

NASA Applied Science:

View from the Goddard Applied Science Manager

Stephanie Schollaert Uz, PhD
Applied Sciences Manager | Earth Sciences Division
NASA Goddard
stephanie.uz@nasa.gov



EARTH FLEET

INVEST/CUBESATS

- NACHOS 2022
- CTIM 2022
- NACHOS-2 2022
- MURI-FD 2023
- SNOOPI* 2024
- HYTI* 2024
- ARGOS* 2024

JPSS INSTRUMENTS

- OMPS-LIMB 2022
- LIBERA 2027
- OMPS-LIMB 2027
- OMPS-LIMB 2032

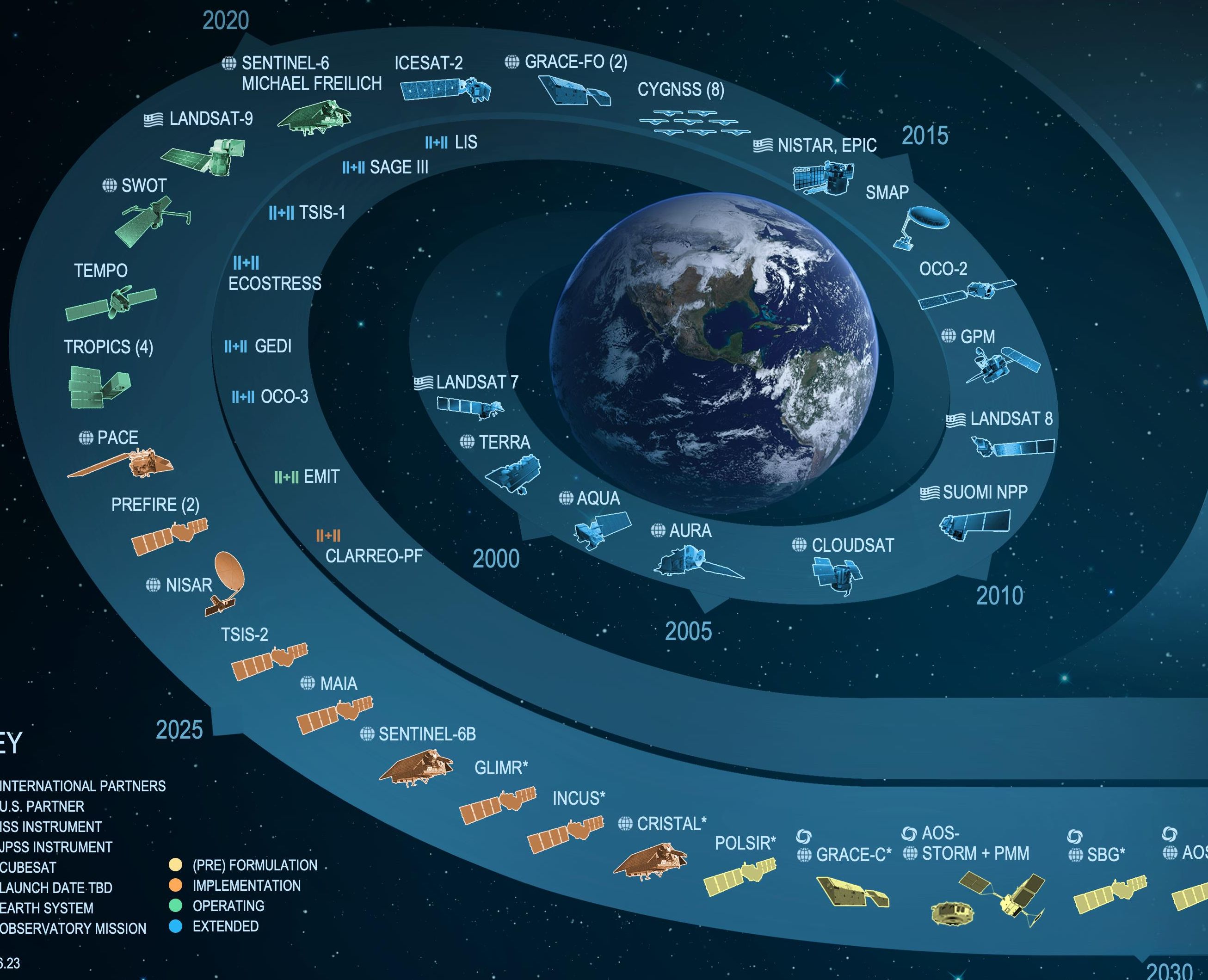
ISS INSTRUMENTS

MISSIONS

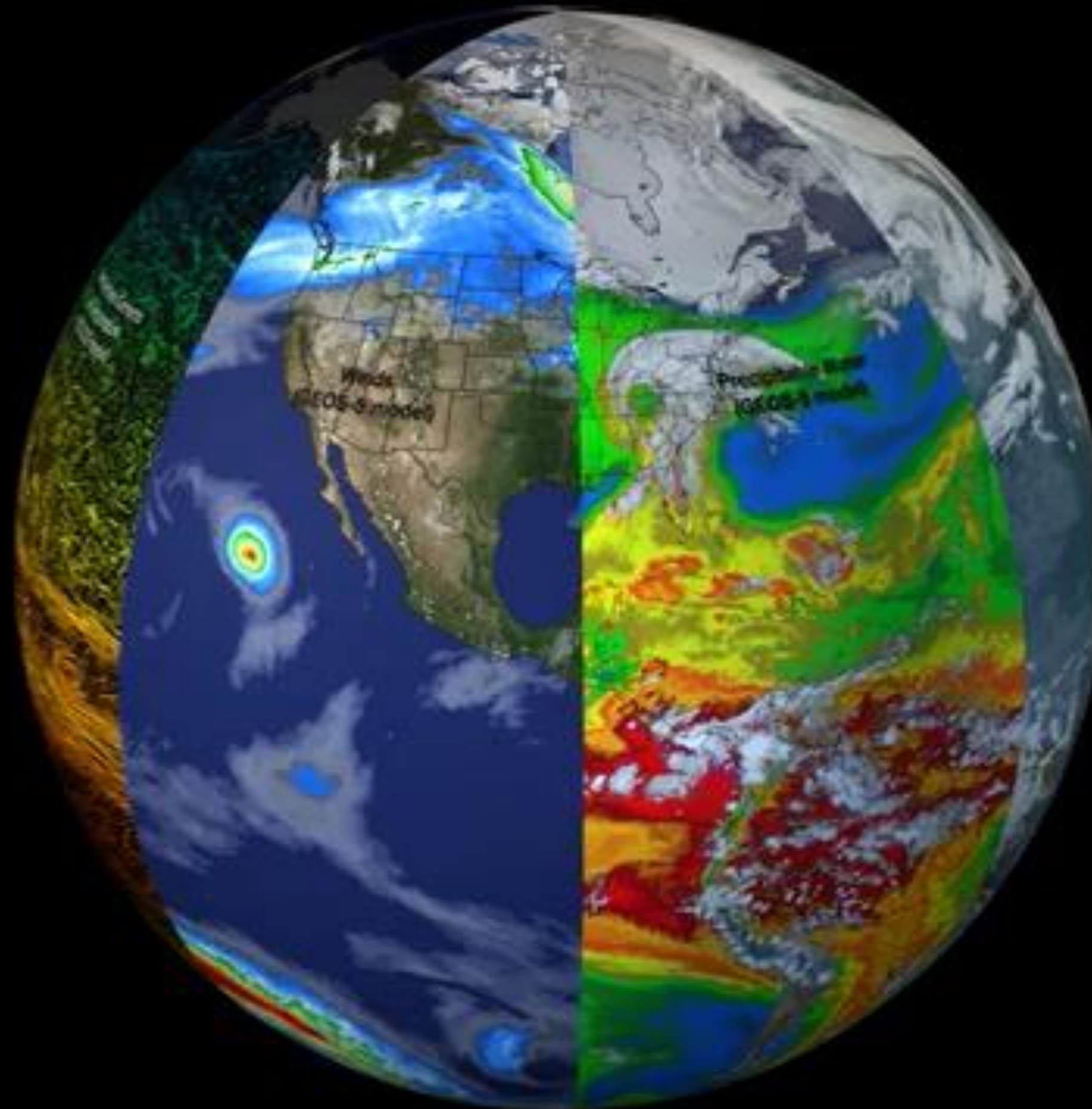
KEY

- INTERNATIONAL PARTNERS
- U.S. PARTNER
- ISS INSTRUMENT
- JPSS INSTRUMENT
- CUBESAT
- LAUNCH DATE TBD
- EARTH SYSTEM
- OBSERVATORY MISSION

