

## Lab 2 Coordinate Reference Systems (CRS)

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*The Lab material is based on course materials "Introduction to Geospatial Technology" from FOSS4G GeoAcademy curriculum (Creative Commons Attribution 3.0 Unported license).*

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### Before you start:

- 1) Create the folder on the local C:\Users\Your Name\Spatial Data Studio\Lab 2
- 2) Under the folder Lab\_2, create folders **original**, **working**, and **final**.
- 3) Download datasets for this lab session from Moodle (Lab\_2\_datasets.zip) and put them into folder **original**.
- 4) Unzip all the files and then delete zipped file to clean up space on the disk.
- 5) Copy all files to working and in the next steps only use files in the working folder.

### Introduction

In this lab, you will explore the effects of various map projections on the characteristics of a map using QGIS.

This lab will focus primarily on shape and area distortions and will examine projections useful for mapping on the global scale as well as on the national level.

This lab includes the following tasks:

- Task 1 – Setting map projections and coordinate systems in QGIS
- Task 2 – Exploring world map projections
- Task 3 – Exploring map distortions by measuring distances
- Task 4 – Defining and changing the coordinate system of the layers
- Task 5 – Exploring national map projections
- Task 6 – Exploring the Universal Transverse Mercator (UTM) coordinate system
- Task 7 – Independent task

### Objective: Explore and understand map projections and coordinate systems

The map projection is a fundamental part of the mapping process, and provides the backbone, or framework, for the map. It is important for the GIS specialist to understand the qualities of the mapped region that are preserved by a given projection, and the qualities that will be distorted or skewed. Additionally, for cartographers, selection of an appropriate map projection is a crucial part of the map design process. This is because we are all used to seeing different parts of the world mapped using specific standard projections that make these areas "look right".

The transformation of the ellipsoid shape of the earth onto a two-dimensional surface cannot be accomplished without some element of distortion, through shearing, tearing, or compression (as discussed in the text). For mapping small Earth areas (large-scale mapping), projection is not a major issue, but as the scale becomes smaller, as in the mapping of continents or subcontinents, distortion becomes a significant factor. Distortion of area, shape, distance, and direction become properties to consider. It is impossible for one projection to maintain all of these properties simultaneously.

Projections are classified according to the properties they preserve. Equal-area (or equivalent) maps, for example, preserve area relationships, but tend to lose conformality (preservation of shape). Conformal projections, on the other hand, maintain shape over small areas but produce areal distortion. In thematic mapping, it is important to maintain correct area properties. Therefore, shape is at times compromised through the choice of an equivalent projection. For small-scale maps, in fact, conformality cannot be maintained over the entire area; rather, the projection may preserve shape best along a standard line, with shape distortion increasing with distance from the line. Another property to consider is distance preservation (equidistance), which preserves distance measurements along great circle arcs. Finally, direction preservation maintains correct direction from one central point to all other points.

There are hundreds of possible projections from which to choose. Some distort less in certain ways than others. **It is up to the map designer to select the projection that produces the least amount of unwanted distortion.** Many computer mapping software packages now allow the GIS specialist to easily switch between various projections, allowing the choice of the one most appropriate. In the selection of a projection, several key elements must be considered:

- Projection properties – Are the properties of the projection suitable to the map's purpose? Considering the properties of shape, distance, direction, and area, which ones must be preserved, and which can be sacrificed? Or is a compromise of all four the best choice?
- Deformational patterns – Is the amount of deformation acceptable?
- Projection center – Can the projection be centered easily on the area being mapped?
- Familiarity – Is the appearance of the map recognizable to the map reader or will it detract from the map's purpose?

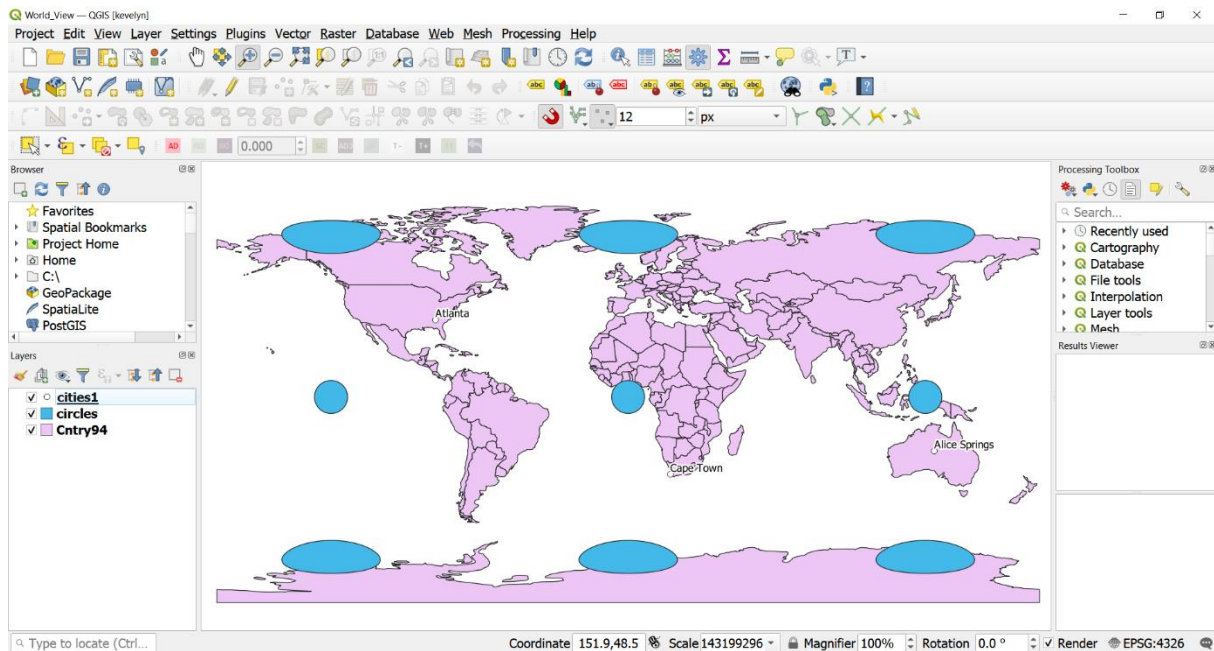
## Task 1 – Setting map projections and coordinate systems in QGIS

In this task, you will explore the effects of various projections on the characteristics of a map. We will focus primarily on shape and area distortions. We will examine projections useful for mapping on the global scale.

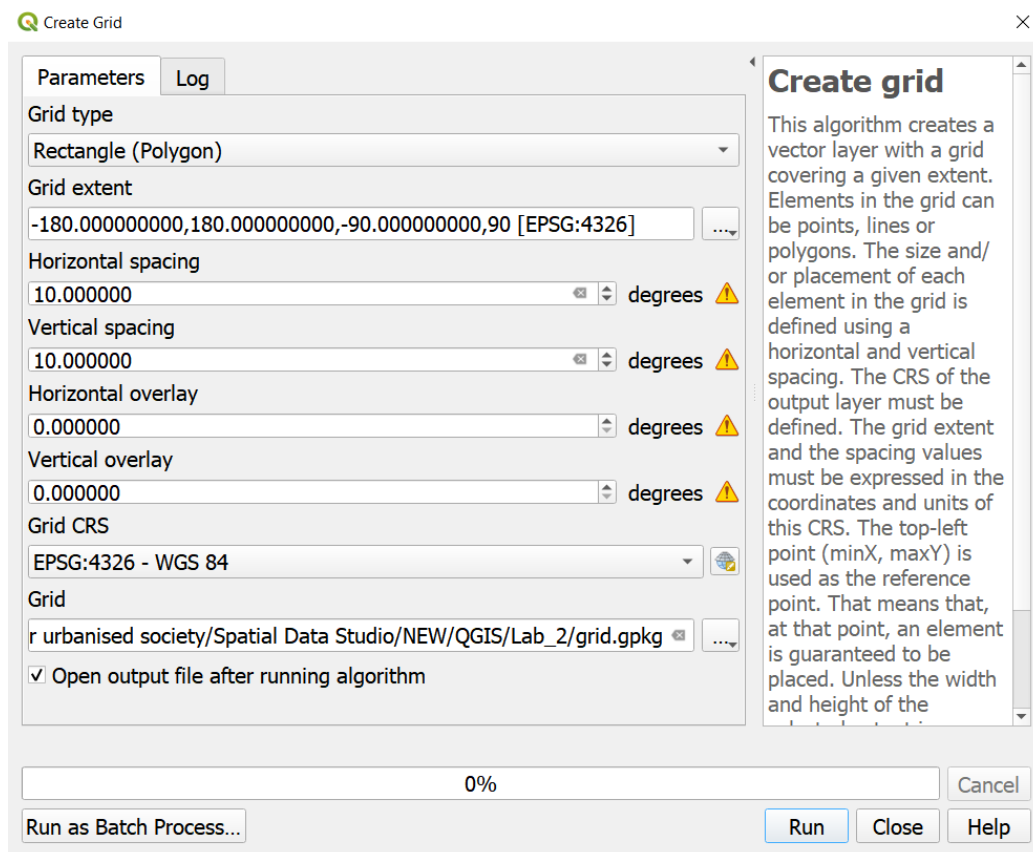
1. Open QGIS project **World\_View.qgz** by clicking Project → Open. You should see the map shown in Figure below. **World\_View.qgz** is a QGIS project file. You should have world countries, three cities (Atlanta, Cape Town and Alice Springs) and circles layer in the project open. The circles (Tissot's indicatrices<sup>1</sup>) will be used in this exercise for illustrating the areal and shape distortion that occurs with various projections. If these circles were displayed on a globe, they would be perfect circles.

