GEO Newsletter

Group for Earth Observation

No 76 - December 2022

Hurricane Ian imaged by GOES-E on September 28, 2022

Image: NOAA

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Useful User Groups

Weather Satellite Reports

This group provided weekly reports, updates and news on the operational aspects of weather satellites.

https://groups.io/g/weather-satellite-reports

SatSignal

This end-user self help group is for users of David Taylor's Satellite Software Tools, including the orbit predictor WXtrack, the file decoders GeoSatSignal and SatSignal, the HRPT Reader program, the remapper GroundMap, and the manager programs - MSG Data Manager, GOES-ABI Manager, AVHRR Manager etc.

https://groups.io/g/SatSignal

MSG-1

This forum provides a dedicated area for sharing information about hardware and software for receiving and processing EUMETCast data.

https://groups.io/g/MSG-1

GEO-Subscribers

This is the official group is for subscribers of the Group for Earth Observation (GEO), aimed at enthusiasts wishing to exchange information relating to either GEO or Earth Observation satellites.

https://groups.io/g/GEO-Subscribers/

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From the Editor

Les Hamilton

What a tempestuous three months we have experienced since the September issue. At that time the Northern Hemisphere was literally on fire, with heatwaves and severe droughts rampant, as documented in ESA's article on page 4. But November proved a major *volte-face* as a succession of Atlantic depressions brought rain to Europe by the bucketfull. In Aberdeenshire where I live, one two-day spell of incessant rain delivered twice the November monthly average precipitation:: rivers flooded, villages were inundated and yet more trees were felled.

Across the Atlantic, following a slow start to *Hurricane Season*, Hurricane Ian, imaged on the cover of this issue, proved to be the most destructive storm to strike the state of Florida since the 1935 Labor Day hurricane. And excessive rainfall and flooding have not been confined to the Northern Hemisphere. Southeast Australia has also had to contend with severe flooding brought on by the prevailing La Niña effect over the Pacific Ocean.

Let's hope things calm down for the Festive Season and New Year. Very best wishes to all readers for health and happiness in 2023, and just maybe - a new Meteor M satellite to whet our appetites.

Contents

UK heatwave

European space Agency

This summer, heatwaves struck Europe, North Africa, the US and Asia with temperatures reaching over 40°C in places—breaking many long-standing records. Images from the Copernicus Sentinel-3 mission show the scale of Britain's heatwave as it baked in extreme temperatures during August 2022.

This image, captured on August 12, shows the United Kingdom's previously green land appear brown (particularly in the southeast) amid the scorching conditions. The heatwave came after months of extreme temperatures and low rainfall had left the landscape parched. The dry conditions are also visible in parts of France, Belgium and the Netherlands.

The severe heatwaves experienced across Europe this summer are a harsh reminder of what is in store for our future. Extreme weather events will happen more frequently and intensely according to the *Intergovernmental Panel on Climate Change* (IPCC). This trend is set to worsen unless the rise in atmospheric greenhouse gas emissions caused by human activities is addressed.

Satellites orbiting our planet play an important role in delivering data to understand and monitor how our world is changing. Their observations and data are critical for improving model predictions of our future climate, mitigation strategies and policy making.

The Copernicus Sentinel-3 mission not only provides two-day global coverage optical data, but it also carries a *Sea and Land Surface Temperature Radiometer* instrument that measures Earth's land surface temperature (how hot the actual surface would feel to the touch). During August 2022, the Sentinel-3 mission recorded extreme land surface temperatures of more than 45°C in the United Kingdom, 50°C in France and 60°C in Spain.

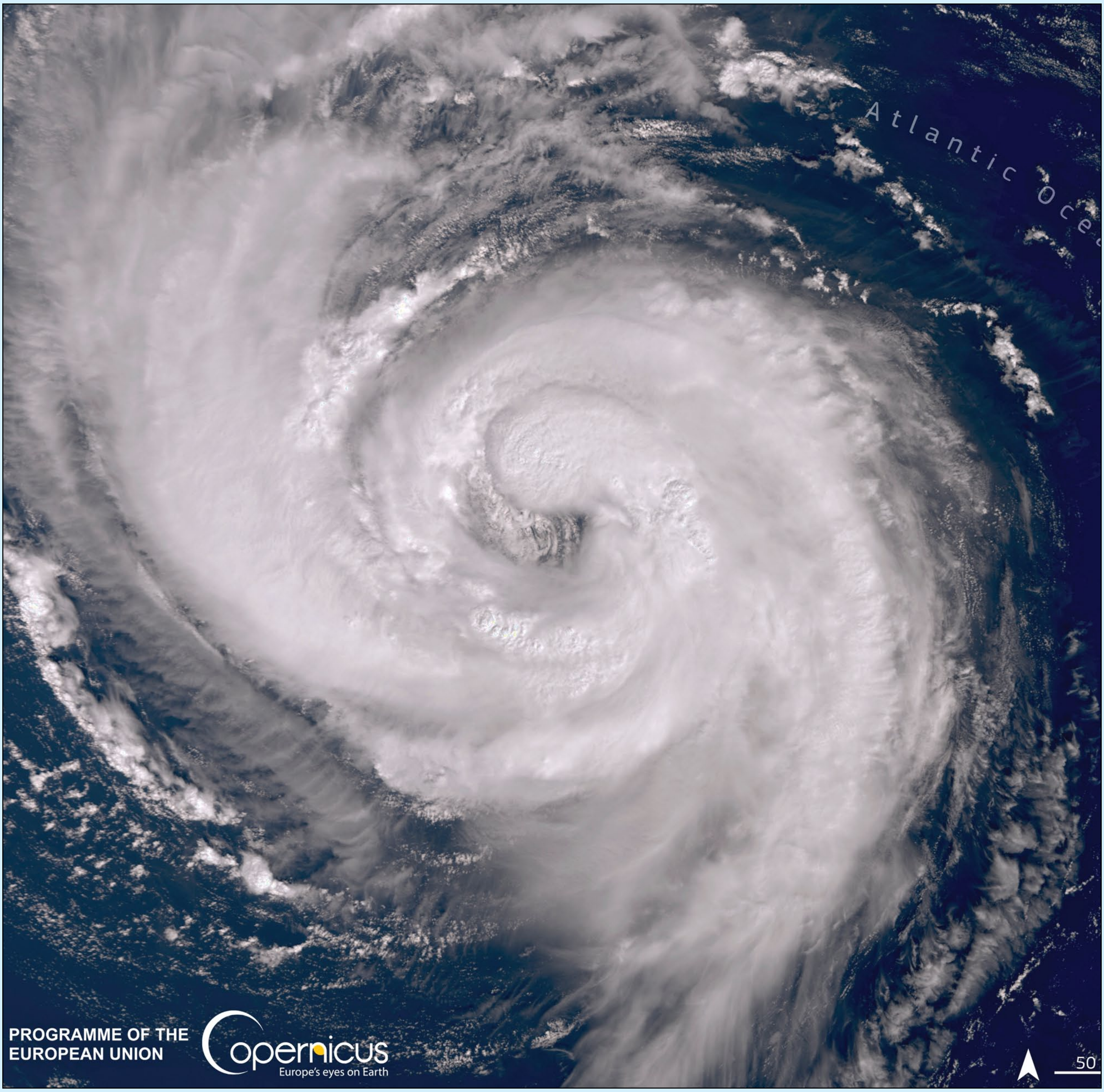
Image contains modified Copernicus Sentinel data (2022) processed by ESA, CC BY-SA 3.0 IGO

Sentinel-3 data has also been merged with archived satellite observations to form a recently released 25-year record of global land surface temperatures (from 1995 to 2020) developed by ESA's *Climate Change Initiative* along with Europe's leading climate scientists. This data record shows a stable increase in global land surface temperature of 0.2°C per decade, with strong regional variability.

Monitoring land-surface temperatures is useful for scientists because the warmth rising from Earth's surface influences weather and climate patterns. These measurements are particularly important for farmers evaluating how much water their crops need and for urban planners looking to improve heat-mitigating strategies.

Late start to the Atlantic Hurricane Season

Copernicus Image of the Day



Credit: European Union, Copernicus Sentinel-3 imagery

This image, acquired by one of the Copernicus Sentinel-3 satellites on 4 September at 13:04 UTC, shows Hurricane Danielle when it was 3,000 km west of the coast of Portugal. It had formed in an anomalous position, at about 38° latitude North, and was is moving towards Europe where it would arrive as a tropical depression. Besides its position, Danielle had another peculiarity, as it was not named by the US National Hurricane Centre until September 2, 2022.

On average, over the years, the first hurricane of the year in the Atlantic Ocean occurs in early August: this was the first time for quarter of a century that there had not been a single named storm in the Atlantic Ocean before the start of September.

A Half Century of Loss in Northwest Greenland

NASA Earth Observatory

Story by Kathryn Hansen

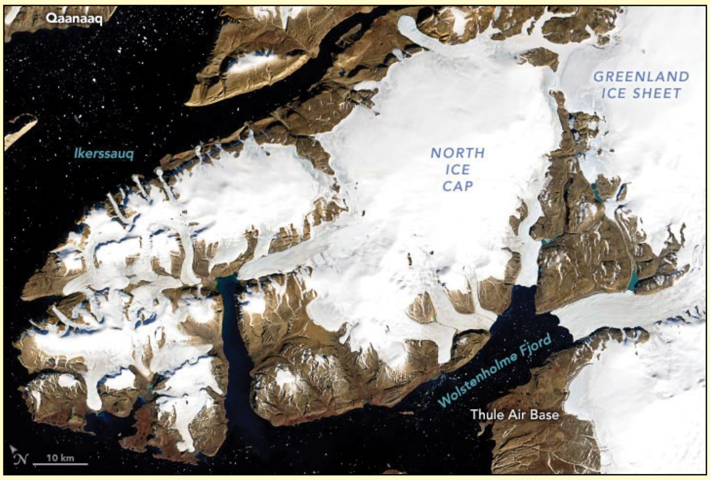


Figure 1
This Landsat 1 image was acquired on September 3, 1973

Figure 1
This Landsat 8 image was acquired on September 20, 2022

NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey.

A pair of satellite images acquired almost 50 years apart reveals striking changes to the glaciers and ice caps in northwest Greenland. Few other satellite comparisons span this much time, especially in such vivid lifelike colour.

Observations of Earth from space are now common. But prior to the 1970s, no Earth-observing satellites had been launched with the specific intent of monitoring our planet's land areas. That changed with the launch of **Landsat 1** in 1972. The Landsat mission continues onward through today, with the launch of **Landsat 9** in September 2021.

This image pair spans the Landsat era so far, revealing changes across a peninsula north of Thule Air Base (Pituffik). The Multispectral Scanner System (MSS) on **Landsat 1** acquired the figure on September 3, 1973. Figure 2, acquired on August 20, 2022, by the Operational Land Imager (OLI) on **Landsat 8**, shows the same area 49 years later.

The 1973 image resembles natural colour, but is actually false color (MSS bands 6-5-4). This becomes apparent along some of the ice-free areas where vegetation shows up as red. But with very little vegetation in northwest Greenland, the false-colour Landsat 1 image appears similar in colour to the natural-colour Landsat 8 image (OLI bands 4-3-2). Bare land is brown, and snow and ice are white.

The similarity in colour makes it easy to see where glacial ice has retreated, narrowed, and in one case surged. Notice the clear retreat of the large glaciers flowing into the water of Wolstenholme Fjord. Isolated ice caps and smaller glaciers throughout the image all generally shrink, and in some places disconnect from each other. In contrast, the large glacier flowing west from North Ice Cap (Nunatarssuaq Ice Cap) appears to lengthen. Such surging behavior might be caused by ice at higher elevations of the ice cap draining into the glacier.

The images were acquired just two weeks apart in their respective years. Notice that in 2022, the edges of the ice caps and glaciers generally appear much grayer than in 1973. A warm summer in 2022 melted away more of the bright-white snow cover exposing darker, dirtier ice. Fresh snowfall might also be present in the 1973 image, although September is early in the accumulation season, which largely runs from September until May.

Inspired by recent research on changes to Greenland's peripheral glaciers, Christopher Shuman searched Landsat data records and identified this image pair.

> *"Because this is such a cold, northern area, I figured that the losses over time would be relatively slow, so we needed almost 50 years to show the change,"*

said Shuman, a glaciologist at University of Maryland, Baltimore County, based at NASA's Goddard Space Flight Center.

The research showed that peripheral glaciers, which are relatively small and disconnected from the main ice sheet, account for a small proportion of Greenland's ice-covered area (about four percent). But peripheral glaciers account for eleven percent of the island's ice loss, which makes them outsised contributors to current sea level rise.

Peripheral glaciers in northwest Greenland have been losing about 3.5 to 7 gigatons of ice per year in recent decades amid accelerated warming, according to the research. That's more than the peripheral glaciers in southeast and southwest Greenland are losing, but less than in north Greenland, where peripheral glaciers have been losing as much as 26 gigatons per year since the early 2000s.

Nicole Soaks the Eastern United States

MODIS Web Image of the Day

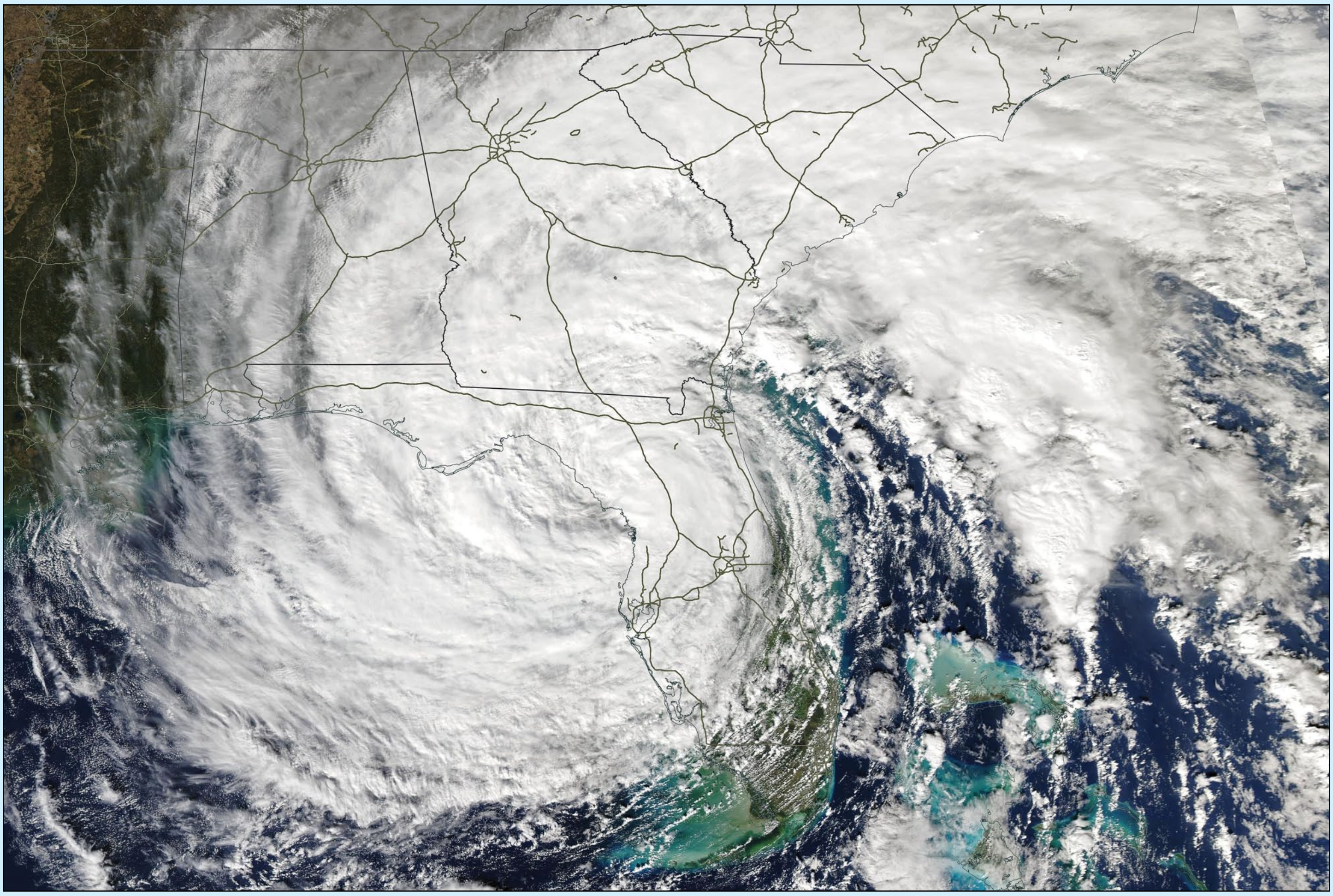


Image Credit: MODIS Land Rapid Response Team, NASA GSFC

On November 10, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Aqua satellite acquired a true-colour image of Tropical Storm Nicole moving northward across the United States. Nicole was a remarkably large storm, with tropical-storm-force winds extending outwards up to 555 kilometres from the centre, especially to the northeast. This image shows convective bands and clouds stretching from southern Florida to Maryland and West Virginia. The cloud-filled centre of Nicole sits near Tampa on Florida's west coast.

