P1.5 The Challenges of Assessing the Future Impact of Space-based Doppler Wind Lidars while Using Today's Global and Regional Atmospheric Models

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1.0 INTRODUCTION

Global measurement of tropospheric wind has been widely recognized as potentially the most significant contribution of satellite remote sensing to NWP. Most of the world's oceans are largely devoid of accurate wind measurements, a deficiency that can best be addressed from space. The deployment of a space-based Doppler Wind Lidar (DWL) would provide the capability to address many of the key issues such as hydrologic and biogeochemical cycles, planetary scale dynamics, and atmospheric-oceanic heat transport. Equally important, it would provide critical wind information for improved operational weather forecasting, and for safe, efficient, and effective military and commercial aviation operations.

Ground-based and airborne-based lidars have demonstrated the ability to make direct measurements of horizontal winds based on determination of the wind-induced Doppler shift in the backscatter signal. However, space-based application of Doppler Wind Lidar technology is without heritage. Thus, optimal design of DWL systems for space deployment must rely upon computer model studies. These model studies include efforts with DWL performance models, atmospheric circulation models and atmospheric optical models (Atlas and Emmitt, 1995; Emmitt, 1995). Once a candidate(s) DWL concept is chosen for an impact study, a full Observing System Simulation Experiment (OSSE) is conducted and evaluated. This paper discusses the benefits and limitations of using today's model atmospheres in a simulation model to assess a future space-based DWL system.

2.0 LIDAR SIMULATION MODEL

Over the past fifteen years, Simpson Weather Associates has been funded by NASA, NOAA and DOD to develop and maintain a Doppler wind lidar simulation model (Emmitt and Wood, 1996; Wood et. al., 1996, Wood et. al., 1993; Emmitt et. al., 1990) to use in evaluating future space-based Doppler lidar concepts and for simulating airborne lidar observations. The DWL simulation model (LSM) is used to address questions of optimum laser wavelength, pulse length, minimum power, scanning strategies, optimal signal processing and wind computation algorithms.

The LSM simulates space-based/airborne coherent and incoherent Doppler lidar wind sounders, producing simulated Doppler lidar winds using either global (ECMWF T213 and T106) or mesoscale (29 km Eta and CSU RAMS) atmospheric model fields as inputs. The LSM's unique atmospheric algorithm library, coupled with atmospheric model fields, provides opaque clouds, cirrus clouds, cloud optical properties, aerosol backscatter, molecular attenuation, atmospheric turbulence and terrain information that must be considered when modeling a space-based DWL.

Currently, the LSM is being used in the global Observing System Simulation Experiments (OSSEs) (Masutani et. al., 1999, Lord et. al., 1997) to evaluate several spaced-based DWL technologies and in the Convection And Moisture Experiment (CAMEX) (Greco et. al., 2000; Wood et. al., 1997) to assess the potential impact of airborne DWL data in hurricane track forecast models.

3.0 GLOBAL SCALE MODEL STUDIES

Since the application of a Doppler wind lidar from space has no heritage, the optimal design of DWL systems for space deployment must rely upon computer model studies. The steps between a notional concept for a DWL and the blueprints for instrument construction include a considerable amount of performance modeling and, for space-based systems, an intensive series of OSSEs. During and subsequent to the Laser Atmospheric Wind Sounder (LAWS) study (Baker et. al, 1995), a method for assessing the potential impact of a new DWL observing system was established. Instrument parameters were provided by the engineering community along with scanning or sampling strategies from the science community. A "Nature Run" is provided

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by a weather prediction center with the realism of the "Nature Run" assessed by a second group of analysts. A series of pre-OSSE instrument performance simulations are conducted using the "Nature Run" as input. Finally, a candidate(s) DWL concept is chosen for a full OSSE, and an impact study is then conducted and evaluated by a technology neutral group.

4.0 REGIONAL SCALE MODEL STUDIES

A collaborative effort is ongoing between SWA and Colorado State University (CSU) in which the nested RAMS model (Nicholls et. al., 2000) is being used to investigate the impact of CAMEX 3 measurements, dropwindsondes and moisture from the Lidar Atmospheric Sensing Experiment (LASE), on hurricane track and intensity forecasts. The 1998 Atlantic Hurricanes Bonnie, shown in Fig. 1., and Danielle are being used as case studies. The experiments are using the LSM to explore potential DWL data coverages that would result from an optimally performing airborne or space-based lidar. A 12 hour RAMS forecast of Hurricane Bonnie was added to the LSM's atmospheric data base for the coverage experiments.

