

# Three years of operations of the Sentinel-1 and Sentinel-3-OLCI PAC at German Aerospace Center

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*Abstract: Copernicus is the European Earth Observation Programme, conducted jointly by the EC, ESA, EUMETSAT and the member states. The Sentinel satellites constitute the Copernicus space segment. Since 2014 already six Sentinel satellites have been launched successfully. The core payload data ground segment (PDGS) for the Sentinel satellites is managed by ESA and operated by national partners. In this core PDGS, DLR has been selected to install and operate Processing and Archiving Centers (PACs) for Sentinel-1 and the data from the Ocean and Land Colour Instrument (OLCI) aboard Sentinel-3. This paper describes the results of the first three years of operations of the S1- and S3-OLCI-PAC at DLR.*

*Daily, around 950 products are being processed based on sensor data from the OLCI instrument on Sentinel-3A, over 330 GB of associated data are stored in the Long-Term Archive of the DLR-PAC. The Sentinel-1A and Sentinel-1B satellites are already supplying many times that amount. Over 10,000 GB (10 TB) and more than 4700 products from the satellite pair are handled every day. In the first three years of operations the DLR-PAC has already processed and archived over 3.8 million data sets. They represent a data volume exceeding 6500 terabytes (6.3 petabytes).*

## 1 Mission Context: the Copernicus Architecture

Copernicus (formerly known as Global Monitoring for Environment and Security (GMES) until December 2012) is an initiative led by the EU (ASCHBACHER & MILAGRO-PÉREZ 2012). The major Copernicus building blocks are: the Space Infrastructure, to be implemented by ESA with the Sentinel satellites, Earth Observation (EO) missions developed by ESA specifically for Copernicus; complemented by Contributing Missions, EO missions built for purposes other than Copernicus, but offering part of their capacity to Copernicus (EU/ESA Missions, EUMETSAT, commercial, international); the In-Situ Infrastructure, coordinated by the EEA; the Services Component in support of the large and diverse user community offering Copernicus Services coordinated by the EC and User (Downstream) Services, intended to be provided by commercial entities.

DLR is contributing to the development and implementation of the Copernicus system in various fields since several years (SCHREIER et al. 2013).

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## 2 Sentinel Space and Payload Data Ground Segment (PDGS) Infrastructure

The Sentinel Space Infrastructure as central part of the Copernicus Architecture is composed of the Sentinel Space Segment and the Sentinel Ground Segment consisting of the Flight Operations Segment and the Payload Data Ground Segment (PDGS).

The Sentinel Space Segment is composed of six satellite series. Sentinel-1, -2, and -3 are pairs of two identical satellites for each mission:

- Sentinel-1A/B are polar orbiting satellites, each carrying a C-Band SAR to ensure the data continuity of the ERS-1/-2, Envisat (ASAR) and Radarsat missions (TORRES et al. 2012);
- the Sentinel-2A/B polar orbiting satellites equipped each with a 13-channel Multi-spectral Imager to provide enhanced continuity of SPOT- and Landsat-type data;
- the Sentinel-3A/B polar orbiting satellites with several sensors (SLSTR, OLCI, SRAL, and MWR) for ocean and land applications building on ERS-2 (AATSR), Envisat (MERIS), and Cryosat (SRAL) heritage sensor technology (DONLON et al. 2012).

Sentinel-4 will be a Geostationary Atmosphere satellite. Sentinel-5P (P stands for Pre-Cursor) and Sentinel-5 are Low-orbit Atmosphere / Air quality satellites. The Sentinel-6 mission will be dedicated to Low-orbit Altimetry.

Since 2014 already six Sentinel satellites have been launched successfully. The first satellite Sentinel-1A was launched on 3<sup>rd</sup> April 2014. The Sentinel-1 mission was completed with the launch of the identical twin satellite Sentinel-1B on 25<sup>th</sup> April 2016. The Sentinel-3A satellite lifted off on 16<sup>th</sup> February 2016. The envisaged launch of Sentinel-3B will be in April 2018. Further Sentinel satellites will be launched in the following years.

In parallel to the satellite development, the associated PDGS for each Sentinel mission has been built up (POTIN et al. 2017; SANTELLA et al. 2013). The Sentinel PDGS consists of the following major constituents (see Fig. 1): Four X-Band Core Ground Stations (CGS) to receive all Sentinel-1/2/3 payload data; seven Processing and Archiving Centers (PAC); three Mission Performance Centres (MPC); a Data Circulation and Dissemination Network (WAN); a Payload Data Management Centre (PDMC); and the Coordinated Data Access System (CDS).

