The effect of ITRF 2022 on policy and regulation

Sapir Carlo Dooley, Catherine Ott, Noah Sharp, Minh Bui, Devon Francis

Introduction

Currently, the National Spatial Reference System (NSRS) is based on the North American Datum of 1986 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88). These datum have worked well so far but a few errors have been found. The NAD 83 datum is non-geocentric, meaning the datum which should be centered at the center of the earth is actually off by about 2.2 meters compared to the International Terrestrial Reference Frame (ITRF) and the World Geodetic System 1984 (WGS84). The NAVD 88 datum is both biased by 1.1 meters and tilted. This error is due to both the technique in which the data was gathered as well as the nature of the location of the survey marks. The data was gathered using ground-based surveying techniques, which are subject to a higher rate of human error, using Electronic Distance Meters, Theodolites, Total Stations, Leveling, and GPS receivers. In addition, many survey marks were set in passive locations, meaning the position of the mark is subject to change over time: either through human interaction, a change in the landscape, or complete removal.

It is necessary to correct these errors through a new geodetic datum. This datum, proposed by the U.S Department of Commerce, is named the International Terrestrial Reference Frame of 2022 (ITRF 2022) based on the State Plane Coordinate System of 2022 (SPCS 2022). ITRF 2022 will be based on the reference ellipsoid GRS 80 and the conformal projection types: Lambert Conformal Conic (LCC), Transverse Mercator (TM), and Oblique Mercator (OM). To address the errors made through ground-based surveying and to account for the ever changing land formations, this new datum will be based on a network of reference stations that will be constantly updating their locations through GPS. This network is named the Continuously Operating Reference System Network (CORS) and is comprised of 2000 cites monitored by 225 organizations.

In this report the effect switching to the new datum will have on the latitude and longitude of coordinates based on previous datum will be explored. This data will be used to determine whether or not the changes will be large enough to have an effect on different areas of public policy. The projected changes in velocity of five locations across Texas will be tracked. Data will be gathered over a 47 year period, measurements every 7 years from 2012 to 2019 and every 10 years thereafter until 2059 will be taken. Once data has been gathered, conclusions can be made on whether or not these changes will have an impact on fields such as construction, oil and gas, environmental regulation, land ownership, renewable energy, infrastructure, disaster relief and much more. For example, if the change is as large as is predicted, wetlands may be in danger of being encroached on and construction companies may be at risk of receiving fines for doing so. If the change is large, without correct translation, oil and gas companies may drill into the wrong areas, costing the companies millions and possibly affecting the surrounding environment. If valuable minerals are found on or under a piece of land, a difference of a few meters can determine who those mineral rights belong to. Without correct location information, entire subdivisions could be built inside of a floodplain or evacuation warnings could miss thousands of people.

Materials and Methods

SI Units

This paper presents units in meters (m); however, the official linear unit of measure in the State of Texas is the U.S Survey-Foot (1,200/3,937 m). Data are shown in meters followed by its survey-foot equivalent (Sft).

Coordinate Systems

NAD83 will be transformed to ITRF 2008, which will then be transformed to ITRF 2008 at specific dates. This will be used to make estimations of ITRF 2022.

Hardware and Software

Location data will be collected using the NGS Coordinate Conversion and Transformation Tool (NCAT). Data will be acquired from five different locations in Amarillo, Midland, Fort Worth, Austin, and Brownsville. Data will be transformed using Geographic Calculator. Changes in distance will be calculated using Microsoft Excel.

Locations

The NAD coordinate (35.19204754, -101.83708191) located in the intersection of Interstate 40 and Interstate 27 will be used for Amarillo. The NAD coordinate (31.98507392, -102.10229874) located in Ulmer Park will be used for Midland. The NAD coordinate (32.75653045, -97.31543541) located in Harmon Field Park Pond will be used for Fort Worth. The NAD coordinate (30.28378870, -97.73252964) which is in Texas Memorial Stadium will be used for Austin. The NAD coordinate (25.9127284840, -97.4718704216) which is located in Porter Early College High School will be used for Brownsville.

