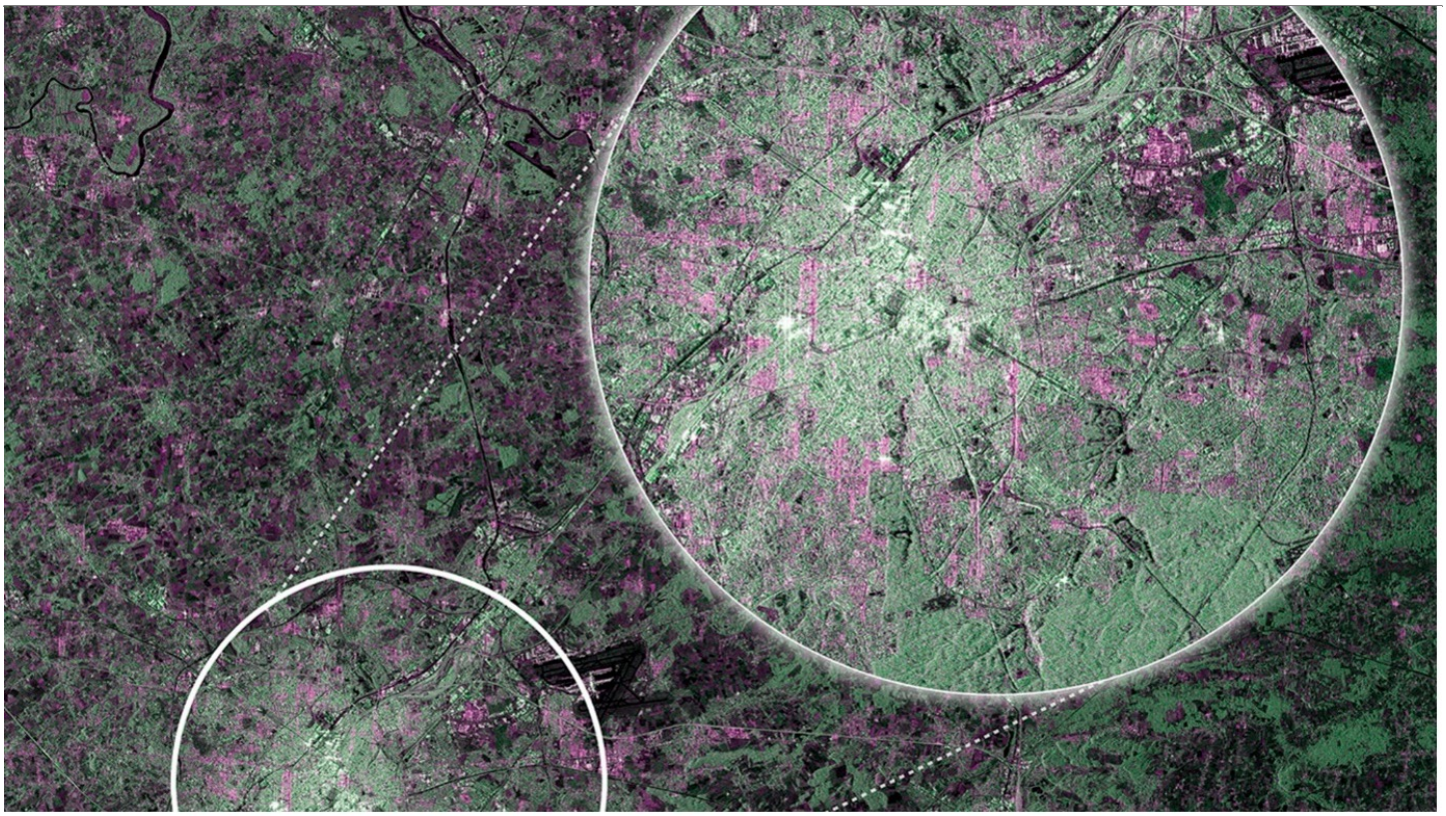
OBSERVER: Celebrating a Decade of Copernicus Sentinel-1

A decade after Sentinel-1A's launch on 3 April 2014, it continues to deliver large amounts of data to users each month. This mission, built on the legacy of pioneering European satellite missions like ERS and ENVISAT, has provided invaluable data across diverse applications—from ocean monitoring to disaster response, far exceeding initial expectations. Despite Sentinel-1B's retirement due to an electrical failure, the mission's legacy continues, with Sentinel-1A still operational and future satellites poised to replenish the constellation. In this week's Observer, we take a close look at Sentinel-1 and celebrate its important contribution to the understanding of our Earth.