Four Core Ground Stations receive payload data in X-Band. Each ground station is able to receive data from all Sentinels. All Core Ground Stations are offering Near-Real Time (NRT) processing services. The CGS are located in Norway (Svalbard), Italy (Matera), Spain (Maspalomas), and Canada (Inuvik).

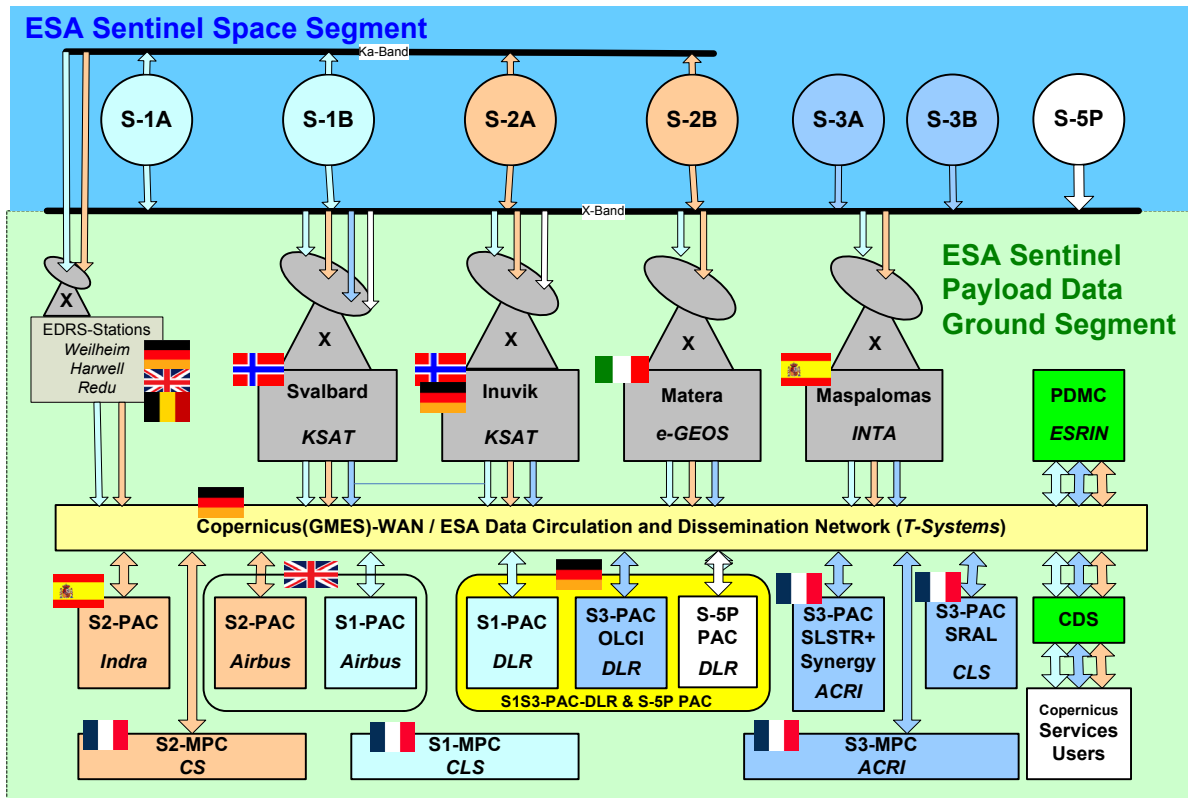


Fig. 1: Overall structure of the Copernicus Payload Data Ground Segment: Ground Stations and PACs

Seven Processing and Archiving Centers are located as follows: Sentinel-1 PAC (Newport, UK); Sentinel-1 PAC (DLR Oberpfaffenhofen, Germany); 2 Sentinel-2 PACs (Newport, UK and Madrid, Spain); Sentinel-3 OLCI-PAC (DLR Oberpfaffenhofen, Germany); Sentinel-3 SLSTR and Synergy PAC (Nice, France); Sentinel-3 SRAL-PAC (Toulouse, France). The S1-PAC and the S3-OLCI-PAC are collocated at DLR’s Earth Observation Center in Oberpfaffenhofen and are integrated, operated and maintained by an experienced team of experts from the German Remote Sensing Data Center (DFD) institute.

### 3 Sentinel-1 and Sentinel-3-OLCI PAC at DLR

In 2011, ESA had started a series of procurement actions to select European providers to offer their facilities for the set-up and operations of the PDGS elements. Within this competitive selection process DLR was selected in 2012 by ESA for the role of a PAC operator of the Sentinel-1 and Sentinel-3 (OLCI instrument) missions (HAHMANN et al. 2013).

