Global Vegetation and Climate Insights Portal (GVCIP): A Google Earth Engine-Based Monitoring Tool

Nicholas Richmond [1], Mohammadreza Narimani [2], Ali Moghimi [2], Alireza Pourreza [2]

1. Department of Mechanical and Aerospace Engineering, University of California, Davis, CA, USA
2. Department of Biological and Agricultural Engineering, University of California, Davis, CA, USA

Abstract

Global environmental challenges, including climate variability and extreme weather events, necessitate innovative monitoring solutions. In regions prone to such phenomena, like California which faces severe droughts and wildfires, the demand for precise and timely environmental data is critical. The Global Vegetation and Climate Insights Portal (GVCIP) harnesses the power of Google Earth Engine to provide an advanced monitoring tool that leverages the comprehensive archives of MODIS and Sentinel data products. This portal enables users to dynamically visualize and analyze global environmental indicators such as NDVI, evapotranspiration, and land surface temperature. The portal is designed to facilitate a variety of tasks, from tracking vegetation health to monitoring climate variables over time. Its interactive mapping feature allows users to explore different environmental data layers globally, adjust time settings for specific analysis periods, and focus on particular geographic areas for detailed insights. The application is particularly valuable in the context of environmental research, agricultural planning, and policy-making, offering an accessible interface suitable for both experts and the general public. By integrating extensive satellite data, the GVCIP provides a robust framework for environmental monitoring. This includes the ability to detect and analyze changes in vegetation and surface temperatures, which are critical for understanding and mitigating the impacts of climate change and extreme weather events. Future developments will focus on enhancing the portal's predictive capabilities using machine learning models to forecast environmental conditions and potential hazards, further empowering researchers and policymakers in their decision-making processes.

Objectives

1. Integrate High-Resolution Satellite Data: Utilize satellite data products like MODIS and ERA5 to ensure high-frequency observations and broad spectral coverage for global and regional environmental monitoring.

2. Enable Advanced Environmental Analysis: Provide tools for dynamic visualization and time-series analysis of key environmental indicators such as NDVI and land surface temperature, tailored to both local and global contexts.

3. Develop a User-Friendly Interface: Create an intuitive and accessible application that allows diverse users, from researchers to policymakers, to easily analyze and interpret environmental data.

Methodology

1. Selection of MODIS and ERA5 for Environmental Monitoring

The selection of appropriate satellite datasets was critical to our project's success, given the need for high-resolution and frequent observations to monitor environmental changes effectively. We chose MODIS (Moderate Resolution Imaging Spectroradiometer) for its comprehensive coverage and spectral capabilities, and ERA5 (the fifth generation of ECMWF atmospheric reanalyses of the global climate) for its detailed atmospheric data. MODIS offers daily global coverage, making it ideal for observing dynamic environmental events and trends over time. Figure 1 illustrates the Aqua satellite, which carries MODIS, highlighting its instrumental role in our data collection framework. Aqua, launched on May 4, 2002, is equipped with several Earth-observing instruments, including MODIS.

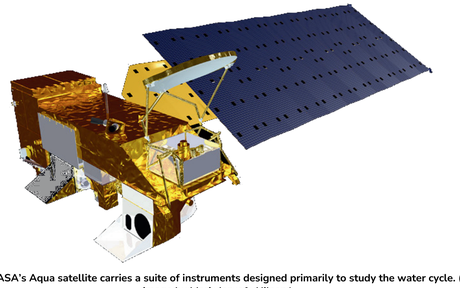

Figure 1. NASA's Aqua satellite carries a suite of instruments designed primarily to study the water cycle. (NASA image by Marit Jentoft-Nilsen.)

2. Land Surface Temperature

Land Surface Temperature (LST) is crucial for monitoring Earth's surface and atmospheric interactions. We use the MODIS sensor on the Aqua satellite to provide daily global LST data with a 1 km spatial resolution. This high-resolution data is essential for applications in agriculture, forestry, and climate monitoring. Our visualization parameters are designed to clearly differentiate temperature variations across diverse landscapes. Figure 2 illustrates the land surface temperature of the United States in 2019, showcasing the detailed thermal patterns captured by MODIS.

