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Part I : A Comparison of AIDS Data from the Concorde With Data Obtained From Rawinsonde and Satellite*

Part II: An Example of ASDAR Winds in the NMC Analysis

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PART I: A COMPARISON OF AIDS DATA FROM THE CONCORDE WITH DATA OBTAINED FROM RAWINSONDE AND SATELLITE*

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1. INTRODUCTION

The Aircraft Integrated Data Systems (AIDS) combined with the Inertial Navigation Systems (INS) constitute a relatively new and valuable source of in situ meteorological data. Details of these systems have been given by Julian and Steinberg (1975), and considerable background on the role of commercial aircraft in global monitoring systems has been given by Steinberg (1973).

Among the aircraft equipped with the AIDS-INS combination are some Concorde supersonic transports (SST's) flown by British Airways. A preliminary data-set, consisting of reports of temperatures and winds from 100 Concorde flights (with four different aircraft involved) made between May and September 1977, has been evaluated by the Upper Air Branch of the National Meteorological Center. Eighty-six flights were between London's Heathrow Airport (LHR) and Washington's Dulles International Airport (IAD), while fourteen flights were between LHR and Bahrain (BAH) on the Persian Gulf.

The purpose of this paper is to present a preliminary evaluation of the AIDS data for the lower stratosphere, as a prerequisite to determining the role they may play in meteorological operations and in the research programs to be undertaken in connection with FGGE - the Global Weather Experiment.

2. TEMPERATURES

Figure 1 is an example of the type of diagram used to compare AIDS data with satellite-rawinsonde information. Here ΔT = 100-mb map temperature minus aircraft temperature; ΔH = 100-mb map height minus aircraft flight level. This diagram is for just one flight--from London's Heathrow Airport to Washington's Dulles International Airport, on June 10, 1977. Especially noteworthy is the temperature bias: the average ΔT (denoted on the figure as $\overline{\Delta T}$) is $-2.8^{o}C$, indicating that the aircraft temperatures are generally higher than the 100-mb map temperatures. The standard deviation is $1.4^{o}C$. It should also be noted that all but one of the aircraft measurements were made within 1 km of the 100-mb surface.

Of course the best kind of comparison would be between AIDS reports and satellite reports, or between AIDS reports and rawinsonde reports. Unfortunately, such a direct comparison is seldom possible, since the collocation of the required data points is rare. For this reason we have based our comparison principally on the daily 100-mb analyses of wind and temperature prepared at the National Meteorological Center. While there are some discrepancies in time, these are never more than 12 hours.

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For the transatlantic routes, most of the comparisons turn out to be indirect comparisons of AIDS data with Vertical Temperature Profile Radiometer (VTPR) data. The reason for this is that VTPR measurements are not taken over land, but are fairly abundant over the North Atlantic, where rawinsonde observations are sparse. Hence the 100-mb analyses are heavily influenced by VTPR data along the London-Washington flight path.

The route between London and Bahrain takes the Concorde over the Adriatic and Mediterranean Seas, near Cyprus and Crete, and over the deserts of Syria and Saudi Arabia. There are several rawinsonde stations along this route, so that the 100-mb analysis for this part of the hemisphere is not so dependent on VTPR data as it is for the North Atlantic.

Figure 2 is a typical ΔT-ΔH scatter diagram, for a flight from London to Bahrain on July 27, 1977. Here $\overline{\Delta T}$ is nearly zero, while the standard deviation (s.d.) is 1.6--compared with $\overline{\Delta T} = -2.8^{\circ}C$ and s.d. = 1.4 for the example shown above the transatlantic route.

The average flight path of the Concorde during the Bahrain-to-London flights takes it below the tropopause, i.e., through portions of the troposphere, where the temperature is more variable than in the lower stratosphere. Consequently more dispersion in temperature occurs than for those flights which take place mainly at stratospheric levels (the transatlantic runs, and the London-to-Bahrain flights).

Table 1 is a summary of the results of temperature comparisons. The values of $[\overline{\Delta T}]$ and of [s.d.(ΔT)] show that Figures 1 and 2 are quite representative of their respective flight series. The table summarizes the following facts. There is a consistent temperature bias over the Atlantic; no bias is in evidence for the London-Bahrain route; standard deviations are consistent over both the Atlantic and the London-to-Bahrain route, but are significantly higher for the Bahrain-to-London flights.

With only temperature comparisons for the transatlantic SST flights showing aircraft temperatures to be higher than NMC-analysis temperatures, it would be impossible to say whether the aircraft reports are too high or the analysis values too low. However, the data from the London-Bahrain flights, while not exactly providing "ground truth," do shed light on this question.

