README: Climate Data and Visualization for EM

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Overview

This folder includes the climate datasets (historical/projection) and visualization for the 8 DOE-EM sites that were deemed to have some level of potential risk associated with future climate change in terms of altering system performance and/or exceeding design requirements. We use the Coupled Model Intercomparison Project (CMIP) climate models (Taylor et al., 2012), which are the standard global climate model ensembles used in the US Global Change Research Program and the Intergovernmental Panel on Climate Change (IPCC). Both historical and future projection datasets (Thrasher et al., 2012) are downscaled to 28 km (0.25 degree) from the coarser 1-degree resolution GCM output.

We define the risk score based on the historical mean, projected mean, and historical standard deviation, when the climate metrics follow a statistically normal distribution, following the approach of Werth (2016). When the distribution is skewed, we define the risk score based on the distribution quantile.

Detailed information

- Data source: https://developers.google.com/earth-engine/datasets/catalog/NASA_NEX-GDDP#image-properties
- Scripts and tools we used to download the datasets: https://pypi.org/project/climate-resilience/
- Climate scenarios:
    - Historical (1950-2005, referred as “historical” in our dataset)
    - Projection RCP4.5 (2006-2099, referred as “rcp45” in our dataset)
    - Projection RCP8.5 (2006-2099, referred as “rcp85” in our dataset)
- Climate models: 21 global climate models, including 'ACCESS1-0', 'bcc-csm1-1', 'BNU-ESM', 'CanESM2', 'CCSM4', 'CESM1-BGC', 'CNRM-CM5', 'CSIRO-Mk3-6-0', 'GFDL-CM3', 'GFDL-ESM2G', 'GFDL-ESM2M', 'inmcm4', 'IPSL-CM5A-LR', 'IPSL-CM5A-MR', 'MIROC-ESM', 'MIROC-ESM-CHEM', 'MIROC5', 'MPI-ESM-LR', 'MPI-ESM-MR', 'MRI-CGCM3', 'NorESM1-M'
- Climate variables:
    - Average annual total precipitation (mm/day)
    - Average daily maximum two-meter surface temperature (tasmax, Celsius degree)

    - Extreme precipitation days, defined as the number of days with precipitation in the top 1% of all days having recordable precipitation (EPA definition)
    - Maximum daily precipitation (mm/day): defined as the maximum daily precipitation in each year
    - Standardized Precipitation-Evapotranspiration Index (SPEI): a diagnostic of long-term drought severity index. They are calculated in monthly temporal frequency. Negative values indicates drier. The data are provided by Florida Institute of Technology.
    - Extreme degree days: similar definition to the growing degree days (https://mrcc.purdue.edu/gismaps/info/gddinfo.htm#:~:text=Growing%20Degree%20Days%20(GDD)%20are,or%20base%20temperature%20(TBASE).), with Tbase = 93F.
    - Heating degree days: the definition can be found at https://www.eia.gov/energyexplained/units-and-calculators/degree-days.php#:~:text=Heating%20degree%20days%20(HDD)%20are,for%20the%20two%2Dday%20period.
    - Cooling degree days: the definition can be found at https://www.eia.gov/energyexplained/units-and-calculators/degree-days.php#:~:text=Heating%20degree%20days%20(HDD)%20are,for%20the%20two%2Dday%20period.
    - Wildfire: The wildfire data are EU classes (low, medium, high, etc.) based on the CFWI (Canadian Fire Weather Index). The wildfire data are provided by the Argonne National Laboratory.