Time Dependent Transformations

Each coordinate, once transformed to ITRF 2008, will be projected to ITRF 2008 at specific dates. These dates include March 1st 2012, March 1st 2019, March 1st 2029, March 1st 2039, March 1st 2049 and March 1st 2059.

Distance Calculations

The coordinate at each time will be compared to the reference point taken on March 1st 2019. Distances will be calculated using this formula:

ArcCos{[Sin(Lat1)*Sin(Lat2)]+[Cos(Lat1) *Cos(Lat2)]} * Cos(Long2 - Long1)

Data - Tables

Amarillo (NAD83 - ITRF2008)

Date (MM/DD/YYYY)	NAD 83 (Latitude, Longitude)	ITRF2008 (Latitude, Longitude)	Distance (Meters)
03/01/2019	(35.19204754, -101.83708191)	(35.19205242, -101.83709449)	1.26659485

Amarillo (ITRF2008-ITRF2008)

Date (MM/DD/YYYY)	Location (Latitude, Longitude)	Distance from 2019 location (Meters)
03/01/2019	(35.19205242, -101.83709449)	0
03/01/2012	(35.19205272,-101.83709348)	0.13425879
03/01/2029	(35.19205199, -101.83709594)	0.16443276
03/01/2039	(35.19205155, -101.83709739)	0.30021177
03/01/2049	(35.19205112, -101.83709884)	0.42456356
03/01/2059	(35.19205068, -101.83710029)	0.56164480

Slope: 0.29952547 Meters

Midland (NAD83 - ITRF2008)

Date (MM/DD/YYYY)	NAD 83 (Latitude, Longitude)	ITRF2008 (Latitude, Longitude)	Distance (Meters)
03/01/2019	(31.98507392, -102.102298741)	(31.98507822, -102.10231079)	1.23050210

Midland (ITRF2008-ITRF2008)

Date (MM/DD/YYYY)	Location (Latitude, Longitude)	Distance from 2019 location (Meters)
03/01/2019	(31.98507392, -102.102298741)	0
03/01/2012	(31.98507855, -102.10230987)	0
03/01/2029	(31.98507775, -102.10231211)	0.09493530
03/01/2039	(31.98507728, -102.10231343)	0.26851757
03/01/2049	(31.98507681, -102.10231475)	0.41381337
03/01/2059	(31.98507634,-102.10231607)	0.53703514

Slope: 0.35641708 Meters

Fort Worth (NAD83 - ITRF2008)

Date (MM/DD/YYYY)	NAD 83 (Latitude, Longitude)	ITRF2008 (Latitude, Longitude)	Distance (Meters)
03/01/2019	(32.75653045, -97.31543541)	(32.75653548, -97.31544648)	1.17811607

Fort Worth (ITRF2008-ITRF2008)

Date (MM/DD/YYYY)	Location (Latitude, Longitude)	Distance from 2019 location (Meters)
03/01/2019	(32.75653548, -97.31544648)	0
03/01/2012	(32.75653567,--97.31544553)	0.09493530
03/01/2029	(32.75653521, -97.31544784)	0.13425879
03/01/2039	(32.75653494, -97.31544920)	0.25117519
03/01/2049	(32.75653467, -97.31545056)	0.37974119
03/01/2059	(32.75653440, -97.31545192)	0.52857737

Slope: 0.19872878 Meters

Austin (NAD83 - ITRF2008)

Date (MM/DD/YYYY)	NAD 83 (Latitude, Longitude)	ITRF2008 (Latitude, Longitude)	Distance (Meters)
03/01/2019	(30.28378870, -97.73252964)	(30.28379321, -97.73254041)	1.14710757

Austin (ITRF2008-ITRF2008)

Date (MM/DD/YYYY)	Location (Latitude, Longitude)	Distance from 2019 location (Meters)
03/01/2019	(30.28379321, -97.73254041)	0
03/01/2012	(30.28379341, -97.73253952)	0
03/01/2029	(30.28379292, -97.73254168)	0
03/01/2039	(30.28379264, -97.73254296)	0.26851757
03/01/2049	(30.28379235, -97.73254423)	0.37974119
03/01/2059	(30.28379207,-97.73254550)	0.50235038

