NATIONAL CLOUD-SEEDING OPERATION 1982-83

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1. GENERAL BACKGROUND

The Meteorological Department Cloud-Seeding Research Programs have carefully observed more than 250 cloud seedings under controlled experimental conditions so that many fundamental aspects are reasonably well understood. In general, clouds in Zimbabawe are suitable for seeding if they are well-rounded cumulus types, with tops reaching to the -10°C level, which is about 6,400 meters above sea level.

In 1972 the National Cloud-Seeding Operation (NACSO) was organized to enhance rainfall amounts over areas where marginal rainfall and occasional drought conditions can produce a severe stress on the agricultural community.

NASCO was originally organized under the control of a broad based committee consisting of representatives from the Ministry of Agriculture, the Division of Water Development, Air Force Zimbabwe, with the Director of Meteorological Services representing the Ministry of Transport. The function of the committee has been to decide the broad thrust of operations within the overall national interests.

During the 1982-83 season, this Control Committee was comprised as follows:

Mr. C.B. Archer, Chairman, Director of Meteorological Services, Representing the Ministry of Transport
Mr. N. Thomas, Agritex, Ministry of Agriculture
Mr. R. H. G. Howden, Agritex, Ministry of Agriculture
Mr. P. Silk, Agritex, Ministry of Agriculture
Eng. J. C. Johnston, Division of Water Develop.
Mr. J. Kreft, Deputy Director of Meteorological Services
Mr. J. S. Stevens, Coordinator, NACSO
W/Cdr. D. Thorne, Air Force Zimbabawe

The Committee met at Meteorological Service Headquarters on 12 October 1982 and approved the arrangements for the 1982-83 season.

2. BASIC PROJECT DESIGN

The Zimbabawe cloud seeding program has been designed to utilize the airborne dispersal of silver iodide particles by direct injection into cumulus cloud developments at the -10°C level. Three aircraft with a pool of fully instrument rated pilots were organized from United Air Charters (UAC). The disposition of the aircraft in the project area were as follows:

Harare Airport:
One turbocharged 56 TC Baron
One standard C55 Baron

Bulawayo Airport:
One standard C55 Baron

A map of the cloud-seeding areas is shown in Figure 1.

For the two aircraft based in Harare and for the one in Bulawayo, the cloud seeding pilots need to be fully competent to fly the aircraft on instruments, in severe turbulence, and during heavy icing conditions. It requires training and practice to enable the cloud seeding operator to carry out the basic procedures in the aircraft, fire the pyrotechnic seeding devices at the critical moment, keep the recently seeded cloud under observation, and maintain a log sheet on aircraft height, ambient air temperature, geographical position, and observe results of the seeding.

During the 1982-83 season, the Project Coordinator carried out preliminary training and reviewed each day of the season from 15 November through 14 April for the feasibility of cloud seeding. Because the season opened with serious water shortages, it was emphasized that every effort must be made to enhance rain by seeding whenever, and wherever possible.

Each day the Project Coordinator makes provisional arrangements for the requirements of aircraft, pilots and cloud seeding operators in both Harare and Bulawayo for the following day. On the day in question, the PC usually begin a decision making sequence at 0730. Seeding potential is continuously reviewed up to the time of take-off or of cancellation for the day.

Accurate timing of take-off is probably the largest single factor in determining the economics of the operation. Ideally, each aircraft should complete its climb to the -10°C level over its seeding area just as the cloud top reaches this level. In such a case, seeding can begin without any waste of flying time, and the maximum possible number of clouds can be seeded before fuel and oxygen consumption enforce a return to base.

If indecision or any other reason causes the aircraft to still be on the ground when it can be clearly seen that clouds are seedable, then $20,000 worth of yield could easily be forfeited while the seeding aircraft is climbing to the proper altitude. The simple alternative of being on station ahead of time is also expensive. Some $500 or more worth of flying time could be wasted while waiting for the clouds to mature. Even more expensive is the risk that a further $20,000 of yield may have to be forfeited because fuel has run too low for the aircraft to remain on station and seed clouds which later reach the -10° msl altitude.