#### 3.1 Tasks of the Sentinel PAC

The following high-level tasks are performed at the PAC:

- reception of Sentinel data from the network of Core Ground Stations (CGS) via electronic link (Copernicus WAN);

- ingestion of these data into the Short-Term Archive (STA) and Mid-Term Archive (MTA) of the Sentinel PGDS;
- in addition ingestion of these data in a Long-Term Archive (LTA) for addressing future science challenges;
- perform consolidation and re-assembly of level-0 data received from CGS;
- perform systematic and request-driven processing of Sentinel data to higher-level products;
- host Sentinel data products within a layered architecture of on-line dissemination elements that facilitate the data access of end-users via public networks;
- share and exchange any locally processed data with a second partner PAC for the purpose of redundancy;
- capability to reprocess large amounts of data.

For Sentinel-1 the second PAC is located in Newport (UK). For Sentinel-3 there exists a work share between the DLR-PAC (responsible for data over land areas) and EUMETSAT (datasets that cover marine areas).

The Sentinel PDGS is operationally embedded in the Copernicus Space Component Data Access (CSCDA, <https://spacedata.copernicus.eu/>) System that has been implemented by ESA in support of Copernicus Service Projects and their users.

Complete, free and open access to Sentinel-1, Sentinel-2 and Sentinel-3 user products for the general public is provided by the Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub, <https://scihub.copernicus.eu/>).

The Sentinel Online web portal provides comprehensive technical information about all Sentinel missions (<https://sentinel.esa.int/>).

### 3.2 Sentinel PAC Project Phases

The project is structured in a phased approach that consists of the Site Preparation Phase (SPP), the Deployment and Test Phase (DTP), the Commissioning Operations Phase (COP), and Routine Operations Phase (ROP). Details about the different aspects of these phases can be found in HAHMANN et al. (2013).

After the development and commissioning phase during the years 2012 – 2014, the Sentinel-1A PAC entered into the routine operations phase in March 2015. In July 2016 the routine operational phase began for Sentinel-1B and for Sentinel-3A OLCI data. The Sentinel-PAC is expected to be complete in April 2018 when the Sentinel-3B satellite will be launched into orbit. Currently the DLR-PAC is contracted by ESA until end of 2019 to fulfil its role as PAC for Sentinel-1 data and Sentinel-3 OLCI data.

In the Routine Operations Phase the following services are provided for ESA: Network Services, LTA (Long-Term Archive) Service, Production and Dissemination Service, and Support Operations such as System Administration, Database Management and Logistics.

The LAN infrastructure is operated in terms of a managed service and is continuously monitored. The LTA Service covers: Systematic ingestion of Sentinel data from the Sentinel PDGS; retrieval of archived data products for the dissemination to end-users on request of ESA; bulk retrieval of data to be used as input for reprocessing activities; systematic ingestion of data

generated in the context of reprocessing campaigns; LTA maintenance activities such as archive monitoring and archive refreshment and data re-transcription.

The Production and Dissemination Service covers systematic processing and generation of Sentinel data products of all levels; transfer of received and processed data into STA, MTA, and LTA; circulation of data products to partner centers via the multi-Sentinel WAN; request-driven dissemination of data products to Sentinel end-users.

Fig. 2 gives an overview about the high-level structure of DLR’s Sentinel PAC showing the components of the LAN Service (operated by T-Systems, Germany), the LTA Service, and the Sentinel-1 and Sentinel-3 OLCI Production and Dissemination Service.

