RESEARCH STUDY:

SEVERE STORMS DOPPLER LIDAR SIGNAL PROCESSING

Final Report Supplement

Contract NAS8-34768

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R. W. Lee

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MANTON CALIFORNIA 96059

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I. Introduction

Contract NAS8-34768 called for the development of algorithms for correcting certain measurement artifacts present in the measurements made during the 1981 flight program. This problem was addressed in Technical Report no. 1, issued in April 1982, and subsequent progress reports. The purpose of this supplement is to summarize the recommended algorithm for the correction of higher-order data errors.

II. The source of higher-order errors

As noted in Technical Report no. 1, there are several sources of error in addition to the drift-angle error treated in that report. These include the non-uniform attitude-measurement delay (due to the non-uniform scanning intervals), possible laser drift, and laser scanning above or below the horizontal. Due to their random natures these errors cannot be corrected by deterministic means.

III. Suggested correction algorithm

Fortunately these higher-order errors are essentially independent from scan to scan. As such the error spectrum they produce is white, and error reduction can be obtained by recourse to spectral filtering.

Where the errors are constant with range, as in the case of most of the instrumental errors, a continuity argument can be used to justify a simple correction algorithm. Consider a time series of mean radial-velocity measurements. Each item in the time series is an average over about 10 km of range. The mean-square difference between adjacent items in the series will arise from that portion of the two-dimensional velocity spectrum which is not averaged out by the 10-km one-dimensional integration. That is, the major part of the variance of the true time series will be due to spatial variations in the wind field with scale sizes on the order of several km. Due to the integration the spectrum of this true time series will be concentrated at low frequencies.

The observed time series will contain in addition variance due to the errors mentioned above. Since the errors are essentially independent from scan to scan, the additional variance in the spectrum will be white. Since these two contributions to the spectrum differ greatly in spectral form, filtering techniques can substantially reduce the white component. A transversal low-pass filter is used to estimate the true component of the time series. The passband is chosen to be sufficiently broad to pass all significant frequency components present in the integrated velocity measurements. This is easily accomplished since the frequency range of the true time series has been greatly restricted by integration along the lidar beam.

Many types of filters could be used to implement this algorithm. The following suggestion makes use of a least-squares fit of a cubic function to the data, to allow for slow changes in the mean radial velocity. Forward and aft scan data sets are considered separately. Radial velocities are averaged over the longest range interval over which the measurements are highly reliable (by signal-to-noise ratio criteria). Each point in the resulting time series is treated independently: a correction for that point is derived from adjacent uncorrected averages, and that correction is applied to measurements at each range gate.

The corrected mean radial velocity for a given point can be derived as a simple weighted mean of the mean apparent velocities in the neighborhood of that point. Using an odd number of points (2M+1) centered on the point in question, let the mean radial velocities be Vi, i=-M to M. For cubic or quadratic approximation (they give the same result for symmetrical filtering), the corrected mean velocity V is

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      sum(Vi)*sum(i**4)-sum(i*i)*sum(i*i*Vi)
V = -------------------------------------- ,
        sum(1)*sum(i**4)-sum(i*i)*sum(i*i)
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where the sums are over the full range of i. For 5 points (M=2), the coefficients of Vi are -.0857, +.3429, +.4857, +.3429, and -.0857. For 7 points they are -.0952, +.1429, +.2857, +.3333, +.2857, +.1429, and -.0952. The weighting is symmetrical about V0, the point to be corrected. The difference between V and V0 is used as a correction factor for all range gates in that data scan.

Note that this algorithm cannot correct errors which vary with range, such as those produced by non-horizontal scans or laser drift. These errors are not amenable to correction. If possible they must be recognized and edited out of the data prior to the application of any smoothing or other corrections.