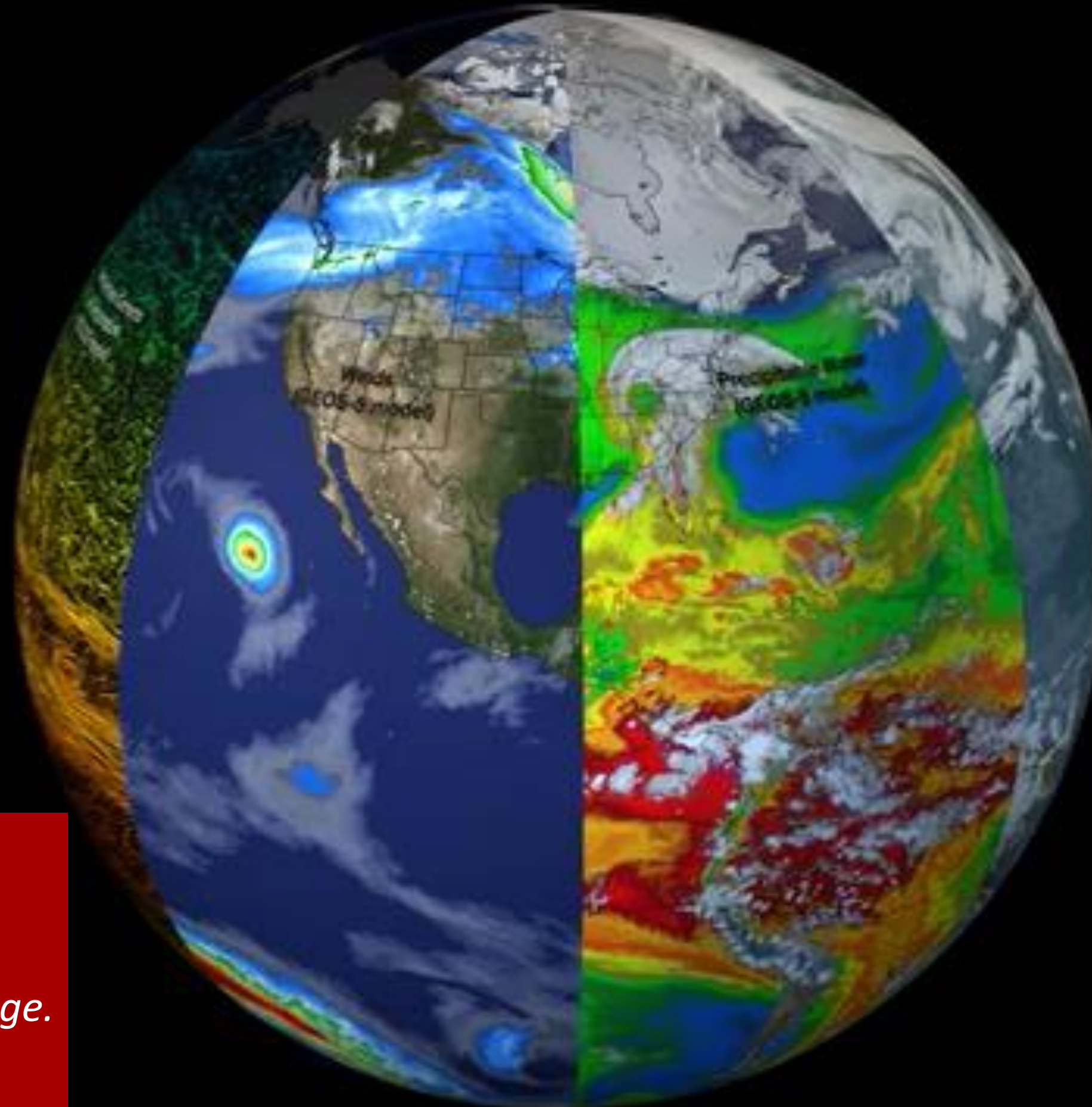
- (PRE) FORMULATION
- IMPLEMENTATION
- OPERATING
- EXTENDED



Earth systems from space: energy/water/carbon cycles



Earth systems from space: energy/water/carbon cycles



*Learning isn't complete
when we acquire knowledge.
It's complete when we
consistently apply that knowledge.*

NASA Applied Science Programs



Program areas tackle challenges on our home planet in areas for which Earth science information can respond to the urgent needs of our time.

What are Earth science applications?

Applications use Earth science data, models, and information products to inform decisions and actions on management, policy, and business