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<sup>1</sup> In the nineteenth century, Nicolas Auguste Tissot developed a method to analyse map projection distortion. Small circles on the earth's surface are projected using different projection types. The resulting ellipse of distortion, or indicatrix, shows the amount and type of distortion at the location of the ellipse.

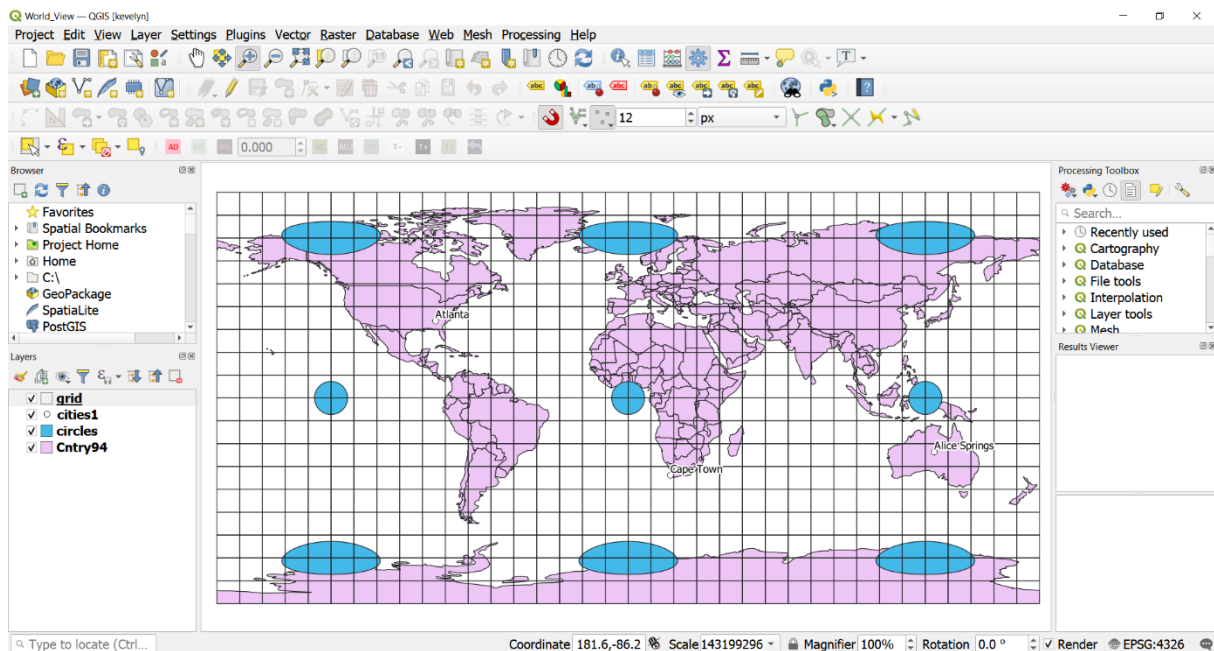


- To better visualise the effect of different projections, we will add graticule to the map. Use Create grid tool from the Processing toolbox to create a grid with 10\*10 degree spacing (see parameters on the figure below) and covering the entire globe.

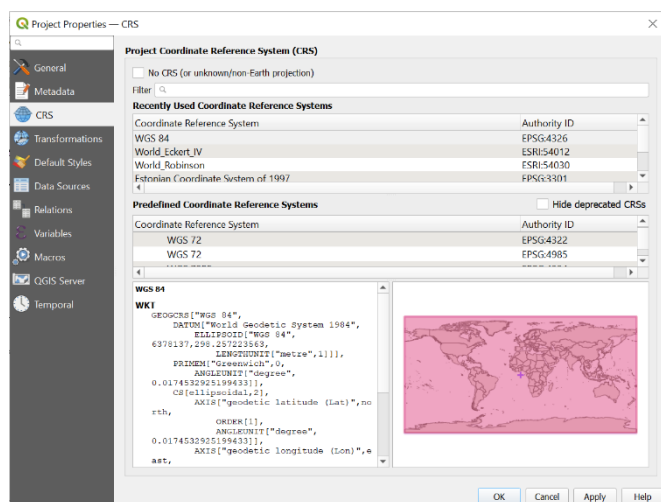


- You should now have grid covering the whole globe. As the grid consists of polygons then you should change the fill color to transparent to make it actually looking like graticule.

Change the grid fill colour transparent from the Symbology and you should have a result similar to this:



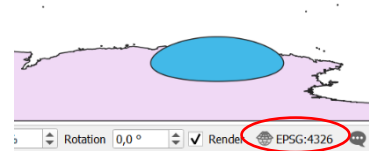
4. Check the Coordinate System of the Cities1, Circles and Cntry94 layers by right-clicking on the layer name and choosing Properties→Information (see CRS). What is the coordinate system of the layers?
5. Check the CRS of the current QGIS project's (qgz) from the status panel or from the menu Project→Properties→CRS. Notice that the map project's view's coordinate system is set to WGS 84. When QGIS is started with a new, empty map, the coordinate system for the project is automatically WGS 84. **But the first layer added to an empty project sets the coordinate system for the project (on-the-fly (OTF) transformation is used), but you can change it if necessary.** Another thing that you might notice is that WGS 84 is an **unprojected coordinate system** but you still see it as **plane** and not a sphere. Although a projection has not yet been chosen by the user, the display is essentially a Plate Carree projection **which is always used as default projection to display data that is in a geographic coordinate system** if a user




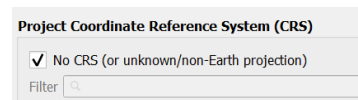
does not define otherwise. In a Plate Carrée projection<sup>2</sup>, linear scale, area, and shape are all distorted increasingly toward the poles as demonstrated with the Circles theme.


6. On-the-fly transformation enables to add subsequent layers so that they are automatically displayed using the project's coordinate system as long as the **data source's coordinate system is defined**. The map layer's CRS does not need to be the same as project's CRS. Let's try this out. Add from your working folder **estonia.shp**. Estonia should automatically nicely place to it's correct location. Check the CRS of **estonia.shp** and you should see that it is not WGS 84. Thanks to the OTF transformation you can see layers with different CRS in correct place, and for viewing and visualising the data this is fine. However, once you start to perform spatial analysis then it is better to have all the data layers in the same projection.

7. Let's remove the project's CRS by clicking on the CRS button in the lower ribbon. This will directly open Project's Properties' CRS tab. Check the "No CRS (or unknown/non-Earth projection)"<sup>3</sup> and click OK. On the ribbon there should



now be displayed "no CRS" symbol: . Remove the **estonia.shp** from the project and add it back again. What happened? Can you find Estonia? If not then use Zoom Full



. You can see that Estonia and world are not in correct size proportions nor location. This is because the project does not have any CRS and OTF can't take place. Switch on the project's CRS again to WGS 84 (EPSG 4326<sup>4</sup>) and Estonia should automatically shift to its correct location.

## Task 2 – Exploring world map projections

Let's examine couple of world map projections. The most common projection over the past centuries is Mercator. The Mercator projection was designed for marine navigation and gives all straight lines on the map as lines of constant compass bearing. For global scale thematic maps, however, the Mercator has too much areal distortion for accurate use.

