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NORTH ATLANTIC TRIAL OF AN AUGMENTED PROGRAMME OF UPPER AIR OBSERVATIONS

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TABLE OF CONTENTS

Appendices

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

REPORT ON NORTH ATLANTIC TRIAL OF AN AUGMENTED PROGRAMME OF UPPER AIR OBSERVATIONS CARRIED OUT FROM 9 MARCH TO 2 APRIL 1952 AS A RESULT OF ACTION BY THE ICAO COUNCIL ON RECOMMENDATION NO. 7 OF THE 3rd SESSION OF THE MET DIVISION

INTRODUCTION

1. With the large increase in long-distance flights during and since World War II, considerable interest developed in determining the most favourable path to follow in the conduct of such flights. It had long been realized that, by following a path other than the standard great circle or rhumb line tracks and so taking advantage of the wind distribution, a flight could often be accomplished in shorter time. Several procedures were developed for planning flights in relation to the wind distribution and in recent years the use of these procedures has become known as "pressure pattern flying".

2. The success with which the various presssure pattern flying techniques may be applied depends largely on the following factors:

a) The accuracy to which the actual wind conditions and altitudes of pressure surfaces are known by meteorologists and by aircrews;

b) The accuracy of the forecasts of those elements for some specified time in the future.

3. Radiosonde and radiowind observations made twice a day at 0300 GMT and 1500 GMT have long formed the basis for determining the actual and forecast values of the elements referred to in paragraph 2. Over the past ten years, while there has been an increase in the number of locations at which these upper air observatiions are taken, the frequency has not generally exceeded two per day although some stations have made four observations daily (either radiosonde, radiowind or both) for varying periods.

4. It has been the belief of many of those connected with long-distance aircraft operations that an increase in the number of upper air observations would increase the accuracy with which the current and forecast wind distribution could be determined and thus increase the success with which the various "pressure pattern flying" techniques could be applied.

5. This is a report on a project conducted over the North Atlantic in the Spring of 1952 in an attempt to evaluate the effect of additional upper air observations on aircraft operations.

HISTORY

6. At the Third Session of the MET Division, held in Paris in February-March 1950, the possibility of improving and unifying the

procedures for pressure pattern flying was discussed. It was decided that, before attempting to lay down world-wide procedures, an experimental programme should be set up in a region where pressure pattern flying techniques are used. Accordingly, the Division made the following recommendation:

Recommendation No. 7

Procedures for Pressure Pattern Flying. It is recommended that;

7.17.1
The following programme be implemented, as soon as practicable by the States concerned, in the North Atlantic Region of ICAO, to serve as a basis for the future establishment of standard meteorological procedures for pressure pattern flying;

7.17.1.1
Radiosonde and radiowind observations should be made at six-hourly intervals, i.e., at 0900 and 2100 GMT in addition to 0300 and 1500 GMT, from all ocean weather stations in the region, as recommended by the Second NAOS Meeting, and from a selection of the other upper air stations in the region. The selection of stations will be established by the ICAO Secretariat after consultation with the States concerned;

7.17.1.2
The parts of radiosonde and radiowind reports up to and including the 400 mb. level from ocean weather stations should be transmitted with minimum delay to those meteorological offices in the region requiring them;

7.17.1.3
Meteorological offices providing advice for pressure pattern flights should prepare upper air charts for the appropriate pressure levels on a six-hourly basis, i.e., for the standard hours 0300, 0900, 1500 and 2100 GMT, and such prognostic charts as may be required for aircraft operations;

7.17.1.4
Forecasts of the "D" values* for the major international aerodromes should be readily available on a request basis from the meteorological offices serving these aerodromes. If the demand becomes too great for satisfactory handling on a request basis, forecasts of the "D" values should be appended to aerodrome forecasts included in the routine meteorological broadcasts to aircraft in flight. For broadcast purposes, forecasts of the "D" values should be in such a form as to permit reasonable

* "D" value is the difference between the actual height above mean sea level and the altitude at which the pressure at that height occurs in the standard atmosphere, i.e., $D = Z - Z_p$ where

Z = actual altitude

Z_p = pressure altitude

determination of the "D" value for any particular time within the period of validity of the forecast;

7.17.2
The above programme be reviewed at the next North Atlantic Regional Air Navigation Meeting of ICAO in order to assess, as far as possible, its value in relation to the economical aspects of the operation of aircraft through the North Atlantic Region;

7.17.3
The Council of ICAO take appropriate action to ensure:

7.17.3.1
That all possible steps are taken to develop more accurate radio and pressure altimeters for use in determining "D" values:

7.17.3.2
That, in the meantime, methods be developed for determining more accurate corrections to values of "D" values as measured by equipment currently in use;

7.17.3.3
That fullest use be made of existing methods in the determination and application of systematic errors arising in the "D" values as computed in the air, and that only corrected values be transmitted in the in-flight reports from aircraft to ground.

It was also agreed by the MET Division that the purpose of paragraph 7.17.1 of Recommendation No. 7 would be served if the following numbers of upper air stations could increase their programme of radiosonde and radiowind observations to four per day:

Western seaboard of Europe	5 stations
Atlantic Ocean including islands	10 stations
Eastern seaboard of North America	7 stations

7. The ICAO Council approved the recommendation at the Second Meeting of its Eleventh Session (29 September 1950) and directed the Secretary General to ask the States concerned for comments on the plan and, in particular, on the practicability of making four radiosonde observations per day. The replies from the States revealed a positive interest in the programme, but indicated that due to staff and financial limitations it would be impossible to carry it out in its entirety.

8. Consequently, the Air Navigation Commission agreed that an intensive experiment for a period of one or two weeks would be an acceptable compromise. A detailed proposal for making such an experiment for the much shorter period was then submitted to States (on 31 July 1951). The replies indicated a willingness of most States to carry out the short period programme but Canada and the United States stated they could not do so during the proposed periods - 25 October to 1 November and 15 to 22 November 1951. In view of the fact that the non-participation of Canada and the United States

in the scheme would mean the absence of important additional observations, the Air Navigation Commission decided to postpone the programme until the Spring of 1952.

9. The following dates were finally chosen, taking into consideration the requirements for a period of great variability in weather conditions and for sufficient advance notice to the States:

9-15 March 1952	Control Week
16-22 March 1952	Test Week
23-29 March 1952	Control Week
30 March - 5 April 1952	Test Week
6-12 April 1952	Control Week

Although only the normal upper air observation programme was to be carried out during the control weeks, it was necessary to include those weeks in the experiment in order to have a basis for evaluating the results of the augmented programme during the test weeks.

PURPOSES

10. The prime purposes of the trial were:

a) To determine whether more frequent observations would materially improve the accuracy of upper air forecasts;

b) To determine whether the benefits derived by air navigation from these more accurate forecasts would justify the additional cost.

11. Further, it was implied in the MET Division's statements that, having an adequate supply of observations and more reliable forecasts and prognostic charts, the meteorological procedures for utilizing these data could be standardized.

ORGANIZATION

12. The MET Division's recommendation concerning the trial gave no suggestions as to how the trial should be conducted and evaluated. The ICAO Secretariat was therefore required to arrange the details of the experiment and evaluate the results.

13. A total of thirty-four upper air stations made four radiosonde observations or radiosonde and radio/radar wind observations per day during the test weeks (2nd and 4th weeks of the trial). A number of these stations made four observations per day during the control weeks also but, in principle, forecasters had upper air charts available only for 0300 and 1500 GMT during the control weeks, whereas during the test weeks they also had available upper air charts for 0900 and 2100 GMT.

14. All operating agencies over the North Atlantic were requested to make careful checks of the forecast winds and the actual winds throughout the five weeks. In addition, the States were asked to check the

accuracy of the "D" value forecasts and the prognostic upper air charts issued by their meteorological offices.

15. The details of the organization of the trial, a description of the data received by ICAO and the methods of analysis used will be found in Appendices A, B and C.

RESULTS OF ANALYSIS

16. The results of the analysis have been divided into three parts to correspond with the three types of data received, as follows:

i) Wind data from the meteorological offices including the wind vector forecasts for certain locations and wind component forecasts for certain routes;

ii) "D" value data from meteorological offices including "D" value forecasts for certain locations for various forecast periods;

iii) Wind data from actual flights including the wind forecasts made for flights and checked by the ICAO Secretariat using original flight data.

17. Wind data from meteorological offices (Appendix D)

17.1 Most of the data received show a reduction in the mean absolute errors of the forecast mean components for a route of 1 to 2 knots in the test period* as compared with the control period*. However, the differences are not considered large enough to be regarded as significant in view of the magnitude of the differences between the errors for the individual weeks and the small number of forecasts involved.

17.2 The detailed analysis of the London and New York wind forecasts for the Shannon-Gander route shows a reduction of 0.5 knot in the New York mean absolute forecast error during the test period as compared to the control period and 1.9 knots in that of the London error. However, neither these reductions nor those found in the standard deviations are large enough to be regarded as significant.

17.3 The computations of the mean absolute errors in making 24-hour persistence "forecast"** for the Shannon-Gander route using both the London and New York "observed" values determined from upper air charts indicate that persistence of the route winds was less marked during the test period than during the control period. It is sometimes maintained that, as forecasting errors tend to be smaller, the more pronounced the persistence. Assuming this to be so, then, if the persistence had been the same during the two periods, a significant difference might have been found in the mean absolute forecast errors and in the standard deviations.

* For convenience, the second and fourth weeks taken together are referred to in this paper, as the "test period" and the first, third and fifth weeks taken together are referred to as the "control period".

** The term persistence "forecast" is used, in this paper, to describe the use of the latest available actual value of an element as the forecast.

17.4 Appreciable differences were noted in the "actual" values as obtained from the analyzed charts at the London and New York offices. Part of these differences was undoubtedly due to the fact that London calculated equivalent tail wind values while New York calculated tail wind components. However, differences from this cause would normally be less than 3 knots whereas the actual differences found in the "actual" values were generally much greater than this. They are shown in graphical form in Appendix G, Figure 1.

18. "D" Value data from Meteorological Offices (Appendix E)

18.1 A large variety of results was obtained in mean absolute and arithmetic errors but, while in most cases an improvement is noted in the test period forecasts, the improvement is not large enough or general enough to be considered significant.

18.2 The analysis of the data provided by two offices on opposite sides of the Atlantic indicates that when the effect of either "forecast difficulty" or "persistence" on the forecast error is eliminated, the residual forecasting "skill" was usually greater during the test period. Before the effect of these factors had been allowed for, the forecasting success at one of the offices appeared to be better during the test period and at the other office about the same or slightly worse.

18.3 The detailed analysis of the Gander and Paris "D" value data (Appendix E, paragraphs 1 - 3) indicates that, in so far as the 11-hour forecasts made at 0400 and 1600 GMT are concerned, forecasts based on the 12-hour persistence of the actual "D" values at 0300 and 1500 GMT would usually have been nearly as accurate, and even in some cases more accurate, during the control period but less accurate during the test period. In general, however, there are indications that the "D" value forecasts for a period up to 12 hours after the time of the latest observations are no more accurate than those which could have been made on the basis of the persistence of the observed values.

18.4 In an attempt to eliminate or compensate for factors such as differences in forecast difficulty, variations in communications, etc., which would tend to obscure the beneficial effects of the additional observations during the test period, the errors in the forecasts of "D" values made at Paris, Keflavik, Gander and New York for their respective aerodromes were grouped together. The results of this compilation of the 11-hour forecast errors are shown in the cumulative frequency curves in Appendix E, Figure 1. These curves indicate that in the extreme (and most important) forecast errors, there was an appreciable improvement during the test period. In principle, the 11-hour forecasts were based on data 13 hours old during the control period and 7 hours old during the test period. Since the 5-hour forecasts were based on the same "aged" data during both the control and test periods the two cumulative frequency curves for forecasts for this time ahead nearly coincide as would be expected and similarly with the two curves for 17-hour forecasts; the curves for 5-hour and 17-hour forecasts are accordingly not shown.

19. Wind data from actual flights (Appendix F)

19.1 No significant difference in the magnitude of the mean errors in forecast wind components for flights, or in the standard deviations of these errors, was found between the control and test periods. The mean absolute error computed from the flight data was 10.1 kts during the control period and 10.3 kts during the test period, with the standard deviations of the errors 12.5 kts and 13.5 kts respectively.

19.2 It should be noted that there was not an even distribution of flights during the five weeks and it happened that the smallest number of cases occurred during the week having the greatest mean absolute error while the largest number occurred during the week with the smallest mean absolute error. Since both weeks were control weeks, the mean absolute error for the control periods was weighted toward the lower value. If the weekly mean errors had been based on the same number of cases, the mean absolute error during the control period would have been 10.3 knots and that during the test period 10.2 knots.

19.3 The ogives and scatter diagrams in Appendix F also show no significant difference between the control and test periods.

19.4 The results of the analysis of the westbound and eastbound flights separately give a somewhat different picture. While again there was no appreciable improvement in forecast accuracy during the test period, a definite decrease was noted in the "bias" (i.e. the deviation from zero of the mean arithmetic error). During the control period the mean arithmetic forecast error for eastbound flights was +4.8 knots (optimistic) while that for westbound flights was about -4.6 knots (pessimistic). During the test period the biases decreased to +2.9 and -2.7 knots respectively. Since the biases were of opposite sign, the change was obscured when all flights were considered together. Possible reasons for the varying magnitude of these biases and their opposite sign at the two offices were sought and it was finally decided that the most likely explanation was that all forecasters concerned had a tendency to make the same errors in forecasting developments in the weather situation. The resulting arithmetic errors in the forecasts of tail wind component made by forecasters on the two sides of the Atlantic would tend to be of opposite sign because of the different directions of flight involved, while the magnitude of the mean errors would depend on the tendency of forecasters to make errors of a particular kind in the type of weather situation prevailing.

19.5 For comparison, the mean absolute and arithmetic errors were determined using the errors computed by the operators and, while the mean absolute errors are slightly less than those based on the components computed by the Secretariat from the flight data, the results are similar in so far as a comparison of the test and control periods is concerned.

19.6 The graph in Appendix C, showing a comparison of the "actual" components as computed by the Secretariat from the flight data with the values computed by the London and New York meteorological officers, clearly shows that there was such a large variation in the determinations of the "actual" conditions that any comparison of forecast errors would be inconclusive.

20. Factors contributing to inconclusive results

Several factors, which were believed to have a masking effect on the benefits of the additional upper air observations, are referred to below. It is not intended to imply that the benefits would be readily seen if these factors were eliminated in a future trial. However, it is believed important to be aware of what factors may be involved and of the need for eliminating them or their adverse effects before such an experiment can be expected to give reliable results.

20.1 Forecast difficulty

20.1.1 It is well known among meteorologists that there is a fairly large variation in the difficulty of forecasting on different occasions. The difficulty is dependent on several factors but mostly on whether or not the atmospheric conditions are in a steady or varying state and, if varying, whether or not the variations are regular or irregular. The degree of forecast difficulty is a particularly important factor when attempting to compare the accuracy of forecasts made over such a short period as five weeks.

20.1.2 Comments from the States regarding this factor follow:

France stated that the difference in the forecast errors (D values) is more readily explained by the fact that the difficulties in forecasting during the test weeks were not the same as those experienced during the control weeks.

The United Kingdom stated that, in so far as the United Kingdom was concerned, it could be demonstrated that the test weeks were more disturbed meteorologically than the control weeks. In elaborating on the statement the United Kingdom stated that this conclusion was based on an analysis of the 24-hour variations in the height of the 1000 mb. surface and that it did not imply that such an index is a measure of forecasting difficulty because, when persistence of weather types is abnormally high, substantial forecasting errors can arise from expecting a change which does not occur. The United Kingdom added that the original statement was made to point out that the period of the trial was too short.

Ireland made the statement that, in so far as there was any difference in the difficulty of making North Atlantic forecasts, it was judged that the second week (test) and the fifth week (control) were slightly more difficult than the others. With regard to the trial carried out at Dublin Airport, Ireland stated that the results must be regarded as inconclusive due mainly to the small variability of the meteorological situation and mentioned that the most frequent variations in the "D" values at Dublin Airport occurred during the first week (control) and the second week (test).

The United States stated that the synoptic situation during the fourth week (test) was exceedingly variable and difficult to forecast over the entire North Atlantic.

20.1.3 The varying and apparently conflicting reports from the States make it clear that, while an attempt has been made in this report to suggest ways of eliminating the factor of forecasting difficulty from the results, it is too complex to determine exactly.

20.2 Variations in communication conditions

20.2.1 The fact that the communication conditions vary across the North Atlantic and consequently the quality and quantity of weather data received at an office are not always the same is easily recognizable as another factor which would affect the results of a short-term experiment. However, because of the extreme difficulty in evaluating this effect on forecast accuracy, no attempt was made to eliminate it.

20.2.2 The following comments from the States regarding communications are noteworthy:

Ireland stated that the test periods were not conspicuously successful due largely to the poor transatlantic meteorological communications at the time and that it would be unfair to ridicule the indifferent results obtained since the additional information was often not received in time to be used in the preparation of the scheduled forecasts. Before consideration was given to scheduling additional upper air soundings, the standard of transatlantic communications should be drastically overhauled in an effort to repair its present unsatisfactory quality. It should not be inferred that the period of the programme was very exceptional from the point of view of transatlantic meteorological communications, since such periods of low serviceability have been by no means uncommon in recent years.

Canada stated that the report from Gander on the receipt of additional reports during the experimental programme was rather disappointing, and that it was impossible to analyze 10 out of 28 sets of extra charts. Moreover, the greatest number of additional reports received for a particular observation time was 22. Radio conditions were poor at intervals, but it was quite probable that some wastage occurred at relay points. It should be a simple matter for communicators to give special traffic such as this the same distribution as regular traffic of the same nature, but there always seemed to be difficulty in superimposing short-term transmissions of extra traffic, on an unscheduled basis, upon scheduled traffic on busy circuits. A reliable though rather cumbersome way of handling it would be by multiple addressed messages. Possibly the best way to minimize loss of traffic, without loading the circuits with lengthy addresses, would be to provide each relay centre with a check list of all reporting stations and have each originating station send, at scheduled times, either its own report or a nil report that would be carried through and checked off at each relay point. This might be considered for any future project of this nature.

20.2.3 There appear to be only two ways to eliminate this factor from the results of such a trial in the future, namely:

a) Improve the communication arrangements so that there is no variation;

b) Conduct the trial over a long enough time to ensure that the variations have an equal effect on the test and control periods.

20.3 Inexperience of forecast centres with use of the additional data

20.3.1 This factor prevailed only during the test period and is one that cannot be accurately assessed. Its effect would be to counteract any increase in forecast accuracy that might result from the additional data, because:

a) Inexperience in handling and plotting such data might result in its being overlooked;

b) Inexperience in analyzing charts at the additional times might result in lower quality in the current analyses and consequently in the prognostic charts;

c) Adoption of new personnel schedules and work-loads at a station for such a short time might not permit utilization of the new data in the most efficient manner.

20.3.2 In this connection Canada stated that, in the larger offices, the upper air work throughout the 24 hours is geared to two sets of observations per day, and to make the fullest use of four sets of observations would involve a considerable reorganization with many ramifications. The potential advantages of a change in procedure were likely to be offset initially by the change in routine. It was therefore difficult to appraise a new procedure until the staff had settled to it. It might also be that the work-load was already so great that with the present staff it was not profitable to analyze more than two sets of upper air observations daily, and that the advantage of more frequent data was almost nullified because it was conducive to more hasty analysis of all the data.

20.3.3 The only way to overcome this factor in the future appears to be to provide adequate staff and give them the preliminary training necessary to ensure that the data will be utilized in as efficient a manner during the test period as during the control period.

20.4 Variations in the skills of the individual forecasters

Due to the fact that the trial was conducted on the basis of periods of one week and forecasters' schedules are often arranged on the same basis, the comparative results might easily be affected by differences in the individual forecaster's skill. However, it is probable that the effect of this factor was small. At least one State took steps to see that it was practically eliminated by scheduling the same forecasters on the same duties throughout the five weeks.

20.5 Variation in frequency of radiosonde and radiowind observations among stations during the control period

Ten stations made four radiosonde/radiowind observations per day during the control period as well as the test period. In addition all the ocean station vessels and a number of land stations made four radiowind observations per day during the control period. While additional charts may not have been analyzed on the basis of these data, there is no doubt that the use of the data in other ways would tend to mask any differences in forecast accuracy that might otherwise prevail between the control and test periods.

20.6 Shortness of period of trial

Most of the above-mentioned reasons for the inconclusive results in connection with the two prime purposes of the trial would have been eliminated by conducting the trial over a much longer period. The following comments from the participants pertain to the length of the trial:

Canada stated that many of the forecasters felt that the usefulness of the extra data was negligible but that possibly the trial was too short to enable this to be properly appraised.

Norway stated that it was obviously very difficult to draw conclusions from tests of such brief duration.

Sweden stated that it was evident that the research has been conducted during too short a time to enable final conclusions to be reached, at least on the strength of the limited material collected by the Scandinavian Airlines System.

United Kingdom noted that a slight overall improvement could be claimed during the test period but the fact that an apparent decrease in accuracy was shown in places in the table of distribution of errors (Appendix E) suggested that the period of the experiment had been too short.

United States:

La Guardia Field, New York, felt that the period of the experiment had been too short to enable an accurate appraisal to be made.

Trans World Airlines feared that the sampling period may have been too short.

20.7 Other factors

It is possible that the following factors may have also contributed to the indifferent results:

a) Short notice given to some of the airlines that prevented them from distributing suitable instructions to aircrews in time;

b) Misunderstanding of basic instructions received from ICAO.

21. Other benefits of additional upper air data

Mention should also be made of other possible benefits from an increased frequency of upper air observations which this trial was not designed to evaluate. These include:

a) Increase in the accuracy of the determination and forecasting of the position and structure of jet streams;

b) Increase in the accuracy of the determination and forecasting of the position and character of the tropopause;

c) Increase in the accuracy of forecasts of en-route weather conditions;

d) Increase in the accuracy of forecasts of terminal weather conditions;

e) Increase in the accuracy, and more rapid dissemination, of forecast amendments.

22. Accuracy of "D" value reports (Appendix H)

In connection with the results of this trial, consideration was given to possible methods of improving the accuracy of the "D" value reports by commercial aircraft and so making the reports more useful to meteorologists. Information was requested from the United Kingdom and the United States on the methods used by their meteorological reconnaissance flights for correcting the indications of the radio altimeter and pressure altimeter and on the accuracy of constant pressure altitudes determined by the flights. Although the replies did not contain any apparent methods for improving the accuracy of "D" value reports by commercial aircraft, they have been included in this report (see Appendix H) because it was believed that the rather complete treatment given to the measurements of "D" values by meteorological reconnaissance flights would be of interest to readers of this report.

CONCLUSIONS

23. Conclusions related to the original purposes of the experiment (see paragraphs 10 and 11)

23.1 Although there are indications of some overall improvement in the "D" value and upper wind forecasts during the test period as compared with the control period, the differences are not considered large enough to be significant.

Conclusion No. 1: The experiment failed to give a reliable indication of the extent to which more frequent observations would improve the accuracy of upper air forecasts.

Conclusion No. 2: The results of the experiment provide insufficient justification for an increase in the frequency of radiosonde and radio/radar wind observations over the North Atlantic.

Conclusion No. 3: Since it cannot be stated conclusively that more reliable forecasts and prognostic charts were available during the trial, it seems inadvisable, for the time being, to attempt to standardize the meteorological procedures for utilizing upper air data for pressure pattern flying.

24. Additional conclusions

24.1 Unsatisfactory communications

Much of the value of the additional observations was lost because of the failure of the observations to reach the meteorological offices in time to be utilized properly. In some cases the observations were not received at all. According to reports from the meteorological offices the reception of the observations currently made is not satisfactory. It therefore appears more profitable at the present to concentrate on communications problems than upon securing an increase in the frequency of observations since any reduction in communication delays will, in effect, reduce the time ahead for which forecasts must be made.

Conclusion No. 4: As a means of improving forecasting accuracy, substantial reduction of delays in the dissemination of upper air data may be preferable to an increase in the frequency of upper air observations.

