

# SPATIAL MAPS

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*STA465: Theory and Methods for Complex Spatial Data*

*Instructor: Dr. Vianey Leos Barajas*

# WORKING WITH SPATIAL DATA STRUCTURES IN R

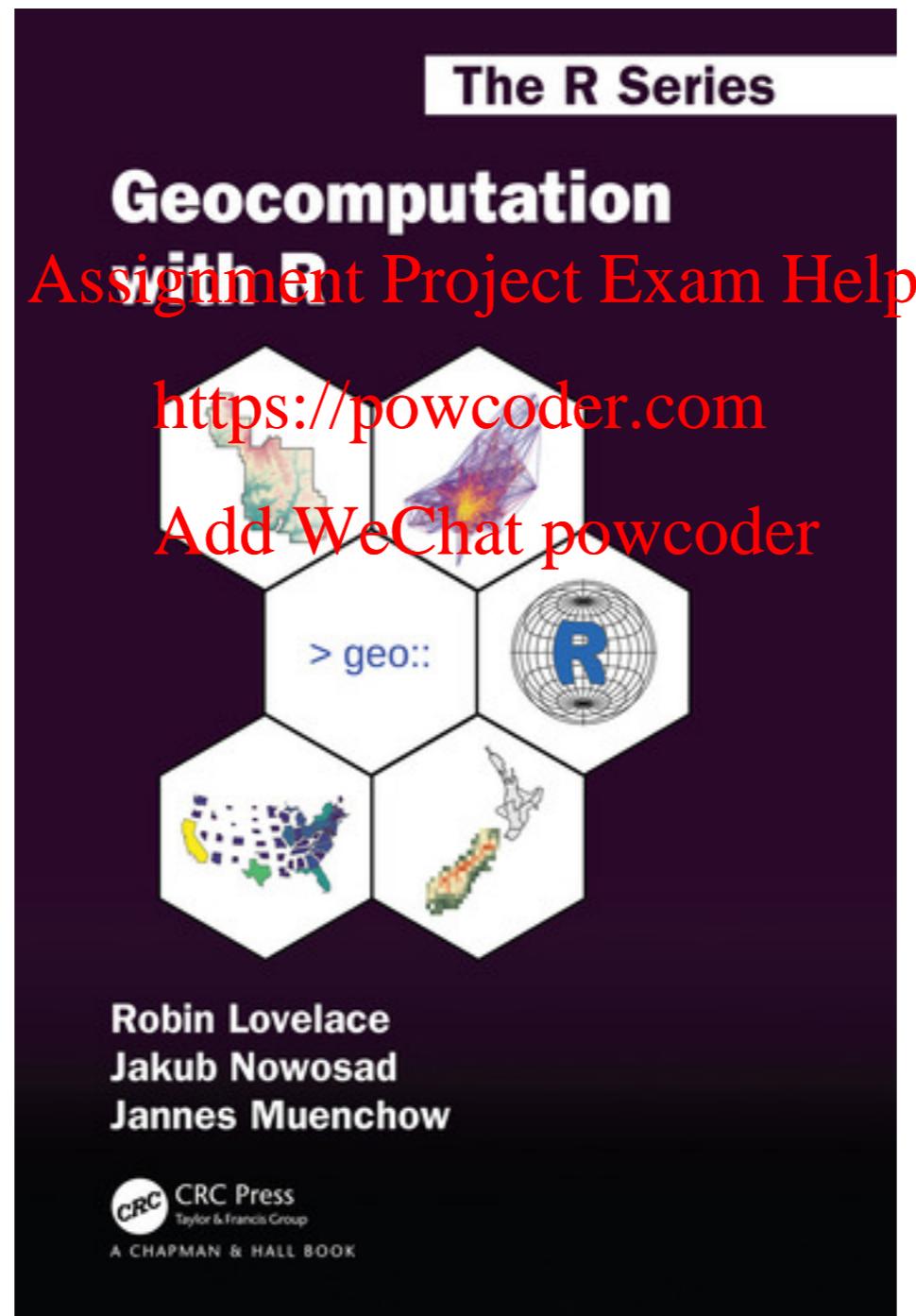
---

- We'll exclusively use R to work with spatial data:
  - There are two books we will use to learn how to work with spatial data structures and plot spatial data in R:
    - [GeoComputation with R](#) Assignment Project Exam Help
    - [Geospatial Health Data: Modeling and Visualization with R-INLA and Shiny](#) https://powcoder.com Add WeChat powcoder
- Spatial data structures:
  - Beyond plotting points
  - Data sets will now have additional structures
  - <https://r-spatial.github.io/sf/reference/index.html>

# GEOCOMPUTATION WITH R

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PDF of book: <https://geocompr.robinlovelace.net>



# R PACKAGES

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*install.packages("sf")*: a class system for geographic vector data

*install.packages("raster")*

*install.packages("spData")*

*remotes::install\_github('Assignment Project Exam')* Help  
~~No need to spDataLarge~~

*library("sp")* <https://powcoder.com>

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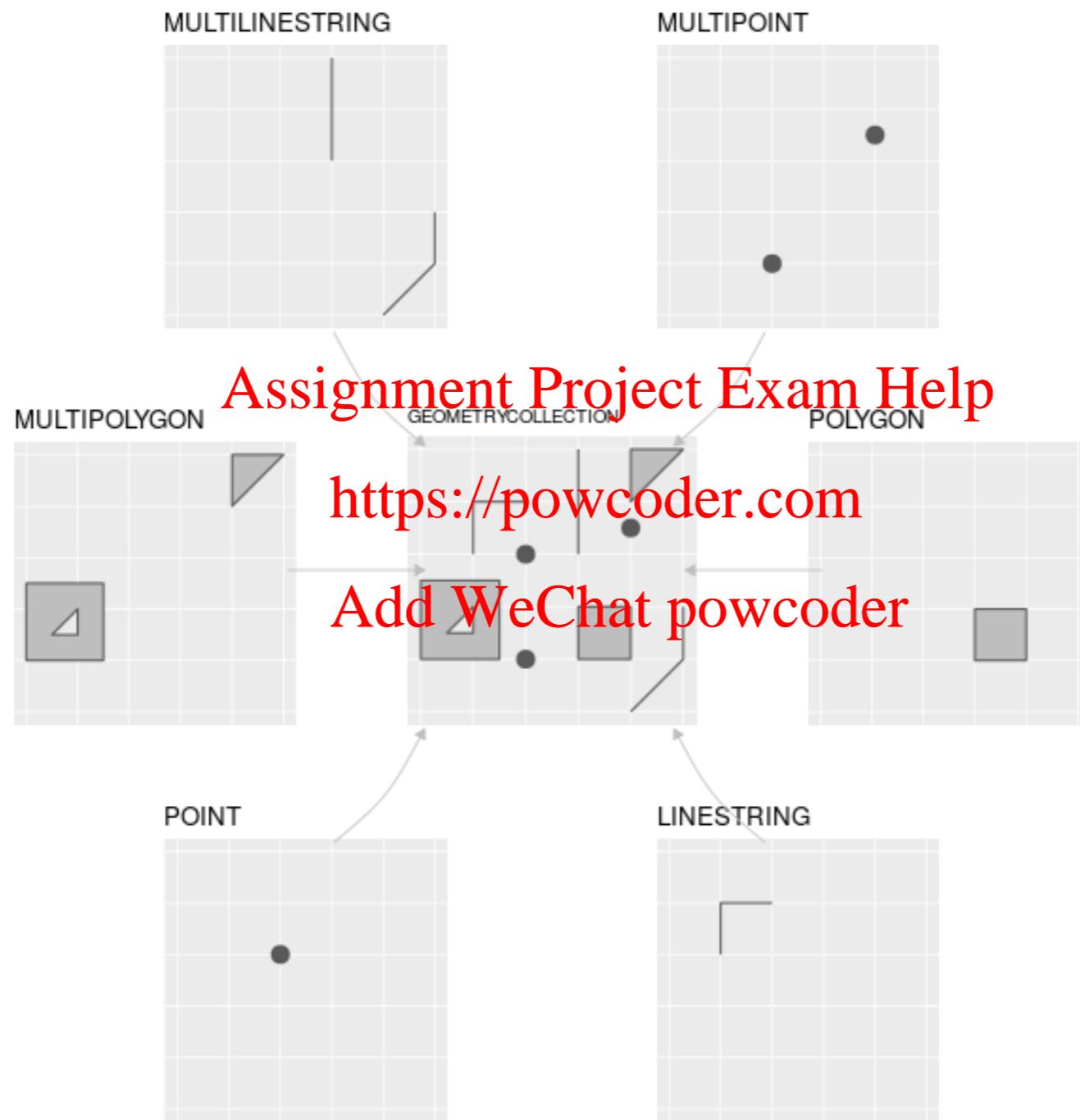
What about ggplot2 or base R?

- *For spatial data structures, we need to go beyond that*
- *We can use it in combination with 'sf' or 'sp' structures*

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# SIMPLE FEATURES (SF)

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*Figure from ‘geocomputation with R’*

# Simple feature geometry types

The following seven simple feature types are the most common, and are for instance the only ones used for [GeoJSON](#):

type	description
POINT	zero-dimensional geometry containing a single point
LINESTRING	sequence of points connected by straight, non-self intersecting line pieces; one-dimensional geometry
POLYGON	geometry with a positive area (two-dimensional); sequence of points form a closed, non-self intersecting ring; the first ring denotes the exterior ring, zero or more subsequent rings denote holes in this exterior ring
MULTIPOINT	set of points; a MULTIPONT is simple if no two Points in the MULTIPONT are equal
MULTILINESTRING	set of linestrings
MULTIPOLYGON	set of polygons
GEOMETRYCOLLECTION	set of geometries of any type except GEOMETRYCOLLECTION

From <https://r-spatial.github.io/sf/articles/sf1.html>

```
## library(spData)
```

```
plot(world)
```

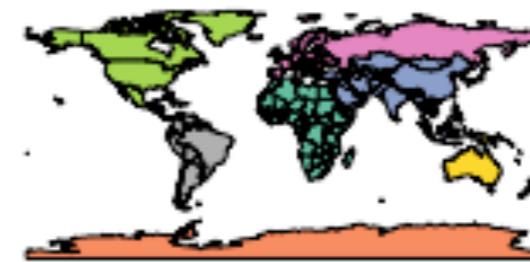
iso\_a2



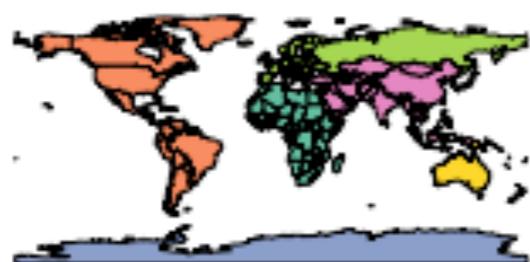
name\_long



continent



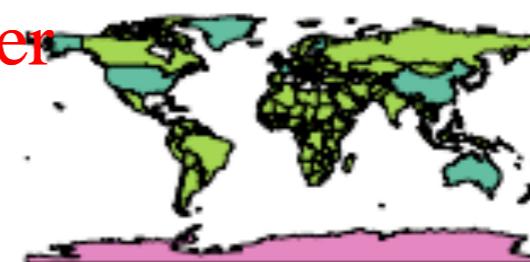
region\_un



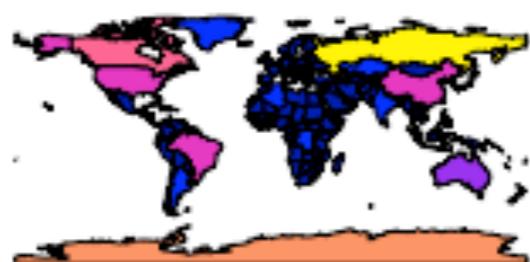
<https://powcoder.com>

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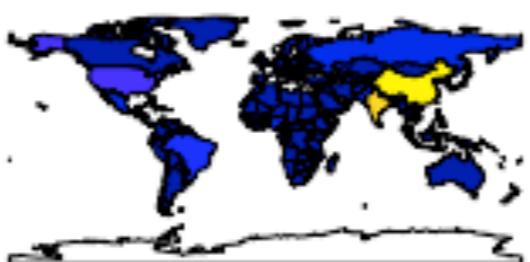
type