- Climate metrics:
    - Hist_mean: The mean of each climate variable over 56 years of the historical period (1950-2005)
    - Hist_std: The standard deviation of each climate variable over 56 years of the historical periods (1950-2005)
    - 1990_2019_mean: The mean of each climate variable over the recent 30 years (1990-2019). The period of 1990-2005 uses the “historical” scenario, the period of 2007-2019 uses the “rcp85” scenario.
    - Rcp45_mean: The mean of each climate variable over the 94 years of the rcp45 scenarios (2006-2099)*
    - Rcp45_max: The maximum of each climate variable over the 94 years of the rcp45 scenarios (2006-2099)**
    - Rcp85_mean: The mean of each climate variable over the 94 years of the rcp45 scenarios (2006-2099)
    - Rcp85_max: The maximum of each climate variable over the 94 years of the rcp45 scenarios (2006-2099)
    - Shifting_rcp45: The shifting of each climate variable in the rcp45 scenario compared to the historical period. The shifting_index is defined as the z-score, which is computed as (rcp45_mean - hist_mean)/hist_std. The shifting_index is quantified as ***

        - shifting_index < 0, labeled as 0 or “negative” (rcp45_mean < hist_mean)
        - 0<shifting_index<1, labeled as 1 or “low” (hist_mean < rcp45_mean < hist_mean + 1* hist_std)
        - 1<shifting_index<2, labeled as 2 or “medium” (hist_mean + 1* hist_std < rcp45_mean < hist_mean + 2* hist_std)
        - shifting_index > 2, labeled as 3 or “high” (rcp45_mean > hist_mean + 2*hist_std)
    - Shifting_rcp85: Same as shifting_rcp45, but with rcp85_mean for rcp85 scenario.
    - Hist_10yr_mean: The mean of each climate variable over 10-year (1995-2004) historical data
    - Mid_rcp45: The mean of each climate variable over 10-year mid-century (2045-2054) for rcp45 scenario
    - Shifting_mid_rcp45: the shifting of each climate variable in the 10-year mid-century (2045-2054) compared to the 10-year historical period (1995-2004)
    - Shifting_mid_rcp85: Same as Shifting_mid_rcp45, but for the rcp85 scenario
    - Mid_rcp85: Same as Mid_rcp45, but for rcp85 scenario
    - Late_rcp45: The mean of each climate variable over 10-year late-century (2085-2094) for rcp45 scenario
    - Late_rcp85: Same for Late_rcp45, but for rcp85 scenario
    - Shifting_late_rcp45: the shifting of each climate variable in the 10-year late-century (2085-2094) compared to the 10-year historical period (1995-2004)
    - Shifting_late_rcp85: Same as Shifting_late_rcp45, but for the rcp85 scenario

    Exceptions:

    * The rcp26_mean and rcp26_max are presented because our SPEI dataset only has historical, rcp26 and rcp85 scenarios

    ** The minimum value is reported here for SPEI because negative value indicates drier condition by the definition of SPEI.

    *** For the extreme precipitation days and maximum daily precipitation, we used the median value because these two climate variables are not normally distributed. The shifting_index is computed by the median, 70 percentile and 95 percentile of the historical period to be consistent with the shifting index for other variables
        - shifting_index < 0, labeled as 0 or “negative” (rcp45_median < hist_median)
        - 0<shifting_index<1, labeled as 1 or “low” (hist_median < rcp45_median < hist_70percentile)
        - 1<shifting_index<2, labeled as 2 or “medium” (hist_70percentile < rcp45_median < hist_95percentile)
        - shifting_index > 2, labeled as 3 or “high” (rcp45_median > hist_95percentile)

- Calculation methods:

    - The ensemble mean among 21 climate models are calculated and reported (for average total precipitation, average daily maximum temperature and average SPEI)
    - For extreme precipitation days and maximum daily precipitation, the climate variables are computed for each individual climate model first, then the mean of those ensemble models are reported. This is because the daily extreme precipitation will be diminished if ensemble mean is used for computing those variables directly.

