Cartographic Systems for the Presentation of Geocoded Satellite Images

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1. Abstract

Geocoded satellite SAR products, which will be produced by several facilities during the ERS-1, SIR-C, J-ERS-1 and Radarsat operational timeframe require cartographic systems and standards for their presentation. The utilization of geocoded SAR image data for topographic mapping and the required accuracies are shown. Although, the German ERS-1 Processing and Archiving Facilty (PAF) will support European mapping systems, an uniform cartographic system (UTM/UPS) is recommended for intercomparability of all senor products. The list of different geocoded ERS-1 SAR products, offered by the German (PAF) is presented.

2. Introduction

Topographic maps are an important factor for the inventory and development industrial and third world countries. They are necessary for every kind of planing, e.g. infrastructur, regional planing. But not every map is usefull for the different requirements. They should be large scale maps with a scale factor of 1:50,000 up to 1:250,000 for a detail imaging of the earth surface. The need of these maps is very important, but the conventional generation by the use of terrestric surveying is too expensive to get a complete coverage of the world. At the present status only a spare coverage of many countries is available (Figure 1, UN).

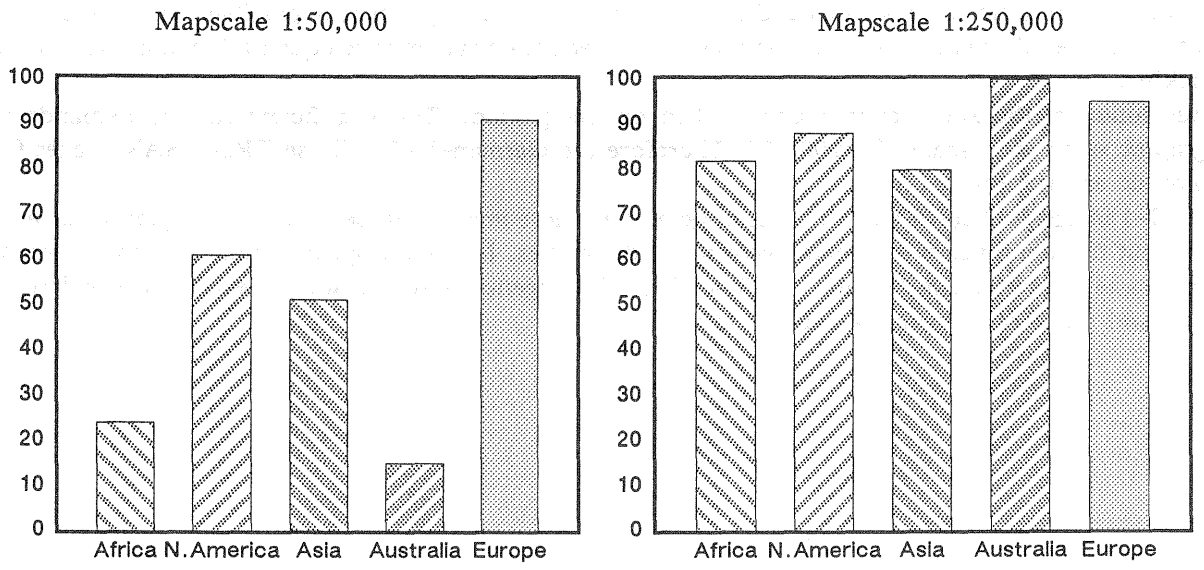

Figure 1: Map Copverage at different Scales

Except in Middle Europe the coverage is sufficient of civil topographic and special thematic maps (United Nations). Some military administrations are equipped with many more detailed topographic maps, but they are not available for civil applications in the normal case.
Additionally; If a sufficient coverage is available, the maps a often old, the update cycle is worser then 10 years or sometimes a few decades. Therefore their use is mostly restricted.
In many countries (USA, Itlay) different mapping systems are in use for national purposes. They uses different projection types, ellipsoids and datum. A homogenous topographic map system is only partially available.

