GIS in Water Resources
Fall 2018
Homework #1 Solution

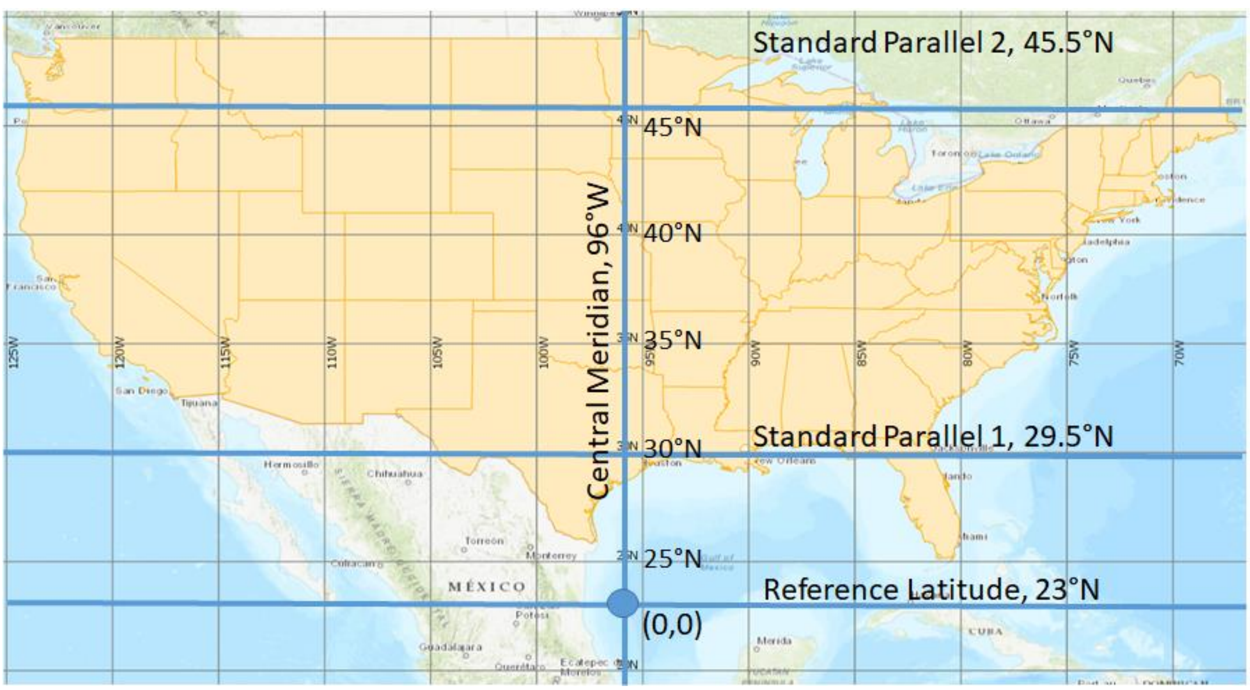
1. Coordinate System Parameters

The map below shows the continental United States in geographic coordinates overlaid by a grid which has 5° x 5° cells. The parameters of the USA Contiguous Albers Equal Area Conic USGS version coordinate system as displayed in ArcGIS are given below. Draw on the map above the Central Meridian, Reference Latitude, and Standard Parallels used in this coordinate system.

Solution:
Reading from the table on p.2, the projection parameters are:
Central Meridian: **96°W**
Reference Latitude (Latitude of Origin) **23°N**
Standard Parallel 1: **29.5°N**
Standard Parallel 2: **45.5°N**
These lines are drawn on the map below.

a) Put a large dot at the intersection of the Central Meridian and Reference Latitude on the map and label this with the (X,Y) coordinates that this location has in the given coordinate system.

Solution: The False Easting and False Northing are both 0 in this projection, so the (X,Y) coordinates at the origin of this projection are **(0,0).**



Coordinate System Details

Projected Coordinate System	USA Contiguous Albers Equal Area Conic USGS version
Projection	Albers
WKID	102039
Authority	Esri
Linear Unit	Meters (1.0)
False Easting	0.0
False Northing	0.0
Central Meridian	-96.0
Standard Parallel 1	29.5
Standard Parallel 2	45.5
Latitude Of Origin	23.0
Geographic coordinate system	GCS North American 1983
WKID	4269
Authority	EPSG
Angular Unit	Degree (0.0174532925199433)
Prime Meridian	Greenwich (0.0)
Datum	D North American 1983
Spheroid	GRS 1980
Semimajor Axis	6378137.0
Semiminor Axis	6356752.314140356
Inverse Flattening	298.257222101

b) What earth surface property does the Albers projection preserve regardless of the projection parameters?

