Climate Scenarios (1976–2099): Potential Evapotranspiration (PET)

These EnviroAtlas maps show projected changes in potential evapotranspiration (PET) for each season (fall, winter, spring, and summer) and annual period following four Shared Socioeconomic Pathways (SSPs, see inset at right) for states and territories outside of the contiguous U.S. (OCONUS): Alaska, Hawaii, Puerto Rico, U.S. Virgin Islands, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. Changes in PET are displayed both in inches and as fractions.

Why is it important to explore potential evapotranspiration projections?

Evapotranspiration is the cumulative amount of water returned to the atmosphere due to evaporation from earth's surface and from plant transpiration. The PET represents the evapotranspiration rate under ideal conditions (i.e., a vegetated surface shading the ground and unlimited water supply).[1] Climate change has contributed to increased terrestrial evapotranspiration, which is likely to increase over land leading to large deficits or surpluses in soil moisture and runoff. Observation-based estimates show a robust positive trend in global terrestrial evapotranspiration between the early 1980s and the early 2010s, and PET is projected to keep increasing.[2]

How can I use this information?

These maps can help quantify the potential risks of exceeding identifiable thresholds in both physical change and impacts on biological and anthropogenic systems. Understanding how evapotranspiration may change in the future is a critical step toward identifying and monitoring possible degradation and changes in trends in supply and demand of many ecosystem services. Identifying the potential threats of a changing climate and contributing factors may also inform community climate adaptation and resiliency strategies. Future changes in PET can be used to estimate changes in agricultural drought risk, soil moisture levels, heat waves, and increased probability of crop loss.[3] These projections can be used with additional datasets in EnviroAtlas, such as Residential Density, Dasymetric Population, Average Annual Precipitation, or any of the Crop Productivity maps, if available.

Shared Socioeconomic Pathways

The Intergovernmental Panel on Climate Change (IPCC) develops climate change scenarios to explore the future global environment. These scenarios were a pillar for a major international climate modeling study, called the sixth phase of the Coupled Model Intercomparison Project (CMIP6).[4] The IPCC and CMIP6 are recognized as the authoritative foundations for exploring global climate change.

CMIP6 scenarios are called Shared Socioeconomic Pathways (SSPs), with names coded to reflect global trends in human activities and changes in radiative forcing that result from changes in atmospheric greenhouse gases (GHGs) and aerosol concentrations. In the SSP labels (like SSP1-2.6), the first number refers to a defined socioeconomic pathway (reflecting trends in population, policy, and economic growth), and the second refers to an increase in radiative forcing ($W\ m^{-2}$) relative to preindustrial conditions. For reference, in comparison to *preindustrial* (1850–1900) *average* (PIA), the 2023 observed global mean near-surface temperature increased by 2.61±0.22°F (1.45±0.12°C).[5]

There are four primary "Tier 1" SSPs.

SSP1-2.6: SSP1 ("Sustainability") assumes widespread global climate change mitigation policies, clean energy technologies, and natural environment conservancy. This scenario assumes very low GHG concentration levels and reflects the international climate policy goal of limiting global warming below 3.6°F (2.0°C) at 2100 compared to PIA.

SSP2-4.5: SSP2 ("Middle of the Road") assumes moderate global climate mitigation and adaptation and a slow progress in climate protection measures. This scenario is a medium GHG concentrations pathway. Global temperatures increase by 4.9±1.3°F (2.7±0.7°C) at 2100 compared to PIA.

SSP3-7.0: SSP3 ("Regional Rivalry") assumes high challenges to mitigation and adaptation. Here, nationalism drives policy, and regional and local take precedence over global issues. Global temperatures increase by 6.5±1.6°F (3.6±0.9°C) at 2100 compared to PIA.

SSP5-8.5: SSP5 ("Fossil-fueled Development") reflects high challenges to mitigation and low challenges to adaptation. It is characterized by steadily increasing GHG concentrations. It represents the upper boundary of the range of scenarios. Global temperatures increase by 7.9±2.2°F (4.4±1.2°C) at 2100 compared to PIA.