- Sites: Please see the appendix at the end of this README, and please refer to the EMsites_handoff.csv file for more information
- File organization:
    - EMsites_handoff.csv
    - Climate variable database
        - Annual_average_tmax_stats.csv
        - Annual_total_precipitation_stats.csv
        - Drought_index_stats.csv
        - Extreme_precipitation_days_stats.csv
        - Maximum_daily_precipitation_stats.csv
        - Extreme_degree_days_stats.csv
        - Heating_degree_days_stats.csv
        - Cooling_degree_days_stats.csv
    - One directory per site
        - Aggregated climate metrics in the historical and projection periods for five climate variables in csv format (stat_matrix.csv)
        - Color-coded shifting_index in HTML format (stat_matrix_static_colors.html, you may need to download it and open with any browser)
        - Visualization of annual total precipitation (annual_total_precipitation_timeseries.png)
        - Visualization of annual average Tmax (annual_average_tmax_timeseries.png)
        - Visualization of extreme precipitation days (extreme_precipitation_days_timeseries.png)
        - Visualization of maximum daily precipitation (maximum_daily_precipitation_timeseries.png)
        - Visualization of drought index (drought_index_timeseries.png)
    - Wildfire
        - EM_CFWI_euClass_RCP85_RCP45.csv
        - EM_extracted_CFWI_timeseries_RCP4.5_annual_mean.csv
        - EM_extracted_CFWI_timeseries_RCP8.5_annual_mean.csv

Examples

All table and figures are shown in Savanha River Site (SRS), South Carolina:

Table 1. Color-coded risk index for climate variables historical RCP45 and RCP85 scenarios

	hist_mean	hist_std	rcp45	rcp85	shifting_rcp45	shifting_rcp85
Annual precipitation (mm/day)	3.24	0.14	3.52	3.58	Medium	High
Extreme precipitation day	2	0.74	2.48	3.17	Low	Medium
Annual avg Tmax (C)	24.79	0.31	26.63	27.5	High	High
Maximum Daily Precipitation (mm/day)	61.79	11.22	67.11	75.09	Low	Medium
Drought Index (SPEI)	-0.01	0.3	0.15	0.22	Negative	Negative
Wildfire (CFWI)	7.24		9.18	7.93	Low	Low

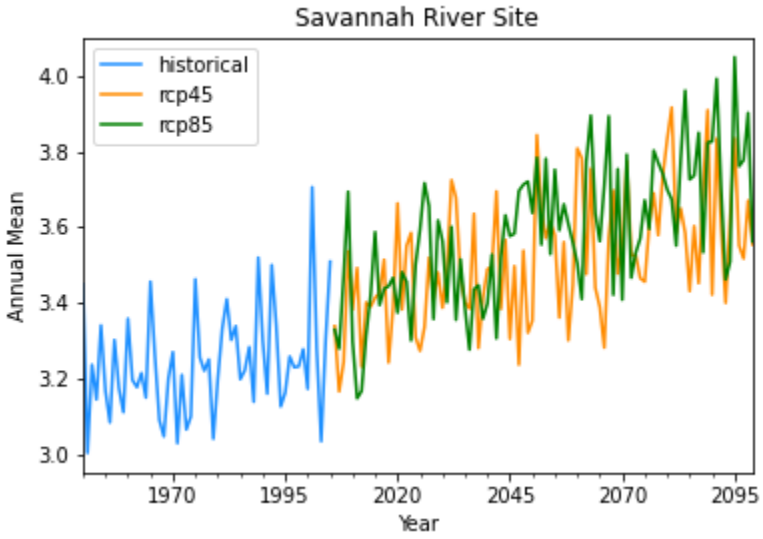

Figure 1. The trend of annual total precipitation (mm/day) in historical and projection periods at SRS. This is the average among multiple models.

