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RESEARCH ARTICLE

AN OVERVIEW OF CHAD RAIN ENHANCEMENT. THE OPEN (CLOUD SEEDING OPERATION) PROJECT

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ABSTRACT

In this paper we try to emphasize the effect of cumulus congestus cloud seeding in sahelian zone, using hygroscopic salts. For this purpose we first studied the climatic variability and impact on agricultural sector, livestock and water. Furthermore, we made a review of cloud seeding experiences abroad, then we studied the OPEN (Cloud Seeding Operations) project, from the point of view of its management, the performed activities and the perspectives of collaboration with other universities.

INTRODUCTION

Chad is located within the inter-tropical belt of the African continent, namely between 7° and 24°N and 13° and 24°E. It is a land-locked country without any access to the sea, and covers an area of 1 284 000 km^2, covering the Lake Chad Basin. As far as topography is concerned, altitudes vary from 200m in the vicinity of the Lake to 3500 km at Emi Koussi pike, an extinct volcano located far north. On the Eastern part of the country are located the Ennedi and Ouaddaï plateau with altitudes around 900m. As far as water resources are concerned, the two main rivers are Logon and Chari originating from the Central African Republic going through the South Western plain to N'Djamena and ending in Lake Chad. Today, it is recognized that this lake has lost nearly 90% of its surface area due climate variability impacts and change occurring in the Sahel zone since the seventies of last century. During the last fifty years, the Lake gradually experienced three main states, of which the Great Lake (20 000 – 25 000 Km^2), the average Lake Chad (15, 000 – 19, 000 Km2), the small Lake Chad (2 000 –13 000 Km^2) and the small dried Lake Chad (2 000 – 6 000 Km^2). These various states directly depend on the variation of rainfall in the Chari basin. Three major factors explain the reduction of the size of the Lake: the natural variability of water intake due to the scarcity of rainfall and the recurrent droughts, the increase of water utilization from the Lake and the rivers, which provide the Lake with water and the climate change (Michael, 2009; NCULE *et al.,* 2012; ROCKSTÖM *et al.,* 2009; BARBIER *et al.,* 2009*;* LEMOALLE, 2014). Regarding climate, although Chad is located in Central Africa region, nevertheless its climate is governed by the same factors as Western Africa, namely the northward displacement of the inter-tropical convergence zone (ITCZ) controlling the summer monsoon rains production. A recent study (BEDOUM *et al.,* 2013; BEDOUM *et al.,* 2015) has shown that inter-annual rainfall variability in Chad exhibited three major periods, namely a humid period (1960-1970), a dry period (1971-1993) and a recovery period (1994-2008) for some areas of the country. Rainfall deficit over 22 years caused a significant decrease in precipitations from 2% up to 37%, which is unprecedented in the Central Africa region. One notes a severe drought over the period going from to 1980-1990 with immediate consequences on agriculture and livestock. (BARBIER, 2009; Jean, 1928; Michael, 2001). Hence today, the issue of freshwater availability is crucial for a sustainable alleviation of people's poverty whose livelihood depends directly on agro pastoral and fishery activities as well as on natural resources. Rainfall enhancement through cloud seeding looks today a promising alternative as already mentioned by the UN Convention to Combat Desertification in countries affected by drought and/or desertification.

