TBEP-CC

Tampa Bay Estuary Program: Climate Change Indicators

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2024-01-12

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Preface

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```

1 Introduction

The Tampa Bay Estuary Program compiles environmental data from multiple partners to report on the status and trends of key indicators of bay health (Monitoring and Indicators Plan). Indicators and reporting methods currently exist for several components of the CCMP, including water quality, benthic and sediment condition, fish communities, seagrasses, and tidal creeks. Open-source methods have been developed using the tbeptools R package (Beck, Schrandt, et al. 2021) that facilitates data synthesis and routine reporting for each of these indicators.

Additional indicators of bay health will complement the existing set of indicators. Key indicators currently missing from TBEP routine reporting products include those related to climate change. The Tampa Bay Regional Planning Council has produced the Regional Resilience Action Plan (RRAP) to assist local governments and municipalities in planning resilience activities in response to climate change. Fundamental to these activities is the identification of robust indicators of the local effects of climate change. These may include data descriptive of sea-level rise, droughts, heat waves, or storm frequency/intensity. The TBEP is supportive of these efforts and intends to identify several climate change indicators that can be operationalized for routine reporting, either through conventional summary graphics or more interactive web-based platforms.

This project will identify appropriate climate change indicators to support the TBEP and its partners in making informed planning decisions. Although the primary goal of TBEP is the management of bay health, these indicators could also be used to support community resilience planning as described in the RRAP. Appropriate data sources will be identified, with emphasis on those that are stable and planned to be reliable sources in the future. Identifying indicators that represent relative risk of climate change impacts will be emphasized, as opposed to indicators that simply measure change. All project activities will leverage open science principles as described in the TBEP Strategic Plan (Burke and Amaral 2020) and Data Management SOP (Beck, Raulerson, et al. 2021).

2 Data

2.1 Task 1. Assessment of available data and coverage

Data descriptive of the risks of climate change can be obtained from several sources. These may include weather or climatological data, long-term tidal gauge data, or in situ water measurements responsive to climate change. Weather and climatological data could be obtained from local weather stations with long-term data, e.g., Tampa International Airport, and could include measures of air temperature, precipitation, and/or storm intensity/frequency. Tidal gauge data are readily available from the NOAA PORTS data retrieval system. Lastly, in situ water measurements could include water temperature, changes in flow hydrology, salinity, and/or pH. Data used to evaluate potential risks related to ocean acidification should also be explored.

The permanency and ease of access of each data source should be noted when making recommendations on indicators to operationalize. Further, indicators that communicate the risks associated with climate change are preferred, as opposed to those that simply indicate change. An example is the number of days in a year when temperature exceeds a critical threshold, as compared to temperature alone. An additional example is frequency of sunny day flooding events, as compared to tidal gauge measurements alone.

```r
if (!"librarian" %in% rownames(installed.packages()))
  install.packages("librarian")
librarian::shelf(
  dplyr, dygraphs, glue, here, leaflet, lubridate, sf,
  tbep-tech/tbeptools,
  RColorBrewer, readr, rnoaa, terra, tidyr, webshot2,
  quiet = T)

# explicitly list packages for renv::dependencies(); renv::snapshot()
library(dplyr)
library(dygraphs)
library(glue)
library(here)
library(leaflet)
library(librarian)
```

```r
library(lubridate)
library(RColorBrewer)
library(readr)
library(rnoaa)
library(sf)
library(tbeptools)
library(terra)
library(tidyr)
library(webshot2)

options(readr.show_col_types = F)
```

2.2 Temperature

2.2.1 Observed

The `rnoaa` R package uses NOAA NCDC API v2, which only goes to 2022-09-15.