24.2 Unreliability of determination of actual conditions

The differences in the actual upper winds determined by various meteorological offices for long routes indicate that the methods of determination used need re-evaluating since their accuracy controls the accuracy of forecast winds.

Conclusion No. 5: It would be useful if a study were made of:

a) the differences between the "actual" upper winds for routes determined by different meteorological offices in the North Atlantic Region;

b) the reasons for these differences;

c) the relative merits of the various analysis techniques used.

24.3 Importance of speed in utilization of data

Consideration of the decrease in the accuracy of forecasts with increase in the period between the time of the basic data and the time for which the forecasts are valid suggests that it might be preferable to make some forecasts (such as "D" value forecasts) by a very simple and rapid method on the basis of data just received rather than rely on a forecast prepared using normal methods on the basis of older data. For example, it appears that, in many localities, an actual "D" value, just computed from the results of a radiosonde report, could be used as a forecast of "D" value at the same place for 12 hours hence with a better chance of success than if the forecast were prepared by normal means on the basis of upper air charts for a time of observation 12 hours, or even as little as 6 hours, earlier. This is perhaps the simplest example of a rapid method of "forecasting" and it seems likely that even better use could be made of methods taking only a little more time.

Conclusion No. 6: It is probable that more rapid procedures could be developed which would ensure that greater use is made of the latest available upper air data in aviation forecasting and would result in worthwhile improvement in forecast accuracy.

24.4 Non-uniformity of collected data and non-standardization of methods for computing wind components

24.4.1 The flight data received were of various types and mixed quality because of the misunderstanding by some airlines personnel of the exact data required and the different methods used in producing them. The fact that there were large variations is clearly indicated by the scatter of results shown graphically in Appendix G, Figure 1.

Conclusion No. 7: It appears essential that any future trial involving collection of meteorological data be preceded by very thorough co-ordination between those conducting the trial and the operators concerned.

24.4.2 It was noted that at London Airport equivalent tail winds were computed while at La Guardia Airport, New York, tail winds components were computed. In addition,at least one airline reported the wind component which would have given the same flight time if the flight had been made along a great circle instead of the track actually flown. While it is probable that the actual effect on aircraft operations of any misunderstanding concerning the type of wind data is usually small, it is evident that on occasions it could be serious.

Conclusion No. 8: A standard method is desirable for stating the mean wind over a route, in relation to its effect on flight time.

24.5 Insufficiency of actual wind data

Since there is so much disagreement as to the actual wind conditions over the North Atlantic at any particular time, it is believed that post-flight reports from aircraft,giving mean route winds, would be beneficial. It is generally agreed that such reports are more reliable than in-flight wind reports for individual zones or sections of routes due to the fact that greater distances and longer time intervals are involved, thereby giving a greater accuracy to the overall route component.

Conclusion No. 9: Valuable additional information would be obtained if pilots-in-command reported to the meteorological office, at point of arrival, the mean route wind (determined by a standard method) and if these reports were transmitted to other interested meteorological offices.

24.6 Non-standardization of forecast verification methods

The variety of procedures which States have used in summarizing their data indicates that there are still no generally accepted procedures for verifying forecasts.

Conclusion No. 10: It is desirable that methods of forecast verification be given further study with a view to the adoption of a small number of standard procedures

24.7 Further trials

The results of the trial indicate that even a considerably longer experiment of this type, in which additional information is available for certain periods only, might not yield results that would be appreciably more conclusive. However, it is believed that conclusive evidence of the effect of more frequent observations on forecasting errors could be obtained with very little expense by conducting an experiment designed to show the effect of the "age" of the basic upper air data used. Such an experiment might be carried over a period of a year or so, on the following lines:

a) One of the larger meteorological offices, which normally make four upper wind forecasts per day for the North Atlantic routes, could compare the accuracy of the forecast mean route wind components based on upper air data 6 to 9 hours old with the accuracy of those based on data 12 to 15 hours old;

b) The forecasts referred to in a) could be checked by means of actual wind components determined by flight checks carried out by one of the larger North Atlantic operators using a rigid procedure carefully worked out so as to fit in with the normal operating procedures of the airline involved and at the same time to provide results of the highest practicable accuracy.

Conclusion No. 11: More definite results might be obtained, in regard to the original purposes of this trial (paragraphs 10 and 11), by carrying out a protracted experiment on the lines indicated in paragraph 24.7 above.

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APPENDIX A

PLAN AND ORGANIZATION

1. The "normal" network of radiosonde observations and radiosonde and radio/radar wind observations in the North Atlantic Region that existed during the period of the trial is shown in Figure 1. The "normal" network prevailed during the control weeks and it should be noted that certain stations made four upper air observations per day as part of the "normal" programme. In addition, although not indicated on the Figures, all ocean station vessels and a number of land stations made radio/radar wind observations at 0900 and 2100 GMT throughout the five weeks.

2. The augmented programme of upper air observations that prevailed during the test weeks is shown in Figure 2. In principle, a total of thirty-four stations made four upper air observations per day during the test weeks. In addition, Barajas (Madrid) Spain, at which two observations per day were made as routine, four observations per day were made whenever possible. At Thorshavn and Sable Island, from which the additional observations were also desired, it was not possible to increase the frequency of observations beyond the normal two per day due to supply and personnel shortages but it is believed that such absences did not materially affect the results of the programme.

3. As a means of evaluating the programme, all operating agencies making flights in the North Atlantic Region were requested to check forecast winds against actual winds throughout the five weeks. It was realized that a mere comparison of planned flight times and actual flight times would not yield valid wind component comparisons. A form was therefore prepared for recording certain elements during a flight so that a verification of the forecast and actual wind components could be carried out by the ICAO Secretariat. A copy of the form is shown in Figure 3.

4. As a further means of evaluating the programme the following proposals were made to States.

Prognostic Analyses

4.1 That 24-hour prognostic analyses for dissemination be issued at 6-hourly intervals, for the 500 mb. level only, by a United States centre for the western part of the region and by a United Kingdom centre for the eastern part of the region, in accordance with the procedures then in force for exchange of analyses.

4.2 That the prognoses be verified by tabulating the differences between forecast and observed values of contour height and of the geostrophic wind vector at a number of points, selected by the States concerned, where observations are available. The tabulations were to be carried out by the States concerned with respect to representative prognoses issued during both the control and test periods and the results communicated to ICAO.

4.3 That States which were able to carry out verification of prognostic charts issued locally for flight purposes utilize the same system.

4.4 That each transatlantic MMO (Main Meteorological Office) make forecast "D" values for its local aerodrome available to operators on a continuous basis in some convenient form such as a tabulation or a graph. Requirements for additional locations within the MMO's responsibility were to be kept to a minimum. In addition, the MMO was to co-ordinate locally the requirement for "D" values for oceanic points in its vicinity and to supply, on request, the forecasts needed for calculating in-flight instrumental "D" value errors or for more precise flight planning. Forecast "D" values for en-route or arrival points were to be made available on request in the form of discrete values or by prognostic charts or in some other convenient form.

4.5 That the exchange of forecast "D" values be restricted to those for the 500 mb. level, which were to be added to the TAFOT/TAMET* messages in the code specified below. States were to determine for which operationally significant points these should be issued; however, at least the following oceanic terminals were to be included: Gander, Goose Bay, New York, Bermuda, Lages, Keflavik, Shannon, Prestwick, Lisbon.

4.6 That the forecast "D" values for the 500 mb. level be made for times 5, 11 and 17 hours from time of issue of the routine TAFOT/TAMET messages and be added at the end of those messages as two five-figure groups using the form:

$$XD_5D_5D_5D_{11} \quad D_{11}D_{11}D_{17}D_{17}D_{17} \text{ or } /D_5D_5D_5D_{11} \text{ etc.}$$

where X = English units (feet)
/ = metric units (metres)

Each 3 figures of "D" represented the forecast "D" value in tens of feet (or metres). For negative values, 500 was to be added to the code figures in a similar manner to the method used for 1000 mb. contour heights in the TEMP code (FM 35) e.g. groups X0400 04508 at the end of the 0400 GMT TAFOT - would mean: Plus 400 feet at 0900 GMT, plus 40 feet at 1500 GMT and minus 80 feet at 2100 GMT.

4.7 That individual MMO's or States tabulate the difference between forecast and observed or computed "D" values for the local aerodromes and communicate the results to ICAO.

5. <u>Development of methods used in the analysis of the data and ideas incorporated in the results</u>

5.1 In an effort to analyze the data in such a way as to produce results of maximum value, a panel of experts was formed. This panel consisted of:

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*TAFOT/TAMET messages are coded aerodrome forecasts normally issued four times a day at about 0400,1000,1600 and 2200 GMT for a period of 24 hours beginning at 0600,1200,1800 and 2400 GMT.

IATA	ICAO Secretariat
Chief Navigating Officer, Trans-Canada Airlines	4 members - Meteorology Activity
Fleet Navigation Officer, Atlantic Division, British Overseas Airways Corporation	1 member - Operations Activity
	1 member - Personnel Licensing and Training Activity

5.2 Day-long meetings of the panel were held in the offices of the Secretariat on:

11 September 1952
16 October 1952
12 February 1953

5.3 These discussions were of considerable benefit to the Secretariat in directing the investigation of the results of the trial and in preparing this report.

6. Annual cost of an augmented programme

6.1 Only a few replies were received from the States giving estimates of the annual additional cost of increasing the frequency of observations:

Canada stated that two additional radiosonde and radio/radar wind observations per day at Sable Island and Seven Islands would cost about $76,000 per year and at Goose Bay about $46,000 per year.

Denmark calculated that two additional radiosonde and radio/radar wind observations per day at Angmagssalik would cost $47,000 per year.

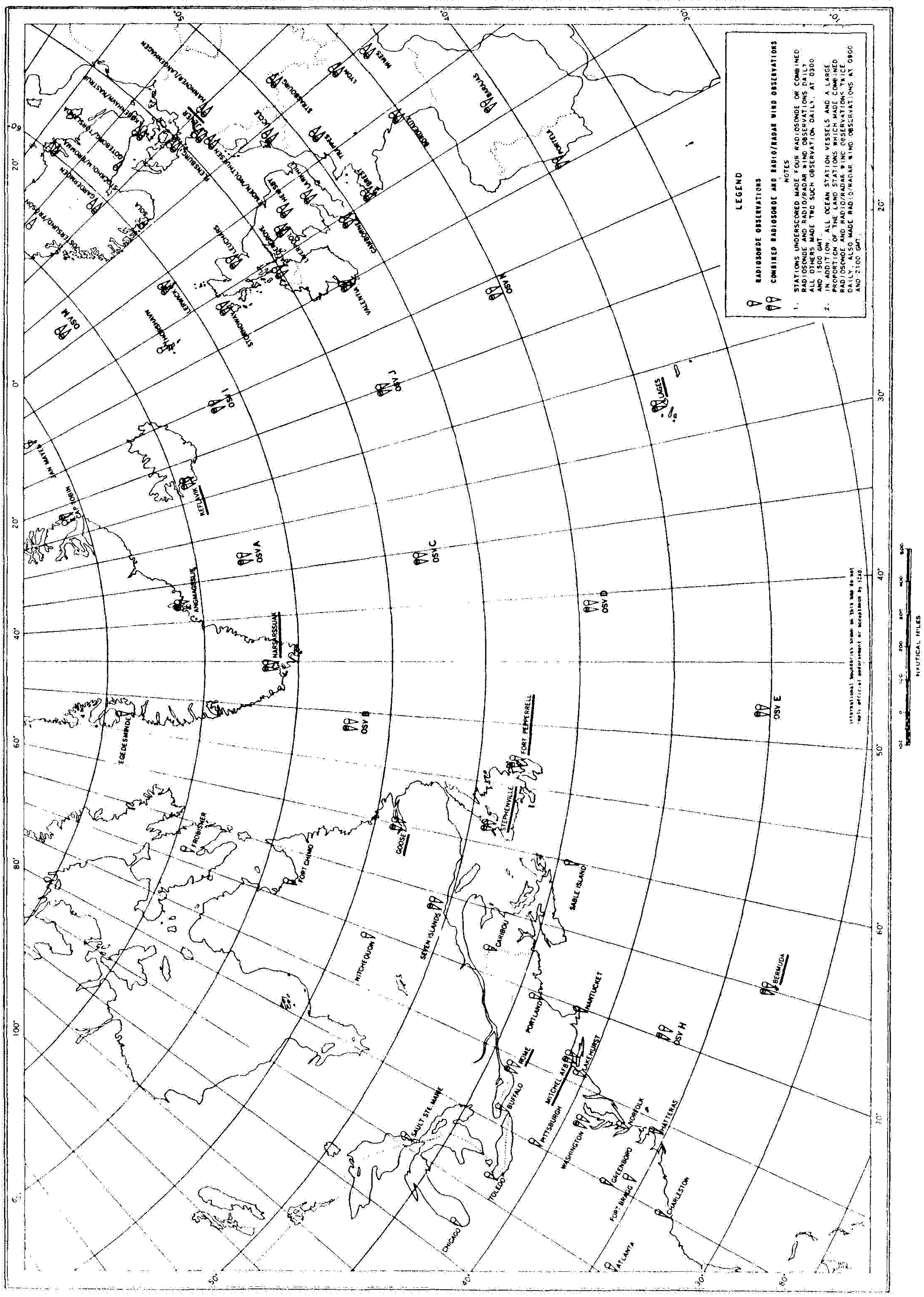
Ireland estimated that the additional observations at Valentia, and their transmission internally, would cost $35,000 per year.

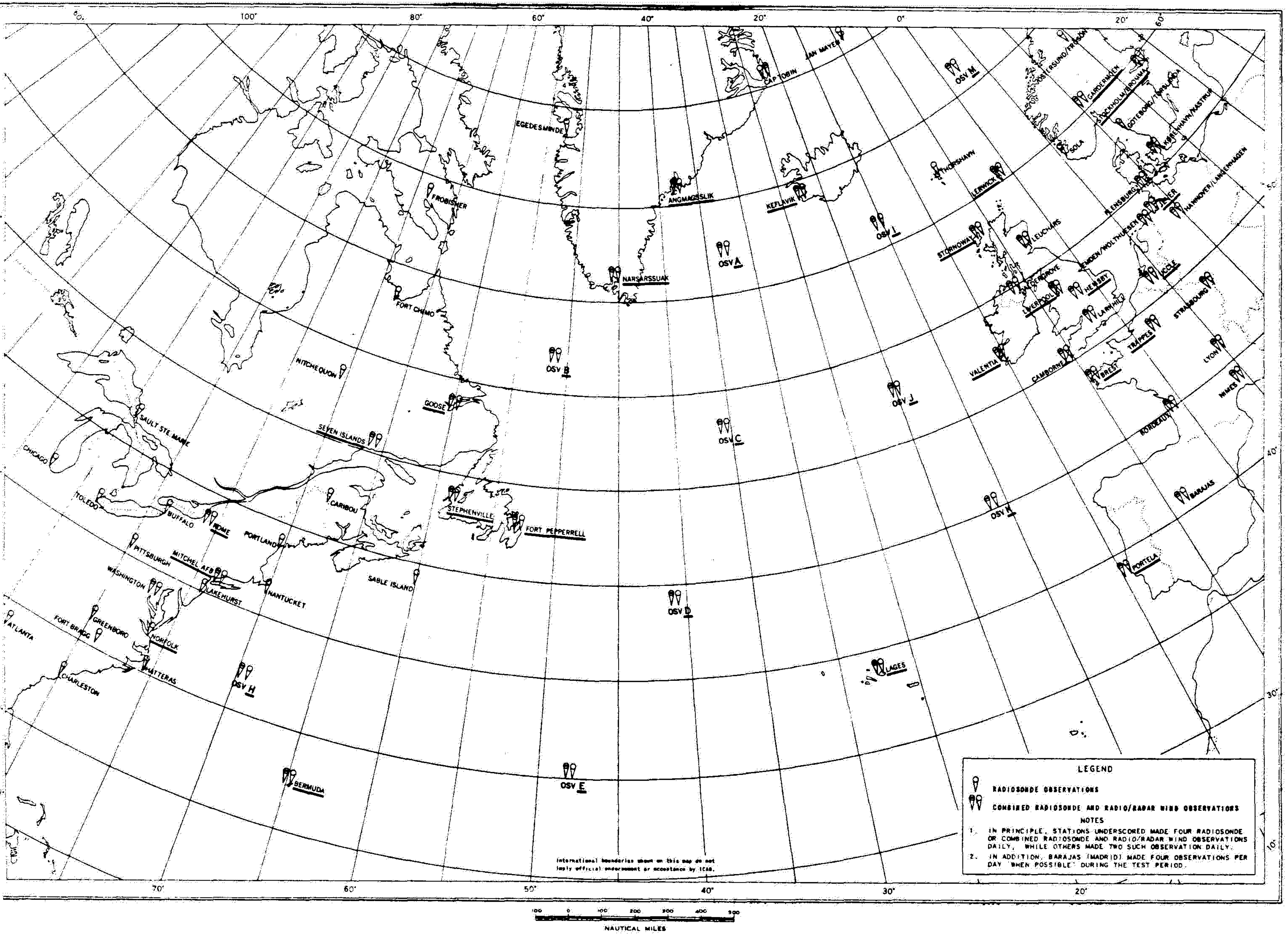
Norway estimated that the additional radiosonde observations at Oslo Airport and Ocean Station Vessel "M" would cost about $33,000 per year.

6.2 It is estimated that the total additional cost to States for the entire augmented programme at the 34 stations would be $500,000 - $1,000,000 (U.S.) per year.

NETWORK OF STATIONS MAKING EITHER RADIOSONDE OBSERVATIONS OR COMBINED RADIO-SONDE AND RADIO/RADAR WIND OBSERVATIONS IN THE NORTH ATLANTIC REGION DURING THE CONTROL PERIOD

FIG. 1





NETWORK OF STATIONS MAKING EITHER RADIOSONDE OBSERVATIONS OR COMBINED RADIO-SONDE AND RADIO/RADAR WIND OBSERVATIONS IN THE NORTH ATLANTIC REGION DURING THE TEST PERIOD

FIG. 2

Figure 3 (Appendix A)

SPECIAL FORM FOR CHECKING FORECAST WINDS

INSTRUCTIONS - to be completed for all North-Atlantic flights from 9 March to 12 April 1952, and forwarded to ICAO

Company ________________ Flight No. ________ Captain ____________
Forecast issued by the ____________ Meteorological Office for the
Route ______________________________
at ______ GMT ____________ 1952

FLIGHT DATA

Route-section or zone	Altitude	Forecast wind	Average true heading	Average T.A.S. (kts)	Flight time	Ground speed# (kts)	Computed wind#

Average flight tail component for the route ______ kts #

Average forecast tail component for the route ______ kts #

Flight plan procedures commenced (e.g. at flight altitude and on course) at - position ______________________ time ________ GMT

Flight plan procedure terminated (e.g. descending and/or turned on to radio/range) at - position ______________ time ________ GMT

NOTES: Enter actual flight time for each section to nearest minute.
Enter # data if computed and available.

Remarks (notes on forecast and flight weather: major deviations from flight plan or expected track; etc.)

APPENDIX B

DETAILED DESCRIPTION OF DATA RECEIVED BY ICAO

1.- Wind Data from Meteorological Offices

1.1 Ireland

Shannon Airport

Mean absolute errors, by weeks (test and control), of tail wind component forecasts for the Shannon-Gander (G.C.) route at the 700 mb. and 500 mb. levels. Forecasts were made five times per day as follows:

Latest Upper Air Chart	Issue Time	Valid Time	Verification Time
1500 GMT (2100 GMT)	0300 GMT	1300 GMT	1500 GMT
0300 GMT	0800 GMT	1800 GMT	1500 GMT
0300 GMT (0900 GMT)	1300 GMT	2200 GMT	0300 GMT (2100 GMT)
0300 GMT (0900 GMT)	1630 GMT	0300 GMT	0300 GMT
1500 GMT	2130 GMT	0800 GMT	0300 GMT (0900 GMT)

Times in brackets refer to test weeks.

1.2 United Kingdom

1.2.1 London Airport

a) Forecast and observed equivalent tail winds for the Shannon-Gander (G.C.) route at the 700 mb. and 500 mb. levels. Forecasts were made four times per day as follows:

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT (0900 GMT)	1800 GMT	0730 GMT	Not verified (0300 GMT)
1500 GMT	0000 GMT	1330 GMT	1500 GMT
1500 GMT (2100 GMT)	0600 GMT	1930 GMT	Not verified (2100 GMT)
0300 GMT	1200 GMT	0130 GMT	0300 GMT

Times in brackets refer to test weeks.

b) Forecast and actual equivalent tail winds for various other routes and times as required by traffic. This information was submitted in a separate tabulation and comprised data on fifty additional forecasts for both the 700 mb. and 500 mb. levels. Each forecast was verified using the appropriate upper level chart for the time nearest the mid-time of the flight.

1.2.2 Prestwick Airport

Forecast and actual tail wind components for the Prestwick-Gander (G.C.) route and other routes at various times during the day as required by the traffic. In most cases, data were submitted for both the 700 mb. and 500 mb. levels. Each forecast was verified using the appropriate upper air chart for the time nearest the mid-time of the flight.

1.3 United States

1.3.1 New York/La Guardia Airport

a) Forecast and actual tail wind components for the New York-Gander (R.L.) route and the Gander-Shannon (G.C.) route. Forecasts were made three times per day as follows:

New York-Gander (R.L.)

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT (0900 GMT)	1800 GMT	0000 GMT	0300 GMT
1500 GMT	0000 GMT	0600 GMT	0300 GMT
0300 GMT	1200 GMT	1800 GMT	1500 GMT

Gander-Shannon (G.C.)

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT (0900 GMT)	1800 GMT	0600 GMT	0300 GMT
1500 GMT	0000 GMT	1200 GMT	1500 GMT
0300 GMT	1200 GMT	0000 GMT	0300 GMT

Times in brackets refer to test weeks.

b) Forecast and actual gradient winds, and the vector differences between them, at the 700 mb. and 500 mb. levels, for following locations:

1. Rome, New York
2. Norfolk, Virginia
3. Goose Bay, Labrador
4. St. Johns, Newfoundland
5. Stephenville, Newfoundland
6. Bermuda
7. Boston, Massachussetts
8. Narsarssuak, Greenland
9. Ocean station vessel A
10. " " " B
11. " " " C
12. " " " D
13. " " " E
14. " " " H

The forecasts were made on the basis of 24-hour prognostic charts, and verified by winds measured from actual charts, as follows:

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT	1200 GMT	0300 GMT	0300 GMT
(0900 GMT)	(1800 GMT)	(0900 GMT)	(0900 GMT)
1500 GMT	0000 GMT	1500 GMT	1500 GMT
(2100 GMT)	(0600 GMT)	(2100 GMT)	(2100 GMT)

Times in brackets refer to test weeks.

c) Summary, by days and weeks (control and test) of mean absolute errors derived from the data under paragraphs 1.3.1(a) and 1.3.1(b) above.

Note.- Gradient winds were verified by measuring the magnitude of the vector difference between the forecast and observed values. Since many of the "actual" winds had to be estimated from the charts, they were considered to represent an area on a hodograph rather than a point. This was defined as the observed direction ± 10 knots. Velocities forecast to less than 10 knots were treated as calm. The vector difference was considered as the vector between the forecast wind vector and the nearest point in the area encircling the "actual" wind on the hodograph.

1.3.2 Westover Air Force Base, Massachussetts (U.S. Air Force)

a) Absolute errors of tail wind component forecasts at the 9000 foot level for the 42°N 68°W - Flores, Azores route and at the 17,000 foot level for the 41°N 60°W - Flores, Azores route. The actual tracks used were "least time" tracks, which during the period, except for one instance, were either rhumb line or great circle. Forecasts were made twice per day as follows:

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT	1000 GMT	0300 GMT	0300 GMT
1500 GMT	2200 GMT	1500 GMT	1500 GMT

b) Absolute errors of wind forecasts at the 9000 foot and 17,000 foot levels for the following locations:

1. Rome, New York
2. Bermuda
3. Stephenville, Newfoundland
4. Goose Bay, Labrador
5. Flores, Azores
6. Ocean Station Vessel C
7. Ocean Station Vessel D
8. " " " E
9. " " " H
10. Point 41.5°N 60°W
11. Point 40°N 40°W
12. Point 40.7°N 50°W

The forecasts were made and verified in accordance with the schedule in paragraph 1.3.2(a). The data were submitted in the form showing, for each forecast, the sum and the mean of the individual errors in the forecasts for the 12 locations with direction and velocity errors listed separately.

