Studying the 2019-2020 Australian Bushfires Using NASA Data

In partnership between NASA Langley Research Center's Atmospheric Science Data Center, Science Directorate, & the NASA Disasters Program

Published Draft

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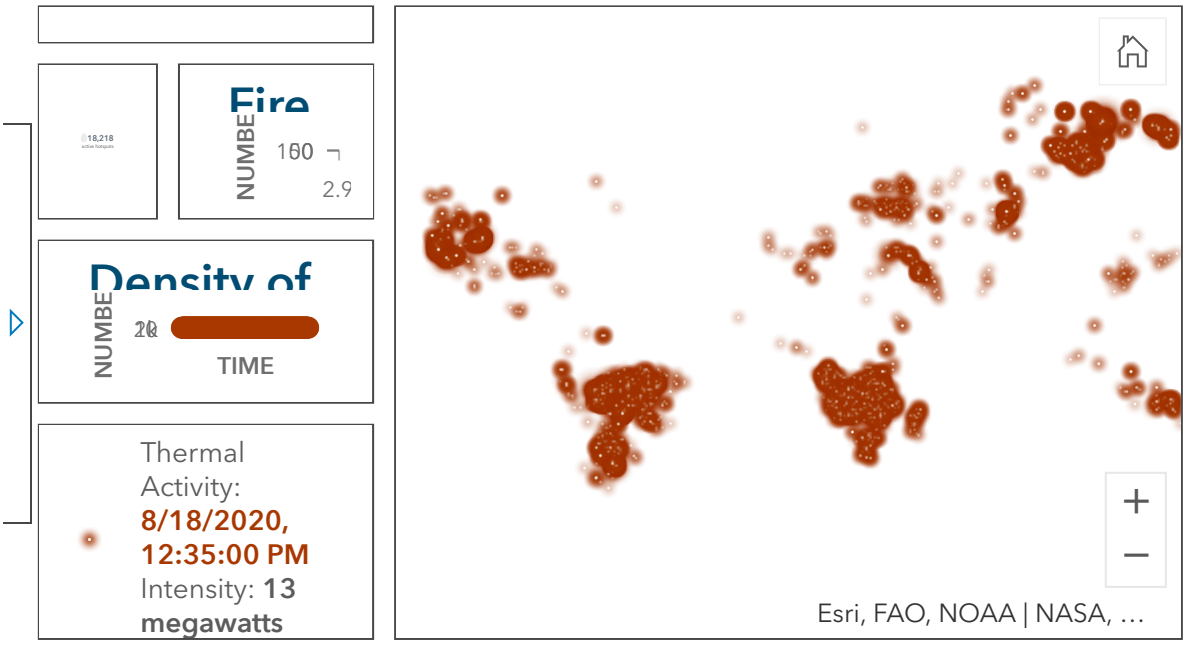
Introduction

Image Credit: Brett Hemmings/Getty Images

The 2019-2020 season has been one of the worst fire seasons on record. Australia has seen unprecedented heat waves, with temperatures reaching 120 F° (49.1 C°) in January across central and eastern Australia. NASA's satellites not only tracked the event in real time, using resources like the Global Actives Fires and Hotspots Dashboard you see below, but also collected large volumes

