R Spatial Basics Agenda

Follow-along example with NJ Bus Stop data

1. Loading data from file
    a. CSV format
    b. Shapefile format
2. Geographic data basics
3. Basic maps
4. Gridded aggregations

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R Spatial Basics

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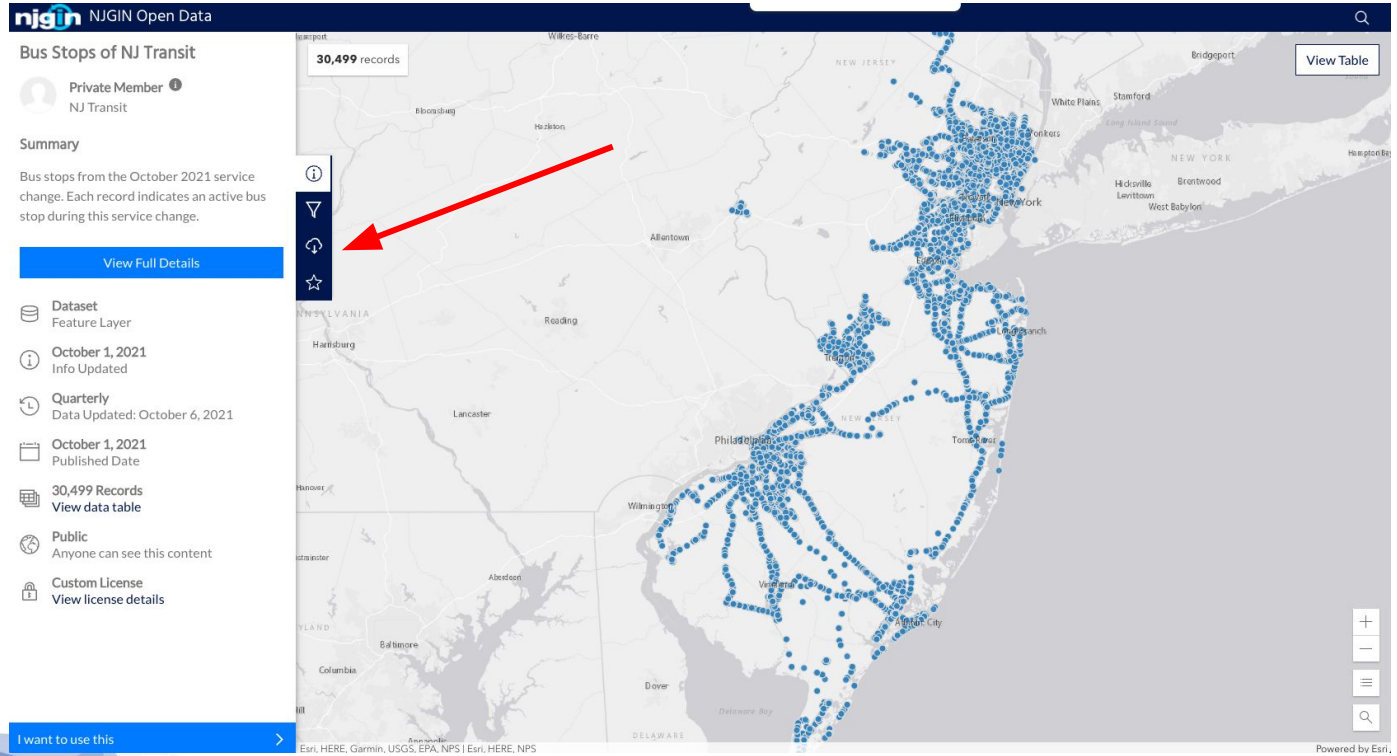
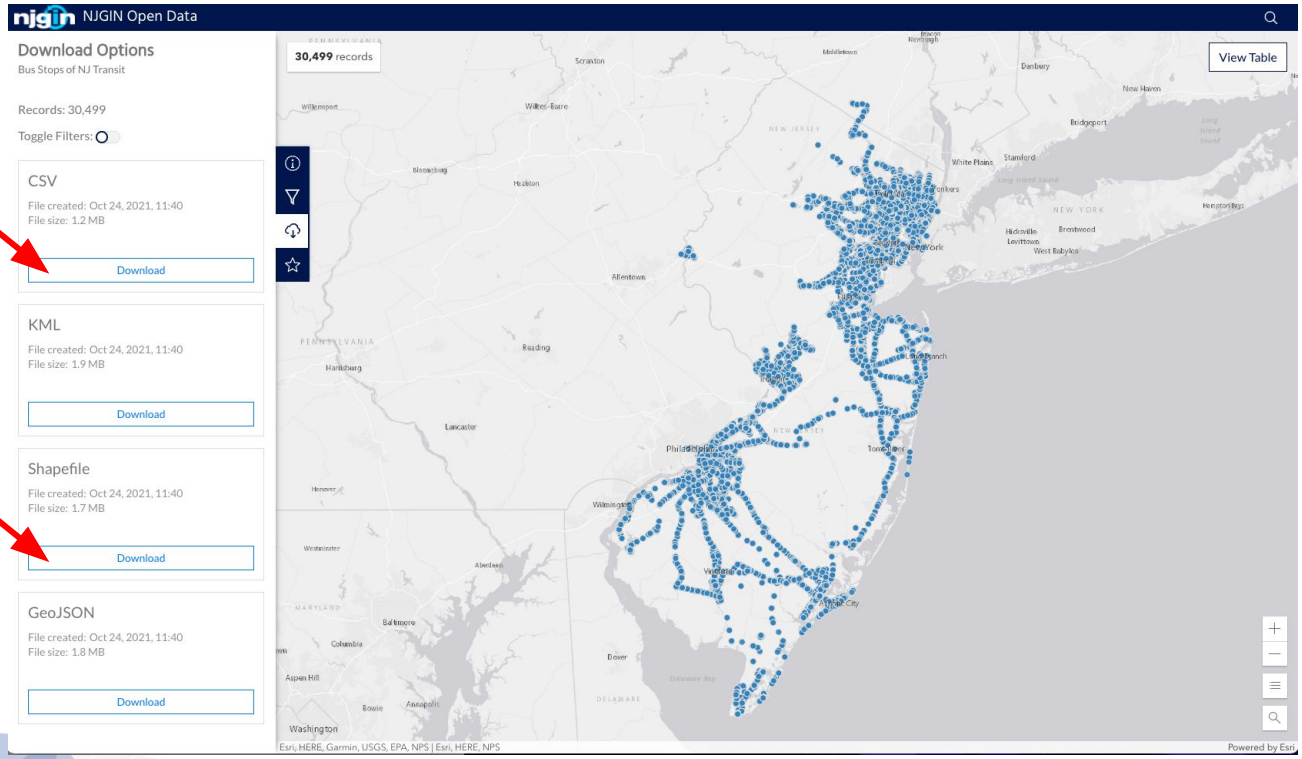
With thanks to David Walling and Chris Ramos for contributing materials to these lessons

