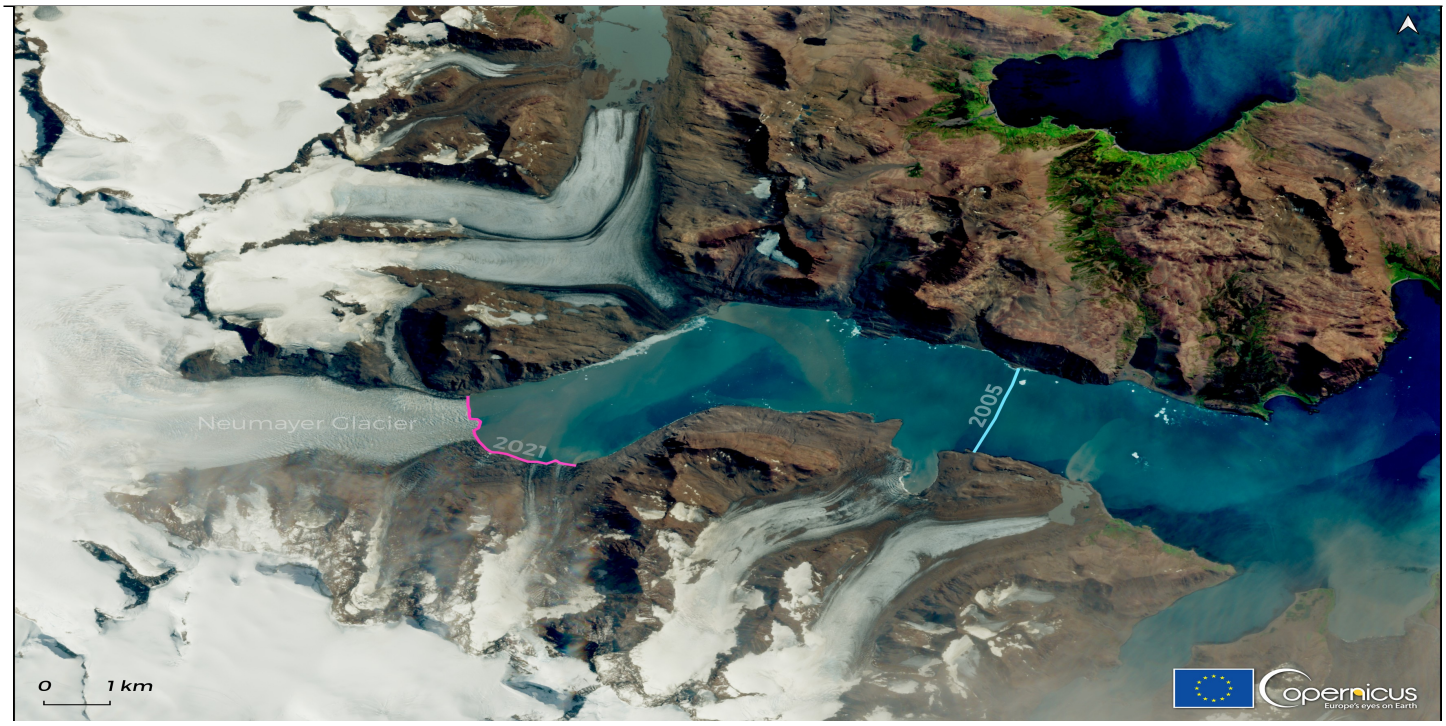
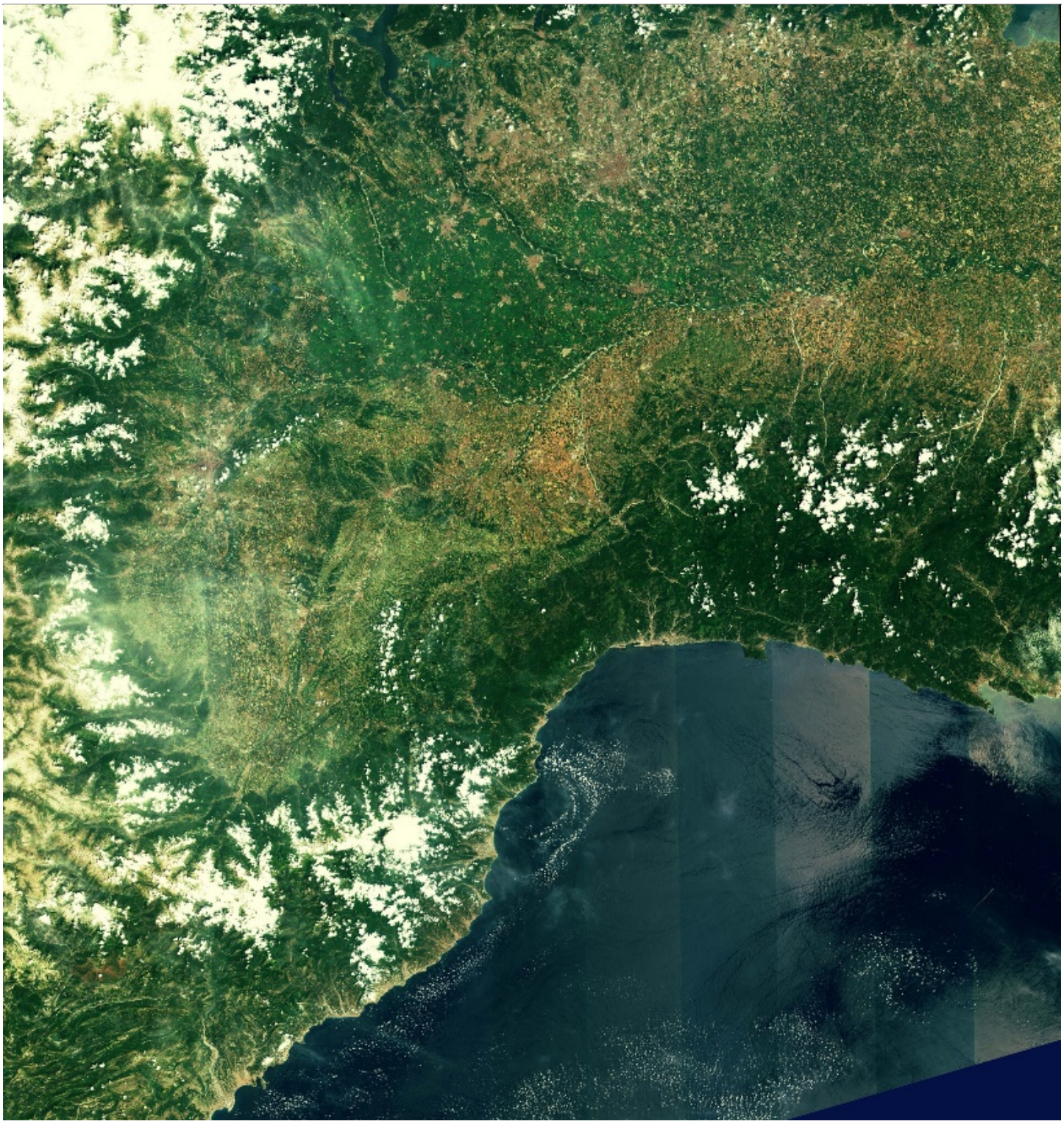
OBSERVER: Celebrating nine years of Copernicus Sentinel-2A