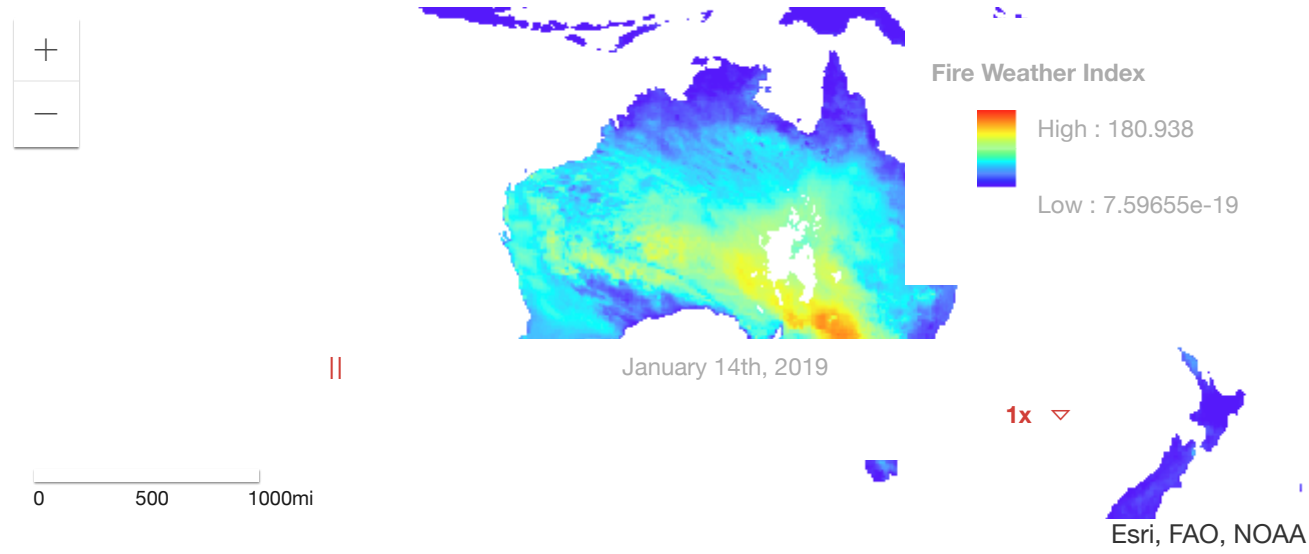
of rich data that scientists and researchers can use to study the event and the regional and global effects of the disaster.

In this Esri StoryMap, we will guide you through the factors leading up to the 2019-2020 Australian Bushfires Disaster, the effect this event has had on air quality and global atmospheric composition, and the science behind researching the tie between disasters and public health. This story map will use data from the ASDC-supported NASA missions such as the Measurements Of Pollution In The Troposphere (MOPITT), Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), Clouds and the Earth's Radiant Energy System (CERES), SAGE III, and Multi-angle Imaging SpectroRadiometer (MISR).



Global Active Fires and Hotspots Dashboard, by the ArcGIS Living Atlas of the World Environment Team

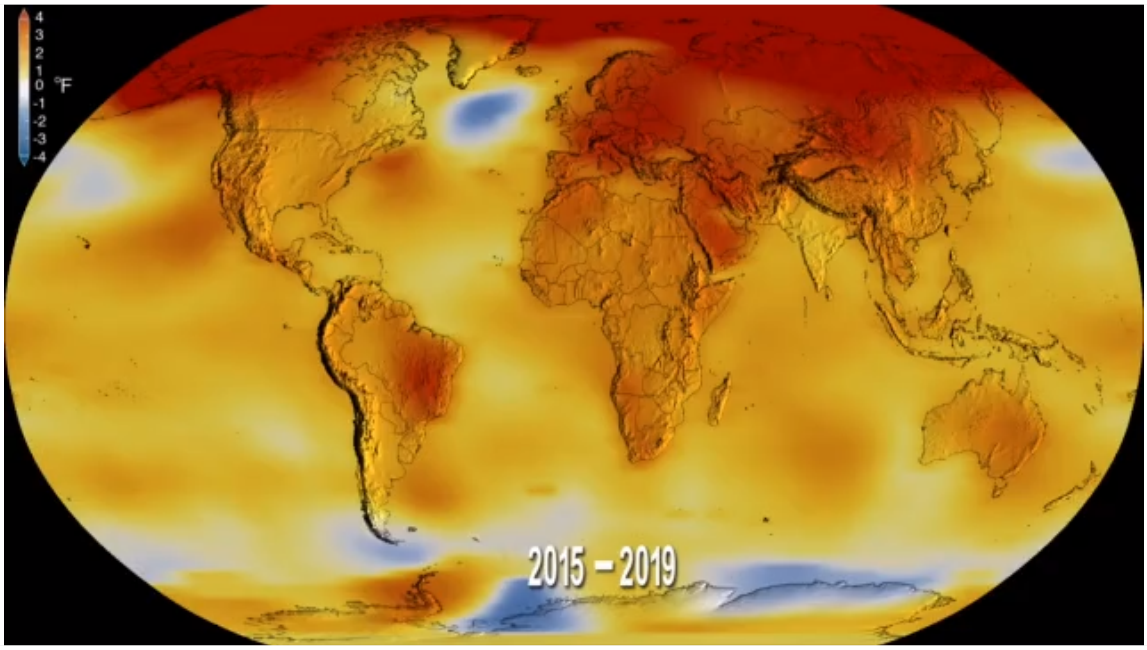
1) Conditions for Fire Activity



Fire Weather Index

By 2019, a combination of long-term warming, rainfall deficiency, and oceanic circulation anomalies made ground conditions in Australia extremely susceptible to fires. NASA's Goddard Space Flight Center has developed the Global Fire WEather Database (GFWED) integrating different weather factors influencing the likelihood of a vegetation fire starting and spreading (see map to the right). It is based on the Fire Weather Index (FWI) System, the most widely used fire weather system in the world.

