

OPTICAL REMOTE SENSORS AS COMPONENTS OF AN AIRBORNE HURRICANE OBSERVING SYSTEM

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1. INTRODUCTION

A recent study by the Hurricane Research Division (Burpee et al., 1996) has shown that additional dropwindsonde observations made around hurricanes can improve the accuracy of hurricane track forecast models. The use of these dropwindsonde data by storm track models was shown to have a positive and statistically significant impact on forecast accuracy. Whether alternatives to dropwindsondes have any significant merit remains an issue for closer examination. In 1995, airborne optical remote sensing instruments such as Lidar Atmospheric Sensing Experiment (LASE) and Multi-center Airborne Coherent Atmospheric Wind Sensor (MACAWS) have been used independently to make measurements around hurricanes. While remote sensing of moisture and winds using laser-based systems will provide higher spatial and temporal resolution than dropwindsondes, the noncontiguous nature of the lidar data products raises issues that are best addressed with the models that are going to assimilate the data.

Over the last 10 years NASA has funded the development of a lidar simulation model (LSM) (Wood et al., 1995; Wood et al., 1993; Emmitt et al., 1990). The LSM is a fully integrated numerical model that was originally designed to simulate a space-based Doppler lidar wind sounder providing global three-dimensional horizontal vector winds. Recent additions to the LSM include an airborne platform, a parameterized water vapor (DIAL) lidar module and the option to use meso-scale atmospheric model inputs. One representation of meso-scale atmospheric inputs employed by the LSM is provided by the National Centers for Environmental Prediction (NCEP) meso-scale, step-mountain eta coordinate model, more commonly known as the meso-scale eta model (Black et al., 1994). As a case study, the LSM has been used to examine the performance of co-located airborne lidar wind and moisture sounders in the environment of the eta model representation of Hurricane Allison (June 4 1995).

2. LIDAR SIMULATION MODEL

The LSM is a unique set of computer models that addresses various questions regarding the feasibility and optimal functionality of a space-based or airborne lidar systems. The LSM is designed to address engineering trades,

measurement accuracies, measurement representativeness, resolution and areal coverage. Figure 1 highlights the major modules of the LSM involving the satellite/aircraft, scanner, laser, signal processing, atmospheric library, line of sight wind, horizontal wind component, water vapor profiler and error modules.

A key component of the LSM is the Atmospheric Generator Model (AGM) that creates atmospheric libraries using meso-scale model data sets in liaison with the LSM optical property models and a terrain data set. One of the meso-scale atmospheric input representations employed by the AGM is the above mentioned mesoscale eta model. Operational since the fall of 1995, the meso-scale eta model, so-named because of the use of a pressure-based vertical coordinate (eta) which is normalized to mean sea level pressure, has a horizontal resolution of 29 km and consists of 50 layers in the vertical between the surface and around 50 mb. This model is run twice daily and provides forecasts up to 36 hours. The primary prognostic variables of the eta model are temperature, specific humidity, horizontal wind components, clouds, surface pressure and turbulent kinetic energy. Figures 2a,b,c present examples of three AGM's mesoscale atmospheric variables (surface horizontal winds, aerosol backscatter and specific humidity) during Hurricane Allison. As a point of interest, Hurricane Allison is positioned off of the west coast of Florida.

3. AIRBORNE LASER SIMULATIONS OVER HURRICANE ALLISON

A 2-hour simulated airborne flight, composed of two one hour linear flight tracks, is shown imposed over the eta model cloud field of Allison (9 km) in Figure 3. The first track is along the western side of Allison heading north and the second track is diagonally over Allison heading southeast. The aircraft altitude is around 33,000 feet in smooth air resulting in no roll, pitch and yaw effects. The fields of view of the Doppler lidar and the water vapor lidar are considered to be co-located in the simulation.

Figures 4a,b show vertical cross-section profiles of simulated line of sight winds from the Doppler lidar and specific humidity from the water vapor sensor along the flight tracks, respectively. The Doppler lidar scanner is a bi-beam configuration with orthogonal azimuth angles at 45° and 315° with a 60° nadir scan angle. The water vapor estimates were averaged over 10 seconds to make a specific humidity measurement. The effects of cloud obscuration on both systems can be clearly seen in the figures. Due to cloud porosity (Emmitt and Séze, 1991) and the smaller diameter

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(~10 m) of the lidar beam, the Doppler lidar is able to penetrate to the PBL in conditions that appear to be totally cloudy to a passive sensor.

