

# OPERATIONAL GEOCODING OF ERS-1 SAR IMAGERY

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## 1. ABSTRACT

The need of higher level radiometrically and geometrically calibrated products for current and future investigations on Earth's environment was one of the reasons to generate standard and precision geocoded SAR imagery from ERS-1 on an operational basis. For the european ground segment of ERS-1, these geocoded images are produced at the German Remote Sensing Data center of DLR. The SAR Geocoding System (GEOS) was especially developed for this purpose and in sight of other spaceborne SAR missions. The paper will show results of the implementation and results of six months ERS-1 SAR geocoding.

Keywords: ERS-1, SAR, Rectification, Workstation

## 2. INTRODUCTION

In July 1992 the European Space Agency (ESA) has launched the European Remote Sensing Satellite ERS-1. Since August ERS-1 send a large amount of very interesting SAR images to the receiving stations. Four european Processing and Archiving Facilities (PAF) are responsible for the generation of different products from ERS-1. The German PAF was built up at the German Remote Sensing Data Center (DFD) of the DLR at Oberpfaffenhofen near Munich. The PAF consist of different subsystems as shown in Figure 1. One of these is the Geocoding System.

## 3. DESIGN AND IMPLEMENTATION OF GEOS

GEOS was designed and coded by a combined effort of severnal european research institutes:

- Institute for Photogrammetrie and Engineering Surveys, University of Hannover, Germany
- Institute for Image Processing and Computer Graphics, DIBAG, Graz, Austria
- Remote Sensing Lab, University of Zuerich, RSL, Switzerland
- Klein & Stekl (K+S), Stuttgart, Germany

The algorithm of GEOS based upon the wellknown equation for computing the Doppler Frequency, the range distance and standard ellipsoid ( Ref. 7). This geometrie is shown in figure 2.

Doppler frequency:

$$F_2(X,Y,Z) = f_D - (2 * (p - s) * (\bar{p}^\circ - \bar{s}^\circ)) / \lambda * |\bar{p} - \bar{s}| = 0$$

Ellipsoid equation:

$$F_1(X,Y,Z) = (X^2 + Y^2) / a^2 + Z^2 / b^2 - 1 = 0$$

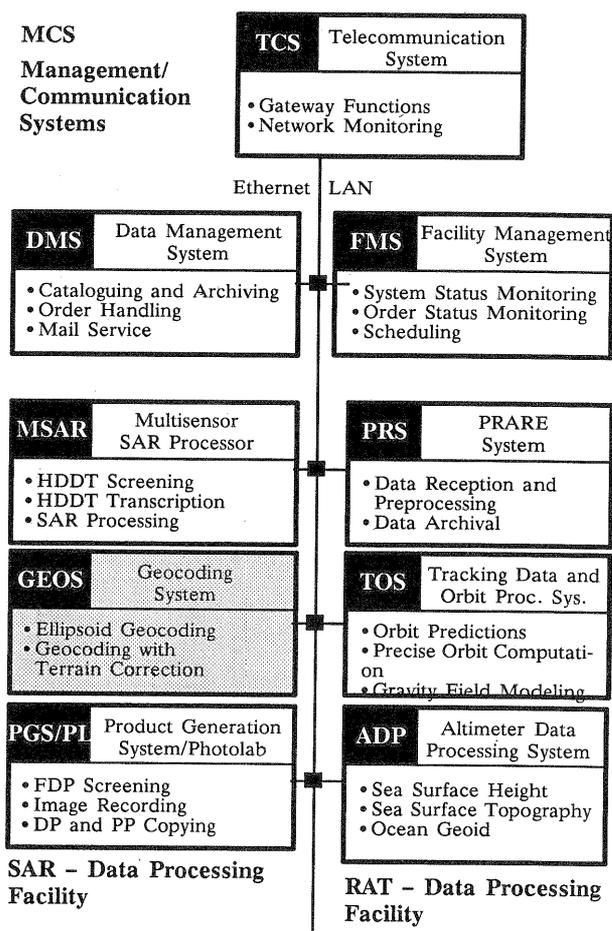


Figure 1: German Processing and Archiving Facility for ERS-1 (D-PAF)

