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IMPACTS OF CLOUD SEEDING ON COOP PRECIPITATION MEASUREMENTS IN THE SOUTHERN PLAINS

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1. INTRODUCTION

The Southern Plains of the United States, in particular Oklahoma and Texas, are economically dependant upon the agriculture industry. In most areas, precipitation is the primary source of water to the agricultural fields. As a result, maintaining and surpassing average precipitation levels can allow more efficient crop production and larger crop yields.

One method of increasing the amount of precipitation in a region is by the modification of existing precipitating clouds through the use of cloud seeding. Specially equipped aircraft inject primarily silver iodide into growing convective towers to stimulate them to grow larger and produce more rainfall.

While some cloud seeding projects in the Southern Plains have been conducted since 1970, very little large-scale analysis has been performed on the resulting change in precipitation amounts. Some individual regions within Texas have performed statistical analyses within their region to show varying results.

This project analyzed county level rainfall amounts from 1970 to 2003 within Oklahoma and Texas. A 34-year climatology of rainfall amounts and categorical amounts of rainfall were determined. From these rainfall climatologies, analysis of the counties that performed cloud seeding and those that did not perform clouding seeding was conducted.

2. DATA COLLECTION

2.1 Cooperative Observing Network Precipitation Data

Monthly precipitation data were collected in each of the 77 counties in Oklahoma and 254 counties in Texas from the Cooperative Observing Network (COOP) locations. In many cases, a county may have more than one observation. In these cases, the total monthly rainfall for the county was averaged across each observation to determine the county mean rainfall amount. If less than 90% of the month's COOP rainfall data was missing, the county was omitted for that particular month.

In addition to computing a rainfall climatology, the number of days that had a certain threshold of rainfall within the month were also determined. These threshold levels were 0.01", 0.10", 0.25", 0.05", 0.75", and 1.00". of rainfall Analysis of this data would help determine whether there were more frequent smaller rainfall events rather than a large one-time rainfall occurrence which would skew the monthly rainfall total.

Deviations for the 34-year climatology were performed using two different techniques. The first calculated the physical amount of rainfall difference between each month and the corresponding month's 34-year climatology. This method would allow the change in physical water over a cloud seeding region to be computed. However, extensive variation in climatological rainfall across the Southern Plains does not allow for spatial comparisons across the entire domain. In consequence, the second technique analyzed each month's percent of normal precipitation to remove any variations in climatological rainfall amounts. The majority of this study applies this second technique during the data analysis.

2.2 Weather Modification Locations

Figure 1 shows a map of the regions in Oklahoma and Texas that performed weather modification between 1970 and 2003. Each of these locations performed clouding seeding during various years; however, the majority of the clouding seeding operations were performed between 1997 and 2003. The locations also performed weather modification projects during various months within the years.

Every county in Oklahoma has performed clouding seeding at sometime, with some counties having more operations carried out than others. In Texas, there were 11 separate cloud seeding operations that ran independently of each other.

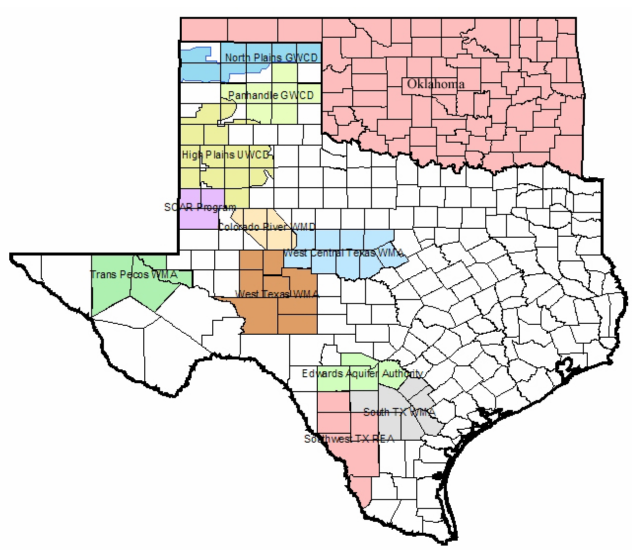

Figure 1. A map of the weather modification areas in Oklahoma and Texas that performed between 1970 and 2003.

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Month	0.01"	0.10"	0.25"	0.50"	0.75"	1.00"	Total
January	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
February	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
March	-1.72%	-4.79%	-7.07%	-14.60%	-24.37%	-22.23%	-12.08%
April	6.53%	9.39%	7.80%	-0.53%	-3.67%	-7.74%	5.21%
May	4.97%	1.49%	1.84%	3.54%	2.84%	5.71%	2.60%
June	1.09%	-0.11%	2.15%	0.82%	2.84%	-0.36%	0.54%
July	1.19%	-3.80%	-4.21%	-0.54%	1.05%	7.60%	3.95%
August	4.16%	4.60%	5.59%	5.07%	5.06%	-1.43%	3.63%
September	-1.35%	-6.20%	-9.47%	-14.63%	-16.31%	-18.61%	-13.02%
October	0.80%	3.75%	7.81%	13.54%	17.72%	23.42%	8.46%
November	11.33%	7.83%	2.62%	-12.06%	-4.25%	-5.02%	5.29%
December	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Average	**3.00%**	**1.35%**	**0.78%**	**-2.15%**	**-2.12%**	**-2.07%**	**0.51%**

Table 1. A table showing the percentage difference between the departure from normal rainfall (categorized and total accumulated) within and outside counties that were cloud seeded between 1997 and 2003.

