

```
# To run this R code for another storm, search the document for "Another storm can be selected here" and update the usa_atcfid.
```

```
if (!require("pacman")) install.packages("pacman")
pacman::p_load(
  tidyverse,
  pins,
  sf,
  tigris,
  ngeo,
  geosphere,
  units,
  readr,
  janitor,
  lubridate,
  countytimezones,
  curl,
  rnaturalearth,
  rnaturalearthdata,
  kableExtra
)
```

```
theme_set(theme_bw())
```

```
# sessionInfo()
# R version 4.0.3 (2020-10-10)
# Platform: x86_64-w64-mingw32/x64 (64-bit)
# Running under: Windows 10 x64 (build 19042)
#
# Matrix products: default
#
# locale:
# [1] LC_COLLATE=English_United States.1252 LC_CTYPE=English_United States.1252
LC_MONETARY=English_United States.1252
# [4] LC_NUMERIC=C LC_TIME=English_United States.1252
#
# attached base packages:
# [1] stats graphics grDevices utils datasets methods base
#
# other attached packages:
# [1] tinytex_0.32 kableExtra_1.3.4 rnaturalearthdata_0.1.0
rnaturalearth_0.1.0
# [5] curl_4.3.2 countytimezones_1.0.0 janitor_2.1.0
units_0.7-2
# [9] geosphere_1.5-10 ngeo_0.4.3 tigris_1.4.1
sf_1.0-1
# [13] pins_0.4.5 forcats_0.5.1 stringr_1.4.0
dplyr_1.0.7
# [17] purrr_0.3.4 readr_1.4.0 tidyr_1.1.3
tibble_3.1.2
```

```

# [21] ggplot2_3.3.5          tidyverse_1.3.1          lubridate_1.7.10
#
# loaded via a namespace (and not attached):
# [1] fs_1.5.0                webshot_0.5.2           filelock_1.0.2          httr_1.4.2
bslib_0.2.5.1           tools_4.0.3
# [7] backports_1.2.1         utf8_1.2.1              rgdal_1.5-23           R6_2.5.0
KernSmooth_2.23-17     rgeos_0.5-5
# [13] DBI_1.1.1              colorspace_2.0-2       withr_2.4.2            sp_1.4-5
tidyselect_1.1.1       compiler_4.0.3
# [19] cli_2.5.0              rvest_1.0.0            xml2_1.3.2             sass_0.4.0
scales_1.1.1          classInt_0.4-3
# [25] proxy_0.4-26           rappdirs_0.3.3         systemfonts_1.0.2     digest_0.6.27
foreign_0.8-80         rmarkdown_2.9
# [31] svglite_2.0.0          pkgconfig_2.0.3        htmltools_0.5.1.1     highr_0.9
dbplyr_2.1.1          rlang_0.4.11
# [37] readxl_1.3.1           rstudioapi_0.13        jquerylib_0.1.4        generics_0.1.0
farver_2.1.0          jsonlite_1.7.2
# [43] magrittr_2.0.1        s2_1.0.6                Rcpp_1.0.6            munsell_0.5.0
fansi_0.5.0           lifecycle_1.0.0
# [49] stringi_1.6.2         yaml_2.2.1              snakecase_0.11.0      grid_4.0.3
mapproj_1.1-1         crayon_1.4.1
# [55] lattice_0.20-41       haven_2.4.1             hms_1.1.0             knitr_1.33
pillar_1.6.1          uuid_0.1-4
# [61] wk_0.4.1              reprex_2.0.0           glue_1.4.2            evaluate_0.14
modelr_0.1.8          vctrs_0.3.8
# [67] cellranger_1.1.0      gtable_0.3.0           assertthat_0.2.1     xfun_0.24
broom_0.7.8          e1071_1.7-7
# [73] rsconnect_0.8.18     class_7.3-17          viridisLite_0.4.0    ellipsis_0.3.2

```

```

# US Census Bureau County Shapefiles

```

```

options(tigris_use_cache=TRUE)

