This, in turn, could be connected with the concentration of chlorides in the cloud droplets that contribute to each layer.

One could then assume that chlorides are supplied only by the updraft (and therefore neglect entrainmental effects). In the ascending air mass the chloride concentration would then be constantly decreasing due to the continuous condensation of water vapor onto the cloud droplets.

Under this assumption it would be possible to relate the chloride concentration of the hailstone shell to the height above cloud base of the region of growth and then to draw important inferences on the growth history of the hailstone.

To reach definite conclusions, however, one should supplement this study on hailstones with detailed observations, on the same hailstorm, of the vertical sea salt concentration profile in the air mass, of inflow of air, the height of cloud base, and radar evolution of the storm cells from which the hailstorm originated.

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Stationarity of Mesoscale Airflow in Mountainous Terrain

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Criteria for stationarity of turbulent atmospheric flow are examined for the mesoscale in a mountain valley in northeastern Utah. Data from four sequences of superpressure balloon flights are used.

The study shows that the horizontal components of the Lagrangian velocities at levels below the ridges of the surrounding mountains are only weakly stationary; the vertical component fits the criteria better. Above the ridge levels all components of the velocities exhibit reasonable stationarity in the turbulent flow.

1. Introduction

Calculations of atmospheric eddy diffusivities have been based on the assumption of stationarity of turbulent flow (Kao and al-Gain, 1968; Kao and Wendell, 1968; Ellis and Wooldridge, 1973). The efficacy of using the diffusivities computed from superpressure balloon data depends on the degree of stationarity and the reproducibility of the turbulent intensity over some time interval.

The conditions stated in turbulence literature for stationarity range from a constant mean wind velocity to a blanket requirement that the random processes not be a function of time (Lumley and Panofsky, 1964). The indicators mentioned by Tatarski (1961) are the mean value and the behavior of the autocorrelation function, if the time interval is constant.

An adequate determination of the properties of a given turbulent atmospheric flow for dispersion calculations requires more than the computation of a mean value and the construction of an autocorrelogram. The variance of the Lagrangian velocity is important since it represents the kinetic energy of the turbulent motion; the ratio of the standard deviation to the mean—the turbulent intensity—provides a physical specification of the dispersive nature of the atmospheric flow (Pasquill, 1962).

Several investigators have used data from constant volume (superpressure) Mylar balloons to measure atmospheric dispersion characteristics. Angell (1960) used them to describe semi-Lagrangian 300-mb flow;

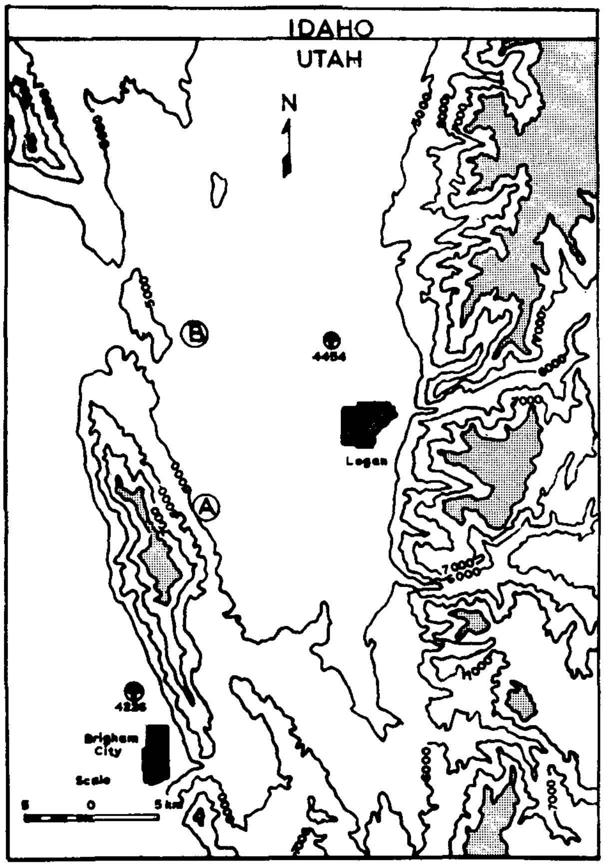

FIG. 1. Topography of the Cache Valley in northern Utah; terrain over 8000 ft is stippled. The Wellsville Mountains form the western rim, the Bear River Range of the Wasatch Mountains the eastern rim. Contours are in feet above mean sea level. Superpressure balloons were launched from site A on 15 September and 7 November 1972, and 27 April 1973. Balloons were launched from site B on 30 November 1972.

