

Generation of Long Time Data Series for ESA heritage TPM missions

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Roberto Biasutti (ESA), Sabrina Pinori (Serco for ESA)

EUROPEAN SPACE AGENCY (ESA) HERITAGE SPACE PROGRAMME (1/2)



The **ESA Heritage Space Programme** (hereafter “Heritage”) responds to the mandate of preserving, making accessible, and valorizing ESA heritage space data and associated information holdings generated by payloads and instruments on-board space platforms from ESA and ESA-managed Third Party Missions with a strong focus on their accessibility and exploitability. Over 40 Earth Observation missions and 80 EO campaigns are included in Heritage.



As part of the programme activities, a particular focus is put on the recovery, reprocessing and the generation of long time series of coherent data in support of climate change monitoring activities, needs and related applications.



Heritage consists of five main streams of activities in EO

1. Heritage Space ESA Inter-directorate Joint Activities
2. EO Heritage Space International Cooperation and Outreach
3. EO Space Data Preservation Systems and Services
4. EO Heritage Space Missions Discovery and Access
5. EO Heritage Space Missions Specific Activities (including data preservation, consolidation, valorisation and Fundamental Data Records)



About THIRD PARTY MISSIONS PROGRAMME

What are TPMs?

Third Party Missions are earth observation missions that are not owned or operated by ESA. The agency has an agreement with these third parties to distribute data products from their missions to scientific users

History?

ESA's TPM arrangement has been operating for over

45 YEARS

providing EO data to users in **Europe** and **worldwide** for research and pre-operational applications development

How many?

TPMs currently include over 60 instruments on more than 50 missions

<60 **50⁺**
INSTRUMENTS MISSIONS



How?

TPM datasets are distributed under specific agreements with the owners or operators of the mission – some sets are available under the free dataset policy, requiring only a fast registration, others are part of a restrained data set and require the submission of a project proposal or service request

Benefits?

Data is offered from a large number of international missions through a single programme. One of the criteria for selecting new missions is that they utilise instruments that offer similar data to those acquired by ESA missions, contributing to a wide range of data that may be used together. Other criteria include degree of innovation, opportunity for new international collaboration and experience to be gained for future missions

Innovation?

IN 2018 ESA changed the agreements with the commercial TPM data providers in order to also include start-ups and entrepreneurs in incubators, to access the data. This greatly supports ESA's Technology Transfer Programme Office (TTPO)

Data Access?

<https://earth.esa.int/eogateway/search?category=Data>

Heritage covers data from ESA and Third Party Missions (TPM), nominally starting 5 years after the end of life of the mission (or 5 years after end of the agreement for TPMs).

In accordance with the CEOS Core standard documents defined in cooperation with international partners and organizations, the following set of activities is implemented:

- ❖ **Assessment** of archived data and information holdings versus “Preserved DataSet Content Best Practice” which defines all the elements to be preserved in any mission phase;
- ❖ **Consolidation** of Level-0 (or Level-1 if Level-0 is not available) datasets (and associated information), and generation of two copies to be stored in two different locations.
- ❖ **Ingestion** in robotic tape libraries in the format of Open Archival Information System (OAIS) standard Submission Information Packages (SIPs).
- ❖ Full datasets **reprocessing**, when feasible, for alignment with the most recent or future missions.
- ❖ Ensuring basic **discoverability** and dissemination through ESA standard systems.

SEASAT (1978-1978) Recovery and Reprocessing (1/2)

Launched by NASA/JPL was the first remote sensing satellite oceans with the **first** Synthetic Aperture Radar (SAR) onboard. Its data over Europe were acquired by the ESA in the Oakhanger-UK station.

The activity started with the recovery of Seasat data holdings available at ESA acquired during the short operational time span of the mission (August to October 1978). During its brief lifetime, the satellite acquired information on ocean phenomena, such as surface and internal waves, currents and sea-surface winds for the study of ocean circulation. It also captured imagery of glaciers, sea ice, coastal regions, volcanoes, forests and land cover.



