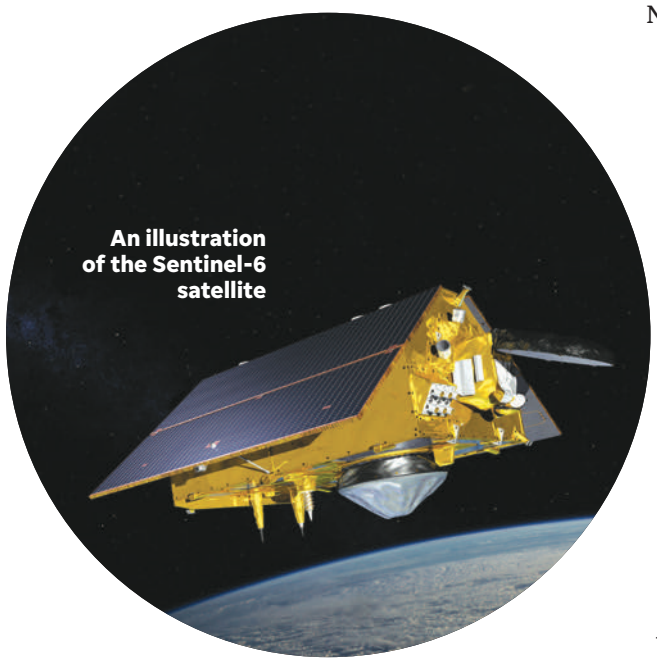
“Earthrise” photo taken by Apollo 8 astronaut Bill Anders in 1968

NASA (2)

EYE IN THE SKY

NEWEST SATELLITE CONTINUES NASA'S EARTH STEWARDSHIP



An illustration of the Sentinel-6 satellite

By Matt Alderton

In a year chock-full of space exploration milestones, it's easy to forget the difference NASA makes here on Earth.

There's no better reminder than NASA's iconic "Earthrise" photo. Taken in 1968 by astronaut Bill Anders, who captured it aboard Apollo 8 as it orbited the moon on Christmas Eve, it was the first-ever color photograph of Earth taken from space. Showing a cerulean planet rising over a gray moon in the vast blackness of space, it triggered in Anders and many others an "aha!" moment where they realized for the first time Earth's inherent fragility. Just two years after "Earthrise" was taken, environmentalists organized the first-ever Earth Day in 1970.

And yet, NASA's most consequential photos of the planet aren't taken by astronauts using consumer-grade cameras. Instead, they're taken by satellites using sophisticated sensors that observe and analyze real-time

CONTINUED »

"Now, we have **27 years of data** from satellites that is exquisitely precise that proves global sea level is rising."

– KAREN ST. GERMAIN,
director, NASA's Earth Science Division

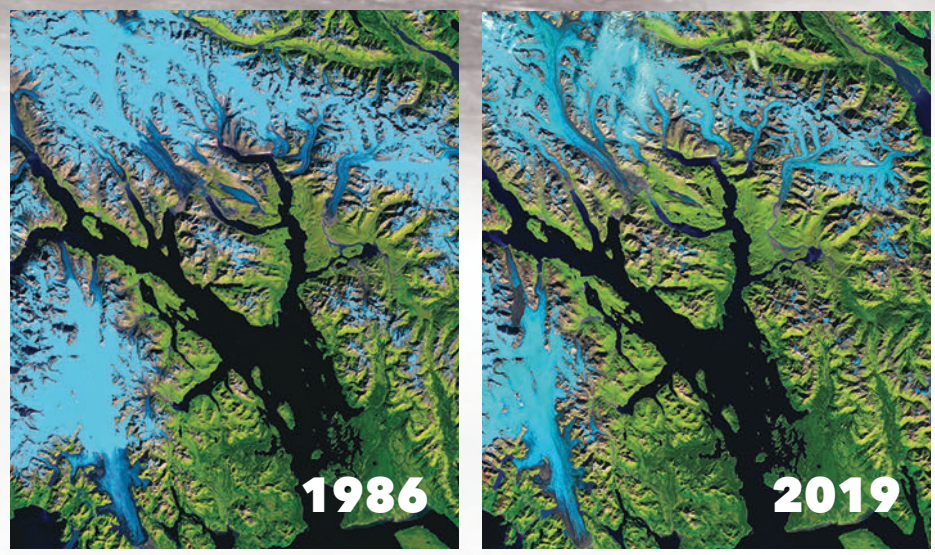
conditions in the air and on the ground.