On 23 June 2015, the first Copernicus Sentinel-2 satellite was launched. It was the second Copernicus satellite sent to space, just a little over one year after the launch of Sentinel-1A. Copernicus' first 'colour-vision' mission, Sentinel-2, aimed to improve our capabilities in monitoring land and vegetation cover as well as crop growth, tracking changes in agricultural practices, managing forests, and supporting disaster relief efforts by mapping floods and burned areas. In this week's Observer, we take a close look at Sentinel-2 and celebrate its important contribution to the understanding of our planet.

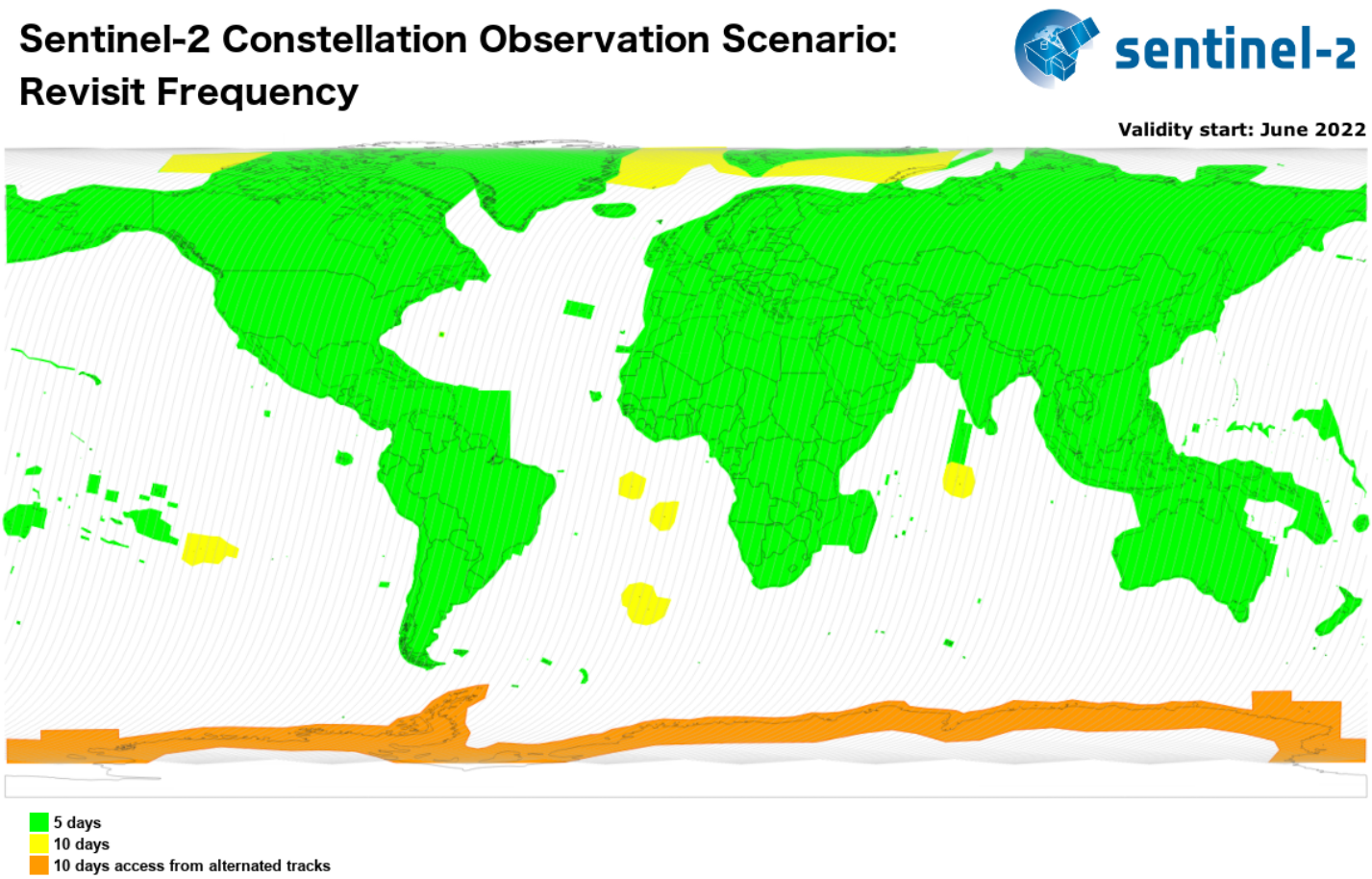
With a swath width of 290 km, Sentinel-2 allows any part of Earth's surface to be revisited at minimum every five days. Nine years ago, the first swath of data from the mission was received shortly after launch and recorded a long strip spanning from the Baltic Sea into the African Sahara. After processing this data, the resulting image showed remarkable detail over the Po Valley, framed by the Alps in the north and the coastal mountains of France and Italy in the south, quickly demonstrating the high resolution and level of detail expected from the mission. Such a wide swath and frequent revisit time, along with the high spatial resolution and advanced multispectral imaging capabilities, has enabled users to see changes in vegetation health and growth with unprecedented accuracy.



