COA 690 / 790 GIS in Marine Science

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Lab 2: Understanding coordinate system

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Exercise 1: Determine and assign coordinate systems

You need to use datums.zip in this exercise.

When a dataset has no coordinate system information (or the information is wrong) the data is almost unusable. You might be able to draw, symbolize, and label the layer, but you can't make valid measurements or comparisons to other layers.

When you come across data like this, you try to find out about it. You look for metadata files in the same folder or nearby folders. You look for any .txt, .xml, .prj, or readme files that might contain coordinate system information. You look for the CD that contains the data or the Web site from which it was downloaded. You ask coworkers if they know of any files or hard copy documentation.

In this exercise, you'll work with two datasets that have no coordinate system information. First you'll determine their coordinate system, then you'll use ArcGIS to add this information permanently to each data source.

Step 1 Find the coordinate system information for the streets shapefile

Suppose you have data and you don't know its coordinate system. For many of you, this may not be too hard to imagine.

The first data source you want to work with is named Streets. You go to a coworker who tells you that your company documents each piece of GIS data it uses in a logbook. You get the book, look up Streets, and find out that it originally came from the U.S. Census Bureau shapefile and has been in use for years. The logbook also tells you that the Geographic Coordinate System (GCS) is NAD27.

Given this information, you can now use ArcCatalog to define the spatial reference for this shapefile.

Step 2 Start ArcCatalog and copy the streets data

If necessary, start ArcCatalog.

To be on the safe side, you'll make a copy of the shapefile and leave the original one alone.

In the ArcCatalog tree, navigate to the **AssignCS** folder within your module folder, (e.g., **…\Datums\AssignCS**).

Copy **Streets27NoPrjFile.shp** to your **MyWork** folder and rename it **Streets.shp**.

Step 3 Assign a spatial reference

In the catalog tree, right-click Streets.shp and choose Properties.

For ArcGIS 9.2 and 9.3 users, click the X,Y Coordinate System Tab.

Click Select.

In the Browse dialog box, open the **Geographic Coordinate Systems** folder then the **North America** folder.

Click **North American Datum 1927.prj** to select it.

Click Add.

The coordinate system is now set to GCS_North_American_1927.

Click OK in all open dialog boxes.

The Streets shapefile now has an additional file called Streets.prj that contains its coordinate system information. Next, you will locate and examine this file.

Step 4 Examine spatial reference metadata

Open Windows Explorer and navigate to your module **MyWork** folder, (e.g., **…\Datums\MyWork**).

The shapefile is composed of seven files with different extensions. You just created the Streets.prj file when you defined the spatial reference in ArcCatalog.

In the Windows Explorer tree, click the **AssignCS** folder.

Streets27NoPrjFile has all the same files as Streets, except that it has no .prj file.

The Hydrants shapefile also has no .prj file.

Step 5 Look at a .prj file

In the Windows Explorer tree, click the **MyWork** folder. In the display (right-hand panel), right-click **Streets.prj** then click Open With or Open.

If you see a message warning you that Windows cannot open the file, click the "Select the program from a list" option and click OK.

In the Open With dialog box, choose a text editor like WordPad or Notepad, but make sure that the "Always use this program…" box at the bottom of the dialog box is unchecked.

Click OK.

A .prj file is a text file. In this one, you see one long line formatted to store the parameters of the Streets GCS: the datum (which includes the spheroid), the prime meridian, and the angular unit of measure.

Now when you add the Streets shapefile to a map, ArcMap can read this .prj file to determine the coordinate system.

Close the Streets.prj text file window.

Next you'll turn your attention to the Hydrants shapefile.

Step 6 Add the Hydrants layer to ArcMap

If necessary, start ArcMap and open a new map document. From the View menu, choose Data View.

Click the Add Data button, navigate to the **AssignCS** folder within your module folder (e.g., **…\Datums\AssignCS**), and add **Hydrants.shp**.

If you get a warning message, click OK.

Open the Data Frame Properties dialog box and click the Coordinate System tab.

The coordinate system of the data is unknown. A note tells you that the data cannot be projected.

Click Cancel on the Data Frame Properties dialog box.

Once again, you're working with undefined data. This time, however, when you go to the GIS logbook, the dataset isn't listed—it's too new. None of your coworkers know what the coordinate system is, but someone suggests that maybe the data came from the city fire department.

You call the fire department and learn that some university students were involved in a project using GPS units to digitize the city's newest fire hydrant installations. Unfortunately, the students and their professor have since moved on without leaving any way to reach them.

You don't have metadata. You can't contact the data provider. Your last resort is to examine the data itself and try to identify its coordinate system. To do this, you'll add a different dataset that covers the same geographic area and project it into a projected coordinate system (PCS) you want to test. If the coordinates match, you've found the right PCS.