Slope: 0.22407687 Meters

Brownsville (NAD83 - ITRF2008)

Date (MM/DD/YYYY)	NAD 83 (Latitude, Longitude)	ITRF2008 (Latitude, Longitude)	Distance (Meters)

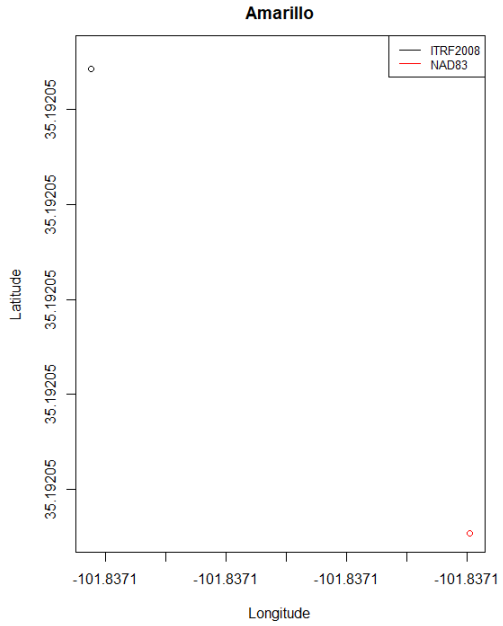
03/01/2019	(25.91272848, -97.47187042)	(25.91273213, -97.47188051)	1.09072353

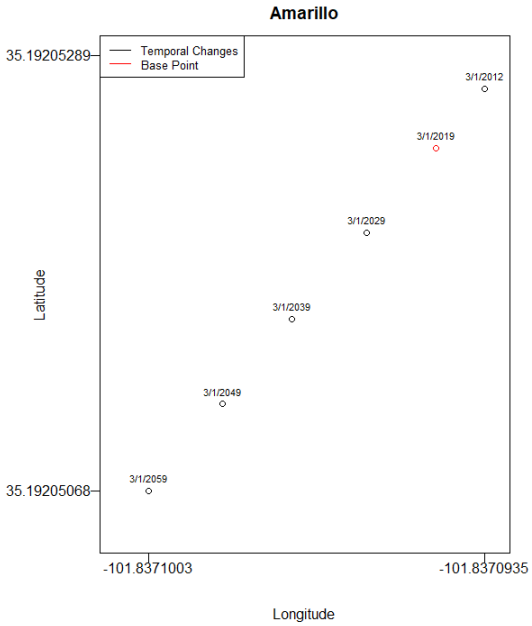
Brownsville (ITRF2008-ITRF2008)

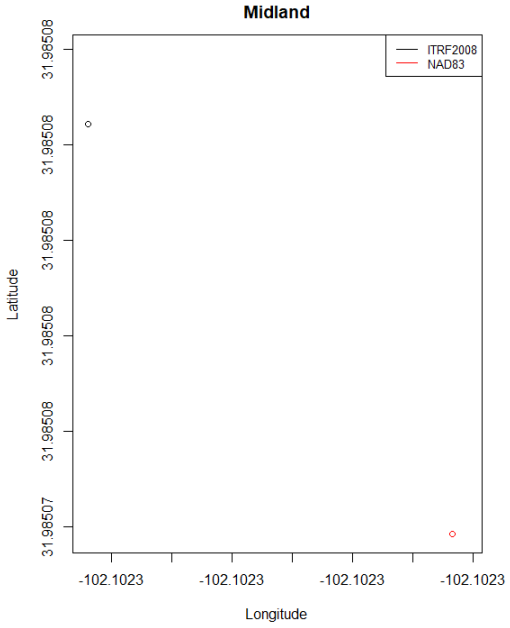
Date (MM/DD/YYYY)	Location (Latitude, Longitude)	Distance from 2019 location (Meters)
03/01/2019	(25.91273213, -97.47188051)	0
03/01/2012	(25.91273237, -97.47187963)	1.01806765
03/01/2029	(25.91273179, -97.47188177)	1.19331819
03/01/2039	(25.91273145, -97.47188302)	1.30168722
03/01/2049	(25.91273112, -97.47188428)	1.41450408
03/01/2059	(25.91273078,-97.47188553)	1.53372668