A Fire Weather Index is similar to fire danger indices used operationally in Australia, in accounting for current and antecedent rainfall, humidity, temperature and wind speed. More examples of Australian fire danger products can be found at the Bureau of Meteorology website.



Heat Wave Breaks Records in Australia

Temperature plays a role in fire susceptibility for a land area. Earth's global surface temperatures in 2019 were ranked the second warmest since 1880, according to independent analyses by NASA and the National Oceanic and Atmospheric Administration (NOAA).

Global temperatures in 2019 were 2 degrees Fahrenheit (1.1 degrees Celsius) warmer than the late 19th Century, according to scientists at NASA’s Goddard Institute for Space Studies (GISS) in New York. 2019's temperatures were second only to those of 2016 and continued the planet's long-term warming trend: the last six years on the instrumental record have been the warmest.

As seen in the figure below, the average annual temperature in Australia has been steadily increasing. The Australian Bureau of Meteorology has placed 2019 as the hottest year on record so far.

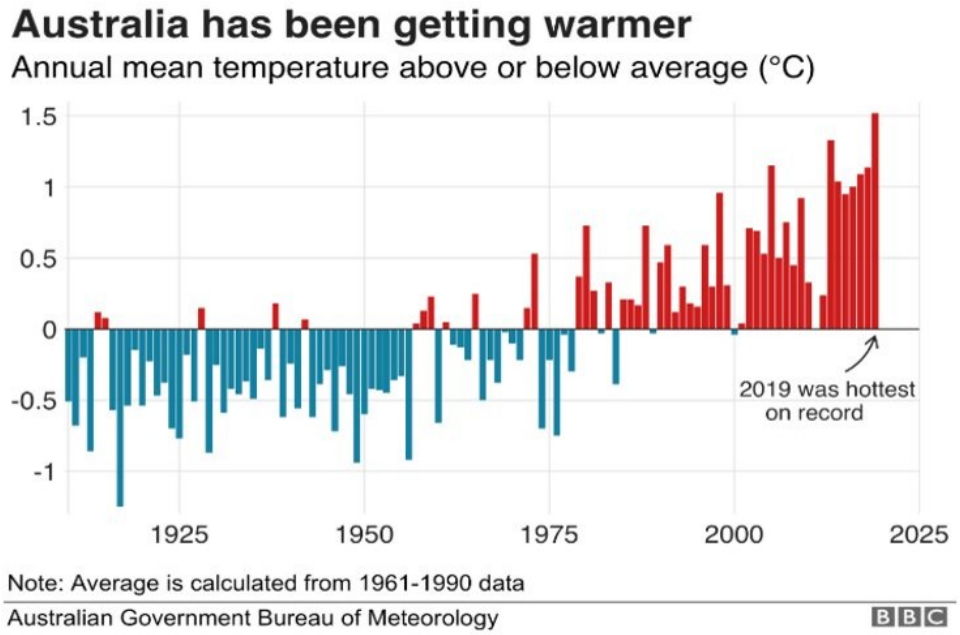


Image Credit: BCC, "Australia fires: A visual guide to the bushfires and extreme heat"