Almost 10 years ago, on 12 April 2014, the first radar images of Earth were captured by Sentinel-1A, just nine days after its launch. The “first light” image below shows Brussels, Belgium and its surroundings. Its vibrant colours provided a tantalising glimpse into the imagery which this new mission would contribute to Europe’s ambitious new Earth Observation programme. Copernicus is now integrated into the larger EU Space Programme, and the data from Sentinel-1 satellites have become an important part of many global efforts to understand and address some of the most pressing environmental challenges of our time.

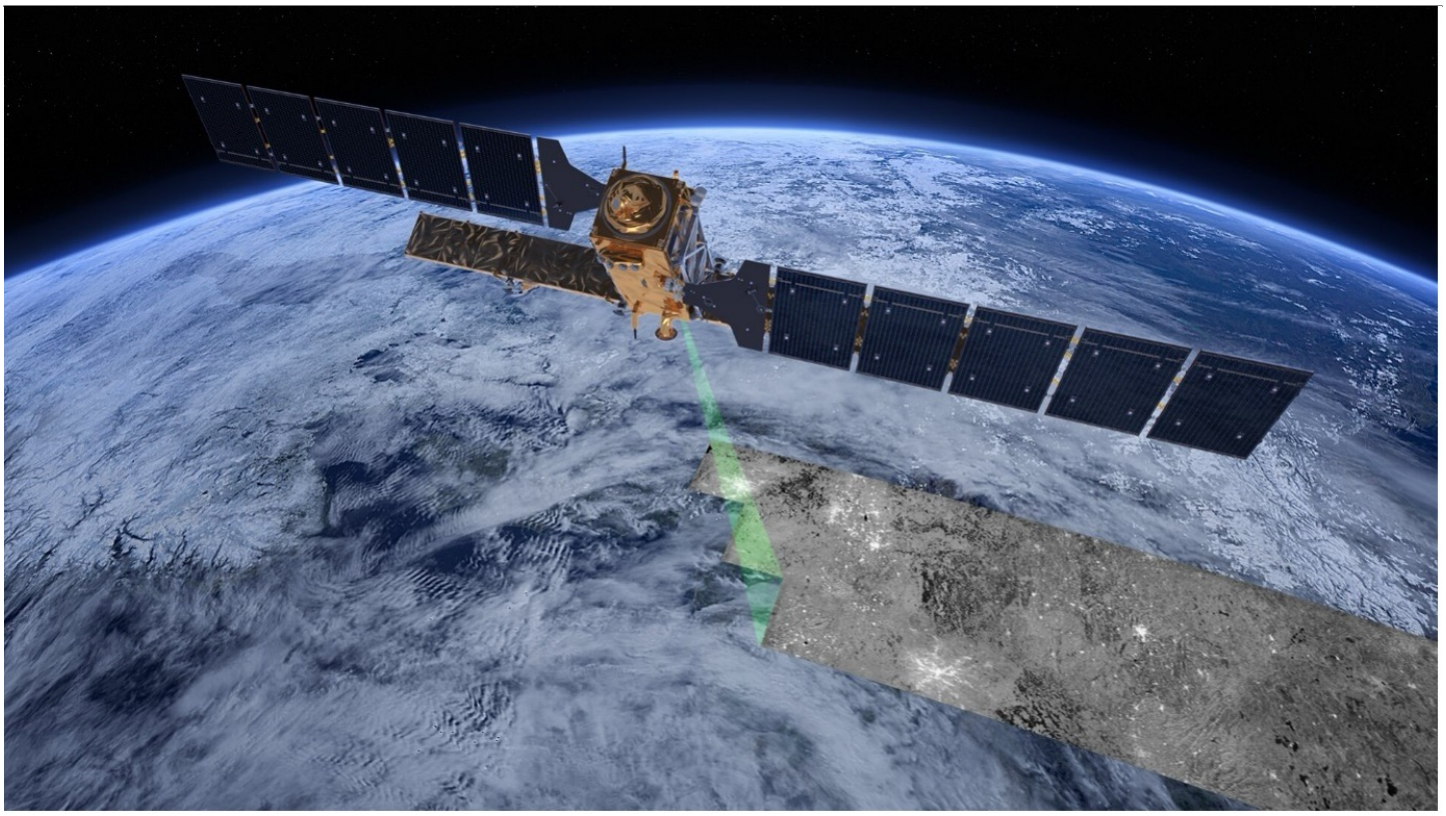


This so-called “first-light image” of Brussels was the first image taken by Sentinel-1A on 12 April, 2014, just nine days after its launch. Credit: European Union, Copernicus Sentinel-1 imagery

The Sentinel-1 satellite mission, instruments, and capabilities

Europe has a long history of radar Earth Observation satellites that stretches back to the 90s. The first were the European Remote Sensing (ERS) satellites ERS-1 and ERS-2, launched in 1991 and 1995 respectively. These satellites were the first radar-equipped satellites designed in Europe specifically for environmental monitoring. Prior to the ERS missions, radar satellite technology had primarily been exploited by the United States and the Soviet Union during the Cold War era, focusing on military and reconnaissance applications. This transition towards scientific and non-military use marked a significant shift in the application of radar satellite technology and set a new standard for Earth Observation. After the ERS mission would come ENVISAT, launched in 2002, adding new capabilities with its Advanced Synthetic Aperture Radar (ASAR) sensor.