A consequence of the restriction of VTPR data to atmospheric regions overlying water surfaces is that, in contrast to the transatlantic routes, the ratio of rawinsonde to satellite data is rather large for the London-Bahrain route. In fact, for the latter there are characteristically only a few satellite data points, and these are located over the Mediterranean. All the other data are rawinsonde data.

Table 1

$[\overline{\Delta T}]_{L-I} = [\overline{\Delta T}]_{I-L} = -2.4^{o}C$

$[s.d.(\Delta T)]_{L-I} = [s.d.(\Delta T)]_{I-L} = 1.6^{o}C$

$[\overline{\Delta T}]_{L-B} = [\overline{\Delta T}]_{B-L} = 0.2^{o}C$

$[s.d.(\Delta T)]_{L-B} = 1.6^{o}C$

$[s.d.(\Delta T)]_{B-L} = 3.0^{o}C$

Key:

$\overline{\Delta T}$:	route average of temperature differences
$[\overline{\Delta T}]$:	temporal average of the route averages of temperature differences
$[s.d.(\Delta T)]$:	average standard deviation of the temperature differences
L-I:	London → Washington
I-L:	Washington → London
L-B:	London → Bahrain
B-L:	Bahrain → London

The good agreement between AIDS temperatures and temperatures derived from the 100-mb analyses over the London-Bahrain route would therefore suggest that the rawinsonde data themselves are in good agreement with the AIDS data. This is in fact borne out by direct comparison of radiosonde-reported temperatures closely collocated in time and space with AIDS measurements.

The good agreement between two independent measurement systems may be offered as nearly conclusive proof of their correctness. But what can be said about the satellite temperatures?

Monthly summaries of satellite-radiosonde temperature comparisons are routinely published. However, these summaries are for average values within latitude bands and for standard atmospheric levels. The result of averaging over latitude bands may be, of course, to mask longitudinallyvarying biases. Even so, as may be seen from Table 2, there are sharp differences from month to month within latitude bands 30-40°N and 40-50°N, and also large differences between the latitude bands. There is an over-all tendency for radiosonde temperatures to be higher than VTPR temperatures. Given the good agreement between AIDS temperatures and radiosonde temperatures, it is not surprising that radiosonde temperatures at 100 mb over middle latitudes should appear high relative to satellite-derived temperatures, just as AIDS temperatures are higher than satellite temperatures.

Table 2

$\overline{\Delta T}$ (100 mb)*

	30°-40°N	40°-50°N
May 1977	0.6°C	-0.6°C
June 1977	-3.0°C	-1.0°C
July 1977	-2.1 C	0.6°C
August 1977	-1.0°C	-0.6°C

*ΔT = VTPR temperature minus radiosonde temperature

Note: This information has been provided by the Indirect Sounding Branch of the National Environmental Satellite Service, NOAA.

3. WINDS

Vector differences were computed between AIDS-measured winds and geostrophic winds deduced from the 100-mb height fields. $|\Delta\vec{V}|$-ΔH diagrams have been constructed in a manner analogous to that of the ΔT-ΔH diagrams.

The results of wind comparisons are shown in Table 3. It appears that difficulties is estimating winds from the height fields, together with the problems inherent in the relatively small samples available, make it impossible to draw definitive conclusions. Actual rawinsonde observations over the Bahrain-London route, while appearing to agree with the AIDS data, are as yet too few in number.

Wintertime wind data are needed to complete the evaluation, since the upper tropospheric-lower stratospheric circulation is much better defined in winter than in summer.

Table 3

$\overline{[|\Delta\vec{V}|]}_{B-L}$ = 15 knots; $\overline{[|\Delta\vec{V}|]}_{L-B}$ = 23 knots

$\overline{[|\Delta\vec{V}|]}_{L-I}$ = $\overline{[|\Delta\vec{V}|]}_{I-L}$ = 13.4 knots

$[\mathrm{rms}|\Delta\vec{V}|]_{L-I}$ = $[\mathrm{rms}|\Delta\vec{V}|]_{I-L}$ = 15 knots

$[\mathrm{rms}|\Delta\vec{V}|]_{L-B}$ = 26 knots

$[\mathrm{rms}|\Delta\vec{V}|]_{B-L}$ = 18 knots

Key:

$[\Delta\vec{V}]$: temporal average of the route averages of vector wind differences

$[\mathrm{rms}|\Delta\vec{V}|]$: average rms vector wind difference

(See table 1 for key to other symbols.)

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4. CONCLUSIONS

Sets of AIDS temperatures obtained from Concorde flights have been found to be internally consistent. Where AIDS reports are nearly coincident in space and time with radiosonde reports, good agreement is found between the data sets.