Those sensors transmit high-resolution photographs as well as radar, multispectral, infrared and thermal images that help governments, businesses and scholars better understand the planet. Because it captures wavelengths that are invisible to the human eye, for example, NASA's multispectral imagery helps farmers assess crop health and estimate yield. By capturing ambient temperature data, its thermal imagery helps public health authorities understand the causes and transmission of waterborne diseases like cholera. Satellite imagery can even warn governments about water scarcity and poor air quality.

"Earth is our awesome planet. We rely on it for food, clean water and air that we can breathe ... imagine if those things were disrupted," says Karen St. Germain, director of NASA's Earth Science Division, whose mission is analyzing data from more than 30 NASA satellites, as well as from instruments that are located on the International Space Station, airplanes, balloons, ships and land. "Information (from satellites) ... helps avoid that."

In an era of accelerating climate change with profound social and economic consequences, satellite imagery is more critical than ever. Which is why NASA continues to develop new and improved platforms to generate it.

Its latest satellite, Sentinel-6 Michael Freilich — named for the late Earth Science Division director — will launch this fall with the goal of helping humanity respond to one of its most pressing climate-change crises: global sea level rise.



NASA EARTH OBSERVATORY

Images showing glaciers shown retreating in Alaska's Glacier Bay National Park.

RISE AND FALL

Since 1880, the average global temperature has increased by 2 degrees Fahrenheit due largely to greenhouse gas emissions from human activities like driving, manufacturing and energy production. Increased temperatures have caused glaciers and ice sheets to melt and seawater to warm, the impact of which is rising oceans, according to the National Oceanic and Atmospheric Administration (NOAA), which says the average global sea level has risen 8 to 9 inches in the last 140 years. In 2019, NOAA reports, global mean sea level was 3.4 inches above the 1993 average — the highest annual average on record.

And agencies like NOAA can quantify sea level rise precisely, thanks to satellites like Sentinel-6.

"When I was a graduate student in 1990, we didn't know quantitatively whether or how sea level was changing. Now, we have 27 years of data from satellites that is exquisitely precise that proves global sea level is rising," explains St. Germain, who notes the extent to which American citizens, businesses and military bases reside on coasts that are susceptible to swelling surf. "Given how much our global economy and national security infrastructure reside on the coast, understanding sea level rise and what it's going to mean is critically important."

It's reminiscent of an earlier environmental crisis in which NASA engaged — ozone depletion.

HOLE PICTURE

Since launching in 1978, NASA's Nimbus 7 weather satellite has been taking measurements using an instrument known as the Total Ozone Mapping Spectrometer (TOMS). In 1985, that instrument confirmed from space what scientists on Earth already had suspected based on ground and air observations — a perilous hole in the ozone layer.

"The TOMS observations that were made in 1985 led us to understand not only that there was depleted ozone over Antarctica, but that the ozone hole was enormous — the size of a continent — and that it was related to chlorofluorocarbons (CFCs), which were a commonly used aerosol propellant at the time in things like hairspray," explains St. Germain, who says NASA's ozone observations were a catalyst for the Montreal Protocol, an international treaty whose signatories agreed in 1987 to phase out the use of CFCs in order to protect the ozone layer.

NASA's latest observations show that Earth's ozone hole was the smallest ever measured.

"That's a complete story of how observations NASA made from space led to an understanding which (led to) policy decisions that have produced positive outcomes for our planet," says St. Germain, who hopes Sentinel-6 will be similarly impactful.

