Regional experiment

16 May – 25 June 2005

Experiment plan

CONTENTS

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I INTRODUCTION

I.1 Scientific goals

Mission :

The Regional Experiment of CarboEurope-IP will produce aggregated regional estimates of ground based data that can be meaningfully compared to those from the smallest downscaled information of atmospheric measurements and continental scale inversion results.

Objectives :

– To determine the spatially explicit regional balance of CO_2 over an area (300*300 km) in South West France at a typical model grid resolution of 2 km every day during a full year based on atmospheric and ground based measurements.

– To provide combined datasets of concentrations, fluxes, and remote sensing, with the highest possible density for developing innovative downscaling and upscaling methods to quantify the carbon balance at the regional scale within a multiple constraint framework.

Going one level of spatial scale lower than the Atmosphere Component, the region, typically 100-500 km in size, is a scale at which both top-down and bottom-up approaches can be reconciled, in such a way that one approach serves to verify the prediction of the other one. This leads to the establishment of the **Regional Experiment (Component 3).**

The scaling problem becomes even more clear, if one considers for instance, that large-scale inversion based sink/source estimates, obtained by a limited number of stations, suffer from a number of errors. On the contrary, measurements from a single location are not necessarily representative of larger regions or grid cells (**representation errors**). Solving for fluxes that do not evenly influence the overall concentration may cause **aggregation errors** and finally, diurnal and seasonal fluctuations in the boundary layer heights are usually poorly represented in large-scale transport models, causing **rectification errors**. These errors can be substantially reduced if at the regional level a good link between the measurements obtained at the surface flux stations and those from high frequency atmospheric concentrations can be established. To achieve this, a region needs to be monitored equally well in spatial and temporal terms. The methodology proposed in the regional experiment of CarboEurope-IP will produce aggregated regional estimates of ground based data that can be meaningfully compared to those from the smallest downscaled information of atmospheric measurements which can currently be expected from a continental scale inversion models (of order 50 km).

We propose to execute a **strategically focussed regional field experiment** in the CarboEurope-IP. The aim is to establish an Intensive Observational Programme both at the ground and in the atmosphere, in order **to quantify with high accuracy the carbon balance**. If successful, this will lay the foundations for implementing an optimised observation network across Europe in the future, and for integrating carbon observations of different nature such as eddy covariance fluxes, plot and regional scale inventories, remote sensing and atmospheric concentrations.

In the past, several regional studies of the carbon fluxes have been conducted, either dominantly based on ground level data and remote sensing (e.g. Boreas, Fife, Oasis), or alternatively focused on atmospheric sampling (eg Cobra, Claire). Based on the experience from those studies, we plan in the Regional Experiment Component of the IP to **combine for the first time various types of ground based Carbon Cycle-related measurements and atmospheric observations with remote sensing** to infer a regional carbon budget.

Methodology :

The central methodology of the experiment is to make both concentration measurements within and above the boundary layer and to couple those via a modelling/data assimilation framework to the flux measurements at the surface and within the boundary layer. This multiple constraint approach has not been tried before (e.g. HAPEX-Sahel, Boreas, Fife) because in these experiments atmospheric concentration measurements were not made. We propose to apply the multiple constraint method for the first time in a regional experiment.

The advent of small specialized airplanes in the past decade, measuring fluxes at a resolution of 1 to 2 km and with comparable accuracy to tower fluxes, has greatly increased the possibilities to provide accurate estimates of spatial heterogeneity. In a previous FP5 project Recab, a European facility and infrastructure was built to use a small low flying aircraft, the Sky Arrow, equipped with a state of the art mobile flux platform to measure surface fluxes of CO2, heat, water vapour and momentum. Overall, unexpected good agreement was obtained between tower based estimates and those of the Sky Arrow for a number of test sites in Europe.

Atmospheric mesoscale models are now powerful tools to study regional CO2 exchange (e.g. Dolman et al., 2003). This development has been further taken up in Recab, so that non-hydrostatic mesoscale models can simulate the surface-atmosphere exchange of CO2 at resolutions comparable to that of flux aircraft and single flux towers (e.g. 1-2 km). For such limited area transport models, the boundary conditions will come from atmospheric coarser scale models used in the Continental Integration Component. A prime requirement to successfully use high resolution meso scale models for CO2 inversion of sources and sinks is the existence of accurate *a priori* flux distribution and high resolution spatially and temporally distributed map of fossil fuel sources. Realistic mapping of the surface fluxes relies on information on land cover, and surface biophysical parameters (LAI, albedo) that can be obtained from high resolution (e.g. Landsat, Spot, Aster) and high repetitiveness (e.g. Vegetatio, Modis, Meris) space borne images.

Inverse methods for determining surface CO2 fluxes have been used in first attempts at high- resolution regional scales both in the USA and in Europe (see for instance <http://biocycle.atmos.colostate.edu/html/regional_inverse_modelling.html>). For the Recab winter cam-paign in the Netherlands, for instance, we were able to considerably narrow down uncertainty in regional fossil fuel emissions, indicating not only the strength of the method, but also is usefulness to check fossil fuel emission inventories.

In addition to high resolution atmospheric transport, we will also use high resolution flux modelling. The atmospheric mesoscale transport models are fitted with land surface packages (SVAT) and are excellent tools to act as a host platform for data assimilation of field and model data, similar to the use in for instance past field experiments like e.g. Bougeault et al. (1989).

In order to separate the anthropogenic sources of CO2 in the target region, we will collect continuously high precision samples of radiocarbon (14CO2) which can unambiguously trace fossil fuel emissions. Wherever possible, based on the Atmosphere Component results that will deliver a "calibration" of CO versus 14CO2, we will use CO as a tracer to eliminate the influence of anthropogenic CO2 advected into the area.

We propose to install a set of ground based surface flux measurements, extra radiosoundings and wind and temperature profilers and perform aircraft measurements with low flying flux aircraft, perform boundary layer sampling with small aircraft, and perform longer trajectories with a research aircraft.

At the inflown boundary of the domain we will install a tall tower high precision measurements of CO2 and 14C, and probably a tower with CO2 measurements at the outflow boundary at the domain.

A special, Intensive Observation Period (IOP) of 6 weeks in the spring of 2005 (from 05/16/05 to 06/25/05) will have high intensity observation of boundary layer development and extra flux aircraft for enhanced spatial sampling. The high temporal resolution will allow us to better parameterize our models to deal with rectification effects.

To have a set of driving variables of surface weather, we will produce a downscaled synoptic weather analysis at 8 km resolution by CNRM, Toulouse. This allows the use of biogeochemical models to produce bottom up estimates periods of up to 20 years at the resolution of the land surface characterization (1-2 km).

Component 3 is an important intersection between all Components with regard to data input (Components 1 and 2) and modelling and data assimilation (Component 4).

I.2 Regional vs. global objectives

The Regional Experiment Component provides a direct link between the ecology and continental scale measurements and models. Continental scale models provide the important boundary conditions for the regional carbon balance. Upscaling of the flux towers is performed with forward meso-scale models and calibrated biogeochemical models for the long term (20 yrs). At the regional scale we will use inverse model techniques similar to those developed at the continental scale, thus establishing a clear methodological link with the larger scale inverse modelling estimates. This level of integration and co-ordination is typical of our comprehensive experimental strategy, comprising repetition of experimental and modelling design at the three main spatial scales: local, regional and continental. The regional experiment will test and provide aggregation algorithms that will be used in the upscaling efforts in the Continental Integration Component.

