AUTOMATIC WARNING OF HAZARDOUS BIRD CONDITIONS

F. R. Hunt

In the paper I presented at last year's meeting of Bird Strike Committee Europe, I described several methods of using radar for the detection of birds hazardous to aircraft. Four points were stressed at that time which are worth repeating.

1. The information produced by such equipments must be displayed to air traffic controllers in a form that is readily interpretable in order that the controllers' workloads are not significantly increased.

2. Personnel are not required to operate the equipment.

3. Increase in maintenance personnel should be minimal.

4. Initial and operating costs should be as low as possible consistent with the other requirements.

For the last two years in Canada, we have been working on two equipments to meet these requirements. The vertical automatic detection system was designed to provide warning of large scale nocturnal migrations which consist mainly of passerine birds. Although these birds are usually small in size, many of them are large enough in size to damage an aircraft's engine or fracture a wind shield if the aircraft is flying at high speed. Thus this type of migration is particularly dangerous to single-engined military aircraft flying at high speed and low altitude on low level training missions.

As was pointed out previously, if a high performance surveillance radar is available in the vicinity of the flying area and there are areas in its coverage free of permanent echoes, then the system developed by Denmark can be employed. If not, the following economical system can be used. It (Fig. 1) consists of a 6 ft. diameter antenna fixed in position so that it is pointing vertically. A cheap off-the-shelf marine radar transmitter-receiver is connected to it and to the Vertical Automatic Detection Equipment (VADE). Fig. 2 shows the block diagram of the latter unit. Commercially available integrated circuits have been used extensively

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and these have provided a cheap but reliable unit. Six counter channels are provided which represent 1000 foot flight levels from 500 to 6500 feet above sea level. There are only two points to note in this diagram as standard circuits have been used. The first is the use of a simple video integrator in each height channel and this was found necessary to prevent interference from a nearby radar working in the same frequency band. The second circuit was added to solve the problem of a bird remaining in the antenna's beam for several seconds. As the bird beats its wings, its echo fluctuates and this often gave rise to multiple counts by that bird. To prevent these multiple counts, the multiple reply gates were added. These provide a dead-time to counting following the initial count of the bird. We have based the dead time length on the maximum time it would take a bird to fly through the beam in any altitude band at a speed of 10 knots. As a matter of interest, typical wing beat patterns obtained with this radar are shown in Fig. 3. The time scale is approximately 1/4 second per large division. Revised tables of bird strike probability, which are of interest to the operational flying people and of the migration traffic rate of interest to ornithologists, have been worked out and include allowances for the dead-times. These tables are similar to those shown last year.

During the autumn migration of 1974, the equipment was operated approximately two nights a week by a technician and myself. A typical night of heavy migration occurred on the 3rd and 4th of October. The sensitivity of the equipment was set for detection of birds with radar cross-sections of 2 sq. cms. or greater. This is less than the 10 sq. cms. recommended for operational use but at that time, we were mainly interested in the performance of the equipment. Fig. 4 shows the counts obtained in each channel. Starting with zero counts shortly after sunset, the number of birds increases very rapidly. Fig. 5 shows the actual migration traffic rate in each height band as well as the total migration traffic rate. Fig. 6 shows the probability of a bird strike per nautical mile flown by an aircraft flying in one of these height bands. In developing this table, it should be noted that we had to assume a bird velocity and for our purposes 25 knots was used. Also we assumed a frontal area for the aircraft of 10 sq. ft. This corresponds to the frontal area of the engine and the wind shield of a single engined aircraft. This might be described as the catastrophic frontal area--i.e., a bird strike to this area could cause the loss of the aircraft and possibly the pilot. During the evening represented, the greatest probability of a bird strike was obtained in the 2000 ft. level at [illegible] GMT when the probability was 2.38 per thousand miles flown. In the next figure (7), section 'a' depicts

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the increase in migration traffic rate with time. Part 'b' shows the bird distribution with height above ground level as the evening progressed. For instance at 0100 hours about 7% of the birds counted were flying between 1200 and 2200 feet, 33% between 2200 and 3200 feet and 40% between 3200 and 4200 feet.

The equipment performed satisfactorily last autumn. During the spring migration of 1975, the equipment has been operated nightly by an ornithologist. Only one major problem arose. This occurred when the antenna was blown over during unexpected winds with average speeds of 40 knots and unknown gust levels. The dent in the antenna and its skirt were banged out and more weight was added to its pedestal. The equipment has operated satisfactorily since that date.