Note.- The wind forecasts were verified by considering a deviation of either one degree or one knot equal to one error. Thus a forecast of 320 degrees 40 knots and actual wind of 300 degrees 50 knots would yield errors of 20 in direction and 10 in speed.

c) Absolute errors in wind forecasts at the 9000 foot level for the 42°N 68°W - Flores, Azores route and at the 17,000 foot level for the 41°N 60°W - Flores, Azores route. The forecasts were made by zones according to the schedule in paragraph 1.3.2 (a) and verified by the same method as described in the note to paragraph 1.3.2 (b).

d) Summaries by weeks (control and test) of mean absolute errors described in preceding paragraphs 1.3.2 (a), 1.3.2(b) and 1.3.2(c).

2.- "D" value data from Meteorological Offices

2.1 Canada

Gander Airport

a) Forecast and actual 500 mb. altitudes and "D" values for Gander and Goose Bay for the times 5, 11 and 17 hours after routine TAFOT issue times, as follows:

Latest Upper Air Chart	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT	1000 GMT	15,21 and 03 GMT)	03 and 15 GMT during
0300 GMT (0900 GMT)	1600 GMT	21,03 and 09 GMT)	control period and 03,
1500 GMT	2200 GMT	03,09 and 15 GMT)	09,15 and 21 GMT
1500 GMT (2100 GMT)	0400 GMT	09,15 and 21 GMT)	during test period,
			as appropriate.

Times in brackets refer to test weeks.

No "actual" values obtained by interpolation were used for verification.

b) Forecast and actual 500 mb. altitudes and "D" values for Ocean Station Vessels "A" and "C". Forecasts were made four times per day as follows:

Latest Upper Air Chart	Issue Time	Valid Time	Verification Time
0300 GMT	1100 GMT	0300 GMT	0300 GMT
0300 GMT (0900 GMT)	1700 GMT	0900 GMT	Not verified (0900 GMT)
1500 GMT	2300 GMT	1500 GMT	1500 GMT
1500 GMT (2100 GMT)	0500 GMT	2100 GMT	Not verified (2100 GMT)

Times in brackets refer to test weeks.

No "actual" values obtained by interpolation were used for verification.

c) Graphs of data described in preceding paragraph 2.1.1(b).

2.2 France

2.2.1 Paris/Orly Airport

a) Forecast and actual "D" values, and errors derived therefrom, for Paris, Brest and Ocean Station Vessel "K" for the times 5, 11, and 17 hours after the routine TAMET issue times in accordance with the schedule in paragraph 2.1(a). However, since all missing actual values throughout the 5 weeks were interpolated, an "actual" value was given for each forecast value.

b) Root mean squares by periods, of the errors referred to in paragraph 2.2.1(a) above.

2.2.2 Paris/Central Service

The same type of data as submitted by the Orly Airport office except that the forecasts were made only twice per day (1000 GMT and 2200 GMT) throughout the five weeks and were based on the normal twice daily upper air observations only.

Note.- This information was submitted for comparative purposes. See special analysis by France (Appendix E).

2.3 Iceland

Keflavik Airport (Information submitted through U.S. Air Force)

a) Forecast and actual "D" values for Keflavik for the times 5, 11 and 17 hours after the routine TAMET issue times as given in the schedule in paragraph 2.1(a). However, since four upper air observations per day were being made at Keflavik throughout the five weeks, actual values were given for all forecasts during both the control and test periods.

2.4 Ireland

2.4.1 Shannon Airport

a) Mean absolute errors, by weeks (control and test), of the forecast altitudes of the 700, 500 and 300 mb. levels and of the forecast surface pressure at the following locations:

1. Valentia, Ireland
2. Ocean Station Vessel "J"
3. Ocean Station Vessel "C"
4. St. Johns, Newfoundland

b) Mean absolute errors, by weeks, of the forecast 500 mb. altitudes for Shannon for the times 5, 11 and 17 hours after the routine TAFOT issue times as given in the schedule in paragraph 2.1(a).

Verification values were obtained by interpolation from the analyzed upper air charts for 0300 and 1500 GMT during the control period and 0300, 0900, 1500 and 2100 GMT during the test period.

2.4.2 Dublin Airport

a) Mean absolute errors, by weeks (control and test), of forecast 700 mb. altitudes for Dublin in the manner described in paragraph 2.4.1(b).

2.5 Norway

Oslo

a) Forecast and actual "D" values, and errors derived therefrom, for Oslo/Gardermoen and Stavanger/Sola based on 12 and 24 hour prognostic charts (approximately the same as 5 and 17 hour forecasts made at the 1000 and 2200 GMT TAMET issue times).

Latest Upper Air Charts	Issue Time (approx.)	Valid Time	Verification Time
0300 GMT	1000 GMT	1500 GMT, 0300 GMT	1500 GMT, 0300 GMT
1500 GMT	2200 GMT	0300 GMT, 1500 GMT	0300 GMT, 1500 GMT

No "actual" values obtained by interpolation were used for verification.

2.6 United Kingdom

London and Prestwick Airports

a) Mean absolute errors by periods (control and test) of forecast 700 mb. and 500 mb. "D" values made by Prestwick for Prestwick in combination with those made by London for London. The forecasts were prepared as follows:

Latest Upper Air Charts	Issue Time	Valid Time	Verification Time
1500 GMT (2100 GMT)	0100 GMT	03, 09, 15, 21 GMT	As appropriate.
0300 GMT	0700 GMT	09, 15, 21, 03 GMT	
0300 GMT (0900 GMT)	1300 GMT	15, 21, 03, 09 GMT	
1500 GMT	1900 GMT	21, 03, 09, 15 GMT	

Times in brackets refer to test weeks.

"Actual" values were obtained by interpolation whenever necessary for verification.

b) Tabulation of distribution of errors described in preceding paragraph 2.6.1(a), according to those exceeding 100 feet, 200 feet, and 300 feet.

2.7 United States

2.7.1 New York/La Guardia Airport

a) Forecast and actual "D" values for New York for the times 5, 11 and 17 hours after the routine TAFOT issue times in accordance with the schedule in paragraph 2.1(a). An "actual" value was given for each forecast made throughout the five weeks, missing values being interpolated; however, since four upper air observations per day were available throughout most of the period from nearby Mitchell Air Base, interpolations were kept to a minimum.

b) Forecast and actual 700 mb. and 500 mb. altitudes, based on 24 hour prognostic charts prepared twice per day during the control period and four times per day during the test period, for the locations listed in paragraph 1.3.1(b).

c) Tabulation of the mean absolute errors by days and weeks (control and test), of the data described in the preceding two paragraphs, 2.7.1(a) and 2.7.1(b).

d) Tabulation showing the effect of the length of the forecast period on the mean absolute forecast error of the "D" value at New York.

2.7.2 Westover Air Force Base, Mass. (US Air Force)

a) Absolute errors of the forecast 700 mb. and 500 mb. altitudes, based on the 24-hour prognostic charts, for the locations listed in paragraph 1.3.2(b). Verification was carried out for two times (0300 GMT and 1500 GMT) throughout the five weeks. Missing "actual" values were interpolated for verification.

b) Absolute errors of the 700 and 500 mb. "D" value forecasts for the EEL intersection (42°N 68°W) for the times 5, 11 and 17 hours after the routine TAFOT issue times in accordance with schedule in 2.1(a). An error value was given for each forecast during control weeks and test weeks, missing values having been interpolated.

c) Summaries of the mean absolute errors, by weeks (control and test), of the data described in the preceding two paragraphs 2.7.2(a) and 2.7.2(b).

2.7.3 Stephenville, Newfoundland (US Air Force Base)

a) Mean absolute errors, by weeks (control and test), of the forecast 700 mb. altitudes, based on the 24 hour prognostic charts prepared twice per day during the control period and four times per day during the test period, for the following locations:

1. St. Johns, Newfoundland	6. Ocean Station Vessel B
2. Lages, Azores	7. " " " C
3. Stephenville, Newfoundland	8. " " " D
4. Goose Bay, Labrador	9. " " " E
5. Bermuda	10. " " " K

b) Mean absolute errors, by weeks, of the forecast 700 mb. altitudes, as indicated in the flight folders, for St. Johns, Newfoundland and Lages, Azores.

2.7.4 Goose Bay, Labrador (US Air Force Base)

a) Graph showing forecast and actual 500 mb. altitudes for Goose Bay for the times 5, 11 and 17 hours after the routine TAFOT issue times in accordance with the schedule shown in paragraph 2.1(a). Radiosonde observations were made at Goose Bay four times per day throughout the five weeks.

2.7.5 Bermuda (US Air Force Base)

a) Graph showing forecast and actual 500 mb. "D" values. Radiosonde observations were made at Bermuda four times per day throughout the five weeks.

3.- Wind data from actual flights

3.1 A total of 804 special forms for checking forecast winds during actual flights were received. A breakdown of the total by routes follows:

Route (both directions)	No. of forms received
North America - Europe (direct)	572
USA - Azores	63
North America - Iceland	40
Iceland - Europe	38
Newfoundland - Azores	37
Internal Europe	13
Internal North America	7
Azores - Portugal	6
Azores - UK or France	6
Azores - Bermuda	4
USA - Bermuda	3
Canada - Portugal	2
USA - South America	2
Iceland - Bermuda	1
South America - Bermuda	1
UNKNOWN	9
Total	804

3.2 Many of the forms were incomplete, some being practically blank. A number were returned to States in an effort to obtain the additional information required but only a very few could be completed, because airlines normally do not keep the necessary records. Only 282 forms were considered complete enough to be used in the analyses contained in this report.

APPENDIX C

ANALYSIS OF DATA

1. Because of the variety of forms and methods used in presenting the data, the following conventions were adopted:

1.1 The forecasts were divided into test and control weeks by using the time of issue of the forecast and not its validity time. Furthermore, as it was believed that any forecasts made before 0600 GMT would be based on upper air charts using data of the previous day, forecasts issued before 0600 GMT on the first day of a control or test week were included in those forecasts for the preceding week except, of course, on the first day of the first control week when all forecasts issued that day were included in the control week.

1.2 It was necessary to ensure that data relating to forecasts for the different times ahead be comparable. Consequently, where any of the forecast "D" values made by a certain office for a certain time and location were missing, all of the other forecast "D" values made by the same office for the same time and location were eliminated from the compilations, except in the case of those from Oslo. For example, if the 11-hour forecast made by Gander for Goose Bay was missing, the 5 and 17-hour forecasts made for the same time were also considered as missing. This procedure was not, however, applied to the Oslo data as it would have left so few cases that the computation of mean values would not have been justified.

1.3 All "actual" "D" values for 0900 and 2100 GMT during the control period were eliminated because most of them were obtained through interpolation.

1.4 Except as noted in paragraph 1.2 all "actual" "D" values submitted for the proper times were used, i.e., 0300, 0900, 1500 and 2100 GMT during the test period and 0300 and 1500 GMT during the control period, even though some of the offices interpolated the missing values. Thus normally each test week would have twice as many forecasts verified as each control week.

1.5 A single procedure was adopted to indicate the time ahead to which a forecast applied. Some States took this as the time of the latest upper air observations while others considered the time of issue of a forecast as the base time. In this report time of issue of a forecast is taken as the base time unless otherwise noted; thus an 11-hour forecast issued at 0400 GMT is valid at 1500 GMT. Actually, some offices called the "D" value forecasts 6, 12 and 18-hour forecasts, but all such forecasts are referred to as 5, 11 and 17-hour forecasts in this report since they are the times originally specified.

1.6 A plus (+) sign has been used to denote tail winds and a minus (-) sign to denote head winds in accordance with standard airline practice, unless otherwise noted.

2. <u>Wind data from meteorological offices (Appendix D)</u>

2.1 Only a limited amount of wind information was received and this is presented in summary form in Appendix "D", mostly in the form of mean absolute and arithmetic errors.

2.2 A detailed analysis of the 500 mb. wind data supplied by New York and London, includes:

a) Frequency table of the distribution of errors.

b) Ogives (cumulative frequency curves) of the distribution of the errors.

c) Mean absolute and arithmetic errors, by periods (control and test), of 24-hour persistence "forecasts".

d) Mean absolute and arithmetic errors by weeks.

e) Standard deviation of the errors.

2.3 No attempt should be made to compare the forecasting success of the various offices as there are other factors involved that make such a comparison meaningless.

3. <u>"D" value data from meteorological offices (Appendix E)</u>

3.1 All the "D" value* data received are presented in summary form in Appendix "E", mostly in the form of mean absolute and arithmetic errors.

3.2 Detailed analyses of the "D" value data from a meteorological office on each side of the Atlantic include:

a) Correlation coefficients.

b) Standard errors of estimate.

c) Serial correlation coefficients.

3.3 Cumulative frequency curves of the absolute errors in the 11-hour forecasts made at Paris, Keflavik, Gander and New York for their respective locations.

3.4 One of the more important factors involved in comparing forecasts over such short periods is the difference in the difficulty in making the forecasts. Two different methods were used in an effort to

*In this report the term "D" value refers to the 500 mb. surface unless otherwise noted.

eliminate this factor from the analysis of the forecast errors and so as to establish more clearly the value of the newer data available during the test period.

3.4.1 Comparison of forecasts based on the same and different "aged" data.

The 5, 11 and 17-hour forecasts made at 1000 and 2200 GMT during the control period were based on the same "aged" upper air data as those issued at all times during the test period, i.e., the forecasts were all based on upper air data seven hours old. Since the forecasts were based on the same aged data and if one assumes that the skill of the forecast office remains the same, then any difference in the forecast accuracy between the two periods must be due to differences in the forecast difficulty plus the effect of other factors such as those mentioned in paragraphs 20.2, 20.3, 20.4 and 20.6 of the body of the report. In this comparison the effect of the other factors is neglected as there appeared to be no possible way of allowing for them.

Since normally there were no 0900 or 2100 GMT observations made during the control period and since it had been decided that no attempt would be made to verify any forecasts for those times during the control period, it was possible to use only the 5 and 17-hour forecasts made at 1000 and 2200 GMT and valid at 0300 and 1500 GMT. To measure the accuracy of these forecasts, correlation coefficients ("r's") were computed for the forecast and corresponding actual values and then converted into "z's"* which have an approximately normal distribution instead of the very "skewed" distribution which "r's" have in the higher ranges. As a consequence of this better distribution, increments of "z" have nearly the same meaning, in terms of difficulty of obtaining them, at all ranges of values, and addition, subtraction and averaging become more legitimate processes than is the case with "r's".

The difference in the "z's" due to the difference in forecast difficulty between the test and control periods is then:

a) = $z_{5T} - z_{5C}$ = difference in forecast difficulty in making the 5-hour forecasts

b) = $z_{17T} - z_{17C}$ = difference in forecast difficulty in making the 17-hour forecasts.

Where

z_{5T} = value of "z" for 5-hour forecasts issued during test period

z_{5C} = value of "z" for 5-hour forecasts during control period

etc.

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*$z = \tan h^{-1} r$

Then

c) $= \frac{(a) + (b)}{2}$ = difference in forecast difficulty in making 11-hour forecasts.

If the answer to (c) is positive it indicates that there was greater difficulty in making 11-hour forecasts during the control period than during the test period. A negative value indicates the reverse.

The next step is to compare the forecasts based on different "aged" data. The forecasts issued at 0400 and 1600 GMT during the control period were based on upper air data 13 hours old, while those issued at all times during the test period were based on data 7 hours old. Since only the 11-hour forecasts issued at 0400 and 1600 GMT during the control period could be properly verified, a comparison could be made involving only those forecasts. Any differences in the accuracy of the 11-hour forecasts issued during the control and test periods must be due to differences in forecast difficulty plus the effect of the differences in amount and "age" of data. i.e.

d) $= z_{11T} - z_{11C}$ = effect of difference in forecast difficulty plus effect of difference in amount and age of data.

Therefore when (c) is subtracted from (d) the remainder is the net effect of the newer data. If the answer is positive it indicates that the forecasts were better during the test period than during the control and, assuming that the effect of other factors can be ignored, that the improvement is due to the effect of the newer data. If the answer is negative it means that in spite of the additional and newer data, factors other than forecast difficulty were large enough to mask any improvement that might have occurred.

While there are certainly objections to this method of attack, it is believed to be helpful in attempting to analyze the "D" value forecasts over such a short period.

3.4.2 Comparison of the forecasts actually made with forecast based on persistence.

This second method of attempting to eliminate the factor of forecast difficulty in the results involves a comparison of the forecast "skill scores". The "skill score" is defined as the amount by which the value of "z" for the correlation between the forecasts for time (t) and the corresponding "actuals" exceeds the value of "z" for the correlation between the latest observations, available at the times of issue of the forecasts, and the "actuals" for the same time (t). If it is assumed that the degree of persistence is a measure of ease of forecasting, then a simple comparison of the two "skill scores" will indicate to what extent the skill was improved by the use of the newer data. If "z" for "forecasts" based on persistence is larger during the test period than during the control period it indicates that there was more persistence (less variability) during the test period than during the control period.

Only the 12-hour-persistence "z's" can be used because it is not possible to compute 6 or 18-hour values during the control period, the observations being made at intervals of 12 hours. The 12-hour-persistence "z's" may fairly be compared with the "z's" for 11-hour forecast (issued at 0400 and 1500 GMT) since the persistence "forecast" could have been available, and the forecast made by normal methods was issued, during the hour following the same observations. The "z's" for the 11-hour forecasts issued at 0400 and 1600 GMT during the control period are therefore compared with the corresponding 12-hour-persistence "z's" during that period to determine the "skill", i.e., the difference between the value of "z" for forecasts as made and that for "forecasts" based on persistence, as follows:

a) = $z_{11C} - z_{12pc}$ = "skill" in making 11-hour forecasts during control period

<u>Where</u>

z_{12pc} = 12-hour-persistence "z" for control period.

b) = $z_{11T} - z_{12pt}$ = "skill" in making 11-hour forecasts during test period plus effect of the "newer" data.

<u>Where</u>

z_{12pt} = 12-hour-persistence "z" for test period.

As was stated in paragraph 3.4.1, the 11-hour forecasts were based on different "aged" data, i.e., data 13 hours old during control period and 7 hours old during test period.

It follows, therefore, that any excess of (b) over (a) is likely to be due, at least in part, to the effect of the newer data available during the test period. As in the comparison of forecasts based on the same and different "aged" data (paragraph 3.1.1) other factors such as those mentioned in paragraphs 20.2, 20.3, 20.4 and 20.6 of the body of the report, may enter into differences between (a) and (b) but no way of allowing for them was apparent.

4. <u>Wind data from actual flights (Appendix F)</u>

4.1 Of the total of 804 forms received, only 282 were used in the statistical analysis due to the large number received incomplete.

4.2 It was realized that a simple comparison of actual flight time with flight plan time would not suffice to determine the accuracy of the forecast winds. Although the average forecast and actual wind components were indicated on the form for each flight, a further analysis using the basic data submitted by the operators was made by the ICAO Secretariat as follows:

4.2.1 The route was considered as that part between commencement and termination of flight plan procedures.

4.2.2 To simplify computations, the progress of each flight along the rhumb line connecting the departure and destination aerodromes was considered whatever the track actually followed.

4.2.3 The forecast winds for the individual route sections were resolved along the rhumb line. The forecast mean tail wind component was computed by adding the "wind distances" in consecutive sections (as determined by multiplying the time spent in a section by the appropriate rhumb line wind component) and then dividing the total "wind distance" by the total route time.

4.2.4 The actual mean tail wind component was determined as follows:

a) The airspeed was resolved along the rhumb line for each section of the track;

b) The "air distances" parallel to the rhumb line in consecutive sections were then computed and added to give the total "air distance" parallel to the rhumb line;

c) The ground distance flown parallel to the rhumb lines was then determined by applying to the length of the rhumb line route considered (see paragraph 4.2.1) a correction for the difference in latitude between that rhumb line route and the track actually flown, as follows:

$$\text{Ground distance} = \left(\frac{\text{cos. mean latitude actual track}}{\text{cos. mean latitude rhumb line route}}\right) \times \text{(length of rhumb line route)}$$

d) The actual mean tail wind component parallel to the rhumb line was then found by subtracting the total air distance from the total ground distance and dividing by the total route time.

4.3 The results have been summarized in Appendix F and include:

a) Mean absolute and mean arithmetic errors by weeks (control and test) as submitted by the operators and as computed by the Secretariat;

b) Standard deviations of the errors;

c) Ogives (cumulative frequency curves) of the distribution of the errors;

d) Mean absolute and mean arithmetic errors and standard deviations for eastbound and westbound flights separately;

e) Scatter diagrams showing relationship of the forecast and actual wind components;

f) Pertinent data extracted and computed from each flight data form used in the above statistics.

4.4 A graph enabling a comparison to be made of actual wind components as determined by flights made about the same time is given in Appendix C, Figure 1. On the same graph are also plotted actual wind components determined from upper air charts by the London and New York meteorological offices.

APPENDIX D

ANALYSIS OF ERRORS OF WIND FORECASTS FOR VARIOUS ROUTES USING "ACTUAL" WINDS DETERMINED FROM CHARTS AS STANDARD OF REFERENCE

1. Analysis of the 500 mb. wind component forecasts prepared at London and New York for the Ireland-Newfoundland route.

TABLE I

Mean absolute and mean arithmetic errors and standard deviations of the errors of forecasts made by normal techniques and mean absolute and mean arithmetic errors of "forecasts" based on persistence

New York/La Guardia Airport Mean tail wind component Gander-Shannon (G.C.)	No. of Fcsts.	18-24 Hour Forecasts made by Normal Techniques			24-Hour-Persistence "Forecasts"	
		Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)	Mean Abs. Error (kts)	Mean Arith. Error (kts)
1st week (control)	14	6.3	-1.9			
2nd week (test)	14	6.6	-2.0			
3rd week (control)	14	8.4	+5.1			
4th week (test)	14	7.8	-2.2			
5th week (control)	14	8.9	+2.4			
Total Control Prd.	42	7.7	+1.9	9.7	8.7	+2.3
Total Test Period	28	7.2	-2.1	9.4	12.3	-1.6
London/London Airport Equivalent tail wind Shannon-Gander (G.C.)						
1st week (control)	14	10.0	-2.2			
2nd week (test)	14	9.1	-2.6			
3rd week (control)	14	10.0	-4.9			
4th week (test)	14	9.3	-1.4			
5th week (control)	14	12.6	-5.6			
Total Control Prd.	42	11.1	-4.2	12.8	10.3	+1.5
Total Test Period	28	9.2	-2.0	11.2	10.6	-3.3

Note 1.- The London forecast and actual figures were equivalent tail winds, while the New York values were tail wind components.

Note 2.- In the arithmetic means a plus sign indicates that a smaller tail wind (or greater head wind) occurred than was forecast, i.e., the actual wind was less favourable than was forecast.

Note 3.- The number of forecasts in each test week is the same as in each control week because the New York forecasts were verified from only two charts per day throughout the five weeks and so for standardization purposes the same number were used in the London data, even though four forecasts per day were verified during the test period at the London office.

1.1 Table I indicates a small reduction in the mean absolute errors and the standard deviations during the test period of both offices; however, when the usual statistical tests are applied these differences are not found to be significant.

1.2 Although there is no significant difference in the forecast accuracy between the control and test periods, an appreciable difference in the mean arithmetic errors (biases) can be noted in paragraph 1. The difference between the mean arithmetic errors for the London and New York data was about six knots during the control period and nearly zero during the test period. This change is shown graphically in Figures 3 and 4 in this Appendix. A similar change in the biases will be noted in the analysis of the wind data from actual flights (see Appendix F, paragraph 2, where the reasons for bias, and for changes therein, are discussed).

