Change in Water Storage Analysis in the Wintergarden Region of Texas from 2002 to 2016

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Abstract

As Texas' population is set to double by 2050, water scarcity becomes a growing concern. Growing cities, such as the city of San Antonio, will soon compete with farmers in the Wintergarden Region for groundwater. Groundwater conservation districts have been formed across the state in an attempt to monitor groundwater use. However, in February of 2012 the Texas Supreme Court ruled that groundwater is a property right and stripped the authority from groundwater conservation districts to regulate it. The goal of this report was to determine if the overall groundwater storage in the Wintergarden Region decreased significantly after this court ruling. Using a change point analysis on water storage data from NASA's GRACE satellite, it was found that the mean water equivalent thickness did decrease by 5.11 cm. However, it is unclear as to whether this decrease was caused by the new court ruling as the time period observed was during the worst drought on record. Further analysis needs to be conducted on current and future data from the GRACE Follow On satellite launched in 2018 to see if groundwater storage continues to decline at faster rates than before the Texas Supreme Court ruling.

Introduction

Water scarcity is becoming a growing concern in the state of Texas as its population is expected to double by 2050 (Potter 2014). Growing cities like San Antonio may soon be competing with farmers and ranchers for water stored in aquifers. According to a report conducted by Texas

A&M in 2012, 86% of irrigated land in Texas was irrigated using groundwater (Wagner 2012). The city of San Antonio currently utilizes the Carrizo-Wilcox Aquifer for aquifer storage and recovery, while farmers in the Wintergarden Region 100 miles away rely on this same water source for irrigation. This could lead to problems with competing users during times of drought when other water resources are scarce.

Due to the state's rule of capture, property owners with access to groundwater are free to draw unlimited amounts from their property (Texas A&M). Many Texans rely on groundwater as their sole water source and are concerned about the future of their supply. As a result, groundwater conservation districts have been created all over Texas since the 1980's in an attempt to monitor groundwater use. Farmers have fought groundwater conservation districts on regulating their water use, claiming it to be unnecessary and a violation of their property rights. Farmers argue that because they depend on groundwater for their livelihood, historically they've been the first to conserve this resource, much more than nearby cities have (Galbraith, Mar. 2012). In 2012 the Texas Supreme Court ruled that regulating groundwater withdraw was a violation of the rights of property owners, on the basis of oil and gas law (Galbraith, Feb. 2012). This ruling effectively stripped groundwater conservation districts of the authority to enforce regulation of groundwater withdraw, leaving farmers' and ranchers' water-use to be self-managed. This report aims to investigate if there was a significant increase in groundwater withdraw in the Wintergarden Region after this court ruling occurred. By analyzing satellite data on groundwater storage, I aimed to answer the question: Are farmers in this region pumping less on average by their own accord? Or are they pumping more because they can?

Wintergarden Region of Texas

The Wintergarden Region was chosen for this study as it is one of largest producers of winter vegetables in the country, producing high water-demanding crops year-round. This region typically receives an average of 50 cm (19.72 inches) of rain per year (US Climate Data 2018) and has two rivers running through, the Nueces and the Frio rivers. However, during times of drought the region is heavily dependent on the Carrizo-Wilcox aquifer for its water source. See Figure 1a and 1b below. In 1995 Zavala County alone had 40,000 irrigated acres for crop production (Odintz 2010). This high level of withdraw could affect other users of the aquifer in the future, such as the growing city of San Antonio.

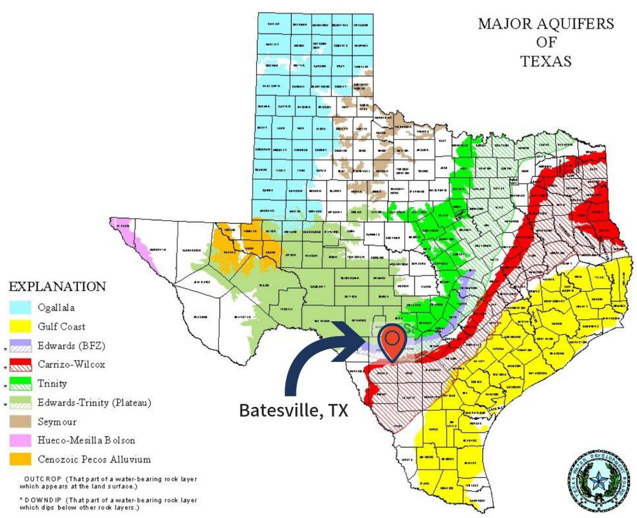

Figure 1a: Major Aquifers of Texas, with Batesville location shown. Image Source: www.twdb.texas.gov/groundwater/aquifer/major