4. CONCLUDING REMARKS

Airborne optical sensors promise to make very high spatial and temporal resolution measurements in hurricane environments, but only as clouds permit. Simulations of these type can help in the design and execution of field experiments to investigate the potential impact of moisture availability and its advection on hurricane genesis, intensification and tracking. Such an experiment (Convection and Atmospheric Moisture EXperiment- CAMEX III) is currently being designed for execution in 1998.

In addition to providing input to airborne field programs, such modeling studies can be designed to explore the potential of future space-borne optical systems. Figures 5a,b show the potential for satellite laser wind coverage over a hurricane such as Fran (Sept 1996). The simulation of the satellite orbit is for a proposed Next-generation Polar-orbiting Operational Environmental Satellite Systems (NPOESS) configuration (i.e., 833 km altitude and 45° nadir scan angle). The figures show that given ~ 1800 km swath width, twice daily coverage of such storms will provide numerous potential wind estimates for model assimilations.

5. REFERENCES

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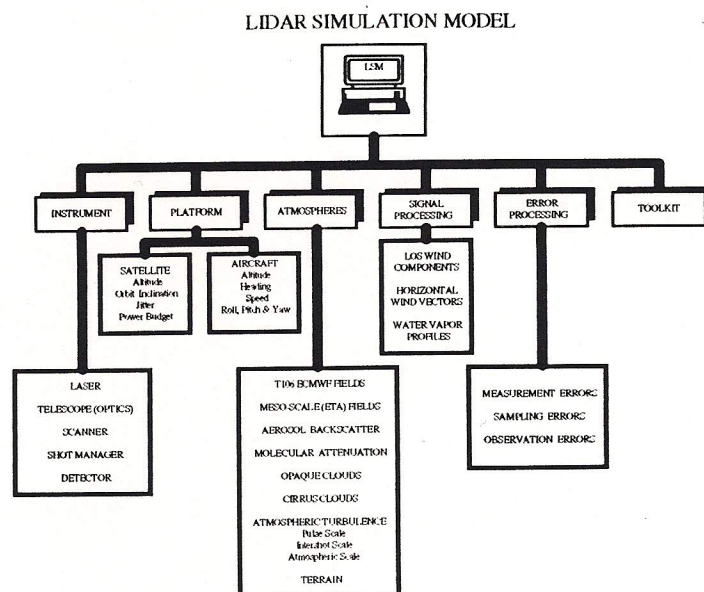


Fig. 1. Block diagram for the Lidar Simulation Model (LSM).

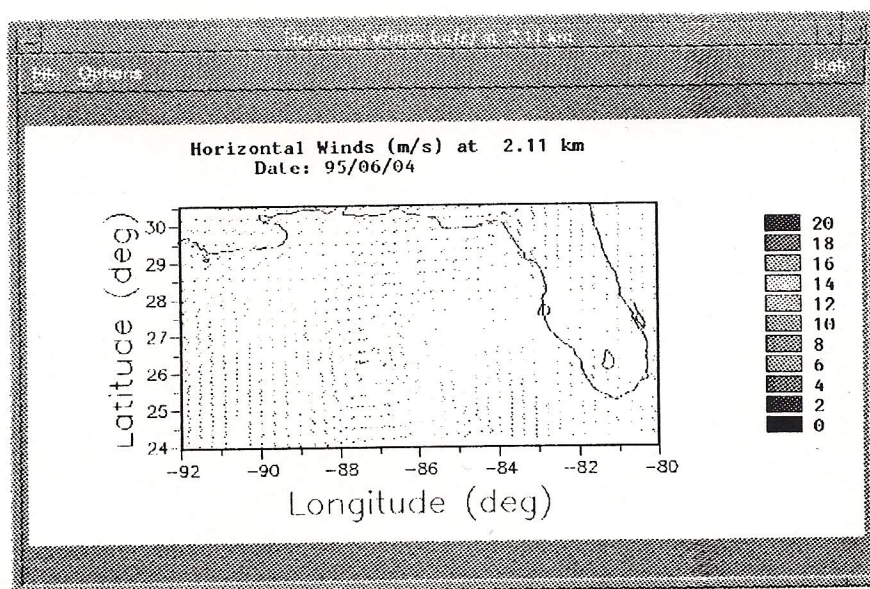


Fig. 2a. Eta (June 4, 1995) horizontal winds (m/s) at 2.11 km generated by the Atmospheric Generator Model (AGM).

