README: Climate Data and Visualization for LM

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Overview

This folder includes the climate datasets (historical/projection) and visualization for the 71 DOE-LM sites identified through the LM Site Questionnaire that were deemed to have some level of potential shifting 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 shifting 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 shifting 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.
    - Flooding (will be available soon if historical data can be found that is of relevance to the study)
    - Groundwater elevation and uranium concentrations (will be available soon if historical data can be found that is of relevance to the study)

- 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
    - 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 for shifting_rcp45, but with rcp85_mean for 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 LMsites_handoff.csv file for more information
- File organization:
    - LMsites_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
        - LM_CFWI_euClass_RCP85_RCP45.csv
        - LM_extracted_CFWI_timeseries_RCP4.5_annual_mean.csv
        - LM_extracted_CFWI_timeseries_RCP8.5_annual_mean.csv

Examples

All table and figures are shown in Ambrosia Lake, NM site):

	hist_mean	hist_std	1990_2019_mean	rcp45_mean	rcp45_max	rcp85_mean	rcp85_max	shifting_rcp45	shifting_rcp85
Annual precipitation (mm/day)	0.83	0.04	0.81	0.86	1.01	0.83	0.93	low	negative
Extreme precipitation day	1.06	1.05	1.15	1.31	5.43	1.27	5.14	low	low
Annual avg Tmax (C)	18.71	0.39	19.43	21.17	22.82	22.26	26.38	high	high
Maximum Daily Precipitation (mm/day)	28.81	12.74	28.56	30.35	83.21	29.45	71.09	low	low
SPEI	-0.02	0.33	-0.13	-0.38	-1.03	-0.70	-1.62	medium	high
Heating Degree Days	6180.67	351.01	nan	5096.57	6211.47	4695.22	6297.89	negative	negative
Extreme Degree Days	0.00	0.00	nan	0.00	0.00	0.00	0.02	high	high
Cooling Degree Days	195.31	84.66	nan	564.59	1023.54	818.87	1837.96	high	high

Table 1. Color-coded shifting index for five climate variables in RCP45 and RCP85 scenarios

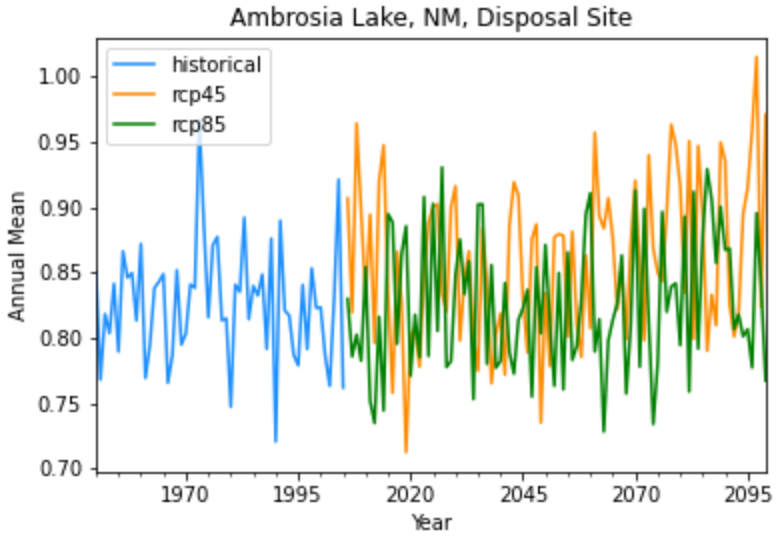

Figure 1. The trend of annual total precipitation (mm/day) in historical and projection periods at the Ambrosia Lake, NM site. This is the average among multiple models.

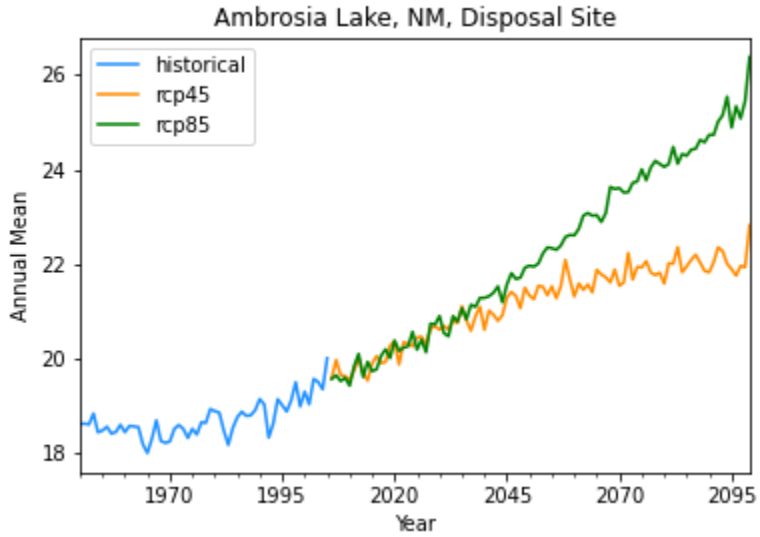

Figure 2. The trend of daily maximum two-meter surface temperature (tasmax, Celsius degree) in historical and projection periods at the Ambrosia Lake, NM site.