The next piece of equipment to be described is used for the detection of flocks of large migrating water-fowl such as geese. It is based upon the electronic counter developed in Denmark but has been modified for our particular use. The equipment counts the number of flocks in a selected sector of the coverage of an air traffic control surveillance radar. Expansion to several sectors in an operational equipment is obtained by duplication of some of the circuits. The overall block diagram is shown in Fig. 8. One change has been made to this block diagram. Based on our increasing knowledge of several Canadian ATC radars, it has become apparent that they are operated with the antenna beam at a low angle of elevation in order to detect low flying aircraft. In consequence, the permanent echo region is extensive and the returns in these regions are very strong. Consequently, we have given up on the idea of using a separate logarithmic receiver connected to the radar's preamplifier. Instead, the same integrated MTI used for the controller's displays is employed. In general we have found that the maintenance on the sites is good and the quality of the integrated MTI video has been excellent.

Since my presentation last year, four circuits have been added. One is a circuit which provides counts of flocks directly to the controller. Formerly, he was required to read a chart in order to determine this number. A long pulse discriminator has been added which reduces the number of false counts when precipitation returns are obtained in the sector. A PRF discriminator has been added in order to reduce interference from an adjacent radar operating in the same frequency band. Provision has also been made to transmit the data to a smaller remote display unit. Built into this remote display unit is a circuit which provides an audible alarm if the flock count exceeds a pre-determined number. In the earlier presentation, charts were provided to the controller to interpret the

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[illegible] found in terms of number of flocks and the [illegible] of a bird strike. With the newer circuits, [illegible] of these charts is questionable. The audible [illegible] tell the controller when the situation is becoming dangerous and since he knows the sector's shape [illegible] and the number of flocks in it, he can readily [illegible] exactly how dangerous the situation is at any

[illegible] equipment has been operated during the last two [illegible] migration seasons. Fig. 9 shows the results obtained [illegible] last year during the snow goose migration. Three [illegible] shown on the y-axis. However, they are all re- [illegible] only the second one need concern us--the flock [illegible] square nautical mile. The maximum reached [illegible] about 1 flock every 4 square nautical miles. [illegible] is assumed to have the frontal dimensions [illegible] ft. (i.e., a 707/DC-8 with its flaps and landing [illegible] and each flock consists of 100 birds on the [illegible] then the probability of a strike is about 1.23 [illegible] miles flown below 5000 feet.

[illegible] this year's spring migration, the equipment has [illegible] at Ottawa during the migration of Canada Geese. [illegible] have not yet been analyzed in detail. However, [illegible] thought to be a typical day, the flock density [illegible] per nautical square mile which is about one-quarter [illegible] at Winnipeg. However, it appears that this [illegible] .06 was equalled or exceeded on 6 or 7 days. [illegible] Ottawa results have been analyzed in detail, a [illegible] will be held with air traffic control in order to [illegible] whether they have an operational use for this [illegible] air traffic control region in Canada has [illegible] equipment which will provide both position and [illegible] all flocks in the immediate vicinity of the airport. [illegible] require a much more expensive equipment, but this [illegible] It remains for air traffic control to decide [illegible] want that sophistication and to find the funds [illegible] decision.

[illegible] equipments there has been no maintenance [illegible] the initial set-up. As is to be expected, [illegible] times are somewhat protracted as one attempts [illegible] method. Once that method has been found, [illegible] be much reduced on similar equipments.