Figure 1b: Texas Rivers map with Wintergarden Region highlighted. Image Source: geology.com/lakes-rivers-waters/texas

Literature Review

Studies have been conducted to estimate the irrigated water use around the state of Texas. Specifically, studies have been conducted for the Panhandle, North Plains, Mesa, Hudspeth, Gateway, Rolling Plains, Coastal Bend, and High Plains, and Lower Neches Valley Regions for production of cotton, corn, wheat, sorghum, alfalfa, hay, soybeans and peanuts (TWDB 2011). Studies have also shown that the excess pumping from irrigation in the Wintergarden Region has resulted in significant loss in storage and even stream flow reversal (Huang 2012). However, there has not been a specific correlation between groundwater storage in the Wintergarden Region and the timing of the recent Texas Supreme Court ruling.

Methods

Using water storage data from NASA's GRACE satellite, I was able to analyze change in water storage over time in the Wintergarden Region to see if the date of the Texas Supreme Court ruling played any significance.

GRACE Satellite Water Storage Data

GRACE (Gravity Recovery and Climate Experiment) is a NASA sponsored project where a satellite measures changes in Earth's gravitational field at different locations around the globe over time. The changes in gravity are assumed to be related to the changes in water storage in a given region. The satellite was launched in March 2002 and had been collecting monthly water storage data for this region until July 2016. The GRACE satellite can provide water equivalent thickness data for regions around the globe 110 km x 110 km in size based on a specified GPS location. For this project I chose to analyze the water equivalent thickness of GPS location 28.9511°N, 99.6178°W or Batesville, Texas as this location lies in the center of the Wintergarden Region. See Figures 2a and 2b below:

