

GEO Newsletter



Group for Earth Observation

Group for Earth Observation

No 74 - June 2022



Enrico Gobbetti captured this AHRPT image transmitted from Meteor M2 on May 11, 2022, six days after the satellite lost attitude control. The limb of Earth shows clearly at the right of the image and the outline of the Mediterranean Sea and surrounding regions are noticeably distorted.

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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

As we head towards another northern hemisphere summer, events around the globe keep reminding us of the need to address the problem of climate change. Already this year an ice shelf in Antarctica has suddenly suffered total disintegration while the extent of the sea ice around the continent fell to an all-time record low since the satellite record commenced in 1979! In Australia, where drought held sway from 2017 to 2019, flooding is now the problem, particularly in the east, where a national emergency was declared in early March. In Spain, some parts of the nation have already experienced their hottest May since records began, as hot, dry air from Africa caused temperatures to soar into the 40s. And to top everything, for the seventh successive year, NOAA are predicting above-average hurricane activity in the Atlantic basin during 2022, forecasting with 70% certainty between 14 and 21 named storms (winds of 63 kph or higher), 6 to 10 of which could become hurricanes (winds of 120 kph or higher) and 3 to 6 of them in categories 3 to 5 (winds of 180 kph or more).

This issue sees the completion of Ed Murashie's trilogy of images dealing with Landsat data. Here he provides an overview/tutorial on some new tools that can be used to download completely free data from these satellites.

And on the topic of satellite data, Richard Osborne details use of the VISAN tool for visualising EUMETSAT SAF satellite products.

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Floodwaters Reach Australia's Channel Country

MODIS Web Image of the Day



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Torrential rains over eastern Australia brought severe flooding to parts of Queensland and New South Wales in early March 2022. Media reported that tens of thousands of residents along the southeastern Australia coast had been evacuated, with about 1,000 rescues in New South Wales by March 1. According to *AccuWeather*, the city of Brisbane received more than 610 mm of rain between February 24-27, setting the record for its wettest three-day period since weather data tracking began in 1840. According to the *Center for Disaster Philanthropy*, the *Insurance Council of Australia* extended the area declared an insurance catastrophe from south-east Queensland into northern New South Wales in order to help prioritise handling more than 15,000 claims already lodged by March 1.

While the floods were nothing short of catastrophic across the coastal regions, the flooding has brought water trickling inland, even to Australia's Channel Country, an

area so named because of the dry river channels that mark the arid interior. The region is also known for its ephemeral lakes, which are dry (or nearly so) most of the year. Channel Country flooding is a fairly common occurrence at the end of summer, but this year's massive flooding has brought large amounts of water to the region.

On March 3, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's **Aqua** satellite acquired a false-colour image of flooding in the Channel Country of southwestern Queensland. This type of false-colour image is particularly useful to separate out deep water (dark blue) and shallow water or moist salt flats (light blue) from dry land (brown) and vegetation (bright green). This image shows water in Lakes Machattie, Mipia and Koolivoo. The floodplains of the Georgina River and Eyre Creek are flushed with green vegetation far northward, heading into the Northern Territory.

Young Impact Crater Uncovered in Yilan

NASA Earth Observatory

Story by Sara E. Pratt



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

Despite China's large land area, only one impact crater (the relatively small Xiuyan crater in Liaoning province) had been discovered there prior to 2020. Then, in 2021, a team of geologists found another crater northwest of Yilan in Heilongjiang Province. The crater was discovered in the heavily forested Lesser Xing'an mountain range, where local residents knew it as 'Quanshan', or 'circular mountain ridge'.

The Yilan crater, slightly larger than Xiuyan, spans about 1.85 kilometres, making it the largest crater on Earth under 100,000 years old. Carbon-14 dating of charcoal and organic lake sediments suggests the crater formed between 46,000 and 53,000 years ago. Barringer Crater in Arizona is also roughly 50,000 years old, but its diameter is rather less at 1.2 kilometres.

In this image, acquired by the Operational Land Imager (OLI) on Landsat 8 on October 8, 2021, the scalloped northern rim of Yilan crater is highlighted by fall foliage. The northern rim—which rises 150 metres above the crater floor—is well-preserved, but the southern third of the crater rim is missing.

Although the asteroid that created this crater struck relatively recently in geologic time, the granite rocks it impacted were much older, having formed about 200 million years ago in the Early Jurassic Period. To investigate the impact structure, the research team drilled down 440 metres into the centre of the crater, where they found hundreds of metres of ancient lake sediments and shattered granite. The team also found unambiguous evidence that the structure was indeed an impact crater. The core revealed shocked quartz, melted granite, glass containing holes formed by gas bubbles, and tear-drop shaped glass fragments—all indicators of a high-intensity impact event.

The researchers continue to investigate the cause of the missing southern rim. However, the presence of lake bed sediments inside the crater suggests that the rim was intact long enough for significant deposits to build up on the lake bottom. Such deposits often produce rich, organic soil and some farm fields can be seen inside the southern part of the crater. The rest of the crater interior is covered with swamps and forest wetlands.

Sea Ice and Cloud Streets in the Labrador Sea

MODIS Web Image of the Day

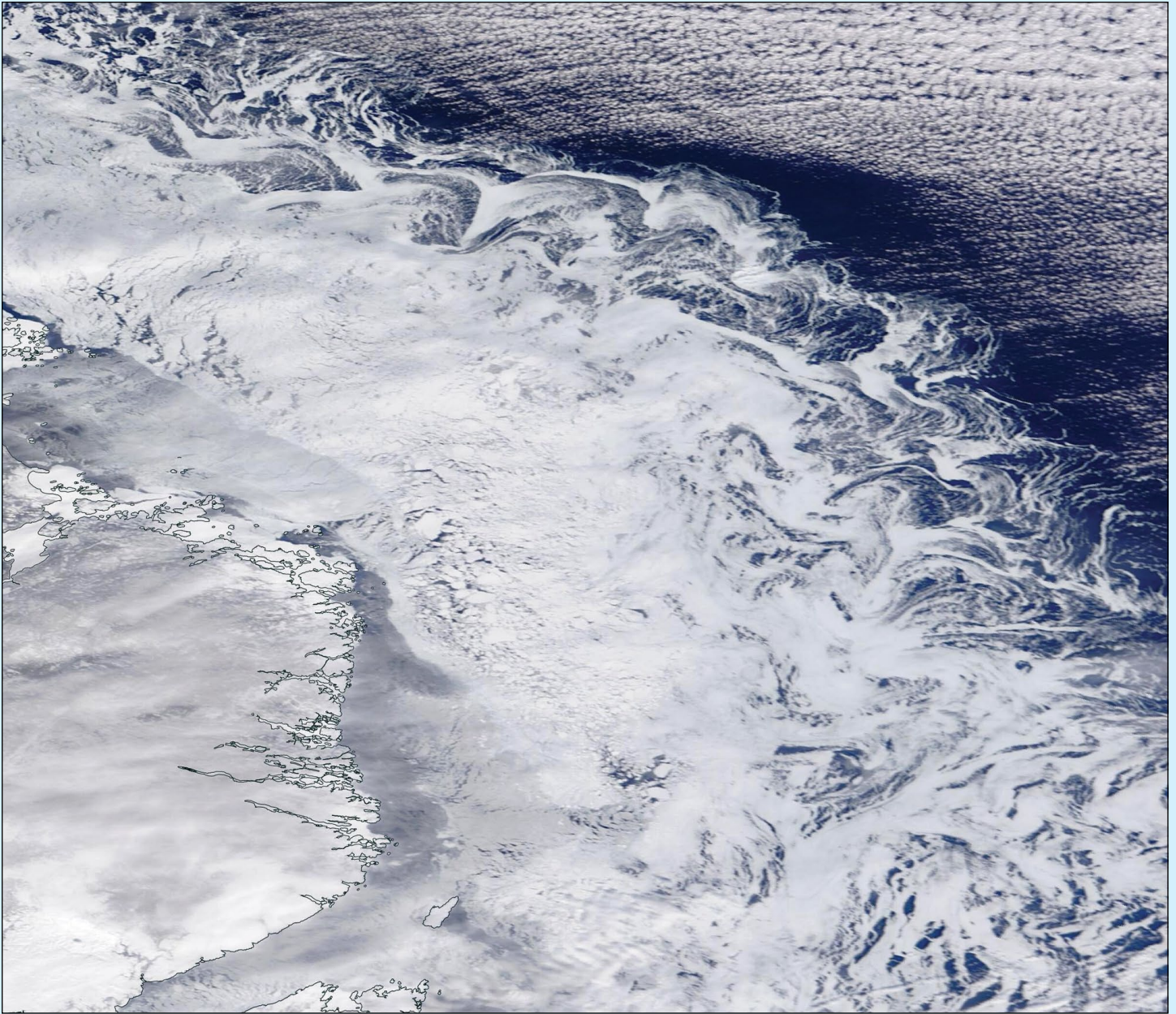


Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Ice and cloud combined to create a fanciful scene over the Labrador Sea between Canada and Greenland in early March 2022. The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-color image on March 2.

Ice hugs the snow-covered coast of Newfoundland and Labrador, Canada, where the frigid off-shore winds chill the relatively fresh near-coast water, allowing the formation of floating sea ice. The water is shallower and less saline than in the open sea, thus ice will form more easily here. The swirling filigrees at the sea ice edge are areas where the ice is thin and more easily moved by winds and currents.

To the east, a large bank of cloud lines up in parallel bands, a pattern One of the most widespread is volcanic ash. Satellite images collected in the days after the eruption show the fine-grained shards of pulverised rock covering several islands, turning land surfaces from lush green to tan and gray. On January 25, 2022, the Operational Land Imager (OLI) on Landsat-8 captured the image opposite showing ash coating much of Tongatapu, Tonga's most populous island. Compare this with the pre-eruption image featured on the front cover. n known as cloud streets. These are formed when strong winds push a mass of cold and dry air across a relatively warm and moist body of water. As the cold air mass moves over the water, it quickly gains moisture necessary to form clouds. The clouds line up in organized rows parallel to the direction of the wind.

Record Low for Great Salt Lake

NASA Earth Observatory

Story by Michael Carlowicz

In late July 2021, the Great Salt Lake in Utah reached its lowest water level on record and has continued dropping since. On July 23, the U.S. Geological Survey (USGS) gauge at the Saltair boat harbour, at the southern end of the lake, recorded the average daily level at 1277.5 metres above sea level, the lowest mark since measurements began in 1875. The previous low was set in 1963.

The Operational Land Imager (OLI) on Landsat-8 acquired these images of the north end of the Great Salt Lake on July 29, 2017, and July 24, 2021. Orange-brown areas along the edges of the lake indicate shallow water, while bright tan and white fringes suggest newly exposed portions of the lake bed. Note, too, the depletion of water in Clyman Bay and Bear River Bay.

According to USGS, water levels in the southern part of the lake are usually a bit higher than the northern half because more tributaries flow into the southern section. The lake is divided by a causeway for the Union Pacific Railroad.

According to water elevation data from USGS (plotted opposite), the Great Salt Lake stood at 1277.4 metres as of August 12, 2021. When full to its historic average level of 1280 metres, the lake spreads across 4,400 square kilometres. At the time of this historic low, it spans about 2460 square kilometres, a 44 percent loss of surface area.

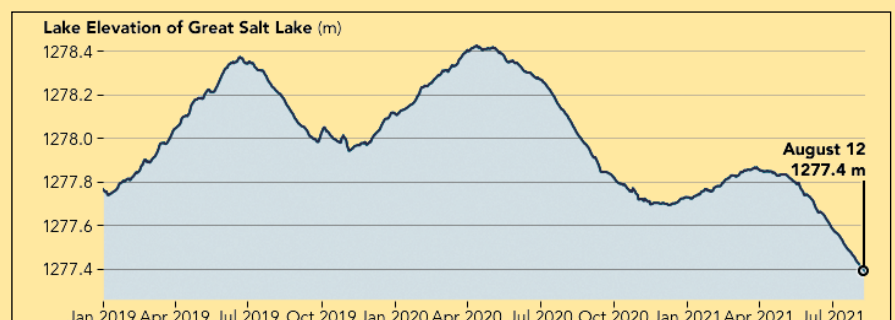
The low lake levels are due to recent trends in precipitation and long-term trends in consumption by humans. Snowfall was modest



Landsat-9 image of the north end of Great Salt Lake on July 29, 2017
NASA Earth Observatory image by Joshua Stevens, using Landsat data from the USGS and lake elevations from the National Water Information System.



Landsat-9 image of the north end of Great Salt Lake on July 24, 2021
NASA Earth Observatory image by Joshua Stevens, using Landsat data from the USGS and lake elevations from the National Water Information System.





This zoomed image of the north of Great Salt Lake emphasises how the lake has declined in recent years
Image: NASA / USGS

to deficient in many areas the previous winter, and recent research showed that snow cover in the mountains around the Great Salt Lake melts at least a week earlier now than 20 years ago.

Like much of the American West, rainfall has also been sparse here for the past two years. In its August 12 report, the *U.S. Drought Monitor* noted that 100% of Utah was experiencing at least severe drought while 50% of the state was in exceptional drought, the highest category.

'Based on current trends and historical data, the USGS anticipates water levels may decline an additional 30 centimetres over the next several months,' USGS Utah Water Science Center data chief Ryan Rowland said in a July 24 statement.

Due to the extreme drought, nearly two-thirds of Utah's river and stream gauges were reporting below-normal flows.

The Great Salt Lake is the largest water body in the

United States after the Great Lakes. It is a terminal basin, which means the water that pours into the lake from rivers and streams has no outlet other than by evaporation. This allows salts and minerals to concentrate in the lake such that it is three to five times saltier than the ocean.

For more than 150 years, humans have been taking more water out of this closed basin—for farming, industry, and human consumption—than is flowing into it. Drought may have contributed to the recent drop in the lake, as have higher-than-normal temperatures. But according to scientists, there has not been a significant long-term change in precipitation in the basin.

In a white paper released in 2016, scientists noted that river flow into the basin—from the Bear, Jordan, and Weber rivers—has dropped 39% since the middle of the 19th century. The volume of water in Great Salt Lake has shrunk by 48% and the lake level has fallen 3.4 meters since 1847.

LANDSAT: Low Cost Landsat Data

Part 3 – Tools for Downloading Free Landsat Imagery

Ed Murashie

For the low cost of not \$4000, not \$2, but **free**, you can download nearly fifty years of Landsat imagery from the *United States Geological Survey* (USGS) website. One of the original goals of Landsat was to make imagery available for \$2 per image but at its peak the cost was closer to \$4000, which significantly reduced the number of distributed images. In 2008 that all changed when the USGS adapted an open data policy with no restrictions on download, usage or redistribution. The only ask is to include an acknowledgement statement acknowledging that the source of the data is the USGS. Since 2008, the number of images downloaded has risen exponentially each year, reaching over 100 million in 2020 and providing over \$3.5 billion dollars of international economic impact ^[1,2].

So how do you get your hands on this free Landsat data? There are three USGS user tools available and we will go through each one briefly so that you can decide which is your favourite.

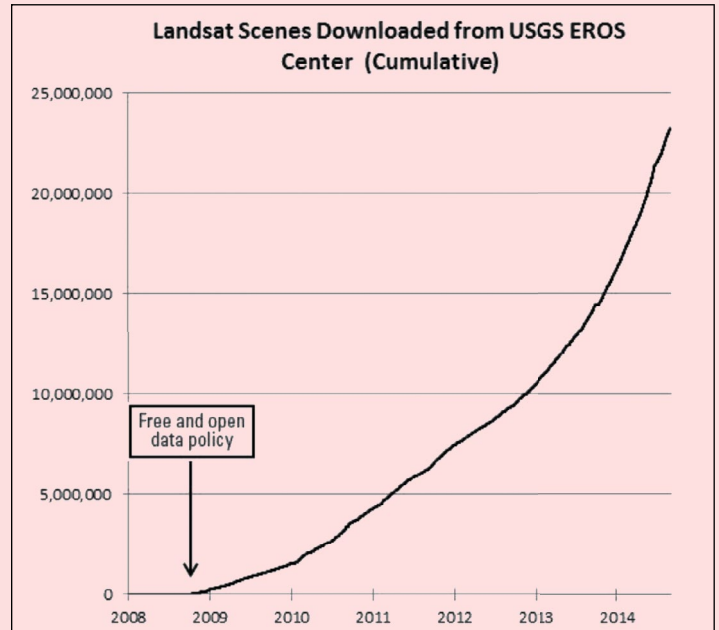


Figure 1 - Exponential growth of downloads of Landsat Data

Global Visualization Viewer (GloVis)

GloVis has been around since 2001 and can be accessed at

<https://glovis.usgs.gov/>

Assuming you want to download images and data, and not just browse, you will need to register. Click on **Login** in the upper left of the screen and either click on **Create New Account** or **Sign In** if you already have an account. The same account login will work for USGS EarthExplorer and LandsatLook 2.0. Once signed in take a quick tour by clicking on **Take Tour** in the upper left of the screen.

To start exploring, click on the **Launch GloVis in Full Screen Mode** button and either a default satellite image or the last image you searched for will be displayed. The screen interface is very user friendly with the ability to select satellite data sets, date range and percentage cloud cover on the left side of the screen. At the bottom of the screen is a timeline, ability to load the next or previous image, view the image metadata, and download the bands. The top of the screen has a home icon to set the current image location as a default, a location icon to jump a map location including a manually entered latitude/longitude, and a settings menu to change the base map, layers and view shortcut keys.

Let's go through an example where we want to find out when construction of Dubai's larger coastal man-made land mass was completed and download the scene (see figures 2, 3 overleaf).

- 1 Either use the mouse to scroll around the map to find the land mass, or click on the location icon in the upper right, click on **Lat/Long**, enter a latitude of 25.0072, a longitude of 54.9876, and then click **Jump to Location**.
- 2 Now select a data set, and for a hint the construction date was after Landsat 5 was operational, so click the toggle next to Landsat 7.
- 3 Leave the default date range which spans the operational life of Landsat 7, and the default cloud cover percentages which defaults to all available images.
- 4 Step through the chronological images by clicking on the **Next** button in lower right corner of the screen until you start to see that construction was completed. A faster method is to change the **Time Scale** to **Year** at the bottom of the screen, then click on different years. Fine tune using the **Next** and **Previous** buttons. The **Timeline View** shows the completion date around 10 July 2007. You will note the stripping in the image as mentioned in Part 2 of this article series.
- 5 To download the image, click on the **Download** button in the lower right corner of the screen and then select the quality of the image with or without georeferencing.

