Using Climate Engine for Cloud-Based Drought Monitoring

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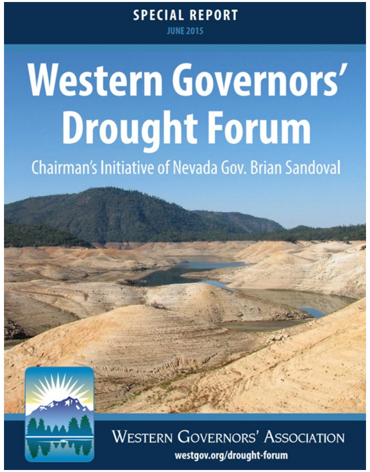
Drought.gov team: *Jimmy Baker, Justin Fain, John Frimmel, Kelsey Satalino, Michael Shaw*

Climate Engine Team (NOAA Western Regional Climate Center (WRCC) / Desert Research Institute (DRI)): *Justin Huntington (Lead), Britta Daudert, Jody Hansen, Katherine Hegewisch, Charles Morton, Thomas Ott*

Climate Engine Background

Collaboration with NIDIS

- 2015 Western Governors' Drought Summit (Las Vegas, NV)
- 2015 - Nevada Drought Forum
- 2015-2016 - Creation of NIDIS CA-NV Drought Early Warning System



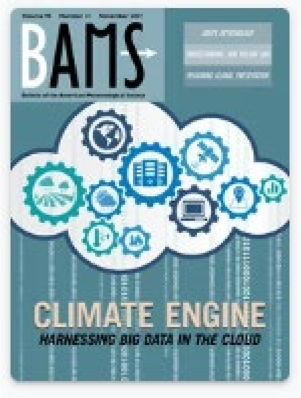
Common Themes Across DOI, USDA, and NIDIS Drought Early Warning System (DEWS) Stakeholders

- Consider both vegetative and hydrologic drought
- Develop and integrate new datasets and tools for place-based drought monitoring and forecasting

CA-NV DEWS Strategic Plan
"Develop and deliver new state-of-the-art cloud computing tools that provide user-friendly drought monitoring data to decision-makers"

Climate Engine.org

- Developed by Western Regional Climate Center (WRCC) / Desert Research Institute (DRI) from the White House Climate Data Initiative and a Google Faculty Research award, led by Justin Huntington.
- Based on Google Earth Engine (GEE), which facilitates cloud-based production of Drought and Climate products
- More than 50% funded by NIDIS



Print Publication:
Nov 2017

Climate Engine.org

How did we get here?

- 2014
  - WRCC/DRI initial release of App/User Interface for accessing, visualizing, subsetting and generating common climate and Earth observation products
- 2020
  - API released allowing automated access to all functionality and more…
  - ClimateEngine.com launched to better server private sector customers with larger support requirements and proprietary data
- 2021
  - Drought.gov team converts numerous foundational NOAA datasets into Cloud-Optimized GeoTIFF, updated daily, hosted on NOAA Open Data Dissemination (NODD) Google Cloud Storage, which are integrated into Climate Engine.
- 2023
  - ClimateEngine.org relaunched for non-commercial applications.
  - WestWide Drought Tracker update released, with data produced Climate Engine

How did we get here?

- 2008
  - Release of Drought.gov
  - Online clearinghouse for drought information and science linking out to partners
- 2018
  - Paradigm shift towards mix of GIS preprocessing (geojson, xyz tiles), integrated products and summary statistics, all guided by user feedback and usability efforts
- 2020
  - Major redesign of Drought.gov, with more interactive, usable and accessible tools. Full shift towards open GIS formats (geojson, xyz tiles) and use of NODD for open access to all.
- 2023
  - Climate Engine instance in a NOAA-managed Google Cloud project at OAR for **operational use on Drought.gov, allowing use-inspired**

Drought.gov is powered through partnerships:

NOAA's OAR-NESDIS-NWS, Climate Program Office (CPO), NCEI, CPC, NASA, USDA
Contractor Support: Riverside, iSciences. Universities: U of Nebraska - Lincoln, UNC-Asheville / NEMAC, NC State / CISESS, and many many more

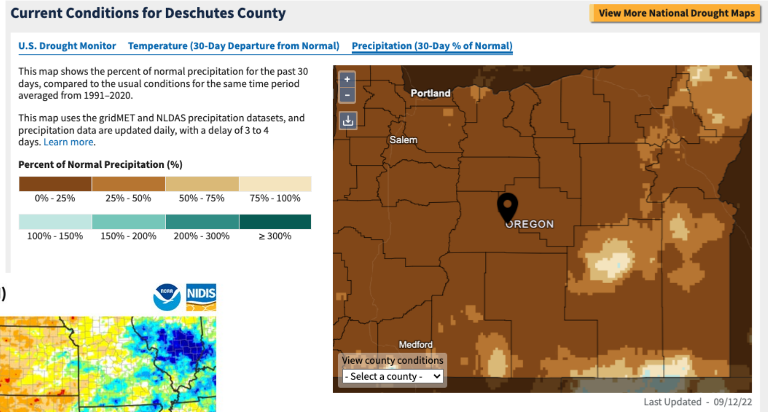
What problems does Climate Engine solve for Drought.gov?

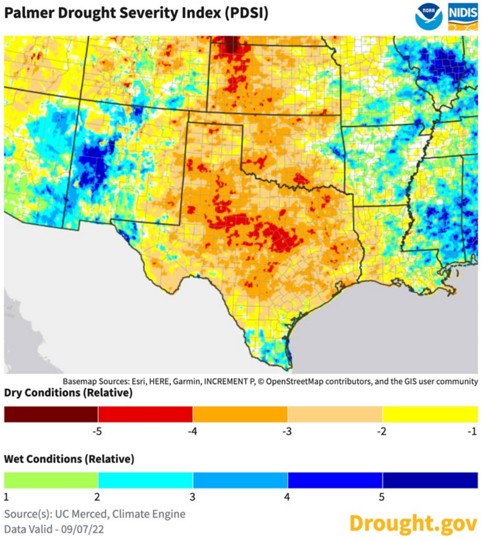
- Massive compute needed for high resolution daily gridded data
  - Not feasible with on-premises equipment and existing codebases.
  - Increase processing speed from hours to minutes
- Integration of data from numerous sources
  - Leverage data wrangling already done by WRCC or Google
- Easy adjustment and standardization of climate reference periods and indices
  - Reference climatology period matters!
- Leverage cloud-based data management in Earth Engine and NOAA Open Data Dissemination (NODD) Cloud Storage
  - Cloud ready formats in NODD benefits everyone!
- Bring the algorithms to the data
- Quickly create products to address user needs and improve communications and usability - ANSWERS NOT FILES

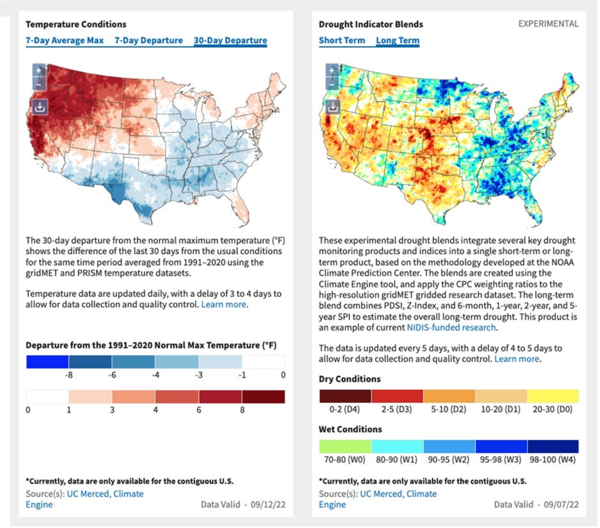
Climate Engine: Powering Data Visualization on Drought.gov

Drought.gov leverages Climate Engine to process large high-resolution gridded datasets with substantially lower costs and effort, and increased standardization for an ‘apples to apples’ comparison.

Includes precipitation, temperature, sub-monthly PDSI, and drought indicator blends, SPI, SPEI, EDDI.