3. THE 1982-83 RAIN SEASON AND SEEDING OPERATIONS

The 1982-83 season followed immediately upon a serious 1981-82 season which produced drought

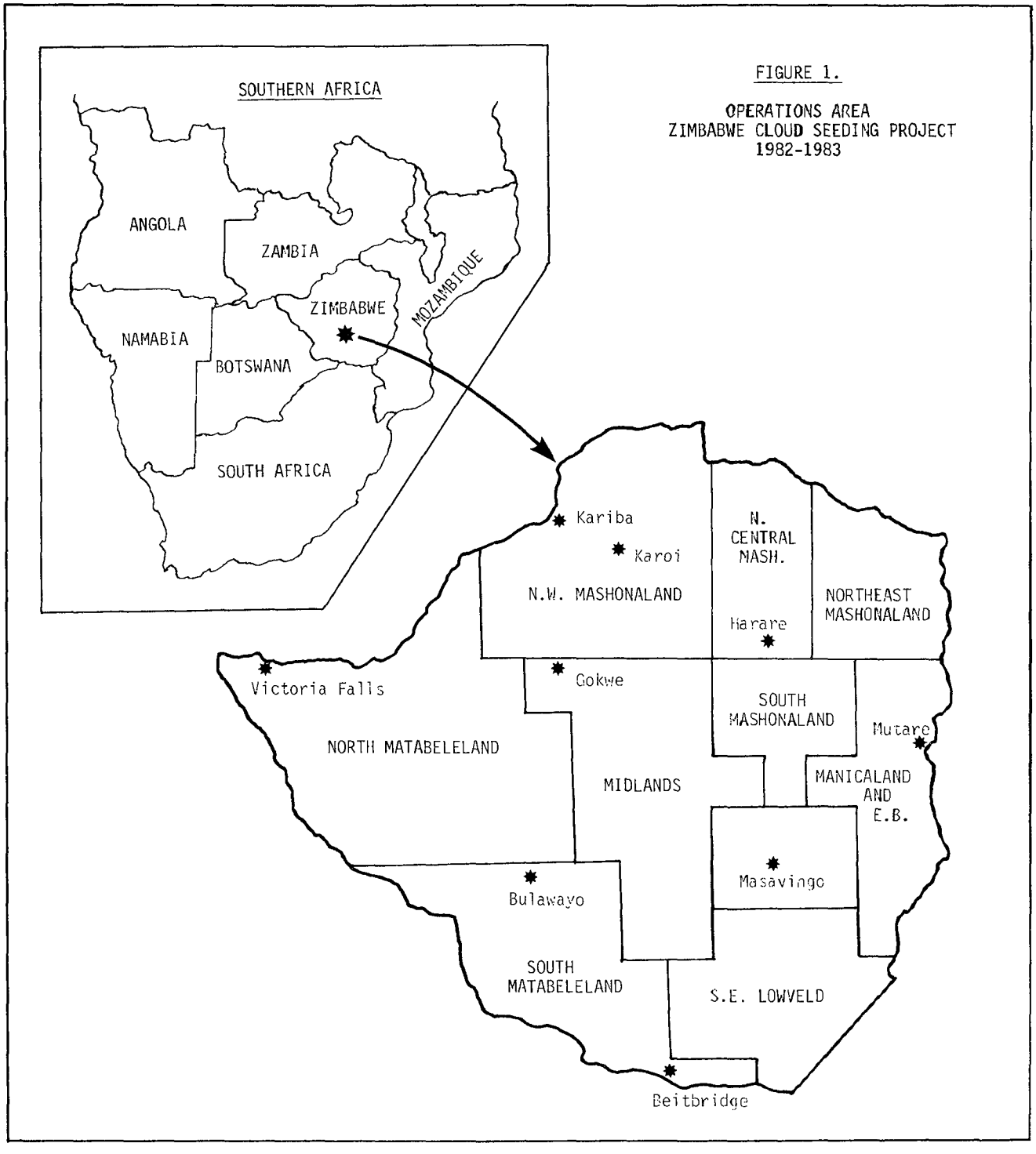


FIGURE 1.

