

Simulation testbed for the assessment of space-based wind measuring systems

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ABSTRACT

A Simulation testbed has been developed to demonstrate and assess space-based wind measuring systems to reduce mission costs, extend mission life, and enable better data collection through impact studies, system trades, pre-OSSEs and the participation in Observing System Simulation Experiments (OSSEs). The numerical testbed is intended to determine the potential impact of proposed space-based and sub-orbital wind observing systems on analyses and forecasts. This paper presents the testbed used for evaluating two recent proposed space-based wind measuring concepts.

1. INTRODUCTION

Since 1983, Simpson Weather Associates has been funded by NASA, NOAA, U.S. DoD, CNRS, Lockheed, General Electric, Northrop Grumman and Ball Aerospace to develop simulation models for space-based and airborne Doppler lidar wind measuring systems, Scatterometer instruments and Cloud Motion Vector Wind Model algorithms. These simulation models are part of a testbed that has been used to evaluate many space-based mission concepts such as the Lidar Atmospheric Wind Sounder (LAWS), Global Tropospheric Winds Sounder (GTWS), Atmospheric Dynamics Mission Aeolus (ADM-Aeolus), Decadal Survey missions (Global Wind Observing System (GWOS), Extended Ocean Vector Winds Mission (XOVWM), Precipitation and All weather Temperature and Humidity (PATH)) and recently the Winds from the International Space Station for Climate Research (WISSCR) and Optical Autocovariance Wind Lidar (OAWL).

The overall goal of the testbed is to provide objective analysis tools that enable systems engineers and Earth scientists to define and model candidate wind sensing mission designs and operation concepts and accurately assess their impacts. The testbed models are designed to address questions such as optimum laser wavelength, pulse length, minimum power, scanning strategies, optimal signal processing and wind computation algorithms. When a concept has proven to warrant a larger study, a full OSSE is conducted and evaluated. In addition, the testbed assist in developing methodologies for assimilating new observations in coordination with the Joint Center for Satellite Data Assimilation (JCSDA).

2. TESTBED OVERVIEW

This testbed provides interactive simulations that allows a user to address issues ranging from system trade studies to global numerical model assimilation and impact studies with an emphasis on sampling in cloudy environments. The testbed simulation models include the Doppler Lidar Simulation Model (DLSM), Scatterometer Simulation Model (SCATTRSM) and Cloud Motion Vector (CMV) algorithm. The Atmospheric Generator Model (AGM) reformats ECMWF and WRF "nature run" atmosphere databases for the simulations and computes needed variables such as aerosol and molecular optical properties, sub grid scale variances and a space view of the model cloud fields.

2.1 DOPPLER LIDAR SIMULATION MODEL

The Doppler Lidar Simulation Model (DLSM) simulates the performance of coherent and direct detection Doppler wind lidars for space-based or airborne remote wind sensors with an emphasis upon realistic representations of the atmosphere along individual line of sights. The current optical property data bases support 2.0518 μm coherent lidars and 0.355 μm , 0.532 μm and 1.06 μm direct detection lidars. A DLSM block diagram is shown in Figure 1. The DLSM^{1,2} is an evolution of existing Doppler lidar simulation models that are currently used for space-based Doppler lidar wind simulations^{3,4,5,6,7}. The DLSM is a fully integrated Doppler lidar simulation model that produces simulated lidar winds and corresponding errors using either global or mesoscale atmospheric model wind fields. The

DLSM can address various types of questions on the feasibility and optimal functionality of a space-based or airborne Doppler lidar system. The DLSM is also designed to address engineering trades, measurement accuracies (line of sight and horizontal wind vector), measurement representativeness, resolution and areal coverage.