```

```

counties_t <- counties(

```

```

  state = c(

```

```

    '01',

```

```

    '05',

```

```

    '09',

```

```

    '10',

```

```

    '12',

```

```

    '13',

```

```

    '15',

```

```

    '22',

```

```

    '23',

```

```

    '24',

```

```

    '25',

```

```

    '28',

```

```

    '33',

```

```

    '34',

```

```

    '36',

```

```

    '37',

```

```

    '42',

```

```

    '44',
    '45',
    '48',
    '50',
    '51'
  ),
  cb = FALSE,
  year = 2020,
  progress_bar = FALSE,
  class = "sf"
) %>%
janitor::clean_names() %>%
select(
  namelsad,
  statefp,
  countyfp,
  geoid,
  geometry
) %>%
rename(
  county_name = namelsad
)

counties_4326 <- st_transform(counties_t, crs=4326)

```

```

## Altering the Monroe County Florida Shapefile
## "Any part of Monroe County, Florida south of Latitude 25° North, as identified
by the United States Census Bureau, will not be used for the purpose of determining
an adjacent county loss trigger under the Hurricane Insurance Protection-Wind Index
Endorsement."

```

```

counties_4326_12087 <- counties_4326 %>%
  filter(
    statefp == "12" & countyfp == "087"
  )

bbox_original_12087 <- st_bbox(counties_4326_12087)
bbox_crop_12087 <- bbox_original_12087
bbox_crop_12087[[2]] <- 25

counties_4326_12087_crop <- st_crop(
  counties_4326_12087 ,
  bbox_crop_12087
) %>%
mutate(
  geometry = geometry %>% st_sfc(crs=4326)
) %>%
  st_sf(crs=4326)

```

```

counties_4326_12087_pseudo <- st_difference(
  counties_4326_12087 %>% st_make_valid(),
  counties_4326_12087_crop %>% st_make_valid()
) %>%
select(
  county_name,
  statefp,
  countyfp,
  geoid,
  geometry
) %>%
mutate(
  county_name = "Monroe Keys County",
  geoid = "12087.2",
  geoid_neighbor = "12087"
)

```

```

## Altering the Honolulu County Shapefile
## "The trailing islands in the state of Hawaii, defined by the United States
Census Bureau as Census Tract 114.98 of Honolulu County, shall not constitute a
triggered county or county adjacent to a triggered county for purposes of
determining a county loss trigger under the Hurricane Insurance Protection-Wind
Index Endorsement."

```

```

counties_4326_15003 <- counties_4326 %>%
  filter(
    statefp == "15" & countyfp == "003"
  )
bbox_original_15003 <- st_bbox(counties_4326_15003)
bbox_crop_15003 <- bbox_original_15003
bbox_crop_15003[[4]] <- 22

```

```

counties_4326_15003_crop <- st_crop(
  counties_4326_15003,
  bbox_crop_15003
)

```

```

## Updating the County File
counties_4326_update <- counties_4326 %>%
  mutate(
    geometry = ifelse(
      geoid == "12087",
      counties_4326_12087_crop$geometry,
      ifelse(
        geoid == "15003",
        counties_4326_15003_crop$geometry,
        geometry
      )
    )
  )

