Food Security from Space

Monitoring Indicators of Water Availability for Agriculture

National Aeronautics and Space Administration

The availability of water plays a vital role in food security. Satellites aid informed agriculture decisions by monitoring changes in the volume and flow of water in Earth's atmosphere, land surfaces, and underground aquifers.

Water Varies from Place to Place and Over Time

Water from rainfall and snowmelt soaks into the land, flowing into rivers and lakes, evaporating or being absorbed by plant roots. The rest either remains as soil moisture to sustain streams and rivers between precipitation events, or drains farther downward to recharge underground aquifers, supporting domestic, municipal, industrial and especially agricultural use in places where surface water is not available. Aquifers can be depleted in places where groundwater is continually consumed faster than it can be recharged. Many U.S. states and most of the rest of the world have sparse observations of water availability or do not make their data available to the public. Thus monitoring water resources from space is essential to better understand and predict agricultural productivity and food security around the world. .

NASA Applied Sciences works with operational partners to identify critical needs where satellite and airborne data can support more informed decisions. For example, NASA data are incorporated into the USDA Foreign Agriculture Service Crop Explorer tool to improve estimates of global agricultural growing conditions such as soil moisture, temperature, precipitation and vegetation health. This tool helps USDA regional crop analysts better predict where there could be too little or too much water in the soil to support crops over the growing season. NASA also partners with USAID on its Famine Early Warning Systems Network, where water availability information is linked with data on vegetation health and other information to predict food insecurity.

Satellite Monitoring of Rain and Snow

NASA estimates global precipitation (rainfall and snowfall) by intercalibrating and merging data retrievals from all precipitation-relevant satellites, using active and passive microwave or optical techniques with help from surface precipitation gauge data and other sources. These long-term, continually updated datasets enable users to characterize this fundamental source of freshwater. Over the winter season, the accumulation of snow on land impacts water availability, flood risk, dam regulation and vegetation growth. Remote sensing is also used to monitor snow depth, snow cover and snow water equivalent (SWE). No single technique currently works for snow under all conditions. Future snow missions will combine capabilities from existing and new sensors.

PHOTO: NSIDC / TONY FERNANDEZ

Snow melts into a river in New Zealand's Aoraki/Mount Cook National Park.

Only 2.5%
of water on Earth is fresh

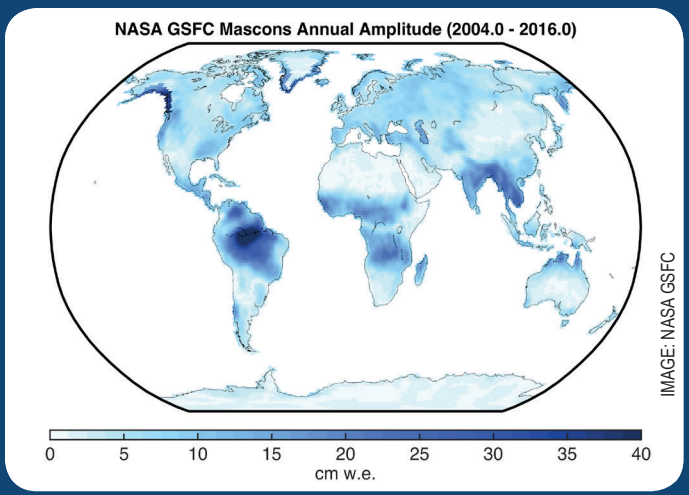
2/3 of that is frozen in glaciers and land ice;
most of the remainder is groundwater and surface water (lakes, rivers, soil moisture)
just a tiny fraction is atmospheric water vapor and precipitation[1]

Worldwide, more than
1.2 BILLION
people rely on freshwater from glaciers and seasonal snowpack[2]

Agricultural production is the largest consumptive use of freshwater[3]

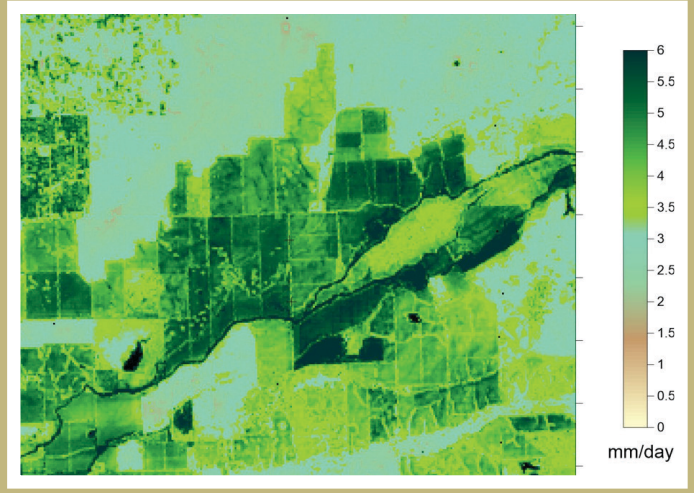
Satellite Monitoring of Terrestrial Water Storage

