

Texas Power Crisis, February 2021

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The Power Crisis of February 2021, Houston, Texas

This is a GitHub repository for Jaslyn Miura's analysis of an analysis of the 2021 power crisis after severe winter storms, in Houston, Texas; using NASA's VIIRS, OpenStreetMap, and American Community Survey data.

By analyzing the number of homes and census tracts that experienced an electricity blackout during the winter storms in Houston, Texas, helps us understand if the impacts were disproportionately felt.

##File Directory:

```
texas-2021-power-crisis
├── data
│   ├── ACS_2019_5YR_TRACT_48_TEXAS.gdb
│   ├── gis_osm_buildings_a_free_1.gpkg
│   ├── gis_osm_roads_free_1.gpkg
│   └── VNP46A1
└── README.md
└── texas_power_crisis_2021.qmd
└── texas-2021-power-crisis.Rproj
```

data:

- ACS_2019_5YR_TRACT_48_TEXAS: census tracts of Texas data
- gis_osm_buildings_a_free_1: buildings in Texas data
- gis_osm_roads_free_1: roads in Texas data
- VNP46A1: Visible Infrared Imaging Radiometer Suite (VIIRS) satellite data of Houston

texas_power_crisis_2021.qmd: Quarto document with complete code of the analysis.

texas_power_crisis_2021.pdf: Rendered quarto document, as a pdf.

Data Access:

The data was accessed through NASA's Level-1 and Atmospheric Archive & Distribution System Distributed Active Archive Center (LAADS DAAC). Where VIIRS data from February 7th, 2021 and February 16, 2021 of the Houston area were obtained for the analysis. The roads and buildings data were accessed through OpenStreetMap. Census tracts of Texas were obtained through the U.S. Census Bureau's American Community Survey.

References:

Level-1 and Atmospheric Archive & Distribution System Distributed Active Archive Center (2021). Visible Infrared Imaging Radiometer Suite [VNP46A1]. NASA. <https://ladsweb.modaps.eosdis.nasa.gov/>

OpenStreetMap contributors (2025). OpenStreetMap [gis_osm_buildings_a_free_1.gpkg, gis_osm_roads_free_1.gpkg] OpenStreetMap Foundation. Available as open data under the Open Data Commons Open Database License (ODbL) at <https://download.geofabrik.de/>.

U.S. Census Bureau American Community Survey (2021). [ACS_2019_5YR_TRACT_48_TEXAS.gdb] American Community Survey. <https://www.census.gov/programs-surveys/acs>

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```

# load in necessary packages
library(terra)
library(tidyverse)
library(tmap)
library(kableExtra)
library(stars)
library(sf)
library(tmaptools)
library(knitr)
library(dplyr)

# read in VIIRS night light data
lights1_07 <- read_stars("data/VNP46A1/VNP46A1.A2021038.h08v05.001.2021039064328.tif")
lights2_07 <- read_stars("data/VNP46A1/VNP46A1.A2021038.h08v06.001.2021039064329.tif")
lights1_16 <- read_stars("data/VNP46A1/VNP46A1.A2021047.h08v05.001.2021048091106.tif")
lights2_16 <- read_stars("data/VNP46A1/VNP46A1.A2021047.h08v06.001.2021048091105.tif")

# Joining the night light rasters of the same day.
lights_07 <- st_mosaic(lights1_07, lights2_07)
lights_16 <- st_mosaic(lights1_16, lights2_16)

```

Night Light Intensity Before and After the Storm.

```

# Creating a bbox of the area of study, Houston.
houston_bbox <- st_bbox(c(xmin = -96.5, ymin = 29, xmax = -94.5, ymax = 30.5),
                         crs = st_crs(4326))

# Checking that the crs of the blackout raster and the crs of the bbox match.
if(st_crs(lights_07) == st_crs(houston_bbox)){
  print("Coordinate reference systems match!")
} else {
  warning("Updating coordinate reference systems to match.")
  # transform data to match
  lights_07 <- st_transform(lights_07, st_crs(houston_bbox))
}

```

[1] "Coordinate reference systems match!"

