Thirty Years Reporting on NASA's Earth Science Program

The Earth Observer

National Aeronautics and Space Administration

May – June 2019. Volume 31, Issue 3

Editor's Corner

Steve Platnick

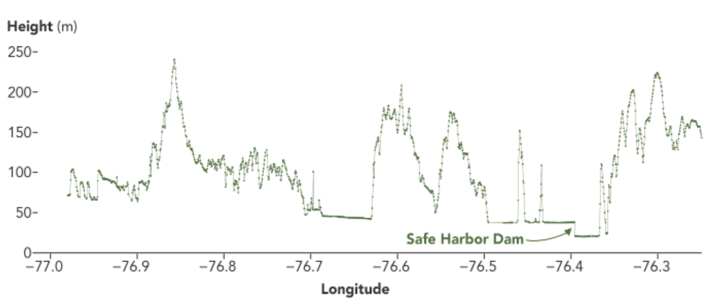
EOS Senior Project Scientist

Another mission has been successfully deployed on the International Space Station (ISS).[1] On May 4, 2019, the Orbiting Carbon Observatory–3 (OCO-3) mission was launched from Cape Canaveral Air Force Station in Florida on SpaceX's Commercial Resupply Mission 17.

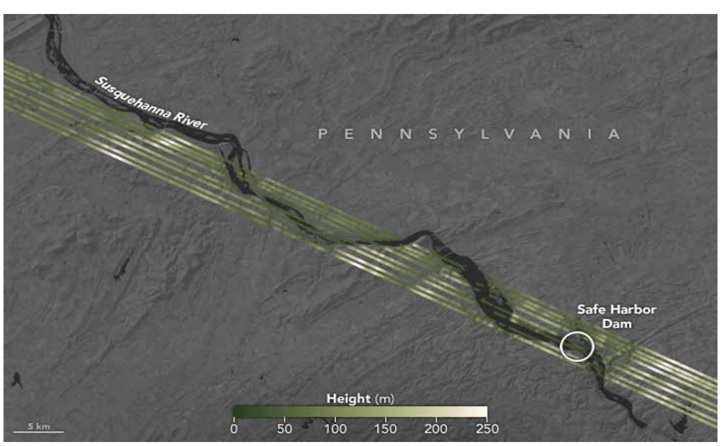
Two robotic arms welcomed OCO-3 upon its arrival at the station on the Dragon capsule: one to pull OCO-3 out of the capsule's trunk and another to install it on the Japanese Experiment Module-Exposed Facility (JEM-EF). This installation was completed by May 10. Over the next two days, a functional checkout took place and OCO-3's Pointing Mirror Assembly (PMA) was deployed. The PMA and context cameras then performed an initial survey of OCO-3's surroundings to make sure nothing unexpected was interfering with its view of Earth. The PMA uses two pairs of mirrors to rotate in two complementary directions—one parallel to Earth's surface, the other

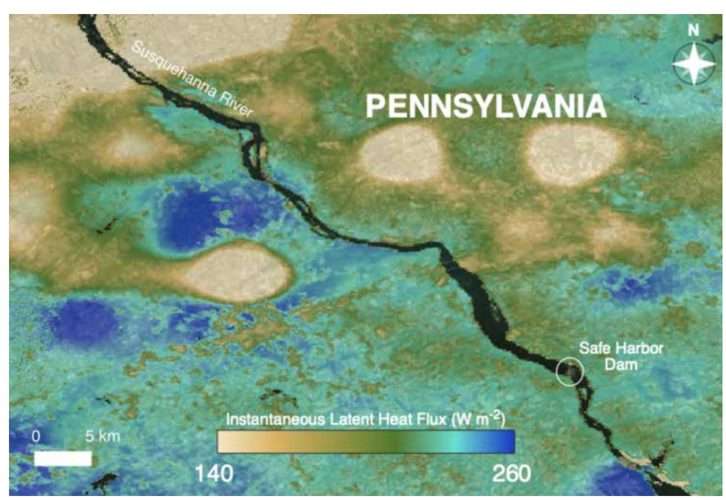
[1] In addition to OCO-3, GEDI, and ECOSTRESS discussed herein, the Stratospheric Aerosol and Gas Experiment III (SAGE III), Total and Spectral Solar Irradiance Sensor-1 (TSIS-1) and Lightning Imaging Sensor (LIS) are currently operational on ISS. The Cloud–Aerosol Transport System (CATS) and Rapid Scatterometer (RapidScat) missions were previous NASA missions that operated on ISS.

continued on page 2



The data shown here are from a single GEDI laser track (one of eight such tracks produced by GEDI's three lasers) and were obtained in April 2019 as the ISS passed over the hills and fields on either side of the Susquehanna River's winding riverbanks in southeastern Pennsylvania. Notice the precipitous drop in the GEDI data plot. The accompanying topographic map with all eight GEDI overpass tracks superimposed on it [*bottom left*] confirms the source of the drop was Safe Harbor Dam, located about 15 km (9 mi) southwest of Lancaster, PA. The ECOTRESS map of instantaneous latent heat flux [*bottom right*] also shows the area around Safe Harbor—but was obtained on August 24, 2018. Blue indicates higher transpiration rates; tan indicates lower transpiration rates. Now that GEDI and ECOSTRESS (and OCO-3) are all installed on the JEM-EF of the ISS, an image pair similar to this one could be obtained on the same day, affording researchers an unprecedented view of ecosystems through near-coincident retrievals of evapotranspiration, biomass structure, carbon dioxide, and solar induced fluorescence. **Image credits:** GEDI Team *https://gedi.umd.edu*, NASA's Earth Observatory *https://earthobservatory.nasa.gov/images/144818/return-of-the-gedis-first-data*; ECOSTRESS—ECOSTRESS Team *https://ecostress.jpl.nasa.gov*.





In This Issue

Reminder: To view newsletter images in color, visit *eospso.nasa.gov/earth-observer-archive.*

perpendicular. This setup allows OCO-3 to point to just about anywhere within view of the ISS and capture snapshot maps of carbon dioxide (CO_2) over areas of interest.

In a manner similar to that of OCO-2, OCO-3 will also measure *solar induced chlorophyll fluorescence* (SIF)—a very faint glow that plants emit during photosynthesis. OCO-3's SIF measurement will have the same high resolution as OCO-2's, and the new PMA adds the ability to swivel and point its sensors at towers on the ground where SIF is monitored locally, collecting data on almost the same spatial scale as these towers so that the satellite measurements can be validated.

OCO-3 builds upon the successful OCO-2 mission, which—since its launch in 2014—has been measuring CO_2 distribution in Earth's atmosphere, and detecting emission hotspots and volcanoes. Complementing OCO-2's Sun-synchronous orbit, OCO-3 will make observations from just after sunrise to just before sunset over a ±52° latitude range.

Two other NASA Earth Science instruments already installed on the JEM-EF are GEDI and ECOSTRESS. *The Earth Observer* reported previously on the successful launch and installation on the JEM-EF of both these missions.[2] Together, these three ISS-mounted instruments offer an unprecedented, synergistic view of ecosystems through near-coincident retrievals of evapotranspiration, biomass structure, CO_2, and SIF.

All GEDI systems received a green light for operation at the end of March 2019, after which the collection of science data began. GEDI's primary mission is to decipher forest structure using lidar to measure the elevation of the canopy and the forest floor, as well as the vertical distribution of leaves and branches. GEDI's three lasers produce eight individual tracks with 25-m diameter footprints, separated by roughly 500 m across track—see lower left image on front cover for illustration of the eight tracks. Each laser fires about 250 times per second to capture detailed profiles of forests, fields, and hills. The *News* story on page 25 of this issue has more information on GEDI, including one of its earliest data retrievals, obtained as GEDI flew over a South Carolina forest in winter 2019.

In addition to observing forest structure, GEDI gathers other topographical information. The top left image on the front cover of this issue shows a profile obtained from one of GEDI's eight tracks as the ISS passed over the hills and fields on either side of the Susquehanna River in southeastern Pennsylvania. The GEDI lasers were able to detect the Safe Harbor Dam, which is located about 15 km southwest of Lancaster, PA.

ECOSTRESS's high-resolution, multispectral, thermal imagery (8 to 12 μm) is being used to measure plant temperature. That information is used to better understand how much water plants need and how they respond to stress. Over 18,000 ECOSTRESS scenes with a nadir spatial resolution of 69 m x 38 m have been acquired to date, with each scene covering an area of 400 km^2. The ECOSTRESS team implemented a new approach for data acquisitions in May 2019 that should allow approximately three times more data to be acquired than originally proposed. The team is working to synchronize ECOSTRESS acquisitions with OCO-3

[2] For ECOSTRESS, see the Editorial of the July–August 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 4**, p. 1]; for GEDI see the Editorial of the November–December 2018 issue [**Volume 30**, **Issue 6,** p. 1].

and GEDI, in order to derive landscape composition, structure, and function. The bottom right image on the front cover shows an ECOSTRESS image of the area around Safe Harbor Dam.

In other mission-related news, more than a trillion new height measurements from NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) are now available to the public through the NSIDC DAAC (*https://nsidc.org/data/icesat-2*).

ICESat-2 was launched in September 2018, and its instrument—the Advanced Topographic Laser Altimeter System (ATLAS)—began collecting data in October 2018. As of this writing, ATLAS and ICESat-2 continue to operate nominally and collect science-quality data. The initial data are repeatable to better than 13 cm for individual measurements, and when heights are averaged over 1 km, that number decreases to 2 to 3 cm. The geolocation of these data is accurate to approximately 10 m—frequently even less.

Over the next several weeks, the mission will catch up to its nominal data latency of about 45 days. ICESat-2 continues the record of polar height data begun with the first ICESat satellite (which operated from 2003 to 2009) and the airborne Operation IceBridge mission, which "bridged the gap" between the two satellites.

This issue of *The Earth Observer* contains a feature article that presents an overview of the Group on Earth Observations Global Agriculture Monitoring Initiative (GEOGLAM) Crop Monitor for Early Warning (CM4EW; *https://cropmonitor.org*). The GEOGLAM community, with international support from the U.S. Agency for International Development (USAID) and NASA Harvest,[3] created CM4EW to address the critical need for enhanced early warning of crop production shortfalls around the world. The goal is to provide transparent and multisource consensus assessments of crop-growing and agroclimatic conditions that are likely to impact production in at-risk countries. The feature also includes a case study of how the CM4EW products have been used as a reliable source of information on crop conditions in Southern Africa to better inform food-security decisions, and to increase access to information on the progress of droughts and other disasters and their impacts on crops. Turn to page 4 to learn more about CM4EW.

Last but not least, as it has done for the past seven years, NASA hosted its seventh annual Earth Day celebration in the Main Hall at Union Station in Washington, DC, April 22 and 23. This year's event took place during a year that features many milestone anniversaries for NASA Earth Science missions—including Landsat 7's twentieth, Terra's twentieth, Aura's fifteenth, and the GPM Core Observatory's fifth. Earth Day 2019 afforded opportunities to acknowledge and celebrate several of these NASA commemorations. This was another extremely successful outreach event for NASA. Many thanks to all participants and the Science Communications Support Office for organizing this activity each year. Turn to page 15 of this issue to learn more about this year's Earth Day celebration at Union Station. ■

[3] NASA Harvest is a new food security and agriculture consortium—led by the University of Maryland—to enhance the use of satellite data in agricultural decision making. The feature article on page 4 of this issue provides additional context for the Harvest program.

List of Undefined Acronyms Used In Editorial and Table of Contents

DAAC	Distributed Active Archive Center
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
GEDI	Global Ecosystems Dynamics Investigation
GEOGLAM	Group on Earth Observations Global Agriculture Monitoring Initiative
GPM	Global Precipitation Measurement
GWIS	Global Wildfire Information System
GOFC–GOLD	Global Observation of Forest and Land Cover Dynamics
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
USAID	United States Agency for International Development.

Increasing Information Access for Food Security Monitoring: Overview of the GEOGLAM Crop Monitor for Early Warning (CM4EW)

Christina Justice, University of Maryland, College Park; justicec@umd.edu
Inbal Becker-Reshef, University of Maryland, College Park; ireshef@umd.edu
Brian Barker, University of Maryland, College Park; bbarker1@umd.edu
Ritvik Sahajpal, University of Maryland, College Park; ritvik@umd.edu
Tamuka Magadzire, Famine Early Warning Systems Network; tmagadzire@fews.net

Introduction

Over 10% of the global population is undernourished—this according to a 2018 report from the United Nations' (UN) Food and Agriculture Organization's (FAO) called *The State of Food Security and Nutrition in the World* (*http://www.fao.org/3/i9553en/i9553en.pdf*). Of this population, the majority are in developing countries where the situation is only worsening. Timely and reliable information on crop conditions and early warning of impending shortfalls of crop production are critical to achieving food security and ensuring sufficient, reliable food availability and access. Satellite-based Earth observations significantly contribute towards providing such crucial crop information, allowing decision makers to track crop development and general condition throughout the growing season, and ultimately supporting decision-making processes related to early disaster response and mitigation measures that reduce food insecurity.

Satellite-based Earth observations significantly contribute towards providing...crucial crop information, allowing decision makers to track crop development and general condition throughout the growing season, and ultimately supporting decision-making processes related to early disaster response and mitigation measures that reduce food insecurity.

In response to the critical need for enhanced early warning of crop production shortfalls—and with international support from the U.S. Agency for International Development (USAID), NASA Harvest,[1] and a range of international partners—the Group on Earth Observations Global Agriculture Monitoring Initiative's (GEOGLAM) developed the Crop Monitor for Early Warning (CM4EW). This article presents an overview of the CM4EW, and a case study of where the CM4EW products have been used as reliable sources of information on current crop conditions in Southern Africa. These tools have been used to better inform food security decisions around the world, and to increase access to information on the progress of droughts and other disasters (e.g., flooding, extreme weather events, regional conflict, pestilence, and disease outbreaks) and their impacts on crops.

Background on CM4EW

GEOGLAM launched the CM4EW following the successful development of the Crop Monitor for the Group of 20 (G20) Agricultural Market Information System (AMIS) [CM4AMIS], which was developed with NASA Applied Sciences and a wide range of international support. In 2011, GEOGLAM and AMIS were both endorsed by the G20 agriculture ministers as part of their *Action Plan on Food Price Volatility and Agriculture*, to increase the availability, quality, and transparency of agricultural information to better inform decision makers. The ministers believed that crop condition information from Earth observations would help provide objective information to market actors and help to mitigate food price spikes that can result from unreliable or incomplete information.

AMIS requested that GEOGLAM develop a platform to provide an international consensus on crop conditions. The CM4AMIS focuses on the four major global commodity crops (wheat, maize, soybeans, and rice) within the major production and export countries and provides an international monthly consensus on crop conditions. The success of the CM4AMIS prompted a parallel effort, the CM4EW, focused on countries at risk of food insecurity. There was recognition of the pressing need for enhanced, reliable, and vetted information on crop condition within these at-risk countries. As a result, the CM4EW was initiated in 2016 through cooperation between the University of Maryland, College Park

[1] Harvest is a new, multidisciplinary program commissioned by NASA and led by the University of Maryland, College Park, to enhance the use of satellite data in decision making related to food security and agriculture, domestically and globally. To learn more visit *https://nasaharvest.org.*

(UMD), UN FAO, the UN's World Food Programme (WFP), USAID's Famine Early Warning Systems Network (FEWSNET), European Commission's Joint Research Center, GEOGLAM Asian Rice Crop Estimation and Monitoring (Asia-RiCE), and the South African Agriculture Research Council (ARC).