3. The Use of Satellite SAR Images for Topographic Mapping

Satellite SAR images data must fulfill the very high accuracy requirements of all carthographic applications, which are set up for the national topographic maps. One of the most limiting demand is the drawing accuracy. In normal topographic maps 0.15 mm in the map is required (Hake). Therefore the drawing accuracy fixes the usefull resolution for satellite maps and the internal relativ accuracy. In a mapscale of 1:50,000 the 0.15 mm are equivalent to 7.50 m on the earth, by using 1:200,000 maps the spatial resolution must less equal than 30 m. The absolute location accuracy has no direct influence to requirements for the resolution.
Some optical sensors fulfill such requirements for topogrphic mapping like the French satellite Spot or the German Metric Camera. They are already in use for generation and updating topographic and thematic maps (Baehr).
The European Space Agency plans to launch the first European Remote Sensing Satellite (ERS–1). An Active Microwave Intrument (AMI) is one part of the payload. The sensor uses the C–band with a frequency of 5.3 GHz. In the near polar orbit plane the repeat cycle can change between 3 and 35 days. This causes different coverage of the earth with different overlapping areas. Due to the all weather capability of an active microwave sensor an whole coverage of land is fastly reachable.
The imaging of two neighbouring areas are seperated by a few days. This causes differences in the radiometric backscatter of these ares and an homgenous mosaicking is hardly possible. The overlapping areas contain the information of the two stripes, which requires a radiometric equalisation and a geometric mosaicking.
The resolution of the AMI senor is about 30 m on the ground. This is sufficient for the demands of topographic maps at a scale of 1:200,000. Therefore the German–PAF will use ERS–1 SAR images for topographic application.
The ERS–1 images will cover all parts of Europe and all these images can be used for topographic investigations, but this approach is connected with many difficulties. In the European countries many different national system are existing (Figure 2). There is no homogeneous system with one reference ellipsoid, position and other cartograhic parameters in use.

