CLOUD SEEDING IN AFRICA

Gregton Consultants

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SPECIAL MISSION

PURPOSE

This document provides the South African Government and the Weather Service with a brief explanation necessary to understand the scope and importance of reintroducing the rainfall enhancement programme with an overview of future climate changes in South Africa particularly in the Eastern Cape Province, using results from the latest available climate model simulations. The document also provides descriptions of the main procedures and the techniques used to achieve weather modification processes as a way to mitigate the environmental impact of climate change.

South Africa’s Water: New ‘Call to Action’

> Unless there is significant action by 2030, there will be a projected 17% shortage in water supply.

The deficit, as stated by the Department of Water and Sanitation’s (DWS) Master Plan, may even be under-reported. “The Master Plan is a ‘call to action’, and rightly so. The report begins with a frank admission that the house is in serious trouble and it is going to take a Herculean effort to deal with multiple fires.”

Extent of the crisis

The call to action outlines the usual themes that explain the causes of the crisis. It offers a level of detail that is uncharacteristic of the DWS and breaks rank with the tradition of the former National Water Resources Strategy report (NWRS2) (2013) which was descriptive, fluffy and has contributed little to progress in water management.

The reality, as reported by the Master Plan, is caused by a lack of investment in water infrastructure and maintenance, resulting in an alarming 56% of all wastewater treatment works and 44% of water treatment works being categorised as in a poor or critical condition, while 11% are described as dysfunctional.

The lack of investment is partly explained by the fact that 41% of municipal water does not generate any revenue, while a further 35% is lost through leakage. DWS estimates that it will take R33 billion each year for the next 10 years to achieve water security and avoid a 17% deficit.

The current budget for DWS is R15.5 billion - a significant financial shortfall. The National Treasury has no plans to increase this amount over and above inflation for the foreseeable future.

The gap in access to water and sanitation is also unacceptable, with over 3 million people unable access a clean water supply and 14.1 million without safe sanitation. Only 64% of South African households have access to a reliable water supply service. The link between access to safe and clean water and sanitation and the cost of medical services to support people who live in unhealthy conditions is unknown.

Counting the costs

Similarly, the overall cost of deteriorating water quality and resultant loss of environmental and ecological resources is unknown. The DWS Master Plan reports that between 1999 and 2011 there was a 500% increase in the deterioration of the ecological condition in South Africa’s main rivers, pushing them beyond the point of recovery.

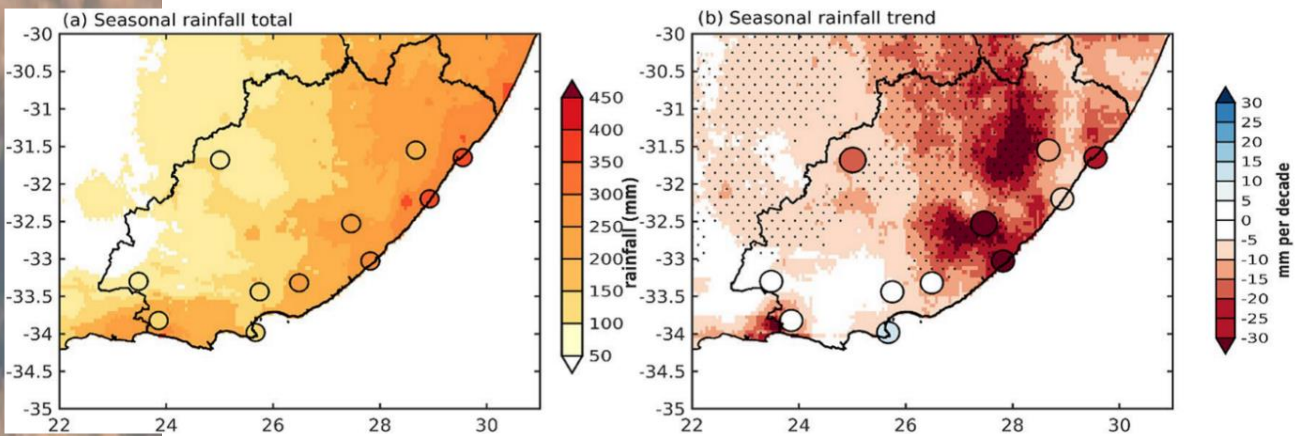
Eastern Cape Climate

South Africa is facing severe pressure with respect to water security due to an increased water demand with increasing population, poor planning and management of water resources, limited investment into water reservoir infrastructure, and recurring droughts over the past decade. Although droughts often happen in South Africa, in recent decades the tendency towards multi-year droughts has increased. For example, summer rainfall time series for various parts of South Africa, including the Eastern Cape and adjoining KwaZulu Natal Province show more multi-year droughts during late 1970s to 2017, than during 1950-late 1970s.

Figure 1:

(a) The mean *SON rainfall in **CHIRPS (shaded; mm) and ***SAWS stations (circles; mm) and (**b**) the corresponding trend in SON rainfall over the period 1981–2018. Stippling or larger circles denotes values significant at a 95% level using a two-tailed Mann–Kendall test

*(Sep,Oct,Nov) **The Climate Hazards Group InfraRed Precipitation ***SA Weather Service