The CM4EW is an international initiative that provides transparent and multisource consensus assessments of crop-growing and agroclimatic conditions that are likely to impact production in at-risk countries. The objective of the CM4EW initiative is to exchange information, build consensus, and reduce uncertainty surrounding crop condition assessments in support of agricultural and humanitarian decision making.

The CM4EW works to increase coordination across agencies and organizations responsible for regular crop assessments in regions most at risk to food insecurity. This initiative brings together the main international food security monitoring agencies and organizations that are already monitoring food security and crop conditions as part of their early warning activities. In addition to those already mentioned in this article, this includes the FAO's Global Information and Early Warning System (GIEWS), WFP Vulnerability Assessment and Mapping (VAM), Asia-RiCE, and the Intergovernmental Authority of Drought and Development Climate Prediction and Applications Centre (IGAD ICPAC). In addition to the main international agencies and organizations, national institutions such as the South African ARC, the Ministry of Agriculture Livestock and Fisheries for Tanzania, and the Office of the Prime Minister in Uganda are involved and come together to develop monthly crop assessments based on satellite observations, meteorological information, field observations, and national reports, which reflect an international consensus on current crop conditions. The CM4EW relies heavily on satellite-derived vegetation indices and agroclimatic indicators from a range of NASA satellites and instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS),[2] Visible Infrared Imaging Radiometer Suite (VIIRS),[3] the Soil Moisture Active Passive (SMAP) mission, and Global Precipitation Measurement (GPM) Core Observatory, as well as on other international satellites such as the European Space Agency's Copernicus Sentinel missions.

The objective of the CM4EW initiative is to exchange information, build consensus, and reduce uncertainty surrounding crop condition assessments in support of agricultural and humanitarian decision making.

These time series datasets, along with crop maps and crop calendars, are compiled into a database accessible through an online interface for use by CM4EW's partners. In addition to the information provided, partners use the interface to submit monthly crop condition assessments from their own organizations' satellite data and ground reports to build consensus crop conditions based on the best available information. This information is summarized in a monthly bulletin on crop conditions over countries at risk of food insecurity—see *The CM4EW Bulletin* on page 6 to learn more.

Early warning of impending shortfalls in crop production can better inform governmental and humanitarian responses to disaster. In many countries at risk of food insecurity, access to frequent and updated information on crop development and condition is scarce due to the high cost that is needed to conduct regular field assessments. Due to these limitations, detailed crop and food security field assessments are infrequent or irregular. In areas where information is scarce and uncertainty is high, consensus-driven, reliable, and timely information on crop conditions as provided by the CM4EW provide frequently updated and key evidence of current conditions and potential shortfalls in production that may impact food security.

Case Study: Operational Use of CM4EW in Africa

The remainder of this article presents a case study of how the information generated by the *CM4EW Bulletins* provides critical information towards government and humanitarian response to food security concerns in Southern Africa over three of the past four growing seasons. (2015–2016, 2017-2018, 2018-2019). It also demonstrates how CM4EW can be used to track the development of drought and natural disasters and their impacts on crop conditions throughout the growing season.

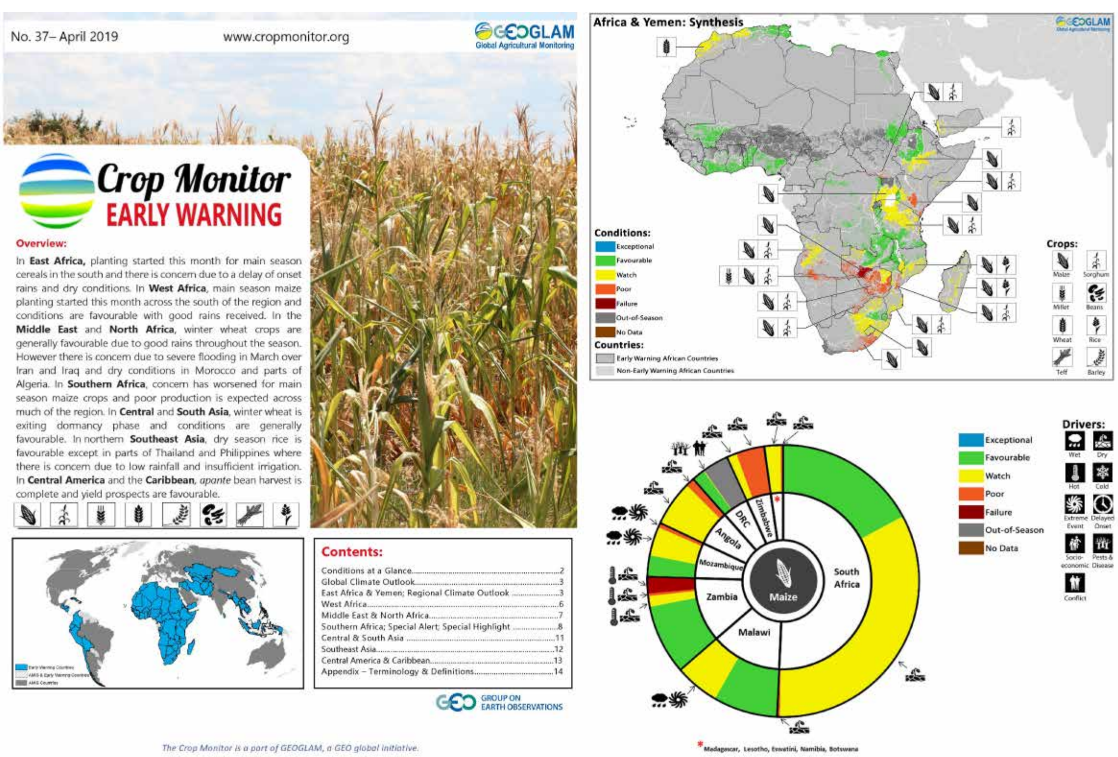
[2] MODIS flies on NASA's Terra and Aqua platforms.
[3] VIIRS flies on NOAA–NASA Suomi National Polar-orbiting Partnership platform and NOAA-20

The CM4EW Bulletin

The primary output of the CM4EW initiative is the monthly *CM4EW Bulletin*, designed to communicate consensus-based actionable information on current crop conditions to agencies concerned with food security and targeted for quick ingestion and use, primarily by users who are not necessarily familiar with remote sensing. The *CM4EW Bulletin* allows users to track current crop conditions throughout the season. This information becomes even more important during times of drought and disaster when early warning of impending shortfalls in production can better inform government responses and humanitarian efforts as well as to increase access to information for disaster coverage by the media.

The monthly bulletins include an overview of conditions by region, summaries of global climatic events that may adversely impact crop production [i.e., El Niño Southern Oscillation (ENSO)], and regional crop condition summaries covering Early Warning areas of interest (e.g., East Africa, West Africa, Southern Africa, Middle East and North Africa, Central and South Asia, Southeast Asia, Central America, and the Caribbean). Crop condition classes within the CM4EW are defined with respect to expected yields over a subnational region as compared to the five-year average, and include the condition classes of *Exceptional*, *Favourable*,* *Watch*, *Poor*, and *Failure*. Textual summaries of current conditions are supplemented with a number of products including crop condition maps indicating subnational conditions with their associated driver of crop conditions (when conditions are other than favourable); crop specific maps with crop-stage calendar; and production weighted pie charts.**

In cases where conditions are other than favourable, primary drivers for these conditions are provided and include such factors as *wet*, *dry*, *hot*, *cool*, *extreme event*, *delayed onset of rains*, *pest and disease*, *socioeconomic*, and *conflict*. Examples of the *CM4EW Bulletin* products are shown here. Archives of this month's current bulletin and previous publications by the CM4EW can be found at *www.cropmonitor.org*.



Products from the April 2019 *CM4EW Bulletin*, including the main cover page, Africa synthesis map (showing current conditions), and a production weighted pie chart for Southern Africa. Several of the Figures in this article come from the *CM4EW Bulletin*. **Image credit:** CM4EW Bulletin, April 2019

* *The Earth Observer*'s normal style is to use American English spellings of words. However, since the labels on the graphics throughout the article use the British spelling of "favourable", we are making an exception on this word.

** For these pie charts, each slice of the pie represents a country's share of total regional production (five-year average). Main producing countries (representing 95% of production) are shown individually, with the remaining 5% grouped together. The proportion within each national slice is coloured according to the crop conditions within a specific growing area; grey indicates that the respective area is out of season. Sections within each "slice" are weighted by the subnational production statistics (five-year average) of the respective country. The section within each national slice also accounts for multiple cropping seasons (i.e. spring and winter wheat). When conditions are other than "favourable," icons are added that provide information on the key climatic drivers affecting conditions.

In Southern Africa, the main cropping season runs from November through May. The 2015-2016 season was one of the driest in over 35 years, due to an El Niño-induced drought. According to the 2016 Southern Africa Development Community (SADC) *Regional Vulnerability Assessment and Analysis Synthesis Report*, following the 2015-2016 cropping season, regional cereal production was 10% below the 5-year average and 40-million people were left food insecure, with 25.6-million of those in need of emergency food assistance. As the season progressed, monthly CM4EW crop condition assessments indicated the severity of the unfolding drought, and in early February 2016 a joint statement released by CM4EW key partners outlined food-security impacts and short-term actions needed to respond to this crisis. This statement included the joint assessment from the *CM4EW Bulletin* reflecting a shared view of current conditions over Southern Africa based on analysis of data from satellite remote sensing and ground reports, and garnered high international visibility.

As the season progressed, monthly CM4EW crop condition assessments indicated the severity of the unfolding drought, and in early February 2016 a joint statement released by CM4EW key partners outlined food-security impacts and short-term actions needed to respond to this crisis.

One example of the satellite-based information sources used as evidence for this statement was MODIS-derived normalized difference vegetation index (NDVI), an indicator of "greenness," as depicted in **Figure 1.** In late February, the SADC, with

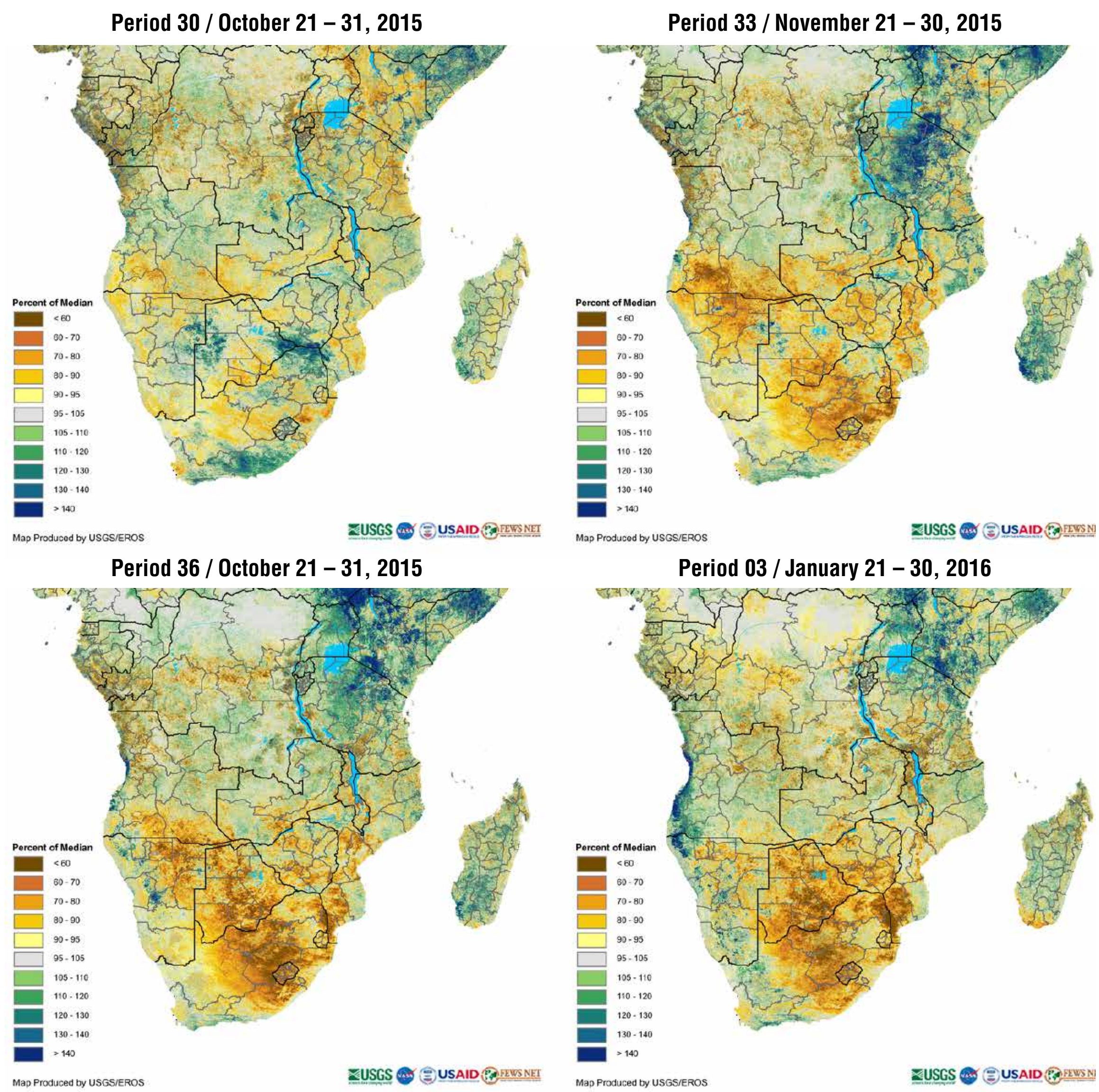


Figure 1. MODIS-derived NDVI expressed as a percent of median* for October 21-31, 2015 [*top left*], November 21-30, 2015 [*top right*], December 21-31, 2015 [*bottom left*], and January 21-31, 2016 [*bottom right*]. **Image credit:** USGS EROS.

* *Percent of median* is expressed as a percentage. Values between 95 and 105 indicate average conditions; values below 95 indicate below-average conditions; and values above 105 represent above-average conditions.

the support of several CM4EW partners including WFP and FAO GIEWS, held a consultative meeting on the impacts of, and response to, the El Niño-induced drought. This ultimately resulted in a recommendation for the declaration of a regional drought disaster by the SADC Council of Ministers in March. The information provided was ultimately used by the government in South Africa to inform their food mobilization response and impact assessments. The SADC has since used the *CM4EW Bulletin* as a source of key information on in-season crop-growing conditions, and has cited such information in seasonal updates and reports to SADC member countries.