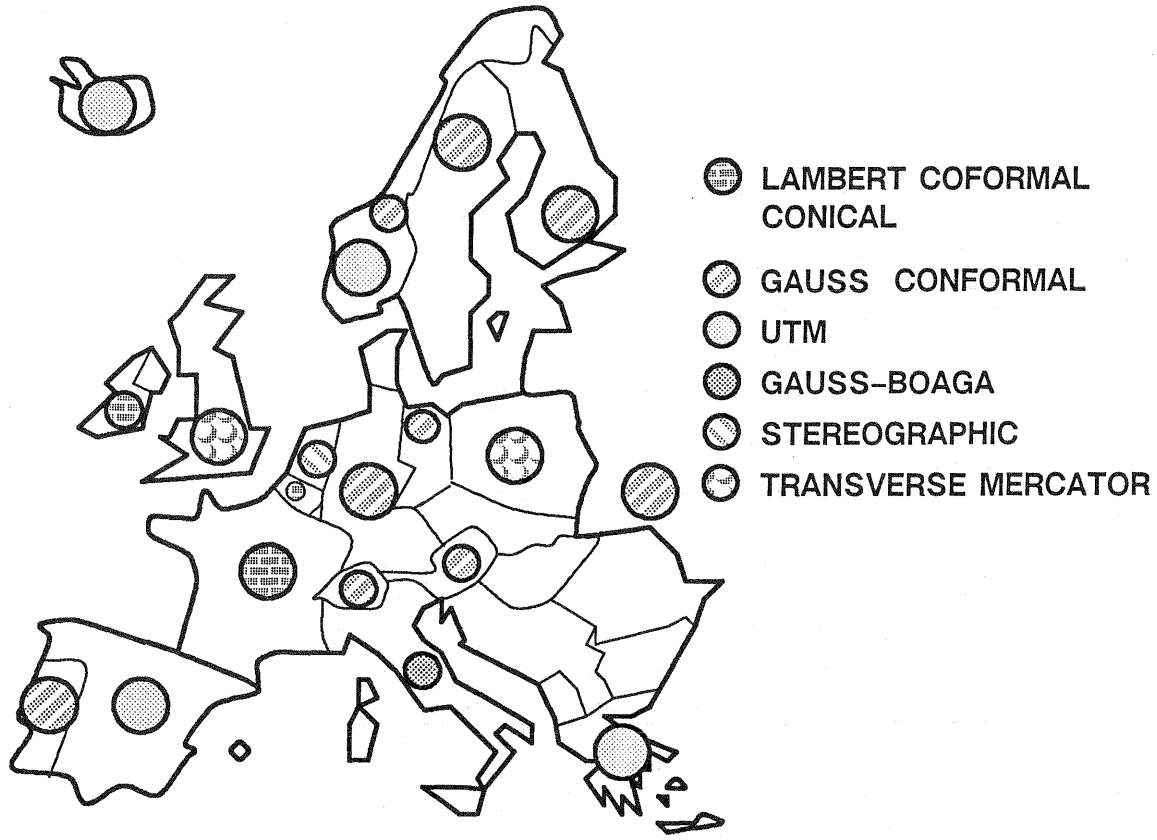

Figure 2: Map Projections in Europe

The ERS-1 products must be referable to these national mapsystems necessarry. There will be an important usage of satellite products in combination with other different data resources like other satellite images, vector data-bases or ordonance surveying information. These information types can be integrated into a Geographic Information System (GIS) and can be use as a data pool for the generation of digital maps. But two assumptions must be fulfilled:

- use of homogeneous mapping system or the portability between them
- use of an uniform data structure.

The German PAF will consider these assumptions. The national mapping system of the ESA member states with their national charateristics will be be supported. Following map projections will integrated in the geocoding system:

Universal Transverse Mercator (UTM)
Universal Polar Stereographic (UPS)
Gauss Conformal Cylindrical
Conformal Conical Lambert

The ERS–1 satellite images will cover not only Europe, additionally images of other parts from all over the world will be taken. In these regions, all national systems will not be supported by the German PAF in an operational manner. UTM with one reference ellipsoid and datum will be used for these countries and to get a coverage also in Europe in one uniform system. Due to the significant distortions of cylindrical projection towards the polar regions, UTM will be used up to latitudes of +/– 80 degree.

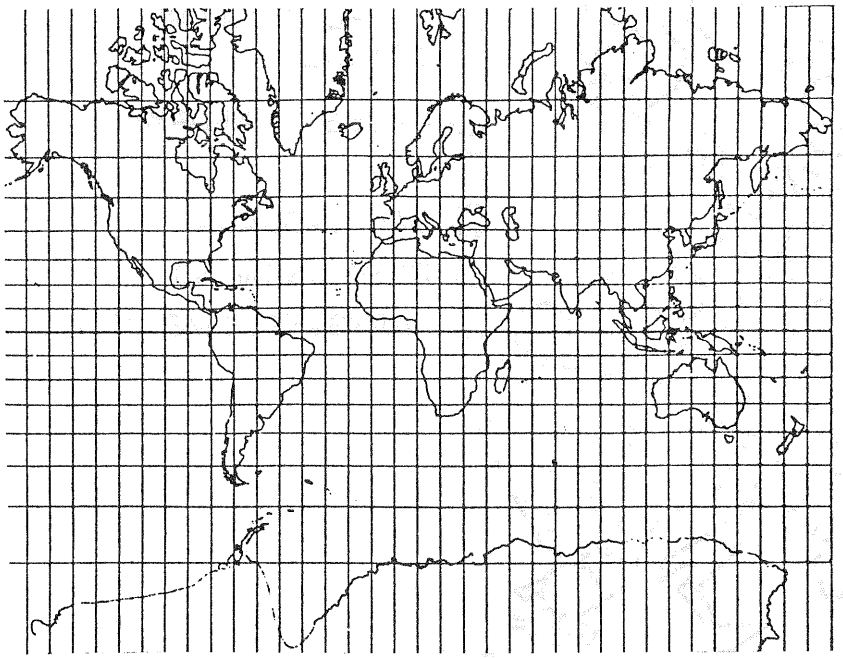

Figure 3: The World in Mercator Projection

The UPS system is standard projection for polar areas down to 80 Degree.