The first Sentinel-2 image captured, showing the Po Valley, framed by the Alps in the north and the coastal mountains of France and Italy in the South. Credit: ESA

The Sentinel-2 satellite mission, instruments, and capabilities

The Sentinel-2 mission is composed of two identical satellites, Sentinel-2A and Sentinel-2B, which are phased 180° apart in the same sun-synchronous orbit to achieve a high revisit frequency of five days at the equator. This configuration ensures comprehensive and timely coverage of Earth's land surfaces, islands larger than a set threshold, and inland and coastal waters.



Map showing Sentinel-2 coverage and revisit time for MSI acquisitions. Credit: ESA

Each Sentinel-2 satellite carries a single payload, the Multi-Spectral Instrument (MSI). The MSI captures imagery in 13 spectral bands, including four bands at 10-metre resolution, six bands at 20-metre resolution and three bands at 60-metre resolution. This wide range of spectral bands, from the visible and near-infrared to the shortwave infrared, enables highly detailed land monitoring.

The MSI operates passively, collecting sunlight reflected from the Earth. As the satellite travels along its orbital path, the instrument acquires new data. The incoming light is split by a beam-splitter and directed onto two separate focal plane assemblies within the instrument: one for the Visible and Near-Infrared (VNIR) bands and the other for the Short Wave Infrared (SWIR) bands. The spectral separation of each band is achieved by stripe filters mounted on top of the detectors.