Agriculture



Disasters



**Ecological
Conservation**



**Health &
Air Quality**



**Water
Resources**



**Capacity
Building**



**Mission
Engagement**



Climate Resilience

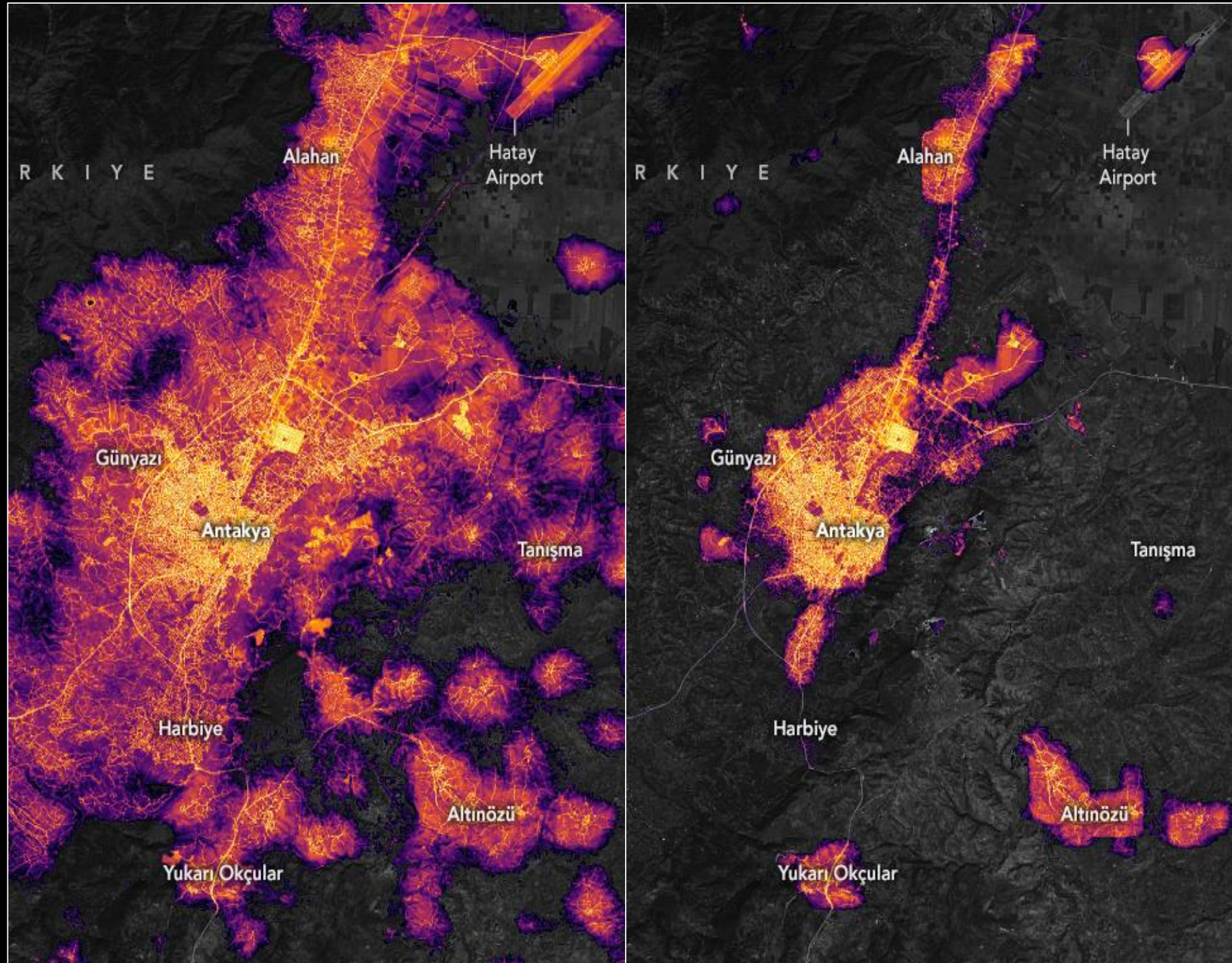


Energy



Wildland Fires

Nighttime lights indicate economic activity



NASA Black Marble nighttime lights over Antakya, Turkey before earthquake on Feb 4, 2023 (left) and after on Feb 8, 2023 (right).
Image source: NASA Earth Observatory, Black Marble VIIRS/Suomi NPP

UN assessments based on NASA Black Marble shared with humanitarian organizations, i.e. Red Cross, Red Crescent to support disaster response

Black Marble also used to detect:
human settlements
energy infrastructure
fires, gas flares
disaster recovery
light pollution
illegal fishing



The POWER Project

Provides solar and meteorological data sets from NASA research for support of renewable energy, building energy efficiency and agricultural needs.

Supported by NASA Earth Science's [Applied Sciences Program](#)

POWER's Web-Based Docs Pages

- > [Data Methodology](#)
- > [Data Services Documentation](#)
- > [Data Access Tutorials](#)

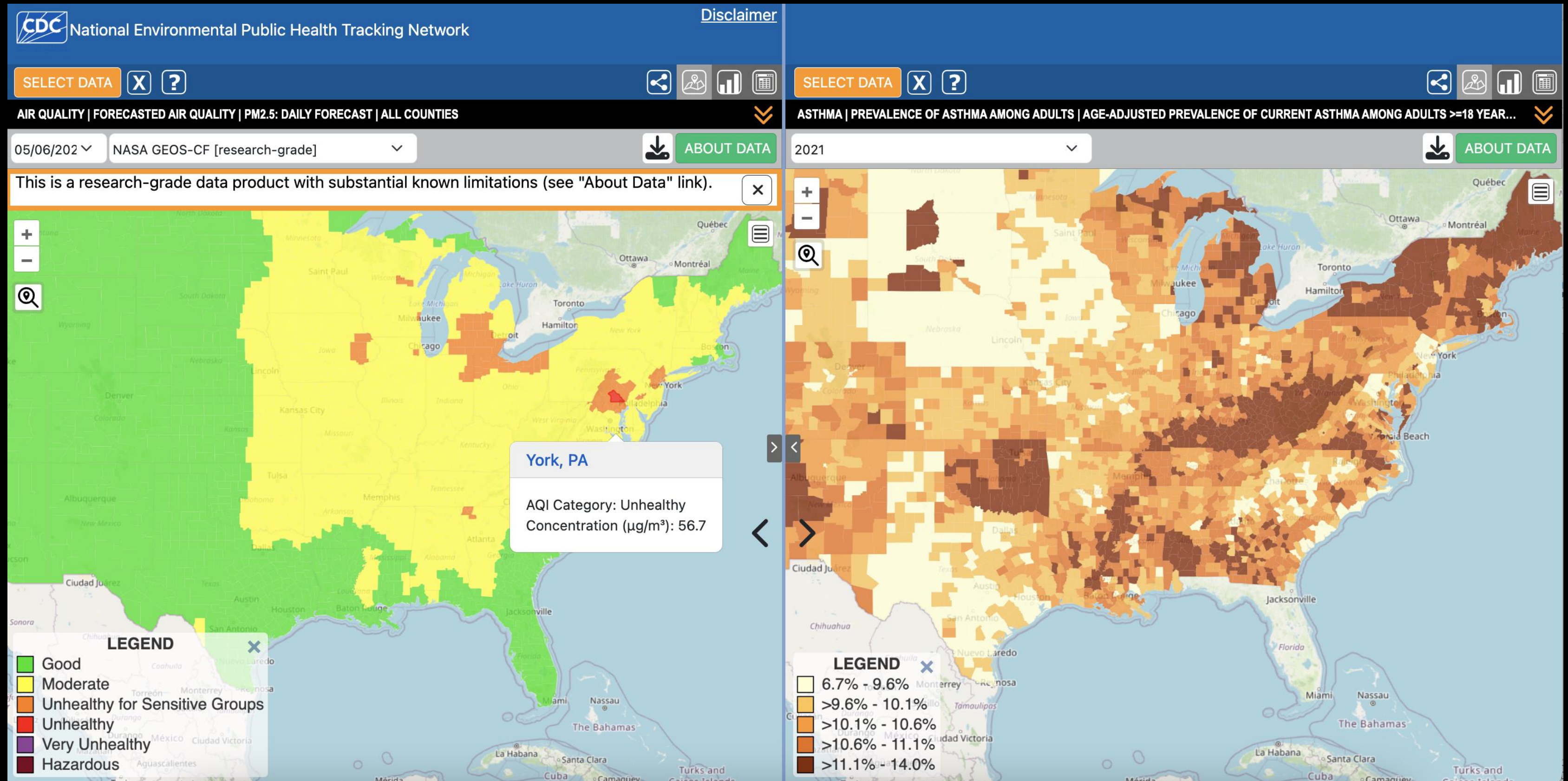
Climate data tailored for renewable energy, building efficiency, and ag
Know your heating and cooling demands

Near-real time active fire mapping



firms.modaps.eosdis.nasa.gov

Integrating environmental data to inform health sector



ephtracking.cdc.gov/DataExplorer

Domestic and International Food Security Support



Food Security from Space

Monitoring Indicators of Vegetation Health on Croplands and Rangelands

National Aeronautics and Space Administration

Farmers and agricultural decision makers rely on many tools to assess production and allocate resources. Freely available global satellite observations provide a timely, synoptic, objective, repeatable method of surveying vegetation, supplementing traditional methods.

Legacy of Support to the Agriculture Community

NASA Earth satellites routinely monitor the amount of land cultivated; crop types grown; yield; calendars and stage (used to approximate when crops are sowed, emerge, reproduce and are harvested); gross primary production; biomass; and water status (i.e. water use efficiency, evapotranspiration). The NASA/U.S. Geological Survey Landsat satellites, operating since 1972, have created the longest space-based database of Earth satellite imagery, enabling us to follow long-term trends like deforestation and crop biomass changes. Its finer-resolution (30-meter) observations, acquired every 16 days, are complemented by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the Terra and Aqua satellites, and the NASA/NOAA Suomi-NPP Visible Infrared Imaging Radiometer Suite (VIIRS), remotely sensing all of Earth daily at 250- to 1,000-meter resolution. The ability to fly over areas frequently is critical for timely agricultural assessments, since changes in crop status can happen in less than a week.