Solution: Area

c) What earth datum is used with this coordinate system?

Solution: North America Geographic Coordinate System of 1983

d) The geographic coordinates of Salt Lake City are: 40° 45' 39" N and 111° 53' 28" W The coordinates of New York City are: 40° 42' 51" N and 74° 0' 22" W. Calculate the coordinates for each of these in decimal degrees. Express your answers using 5 digits following the decimal point.

Solution: The LatLong spreadsheet used for Exercise 2, is adapted for this problem:

SiteID	SiteName	Latitude	Longitude	LatDeg	LatMin	LatSec	LongDeg	LongMin	LongSec	LatDD	LongDD
1	Salt Lake City	40° 45' 39"	111° 53' 28"	40	45	39	111	53	28	40.76083	-111.89111
2	New York City	40° 42' 51"	74° 0' 22"	40	42	51	74	0	22	40.71417	-74.00611

For example, for Latitude of Salt Lake City: ϕ = 40+45/60+39/3600) = - 40.76083 and for Longitude of Salt Lake City: λ = -(111+53/60+28/3600) = - 111.89111. The results for both cities are:

Salt Lake City: (ϕ,λ) = (**40.76083, -111.89111**)
New York City: (ϕ,λ) = (**40.71417, -74.00611**)

e) Note that the latitude of Salt Lake City and New York City is almost the same. Assuming a spherical earth with radius 6371.0 km, calculate the distance in km that New York is East of Salt Lake City along a latitude parallel.

Solution:
If A is Salt Lake City and B is New York City, then the distance along a latitude parallel ϕ, is given by **AB = Re*Cosϕ*$\Delta\lambda$**. Re = 6371.0 km. Let's take the average of the two latitudes, **ϕ =** (40.76083 + 40.71417) / 2 = 40.73750 in decimal degrees = 40.73750 * (π/180) radians = **0.71100 radians**. Similarly, **$\Delta\lambda$** = -74.00611 – (-111.89111) **=** 37.88500° = 37.88500* (π/180) radians **= 0.66122 radians. AB =** 6371.0 *Cos(0.71100)*(0.66122) = **3191.9 km**.

f) Determine the distance that Salt Lake City is north of the Latitude of Origin (23°N) in km.

Solution:
If the Origin is O and Salt Lake City is A, then the distance **North on OA** is OA = **Re*$\Delta\phi$** where **$\Delta\phi$** = 40.76083 – 23 = 17.76083° = 17.76083* PI()/180 radians = 0.30999 radians. Hence distance North on OA = 6371.0 * 0.30999 = **1974.9 km**.

g) Calculate the great circle distance between New York and Salt Lake City in km assuming a spherical earth with radius 6371.0 km.

Solution:
The formula for great circle distance is shown below, as is a solution worked out in Excel, as explained in class.

$$Dist = R_e ArcCos[Sin\phi_A Sin\phi_B + Cos\phi_A Cos\phi_B Cos(\lambda_A - \lambda_B)]$$

Location	Point	Phi	SinPhi	CosPhi	Lamda	LA - LB	Cos(LA-LB)
Salt Lake City	A	0.7114	0.6529	0.7574	-1.9529	-0.6612	0.7892
New York	B	0.7106	0.6523	0.7580	-1.2917		
Parenthesis	0.879001						
Distance (km)	3166.601						

Great Circle Distance = 3166.0 km

h) Comment on the difference between the answers to (e) and (g) and the potential for fuel saving by airlines flying on great circle routes.