Kao and al-Gain (1968), Kao and Wendell (1968), Orgill *et al.* (1971), and Ellis and Wooldridge (1973) analyzed balloon data to compute diffusivities on the mesoscale. Wooldridge and Reiter (1970) used Southern Hemisphere GHOST data for hemispheric calculations. These balloons are sensitive to air motions and closely approximate turbulent flow patterns (Booker and Cooper, 1965; Hanna and Hoecker, 1971; Cherry, 1971).

2. Procedures

This note examines the following indicators of a limited data set for stationarity of mesoscale flow: the means, variances, turbulent intensities, and the autocorrelograms of the components of the Lagrangian velocities. The data were derived from superpressure balloons flown from sites in the Cache Valley of northeastern Utah (see Fig. 1); the balloons were towed to altitude with 100 g pilot balloons and fused for release. Double-theodolite tracking fixed the location of each balloon at 20 s intervals. The velocity components were taken relative to the approximate mean flight path of the balloons: transverse (u_L), longitudinal (v_L) and vertical (w_L).

3. Results

The data used here to examine the stationarity of atmospheric flow were obtained on four separate days: Table 1 displays the properties listed above for those days.

a. 15 September 1972 (*Site A, Fig. 1*)

The mean values and the variance of the horizontal components of the Lagrangian velocities varied over differences of approximately a factor of 2. Although the variance of the vertical component was sharply lowest during the second flight, a corresponding low mean value resulted in a nearly constant vertical turbulent intensity. The horizontal turbulent intensities fluctuated over a factor of 3 or 4. The autocorrelograms for the vertical component (Fig. 2) were

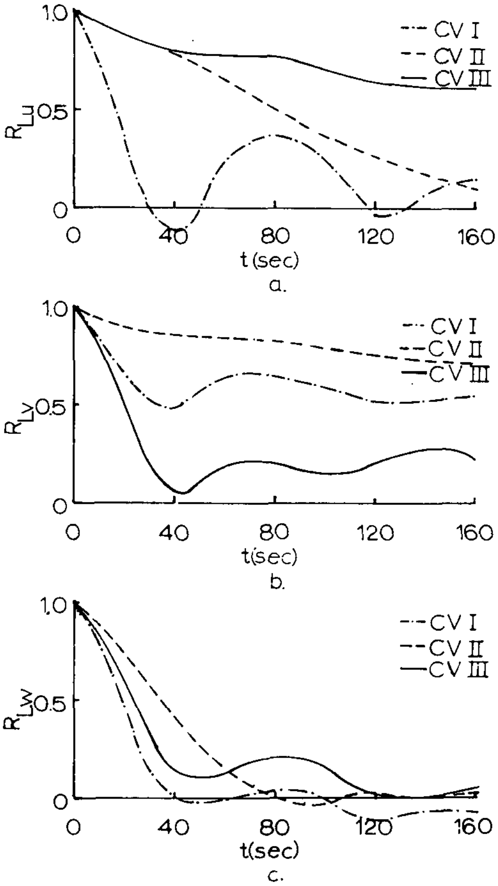

FIG. 2. Autocorrelograms of Lagrangian velocities for three superpressure balloon flights (CV I, CV II, CV III) on 15 September 1972: (a) lateral component; (b) longitudinal component; (c) vertical component.

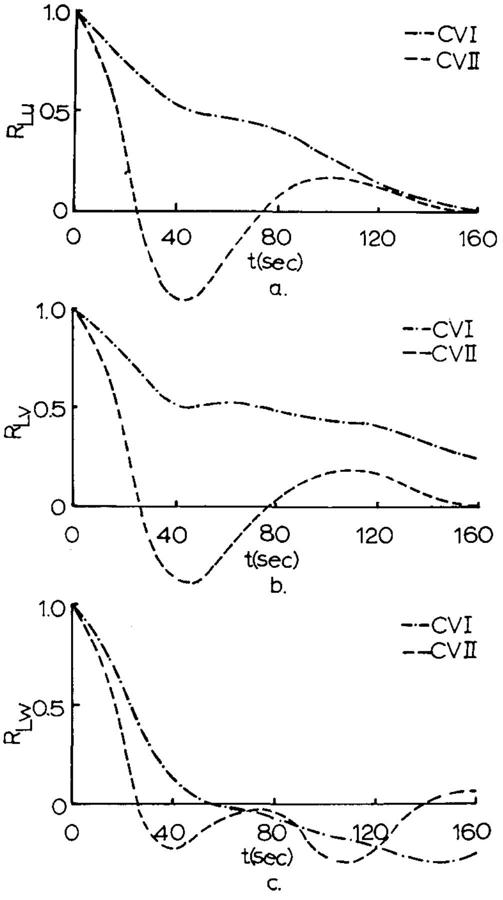

FIG. 3. As in Fig. 2 except for two flights (CV I and CV II) on 7 November 1972.