For the Washington-London route, the mean difference between temperatures measured by AIDS and those given by 100-mb objective analyses is 2.4°C (AIDS higher), with standard deviation 1.6°C. For the London-Bahrain route, there is no significant mean difference in temperatures. The difference in results for the two routes is explained on the basis of different data-sources for the 100-mb maps. Analyses over the Atlantic are largely determined by Vertical Temperature Profile Radiometer (VTPR) measurements, whereas analyses over the Mediterranean and Middle East are influenced primarily by rawinsonde data.

The difference in mean standard deviation between eastbound (s.d. = 1.6°C) and westbound (s.d. = 3.0°C) legs on the London-Bahrain route can be explained by differences in mean flight levels. At the lower cruise altitude on the Bahrain-to-London run, the aircraft is often near the tropopause. By contrast, the higher cruise path on the London-to-Bahrain leg takes the aircraft mainly through the more quiescent lower stratosphere.

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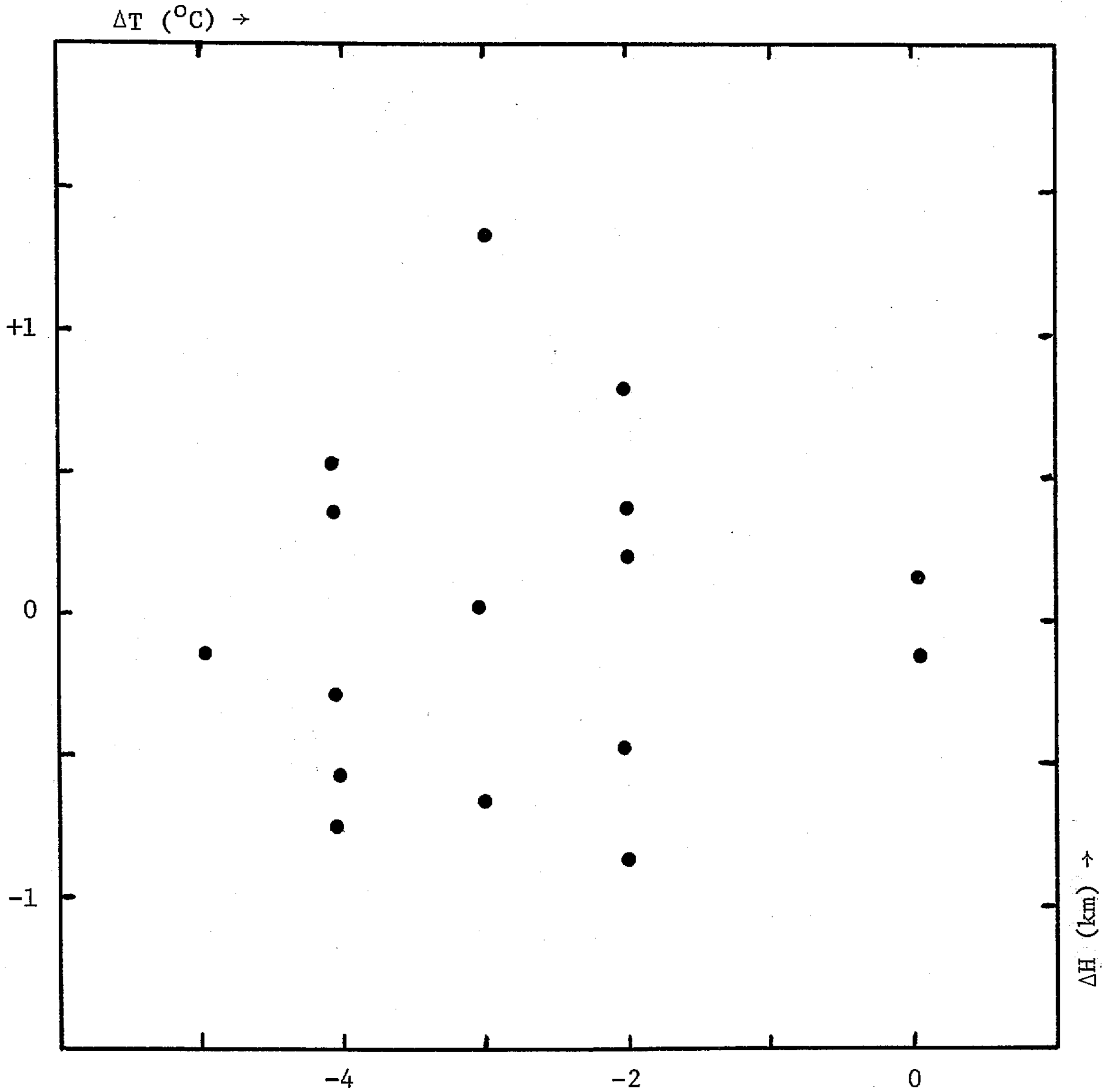

Figure 1. Scatter-diagram of ΔT versus ΔH, where ΔT = 100-mb map temperature minus Concorde AIDS temperature; ΔH = 100-mb map height minus aircraft flight level. Data are for flight from London's Heathrow Airport (LHR) to Washington's Dulles International Airport (IAD), June 10, 1977. $\overline{\Delta T}$ = 2.8°C; s.d.(ΔT) = 1.4°C.