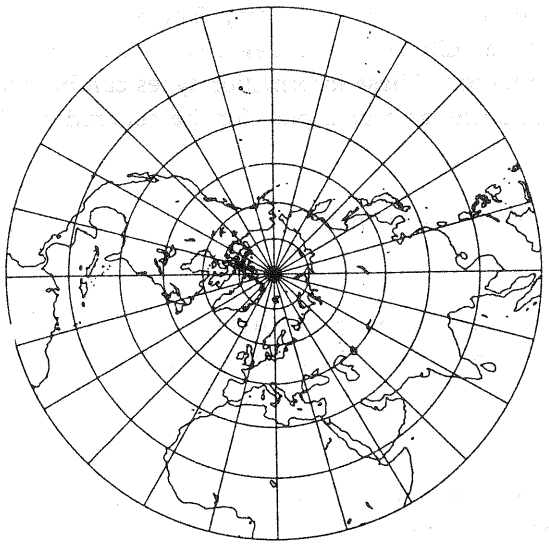

Figure 4: The Polar Region in UPS Presentation

UPS causes some problems by the digital handling of the raster data. The coordinate lines are not a rectangular linear grid like UTM. Coordinate lines with a constant latitude are in every case circles with a constant radius for equal latitude. Therefore, a normal rectangualar presentation aligned to cartographic grid and processing in an image display system is not possible. This effect has to be taken into account and detailed investigations concerning digital presentations have to be performed.
Even for UTM the original data structure and pixel size is unsuitable for the integration in an uniform data base. This problems appears by the usage of all other remote sensing and raster data.