After making landfall near Vero Beach on Florida's East Coast as a Category-1 hurricane with maximum sustained winds of 121 kph, the storm weakened as it crossed the state. According to the *National Hurricane Center*, near the time this image was acquired, Nicole had become a tropical storm and was carrying maximum sustained winds of 70 kph. It was located about 70 km north of Tampa, Florida and about 265 km southeast of Tallahassee, Florida and was moving northwest. By 10:00 pm EST on November 10, Nicole had further weakened to become a tropical depression with maximum sustained winds of 55 kph. However, it remained a super-soaking storm as it crossed the US Southeast and Mid-Atlantic states.

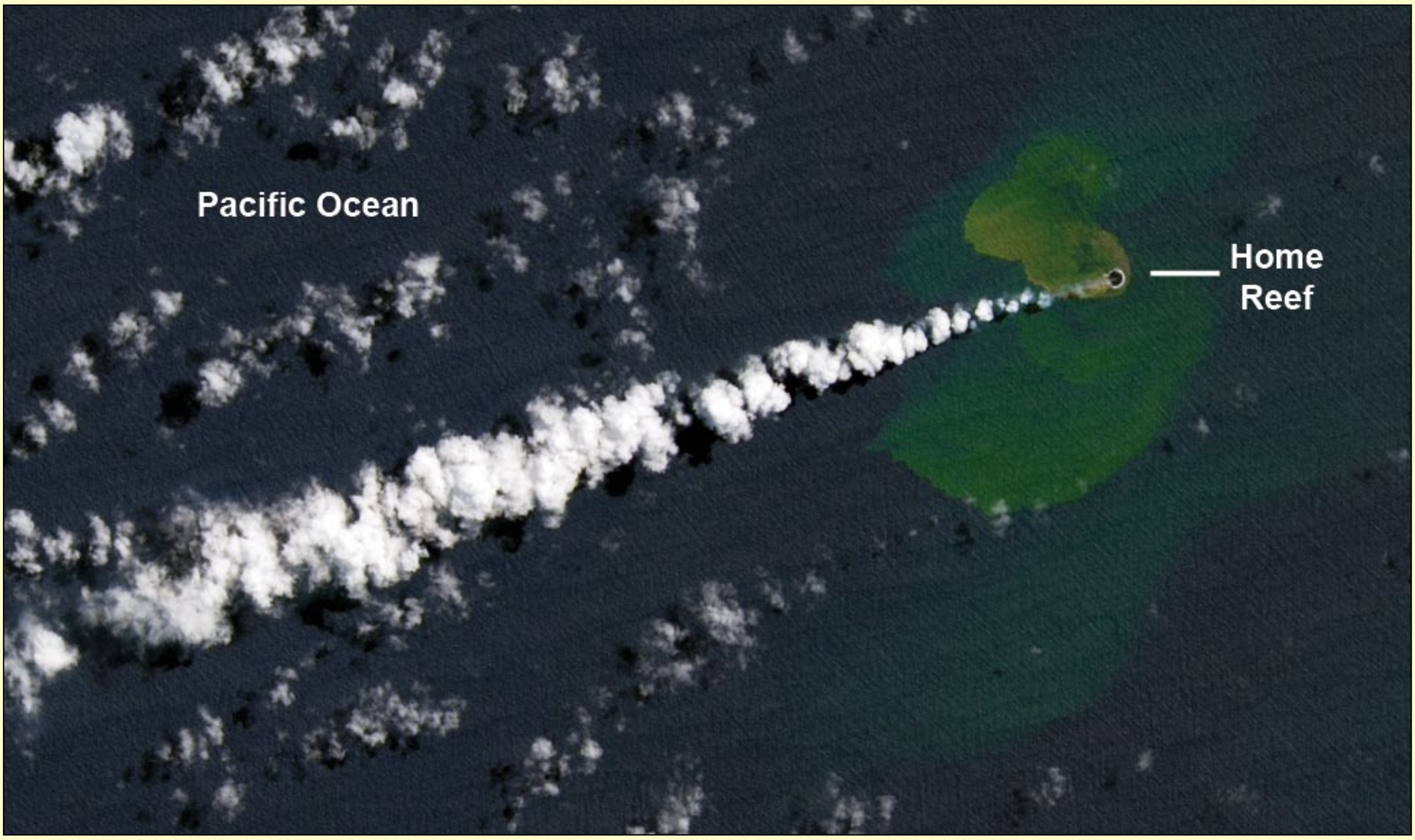
According to meteorologist Jeff Masters, writing for Yale Climate Connections, 'Nicole was just the fourth hurricane on record to hit the contiguous US after October, and the second-latest landfalling hurricane on record. Only Hurricane Kate in 1985, which hit the Florida Panhandle as a category-2 storm with 160 kph winds on November 21, made landfall later in the season.'

Nicole brought a devastating storm surge which caused severe beach erosion to parts of Florida, especially Volusia County, where beach front homes were destroyed as the surge undercut the sand beneath the houses and parts of the roadway crumbled. Coastal flooding occurred as far north as Charleston, South Carolina, including record high water levels of 1.3 metres above high tide measured at Jacksonville, Florida. The storm was also responsible for the deaths of five people in Florida.

Home Reef Erupts

NASA Earth Observatory

Story by Adam Voiland



NASA Earth Observatory image by Lauren Dauphin, using Landsat data from the U.S. Geological Survey.

In the southwest Pacific Ocean, a seafloor ridge that stretches from New Zealand to Tonga has the highest density of underwater volcanoes in the world. On September 10, 2022, one of them awoke. In the days since, the Home Reef seamount in the Central Tonga Islands has repeatedly oozed lava, ejected plumes of steam and ash, and discolored the surrounding water.

Eleven hours after the eruption began, a new island rose above the water surface. The Operational Land Imager-2 (OLI-2) on Landsat 9 captured this natural-colour view of the young island on September 14 as plumes of discolored water circulated nearby. Previous research suggests that these plumes of superheated, acidic seawater contain particulate matter, volcanic rock fragments, and sulfur.

On September 14, researchers with Tonga Geological Services estimated the area of the island to be 4,000 square metres and the elevation to be 10 meters above sea level. By September 20, the island had grown to cover 24,000 square metres. The new island is located southwest of Late Island, northeast of Hunga Tonga-Hunga Ha‘apai, and northwest of Mo‘unga‘one.

Home Reef sits within the Tonga-Kermadec subduction zone, an area where three tectonic plates are colliding at the fastest converging boundary on the planet. The Pacific Plate here is sinking beneath two other small plates, yielding one of Earth’s deepest trenches and most active volcanic arcs.

Islands created by submarine volcanoes are often short-lived, though they occasionally persist for years. Home Reef has had four recorded periods of eruptions, including events in 1852 and 1857. Small islands temporarily formed after both these events, and eruptions in 1984 and 2006 produced ephemeral islands with cliffs that were 50 to 70 meters high. An island created by a 12-day eruption from nearby Late‘iki Volcano in 2020 washed away after two months, while an earlier island created in 1995 by the same volcano remained for 25 years.

“The volcano poses low risks to the aviation community and the residents of Vava‘u and Ha‘apai,”

stated the Tonga Geological Service in an update issued on September 20.

“All mariners are, however, advised to sail beyond 4 kilometers distance from Home Reef until further notice.”

The service also noted that most ash should fall within a few kilometers of the vent.

The Caspian Sea's Shrinking Coastline

NASA Earth Observatory

Story by Joanne Howl, adapted for Earth Observatory by Kathryn Hansen

Measured by surface area, the Caspian Sea is Earth's largest inland water body, spanning about 371,000 square kilometres. Measured by economic, social, and biodiversity standards, it is priceless.

The Caspian Sea supports a commercially important fishery, supplies water for agriculture, and provides recreation and work opportunities for people living nearby. Its waters are also home to several threatened species, including an estimated 90% of the planet's last-remaining sturgeon. In the northern Caspian, shallow waters teem with molluscs, crustaceans, fish, and birds. Seals raise their pups on winter ice that usually only forms in this part of the lake. And all rely on a healthy water level for their existence. However, the Caspian Sea is rapidly shrinking.

On September 19, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite acquired a natural-colour image (figure 1) of the northern Caspian Sea. Part of the sprawling Volga River Delta (dark green) is visible along the left side of the image. Sediments, carried into the lake by the Volga and stirred up from the shallow lake bed by currents, colour the water with swirls of light green and tan. Light gray areas along the shoreline and patches of white to the southeast are probably salt and other minerals left behind after evaporation.

For comparison, figure 2 was acquired by Terra MODIS on September 20, 2006. There is no light-coloured, salt-laden halo along the northern shore and only a relatively small salt crust in the east and south. Water filled the serpentine area that, twelve years later, has become a thick mineral crust.

Radar altimetry data collected by multiple satellites and compiled by NASA's *Global Water Monitor* indicate that the Caspian's water levels have been dropping since the mid-1990s. Other research suggests that the decline could continue as climate change brings warmer air temperatures and increased evaporation.

In one study, scientists ran several models to estimate future water losses due to climate change. They projected that by 2100, water levels in the Caspian Sea could drop by another 8 to 30 metres. The use or diversion of water for human activity is also an important driver of water loss in the Caspian. Accounting for this factor adds up to 7 metres of further loss, they found.

