Progress in Circumventing Limitations of Upper Wind Records

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ABSTRACT

Climatological upper wind records have been found to be inadequate for certain statistical analyses such as the computation of interlevel correlation coefficients, time series analysis and persistence analysis. This article presents a comparison of upper wind data as observed and made available for climatological purposes with that of upper wind records that have been made serially complete. During the winter months at Kennedy Space Center the mean wind speed, as derived from the serially completed wind records, can be as much as 10 meters per second greater than the mean wind speed derived from the observed wind data.

1. Introduction

Widespread use of improved wind measuring equipment such as the AN/GMD-( ) rawin set is providing the potential for an ever improving upper wind record. This potential is being realized in direct proportion to the care with which instruments are maintained and observations recorded. However, even the practical operational potential for obtaining upper wind records, using balloon techniques, is not being reached, at least in terms of routine daily results from an extensive network of stations.

Meanwhile, problems calling for reliable collections of upper wind observations persist, not only for geophysical research but especially for missile/space vehicle engineering design and related purposes. The problems have necessitated continuing attention to the limitations of upper wind records (Charles, 1959). In particular, observations absent from the records for any one of a variety of reasons can significantly reduce the confidence in and utility of research or engineering study conclusions. Furthermore, this condition creates problems in the statistical interpretation of the data, and often complicates the computer programs used in handling incomplete records.

The first large United States climatological effort in which missing upper wind observations were systematically inferred was a project that resulted in a three-part publication (U. S. Navy, 1954). Here geostrophic scaling (with corrections for radius of curvature) of daily isopleth maps showing the height of constant pressure surfaces was the only technique employed. The next project of similar scope saw the scaling process supplemented by interpolations and extrapolations from appropriate tabulating-machine arrays of observational data. After computations and analysis for a specialized planning program (Federal Civil Defense Administration, 1957), these data were used in a cooperative project of the U. S. Weather Bureau and Sandia Corporation (Charles, 1958).

Several smaller projects followed in which time or fund limitations, or unavailability of suitable constant-pressure charts, precluded the use of map scaling as a primary tool. Therefore, it was necessary to try other techniques. Graphical time-section analysis (abscissa: time; ordinate: height) soon appeared to be particularly suited to reasonably prompt serial completion for a single station. This analysis tool was recently adopted to help meet requirements of the National Aeronautics and Space Administration.

Concurrently, equipment design and performance problems have focused attention on the quality of original winds aloft observations. Unfortunately, this quality is often of a somewhat lower order than that for radiosonde punched records, where primary limitations are of a different nature (Bean and Cahoon, 1961). Investigation of upper wind verification procedures by Essenwanger *et al.* (1961) has resulted in a design which has proved helpful in connection with a group of applied meteorological problems.

2. Records of serially complete data

At present a new punched card deck containing serially completed upper wind observations is being established at the National Weather Records Center. These data are tabulated for one-kilometer intervals from the surface through 27 km above mean sea level. Wind direction is given in whole degrees and wind speed in whole meters per second. Stations "qualifying" for inclusion in the punched card deck must have been using a ground meteorological director [AN/GMD-( )]

TABLE 1. Comparison of average observed and serially complete data for January and July, 1956–1961, at Kennedy Space Center for levels from 2–24 km. All speed are in m sec^{-1}.

Level (km)	January observed	January SC* data	July observed	July SC* data
2	11.2	11.4	5.1	4.4
4	17.7	18.1	5.2	4.9
6	24.4	26.0	5.7	5.5
8	31.1	35.2	6.7	5.7
10	38.1	43.8	9.1	6.9
12	43.9	54.2	12.2	9.0
14	40.6	51.1	12.2	9.7
16	31.2	37.5	8.1	7.1
18	19.1	24.1	9.6	8.8
20	10.1	12.4	13.9	14.1
22	8.4	10.6	17.7	17.4
24	8.7	10.4	20.1	19.0

* Serially complete.

or the Weather Bureau Radio Theodolite (WBRT) electronic tracking equipment steadily for a minimum period of five years. Included are only those hours of scheduled observations when the modern equipment was used routinely.

Serial completion is underway initially for two stations, Kennedy Space Center, Florida and Santa Monica, California. The records analysis and card punching are being performed by the U. S. Weather Bureau at the National Weather Records Center under funding being provided by the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration.

The new punched card deck includes a coded identifier showing data characteristics for each level of each observation. The code indicates that the accompanying punched data were observed, corrected observed (or transferred), interpolated, or extrapolated. Rules have been established to define explicitly an "interpolated" value to differentiate it from one that does not meet the criteria established and is thus "extrapolated."

Three 80-column punched cards are used to complete a sounding as described above.

3. Preliminary results

Analyses of the punched data are presently underway at the Marshall Space Flight Center. Detailed results will be published separately. Meanwhile, a few preliminary comparisons of selected observed and serially completed data may be of interest.

Data selected for initial comparisons are from Kennedy Space Center for January and July for the years 1956 to 1961, inclusive, and for levels at 2-km intervals from 2 to 24 km. Table 1 is based on this entire record and simply lists average wind speed for the original observations and for the serially complete data.