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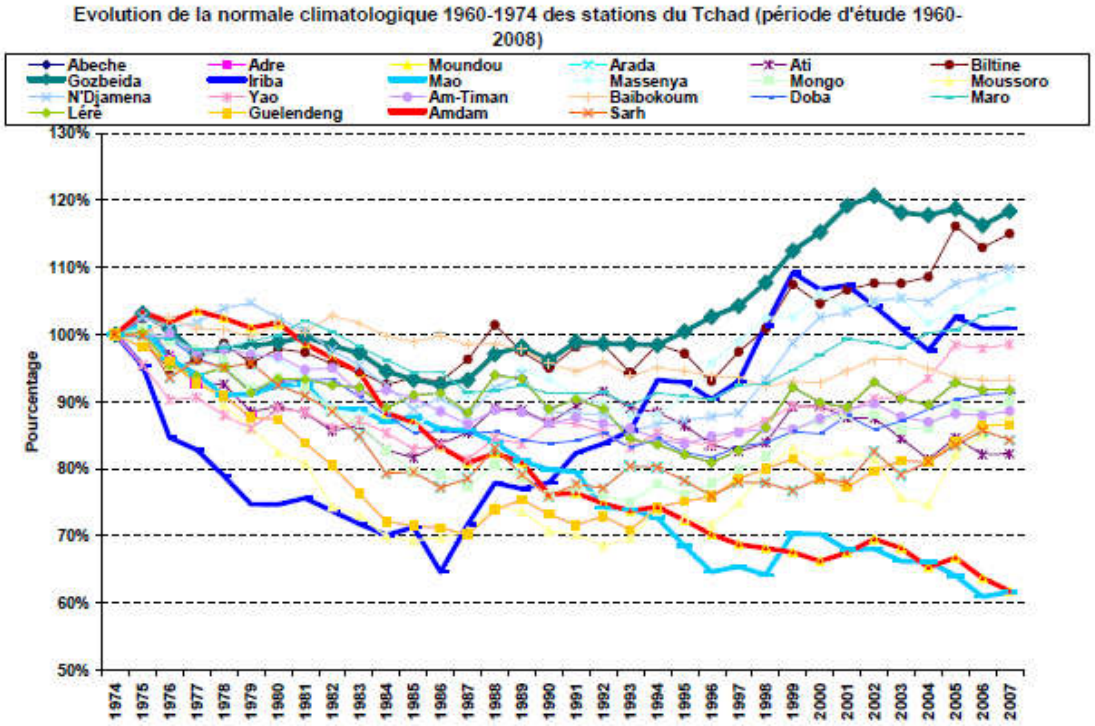

Fig. 1. Evolution of climatologic normal 1960-1974 for stations in Chad (study period 1960-2008)

Project objectives and design (*capacity building, logistics for cloud seeding operations, analytical capabilities*)

OPEN (Cloud Seeding Operation) was an initiative of Chad President, launched in 2010. It is officially created by a presidential decree in 2011. Its main objectives comprise mitigation of late start or earlier stop of monsoon rains, feeding water dams, bringing crops to maturity, enabling large scale reforestation, increasing the low levels of water tables, and combating climate change impacts. The main project design is built around utilization of hygroscopic seeding technique developed in South Africa (Mather *et al.,* 1997) using aircraft and hygroscopic flares. Chad having no previous experience in cloud seeding operations had to build capacity for pilots, meteorologists and scientists involved in operational activities. So, most of the training was done by action. The main project's logistics comprise a twin engine Beech craft 200 aircraft equipped with hygroscopic seeding equipment to burn flares at cloud base, and a data acquisition Droplet Measurement Technology (DMT) platform for aerosol, cloud condensation nuclei and cloud droplets measurements. Four Band-C weather radars manufactured by VAISALA have been acquired and are on the way to be installed. The OPEN operational team is equipped with desktop and laptop computers and utilizes a number of software both for airborne platform data processing and gridded reanalysis of climate data, radio probe data, etc. Between 2010, beginning of the project's operational activities and now, 203 flights were accomplished, 60% of which were seeding experiments, and 40% documentation of aerosols over the whole Chad territory. These data are being regularly processed.

Cloud seeding experiments (*on procedures and summary of conducted activities*)

It's worth mentioning that Chad is one of the few Sahelian countries which never attempted rainfall enhancement before. So, it was really a challenge to face this issue all of a sudden. Cloud seeding experiments were conducted during the monsoon rain season, which generally start from June and end up in October in Chad. Since its launching in 2010, OPEN project performed seeding operations discontinuously every year. The project's management elaborated a set of procedures for all its components, namely: the pilots, the meteorological team, the radar team, the science team, and the users from the agricultural, water resources and environment departments, as well as, the research community comprising the universities and the Research National Council. Between 2010 and 2014 we note a total of 203 flights all over the country, 60% of which are seeding experiments; the remaining 40% are aerosol documentation over various parts of Chad. The map below shows the areas were these flights took place, as well as the Band-C radars expected locations. Seeding experiments were conducted using hygroscopic pyrotechnic flares, below the cloud base, within the updraft region, targeting primarily *Cumulus Congestus* clouds appearing after noon time. All operations are performed with a support of cloud microphysical measurements from take off to landing, and no particular target area was set. As shown on the map, two areas located in the Center of the country concentrate the most of the operational seeding activity, while the desert fringe and the Southern Sudanian zone were less concerned. This is mainly due to the lack of additional aircraft at the moment. Data processing is done after every campaign, and a qualitative evaluation of the impact of the project is now on its way. By now, it will be hazardous to attempt any statistical evaluation due to lack of accompanying radar observations.