```

# Using the houston_bbox to crop the blackout raster to the area of study.
lights_07_houston <- st_crop(lights_07, houston_bbox)
lights_16_houston <- st_crop(lights_16, houston_bbox)

# Creating a map of night light luminescence on Feb. 7, 2021.
lights_07_map <-
  tm_shape(lights_07_houston) +
  tm_raster(col.scale = tm_scale_continuous(values = "-brewer.greys"),
             col.legend = tm_legend(title = "Night Light Luminescence",
                                     orientation = "landscape")) +
  tm_title(text = "Houston Lights on Feb. 7, 2021 (before storm)") +
  tm_compass(type = "8star",
              size = 2,
              color.dark = "white",
              color.light = "black",
              text.color = "white",
              position = c("right", "bottom")) +
  tm_scalebar(size = 1) +
  tm_components(c("tm_compass", "tm_scalebar"),
                position = c("left", "bottom"))

# Creating a map of night light luminescence on Feb. 16, 2021.
lights_16_map <- tm_shape(lights_16_houston) +
  tm_raster(col.scale = tm_scale_continuous(values = "-brewer.greys"),
             col.legend = tm_legend(title = "Night Light Luminescence",
                                     orientation = "landscape")) +
  tm_title(text = "Houston Lights on Feb. 16, 2021 (after storm)") +
  tm_compass(type = "8star",
              size = 2,
              color.dark = "white",
              color.light = "black",
              text.color = "white",
              position = c("right", "bottom")) +
  tm_scalebar(size = 1) +
  tm_components(c("tm_compass", "tm_scalebar"),
                position = c("left", "bottom"))

tmap_arrange(lights_07_map, lights_16_map, nrow = 1)

```

Houston Lights on Feb. 7, 2021 (before storm) Houston Lights on Feb. 16, 2021 (after storm)

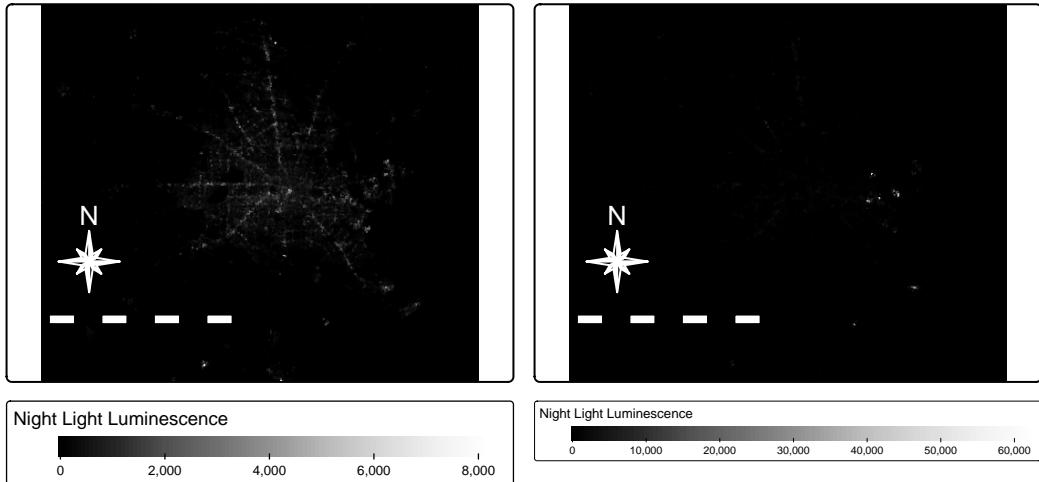


Figure 1: Comparing the night light luminescence before and after the February 2021, winter storm.

Creating a Blackout Mask.

```
# Creating a raster of the change in night light intensity.
blackout <- (lights_07 - lights_16)

# Checking that the crs of the blackout raster and the crs of the bbox match.
if(st_crs(blackout) == st_crs(houston_bbox)){
  print("Coordinate reference systems match!")
} else {
  warning("Updating coordinate reference systems to match.")
  # transform data to match
  blackout <- st_transform(blackout, st_crs(houston_bbox))
}

[1] "Coordinate reference systems match!"
```

```

# Using the houston_bbox to crop the blackout raster to the area of study.
houston_cropped <- st_crop(blackout, houston_bbox)

# Create raster mask of the same resolution and extent
blackout_mask <- houston_cropped

# Setting the values in the mask raster that are less than 200 to be NA values
blackout_mask[blackout_mask < 200] <- NA

# Vectorizing the masked raster.
masked_sf <- blackout_mask %>%
  st_as_sf() %>%
  st_make_valid()

# Setting the crs of of the mask vector.
houston_transformed <- st_transform(masked_sf, crs = st_crs(3083))

```

Excluding highways from the cropped blackout mask