OPERATIONS AREA
ZIMBABWE CLOUD SEEDING PROJECT
1982-1983

conditions over most of Zimbabwe except for the northeast corner. Since records have been organized dating to 1887, this is the first known case of two successive droughts of such severity. The odds against this occurrence are on the order of 100 to 1.

From about 10 November until 28 December, there were several occasions when the onset of "the rains" seemed likely within the next two days. At Christmas the prospect seemed no worse than a late start to the rain period. However, on 29 December the Botswana Upper High reformed and seriously restricted the approach of rain. Hopes revived on about 13 January as Cyclone Elinah moved into the Mozambique Channel. Welcome scattered rain and showers occurred until 23 January, although south of the watershed the showers were few.

On 25 January hopes returned for resumption of rain in northern areas but were once again dashed on the 28th with clear weather. A spell of intermittent rainshowers beginning on 1 February brought some relief to most areas and this situation continued until the 14th. Very dry air generally prevailed from February 16th until about March 2nd. From March 3rd to 10th there was some rain in most districts. After another dry interval, the period from March 20th until the 25th offered many convective clouds but relatively few showers. The first half of April gave unusually hot humid weather which offered only a scattering of convective clouds.

By the end of the season about half of the country, much of the northeast, most of the central watershed area, plus southeast and south Matabeleland had received only 40% to 60% of normal rainfall. Many districts expecting 900mm of rain received a scant 600mm, while districts which usually averaged 600mm received only 300mm.

The main cause of this serious shortage of rainfall was the recurring formation in the middle levels of the atmosphere, of an anti-cyclonic circulation which was much more extensive than the notorious "Botswana Upper High" and much more serious. Much of the southern half of Malawi and Southern Zambia also suffered drought.

During the first seven weeks of the season, moisture in the lower levels often produced apparently favorable cumulus clouds to develop, only to be overlayed by very dry air at about the -6°C level. In spite of the favorable appearance to farmers desperate for rain on the ground below, these clouds were simply not quite high enough for successful seeding.

During early January, a time when the atmosphere would normally contain high moisture content, there was exceptionally dry middle level air down to 4,000m above sea level. Instead of the main rains being in full spate, there were blue skies and searing hot sunshine.

Throughout the operations area, the numbers of clouds seeded totaled 2,184. The seeding events in each quarter square are shown in Figure 2. A comparison between seeded clouds in the 1981-1982 and 1982-1983 seasons are listed as follows.

	82-83	(81-82)
Northwest Mashonaland	179	769)
North Central Mashonaland	315	)
Northeast Mashonaland	110	517)
North Matabeleand	460	571)
Midlands	307	358
South Mashonaland	252	321
Manicaland/Eastern Border	125	89
Victoria	25	7
South Matabeleland	411	366
Southeast Lowveld	-	8
	2,184	3,006

The program provided three aircraft each day, except for Christmas Day and New Year's Day. Following is a tabulation of general operational information relevant to the 1981-82 and 1982-83 seasons:

	82-83	(81-82)
Number of days programmed for operation	149	151
Number of days selected for seeding	75	85
Selected days as percentage of programmed days	50.4%	56%
Number of days suitable for all three aircraft	14	11
Number of days suitable for only two aircraft	34	32
Number of days suitable for only one aircraft	36	44
Number of days unsuitable for any aircraft to try	65	
Total number of programmed aircraft days	447	447
Number of aircraft days weather unsuitable (too dry/too wet)	301	306
Number of aircraft days selected and flown / Number of sorties flown	146	141
Number of successful sorties	133	139
Percentage of sorties on which seeding carried out	91%	98%

It is interesting to note that most of the seeding was achieved on relatively few days. Twenty-five percent of the seeding was accomplished on 5% of the days, and 50% of the seeding was accomplished on 13% of the days. By contrast, the last 6% of the seeding required the effort of 14% of the days.