Range equation:

$$F_2(X,Y,Z) = r_0 - m_r * j - |\bar{p} - \bar{s}| = 0$$

(Ref.1)

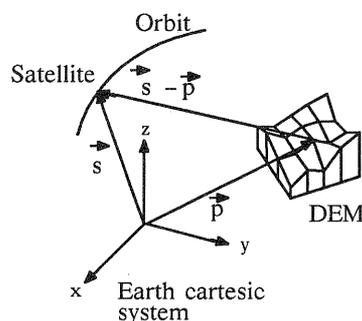


Figure 2: Satellite SAR Geometrie

GEOS was developed on the top of the image processing software UPSTAIRS and the UNIX of the SUN OS. It is running on different SPARC-processors. Following system software is necessary:

- SUNOS 4.1.1
- SUN Fortran 1.3 runtime library
- SUN Openwindow 3.0
- UPSTAIRS image processing kernel

- All modules can be called by the UPSTAIRS basic menu handler: Each function is supported by a triple key identification.
  - A special Geocoding Module Scheduler (GMS) guarantees a full automatic or step by step generation of standard products.
  - A parameter pool stores every necessary processing parameter as input or status control.
  - Image and Digital Elevation Data exchange by different formats, e.g. SUN rasterfile format.
  - Each module creates STATUS and ERROR files.
  - A message handler gives information about the status of each module via network to the Facility Management System.
- GEOS is designed and implemented to allow flexible input of data and parameter. The actual implementation can handle output files from the following SAR processors:

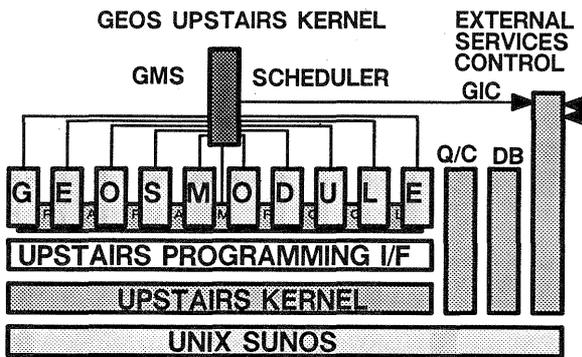


Figure 3: General GEOS SW Modularity

GEOS is structured in different modules (Figure 3), which uses many functions of the UPSTAIRS kernel. The intertasking between different modules is guaranteed by several features:

- D-PAF MSAR (based on the VMP)
  - ESA's Verification Mode Processor (VMP)
  - ESA's Fast Delivery Processor (FDP)
- Also the ESA ground range products (PRI, UI16) are as input possible.

#### 4. GEOCODING HARDWARE-SYSTEM

Working with satellite SAR-images need a very high computing power and disk-storage capacity. Figure 4 shows the actual hardware configuration.