Data download



Download Shapefile and CSV file



Geographic data basics

- Geographic coordinate systems (GCS): where on the ellipsoid did this happen?
- Projected coordinate systems (PCS) are flattened-out
- R handles projection math for us

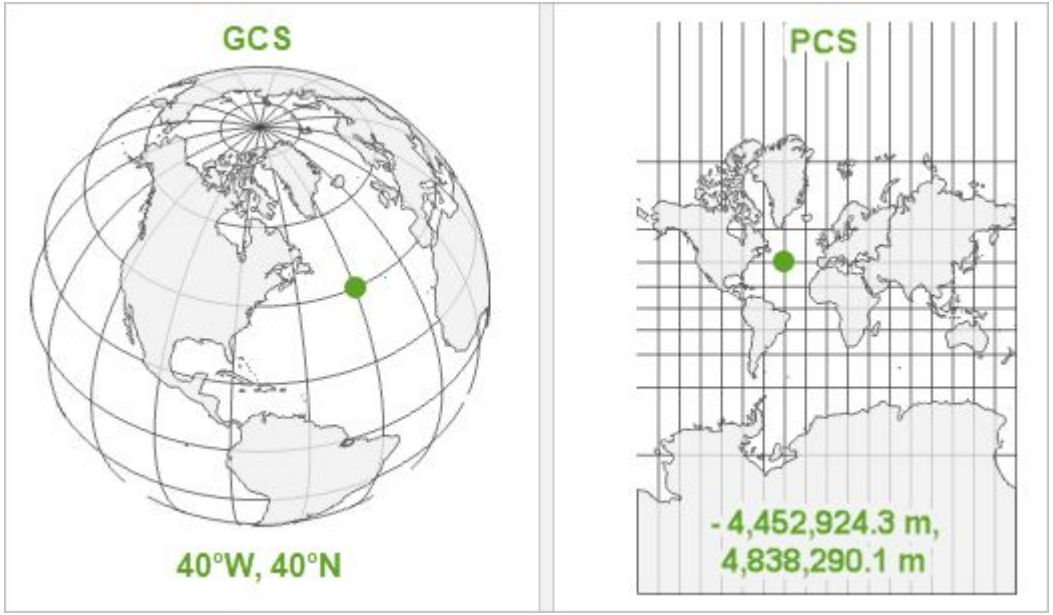


image source: https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/gcs_vs_pcs/

Loading data from file

- comma-separated values
  - single file in text format
  - columns are separated by commas
  - rows are separated by newlines

```
column1,column2
value1,value2
```

- shapefiles
  - collection of files
  - contains spatial metadata

Creating simple features from a CSV

- "Simple features" refers to a spatial data standard used by ArcGIS, the R **`sf`** library, and other geospatial software

```
bus_csv <- read.csv('data/Bus_Stops_of_NJ_Transit.csv')
head(bus_csv)
```

```
##     FID COUNTY DLAT_GIS DLONG_GIS LINE STOP_NUM STOP_TYPE STREET_DIR
## 1 30448  Essex 40.72093 -74.22520   37    17819        NS          N
## 2 30449  Essex 40.72093 -74.22520  107    17819        NS          N
## 3 30450  Essex 40.72115 -74.22518   90    17841        NS          S
## 4 30451  Essex 40.79417 -74.23053   97    19442        NS          N
## 5 30452  Essex 40.79419 -74.23067   97    19445        FS          S
## 6 30453  Essex 40.77684 -74.17063   99    18659        NS          E
```

Creating simple features from a CSV

- After loading the CSV formatted data, we convert to a simple features format with the function **`st_as_sf()`** from library **`sf`**
- We don't know the CRS, so we guess a common one: WGS84 (not recommended in real life)

```
library(sf)
```

```
## Linking to GEOS 3.8.1, GDAL 3.2.1, PROJ 7.2.1; sf_use_s2() is TRUE
```

```
bus_sf <- bus_csv %>% st_as_sf(.,coords=c("DLONG_GIS","DLAT_GIS"), crs=WGS84)
```