Step 7 Examine coordinates for the hydrants layer

In the ArcMap display, move your mouse over a fire hydrant and read the coordinates in the status bar.

You see x-coordinates over 400,000 and y-coordinates over 3,700,000. These are definitely not latitude-longitude coordinates.

Now you have to do some investigating to compare these numbers with numbers in some of the more common projected coordinate systems used by your organization.

Step 8 Insert a data frame and set its spatial reference

The most commonly used coordinate system in your organization is the State Plane Coordinate system, specifically the NAD27 version.

In ArcMap, from the Insert menu, choose Data Frame.

Right-click anywhere in the empty ArcMap display and click Data Frame Properties or Properties. In the Data Frame Properties dialog box, click the Coordinate System tab.

In the Select a coordinate system pane, click the **Predefined** folder, the **Projected**

Coordinate Systems folder, the **State Plane** folder, and the **Nad 1927** folder.

Scroll down and click **NAD 1927 State Plane California V FIPS 0405**. (This zone covers Kern, Los Angeles, San Bernardino, San Luis Obispo, and Ventura counties in southern California.)

Click OK to close the Data Frame Properties dialog box.

The ArcMap display doesn't look any different because there's still no data in the data frame.

Step 9 Add a layer to the data frame

Click the Add Data button, navigate to your module **MyWork** folder (e.g., **C…\Datums\MyWork**) and add **Streets.shp**.

Move your mouse over the display and note the coordinates in the status bar.

The x-coordinates are in the range of 2,200,000 and the y-coordinates are around 200,000. These numbers do not match the coordinates of the Hydrants layer (around 1,000,000 for the x-values and 3,700,000 for the y-values).

You can be sure that this is not the correct PCS. The second most common PCS that your organization uses for data in your area is the Universal Transverse Mercator system—specifically, UTM Zone 11 North.

Step 10 Change the spatial reference

Open the Data Frame Properties dialog box and click the Coordinate System tab, if necessary.

In the Select a Coordinate System pane, click the **Predefined** folder, the **Projected Coordinate Systems** folder, then the **Utm** folder.

Here there are several choices. Remember that in this situation you're picking not only a PCS but also a GCS. You'll pick WGS84 because it is the datum typically used by GPS units, and that is how the hydrants data was collected.

Click the **WGS84** folder then click **WGS 1984 UTM Zone 11N**.

Click OK on the Data Frame Properties dialog box.

A warning message displays.

Click Yes on the warning message to apply the new coordinate system.

Move your mouse over the display and note the coordinates in the status bar.

This time the x-coordinates are about 480,000 and the y-coordinates are near 3,700,000. These numbers are almost identical to those for the Hydrants layer. You have a match.

In Step 4, you used ArcCatalog to assign a GCS to the Streets shapefile. For the Hydrants layer, you will now define both a GCS and a PCS.

Question: Did you pick the right GCS when you chose WGS84? What if you choose NAD27, NAD83?

Step 11 Copy the Hydrants shapefile

Exit ArcMap without saving your changes.

Exiting ArcMap releases a hold on the Hydrants shapefile. You have to do this in order to assign the spatial reference in ArcCatalog.

Make ArcCatalog active. In the Catalog tree, open the **AssignCS** folder in your module folder.

Copy the **Hydrants** shapefile to your module **MyWork** folder. You don't have to rename it. (If you need instructions for copying, refer to Step 2.)

Step 12 Assign a spatial reference to the data

In the Catalog tree, right-click the copied shapefile (the **MyWork** folder should be selected in the tree) and choose Properties.

ArcGIS 9.2 and 9.3 users: Click the X,Y Coordinate System tab.

Click Select.

In the Browse dialog box, open the **Projected Coordinate Systems** folder, then the **Utm** folder, then the **Wgs 1984** folder.

Click **WGS 1984 UTM Zone 11N.prj**.

Click Add.

The coordinate system name and details appear in the Spatial Reference Properties dialog box. Note that the Details box contains both the PCS information (projection name and parameters) and the GCS information (angular unit, prime meridian, and datum).

Click OK in all open dialog boxes.

The shapefile now has an extra file called Hydrants.prj that contains its coordinate system information. If you want, you can confirm this in Windows Explorer.

In this exercise, you created .prj files in ArcCatalog for two shapefiles. These operations are permanent when you complete them.

In the next exercise, you will use the Streets shapefile, the Hydrants shapefile, and a new Parcels shapefile. Each of them will have a different GCS, so you will get to see how datum transformations work.

Close ArcCatalog.

Exercise 2: Transform coordinate systems

You need to use datums.zip for this exercise.