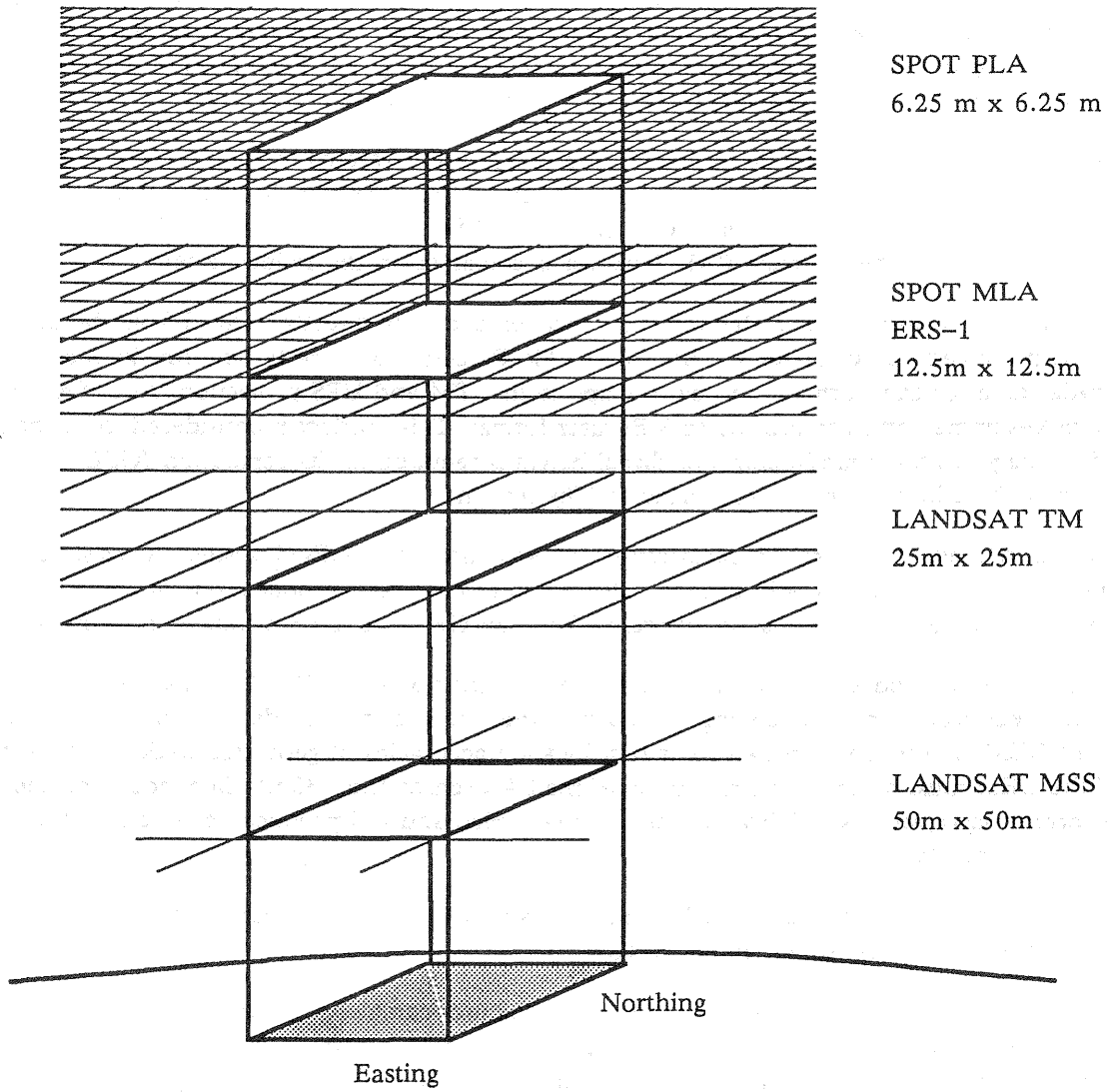

Figure 5: Pixel Hirarchy System

All the data sources can be transformed into one pixel hierachy system with rectangular coordinates. (Figure 5; Guertin). Each stored pixel size can be computed by the factor 2 from the next level. This can be done without any time consuming resampling and no change of radiometric contents. These system will be adapted by the German PAF.

4. ERS-1 Geocoded SAR Products by the German PAF

Besides the fast delivery SAR products, generated at the ERS-1 data receiving stations, four national Processing and Archiving Facilities (PAF) are in charge to produce precise off-line SAR products. The German PAF will produce standard SAR images and the geocoded SAR products, refered to in this paper.

The geocoded SAR products will be available on two media: photoprint and digital. The digital products will be distributed on Computer Compatible Tape (CCT). With respect to technological development, it is further envisaged to support Optical Disks.
A working group, consisting of nearly all countries which will deliver SAR products, has established a standard format for presentation of digital SAR data on CCT (CEOS, 1988). On tape, information of the satellite parameters, processing modes and – what is of interest for geocoded products – the applied cartographic projection, datum shifts and precise coordinates are given. Each pixel of the geocoded product is scaled to 8 bit and corresponds to 12.5m * 12.5m on ground.

The SAR geocoded products can be devided in two categories: corrected to ellipsoid with system geometry accuracy and corrected to the actual earth shape with Digital Elevation Models (DEM) and refined in accuray with Ground Control Points (GCP) (Schreier,1988). Figure 6 shows a list of geocoded SAR products envisaged by the German-PAF. This list is explained in the following text.

The ellipsoid corrected products, which utilize a location accuracy directly derived from the SAR-Processor will be produced on two systems. The ISAR-SAR-Processor will use the intermediate complex processed radar data for transformation to earth ellipsoid in UTM and UPS projection. After Geocoding, the data is look-summed and compressed to 8 Bit user format. This product is considered to be the standard geocoded image, as no ground control or digital height is required for its generation (GEC). Of course, it suffers from slight location errors especially in hilly terrain.

For special requests in terms of cartographic presentation, the GEOS system, consisting of special equipped UNIX workstations, will produce also ellipsoid corrected products out of the standard SAR-processor output (GES). There is no difference between GEC and GES products in terms of geometry.

