U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 333

THE ABILITY OF THE NMC AND U.K.M.O. MODELS TO PREDICT AIRCRAFT FLIGHT TIME

John E. Newell
Automation Division

July 1987

1. Introduction

Over the years NMC has assembled a variety of techniques by which the quality of forecasts may be evaluated. The S1 score originated more than thirty years ago as a means of determining the skill of sea-level pressure and 500 mb height progs. The SUMAC method, in which the forecasts are verified against radiosonde reports, was begun in the early sixties and expanded in scope in the following years. Programs exist which match the forecasts against analyses, which are taken to be truth. These methods express the accuracy of the prediction in terms of a number such as the S1 score, which is dimensionless, or a quantity such as the RMS vector error, with units of velocity. Scientifically, these statistics are quite acceptable; from a practical or operational point of view, they are deficient, however. This is so because they do not provide satisfactory information to the users of the forecasts. In particular, statistics on vector error are virtually useless for aviation flight planning, because they are not geared to the way airlines operate. The aviation world does not think in terms of vector errors or anomaly correlation coefficients; instead flights arrive ahead of or behind schedule and it is through this difference between forecast flight time, based on the wind predictions, and actual flight time, determined by the encountered winds, that the impact of errors in the forecast is shown.

An aircraft must depart with sufficient fuel to reach its destination even in the event of stronger than forecast headwinds. Carrying a large excess of fuel overloads the aircraft, causing a higher consumption rate than if it were more lightly loaded. The extra fuel may also prevent carrying more passengers or cargo. It may be possible for us to be of greater assistance to the aviation community if we devise other means of assessing the quality of our aviation forecasts. The work reported in this note is an attempt to do just that. Further information on the effect of wind forecasts on aircraft fliight times, using a different method, may be found in the publication cited in the reference.

2. The Computations

A computer program written by A. J. Desmarais was used to simulate aircraft flights between various locations in North America. For a given flight, the input consisted of N pairs of latitude-longitude values used to divide the flight route into N-1 flight legs. For each flight leg the code requires a value of true air speed and of flight altitude.

Fields of the U and V components of the winds at 300, 250, 200 and 150 mb are read in. It is assumed that these isobaric fields coincide with 30000, 35000, 40000 and 45000 feet, respectively. The code finds the midpoint and length of each leg. It computes the true course at each midpoint and interpolates values of U and V component to the midpoint. Aircraft heading needed to maintain true course is determined and the ground speed is computed. From this follows the time needed to traverse the flight leg. Total time enroute is computed from the N-1 values of flight leg time.

When the aircraft flight is simulated using forecast winds, the output of the code is a forecast flight time; when analyzed winds are used, the result may be regarded as an actual or observed flight time. The difference between the forecast and analyzed times represents a measure of error of the wind prediction. The error so determined is more familiar to aviation interests than a quantity such as RMS vector error.

From the beginning of December 1986 to the end of February 1987, flights were simulated using the 24-hour wind forecasts produced operationally by NMC in the AVN Network. At the same time 24-hour wind forecasts available from the United Kingdom Meteorological Office

(UKM) were used to produce a separate set of forecast times enroute. Each forecast was verified against both the NMC Analysed Winds and the UKM Initialized Winds. Only forecasts originating at 00Z were used.

Five flight routes were chosen; these are shown in Table 1, along with the flight distance and average flight time.

ORIGIN	DESTINATION	DISTANCE (N MI)	AVERAGE TIME (HOURS)
BOSTON	LOS ANGELES	2250	5.00
NEW YORK	SAN FRANCISCO	2208	5.00
WASHINGTON	ANCHORAGE	2928	6.25
MIAMI	SAN DIEGO	1983	4.75
CHARLESTON,S.C.	SEATTLE	2128	4.75

TABLE 1

All flights were flown at 35000 feet altitude with a true airspeed of 500 knots. The same route was flown daily for each of the five tracks; no attempt was made to find a best route between two locations. The printed output of the program provides a time enroute between origin and destination, rounded off to the nearest hundreth of an hour. The errors for the flights simulated over the three month period were tabluated manually and their distribution is shown in Figs. 1 and 2. The magnitude of the forecast flight time error is shown as the abscissa; the ordinate is the percentage of flights whose error magnitude is less than the abscissa value.

3. Discussion of results

Fig. 1, which uses the NMC analyzed winds to verify the forecasts, is based on 410 flights; Fig.2, using the UKM initialized winds, is based on 400 flights. Overall, both forecasts perform quite well, without regard to the verification source. Close to 90 percent of all flights have errors less than 6 minutes (.10 hour). For flights of 5 to 6 hours duration, an error of that size of less is quite acceptable. At 9 minutes (.15 hour) the percentage has climbed to 95. In both figures the plotted points for the NMC forecast show a higher percentage than those of UKM. In terms of having fewer errors above a certain magnitude, the NMC wind forecasts may be regarded as superior to those of UKM.