Creating simple features from a CSV

metadata

data

```
## Simple feature collection with 6 features and 10 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: -74.23067 ymin: 40.72093 xmax: -74.17063 ymax: 40.79419
## Geodetic CRS:  WGS 84
##     FID COUNTY LINE STOP_NUM STOP_TYPE STREET_DIR        DESCRIPTION_BSL
## 1 30448  Essex   37    17819        NS          N GROVE ST AT HERPERS ST
## 2 30449  Essex  107    17819        NS          N GROVE ST AT HERPERS ST
## 3 30450  Essex   90    17841        NS          S GROVE ST AT HERPERS ST
## 4 30451  Essex   97    19442        NS          N HARRISON AVE AT ELM ST
## 5 30452  Essex   97    19445        FS          S HARRISON AVE AT ELM ST
## 6 30453  Essex   99    18659        NS          E HELLER PKWY AT LAKE ST
##   DIRECTION_OP    MUNICIPALITY                              GlobalID
## 1           Ou   IRVINGTON TWP 9dd47d93-3ac8-4167-85bd-20fefa063e33
## 2           Ou   IRVINGTON TWP f3cde248-5286-4a0d-8710-94c38b3bafd8
## 3           Ou   IRVINGTON TWP 8fc8919f-8a25-4eec-aa65-f5c9d6d793dd
## 4           In WEST ORANGE TWP 65a3bde8-d8f0-475d-9f49-ff86a81d387f
## 5           Ou WEST ORANGE TWP 4a3fa65f-a13a-4f07-bfcd-977f7562c5c4
## 6           In          NEWARK 70298ad9-9b33-419d-b883-1d2434264126
##                    geometry
## 1  POINT (-74.2252 40.72093)
## 2  POINT (-74.2252 40.72093)
## 3 POINT (-74.22518 40.72115)
## 4 POINT (-74.23053 40.79417)
## 5 POINT (-74.23067 40.79419)
## 6 POINT (-74.17063 40.77684)
```

Shapefile basics

- Shapefiles are really collections of files

dBASE table file

Main file

Index file

Metadata file

Optional codepage file (identifies character set to use)

Projections definition file

Creating simple features from a shapefile

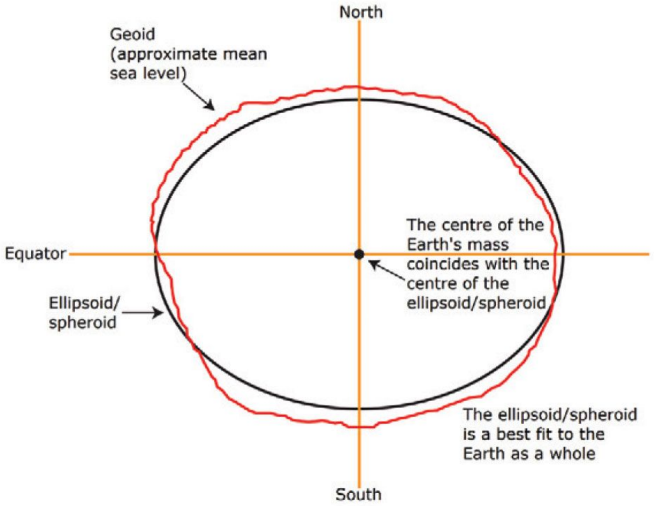
- We can load shapefiles directly with **`st_read()`**
- The CRS will be read from the shapefile **`.prj`** file

```
bus <- st_read('data/Bus_Stops_of_NJ_Transit.shp')
```

```
## Reading layer 'Bus_Stops_of_NJ_Transit' from data source
##   '/Users/kpierce/data_trainings/PAP-TACC-2022/data/Bus_Stops_of_NJ_Transit.shp'
##   using driver 'ESRI Shapefile'
## Simple feature collection with 30499 features and 12 fields
## Geometry type: MULTIPOINT
## Dimension:     XY
## Bounding box:  xmin: -8406962 ymin: 4712207 xmax: -8230860 ymax: 5050000
## Projected CRS: WGS 84 / Pseudo-Mercator
```

Reference frames

Geocentric (WGS84)



Regional (New Jersey state planar)

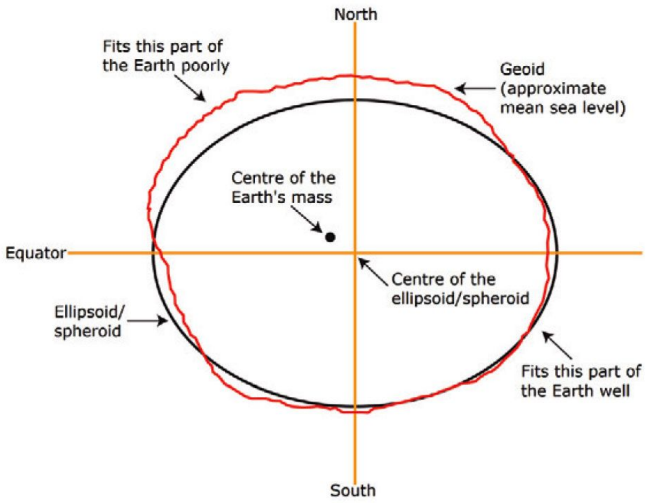


image source:
https://csegrecorder.com/articles/view/datums-projections-and-coordinate-systems