I.3 CarboEurope vs. side projects

I.3.1 CoSMOS

CoSMOS is an ESA airborne campaign to be performed in 2005 (April-May-June) in the frame of the SMOS (Soil moisture and ocean salinity) programme. The SMOS sensor, to be onboard a satellite, is a L-band radiometer, from which it will be possible to retrieve both the surface moisture of land surfaces and the surface salinity of the ocean. For the spring 2005 validation campaign, the aircraft will be the Convair 580 from Environment-Canada. The airborne instrumentation will include a L-band radiometer (TUD) fully polarimetric, and able to measure at two distinct incidence angles (nadir and 40°). Over the Toulouse area, the flight height will be 500 m for a ground resolution of 300-350 m. The frequency of flights will be about one every 3 days, i.e. 30 flights during the 3 month period. The specific objectives over the Toulouse region will be to:

- test the assimilation of future SMOS data in near-operational conditions, in a data rich area (operational atmospheric measurements and soil moisture products at a resolution of 8 km will be available)
- generalise the results of long term in situ measurements like those performed since 2003 at the SMOSREX site near Toulouse by Météo-France, CESBIO, ONERA and INRA
- assess the use of the future SMOS data at the regional scale
- complete the research effort on the L-band emission of forests started during EUROSTARSS (2001), a previous ESA campaign.

During the flights around Toulouse, the airplane will overpass several ground-based stations, installed on various landscapes, and on which meteorological as well as ground parameters (temperature and water) will be measured.

I.3.2 The « Sud-Ouest» Project : land surface functioning at the mesoscale

The general scientific objective of the "Sud-Ouest" project is to understand the respective role of ecosystems, climate and human activities in the evolution of land surface status and functioning at the regional scale, taking into account land use and land cover heterogeneities and the interactions between processes. In terms of applied research, the project addresses land management issues such as land cover evolution, water consumption by agriculture as well as the possible impacts of climate change and agri-environmental policies.
The main experimental zone of the project is an area of 50 x 50 km2 located near Toulouse, France, in the upper part of the Garonne river basin (see figure). The altitude is of about 100-200 m, the terrain is rather flat with low hills organised around the plain. This zone is mainly devoted to agriculture. Corn, sunflower, and wheat are the dominant crops. The wet seasons are fall and spring, while summer is generally hot and dry. Irrigation is required to obtain reasonable yield with summer crops.

The approach is based on five main components : i) ground experiments performed over three sites located in the experimental zone, ii) modelling of surface processes, iii) combination of models with remotely sensed data and development of upscaling/downscaling techniques, iv) land use mapping and retrieval of surface parameters with remote sensing and v) spatialization of the models over the whole experimental zone.
In a first step, the project focuses on land cover monitoring, the assessment of the surface energy budget, evapotranspiration and carbon fluxes. Time series of SPOT satellite data are acquired continuously since 2002, with a time sampling of about one month. These data are used at their full resolution (20m) for land cover mapping and for driving vegetation and SVAT models in order to estimate water balance, evapotranspiration, irrigation needs, carbon uptake and net primary productivity. Modelling of soil carbon release (heterotrophic respiration) is in progress. In addition to this high resolution data set available over the 50x50 km2 main experimental zone, medium resolution remotely sensed data (SPOT-VEGETATION and ENVISAT-MERIS, 300m to 1km resolution) are also used over a larger area to develop and test upscaling methods.
The "Sud-Ouest" project is lead by CESBIO, and collaborations have been established with several laboratories such as CNRM (Toulouse), ESAP (Toulouse), INRA (Avignon, Bordeaux, Toulouse) and ONERA (Toulouse).

figure I.3.2-a ***: Map of the Midi-Pyrénées region and the experimental zone***

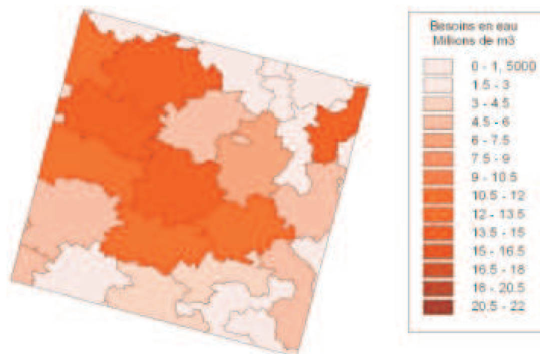


figure I.3.2-b : Example of results : crop water requirement per county (106 m3) in july 2002 (for wheat, maïze, sunflower, and soybean) Experimental area

I.4 Experimental area

The experimental domain covers an area of about 250km (W-E) * 150km (S-N). It is bounded to the West by the Atlantic ocean, the shoreline being quite rectilinear along a NNE orientation.

The western half of the domain is characterized by the presence of the Landes forest, 80% of which is included in the Regional Experiment area (see figure below). It is mainly composed of pines (*pinus pinaster)*. It is an artificial and commercial forest, whose parcels are regularly uprooted and then sown again. Clearings of various sizes are composed of agricultural parcels, mainly maize, but also grasslands and pastures (mainly in the southern part of the forest), or other cultivations like vegetables. Close to the western cost, large ponds can be observed. Inside the forest, the population is scarce, and only villages and small cities can be encountered. However, several military areas occupy a large surface (at least partially deforested).

The other major landscape of the domain is composed of cultivated parcels. Most of them are cereals, with the exception of the Garonne river valley (crossing the domain from SE to NW) where there are fruit trees, and the large "Bordeaux" vineyards, east of the Bordeaux city.

The NE corner presents the extremity of a vast, little cultivated region, mainly composed of woods and pastures.

Two major cities are located close to the SE (Toulouse) and NW (Bordeaux) corners of the domain. A little less than one million inhabitants live in Toulouse and its suburbs, about one and half times that of Bordeaux. Given the dominant winds in spring (see wind roses below), the domain could be affected by the plumes of the cities. The population of the other cities inside the domain is one order of magnitude lower than that of Toulouse or Bordeaux.

The Landes forest and the valley of the Garonne river are quite flat areas, whereas the rest of the domain is mainly composed of gentle hills. Outside of the domain, to the South, the Pyrenees mountain range presents a W-E barrier culminating above 3000m height. This has a strong influence on the generation of local winds on the domain. To the East and North-East, the terrain elevates progressively toward the so-called Massif Central, culminating at 1800m and reaching about 1000m,100km far from the domain.

