TECH LIBRARY KAFB, NM

0060990

NASA CONTRACTOR REPORT

NASA CR-1

c. 1

NASA CR-1945

SOME ANALYSES OF THE VARIABILITY OF ATMOSPHERIC PARAMETERS AT LOW ALTITUDES SIGNIFICANT FOR AIRCRAFT NOISE PROPAGATION

by David T. Chang

Prepared by
ALLIED RESEARCH ASSOCIATES, INC.
Concord, Mass. 01742
for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JANUARY 1972

ERRATA

NASA Contractor Report CR-1945

SOME ANALYSES OF THE VARIABILITY OF ATMOSPHERIC PARAMETERS AT LOW ALTITUDES SIGNIFICANT FOR AIRCRAFT PROPAGATION

By David T. Chang
January 1972

The word "Noise" was inadvertently omitted from the title of this contractor report. The title should be "Some Analyses of the Variability of Atmospheric Parameters at Low Altitudes Significant for Aircraft Noise Propagation." The correction should be made on the cover, the standardized machine-compatible title page, and page 1.

Issued October 1972

Errata inserted
7-Nov 72 JM

1. Report No. NASA CR-1945	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SOME ANALYSES OF THE VARIABILITY OF ATMOSPHERIC PARAMETERS AT LOW ALTITUDES SIGNIFICANT FOR AIRCRAFT NOISE PROPAGATION		5. Report Date January 1972
		6. Performing Organization Code
7. Author(s) David T. Chang		8. Performing Organization Report No. 9G77-F
		10. Work Unit No.
9. Performing Organization Name and Address Allied Research Associates, Inc. Virginia Road Concord, MA 01742		11. Contract or Grant No. NAS1-9837
		13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Analyses of the variabilities of temperature, relative humidity, wind speed and direction in the lowest few thousand feet of the atmosphere are presented. The results of these analyses are discussed in terms of the meteorological data acquisition procedures necessary to monitor these changes in atmospheric parameters to support aircraft flyover noise measurements and aircraft noise certification programs.

The data used in this study were taken at Wallops Station, Virginia, and consisted primarily of sequential radiosonde ascents to approximately 5000 ft spaced some half-hour to an hour apart. The weather covered by the data sample was predominantly that of clear skies and calm-to-light surface winds associated with well established high-pressure systems. Under these restrictive weather conditions, the study shows that the largest variabilities in temperature and humidity occur during the early morning hours resulting from the effects of direct solar heating of the surface. These rapid changes apparently do not penetrate above approximately 1000 ft. In the late morning hours, the atmosphere appears to become stabilized so that net changes in temperatures and relative humidities at all levels are insignificant even in time periods exceeding three hours. By noon, however, turbulent fluctuations in surface wind and the wind speed itself increase to levels which would make the microphone recording of acoustic signals in the field difficult.

Based on the results of the data analyses, procedures for the acquisition of meteorological data to support aircraft flyover noise measurements are suggested. The development of new measurement techniques, such as by remote means, for monitoring changes in temperature and relative humidity at higher levels (approximately 1000 ft) is recommended.

17. Key Words (Suggested by Author(s)) Aircraft Noise Meteorological effects on sound propagation		18. Distribution Statement Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 72	22. Price* $3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

TABLE OF CONTENTS, contd.

LIST OF FIGURES

LIST OF FIGURES, contd.

LIST OF TABLES

SOME ANALYSES OF THE VARIABILITY OF ATMOSPHERIC PARAMETERS AT LOW ALTITUDES SIGNIFICANT FOR AIRCRAFT NOISE PROPAGATION

By David T. Chang
Allied Research Associates, Inc.

1. INTRODUCTION

1.1 Background and Objectives

The dependence of noise attenuation, including that of aircraft noise, on atmospheric parameters is well known from laboratory measurements (e.g., Harris, Ref. 1). Apart from losses due to geometric spreading, noise attenuation derives from at least two types of gaseous absorption: classical, resulting from energy dissipation through heat conduction; and molecular, resulting from the relaxative process of oxygen molecules. Both of these are dependent on the temperature of the gas through which the noise propagates. In the case of molecular absorption, there is also a dependence on humidity. Controlled laboratory measurements have also established quantitative relationships between the attenuation and these two atmospheric parameters of temperature and humidity. Qualitatively, these relationships have to some extent been verified in field measurements by Burkhardt et al (Ref. 2) and others.

The theoretical and experimental results alluded to above show the necessity of having adequate meteorological data in support of any measurement program of aircraft flyover noise. While such data support has been provided in some past programs, the resulting temporal and spatial coverage of the meteorological data have often not been adequate. This inadequacy of the supporting data, and the ambiguity it introduces in the interpretation of the noise measurements, have been discussed by Sherr and Chang (Ref. 3) and Bishop et al (Ref. 4). In these studies, it was suggested that problems in providing adequate meteorological support for aircraft noise measurements result from a lack of systematic knowledge of the statistical variabilities of atmospheric parameters on a time and space scale commensurate with aircraft flyover noise measurements. The primary objectives of this study, therefore, are: (1) to define the magnitude of the expected variabilities in atmospheric parameters from analysis of actual meteorological measurements; and (2) to recommend proper procedures and measurements to provide adequate meteorological data support to aircraft noise measurements.

1.2 The Approach

With respect to the specific problem of aircraft flyover noise measurements, we are concerned with the three-dimensional structure of the atmosphere in a volume bounded below by the surface of the earth and above by the flight altitude of the aircraft ~ 2000 ft. The lateral extent of this volume may be on the order of a few miles. Within this volume horizontal stratification and temporal stationarity of meteorological parameters cannot, in general, be assumed in view of the fact that the lower boundary is contiguous with ground surfaces having different thermal properties. In order to define objectively the expected variabilities in this layer, a large body of meteorological data is required. The first task of this study was to assemble and to acquire the necessary data.

Traditionally, the atmospheric layer in question has not been of particular interest to the majority of meteorologists. The synoptic meteorologist is interested in atmospheric changes occurring on a time scale of hours and a spatial scale of hundreds of miles. The micrometeorologist, on the other hand, is interested in fine-scale atmospheric features near the surface of the earth. Their tower measurements seldom extend to the heights of interest to aircraft noise measurements. There are, therefore, very few sets of data useful for this study. In fact, the only consistent sets of useful data are the limited number of special radiosonde ascents made in support of past aircraft flyover noise measurements. These were made with special radiosondes modified to provide high vertical resolution measurements of the lowest 5000 ft of the atmosphere at relatively high repetition rates. They have the additional virtue of having been made at airport locations.

While useful, these special data sets are limited in number and cover a limited number of synoptic situations. In order to increase the data sample, a special data acquisition program was proposed to be undertaken by the Weather Bureau* Support Facility at Wallops Station under NASA/Langley direction. However, the proposed program was never fully implemented due to a number of problems. As a result, a majority of the data used in this study were the ones previously obtained in support of actual experimental noise measurements. Since the dominant synoptic situation covered by these data was that of clear, well-settled weather associated with high-pressure systems, it was not possible to stratify the data sample by synoptic types. However, the analysis of the data shows that under the clear sky conditions common to most of the data sets, the variabilities of the atmosphere are highly dependent on the time of day.

*Now known as the National Weather Service.

The following sections of the report present first a short discussion of the choice of Wallops Station as the measurement site and some of the problems encountered in obtaining the data. Also discussed are some of the limitations of the data sample. In Section 4, the results of the analysis of the temporal and spatial variabilities of temperature, humidity, and winds are discussed. The results of these analyses are discussed in Section 5 and culminate in recommendations for the design of meteorological data acquisition programs for aircraft noise measurements.

2. DATA ACQUISITION PROGRAM

2.1 Measurement Site

All of the data used in this study were obtained at Wallops Station by personnel of the Weather Bureau Support Facility. The choice of Wallops Station as the measurement site was dictated by a number of factors. The station is well equipped with facilities and experienced personnel to make the specialized radiosonde launches required for this study. In fact, the Weather Bureau Support Facility had, in the past, been called upon to provide similar meteorological data support for aircraft noise measurement programs conducted at the Wallops Station Airfield. From these programs a body of special radiosonde data, suitable for this study, already exists for Wallops Station. The availability of these data made it possible to reduce the reliance of the study on the acquisition of new data. More than half of the data sample analyzed and used in this study was in fact taken from the data files of past programs conducted at Wallops.

Since the purpose of the measurement phase of the program was to obtain meteorological data representative of major airport locations where aircraft noise certification and testing would take place, the choice of Wallops is perhaps appropriate. Its coastal location and low terrain are representative of the geography of a number of major coastal airports. At these airports, the meteorology of the lowest few thousand feet of the atmosphere is often dominated by the temperature and moisture differences between the air over the land and the air over the adjacent waters. The data from Wallops should provide some insight into the effect of this contrast on the spatial and temporal changes in meteorological parameters at coastal airport locations.

The general locale of the Wallops Station area is shown in Figure 2-1. The station airport facilities and runways are located inland on the Delmarva Peninsula. It was at these facilities that past aircraft noise measurement programs were conducted. In these tests, meteorological data support was provided by a transportable radiosonde receiver unit located near the airfield. With this unit, balloon tracking was achieved by means of manually operated double theodolites located at the ends of a measured baseline. The Station's regular radiosonde facilities are permanently located on Wallops Island, some five miles from the airfield. Here the sondes are automatically tracked. It is also from these facilities that Wallops Station releases the regularly scheduled radiosonde ascents at 0000 GMT and 1200 GMT. With the transportable unit operating near the runways and the automatic receiver operating on the Island, it would be possible to obtain upper-air data to investigate the variability of atmospheric parameters on a horizontal scale commensurate with the aircraft flyover noise problem.

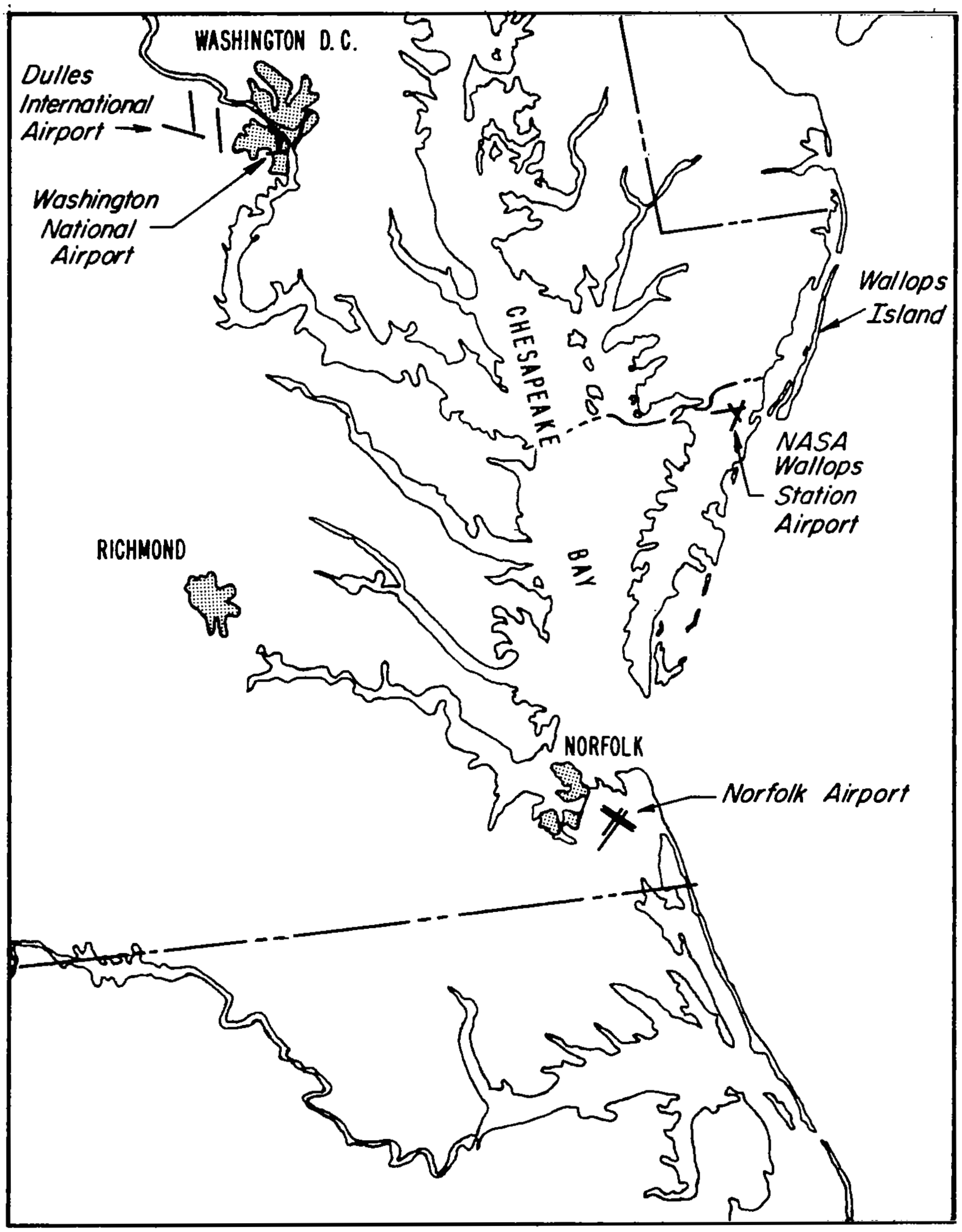


Figure 2-1 Map showing Location of Wallops Station and Adjacent Areas

An additional advantage for selecting Wallops Station is the proximity of a number of other weather stations. In the map shown in Figure 2-1, it is easily seen that the regular weather observations made at Washington, D. C., and Norfolk, Virginia, can be used to help define the synoptic situation over Wallops.

2.2 Data Acquisition Plan

From the outset of the study, it was the plan to make use of whatever data were already available from previous aircraft noise measurement programs and to increase and improve the data sample with additional measurements. A task performed during the early stages of this study was the preparation of an experimental data acquisition plan. This plan was based on a preliminary analysis of the radiosonde data already at hand, and on discussions with NASA/Langley personnel and staff members of the Weather Bureau Support Facility at Wallops Station.

The initial data provided by NASA/Langley consist of a number of sequences of meteorological data obtained in 1969 at Wallops Station in support of the "Quiet Helicopter" and other aircraft programs. Preliminary examination of these data revealed a number of deficiencies. The most serious, perhaps, is the bias of the data sample towards the early morning hours just prior and subsequent to sunrise. The reason for this preferred time period is the generally light-to-calm winds expected - a highly desirable feature in aircraft noise measurements. The synoptic situations covered by the data sample are also rather limited; restricted generally to high-pressure systems. The temporal spacing of the data was often not ideal. In a few instances, radiosonde ascents were made at time intervals equal to or exceeding an hour. Since each individual ascent measured either temperature or relative humidity, the result is that consecutive temperature or humidity profiles were available at intervals exceeding two hours. At this temporal resolution, the rapid changes in meteorological parameters in the surface layer, especially at sunrise, were often not resolved. In addition, no measurements were made to define the horizontal variability of the meteorological parameters. Some of the difficulties encountered in the analysis of these data were discussed in a paper by Sherr and Chang (1970).

The results of this initial analysis provided the basis for the Data Acquisition Plan submitted during the early months of this study. The essence of the plan is contained in the following recommendations.

1) Conduct a regularly scheduled program of special radiosonde ascents at Wallops Station, at a location near the runway, using the transportable radiosonde equipment available to the Weather Bureau Support Facility. These ascents should be made on a regularly scheduled basis to provide a data sample of most of the synoptic situations encountered at a location such as Wallops. The recommendation is that the schedule, once initiated, should be maintained except when conditions

such as high surface winds, precipitation or extreme low cloudiness make operations difficult or extremely unrealistic as far as aircraft noise measurements are concerned.

2) The radiosonde units should be modified to terminate data transmission after $\sim$5000 ft of ascent. This modification would make it possible to obtain sequential ascents spaced some 30 minutes apart without transmission interference between sequentially launched radiosondes. It was also recommended that special radiosondes be used such that both temperature and humidity can be sampled simultaneously at a rate of every 15 seconds of vertical ascents ($\sim$250 ft).

3) Each sequence of measurements should consist of six or more radiosonde ascents to extend into the period well beyond local sunrise.

4) Spatial variability of meteorological parameters should be sampled during each sequence, or as often as possible, by simultaneous launches of radiosondes at the airfield and on the Island making use of the permanent radiosonde facilities located on the Island. Since the facilities on the Island operate at a different transmission frequency than the portable unit, no radio interference problems between the simultaneously launched radiosondes were expected.

It was hoped that the proposed data acquisition plan could be adhered to through a period of nine to twelve months so that the data sample would contain sufficient cases of the different synoptic situations for statistical analysis.

2.3 Program Implementation

The actual data acquisition program implemented at Wallops Station fell short of the desirable goals due to a number of problems involving personnel shortage and conflicting requirements by other programs. As indicated previously, balloon tracking for the transportable radiosonde unit is achieved by manually operated theodolites. This type of tracking, while providing high resolution height data at low balloon heights, requires the participation of a relatively large crew. As a consequence, the strict adherence to the proposed measurement plan would have required the commitment of a considerable amount of regularly scheduled manhours by the personnel of the Weather Bureau Support Facility. Subsequent events proved that the conflicting requirements for meteorological support by other programs at Wallops Station, especially sounding rocket launches, made the maintaining of any schedule in data acquisition impossible. These difficulties were further aggravated by the range requirement that during the countdown and hold phases prior to launch of a sounding rocket, the special radiosondes could not be launched, even if the crew were available, due to possible radio interference with the telemetry from the rocket.

These difficulties resulted in a much smaller data sample than originally anticipated. Furthermore, the data that were obtained were not ideally distributed through the months of the year, or even the seasons. Any conclusions drawn based on the results of this study should, therefore, be prefaced by the limitations of the data sample.

3. DATA SAMPLE

3.1 General

Basically, three types of data were analyzed in this study. The most important are the upper air data obtained by special radiosonde ascents made at Wallops Station. The characteristics of these data are discussed in detail in a subsequent section. These were supplemented by data of surface temperature, relative humidity, wind speed and direction, measured and recorded by standard U. S. Weather Bureau hygrothermographs and anemometers at locations in the vicinity of the runways. The continuous nature of these data provides accurate timing for the occurrence and passage of such meteorological events as fronts, sea breezes and the onset of significant surface heating. In addition to these onsite data, conventional synoptic observations made at the regularly scheduled observation times at Wallops and nearby stations were also used.

The conventional synoptic data included the regularly scheduled twice-daily radiosonde launches at 1200 GMT and 0000 GMT from Wallops Island; the reports of surface observations of cloud cover and weather conditions over Wallops, and the surface and 850 mb weather maps for the days for which the special radiosonde launches were made. The regularly scheduled radiosonde launches from the Island were found to be particularly useful in supplementing the meager spatial data obtained as part of the special radiosonde data acquisition programs. The other data, consisting of surface observations and weather maps, were used primarily in identifying the synoptic and cloud-cover situation corresponding to each sequence of the special radiosonde measurements.

3.2 Size and Distribution of the Data Sample

A total of 206 special radiosondes were examined in this study. These included the 108 obtained in 1969 at Wallops Station in support of the Quiet Helicopter and other programs. The remaining 98 were obtained in 1970 and 1971 subsequent to the initiation of this study. Not all of the data sets examined were found useful. In particular, a small number of the soundings made in 1969 contained tracking problems or "garbled" data. In at least one case, the computer printout of tracking data and, therefore, the height information, corresponding to one of the runs was missing altogether. After eliminating these cases the data sample was reduced to 182 valid soundings, 98 of which are temperature soundings with the remaining 84 being humidity soundings.

In the previous section, it was noted that the 1969 data were biased towards certain months of the year. Even with the set of data acquired subsequent to the initiation of this study, the data sample remains unequally distributed between the months of the year and between the seasons. This is evident in the summary (Table 1) which shows the number of profiles vs months of the year. A more detailed listing of the data sample is given in the Appendix. No soundings were made for the months of February, September and December. As far as the seasonal distribution of the data is concerned, the sample is biased towards the winter and spring.