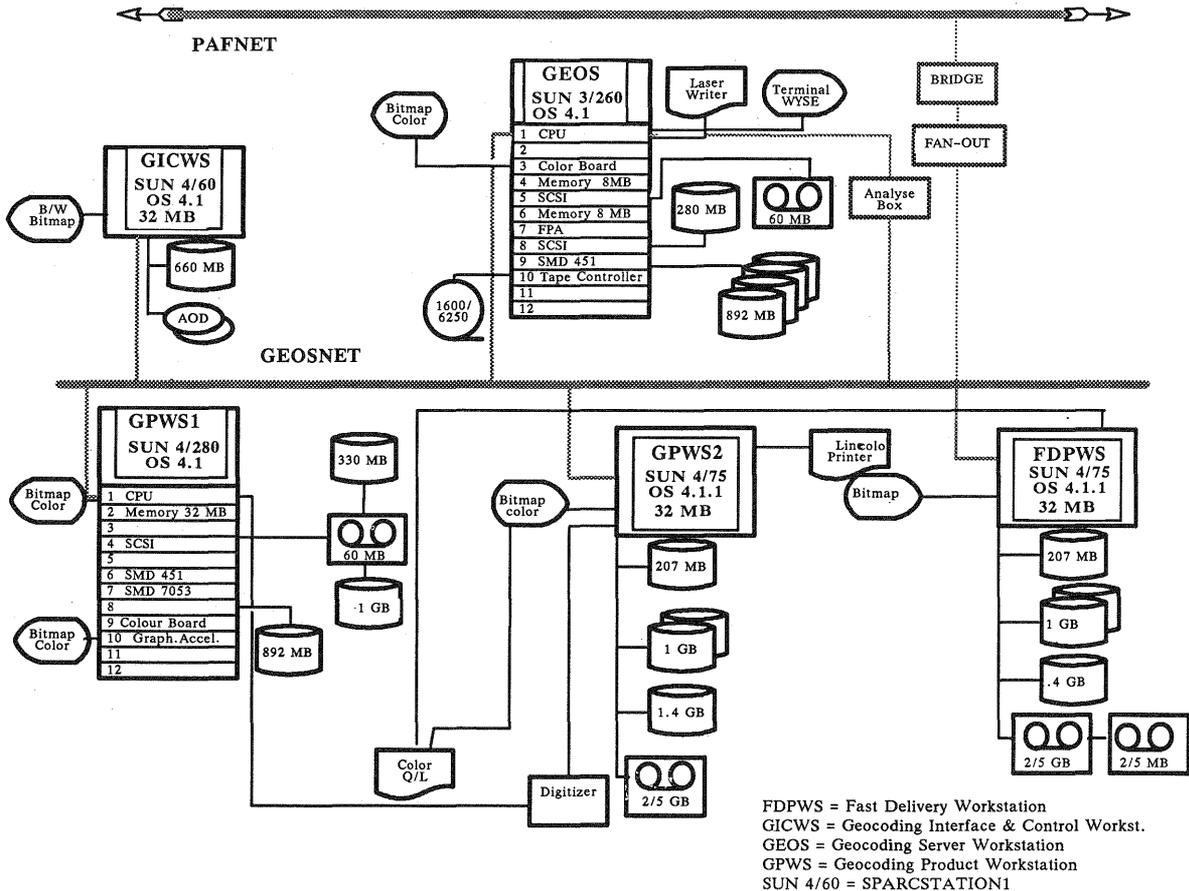


Figure 4: Hardware Configuration of GEOS

GEOS is implemented on different SUN-workstations, each of them in a standalone configuration. They are all connected via Ethernet in a the local subnet GEOSNET. The Geocoding software is installed on every production workstation (GPWS) (Ref. 4). They are complete independent and equipped with up to 3 GB local disk capacity. The Geocoding Interface and Controll Workstation (GICWS) is the interface system to all other subsystems of the D-PAF. Two optical WORM disk drives (capacity 2 GB) are installed at this Sparcstation, which writes the final and controlled products to the archive media.

At the Geocoding Server Workstation (GEOS) the Digital Elevation database and a image database is implemented. The GEOS-Server is the networkserver for the internal GEOS net in the case of breakdown of our DFD network.

### 5. ERS-1 SAR GEOCODED PRODUCTS

The key to any mosaiking of spaceborne satellite imagery is the availability of geocoded image data sets. Geocoding means the rectification and "remapping" of the image data set – given in its original satellite geometry – to a predefined cartographic projection system. This serves two needs:

First, the data shall fit at borders and overlapping areas and therefore are suitable for input to a seamless image mosaik.

Second, each data pixel can be identified by an absolute cartographic location and therefore referenced to other geocoded information, e.g. baseline data in geographic information systems including vektordata or text information from different sources (Ref. 5).

PRODUCT IDENTIFICATION	SAR.GEC	SAR.GTC01	SAR.GTC02
Name	Geocoded Ellipsoid Corrected	Geocoded Terrain Corrected	Geocoded Terrain + Incidence Angle Mask
Input Data	TSD	TSD/DEM	TSD/DEM
Number of Looks	3	3	NA
Spatial Resolution R/A [m]	30	30	30
Location Accuracy R/A	approx. 100 m	< 50 m	< 50 m
Geometric Presentation	UTM/UPS	UTM/UPS	UTM/UPS
Resampled Pixel Size [m]	12.5	12.5	12.5
Number of Pixels in x	8200-11400	8200-11400	8200-11400
Number of Pixels in y	8200-11400	8200-11400	8200-11400
Bits per Pixel or Sample	16	16	8
Amount of Data [MBytes]	134 - 262	134 - 262	67 - 132
Area Covered [km ]	100 x 100	100 x 100	100 x 100
Medium for Distribution	CCT, EXC F/P	CCT, EXC F/P	CCT, EXC