Due to the pressing need for rain, aircraft had to be flown in barely marginal conditions with the hope of fortuitous success, which seldom materialized. It is noted that 65 days, or 44% of the working period, was spent in readiness and anticipation for seeding that had to be cancelled, usually because the atmosphere was too dry for development of suitable clouds.

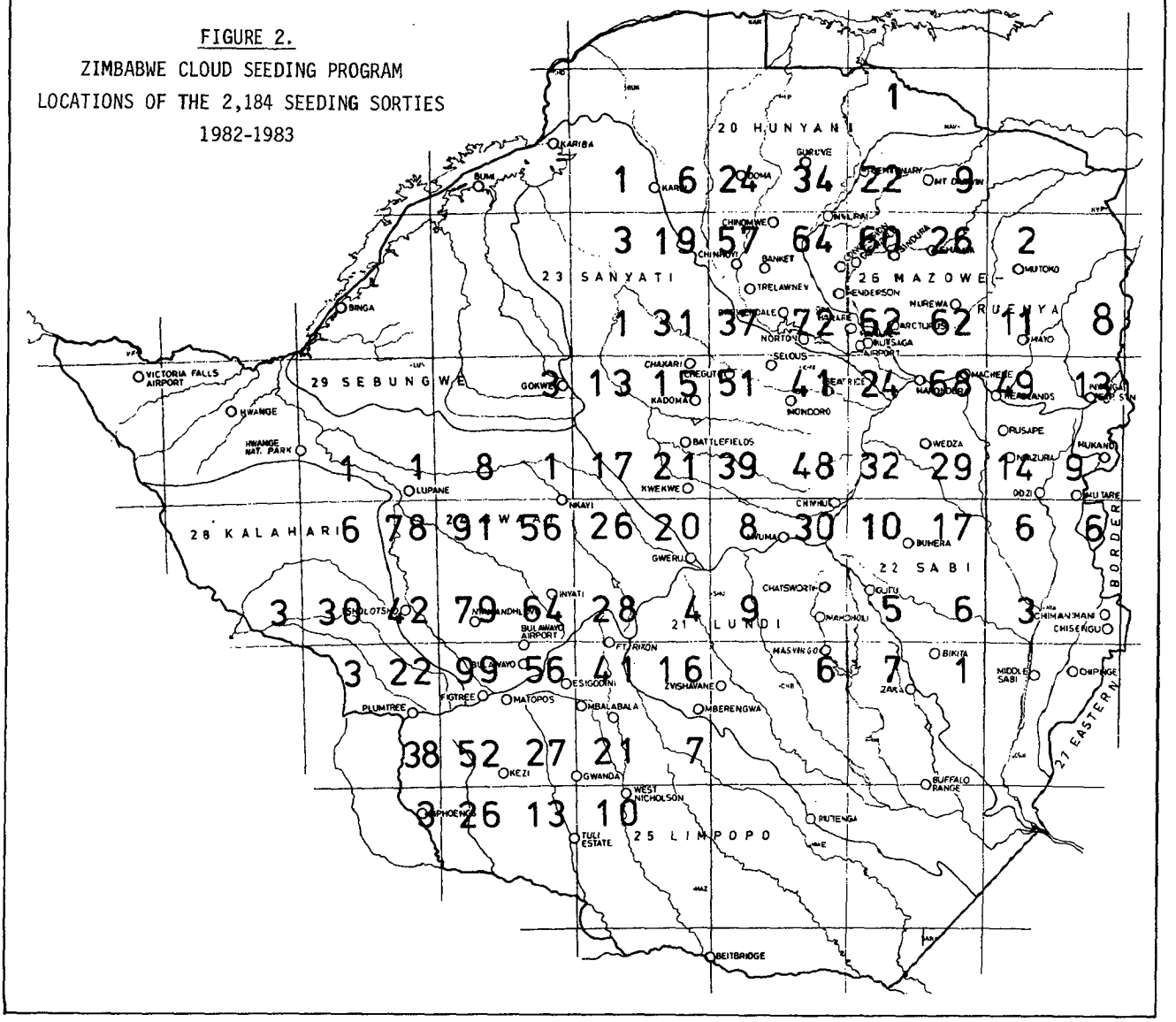
Three aircraft are deployed on days when clouds suitable for seeding are scattered over a wide area. Normally at least 60 clouds, and

FIGURE 2.