Equally significant in defining the synoptic climatology of coastal airport locations is the distribution of the data sets among the hours of the day. As previously indicated, sequences of the 1969 radiosonde ascents were, for the most part, initiated prior to or near sunrise, generally at or prior to 1100 GMT (or 0600 EST), terminating three or four hours later at 1400 or 1500 GMT. However, in at least four cases, soundings were made well into the late afternoon and early evening, providing opportunities to examine atmospheric variabilities during these hours. The data acquired in 1970 and 1971, subsequent to the initiation of this study, were designed to provide some information of atmospheric variabilities between the early morning and late afternoon. It is unfortunate, however, that with the data sample, analysis of the time-of-day influence on atmospheric variability cannot be made independent from seasonal effects. This limitation arises from the fact that the total sample of all data made in the late morning-to-noon period contains also the total summer sample. On the other hand, all of the spring measurements covered only the sunrise transition period and, despite every effort to obtain data covering a variety of synoptic situations, the data sample is still heavily biased towards the synoptic situation represented by settled weather resulting from a well-developed high-pressure system over the mid and south Atlantic states. Associated with this type of weather pattern are clear skies and calm winds conducive to surface radiative cooling effects at night and rapid heating and drying shortly after sunrise.

3.3 Data Reduction

The radiosonde data received from Wallops Station, through NASA/Langley, consist of the recorder output traces of the signal received from the radiosonde transmitters, with the temperature and/or humidity values hand-entered at 15-second intervals. The radiosonde balloon tracking data are separately provided as computer printouts of balloon heights, total wind speed, the north-south, east-west components of wind speed, and wind direction at 15-second intervals computed from the double theodolite data of azimuth and elevation angles. The profiles of temperature, relative humidity, wind speed and wind direction were simply plotted using a linear height scale. Examples of these profiles are found throughout this report.

In reducing these data, two types of problem were encountered. The first is that resulting from radiosonde transmitter malfunction so that the data received

TABLE 1

SUMMARY OF DISTRIBUTION OF DATA SAMPLE

Season	Month	Year	No. of Daily Sequences	No. of Soundings Temperature	No. of Soundings Relative Humidity
	January	1971	2	11	8
	February	1971	0	0	0
	March	1969	8	20	16
	April	1969	3	16	14
	May	1970	1	4	3
	June	1970	3	12	12
	July	1970	1	6	6
	August	1969	3	15	13
	September	1969	0	0	0
	October	1969	2	5	6
	November	1969	2	9	6
	December	1969	0	0	0
Winter				31	24
Spring				32	29
Summer				21	19
Fall				14	12

were judged to be "garbled" and were generally noted on the recorded data by members of the radiosonde launch crew as such. The total number of such unusable data sets was 26, constituting, in fact, the entire sample of data noted in the Appendix as "N. G."

The second type of problem resulted from tracking or balloon ascent rate. Nominally, the balloons are inflated such that they rise a a more or less constant rate of 1000 ft/min. at least through the first four or five minutes after release.

However, departures from this nominal ascent rate were found, and in some instances, these departures introduced ambiguities into the data. Figure 3-1 for example, shows the height locations at 15-second intervals of balloons launched at 1620 GMT and 1705 GMT, 9 June 1970. The balloon launched at 1620 GMT followed the nominal rate of ascent of 1000 ft/min. for the first three minutes and 45 seconds, after which its ascent rate, as indicated by its positions at 15-second intervals, became quite irregular. The rise of the balloon released at 1705 GMT was much slower, only some 500 ft/min. and decreased to less than 250 ft/min. six minutes after release. This suggests that a slow leak had developed in the balloon.

The features most disturbing in the plots of balloon rise (Figure 3-1) are the apparent up-down motion of the 1620 GMT balloon between 4 minutes, 30 seconds and 5 minutes, 30 seconds, and of the 1705 GMT balloon 3 minutes, 45 seconds and 4 minutes, 45 seconds. While it is possible that the type of balloon motions indicated result from actual atmospheric motion, it is highly unlikely that such violent downdrafts occurred on the day in question with no significant weather event anywhere in the mid-Atlantic states. The wind speed and direction deduced from the same tracking data suggest that the apparent up-down motion of the balloons resulted from errors in the theodolite azimuth and elevation angles used as input in the computations of balloon altitude, wind speed, and direction. At precisely the same time intervals after launch that the data shown in Figure 3-1 suggest the up-down motions of the balloons, the wind data exhibit unrealistic directional and speed shear. This may be seen in the wind profiles shown in Figures 3-2 and 3-3. In plotting the data, the height data previously shown in Figure 3-1 were reinterpreted such that a monotonic and smooth rise of the balloons were assumed. The wind data at the specified 15-second intervals were, however, plotted as computed and presented in the printouts. The unrealistic shears in speed and direction at the disputed heights are evident.

Data ambiguity resulting from apparent errors in the theodolite tracking data, such as those shown in Figure 3-1, were found to occur in many of the ascents made in 1970 subsequent to the initiation of the study, and apparently resulted from the establishment of a new baseline for the theodolites. Since the ascents with this type of tracking data ambiguity constitute a substantial portion of the data, it was necessary to deduce the "true" height data by simple linear interpolation. Figure 3-4 shows, for example, the temperature profiles for 9 June 1970 using the interpolated heights. The data appear to be reasonable, with the double value temperature at the disputed heights appropriately eliminated.

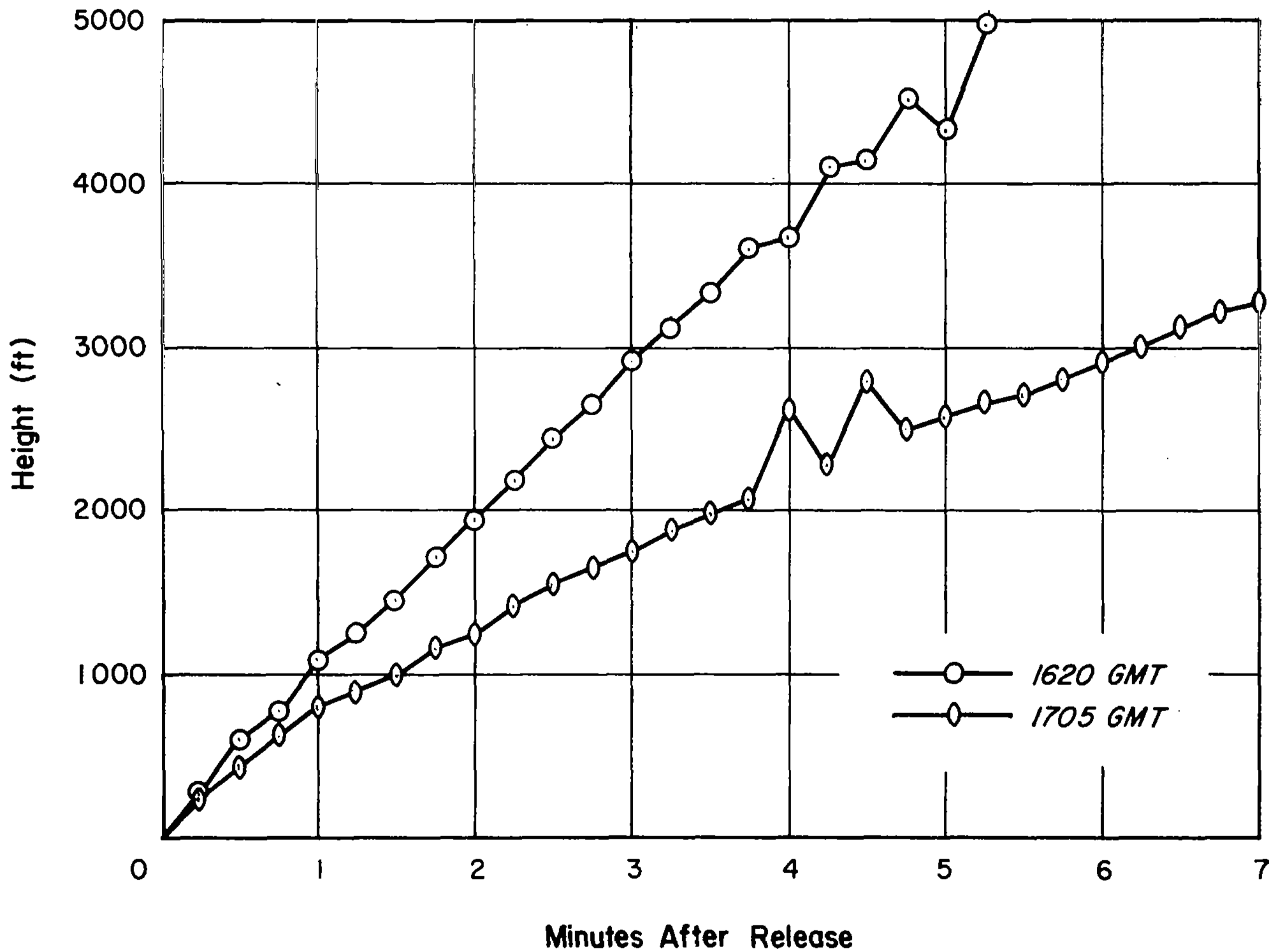


Figure 3-1 Height vs. Time Plots of Two Balloons Sequentially Launched an Hour Apart on 9 June 1970

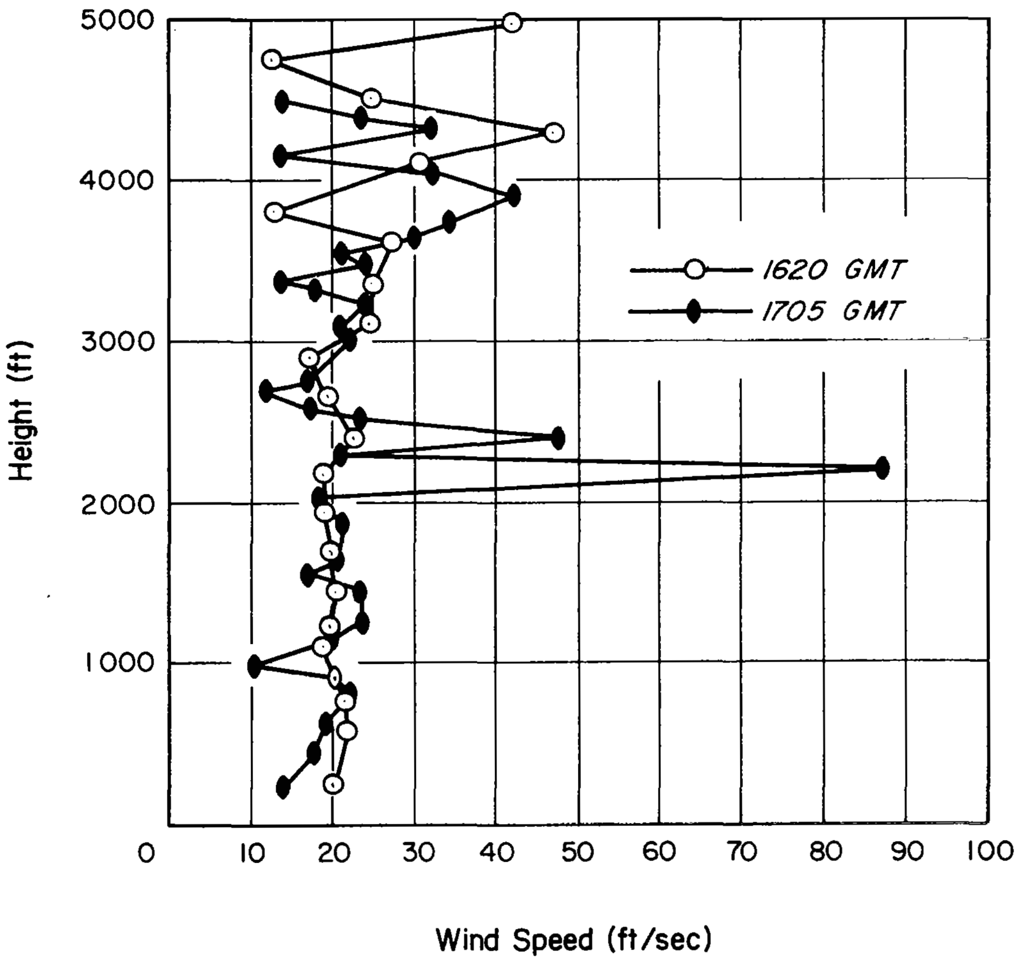


Figure 3-2 Wind Speed Profiles Deduced from Radiosonde Ascents Made on 9 June 1970

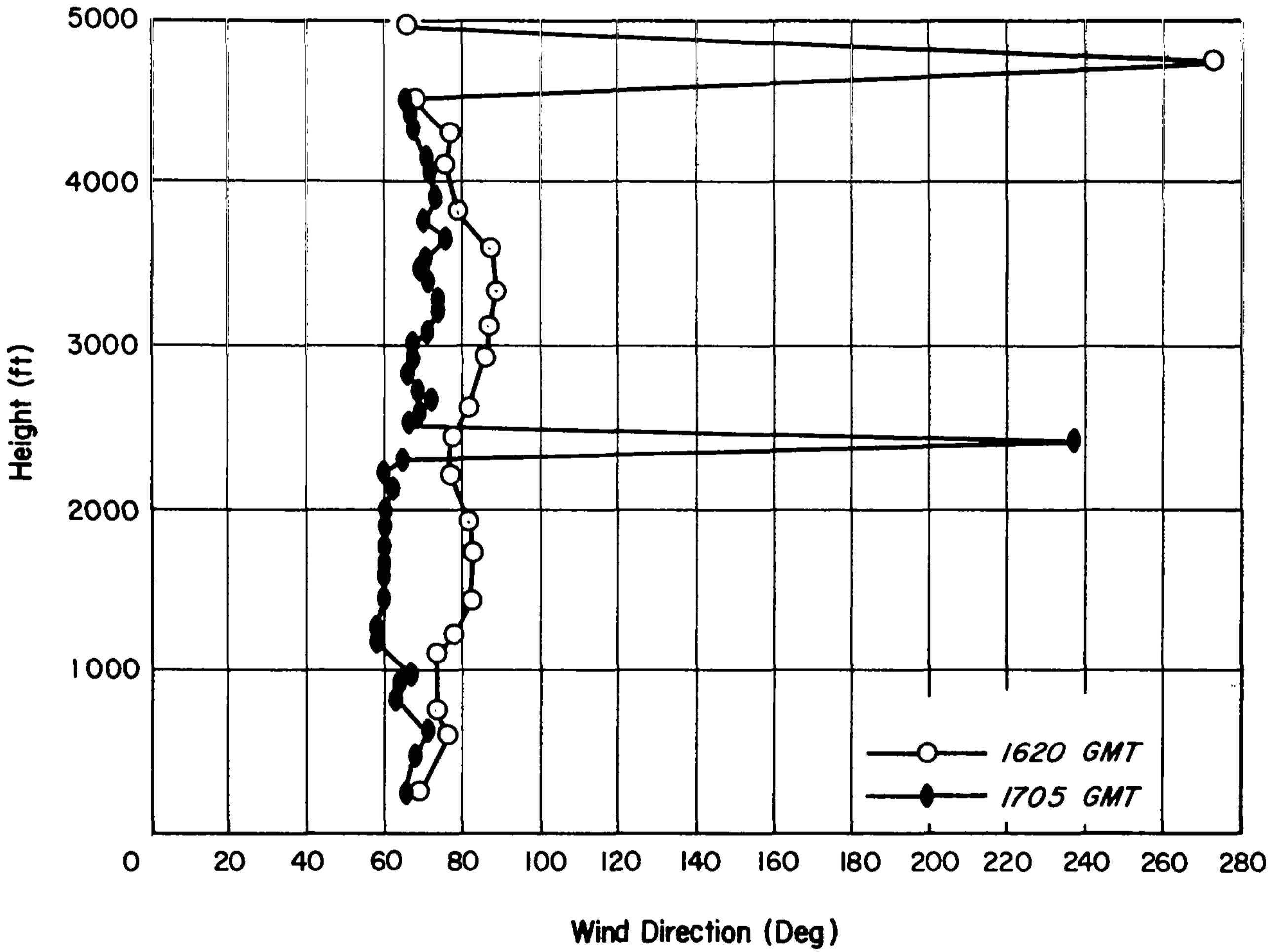


Figure 3-3 Wind Direction Profiles Deduced from Radiosonde Ascents Made on 9 June 1970

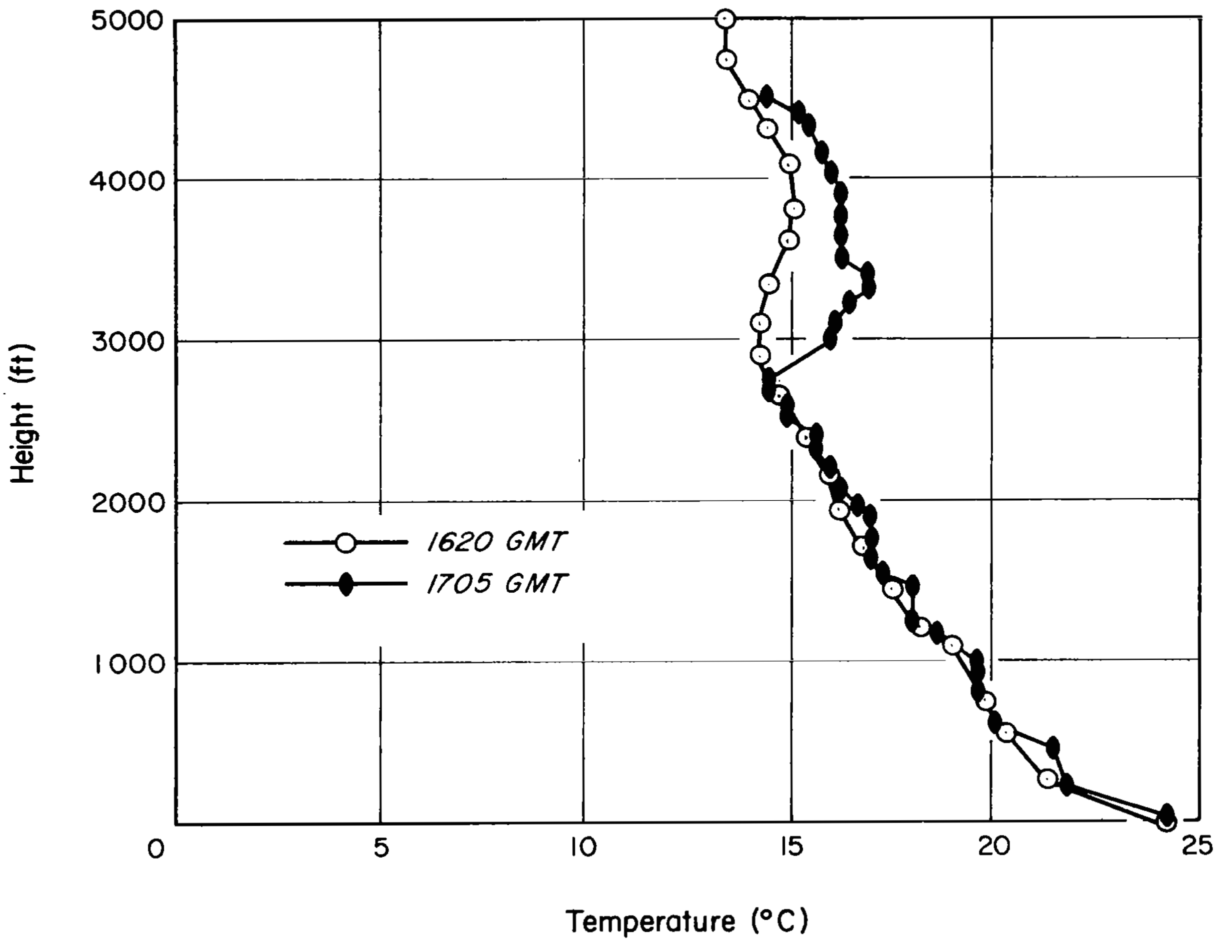


Figure 3-4 Temperature Profiles Deduced from Radiosonde Ascents Made on 9 June 1970 using "Smoothed" Height Data

4. RESULTS AND DISCUSSIONS

4.1 Temperature Variabilities

4.1.1 Temporal Variabilities

In Section 3 it was noted that under the clear sky and light surface wind conditions associated with an established high-pressure system, the properties of the surface layer of the atmosphere undergo large and rapid changes during the early morning hours. This type of situation characterized the early morning hours of 17 March 1969. The 1200 GMT (0700 EST) surface observations from Wallops Station reported clear skies and calm conditions. All of the stations in the mid-Atlantic states were in fact reporting clear skies with light-to-calm surface winds, as may be seen in the simplified 1200 GMT surface analysis shown in Figure 4-1. The only exception to the clear-sky conditions in this area is Salisbury, Maryland, which was reporting fog, a characteristic feature of a "stable" temperature regime prior to "lifting" by solar heating. The high-pressure system which dominated this region for the few days before 17 March was, in fact, in the process of being pushed out to sea by the storm developing over the Gulf of Mexico. On this day, six hourly temperature profiles were obtained between the hours of 1100 GMT and 1600 GMT. These are shown plotted in Figure 4-2. Also shown in this figure is the regularly scheduled 1200 GMT temperature profile made on the Island. Qualitatively, the profile-to-profile changes shown in Figure 4-2 are representative of those encountered in many of the 1969 radiosonde sequences analyzed. The magnitude of the changes shown are perhaps larger than those normally encountered.