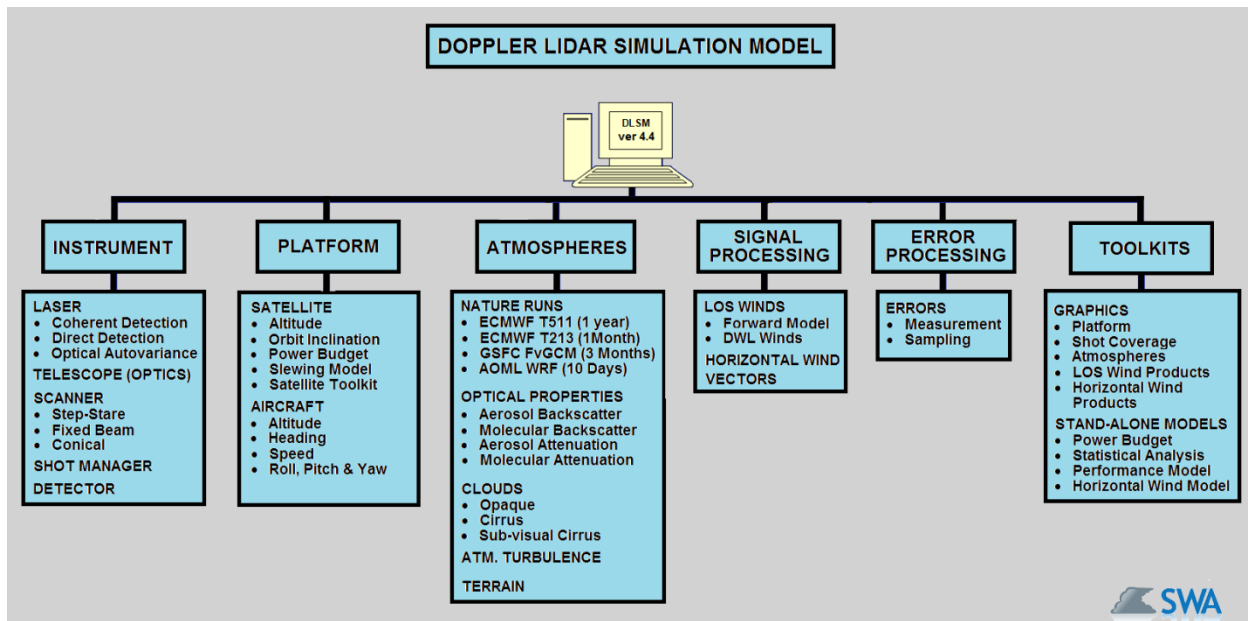


Figure 1: Doppler Lidar Simulation Model (DLSM) block diagram highlighting the major modules of the DLSM.

The DLSM's Shot Coverage Model (SCVM) allows the user to simulate satellite and aircraft missions with a variety of laser scanner patterns. The SCVM provides ASCII records of platform track and laser shot coverage (spatial and temporal). In 2012, an option was added to the DLSM to support coverage input files generated from Satellite Toolkit (Analytical Graphics, Inc). In recent studies, the STK was used to generated equatorial space station and DWL shot location records for a T511 four month period (July-Oct 2005). The data sets had additional satellite slewing information for adaptive targeting simulations where the satellite can rotate allowing DWL line of sight to reach areas of high interest. Also included is a day/night flag for the OAWL and direct detection systems.

One of the largest challenges using "nature run" model atmosphere fields in testbed simulations is the generation of needed variables that the NR does not provide. The DLSM's atmospheric library is made up of an extensive set of integrated atmospheric data bases created by the Atmospheric Generator Model (AGM). The library provides needed meteorological inputs not provided by "nature runs" including defining cloud types, cloud optical properties, aerosol and molecular optical properties such as backscatter, scattering and attenuation and atmospheric sub-grid turbulence.

Inventory (as of 2013) of the atmospheric library consists the T511 ECMWF Nature Run for 7/1/2005 - 10/31/2005 for global simulations and AOML WRF 8/1/2005 - 8/10/2005 (grid resolutions of 27, 9, 3 and 1 km.) for mesoscale simulations. A new ECMWF Nature Run, T1148, is being considered for future OSSE. Figure 2 shows an example of the generated aerosol backscatter under enhanced and background conditions for the 500 mb level 07/01/2005 00Z. Figure 3 shows an example of the generated satellite view of clouds at 800 and 200 mb for ECMWF T511 nature run 07/01/2005 00Z.

