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EXPERIMENTS ON THE DISSIPATION OF WARM FOG BY HELICOPTER-INDUCED AIR EXCHANGE OVER THULE AB GREENLAND

by

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PREFACE

These studies were conducted over Thule AB, Greenland, in late summer 1964 by Mr. J. R. Hicks, meteorologist, Environmental Research Branch, U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL), under the general direction of Dr. R. W. Gerdel, Branch Chief, as part of the Arctic Whiteout Dispersal project.

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EXPERIMENTS ON THE DISSIPATION OF WARM FOG BY HELICOPTER-INDUCED AIR EXCHANGE OVER THULE AB, GREENLAND

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During mid and late summer, a shallow advection fog frequently forms over the open water of North Star Bay just north of Thule Air Base, Greenland. Light northerly winds, 4-6 knots, move this fog inland between North and South mountains over Thule AB. Occasionally the fog dissipates as it progresses inland over the runways due to radiational heating of the land. During these periods, one end of the field is operating under Visual Flight Rules for light aircraft and helicopters, but the field is closed for larger aircraft which must make their approach from the sea. It is not uncommon for incoming air traffic to be halted for as long as a week or more.

This situation is particularly troublesome because it occurs at times when air transportation is needed most; i.e., when major research projects are being activated and personnel replacement and area resupply are being completed before the long arctic night sets in. The need for keeping this base open for air traffic is therefore great.

Theoretical considerations

One approach to the problem of clearing such fogs appears to be that of replacing the fog layer with a volume of relatively dry and warm air which would reduce the relative humidity and allow the fog droplets to evaporate and disappear. This approach has been tried by introducing heat which had been generated on the ground by burning fuel in great quantities (the "FIDO" system). Such procedures were used to clear fog from airfields in Great Britain during World War II. Later tests in the United States proved the system to be too unreliable and economically unfeasible.

A second approach to the problem is to replace the fog with warmer air from the inversion layer usually found above. This might be accomplished by helicopters such as the U. S. Army's H-34.

Another approach using the warm air principle was used in a series of tests performed in Japan*. The system used there was to release water droplets from a helicopter above the fog. These falling droplets were thought to cause sufficient air movement downward to dissipate the fog through the process of adiabatic heating by compression.

The experiments conducted in Japan met with considerable success in the case of thin fogs, but little or no effect was noted on thick fogs, or fogs which were in a stable equilibrium condition. Furthermore, the possibility of the clearing being caused by the downwash from the helicopter was never really eliminated. Many scientists felt that it was probably the helicopter downwash which caused the air exchange rather than the falling droplets.

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*Magono, Kikuchi, Nakamura and Kimura (1963) An experiment on fog dispersion by use of downward air current caused by fall of water drops, Journal of Applied Meteorology, vol. 2, no. 4, p. 484-493.

Design of experiments

A study to determine the presence of warm air directly over the fog, and to estimate the chance of success in replacing the fog with this warm air was made during the period 1 July to 23 August 1963.

Arbitrarily, only two parameters were considered to be important in this study: the potential temperature (θ_{sfc}) and the height of the top of the fog.

Potential temperature (θ_{sfc}). This was considered to be the temperature which a parcel of air would achieve if it were moved adiabatically from a point 280 ft above the top of the fog down to the height of the runway. A potential temperature of 1.5C or more above the surface temperature was determined to be sufficient to evaporate the liquid water contained in the fog ($\approx$ 0.10 g/m^3) and to keep it in the vapor state. Calculations show that a drop in air temperature of $\approx$ 0.2C could be expected due to the vaporization of the liquid water, and that an increase in temperature of 0.3C would be needed to maintain the total water content of the fog in the vapor state.

Height of the top of the fog. It was believed that if the top of the fog was 1000 ft or less, the chance of successful dissipation was good. These temperature and height parameters were selected intuitively since it was not known to what depth a helicopter could cause downward displacement of air under different conditions of atmospheric stability.

A third parameter, stability with respect to the dry adiabatic lapse rate within the fog layer, was studied but did not enter into the prediction; however, a layer having unstable equilibrium would be set in motion more easily and, hence, air would be exchanged to greater depths than could be accomplished in a layer having stable equilibrium.