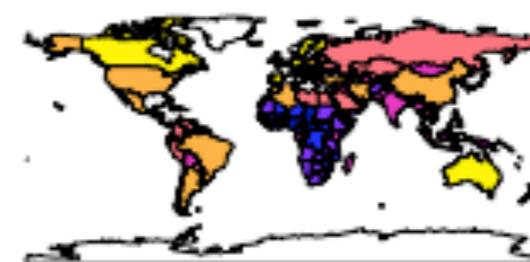
area\_km2



pop



lifeExp



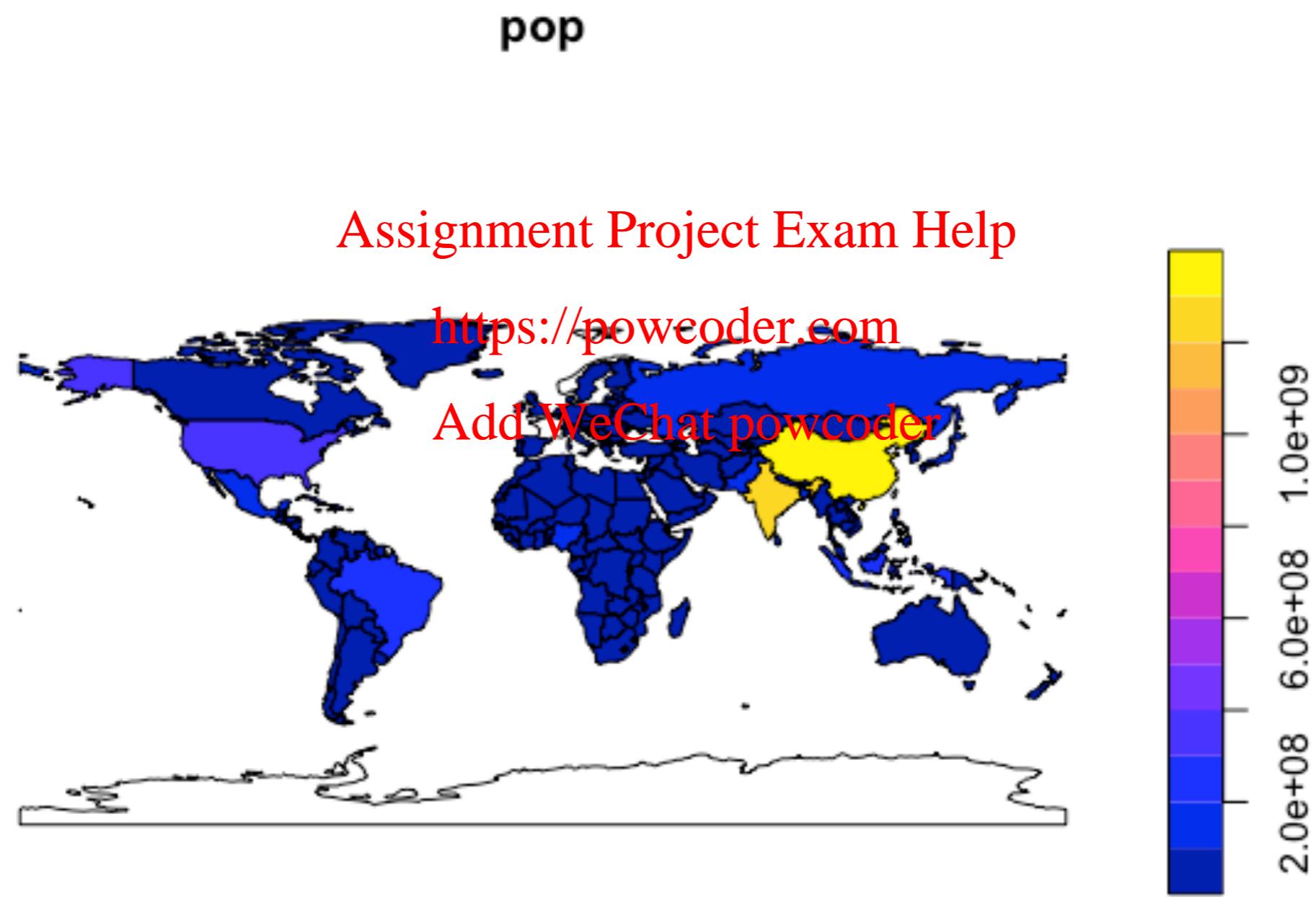
```
## library(spData)
```

## *world*

```
> world
Simple feature collection with 177 features and 10 fields
geometry type:  MULTIPOLYGON
dimension:        XY
bbox:             xmin: -180 ymin: -90 xmax: 180 ymax: 83.64513
geographic CRS: WGS 84
# A tibble: 177 x 11
```

# Assignment Project Exam Help

```
plot(world["pop"])
```

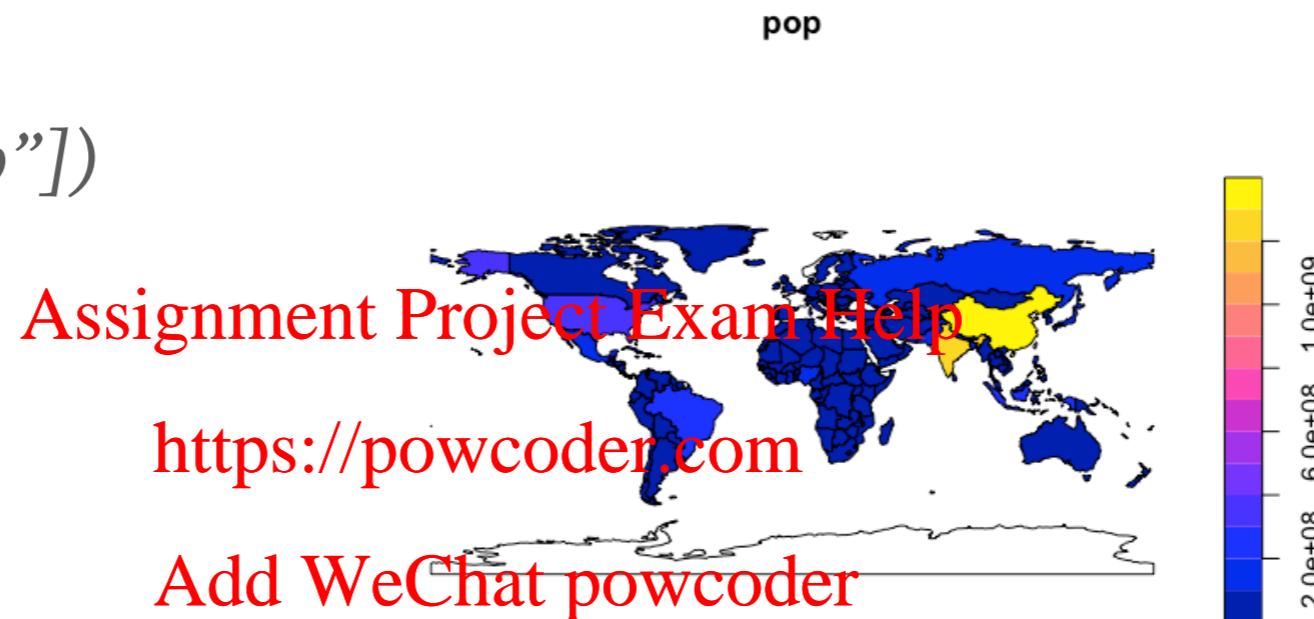


# SPATIAL DATA

---

- How is the data structured here?

*plot(world[“pop”])*



# ASIA

---

```
> world_asia = world[world$continent == "Asia", ]  
> asia = st_union(world_asia)  
> plot(asia)
```

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```
> world_asia = world[world$continent == "Asia", ]  
> india = world[world$name_long == "India", ]  
> plot(st_geometry(india), expandBB = c(0, 0.2, 0.1, 1), col = "gray", lwd =  
 3)  
> plot(world_asia[0], add = TRUE)
```

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```

> library(sf)
> library(ggplot2)
> library(viridis)
> nc <- st_read(system.file("shape/nc.shp", package = "sf"),
+               quiet = TRUE
+ )

```

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```

> nc
Simple feature collection with 100 features and 14 fields
geometry type:  MULTIPOLYGON
dimension:      XY
bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
geographic CRS: NAD27
First 10 features:

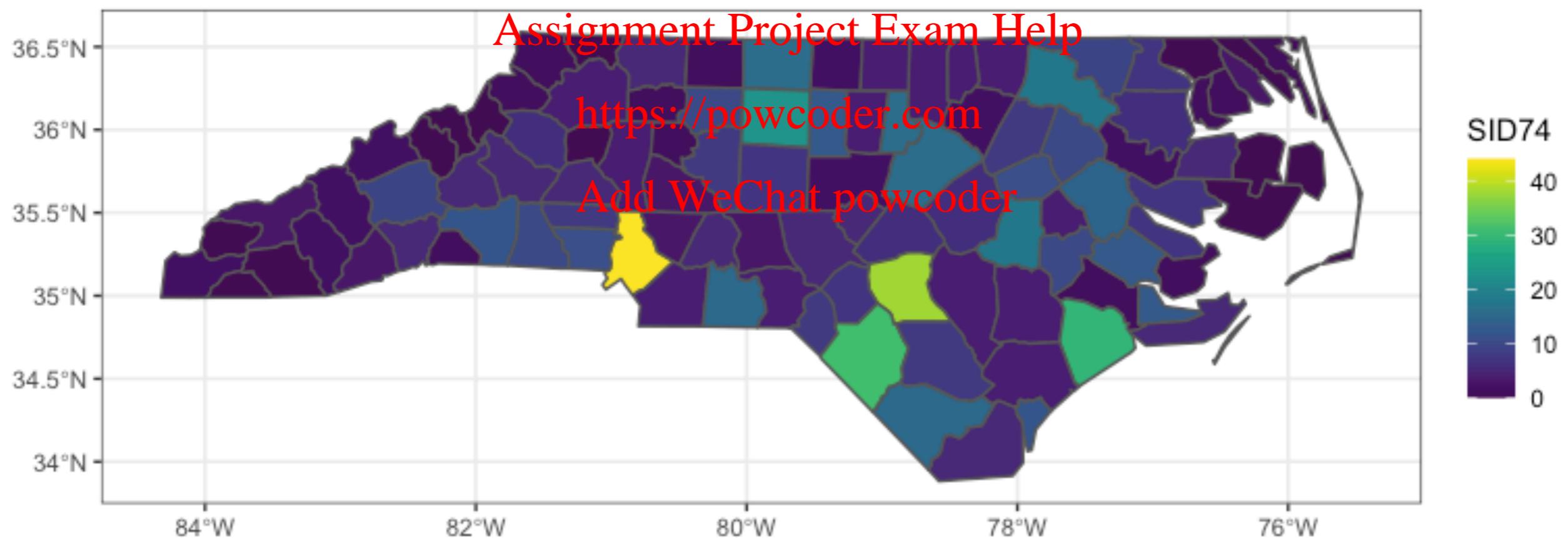
```

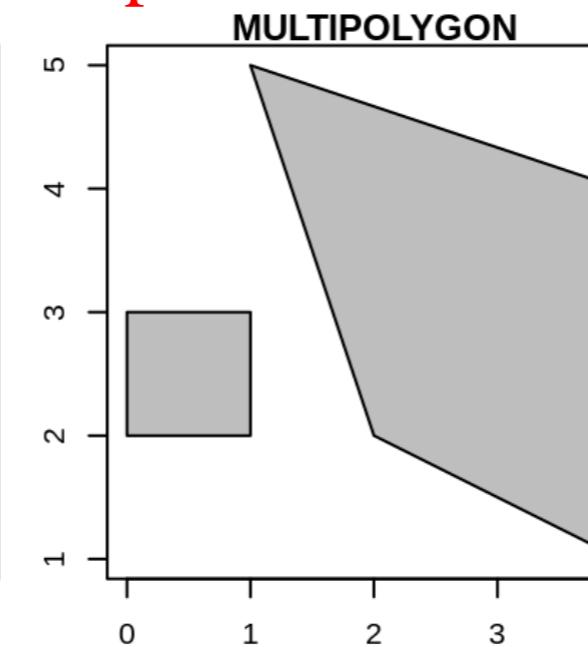
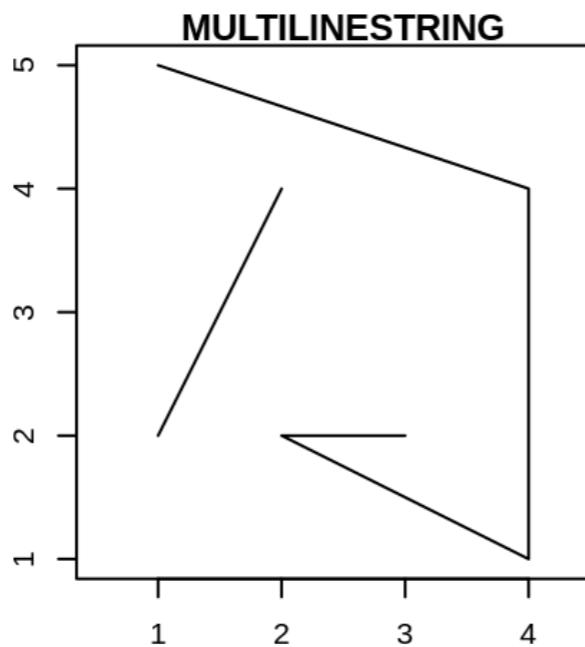
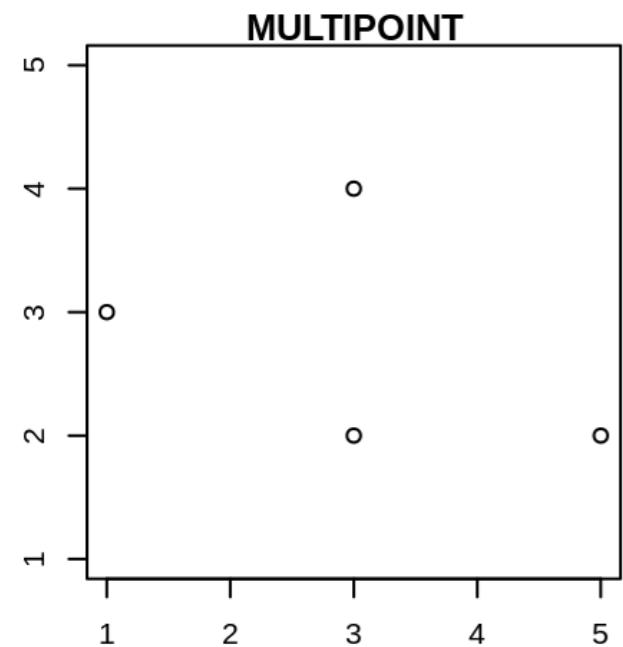
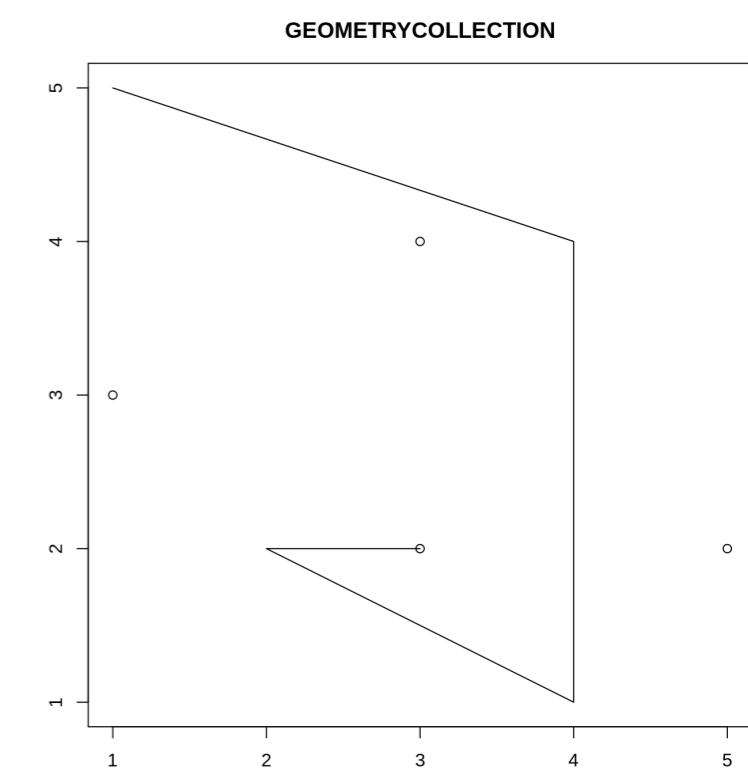
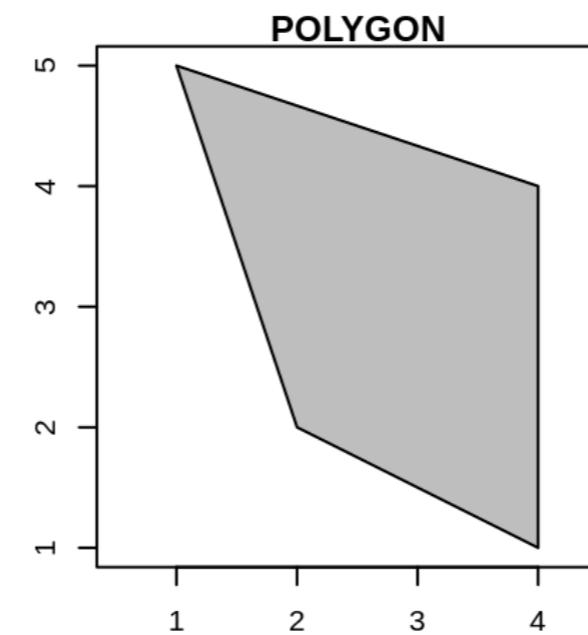
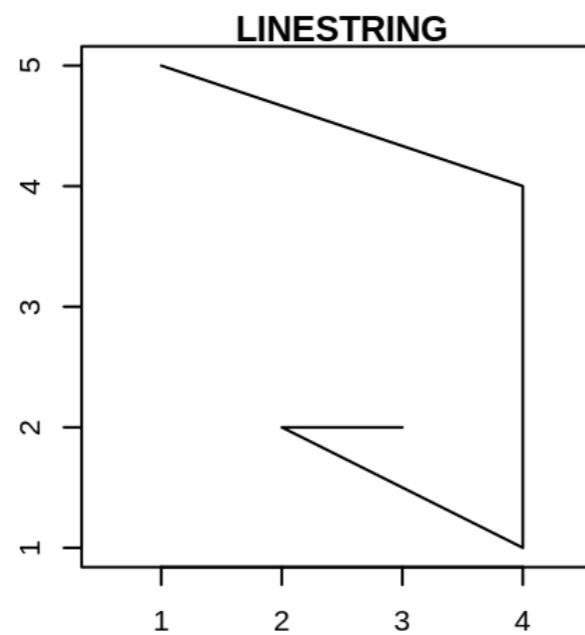
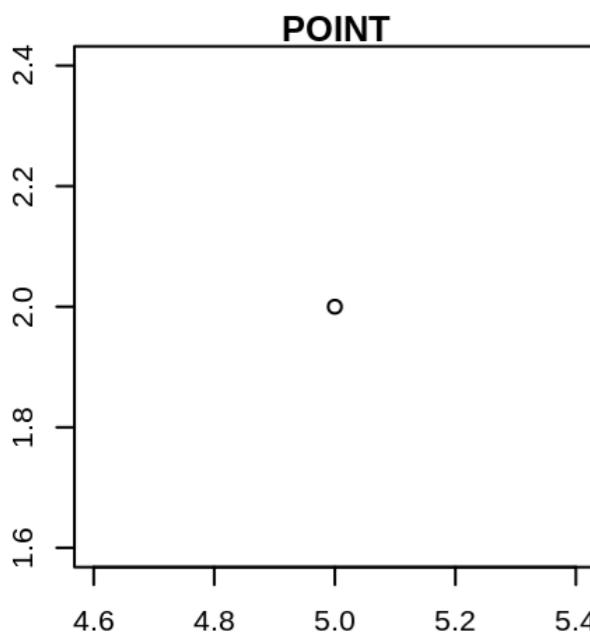
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	AREA	PERIMETER	CNTY_	CNTY_ID	NAME	FIPS	FIPSNO	CRESS_ID	BIR74	SID74	NWBIR74	BIR79	SID79	NWBIR79	geometry
1	0.114	1.442	1825	1825	Ashe	37009	37009		5	1091	1	10	1364	0	19 MULTIPOLYGON (((-81.47276 3...
2	0.061	1.231	1827	1827	Alleghany	37005	37005		3	487	0	10	542	3	12 MULTIPOLYGON (((-81.23989 3...
3	0.143	1.630	1828	1828	Surry	37171	37171		86	3188	5	208	3616	6	260 MULTIPOLYGON (((-80.45634 3...
4	0.070	2.968	1831	1831	Currituck	37053	37053		27	508	1	123	830	2	145 MULTIPOLYGON (((-76.00897 3...
5	0.153	2.206	1832	1832	Northampton	37131	37131		66	1421	9	1066	1606	3	1197 MULTIPOLYGON (((-77.21767 3...
6	0.097	1.670	1833	1833	Hertford	37091	37091		46	1452	7	954	1838	5	1237 MULTIPOLYGON (((-76.74506 3...
7	0.062	1.547	1834	1834	Camden	37029	37029		15	286	0	115	350	2	139 MULTIPOLYGON (((-76.00897 3...
8	0.091	1.284	1835	1835	Gates	37073	37073		37	420	0	254	594	2	371 MULTIPOLYGON (((-76.56251 3...
9	0.118	1.421	1836	1836	Warren	37185	37185		93	968	4	748	1190	2	844 MULTIPOLYGON (((-78.30876 3...
10	0.124	1.428	1837	1837	Stokes	37169	37169		85	1612	1	160	2038	5	176 MULTIPOLYGON (((-80.02567 3...

