

Part 1: Datum Transformations in ArcMap, ITRF2008 to NAD83(2011)

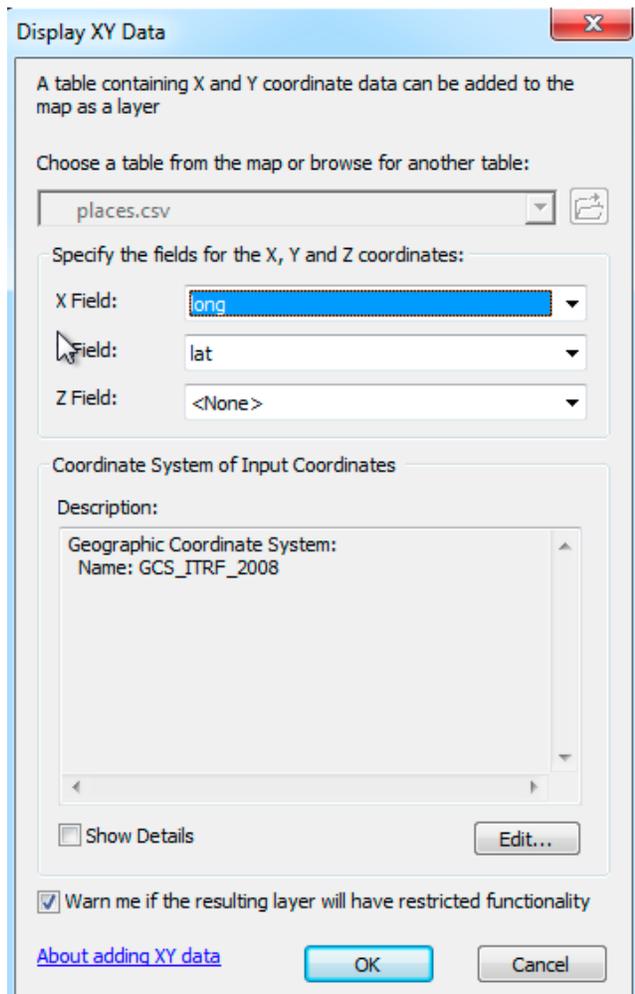
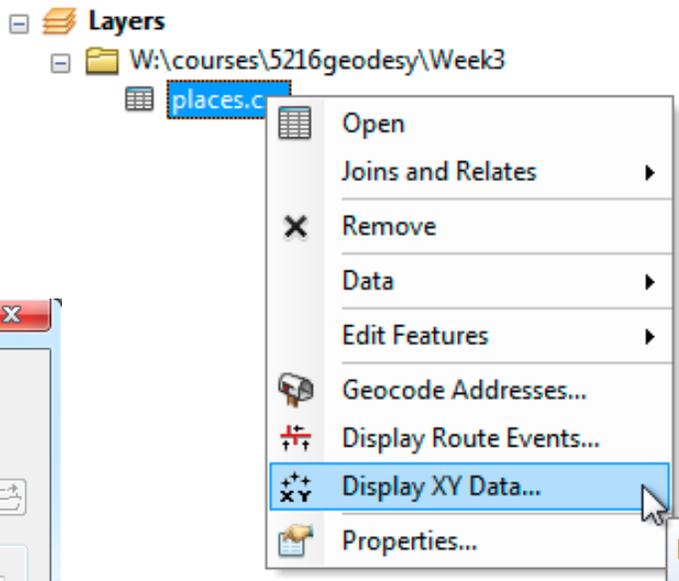
Where possible, ArcMap will perform a datum transformation among geographic coordinate systems using our $X' = T + xRX$ equation. Let's do this to transform from a ITRF2008 to an NAD83(2011) geographic system.

place	lat	long
StPaul	44.9537	-93.09
Chicago	41.8781	-87.6298
NewYork	40.7128	-74.0059
Reykjavik	64.1265	-21.8174
Paris	48.8566	2.3522
BuenosAires	-34.6037	-58.3816
Tokyo	35.6895	139.6917

Create a .csv file with the data on the right. One easy way is to type it into an Excel spreadsheet, then export as a Windows csv. I'll use lat for latitudes, and lon or long for longitudes in the following instructions.