These data (all Level-0 acquired over Europe and a few higher-level products) were migrated in the past years from old technology media to new ones and were stored, together with some supporting documentation, at ESA-ESRIN (Italy) and at Deutsches Zentrum für Luft-und Raumfahrt (DLR).

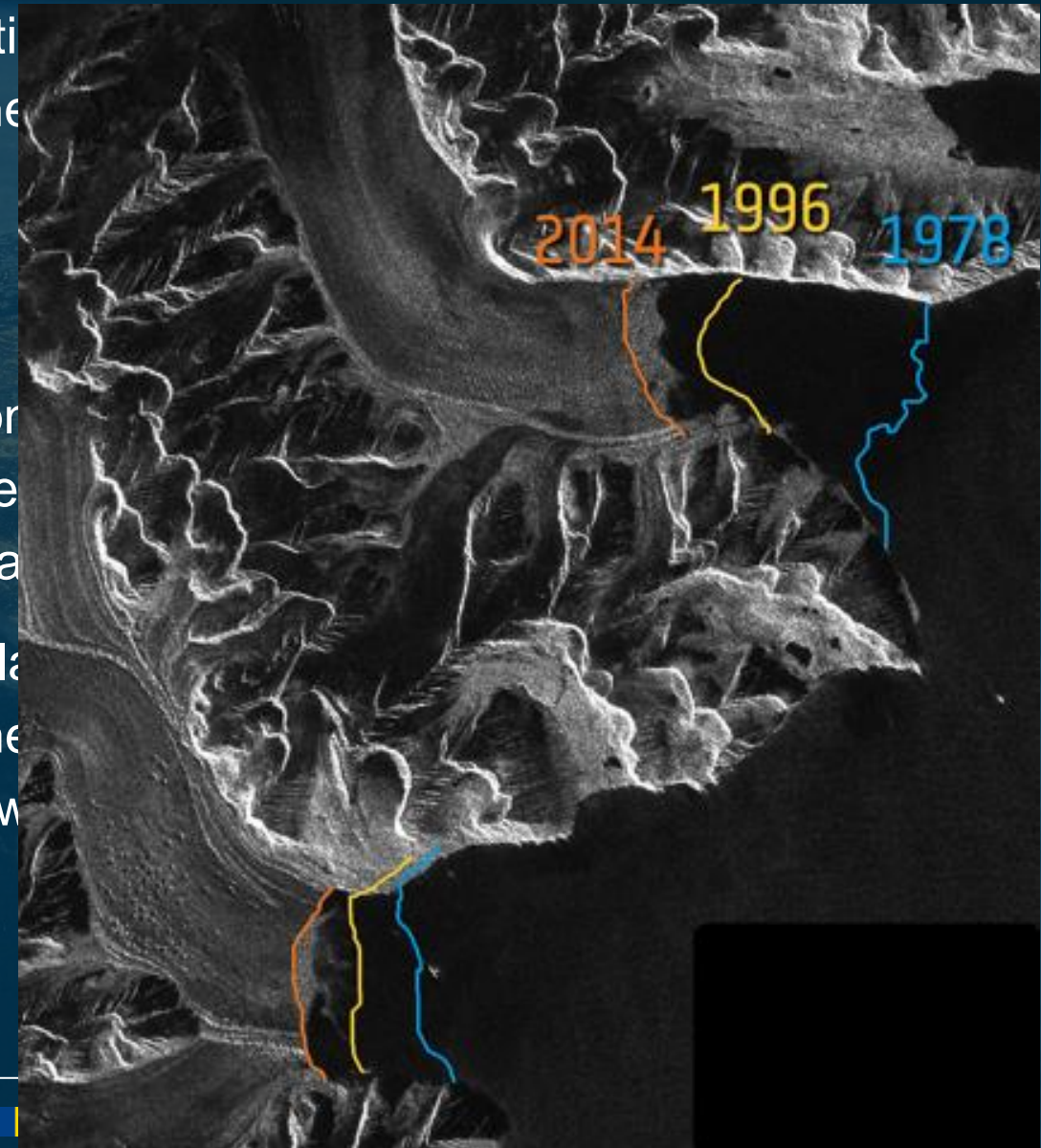
SEASAT Recovery and Reprocessing (1/2)



Level-1 recovered products were used in a pilot application of SEASAT data over Greenland in combination with data from ERS-2 and Sentinel-1 to assess the usefulness of this recovery exercise. The project was the first of the Observation space-borne dataset recovery.