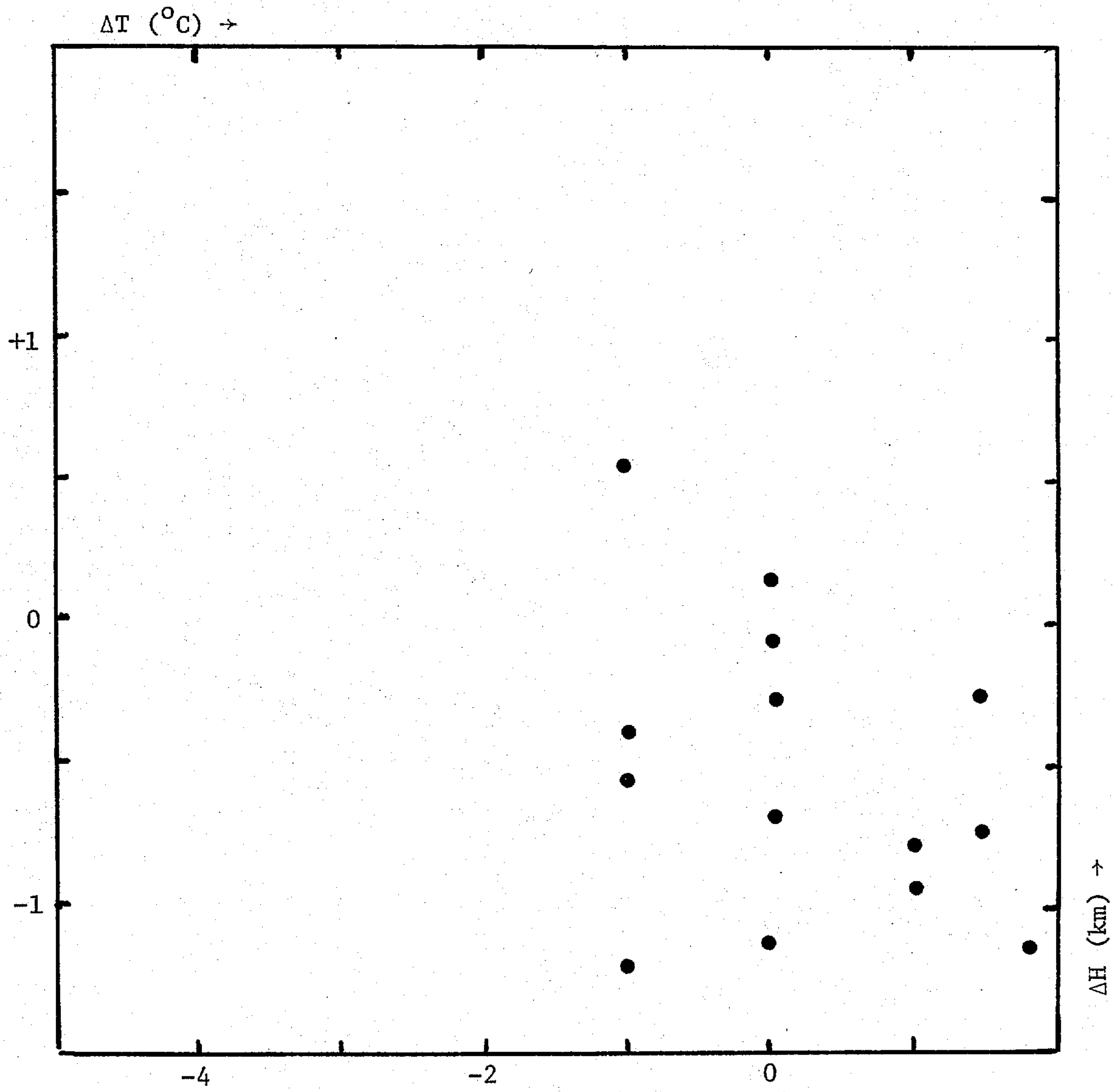

Figure 2. Scatter diagram of ΔT versus ΔH, for flight from London to Bahrain, July 27, 1977. $\overline{\Delta T}$ = 0.2°C; s.d.(ΔT) = 1.6°C.