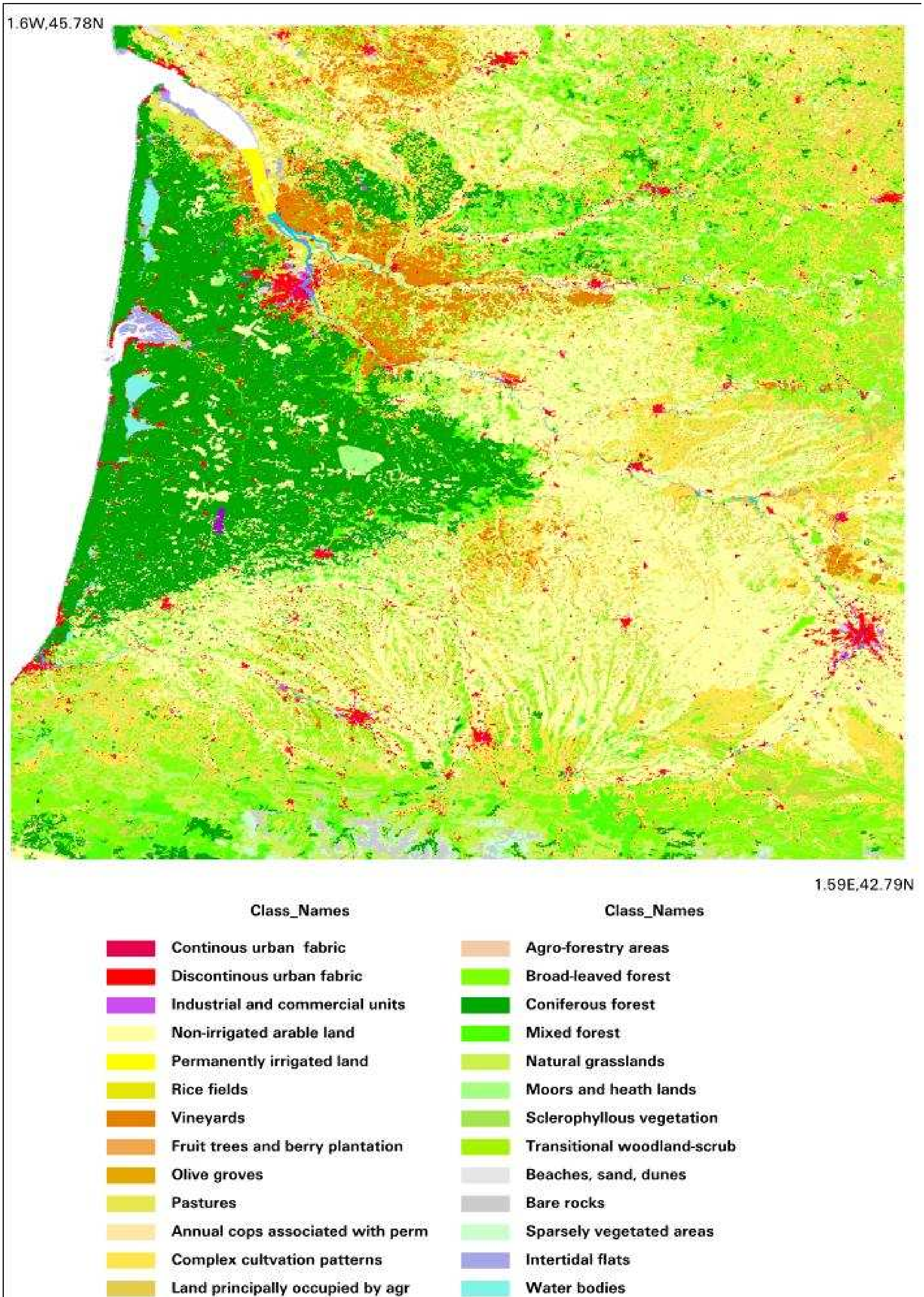


figure I.4-a ***: Land cover with 250m resolution for the south west region of France***

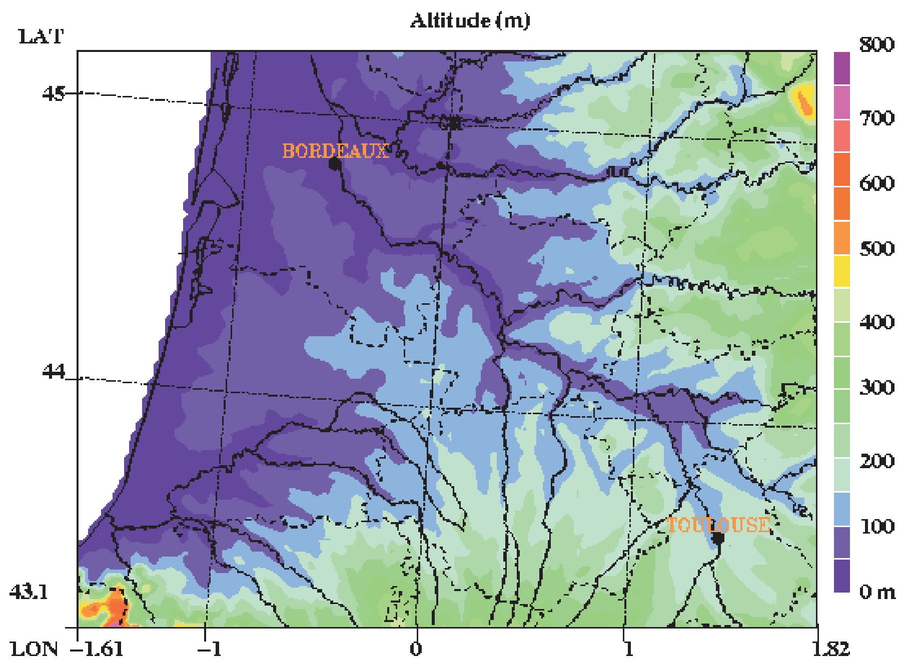


figure I.4-b ***: Orography of south-west of France***

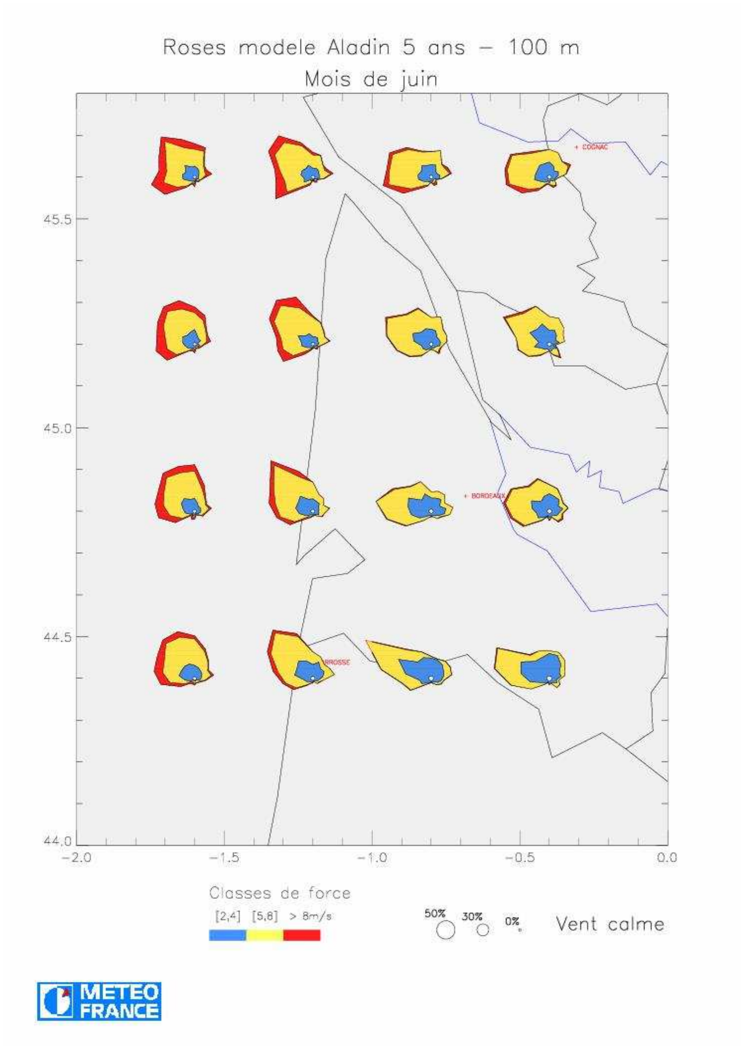


figure I.4-c ***: Wind roses calculated at 100 m according to ALADIN analysis, statistic over 5 year for june***

II FIELD ACTIVITIES: PERMANENT STATIONS

II.1 General overview of the sites

The sites layout is presented in the figure below. The sites related to the CoSMOS and Continental Biosphere programmes are located in the vicinity of Toulouse city, in the eastern part of the domain. The CarboEurope sites are located in the Landes forest area, and in the "intermediate" region, close to the transition between the forested and cultivated areas. This spreading allows us to document the principal land covers:

– the surface energy budget is measured above a mature pine forest, a recently sown forest, a vineyards, maize fields, a wheat field, a rape field, a bean field and grasslands.

– meteorological parameters and temperature and moisture below the surface are measured on most of the above-mentioned sites, plus on a deciduous forest (Agre forest, North of Toulouse city) and a fallow site. Some extra data are collected on operational platforms (close to the sea and the large ponds in the Landes area).

Note that some of these stations are involved in long-term (i.e. > one year) measurement programs.

