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TITLE: LAWS Simulations - Sampling Strategies and Wind Computation Algorithms

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ACCOMPLISHMENTS in 1987/88:

In general, work has continued on developing and evaluating algorithms designed to manage the LAWS lidar pulses and to compute the horizontal wind vectors from the line-of-sight (LOS) measurements. These efforts fall into three categories: 1) Improvements to the Shot Management and Multi-Pair Algorithms (SMA/MPA); 2) Observing System Simulation Experiments; and 3) Ground-based simulations of LAWS.

Shot Management and Multi-Pair Algorithm Improvements

Various forms of shot management have been examined. In particular, several combinations of scan angle, scan rate and pulse repetition frequency (PRF) were simulated and evaluated for shot coincidence and shot density (spatial). Although it is possible to achieve shot intersections by controlling all three of the scanner/lidar parameters, mid-scan or scan to scan variations in scan angle and scan rate have been ruled out because of engineering considerations. However, shot timing or a variable PRF has been kept as a viable option.

Prior to invoking a variable PRF, the Multi-Pair Algorithm (MPA) was revised for use with a fixed PRF by improving the matching of nearest shots to form shot pairs. MPA I used a look-up table to match shots and did not consider the effects of the earth's rotation. MPA II includes the change in sampled volume displacement as a function of latitude. A comparison of MPA I, MPA II and the least squares approach for 100 x 100 km^2 areas is shown in Table 1.

While the advantages of the MPA (I or II) over the least squares approach are significant the MPA II showed modest improvement 10-50% over the MPA I. Further improvement may be possible with an "assumed" coincidence shot schedule yet to be developed.

Table 1
RMS Speed Error
(Input: Gradient* and Random** Wind Field)

	150-650	600-1250	1200-1450	150-1450 km
Least Squares	32.680(33.12)	8.963(10.05)	11.294(9.400)	17.387(23.41)
MPA I	1.241(0.988)	0.615(0.314)	0.626(0.324)	0.826(0.692)
MPA II	0.890(0.761)	0.577(0.319)	0.552(0.459)	0.724(0.551)

*$u_o = v_o = 2.0$ m s^{-1}, $\frac{du}{dx} = \frac{dv}{dy} = 10^{-5}$ sec^{-1}, $\sigma_u = \sigma_v = 0.15$ m s^{-1},

**σ_w(vertical velocity variations) = 0.05 m s^{-1}, σ_{noise}(LOS measurement uncertainty) = 1.0 m s^{-1}

Observing System Simulation Experiments

Efforts to assess the potential impact of LAWS on global scale weather forecasts are on-going in a set of GCM experiments being conducted by SWA and NASA/GSFC. The amount of data generated by the LAWS Simulation Model (LSM) has required modifications to the assimilation/analysis programs that provide input to the forecast models.

Figures 1-3 show the simulated LAWS winds and their sampling related errors using ECMWF Nature Run data as input. The along and cross track errors are obvious in Figure 3. The absence of data near the sub-satellite ground track is due to a cut-off for wind estimates made from shot pairs having angular separation 175-180°. In simulations used as input to the forecast impact studies, cloud fields and topography are included.

Ground-based Simulations of LAWS

During the period November 16-19, SWA conducted a series of experiments at MSFC using the ground-based scanning CO_2 Doppler lidar. The experiments were designed to answer some questions regarding lag-angle compensation, optimum pulse length, single shot signal quality, and space-based lidar shot management. Review of the data collected shows that we have enough data to work on three of the primary objectives of those tests:

i) downwind/crosswind line-of-sight (LOS) variance comparisons;

ii) single-shot/poly-shot velocity comparisons; and

iii) LAWS sampling simulations.

We completed the sampling simulation using 10 sequential VADs obtained on 17 November when the winds aloft were between 20 and 30 m s^{-1}. This block of VADs allowed us to simulate shots taken 20 to 25 km apart (we assumed Taylor's hypothesis). The results of these simulations were presented at the CLEO '88 meeting in April in Anaheim, CA.

The quality of the VADs, in terms of data loss, required substantial editing before trying to fit a sine wave to the LOS velocities. In Figure 4a a typical VAD is shown without any editing. If the data losses were easily identifiable (and unambiguous) from the velocity information, then editing would be straightforward as it often is with other types of sensors. In our case a positive but varying velocity is reported when the SNR is insufficient to get a good peak detection. A low band pass filter on the velocity data was tried but good data were often filtered out and if a large contiguous section ($\sim 90°$) of the sine wave was bad, then the band pass filter performed very poorly.