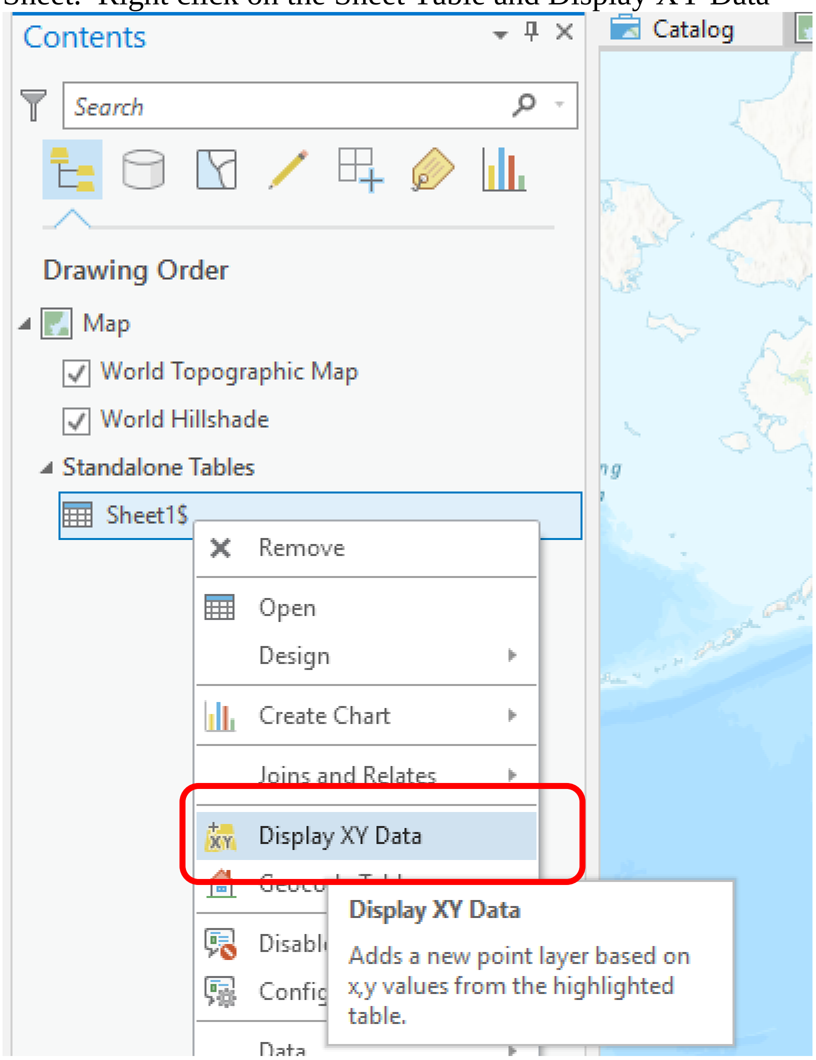
In this case, the Great Circle (g) lies almost along the parallel line used in part (e), so the difference in the distance between them = 3191.9 – 3166.0 = 25.9 km = 0.8% difference is quite small.

i) Use ArcGIS Pro to determine the precise coordinates of Salt Lake City and New York City in the USA Contiguous Albers Equal Area Conic USGS version coordinate system.