Climate Engine on Drought.gov: Infrastructure

Drought.gov
400 product generation requests nightly to produce and export Cloud-Optimized GeoTIFFs

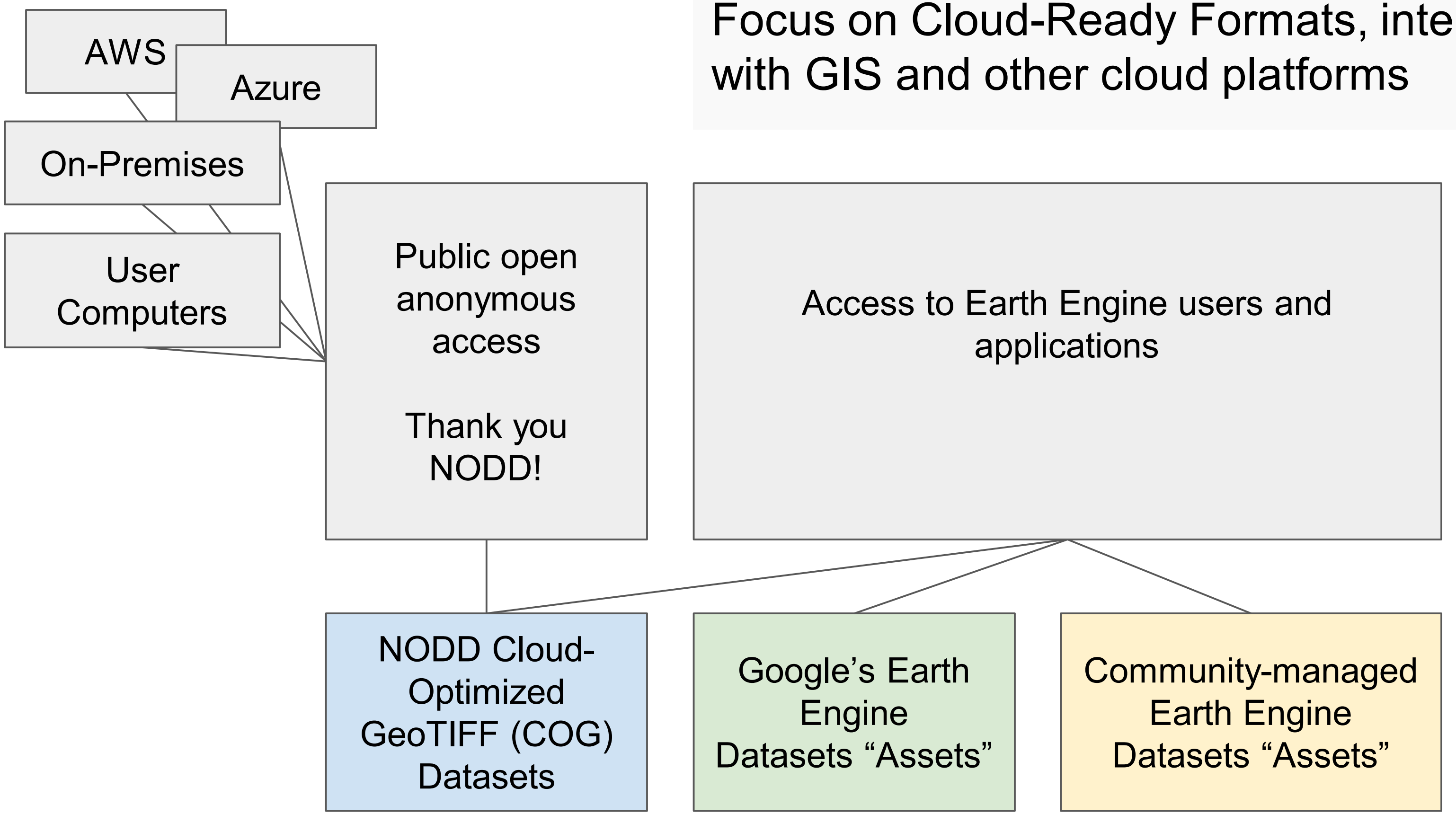
Climate Engine API
Docker containerized web application running in Google's Cloud Build/ Cloud Run

Earth Engine (NOAA fixed price contract)
Python 'Earth Engine' scripts for common climate operations and metrics (SPI/SPEI/PET/EDDI)
Publicly available pricing for operations at $2000/mo +

NODD Cloud-Optimized GeoTIFF (COG) Datasets	Google's Earth Engine Datasets "Assets"	Community-managed Earth Engine Datasets "Assets"

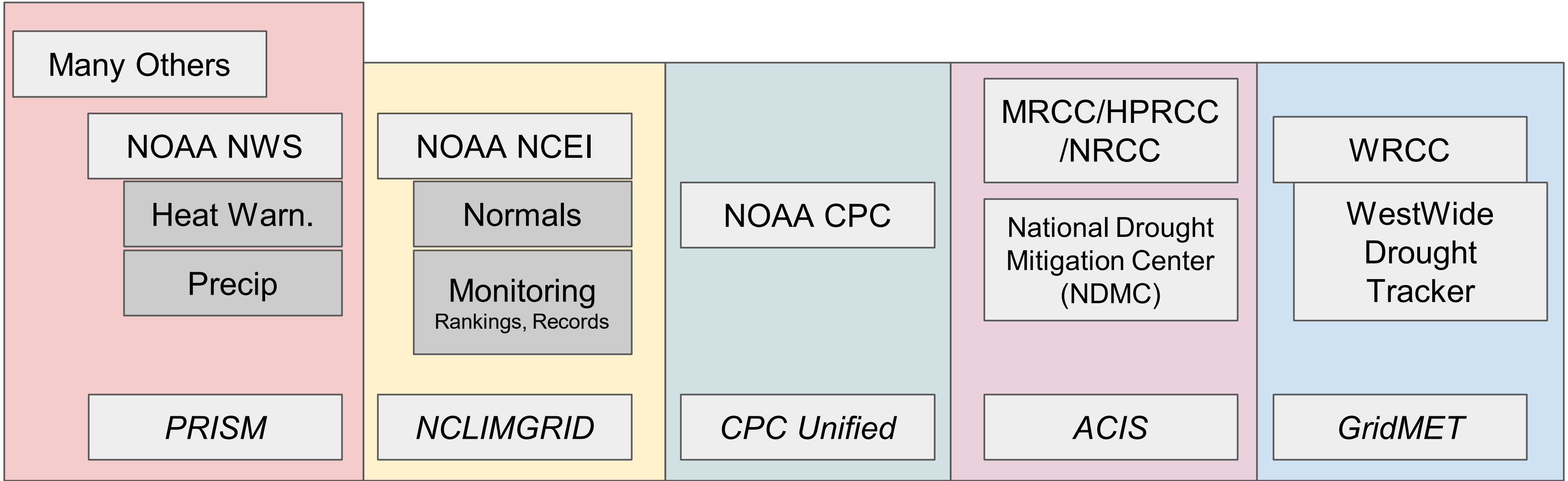
Climate Engine on Drought.gov: Input Data

Focus on Cloud-Ready Formats, interoperability with GIS and other cloud platforms