ZIMBABWE CLOUD SEEDING PROGRAM

LOCATIONS OF THE 2,184 SEEDING SORTIES

1982-1983



hopefully more than 100 clouds, can be seeded on days when all three aircraft are flown.

The following tabulation of data from airborne observations illustrates the differences between the 1981-82 and 1982-83 seasons:

	1982-83	(1981-82)
Number of cartridges fired	2,642	(3,886)
Number of clouds seeded	2,184	(3,006)
Number of clouds observed	1,283	(1,679)
Number of clouds observed to rain	198	(301)
Number of clouds observed to grow but not possible to observe base	942	(1,294)
Number of observed no change	23	(3)
Number of observed collapses	120	(81)
Number of clouds not observed	901	(1,327)

4. COST AND YIELD

The monetary outlay for the 1982-83 operation was approximately $303,000.

Research programs carried out in Zimbabawe from 1968 through 1978 designed to evaluate the average yield of one cloud seeding sortie, gave an answer of more than 120 x 10^3 m^3 or 120,000 tons of additional water.

Of the 2,184 clouds seeded during the 1982-83 season, a total of 1,283 clouds were observed from cloud-top height after seeding. It was possible to observe rain falling from the base of 198 clouds. Vertical development was seen in the case of 942 clouds where the cloud base was obscured from view. These last two figures represent a positive reaction in the case of 1,140, out of 1,283 clouds, about 89%.

In 120 cases the clouds collapsed, probably because the stimulation of marginal clouds in a dry atmosphere accelerated their dispersal by evaporation. Counting the 23 cases where seeding made no change, in 143 or 11% of the cases seeding was unsuccessful.

If the 89% success rate is applied to all 2,184 clouds seeded by aircraft, then 1,940 clouds produced a positive response.

The total cost of the 1982-83 operation includes the purchase of 5,000 pyrotechnic cloud seeding cartridges. Including training and test firings, 2,660 cartridges were used. To arrive at a reasonable estimate of cost, a credit of $45,967 must be applied for the 2,340 cartridges still held in stock. A fair estimate of costs attributable to the 1982-83 cloud seeding season is approximately ZIM. $257,100. Thus, the estimated cost of one successful seeding sortie to give 120,000 tons of additional water is calculated as:

$$\frac{\$257,100}{1,940} = \$132.53 \quad (\$85.59)$$

The cost of additional precipitation per 100,000 tons or 100 x 10^3 m^3 was:

$110.50 ($71.00)

The cost of seeding a single cloud in 1982/83 was greater than in 1981-82 as shown by the figures in brackets. The explanation is relatively simple. In 1981-82 a record number of 3,006 clouds were seeded compared with 2,184 clouds during the 1982-83 season. Input costs also escalated. Following a general rise, there was the devaluation of the Zimbabwe dollar in December and a very large increase in the cost of aviation fuel on 9 February 1983.

5. FINAL COMMENTS

The 1982-83 season was disappointing for all concerned. Being the second drought season in succession for so much of the country, the need for rain was greater than ever before yet the recurring persistence of a very dry layer of air in the middle elevations definitely ruled out the chance of seeding on many days.

The cost data show how vitally important it is for the success of seeding, especially in a poor year, that aircraft and crews are always available on call and that the coordinator is alert to every possible opportunity. There is a strong emphasis on the critical judgement required of the coordinator to identify the right seeding opportunity and to time the aircraft takeoff to achieve the greatest possible gain for the lowest cost.

Thanks for due to Messrs. United Air Charters and the pilots for their customary efficiency and cooperation, and to the Director of Civil Aviation and the Harare Airport Radar Controllers for their invaluable assistance. Finally, we offer thanks to all those persons who volunteered to act as seeding operators.