OPENET

FILLING THE BIGGEST DATA GAP IN WATER MANAGEMENT

Frequently Asked Questions for Rosedale-Rio Bravo Water Accounting Platform

This FAQ may be revised as the OpenET project develops. Please anticipate changes as we work toward a launch in 2021.

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Overview

What is OpenET?

OpenET is a collaborative effort to develop an operational system for mapping evapotranspiration (ET) at the scale of individual fields. The OpenET team is building a new web-based platform with data visualization and access tools to fill a critical data gap in water management across the western U.S. OpenET leverages publicly available information to provide accurate and trusted satellite-based data on ET and consumptive water use at a low cost to farmers and water managers.

What does the ET in OpenET stand for?

ET, short for evapotranspiration, is the process by which water is transferred from the land to the atmosphere. It includes both evaporation from soil and transpiration from plant leaves. ET is a core driver of the Earth's water cycle, returning water to the atmosphere to fall again as precipitation.

For irrigated agriculture, ET is a measure of the water used to grow food and is the biggest share of water use in most arid environments around the world. In most agricultural regions, ET is also an accurate measure of consumptive use of water by agriculture.

What is consumptive water use?

Consumptive water use is water that is removed from available supplies as a result of its use. It does not return back to the local system.

Why is OpenET being developed?

Sustainable water management is one of the most challenging issues of our time, especially in the arid western U.S. Maximizing the benefits of water supplies requires careful measurement of availability and use. However, one critical information gap is compounding this challenge: the lack of accurate, trusted consumptive water use data for irrigated agriculture, which accounts for the majority of water use in the western U.S. To date, access to this data has been limited and expensive, keeping it out of the hands of most water users and decision-makers. OpenET aims to change this and support sustainable water management and innovation in water conservation.

Who is developing OpenET?

The project is being led by NASA, the Desert Research Institute (DRI), and Environmental Defense Fund (EDF), with in-kind support from Google Earth Engine. The technical team brings expertise in satellite-based estimation of ET, cloud computing, and user-driven website design. It includes approximately 30 researchers and practitioners from NASA, DRI, U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), University of Nebraska, University of Idaho, University of Wisconsin, University of Maryland, California State University Monterey Bay, University of Montana, Google Earth Engine, and web development firm HabitatSeven.
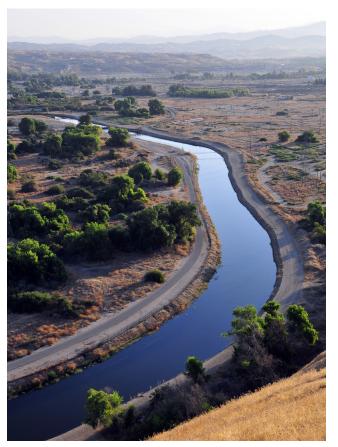
Who are the OpenET partners and early adopters?

The project has been user-driven from the start to ensure it best serves the needs of a broad range of water users and decision-makers. Since its inception, OpenET has been dedicated to demonstrating value in providing benefits to agriculture and supporting sustainable land and water management practices. The OpenET community includes partnerships with more than 45 stakeholder entities and organizations. This includes growers and agricultural groups making irrigation scheduling and other decisions at the field scale, water district managers building water accounting and trading platforms, and state and federal agencies making drought and water budget assessments at large

scales. The insights learned through these partnerships are integral to the success of OpenET, including defining user requirements, providing feedback on the website design, and testing the beta versions of the user interface.

What is the role of Google Earth Engine?
The models used in OpenET ingest hundreds of terabytes of satellite and meteorological data, which is computationally expensive. Google Earth Engine provides a common computing platform where all of the satellite-based ET models used in OpenET can be implemented and run using consistent inputs. This allows the scientific community to collaborate on software development and produce the most accurate and consistent ET data possible. In addition, Google Earth Engine allows the OpenET team to store, rapidly compare, and analyze results from the ET models, enabling expedited progress on evaluation of model results and identification of opportunities to improve the ET estimates from both individual models and the full ensemble of models. OpenET uses Google Earth Engine to efficiently produce daily and monthly ET images across the western U.S. and to calculate data summaries for millions of agricultural fields or other regions of interest. This data is then exported to the OpenET web-based platform for data visualization and distribution. The Google Earth Engine team is supporting implementation of the ET models and providing the cloud computing resources as an in-kind contribution to the effort.

