

# Heritage Missions

## Long Time Series of EO Data

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13<sup>th</sup> Climate Change Initiative Colocation Mtg  
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# What are Heritage Missions?

All no longer operational EO Missions for which ESA archives, manages, valorises and distributes data

Data are covered by the *Heritage Space Programme* starting five years after end of satellite operations or agreement with the 3<sup>rd</sup> party operator

## ESA's Heritage Space Programme

- Preserves, keeps accessible and curates
- 40+ years of Earth Observation heritage data
- 150+ ESA and Third Party heritage missions & ESA dedicated EO Campaigns data from mid 70's

## Heritage data provide the capability to:

- Look back in time
- Understand changes affecting our planet
- Shape our actions and future





# Earth Observation Heritage Missions





ERS-1



ERS-2



Envisat













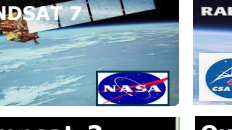


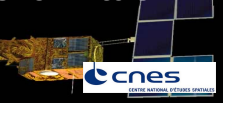










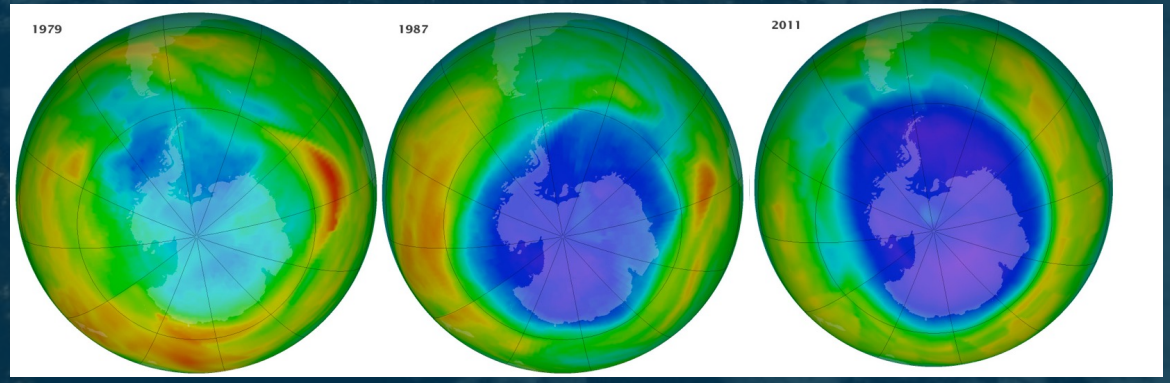
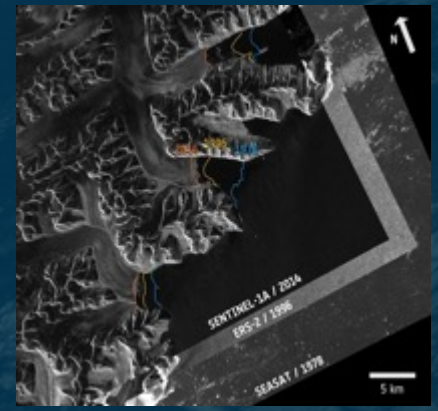
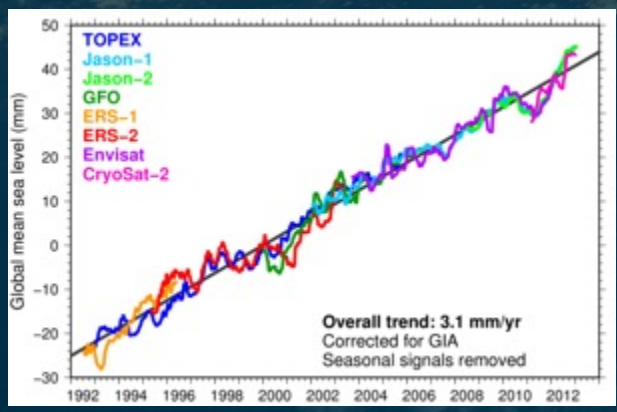
GOCE

ESA Heritage Missions




EO Campaigns

 HCMM	 Nimbus 7	 MOS-1/1b	 JERS-1	 LANDSAT 1-2-3	 MODIS Terra/Aqua	 IRS-P3
 Quickscat	 SEASAT	 ADEOS-1	 ALOS-1	 LANDSAT 4-5	 LANDSAT 7	 RADARSAT-1
 Ikonos-2	 SPOT 1 to 5	 Orbview-2 SeaWiFS	 POES AVHRR 7 to 17	 Komsat-1	 Komsat-2	 QuickBird-2
 IRS-1C/1D	  Thematic Collections		ESA Heritage Third Party Missions			