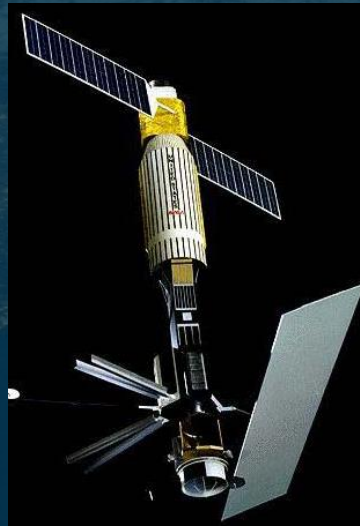
Comparing data from three generations of radar missions – Seasat, ERS and Sentinel-1 – the retreat of two large glaciers in SE Greenland over a 36-year period is evident in the side image.

The glaciers show significant retreat, with the upper glacier retreating by about 5.5 km over the past 36 years. This melting is contributing to sea-level rise and the release of more freshwater into the North Atlantic.



JERS-1/SEASAT/ALOS – L-BAND RADAR

L-band SAR is particularly useful for geoscientific research on wetland and forest change mapping. The capability to penetrate canopy with long radar wavelength (L-band SAR) allows the monitoring of flooded vegetation, the retrieval of aboveground biomass, and the estimation of soil moisture.



