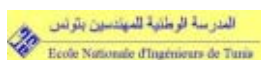


SPARC

Contract No.

SPARC EXPERIMENTERS HANDBOOK

DRAFT



Contents

LIST OF PARTICIPANTS	3
OVERVIEW OF THE CAMPAIGN	5
CHAPTER 1 - DESCRIPTION OF THE STUDY AREA: BARRAX	8
1.1. OVERALL DESCRIPTION OF THE AREA	8
1.2. PARTICULAR DESCRIPTION OF THE DIFFERENT STUDY AREAS CONSIDERED FOR DIFFERENT RESOLUTION SENSORS.....	10
CHAPTER 2 - SATELLITE DATA ACQUISITIONS.....	12
2.1 CHRIS/PROBA ACQUISITIONS	12
2.2 MERIS ACQUISITIONS	15
CHAPTER 3 - AIRBORNE DATA ACQUISITION.....	17
3.1 HYMAP.....	17
3.2 ROSIS.....	18
3.3 FLIGHTLINES COORDINATES	20
CHAPTER 4 - ATMOSPHERIC MEASUREMENTS.....	23
4.1 RADIOSOUNDINGS	23
4.2 SPECTRAL RADIANCE MEASUREMENTS	23
4.2.1 Instruments	23
4.2.2 Measurement Plan	26
4.3 RADIANCE MEASUREMENTS IN THE OXIGEN-A ABSORPTION BAND FOR MERIS VALIDAT	28
CHAPTER 5 - GROUND RADIOMETRIC MEASUREMENTS.....	29
5.1 SOLAR RANGE GROUND RADIOMETRIC MEASUREMENTS.....	29
5.1.1 Instrumentation.....	29
5.2 THERMAL INFRARED GROUND RADIOMETRIC MEASUREMENTS.....	31
5.2.1 Instrumentation.....	31
5.2.2 Measurement plan	33
CHAPTER 6 - VEGETATION MEASUREMENTS	34
6.1 INSTRUMENTATION.....	34
6.2 MEASUREMENT PROTOCOLS	39
6.2.1 Crop phenology	39
6.2.2 LAI	40
6.2.3 fCover	40
6.2.4 Leaf chlorophyll	40
6.2.5 Leaf water.....	40
6.2.6 Dry leaf / canopy biomass	40
6.2.7 Total canopy height	41
6.2.8 Canopy structure: Leaf size/angle distribution	41
6.2.9 Row direction	41
6.2.10 Plants density.....	41
6.2.11 Soil moisture.....	42
6.2.12 Soil roughness	42
6.3 VEGETATION SAMPLING STRATEGY	44
6.3.1 Some statistical consideration	44
6.3.2 Sampling strategy scheme	44
6.3.3 VALERI sampling strategy	45
6.4 VEGETATION MEASUREMENTS PLANNING	46
CHAPTER 7 - REFERENCE METEOROLOGICAL DATA	47
CHAPTER 8 - TECNOLOGICAL TESTINGS	50

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Overview of the campaign

The reason for the selection of the days 12th, 13th, 14th of July to carry out the campaign is the coincidence with three consecutive days of CHRIS/PROBA overpasses. Since most of the other planned activities are somehow flexible in dates (more continuous satellite overpasses) the particular orbit of PROBA is the driver in choosing the preferable dates for the campaign.

For those not familiar with PROBA, the satellite was launched in a kind of orbit that has some special features. It makes possible to have coverage over a given site for 2 or 3 consecutive days, and then several days (around 6 at the latitude of Barrax) in between where access to the site is not possible due to the orbital coverage. The situation over Barrax on 12-13-14 July is particularly favourable, because PROBA will almost pass over (-4° across-track zenith angle) on 13th of July, and then on 12th of July (+20° across-track zenith angle) and on 13th of July (-27° across-track zenith angle) we have additional multi-angular coverage. Each orbit provides 5 images with different view angles (-55°, -36°, 0°, +36°, +55° along-track zenith angles). Then, it seems these are the optimum dates for the campaign for angular coverage. Overpass times are 11:07, 11:19 and 11:32 (UT) for the three days, 12-13-14 July respectively:

Date	Time	Minimum Satellite Zenith Angle	Solar Zenith Angle	Satellite altitude (km)
12 July	11:07	+20	22	667
13 July	11:20	-4	21	668
14 July	11:32	-27	20	668

Note that 3 multiangular CHRIS/PROBA datasets have been already acquired over Barrax in the previous weeks, and the quality of the data is excellent (both geometrically and radiometrically). The plan is to get a multiangular reference dataset with 15 angles (5 angles along each of the 3 different orbits) and 62 spectral channels per angle during this concentrated campaign. This intensive dataset plus the multitemporal series of CHRIS data being collected over Barrax from April to October 2003 will represent the SPECTRA reference dataset for SPECTRA-related studies. Specific atmospheric measurements are planned for each PROBA overpass on each day.

The activities planned over Barrax this summer originated from the combination of a number of initially not connected initiatives coming under different funding:

- Field activities in the framework of the EU project DEMETER,
- MERIS / ASAR synergy studies within an ENVISAT AO project,
- MERIS validation activities within the framework of another ESA project,
- CHRIS/PROBA acquisitions and data analysis under the framework of another initiative,
- MSG/SEVIRI validation activities under funding by EUMETSAT LSA SAF,
- Barrax as an additional site for VALERI activities,
- background activities for vegetation fluorescence modelling and validation studies,
- background activities for SPECTRA studies,
- and others.

Moreover, parallel activities related to definition of core sites for satellite validations for CHRIS and ENVISAT data have motivated the interest in getting involved in this activity by other people, with activities also related to AATSR and ASTER thermal data validation. Another team will come from Tunisia to participate in the campaign under the Spain-Tunisia bilateral agreements for cultural/scientific cooperation. The planned tests of the airborne vegetation fluorimeter under construction will not be possible during this campaign because the instrument is not yet available, but the technological component of the campaign will consist on the testing of new electro-acoustic detectors for potential use in hyperspectral remote sensing applications (from another EU project). At the end, the activities have become relevant enough to go one step forward and try to convert the independent activities into a more coherent programme.

For this reason, it was suggested to ESA to convert the different unconnected activities planned in Barrax for this summer into a formal ESA campaign, under the framework of SPECTRA related activities. This idea had been accepted, and a formal ESA contract has been established for this campaign.

For MERIS it is only possible to get Full Resolution data for one day during the campaign, 14th of July, but at least this image will be surely available:

Orbit	Track	Frame	Date	Time
7162	94	2835	2003/07/14	10:34:09

DLR will be in charge of the flights, with final confirmation of aircraft availability exactly for the days of CHRIS/PROBA overpass. The sensors to be used are HYMAP and ROSIS, which are both quite well suited for our activity. The agreement included that DLR will perform the geocoding of all the airborne data (by using PARGE software and all available aircraft navigation/attitude data) while the University of Valencia will perform the atmospheric correction of the data, to make radiometric processing compatible with the procedures applied to CHRIS and MERIS data. The plan is to acquire one line of HYMAP data (126 spectral channels, app. 5 m resolution) and 4 lines with ROSIS data (115 spectral channels, app. 1 m resolution) simultaneously to the CHRIS overpass by 13 July around 11:20 with flight lines parallel to the principal plane (towards the sun).

Due to the other activities around in the framework of preparations for SPECTRA, and noting that many people involved in the campaign are also involved in parallel SPECTRA studies, it seems a good idea to put in common such related activities. Most of the activities to be performed in the campaign are highly relevant for SPECTRA, but in particular the issues related to retrieval of biophysical parameters from CHRIS and MERIS data will be of particular relevance, while scaling issues and complementary between SPECTRA (covering only local sites) and global sensors such as MERIS / SEVIRI are also key elements. Another aspect of the campaign is the use of CHRIS data to test geometric and atmospheric processing procedures to be developed for SPECTRA. CHRIS data also serves for SPECTRA simulation studies, as model-simulated Barrax scenes can be compared with actual data.

With the addition of the airborne component provided by the ESA support, the scaling from ground measurements to the SEVIRI resolution can now be done in with the following progression:

```

Field measurements --->
  ROSIS (1 m) --->
    HYMAP (5 m) --->
      CHRIS (34 m) --->
        MERIS FR (300 m) --->
          MERIS RR (1200 m) --->
            SEVIRI (+3000m)
    
```

Concerning atmospheric measurements, we plan to launch 2 radiosounding balloons every day of the campaign, one in the early morning (to get stable atmospheric condition) and the other just at the time of satellite/aircraft overpass. The combination of radiosoundings / lidar / sunphotometers / high spectral resolution sky radiance measurements will allow addressing a number of issues such as:

1. Aerosols optical thickness retrievals (more related aerosols parameters), by different methods and techniques.
2. Atmospheric correction of the satellite data, with several algorithms to be tested for CHRIS and MERIS.
3. High spectral resolution radiance measurements in the O2-A band for validation of MERIS pressure retrievals for Rayleigh corrections.

Vegetation measurements will focus on three main parameters: LAI, fCover, Chlorophyll. These three parameters are the official products being validated in the context of MERIS and SEVIRI activities.

Obviously, for validation it is convenient to measure additional information about canopy architecture: canopy height, leaf size, etc. and other relevant information about phenology of each type of crop. Radiometric measurements at the leaf and canopy levels will be performed by using the several available radiometers with different fields of view and different setups. At least 4 radiometers (two GER and two ASD) will participate in the campaign, two of them mounted in adapted hoist, with angular FOV ranging from 1 to 25 degrees. Different methods to measure LAI and chlorophyll will be used, as well as for fCover, including regular, hemispheric and stereoscopic digital photos. Some intercomparison of methods is planned before or after the main campaign, preferably before depending on the weather conditions and availability of the different teams.

Maps of the status of vegetation are already prepared as part of the background DEMETER activities already on going, and other satellite data (Landsat) are also available as part of the DEMETER project. Since we have already performed two other airborne campaigns this year in Barrax for the TerraSAR programme, some aspects of the campaign preparations are well advanced.

Although everybody would prefer that this is not the case, if extremely bad weather conditions develop during the planned campaign period 12-14 July, a backup solution is considered for 28 and 29 July, where CHRIS/PROBA overpasses are also possible. The initial backup dates July 20 and 21 have been discarded because they overlap with IGARSS, a clearly undesirable situation. As weather forecasts become more significative as the campaign approach, potential backup solutions will become more precisely defined in case they become finally necessary, hopefully not.

Chapter 1 - DESCRIPTION OF THE STUDY AREA: BARRAX

1.1. OVERALL DESCRIPTION OF THE AREA

The chosen test area for data collection is located in Barrax in the south of Spain ca. 200 km away from Valencia and ca. 20 km away from Albacete. The area around Barrax has been used for agricultural research for many years. The test area has a rectangular form and an extent of 5 km x 10 km = 50 km².

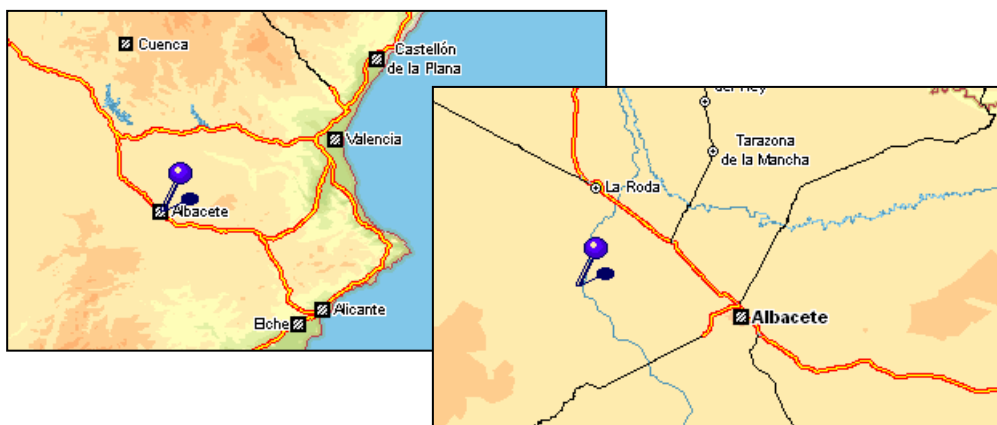


Figure 1.1. Distance from the test site in Barrax to Albacete is 20 km and to Valencia and Mediterranean ca. 200 km.

Barrax test site is situated within La Mancha, a plateau 700 m above sea level. The test site is located in the west of province of Albacete. It is 20 km far away from the capital town Albacete (coordinates 30°3' N, 2° 6' W). The area is characterised by a flat morphology and large, uniform land-use units. Differences in elevation range up to 2 m only. The regional water table is about 20-30 m below the land surface.

The climatic conditions accord the Mediterranean features: high precipitations in spring and autumn and the minimum in summer. The annual rainfall averages is about 400 mm. Furthermore, the region has high continentality with high thermal oscillations during all seasons. La Mancha represents one of the driest regions of Europe.

The region consists of approximately 65% dry land and 35% irrigated land with different agricultural fruits.

The test area has the following co-ordinates (related to UTM, Zone 30, DATUM WGS84):

Geographical corner coordinates:

Corner1: 575505.9523E 4323210.7146N
 Corner2: 585226.6519E 4325555.7469N
 Corner3: 575039.5028E 4325144.3194N
 Corner4: 584760.2034E 4327489.3472N

Figures 1.2 and 1.3 give an impression of the test site.