Note first the temperature values at the surface. In the interval of five hours, the surface temperature steadily increased from -3°C to 16.5°C, a total change of almost 20°C. At higher levels, the total change in temperature is considerably less. At 3000 ft, for example, the spread in temperatures, as shown in the figure, is only 4°C. It is perhaps significant to note that the changes in temperatures at all levels above the surface are not systematic and monotonic as those exhibited by the temperatures at the surface. Some of this is undoubtedly due to the uncertainty in the measurements themselves.

The second important feature in the profiles is the "burning off" of the surface inversion. The three-hourly profiles at 1100, 1200 and 1300 GMT all exhibit a marked surface inversion with the top of the layer at ~ 300 to 400 ft. This feature is formed as a result of the radiative cooling of the surface on cloudless and calm nights. Sometime between 1300 GMT and 1400 GMT, the surface received sufficient direct solar radiation such that by 1400 GMT, the inversion layer is destroyed and the lapse rate in this lower 400 ft in fact becomes highly convective due to the rapid heating of the surface itself. It is these processes which bring about the rapid

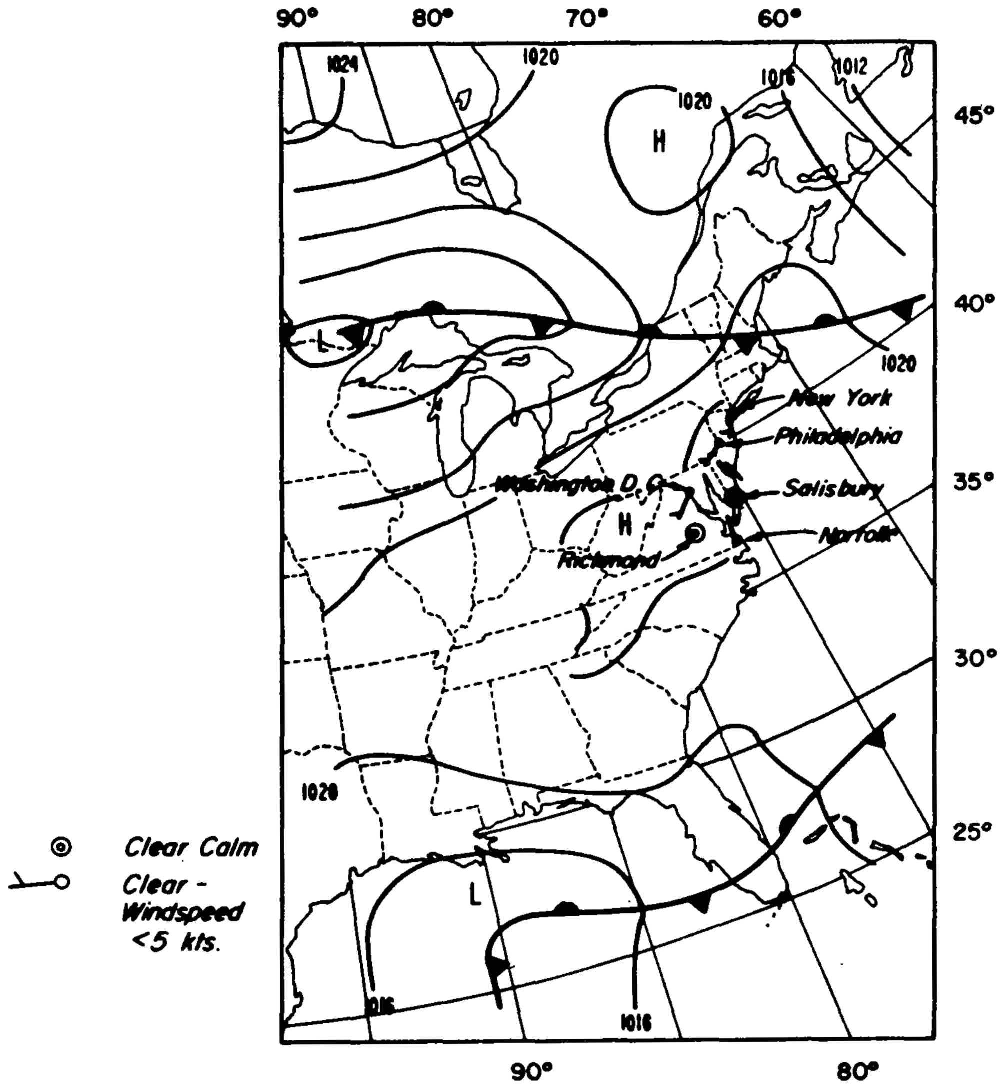


Figure 4-1 Simplified 1200 GMT Surface Analysis for 17 March 1969

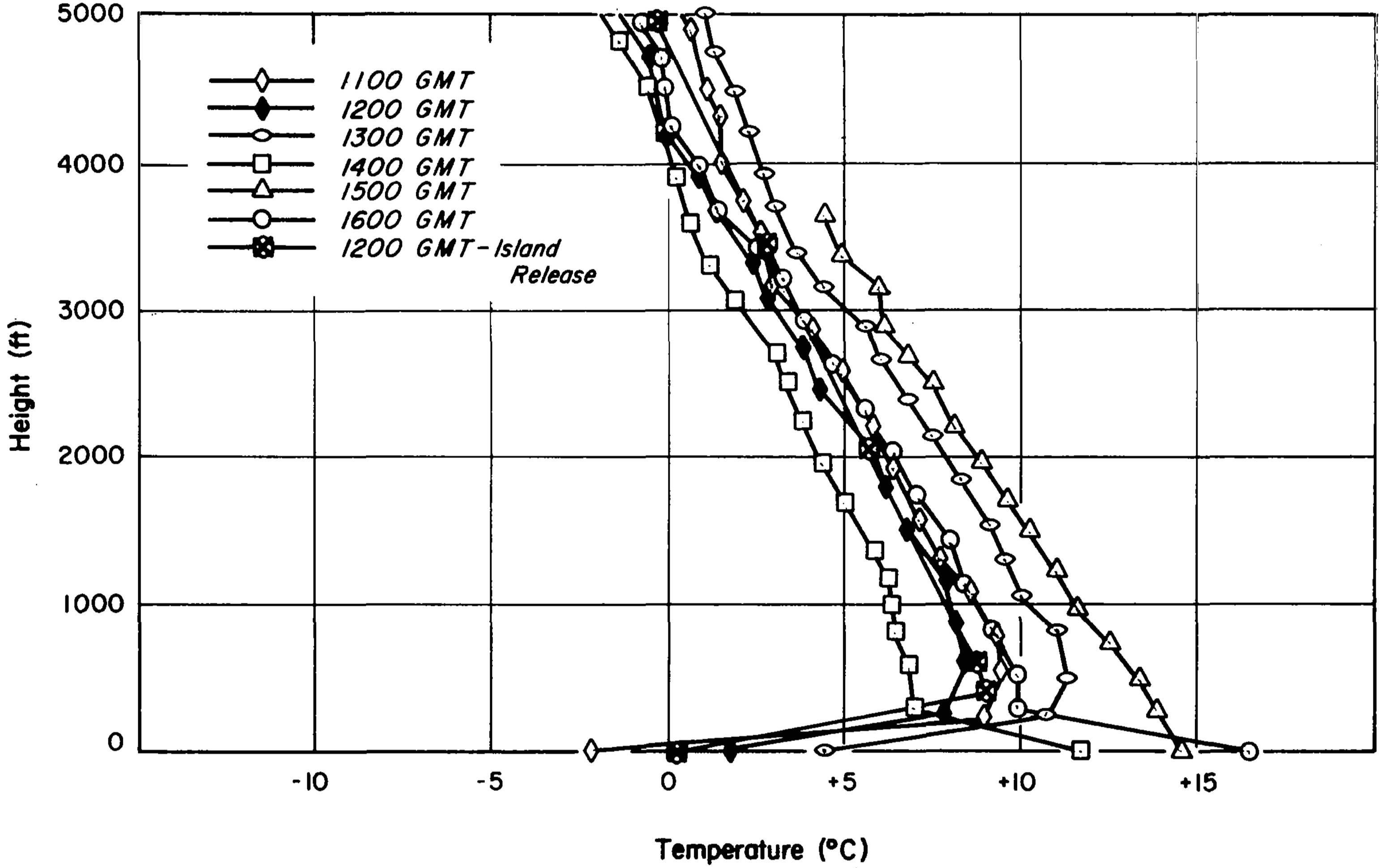


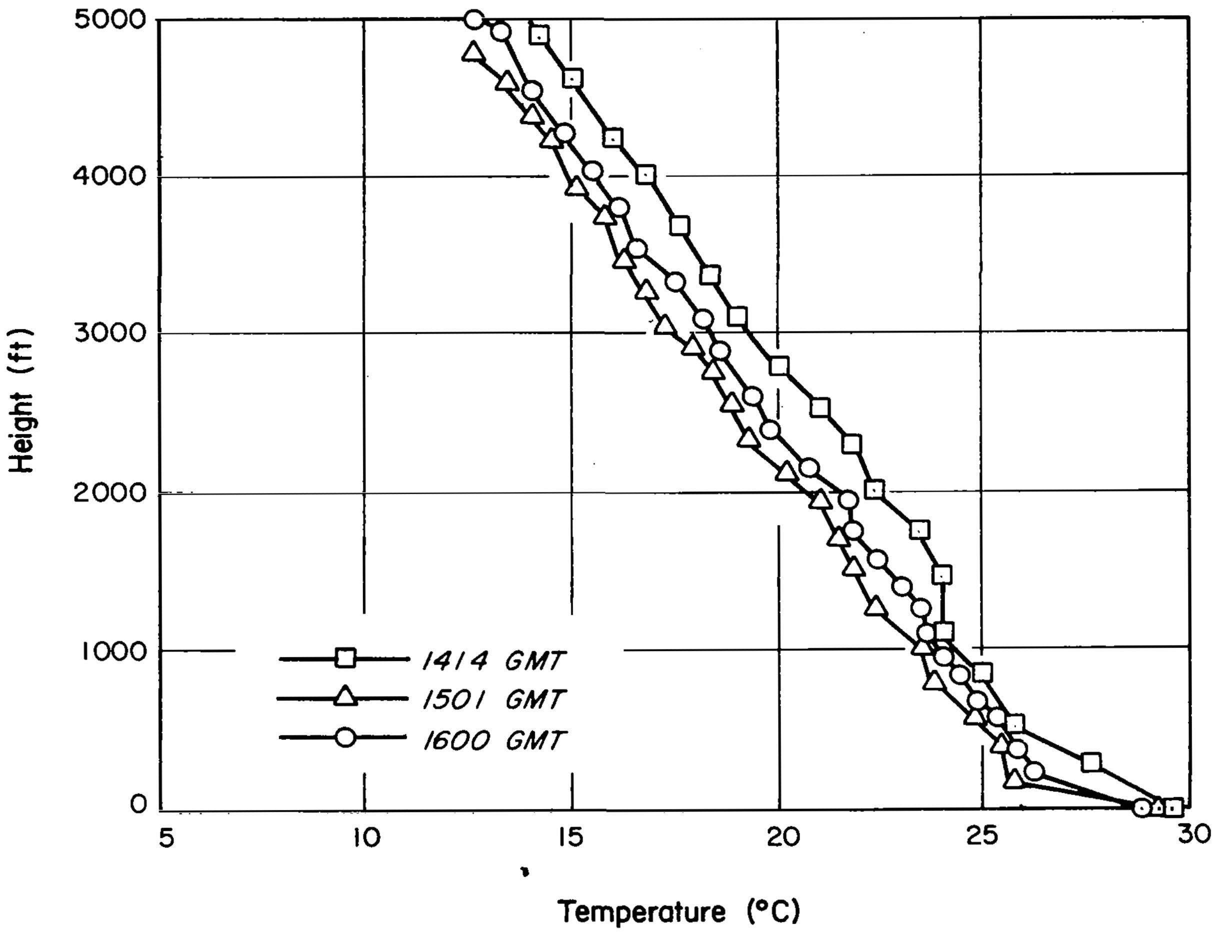
Figure 4-2 Temperature Soundings for 17 March 1969 between 1100 GMT and 1600 GMT

and large changes in the temperature structure of the lower atmosphere during the early morning hours, making it impossible to use surface measurements to infer the structure of the atmosphere above.

On 7 July 1970, the weather pattern over the mid-Atlantic states was again dominated by a ridge of high pressure. The 1200 GMT surface observations over the region all recorded clear skies and calm-to-light surface winds. Again, a sequence of 6-hourly, or nearly hourly, temperature soundings was made at Wallops Station. However, the sequence was initiated subsequent to 1400 GMT (0900 EST) which, in July, is well after sunrise such that surface heating, and the resulting heating of the layer air immediately above the surface, had sufficient time to stabilize. The profile-to-profile changes for this sequence are characteristically different from those shown for the 17 March sequence. In fact, the differences between the profiles at all levels are so small, it was necessary to use two separate figures (Figures 4-3a and 4-3b) to adequately illustrate individual data points. Apart from the small differences between the profiles, the lack of a surface inversion layer and the monotonic decrease of temperature with height at all levels for all profiles are of significance. With this type of profile there is an obviously high correlation between surface temperature and temperatures at all levels.

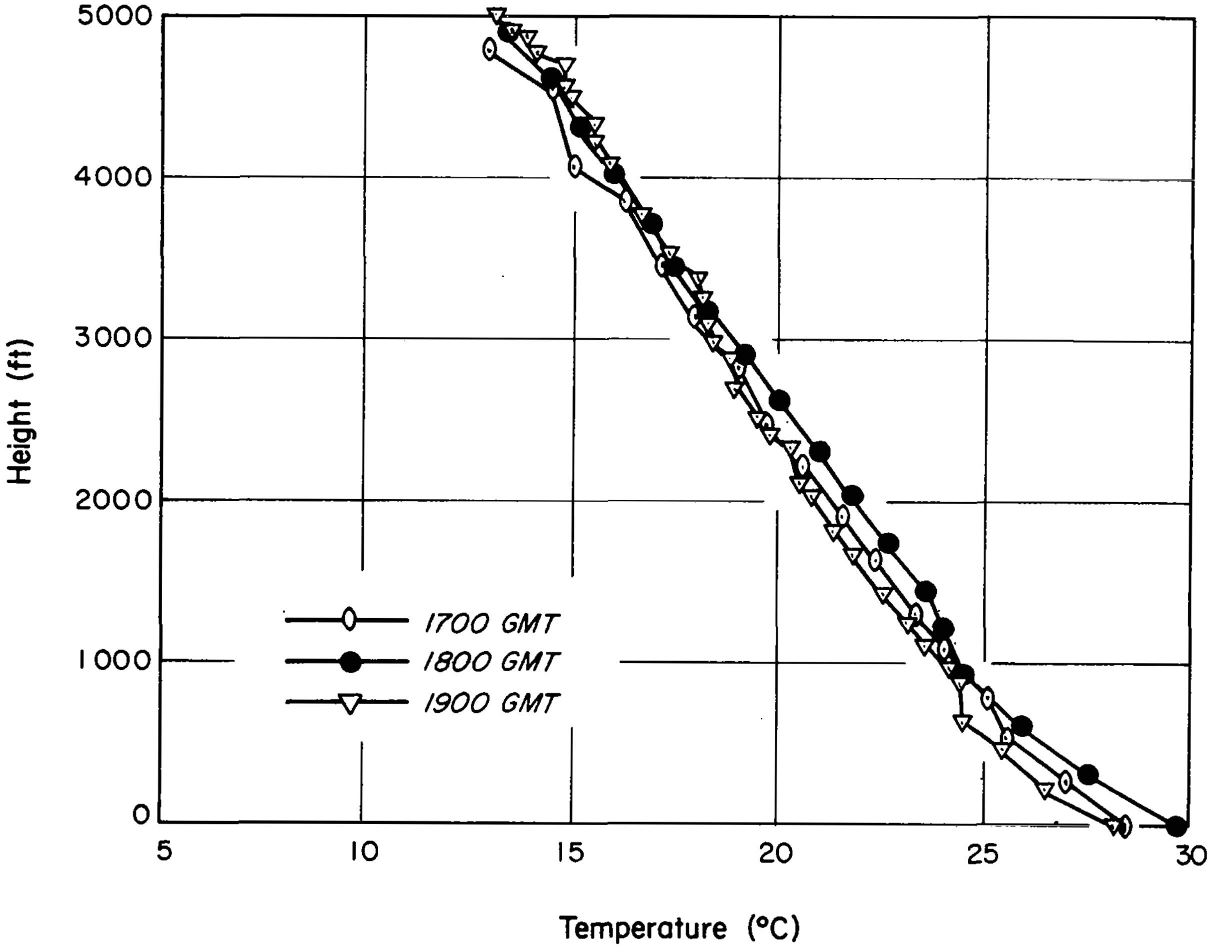
Figure 4-4 shows another example of a sequence of temperature soundings which exhibits small temporal changes and a high correlation between surface temperatures and temperatures at all levels. The data are taken from the ascents made on 23 January 1970 between the hours of 1600 GMT and 2000 GMT, well after sunrise. The synoptic situation over Wallops Station and the mid-Atlantic states was again similar to that for the previous two cases. The temperature structure in the low atmosphere on this day, as shown in Figure 4-4, was not unlike that for the 7 July 1970 case. Under clear skies and maximum solar heating, the temperature lapse rate in the lowest 300 ft is highly convective, being in excess of $10^{\circ}C/1000$ ft. Above the surface convective layer the temperature falls off monotonically with height at a nearly constant lapse rate of $\sim 3^{\circ}C/1000$ ft. The profile-to-profile changes in temperature at all levels are small with differences between sequential profiles being generally less than $0.5^{\circ}C$.