# Heritage Data Consolidation (including media transcription) & Archiving

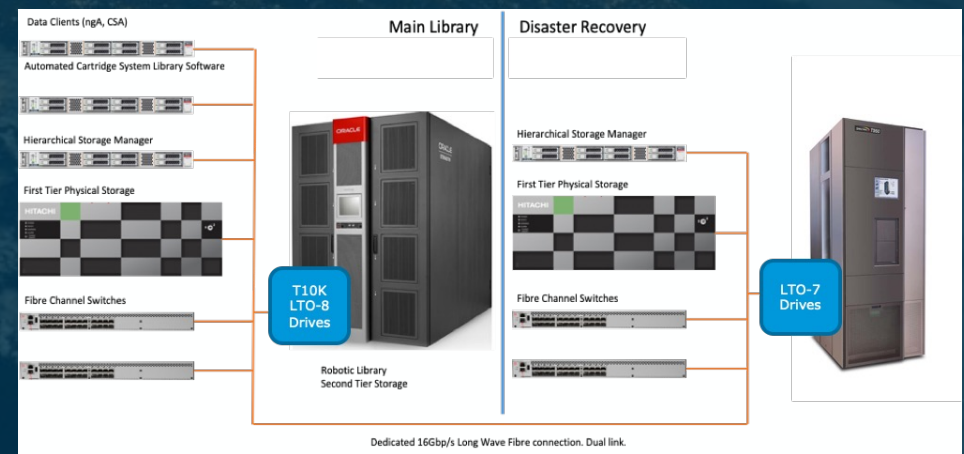
**All EO heritage missions: data & information *consolidation, archiving/preservation to prevent loss***



ERS SAR Master consolidation overall results	2016	2022
Estimated completeness ERS-1 (data coverage vs recorded unavailabilities)	82%	95%
Estimated completeness ERS-2 (data coverage vs recorded unavailabilities)	88%	97%

Sensor / Type of product	Estimated completeness % (data coverage vs recorded unavailability's)
RA / ERAC	97.82%
MWR / EMWC	97.83%
SWM / EWAC	93.56%
WSC / EWIC	96.06%
ATSR-1 / RATSr	99.50%
Telemetry / EGH	96.69%

Sensor / Type of product	Estimated completeness % (data coverage vs recorded unavailability's)
RA / ERAC	96.53%
MWR / EMWC	97.56%
SWM / EWAC	84.62% (*)
WSC / EWIC	86.16% (*)
ATSR-2 / EATC-2	91.51%
GOME / EGOC	98.95%
Telemetry / EGH	82.74%





**High priority missions: *valorisation* activities to facilitate data exploitability & usability, and generation of *few Fundamental Data Records (FDRs)***

- Improve data quality (e.g. new algorithms, new auxiliary files)
- Align heritage missions datasets to new missions (e.g. Sentinels) using new IPFs / algorithms to generate long time data series
- Change data format to facilitate usability and better exploit modern technologies/tools (e.g. Data Cubes)
- Ensure compliance to CEOS Analysis Ready Data (ARD) specifications
- Generate new products

Mission	Instrument	Product type	
ERS	AMI/SAR	SAR_IMM_1P	
ERS	AMI/SAR	SAR_IM__BP	
ERS	AMI/Scatterometer	WSC_ASP_15	
ERS	AMI/Scatterometer	WSC_ASH_2P	
ERS	AMI/Scatterometer	WSC_ASN_2P	
ERS	AMI/Scatterometer	WSC_HEY_1P	
ERS	AMI/Scatterometer	WSC_UWI_2P	
ERS	ATSR-1/2	ATS_TOA_1P/AT_1_RBT	
ERS	ATSR-1/2	ATS_TOA_1A	
ERS	AMI/SAR	SAR_IMM_1P	Snow-CCI

*ERS Full (Re)processing activities (example)*



# Heritage Data and Information Discovery and Access



All EO heritage missions: *Discoverability/accessibility* possibly with same performance as new missions

- Online access through ESA dissemination systems
- Open and free according to ESA EO Data Policy
- User Registration and acceptance of Terms and Conditions of use
- Restrained dataset access initiated via *Data Service Requests*
- Visualization and analysis tools

DATA ACCESS <https://earth.esa.int/eogateway/missions/heritage-missions>



- **ERS and Envisat** missions duration: 1991-2012
- *More than 2 Petabytes of data*
- *Two decades of global change records*