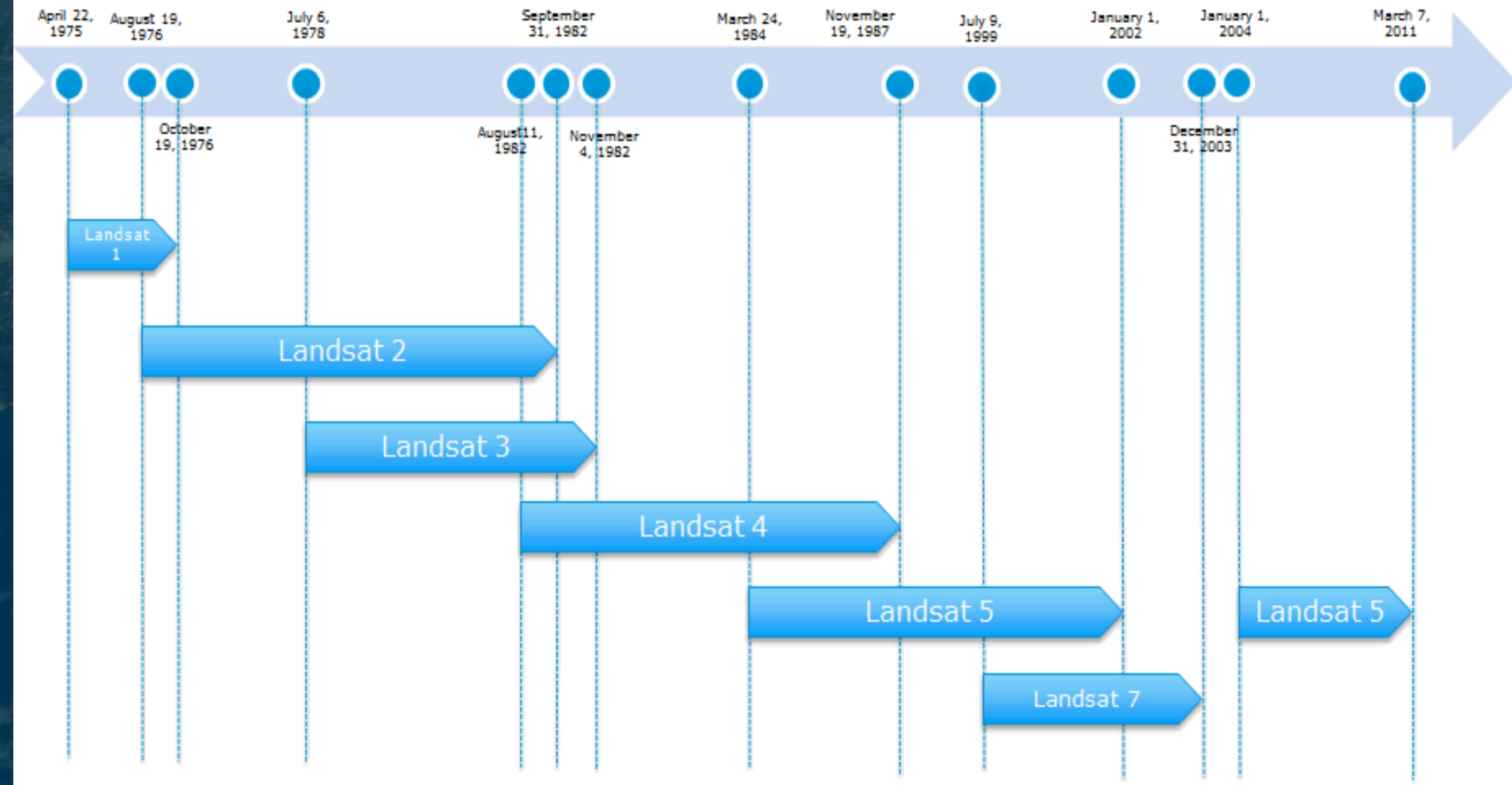
The complete SEASAT and JERS-1 SAR datasets have been reprocessed and aligned to the more recent ALOS PALSAR dataset producing a long time series of coherent data spanning from 1978 to 2011 (with gaps between the three missions operational lifetime). **These SAR data are now accessible on an open and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

LANDSAT LONG TIME DATA SERIES

NASA-NOAA-EOSAT-USGS

Landsat satellites' series are the world's longest running system of satellites for optical remote sensing of land, coastal areas, and shallow waters (first satellite launched in 1972).