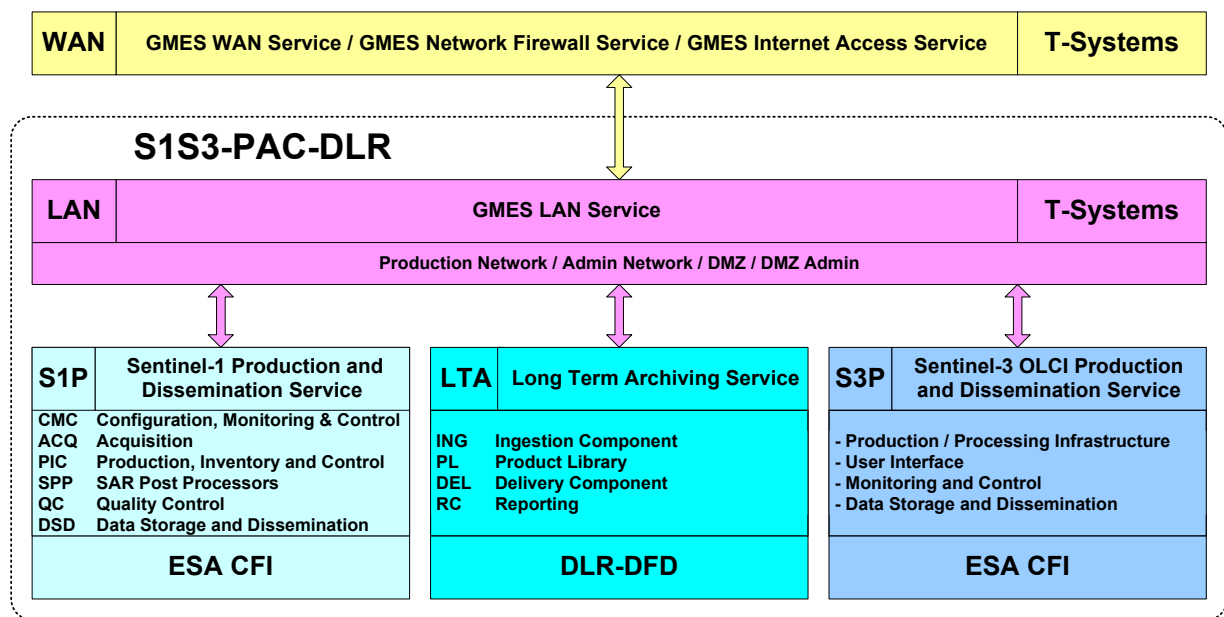


Fig. 2: Overall structure of the Sentinel-1 and Sentinel-3-OLCI PACs at DLR-DFD

## 4 Long-Term Archive service of DLR-PAC

In the scope of the Sentinel-PAC project, DLR’s existing data archive (the so-called German Satellite Data Archive) was significantly enhanced in the year 2013. DLR has a robotic storage library available that will be to manage about 10,000 storage slots (Fig. 3). The storage tape technology which is utilized is the T10000C tape drive standard of Oracle through which it is possible to store up to 5 TB of data natively on one single cartridge. In its final configuration the DLR tape archive is able to host 50 PB (50 Million GB) of data.



Fig. 3: DLR's StorageTek SL 8500 Robotic Tape Library

#### 4.1 Data Ingestion into the LTA

In the planning phase of the project (in the year 2012) the following Sentinel data capacity requirements were expected:

- approx. 2150 TB per year for Sentinel-1 data products (6 TB per day),
- approx. 600 TB per year for Sentinel-3 OLCI data products (1.6 TB per day).

In the course of the project it became apparent that these numbers had to be adjusted. The Sentinel-1A and Sentinel-1B satellite pair is already supplying over 10,000 GB (10 TB) and more than 4700 products per day (numbers from end of 2017). The daily Sentinel-1 data volume that needs to be archived in the DLR-PAC LTA is expected to further increase in the coming years up to 16 TB per day.

Regarding Sentinel-3 data the data volume is below the presumed amount. Daily, around 950 products are being processed based on sensor data from the OLCI instrument on Sentinel-3A, over 330 GB of associated data are stored in the Long-Term Archive of the DLR-PAC. These numbers will increase when Sentinel-3B starts acquiring data after its launch in April 2018.

In the first three years of operations the DLR-PAC has already processed and archived over 3.8 million datasets. They represent a data volume exceeding 6500 terabytes (6.3 petabytes). Table 1 provides a summary of the archived data in the LTA, whereas figures 4 and 5 show the archived Sentinel-1 and Sentinel-3 OLCI datasets over the course of the project.

Despite this enormous amount of data, the DLR-PAC is configured to additionally reprocess existing Sentinel data at any time with the latest algorithms to generate useful new geo-temporal data sets.

Tab. 1: Summary of Data archived into the LTA until end of 2017

Satellite mission	Number of products	Data Volume in GB	Data Volume in TB	Products / day	GB / day
Sentinel-1	3,181,731	6,451,848	6,301	2841	5761
Sentinel-3 OLCI	642,009	227,326	222	940	333
<b>Total data ingestion</b>	<b>3,823,740</b>	<b>6,679,174</b>	<b>6,523</b>		