During the three month period, the largest forecast error noted was .32 hour for the NMC model and .31 hour for the UKM forecast. These two errors both occurred at the same verifying time of 27 Feb. at 00Z, on the BOS-LAX Track, when the wind factor of the NMC analysis was minus 100 knots, its highest value during the period examined. For the same case, if we verify the forecasts against the UKM initial winds, the errors are .20 hour and .19 hour respectively.

The analyzed and forecast winds used here were taken from the 65 by 65 Northern Hemisphere Polar Stereographic Grid as a matter of convenience. The resolution of both forecast models is such that displaying their output on this grid would tend to lessen the strength of wind maxima.

A word is in order concerning the limitations caused by our use of the NMC analysis and UKM initialization to provide the verifying winds. Because the two sets of verifying winds are totally independent of each other and because the two yield approximately the same results when matched against the winds forecast by either model, it seems reasonable to conclude that each is a good approximation to the winds actually occurring in the atmosphere.

REFERENCE

1. Forrester, D.A. 1987: Monitoring of equivalent headwind and temperature forecasts from the 15-level coarse mesh model. Special Investigations Technical Note No. 49, United Kingdom Meteorological Office, Bracknell.

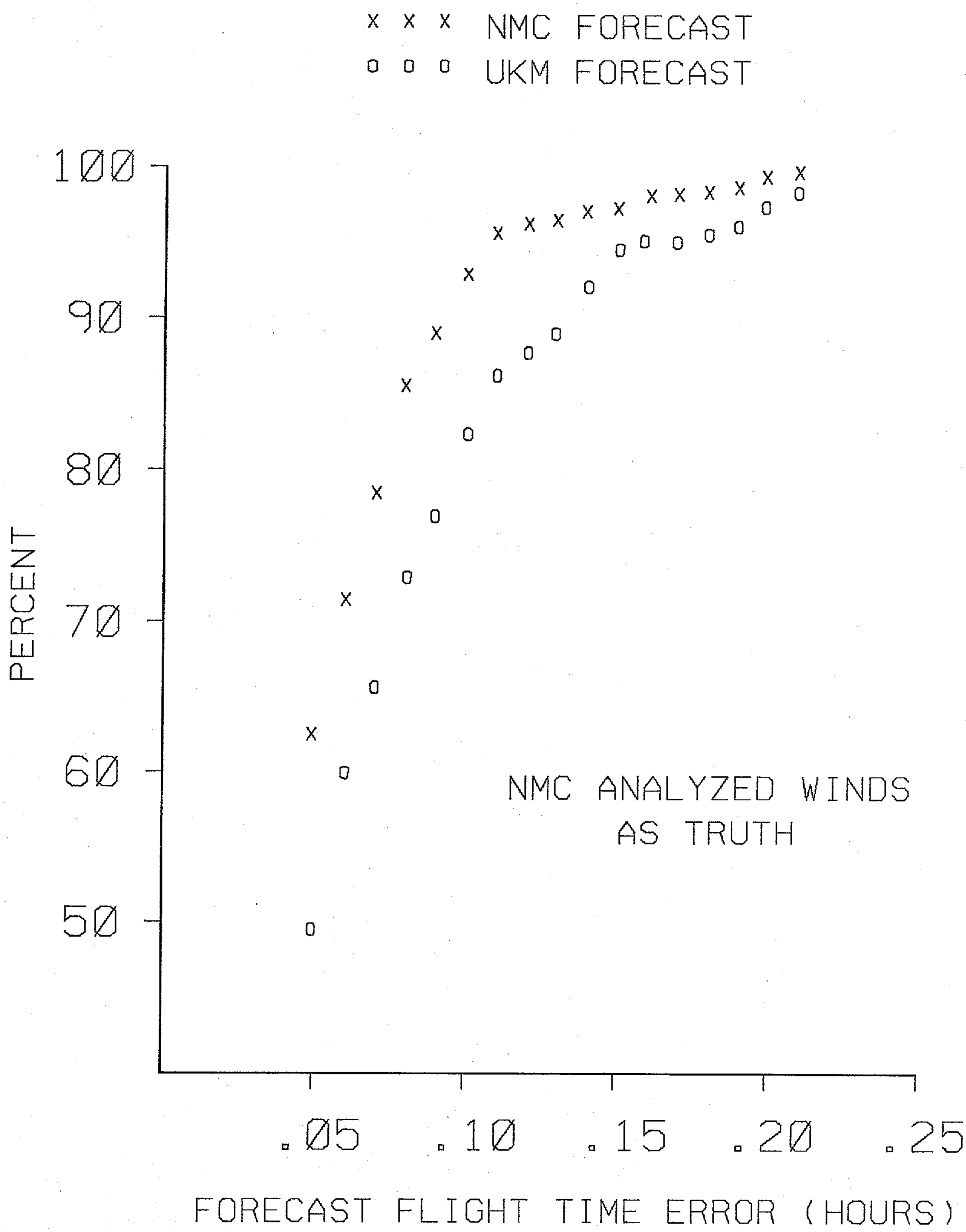
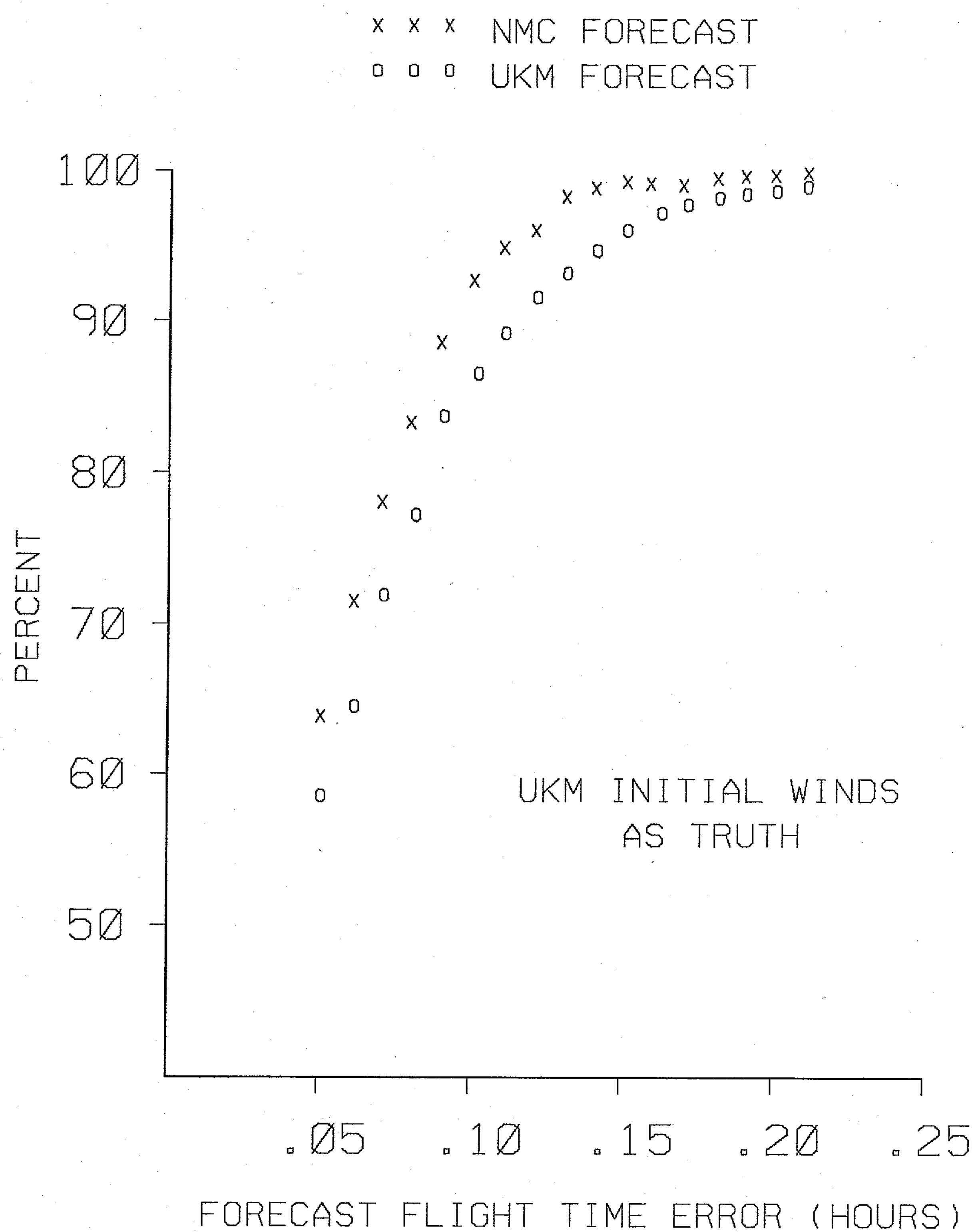

x x x NMC FORECAST
o o o UKM FORECAST
100
90
80
70
60
50
PERCENT
NMC ANALYZED WINDS
AS TRUTH
.05
.10
.15
.20
.25
FORECAST FLIGHT TIME ERROR (HOURS)

FIG. 1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.05
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.20
.25
FORECAST FLIGHT TIME ERROR (HOURS)

FIG. 2