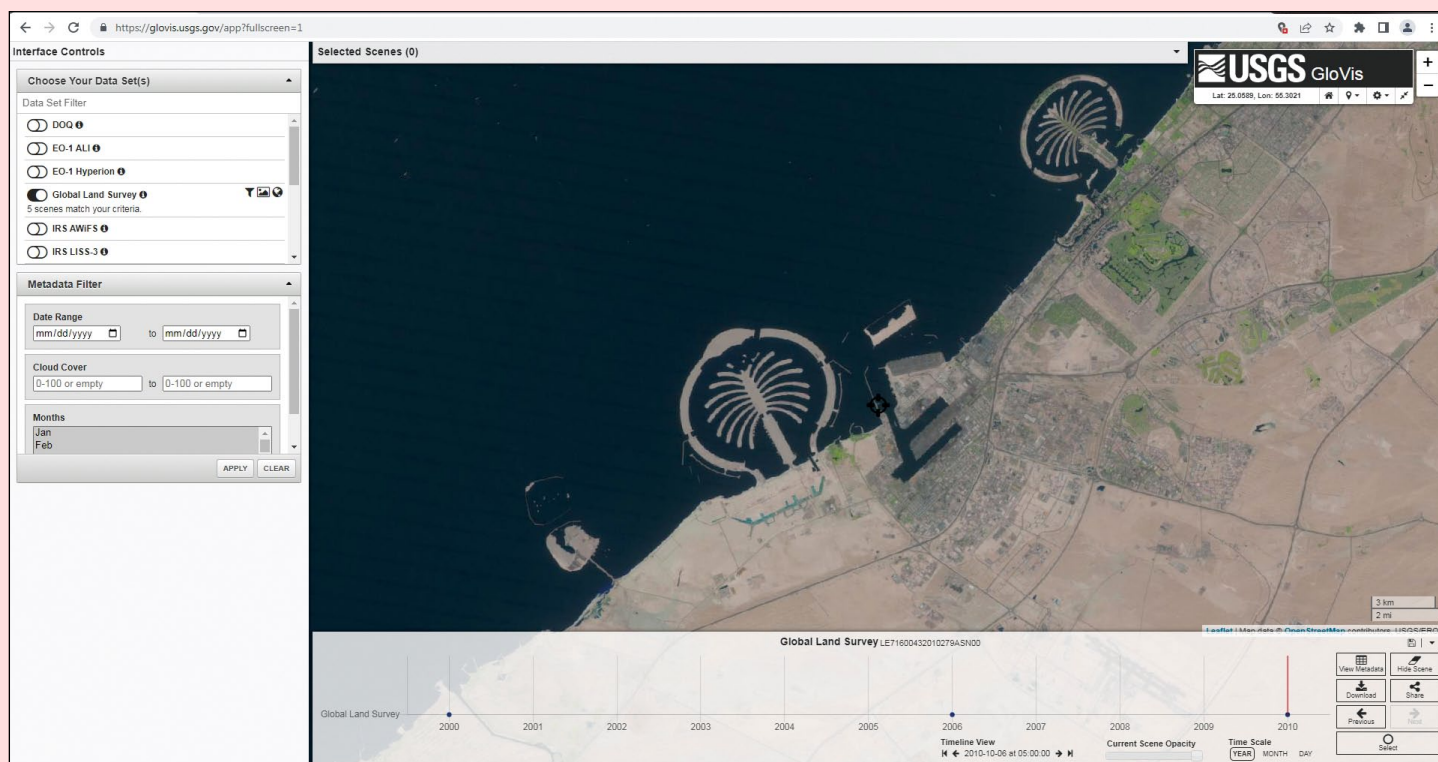


Figure 2 - The GloVis launch screen showing Dubai's man-made Islands



Figure 3 - GloVis showing Landsat Stripping and the answer to the example

A Level-1 GeoTIFF Data Product will be downloaded as a compressed tar.gz file which can be decompressed using free programs like 7-Zip. Once decompressed you will have a TIFF file of each band and a few ancillary files.

EarthExplorer

USGS EarthExplorer is a later improved tool with more capability, including a wider range of search criteria, a longer list of satellite and aerial imagery data sets, and the ability to bulk download data. To get started go to

<https://earthexplorer.usgs.gov/>

If you tried GloVis, you will notice in the upper right of the screen you are already logged in. If not click on **Login** and either sign in or click on **Create New Account** to do so.

All of the controls except zooming are located in a tabbed menu on the left side of the screen. The **Search Criteria** tab allows you to search by feature, like the Grand Canyon, an address/place, a path/row number, by uploading either a KML/KMZ or shapefile, using a map, or by entering coordinates of a single point, polygon, circle or predefined area. If you know what you want, EarthExplorer has a way for you to find it. Also on the **Search Criteria** tab are the tools for selecting a date range and cloud cover percentage. The **Data Sets** tab allows you to select data sets ranging from aerial imagery, digital elevation, to satellites including Landsat 1 through Landsat 9. The **Additional Criteria** tab allows you to select applicable options like path/row, sensor, collection category and others for the data set you chose.

Mount Pinatubo is the largest volcano eruption since the Landsat program has been operational

<https://thelistwire.usatoday.com/lists/12-of-the-most-powerful-volcanic-eruptions-in-history/>

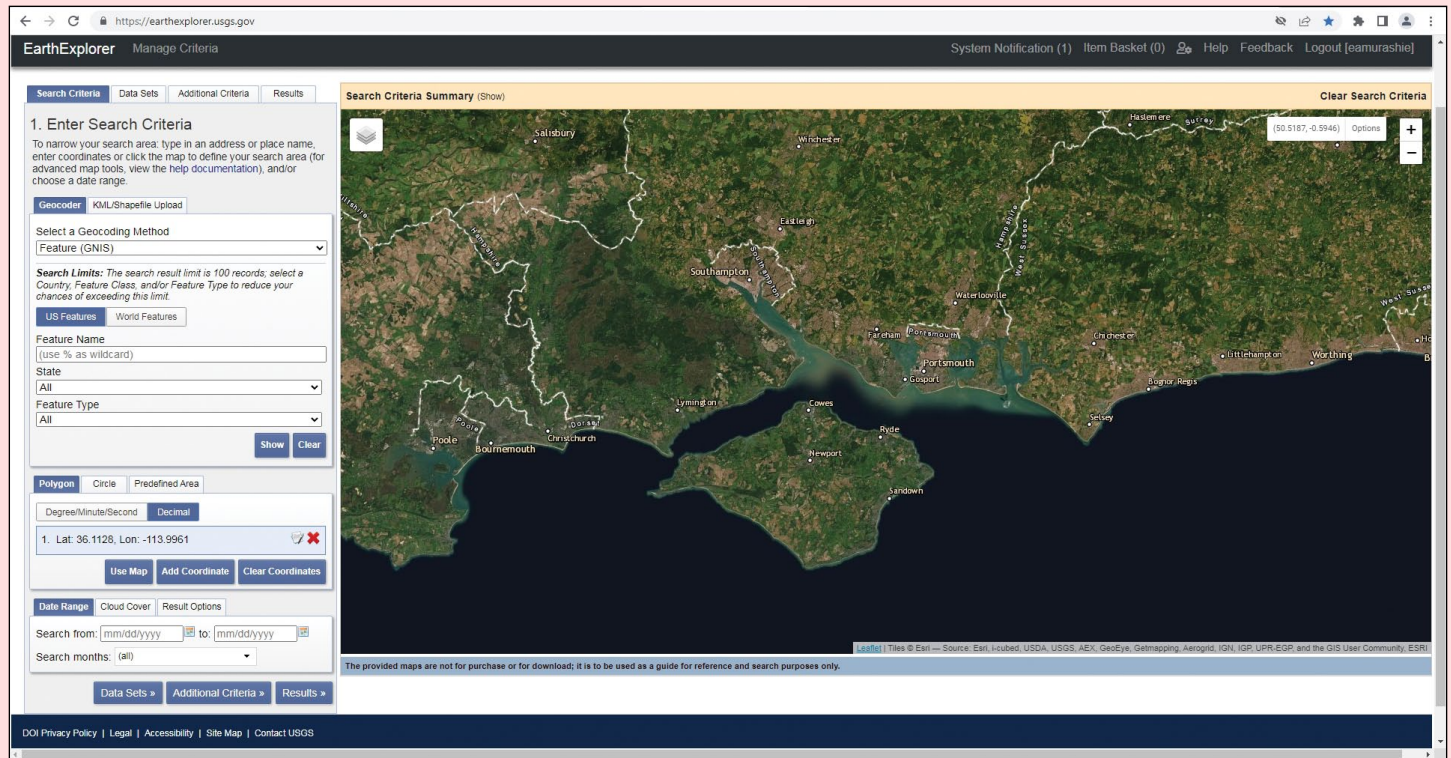


Figure 4 - EarthExplorer Home Screen

Let's use EarthExplorer to see what the mountain looked like before and after the eruption on June 15, 1991.

On the **Search Criteria** and **Geocoder** tabs, make sure the default of **Features** is set, then click the **World Features** tab. Enter Mount Pinatubo for the **Feature Name** and then click **Show**. Mount Pinatubo should show up under **Placename**, click on it to select.

- 1 Click the **Date Range** tab and enter a range of **01/01/1990** to **01/30/1992**. With this wide range we can be sure to find a cloud free image before and after the eruption.
- 2 Click the **Cloud Cover** tab and move the slider for a range of **0%** to **20%**.
- 3 Click on the **Data Sets** tab at the top of part of the screen.
- 4 Click the **+ sign** next to Landsat to expand the selections. Landsat 5 was the newest satellite during the selected date range and the thematic mapper sensor had the highest resolution. Collection 2 Level-2 has the highest processing and therefore a higher mapping precision, so click on **Landsat Collection 2 Level 2 Landsat 4-5 TM C2 L2**. For more information on this collection go to

<https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-4-5-tm-collection-2-level-2-science>.

- 5 Click either the **Results tab** or **Results button** and you will be presented with eight image thumbnails and options.
- 6 Scroll down the results to the last thumbnail dated 1990/01/20 since it looks to be one of the most cloud free images. Click on the footprint icon next to the thumbnail to see the scene coverage on the map.
- 7 Click the download icon to the right of the footprint to download the data. Click the **Product Options** button to see a list of available TIF files. Click the file ending in **SR_B2.TIF** to download the single band 2 image then click **Close**.
- 8 To download multiple single images, or the entire scene dataset, click the shopping basket next to each band, or **Add All to Bulk**, or the diskette and download arrow icon next to the thumbnail to make your selection. To download your selection, click on **Item Basket** at the top right of the screen, then click **Start Order**, and **Submit Product Selections**.

Text continues on page 13

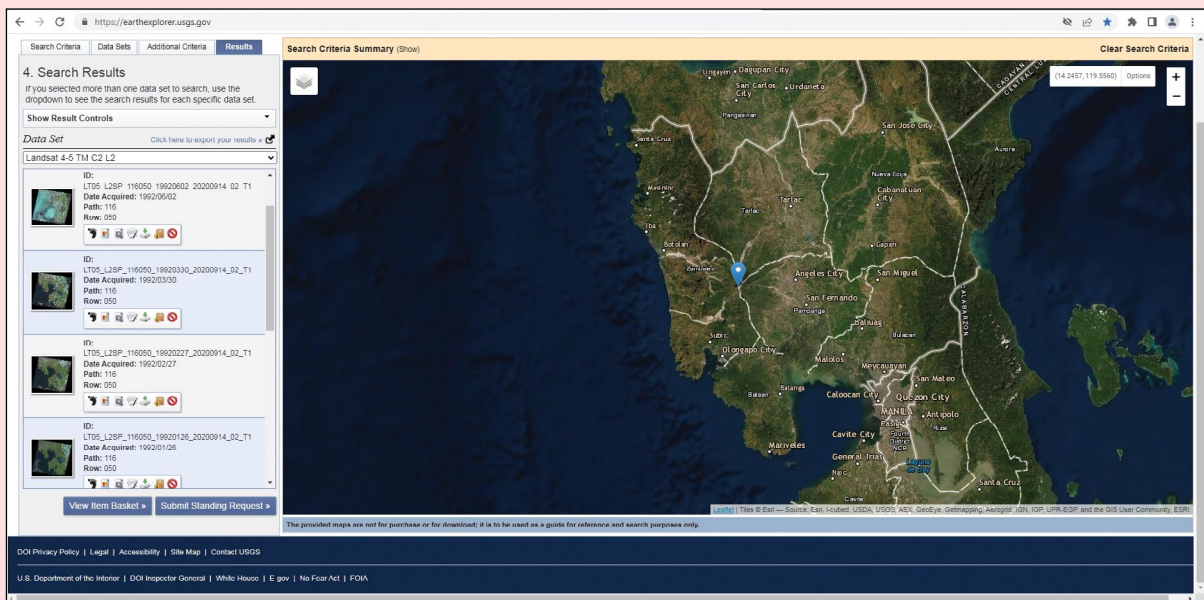


Figure 5 - Mount Pinatubo search results screen



Figure 6 - Pinatubo before the eruption
1990/JAN/20 Landsat 5 Thematic Mapper Band 2



Figure 7 - Pinatubo after the eruption
1992/JAN/26 Landsat 5 Thematic Mapper Band 2

- 9 Repeat steps 7 and 8 to select and download the 1992/1/26 image as the after eruption image.
- 10 Load the images in your favourite image processing program to adjust the contrast, brightness, and sharpness to your liking. Personally I use Irfan View.

LandsatLook 2.0

In the newest tool, the USGS took their Landsat data put it in the cloud and using cloud based tools processed it to convert it to cloud optimized GeoTIFF format, making it faster to manipulate. No longer are you dealing with individual scenes but instead a pixel mosaic. The reflectance data was also stored and can be used to remove highly reflective pixels, for example from a cloud, and use another pixel from the same timeframe instead.

To start, go to

<https://landsatlook.usgs.gov/>

which takes you to the welcome screen. From there you can click on About in the upper right corner to access an instructional video or the user's guide. If you are going to be downloading data you will need to login using the same credentials as used for Earth Explorer, just click on the user icon. To start exploring simply click on Explore.

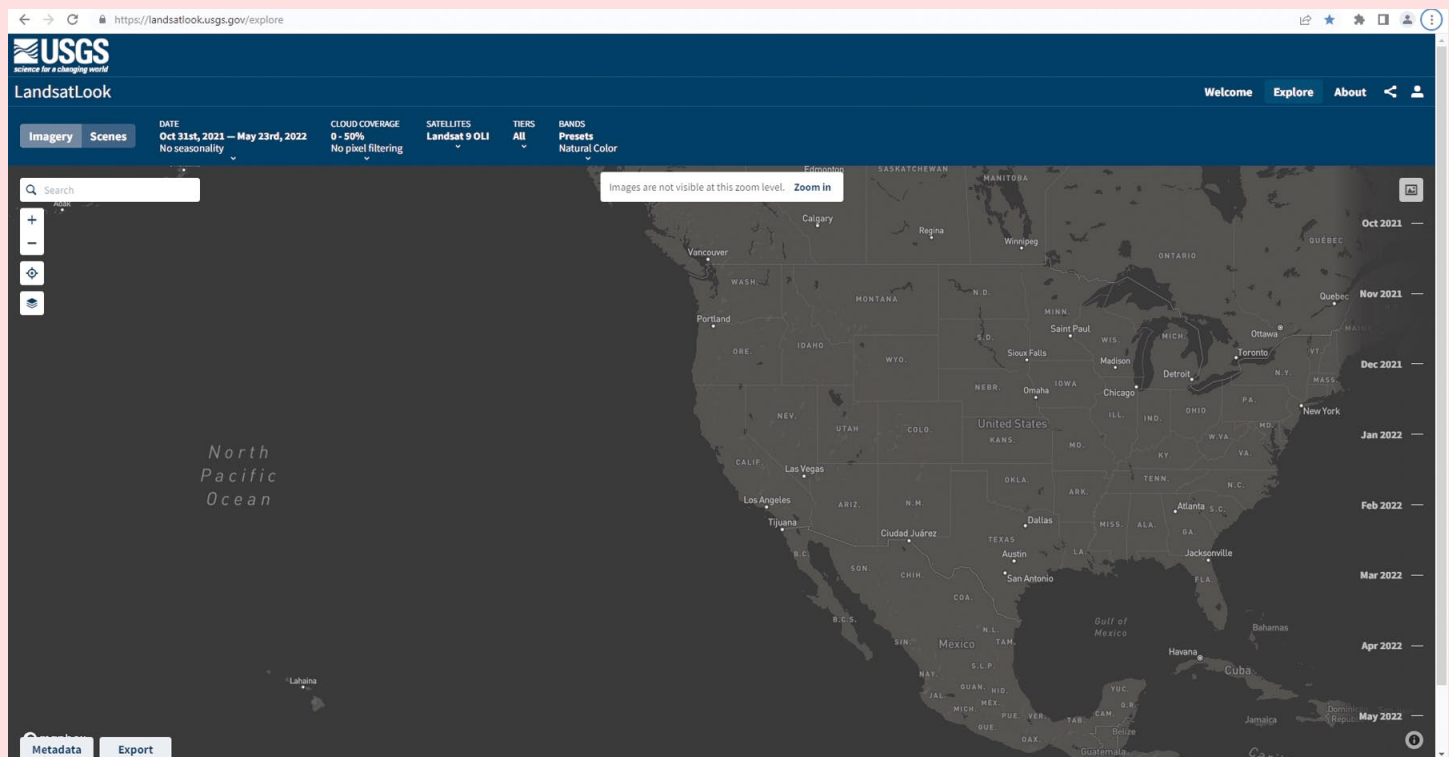


Figure 8 - The LandsatLook 2.0 'Explore' Home Screen

The second bar down is the menu bar and the options are:

Imagery | Scene

Allows either displaying the imagery or the Landsat scene information in path/row format.

Date

Allows either selecting a date range using a calendar format or manually inputting a date range. Depending on which satellite(s) are selected, you may get a date warning notifying you that the satellite(s) were non-operational during that period. The selected date range will show up on the right side of the screen as a vertical timeline.

Cloud Coverage

Filters images with a range of percentage cloud coverage. Clouds or highly reflective pixels can be replaced with other pixels in the same month if Filter pixels is enabled.

Satellites

Allows satellite selection and provides the date range they were operational.

Tiers

Allows filtering images by the amount of GEO processing and precision ranging from Real Time with little processing to **Tier 1** with maximum precision.

Bands

Allows selecting processing **Presets** like **Natural Color**, **Custom 1 band** for displaying one band like Red, or **Custom RGB** where you can assign different bands to red green and blue. Or you can select **Formulae** and then predefine band ratios like **Enhanced Vegetation Index**.

The icons on the left side of the screen let you type in a location of interest, zoom in or zoom out, select your location, or enable map labels. The **Metadata** button on the bottom of the screen lets you display the metadata of all the scenes used to create the pixel mosaic and download each scene data if logged in. The **Export** button lets you export a time-lapse GIF, the current pixel mosaic, the search metadata or metadata search code. The right side of the screen is a vertical timeline with a picture box above it which when clicked will load the best image of the month for the date range. It will turn into a play button and when click will animate the images.

Let's run through an example

Let's say you saw NASA's Earth Observatory 24 May 2022 email

<https://earthobservatory.nasa.gov/images/149857/cabo-de-gata-nijar-natural-park>

and you were intrigued since the images were Landsat 9 OLI-2 images and you wanted to learn more about the Cabo de Gata—Nijar Natural Park and surrounding area.

- 1 Click on the magnifying glass search icon and type in **Almería Spain**. With all of the menu defaults selected, the best image of the south coast of Spain is displayed in natural colour.
- 2 Using the mouse to pan and its wheel to zoom in, you can get a similar image to NASA's image. To appreciate the use of single pixel mosaics, know that the image of Spain is comprised of four separate Landsat scenes, yet it looks seamless.
- 3 To save the image, click on the **Export** button at the bottom of the screen, then click the download icon to the right of Map View.
- 4 To download the scenes, click on the **Metadata** button and then either click on **SR Bands** for surface reflectance data or **ST Bands** for surface temperature bands to the right of the scene of interest. Another window will open, click the download icon to the right of the band of interest.
- 5 To appreciate the power of cloud computing, click on the picture above the vertical timeline. When the images have been loaded, the icon turns into a play button, click on it to play an animation of the best image from each month. You may find months with no images, those appear as just a base map.