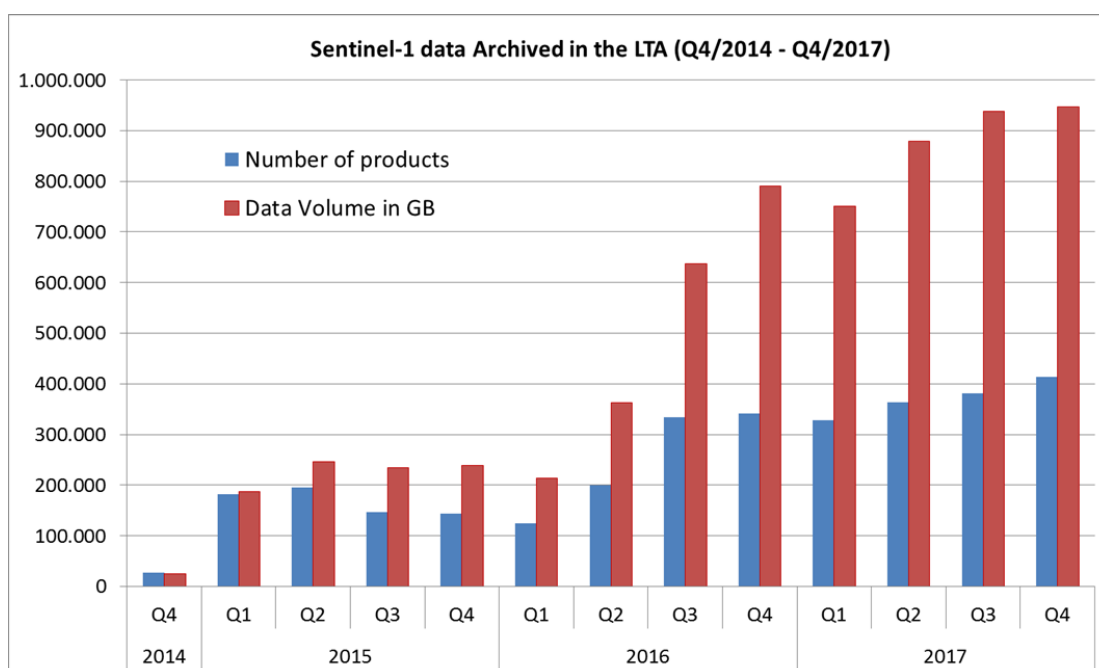


Fig. 4: Sentinel-1 data archived in the DLR-PAC LTA (per quarter, Q4/2014 – Q4/2017)

The reason for the major increase of the data volume in Q3/2016 is the start of archiving of Sentinel-1B data during this period. Further data volume increases occurred due to start of data reception/transmission via the EDRS-A system (European Data Relay Satellite) from November 2016 (Sentinel-1A) respectively March 2017 (Sentinel-1B) onwards.



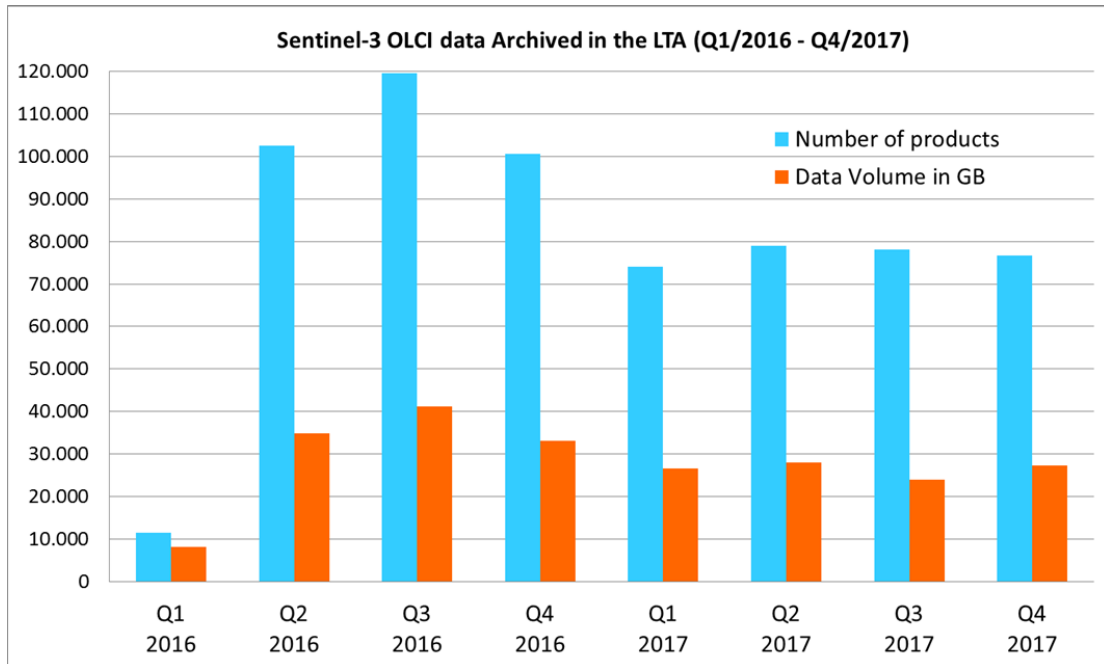


Fig. 5: Sentinel-3 OLCI data archived in the DLR-PAC LTA (per quarter, Q1/2016 – Q4/2017)

Fig. 6 shows the current and expected data volume growth in DLR’s Long-Term Archive for the years 2014 until 2025.