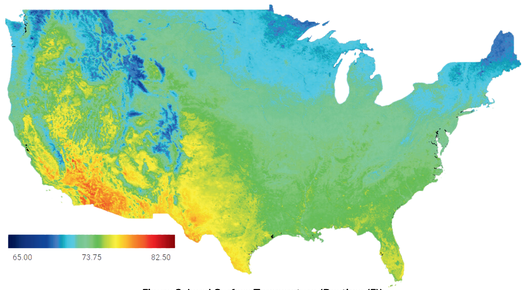

Figure 2: Land Surface Temperature (Daytime (F))

3. Evapotranspiration Insights Using MODIS

Evapotranspiration (ET) is a crucial component in understanding water dynamics and its interaction with the atmosphere. Utilizing the MODIS instrument on the Aqua satellite, we access ET data with an 8-day temporal resolution. This allows us to capture the water cycle's impact on various ecosystems accurately. The spatial resolution and comprehensive spectral data from MODIS enable effective monitoring of ET across diverse landscapes. Figure 3 presents a visualization of evapotranspiration across the United States in 2019, highlighting areas of high and low water flux, essential for agricultural management and climate studies.

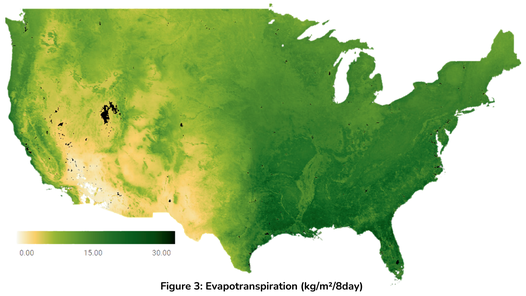

Figure 3: Evapotranspiration (kg/m²/8day)

4. Leaf Area Index Insights Using MODIS

The Leaf Area Index (LAI) is a crucial parameter for assessing plant canopy and understanding its interaction with the atmosphere. Utilizing the MODIS sensor on the Aqua satellite, we access high-resolution LAI data that provides insights into vegetation health and productivity across diverse ecosystems. This data is particularly important for applications in agriculture and climatology, where understanding the distribution and density of leaf coverage can influence everything from water usage to carbon sequestration strategies. Figure 4 showcases a visualization of the leaf area index across the United States in 2019, providing a representation of vegetation density variations essential for ecological monitoring and agricultural management.

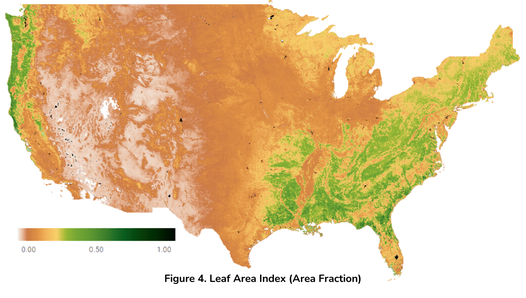

Figure 4. Leaf Area Index (Area Fraction)

5. Fraction of Photosynthetically Active Radiation Insights Using MODIS

Fraction of Photosynthetically Active Radiation (FPAR) is vital for assessing vegetation health and photosynthetic activity. Utilizing the MODIS sensor on the Aqua satellite, we provide high-resolution FPAR data essential for agricultural and ecological analysis. This data helps in understanding the amount of solar radiation absorbed by chlorophyll in plants, crucial for their growth. Figure 5 showcases the FPAR distribution across the United States in 2019, highlighting areas of significant photosynthetic activity essential for monitoring vegetation health.

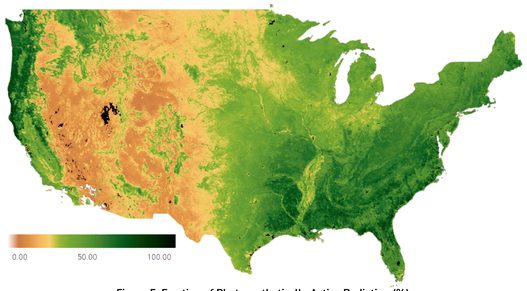

Figure 5: Fraction of Photosynthetically Active Radiation (%)

6. Normalized Difference Vegetation Index (NDVI) Insights Using MODIS

The Normalized Difference Vegetation Index (NDVI) is a vital measure derived from MODIS on the Aqua satellite to assess vegetation health and productivity. By calculating the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), NDVI provides a clear indicator of plant health. This data is critical for agricultural management, environmental monitoring, and assessing ecosystem responses to climate variations. Figure 6 displays the NDVI across the United States in 2019, offering a detailed view of vegetation health and stress levels, essential for sustainable land management practices.