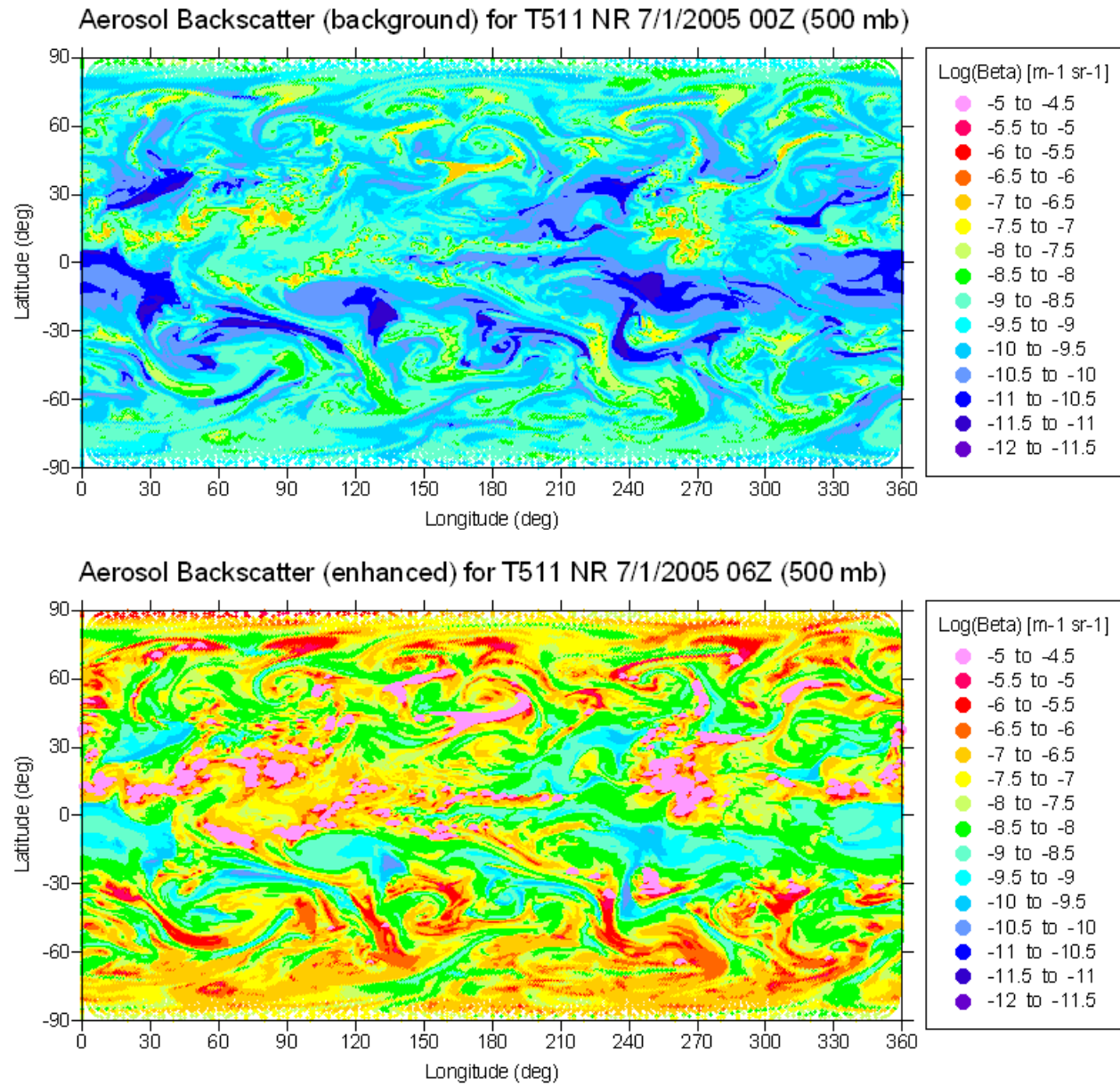


Figure 2: Enhanced and background ECMWF T511 dependent aerosol backscatter fields for 500 mb. The backscatter was organized by model relative humidity.