SEA VIEW

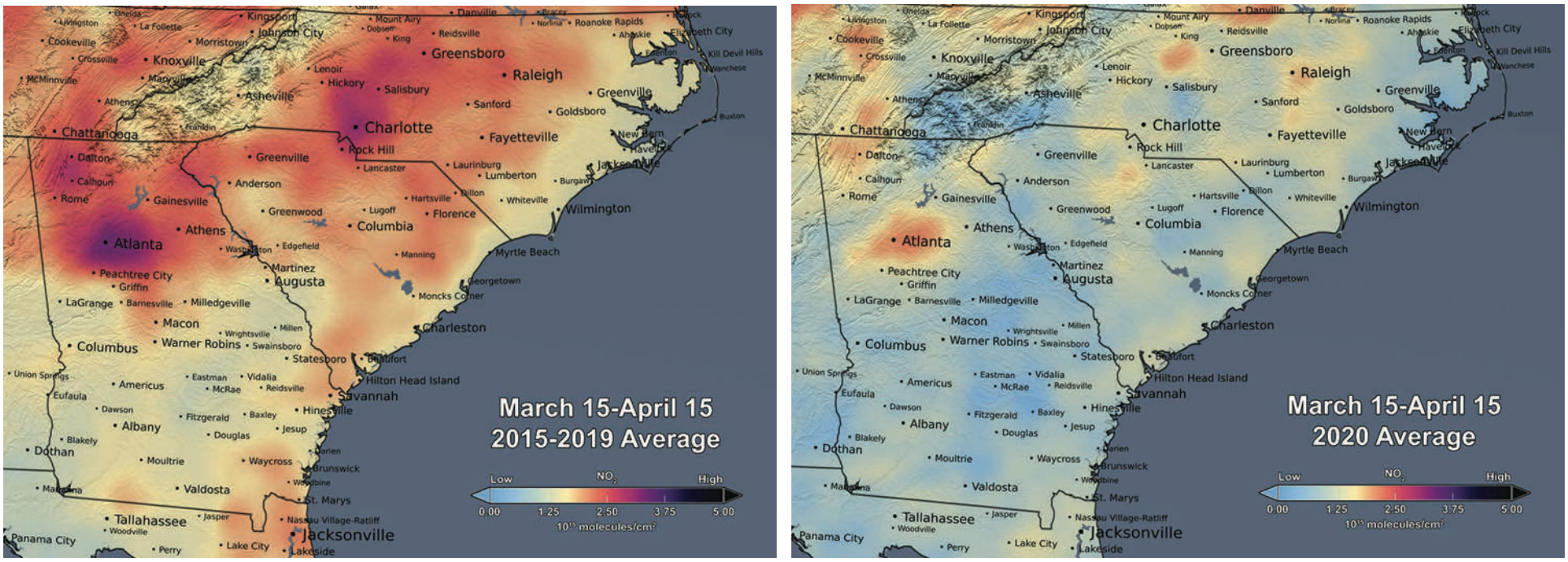
NASA has been measuring global sea level rise since 1992 when it launched the TOPEX/Poseidon satellite, whose measurements of ocean surface topography catalyzed nearly three decades of valuable research about sea level rise from climate change.

A joint mission between NASA and the European Space Agency (ESA), Sentinel-6 will be NASA's fourth "ocean altimeter" mission, behind TOPEX/Poseidon, 2001's Jason-1, 2008's Jason-2 and 2016's Jason-3. Launching on Nov. 10, it will be the first of two new satellites designed to measure the oceans' height. The mission's second satellite will follow in 2025.

Although it will perform the same task as its predecessors, Sentinel-6 will do it faster and better thanks to a next-generation radar altimeter that uses radio waves to measure water levels, according to project manager Parag Vaze, who says the new satellite will be able to analyze more data in greater detail within a shorter timespan — digesting sea level measurements down to the centimeter for 90 percent of the world's oceans in a matter of days instead of months.