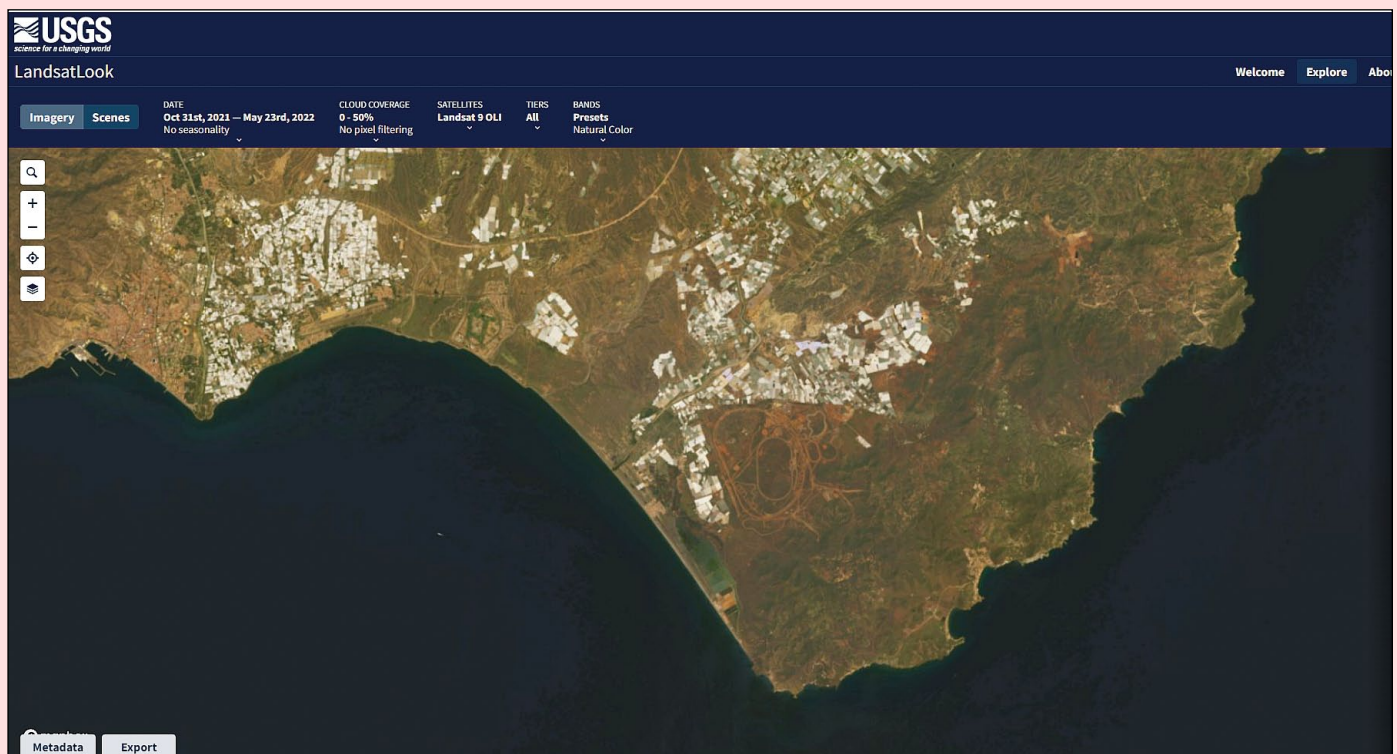


Figure 9 - Almería, Spain Pixel Mosaic Screen

I hope you found the article series informative and now have a new source for Landsat and other satellite images.

References to USGS Web Pages

- 1 <https://www.usgs.gov/news/featured-story/landsat-seen-stunning-return-public-investment>
- 2 <https://www.usgs.gov/news/landsat-milestone-one-hundred-million-downloads>

Wildfires Char South Korea

NASA Earth Observatory

Story by Adam Voiland

Amid dry weather and strong winds, thousands of firefighters raced to put out fires that burned through forests in coastal South Korea in early March 2022.

In NASA satellite data, the first signs of the fires began to appear on March 3-4, in the coastal areas of Uljin and Samcheok. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured the natural-color image shown above

on March 5. At the time, strong westerly winds sent smoke plumes streaming toward southern Japan. By March 7, the smoke had thinned somewhat as winds slackened and the weather turned foggy, but the satellites continued to detect fire activity.

The blazes have destroyed more than 300 homes, forced more than 7,000 people to evacuate and charred nearly 17,000 hectares (170 square kilometres), according

to news reports. At times, flames neared a nuclear power plant and gas facilities, but firefighters succeeded in fending them off. Around 18,000 people and dozens of helicopters were mobilised to fight the fires.

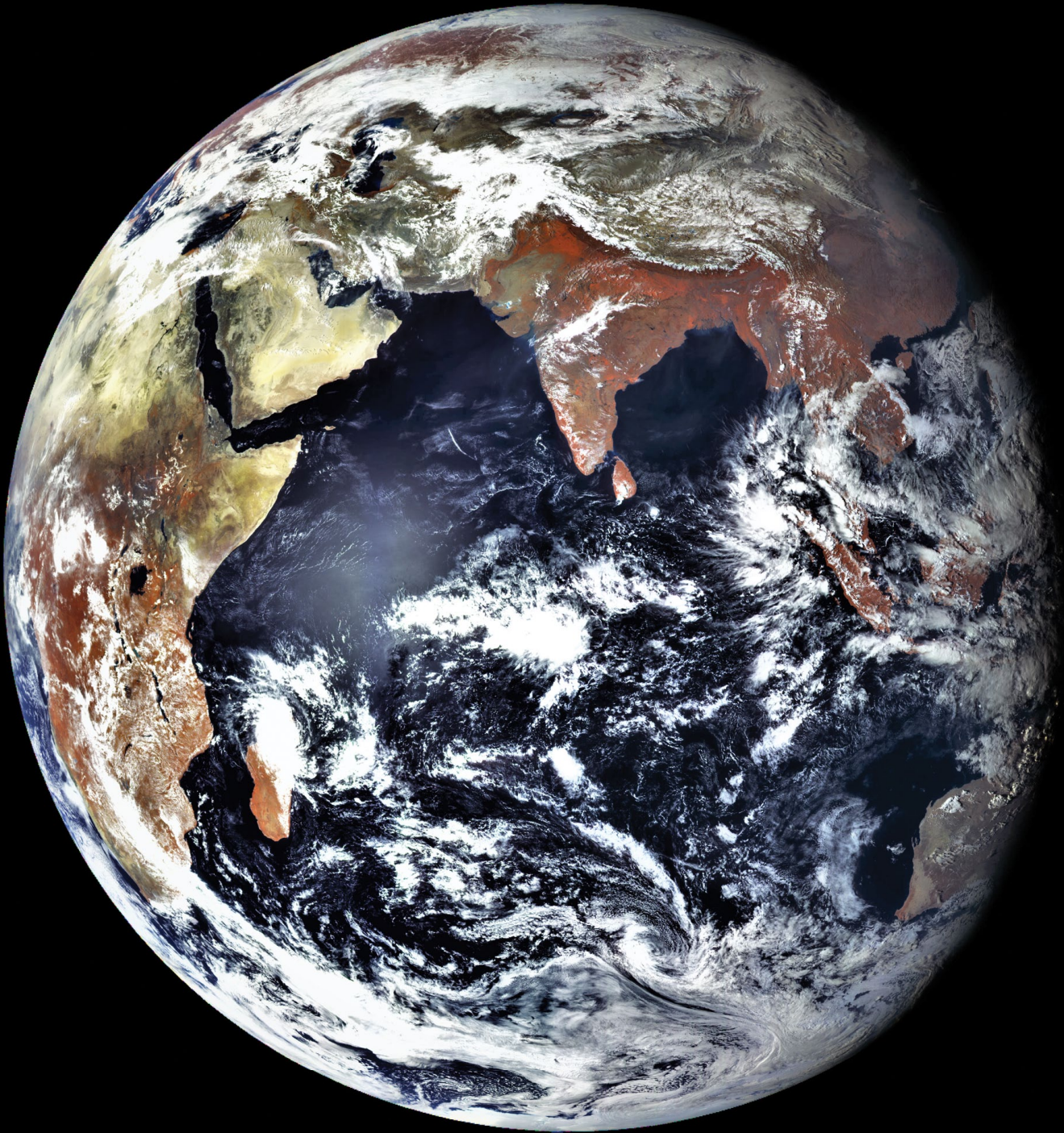
Most forest fires in South Korea (58 percent) occur in the spring when forests tend to be the driest and vegetation is primed to burn, according to research published in Applied Sciences.



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

Electro L3

Image from Enrico Gobbetti



This full Earth image was received directly from the Elektro-L3 geostationary satellite at AZ 108°, EL 08° by Enrico Gobbetti using a 150 cm dish with LNB, an Airspy Mini High Performance SDR Receiver and *Satdump* software to record the data. Elektro L3 transmits every 3 hours starting from UT 00.42, and I receive it at UT 09.42, 12.42 and 16.42. The image was received at a frequency of 1691 MHz at 09.42 UT on March 22, 2022.

Cloud Party in the Pacific

NASA Earth Observatory

Story by Adam Voiland, with information from Michael Garay
(NASA Jet Propulsion Laboratory).

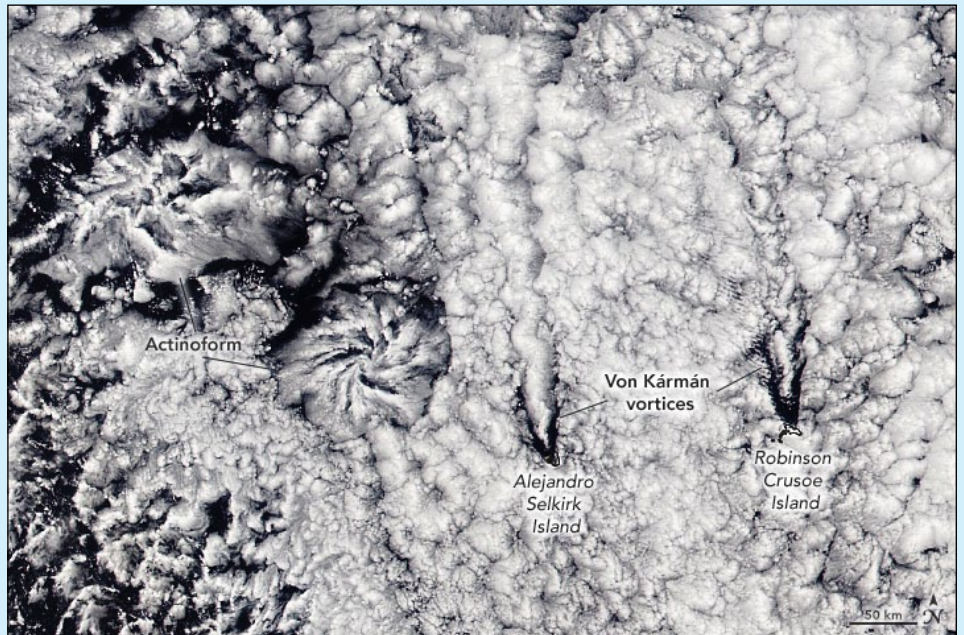
One of the first features that scientists noticed in April 1960 after NASA launched TIROS-1, the first weather satellite, were peculiar hexagonal 'cells' that appeared in clouds over the ocean. With diameters ranging between 50 and 100 kilometers, the features were sufficiently large never to have been recognised from the ground.

The phenomenon came to be called **mesoscale cellular convection (MCC)**. Meteorologists soon grouped these cloud systems into two main classes. The centres of 'closed' cells were clouded over, while 'open' cells had clear centres. By the time TIROS-5 was launched in 1962, researchers had identified a third class of MCC—an intermediate type with a radial structure that looked similar to flowers or wagon wheels. They named them **actinoform clouds**, derived from the Greek word *aktinos*, meaning 'ray.'

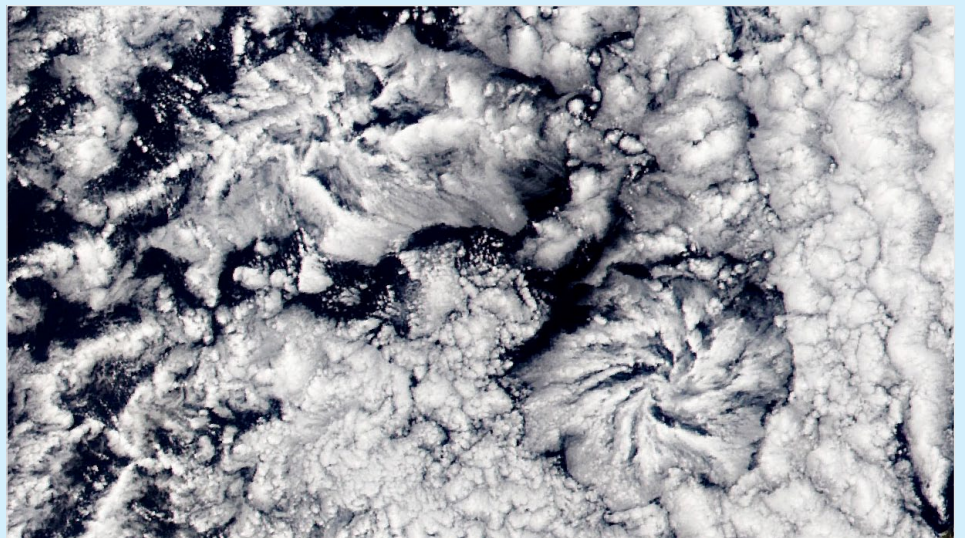
Though actinoform clouds were initially thought to be rare, satellite observations collected in the past few decades have made it clear that they are fairly common. The clouds are regularly spotted in imagery of the ocean. They can last up to 72 hours and often bring drizzling rain.

On March 11, 2022, the Visible Infrared Imaging Radiometer Suite (VIIRS) on the NOAA-20 satellite captured this image of two actinoform clouds to the west of Alejandro Selkirk and Robinson Crusoe islands in the Pacific Ocean. The cloud farther to the east has a classic actinoform shape, while its partner to the northwest has a more linear, diffuse form.

It is not clear why actinoform clouds develop, but they show up where marine stratocumulus clouds occur—typically in stable air along the western coasts of major landmasses. Researchers suspect that ocean currents and water temperatures may play a role in their formation.



NOAA 20 image captured on March 11, 2022
NASA Earth Observatory image by Lauren Dauphin, using VIIRS data from NASA
EOSDIS LANCE, GIBS/Worldview, and the Joint Polar Satellite System (JPSS).



Close-up of the Actinoform Clouds

Other eye-catching clouds were also on display on March 11. Faint rows of von Kármán vortices appear north of the two islands. The spiraling cloud patterns form when winds become diverted around elevated areas, often islands, rising from the ocean.

The two islands beneath the clouds are volcanic mountains off the coast of Chile. Alejandro Selkirk island was named after a Scottish sailor who spent four years as a castaway on the

neighbouring island after his captain abandoned him after an argument.

Alexander Selkirk's ordeal served as partial inspiration for the novel: 'The Life and Adventures of Robinson Crusoe'. Once known as Más a Tierra, the smaller of the islands was renamed Robinson Crusoe Island in 1966 in honour of the book. At the same time, Alejandro Selkirk island, formally known as Isla Más Afuera, was given its name.

Greening in Mali

MODIS Web Image of the Day

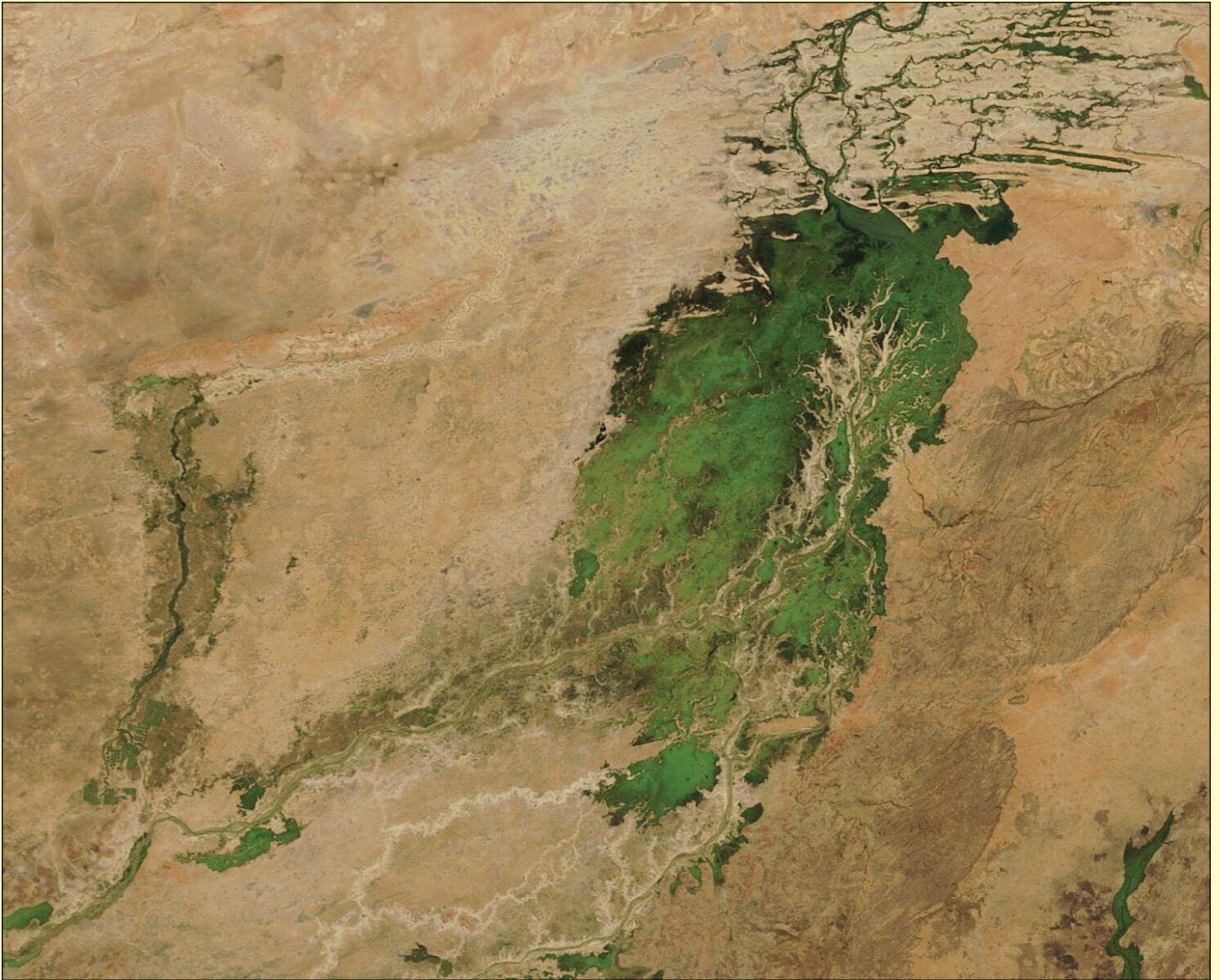


Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Spanning an area a little larger than twice the size of the state of Texas, the land-locked African country of Mali sits on the edge of both the Sahara Desert and the African Sahel. The hot, dry climate provides little arable land, especially in the desert north. The Sahel, located mostly in the south, has a slightly gentler climate than the north, with the hot and dry season (February to June) giving way to a warm rainy season (June to early November) and then a cooler dry season.