CCT	Computer Compatible Tape	X	Range or Longitude
F/P	Film and/or Print	Y	Azimuth or Latitude
SRDI	SR Detected Image	E	Earth Ellipsoid
EXC	Exabyte Cassette	DEM	Digital Elevation Model
TSD	Three Look SRDI	NA	Not Applicable

Tab.1: Parameter of Geocoded Products

Various products are available from the GEOS system as listed in table 1. The geometrie of SAR-images has a strong relationship to the topographie of the mapped area. Therefore it will be very usefull to correct the influence of undulated terrain. The height information is not worldwide available, so GEOS products are seperated into two groups.

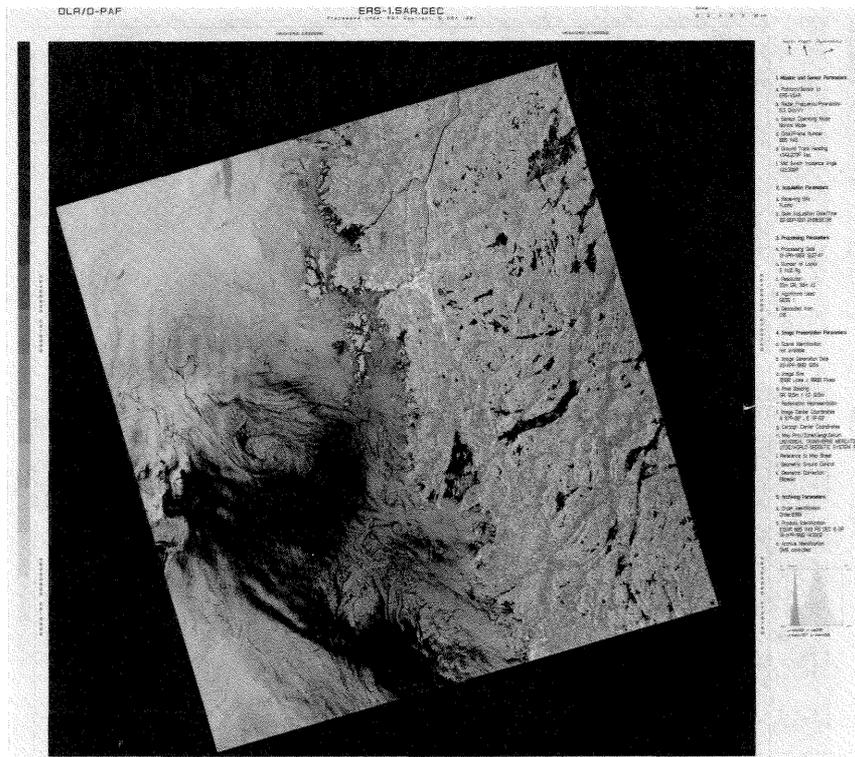


Figure 5: Ellipsoidcorrected Product (GEC) from the Swedish Coast

### GEC: Geocoded Ellipsoid Corrected

Here, the geolocation is solely computed by the radargrammetric parameters and the precise orbit information, also generated at D-PAF. The earth is approximated by the WGS84 ellipsoid.

Fast Delivery Products, generated at the ESA receiving stations Kiruna, Fucino and Maspalomas are also geocoded to GEC products.

To cope with large terrain offsets and plateaus, it is possible to extend the ellipsoid to a mean height, approximating the earth surface of the imaged region. This mean height is computed from a global elevation model in 5 arcmin resolution (ETOPO5)

Within the commissioning phase of ERS-1, the validation of GEC was performed with GPS measured Active Reflector Calibrators (ARCs) and map based control points. The mean geospatial error of GEC resulted in about 40 m in flat terrain.

