Stream Temperature Model Application - NRSA/NAWQA

Libraries & Directories

```
library(StreamCatTools)
library(tidyverse)
library(data.table)
library(sf)
library(prism)
library(lubridate)
library(knitr)
library(spmodel)
library(readr)

# NHDPlus directory
nhd_dir <- 'C:/Users/RHill04/WorkFolder/GIS/NHDPlusV21/'
```

Prep data for Powell Center analysis

```
pts <- fread('../data/FishSiteCOMIDs.csv')  %>%
  left_join(
    read_rds(paste0(nhd_dir, 'cat-pour-points.rds'))  %>%
      rename(COMID = FEATUREID)  %>%
      dplyr::select(-AreaSqKM, -SOURCEFC, -GRIDCODE) %>%
      na.omit()
  ) %>%
  st_as_sf(coords = c('LON_DD', 'LAT_DD'),
           crs = 4269)

comids <- pts %>%
  pull(COMID) %>%
  na.omit()
```

NHDPlus flow metrics

Modeled monthly (July and August) flow estimates for each site (source: USGS)

```
nhd_dir <-
  paste0(nhd_dir, 'NHDPlusNationalData/NHDPlusV21_National_Seamless_Flattened_Lower48.gdb')

nhd_flow <-
  st_read(dsn = paste0(nhd_dir),
          layer = 'NHDFlowline_Network') %>%
  st_drop_geometry() %>%
  dplyr::select(COMID, QE_07, QE_08) %>%
  pivot_longer(!COMID, names_to = 'tmpcol', values_to = 'nhdflow') %>%
  mutate(month = str_replace(tmpcol, 'QE_0', '') %>%
```

```
          as.integer()) %>%
  dplyr::select(-tmpcol)
```

```
Reading layer `NHDFlowline_Network' from data source

`C:\Users\RHill04\WorkFolder\GIS\NHDPlusV21\NHDPlusNationalData\NHDPlusV21_National_Seamless_Flat
tened_Lower48.gdb'
  using driver `OpenFileGDB'
Simple feature collection with 2691339 features and 137 fields
Geometry type: MULTILINESTRING
Dimension:     XYZM
Bounding box:  xmin: -124.7332 ymin: 24.63052 xmax: -66.94983 ymax: 49.37661
z_range:       zmin: 0 zmax: 0
m_range:       mmin: -2.35e-05 mmax: 100
Geodetic CRS:  NAD83
```

StreamCat (sc) static metrics

Static watershed/local catchment metrics:

- Elevation (Cat)
- Calcium oxide content of underlying lithology (Ws)
- Base flow index (Ws)
- Water table depth (Ws)
- Watershed area (Ws)
- Runoff (ws)
- Sand soil content (Ws)
- Topographic wetness index (Ws)
- National Anthropogenic Barriers dam normal storage (screened dams of NID) (Ws)

```
# comids_missing <- flow$COMID %>%
#   na.omit()

#Pull in static watershed metrics
sc <-
  sc_get_data(metric = 'Runoff,Sand,WtDep,WetIndex,NABD_NRMSTOR,BFI,ELEV,CAO',
              aoi = 'catchment,watershed',
              comid = comids) %>%
  dplyr::select(COMID, ELEVCAT, CAOWS, BFIWS, WTDEPWS,
                WSAREASQKM, RUNOFFWS, SANDWS, WETINDEXWS,
                NABD_NRMSTORWS)
```

StreamCat Year-Specific NLCD data

Riparian forest cover (catchment)

```
riparian_forest <-
  sc_nlcd(year = '2001, 2004, 2006, 2008, 2011, 2013, 2016, 2019',
```

```
          aoi = 'riparian_watershed',
          comid = comids) %>%
  dplyr::select(COMID,
                grep('CONIF|DECID|MXFST', names(.))) %>%
  pivot_longer(!COMID, names_to = 'tmpcol', values_to = 'PCTFSTXXXXWSRP100') %>%
  mutate(year = as.integer(
    str_replace_all(tmpcol, 'PCTMXFST|PCTDECID|PCTCONIF|WSRP100', ''))) %>%
  group_by(COMID, year) %>%
  summarise(PCTFSTXXXXWSRP100 = sum(PCTFSTXXXXWSRP100))
```

Crop cover (watershed)

```
crop <-
  sc_nlcd(year = '2001, 2004, 2006, 2008, 2011, 2013, 2016, 2019',
          aoi = 'watershed',
          comid = comids) %>%
  dplyr::select(COMID,
                grep('CROP', names(.))) %>%
  pivot_longer(!COMID, names_to = 'tmpcol', values_to = 'PCTCROPXXXXWS') %>%
  mutate(year = as.integer(
    str_replace_all(tmpcol, 'PCTCROP|WS', ''))) %>%
  dplyr::select(-tmpcol)
```

Urban cover (watershed)

```
urban <-
  sc_nlcd(year = '2001, 2004, 2006, 2008, 2011, 2013, 2016, 2019',
          aoi = 'watershed',
          comid = comids) %>%
  dplyr::select(COMID,
                grep('PCTURBLO|PCTURBMD|PCTURBHI', names(.))) %>%
  pivot_longer(!COMID, names_to = 'tmpcol', values_to = 'PCTURBXXXXWS') %>%
  mutate(year = as.integer(
    str_replace_all(tmpcol, 'PCTURBLO|PCTURBMD|PCTURBHI|WS', ''))) %>%
  group_by(COMID, year) %>%
  summarise(PCTURBXXXXWS = sum(PCTURBXXXXWS))
```

Lake/Reservoir (open water) in watershed (watershed)