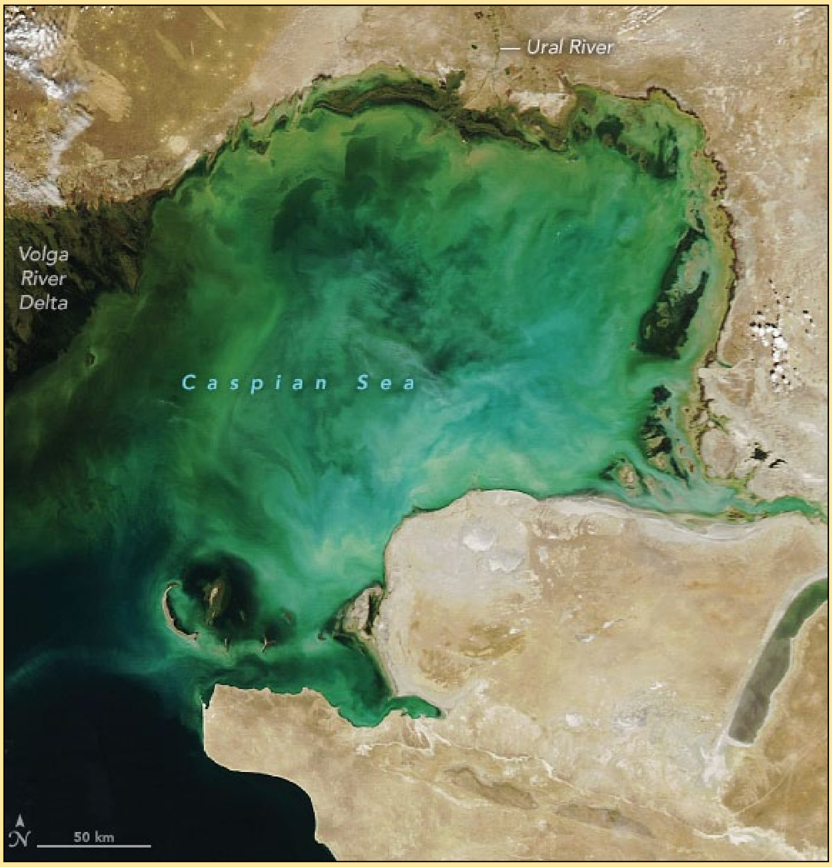


Figure 1 - Caspian Sea in 2006

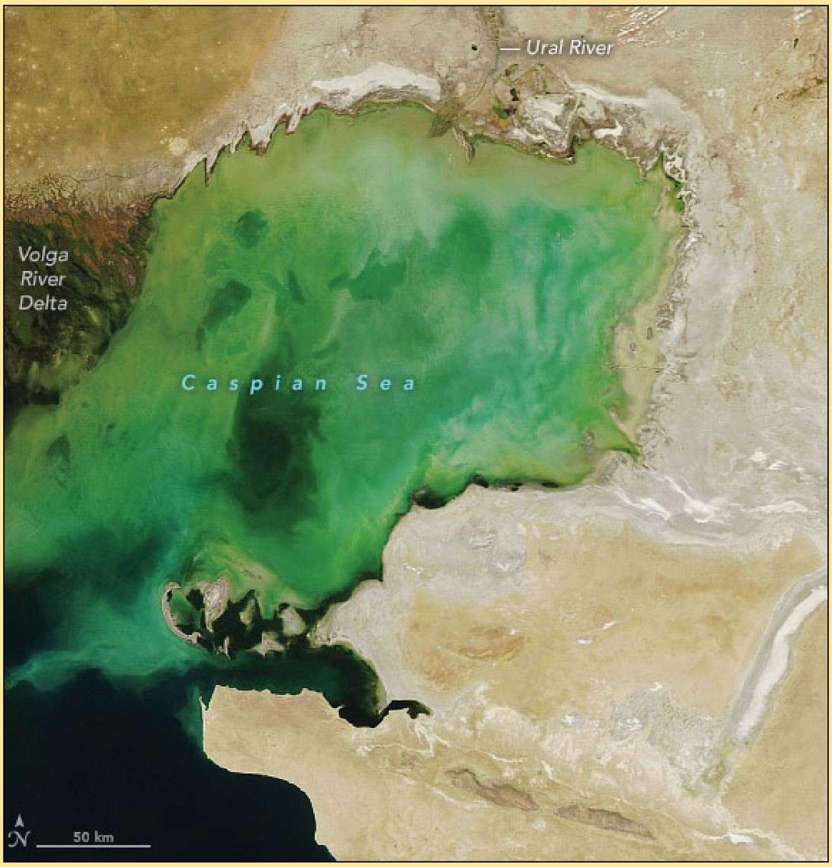


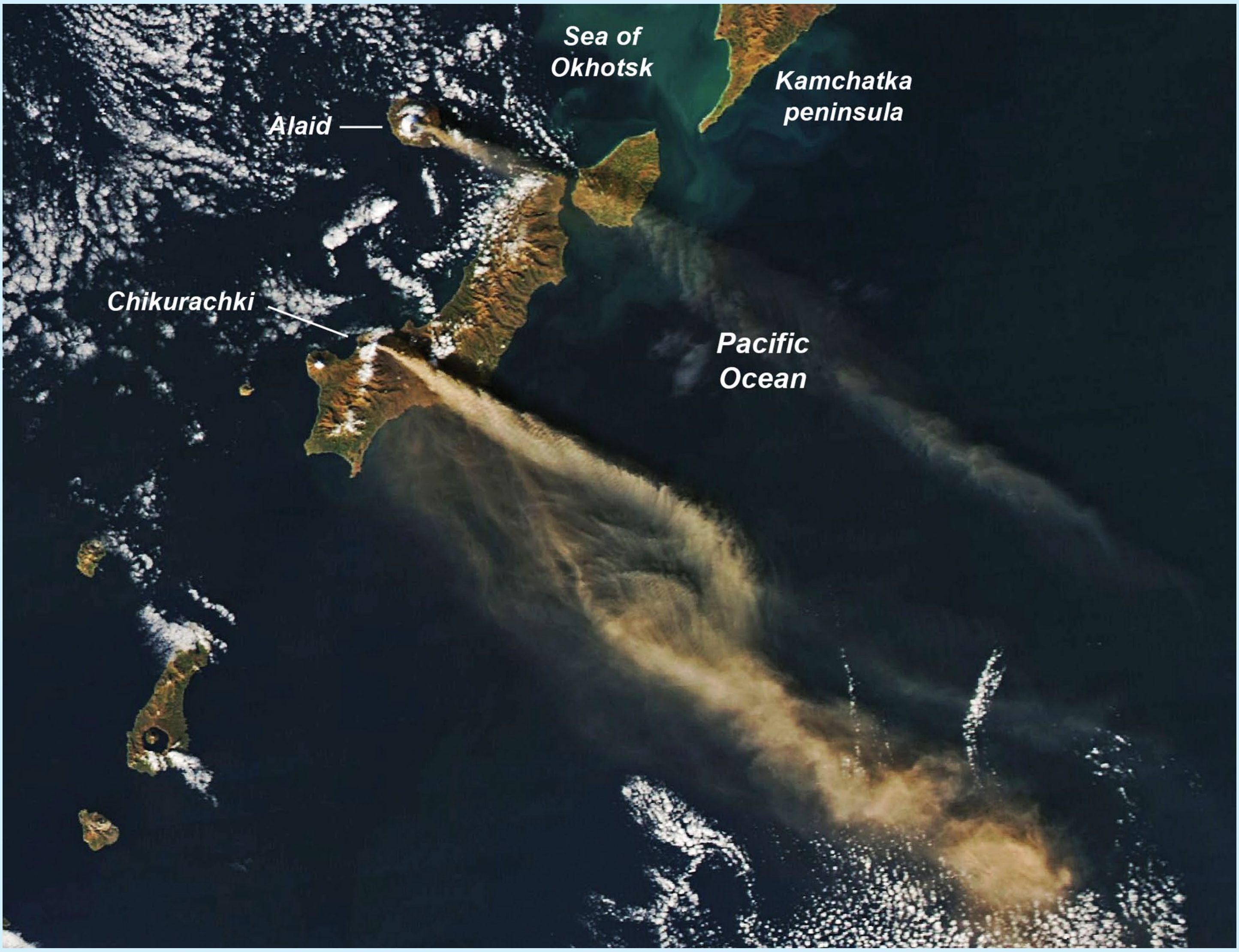
Figure 2 - Caspian Sea in 2022

NASA Earth Observatory images by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

Volcanic Plumes in the Kuril Islands

NASA Earth Observatory

Story by Kathryn Hansen



NASA Earth Observatory image by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview

More than 50 islands comprise the Kuril Islands, an archipelago that extends from the Kamchatka Peninsula to Japan. The island chain contains dozens of active volcanoes capable of unleashing explosive eruptions. In October 2022, eruptions at two volcanoes, Chikurachki and Alaid, simultaneously sent plumes of ash streaming over the Pacific Ocean.

The two plumes are visible in this natural-colour image above, acquired on October 16, 2022, with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite. Around the time this image was acquired, winds had carried the ash more than 500 kilometers toward the southeast.

The fainter of the two plumes came from Alaid, the island chain's tallest and northernmost volcano. According to the *Kamchatkan Volcanic Eruption Response Team*, activity at the volcano had been ongoing since October 7, followed by explosive activity on October 16. The explosive event lofted ash almost four kilometres above sea level.

The more prominent plume came from Chikurachki—one of at least five active volcanoes on Paramushir Island. Explosive activity from this volcano also began on October 16, sending ash up to 4.5 kilometers. The aviation colour code was raised to orange, the second-highest level on the scale, alerting the aviation sector of the actively erupting volcano and its minor ash emissions. Ash emissions waned on October 17, and by October 18, the volcano was emitting only puffs of steam and gas.

Volcanoes in the Kurils and similar island arcs in the *Pacific Ring of Fire* are fed by magma generated along the boundary between two tectonic plates, where one plate is being driven beneath the other, a process known as subduction.

Deadly Flooding in Pakistan

Les Hamilton

Based on a MODIS Web Image of the Day Report

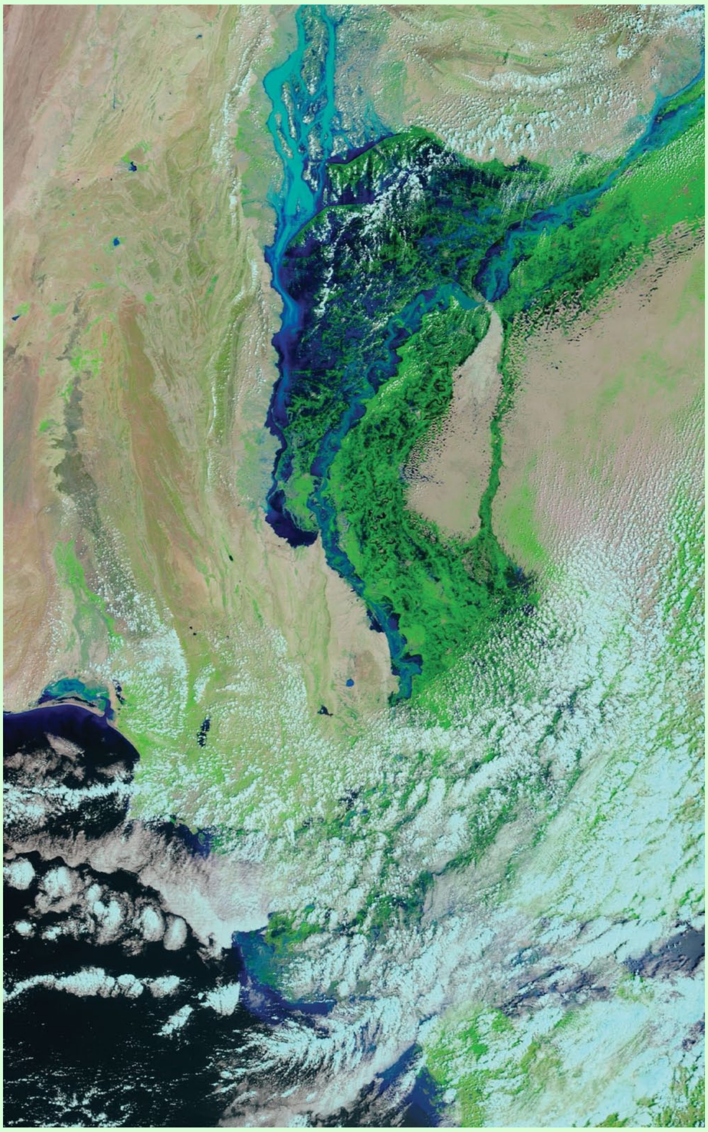
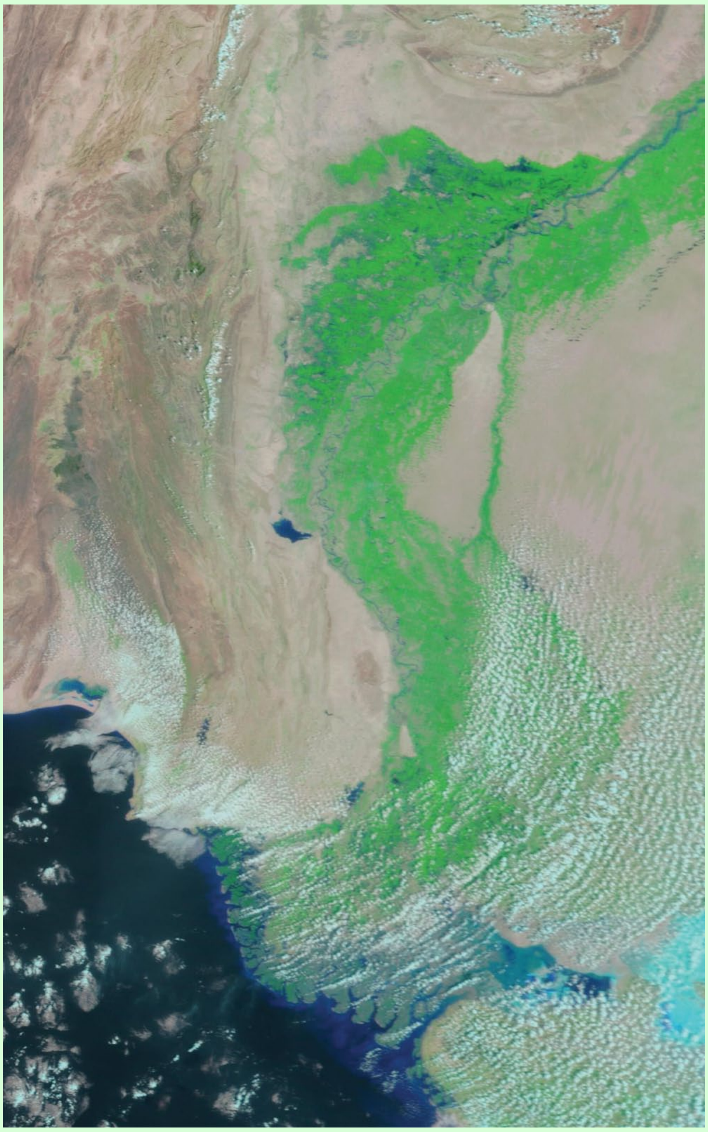



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Severe monsoon rains have battered Pakistan since mid-June 2022, creating a massive disaster that has affected about 30 million people. According to the *Pakistan National Disaster Management Authority* (NDMA), as of August 29 an estimated 1,136 people had died since June 14 with an additional 1,634 being injured. Floodwaters damaged more than 3,400 kilometres of roads—more than the straight-line north-to-south distance across the United States from its border with Alberta, Canada and the Mexico border. The NDMA reported that 162 bridges and 170 shops had been damaged and 735,375 livestock had died.

Reliefweb, a publication of the UN Office for the *Coordination of Humanitarian Affairs* (OCHA) states that floods have affected Balochistan, Sindh, Gilgit-Baltistan, Punjab, Azad Jammu and Kashmir, and Khyber Pakhtunkhwa (KPK) provinces of Pakistan. As of August 29, they reported that around one million homes had been totally or partially damaged, leaving behind millions in need of urgent shelter.

The left-hand image above shows the Indus River and adjacent floodplain in the Sindh province of Pakistan as acquired by the MODIS instrument on board NASA's Terra satellite on August 27, 2022. The right-hand image shows the identical scene on September 27, 2021.

This type of false-colour image uses infrared and visible light (MODIS bands 7,2,1) to help distinguish water from land. Water appears in various shades of blue, depending on depth and any sediment present in the water, with the deepest water looking the darkest. Vegetation shows as bright green while open or sparsely vegetated land looks tan. Cloud ranges from white to electric blue.

These images clearly show the difference between a more normal monsoon season such as in 2021, when the flood plains near the Indus were green and the river remained within its banks, and the catastrophic and deadly inundation of the 2022 monsoon.

VISAN Gallery

Richard Osborne

In Issue 74 of the GEO Newsletter [1], I described my early attempts to use the VISAN tool for visualising Satellite Application Facility (SAF) products. Since that time, I have produced a series of Python scripts which allows the use of VISAN across a number of the SAF areas. Whilst VISAN does not have the analytical features of, say, NASA Panoply or ESA SNAP, it does have have an interactive 3D globe visualisation capability that provides a useful "quick-look" feature. It also allows multiple input files which are not geographically related to be viewed on a single image.

To demonstrate the capabilities of VISAN, I have prepared a short gallery of globe images. They are not related in time as they are prepared, at random, from some of my archived data.

Any reader interested in obtaining further information, including sample scripts, can be obtained from me at the following emil address

