

Sentinel-3

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Sentinel-3 in the Copernicus Ecosystem

Welcome. In this video, we explore one of the most technically sophisticated missions within the Copernicus Earth Observation Programme: Sentinel-3. To understand what makes it distinctive, it helps to briefly place it within the broader context of the programme. Sentinel-1 is a radar mission that provides structural and surface deformation information regardless of cloud cover or lighting conditions. Sentinel-2 delivers high-resolution multispectral optical imagery, optimised for detailed land surface analysis at field and landscape scale. Sentinel-5P monitors the composition of the atmosphere, tracking pollutants and greenhouse gases at global scale. Sentinel-3 was designed with a different philosophy altogether.

Its mission is centred around the systematic observation of large-scale environmental dynamics: temperature, ocean conditions, vegetation status at regional scale, atmospheric composition, and climate-related processes. While Sentinel-2 can resolve individual fields and urban blocks at ten meters, Sentinel-3 operates at coarser spatial resolution but compensates with broader geographic coverage, stronger temporal consistency, and a fundamentally different measurement capability: the ability to measure the physical temperature of the Earth's surface. This makes Sentinel-3 not simply an imaging system, but an environmental monitoring platform in the full scientific sense. Its role is to observe how environmental variables evolve over time, contributing to our understanding of climate, ecosystems, agriculture, and urban thermal dynamics.

Mission Architecture and Instruments

The Sentinel-3 constellation consists of multiple satellites operating in a coordinated manner to ensure continuous global coverage and a high temporal revisit capability. Like other

Copernicus missions, Sentinel-3 operates in a sun-synchronous orbit, meaning it passes over the same locations at approximately the same local solar time during each revisit. This stabilizes illumination geometry and ensures that observations acquired at different times remain comparable. What makes Sentinel-3 architecturally unique within the Copernicus family is its payload. Unlike Sentinel-2, which is built around a single multispectral instrument, Sentinel-3 incorporates multiple complementary instruments, each designed to observe a different component of the Earth system.

SLSTR: Sea and Land Surface Temperature Radiometer

The most important instrument for our discussion is the Sea and Land Surface Temperature Radiometer, known as SLSTR. This instrument is specifically designed to measure land and sea surface temperatures with high radiometric precision. It operates across multiple spectral channels, including visible, near-infrared, and thermal infrared wavelengths. The thermal infrared region is particularly important because all objects above absolute zero emit thermal radiation. By measuring this emitted radiation, Sentinel-3 can estimate the physical temperature of the Earth's surface. This is fundamentally different from Sentinel-2, which measures reflected solar radiation. SLSTR measures radiation that the surface itself emits.

OLCI: Ocean and Land Colour Instrument

The second major instrument is the Ocean and Land Colour Instrument, or OLCI. This is a multispectral optical instrument designed to measure reflected radiation across a large number of spectral bands. OLCI is particularly important for monitoring vegetation, water quality, chlorophyll concentration, and environmental conditions over both land and ocean surfaces. Although Sentinel-2 provides higher spatial resolution for detailed land observation, Sentinel-3 OLCI offers broader regional coverage and strong spectral sensitivity, making it useful for large-scale environmental assessments, vegetation monitoring at continental scale, and atmospheric correction support.

SRAL and Atmospheric Capabilities

The third instrument is the Synthetic Aperture Radar Altimeter, or SRAL. This instrument is more strongly associated with oceanography and water surface measurements, but it contributes to hydrological and environmental studies by enabling precise measurement of surface elevation, particularly for oceans, rivers, lakes, and ice surfaces. Its contribution is especially relevant for sea level monitoring, inland water dynamics, and hydrological analysis related to climate.

Finally, Sentinel-3 incorporates atmospheric observation capabilities that support the characterization of atmospheric particles, aerosols, and gases. This atmospheric dimension becomes particularly important when Sentinel-3 data is integrated with other missions such as Sentinel-5P, which focuses specifically on atmospheric composition, or with weather forecasting services. Together, these systems contribute to a more complete understanding of how surface observations connect to atmospheric dynamics.

What Sentinel-3 Measures

Environmental Variables

To properly understand the analytical value of Sentinel-3, it is necessary to move beyond the idea of satellite imagery as a visual product and think instead in terms of geophysical variables. Sentinel-3 generates multidimensional datasets that describe the physical state of the Earth system numerically. Each pixel is not simply a visual element, but a container of physical information describing environmental conditions at a specific location and a specific time.