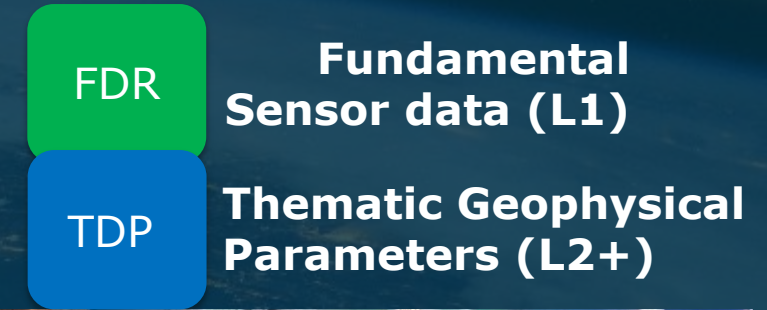
## **Ongoing activities:**

- *Recovery of additional data to fill gaps and extend ESA data holdings*
- *Data quality improvements and format alignments with Sentinels missions*
- *Generation of Fundamental Data Records (FDR) & Thematic Data Products (TDP)*
- *Generation of Analysis Ready Data (ARD) in alignment with Sentinels missions*



# ESA Fundamental Data Records (FDR4\*) projects

- Addressing valorisation of heritage assets (e.g. ERS-1/-2, Envisat)
- Generating ESA-specific multi-mission long-term datasets
- Relevance for applications and ESA CCI
- Two projects started in 2019 with 3-year duration
  - for Altimetry (FDR4ALT)
  - for Atmospheric Composition (FDR4ATMOS)



## Key aspects

- Pursue harmonization of different sensors and improve calibrations
- Uncertainty characterization based on EO metrological guidelines
- Target a wider user community
- Allow interoperability and continuity towards current & future projects



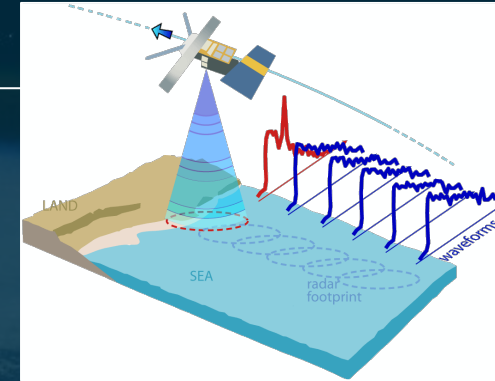
Completion and data opening to users  
by Q4 2023

Follow-on activities will be  
started in 2024



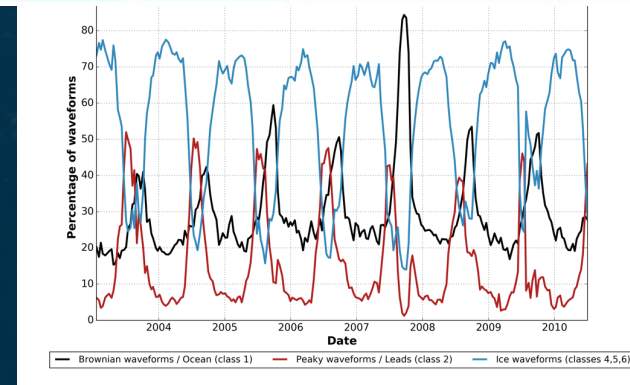
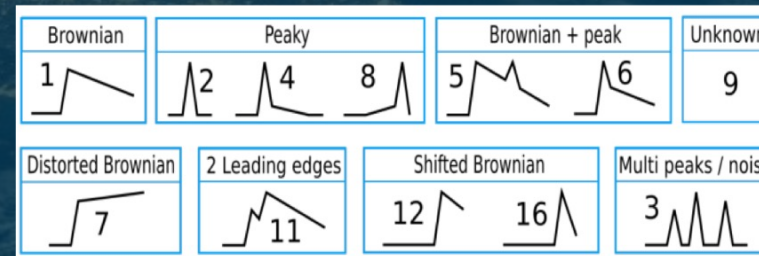
# FDR4ALT

- **ERS-1/-2, ENVISAT Altimeters and Radiometers**
- **2 FDRs** for Altimetry and Microwave Radiometry
- **6 TDPs** for different Earth surfaces and for different user communities
  - Best state-of-the-art algorithms and corrections adopted
  - Many **synergies exploited** (EMIR, FIDUCEO, REAPER, CCIs, C3S, CRYO-TEMPO, ...)
  - Clear **improvements respect to existing datasets**



## 2 ERS-1, ERS-2 & Envisat FDRs !

- **ALT FDR** - Harmonized time series of altimeter data. Instrumental effects corrected (e.g. pulse-blurring). Added waveform classification (first time for ERS), quality flags, distance to coast as for S3 products
- **MWR FDR** - Harmonized time series at native observation rate (7Hz). All calibrations and instrumental corrections revised (e.g. sidelobe, radiometric models, ...). E2 coverage of post-tape failure period