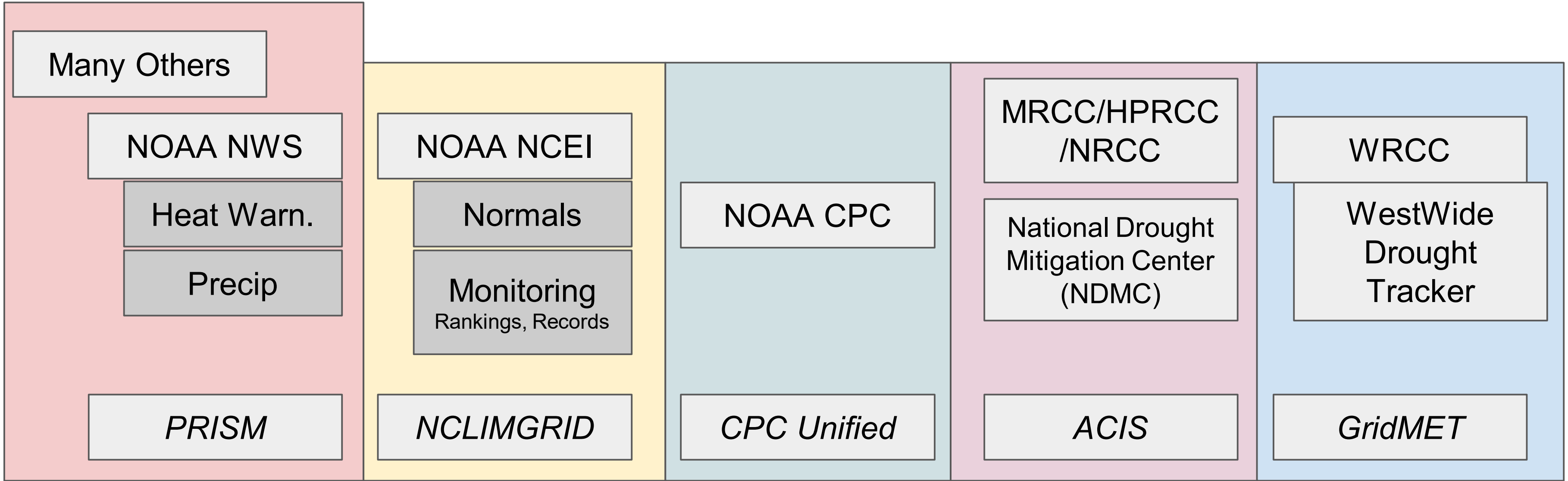
Climate Engine on Drought.gov

- Standardized Database of Drought Indicators and Indices
  - Multiple partners using different pipes of data based on different foundational datasets, with different algorithm methods (SPI/SPEI/EDDI/PET), different climatology periods



Climate Engine on Drought.gov

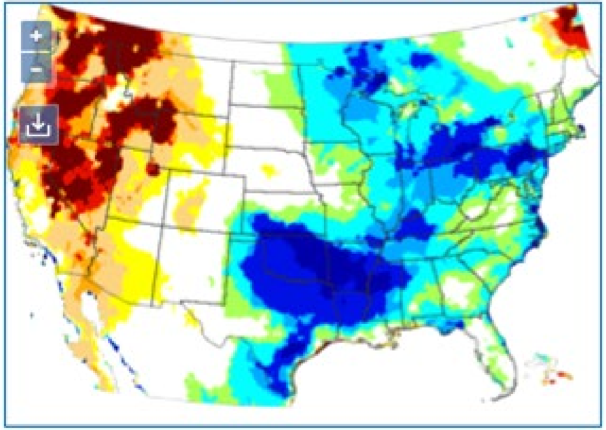
- Standardized Database of Drought Indicators and Indices
  - New capability to generate daily indices and climatological from ALL foundational datasets using the same algorithm methods (SPI/SPEI/EDDI) and climatology periods.
  - Examine differences by day at a point or annual averages across the grids



EDDI products from gridded temperature datasets, generated from Climate Engine using a 1991-2020 reference period and a nonparametric distribution type

1-Week

NLDAS2(Har.) NLDAS2(P-M)
GRIDMET(Har.) GRIDMET(P-M) ERA5
NCLIMGRID ACIS PRISM CPC



Legend

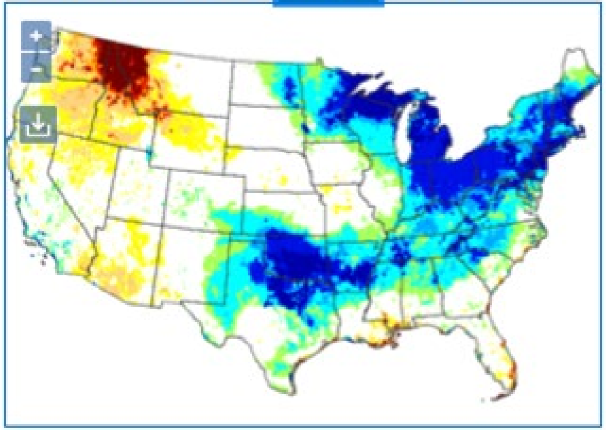
Drought Conditions

ED4 ED3 ED2 ED1 ED0

Wet Conditions

2-Week

NLDAS2(Har.) NLDAS2(P-M)
GRIDMET(Har.) GRIDMET(P-M) ERA5
NCLIMGRID ACIS PRISM CPC



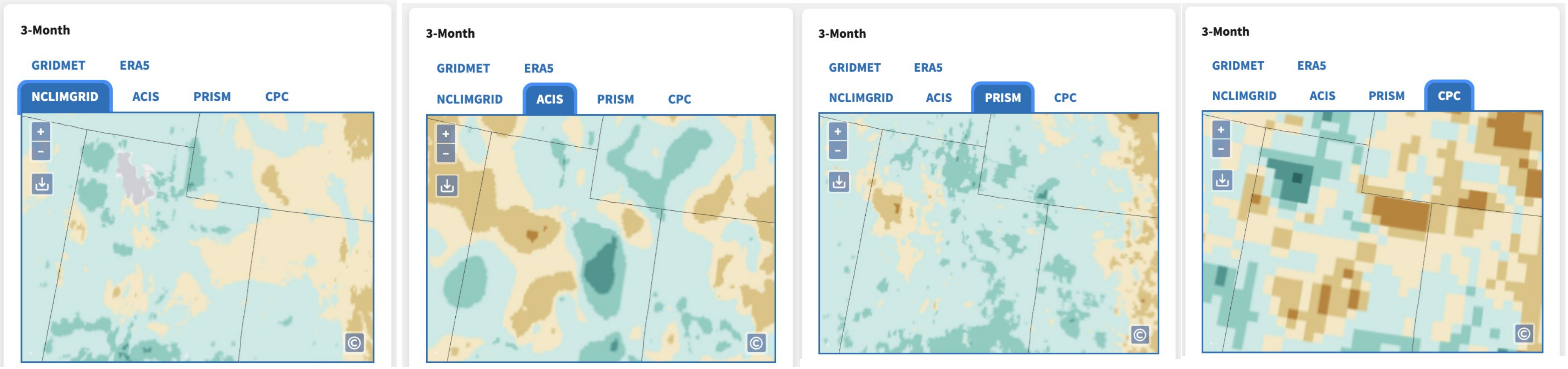
Legend

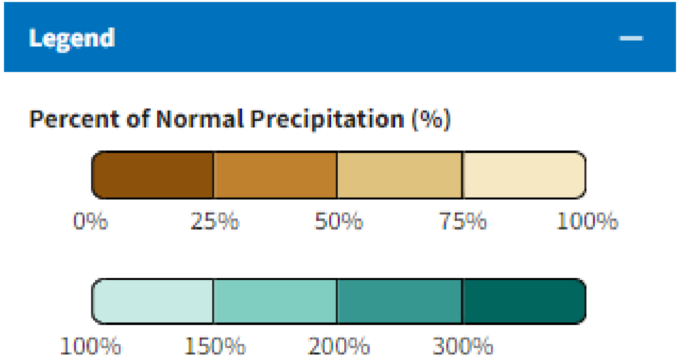
Drought Conditions

ED4 ED3 ED2 ED1 ED0

Wet Conditions

3 month percent of normal precipitation:





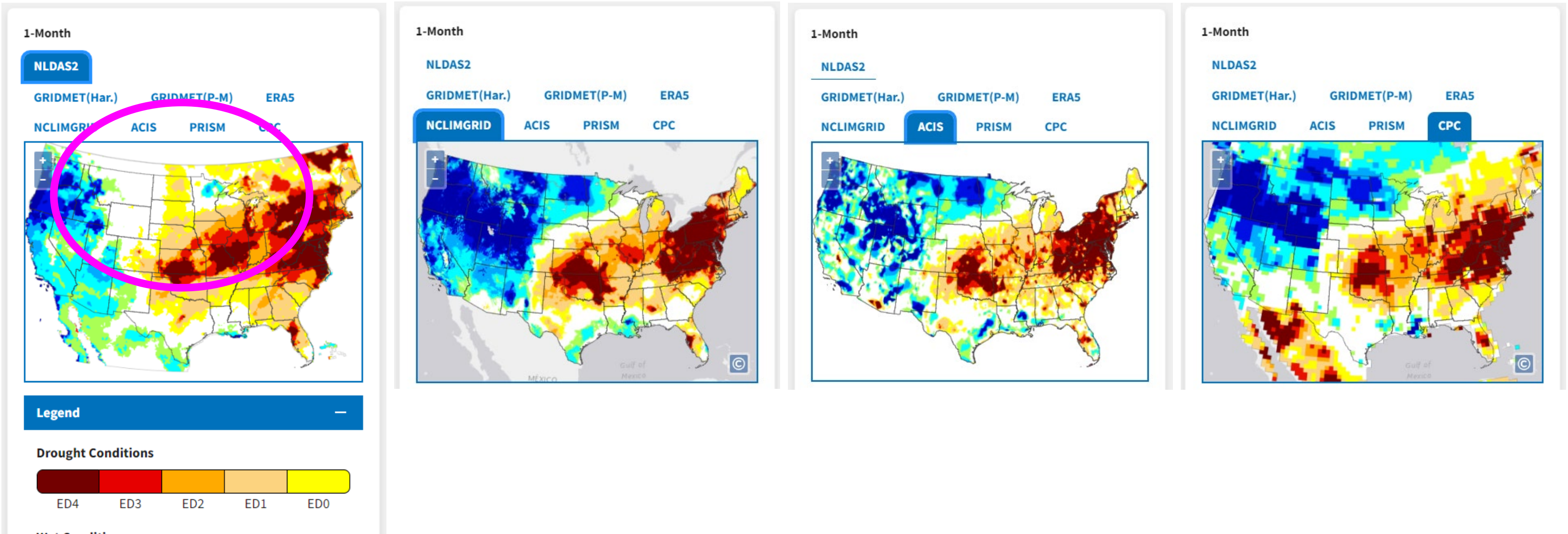
GeoTIFF Download:

Dataset	Precipitation	Percent of Normal Precip.	Temperature Departure from Normal	SPI	SPEI	EDDI	Coverage and Resolution	Latency
nClimGrid-Daily	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	ConUS 4km	4-6 days
ACIS "Grid 1"	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	ConUS 4km	3-5 days
CPC Daily ConUS Precip.	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	Not Available	ConUS 25km	3-5 days
PRISM	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	ConUS 4km	3-5 days
GridMET	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	ConUS 4km	3-5 days
ERA5 (ConUS Subset)	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	ConUS 30km	7-10 days
CPC Daily Unified	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	Global 0.5 deg	4-6 days
ERA5 (Global)	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	1-Week, 2W, 1-Month, 2M, 3M, 6M, 9M, 12M	Global 50km	7-10 days
CMORPH	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	Not Available	Global 8km	2-4 days
GPM IMERG	1-Month, 2M, 3M, 6M, 9M, 12M	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	1-Month, 2M, 3M, 6M, 9M, 12M	Not Available	Not Available	Global 10km	2-4 days

400+ daily indices and indicators derived from foundational datasets, processed each night in under an hour

Climate Engine on Drought.gov

- Key Benefits
  - Short term:
    - Standardized set of foundational dataset and derived drought indices from identical algorithms, and climatology periods, publicly available in Cloud-ready GIS format (COG) on NOAA NODD.



Climate Engine on Drought.gov

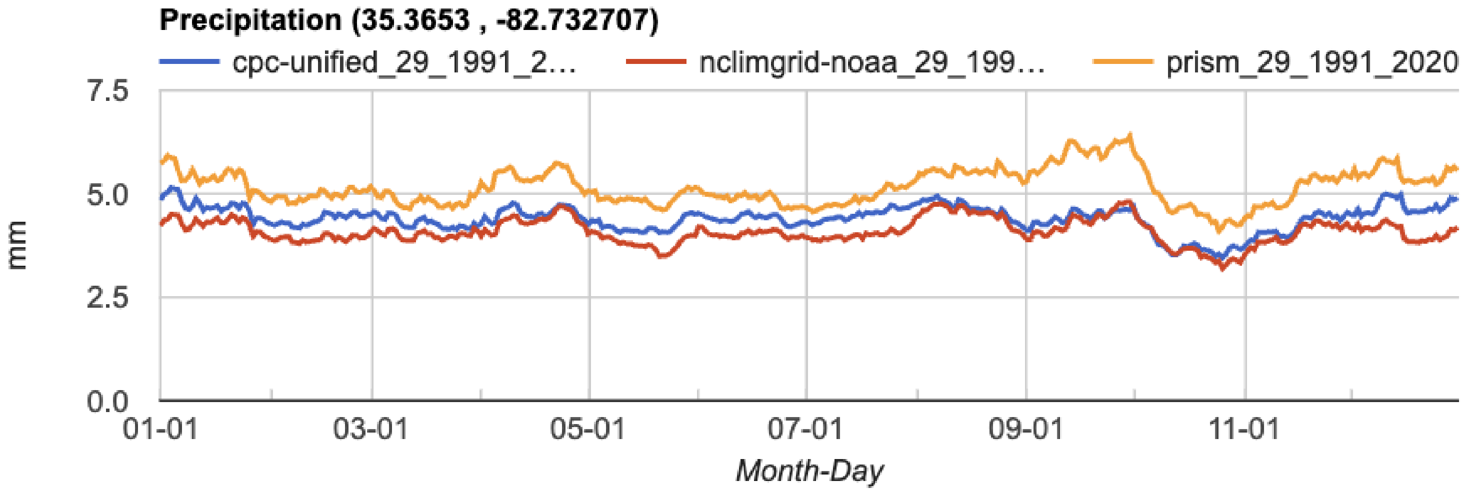
- Key Benefits
  - Medium term (months):
    - Basis for future exploration of product differences and tool development
    - Basis for future multi-indicator drought indices (a.k.a. blends), based on R-to-O of machine learning project at NASA
    - Improved communication of uncertainties and confidence
    - Add new algorithms/metrics ideas:
      - SESR [?] for Flash Drought
      - Heating/Cooling Degree Days
      - More work with thresholds, counts and probabilities
    - New datasets
      - NWS models
      - NESDIS satellite products

Climate Engine on Drought.gov

- Key Benefits
  - Longer term (6 months+):
    - Inclusion of more NOAA data in pool (data lake) of cloud-ready data on NODD and in the Earth Engine catalog.
    - Incorporate more forecasts and projections. What would help your climate monitoring work?
    - Composite datasets that span historical, near-real-time and forecast timescales, accounting for bias and resolution differences (nClimGrid + MRMS + HRRR), allowing future and real-time events to be put into a climate context.
    - Integration of socioeconomic impact products
    - Use of the cloud and standardized database for NIDIS funded research to save time, effort and cost of per-project data management.
    - Easier R-to-O of NIDIS funded research using platforms such as ArcGIS Online, Climate Engine, Earth Engine, Docker-based containerization