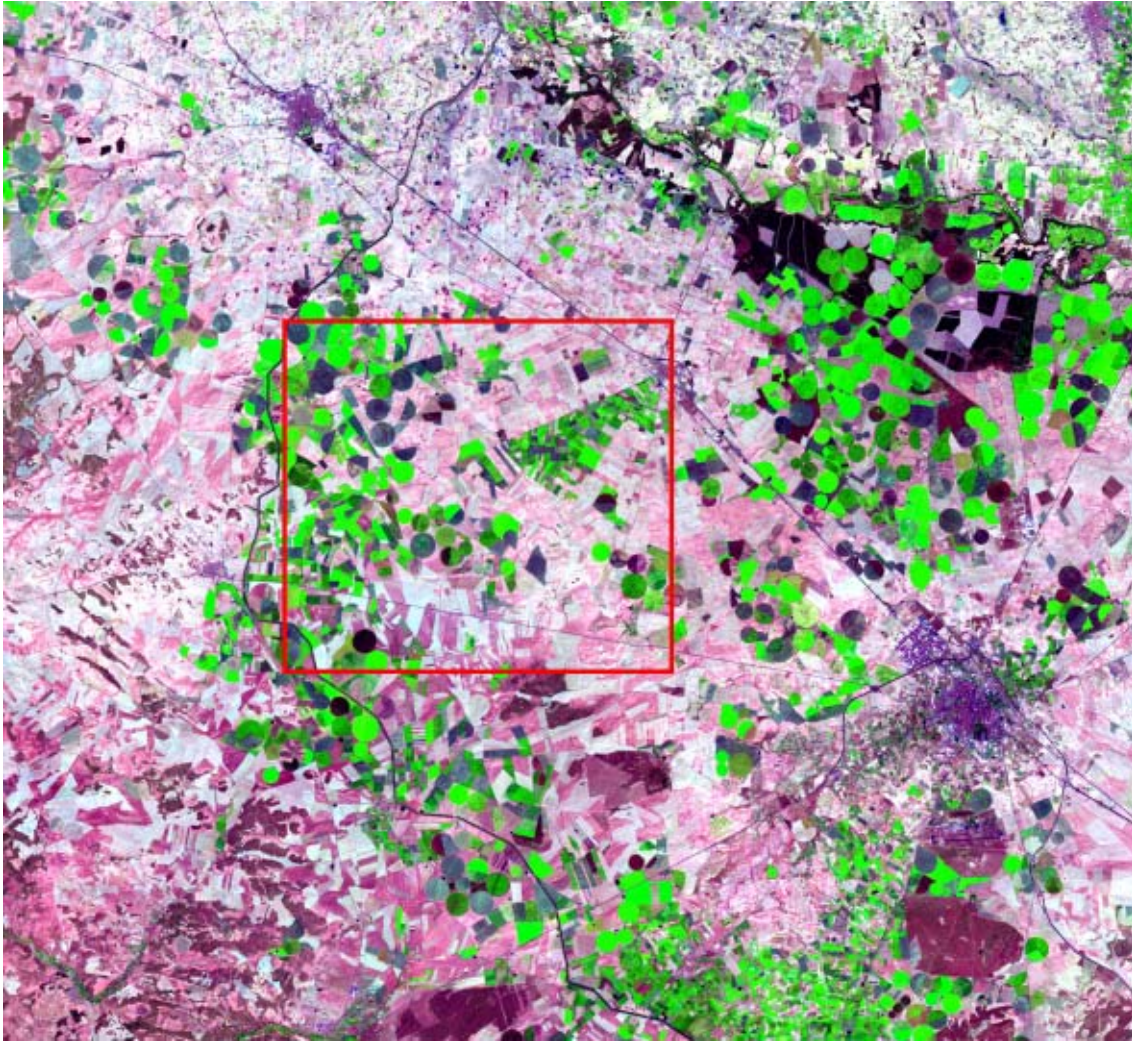


Figure 1.2. Landsat TM Satellite image of the test site in summer. Study area is shown as a red square.

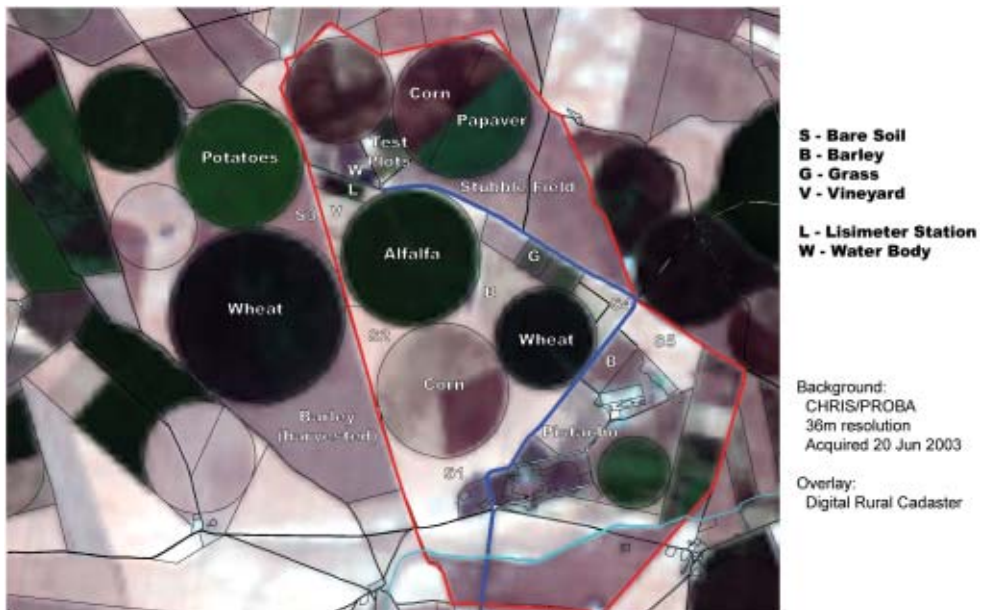


Figure 1.3. Agricultural land use in the test site.

1.2. PARTICULAR DESCRIPTION OF THE DIFFERENT STUDY AREAS CONSIDERED FOR DIFFERENT RESOLUTION SENSORS

The Barrax test site is included in a bigger area used in EC's DEMETER project. The DEMETER study area is defined so that it takes advantage of overlaps of coverage among different satellite orbits to get more frequently images of the area. As it can be seen in figure 1.4, the Barrax area is in the overlap between Landsat reference grid images 200-33 and 199-33, what makes easier to get coverage of the area from two different satellite orbits.

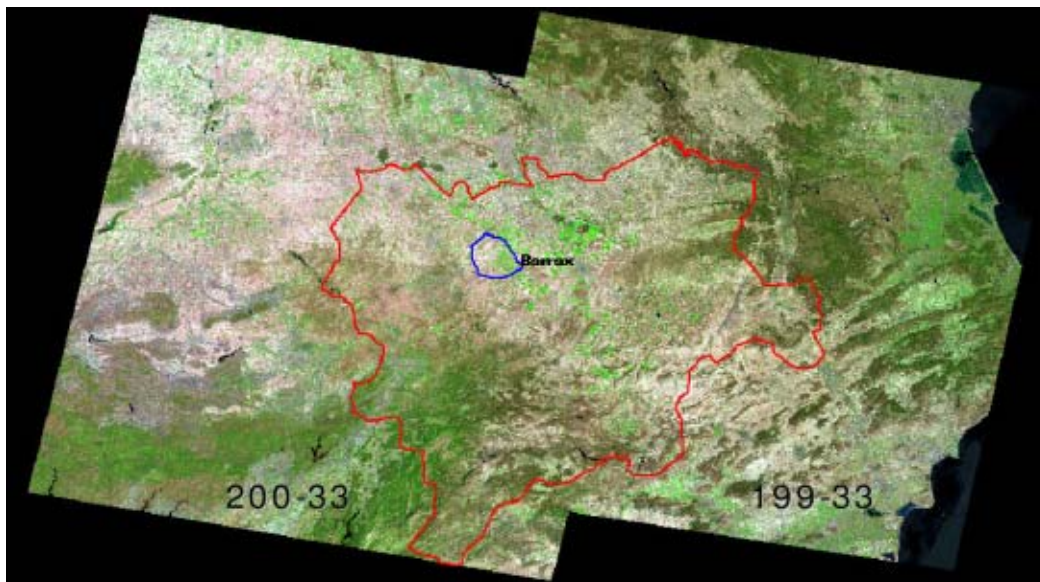


Figure 1.4. Barrax area is in the overlap between Landsat reference grid images 200-33 and 199-33.

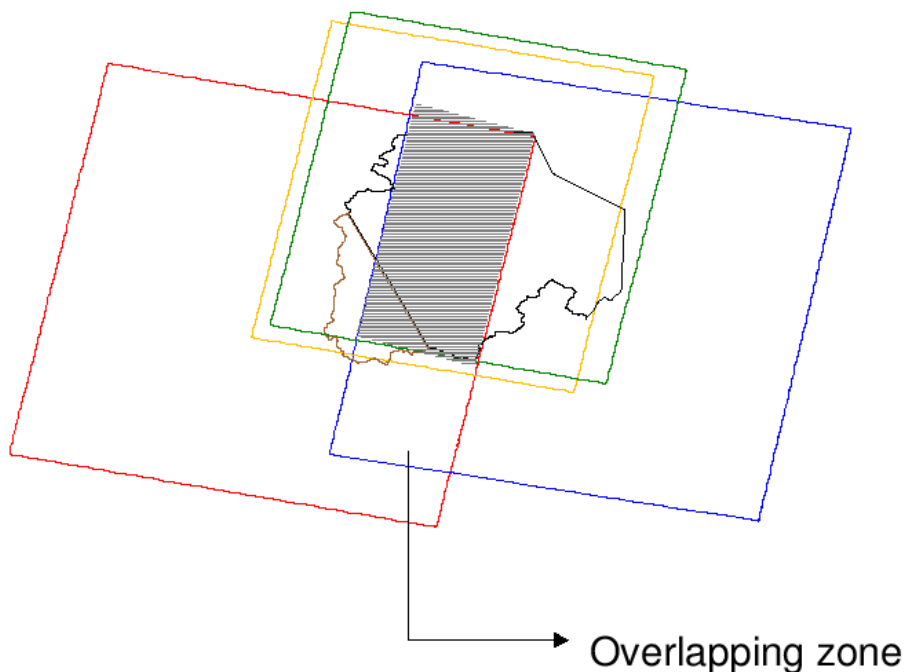


Figure 1.5. Overlapping zone from different satellite images.

When combining coverages from different satellites, an overlapping zone is defined where most intensive field activities are focused. This overlap zone is about 30 by 30 square kilometres, and is representative of the hydrological system and agricultural practices in the whole management area.

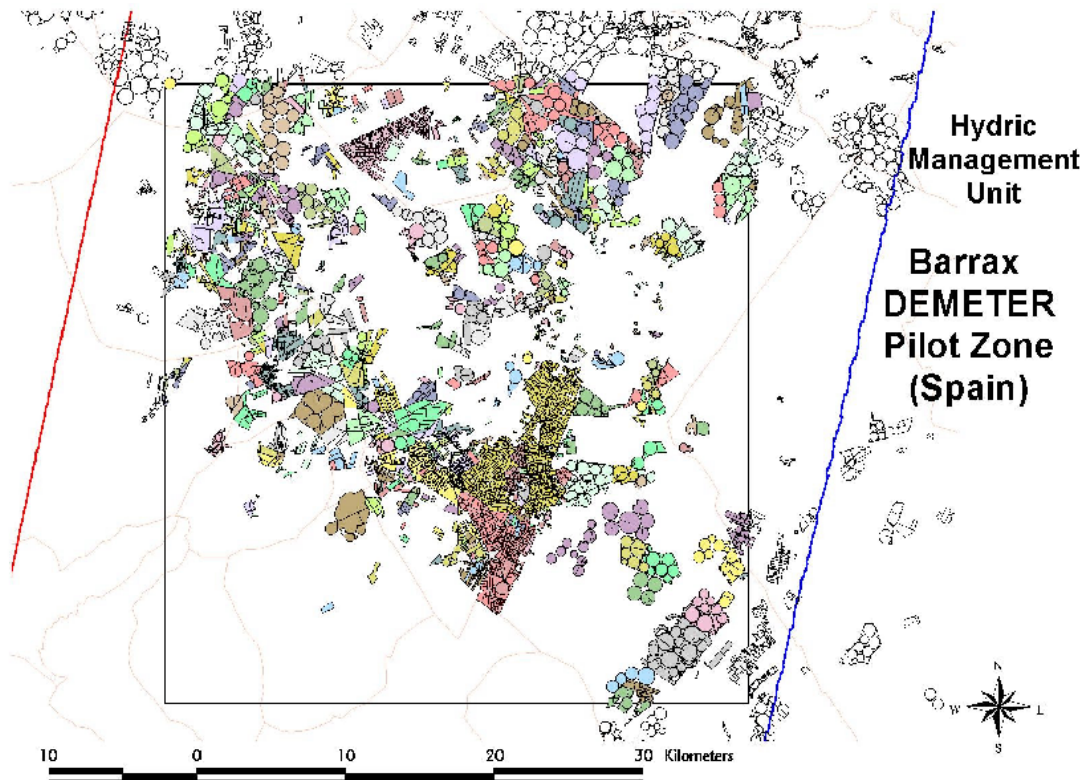


Figure 1.6. Location of the most intensive field activities.

Chapter 2 - SATELLITE DATA ACQUISITIONS

2.1 CHRIS/PROBA ACQUISITIONS

CHRIS (Compact High Resolution Imaging Spectrometer) is a physically compact payload as its name implies (weighing under 15 kg) and operates in the 'push-broom' mode. Its main applications will be in environmental monitoring, forestry inventory and precision farming.

From a 600 km orbit, CHRIS can image the Earth in a 14 km swath with a spatial resolution of 18 m (this is somewhat variable as the altitude varies around the orbit). Using PROBA's agile steering capabilities in along and across track directions enables observation of selectable targets well outside the nominal field of view of 1.3°. Images will generally be acquired in sets of 5, these being taken at along track angles of ± 55 degrees, ± 36 degrees, and as close to nadir as possible.

CHRIS operates over the visible/near infrared band from 400 nm to 1050 nm and can operate in 63 spectral bands at a spatial resolution of 36m, or with 18 bands at full spatial resolution. Spectral sampling varies from 2-3 nm at the blue end of the spectrum, to about 12 nm at 1050nm. Sampling is about 7nm near the red edge (~690-740nm). The instrument is very flexible and different sets of bands can be used for different applications.

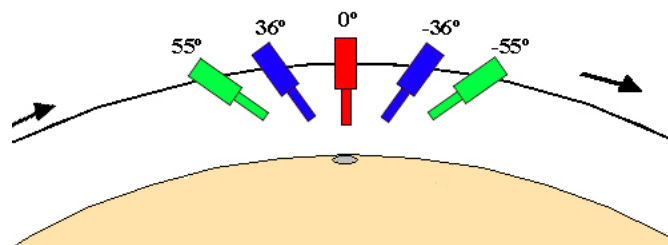


Figure 2.1. Illustration of how CHRIS can hold a target in view by using PROBA's pitch control.