```

```
    ) %>%
    st_sfc(crs=4326)
  ) %>%
  st_sf(crs=4326)
```

```
## US Census Bureau County Adjacency File
```

```
county_adjacency_pin <-
pin("https://www2.census.gov/geo/docs/reference/county_adjacency.txt")
```

```
county_adjacency <- read_delim(
  county_adjacency_pin,
  "\t",
  escape_double = FALSE,
  trim_ws = TRUE,
  col_names = FALSE
) %>%
select(
  X2,
  X4
) %>%
rename(
  geoid = X2,
  geoid_neighbor = X4
) %>%
fill(geoid, .direction="down") %>%
group_by(geoid) %>%
nest() %>%
ungroup()
```

```
counties_4326_update <- left_join(
  counties_4326_update %>%
  select(
    county_name,
    statefp,
    countyfp,
    geoid
  ),
  county_adjacency
) %>%
full_join(
  counties_4326_12087_pseudo %>%
  tibble() %>%
  nest(geoid_neighbor)
) %>%
drop_na(
  geometry,
  data
)
counties_5070_update <- counties_4326_update %>% st_transform(crs=5070)
```

```

# IBTrACS
ibtracs_shape_zip <- tempfile()

curl_download(
  'https://www.ncei.noaa.gov/data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/shapefile/IBTrACS.since1980.list.v04r00.points.zip',
  ibtracs_shape_zip
)

ibtracs_shape_unzip <- tempfile()

unzip(
  zipfile = ibtracs_shape_zip,
  exdir = ibtracs_shape_unzip
)

remove(ibtracs_shape_zip)

ibtracs_shape <- list.files(
  ibtracs_shape_unzip,
  pattern = ".shp$",
  full.names = TRUE
)

remove(ibtracs_shape_unzip)

ibtracs_4326 <- read_sf(ibtracs_shape) %>%
  clean_names() %>%
  select(
    usa_atcfid,
    usa_wind,
    usa_pres,
    name,
    season,
    basin,
    iso_time,
    starts_with("usa_r64"),
    track_type
  ) %>%
  filter(
    basin %in% c("NA", "EP")
  ) %>%
  mutate(
    name = name %>% str_to_title(),
    hurricane_name = str_c(
      name,
      usa_atcfid %>% str_trunc(4, side = "left", ellipsis = ""),
      sep = ", "
    )
  )

```

```

    ) %>%
    str_trim(),
    season = season %>% as.numeric(),
    iso_time = iso_time %>% as_datetime()
  ) %>%
  select(-name) %>%
  mutate(
    across(
      starts_with("usa_r"),
      as.numeric
    )
  )

```

Constructing Hurricane Corridors

```

bearing_map <- function(geometry, lon_lead, lat_lead) {
  bearing(
    st_coordinates(geometry),
    c(lon_lead, lat_lead)
  ) %>%
  set_units(degrees)
}

```

Another storm can be selected here

```

points_4326 <- ibtracs_4326 %>%
  arrange(iso_time) %>%
  filter(usa_atcfid=="AL052019") %>%
  group_by(usa_atcfid) %>%
  mutate(
    lat = map(geometry, 2) %>% unlist(),
    lon = map(geometry, 1) %>% unlist(),
    lat_lead = lead(lat),
    lon_lead = lead(lon),
    lat_lag = lag(lat),
    lon_lag = lag(lon),
    usa_wind_lead = lead(usa_wind),
    usa_wind_lag = lag(usa_wind),
    point_prior_hu = if_else(
      usa_wind_lead >= 64 & usa_wind < 64,
      1,
      0
    ),
    point_after_hu = if_else(
      usa_wind_lag >= 64 & usa_wind < 64,
      1,
      0
    ),
    hu = if_else(usa_wind >= 64, 1, 0) %>% as_factor,
    wind_extent_hu_m = pmax(
      usa_r64_ne,

```

```

    usa_r64_se,
    usa_r64_nw,
    usa_r64_sw,
    na.rm = T
  )*1852,
bearing_accurate = pmap(
  .l = list(
    geometry=geometry,
    lon_lead=lon_lead,
    lat_lead=lat_lead
  ),
  .f = bearing_map
)
) %>%
ungroup() %>%
rowwise() %>%
mutate(
  distance_to_next = distGeo(
    c(lon, lat),
    c(lon_lead, lat_lead)
  ),
  wind_extent_hu_m = wind_extent_hu_m %>% replace_na(0)
) %>%
ungroup()

buffers_5070 <- points_4326 %>%
  st_transform(crs=5070) %>%
  ungroup() %>%
  mutate(
    geometry = st_buffer(
      st_geometry(.),
      dist = wind_extent_hu_m,
      nQuadSegs = 180
    )
  ) %>%
  ungroup()

## Interpolating Hurricane Status Transition Points
### Hurricane Dissolution (end points)
points_4326_e1 <- points_4326 %>%
  arrange(iso_time) %>%
  group_by(usa_atcfid) %>%
  mutate(
    lag_wind_extent_hu_m = lag(wind_extent_hu_m),
    lag_distance_to_next = lag(distance_to_next),
    bearing_accurate = lag(bearing_accurate),
    lag_iso_time = lag(iso_time)
  ) %>%
  ungroup() %>%
  filter(point_after_hu==1) %>%