- ESA has been acquiring LANDSAT data since 1975

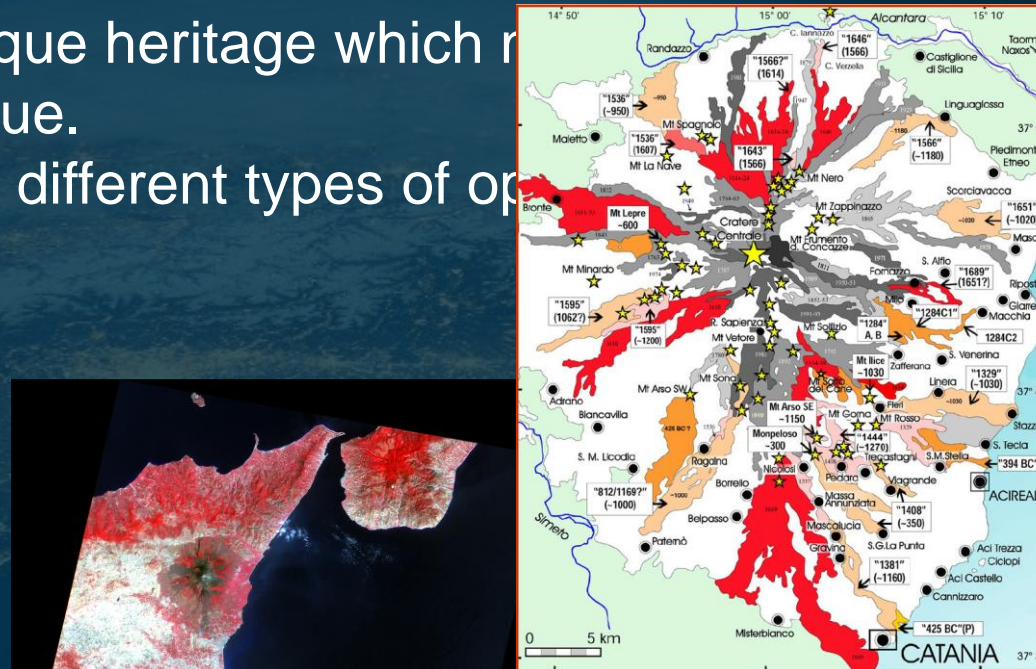


LANDSAT LONG TIME DATA SERIES

The ESA Landsat dataset is a unique heritage which has been created and valorised for its peculiarity and historical value.

Landsat satellites hosted onboard different types of optical and thermal emission sensors:

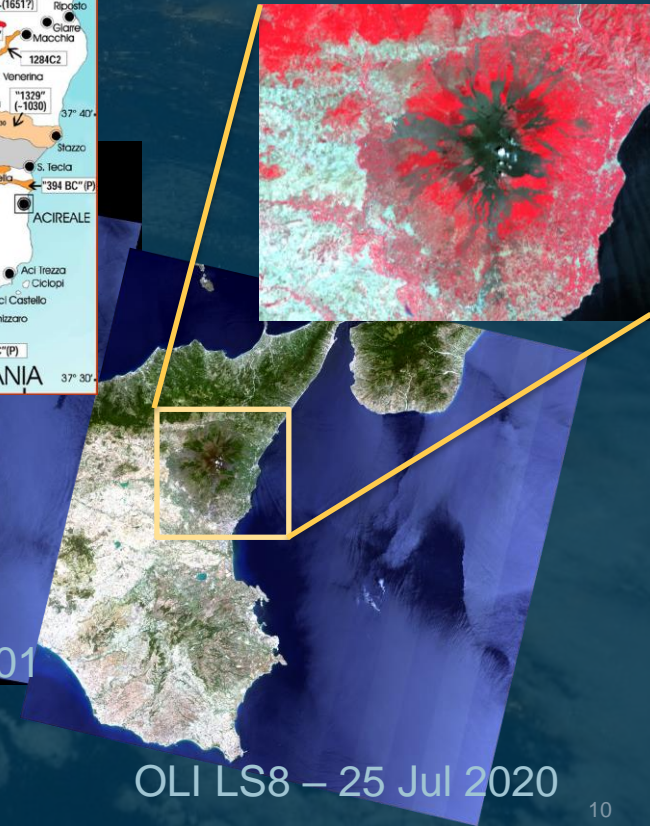
- **MSS** (Multi-Spectral Scanner) instrument with only 4 bands in the VIS-NIR;
- **TM** (Thematic Mapper) and **ETM+** (Enhanced Thematic Mapper Plus), 7 and 8 spectral bands respectively;
- **OLI-TIRS** (Operational Land Imager - Thermal Infrared Sensor) with 9 bands in VIS-NIR-SWIR and 2 bands in the Thermal Infrared