Add the table to an ArcMap data frame.

Right click on the table (in the right figure, mine is named places.csv), and select **Display XY Data** from the dropdown.

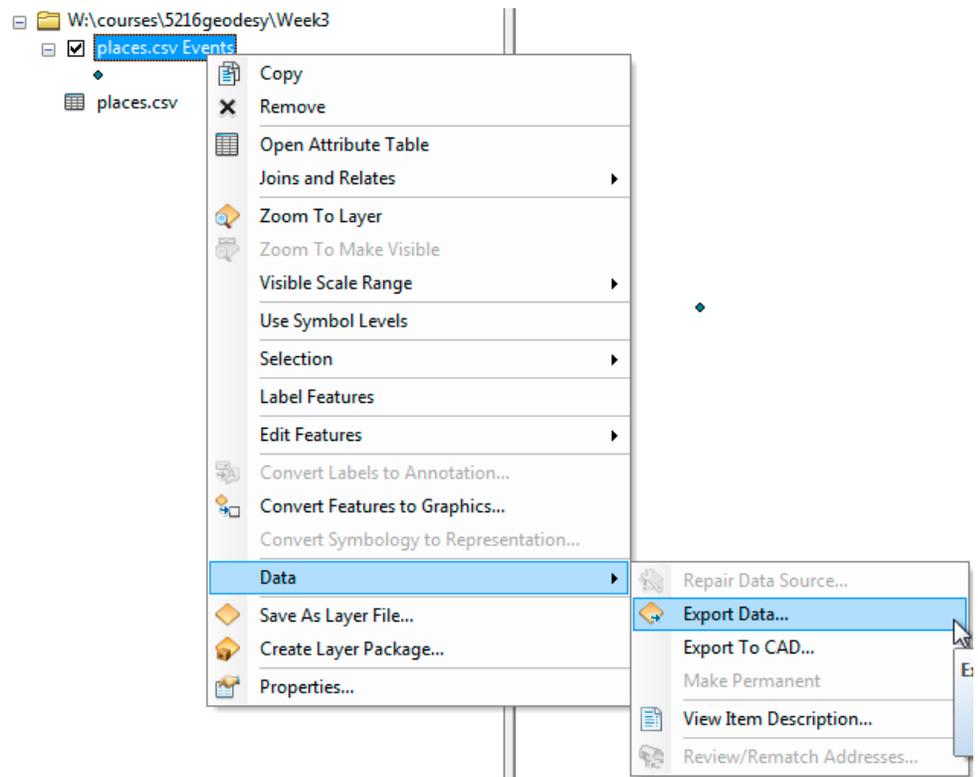


This opens the window at left, with choices for x, y, and the coordinate system. Make long the x, lat the y, and Edit the coordinate system to select the ITRF2008 geographic coordinate system for output, under geographic - world, then selecting from the ITRF

This should create a layer, here named *places.csv Events* (see at right)