Yet a third class of temperature variability was encountered in the data sample illustrating the effects of high and middle clouds on the temporal changes in the temperature structure in the surface layer. On 6 March 1969, Wallops Station was located at the western edge of a high-pressure system located in the Atlantic, with a rapidly intensifying cyclone which, at 1200 GMT, was centered over the Mississippi-Alabama region. In advance of the cyclone center, the stations in the mid-Atlantic states, at 1200 GMT, were reporting total or partial cloud cover. Wallops Station at this time was reporting 6/10 cover by high and middle clouds. During the early morning on this day, two temperature-sonde ascents were made at 1214 GMT



a) Soundings between 1414 GMT and 1600 GMT

Figure 4-3 Temperature Soundings for 7 July 1970



b) Soundings between 1700 GMT and 1900 GMT

Figure 4-3 Cont'd

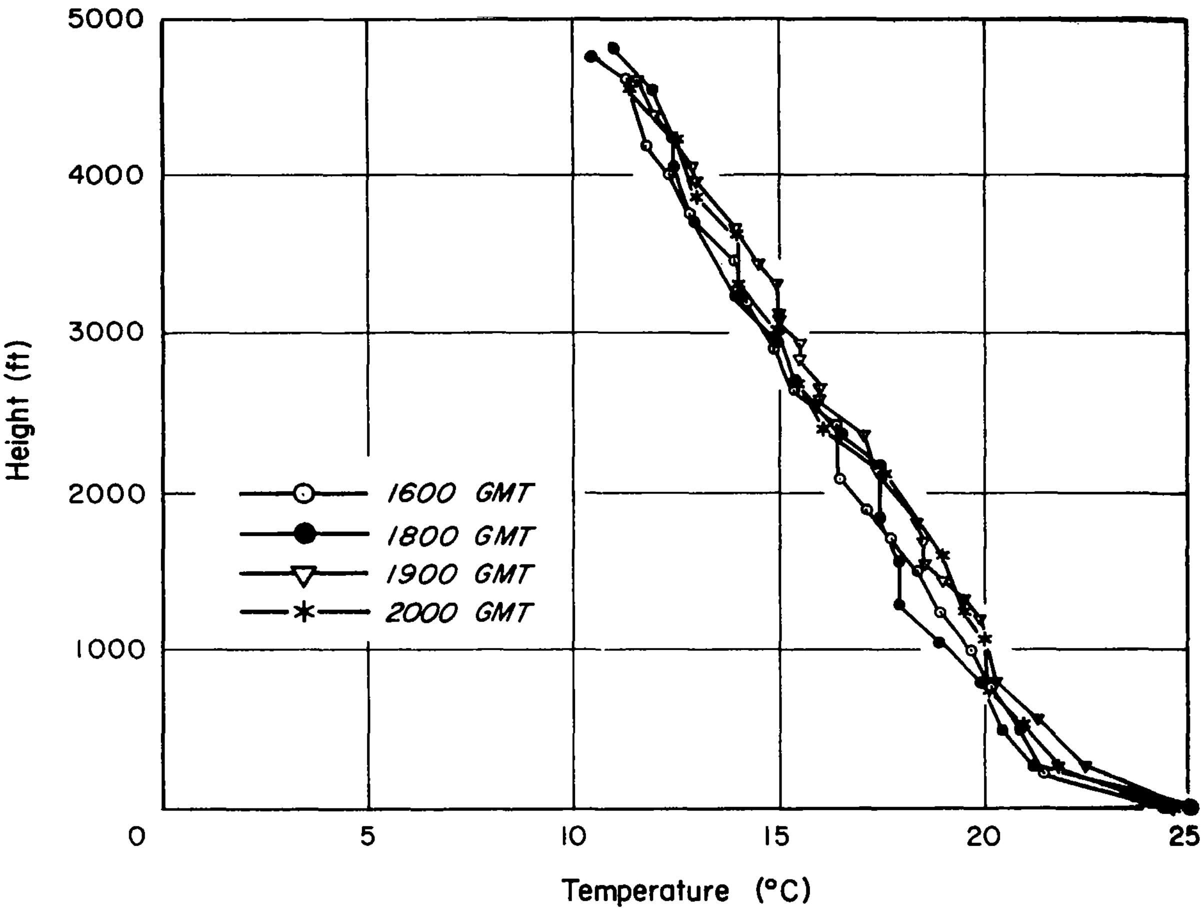


Figure 4-4 Temperature Soundings for 23 January 1970 between 1600 GMT and 2000 GMT

and 1314 GMT. The data from these ascents are shown analyzed in Figure 4-5 together with the data from the regularly scheduled ascents at 1200 GMT made on the Island. Analysis of the 1200 GMT ascent above 5000 ft and not shown in the figure, reveals a saturation level (RH = 100%) at the 550 mb level, confirming the presence of middle level clouds. The analyses of the data below 5000 ft shown in Figure 4-4 indicate that under cloudy sky conditions the temporal changes in temperature, even during the morning hours, are effectively suppressed.

In order to arrive at data useful in the specifications of meteorological data requirements adequate to support aircraft noise measurements, the statistics of the variabilities in atmospheric temperatures were analyzed. The absolute temperature differences

$$\Delta T = \left| T_t - T_{t + \Delta t} \right|$$

were computed for all sequences of temperature profiles with Δt = 1 hour, 2 hours, and 3 hours. The means and standard deviations of these ΔT values were computed for the entire data sample without stratification by time of day or synoptic condition. The results are shown in Figure 4-6. Also shown in this figure are the maximum values of ΔT found in the entire data sample. The most interesting feature in the data shown is that the mean value of ΔT, at and above 1000 ft, tends to stabilize at $\sim 1.2^{\circ}C$ and appears to be independent of the time difference, Δt. Similarly, the maximum values of ΔT and the standard deviation in each case tend to be independent of the time difference Δt above 1000 ft. Below 1000 ft, and especially at the surface, the values of mean standard deviation and the maximum values of ΔT are, on the other hand, highly dependent on Δt and on height. On the average, the surface temperature difference between measurements was found to exceed $4^{\circ}C$ where such measurements were made three hours apart. In at least one case, this difference exceeded $14^{\circ}C$. When the time interval between measurements was reduced to one hour, the mean value of ΔT was reduced to $\sim 1.8^{\circ}C$.

The data shown in Figure 4-6 reflect the dominating influence, during the early morning hours and clear sky conditions, of surface effects on the temporal atmospheric structure. The influence of the surface diminishes with altitude and apparently all but vanishes above 1000 ft, as the data in Figure 4-6 indicate. To further investigate the suggestion that the principal cause of the observed temporal variability is the surface heating during the early morning hours, the data sample was stratified according to the time of day and the mean values of ΔT separately computed. Three classes of the data were defined: Dawn, for all of the data sequences initiated prior to 1100 GMT; Late Morning - Noon for all of the data sequences initiated subsequent to 1400 GMT, but prior to 1700 GMT; and Evening, for all of the sequences initiated subsequent to 1700 GMT. The results of these computations

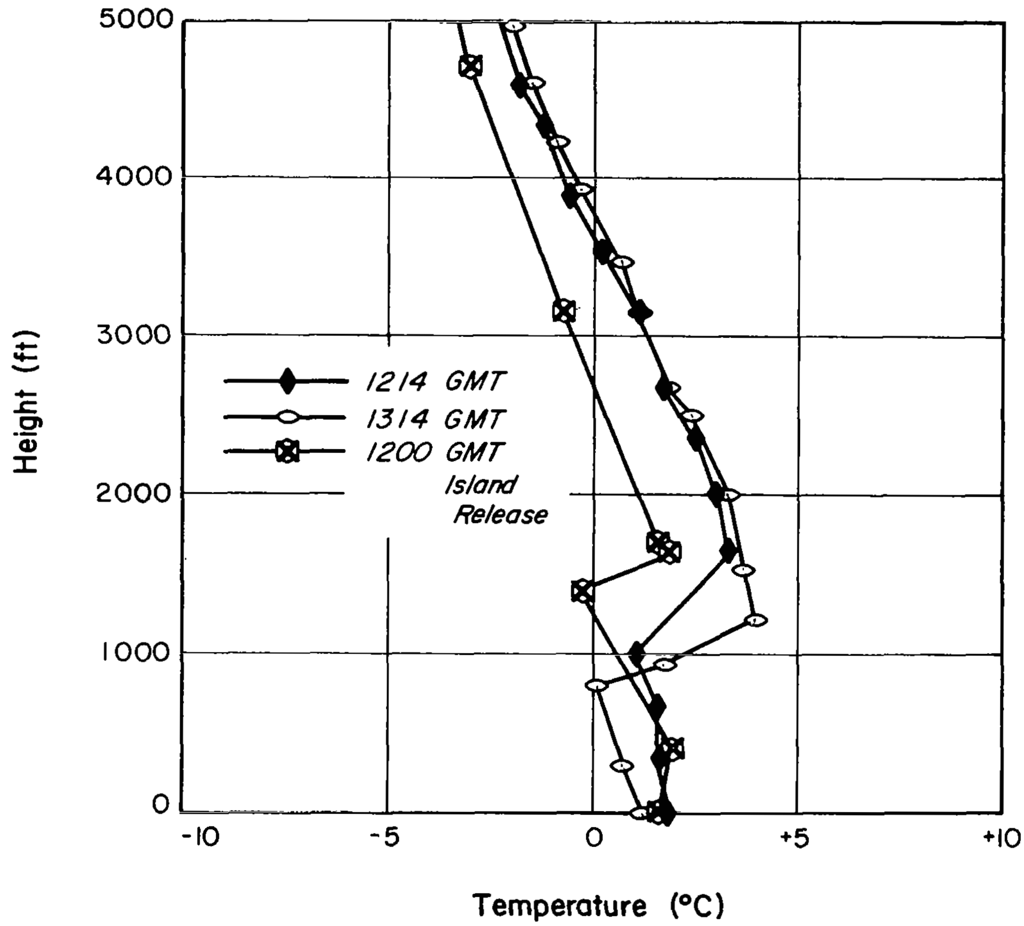


Figure 4-5 Temperature Soundings for 6 March 1969 between 1200 GMT and 1314 GMT

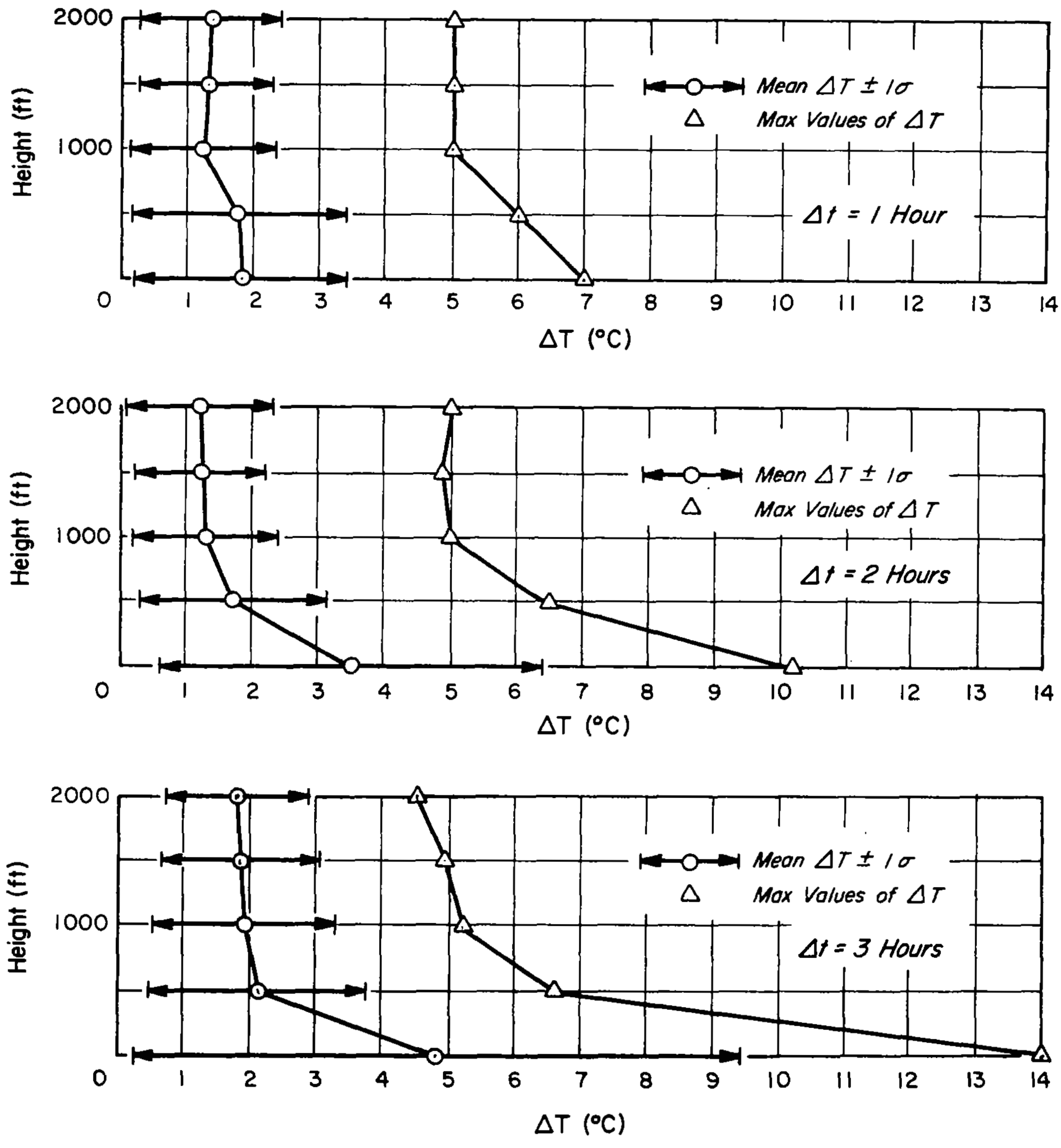


Figure 4-6 Analysis of Temporal Variability of Temperature Using all Data where $\Delta T = \left| T_t - T_{t + \Delta t} \right|$

are shown in Figure 4-7. It is clear from this figure that the set of Dawn data dominates the total data sample. The mean ΔT values computed for the Late Morning - Noon sample are independent of height and of time lapse, Δt. More significant is the fact that the mean values of ΔT for this sample are generally $< 1^{\circ}C$, which is within the limits of uncertainty of the measurements themselves. It is also important to note that the Late Morning - Noon sample would almost be identical to the summer data sample if the data were stratified by season. It is during the summer months that one would expect maximum surface heating effects. The results shown in Figures 4-6 and 4-7 suggest that by late morning the heating effect of the surface is generally stabilized even under the intense summer sun.

4.1.2 Temperature Lapse Rate

The variability of atmospheric temperature in the vertical was touched upon in Section 4.1.1 in which it was suggested that under "ideal" conditions the temperature falls off monotonically and at a constant rate with height. On the other hand, the data for 17 March 1969 and 6 March 1969, in Figures 4-2 and 4-5, show that temperature inversions at the surface and in the free atmosphere will modify the rate at which the temperature changes with height. In the investigation of the shape of the temperature profiles, the lapse rate, γ, defined as $\left(-\frac{\Delta T}{\Delta Z}\right)$ was used instead of the absolute values of temperature. This standard meteorological parameter permits a direct comparison of temperature profiles having large differences in absolute values of temperature. The lapse rate is generally expressed in terms of degrees per kilometer or degrees per 1000 ft of ascent.

On 29 April 1969, the sequence of temperature-sonde ascent data shows dramatically the changes in lapse rate during the course of a day. On this day, a complex frontal system with its cloudiness and precipitation passed over Wallops Station at approximately 1200 GMT as may be seen in the 1200 GMT surface weather analysis shown in Figure 4-8. This weather situation is totally unlike the clear sky conditions of a high-pressure system associated with most of the other data samples. A total of seven valid temperature soundings were made on this day between the hours of 1000 GMT and 2130 GMT. The sequence temperatures at the surface, 1000 ft and 2000 ft levels, are shown plotted in Figure 4-9. In this figure, the lapse rate in each of the 1000-ft layers is simply equal to the numerical difference between the temperature values plotted for the bottom and top of the layer.

At 1000 GMT the lowest of the three temperature values was the $15.4^{\circ}C$ measured at 2 km. However, the surface temperature of $16^{\circ}C$ was colder than the $17.3^{\circ}C$ measured at 2000 ft, showing that a surface inversion with a lapse rate of $-1.3^{\circ}/1000$ ft existed at this time. Above the inversion, the lapse rate was $\sim 0.6^{\circ}C/1000$ ft. By 1400 GMT, the temperature in the lowest 2000 ft was nearly isothermal;