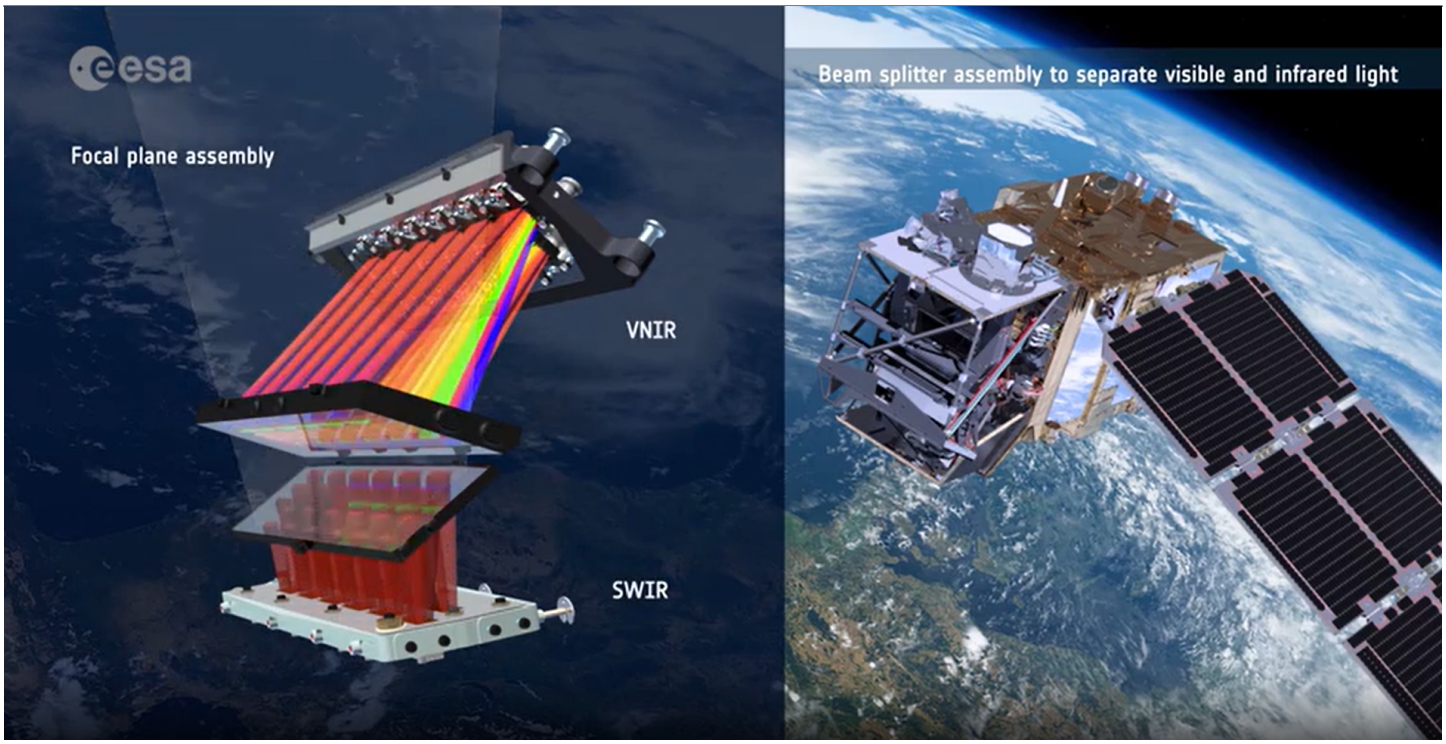


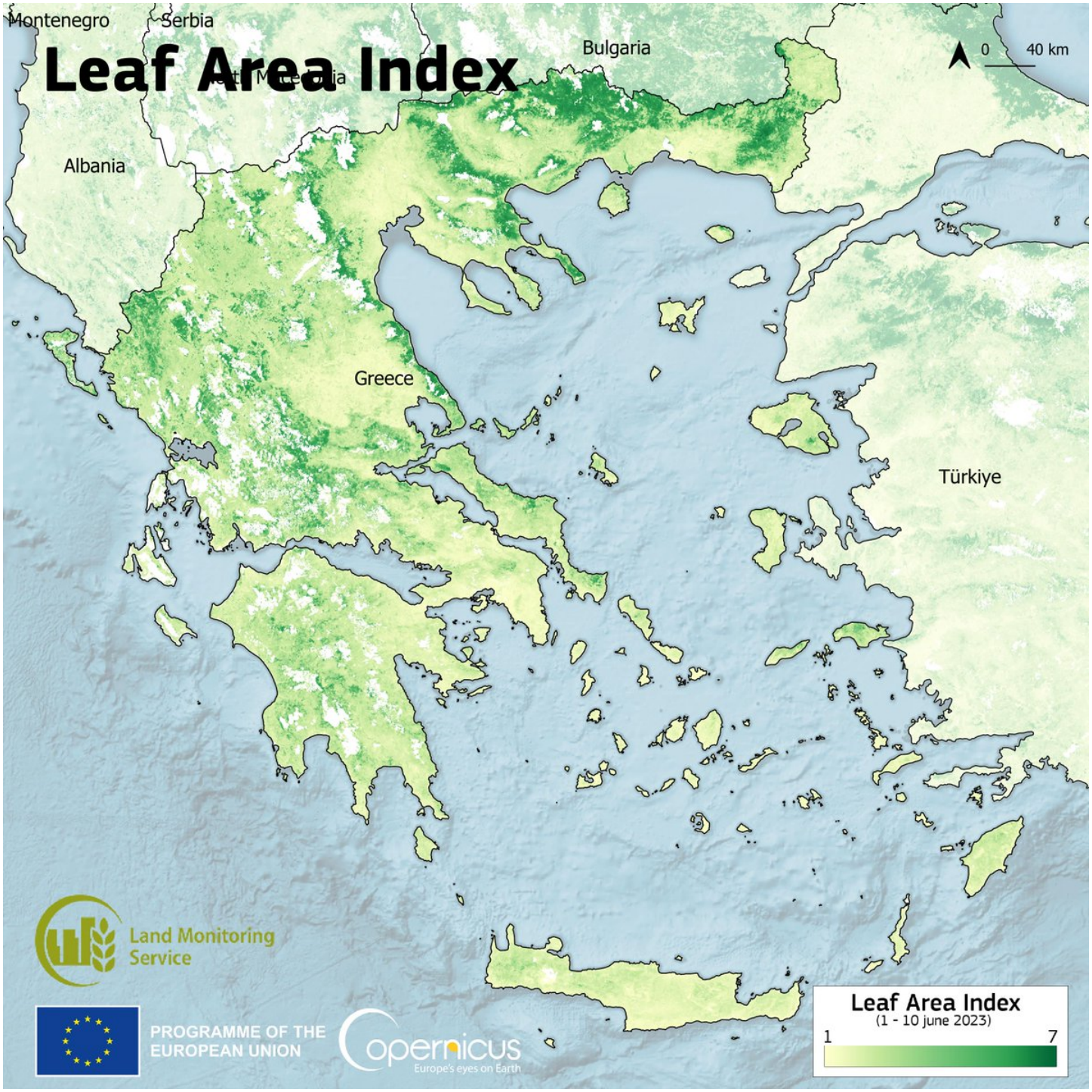
Illustration showing the separation of VNIR and SWIR bands in the MSI. Credit: ESA