Climatology Comparison Tool

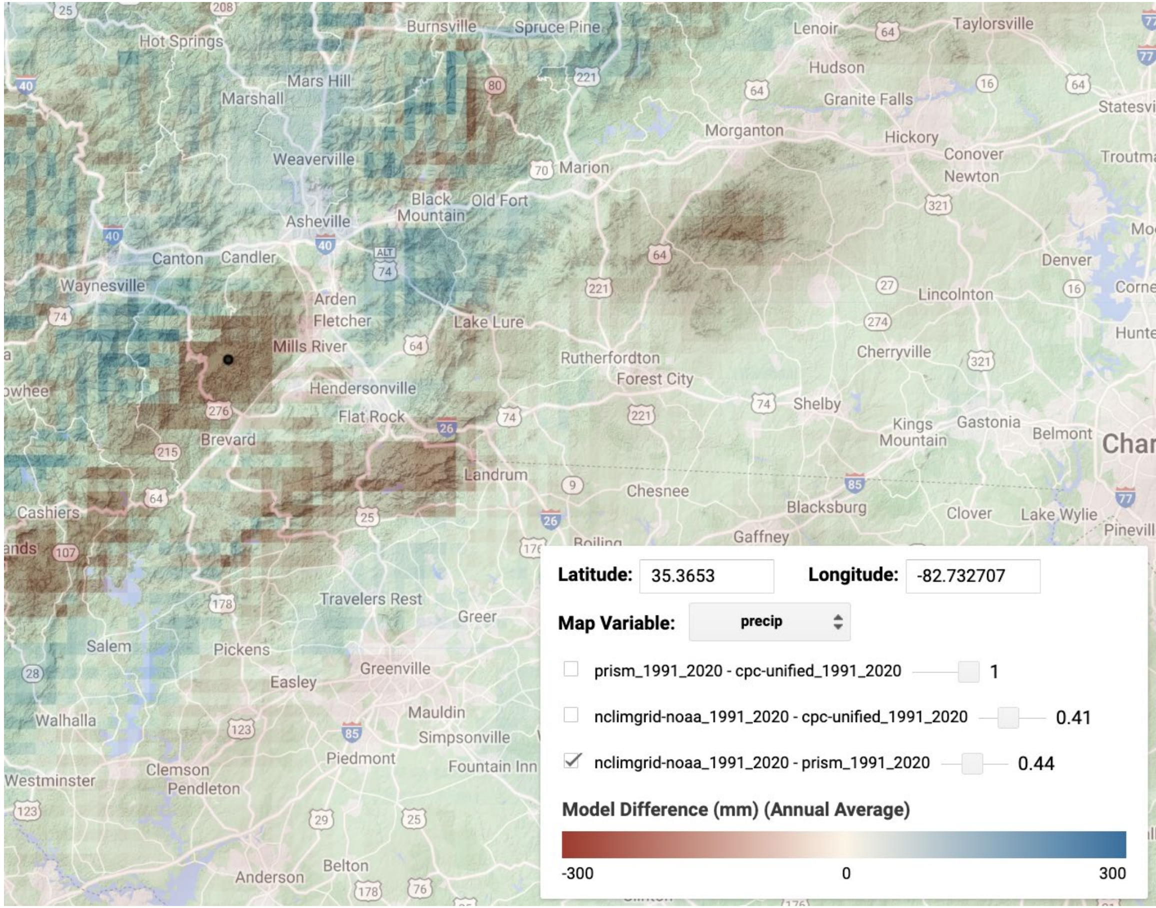
- Prototype developed by Climate Engine team
- Based on cloud-ready foundational datasets in Earth Engine
- Built using ‘Earth Engine Apps’
- Adjust dataset, window, climatology period
- Example of targeted tool built on large database



Climatology Comparison Tool

- Features
  - Datasets
    - nClimGrid
    - PRISM
    - CPC Unified
    - GridMET
    - DayMet (ORNL)

"Within 60 seconds of being introduced to the tool I had saved a png of a climatology comparison of 1971-2000, 1981-2010, and 1991-2020 that would have taken me over a day to do on my own (including processing time)."



Conclusions

- Why does this matter?
  - A tool for rapid user-focused product development from all foundational climate datasets, towards answers, not files

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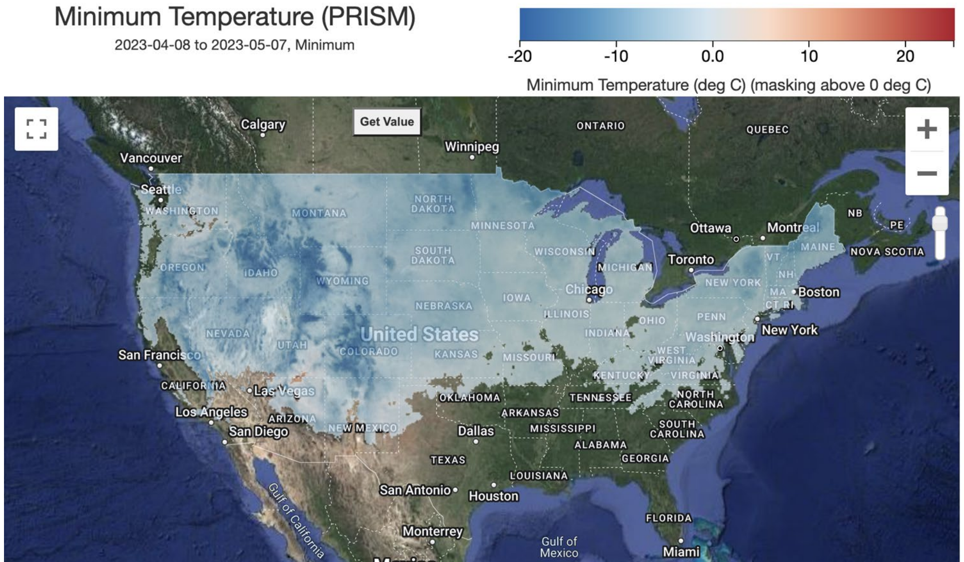
    - Where min temp is below freezing over last 30 days



Conclusions

- Why does this matter?
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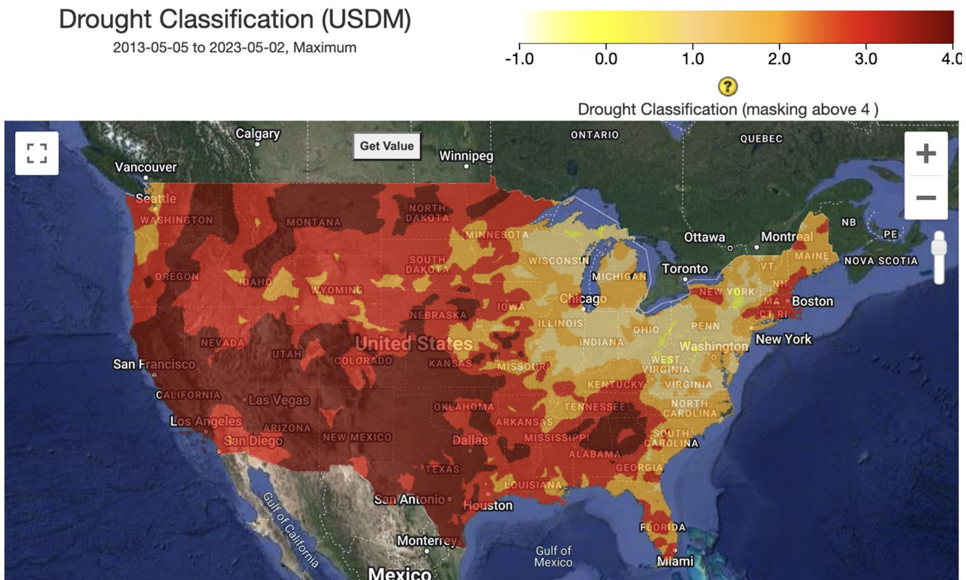
    - Most severe drought category over last 10 years



Conclusions

- Why does this matter?
  - A tool for rapid user-focused product development from all foundational climate datasets, towards answers, not files
    - Where min temp is below freezing over last 30 days
    - Most severe drought category over last 10 years
  - Standardize indicators and indices used for climate monitoring, and embrace and explore differences
  - Low cost, scalable, faster R-to-O and R-to-Action platform

Thank You!