```

# read in OSM roads data, where roads are categorized as highways.
roads <- st_read("data/gis_osm_roads_free_1.gpkg",
                  query = "SELECT * FROM gis_osm_roads_free_1 WHERE fclass='motorway'")

# Checking that the crs' of the roads and houston_transformed match.
if(st_crs(roads) == st_crs(houston_transformed)){
  print("Coordinate reference systems match!")
} else {
  warning("Updating coordinate reference systems to match.")
  # transform data to match
  roads <- st_transform(roads, st_crs(houston_transformed))
}

```

Warning: Updating coordinate reference systems to match.

```

# Cropping the highways to Houston area.
roads_cropped <- st_crop(roads, houston_transformed)

# Creating a 200m buffer around all highways.
highways_buff_200m <- st_buffer(roads_cropped, dist = 200)

```

```

# Combining the buffer geometries and creating one buffer shape.
highways_buff_union <- st_union(highways_buff_200m) %>%
  st_as_sf()

# Filtering using st_disjoint to find blackout areas outside of the buffer.
blackout_area <- houston_transformed %>%
  st_filter(y = highways_buff_union, .predicate = st_disjoint)

```

Homes in Houston Impacted by Blackouts.

```

# read in OSM houses data
houses <- st_read("data/gis_osm_buildings_a_free_1.gpkg", query = "SELECT *
FROM gis_osm_buildings_a_free_1
WHERE (type IS NULL AND name IS NULL)
OR type in ('residential', 'apartments', 'house', 'static_caravan', 'detached')")

# Checking that the crs of the houses and the crs of the blackout_area vector match.
if(st_crs(houses) == st_crs(blackout_area)){
  print("Coordinate reference systems match!")
} else {
  warning("Updating coordinate reference systems to match.")
  # transform data to match
  houses <- st_transform(houses, st_crs(blackout_area))
}

```

Warning: Updating coordinate reference systems to match.

```

# Filtering using st_intersects to find the houses in the blackout region.
blackout_houses <- houses %>%
  st_filter(y = blackout_area, .predicate = st_intersects)

# Creating a map of the house in Houston that experienced a blackout
tm_shape(blackout_houses, bbox = houston_bbox) +
  tm_polygons(col = "maroon") +
  tm_basemap("CartoDB.Positron") +
  tm_title(text = "Houses Impacted by the Blackout") +
  tm_compass(type = "8star",
             size = 2,

```

```

    position = c("right", "bottom")) +
tm_scalebar(text.size = 0.5) +
tm_components(c("tm_compass", "tm_scalebar"),
position = c("left", "bottom"))

```

Houses Impacted by the Blackout

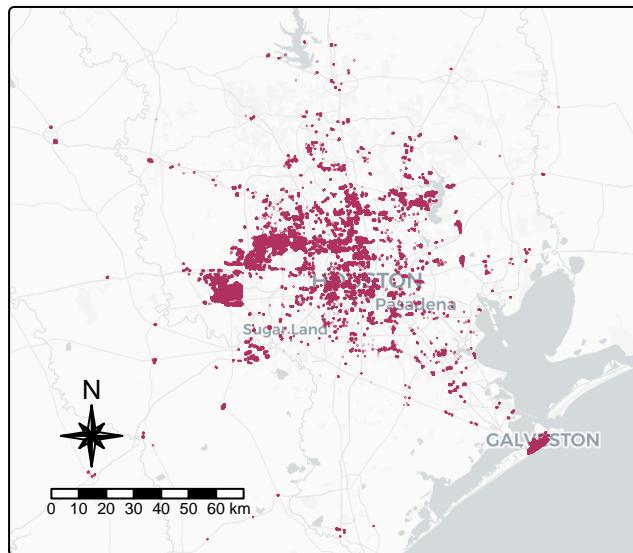


Figure 2: Figure 2: The homes in Houston, Texas that experienced a blackout during the February 2021, winter storm.

