DOPPLER LIDAR WIND MEASUREMENTS: RECENT PROGRESS AND CURRENT STATUS

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1. INTRODUCTION

Doppler lidar continues to evolve as an important tool for studying and characterizing atmospheric winds. Recently advancements have been made in both technology and novel applications of the technique for important environmental issues. Doppler lidar systems are generally classified in one of two categories based on the detection technique employed to measure the Doppler shirt of the atmospheric return: direct detection or heterodyne (coherent detection). In this paper we present some recent accomplishments in the application of coherent Doppler lidar to climate, weather, and energy research at NOAA's Earth System Research Laboratory, and briefly discuss planned future activities. A companion paper in this session focuses on direct detection Doppler developments within NASA [1].

At NOAA, we have developed and deployed a number of Doppler instruments over the past several years. Currently, our work is focused on the role of atmospheric boundary layer processes in currently important issues such as horizontal and vertical mixing of pollutants and greenhouse gases, dynamics associated with cloud formation and breakup under different aerosol-loading regimes, and effects of atmospheric turbulence and variability on wind energy efficiency and reliability. To best address these issues, we employ one of two pulsed Doppler instruments: a solid state, High Resolution Doppler Lidar (HRDL) and a CO_2 isotope Doppler system. Both systems can be deployed on both land surface and ship platforms; the HRDL instrument has also been flown on research aircraft.

2. ATMOSPHERIC STUDIES USING GROUND-BASED SYSTEMS

Understanding the stable boundary layer, and its often-associated low level jet, is important for modeling and predicting transport and mixing between the surface and free atmosphere at night. The stable layer can serve as a lid, trapping pollutants and other constituents, but can also be characterized by mixing events resulting from shear-induced turbulence. The low-level jet, which often overlies a surface-based layer at night, plays an important role in vertical mixing through the layer. During several recent field experiments we have applied the NOAA HRDL instrument to investigate the temporal variability of wind velocity and wind velocity turbulence in the stable boundary layer and low-level jet. Results of the lidar measurements have been used to develop an understanding and scaling between the turbulence in the boundary layer and the strength of the low-level jet under both moderately stable and very stable conditions [2].

Because performance and efficiency of wind turbines in the stable layer is an important current topic relating to the efficiency of wind power generation, we have also applied lidar techniques to study winds and turbulence at a proposed U.S. Department of Energy wind turbine research site. Results showed that under nighttime conditions shear often exceeded that specified by the International Electrotechnical Commission (IEC) for a "normal" wind profile.

3. SHIP-BASED STUDIES FOR CLIMATE AND AIR QUALITY RESEARCH

Because of the difficulties in making remote measurements of winds from ship platforms, winds in the marine boundary layer have not been widely studied. To enable studies of winds in the marine environment, we developed a technique for compensating lidar beam pointing for the linear motion of the moving platform as well as the roll, pitch and yaw induced by the sea state. The motion compensation system relies on a GPS-based motion sensor to provide information for redirecting the lidar beam by means of a 3-axis scanner through which the beam is directed. Our data indicate that we can direct the lidar beam to within 0.5 degrees of the intended pointing direction under most sea-state conditions.

Utilizing the motion compensation capability, we have deployed both the HRDL and CO_2 isotope instruments during ship-based campaigns to investigate the relationships between ocean surface characteristics and the marine boundary layer wind field, to characterize the marine boundary layer depth and mixing for air quality studies, and to study the wind field, as well as the updraft and outflow, under cumulus, stratocumulus and stratus clouds during formation and breakup of the clouds under different aerosol and precipitation regimes.

Mixing layer depth is a key parameter for characterizing and predicting surface air pollution values. Based on measurements of the wind speed and direction, as well as the horizontal and vertical velocity variance profiles, we developed a new technique for remotely estimating mixing layer height [3]. In addition to providing a continuous record of mixing layer height, the technique enables adjustment of surface-measured values of pollutant fluxes based on depth of the layer. As part of the same air quality study, we also used horizontal and vertical wind measurements from the NOAA ship Ronald H. Brown in the Gulf of Mexico near Houston to show that the low-level jet directly affects mixing between the surface and upper layers, impacting the measured concentrations of pollutants on the ship.

4. AIRBORNE INVESTIGATIONS OF TRANSPORT AND MIXING

In addition to the land and ship-based field deployments, the HRDL instrument has been deployed on a Falcon jet and Twin Otter aircraft for boundary layer studies in the central US. During the International H_2O Project, which was aimed at improving understanding of convection and precipitation processes over the central U. S, Great Plains, we measured horizontal and vertical velocity winds and turbulence within the boundary layer. The data were used to characterize surface exchange mechanisms within the boundary layer and to observe transport by the Great Plains low-level jet. A water vapor lidar co-installed on the Falcon aircraft provided simultaneous measurements of water vapor. Observations from the two instruments were combined to estimate vertical and horizontal flux of water vapor in the atmosphere for comparison with forecast models [4].

We have also deployed HRDL on a Twin Otter aircraft for boundary layer studies over the Colorado mountains and plains. Because it flies slowly at heights ranging to about 6000 m ASL, the Twin Otter offers an ideal platform for high resolution remote sensing of the boundary layer.

5. FUTURE DIRECTIONS

Current plans for future research involving Doppler lidar include participation in a major field experiment, which will include aircraft, ship, and ground stations, in California during the summer of 2010. The experiment is aimed at improving understanding of emissions that affect air quality and aerosol formation and the inter-regional and interstate transport of pollutants. Preparation for the experiment will include lidar measurements in Colorado during the summer of 2009.

We are also investigating the application of commercial 1.5 μm Doppler lidar technology for extended field deployments. Operation at 1.5 μm makes use of off-the-shelf optical communications technology, enabling smaller and cheaper, albeit less powerful, systems for measurement of winds in high aerosol scenarios such as the boundary layer of at the base of clouds.

7. REFERENCES

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