NASA works with operational partners to identify critical needs where satellite and airborne data can inform decision making. For example, the U.S. Department of Agriculture produces monthly estimates of global agricultural yield based on Landsat 8 and MODIS imagery that are used by the Chicago Board of Trade to set global commodity prices. Additionally, the Office of the Prime Minister of Uganda uses satellite data to trigger its Disaster Risk Financing Fund, a critical form of autonomous smallholder farm aid.

Gross Primary Production and Crop Yield

A combination of Earth observations and models support agriculture decisions. Estimates of gross primary production (GPP) — the rate biomass is produced — provide data to help determine the yields of crops and fodder for animals in rangeland systems. Satellites observe individual crops and fields, their development over the growing season and the effectiveness of management practices and interventions.

Crop-type Indicators

Thirty-meter observations from Landsat and 250-meter observations from MODIS monitor agricultural areas using the normalized difference vegetation index (NDVI), which distinguishes vegetated areas from other land surface types. These maps are used to distinguish individual crop types, and vegetated/non-vegetated areas. Measurements of NDVI over the growing season can help identify periods of crop stress and are most useful when acquired at individual fields of known crop types and calendars. Knowing stress levels when allocating photosynthate into yield provides a strong indication of crop vigor.

Landsat 8 and the European Space Agency (ESA) Sentinel-2a and Sentinel-2b provide routine land imaging and 30-meter data for crop identification, while the Harmonized Landsat and Sentinel-2 project produces 30-meter observations every 3.7 days (at the Equator). Landsat 9, planned for launch in 2020, will reduce the equatorial revisit frequency to 3 days.

About 11%
of Earth's land surface
is used to grow crops.

1.87 billion hectares
(4.6 billion acres) globally¹

Country	Percentage
INDIA	9.6%
U.S.	8.9%
CHINA	8.8%
RUSSIA	8.3%

Countries with the highest
net cropland areas²

**Largest U.S. crops
by acreage³**

\$193.5 billion
2017 market value of
U.S. agricultural crops⁴

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.

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 precipitation¹

**Worldwide, more than
1.2 BILLION
people rely on freshwater
from glaciers and
seasonal snowpack²**

**Agricultural production is
the largest consumptive
use of freshwater³**

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

PHOTO: NASA / JOWITERNISZ

Food Security from Space

Monitoring Indicators of Water Quality for Agriculture and Aquaculture

National Aeronautics and Space Administration

Access to clean water is essential to human health and plays a critical role in food safety and security. From space, satellites observe water supplies to detect and monitor harmful algal blooms and dissolved and suspended matter. These contaminants have implications across the food web.

Water Quality Affects Seafood and Aquaculture

As Earth's population grows, our waterways face increasing pressures. Pollutants such as agricultural fertilizers and livestock waste make their way into our streams, rivers and lakes, with detrimental impacts on water quality.

Runoff of sediments impacts water clarity and starves submerged aquatic vegetation of adequate light, adversely impacting the habitat of crabs and other bottom dwellers. Runoff of nitrogen and phosphorus from farms contributes to an imbalance of nutrients that can fuel the growth of algal blooms that are larger than aquatic life forms that consume algae can eat. When these large blooms decompose, they leave behind areas of water with low oxygen content, popularly referred to as 'dead zones,' that kill almost all fish and marine life there. As runoff has increased, so too have the number of such dead zones. In fact, by 2017 a dead zone in the Gulf of Mexico had expanded to the size of New Jersey.

In addition to localized runoff, large-scale climate changes also adversely impact aquatic ecosystems. For example, shellfish face a dual threat. Not only are they harmed by more frequent algal blooms, but excess atmospheric carbon dioxide is being absorbed into their waters, changing its pH and leading to acidification. Some species are able to adapt to warming and changing chemistry; others shift their habitats poleward. Those who cannot adapt or move, perish.

Water Quality Affects Livestock

While runoff from animal mortality and byproducts adversely impacts the quality of waters downstream, water quality, in turn, impacts the health of livestock.

Livestock are less sensitive to poor water quality than humans, but can nevertheless be adversely affected by contaminants. Poor water quality degrades livestock growth, lactation and reproduction, resulting in economic losses to farmers. Higher-quality water sources result in larger, healthier livestock, with decreased incidences of disease.

\$4.6 billion
estimated U.S. annual
economic losses from
declining quality of
freshwater systems¹

**According to the U.S. EPA,
the fishing and shellfish
industries lose tens
of millions of dollars
each year due to
harmful algal blooms²**

**Excess nutrient
runoff necessitates
installation of expensive
nitrate removal
systems at water
treatment facilities,
raising costs 80-fold³**

NOAA established the National Shellfish Initiative in partnership with shellfish farmers and restoration organizations to increase populations of bivalves in coastal waters.

PHOTO: NOAA

Water quality impacts livestock health, growth, lactation, and reproduction.

PHOTO: SHUTTERSTOCK

Food Security from Space

Monitoring Indicators of Air Quality on Crop Yields

National Aeronautics and Space Administration

While its effects are often overlooked, air pollution negatively impacts crops around the world, resulting in significant economic losses. While its effects are often overlooked, air pollution negatively impacts crops around the world, resulting in significant economic losses, with the greatest economic loss occurring in the United States. Satellites can give farmers, scientists and policy makers important knowledge of how air quality affects food security, enabling more informed decision-making to ensure access to food resources.

Effects of Air Pollution on Plants

Ozone (O₃) is the most destructive pollutant to crops. While scientists have been working with farmers for decades to identify and breed ozone-tolerant varieties to maintain high crop productivity, the issue continues to persist, and resulting crop losses are projected to increase in many regions of the world over the next decade.

When elevated concentrations of surface-level ozone are taken up through a plant's stomata (the tiny pores on the lower surfaces of leaves), it results in a chemical reaction that hurts the plant, resulting in reduced crop yields. Ozone injury to plants is often visible as a fine tan- to dark-colored stippling pattern on the upper surface of leaves that accumulates throughout the growing season. Therefore, the lowest, oldest leaves on ozone-sensitive plants typically show the greatest amount of damage by the end of the growing season. However, the impact of ozone on plants isn't always obvious to the naked eye. Periods of stagnant air can cause ozone levels to exceed crop injury thresholds and seriously affect the overall health of plants, ultimately reducing their growth and yields. This effect is referred to as "hidden" ozone injury.

While ozone pollution has been shown to have a clear, negative impact on plant health, the impact of pollution from particulate matter (PM), such as dust and smoke, is more complicated (e.g., Schiferl and Heald, 2018). Depending on its concentration, particulate matter in the atmosphere can either reduce or enhance crop yields. For example, particulate matter can diffuse sunlight, creating a more even and efficient distribution of photons that can actually offset a reduction in total sunlight reaching a plant as a result of haze.

Air pollution can also negatively impact the pollinators of crops. About 40 percent of crops rely on insect pollination to some extent. By pollinating many species of crops and flowers, honey bees and other pollinators are integral to the health of ecosystems and the security of food resources. Overall, air pollution has likely contributed to a decline in honey bees, though many other factors may have contributed.

**The economic impact of
crop yield loss due to air
pollution is significant in
many world regions**

\$11-18 Billion
in global annual
crop losses for wheat,
corn, and soybeans¹

\$3.1 Billion
in crop losses for
the United States, the
country with the greatest
economic loss²

8.6 Billion
estimated global population
by 2030, increasing demand
for food resources (UN)³

Characteristic ozone-induced injury on the topside of green bean plant leaves. The stippling, which does not occur on veins, is associated with dark pigments accumulating within injured cells. Ozone injury symptoms often vary with different crops.

PHOTO: DR. JOHN SHELLEY

As shown in an early field study in the 1970s, ozone-sensitive varieties of potatoes (left rows) show reduced growth and lower yields than ozone-tolerant varieties (right rows).