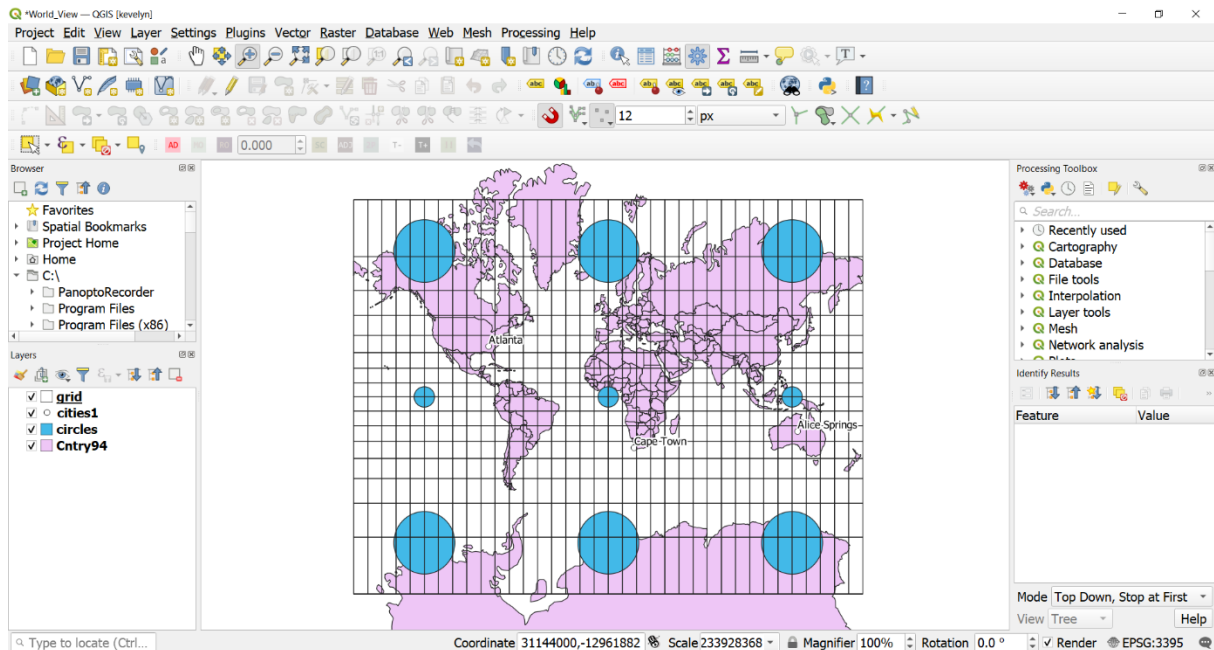
1. Let's change the project's CRS to the World Mercator projection (EPSG 3395) from the status bar lower right corner. Notice how your map changed. Your circles are now circles everywhere but the their size is considerably different. The Mercator projection, a conformal projection (except at the poles), has straight meridians and parallels that intersect at right angles. Scale is truest along the equator, and becomes more distorted at higher latitudes, as

<sup>2</sup> Also known as equirectangular, equidistant cylindrical, simple cylindrical, or rectangular, this projection is very simple to construct because it forms a grid of equal rectangles. Because of its simple calculations, its usage was more common in the past. In this projection, the polar regions are less distorted in scale and area than they are in the Mercator projection (ESRI). In particular, the Plate Carrée has become a standard for global raster datasets, such as Celestia and NASA World Wind, because of the particularly simple relationship between the position of an image pixel on the map and its corresponding geographic location on Earth (Wiki).

<sup>3</sup> Checking this setting will disable ALL projection handling within the QGIS project, causing all layers and map coordinates to be treated as simple 2D Cartesian coordinates, with no relation to positions on the Earth's surface. It can be used to guess a layer CRS (based on its raw coordinates or when using QGIS for non earth uses like role-playing game maps, building mapping or microscopic stuff. In this case: (1) No reprojection is done while rendering the layers: features are just drawn using their raw coordinates; (2) The ellipsoid is locked out and forced to None/Planimetric; (3) The distance and area units, and the coordinate display are locked out and forced to "unknown units"; all measurements are done in unknown map units, and no conversion is possible. Source: [QGIS Documentation](#)

<sup>4</sup> EPSG Geodetic Parameter Dataset (also EPSG registry) is a public registry of geodetic datums, spatial reference systems, Earth ellipsoids, coordinate transformations and related units of measurement. Each entity is assigned an EPSG code between 1024-32767, along with a standard machine-readable well-known text (WKT) representation. (Wiki) The EPSG codes are unique and they are very useful to use for searching and identifying the CRS-s in GIS programmes.

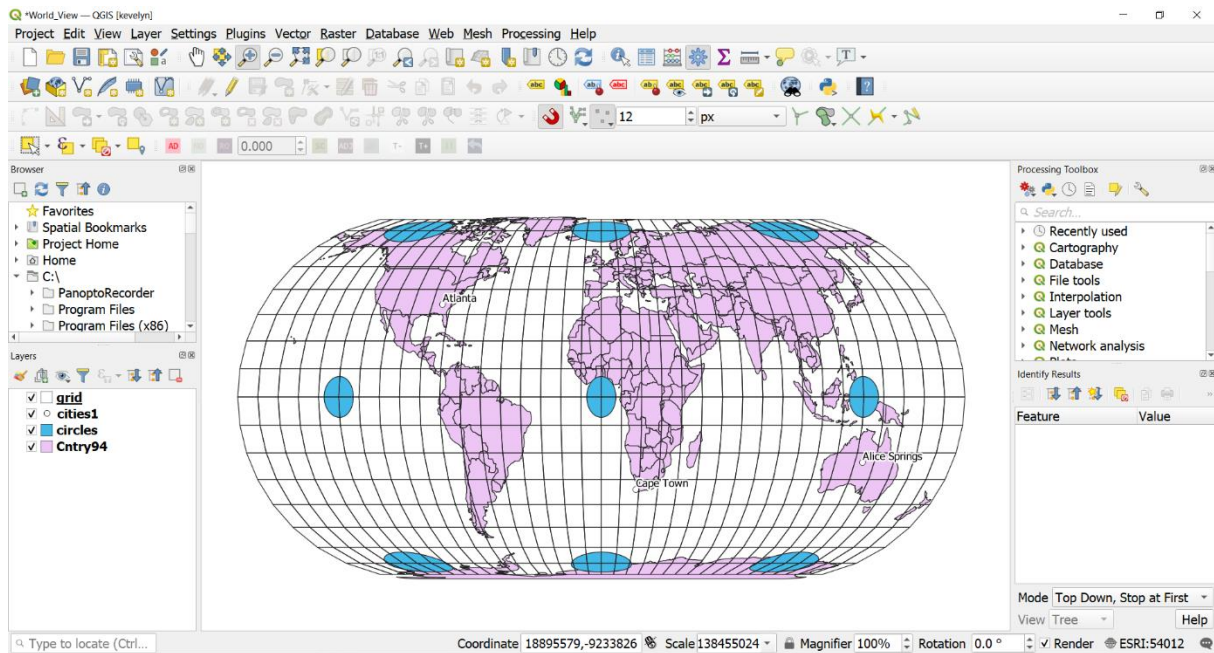
evidenced by the increasing size of the circles. The Mercator is best for larger scale maps<sup>5</sup> of areas at low latitude. Small-scale maps have much distortion of area and distance. The Mercator map is much less desirable for mapping continents than other projections as it **has significant distortion and can promote geographical misconceptions. In general, rectangular maps are not recommended for use in mapping the world.** Equivalency (the property of equal area) and conformality are better preserved using non-rectangular maps.



- Let's now explore a map projection more suitable for mapping the entire world: the Eckert IV projection. The Eckert IV map projection is an equal-area pseudocylindrical map projection with straight parallel latitude lines and equally spaced meridians. Change the CRS of the project to the Eckert IV projection (World\_Eckert\_IV ESRI: 54012). Notice how your map (graticule, circles) changed. How did the graticule change? What happened to the circles? The circles are not anymore circles but their area should be more or less the same. The Eckert IV is useful for world maps as it is equal-area and is pleasing to the eye. Its standard parallels are at 40° 30'N and 40° 30'S. This map is only distortion free where the standard parallels intersect the central meridian.

<sup>5</sup> A map is classified as small scale or large scale or sometimes medium scale. Large scale maps are usually 1:0 – 1:600 000 and represent for example town. Medium scale maps are usually 1:600 000 – 1:2 000 000 and mostly a whole country maps are in this range. Small scale maps are 1:2 000 000 – 1:∞ and world or regions are mapped in this scale. (Wiki)





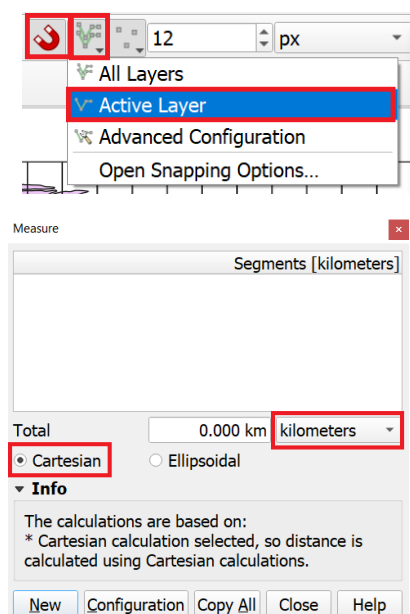


- Find another equal-area projection suitable for the whole world that is not mentioned in this tutorial or lecture. Change your project's CRS into selected map projection and create a map of your home country's **location in the world** and **add it to your independent task's report** (see Independent task in the end of this tutorial).

