OBSERVATIONS CARRIED OUT IN AN EQUATORIAL FOREST AFTER SILVER IODIDE SEEDINGS FROM A GROUND GENERATOR

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Abstract. Seeding experiments have been conducted at certain periods of the year since 1975 near the dam of Ayame, Ivory Coast, in order to increase the water supply of a small river, "La Bia", which flows for 220 km in a humid and dense forest. The region is hilly and covered with forest and cacao or coffee plantations. Silver iodide is daily released from a vortex generator at the time of cumulus convection during the dry season, generally from December to April.

The seeding effects are discussed in the context of the climatological conditions of southern Ivory Coast by considering a numerical cloud model, the analysis of silver content in rain samples, and the map of isohyets.

1. INTRODUCTION

Several climatological studies in West Africa show that, for the rainy seasons of the last fifteen years, the rainfall was below normal. Moreover, these rainy seasons were shorter than before. In most cases they began later and ended earlier. This situation has been well documented by Todorov (1985) for the Sahel region where the rainfall amounts began to decrease about 1968. This is a phenomenon which has continued until now, together with a concomitant shortening of the rainy season. The impact of these droughts has ranged from complete crop failure to sharply reduced productions. As seeds planted in the soil failed to emerge, farmers in some locations have had to re-sow several times during the season, and plants did not have enough time to mature.

In the southern part of the Ivory Coast, a seeding experiment with silver iodide released from the ground has been run since 1975 in the Ayame region (Lat. 5°40'N, long. 3°08'W), 50 km north of the Atlantic Ocean (Fig. 1). The experiment is intended to increase the water supply of a small river, "La Bia", on which the Company "Energy Electrique de Cote d'Ivoire" has built a dam. The region is hilly and covered with humid forest and cacao or coffee plantations. This situation seems favorable both for convection and humidification of the lower layers of the atmosphere.

The annual oscillation of the Intertropical Convergence Zone (ITCZ, or ZCIT in French) accounts for the existence of four seasons in the southern part of Ivory Coast (Fig. 2). From one year to the next in the Ayame region, it is possible to distinguish the following:

1) 15 December-28 February: great dry season (Zones A and B)

2) 1 March-14 July: great rainy season (Zone C)

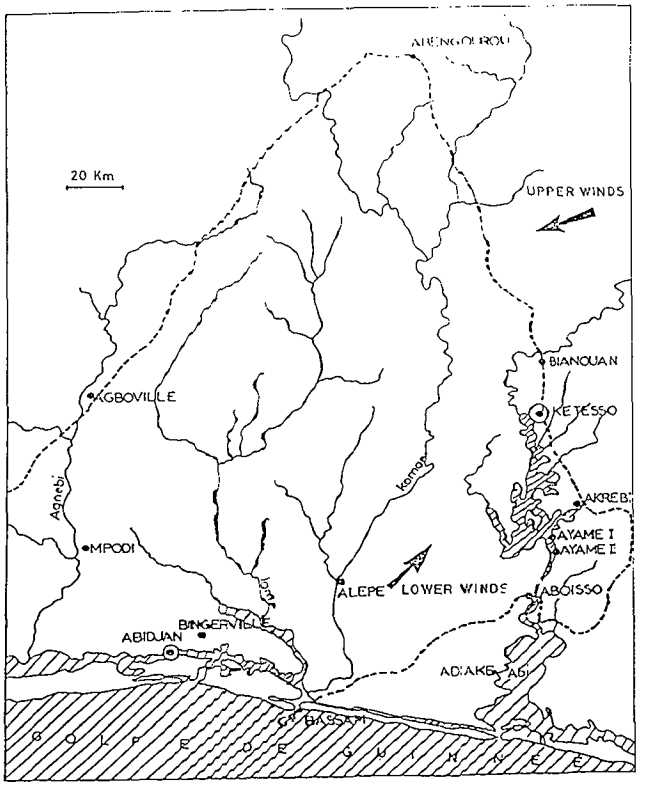

Fig. 1: Map of the region of Ayame (Ivory Coast)

3) 15 July-30 September: small dry season (Zone D). The ITCZ is at its northernmost position

4) 1 October-14 December: short rainy season caused by the movement of Zone C toward the south.