PART II: AN EXAMPLE OF ASDAR WINDS IN THE NMC ANALYSIS

Ronald D. McPherson and Glenn E. Rasch

1. INTRODUCTION

The ASDAR (Aircraft to Satellite DAta Relay) system is identical to the AIDS/INS system described in the companion note as far as the sensors are concerned. The only difference is in the method of transmission of the data: whereas the AIDS/INS system records the meteorological data on inflight recorders, the ASDAR system transmits automatically to ground readout, using a relay by geostationary satellite. The ASDAR data are thus available for operational use somewhat earlier than the recorded data.

At present, only one aircraft is equipped with ASDAR: a Boeing 747 operated by Pan American World Airways. Beginning in March, 1977 data from this aircraft have been available at the NMC on a delayed basis. A preliminary evaluation was done by comparing the aircraft winds with nearby radiosonde winds. Although the sample of such collocated pairs was too small for statistical meaning, the quality of the data was nonetheless impressive. The data were then introduced into an experimental (offline) version of the NMC operational global analysis. The agreement between analysis and data was excellent. On the basis of this evaluation, the wind data were admitted to the NMC operational data base beginning June 28, 1977. The temperature data are not now considered because of an error in the inflight algorithms which format the sensor data; the error results in random fluctuations of up to 5^{o}C.

With only one ASDAR-equipped aircraft flying mostly international, overwater routes, the opportunities for comparison with other wind data have been limited. One such opportunity occurred on September 26, 1977. The aircraft was enroute from (presumably) Australia to New York; the first data from this flight to reach NMC was from a position of 8.5S, 144.3W at 0704GMT. Subsequent reports entered the operational analyses at 06GMT, 12GMT, and 18GMT. Reports from the last segment of the flight entered the 00GMT 27 September analysis and cover the portion of the flight path from about 92W eastward to New York. Several radiosonde stations are located near this route, thus offering an unusual opportunity for comparison of winds from ASDAR and radiosondes.

2. COMPARISON WITH NEARBY RADIOSONDES

The ASDAR data are plotted on Figure 3. As presently received at NMC, the ASDAR data are spaced at approximately 0.5^{o} intervals. It is necessary to apply a thinning procedure to the data to avoid overwhelming the analysis and plotting routines with closely-spaced reports. Only those reports east of 92W were within the $\pm$ 3 hour "window" allowed for the analysis. Radiosonde stations at Springfield, Illinois (72532); Flint, Michigan (72637); Buffalo, New York (72528); and New York City (74486) are sufficiently near the flight path that their reports can be used for comparison purposes. Unfortunately the Buffalo wind report was missing on this particular occasion, so that only three reports are available for flight-level comparison. These are presented in Table 4.

Table 4. Comparison of ASDAR flight-level winds with radiosonde winds at Springfield, Flint, and New York. Wind speeds are in knots. Radiosonde winds are given at the altitude nearest the flight level.

ASDAR				Radiosonde			
Position	Time	Altitude (m)	Wind	ID	Position	Altitude (m)	Wind
42.2N,90.1W	2112Z	11220	289/097	72332	40.7N,89.7W	10680	295/097
42.2N,83.4W	2142Z	11220	286/091	72637	43.0N,83.7W	11960	290/088
40.5N,74.3W	2246Z	9990	232/074	74486	40.7N,73.8W	9440	225/074

The agreement in both direction and speed is impressive.

The last entry in Table 4 represents the beginning of the aircraft's descent into New York. Measurements taken during this period thus constitute a wind profile, which may be compared to the profile obtained from the New York radiosonde. This comparison is plotted in Figure 4. Once again, some thinning has been performed on both profiles. It is clear that the agreement in direction is excellent; the ASDAR profile shows somewhat lower wind speeds below 5 km, but the agreement is nevertheless quite good.

3. COMPARISON OF NMC ANALYSIS WITH AND WITHOUT ASDAR

Figure 3 shows the 250 mb analysis of streamlines and isotachs at 0000GMT September 27, 1977 produced by the NMC operational analysis system. All of the ASDAR data which are plotted east of 92W were used in the analysis, as well as some reports which are not plotted. A total of 11 ASDAR winds were used in this analysis. The 250 mb level is the closest level available for display to that of the ASDAR reports. Nine of the 11 reports were actually slightly closer to 200 mb than 250 mb. However, all 11 reports influenced the 250 mb level since the analysis is done three-dimensionally. It is evident that the analysis reflects the data: both direction and speed are in good agreement.

This is confirmed in Table 5, which shows the root-mean-square fit of the analyzed 200 mb winds to observed winds from different sources. Two cases are shown: one in which the ASDAR winds were used in the analysis, and one where they were excluded. In the first case, the table shows that the analysis fits the ASDAR data to about the same degree as radiosondes and cloud-tracked winds, and slightly more closely than other aircraft. The latter is probably a result of greater internal consistency of the ASDAR data.