Data analysis

Sixty-four radiosonde ascents made during actual periods of fog over the Thule area were analyzed and, using the criteria described in the preceding section, estimates were made on the probability of clearing the fog by the air-exchange method. The results of these studies are shown below.

Prediction of success	Stability characteristics
	stable = 13
Yes = 41	unstable = 16
	neutral = 12
	stable = 7
No = 8	unstable = 1
	neutral = 0
	stable = 6
Marginal = 15	unstable = 6
	neutral = 3

The tabulated data for these soundings are contained in Table I (p. 6) and a sample plot of one sounding is shown in Figure 1.

Flight tests

Several flights were made over the Thule area in July 1964 to test the effectiveness of the H-34 helicopter as an air exchanger. The results of these flights follow.

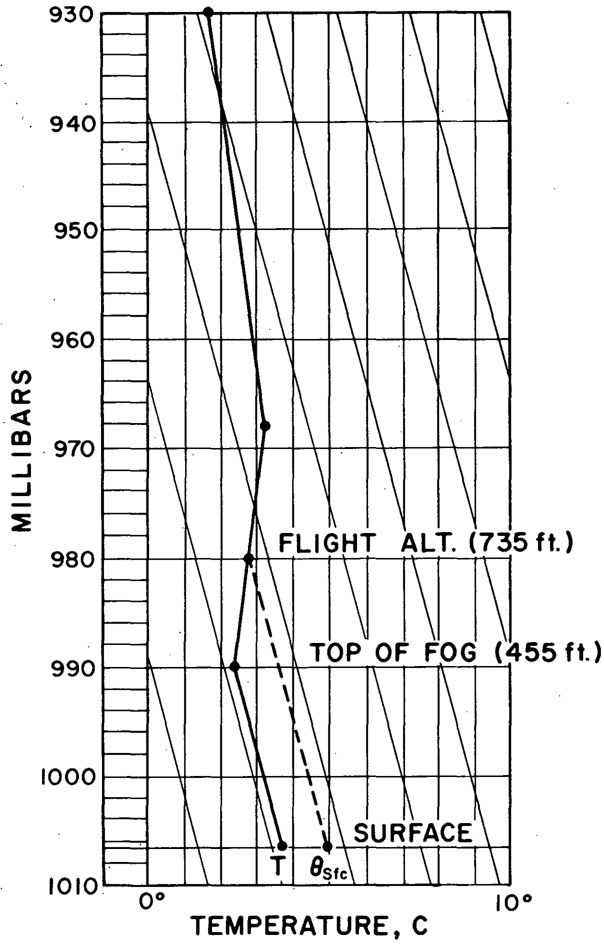

Figure 1. Radiosonde plot showing method for deriving potential temperature. Thule AB, 6 July 1963, 0700 LST. Diagonal lines are dry adiabats.

Flight 1.

Date:	19 July 1964
Time:	1430-1434 hours
*Temp (sfc):	0C
Temp (top of fog):	0C
*Wind (sfc):	270/04
*R. H.:	79%
Visibility (sfc):	estimated 300 ft in fog
Height of top of fog:	approximately 250 ft

A 4-min flight at an altitude of 270 ft was made at an airspeed of about 4 knots. The direction of the flight was almost upwind. A clear path about 75 yards wide and 500 yards long was observed immediately after the run. This path was in an

*These data were taken at the Thule AB weather observation station and do not necessarily represent the conditions where the flight was made.

area in which the fog was quite thin, i.e., not dense; some nearby areas contained holes through which the ground could be seen.

Flight 2.

Date:	19 July 1964
Time:	1436-1440 hours
*Temp (sfc):	0C
Temp (top of fog):	0.5C
*Wind (sfc):	270/04
*R. H.:	79%
Visibility (sfc):	estimated 200 ft in fog
Height of top of fog:	estimated 280 ft

A 4-min flight, similar to Flight 1 of this series, was made over a denser area of fog on North Star Bay near Thule Air Base. As before, clearing occurred in the wake of the helicopter. The downdraft from the helicopter reached the surface of the water and ripples were observed on an otherwise smooth water surface.

Flight 3.

