hybrid DWL