Table 5. Root-mean square fits of the 200 mb wind analysis to wind observations from radiosondes, tracking of clouds in satellite imagery, ASDAR, and other aircraft. Values are in knots. Parenthetical numbers denote the number of observations in each category.

Analysis/Data Type	Radiosonde	Satellite	ASDAR	Other Aircraft
With ASDAR	10.1 (573)	11.6 (105)	11.4 (9)	14.5 (123)
Without ASDAR	10.1	11.8	12.2	14.5

In the second case, the table indicates that the analysis fits the ASDAR data to about the same degree, whether used in the analysis or not. Given the agreement between the ASDAR winds and nearby radiosonde winds indicated by Table 4, this is the expected result. The analysis performed without ASDAR is shown in Figure 5: even a very careful examination will fail to reveal significant differences.

4. CONCLUSION

For the one case discussed in this note, the ASDAR data are in remarkable agreement with winds from radiosondes near the aircraft's flight path, both in level flight and on descent to its destination. Because of the good agreement, inserting the data into the NMC analysis model made virtually no difference in the resulting analysis. This suggests that the ASDAR winds are of at least the same quality as the radiosonde winds; and that their use in areas where there are no radiosondes ought to improve the quality of the wind analyses to the same level as in areas where radiosondes are present.

Thus far, the data volume from only one aircraft is too small and too sporadic to have a significant impact on operational numerical weather prediction. But with the same quality data from a larger number of aircraft, the prospects appear to be promising.