### Task 3 – Exploring map distortions by measuring distances

Now we will do some distance measurements on different CRS's to see how CRS affects the distances. We will measure distances between Atlanta, Cape Town and Alice Springs.

- First, switch make sure that your project's CRS is WGS 84 (EPSG 4326). If it is not then switch to WGS 84.
- Turn the snapping on from Snapping Toolbar by clicking on magnet button . If you don't have the toolbar opened, choose from the menu View→Toolbars→Snapping Toolbar and it should appear. Make sure that it's activated (should be grayish). Then switch snapping to Active layer only to ensure that your mouse cursor would snap only to the city points and not other layers. Snapping helps to automatically attach your cursor to geometric objects so that they are properly connected and less errors happens in digitalising or measuring distances.
- Now click on the Measure tool . The Measure window will appear. Switch the measurement to Cartesian and switch your measurement units from map units to kilometres. Click on the cities1 layer in the layer panel to make it active (important for snapping). Click on the



point for Atlanta, in the United States (if you snapping is switched on correctly then a small rectangle should appear around the point). Move the cursor to the point for Cape Town, South Africa, then click on the point and right-click to end the line. The distance between Atlanta and South Africa will be displayed in kilometres.





**What distance did you get? Please fill the Quiz Lab 2 Q5 in Moodle.**

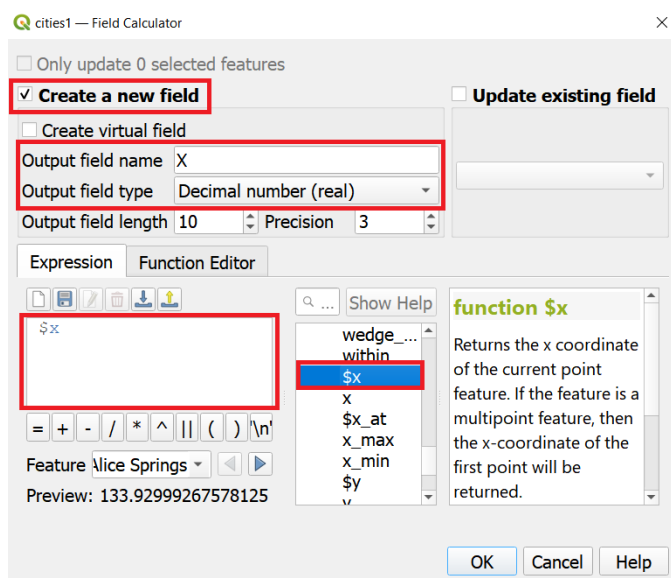
4. Switch the measurement to Ellipsoidal in the Measure window. Leave units to kilometres. Perform the measurement between Atlanta and Cape Town again. What result did you get? The result should be 13067 km which is the actual true distance as it is done on the sphere and avoiding the distortions caused by the projection (currently Plate Carree). The distance calculation on a sphere is done by using the **haversine formula**. It determines the great-circle distance between two points on a sphere given their longitudes and latitudes (Wiki). The distance measurement between two geographic locations on Earth is always the most accurate if using haversine formula.

What about equidistant projections? They should be showing the distances accurately. Switch your project's CRS to World Azimuthal Equidistant (ESRI: 54032). Measure the ellipsoidal distance from Atlanta to Cape Town in kilometres. You should again receive 13067 km because the measurement is being done independently from the projection. Now measure the cartesian distance in kilometres.


**What distance did you get? Please fill the Quiz Lab 2 Q6 in Moodle.**

It should be closer to the ellipsoidal distance than the value you obtained when performing cartesian measurement on WGS 84 (Plate Carree) but it is still not accurate enough. This is **because the equidistant projections show only correct measurements if the projection is centered to the origin of the measurement**. In our case either to Atlanta or to Cape Town. Otherwise, the result is very wrong even in equidistant projection.


5. Let's center our current equidistant projection to Atlanta and see if this will enable to measure the cartesian distance correctly. For that, we need to define our CRS based on the existing World Azimuthal Equidistant projection and change its latitude and longitude of origin to Atlanta. For that, we need to know Atlanta's coordinates. Switch your project's CRS to WGS 84 and open the attribute table of **cities1.shp**. Switch on editing mode  and open field calculator . Create a new field with name "X" and the field type Decimal number. Under Geometry group find function called "\$X". This returns the coordinates of the features to the new field. Click OK. X field with longitude is added to the table. Repeat the procedure for Y and use function "\$Y". This will add latitude to the attribute table. Switch off the editing mode by






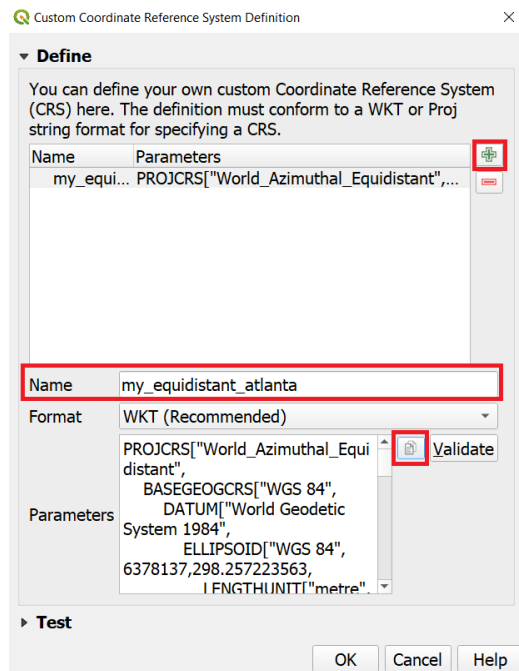
clicking  and save the changes. Now you have Atlanta's coordinates and you can create a custom CRS.

6. From the main menu choose Settings→Custom

Projections... Click Add new CRS  and name your new projection my\_equidistant\_atlanta. Keep the format as WKT and to bring in the existing World Azimuthal Equidistant projection WKT click on the Copy parameters from existing

CRS button  . Choose World\_Azimuthal\_Equidistant (ESRI: 54032) and click ok. The parameters window should be filled with the respective parameters.

7. Atlanta's coordinates are X = -84.3492 and Y = 33.7957 (4 places after comma is more than enough). Scroll down in the Parameter's window until you find "Latitude of natural origin" and "Longitude of natural origin". Change the Latitude and Longitude of natural origin to Atlanta's coordinates. You can now try to click Validate and it should say that WKT string is valid. However, if you click OK then it gives you an error because there is already projection definition with ID ESRI: 54032. Therefore, you need to change the ID. Scroll down in the parameters and find the ID in the end. Delete "ID["ESRI",54032]" and click OK. Your defined CRS should be now ready. Switch your project's CRS to your custom defined CRS. You can find it by the name (my\_equidistant\_atlanta). Your map should now be centered to Atlanta.



Custom Coordinate Reference System Definition

Define

You can define your own custom Coordinate Reference System (CRS) here. The definition must conform to a WKT or Proj string format for specifying a CRS.

Name	Parameters
my_equi...	PROJCRS["World_Azimuthal_Equidistant",...

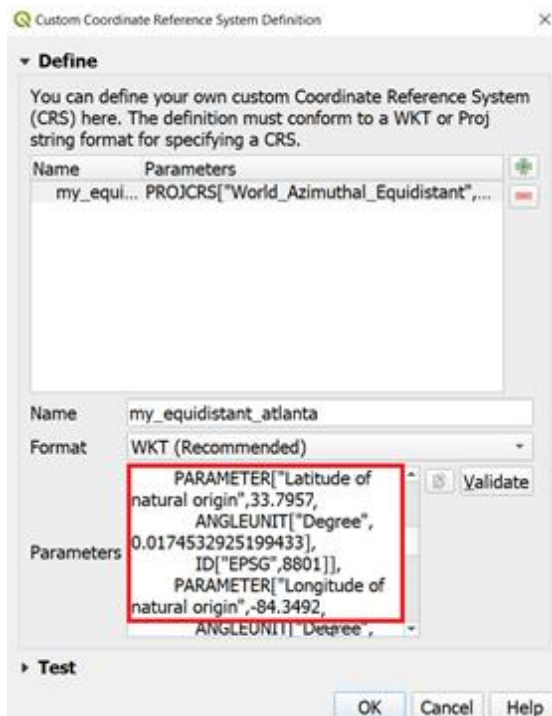
Name: my\_equidistant\_atlanta

Format: WKT (Recommended)

Parameters: PROJCRS["World\_Azimuthal\_Equidistant", BASEGEOGCRS["WGS 84", DATUM["World Geodetic System 1984", ELLIPSOID["WGS 84", 6378137,298.257223563, LENGTHUNIT["metre",

Test

OK Cancel Help



Custom Coordinate Reference System Definition

Define

You can define your own custom Coordinate Reference System (CRS) here. The definition must conform to a WKT or Proj string format for specifying a CRS.