Sentinel-1 represents the next evolution of Europe's radar-equipped satellites, building upon the foundations of its precursors. The mission is designed as a two-satellite constellation, initially made up of Sentinel-1A and Sentinel-1B. The satellites orbit in a Sun-synchronous, near-polar (98.18° inclination) orbit, ensuring a consistent long-term data archive. Each satellite is equipped with a C-band synthetic-aperture radar (SAR) instrument which operates in four modes and provides a spatial resolution down to 5 metres and a swath of up to 410 km. The SAR instrument allows for data collection in all weather conditions, including through cloud cover, as well as at night.
Although Sentinel-1B was retired on August 3, 2020 due to an electrical failure, Sentinel-1A remains fully operational, and has far exceeded its life expectancy of 7 years. Even when one of its solar panels was damaged by a collision with a millimetre-sized particle of space debris in 2016, this was not enough to affect Sentinel-1A’s routine operations.



The Copernicus Sentinel-1 satellite features an advanced synthetic aperture radar, providing detailed imagery for marine applications, including the surveillance of shipping lanes, sea ice, icebergs, and oil spills, as well as supporting the monitoring of land cover changes, ground deformation, ice shelves, and glaciers. Additionally, its data supports emergency response to disasters like floods and humanitarian relief efforts during crises. Credit: ESA/ATG medialab

Use cases

The capabilities of the radar instrument on the Sentinel-1 satellites make them able to support a wide variety of applications such as monitoring the oceans, including shipping lanes, sea ice, and oil spills; mapping changing land cover, ground deformation, ice shelves, and glaciers; and supporting emergency response to disasters like floods and humanitarian relief efforts during crises.