Key Characteristics:

Spatial sampling interval	18m on ground at nadir
Image area	14 km X 14 km (748 X 748 pixels)
Number of images	Nominal is 5 downloads at different view angles
Data per image (for a 14x14 km ²)	131 Mbits
Spectral range	410nm to 1050 nm
Number of spectral bands	19 bands at a spatial resolution of 18m 63 bands at a spatial resolution of 36m
Spectral resolution	1.3 nm @ 410nm to 12 nm @ 1050nm (i.e it varies across the spectrum)

Programmable operation:

Across track pixel size	18m or 36m
Along track pixel size	finest resolution is 18m but can be made coarser by changing the integration time
Spectral	variable bandwidth and band location
Digitisation	12 bits
Signal-to-noise ratio	200 @ a target albedo of 0.2

Table 2.1. Key characteristics of CHRIS/PROBA.

Three images were acquired for the Barrax study site before SPARC campaign. Figures 2.2 and 2.3 shows two CHRIS/PROBA images acquired with the same co-ordinates configuration that will be used for SPARC campaign. In the 20/05/2003 image only 4 angles could be acquired, but in the 12/06/2003 were acquired all the angles.

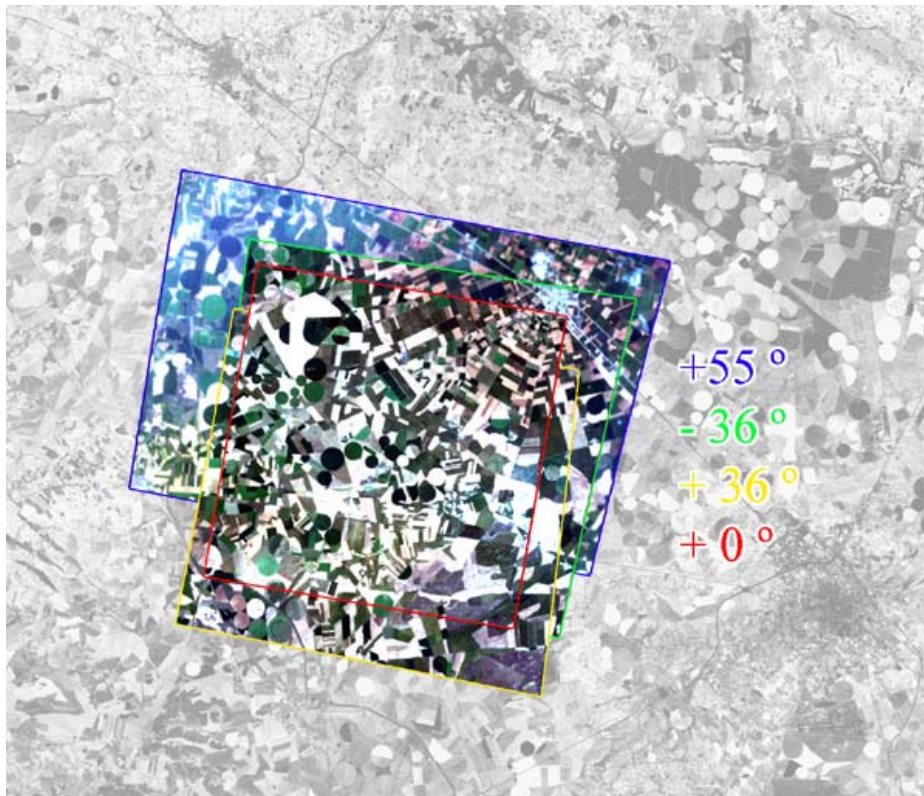


Figure 2.2. CHRIS/PROBA image acquired at 20/05/2003.

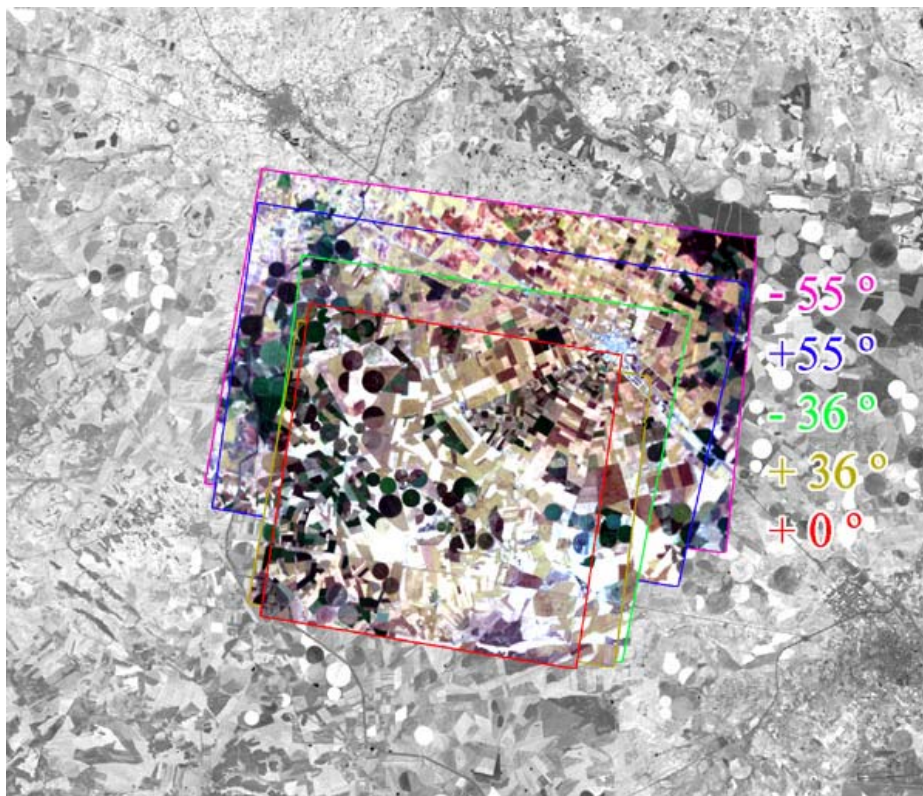


Figure 2.3. CHRIS/PROBA image acquired at 12/06/2003.

The small cross marked in red in figure 2.4 indicates the point where PROBA is supposed to point when acquiring images of the Barrax area; that is, the indicated coordinates of the scene centre used to program satellite acquisitions by the satellite operators.

In figure 2.4 the area shown in red corresponds to the area of overlap of the different angular views for the CHRIS/PROBA image acquired on 20 May 2003. The area shown in blue corresponds to the area of overlap of the different angular views for the CHRIS/PROBA image acquired on 12 June 2003. The background image is a Landsat TM false-colour composition used as reference.

Although with only two images there is not enough statistics, we can assume that the overlap between the areas shown in red and in blue in figure 2.4 is the most likely expected area to be included in all the views for the different CHRIS/PROBA acquisitions during SPARC. This overlap area should be the area where most intensive ground measurements have to be performed during SPARC.

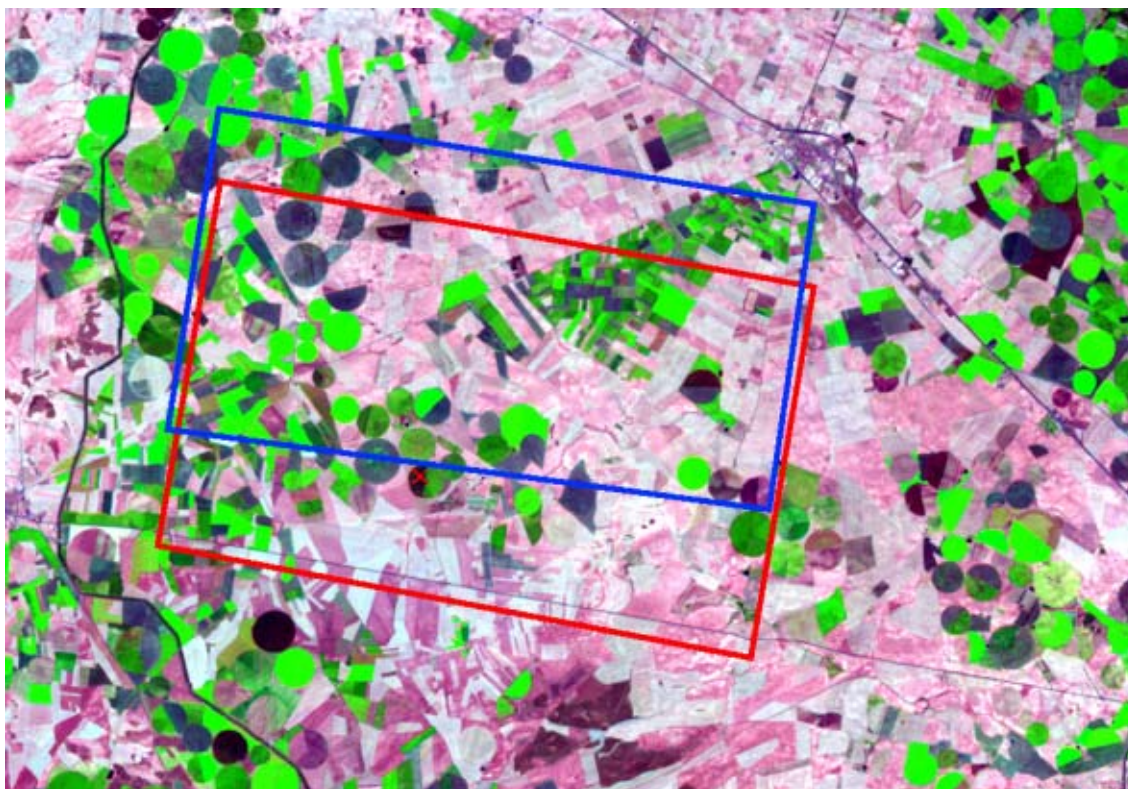


Figure 2.4 Overlap areas in CHRIS/PROBA images acquired on the 20th of May (red) and on the 12th of June (blue).

The PROBA acquisitions programmed during the SPARC campaign were shown in the Overview section.

For more information, please visit the CHRIS-on-PROBA Mission Web Page:

<http://www.chris-proba.org.uk>

2.2 MERIS ACQUISITIONS

MERIS is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range installed on board of ESA's Earth Observation satellite ENVISAT. Fifteen spectral bands can be selected by ground command, each of which has a programmable width and a programmable location in the 390 nm to 1040 nm spectral range.

The instrument scans the Earth's surface by the so called 'push broom' method. CCDs arrays provide spatial sampling in the across track direction, while the satellite's motion provides scanning in the along-track direction.

MERIS is designed so that it can acquire data over the Earth whenever illumination conditions are suitable. The instrument's 68.5° field of view around nadir covers a swath width of 1150 km. This wide field of view is shared between five identical optical modules arranged in a fan shape configuration. In the calibration mode, correction parameters such as offset and gain are generated, which are then used to correct the recorded spectra. This correction can be carried out either on board or on the ground.

The Earth is imaged with a spatial resolution of 300 m (at nadir). This resolution is reduced to 1200 m by the on board combination of four adjacent samples across track over four successive lines.

The scene is imaged simultaneously across the entire spectral range, through a dispersing system, onto the CCD array. Signals read out from the CCD pass through several processing steps in order to achieve the required image quality. These CCD processing tasks include dumping of spectral information from unwanted bands, and spectral integration to obtain the required bandwidth. On-board analogue electronics perform pre-amplification of the signal and correlated double sampling and gain adjustment before digitisation. The on-board digital electronics has three major functions: it completes the spectral integration, performs offset and gain corrections in full processed mode, and creates the reduced-resolution data when required.

The calibration of MERIS is performed at the orbital south pole, where the calibration diffuser is illuminated by the sun by rotating a calibration mechanism.

The engineering requirements on the instrument, which have been derived from the ENVISAT mission requirements, are as follows:

- Spectral range: 390 nm to 1040 nm
- Spectral resolution: 1.8 nm
- Band transmission capability: Up to 15 spectral bands, programmable in position and width
- Band-to-band registration: Less than 0.1 pixel
- Band-centre knowledge accuracy: Less than 1 nm
- Polarisation sensitivity: Less than 0.3%
- Radiometric accuracy: Less than 2% of detected signal, relative to sun
- Band-to-band accuracy: Less than 0.1%
- Dynamic range: Up to albedo 1.0
- Field of view: 68.5°
- Spatial resolution: 300 m at nadir

Figure 2.5 shows the area that will be covered by the MERIS image of the day 14/06/2003, and table 2.2 indicates the details of the acquisition.

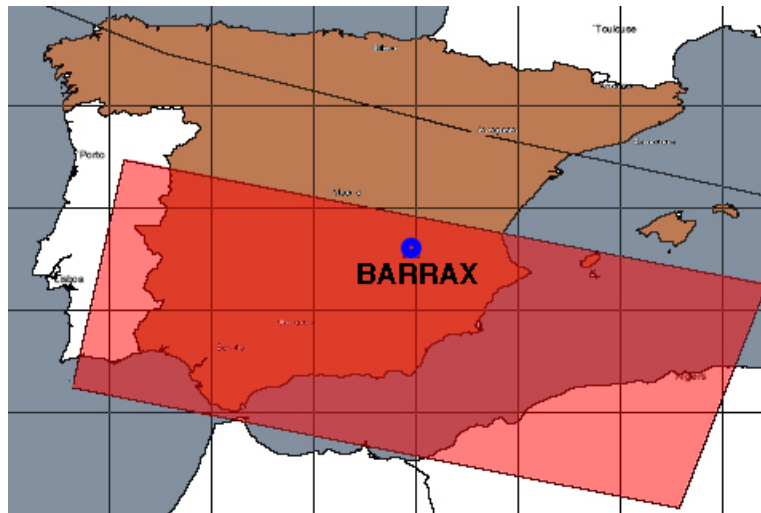


Figure 2.5. Area that will be covered by the MERIS image of the day 14/06/2003.

Orbit	Track	Frame	Date	Time (UT)	Solar zenith angle
7162	94	2835	2003/07/14	10:34:09	33.5°

Table 2.2. MERIS acquisition programmed during the SPARC campaign.

Chapter 3 AIRBONE DATA ACQUISITION

3.1 HyMap

The HyMap Imaging Spectrometer is an Australian development which provides the best available signal to noise ratio, with a calibration precision similar to that of AVIRIS. An advanced sensor stabilisation system gives geometrically superior images. It is designed for operation in unpressurised light aircraft, with easy installation attached to seat rails (Figure 3.1).



Figure 3.1. The HyMap instrument.