The rainy season fills the Niger River, the Bani River, and several streams, which all come together at the **Inland Niger Delta**, creating a heartland of brilliant green in southern Mali. During the dry season, the Inland Delta shrinks dramatically to roughly 3,900 square kilometres. By November, the Delta can expand to 20,000 square kilometres. This wealth of water

provides a boon for people, and excellent habitat for migrating birds and West African manatees. As waters recede, the fertile floodplains provide excellent agricultural land, ripe for rice or pasture.

On November 17, 2021, The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-colour image of the gorgeous greening of the Inland Niger Delta. The complex arrangement of river channels, lakes, and swamps is evident. The tree-like, branching tan area is actually an area of higher elevation, which remains dry. Wherever water seeps, especially close to the rivers, the arid, tan land has burst forth in green. Away from the rivers, a faint wash of green sits atop the tans that mark near-desert conditions, representing the tenacity of plants to grow when given even a little rain.

Lofoten, Norway

European Space Agency

Extending around 175 kilometres from north to south, the Lofoten archipelago comprises five main islands (Austvågøya, Gimsøya, Vestvågøya, Flakstadøya, and Moskenesøya), as well as many small islands and skerries. Lofoten is known for its distinctive scenery, with dramatic mountains and peaks, sweeping beaches, deep blue fjords and sheltered bays.

Svolvær, the chief town and port of the Lofoten island group, is located on the southern coast of Austvågøya, the easternmost island of the archipelago. The economy largely depends on cod fisheries, with the town's population swelling during the spawning season as fishermen flock in. The fjord of Vestfjorden lies between the archipelago and the mainland.

Although lying entirely within the Arctic Circle, Lofoten experiences one of the world's largest elevated temperature anomalies relative to its high latitude. Due to a convergence of the Gulf Stream with two underwater currents, the North Atlantic Current and the Norwegian Current, the weather in Lofoten remains anomalously warm.

The colours of this image, acquired on 24 November 2020, come from the combination of two 'polarisations' from the Copernicus Sentinel-1 mission which have been converted into a single image. This remote sensing technique allows us to detect where differences between the polarisations are higher. These differences are visible in shades of blue in the image, such as the choppy Norwegian Sea, wetlands and mires such as those on the northern tip of Andøya and wet snow on hilltops and in mountains (bottom-right corner of the image).

What appears in yellow indicates what has fewer differences between polarisations, such as forests and other vegetated land, as well as built-up areas.

Sentinel-1 is a radar mission and, unlike optical cameras, the images

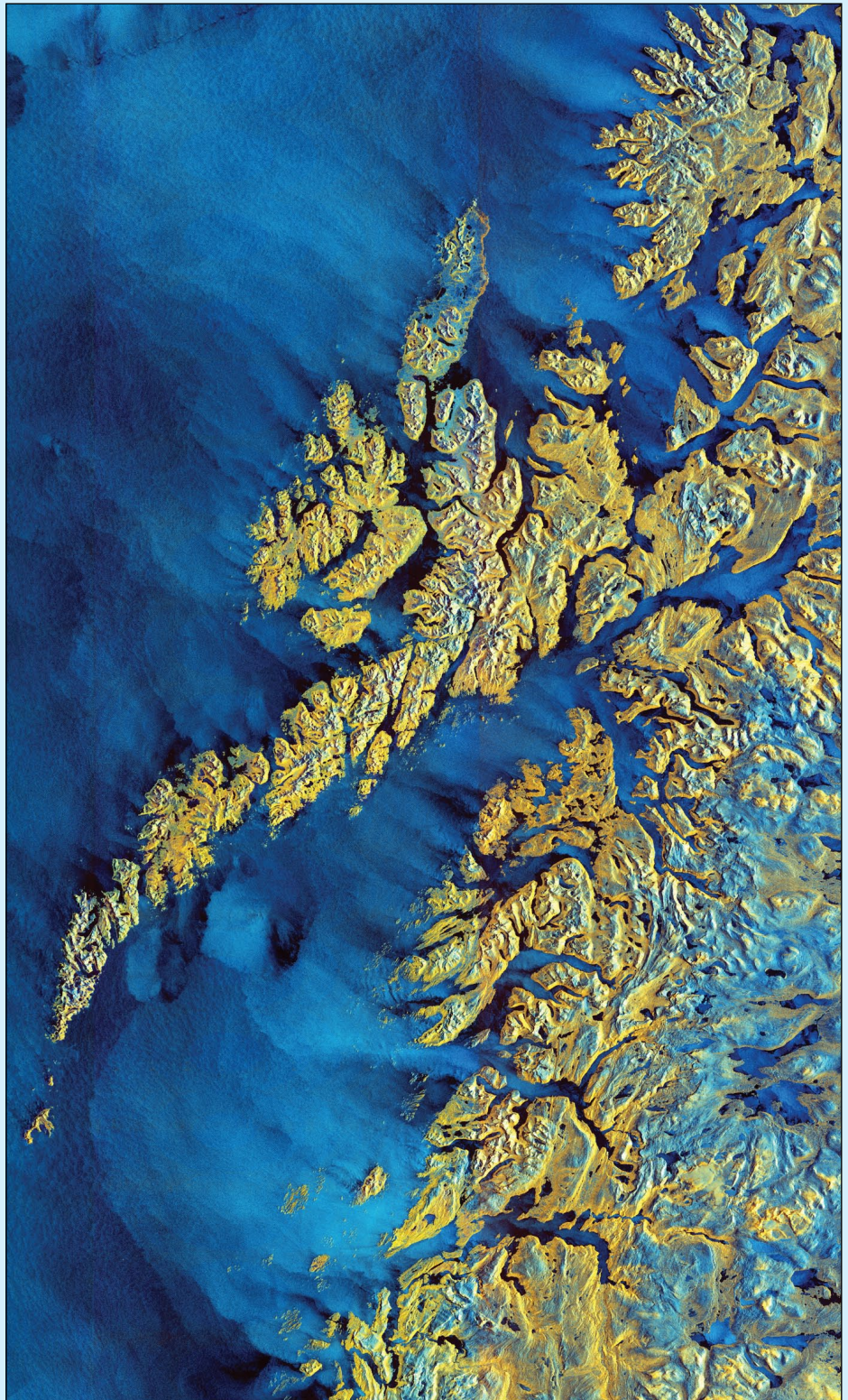


Image contains modified Copernicus Sentinel data (2020), processed by ESA, CC BY-SA 3.0 IGO

are usually black and white when they are received. By using a technology that aligns the radar beams sent and received by the instrument in one orientation—either vertically or horizontally—the resulting data can

be processed in a way that produces coloured images such as the one featured here.

This technique allows scientists to analyse Earth's surface better.

Ice Shelf Collapse in East Antarctica

NASA Earth Observatory

Story by Kathryn Hansen

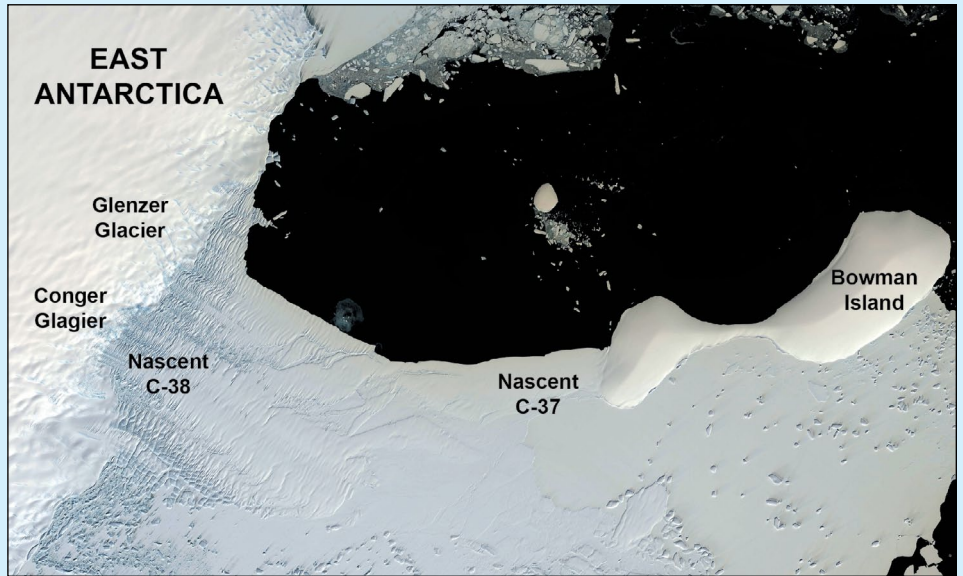
It is relatively common for ice shelves in Antarctica to spawn icebergs. It is less common for an ice shelf to completely disintegrate. In March 2022, an ice shelf in East Antarctica did both. The collapse has reshaped a part of the Antarctic landscape where coastal glacial ice was once thought to be stable.

The change happened fast. At the start of March the floating shelf fed by the Glenzer and Conger glaciers was still intact. By the middle of that month, it had fallen apart. Images acquired by the Operational Land Imager (OLI) on NASA's Landsat-8 satellite show the shelf before (figure 1) and after (figure 2) the shelf disintegrated.

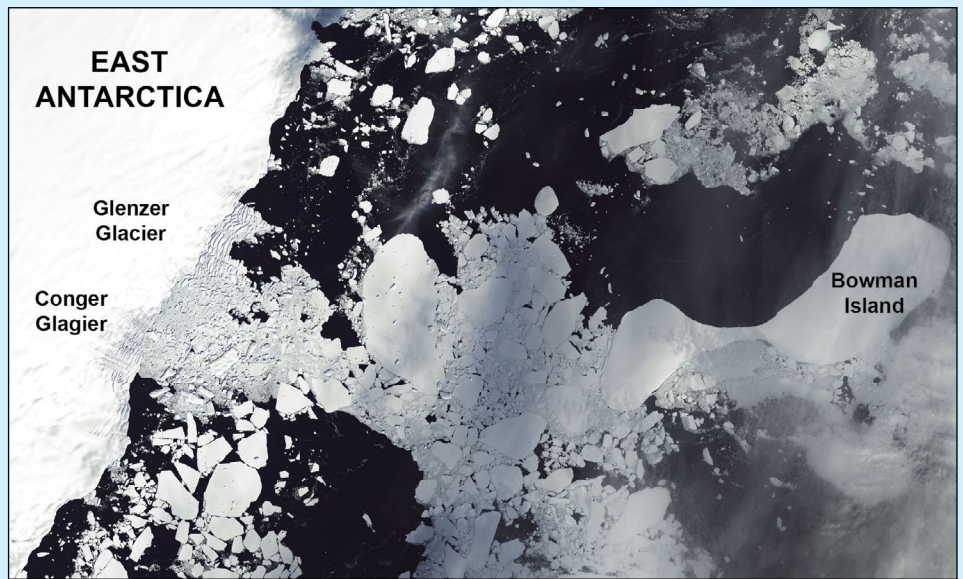
'The whole shelf collapsed in just around two weeks,' said Christopher Shuman, a University of Maryland, Baltimore County, glaciologist based at NASA's Goddard Space Flight Center. The icy remnants of both glacial shelf ice and adjacent sea ice dispersed from the waters around Bowman Island within weeks. *'All of this took less than a month,'* Shuman said. *'It was quite the blowout.'*

The progression of the collapse is visible in the image series on the following page. Images were acquired with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites.

Figure 3 shows the ice shelf floating on the Mawson Sea on February 22, 2022, prior to the collapse. Fast ice—a type of sea ice that becomes 'fastened' to the edges of ice shelves, coastlines, and icebergs—is also part of the mix. For two years prior to this image, the shelf was already in a state of decline. According to Catherine Walker of the Woods



An early March Landsat-8 image of the intact ice shelf
Image: NASA



A mid March Landsat-8 image of the same region after the shelf disintegrated
Image: NASA

Hole Oceanographic Institution, the shelf was losing ice at an average rate of about one square kilometre per day through the natural process of iceberg calving.

But in early March 2022, the shelf in front of the Glenzer Glacier calved a substantial iceberg. Named C-37, the berg initially measured about 144 square kilometres. A few pieces broke off, such that C-37 measured about 81 square kilometres on March 12 when MODIS acquired the image shown in figure 4. The

substantial loss of ice meant that the shelf became disconnected from Bowman Island. Note that some sea ice remained attached to the island.

'Without being supported by a land anchor, the ice shelf was destabilised and primed to collapse,' said Jonathan Wille, a postdoctoral researcher at the Université Grenoble Alpes.

According to Wille, an atmospheric river on March 15 appears to have triggered the shelf's final collapse.



Figure 3 - MODIS image of the floating ice shelf on February 22, 2022, prior to the collapse.

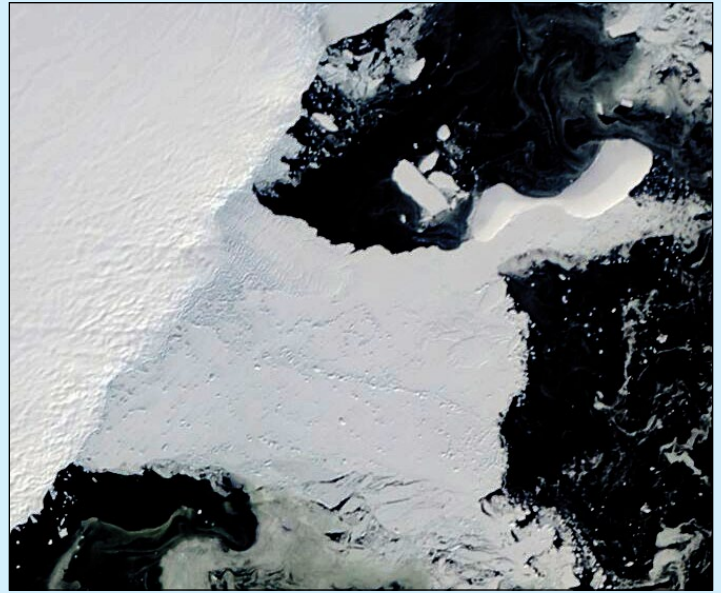


Figure 4 - MODIS image showing iceberg C-37 floating away from the ice shelf on March 12, 2022.

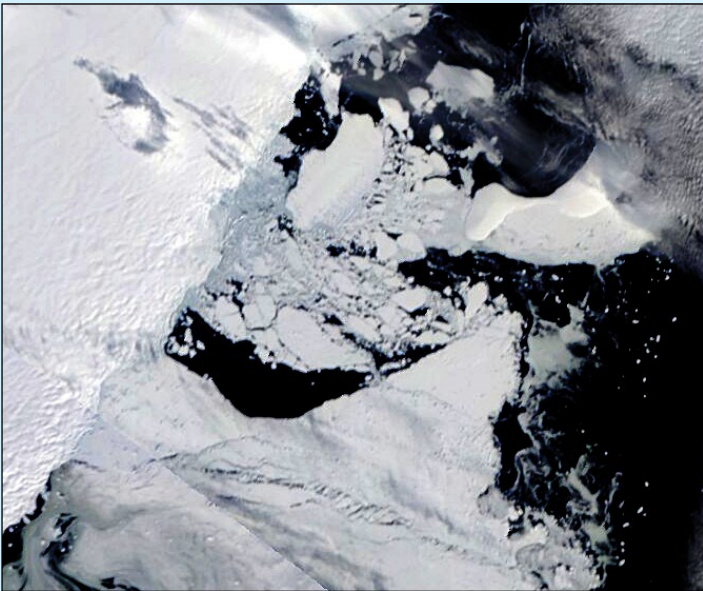


Figure 5 - MODIS image showing the final collapse of the ice shelf on March 16, 2022.

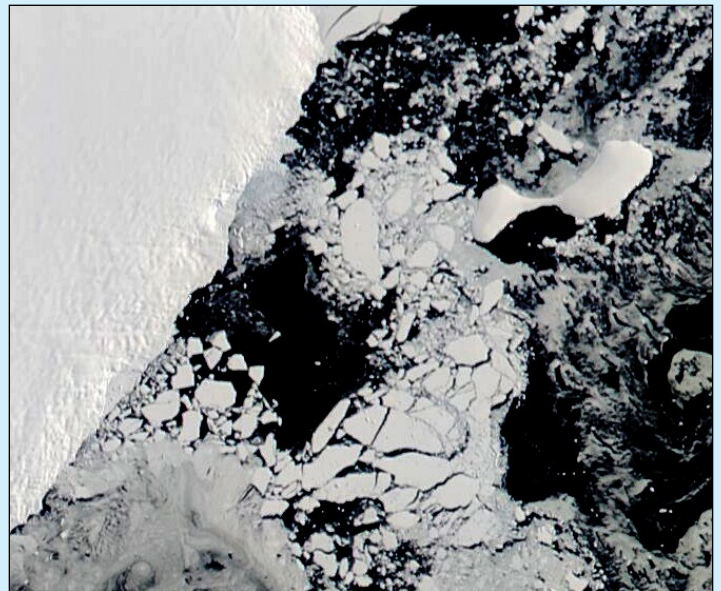


Figure 6 - MODIS image showing how the crumbled ice shelf had dispersed by March 21, 2022.

The weather system—which caused temperatures in eastern Antarctica to soar 40 degrees Celsius above normal—also enhanced ocean swells and amplified winds near the vulnerable shelf. This most likely caused the ice in front of Conger Glacier to break apart and quickly disperse.

Figure 5 shows the area on March 16 after the final collapse. The event spawned Iceberg C-38, which at the time measured about 415 square kilometres. The final image in the series (figure 6) shows the crumbled shelf ice and fast ice as it dispersed in the sea on March 21.

The loss of an ice shelf is problematic because it can indirectly contribute to sea level rise. *‘Ice shelves are essentially the ‘safety band’ holding up the rest of the Antarctic Ice Sheet,’* explained Walker. When they collapse, the ice behind them can flow

into the ocean more quickly. *‘And that is what raises sea levels.’*

By Antarctic standards, the ice shelf and glaciers that it held back are relatively small, so the impacts from the collapse are expected to be minimal. Scientists are more concerned about the location of the collapse.

‘All of the previous collapses have taken place in West Antarctica, not East Antarctica, which until recently has been thought of as relatively stable,’ stated Walker. *‘This is something like a dress rehearsal for what we could expect from other, more massive ice shelves if they continue to melt and destabilise. Then we’ll really be past the turnaround point in terms of slowing sea level rise.’*

NASA Earth Observatory images by Lauren Dauphin, using Landsat data from the U.S. Geological Survey and MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

DISCOVR and EPIC

Les Hamilton



The **Deep Space Climate Observatory (DSCOVR)** is a joint satellite mission between NASA, NOAA, and the US Air Force, located at the Earth-Sun Lagrange-1 point. This location lies directly between Earth and the Sun and some 1.5 million kilometres from Earth, where the gravitational attractions of Earth and Sun are in near equilibrium (figure 1). As a consequence, only minimal station-keeping manoeuvres are required to maintain a satellite's position at the L1 point where it will orbit the sun with the same period as Earth. In fact, the satellite actually moves around this equilibrium point in a lissajous halo orbit roughly orthogonal with the Earth-Sun line.