Continued Severe Rainfall Deficiency

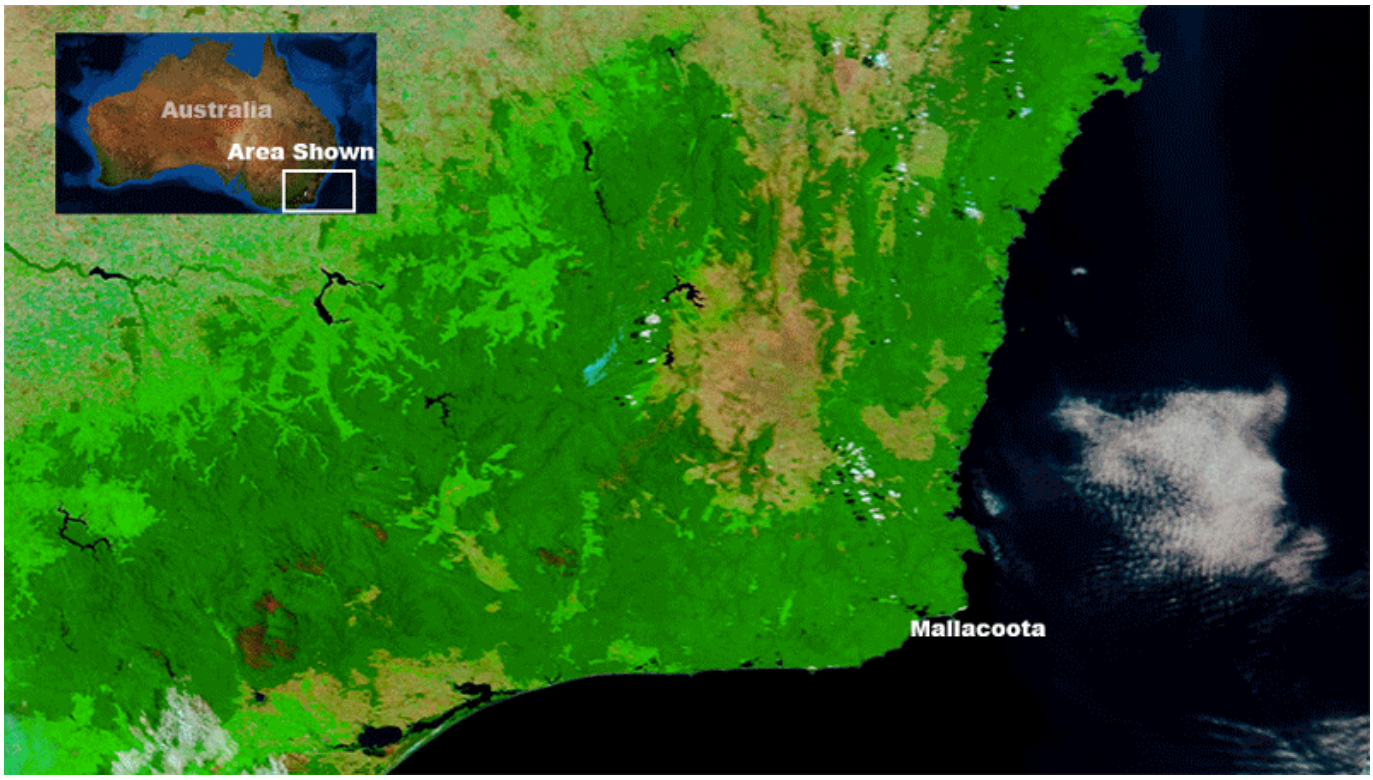
In addition to changes in long term temperature trends, Australia experienced an unusual amount of rainfall deficiencies recently. The AU Bureau of Meteorology has been monitoring and researching the record-setting Australian drought. This drought is notably marked by three consecutive dry winters in 2017, 2018, & 2019 over the southeast region of Australia, all of which rank as the driest 10% of winters since 1900.

Image Credit: The Australian Government's Bureau of Meteorology, "Rainfall deficiencies for the 26 months starting in April 2018"

Compiled from images taken on January 4th, 2020, the GIF above shows images from the JMA HIMAWARI-8 satellite of Australia's eastern coast overlaid with Aqua MODIS Thermal Anomalies points (in red). Image Source: NASA Disasters Team

2) An Unprecedented Fire Season

An area roughly the size of Iceland was burned, smoke from the fires affected air quality for at least 30% of Australians and circulated across the globe, and dramatic impacts on the Australian ecosystem were dire, with hundreds of millions of animals estimated to have perished.



Geographic Extent & Burn Scars

Created using special imagery from NASA's MODIS satellites, this GIF shows burn areas from fires, seen by doing a before-and-after comparison.