The consensus crop conditions provided from the ***CM4EW Bulletin*** *... proved important in building evidence throughout the growing season towards final crop conditions and agreement over the areas worst affected by drought and where lowered yields resulted... .*

During the 2017-2018 main cropping season in Southern Africa, dry conditions at key stages in crop development caused increasing concern for regional production and high uncertainty in national crop conditions due to the difficulty in assessing the extent of the damage. The season started normally with rains in November that lasted through December, but then came an extended dry spell with unusually high temperatures in January. While rainfall picked up later in February, early-planted crops were already damaged beyond recovery, leading to reduced yields across the worst-affected areas. This seasonal progression from initial concern in January through to post-harvest conditions at the end of the season in July is shown in **Figure 2**.

The consensus crop conditions provided from the *CM4EW Bulletin*—i.e., combining Earth observations with field-based observations and national reports—proved important in building evidence throughout the growing season towards final crop conditions and agreement over the areas worst affected by drought and where lowered yields resulted, shown as poor conditions in the bottom panel of **Figure 2**—on page 9. Following this early season drought in 2018, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) put out a special report for Southern Africa that voiced support for products like the monthly *CM4EW Bulletin* and requested more-frequent and -detailed information on current crop conditions as can be provided from satellite-based remote sensing sources combined with national reporting and field assessments.

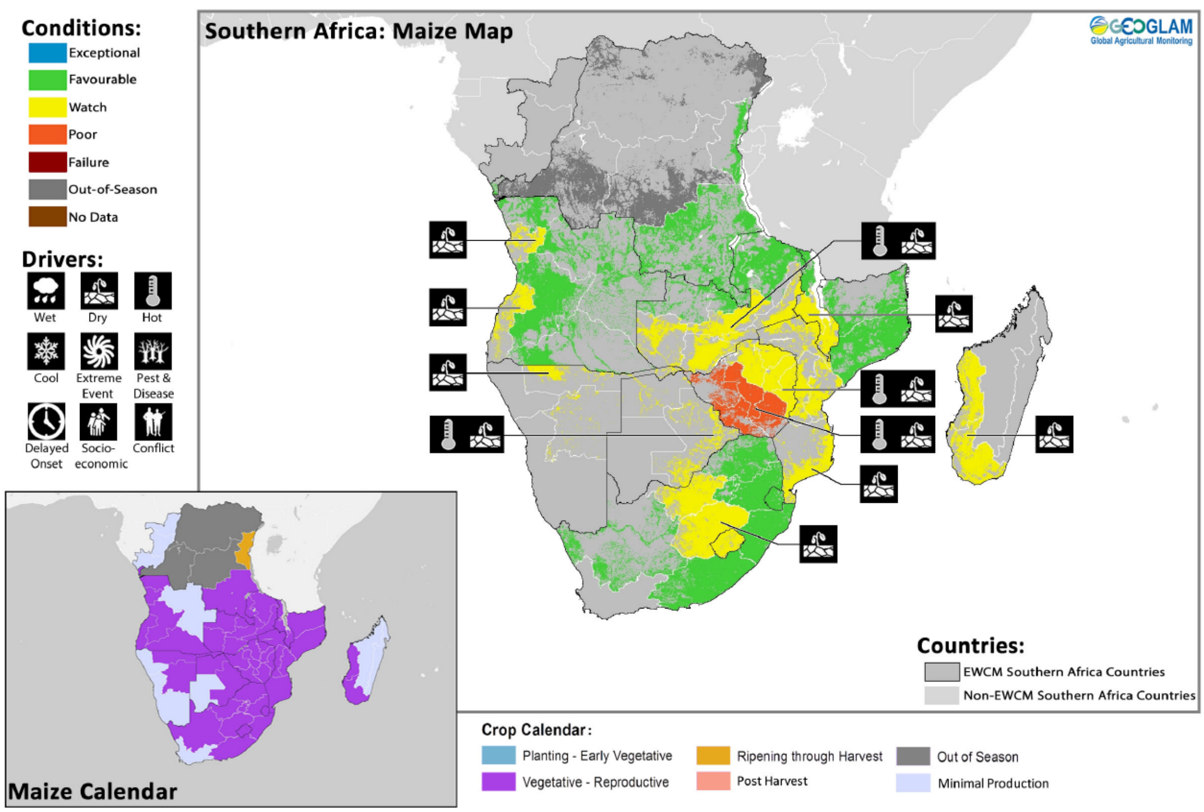
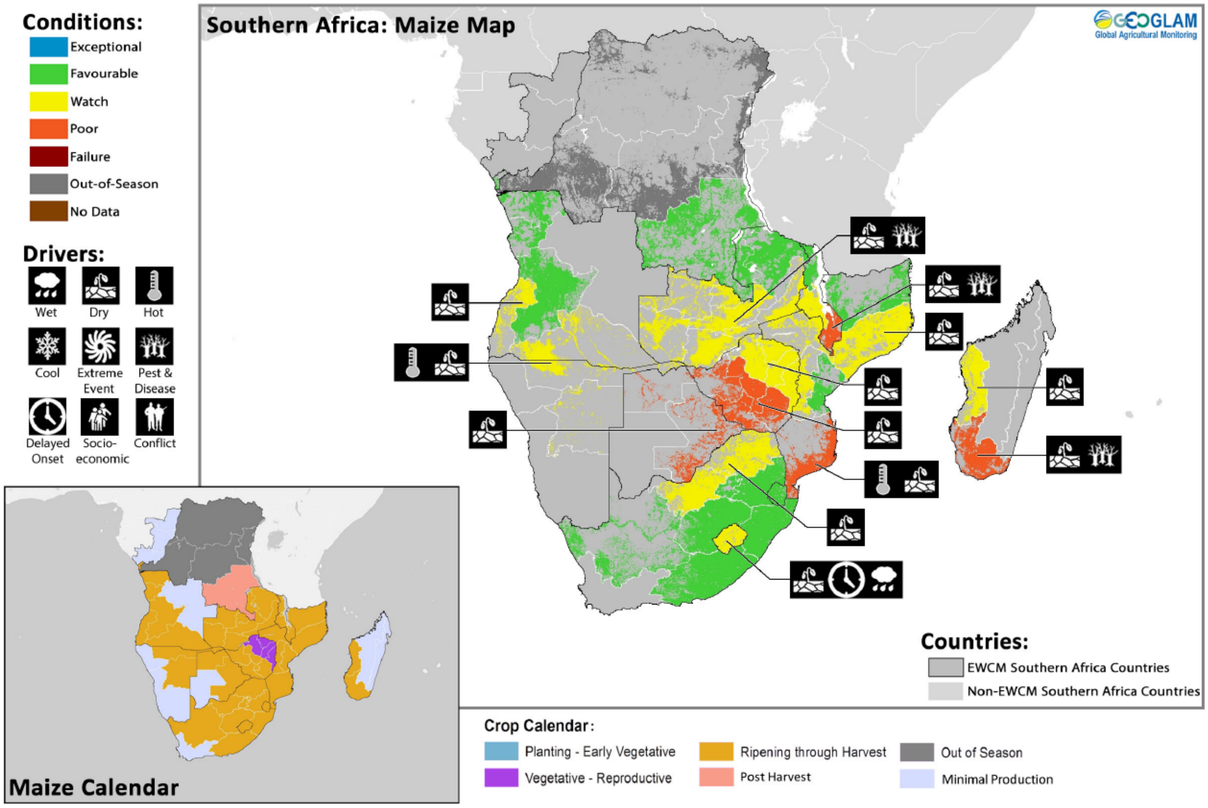
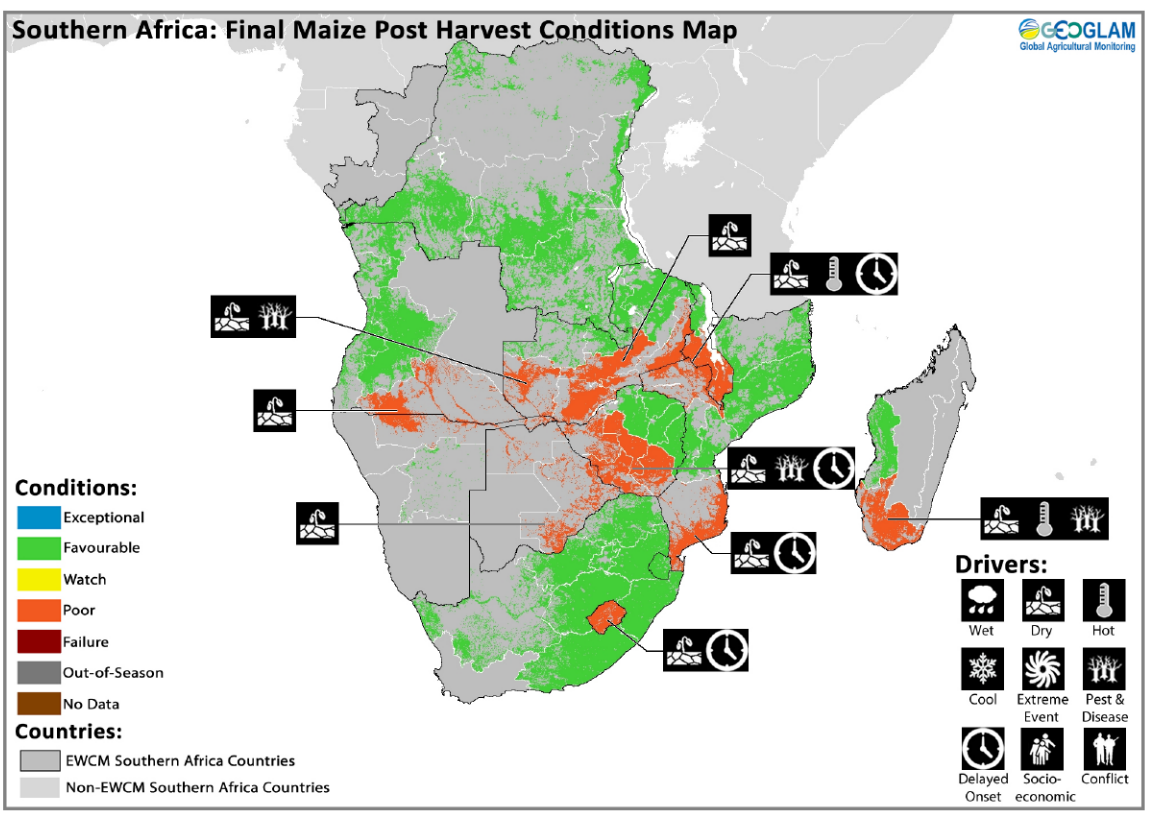


Figure 2. Southern Africa crop condition map summarizing maize condition for January 2018 [*above*], March 2018 [*next page, top*], and the June 2018 final post-harvest [*next page, bottom*]. Crop conditions over the main growing areas are based on a combination of inputs including remotely sensed data, ground observations, field reports, and from national and regional experts. **Image credit:** *CM4EW Bulletin*, February, April, and July 2018.


Southern Africa: Maize Map
GEOGLAM
Global Agricultural Monitoring
Conditions:
Exceptional
Favourable
Watch
Poor
Failure
Out-of-Season
No Data
Drivers:
Wet
Dry
Hot
Cool
Extreme Event
Pest & Disease
Delayed Onset
Socio-economic
Conflict
Countries:
EWCM Southern Africa Countries
Non-EWCM Southern Africa Countries
Maize Calendar
Crop Calendar:
Planting - Early Vegetative
Vegetative - Reproductive
Ripening through Harvest
Post Harvest
Out of Season
Minimal Production


Southern Africa: Final Maize Post Harvest Conditions Map
GEOGLAM
Global Agricultural Monitoring
Conditions:
Exceptional
Favourable
Watch
Poor
Failure
Out-of-Season
No Data
Countries:
EWCM Southern Africa Countries
Non-EWCM Southern Africa Countries
Drivers:
Wet
Dry
Hot
Cool
Extreme Event
Pest & Disease
Delayed Onset
Socio-economic
Conflict

The current (2018-2019) cropping season marks another case of concern for food security in the region.

The current (2018-2019) cropping season marks another case of concern for food security in the region. The rains, which normally begin in November, were delayed by a month across many parts of Southern Africa. The CM4EW December 2018 monthly assessment reported initial concern across the Southern Africa region—see **Figure 3**—with emphasis on the expectation for worsening conditions due to 2018-2019 precipitation forecasts. Precipitation forecasts for early 2019 showed high probability for reduced precipitation amounts and potential for El Niño development, which could lead to further rainfall reductions across the region.

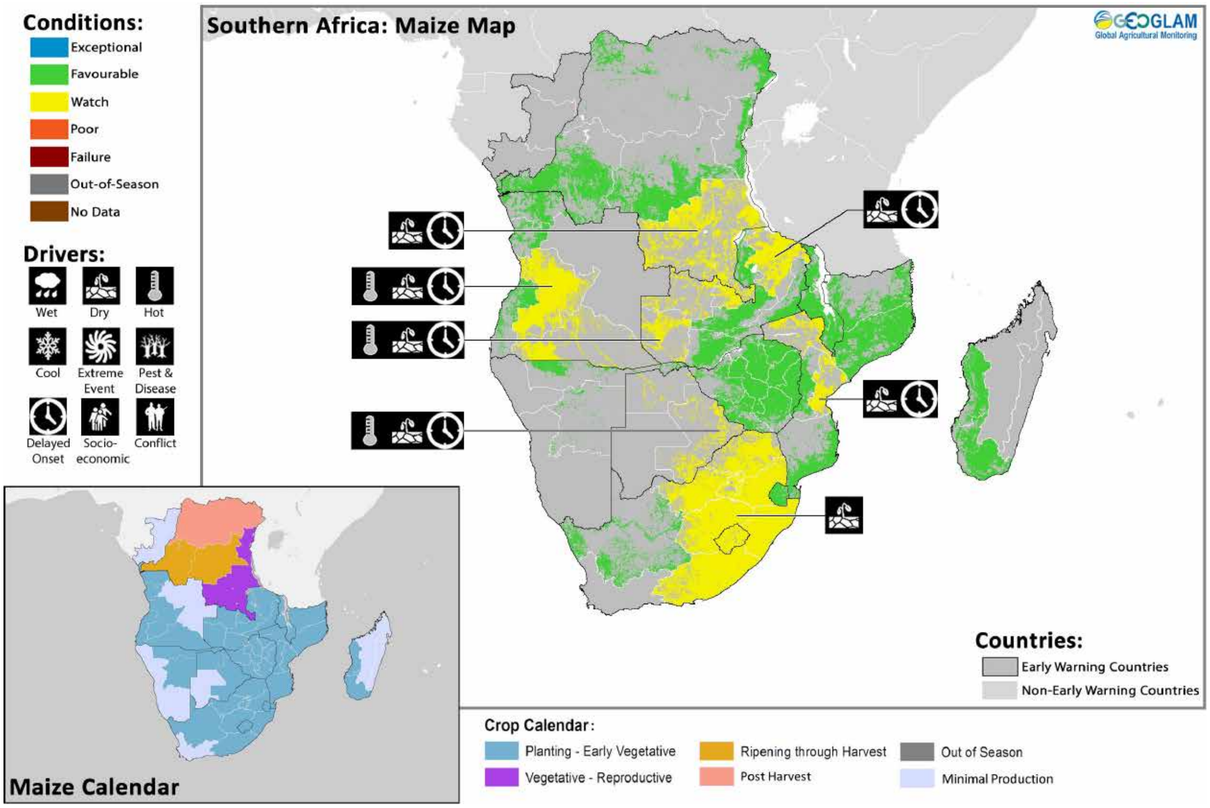


Figure 3. Southern Africa maize map summarizing crop conditions as of November 28, 2018. **Image credit:** *CM4EW Bulletin*, December 2018.