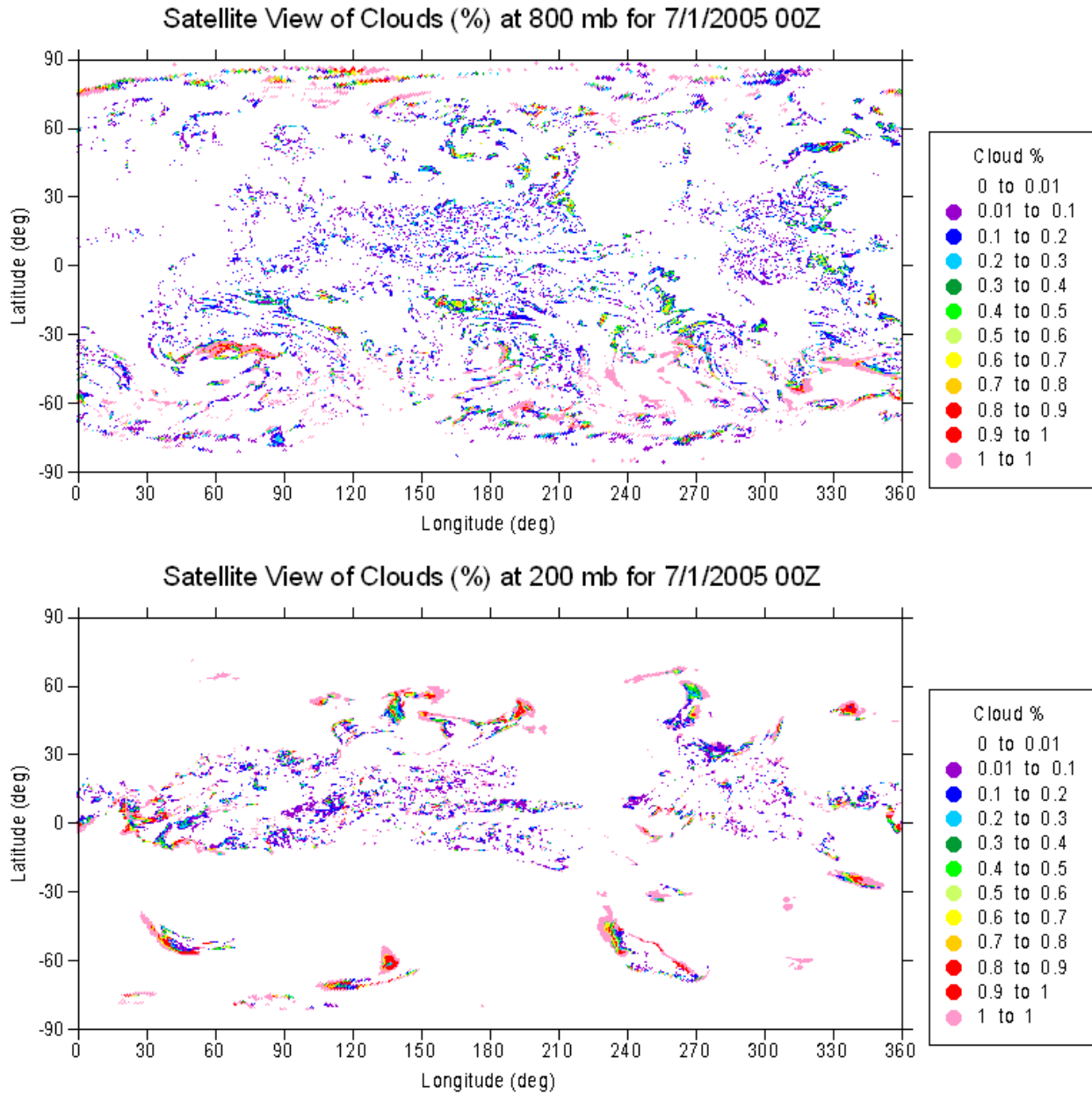


Figure 3: Satellite view of clouds at 800 and 200 mb for ECMWF T511 nature run 07/01/2005 00Z.

2.2 SCATTEROMETER SIMULATION MODEL

The SCATTRSM produces simulated Ocean wind speeds and directions at 10 M using ECMWF or AOML "nature Runs". Current supported scattermeters are QuikScat (25 km resolution) - Ku band and ASCAT (50 km resolution) - C band. Wind speed and direction errors due to low/high wind speeds and precipitation^{8,9} are included. Land and precipitation quality data flags are also included. SCATTRSM is based upon DLSS architecture. An example of a 24 hour simulation for QuikScat platform is shown in Figures 4.

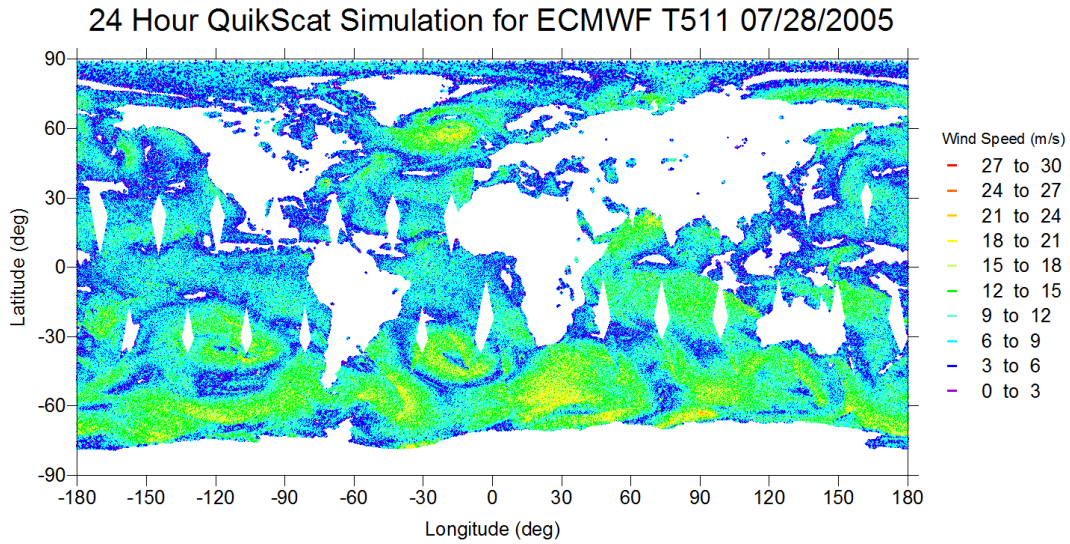


Figure 4: An example of a 24 hour simulation of a QuikScat platform for the ECMWF T511 nature run 07/28/2005