Image Source: "Satellite Images Show Massive Burn Areas From Devastating Australian Bushfires", Chris Dolce, The Weather Channel

Fire Counts

Bushfires engulfed many parts of the Australian continent, igniting in the north and moving to the more populous south and southeast areas. Over 10 million hectares of land were affected by the wildfires. This map shows fire counts/hotspot information using the Fire Information for Resource Management System (FIRMS) **Visible Infrared Imaging Radiometer Suite (VIIRS) Suomi National Polar-orbiting Partnership (S-NPP) 375m** and **Moderate Resolution Imaging Spectroradiometer (MODIS) Collection 6** data products from October 2019 through January 2020.

Click the time-slider below to visualize and inspect the fire detections observed during this time period.

Population Density

select "Global Population" on the right

The fires primarily occurred on Australia's southeast coast, the most densely populated region of the continent. According to UN Environment, about 5,900 buildings were destroyed, including over 2,800 homes.

You can learn more about population dynamics with regards to the fires here, and the demographic landscape here.

Australian Bushfires: Mapping Population …

Massive wildfires have burned over 15 million acres of land across Australia in the current fire season. Two…

https://www.directrelief.org/2020/01/australian-bushfires-mapping-population-dynamics/

Forest Loss

select "Forest Loss in AU for 2019" on the right

Initial studies have provided estimates that the fires destroyed roughly 20% of the continent's forests and put much more flora at

risk, including the extremely rare wild Wollemi Pine trees. Fewer than 200 of these prehistoric trees remain in a secluded area about 125 miles northwest of Sydney, and firefighters were deployed on a special mission to save them.

You can learn more about the Wollemi Pine trees in articles such as this one, and learn more about the effects of the fires on Australia's forests in this study.

Bushfires burned a fifth of Australia's fores…

Australia's wildfires have destroyed more than a fifth of the country's forests, making the blazes "globally…

https://phys.org/news/2020-02-bushfires-australia-forest.html

Ecological Effects

select "Biodiversity Hotspots" on the right

Australia is suffering from ongoing ecological and biodiversity impacts, including the loss of millions of animals. The map on the left shows terrestrial species richness, information on bird populations, and biodiversity hotspots, home to many of the affected species.

You can learn more about the impacts of the fires on Australian wildlife through The University of Sydney's work on their website and in news articles like this one.

Number Of Animals Feared Dead In Austra…

SYDNEY — The number of wildlife estimated to have died in Australia's wildfire catastrophe has skyrocketed …

https://www.huffpost.com/entry/billion-animals-australia-fires_n_5e13be43e4b0843d361778a6

Try turning different data layers on and off to see if you can spot any patterns.

3) Atmospheric Composition

Smoke from the fires travelled across the Pacific Ocean, as seen in this image showing a 10 day aerosol optical depth average from MOIDS-Terra between January 1-10, 2020. Image credit: Jean-Paul Vernier and Sanjana Paul. Data processed through https://giovanni.gsfc.nasa.gov/giovanni

The geographic impact of the fires and the smoke they spread was felt acutely on the surface of the Earth, affecting forests, animal populations, human lives and infrastructure, and leaving burn scars on vast swaths of land. The fires also had an unusually impactful effect on global atmospheric composition, with phenomenon usually only seen in large volcanic eruptions like smoke plumes reaching the stratosphere occurring.

MISR Plume Height

The geographic region where the plume height data is aggregated.

We can tell the height of a cloud or smoke plume above Earth's surface by viewing it from space at different angles. A plume located high above the surface will appear to move considerably relative to the underlying surface when view at different angles, whereas a plume closer to the surface will appear to shift less.

The Multi-angle Imaging SpectroRadiometer (MISR) instrument aboard the NASA Terra satellite contains nine cameras that image Earth at a wide range of angles, allowing us to observe the apparent shift (called parallax) of smoke plumes from the wildfires in Australia, and to use this to determine the height. Plume height gives an indication of fire intensity, and is also important as an input to air quality models that predict where the smoke will go, and who it might affect downwind. In this visualization, MISR-retrieved plume heights are represented as circles with progressively lighter colors for higher elevation. Hot spots on the surface, derived from infrared brightness anomalies (at about 4 microns) in MODerate resolution Imaging Spectroradiometer (MODIS) imagery, are shown as red 3D circles.

Active Aerosol Plume (AAP) Project, V. Flower, R. Kahn, K. Junghenn-Noyes, visualized by Jeremy Kirkendall, NASA Disasters Program.