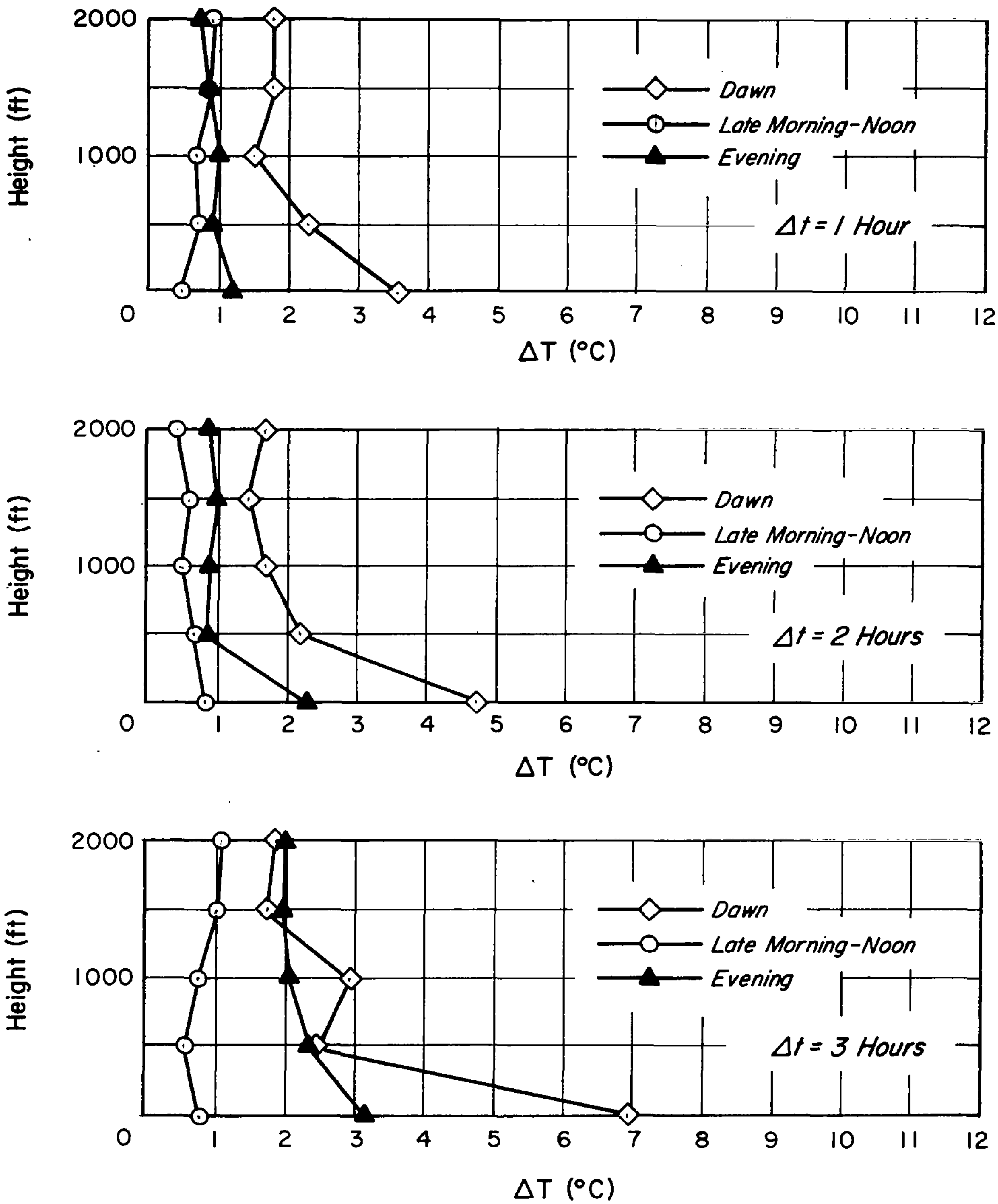


Figure 4-7 Temporal Variabilities of Temperature Stratified by Time of Day

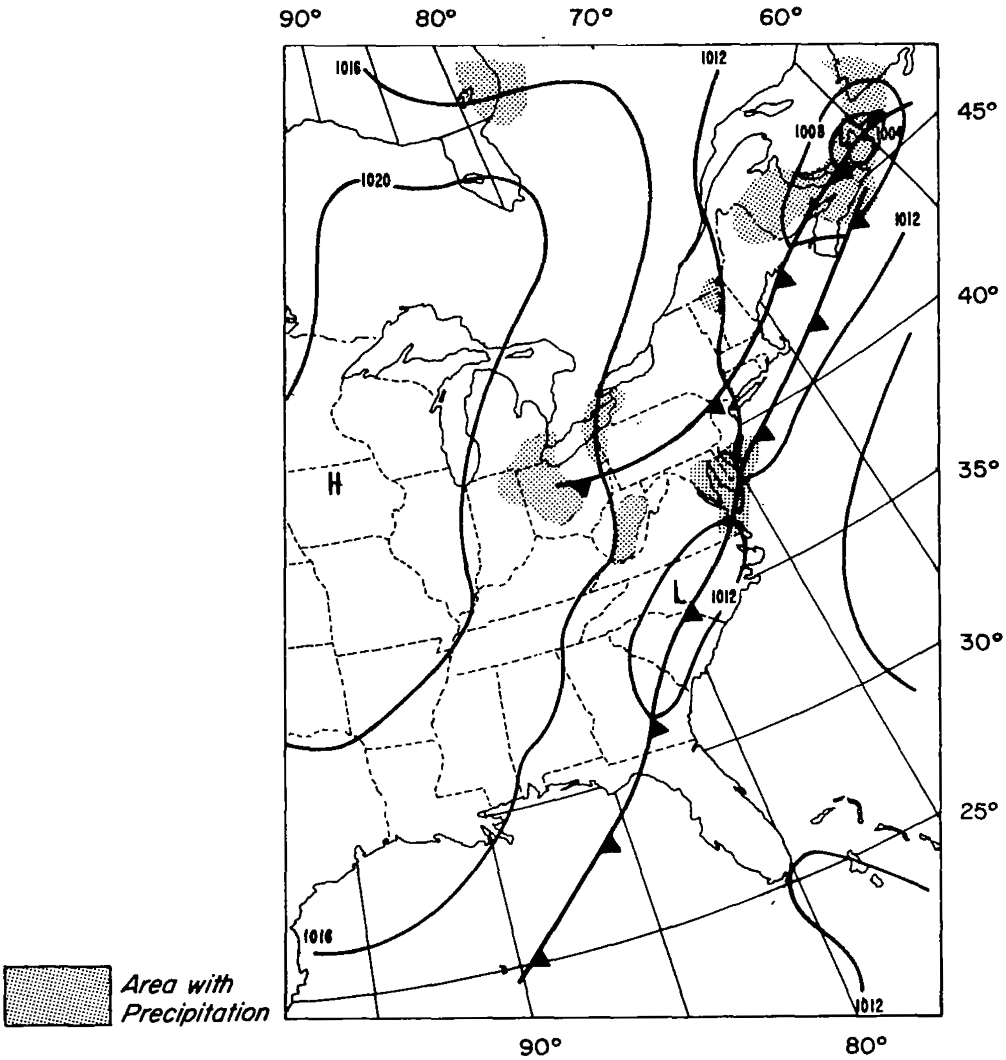


Figure 4-8 Simplified 1200 GMT Surface Analysis for 29 April 1969

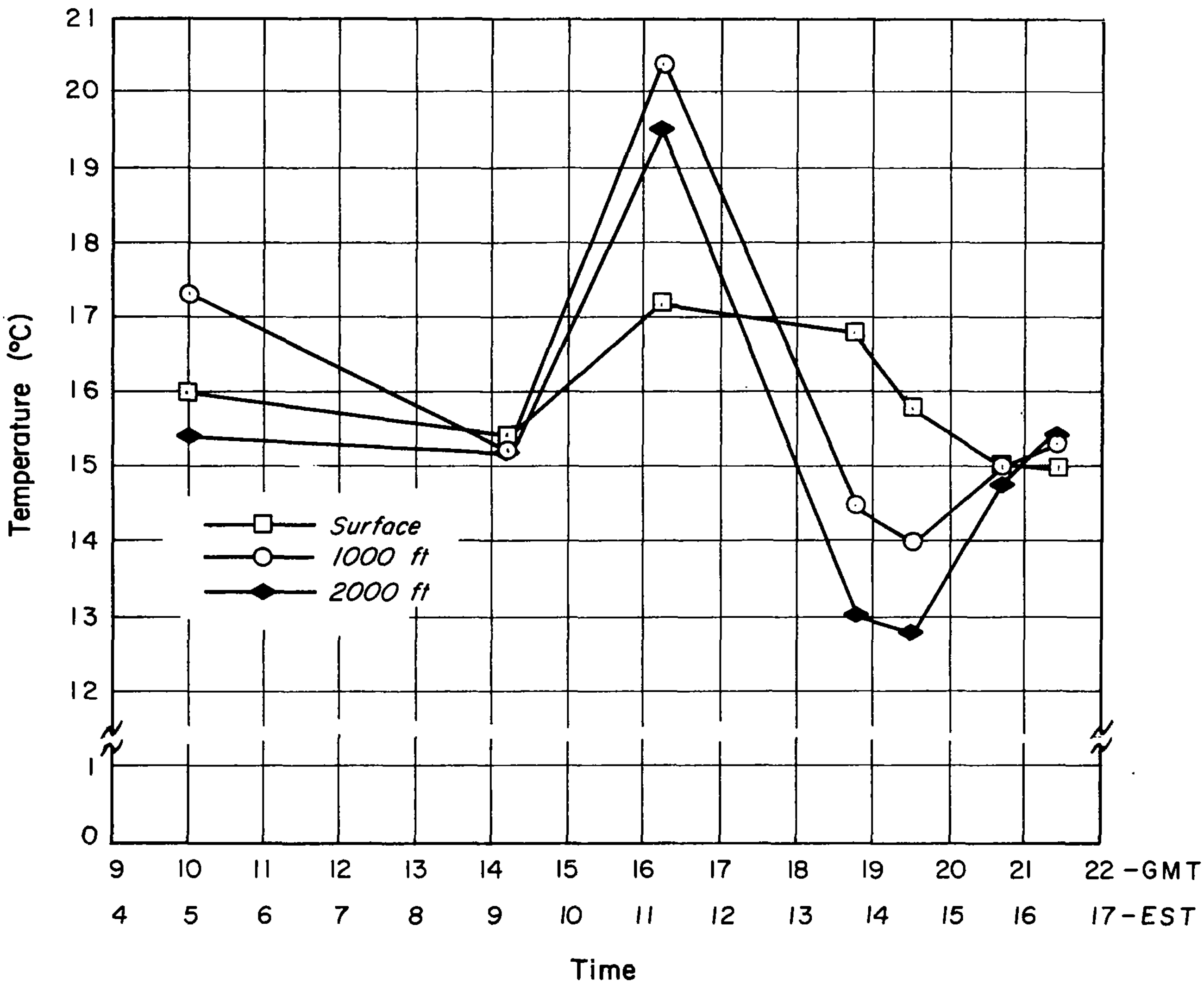


Figure 4-9 Temporal Changes in Temperature for Wallops Station on 29 April 1969

i.e., $\gamma = 0$, as indicated by the fact that the temperatures at all three levels were at $\sim 15.3^{\circ}C$. At 1610 GMT, a steep lapse rate, with $> 3^{\circ}C/1000$ ft was found in the first 1000-ft layer. However, the negative lapse rate above indicates that a second inversion has formed with the top of the inversion at or above 2000 ft. The layer lapse rates between 1300 and 1500 GMT show the normal decrease of temperature with height with a more convective, i.e., larger value of γ in the lower layer. By 2040 GMT, the temperature again became isothermal which by 2120 GMT showed the formation of a surface inversion.

The sequence of complex lapse rate changes and reversals on 29 April 1969 are the apparent result of changes in the weather pattern (early part of the day) and the onset of a sea breeze subsequent to the clearing which apparently occurred after 1600 GMT. Compare now the sequence of temperature data for 7 July 1970 shown in Figure 4-10. At all times during this day the temperature decreased monotonically with height. The lapse rates at the surface were large, and to be expected on a clear day in summer. Above 1000 ft, the lapse rates are almost independent with height and time.

In order to translate the examples shown to useful information for experimental planning, the mean layer lapse rates were computed from the data sample. The results of these calculations are shown in Table 2. When all of the data were included in the computation, the lapse rate in each of the layers was found to approximate the standard lapse rate of $\sim 2.0^{\circ}C/1000$ ft (or $6.5^{\circ}C$ km). However, as the results of the computations using stratified samples show, the standard value is not applicable in a number of instances, especially in the lowest surface layer. As expected, the largest lapse rates were found for the spring and summer months in the lowest 500-ft layer. What is perhaps unexpected is the large lapse rate found in this layer for the winter months. A partial explanation for this apparent discrepancy is the fact that the winter data sample contains a large percentage of measurements made in January 1971. These data were obtained well after sunrise when surface inversions had dissipated even during the winter months. This fact suggests that the lapse rate in this surface layer is more dependent on the time of day than on season. The computed mean lapse rates for the three time periods of day shown in Table 2 certainly bear this out.

4.1.3 Spatial Variabilities

As indicated previously, the program to acquire systematic upper-air data to define the spatial variabilities of atmospheric parameters was never fully impemented. In fact, only two ascents were made on Wallops Island specially for this program. The first of these was made at 1530 GMT on 20 January 1971 and the second at 1530 GMT on 22 January 1971. These were ascents which provided

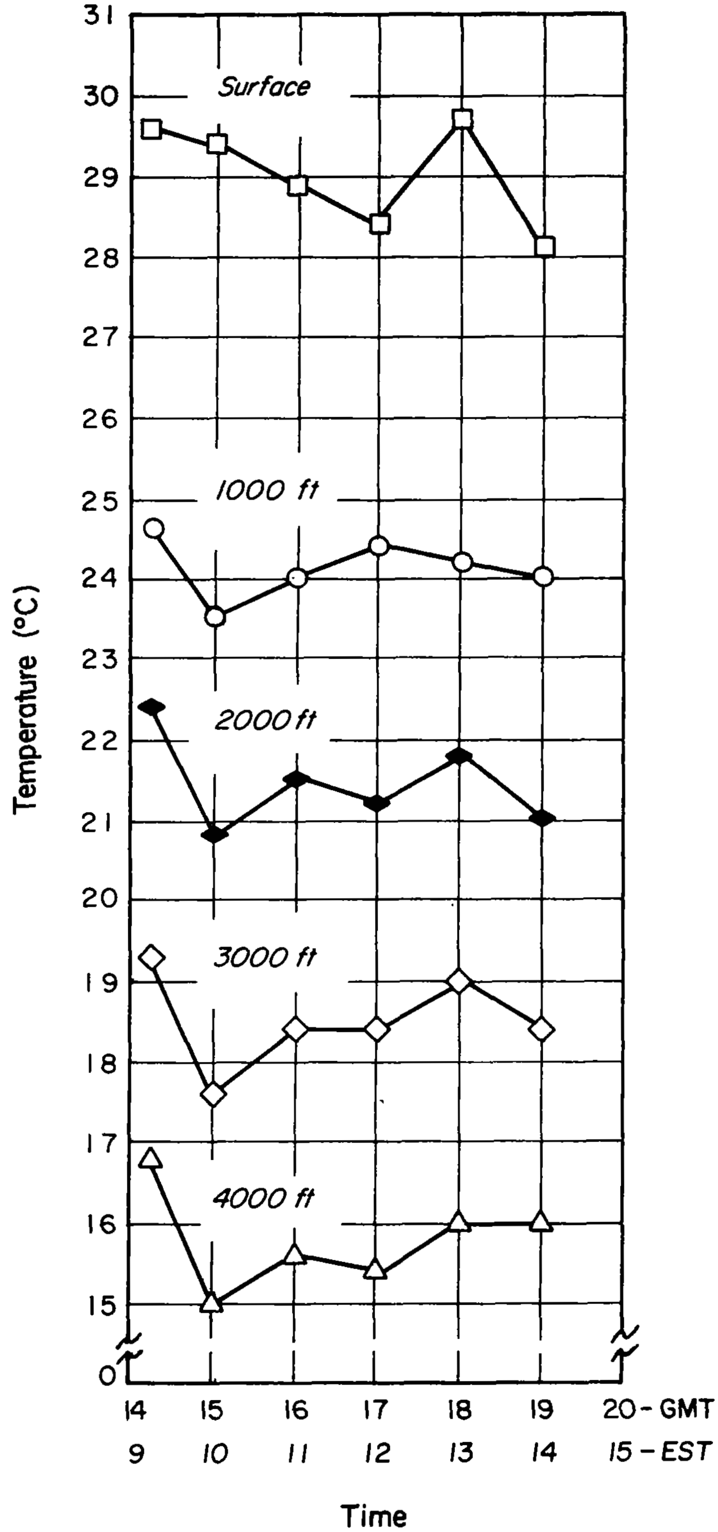


Figure 4-10 Temporal Changes in Temperature for Wallops Station on 7 July 1970

TABLE 2

COMPUTED MEAN TEMPERATURE LAPSE RATES

Mean Lapse Rate ($^{o}C/1000$ ft)

	0-500 ft	500-1000 ft	1000-1500 ft	1500-2000 ft
All Data *	2.0	2.5	2.3	1.5
Spring	3.2	1.8	2.2	1.8
Summer	3.7	2.6	2.6	2.5
Fall	.64	2.3	2.1	2.0
Dawn	.66	1.9	2.1	2.5
Late Morning - Noon	3.4	2.6	2.5	1.8
Evening	2.0	2.5	2.6	2.3

simultaneous measurements of temperature and humidity. Of the resulting four profiles, two each of temperature and humidity, only the temperature profile at 1530 GMT on 20 January 1971 had a corresponding temperature profile made at the airfield. These two simultaneous profiles are shown in Figure 4-11. The profiles are similar at all levels, even in the abrupt change of lapse rate at 4000 ft. With the exception of the values at the surface, the temperatures measured by the Island ascent are consistently warmer than the ones measured by the airport ascent. However, the absolute temperature difference between the two soundings is less than $1^{\circ}C$ at all levels up to 4000 ft.

For the second of the special Island ascents, the closest airport temperature sounding in time was made one hour earlier at about 1527 GMT. These profiles are shown in Figure 4-12. Below 3000 ft, the two profiles are for all practical purposes identical. At 3000 ft, the Airport sounding shows what appears to be an inversion, characteristic of subsidence. No indication of this subsidence inversion is found at this level in the Island profile. However, at the top of the sounding at approximately 5000 ft, there is an abrupt change in temperature gradient to a stable regime which can be part of the same stable layer found at the lower level over the Island.

In order to increase the sample of data useful in defining the spatial variabilities of atmospheric parameters, the radiosonde ascents made on the Island at the regularly scheduled times of 1200 GMT and 0000 GMT were acquired and compared to the Airport data whenever simultaneous ascents were available. An example of such a comparison was shown previously in Figure 4-5 for 6 March 1969. On this day, a temperature sounding was launched at the Airport at 1200 GMT. Both temperature soundings at this time show a nearly isothermal surface layer and a very stable inversion layer with the top at approximately 1600 ft. Above the inversion, the temperatures decreased monotonically with height at nearly constant and identical lapse rates. Furthermore, in the surface layer up to about 1000 ft, the absolute difference in temperatures between the two profiles are again negligible. In the stable layer and above, these differences increase to a maximum value of $2^{\circ}C$. Indeed, the maximum temperature difference at any level between simultaneous profiles in all of the data examined was $3^{\circ}C$, with most of the difference being on the order of less than $2^{\circ}C$. Table 3 shows the results of the comparison study using the regularly scheduled ascents on the Island. In this table, ΔT represent the absolute difference in temperature measured by the Island and Airport ascents; i.e.,

$$\Delta T = \left| T_I - T_A \right|$$

where the subscripts I and A refer to the Island and Airport, respectively.

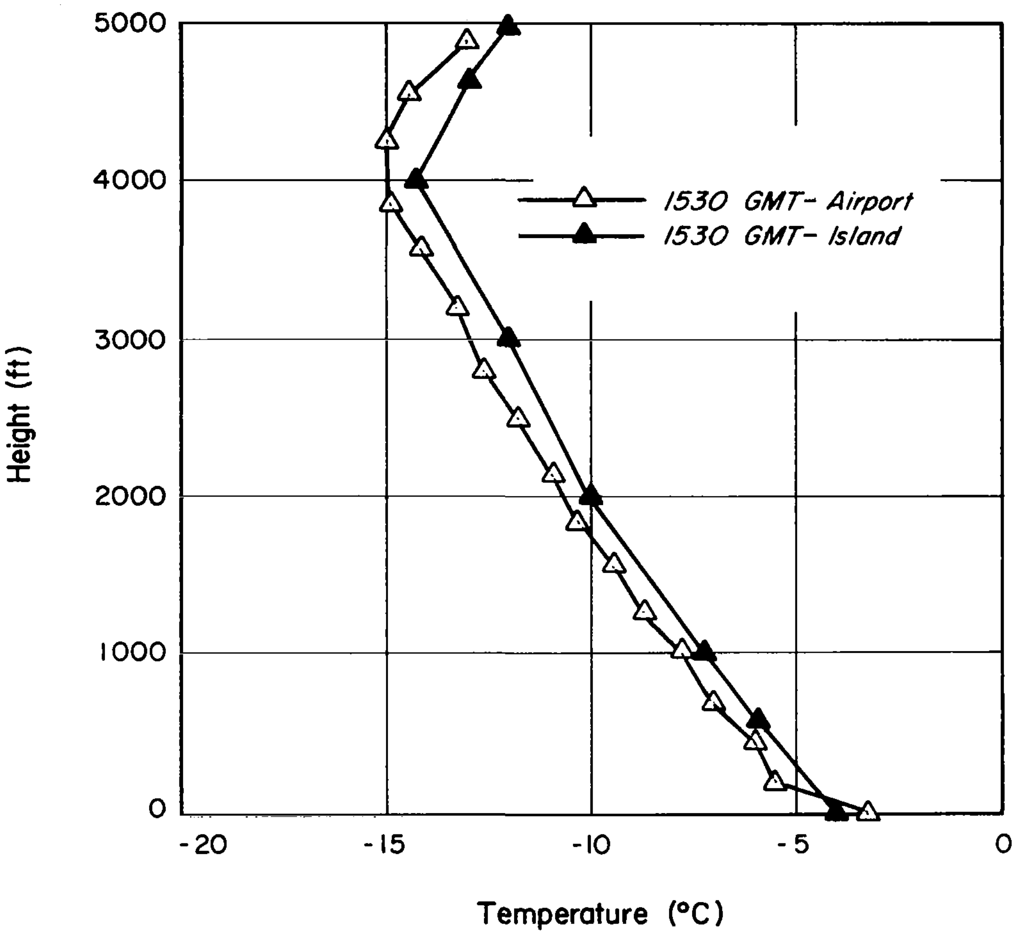


Figure 4-11 Comparison of Temperature Profiles over Wallops Station and Wallops Island on 22 January 1971

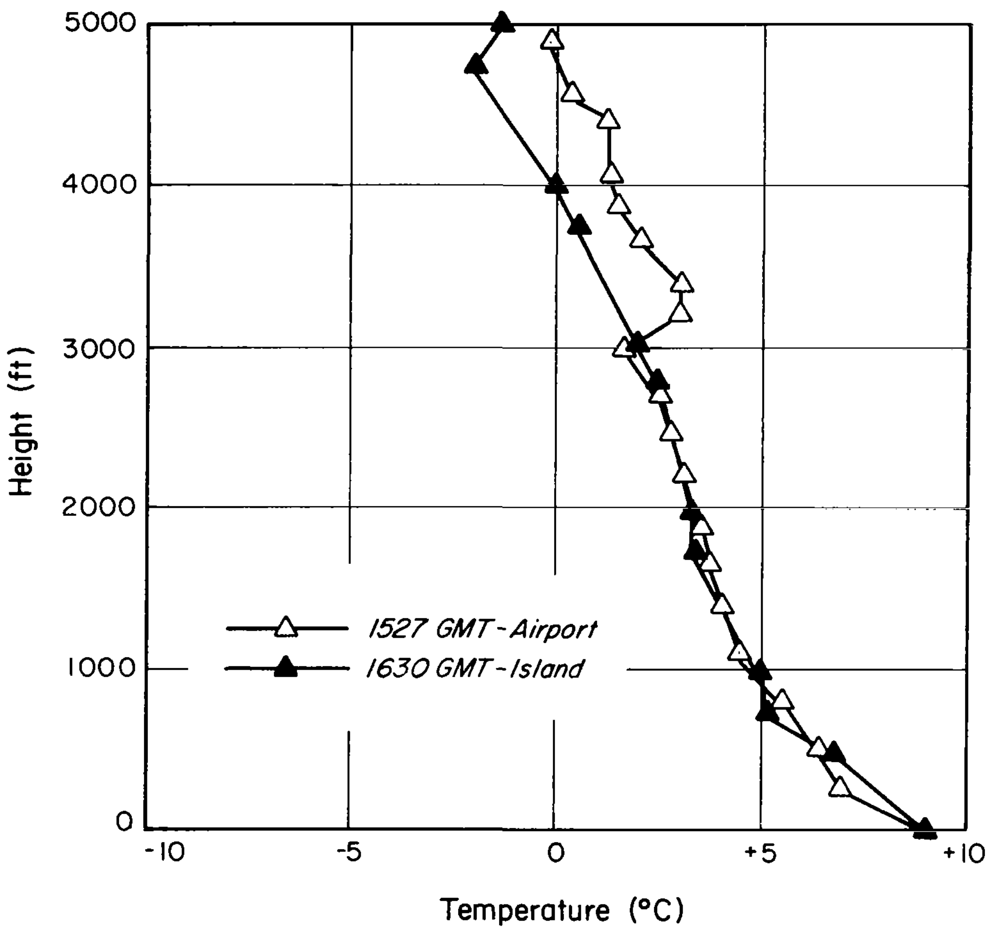


Figure 4-12 Comparison of Temperature Profiles over Wallops Station and Wallops Island on 20 January 1971

TABLE 3
SPATIAL DIFFERENCES IN TEMPERATURE

$$\Delta T = \left| T_I - T_A \right|$$

	Surface	500 ft	1000 ft	1500 ft	2000 ft
Mean ΔT	$1.2^{\circ}C$	$1.0^{\circ}C$	$1.1^{\circ}C$	$1.6^{\circ}C$	$1.3^{\circ}C$
Max ΔT	$2.5^{\circ}C$	$3.0^{\circ}C$	$3.0^{\circ}C$	$2.9^{\circ}C$	$3.2^{\circ}C$