- NCEI Web Services | Climate Data Online (CDO) | National Center for Environmental Information (NCEI)
- Data Tools | Climate Data Online (CDO) | National Climatic Data Center (NCDC)

2.2.1.1 Weather stations

- Tampa International Airport
  - Start Date: 1939-02-01
  - End Date: 2024-01-07

Got token at ncdc.noaa.gov/cdo-web/token. Added variable `NOAA_NCDC_CDO_token` to:

- locally:

  ```r
  file.edit("~/.Renviron")
  ```

- on GitHub: Repository secrets in Actions secrets · tbep-tech/climate-change-indicators
- GCHN readme
  - `PRCP`: Precipitation (tenths of mm)
  - `TMAX`: Maximum temperature (tenths of degrees C)

– `TMIN`: Minimum temperature (tenths of degrees C)

```
# provide NOAA key
options(noaakey = Sys.getenv("NOAA_NCDC_CDO_token"))

# Specify datasetid and station
stn     <- "GHCND:USW00012842" # TAMPA INTERNATIONAL AIRPORT, FL US
stn_csv      <- here("data/tpa_ghcnd.csv")
stn_meta_csv <- here("data/tpa_meta.csv")

if (!file.exists(stn_meta_csv)){
  # cache station metadata since timeout from Github Actions
  stn_meta <- ncdc_stations(
    datasetid = "GHCND",
    stationid = stn)
  write_csv(stn_meta$data, stn_meta_csv)
}
read_csv(stn_meta_csv)
```

```
# A tibble: 1 x 9
  elevation mindate    maxdate    latitude name                 datacoverage id
      <dbl> <date>     <date>        <dbl> <chr>                       <dbl> <chr>
1       1.8 1939-02-01 2024-01-09     28.0 TAMPA INTERNATION~             1 GHCN~
# i 2 more variables: elevationUnit <chr>, longitude <dbl>
```

```
if (!file.exists(stn_csv)){

  date_beg <- stn_meta$data$mindate
  date_end <- stn_meta$data$maxdate
  max_rows <- 1000
  vars     <- c("PRCP","TMIN","TMAX")

  n_vars     <- length(vars)
  days_batch <- floor(max_rows / n_vars)
  dates <- unique(c(
    seq(
      ymd(date_beg),
      ymd(date_end),
      by = glue("{days_batch} days")),
    ymd(date_end)))
```

```r
n_i <- length(dates) - 1
for (i in 1:n_i){
  # for (i in 14:n_i){
  date_beg <- dates[i]
  if (i == n_i){
    date_end <- dates[i+1]
  } else {
    date_end <- dates[i+1] - days(1)
  }
  print(glue("{i} of {n_i}: {date_beg} to {date_end}  ~  {Sys.time()}"))

  # retry if get Error: Service Unavailable (HTTP 503)
  o           <- NULL
  attempt     <- 1
  attempt_max <- 10
  while (is.null(o) && attempt <= attempt_max) {
    if (attempt > 1)
      print(glue("  attempt {attempt}", .trim = F))
    attempt <- attempt + 1
    try(
      o <- ncdc(
        datasetid  = "GHCND",
        stationid  = stn,
        datatypeid = vars,
        startdate  = date_beg,
        enddate    = date_end,
        limit      = max_rows) )
  }

  if (i == 1) {
    df <- o$data
  } else {
    df <- rbind(df, o$data)
  }
}
stopifnot(duplicated(df[,1:2])|> sum() == 0)

df <- df |>
  mutate(
    date     = as.Date(strptime(
      date, "%Y-%m-%dT00:00:00")),
```

```
      datatype = recode(
        datatype,
        PRCP = "precip_mm",
        TMIN = "temp_c_min",
        TMAX = "temp_c_max"),
      value    = value / 10) |>
    select(
      -station, # station         : all "GHCND:USW00012842"
      -fl_m,    # measurement flag: 3,524 are "T" for trace
      -fl_t,    # time        flag: all "2400"
      -fl_q)    # quality     flag: all ""

  write_csv(df, stn_csv)
}

d <- read_csv(stn_csv)

d |>
  select(date, datatype, value) |>
  filter(datatype %in% c("temp_c_min","temp_c_max")) |>
  pivot_wider(
    names_from  = datatype,
    values_from = value) |>
  dygraph(main = "Daily Temperature (ºC)") |>
  dyOptions(
    colors = brewer.pal(5, "YlOrRd")[c(5,3)]) |>
  dySeries("temp_c_min", label = "min") |>
  dySeries("temp_c_max", label = "max")
```