Land Surface Temperature and Heat Fluxes

The most central variable produced by Sentinel-3 is Land Surface Temperature, commonly abbreviated as LST. This parameter represents the physical temperature of the Earth's surface itself. It is not the same as air temperature measured by a weather station. Instead, it describes the thermal state of the ground, vegetation, urban surfaces, or water bodies as observed from space through thermal infrared measurements. LST is an extremely important environmental variable because surface temperature controls many physical processes: energy balance, water stress in vegetation, urban heat accumulation, and climatic dynamics. In practice, LST is always provided alongside an uncertainty value, which quantifies the expected error margin and helps analysts understand the reliability of the retrieved temperature.

Alongside LST, Sentinel-3 provides two closely related variables that describe how energy is exchanged between the Earth's surface and the atmosphere: latent heat flux and sensible heat flux. Latent heat flux is associated with phase changes of water, particularly evaporation and transpiration. When water evaporates from a surface or is released by vegetation through transpiration, energy is absorbed from the surface and transferred into the atmosphere. In agricultural environments, latent heat is strongly connected to evapotranspiration and vegetation activity.

Sensible heat flux, by contrast, represents direct heat transfer between the surface and the air without phase change. Urban surfaces dominated by asphalt and concrete tend to exhibit strong sensible heat flux because these materials absorb solar radiation and release heat directly into the atmosphere. The balance between these two fluxes is extremely diagnostic. In vegetated and well-watered areas, latent heat tends to dominate because energy is consumed

by evapotranspiration. In dry or highly urbanized areas, sensible heat dominates, leading to stronger surface warming. This balance is one of the most informative indicators in the entire dataset.

Soil, Atmosphere and Additional Variables

Sentinel-3 also provides soil wetness information, which estimates the amount of moisture present in the soil. This variable is critical for agriculture because soil moisture directly influences crop growth, irrigation efficiency, runoff generation, and drought risk.

Among the atmospheric variables, the dataset includes cloud fraction, which describes how much of the observed area is covered by clouds and therefore affects the reliability of surface measurements. Dew point temperature indicates the atmospheric moisture content and is related to condensation, fog formation, and moisture-related environmental conditions. Solar radiation describes the incoming solar energy reaching the surface, which drives photosynthesis, evaporation, thermal dynamics, and ecosystem productivity. Thermal radiation describes the energy emitted by the Earth's surface back into the atmosphere and space. Together, incoming solar radiation and outgoing thermal radiation define the Earth's radiative balance.

Total column water vapor and total column ozone provide integrated measurements of atmospheric moisture and ozone abundance. Ozone plays a critical role in absorbing harmful ultraviolet radiation, while water vapor is one of the most important greenhouse gases and strongly influences cloud formation and energy transfer. Specific humidity measures the mass of water vapor in the air relative to the total air mass; unlike relative humidity, it is independent of temperature, which makes it particularly useful for weather forecasting and atmospheric modeling.

Surface pressure influences weather systems and wind patterns. Wind speed and direction are reconstructed through two orthogonal components: the u-wind, oriented east-west, and the v-wind, oriented north-south. Together they describe atmospheric circulation dynamics that influence pollution dispersion, evapotranspiration, and thermal comfort. Additional variables include skin temperature at the surface-atmosphere interface, snow albedo and snow depth for hydrological and climate analysis, and temperature profiles through different atmospheric layers.

The key point is that these variables should never be interpreted in isolation. Their true value emerges through integration. A region with elevated land surface temperature, low soil wetness, high sensible heat flux, and low vegetation activity may indicate drought stress or degraded environmental conditions. An urban area with high thermal radiation and low latent heat may correspond to strong heat island effects. Environmental systems are interconnected, and it is precisely this interconnection that makes Sentinel-3 so powerful when used within a multi-layer analytical environment.

Applications in Urban Environments

The Heat Island Effect

One of the most important applications of Sentinel-3 data is the analysis of the Urban Heat Island effect. Urban areas tend to accumulate and retain more heat than surrounding rural areas. This happens primarily because urban materials such as asphalt, concrete, and dense infrastructure absorb solar radiation during the day and release it slowly during the night, accentuating the thermal differential with surrounding rural areas. Urban areas also tend to have less vegetation, which would otherwise contribute to natural cooling through evapotranspiration. As a result, cities retain heat for longer periods, reaching significantly higher temperatures compared to neighboring undeveloped areas.