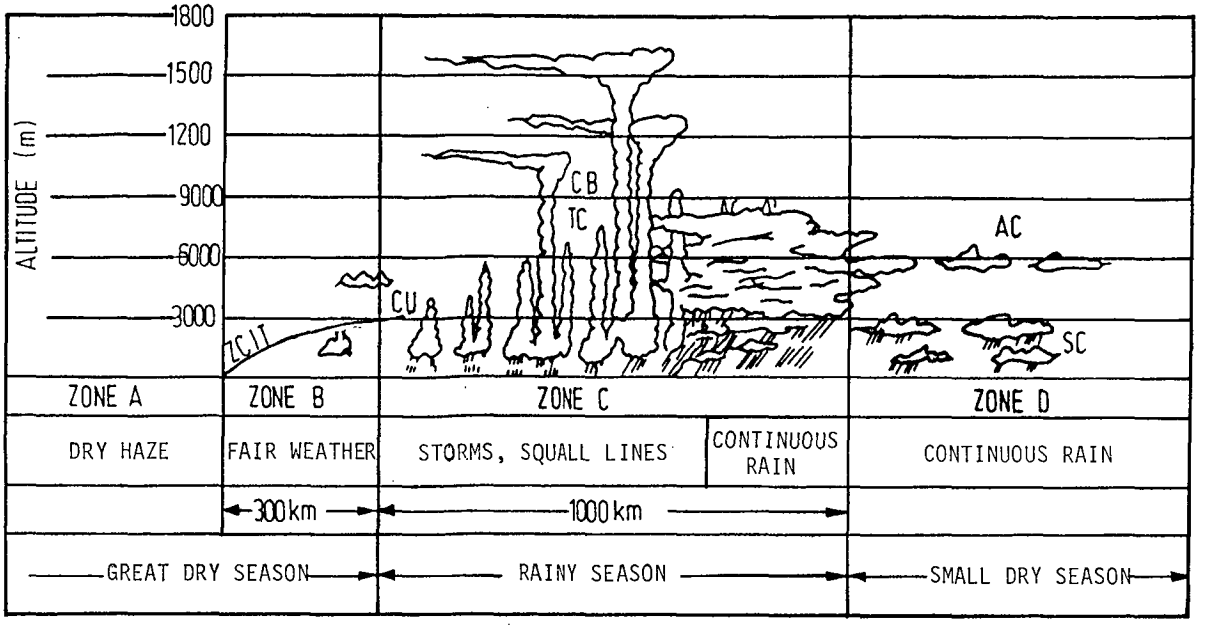

Fig. 2: North-South cross section of the Intertropical Convergence Zone (from ASCENA, 1979).

In fact, March and April occupy an inconsistent stormy period which may be either rainy or, as it has been observed for a few years, rather dry. From one year to the next, cloud seeding was conducted when rains were produced from supercooled clouds which did not have a great vertical extent. The central periods of the rainy season and of the great dry season were not seeded.

2. THE AgI GROUND SEEDING

The type of generator used to release the silver iodide particles is the acetone vortex burner described by Dessens and Pham Van Dinh (1968). The solution consists of 98.0% acetone, 1.4% AgI, and 0.6% NaI (weight percentages). The generator is used with a nozzle type "Monarch New system, 0.75,30°" under a pressure of 1.3 atm. The solution flow rate is 1.1 lh^{-1} giving a silver iodide output of (11.4 x 1.1) ≈ 12.5 gh^{-1}. The number of ice forming nuclei (IFN) active at -15°C produced per gram of silver iodide being 0.8 x 10^{14} (Pham Van Dinh, 1973), the number N of nuclei released per hour by the generator is then about 10^{15}.

The first location of the generator was Ayame II (1975-1976) with the intention of seeding the clouds above Ayame I. This is a station where the rain is measured and collected for analysis. In fact, by convective situation, the transport of the nuclei by the SW lower winds has been found negligible. For this reason the generator was moved toward the north (Akrebi, 1977-1978; Ketesso, 1979-1984), in order to have the seeded rainfalls in the watershed of the Bia River.