Viewing a Cross-cut of a Smoke Plume

Particulate matter has also been found to reach stratospheric levels. Smoke plumes reached a 30 km height due to the self-lofting of the smoke by radiative heating, the highest observed layer since Mt. Pinatubo erupted in 1991, and one of the highest smoke plumes from a fire ever observed.

NASA's satellite sensors, such as the CALIPSO space borne LiDAR, which examines vertical profiles of the atmosphere, provided novel information about the impacts of the smoke on stratospheric composition. Below, you are seeing a cross-cut of a cloud similar to that in the image to the left.

Image Credit: Jean-Paul Vernier, NASA Langley Research Center

Left Image Credit: CNN

Pyrocumulonimbus Clouds

Image Credit: Australian Bureau of Meteorology

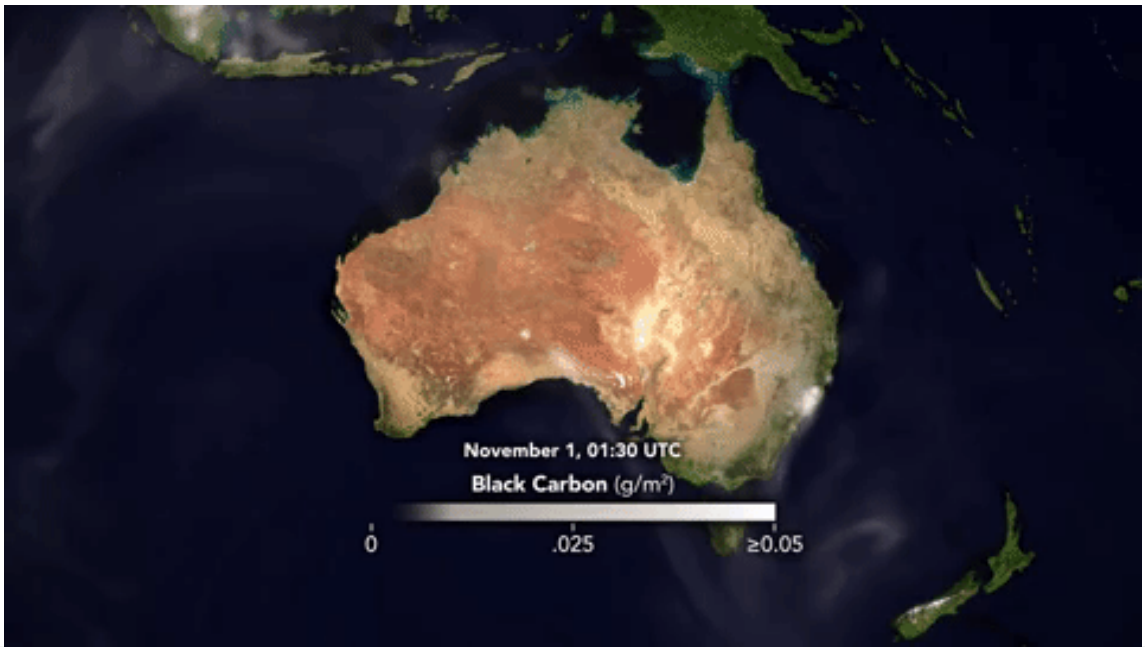
The Australian bushfires also drove thunderstorms by leading to the formation of pyrocumulonimbus clouds - clouds formed by smoke plumes - which can then enter into a feedback loop causing additional fires on the ground.

To the right, you can see rain begin to fall on drought and fire-ravaged country near Tamworth, Australia ahead of predicted further wet weather across NSW and Victoria this week, seen here on Jan. 15, 2020.

Right Image Credit: Brook Mitchell, Getty Images, "Intense Thunderstorms Bring Relief and Problems to Fire-Ravaged Australia"

NASA Cloud Data

If you would like to learn more about cloud formation, properties, and data, please visit the NASA Worldview Website and search 'Cloud'.



NASA Animates World Path of Smoke and Aerosols from Australian Fires

NASA tracked the movement of smoke from the Australian fires, traveling more than 9.3 miles (15 kilometers) high and across the Pacific Ocean.

Two instruments aboard NASA-NOAA's Suomi National Polar-orbiting Partnership (NPP) satellite, VIIRS & OMPS-NM, provide unique information to characterize and track this smoke cloud. The VIIRS instruments provided a "true-color" view of the smoke with visible imagery. The OMPS series of instruments comprise the next generation of back-scattered UltraViolet (BUV) radiation sensors. OMPS-NM provides unique detection capabilities in cloudy conditions that VIIRS does not, so together both instruments track the event globally.