**Ocean & Coastal**



**Inland water**



**Land ice**



**Sea ice**



**Atmosphere**



**Ocean Waves**



- **Task A:** Correction of **SCIAMACHY** degradation + incorporation of Moon measurements
- **Task B:** Creating FDRs from **ERS-2 GOME and Envisat SCIAMACHY** (17 years of data, since 1995)
- **3 FDRs** (calibrated reflectance / irradiance for UV-VIS-NIR) + **SCIAMACHY L1/L2 reprocessing** (NetCDF)

▪ The project focuses on production and validation with **clear improvements vs current ESA reference products**

	Spectral Region (nm)	Target
UV	325 - 335	O <sub>3</sub>
	312 - 326	SO <sub>2</sub>
VIS	425 - 497	NO <sub>2</sub>
NIR	750 - 780	Cloud Parameters

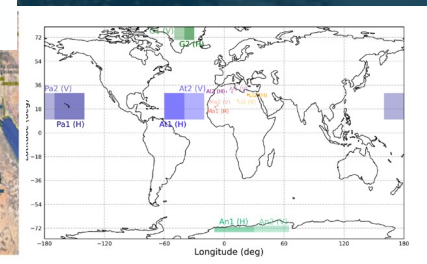
**Task B**

- **Harmonisation** of spectrally highly resolved radiances never done (done at Level 2, i.e. ESA CCI / GOME Evolution project)
- Challenges for different orbits / local times / illumination conditions / resolutions  
**No exact co-locations -> Cross-calibration based on (limited) matching scenes**

- FDRs benefit DOAS-type L2 retrievals (instrument agnostic)
- Ambition of continuity with other **GOME-like** instruments



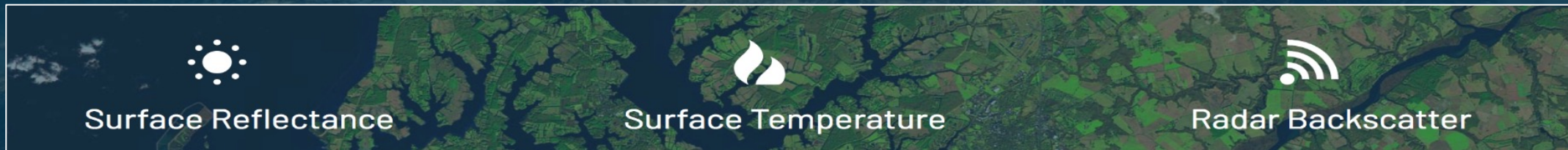
**Over oceans & ice**





# CEOS-ARD ANALYSIS READY DATA

CEOS: « Analysis Ready Data are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets »



## CEOS-ARD SR

Sentinel-2  
Proba-V  
MERIS

## CEOS-ARD ST

Sentinel-3  
(A)ATSR

## CEOS-ARD NRB

Sentinel-1  
(A)SAR

Pilot activities completed

Follow-on activities will be started in 2024



# ERS-1, ERS-2 and Envisat – reprocessing status

## OPTICAL SENSORS

### **MERIS** - Processor MEGS9 - 4<sup>th</sup> reprocessing completed in 2020

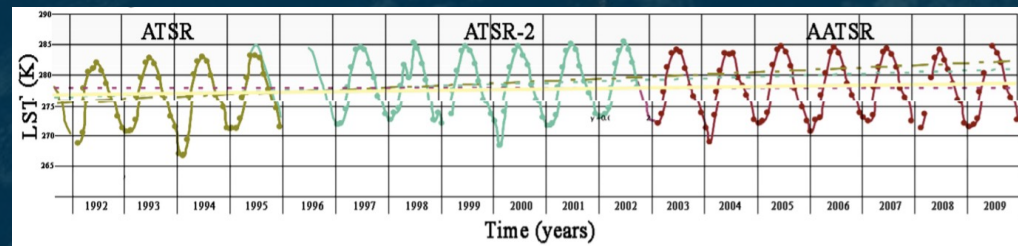
- Harmonisation with Sentinel-3 OLCI
- Ortho-geolocation (toward ARD)
- Calibration
- Level-2 improvement, incl. pixel identification, cloud screening, water vapour, atmospheric transmission, ECMWF ERA-interim data....
- Uncertainties

ARD  
Reprocessing  
in 2024

### **(A)ATSR** - Processor Fast v2.05 - 4<sup>th</sup> reprocessing L1B completed

### **ATSR-1 and ATSR-2** - Processor Fast v2.05 - 4<sup>th</sup> reprocessing L1B completed

- Harmonisation with Sentinel-3 SLSTR
- Ortho-geolocation (toward ARD)
- Calibration, incl. 12 micrometers correction
- Cloud Masking
- Uncertainties