PHOTO: DR. JOHN SHELLEY

Vegetation Health

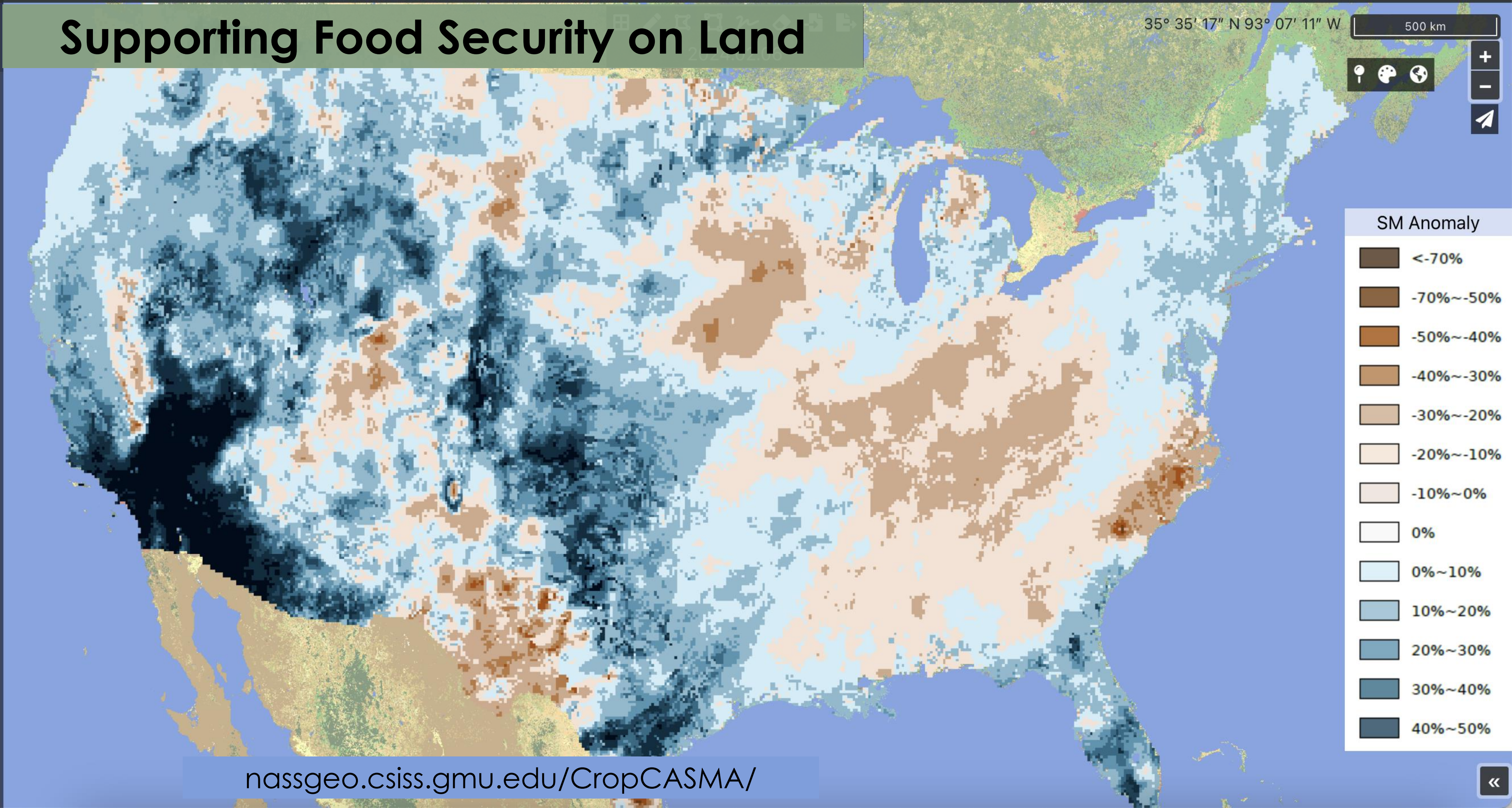
Water Quality

Air Quality

Water Availability

science.gsfc.nasa.gov/610/applied-sciences/food.html

Supporting Food Security on Land



Supporting Food Security on the Ocean, Coasts, & Inland Waters



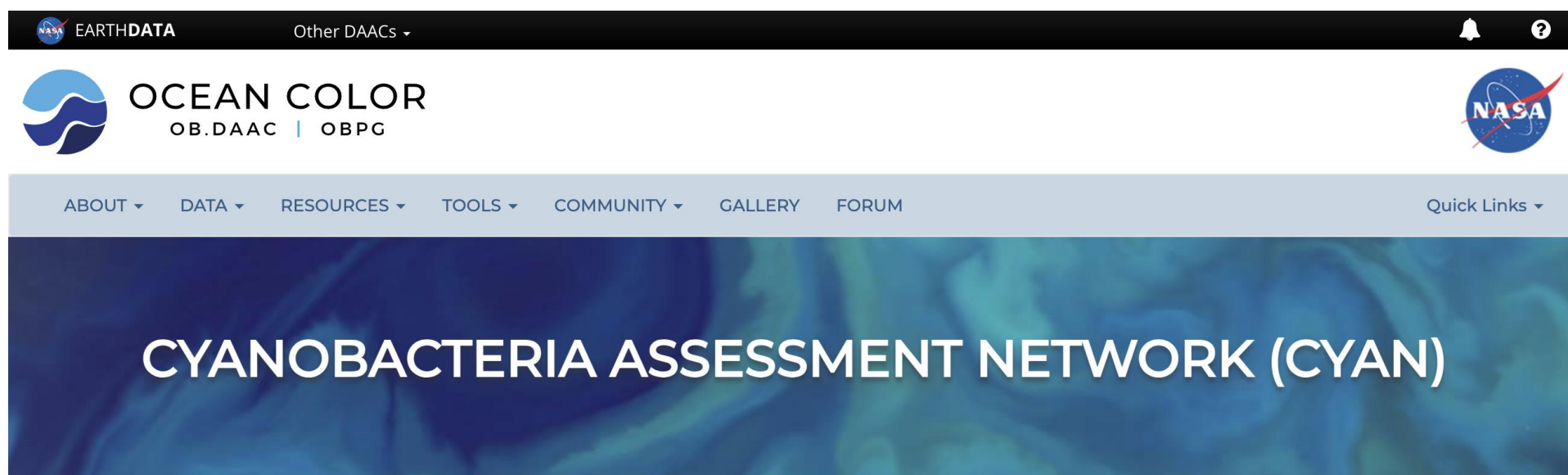
Toxic algae's return to Utah Lake could force it to close for holiday