Change coordinate reference systems

- Coordinate reference systems (both geographic and projected) are described by codes
- ESRI maintains a database of codes at https://spatialreference.org/ref/esri/
- We'll define two CRS codes as variables so we can reference them by name, making our script easier-to-read

```
WGS84 = 4326
NJ_PLANAR = 'ESRI:102311'
```

- WGS84 is our geocentric geographic reference system
- NJ_PLANAR is our regional projected reference system

Change coordinate reference systems

```
bus_wgs84 <- st_transform(bus, crs=WGS84)
```

```
head(bus_wgs84)
```

```
## Simple feature collection with 6 features and 12 fields
## Geometry type: MULTIPOINT
## Dimension:     XY
## Bounding box:  xmin: -74.23071 ymin: 40.72092 xmax: -74.17066 ymax: 40.79424
## Geodetic CRS:  WGS 84
```

Change coordinate reference systems

```
bus_nj <- st_transform(bus, crs=NJ_PLANAR)
```

```
head(bus_nj)
```

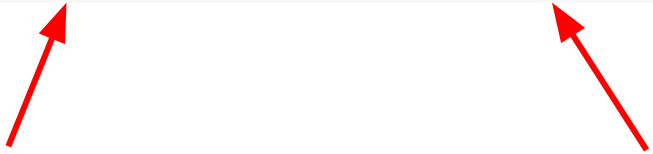
```
## Simple feature collection with 6 features and 12 fields
## Geometry type: MULTIPOINT
## Dimension:     XY
## Bounding box:  xmin: 172725.2 ymin: 209594.1 xmax: 177799.7 ymax: 217734.3
## Projected CRS: NAD_1983_HARN_StatePlane_New_Jersey_FIPS_2900
```

Map the bus stops

- Point locations
- Basemaps
- Choropleth maps

Mapping point locations

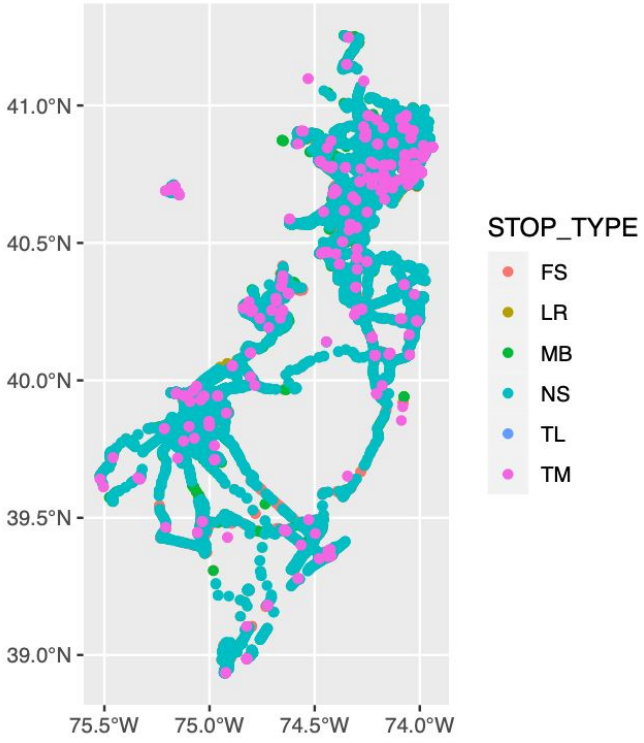
```
nj_bus_map <- ggplot() +
  geom_sf(data=bus_wgs84, aes(color=STOP_TYPE), inherit.aes = FALSE)
```