```



```

mutate(
  mid_distance_to_lead = lag_distance_to_next*((usa_wind_lag - 64)/(usa_wind_lag
- usa_wind)),
  wind_extent_hu_m_guess_last =
    pmax(
      lag_wind_extent_hu_m/2,
      lag_wind_extent_hu_m*(1 -((usa_wind_lag - 64)/(usa_wind_lag - usa_wind)))
    ),
  iso_time = iso_time - minutes(
    round(
      difftime(
        iso_time,
        lag_iso_time,
        units = "mins"
      )*(mid_distance_to_lead/distance_to_next)
    )
  ),
  wind_extent_hu_m = wind_extent_hu_m_guess_last,
  interpolated_hu = T,
  hu = 1 %>% as_factor,
  distance_to_next = mid_distance_to_lead,
  usa_wind = 64
) %>%
arrange(iso_time) %>%
select(
  usa_atcfid,
  hurricane_name,
  season,
  iso_time,
  wind_extent_hu_m,
  bearing_accurate,
  lon,
  lon_lag,
  lat,
  lat_lag,
  usa_wind,
  interpolated_hu,
  hu,
  distance_to_next,
  basin
) %>%
ungroup()

```

```

points_4326_e2 <- points_4326_e1
for (i in 1:dim(points_4326_e2)[1]) {
  points_4326_e2$geometry[i] <- destPoint(
    c(
      points_4326_e2$lon_lag[i],
      points_4326_e2$lat_lag[i]
    ),

```

```

    points_4326_e2$bearing_accurate[i],
    points_4326_e2$distance_to_next[i]
  ) %>% st_point() %>% st_sfc()
}
interpolated_end_hu_5070 <- points_4326_e2 %>%
  select(
    - lat,
    - lat_lag,
    - lon,
    - lon_lag
  ) %>%
  st_transform(crs=5070) %>%
  ungroup() %>%
  mutate(
    geometry = st_buffer(
      st_geometry(.),
      dist = wind_extent_hu_m,
      nQuadSegs = 180
    )
  ) %>%
  ungroup()

### Hurricane Inception (start points)
points_4326_s1 <- points_4326 %>%
  arrange(iso_time) %>%
  group_by(usa_atcfid) %>%
  mutate(
    lead_wind_extent_hu_m = lead(wind_extent_hu_m),
    lead_iso_time = lead(iso_time)
  ) %>%
  filter(point_prior_hu==1) %>%
  ungroup() %>%
  mutate(
    mid_distance_to_lead = distance_to_next*((usa_wind_lead - 64)/(usa_wind_lead -
usa_wind)),
    wind_extent_hu_m_guess_first =
      pmax(
        lead_wind_extent_hu_m/2,
        lead_wind_extent_hu_m*(1 -((usa_wind_lead - 64)/(usa_wind_lead -
usa_wind)))
      ),
    iso_time = iso_time + minutes(
      round(
        difftime(
          lead_iso_time,
          iso_time,
          units = "mins"
        ) *(mid_distance_to_lead/distance_to_next)
      )
    ),
  ),