1.3 An examination of the 24-hour mean absolute errors of forecasts which could have been made on the basis of persistence reveals that there was greater persistence, and therefore perhaps less forecast difficulty, during the control period than during the test period. The difference in accuracy between the forecasts made by normal techniques during the trial and those based on 24-hour persistence, in terms of mean absolute errors, is shown in the following table:

TABLE II

	Mean absolute errors (kts)		Reduction in mean absolute error of forecasts made by normal techniques as compared with persistence "forecasts"
	Forecasts made by normal techniques	Persistence "forecasts"	
New York/La Guardia Airport			
Control Period	7.7	8.7	1.0
Test Period	7.2	12.3	5.1
London Airport			
Control Period	11.1	10.3	-0.8
Test Period	9.2	10.6	1.4

Thus the reduction in the mean absolute errors of the actual forecast as compared with those of the persistence forecasts was appreciably greater during the test period than during the control period. However, even though the forecasts appear to be appreciably better during the test period after the factor of persistence is eliminated, it is believed that the size of the sample is still too small for the improvement to be considered significant.

1.4 In order to show more precisely the distribution of the errors of wind forecasts, the errors of the two offices are combined in the following frequency distribution table:

TABLE III

	No. of Fcsts.	Percentage of errors (knots) which equalled value shown (± 2 kts) -40	-35	-30	-25	-20	-15	-10	-5	0	+5	+10	+15	+20	+25	+30	+35	+40
Control Period	84	0	1	1	1	5	10	8	20	14	15	15	4	4	2	0	0	0
Test Period	56	0	0	4	0	5	7	14	11	20	23	9	5	2	0	0	0	0

Note.- In this table the signs of the New York components are changed from the original data, in order that the same sign may indicate an error in the same direction with the two sets of data. Thus a plus error indicates that the eastbound tail winds (or westbound head winds were forecast too low.

1.5 Figures 1 and 2 show comparisons of the cumulative frequency curves of these errors between the control and test periods for each of the two offices.

2. A summary of mean absolute and mean arithmetic errors and standard deviations of the errors of the 500 mb. wind forecasts received from other meteorological offices is contained in Table IV.

TABLE IV

SUMMARY OF MEAN ABSOLUTE AND MEAN ARITHMETIC ERRORS AND STANDARD DEVIATIONS OF THE ERRORS OF 500 mb. WIND FORECASTS RECEIVED FROM OTHER METEOROLOGICAL OFFICES

		No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
United Kingdom					
1. **London Airport**					
Comparison of forecast and observed equivalent tail winds for routes other than the Shannon-Gander (G.C.) issued at irregular times.	Control Period	28	10.5	-6.8	10.2
	Test Period	21	8.5	+3.3	9.2
2. **Prestwick Airport**					
Comparison of forecast and observed wind components for the Prestwick-Shannon (G.C.) and other routes issued at irregular times.	Control Period	36	10.8	-6.4	13.6
	Test Period	31	9.5	+3.8	11.9
Ireland					
Shannon Airport					
Comparison of forecast and observed wind components for the Shannon-Gander (G.C.) route.	1st week (control)	35	8.0		
	2nd week (test)	35	7.0		
	3rd week (control)	35	4.9		
	4th week (test)	35	4.7		
	5th week (control)	35	8.7		
	Control Period	105	7.2		
	Test Period	70	5.9		

TABLE IV (Cont'd)

United States

1. New York/La Guardia Airport

a) Comparison of forecast (from 24-hour prognostic charts) and observed wind vectors for 15 locations (per forecast) over North Atlantic. See Appendix B, paragraph 1.3.1 for list of locations and method of verification. Errors are average per location.

	No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
1st week (control)	14	15*		
2nd week (test)	28	16*		
3rd week (control)	14	14*		
4th week (test)	28	15*		
5th week (control)	14	15*		
Control Period	42	15*		
Test Period	56	15*		

b) Comparison of forecast (from flight forecast charts) and observed wind components for the New York-Gander (R.L.) route.

	No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
1st week (control)	21	6		
2nd week (test)	21	9		
3rd week (control)	21	9		
4th week (test)	21	10		
5th week (control)	21	10		
Control Period	63	9		
Test Period	42	9		

2. Westover Air Force Base (USAF)

a) Comparison of forecast (from 24-hour prognostic charts) and observed wind components for Westover-Lages (G.C. or R.L.) route (zones 12-7).

	No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
1st week (control)	14	9		
2nd week (test)	14	11		
3rd week (control)	14	6		
4th week (test)	14	8		
5th week (control)	14	9		
Control Period	42	8.0		
Test Period	28	9.5		

* See paragraphs referred to in first column for units and interpretation.

TABLE IV (Cont'd)

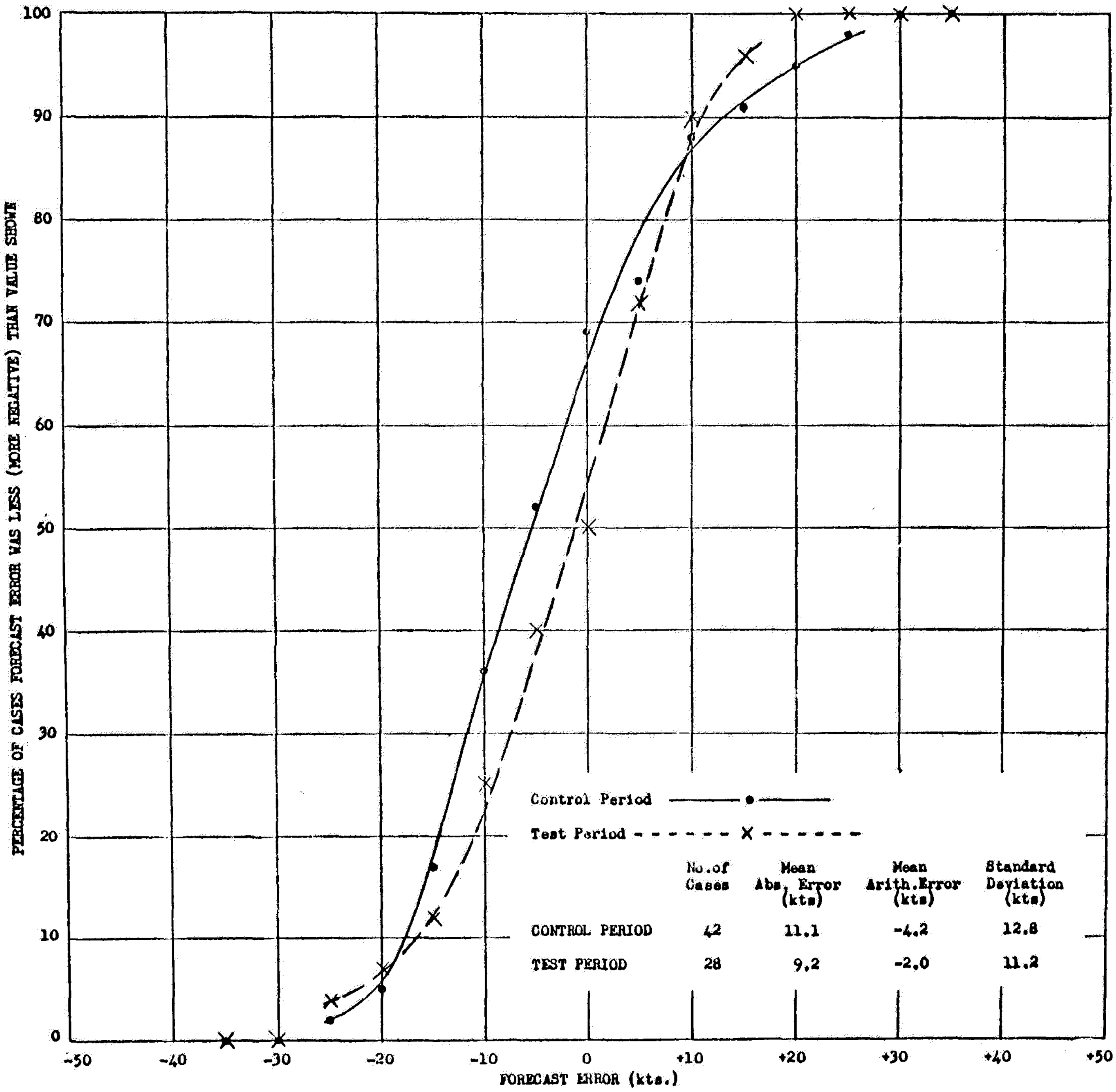
b) Comparison of forecast (from 24-hour prognostic charts) and observed wind vectors for 12 locations (per forecast) over the North Atlantic. See Appendix B, paragraph 1.3.2 for list of locations and method of verification. Errors are average per location.

	No. of Fcsts.	Mean Abs. Error	Mean Arith. Error	Standard Deviation
1st week (control)	14	46*		
2nd week (test)	14	46*		
3rd week (control)	14	41*		
4th week (test)	14	56*		
5th week (control)	14	43*		
Control Period	42	47*		
Test Period	28	51*		

* See paragraphs referred to in first column for units and interpretation.

FIGURE 1 (APPENDIX D)

CUMULATIVE FREQUENCY CURVES OF FORECAST ERRORS OF EQUIVALENT TAIL WIND COMPONENTS FOR THE SHANNON-GANDER(G.C.) ROUTE MADE AT LONDON AIRPORT.



	No. of Cases	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
CONTROL PERIOD	42	11.1	-4.2	12.8
TEST PERIOD	28	9.2	-2.0	11.2

FIGURE 2 (APPENDIX D)

CUMULATIVE FREQUENCY CURVE OF FORECAST ERRORS OF TAIL WIND COMPONENT FOR THE GANDER-SHANNON(G.C.) ROUTE MADE AT NEW YORK/LaGUARDIA AIRPORT

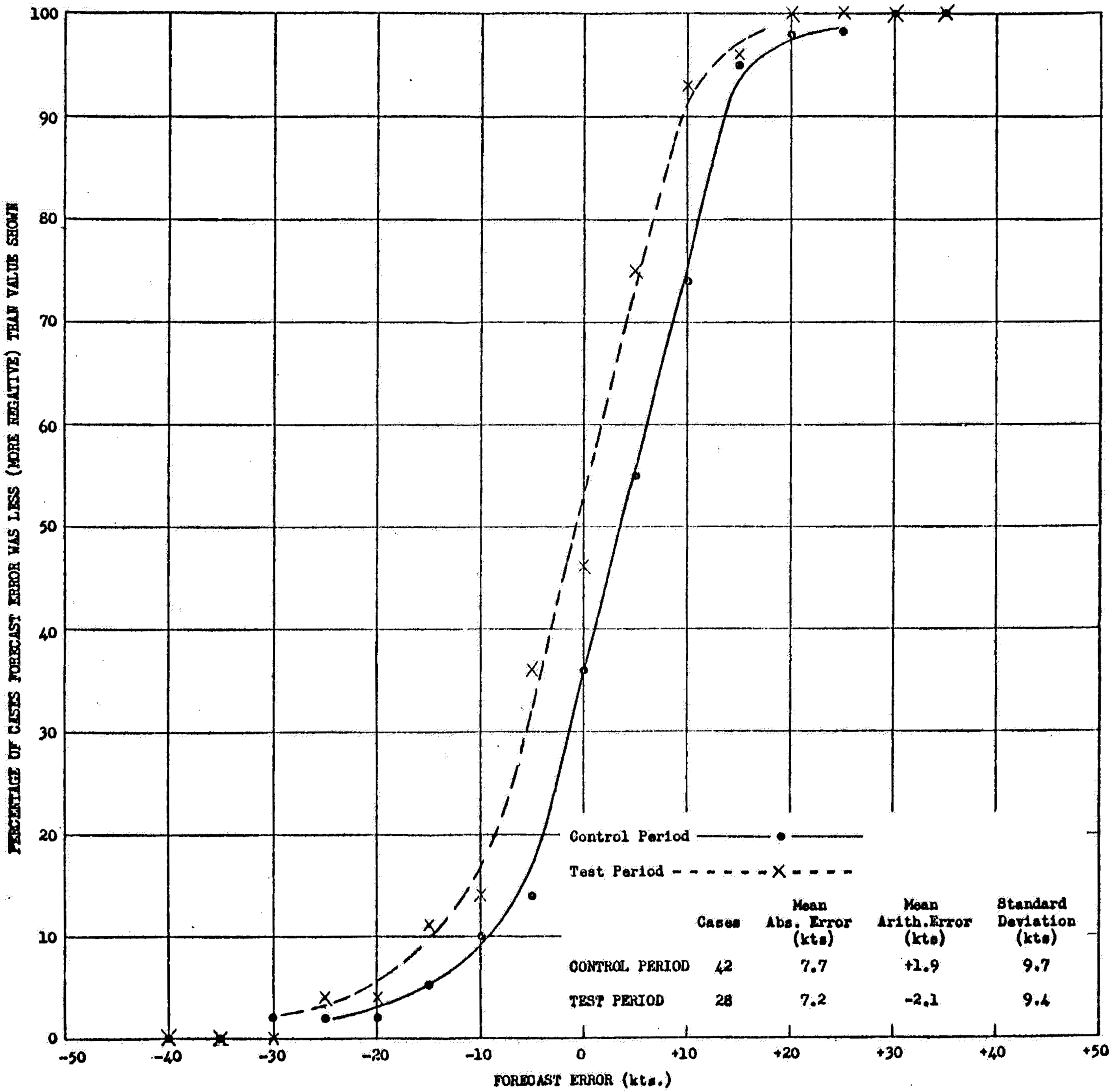


FIGURE 3 (APPENDIX D)

CUMULATIVE FREQUENCY CURVES OF FORECAST ERRORS OF TAIL WIND COMPONENTS (NEW YORK/LaGUARDIA AIRPORT) AND EQUIVALENT TAIL WINDS (LONDON AIRPORT) FOR THE GANDER-SHANNON (G.C.) ROUTE DURING CONTROL PERIOD

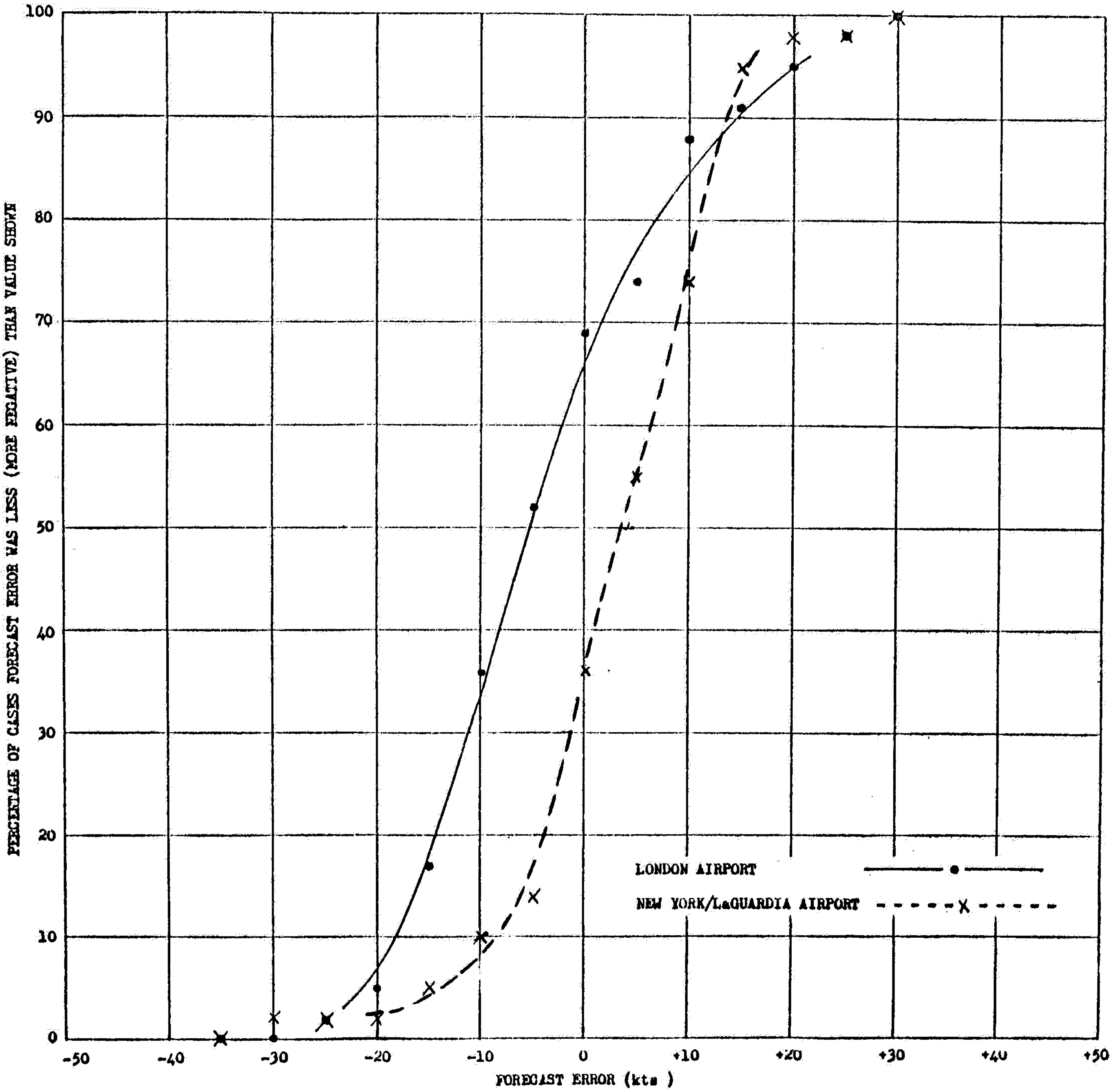
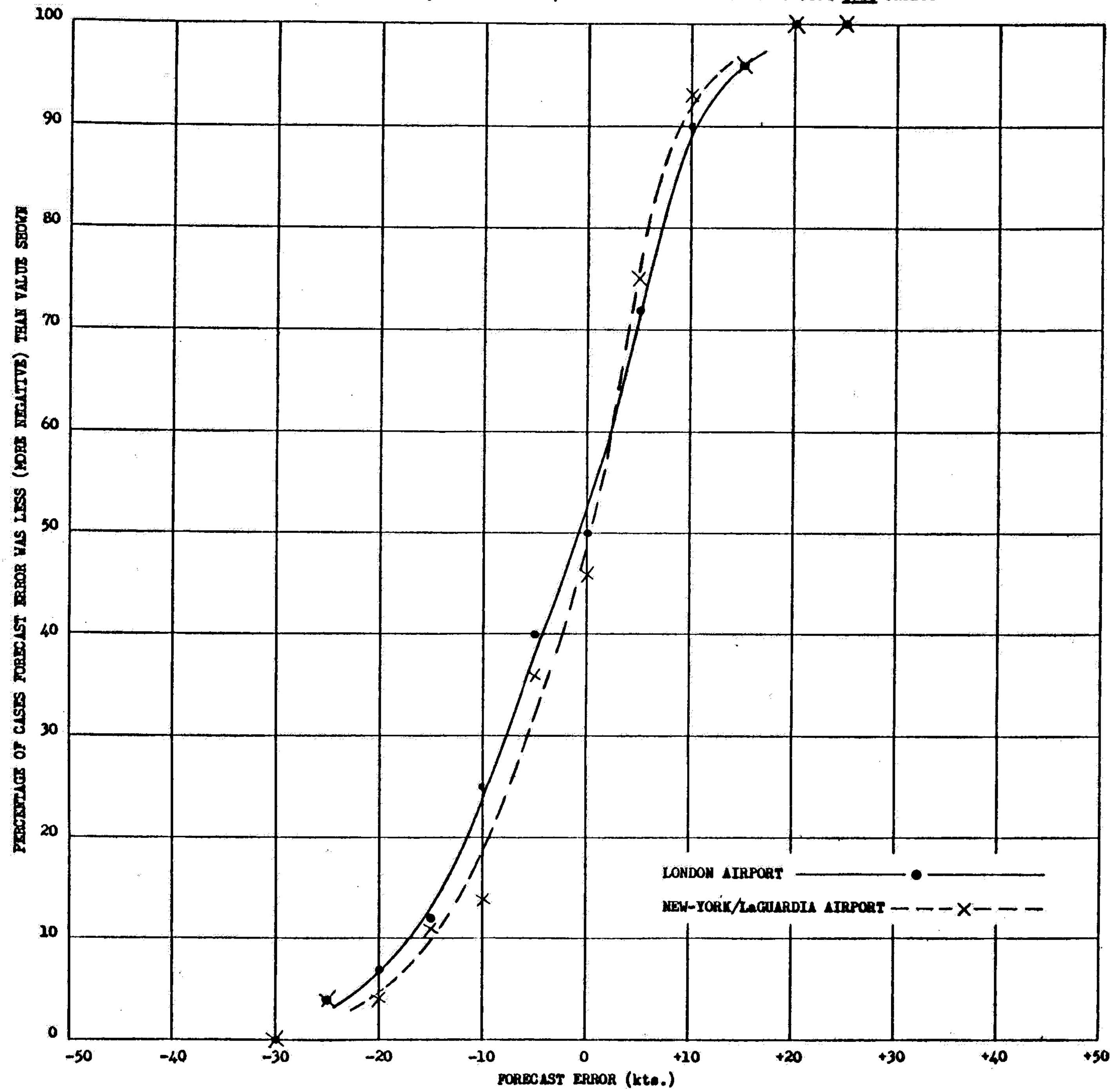


FIGURE 4 (APPENDIX D)

CUMULATIVE FREQUENCY CURVES OF FORECAST ERRORS OF TAIL WIND COMPONENTS (NEW YORK/LaGUARDIA AIRPORT) AND EQUIVALENT TAIL WINDS (LONDON AIRPORT) FOR GANDER-SHANNON ROUTE DURING TEST PERIOD



APPENDIX E

ANALYSIS OF "D" VALUE DATA FROM METEOROLOGICAL OFFICES

1. Analysis of "D" value forecasts prepared at Gander, Newfoundland

1.1 "D" value forecasts for Gander, Newfoundland, prepared at Gander

1.1.1 Summary of errors

TABLE I

Mean absolute and mean arithmetic errors

	No. of Fcsts.	5-Hr. Fcsts.		11-Hr. Fcsts.		17-Hr. Fcsts.	
		Mean Abs. Error (ft.)	Mean Arith. Error (ft.)	Mean Abs. Error (ft.)	Mean Arith. Error (ft.)	Mean Abs. Error (ft.)	Mean Arith. Error (ft.)
1st week (control)	13	144	-63	225	-107	211	-91
2nd week (test)	25	96	+ 2	128	- 6	186	-21
3rd week (control)	13	119	+27	164	- 59	151	-22
4th week (test)	22	149	+45	183	+ 15	235	- 8
5th week (control)	12	142	-95	155	-128	209	-91
Control Period	38	135	-42	182	- 97	198	-67
Test Period	47	121	+22	154	+ 3	209	-15

Note.- The large difference in the number of forecasts during each test week as compared to the control weeks is due to the fact that twice the number of forecasts were verified during each test week (see Appendix C, paragraph 1.4).

TABLE II

Correlation coefficients, standard errors of estimate and values of "z"

	No. of Fcsts.	Correlation Coefficient between actual and fore-cast "D" values r	Standard error of estimate of fore-casts Sy (ft.)	"z"
5-Hr. Forecasts				
Control Period	38	0.92	116	1.59
Test Period	47	0.91	109	1.54
11-Hr. Forecasts				
Control Period	38	0.82	215	1.15
Test Period	47	0.81	205	1.11
17-Hr. Forecasts				
Control Period	38	0.78	228	1.03
Test Period	47	0.67	249	0.81

A comparison of the mean absolute errors (Table I) indicates that 5 and 17-hour forecasts had about the same accuracy during the test period as during the control period while the 11-hour forecasts were more accurate on the average by 28 feet during the test period. The correlation coefficients, etc., given in Table II, indicate that the accuracy of the 5 and 11-hour forecasts was about the same in the control and test periods but that the 17-hour forecasts were more accurate during the control period. This apparent discrepancy is due to the fact that the distribution of the errors is not reflected in the mean absolute errors, while it is reflected in the correlation coefficients.