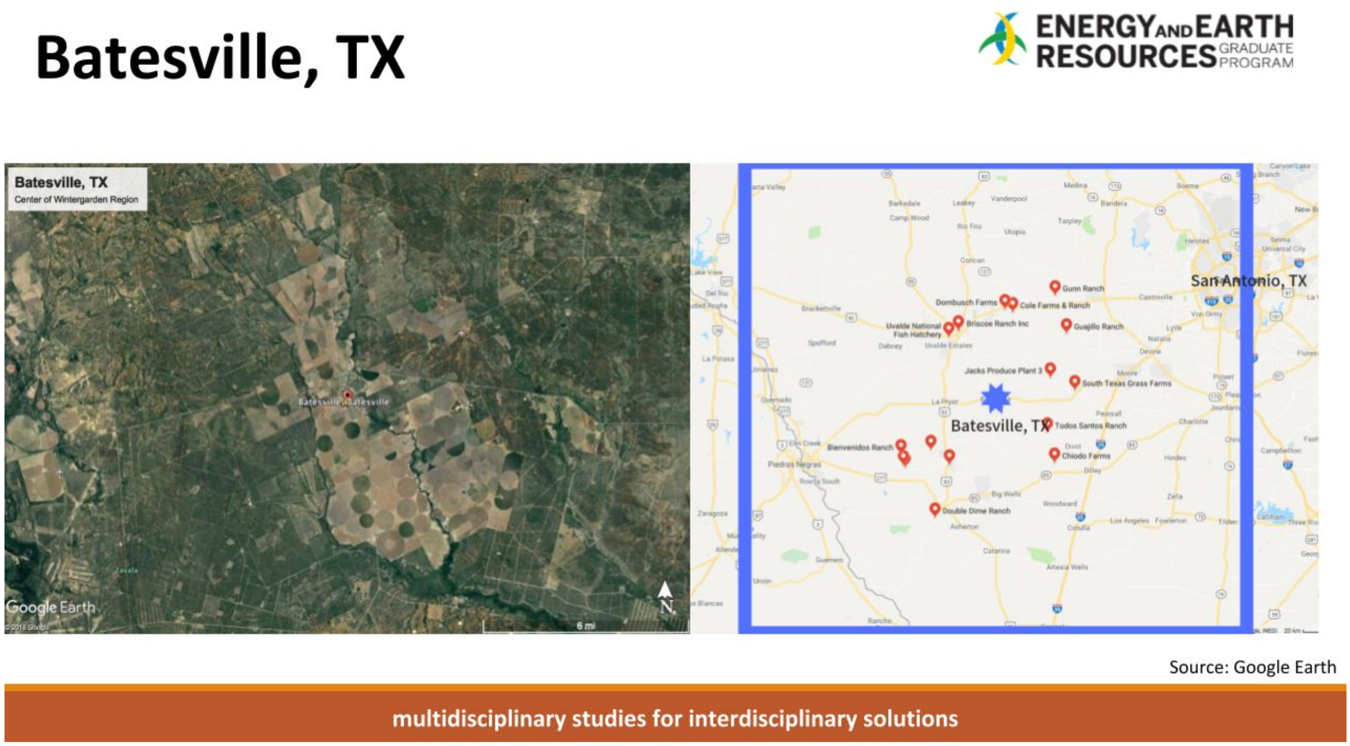

Figure 2a: Batesville, TX Google Earth Image. Crop circles show region is heavily irrigated. Image Source: Google Earth, Batesville TX

Figure 2b: Batesville, TX Google Map Image. Blue box shows area selected for GRACE water storage data. Image Source: Google Maps, Batesville TX

Data Analysis

By downloading available data from the NASA website, I was able to plot the change in water equivalent thickness from April 2002 to July 2016 (See Figure 3). To access the NASA data for the region surrounding Batesville TX, I used the 'skdaccess' package in Python developed by the Haystack Observatory Astro & Geo Informatics Group at MIT (Pankratius 2018). I wanted to see if there was any statistical evidence for an increase in the decline of water equivalent thickness after the Texas Supreme Court ruling in February 2012. I was able to do this using the 'changepoint' package in R.

Change point analysis (or change detection) is a set of techniques that detect abrupt changes in the statistical model of a given time series. I used a change point analysis to detect a change in the mean of water equivalent thickness. Since I was only observing whether there was a change around 2012, I used the "at most one change" (AMOC) setting for this analysis. In preliminary analysis, I first removed seasonality from the data before applying the changepoint detection. However, I found there was very little difference between the change in mean with or without accounting for seasonality. With this, I decided not to remove seasonality for my analysis.

Results

Using the 'changepoint' package in R, I found a changepoint occurs at data point 104, or on March 17th 2011. The mean water equivalent thickness from April 2002 to March 2011 had been -0.07cm. After the change point, the mean water equivalent thickness changed to -5.18 cm. See Figures 3 and 4 below:

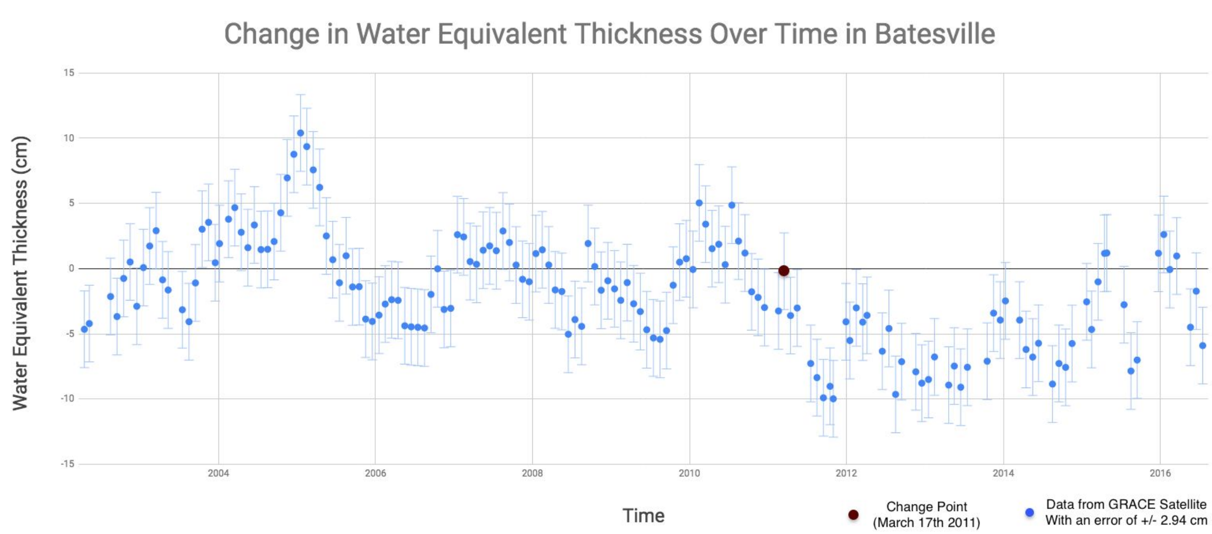

Figure 3: Change in water equivalent thickness over time for the Batesville region. The red dot indicates the change point on March 17th 2011.

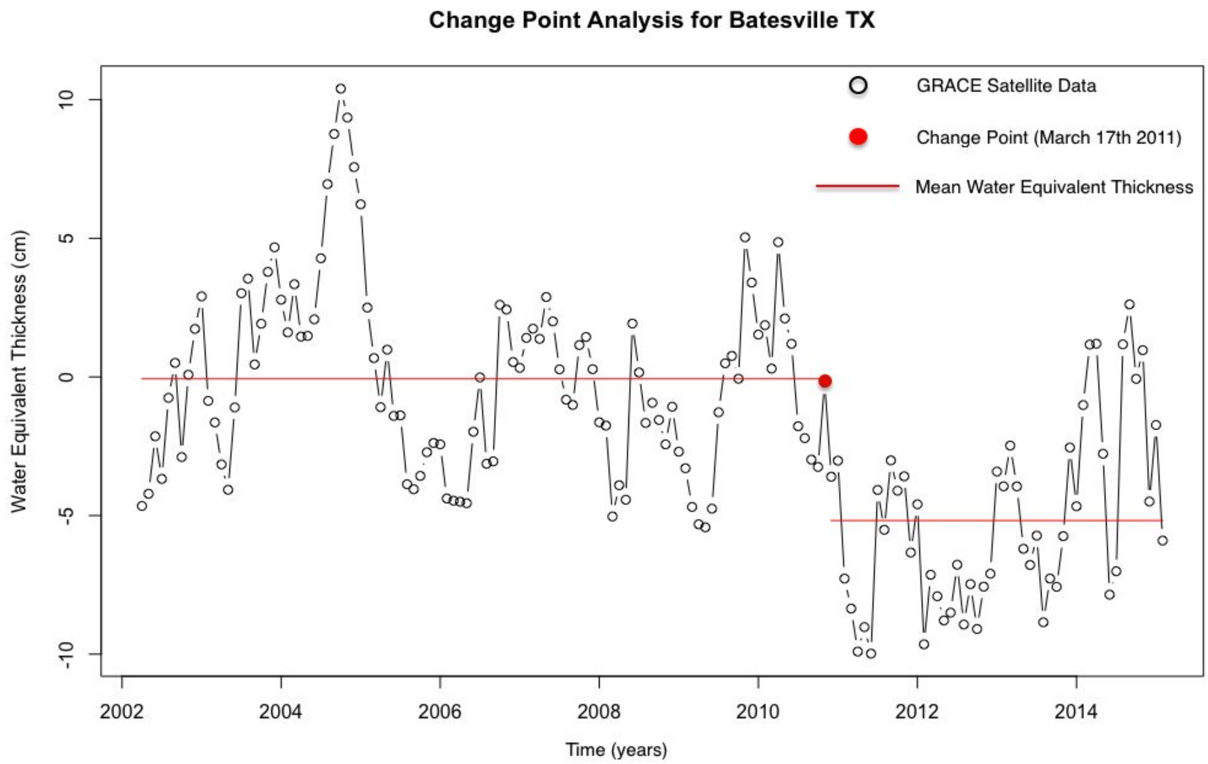

Figure 4: Change in water equivalent thickness over time. Here we can see the mean water equivalent changed from -0.07cm to -5.18 cm after the change point.