Project's perspective (*management, new acquisitions, linking with universities, contribution to CILSS (Intergovernmental Committee of Struggle against Drought) sub-regional rain enhancement initiative*)

The project is now on its way to be transformed into a permanent rainfall enhancement program. This will result in

strengthening of the overall capacity of the program as well technical as human. Weather modification being strongly relying in research, implication of country's universities will be a key component of success. This aspect might be the main cause why since the 1960s when a number of countries in the Sahel region tried to use this technique to mitigate drought, none of them has yet reached a breakthrough.

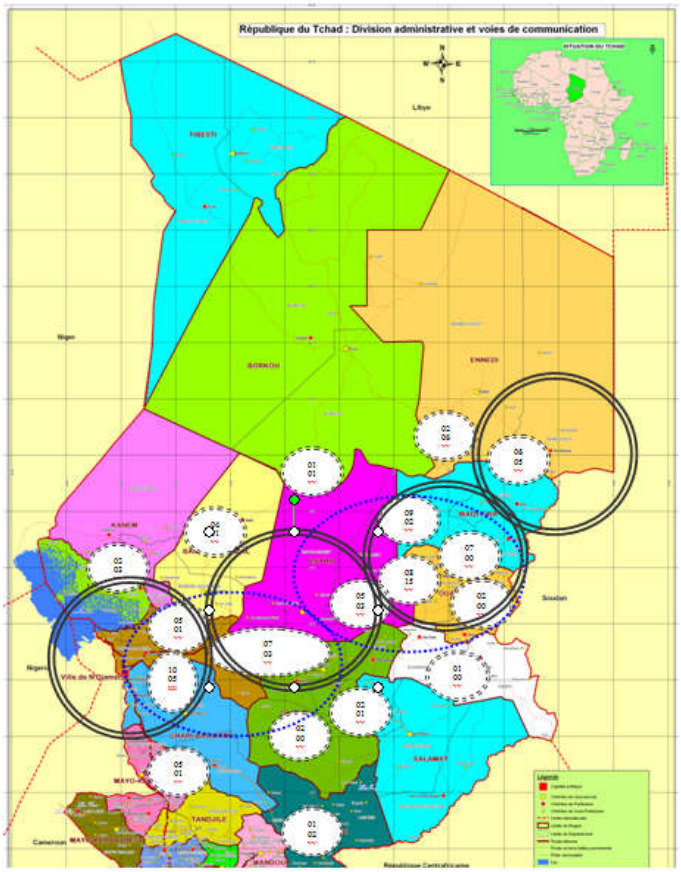

Fig. 2. Areas of flight and Band-C radars expected locations

Fig. 3. typical traces of flare plumes below cloud base from a seeding experiment

The challenge however will be to perform cloud seeding experiments in vast areas and address a number of issues at a time, common nearly to all countries of the sub-region.

So, by recommending the development and implementation of a sub-regional program on rainfall enhancement via cloud seeding, the CILSS Head of States have shown the right direction to move. There is no doubt that only by putting together both technical and human resources the countries can achieve significant results in this area.

Concluding remarks

Chad took five years ago, a courageous decision to embark on rainfall enhancement via cloud seeding and built in few years capacities to deal with both the operational aspect and the scientific aspect. The choice of one seeding method was a very clever decision. As a perspective, it would be important to treat the microphysical data of cloud obtained in order to compare them with similar results obtained previously and determine the optimal conditions for future experiences.

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