```
> ggplot(data = nc, aes(fill = SID74)) + geom_sf() +  
+   scale_fill_viridis() + theme_bw()
```





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# R CODE:

---

```
# the rbind function simplifies the creation of matrices  
## MULTIPOINT  
  
multipoint_matrix = rbind(c(5, 2), c(1, 3), c(3, 4), c(3, 2))  
st_multipoint(multipoint_matrix)  
#> MULTIPOINT ((5 2), (1 3), (3 4), (3 2))  
## LINESTRING  
  
linestring_matrix = rbind(c(1, 5), c(4, 4), c(4, 1), c(2, 2), c(3, 2))  
st_linestring(linestring_matrix)  
#> LINESTRING (1 5, 4 4, 4 1, 2 2, 3 2)
```

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```
## POLYGON  
  
polygon_list = list(rbind(c(1, 5), c(2, 2), c(4, 1), c(4, 4), c(1, 5)))  
st_polygon(polygon_list)  
#> POLYGON ((1 5, 2 2, 4 1, 4 4, 1 5))
```

# R CODE:

---

```
## MULTILINESTRING
multilinestring_list = list(rbind(c(1, 5), c(4, 4), c(4, 1), c(2, 2), c(3, 2)),
                             rbind(c(1, 2), c(2, 4)))
st_multilinestring(multilinestring_list)
#> MULTILINESTRING ((1 5, 4 4, 4 1, 2 2, 3 2), (1 2, 2 4))
```

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```
## MULTIPOLYGON
multipolygon_list = list(list(rbind(c(1, 5), c(2, 2), c(4, 1), c(4, 4), c(1, 5))),
                         list(rbind(c(0, 2), c(1, 2), c(1, 3), c(0, 3), c(0, 2))))
st_multipolygon(multipolygon_list)
#> MULTIPOLYGON (((1 5, 2 2, 4 1, 4 4, 1 5)), ((0 2, 1 2, 1 3, 0 3, 0 2)))
```

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**RASTER DATA**  
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# RASTER DATA

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- Consists of a raster header and matrix — whose rows and columns represent equally spaced cells (aka pixels)
- Raster maps usually represent continuous phenomena such as elevation, population density or spectral data
- Can represent discrete features such as soil or land-cover classes with the help of a raster model

# RASTER DATA

---

*The cell of one raster layer can only hold a single value:*

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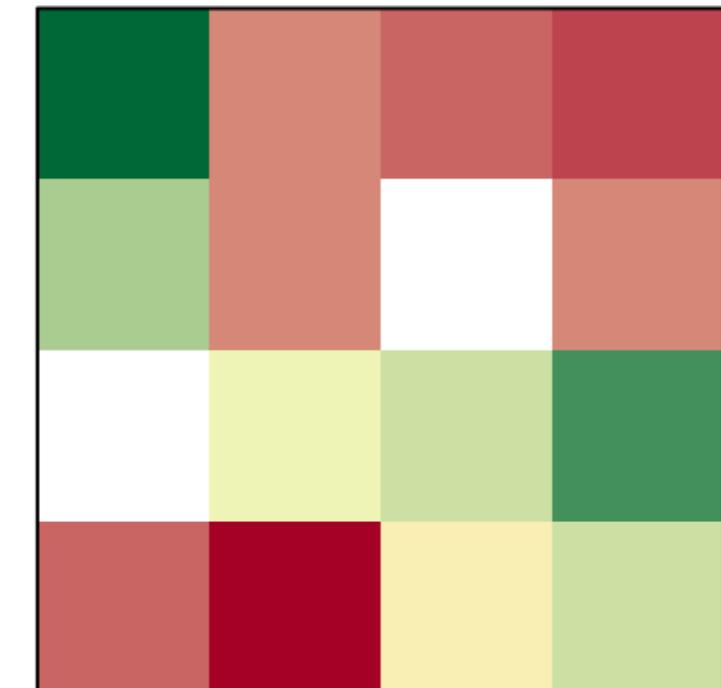
**A. Cell IDs**

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

**B. Cell values**  
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100	28	22	15
73	31	NA	30
NA	59	62	91
25	6	53	66

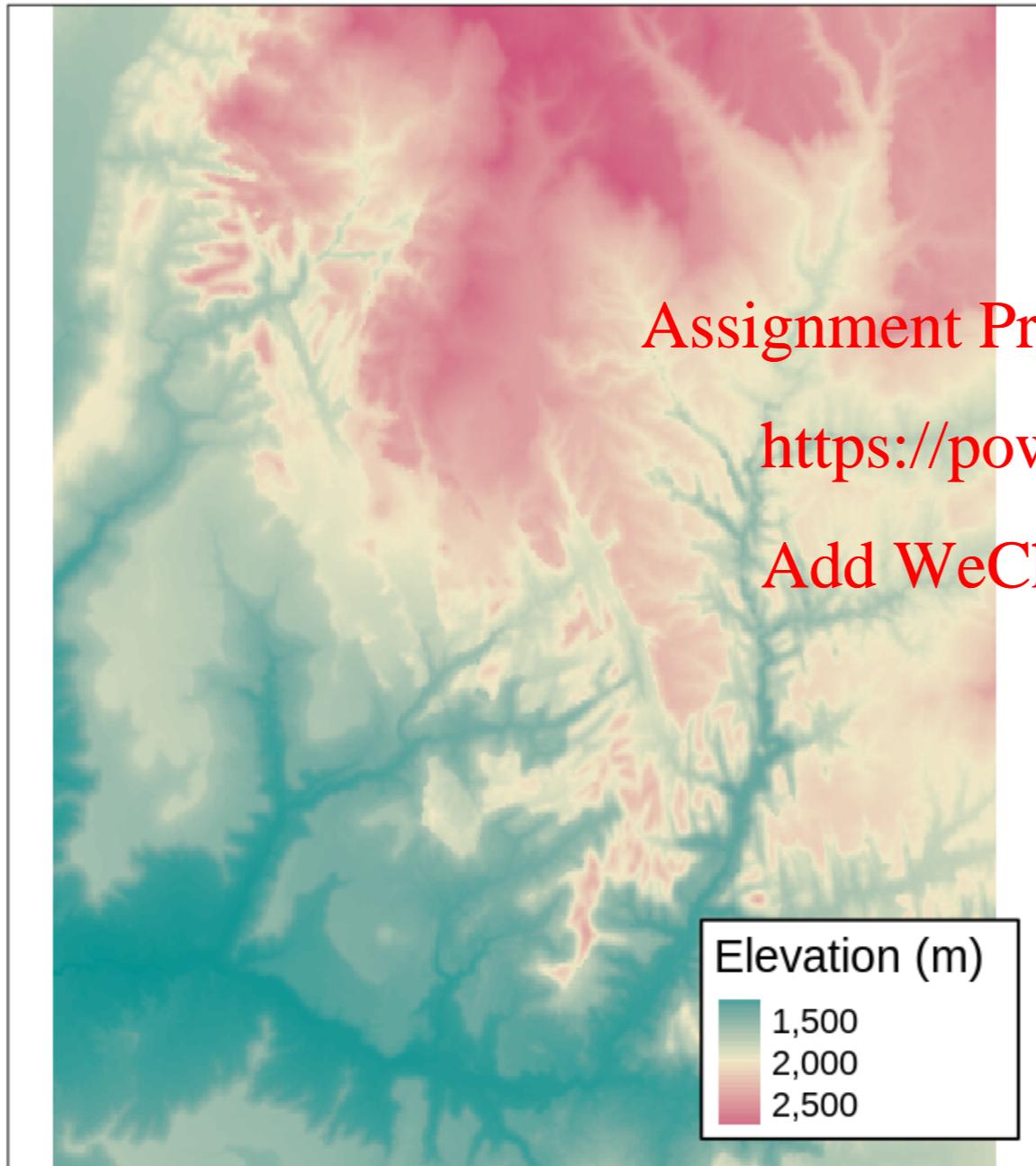
**C. Colored values**



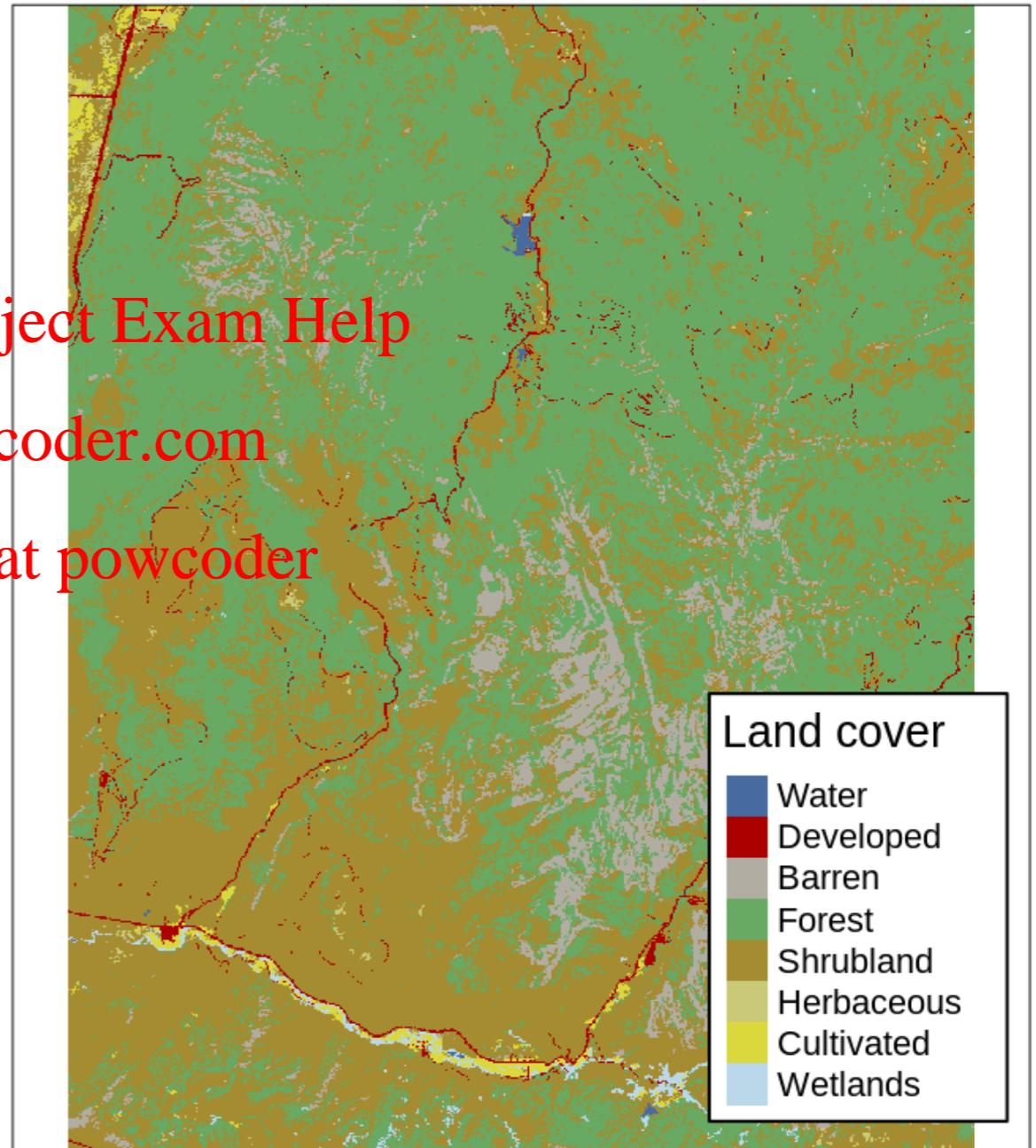
# CONTINUOUS AND CATEGORICAL RASTERS

---

A. Continuous data



B. Categorical data



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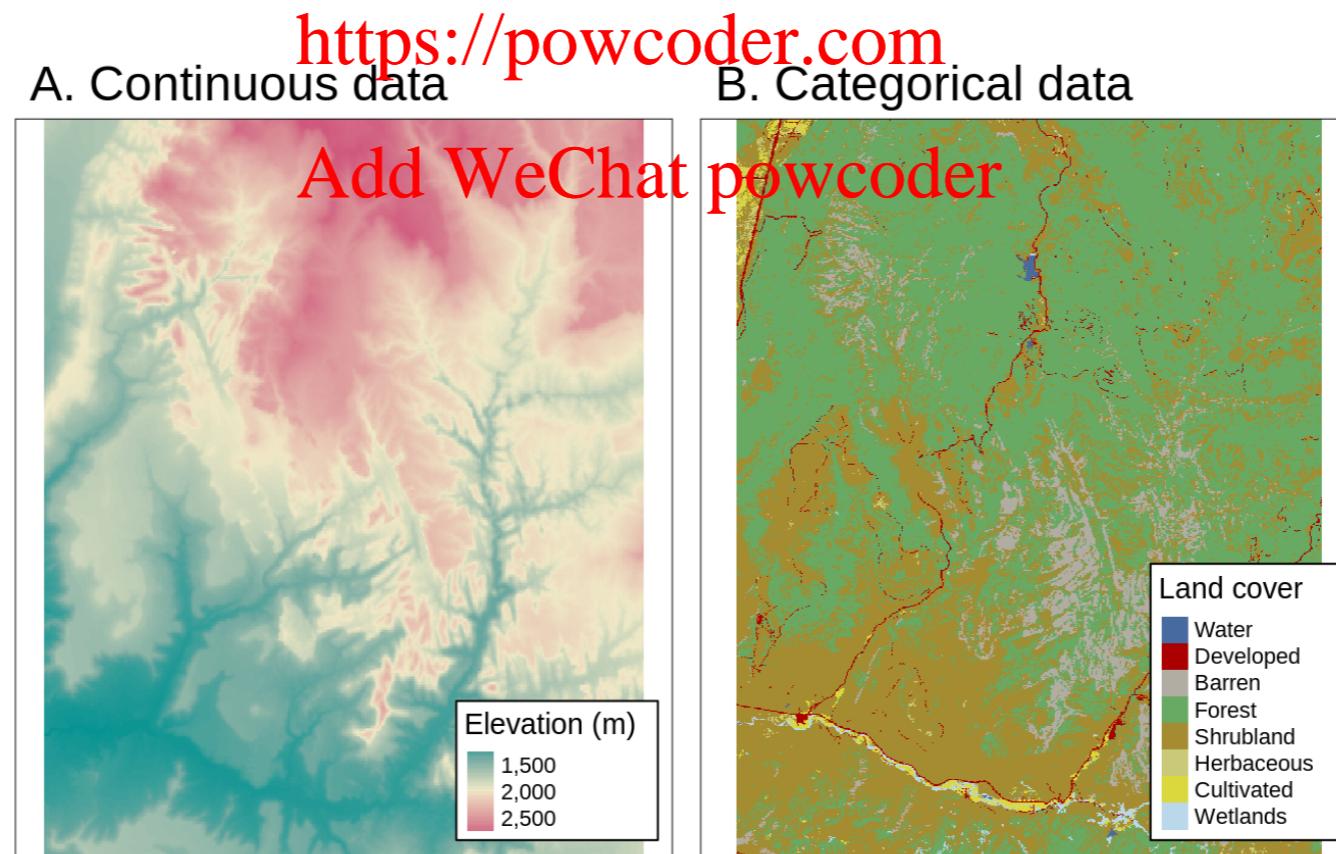
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# WHAT CAN WE DO?

---

- Given a coordinate, we can:
    - Identify elevation
    - Connect to land cover type
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# DATA STRUCTURE IN R

---