Credit: Santa Barbara Mariculture

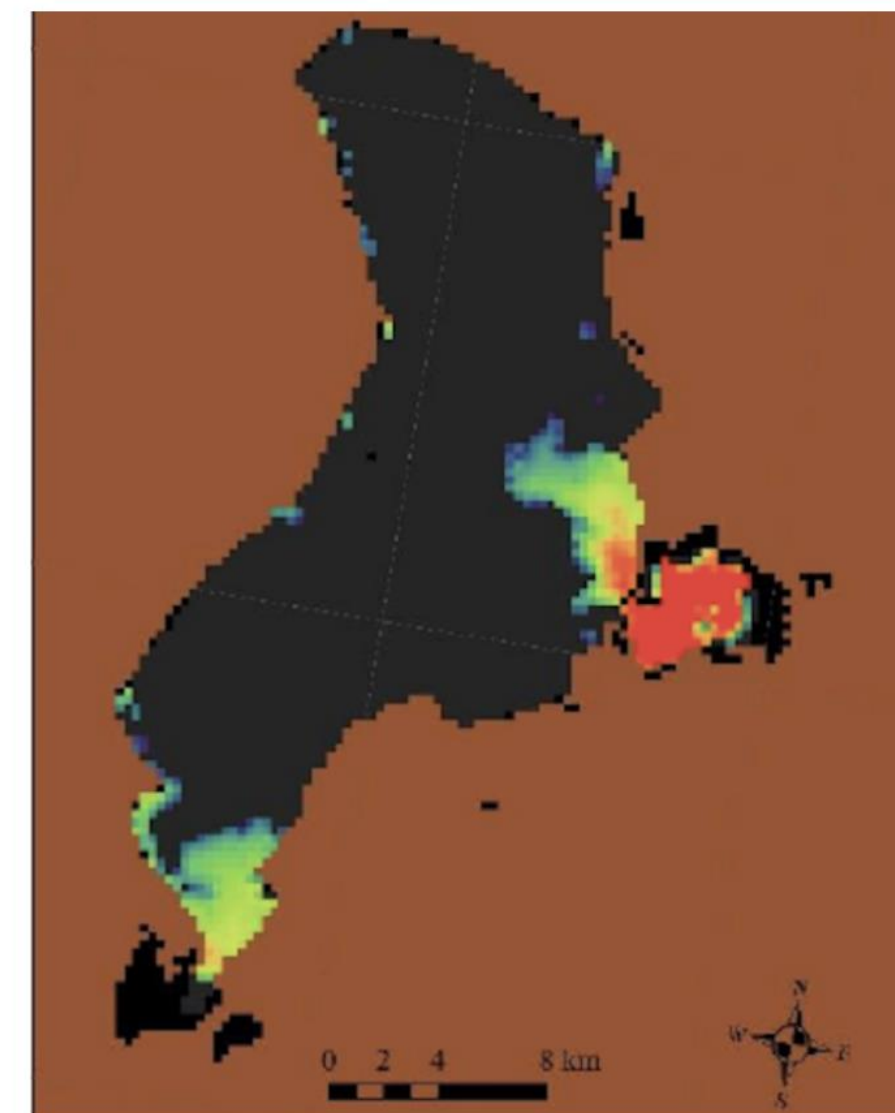
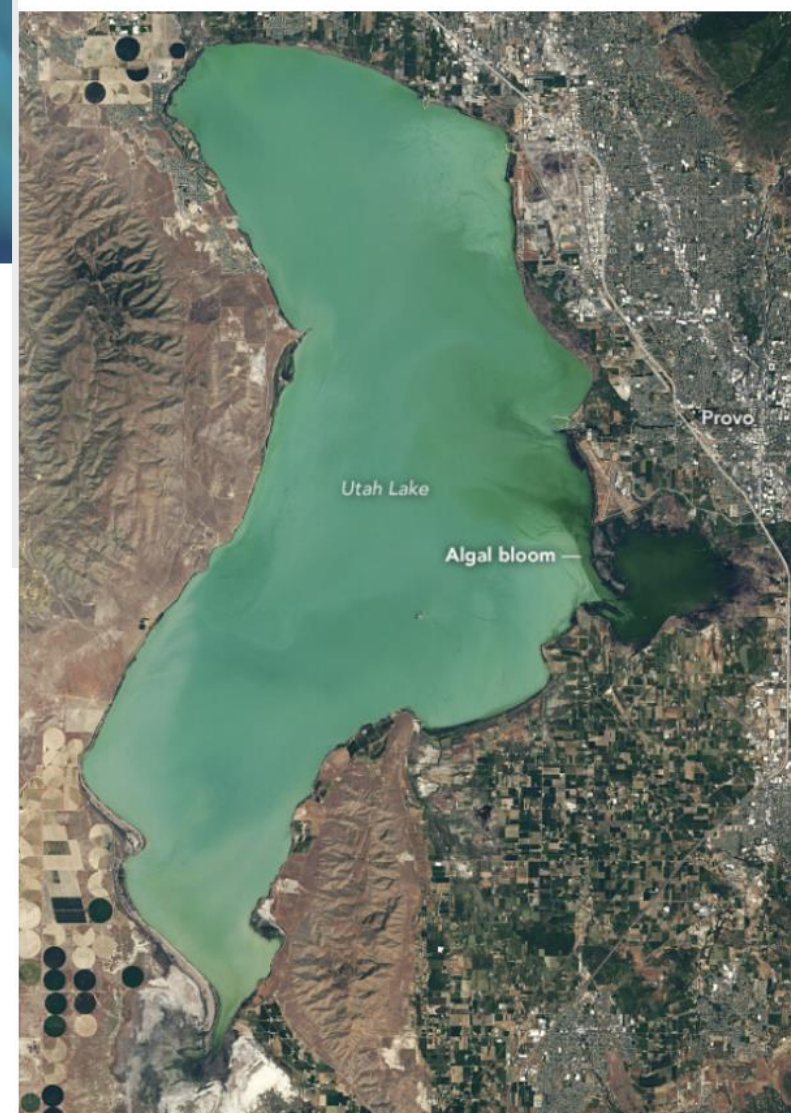
'The commercial fishing business is not easy. As the ocean is warming, stocks are shifting northward. People who survive in this business are using this technology to find fish more efficiently, comply with all the rules and regulations and limit bycatch and waste.'

~Capt. Bill Bright, Northwest Atlantic fishing fleet



Satellite data lead to earlier warnings of hazardous algae than other detection approaches, resulting in ~\$370,000 in savings for Utah Lake bloom in July 2017

*Source: GeoHealth & NASA Earth Observatory
Image of the Day August 4, 2020*



On the left, Utah Lake viewed by Landsat 8 on June 20, 2017 showing the algal bloom as a darker water color. On the right, a European Space Agency's Sentinel-3 satellite image of Utah Lake on June 21, 2017. Red, orange and yellow show elevated concentrations of cyanobacteria (algae), blue and green indicate lower concentrations with black indicating undetectable levels.

Questions for Partnerships with Practitioners:

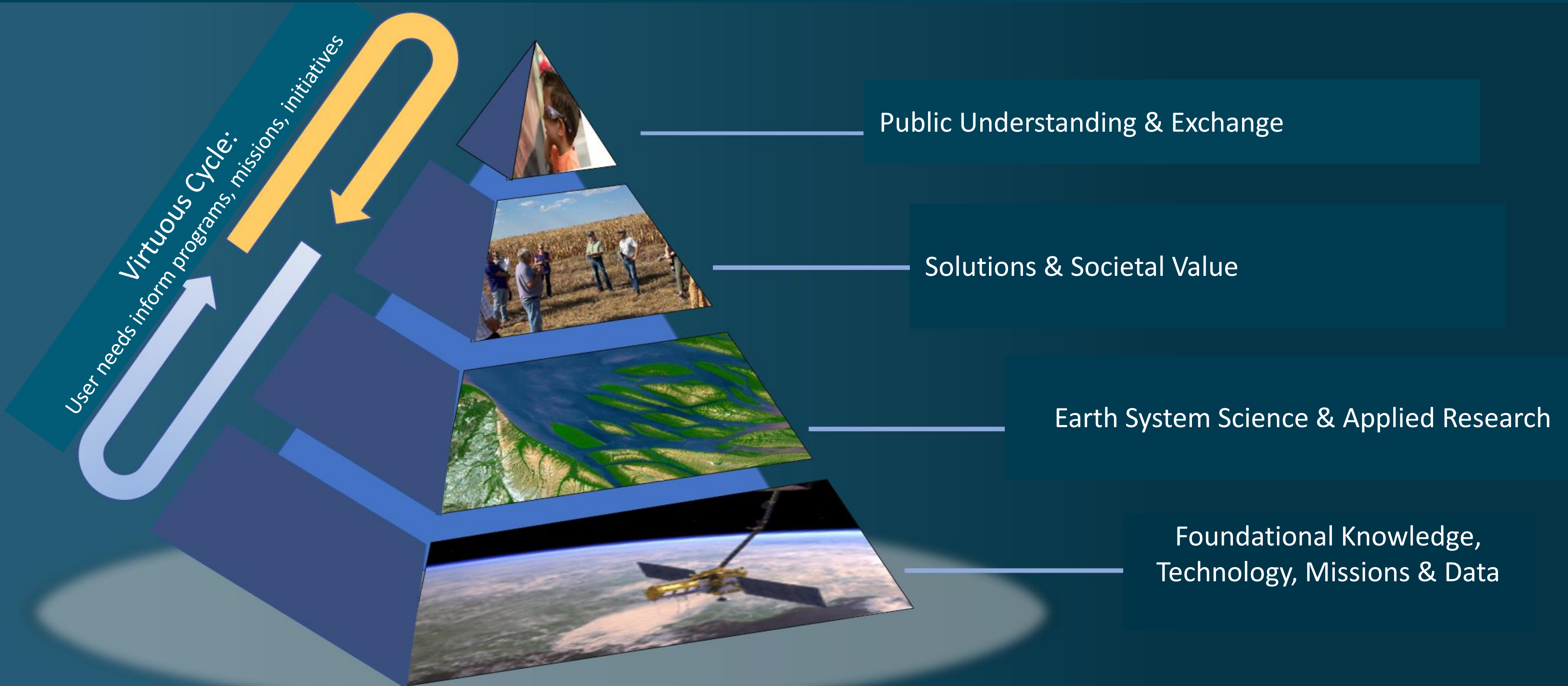
- Who are the decision makers?
- How do they currently get their information?
- Do they have information gaps that NASA data products could fill?
- What temporal and spatial scales do they need?
- What decisions or policies could our data products inform? When do they need to make decisions?
- Do they have technical capacity or need an intermediary?
- Is a formal agreement required, i.e. exchanging money or proprietary information?

