Design and Calibration of Autonomous Coherent Doppler Lidar for Space Missions

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Summary of Results

Developed a new algorithm for the simulation of three dimensional homogeneous turbulent velocity fields. For typical atmospheric conditions it is impossible to produce a simulated velocity field that simultaneously satisfy a given spatial correlation and the corresponding spatial spectrum because of spectral aliasing. The new algorithms produce a turbulent velocity field which has accurate spatial correlations which is required for performance predictions from space-based systems.

Developed a new algorithm for extracting the spatial statistics of the atmospheric velocity field using coherent Doppler lidar. The performance of the algorithm was compared with past methods and the new algorithm produces useful results for space-based data, which was not possible before.

Developed new methods for verification of the errors in ground-based and space-based Doppler lidar wind measurements. These new methods do not require independent in situ data. This is an important issue for the verification of space-based Doppler lidar measurements of the global wind field. The performance of the new algorithm was compared with past results for both space-based and ground-based operation. The new algorithm has the best performance and is the only algorithm that performed satisfactory for space-based operation.

The performance of coherent Doppler lidar for a space missions with various scanning geometries was determined using computer simulation which contained the effects of random instrumental velocity errors, wind shear, wind variability along the range-gate and from shot-to-shot, and random variations in atmospheric aerosol backscatter over the measurement volume. The bias in the velocity estimates was small and the accuracy in the is typically less than 0.5 m/s for high signal conditions. For a large number of shot per velocity estimate, the threshold signal level for acceptable estimates is proportional to the number of shots to the minus one half power. This agrees with previous results determined for ground-based measurements.

The use of multi-element optical detectors for autonomous operation of coherent Doppler lidar was shown to be a very promising technique. Optimal detector geometries were determined by computer simulation of performance: for ground-based testing with a fixed calibration target and for space-based operation using the random surface returns.

The effects of refractive turbulence on ground-based calibration of coherent Doppler lidar was determined by computer simulations and compared with theoretical predictions. New techniques were required to correctly predict performance for the focused beam geometry commonly used for verification of space-based operation.

An improved velocity estimator was evaluated for space-based applications were signal shot measurements are used to produce vector wind measurements. This permits more accurate measurements when

the signal level is not known a priori or not available from multiple shot measurements.

The average Doppler lidar signal spectrum including the effects of velocity turbulence was derived and calculated. This permits new estimation algorithms for turbulence based on spectral estimates.

In situ atmospheric measurements were conducted and analyzed using an instrumented kite-platform. This work helps provide the required in situ data for verification of Doppler lidar velocity statistics.

Publications in Refereed Journals

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"Simulation of three dimensional turbulent velocity fields", R. G. Frehlich, L. Cornman, and R. Sharman, J. Appl. Meteor., J. Appl. Meteor., Vol. 40, 246-258, (2001).

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"In situ turbulence measurements over a desert basin using a kite/tethered-blimp platform", F. Eaton, B. B. Balsley, R. G. Frehlich, R. J. Hugo, M. L. Jensen, and K. A. McCrae, Optical Engineering, Vol. 39, 2517-2526, (2000).

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