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**BACCHUS-DOC Radar and Optical Campaign*****Final Report******DATE: 05. May 2006*****Contact (DLR):**

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1 INTRODUCTION

In the framework of its Earth Observation Envelope Programme the European Space Agency (ESA) carries out ground-based and airborne campaigns to support geophysical algorithm development, calibration/validation, etc., and applications development related to land, oceans and atmosphere.

One of the supported activities is the BACCHUS project, which is an area mapping project of vineyards near Frascati (Italy). For this project the Agency requires high resolution geo-referenced airborne SAR data of different wavelength and polarisation (preferably polarimetric).

1.1 OBJECTIVES OF BACCHUS-DOC

An airborne SAR survey is the objective of the present contract to generate an ortho-rectified high resolution reference data set for immediate use within the BACCHUS project and to demonstrate the potential of airborne radar remote sensing. Analysis of airborne SAR data will complement the high resolution visible data set, the coincident in-situ measurements and the additional available satellite data (ERS, SPOT, LANDSAT, IKONOS, QUICKBIRD) to test the grade of reliability to measure vineyard surfaces according to the plantation schemes and assess the optimal performances for defining operational survey recommendations.



Figure 1.1: Typical structure of a vineyard. The vines are tied to concrete poles. Up to 6 steel wires run from pole to pole. In other yards wooden or steel poles are used.

The main scientific objectives of the BACCHUS-DOC campaign are the following:

- Investigation on polarimetric radar potentialities for the estimation of parameters useful for vine inventory and characterisation (i.e. vineyard limits, row spacing, row orientation, metallic/non metallic poles and wires for vineyard trellising, rate of missing plants, production estimate).
- Assessment of the sensitivity of polarimetric measurements to the grape biomass.
- Assessment of polarimetric radar potentialities for the estimation of soil parameters such as roughness and moisture.

2 AREA OF INTEREST

The area of interest (AoI) is located near the city of Frascati, Italy. Details are given below (Figure 2.1).

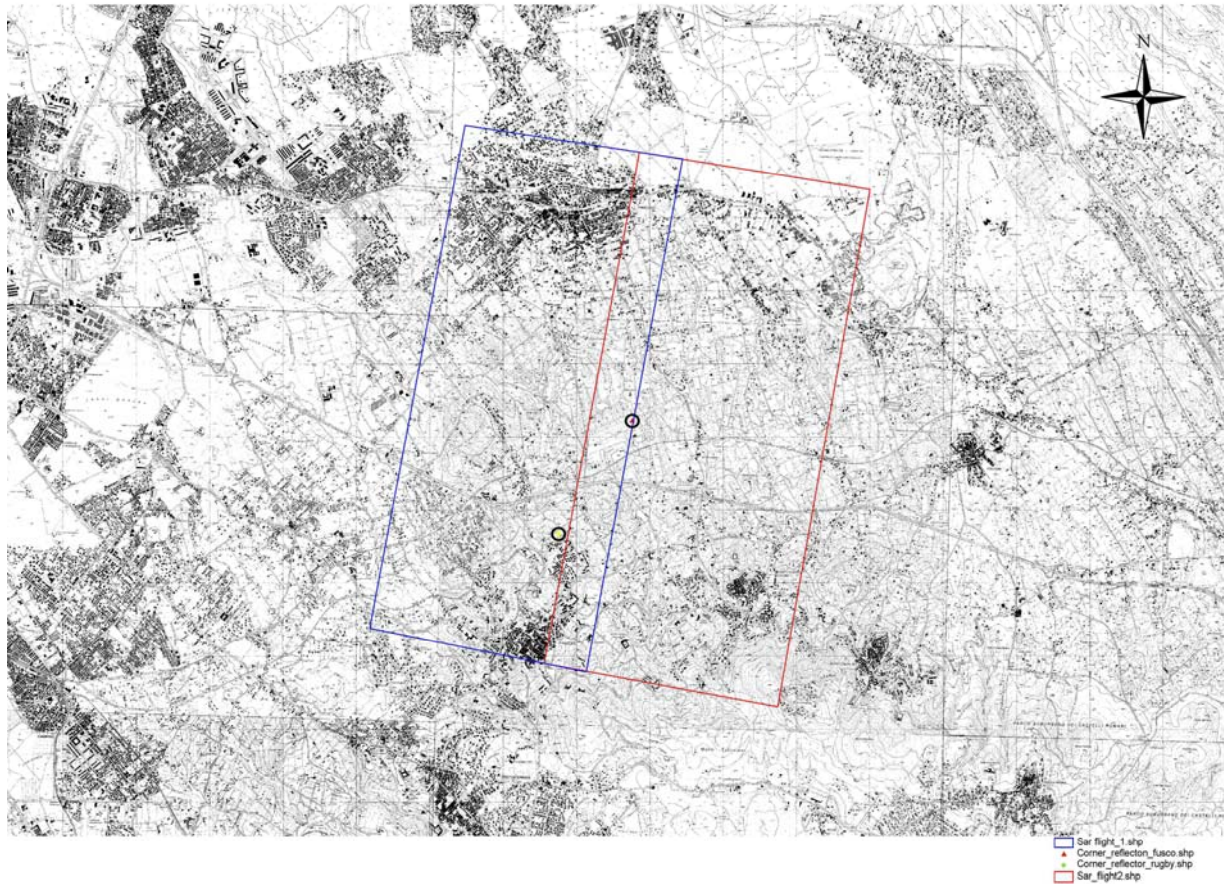


Figure 2.1: The Frascati area of interest for BACCHUS-DOC.

Coordinates of the area of interest:

Datum: WGS84, Projection: UTM, Zone 33N

Rectangle 1 (left, **blue**, main axis orientation ca. 9° with respect to true North)

	X	Y	
NW	306 408	4 638 242	(ULL)
NE	309 452	4 637 765	(URL)
SW	305 123	4 631 272	(LLL)
SE	308 165	4 630 795	(LRL)

Rectangle 2 (right, **red**, main axis orientation ca. 9° with respect to true North)

	X	Y	
NW	308 855	4 637 899	(ULR)
NE	311 849	4 637 493	(URR)
SW	307 583	4 630 878	(LLR)
SE	310 780	4 630 382	(LRR)

The orientation of the area of interest was chosen with respect to ERS-2 radar look direction and orbit, which will be right looking and descending during October 2005. The ERS-2 platform heading will be 189° true at a time of overpass of ca. 10 am UT.

To be able to compare the airborne with spaceborne SAR data it is important to maintain the same look direction. Hence results the modified orientation of the area of interest. Contrary to ERS E-SAR operates in left looking configuration. The platform heading becomes 9° true therefore.

Figure 2.1 shows two strips (red and blue rectangles) of size 3 x 7km each overlapping by ca. 500 m. The total area covered is 24.5 sqkm. Two radar reflectors, trihedral corner reflectors indicated by circles in Fig. 2.1, are used as ground control points (GCP) for georeferencing purposes.



Figure 2.2: Vineyards in the area of interest near Frascati.

3 BACCHUS-DOC DATA ACQUISITION CAMPAIGN

3.1 INSTRUMENTATION USED FOR THE CAMPAIGN

3.1.1 The DLR E-SAR system

E-SAR is a Synthetic Aperture Radar (SAR) system onboard a DLR Dornier DO 228 aircraft. The sensor operates in 5 frequency bands, X-, C-, S-, L- and P-band, hence it covers a range of wavelengths from 3 to 80 cm. The polarisation of the radar signal is selectable, horizontal as well as vertical. In polarimetric mode the polarisation is switched from pulse to pulse.



Figure 3.1: The E-SAR radar installed onboard a DLR DO 228 aircraft

3.1.2 Observation modes

For the campaign DLR's experimental E-SAR system was operated in high resolution – narrow swath mode at C- and L-bands. The modes of observation are summarised in the table below.

Table 3.1: E-SAR modes of operation

Mode of operation	HR-NS, strip map mode
Scene size [km]	5.5 x 7 (two 3 x 7 km swaths overlapping by 0.5 km)
Polarisation (L-Band)	HH / HV / VV / VH (polarimetric)
Polarisation (C-Band)	VH / VV (dual-polarisation)

3.1.3 Corner reflectors and GPS

For the support of the SAR operation one set of two 90cm radar reflectors and a GPS monitoring receiver (equipment) were required on ground. DLR provided and installed 2 trihedral corner reflectors (size: 90 cm) in the field. DLR further provided one GPS set for SAR operation (aircraft positioning) and corner reflector positioning.