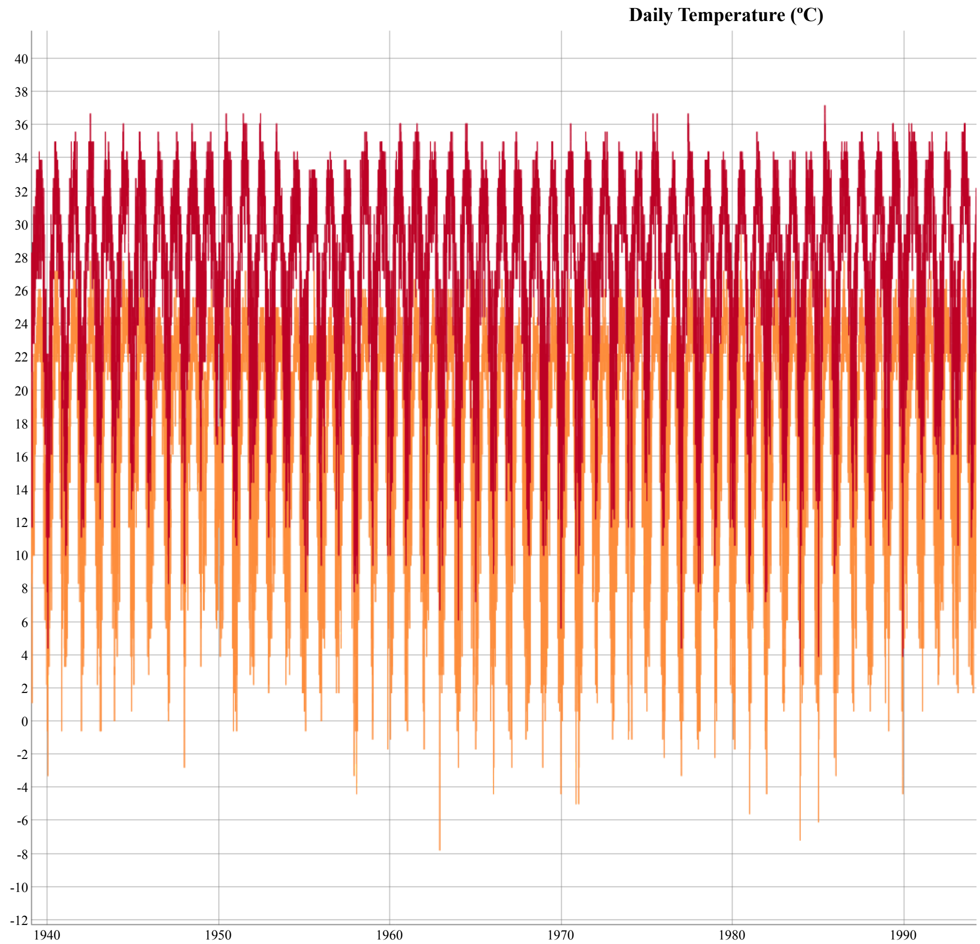

Figure 2.1: **?(caption)**

```r
d |>
  select(date, datatype, value) |>
  filter(datatype %in% c("precip_mm")) |>
  pivot_wider(
    names_from  = datatype,
    values_from = value) |>
  dygraph(main = "Daily Precipitation (mm)") |>
  dySeries("precip_mm", label = "precip")
```