1.1.2 Comparison of the forecasts by the two methods described in Appendix C, paragraph 3.4.

a) Comparison of forecasts based on the same and different "aged" data

TABLE III

Forecasts based on same "aged" data (7 hours old in control and test periods)	Test "z"	Control "z"	Difference in forecast difficulty as represented by differences in "z"
5-hour forecasts	1.54	1.59	-0.05
17-hour forecasts	0.81	1.03	-0.22

i) The difference in forecast difficulty in making 11-hour forecasts based on data 7 hours old is approximately the mean of the differences for 5 and 17-hour forecasts,

i.e., $\frac{-0.05 + (-0.22)}{2} = -0.14$ or forecast difficulty less during control period than during test period.

TABLE IV

Forecasts based on different "aged" data (7 hours old in test period and 13 hours old in control period)	Test "z"	Control "z"	Difference in forecast difficulty plus effect of different "aged" data as represented by difference in "z"
11-hour forecasts	1.11	1.15	-0.04

ii) Effect of using data 7 hours old instead of 13 hours old in making 11-hour forecasts is then:

(difference in forecast difficulty plus effect of different "aged" data) minus (difference in forecast difficulty) = effect of different "aged" data.

-0.04 - (-0.14) = 0.10 or effect of having newer data during test period is to <u>increase</u> "z" by 0.10 i.e. to improve the forecasting.

This result should be compared with the <u>decrease</u> shown in Table IV for 11-hour forecasts of 0.04 during the test period as compared with the control period when differences in forecasting difficulty are not taken into account. The inference from this result is that additional upper air observations would improve the accuracy of the "D" value forecasts issued during those parts of the day which would result in more recent data being available to the forecaster.

b) <u>Comparison of forecasts made during trial with "forecasts" which could have been made on the basis of persistence</u>

<u>TABLE V</u>

<u>12-hour "forecasts" based on persistence of actual "D" values</u>

	No. of Fcsts.	Correlation Coefficient r	"z"
Control Period	38	0.82	1.15
Test Period	47	0.76	0.99

<u>TABLE VI</u>

<u>"Skill" scores ("z" for forecasts based on normal techniques minus "z" for persistence "forecasts")</u>

	"z" for 11-hour forecasts based on normal techniques (from Table IV)	"z" for 12-hour persistence "forecasts" (from Table V)	"Skill"
Control Period	1.15	1.15	0.00
Test Period	1.11	0.99	0.12

First of all it is clear that the persistence was greater during the control period than during the test period, and if it is assumed that the persistence (or rather the lack of it) is a measure of forecast difficulty, then the forecast difficulty was greater during the test period than during the control period - the same result as was obtained by the first method [preceding paragraph 1.1.2(a)]. When this factor of persistence, or forecast difficulty, is eliminated, the "skill" score during the control period is zero while during the test period it is 0.12.

c) Results of the two methods of comparison

Although at first glance it appeared that the forecasts made during the test period were no more accurate than were those made during the control period, the methods used in subparagraphs 1.1.2 (a) and 1.1.2 (b) above indicate that the difficulty in making forecasts during the test period was greater and that when this difference in forecast difficulty or persistence was taken into consideration, the forecasting success was greater during the test period. However, the improvement in the test period as indicated by the two methods is so small that, in view of the small size of sample, it cannot be considered significant.

1.2 "D" value forecasts for Goose, Labrador, prepared at Gander

1.2.1 Summary of errors

TABLE VII

Mean absolute and mean arithmetic errors

	No. of Fcsts.	5-Hr. Fcsts. Mean Abs. Error (ft.)	5-Hr. Fcsts. Mean Arith. Error (ft.)	11-Hr. Fcsts. Mean Abs. Error (ft.)	11-Hr. Fcsts. Mean Arith. Error (ft.)	17-Hr. Fcsts. Mean Abs. Error (ft.)	17-Hr. Fcsts. Mean Arith. Error (ft.)
1st week (control)	13	152	+ 3	135	-41	210	-68
2nd week (test)	25	101	-16	108	+ 4	147	+ 1
3rd week (control)	13	155	-10	124	- 5	178	-22
4th week (test)	16	119	-44	122	- 8	191	-23
5th week (control)	12	162	-10	237	-27	235	-55
Control Period	38	156	- 1	163	-24	207	-49
Test Period	41	108	-27	113	- 1	164	- 8

TABLE VIII

Correlation coefficients, standard errors of estimate and values of "z"

	No. of Fcsts.	Correlation Coefficient between actual and fore-cast "D" values r	Standard error of estimate of fcsts. Sy (ft.)	"z"
5-Hr. Forecasts				
Control Period	38	0.86	216	1.29
Test Period	41	0.86	116	1.29
11-Hr. Forecasts				
Control Period	38	0.82	218	1.15
Test Period	41	0.81	153	1.12
17-Hr. Forecasts				
Control Period	38	0.77	250	1.01
Test Period	41	0.67	208	0.81

A comparison of the absolute mean errors indicates that all forecasts were more accurate by 40-50 feet during the test period, but the table of correlation coefficients, etc., indicates that there was little difference in the 5 and 11-hour forecasts and that the 17-hour forecasts were actually more accurate during the control period than during the test period. This situation is similar to that revealed in the analysis of the forecasts for Gander. (See paragraph 1.1.1.)

1.2.2 Comparison of the forecasts by the two methods described in Appendix C, paragraph 3.4

a) Comparison of forecasts based on the same and different "aged" data

TABLE IX

Forecasts based on same "aged" data (7 hours old in control and test periods)	Test "z"	Control "z"	Difference in forecast difficulty as represented by difference in "z"
5-hour forecasts	1.29	1.29	0
17-hour forecasts	0.81	1.01	-0.20

i) The difference in forecast difficulty in making the 11-hour forecasts based on data 7 hours old is approximately the mean of the differences for the 5 and 17-hour forecasts,

i.e., $\frac{0 + (-0.20)}{2} = -0.10$ or forecast difficulty less during the control period than during the test period.

TABLE X

Forecasts based on different "aged" data (7 hours old in test period and 13 hours old in control period)	Test "z"	Control "z"	Difference in forecast difficulty plus effect of different "aged" data as represented by difference in "z"
11-hour forecasts	1.12	1.15	-0.03

ii) Effect of using data 7 hours old instead of 13 hours old in making 11-hour forecasts is then:

$-0.03 - (-0.10) = 0.07$ or effect of having the additional or newer data during the test period is to increase "z" by 0.07

This result should be compared with the decrease in "z" shown in Table X for 11-hour forecasts of 0.03 during the test period as compared with the control period.

b) Comparison of forecasts with those based on persistence

TABLE XI

12-hour "forecasts" based on persistence of actual "D" value

	No. of Fcsts.	Correlation Coefficient r	"z"
Control Period	38	0.84	1.22
Test Period	41	0.80	1.09

TABLE XII

"Skill" scores ("z" for forecasts based on normal techniques minus "z" for persistence "forecasts")

	"z" value for 11-hour actual forecasts (from Table X)	"z" value for 12-hour persistence "forecasts" (from Table XI)	"Skill"
Control Period	1.15	1.22	-0.07
Test Period	1.12	1.09	+0.03

As was found in the forecasts for Gander, the persistence was greater during the control period than during the test period. After eliminating the persistence factor it was found that the "skill" score was 0.10 better during the test period than during the control period.

c) Results of the two methods of comparison

Both methods indicate that there was greater forecast difficulty or less persistence during the test period and that when these factors were eliminated the forecasting success was greater during the test period than during the control period.

1.3 Results of analyses of "D" value forecasts prepared at Gander, Newfoundland

The results of the analyses of the "D" value forecasts prepared at Gander for Gander and Goose are very similar. It is noteworthy that in spite of the fact that the correlation coefficients, as determined from the original data, indicate no improvement and, in some cases, deterioration of the forecast accuracy during the test period, these analyses do indicate that there actually was an improvement in the forecast accuracy after the factor of forecast difficulty is taken into consideration. In both cases, however, the increase in accuracy is so small that it cannot be considered significant.

2. Analysis of "D" value forecast prepared at Orly, Paris, France for Paris (Trappes) and OSV "E"

2.1 "D" value forecasts for Paris (Trappes) prepared by Orly

2.1.1 Summary of errors

TABLE XIII

Mean absolute and mean arithmetic errors

	No. of Fcsts.	5-Hr. Fcsts. Mean Abs. Error (m)	5-Hr. Fcsts. Mean Arith. Error (m)	11-Hr. Fcsts. Mean Abs. Error (m)	11-Hr. Fcsts. Mean Arith. Error (m)	17-Hr. Fcsts Mean Abs. Error (m)	17-Hr. Fcsts Mean Arith. Error (m)
1st week (control)	12	25	+ 9	41	+14	33	+11
2nd week (test)	26	28	+ 7	37	+13	45	+ 3
3rd week (control)	11	33	+ 8	76	+39	83	+46
4th week (test)	26	35	- 2	44	- 1	54	+ 2
5th week (control)	11	30	-16	42	+11	64	-47
Control Period	34	29	- 1	53	+11	61	+ 2
Test Period	52	32	+ 3	41	+ 6	50	+ 3

TABLE XIV

Correlation coefficients, standard errors of estimate and values of "z"

	No. of Fcsts.	Correlation Coefficient between actual and forecast "D" values r	Standard error of estimate of forecasts Sy (m)	"z"
5 Hr.-Forecasts				
Control Period	34	0.90	44	1.46
Test Period	52	0.91	41	1.54
11-Hr. Forecasts				
Control Period	34	0.79	60	1.07
Test Period	52	0.88	48	1.36
17-Hr. Forecasts				
Control Period	34	0.69	69	0.85
Test Period	52	0.74	63	0.95

Tables XIII and XIV indicate about the same difference between the forecast accuracy of the control period as compared with the test period.

2.1.2 Comparison of the forecasts by the two methods described in Appendix C, paragraph 3.4

a) Comparison of forecasts based on the same and different "aged" data

TABLE XV

Forecasts based on same "aged" data (7 hours old in control and test periods)	Test "z"	Control "z"	Difference in forecast difficulty as represented by difference in "z"
5-hour forecasts	1.54	1.46	0.08
17-hour forecasts	0.95	0.85	0.10

i) The difference in "forecast difficulty" in making 11-hour forecasts based on data 7 hours old is approximately the mean of the difference for the 5 and 17-hour forecasts,

i.e., $\frac{0.08 + 0.10}{2} = 0.09$ or "forecast difficulty" greater during control period than during test period.

TABLE XVI

Forecasts based on different "aged" data (7 hours old in test period and 13 hours old in control period)	Test "z"	Control "z"	Difference in forecast difficulty plus effect of different "aged" data as represented by difference in "z"
11-hour forecasts	1.36	1.07	0.29

ii) Effect of using data 7 hours old instead of 13 hours old in making 11-hour forecasts is then:

$0.29 - 0.09 = +0.20$ or effect of having newer data during test period is to increase "z" by 0.20.

This result should be compared with the increase in "z" shown in Table XVI for 11-hour forecasts of 0.29 in the test period as compared with the control period when differences in forecast difficulty are not taken into account.

b) Comparison of forecasts made during the trial with "forecasts" which could have been made on the basis of persistence

TABLE XVII

12-hour "forecasts" based on persistence of actual "D" values

	No. of Fcsts.	Correlation Coefficient r	"z"
Control Period	34	0.96	1.82
Test Period	52	0.88	1.36

TABLE XVIII

"Skill" scores ("z" for forecasts based on normal techniques minus "z" for persistence "forecasts")

	"z" for 11-hour actual forecasts (from Table XVI)	"z" for 12-hour persistence "forecasts" (from Table XVII)	"Skill"
Control Period	1.07	1.82	-0.75
Test Period	1.36	1.36	0

c) Results of the two methods of comparison

According to the first method [paragraph 2.1.2(a)], the "forecast difficulty" during the control period was greater than during the test period, but the results of the second method indicate that there was more persistence in the "D" values (and so, perhaps, less forecast difficulty) during the control period. Although these results apparently contradict each other, it must be remembered that there is no absolute method for computing the "forecast difficulty" factor and that these two methods have been used only in an attempt to find some indications. The important result of both methods in this analysis is that they both indicate that the forecasts made during the test period were more successful than those made during the control period. However, as in the previous analyses, the improvement is not great enough to be considered significant in view of the small size of the sample.

2.2 "D" value forecasts for OSV "K" prepared at Orly

2.2.1 Summary of errors

TABLE XIX

Mean absolute and mean arithmetic errors

	No. of Fcsts.	5-Hr.-Fcsts. Mean Abs. Error (m)	5-Hr.-Fcsts. Mean Arith. Error (m)	11-Hr.-Fcsts. Mean Abs. Error (m)	11-Hr.-Fcsts. Mean Arith. Error (m)	17-Hr. Fcsts. Mean Abs. Error (m)	17-Hr. Fcsts. Mean Arith. Error (m)
1st week (control)	11	49	+ 2	50	+16	53	+ 6
2nd week (test)	26	53	- 6	67	-23	87	-46
3rd week (control)	10	46	- 7	65	+15	95	+21
4th week (test)	26	45	-13	52	-16	55	-21
5th week (control)	13	48	+11	71	+40	79	+49
Control Period	34	48	+ 3	62	+25	76	+27
Test Period	52	49	-10	60	-20	71	-34

TABLE XX

Correlation coefficients, standard errors of estimate and values of "z"

	No. of Fcsts.	Correlation Coefficient between actual and forecast "D" values r	Standard error of estimate of forecasts Sy (m)	"z"
5-Hr. Forecasts				
Control Period	34	0.80	57	1.09
Test Period	42	0.86	65	1.29
11-Hr. Forecasts				
Control Period	34	0.72	73	0.91
Test Period	42	0.85	67	1.25
17-Hr. Forecasts				
Control Period	34	0.67	85	0.81
Test Period	42	0.80	75	1.09

The mean absolute errors shown in Table XIX indicate very little difference in the errors between the control and test periods but the correlation coefficients, etc., in Table XX show a rather pronounced increase in the accuracy during the test period, particularly in the 11 and 17-hour forecasts.

2.2.2 Comparison of the forecasts by the two methods described in Appendix C, paragraph 3.4

a) Comparison of forecasts based on the same and different "aged" data

TABLE XXI

Forecasts based on same "aged" data (7 hours old in control and test periods)	Test "z"	Control "z"	Difference in forecast difficulty as represented by differences in "z"
5-hour forecasts	1.29	1.09	0.20
17-hour forecasts	1.09	0.81	0.28

i) The difference in "forecast difficulty" in making 11-hour forecasts based on data 7 hours old is approximately the mean of the differences for the 5 and 17-hour forecasts,

i.e., $\frac{0.20 + 0.28}{2} = 0.24$ or forecast difficulty greater during the control period than during the test period.

TABLE XXII

Forecasts based on different "aged" data (7 hours old in test period and 13 hours old in control period)	Test "z"	Control "z"	Difference in forecast difficulty plus effect of different "aged" data as represented by difference in "z"
11-hour forecasts	1.25	0.91	0.34

ii) Effect of using data 7 hours old instead of 13 hours old in making 11-hour forecasts is then

$0.34 - 0.24 = 0.10$ or effect of having newer data during the test period is to increase "z" by 0.10 i.e., to improve the forecasting.

This result should be compared with the increase in "z" shown in Table XXII for 11-hour forecasts of 0.34 in the test period as compared with the control period. While the increase in "z" was sharply reduced (from 0.34 to 0.10) after the difference in forecast difficulty was eliminated, it should be noted that there still was some improvement in "z" during the test period.

b) Comparison of forecasts made during the trial with "forecasts" which could have been made on the basis of persistence

TABLE XXIII

12-hour "forecasts" based on persistence of "D" values

	No. of Fcsts.	Correlation Coefficient r	"z"
Control Period	34	0.78	1.03
Test Period	42	0.91	1.54

TABLE XXIV

"Skill" scores ("z" for forecasts based on normal techniques minus "z" for persistence "forecasts")

	"z" for 11-hour forecasts (from Table XXII)	"z" for 12-hour persistence "fore-casts" (from Table XXIII)	"Skill"
Control Period	0.91	1.03	-0.12
Test Period	1.25	1.54	-0.29

c) Results of the two methods of comparison

The two methods both indicate that there was greater forecast difficulty during the control period, but while the first method [paragraph 2.2.2 (a)] showed that there was some improvement in the forecasts during the test period, the second method [paragraph 2.2.2(b)] indicated a deterioration in the forecast "skill". It is difficult to explain the varying results but it should be noted again that there is no particularly close relationship between the two methods and neither is considered to be without weaknesses which would be emphasized by the small size of the sample involved here. The reason for the apparent decrease in "skill" during the test period in Table XXIV above, is the fact that the increase in the "z" for 11-hour forecasts was more than offset by the large increase in "z" for the 12-hour persistence "forecasts".

3. Summary of forecasts made for Paris (Trappes) and OSV "K" by the Paris Central Service

3.1 "D" value forecasts for Paris (Trappes) and OSV "K" prepared by Paris Central Service

3.1.1 Summary of errors

TABLE XXV

Mean absolute and mean arithmetic errors

	No. of Fcsts.	5-Hr. Fcsts. Mean Abs. Error (m)	5-Hr. Fcsts. Mean Arith. Error (m)	11-Hr. Fcsts. Mean Abs. Error (m)	11-Hr. Fcsts. Mean Arith. Error (m)	17-Hr. Fcsts. Mean Abs. Error (m)	17-Hr. Fcsts. Mean Arith. Error (m)
Paris, (Trappes)							
1st week (control)	13	33	+ 1			39	+16
2nd week (test)	13	24	+ 9	47	+20	50	+36
3rd week (control)	13	51	+23			75	+48
4th week (test)	13	26	+10	36	-13	43	- 7
5th week (control)	12	26	- 8			59	+16
Control Period	38	37	+ 6			59	+16
Test Period	26	25	+10	42	+ 4	47	+15
OSV "K"							
1st week (control)	13	60	+ 3			51	+ 7
2nd week (test)	13	44	-19	70	-51	82	-59
3rd week (control)	13	38	+10			61	+40
4th week (test)	13	35	-16	48	-20	63	-33
5th week (control)	13	36	+ 9			52	+10
Control Period	39	45	+11			55	+19
Test Period	26	40	-18	59	-36	73	-46

TABLE XXVI

Correlation coefficients, standard errors of estimate and values of "z"

	No. of Fcsts.	Correlation Coefficient between forecast and actual "D" values r	Standard error of estimate of forecasts Sy (m)	"z"
Paris (Trappes)				
5-Hr. Forecasts				
Control Period	38	0.89	50	1.41
Test Period	26	0.95	28	1.82
17-Hr. Forecasts				
Control Period	38	0.86	55	1.29
Test Period	26	0.89	51	1.41
OSV "K"				
5-Hr. Forecasts				
Control Period	39	0.80	57	1.09
Test Period	26	0.93	47	1.66
17-Hr. Forecasts				
Control Period	39	0.73	72	0.93
Test Period	26	0.84	73	1.22

3.1.2 The types of analyses given in paragraphs 1 and 2 of this appendix could not be carried out on the data in the above Tables XXV and XXVI because of the lack of 11-hour forecasts which could be verified by observations during the control period. The tables are presented for the purpose of comparison with Tables XIII and XIV.

4. Special Analysis by France

4.1 In order to get some idea of the relative difficulties involved in forecasting during the periods, the same work that was carried out at Orly was also carried out at Paris Central Service, except that at Paris only two observations per day were used, even during the test period. Forecasts were made by both offices for Paris (Trappes), Brest and OSV "K". The forecast errors for the three points were combined and the results follow in the form of root mean squares:

TABLE XXVII

	5-Hr. Fcsts.* (gpm)	11-Hr. Fcsts.* (gpm)	17-Hr. Fcsts.* (gpm)
By Orly Airfield			
Control Period	52.2	65.0	74.9
Test Period	41.2	49.1	63.3
By Paris (Central Service)			
Control Period	48.7	64.5	81.4
Test Period	32.4	45.5	54.8

A comparison of the root mean square values shows that:

a) during the control period (during which the 2 forecast centres had available only 2 radiosondes a day), the root mean squares of the errors made in the two centres were approximately the same;

b) during the test period, the forecasts contained fewer errors both at Paris (where the use of only 2 observations was continued) and at Orly (where 4 observations were used);

c) the errors were considerably less serious at Paris that at Orly during the test period.

4.2 The errors were then divided according to Gauss's law and the probability of the Orly forecast being more inaccurate than the Paris forecast was calculated, with the following result:

* In the report from France these forecasts were referred to as 12-hour, 18-hour and 24-hour forecasts respectively, but they have been changed here to conform to the practice followed in this report of using the time of issue as the base time for the forecast period (see Appendix C, paragraph 1.5).

TABLE XXVIII

	5-Hr. Fcsts.	11-Hr. Fcsts.	17-Hr. Fcsts.
Test period	0.58	0.52	0.55
Control period	0.52	0.50	0.47

France concluded that:

a) The greater accuracy noted in the "D" value forecast at Orly during the test period is probably not due to the increased number of observations made during that period.

b) It is more readily explained by the fact that the difficulties in forecasting during the test period were not the same as those experienced during the control period.

5. Results of analyses of "D" value forecasts prepared at Paris, France

5.1 In the special analyses by France (paragraph 4), the forecast errors for the three locations (Trappes, OSV "K" and Brest) were combined, and the results indicate that while the "D" value forecasts during the test period were more accurate, the improvement was probably due to the decrease in forecast difficulty in the test period as compared with the control period.

5.2 In the analysis made by the Secretariat, the forecasts for Trappes and OSV "K" were considered separately, and, in general, it was found that the difficulty of forecasting "D" value for Trappes was about the same in both periods, while for OSV "K" the forecast difficulty was much less during the test period. It is likely that a similar analysis of all three locations combined would give a result similar to the one obtained in paragraph 4, namely that the forecast difficulty during the control period was greater than during the test period. In the attempt by the Secretariat to eliminate the effect of the difference in forecast difficulty, the test period showed a greater residual forecast "skill", except in the case of one of the two comparisons made for OSV "K", but the improvement, when it did occur, was not large enough to be considered significant.

5.3 Neither the special analysis by France nor the analysis made by the Secretariat indicate a significant increase in the accuracy of "D" value forecasts made at Paris which could be ascribed to the additional upper air observations.

6. Further summaries of errors in "D" value forecasts

6.1 Tables XXIX to XXXI and Figure 1 contain the following summaries of "D" value data:

Table XXIX - Summaries of errors in 500 mb. "D" value forecasts for certain locations, mainly aerodromes. (Summaries for Ireland given as received; others computed from original data by Secretariat.)

Table XXX - Summaries of errors in 500 mb. "D" value forecasts for three ocean station vessels made by various meteorological offices. (Summaries for Shannon given as received; others computed from original data by Secretariat.)

Table XXXI - Summaries of errors in 500 mb. "D" value forecasts for 14 radiosonde stations, for verification of New York's 24-hour prognostic charts. (Prepared from original data by Secretariat.)

Figure 1 - Cumulative frequency curves of the combined errors in the 11-hour 500 mb. "D" value forecasts prepared at Paris, Gander, Keflavik and New York for their respective locations.

6.2 Tables XXIX and XXX show that, although, in general, the errors were smaller during the test period than during the control period, this was not invariably the case with individual stations. Further, there was considerable variation in the mean errors for the separate weeks of the control period and of the test period.

6.3 The same features mentioned in above paragraph 6.2 are evident in Table XXXI. It is also noticeable that the errors vary considerably from one station to another, although the forecasts were all based on the same prognostic charts (i.e., those prepared in the New York/La Guardia Meteorological Office).

6.4 Figure 1 shows that while there was little difference in percentage frequency of most of the forecast errors between the control and test periods, there was an appreciable decrease in the extreme errors during the test period. In principle, the forecast errors in this graph were computed from forecasts based on data 7 hours old during the test period and 13 hours old during the control period.

TABLE XXIX

SUMMARY OF 500 MB. "D" VALUE DATA RECEIVED FROM OTHER METEOROLOGICAL OFFICES

Note.- Mean errors are stated to the nearest ten or the nearest unit depending on the form in which the data were received.