A new data frame has no coordinate system. When you add your first layer to it, the data frame takes on that layer's coordinate system. For any subsequent layers that you add, one of two things happens. If the new layer's coordinate system already matches the data frame, the layer is added without question. If the new layer's coordinate system is different, you get a Geographic Coordinate System (GCS) warning and ArcMap changes the coordinate system of the new layer to match the existing one. This operation is called a datum transformation (or coordinate system transformation). For all new layers that you add, ArcMap does these transformations automatically so that layers with different GCSs can be displayed together. (The transformations are done "on the fly," meaning they are applied only inside the data frame; the GCSs of the datasets on disk are not changed.)
It's great that ArcMap does datum transformations for you, but complications arise because there may be multiple versions of a transformation. For example, ArcMap has several formulas that convert from NAD27 to NAD83. Each works best for a particular region.

Similarly, there are over 20 different transformations from NAD27 to WGS84.

For each datum transformation, ArcMap has to pick a default formula. For the NAD27 to NAD83 transformation, it uses NAD_1927_To_NAD_1983_NADCON, which is optimized for the continental United States. If your data happens to lie in Alaska or Canada, your features may still not line up properly until you override the default transformation and pick the optimal one. The default NAD27 to WGS84 transformation is NAD_1927_To_WGS_1984_1, which is the optimal transformation only for Caribbean data.
In this exercise, you will see how ArcMap applies its default datum transformations and you will learn how to change these settings.

Step 1 Start ArcMap and add a layer

Start ArcMap and open a new map document.
Click the Add Data button, navigate to the **TransformCS** folder within your module folder (e.g., **…\Datums\TransformCS**) and add **Streets.shp**.

Step 2 Check the data frame's coordinate system

Open the Data Frame Properties dialog box and click the Coordinate System tab.
The coordinate system is set to GCS_North_American_1927.
Click the Transformations button.

Since the data frame has only one layer, the "Convert from" and "Into" datums are the same and no transformations are listed in the "Using" box. If you know the transformation you

want, you can set it up ahead of time; otherwise, you can let ArcMap apply a default transformation.

In the next step, you'll add a layer with a NAD83 GCS and let ArcMap set the datum transformation.
Click Cancel on the GCS Transformations dialog box and on the Data Frame Properties dialog box.

Step 3 Add a second layer with a different GCS

Click the Add Data button. Navigate, if necessary to the **TransformCS** folder and click to add **ParcelsNAD83GRS80**.
A warning message tells you that the new layer's GCS is different from the data already in the map. It also tells you that you may need to change the geographic transformation in order to avoid alignment problems.
Click Close or OK on the warning message.

You need to zoom in to see the parcels.

In the table of contents, right-click the parcels layer and click Zoom To Layer. That brings you a bit too close.
In the map scale box, type **8000** and press Enter.

Although the two layers have different GCSs, they align nicely. It looks like ArcMap picked the best available datum transformation. Now you'll take a look to see which one it is.

Step 4 Check the datum transformation

Open the Data Frame Properties dialog box, click the Coordinate Systems tab, if necessary, then click Transformations.

In the GCS Transformations dialog box, both GCSs found in the data frame are listed.
Click GCS_North_American_1983, the GCS of the Parcels layer.

ArcMap has transformed the NAD83 datum to NAD27 using the NAD_1927_To_NAD_1983_NADCON formula. As you may have seen in the exercise introduction, this transformation is optimized for the continental United States and is therefore the best choice for your southern California data.
Click the Using drop-down arrow to see all the available transformations.
Some of them have descriptive names, but others don't. Later in this exercise, you'll learn how to use a table that helps you find the best transformation for your area of interest. You should always confirm that you are using the optimal transformation—even when you don't notice alignment problems in your data display.

Click Cancel on the GCS Transformations dialog box and on the Data Frame Properties dialog box.

Step 5 Add a third layer in still another GCS

Click the Add Data button. Navigate, if necessary, to the **TransformCS** folder and add **Hydrants**.
Again, click Close or OK on the GCS warning message.
The hydrant points show up, but not in the correct locations. Each fire hydrant should lie inside a parcel and near its edge. These hydrants are shifted to the left by about four parcel lengths. What went wrong? ArcMap's default datum transformation is probably not the optimal one.

Step 6 Check the datum transformation

Open the Data Frame Properties dialog box, click the Coordinate Systems tab, if necessary, and click the Transformations button.
In the Convert from pane, click GCS_WGS_1984 (the GCS of the hydrants layer).
The default transformation applied by ArcMap is either listed as None or as NAD_1927_To_WGS_1984_1. In either case, the data is not in its correct location.

Click the Using drop-down arrow to see the other transformations.
There are over twenty. How do you know which one to use? If there were only a few, you could try them all, but with so many choices that would take a while.
Fortunately, ArcMap comes with a file called geographic_transformations.pdf that lists supported datum transformations and the areas for which they are optimized. This file has also been included in the datafolder “TransformCS” after you unzip datums.zip.