Geographic and Temporal Scale

What geography is covered by OpenET?
OpenET will cover 17 western U.S. states: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. Over time, the intent is to expand OpenET to also include coverage of other arid regions in the U.S. and across the globe.

At what spatial scale will the data be available?
OpenET is produced at a spatial resolution of 30m x 30m (0.22 acres). OpenET data can also be aggregated for individual fields or other locations of interest by calculating the average data value for the field at each timestep. For the Rosedale-Rio Bravo Water Accounting Platform, the data will be available at the parcel level. Rosedale-Rio Bravo Water Storage District provided the OpenET team with yearly APN boundary shapefiles.

At what time intervals will you be able to provide data (daily, monthly, yearly)?
OpenET will provide data at daily, monthly, and yearly timesteps. Since production and storage of daily datasets can be expensive, it is likely that daily data will only be available for irrigated agricultural regions for recent time periods. For the Rosedale-Rio Bravo Water Accounting Platform, the data will be available at monthly timesteps.

What is the expected data latency?
Our goal is to provide monthly ET data across the western U.S. with a data latency of six weeks or less. For daily data, we recognize the importance of providing data within two days of satellite overpass for irrigation management applications, and we are working hard to come as close as possible to achieving this target for daily data products.

Applications of the Data

How can OpenET data be used?
Reliable and widely available ET data at the field scale can be used to:
- Expand ET-based irrigation practices that maximize "crop per drop" and reduce costs for fertilizer and water.
- Develop more accurate water budgets and innovative management programs that ensure adequate supplies of water for agriculture, people and ecosystems.
- Support water trading programs that protect the financial viability of farms during droughts, while ensuring that water is also available for other beneficial uses.

OpenET is *not* intended to be a new irrigation scheduling tool. Our goal is to provide transparent, credible, and easily accessible ET data only. OpenET does not take the next steps of integrating that data with soil moisture, nutrient

content, and other information critical for making decisions or recommendations about when to turn an irrigation system on or off. However, OpenET *will* make the ET estimates used by such tools much more cost-effective to retrieve, and in many cases more accurate.

Why can't farmers just use meters to track their water use?
OpenET is not intended to replace meters where they are desired or preferred. However, there are two reasons that OpenET may be a complementary and/or alternative source of information:

1. Meters are expensive, both to purchase and to maintain, and do not necessarily lead to more accurate estimates of water use. OpenET can provide a cost-effective alternative to meters for tracking *changes in water use over time* at a geographic scale that is not possible with solely on-the-ground approaches to measurement. In addition, OpenET can provide historic data as far back as 1984, which can be valuable in locations where meters have only been installed recently.

2. Meters measure the volume of water pumped or diverted, but they do not necessarily measure the amount of water actually lost to the local system. Some water that is pumped or diverted may re-enter the local water supply as runoff or groundwater recharge. Water managers and growers will often need both sources of data – applied water as measured by meters and estimates of ET – to best understand their water budgets over time.

Ensemble of Models

Why are you using multiple models to measure ET, rather than narrowing down to the "best" model?
OpenET will provide data from multiple models that are used to calculate ET and also provide a single ET value, or "ensemble value," from those models for each location. The models that will be included are listed in the table at right. Each model has its own strengths and limitations for different geographies, crops, and conditions.

Some models were developed for global monitoring applications and others focus on local-scale irrigation management. Several models leverage gridded meteorological reference ET data for time integration between Landsat satellite overpass dates, and other models utilize coarser resolution data from geostationary satellites.

Currently, a key challenge for practitioners in working with ET data is that there are multiple methods and sources of information, leading to confusion about the "correct" number. By working with an ensemble of ET models, the OpenET team can identify consistent biases within different models and work to explain and resolve those differences.

We will include many models in an intercomparison study to determine which provide the highest accuracy for different crops, land cover types, regions, or seasons. We will use the results from the intercomparison study to calculate a single value from the ensemble of models, taking advantage of the strengths of each.