2.3 CLOUD MOTION VECTOR (CMV) ALGORITHM

The Cloud Motion Vector (CMV) algorithm simulates cloud track winds from ECMWF and AOML WRF "nature runs" for Observation System Simulation Experiments. Simulated cloud motion winds are produced for all geosynchronous satellites in an area extending 60 from the sub-point. Slow bias is included in the simulations.

3. TESTBED APPLICATION: SIMULATING DWL CONCEPTS FOR ISS SCIENCE MISSIONS

Prior to the launch of a space-based DWL, it is essential to assess its potential impact on science data products. OSSEs are observing system impact assessments providing objective quantitative evaluations of such future observing systems. However OSSEs are expensive in cost and manpower. Recently the ISS concept missions for WISSCR and OAWL were modeled and simulated in the testbed for a series of Pre-OSSE evaluations¹⁰. Figure 5 shows the aerosol and molecular DWL data coverage depicting the Observation Errors for WISSCR and OAWL at 11km (a) and boundary layer (b).

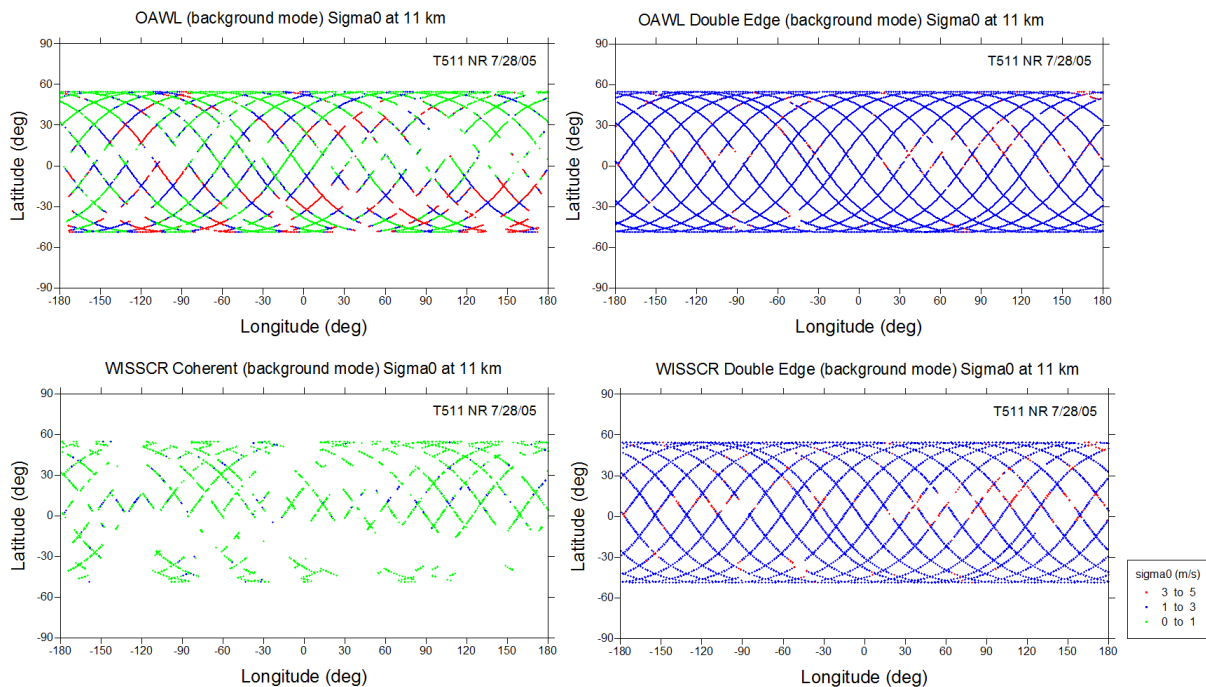


Figure 6a: Aerosol and molecular DWL data coverage depicting Observation Errors for WISSCR and OAWL at 11km.