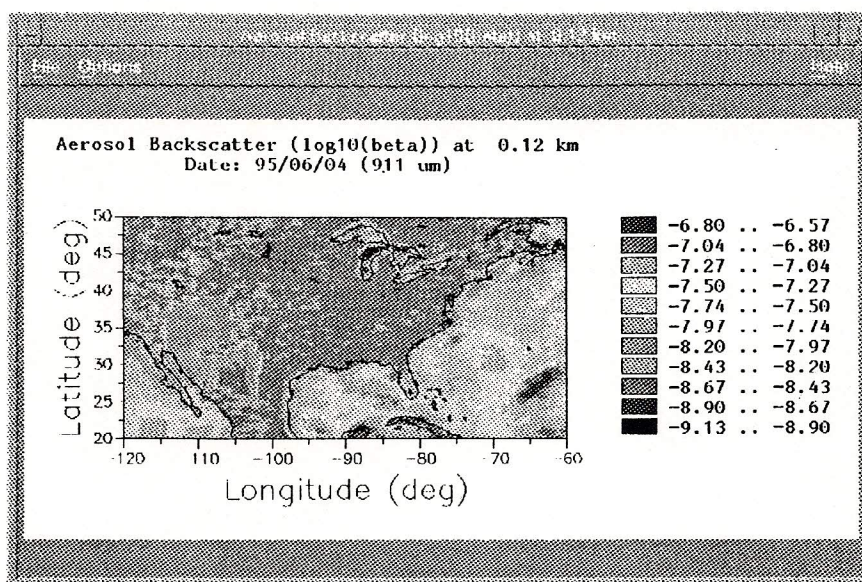


Fig. 2b. 9.11 μm aerosol backscatter ($\text{m}^{-1} \text{sr}^{-1}$) at the surface generated by the Atmospheric Generator Model (AGM) using the eta (June 4, 1995) model data set and the Lidar Simulation Model's optical property models.

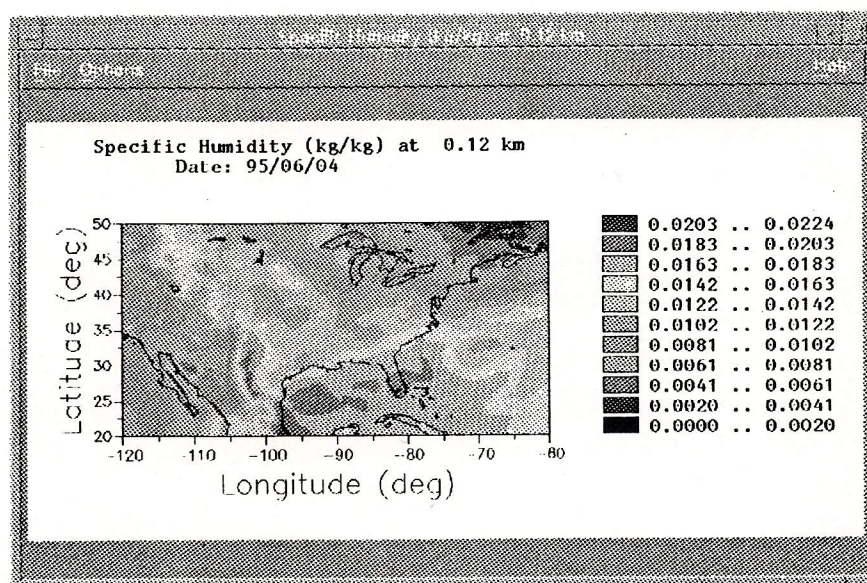


Fig. 2c. Eta (June 4, 1995) specific humidity at the surface generated by the Atmospheric Generator Model (AGM).