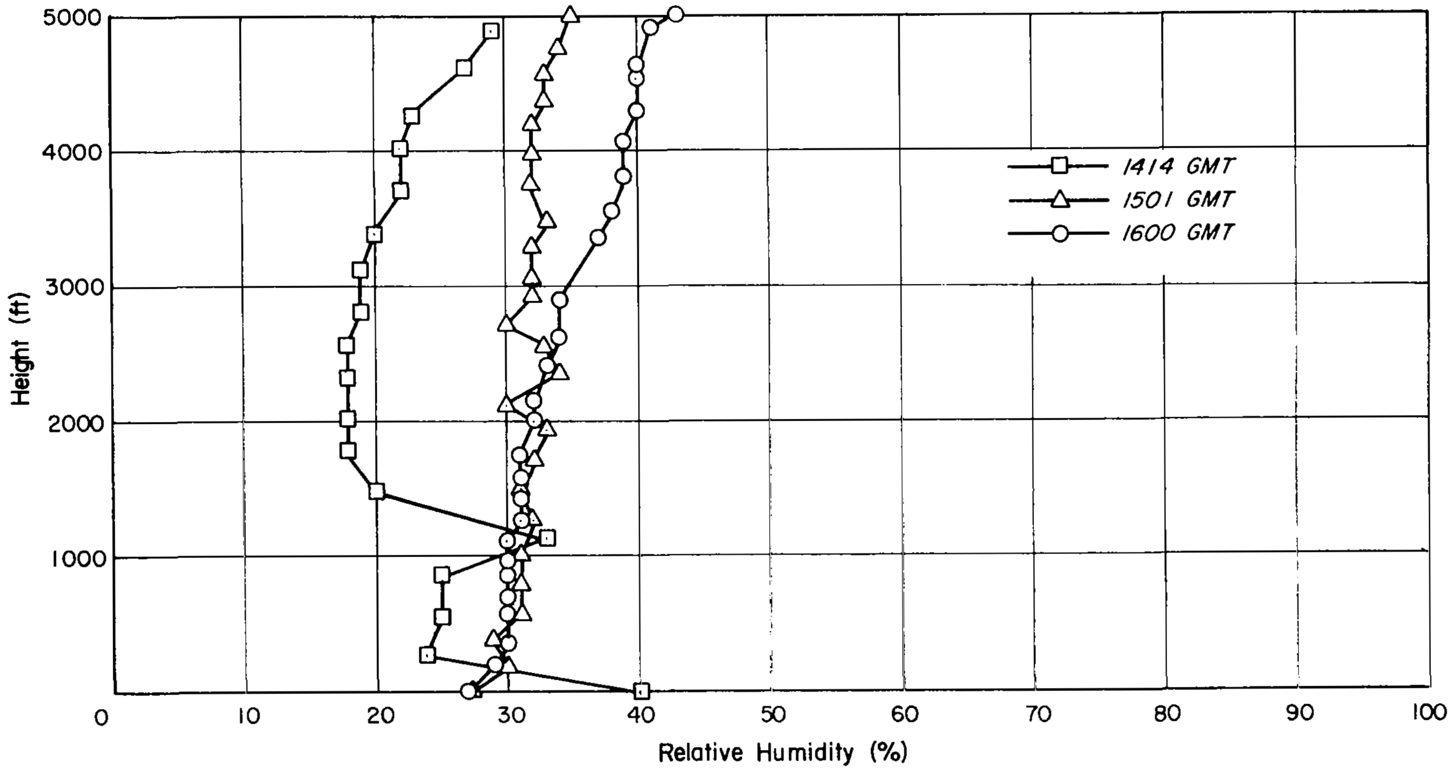
4.2 Moisture Variabilities

4.2.1 Temporal Variabilities

As is the case with atmospheric temperatures, the temporal variabilities of atmospheric moisture in the lowest 2000 ft at Wallops Station were found to be dependent on the time of day. Rapid changes in relative humidity were generally found in the Dawn data sequences and in the layers of the atmosphere close to the surface. In fact, there is a high correlation between rapid changes in relative humidity and in temperature.

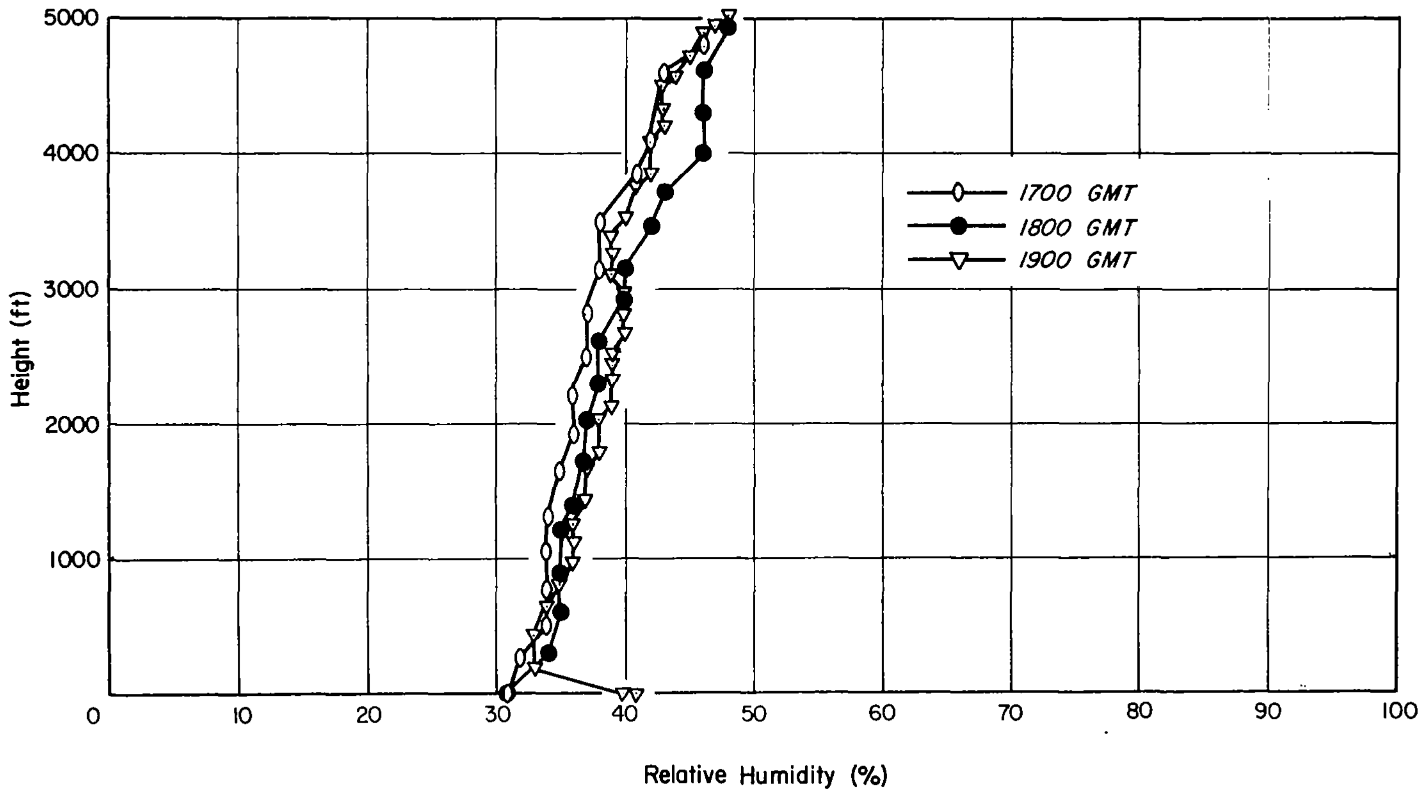
In Section 4.1, it was shown that the temporal variabilities in the atmospheric temperature profiles obtained for 7 July 1970, between the hours of 1400 GMT and 1900 GMT, were inconsequential. Figures 4-13a and 4-13b show the corresponding profiles of relative humidity for this date. With the exception of the 1414 GMT profile, the temporal variabilities of relative humidity below 3000 ft during this time period were also not large. In fact, the sequence of measurements has some of the smallest temporal changes in relative humidity found in the entire data set. At the other extreme of humidity variabilities is the set of measurements made on 8 April 1969 in the early morning hours. The sequential profiles of relative humidity for this day are shown in Figure 4-14. The large values at the surface are typical of the early morning hours.

Again, as in the case of the temperature profiles, the temporal variabilities of relative humidity were analyzed in terms of the absolute difference in relative humidities between profiles taken at time intervals of 1 hour, 2 hours and 3 hours. Figure 4-15 shows the mean values of $\Delta(RH)$ for these time intervals for all of the data samples and stratified as before according to the time of day. As expected, the value of $\Delta(RH)$ generally increases with increasing values of Δt, the time difference between "sequential" profiles, and with decreasing altitude. The maximum values of $\Delta(RH)$ are found at the surface. The Late Morning - Noon sample exhibits mean $\Delta(RH)$ values which are nearly time-independent and height-independent, reflecting similar trends, or lack of them, in the temperature data for this time period. Another



a) Soundings between 1414 GMT and 1600 GMT

Figure 4-13 Relative Humidity Soundings for 7 July 1970



b) Soundings between 1700 GMT and 1900 GMT

Figure 4-13 Cont'd

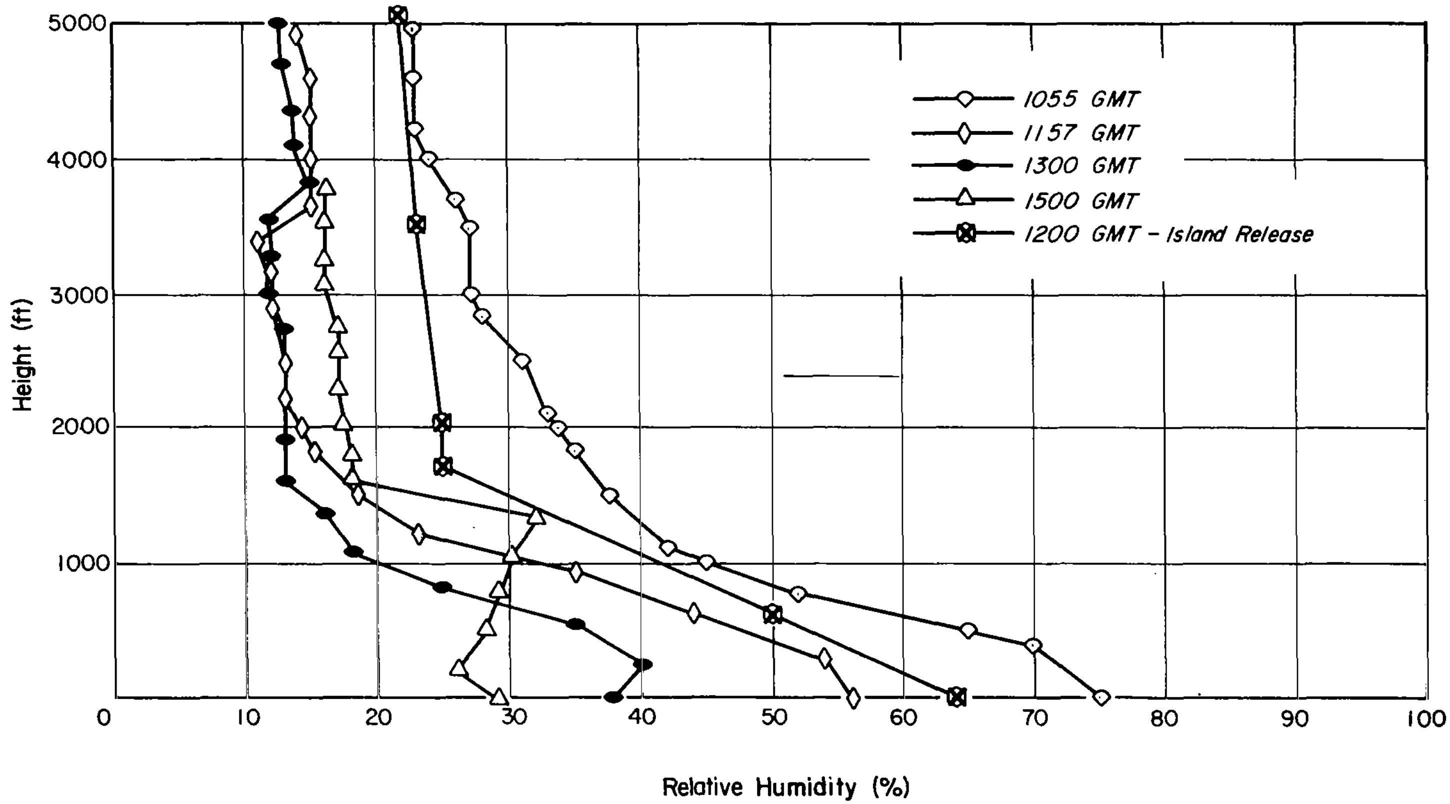


Figure 4-14 Relative Humidity Soundings for 8 April 1969

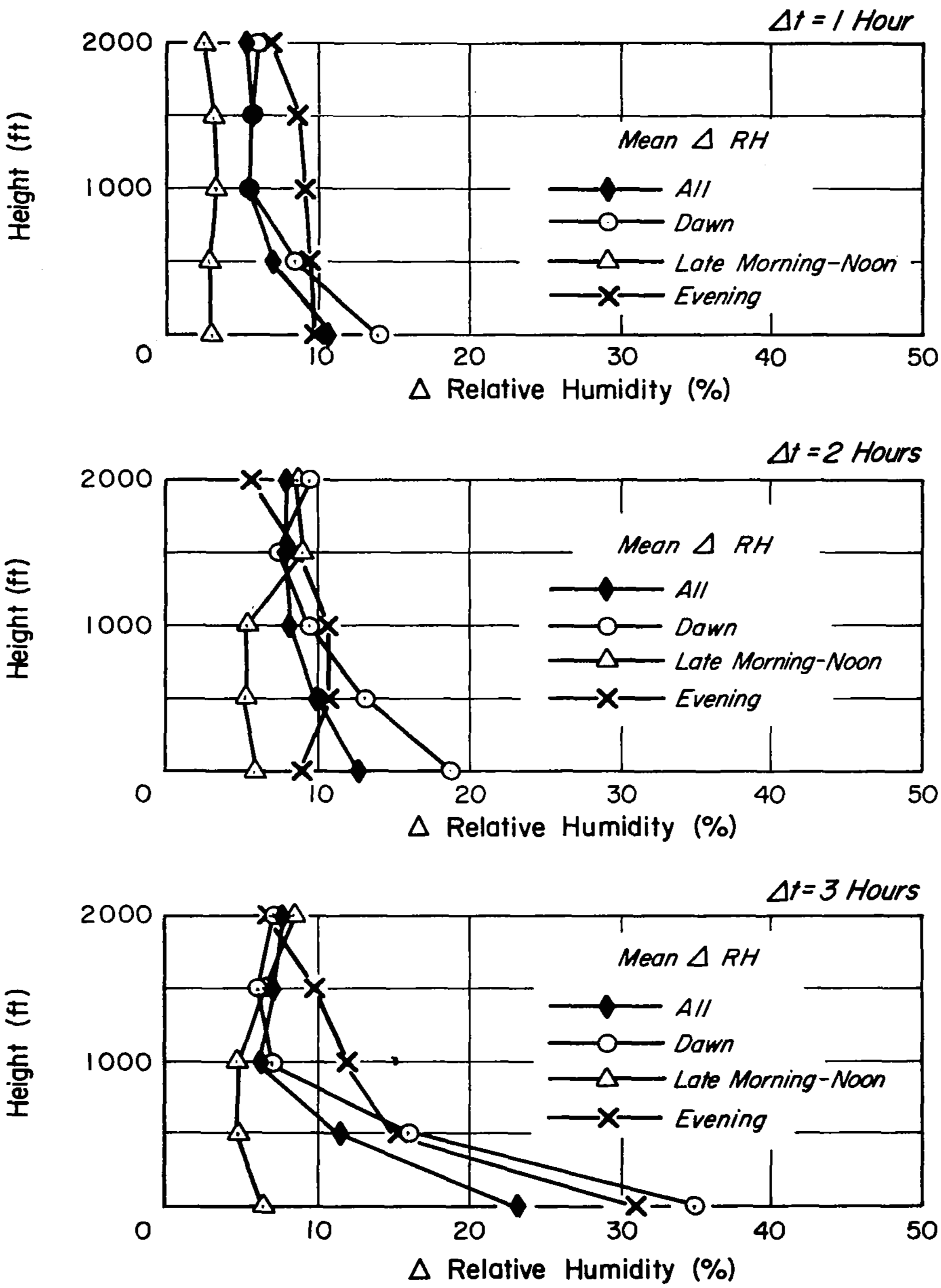


Figure 4-15 Analysis of Temporal Variabilities of Relative Humidity where $\Delta RH = \left| RH_t - RH_{t + \Delta t} \right|$

significant feature in the profiles shown is the almost constant values of Δ(RH) above 1000 ft. This feature was also found for the temperature data shown in Figure 4-7. These statistical data further substantiate the suggestion of high correlation between temporal variabilities in temperature and relative humidity.

4.2.2 Relative Humidity Profiles

The profiles of relative humidity exhibit a greater variety of "shapes" than did the profiles of temperature. Also, unlike temperature profiles, no standard lapse rate exists against which vertical changes in relative humidity can be compared. However, the profiles do exhibit certain characteristic shapes. The sequence of profiles shown previously in Figures 4-13a and 4-13b with their generally increasing values of relative humidity are typical of the late afternoon and evening profiles in the data sample. However, more typical of the early and late morning profiles are the sequences made on 8 April 1969 shown previously in Figure 4-14. Characteristic of these profiles are the high values of relative humidity and the layered structure below 1000 ft.

These features of the individual profiles are preserved even in the mean values shown in Figure 4-16. To arrive at these mean normalized profiles, the individual profiles were normalized to a value of RH = 0 at the surface. All points above the surface were computed from the mean value of the vertical gradient (or lapse rate) of relative humidity. By using gradient values and normalization, the characteristic profile shape is preserved without having to deal with the large differences in absolute values of relative humidity between profiles.

The Dawn profile shows that on the average, there is a moist layer at least 1000 ft deep at the surface. Above this layer, the relative humidity tends to fall off rapidly with height, with the relative humidity at 2000 ft on the average being some 8 to 9% less than the surface on the top of the moist layer. The Late Morning - Noon profile shows less well-defined structures with the vertical variability greatly reduced. By evening, the vertical variability remains small. However, there is an indication that above 1500 ft, the relative humidity falls off more rapidly.