```

# Creating a table with the total number of homes that experienced a blackout.
blackout_houses_df <- blackout_houses %>%
  group_by(type) %>%
  summarise(Count = n()) %>%
  st_drop_geometry() %>%
  ungroup() %>%
  bind_rows(tibble(type = "Total", Count = sum(.Count))) %>%
  kable(col.names = c("Home Type", "Count"),
        caption = "Counts of types of homes that experienced a blackout")

blackout_houses_df

```

Table 1: Counts of types of homes that experienced a blackout

Home Type	Count
apartments	775
detached	257
house	18648
residential	1020
static_caravan	79
NA	118370
Total	139149

Figure 3: The total amount of homes in Houston, Texas that experienced a blackout during the February 2021 winter storms was 139,149 homes.

Census Tracts in Houston Impacted by the Blackout.

```
# read in ACS median household income by census tract data.
ACS_geometry <- st_read("data/ACS_2019_5YR_TRACT_48_TEXAS.gdb",
                        layer = 'ACS_2019_5YR_TRACT_48_TEXAS')
ACS_attributes <- st_read("data/ACS_2019_5YR_TRACT_48_TEXAS.gdb",
                           layer = "X19_INCOME")

# joining the ACS geometry and attribute data
census_tracts <- left_join(ACS_geometry, ACS_attributes, by = c("GEOID_Data" = "GEOID"))

# Data cleaning of the ACS census data.
census_tracts <- census_tracts %>%
  select("B19013e1", "GEOID", "Shape") %>%
  rename(median_income = B19013e1)

# Checking that the crs' of the houses and blackout_houses vector match.
if(st_crs(census_tracts) == st_crs(blackout_houses)){
  print("Coordinate reference systems match!")
} else {
  warning("Updating coordinate reference systems to match.")
  # transform data to match
  census_tracts <- st_transform(census_tracts, st_crs(blackout_houses))
}
```

Warning: Updating coordinate reference systems to match.

```
# Cropping the census tracts to the Houston area.  
houston_census <- st_crop(census_tracts, blackout_houses)  
  
# Census blocks that have experienced the blackout  
blackout_census <- houston_census %>%  
  st_filter(y = blackout_houses, .predicate = st_intersects) %>%  
  mutate(blackout = TRUE)  
  
# Saving the census GEOIDs that experienced a blackout  
blackout_census_ids <- blackout_census$GEOID  
  
# Creating a map of census tracts that experienced a blackout  
tm_graticules() +  
  tm_shape(houston_census) +  
    tm_polygons(fill = "white",  
                borders = "black") +  
  tm_shape(blackout_census) +  
    tm_polygons(fill = "maroon") +  
    tm_add_legend(type = "fill",  
                  labels = "Blackout",  
                  col = "maroon") +  
  tm_title(text = "Census blocks that experienced blackout")
```

Census blocks that experienced blackout

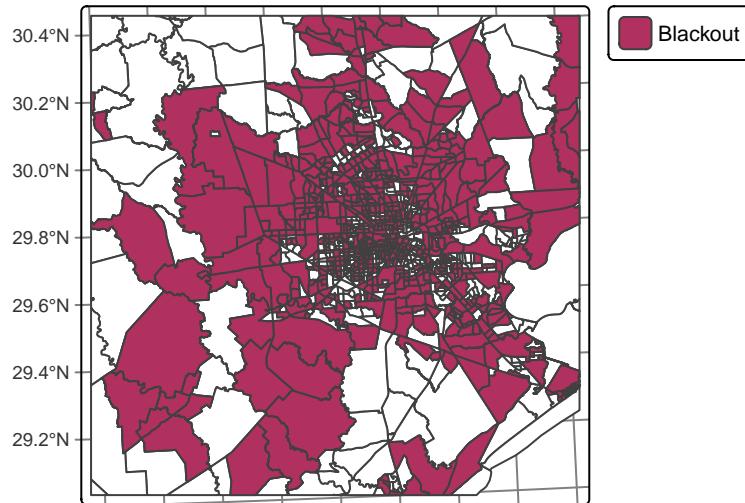


Figure 3: Figure 4: The census tracts in Houston, Texas that experienced a blackout during the February 2021, winter storm.

Distributions of Median Household Income by Census Tracts in Houston During the Blackout

```
# Creating a true or false column for experiencing a blackout or not.
no_blackout_census <- houston_census %>%
  mutate(blackout = GEOID %in% blackout_census_ids)