Monitoring of oceans and ice

Sentinel-1's radar data is important for the Copernicus Marine Service (CMEMS), providing essential information regarding the state and dynamics of coastal zones. These applications not only help protect and manage the marine environment and its resources but also aim to keep vessels safe at sea. Radar images from Sentinel-1 generate timely maps of sea-ice conditions for safe passage in increasingly busy Arctic waters, distinguishing between thinner, more navigable first-year ice and the dangerous, much thicker multiyear ice. This capability is particularly suited to generating high-resolution ice charts, monitoring icebergs, and forecasting ice conditions. Additionally, data from Sentinel-1 can be used to track the paths of oil slicks and other pollutants, contributing to environmental protection and maritime safety. Users can now easily access relevant derived information products using the viewers in the new Copernicus Arctic and Coastal Hubs.

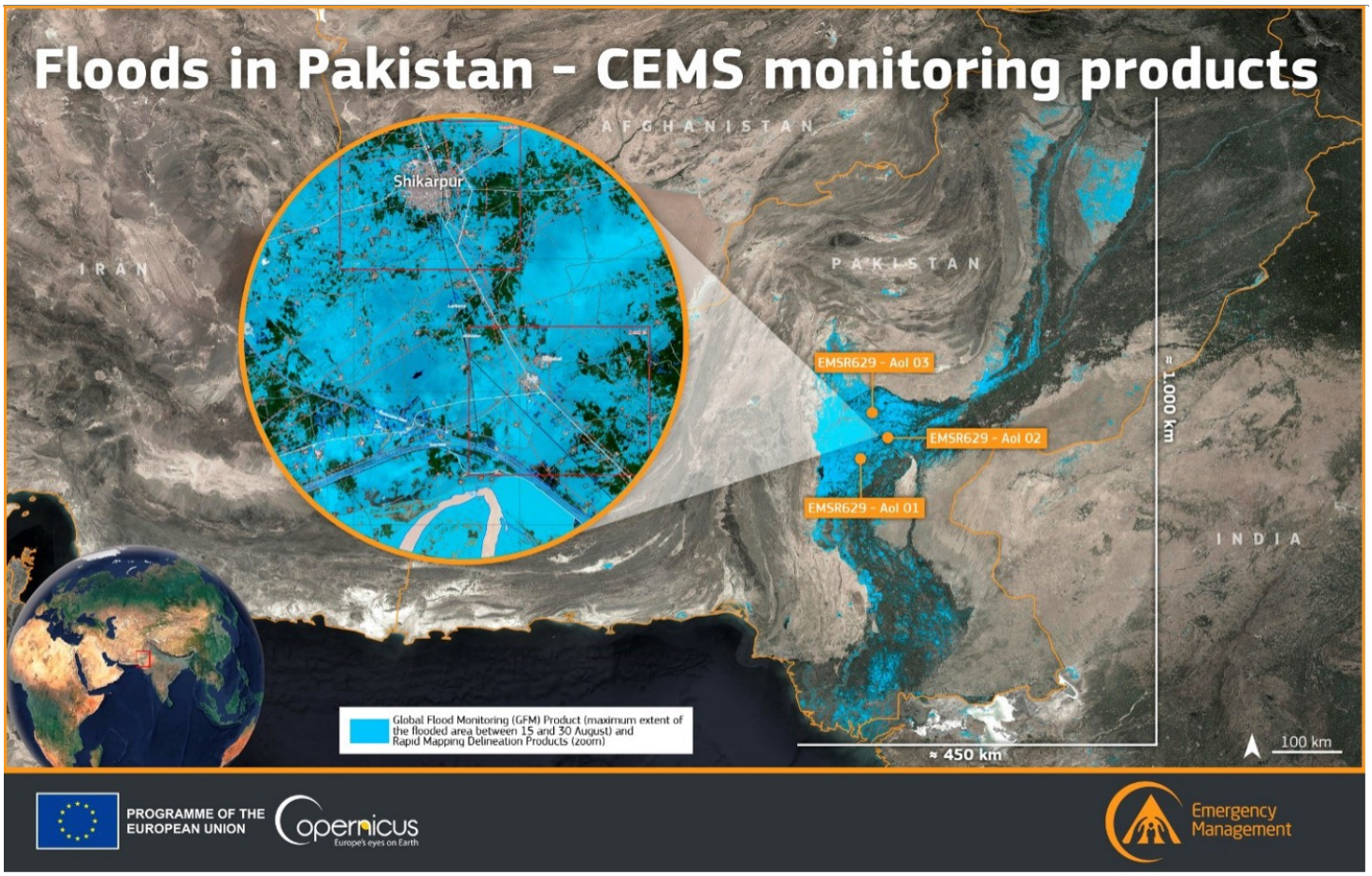
Monitoring land changes

The Sentinel-1 satellite mission has opened up new possibilities for many land applications. The