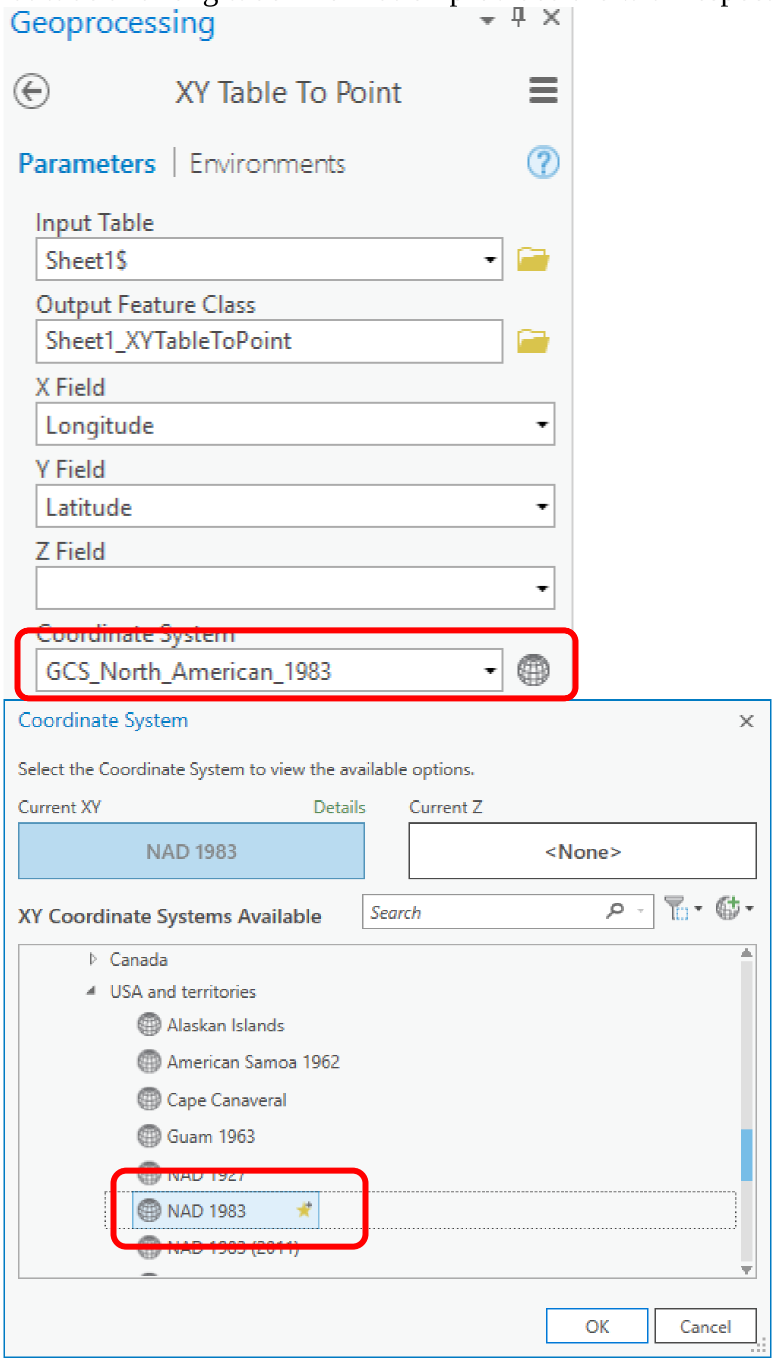
This can be done as follows
Use Excel to create a table with decimal degree Latitude and Longitude (This should be your answer to (d) above.

	A	B	C
1	Name	Latitude	Longitude
2	Salt Lake City	40.	-111.
3	New York City	40.	-74.

Open ArcGIS Pro and create a new project with a Map. Use Add Data to add your Excel Sheet. Right click on the Sheet Table and Display XY Data