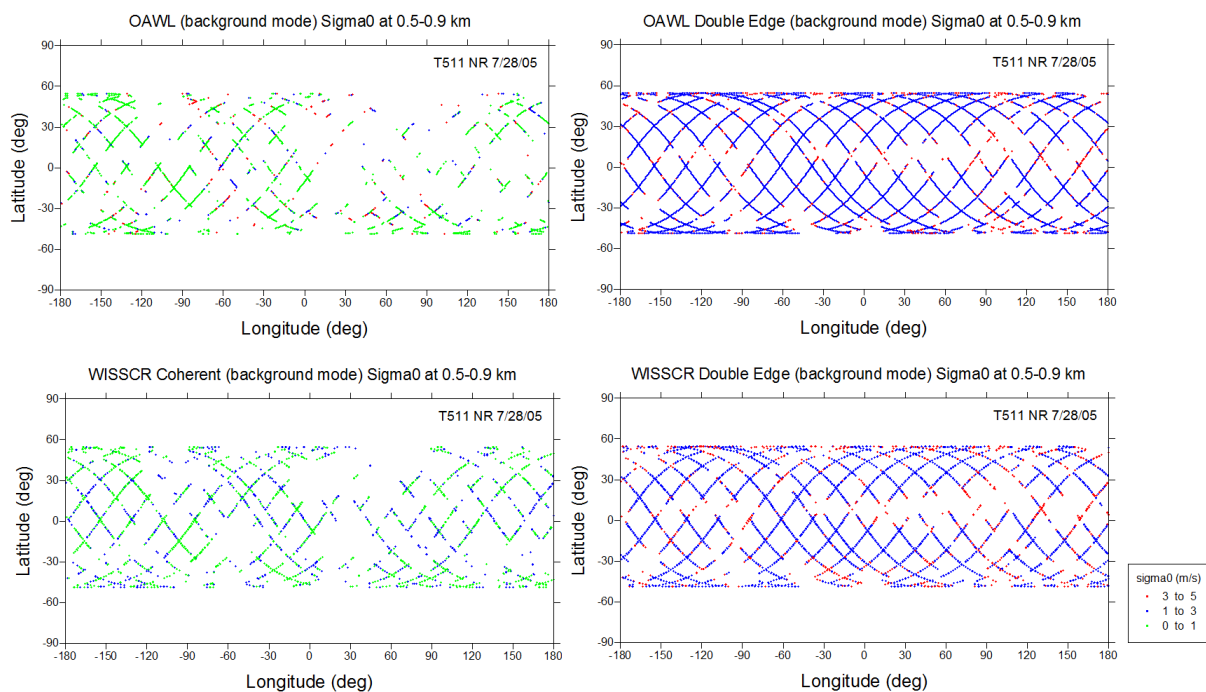


Figure 6b: Aerosol and molecular DWL data coverage depicting the Observation Errors for WISSCR and OAWL at boundary layer.

Global Performance diagrams (shown in figure 7) were generated for 6 weeks to evaluated the data products for the two DWL concepts. Both enhanced aerosols and background mode aerosols were considered to bracket the simulation performances.