Data acquisition by the MSI is extensive, with each satellite capable of storing and downloading up to 1.6 terabytes of raw data per orbit. The Sentinel-2 mission was originally planned for seven years but has the potential today to be extended up to a maximum of twelve years, depending on the depletion of on-board consumables. Each satellite carries 123 kilograms of propellant, including the amount needed for deorbiting manoeuvres at the end of its operational life.

Copernicus Sentinel-2 on land

Sentinel-2 data is extensively used by many Copernicus Services. With its systematic and frequent coverage, it makes a significant contribution to the Copernicus Land Monitoring Service (CLMS), providing input data for land cover change mapping supporting the assessment of bio-geophysical parameters of vegetation such as Leaf Area Index (LAI) and also those in new products like High Resolution Vegetation Phenology and Productivity (HR-VPP). Sentinel-2's imagery also feeds into the Dynamic Land Cover product, and Tree Cover Density, Dominant Leaf Type, and Forest Type products, offering insight into forest composition and health. These high-resolution datasets are instrumental for conservation efforts and policymaking. In particular, the data may support the implementation of the EU Regulation on Deforestation-free products, allowing for traders and food processing operators to perform first compliance checks with their suppliers to make sure that their commodities don't contribute to deforestation. Similarly, Sentinel-2 data is used in support of the Habitats Directive, with emerging services such as EU Grassland Watch leveraging CLMS products to support monitoring of protected grasslands to help conservation efforts on the ground. Finally, Sentinel-2 data also supports European Green Deal targets by enabling more sustainable farming practices, such as smart farming, which reduce the amounts of pesticides and fertilisers farmers use by allowing them to adjust their inputs based on crop health and soil condition. Startups

like Onesoil process Sentinel-2 and Sentinel-1 data using sophisticated AI algorithms to mark field boundaries, detect crop types, and determine the required amount of fertiliser to apply. Onesoil is just a single example, but there is an entire ecosystem of companies developing services for agriculture which use Sentinel-2 data.



Copernicus Land Monitoring Service Product based on Leaf Area Index (LAI) using Copernicus Sentinel-2 data. Credit: European Union, CLMS

Copernicus Sentinel-2 at sea

While Sentinel-2 was originally designed to focus on providing data over land, the mission has also proved its worth for the Copernicus Marine Service (CMEMS) and coastal monitoring. For example, Sentinel-2's high-resolution data is used in CMEMS ocean colour products which include information on total suspended solids and turbidity in coastal areas. The ocean colour products are important for downstream applications related to the implementation of environmental policies and sustainable management of coastal areas.