The IGS station ‘INGR’ located in Rome and operated by the AGENZIA SPAZIALE ITALIANA was selected as the geographical reference. The data of this station were used for all static DGPS survey work, i.e. the positioning of the radar reflectors and the GPS monitoring receiver at Ciampino airport. The INGR station’s position was cross-checked with data of the EUREF station ‘AQUI’ which is located in L’Aquila.

3.2 TEST AREA COVERAGE

3.2.1 Flight schedule

The executed mission schedule for the DLR aircraft and crew is given in Table 3.2 below.

First mission: Weeks 39/40, September 26 – October 7, 2005

Date	Action
5 October	DLR DO228 departs from OP (ETD: 08:30 h local time)
5 October	DLR DO228 arrives in Ciampino (11:30 h local time)
5 October	Set-up of radar reflectors, positioning using DGPS (duration ~ 4 h)
5 October	Data acquisition flight (Departure: 16:50 h local time)
6 October	Removal of radar reflectors (duration ~ 2 h)
6 October	DLR DO228 departs from Ciampino (11:00 h local time)
6 October	DLR DO 228 arrives in OP (13:30 h local time)

Second mission: Weeks 43/44, October 25 – November 01, 2005

Date	Action
25 October	DLR DO228 departs from OP (07:30 h local time)
25 October	DLR DO228 arrives in Ciampino (10:00 h local time)
25 October	Set-up of radar reflectors, positioning using DGPS (duration ~ 3 h)
25 October	Data acquisition flight (Departure: 14:15 h local time)
26 October	Removal of radar reflectors (duration ~ 2 h)
26 October	DLR DO228 departs from Ciampino (12:00 h local time)
26 October	DLR DO 228 arrives in OP (14:00 h local time)

Table 3.2: Actual DLR mission execution

3.2.2 Data acquisition flight geometry

The test area (size 5.5 x 7 km) was covered by 2 parallel image strips in southwest - north-east direction. Both strips are 3 km wide. In order to cover the width of the test area, the two strips overlap by 0.5 km (Figure 3.2).

For the data acquisition flights there were two parallel flight tracks (Tracks 1 and 2) east of the area, which are 2.5 km apart (Figures 3.2 and 3.3).

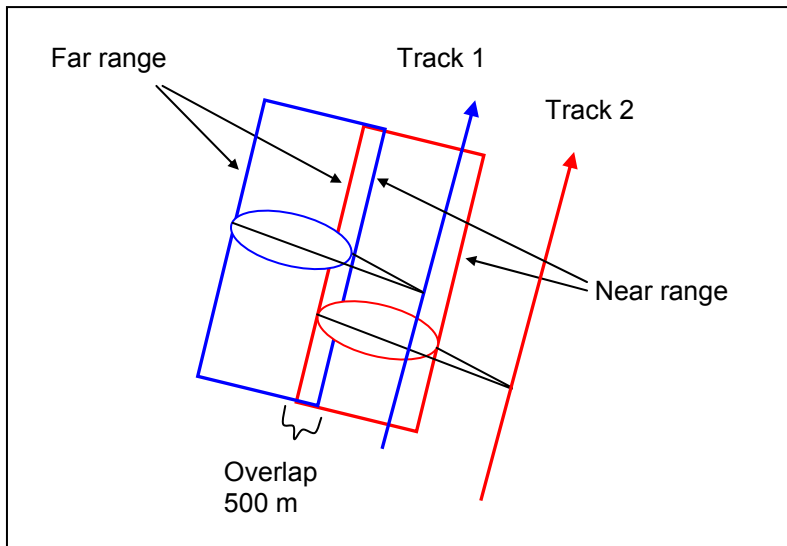


Figure 3.2: Area coverage by E-SAR

The coordinates of the upper and lower right corners of the western strip (blue) as given above in Section 2 were used as reference in planning the flight tracks.

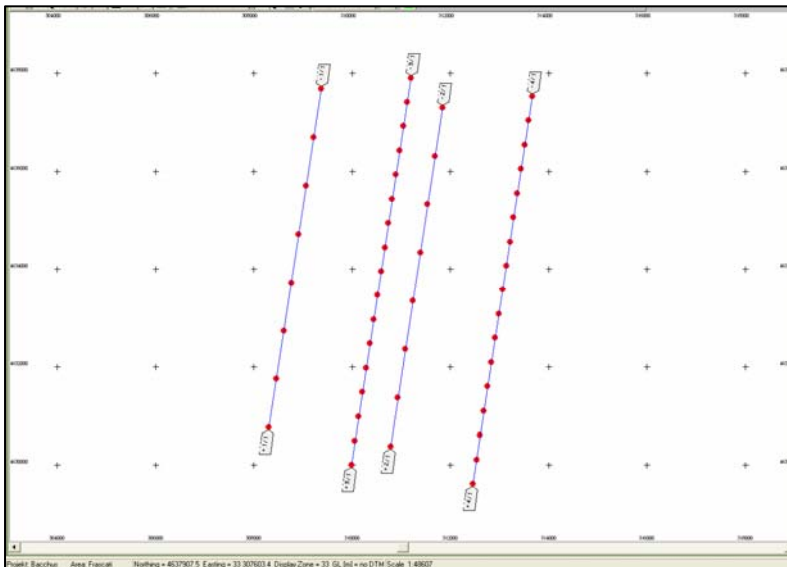


Figure 3.3: Flight track planning for E-SAR

The flight geometry was calculated for Flight Level 120 corresponding to an altitude of approx. 12000ft or 3600m above sea level depending on air pressure and temperature.

The ground level varies between 100m in the North and 400m in the South. The main test sites including the CR positions have an elevation of around 200m (a.s.l.). We assumed an average ground elevation of 190m above sea level for the calculation of the radar range de-

lay. In E-SAR we must keep the range delay constant. Hence the radar images are slightly rotated clockwise with respect to the planned rectangles.

Each flight track is offset from the near range edge of each strip by approx. 1770m to the East. The aircraft track heading was set to 9° off true North (opposite to ERS-2). The radar look direction consequently resulted to 279° which corresponds well with ERS-2!

The magnetic declination for the Frascati area is 1° 47' E! The undulation (or height difference between the geoid and the WGS84 ellipsoid) is given to 49.09m (EGM96)!

The details of the flight tracks (lines 3 and 4) are listed in Table 3.3 below. All levels are given with respect to the WGS84 ellipsoid. 1ft corresponds to 0.3048m.

Table 3.3: Flight track parameters (Line 1 is the reference)

Line	GALT [ft]	AGL [ft]	GL [ft]	DTK [°]	Length [km]	Start-Lat. [N d.dd]	Start-Lon. [E d.dd]	End-Lat. [N d.dd]	End-Lon. [E d.dd]
1	12200	11416	784	9	7	41.8055472	12.6924639	41.8680722	12.7029861
2	12200	11416	784	9	7	41.8027333	12.7223099	41.8652578	12.7328644
3	12200	11416	784	9	8	41.7990897	12.7128427	41.8705470	12.7248958
4	12200	11416	784	9	8	41.7962701	12.7426842	41.8677252	12.7547699

3.3 GPS-CONDITIONS ON DAY OF FLIGHT

E-SAR operation and corner reflector positioning are based on differential GPS data acquisition and processing. The quality of the final data product depends on the quality of the GPS constellation and measurement expressed by the PDOP. The PDOP, as a rule of thumb, should not exceed a limit of 2.5 to obtain good data. This limits E-SAR operations to periods when this condition is fulfilled. For BACCHUS-DOC see the diagrams provided below.