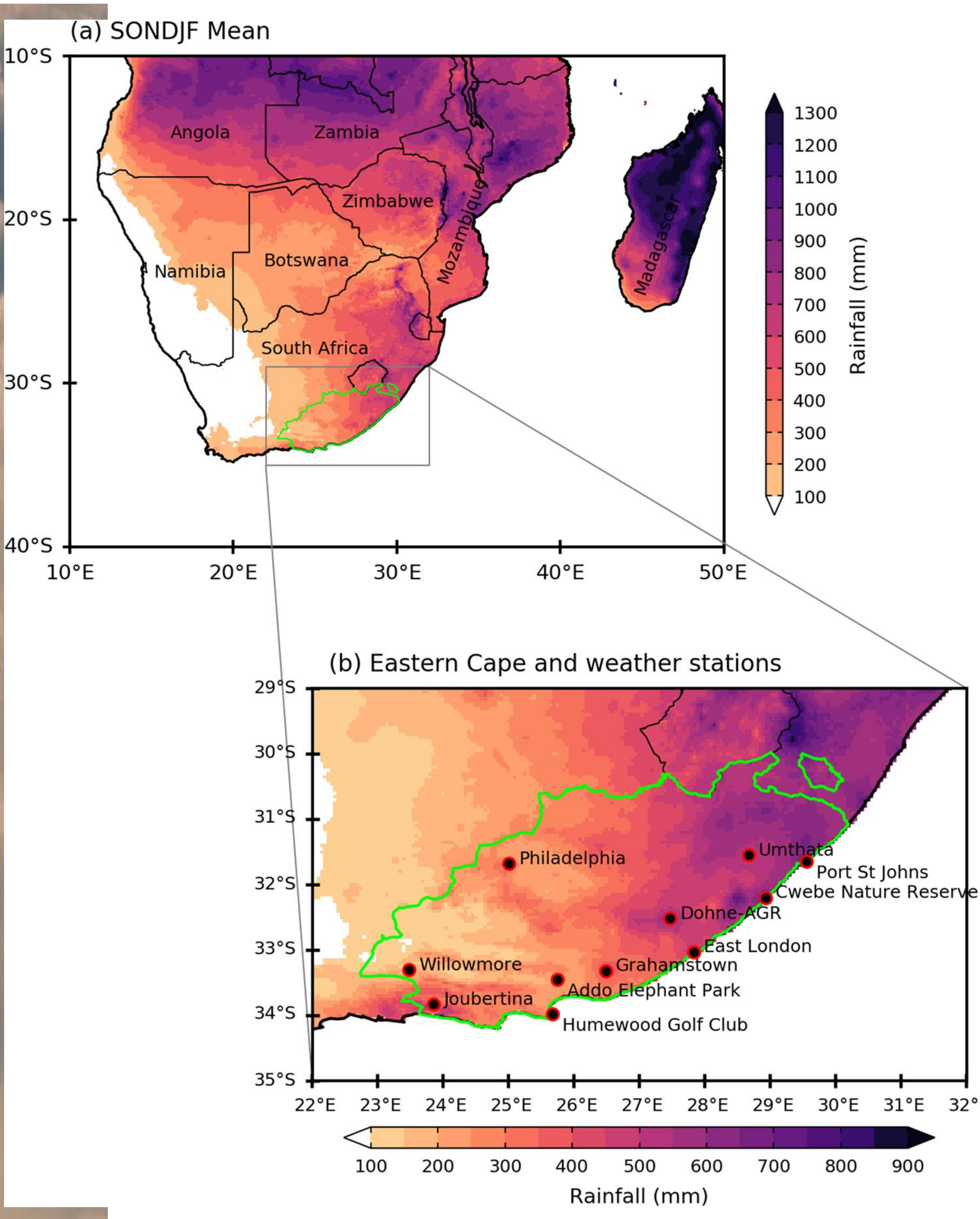
Much of the Eastern Cape Province in South Africa has been experiencing a severe drought since 2015. This drought has had major socio-economic effects particularly on the large impoverished rural population as well as on some urban areas where supplied water services have broken down in several cases. The region is influenced by both midlatitude and tropical systems leading to a complex regional meteorology that hitherto has not been much studied compared to other parts of South Africa.

Here, the ongoing drought is examined in the context of long-term trends and the interannual rainfall variability of the region. Although the region has experienced drought in all seasons since 2015, focus here is placed on the spring (September–November) which shows the most consistent and robust signal. On average, this season contributes between about 25–35% of the annual rainfall total. Based on CHIRPS data, it is found that this season shows a significant decreasing trend in both rainfall totals as well as the number of rainfall days (but not heavy rainfall days) for spring over most of the province since 1981. On interannual time scales, the results indicate that dry (wet) springs over the Eastern Cape are associated with a cyclonic (anticyclonic) anomaly southeast of South Africa as part of a shift in the zonal wavenumber 3 pattern in the midlatitudes.

Eastern Cape Climate

In October 2019, the Eastern Cape Province (see Fig. 2 for its location in South Africa) was declared a drought disaster region following pronounced water shortages in many urban and rural areas. The Eastern Cape is of interest not just because of the severe drought that it is currently experiencing but also because its western parts lie near the transition zone between the summer (most of southern Africa) and winter rainfall regions (southwestern South Africa) and because it is a region of sharp vegetation, soil moisture and topographic gradients (Fig. 3a). As a result, the meteorology here is complex and often involves interactions with the regional topography or the neighbouring warm Agulhas Current.

Fig. 2 **a** The mean austral spring and summer (September–February) rainfall (shaded; mm) across southern Africa based on CHIRPS data from 1981 to 2018. **b** A zoomed in version of the mean spring and summer rainfall for the southeast region of the domain. The green polygon in both panels illustrates the location of the Eastern Cape Province in South Africa. Also shown in panel **b** are the locations of the South African Weather Service rain-gauges used in the study



Eastern Cape Climate

Precipitation over the Eastern Cape region is influenced by weather systems from both the tropics and mid-latitudes, ranging from small-scale convective storms to synoptic-scale tropical-extratropical cloud bands (known locally as tropical-temperate troughs—TTTs). These cloud bands are the major synoptic rainfall producing system over subtropical southern Africa during the early to mid-summer.