The initial one-month delay in the start of the rainy season...resulted in reduced planted area across some of the key maize-growing areas of South Africa and Zambia.

The initial one-month delay in the start of the rainy season (described above) resulted in reduced planted area across some of the key maize-growing areas of South Africa and Zambia. Some rainfall came early in January, reducing rainfall deficits in the eastern portions of the region. However, this was followed by a number of long dry spells, the most significant of which lasted between four and six weeks from mid-February to late-March across the central and western portions of the region, resulting in widespread crop wilting across the worst affected areas of Angola, Namibia, Botswana, Zimbabwe, and the southern parts of Zambia and Mozambique. The high-producing region of southern Zambia was at the epicenter of this dry spell. Analysis of the Climate Hazards Center InfraRed Precipitation with Station (CHIRPS) rainfall dataset[4] indicates that a number of districts in southern Zambia, in addition to parts of Namibia, Botswana, and southern Angola, experienced their driest season since at least 1981, with implications not just for crops but also for livestock and water security. This has resulted in poor conditions across much of the region and failure across the worst-affected areas of southern Zambia, as shown in the May 2019 *CM4EW Bulletin*—see **Figure 4** next page.

[4] CHIRPS is a 30+-year, quasiglobal, rainfall dataset curated by the Climate Hazards Group at the University of California, Santa Barbara. Spanning 50°S to 50°N (and all longitudes), starting in 1981 and continuing to the near-present CHIRPS incorporates 0.05°-resolution satellite imagery with *in situ* station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

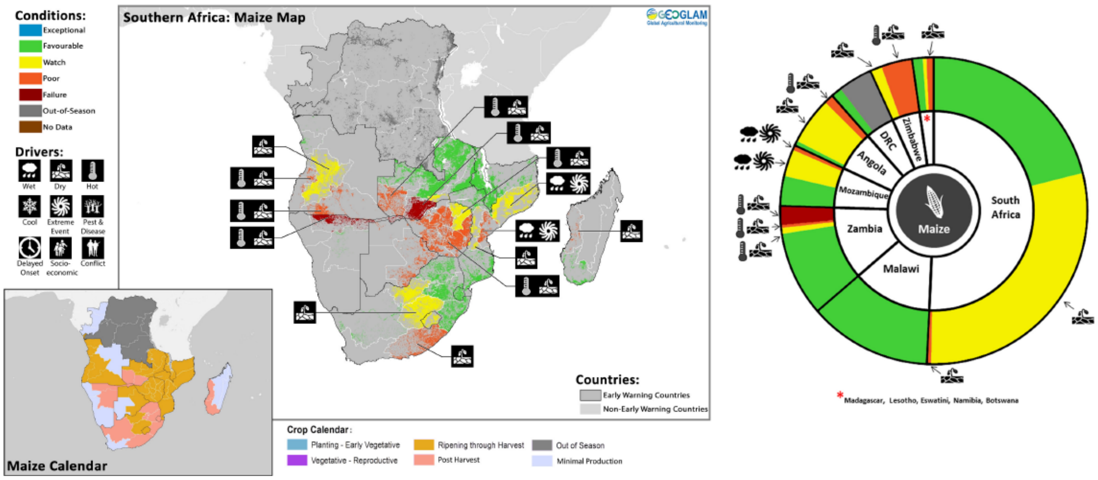


Figure 4. Southern Africa maize crop condition map summarizing crop conditions and drivers as of April 28, 2019, and associated production-weighted pie chart. **Image credit:** CM4EW Bulletin, May 2019.

Graphs produced by NASA Harvest, including NASA-sourced data as shown in **Figure 5** and **Figure 6** (next page), depict the severity of the current situation in Free State Province, South Africa, and Southern Province, Zambia, two major maize-producing areas for Southern Africa. From the start of the season in November 2018, in Free State, South Africa, cumulative precipitation was well below the five-year average, as were the NDVI, evaporative stress index (ESI), and soil moisture. The downward trend in all these parameters continued until some rainfall in late January and early February improved crop development, as shown in Figure 5. Despite improvements, however, production prospects still remain below average.

In Southern Province, Zambia, this same pattern of delayed rains was present at the start of the season followed by a number of long dry spells that negatively affected crop growth, the latest and most damaging of which was the six-week dry spell across the high-producing region of Southern Zambia. Cumulative precipitation, nationally, is at record lows and far below the five-year average (as shown in Figure 6) in addition to significantly below-average NDVI, ESI, and soil moisture levels. In normal years, Zambia is a surplus maize producer and an important regional exporter. Following impacts from drought, national maize production is expected to be below average for the second consecutive year. While production and carry-over stock may be sufficient to meet domestic markets, regional export potential will most likely be negatively affected.

The 2018-2019 maize harvest was completed in May. With widespread drought conditions and below-average production and production prospects across key producing areas, regional maize supply is of increasing concern. The CM4EW reporting has tracked this development throughout the season and worked to give the most updated analysis to current conditions. In response to the 2018 request from OCHA, midmonthly updates have been activated for Southern Africa, and will continue to be regularly updated until the end of the season to ensure continuity in the flow of updated and accurate information throughout the season.

Plans for the Future of CM4EW

While the CM4EW partnered initially with the main international organizations in monitoring food security, this initiative is now working to build capacity at the regional and national scales for crop-condition monitoring, and is engaging in partnerships with local institutions and organizations to strengthen and expand the Early Warning community. Given the importance of forecasts in predicting crop outcomes, the CM4EW has recently started to integrate short-term and seasonal regional forecasts into the monthly bulletins in partnership with the University of California Santa

Given the importance of forecasts in predicting crop outcomes, the CM4EW has recently started to integrate short-term and seasonal regional forecasts into the monthly bulletins in partnership with the University of California Santa Barbara Climate Hazards Center.

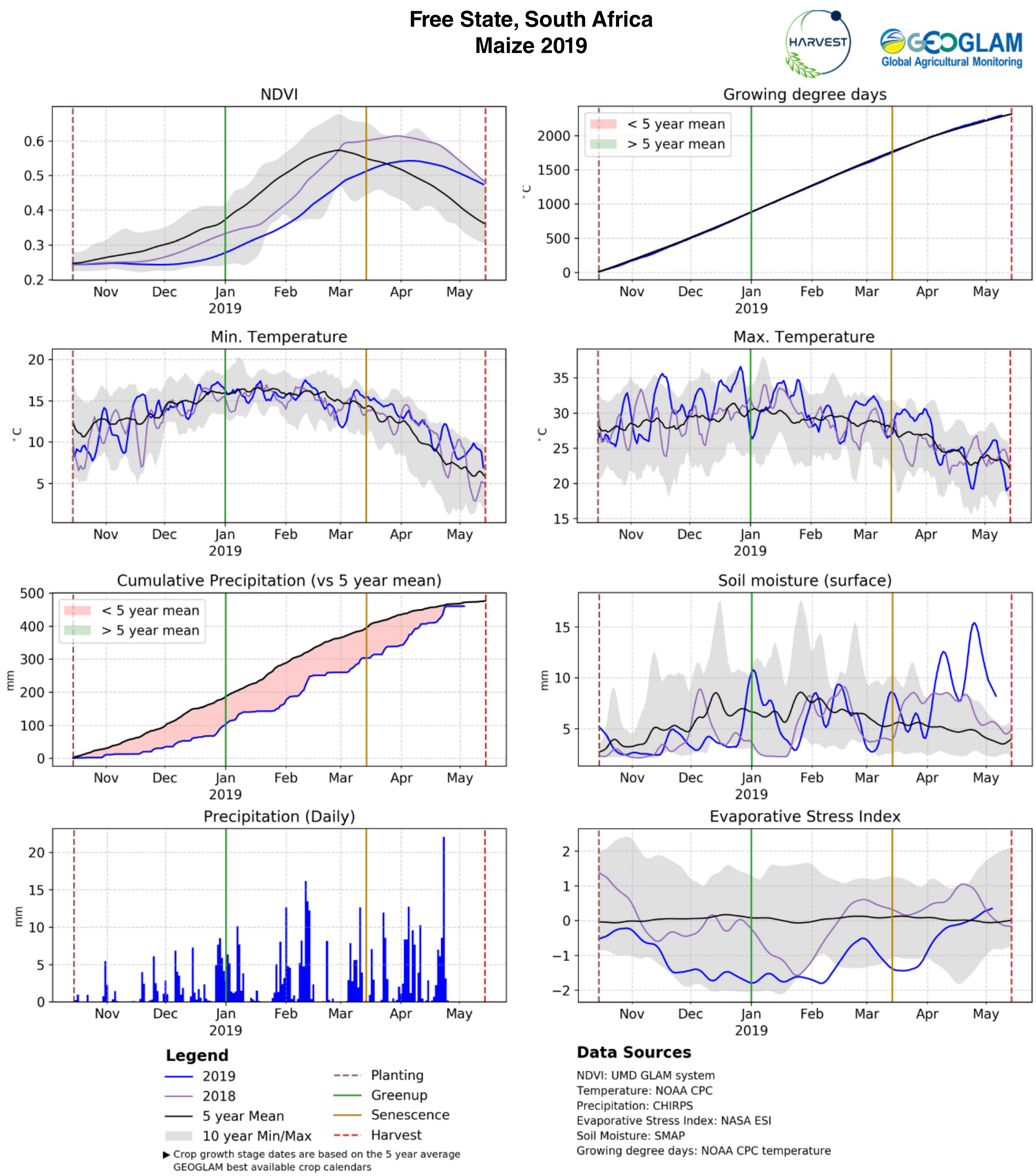


Figure 5. Agroclimatic indicators over maize regions in Free State, South Africa, during the 2019 summer cropping season. Drier-than-average conditions early in the season followed by rain events in early January and early-to-mid-February have helped to spur crop development. **Image credit:** NASA Harvest.

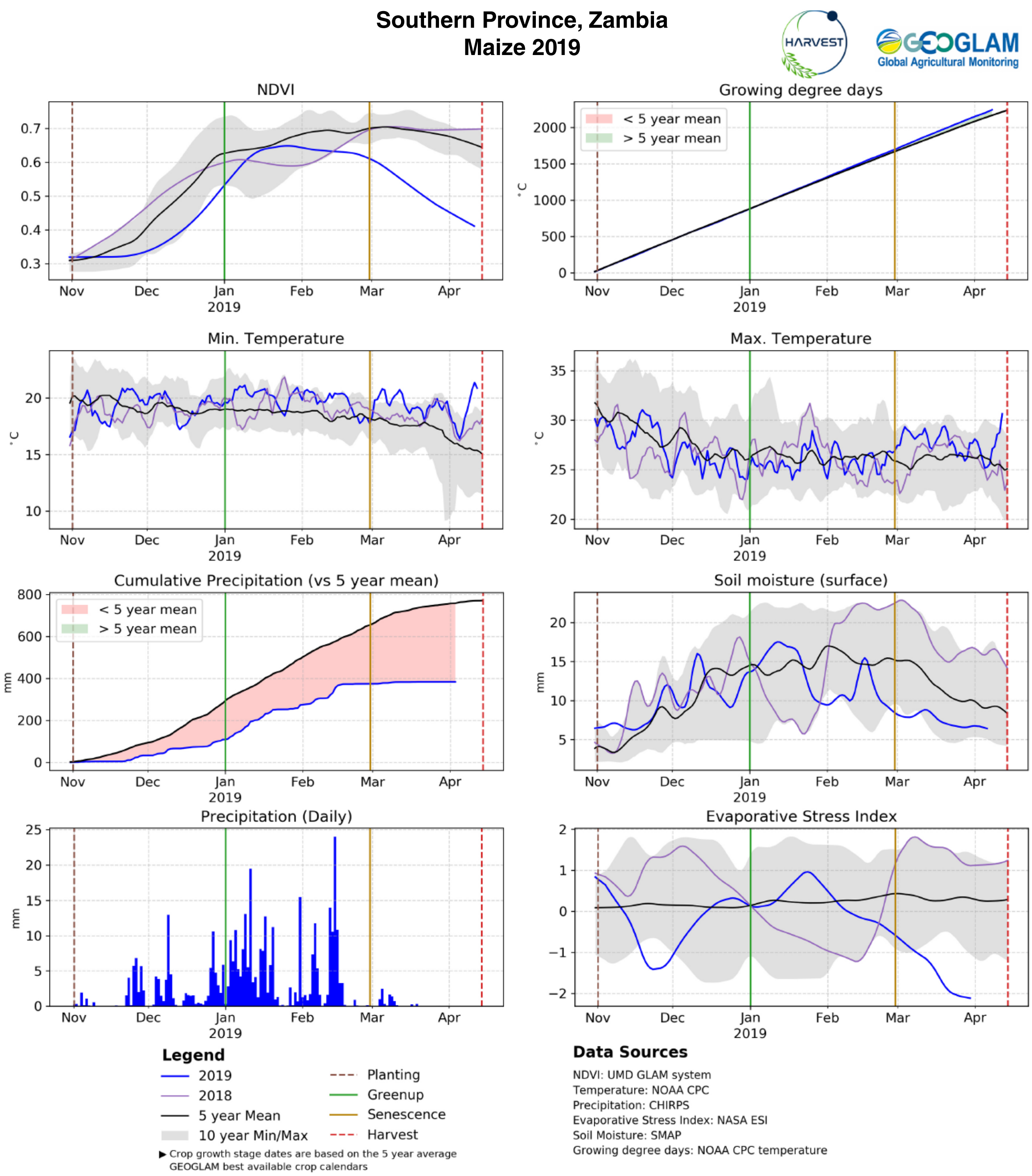


Figure 6. Agroclimatic indicators over maize regions in Southern Province, Zambia, during the current 2019 summer cropping season. Drier-than-average conditions early in the season were followed by a number of long dry spells later on, further damaging crop development. **Image credit:** NASA Harvest.

Barbara Climate Hazards Center. These forecasts provide insight into and early warning of climate events that may impact crop production, such as precipitation and temperature anomalies and the El Niño Southern Oscillation (ENSO). Additionally, in many Early Warning countries, rangelands are an important part of food security and population livelihood. This year the CM4EW will partner with the rangeland community to develop a rangelands-monitoring component as part of reporting activities. Most recently, in response to the OCHA request last year for more-detailed and -frequent in-season reporting efforts as provided by CM4EW, the CM4EW community is now publishing midmonth updates and special reports for countries and regions where more-detailed and -frequent reporting is necessary at the height of the season and in the face of natural disaster. These special reports include additional remote sensing information and analysis, updated forecasts, and integrated market and trade information to tell the full story of current conditions and to provide up-to-date information. The first special highlight, published in March 2019, provided an update to midmonthly conditions across Southern Africa and outlined the early development and impacts from Cyclone Idai in Mozambique and surrounding countries. This reporting continued in the main April *Bulletin,* and updates tracking the spread of the disaster and the status of recovery efforts continued through mid-April.