	No. of Fcsts.	5-Hr. Fcsts. Mean Abs.Error (ft)	5-Hr. Fcsts. Mean Arith.Error (ft)	11-Hr. Fcsts. Mean Abs.Error (ft)	11-Hr. Fcsts. Mean Arith.Error (ft)	17-Hr. Fcsts. Mean Abs.Error (ft)	17-Hr. Fcsts. Mean Arith.Error (ft)
Iceland Keflavik Airport							
1st week (control)	15	130	-40	150	-50	180	-70
2nd week (test)	25	100	-10	120	-20	160	+20
3rd week (control)	13	50	00	80	00	120	-30
4th week (test)	24	80	-20	140	-50	210	-80
5th week (control)	12	110	+20	140	+90	230	+150
Control Period	40	100	-10	130	00	180	+10
Test Period	49	90	-10	130	-30	190	-30
Ireland Shannon Airport (by Shannon)							
1st week (control)	28	94	not available	137	not available	167	not available
2nd week (test)	28	80		95		171	
3rd week (control)	28	76		141		197	
4th week (test)	28	148		171		203	
5th week (control)	28	119		188		246	
Control Period	84	96		155		203	
Test Period	56	114		133		187	
Dublin Airport (by Dublin) 700 mb.							
1st week (control)	28	52	not available	83	not available	121	not available
2nd week (test)	28	61		81		92	
3rd week (control)	28	64		80		93	
4th week (test)	28	45		70		130	
5th week (control)	28	89		90		123	
Control Period	84	68		84		112	
Test Period	56	53		76		111	

TABLE XXIX (Cont'd)

Norway Gardermoen (by Oslo)	No. of Fcsts.	5-Hr. Fcsts. Mean Abs.Error (m)	5-Hr. Fcsts. Mean Arith.Error (m)	No. of Fcsts.	17-Hr. Fcsts. Mean Abs.Error (m)	17-Hr. Fcsts. Mean Arith.Error (m)
1st week (control)	13	49	-10	10	86	+ 4
2nd week (test)	14	27	+ 7	14	45	+11
3rd week (control)	6	70	+13	11	42	+28
4th week (test)	11	15	- 2	11	59	-19
5th week (control)	7	44	- 1	6	61	-45
Control Period	26	52	- 2	27	63	+ 3
Test Period	25	22	+ 3	25	51	- 3
Sola (by Oslo)						
1st week (control)	14	40	+ 3	10	43	+ 9
2nd week (test)	14	38	- 1	14	58	- 6
3rd week (control)	6	41	+ 8	11	27	+ 5
4th week (test)	11	17	-14	11	63	-27
5th week (control)	7	30	-21	6	52	-52
Control Period	27	38	- 2	27	39	- 6
Test Period	25	29	- 6	25	56	-15

TABLE XXIX (Cont'd)

United States New York, N.Y. (by La Guardia Field)	No. of Fcsts.	5-Hr. Fcsts. Mean Abs. Error (ft)	5-Hr. Fcsts. Mean Arith. Error (ft)	11-Hr. Fcsts. Mean Abs. Error (ft)	11-Hr. Fcsts. Mean Arith. Error (ft)	17-Hr. Fcsts. Mean Abs. Error (ft)	17-Hr. Fcsts. Mean Arith. Error (ft)
1st week (control)	14	150	+50	320	+130	330	+180
2nd week (test)	28	120	-30	150	- 80	150	-100
3rd week (control)	14	60	+20	90	- 10	60	+ 20
4th week (test)	28	110	-40	150	- 10	90	- 30
5th week (control)	14	100	-10	110	- 40	120	- 30
Control Period	42	110	+20	150	+ 30	170	+ 60
Test Period	56	120	-40	150	- 50	170	- 70
EEL Intersection (42°N 68°W) (by Westover Airfield, Mass, USAF)							
1st week (control)	28	179	not available	208	not available	301	not available
2nd week (test)	28	177		191		210	
3rd week (control)	28	142		169		144	
4th week (test)	28	221		195		205	
5th week (control)	28	124		152		156	
Control Period	84	146		176		200	
Test Period	56	133		194		136	

TABLE XXIX (Cont'd)

United Kingdom
London and Prestwick Airports
(for their respective airports combined)

	Mean Absolute Errors				
	No. of Fcsts. (Approx.)	2-Hr. Fcsts. (ft)	8-Hr. Fcsts. (ft)	14-Hr. Fcsts. (ft)	20-Hr. Fcsts. (ft)
Control Period	84	93	124	190	234
Test Period	107	83	115	153	206

	Percentage of Errors Exceeding 100,200 and 300 ft.				
	No. of Fcsts. (Approx.)	2-Hr. Fcsts. %	8-Hr. Fcsts. %	14-Hr. Fcsts. %	20-Hr. Fcsts. %
Errors exceeding 100 ft.					
Control Period	84	15	34	56	70
Test Period	107	8	33	54	56
Errors exceeding 200 ft.					
Control Period	84	0	2	24	39
Test Period	107	2	4	15	27
Errors exceeding 300 ft.					
Control Period	84	0	0	5	14
Test Period	107	0	0	2	10

TABLE XXX

SUMMARY OF THE ERRORS IN 500 MB. "D" VALUE FORECASTS FOR OCEAN STATION VESSELS BY VARIOUS METEOROLOGICAL OFFICES

Note.- Mean errors are stated to the nearest ten or the nearest unit depending on the form in which the data were received.

	By New York/La Guardia		By Gander		By Shannon	
	No. of Fcsts.	Mean Abs. Error (ft)	No. of Fcsts.	Mean Abs. Error (ft)	No. of Fcsts.	Mean Abs. Error (ft)
OSV "C"						
1st week (control)	15	160	16	142	not	135
2nd week (test)	26	130	24	138	available	189
3rd week (control)	15	260	14	217		210
4th week (test)	26	220	19	146		145
5th week (control)	14	190	12	117		225
Control Period	44	210	42	160		190
Test Period	52	190	43	141		167
OSV "A"						
1st week (control)	15	230	16	140		
2nd week (test)	26	250	23	260		
3rd week (control)	15	180	14	200		
4th week (test)	26	320	14	130		
5th week (control)	14	230	10	190		
Control Period	44	220	40	190		
Test Period	52	290	37	210		
OSV "B"						
1st week (control)	15	180				
2nd week (test)	26	170				
3rd week (control)	15	130				
4th week (test)	26	150				
5th week (control)	14	230				
Control Period	44	180				
Test Period	52	170				

Note.- The length of the forecast periods varied between offices, but generally was 24 hours from the time of the latest upper air charts.

TABLE XXXI

SUMMARY OF ERRORS IN 500 MB. "D" VALUE FORECASTS PREPARED FROM 24-HOUR PROGNOSTIC CHARTS AT NEW YORK/LA GUARDIA AIRPORT

	No. of Fcsts.	Mean Abs.Error (ft)	Mean Arith.Error (ft)	Mean Abs.Error (ft)	Mean Arith.Error (ft)	Mean Abs.Error (ft)	Mean Arith.Error (ft)
		Rome, New York		Norfolk, Virginia		Goose, Labrador	
1st week (control)	14	300	+180	330	+140	110	+ 10
2nd week (test)	26	170	- 40	190	-150	190	- 40
3rd week (control)	14	100	+ 10	130	+ 50	160	+ 30
4th week (test)	26	180	- 20	160	+ 30	150	- 40
5th week (control)	14	160	+ 60	110	+ 30	200	- 70
Control Period	42	190	+ 90	180	+ 80	160	- 10
Test Period	52	180	- 30	180	- 60	170	- 40
		Argentia, Nfld.		Stephenville, Nfld.		Bermuda	
1st week (control)	14	260	- 10	230	+ 40	220	+120
2nd week (test)	26	250	-140	240	-110	160	- 50
3rd week (control)	14	210	- 20	150	+ 20	240	+ 50
4th week (test)	26	270	- 20	250	- 20	120	- 50
5th week (control)	14	220	+200	250	+210	140	+ 40
Control Period	42	230	+ 60	200	+ 80	200	+ 70
Test Period	52	260	- 80	240	- 60	140	- 50
		Narsarssuak, Greenland		Boston, Mass.		OSV "A"	
1st week (control)	14	170	- 10	160	+ 70	250	+ 50
2nd week (test)	26	280	+210	170	- 20	250	+ 30
3rd week (control)	14	240	- 70	260	+130	190	-110
4th week (test)	26	380	+190	190	- 90	320	+110
5th week (control)	14	310	- 10	160	- 10	230	00
Control Period	42	220	- 60	190	+ 60	230	- 20
Test Period	52	330	+200	180	- 50	290	+ 70

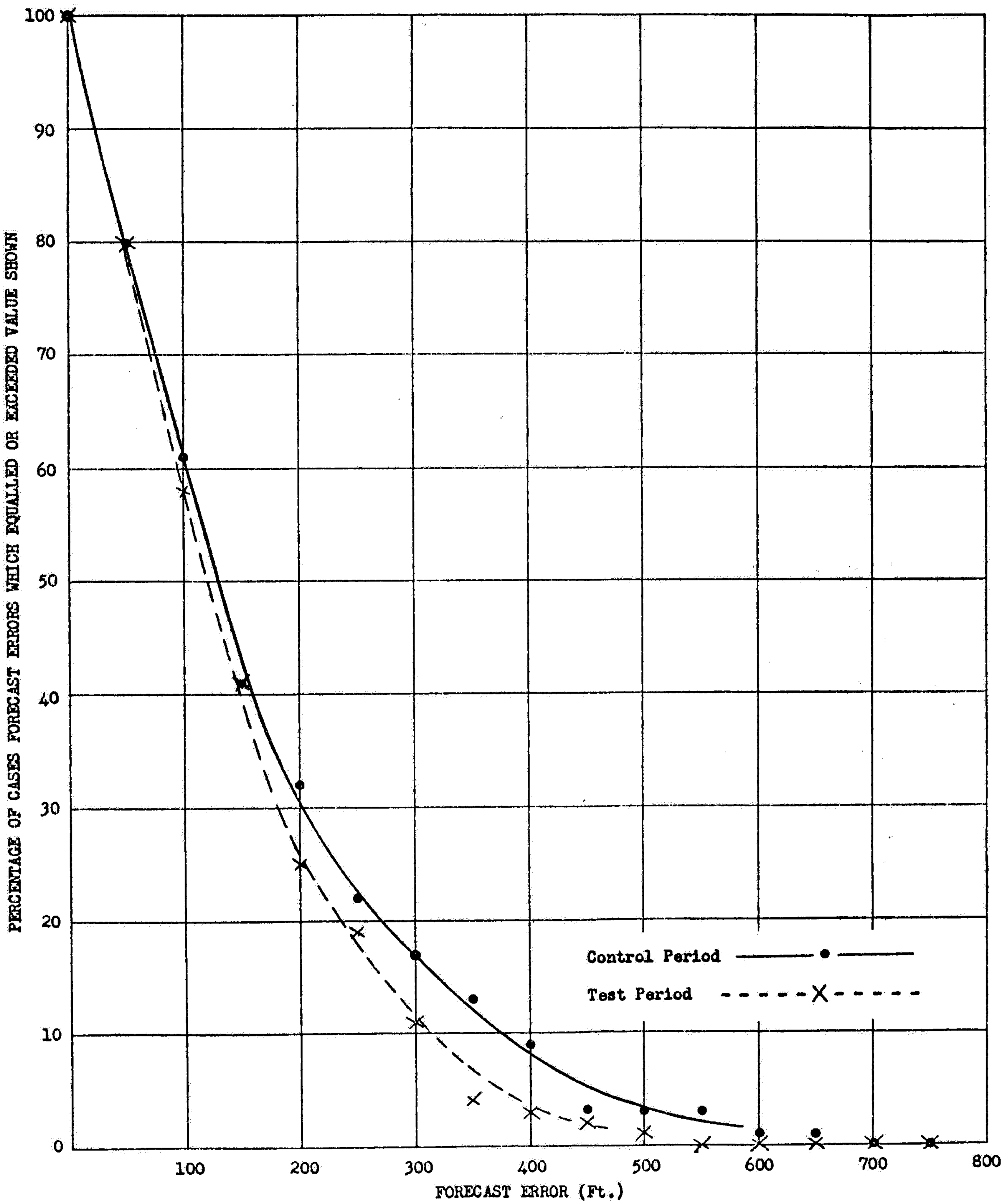
TABLE XXXI (Cont'd)

	No. of Fcsts.	Mean Abs. Error (ft)	Mean Arith. Error (ft)	Mean Abs. Error (ft)	Mean Arith. Error (ft)	Mean Abs. Error (ft)	Mean Arith. Error (ft)
		OSV "B"		OSV "C"		OSV "D"	
1st week (control)	14	190	-160	170	+ 20	250	+ 20
2nd week (test)	26	170	- 20	130	- 90	200	-100
3rd week (control)	14	140	00	280	- 80	260	+ 10
4th week (test)	26	150	+ 20	220	+ 90	240	+ 30
5th week (control)	14	230	-110	200	+ 40	210	+ 60
Control Period	42	190	- 90	220	- 10	240	+ 30
Test Period	52	170	00	180	00	220	- 40
		OSV "E"		OSV "H"			
1st week (control)	14	170	- 50	300	+200		
2nd week (test)	26	150	+ 20	170	-120		
3rd week (control)	14	120	- 50	90	+ 20		
4th week (test)	26	170	-150	130	- 50		
5th week (control)	14	110	- 60	130	- 20		
Control Period	42	130	- 50	170	+ 70		
Test Period	52	160	- 70	150	- 90		

	No. of Fcsts.	Mean Abs. Error (ft)	Mean Arith. Error (ft)
		ALL LOCATIONS COMBINED	
1st week (control)	196	220	+40
2nd week (test)	364	200	-40
3rd week (control)	196	180	0
4th week (test)	364	210	0
5th week (control)	196	190	+10
Control Period	588	200	+20
Test Period	728	200	-20

FIGURE 1 (APPENDIX E)

CUMULATIVE FREQUENCY CURVES OF 11 HOUR 500 MB "D" VALUE FORECAST ERRORS MADE AT PARIS, KEFLAVIK, GANDER AND NEW YORK FOR THEIR RESPECTIVE LOCATIONS COMBINED



APPENDIX F

ANALYSIS OF ERRORS OF WIND FORECASTS FOR VARIOUS ROUTES, USING "ACTUAL" WINDS DETERMINED FROM FLIGHT DATA AS STANDARD OF REFERENCE

1. Although 804 special flight data forms for checking forecast winds were received, many were incomplete and only 282 could be used in the analysis which follows.

TABLE I

Mean absolute and mean arithmetic errors of forecasts of tail-wind components or equivalent tail winds and standard deviations of these errors

A.- Summary of errors computed from flight date forms by Secretariat (See Appendix C, paragraph 4.2)
All flights (all routes and all altitudes)

	No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)	Standard Deviation (kts)
1st week (control)	61	10.1	-0.3	
2nd week (test)	61	10.8	+2.8	
3rd week (control)	69	9.6	+0.4	
4th week (test)	50	9.6	-3.2	
5th week (control)	41	11.0	-0.5	
Control Period	171	10.1	+0.2	12.5
Test	111	10.3	-2.9	13.5
Westbound Flights (Europe to North America - direct - all altitudes)				
Control Period	87	9.7	-4.7	12.2
Test Period	53	9.5	-2.9	12.8
Eastbound Flights (North America to Europe - direct - all altitudes)				
Control Period	64	9.7	+5.1	12.2
Test Period	44	9.8	+1.7	12.4

B.- Summary of errors using components appearing on forms as originally submitted by operators
All flights (all routes and all altitudes)

	No. of Fcsts.	Mean Abs. Error (kts)	Mean Arith. Error (kts)
Control Period	163	9.8	-0.6
Test Period	109	9.7	-0.9

Note.- In the mean arithmetic errors above a plus sign indicates that on the average, a smaller tail wind (or greater head wind) occurred than was forecast, i.e., the actual wind was less favourable than forecast.

2. The statistics given in Table I give no evidence of a significant improvement in the forecasts during the test period as compared with those during the control period. However, the breakdown of the flight data into westbound and eastbound flights shows an appreciable decrease in the biases (mean arithmetic errors) in both the westbound and eastbound flights. This reduction in the biases is similar to that found in the analysis of the London and New York wind component forecasts (see Appendix D, Figures 3 and 4). The fact that the biases of the errors in forecast tail winds for westbound flights are of opposite sign to those for eastbound flights indicates bias of the same sense in terms of wind direction, and suggests that the forecasters on both sides of the Atlantic tended to make the same kind of errors in particular situations. Thus biases of the sign actually found during the control period could have occurred if there had been a tendency on the part of all forecasters involved to underestimate the magnitude of the unusually strong easterlies which occurred during the third week and to be late in forecasting the pronounced reduction in the westerlies which occurred during the fifth week (see Appendix G, Figure 1). The greater bias during the control weeks than during the test weeks might, in the same way, merely be an indication of a prevalence during the control weeks of a type of situation encouraging forecasting errors in one direction.

3. Table II at the end of this appendix shows the pertinent data from each special flight data form which was used in the statistics in this appendix. A blank space indicates that the information was missing from the original form. The computation of tail-wind components by ICAO was carried out in accordance with the procedure outlined in Appendix C, paragraph 4.2. The times are listed just as received on the flight data forms although an inconsistency between the issue time of the forecast and the departure time along the route appears in some cases such as Nos. 9 and 27 in the first week.

4. The scatter diagrams (Figs. 1 and 2) at the end of this appendix show individually the relationship of the forecast and actual component values. While there were more cases during the control period (Fig. 1) the distribution of the errors is about the same as shown during the test period (Fig. 2). The cumulative frequency curves (Fig. 3) clearly show that even in the frequency of extreme errors there was practically no difference between the two periods.

TABLE II

SUMMARY OF SPECIAL FLIGHT DATA FORMS USED IN THE ANALYSIS SUMMARIZED IN TABLE I

	No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms: Fcst.	Mean tail wind components: As received on flight data forms: Actual	Mean tail wind components: As computed by ICAO: Fcst.	Mean tail wind components: As computed by ICAO: Actual	Remarks
1st week (control)	1	8/3	2030	EINN	EINN-CYQX	2308	G.C.	180	-17	-11	- 8	-18	
	2	8/3	2030	EINN	EINN-CYQX	2313	G.C.	200	-17	-14	- 9	-24	
	3	8/3	2200	CYQX	CYQX-EINN	0511	G.C.	170	-10	+ 1	- 9	- 6	
	4	9/3	2030	EINN	EINN-CYQX	0240	G.C.	180	- 6	+ 1	-11	- 7	
	5	9/3	2030	CYQX	CYQX-CSAZ	2326	G.C.	170	+23	+23	+22	+17	
	6	9/3	1700	KLGA	KIDL-EINN	1700	R.L.	170	+10	+13	+11	+10	
	7	9/3	2300	EINN	EINN-CYQX	0000	G.C.	180	- 3	- 8	- 6	+ 1	
	8	10/3	0130	CYQX	CYQX-EINN	0332	R.L.	170	+10	+ 4	+18	+ 1	
	9	10/3	0213	GALA	EINN-CYQX	0213	G.C.	160	- 9	+ 1	-10	+ 2	
	10	10/3	1800	FFOL	FFOL-CYQX	1830	G.C.	180	-31	-30	- 4	+ 4	
	11	10/3	1900	EINN	EINN-CYQX	2311	G.C.	180	+ 5	-11	+ 3	-17	
	12	10/3	2030	CYQX	CYQX-EINN	2300	R.L.	170	+18	+14	+14	+15	
	13	10/3	2100	EINN	EINN-CYQX	2130	G.C.	180	+ 8	+ 8	+ 5	- 5	
	14	10/3	2330	GGBA	GGBA-CYQX	0030	G.C.	140	0	+ 7	- 5	+20	
	15	10/3		EINN	EINN-CYQX	2253	Comp.	140	+ 4	+14	+10	+ 8	Via 58°N 30°W
	16	11/3	0630	CSAZ	CSAZ-CYQX	0805	G.C.	180	-34	-38	-30	-44	
	17	11/3	1230	KLGA	CYVW-CSAZ	2100	G.C.	190	+39	+26	+44	+26	
	18	11/3	1600	GALA	GGBA-CYQX	2137	Comp.	180	- 7	- 6	-13	-13	Via 57°N 30°W
	19	11/3	1700	KLGA	CYQX-EINN	0316	R.L.	170	+11	+ 1	+11	+ 6	
	20	11/3	2000	TFKF	TFKF-CYYR	0130	G.C.	140	-10	- 6	0	+ 6	
	21	11/3	2200	EINN	EINN-CYQX	0119	G.C.	180	- 7	- 4	- 6	-10	
	22	11/3	2210	EINN	EINN-CYQX	2210	G.C.	150	-14	0	-17	-18	
	23	11/3	2300	EINN	EINN-CYQX	2300	R.L.	140	-11	+ 4	-13	+ 6	
	24	11/3		EINN	EINN-CYQX	120130	Comp.	160	+ 7	+ 7	-10	-18	Via 57°N 40°W
	25	12/3	1230	KLGA	CYQX-EINN	2130	R.L.	170	+20	0	+15	- 2	
	26	12/3	1930	EINN	EINN-CYQX	2345	G.C.	200	- 7	0	-15	- 5	
	27	12/3	1930	EINN	EINN-CYQX	2330	G.C.	180	+ 3	+ 2	-19	+ 4	
	28	12/3	2030	CYQX	CYQX-FFOL	0400	R.L.	170	+ 2	- 3	- 2	+ 5	
	29	12/3	2100	KLGA	CYQX-EINN	0442	G.C.	170	+18	- 1	+24	- 3	
	30	12/3	2200	KLGA	CYQX-EINN	0209	G.C.	150	+16	+ 3	+23	+ 2	
	31	12/3		GGBA	GGBA-CYQX	0015	Comp.	140	+ 3	+ 8	+ 7	0	Via Cape Farewell
	32	13/3	0000	GGBA	GGBA-CYQX	0044	G.C.	180	-20	+14	-10	+19	
	33	13/3	0400	CYQX	CYQX-EINN	0931	R.L.	70	+12	+12	+10	+10	
	34	13/3	0040	CSAZ	CSAZ-CYQX	0330	R.L.	200	-15	-11	-22	- 9	
	35	13/3	1735	KLGA	CYVW-CSAZ	0200	R.L.	170	+28	+46	+35	+48	
	36	13/3	1900	GGBA	GGBA-CYQX	1900	G.C.	120	- 4	+ 3	- 4	+12	
	37	13/3	2130	KLGA	KIDL-EINN	2000	R.L.	170	-21	-12	-20	-14	

TABLE II (Cont'd)