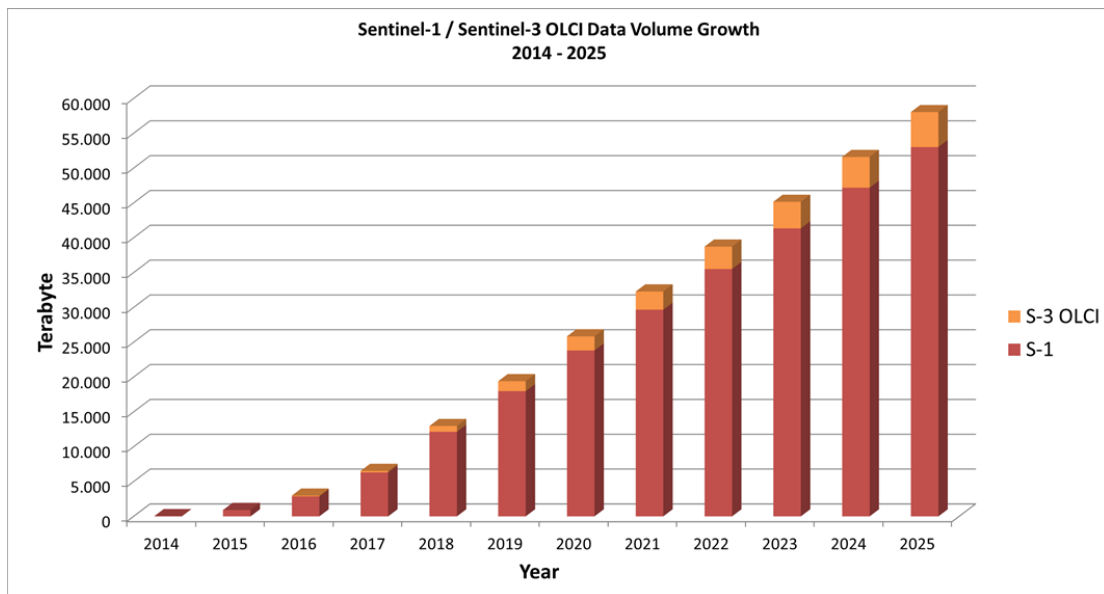


Fig. 6: Current and expected Sentinel-1 and Sentinel-3 OLCI Data Volume growth at DLR-PAC LTA in the timeframe 2014 – 2025



Fig. 7 summarizes the distribution of the archived Sentinel-1 and Sentinel-3 OLCI products with regard to the product types.