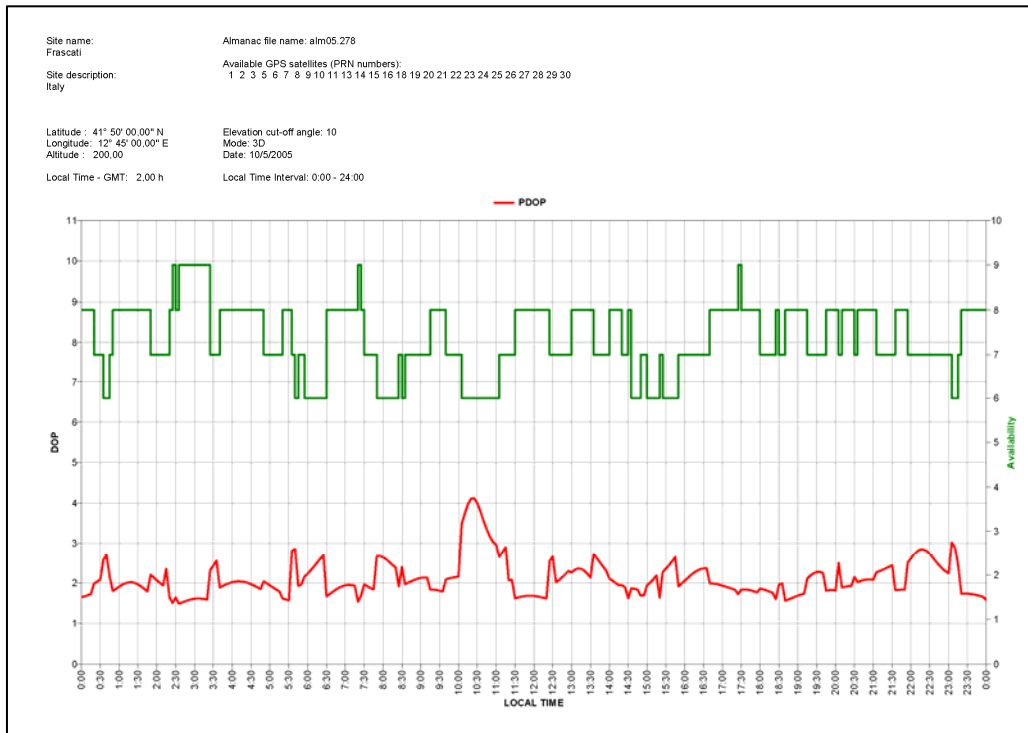


Figure 3.4:
GPS availability and PDOP for October 05, 2005.
ALM05.278

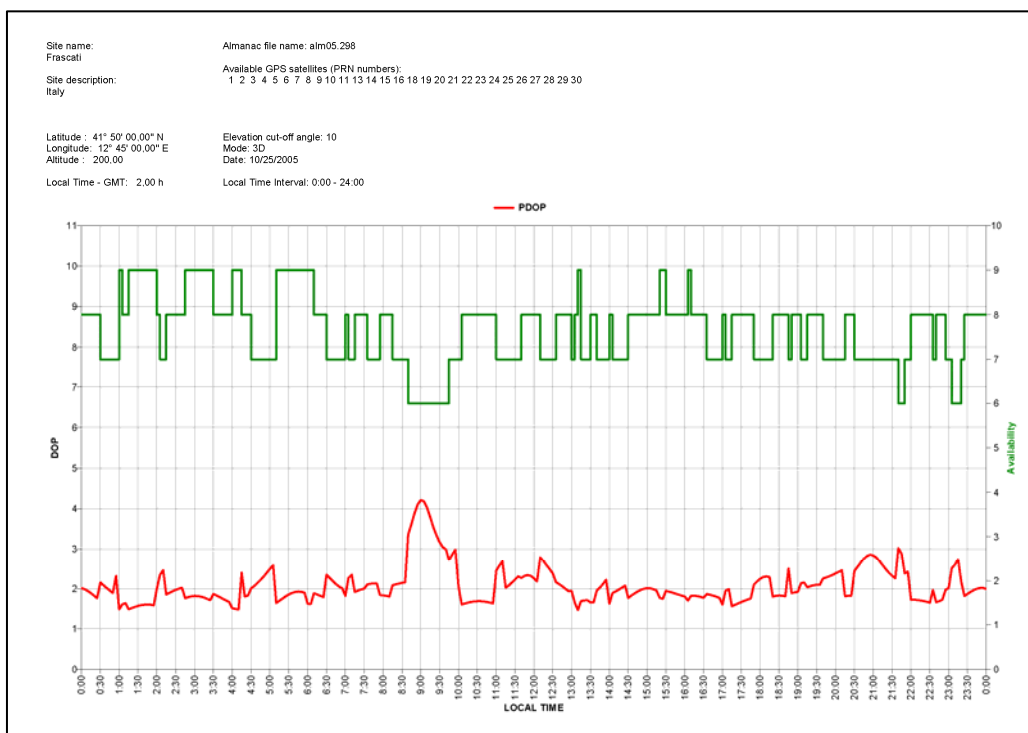


Figure 3.5:
GPS availability and PDOP for October 25, 2005.
ALM05.298

3.4 AIRBORNE DATA ACQUISITION

First data acquisition flight: 05. October 2005

System start-up: 14:38 h (GPS time)

System shut-down: 16:48 h (GPS time)

Table 3.4: E-SAR data acquisition (Mission 1)

Pass	Line	Radar mode	Heading [deg]	Time (start) [hh:mm]	Time (stop) [hh:mm]
1	3	C-vh/vv	9	15:16	15:19
2	4	C-vh/vv	9	15:28	15:30
3	3	C-vh/vv	9	15:39	15:41
4	3	L-pm	9	15:51	15:53
5	4	L-pm	9	16:03	16:05
6	3	L-pm	9	16:14	16:16
7	4	L-pm	9	16:25	16:27

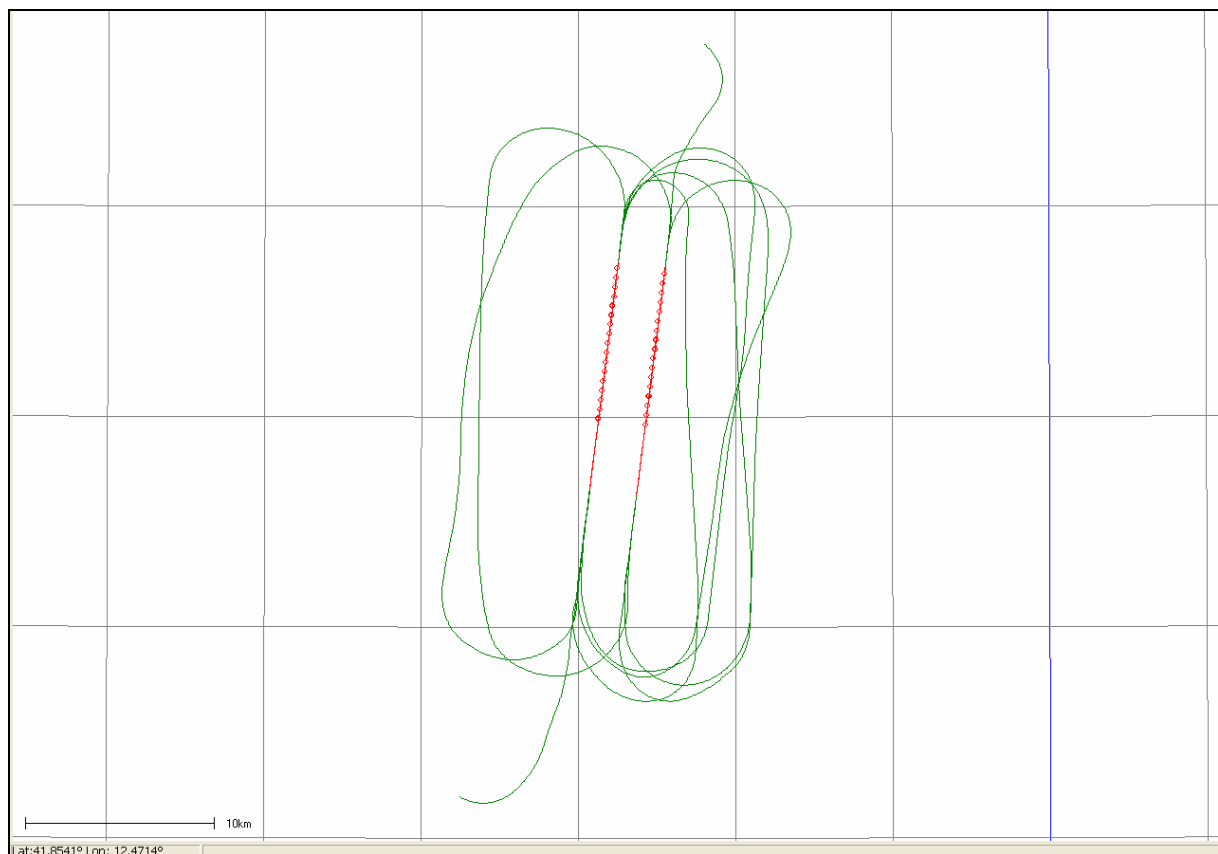


Figure 3.6: Actual flight pattern during data acquisition overhead area 'Frascati' (Mission 1)