MSS LS4 – 29 Aug 1983



ETM+ LS7 – 13 Jul 2001

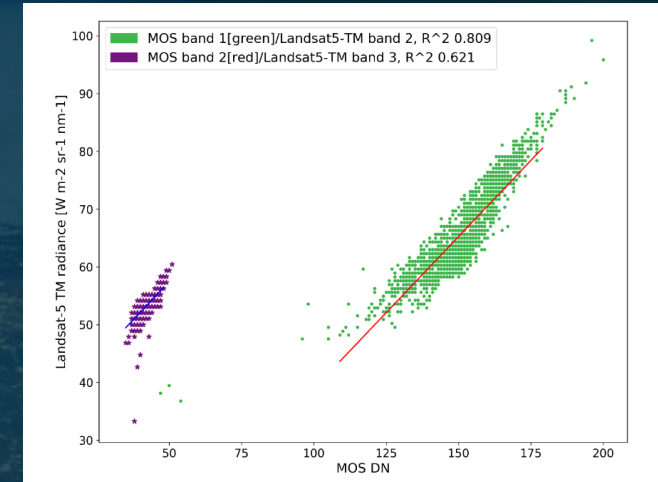


OLI LS8 – 25 Jul 2020

- Major improvements have been conducted regarding the MSS processing, both radiometry and geometry had been strongly improved vs the older ESA processor. The processor uses the information of the full strip in order to process a scene, partially overcoming in this way the lack of auxiliary data (Payload Control Data - PCD) quite often corrupted or not present.
- The product generation system of MSS has been aligned to the TM and ETM+
- We are planning a new data reprocessing in collaboration with USGS with the following goals
 - have a common data format and metadata
 - Generate an ARD MSS product
 - Be able to release more data (in the processing we had around 7% of failures, mainly due to location issues)

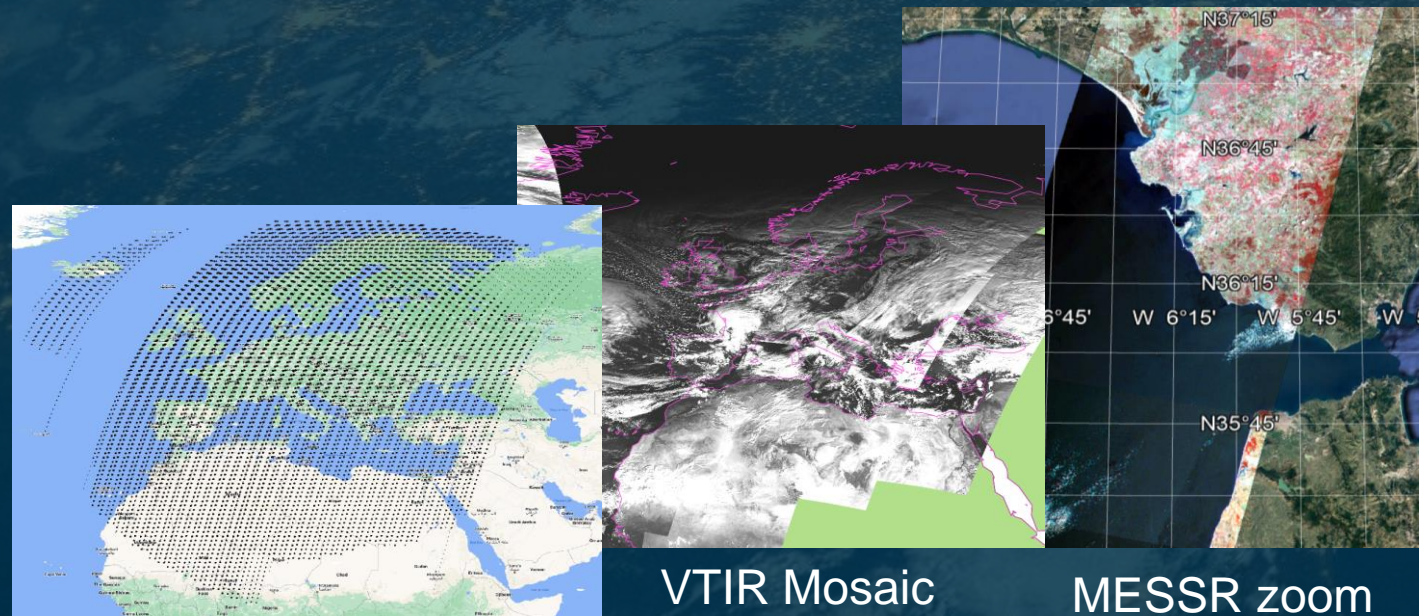
MOS-1 AND MOS-1b

Multispectral Electronic Self-Scanning Radiometer (**MESSR**) and Visible and Thermal Infrared Radiometer (**VTIR**) products from the National Space Development Agency of Japan (NASDA) Marine Observation Satellites (MOS-1 and -1b) were received by ESA between 1987 and 1993.