Instead of using FFT's and band pass filtering we chose a method that uses the amplitude of the signal for editing the winds. Figures 4a-c demonstrate the method for extracting useful LOS wind information from noisy Doppler lidar measurements. The method uses the maximum signal amplitude at the 90th range gate as a threshold value to be compared with signal amplitude at range gates where good data are expected. Part a) shows the signal drop-out for a VAD of LOS wind velocities as a function of lidar azimuth at range gate 22. Part b) shows the corresponding SNR (solid line) for range gate 22 and the threshold SNR (dotted line) found at range gate 90. The circles in part c) depict LOS wind velocities after filtering out the noise. A sine fit to the date is also shown.

This approach is conservative in so far that it uses only the best velocity data. While the sine fitting part of the software cannot handle biased noise very well, it can handle a VAD made up of very few good values including clustering in partial sectors.

The sine fitted VADs provided the "true" wind speeds and directions against which shot-pair estimates of the winds could be compared. The individual LOS measurements (processed through the Poly-pulse pair processor) were paired so as to simulate the relative perspectives through the boundary layer that would be achieved from a polar orbitor. In order to obtain enough pairs to make a meaningful statistical statement on errors, the shot pair estimates were grouped by angles into 12 bins. In Figures 5-7, the errors in the estimates of the U (cross track in this instance) and V (along track) components as well as the total wind speed indicate the same pattern of errors resulting from the numerical simulation. However, the amplitude of the errors are slightly large, i.e., 3-5 m s^{-1} in the mid-range.

CURRENT RESEARCH AND PLANS FOR 1988/89

During the next six months, efforts will be focused upon the following three areas:

* Develop a fully documented set of gridded wind/clouds/aerosol fields for use in the Phase a/b LAWS feasibility and trade studies. Included in the set would be:

Pure structures	-	divergence vorticity deformation random (u,v,w)
Model outputs	-	global scale with clouds with aerosols
		regional scale with clouds with aerosols

* Use single shot data from MSFC's (or NOAA's) ground based lidar system to assess errors associated with incorrect height assignment of LOS velocities obtained in regions of known wind shear and aerosol gradients. Software will be developed for rapid assimilation of backscatter data collected during the 88/89 globe missions.

* Complete the Baseline and Bracket OSSES being run at GSFC.

PUBLICATIONS

Emmitt, G.D. and J.W. Bilbro, 1987: Error analysis for horizontal wind vector computation using line-of-sight component measurements from a space-based Doppler lidar. Submitted to special issue of Appl. Optics.

Emmitt, G.D., 1987: Contributor to Laser Atmospheric Wind Sounder (LAWS); Instrument Panel Report (Chairman R.J. Curran), NASA Earth Observing System, Vol. IIg, NASA Headquarters, Washington, D.C.

Emmitt, G.D. and J.W. Bilbro, 1987: Assessment of error sources for one component wind measurements with a space-based Doppler lidar. Paper presented at the Optical Society's Fourth Conference on Coherent Laser Radar: Technology and Applications, Aspen, CO, July.

Emmitt, G.D., 1987: Error analysis for total wind vector computations using one component measurements from a space-based Doppler lidar. Optical Society's Fourth Conference on Coherent Laser Radar: Technology and Applications, Aspen, CO, July.

Emmitt, G.D. and S.H. Houston, 1987: Impact of a space-based Doppler lidar wind profiler on our knowledge of hurricanes and tropical meteorology. AMS 17th Conference on Hurricanes and Tropical Meteorology, Miami, FL, April.

Emmitt, G.D., 1988: Direct measurement of boundary layer winds over the oceans using a space-based Doppler Lidar Wind Sounder. AMS Third Conference on Satellite Meteorology and Oceanography, Anaheim, CA, February.

Emmitt, G.D. and S.A. Wood, 1988: Ground-based simulation of a space-based Doppler lidar atmospheric wind sounder. Optical Society's Conference on Lasers and Electro-Optics, Anaheim, CA, April.

Emmitt, G.D. and S.A. Wood, 1988: Subvisible cirrus in space-based Doppler lidar simulations. Atmospheric Transmission Conference, AFGL, Hanscom, MA, June.