Above Image & Copy Credit: NASA/Colin Seftor

Left Image: Gif showing transport of black carbon from the Australian fires. Source: "Aussie Smoke Plumes Crossing Oceans", Joshua Stevens

Stratospheric Transport

This animation shows RGB color images from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Aqua satellite for December 31, 2019 through January 5, 2020. A plume of brown smoke extends from the southeastern coast of Australia, over the Tasman Sea and beyond into the Pacific Ocean.

The overlaid vertical cross sections show CALIPSO LiDAR observations for these same days. The bright colors indicate the presence of small particles (aerosols) and the white color indicates clouds. Visible in each of the cross sections near 40 degrees south is a thick layer of smoke from the fires at altitudes above 9 miles (14.5 km). The dark shading below these layers is due to the absence of LiDAR signals below the opaque smoke layers. These layers contain very small particles and have optical properties similar to smoke.

The sequence of CALIPSO and MODIS tracks in the animation indicates the continued transport of the smoke layer to the east. As of Jan. 5, 2020, smoke was detected more than 4,000 miles from the source.

Video & Text Credit: NASA Langley/Roman Kowch

The footprint of the massive Australian bushfires has been visible in the stratosphere for several months. This cross-section of stratospheric aerosols from April 2020 using observations from the Stratospheric Aerosol and Gas Experiment III (SAGE III), installed on the International Space Station (ISS) since 2017, has captured smoke layers traveling in the stratosphere all the way from a few kilometers above the tropopause (the boundary between the troposphere and stratosphere) to 34 km in height. The map in the top-right corner shows the positions of the SAGE III measurements used to create the cross-section. SAGE III/ISS follows a series of instruments using the sun and moon to derive atmospheric aerosol composition that started back in the late 1970's. Since then, no fires have had such an impact on stratospheric aerosols. The latest major event reaching similar levels was the Mt. Pinatubo volcanic eruption in June 1991, which had significant cooling impacts on the Earth's climate system.

Image and Text Credit: Jean-Paul Vernier and Allison Leybold

4) Particulate Matter & Public Health

Wildfires produce fine particulate air pollution, which can threaten human health even during relatively short exposures. As a result of

intense smoke and air pollution stemming from the fires, in January 2020 reports indicated that Canberra measured the worst air quality index of any major city in the world. Canberra and Sydney saw levels of PM 12 to 20 times higher than the levels considered hazardous. Smoke from the Australian bushfires also drifted across the Pacific Ocean, leading to hazardous air quality in not only major cities in Australia, but also New Zealand and South America after smoke reached Argentina and Chile.

Particulate Matter Observed by Satellites

NASA's Multi-angle Imaging SpectroRadiometer (MISR) mission reveals valuable insights into many different aspects of our planet, using cameras that scan the planet at 9 different angles. One such piece of information is global aerosol optical depth (AOD) distribution and prevalence. Aerosol optical depth can be used as an indicator for particulate matter in the atmosphere of a particular location, informing us about the composition of the atmospheric column and how safe it is for humans to breathe the air around them.

The image service on the right shows global AOD distribution using the MI3MAENF_002 dataset. Zoom out to get a wider perspective of the world, or focus on a particular area of interest to you. You can

also view a time lapse of how aerosol optical depth changes over a certain timeframe.

The GIF below shows samples of MISR swaths over Australia during part of the intense 2019-2020 fire season, showing increased optical depth caused by particulate matter from the fires, leading to poor air quality for Australians.

Aerosol Optical Depth, from a MISR data product stored at the Atmospheric Science Data Center, over Australia, November 7-11 2019. Click here to learn how to create a GIF like this yourself.

Ground Station Data for Monitoring Air Pollution in Australia

Data collection from ground monitoring stations can provide much more localized and time sensitive insights about air quality in a given area. In the image to the right, we can see air quality indices from different stations. Click the button in the top right corner to open the website and view real-time ground station data all over the world.