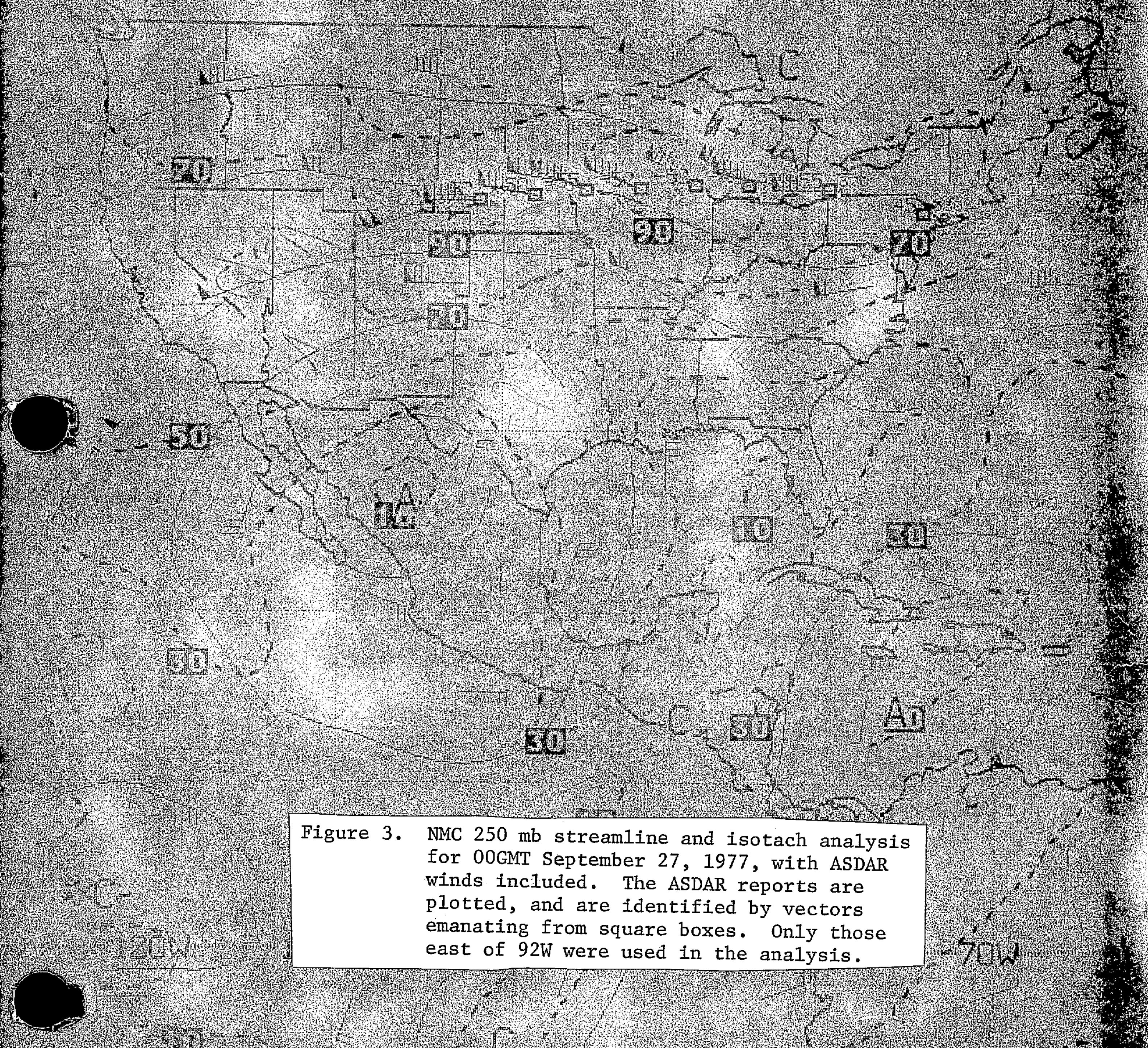

Figure 3. NMC 250 mb streamline and isotach analysis for 00GMT September 27, 1977, with ASDAR winds included. The ASDAR reports are plotted, and are identified by vectors emanating from square boxes. Only those east of 92W were used in the analysis.

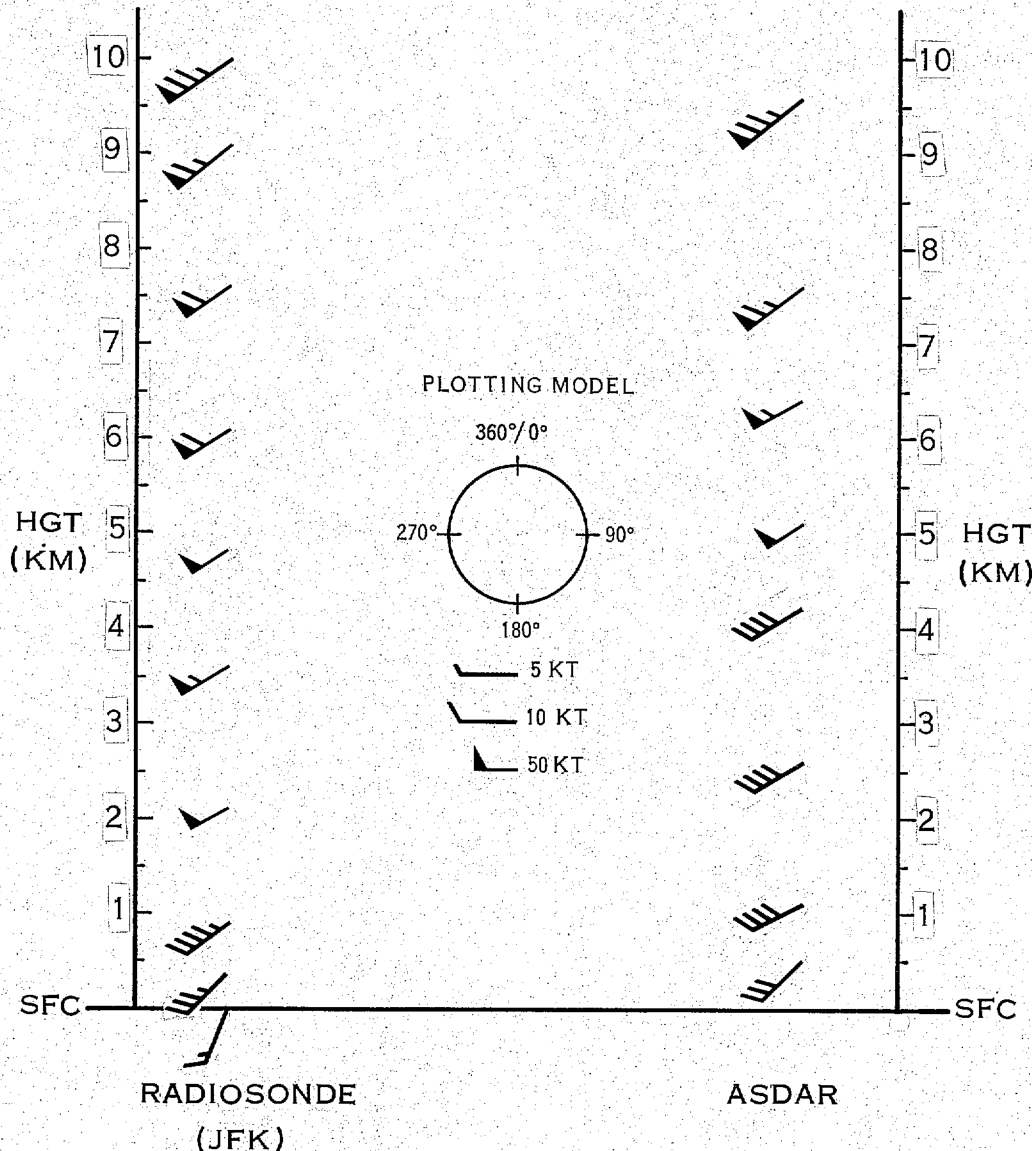

Figure 4. Wind profile obtained by the ASDAR-equipped aircraft on descent into JFK Airport, New York, between 2246 GMT 26 September 1977 and 0001 GMT 27 September 1977, compared to the wind profile obtained by the JFK radiosonde for 0000 GMT 27 September 1977. Wind arrows indicate direction from which the wind is blowing; bars and flags on each arrow indicate speed.