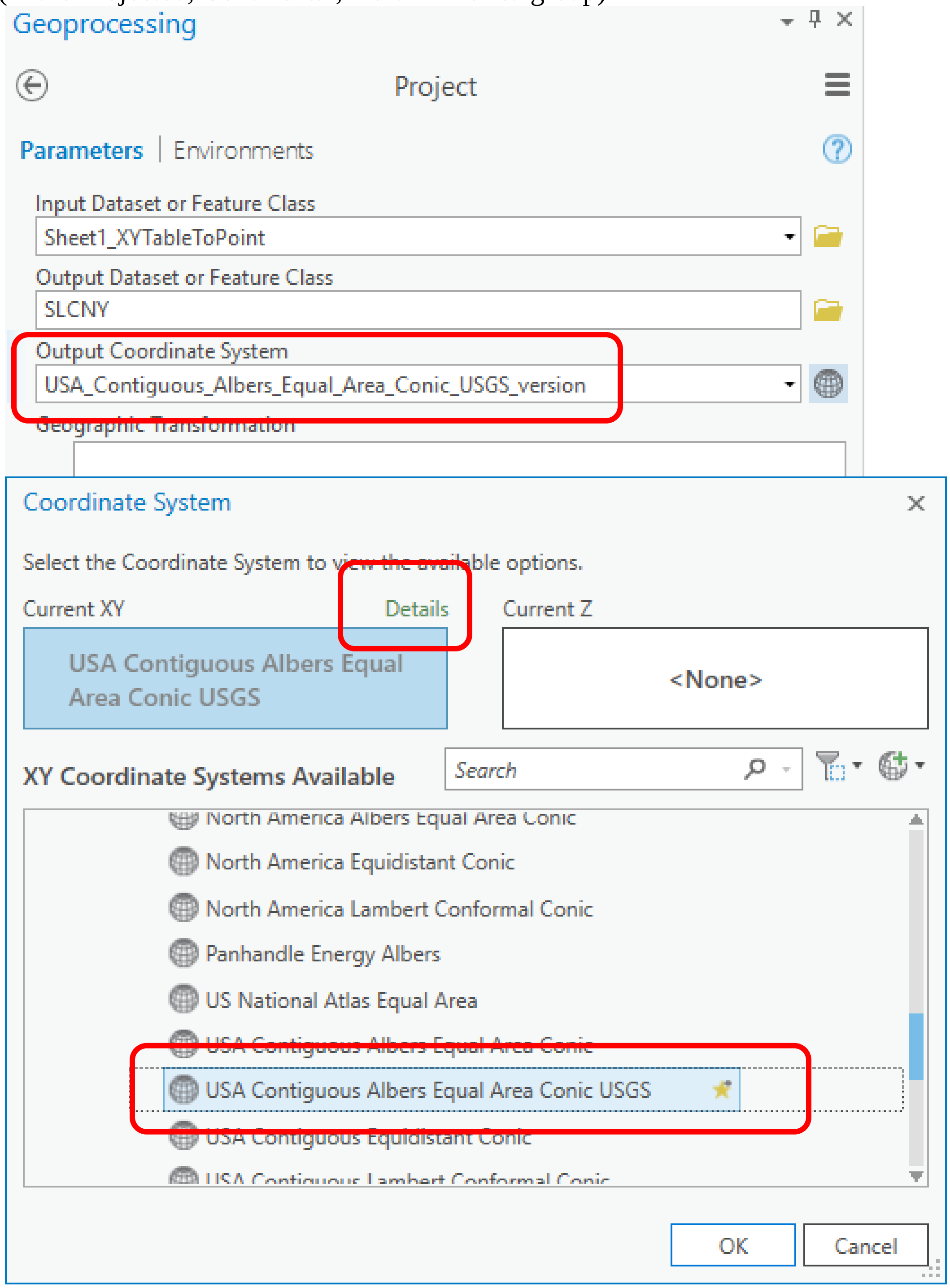


In the XY Table to Point Geoprocessing tool that opens set the Spatial Reference to NAD 1983 in the North America, USA and territories group. Here we are assuming the latitude and longitude information provided are with respect to the NAD 1983 datum.



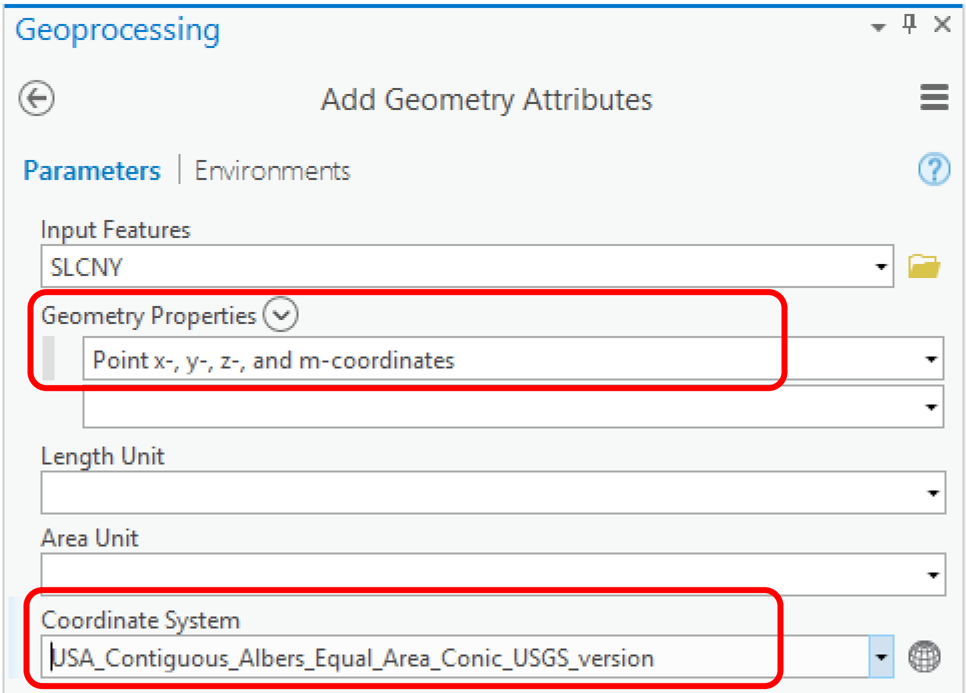
You should see two dots on your map, one for Salt Lake City and one for New York.