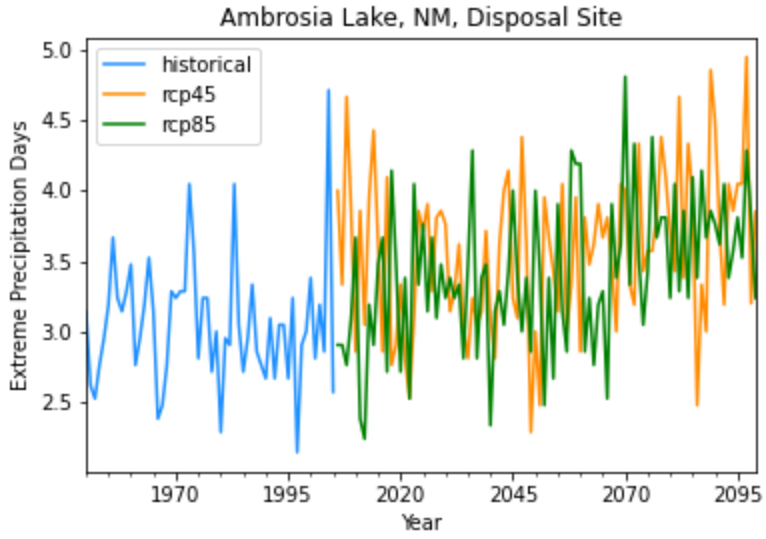

Figure 3. The trend of extreme precipitation days in historical and projection periods at the Ambrosia Lake, NM site.

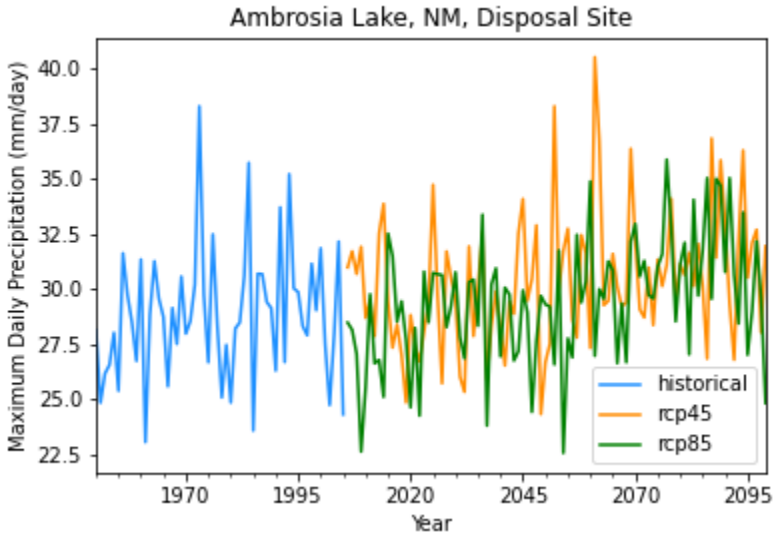

Figure 4. The trend of maximum daily precipitation (mm/day) in historical and projection periods at the Ambrosia Lake, NM site.

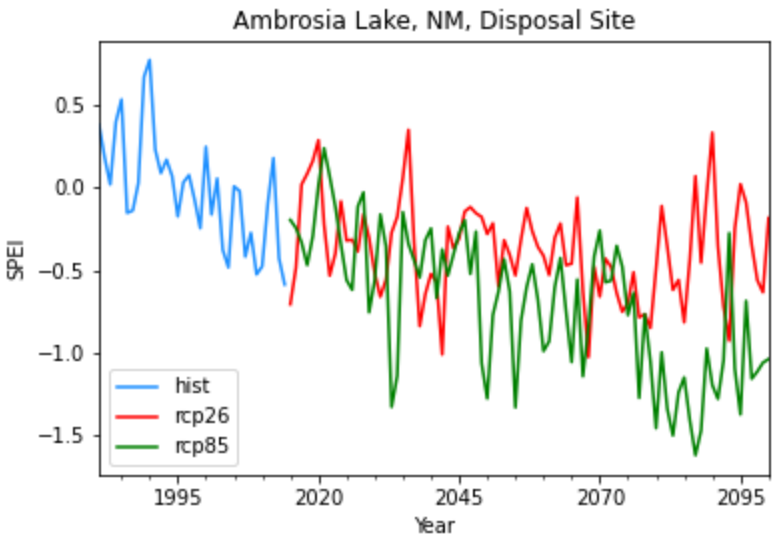

Figure 5. The trend of SPEI in historical and projection periods at the Ambrosia Lake, NM site.