Figure 5 shows an example of a very interesting image from a coastal area in Sweden. A lot a different structure on the sea surface can be seen very clearly.

### GTC01: Geocoded Terrain Corrected

GTC products are corrected with high resolution Digital Elevation Models (DEM) to cope with the radargrammetric distortions induced by undulated terrain. GTC products can only be produced for areas where DEM data is available at D-PAF. The availability of the DEM data is frequently reported to the ESA Earthnet ERS-1 Central facility (EECF) to allow the proper ordering of this data.

As both the radargrammetric parameters and the high resolution DEM do not match perfectly, it is necessary to adjust the input parameters of GTC by means of a few tiepoints. These tiepoints are automatically generated out of the DEM by means of SAR simulation techniques (Ref. 3).

The accuracy of geolocation, derived for GTC products, thus is about 30 m.

Figure 6 gives an example of the terraincorrected products. It presents the area of the Rhine Valley (left side) with the river Rhine and a parallel canal, eastwards is the Black Wood Forest. The complete scene covers an area of 100 km x 100 km and is correctly orientated to cartographic north. The annotation contains all for the user necessary information like scene and product identification, coordinate of the image center, acquisition time and processing paramter.

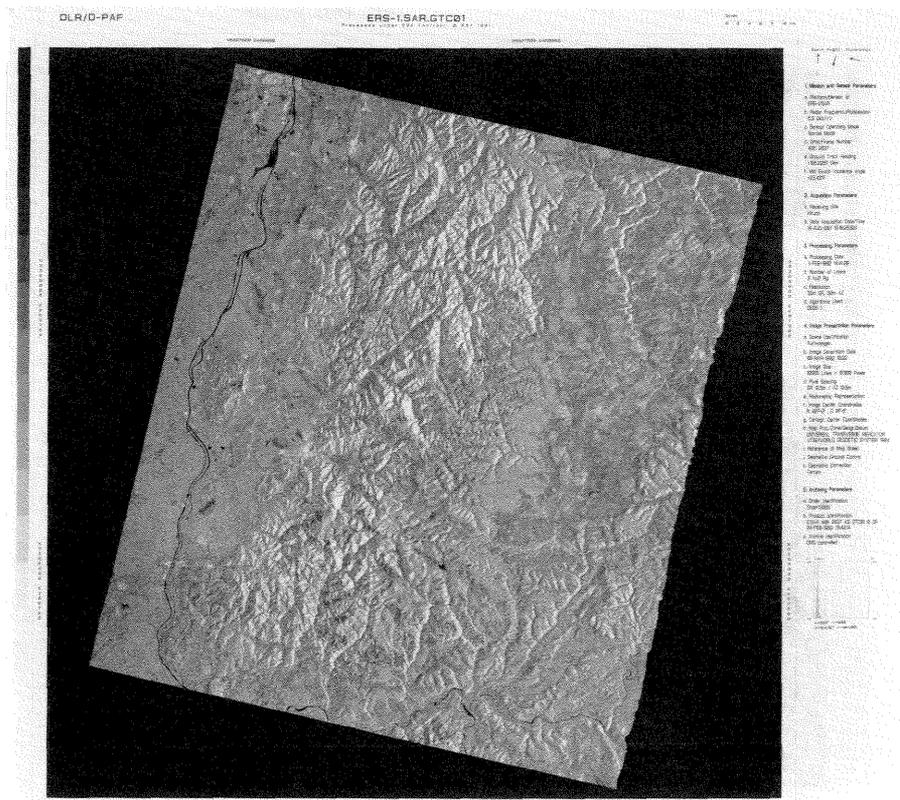


Figure 6: Terraincorrected Product (GTC01) from the Rhine Valley

## 6. OPERATIONAL ASPECTS

Geocoding and mosaiking of dozens or even hundreds of satellite image data can only be performed in an operational environment. The dedicated functions within the German Processing and Archiving Facility (D-PAF) are designed to support this goal (Ref. 6).

After the commissioning phase of ERS-1 GEOS is now working in an operational mode since February 1992. A minimum of operator interaction is necessary. The setup of the product generation, order identification and the final quality control in an interactive image processing tool are the only working parts of the operator.