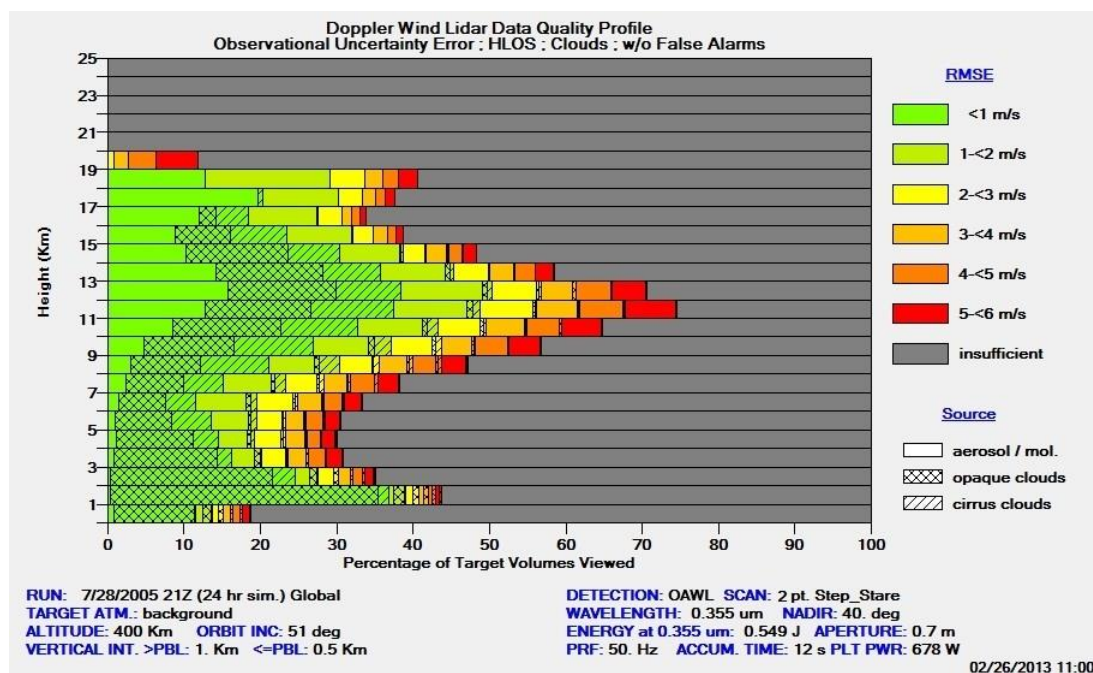


Figure 7a. Global Observational Uncertainty Error Performance Diagram for the OAWL concept using the background aerosol mode. The simulation period was 7/28/2005 21Z - 7/29/2005 21Z.

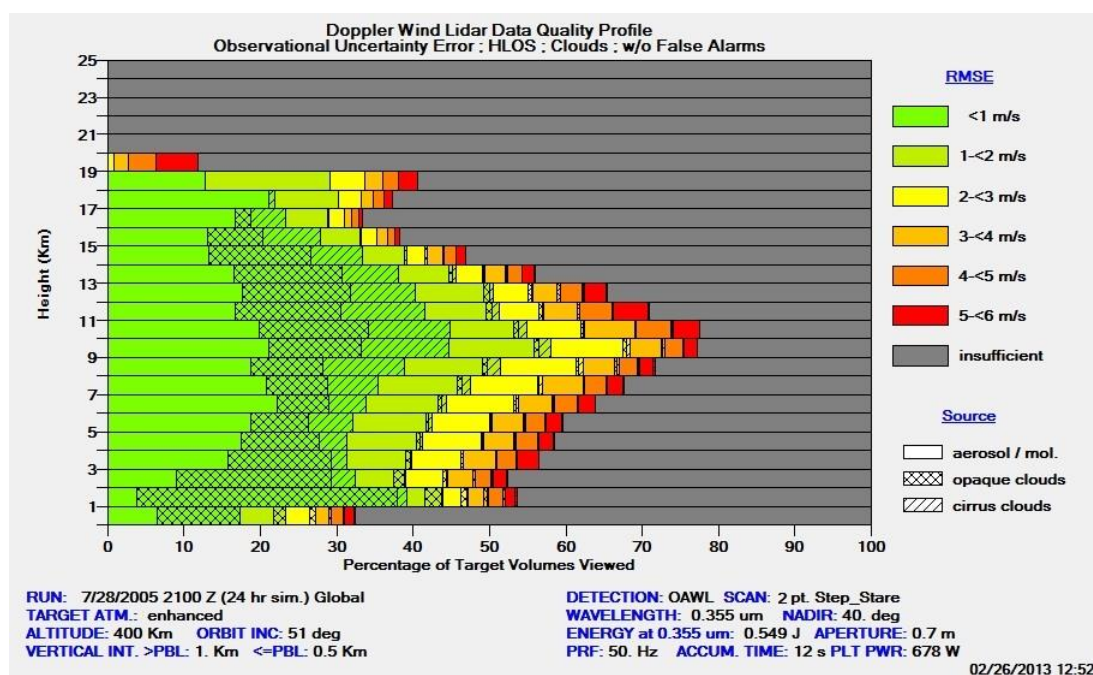


Figure 7b. Global Observational Uncertainty Error Performance Diagram for the OAWL concept using the enhanced aerosol mode. The simulation period was 7/28/2005 21Z - 7/29/2005 21Z.