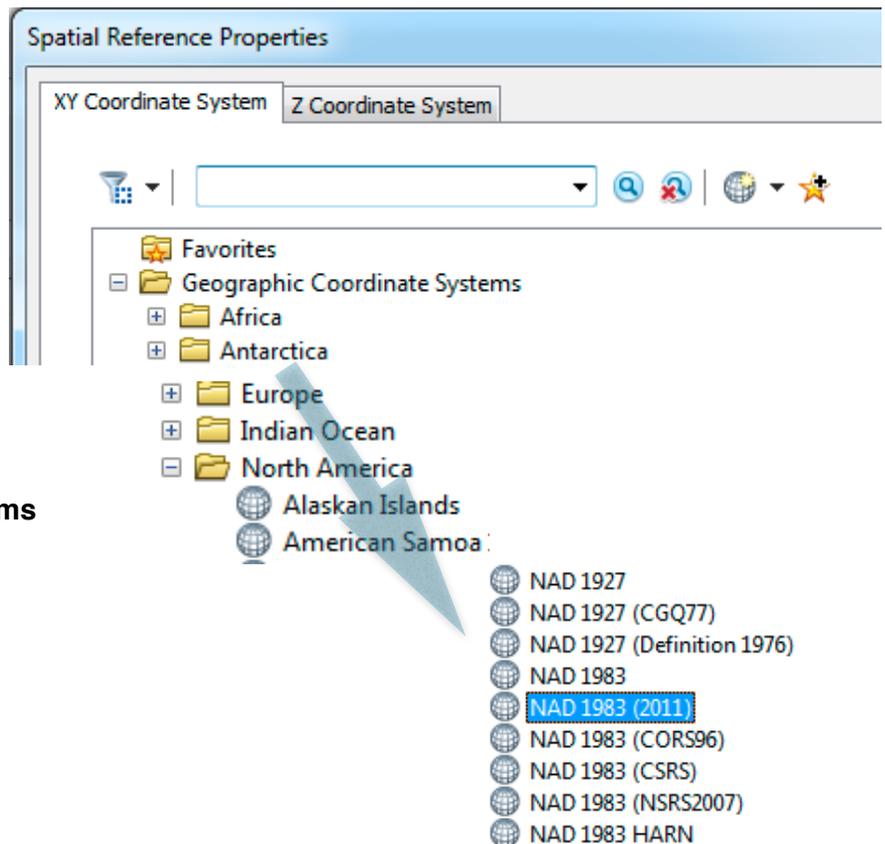
Right click on this new event layer, and **Export Data** to a new shapefile.

Display and label the points, and verify that they are in the proper relative locations.



Open the **Project** tool in the ArcMap toolbox, and project the point shapefile to the

NAD1983(2011) geographic coordinate system

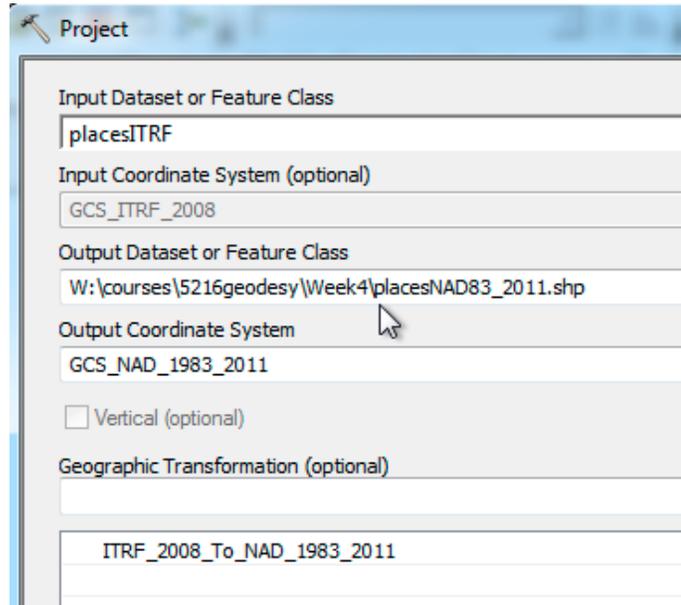


You'll find the output coordinate system under

- Geographic Coordinate Systems
- North American
- NAD1983 (2011)

Your projection panel should look something like this before you execute it.

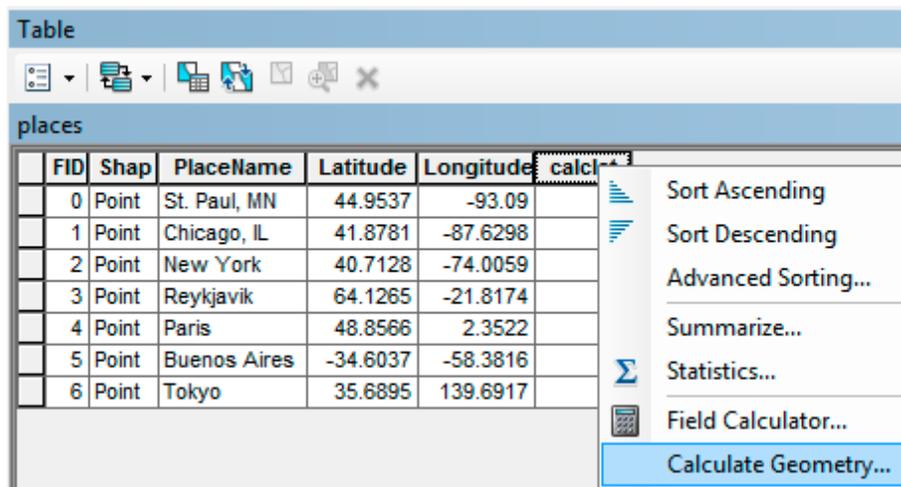
You're applying the 3D datum transformation we've talked about, from ITRF2008 coordinates to NAD83(2011) coordinates, for the shapefile's points.