Date:	19 July 1964
Time:	1442-1446 hours
*Temp (sfc):	0C
Temp (top of fog):	2.0C
*Wind (sfc):	270/04
*R. H. (sfc):	79%
Visibility (sfc):	estimated 300 ft in fog
Height of top of fog:	280 ft

This flight was made at the level of the top of the fog about midway between Dundas Mountain and Thule AB. The area was covered by a thin layer of fog in which some openings already existed. Clearing was noted in the wake of the H-34. No doubt this hole was caused by the helicopter but it was not much different in appearance from some of the other nearby openings in the fog layer.

Flight 4.

Date:	19 July 1964
Time:	1450-1455 hours
*Temp (sfc)	0C
Temp (top of fog):	2.0C
*Wind (sfc):	260/03
*R. H. (sfc):	79%
Visibility (sfc):	estimated 200 ft in fog
Height of top of fog:	300 ft

This flight was made at an altitude of about 325 ft, i.e., approximately 25 ft above the fog. An airspeed of 4-6 knots was maintained and a flight path over the entire length of the pier at Thule AB was used. A clear path about 75 yards wide was established for the entire length of the pier (Fig. 2). This clear area remained for about 10 minutes, after which it began to fill in and become ragged at the sides.

*These data were taken at the Thule AB weather observation station and do not necessarily represent the conditions where the flight was made.

Twenty minutes after clearing had been accomplished, the area had drifted away from the pier and had filled in almost completely.

Conclusions and Recommendations

These tests have demonstrated that certain types of shallow fogs can be dispersed by the downwash created by helicopters flying at near-hovering airspeeds at altitudes a few feet above the top of the fog. One helicopter can clear an area about 75 yards wide by a mile long every 10-15 minutes.

This system requires unsafe flying techniques, i. e., near-hovering airspeeds during which time the helicopter is operating at almost full power, low alititudes, and positions where an engine failure would probably result in a crash since the aircraft would have to descend through the fog to an unknown landing area. Therefore, this technique is recommended for emergency use only.

Figure 2. Results of one pass by helicopter over a 300 ft thick "warm" fog. Cleared strip is about 75 yards wide by 500 yards long.

Table I. Radiosonde data taken during periods of fog at Thule AB for the summer of 1963.

Date 1963	Time LST	Surface Press. (mb)	Surface Temp (°C)	Top of fog Press. (mb)	Top of fog Height (ft)	Ht. 280 ft above top of fog (ft)	Stability S.	Stability U.	Stability N.	Potential temp θ_{sfc} (°C)	Poss?	Remarks
1 July	1300	1014	+1.8	1002	336	616		X		+ 1.0	No	
2	0100	1007	+1.5	962	1232	1512	X			+ 5.5	Yes	
2	1902	1007	-1.0	970	1008	1288			X	+ 6.0	?	
3	0100	1005	-0.6	970	960	1240	X			+ 4.5	Yes	
5	0700	1008	+0.9	996	616	896		X		+ 3.0	Yes	
6	0700	1007	+3.5	990	455	735			X	+ 5.0	Yes	
6	1303	1006	+4.4	988	500	780		X		+ 6.0	Yes	
6	1904	1st significant level = 600 mb					X				No	$\theta_{sfc} > T_{sfc}$ for all levels.
14	1900	1007	+4.2	972	970	1250	X			+ 7.5	Yes	
15	0102	1006	+2.3	975	860	1140	X			+ 8.6	Yes	Inversion from surface.
15	0711	1006	+1.0	986	560	840		X		+ 2.8	Yes	
15	1310	1003	+1.8	978	695	975		X		+ 3.1	?	
15	1910	1002	+0.6	973	810	1090	X			+ 3.1	Yes	
16	0100	1001	+0.9	978	635	915	X			+ 3.4	Yes	
16	0701	1008	+0.4	983	700	980		X		+ 2.8	Yes	
16	1301	1006	+1.8	995	300	580		X		+ 3.7	Yes	
16	1915	1007	+0.2	998	249	529			X	+ 2.0	Yes	
17	0100	1010	-1.4	988	616	896	X			+ 3.0	Yes	
17	0737	1012	+1.0	1002	280	560			X	+ 3.5	Yes	
17	1304	1014	+3.0	997	475	755		X		+ 6.8	Yes	
17	1900	1014	0.0	958	1568	1848	X			+11.0	?	Deep inversion
18	0103	1014	0.8	975	1095	1375	X			+ 7.0	?	
18	0703	1013	+1.2	1002	310	590		X		+ 3.6	Yes	
18	1333	1013	+1.2	998	410	690		X		+ 1.4	?	Inv at 980 mb
18	1900	1013	+1.0	992	580	860		X		+ 2.8	Yes	
19	0100	1011	+0.8	992	530	810			X	+ 4.0	Yes	
19	0701	1011	0.0	1002	255	535		X		+ 1.5	?	Steep inv at 1002 mb
19	1302	1011	+2.2	1001	280	560		X		+ 4.0	Yes	Steep inv at 1000 mb
19	1901	1013	-1.0	987	728	1008			X	+ 1.8	Yes	
20	0101	1013	-0.2	986	760	1040			X	+ 4.0	Yes	
20	0704	1015	+1.0	1000	420	700	X			+ 3.5	Yes	
20	1350	1016	+0.5	984	896	1176			X	+ 3.6	Yes	