In 2018, Aurélie Shapiro from WWF Germany led a team on an expedition with WWF-Mozambique to create the first complete marine landscape map of the Quirimbas Archipelago using different data collection methods and Sentinel-2 satellite data. By processing Sentinel-2 imagery, the team was able to observe underwater ecosystems such as coral reefs, mangroves, and seagrasses. This information is crucial for the management of the Quirimbas National Park, a UNESCO Biosphere Reserve that supports a diverse marine life and the livelihoods of more than 100,000 local people. The use of Sentinel-2 data has enabled detailed, cloud-free mapping and monitoring of marine habitats, supporting sustainable fisheries management and zoning efforts.

Marine litter is also another area where Sentinel-2 can help, as highlighted by recent advancements by the European Commission's Joint Research Centre and an international team of researchers. By analysing a six-year historical series of 300,000 Sentinel-2 images of the Mediterranean Sea they were able to identify litter patches and create the most detailed map of litter pollution to date.

Copernicus Sentinel-2 in support of emergency management

The Copernicus Emergency Management Service (CEMS) uses Copernicus Sentinel-2 satellite data to provide rapid, reliable, and detailed geospatial information to support the management of disasters. Its European Forest Fire Information System (EFFIS) integrates Copernicus Sentinel-2 data at 20m spatial resolution for the detection and monitoring of wildfires, allowing the mapping of burnt areas and fire severity assessment.

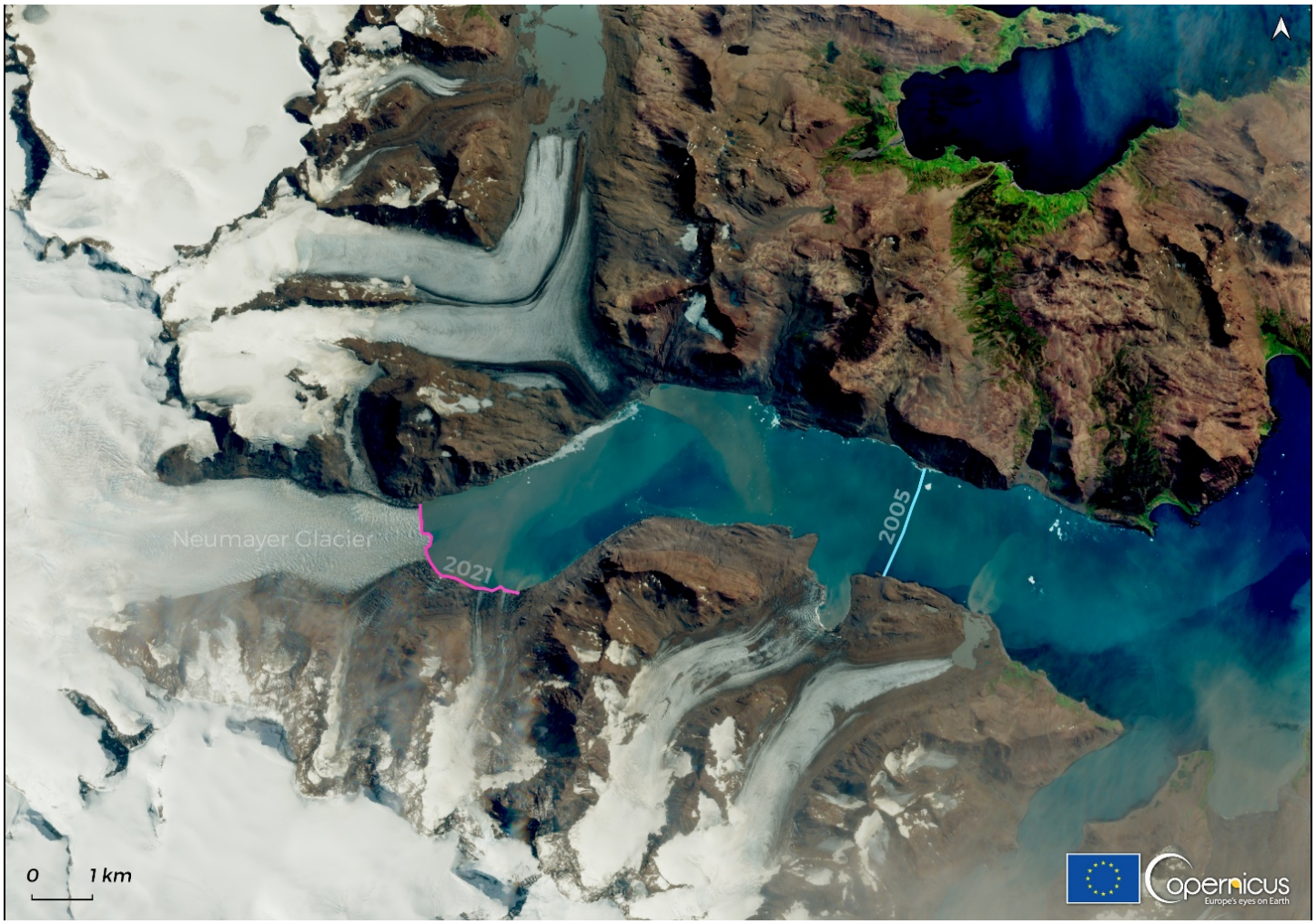
This data visualisation, based on a product from the Rapid Mapping module of the Copernicus Emergency Management Service, shows the extent of a serious fire in Mexico in April 2023. The image shows the 3rd delineation monitoring of the fire (9 April 2023) and was produced with Copernicus Sentinel-2 data. Credit: European Union, Copernicus Emergency Management Service