Conventional remote sensing techniques for monitoring terrestrial water storage infer land properties by relating them to measurements of visible, microwave or other radiant energy emitted or reflected from Earth's surface down to the first several centimeters of the soil column. Using precise, satellite-based measurements of changes in Earth's mass over space and time, it is possible to calculate anomalies (departures from the long-term mean) of terrestrial water storage, including deep soil moisture and groundwater. This technology has proven valuable for observing droughts and the impacts of irrigated agriculture on groundwater supplies. Additionally, satellite imaging and altimeter products of lake and reservoir height, which can be used to compute volume, are based on a long-term satellite data set that spans several decades (i.e. since the launch of the Topex/Poseidon satellite in 1992).



The amplitude of the seasonal cycle of terrestrial water storage, equivalent height of water in centimeters, from 2004 to 2016. The highest terrestrial water storage is found in the wet tropics (e.g. Amazon basin) and in regions of substantial glacier and ice sheet ablation (e.g. gulf coast of Alaska).

Satellite Monitoring of Evaporative Stress



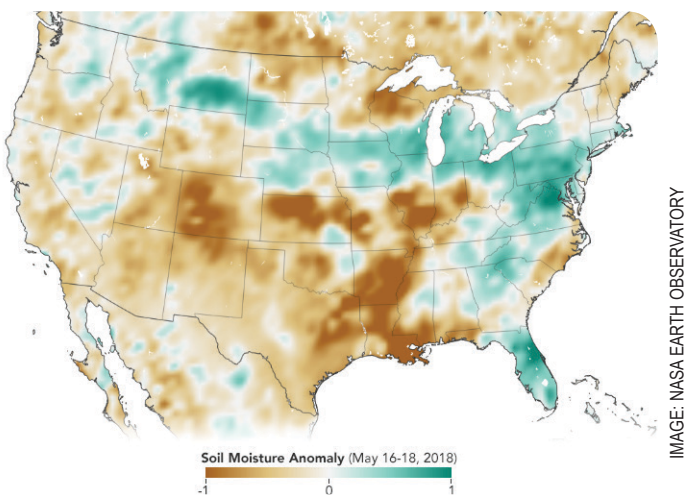
Vineyards in California: ET at 30-meter resolution over a 9 x 9 kilometer area, generated with Landsat thermal imagery. The ability to quantify water use from cloud-free satellite imagery at field scale, by crop and landcover type, informs water management and irrigation practices to conserve resources and improve efficiency.

Evapotranspiration (ET) directly reflects water availability and is an effective indicator of plant health, as detailed in the Vegetation fact sheet. The Evaporative Stress Index highlights areas where ET is anomalously low, signaling depleted soil moisture reserves associated with agricultural drought. ET products from satellite thermal sensors with 100-meter to 5-kilometer resolution can be used to assess changes in evaporative stress. These heritage sensors have long records in order to monitor changes in Earth's climate.

Satellite Monitoring of Soil Moisture

Changes in soil moisture are a direct response to weather variability and can be used to detect water-related stress that can hinder plant growth and reduce crop yields. Passive microwave satellites provide a reliable estimate of surface soil moisture (top 2 to 5 centimeters).

Hydrologic models with integrated satellite-based soil moisture observations are used to estimate soil moisture profiles to 1 meter depth, which is important for agricultural productivity. The use of surface soil moisture in hydrologic models enhances their performance and corrects for precipitation-related uncertainties.



The amount of water contained in the top few centimeters of soil is small on a global scale, but these data are critical for agricultural analysts who monitor commodity production and humanitarian needs.