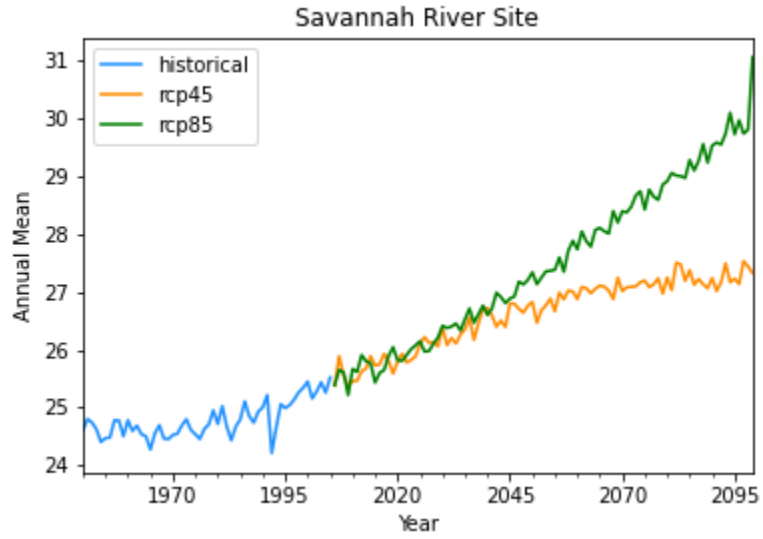

Figure 2. The trend of daily maximum two-meter surface temperature (tasmax, Celsius degree) in historical and projection periods at SRS.

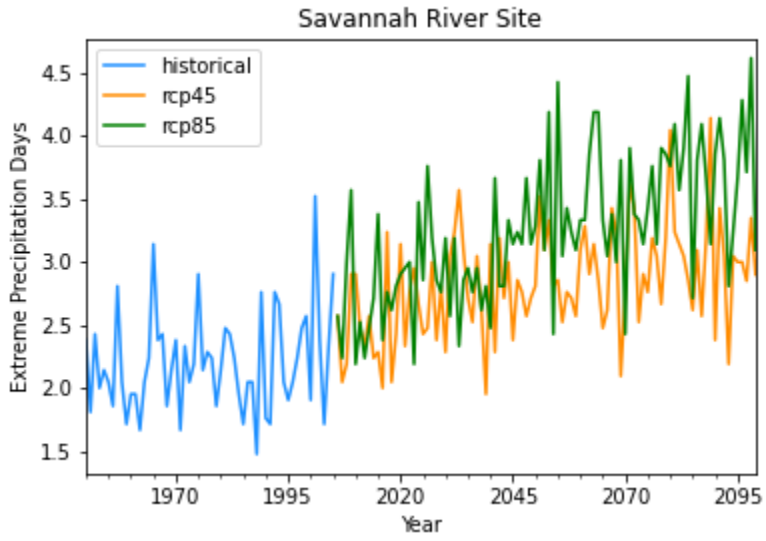

Figure 3. The trend of extreme precipitation days in historical and projection periods at SRS.

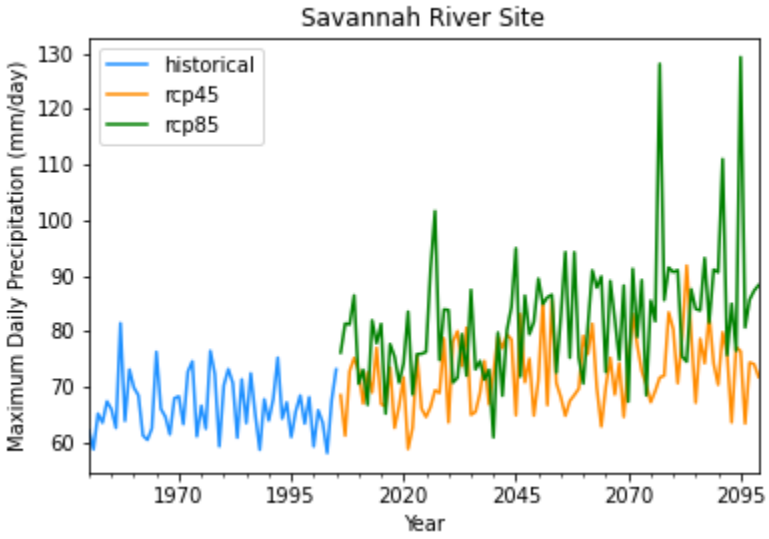

Figure 4. The trend of maximum daily precipitation (mm/day) in historical and projection periods at SRS.

