Sentinel-1: Satellites for rapid disaster response

by Aurélien Genin, Alexandra Knoblauch and Katia Todorov - 18/09/2025

EPFL
Image Processing for Earth Observation

What is Sentinel-1?

To provide rapid response in the event of natural disasters over the globe, the **International Charter: Space and Major Disasters** was established in 2000. It gathers 17 space and environment agencies throughout the world that agreed to provide free and quick satellite products after events such as earthquakes, landslides, floods, oil spills, forest fires, tsunamis, volcanic eruptions… As of today, the charter can rely on 270 satellites to produce maps for rescue services and to assess the damage. It has been activated more than 1,000 times in 144 countries.

Sentinel-1 satellites orbit the Earth at an altitude of 693 km, , completing one full cycle every 12 days with 175 orbits per cycle. Two satellites, **Sentinel-1A and Sentinel-1C**, follow the same orbit with a 180° phase shift. This configuration allows full Earth coverage every **6 days**, with radar data transmitted to the Copernicus program within one hour of acquisition.

The Sentinel-1 satellites are part of the **Copernicus** programme. It was launched by the European Union in 1998 to provide a constant eye on Earth for civilian purposes.

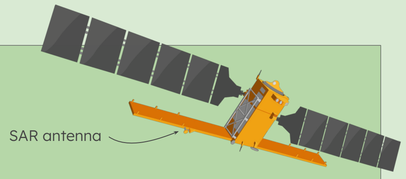
The space segment of Copernicus is composed of the Sentinel satellites. This fleet is composed of around 20 satellites and instruments, organized in six families for different applications: Radar imaging with Sentinel-1, high resolution optical imaging with Sentinel-2, oceans and soils surveillance with Sentinel-3, atmosphere composition measurements with Sentinel-4 and Sentinel-5, and ocean altimetry with Sentinel-6.

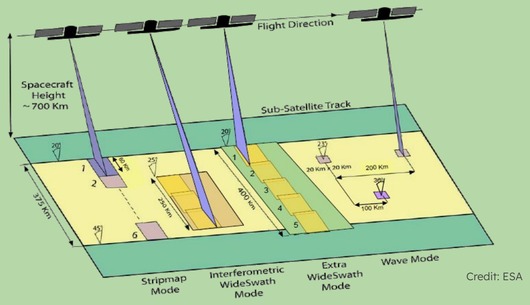
The data acquired by these instruments and satellites is shared openly, freely and globally by Copernicus. It is used for various applications:

- Climate change assessment and biodiversity surveillance;
- Marine world surveillance (sea surface temperature, sea ice coverage, sea currents, illegal oil discharges…)
- Atmosphere surveillance;
- Agriculture and land use monitoring;
- Rapid disaster response.

References: Sentinel-1 SAR Instrument; Disasters Charter

What are the characteristics of the Sentinel-1 sensor?





Active Synthetic Aperture Radar System

The Sentinel-1 sensor is an **active sensor** system carrying a 12 m long **Synthetic Aperture Radar (SAR)** antenna. This makes the satellite suitable to capture measurements during **day and nighttime** and **through clouds**, making it capable to help after a major disaster no matter the weather.

Resolution and Coverage

The sensor provides high to medium **resolutions** of up to 5 m for land, coastal and ice observation with geographical **coverage** of up to 400 km. The sensor works in **C-band** and thus with wavelengths of 3.75 to 7.5 cm.

Interferometric SAR

The instrument emits microwave pulses allowing for fast scanning in elevation and azimuth (to meet image performance requirements). The SAR instrument is thus a **non-optical imaging** sensor and reconstructs images of the surface by emitting its own microwave pulse signals towards the Earth at specific angle. Returned backscatter echo is received by the instrument antenna shortly after at a different location as the satellite travels. An image of the earth's surface is reconstructed using the **amplitude** of the returned signal (strength of radar response) and the **phase** information (fraction of one SAR wave). By using **Interferometric SAR (InSAR)** the phase difference between two SAR observations of the same area is exploited to extract information about the Earth's surface. This allows to detect small-scale deformation patterns in the landscape particularly useful for disaster monitoring.