```
raster_filepath = system.file("raster/srtm.tif", package = "spDataLarge")
new_raster = raster(raster_filepath)
```

## Assignment Project Exam Help

```
new_raster
#> class      : RasterLayer    https://powcoder.com
#> dimensions : 457, 465, 212505 (nrow, ncol, ncell)
#> resolution : 0.000833, 0.000833 (x, y) Add WeChat powcoder
#> extent     : -113, -113, 37.1, 37.5 (xmin, xmax, ymin, ymax)
#> coord. ref. : +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
#> data source: /home/robin/R/x86_64-pc-linux.../3.5/spDataLarge/raster/srtm.tif
#> names      : srtm
#> values     : 1024, 2892 (min, max)
```

# COORDINATE REFERENCE SYSTEM (CRS)

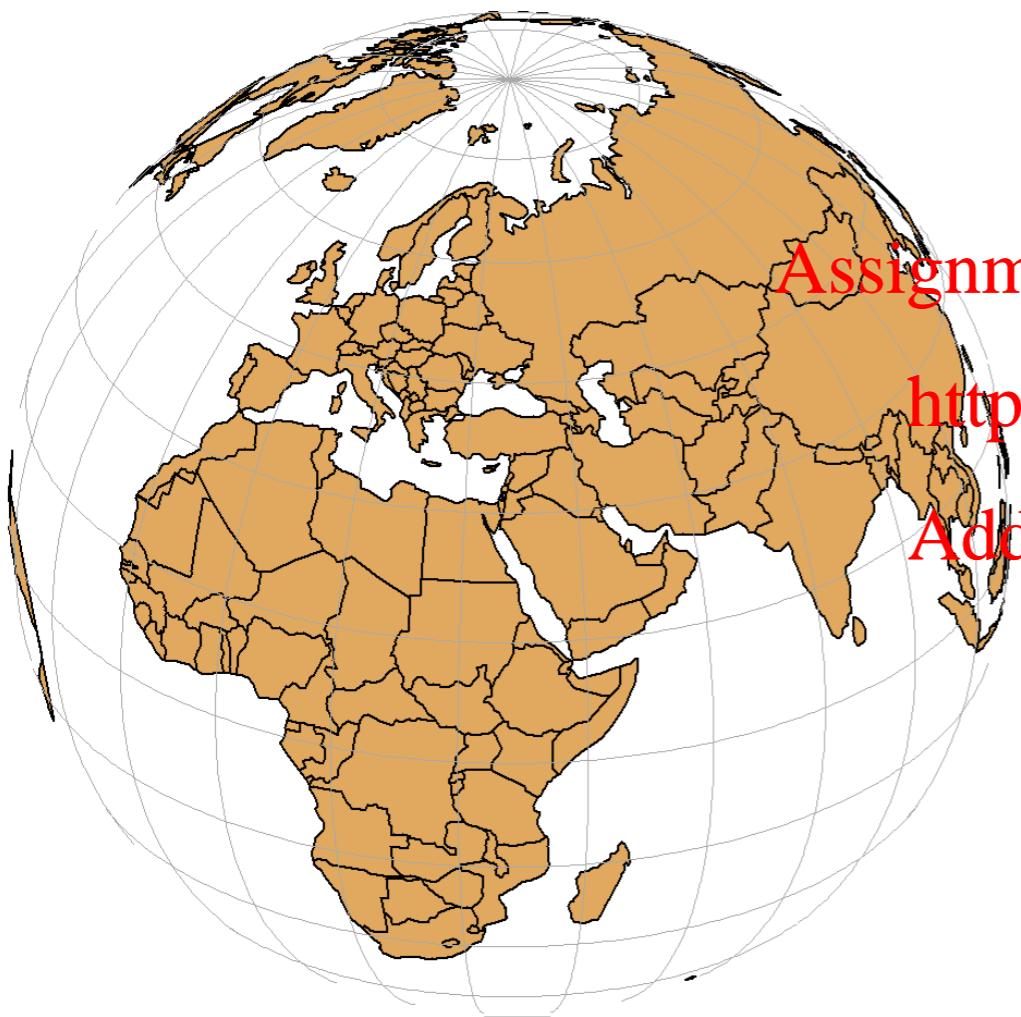
Assignment Project Exam Help

<https://powcoder.com>

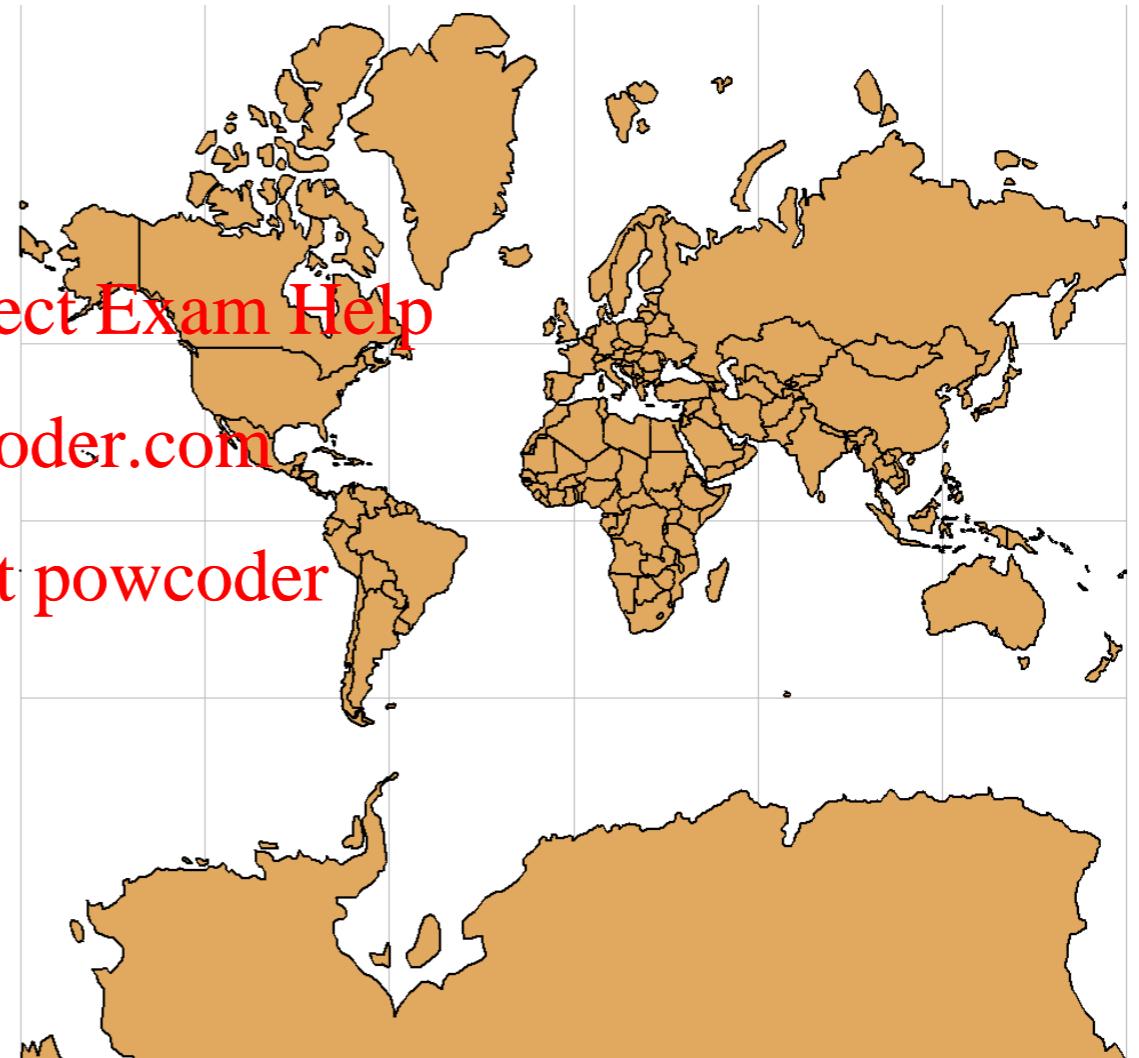
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# 3D AND 2D EARTH SURFACES

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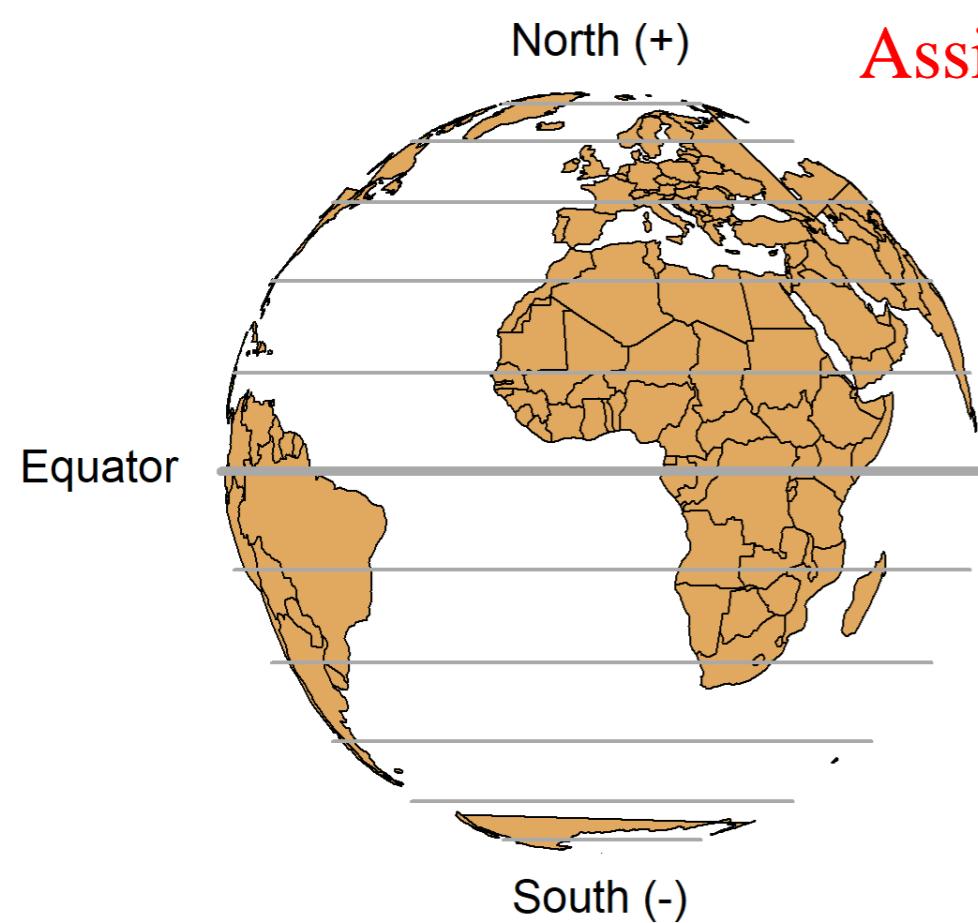


*From 'geospatial health data'*

# GEOGRAPHIC COORDINATE SYSTEMS

---

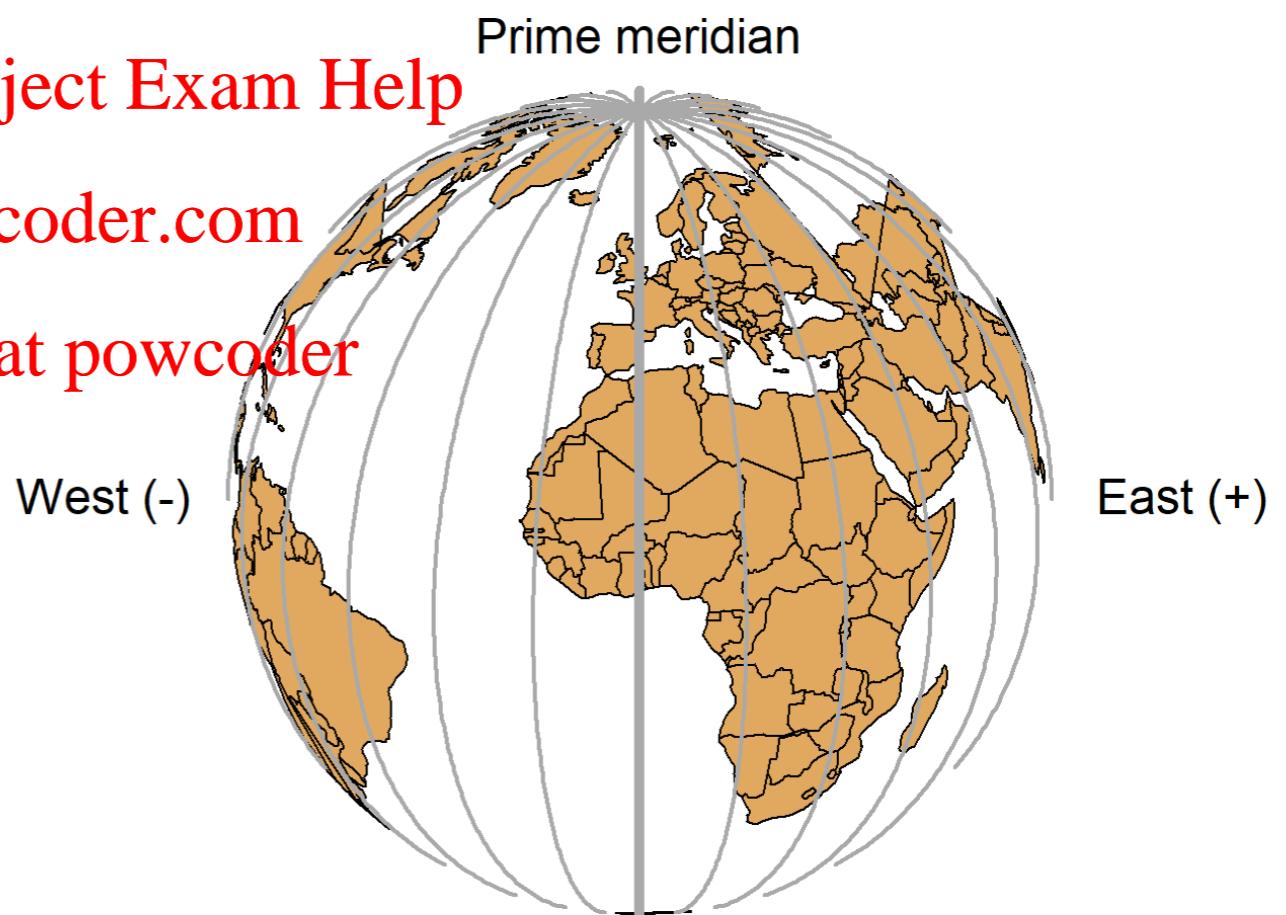
*A geographic coordinate system specifies locations on the Earth's three-dimensional using latitude and longitude values.*



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# PROJECTED COORDINATE SYSTEMS

---

- Map projections are transformation of the Earth's three-dimensional surface as a flat two-dimensional plane
- All map projections distort the Earth's surface in some fashion. Can only **Assignment Project Exam Help**