The CM4EW provides an important advance in the use of Earth observations for food security and has helped to raise the awareness and demand for Earth observations, such as those provided by NASA and other space organizations and the private sector, in support of crop monitoring and food security decisions.

Conclusion

In the short time since being initiated in 2016, the CM4EW has been recognized as a reliable source of vetted information on current crop conditions through its use by humanitarian and governmental organizations, and is already being used to inform agricultural decision making at the national scale. The CM4EW provides an important advance in the use of Earth observations for food security and has helped to raise the awareness and demand for Earth observations, such as those provided by NASA and other space organizations and the private sector, in support of crop monitoring and food-security decisions. Analysis of satellite data offers key insight into crop conditions and development throughout the growing season, allowing early detection of potential impacts on production. With early warning of production shortfalls and increased reliability of crop-growing conditions and status, actions can be taken by government and humanitarian organizations to trigger relief response mechanisms in advance of serious food security concerns. ■

Hands-On with NASA: An Earth Day Experience

Doug Bennett, NASA's Goddard Space Flight Center, Global Science and Technology, Inc., doug.bennett@nasa.gov
Heather Hanson, NASA Goddard Space Flight Center, Global Science and Technology, Inc., heather.h.hanson@nasa.gov

Introduction

According to Earth Day Network, an estimated 1-billion people in 192 countries now participate in what has become the largest day of action in the world for the general public—Earth Day. The first Earth Day, which took place in 1970, is credited with launching the modern environmental movement, leading to passage of landmark laws in the U.S., including the *Clean Air, Clean Water, and Endangered Species Acts*. Earth Day 2019 (April 22) was specifically designated to focus our attention on an ever-widening set of global environmental challenges, from climate change to air and water pollution to loss of biodiversity.

Next year—2020—will mark Earth Day's fiftieth anniversary. This momentous celebration comes during a season of milestones for NASA. Last year was the agency's sixtieth anniversary, and the sixtieth anniversary of the launch of Explorer 1—the first satellite launched by the U.S. Several other prominent NASA Earth Science anniversaries—including Landsat 7's twentieth, Terra's twentieth, Aura's fifteenth, and the Global Precipitation Measurement (GPM) Core Observatory's fifth—either have occurred or will occur during 2019. In addition to Earth Science anniversaries, February marked the sixtieth anniversary of the launch of Vanguard II, which laid the foundation for space-based remote sensing as we know it today,[1] and July will mark the fiftieth anniversary of the Apollo 11 Moon landing. Earth Day 2019 afforded opportunities to acknowledge and celebrate several of these NASA commemorations.

[1] To learn more about Vanguard, see "The Vanguard of Earth-Observing Satellites" in the March–April 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 2**, pp. 7-18—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Mar_Apr_2019_color_508.pdf#page=7*].

Celebrating Earth Day with NASA

Organized by the Science Mission Directorate's Science Communications Support Office (SCSO), NASA hosted its seventh annual Earth Day celebration at Union Station in Washington, DC, on April 22 and 23. The two-day event, which was free and open to the public, took place inside Union Station's historic Main Hall—see **Photo 1**. This central transportation hub is used by 25,000 to 30,000 people daily, enabling NASA to reach a large number of citizens in addition to nearly 500 students invited from local middle- and high-schools, including some from underserved communities.

NASA's exhibit featured 23 hands-on activities. Among the many possibilities, these enabled visitors to (for example) measure surface height using a miniature size ICESat-2 satellite; make Earth-imagery flipbooks; explore Earth's nearest neighbor, the Moon; use robotic arms to learn how robots service satellites in space; discover how NASA satellites monitor the health of plants by measuring reflected light at several wavelengths; and more—see **Table** on page 17 for a full listing. In addition to the hands-on activities, the exhibit featured a *Celebrate Apollo: Touch the Moon* module. This "touch-the-moon" experience allowed individuals to touch a sample of lunar rock—and is an activity created to celebrate the fiftieth anniversary of the Apollo Program.[2]

Each participating student and members of the general public were given an activity passport listing

[2] The Apollo Program began in 1963, and was designed to land humans on the Moon and bring them safely home to Earth. From October 2018 through December 2022, NASA plans activities to celebrate the 50th anniversary of the Apollo missions that landed a dozen Americans on the the moon between 1969 and 1972.

Photo 1. The NASA Earth Day 2019 exhibit took place inside the Main Hall of Washington, DC's Union Station. **Photo credit:** NASA

the 23 activities. After completing six or more such activities, participants could redeem their passport to receive a NASA drawstring bag filled with a wide range of NASA science materials. This was a successful approach: Nearly 1700 activity passports were distributed during the event. Student groups, families, and friends were encouraged to use a single passport during their visit, thus the number of actual participants is estimated to be much higher than 1700.

Photos 2–7 highlight how participants engaged with NASA's hands-on activities during the Earth Day event.

Photo 2. A group of eager local secondary school students takes a photo in front of a large inflatable Earth at the *#PictureEarth Selfie Station*, which encouraged participants to post photos on social media using the *#PictureEarth* hashtag. **Photo credit:** NASA

Photo 3. Participants at the *Global Precipitation Measurement (GPM) Mission* activity learned how data from NASA's GPM Mission are used in a variety of real-world applications to improve life around the world. **Photo credit:** NASA

Photo 4. Participants at the *Beyond Blue: Why Ocean Color Really Matters* activity discovered how NASA monitors ocean-color variations to detect microscopic marine life, such as phytoplankton. **Photo credit:** NASA

Photo 5. NASA staff demonstrated how ultraviolet (UV) light reacts with UV-sensitive beads, causing them to change color. Participants were shown how to assemble bracelets using the special beads. **Photo credit:** NASA

Photo 6. Students learned how clouds form by creating their own "cloud in a bottle" at the *NASA GLOBE Program* activity station. **Photo credit:** NASA

Photo 7. Enthusiastic throngs of students and visitors discovered how NASA science missions continually yield new insight into how and why planet Earth is changing. **Photo credit:** NASA

Table. Hands-On Activities at NASA's 2019 Earth Day celebration.

Activity Title	Description
What's Binary Code?	Participants used different-colored beads to encode the initials of their first and last names, demonstrating how computers process and store data using binary code.
Ultraviolet Beads	Participants became ultraviolet (UV) detectives, using specially designed UV-sensitive beads. They walked away with their very own UV-detection bracelet, demonstrating how NASA keeps a close eye on the Sun's UV radiation.
The Notion of Ocean Motion	In this hands-on activity participants explored how water moves throughout the ocean. By pouring fresh water on top of salt water in a tube, participants discovered how fluids move depending on their densities.
Earth Observatory (EO) for Kids: DIY Earth Science Flipbook	*EO Kids* is a new downloadable publication from NASA's Earth Observatory that is designed to make Earth science fun and engaging for kids. Participants were encouraged to explore stories and NASA data, and learn about our planet from a satellite's perspective, while making their own flipbook.
Exploring Earth's Neighbor: The Moon	Participants "claimed" their very own landing site on the Moon, while discovering how similar—yet quite different—the Moon and Earth are.
Spectral Signatures	In this hands-on activity, participants discovered how spectrometers work and how spectral signatures are used to classify land cover, demonstrating the way Landsat satellites use spectrometers to observe Earth's surface.
Spectral Measurements, Plant Health, and Your Health!	In this activity, participants learned how NASA helps monitor the world's food supply, discovering how satellite observations can detect the health of plants by measuring multiple wavelengths of reflected solar light. These observations provide scientists with data to help predict when and where crops are at risk from drought or air pollution.
Earth's Magnetic Shield	Participants explored how NASA studies the intense magnetic storms coming from the Sun, how those can interact with Earth's magnetic field and affect communications, and what can be done to protect astronauts in orbit as well as minimize or avoid power grid failures on Earth.
Understanding Earth's Water Cycle	Participants learned what the water cycle is, why it's important, and why it is the primary physics mechanism observed by the Joint Polar Satellite System (JPSS).
Beyond Blue: Why Ocean Color Matters	Participants discovered how NASA detects ocean life, and learned what phytoplankton are. This activity demonstrated that, while our ocean is generally seen as blue, it is really better described as being a broad spectrum of colors, depending on the microscopic life it hosts. Such variations are visible from space, thanks to NASA satellite technology.
The Global Precipitation Measurement (GPM) Mission	The GPM Core Observatory celebrated its fifth anniversary this year, and the data gathered from this mission are being used in a variety of real-world applications. Participants learned about the science and technology behind this mission and how the data are used to improve life all around the world.
The Greenhouse Effect on Earth and Other Planets	Our atmosphere works very much like a "greenhouse," allowing some heat from sunlight to stay trapped near the surface, thereby preventing Earth's oceans from freezing. Participants found out how this works on an Earth-sized scale and on other planets, with a science demonstration.
Satellite Servicing: Using Robots to Extend Satellite Lifetimes	Participants were invited to drive robot arms to learn about the tasks robots can perform in space—such as refueling satellites to keep them operational—and more about this new era of serviceable satellites.
NASA GLOBE Program	Participants were invited to create their own "cloud in a bottle" to visualize how clouds form. Also, participants learned to measure the temperature of an object without a thermometer touching it by using a hand-held infrared thermometer.

Activity Title	Description
Measure Heights with ICESat-2's Mini-Altimeter	Participants discovered how the ICESat-2 satellite (launched September 15, 2018) measures the height of Earth's ice, land, and water using a laser. Each participant made their own landscape and then measured it under the path of the "ICESat-2 mini-satellite," which took real-time measurements.
Earth Science Technology Office	Launching satellites into space to observe Earth is complicated—and expensive. From tiny satellites to smart sensors, NASA is building new technologies that will help us see our home planet as never before.
Worldview: Explore Your World	Visitors interactively explored and visualized NASA Earth science data to see hurricanes forming, wildfires spreading, icebergs drifting, and city lights illuminating. They could also take a snapshot, create an animated GIF, or compare imagery from two dates to view changes over time.
Physics of the Cosmos	Participants were invited to see a Spandex model of how a black hole warps the fabric of spacetime.
Hubble Space Telescope	Participants experienced the Hubble Space Telescope (HST) like never before, using augmented reality to "fly" through Hubble images and see how astronauts have repaired the HST in space.
Citizen Science with GLOBE Observer	Participants learned how to be a citizen scientist by using the free GLOBE Observer app to collect data that connects to information from NASA satellites, and practice their observational skills for looking at clouds, land cover, trees, and mosquito habitats.
Space Rocks	Participants became space rock experts and learned how to tell the difference between a meteorite and an Earth rock. They also learned about the goals of the Origins, Spectral Interpretation, Resource Identification, Security—Regolith Explorer (OSIRIS–REx) mission to a near-Earth asteroid.
Dynamic Planet	Participants used this touchscreen interface to drive a spherical display that showed a variety of remote-sensing satellite datasets.
#PictureEarth Selfie Station	Participants were invited to celebrate Earth Day with NASA and people all around the world by posting photos from this Earth Day selfie station on social media using the *#PictureEarth* hashtag.

Summary

NASA's 2019 Earth Day event at Union Station once again offered an exceptional opportunity to engage and enlighten a diverse cross section of citizens about NASA's key role in exploring and understanding our home planet. Face-to-face interactions between NASA staff, the general public, teachers, and student groups still prove to be one of the most effective and inspiring ways to connect with those who know little about the essential roles NASA plays in seeking new knowledge and understanding of not just our home planet, Earth, but of the Sun, the solar system, and the universe beyond.

To view more photos from these and other events supported by the SCSO, visit *https://www.flickr.com/photos/eospso/albums/with/72157681039942371*. ■

Summary of the 2018 GWIS and GOFC-GOLD Fire Implementation Team Meeting

Krishna Vadrevu, NASA's Marshall Space Flight Center, krishna.p.vadrevu@nasa.gov
Jesus San-Miguel-Ayanz, European Commission, Joint Research Center, Ispra, Italy, jesus.san-miguel@ec.europa.eu
David Roy, Michigan State University, roydavi1@msu.edu
Martin Wooster, Kings College, London, United Kingdom, martin.wooster@kcl.ac.uk
Ivan Csiszar, National Oceanic and Atmospheric Administration,ivan.csiszar@noaa.gov
Louis Giglio, University of Maryland, College Park, lgiglio@umd.edu
Everett Hinkley, United States Forest Service, ehinkley@fs.fed.us
Wilfrid Schroeder, National Oceanic and Atmospheric Administration, wilfrid.schroeder@noaa.gov
Chris Justice, University of Maryland, College Park, cjustice@umd.edu

Introduction

The third joint Global Wildfire Information System (GWIS) and Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)[1] – Fire Mapping and Monitoring Implementation Team (Fire-IT) meeting was held October 1-2, 2018, at the Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, College Park. GWIS sponsored the meeting while the GOFC-GOLD Fire-IT facilitated it. Nearly forty researchers from academia, government and non-government organizations participated in the meeting.

The meeting's goals were to review recent progress made by the Fire-IT, discuss recent developments, determine prospects of satellite-based fire monitoring and science for forest and natural resource management and other applications, and to promote collaborations in the international fire remote sensing community.

After some brief background on GWIS, GOFC-GOLD, and the Fire-IT, this article will then summarize the highlights of the GWIS and GOFC–GOLD Fire-IT meeting. The full presentations are available at *http://gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2018/index.php*.

Background on GWIS, GOFC-GOLD, and Fire-IT

The GWIS is an initiative of the Group on Earth Observations (GEO)[2] and the European Union's Earth-Observation Copernicus[3] program and is hosted by the European Commission, Joint Research Center (JRC), Italy. The GWIS aims to bring together GOFC-GOLD Fire-IT and existing GOFC-GOLD regional networks and information sources to provide a comprehensive view and enable evaluation of fire regimes and effects at a global scale via the Internet. The GWIS is supported by several partner organizations and space agencies and provides support for U.S.-funded investigators through the Applied Science Program of NASA's Earth Science Division.

GOFC–GOLD focuses on international coordination of enhanced Earth observations. It aims to improve the quality and availability of space-based and *in situ* observations at regional and global scales, and to encourage the generation and distribution of appropriate, timely, and validated products.

The Fire-IT is one of two GOFC–GOLD implementation teams (the other being Land Cover Characteristics and Changes). The activities that fall under the Fire-IT are aimed at refining and articulating the international observation requirements and making the best possible use of fire products from the existing and future satellite observing systems, for fire management, policy decision-making and global change research.[4] The Fire-IT is composed of experts from national and international space agencies, governmental, and non-governmental environmental organizations and universities. Three individuals co-chair the Fire-IT: Currently, they are **David Roy** [Michigan State University, U.S.],

[1] GOFC–GOLD is classified as a technical panel under the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information's (NCEI) Global Observing Systems Information Center's (GOSIC) Global Terrestrial Observing System (GTOS). It is an integrated, coordinated, international program working to provide ongoing space-based and *in situ* observations of the land surface to support sustainable management of terrestrial resources at different scales.