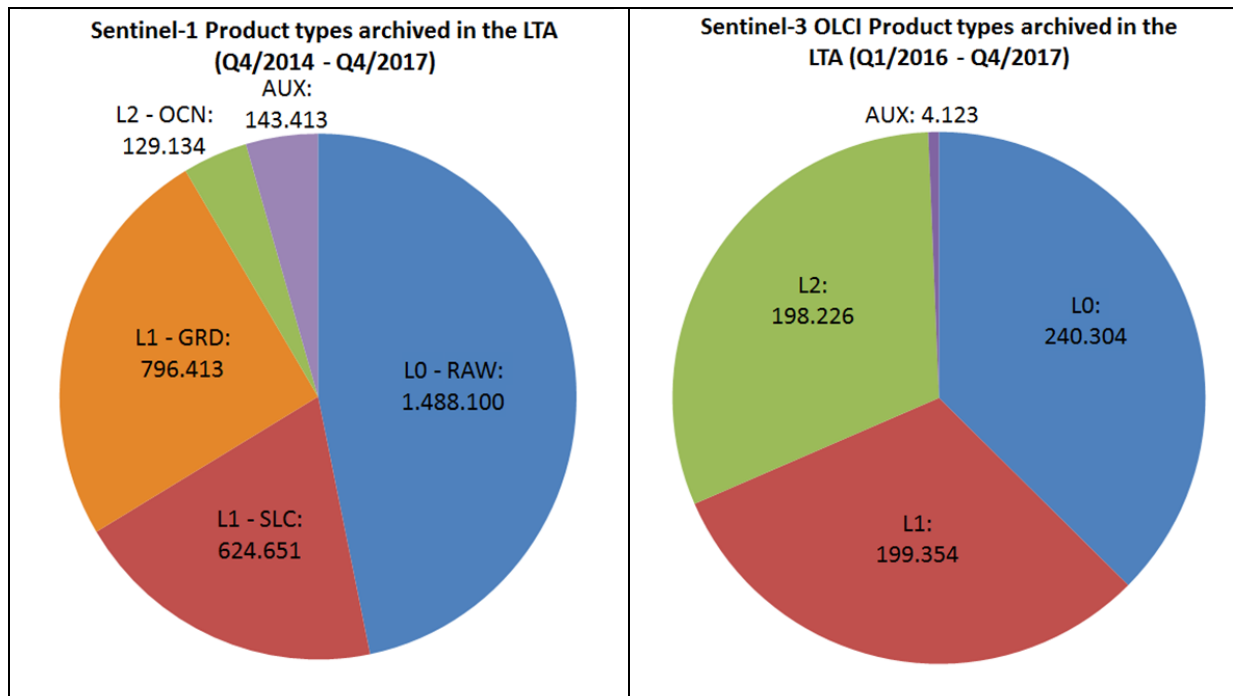


Fig. 7: Distribution of the archived Sentinel-1 and Sentinel-3 OLCI Data Product types until end of 2017

#### 4.2 Data Retrieval from the LTA

The data retrieval from the LTA for Sentinel-1 data has started in June 2015. Operational data retrieval from the LTA for Sentinel-3 OLCI data has started in April 2016, only two months after the launch of the Sentinel-3A satellite.

The total amount of retrieved datasets is more than 70,000, whereas the data volume has reached almost 50 TB. The following table summarizes the data retrievals from the LTA until end of 2017.

Tab. 2: Summary of Data retrieved from the LTA until end of 2017

Satellite mission	Number of products	Data Volume in GB	Data Volume in TB
Sentinel-1	69,847	49,382	48.22
Sentinel-3 OLCI	2,665	895	0.87
<b>Total data retrievals</b>	<b>72,512</b>	<b>50,277</b>	<b>49.10</b>

The amount of data retrievals requests from the LTA, especially for Sentinel-1 data is expected to increase significantly from Q1/2018 onwards. Reason for this assumption is that ESA will no

longer be able to hold all the Sentinel-1 datasets on their Short Term Archive. The data deletion is planned to be started with Sentinel-1 L0 data older than 1 year. Sentinel-1 L1 data will follow on a later stage; Sentinel-3 data will be affected afterwards.

The DLR-PAC LTA will then ensure that all Sentinel datasets remain accessible for the data users also in a long run perspective.

## 5 Data access support for the CMEMS project

On request of ESA DLR-PAC is providing a dedicated data access support for the Copernicus Service Project CMEMS (Copernicus Marine Environment Monitoring Service, <http://marine.copernicus.eu/>). DLR-PAC has established a FTP server that is used to provide access to Sentinel-1 data in a timely manner for the members of the CMEMS project since September 2014. CMEMS is the successor project to the Copernicus Service Project MyOcean since May 2015.

CMEMS focuses on the provision of coastal and marine environment applications in the fields of marine safety, marine resources, and weather, climate and seasonal forecasting. A wide range of data is delivered by the service (e.g. temperature, salinity, sea level, currents, wind and sea ice). An important application is e.g. the derivation of sea ice drift observations and ice deformation (divergence, shear, vorticity) information (PEDERSEN & SALDO 2016).

Sentinel-1 products with two different “product Timeliness Categories” are provided via the FTP server: so-called “Fast-24h” products (share of around 70%) and “NRT-3h” products (30%). The number of delivered Sentinel-1 products and the corresponding data volume has significantly increased in the last three years. Tab. 3 and figures 8 and 9 summarize these values. More than 420,000 products and more than 310 TB of data have been provided for the CMEMS project members. On a monthly average CMEMS has access to about 12,000 Sentinel-1 products (data volume around 9 TB).