  - Area <https://powcoder.com>
  - Direction [Add WeChat powcoder](#)
  - Shape
  - Distance properties

# PROJECTION TYPES

---

- **Conic** — projected onto a cone along a single line of tangency or two lines of tangency
  - Best suited for maps of mid-latitude areas
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- **Cylindrical** — maps the surface onto a cylinder
  - Most often used for plotting the world
- **Planar** — projects data onto a flat surface touching the globe at a point or along a line of tangency
  - Typically used in mapping polar regions

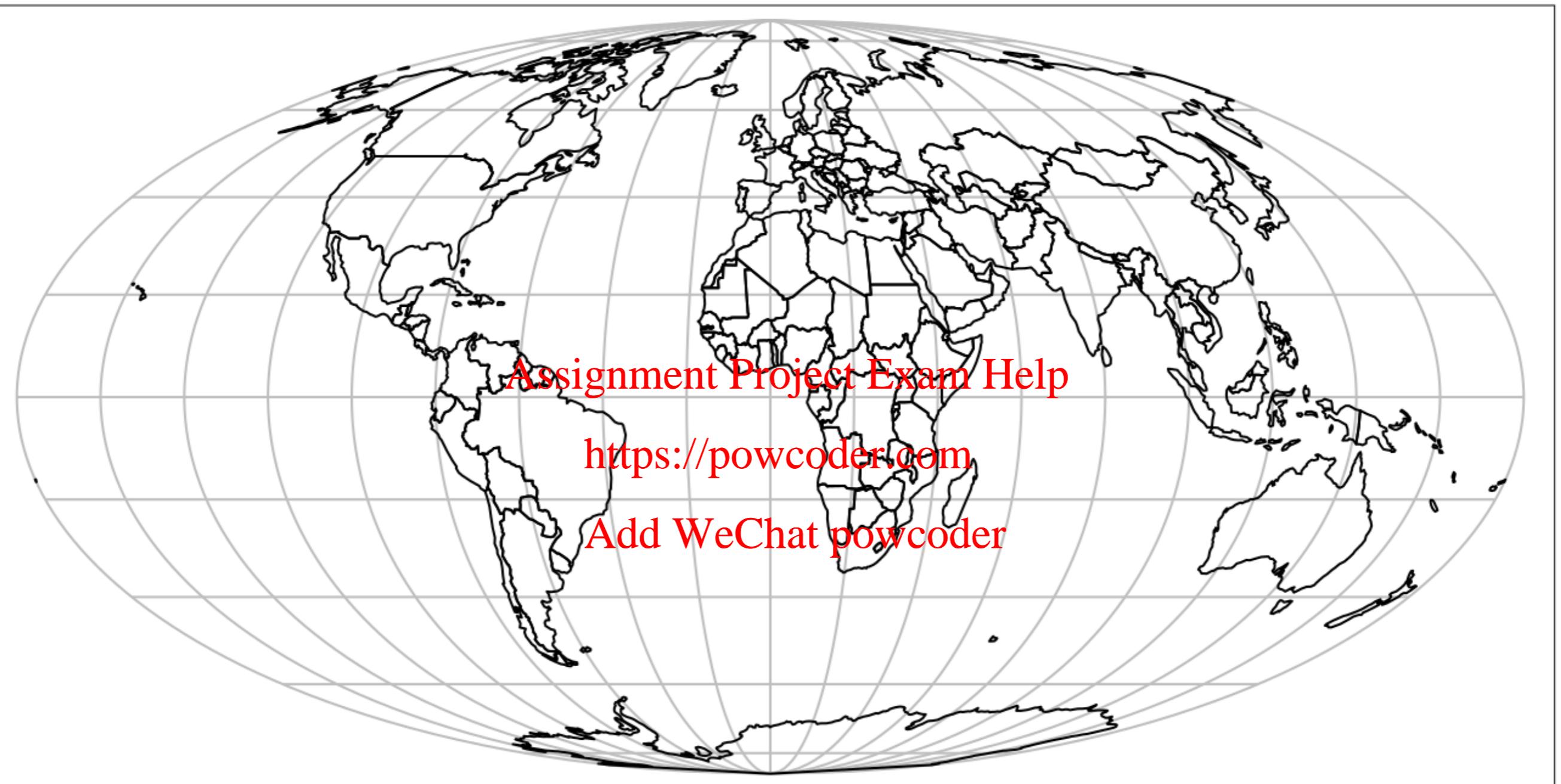
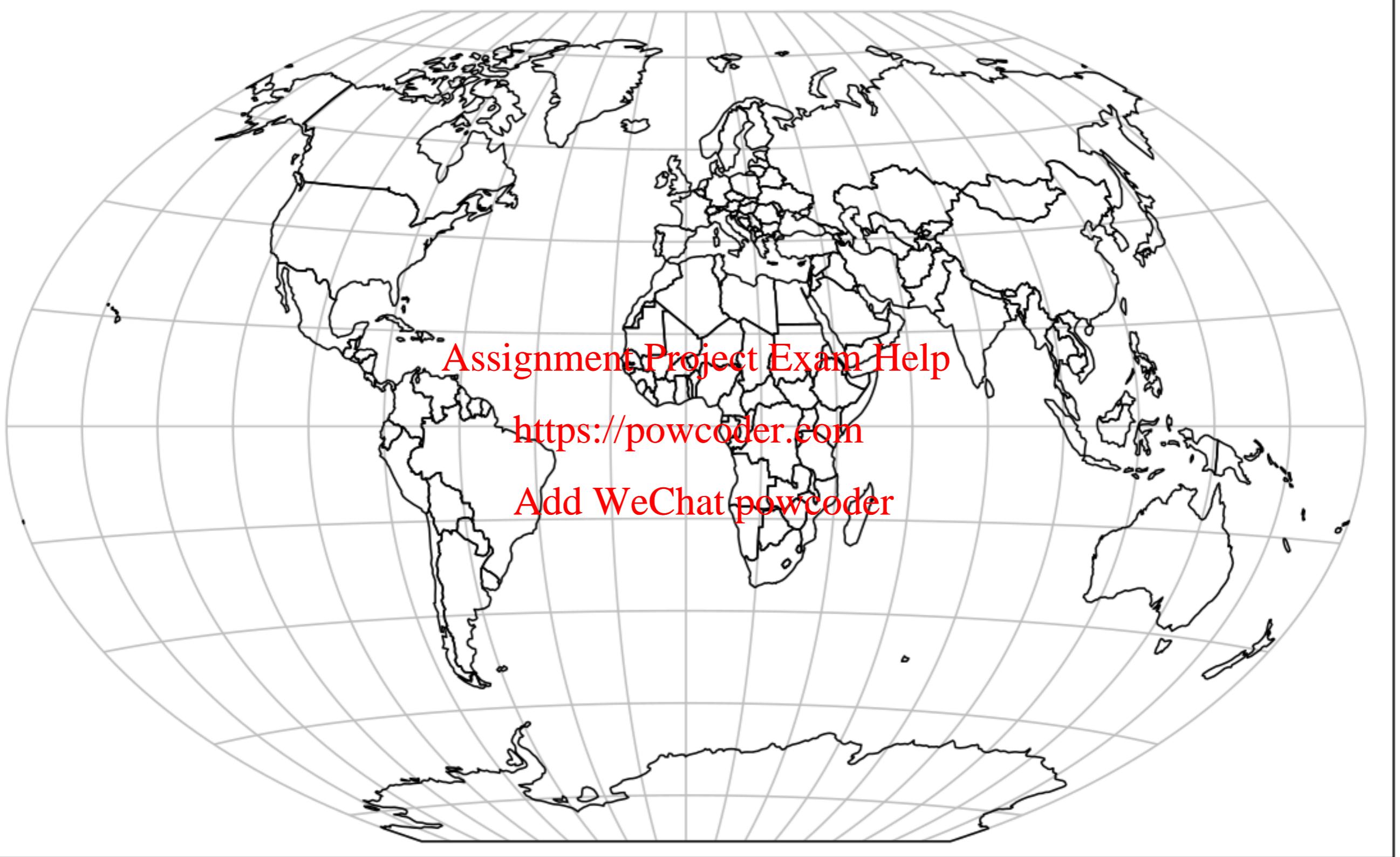


FIGURE 6.2: Mollweide projection of the world.



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FIGURE 6.3: Winkel tripel projection of the world.



FIGURE 6.4: Lambert azimuthal equal-area projection centered on longitude and latitude of 0.

# PROJECTED COORDINATE SYSTEMS

---

- Universal Transverse Mercator — UTM
  - Preserves local angles and shapes.
  - Divides Earth into 60 zones of 6 degrees of longitude in width
  - Each zone uses transverse Mercator projection to map a region of
- Position on Earth given by UTM zone number, hemisphere, and easting/northing coordinates in zone (measured in meters)
  - Eastings are referenced from the central meridian of each zone, and northings are referenced from the equator. The easting at the central meridian of each zone is defined to have a value of 500,000 meters

# BACK TO PREVIOUS DATA SET:

---