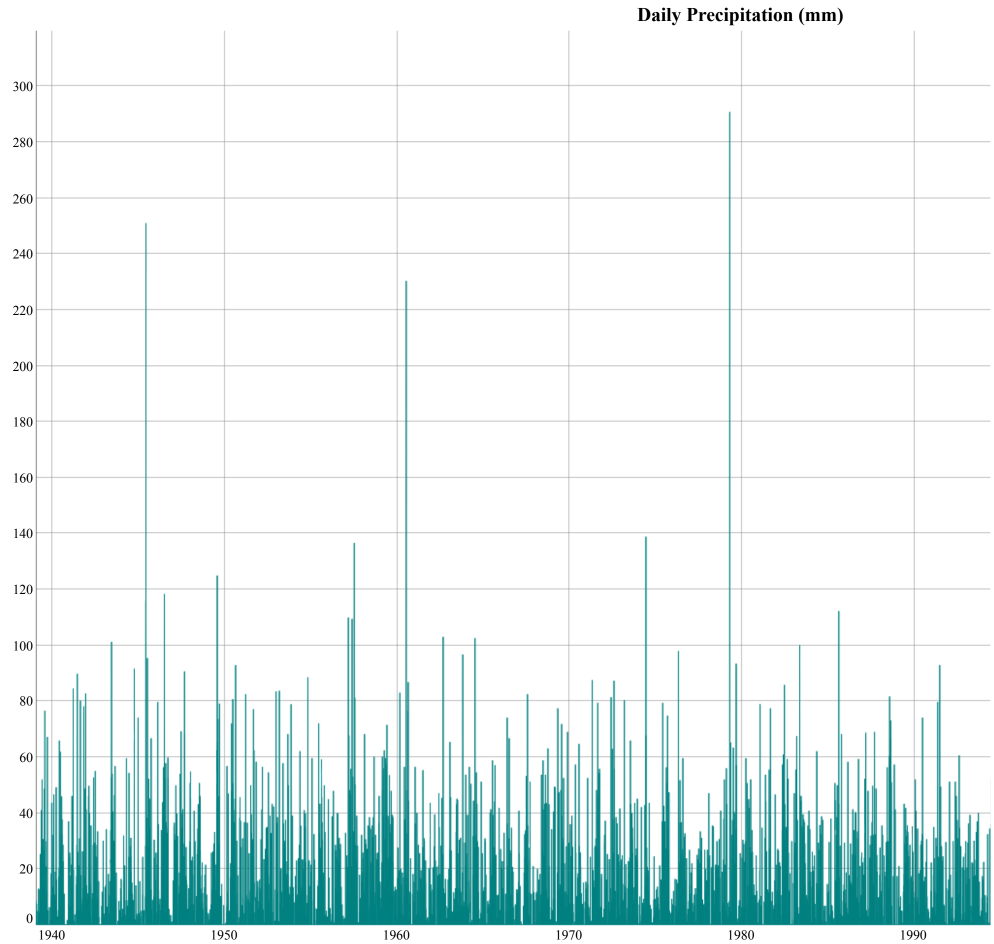

Figure 2.2: **?(caption)**

2.2.1.2 Satellite

2.3 Precipitation

2.4 Sea Level Rise

Sea level rise occurs from principally two sources: 1) thermal expansion; and 2) freshwater inputs from glacial melting. Data for these trends can be obtained from NOAA's Sea Level Trends (Figure 2.3)

Types of data:

1. Observed (past, present) - tide gauge - satellite, e.g. Laboratory for Satellite Altimetry / Sea Level Rise
   - Level-3 products distributed through NOAA CoastWatch (Sea Level Anomaly and along-track altimetry)
2. Projected (future). modeled

2.4.1 Gauges

- PORTS: Tampa Bay PORTS - NOAA Tides & Currents

2.4.2 Satellite

- NOAA / NESDIS / STAR - Laboratory for Satellite Altimetry / Sea Level Rise

```
slr_nc    <- here("data/slr/slr_map_txj1j2.nc")
r_slr_gcs <- rast(slr_nc)  # 0.5 degree resolution
r_slr_mer <- projectRasterForLeaflet(r_slr_gcs, method="bilinear")

b <- st_bbox(tbsegshed)
r_slr_tb_mer <- rast(slr_nc) |>
  crop(b) # |>
  # projectRasterForLeaflet(method="bilinear")
# only one value for Tampa Bay extracted at 0.5 degree resolution
# values(r_slr_tb_mer, mat=F, na.rm=T)  # 5.368306

b <- st_bbox(tbshed)
plet(r_slr_mer, tiles=providers$Esri.OceanBasemap) |>
```