In Geoprocessing locate the Project tool and Project your Point Layer to a new Feature Class with USA Contiguous Albers Equal Area Conic USGS version coordinate system (in the Projected, Continental, North America group)



Click on Details for the coordinate system selected to verify that the details of this coordinate system are the same as specified above on page 2.

Locate the Add Geometry Attributes Tool and Run it for this Projected Feature Class

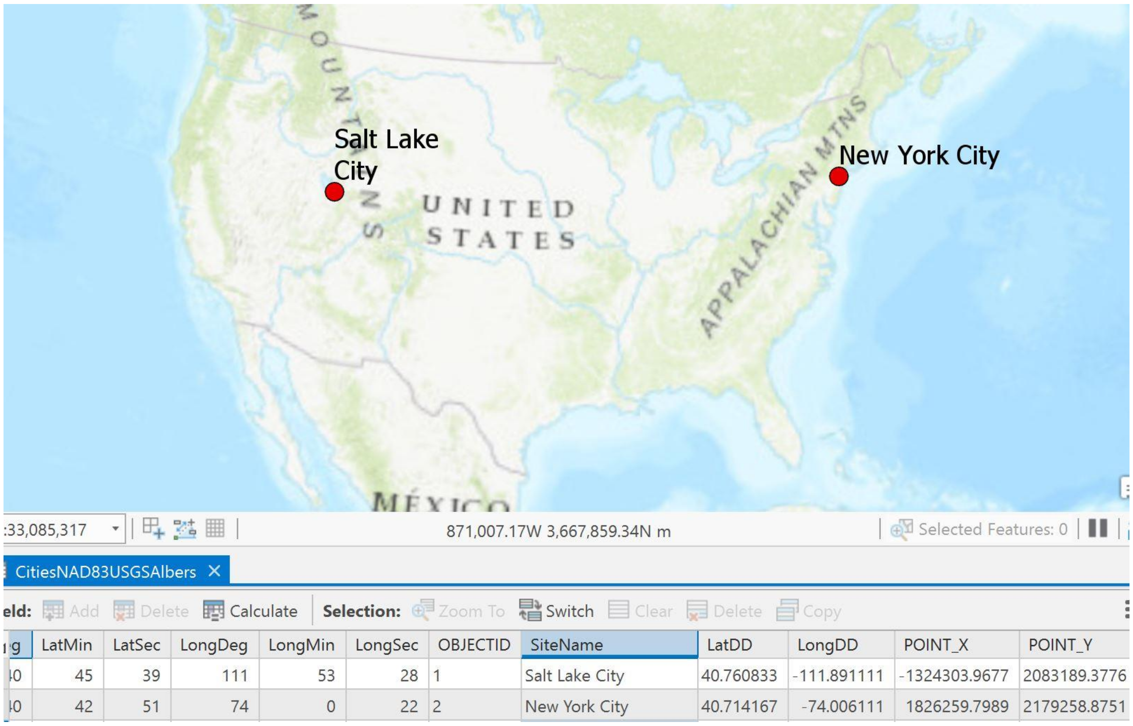


Open the attribute table of the Feature class and report the values of Point_X and Point_Y fields.

Solution: After following the instructions above, the map on the next page was created from which the coordinates are found from the Attribute table of the NAD 83, USGS Albers Projection as:

City	X-Coordinate (m)	Y-Coordinate (m)
Salt Lake City	**-1324304.0**	**2083189.4**
New York City	**1826259.8**	**2179258.9**

Table 1. Coordinates in USGS Albers Projection



j) Reconcile your answer to (f) with results from (i) and comment on any differences.

Solution:

The answer to question (f) was **1974.9 km**, as the distance that Salt Lake City is north of the Origin. The corresponding figure from part (i) is the Point_Y value of Salt Lake City, which is **2083.2 km.** The difference between these values is **108 km,** which is about a 5% difference. That is a fairly significant amount. The USGS Albers Equal Area Conic Projection preserves area but it is apparent that this leads to some significant distance distortion, especially over long distances.

k) Use the projected coordinates from (i) to calculate the distance from Salt Lake City to New York.