	No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms: Fcst.	Actual	As computed by ICAO: Fcst.	Actual	Remarks
	38	13/3	2200	EINN	EINN-CYYR	0000	Comp.	100	+12	+17	+ 9	+17	Via 57°N 30°W
	39	13/3		GGBA	GGBA-CYQX	140015	G.C.	140	+ 3	+17	- 2	+12	
	40	13/3		CYQX	CYQX-GGBA	0603	Comp.	170	- 2	- 4	+ 3	+ 2	Via 51°N 20°W
	41	14/3	1030	EINN	EINN-CYQX	1215	G.C.	140	- 2	+12	- 8	+ 5	
	42	14/3	1930	CYQX	CYQX-EINN	0331	G.C.	170	+ 5	- 4	+16	0	
	43	14/3	2000	EINN	EINN-CYQX	2308	G.C.	60	-21	- 8	- 3	- 3	
	44	14/3	2000	EINN	EINN-CYQX	2129	G.C.	180	-21	-19	-19	-16	
	45	14/3	2000	EINN	EINN-CYQX	0130	G.C.	80	- 5	-10	- 3	- 8	
	46	14/3	2200	CYQX	CYQX-FFOL	2252	G.C.	170	+20	+15	+ 7	+ 2	
	47	14/3	2200	CYQX	CYQX-EINN	2300	R.L.	190	-	+20	+ 8	+27	
	48	14/3		CYQX	CYQX-EINN	0323	R.L.	170	+ 6	+ 5	0	0	
	49	14/3		KLGA	KIDL-EINN	2120	R.L.	150	+30	+25	+37	+31	
	50	15/3	0030	CYQX	CYQX-GGBA	0400	R.L.	180	+18	+24	+ 5	+16	
	51	15/3	1700	EINN	EINN-CYYR	2300	G.C.	160	+23	+23	-12	- 9	
	52	15/3	1800	GALA	EINN-CYQX	2200	G.C.	120	-22	0	-23	-11	
	53	15/3	1845	KLGA	KIDL-EINN	2200	G.C.	210	+24	+11	+36	+15	
	54	15/3	1845	KLGA	KIDL-EINN	2100	R.L.	170	+36	+30	+35	+17	
	55	15/3	1845	KLGA	KIDL-EINN	2230	R.L.	170	+35	+23	+31	+27	
	56	15/3	2030	EINN	EINN-CYQX	2200	G.C.	180	-22	-20	-13	-39	
	57	15/3	2200	CYQX	CYQX-EINN	0000	G.C.	190	+18	-	+20	+25	
	58	15/3	2200	EINN	EINN-CYQX	2330	G.C.	180	-12	-17	-15	-25	
	59	15/3	2330	KLGA	KIDL-EINN	0430	R.L.	190	+34	+25	+31	+29	
	60	16/3	0130	TFKF	TFKF-CYYR	0400	G.C.	140	+ 8	+17	+13	+17	
	61	16/3	0200	CSAZ	CSAZ-CYQX	0330	R.L.	180	-21	-32	-15	-31	
2nd week (test)	1	16/3	1400	EINN	EINN-CYQX	1630	G.C.	180	-20	-35	-14	-53	
	2	16/3	1730	KLGA	CYQX-EINN	0400	G.C.	190	+35	+20	+29	+23	
	3	16/3	2030	CYQX	CYQX-EINN	0300	G.C.	170	+20	+23	+28	+27	
	4	16/3	2100	CYQX	CYQX-CSAZ	2350	R.L.	190	+ 8	+10	+11	+ 6	
	5	16/3	2100	CYQX	CYQX-EINN	0400	G.C.	170	+28	+38	+39	+19	
	6	16/3	2200	EINN	EINN-CYYR	2212	G.C.	160	-25	-11	- 3	-14	
	7	16/3	2200	EINN	EINN-CYYR	0100	G.C.	180	-30	+16	-21	- 6	
	8	17/3	0200	TFKF	TFKF-CYYR	0200	R.L.	160	+10	- 6	+24	- 1	
	9	17/3	1400	CYQX	CYQX-EINN	2030	G.C.	190	+33	+35	+32	+32	
	10	17/3	1500	GALA	GGBA-CYQX	2022	G.C.	180	-15	- 5	-10	- 6	
	11	17/3	1800	KLGA	CYQX-EINN	0200	G.C.	170	+34	+45	+36	+48	
	12	17/3	2130	CYQX	CYQX-GGBA	2200	R.L.	190	+20	+47	+36	+62	
	13	17/3	2200	EINN	EINN-CYQX	2300	Comp.	120	-32	-32	-26	-35	
	14	17/3	2300	EINN	EINN-CYQX	2300	G.C.	140	-39	-42	-39	-44	
	15	18/3	0540	CSAZ	CSAZ-CYVW	0700	R.L.	180	-16	-20	-18	-22	
	16	18/3	1930	CYQX	CYQX-CSPT	0100	G.C.	170	+14	+26	+21	+29	

TABLE II (Cont'd)

No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms		Mean tail wind components: As computed by ICAO		Remarks
								Fcst.	Actual	Fcst.	Actual	
17	18/3	2100	EINN	EINN-CYQX	2200	G.C.	160	-25	-42	-39	-43	
18	18/3	2245	EINN	CYQX-EINN	2256	G.C.	100	-33	-19	-39	-20	
19	18/3	2300	EINN	EINN-CYQX	0000	R.L.	100	-27	-28	-31	-31	
20	19/3	0130	CYQX	CYQX-EINN	0400	G.C.	190	+44	+42	+55	+30	
21	19/3	0300	FFOL	FFOL-CYQX	2000	G.C.	180	-34	-55	-41	-48	
22	19/3	1000	EINN	EINN-CYQX	2300	G.C.	100	-35	-37	-34	-36	
23	19/3	1825	KLGA	CYQX-EINN	0100	G.C.	190	+50	+44	+49	+49	
24	19/3	1830	CYQX	CYQX-GGBA	2200	G.C.	180	-34	-38	-44	-47	
25	19/3	2000	GALA	GGBA-CYQX	0300	G.C.	100	-46	-41	-49	-42	
26	19/3	2000	EINN	EINN-CYQX	2030	R.L.	100	-29	-29	-35	-30	
27	19/3	2030	CYQX	CYQX-EINN	2300	G.C.	170	+32	+24	+44	+26	
28	19/3	2215	GGBA	GGBA-CYQX	2330	G.C.	100	-33	-38	-36	-35	
29	20/3	0500	CSAZ	CSAZ-CYVW	0600	G.C.	160	0	+ 7	-10	- 8	
30	20/3	0730	GALA	GGBA-CYQX	1300	R.L.	80	-32	-27	-29	-25	
31	20/3	1130	KLGA	CYQX-EINN	2143	G.C.	170	+44	+20	+32	+23	
32	20/3	1600	EINN	EINN-CYQX	1915	R.L.	180	-36	-36	-37	-50	
33	20/3	1630	CYQX	CYQX-GGBA	2230	G.C.	150	+34	+30	+45	+27	
34	20/3	1630	CYQX	CYQX-GGBA	2230	G.C.	150	+34	+30	+41	+35	
35	20/3	1800	GALA	GGBA-TFKF	2230	R.L.	180	-28	-43	-19	-57	
36	20/3	2000	CYQX	CYQX-CSAZ	0000	G.C.	170	+ 5	+ 5	+ 6	+ 2	
37	20/3	2015	EINN	EINN-CYQX	0100	G.C.	100	-42	-31	-49	-41	
38	20/3	2030	CYQX	CYQX-EINN	0100	G.C.	190	+23	+34	+49	+38	
39	20/3	2030	CYQX	CYQX-EINN	0300	G.C.	170	+23	+12	+29	+19	
40	20/3	2100	EINN	EINN-CYQX	2200	R.L.	140	-33	-29	-34	-28	
41	20/3		GALA	EINN-CYQX	2240	G.C.	100		-21	-29	-26	
42	20/3		CYQX	CYQX-TFKF	1246	G.C.	150	+20	+15	+31	+25	
43	21/3	1430	CYQX	CYQX-EINN	2200	G.C.	150	+22	+24	+24	+28	
44	21/3	1800	TFKF	TFKF-CYQX	2100	R.L.	120	-36	-31	-35	-54	
45	21/3	1900	KLGA	CYQX-EINN	0310	G.C.	170	+36	+22	+42	+23	
46	21/3	2000	CYQX	CYQX-GGBA	2200	G.C.	190	+22	+28	+28	+11	
47	21/3	2000	EINN	EINN-CYQX	0000	G.C.	180	-55	-47	-56	-45	
48	21/3	2030	CYQX	CYQX-EINN	0230	G.C.	190	+25	+41	+23	+25	
49	22/3	0001	EINN	EINN-CYQX	0100	G.C.	120	-28	-26	-35	-29	
50	22/3	0015	GGBA	GGBA-CYQX	0200	L.L.	85	-33	-55	-35	-36	
51	22/3	0730	GALA	EINN-CYQX	1300	G.C.	100	-43	-12	-44	- 8	
52	22/3	1800	KLGA	CYQX-EINN	0700	G.C.	190	+21	+18	+23	+14	
53	22/3	1800	GALA	EINN-CYQX	0200	R.L.	140	-22	- 9	-27	- 3	
54	22/3	1800	GALA	EINN-CYQX	0148	R.L.	120	-22	-11	-25	- 6	
55	22/3	1800	KLGA	CYQX-EINN	0230	G.C.	170	+26	+ 7	+18	+ 5	
56	22/3	2030	CYQX	CYQX-EINN	0130	G.C.	170	+23	+23	+25	+13	
57	22/3	2030	CYQX	CYQX-EINN	0030	G.C.	170	+25	+16	+28	+24	
58	22/3	2115	GGBA	GGBA-CYQX	2315	R.L.	140	-27	-14	-24	-16	
59	22/3	2200	EINN	EINN-CYQX	2200	R.L.	180	-46	-24	-26	-19	

TABLE II (Cont'd)

	No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms: Fcst.	Actual	As computed by ICAO: Fcst.	Actual	Remarks
	60	22/3	2330	EINN	EINN-CYQX	0000	G.C.	180	-44	-24	-27	-20	
3rd week (control)	1	23/3	0811	CYQX	CYQX-GGBA	0800	L.L.	90	+21	+11	+18	+ 8	
	2	23/3	1200	EINN	EINN-CYQX	1500	G.C.	180	-27	-19	-14	-22	
	3	23/3	1800	CYQX	CYQX-CSAZ	0000	R.L.	170	+45	+52	+29	+55	
	4	23/3	1800	CYQX	CYQX-CSAZ	0000	R.L.	170	+17	+15	+20	+15	
	5	23/3	1830	KLGA	KIDL-GALA	0000	R.L.	150	+35	+29	+33	+30	
	6	23/3	1900	CYQX	CYQX-EINN	0330	G.C.	170	+22	0	+23	+ 8	
	7	23/3	1900	CYQX	CYQX-GGBA	0030	G.C.	190	+24	+11	+18	+12	
	8	23/3	2000	EINN	EINN-CYQX	2300	G.C.	100	-11	+ 3	- 5	+ 4	
	9	23/3	2000	EINN	EINN-CYQX	2200	G.C.	100	-11	-12	- 9	+ 4	
	10	23/3	2030	CYQX	CYQX-GGBA	2330	G.C.	90	+11	+ 4	+13	+ 1	
	11	23/3	2100	FFOL	FFOL-CYQX	0100	G.C.	180	-23	-20	-32	-18	
	12	23/3		CYQX	CYQX-GGBA	0700	G.C.	190	+23	+25	+32	+31	
	13	24/3	0015	EINN	EINN-CYQX	0138	G.C.	100	-13	+ 2	- 9	+ 4	
	14	24/3	1330	EINN	EINN-CYQX	1600	G.C.	180	-12	-12	- 6	-14	
	15	24/3	1430	CYQX	CYQX-EINN	2030	G.C.	170	+11	- 6	+ 9	- 9	
	16	24/3	1700	FFOL	FFOL-CYQX	1900	G.C.	140	-21	- 6	-20	- 5	
	17	24/3	1730	CYQX	CYQX-GGBA	2200	G.C.	190		+13	+13	+ 3	
	18	24/3	2020	GGBA	GGBA-CYQX	2100	R.L.	140	-13		+ 1	+23	
	19	24/3	2030	CYQX	CYQX-EINN	0200	G.C.	170	- 7	-10	- 7	- 7	
	20	24/3	2030	CYQX	CYQX-CSPT	2300	R.L.	190	+26	+42	+29	+36	
	21	24/3	2030	CYQX	CYQX-GGBA	0400	L.L.	190	+24	+11	+18	+24	
	22	24/3	2100	EINN	EINN-CYQX	2300	G.C.	120	- 2	+14	- 2	+ 8	
	23	24/3	2200	GGBA	GGBA-CYQX	2330	R.L.	180	-13	- 9	- 5	- 5	
	24	24/3	2300	GGBA	GGBA-CYQX	0000	R.L.	160	-13	+13	- 4	+15	
	25	25/3	0400	CSAZ	CSAZ-CYVN	0600	G.C.	160	-21	-51	-37	-62	
	26	25/3	0630	CYQX	CYQX-GGBA	2130	R.L.	130	+14	- 1	+ 9	-15	
	27	25/3	1250	KLGA	CYVN-CSAZ	2200	G.C.	170	+52	+72	+40	+66	
	28	25/3	1430	CYQX	CYQX-EINN	1430	Comp.	90	+14	- 8	+13	- 8	Via 49°N 30°W
	29	25/3	1930	EINN	EINN-CYQX	2200	R.L.	80	+ 1	+ 5	+ 3	+15	
	30	25/3	1930	EINN	EINN-CYQX	2230	G.C.	180	- 7	+ 9	- 8	+ 9	
	31	25/3	1930	EINN	EINN-CYQX	2330	G.C.	100	-17	- 9	0	+ 3	
	32	25/3	2000	GALA	EINN-CYYR	2356	G.C.	180	+ 6	+17	+ 4	+ 7	
	33	25/3	2000	KLGA	KIDL-CYQX	2330	G.C.	170	+13	+17	+24	+22	
	34	25/3	2030	CYQX	CYQX-EINN	0300	Comp.	190	0	- 5	- 1	-14	Via 49°N 30°W
	35	25/3	2200	EINN	EINN-CYQX	2300	G.C.	120	+10	+ 5	+15	+ 6	
	36	26/3	0310	CYYR	CYYR-GGBA	0430	G.C.	190	- 7	-20	+ 1	-17	
	37	26/3	0400	EINN	EINN-CYQX	0800	G.C.	180	+ 8	+18	+ 4	+15	
	38	26/3	1900	KLGA	KIDL-EINN	2230	G.C.	190	+23	+20	+23	+ 6	
	39	26/3	1930	CYQX	CYQX-EINN	0200	Comp.	170	- 6	-20	-25	- 9	Via 48°N 35°W
	40	26/3	1930	EINN	EINN-CYQX	1930	G.C.	180	+16	+22	+19	+22	

TABLE II (Cont'd)

No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms		Mean tail wind components: As computed by ICAO		Remarks
								Fcst.	Actual	Fcst.	Actual	
41	26/3	2000	CYQX	CYQX-GGBA	2130	Comp.	110	+ 4	-10	- 1	-13	Via 48°N 30°W
42	26/3	2100	GGBA	GGBA-CYQX	0030	G.C.	140	+ 2	+12	+ 5	+19	
43	26/3	2300	EINN	EINN-KIDL		Comp.	120	+ 6		+ 8	+12	Via 57°N 40°W
44	26/3	2330	CYQX	CYQX-EINN	0417	Comp.	150	+ 3	-20	- 6	-13	Via 49°N 35°W
45	26/3	2350	EINN	EINN-CYQX	0500	G.C.	180	+ 9	+14	+15	+12	
46	26/3		EINN	EINN-CYQX	0130	G.C.	120	+20	+11	+15	+13	
47	27/3	0400	EINN	EINN-CYQX	0630	Comp.	80	+26	+25	+23	+19	Via 53°N 45°W
48	27/3	0500	CSAZ	CSAZ-CYQX	0600	G.C.	160	-52	-34	-41	-37	
49	27/3	1200	FFOL	FFOL-CYQX	1600	G.C.	100	+21	+22	+ 9	+13	
50	27/3	1735	ILGA	CYVR-CSAZ	0047	G.C.	170	-40	-25	-44	-33	
51	27/3	2000	CYQX	CYQX-EINN	0200	G.C.	170	-25	-40	-25	-39	
52	27/3	2000	CYQX	CYQX-EINN	2230	G.C.	170	-25	-33	-23	-28	
53	28/3	0600	CYQX	CYQX-GGBA	0900	G.C.	190	-24	-30	-22	-26	
54	28/3	1430	CYQX	CYQX-EINN	2126	Comp.	190	-25	-10	-41	-23	Via 56°N 20°W
55	28/3	1600	CYQX	CYQX-GGBA	2130	L.L.	130	-20	-16	-22	- 9	
56	28/3	2030	CYQX	CYQX-EINN	0330	G.C.	170	-19	-21	-22	-23	Planned via 57°N 30°W
57	28/3	2030	CYQX	CYQX-EINN	0300	Comp.	130	-19	-22	-19	-27	Via 54.7°N 30°W; planned - 57N 30W
58	28/3	2030	CYQX	CYQX-EINN	2200	Comp.	170	-26	-22	-26	-28	Planned via 57°N 30°W
59	28/3	2100	EINN	EINN-CYQX	0000	G.C.	180	+16	+31	+18	+41	
60	28/3	2315	GGBA	GGBA-CYQX	0100	R.L.	140		+38	+34	+33	
61	29/3	0800	EINN	EINN-CYQX	0300	G.C.	140	+22	+20	+24	+20	
62	29/3	1800	EINN	EINN-CYQX	2300	G.C.	100	+18	+16	+27	+27	
63	29/3	1800	EINN	EINN-CYQX	2300	G.C.	140	+19	+20	+33	+31	
64	29/3	1930	CYQX	CYQX-EINN	2330	Comp.	170	- 8	-29	-13	-29	Via 54°N 35°W; planned-57°N 35°W
65	29/3	1930	CYQX	CYQX-FFOL	0300	G.C.	170	-11	-27	-17	-26	Planned via 57°N 35°W
66	29/3	1930	CYQX	CYQX-EINN	0130	Comp.	170	- 2	-18	-17	-27	
67	29/3	2115	GGBA	GGBA-CYQX	2300	R.L.	140	+21	+31	+20	+31	
68	29/3	2300	CYQX	CYQX-GGBA	0900	G.C.	190	-11	-14	-18	-15	
69	30/3	0230	CYQX	CYQX-EINN	0730	G.C.	170	-20	-16	-12	-15	
70	30/3	0300	CSAZ	CSAZ-CYQX	0500	R.L.	180	- 4	- 5	0	- 5	
4th week (test)												
1	30/3	1030	FFOL	FFOL-CYQX	1230	G.C.	180	+15	+13	+15	+16	
2	30/3	1750	GALA	EINN-CYQX	2200	R.L.	140	+10		+24	+30	
3	30/3	1930	EINN	EINN-CYQX	2200	G.C.	160	+16	+18	+24	+29	
4	30/3	2300	EINN	EINN-CYQX	0100	R.L.	120	+ 9	+19	+16	+14	
5	31/3	0030	CYYR	CYYR-GGBA	0600	G.C.	150	+ 8	+ 3	-10	-11	
6	31/3	0030	CYQX	CYQY-CSAZ	0100	R.L.	190	+ 7	-11	+ 7	-15	
7	31/3	1145	FFOL	FFOL-CYQX	1300	R.L.	180	+12	+19	+ 8	+22	
8	31/3	1430	CYQX	CYQX-EINN	2030	G.C.	170	-12	-17	-20	-21	
9	31/3	1500	GALA	GGBA-CYQX	2200	G.C.	140	+10	0	+19	+ 8	
10	31/3	1700	CYQX	CYQX-GGBA	2200	G.C.	150	+ 7	-10	-13	+ 5	
11	31/3	1800	GALA	GGBA-CYQX	0100	G.C.	100	- 2	- 3	+10	+ 3	

TABLE II (Cont'd)

	No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms		Mean tail wind components: As computed by ICAO		Remarks
									Fcst.	Actual	Fcst.	Actual	
	12	31/3	2000	EINN	EINN-CYQX	2100	R.L.	120	+11	+16	+13	+17	
	13	31/3	2200	EINN	EINN-CYQX	2330	R.L.	180	+10	+13	+12	+14	
	14	31/3	2030	CYQX	CYQX-EINN	0300	G.C.	170	-11	- 3	-15	-14	
	15	1/4	0445	CYQX	CYQX-ZQUK	0800	R.L.	220	- 1	- 2	- 1	-13	
	16	1/4	1200	KLGA	CYVW-CSAZ	1900	R.L.	170	+14	+48	+17	+47	
	17	1/4	2130	GALA	GGBA-CYQX	0300	G.C.	180	- 2	- 3	+ 6	+ 1	
	18	1/4	2300	EINN	EINN-CYQX	0030	G.C.	180	+ 7	- 4	+10	- 2	
	19	2/4	0130	CYQX	CYQX-EINN	0330	G.C.	170	- 4	0	- 7	0	
	20	2/4	0315	CYQX	CYQX-GGBA	0400	L.L.	150	+ 7	+ 2	- 1	- 2	
	21	2/4	0400	CYQX	CYQX-GALA	0430	Comp.	170	- 9	- 3	-15	+ 8	Via 51°N 10°W
	22	2/4	1817	GALA	EINN-CYQX	2210	G.C.	160	- 7	- 8	-10	+ 2	
	23	2/4	2000	EINN	EINN-CYQX	0000	G.C.	180	-16	-14	-18	-19	
	24	2/4	2000	EINN	EINN-CYQX	2300	G.C.	180	-16	-19	-20	-23	
	25	2/4	2000	GALA	GGBA-TFKF	0100	R.L.	180	-25	-38	-38	-28	
	26	2/4	2200	CYQX	CYQX-EINN	0257	G.C.	150	- 8	- 5	-13	-10	
	27	2/4	2030	CYQX	CYQX-EINN	2300	G.C.	170	+ 5	+10	+18	+10	
	28	2/4	2030	EINN	CYQX-EINN	0300	R.L.	170	+21	+ 8	+19	+34	
	29	2/4	2030	CYQX	CYQX-EINN	0430	R.L.	170	+ 7	+10	+19	+14	
	30	3/4	0500	CSAZ	CSAZ-CYYT	0600	R.L.	140	-42	-40	-41	-38	
	31	3/4	2030	EINN	EINN-CYQX	2200	G.C.	80	-35	-28	-32	-34	
	32	3/4	1430	FFOL	FFOL-CYQX	1500	G.C.	140	-18	-29	-20	-36	
	33	3/4	2030	CYQX	CYQX-CSAZ	0000	G.C.	170	+35	+33	+28	+32	
	34	3/4	2200	EINN	EINN-CYQX	2300	G.C.	180	-47	-47	-43	-56	
	35	4/4	0100	CYQX	CYQX-FFOL	0330	G.C.	170	+20	+35	+39	+41	
	36	4/4	1500	EINN	EINN-CYQX	1530	R.L.	100	-29	-33	-33	-27	
	37	4/4	1600	CYQX	CYQX-EINN	2126	G.C.	170	+39	+55	+40	+65	
	38	4/4	2000	EINN	EINN-CYQX	2130	G.C.	120	-40	-29	-42	-36	
	39	4/4	2000	EINN	EINN-CYQX	2300	G.C.	100	-43	-30	-39	-40	
	40	4/4	2000	EINN	EINN-CYQX	2130	G.C.	180	-28	-22	-34	-16	
	41	4/4	2000	EINN	EINN-CYQX	0000	G.C.	100	-42	-28	-39	- 3	
	42	4/4	2200	CYQX	CYQX-EINN	0300	G.C.	210	+31	+66	+48	+59	
	43	5/4	1800	GALA	GGBA-CYQX	0006	Comp.	140	-11	-13	-21	- 7	Via 60°N 15°W
	44	5/4	2000	EINN	EINN-CYQX	2300	G.C.	100	-31	-21	-30	-19	
	45	5/4	2000	EINN	EINN-CYQX	0000	G.C.	140	-32	-29	-36	-26	
	46	5/4	2030	CYQX	CYQX-EINN	0400	G.C.	70	+22	+16	+12	+17	
	47	5/4	2030	CYQX	CYQX-EINN	0100	G.C.	170	+27	+ 9	+22	+11	
	48	5/4	2030	CYQX	CYQX-EINN	0030	G.C.	170	+37	+20	+30	+29	
	49	5/4	2300	EINN	EINN-CYQX	0015	G.C.	160	-40	-27	-39	-20	
	50	5/4	2350	CYQX	CYQX-EINN	0600	G.C.	190	+22	+10	+16	+ 3	
5th week	1	6/4	0700	CYQX	CYQX-EINN	0756	G.C.	70	+ 7	+ 2	+ 6	+ 5	
(control)	2	6/4	1700	GALA	GGBA-TFKF	2137	R.L.	180	-16	-21	-24	-39	

TABLE II (Cont'd)