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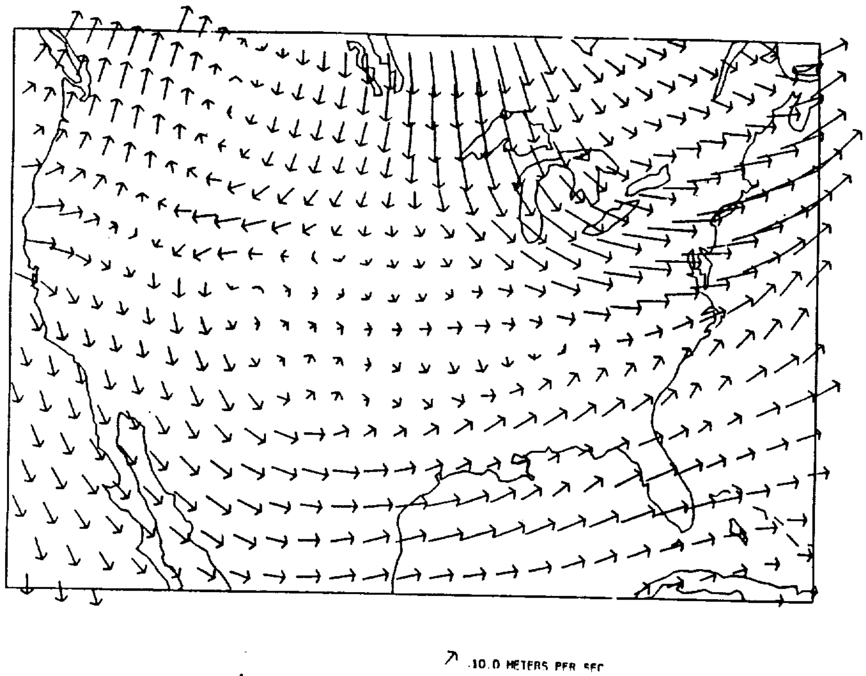

Figure 1.

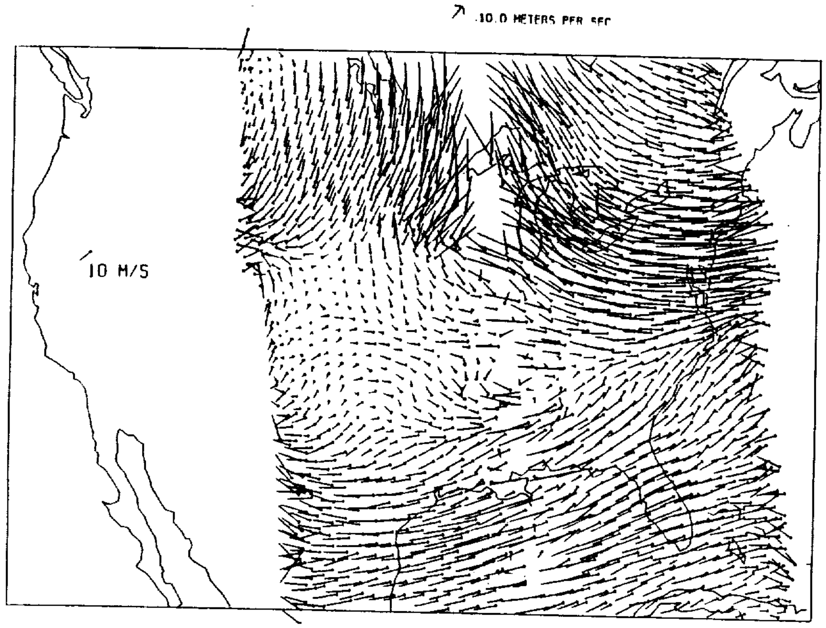

Figure 2.

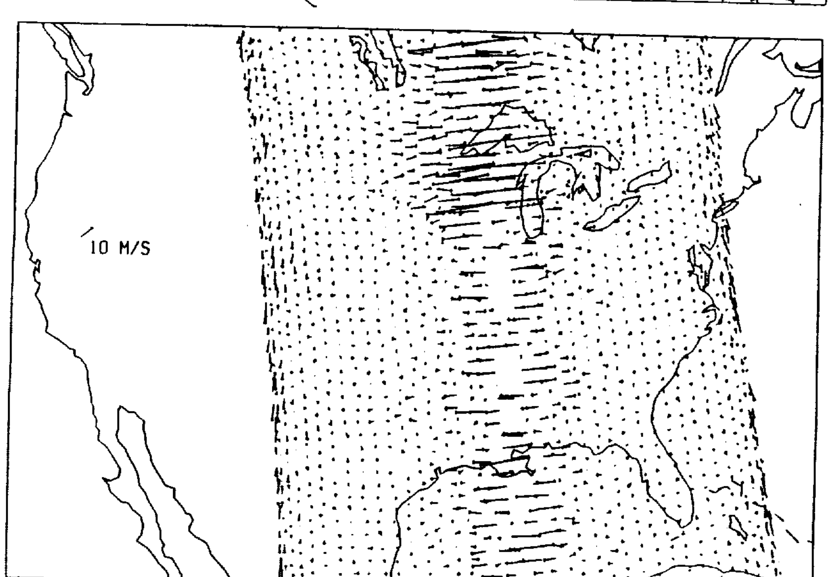

Figure 3.