Tab. 3: Summary of Sentinel-1 data provided for the CMEMS project until end of 2017

Year	Number of products	Data Volume in TB
2015	78,269	43.33
2016	158,285	98.49
2017	185,558	174.44
<b>Total (2015-2017)</b>	<b>422,112</b>	<b>316.26</b>

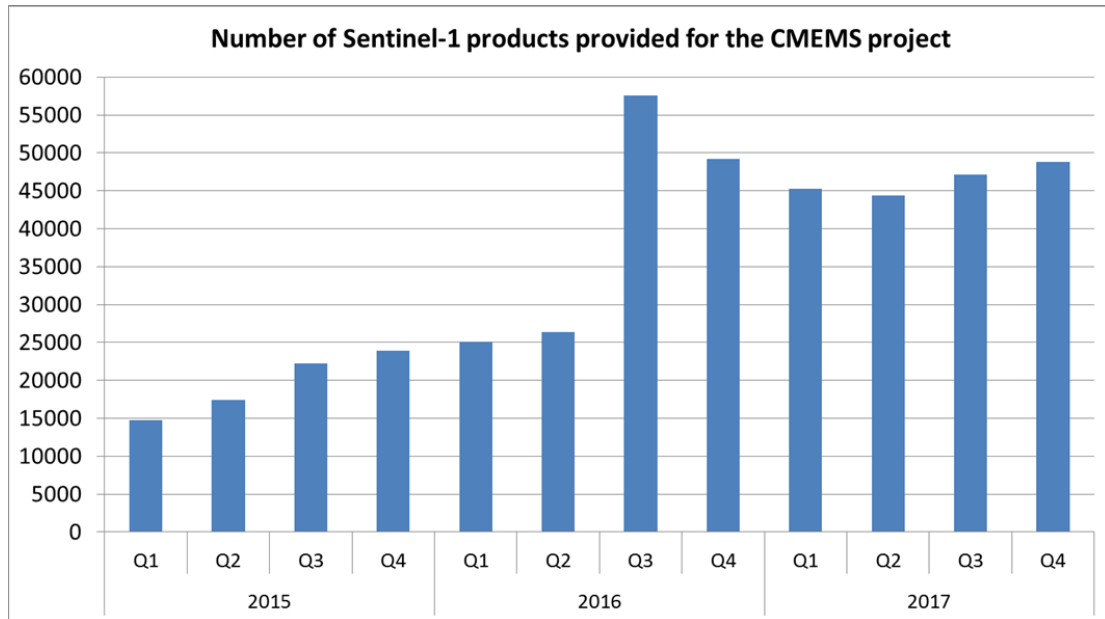


Fig. 8: Number of Sentinel-1 products provided for the CMEMS project (per quarter, 2015-2017)

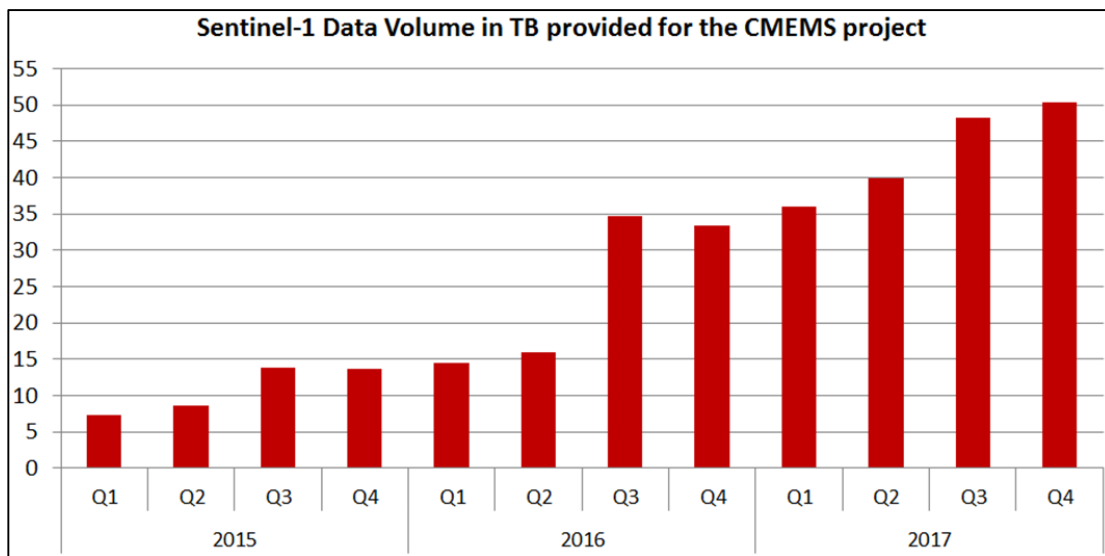


Fig. 9: Sentinel-1 Data Volume in TB provided for the CMEMS project (per quarter, 2015-2017)

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