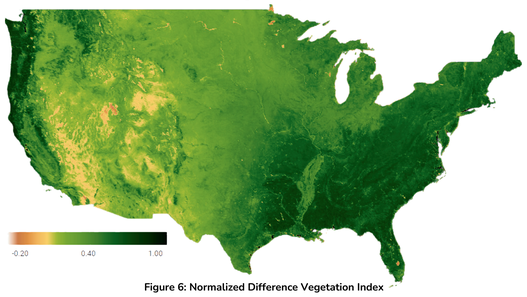

Figure 6: Normalized Difference Vegetation Index

7. Mean 2-meter Air Temperature Insights Using ERA5

Mean 2-meter air temperature, provided by the ERA5 dataset, offers critical insights into climatic conditions. Leveraging data from the ECMWF (European Centre for Medium-Range Weather Forecasts), this parameter is calculated daily and is essential for understanding atmospheric stability and energy balance. The data spans a temperature range from 250 K to 320 K, showcasing thermal variations crucial for weather forecasting and climate research. Figure 7 presents the mean air temperature across the United States for the year 2019, highlighting regional climate variations and providing a detailed overview of temperature distributions essential for meteorological and environmental analysis.

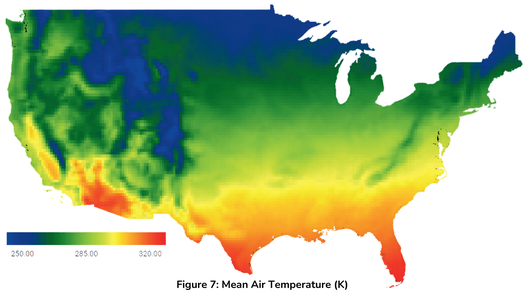

Figure 7: Mean Air Temperature (K)

8. Insights into Precipitation Patterns Using ERA5 Data

Precipitation monitoring is critical for environmental and hydrological studies. The ERA5 dataset from ECMWF provides daily precipitation data with comprehensive global coverage. This dataset offers fine granularity that helps in understanding precipitation distribution, crucial for agricultural planning and water resource management. Figure 8 depicts the precipitation across the United States for the year 2019, illustrating varied rainfall patterns that are essential for predicting water-related events and managing water resources effectively.

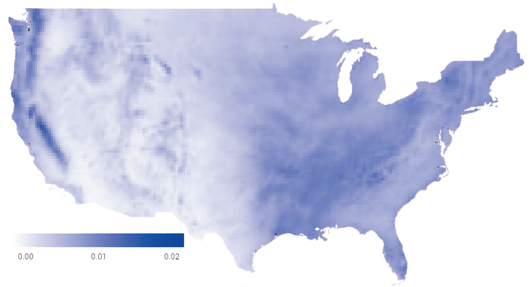

Figure 8: Total Daily Precipitation (m)

App Development

We developed an interactive application using Google Earth Engine that allows users to explore environmental data globally. This app features a selection panel where users can choose from eight different environmental parameters including evapotranspiration, leaf area index, photosynthetically active radiation, NDVI, land surface temperature, mean air temperature, and precipitation for the year 2019. After selecting a product from the dropdown menu, users can click any location on the world map to retrieve and display time-series data for that specific area throughout the entire year. Figure 9 illustrates this functionality, showing the dropdown menu for product selection and the subsequent chart visualization of the time-series data obtained from a selected geographic region.

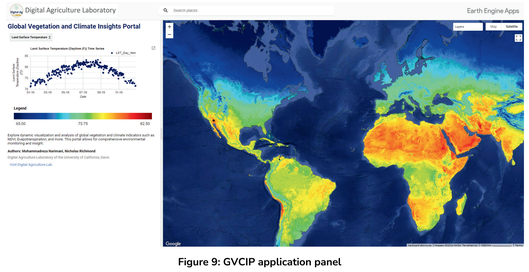

Figure 9: GVCIP application panel

Try our app

https://bit.ly/GVCIPESEARCH