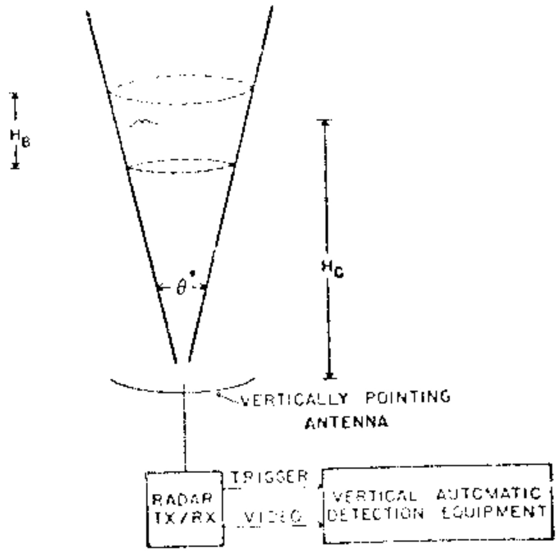

Fig. 1. Vertical Automatic Detection System

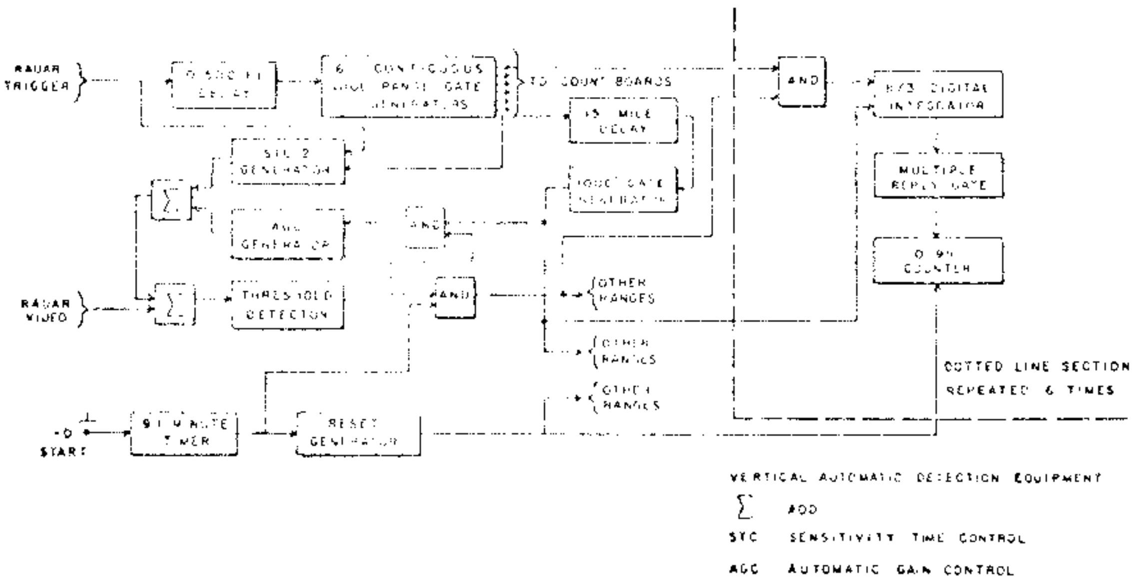

Fig. 2. Vertical Automatic Detection Equipment

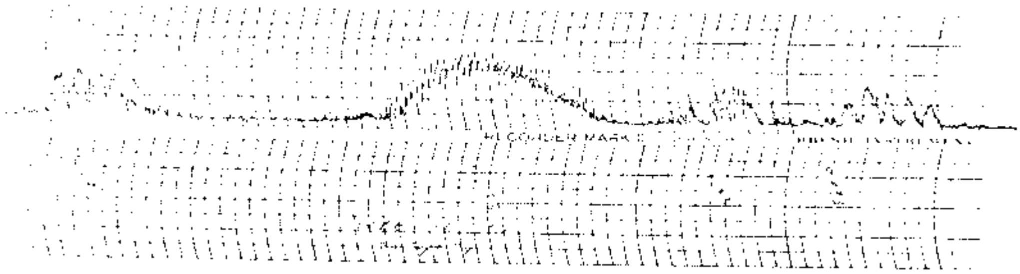

Fig. 5. Typical Wing Beats from Vertical Radar

BIRD COUNT/CHANNEL
VADE PROGRAM F84--100575

DATE - 3-4/10/74

TIME GMT	CHANNEL NUMBER 1	2	3	4	5	6
2310	0	0	0	0	0	0
2319	0	0	0	1	0	0
2329	0	1	0	1	0	0
2338	0	0	3	2	3	0
2348	0	0	3	6	2	0
0	0	0	2	2	2	0
10	0	0	3	3	2	1
19	0	0	9	2	3	0
29	0	0	4	10	4	0
38	0	1	3	8	3	0
48	0	1	5	2	2	0
58	0	0	5	9	4	0
109	0	2	5	9	6	0
119	0	0	7	17	4	3
138	0	11	1-	21	5	2
147	0	19	26	15	12	1
157	0	19	19	14	6	0
206	3	9	18	23	7	3
216	0	13	18	12	8	1
225	0	20	13	12	5	1
235	0	12	16	12	3	0
244	2	8	20	19	4	3
253	1	26	16	6	2	1
303	0	13	17	6	2	2
312	1	13	15	5	5	1
322	1	11	12	7	2	0