Name	Parameters
my_equi...	PROJCRS["World_Azimuthal_Equidistant",...

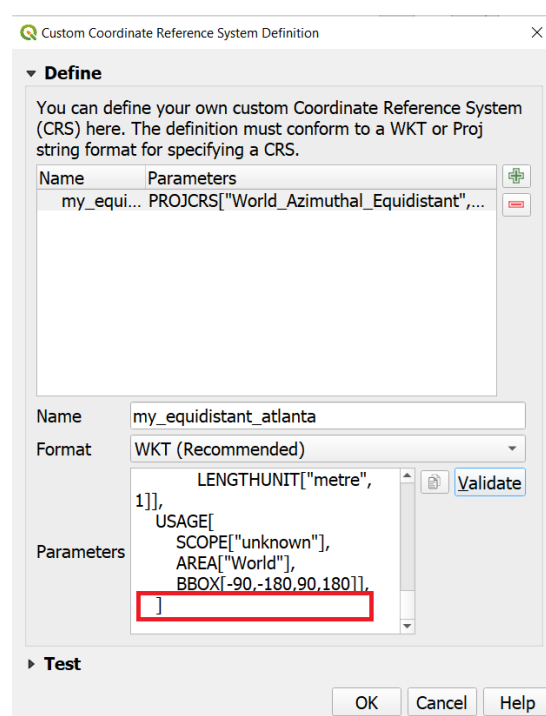
Name: my\_equidistant\_atlanta

Format: WKT (Recommended)

Parameters: PARAMETER["Latitude of natural origin",33.7957, ANGLEUNIT["Degree", 0.0174532925199433], ID["EPSG",8801]], PARAMETER["Longitude of natural origin",-84.3492, ANGLEUNIT["Degree",

Test

OK Cancel Help



Custom Coordinate Reference System Definition

Define

You can define your own custom Coordinate Reference System (CRS) here. The definition must conform to a WKT or Proj string format for specifying a CRS.

Name	Parameters
my_equi...	PROJCRS["World_Azimuthal_Equidistant",...

Name: my\_equidistant\_atlanta

Format: WKT (Recommended)

Parameters: LENGTHUNIT["metre", 1]], USAGE[ SCOPE["unknown"], AREA["World"], BBOX[-90,-180,90,180]],

Test

OK Cancel Help

8. Perform the distance measurement from Atlanta to Cape Town in Cartesian system. What result did you get? It should be exactly same as ellipsoidal. Therefore, you can see that measurements on equidistant projections can be only correct if centered to the measurement point of origin.
9. Let's now measure distance between Atlanta and Alice Springs. First, switch your project's CRS to WGS 84 (EPSG: 4326). Perform the measurement in cartesian and ellipsoidal. What result did you receive in both?

**Please fill the Quiz Lab 2 Q7 and Q8 in Moodle.**

There is very big difference between ellipsoidal and cartesian measurement. This time is not fully the problem of the map projection distortion. Cartesian distance is not the actual distance between Atlanta and Alice Springs. Since in cartesian system QGIS measures directly between Atlanta and Alice Springs (along your measure line) heading East from Atlanta. With this projection and centering, QGIS does not know that the "World is round". With the Cartesian method the distance between these two cities is measured "on the flat Earth". What it should do is measure to Alice Springs by heading West from Atlanta instead of East since heading West is a shorter distance than heading East. Something like this:



10. Let's see if switching the CRS to our defined CRS which is centered to Atlanta would improve the measurement. Switch your project's CRS to my\_equidistant\_atlanta that you created in the previous step. Measure the distance in cartesian system. You should now receive the same value as in ellipsoidal system.

## Task 4 – Defining and changing the coordinate system of the layers

Although we changed the project's CRS, the coordinate system of the layers remained unchanged. In this task, we will look how you can change your datasets from one coordinate system to another and define coordinate systems if they are not set in the file properties.

### ***Defining spatial reference system (coordinate system) of the layers***


In some cases, layer(s) may have no spatial reference system information. If there isn't enough information, QGIS will be unable to project the data in each layer and display it correctly. In this case, you'll have to supply the necessary coordinate system information yourself. Generally, if you have a **layer whose dataset does not have a coordinate system defined and you know which coordinate**

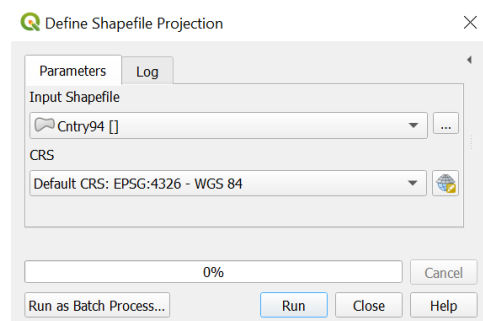
**system it is using, you should use** the Define Shapefile Projection tool for shp files and Assign Projection for gpkg files in Processing Toolbox to assign projection information to your data. This tool overwrites the coordinate system information (map projection and datum) stored with a dataset. **The only use for this tool is for datasets that have an unknown or incorrect coordinate system defined i.e., the geometries are not reprojected, they are just assigned to a different CRS.** If you do not know the coordinate system of the layer then please do not use the tool, it will make your data unusable if you choose a wrong coordinate system.

If you do not know the spatial reference system of your dataset then there are some simple rules how you could be very likely to identify the spatial reference system by simply looking at data:

1) if your data is in geographic coordinates and originates from GPS or remote sensing sources then it is very likely WGS84.

2) if your data is in projected coordinates and it is about some specific country then it is very likely in the national coordinate system of this country.

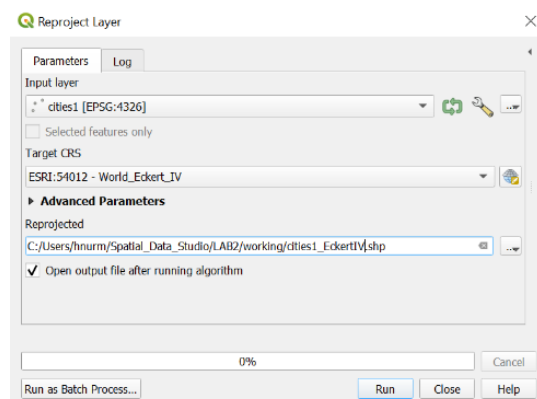
1. For the shp-files, the spatial reference system is stored in the \*.prj file. "PRJ" files contain an entire spatial reference, not just a projection. Explore the contents of **Cntry94.prj** by right-clicking on the file in Windows Explorer and choose Edit with Notepad or Edit. As you see, the \*.prj file is just text file where the spatial reference system information is stored.
2. Let's do a little experiment. Set the project's CRS back to WGS84 (EPSG:4326). Remove Cntry94 from the Layers List (right-click on the layer name and choose "Remove Layer"). Save your project World\_view.qgz. Delete the file **Cntry94.prj**. Add the same layer again to the project. The Cntry94 should open nicely and still show in the right place.
3. Change the project's CRS into Eckert IV. **What happened? Please answer the Quiz Lab 2 Q9 in Moodle.**
4. As we know that the spatial reference system of Cntry94 is WGS84 then we can define it by using Define Shapefile Projection tool. Open Processing Toolbox from menu the Processing Toolbox or by clicking on  button. Use search to find Define Shapefile Projection tool and define the spatial reference system for Cntry94 as WGS84. What happened? Check the working folder in Windows Explorer, do you find a new Cntry94.prj file?




### ***Transforming (projecting) the spatial reference system of the layers***

If you want to change the coordinate system of the layers or project geographic coordinate system to projected coordinate system, you need to use Reproject Layer tool. The "Reproject Layer" tool is really a Spatial Reference System transformation tool which applies mathematical functions to transform data from one CRS to another. For raster layers you should use GDAL Wrap (reproject).

1. Use search to find Reproject Layer tool from the Processing Toolbox and project layer **cities1.shp** to Eckert IV (EPSG 54012). Save it as a new file with suitable name.
2. Project also layers Cntry94 and Circles to Eckert IV.