No.	Date	Issue Time of Fcst. (GMT)	MMO	Route	Dept. Time along route (GMT)	Track	Altitude (in hundreds of feet)	Mean tail wind components: As received on flight data forms — Fcst.	Actual	As computed by ICAO — Fcst.	Actual	Remarks
3	6/4	2000	EINN	EINN-CYQX	2200	G.C.	140	-32	-17	-19	-30	
4	6/4		CYQX	CYQX-GGBA	2200	G.C.	190	+23	+20	+29	+31	
5	7/4	0230	EINN	EINN-CYQX	2330	G.C.	120			-38	-15	
6	7/4	0800	EINN	EINN-CYQX	0830	G.C.	100	-23	-35	-20	-26	
7	7/4	1500	EINN	EINN-CYQX	1600	G.C.	120	-33	-43	-35	-35	
8	7/4	1500	EINN	EINN-CYQX	1630	G.C.	80	-21	-24	-26	-23	
9	7/4	1800	FFOL	FFOL-CYQX	1900	G.C.	180	-31	-28	-32	-57	
10	7/4	1900	KLGA	CYQX-EINN	0230	G.C.	150	+47	+49	+45	+40	
11	7/4	2100	CYQX	CYQX-GGBA	2130	G.C.	190	+45	+51	+44	+55	
12	7/4	2130	EINN	EINN-CYQX	2300	G.C.	180	-45	-42	-44	-45	
13	7/4	2350	CSAZ	CSAZ-CYVW	0700	G.C.	180	-26	-54	-29	-58	
14	7/4		GGBA	GGBA-CYQX	0350	G.C.	100	-21	-32	-20	-31	
15	7/4		EINN	EINN-CYQX	0300	G.C.	120	-18	-39	-14	-25	
16	8/4	1530	GALA	GGBA-TFKF	2135	R.L.	180	0	-32	-12	+11	
17	8/4	1730	EINN	EINN-CYQX	0200	G.C.	80	-12	-12	-22	-13	
18	8/4	2000	EINN	EINN-CYQX	0030	G.C.	180	-54	-12	-33	-23	
19	8/4	2000	TFKF	TFKF-CYQX	0200	G.C.	180	+12	- 7	+ 4	- 9	
20	8/4	2230	EINN	EINN-CYQX	0200	Comp.	140	-35	-18	-38	-30	Via 56°N 20°W
21	8/4	2230	EINN	EINN-CYQX	0515	Comp.	160	-30	+ 4	-38	-32	Via 56°N 20°W
22	8/4	2230	CYQX	CYQX-GGBA	2330	R.L.	190	+47	+24	+60	+28	
23	8/4	2330	GGBA	GGBA-CYQX	0100	G.C.	140	-11	- 9	-10	-14	
24	9/4	0100	EINN	EINN-CYQX	0800	G.C.	160	-31	- 7	-37	-18	
25	9/4	2000	EINN	EINN-CYQX	2300	G.C.	180	-31	-24	-46	-28	
26	9/4	2000	EINN	EINN-CYQX	2300	G.C.	180	-31	-17	-49	-24	
27	9/4	2300	EINN	EINN-CYQX	2333	G.C.	160	-41	-20	-31	-16	
28	9/4		CYUL	CYYR-GGBA	2028	L.L.	170	+16	+18	+17	+12	
29	10/4	2030	EINN	EINN-CYQX	2300	G.C.	180	-32	-19	-20	-14	
30	10/4	2030	CYQX	CYQX-EINN	2300	G.C.	150	+30	+28	+33	+40	
31	10/4	2030	EINN	EINN-CYQX	2230	G.C.	180	-33	-13	-19	- 6	
32	10/4	2130	KLGA	CYQX-EINN	0330	G.C.	190	+15		+30	+10	
33	11/4	0100	GGBA	GGBA-CYQX	0130	Comp.	100	-19	-23	-27	-21	Via 59°N 15°W
34	11/4	0800	CYQX	CYQX-EINN	0900	G.C.	90	+20	+11	+20	+13	
35	11/4	1800	GALA	EINN-CYQX	2330	R.L.	100	-35	-15	-34	-15	
36	11/4	2000	EINN	EINN-CYQX	2330	G.C.	120	-34	-31	-28	-25	
37	11/4	2000	EINN	EINN-CYQX	2300	G.C.	100	-34	0	-24	-22	
38	11/4	2000	EINN	EINN-CYQX	2200	G.C.	180	-36	-34	-26	-25	
39	11/4	2300	EINN	EINN-CYQX	2330	R.L.	180	-28	-25	-27	-28	
40	11/4		TFKF	TFKF-CYQX	0242	R.L.	100	-19	-39	-15	-36	
41	12/4	0100	EINN	EINN-CYQX	0300	R.L.	140	-28	-23	-31	-18	

Notes: Plus (+) equals tail wind component; minus (-) equals head wind component

* L.L. = Lindy line, i.e. the track that is the same distance on one side of the Great Circle track as the Rhumb line track is on the other side.

G.C. = Great Circle

R.L. = Rhumb line

Comp. = Composite track, i.e., a combination of two or more sections, each a Rhumb Line or Great Circle, the turning point(s) being indicated in the remarks.

FIGURE 1 (APPENDIX F)

FORECAST AND ACTUAL TAIL WIND COMPONENTS AS OBTAINED FROM ACTUAL FLIGHT REPORTS
(ALL ROUTES AND ALL ALTITUDES) DURING THE CONTROL PERIOD

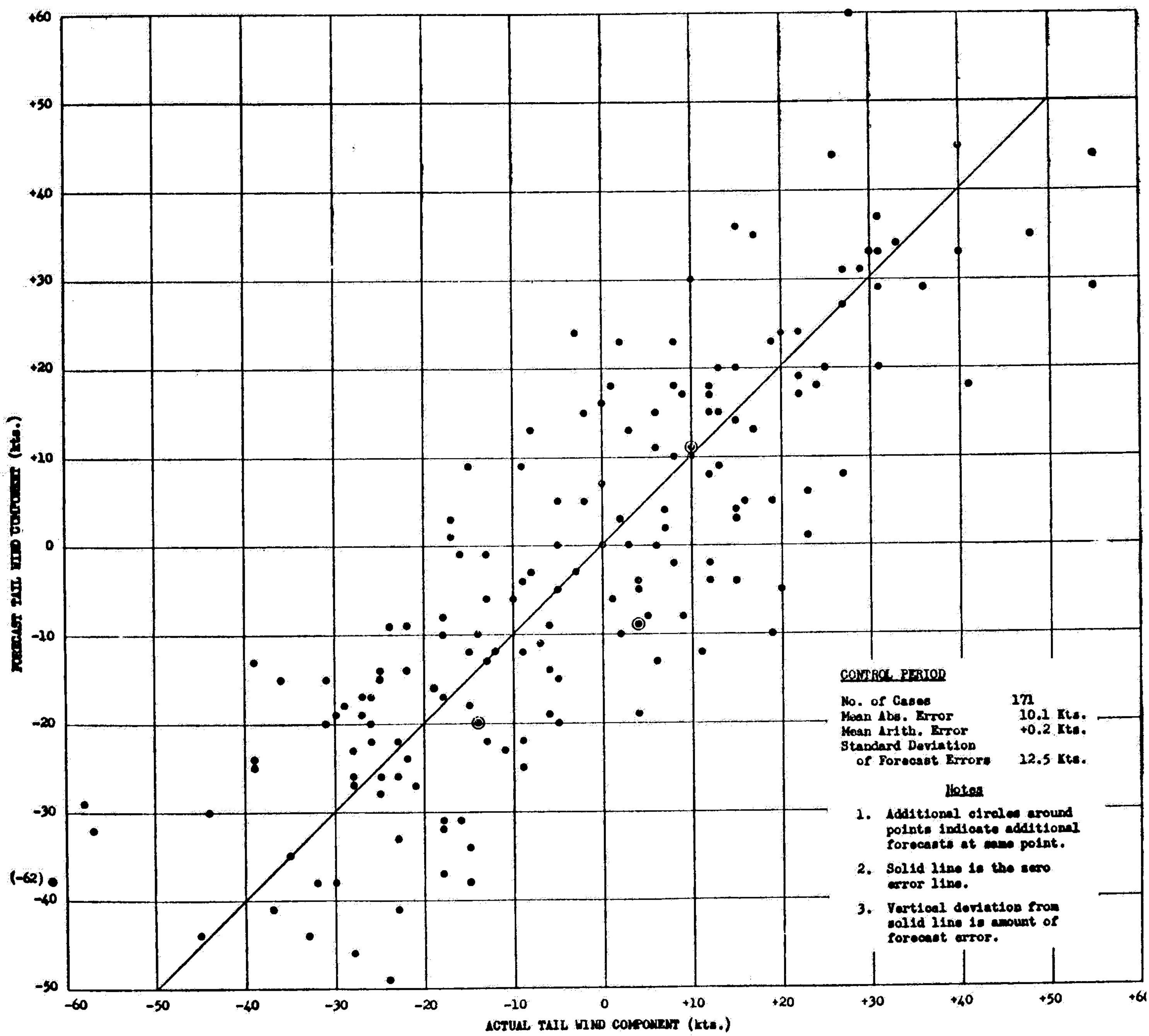


FIGURE 2 (APPENDIX F)

FORECAST AND ACTUAL TAIL WIND COMPONENTS AS OBTAINED FROM ACTUAL FLIGHT REPORTS (ALL ROUTES AND ALL ALTITUDES) DURING THE TEST PERIOD

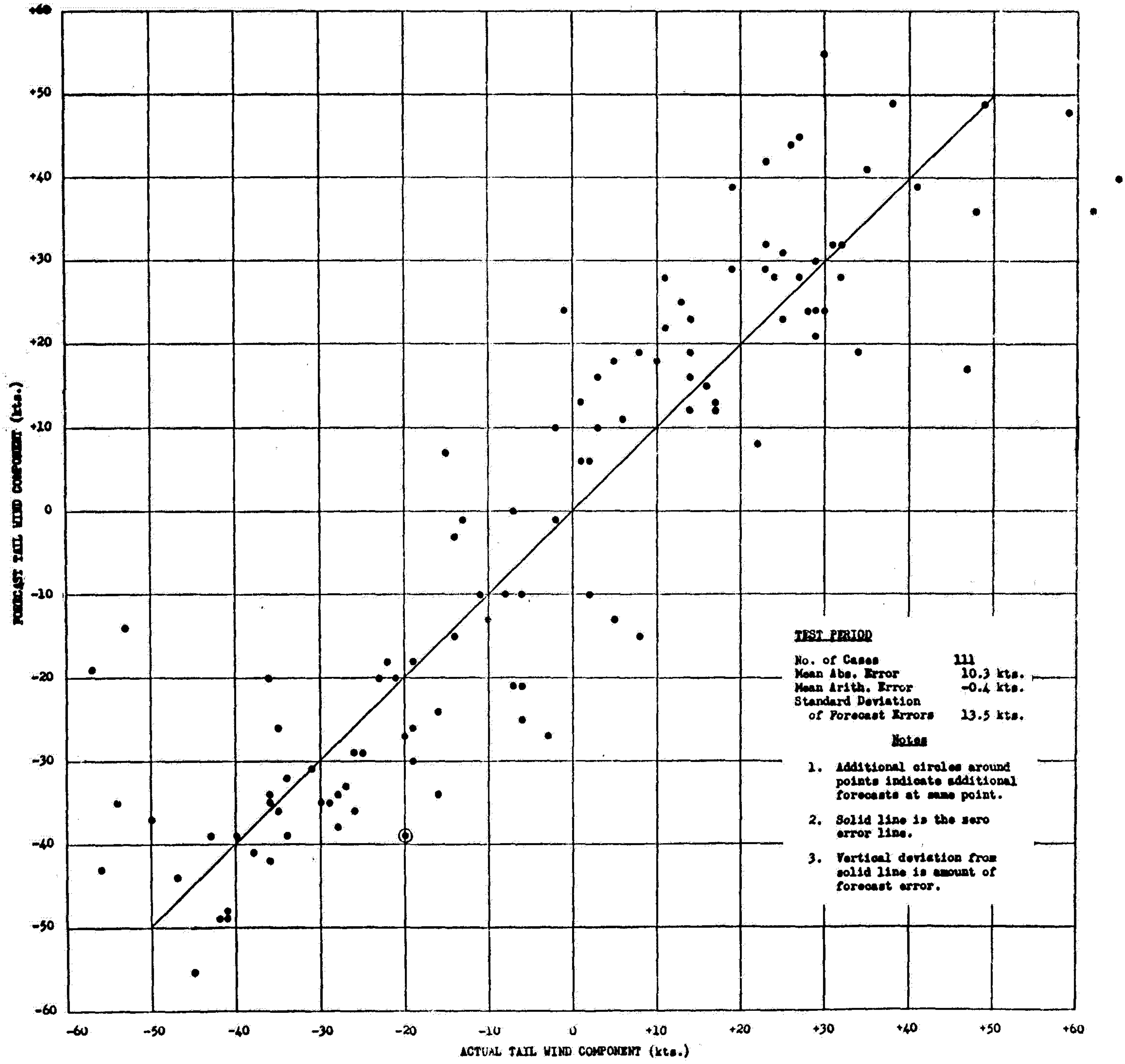
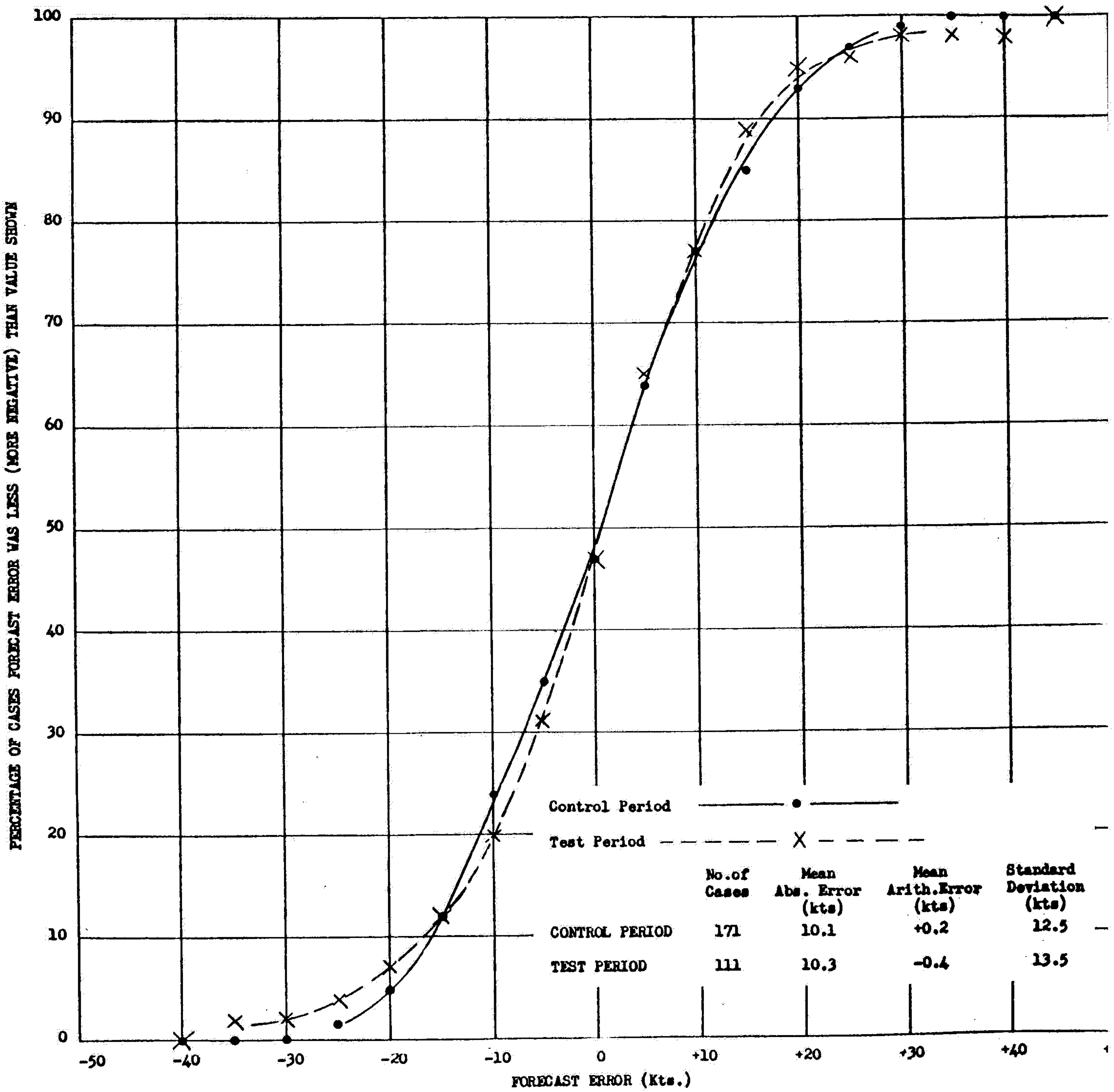


FIGURE 3 (APPENDIX F)

CUMULATIVE FREQUENCY CURVES OF FORECAST ERRORS OF TAIL WIND COMPONENTS AS OBTAINED FROM ACTUAL FLIGHT REPORTS (ALL ROUTES AND ALL ALTITUDES)



APPENDIX G

SUMMARY OF 500 mb. ACTUAL TAIL WIND COMPONENTS FOR THE SHANNON-GANDER (G.C.) ROUTE AS COMPUTED FROM FLIGHT DATA BY THE SECRETARIAT AND AS REPORTED BY THE LONDON AIRPORT AND NEW YORK/LA GUARDIA AIRPORT METEOROLOGICAL OFFICES

1. In order to demonstrate the type of wind circulation that actually prevailed over the Shannon-Gander (G.C.) route during the trial, the components, as determined from the analyzed 500 mb. charts at the London Airport and New York/La Guardia Airport meteorological offices were plotted on a graph. In addition, the actual components as computed by the Secretariat from flight data for the Shannon-Gander or Gander-Shannon (G.C.) routes and for the 14 000 - 22 000 foot altitudes were also plotted.

2. The graph is included as Figure 1 to this appendix. In examining the graph the following points should be taken into consideration:

a) The London Airport values are equivalent tail winds as received. For the purpose of uniformity, two values a day instead of four are shown during the test weeks.

b) The New York/La Guardia Airport values are tail wind components as received but with the signs (plus or minus) reversed in order that the directions (east or west) denoted by the signs correspond to those of the London Airport values.

c) The actual component values computed by the ICAO Secretariat from the flight forms were taken from only those flights which indicate the route as the Gander-Shannon or Shannon-Gander (G.C.) route and which indicated the altitude as 14 000 to 22 000 ft. inclusive. The signs of the components computed for the Gander-Shannon flights were reversed to make the directions denoted by the signs correspond to those of the other values on the graph. The placing of these values on the graph in regard to time was accomplished by determining the approximate time that the flight was at the half-way point along the route and then placing the value on the graph on the nearest 0300 or 1500 GMT ordinate.

3. The variation in the type of wind circulation during the trial is clearly shown on the graphs. Except for the first week when the tail-wind components (and equivalent tail winds) were within about 10 knots of zero, the trial was quite remarkable in the large variations between strong westerly circulation and strong easterly circulation that occurred over the Shannon-Gander (G.C.) route at about one week intervals.

4. The wide disagreement between the "actual" components on a good many dates is probably the most surprising feature shown on the graph. The major reasons for the disparity seem likely to have been:

a) Variations in the quality of the original data on flight data forms;

b) Differences in analysis techniques used by the London Airport and New York/La Guardia Airport meteorological techniques as well as differences in the amount of data available at the two offices.

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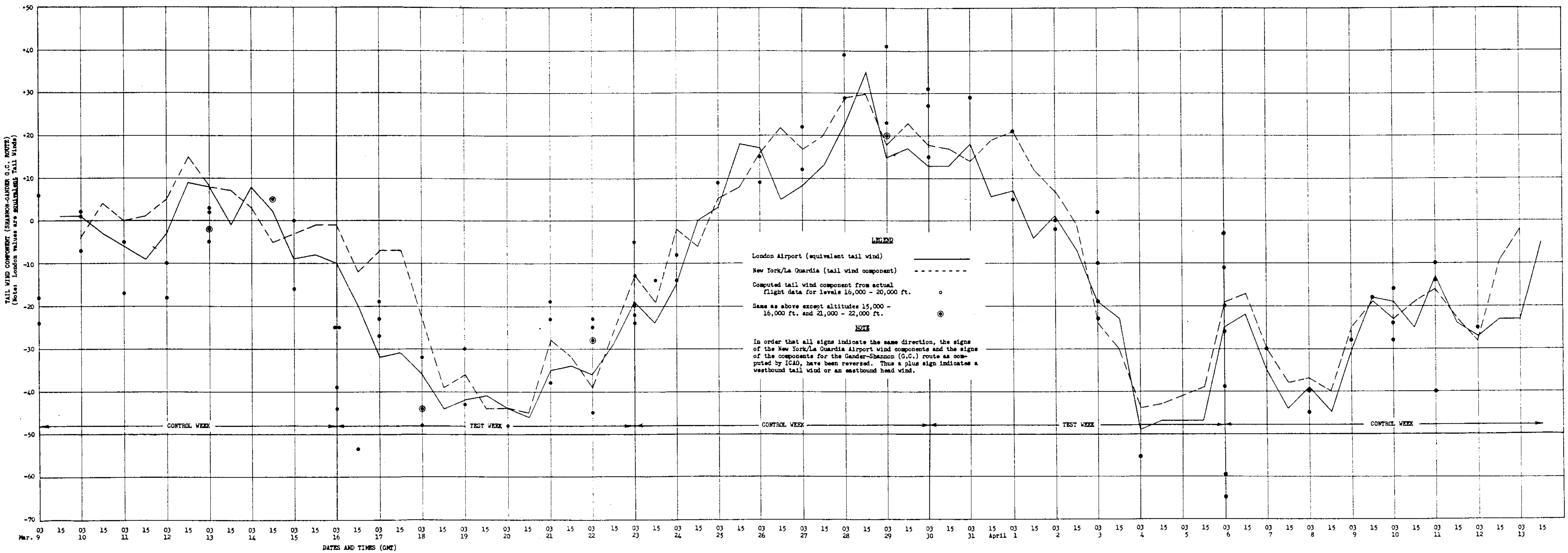
FIGURE 1 (APPENDIX G)

ACTUAL 500 mb. TAIL WIND COMPONENTS FOR THE SHANNON-GANDER (G.C.) ROUTE AS COMPUTED FROM FLIGHT DATA BY ICAO AND AS REPORTED BY THE LONDON AIRPORT AND NEW YORK/LA GUARDIA AIRPORT METEOROLOGICAL OFFICES



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APPENDIX H

INFORMATION OBTAINED FROM THE UNITED KINGDOM AND THE UNITED STATES CONCERNING THE ACCURACY OF "D" VALUE REPORTS FROM METEOROLOGICAL RECONNAISSANCE FLIGHTS

1. The United Kingdom replied that on its meteorological reconnaissance flights the radar and pressure altitudes are not normally used for obtaining absolute heights on account of the inaccuracies of both instruments. The altitude of a particular pressure surface is computed from the temperatures observed on the climb and again on descent, the radio altimeter readings being used intermediately to determine *changes* of altitude along the high level track. The accuracy of the altitudes so determined is considered to be so high that aircraft observations have been used as a standard against which radiosonde computed altitudes have been compared.

2. The United States gave the following description of its methods for determining the altitude of constant pressure surfaces:

The altitude of the constant pressure surface is usually obtained from a spiral sounding. After obtaining this constant pressure altitude, the radar altimeter and the pressure altimeter are read. If the aircraft were flown at the same altitude on the radar altimeter as the altitude determined for the constant pressure surface, the pressure altimeter under standard conditions would indicate the standard altitude of the constant pressure surface (9,880 feet for 700 mb., 18,281 feet for 500 mb.). Any deviation would be the calibration value.

Since it is impracticable to fly exactly at the altitude of the constant pressure surface, the aircraft is levelled off as close to this altitude as possible and the calibration value is determined in the following manner:

The difference (in geometric feet) between the radar altitude and the altitude of the constant pressure surface is converted into pressure feet (geopotential feet) and applied to the standard altitude of the constant pressure surface (9,880 feet for 700 mb., 18,281 feet for 500 mb.). The difference is the calibration value. The calibration value, either plus or minus, is applied to the pressure altimeter. After calibrating the pressure altimeter, the altitude of the constant pressure surface can be obtained by flying at the *standard* altitude of the constant pressure surface on the pressure altimeter (9,880 feet for 700 mb. surface, 18,281 feet for 500 mb.) and reading the *actual* altitude of the constant pressure surface from the radar altimeter.

As a rule, weather reconnaissance flights do not report "D" values. The method of calibrating the pressure altimeter enables them to report the altitude of a constant pressure surface. On those occasions when calibration of the pressure altimeter is not possible, "D" values are reported in lieu of the

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