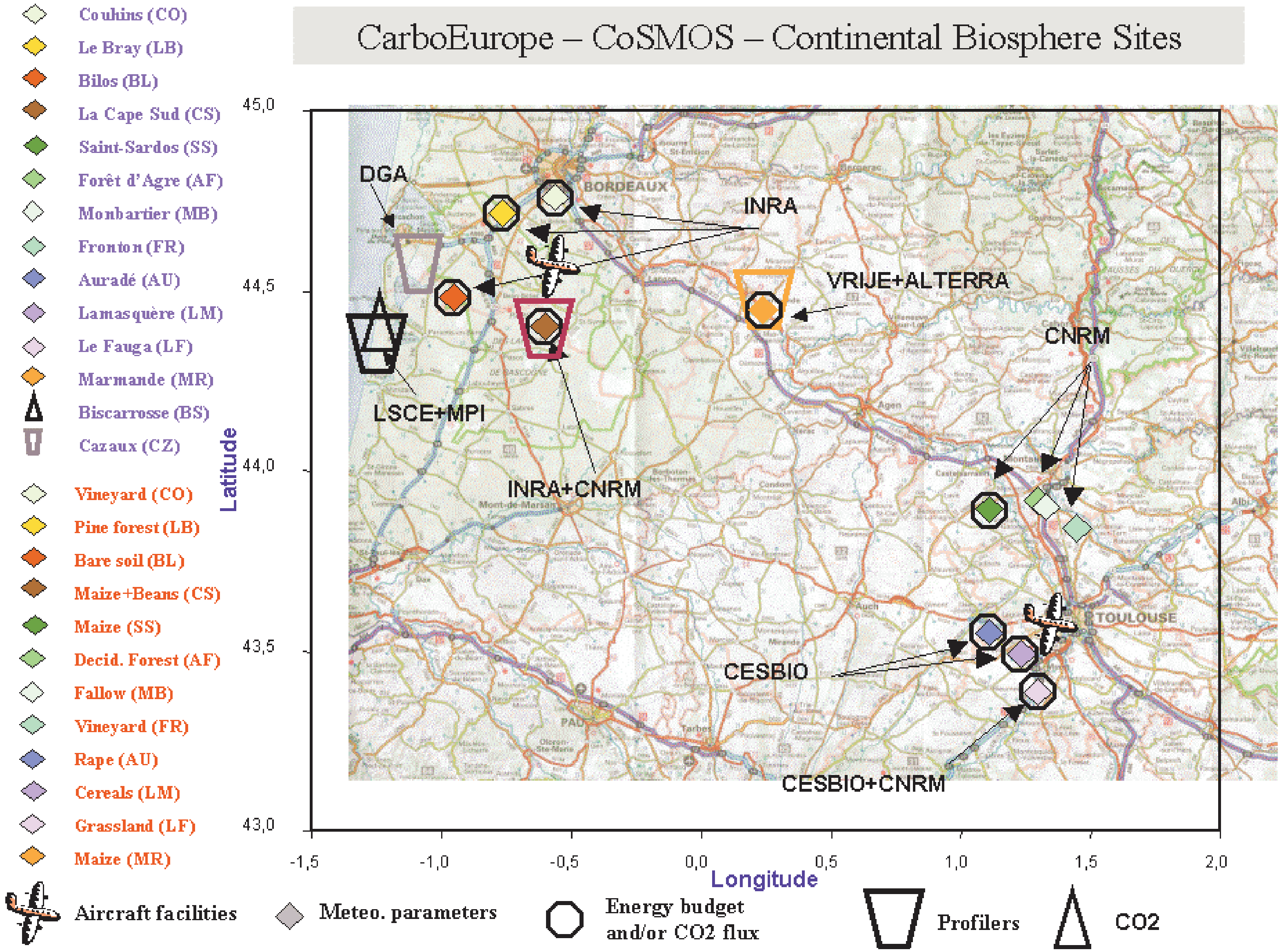
The CO2 concentration is accurately measured on a 50m tower located 2 km from the shoreline, in order to monitor the upwind conditions for the westerlies which are the most frequent winds in this period of the year. At the same place, the CO2 column is measured with a Fourier transform, infra-red radiometer. In the central part (close to Marmande), the CO2 profile is measured up to 20m.

Wind profiling systems are located in the western half of the domain: UHF radars, measuring between ~200m and ~3000m altitude are located in Cazaux and la Cape Sud, which are at about 10 and 40 kilometers from the shoreline, respectively. This would allow to control the development and penetration of the sea breeze during the course of the day for weak synoptic wind conditions. At La Cape Sud, a Sodar will complement (with overlapping) the UHF wind profile in the lowest layers (50-500m).

A RASS-Sodar, located in the central part of the domain (Marmande), measures the temperature and wind profiles up to an altitude of about 1km.

The map below indicates where the sites are located, their name and abbreviation, the land-use and the main groups operating the instruments. The following table summarizes the measured parameters by the surface platforms.

figure II.1-a *: CARBOEUROPE COSMOS continental biosphere sites*



	Parameter \ Site	BS	CZ	BL	LB	CS[1]	CS[2]	CO	MR	FR	AF	MB	SS	LF	AU	LM
		Carbo_Europe sites														
										CoSMOS sites						
													Continental Biosphere sites			
Meteorology	Pressure		•	•	•		•		•	•	•	•	•	•	•	•
	Temperature	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Canopy tempe.														•	•
	Moisture	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Incoming radiation		•	•	•	•	•	•	•	•	•(3)	•	•	•	•	•
	Light interception														•	•
	Net radiation			•	•	•	•	•	•	•	•(3)	•	•	•	•	•
	Wind	•	•	•	•	•	•	•	•	•	•(3)	•	•	•	•	•
	Rain	•	•	•	•	•	•	•	•	•	•(3)	•	•	•	•	•
CO_2	Concentration	•		•	•	•	•	•	•				•	•	•	•
	PPFD			•	•	•		•							•	•
	Soil emission														•	•
Soil	Temperature			•	•		•			•	•	•	•	•	•	•
	Moisture			•	•		•			•	•	•	•	•	•	•
	Soil heat flux			•	•		•						•	•	•	•
Eddy flux	Sensible heat flux			•	•	•	•	•	•				•	•	•	•
	Latent heat flux			•	•	•	•	•	•				•	•	•	•
	Momentum flux			•	•	•	•	•	•				•	•	•	•
	CO_2 flux			•	•	•	•	•	•				•	•	•	•
	Ozone flux					•	•									
	NOx flux						•									

<u>table II.1-a</u> ***: Surface measurements***

(1) maize
(2) beans
(3) measured below the canopy

<u>table II.1-b</u> ***: Sites abbreviations and land use***

Site and abbreviation	Land use and abbreviation
Couhins (CO)	Vineyard (CO)
Le Bray (LB)	Pine forest (LB)
Bilos (BL)	Bare soil (BL)
La Cape Sud (CS)	Maize+Beans (CS)
Saint-Sardos (SS)	Maize (SS)
Forêt d'Agre (AF)	Decid. Forest (AF)
Monbartier (MB)	Fallow (MB)
Fronton (FR)	Vineyard (FR)
Auradé (AU)	Cereals (AU)
Lamasquère (LM)	Cereals (LM)
Le Fauga (LF)	Grassland (LF)

Site and abbreviation	Land use and abbreviation
Marmande (MR)	Maize (MR)
Biscarrosse (BS)	Coastal area (BS)
Cazaux (CZ)	Military area (CZ)

II.2 Surface-layer measurements

II.2.1 CO2 concentration

The CEL-Biscarosse site

For tower measurements at the in-flow CO2 measurements will be performed at CEL-Biscarosse. The site is surrounded by a lot of small sandhills (50-70m above sea level –asl-) covered with pines. CEL recommends the installation of the instruments on the HF tower. It is a 50 m high concrete tower, located on a hill about 70 m asl. There are two platforms located at 47m and about 40m. It is located at 2km from the Atlantic Ocean. In terms of facility for our experiment at this point the situation is satisfying:

- air inlet may be fixed to the tower and there is a cable track from the top to the base of the tower;
- electricity is available and there is enough power for both CARIBOU (5kW) and FTIR (6kW);
- the CARIBOU may be installed within the tower together with 5 high pressure tanks;
- telephone connections may be installed;
- the FTIR container (~10 tons) may be installed on firm ground close to the tower;
- daily access to the site is possible for a couple of well identified scientists;
- flying over the tower with the Piper Aztec is possible, even so there are of course a lot of restrictions.