During the seeding periods (Table 1), the generator was operated every day between 10.00 and 14.00 (time UT), when the convection was well developed.

Table 1 : *Locations of the generator and seeding periods.*

		Month											
Location	Year	J	F	M	A	M	J	J	A	S	O	N	D
AYAME	1975											*	*
	1976			*	*								
AKREBI	1977									*	*	*	*
	1978				*	*							
KETESSO	1979												*
	1980	*	*	*	*	*							
	1981												
	1982												*
	1983	*	*	*	*							*	*
	1984	*	*	*	*								

3. THE RESULTS

a. Numerical simulation

Achy and Rosset (1980) have calibrated a one-dimensional cumulus cloud model for tropical conditions. Their model gives good results at Abidjan for the amount of rainfall during the period of transition between the dry and rainy seasons. It may also be used in the Ayame region, 140 km from Abidjan in the ENE direction where the sounding results from Abidjan have been found valid on several occasions thanks to a supplementary sounding. The results of the model for seeded days are given in Table 2.

Table 2 : *Comparison of the rain forecasted by a numerical model with the rain observed after seeding.*

Day	Cloud top height, in km	Predicted rain, in mm	Observed rain, in mm
19 Feb 1983	2.0	0.0	7.0
24 Mar 1983	7.6	5.0	7.0
29 Mar 1983	13.0	17.0	20.0
31 Mar 1983	1.6	0.03	35.0
24 Apr 1983	12.6	7.5	35.0
10 Nov 1983	2.8	2.8	18.5
19 Dec 1983	13.8	17.4	2.0
17 Jan 1984	7.0	8.6	32.5

It is interesting to observe that in all the cases but one the rainfall after seeding is above the forecasted rain. However, in some cases AgI may not have a role in the difference between predicted and observed rain. The only case where rainfall is below the model prediction concerns a well-developed cloud, with a cumulonimbus top height of 13.8 km. Some persons believe it is possible that seeeding might reduce rain in the case of such a cloud (Todd, 1985).

The use of a numerical model in this region of Africa may be an efficient method of control of the seeding effects because the weather is often very similar from one day to the next. This allows a more exact calibration of the model.

b. Silver content of the rain

The spatial and temporal variations of the silver content of precipitation have been investigated in a number of earlier studies and interpreted as a proof of the interaction of the AgI particles with the cloud droplets. Measurements of the silver content of the precipitation falling at Ayame have been conducted since 1979 with the automatic precipitation collector (Lacaux et al, 1985). The collected samples are immediately frozen. The technique used for the subsequent silver analysis is the flameless atomic absorption.

The average background silver concentration for 32 samples of rain falling at Ayame from non-seeded clouds is $(0.7 \pm 0.7)\ 10^{-8}$ g.l^{-1}. During the seeded periods, the silver concentration at a distance of 45 km to the south of the generator has been found on several occasions one order larger than the background, mainly when the monsoon lower layer is thin, and when the winds in the Harmattan upper layer are low.

Two examples of sample analysis are given in Table 3. The fact that silver is found in several successive samples, each of them corresponding to 1 to 4 mm of rain, means that silver iodide has scattered in the cloud for a long time, and then may have nucleated ice crystals and increased rain on an area of several km^2.

Table 3 : *Silver concentration, in g.l x 10^{-8}, in two sequences of rainfall.*

Sample n°	1	2	3	4	5	6	7	8	9	10
19 Dec 1983	b*	b	5.0	8.7	7.3	6.4	b	b	b	b
16 Feb 1984	9.0	7.3	4.3	b	b	b	b	b	b	b

*b = background, ~ 10^{-8}

c. Precipitation amounts

The mean annual precipitation amounts in the Ivory Coast are given on Fig. 3a. In the region of Ayame, the isohyets are nearly parallel to the coast and some interesting observations have been made as the seeding was operated at Ayame.