Average flight altitude (GPS, in coordination with ATC): 12198 ft (+/- 26 ft)

Weather observations: cloudy, turbulent, rain showers before flight, dry during flight

Second data acquisition flight: 25. October 2005

System start-up: 12:02 h (GPS time)

System shut-down: 14:21 h (GPS time)

Table 3.5: E-SAR data acquisition (Mission 2)

Pass	Line	Radar mode	Heading [deg]	Time (start) [hh:mm]	Time (stop) [hh:mm]
1	3	C-vh/vv	9	12:42	12:44
2	4	C-vh/vv	9	12:54	12:56
3	3	C-vh/vv	9	13:05	13:07
4	3	L-pm	9	13:16	13:18
5	4	L-pm	9	13:26	13:29
6	3	L-pm	9	13:37	13:39
7	4	L-pm	9	13:48	13:50

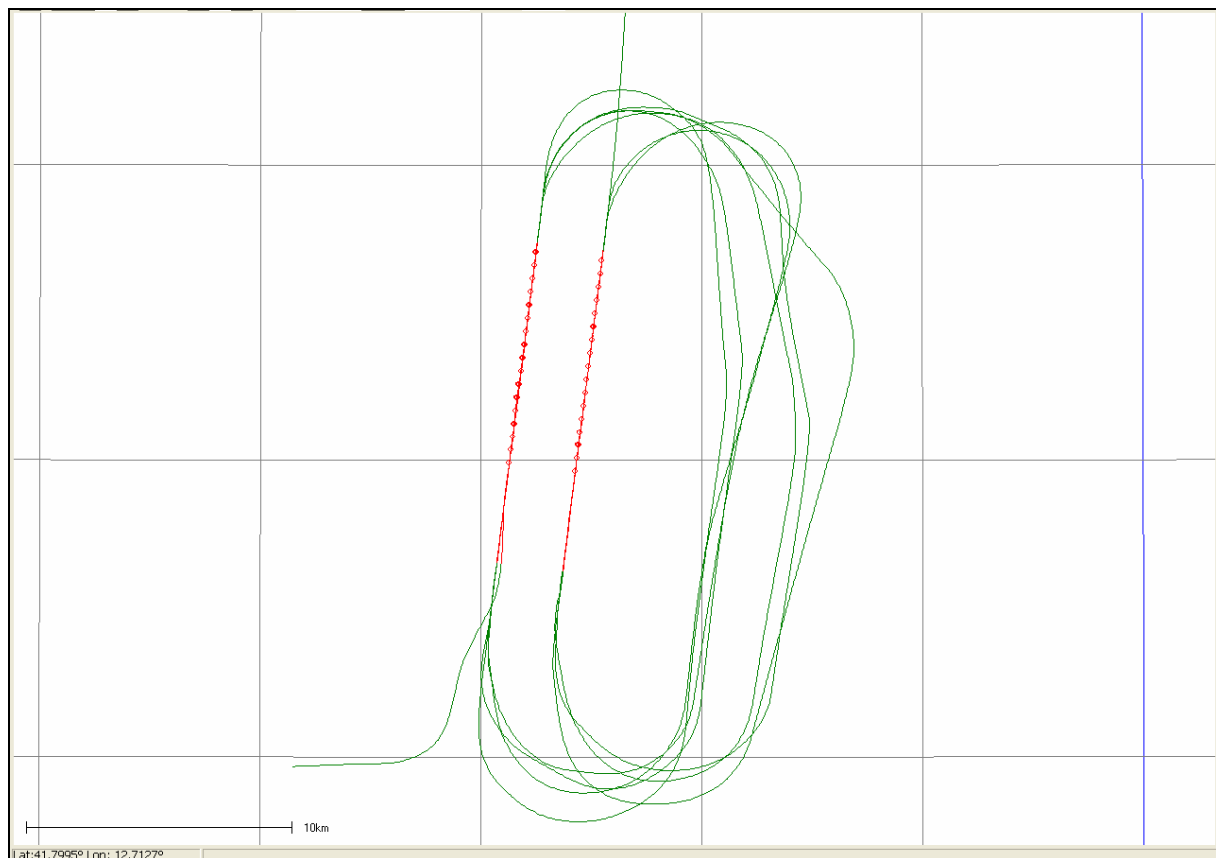


Figure 3.7: Actual flight pattern during data acquisition overhead area 'Frascati' (Mission 2)

Average flight altitude (GPS, in coordination with ATC): 12198 ft (+/- 6 ft)

Weather observations: few clouds, low turbulence, dry conditions before / during flight

3.5 CORNER REFLECTOR INSTALLATION AND POSITIONING

During the field visit on September 8, 2005, suitable locations for the radar reflectors (CR) were found. The first location was at the Frascati rugby stadium (named RUGY), the second in the field near a winery (named VINE). Later for the second mission the first location had to be changed to a piece of grassland on a road side (named GRAS).

The radar reflectors were installed by DLR with the support of the BACCHUS team. At each CR position 15 minutes of GPS data were recorded. The positions were later DGPS processed by DLR with reference to 'INGR' GPS station.



a



b



c

Figure 3.8: 90cm foldable CR locations in the field for BACCHUS-DOC (a: 'RUGY', b: 'VINE', c: 'GRAS') 'GRAS' was used during the second mission as a better alternative for 'RUGY'!

Table 3.6: CR positions for BACCHUS-DOC after DGPS processing

CR	Size [cm]	Azi [°]	Elev [°]	Look-dir. [°]	Pos (Latitude) [DMS]	Pos (Longitude) [DMS]	Height [m]
First mission							
VINE	90	9	2	99	N 41° 50' 16.57302"	E 12° 41' 35.73657"	200.474
RUGY	90	9	10	99	N 41° 49' 19.37984"	E 12° 41' 02.33789"	289.337
Second mission							
VINE	90	10	3	100	N 41° 50' 16.57072"	E 12° 41' 35.72314"	200.478
GRAS	90	10	10	100	N 41° 49' 26.96705"	E 12° 40' 47.11835"	268.229

CR azimuth angles were measured with magnetic compass!

3.6 GPS MASTER STATION INSTALLATION AND POSITIONING

The GPS master station was set up on the premises of Ciampino airport close to the DLR aircraft next to the general aviation parking area. The distance to the aircraft was approx. 50m. The photograph (Figure 3.9) shows the DLR aircraft. The GPS station of type Ashtech (Thales) Z-Extreme was placed on the strip of grass visible on the left. For the two missions the DLR aircraft was parked on different parking lots. Hence the GPS had to be placed at different locations on the grass strip, named 'CIAM' (Mission 1) and 'CIA2' (Mission 2).



Figure 3.9: The DLR aircraft at Ciampino airport

The geographical position of the phase centre of the GPS antenna was measured with respect to the position of the IGS GPS reference station 'INGR' and the result cross-checked using the EUREF GPS station 'AQUI' (see Table 3.7). The reference data was obtained via internet. The static DGPS processing was carried out using Waypoint's GrafNet software.

Datum: WGS84, (processing datum)

Control IDs: INGR, AQUI (reference stations)

Table 3.7: GPS station positions for BACCHUS-DOC after DGPS processing

Station	Pos (Latitude) [DMS]	Pos (Longitude) [DMS]	Height [m]	SDHori [m]	SDHeig [m]
AQUI	N 42° 22' 05.65989"	E 13° 21' 00.89040"	713.116	0.005	0.004
INGR	N 41° 49' 41.09962"	E 12° 30' 53.27529"	104.417	0.005	0.004
CIAM	N 41° 47' 44.24973"	E 12° 35' 41.54639"	170.993	0.006	0.005
CIA2	N 41° 47' 36.91338"	E 12° 35' 46.6679"	173.448	0.005	0.005

4 QUICK DATA ANALYSIS

4.1 GPS AND INS DATA CHECK

GPS and INS data are recorded on PCMCIA ATA PC Cards. The data was downloaded to a notebook PC. The data check consists of the following steps:

1. Download and de-compression of GPS data using Ashtech's Download 3.2.
2. Download and pre-process airborne GPS and INS data using IGI's AeroOffice 5.0b.
3. Run Waypoint's GrafNav 7.5 for a test on kinematic DGPS processing.
4. Run IGI's AeroOffice 5.0b for combining GPS and INS data.

These steps were executed after each data acquisition flight!