Further analysis under a conventional statistical approach must recognize two characteristics of this sample. First, wind speed, with its zero lower bound, is not distributed according to the Gaussian normal distribution. Secondly, persistence or autocorrelation is present.

Concerning distribution, it is known that we may assume more safely that the zonal and meridional components of wind are normally distributed. Table 2 shows average wind speed by month and by component where positive values refer to winds from the west and south for zonal and meridional components, respectively.

Table 2 differences may be summarized as follows:

1. Zonal component

a. January. The serially complete data yield mean values which are greater than the observed at all levels, by amounts that increase with height to the 12- and 14-km levels, then decrease above. Maximum differences of westerlies are on the order of 10 m sec^{-1} around the level of maximum wind.

b. July. Differences near zero, except observed easterlies are 3 to 4 m sec^{-1} greater at 12 and 14 km.

2. Meridional component

a. January. Differences generally less than 3 m sec^{-1} at all levels.

TABLE 2. Comparison of zonal and meridional components of average observed and serially complete data for January and July, 1956–1961, at Kennedy Space Center for levels from 2–24 km. All speeds are in m sec^{-1}.

Level (km)	Zonal component January Observed	Zonal component January SC* data	Zonal component July Observed	Zonal component July SC* data	Meridional component January Observed	Meridional component January SC* data	Meridional component July Observed	Meridional component July SC* data
2	7.7	8.8	0.9	−0.1	−0.3	1.0	2.1	2.1
4	15.4	16.6	0.8	0.6	0.5	1.2	1.7	2.5
6	22.1	24.7	−0.1	0.9	1.0	2.8	0.9	2.9
8	28.9	33.4	−1.5	0.0	1.8	3.2	−0.1	2.9
10	35.7	41.6	−2.6	−0.8	2.8	4.3	−1.4	1.9
12	43.9	54.2	−4.5	−0.2	2.9	4.6	−3.5	0.5
14	40.6	51.1	−5.5	−2.5	1.9	5.2	−5.4	−1.3
16	31.2	37.5	−6.0	−5.1	1.4	4.3	−2.9	−1.2
18	19.1	24.1	−8.9	−8.5	0.7	2.1	−1.2	−0.7
20	10.1	12.4	−13.6	−13.9	0.1	0.1	−0.8	−0.8
22	8.4	10.6	−17.3	−17.1	0.6	0.4	−0.3	−0.4
24	8.7	10.4	−19.9	−18.8	1.1	1.2	−0.2	−1.1

* Serially complete.

TABLE 3. Values of "t" based on randomly-selected dates.

Level (km)	Zonal component January	Zonal component July	Meridional component January	Meridional component July	$t_{2(1-P)}=10$ per cent
10	−2.83		−0.78		±2.35
12	−2.07		−0.21		±2.35
14	−2.11		−0.59		±2.35
16	−2.23		−1.69		±2.13
18	−1.99		−0.25		±2.13
20	−1.24	0.65	1.05	0.89	±2.13
22	−0.03	0.53	−0.07	0.96	±2.13
24	1.42	−2.09	0.93	−0.11	±2.13

b. July. Serially complete data produce greater mean values than observed data at levels from 4 to 18 km, otherwise differences near zero. Maximum differences are on the order of 4 m sec^{-1} around the level of maximum wind.

4. Interpretation of differences

More specific interpretation of differences can proceed readily where operational or design requirements can be expressed quantitatively. Otherwise, we may wish to apply an established and pertinent method of statistical inference. Here, with population variance estimated, we select and apply the "t" test to wind component results for the months of January and July comprising the six-year record.

The "t" test requires independent observations and elimination of the autocorrelation present in the data set being examined. We assume that one January is independent of the next January for the present preliminary assessment. Randomly selected observations are used with each January and July of each year representing a single observation or element in a new sample. Inevitably, we now have a rather small sample, but presumably these interim results are of some interest.

Table 3 shows computed "t" values for those levels with at least four years of records when data initially were serially incomplete. Following Barger (1960), a suggested threshold "two-tail" tabular value of "t" corresponding to available degrees of freedom is also included for reference (Hald, 1962). Significant or near-significant differences are evident for wind speed and zonal wind near the level of maximum wind in winter.

A valid comparison of the wind statistics presented in this article cannot be made with those computed earlier by Smith and Vaughan (1961), because the periods of records are different. We have presented in Tables 1 and 2 mean values, whereas Smith and Vaughan presented median values.

5. Summary

Serially complete data permit the computation of interlevel correlations, time series analyses and persistence analyses. Extensive use of winds aloft observations for these types of studies is comparatively recent. However, the fact that strong winds aloft quickly carry balloons beyond the range of ground tracking equipment, thus presumably biasing available high altitude wind data, has long been a matter for concern. Recent data reaffirm that such concern is appropriate in the winter season when strong westerly winds aloft occur. However, preliminary results for a season of more moderate and varying winds aloft raise interesting questions worthy of further study. At first glance it would certainly appear that the use of modern electronic tracking equipment has indeed curtailed pronounced bias in lower stratosphere wind records, at least for seasons or regions of moderate winds aloft.

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