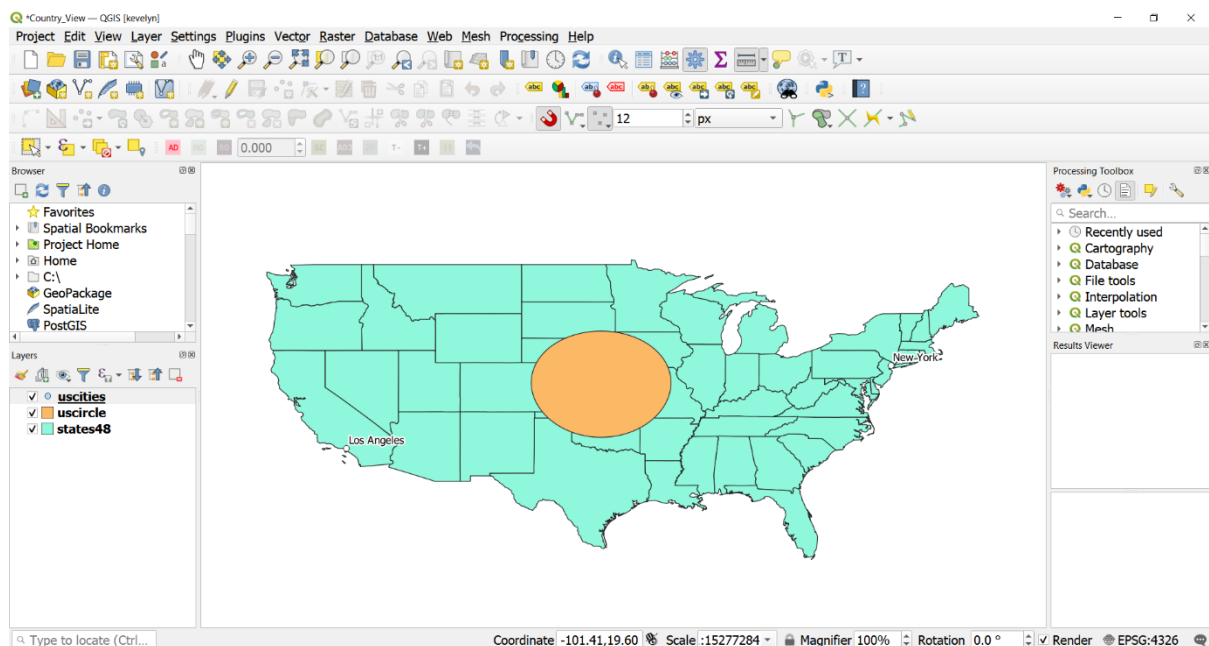
3. Save your project.
4. Open a new empty project . Add your projected layers to the new project. Check the coordinate system of the project (on the status bar lower corner you can see the EPSG code).  
**What is the coordinate system? Please answer the Quiz Lab 2 Q10 in Moodle.**
5. Change the project's CRS to Mercator (EPSG 3395). How did the map change? Check the CRS of the layers. Did the coordinate system of the layer change?
6. Save and close the project.

## Task 4 – Exploring national map projections

Projections suitable for mapping the world are not necessarily the best for mapping smaller areas, such as continents or countries. When mapping at such a scale in the mid-latitudes it is important to use a projection that centers on the area being mapped and has a standard line, or lines, passing through the area being mapped.

In this task, we will look at a map of the contiguous United States using a few different projections.

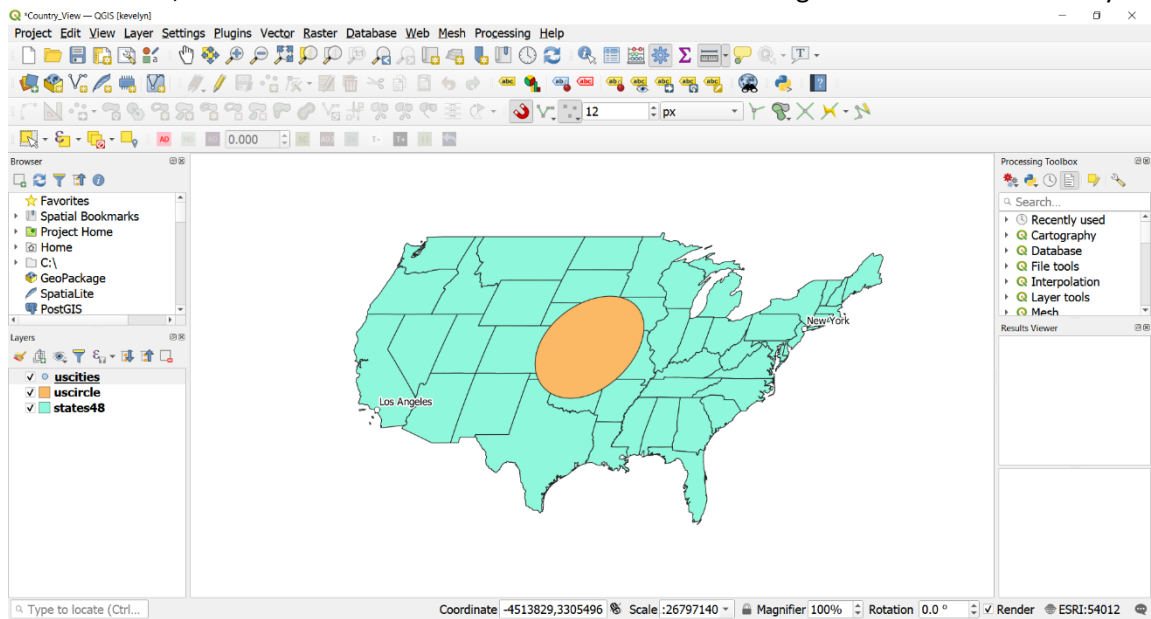
Country\_View.qgz is an unprojected map of the lower 48 states comprised of three themes: United States, LA & NYC, and Circle (centered on -97.50, 39.00). You can see it does not look quite right given the default projection. The circle shows some obvious skewing.



The distance property is more difficult to judge. Let's do some measurements.

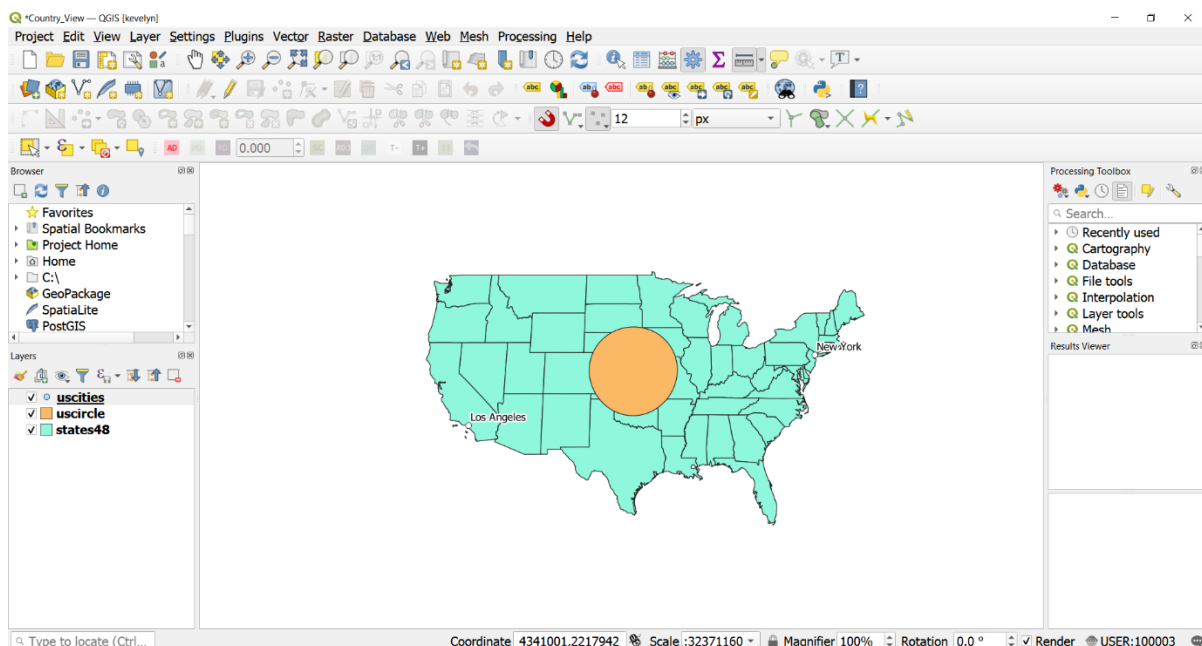
1. As before use the Measure tool to measure the distance between Los Angeles and New York City in kilometers in cartesian and ellipsoidal system. Don't forget to switch on the snapping on the active layer. The ellipsoidal distance should be accurate: 3939 km. Cartesian, however, is significantly off by almost a thousand kilometres.

- Switch the project's CRS to the Eckert IV projection. The Eckert IV did a nice job with the whole world, but we will see how it fares with a single mid-latitude country.



There clearly is a great deal of distortion using this projection, most obviously the shearing. Part of the problem lies in the fact that this projection is centered at 0 degrees longitude.