The system is realised as a whisk-broom scanner with an axe head double mirror. In four individual spectrometer units the wavelength range between 400 and 2500 nm is covered in 125 spectral bands with a bandwidth of approx. 16 nm. The instrument offers an extremely high signal to noise ratio (SNR) of more than 500:1 which is more than most existing imaging spectrometers including AVIRIS can realise.

Summary specifications of HyMap are as follows:

- 128 spectral bands in VIS, NIR, SWIR
- Bandwidths of approx. 16 nm; high signal to noise >500:1
- 5m spatial resolution; 60° swath width
- 260 Mbyte data for a flight line 2.5km by 10km
- On-board radiometric and spectral calibration
- Ground calibration facility with traceable standards
- Operates in aircraft equipped with standard aerial camera ports
- Rapid installation, typically in 2 hours
- 3 axis gyro stabilised platform
- Interface to GPS or DGPS
- Data retrieval and pre-processing software

Spectrometer Characteristics:

Wavelength range: 450nm - 2.5 μm, bandwidth: ~16nm, 128 bands. The Hymap provides a signal to noise ratio (>500:1)

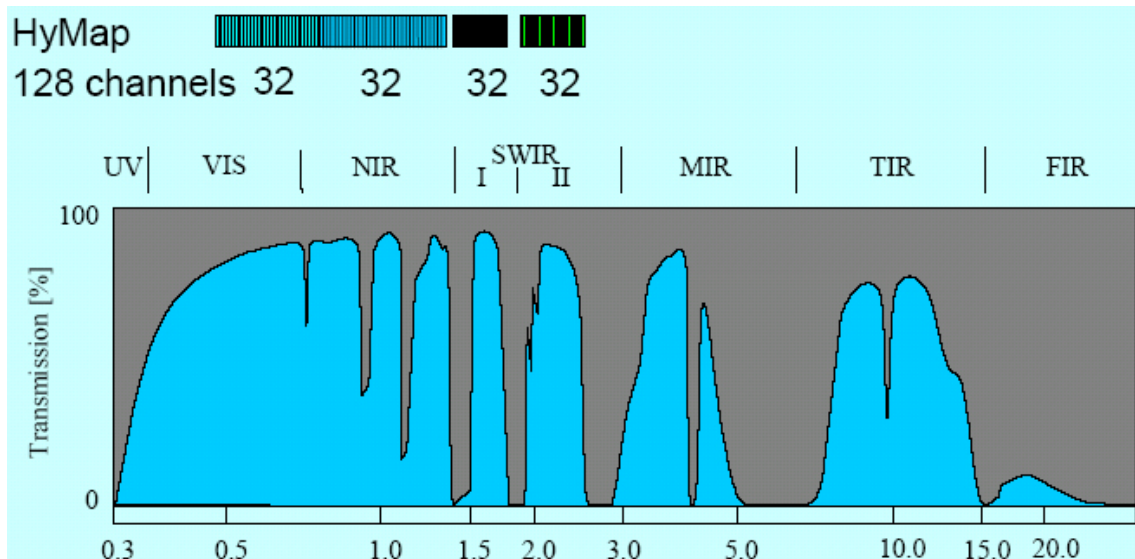


Figure 3.2. Hymap spectral coverage.

Main geometric parameters:

FOV:	61.3 degrees (512 pixels)
IFOV:	2.5 mrad along track, 2.0 mrad across track
GIFOV:	3 - 10 m (typical operation range)

For more information, please visit the HyVista's HyMap Home Page:

<http://www.hyvista.com/hymap.html>

3.2 ROSIS

ROSI (Reflective Optics System Imaging Spectrometer) is a compact airborne imaging spectrometer, which had been developed jointly by Dornier Satellite Systems (DSS, former MBB), GKSS Research Centre (Institute of Hydrophysics) and German Aerospace Center (DLR, Institute of Optoelectronics) based on an original design for a flight on ESA's EURECA platform.

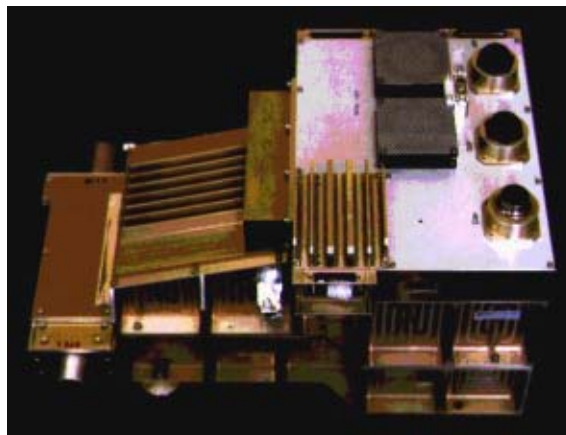


Figure 3.3. ROSIS optical modul.

The detector chip is a 2-dimensional CCD array (Thomson THX 7895). One dimension is used to scan a narrow cross track line on the ground. The second dimension is for acquiring the spectral information of each of these cross track pixels.

ROSIS can be operated in different modes. This means that the user can select interesting areas (also dark references), lines or pixels on the detector array via PC programming. The mode configuration can be adapted to optimize the user's data needs. Some of these modes are used only for test or calibration purposes.

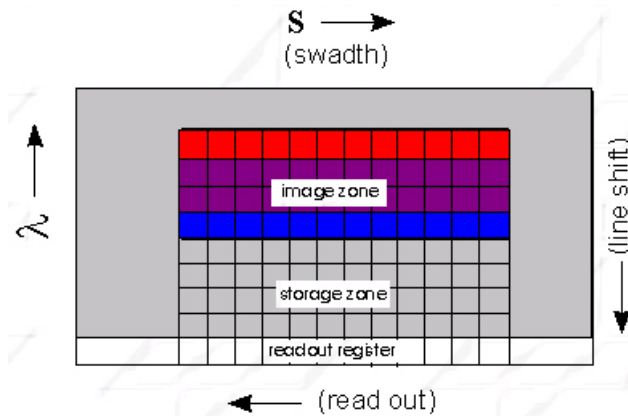


Figure 3.4. Thomson THX 7895 CCD array.

Spectrometer Characteristics:

Wavelength range: 430nm - 850nm, bandwidth: min 15.2nm, 84 bands in spectral mode, 32 bands in imaging mode.

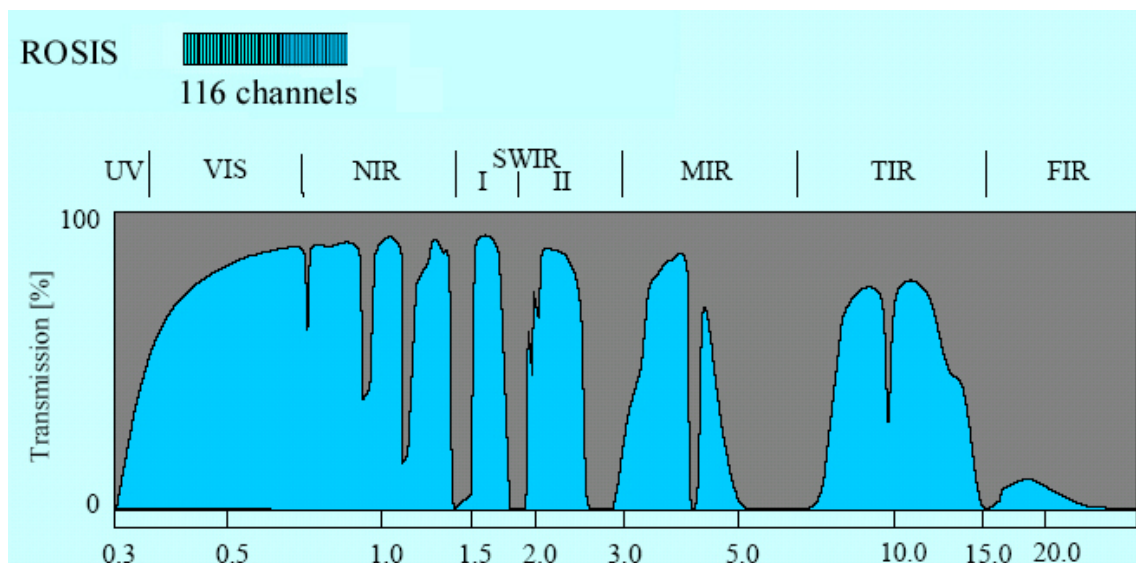


Figure 3.5. ROSIS spectral coverage.

Main geometric parameters:

FOV:	16 degrees (500 pixels in image mode) (167 pixels in spectral mode)
I FOV:	0.56 mrad
GIFOV:	5.6 m at 10km altitude

For more information, please visit the DLR's ROSIS Home Page:

<http://www.op.dlr.de/ne-oe/fo/rosis/home.html>

3.3 FLIGHTLINES COORDINATES

Hymap and ROSIS will be operated onboard a DLR Dornier DO 228 aircraft. To obtain the flight coordinates we have used the overlap between the MERIS image (figure 2.5) and the most likely expected area to be included in all the views for the different CHRIS/PROBA acquisitions during SPARC (figure 2.4).

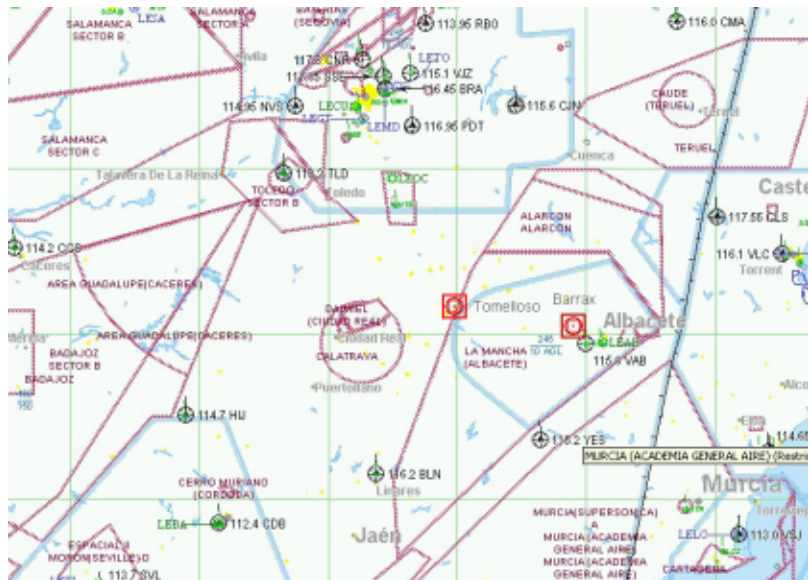


Figure 3.6. Sketch showing the use of airspace over the test area.

Figure 3.6 indicates that the test site is located in a special use airspace. This temporarily restricted airspace (TRA) is managed by the Spanish airforce. DLR has to request permission for entering this airspace before each mission.

The flight will take place the 13th of July 2003, at the same time as the CHRIS/PROBA acquisition (11:20). The flight will be parallel to the principal plane (in the sun direction), in order to reduce angular effects in the images. The final configuration is shown in figure 3.7, with one HyMap flight line (coverage in cyan colour), and four ROSIS flight lines (coverage in yellow colour). The areas delimited in blue and red correspond to the overlapping areas of CHRIS/PROBA images previously acquired over Barrax (20th of May in red and 12th of June in blue) and indicate the most probable coverage of CHRIS/PROBA imagery during SPARC. This prevision has been used to finally place the flight lines.

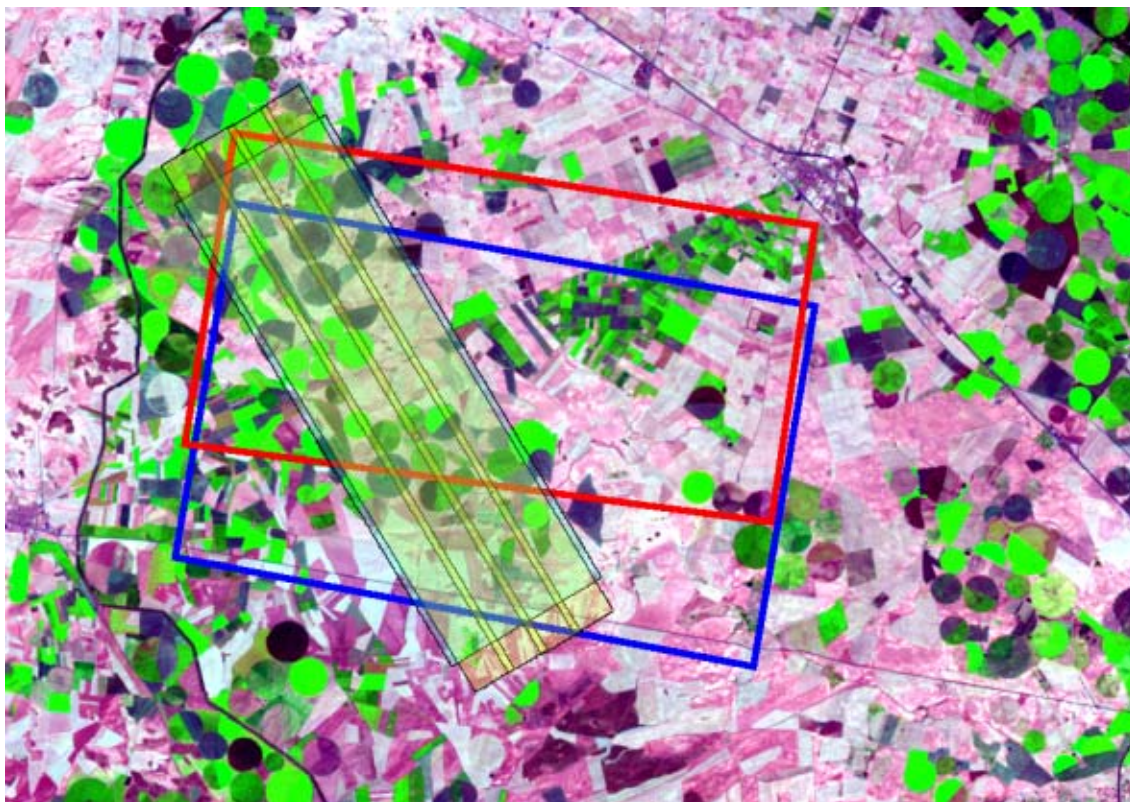


Figure 3.7. Flight configuration for SPARC campaign corresponding to the 13th of July.