After the projection completes successfully, open the data table for the projected, 2011 data layer.

You should see a couple of organizing columns, then the place name, then the ITRF2008 lat and long you entered.

Click on the **Table options** icon in the upper left of the  table, add two new fields named something like 2011lat and 2011 long, that are double, with a precision of 14 and a scale of 8, and calculate the lat and long values by right clicking on the appropriate column, and **calculating geometry** (see panel below).



Verify you get values similar to the figure below (my 2011 coordinates are named 2011lat and 2011lon):

FID	Sha	PlaceName	Latitude	Longitud	2011lat	2011lon
0	Point	St. Paul, MN	44.9537	-93.09	44.953692	-93.089992
1	Point	Chicago, IL	41.8781	-87.6298	41.878092	-87.629794
2	Point	New York	40.7128	-74.0059	40.712792	-74.005899
3	Point	Reykjavik	64.1265	-21.8174	64.12649	-21.81742
4	Point	Paris	48.8566	2.3522	48.856593	2.352179
5	Point	Buenos Aires	-34.6037	-58.3816	-34.60368	-58.381606
6	Point	Tokyo	35.6895	139.6917	35.6895	139.691703

Export this table as a text file (**Table options**, **Export**, then select text when specifying output)

Use the spherical formula to calculate the great circle distance between the ITRF2008 and NAD83(2011) versions of these points (you did this for a spreadsheet in week 2) with an average earth radius of 6,371,000 meters, and an angle to radians conversion of 57.29577957, or use the radians function in Excel.

Note that you should preserve at least nine digits to the right of the decimal for the DD latitudes and longitudes in your calculations, to avoid rounding errors when you do the calculations. Do this for all calculations in parts 1 through 4.

Finally, convert the output meters (same as earth radius units) to centimeters, and enter the shift to the nearest centimeter into a table with the data that is shown in the figure above.

Your shifts should be between about 25 and 200 centimeters.

Turn in a table like the one above (can be a spreadsheet), with the added centimeter datum shift column.

ArcMap is applying the $X' = T + xRX$ equation that we've gone over in class for this datum transformation. They use the T and R matrix values published in the Snay and similar papers we've read in class, and for every coordinate in a data set, convert them to lat/lon if they aren't already in lat/lon, and apply the equations. All the ITRF and WGS84 to NAD83 family of datum transformations in ArcMap are applying this kind of equation. It is just the Ts and Rs that vary slightly depending on the version of the ITRF datum (e.g., 2000, 2004, 2007, 2008, etc.), and the version of the NAD83 (e.g., 1986, 1996, 2007, 2011).

Part 2: Datum shifts using the HTDP software, ITRF(2008) to NAD83(2011)

We will use the HTDP software from the US NOAA/NGS website to calculate the same shifts as in part 1, but only for the points in the U.S., plus Los Angeles. For convenience, I've converted them to DMS format, required for HTDP input, shown below with latitude (all north) then longitude (all west).

StPaul = 44 57' 13.32", 93 05' 24.00"
 Chicago = 41 52' 41.16", 87 37' 47.28"
 New York = 40 42' 46.08", 74 00' 21.24"
 Los Angeles = 34 03' 7.92", 118 14' 37.32"

HTDP is also applying the $\mathbf{X}' = \mathbf{T} + \mathbf{xRX}$ equation that we've gone over in class for this datum transformation.