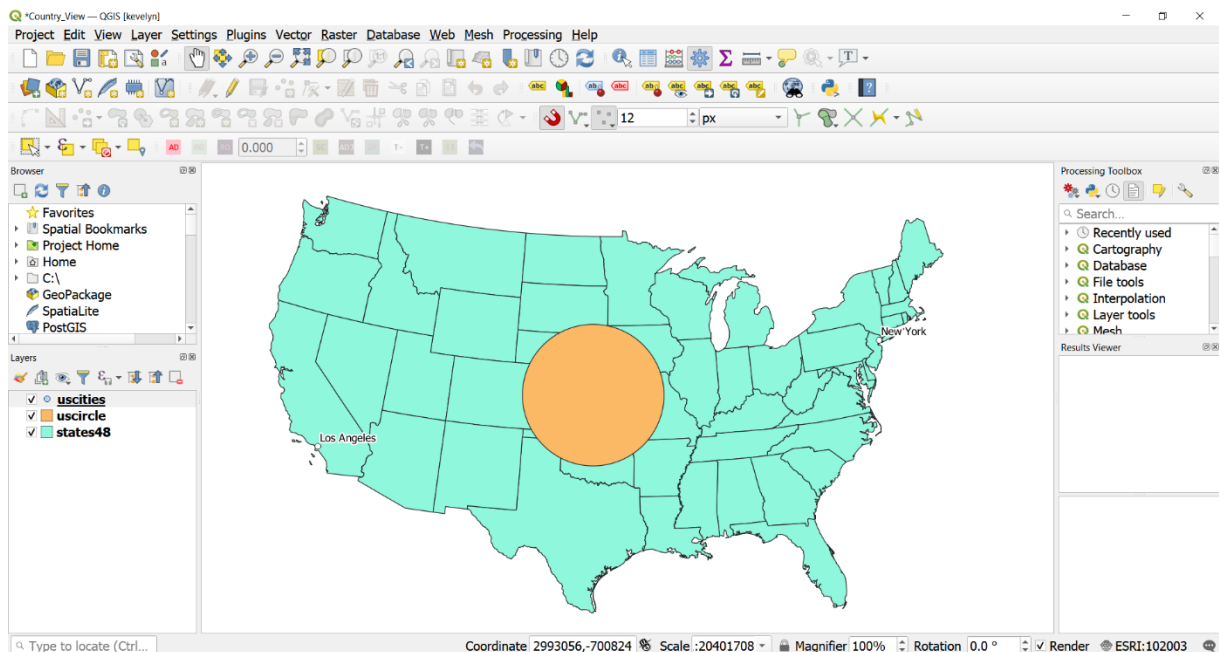
- Let's center the Eckert IV projection on the United States by creating a custom CRS based on the World Eckert IV projection. Use the instructions from Task 3 and re-center the World Eckert IV projection (ESRI 54012). This will center the projection down the middle of the country. To accomplish this, replace "Longitude of origin" value 0 with -96.0 (essentially replacing the central meridian of 0 with -96.0). Name your projection "my\_eckert\_IV\_US".
- Switch your project's CRS to your new custom CRS "my\_eckert\_IV\_US". How did the map change?





This is a distinct improvement in shape, but there is still some skewing. The Eckert IV projection is primarily used for mapping the entire world. For mapping large countries, at mid-latitudes, such as the United States, other projections are more appropriate. The Lambert azimuthal, Albers equal-area, Bonne equal-area, and Lambert conformal conic projections are examples of suitable projections for mapping the entire U.S. Because it has two standard parallels, the Albers equal-area projection is particularly good for larger countries with a significant east-west extent. Let's try Albers on our map.

5. Switch the project's CRS to USA\_Contiguous\_Albers\_Equal\_Area\_Conic (ESRI: 102003). The Albers conic projection has low scale distortion for an area the size of the U.S. As the area being mapped decreases in size, distortion is less of an issue.



6. Let's try another map projection to see what changes. Switch project's CRS to USA\_Contiguous\_Lambert\_Conformal\_Conic (ESRI: 102004). Not too much changed between Albers and Lambert. They are both similar map projections. The conic projections function quite well for mapping the larger states in the U.S. In terms of thematic mapping, it is important that maps at this scale are equal-area. Any other properties important to the particular map should also be considered when selecting a proper projection.
7. Save and close.

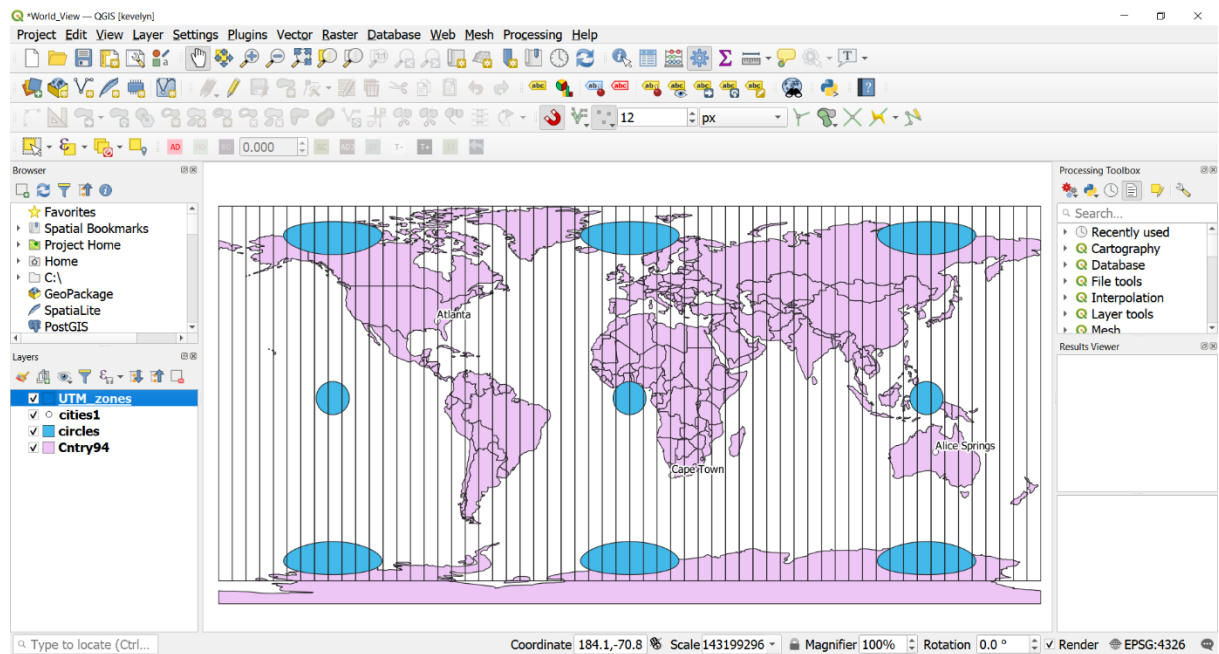
## Task 5 – Exploring the Universal Transverse Mercator (UTM) Coordinate System

The Universal Transverse Mercator (UTM) grid (shown in the figure below) is a plane coordinate system that spans almost the entire globe. It is probably the best-known plane coordinate system of international scope. For the UTM system, the globe is divided into sixty zones, each comprised of six degrees of longitude. Each zone has its own central meridian. The limits of each zone are 84 degrees north and 80 degrees south. UTM uses the Transverse Mercator projection that can map a region of large north-south extent with low distortion. The zones are numbered 1 to 60, where zone 1 begins



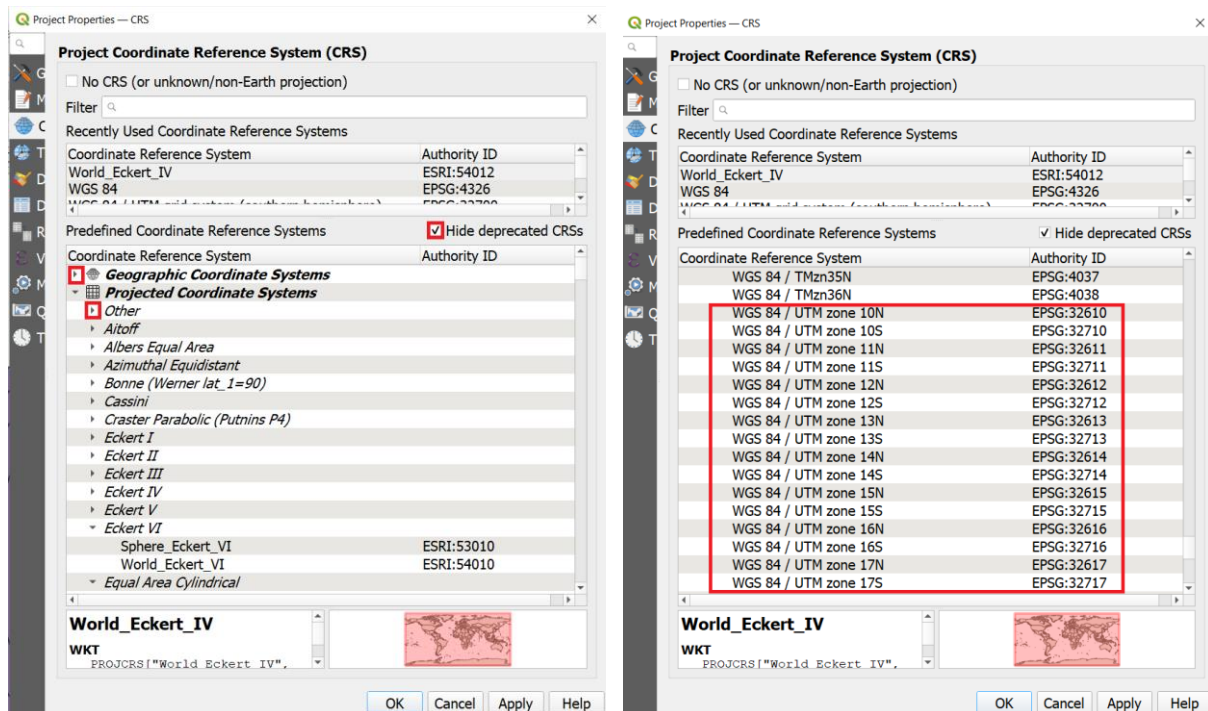
at -180° Longitude and zones increase heading East back to +180° where zone 60 ends. All zones are also divided by equator into N and S.