```
> world
Simple feature collection with 177 features and 10 fields
geometry type:  MULTIPOLYGON
dimension:      XY
bbox:           xmin: -180 ymin: -90 xmax: 180 ymax: 83.64513
geographic CRS: WGS 84

> nc
Assignment Project Exam Help
Simple feature collection with 100 features and 14 fields
geometry type:  MULTIPOLYGON https://powcoder.com
dimension:      XY
bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
geographic CRS: NAD27
```

```
new_raster
#> class       : RasterLayer
#> dimensions  : 457, 465, 212505  (nrow, ncol, ncell)
#> resolution   : 0.000833, 0.000833  (x, y)
#> extent       : -113, -113, 37.1, 37.5  (xmin, xmax, ymin, ymax)
#> coord. ref. : +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
#> data source  : /home/robin/R/x86_64-pc-linux.../3.5/spDataLarge/raster/srtm.tif
#> names        : srtm
```

# CRS OPTIONS

code	note	prj4	prj_method
4265	Monte Mario	+proj=longlat +ellps=intl +no_defs +type=crs	(null)
4266	M'poraloko	+proj=longlat +ellps=clrk80ign +no_defs +type=crs	(null)
4267	NAD27	+proj=longlat +datum=NAD27 +no_defs +type=crs	(null)
4268	NAD27 Michigan	+proj=longlat +a=6378450.04754889 +b=6356826...	(null)
4269	NAD83	+proj=longlat +datum=NAD83 +no_defs +type=crs	(null)
4270	Nahrwan 1967	+proj=longlat +a=6378249.145 +rf=293.465 +no_d...	(null)
4271	Naparima 1972	+proj=longlat +ellps=intl +no_defs +type=crs	(null)

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```
> View(rgdal::make_EPSG())
> unique(rgdal::make_EPSG()$prj_method)
[1] "(null)"                                     "Transverse Mercator"
[3] "Oblique Stereographic"                    "Transverse Mercator (South Orientated)"
[5] "Hotine Oblique Mercator (variant B)"      "Lambert Conic Conformal (1SP)"
[7] "Krovak"                                     "Cassini Soldner"
[9] "Mercator (variant A)"                     "Lambert Conic Conformal (2SP)"
[11] "Lambert Azimuthal Equal Area (Spherical)" "Lambert Conic Conformal (West Orientated)"
[13] "Tunisia Mining Grid"                     "Lambert Conic Near-Conformal"
[15] "Hotine Oblique Mercator (variant A)"      "New Zealand Map Grid"
[17] "American Polyconic"                      "Bonne (South Orientated)"
[19] "Albers Equal Area"                       "Laborde Oblique Mercator"
[21] "Polar Stereographic (variant C)"         "Polar Stereographic (variant B)"
[23] "Lambert Azimuthal Equal Area"            "Lambert Conic Conformal (2SP Belgium)"
[25] "Hyperbolic Cassini-Soldner"              "Transverse Mercator Zoned Grid System"
[27] "Polar Stereographic (variant A)"         "Equidistant Cylindrical (Spherical)"
[29] "Equidistant Cylindrical"                  "Modified Azimuthal Equidistant"
[31] "Mercator (variant B)"                    "Lambert Cylindrical Equal Area (Spherical)"
[33] "Mercator (1SP) (Spherical)"              "Popular Visualisation Pseudo Mercator"
[35] "Guam Projection"                        "Krovak (North Orientated)"
[37] "Krovak Modified"                         "Krovak Modified (North Orientated)"
[39] "Geographic/topocentric conversions"    "Geocentric/topocentric conversions"
[41] "Lambert Conic Conformal (2SP Michigan)" "Colombia Urban"
[43] "Lambert Cylindrical Equal Area"          "Equal Earth"
```

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# CRS

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- Specifies how coordinates are related to locations on Earth
- CRS is either geographic or projected
- In R, CRS specified using `proj4` strings that specify:
  - Projection [Assignment Project Exam Help](https://powcoder.com)
  - Ellipsoid <https://powcoder.com>
  - Datum [Add WeChat powcoder](https://powcoder.com)

# SELECTING AND SETTING CRS

---

- Depending on the data set you work with, it may already have a defined CRS — typically comes as a `shape` file (.shp)
- What if it doesn't?
  - There will be choices to be made!  
<https://powcoder.com>
  - Don't make an assumption without thoroughly contacting people who know the data best  
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  - <https://www.spatialreference.org>
- There are some commonly used CRS, for example:
  - WGS84/4326

# SETTING AND CHANGING A CRS

---

```
vector_filepath = system.file("vector/zion.gpkg", package = "spDataLarge")
new_vector = st_read(vector_filepath)
```

```
st_crs(new_vector) # get CRS
#> Coordinate Reference System:
#> No EPSG code
#> proj4string: "+proj=utm +zone=12 +ellps=GRS80 ... +units=m +no_defs"
```