In some cases, the ensemble value might be drawn from a single model. In others, it might be a weighted average of just a few models or of the full ensemble. Most importantly, it will represent a single value from the ensemble that is endorsed by many of the leading national experts in remote sensing of ET. For the Rosedale-Rio Bravo Water Accounting Platform, the ensemble value is currently calculated as an average of four models, METRIC, PT-JPL, SIMS, and SSEBop.

Another advantage of using an ensemble of models is that, in most cases, we expect to see a range of ET values across the ensemble. This can provide a useful measure of uncertainty or measurement error of the remotely sensed ET data in regions where no ground-based measurements exist. In addition, the range across the ensemble can allow OpenET users to evaluate estimates of ET data against the range of values from OpenET.

Initial Ensemble of ET Models

Acronym	Name	Primary References
ALEXI/ DisALEXI	Atmosphere-Land Exchange Inverse / Disaggregation of the Atmosphere-Land Exchange Inverse	Anderson et al., 1997; Anderson et al., 2013
METRIC	**M**apping **E**vapo**t**ranspiration at high **R**esolution with **I**nternalized **C**alibration model	Allen et al., 2005; Allen et al., 2007
PT-JPL	**P**riestley-**T**aylor **J**et **P**ropulsion **L**aboratory	Fisher et al., 2008
SEBAL	**S**urface **E**nergy **B**alance **A**lgorithm for **L**and	Bastiaanssen et al., 1998
SIMS	**S**atellite **I**rrigation **M**anagement **S**upport	Melton et al., 2012; Pereira et al., 2020
SSEBOP	**O**perational **S**implified **S**urface **E**nergy **B**alance	Senay et al., 2014; Senay et al., 2018

How is the ensemble value generated?
At present, the ensemble value is calculated as the average of four models, METRIC, PT-JPL, SIMS, and SSEBop. This approach is likely to change once the intercomparison study is complete.

What limitations should I keep in mind about the models and the ensemble?
It is important to keep in mind that the data from OpenET do not represent a direct measurement of ET but rather an estimate, or calculation, of ET based on the measurement of other variables in the environment. Our goal is to be as transparent as possible about the quality of satellite images and other data sets, methodologies, and equations used in the calculations. The results from the intercomparison study will be used to inform the overall accuracy for the data from OpenET.

Satellite-based Measurements

How do satellites provide data about water on the ground?
The majority of the models included in the OpenET platform are based on the energy balance approach. This approach relies on satellite measurements of spectral radiance (the amount of light energy reflected off the land surface measured in specific wavelengths) and surface temperature combined with ground-based measurements of other key variables that govern the surface energy exchange. The only component of the surface energy balance that is not directly or indirectly measured by satellites and weather stations is ET, leaving it as the "residual" variable to solve for by applying a model or algorithm such as the ones available through the OpenET platform. For a brief overview of how the approach works, please see this NASA video: https://youtu.be/c6OmfYEgzA0.

The discrepancy between the various energy balance approaches primarily relates to different methods for correcting for atmospheric instability, interpolation between satellite images, and pre-processing of satellite and meteorological inputs to the models. A key strength of satellite-driven energy balance approaches is that they provide a measurement of actual ET from each field and have been shown to be almost as accurate as ground-based measurements in many studies. One key limitation for many of these models is that, traditionally, they have usually typically required supervised operation and calibration by an expert to achieve maximum accuracy. The OpenET team is currently working hard to overcome this limitation and fully automate these approaches.

SIMS, or the Satellite Irrigation Management Support system, relies instead on a reflectance-based approach. SIMS converts the normalized difference vegetation index (NDVI), a satellite-based measure of the density and health of vegetation, to crop fractional cover, the fraction of the ground that is covered by vegetation. It then combines this with estimated canopy height and a stomatal control factor (to account for physiological differences between crops)

to calculate a crop coefficient for every 0.22-acre pixel in each satellite scene. Combining crop-coefficient data with California Irrigation Management Information System (CIMIS) data (or other ground-based estimates of reference ET) facilitates daily estimation of actual ET following approaches recommended by the Food and Agriculture Organization of the United Nations (FAO). Strengths of this approach include estimation of irrigation requirements under well-watered conditions, full automation, and the ability to integrate data from multiple satellites to increase the number of available observations. Limitations include underestimation of soil evaporation and a limited ability to detect short-term or intermittent deficit irrigation.