The Air Force's role in this mission was to provide the SpaceX Falcon 9 rocket which launched DSCOVR, NOAA's first operational deep space satellite, from Cape Canaveral in February 2015.

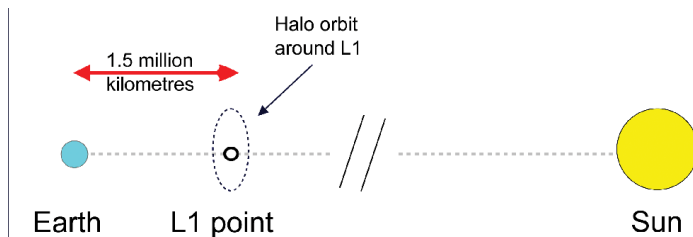


Figure 1 - Location of DISCOVR at Lagrange Point 1
(Not to scale)

NASA built the spacecraft and performed its on-orbit checkout and now operates the two Earth-facing science instruments, the Earth Polychromatic Imaging Camera (EPIC) and the National Institute of Standards and Technology Advanced Radiometer (NISTAR).

Once in orbit, NOAA took over the operation of the 570 kilogram spacecraft and provides the solar wind plasma and interplanetary magnetic field measurements which are critical to maintaining the accuracy of lead times (up to 60 minutes) for space weather alerts and forecasts. Space weather has the potential to seriously disrupt power grids, telecommunications and GPS, and NOAA supplies these geomagnetic storm warnings to support key industries such as commercial airlines, electric power companies and GPS-related facilities.

From its vantage point, DSCOVR has a continuous view of both the Sun and of the sunlit side of the Earth, monitors variable solar wind conditions, provides early warning of approaching coronal mass ejections and observes phenomena on Earth, including changes in ozone, aerosols, dust and volcanic ash, cloud height, vegetation cover and climate.

NOAA operates DSCOVR from its *Satellite and Product Operations Facility* in Suitland, Maryland and the space data acquired is processed for accurate weather

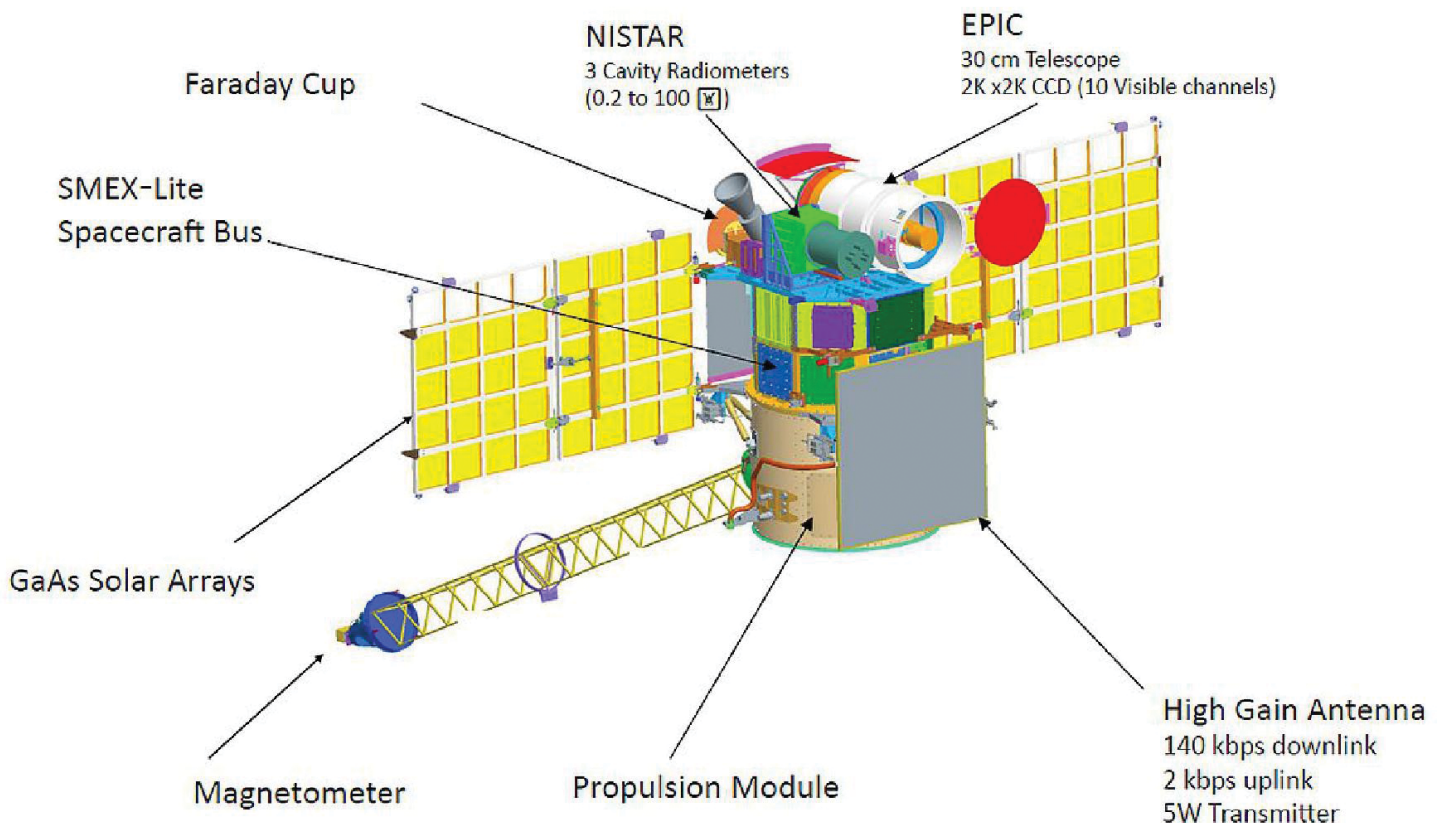


Figure 2 - The Earthward side of the deployed DSCOVR spacecraft and its complement of components and sensors.
(Image credit: NASA)



Figure 3 - EPIC captured this image of the Moon emerging from behind the Earth on October 2, 2020
Image: NASA

forecasting purposes at the *Space Weather Prediction Center* in Boulder, Colorado.

EPIC

An important part of DISCOVER's payload is NASA's *Earth Polychromatic Imaging Camera* (EPIC), which provides ten narrow band images in of the entire sunlit face of Earth.

After the spacecraft entered its operational phase, NASA began releasing near-real-time images of Earth through the EPIC instrument's website

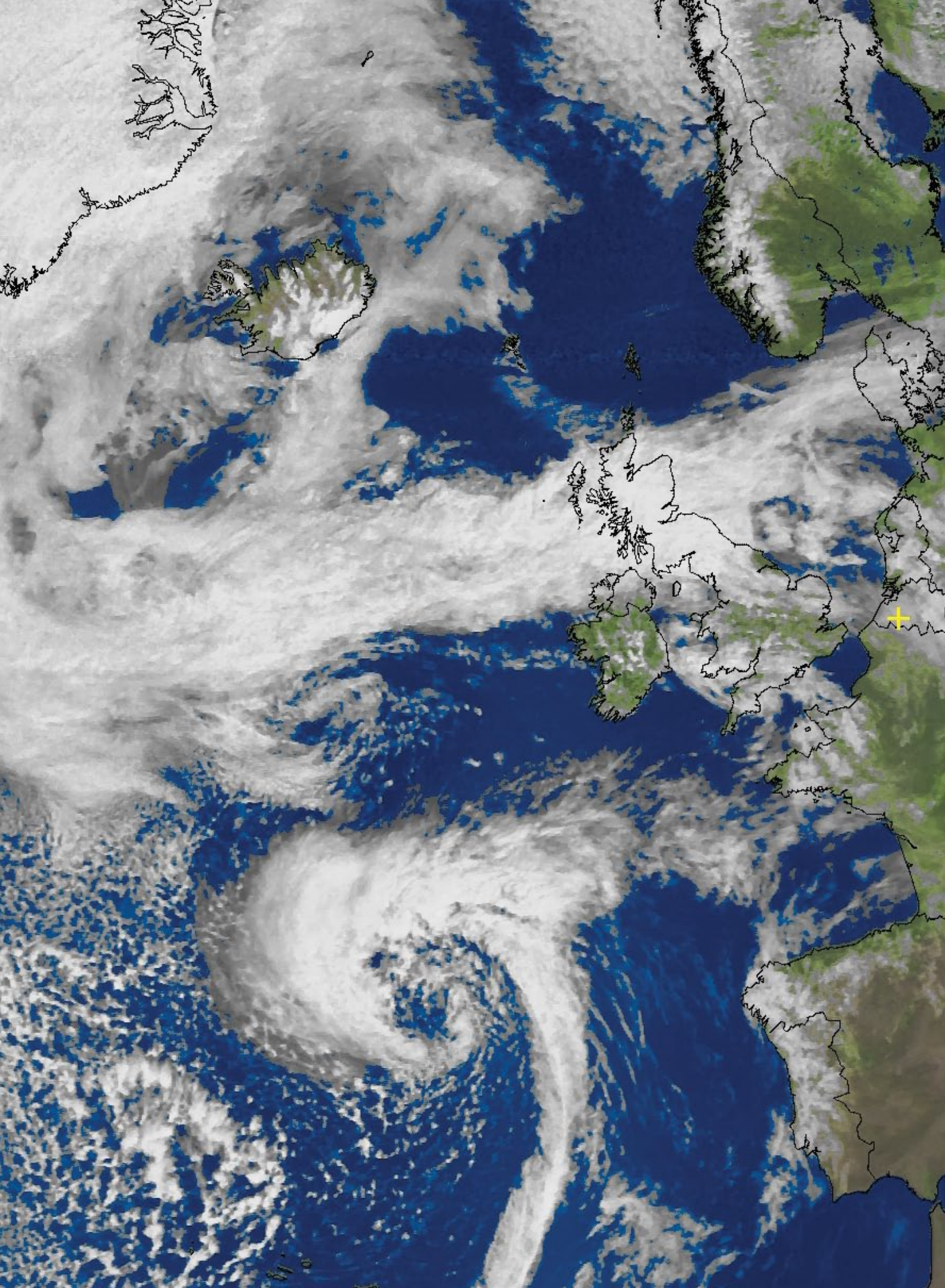
<https://epic.gsfc.nasa.gov/galleries>

As an Earth viewing instrument, EPIC has a unique view of the planet, taking between 13 and 21 images daily at local

noon and is able to process them faster than other Earth observation satellites.

The instrument consists of a 30 centimetre aperture Cassegrain telescope which focuses its images on a 2048 x 2048 charge-coupled device (CCD), using two filter wheels, and containing a set of 10 bands at ultraviolet (UV), visible, and near-infrared (NIR) wavelengths in the range 317 to 780 nanometres.

DISCOVER's spacecraft is giving EPIC a unique angular perspective that will be used in science applications to measure ozone, aerosols, cloud reflectivity, cloud height, vegetation properties, and UV radiation estimates at Earth's surface.



With Meteor LRPT inactive, many enthusiasts turned their attention to the NOAA APT data streams, including André T'Kindt from Ronse in Belgium, who sent in this excellent NOAA 18 image acquired on May 16, 2022.

Uyuni Salt Pan Drying Out

MODIS Web Image of the Day



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Seated on the high Altiplano of Bolivia, **Salar de Uyuni** shimmers bright white in satellite imagery, thanks to the thick, salt-rich mineral crust that spans roughly ten thousand square kilometres. The Altiplano plateau was formed during the uplift of the Andes Mountains, which surround the region. This plateau harbours fresh and saltwater lakes as well as several salars (salt flats) but the largest salar in all of Bolivia—and the largest on Earth—is Salar de Uyuni.

Most of the year, this enormous salt flat wears a thick, nearly unbroken, salty crust. During the rainy season, however, water often collects in Salar de Uyuni, dissolving some of the salt and expanding the size of the salt flat. The expansion is always temporary, as the hot dry season drives rapid evaporation that once again shrinks Salar de Uyuni as well as the other salars of the Altiplano.

Abundant rainfall around the Altiplano in the 2021-2022 rainy season filled Salar de Uyuni beyond the brim. According to an article published by NASA's Earth Observatory on February 19, 2022, hydrologist Jorge Molina Carpio of the Universidad Mayor de San Andrés explained that the extent of the filling of Salar de Uyuni this year is above normal. The rainy season started earlier than

in previous years (in November 2021), and rainfall was well above average over the southern Altiplano. He stated:

'This was probably related to the onset of a significant La Niña event. Strong La Niñas during the rainy season are related to positive rainfall anomalies in the southern Altiplano.'

Despite the abundance of water in the Salar de Uyuni by February 2022, the onset of the dry season has seen rapid shrinking.

The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Aqua satellite acquired this true-colour image of the Salar de Uyuni on April 21, 2022. Most of the salt flat appears bright white, indicating dry conditions. A few gray and blue-gray areas mark remaining moisture both in Salar de Uyuni and the smaller Salar de Coipas. This is in marked contrast to the conditions seen on February 11, 2022, when the salt crust of the Salar de Coipas was almost entirely dissolved as that salt flat filled with fresh rainwater. The salty crust of Salar de Uyuni was still present, especially in the western section, but it was also filled with water, colouring it with swirls of blue, gray, and brown.

Antarctic Sea Ice Reaches Record Low

NASA Earth Observatory

Story by Kathryn Hansen

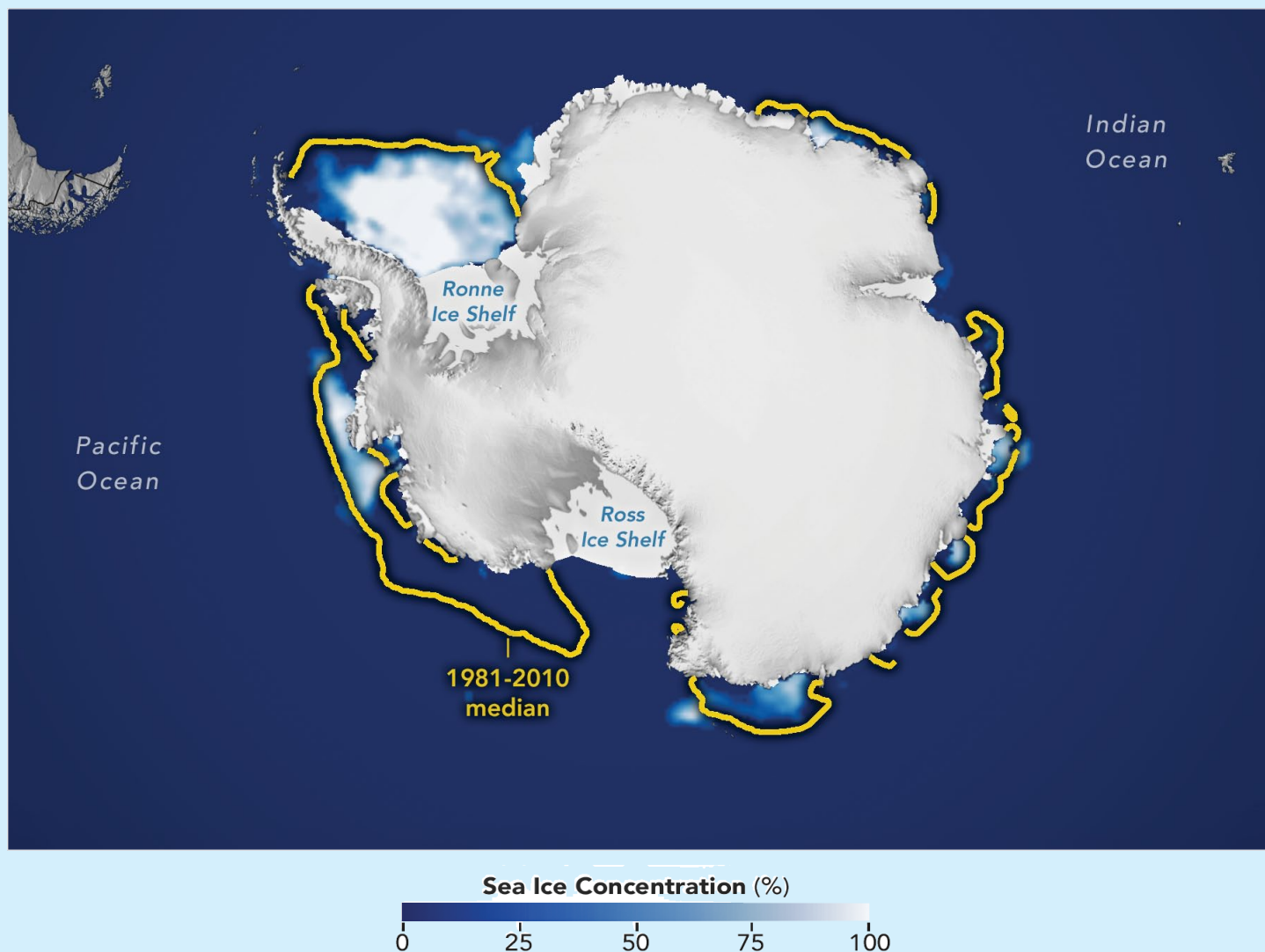


Figure 1 - Antarctic Sea Ice Minimum - February 2022

In February 2022, sea ice around Antarctica reached the lowest extent ever observed since the start of the satellite record in 1979. It marks the first time that the ice was observed to shrink below two million square kilometres.

Sea ice in southern polar waters reached its lowest extent on February 25, 2022, at 1.92 million square kilometres, 190,000 square kilometres below the previous record-low reached on March 3, 2017. Compared to the average minimum, the sea ice this year is missing an area about twice the size of California.

Figure 1 shows the ice extent on the day of its record low. Extent is defined as the total area in which the ice concentration is at least 15%. The yellow outline shows the median sea ice extent for February from 1981–2010. A median is the middle value: that is,

half of the extents were larger than the yellow line and half were smaller.

The 2021–2022 melting season began earlier than usual, after the ice reached its seasonal maximum extent on September 1, 2021, and then quickly declined through the austral spring and summer. According to Walt Meier, a sea ice researcher at the *National Snow and Ice Data Center*, winds were the main reason for the low ice conditions this year. He explained that the winds around the continent were ‘much stronger than normal,’ which quickly pushed ice north into warmer waters where it melted. An exception was in the Weddell Sea, where winds pushed the ice edge south.