Use the unprojected WGS84 data; **`geom_sf()`** will project the data onto the map plane

color the points by the value in column **`STOP_TYPE`**

Mapping point locations



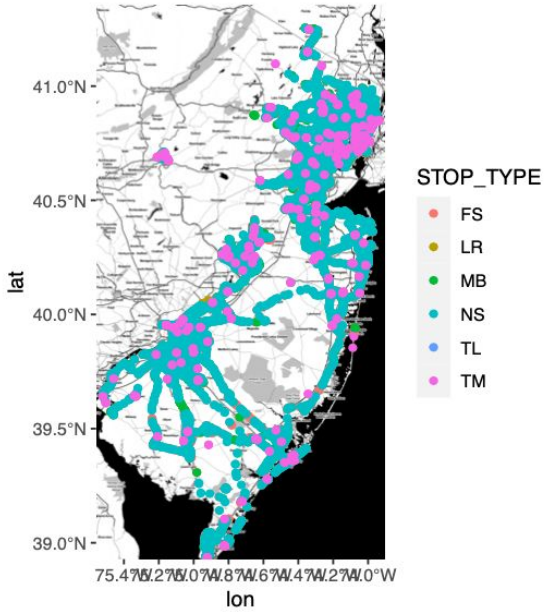
Adding map layers

- Our map needs a background to provide context
- Open Street Maps provides free map tiles
  - download tiles corresponding to bounding box
  - different tile themes available (http://maps.stamen.com/)
- Libraries **`ggplot`** and **`ggmap`** allow us to build layered maps in R

```
nj <- read_sf(
  'https://opendata.arcgis.com/datasets/5f45e1ece6e14ef5866974a7b57d3b95_1.geojson'
  )
nj <- nj %>% st_transform(crs=WGS84)
nj_bbox <- unname(st_bbox(nj))
nj_base_map <- get_stamenmap(bbox=nj_bbox, maptype="toner", force=TRUE)
```

Adding map layers

```
library(ggmap)
nj_bus_map <- ggmap(nj_base_map) +
  geom_sf(data=bus_wgs84, aes(color=STOP_TYPE), inherit.aes = FALSE)
```



Choropleth map of 2010 population

The state boundary map we used for the bounding box contained some additional data:

```
## Simple feature collection with 6 features and 22 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -75.41973 ymin: 38.92852 xmax: -73.90245 ymax: 41.13372
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 23
##   OBJECTID COUNTY     COUNTY_LABEL  CO    GNIS_NAME GNIS  FIPSSTCO FIPSCO  ACRES
##      <int> <chr>      <chr>         <chr> <chr>     <chr> <chr>    <chr>   <dbl>
## 1        1 ATLANTIC   Atlantic Cou~ ATL   County o~ 8822~ 34001    1      3.91e5
## 2        2 BERGEN     Bergen County BER   County o~ 8822~ 34003    3      1.53e5
## 3        3 BURLINGTON Burlington C~ BUR   County o~ 8822~ 34005    5      5.25e5
## 4        4 CAMDEN     Camden County CAM   County o~ 8822~ 34007    7      1.46e5
## 5        5 CAPE MAY   Cape May Cou~ CAP   County o~ 8822~ 34009    9      1.83e5
## 6        6 CUMBERLAND Cumberland C~ CUM   County o~ 8822~ 34011    11     3.21e5
## # ... with 14 more variables: SQ_MILES <dbl>, POP2010 <int>, POP2000 <int>,
## #   POP1990 <int>, POP1980 <int>, POPDEN2010 <int>, POPDEN2000 <int>,
## #   POPDEN1990 <int>, POPDEN1980 <int>, REGION <chr>, GLOBALID <chr>,
## #   Shape_Length <dbl>, Shape_Area <dbl>, geometry <MULTIPOLYGON [°]>
```