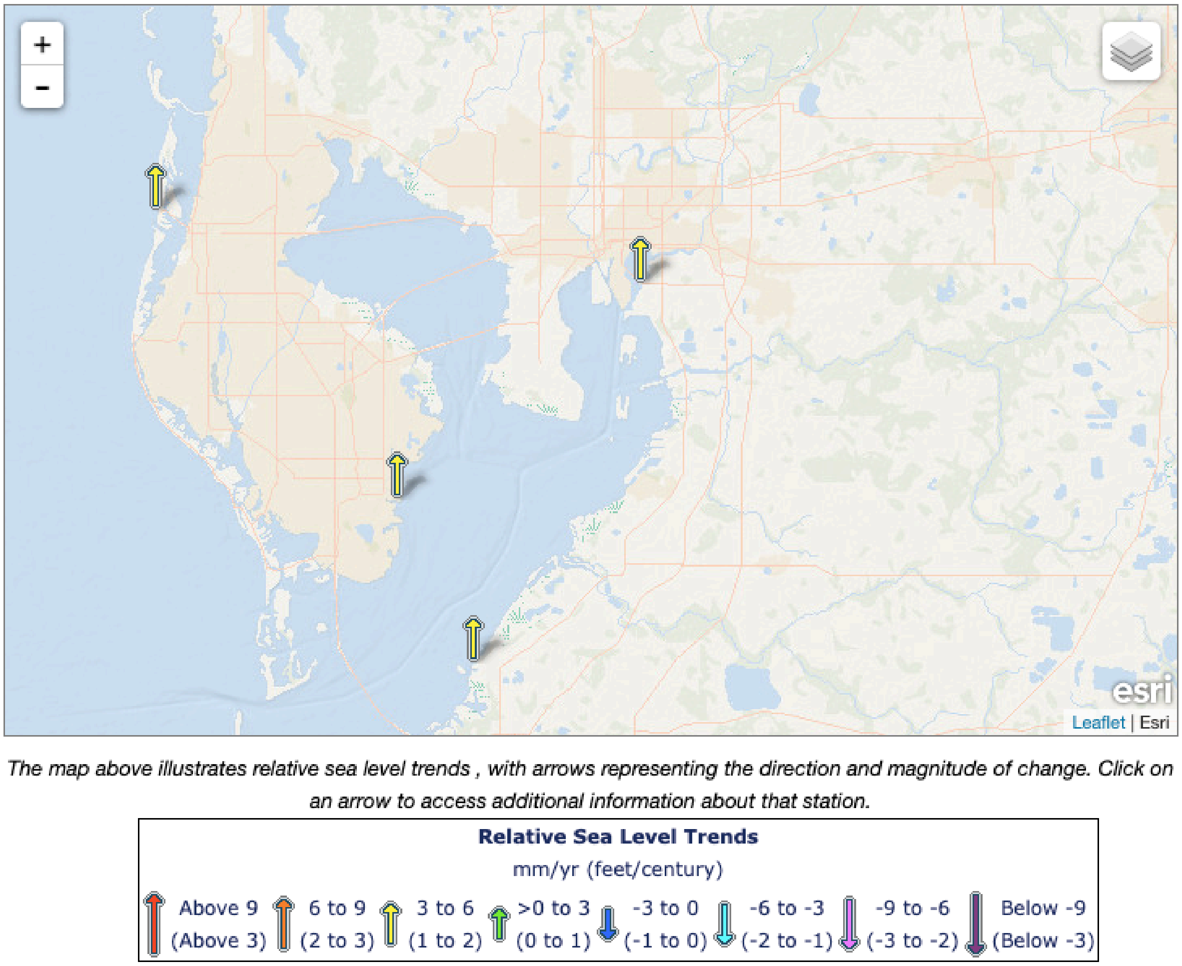

Figure 2.3: Screenshot of NOAA's Sea Level Trends zoomed into the Tampa Bay.

```r
addProviderTiles(providers$CartoDB.DarkMatterOnlyLabels) |>
addPolygons(data = tbsegshed) |>
fitBounds(
  lng1 = b[["xmin"]], lat1 = b[["ymin"]],
  lng2 = b[["xmax"]], lat2 = b[["ymax"]])
```

Figure 2.4: **?(caption)**

2.5 Severe Weather

- SWDI vignette
- rnoaa

References

Beck, Marcus W., G. E. Raulerson, M. C. Burke, J. Whalen, S. Scolaro, and E. T. Sherwood. 2021. "Tampa Bay Estuary Program: Data Management Standard Operating Procedures." St. Petersburg, Florida.

Beck, Marcus W., Meagan N. Schrandt, Michael R. Wessel, Edward T. Sherwood, Gary E. Raulerson, Adhokshaja Achar Budihal Prasad, and Benjamin D. Best. 2021. "Tbeptools: An R Package for Synthesizing Estuarine Data for Environmental Research." *Journal of Open Source Software* 6 (65): 3485. https://doi.org/10.21105/joss.03485.

Burke, M., and M. Amaral. 2020. "2021-2025 Strategic Plan." St. Petersburg, Florida.