Variable added to interact with reservoir size to account for stations that occur below natural lakes or man made reservoirs.

```
water <-
  sc_nlcd(year = '2001, 2004, 2006, 2008, 2011, 2013, 2016, 2019',
          aoi = 'watershed',
          comid = comids) %>%
  dplyr::select(COMID,
                grep('PCTOW', names(.))) %>%
```

```
  pivot_longer(!COMID, names_to = 'tmpcol', values_to = 'PCTOWXXXXWS') %>%
  mutate(year = as.integer(
    str_replace_all(tmpcol, 'PCTOW|WS', ''))) %>%
  group_by(COMID, year) %>%
  summarise(PCTOWXXXXWS = sum(PCTOWXXXXWS))
```

PRISM Climate Data

Air temperature

```
years <- 1990:2020

# Set the PRISM directory (creates directory in not present)
prism_set_dl_dir("../data/prism_data", create = TRUE)

# Download monthly PRISM rasters (tmean)
get_prism_monthlys('tmean',
                   years = years,
                   mon = 7:8,
                   keepZip = FALSE)
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```
tmn <- pd_stack((prism_archive_subset("tmean","monthly",
                                      years = years,
                                      mon = 7:8)))

# Extract tmean at sample points and massage data
tmn <- terra::extract(tmn,
                      # Transform pts to CRS of PRISM on the fly
                      pts %>%
                        st_transform(crs = st_crs(tmn))) %>%

  # Add site IDs to extracted values
  data.frame(COMID = pts$COMID, .) %>%

  # Remove front and back text from PRISM year/month in names
  rename_with( ~ stringr::str_replace_all(., 'PRISM_tmean_stable_4kmM3_|_bil', '')) %>%

  # Pivot to long table and calle column tmeanPRISM
  pivot_longer(!COMID, names_to = 'year_month',
               values_to = 'tmeanPRISM') %>%

  # Create new column of year
  mutate(year = year(ym(year_month)),
         month = month(ym(year_month))) %>%

  dplyr::select(-year_month)
```

Precipitation

```
get_prism_monthlys('ppt',
                   years = years,
                   mon = 7:8,
                   keepZip = FALSE)
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```
ppt <- pd_stack((prism_archive_subset("ppt","monthly",
                                      years = years,
                                      mon = 7:8)))

ppt <- terra::extract(ppt,
                      pts %>%
                        st_transform(crs = st_crs(ppt))) %>%
```

```
  data.frame(COMID = pts$COMID, .) %>%
  rename_with( ~ stringr::str_replace_all(., 'PRISM_ppt_stable_4kmM3_|_bil', '')) %>%
  pivot_longer(!COMID, names_to = 'year_month',
               values_to = 'pptPRISM') %>%
  mutate(year = year(ym(year_month)),
         month = month(ym(year_month))) %>%

  dplyr::select(-year_month)
```

Combine data for modeling

```
nlcd_years <-
  data.table(year = c(2001, 2004, 2006, 2008, 2011, 2013, 2016, 2019)) %>%
  mutate(merge = year) %>%
  setkeyv('merge')

st_years <-
  data.table(year = 1990:2020) %>%
  mutate(merge = year) %>%
  setkeyv('merge')

nearest <-
  nlcd_years[st_years, roll = 'nearest'] %>%
  dplyr::select(year, i.year) %>%
  rename(nlcd_year = year,
         year = i.year)

powell.data <- tmn %>%
  left_join(nearest, join_by(year)) %>%
  left_join(ppt,
            join_by(COMID, year, month)) %>%
  left_join(sc, join_by(COMID)) %>%
  left_join(riparian_forest,
            join_by(COMID == COMID,
                    nlcd_year == year)) %>%
  left_join(crop,
            join_by(COMID == COMID,
                    nlcd_year == year)) %>%
  left_join(urban,
            join_by(COMID == COMID,
                    nlcd_year == year)) %>%
  left_join(nhd_flow,
            join_by(COMID == COMID,
                    month == month)) %>%
  left_join(water,
            join_by(COMID == COMID,
                    nlcd_year == year)) %>%
  left_join(pts,
            join_by(COMID == COMID)) %>%
  mutate(month = as.character(month),
```

```
         COMID = as.character(COMID)) %>%
  st_as_sf(crs = 4269) %>%
  st_transform(crs = 5070)

# Grab values from nearest site for WTDEP NA value

ptna <- powell.data  %>%
  filter(is.na(WTDEPWS)) %>%
  dplyr::select(COMID) %>%
  distinct()

dist_matrix <- st_distance(pts)
names(dist_matrix) <- pts$COMID
rownames(dist_matrix) <- pts$COMID

nearest <- dist_matrix[, grep(ptna$COMID, names(dist_matrix))]
nearest <- data.frame(nearest) %>%
  distinct() %>%
  arrange(nearest) %>%
  slice_head(n=6) %>%
  row.names()

powell.data$WTDEPWS[powell.data$COMID == ptna$COMID] <- mean(powell.data$WTDEPWS[powell.data$COMID

# Write output file for modeling
write_rds(powell.data,
          file = '../data/powell_data.2024.07.31.rds',
          compress = "xz")
```

Predict stream temperatures

```
sp.mod <- read_rds('../data/splm_selected.2024.08.08.rds')

powell.pred <- predict(sp.mod,
                       newdata = powell.data,
                       se.fit = TRUE,
                       local = list(parallel = TRUE,
                                    ncores = 30))


outdf <-
  powell.data %>%
  dplyr::select(COMID, year, month) %>%
  mutate(wt_pred = powell.pred$fit,
         wt_se.fit = powell.pred$se.fit) %>%
  st_drop_geometry()

length(comids)

test <- powell.data %>%
```

```
  pull(COMID) %>%
  na.omit() %>% unique()
```

Write output file

```
write_rds(outdf,
          file = '../data/powell-long-term-water-temperature-predictions.2024.08.08.rds',
          compress = "xz")
```