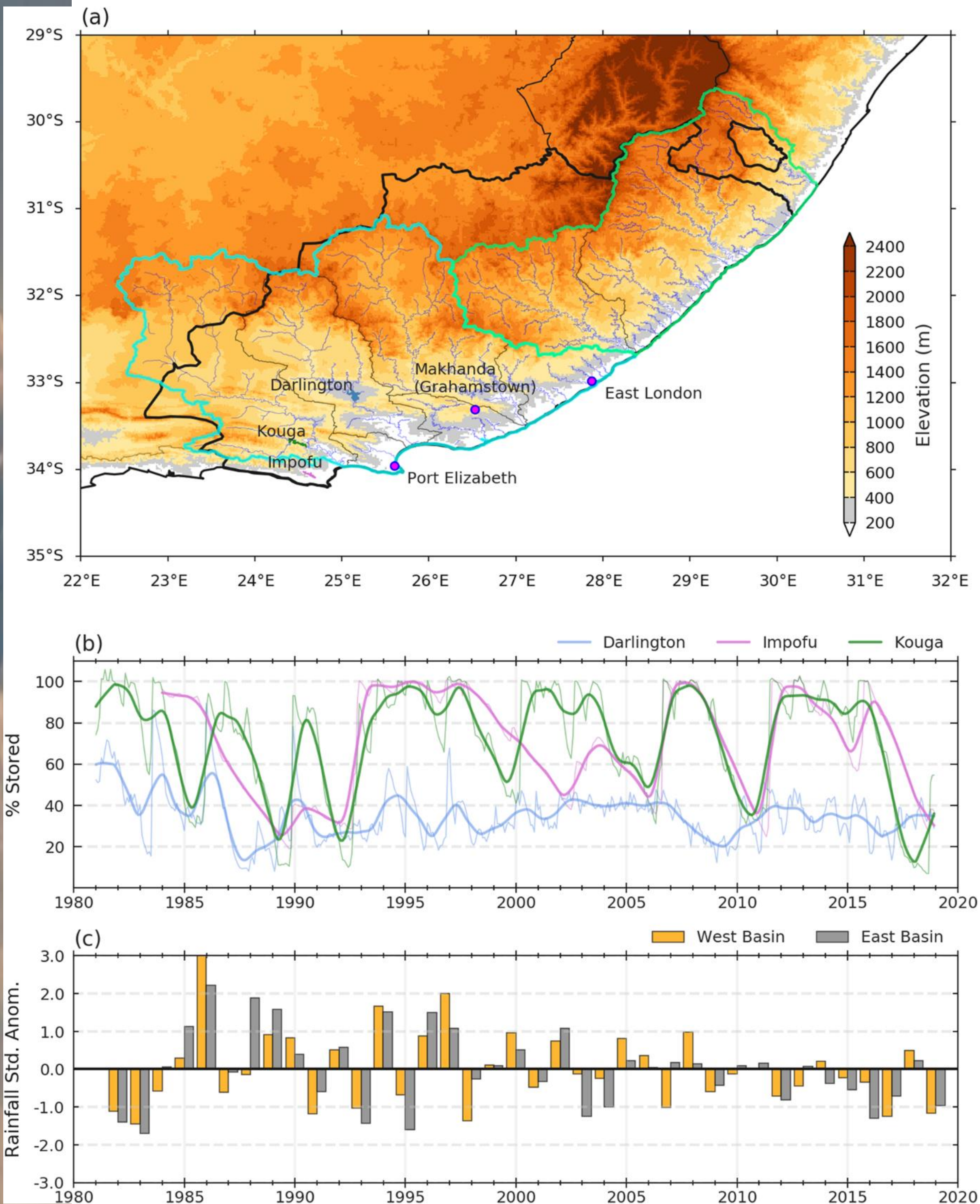


Fig. 3 Panel **a** illustrates the topography (shaded; m) of the domain along with the various rivers and river basins. The river basins have been merged into a “west” and “east” basin to highlight some of the regional rainfall differences. Also shown are the locations of the main dams of the region that have seen large water level drops as well as locations of the main towns/cities. Panel **b** shows the smoothed monthly dam levels (given in % stored) from around 1981 until 2018, while panel **c** shows the austral summer rainfall standardized anomalies, based on CHIRPS, for the regions defined as west and east basin in panel **a**

Also shown in Fig. 3a are the catchment areas of the main dams supplying the province’s largest municipality (Nelson Mandela Bay) which contains the major coastal city of Port Elizabeth (located near 34° S) (termed the “west” basin) as well as those for rivers draining the wetter north-eastern part of the province (termed the “east” basin). The impact of the current drought can be seen in the levels (Fig. 2b) of two of the larger supply dams (Impofu and Kouga). After being close to full in 2015, both dams have fallen to their lowest levels since 1985 with the decline during 2017–2019 being especially sharp. As of June 2020, the Kouga dam sits at 7% with the combined supply dam capacity for the Nelson Mandela

Bay metro having fallen below 20%. Several other major towns in the province (Grahamstown, Graaff-Reinet, Bedford and Queenstown) have also been experiencing very severe water shortages. The ongoing drought has already cost the province over R120 million for drought relief measures. Due to the increased threat to water security in the Eastern Cape and more broadly, South Africa as whole, understanding the variability and trends in rainfall features that influence water availability over this region is of crucial importance for effective management and planning. Furthermore, relatively little work has been done on the climate of the Eastern Cape region compared to other parts of South Africa despite it being an important agricultural part of the country with a sizeable rural population. The region is also one of the least developed of South Africa’s nine provinces with many impoverished rural settlements which are particularly vulnerable to drought and severe weather events. It has also been impacted severely by the COVID-19 crisis with almost 20% of South Africa’s total of ~ 400,000 cases by late July 2020 as compared to having less than 12% of the national population.

Here, focus is placed on the spring season (September– November SON) which seems to show the strongest and most consistent drought signal since 2015. As discussed below, SON contributes between 25 and 35% of the annual rainfall over the Eastern Cape on average. Furthermore, given its importance for agriculture (fruit, dairy and angora goats are the main exports), severe drought is highly problematic at this time of year when solar insolation, ground temperatures and potential evapotranspiration are also increasing. Thus, the aims of the study are to investigate the post-2015 drought within the context of previous large anomalies in spring rainfall over the last forty years and any long-term rainfall change and to examine the potential mechanisms associated with spring drought in the region.

Rainfall Means and Trends

Figure 4 plots standardized anomalies of SON rainfall for the period 1981–2018 for the 11 available SAWS stations together with CHIRPS data averaged from the 4 grid points surrounding each station (small red boxes in Fig. 1b). Note that the annual cycle from the two datasets is the same for each case (not shown). The time series are correlated at 95% significance at each station with r values ranging from 0.61to 0.90. Note that it is possible that topographic effects or other local forcing may lead to the differences between the time series. Although the sign of the anomalies is almost always the same for each station, there are some springs when there are sizeable differences in magnitude at some stations. However, the correspondence between the two time series during the almost 40 year period at both coastal and inland stations provides sufficient confidence in the ability of the CHIRPS data to adequately represent rainfall variability and change across the province. All of the stations except the two western near-coastal locations (Joubertina and Humewood) show a decreasing tendency in spring rainfall but only the negative trends at Dohne and Philadelphia are statistically significant.