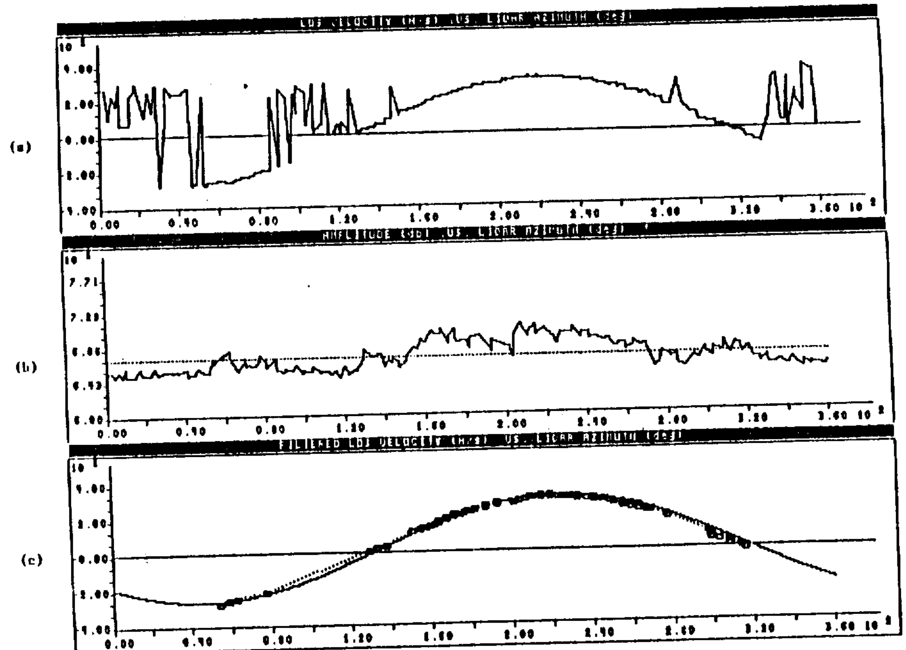

Fig. 4 An example (18 Nov, 13:10) of VAD editing and sine fitting to recover u, v and w components of the wind from a ground-based lidar. Panel (a) unedited VAD display of LOS velocity (m s^{-1}) vs azimuth in degrees; Panel (b) amplitude (db) in the 22nd range gate vs azimuth compared to the amplitude threshold at the 90th range gate; and Panel (c) edited and sine fitted VAD.

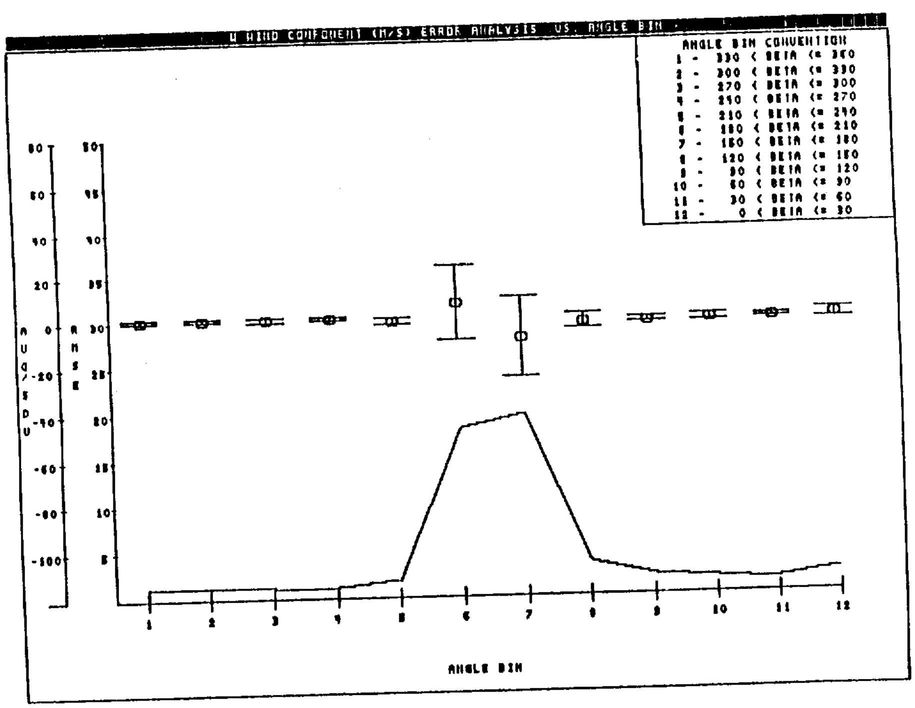

Fig. 5 U component errors across the track of a simulated spaced-based lidar scan.