Collaboration in Basic/Applied Research, Applications:

- Respect practitioner time; share examples of your work that may be relevant to their decisions; help them see the art of the possible
- Demonstrate added value to their decisions through a proof-of-concept example prior to writing a proposal, just as with basic research proposals. *Yes, all have full-cost accounting but need to demonstrate a concept has merit before seeking funding.*
- Aim to improve their quality of their work flow with your data or product; do not just use practitioners for validation data and future funding.
- If exchanging money or proprietary information, talk to lawyers early and often about developing a formal agreement.

NASA Earth Science to Action Strategy

<https://science.nasa.gov/earth-science/earth-science-to-action/>



Earth.gov

Earth Information Center

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Explore our changing planet



One government working for **one planet.**

The Earth Information Center consolidates data and insights on how Earth is changing from across the US federal government. Earth.gov is also the gateway to other interagency cooperative efforts for our planet, like the U.S. Greenhouse Gas Center. Discover how these data are being used to prepare for climate change and mitigate, adapt and respond to environmental challenges across the country.





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Nine themes, one Earth.

Agriculture

Air Quality

Biodiversity

Disasters

Sustainable Energy

Greenhouse Gases

Sea Level Rise

Wildfires

Water Resources



NASA CENTER FOR CLIMATE SIMULATION
HIGH PERFORMANCE COMPUTING FOR SCIENCE



HOME

USERS

SERVICES

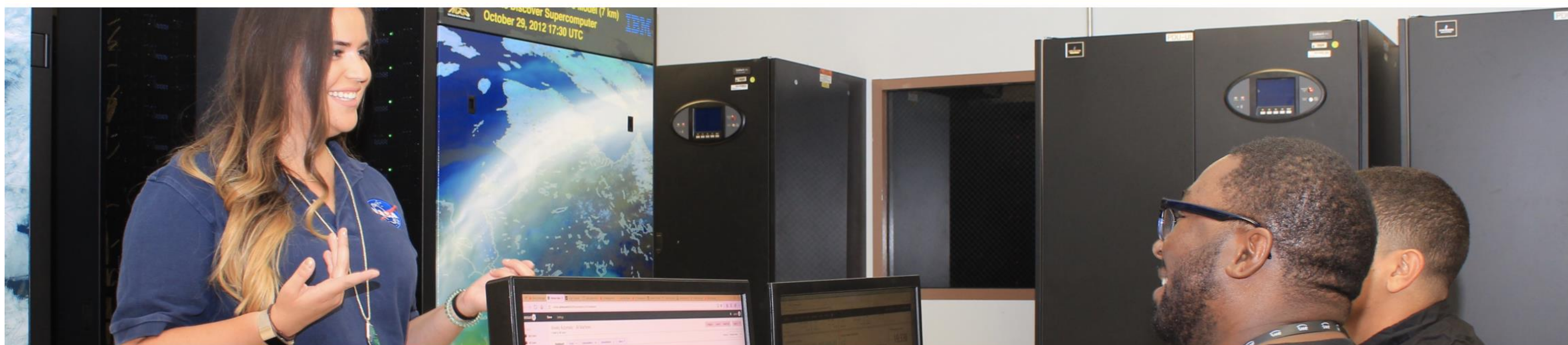
SYSTEMS

SCIENCE & TECHNOLOGY

NEWS & EVENTS

ABOUT US

SEARCH



SERVICES HOME

SUPERCOMPUTING

CLOUD

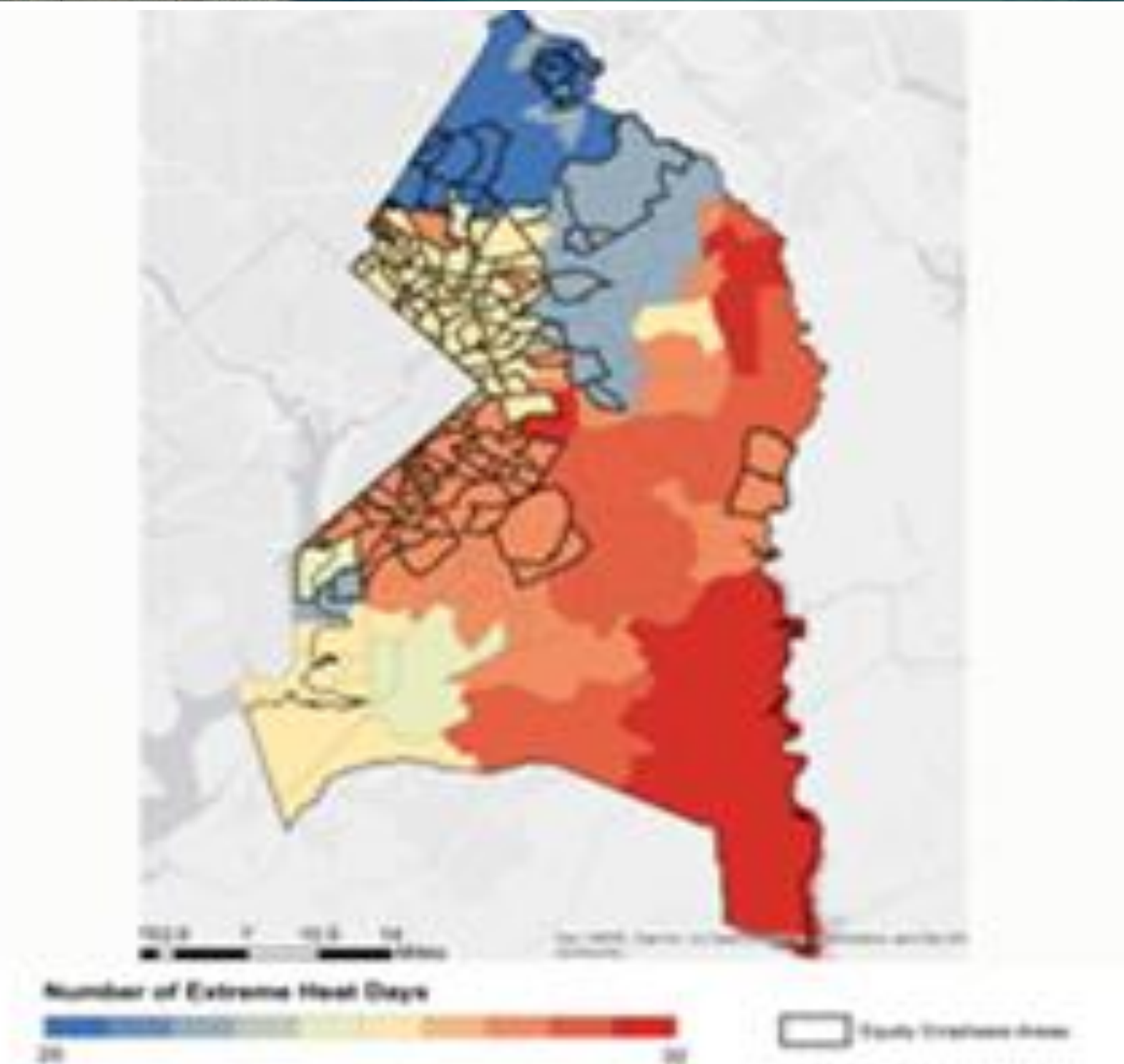
VISUALIZATION

DATA SHARING & TOOLS

CDS

// NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)