This effect has several practical consequences. It increases energy consumption for cooling systems, raising economic costs. It creates health risks, particularly for vulnerable populations, through increased exposure to heat. It also contributes to air quality deterioration, since higher temperatures can promote the formation of air pollutants such as ozone. In agricultural areas adjacent to urban centers, elevated temperatures can affect growing conditions and crop performance. Using Sentinel-3 thermal data, it becomes possible to spatially identify areas with elevated surface temperatures across urban environments. Zones with poor vegetation coverage and high building density often exhibit significantly higher thermal signatures compared to parks or peri-urban green areas.

Identifying heat accumulation zones allows urban planners to implement targeted cooling strategies: the creation or expansion of green spaces, the introduction of cool roofs, or the use of reflective materials in construction to reduce heat absorption. Monitoring these zones over time then makes it possible to evaluate whether such interventions are actually reducing thermal stress. This type of analysis is particularly critical in urban planning, helping to assess the effectiveness of climate resilience measures and to guide decisions about future urban development.

Applications in Agriculture

Thermal Stress and Water Management

In agricultural contexts, the role of Sentinel-3 is equally important, though the interpretation shifts toward a different set of processes. Crops are strongly sensitive to temperature conditions. Elevated surface temperature can indicate water stress, drought conditions, reduced evapotranspiration efficiency, or declining vegetation health. Because these thermal signals often appear before visible symptoms of stress become evident, Sentinel-3 can act as an early indicator for agricultural risk.

A field that exhibits unusually high surface temperature compared to surrounding areas may indicate insufficient irrigation, a soil moisture deficit, or crop stress. This becomes especially

powerful when thermal information is combined with vegetation indices derived from Sentinel-2. If Sentinel-2 indicates reduced vegetation vigour through lower NDVI values, and Sentinel-3 simultaneously shows elevated surface temperatures in the same region, the combined interpretation strongly suggests active stress conditions affecting the crops. This type of multi-source integration allows agricultural monitoring to move from simple observation toward more robust diagnostic analysis.

Drought monitoring represents a particularly important application. At regional scale, OLCI contributes by monitoring crop cycles and biomass trends, providing the broader vegetation context within which thermal anomalies can be interpreted. Surface temperature anomalies often precede the visible degradation of vegetation condition. This means thermal monitoring can act as an early indicator of drought impact. When integrated with meteorological forecast services and soil moisture estimations, Sentinel-3 becomes part of a larger environmental intelligence framework supporting agricultural risk management. By monitoring temperature and moisture levels over time, agricultural managers can anticipate periods of water scarcity and adjust farming practices to reduce the impact.

The latent and sensible heat information is also directly applicable in agricultural management. By comparing these two fluxes across different fields, analysts can assess the efficiency of water use in crops. If a field is producing a large amount of sensible heat and a low amount of latent heat, it could indicate that the crops are under water stress and that transpiration is suppressed. Combined with soil wetness data, these variables allow a nuanced and physically grounded interpretation of crop status.

Broader Environmental Monitoring

Beyond urban and agricultural applications, Sentinel-3 supports a wide range of environmental monitoring activities. Through OLCI, it contributes to the observation of vegetation dynamics over large territories, supporting the monitoring of crop cycles, biomass trends, and ecosystem behavior at scales that Sentinel-2 alone cannot efficiently cover. For urbanization studies, OLCI can contribute to broader land cover interpretation and environmental quality assessment, especially when integrated with higher-resolution datasets.

In coastal and marine environments, sea surface temperature data from SLSTR plays a critical role. Rising sea temperatures can indicate stress on marine ecosystems, including coral bleaching and changes in fish migration patterns. Monitoring the temperature of water bodies also supports the analysis of pollution dynamics and sediment transport in rivers, lakes, and estuaries.

For wildfire monitoring, the ability of Sentinel-3 to detect thermal anomalies allows early identification of active fire events in forests and grasslands, supporting early warning systems and rapid response efforts. Surface temperature and thermal radiation data also contribute to climate research, enabling the assessment of long-term warming trends and regional climate variability. Combined with historical climate records, these datasets support the modeling of

future climate scenarios and inform environmental policy. In all these cases, Sentinel-3 is not simply providing images, but structured measurements of the physical state of the environment.

Visualization in EagleArca

Within the EagleArca platform, Sentinel-3 data is available through two distinct layer types, each serving a different analytical purpose.