Land Surface Temperature ATSR-1, ATSR-2, (A)ATSR time series

FDR4ATSR Project  
under preparation



# ERS-1, ERS-2 and Envisat – reprocessing status ATMOSPHERIC SENSORS

## **GOMOS** - Processor L1&L2 ALGOM - Reprocessing completed in 2017

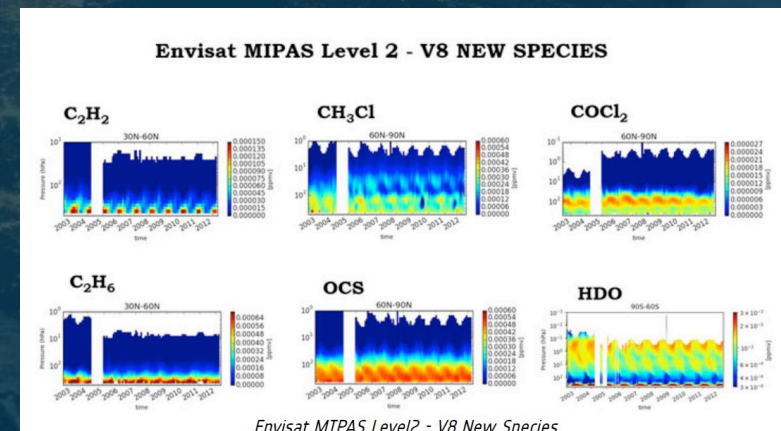
- Incl. New L2 UFP – User Friendly Product – in NetCDF format

## **MIPAS** - Processor L1 MICAL v8.03 & L2 ORM v8.22 - Reprocessing completed

L1 available since 2019 – L2 available since July 2021

- Harmonization with S5 - TROPOMI
- New detectors non-linearity coefficients
- Use of accurate DORIS Precise Orbit State Vectors
- Upgraded pointing correction model
- Six additional species: C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>6</sub>, COCl<sub>2</sub>, CH<sub>3</sub>Cl, OCS and HDO

No further activity planned



## **GOME (ERS-2) and SCIAMACHY (ENVISAT)** improvement and reprocessing

Next activities in FDR4ATMOS FO



# ERS-1, ERS-2 and Envisat – reprocessing status

## ACTIVE and PASSIVE RADAR

**ENVISAT ASAR** - Processor PF ASAR V6.03 - Online processing with On-The-Fly (OTF) system in operation

**ERS-1/ERS-2 SAR** - Processor PF ERS V6.05 - Online processing with On-The-Fly (OTF) system in operation

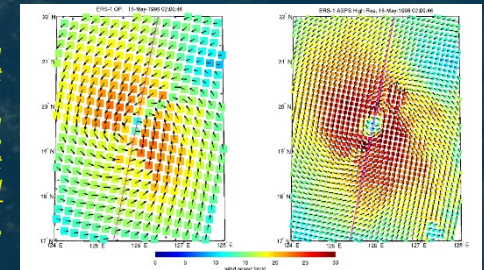
Processor improvements ongoing,  
ARD pilot projects completed

Bulk processing performed to support  
CCI projects (e.g. SNOW)

**ERS-1/ERS-2 SCATT** - ASPS v10.04 L1/L2 - Reprocessing completed and data available to users in 2016

- Incl. Re-fined calibration of the 3 backscattering measurements, CMOD5N geophysical forward model, Sea-ice probability, sea-ice flag

ERS-1 observation of Typhoon Bart occurred on May 1996: left picture is from ERS-1 operational product (UWI) with 25 km grid spacing; right image is from high resolution product (ASPS H) with 12.5 km grid spacing (from 2017 EUMETSAT Meteorological Satellite Conference – S. Pinori)



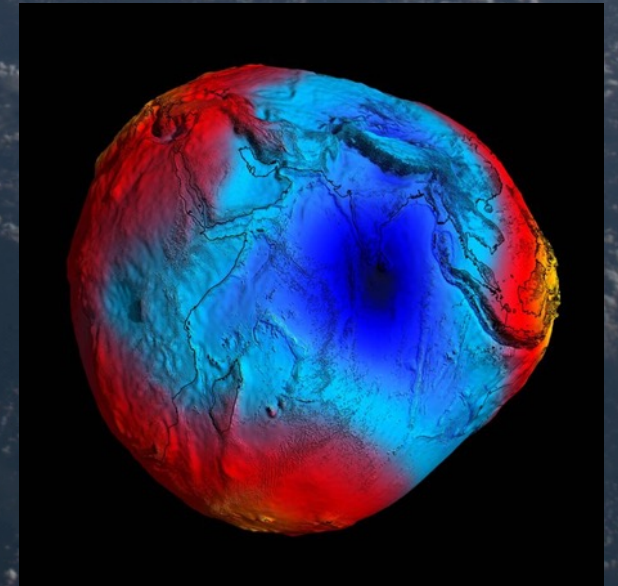
**Radar Altimeter and MicroWave Radiometer (MWR)**