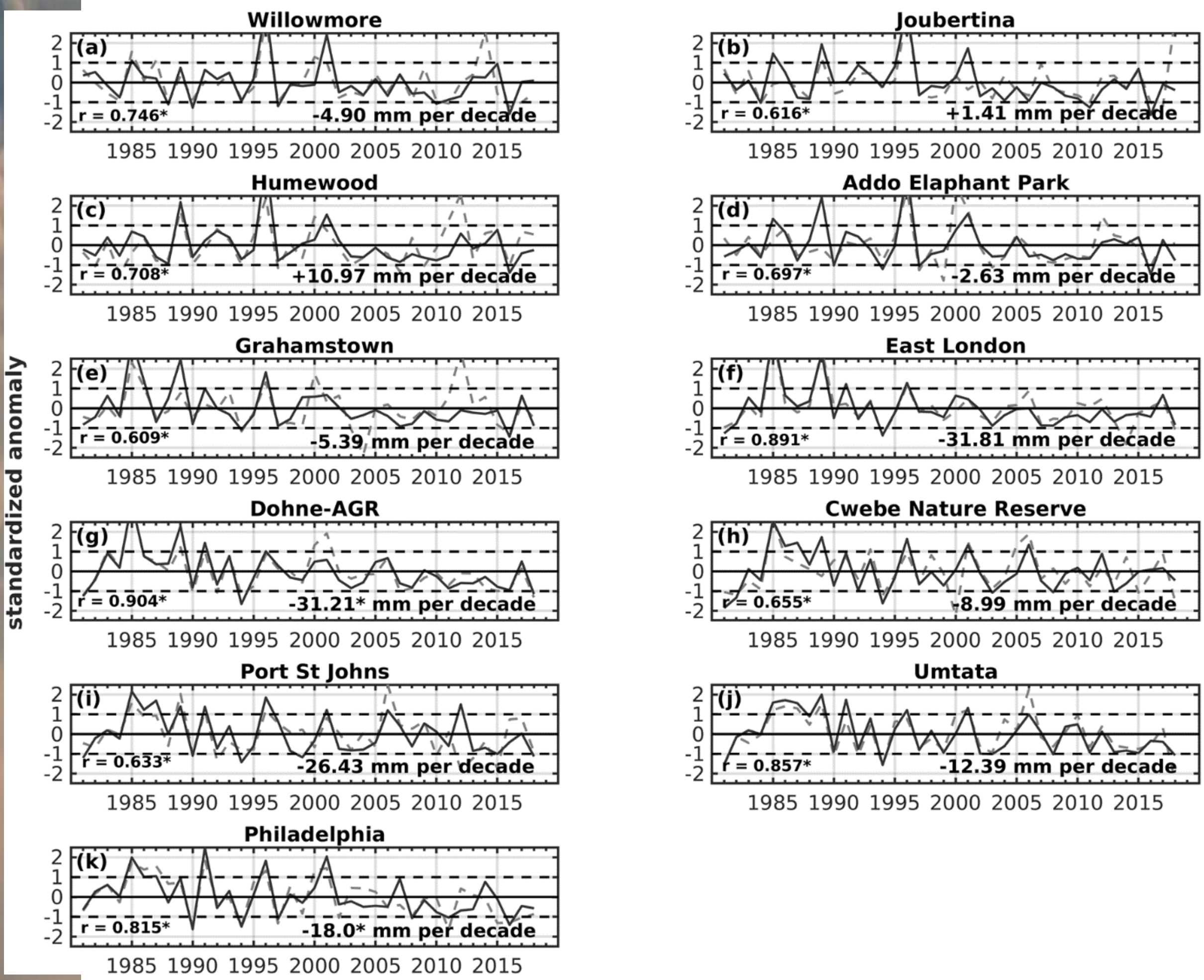


Fig. 4 Spring (SON) standardised anomalies for the eleven stations (grey-dashed line) across Eastern Cape (see Fig. 2b) and the corresponding CHIRPS (black-solid line) anomalies. The station names are indicated at the top of each panel. The correlation between the two datasets is given at the bottom left of each panel.

The trend in SON rainfall for each station is given the bottom right hand corner of the panel (in mm per decade). For both the correlation and the trend analyses, the asterisk denotes significance at the 95% level using a Student t-test

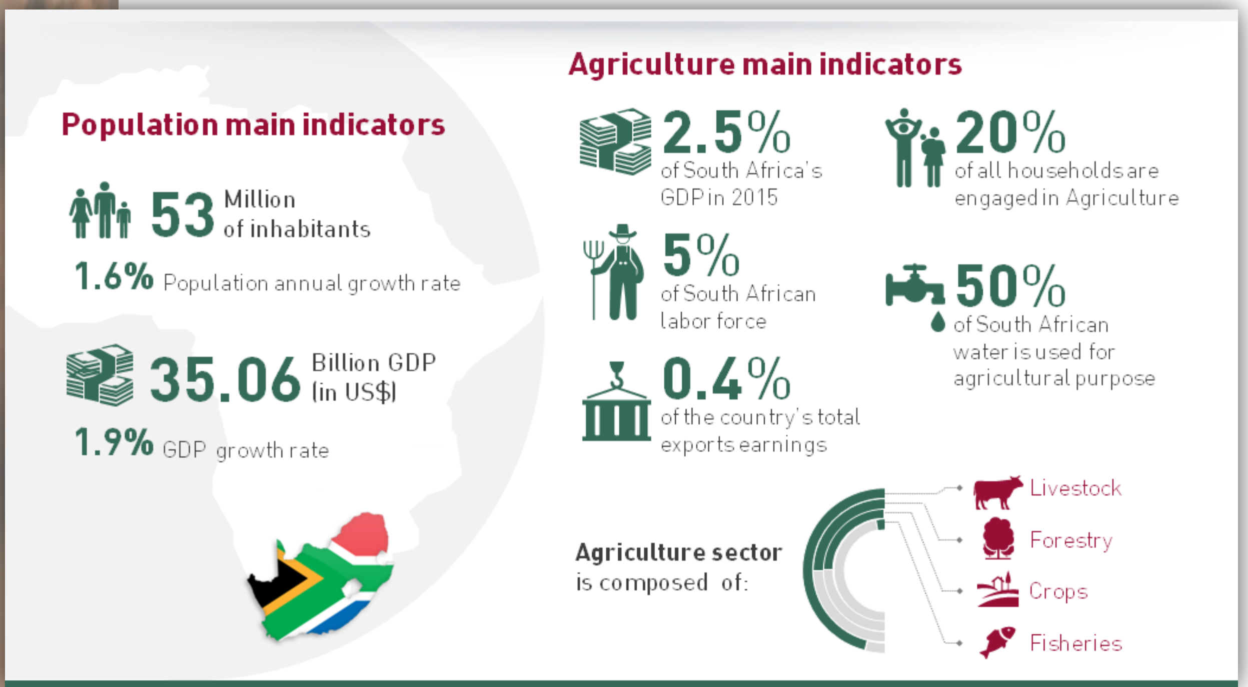
Role Agriculture in South African Economy

South African population annual growth currently stands at 1.6%. Meaning, the country will be home to over 80 million people by 2035. Therefore, food production must more than double—against fewer natural resources—if the country is to feed her rising population. Agriculture's contribution to total Gross Domestic Product (GDP) has been declining since 1960 when the sector contributed 10% to 2.5% in 2015. The trend is a global phenomenon, as countries develop from primary industries based economy to the secondary or tertiary sector based.