Graph showing daily measurements of the air quality index (AQI) at the Brooklyn monitoring station in Australia over the month of January 2020. Image credit: Danielle Groenen

Poor Air Quality and Healthcare

80% of Australians have been exposed to poor air quality as a direct or indirect result of the fires. Poor air quality can be associated with

an increased risk of asthma, bronchitis, and chronic obstructive pulmonary disease, among other health issues. Large particles from smoke exposure can irritate the eyes, nose, and mouth, and worsen existing respiratory and cardiovascular issues.

Healthcare costs for this past fire season were the highest on record, likely due to the correlation between poor air quality and poor public health. This is particularly evident in New South Wales, the region where many of the fires occurred.

New studies, such as the one this graphic is a part of, led by researchers at the University of Tasmania, and news coverage focused on the health issues caused by the smoke from the bushfires. Click the link below to read more.

Summer bushfire smoke caused health prob…

Two-thirds of people living in a fire-affected part of New South Wales this summer suffered from at least one…

https://www.theguardian.com/australia-news/2020/jun/11/summer-bushfire-smoke-caused-health-problems-in-two-thirds-of-people-living-in-parts-of-nsw

Image Credit: Fay Johnston, Nicolas Borchers-Arriagada, Geoffrey Morgan, Bin Jalaludin, Andrew Palmer. Grant Williamson and David Bowman. A rapid assessment of health and economic impacts of smoke associated with the extreme Australian fire season of 2019-20. Plenary Presentation, Third International Smoke Symposium of the International Association of Wildland Fire. April 2020.

Aboriginal Fire Management Practices

To limit the spread of vicious fires, Aboriginal fire management in Australia by Indigenous communities focuses on "defensive burning" - starting many small firs throughout the course of the year to get rid of undergrowth that can cause larger fires to spiral out of control. In Northern Australia, fire management programs led by Indigenous communities consistently perform well, and stand to gain financially as well due to Australia's cap-and-trade program.

While the burning techniques employed in the savannah landscape of Northern Australia may not be directly suited to Southern Australia, which has a more temperate climate and different vegetation, there are still valuable lessons to be learned in the Indigenous fire management successes of the North.

Image credit: Matthew Abbott/The New York Times. "Reducing Fire, and Cutting Emissions, the Aboriginal Way"

Exploring NASA's Data

Research from NASA Langley

What happens in the different layers of the atmosphere may seem far away, but affects all of us on the surface of the Earth. It is important for scientists to be able to use remote sensing data to provide valuable insights into this information.

Data stored at the Atmospheric Science Data Center (ASDC) at NASA's Langley Research Center are supporting scientists' important work in this area, including NASA Langley scientists like Jean-Paul Vernier collaborating with the Australian Bureau of Meteorology. Skillsets in atmospheric research at Langley are being used to better understand the lead up, impacts, and feedback from bushfires and other events to improve forecasting and responses in the future.

Continuing Fire Research across the Globe

NASA’s satellite instruments are often the first to detect wildfires burning in remote regions, and the locations of new fires are sent

directly to land managers worldwide within hours of the satellite overpass.

Together, NASA instruments detect actively burning fires, track the transport of smoke from fires, provide information for fire management, and map the extent of changes to ecosystems, based on the extent and severity of burn scars. NASA has a fleet of Earth-observing instruments, many of which contribute to our understanding of fire in the Earth system.

In the video to the left, you can see how NASA studied the fire weather that led up to the 2020 Arizona Bushfire. On the afternoon of June 13, 2020, a vehicle fire near the intersection of Bush Highway and State Route 87 ignited the brush and grass nearby. As of June 25, 2020, the Bush Fire is one of the five largest fires in Arizona's history.

You can learn more about the Atmospheric Science Data Center (ASDC) here:

ASDC Website

You can find GIS-ready atmospheric data here:

ASDC ArcGIS Portal

You can explore more NASA Disasters resources here:

NASA Disasters Website

Have More Questions? Experts at NASA's Earthdata Forum are here to help!

The new Earthdata Forum, available at forum.earthdata.nasa.gov, provides a central location where data users can interact with subject matter experts from multiple DAACs to discuss general questions about research needs and data applications, and receive help on specific queries about accessing, viewing, and manipulating NASA Earth observing data.

This storymap was created by members of the Science Outreach Team at NASA Langley Research Center's Atmospheric Science Data Center, and members of the NASA Disasters Team.

To learn more about the Atmospheric Science Data Center, please visit asdc.larc.nasa.gov. To learn more about the disasters program, please visit disasters.nasa.gov.

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