[2] GEO is a unique global network connecting government institutions, academic and research institutions, data providers, businesses, engineers, scientists, and experts to create innovative solutions to global challenges at a time of exponential data growth, human development, and climate change—circumstances that transcend national and disciplinary boundaries.

[3] Copernicus—the European Union's Earth observation program—is coordinated and managed by the European Commission, (effectively the EU's executive branch but with legislative powers), in partnership with the European Space Agency (ESA). To learn more visit *https://www.copernicus.eu/en.*

[4] For more details on the activities of the Fire-IT (as of September 2017) as well as those of other GOFC–GOLD elements, please see "Summary of the GOFC-GOLD Twentieth-Anniversary Regional Networks Summit" in the January–February 2018 issue of The Earth Observer [**Volume 30**, **Issue 1**, pp. 29-35—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Jan_Feb_2018_color508_0.pdf#page=29*]. Note: The Fire-IT is summarized on p. 31.

GWIS-GOFC GOLD meeting participants, College Park, MD, 2018. **Photo credit**: GOFC team

Martin Wooster [King's College London, U.K.], and **Jesus San-Miguel-Ayanz** [European Commission, JRC].

Thematic Science Presentations

The meeting commenced with opening remarks from the co-chairs (listed in previous paragraph), followed by several thematic science presentations.

Ivan Csiszar and **Wilfrid Schroeder** [both from the National Oceanic and Atmospheric Administration (NOAA)] provided updates on the active fire products generated by NOAA geostationary and polar-orbiting platforms. The polar-orbiting NOAA-20 satellite is now operational and flying 50 minutes apart from the Suomi National Polar-orbiting Partnership (NPP) satellite. Both satellites carry Visible Infrared Imaging Radiometer Suites (VIIRS), each imaging the entire globe every 12 hours or less, depending on the latitude. Csiszar described the two VIIRS active-fire global datasets that are generated at NOAA for both Suomi NPP and NOAA-20: a 750-m (~2460-ft) product based on the heritage Moderate Resolution Imaging Spectroradiometer (MODIS) fire algorithm and a newer 375-m (~1230-ft) product that uses a customized contextual algorithm. He noted that there is good agreement between the active fire detection statistics for both platforms, with the two-satellite configuration providing improved coverage over Suomi NPP alone. In addition to routine, near-real-time, fire-monitoring applications, he explained that the VIIRS active fire products are also used for smoke and air-quality monitoring and forecasting, and that VIIRS algorithm refinements are underway to incorporate atmospherically corrected fire radiative power (FRP) retrievals, to evaluate stringent tests to refine fire detection, and to consider a combined Suomi NPP and NOAA-20 higher-level product where confidence is partially determined based on the view angle. Csiszar stated that NOAA plans to transition to fully global operation using the VIIRS 375-m active fire detection product and phase out the 750-m product. Reprocessed, science-quality versions of the VIIRS fire products for Suomi NPP are generated by the NASA Suomi NPP Land Science Investigator-led Processing System (SIPS).[5] NASA is also generating Suomi NPP VIIRS global active fire data at both 375-m and 750-m resolutions in forward-processing mode.

Csiszar and Schroeder also presented details on the Advanced Baseline Imager (ABI), the radiometer on NOAA's GOES-R-series satellites (*https://www.goes-r.gov*), as an additional asset for detecting fires. The ABI views Earth with 16 spectral bands: two visible, four near-infrared, and ten infrared bands. Csiszar explained that the active fire product for GOES-R primarily uses the midwave infrared and infrared spectral bands, complemented by other bands, to locate fires and retrieve FRP and subpixel fire characteristics. In addition to fires, the GOES-R series has the ability to monitor smoke plumes in near-real time; this capability is particularly useful for fire management and mitigation efforts.

Schroeder noted that GOES-R series fire products are being validated using reference data from the Operational Land Imager (OLI) on Landsat 8. He also added that the use of GOES-17 data is currently being evaluated. Schroeder pointed out that the Landsat 8/OLI near-real-time active-fire algorithm is now implemented operationally at NOAA's Hazard Mapping System (HMS) and the U.S. Forest Service. He added that Landsat 8 image composites over the conterminous U.S. (CONUS), Alaska, and Hawaii are used in support of fire-data analysis by NOAA/HMS.

[5] NASA'S Earth Science Data and Information System (ESDIS) supports SIPS (geographically distributed around the U.S.) for data processing. There are four Suomi NPP SIPS: land, atmosphere, ocean, and sounders. Learn more at *https://earthdata.nasa.gov/about/sips*.

Furthermore, Sentinel-2[6] active fire products are being implemented, mimicking the Landsat 8/OLI data application for the U.S.

Mitch Goldberg [NOAA] presented details on the Coordination Group for Meteorological Satellites (CGMS), which was created in 1972 with activities governed by charter to consider common interests relating to the design, operation, and use of planned meteorological satellites. The mandate was later changed to include low-Earth-orbit (LEO) satellites. Currently, CGMS has an action to consider pilot projects related to fire, aerosols, and flood mapping. Goldberg noted that CGMS invited the AeroSat consortium[7] members and GOFC-GOLD team to provide an update on their research activities and to strengthen aerosol and fire studies, worldwide. He mentioned that one such endeavor is the Aerosol Comparisons between Observations and Models, or AEROCOM, project (*https://aerocom.met.no/*)

Martin Wooster [Kings College London, U.K.] provided updates on geostationary active fire systems and the FRP products, including forthcoming fire products from the European Space Agency's (ESA) polar-orbiting Sentinel-3 satellite. In terms of existing data products, he noted that a Meteosat Second Generation (MSG) FRP-PIXEL product for Africa is currently available from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)'s Land Surface Analysis Satellite Application Facility (LSA SAF) that provides information on the location, timing, and FRP of fires detected every 15 minutes across Earth's full disk at the native spatial resolution of the Spinning Enhanced Visible and Infrared Imager (SEVIRI). Shifting to another geostationary platform, Wooster explained that the Japanese Himawari-8 Advanced Himawari Imager (AHI) now provides views of Asian and Australian fires at an unprecedented 10-minute temporal resolution and 2-km (~1.2-mi) nadir thermal-channel spatial resolution. Onboard ESA's Sentinel-3 polar-orbiting Sentinel-3A and -3B satellites is the Sea and Land Surface Temperature Radiometer (SLSTR), which employs an along-track scanning, dual-view mechanism (nadir and backward oblique) to image Earth in nine channels in the visible-near infrared (VIS/NIR), thermal infrared (TIR), and short-wave infrared (SWIR). The SLSTR also provides two dedicated channels for fire and high-temperature event monitoring at 1-km (~0.6-mi) resolution, with detectors that can retrieve FRP over even very-high-intensity and very-large fires. The Sentinel-3 fire products are currently expected to become fully operational in 2019.

Francesca Di Giuseppe [European Centre for Medium-Range Weather Forecasts (ECMWF), U.K.] presented updates on fire danger assessment from the ECMWF Integrated Forecasting System (IFS). Since the end of 2017, the ECMWF has been serving as the computational center for the Fire-Copernicus Emergency Management Service providing the meteorological inputs and forest fire danger indices for the European Forest Fire Information System (EFFIS) and Global Wildfire Information System (GWIS) on a daily basis. Thirty-eight years of global fire danger using the ECMWF reanalysis (ERA) interim datasets at 80-km (~50-mi) resolution, derived from daily data and fire weather indices are available from *https://zenodo.org/communities/wildfire*. Further, the open source version of the ECMWF fire forecast model is available from *https://software.ecmwf.int/stash/projects/CEMSF/repos/geff/browse*.

Everett Hinkley [U.S. Forest Service (USFS)] provided an overview of the USFS—an agency of the U.S. Department of Agriculture (USDA) that supports wildfire management. He reported that an average of 5.9-million acres are burned annually in the U.S. The National Interagency Coordination Center (NICC) coordinates with ten local Geographic Area Coordination Centers (GACC) to mobilize suppression resources to support wildland fire and other incidents throughout the U.S. Additionally, the NICC, located in Boise, ID, also coordinates with GACCs to provide national-level, intelligence-related data products from the GACC's Predictive Services Unit, to be used by the wildland fire community in response planning and incident-management decision making. As an example, he described the USFS's National Infrared Operations (NIROPS) unit, which provides fire fighters with high-resolution airborne infrared imagery and fire-detection imagery to help them in their response.[8]

Alan Cantin [Canadian Forest Service] presented an outline of the fire-danger products generated in the Global Early Warning System–Fire (EWS-Fire).[9] The fire-danger indicators currently presented in GFEWS are components of the Canadian Forest Fire Weather Index (FWI) System. The GFEWS provides 1-to-10-day forecasted FWI data based on the Canadian Meteorological Centre's (CMC) Global Deterministic Forecast System. The FWI System components are currently calibrated to commonly used threshold values that identify low-to-extreme conditions. As such, the GFEWS provides a means of comparing relative fire-danger conditions between countries, continents, and biomes, and the 1-to-10-day forecast highlights the expected fire-danger trend. This type of information is useful for large-scale fire-management decision-making such as planning cross-border suppression resource exchanges. The fire indicators are being calibrated to the local fire regime,

[6] ESA's Copernicus Sentinel missions (*https://sentinel.esa.int/web/sentinel/home*) are designed to fulfill the operational needs of the Copernicus programme, mentioned earlier.

[7] AEROSAT is a consortium of experts on aerosol remote sensing from ground, aircraft and space. *https://aerocom.mpimet.mpg.de/index.php?id=2404*.

[8] A detailed description of NIROPS can be found at at *https://fsapps.nwcg.gov/nirops/pages/about*.

[9] To learn more about Global EWS-Fire, visit *http://gfmc.online/gwfews/overview.html*.

which includes the influences of fuel, ignition sources, climate, fire management, and fire-suppression policies. Cantin stated that future developments include refinement of the system by including fuel/fire behavior modeling, adding additional base layers such as land cover, and smoke forecasts to the system, and integration with GWIS and other global databases. More details can be found at *http://gfmc.online/gwfews/index-12.html* and *http://canadawildfire.ualberta.ca/gfews*.

Domingos Viegas [University of Coimbra, Portugal] presented a study focusing on the calibration of the Canadian Fire Danger Rating System over European Commission countries. The fire weather index output from the Canadian Forest Fire Danger Rating System (CFFDRS) has been used to assess the risk of fires or a large area burned in a given day for different areas in the European Union. The FWI is solely based on meteorological data. Viegas explained that data from the period 2006 to 2015 over the local administrative units designated as NUTS3 over Europe were used for calibration.[10] For each region and season, the probability of occurrence of FWI values and the corresponding number of fires (NF) and burnt areas (BA) on a daily basis were calculated using a probability distribution fitting approach. Using the probabilities of FWI, NF, and BA, the limits that define each class of fire risk danger (i.e., very low, low, moderate, high, very high) were established for the entirety of Europe. The results were added to the GWIS system.

Louis Giglio [University of Maryland, College Park] provided an update on the MODIS and VIIRS burnt area products. The MODIS Collection 6 product (MCD64A1) is defined for the global land surface from November 2000 to present. Operational production of MCD64A1 began in late 2016, and the products were publicly released February 2017. Compared to the MODIS Collection 5 products, a nearly 26% increase in burned area was observed globally. The MODIS burned area products are being validated to Stage 3 following the Committee on Earth Observations (CEOS) Land Product Validation (LPV) burnt area validation protocols using independent reference data from OLI. The Stage 3 Landsat independent reference dataset will be used to validate the forthcoming science-quality VIIRS burned area product (VNP64A1).

Mihai Tanase [University of Alcala, Spain] presented burned area products derived as a part of the fire-climate change initiative (Fire CCI). The current product is MODIS Fire_cci v5.1, released in February 2018. It was obtained by combining spectral information from MODIS at 250-m (~820-ft) resolution and thermal information from the MODIS active fire products. Fire CCI v5.1 is available for years 2001 to 2017 at two different resolutions: pixel (~250 m, or ~820 ft), and grid (25 km, or ~16 mi). In addition, the new Fire_cci AVHRR[11]-Land Long Term Data Record (LTDR) burned area product v1.0 (FireCCILT10) has been released. This product is based on the AVHRR-LTDR v.5 dataset, covers the period 1982 to 2017, and is provided in monthly 0.25° files. Specific to Africa, a small fire database for sub-Saharan Africa has also been developed with inputs from Sentinel-2 reflectance measurements in the short- and near-infrared wavebands and the MODIS active fire product.

Amber Soja [National Institute of Aerospace] presented updates on the NASA Wildland Fire Program. The wildfire program focus areas include pre-fire, active-fire and post-fire mapping. She also reported on the U.S. investigators funded through the NASA Applied Sciences Program in support of the Global Earth Observations (GEO) GWIS. Soja reported that three projects were funded as a part of the GEO GWIS *A.50* GEO work program. One project will pursue developing enhancements to the global wildfire fire information system, to generate a fire danger rating and applications in Indonesia [led by Robert Field, Columbia University]. Another project will work to develop a harmonized multisensor, global, active-fire dataset [Louis Giglio and Wilfrid Schroeder, University of Maryland]. The third will use the NASA polar-orbiting fire product record to enhance and expand the GWIS [led by Luigi Boschetti, University of Idaho, and David Roy, Michigan State University]. All of the investigators were participants at the GWIS GOFC-GOLD Fire-IT meeting.

Jesus San-Miguel-Ayanz [JRC] clarified that all the products generated from the above three projects will be integrated into the GWIS. He also stated that GWIS is collaborating with NASA ARSET on training materials and webinars and the United Nations Office for Disaster Risk Reduction (UNISDR) on their global risk-assessment framework (GRAF).

Overview Presentations

After the thematic science presentations there was a series of overview presentations that covered the fire-related activities of several of the regional GOFC–GOLD Regional Network(s).[12] These are summarized in **Table 1**.

[10] To meet the demand for statistics at a local level, Eurostat maintains a system of Local Administrative Units (LAUs) compatible with maps made for NUTS, which stands for Nomenclature of Territorial Units for Statistics, and is a hierarchical system for dividing up the economic territory of the European Union (EU). These LAUs are the building blocks of the NUTS, and comprise the municipalities and communes of the EU.

[11] AVHRR stands for the Advanced Very High Resolution Radiometer, which has flown on a series of NASA, NOAA, and international satellites over the past four decades. The last AVHRR was launched on Metop-C in November 2018.

[12] The "Summary of the GOFC-GOLD Twentieth-Anniversary Regional Networks Summit" previously referenced in footnote 4 on page 19, contains a complete list of the GOFC-GOLD Regional Networks, their research foci, and new opportunities (as of 2017).

Table 1. Summary of presentations on regional GOFC-GOLD Regional Network activities.

Speaker [Affiliation]	**GOFC-GOLD Regional Network Described**
Jesus Anaya [University of Medlin, Colombia]	Latin America Fire Network [Red Latinoamericana de Teledetección e Incendios (ReDLatif)]
Natasha Ribeiro [Eduardo Mondlane University, Mozambique]	Miombo Network
Ioannis Gitas [University of Thessaloniki, Greece]	Mediterranean Fire Regional Information Network (MEDRIN)
Krishna Vadrevu [NASA's Marshall Space Flight Center]	South Asia Regional Information Network (SARIN) and Southeast Asia Regional Research Information Network (SEARRIN)
Philip Frost [Council for Scientific and Industrial Research, South Africa]	South Africa Fire Network (SAFNET)

There were several other presentations on fire research and monitoring activities around the world, which are summarized in **Table 2**.