Next Activities in FDR4ALT FO



## **GOCE** is ESA's first Earth Explorer Mission covered by the Heritage Space Programme

- *First gradiometer in space*
- *Best geoid ever*
- *Mission duration: March 2009 – October 2013*
- *More than 2 TB of data*
- *Latest reprocessed Level 1b and Level 2 products available to users*





## Living Collection, 80+ Campaigns currently included

- *ground-based*
- *ship-borne*
- *balloon-borne*
- *airborne*
- *small satellite field experiments that validate orbiting ESA EO satellites and support future mission development*



Full list of ESA EO Campaigns Data Collections available on [ESA Earth Online](#)

*Online access upon registration*



- *ALOS (AVNIR/PRISM/PALSAR)*
- *DMC 1<sup>st</sup> Generation*
- *IKONOS-2*
- *IRS-1C/1D*
- *JERS-1 (SAR/Optical)*
- *Kompsat-1/2*
- *Landsat 1-7 Series (MSS, TM)*
- *MOS-1/1b*
- *NOAA POES AVHRR*
- *QuickBird-2*
- *IRS-P3*
- *SeaSat*
- *SPOT-1 to 5*

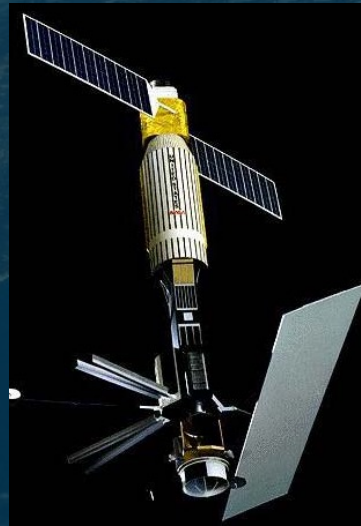


**Full list of Heritage TPM ESA  
Data collections available on  
[ESA Earth Online](#)**



# JERS-1/SEASAT/ALOS – L-BAND RADAR

The complete **SEASAT and JERS-1 SAR** datasets available at ESA have been reprocessed and aligned to the **ALOS PALSAR** dataset producing a long time series of coherent data spanning from 1978 to 2011 (with gaps between the three missions operational lifetime). These SAR data are now accessible on an open and free basis for all users through ESA.



Reprocessing of **JERS-1 SAR** data with new orbit AUX files ongoing to improve geolocation.

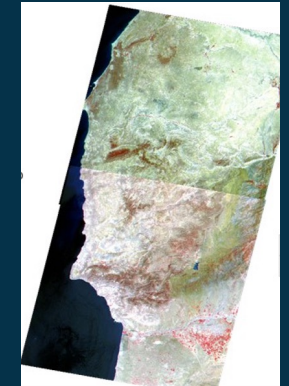
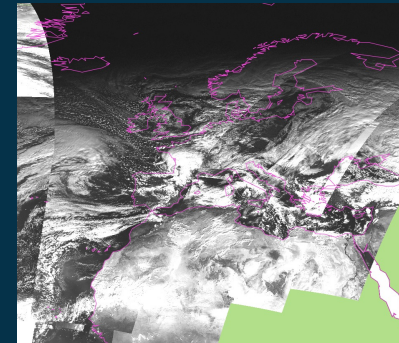