1. During the years without seeding (1981, 1982), the isohyets had a shape which was very similar to that of the map of Fig. 3a. During the seeded years (1980, 1983 and 1984), the isohyets near Ayame are more or less perpendicular to the coast. This is particularly visible on the map for the year 1984 (Fig. 3b) the isohyet 1600 mm has moved 40 km toward the north.

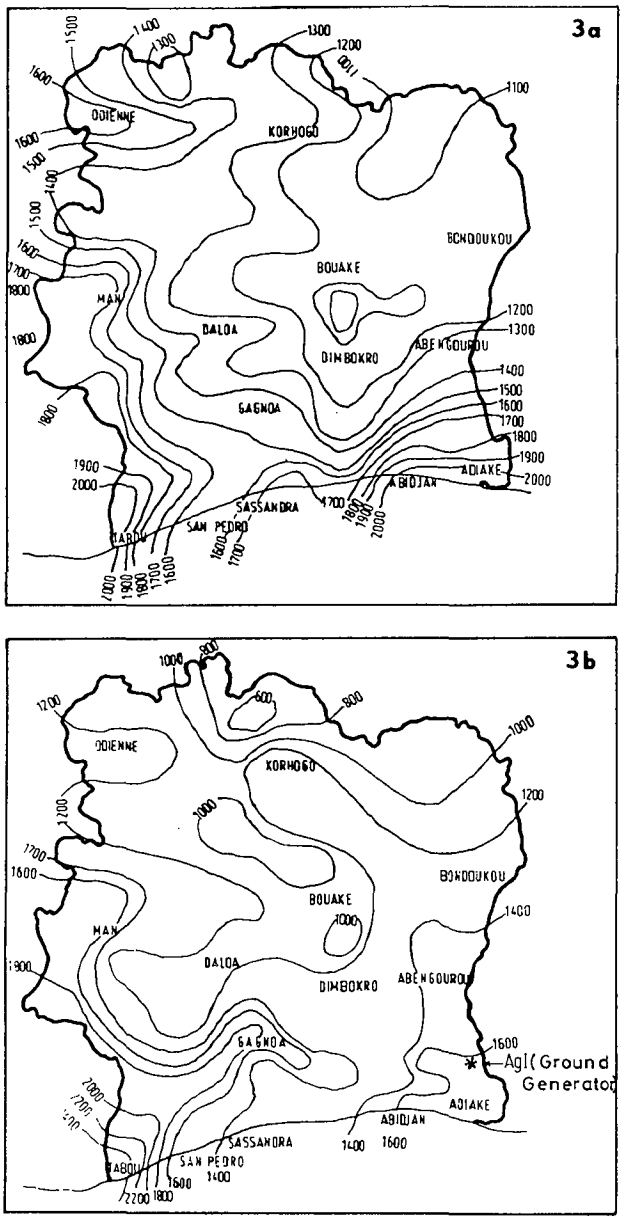

Fig. 3: Map of Ivory Coast with the isohyets drawn with the mean annual amounts of precipitation for the period 1952-1982 (upper part, no seeding) and for the year 1984 (lower part, seeding).

2. The precipitation amounts are monthly available since 1975 at Adiake, Aboisso, Ayame and Alepe and since 1977 at Bianouan. During the 17 months of the third period (AgI released from Ketesso), the amount of precipitation at Bianouan (1362 mm) has been higher than the amount at Aboisso (1329 mm), Ayame (1316 mm) and Alepe (1105 mm).

Due to the short time of observation, these results are not statistically significant.

4. CONCLUSION

The Ayame seeding project, based on a preliminary experiment by H. Dessens (1958), is the equatorial repetition of a project in a marine climate which was conducted at Mimizan, France, by H. Dessens (1968). The result of the Mimizan experiment was an increase of the rain up to 15% in an area of about 800 km centered at 40 km downwind from the generator (Lacaux and Dessens, 1973). Three physical types of control (numerical model, silver content analysis, rain amounts) have been made for the Ayame project, and their results are in agreement with the practical results of the Mimizan project. A next step in the project may be to control the effect of the seeding day-by-day, in order to confirm the hypothesis by Todd (1985) that the seeding has a positive effect only when the convective clouds are not too much developed.

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