Steve.Ansari@noaa.gov

https://www.drought.gov

https://www.climateengine.org

Prototype Climatology Tool:
https://dri-apps.earthengine.app/view/climatology-comparison-explorer

FAQs

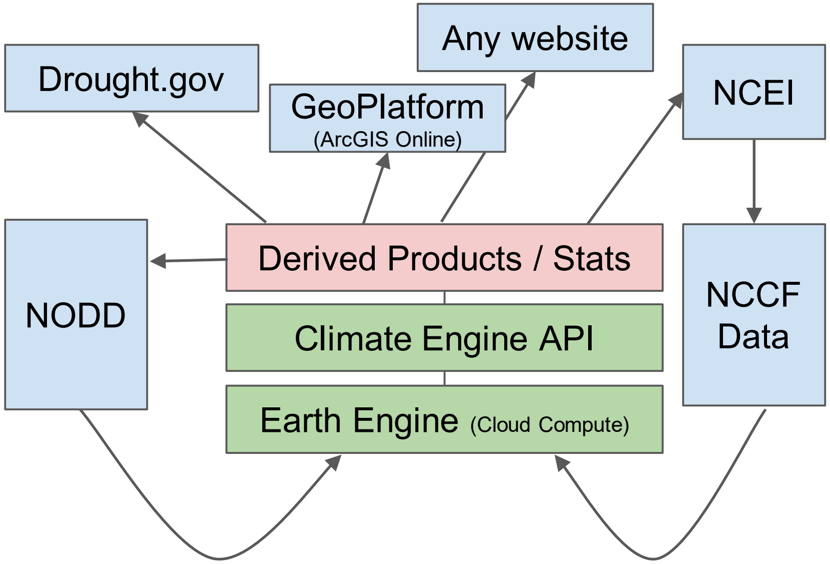
- **Where does Climate Engine fit in the architecture of NOAA?**
  - Cloud-based API to perform data analysis, climatological comparison, subsetting, and visualization optimized for large-scale gridded data. Use cases are similar to current NOAA-used middleware (THREDDS, Live-Access Server, ERDDAP), NASA Giovanni, Python notebooks and ArcGIS Online).

FAQs

- **What is the difference between Climate Engine and the NOAA GeoPlatform (ArcGIS Online)?**
  - Earth Engine and ArcGIS Online are both cloud "Software as a Service (SaaS)" options. Climate Engine is an analysis/subsetting/extraction tool built on Earth Engine (EE), taking advantage of EE's powerful raster processing capabilities. ArcGIS Online is optimized for 'vector' GIS data (point/line/polygon) and content development such as StoryMaps. The results of Climate Engine may be integrated in ArcGIS-Online in multiple ways and the tools complement each other.

FAQs

- **NESDIS Common Cloud Framework (NCCF) is moving everything to Amazon Cloud. How does that relate?**
  - Climate Engine builds on existing open data in cloud-ready formats produced by NCCF. These data may be imported directly in Earth Engine and Climate Engine.
  - Drought.gov is focused on interoperability between NCCF, ArcGIS Online and the NOAA Open Data Dissemination (NODD) program.



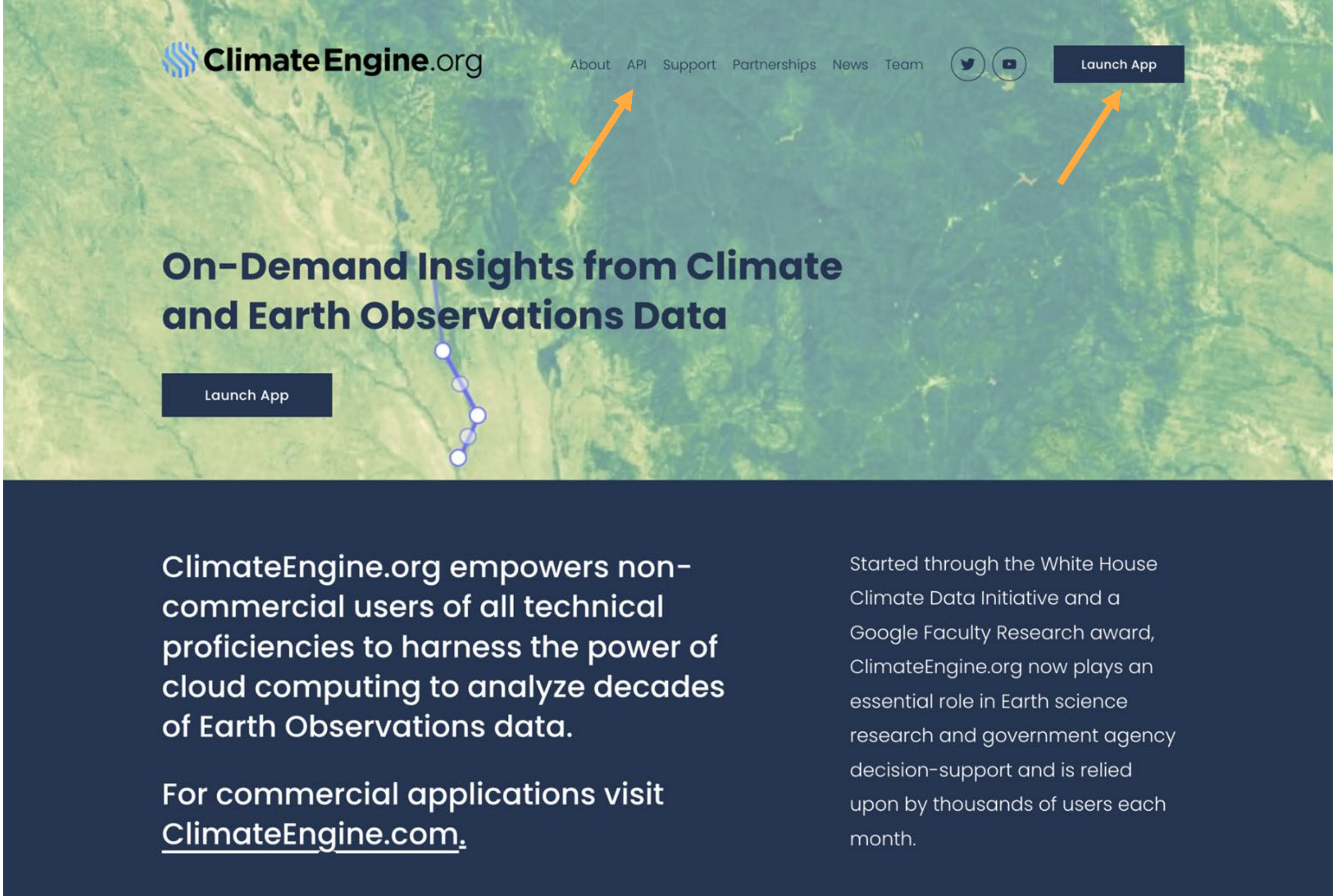
Why Google Earth Engine (GEE) ?

- Purpose is to flip the paradigm of 90% data management, 10% science
- Massive parallel processing of gridded data
- Large pool of Federal data, growing weekly: NOAA (57), NASA (137), USGS (157), DOI (15), ESA (33), ECMWF (7)
- Datasets within GEE are interoperable for intercomparison, GEE handles reprojections
- Complements 'BigQuery' cloud database solution for spreadsheet/tabular/point/line/polygon data
- Proven fast product creation from NASA DEVELOP internship program
- Proven operational gov't use at USGS for next generation of land cover products
- Proven AI/ML ready environment: example for global landcover classification: NASA / Journal Article
- Free for research, contract vehicle with SAIC and NOAA for operations
- Climate Engine uses script templates for common climate analysis and wraps it in a User Interface and REST API

New NOAA Datasets in NODD and Climate Engine

Addition of new foundational NOAA gridded datasets, by Drought.gov team, in Cloud-Optimized GeoTIFF (COG) format configured in Climate Engine and available for use in Earth Engine.

1. NOAA NCEI nClimGrid-Daily (?)
   (ConUS, Temp/Precip, 5 km, latency 3-4 days, 1951-present, SPI/SPEI/EDDI enabled)
2. NOAA NCEI nClimGrid-Monthly (?)
   (ConUS, Temp/Precip, 5 km, latency 5 days after end of month, 1895-present, SPI/SPEI/EDDI enabled)
3. NOAA NRCC ACIS Gridded Temp/Precip (?)
   (ConUS, Temp/Precip, 5 km, latency 3 days, 1950-present, SPI/SPEI/EDDI enabled)
4. NOAA CPC Global Daily Unified Temp/Precip (?)
   (Global, Temp/Precip, 0.5 deg / ~50 km, latency 3 days, 1948-present, SPI/SPEI/EDDI enabled)
5. NOAA CPC ConUS Daily Unified Precipitation (?)
   (ConUS, Precip, 0.25 deg ~25 km, latency 3 days, 1979-present, SPI enabled)
6. NOAA CPC CMORPH Satellite Precipitation (?)
   (Global, Precip, 8 km, latency 3 days, 1979-present, SPI enabled)


ClimateEngine.org
About
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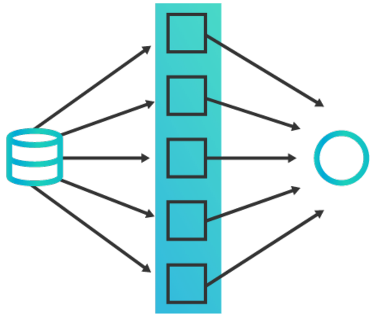
Support
Partnerships
News
Team
Launch App
On-Demand Insights from Climate and Earth Observations Data
Launch App
ClimateEngine.org empowers non-commercial users of all technical proficiencies to harness the power of cloud computing to analyze decades of Earth Observations data.
For commercial applications visit ClimateEngine.com.
Started through the White House Climate Data Initiative and a Google Faculty Research award, ClimateEngine.org now plays an essential role in Earth science research and government agency decision-support and is relied upon by thousands of users each month.