Discussion

I found this result to be very interesting. We do see a drop in the average water storage, however the change occurs almost a year before the Texas Supreme Court ruling took place. This suggests that the increase in pumping from the aquifer was not necessarily caused by the court ruling, but possibly by something else.

The 2011 drought in Texas was the most severe drought on record. Farmers and ranchers lost an estimated $8 billion due to loss of crop and livestock (State Impact 2013). It's very likely that this decline in aquifer storage was due to severe drought conditions in the region. Without rainwater or surface water to supplement irrigation, farmers in the Wintergarden Region were entirely dependent on groundwater for crop production.

This major weather event makes it very difficult to draw any conclusions on whether the Texas Supreme Court ruling in 2012 changed irrigation trends in the Wintergarden Region. Further analysis would need to be conducted with future data to see if after coming out of the drought in 2016 water storage trends remained at these levels.

Conclusion and Future Work

The Wintergarden Region in Texas is a major producer of winter vegetables which relies on the Carrizo-Wilcox aquifer for irrigation. Other water users, such as the City of San Antonio, also depend on this aquifer making groundwater conservation of utmost importance. Despite groundwater conservation districts attempting to monitor groundwater withdrawal by private landowners, the Texas Supreme Court ruled in 2012 that groundwater is a property right and property owners are free to pump as much as they please. Farmers have claimed they are the front-runners in the state for conservation of their local aquifers as they depend on this resource for their livelihood. This study investigated whether groundwater storage in the Wintergarden region changed significantly after the Texas Supreme Court ruling with the new “hands off” regulation approach.

Using a change point analysis of the GRACE satellite data for water storage, it was found that average water equivalent thickness did decrease by 5.11 cm. However, the change point occurs in March 2011, almost a year before the court ruling and at the beginning of the worst drought on record in Texas. Further analysis on future data would need to be done to conclude whether this change in water storage occurred because of the drought, or due to change in regulation.

In May of 2018 NASA launched a second satellite, GRACE Follow On (GRACE-FO) to track water movement on Earth. GRACE-FO features two satellites that will increase the accuracy of measurements of changes in Earth's gravitational field due to changes in water storage (Dakwala 2018). With future data from the GRACE-FO satellites, I will continue to analyze water storage in the Wintergarden Region to observe if there is statistical evidence for a significant decrease in water storage after the Texas Supreme Court Ruling in 2012.

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Appendix A: Python Script for GRACE data conversion to CSV

```
#Download GRACE data from: https://grace.jpl.nasa.gov/data
#Following these instructions: https://github.com/MITHaystack/scikit-
dataaccess/blob/master/skdaccess/docs/skdaccess_manual.pdf

pip install scikit-dataaccess==1.1.0

#Open Python
iPython

import skdaccess
import matplotlib.pyplot as plt

from skdaccess.geo.grace import DataFetcher as GR_DF
from skdaccess.framework.param_class import *

#Chose a Location to Observe using GPS Coordinates (Latitude, Longitude)
#Batesville TX has location Latitude: 28.9511 Longitude: -99.6178
geo_point = AutoParam((28.9511, -99.6178)) # Location Batesville TX

#Set Date Range: April 17 2002 to September 30 2016
grace_fetcher =
GR_DF([geo_point],start_date='2002-04-17',end_date='2016-09-30',resample=False)
grace_data = grace_fetcher.output().get()

#Preview Data
grace_data.tail

#Plot Results
plt.plot(grace_data['Grace'])
plt.show()

#Save to CSV File
grace_data.to_csv('Grace_Data_Batesville_TX.csv')
```

Appendix B: Change Point Analysis in R

```
#At most One Change Analysis
#Not removing seasonality

data = read.csv('Batseville_TX_Grace.csv', header=TRUE)

library(changepoint)

#Create a Time Series
ts_data = ts(data$Grace, frequency=12, start=c(2002,04))

plot(ts_data)

#Change Point Analysis Function
Change_Point = cpt.mean(ts_data, penalty="MBIC", pen.value=0, method="AMOC", Q=5,
test.stat="Normal", class=TRUE, param.estimates=TRUE, minseglen=1)

#Show Changepoint Location
Change_Point

#Calculate Means
param.est(Change_Point)
```