However, despite its declining contribution to the GDP, agriculture remains a significant provider of employment in South Africa, especially in the rural areas. The sector is a major foreign exchange earner. Commercial agriculture is estimated to contribute more than 5% of the country's labour force. In 2013, it generated about R147.4 billion in income and R116.9 billion in expenditure. The sector still remains one of the primary creators of jobs in the country with nearly 20% of all households engaged in agriculture.

Agriculture sector

South Africa classifies 79.4% of its land as agricultural, with the permanent pasture accounting for 69.2%— suitable for grazing and livestock farming. Animal husbandry is by far the largest agricultural sector in the country. In 2011, arable land was 9.9%, forest 7.6%, permanent crops 0.3% and the rest of agricultural activities accounted for 13%. The country's rainfall is not evenly distributed across the country, with water availability being one of the limiting factors of production in South Africa. Currently, up to 1.3 million hectares of land are irrigated, producing 30% of the country's crops. Up to 50% of the country's water is used for agricultural purposes.



What Climate Change Means For the SADC Region

The SADC region is vulnerable to climate variability and climate change. SADC's vulnerability to climate change is not only caused by climate change but is a combination of social, economic and other environmental factors that interact with climate change. Furthermore, within the southern Africa region, the adaptive capacities are not uniform and therefore it is difficult to have a uniform assessment of the impacts of climate on the sub-continent.

The region's adaptive capacity is influenced by a range of factors such as the level of economic development, education, access to credit and adoption of technology.

1. Climate change impacts on Society: impacts on health and human security.

Global warming and climate change will have impacts on several sectors including health and human security. The SADC region is perceived to be overly vulnerable to climate change impacts mainly in the agricultural and water sectors that directly or and indirectly impact on health. As a result of crop and pasture failure, many people in countries such as Botswana are abandoning crop production and moving either to cities or bigger settlements in search of economic opportunities.

2. Climate change challenges to human security:

SADC's growing populations, urbanization, land degradation, drought and desertification, unsustainable consumption and waste and the threat by climate change will contribute to human stress on the region's ability to meet food security, energy security, economic security and other forms of human security.

3. Climate change and health:

The SADC region has a heavy disease burden largely caused by vector-borne diseases that are influenced by climatic elements (see Figure 5). Though there are few studies on climate change and health specific to the SADC region4.

While more emphasis is on malaria and HIV/AIDS, there is a growing interest by various research groups on the links between climate change and direct impacts between climate change and socioeconomic disruptions and their impact on the health sector.

4. Conflict over resources:

The impacts of global warming and climate change on rainfall patterns are already visible: a number of countries in the SADC region are observing changes in the length of growing season. This has led to a drop in agricultural productivity. The number of countries in the SADC region reporting depressed crop yield is increasing and persistent. This has led to, or worsens, food-insecurity and an unsustainable increase in food prices across the board. Reduction of arable land, widespread shortage of water, diminishing food and fish stocks, increased flooding and prolonged droughts are already happening.

The impact is already culminating in conflict over resources such as the conflict over the fishing in the Zambezi, water along the main river basins and land within some SADC countries.

5. Environmentally-induced migration

The impact of global warming and climate change on the SADC region already contributes to inside country migration. With more crop failure associated with recurrence of droughts, more and more people, especially the subsistence farmers abandon their land and migrate into towns and cities to seek alternative income generating opportunities.

Climate change is expected to exacerbate the environmentally induced migration patterns.

The challenge for the SADC Member States is to identify the appropriate policy options to address the phenomenon. SADC may consider developing policy responses to assist those Member States most vulnerable and also taking into account the most pressing needs of the island Member States.

6. Economy (agriculture, trade, tourism)

In the SADC region, agriculture, trade in agricultural commodities and tourism play a critical role in the formal and informal economy, in sustaining rural livelihoods and in food security. The region is highly vulnerable to climate change because of the heavy reliance on rain-fed agriculture. As global warming and climate change alter the natural environment and quality of rangeland deteriorates, this then leads to a negative impact on wildlife as the basic resource for tourism in SADC.

The total international tourist arrivals into the SADC region are 21 million in 2008 and 19 million in 2009. The tourism brought in receipts of 13billion in each of the two years.

The SADC region is embarking on several sectoral policies and some of these policies have been concluded and are being implemented, for example the water sector which is founded on the principles of Integrated Water Resources Management (IWRM).

It is an important consideration that while SADC places priority on climate change adaptation, it is important to recall that adaptation is required because climate change is already underway and further warming from existing emissions is inevitable. Mitigation of greenhouse gases does present opportunities for economic development through and by allowing, through careful planning, technology transfer, foreign direct investments and improved conservation of forests. SADC must also identify opportunities where climate change adaptation will also be coupled with greenhouse gas (GHG) mitigation.

The Mission

The search for rainfall augmentation opportunities must begin with a comprehensive study of the natural rainfall processes. This has been accomplished in the study areas using sophisticated meteorological radars and instrumented aircraft.