info@woodcroft.me.uk

Reference

1 Visualising EUMETCast SAF Products using the VISAN Tool
GEO Quarterly No 74, page 35

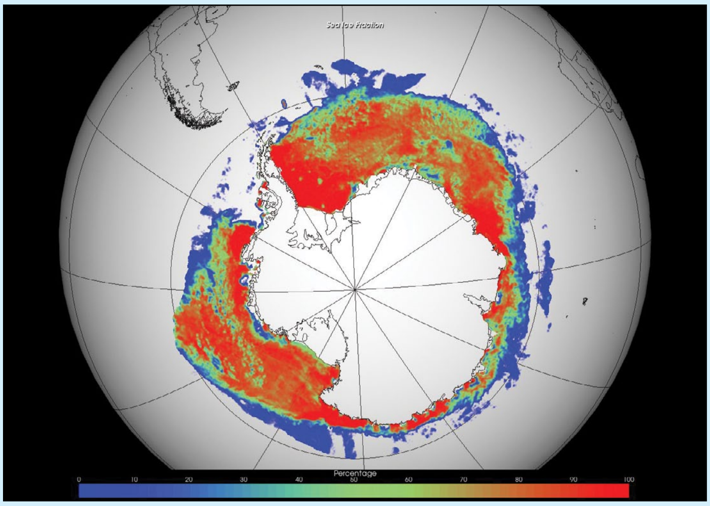


Figure 1
Antarctic Sea Ice Concentration from AMSR-2 sensor on GCOM satellite

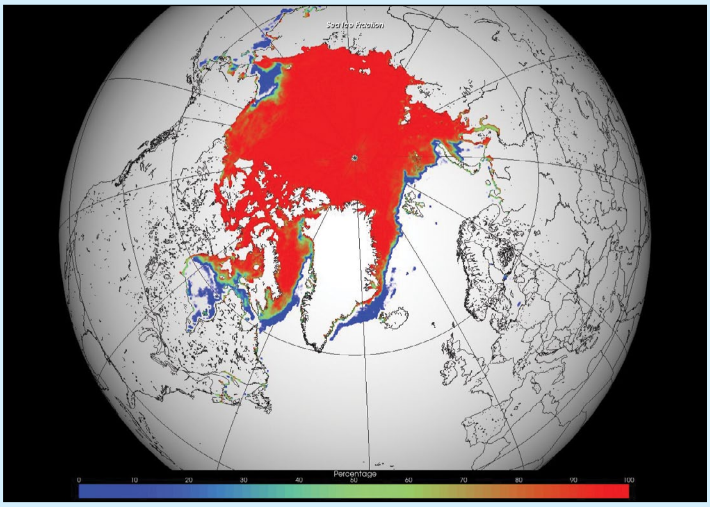


Figure 2
Arctic Sea Ice Concentration AMSR-2 sensor on GCOM satellite

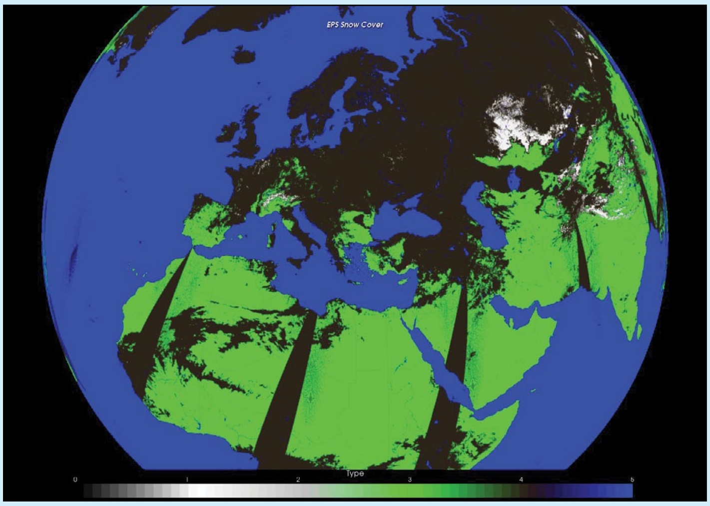


Figure 3
Global Snow Cover from METOP observations

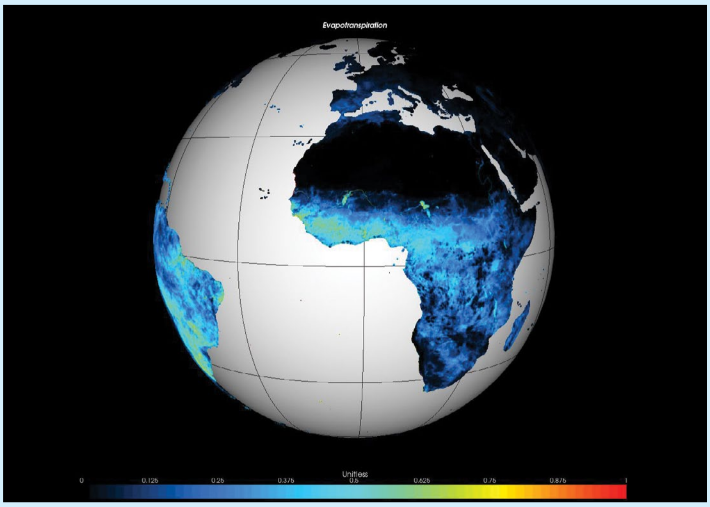


Figure 4
Evapotranspiration from MSG observations

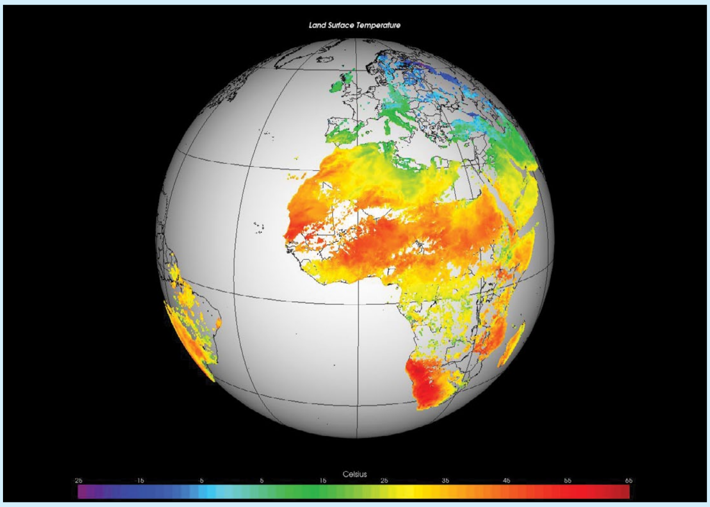


Figure 5
Land Surface Temperature from MSG observations

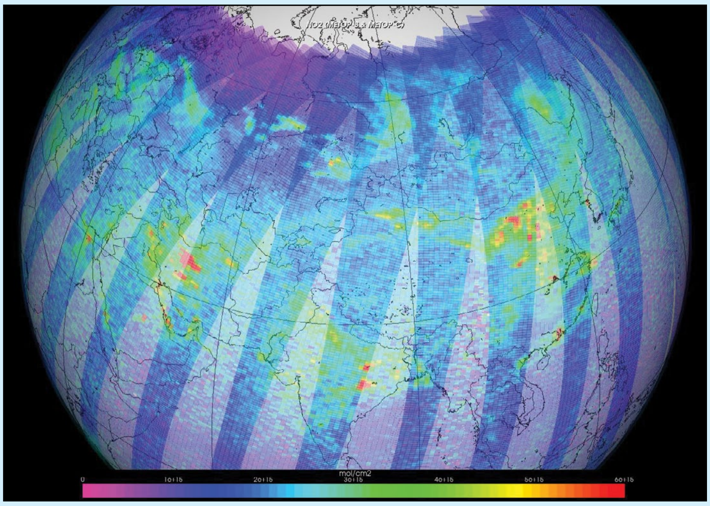


Figure 6
Nitrogen Dioxide (NO_2) levels from GOME sensor on METOP. The “hot-spots” are clearly visible as red areas.

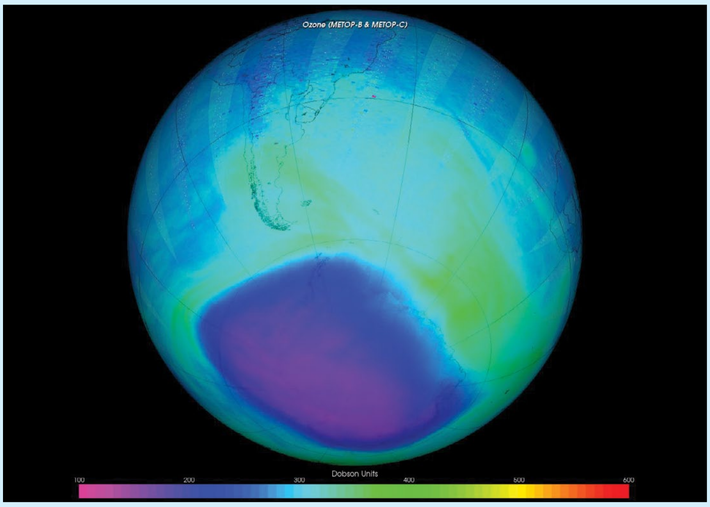


Figure 7
Ozone levels from GOME sensor on METOP. The depletion over the Antarctic is clearly visible

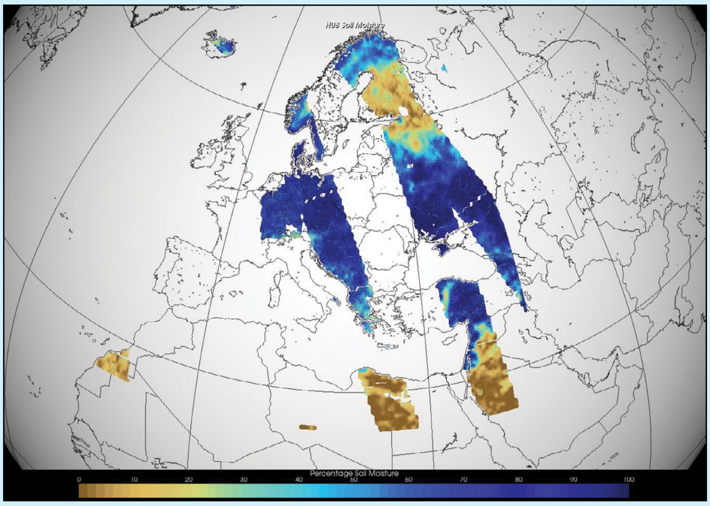


Figure 8
Soil Moisture levels from METOP observations

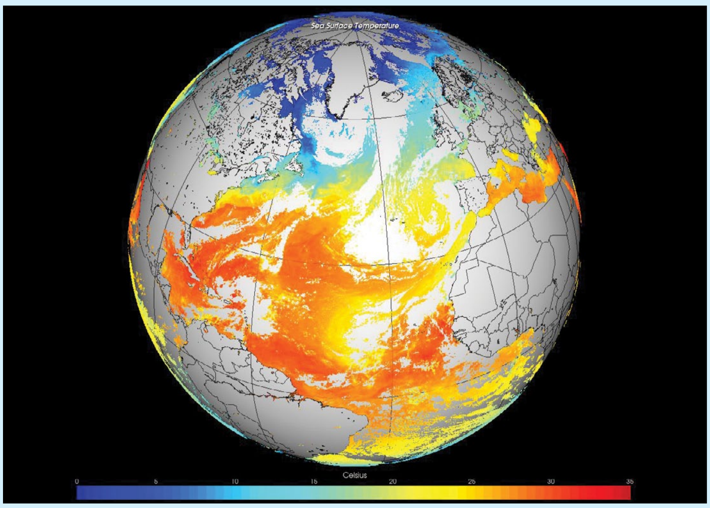


Figure 9
Sea Surface Temperature from MSG and GOES observations. The MSG and GOES data is provided in two separate files which are combined prior to image generation.

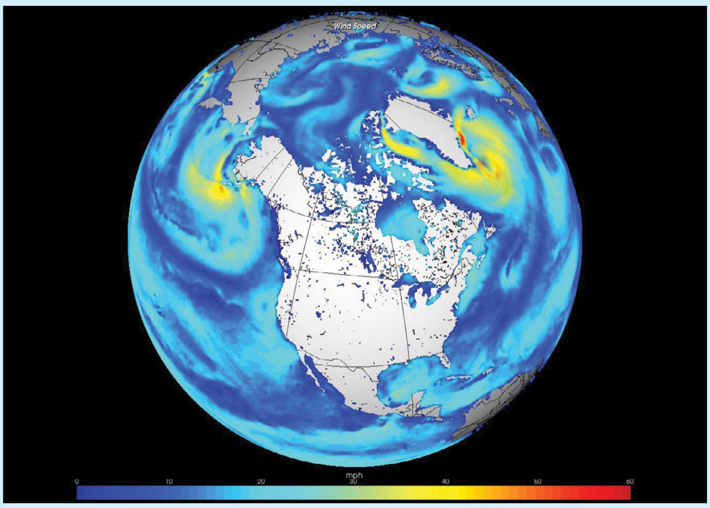
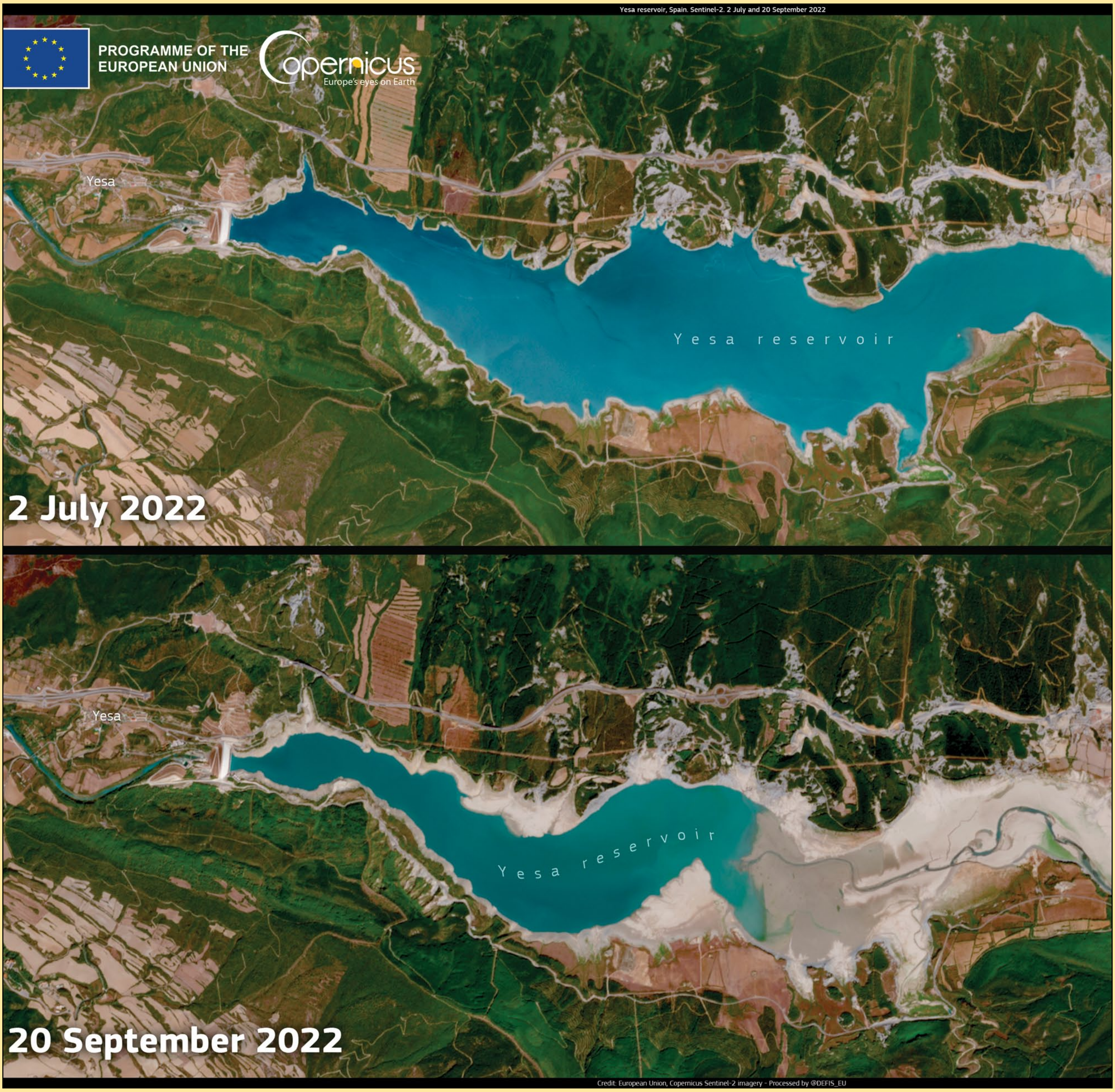


Figure 10
Wind Speed from METOP observations

Spain's Yesa Reservoir Severely Affected by Extreme Drought

Copernicus Image of the Day



Credit: European Union, Copernicus Sentinel-2 imagery

The Yesa reservoir, situated in the Pyrenees mountain range in Spain, is a source of drinking water for tens of thousands of people living in the Navarra and Aragón autonomous regions. After a very dry summer, in which several heatwaves with record-breaking temperatures hit Western Europe, Spain remains gripped by an extreme drought. The Yesa reservoir is currently at 16% of its capacity, the lowest level recorded at this time of the year since 1980.

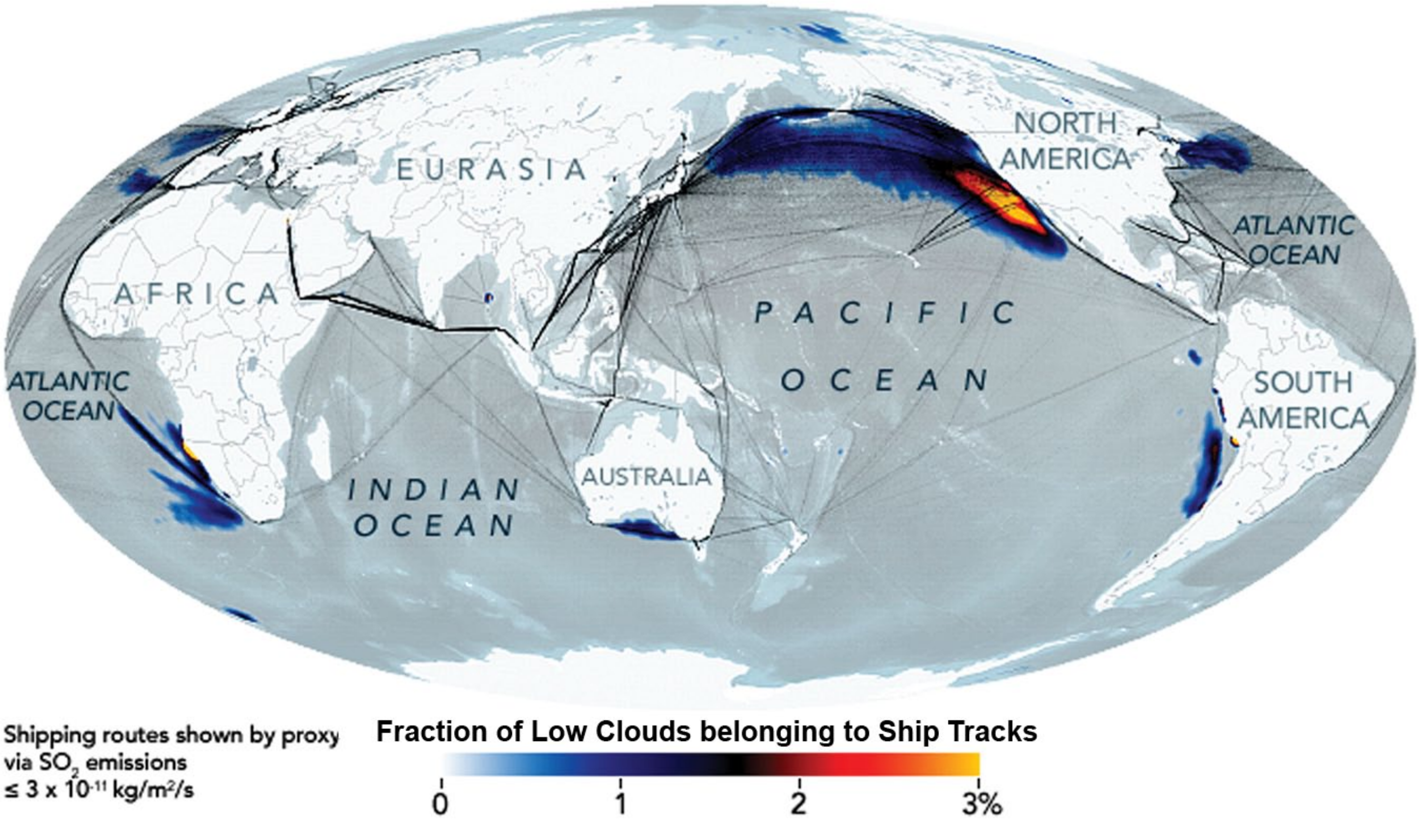
The striking difference in water levels is visible in these images, acquired on 2 July 2022 (above) and 20 September 2022 (below) by Copernicus Sentinel-2 satellites.