quite stable, while those for the horizontal showed large changes in configuration from one flight to another, with corresponding changes in the Lagrangian integral time constant.

b. 7 November 1972 (*Site A, Fig. 1*)

Two superpressure balloons launched in the lee of the mountains on the west side of the valley flew at an average altitude of 370 m above the valley floor. As in the 15 September flights, the autocorrelograms (Fig. 3) for the horizontal wind components differed markedly over a period of approximately 2 h, with longer time constants during the earlier flight. The corresponding correlograms for the vertical component exhibited only a slightly longer time constant for the first flight. Mean values for the horizontal components changed sign from the first flight to the second, with sharply increased variances. Turbulent intensities for all components increased with time by a factor of 2 or less.

c. 30 November 1972 (*Site B, Fig. 1*)

The mean wind values at an average height of 820 m above the valley floor for the first balloon flight on 30 November were so low that the turbulent intensity calculations (with mean wind speeds as denominators) became unstable; the values are in parentheses in Table 1. The variances of the relative Lagrangian velocity components decreased sharply over the $2\frac{1}{2}$ h study period with the largest variance and turbulent intensity in the vertical component. The autocorrelograms (Fig. 4) indicate a somewhat shorter time constant for the second flight in the horizontal components, and for the first flight in the vertical component.

d. 27 April 1973 (*Site A, Fig. 1*)

Superpressure balloons on this date attained an average flight level of 2090 m above the valley floor, or nearly 1 km above the mountain ridge to the west (upwind). The autocorrelograms (Fig. 5) and the

TABLE 1. Statistical moments and turbulent intensities (MKS units) for the Lagrangian velocities from four sequences of superpressure balloon flights in Cache Valley of northern Utah.*

Balloon (C–V)	Launch time (MST)	Mean value			Variance			Turbulent intensity		
		u_L	v_L	w_L	u_L	v_L	w_L	u_L	v_L	w_L
15 September 1972										
I	0935	−0.3	2.0	0.5	0.5	4.8	1.0	2.1	2.1	2.0
II	1032	−0.2	1.4	0.2	0.3	2.3	0.2	2.4	1.1	2.2
III	1140	−0.2	3.3	0.5	0.6	3.5	0.7	4.2	0.6	1.8
7 November 1972										
I	1005	−0.7	0.8	0.3	2.6	2.0	0.8	2.2	1.7	3.0
II	1128	1.4	−1.0	0.3	18.7	9.2	1.8	3.0	3.1	5.0
30 November 1972										
I	1015	0.07	−0.05	0.1	3.2	2.8	8.8	(24.4)	(36.8)	(33.3)
II	1153	0.6	0.4	0.3	0.9	0.7	3.1	1.6	2.0	6.8
27 April 1973										
I	0948	−0.5	6.7	0.5	11.4	125.6	6.3	7.0	1.7	4.6
II	1112	−1.5	8.6	−0.3	8.7	110.8	9.2	1.9	1.2	8.7

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* Values in parentheses are unstable due to extremely low mean values.

Lagrangian integral time constants changed only slightly from the first to the second flights. The variance of the longitudinal component exceeded variances for the transverse and vertical components by more than an order of magnitude on both flights. Turbulent intensities for the horizontal components decreased with time, while those for the vertical component increased.

4. Conclusions

The data from the four sets of superpressure balloon flights discussed above exhibited varying degrees of stationarity in terms of change with time of autocorrelograms, means, variances and turbulent intensities. The choice of coordinate system, with transverse component perpendicular to the mean flight path, rendered the mean values and turbulent intensities for that component unreliable as indicators of stationarity. When the atmospheric circulation described a horizontal vortex in the lee of a mountain, as in the November cases, the means and turbulent intensities for both horizontal components were questionable indicators.