Meteorological parameters are measured on another pylon closer from the sea. Data can be made available daily during the intensive campaign. Vertical profiles of wind speed and direction are also measured every 15 min with a SODAR, up to 1 km high. These data can be used to detect the elevation of the atmospheric boundary layer (if it is lower than 1km).

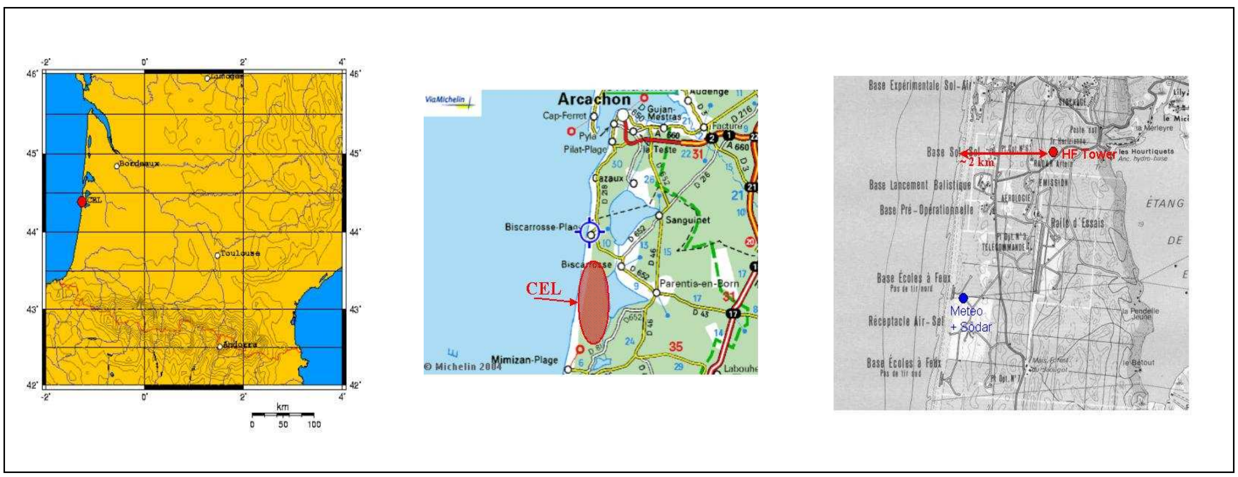


figure II.2.1-a ***: Location of Centre d'Essai des Landes (CEL) at Biscarosse***

figure II.2.1-b ***: The HF Tower and surroundings***.

The Marmande site

At the Marmande site (see location in section II.1), the CO2 profile is measured at five levels up to 20m. This site is representative of the core of the domain, i.e. it is located in the middle of the area, between the western (Atlantic ocean shoreline) and eastern (Toulouse city) edges. Whereas the Biscarrosse measurements represents the initial CO2 concentration for the incoming airmass (assuming westerlies), the Marmande ones analyses the airmass which has travelled for several hours above the continent. However, it must be kept in mind that, while the Biscarrosse system is located on a 50m tower, itself built on the top a 70m hill, and can therefore be considered as representative of boundary-layer conditions (above surface layer), the Marmande profile is measured over a flat, low-altitude field in the valley of the Garonne river, and would probably not overpass the top of the surface layer, and thus is influenced by the local conditions. Furthermore, a PP Systems CIRAS-SC IRGA is used to analyse the sample air for H_2O and CO_2. This analyser, which is thermostated and compensates for cell pressure and temperature, and is calibrated twice a day, allows to measure CO2 concentration with an absolute accuracy better than 1ppm.

II.2.2 Surface flux

Flux measurements at the surface are related to friction velocity (u_*), energy budget and fluxes of trace species. In general, on the various sites of the Carbo Europe regional experiment, the two former are measured together with the flux of CO2. Considering that the surface energy balance could be written as the distribution of net radiation R_n into sensible heat flux (H), latent heat flux (LE) and ground heat flux (G), the standard equipment involves a three-dimensional sonic anemomenter, measuring the three wind component at a rate generally comprised between 10 and 50 s^{-1}, an infra-red gas analyser measuring CO2 and H2O concentrations at a similar rate, a heat flux plate and one or several radiometers.

u_*, H, LE and CO2 flux are computed using eddy covariance technique. The basic instruments and methods have been standardised throughout the Euroflux network (Aubinet et al., 2000). The eddy covariance (EC) system consists of a 3D sonic anemometer coupled with an open or close path CO_2/H_2O InfraRed Gas Analyzers (IRGA) as shown in the Figure below:

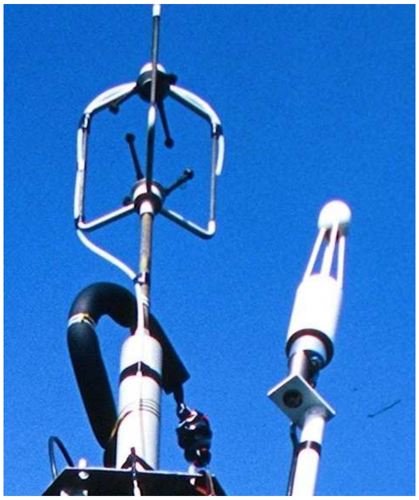


figure II.2.2-a ***: EC system composed of a 3D sonic anemometer and an open path infrared gas analyzer Li-7500 (Licor, Lincoln, NE, USA)***

Eddy fluxes are then calculated for each half an hour as the covariance between the vertical wind speed *w* and the scalar *c* (CO_2 or H_20):

$$F_c = \overline{w'c'} = \overline{(w - \overline{w})(c - \overline{c})}$$

where the primes denote fluctuations around the average and the overbars time average.

The above mentioned fluxes are measured on the following surfaces (for the meaning of the abbreviations, see table II.1-b):

- Vineyard : CO
- Pine forest : LB
- Bare soil (recently soot pine trees) : LB
- Maize : CS_1, SS and MR
- Beans : CS_2
- Rape : AU
- Grassland : LF
- Wheat : LM