```

```

    wind_extent_hu_m = wind_extent_hu_m_guess_first,
    interpolated_hu = T,
    hu = 1 %>% as_factor,
    distance_to_next = mid_distance_to_lead,
    usa_wind = 64,
  ) %>%
  arrange(iso_time) %>%
  select(
    usa_atcfid,
    hurricane_name,
    season,
    iso_time,
    wind_extent_hu_m,
    bearing_accurate,
    lon,
    lat,
    distance_to_next,
    usa_wind,
    interpolated_hu,
    hu,
    basin
  )

points_4326_s2 <- points_4326_s1
for (i in 1:dim(points_4326_s2)[1]) {
  points_4326_s2$geometry[i] <- destPoint(
    c(
      points_4326_s2$lon[i],
      points_4326_s2$lat[i]
    ),
    points_4326_s2$bearing_accurate[i],
    points_4326_s2$distance_to_next[i]
  ) %>% st_point() %>% st_sfc()
}

interpolated_start_hu_5070 <- points_4326_s2 %>%
  select(
    - lat,
    - lon
  ) %>%
  st_transform(crs=5070) %>%
  ungroup() %>%
  mutate(
    geometry = st_buffer(
      st_geometry(.),
      dist = wind_extent_hu_m,
      nQuadSegs = 180
    )
  ) %>%
  ungroup()

```

```

### Combine Interpolated Data
buffers_5070_new <- buffers_5070 %>%
  as_tibble() %>%
  mutate(
    interpolated_hu = F
  ) %>%
  full_join(
    interpolated_start_hu_5070 %>%
      as_tibble()
  ) %>%
  full_join(
    interpolated_end_hu_5070 %>%
      as_tibble()
  ) %>%
  st_sf(crs=5070)

```

```

### Creating Polygon Pairs
status_change_function <- function(x) {
  x <- rle(x)$lengths
  rep(seq_along(x), times=x)
}

```

```

poly_5070 <- buffers_5070_new %>%
  ungroup() %>%
  arrange(usa_atcfid, iso_time) %>%
  mutate(
    hu_status_change = status_change_function(hu %>% as.numeric())
  ) %>%
  group_by(usa_atcfid, hu, hu_status_change) %>%
  mutate(
    geometry_lag = lag(geometry) %>% st_sfc()
  ) %>%
  slice(2:n()) %>%
  ungroup()

```

```

geo_union_function <- function(x, y, ...) st_union(x, y)

```

```

poly_5070$geometry <- map2(
  poly_5070$geometry,
  poly_5070$geometry_lag,
  geo_union_function
)

```

```

poly_5070 <- poly_5070 %>%
  select(-geometry_lag) %>%
  mutate(
    geometry = st_sfc(geometry, crs = 5070)
  )

```

```

### Convex Hull
hull_5070 <- poly_5070 %>%
  group_by(usa_atcfid, iso_time) %>%
  mutate(
    geometry = st_convex_hull(geometry)
  ) %>%
  ungroup()

# Finding Triggered Counties
triggered_direct <- st_intersection(
  hull_5070,
  counties_5070_update %>% st_make_valid()
) %>%
  tibble() %>%
  select(-geometry) %>%
  arrange(usa_atcfid, iso_time) %>%
  group_by(usa_atcfid, geoid) %>%
  ungroup() %>%
  select(
    usa_atcfid,
    geoid,
    county_name,
    data,
    hurricane_name,
    season,
    iso_time,
    statefp,
    countyfp,
    interpolated_hu
  )

triggered_direct_4326_t <- triggered_direct %>%
  select(
    usa_atcfid,
    geoid,
    iso_time,
    county_name
  ) %>%
  group_by(usa_atcfid, geoid) %>%
  slice_min(iso_time) %>%
  ungroup() %>%
  left_join(
    counties_4326
  ) %>%
  st_sf(crs=4326)

triggered <- triggered_direct %>%
  unnest("data")%>%