Fig. 6. Bird Counts per Channel, 3-4/10/74

BIRD MIGRATION TRAFFIC RATE/NAUTICAL MILE FRONT/HOUR
VADE PROGRAM P64--100574

DATE = 3-4/10/74
ANTENNA BEAMWIDTH = 1.1 DEGREES
COUNT TIME = 9.1 MINUTES

TIME GMT	MEAN HEIGHT IN FEET (ASL) 1000	2000	3000	4000	5000	6000	TOTAL
2310	0	0	0	0	0	0	0
2319	0	0	0	569	0	0	569
2329	0	1234	0	569	0	0	1803
2338	0	0	2365	1147	1374	0	4886
2348	0	0	2365	3561	907	0	6833
0	0	0	1566	1147	907	0	3620
10	0	0	2365	1736	907	371	5378
19	0	0	7385	1147	1374	0	9906
29	0	0	3174	6149	1851	0	11174
38	0	1234	2365	4832	1374	0	9805
48	0	1234	3994	1147	907	0	7281
58	0	0	3994	5485	1851	0	11330
109	0	2479	3994	5485	2836	0	14794
119	0	0	5656	11155	1851	1139	19812
138	0	14224	11872	14339	2339	759	43533
147	0	25555	24123	9657	6063	371	65768
157	0	25555	16727	9929	2636	0	54849
206	9021	11527	15732	16013	3345	1139	56777
216	0	16974	15732	7514	3865	371	44455
225	0	27035	10965	7514	2339	371	48223
235	0	15592	13784	7514	1374	0	38265
244	5997	10197	17737	12711	1851	1139	49633
253	2990	36242	13784	3561	907	371	57855
303	0	16974	14751	3561	907	750	36944
312	2990	16974	12831	2442	2339	371	37947
322	2990	14224	10051	4191	907	0	32364

Fig. 5. Migration Traffic Rate, 3-4/10/74

BIRD STRIKE PROBABILITY/NAUTICAL MILE FLOWN
VADE, P75, 41074

DATE = 3-4/10/74
ANTENNA BEAMWIDTH = 1.1 DEGREES
FRONTAL CROSS-SECTION OF AIRCRAFT = 10 SQ.FT.
ASSUMED VELOCITY OF BIRDS = 25 KNOTS
COUNT TIME = 9.1 MINUTES

TIME GMT	1000	2000	MEAN HEIGHT IN FEET (ASL) 3000	4000	5000	6000
2310	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2319	0.00E+00	0.00E+00	0.00E+00	3.74E-05	0.00E+00	0.00E+00
2329	0.00E+00	8.12E-05	0.00E+00	3.74E-05	0.00E+00	0.00E+00
2338	0.00E+00	0.00E+00	1.56E-04	7.55E-05	9.04E-05	0.00E+00
2348	0.00E+00	0.00E+00	1.56E-04	2.34E-04	5.96E-05	0.00E+00
0	0.00E+00	0.00E+00	1.03E-04	7.55E-05	5.96E-05	0.00E+00
10	0.00E+00	0.00E+00	1.56E-04	1.14E-04	5.96E-05	2.44E-05
19	0.00E+00	0.00E+00	4.86E-04	7.55E-05	9.04E-05	0.00E+00
29	0.00E+00	0.00E+00	2.09E-04	4.05E-04	1.22E-04	0.00E+00
38	0.00E+00	8.12E-05	1.56E-04	3.18E-04	9.04E-05	0.00E+00
48	0.00E+00	8.12E-05	2.63E-04	7.55E-05	5.96E-05	0.00E+00
58	0.00E+00	0.00E+00	2.61E-04	3.61E-04	1.22E-04	0.00E+00
109	0.00E+00	1.63E-04	2.61E-04	3.61E-04	1.87E-04	0.00E+00
119	0.00E+00	0.00E+00	3.73E-04	7.34E-04	1.22E-04	7.50E-05
138	0.00E+00	9.36E-04	7.82E-04	9.43E-04	1.54E-04	4.94E-05
147	0.00E+00	1.68E-03	1.59E-03	6.35E-04	3.99E-04	2.44E-05
157	0.00E+00	1.68E-03	1.10E-03	5.87E-04	1.87E-04	0.00E+00
206	5.94E-04	7.59E-04	1.04E-03	1.05E-03	2.20E-04	7.50E-05
216	0.00E+00	1.12E-03	1.04E-03	4.94E-04	2.54E-04	2.44E-05
225	0.00E+00	1.78E-03	7.21E-04	4.94E-04	1.54E-04	2.44E-05
235	0.00E+00	1.03E-03	9.07E-04	4.94E-04	9.04E-05	0.00E+00
244	3.99E-04	6.71E-04	1.17E-03	8.36E-04	1.22E-04	7.50E-05
253	1.97E-04	2.39E-03	9.07E-04	2.34E-04	5.96E-05	2.44E-05
303	0.00E+00	1.12E-03	9.71E-04	2.34E-04	5.96E-05	4.94E-05
312	1.97E-04	1.12E-03	8.44E-04	1.54E-04	1.54E-04	2.44E-05
322	1.97E-04	9.36E-04	6.61E-04	2.76E-04	5.96E-05	0.00E+00