Result summary:

1. The GPS data recorded at the CR locations could be downloaded and de-compressed without errors! There was no need for repeating the measurements. The GPS data of the master station at Ciampino airport was recorded and converted without errors, too.
2. All airborne GPS and INS data was successfully downloaded and pre-processed! No errors, no loss of data!
3. Kinematic DGPS processing was executed without problems. The data quality showed up to be high.
4. The test run on GPS and INS combination was completed successfully.

As soon as the reference GPS data (stations INGR and AQU1) were available the final static and kinematic DGPS processing was performed. For INGR it became necessary to have the coordinates of the station confirmed. For this purpose AQU1 was employed to resolve an ambiguity on INGR's geographical position!

Result summary:

1. Static DGPS processing was performed using Waypoint's GrafNet 7.5 successfully on all static GPS data sets. The results are shown in Tables 3.6 and 3.7.
2. Kinematic DGPS processing was performed using Waypoint's GrafNav 7.5 successfully for the two data acquisition flights. The estimated standard deviation of the aircraft position resulted to be smaller than 6cm for both flights.
3. The combination of GPS and INS data resulted in GPS and INS position differences of less than 10cm.

4.2 SAR RAW DATA TRANSCRIPTION AND SURVEY PROCESSING

On board SAR raw data is recorded on SONY SD-1 tape. Radar housekeeping and sensitivity-time-control data is recorded on hard disk. After each flight mission on the return to

Oberpfaffenhofen we transcribed/transferred this data to a raid array which is connected to the SAR processor. Survey processing was performed to check completeness of the data and estimate the test area coverage. Results of survey processing are shown in Figure 4.1.

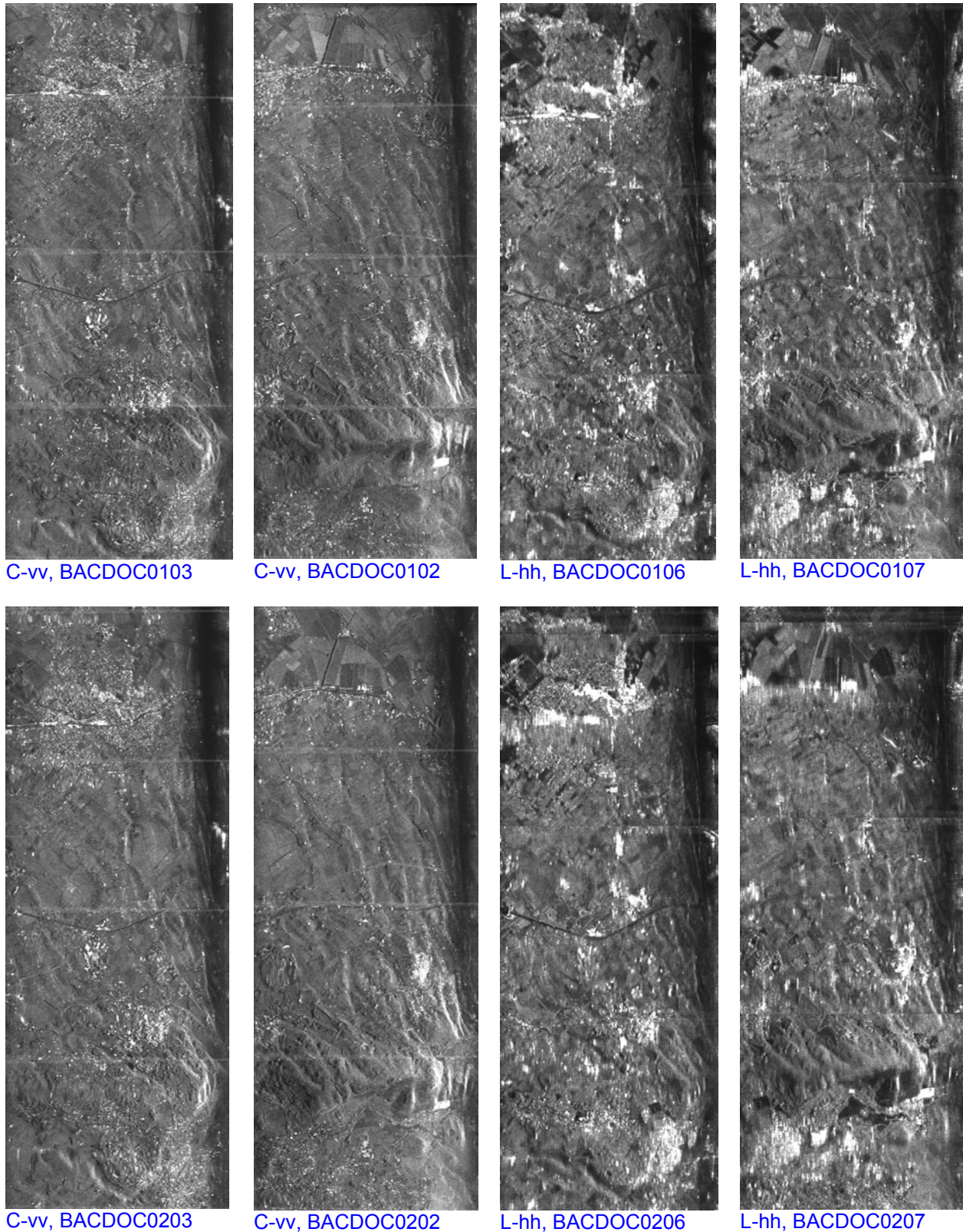


Figure 4.1: E-SAR survey image results for BACCHUS-DOC campaign

4.3 QUICK DATA ANALYSIS SUMMARY

All GPS and INS data could be processed successfully. The results obtained have very good quality.

In total 14 radar passes (7 per flight mission) were recorded and the data transferred to raid archive. All data is archived in the DLR DIMS as RAW product.

The survey images shown in Figure 4.1 represent those data sets selected for precision processing. Criteria are the saturation level in the radar data and platform attitude during data acquisition.

The survey images show all radar reflectors clearly visible. Swath size, position and overlap are sufficient for good coverage of the specified test area.

5 PRECISION DATA PROCESSING

E-SAR data processing at DLR-HR is split into two major tasks (Figure 5.1):

- **SAR data processing.** This task is split into three consecutive steps. At first the raw data is transcribed from high density tape to disk. In the second step it is de-formatted and survey processed. The final step is the precision processing to full resolution which includes motion compensation. The output is a fully focussed and calibrated image.
- **SAR image geo-coding.** Employing either an E-SAR or an externally provided DEM the calibrated intensity images are geo-referenced and geometrically and radiometrically terrain corrected. Auxiliary information is generated to allow incidence angle dependent radiometric correction of the data.

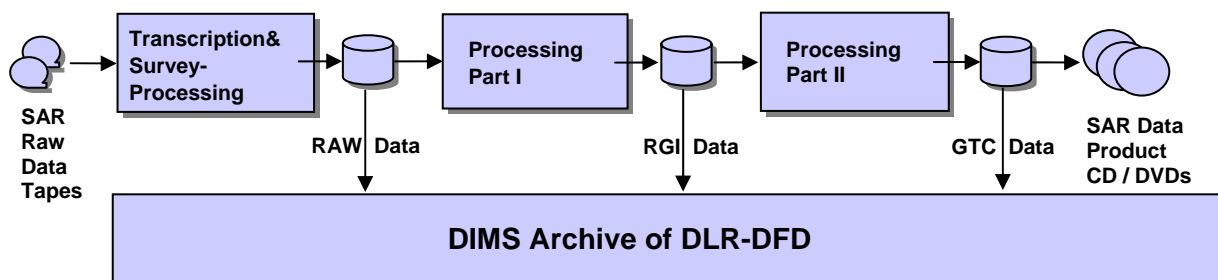


Figure 5.1: SAR data flow for the full performance E-SAR processor of DLR indicating also the available SAR data products (RAW, RGI and GTC), which are stored in the central remote sensing data archive of DLR (DIMS).

5.1 DEM GENERATION

Tor Vergata University provided a Digital Elevation Model of regional size to DLR-HR for use in the geo-coding process (Figure 5.2a) in GeoTIFF format. The coordinate system is UTM, zone 33, WGS84. The local elevations are represented as orthometric heights or heights above sea level. The posting is 10m. For the purpose of geo-coding the E-SAR radar data efficiently DLR-HR cut out an 8x7km section just large enough to cover the Frascati test area (Figure 5.2b). The DEM was re-sampled to a 1m posting and the geoid undulation, which is

48.5m for the area (ref: EGM96), added, so that the elevation values now represent heights above the WGS84 ellipsoid.