Sentinel-6 will also be able to measure ocean altitude closer to the coasts than previous satellites, and will have secondary instruments on board to measure temperature and humidity in the atmosphere above the oceans. In addition to helping NASA forecast sea level rise, such data will help meteorologists improve hurricane forecasts, logistics companies improve ship routing, fishermen keep tabs on ocean currents, marine biologists protect endangered species and governments respond to environmental catastrophes such as oil spills.

CONTINUED »



NASA'S SCIENTIFIC VISUALIZATION STUDIO

While airplanes and cars were parked and industrial production slowed during the COVID-19 pandemic, NASA imagery shows the reduction of nitrogen dioxide emitted from burning fossil fuels.

ANALYZING EARTH WHILE THE WORLD TOOK A BREATHER

COVID-19 put a wrench in 50th anniversary Earth Day celebrations in April, which took place online due to the pandemic. It could not, however, dampen the day's spirit. In fact, Earth Day's environmental mission made new strides during the pandemic, when stay-at-home orders gave scientists the opportunity to analyze the Earth under new, eco-friendlier circumstances. With drivers staying home, planes parked in hangars and factories sitting idle, they wondered what the impact would be on the planet.

In order to answer that question, NASA's Earth Science Division established two portals – one exclusive to NASA, the other shared with international partners – to publicly collect and share Earth observations made from space. First, NASA scientists watched light pollution. When light at night declined relative to pre-pandemic levels, it indicated decreased economic activity. Next, the scientists correlated decreased economic activity with other observations, like concentrations of the air pollutant nitrogen dioxide in the atmosphere. In the northeast United States alone, nitrogen dioxide declined by 30 percent in March 2020 compared to March 2019.

NASA Earth Science Division director Karen St. Germain says it's too early to draw conclusions from pandemic data. While researchers continue their work, however, citizen scientists can explore on their own at *eodashboard.org* and *earthdata.nasa.gov/covid19*.

– Matt Alderton

"The oceans make a very, very large contribution to weather patterns around the world," Vaze says. "Being able to understand — and more importantly, predict — those weather patterns in the ocean just like we do in the atmosphere … has all sorts of societal applications, from commerce and shipping to agriculture."

SCIENCE FOR SOCIETY

Sentinel-6 offers a preview of NASA satellites to come. Also in development are the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission, which will help scientists identify harmful algal blooms in oceans by measuring water color; the Surface Water Ocean Topography (SWOT) mission, which will give scientists their first comprehensive view of Earth's freshwater bodies from space; and the Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission, which will improve air-quality forecasts by measuring atmospheric pollution over North America on an hourly basis and at a high spatial resolution. Launching in 2022, each will yield new data that governments and businesses can use to become more efficient, productive and intelligent.

What makes NASA's Earth observations so critical, however, isn't just what they can do for the economy. Ultimately, it's what they can do for existence, suggests data from the World Economic Forum, whose 2020 Global Risks Report names escalating environmental threats — including extreme weather, natural disasters, biodiversity loss and climate action failure — as humanity's most pressing concerns.

"Humans are a big part of the overall Earth system," says Lawrence Friedl, director of the Applied Sciences Program within NASA's Earth Science Division. "If people can gain a better understanding of how the decisions they make are both influenced by the environment and affect the environment, we can have a more sustainable future."

In service of that future, St. Germain set two main objectives when she took the reins of the Earth Science Division in June. One is making it easier for end users to access and use NASA's Earth observations. The other is increasing the speed and quality of those observations by leveraging new technology and international partnerships. Because they're the size of a suitcase instead of a school bus, new, miniaturized "smallsats" can help NASA iterate more quickly and affordably, as can collaborations like its Sentinel-6 endeavor with ESA, which accelerates progress through cost sharing.

"To understand, predict and help people prepare is more important now than ever. And I believe that what we do in the next decade is really going to lay the foundation for how well we're able to manage in the rest of the century beyond that," St. Germain says.