The NEX-GDDP-CMIP6 dataset is comprised of global downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 6 (CMIP6) and across two of the four "Tier 1" greenhouse gas emissions scenarios known as Shared Socioeconomic Pathways (SSPs). The CMIP6 GCM runs were developed in



Number of extreme heat days in Prince George's County near NASA Goddard. Credit: PGC Climate Action Plan Fig. V-1. Daily Maximum Temperature, 90th percentile (CDC National Environmental Public Health Tracking Network, 2016)

- Working with local practitioners in Prince George's County, Maryland to make global data useful for local climate action around their priorities:
 - Heat Impacts including heat islands
 - Extreme precipitation events and associated flooding
 - Tree canopy cover
 - Sea level rise and tidal flooding
- Developing downscaled climate data products to address county's Climate Action Plan and implementation

Partners:



Earth.gov

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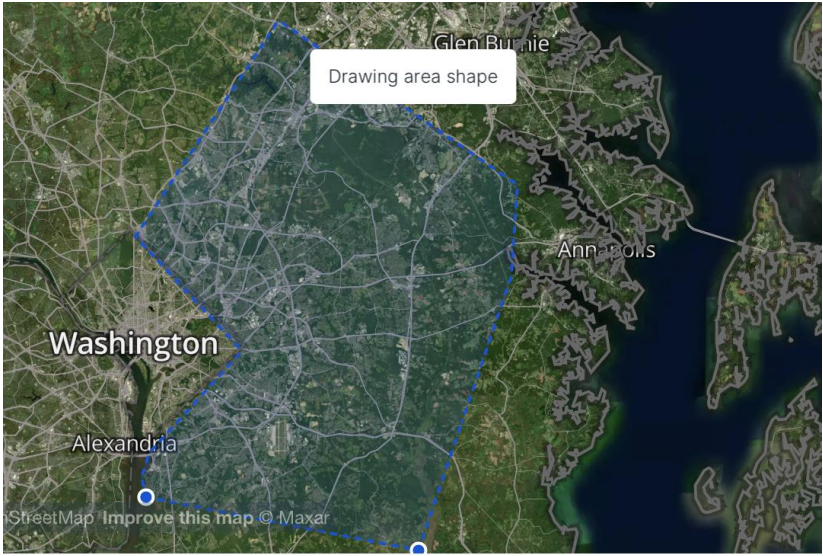
Explore our changing planet



One government working for one planet.

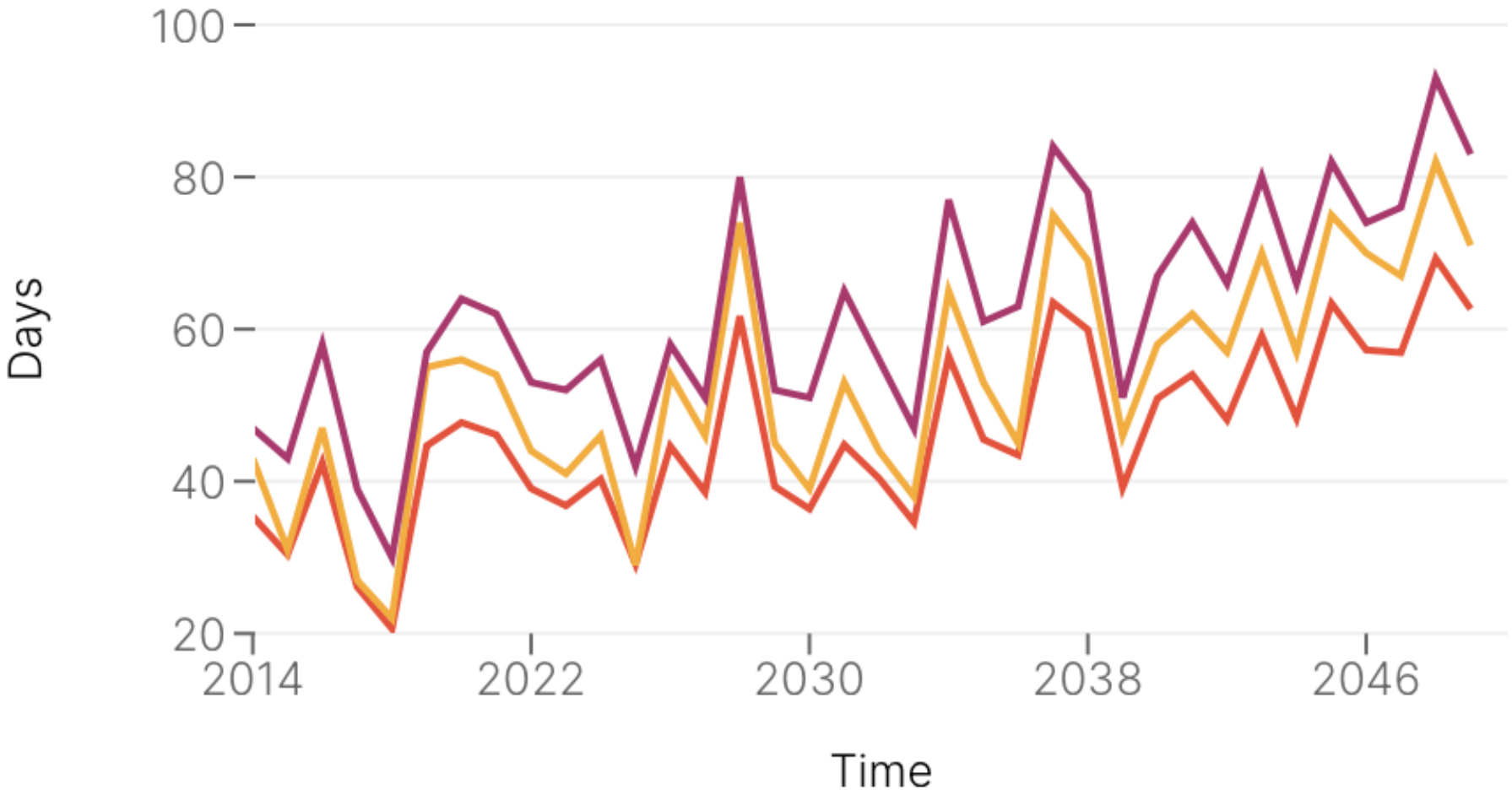
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LEGEND ● Min ● Average ● Max ● St Deviation ● Median

Days Above 90°F (SSP245)



Number of extreme heat days in Prince George's County, MD near NASA Goddard. *Source: NEX-GDDP-CMIP6 from earth.gov*

NASA Actionable Science

Innovative new missions for climate-quality observations

Modeling efforts to understand and predict change

Open science and applications

Partnerships to reach new audiences

Earth Science to Action framework