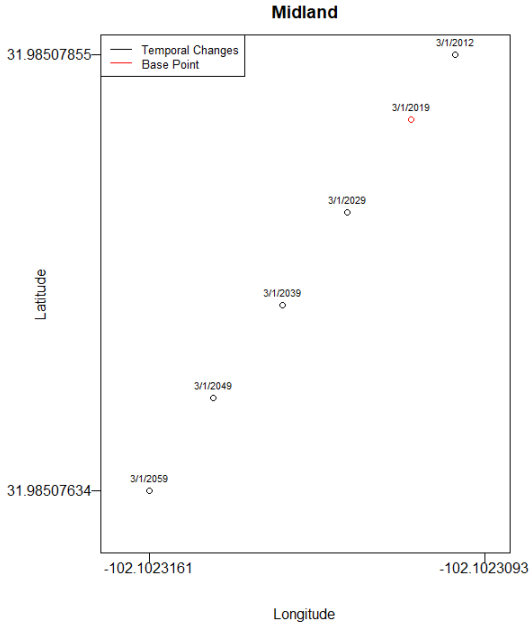
Slope: 0.26915885 Meters

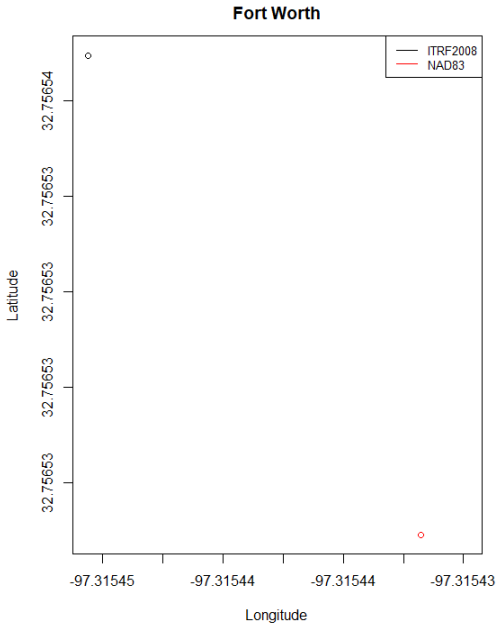
Data – Graphs

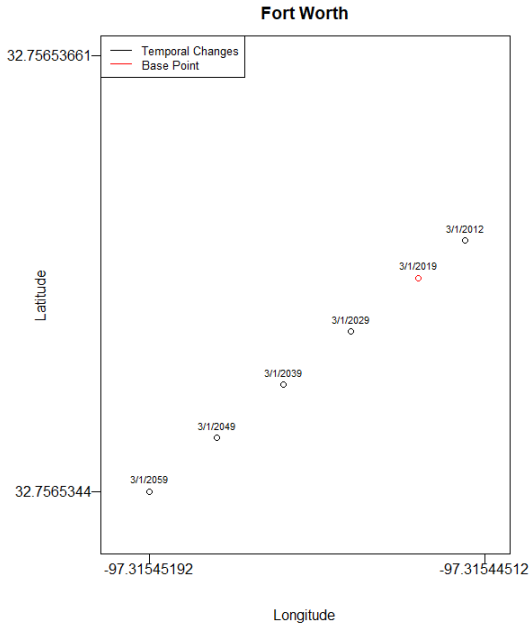


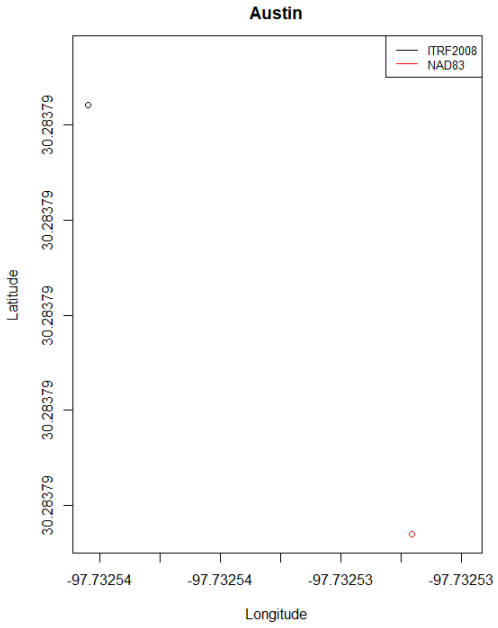


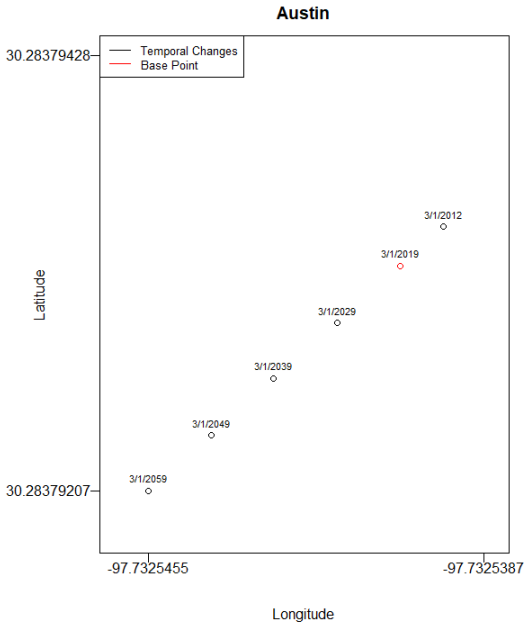

Midland
ITRF2008
NAD83
Latitude
31.98508
31.98508
31.98508
31.98508
31.98508
31.98507
-102.1023
-102.1023
-102.1023
-102.1023