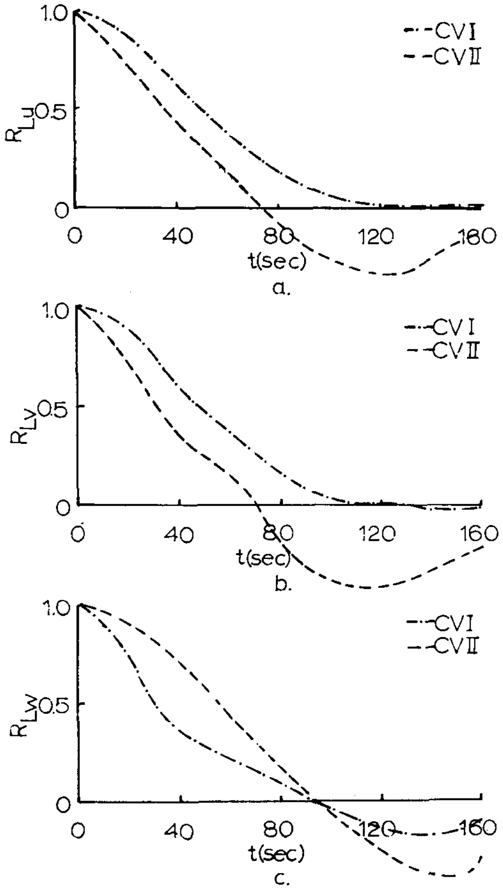

FIG. 4. As in Fig. 2 except for two flights (CV I and CV II) on 30 November 1972.

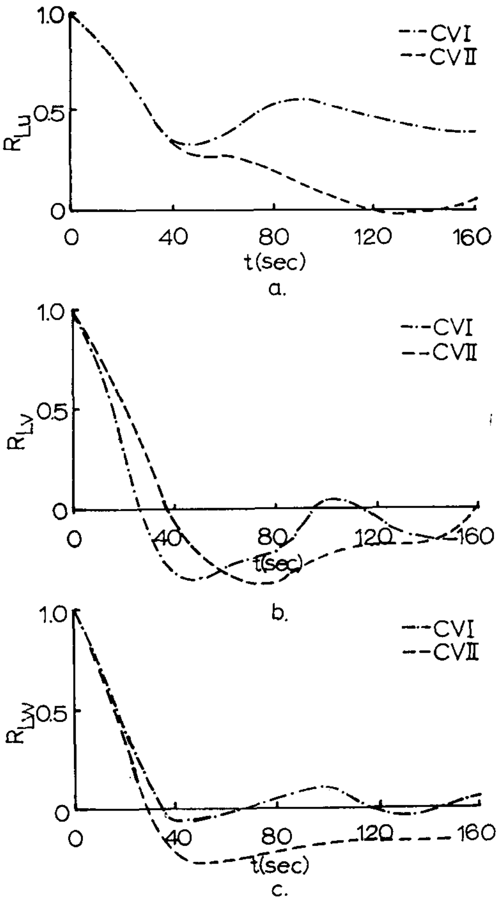

FIG. 5. As in Fig. 2 except for two flights (CV I and CV II) on 27 April 1973.

The first three balloon sequences were contained within the valley circulation regimes, with only weak stationarity suggested. The turbulent intensities varied only by factors of 2 or 3 in these sequences. The flight sequence on 27 April 1973, flown well above ridge levels, resulted in stable correlograms and variances.

Fluctuations with time in the horizontal components of the Lagrangian velocities exceeded those of the vertical component generally. This may result from the presence of horizontal meanders which occurred on a scale larger than the few kilometers of flight paths over which the data were taken or it may reflect the changing from nighttime circulation patterns to daytime patterns during late morning hours. The vertical velocity components for the four cases presented here showed the highest degree of stationarity, lending weight to the hypothesis of the presence of horizontal meanders. The vertical diffusion is responsible for most of the efflux of aerosols since Cache Valley is effectively bounded on all but the northern end by mountain ranges. Thus these limited data indicate that the vertical eddy flux diffusivities derived from superpressure balloon flights can be used to compute turbulent flux in a valley dispersion model.

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Experimental Results with a Rain Analyzer

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ABSTRACT

The rain analyzer is an instrument with which the main part of the raindrop size spectrum can be determined. During measurements of the rain attenuation of millimeter waves, rainfall was recorded both with rain analyzers and with standard rain gages. The observed millimeter-wave attenuation is somewhat more directly related to rainfall rates obtained with the analyzer than to those measured with rain gages. The average drop-size distribution measured during the experiment is similar to that of Laws and Parsons.

1. Introduction

For measurements of the attenuation of electromagnetic waves at $\lambda = 5.77$, 3.3 and 2 mm by rain an instrument was used that permits the recording of a substantial part of the raindrop size spectrum. This rain analyzer was first described by Lammers (1969). The drop diameters are analyzed by an electrostatic method: raindrops fall through a sampling area onto a first grid, connected to a dc voltage source. They assume an electrostatic charge, which is related to their size. This charge is transported to a second grid,

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