Water Availability Products Derived from Space-based Sensors

Product	Satellite Sensors*	Spatial Resolution	Period	Frequency
Lake Extent River Width	Landsat MODIS	30m 250m	1972–present 2000–present	16 days Weekly
Lake and River Surface Water Elevation	Topex/Poseidon, Jason, Sentinel radar altimeters	300m	1992-2006	10 days to monthly
Precipitation Rate	GPM international constellation of passive microwave and GEO-IR	0.1°	2000–present	30 min
Snow Cover	MODIS	500m, 5km	2000–present	8 day
SWE and Snow Depth	AMSR2	25km	2012–present	Daily
Surface Soil Moisture	AMSR2 SMAP	9-25km 9-15km	2012–present 2015–present	Daily Daily
Terrestrial Water Storage Anomalies	GRACE GRACE-FO	150,000km^2 (0.5 degrees)	2002–2017 2018–present	Monthly Monthly
Evaporative Stress Index	GOES, MODIS, VIIRS	4-5km	2000–present	Weekly

** Satellites operated by NASA and other U.S. and international agencies*

Water Availability Products from Land Data Assimilation Systems (LDAS)

LDAS uses water or energy balance models to estimate water availability in regular products with continuous spatial and temporal coverage.

Product (Precipitation, Soil Moisture, SWE, TWS, ET) *	Model	Spatial Resolution	Period	Frequency
GLDAS (Global)	Multi-model Ensemble	0.25°	1948-present	Daily
FLDAS (Global)	Noah Land Surface Model	0.1°	1982-present	Daily, monthly
NLDAS (North America)	Multi-model Ensemble	0.125°	1979-present	Hourly, monthly
FLDAS (Central Asia)	Noah Land Surface Model	0.01°	2000-present	Hourly, monthly

** Versions generated using different sets of forcing data*

Data Sources and Training

The information presented here focuses on NASA resources and datasets distributed through the Goddard Earth Science Data and Information Services Center.

USDA Foreign Agriculture Service Crop Explorer tool: ipad.fas.usda.gov/cropexplorer/

Webinar: Water Resources: arset.gsfc.nasa.gov/water

Webinar: Drought: arset.gsfc.nasa.gov/water/webinars/drought17

References

[1,3] World Bank: blogs.worldbank.org/opendata/chart-globally-70-freshwater-used-agriculture

[2] Got Snow: neptune.gsfc.nasa.gov/uploads/images_db/Got_SnowSM.pdf

NASA Food Security Program

We live in a hungry world. A rapidly growing world population, its socioeconomic development, and finite natural resources in the midst of more frequent extreme weather and a changing climate, all increase our vulnerability to any disruption in the food system. Maintaining situational awareness about food production requires the global view of Earth as a system that only a fleet of satellites can provide.

IMAGE: NASA EARTH OBSERVATORY

Agribusiness in the Colorado River floodplain where the Mohave nation meets Arizona, Nevada, and California: commodity crops alfalfa, corn, and soybeans are grown in rectangular and round fields.

To help address these urgent challenges, NASA sponsors Harvest, a Food Security and Agriculture Consortium led by the University of Maryland. NASA partners with operational agencies such as the U.S. Department of Agriculture (USDA), the U.S. Agency for International Development (USAID) and the National Oceanic and Atmospheric Administration (NOAA), along with international organizations and private industry, to advance the use of remotely-sensed data for more informed decision-making.

We also have a team of NASA scientists with expertise in food and water systems, working with universities, governmental and non-governmental organizations to support the food security and agriculture communities in a more agile and futuristic way.

These researchers draw on the ingenuity of NASA with its unique technological and scientific capabilities in synergy with the NASA Harvest Consortium.

The Harvest Consortium is a NASA-funded collection of partners with domestic and international activities that are enhancing the use of satellite data in agricultural decision-making. Harvest places a strong emphasis on transitioning research to operations.

The NASA Food Security Program also:

- Fosters the assimilation of satellite and airborne remote sensing data into Earth systems models and other tools designed to address global food security challenges.
- Explores the research needs, sources of uncertainty and technical barriers that limit the operational use of Earth observations in decisions.
- Works with NASA's Earth Science Technology Office to advance state-of-the-art technology to public and private agencies focused on global food security challenges.
- Works with current and future NASA missions before and during their formulation to ensure that food security science and applications are incorporated into new satellite missions.
- Represents NASA on government initiatives, assisting interagency programs in the use of NASA resources.

PHOTO: SIMONSKAFAR/ISTOCK

A new generation of farmers uses aerial and satellite remote sensing imagery to help efficiently manage croplands. Farmers monitor a range of variables that affect their crops—such as soil moisture, surface temperature, photosynthetic activity, and more.

Further Reading

NASA Food Security Program: science.gsfc.nasa.gov/610/applied-sciences/food.html

NASA Harvest: nasaharvest.org

FS-2019-8-415-GSFC