Longitude

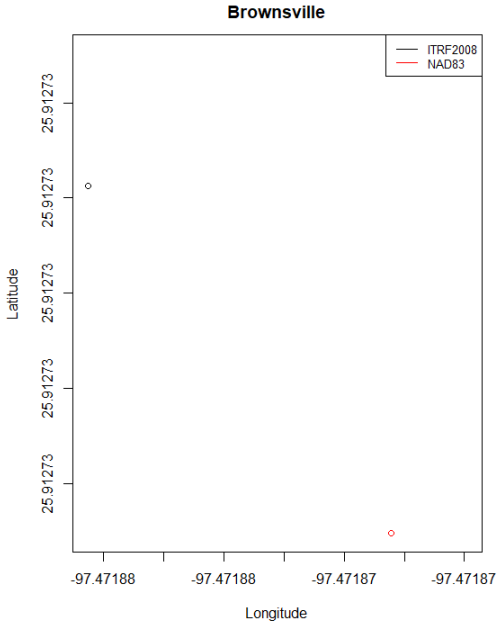

Midland
Temporal Changes
Base Point
3/1/2012
3/1/2019
3/1/2029
3/1/2039
3/1/2049
3/1/2059
Latitude
31.98507855
31.98507634
-102.1023161
-102.1023093
Longitude

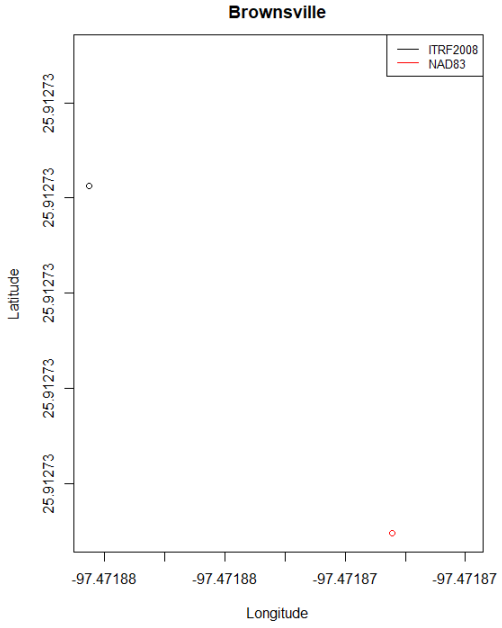

Fort Worth
ITRF2008
NAD83
Latitude
32.75654
32.75653
32.75653
32.75653
32.75653
-97.31545
-97.31544
-97.31544
-97.31543
Longitude