In the case that it would be impossible to acquire the images due to adverse weather or mechanical conditions, there are two possible configurations for days 12th and 14th of July, as shown in figure 3.8.

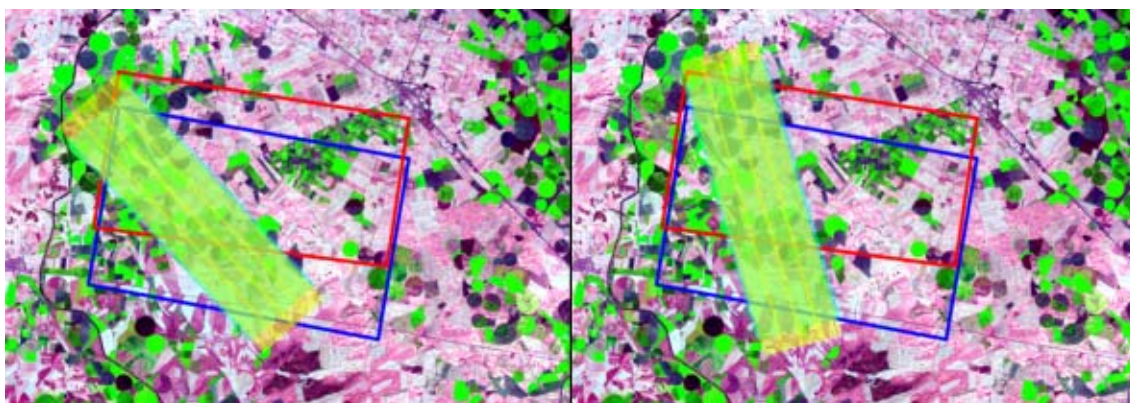


Figure 3.8. Alternative flight configuration for SPARC campaign for backup on the 12th of July (left) and the 14th of July (right).

Flight lines start and ending coordinates for the programmed acquisition day:

13 th July	UTM, Zone 30 North Datum: European 50 mean		WGS84		WGS84 Decimal degrees	
HyMap	576322E	4326468N	39°04'55.77"N	-2°07'07.61"E	39.082157N	-2.118779E
	581448E	4317892N	39°00'15.93"N	-2°03'37.97"E	39.004425N	-2.060546E
ROSI	577447E	4327118N	39°05'16.49"N	-2°06'20.52"E	39.087914N	-2.105700E
	582548E	4318542N	39°00'36.64"N	-2°02'51.96"E	39.010178N	-2.047767E
	576672E	4326693N	39°05'02.95"N	-2°06'52.95"E	39.084153N	-2.114708E
	581823E	4318092N	39°00'22.29"N	-2°03'22.29"E	39.006192N	-2.056192E
	575947E	4326268N	39°04'49.40"N	-2°07'23.29"E	39.080389N	-2.123136E
	581098E	4317667N	39°00'08.75"N	-2°03'52.61"E	39.002431N	-2.064614E
	575197E	4325843N	39°04'35.85"N	-2°07'54.67"E	39.076625N	-2.131853E
580348E	4317217N	38°59'54.40"N	-2°04'23.98"E	38.998444N	-2.073328E	

Chapter 4 - ATMOSPHERIC MEASUREMENTS

4.1 RADIOSOUNDINGS

Date	Radiosounding launches
11 July	18:00 (preliminary test)
12 July	8:00 (atmospheric stable conditions)
	13:00 (satellite overpass)
13 July	8:00 (atmospheric stable conditions)
	13:00 (satellite / aircraft overpass)
14 July	8:00 (atmospheric stable conditions)
	13:00 (satellite overpass)

Note: hours are in Spanish Official Time (UT +2h).

4.2 SPECTRAL RADIANCE MEASUREMENTS

4.2.1 Instruments

• Spectroradiometer Licor 1800

Measurement range 300-1100 nm with a bandwidth of 6 nm and a precision of 1 nm.

The Licor 1800 is a portable monochromator spectroradiometer controlled by a PC and manufacturer's software. The optical receptor is a PTFE (Teflon) dome cosine receptor with a 2π steradian field of view. The monochromator is a motor-driven scanning type holographic grating which disperses the radiation into its spectral components, with a 6 nm FWHM. The entrance to the monochromator is a filter wheel with seven filters and an opaque target. The detector, located at the exit slit of the monochromator, is a silicon photodiode operating in the photovoltaic mode.

For the measurement of the direct component a radiance limiting tube (collimator) with a FOV of 4.6 degrees and a system of alignment was coupled to the Teflon diffuser of the receptor (figure 4.1). In this case, the spectroradiometer was oriented manually on a tripod with the help of a three-axis joint.



Figure 4.1. Licor 1800 Spectroradiometer. Direct irradiance measurements

• Spectroradiometer Optronic 754-O-PMT

Measurement range 250-800 nm with a bandwidth of 1 nm. Precision 0.1 nm.

The Optronic OL-754 is a high-precision portable spectroradiometer in the 250-800 nm range. It has a double monochromator and a photomultiplier as the sensor element. The double monochromator has two concave holographic grids with 1200 lines/mm and a focal distance of 160 mm. The FWHM is 1 nm and the band pass precision is 0.05 nm. The wavelength precision varies with respect to the nominal scale value and has an average value of ± 0.05 nm.

For measuring the global irradiance the aperture of the optical head is connected to an integrating sphere (Figure 4.2), with two purposes: minimising the cosine error, and reducing the external source to a point source. This integrating sphere is a 15 cm diameter aluminium sphere with an inner lining of high purity compact teflon with a reflectivity of over 99%. The radiation enters the integrating sphere through a 3.175 cm aperture (entrance slit) and, after being reflected in the interior, it leaves through a 0.19 cm aperture (exit slit) at 90° to the incident direction. A hemispherical dome of fused quartzite is attached over the entrance slit of the integrating sphere to protect the teflon lining and to correct for the cosine error.

For the direct irradiance measurements a collimator is used to limit the field of view to 5.72 degrees. This is attached to the entrance point of the integrating sphere after removing the quartz dome. It is protected by a quartz window and inside it has a number of apertures to reduce the field of view and also to act as baffles of stray light. The collimator has a mechanism for aligning the aperture with the solar disc. For measurements of the direct solar irradiance the spectroradiometer is mounted on a tripod with a fixture that permits movement in three directions, similar to that used by the Licor 1800. In addition, the mobility of the integrating sphere, which permits the entrance point of the optical head to be rotated through 360°, could also be used.



Figure.4.2 Optronic OL-754 with the integrating sphere

• Cimel 318 sunphotometer

The instrument is an automatic sunphotometer (Figure 4.3) which measures routinely sun direct irradiance and sky radiance in the almucantar and principal planes. It can also be operated manually in order to perform direct individual measurements of sky radiance or sun irradiance. In the automatic mode it is still possible to program user actions in order to increase the measurement frequency, if needed.

As can be seen in the picture, the instrument is deployed in the field on a tripod, and it is driven by an electronic box and fed by a solar panel connected to a battery. It consists of two motors (zenithal and azimuthal) that moves the optical head. The optical head is recognisable in the figure by its twin

collimator of 1.2° FOV. For pointing at the sun, the optics head is equipped with a four quadrant sensor which seeks the sun actively.

The sunphotometer is calibrated by means of a lamp (for the sky radiance) and by Langley plots or calibration transfer from other calibrated sunphotometers (for direct sun measurements). It measures direct component for 5 channels (440, 670, 870, 936, 1020nm) and sky radiance for 4 channels (440, 670, 870, 1020nm). It also measures direct irradiance and sky radiance for three polarised channels centered in 870nm, but they are not calibrated right now.

From wavelengths 440, 670, 870 and 1020nm the aerosol optical thickness can be retrieved. Aerosol size distribution functions can be also retrieved from sun and sky measurements. Finally, columnar water vapour content is retrieved using the 936nm wavelength.



Figure 4.3 CIMEL 318 sunphotometer

• Microtops II sunphotometer

This instrument is a manual sunphotometer (Figure 4.4) which gives direct measurements of the columnar ozone amount, the precipitable water vapour content and the aerosol optical depth at 1020 nm. It has 5 channels, each of which is formed by a collimator with a field of view of 2.5 degrees, baffles to eliminate internal reflections, a narrow band interference filter and an appropriate photodiode for each wavelength. Three of the channels are used to find the columnar ozone, one for the water vapour content and the other for the aerosol optical depth. Table 4.1 details, for each channel, the central wavelength and the FWHM of the interference filter.

Table 4.1. Characteristics of the Microtops II channels

Chanel	λ (nm)	FWHM (nm)	Measurement
1	300.0±0.3	2.4±0.4	ozone content
2	305.5±0.3	2.4±0.4	ozone content
3	312.5 ±0.3	2.4±0.4	ozone content
4	940.0±1.5	10.0±1.5	water vapour
5	1020.0±1.5	10.0±1.5	aerosol optical depth



Figure 4.4 Sunphotometer Microtops II

• LIDAR

Ground-based LIDAR (Light Detection And Ranging) mobile laboratory with autonomous power system from CIEMAT. The main technical characteristics of LIDAR system are given in table 4.2.

Table 4.2. Technical characteristics of LIDAR system

Emission line	
Laser system	Nd:YAG
Wavelength	532 o 355 nm
Energy per pulse	600 o 275 mJ
Frequency	20 Hz
Pulse width	10 ns
Beam divergence	~0.2 mrad
Beam diameter	5 cm
Detection line	
Periscope	
Azimuth	0.2 mrad. 0-360°
Zenith	0.2 mrad 0-180°
Telescope	
Diameter	Newtonian 300 mm
Focal length	999 mm
Field of view	1.3 mrad (selectable with iris)
PMT	
Quantum efficiency	Hamamatsu R928 25 % ($\lambda=300\text{nm}$), 12% ($\lambda=532\text{nm}$)
Max. HV anode-cathode	-1250 V
Response time	2.2 ns.
Current gain	1.0×10^7
Range	Entre 2 y 6 Km
Spatial resolution (typical)	1.5 m - 30 m



Figure 4.5 CIEMAT Mobile laboratory carrying LIDAR and related devices.

4.2.2 Measurement plan

It is planned to take measurements of

- Spectral global irradiance on a horizontal plane in the range 300-1100 nm
- Spectral direct irradiance at normal incidence in the range 300-1100
- Columnar ozone content
- Columnar precipitable water vapour content
- Spectral sky radiance. Wavelengths: 440, 670, 870, 936, 1020 nm

The products that will be obtained from these measurements are

a) Immediate

- Spectral global irradiance on a horizontal plane.
Range: 300-1100 nm. Band pass: 1 nm
- Spectral direct irradiance on a horizontal plane.
Range: 300-1100 nm. Band pass: 1 nm
- Spectral diffuse irradiance on a horizontal plane. Range: 300-800 nm
Range: 300-1100 nm. Band pass: 1 nm
- Columnar ozone content from Microtops
- Columnar precipitable water vapour content from Microtops

b) To elaborate

- Columnar precipitable water vapour content from Cimel
- Spectral absorption in the A and B oxygen bands. Band pass: 0.1 nm
- Spectral aerosol optical depth (AOD). Range 400-700 nm
- AOD for 870 and 1020 nm
- Relationship between the AOD for 500 nm and the air mass backtrajectories
- Aerosol vertical distribution over Barrax site during satellite overpasses from LIDAR

4.3. Radiance measurements in the oxygen-a absorption band for MERIS validations

Measurements in the oxygen-a absorption band require high resolution instrument, because of the fact that this band is not wider than 10 nm, as shown in figure 4.6. The 0.1 nm precision Optronic 754-O-PMT spectroradiometer appearing in figure 4.2 will be used in this matter.

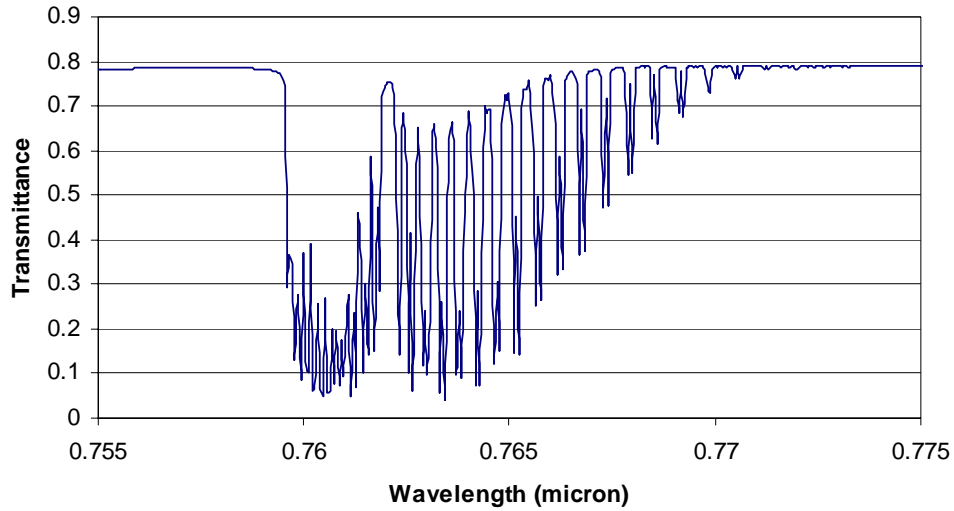


Figure 4.6 MODTRAN4 simulation of oxygen-a absorption band transmittance in the top of the atmosphere.

Chapter 5 - GROUND RADIOMETRIC MEASUREMENTS

5.1 SOLAR RANGE GROUND RADIOMETRIC MEASUREMENTS

5.1.1 Instrumentation

• GARMIN's GPS 12 cx color personal navigator™

The Garmin GPS 12CX color-display Personal Navigator (figure 5.1) provides satellite navigation you can count on.

- Receiver: 12 parallel channel receiver continuously tracks and uses up to twelve satellites to compute and update a position
- Acquisition Times:
 - Warm: approx. 15 seconds
 - Cold: approx. 45 seconds
 - Autolocate™: approx. 5 minutes
 - Ezinit: aprox 45 seconds
 - Update Rate: 1/second, continous
- Accuracy:
 - Position: 15 meters RMS. The RMS is subject to accuracy degradation to 100m 2DRMS under the United States Department of Defense-imposed Selective Availability Program.