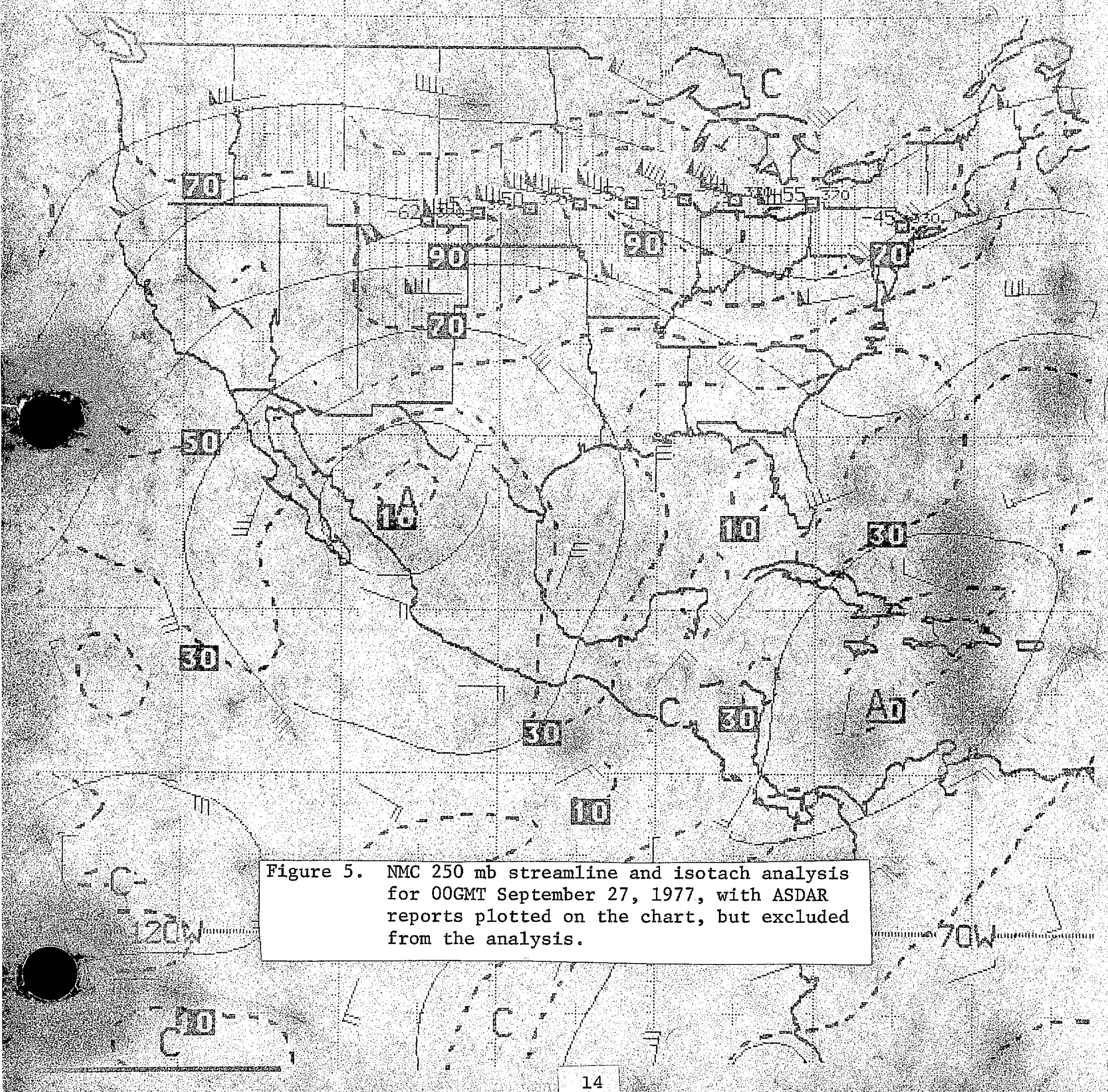

Figure 5. NMC 250 mb streamline and isotach analysis for 00GMT September 27, 1977, with ASDAR reports plotted on the chart, but excluded from the analysis.