How many satellites are involved in providing the data?
OpenET builds upon decades of investment by NASA, USGS, the National Oceanic and Atmospheric Administration (NOAA) and the European Space Agency (ESA) to develop, launch, and operate a constellation of Earth-observing satellites, and to establish the ground data systems required to capture, process, store, and distribute satellite data. All of the models in the initial OpenET ensemble leverage data from Landsat satellites to produce field-scale ET estimates, which is the primary satellite dataset used by the OpenET platform. However, multiple models implemented within the OpenET framework also integrate data from other satellites, including GOES, Sentinel-2, Suomi NPP, Terra, and Aqua, to produce ET data at a range of spatial and temporal scales.

Will you validate the data from satellites? How?
The OpenET team is currently initiating one of the largest intercomparison and accuracy assessments of ET models conducted to date. We are comparing the satellite-derived ET data against three ground-based approaches that quantify ET, or track changes in consumptive water use over time, including:

1. ET measurements collected by flux tower stations throughout the continental U.S.
2. Groundwater pumping records.
3. Water balances at the watershed scale.

The primary dataset for the intercomparison has been collected from a network of flux towers that use eddy covariance methods to measure the exchanges of carbon dioxide, water vapor, and energy between the land surface terrestrial ecosystems and the atmosphere. These tower stations are critical because they provide ground measurements of ET for comparison against a very specific set of locations with known land use types and characteristics. These estimates are derived directly from micrometeorological measurements used to calculate water and energy fluxes from the land surface. The ground measurements used in the OpenET analysis are from more than 120 flux tower sites across the U.S., including Ameriflux

sites and additional locations within agricultural fields from collaborators at USDA, USGS, University of California Cooperative Extension, and other university partners. We have developed an extensive, automated screening process to identify any outliers or gaps in the instrument measurement record, and we have reviewed the sites using aerial imagery as well as wind speed and direction data from the towers to ensure that the location is representative of the surrounding field or land cover type.

Comparisons against groundwater pumping records also provide an additional check on the satellite-based ET data for more agricultural fields than can be covered with eddy covariance station measurements alone. This analysis can offer insight into differences between the volume of water that is pumped for irrigation and the consumptive use of water through ET.

Finally, contrasting satellite measurements against watershed-scale water balances is a useful tool to test the hypothesis that random errors will cancel one another out and model agreement across the ensemble will improve when data is aggregated over larger areas. Although watershed-scale water balances can have higher uncertainty than some of our other comparison approaches, they are useful additional data points to include in the broader intercomparison effort.

While this validation effort is an important step for OpenET because the models are being applied across a broader set of geographies and land cover types than ever before, it is worth noting that the individual models have been previously validated in more narrowly defined contexts.

Funding

How is OpenET being funded?
Development of the OpenET platform is supported by the S.D. Bechtel, Jr. Foundation, the Gordon and Betty Moore Foundation, the Walton Family Foundation, Lyda Hill, the Water Funder Initiative, the Windward Fund, and the NASA Applied Sciences Program. In-kind support is provided by partners in the agricultural and water management communities, Google Earth Engine, and the Water Funder Initiative. OpenET will need to secure additional funding to cover the transition of OpenET to its long-term home and to allow the team sufficient time to test funding models, licensing contracts, and other aspects critical to supporting the platform long term.

Why does OpenET need ongoing funding and support once the platform has been built?
One goal of OpenET is to continually provide the best available science-based estimates of ET. This requires a team of researchers and programmers to update the code as the science and underlying input data improves and as

cloud computing and the Google Earth Engine platform evolve. We also expect ongoing computing and data charges and administrative and management needs associated with initiating and maintaining contracts and coordinating efforts between OpenET's scientific community and its users. OpenET also anticipates the need to provide user support and the development of training resources for the OpenET user community.

Who owns OpenET?
Currently, OpenET is "owned" by the project's fiscal sponsor, the Windward Fund. We are in the process of scoping a transition plan for OpenET, to be implemented in 2021 or 2022.