# Plotting the median household income of census tracts
ggplot(data = no_blackout_census, aes(x = blackout, y = median_income)) +
  geom_boxplot() +
  scale_x_discrete(labels= c("No Blackout", "Blackout")) +
  labs(title = "Median Household Income of Census Tracts",
       x = NULL,
       y = "Median Household Income") +
  theme_minimal()
```

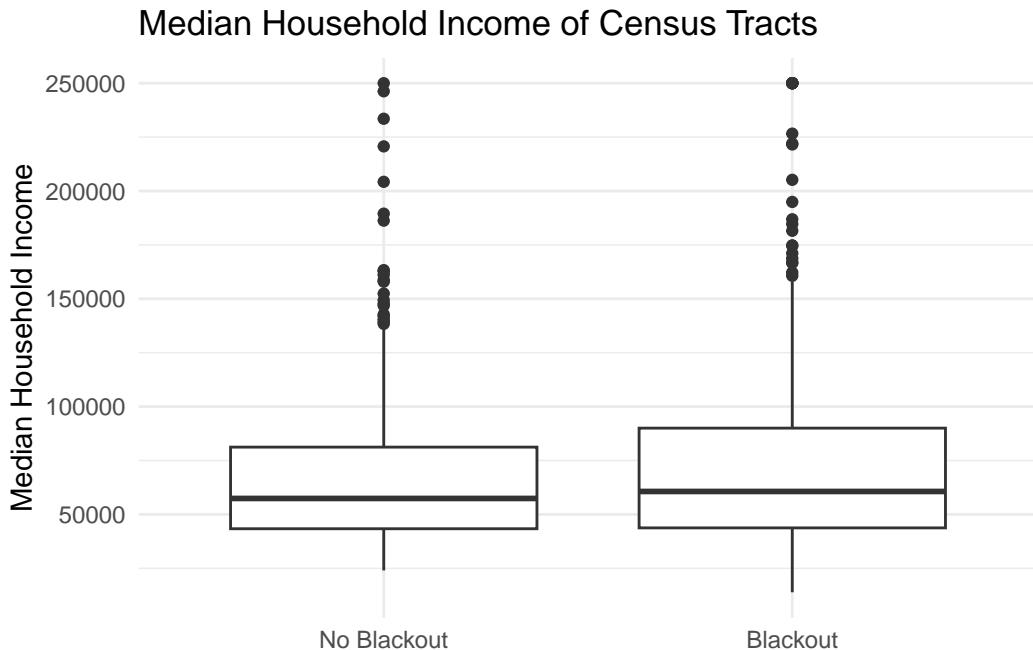


Figure 4: Figure 5: The distribution of median household income by census tracts that did or did not experience the blackout, during the February 2021, winter storm.

Refelction

The winter storms of February 2021 impacted almost 140,000 homes in Houston, Texas, causing electricity blackouts. Based on our analysis, it was found that the homes that experienced a blackout were in about 711 out of 1071 census tracts in Houston. The distribution of Median Household Income of Census Tracts that did or did not experience a blackout, shows that there wasn't much of a disproportionate impact of the storms felt. This is represented in the boxplot, as the ranges of the median household income are very similar. While climate change intensifies weather events that affect communities regardless of income, it is often expected that households with lower median income would be impacted more; therefore we'd expect the median household income of census tracts that did not experience a blackout to be much higher. Since household's with higher median income could have or live in a region with more resources and infrastructure equipped to handle emergency events, such as a blackout. In this study we are limited to VIIRS night light data from the selected days before and after the storm that had the least cloud cover. Given more night light data from each day of the storm, we'd likely obtain a more accurate change in night light intensity and blackout experience over the entire time frame of the winter storm.

References:

Level-1 and Atmospheric Archive & Distribution System Distributed Active Archive Center (2021). Visible Infrared Imaging Radiometer Suite [VNP46A1]. NASA. <https://ladsweb.modaps.eosdis.nasa.gov/>

OpenStreetMap contributors (2025). OpenStreetMap [gis_osm_buildings_a_free_1.gpkg, gis_osm_roads_free_1.gpkg] OpenStreetMap Foundation. Available as open data under the Open Data Commons Open Database License (ODbL) at <https://download.geofabrik.de/>.

U.S. Census Bureau American Community Survey (2021). [ACS_2019_5YR_TRACT_48_TEXAS.gdb] American Community Survey. <https://www.census.gov/programs-surveys/acs>