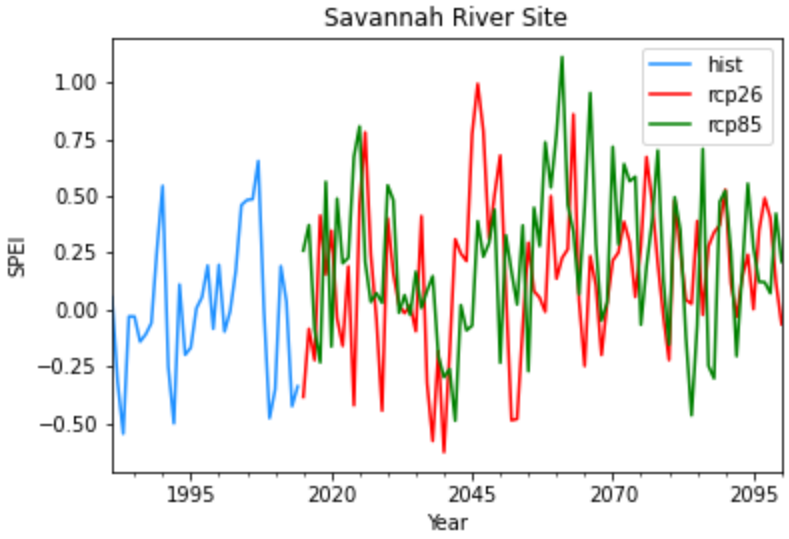

Figure 5. The trend of SPEI in historical and projection periods at SRS.

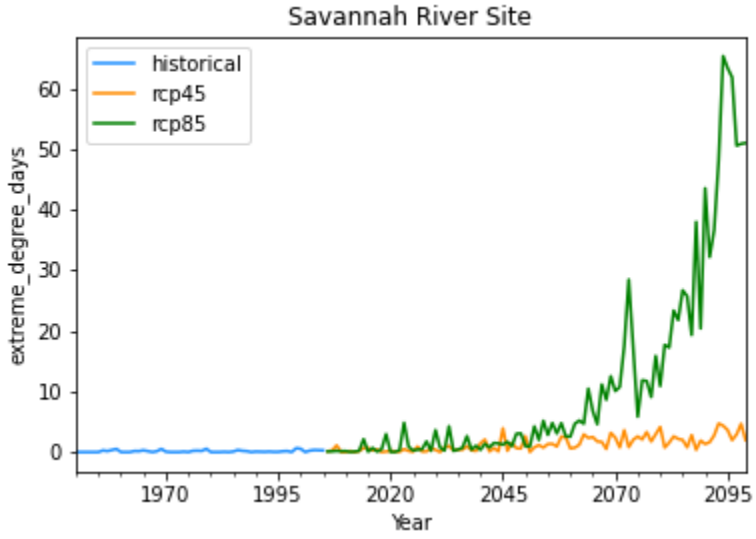

Figure 6. The trend of extreme degree days in historical and projection periods at SRS.

References:

Taylor, K. E., Stouffer, R. J., & Meehl, G. A., 2012: An overview of CMIP5 and the experiment design, B. Am. Meteorol. Soc., 93, 485–498, https://doi.org/10.1175/BAMS-D-11-00094.1

Thrasher, B., Maurer, E. P., McKellar, C., & Duffy, P. B., 2012: Technical Note: Bias correcting climate model simulated daily temperature extremes with quantile mapping. Hydrology and Earth System Sciences, 16(9), 3309-3314. doi:10.5194/hess-16-3309-2012

Werth, D., (2016), Climate Change Resilience Planning at the Savannah River Site, Part 2 , SRNL-STI-2016-00601