Regression between the MOS (MESSR) digital numbers and Landsat-5 TM radiance data for band 1/2 and 2/3 combinations.

The first-ever full processing of ESA MOS-1/1b MESSR and VTIR data holdings into Level-1 products has been successful and shows very good results in comparison to Landsat-5 TM radiometry, further work is ongoing.



MOS MESSR data distribution



AVHRR TIMELINE

Data of the Advanced Very High Resolution Radiometer (AVHRR) onboard many National Oceanic and Atmospheric Administration (NOAA) TIROS satellites – and since 2006 on EUMETSAT MetOp-satellites, is the only source to provide long time series based on an almost unchanged sensor of the last 40 years with daily availability and 1.1 km spatial resolution.



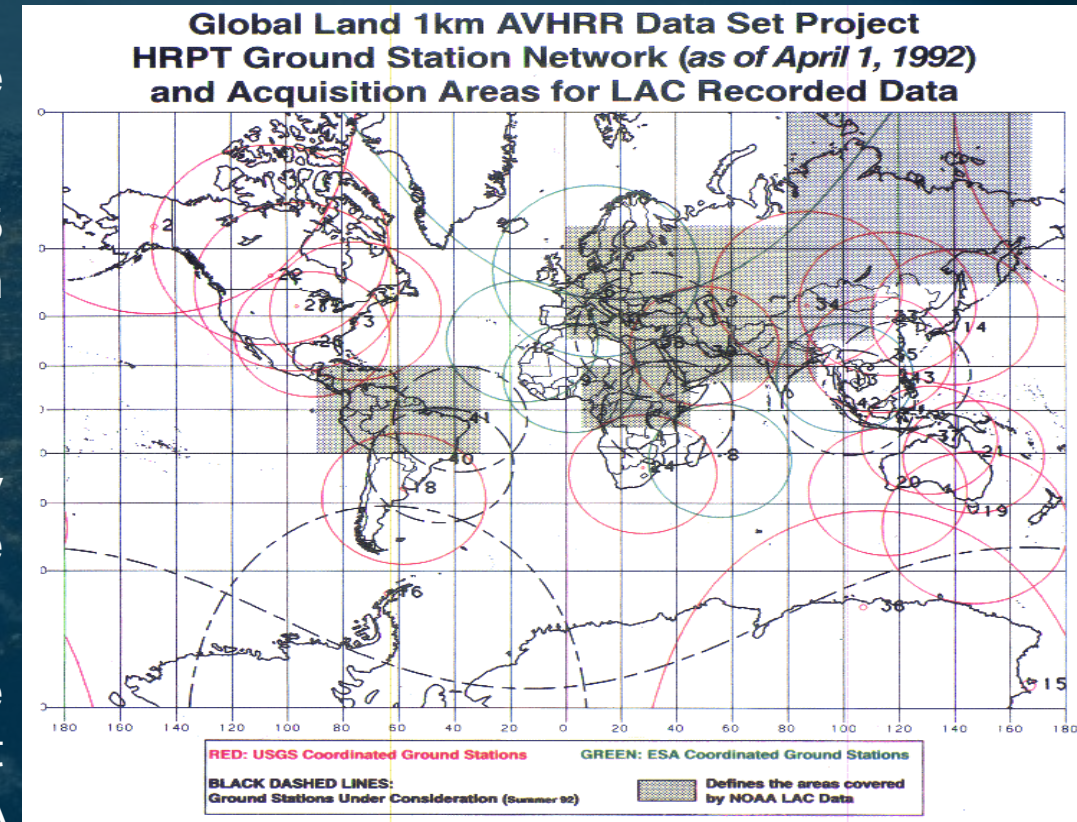
The project covered the following main objectives:

- **Generate an AVHRR European Master Data Set** (Level-0 and Level-1) based on the harmonisation and combination of ESA & University of Bern (UniBern) AVHRR holdings (“Core Data Set”), complemented in gaps with data from other agencies and organisations;
- **Assess** benefit to supplement the AVHRR European Master Data Set with the alignment of the worldwide data set collected in the frame of the “1Km” Project carrying out a technical feasibility analysis of the reprocessing effort and cost;
- **Consolidate** the preserved data set composition for the AVHRR European Master Data Set and collect or generate the relevant information and documentation with relevant metadata as a complement to the AVHRR Data Records;
- **Validate** the AVHRR European Master Data Set reprocessing baseline and reprocessed Data Sets with data experts; Data Set promotion and outreach related activities.

1 Km Project Data: 1st April 1992 - end 1999

USGS, NOAA, ESA and other non-US AVHRR receiving stations collected a global land 1-km multi-temporal AVHRR data

- 23 stations worldwide plus the NOAA local area coverage (LAC) on-board recorders.
 - The global land 1-km AVHRR dataset is composed by 5 channels, raw AVHRR dataset at 1.1 km resolution from NOAA-11 and NOAA-14 satellites covering land surfaces, inland water and coastal areas.
- The 1km project dataset acquired by ESA stations responsibility has been aligned with the Level-1b Master Dataset over Europe and is now accessible through the ESA dissemination system.
- Stitched data from stations under USGS responsibility are available at ESA but not suitable for reprocessing and alignment to European Master Dataset. Coordination ongoing with NOAA and USGS to retrieve the 31,597 original (non-stitched) data.



AVHRR Time Series - Essential Climate Variable (ECV)

The World Meteorological Organization (WMO) reported that a time series of at least 30 years is needed to retrieve statistically significant changes of ECVs. Considering that these are extended periods of time, only a limited selection of satellites and sensors can be used for global monitoring – one of these is the AVHRR onboard of NOAA satellites (since 1978) and on the EUMETSAT platform Metop (since 2006). Datasets from AVHRR sensor can contribute significantly to these listed ECVs.

The Essential Climate Variables	
Domain	Essential Climate Variables
Atmospheric (over land, sea and ice)	Surface: Air temperature, precipitation, air pressure, surface radiation budget, wind speed and direction, water vapour.
	Upper air: Earth radiation budget (including solar irradiance), upper air temperature (including MSU radiances), wind speed and direction, water vapour, cloud properties.
	Composition: Carbon dioxide, methane, ozone, other long-lived greenhouse gases, aerosol properties.
Oceanic	Surface: Sea surface temperature, sea surface salinity, sea level, sea state, sea ice, currents, ocean colour (for biological activity), carbon dioxide partial pressure.
	Sub-surface: Temperature, salinity, currents, nutrients, carbon, ocean tracers, phytoplankton.
Terrestrial	River discharge, water use, ground water, lake levels, snow cover, glaciers and ice caps, permafrost and seasonally-frozen ground, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), biomass, fire disturbance, soil moisture.

- The emergence of large volumes of data raises new issues in terms of discovery, access, exploitation, and visualisation of data, with profound implications on how users do “data-intensive” Earth Science.
- The time series projects, managed by ESA, have outlined the importance of assuring that long-term series datasets are:
 - ✓ **homogeneous** (data gap consolidation during operations or at mission end);
 - ✓ **consistent** (inter-sensor consistency is one of the main requirements from the user community using long-term data series, i.e. to preserve the data and the knowledge of the family of sensor consistency and evolution and cross-validation assessment within the same family of sensors as AVHRR);
 - ✓ **including** not only measure of the **uncertainty** (inter-sensor performance degradation) but also all **ancillary data** (like telemetry)
 - ✓ **accessible** together with processing chains (and power) and information extraction tools to maximise usability and impact for the EO community.