Step 7 Find the best transformation for your area

Open Windows Explorer.
In Windows Explorer, navigate to the **TransformCS** folder within your module folder (e.g., **…\Datums\TransformCS**).
Double-click **geographic_transformations.pdf** to open the file. You might need to click the Rotate Clockwise button to change the orientation of the document.

Navigate to page **34** of the document.
At the bottom of the page begins a list of transformations for North America. The left column shows the area for which the transformation is best suited and the right lists the transformation.
Scroll down to page 37 and locate United States (contiguous states west of Mississippi River) in the left column. The transformation for this region, and the one that therefore best fits your California data, is NAD_1927_To_WGS_1984_6. If the transformation is listed

twice, choose either one.

Step 8 Apply the new datum transformation

Close Adobe Reader and make ArcMap active.
In ArcMap, the Geographic Coordinate System Transformations dialog box should still be open. From the Using drop-down list, choose NAD_1927_To_WGS_1984_6.
Click OK on the GCS Transformations dialog box and on the Data Frame Properties dialog box.

It looks like the new transformation has fixed the problem. The fire hydrants have shifted to the right and appear to be positioned inside parcels.
But is everything really as good as it seems?

Step 9 Check your results

Click the Zoom In tool on the Tools toolbar. Zoom in on the fire hydrant in the bottom cul de sac (in the lower left corner of the parcels data). You may have to use the tool a few times to see that the hydrant is not really inside the parcel but out in the street.

Question: Why is this happening? Think hard, from data collecting process, parcel data quality to datum transformation.

Next, you'll identify how far you'd have to move the hydrant to get it back inside the parcel and off the street.
To make the measurement you should be zoomed in really close. Set your map scale to **1:100**.
On the Tools toolbar, click the Measure tool.
For ArcGIS 9.2 users, in the Measure window, set the Distance Units to Feet.
Click on the hydrant and then click inside the parcel to get a distance.

It is about one and a half to two feet from the hydrant to the edge of the parcel. So the hydrant points are still off by that amount. (It would be nice to have a precise air photo to compare positions, but this is a new subdivision and air photos don't yet exist for it.)

Step 10 Solve the problem

Getting back to the reason for the problem, take another look at the datum transformation.
Open the Data Frame Properties dialog box, click the Coordinate System tab, and click Transformations.
In the Convert From pane, click GCS_WGS_1984.
Note that the method is Geocentric Translation. This is a three-parameter transformation, which is a relatively low-accuracy transformation—especially when you're going from a

local datum to an earth-centered datum (because the origins of the two coordinate systems are far apart).
An easy solution would be to change the data frame's coordinate system so that the NAD_1927_To_WGS_1984_6 transformation doesn't have to be applied. You can do this by changing the data frame's GCS from NAD27 to NAD83. What does that do for you? First, it still lets you apply the very accurate NADCON transformation to align the streets and parcels. Second, it lets you transform between WGS84 and NAD83 (instead of between WGS84 and NAD27) to align the parcels and hydrants. This is an advantage because WGS84 and NAD83 are both earth-centered datums with similar specifications; consequently, this transformation is more accurate.
Click Cancel on the GCS Transformations dialog box.

Step 11 Change the coordinate system of the data frame

Make sure the Data Frame Properties dialog box is open and the Coordinate System tab is selected.
In the Select a coordinate system box, open the **Predefined** folder, then the **Geographic Coordinate Systems** folder, then the **North America** folder.
Scroll down and click **North American Datum 1983**.

Click OK on the Data Frame Properties dialog box. If you get a GCS warning, click Yes.
The hydrant has moved inside the parcel boundary, where it should be.

Step 12 Check your results again

Click the Measure tool, if necessary, and measure the distance from the edge of the parcel to the new location of the hydrant. It's about half a foot away.
If you like, check the locations of some other hydrants to make sure they are all within parcel boundaries.
Click Cancel on the GCS Transformations dialog box and on the Data Frame Properties dialog box.
It may seem like you used a little sleight-of-hand, but all you really did was take advantage of the fact that some datum transformations work a little bit better than others. Here are a few points to remember:

- Conversions between NAD27 and NAD83 are highly accurate because they use a grid-on-grid transformation method.
- Conversions between NAD83 and WGS84 are accurate because both datums are earth-centered and have similar specifications.
- Geocentric translations between local and earth-centered datums (like NAD27 and WGS84) may lack the desired accuracy at large scales.

Step 13 Save and close the project

From the File menu, choose Save As.

In the Save As dialog box, navigate to your module MyWork folder (e.g., **…\Datums\MyWork**). Name the file **myTransform** and click Save. Close ArcMap when you are finished.