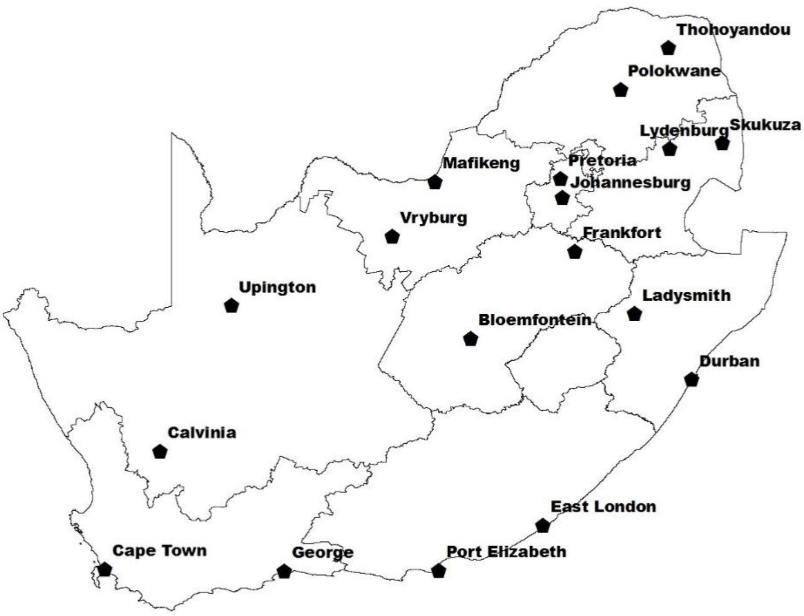
These studies have recognized that many of the region's convective storms are inefficient in terms of rainfall production, i.e. only about 30 percent of the atmospheric water vapour entering the storms reaches the ground as precipitation. Thus, the search for augmentation opportunities has centred on a means of increasing rainfall production efficiency. The research has also recognized the efficiency of rainfall formation via a collision-coalescence process which has been shown to occur in certain storms in both the Carolina and Bethlehem study areas.

Due to the unreliable rainfall pattern in Eastern Cape, it is of paramount importance mitigation measures are employed, such as implementing a Rainfall Enhancement Programme through the South African Weather Service.

The MISSION would involve specially modified aircraft being stationed at main climate stations located in the Eastern Cape preferably Port Elizabeth and East London where they would conduct cloud seeding and reconnaissance flights to cover the dry regions of the Province.

We have been modifying and operating aircraft for cloud seeding and atmospheric research operations in Africa for a number of years. Our aircraft are capable of seeding at cloud base and at cloud tops with various configurations. As such we have successfully met the needs of our clients, most significantly and recently being the Zimbabwean government.

Zimbabwe has been involved in cloud seeding ever since the 1970s and the advantages of cloud seeding were apparent and the agriculture industry of that time gained enormously resulting in the country being dubbed "The Bread Basket of Africa".



Duration of Contract

While actual cloud seeding missions are grouped together as seasonal initiatives, evaluating the effect of seeding in an operational program is essential if the effort is to have long-term credibility. Comprehensive data collection and establishment of the results, for the purposes of quality assurance and program monitoring, can require periods of up to three to six years of continuous rain augmentation.

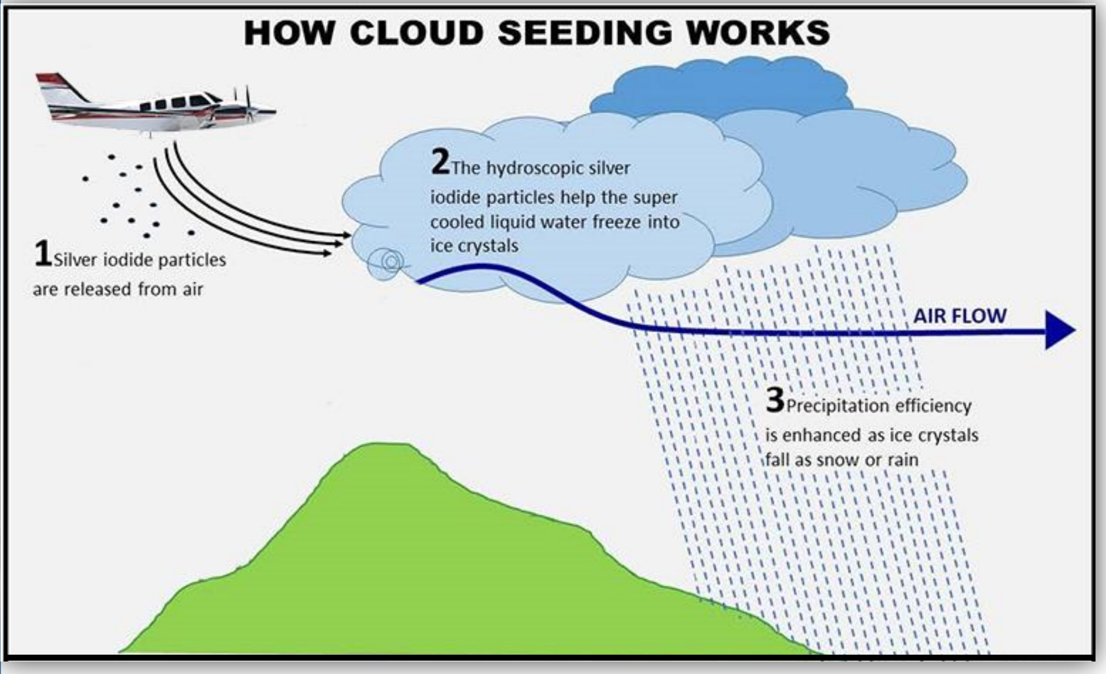
Contract duration should ideally therefore be structured with service related terms as the mitigating factor, over an extended period.