Open data retrieved by the Copernicus Sentinel satellites provide key information useful to accurately map water bodies and extract critical information during periods of drought.

Fuel Regulation Reduced Air Pollution from Shipping

NASA Earth Observatory

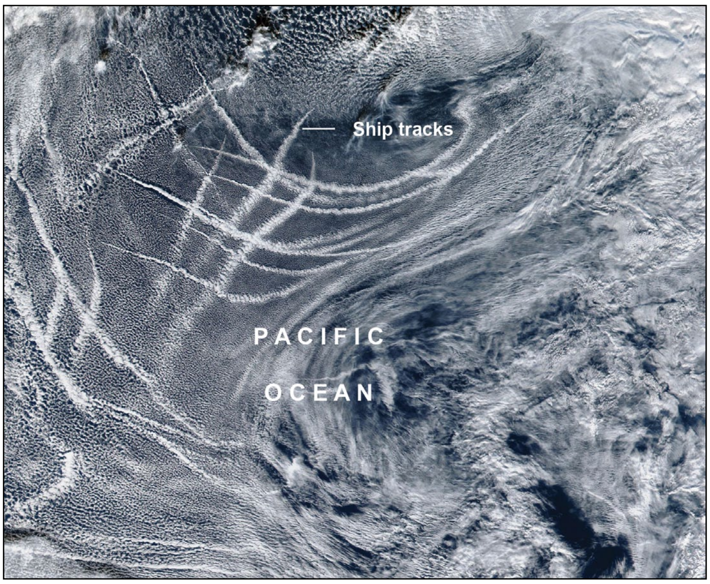
Story by Sally Younger/NASA's Earth Science News Team



Ship tracks, the polluted marine clouds that trail ocean-crossing vessels, are a signature of modern trade. Like ghostly fingerprints, they trace shipping lanes around the globe, from the North Pacific to the Mediterranean Sea. But in 2020, satellite observations showed fewer of those pollution fingerprints.

Drawing on nearly two decades of satellite imagery, researchers found that the number of ship tracks fell significantly after a new fuel regulation went into effect. A global standard implemented in 2020 by the International Maritime Organization (IMO)—requiring an 86% reduction in fuel sulphur content—probably reduced ship track formation. COVID-19-related trade disruptions also played a small role in the reduction.

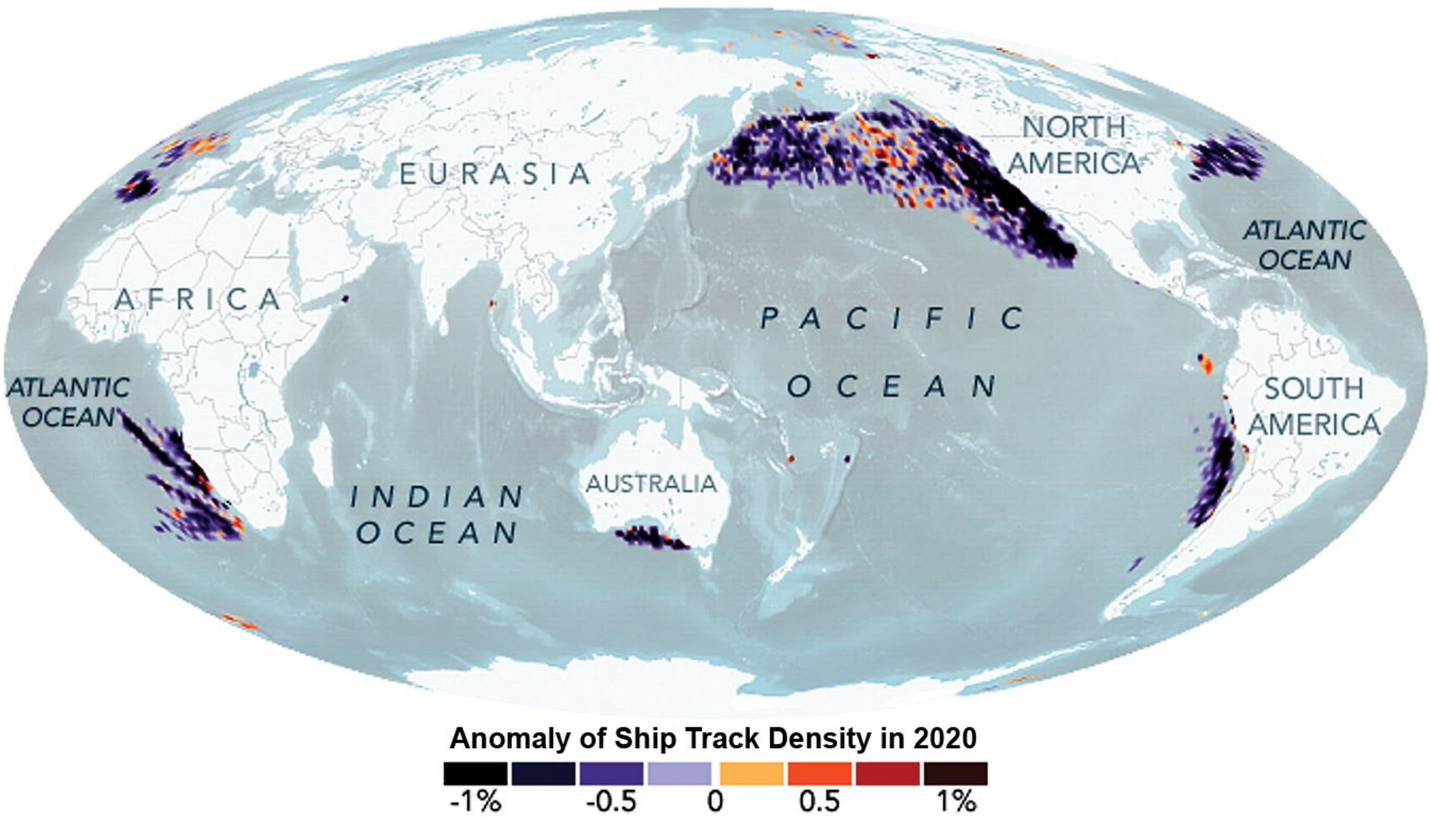
Scientists used advanced computing techniques to create the first global climatology (a history of measurements) of ship tracks. They used artificial intelligence to automatically identify ship tracks across 17 years of daytime images captured between 2003 and 2020 by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite. The map at the top of this page shows the density of ship tracks identified between those years, calculated as a percentage of the total low-level marine cloud layer.



Ship Tracks over the Pacific Ocean imaged by Suomi NPP on December 7, 2021

"*Without this kind of complete and large-scale sampling of ship tracks, we cannot begin to completely understand this problem,*" said lead author Tianle Yuan, an atmospheric scientist at NASA's Goddard Space Flight Center.

Ship tracks were first observed as 'anomalous cloud lines' in early weather satellite images



acquired in the 1960s. They are formed by water vapour coalescing around small polluting aerosol particles in ship exhaust. These highly concentrated droplets scatter more light—and therefore appear brighter—than non-polluted marine clouds, which are seeded by larger particles such as sea salt. A criss-crossing pattern of ship tracks off the Pacific coast of North America is visible in the natural-colour image above, acquired on December 7, 2021, with the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP satellite.

By capping fuel sulphur content at 0.5% (down from 3.5%), IMO's global regulation in 2020 changed the chemical and physical composition of ship exhaust. Less sulphur emissions mean there are fewer of the aerosol particles released to form detectable ship tracks.

According to Yuan and colleagues, similar but regionally defined sulphur regulations—such as an IMO Emission Control Area in effect since 2015 off the west coast of the USA and Canada—had not had the desired effect because operators altered their routes and charted longer courses to avoid the designated zones.

While analysing 2020 data, the researchers found that ship-track density fell that year in every major shipping lane. (See the map above.) Ship-based tracking data indicated that the COVID-19 pandemic played a role by decreasing global shipping traffic by 1.4% for a few months. But this change alone could not explain the large decrease in observed ship tracks, which remained at record-low levels through several months of 2021 (the most recent data analysed). The researchers concluded that the new global fuel regulation played the dominant role in reducing ship tracks in 2020.

Over the long span of their analysis, Yuan and colleagues also found that fluctuations in economic activity leave distinct traces in the satellite record. In particular, Trans-Pacific ship track patterns between Asia and the Americas reflect dips and spikes in trade. As outlined in the study, a general upward trend in shipping activity between 2003 and 2013—reflected in ship-track clouds—reversed for about a year in the aftermath of the 2008 global financial crisis. An even sharper decrease between 2014 and 2016 likely reflected a slowdown in Chinese imports and exports of raw materials and commodities.

Beyond their world trade significance, ship tracks can serve as case studies for an element of climate change. '*Ship tracks are great natural laboratories for studying the interaction between aerosols and low clouds, and how that impacts the amount of radiation Earth receives and reflects back to space*,' Yuan said. '*That is a key uncertainty we face in terms of what drives climate right now*.'

NASA Earth Observatory images by Joshua Stevens, using data courtesy of Yuan, T., et al. (2022) and VIIRS data from NASA EOSDIS LANCE, GIBS/Worldview, and the Suomi National Polar-orbiting Partnership. .

Ozone Hole Continues Shrinking in 2022

NASA Earth Observatory

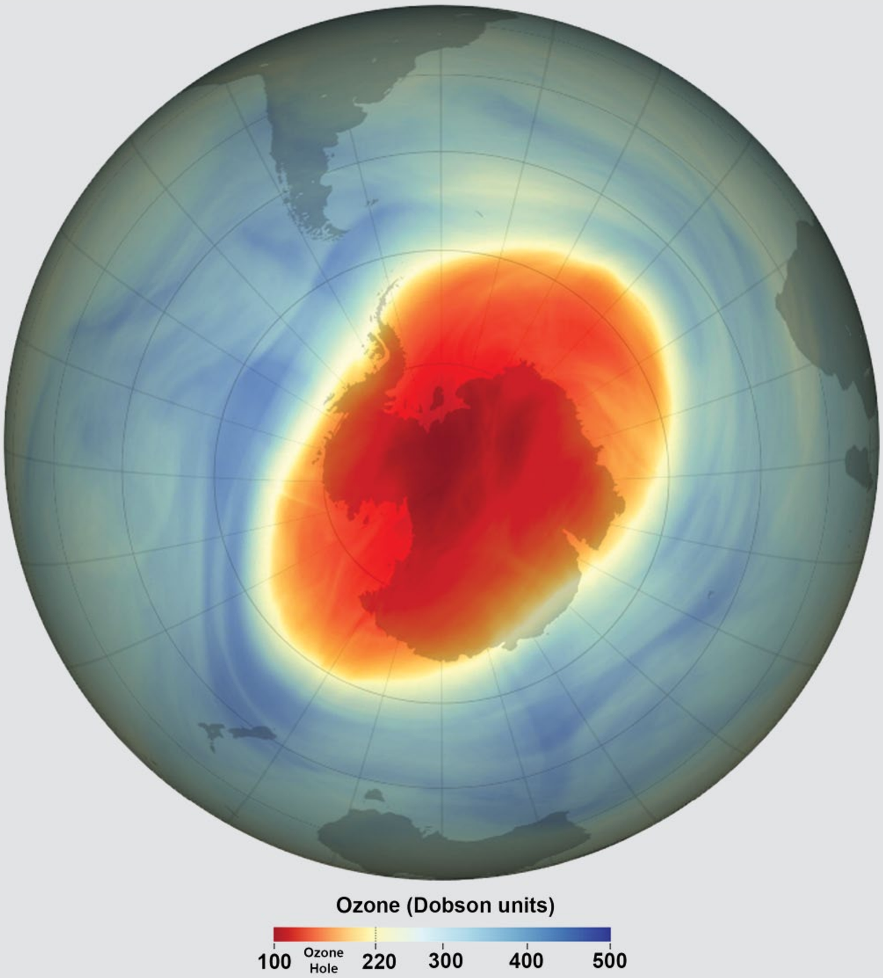
Story by Kathryn Cawdrey, NASA Earth Science News Team

The annual Antarctic ozone hole reached an average area of 23.2 million square kilometres between September 7 and October 13, 2022. This depleted area of the ozone layer over the South Pole was slightly smaller than the average for the same period last year and generally continued the overall shrinking trend of recent years.

> '*Over time, steady progress is being made, and the hole is getting smaller*,' said Paul Newman, chief scientist for Earth sciences at NASA's Goddard Space Flight Center. '*We see some wavering as weather changes and other factors make the numbers wiggle slightly from day to day and week to week. But overall, we see it decreasing through the past two decades. The elimination of ozone-depleting substances through the Montreal Protocol is shrinking the hole*.'

The ozone layer—the portion of the stratosphere that protects our planet from the Sun's ultraviolet rays—thins to form an 'ozone hole' above the South Pole every September. Chemically active forms of chlorine and bromine in the atmosphere, derived from human-produced compounds, attach to high-altitude polar clouds each southern winter. The reactive chlorine and bromine then initiate ozone-destroying reactions as the Sun rises at the end of Antarctica's winter.

Researchers at NASA and NOAA detect and measure the growth and breakup of the ozone hole with instruments aboard the Aura, Suomi NPP, and NOAA-20 satellites. On October 5, those satellites observed a single-day maximum ozone hole of 26.4 million square kilometres, slightly larger than last year. The map at the top of this page shows the size and shape of the ozone hole over the South Pole on that day.



NASA Earth Observatory image by Joshua Stevens, using data courtesy of NASA Ozone Watch and GEOS-5 data from the Global Modeling and Assimilation Office at NASA GSFC

When the polar sun rises, NOAA scientists also make measurements with a Dobson Spectrophotometer, an optical instrument that records the total amount of ozone between the surface and the edge of space—known as the **total column ozone value**. Globally, the total column average is about 300 Dobson Units. On October. 3, 2022, scientists recorded a lowest total-column ozone value of 101 Dobson Units over the South Pole. At that time, ozone was almost completely absent at altitudes between 14 and 21 kilometres—a pattern very similar to last year.

Some scientists were concerned about potential stratospheric impacts from the January 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano. The 1991 Mount Pinatubo eruption released substantial amounts of sulfur dioxide that amplified ozone layer depletion. However, no direct impacts from Hunga Tonga have been detected in the Antarctic stratospheric data.

What is the Ozone Hole?