Figure 5.1. GARMIN's GPS 12CX

• ASD FieldSpec Pro FR Spectroradiometer

The FieldSpec Pro (Fig.5.2) is a highly portable, general-purpose spectroradiometer. A fiber optic bundle for light collection. Inside the instrument, light is projected from the fiber optics onto a holographic diffraction grating where the wavelength components are separated and reflected for independent measurement by the detectors. The response of each detector is digitised to 16-bit precision.

The Visible/Near Infrared (VNIR) portion of the spectrum, the 350-1050 nanometer wavelength domain, is measured by a 512-channel silicon photodiode array. Each channel is geometrically positioned to receive light within a narrow (1.4 nm) bandwidth. The VNIR spectrometer has a spectral resolution (FWHM of a single emission line) of approximately 3 nm at around 700 nm.

The Short-Wave Infrared (SWIR), also called Near Infrared (NIR), portion of the spectrum is acquired with two scanning spectrometers. These differ from the array used in the VNIR in that they measure wavelengths sequentially, rather than simultaneously. Each spectrometer consists of a concave holographic grating and a single thermoelectrically cooled indium gallium arsenide (InGaAs) detector. The gratings are mounted about a common shaft that oscillates with a period of about 200 milliseconds (100 ms/scan). Unlike the VNIR, each SWIR spectrometer has only one detector, which is exposed to different wavelengths of light as the grating oscillates. The first spectrometer (SWIR1) measures light between about 900 – 1850 nm; the second (SWIR2) covers the region between about 1700 – 2500 nm. The sampling interval for each SWIR region is about 2 nm, and the spectral resolution varies between 10 nm and 12 nm, depending on the scan angle at that wavelength.

Light may be collected with a bare fiber optic, that has a field of view (FOV) of 25°, or with the use of fore-optic devices, that provide FOV of 8° or 1°, and Remote Cosine Receptors (RCR) for full-hemisphere albedo measurements.



Figure 5.2. ASD FieldSpec Pro-FR Spectroradiometer

• GER 3700 Spectroradiometer

The GER 3700 Spectroradiometer (fig.5.3), with a spectral range of 300 to 2500 nm, has 704 measurement channels. Spectral resolution of 1.5 nm from 300 to 1050 nm, 6.5 nm from 1050 to 1900 nm and 9.5 nm from 1900 to 2500 nm. Their scan time is 50 ms and it has a field of view (FOV) of 6° circular. Spectrum averaging is selectable from 4 to 9.



Figure 5.3 GER 3700 Spectroradiometer

• Spectralon reference panel

Physical Properties

- Density: 1.25 - 1.5 g/cm³
- Water Permeability: <0.001% (Hydrophobic)
- Hardness: 20 - 20 Shore D
- Coefficient of Linear Expansion: 5.5 - 6.5 x 10⁽⁻⁵⁾ in/in-F[°], 10⁽⁻⁴⁾C(-1)
- Thermal Stability: to 350°C
- Vacuum Stability: No outgassing except for entrained air
- Flammability: Non-flammable (UL rating V-O)

Spectralon reflectance material is a perfectly diffuse reflecting material that is ideal for applications ranging from the UV-VIS to the NIR-MIR wavelength region. Spectralon is a highly lambertian, thermoplastic material that can be machined into a wide variety of shapes to suit any reflectance component requirement. Typical applications include back-light illuminators, lamp housings, integrating spheres, laser cavities and calibration targets. Three grades of Spectralon reflectance material are available for component fabrication.

5.2 THERMAL INFRARED GROUND RADIOMETRIC MEASUREMENTS
5.2.1 Instrumentation
• CIMEL 312 radiometer

The CIMEL CE-312 is a radiance-based thermal-infrared radiometer composed of two major components: an optical head containing the detector and optics, and the electronic unit which performs the data storage. The detector includes one broad-band filter, 8-14 μm, and three narrower filters, 8.2 – 9.2 μm, 10.5 – 11.5 μm and 11.5 – 12.5 μm (Table 5.1). A external temperature probe can be added by the user into the control unit. It allows to collect the temperature of an external blackbody especially for the estimation of absolute emissivity. A set of 6 different scenarios is available to collect data depending on the user desires.

Table 5.1. Thermal Infrared radiometer CIMEL CE312 specifications

Spectral pass-band:	Channel 1: 8-13 μm Channel 2: 11.5-12.5 μm Channel 3: 10.5-11.5 μm Channel 4: 8.2-9.2 μm
Temperature range	-80 to +50° C
Resolution	8 mK for the broad band 50 mK for the other bands (at 20° C)
Response time	1 second
Field of view	10°
Readout data	Local display Transferable on PC

• Infrared temperature transducer EVEREST 3000.4ZLC

The Everest thermometer, model 3000.4ZLC single band 8-14 μm collect the infrared radiation from the sample converting it into electrical signal. With the suitable calibration process, the electrical signal is converted to a signal in terms of temperature. It is scaled from -40°C to 100°C with a resolution of 0.1 K, an accuracy of ± 0.5 K and a repeatability of ± 0.1 K. The Field of View -FOV- is 4° . With adjustable emissivity equal to unity. The output signal is in mV ($10 \text{ mV}/^{\circ}$), and the power requirements is 5V to 26V DC. Power supply was provided by an auxiliary Einhell power station.

Table 5.2. EVEREST 3000.4ZLC transducer specifications.

Spectral pass-band:	Single band: 8-14 μm
Operating range	from -40°C to 100°C
Accuracy	0.2 K
Field of view	4°
Resolution	± 0.5 K
Repeatability	± 0.1 K
Other characteristics	Adjustable emissivity equal to unity ($\epsilon=1$). Readout Data: Local display and transferable on PC by a Datalogger.

• Infrared radiometer RAYTEK ST8

A portable RAYTEK, model ST8 single band 8-14 μm , with a FOV of 8 degrees, and with adjustable emissivity operation mode will be used. It ranges up to 100°C with a sensitivity of 0.1 K and an accuracy of 0.5K. It has a laser beam that helps to locate the target for the measurements.

• RAYTEK THERMALERT MID

Infrared sensor in single band 8-14 μm , with a FOV of 20 degrees, and with adjustable emissivity operation mode will be used. It ranges up to 600°C with a sensitivity of 0.1 K and an accuracy of 0.5K.

• Thermocouple Type K.

The water and surface temperature measurement will be measured with different thermocouples with error lower than 0.1°C .

• Calibration source EVEREST 1000

A calibration source EVEREST model 1000 will be used to calibrate the radiometers. Its operating range is from 0°C to 60°C , with a resolution of 0.1K, with an absolute accuracy of 0.3 K over entire range.

Details of the instruments are given in Table 5.3.

Table 5.3. Thermal Infrared instrument settings.

MODEL	SPECTRAL BANDS	RANGE OF TEMPERATURE	ACCURACY	FOV
Cimel CE 312	8-13 μm 8.2-9.2 μm 10.3-11.3 μm 11.5-12.5 μm	-80 To 60° C	0.1° C	10°
Everest 3000.4ZLC	8-14 μm	-40 to 100° C	0.5° C	4°
Raytek ST8	8-14 μm	-30 to 100° C	0.5° C	8°
RAYTEK THERMALERT MID	8-14 μm	-40 to 600° C	0.5° C	20°
Calibration Source: EVEREST 1000		0 to 60 °C	0.3° C	

5.2.2 Measurement plan

A set of thermal radiometric measurements will be carried out in the framework of the SPARC-2003 project. The retrieval of bio-geophysical parameters such as land surface emissivity and temperature is the main aim of these measurements. To this end, radiometric measurements will be carried out in the thermal infrared region with various instruments that include fixed FOV and single band or multi bands radiometers. In addition, a thermocouple for thermometric temperatures measurements and a black body (calibration source) for calibration purposes will be used.

Therefore, the experimental work of the Global Change Unit of the University of Valencia will be the measurement of thermal radiometric temperatures, emissivities, atmospheric radiances, air temperature, temperature transects and angular measurements within the BARRAX area (see Table 5.4). Transects will be performed concurrently to the ENVISAT flights over the region. The transects will be carried out taking temperatures measurements with three field radiometers (CIMEL, RYTEK and EVEREST), at regular steps (3 meters).

Table 5.4. Field work foreseen by Global Change Unit during SPARC-2003.

Date	Sample	Work
12/07/2003	Bare soil, alfalfa, wheat, corn, barley, water	-Brightness temperature -Sky temperature at nadir -Angular measurements
13/07/2003	Bare soil, alfalfa, wheat, corn, barley, water	-Brightness temperature -Sky temperature at nadir Simultaneously with flights
14/07/2003	Bare soil, alfalfa, wheat, corn, barley, water	-Brightness temperature -Sky temperature at nadir -Angular measurements -Transects simultaneously with ENVISAT overpasses

Chapter 6 - VEGETATION MEASUREMENTS

6.1. INSTRUMENTATION

• LI-COR LAI-2000 instrument

The LAI-2000 (Li-Cor inc., Lincoln, NE, in fig. 6.1) uses a fish-eye lens with an hemispheric field of view ($\pm 148^\circ$). The detector is composed of five concentric rings (sensitive to radiation below 490nm). Each ring responds over a different range of zenith angles. Light attenuation through the canopy is measured and light transmittance is calculated as the ratio of below: above canopy readings for each of the 5 angles. This ratio is used to calculate several variables, including leaf area index, gap fraction, and mean tilt angle (a number representing the foliage orientation).



Figure 6.1 LAI2000 Plant Canopy Analyser

• Tracing Radiation and Canopy Architecture (TRAC)

TRAC measures canopy *gap size distribution* in addition to canopy *gap fraction*. TRAC uses a walking and high frequency sampling technique to record the transmitted direct light along a transect (fig. 6.2).

The TRAC instrument is composed of a complete optical measurement and data-logging unit:

- Photo-sensors in the 400 to 700 nm waveband
- Built-in 512 K battery-backed memory
- Serial interface to personal computer
- Rugged, high reliability construction
- Easy, single button operation



Fig 6.2. Tracing Radiation and Canopy Architecture (TRAC)

• **Digital camera NIKON Coolpix5000 with a NIKON FC-E8 fisheye converter**

Hemispherical canopy photography is a technique for studying plant canopies via photographs acquired through a hemispherical (fisheye) lens from beneath the canopy (oriented towards zenith) or placed above the canopy for downwards looking. Therefore, it can be used for any canopy type.

A hemispherical photograph allows you to derive, among others, vegetation structural characteristics such as, gap fraction, leaf area index (LAI) and average leaf inclination angle (ALA). It provides a permanent record and is therefore a valuable information source for position, size, density, and distribution of canopy gaps. The view angle is equal to 183° and allows the gap fraction to be evaluated in all viewing directions, which increases the accuracy of the derived biophysical variables (LAI, ALA).



Fig 6.3. NIKON Coolpix5000 with the NIKON FC-E8 fisheye converter.

• **Chlorophyll Content Meter**

The New CCM-200 Chlorophyll Content Meter (fig. 6.4.) from Opti-Sciences accurately determines chlorophyll content in plants and crops. Especially useful for improving Nitrogen management programs, the CCM-200 is also an ideal instrument for research and teaching. The CCM-200 provides agronomists, researchers, and teachers with reliable, repeatable chlorophyll content readings. The ample on-board data storage and hand-held design make the CCM-200 the most field efficient, affordable chlorophyll content meter on the market.

Changes in chlorophyll content can occur as a result of nutrient deficiencies, exposure to environmental stress, exposure to certain herbicides, and differences in light environment during growth (shading). Chlorophyll content can be used to manage nutrient optimization programs that both improve crop yield and help protect the environment. Testing for herbicide damage can indicate the need for a change in herbicide selection or application methods; in order to maintain good weed control while having minimum impact on crop health.

Observation of changes in chlorophyll content have applications in basic photosynthesis research. The CCM-200 illustrates changes in chlorophyll content which can be correlated to plant health and condition. This data can even be used to compliment chlorophyll fluorescence and gas analysis measurements.

Laboratory methods for determination of chlorophyll content are both time consuming and destructive to the sample. Typically a sample must be detached, ground up in a solvent, then assayed in a spectrophotometer. A sample can be measured only once precluding the monitoring of trends in chlorophyll content over the growing cycle. The CCM-200 provides non-destructive, rapid measurements of relative chlorophyll content without the need to detach and grind a sample.

Chlorophyll has several distinct optical absorbance characteristics that the CCM-200 exploits to measure relative chlorophyll concentration without destructive sampling. Strong absorbance bands are present in the blue and red but not in the green or infrared bands, hence the green appearance of a leaf. By measuring the amount of energy absorbed in the red band an estimate of the amount of chlorophyll present in the tissue is possible. Measurements in the infrared band show absorbances due to cellular

structure materials. By using this infrared band to quantify bulk leaf absorbance, factors such as leaf thickness can be taken into account in the CCI (Chlorophyll Content Index) value.



Fig. 6.4 Chlorophyll Content Meter CCM-200

Table 6.1- CCM-200 Technical Specifications

Measured Parameters:	Optical Absorbance in two wavebands.
Measurement Area:	3/8" diameter circle.
Accuracy:	+/- 1 CCI Unit.
Sample Acquisition Time:	2-3 seconds.
Source:	2 LEDs.
Detectors:	2 Silicon photodiodes with integral amplifiers for absorbance measurement and source power monitoring for temperature compensation.
Storage Capacity:	4,096 test data sets.
Digital Output:	RS-232 port.
User Interface:	<p>Display: 16 x 2 alphanumeric LCD.</p> <p>Keyboard: 4 keys for control and data manipulation.</p>
Power Supply:	Internal 9V alkaline battery.
Dimensions:	152 mm x 82 mm x 25 mm.
Weight:	180 g

• Stereo-vision system for 3D vegetation and soil structural characterisation

For the three dimensional reconstruction of the study site, we will use different techniques: a stereo-vision system and a new three dimensional model of the vegetation, both developed by the Remote Sensing Unit of the University of Valencia.

On one hand, the stereo-vision system consists in the analysis of different images of the same scene obtained from different angles. Considering that an image is a projection of an object in a 3D plane, from two images of the same object taken from different angles of vision, we can calculate the 3D co-ordinates of the points of that object in the real world. The procedure for this 3D reconstruction is:

- Calibrate the cameras: determination of the relation between the 2D images and the 3D information of the scene.
- Matching points: correspondences between pairs of images.
- 3D reconstruction: using the calibration of the cameras and the positions of each point in both images, can be calculated the 3D co-ordinates in the reference system.
- Interpolation: It is necessary to assign a value to the points that have not any elevation data in the digital elevation model.