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How were the data for this map created?

These maps were created using bias-corrected data from NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)[6], which is the first downscaled dataset to include localized projections for the United States and all territorial lands. The NEX-GDDP-CMIP6 temperature datasets (0.25° × 0.25°) were obtained in a gridded format for the 35 members of the CMIP6 global climate model ensemble. NEX-GDDP-CMIP6 data are shown in EnviroAtlas as projected changes between periods reflecting recent history (1976–2005), near-term future (2025–2054), mid-century (2045–2074), and end-of-century (2070–2099). Each value is the ensemble median, and the ensemble minima and maxima provide ranges for each HUC12 and SSPs for each season (fall, winter, spring, and summer) and annual period. Using the NEX-GDDP-CMIP6 temperature datasets, PET was calculated using the Hamon PET method[1]. Like other temperature-based PET models, Hamon is based on an empirical relationship between temperature and net radiation. See the PET Technical Fact Sheet for a detailed description of methods, formulas, and limitations for this dataset. Because of low historical PET values, the data for Alaska is not available in fraction units.

What are the limitations of these data?

All national geospatial data within EnviroAtlas are estimates, particularly with regard to projecting climate variables into the future. The aggregated datasets reflect plausible future trajectories based on the state of the science. Even though this dataset is the first known downscaled dataset available throughout the OCONUS locations, it originates from one modeling source based on a specific methodology.[7] Datasets for these regions from other comparable data sources may show different ranges of variability. EnviroAtlas provides the ensemble median, maximum, and minimum to illustrate variability so plausible regional trends can be evaluated and analyzed. Furthermore, climate change metrics were computed using 30-year periods to remove artifacts from single-year events. Due to the lack of validation data over oceans, NEX-GDDP-CMIP6 values over smaller island areas may have lower confidence.[6,7]

How can I access these data?

EnviroAtlas data, including seasonal and annual climate projections, can be viewed in the interactive map, accessed through web services, or downloaded. The NEX-GDDP-CMIP6 data can be acquired from the NASA Center for Climate Simulation.

Where can I get more information?

Additional information on climate change can be found at the EPA website. For information on how the data were created, see the metadata. For specific questions about the NEX-GDDP-CMIP6 data, please see the NASA Center for Climate Simulation technical note.[7] For additional information about the SSP scenarios, please visit the IPCC website. Specific questions about these maps should be directed to the EnviroAtlas Team.

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Selected Publications

1. Hamon, W.R. 1961. Estimating potential evapotranspiration. *Journal of Hydraulic Engineering* 87:107–120.
2. Douville, H., et al. 2021. Water cycle changes. Pages 1055–1210 *in* Masson-Delmotte, V., et al. (eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, U.K, and New York, NY, USA.
3. Gavahi, K., et al. 2020. Multivariate assimilation of remotely sensed soil moisture and evapotranspiration for drought monitoring. *Journal of Hydrometeorology* 21:2293–2308.
4. Lee, J.-Y., et al. 2021. Future global climate: Scenario-based projections and near-term information. Pages 553–672 *in* Masson-Delmotte, V., et al. (eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, U.K., and New York, NY, USA.
5. World Meteorological Organization (WMO). 2024. State of the Global Climate 2023. World Meteorological Organization, Geneva, Switzerland, 53 pp.
6. Thrasher, B., et al. 2022.NASA Global Daily Downscaled Projections, CMIP6. *Scientific Data* 9**:** 262.
7. Thrasher, B., et al. 2012. Technical Note: Bias correcting climate model simulated daily temperature extremes with quantile mapping. *Hydrology and Earth System Sciences* 16:3309–3314.

NEX-GDDP-CMIP6 Disclaimer: "This data is considered provisional and subject to change. This data is provided as is without any warranty of any kind, either express or implied, arising by law or otherwise, including but not limited to warranties of completeness, non-infringement, accuracy, merchantability, or fitness for a particular purpose. The user assumes all risk associated with the use of, or inability to use, this data."