It is important to recognize that the "typical" profile shapes shown in Figure 4-16 are typical only in the mean. Departures from these shapes are common. Figure 4-17 shows, for example, the relatively complicated changes in humidity structure for 28 April 1969 resulting from the complex changes in synoptic events discussed previously in Section 4. 1. Even on a day with well settled weather, as that found on 7 July 1970, the vertical distribution of relative humidity can depart from the mean profiles. The hourly values of relative humidities for the surface and at 1000 ft intervals for this day are shown plotted in Figure 4-18. From this figure it may be seen that prior to the "drying out" of the surface moisture, no

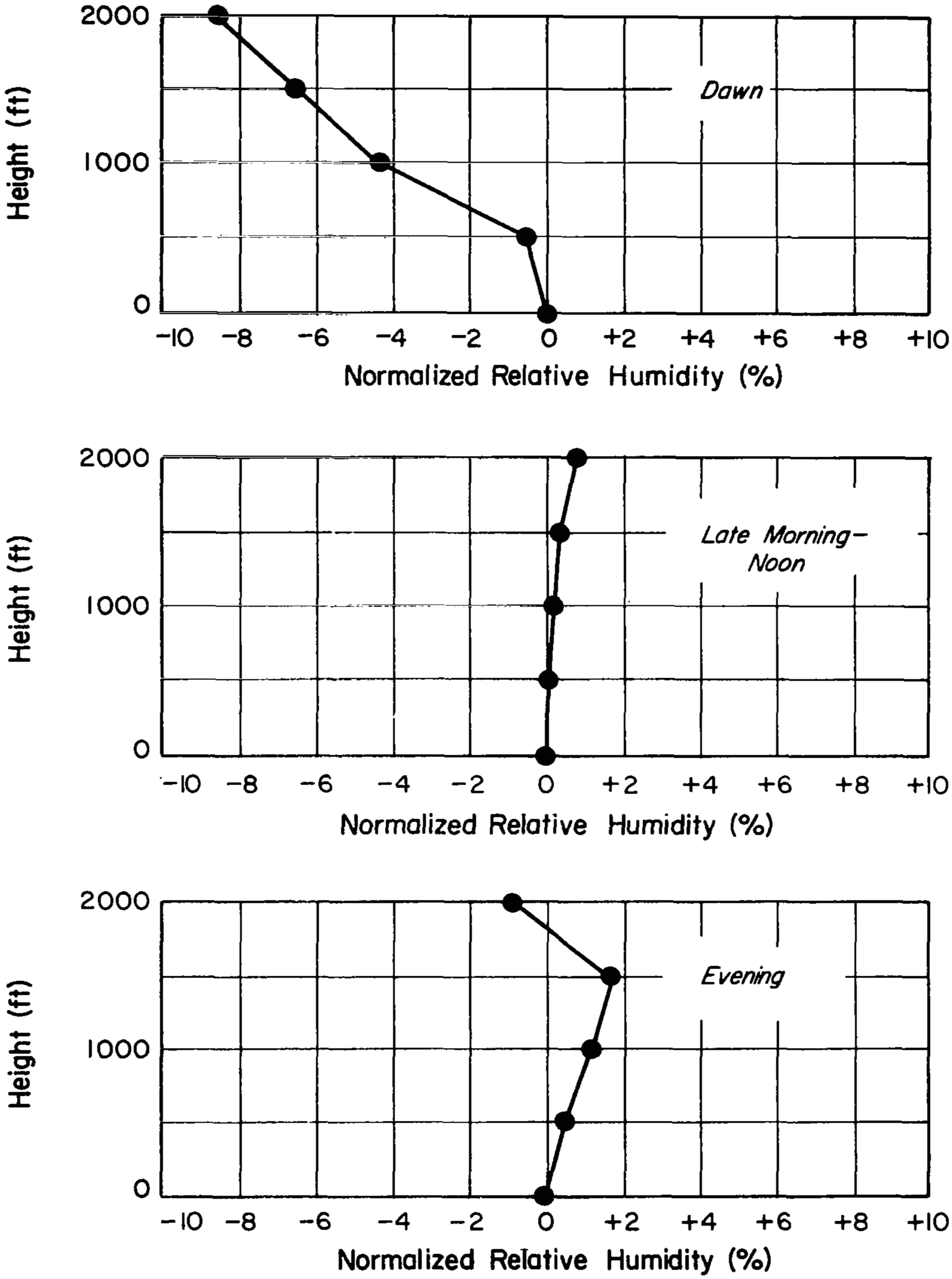


Figure 4-16 Normalized Relative Humidity Profiles

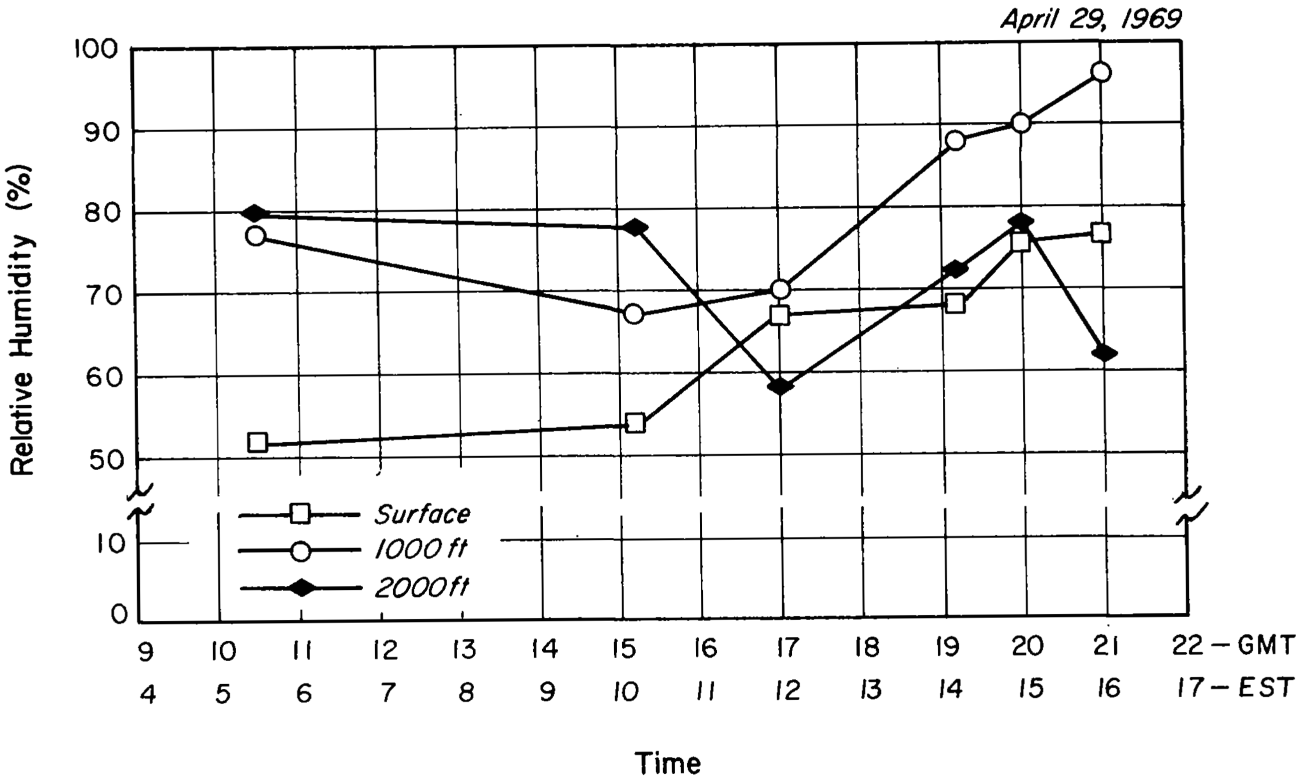


Figure 4-17 Temporal Changes in Relative Humidity for Wallops Station on 29 April 1969

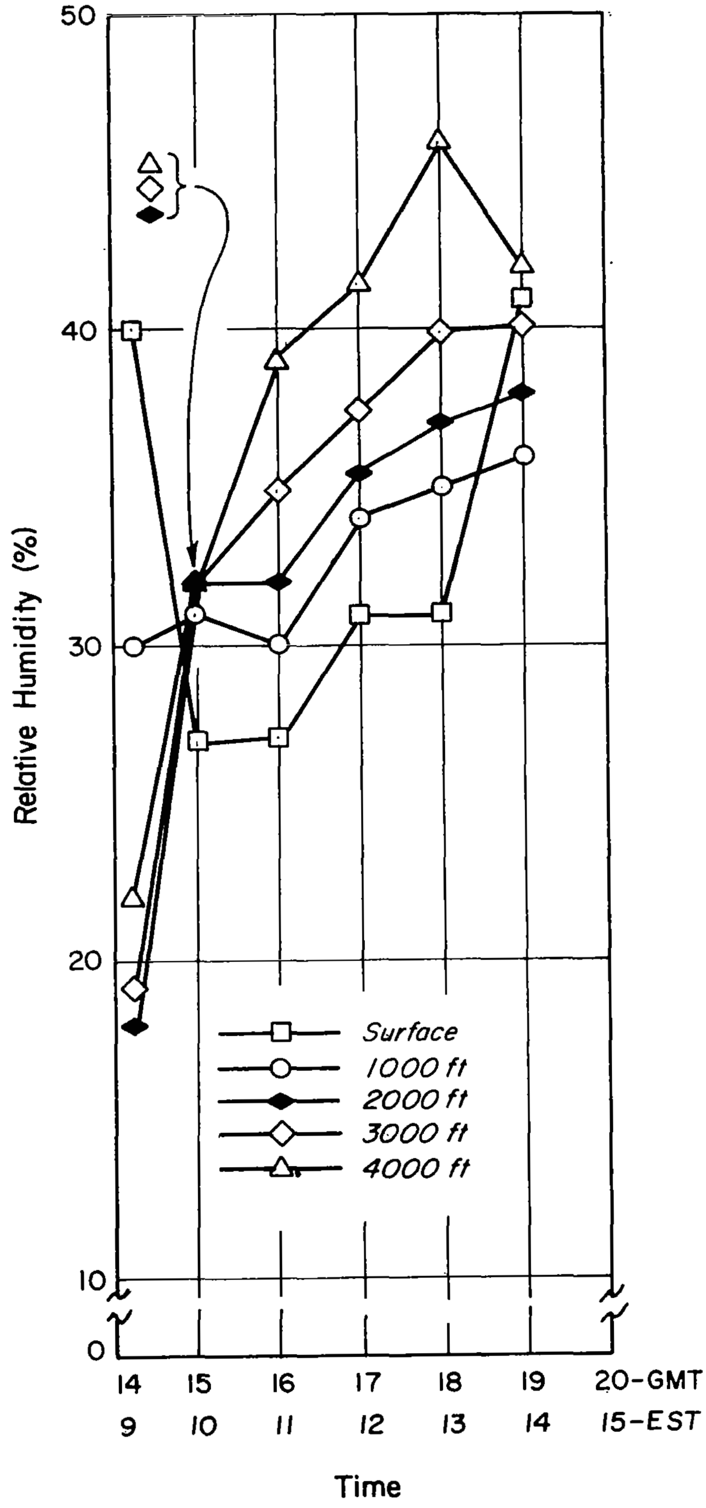


Figure 4-18 Temporal Changes in Relative Humidity for Wallops Station on 7 July 1970

layer structure existed at the surface. Instead, the relative humidity decreases rapidly with height from the surface to 2000 ft. The data for 1500 GMT show that by this time the relative humidity increases with height from the surface to 1000 ft and remains nearly constant to 4000 ft. In the late morning hours, the profiles do show a small increase in relative humidity with height, characteristic of the mean profile for this time period. These two examples suggest that the mean profiles of relative humidity should be used only for the planning of meteorological data support and not in actual computations requiring detailed and accurate values of relative humidity.

4.2.3 Spatial Variabilities

Neither of the two special radiosondes launched on the Island on 20 January 1971 and 22 January 1971 corresponded, in time, to any of the relative humidity sondes launched on these two days at the Airport. It was necessary, therefore, to compare these data with the Airport launches which occurred nearest to them in time. Figure 4-19 shows the 1530 GMT Island launch of 22 January 1971 with the 1502 GMT launch on the same day at the Airport. The Island data from the 1630 GMT launch on 20 January are shown plotted in Figure 4-20. Also plotted in this figure are the data from the 1756 GMT launch made on the same day at the Airport. From just these two sets of data it is clear that comprehensive conclusions cannot be drawn. Perhaps the only statement that can be made regarding the data, when compared with the temperature data shown previously, is that the spatial difference in relative humidity is much more pronounced than spatial differences in temperature.

As in the case of the temperature data analysis, the relative humidities deduced from the regularly scheduled radiosonde data from Wallops Island were used to increase the spatial data sample. Differences between the Island and the corresponding Airfield measured values of relative humidity were computed for each data pair and at each 500-ft height increment. The results of these calculations are shown in Table 4 where $\Delta(RH) = \left| (RH)_A - (RH)_I \right|$ with the subscripts A and I denoting, respectively, the Airfield and the Island.

It is interesting to note that the largest values in Table 4 are found for the surface. This is not an unexpected result in view of the proximity of the Island to the Atlantic Ocean. More significant is the fact that while the values of $\Delta(RH) = RH_A - RH_I$ were of both signs, positive and negative, for the other four levels, the values of $\Delta(RH)$ for the surface were all < 0 showing that in general the air over the Island was much more moist, and in at least one instance the difference in surface relative humidity between the Island and the Airport exceeded 50%.

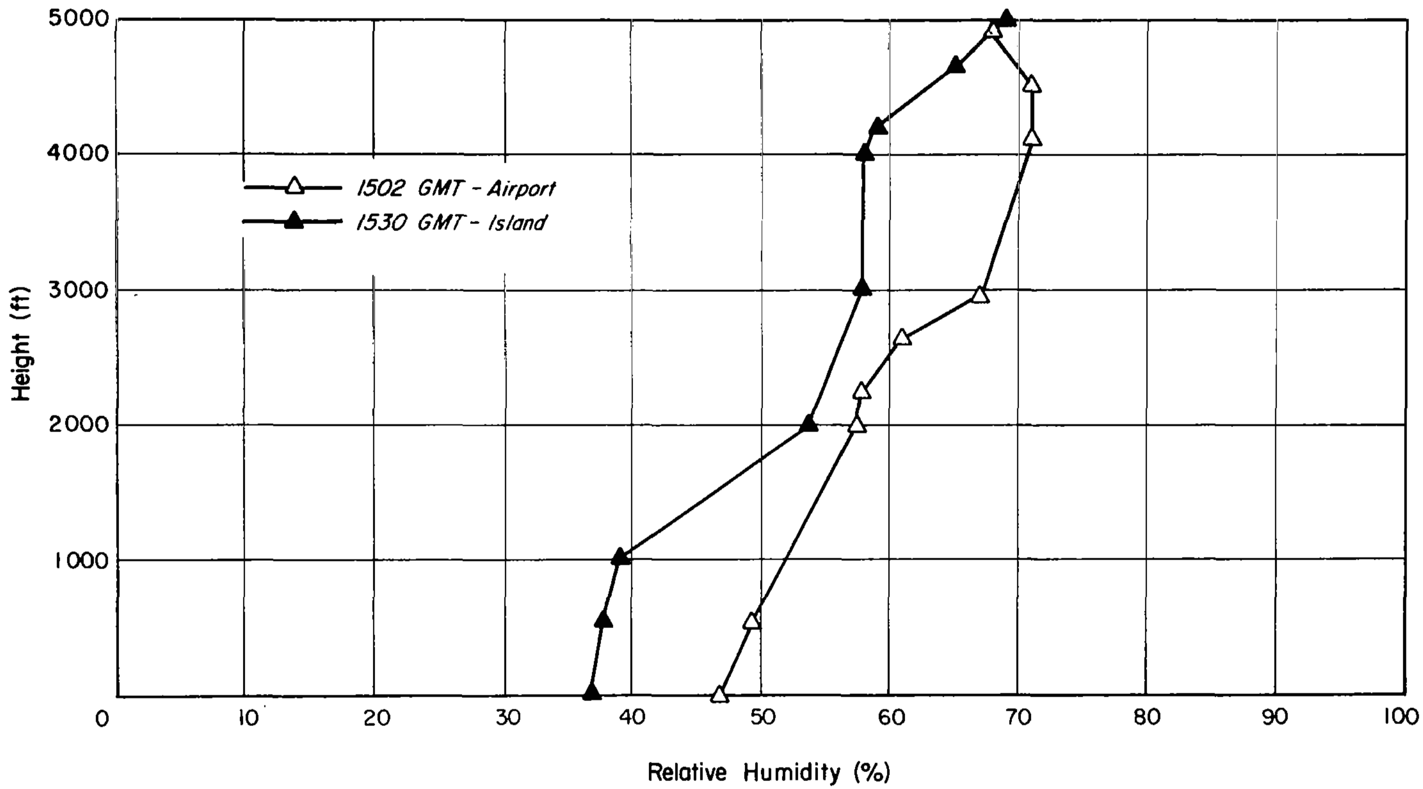


Figure 4-19 Comparison of Relative Humidity Profiles over Wallops Station and Wallops Island on 22 January 1971

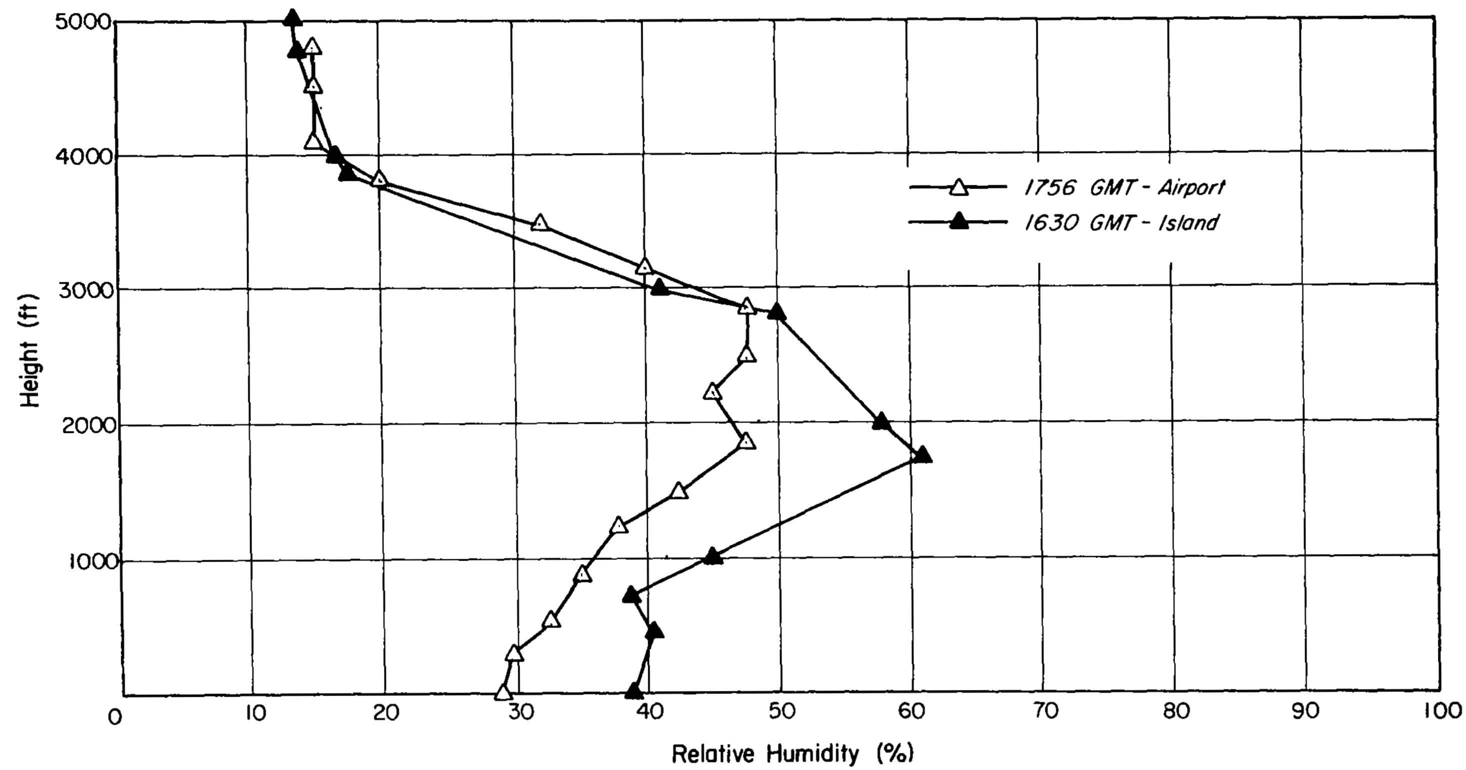


Figure 4-20 Comparison of Relative Humidity Profiles over Wallops Station and Wallops Island on 20 January 1971

TABLE 4

SPATIAL DIFFERENCES IN RELATIVE HUMIDITY

	Surface	500 ft	1000 ft	1500 ft	2000 ft
Mean Δ(RH)	22%	11%	5%	8%	7%
Max Δ(RH)	53%	22%	19%	27%	16%

4.3 Wind Variabilities

The effect of wind on noise propagation, i.e., velocity, is well known. Less known, however, is its effect on noise attenuation. However, from an experimental point of view, the magnitude of the wind speed and its "gustiness" at microphone levels is of great importance in obtaining useful noise measurements. It has been the recommended practice to make outdoor noise measurements only when the wind speeds at microphone levels are 10 ft/sec or less. At higher wind speeds, there is an apparent likelihood that spurious noise signals will be induced in the microphone. It is because of this operational requirement that most of the past flyover noise measurements have been made in the early morning hours when surface wind speeds are expected to range from calm-to-light and the turbulence suppressed. This is evident, for example, in the recorded wind speed and direction for 21 January 1971 reproduced in Figure 4-21. Up to 0830 EST, the surface wind speed at Wallops was essentially calm. By 0830 GMT, the wind direction shows definite inclination towards 180°, while the surface wind speed, though still light, begins to exhibit some positive value. As the day progresses, the wind speed, and turbulent fluctuations in the wind speed, increase. By 1600 GMT, the mean wind speed increased to a point where it exceeded the maximum value of 6 knots ($\sim$ 10 ft/sec) recommended for noise measurements.