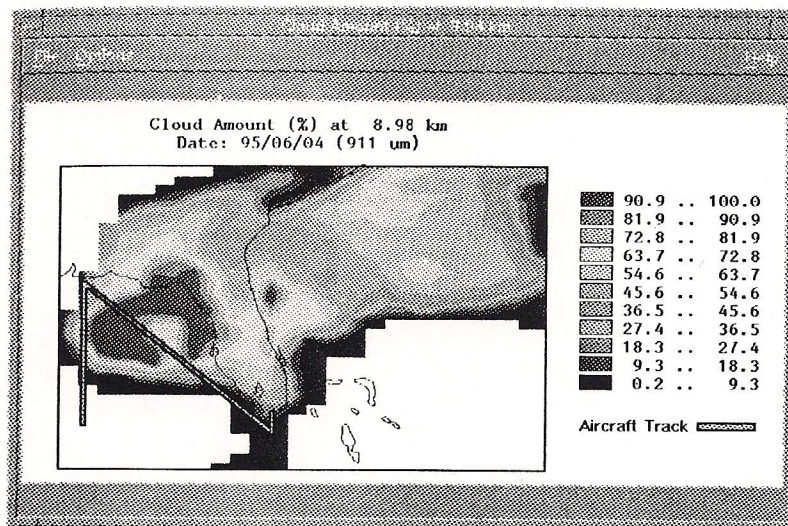


Fig. 3. Two hour simulated aircraft track depicted over eta mesoscale model of Hurricane Allison's (Juen 4, 1995) 8.9 km cloud field.

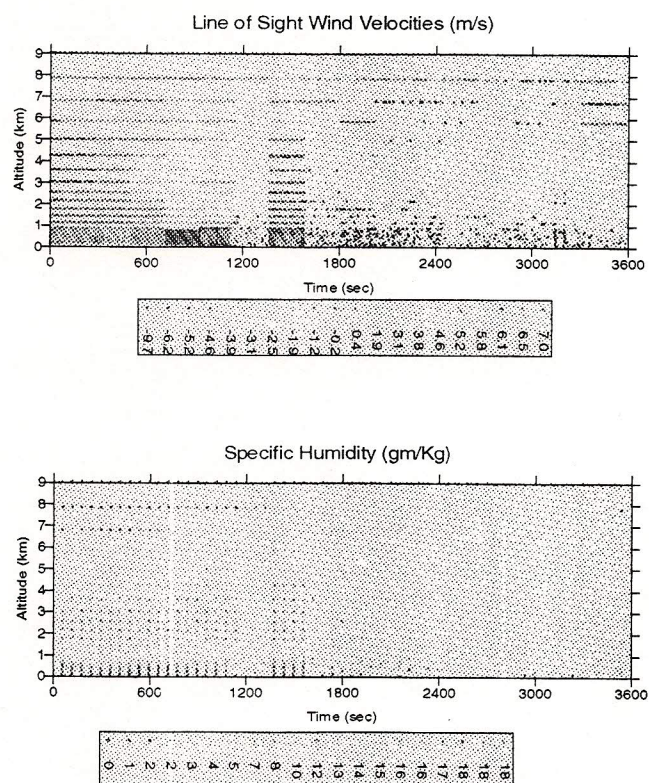


Fig. 4a. Vertical cross-section of simulated Doppler lidar line-of-sight wind velocities (m/s) and DIAL specific humidity (gm/kg) along flight track 1. Aircraft altitude is 10 km.