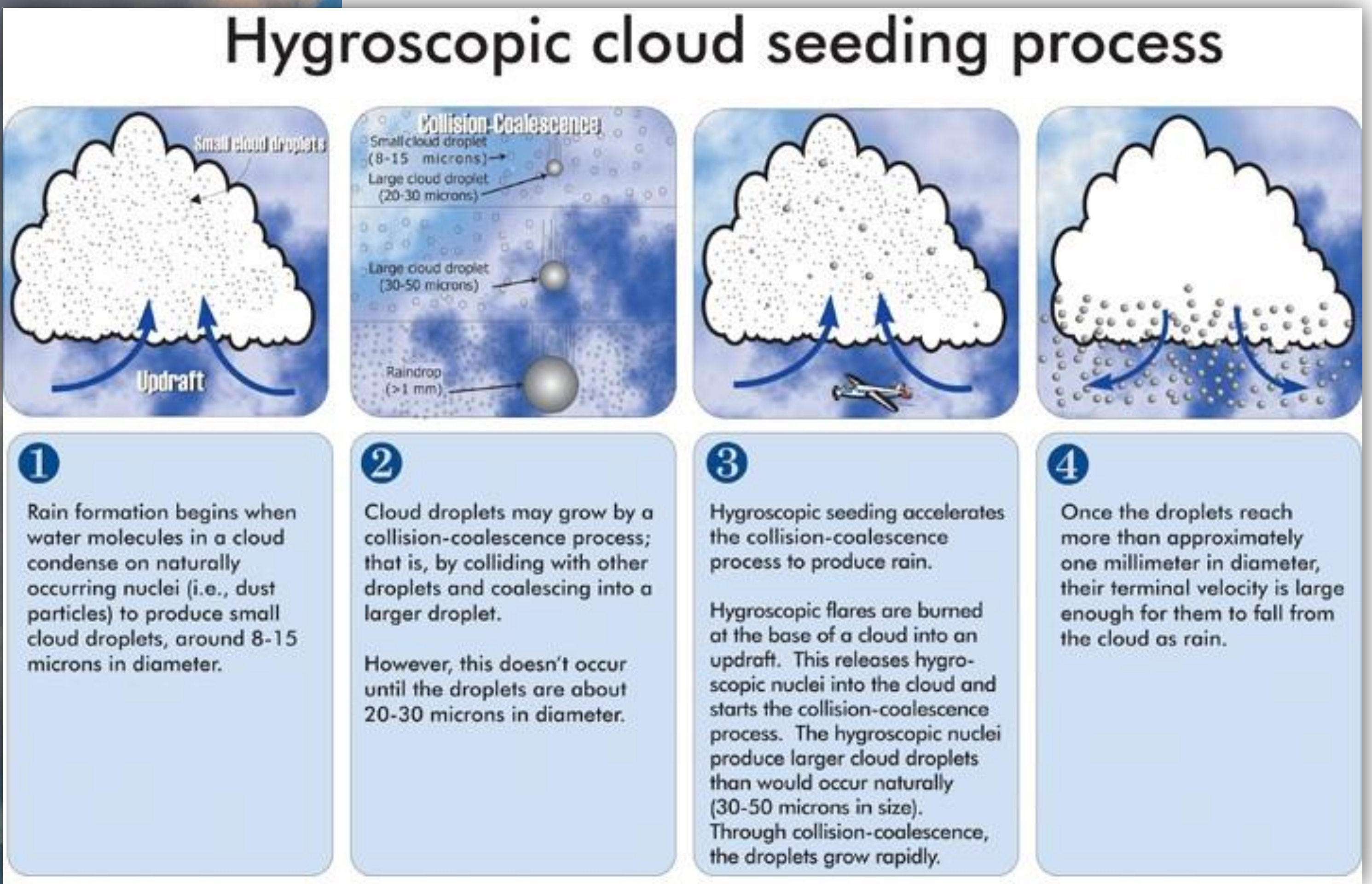
Equipment

Aircraft instrumentation

In addition to cloud seeding modifications, airborne platforms for atmospheric research are also essential. These consist of instrumentation that have the capability of measuring in situ microphysical properties of clouds and their thermodynamic environment, documenting the composition of clouds and diagnosing the physical processes within them.

Cloud Seeding Process





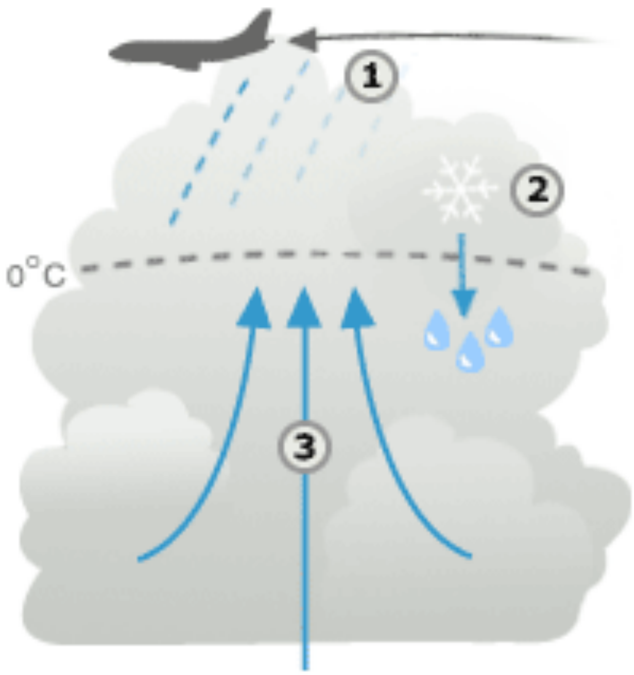
Hygroscopic cloud seeding disperses salts through flares containing silver iodide crystals in the lower portions of clouds.

Hygroscopic & Dynamic cloud seeding

The objective is to enhance rainfall by promoting the coalescence process using hygroscopic salt nuclei generated by pyrotechnic flares or a fine spray of a highly concentrated salt solution. These crystals apparently induce the super-cooled water droplets in a cloud to freeze, thus acting as nuclei for what eventually reaches the ground as raindrops.

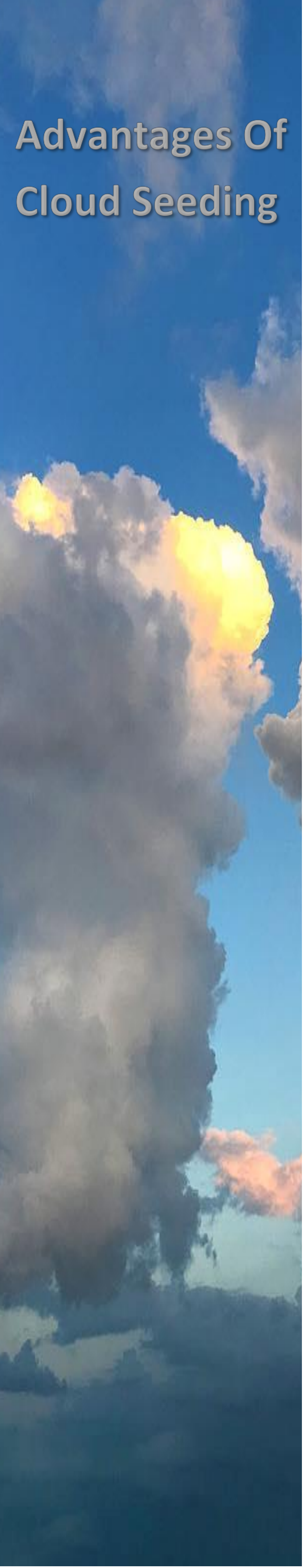
Silver iodide is the primary component of silver iodide-based ice-nucleating complexes used in cloud seeding. The published scientific literature clearly shows no environmentally harmful effects arising from cloud seeding.