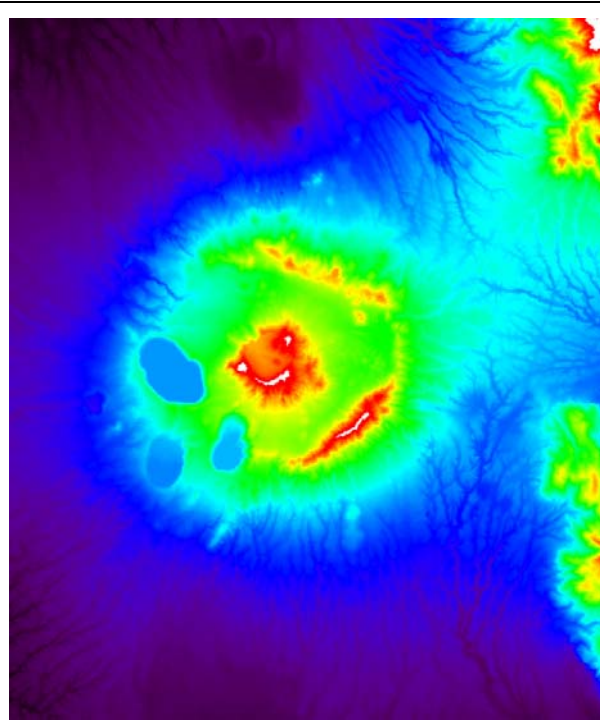


Figure 5.2a: DEM in original size provided by Tor Vergata University.

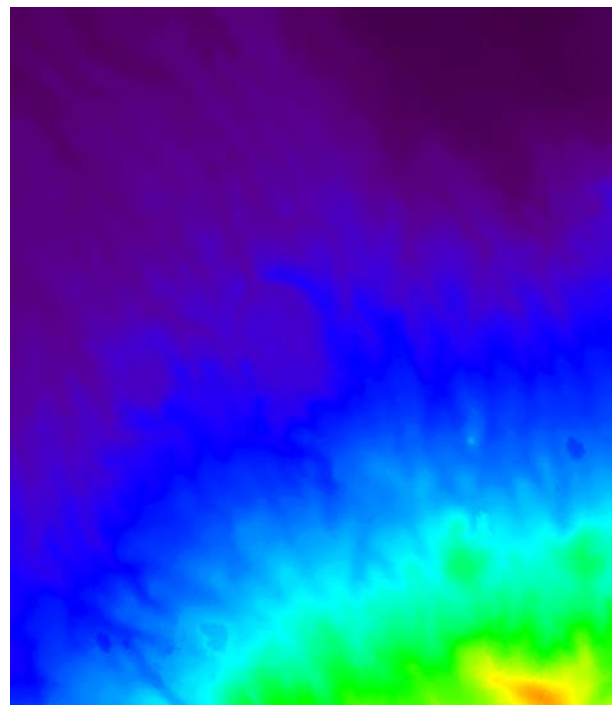


Figure 5.2b: Resampled DEM cutout for the Frascati test site (performed by DLR-HR). Coordinates (UTM-33, WGS-84): LLC(4630282/305023), URC(4638351/311962)

5.2 DATA PROCESSING PARAMETERS

SAR imaging, in general, is sensitive to aspect angle variations for structured and orientated targets. Vineyards must be regarded as such targets due to their layout. They feature parallel rows of equidistant poles with the plants in between.

The objectives of the BACCHUS-DOC SAR mission were to obtain radar imagery for measuring any change in grape biomass. Considering the radar imaging properties of orientated targets it is extremely important to exclude any aspect angle variations from one flight to the next. Aspect angle variations result from different aircraft drift, different flight altitude and different deviations from the desired flight track. Furthermore, a reliable and stable operation of the radar system is as well important. Radiometric stability and polarimetric phase stability must be high.

For BACCHUS-DOC the wind conditions (direction and speed) at flight level were very similar for the two events. Hence, the difference in wind induced aircraft drift was quite low. However, the rather instable atmosphere present during the first mission led to comparatively large vertical deviations from the flight track. With the help of the Precision Navigation System we could keep the horizontal deviations in limits. The effects on image quality are negligible. The flight geometry errors as experienced during the two missions are summarised in Table 5.1 below. For the individual overpasses the average, min and max values and range of variation are listed.

Table 5.1: Summary of flight geometry errors

Overpass	Parameter	Average	Min	Max	Range
0102	Altitude above ground [m]	3476	3472	3480	- 4 / + 4
	Drift [°]	2.8 (left)	1 (left)	4.8 (left)	- 1.8 / + 2
	Horizontal deviation from desired track [m]	0 (right)	2 (left)	1.7 (right)	- 2 / + 1.7
0103	Altitude above ground [m]	3476	3471	3490	- 5 / + 14
	Drift [°]	3.2 (left)	2.2 (left)	5.2 (left)	- 1 / + 2
	Horizontal deviation from desired track [m]	0 (right)	4 (left)	2 (right)	- 4 / + 2
0106	Altitude above ground [m]	3476	3469	3484	- 7 / + 8
	Drift [°]	2.6 (left)	0.9 (left)	4.7 (left)	- 1.7 / + 2.1
	Horizontal deviation from desired track [m]	0 (right)	2.4 (left)	2.1 (right)	- 2.4 / + 2.1
0107	Altitude above ground [m]	3475	3472	3479	- 3 / + 4
	Drift [°]	2.2 (left)	0.4 (left)	4.9 (left)	- 1.8 / + 2.7
	Horizontal deviation from desired track [m]	0.5 (right)	3 (left)	4 (right)	- 3.5 / + 3.5
0202	Altitude above ground [m]	3477.5	3476	3478.8	- 1.5 / + 1.3
	Drift [°]	0.2 (left)	2.3 (right)	2.8 (left)	- 2.5 / + 2.6
	Horizontal deviation from desired track [m]	0.5 (left)	5.5 (left)	4.5 (right)	- 5 / + 5
0203	Altitude above ground [m]	3476	3473.6	3478	- 2.4 / + 2
	Drift [°]	1 (left)	1.6 (right)	3 (left)	- 2.6 / + 2
	Horizontal deviation from desired track [m]	0 (right)	5.5 (left)	5 (right)	- 5.5 / + 5
0206	Altitude above ground [m]	3477.5	3475.3	3479.7	- 2.2 / + 2.2
	Drift [°]	0.3 (left)	2.3 (right)	2.9 (left)	- 2.6 / + 2.6

	Horizontal deviation from desired track [m]	0 (right)	7 (left)	6 (right)	- 7 / + 6
0207	Altitude above ground [m]	3477.5	3475.5	3480.2	- 2 / + 2.7
	Drift [°]	2.2 (left)	0.4 (left)	4.9 (left)	- 1.8 / + 2.7
	Horizontal deviation from desired track [m]	1 (right)	7.5 (left)	10 (right)	- 8.5 / + 9

The drift information in this Table reads as follows: 2.2° (left) means left wing forward, aircraft rotated by 2.2° clockwise around vertical axis which is pointing up. For this evaluation and the SAR processing we have assumed an average ground level elevation of 190m above the WGS84 ellipsoid.

The parameters and settings which were used for SAR processing are summarised in Table 5.2. They are based on the post-processed navigation data and system housekeeping data. The squint angle is derived from the radar data using a robust Doppler Centroid Estimator.

Table 5.2: Parameters and settings for SAR processing

Image	Radar frequency	Altitude [m]	Squint [°]	Range Delay [µs]	Looks / Overlap	Azimuth resolution [m]
BACDOC0102	C	3476.27	3.37	28.3	4 / 50%	2
BACDOC0103	C	3477.25	3.67	28.3	4 / 50%	2
BACDOC0106	L	3475.17	1.41	28.3	4 / 50%	2.5
BACDOC0107	L	3475.34	1.25	28.3	4 / 50%	2.5
BACDOC0202	C	3477.51	1.51	28.3	4 / 50%	2
BACDOC0203	C	3476.13	1.72	28.3	4 / 50%	2
BACDOC0206	L	3477.39	-1.19	28.3	4 / 50%	2.5
BACDOC0207	L	3477.23	-1.72	28.3	4 / 50%	2.5

The parameters altitude and squint as listed in Table 5.2 are quite similar for both missions. The slightly different squint angles of L- and C-bands result from different antenna characteristics. We have a squint angle change of about 2° - 3° intra-band from one mission to the next, which is very low, but what should be regarded as being at the limit for the purpose of the experiment. The variations in flight altitude and the horizontal deviations off the desired track lead to aspect angle variations of fractions of a degree, what in fact is negligible.