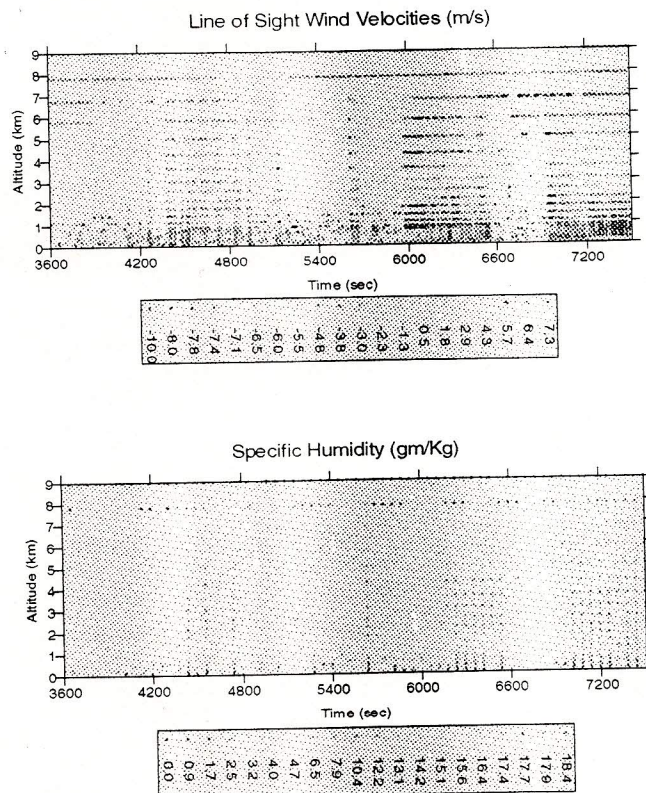


Fig. 4b. As for Fig. 4a except for track 2.

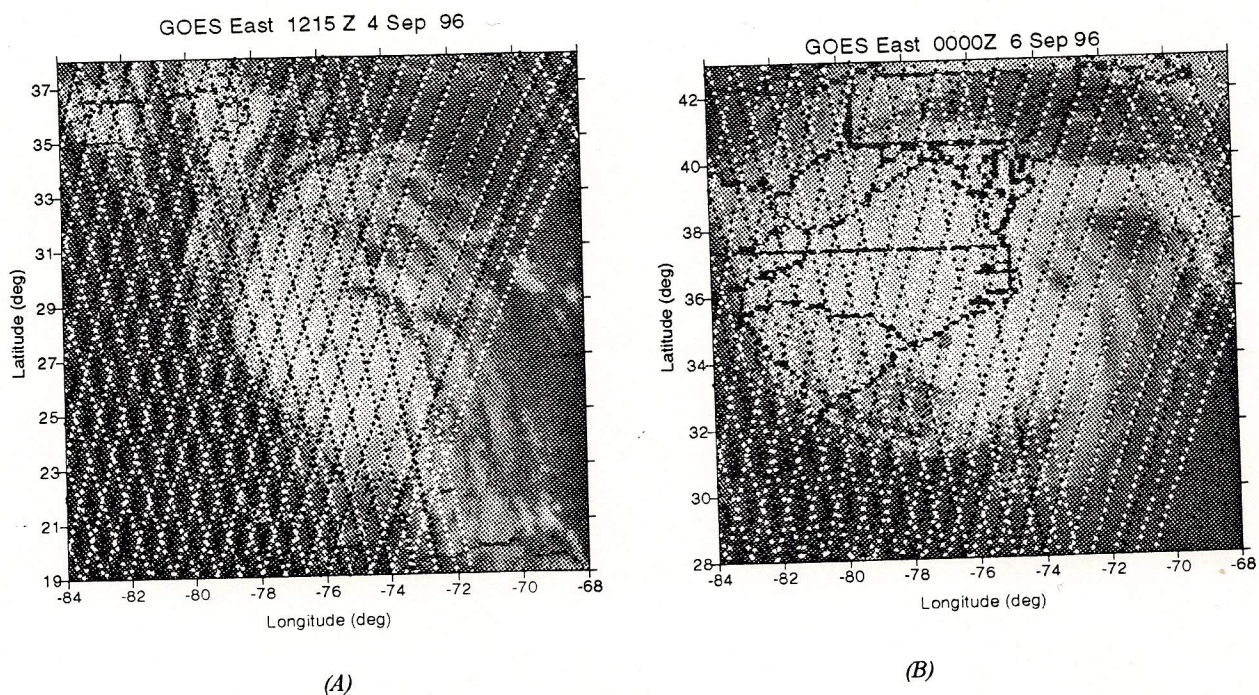


Fig. 5. 24-hour coverage for a Doppler wind lidar on a Next-generation Polar-orbiting Operational Environmental Satellite System (NPOESS) at an 833 km orbit and a 45° nadir scan angle over Hurricane Fran for (a) September 4, 1996, 1215Z and (b) September 6, 1996, 0000Z. Forward laser shots are depicted as white dots and aft laser shots are depicted as black dots.