# MOS-1 and MOS-1b - MESSR and VTIR

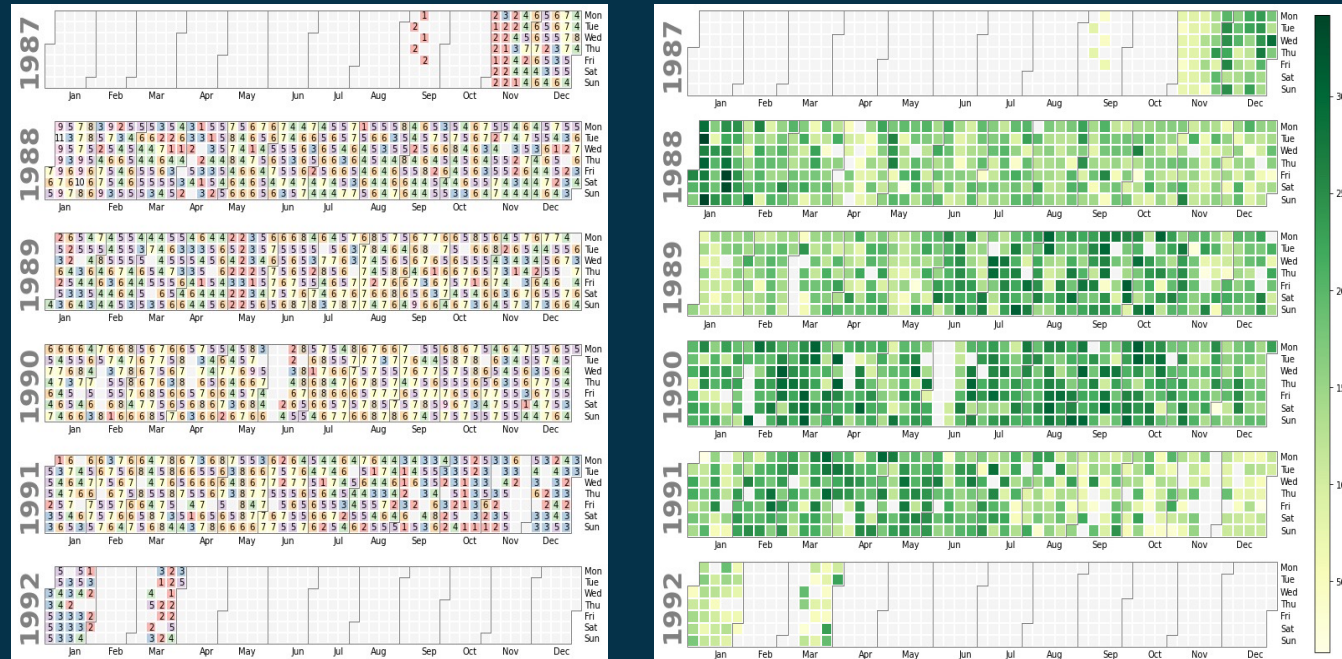
## First MOS-1/1b MESSR and VTIR bulk data processing completed:

- Data over Europe from 1987 to 1992
- Total number of Level 1 MESSR scenes 287179
- Total number of Level 1 VTIR files 7085
- Data release planned by Q4 2023

VTIR scenes (1 band)  
projected on a map



Data set completeness for MOS 1 – MESSR (L0 products, left – L1 scenes, right)



MSRR scenes over West Africa (orbit 16973 acquired on 20 June 1990)

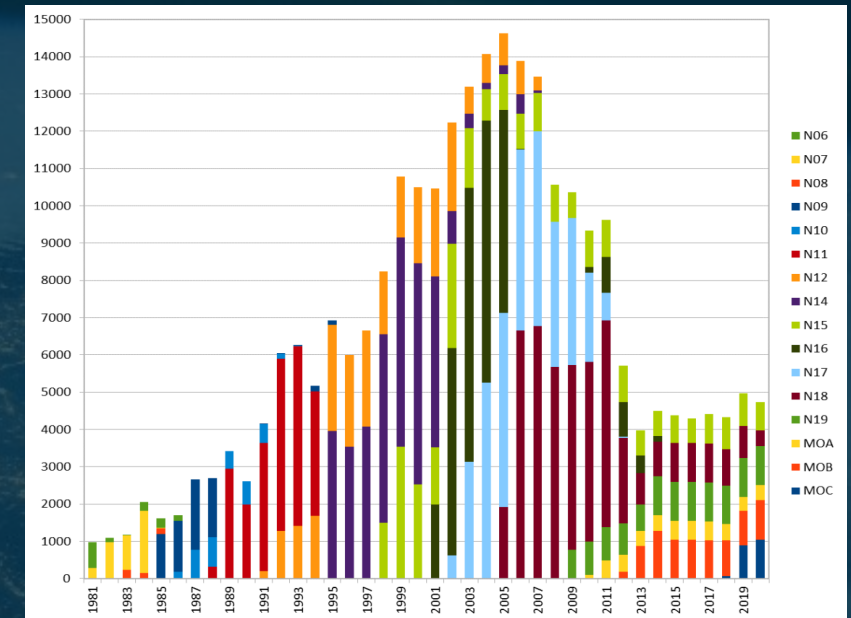
## Data Quality Summary:

- More than 99% of Level 0 processed correctly
- Ground Control Point (GCP) RMSE ~1 km
- Good usage of GCP when scenes not cloudy
- Further improvements identified for implementation in 2024



# AVHRR European Dataset

- Long time series (1981–2021) of **AVHRR** data from different platforms (POES, MetOp)
- Unique source to retrieve ECVs to investigate climate change over last 40 years
- Data from University of Bern, Dundee Station and ESA holdings: **more than 260.000 data products reprocessed to Level-1b and Level-1c**
- In addition ESA holds the full dataset outside Europe from the 1KM project (1992-1998)
- All data **safely archived at ESA** and accessible free of charge via ESA dissemination services
- Extension to better cover Greenland and extend back to 1979 planned in 2024