Learn more about the ozone hole in this YouTube video from NASA

https://www.youtube.com/watch?v=Q15t5NQ1Aik

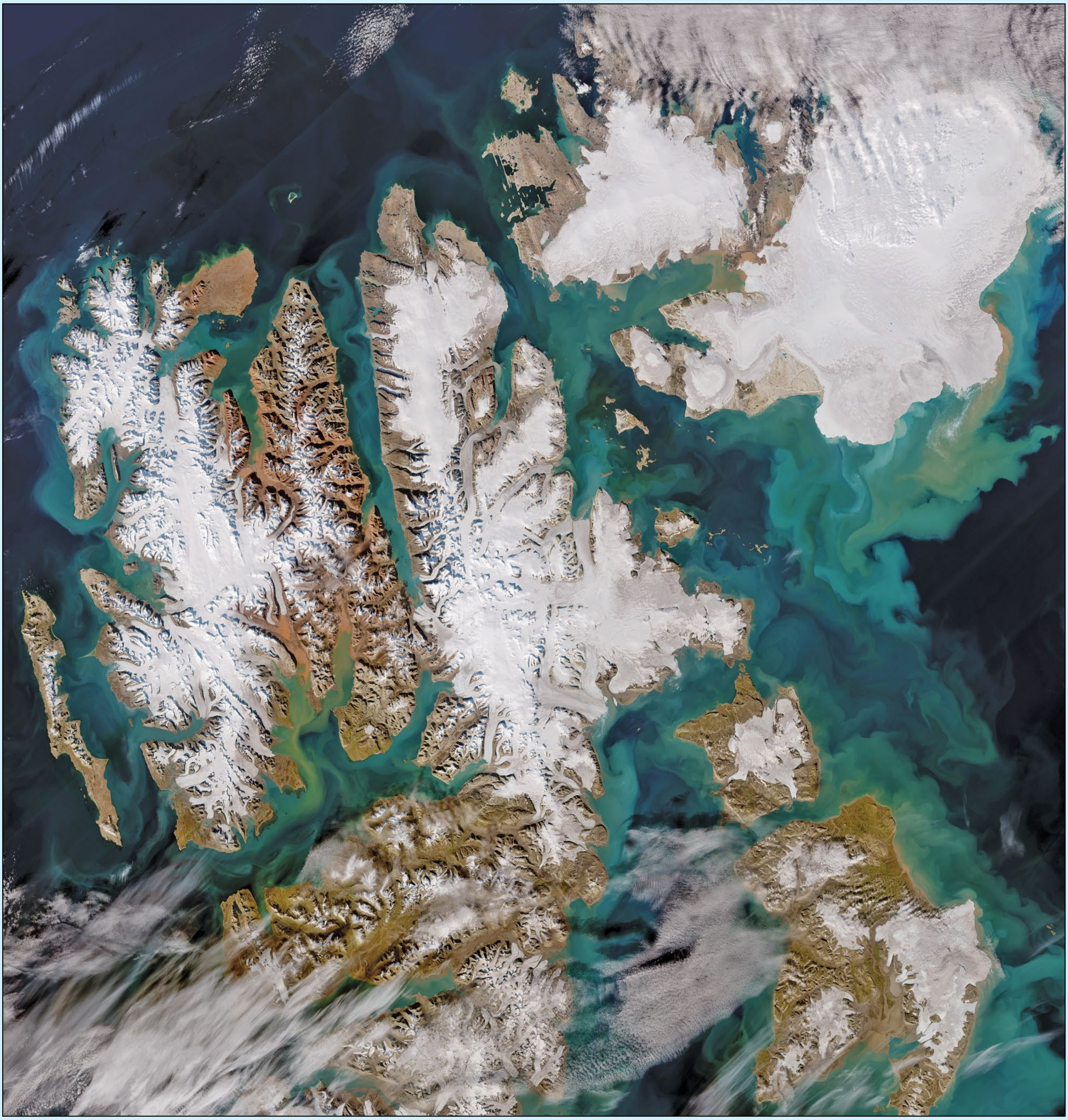
NASA Ozone Watch

Follow the status of the oxone hole at

https://ozonewatch.gsfc.nasa.gov/

Svalbard

European Space Agency



Svalbard archipelago

Image contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO

Extremely high temperatures recorded this summer caused record melting across Svalbard—one of the fastest warming places on the planet. The Copernicus Sentinel-2 mission captured this rare, cloud-free acquisition of the Norwegian archipelago during August 2022.

Located north of mainland Europe, Svalbard is approximately midway between the northern coast of Norway and the North Pole. The archipelago, which spans around 62 700 square kilometres, is composed of nine main islands. The largest is Spitsbergen, visible above in the far-left, followed by

Nordaustlandet in the top-right and Edgeøya in the bottom-right.

Spitsbergen, which is around the same size as Switzerland, has a mountainous terrain with most of the island covered with glaciers. Its highest point it Mount Newton, around 1717 metres, in the northeast. The island is deeply indented by fjords. The longest fjord of the archipelago is Wijdefjorden, shown opposite,which is 108 kilometres long. Opening on Spitsbergen's north coast, it runs roughly southwards into the interior, separating Andrée Land in the west from Margaretas Land in the east.

Also on Spitsbergen lies the Svalbard Satellite Station—SvalSat for short—which is operated by Kongsberg Satellite Services (KSAT), and has worked with a range of Earth observation missions including Aeolus, Swarm, CryoSat and all Copernicus Sentinel satellites.

The station is also important to the Galileo satellite navigation system, Europe's global navigation satellite system. Its location makes it one of the most remote Galileo ground stations in the world.

This summer saw exceptionally warm air temperatures in Svalbard according to the Norwegian Meteorological Institute. An average of 7.4 °C was recorded during June, July and August compared with the 5.5°C average recorded during the 1991-2020 period. The heatwave caused exceptional levels of melting, which ultimately contributes to sea level rise.

The image on the previous page, captured on August 21, shows the large, colourful sediment discharges in the Arctic Ocean. This is probably due to sediments eroded from bedrock by the flow of ice and then carried by meltwater into the Arctic Ocean. There is also some phytoplankton present in the waters, as seen in the far right, which colours the water turquoise and green.

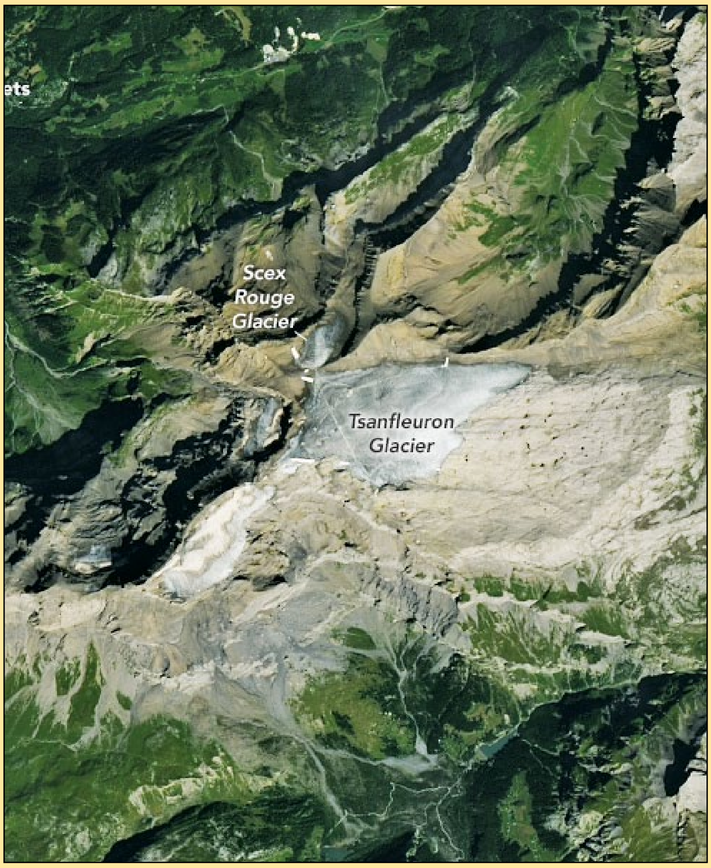
Data acquired by the Copernicus Sentinel satellites are used to detect changes in Earth's surface in great detail and monitor the effects of climate change on remote environments such as the Arctic region.

A high resolution view of Wijdefjorden
Image contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO

Rocky Road for Swiss Glaciers

NASA Earth Observatory

Story by Kathryn Hansen



NASA Earth Observatory images by Lauren Dauphin, using Landsat data from the U.S. Geological Survey. .

In 2022, glaciers in the Swiss Alps melted more than any other year on record. This was the latest downturn for the country's glaciers, which have lost more than half of their volume of ice since the 1930s.

This pair of natural-colour images shows the changes to a glaciated area in western Switzerland in just over two decades. The right image was acquired on August 25, 2022, with the Operational Land Imager-2 (OLI-2) on Landsat 9. For comparison, the left image shows the same area on August 15, 2021, acquired with the Enhanced Thematic Mapper Plus (ETM+) on Landsat 7.

The images feature the **Tsanfleuron** and **Scex Rouge** glaciers, located in the **Diablerets** mountain group. The glaciers rest on different sides of a mountain slope but have long been connected at Tsanfleuron pass. According to Matthias Huss, director of the Swiss Glacier Monitoring Network (GLAMOS), melting during summer 2022 exposed a rocky path between the two glaciers at Tsanfleuron pass for the first time in several thousand years.

The pass is located near the highest point of the two glaciers in an area where snowfall has historically accumulated. The snow eventually turns into a compressed porous layer, known as 'firn', which in turn becomes glacial ice. In a healthy state, the pass should remain snow-covered all year, but in recent decades winter snow has disappeared in summer, allowing the firn and ice to melt. The record losses in 2022 finally exposed the bare ground between the glaciers.

The melting season for Switzerland's snow and ice typically starts in May and ends in early October. Melting in 2022 caused the Tsanfleuron and Scex Rouge glaciers to thin by an average of 4 metres—about triple the average degree of thinning observed at Swiss glaciers in the past decade, according to Huss. GLAMOS data show that across Switzerland in 2022, glaciers lost about 6% of their remaining volume—exceeding the previous record in 2003 when losses were almost 4%.

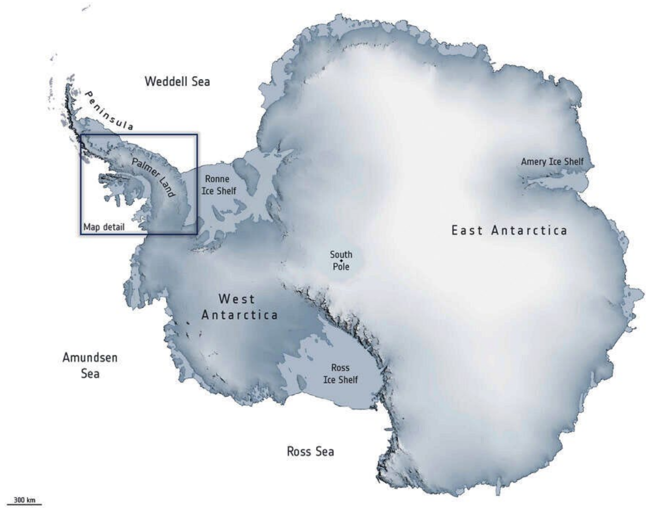
One reason for the significant amount of melting in 2022 was the small amount of snowfall the previous winter. The snow melted quickly, speeded up in spring by the warming effect of dust from the Sahara Desert falling on the snow. By early summer, the glaciers had lost their protective blanket of snow, leaving them vulnerable to the summer heat.

Despite the summer heat, melting stopped relatively early this year. 'Already from mid-September onwards there was a bit of fresh snow every week,' said Huss. 'This does not change anything regarding the incredible losses of 2022, but at least they are not going on at the moment.'

Seasonal changes in Antarctic ice sheet flow Dynamics

European Space Agency

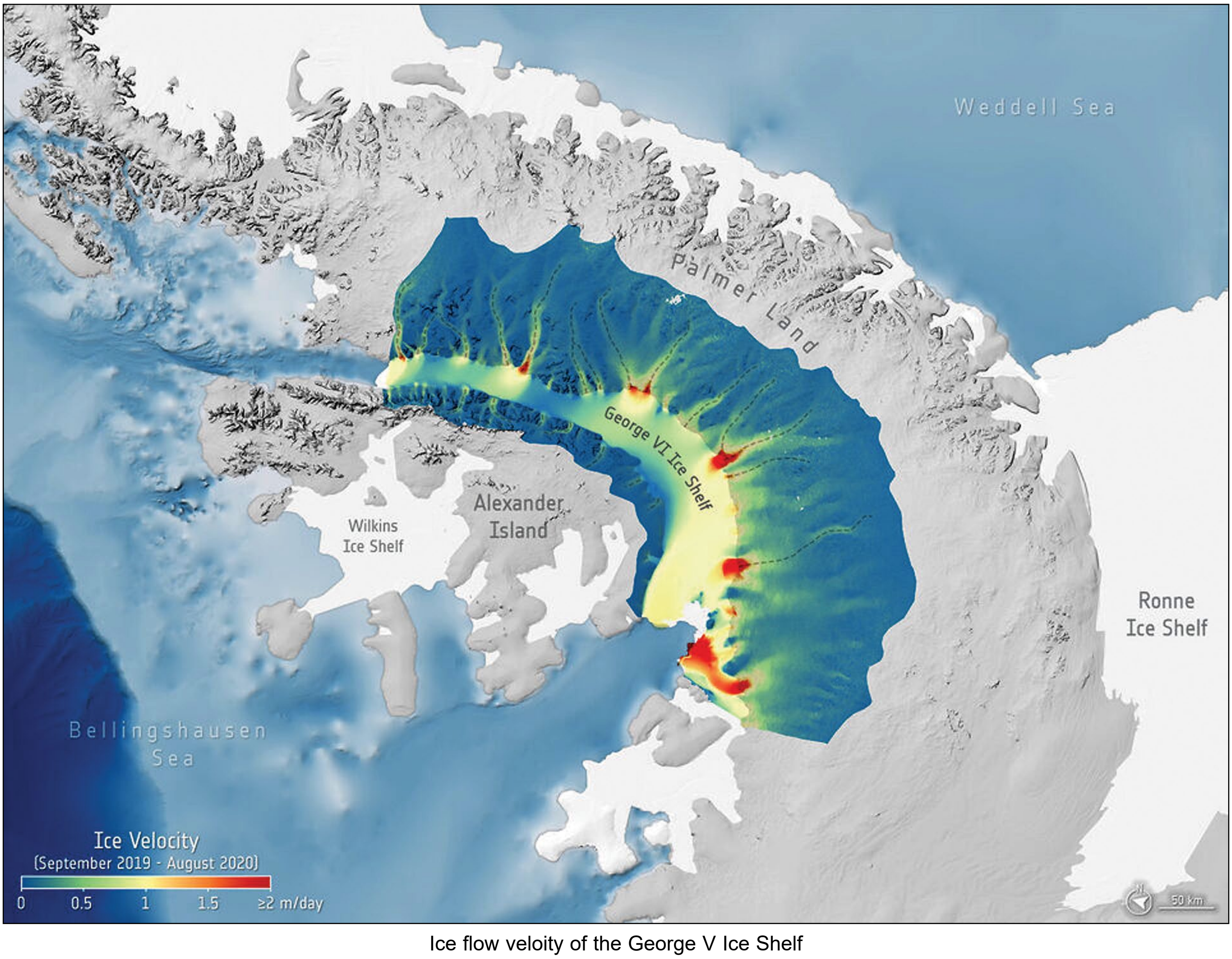
Certain estimates of Antarctica's total contribution to sea-level rise may be over, or even underestimated, after researchers detected a previously unknown source of ice loss variability. In a new paper published in *The Cryosphere*, researchers using Copernicus Sentinel-1 data, found that glaciers feeding the George VI Ice Shelf speed up by approximately 15% during the Antarctic summer. This is the first time that such seasonal cycles have been detected on land ice flowing into ice shelves in Antarctica.



Antarctica

Although it is not unusual for ice flow in the Arctic regions to speed up during summer, scientists had previously assumed that ice in Antarctica wasn't subject to the same seasonal movements. This was partly because temperatures remain below freezing for most of the year, but also due to the lack of systematic monitoring of ice flow over the continent's ice margins.

Prior to the detailed records of ice speed made possible by Sentinel-1 satellites, scientists wanting to study short-term variations in Antarctic-wide ice flow relied on information collected by optical satellites such as NASA's Landsat 8.



Ice flow veloity of the George V Ice Shelf

The advantage of radar as a remote sensing tool is that it can image Earth's surface through rain and cloud, and regardless of whether it is day or night. This is particularly useful for monitoring areas prone to long periods of darkness.

Thomas Nagler, co-author of the paper and ENVEO's CEO, commented, *"Optical measurements can only observe Earth's surface on cloud-free days during summer months, but by using Sentinel-1 radar imagery, we were able to discover seasonal ice-flow change thanks to the ability of these satellites to monitor year-round and in all-weather conditions."*

The causes of these seasonal changes are uncertain. They could be caused by surface meltwater reaching the base of the ice, acting as a lubricant, or it could also be due to relatively warm ocean water melting the ice from below, thinning the floating ice and allowing upstream glaciers to move faster.