One month after the sea ice reached its annual minimum, Meier said that the rate of growth looked normal. Even the heatwave that sent Antarctica’s

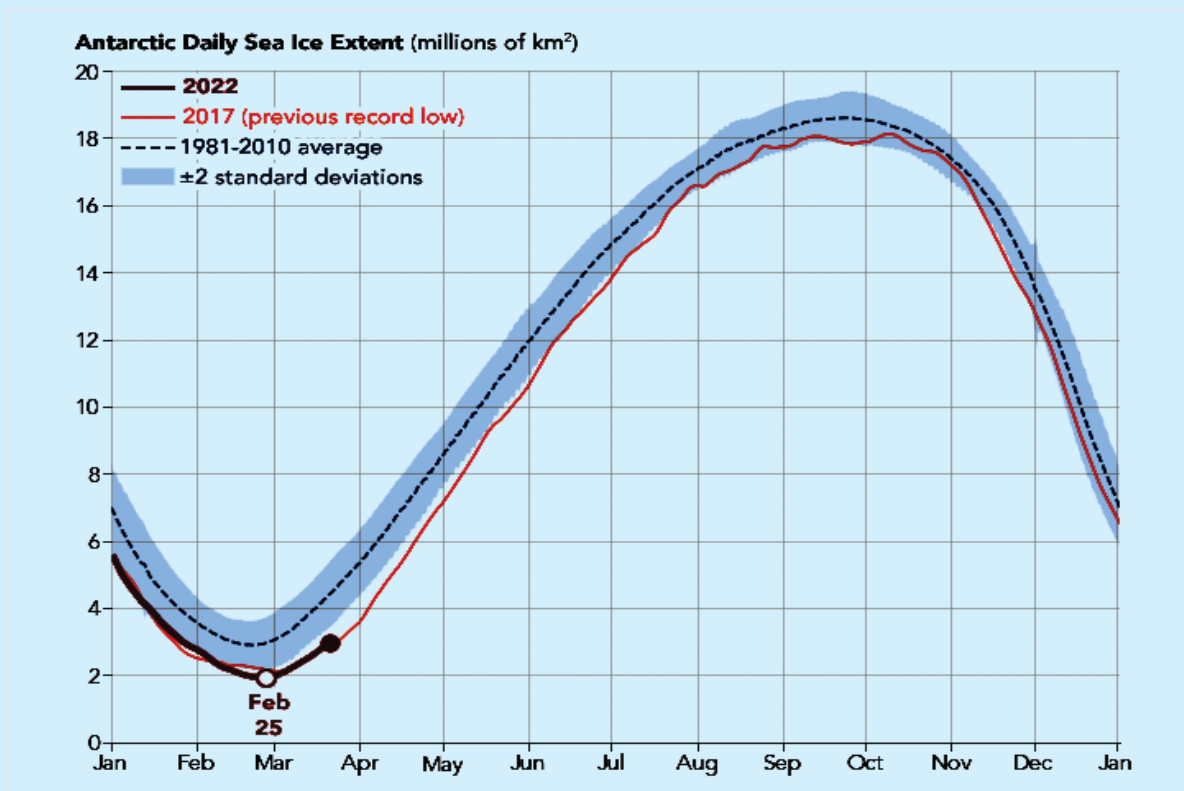


Figure 2 - Antarctic Daily Sea Ice Extent by Year (1978-2022)

air temperatures soaring in the third week of March did not seem to have slowed the growth. 'It is really the ocean temperatures that count,' Meier said, 'and a brief heat wave won't affect things too much in that regard.'

It remains to be seen how much ice will regrow this year. While it is common for Antarctic sea ice to melt nearly all the way back to the coastline during the austral summer, the ice grows unconstrained through autumn and winter. After months of growth (February to September), new sea ice typically spans an area of ocean about twice the size of the continental United States.

From year to year, Antarctic sea ice can be highly variable. Since 2013 it has reached both its highest high and its lowest low since record keeping began. A surge of sea ice growth in 2014 and 2015 enhanced a small upward trend in the long-term record. But over the past seven years, sea ice has generally been at or below average, including record-low minima in 2017 and 2022. The long-term trend now appears flat and, because of the variability, is not considered statistically significant.

In contrast, sea ice in the Arctic shows a clear downward trend. That means that globally, the planet is losing sea ice. 'Overall, for the Arctic and Antarctica combined,' Meier said, 'the trend is definitely still downward' (figure 3).

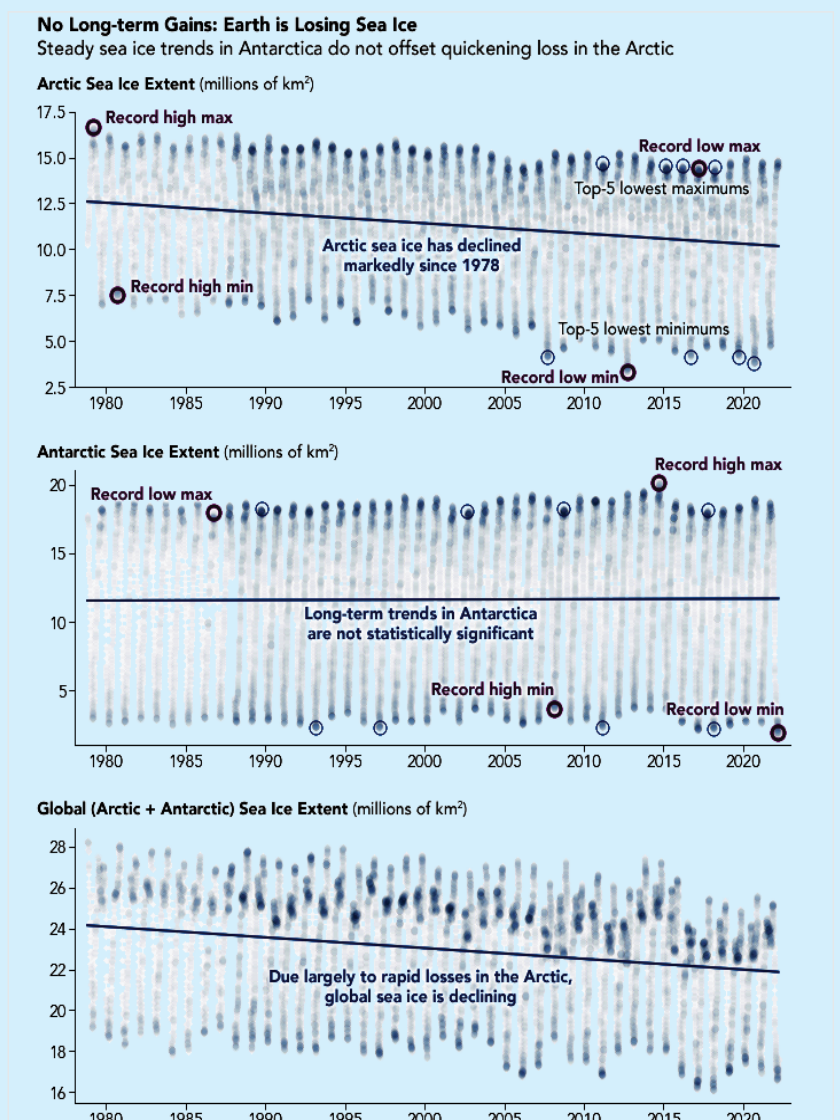


Figure 3 - Antarctic Sea Ice Trends

Flooding in Eastern Australia

NASA Earth Observatory

Story by Sara E. Pratt

Just over three months into 2022, Sydney, Australia, has already received a year's worth of rain. The deluge brought more flooding to the already rain-soaked southern and central coasts of New South Wales, prompting evacuations.

On April 7, torrential downpours brought a month's worth of precipitation—more than 100 millimetres—to parts of the city. The storm pushed rain gauges past 1,223 millimetres, already, in early April, 10 millimetres above the annual mean.

The excessive rain began in late 2021 with the rainiest November on record. It continued with more rain and flooding in February and March 2022. On March 9, Australia declared a national emergency.

The ground was saturated and rivers were swollen when the Operational Land Imager-2 (OLI-2) on Landsat 9 acquired these images on April 4, 2022. The ongoing impacts of flooding can be seen in the muddy rivers, inundated land, and sediment plumes draining from rivers along the coast.

Near the top of figure 1, north of Newcastle, a large lobe of brown floodwater has inundated the Hunter Wetlands. A plume of sediment can also be seen discharging from the mouth of the Hunter River and flowing along the beach in Worimi National Park. Sydney and its harbour can be seen at the bottom left of the image. North of Sydney are the brown, sediment-laden waters of the Hawkesbury River, which are seen in more detail in figure 2, on the following page.

The Hawkesbury River originates to the west, where the Colo and

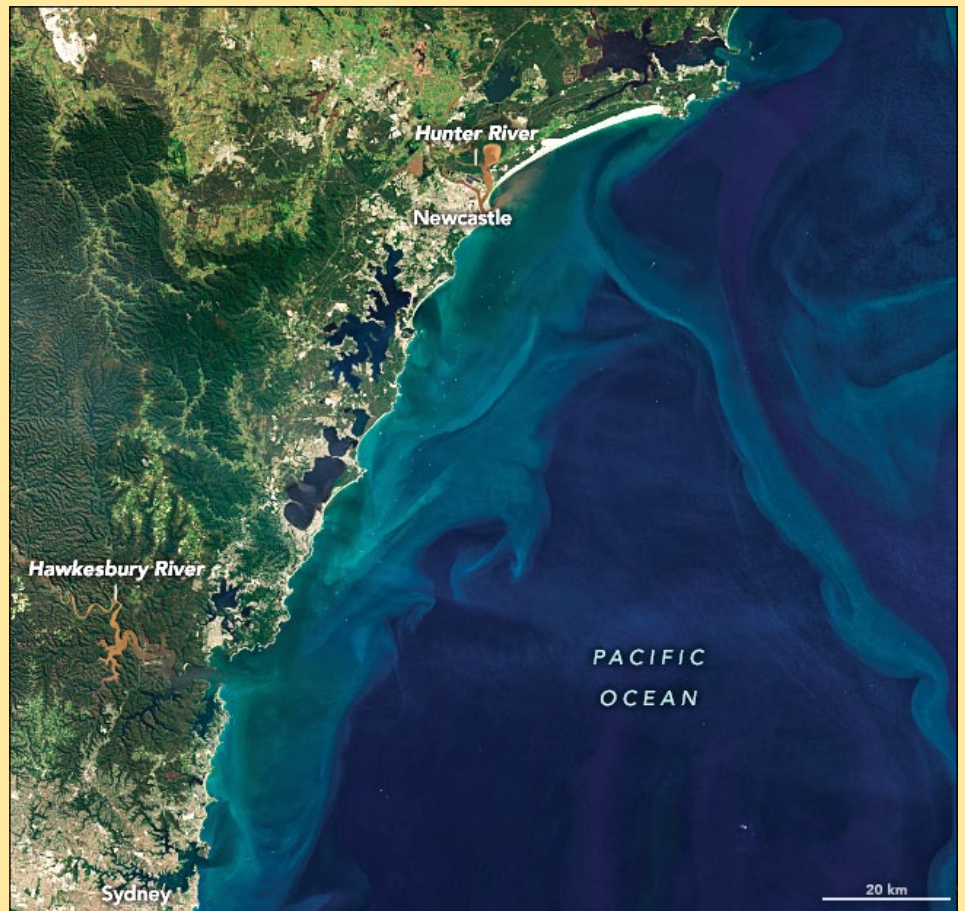


Figure 1 - Landsat-9 image showing flooding from Newcastle to Sydney
NASA Earth Observatory image by Joshua Stevens
using Landsat data from the U.S. Geological Survey

Nepean rivers join. Areas of the Hawkesbury-Nepean Valley were some of the hardest hit in the March 2022 floods, which left thousands of homes damaged and uninhabitable.

Several climate systems influence Australia's weather. The El Niño Southern Oscillation (ENSO), a coupled atmospheric and ocean circulation pattern in the tropical Pacific, is currently in its La Niña phase, which typically brings more rain and cooler temperatures to eastern Australia. The Southern Annular Mode (SAM) describes the north or south movement of strong westerly winds in the Southern Hemisphere. With the winds farther south, the SAM has recently been in a positive phase, which increases rainfall in

eastern Australia in the summer. The interaction of the two climate modes exacerbates the amount of moisture in the atmosphere available for precipitation, according to research by team at Australian National University, CSIRO, and the University of New South Wales.

The extreme precipitation in the summer of 2021–22 comes after a three-decade period when southeastern Australia had seen an overall decline in rainfall, according to Australia's Bureau of Meteorology. However, the distribution of rainfall throughout the year has also changed, with summer rains intensifying, winter rains decreasing, and the intensity of short-duration, heavy rainfall increasing.



Figure 2 - This Landsat-9 image shows the sediment-laden waters of the Hawkesbury River meandering their way towards the ocean north of Sydney
NASA Earth Observatory image by Joshua Stevens using Landsat data from the U.S. Geological Survey

Meteor M N2 Attitude Problem

Les Hamilton

On May 5 this year, followers of the Russian **Meteor M N2** oceanographic satellite started to observe seriously distorted imagery. It was clear that the satellite, instead of pointing directly downward towards Earth's surface, was presenting angled views that included Earth's limb framed by the blackness of space.

It was apparent that the satellite was experiencing attitude control problems, and the skewed pointing started to show the Earth's limb as in the AHRPT image opposite, obtained on May 9 by Enrico Gobbetti.

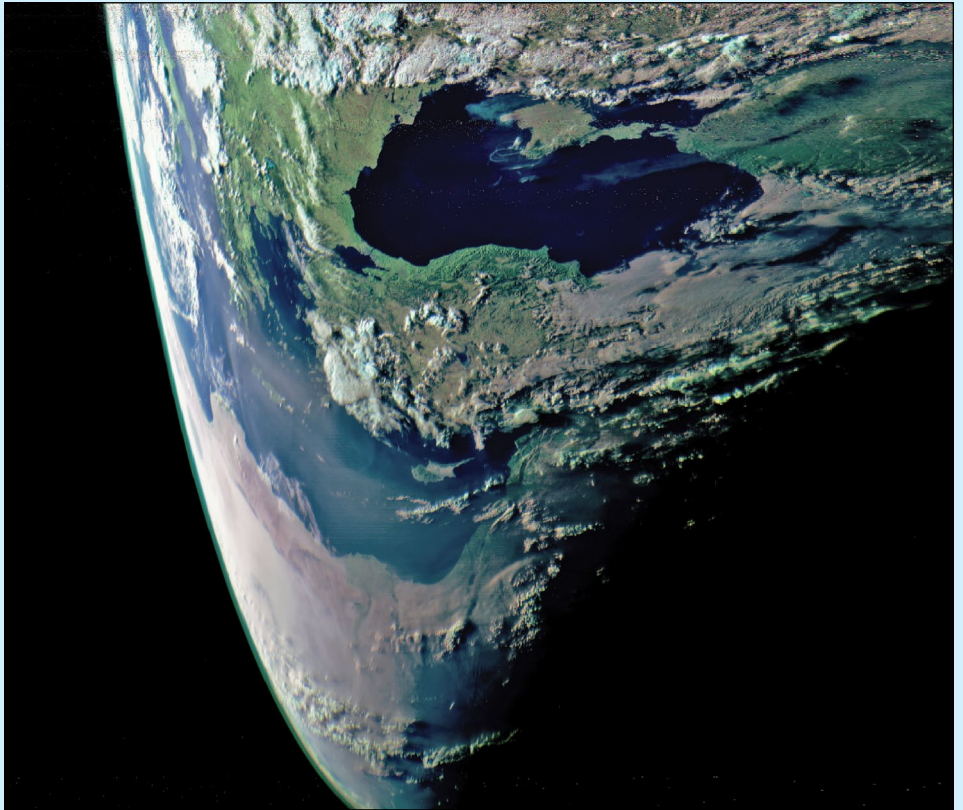
Two days into the problem, the LRPT data stream was discontinued, although readers like Enrico, who have the equipment to receive Meteor's high resolution AHRPT data continued to view images such as the one on the front cover of this issue, which was received two days later and another on May 13 (overleaf).

This was by no means an unfamiliar scenario: such behaviour had been recorded several times previously, but the satellite's attitude had always been rectified within just a few days: but not this time.

Meteor M N2 was launched in July 2014 with a projected lifetime of five years, which implies that it is now operating almost three years beyond that. With the launch failure of Meteor M N2-1, the accident to Meteor M N2-2, and the delayed launches of Meteors M N2-3 and M N2-4, the ageing satellite is clearly now starting to struggle.

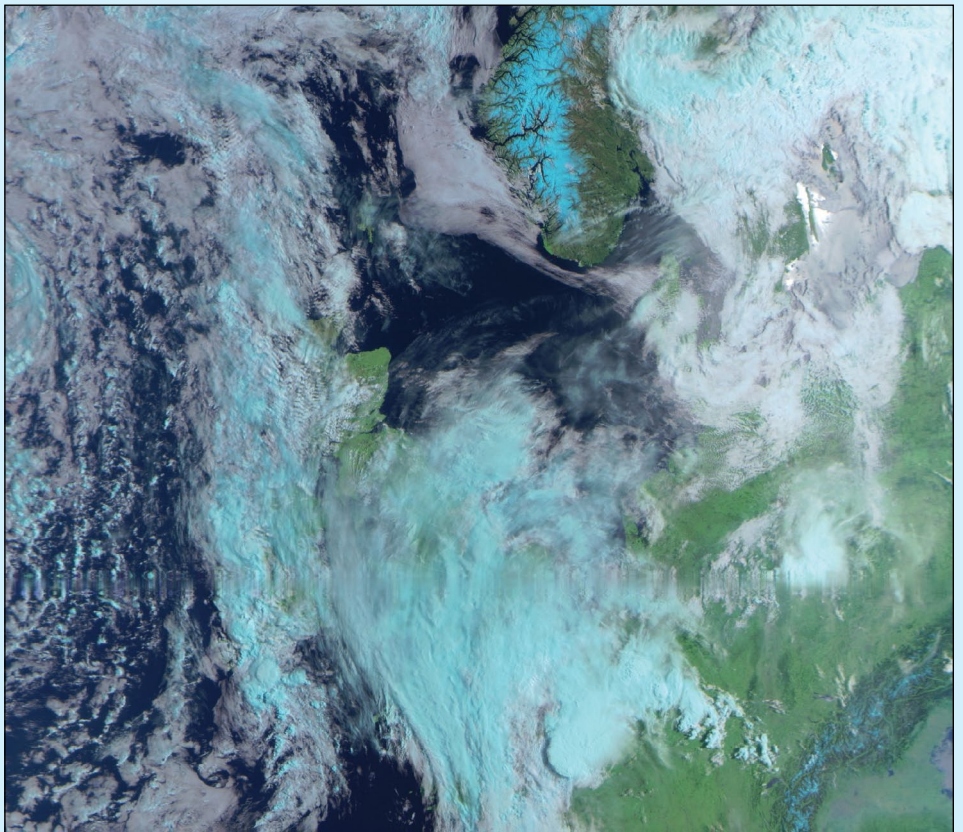
As the days turned into weeks, many observers were fearing the worst, and that the LRPT could not be restored—until, fifteen days later, on May 20, Meteor came to life again.

There are still no definite dates for the delayed Meteors to launch. Just maybe this latest unfortunate episode may hasten the launch of Meteor M N2-3. But don't hold your breath.