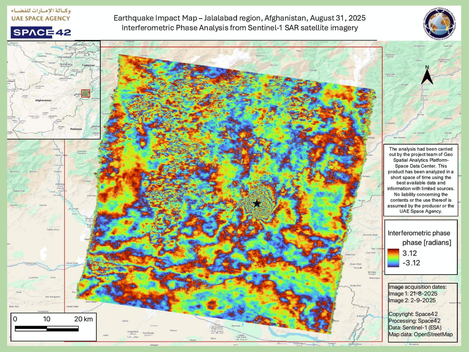
Acquisition Modes

The radar uses **4 different acquisition modes:** Stripmap, Interferometric Wide Swath, Extra Wide Swath and Wave. **Interferometric Wide Swath** is the primary mode over land surfaces as it has low operational costs and allows regular monitoring of specific areas for example to assess large scale earthquakes. It acquires data with a 250 km swath (scan width) and 5 x 20 m resolution by using Terrain Observation with Progressive Scans (**TOPSAR**) producing a more uniform signal-to-noise-ratio. The **Wave mode** is used over oceans.

Polarisation

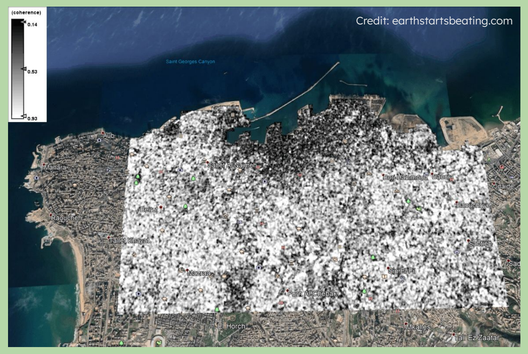
The sensor has **dual polarisation capability** and can transmit either vertical or horizontal polarisation signals and receive both polarisations simultaneously. This allows for improved classification of point targets and distributed target areas, which is helpful for assessing hazard types across different scales.

How Sentinel-1 helps in major disasters



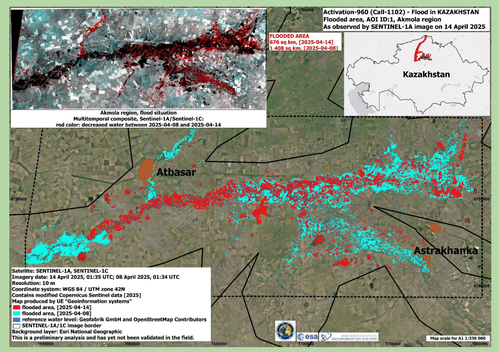
Earthquake in Afghanistan (31/08/2025)

Radar images enable to perform interferometry between two different epochs. The interference pattern reveals subtle changes in the ground elevation, in the order of the radar wavelength (~1cm for Sentinel-1). When an earthquake occurs, this allows to identify the epicenter and observe landslides. The map above shows the interferometric phase map for the earthquake which happened near Jalalabad in Afghanistan in 2025.



Explosion in Beirut, Lebanon (04/08/2020)

Sentinel-1 satellites produce time series of the Earth in radar bands. Thanks to this, radar images can be compared before and after a major disaster to easily identify the damage. The image above shows the aftermath of the explosion in the port of Beirut, Lebanon in 2020. The greyscale shows the similarity between an image taken a week before the explosion and one taken two days after. It reveals the extent of the damage around the port, as well as other damage further in the city.



Flood in Kazakhstan (07/04/2025)

In radar images, water appears very dark because it reflects the beam in a specular manner, so that very little of the signal is returned to the sensor. This allows easy detection of flooded regions by comparing images before and after a flood. The map above shows the impact of a flood which happened in the Akmola region in northern Kazakhstan in 2025. It was produced using Sentinel-1 images taken just before and after the disaster.