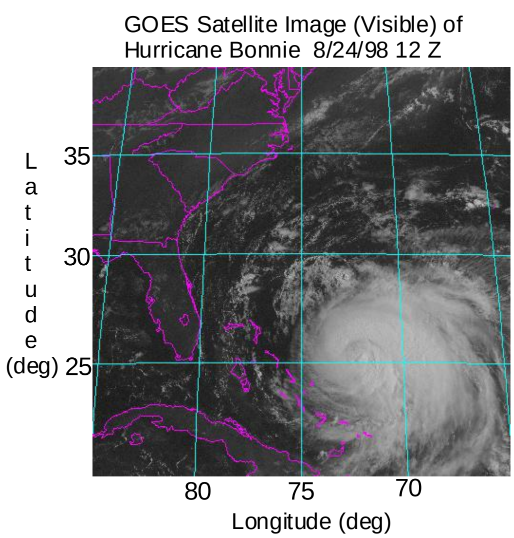

Fig 1. GOES Visible Image of Hurricane Bonnie at 8/24/98 12 Z.

Several experiments are underway or being planned in which the analysis and forecast fields of the Eta model, the NCEP Reanalysis, and the CSU RAMS during Hurricanes Bonnie and Danielle are being used to provide the "real" atmosphere for the LSM. A benefit of using a fine-mesh meso-scale model atmosphere instead of a global model atmosphere is the higher temporal and spatial resolution that is closer to the scale of a DWL measurement volume. However, it must be recognized that there are still very important model limitations that must be considered from a space-based DWL system point of view such as the characterization of wind variance, clouds, and aerosol backscatter.

4.1 SUB-GRID SCALE WIND VARIANCE

The current version of the LSM has two options for estimating the wind variance on the sub-grid scale of the model. The first method computes the wind variance on the grid scale (3 x 3 x 3) and then scaling the variance to smaller scales by the Von Karman relationship. This "reasonable" approach has been used for many years but has not been fully verified by real data. Although the meso-scale models generate a value for the dissipation rate, we do not have confidence in the numbers. This is especially true for heights above the PBL. The second method represents the uncertainties by scaling them to 20 % of the mean model wind speed (RAMS example shown in Fig. 2). Comparisons of the uncertainties with the NMC rawinsonde profiles suggest that the simulated variances using the 20 % rule are not unreasonable.

One of the most challenging issues to representing realistic atmospheres on the lidar shot scale is the correlation of wind variations with backscatter structure. Fig. 3 compares the vertical wind structure between two Hurricane Bonnie RAMS 12 hour forecast wind profiles and the real dropwindsonde profiles. Although there is evidence in real data that aerosol concentrations can be correlated with vertical wind flow, we have not been able to include such in the LSM. Also, one would expect higher aerosol concentrations near the ground under higher wind speeds.

4.2 CLOUDS DERIVED FROM THE RAMS OUTPUTS

Currently the LSM uses the total condensate, temperature and liquid water content (LWC) to parameterize the presence of opaque and cirrus clouds within a model grid (15km resolution). LWC and cloud fraction examples for the Hurricane Bonnie RAMS 12 hour forecast are shown in Fig. 4 and Fig. 5, respectively. While the resulting cloud amounts and distributions are plausible and consistent with the model physics, we have little validation based upon real data taken with lidars for various cloud conditions.

Cloud optical properties and cloud porosity parameterizations are based upon extensive data bases from available literature, the cloud types and the atmospheric model inputs. The LSM has a cloud porosity function that was derived from some preliminary analyses of LITE data. Given the porosity found (> 50% of all lidar shots that intercept cloud also exhibit an earth's surface return), the exclusion of this effect in an OSSE will tend to under represent the data coverage of the simulated DWL. More specifically, since coherent systems can make useful wind measurements along a single LOS while current direct detection concepts require multiple LOS samples, the omission of porosity will understate the potential impact of the coherent concepts.

4.3 BACKSCATTER VARIABILITY

The LSM provides several options for computing aerosol backscatter and attenuation coefficients. The foremost option couples FASCODE (Gallery et al., 1983) with LSM unique databases and model atmospheres to produce aerosol backscatter and attenuation profiles as a function of the DWL's wavelength. The optical property's natural variability due to altitude, location, seasons, and meteorological conditions are taken into consideration. A simpler option couples the distribution of expected backscatter directly to the model atmosphere's relative humidity as shown in Fig. 6. and Fig. 7. However, the distribution of backscatter variability on scales affecting single LOS processing, as mentioned in section 4.1, is coarse at best. It is important to consider that the effects of backscatter variability within a shot's illuminated volume can lead to erroneous height assignments for any detection technique. Thus, the emphasis in this case is on representing the vertical structure of the aerosol/cloud distributions.

5. CONCLUDING REMARKS

This paper has highlighted several of the challenges one is faced with when trying to use today's atmospheric models to assess future impacts of a Space-based Doppler Wind Lidar system. While mesoscale atmospheres do provide model inputs at fine resolutions, they still are not at the scale of a DWL's measurement volume. However, it is noted that while we have tried to remain conservative with a DWL's performance with respect to the wind variance, clouds, and aerosol backscatter effects, significant impacts are being revealed in model studies.

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