```

```

mutate(
  trigger = if_else(
    geoid == geoid_neighbor,
    "direct",
    "indirect"
  ),
  county_name = ifelse(
    trigger == "indirect",
    NA,
    county_name
  ),
  geoid = if_else(
    geoid == geoid_neighbor,
    geoid,
    geoid_neighbor
  )
) %>%
select(
  - geoid_neighbor,
  - county_name
) %>%
left_join(
  counties_5070_update %>%
  tibble() %>%
  select(
    county_name,
    geoid
  )
) %>%
rowwise() %>%
mutate(
  calc_local_time(iso_time, geoid %>% str_trunc(width=5))
) %>%
mutate(
  localtime = with_tz(iso_time, local_tz)
) %>%
group_by(
  usa_atcfid,
  geoid,
  hurricane_name,
  county_name
) %>%
summarize(
  start_iso_time = min(iso_time),
  end_iso_time = max(iso_time),
  start_time = min(localtime),
  end_time = max(localtime),
  time_zone = first(local_tz)
) %>%
ungroup()

```

```

triggered_4326 <- triggered %>%
  left_join(
    counties_4326 %>%
      tibble() %>%
        select(
          geoid,
          geometry
        )
  ) %>%
  mutate(
    geometry = ifelse(
      geoid == "15003",
      counties_4326_15003_crop$geometry,
      geometry
    )
  ) %>%
  filter(
    geoid != 12087.2
  ) %>%
  st_sf(crs=4326)

```

Triggered Counties Map

```

north_america_4326 <- ne_countries(
  continent = 'north america',
  returnclass = "sf"
) %>%
  st_transform(crs=4326)

```

```

ggplot() +
  geom_sf(
    data = north_america_4326,
    fill = "#f7f7f7"
  ) +
  geom_sf(
    data = counties_4326,
    fill = "#f7f7f7"
  ) +
  geom_sf(
    data = triggered_4326,
    fill = "#67a9cf"
  ) +
  geom_sf(
    data = hull_5070 %>%
      st_transform(crs=4326) %>%
      st_union() %>%
      st_crop(
        xmin = triggered_4326 %>%
          st_bbox() %>%

```

```

    pluck(1) - .3,
    ymin = triggered_4326 %>%
      st_bbox() %>%
        pluck(2) - .3,
    xmax = triggered_4326 %>%
      st_bbox() %>%
        pluck(3) + .3,
    ymax = triggered_4326 %>%
      st_bbox() %>%
        pluck(4) + .3,
  ),
  color = "#ef8a62",
  alpha = .5,
  fill = "#ef8a62",
  size = 1,
  show.legend = FALSE
) +
geom_sf(
  data = triggered_direct_4326_t,
  fill = NA
) +
geom_sf(
  data = hull_5070 %>%
    st_transform(crs=4326) %>%
    st_union() %>%
    st_crop(
      xmin = triggered_4326 %>%
        st_bbox() %>%
          pluck(1) - .3,
      ymin = triggered_4326 %>%
        st_bbox() %>%
          pluck(2) - .3,
      xmax = triggered_4326 %>%
        st_bbox() %>%
          pluck(3) + .3,
      ymax = triggered_4326 %>%
        st_bbox() %>%
          pluck(4) + .3,
    ),
  color = "#ef8a62",
  fill = NA,
  size = 1,
  show.legend = FALSE
) +
coord_sf(
  xlim =
    c(
      triggered_4326 %>%
        st_bbox() %>%
          pluck(1),

```



```

    triggered_4326 %>%
      st_bbox() %>%
      pluck(3)
  ),
  ylim =
    c(
      triggered_4326 %>%
        st_bbox() %>%
        pluck(2),
      triggered_4326 %>%
        st_bbox() %>%
        pluck(4)
    )
  ) +
  theme(
    panel.background = element_rect(fill = "aliceblue")
  ) +
  ggtitle(
    paste0(
      "Hurricane ",
      hull_5070$hurricane_name %>% first()
    ),
    subtitle = paste0("IBTrACS")
  )
)

```

Triggered Counties

```

triggered_4326 %>%
  tibble() %>%
  select(
    county_name,
    geoid,
    start_time,
    end_time
  ) %>%
  mutate(
    trigger_interval = interval(start = start_time, end=end_time)
  ) %>%
  select(
    county_name,
    geoid,
    trigger_interval
  )
)

```