These results imply that similar seasonal variability may exist at other, more vulnerable sites in Antarctica, such as the Pine Island and Thwaites glaciers in West Antarctica.

Co-author Ian Willis stated, '*It's the first time this seasonal signal has been found on the Antarctic Ice Sheet, so the questions it raises regarding the possible presence and causes of seasonality elsewhere in Antarctica are really interesting. We look forward to taking a closer look at, and shedding light on, these important questions*.'

Radar vision

Sentinel-1A was the first satellite to be launched for Copernicus—the Earth observation component of the European Union's space programme. Carrying advanced radar technology and providing an all-weather, day-and-night supply of imagery of Earth's surface, the ambitious Sentinel-1 mission raised the bar for spaceborne radar and set the stage for Europe's Copernicus programme.

Mark Drinkwater, Head of the ESA's Earth and Mission Science Division commented: '*Systematic, year-round monitoring of Antarctica with the Copernicus Sentinels has revolutionised our insight into the variability in ice-sheet behaviour on shorter timescales than ever before.*'

Over the past few decades, the Antarctic Peninsula ice has undergone some of the most dramatic changes in response to climate warming. While we often think that what happens in Antarctica won't affect us in Europe, the

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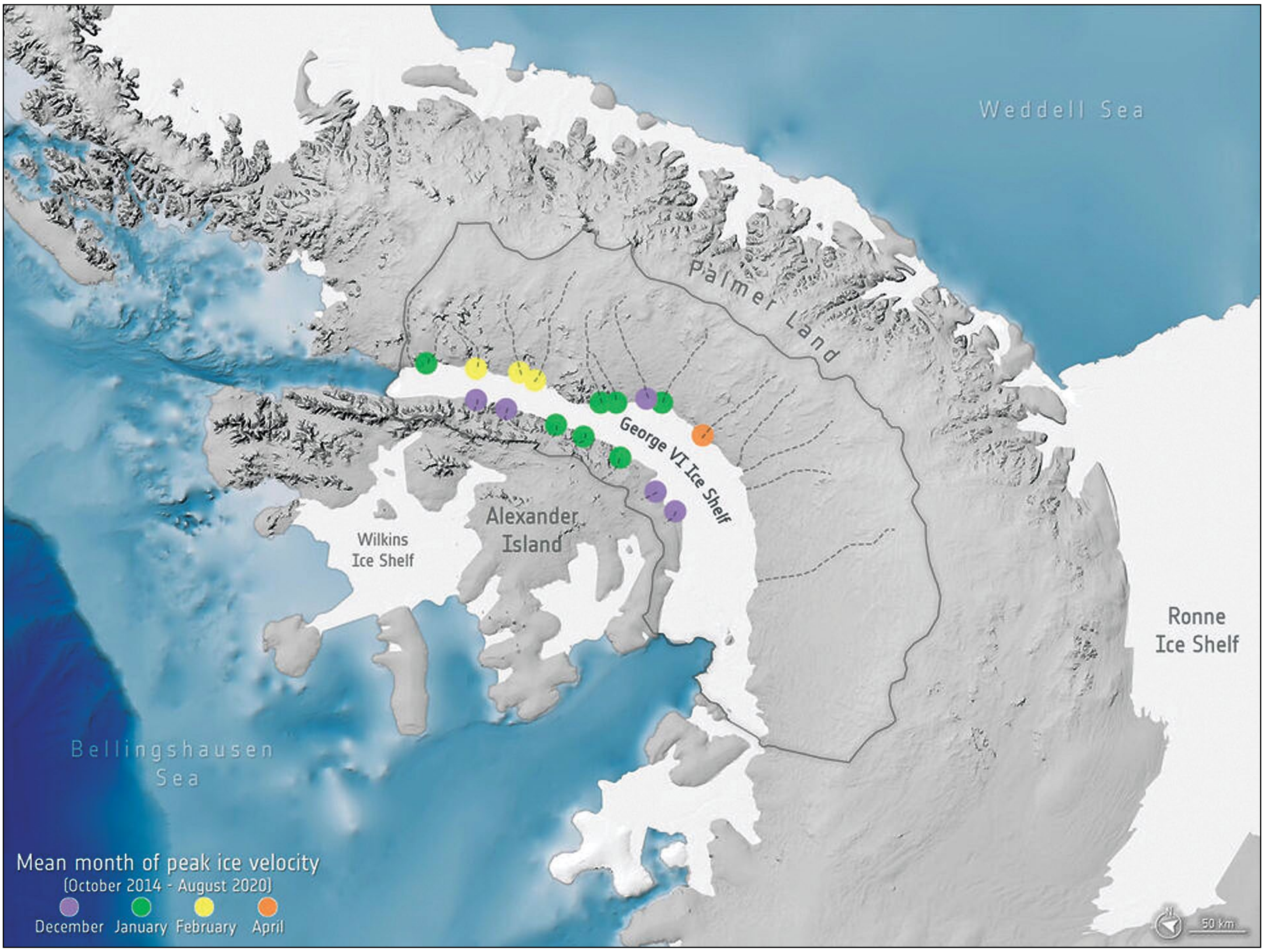

Timing of peak ice flow velocity

Seasonal Greening of the Inner Niger Delta

NASA Earth Observatory

Story by Kathryn Hansen

Each year from around August to December, a burst of green overtakes the typically brown landscape of central Mali. The greening is due to aquatic grasses and other vegetation taking advantage of the seasonal inflow of water that spreads across the Inner Niger Delta—the largest inland delta in western Africa. In October 2022, water reached the highest levels seen in more than 50 years.

The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite acquired figure 1 on November 3, 2022, about a week after water levels peaked in the southern part of the inland delta. For comparison, figure 2 was acquired by MODIS on NASA's Aqua satellite shows the same area in May 2022—a time of year when the delta is relatively dry.

The Niger River's headwaters lie about 900 kilometres to the southwest in the Guinea Highlands. Wet season rains across the Upper Niger Basin cause the Niger River to swell, which then flows northeast toward the inland delta. Joined by the Bani River near Mopti, water from the river systems spreads across the floodplain into a broad network of channels, wetlands, and islands.

The process plays out over months, with flooding influenced by the cumulative amount of rainfall across the entire wet season. The timing of the wet season varies across the Upper Niger Basin. In the mountainous upper reaches of the Niger River, the wet season extends from March to October. Across the entire West Africa region, the wettest month is usually August.

Despite these variations, the amount of rainfall across the

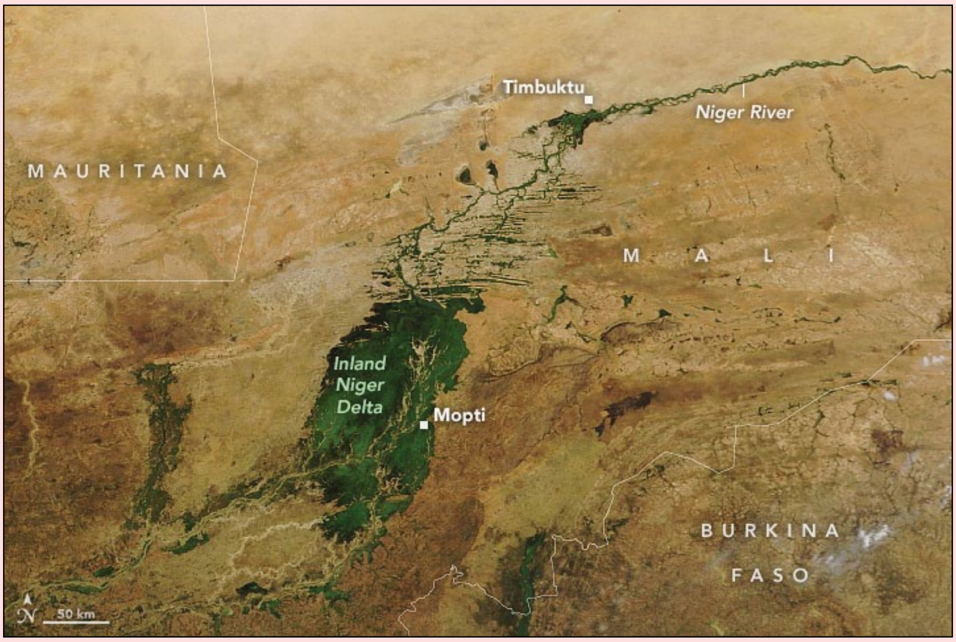

Figure 1 - The inner Niger Delta on November 3, 2022
NASA Earth Observatory images by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

upper basin in July and August is usually a good indication of the amount of flooding that will happen across the delta by October through December. In July and August 2022, rainfall was well above the 2001–2021 average. According to a bulletin from OPIDIN, flooding on the Inner Niger Delta peaked at the town of Mopti in late October 2022 at 675 centimetres—the highest levels seen since 1969. Water inundated 19,000 square kilometres of the delta.

As the parched landscape becomes saturated, the delta

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Figure 2 - The inner Niger Delta during May, 2022
NASA Earth Observatory images by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

More Flooding in Australia's Soggy Southeast

NASA Earth Observatory

Story by Kathryn Hansen

After an extremely wet October, southeast Australia continued to see heavy rainfall throughout November 2022. With soils already saturated and dams full, the latest storms have added to ongoing flooding across New South Wales and Victoria.

Widespread flooding is visible in figure 1, a false-colour image acquired on November 18, 2022 by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Water appears light to dark blue.

Vegetation is green and bare land is brown. For comparison, figure 2 (overleaf), a MODIS image from the Aqua satellite, shows the same area on June 28, 2022, prior to the excessive rainfall.

In the week leading up to November 14, large parts of New South Wales and Victoria experienced more than 50 millimetres of rain. The town of Forbes, New South Wales, had the highest daily total for the week, 118 millimetres falling in the 24-hour period spanning November 13–14.

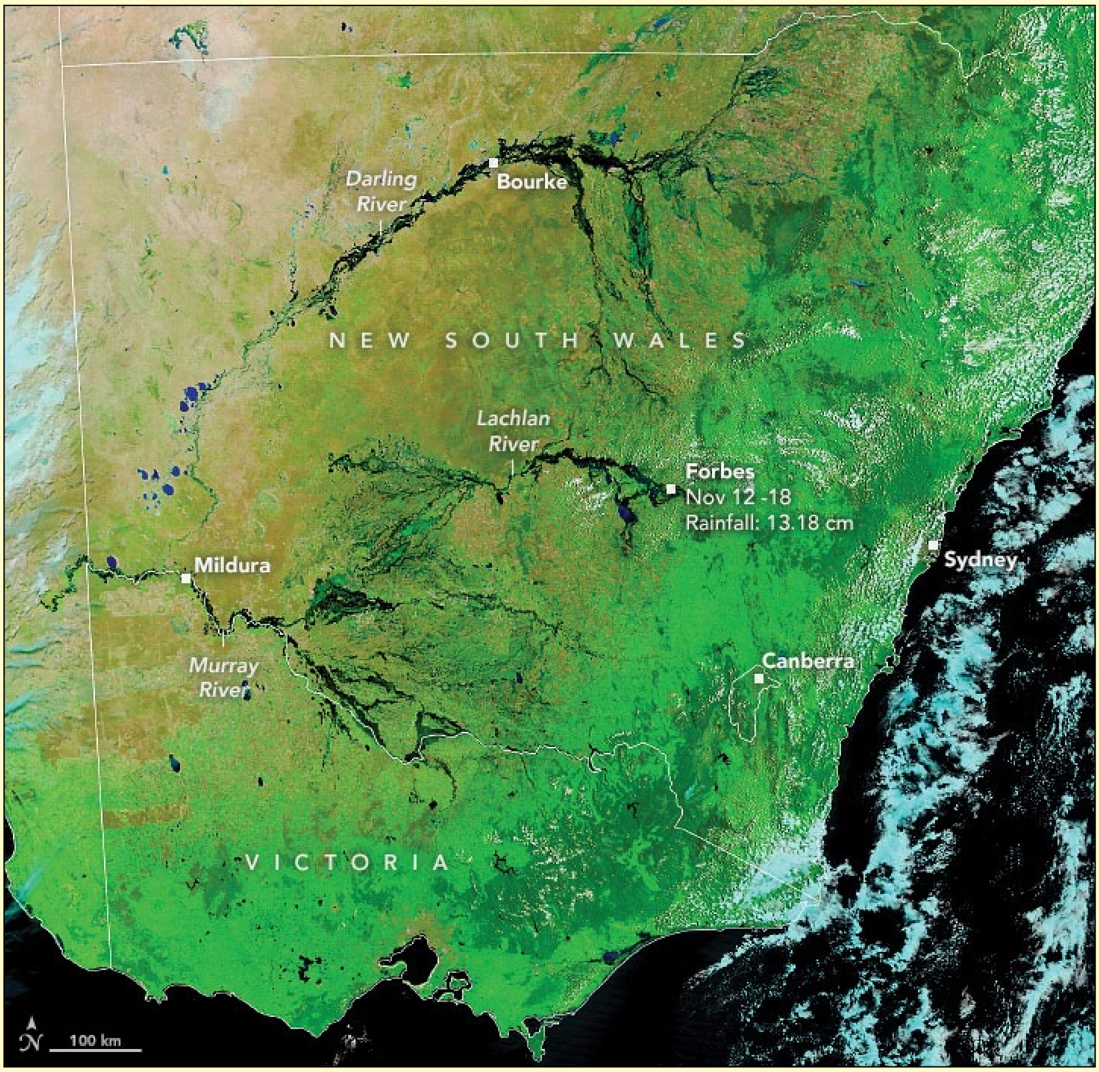

Figure 1
This MODIS image from NASA's Terra satellie was acquired on November 18, 2022
NASA Earth Observatory image by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview

The abundant rain across the region caused rivers to rise and flood nearby towns. Forbes saw its third major flood event in just four weeks as waters on the Lachlan River rose faster than expected.

October 2022 was the wettest October on record in the Murray-Darling basin, an area that includes the permanent and impermanent rivers and streams pictured above. With soils already saturated, rainfall in November quickly led to flash flooding across New South Wales and Victoria. Emergency responders rescued hundreds of people stranded by flood waters across the region.

Water that seeps deep into the soil can influence groundwater levels for months. The map (figure 3) depicts shallow groundwater storage in Australia from November 11–14, 2022, as measured by the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) satellites. The colours depict the wetness percentile: that is, how the levels of groundwater compare with the long-term record (1948–2012). Blue areas have more abundant water than usual, and orange and red areas have less.