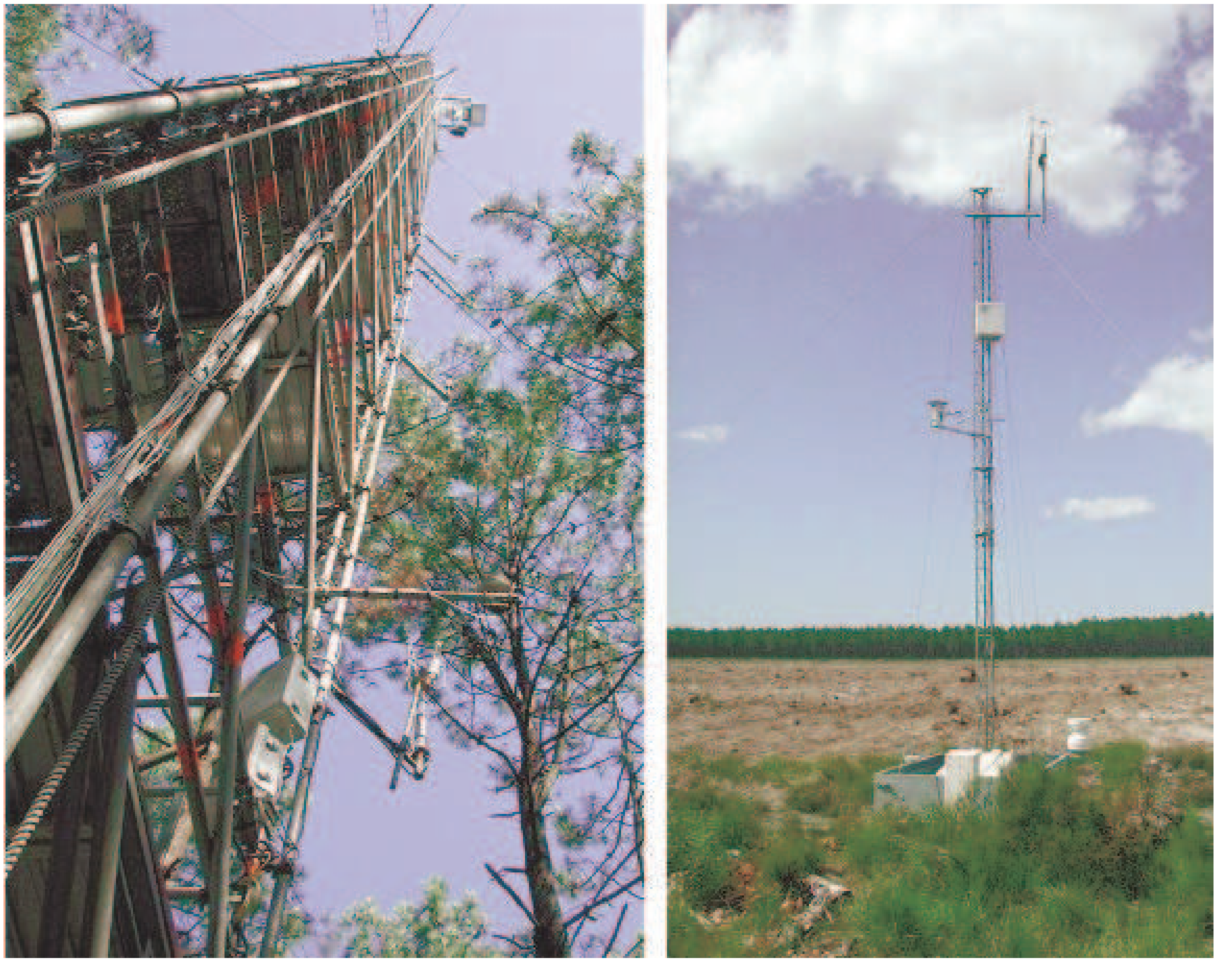


figure II.2.2-b

The height at which the measurements are done depends on the height of the canopy. Heavy tall structures are required to measure the fluxes avove the Landes, pine forest (see the 40 m tower at the LB site above left), whereas light structures, 2 to 6m high, can be installed on areas with low vegetation (see the mast at the BL site, above right).

CO, LB and BL, as well as the twin sites CS_1 and CS_2, are located in the western part of the experimental area. MR is a quite intermediate site, whereas SS, AU, LM and LF are located close to Toulouse city, at the eastern edge of the domain.

The LB and BL sites are part of the long-term Carbo Europe measuring network, and are on operation from several years. Long-term measurements are also performed at the AU and LM sites. On SS and LF sites, the energy budget components are continuously measured from more than one year, however the CO2 flux is measured from spring 2005 only.

In addition to the flux mentioned above, some extra measurements are performed on some sites:

- Photosynthetic photon flux density (PPFD) (incoming, and/or reflected and/or diffuse) is measured on the sites CO, LB, BL, CS1, AU and LM
- Soil emission of CO2 is measured on AU and LM
- Ozone turbulent flux (deposition) is measured on sites CS1 and CS2
- NOx flux is measured on CS2 site with relaxed eddy-acculumation (REA) and emission chambers techniques.

figure II.2.2-c ***: net, reflected and global radiation as well as incident, reflected and diffuse PPFD measured above the pines at the LB site***

II.2.3 Meteorological Stations

Meteorological and (sometimes) hydrological parameters are measured on the flux sites described above, but also on specific sites (the CoSMOS sites in the Toulouse area), and in operational and military stations (see the summary table in II.1). If we discard radiation measurements, already described in the sub-section dedicated to flux measurements, the basic meteorological parameters, systematically measured, are air temperature and moisuture, wind speed and direction, and rainfall. Above bare soil or short vegetation, temperature and moisture are generally measured at a conventional height of 1.5-2m. Over such areas, however, wind could be measured either at 2m or at 10m. For rapidly growing vegetation (such as maize in June), it could be necessary to take the experimental devices up, in order to maintain the measurement height above the displacement height quite constant. For tall vegetation, like pines in the Landes area, measurements should be made inside and above the canopy. For the AF site, however (CoSMOS site), inside a deciduous forest, measurements are made only below the canopy.

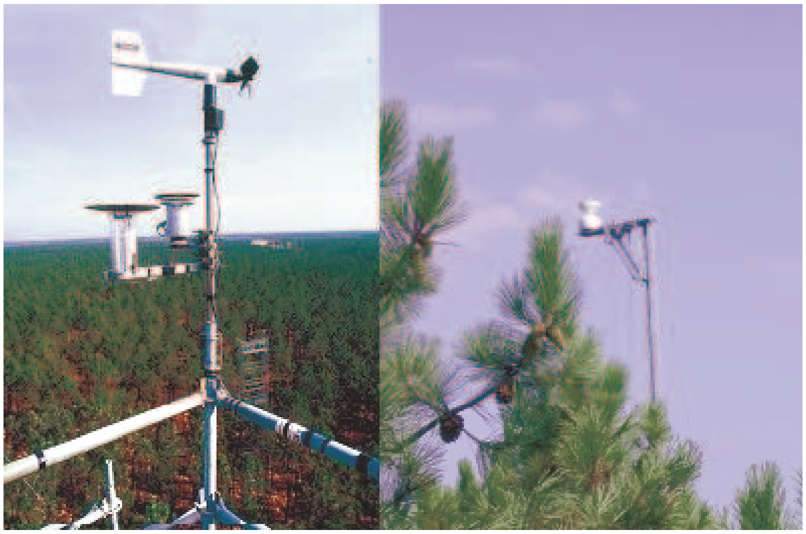


figure II.2.3-a ***: left: mean wind speed and direction, air temperature and humidity; right: rainfall measurements over a maritime pine forest measurement site (Le Bray site).***

15 stations are equipped with these four basic parameters. On most of them, atmospheric pressure is also measured. The temperature and water profiles are measured below the surface on ten of these stations, mainly in the eastern part of the domain.

figure II.2.3-b ***: Meteorological measurements above a maize field***

II.2.4 CoSMOS sites

Validation Sites in the Toulouse region

Seven validation sites will be used (table II.2.4 a):

1. SMOSREX/Le Fauga (LF):	43°23'07" N – 1°17'32" E – 186 m / Transect 2
2. Lamasquère (LM):	43°29'36" N – 1°14'14" E – 180 m / Transect 3
3. Auradé (AU):	43°32'59" N – 1°06'28" E – 245 m / None
4. St-Sardos (SS):	43°53'45" N – 1°06'42"E – 187 m / Transect 5
5. Agre Forest (AF):	43°56'15" N – 1°16'34" E – 122 m / Transect 5
6. Montbartier (MB):	43°55'13" N – 1°17'56" E – 106 m / Transect 6