Fig. 6. Bird Strike Probability, 3-4/10/74

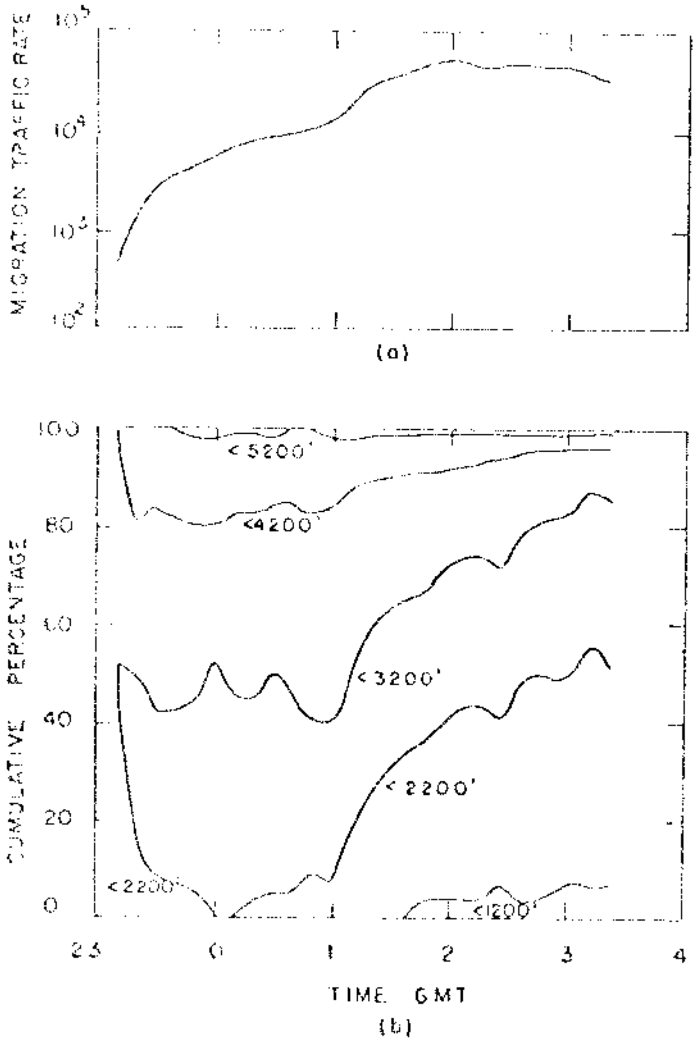

Fig. 7. Migration Traffic Rate and Height Distribution, 3-4/10/74