Supporting climate change monitoring and mitigation with Sentinel-2 data

Sentinel-2 can also help monitor ice and snow bodies around the world. CLMS has a range of High-Resolution Snow and Ice (HR-S&I) Monitoring Products, which include Fractional Snow Cover (FSC), River and Lake Ice Extent (RLIE), among others, which provide snow and ice information over European countries at high resolution (20 m x 20 m) and are derived from data delivered by the

Sentinel-2 mission.

Besides monitoring snow cover and lake ice and thanks to its stable sensing geometry and high resolution, Copernicus Sentinel-2 also helps monitor spatial changes of ice bodies such as glaciers over time. For example, Sentinel-2 can track the distribution of snow and the rate at which it melts or monitor the terminus where a glacier meets a lake or ocean, enabling an understanding of its dynamics over time. In this way, Sentinel-2 not only helps to understand how snow cover and glacier ice change over time, but is also useful to researchers studying how melting ice affects sea levels.



Sentinel-2 image from 22 January 2021, showing the status of the Neumayer Glacier, of the largest tidewater glaciers in South Georgia. Comparing the glacier terminus as seen in the 2021 Sentinel-2 image (line in magenta) with a Landsat-8 image acquired in April 2005 (line in cyan) shows that the glacier has shrunk by more than 8 km in 16 years.

Looking ahead

Although much has been achieved in almost a decade of Sentinel-2, there is still more to come. A growing number of researchers in academia and industry are using AI algorithms to process the massive data streams from the Copernicus satellites, including Sentinel-2, and new algorithms in the

pipeline will enable even more to be extracted from the mission's data.

Furthermore, the continuity of the mission in the coming years will be ensured by the launch of new Sentinel-2 satellites (Sentinel-2C and Sentinel-2D), which will take over from the first Sentinels-2A and 2B. Sentinel-2C is expected to be launched this year in September. Furthermore, the Copernicus Sentinel-2 Next Generation is in development and will support Copernicus Services related to land, coastal areas, climate change, emergency management, and security. With an expansion of Sentinel-2's ground segment and improved remote sensing capabilities, Sentinel-2 Next Generation will provide global measurements with higher accuracy.

As we reflect on nearly a decade of Sentinel-2's unique contribution, we celebrate its impact on our understanding of the planet and look forward to an exciting future with the next generation of Sentinel-2 satellites. Together, they will continue to inspire innovation and entrepreneurs, and provide invaluable information to help ensure a sustainable and resilient Earth for generations to come.