satellites' frequent revisits over the same area allow for the close monitoring of land changes, which is particularly useful in applications related to agriculture, forest management, and ground motion analysis. The Copernicus Land Monitoring Service (CLMS) provides a wide range of products based on Sentinel-1 data, including land cover and land use maps, vegetation monitoring, soil moisture, and water resource monitoring. Products such as Soil Moisture Index are relevant for agriculture as they can be used to make informed decisions about water usage to optimise crop health and productivity. For forest monitoring and management, numerous products based on Sentinel-1 data are available. These products facilitate the detection of clear-cut and partial-cut areas, forest type classification, biomass estimation, and disturbance detection, supporting deforestation monitoring in Europe and beyond. For ground motion analysis, the European Ground Motion Service (EGMS), part of CLMS, uses Sentinel-1 Interferometric SAR (InSAR) data to monitor ground motion with millimetre accuracy, allowing authorities to keep an eye on the structural integrity of infrastructure such as dams, bridges, railways, and buildings effectively. It also supports urban planning by providing data-driven insights into the likelihood of natural hazards such as landslides or subsidence, enabling informed decisions about where to build new infrastructure.

Support to emergency and disaster response

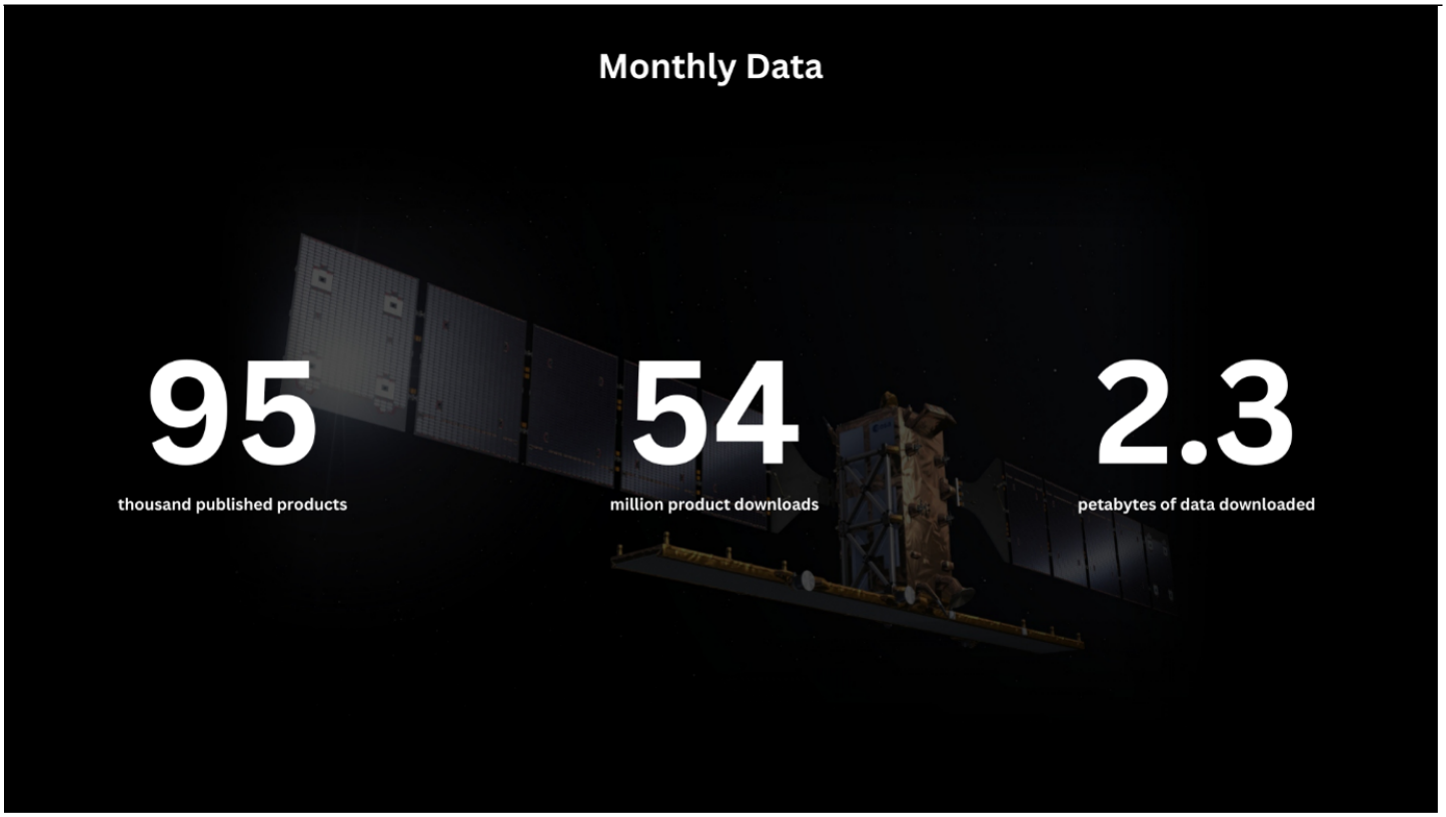
Data from Sentinel-1 is used extensively by the Copernicus Emergency Management Service (CEMS), as the ability of SAR instruments to delineate flooded areas, see through clouds or thick smoke, and detect land changes is particularly useful for emergency situations. Sentinel-1 SAR data facilitates the identification of shifts in terrain and infrastructure damage following urban disasters, enabling precise assessments crucial for recovery planning and community impact evaluations. Moreover, this data is invaluable in land movement scenarios, like landslides or earthquakes, where it aids in detecting terrain alterations through the comparison of