5.3 AREA COVERAGE AND IMAGE EXAMPLES

Area coverage of the geo-referenced image data is almost 100% of what was specified. The lower right corner is missing which is due to imaging hilly terrain with a constant range delay setting. The Frascati test site features a variation in ellipsoidal ground elevation from around 120m in the North to around 450m in the South near the town of Frascati. For E-SAR we calculated the range delay for an average ground elevation of 190m, which is a compromise.

Representative image examples are shown here to give an impression of the work performed.

Figure 5.3 shows geo-coded C-band images of the area at the two mission dates.

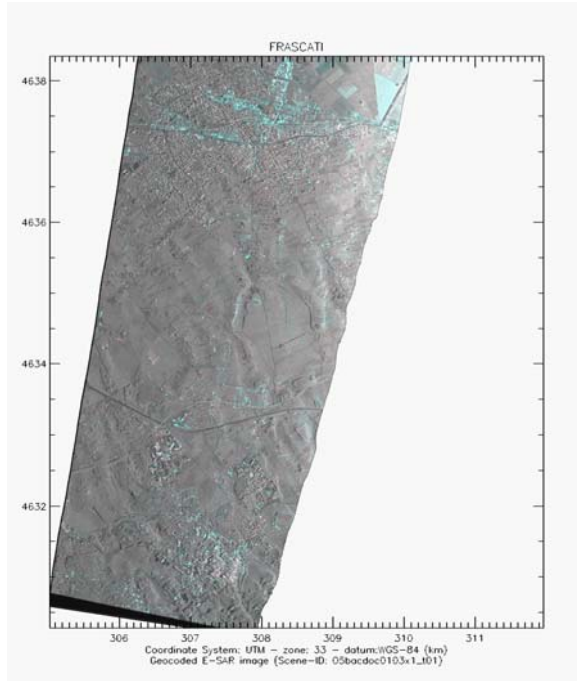


Figure 5.3a: C-band vh/vv of Bacchus-Doc mission 01, Oct 5, 2005. Flight line 3.

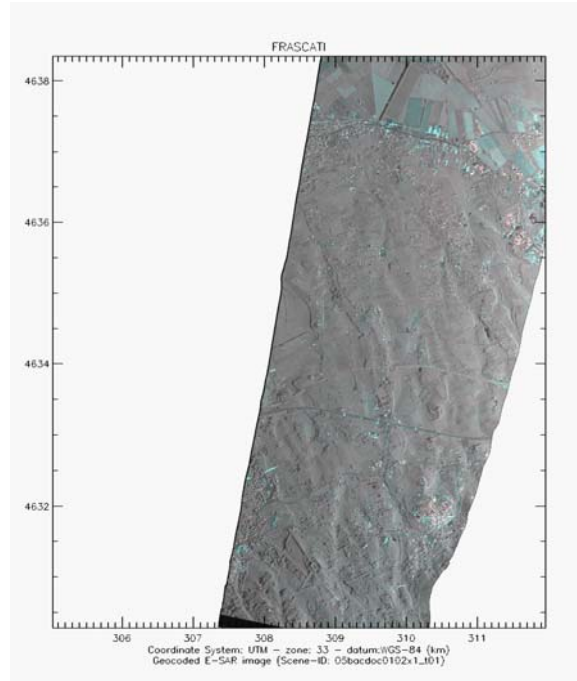


Figure 5.3b: C-band vh/vv of Bacchus-Doc mission 01, Oct 5, 2005. Flight line 4.

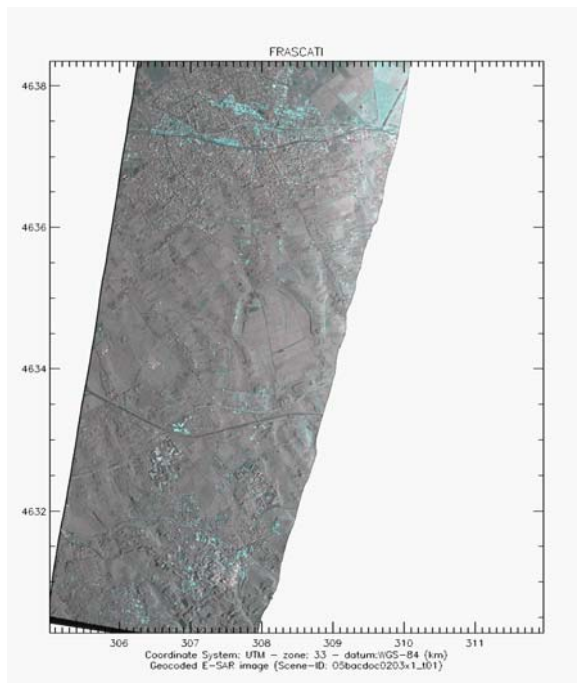


Figure 5.3c: C-band vh/vv of Bacchus-Doc mission 01, Oct 25, 2005. Flight line 3.

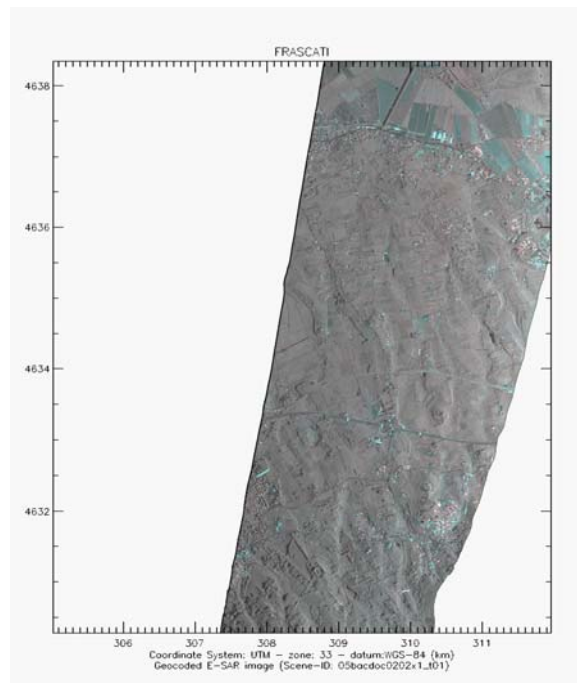


Figure 5.3d: C-band vh/vv of Bacchus-Doc mission 01, Oct 25, 2005. Flight line 4.

Figure 5.4 shows geo-coded L-band images of the area at the two mission dates.

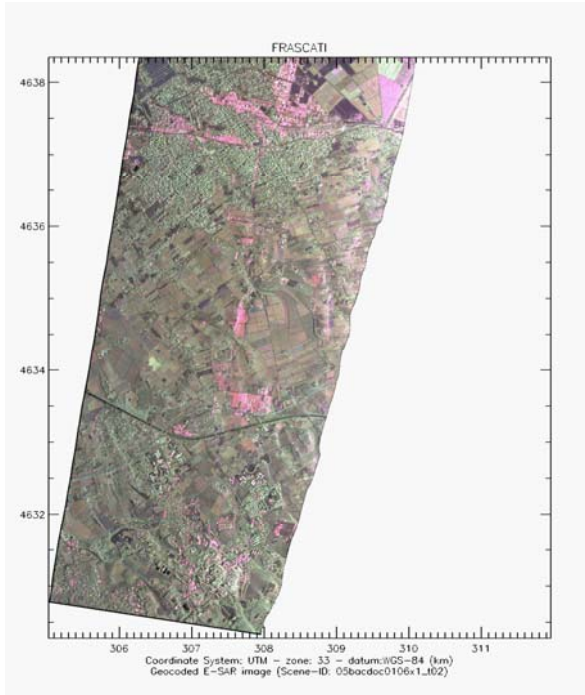


Figure 5.4a: L-band hh/vv/vh of Bacchus-Doc mission 01, Oct 5, 2005. Flight line 3.