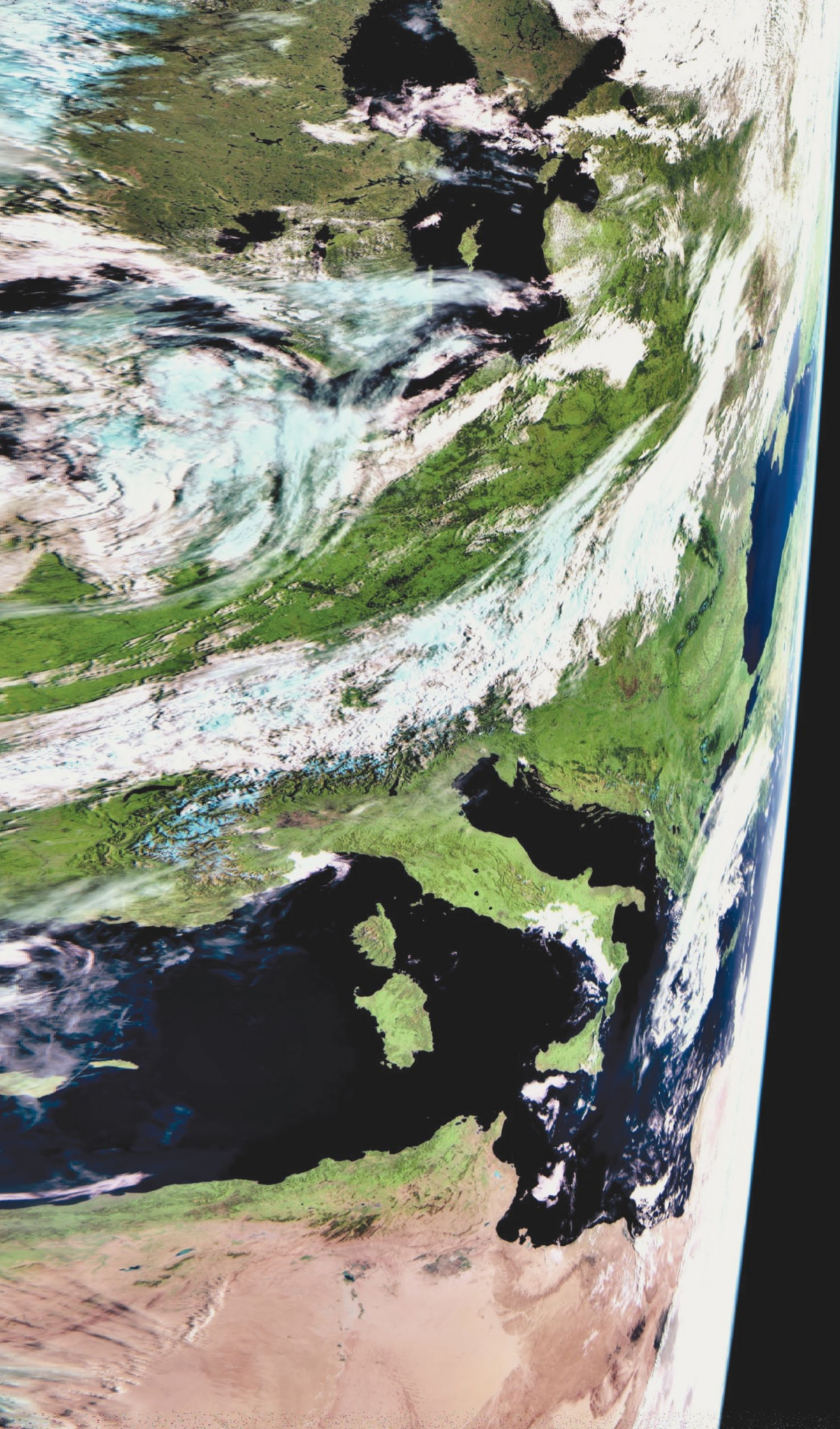


In this high resolution AHRPT image from Meteor M N2 on May 9, 2022, a distorted Mediterranean sea snakes round the exposed limb of Earth.

Image: Enrico Gobbetti



Taken from the 07:29 UT pass on May 20, 2022, this is a section from the first cohesive LRPT image received from Meteor M N2 following its recovery.



This high resolution AHRPT image from Meteor M N2 dates from May 13, 2022 and still shows distortion due to the satellite's loss of attitude control. The Earth's limb is prominent at the right of the image, with the Black Sea in particular, hugely distended.
Image: Enrico Gobbetti

Great Barrier Reef

MODIS Web Image of the Day

When viewed from space, Australia's Great Barrier Reef appears to be a string of precious gems strung across the Coral Sea just off the Queensland coast. When viewed from Earth, the uniqueness of this precious ecosystem becomes even more obvious. According to the United Nations Education, Science and Cultural Organization (UNESCO) World Heritage Convention, the Great Barrier Reef is a site of remarkable variety and beauty. It contains the world's largest collection of coral reefs, with 400 types of coral, 1,500 species of fish, and 4,000 types of mollusc. It also holds great scientific interest as the habitat of species such as the dugong ('sea cow') and the large green turtle, which are threatened with extinction. Because the diversity of species and habitats and their unique interconnectivity make the Great Barrier Reef one of the richest and most complex natural ecosystems on Earth, this natural wonder was inscribed on the World Heritage List in October 1981.

Despite the fact that no other World Heritage property contains such biodiversity, the Great Barrier Reef is in trouble. In early March 2022, sea temperatures across the reef spiked, creating heatwave conditions. On April 1, the Australian Government's *Great Barrier Reef Marine Park Authority* confirmed that these warm temperatures had created a mass bleaching event of the reef, with bleaching observed at multiple reefs in all four management areas of the Reef. This was considered to be largely consistent with the spatial distribution of the heat stress experienced over summer. This is the fourth time in six years that the Great Barrier Reef has been impacted by bleaching, and it the first time it has occurred during La Niña conditions. Typically, La Niña brings cooler temperatures to local waters.

Bleaching is a stress response by coral and does not necessarily mean that the coral has died. Corals have a symbiotic relationship with



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

a type of microscopic alga known as zooxanthellae. The colourful zooxanthellae live within the coral, providing oxygen and helping the coral to remove wastes. In turn, the coral provides the algae with a protected environment and the compounds they need for photosynthesis. The zooxanthellae also provide the glorious colours that we associate with coral. When coral become stressed—most often by a rise in ocean temperature of as little as 1°C—the corals expel the algae, exposing the pale white 'skeleton' of the coral. This bleaching isn't immediately fatal to the coral, but it weakens them, opening them to disease, starvation, and death. If conditions return to normal and the symbiotic relationship is repaired, coral may recover from a bleaching event.

The *Great Barrier Reef Marine Park's* website stated on April 1 that water temperatures had cooled since early March but noted that most of the Marine Park was continuing to experience the effects of significant heat stress. Localised weather patterns will remain critical in determining the overall extent

and severity of coral bleaching. The website also noted that the Reef Authority is now working with its partners to conduct in-water surveys to complement aerial surveys of the reef. This will provide more detailed information about bleaching intensity, mortality and depth range of bleaching impacts.

On March 31, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-colour image of the Great Barrier Reef. The reef remains sparkling with blue tones throughout the length visible in this image.

The MODIS instrument is useful for measuring Sea Surface Temperatures (SSTs), which are correlated with coral bleaching events, but true-colour images do not usually show substantial colour changes in bleaching events, as coral sits underneath water and thus reflectivity may not change substantially. Currently, airplane flights or inspection by diving are more sensitive for estimating the amount of bleaching on any given coral reef than most satellites.

Yukon-Kuskokwim in Colorful Transition

NASA EarthObservatory

Story by Kathryn Hansen

The Yukon-Kuskokwim Delta is one of the world's largest deltas, and it stands as a remarkable example of how water and ice can shape the land. This image shows the delta's northern lobe, where the Yukon River spills into the Bering Sea along the west coast of Alaska.

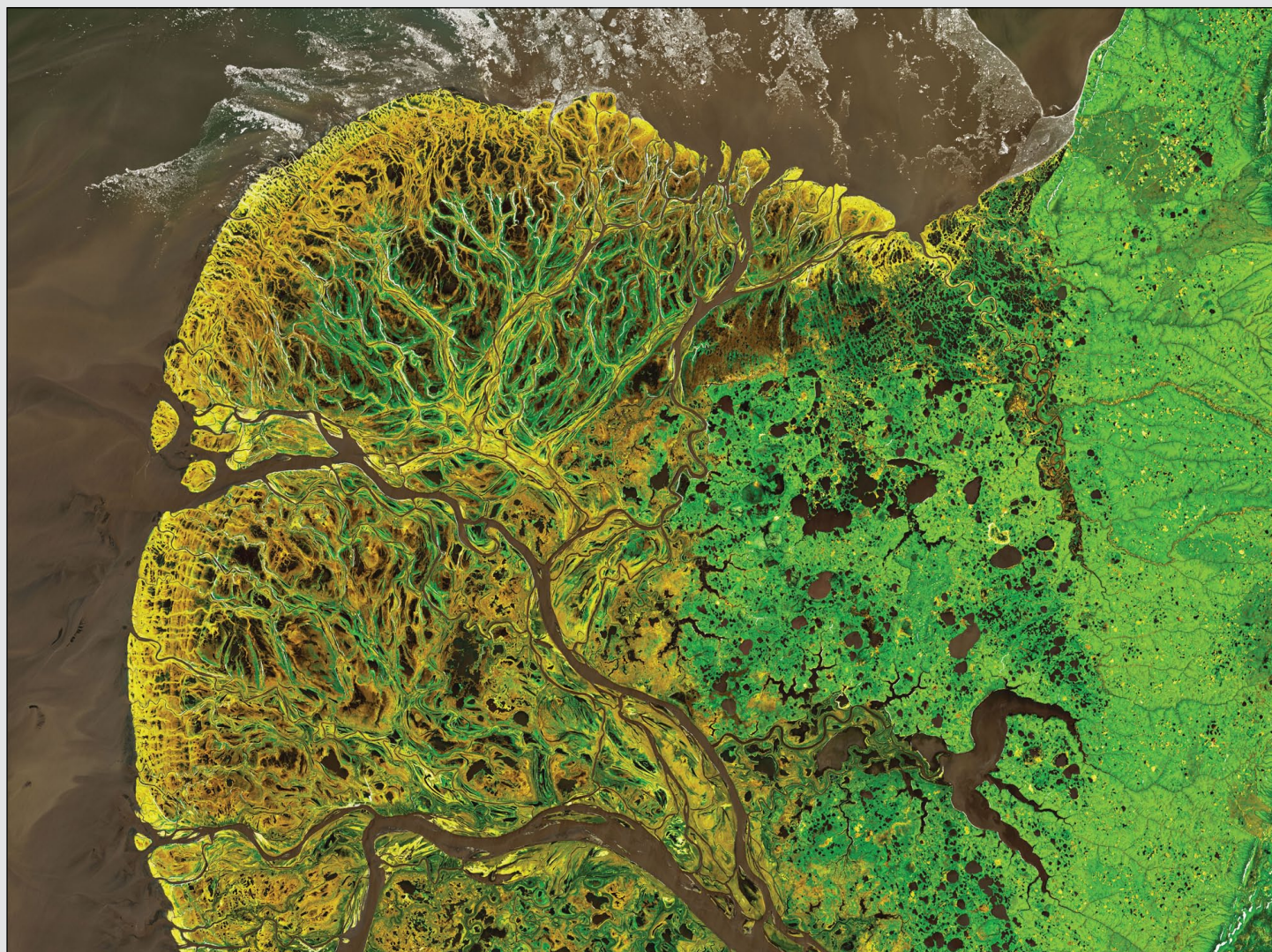


Figure 1 - Landsat-8 captured this image of the delta of the Yukon River on May 29, 2021
NASA Earth Observatory image by Joshua Stevens, using Landsat data from the U.S. Geological Survey.

The Yukon Delta is an exceptionally vivid landscape, whether viewed from the ground, from the air, or from low-Earth orbit. The vivid landscape is captured in figure 1, acquired with the Operational Land Imager (OLI) on Landsat 8 on May 29, 2021. The image is a composite, blending the natural-colour imagery of water with false-colour image of the land.

While the image could be considered a work of art, there are some useful aspects to looking at the land in this way. For example, you can easily distinguish areas of live vegetation (green) from land that is bare or contains dead vegetation (light brown) from the network of sediment-rich rivers and ponded flood water (dark brown). A sprinkling of thermokarst lakes are also part of the scene.

In general, the green areas across the delta are tall willow shrublands. They are especially apparent on either side of the river channels in the detailed image above. The light-brown areas are primarily moist sedge meadows which appear brown because much of it is the dead remains of last year's growth. Away from the delta (right side of the image) the vegetation is shrub-tussock tundra.

'To me, one of the interesting things about the delta is that it is a highly transitional area, with some elements of Arctic tundra and some of boreal forest,' said Gerald Frost, a scientist at ABR, Inc.—Environmental Research and Services in Fairbanks, Alaska.

The delta also transitions with the seasons. At the time

of this image, the signature of spring flooding is written across the delta. Melting snow and ice cause the rivers to spill over their banks and by late May, many of the marshes are filled with floodwater, which appears as dark-brown ponds.

According to Lawrence Vulis, a graduate student at the University of California, Irvine, the delta would have appeared much more inundated immediately following the melting of snow and ice a few weeks prior to this image. Stream gauges and satellite images suggest that the bulk of the flooding had already subsided. Still, the flooding was recent enough that plenty ponding remained on May 29. As summer advances, the floodwater will continue to recede and the wetlands will continue to green up with vegetation.

Also notice the colourful water where the delta meets the Bering Sea. This is a product of glacial runoff far upstream, which carries a large amount of sediment toward the coast. This sediment is also instrumental to the formation of tall levees on the sides of the channels, deposited there when floodwaters spill over their banks. These levees support stands of tall willows—important habitat for moose.

‘Interestingly, tall shrubs have expanded a lot on the delta in recent decades, and the moose have followed,’ Frost said. ‘Today, the delta has one of the highest moose densities in the state of Alaska.’

The delta did not always look this way. Studies have shown that the modern Yukon Delta is just a few thousand years old. It’s young age “is incredible to think about,” Vulis said. “We are used to thinking about relatively ancient landscapes, but modern river deltas have only formed in the last 10,000 to 8,000 years since global sea level has stabilised.”

The delta could quite possibly look different in the future. ‘The Yukon and other Arctic deltas are thought to be particularly vulnerable to climate change,’ Vulis noted, ‘due to the roles of permafrost and ice in shaping these deltas.’

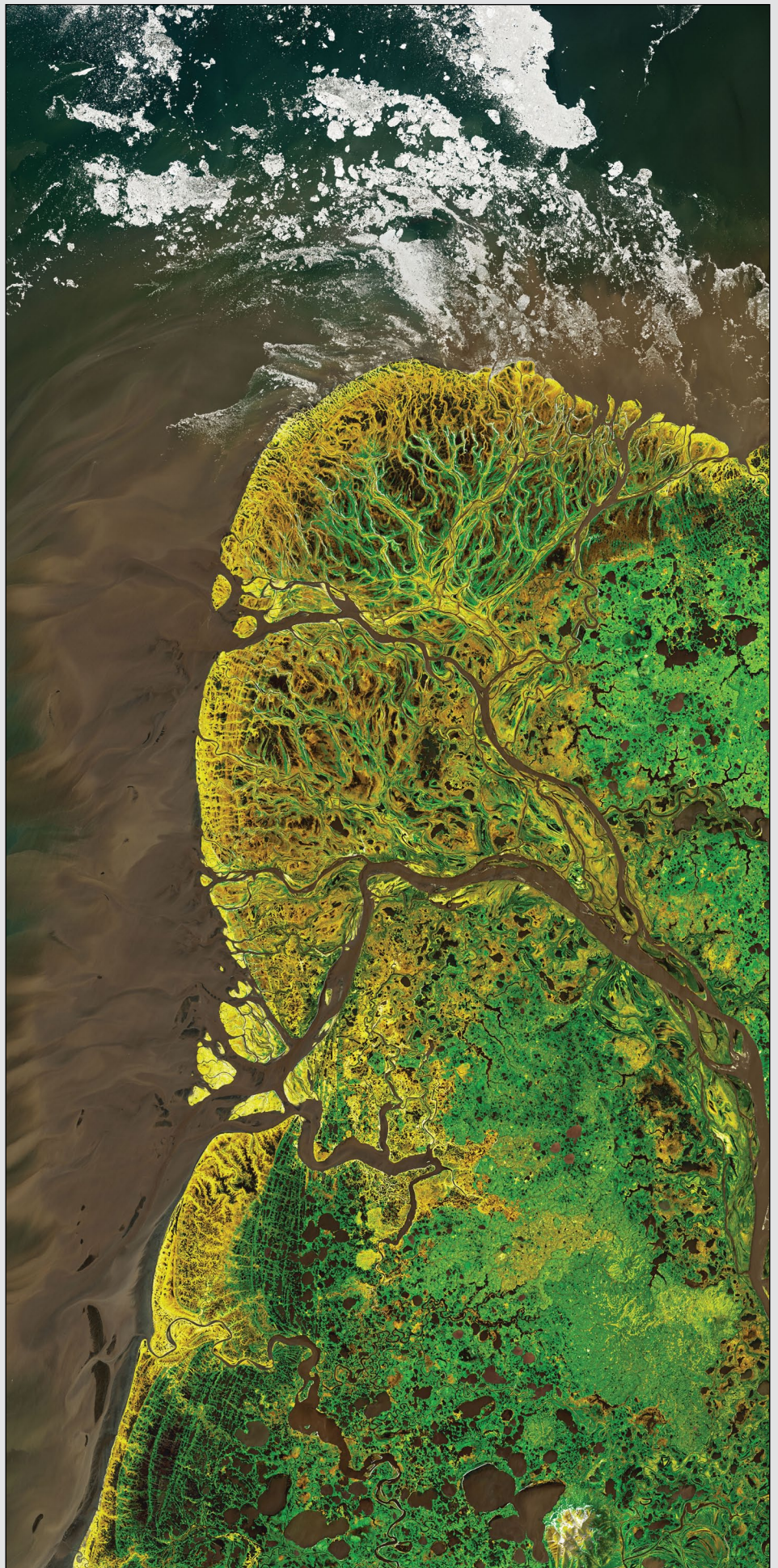


Figure 2 - A wider view showing the Yukon River making its way towards the Bering Sea
NASA Earth Observatory image by Joshua Stevens
using Landsat data from the U.S. Geological Survey.