The most precise geocoded products will use Digital Elevation Models (DEM) and Ground Control Points (GCP) for rectification and geocoding. Of course, their generation will depend on the availability and quality of DEMs at the German PAF. For best location accuracies of geocoded SAR products, the mesh size of the DEM must be about the resolution of the SAR sensor (i.e.: 30m). Dependend on the structure of the terrain, large mesh size DEM can be down-sampled and will produce accuracies, which fulfill the aspired requirements.

If a full frame scene in covered by DEMs, all data is precisely geocoded and resampled to the required map projection in the list stated above (GTS).

Having in mind the utilization of geocoded products, the user can also order a map frame product (GMS). There, the precisely geocoded and terrain corrected SAR data is generated only within the borders of a specified national topographic map with appropriate scale. It is envisaged to support al least the topographic maps of European ESA member states. The prodcut will show only one scene; no mosaicking will be performed to fill the map frame.

The last product, which derives from precise geocoding with DEM, shows no radar backscatter data, but the local radar backscatter geometry.
Tackling with radiometric correction of terrain corrected geocoded prodcuts, it is obvious, that backscatter effects like foreshortening, layover and shadow can hardly be restituted by using only the SAR and DEM information (Bayer, 1988). Instead, the user of geocoded radar data will be supported by a

NAME	EXPLANATION	INPUT	LOCATION ACC.	RADIOMETRY	CARTOGRAPHY	FACILITY
SAR.GEC	GEOCODED ELLIPSOID CORR. FROM COMPLEX DATA	COMPLEX SEPERATED LOOKS	DIRECTLY DERIVED FROM PROCESSOR	RESAMPLED FROM COMPLEX DATA	UTM / UPS	ISAR
SAR.GES	GEOCODED ELLIPSOID CORR. FROM DETECED DATA	DETECTED 3 LOOKS	DIRECTLY DERIVED FROM PROCESSOR	RESAMPLED FROM 8 BIT DETECTED DATA	UTM / UPS OTHERS (EUROPE)	GEOS
SAR.GTS	GEOCODED TERRAIN CORR. FROM DETECTED DATA	DETECTED 3 LOOKS PLUS DEM	REFINED WITH GCP AND DEM (BETTER 50 m depends on DEM)	RESAMPLED FROM 8 BIT DETECTED DATA	UTM / UPS OTHERS (EUROPE)	GEOS
SAR.GMS	GTS IN MAP FRAME PRESENTATION	DETECTED 3 LOOKS PLUS DEM	REFINED WITH GCP AND DEM (BETTER 50 m depends on DEM)	RESAMPLED FROM 8 BIT DETECTED DATA	UTM / UPS OTHERS (EUROPE)	GEOS
SAR.GIM	GTS OR GMS INCIDENCE ANGLE	GEOMETRY FROM GTS AND GMS PLUS DEM	N.A., SAME AS GTS, GMS	N.A. INCIDENCE ANGLE CODED BETTER 3 DEG.	UTM / UPS OTHERS (EUROPE)	GEOS

Figure 6: List of German PAF goecoded SAR products

geocoded "Layover, Shadow and Incidence Angle Mask" (GIM), which indicates for layover and shadow condition and shows the local incidence angle used in SAR geocoding with DEM. This data comes in the same cartographic presentation as the ordered terrain corrected product and codes the information above in one 8 bit binary layer.
Using this data, a thematic interpretation of SAR images can guarantee comparison of test sites with the same range of incidence angles or could often explain some spurious backscatter behaviour (Bönsch, 1988).

5. Conclusions

The geocoded products are only single images which are generated and presented in a complex operational processing system. The GTS product has a maximum size of a full frame of the ERS-1 SAR image. No mosaicking and interpretation is planed in the German PAF for the standard products.
Besides, the German Remote Sensing Data Center at DFVLR plans investigations in these spare fields. Together with other institutes of the FRG , a "Radar Map of the Federal Republic of Germany" within the scope of an Announcement of Opportunity of ESA for ERS-1 will be done.
This project aims at the operational production of a SAR atlas of 1:200,000 scale in Gauss-Krueger or other coordinate system for the area of the FRG including Berlin (West) in digital and analogue format. For selected areas thematic products like land use maps will be evaluated.

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