Table 2. Summary of presentations on national fire research and monitoring activities.

Speaker [Affiliation]	**Topic Discussed**
Josh Johnston [Canadian Forest Service]	Canada Fire Information System
Alberto Setzer [Instituto Nacional de Pesquisas Espaciais, Brazil]	Brazilian Wildfire Information System
Adam Leavesley [Australian Capital Territory (ACT) Parks and Conservation Service, Australia]	Fire Research and Monitoring Activities in Australia
Peng Gong [University of Tsinghua, China]	Land Cover and Fire Research Project Activities in China
Ilze Pretorius [Scion (Crown Research Institute), New Zealand]	Fire Research Project Activities in New Zealand

Extended Discussion

An extended discussion session followed, chaired by **David Roy**. It focused on identifying key issues and fire research needs and priorities; those deliberations are summarized here.

Fire Data Product, Validation, and Distribution Systems

Participants recognized the proliferation of fire products and their distribution systems and an increasing need for quality control, and assessment of fire product usage. There was a discussion of how to ensure meaningful burned area product validation, including the strong recommendation for product quality assessment before validation. The need to develop validation protocols for Sentinel-2 and Landsat-8 burned area products was highlighted as an issue. There is also a need to revisit and update the CEOS LPV burned area product validation protocol. This discussion also covered the difficulties in validating active-fire-detection and -characterization products. Participants emphasized the need for coordinated validation airborne campaigns that include opportunities to validate active fire and characterization products from different sensors and instruments, subject to organizational constraints. They also identified the need for a survey of users of satellite fire products and recommended not just review article publications (currently being generated by members and affiliates of the GOFC-GOLD Fire-IT in *Remote Sensing of Environment*), but also general science and applications usage surveys.

Supporting-Mission Advocacy

Advocacy for the Sentinel-3 and EUMETSAT Polar System Second Generation (EPS-SG) METimage missions was recommended as critical for mid-morning polar fire observations. Currently, data from the GOES-R series are processed at the EUMETSAT Land Surface Analysis (LSA) satellite applications facility (SAF). Since EUMETSAT also receives Himawari geostationary products from the Japanese Meteorological Agency, there is a need to encourage porting the SEVIRI fire algorithm from LSA-SAF to Himawari data to generate near-real-time fire products.

Fire Early-Warning Systems

Discussion of fire early warning systems emphasized the need for integrating satellite-derived phenology and fuel moisture products. It was noted that the ECMWF could improve the distribution of fire forecast products soon and that there is a potential for extended range forecasts. For fire emissions reporting, participants noted the need to update and broaden the GOFC–GOLD Reducing Emissions from Deforestation and Degradation (REDD) sourcebook to include approaches combining polar and geostationary fire data.

SAR Measurements for Burned-Area Mapping

The availability of Sentinel-1A (launched 2014) and Sentinel-1B (launched 2016) Synthetic Aperture Radar (SAR) C-band (5.6-cm) data was recognized as having the potential to be used for burned area mapping. Further research on the use of SAR data for fire research was recommended and recognized as needed for burned area mapping in persistently cloudy regions.

Sustained Funding and Resource Leverage

While participants recognized the importance of sustained funding for the GOFC–GOLD regional networks, they also acknowledged that acquiring consistent sources of funding can be challenging. One such funding source is Global Change System for Analysis, Research, and Training (START), through the NASA Land Cover Land Use Change (LCLUC) program, which will continue to support network meetings and training activities—although it was noted that cost-share proposals are encouraged and needed. Participants agreed to pursue funding opportunities for regional network activities through European Union and U.S. support and via international proposal calls. For capacity building, participants identified the need to formulate a coordinated GOFC-GOLD fire GWIS training team willing and able to travel to different regions and deliver training on fire remote sensing. Open source software and cloud computing platforms were recommended, in addition to free sharing of training materials through the GOFC website. Participants advocated the need to expand GOFC-GOLD fire representation and elevate its activities through international programs such as CGMS, CEOS Disasters Working Group, Global Forest Observations Initiative (GFOI), and contributing to the United Nations Sustainable Development Goals (SDG's).

Conclusion

The overall consensus was that this meeting was successful in achieving its goals. The meeting's presentations and discussion sessions focused on synergies among various approaches and provided recommendations on how to improve the role of Earth observations, ground data, and modeling techniques to improve global fire mapping and monitoring efforts. Participants identified the need to develop regionally consistent fire products, and all participants agreed on the need to develop effective strategies to transition from research to operational products to aid in fire management efforts. Common issues that surfaced during the discussions included the need to strengthen research, capacity building, and training activities through GOFC-GOLD and GWIS partnerships. Overall, the meeting was highly successful in addressing fire mapping and monitoring including enhancing of GWIS. The meeting finished with a discussion of the next joint GWIS and GOFC-GOLD Fire-IT meeting that is currently planned for fall 2019 in, Rome, Italy. ■

Return of GEDI's First Data Reveals the Third Dimension of Forests

Jessica Merzdorf, NASA's Goddard Space Flight Center, jessica.v.merzdorf@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

NASA's Global Ecosystem Dynamics Investigation (GEDI) mission was launched in December 2018.[1] From its perch aboard the International Space Station, GEDI's powerful lasers create detailed three-dimensional maps of Earth's forests and topography—providing innovative and unique spaceborne observations. In January 2019, GEDI's lasers were turned on for the first time and the instrument is now giving scientists a first glimpse of the insights it will provide in years to come.

The GEDI mission provides scientists detailed information about forest structure: e.g., how tall the forest is, how dense its branches are, and the vertical and horizontal distribution of its foliage. All of this yields crucial insights into Earth's global carbon cycle by fostering a better understanding of how forests store carbon and what happens to that carbon when they are cut down or disturbed.[2] Forests support numerous plant and animal species, and characterizing their structure can help biologists better understand Earth's forest habitats and biodiversity.

When scientists process GEDI's data, the resulting measurements reveal the vertical structure of the forest. The GEDI image shown in the **Figure** below is of a South Carolina woodland.[3]

[1] The University of Maryland has a lead role on the GEDI mission, and is contractually responsible for the entirety of the mission.
[2] To learn more about GEDI, visit *https://gedi.umd.edu*.
[3] To see what GEDI saw as it flew over southeastern Pennsylvania, see the front cover of this issue. The image was taken from *https://earthobservatory.nasa.gov/images/144818/return-of-the-gedis-first-data*.

"GEDI provides a vertical record, not only of how tall trees are, but how much canopy material there is at any height," said **Ralph Dubayah** [University of Maryland, College Park (UMD)—*GEDI Principal Investigator (PI)*]. "GEDI will make over 10 billion individual observations of canopy structures, which is orders of magnitude more than we have ever had."

This level of detail is what sets GEDI apart and gives it the power to see the details of Earth's forests, the team explained.

"The instrument team at [NASA's] Goddard [Space Flight Center (GSFC)] did an amazing job delivering this incredibly capable science instrument. GEDI brings together several challenging and state-of-the-art technologies to enable this very difficult measurement that's needed to achieve our science goals," said **Bryan Blair** [NASA's GSFC—*GEDI Deputy PI and Instrument Scientist*].

"We're very excited that GEDI is now in orbit and taking measurements," said **Michelle Hofton** [UMD—GE*DI Co-Investigator*]. "This ability to precisely capture Earth's surface structure and its underlying topography is unique to GEDI. We're thrilled at the expansive coverage we're getting every day and looking forward to the discoveries that will be made using the data." ■

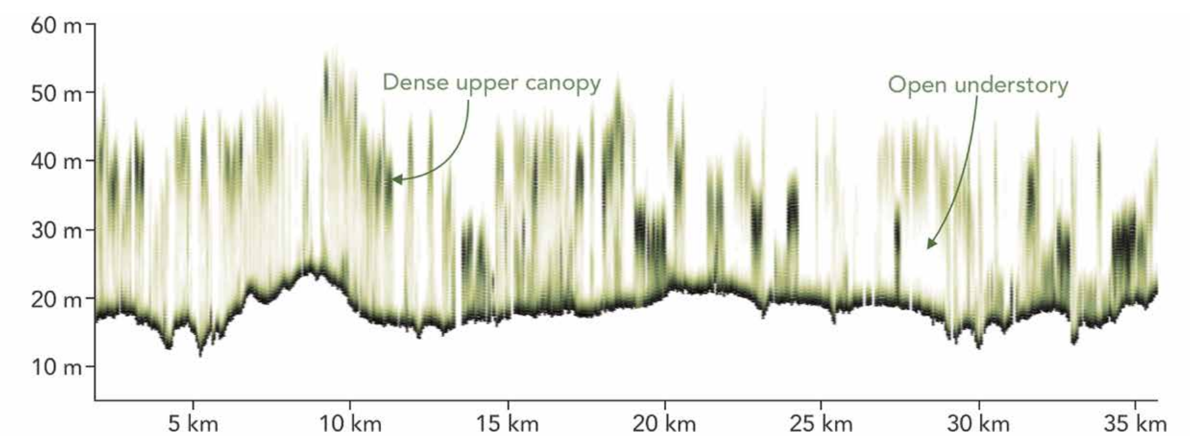


Figure. This graph shows data from GEDI that reveal the vertical structure of a forest in South Carolina. Notice that GEDI not only detects the treetops, but also reveals details about the canopy below. Darker shades show where the leaves and branches are denser, while the lighter areas show where the canopy is less dense. **Image credits:** Joshua Stevens [NASA's Earth Observatory], Bryan Blair [GSFC], Michelle Hofton and Ralph Dubayah [both at UMD].

Help NASA Measure Trees with Your Smartphone

Kate Ramsayer, NASA's Goddard Space Flight Center, Ramsayer, kate.d.ramsayer@nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

Healthy forests play a crucial role in Earth's ecosystem as growing trees take up carbon from the atmosphere. NASA satellites and airborne missions study forests to see how carbon moves through ecosystems—and now citizen scientists can help investigate this key question as well by using their smartphone to measure tree height.

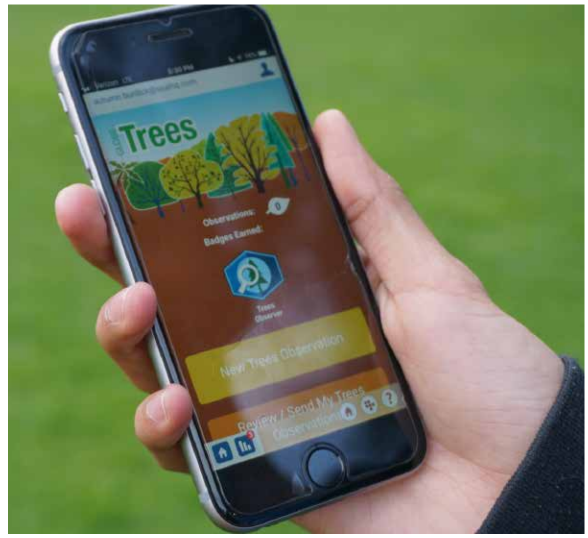
The *GLOBE*[1] *Observer* app provides a step-by-step guide for people to collect scientific data on their surroundings. With the new GLOBE Trees feature of the app—shown in the photo—they can now measure the height of trees in their vicinity.

"With the GLOBE Observer, everyone can become a citizen scientist and easily take measurements to better understand their local ecosystem," said **Brian Campbell** [NASA's Goddard Space Flight Center—*GLOBE Trees Science Lead*]. Observers can measure one tree or hundreds. The data points—along with a GPS tag of the tree's location—are sent back to NASA and collected in a database. Anyone can visualize all of the tree height and other GLOBE data simply by visiting the GLOBE website.

The GLOBE Program has helped teachers and students gather scientific data for more than 20 years, and was expanded in 2016 with the addition of GLOBE Observer to bring in other citizen scientists as well. The tree-height project is the latest in a suite of tools that people can use to study their surroundings, following efforts to observe clouds, mosquito habitat, and land cover.[2]

The land-cover tool allows citizen scientists to document the vegetation and terrain around them, Campbell said, and adding in the height measurements gives a more-complete, three-dimensional portrait of the ecosystem. Scientists need that third dimension to calculate how much carbon is stored in a tree or in a forest—and now citizen scientists can collect the data as well.

Tree height measurements could also help scientists working on NASA missions such as the Global Ecosystem Dynamics Investigation (GEDI)[3] and the Ice, Cloud and land Elevation Satellite-2 (ICESat-2), both of which use lasers to measure the height of Earth's surface below them as they orbit our planet. GEDI, in particular, is focused on measuring the three-dimensional properties of Earth's forests.



The GLOBE Trees tool is easy to use: by tilting their smartphone up and down, then pacing off the distance to a tree, citizen scientists can measure tree height and add to the GLOBE database. **Image *credit***: NASA

"ICESat-2 will measure the heights of forest canopies worldwide—and the GLOBE Observer app is another way to collect even more data," said **Tom Neumann** [GSFC—*ICESat-2 Project Scientist*]. Citizen scientists in the U.S. and in more than 100 other countries will gather tree heights from many more places than the ICESat-2 scientists alone could measure.

"GLOBE measurements are going to be useful for the validation of tree heights we're getting from ICESat-2," Neumann said. Once the GLOBE data start coming in, the mission will analyze the information to see where a cluster of citizen-scientist acquired measurements overlap with ICESat-2's measurements, and compare the two sets. "It'll be interesting to see what the difference is."

The GLOBE Observer app can be downloaded for free on *Google Play* and the *App Store*.

For more information on GLOBE Observer, visit: *https://observer.globe.gov.*

To access GLOBE data, visit: *https://vis.globe.gov/GLOBE.* ■

[1] GLOBE stands for Global Learning and Observations to Benefit the Environment.
[2] To learn more about GLOBE, *Globe Observer,* and its tools (as of 2017), see "GLOBE Observer: Citizen Science in Support of Earth System Science " in the November-December 2017 issue of *The Earth Observer* [**Volume 29**, **Issue 6**, pp. 15-21—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Nov_Dec_2017_color_508.pdf#page=15*].
[3] To learn more about GEDI see the related *News* story on page 25 of this issue, as well as the *Editorial* on page 2.

Data with Flippers? Studying the Ocean from a Seal's Point of View

Carol Rasmussen, NASA/Jet Propulsion Laboratory, carol.m.rasmussen@jpl.nasa.gov

EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

Scientist **Lia Siegelman** [University of Western Brittany, France] is using a surprising data source to study the ocean around Antarctica—one that has flippers and bears a passing resemblance to Jabba the Hutt (from *Star Wars* films).

Siegelman is currently a visiting research scientist at NASA/Jet Propulsion Laboratory. She is using data from a single tagged southern elephant seal—shown in **Photo 1**—to study small-scale ocean features in a little-known part of the ocean around Antarctica.