This above example, illustrating the increasing surface wind speeds and turbulence subsequent to sunrise, is typical of the temporal changes in surface wind conditions found in the data sample. Table 5, for example, shows the hourly mean maximum and minimum values of surface wind speed derived from all of the cases between the morning hours of 1000 GMT and 1400 GMT. The mean values tabulated were derived for each of the time intervals defined by the specified hour $\pm$ 1/2 hour. Also shown in the table are the maximum instantaneous values found in the entire data sample for that hourly interval. It is clear that while the mean wind speed may remain well within the recommended limits, instantaneous values and gusts may well exceed this value. An example of this possibility is shown in Figure 4-22 which reproduces the wind data for 8 April 1969. This set of uncharacteristic data has a number of time intervals during the morning hours in which the

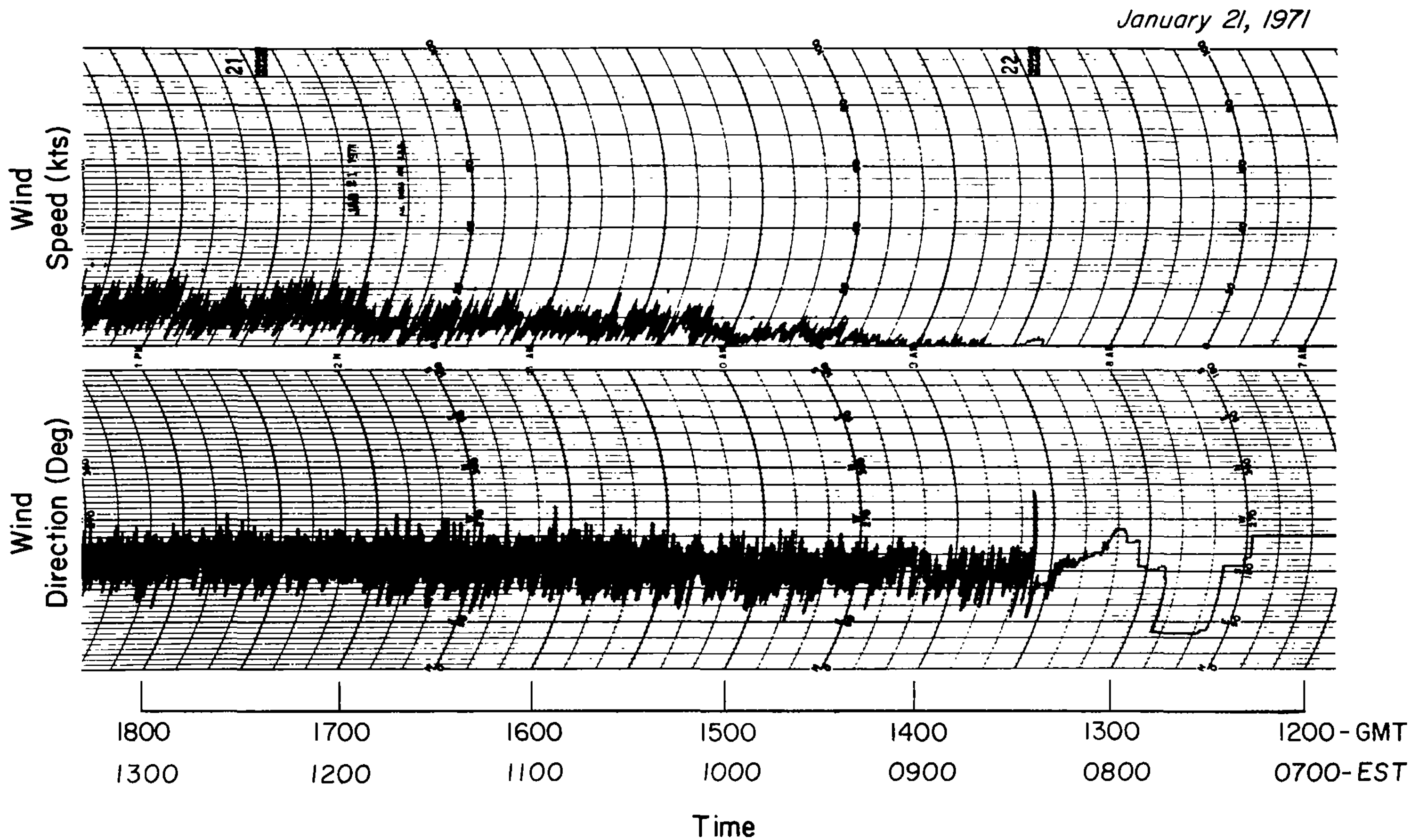


Figure 4-21 Surface Wind Data for 21 January 1971

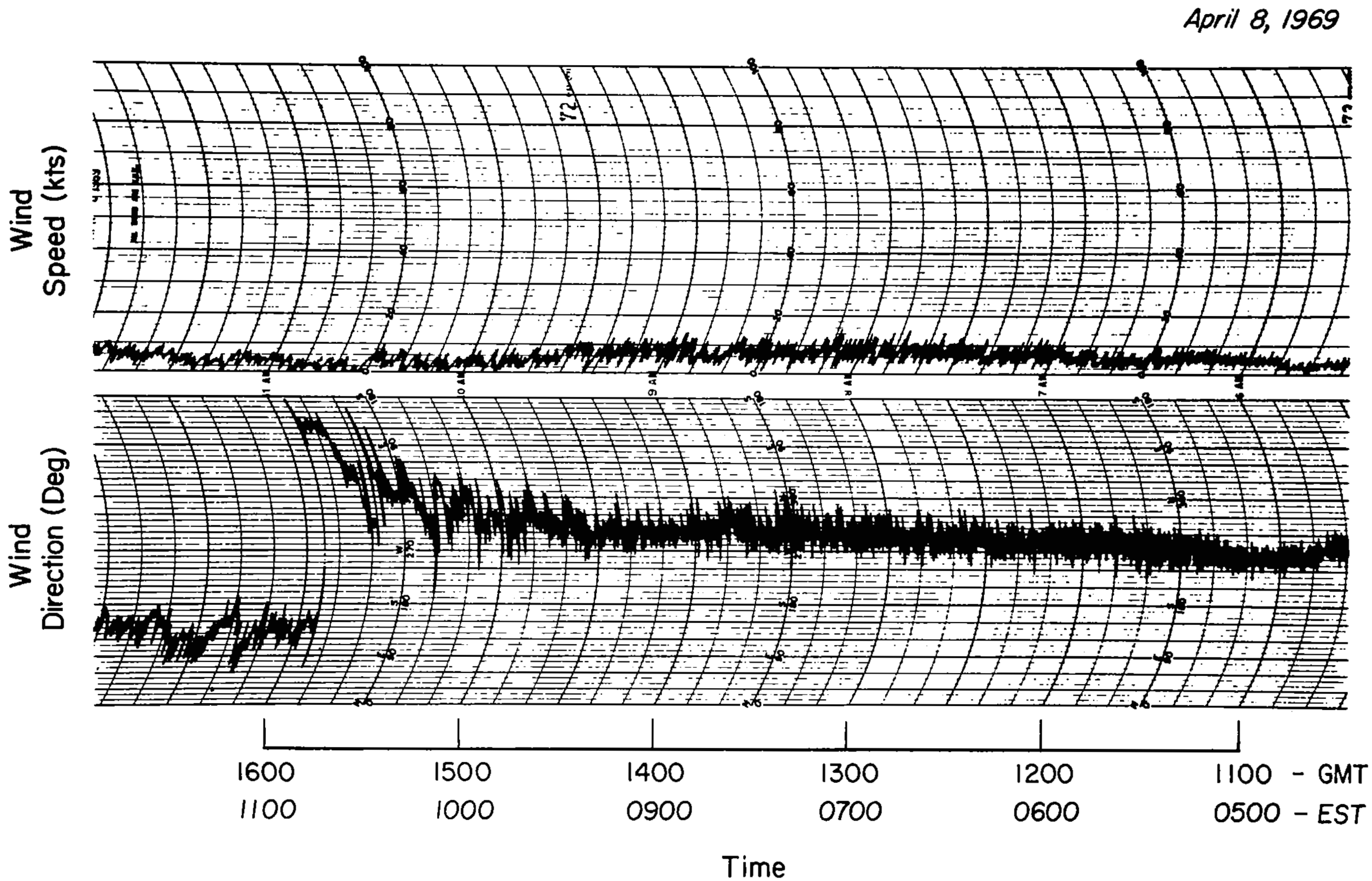


Figure 4-22 Surface Wind Data for 8 April 1971

mean wind speed is less than the recommended 6 knots or (~ 18 ft/sec). However, the wind is "gusty" and it is evident that for no significant time interval does the wind speed remain below 6 knots.

TABLE 5

TEMPORAL VARIABILITY OF SURFACE WIND SPEED (FT/SEC)

	Time (GMT)				
	1000	1100	1200	1300	1400
Averaged Hourly Mean	5	6	9	11	13
Mean of Hour Max.	6	11	14	18	19
Mean of Hourly Min.	4	3	5	5	6
Individual Max.	12	22	24	27	47

As far as the variabilities in wind speed and direction at other levels are concerned, the examples shown previously in Figures 3-2 and 3-3 are illustrative. With the clear weather patterns associated with the data sample, the wind profiles exhibited very little directional and speed shear in the early and late morning sequences. Some of the late afternoon sequences did exhibit shears resulting from the sea breeze effects. However, the number of cases with such shears was too small to permit statistical analysis.

5. CONCLUDING REMARKS

5.1 Summary of Results

The meteorological data sample analyzed in this study was derived primarily on days with well-settled weather and clear skies, conditions typical of high-pressure systems. Analyses of these data, discussed in detail in Section 4, show that under these rather restrictive synoptic conditions, the variabilities of atmospheric parameters, especially those of temperature and relative humidity, fall into three categories corresponding to the time of day.

5.1.1 Periods of Rapidly Changing Temperature and Humidity

During the early morning hours, at and shortly after sunrise, maximum values of temporal changes in both temperature and relative humidities are found within the surface layer up to approximately 1000 ft. In a three-hour interval, the mean net change in surface temperature in this time period exceeded $7^{\circ}C$. At the higher noise frequencies, using nominal values of surface temperature and relative humidities, this change in temperature represents a change in the noise attenuation of the order of $\pm$ 5 db/1000 ft. More significant are the corresponding changes in relative humidity. In the mean, the net change in surface relative humidity for a three-hour interval during the early morning hours was found to exceed 30%. Even at the high values of relative humidity found during these early morning hours, a 30% change in relative humidity could well mean a change in the noise attenuation coefficient, at the high frequencies, well in excess of 15 db/1000 ft. These large and rapid changes in atmospheric parameters are, fortunately, restricted to the surface and near-surface layers. Above 1000 ft, the data show that the variabilities are generally suppressed to levels which may be considered insignificant compared to the accuracies of the measurements.

The type of variability profile characteristic of the morning hours is, to a lesser extent, also found for the late afternoon and early morning samples. The dependence of the magnitude of variability in both temperature and relative humidity is still evident. However, the absolute values of temperature and humidity changes at all levels are considerably reduced.

5.1.2 Period of Minimum Changes in Temperature and Humidity

During an approximately three-hour period subsequent to 1400 GMT and prior to the onset of large turbulent fluctuations, the temporal variabilities of temperature and moisture are negligible, generally less than $1^{\circ}C$ for temperature and less than 10% for relative humidity, and are nearly independent with altitude. In fact, it is only during these hours that a high correlation exists between surface and upper-air values such that the profiles of temperature and relative humidity up to aircraft altitudes may be extrapolated using surface values. More importantly, it appears that during this time data from a single radiosonde ascent can be truly representative of the whole period, thus providing nearly ideal conditions for aircraft noise measurements. From the limited data available, it also appears that this "stable" period is extended into the early afternoon hours when high and middle clouds are present.

5.1.3 Spatial Variabilities

The results of the analysis show that lateral variabilities of atmospheric parameters, using limited data, have smaller values than expected despite the large differences in surface characteristics in the vicinity of the Wallops Airport and the Island. These differences did manifest themselves in the large differences in the surface values of relative humidity between the Island and the Airport, which on occasion exceeded 50%. However, this systematic difference did not appear to "penetrate" to the higher levels.

5.1.4 Wind Variabilities

With the predominance of high-pressure systems and early morning hour measurements, the wind data show no appreciable shear in either direction or speed with height. As far as the surface wind speeds are concerned, no unexpected results were found. In general, calm-to-light wind conditions prevailed during the early morning hours. Shortly after sunrise, wind speeds begin to increase and as the surface "heats up", turbulent fluctuations in wind speeds and direction increase. Maximum values of both the speed and fluctuations are generally reached shortly after local noon.

5.2 Recommended Procedures for Obtaining Meteorological Data to Support Aircraft Noise Measurements

5.2.1 Optimum

Based on the results of the analyses presented in Section 4 and summarized in Section 5.1, it is clear that under the restrictive weather conditions associated with the data sample, the best time period to perform aircraft noise measurements is during the late morning hours, subsequent to about 1400 GMT when the variability of the vertical distributions of meteorological parameters are at a minimum. This lack of significant change in temperature and relative humidity makes it possible to use a single set of vertical profiles for the definition of the atmospheric structure. The vertical measurements should be supplemented by continuous measurements of surface parameters at one or more locations in the vicinity of the Airport. These measurements should be displayed in real time to identify, for operational purposes, (1) the time at which surface values of temperature and humidity become stabilized, and (2) the time of the onset of high surface winds and turbulence. The first of these time marks would initiate both the aircraft flight program and the acquisition of the upper-air data by radiosonde ascent. The second of the time marks would signal the termination of useful data acquisition. In the presence of clouds at high or middle levels, this optimum time period is probably extended into the early afternoon hours.

5.2.2 Acceptable

Since on clear days the time interval is very short during which the upper-air parameters are stabilized and surface wind speeds remain acceptable, it appears more than likely that many of the future aircraft noise measurements will continue to be made in the early morning hours. The results of this study suggest that to obtain useful meteorological data during this time period, it will be necessary to monitor, on a continuous basis, surface parameters, and at least at half-hour intervals, parameters at an elevation of a few hundred to 1000 ft above the surface. However, the study also suggests that a single radiosonde launch sometime during the experimental period appears adequate to define the atmospheric parameters above this surface layer (about 1000 ft at Wallops) provided no significant synoptic event, such as a frontal passage, takes place locally.

In the light of the above discussion, it appears that during the late morning hours, continuous surface measurements and measurements at airport tower levels, will be sufficient to monitor the layer of the atmosphere in which the largest variabilities occur. These measurements, together with a single set of radiosonde measurements will provide adequate definition of atmospheric structure for the noise measurements. At other times of the day, it appears that systematic sequential radiosonde ascents at 1/2 hourly intervals will still be required to monitor the large changes of parameters up to 1000 ft.

6. REFERENCES

1. Harris, C. M., 1963: "Absorption of Sound in Air in the Audio-Frequency Range," Journal of the Acoustical Society of America, Vol. 35.

2. Burkhardt, M. D., H. B. Karplus and H. J. Sabine, 1960: Sound Propagation Near the Earth's Surface as Influenced by Weather Conditions, Technical Report, Contracts AF 33(616)-2470 and AF 33(616)-5091, Armour Research Foundation of Illinois Institute of Technology.

3. Sherr, P. E. and D. T. Chang, 1970: "Meteorological Aspects of the Aircraft Noise Problem," Proc. of the Fourth National Conference on Aerospace Meteorology, American Meteorological Society.

4. Bishop, D. E., M. A. Simpson and D. T. Chang, 1971: Experimental Atmospheric Absorption Values from Aircraft Flyover Noise Signals, Final Report, Contract NAS-168, Bolt, Beranek and Newman, Inc., Van Nuys, California.

APPENDIX

The Appendix contains a listing of the special radiosonde ascents made at Wallops Station which provided the upper air meteorological data used in this study. The 1970 and 1971 ascents were made especially for this study. The remaining data sets were obtained in support of other NASA programs at Wallops.

The ascents are tabulated by date and time of launch, given in Greenwich Mean Time (GMT). The specific parameter or parameters, i. e., temperature and/or relative humidity measured for each of the ascents is also indicated. The notation "N. G." denotes "garbled" data or that the data are otherwise unusable.

SUMMARY TABULATION OF UPPER AIR DATA

Date	Time (GMT)	Type of Ascent	
		Temperature	Relative Humidity
5 March 1969	1235	N.G.	
	1307		X
	1337	X	
	1500		N.G.
6 March 1969	1214	X	
	1246		X
	1315	X	
	1348		X
13 March 1969	1123	X	
	1150		X
	1218	X	
	1245		X
	1313	N.G	
14 March 1969	1100	X	
	1130		X
	1200	X	
	1230		X
	1300	X	
	1330		N.G.
	1355	X	
15 March 1969	1140	X	
17 March 1969	1100	X	
	1130		X
	1200	X	
	1230		X
	1300	X	
	1330		N.G.
	1400	X	
	1430		X
	1500	X	
	1530		X
	1600	X	
25 March 1969	1600	N.G.	
	1645		X
28 March 1969	1055	X	
	1125		X
	1155	X	
	1225		N.G.
	1255	X	
	1325		X
	1355	X	
	1425		X
	1455	N.G.	
	1525		X

Date	Time (GMT)	Type of Ascent	
		Temperature	Relative Humidity
8 April 1969	1030	N. G.	
	1055		X
	1128	X	
	1157		X
	1228	X	
	1300		X
	1330	X	
	1400		X
	1430	X	
	1500		X
	1555	X	
9 April 1969	1050	X	
	1130		X
	1150	X	
	1230		X
	1250	N. G.	
	1400		X
	1430	X	
29 April 1969	0954	X	
	1032		X
	1115	N. G.	
	1408	X	
	1510		X
	1610	X	
	1704		X
	1815	X	
	1845	X	
	1908		X
	1934	X	
	2002		X
	2038	X	
	2056		X
	2128	X	
10 July 1969	1005	N. G.	
	1045		X
	1210	N. G.	
	1320		X
	1345	X	
	1415		X
	1440	X	
11 July 1969	1020		N. G.
	1050		X
	1115	X	
	1145		X
	1215	X	
	1245		N. G.
	1315	X	
	1345		N. G.
	1415	X	

Date	Time (GMT)	Type of Ascent	
		Temperature	Relative Humidity
26 August 1969	1800	X	
	1845		X
	1920	N. G.	
	1947		X
	2020	N. G.	
	2100		X
	2130	X	
	2200		X
	2250	X	
	2320		X
(27 August 1969)	0007	X	
28 August 1969 (Morning)	1000	N. G.	
	1044		X
	1110	X	
	1145		X
	1230	X	
	1300		N. G.
	1330	X	
	1415		X
28 August 1969 (Night)	2030	X	
	2100		X
	2130	X	
	2200		X
	2230	X	
	2300		X
	2330	X	
29 August 1969	1700	X	
	1900		X
	1930	X	
	2000		N. G.
	2030	X	
	2100		X
	2145	X	
24 October 1969	1105	N. G.	
	1140		X
	1208	X	
	1230		X
	1300	X	
	1330		X
	1400	N. G.	
	1430		N. G.
31 October 1969	1108	N. G.	
	1135		X
	1205	X	
	1232		X
	1303	X	
	1330		X
	1355	X	

Date	Time (GMT)	Type of Ascent	
		Temperature	Relative Humidity
8 November 1969	1135	X	
	1200		X
	1230	X	
	1300		X
	1330	X	
	2400		X
	1430	X	
	1520		X
	1545	X	
	1635		X
	1651	X	
	1830	X	
	1855		X
13 November 1969	1135	X	
	1205		N. G.
	1235	X	
19 May 1970	1425	X	
	1500		X
	1520	X	
	1546		X
	1655	X	
	1725		X
	1820	X	
9 June 1970	1620	X	X
	1705	X	X
23 June 1970	1500	X	X
	1559	X	X
	1700	X	X
	1755	X	X
	1855	X	X
30 June 1970	1420	X	X
	1503	X	X
	1600	X	X
	1800	X	X
	1904	X	X
7 July 1970	1414	X	X
	1501	X	X
	1600	X	X
	1700	X	X
	1800	X	X
	1900	X	X

Date	Time (GMT)	Type of Ascent	
		Temperature	Relative Humidity
20 January 1971	1430	X	
	1502		X
	1530	X	
	1614		X
	1650	X	
	1817	X	
	1842		X
	1923	X	
	1954		X
21 January 1971	1432	X	
	1500		X
	1525	X	
	1600		X
	1626	X	
	1735	X	
	1756		X
	1826	X	
	1852		X
	1923	X	

NASA-Langley, 1972 —— 2 CR-1945