pre- and post-event images. Finally, the ability of radar imagery to quickly and efficiently detect the extent of flooded areas is very effective in supporting emergency response and disaster relief operations. This capability was recently demonstrated during the 2022 floods in Pakistan, where Sentinel-1 imagery used by the CEMS GloFAS Global Flood Monitoring (GFM) system, proved instrumental in the real-time monitoring and assessment efforts coordinated by various international and local agencies.



Data visualisation combining Rapid Mapping and Global Flood Monitoring (GFM) data. The blue area shows the maximum extent of the flooded area between 15 and 30 August 2022 as reported by GFM, and a detail from the Rapid Mapping Delineation Product for the Shikarpur AoI is presented in the zoom. Credit: European Union, Copernicus Emergency Management Service

A decade of data production with much more to come

Since its launch, the Sentinel-1 satellite mission has provided a vast amount of data across a myriad of applications, from environmental monitoring to disaster response. The Sentinel-1 satellites currently publish over 95,000 products monthly, with over 2.3 petabytes of data downloaded by users worldwide, and are the only radar satellites whose data is available to users on a full, free, and open basis.



Sentinel-1A provides a massive amount of data across thousands of products to users worldwide. Credit: ESA

Looking to the future, the Sentinel-1 satellite mission is set to be bolstered by the upcoming launches of Sentinel-1C and 1D, with Sentinel-1C launching first to replace the now retired Sentinel-1B. These new additions will continue the Sentinel-1 legacy and ensure that users will have the data needed to feed their services in the future, as well as improve the overall performance and data quality of the constellation.

Copernicus Sentinel-1 has made a significant impact on our ability to observe and understand the Earth. As we look back on a decade of innovation and forward to the future, we celebrate Sentinel-1’s contributions and the potential of Copernicus to support us in addressing some of the most important challenges of our time.