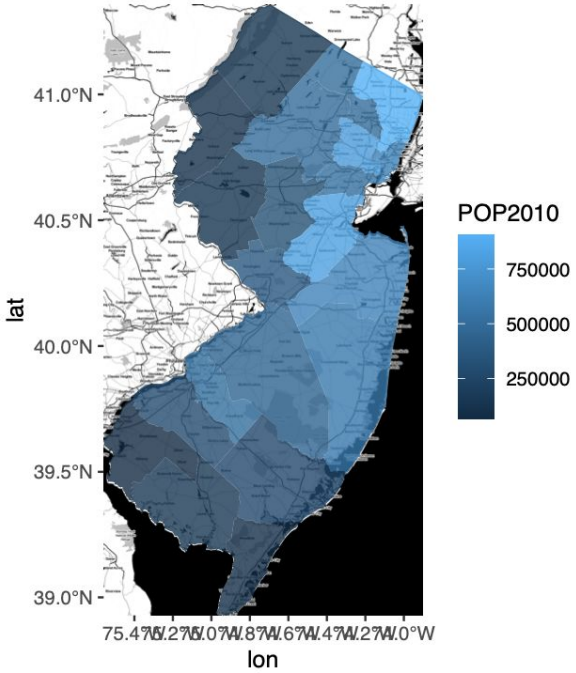
Choropleth map of 2010 population

The state boundary map we used for the bounding box contained some additional data:

```
## Simple feature collection with 6 features and 22 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: -75.41973 ymin: 38.92852 xmax: -73.90245 ymax: 41.13372
## Geodetic CRS:  WGS 84
## # A tibble: 6 x 23
##   OBJECTID COUNTY     COUNTY_LABEL  CO    GNIS_NAME GNIS  FIPSSTCO FIPSCO  ACRES
##      <int> <chr>      <chr>         <chr> <chr>     <chr> <chr>    <chr>   <dbl>
## 1        1 ATLANTIC   Atlantic Cou~ ATL   County o~ 8822~ 34001    1      3.91e5
## 2        2 BERGEN     Bergen County BER   County o~ 8822~ 34003    3      1.53e5
## 3        3 BURLINGTON Burlington C~ BUR   County o~ 8822~ 34005    5      5.25e5
## 4        4 CAMDEN     Camden County CAM   County o~ 8822~ 34007    7      1.46e5
## 5        5 CAPE MAY   Cape May Cou~ CAP   County o~ 8822~ 34009    9      1.83e5
## 6        6 CUMBERLAND Cumberland C~ CUM   County o~ 8822~ 34011    11     3.21e5
## # ... with 14 more variables: SQ_MILES <dbl>, POP2010 <int>, POP2000 <int>,
## #   POP1990 <int>, POP1980 <int>, POPDEN2010 <int>, POPDEN2000 <int>,
## #   POPDEN1990 <int>, POPDEN1980 <int>, REGION <chr>, GLOBALID <chr>,
## #   Shape_Length <dbl>, Shape_Area <dbl>, geometry <MULTIPOLYGON [°]>
```

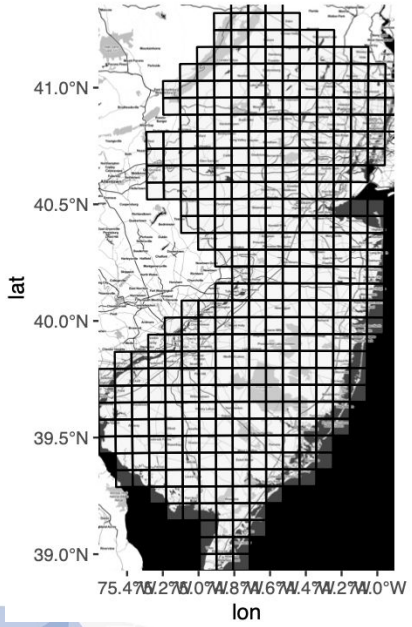
Choropleth map of 2010 population

```
nj_map <- ggmap(nj_base_map) +
  geom_sf(data=nj, aes(fill=POP2010), inherit.aes = FALSE, color = NA, alpha = 0.8)
```