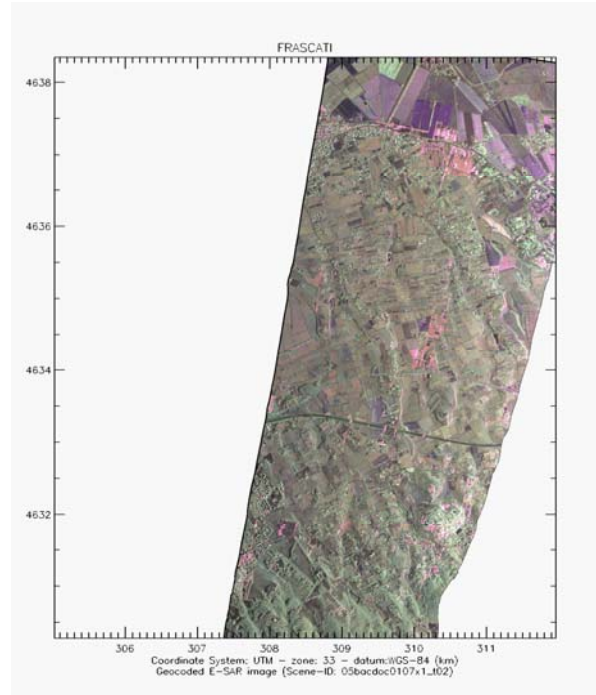


Figure 5.4b: L-band hh/vv/vh of Bacchus-Doc mission 01, Oct 5, 2005. Flight line 4.

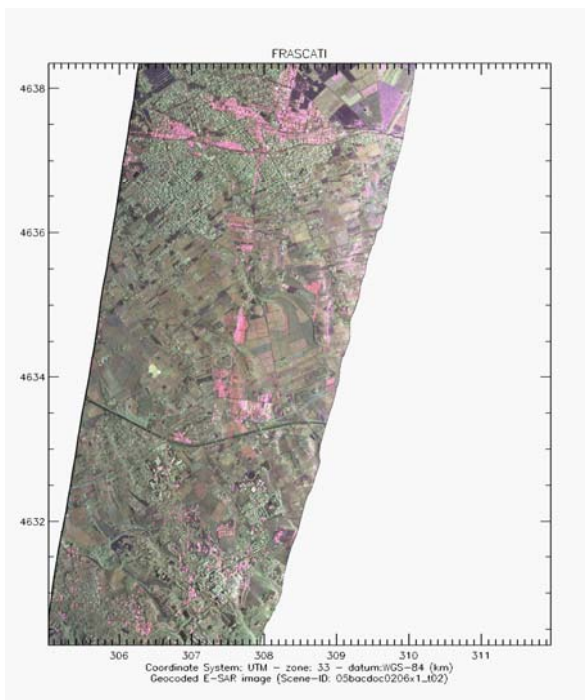


Figure 5.4c: L-band hh/vv/vh of Bacchus-Doc mission 01, Oct 25, 2005. Flight line 3.

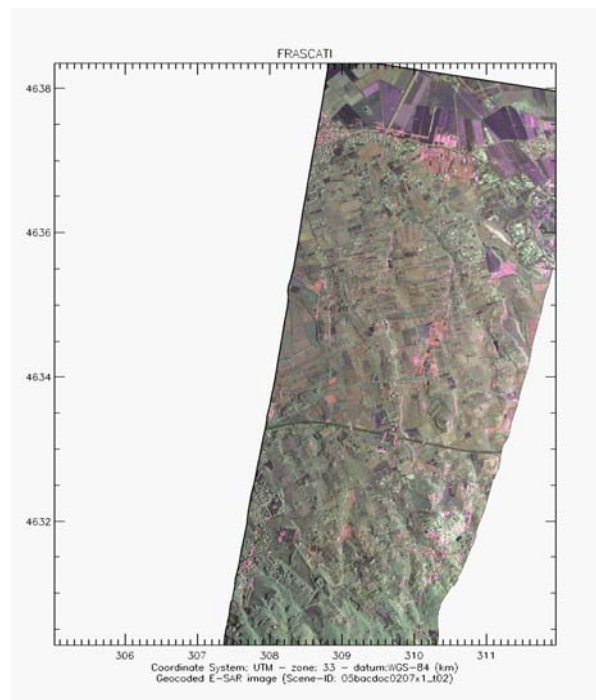


Figure 5.4d: L-band hh/vv/vh of Bacchus-Doc mission 01, Oct 25, 2005. Flight line 4.

5.4 RADIOMETRIC CORRECTIONS

SLC products feature system dependent corrections (antenna gain, receiver and processor gain). Image products in radar geometry represent radar brightness β . Terrain elevation de-

pendent radiometric correction (radar range and antenna gain variation) based on the DEM has been additionally applied to the geo-coded Bacchus-Doc image products.

For further evaluation of the geo-coded image data, for example for obtaining radar backscatter values, the user has to convert radar brightness β into radar backscatter coefficient σ^0 by performing a further local incidence angle dependent radiometric correction. The local incidence angle to be used for this operation is derived from the DEM.

6 DATA QUALITY ANALYSIS

Quality control is carried out by analysing the characteristics of radar reflectors deployed as ground control points. The parameters radar cross section (RCS), resolution and geographic position are checked. Visual inspection of the image is used to check for any other artefacts. Overall radiometric image quality is judged on the basis of radiometric range profiles.

System calibration is carried out before any mission at the Oberpfaffenhofen calibration test site. Radiometric and polarimetric calibration parameters are established here. They were kept unchanged for the whole period of installation.

Table 6.1: Ground control point parameters obtained from radar image data

Scene-ID	Frequency-polarisation	CR name	Radar cross section [dBm ²]		Resolution in radar geometry	
			nominal	measured	Range [m]	Azimuth [m]
BACDOC0102	C-vv	Vine	29.33	29.91	1.97	2.14
BACDOC0103	C-vv	Rugy	28.93	29.86	2.06	2.01
BACDOC0106	L-hh	Rugy	16.75	17.20	2.11	2.63
	L-vv			17.48	2.11	2.51
BACDOC0107	L-hh	Vine	17.13	18.70	2.11	2.76
	L-vv			17.56	2.01	2.70
BACDOC0202	C-vv	Vine	29.32	29.32	2.01	2.61
BACDOC0203	C-vv	Gras	29.25	29.43	2.01	2.04
BACDOC0206	L-hh	Gras	16.98	17.92	2.06	2.60
	L-vv			16.94	2.01	2.60
BACDOC0207	L-hh	Vine	17.03	17.42	2.01	2.68
	L-vv			16.48	2.11	2.62

Table 6.1 lists the RCS values of the corner reflectors and the resolution in radar geometry obtained. With one exception (BACDOC0202) the obtained range and azimuth resolution meets the specification within 10% of the nominal values, which are 2m in slant range and 2m (for C-band) and 2.5m (for L-band) in azimuth directions.

The nominal bore-sight RCS values are derived from theory for 90cm trihedral corner reflectors. This holds for the ideal case when the pointing vectors of the radar and the CR are matching. In the normal, the off-bore-sight case the pointing vectors are not congruent due to

different elevation and azimuth angles and the RCS is lower. To approximate off-bore-sight RCS values a cosine law is used. Thus we have calculated the different nominal values.

The measured RCS values differ from the nominal values between 0dB and 1.6dB, on average only by 0.56dB. The instability in the values in L-band mainly results from a rather low signal-to-clutter ratio of the 90cm size corner reflectors employed. Another error source is the radar itself which has stability in the order of 0.5 - 1dB.

7 SUMMARY

The BACCHUS-DOC radar campaign consisting of two E-SAR flight missions in October 2005 (pre-vintage and post-vintage) was successfully executed by DLR over the test area 'Frascati' in collaboration with the University Tor Vergata and ESA-ESRIN. A complete set of radar measurement data processed by DLR-HR up to Level 1b (geo-coded image products) was collected and delivered (Table 7.1). Application specific evaluation of the data is underway at University Tor Vergata.

Table 7.1: BACCHUS-DOC deliverables

No	Scene-ID	Comment	Frequency	Polarisation	Medium
1	I05BACDOC0102X1_T01	Frascati	C	DP	DVD-R
2	I05BACDOC0103X1_T01	Frascati	C	DP	DVD-R
3	I05BACDOC0202X1_T01	Frascati	C	DP	DVD-R
4	I05BACDOC0203X1_T01	Frascati	C	DP	DVD-R
5	I05BACDOC0106X1_T02	Frascati	L	PM	DVD-R
6	I05BACDOC0107X1_T02	Frascati	L	PM	DVD-R
7	I05BACDOC0206X1_T02	Frascati	L	PM	DVD-R
8	I05BACDOC0207X1_T02	Frascati	L	PM	DVD-R
9	BACDOC_Ancillary_Data				CD-R