Figure 6.5 shows the stereo-vision system constructed by the University of Valencia.

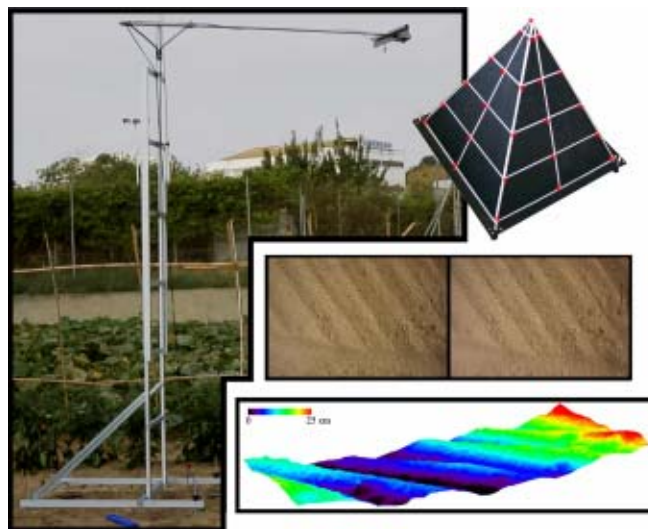


Fig 6.5. Stereo-vision system

On the other hand, the Remote Sensing Unit of the University of Valencia has developed a new method to model the vegetation generating a three dimensional model of the plant. This model allows doing a better description of the plants, and once it is generated, different plant properties can be studied.

The measurement method in the field is easy and fast. It is necessary to take photographs of the plants from different angles. A minimum of one photograph is necessary to model a plant with azimuthal symmetry, and a maximum of three photographs is sufficient to describe complex plants (one from the top of the plant and two from the most significant sides with an angle of 90 degrees). Figure 6.6 shows examples of these measurements.

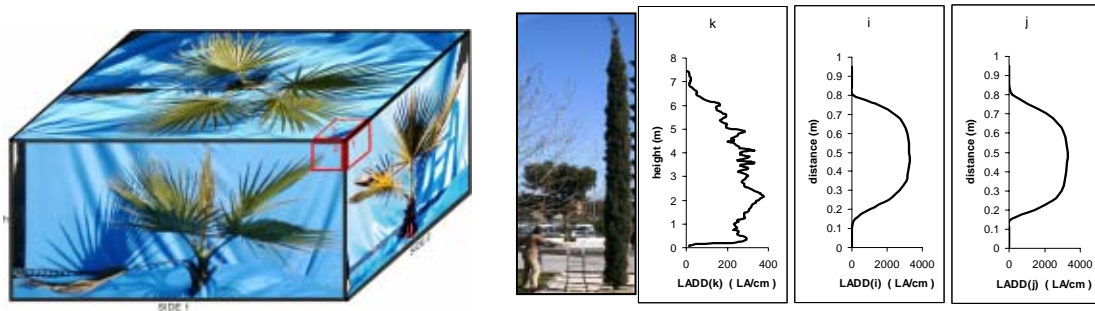


Figure 6.6. Three views of the plant for 3D reconstruction and example of the vegetation

It allows measuring LAI, cover percentage of vegetation and orientation without any dependence of the solar illumination conditions, height, angle of the leaves with the stem, vegetation distribution as a function of the height, distribution in the horizontal directions, etc. Moreover, the obtained model can be used as an input in radiative transfer models.

• **Cameras RICOH RCD 5300**

Two digital cameras RICOH RCD 5300 (fig.6.7) for the acquisition of stereo-pair images. Set on top of an aluminium structure they capture a picture of the same scene from two separate points of view, that allow reconstructing the three-dimensional structure of the scene by means of stereo-vision.

- 1792 x 1200 pixel resolution and the possibility of acquire images with 896x600 pixel resolution.
- The image is saved in JPG format with three levels of compression.
- Each camera has 8MB of internal memory and a 32MB SmartMedia memory card.
- Zoom 3.0x, manual and auto or panoramic focus, flash, connection to a TV.
- Remote control RICOH DR-3 (infrared).



Figure 6.7 Digital cameras RICOH RCD 5300, 32MB SmartMedia memory card and Remote control RICOH DR-3.

• **Portable colour TV**

A portable colour TV that allows remote viewing and pointing of the digital cameras for stereovision image acquisition.

- TFT 2.5" LCD picture.
- AC input.
- AV & Earphone Jack.



Figure 6.8. Portable TV.

• **Hand-held laser distance meter DISTO™**

It is a one-person operated unit, measuring distances from 0.3m to over 100m. Measured areas and volumes comfortably and quickly with ± 3 millimetre accuracy, even in difficult or unreachable places. Convenient measuring from any edge of the unit, an integrated calculator, easy tripod mounting, plus a positioning bracket for marking measured points make the DISTO™ lite the craftsman's choice and designed for indoor and outdoor measurement.



Figure 6.9 Hand-held laser distance meter.



Figure 6.10 Pyramid of calibration.

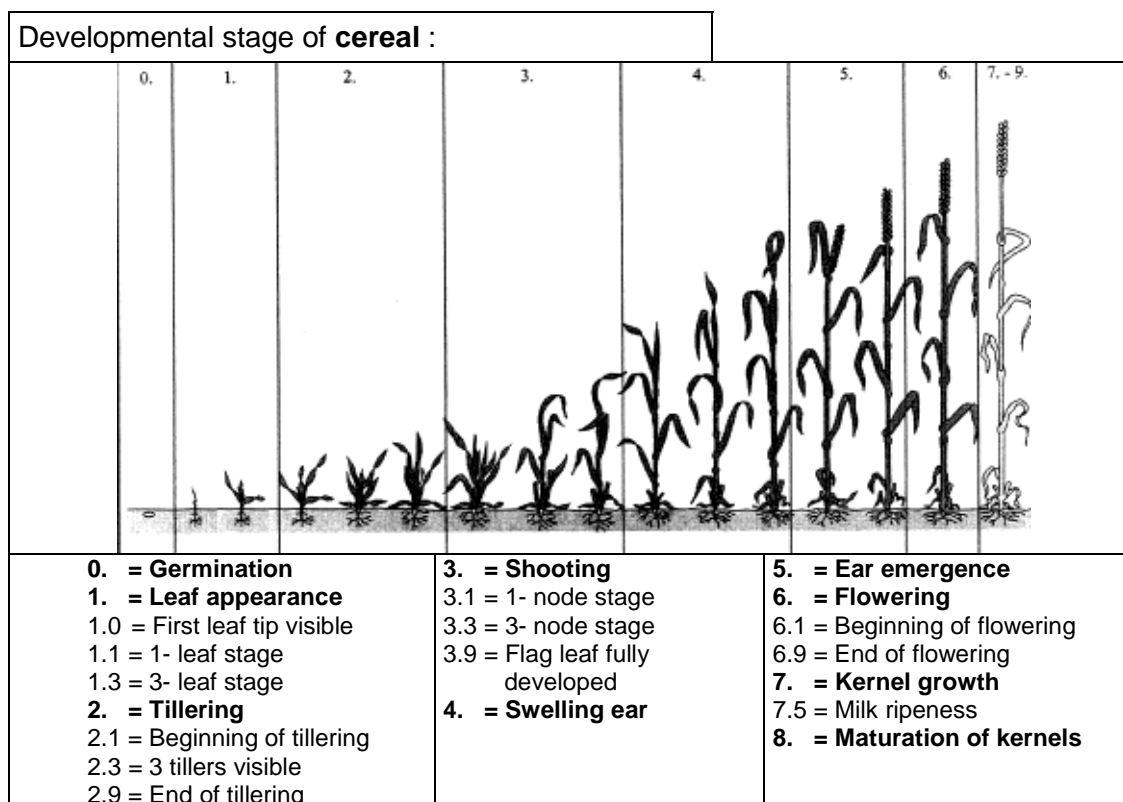
• **Calibration Target**

It is a pyramid (figure 6.10) with 37 control points distributed along the white lines crosses, used for calibration of the stereovision cameras set-up for a quantitative 3-D reconstruction of the scene.

6.2 MEASUREMENT PROTOCOLS

6.2.1 Crop phenology

A phenological state is the growth stage during which the plants exhibit particular physiological and/or morphological characteristics. It can be determined by comparing the plant morphology to stages defined for that crop (figure 6.11). The stage in which is the 50% of the plants is usually assumed.



Developmental stage of Legumes :		
Stand height:		cm
0.	Germination	
1.	Leaf development	
1.5	5 Leaf blades expanded	
1.9	9 or more leaf blades expanded	
2.	Tillering	
2.1	First side tiller visible	
2.5	5 th side tillers visible	
2.9	9 th or more side tillers visible	
3.	Main stem elongation	
3.1	First expanded internode	
3.5	5 th expanded internode	
3.9	9 th expanded internode	
5.	Flower buds visible wrapped in leaves	
5.5	Single flower buds can be recognized	
5.9	First petals visible	
6.	First blossoms opened	
6.5	50 % blossoms opened	
6.9	end of flowering	

Figure 6.11 Standard crop phenology scale, for cereals and legumes.

Existing procedures for growth stage description which are available in the agronomic literature should be used. These vary between crops and sometimes between countries or research groups. Growth stage descriptions developed for remote sensing studies are also available. The system actually employed should be referenced or presented in full. A simplification of an existing system is permissible.

The minimum sample size is one in case of a uniform stand. The identification of different growth stages and the associated proportions of the canopy are important especially for larger, heterogeneous areas and at certain growth stages when the canopy changes very rapidly.

6.2.2 Green vegetation cover fraction

It will be evaluated from a digital picture, taken from the vertical direction and at a constant height, with the Sun in such a position that shadows proportion is minimal. In order to obtain the green vegetation cover fraction a classification of the registered image will be performed.

6.2.3 Wet and dry biomass

This is the mass of plant material within a defined area divided by the area size ($\text{kg}\cdot\text{m}^{-2}$). For taking the measurements, cut all of the plants from a pre-defined area. If applicable, separate plants into components (stems, leaves, fruits) and place into separate containers (plastic, bags, etc.). Weigh each component within a few hours (preliminary test can be used to determine permissible elapsed time). Dry the plants at 70°C until constant weight is reached and weigh again. From the two masses and the known sampled area, wet and dry biomass can be calculated. Water content is calculated as the percentage of wet (or dry) mass, or per unit area (volume) when biomass (biomass and height) are known.

Sample size depends on the size of the individual plants and available drying facilities. A minimum of 150 grams of matter for small crops or plant components should be in one sample. The minimum number of samples is five.

6.2.4 Water content

This parameter is the mass of water in a plant sample divided by the mass of the entire plant sample before drying (i.e. on a wet biomass basis). Units are percent or dimensionless, although when plant height and/or biomass are known, water content can also be expressed in kg/m^3 or kg/m^2 , respectively). It is given from the biomass evaluation procedure directly, for each one of plant components.

6.2.5 Leaf Area Index

It will be calculated by means of the LICOR 3000 device in the laboratory, from destructive samples. Comparative measurements will be done with other systems in the field (SUNSCAN, TRAC, LICOR 2000, hemispherical camera...), in order to validate those from the laboratory.

6.2.6 Leaf Chlorophyll

The leaf chlorophyll content will be measured with the CCM-200 Chlorophyll Content Meter (figure 6.4). However, it performs relative measurements, so calibration measurements must be made before using laboratory analysis methods. Absolute chlorophyll values will be measured by means of leaf pigments extraction and absorption spectrometry. Samples must be 1 cm diameter, to be placed in a laboratory tube with N,N-Dimethylformamide (DMF) for 20h. Next, extinction coefficients for Chl_a and Chl_b in 664.5 and 647 ($A_{664.5}$ and A_{647}) are calculated by means of absorption measurements with a spectrometer. Then, chlorophyll contents are obtained by applying the equations

$$\text{Chl} = 17.90A_{647} + 8.08A_{664.5}$$

$$\text{Chl}_a = 12.70A_{664.5} - 2.79A_{647}$$

$$\text{Chl}_b = 20.70A_{647} - 4.62A_{664.5}$$

6.2.7 Plant density

This is the number of plant stems per unit area. For row crops, the method consists in counting the number of stems along the row and converting it into density using the average row width. For randomly distributed plants, count the number of stems within a predefined area. One or several stems may be originated from a root system of one plant.

Sample size varies with the crop. The area included in one sample should be large enough to contain a minimum of 30 (for large, e.g. corn) or 60 (smaller crops, e.g. cereals) stems. For rice, a sample area of 25x25 cm can be sufficient. A minimum of three samples should be taken in a homogeneous canopy, but the number should be increased for heterogeneous canopies and/or for larger areas.

6.2.8 Plant height

This is the distance between the canopy component of interest and the soil surface for non flooded fields. For the measurement, it must be placed a measuring stick near selected plants. Take a sufficient number of measurements to obtain a representative value. Several height parameters are useful; in the general order of decreasing importance they are:

- Total maximum height (to the top of the canopy).
- Height from the ground to the highest green leaf.
- Fruit length and diameter.
- Height from the ground to the lowest green leaf.
- Distance between leaves along the stem (internodal distance).
- Stem diameter near the ground.

A minimum of five measurements are recommended for relatively uniform canopies. This number should be increased as canopy variability and/or the area measured increase.

6.2.9 Plant row direction

It can be defined as the orientation of the plant rows, given in degrees or geographic direction. It must be identified the row direction of the plants, if any, and relate it to the North direction. This can be done in situ or from aerial photographs with a scale large enough, so that the row direction can be recognized. Note that plant row direction may not coincide with tillage direction.

Only one observation is needed if the row direction remains constant. However, it is important to ascertain that this is the case, as FOW direction may vary due to the field shape, cultivation pattern and natural obstacles (topography, woody, vegetation, etc...). In these instances, aerial photographs are the preferred method.

6.2.10 Canopy structure

This is the three dimensional location and orientation of plants and plant components in the canopy. A direct measurement would involve a reconstruction of the three-dimensional distribution of the canopy. Although very desirable, not rapid and effective method has been developed yet.