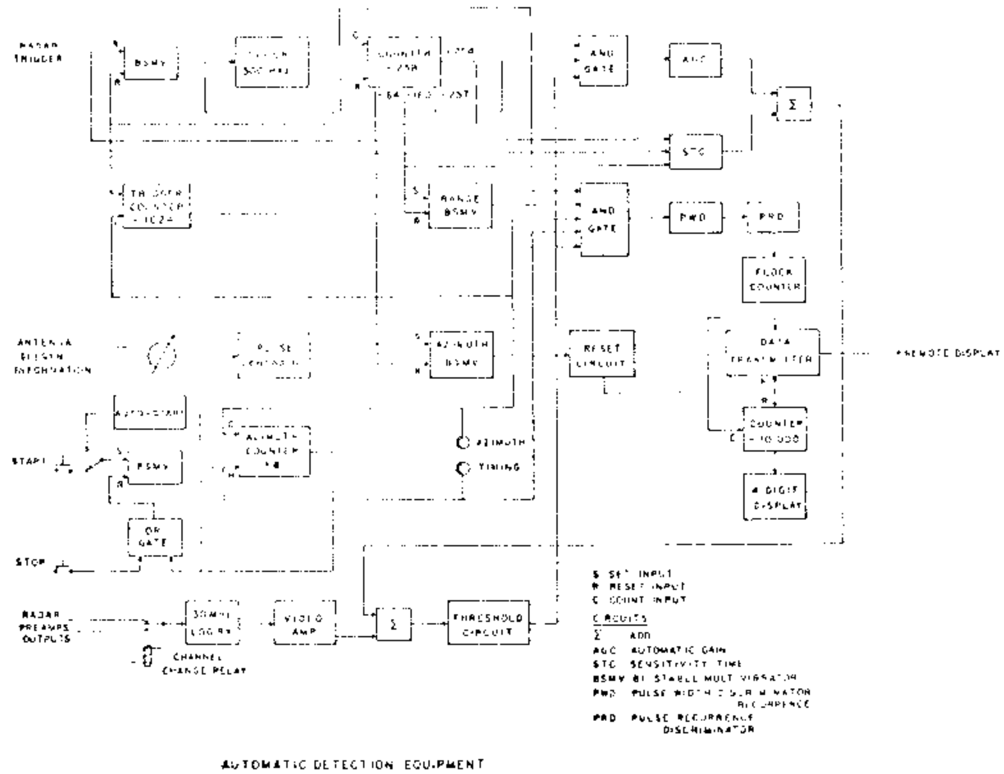

Fig. 8. Sector Automatic Detection Equipment

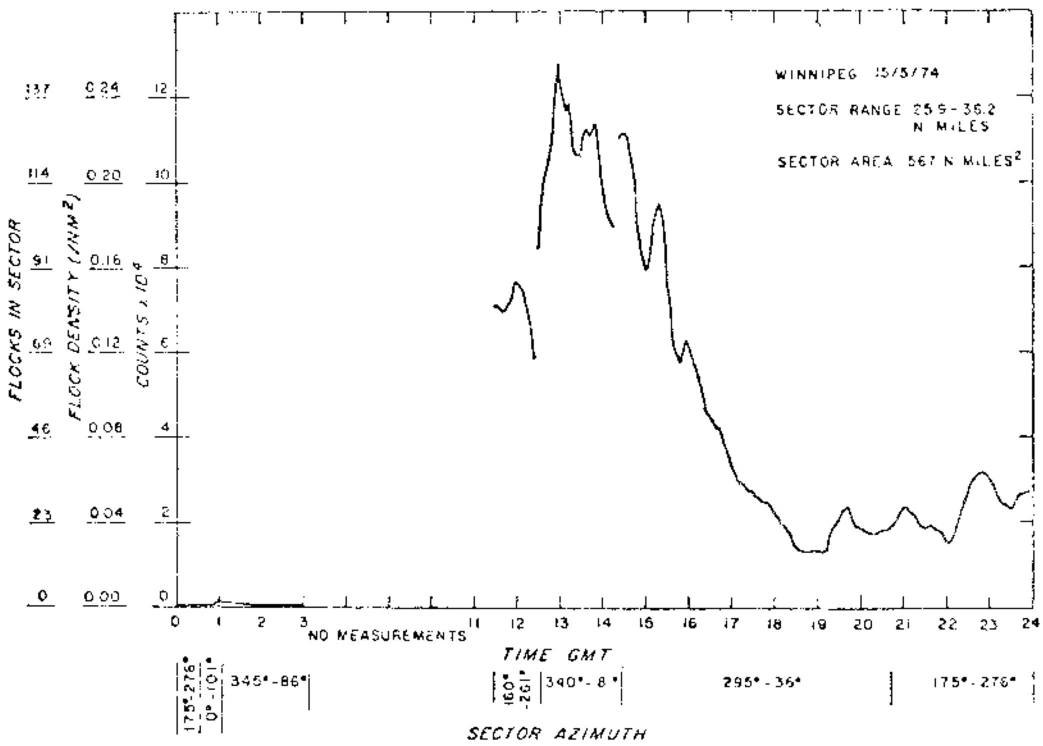

Fig. 9. Snow Goose Migration from SAFE, 15/5/74