The throughput is highly correlated with the used hardware. The computing of one GEC takes one a SUN Sparcstation II 3 hours, if the product the generated using SUN 4/280 it takes up to 8 hours. With the currently used configuration it is possible to produce 100 GEC per months.

The generation of the terrain corrected products need much more computing time. This is caused by more resampling steps ( e.g. Digital Elevation Models) for every pixel and the maximum image size of 8 200 x 11 400 pixel (Ref. 2).

## 7. PLANNED DEVELOPMENTS FOR GEOS

Germany has built up a receiving station in Antarctica (GARS). At this station works a real-time quick-look processor from the German company Dornier. Many outputparameter are different from the MSAR or VMP. This causes some modification in the software of GEOS. Figure 7 shows an impressive image of the Antarctic Peninsula. The image was received at GARS, processed by MSAR and GEOS.

In 1993 the NASA space shuttle will bring the X-SAR system into the space. The parameters of this systems a in many cases different from ERS-1, e.g. orbit. Therefore the verification will be intergrated into GEOS to allow also the geocoding of X-SAR images.

In the next years new computer hardware will be available, e.g. multiprocessor CPU like the Galaxy from SUN. The GEOS system has to be modified to use the increasing computer power. The product generation time will go down to less than 1 hour (Ref. 8).

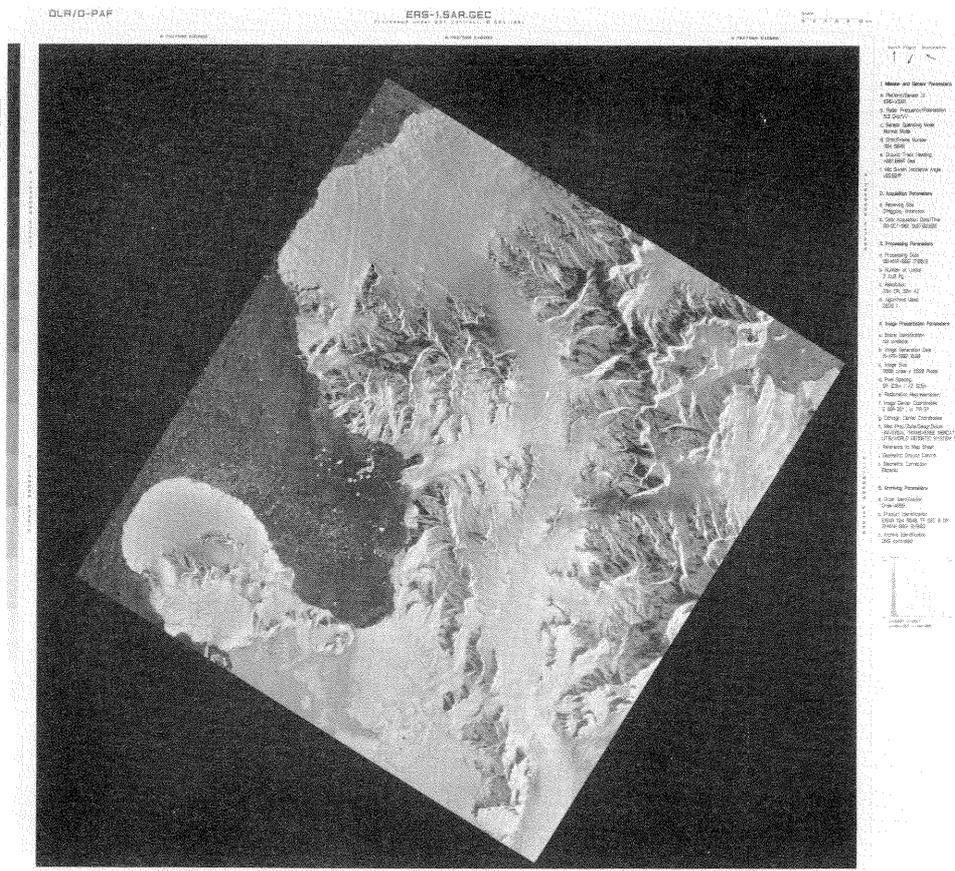


Figure 7: GEC Product of Antarctica

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