The following approach can be used to characterize the leaf distribution: leaf position is determined by placing a gridded horizontal plate beneath the canopy (x, y coordinates) and by measuring its height (z) above the plate; leaf inclination angle (in degrees) is measured with an inclinometer; leaf azimuth angle is determined (for 45° increments) using a small plate equipped with a circular bubble level and a dowel attached perpendicularly to the face of the plate. To measure the relevant physical dimensions of each canopy component (leaves, stems, heads), one should first select an appropriate geometric model for that component (e.g., cylinder, ellipsoidal disk, plate) and then measure the length, width, diameter or axes as appropriate for the assumed model (for stems, diameters at bottom and top should be measured). Among the numerous parameters describing canopy structure, two types deserve special attention: leaf dimensions and the orientation of leaves and stems. It is also helpful to Xerox plant components for a permanent record.

For a qualitative characterization of the canopy, photographs can be taken showing the vertical profile of one plant or one group of plants, preferably with a gridded background plate put vertically behind a plant row.

6.2.11 Soil moisture

It is defined as the amount of water held in a unit mass (gravimetric basis) of soil. The weight of water in a soil sample is divided by the weight of the sample after drying. Units are $\text{g}\cdot\text{g}^{-1}$ (gravimetric basis). Bulk density should also be determined where gravimetric samples are taken.

Although various methods for measuring soil water content are available, the destructive sampling method has been widely used because of its simplicity. A sample of soil is taken from a layer of the soil profile to be characterized. This can be accomplished using a spatula for gravimetric moisture content.

The moist samples should be weighed as soon as possible and then dried at 105°C to a constant weight (generally 24 hours or less). Alternatively, drying in a microwave oven can produce good results and take much less time (less than 1 hour depending on sample size); a preliminary test should be carried out to calibrate this method of drying against the above standard. Using wet and dry soil masses and the volume (if known) water content values can be calculated.

It is recommended for ASAR/ENVISAT that the layer 0 to 5 cm in depth always be sampled and reported to ensure comparability of results among different studies. To obtain representative mean values, it is recommended as a general guideline that 5 or more (minimum 3) individual samples be taken.

6.2.12 Soil roughness

Soil roughness is the shape of the soil-air interface in three dimensions. The roughness components are clods or soil aggregates random, furrows or rows (periodic), and slope or inclination of the surface (monotonic). In practice, it can be described by the spatial correlation function of surface roughness in two perpendicular directions.

Optimally, the measurements technique should produce data with horizontal and vertical resolutions of one-tenth of the radar wavelength studied. In addition, measurements should be made over a consecutive length of up to 10 times the largest roughness periodicity (e.g. across 10 rows of a crop). For distinct periodic surfaces (e.g. plowed) these measurements should provide slope angle distribution as well.

Some methods are photographs of a gridded metal panel inserted into the soil and levelled which are subsequently digitized, water resistant paper attached to the metal plate and the cross section sprayed with a colour spray paint. It is important that surface roughness is not changed during the panel insertion or spraying. This is impossible to achieve under some conditions, e.g. for a loose, dry soil where this approach should be avoided.

6.3 VEGETATION SAMPLING STRATEGY

6.3.1 Some statistical considerations

Several campaigns concerning remote sensing activities have been performed before in Barrax. Thus, statistical information on vegetation sampling from them is available, including mean and standard deviation values from Barrax 2000 campaign of some biophysical parameters for different crops (figure 6.12). This can provide some guidance about the number of samples and sampling strategy to be followed in SPARC in order to meet the statistical requirements for sample significance.

BIOMASS (g/m ²)			
crop	mean	σ	N
alfalfa	196	33	15
corn	220	96	15
Sugar-beet	254	85	4

LAI			
crop	mean	σ	N
alfalfa	3.80	0.62	15
corn	2.3	0.3	15
Sugar-beet	1.5	0.3	4

CHLOROPHYLL (mg/l)			
crop	mean	σ	N
alfalfa	24.6	3.0	15
corn	26	3.5	15
Sugar-beet	9	2.4	4

WATER CONTENT (g/m ²)			
crop	mean	σ	N
alfalfa	730	172.4	15
corn	1500	845	15
Sugar-beet	1778	663	4

Figure 6.12 Barrax 2000 vegetation sampling

6.3.2 Sampling strategy scheme

The sampling strategy to be followed in choosing measurement points is designed according to statistical criteria. Nevertheless, most times experimental constraints become critical, and finding a balance between what is mathematically optimal and what is experimentally possible requires some compromise.

According to statistical requirements, between 4 and 15 sampling areas will be taken to fully characterize a crop, according to its size and heterogeneity. These areas should be chosen randomly, but it is not operationally very often (high plant densities, very wet soils or tall plants may cause moving across the crop to be very hard). So, the aim is to perform random sampling in crops where it is possible, but restrict sampling to crop geometrical constraints when it is not. For example, taking samples in 1.80 meters high corn crops following the circular track made by irrigation pivot wheel could be a good idea.

Once sampling areas are chosen, a strategy to take samples inside each area is again needed. The above considerations on the choice of areas are again useful in point sampling within the sampling area: random criterion is mathematically supported, so it is the one to be followed when field crop configuration allow it; however, it is sometimes difficult to move around one measurement point to take samples randomly, so mobility requirements must be taken into account in such cases, and a sampling strategy that make sampling easier must be followed.

6.3.3 VALERI sampling strategy

In the case of VALERI, the aim is to measure LAI, green vegetation cover fraction and clumping index parameters. The sampling strategy scheme is already set.

In order to measure the aforementioned parameters the following items should be considered:

1. At least 6 ground control points (crossing roads, farms...) to test the images geo-referencing will be acquired.
2. The GPS position at each ESU (Elementary Sampling Unit) location will be acquired.
3. In order to sample each vegetated pivot, different ESU measurements will be distributed by transects. Each ESU measurement will be separated a larger distance than the GPS sensibility (15m).
4. For each ESU (20x20 m) different measurements of FVC, LAI and clumping will be taken. Different sampling strategies will be considered (figure 6.13) depending on the instrumentation and vegetation characteristics.

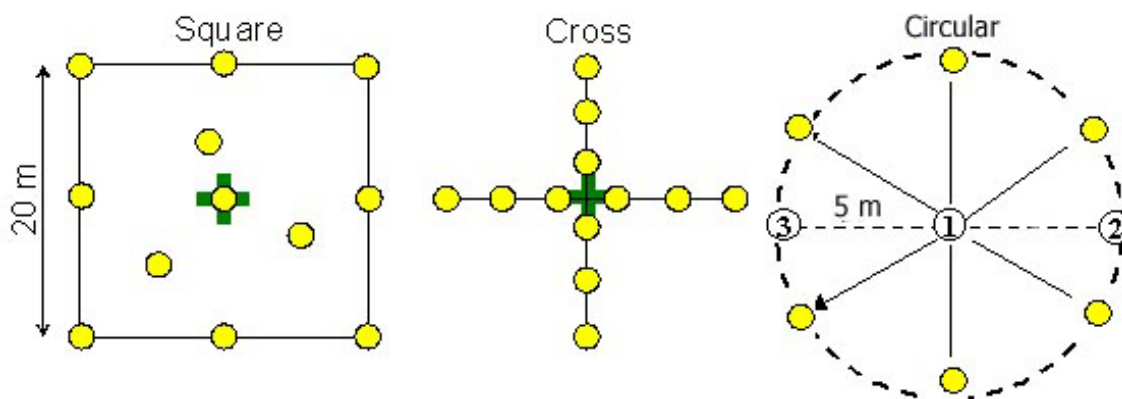


Figure 6.13. Sampling strategy in order to characterise each ESU

5. Finally, an inter-comparison exercise will be carried out in order to analyse LAI estimations derived from the different instruments.

6.4. VEGETATION MEASUREMENTS PLANNING

Sampling for each crop is currently being defined, as well as the measurements which must be made simultaneous with satellite/aircraft overpasses (chlorophyll and water, surely) and which not (LAI and FCV). Figure 6.14 shows the land use in Barrax one week before the campaign (updated 7 July).

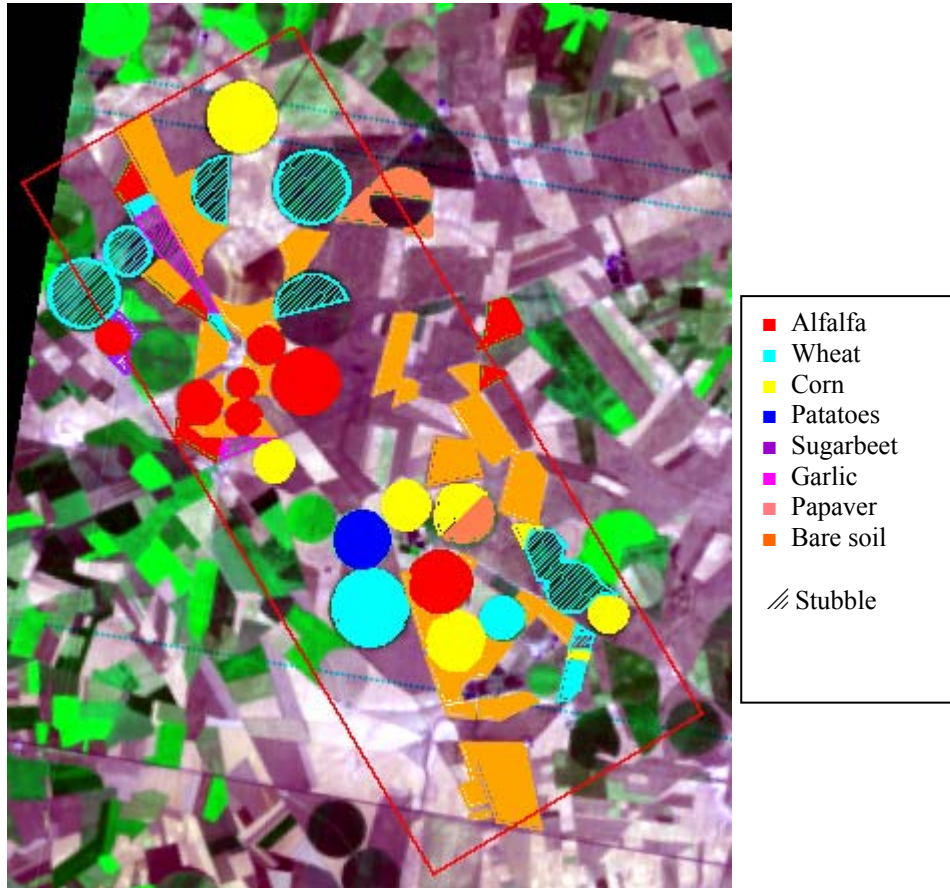


Figure 6.14. Land use classification map. Situation one week before the campaign.

Chapter 7 - REFERENCE METEOROLOGICAL DATA

The University of Castilla-La Mancha, through the "Escuela Técnica Superior de Ingenieros Agrónomos", operates three agro-meteorological stations in the study area of Barrax (fig. 7.1):

- a) Tiasas-Anchor Station (39° 02' 31" N; 2° 04' 55" W)
- b) Tiasas-Lysimeter Station (39° 03' 30" N; 2° 05' 24" W)
- c) Blancares Station (39° 06' 45" N; 2° 06' 40" W)

These stations belong to the Permanent Station Network of the University of Castilla-La Mancha and are connected by modem with the central computer at the Institute for Regional Development in Albacete. The data are compiled and stored automatically for later treatment, as well as being accessible in real time. Measurements are done by all sensors every 30 seconds and are stored every 10 minutes.



Fig. 7.1 Las Tiasas-Anchor and Lysimeter permanent meteorological stations at Barrax.

The following measurements are available from each station:

- Tiesas-Anchor Station

Anemometer (10m)	Soil moisture (0,90m)
Wind direction (10m)	Atmospheric pressure
Temperature and relative humidity (10m)	Evaporation
Anemometer (2m)	Precipitation
Temperature and relative humidity (2m)	Reflected short radiation
Temperature (0,5m)	Shortwavelength net radiation
Shortwavelength incident radiation	Diffuse radiation
Soil temperature (0,50m)	Long wavelength incident radiation
Soil thermal flux (0,05m)	Long wavelength reflected radiation
Soil thermal flux (0,10m)	Long wavelength net radiation
Soil thermal flux (0,20m)	Soil temperature (0,10m)
Soil thermal flux (0,30m)	Soil temperature (0,25m)
Soil moisture (0,30m)	Soil temperature (0,35m)
Soil moisture (0,60m)	

- Tiesas-lysimeter Station

Pluviometer
Temperature and Relative humidity (2m)
Temperature Sensor
Relative humidity Sensor
Piranometer (2m)
Radiometer neto (2m)
Anemometer (2m)
Reflectometer for hydric soil content
Evaporimetric bucket
CR10 Datalogger
Reference Lisimeter
Herbal Crop Lisimeter
Ligneous Crop Lisimeter

- Blancares-Station

Pluviometer	Moisture Sensor
Temperature and Relative Moisture (2m)	CR500 Datalogger
Temperature Sensor	

Chapter 8 - TECHNOLOGICAL TESTINGS

The group of Electronics Eng. Dept. at the University of Valencia is co-leading a EU-funded project called 'SMARTSPECTRA. Smart Multispectral System for Commercial Applications' (IST-2001-37306) included in the 'Information Society Technologies' program. It started in July 2002 and will last 3 years.

One of the applications of this system is remote sensing so field test will be required during the project. Even though a first prototype is not fully available we propose to test the Acoustic Optic Tunable Filter (AOTF), which is a core technology in the system, attached to the FiledSpec.Pro and two cameras. One covering the VIS spectrum (CCD based) and the other the NIR (Vidicon based).

The main characteristics of the AOTF are:

CVA Series 100

Specifications	CVA100-.40-1.0
Device Type	Image Quality AOTF Aperture Size: 10 x 10 mm (Depends on the CCD Sensing Area)
Wavelength Range	400 - 1000 nm
Spectral Resolution	1.0-5.0 nm
Spatial Resolution	> 480 TV lines x 720 TV lines
Working Distance	(Depends on Camera Lens)
Field of View	(Depends on Sensing Area of CCD Camera)
Connection with Front Objective Lens	Nikon 35 mm SRL camera lens
Connection with Camera	C-Mount
CCD Camera	1/2", 2/3", 1"
Driving Power	1 - 2 Watts
RF Connector	SMA
Drive Frequency	107 to 213 MHz
Weight	0.38 kg
Dimensions (W x L x H)	152.4 x 228.6 x 54.5 mm

We propose to acquire samples of vegetation from an elevated platform in order to check quantum efficiency with daylight conditions.