Fort Worth
Temporal Changes
Base Point
3/1/2012
3/1/2019
3/1/2029
3/1/2039
3/1/2049
3/1/2059
Latitude
32.75653661
32.7565344
-97.31545192
-97.31544512
Longitude

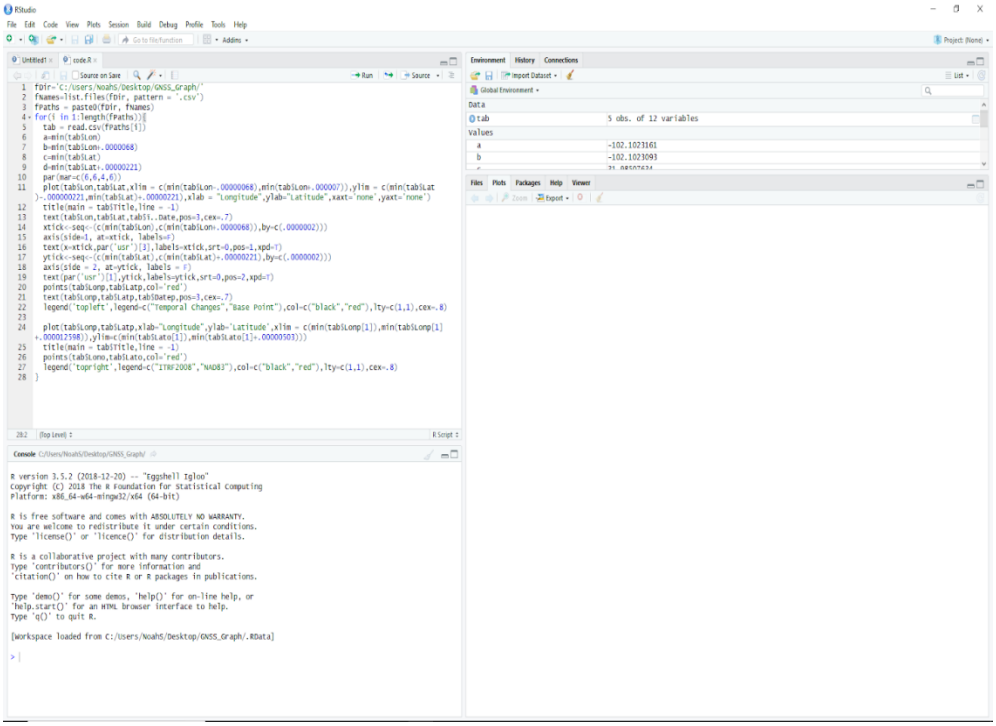

Austin
ITRF2008
NAD83
Latitude
30.28379
30.28379
30.28379
30.28379
30.28379
-97.73254
-97.73254
-97.73253
-97.73253
Longitude


Austin
Temporal Changes
Base Point
Latitude
30.28379428
30.28379207
3/1/2012
3/1/2019
3/1/2029
3/1/2039
3/1/2049
3/1/2059
-97.7325455
-97.7325387
Longitude