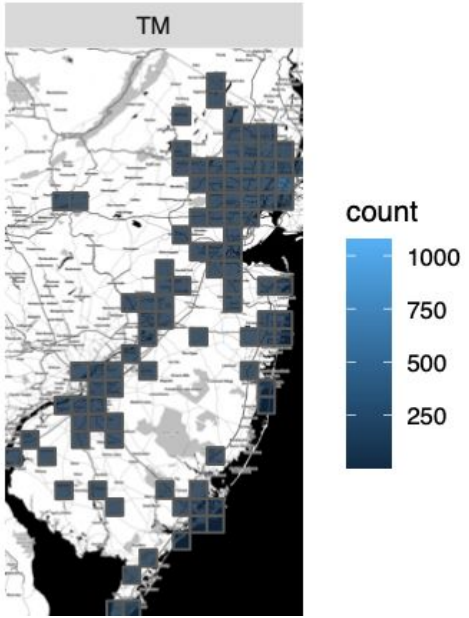


Gridded (“fishnet”) mappings

Overlay grid



Aggregate points into grid cells



Define spatial extent for 5-mi grid

- project the NJ border into the regional planar CRS
- convert 5-mile grid to meters (1,609m/mi)

```
nj_flat <- st_transform(nj, crs=NJ_PLANAR)
fishnet_width <- 1609 * 5
```

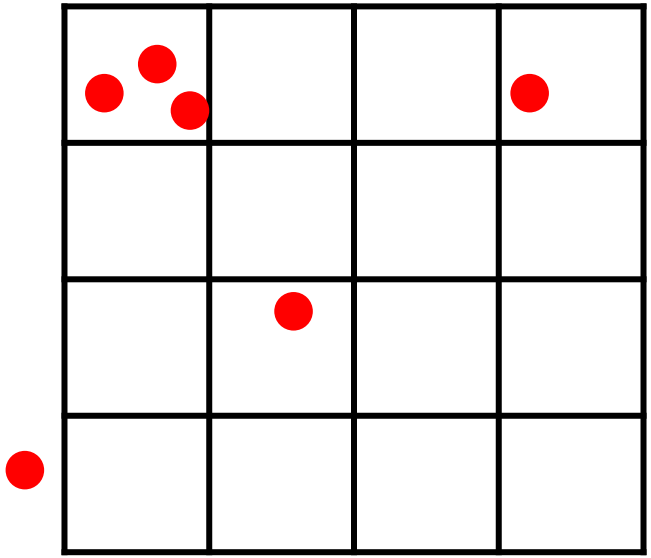
- remove interior county borders from shape

```
nj_border <- st_make_valid(st_union(nj_flat))
```

Create grid and convert to `sf`

```
net <- st_make_grid(
  x=nj_border, cellsize=fishnet_width, what='polygons', square=TRUE, crs=NJ_PLANAR
  )
net_agg <- st_as_sf(net) %>% tibble::rowid_to_column(., "net_id")
net_intersect <- st_intersects(nj_border, net_agg)
fishnet <- net_agg[unique(unlist(net_intersect)),]
```

Point-in-polygon join



Point-in-polygon join

```
bus_net <- st_join(bus_nj, fishnet, join=st_within) %>%
    st_drop_geometry()
```

- point data is left argument
- polygon data is right argument
- polygon geometry is implicitly dropped by st_join, and only point geometry is retained
- we intentionally drop point geometry to retain only the bus stop ID data and the fishnet ID data

Finalize bus stop fishnet

Aggregate on `net_id`

```
bus_net_summary <- bus_net %>%
  group_by(net_id, STOP_TYPE) %>%
  summarise(count=n())
```

Rejoin fishnet geometry

```
bus_net_final <- st_as_sf(
  left_join(
    fishnet,
    bus_net_summary,
    by='net_id'
    ),
  crs=st_crs(fishnet))
```

Map bus stop counts by type

```
bus_type_map <- ggmap(nj_base_map) +
  geom_sf(
    data=st_transform(bus_net_final, crs=WGS84),
    aes(fill=count),
    inherit.aes = FALSE, alpha=0.8
    ) +
  facet_wrap(facets='STOP_TYPE', nrow=3)
bus_type_map
```