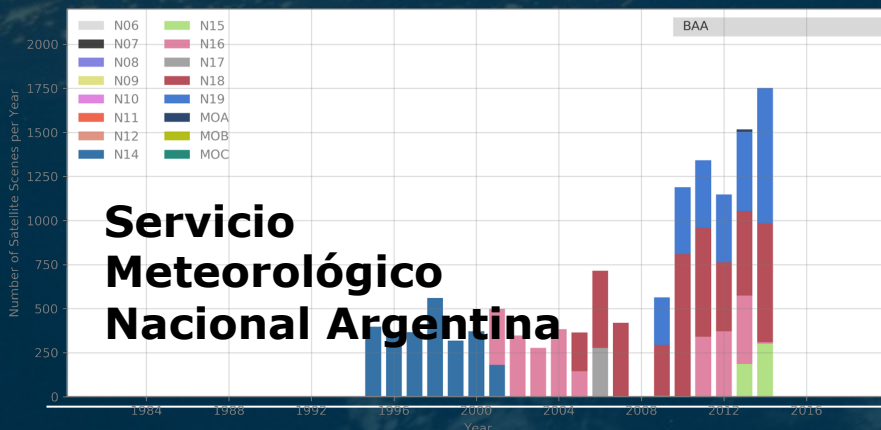
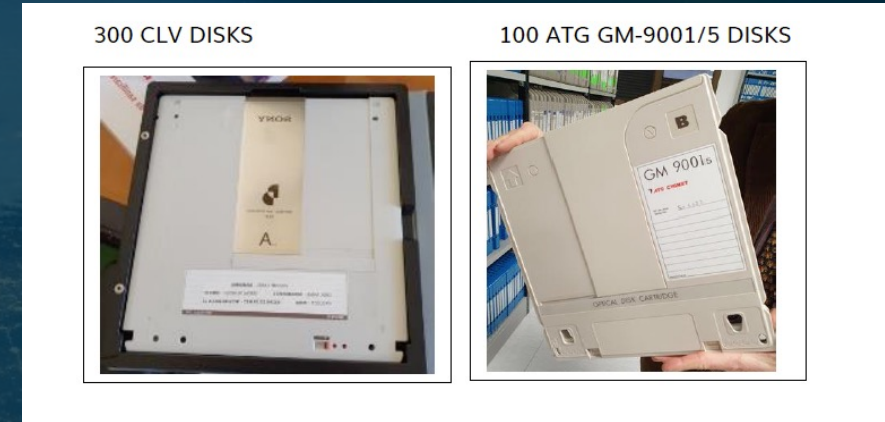


**FDR4AVHRR Project will be kicked off in Q1 2024**



# AVHRR Data Outside Europe

- **Recovery project under ESA lead** ongoing in the frame of CEOS WGISS to unfold and make accessible 1km AVHRR data from regional archives (open and free)
- **ESA transcribing unique data from old media**
- **ESA recovering data outside Europe from other organizations** (focus now on Africa / South America / Pacific - Hawaii, Asia and Australia)
- Objective to reprocess to Level-1b/1c (same as Europe)





- Transcription, processing, and repatriation of the full **IRS-1C/1D multispectral data (LISS-III, WiFS, PAN)** archives at GAF acquired in Neustrelitz **from 1996 to 2005 and covering Europe and northern Africa.**
- Recovery and reprocessing of **IRS-P3 Modular Optoelectronic Scanner (MOS)** data acquired in the **late 90's over Europe** by merging datasets available at ESA and DLR.
- Discussions with USGS to reprocess the full **Landsat 1-5 MSS** data collection to obtain a CEOS Analysis Ready Data specifications compliant product.
- Coordination with CNES to reprocess all ESA **SPOT-1/2** unique data holdings acquired at Maspalomas station and other SPOT data acquired by e-Geos at Fucino in the 90's.
- **Nimbus-7 CZCS** data being transcribed from Optical disks. Recovery project will be started in 2024.



1. ESA Heritage Data Holdings consists of 150+ ESA and Third Party missions & ESA EO Campaigns data from mid 70's → providing a unique capability to look back in time
2. These assets are preserved, maintained accessible (open and free) and curated in the frame of the Heritage Space Programme; Several activities are ongoing to:
  - Recover unique data from old media and private/public entities not providing access
  - Generate new products from heritage data and build long time series with newer missions

→ **Several new datasets accessible by end 2023**

What are CCI projects and climate users community needs/requirements for the recovery / consolidation / reprocessing / reformatting of specific heritage datasets ?

1. Datasets available at ESA
2. Datasets not accessible to users (e.g. from other organizations, commercial, on tapes)

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