Table I(Cont'd). Radiosonde data taken during periods of fog at Thule AB for summer of 1963.

Date 1963	Time LST	Surface Press. (mb)	Surface Temp (°C)	Top of fog Press. (mb)	Top of fog Height (ft)	Ht. 280 ft above top of fog (ft)	Stability S.	U.	N.	Potential temp θ_{sfc} (°C)	Poss?	Remarks
20 July	1900	1018	-1.5	1000	504	784			X	+ 1.5	Yes	
21	0157	1018	0.0	996	616	896			X	+ 3.0	Yes	
21	0713	1018	+0.5	1008	280	560		X		+ 1.3	?	Sharp inv above 1008 mb
21	1301	1019	+1.0	1010	250	530		X		+ 3.5	Yes	
21	1901	1019	+0.6	968	1440	1720	X			+ 1.6	?	Inv from sfc
22	0100	1019	+0.3	1008	300	580			X	+ 3.0	Yes	
22	0702	1018	+0.8	1007	310	590		X		+ 4.0	Yes	
22	1301	1020	+1.7	1010	280	560		X		+ 3.6	Yes	
22	2003	1021	+0.4	1002	550	830			X	+ 3.0	Yes	
23	0100	1021	+0.4	1005	448	728		X		+ 2.0	Yes	
23	0700	1021	+1.0	1007	392	672		X		+ 2,8	Yes	
23	1304	1021	+1.6	1011	570	850		X		+ 3.4	Yes	
23	1901	1019	-0.9	990	810	1090	X			+ 3.6	Yes	
24	0107	1016	+1.1	996	560	840			X	+ 5.8	Yes	
24	0729	1013	0.0	990	640	920	X			+12.5	Yes	Inv from sfc
29	1301	1001	+4.7	991	280	560		X		+ 6.8	Yes	
6 Aug	1300	1006	+4.4	983	640	920			X	+ 5.8	?	
6	1900	1007	+3.4	827	5000	5280	X				No	Layer too deep
7	0701	1010	+5.4	932	2184	2464	X			+ 6.7	No	Too deep
8	0103	1007	+3.5	948	1904	2184	X			+ 7.0	No	Too deep
9	1306	1009	+3.8	963	1260	1540		X		+ 6.5	?	Deep layer
10	0100	1018	+3.1	943	2100	2380	X			+ 7.5	No	Deep layer
13	0700	1012	+4.5	850	>4500		X				No	Too deep
14	0101	1015	+2.8	902	3164		X				No	Too deep
14	0750	1012	+4.5	980	896	1176			X	+ 5.5	?	Deep layer
17	0101	998	+2.9	967	810	1090	X			+ 4.8	Yes	
17	1300	999	+3.1	958	1140	1420		X		+ 4.5	?	Deep layer
18	0101	1002	+1.0	976	728	1008	X			+ 2.5	Yes	
19	0700	1005	+4.2	974	870	1150	X			+ 9.0	Yes	
20	0101	1006	+2.5	934	2045	2325	X			+11.0	?	Deep layer
23	0102	1016	+3.4	970	1288	1568	X			+ 8.2	?	Inv from sfc
23	1314	1011	+3.8	938	2020	2300	X			+ 8.5	?	Deep layer