Why Climate Engine?



- It's **FAST**.
  - "No Code" solution for common climate questions
  - Efficient parallel processing of large stacks of historical data. "Hours to minutes" speed improvement
  - Brings cloud processing to the data, leading to efficiencies in productivity
- It's **ACCESSIBLE**.
  - API for easy automated access
  - Supports Cloud-Optimized GeoTIFF (COG) format and legacy Earth Engine imported data.
  - Access to ~1000 Google-managed datasets
    + NOAA NODD datasets
    + NIDIS managed data on Google Cloud Storage
- It's **INTEROPERABLE**.
  - Through Free Egress Data Transfer in NODD and NESDIS Amazon contracts, there is interoperability between AWS and Google services

ClimateEngine.com: Private Sector Applications

BMO

Climate Engine provides science expertise and geospatial infrastructure through Google Cloud to allow BMO to track and monitor asset risks in their REIT portfolios and branches.

CN

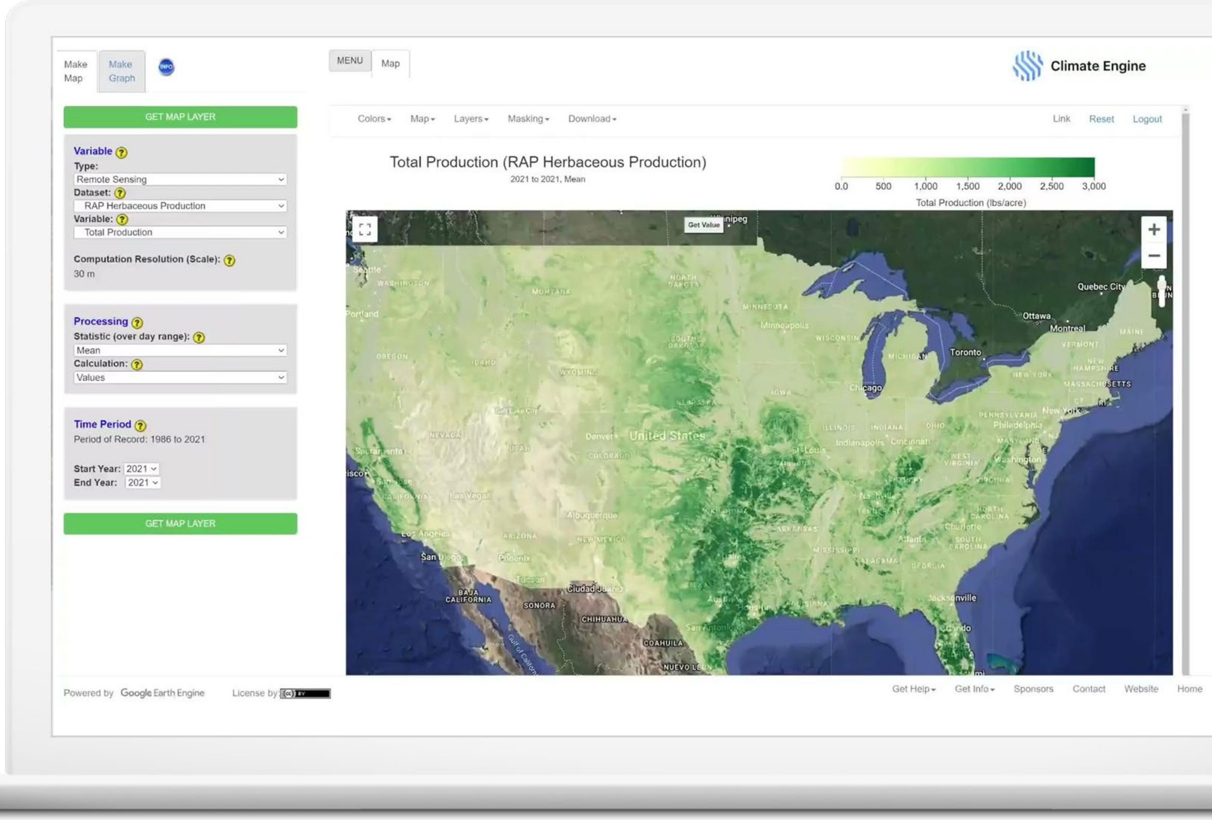
Climate Engine provides historical wildfire risk and wildfire forecast insights for CN Railway assets across North America.

SC Johnson

Climate Engine provides mosquito weather forecasting into SC Johnson's inventory data systems to help them better predict demand and track potential inventory shortages.

Bureau of Land Management: Research to Decisions

- Rangeland vegetation and climate monitoring
- Supporting decisions related to grazing permit renewals
- Assessing trends in vegetation
- Assessing target areas for riparian restoration, and success (or failure) of riparian restoration projects



Navajo Nation Applications

"Using Climate Engine's Drought Severity Evaluation Tool (DSET) allows the science to influence the natural-resource management decision-making process. The user-centric design focuses on the ability to conduct analyses and generate visualizations, such as customizable maps and time series, that can be directly imported into drought reports"

"The contribution of Navajo ground-based data has created a unique opportunity to take global data and tailor it to produce meaningful data analyses that can be used for drought reporting."

- Nikki Tulley, Navajo Nation, NASA, U of AZ PhD Student, Ladies of Landsat

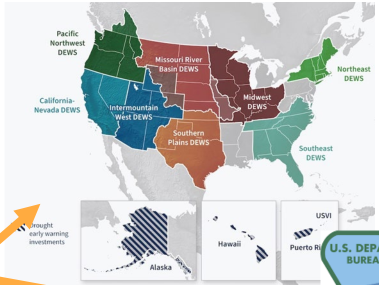
DRI, NASA, NIDIS, Navajo Training

Nikki Tulley & Interior Sec. Deb Haaland

Source: USGS

https://wwao.jpl.nasa.gov/water-portfolio/water-projects/nasa-navajo-drought-severity-tool-user-guide/
https://www.youtube.com/watch?v=CAdx_gtbxvI&ab_channel=USGS

Current and Potential Training for Adoption and Supporting Better Decision Making

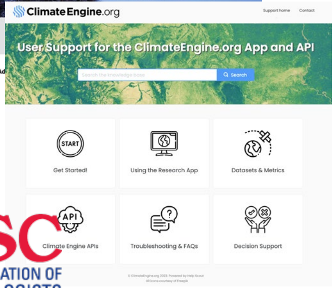


Climate Engine App for Research Purposes (govt, edu)

Climate Engine API for Operational or Research

NIDIS Drought Monitoring Use Case for NOAA (current setup)