The URL for HTDP is:

http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp_transform.html

We want to convert from WGS84/ITRF2008 to NAD83(CORS96/2007/2011).

Use the interactive HTDP tool to transform position between two reference frames or dates. The tool is a bit fiddly, so you may have a few attempts before you get the formatting correct.

Your answers may vary slightly from the ArcMap output in Part 1, as the epochs (times of calculation) are different, and there is some fit difference from point to point.

Set the start and stop epoch of 1/1/2008. Specify a zero height for Z. Note that W longitudes are entered as positive numbers. Note that you have to be careful in entering the coordinates in HTDP. They need to have the same number of digits to the right of the decimal place for all entries, and a decimal value of Z, e.g., 0.0

You should compute and record the ground distance for latitude and longitude on the Earth's surface, again using the great circle distance formula, spherical approximation, with a radius of 6,371,000 meters, and enter the angle in radians. Remember to convert your shift distance answers from meters to centimeters.

Enter your shifts in a table similar to part 1, with a column for the point name, latitude and longitude in ITRF, latitude and longitude in NAD83(2011), and the great circle calculated datum shift in centimeters.

3. Conversion between NAD83 versions using the NADCON 5 software

Use the NADCON5 software, available at the NGS website:

<https://www.ngs.noaa.gov/NADCON5/index.shtml>

to calculate the position shift due to the datum transformation for our U.S. points from NAD83(1986) to NAD83(2011). Coordinates are provided below in decimal degrees:

Point	Latitude	Longitude
St Paul	44.9537	-93.09
Chicago	41.8781	-87.6298
New york	40.7128	-74.0059
Los aAngeles	34.0522	-118.2437

NADCON5 uses a grid-based solution, as do most of the shifts between the NAD83 family of datums.

As with the previous parts, convert the shifts to a surface distance, using the spherical great circle distance approximation, with an average earth radius of 6,371,000 meters, and an angle to radians conversion of 57.29577957.

Make sure to convert the datum shift values to centimeters.

Compare the shifts due to changes within the U.S. NAD83 datum family to the shifts between the ITRF2008 and NAD83(2011) datums you calculated in parts 1 & 2.

A note on NADCON5, it is a beta version, so may be a bit slow, erratic, or crash. It seemed to work better with the Windows Explorer and Firefox browsers than Safari and Opera, but that is on a Mac, so perhaps it may not be the same in the MS Windows operating system. Have patience, and let me know if you have issues.

4: Datum shifts for NAD83(2011) through time

Here we're looking at how the coordinates have shifted through time, due to both plate movements and due to recalculations of positions.

Use the HTDP software from the US NOAA/NGS website to calculate the shift through time for the points below. Again, the URL for HTDP is:

http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp_transform.html

This does not use the same $\mathbf{X}' = \mathbf{T} + \mathbf{sRX}$ equation to transform between time, but rather it also includes the changes in the R values through time. This is a similar model to our $\mathbf{X}' = \mathbf{T} + \mathbf{sRX}$, but adds an additional matrix that represents the average velocity of each parameter due to plate tectonics, so it gives an estimate of position shifts since measurement.

Use the same positions as in parts 2 & 3, here expressed as DMS, the preferred format for HTDP:

StPaul = 44 57' 13.32", 93 05' 24.00"
Chicago = 41 52' 41.16", 87 37' 47.28"
New York = 40 42' 46.08", 74 00' 21.24"
Los Angeles = 34 03' 7.92", 118 14' 37.32"

Use the tool to interactively transform position between two dates for the NAD83(2011) data frame. Set the start epoch of 1,1,1986 and the stop epoch of 1,1,2017. Specify a zero height for Z. Note that W longitudes are entered as positive numbers. Note that you have to be careful in entering the coordinates in HTDP. They need to have the same number of digits to the right of the decimal place for all entries, and a decimal value of Z, e.g., 0.0

You should compute and enter the ground distance for latitude and longitude on the Earth's surface. As above, use the great circle distance formula, with a value of 6,371,000 meters for the earth radius, and enter the angle in radians. Remember to convert your shift distance answers from meters to centimeters.