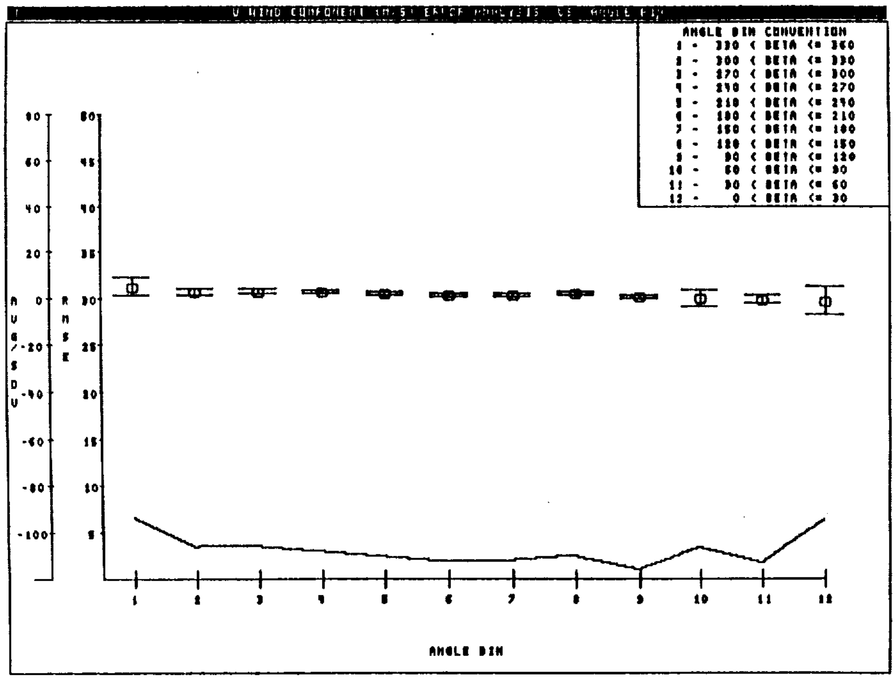

Fig. 6 V component errors along the track of a simulated spaced-based lidar scan.

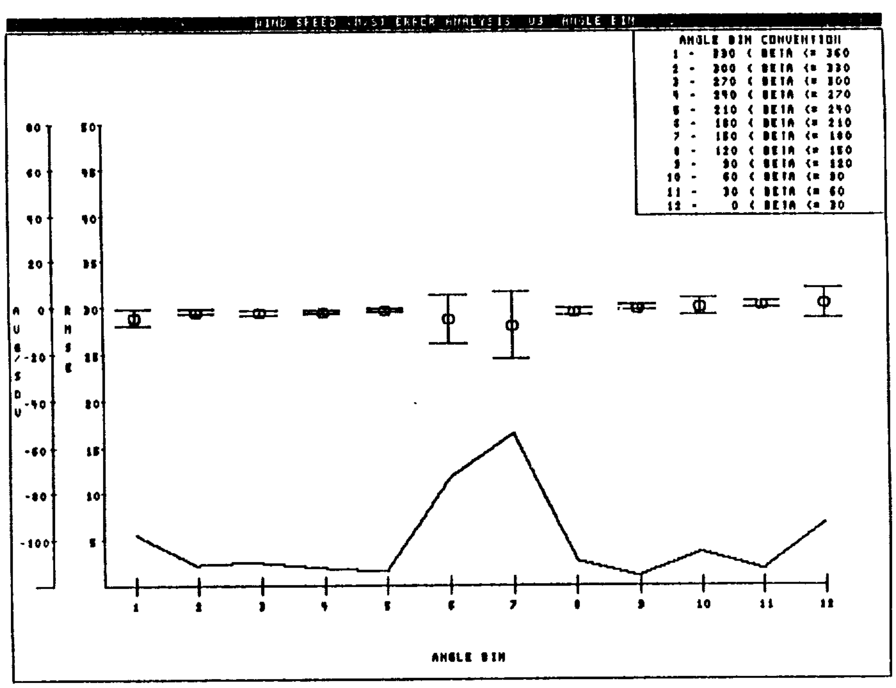

Fig. 7 Errors in total wind speed estimates from a simulated space-based lidar scan.