The extent to which such rainfall affects the groundwater level varies by location and depends on a range of factors

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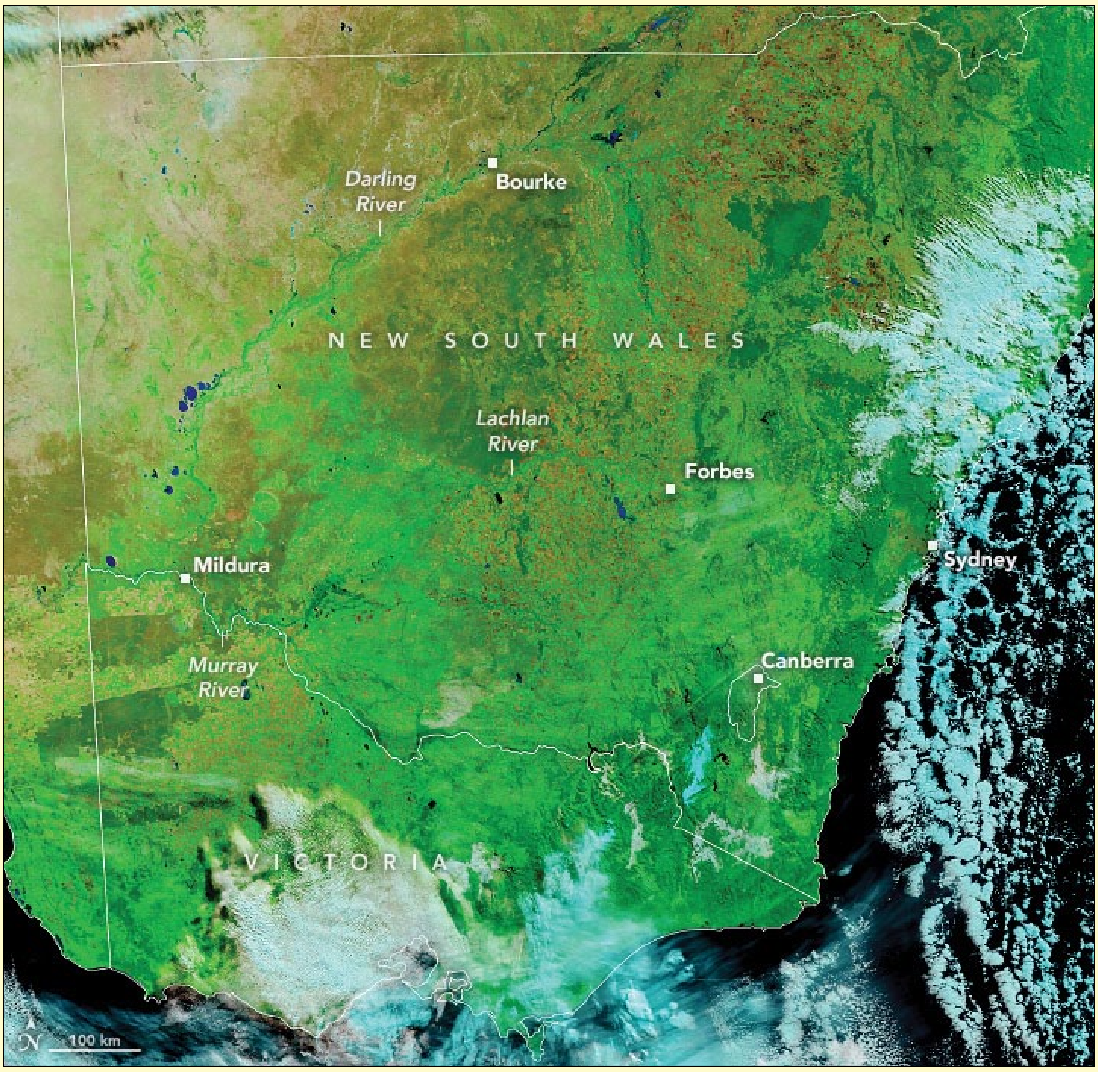

Figure 2
This MODIS image from NASA's Aqua satellie was acquired on June 28, 2022
NASA Earth Observatory image by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview

continued from page 24

such as soil type, aquifer depth, and vegetation. Time is also a factor, as rainfall accumulations from months past can influence current groundwater levels.

One reason for the wetness is most likely La Niña, which has returned for three consecutive years. La Niña events can influence weather in different ways across the planet. In Australia, they usually bring heavy rainfall and flooding.

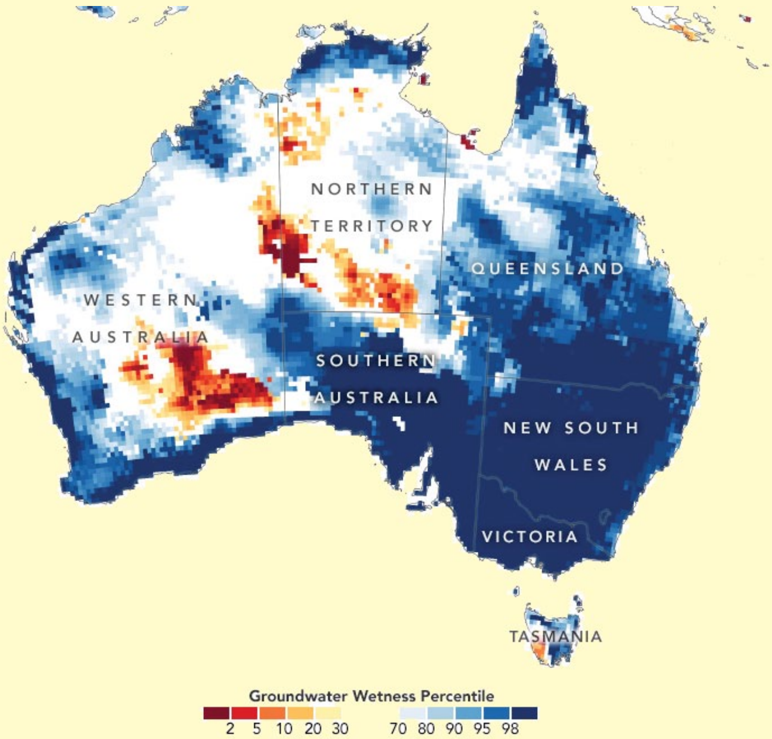

Figure 3
NASA Earth Observatory image by Lauren Dauphin, using GRACE data from the National Drought Mitigation Center.

Hudson Bay's Nastapoka Arc

NASA Earth Observtory

Story by Sara E. Pratt

NASA Earth Observatory image by Lauren Dauphin, using VIIRS data from NASA EOSDIS LANCE, GIBS/Worldview, and the Joint Polar Satellite System (JPSS).

In northeastern Canada, just south of the Arctic Circle, the Hudson Bay spans more than 1.2 million square kilometres. It is the world's second-largest bay, after the Bay of Bengal, and the site of a geologic puzzle.

The southeastern shore of the bay forms a 155-degree curve, called the Nastapoka Arc, which appears to be part of a nearly perfect circle 450 kilometres in diameter. The imaginary circle traces the coast of Quebec on one side and grazes the Ontario shore on the other. At its centre lie the Belcher Islands. Such a smoothly curved feature is not often found in nature and has prompted much geologic debate.

This image, acquired on August 16, 2022, by the Visible Infrared Imaging Radiometer Suite (VIIRS) on the NOAA-20 satellite, shows Hudson Bay and its curved southeastern shore.

This shoreline traces the boundary between two distinct groups of rocks. Onshore, the Superior Province gneisses are hard metamorphic rocks that formed 3 billion to 2.7 billion years ago. Offshore lie the Nastapoka Group supracrustal rocks, which formed during the early Proterozoic Eon, 2.5 billion to 1.6 billion years ago.

These rock formations are part of the largest single belt of Archean-aged rocks in the world (the Archean Eon lasted from 4 billion to 2.5 billion years ago). They form the core of the Canadian Shield and the North American craton, the stable central core of the continent on to which other microcontinents would later accrete to build the landmass we know today. This tectonic history is key to the prevailing theory for the arc's formation.

Geologists now generally believe the arc resulted from a continental collision, a 2-billion-year-old mountain-building episode called the Trans-Hudson orogeny. As ancient continents collided, the crust buckled and fractured into slices that could thrust past each other to accommodate the compression. This formed a fold-and-thrust belt, the remnants of which are exposed today in the folds of the Belcher Islands. Farther to the east, where the Nastapoka Arc lies today, the collision produced a foreland basin. Gravity data collected in the early 1990s suggests the load placed on the crust by the fold-and-thrust belt could

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Seasonal Greening of the Inner Niger Delta

continued from page 23

greens. Partly floating long-stemmed grasses dominate the delta, including *Echinochloa stagnina*. This species, known locally as bourgou, is often planted by people and used for animal feed. There is also plenty of wild rice, or *Oryza longistaminata*. The light-brown areas branching across the greenery are sand ridges and drying stream channels.

The flooding progresses from the southwest to the northeast. After peaking at Mopti, water levels are next expected to peak in the central part of the delta during the last week of November, and then peak in the north over a week later.

Hudson Bay's Nastapoka Arc

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have caused the centre of the basin to sink, forcing up the edges, resulting in the curvature.

Other theories have also been put forth. In the late 1960s, Canadian astrophysicist Carlyle Beals suggested the arc could be the rim of an ancient impact structure, with the Belcher Islands representing the crater's uplifted central peak. However, a field investigation in the 1970s turned up none of the usual evidence indicative of an impact, such as shocked quartz, radial fractures, melted rocks, or shatter cones.

Around that time, another researcher suggested the shoreline was a scar marking where a continent had pulled apart, or rifted. A nearby tectonic plate with a somewhat curved edge suggests it may have once fit together with the arc like two puzzle pieces.

The debate continues today. In the mid-2000s, a researcher suggested that the curving shoreline of Hudson Bay could be an ancient impact crater that has been so reworked by geologic processes that the evidence of impact has been obscured.

Seasonal changes in Antarctic ice sheet flow dynamics detected for the first time

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environmental changes happening in Antarctica will be felt at a global scale. When the ice sheets melt, sea level around the planet will rise—displacing millions of people and dramatically changing coastlines.

This new evidence of a connection between Antarctic circumpolar ocean conditions and seasonal ice flow sheds new light on the regional factors contributing to dynamic ice loss and sea-level rise.

At the forthcoming ESA Council at Ministerial Level in November 2022, ESA seeks a second phase of funding for its Copernicus Space Component Programme, enabling the first satellites of the Next Generation Sentinel-1 and Sentinel-3 Topography series to be developed and further securing the outlook for long-term persistent monitoring of Antarctic ice sheet.

With the Next Generation of the Copernicus Sentinels, together with the ROSE-L, CRISTAL and CIMR Sentinel Expansion missions already in development, Drinkwater added that their combined capabilities are going to provide critical input data for ESA's pilot Digital Twin Antarctica and the Destination Earth (DestinE) initiatives. These digital replicas will in turn will enable us to better predict the speed and consequences of the ice sheet's demise.

Italy's Stromboli Erupts

European Spae Agency

A volcano on the Italian island of Stromboli erupted early on the morning of October 9, 2022, releasing huge plumes of smoke and a lava flow pouring into the sea. The Copernicus Sentinel-2 mission captured this image of the aftermath less than five hours after the eruption.

The eruption caused the partial collapse of the crater terrace which was followed by major flows of lava stretching to the sea and enormous plumes of smoke rising several hundred metres above the volcano.

This Sentinel-2 image has been processed in true colour, using the shortwave infrared channel to highlight the new flow of lava. The northernmost island of the Aeolian archipelago, located just off the northern tip of Sicily, Stromboli's volcano has been erupting almost continuously for the past 90 years.

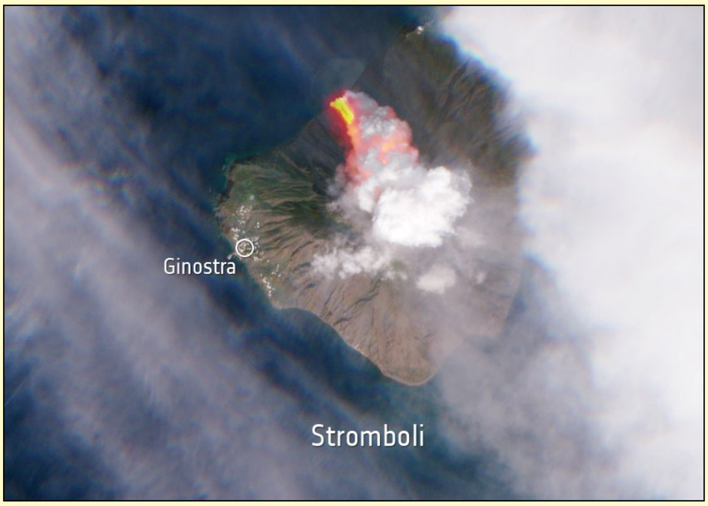

Image contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO

Currently Active Satellites and Frequencies

Polar APT/LRPT Satellites			
Satellite	Frequency	Status	Image Quality
NOAA 15	137.6200 MHz	On	Good
NOAA 18	137.9125 MHz	On	Good
NOAA 19	137.1000 MHz	On	Good [1]
Meteor M N1	137.0968 MHz	Off	Dead [8]
Meteor M N2	137.1000 MHz	On	Good
Meteor M N2-2	137.9000 MHz	Off	Failed [12]

Polar HRPT/AHRPT Satellites				
Satellite	Frequency	Mode	Format	Image Quality
NOAA 15	1702.5 MHz	Omni	HRPT	Weak
NOAA 18	1707.0 MHz	RHCP	HRPT	Good
NOAA 19	1698.0 MHz	RHCP	HRPT	Good
Feng Yun 1D	1700.4 MHz	RHCP	CHRPT	None: Device failure
Feng Yun 3A	1704.5 MHz	RHCP	AHRPT	Inactive [2,10]
Feng Yun 3B	1704.5 MHz	RHCP	AHRPT	Active [2]
Feng Yun 3C	1701.4 MHz	RHCP	AHRPT	Active [2]
Metop A	1701.3 MHz	RHCP	AHRPT	Good
Metop B	1701.3 MHz	RHCP	AHRPT	Good
Metop C	1701.3 MHz	RHCP	AHRPT	Commissioning
Meteor M N1	1700.00 MHz	RHCP	AHRPT	Dead [8]
Meteor M N2	1700.0 MHz	RHCP	AHRPT	Good
Meteor M N2-2	1700.0 MHz	RHCP	AHRPT	System failure [12]

Geostationary Satellites				
Satellite	Transmission Mode(s)		Position	Status
Meteosat 8	HRIT (digital)	LRIT (digital)	41.5°E	IODC
Meteosat 9	HRIT (digital)	LRIT (digital)	3.5°E	On [5]
Meteosat 10	HRIT (digital)	LRIT (digital)	9.5°E	Off [4]
Meteosat 11	HRIT (digital)	LRIT (digital)	0°W	On [3]
GOES-13	GVAR 1685.7 MHz	LRIT 1691.0 MHz	60°W	Off
GOES-14	GVAR 1685.7 MHz	LRIT 1691.0 MHz	105°W	Standby
GOES-15 (W)	GVAR 1685.7 MHz	LRIT 1691.0 MHz	128°W	On [6]
GOES-16 (E)	GRB 1686.6 MHz	HRIT 1694.1 MHz	75.2°W	On[6,9]
GOES-17	GRB 1686.6 MHz	HRIT 1694.1 MHz	137.2°W	[11]
MTSAT-1R	HRIT 1687.1 MHz	LRIT 1691.0 MHz	140°E	Standby
MTSAT-2	HRIT 1687.1 MHz	LRIT 1691.0 MHz	145°E	On
Feng Yun 2D	SVISSR	LRIT	123.5°E	Backup/Off [7]
Feng Yun 2E	SVISSR	LRIT	86.5°E	On
Feng Yun 2F	SVISSR	LRIT	112.5°E	Standby
Feng Yun 2G	SVISSR	LRIT	99.5°E	On
Feng Yun 2H	SVISSR	LRIT	86.5²E	
Feng Yun 4A	HRIT (digital)	LRIT (digital)	99.5°E	On

Notes

1 LRPT Signals from Meteor M N2 may cause interference to NOAA 19 transmissions when the two footprints overlap.
2 These satellites employ a non-standard AHRPT format and cannot be received with conventional receiving equipment.
3. Meteosat prime Full Earth Scan (FES) satellite
4 Meteosat backup Full Earth Scan (FES) satellite
5 Meteosat prime Rapid Scanning Service (RSS) satellite.
6 GOES 15 also transmits EMWIN on 1692.700 MHz
GOES 16 also transmits EMWIN on 1694.100 MHz
GOES 17 also transmits EMWIN
7 There has been no imagery from Feng Yun 2D since June 30, 2015. Since Feng Yun 2G is operating from the same position (86.5°E), it is likely that FY-2D is now in standby as a backup satellite.
8 On March 20, 2016, Meteor M1 suffered a catastrophic attitude loss, frequently pointing its sensors towards the sun. The following day all signals ceased and it seems highly probable that this satellite is now incapable of imaging the Earth.
9 GOES Rebroadcast (GRB) provides the primary relay of full resolution, calibrated, near-real-time direct broadcast space relay of Level 1b data from each instrument and Level 2 data from the Geostationary Lightning Mapper (GLM). GRB replaces the GOES VARiable (GVAR) service.
10 Although Feng Yun 3A's status is recorded on the wmo-sat website as 'inactive (end of operation)', it continues (as of June 2018) to transmit imagery.
11 GOES 17 is expected to start operations during January 2019.
12 Following a collision with a micrometeorite, the power system aboard Meteor M2-2 has all but failed and is no longer capable of powering the AHRPT/LRPT instrument.