Weighing as much as a midsize pickup truck, southern elephant seals may look sluggish on land, but in the water they're endurance athletes. They spend 9-10 months of each year at sea, swimming thousands of miles and continually diving to depths as great as 3300 ft (1000 m). "Even when they sleep, they dive—they float down like a leaf," Siegelman said. They average about 80 dives a day, spaced less than half-a-mile (700-m) apart, returning to the surface briefly for air but staying underwater up to two hours at a time.

With all this diving, a tagged elephant seal collects data from the top layer of the Southern Ocean in the vicinity of their dives. Some seals even forage under Antarctic sea ice, where conventional ocean instruments can't go. As global warming changes important ocean currents in ways that affect Antarctic melt rates, any additional data from these dangerous, remote seas is likely to be valuable. That's why Siegelman and her colleagues explore using seal data to better understand the ocean environment.

For more than two decades, scientists have been tagging seals on the Kerguelen Islands, a French territory in the Antarctic, to study the animals' behavior. In 2014, the researchers began using a new type of sensor that records every dive, providing an oceanographic data set with very high resolution.

The animals are tagged as part of the SO-MEMO program[1] operated by the French National Center for Scientific Research [Centre National de la Recherche Scientifique (CNRS)]. The tag—actually, sensors with

[1] SO-MEMO stands for Système d'Observation Mammifère marin Echantillonneur du Milieu Océanique, (roughly, in English, Observing System - Mammals as Samplers of the Ocean Environment).

Photo 1. Female elephant seals basking, with a tagged seal in the background. **Photo credit**: Etienne Pauthenet [Sorbonne University]

Photo 2. A scientist gluing a tag to a seal on Kerguelen Island. Scientists tag seals in molting season (when they return to land to shed fur and dead skin) and remove the tags in breeding season. If they can't locate a seal and retrieve the tag, the tag falls off with the fur and skin in the next molting season. **Photo credit**: Etienne Pauthenet [Sorbonne University]

antennas—is glued to the seals' heads—shown in shown in **Photo 2**—when the animals come ashore either to breed or to *molt* (shed dead skin). This is all done in accordance with ethical standards for animal treatment.

Siegelman and her co-authors analyzed a three-month foraging voyage by a female seal, during which the animal logged an impressive 3520 mi (5665 km) and dove 6942 times. Most seals from the Kerguelen Islands forage to the east, but this particular seal made a beeline to the west to an area in the Antarctic Circumpolar Current where there's a standing *meander*—a place where the topography of the ocean floor creates a permanent bend in the path of the current.

The seal spent about a third of her entire voyage zigzagging in the meander, providing a wealth of data from a region where few direct oceanographic measurements have been made. The researchers used the data to identify the location of sudden changes in water density called fronts, like the cold and warm fronts in the atmosphere. These oceanic features have a width of only 3-12 mi (5-20 km). The sharp dividing lines between denser and lighter waters pull nutrients up from the depths, fertilizing microscopic ocean plants called phytoplankton. The increased food supply works its way up the food chain into a lavish buffet for elephant seals. The researchers saw the effects of this bounty in the short lunges the seal made during her dives, as if after nearby prey.

"I hope this [result] will encourage physicists and biologists to use those very rich data from seals," Siegelman said. A paper on the research, titled "Submesoscale ocean fronts act as biological hotspot for southern elephant seal," was published this month in the journal *Scientific Reports*. Co-authors are from Caltech, the University of Western Brittany, and the University of Western Australia. ■

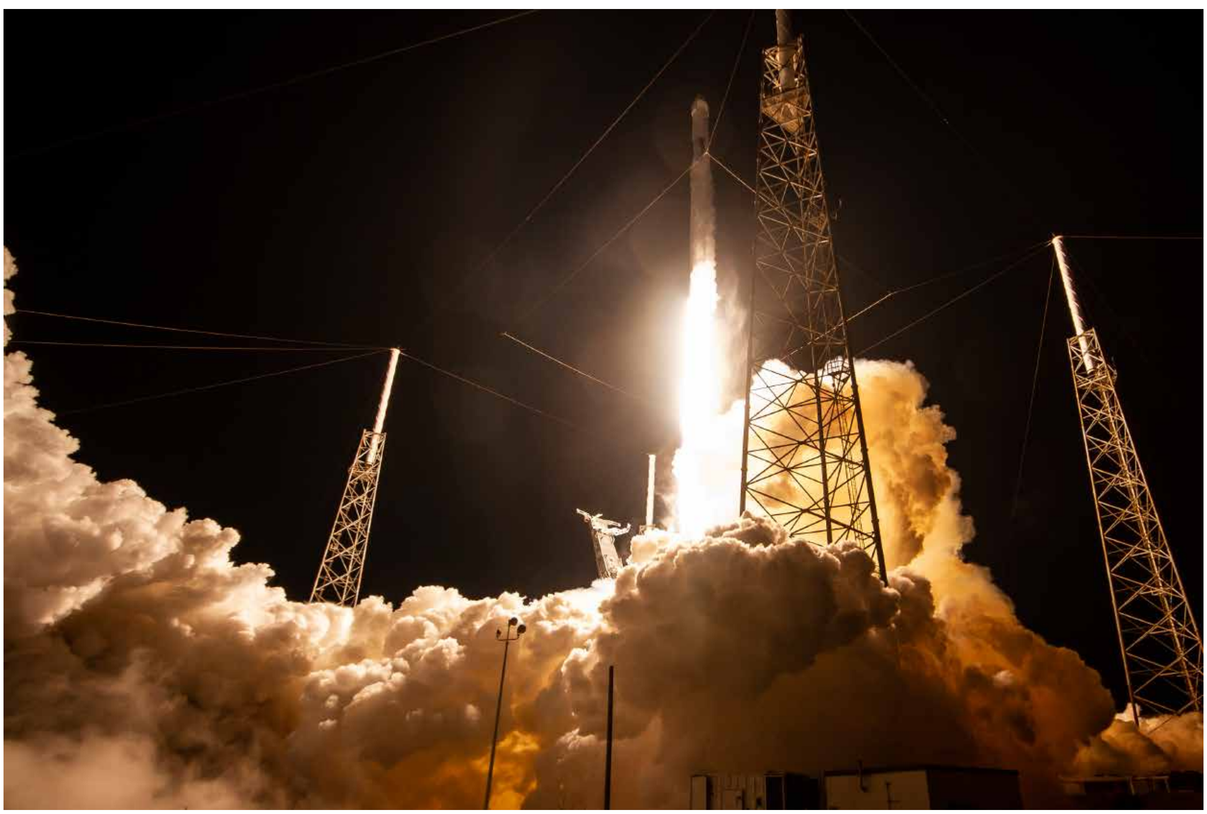
NASA Earth Science in the News

Samson Reiny, NASA's Goddard Space Flight Center, Earth Science News Team, samson.k.reiny@nasa.gov

EDITOR'S NOTE: This column is intended to provide a sampling of NASA Earth Science topics reported by online news sources during the past few months. Please note that editorial statements, opinions, or conclusions do not necessarily reflect the positions of NASA. There may be some slight editing in places primarily to match the style used in *The Earth Observer*.

SpaceX Just Blasted a Critical NASA Instrument into Space, May 5, *mashable.com*. NASA's carbon-detecting sleuth has left Earth. SpaceX launched the Orbiting Carbon Observatory-3 (OCO-3) to the International Space Station (ISS) at 2:48 AM ET on Saturday, May 4, 2019, aboard the company's dependable Falcon 9 rocket. After NASA's cargo load arrives at the ISS, astronauts will use a long robotic arm to attach the refrigerator-sized instrument to the side of the Earth-orbiting station. OCO-3 will peer down on Earth, keeping tabs on the planet's amassing carbon dioxide emissions, which are now at their highest levels in millions of years. "Carbon dioxide is the most important gas humans are emitting into the atmosphere," **Annmarie Eldering** [NASA/Jet Propulsion Laboratory—*OCO-3 Project Scientist*] told Mashable in February. "Understanding how it will play out in the future is critical."

Scientists Accidentally Built a Highly Accurate Ozone Detector while Trying to Build Something Else, May 3, *techtimes.com*. A NASA scientist tasked to develop an instrument to detect hydroxyl has instead accidentally created a highly accurate ozone detector. "Research and development are never wasted," said **Tom Hanisco** [NASA's Goddard Space Flight Center].



SpaceX's Dragon lifted off on a Falcon 9 rocket from Space Launch Complex 40 at Cape Canaveral Air Force Station in Florida on Saturday, May 4, with more than 5,500 pounds of research equipment, cargo and supplies that will support dozens of investigations aboard the International Space Station. **Image Credit:** SpaceX

"When we started this development effort, ozone was the farthest thing from our minds." Hanisco and his team originally set out to build an instrument that can measure hydroxyl, a short-lived and highly reactive chemical. Hydroxyl can cleanse the atmosphere of methane, a greenhouse gas that is even more effective at absorbing heat than carbon dioxide. The scientists wanted to build the detector using the technique called gas filter correlation spectroscopy. The idea was to fill a cavity with hydroxyl produced by the prototype instrument. Once filled, the hydroxyl would block all the wavelengths that the chemical absorbs. However, during testing, the prototype instrument encountered technical difficulties and produced ozone instead of hydroxyl. It turns out that the instrument is highly sensitive to ozone, so—instead of pursuing their original goal—the scientists tweaked and improved the instrument's sensitivity to ozone. Hanisco said that the prototype instrument, which has been dubbed the Rapid Ozone Experiment, or ROZE, is up to 100 times more accurate than the best commercial ozone-detecting instruments today. This summer, ROZE wiil fly on a DC-8 aircraft during the Fire Influence on Regional to Global Environments Experiment-Air Quality (FIREX–AQ) field campaign, which will measure trace gases and aerosol emissions caused by wildfires in the western U.S. and agricultural fires in the southeastern U.S. Although testing ozone measurements isn't a focus of FIREX-AQ, the flight opportunity gives Hanisco and his team a chance to operate ROZE under flight conditions.

NASA Research Shows Humans Have Been Influencing Drought for Over a Century, May 1, *earther.gizmodo.com*. Climate change used to be thought of as a *future* problem. Now people are finally starting to view it as a *present* problem, but new research looking at drought shows it's been stalking humanity for much longer. The findings, published in *Nature*, use tree rings and climate models to take a global look at drought back to 1400 and compare it to what's happened in the past 120 or so years. The results show that a clear human influence on global drought is apparent as early as 1900 and that the influence is likely to become even clearer in the coming decades if carbon emissions keep rising. "Climate change—despite its new prominence—is not new," **Kate Marvel** [NASA's Goddard Institute for Space Studies], who led the new study, told Earther. "It's something that has been happening for a long time." In an effort to understand if humans are causing drought patterns to shift, scientists at NASA took regional and global looks at drought to sift through the noise of natural variability and the rising signal of climate change. Marvel likened the whole thing to listening to a symphony: Natural variability—random weather events, things like El Niño, volcanoes, and more—have been playing a pretty standard tune for centuries. But recent climate change has altered the composition.

Satellite Confirms Key NASA Temperature Data: The Planet Is Warming—and Fast, April 17, *washingtonpost.com*. New evidence suggests one of the most important climate change datasets is getting the right answer. Analysis of a high-profile NASA temperature dataset[1] shows that the last five years have been the hottest on record, and the globe is a full degree Celsius (or 1.8 degrees Fahrenheit) warmer than in the late 1800s. This result has found new backing from independent satellite records—suggesting the findings are on a sound footing. If anything, the researchers found, the pace of climate change could be somewhat more severe than previously acknowledged, at least in the fastest warming part of the world—its highest latitudes. "We may actually have been underestimating how much warmer [the Arctic's] been getting," said **Gavin Schmidt** [NASA's Goddard Institute for Space Studies—*Director*], which keeps the temperature data, and who was a co-author of the new study released in *Environmental Research Letters*.

*See news story in this issue.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Samson Reiny*** *on NASA's Earth Science News Team at samson.k.reiny@nasa.gov and let him know of upcoming journal articles, new satellite images, or conference presentations that you think would be of interest to the readership of* ***The Earth Observer****.* ■

[1] To learn more about this dataset, visit *https://data.giss.nasa.gov/gistemp*.

Earth Science Meeting and Workshop Calendar

NASA Community

August 27–29, 2019
Aura Science Team Meeting, Pasadena, CA
https://mls.jpl.nasa.gov/aura2019

September 25-27, 2019
Sounder Science Team Meeting
Washington, DC area [Venue TBD]
https://airs.jpl.nasa.gov

October 21–25, 2019
OST Science Team Meeting, Chicago, IL
https://sealevel.jpl.nasa.gov/science/ostscienceteam/scienceteammeetings

Global Science Community

July 28–August 2, 2019
International Geoscience and Remote Sensing Symposium (IGARSS), Yokohama, Japan
https://igarss2019.org

July 28–August 2, 2019
Asia Oceania Geosciences Society (AOGS) Annual Meeting, Singapore
http://www.asiaoceania.org/aogs2019/public.asp?page=home.htm

August 25–29, 2019
American Chemical Society (ACS) National Meeting, San Diego, CA
https://www.acs.org/content/acs/en/meetings/national-meeting.html

September 22–25, 2019
Geological Society of American (GSA), Phoenix, AZ
https://community.geosociety.org/gsa2019/connect/events

December 9–13, 2019
AGU Fall Meeting, San Francisco, CA
https://events.jspargo.com/AGU19/Public/enter.aspx

Code 610
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

PRSRT STD
Postage and Fees Paid
National Aeronautics and Space Administration
Permit 396

Official Business
Penalty for Private Use: $300

(affix mailing label here)

eospso.nasa.gov

The Earth Observer

The Earth Observer is published by the Science Communication Support Office, Code 610, NASA's Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available in color at *eospso.nasa.gov/earth-observer-archive*.

Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. Newsletter content is due on the weekday closest to the 1st of the month preceding the publication—e.g., December 1 for the January–February issue; February 1 for March–April, and so on.

To subscribe to *The Earth Observer*, or to change your mailing address, please call Cindy Trapp at (301) 614-5559, or send a message to *Cynthia.trapp-1@nasa.gov*. If you would like to stop receiving a hard copy and be notified via email when future issues of *The Earth Observer* are available for download as a PDF, please send an email with the subject **"Go Green"** to *cynthia.trapp-1@nasa.gov*. Your name and email address will then be added to an electronic distribution list and you will receive a bi-monthly email indicating that the next issue is available for download. If you change your mind, the email notification will provide an option for returning to the printed version.

The Earth Observer Staff

Executive Editor:	Alan B. Ward (*alan.b.ward@nasa.gov*)
Associate Editor:	Heather H. Hanson (*heather.h.hanson@nasa.gov*)
Assistant/Technical Editor:	Mitchell K. Hobish (*mkh@sciential.com*)
Technical Editor:	Ernest Hilsenrath (*hilsenrath@umbc.edu*)
Assistant Editor:	Douglas Bennett (*douglas.bennett@nasa.gov*)
Design, Production:	Deborah McLean (*deborah.f.mclean@nasa.gov*)

Scan code to access
The Earth Observer
archive online

Printed on Recycled Paper

NP-2019-6-383-GSFC