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

Appendix

Name	Name Abbreviation	StateCode
Ambrosia Lake, NM, Disposal Site	AMB	NM
Amchitka, AK, Site	AMC	AK
Bluewater, NM, Disposal Site	BLU	NM
BONUS, PR, Decommissioned Reactor Site	BON	PR
Bronco, CO, Site	BRO	CO
Burrell, PA, Disposal Site	BUR	PA
Burris Park, CA, Site	BRP	CA
Canonsburg, PA, Disposal Site	CAN	PA

Casper, WY, Calibration Model	CSC	WY
Central Nevada Test Area, NV	CNT	NV
Colonie, NY, Site	CLN	NY
Durango, CO, Disposal Site	DUD	CO
Durango, CO, Processing Site	DUP	CO
Edgemont, SD, Disposal Site	EDG	SD
Falls City, TX, Disposal Site	FCT	TX
Fernald Preserve, OH, Site	FER	OH
Gasbuggy, NM, Site	GSB	NM
George West, TX, Calibration Model	GWC	TX
Gnome-Coach, NM, Site	GNO	NM
Grand Junction Regional Airport, CO, Calibration Model	GAC	CO
Grand Junction, CO, Calibration Model	GJC	CO
Grand Junction, CO, Disposal Site	GRJ	CO
Grand Junction, CO, Processing Site	GJT	CO
Grand Junction, CO, Site	GJO	CO
Grants, NM, Calibration Model	GNC	NM
Green River, UT, Disposal Site	GRN	UT
Gunnison, CO, Disposal Site	GUD	CO
Gunnison, CO, Processing Site	GUP	CO
Hallam, NE, Decommissioned Reactor Site	HAL	NE
L-Bar, NM, Disposal Site	BAR	NM
Laboratory for Energy-Related Health Research, CA, Site	LEH	CA
Lakeview, OR, Disposal Site	LKD	OR
Lakeview, OR, Processing Site	LKP	OR
Lowman, ID, Disposal Site	LOW	ID
Maxey Flats, KY, Disposal Site	MAX	KY
Maybell West, CO, Disposal Site	MAW	CO
Maybell, CO, Disposal Site	MAY	CO

Mexican Hat, UT, Disposal Site	HAT	UT
Monticello, UT, Disposal and Processing Sites	MNT	UT
Monument Valley, AZ, Processing Site	MON	AZ
Mound, OH, Site	MND	OH
Naturita, CO, Disposal Site	NAD	CO
Naturita, CO, Processing Site	NAP	CO
Parkersburg, WV, Disposal Site	PKB	WV
Pinellas County, FL, Site	PIN	FL
Piqua, OH, Decommissioned Reactor Site	PIQ	OH
Pre-Gondola and Trencher, MT, Site	PGD	MT
Pre-Schooner II, ID, Site	PSC	ID
Rifle New, CO, Processing Site	RFN	CO
Rifle Old, CO, Processing Site	RFO	CO
Rifle, CO, Disposal Site	RFL	CO
Rio Blanco, CO, Site	RBL	CO
Riverton, WY, Processing Site	RVT	WY
Rocky Flats, CO, Site	RFS	CO
Rulison, CO, Site	RUL	CO
Salmon, MS, Site	SAL	MS
Salt Lake City, UT, Disposal Site	SLD	UT
Salt Lake City, UT, Processing Site	SLP	UT
Sherwood, WA, Disposal Site	SHE	WA
Shiprock, NM, Disposal Site	SHP	NM
Shirley Basin South, WY, Disposal Site	SBS	WY
Shoal, NV, Site	SHL	NV
SiteAPlotM, IL, Decommissioned Reactor Site	SAM	IL
Slick Rock East, CO, Processing Site	SRE	CO
Slick Rock West, CO, Processing Site	SRW	CO
Slick Rock, CO, Disposal Site	SRD	CO
Spook, WY, Disposal Site	SPK	WY

Tonopah Test Range, NV, Site	TTR	NV
Tuba City, AZ, Disposal Site	TUB	AZ
Utah, UT, Site	UTA	UT
Weldon Spring, MO, Site	WEL	MO