1. Open again World\_View.qgz. Switch your project's CRS to WGS 84. Add **UTM\_zones.shp** to your map view and make the fill colour of the zones transparent.



2. What UTM zone does your home country/county/state fall into? Hint: you can use Identify Features tool to find out.
3. Coordinate systems can be also searched based on the classification which can be useful if you don't know the exact EPSG that you are looking for but you do know the region and properties, for example global WGS84 UTM. Open project's CRS and first check the "Hide deprecated CRSs" which helps to reduce the list and avoid choosing an CRS that is out of date. Then scroll up in the Coordinate Reference System list and close the Geographic Coordinate System group by clicking on the arrow in front of the group name as we know that UTM is projected CRS and therefore we should not search from geographic CRS-s. Projected CRS-s are grouped by projection properties or names. Close some of them and you can see how many different CRS-s there are<sup>6</sup>. Scroll down until you find WGS84 UTM zones. WGS84 UTM N has EPSG codes from 32601 to 32660 and UTM S has EPSG codes from 32701 to 32760.

<sup>6</sup> QGIS has support for approximately 7000 known CRSs ([QGIS Documentation](#))



4. Create a separate layer of your home country (or if you want more precise borders then download your country borders from [GADM database](https://gadm.org/)) and project this into your home country's zone. If your country falls into several zones, then map your home city. How does the map look like? **Include a map of your home country in UTM projection into your Independent task report (see task 6).**

## Task 6 – Independent task

For the independent task report, make an overview of your home country's national coordinate system:

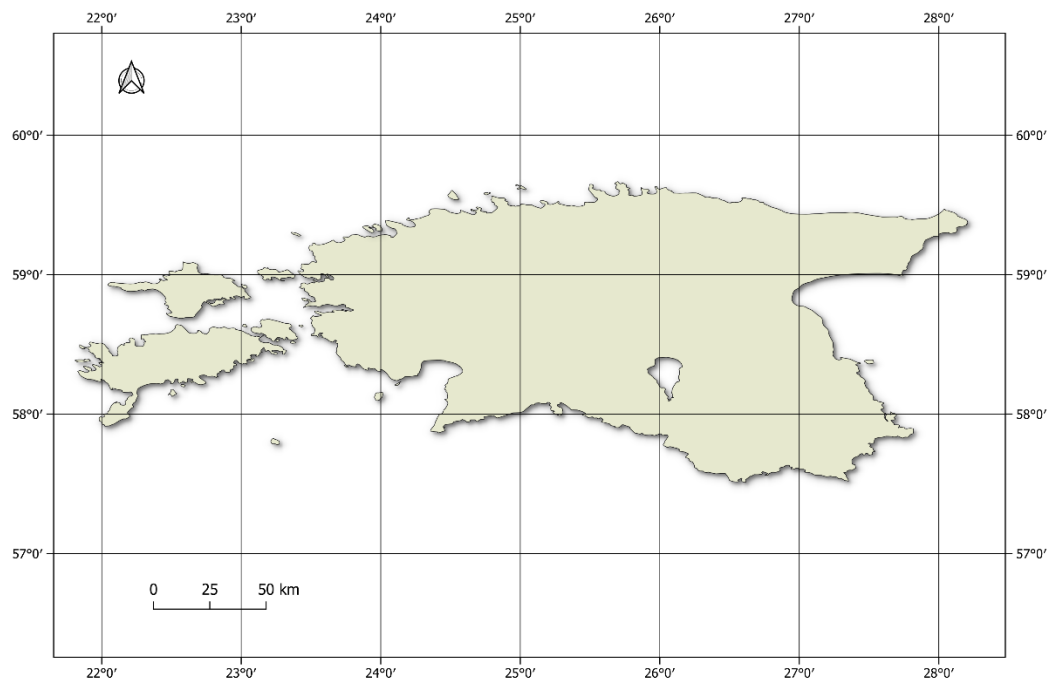
- Find out what horizontal and vertical Datum is used in your country and if and how it has changed through time. Give a short historical overview if possible.
- What is the national projected coordinate system for your country – give the specifics, peculiarities, changes over time.

In addition, include properly formatted (north arrow, scalebar, graticule (see in the end of the tutorial for guideline for graticule with coordinates) following maps of your country:

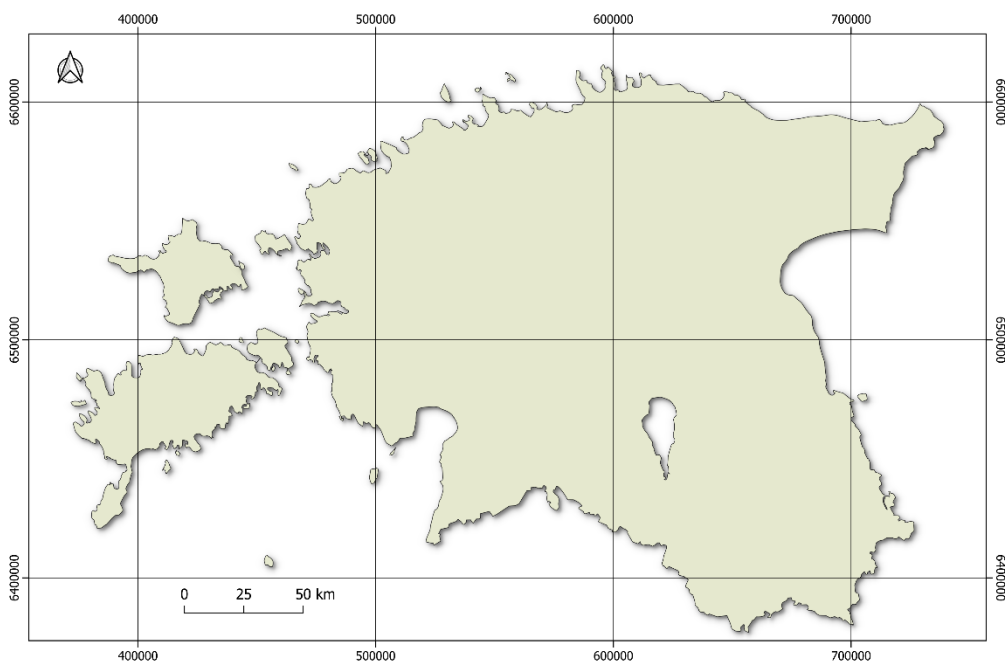
- 1) location map of your home country in freely chosen equal-area projection suitable for the whole world from task 2;
- 2) map of your home country in WGS84 coordinate system (note that your actual map will be showing Plate Carree);
- 3) in your country's **projected** national coordinate system (note that for this map the graticule units have to be **metric e.g. meters or kilometres**);
- 4) in UTM from task 5. If your country's national coordinate system is also UTM then make the 3<sup>rd</sup> map in regional coordinate system. For example, European regional coordinate system is known as ETRS89 which is using Lambert Azimuthal Equal Area (LAEA) projection.

**Example maps:**

### Estonia: EWGS 84, EPSG: 4326 projected as Plate Carree



### Estonia: Estonian National CRS 1997, EPSG: 3301



### How to make a grid with coordinates?

For adding a graticule with coordinates, you need to make the grid in Layout view. Once you add your map to the layout, then on the right side of the window there should be Item Properties tab open. Scroll down to Grids and click on the + button to add a new grid to the map. Now click on Modify Grid. Add grid with suitable interval, coordinates (you can adjust their orientation, format, coordinate precision etc.).