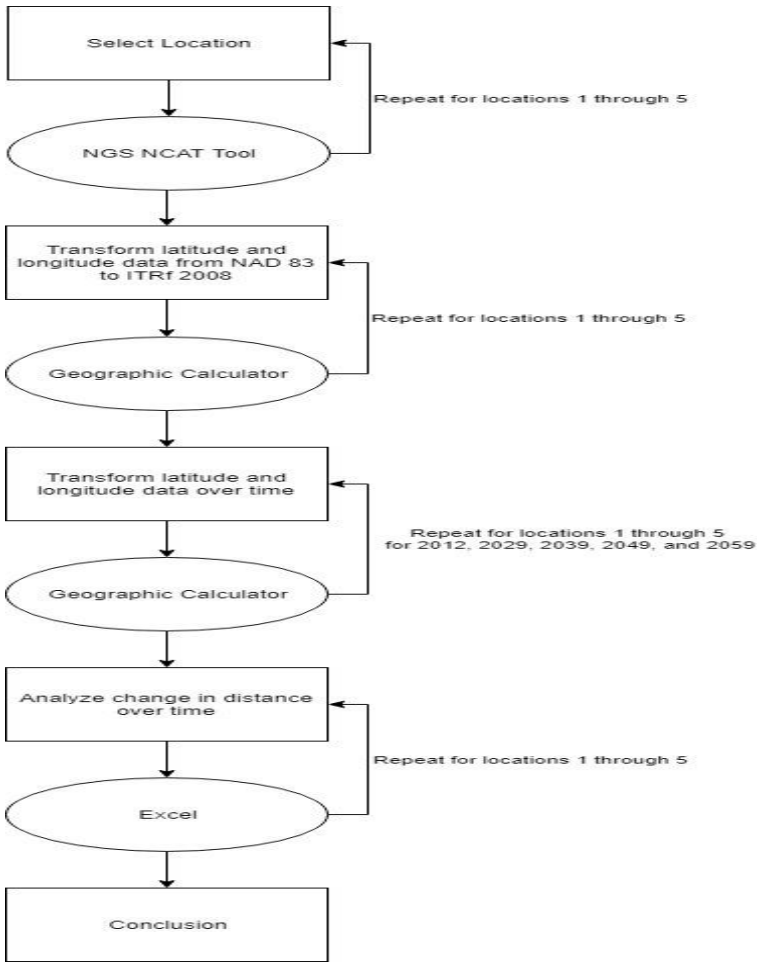

Brownsville
ITRF2008
NAD83
Latitude
25.91273
25.91273
25.91273
25.91273
25.91273
-97.47188
-97.47188
-97.47187
-97.47187
Longitude


Brownsville
ITRF2008
NAD83
Latitude
25.91273
25.91273
25.91273
25.91273
25.91273
-97.47188
-97.47188
-97.47187
-97.47187
Longitude

RCode for graphs



Workflow



Results

Summary Statistics

Distance from NAD 83 coordinate to ITRF 2008 coordinate	*Average*	1.23740245 Meters
	Maximum	1.26659485 Meters
	Minimum	1.09072353 Meters

Conclusion/Discussion

Since data was taken using ITRF 2008, only preliminary predictions can be made. Since ITRF 2022 has not been released results must be assumed to match. In order to correct for these possible errors, a reassessment must be made when the datum is officially released. The Data, when translated from NAD83 to ITRF2008, shows that each location shifted or will shift anywhere from approximately 1.09 meters in Brownsville to approximately 1.26 meters in Amarillo. However, once data was translated and projected over time using the same datum, the changes in location were shown to be much more gradual. This is as expected since the CORS base stations are able to take constant measurements. When the initial shift is made all manner of policies, laws, statutes, regulations, and permits will be greatly affected by a shift of more than a meter. If locations need to be found with centimeter level accuracy, in phase 1 and 2 assessments and 1 for example, extreme care must be taken during that initial shift. In the short term, from around 1 to 10 year spans, changes will be slight year to year; and because ITRF 2022 will be constantly updated, existing structures should not be affected so long as their coordinates are updated before any major developments are made. In the long term, careful calculations must be taken when calculating changes in distance because so many vectors must be taken into consideration.

References

Dr. Stacey D. Lyle Personal Interview. February-April, 2019.

Stone, William. “2022 is Coming – Will You Be Ready? (or NAD83 and NAVD88 Are Going Away).” UGIC 2015 Snowbird Conference Center, Snowbird, Utah. 11 May 2015. Keynote Address.