3. PRECIPITATION ANALYSIS

Table 1 shows the percentage difference between the departure from normal rainfall (categorized and total accumulated) within and outside counties that were cloud seeded between 1997 and 2003. Data in red indicate those departures that are negative. These values only indicate the difference between cloud seeded and non-cloud seeded counties and do not directly indicate whether the rainfall was above or below normal.

Figure 2 shows a spatial analysis of the departure from normal rainfall (0.10”, 0.75”, and total, respectively) within and outside counties that were cloud seeded (shaded) between 1997 and 2003 for the month of July. Figure 2A and 2B indicates the change from normal “number of days greater than the threshold”, while Figure 2C indicates the change from normal monthly precipitation. Those counties in red indicate that less rainfall was received than normal and the counties in blue show that more rainfall was received than normal. Counties that have missing rainfall data are indicated in white.

3.1 Total Rainfall Analysis

The majority of cloud seeding occurred between the months of April and October. During these months (with the exception of September), the departure from normal total rainfall observed within the cloud seeded counties was higher than those counties with no cloud seeding. Overall, cloud seeding contributed an additional 0.51% more to the total rainfall; however, this value is over 3% if only the months of April – August are considered.

The three summer months (June, July and August) are times when many crops are growing and/or planted and need extra irrigation during the climatologically dry times. During these months, cloud seeding added approximately 2.7% more total rainfall to the modified counties.

The negative values in March and September are likely of times where strong synoptic forcing dominated the region.

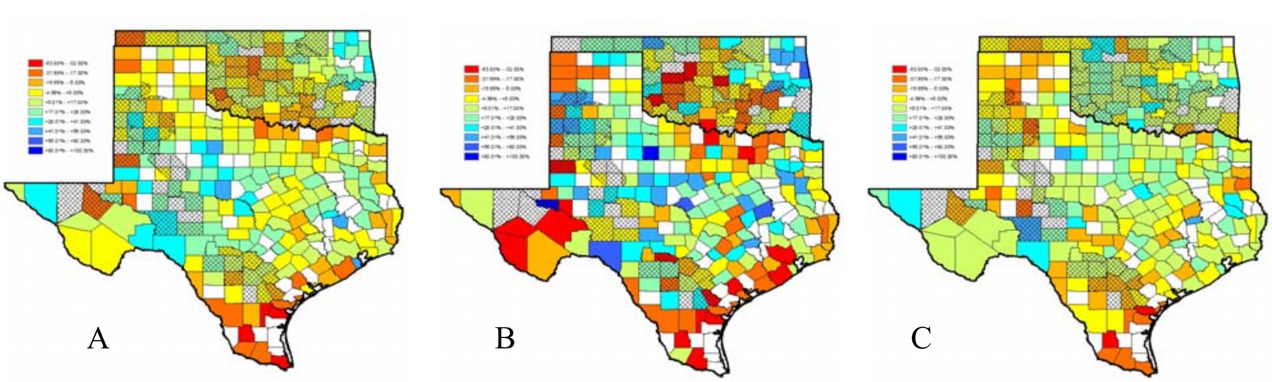

Figure 2. Map of the departure from normal rainfall (0.10”, 0.75”, and total, respectively) within and outside counties that were cloud seeded (shaded) between 1997 and 2003 for the month of July. White counties indicate missing data.

3.2 Categorical Rainfall Analysis

On average, cloud seeding resulted in more days than average that received smaller (0.01”, 0.10” and 0.25”) of rainfall and less than average that received larger (0.50”, 0.75” and 1.00”) of rainfall. By comparing the percent difference of total rainfall to the percent difference of categorical rainfall amounts, we can see a matching pattern. Those months with higher percentages of difference of total rainfall had higher number of days with smaller rainfall and vise versa. This indicates that cloud seeding has more of an impact on marginal to small rainfall amount days than heavy rainfall days.

4. CONCLUSIONS

The results of this study offer an initial insight on the impacts cloud seeding contributes to the rainfall in the Southern Plains. This study has determined the cloud seeding generally impacts months where synoptic forcing in the atmosphere is minimal. Additionally, cloud seeding increases the number of days that receive smaller (0.01”, 0.10” and 0.25”) rainfall.

Given the millions of acres which are cloud seeded, the overall increase of ~0.50% to ~3.00% results in millions of gallons of water that are added to the area. The cost of the addition of this water through cloud seeding methods is only a fraction of the cost that would be required to manually irrigate the fields this amount.

5. ACKNOWLEDGEMENTS

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