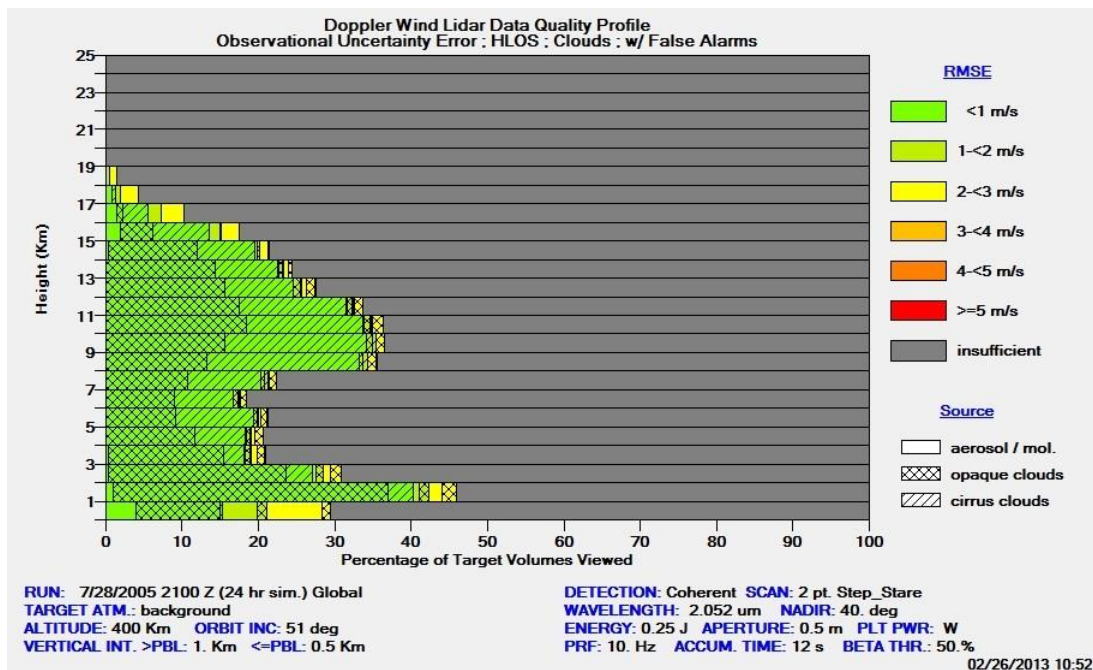


Figure 7c. Global Observational Uncertainty Error Performance Diagram for the WISSCR concept using the background aerosol mode. The simulation period was 7/28/2005 21Z - 7/29/2005 21Z.

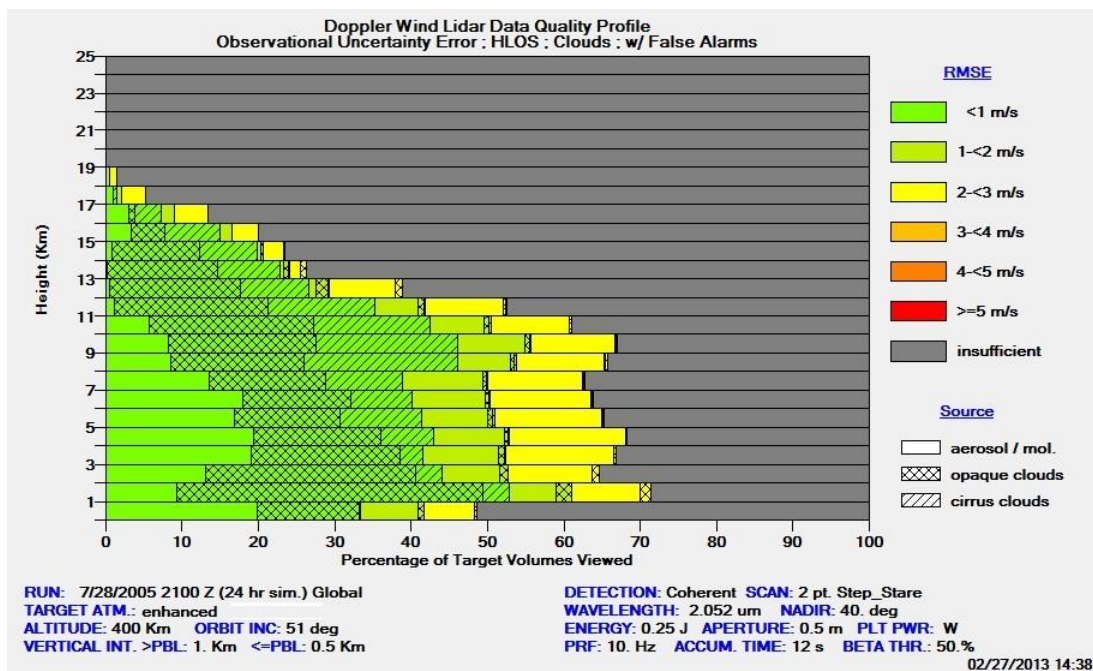


Figure 7d. Global Observational Uncertainty Error Performance Diagram for the WISSCR concept using the enhanced aerosol mode. The simulation period was 7/28/2005 21Z - 7/29/2005 21Z.

The Pre-OSSE evaluations showed that the vertical coverage of quality “aerosol winds” for the OAWL system is much greater than that for the WISSRC coherent system. The WISSRC coherent system is the better PBL wind observing system while the OAWL provides the better quality aerosol winds in the mid and upper troposphere. After

impact studies were completed and evaluated by a technology neutral group, two OSSEs were conducted, respectively at NOAA NCEP and NOAA AOML, for both DWL concepts.

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. This testbed continues to provide a useful means for evaluating future space-based observing systems especially wind measuring systems.

5. REFERENCES

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