7. Fronton (FR): 43°51'18" N – 1°26'18"E – 105 m / Transect 6

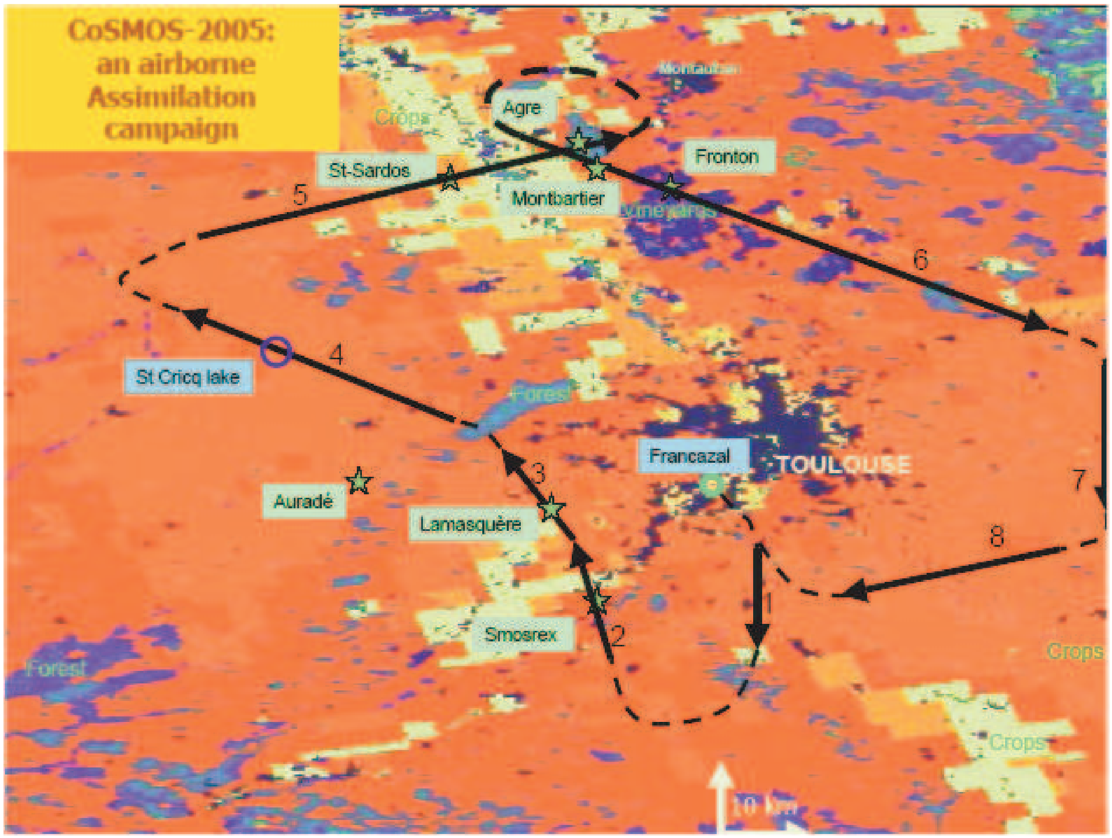


figure II.2.4-a ***: Land use map of the Toulouse region, and the scheduled transects of the CoSMOS campaign (1 to 8). The validation sites (SMOSREX, Lamasquère, Auradé, St-Sardos, Agre, Montbartier, and Fronton) are indicated.***

Instrumentation :

Météo-France will perform automatic, continuous measurements over sites 4, 5, 6, 7. The data will be transmitted to Météo-France in Toulouse automatically by using a GSM transmission.
INRA will make local intensive measurements on sites 5, 6, 7 (mainly biomass estimates and litter water content).
CESBIO will perform both intensive and continuous measurements on sites 2 and 3.
Site 1 (SMOSREX) is common to CESBIO, Météo-France and INRA, and includes automatic multiangular radiometric measurements at L-band together with routine automatic meteorological and soil measurements.

SITE	Type	Observations
1- SMOSREX	Fallow	Met, SM + Temp profile, Soil Density, biomass, H2O+CO2 **flux**, TIR, μW (LEWIS)
2- Lamasquère	Corn or Wheat or Sunflower	Met, SM + Temp profile, Soil Density, biomass, H2O+CO2 flux, TIR (TbC), hemispheric photos
3- Auradé	Sunflower or Colza	Met, SM + Temp profile, Soil Density, biomass, H2O+CO2 flux, TIR, hemispheric photos
4- St-Sardos	Corn	Met, SM + Temp profile, Soil Density, biomass, H2O+CO2 flux
5- Agre Forest (stand 111)	Oak + Coppice	**Met, SM + Temp profile, Soil Density,** INRA : litter water content, hemispheric photos, biomass, additional raingauges
6- Montbartier	Crop TbD	**Met, SM + Temp profile, Soil Density** INRA : leaf area index, biomass
7- Fronton (La Palme)	Vineyard	**Met, SM + Temp profile, Soil Density,** INRA : hemispheric photos, leaf area index, biomass

table II.2.4 a ***: Validation Sites of CoSMOS-Toulouse. The new instrumentation, specific to the CoSMOS experiment is in* bold *for Météo-France and in* blue *for INRA.***

Over sites 5, 6, 7, the following automatic measurements will be performed by Météo-France:

- Air temperature and humidity at a height of 1.5 m
- Wind speed and wind direction at a height of 10 m
- The atmospheric pressure
- Dew (detection of the presence of liquid water at the surface)
- Rain rate
- Incident radiation (shortwave and longwave)
- Upwelling radiation (shortwave and longwave)
- A 5 point soil moisture profile: 0-6 cm, 10 cm, 20 cm, 30 cm, 40 cm.
- A 3 point soil temperature profile : 1 cm, 5 cm, 20 cm.

II.2.5 Continental Biosphere sites

The St-Sardos and Le Fauga sites are described elsewhere (see above sections and Appendix), because they are common sites of the CarboEurope and Continental biosphere projects. This section is thus focused on the Auradé and Lamasquere sites, in complement of the informations given in the CoSMOS section (see above).

Most information concerning present and past management, detailed information concerning site location, former land cover, map, and satellite pictures have been collected in 2004. A data base is under construction. Detailed description of soil profile has still to be done. For more details see Appendix.

The Auradé site is located on a plateau. Surface area of the plot is 14 ha. It is cultivated on a wheat-sunflower-wheat-rapeseed rotation basis. The parcel is tilled and fertilised, and will be covered with rapeseed in 2005.

The Lamasquere site is located in a flat large alluvial valley. Surface area of the plot is 37 ha.

It is cultivated on a wheat-corn-corn- sunflower rotation basis. The parcel is tilled, irrigated and fertilised, and will be covered by wheat in 2005.

figure II.2.5-a ***: The Lamasquere (left) and Auradé (right) sites***

The Auradé and Lamasquère sites were equipped in March and July 2004, respectively, with meteorological and flux stations running on batteries and solar panels.
Other parameters (soil heat flux, light interception, canopy radiative temperature…) were also recorded. Concerning the footprint analysis data were sent to Mathias Goeckede for the standardised footprint analysis.
Phenology, leaf area index, plant area index biomass and height were measured regularly throughout the 2004 season. Biometric relationships were already obtained for several crops on our two plots and on surrounding plots in Lamasquère. LAI and PAI were also estimated

II.3 Boundary-layer profiling

II.3.1 UHF wind profilers

Two UHF radars, wind profilers will be operated during the campaign. Both are identical (Degreane PCL1300). They are composed of five beams, one pointing vertically and the others, with a zenital angle of 17° and orientated along the West, East, North and South. The wind component along each beam direction is deduced from the Doppler shift of the backscattered signal. The three wind component (N,E and vertical) are thus deduced from the redundant five radial velocities, with the assumption that the horizontal gradient of the wind is weak in the volume scanned by the radar.

The range of altitudes covered by the instrument is variable, depending on atmospheric conditions and electronic parameters. In general, the profile of the horizontal wind is valid between ~200 and ~2000m. The time resolution of the profiles is 6 min.
Only the horizontal wind will be routinely computed. Other parameters (vertical wind, C_n^2 and dissipation rate of TKE) could be deduced for some situations using dedicated processing softwares.
The radars will be operated continuously during the campaign. One belongs to a French military agency, and is located at the Cazaux military area (about ten kilometres from the shoreline). The other belongs to CNRM, and will be installed on the site "La Cape Sud" (CS), about 50 km from the shoreline.

figure II.3.1-a ***: The UHF Degreane PCL1300 wind profiler***

II.3.2 Modified ceilometer

A commercial ceilometer (Vaisala CT25K), originally designed to measure the height of cloud bases, has been modified in order to retrieve the height of the atmospheric boundary layer.

The instrument has a laser diode at a wavelength of 905nm. The backscattered light is analysed with a vertical resolution of 7.5m, and a profile could be obtained every 2 min. up to about 2km in height. The top of the boundary layer is deduced from sharp transitions in the profile of the backscattered signal, related to the difference in aerosol and/or water vapour concentrations between the boundary layer and the overlying free troposphere.