Solution:

Using Pythagoras Theorem with the coordinates below, and values to the nearest km

City	X-Coordinate (m)	Y-Coordinate (m)
Salt Lake City	**-1324304.0 (-1324.3 km)**	**2083189.4 (2083.2 km)**
New York City	**1826259.8 (1826.3 km)**	**2179258.9 (2179.3 km)**

$Distance = \sqrt{(1826.3 - (-1324.3))^2 + (2179.3 - (2083.2))^2}$ = **3152.1 km**

l) Explain why the distances from answers (e), (g) and (k) are different and provide a brief interpretation of these differences.

Solution:

The distances between Salt Lake City and New York City from the three solutions are given in the table below. The Great Circle distance is the value between the other two and because of the way it is calculated, it is probably the most reliable value.

Question	Method	Distance (Km)
(e)	Along the parallel	3191.9
(g)	Great Circle	3166.0
(h)	Projected to USGS Albers	3152.1

m) Noting that the UTM system has zones 6^o wide and are counted from zone 1 immediately east of the international dateline (-180^o to -174^o) with central meridian -177^o, determine the UTM zones for each of Salt Lake City and New York City.

Solution:

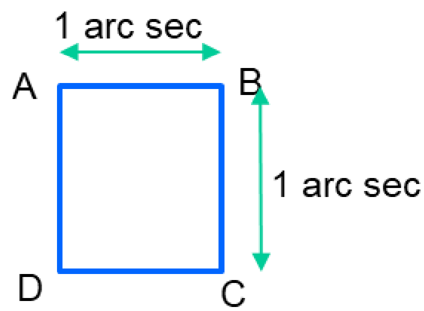
Starting at 180^{o}W and proceeding eastwards in 6^o decrements, means that (180 – 111.9)/6 = 11.35. This means we cross 11 complete zones and Salt Lake City lies in **UTM Zone 12**. Similarly for New York City, (180 – 74.0)/6 = 17.6. This means that New York City is in **UTM Zone 18.**

2. Sizes of DEM Cells

The National Map Elevation Products (3DEP) have data available at 1 arc-sec resolution for most of North America.

The geographic coordinates of UT Austin are: 30° 17' 10" N and 97°44' 22" W. The geographic coordinates of Logan Utah are: 41° 44' 45" N and 111° 48' 30" W 41.

Assuming the earth is spherical with a radius of 6371 km, determine the lengths of the lines AB and BC in meters at these locations.



Determine the area of a 1 arc sec grid cell in Logan and in Austin in m^2.

Solution:

Distance **AB = Re*Cosϕ*$\Delta\lambda$**

Distance **BC = Re*$\Delta\phi$**

In both cases, $\Delta\phi = \Delta\lambda$ = 1" = (1/3600)° = (1/3600) * π/180 = **4.848 x 10^{-6}**

Re = 6371.0 km = 6371000 m

The conversion of latitude and longitude to decimal degrees is given below:

City	LatDeg	LatMin	LatSec	LongDeg	LongMin	LongSec	LatDD	LongDD
Austin	30	17	10	97	44	22	30.28611	-97.73944
Logan	41	44	45	111	48	30	41.74583	-111.80833

For Austin, ϕ = 30.28611 * π/180 = 0.5286, Cos(ϕ) = 0.8635, **AB = Re*Cosϕ*$\Delta\lambda$** = 6371000 * 0.8635 * 4.848 x 10^{-6} = 26.67 m and **BC = Re*$\Delta\phi$ =** 6371000 * 4.848 x 10^{-6} = 30.89 m
The computations are done similarly for Logan, with results given in the table below.

City	**Distance AB (m)**	**Distance BC (m)**	**Area = AB*BC (m^2)**
Austin	**26.67**	**30.89**	**711.81**
Logan	**23.05**	**30.89**	**823.82**

The general conclusion to be drawn from this analysis is that 1 arc-second = 1” is approximately 30m, and that as the latitude moves north, the actual earth area covered by 1” x 1” Digital Elevation Models gets progressively smaller.