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```
new_vector = st_set_crs(new_vector, 4326) # set CRS
#> Warning: st_crs<- : replacing crs does not reproject data; use st_transform for
#> that
```

# SETTING AND CHANGING A CRS

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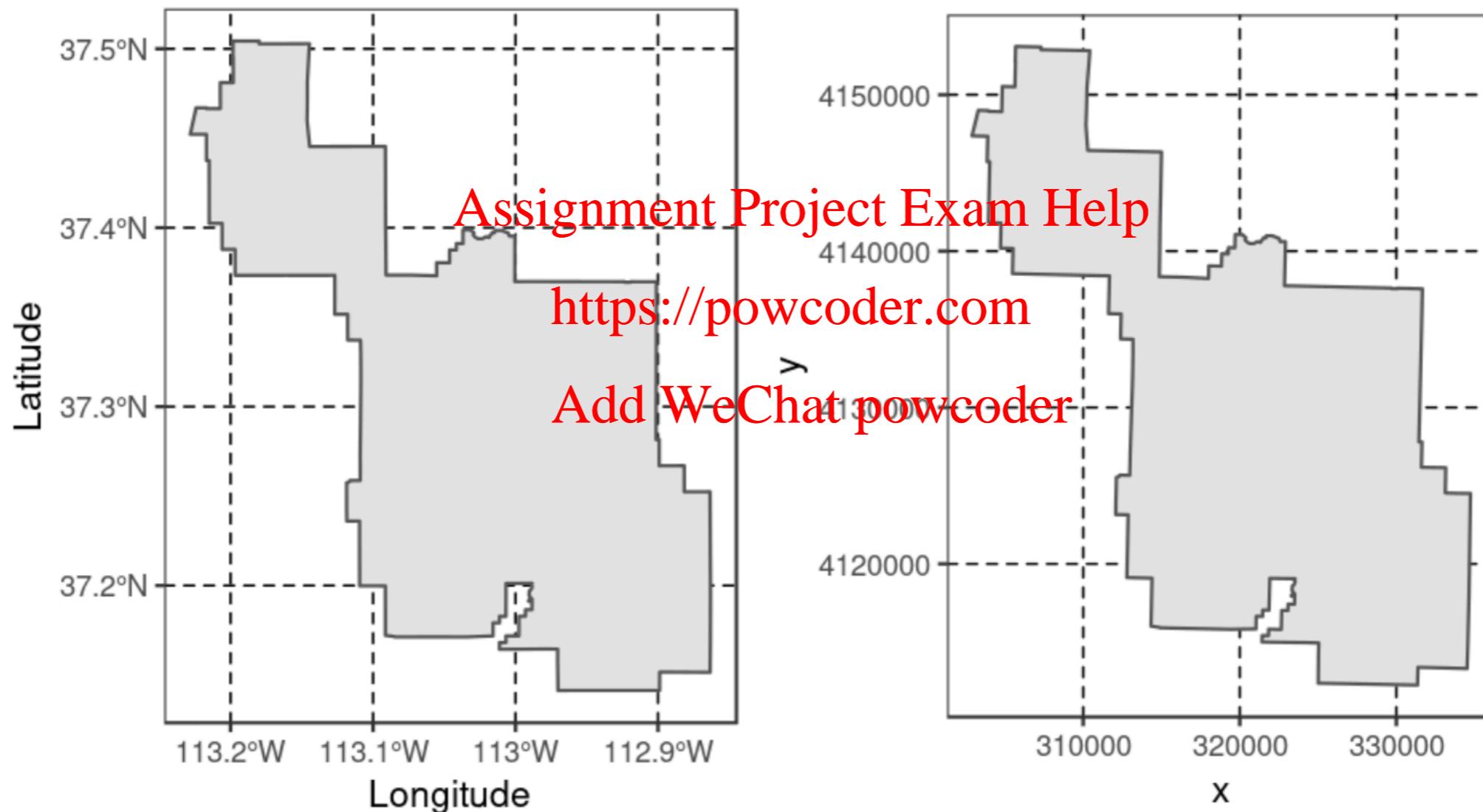


FIGURE 2.13: Examples of geographic (WGS 84; left) and projected (NAD83 / UTM zone 12N; right) coordinate systems for a vector data type.

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```
projection(new_raster) # get CRS  
#> [1] "+proj=longlat +datum=WGS84 +no_defs"
```

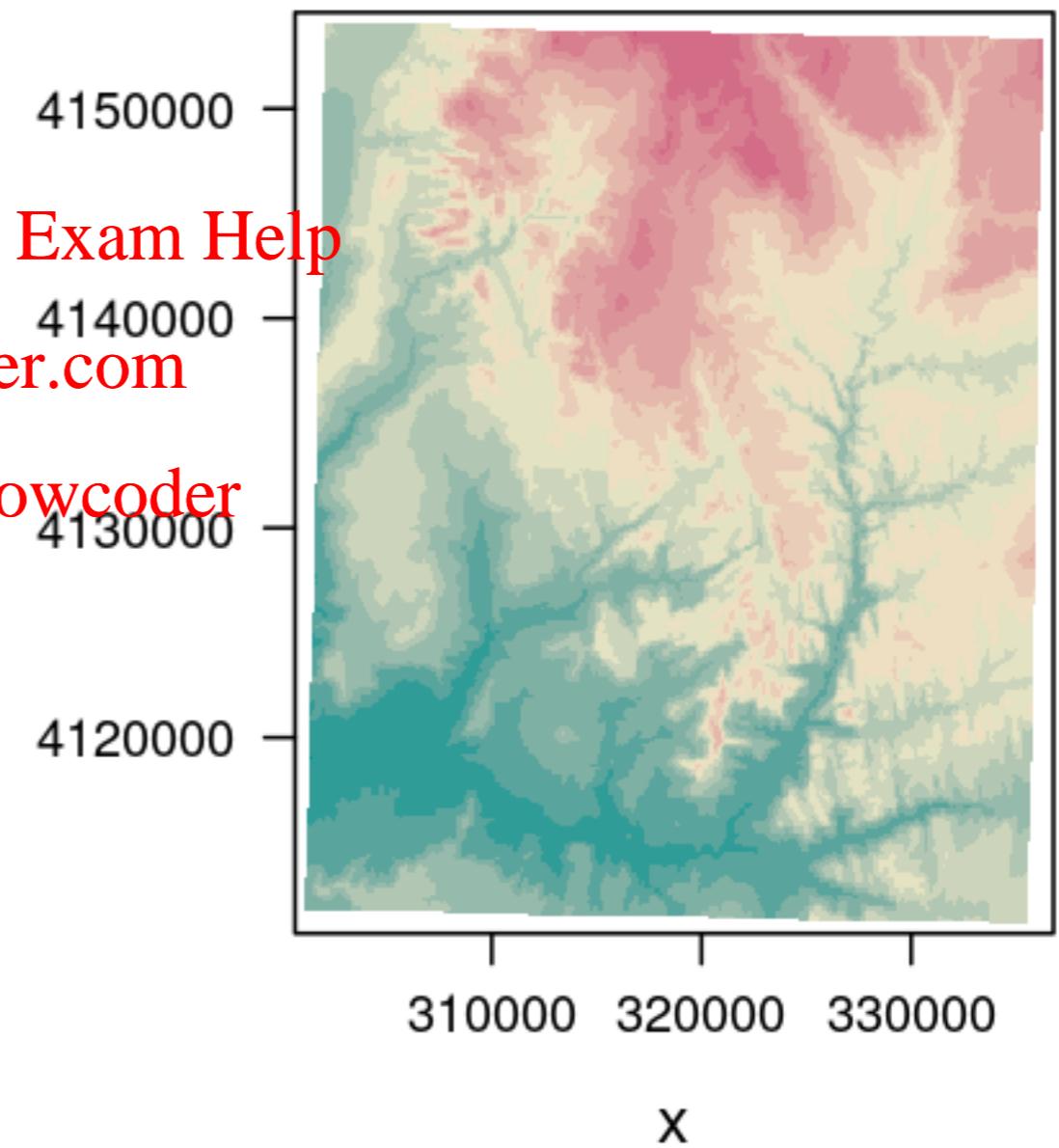
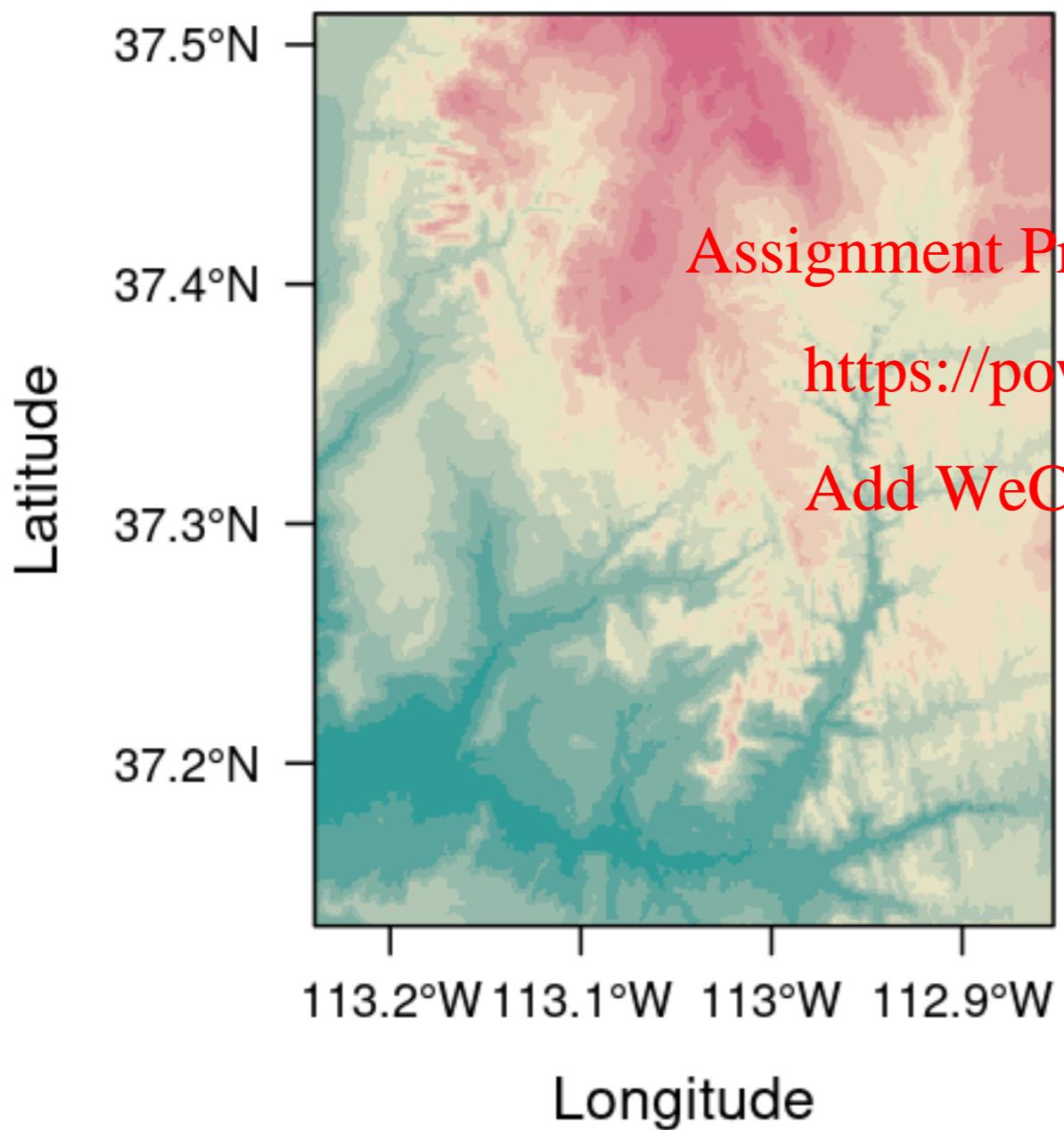
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```
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projection(new_raster) = "+proj=utm +zone=12 +ellps=GRS80 +towgs84=0,0,0,0,0,0,0  
+units=m +no_defs" # set CRS  
#> Warning in showSRID(uprojargs, format = "PROJ", multiline = "NO", prefer_proj =  
#> prefer_proj): Discarded datum Unknown based on GRS80 ellipsoid in CRS definition
```

# SETTING AND CHANGING A CRS

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# MANIPULATING SPATIAL DATA STRUCTURES

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# COMBINING/MODIFYING SPATIAL DATA STRUCTURES

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- You want to combine two data sets — but they have different CRS...
- You have two data sets, one with points and one with multipolygons — how do you combine them?  
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- Overlaying multipolygons, strings, points
- Computing distances, areas from spatial data structure!