Visualising EUMETCast SAF Products using the VISAN Tool

Richard Osborne

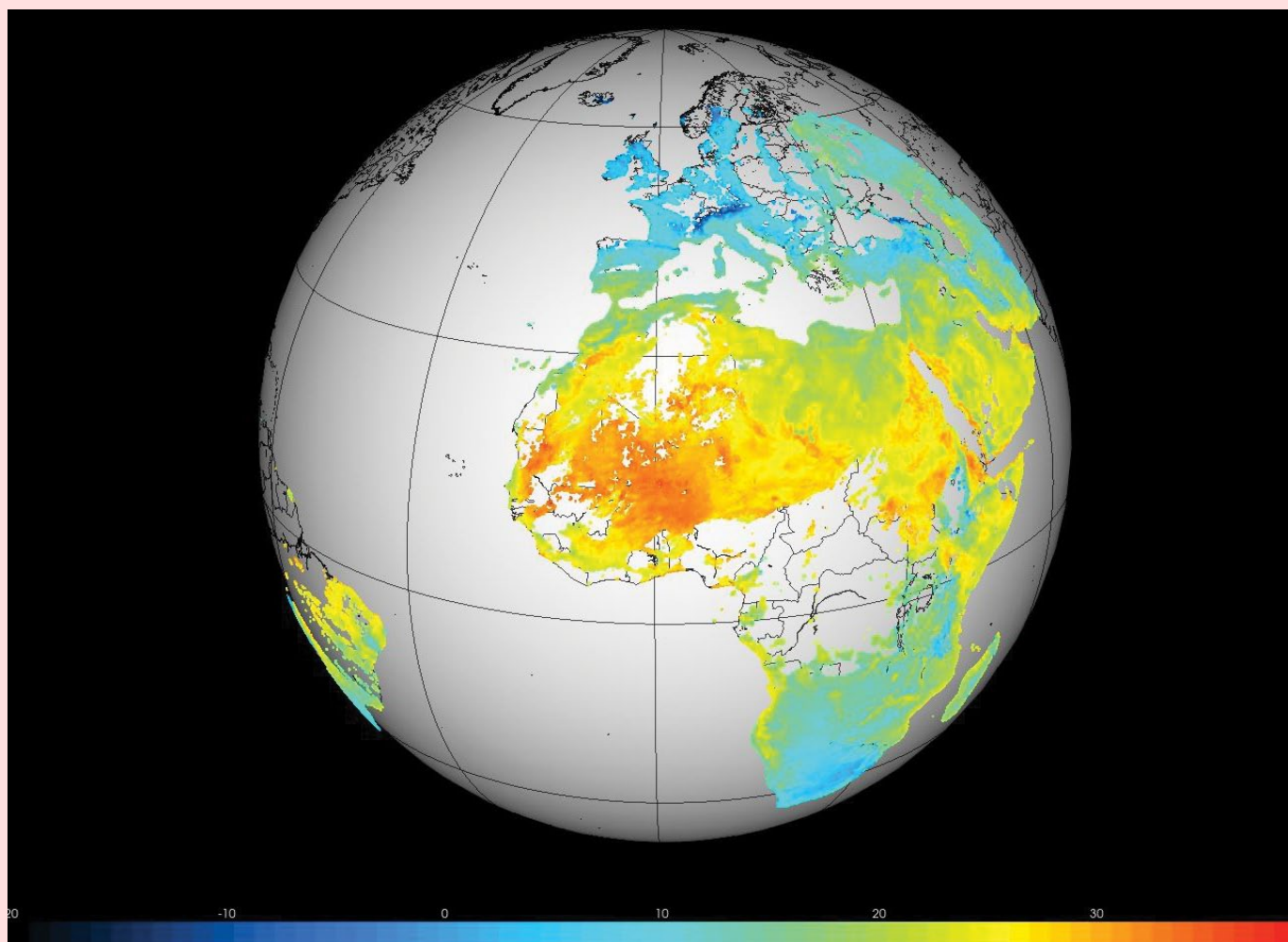


Figure 1 - VISAN 3D Globe image of LSA Land Surface Temperature derived from LST data over EUMETCast and co-ordinates from LSA website.

In the recent thread on “NWC ‘Cloud Types’ on EUMETCast” in the MSG-1 Groups website, Ernst Lobsiger has alluded to my article on visualising SAF data in Geo Newsletter No 72. Since submitting the piece, I have continued to look for visualisation tools and methods that I may have missed since that time. Recently, I came upon the Atmospheric Toolbox

<https://atmospherictoolbox.org>

that provides tools for ingesting, processing, and analysing atmospheric remote sensing data. This includes data from Sentinel-5P and the GOME-2 instrument on MetOp.

The component of particular interest to me is called VISAN which is the graphical front-end visualisation tool for the toolbox. VISAN can display data on a number of common 2D map projections and also a 3D globe. The graphical visualisation element is fully interactive with the ability to zoom and pan under mouse control and also to rotate the 3D globe. Preparation of data and launching of the graphical element is done through a *Python* driven command line interface from a special VISAN development environment. Note that VISAN can only be installed as a

CONDA environment and *Python* scripts must be launched within the dedicated VISAN environment. This is because VISAN is built on *wxPython* which is not present in the normal *Python* environment.

Whilst the VISAN visualisation tool is primarily intended to interact with another component of the toolbox called HARP, it can also be supplied with low level data from any source provided that it is in the correct format and this is the feature that is of particular interest to me. The data needs to be supplied as three separate one dimensional (1D) *Python Numpy* arrays containing the data to be visualised along with corresponding latitude and longitude coordinates for each data point or pixel. In case this sounds like a daunting task, I found it surprisingly easy to extract the required data in the correct format using *Python* from both netCDF and HDF5 files that contained full geo-referencing data. Also, in my article, I mentioned the Land Surface data for the MSG full disk contained no geo-referencing information and this needed to be supplied in some form to allow the data to be projected onto a map. The LSA website provides HDF5 files with the necessary co-ordinate data. I was able to easily convert this into the

required latitude and longitude *Numpy* arrays which I submitted with the data in a *Numpy* array allowing me to visualise the data on the 3D globe. An example output of the Land Surface Temperature is shown in Figure 1.

The NWC Cloud Type data file contains a reduced set of geo-location data and the end-user is expected to extrapolate between those to provide a complete set, so that each pixel has a unique latitude and longitude co-ordinate. VISAN cannot accept this data as it needs full geo-referencing. However, the NWCSAF readers in *Satpy* provide this function allowing a complete geo-referenced image to be produced as shown in the MSG-1 Groups thread. By inserting only ten lines of extra *Python* code into the *Satpy* NWC Cloud Type script, I was able to produced three *Numpy* arrays with which to feed the VISAN tool. The result is shown in

Figure 2. The colours are not correct because I still have work to do to produce the correct colour lookup table for the Cloud Type products but the image gives the idea. Management of the colour table is under-developed at present but I have had a short discussion with the author and I am hopeful of improvement.

I am hoping to experiment with VISAN and *Python* in combining certain files from the HSAF facility because the the current file structure can cause unwanted artifacts with *Panoply*, *McIDAS-V* etc. Incidentally, the VISAN installation also has a simple browser that can be used to investigate the data structure and values of any netCDF or HDF5 file which is useful in identifying the name of variables of interest.

P.S. For more information, please post a request on the MSG-1 Groups website.

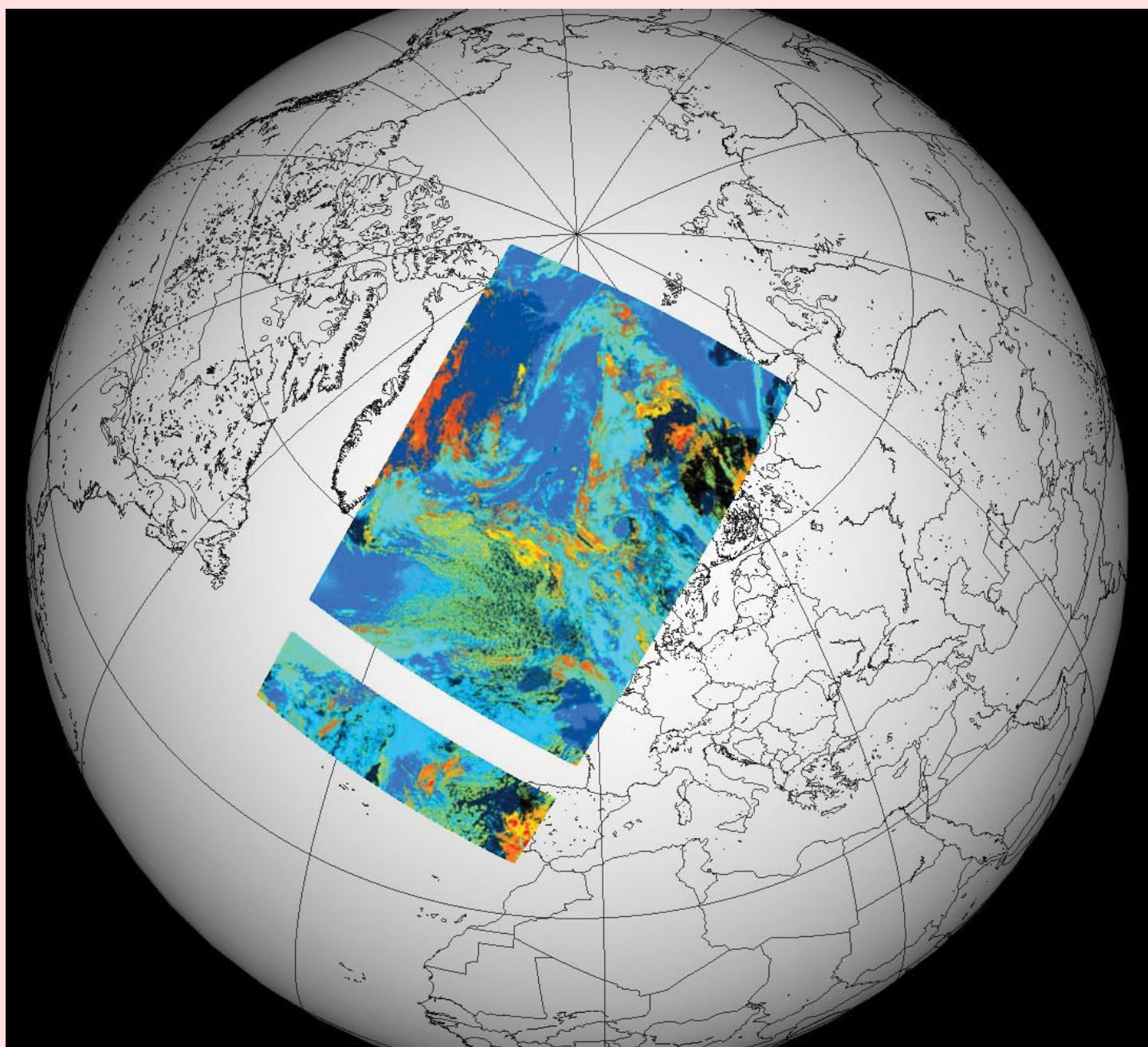


Figure 2 - VISAN 3D Globe image of NWC Cloud Type from METOP-B derived from data provided by Satpy script (experimental so colours are incorrect).

Lake Mead Drops to a Record Low

NASA Earth Observatory

Story by Michael Carlowicz and Kathryn Hansen

Lake Mead is the largest reservoir in the United States and part of a system that supplies water to at least 40 million people across seven states and northern Mexico. It stands today at its lowest level since Franklin Delano Roosevelt was president. This means less water will be portioned out to some states in the 2022 water year.

As of August 22, 2021, Lake Mead was filled to just 35% of its capacity. This low water level comes at a time when 95% of the land in nine Western states is affected by some level of drought (64% is extreme or worse). It continues a 22-year megadrought that may be the region's worst dry spell in twelve centuries.

The natural-colour images on these pages were acquired by NASA's Landsat-7 and Landsat-8 satellites in August 2000 and most recently in August 2021. The tan fringes along the shoreline in 2021 (figure 2) are areas of the lake bed that would have been underwater when the reservoir was filled closer to capacity. The phenomenon is often referred to as a 'bathtub ring'.

The lake elevation data in figure 3, below, come from the *US Bureau of Reclamation*, which manages Lake Mead, Lake Powell, and other portions of the Colorado River watershed. At the end of July 2021, the water elevation at the Hoover Dam was 325.4 metres above sea level, its lowest since April 1937 at a time when the lake was still being filled. The elevation at the end of July 2000, around the time of the Landsat-7 image in figure 1, was 365.8 metres.

At maximum capacity, Lake Mead reaches an elevation 372 metres near the dam and would hold 36 cubic kilometres of water. The lake last approached full capacity



Figure 1 - Lake Mead on August 7, 2000
NASA Earth Observatory images by Lauren Dauphin, using
Landsat data from the U.S. Geological Survey



Figure 2 - Lake Mead on August 9, 2021
NASA Earth Observatory images by Lauren Dauphin, using
Landsat data from the U.S. Geological Survey

in the summers of 1983 and 1999. It has been dropping ever since.

In most years, about 10% of the water in the lake comes from local precipitation and groundwater, with the rest coming from snowmelt in the Rocky Mountains that flows down to rivers, travelling through Lake Powell, Glen Canyon and the Grand Canyon on the way. The Colorado River basin is managed to provide water to millions of people—most notably the cities of San Diego, Las Vegas, Phoenix, and Los Angeles—and also to approximately five million acres of farmland in the Southwest. The river is allotted to states and to Mexico through laws like the 1922 *Colorado River Compact* and by a recent drought contingency plan announced in 2019.

With the Lake Mead reservoir at 35% of capacity, Lake Powell at 31%, and the entire Lower Colorado system at 40%, the *Bureau of Reclamation* announced on August 16 that water allocations would be cut over the next year.

“The Upper [Colorado] Basin experienced an exceptionally dry spring in 2021, with April to July runoff into Lake Powell totalling just 26% of average despite near-average snowfall last winter,” the USBR statement said. “Given ongoing historic drought and low runoff conditions in the Colorado River Basin, downstream releases from Glen Canyon Dam and Hoover Dam will be reduced in 2022 due to declining reservoir levels. In the Lower Basin the reductions represent the first ‘shortage’ declaration—demonstrating the severity of the drought and low reservoir conditions.”

For the 2022 water year, which begins on October 1, Mexico will receive 80,000 fewer acre-feet, approximately 5% of the country’s annual allotment and Nevada’s take will be cut by 21,000 acre-feet (about 7% of the state’s

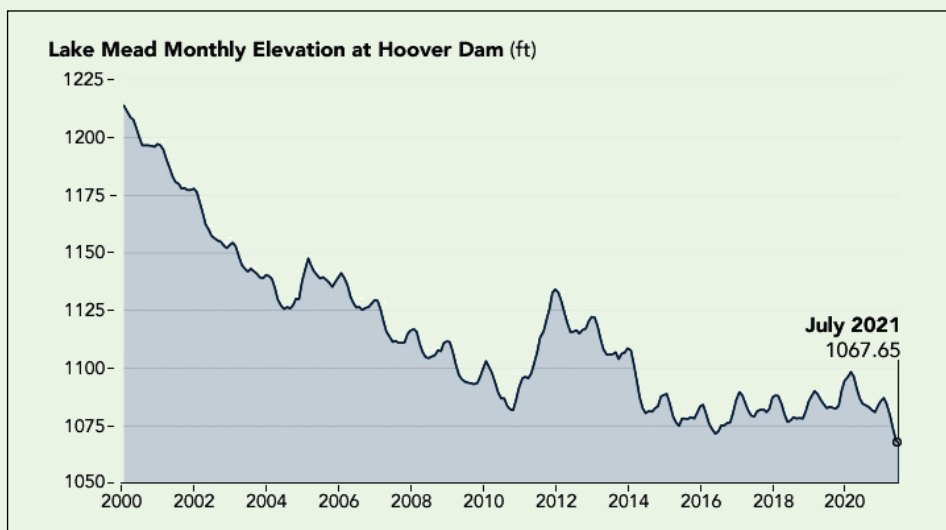


Figure 3 - Lake Mead water level - 2000 to 2021
Credit: Geological Survey and lake elevation data from the Bureau of Reclamation.

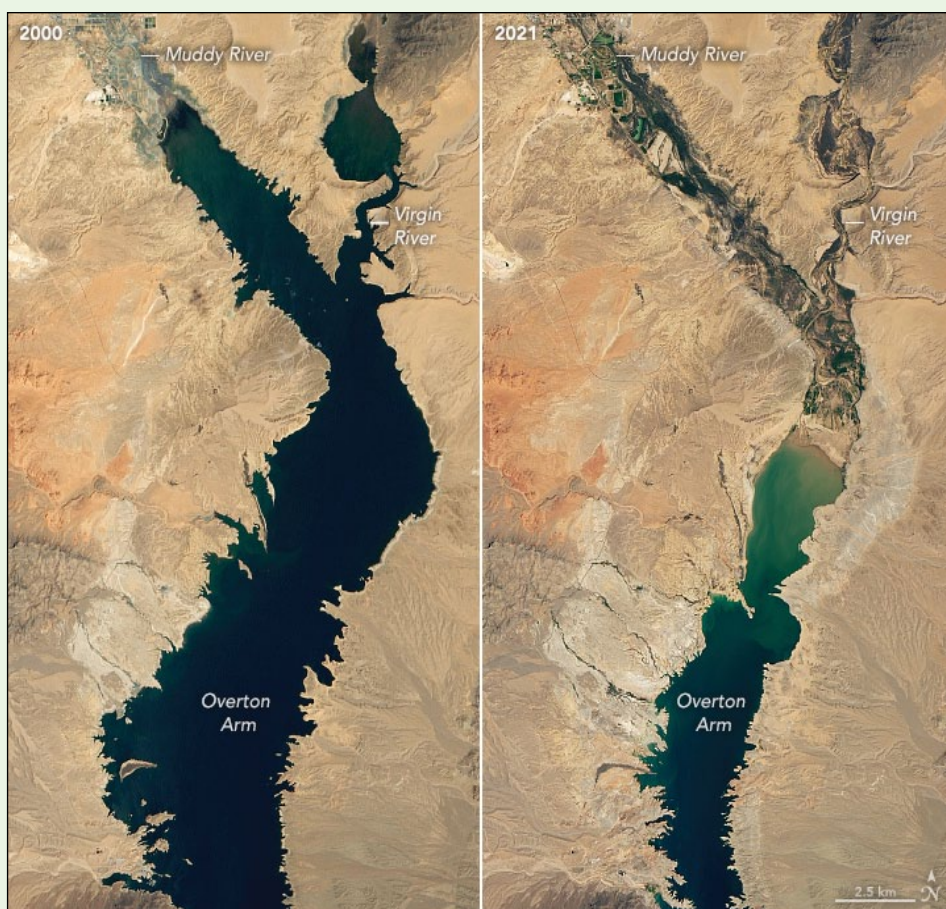


Figure 4 - These zoomed image segments compares the changes in water level in the Overton Arm of Lake Mead between 2000 (left) and 2021.
Credit: NASA Earth Observatory images by Lauren Dauphin using Landsat data from the U.S. Geological Survey

annual apportionment). The biggest cuts will come to Arizona, which will receive 512,000 fewer acre-feet, approximately 18% of the state’s annual apportionment and 8% of the state’s total water use (for agriculture and human consumption).

Note

One acre-foot is equivalent to 1.233 million litres and would be sufficient water to supply one or two households with their water needs during an entire year.

Sediment in the Caspian Sea

MODIS-Web Image of the Day



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

The Caspian Sea wins the prize for being the largest closed body of water on Earth, with a volume estimate at about 78,000 cubic kilometres and spanning a surface area of roughly 380,000 square kilometres: that's an area larger than the country of Germany.

The Caspian Sea is sometimes divided into three parts, ecologically speaking. In the north, the sea is shallow, with a mean depth of only about 10 metres, while the central sea deepens to 788 metres. The deepest part of the Caspian Sea reaches 1,025 metres in its southern section.

Despite the deep water, the southeastern Caspian Sea just off the coast of Turkmenistan hosts a wide area of marine shallows, where the mud-covered bottom lies under a layer of water

that remains less than 30 metres. This coastal shelf stretches 200 kilometres from north to south and 120 kilometres from the shoreline into the sea. Beyond this shelf, the sea floor takes a deep plunge; however, the waters over the shelf are perpetually turbid as the ever-active wind stirs mud and sediment up from the shallows.

On May 23, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-colour image of brightly-coloured sediment in the Caspian Sea off of the coast of Turkmenistan. A small region of the coast of Iran is also visible at the bottom of the image. The gorgeous colour lies almost entirely over the shelf of marine shallows located in this section of the of the Caspian Sea.

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 | System failure ^[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 B | 1701.3 MHz | RHCP | AHRPT | Good |
| Metop C | 1701.3 MHz | RHCP | AHRPT | Good |
| 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 | Active ^[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 | 86.5°E | |
| 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 been compromised. AHRPT is still being transmitted when the solar panels are sunlit, but there is insufficient battery power to enable the LRPT stream..