WRCC/DRI for Research/Education Purposes



Google Earth Engine for NOAA R2O Purposes

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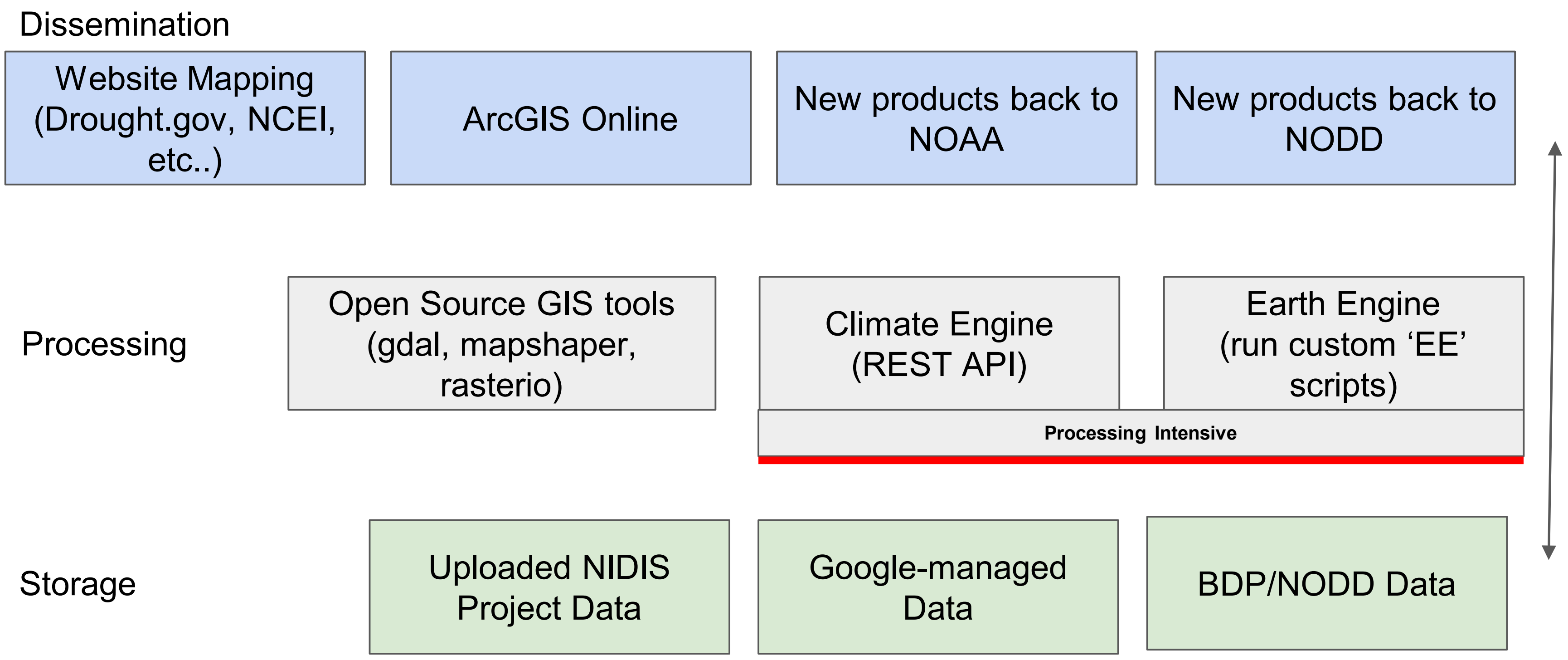
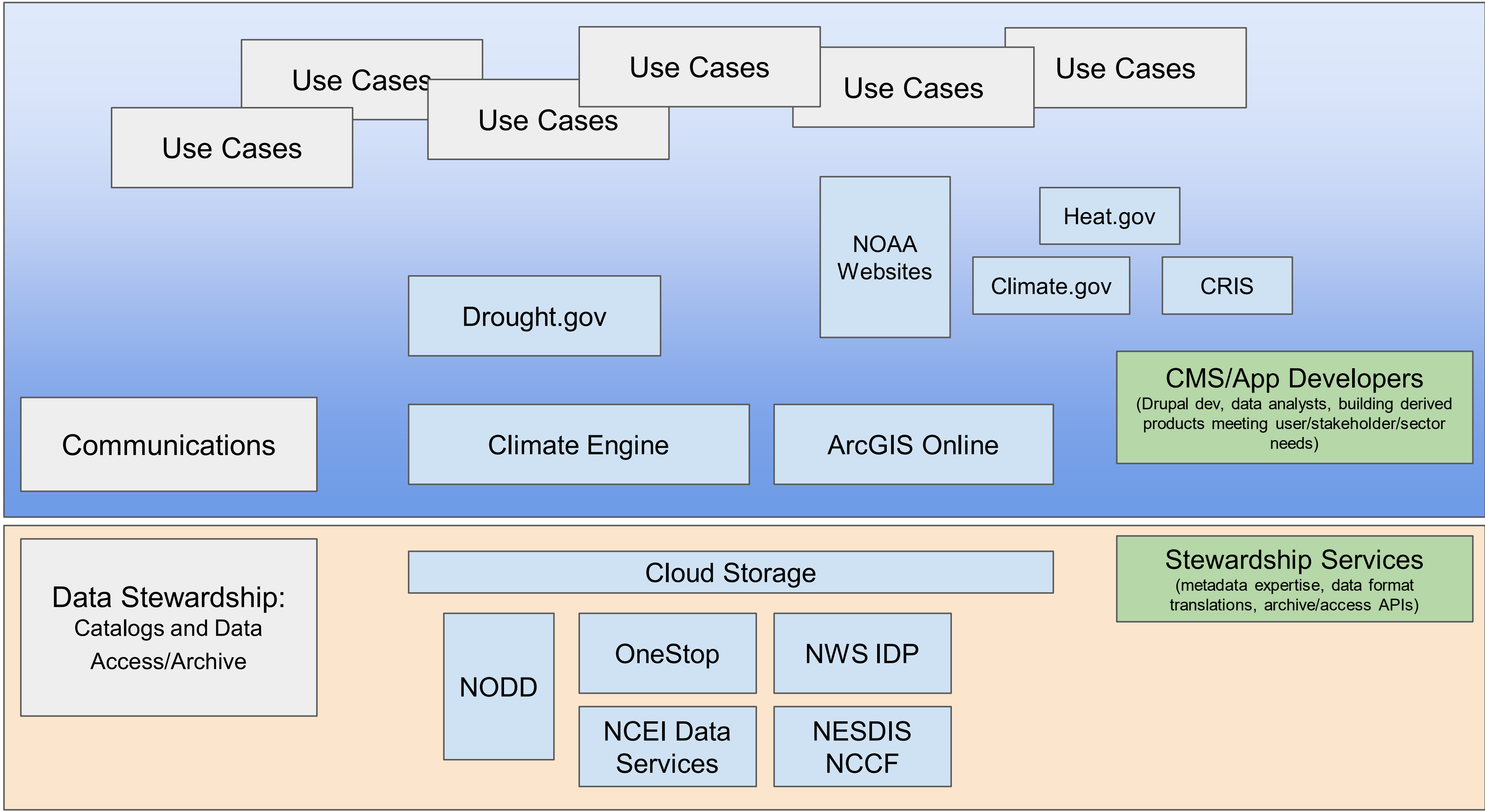
FAQs

- **What are the Drought.gov benefits?**
  - Standardizing products for users, which is important in a changing climate. (input data, algorithm type, climatology period)
  - Create an unprecedented number of drought indices, not computationally feasible on premises and complex to manage in the cloud outside of Climate Engine.
    NCEI: 2 daily indices. Climate Engine: 36 daily indices
  - R-to-O from a NOAA Regional Climate Center (RCC), pilot for other Earth Engine based efforts in a NOAA Cloud environment.
  - Creation of indices used for next generation of multi-indicator indices (blends), implementing NASA’s machine learning based indicator research.

Climate Engine in the Drought.gov architecture





Use Cases
Use Cases
Use Cases
Use Cases
Use Cases
Use Cases
NOAA Websites
Heat.gov
Drought.gov
Climate.gov
CRIS
CMS/App Developers
(Drupal dev, data analysts, building derived products meeting user/stakeholder/sector needs)
Communications
Climate Engine
ArcGIS Online
Data Stewardship:
Catalogs and Data Access/Archive
Cloud Storage
Stewardship Services
(metadata expertise, data format translations, archive/access APIs)
NODD
OneStop
NWS IDP
NCEI Data Services
NESDIS NCCF

Why NIDIS?

- Foundation of Continuous Engagement
- Trusted Relationships
- Connects Lessons about Use of Information with User Needs
- Reviews and Considers NOAA’s capacity to respond
- Review and Prioritize Product and Service Development
- Respond to User Needs and Deliver Products to Users
- Evaluates Impact