The Heat Island Layer

The first is the Heat Island layer. This layer aggregates Sentinel-3 data over an extended period, typically at least one year, and calculates average land surface temperatures across different seasons. This temporal aggregation allows users to identify persistent heat accumulation zones, analyze seasonal temperature patterns, and evaluate long-term trends in urban thermal behavior. Users can compare summer and winter thermal patterns, identify hotspot areas, and examine how these relate to land cover, vegetation density, or infrastructure distribution.

When combined with Sentinel-2 classification data, the Heat Island layer provides a powerful tool for understanding how urban morphology and the distribution of green spaces influence thermal dynamics. The layer also enables the monitoring of long-term trends in urban heat island development, identifying areas that may be getting progressively warmer over the years. Since elevated temperatures promote the formation of pollutants such as ozone, this information is directly relevant for air quality assessment alongside thermal risk evaluation.

The Sentinel-3 Daily Data Layer

The second layer is the Sentinel-3 Daily Data layer. Unlike the aggregated Heat Island product, this layer is updated every time new data from Sentinel-3 becomes available, which is typically every 24 hours, providing near-real-time access to environmental variables. These include land surface temperature, latent heat, sensible heat, soil wetness, and wind components, as well as atmospheric parameters such as specific humidity, solar radiation, ozone, and water vapor. For coastal areas, sea surface temperature is also included, which is important for understanding oceanic processes and climate-related phenomena.

This daily update capability makes the layer particularly valuable for dynamic decision-making. Farmers can monitor evolving thermal and moisture conditions. Urban managers can track heat accumulation during heat waves. Environmental analysts can follow atmospheric dynamics in near real time. The key value of both layers within EagleArca is not simply visualization, but integration. Because all layers within the platform are georeferenced within the same coordinate system, Sentinel-3 products can be seamlessly combined with Sentinel-2 classification, Digital Elevation Models, infrastructure layers, or meteorological datasets. This spatial consistency transforms what might otherwise be disconnected measurements into a

coherent and interpretable view of the environment.

Integration with Other Sentinel Missions

One of the most important conceptual points about Sentinel-3 is how it fits within the broader Copernicus ecosystem. Sentinel-3 is not a replacement for Sentinel-1 or Sentinel-2. Rather, it contributes a different and complementary dimension to the overall observational framework.

Sentinel-2 provides spatially detailed multispectral observations at ten-meter resolution, enabling field-level analysis of vegetation, soil, water, and urban surfaces. Sentinel-3 provides the thermal and environmental context that helps explain many of the patterns visible in Sentinel-2 data. When crops show anomalous spectral behavior in Sentinel-2, Sentinel-3 thermal and moisture data can help diagnose whether the cause is heat stress, water deficit, or some other environmental factor.

When urban areas show dense built-up patterns in Sentinel-2 classification, Sentinel-3 can reveal the thermal consequences of that urbanization. Sentinel-1, meanwhile, contributes structural and deformation information through radar observation, working independently of cloud cover. Together, the three missions create a much richer understanding of the territory than any single system could provide.

A critical aspect of interpretation is also understanding the scale at which Sentinel-3 operates. Its spatial resolution is coarser than that of Sentinel-2, but this is compensated by broader coverage and strong temporal consistency. Sentinel-3 is not the right tool for identifying individual buildings or narrow agricultural rows. However, it is extremely effective for understanding large-scale environmental processes: heat distribution across metropolitan areas, drought evolution across agricultural regions, vegetation dynamics over large ecosystems, and temperature anomalies at continental scale.

The Role of Sentinel-3 in Modern Earth Observation

Sentinel-3 is a mission designed not simply to observe the Earth visually, but to measure the physical state of the environment. Through its instruments, particularly SLSTR and OLCI, it provides critical information about surface temperature, vegetation dynamics at regional scale, atmospheric composition, environmental stress, and climatic behavior.

Its applications in urbanization include heat island analysis, environmental quality assessment, urban climate resilience studies, and the long-term monitoring of thermal patterns. In agriculture, Sentinel-3 supports drought monitoring, early detection of thermal stress, crop condition assessment, and water management evaluation. In environmental science, it contributes to coastal analysis, wildfire detection, ecosystem monitoring, and climate research.

When integrated with Sentinel-1, Sentinel-2, elevation models, meteorological services, and GIS-based platforms such as EagleArca, Sentinel-3 becomes part of a comprehensive environmental monitoring ecosystem capable of supporting both operational analysis and long-term decision-making. Ultimately, Sentinel-3 demonstrates how modern satellite systems are evolving beyond simple imaging toward continuous, multidimensional observation of the Earth system, enabling us to better understand the complex interactions between climate, environment, human activity, and territorial dynamics.

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