The Dynamic seeding concept is to seed super cooled clouds with large enough quantities of ice nuclei to cause glaciation of the cloud. Due to seeding, super cooled liquid water is converted into ice particles, releasing latent heat, increasing buoyancy, and thereby invigorating cloud updrafts. In favourable conditions, this will cause the cloud to grow larger, process more water vapour, and yield more precipitation.



In a cloud top seeding mission, an aircraft releases Silver Iodide flares (1), super cooled liquid water is converted into ice particles (2), releasing latent heat, increasing buoyancy, and invigorating cloud updrafts (3).

Advantages Of Cloud Seeding



A break through study of cloud seeding by aircraft involving University of Colorado and University of Wyoming researchers took place in 2017 in the mountains of southwest Idaho. It captured attention after its results were published this year in the Proceedings of the National Academy of Sciences. For the first time, researchers — in a second aircraft flying near the cloud-seeding plane — could see silver iodide enter the clouds and form snow crystals.

1. Cloud seeding provides necessary environment for the rainfall to occur. It releases such substances like silver iodide, potassium iodide and dry ice etc. that facilitates and stimulates the cloud formation process. It makes the precipitation system more fast and efficient.

2. People all over the world especially farmers see rain as a major source of water. Without rain it would be very difficult or almost impossible to meet the world’s water demand. Cloud seeding is the revolutionary technology that would help to cope up with such drought conditions. Its major advantage or function is that it can cause rainfall by its mechanism.

3. There are many areas of the world which are experiencing water shortage and drought. As a result of such conditions such areas are not suitable for living and crops are also dying due to water shortage. Cloud seeding would help to regulate the water and precipitation process in such areas to make them hospitable and to promote living there. This would help to utilize the land by providing the major need of life.

4. Many areas of the world are experiencing the severe weather conditions that would create unsuitable conditions for the crops. Cloud seeding would help to regulate water vapours in the atmosphere that helps to avoid creating such damaging weather conditions such as hail or storms.

5. Water is the basic necessity for the growth of corps. Cloud seeding helps to provide this basic necessity by its mechanism. This would increase the agricultural products thus increasing the economy especially of the developing countries and the drought regions. For human living, water is basic need of life thus providing the basic component of life, it makes the inhospitable regions hospitable and increases the tourism and living in such areas. This also regulates the economy.

6. As a direct advantage, water levels in major water reservoirs are maintained.

ENDNOTES

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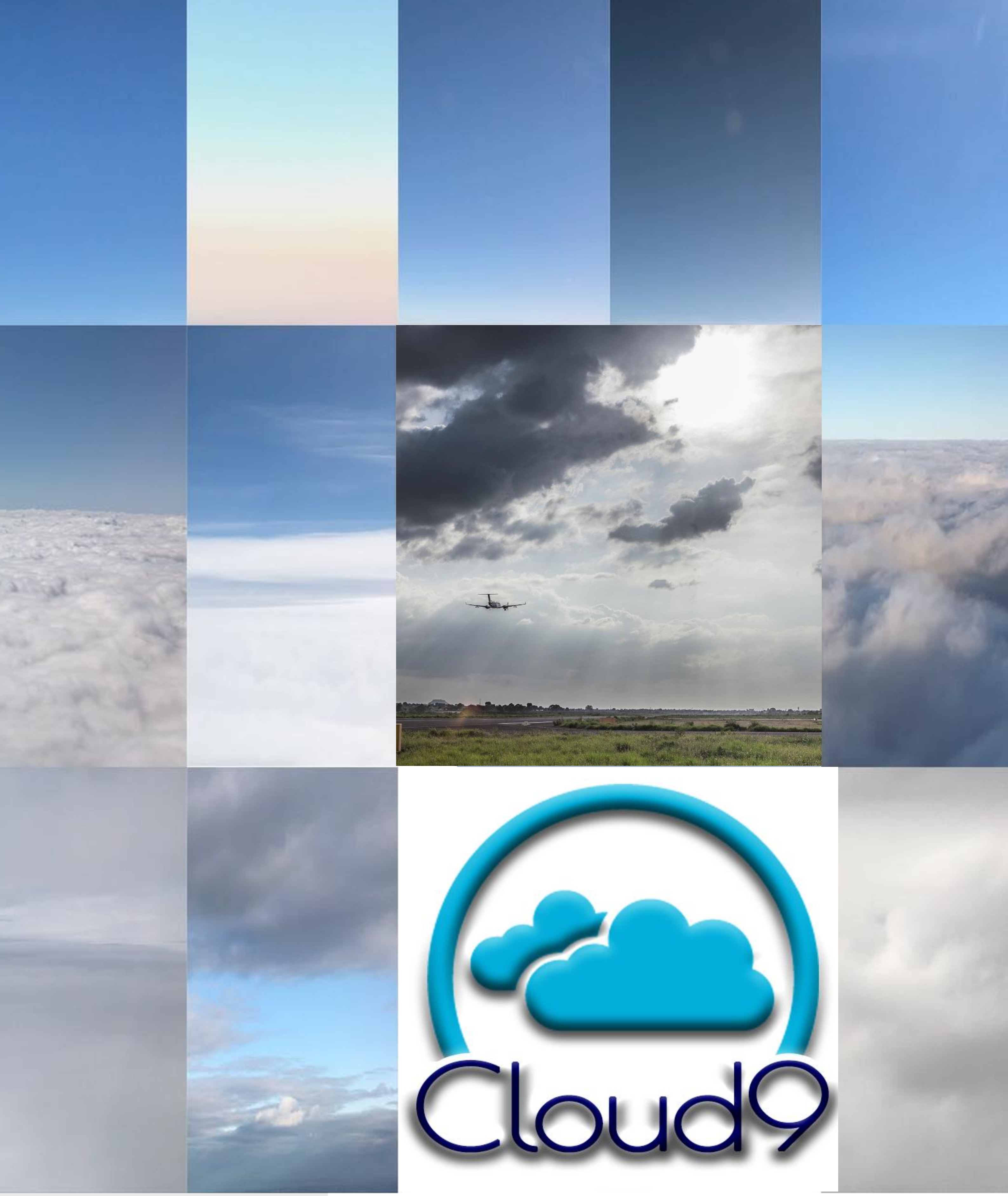

About Special Mission – Cloud9

Special Mission – Cloud9 aims to generate rain augmentation science focused on Africa, as well as to ensure that this science has a fundamental impact on human development across the continent. This brief was compiled by members of Cloud9 research team.