The ceilometer will be installed close to the CNRM UHF radar, at LaCape Sud (CS site). It will be operated continuously during the campaign. Simultaneous analyses of the backscattered radar and laser signals would help to improve the determination of the boundary-layer height.

figure II.3.2-a ***: Vaisala CT25K ceilometer***

II.3.3 Doppler Sodars/RASS

Within the regional experiment of CarboEuropeIP the Vrije Universiteit Amsterdam will operate a sound detection and ranging (SODAR) system, extended by radio-acoustic sounding system (RASS) in an agricultural field (maize) near the town of Marmande (MR). The exact location has been determined taking into account constraints like the power requirements of the equipment, and the distance from farms and other residential buildings which should be such that sound disturbance is minimal. The SODAR that will

be used is XFAS52 flat array SODAR manufactured by Scintec AG in Tübingen, Gemany (see appendix for details).
The prime use of a SODAR is to obtain vertical profiles of the three-dimensional wind speed. Therefore, an antenna emits short sound pulses which are subsequently back-scattered on temperature inhomogeneities. The Doppler shift between emitted and back-scattered frequencies of the sound waves determines the wind speed in one direction. Combing emitted and back-scattered pules in different directions then gives the three-dimensional wind speed field.

The strengths of the back-scattered signal relative to the emitted signal is a measure of the vertical profile of virtual temperature. The latter can be however be more accurately measured when the SODAR is extended by a RASS system. The RASS system emits monochromatic radio waves that are back-scattered on the sound waves. Doppler shifts between emitted and back-scattered waves are determined by the speed of sound which can subsequenty be used to determine the virtual temperature. It appears that due to Bragg resonance, the strength of the back-scattering of radio waves depends on the frequency of the sound wave as a function of the virtual temperature. Vertical profiles of virtual temperature are thus derived from time series of peaks of the back-scattered radio wave signal as emitted sound pulses with different frequencies travel vertically through the atmosphere.

A SODAR only measures profiles of wind speed in dry conditions. In rainy conditions, the velocity of the rain drops is measured rather than the wind speed. Furthermore, the maximum height by the XFAS52 SODAR is about 2000 m. Back-scatter of the sound waves requires however temperature inhomogeneities that are much stronger than the inhomogeneities due to the molecular movements of the air. The maximum measurement height is therefore mostly confined to the atmospheric boundary layer where turbulent motions of eddies create strong temperature inhomogenities. Typical measurement heights are therefore a few hundred meters in conditions when the atmospheric boundary layer is stably stratified to 2000 m or even higher in the fully-developed turbulence of afternoon convective boundary layer.

The RASS operates in both dry and rainy conditions. Also, as the radio waves back-scatter on the sound waves it does not require temperature inhomogenities to operate successfully. It can therefore usefully measure vertical profiles of virtual temperature in both stably and unstably stratified atmospheric boundary layers. However, the radio waves are emitted in concentric circles spheres and thus the intensity of the emitted waves decreases rapidly with height. The maximum measurement height of the RASS is thus limited by the strength of the emiited radio waves and is for the RASS extension of the XFAS52 SODAR about 700 m.

The SODAR system will also be used to obtain vertical profiles of turbulence parameters such as the Turbulent Kinetic Energy and the structure function of temperature. To obtain the vertical velocity variances (which together make up the TKE), the relative spectral broadening of the backscattered sound waves are determined in the different directions. The structure function of temperature is determined from the strength of the back-scattered sound waves relative to the emitted sound waves. This procedure needs however calibration for which turbulence data obtained by the Sky Arrow aircraft, or a surface eddy-correlation system (available at the Marmande site) will be used.

A simpler Doppler sodar (Remtech PA1, without RASS system) is operated at the La Cape Sud (CS) site, in order to extends (with overlapping) the wind profile measured by the UHF radar towards lower layers. This system is operating between 50 and about 500m altitude, depending on atmospheric conditions.
In the end, a Doppler sodar is operated by a French military agency at the Biscarrosse site, close to the shoreline. The wind profile is measured in similar conditions as at the CS site.
Combining UHF radars and Doppler sodar systems, the wind profile in the boundary layer is thus continuously measured at about 0, 10, 50 and 120 km from shoreline (at the BS, CZ, CS and MR sites, respectively).

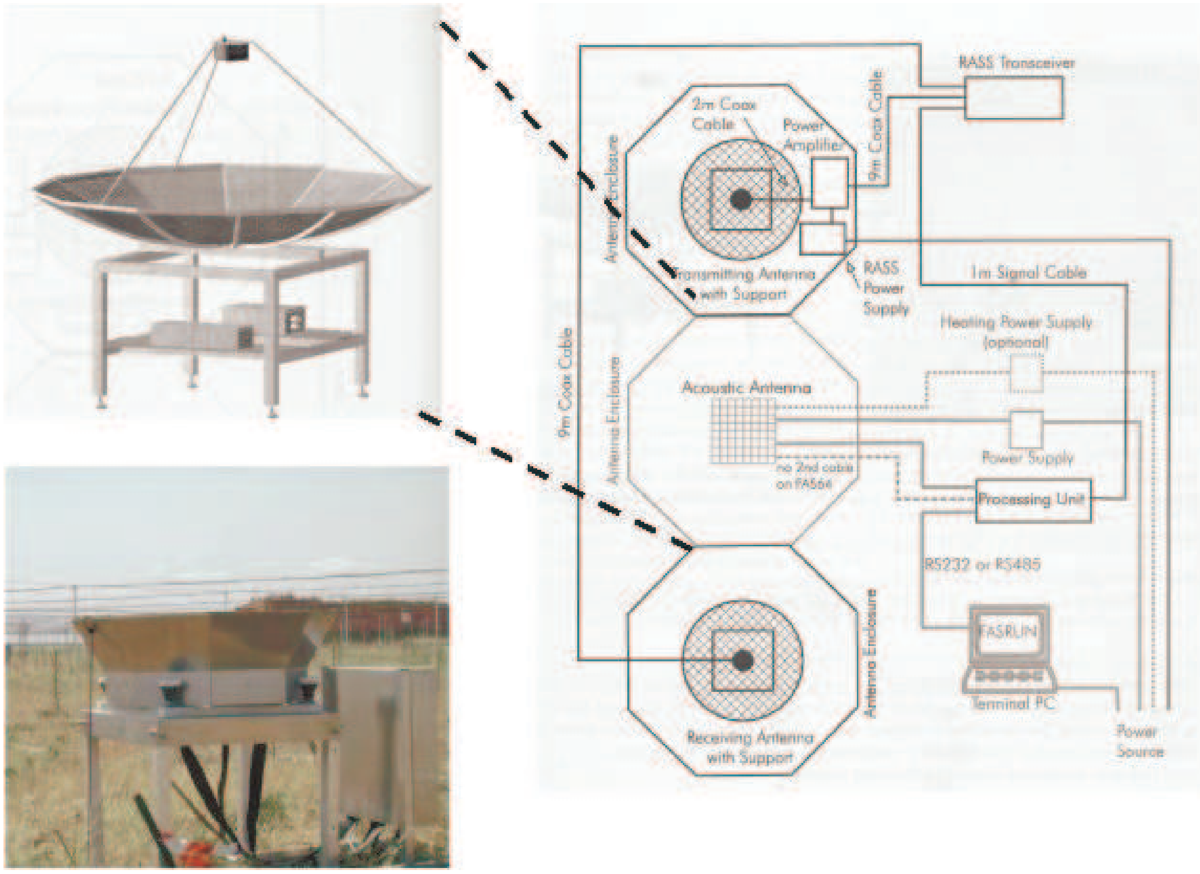


figure II.3.3-a ***: Right : Scheme of the Sodar with the RASS extension (Vrije University (VU)) ; upper left: acoustic antenna of the VU RASS; lower left: acoustic antenna of CNRM Sodar.***

II.4 Other measurements

Contents	Author(s)	Nr. Pages	Nr Illust.
Description of complementary measures (meteo. Operational network, military sites, electricity company sites, etc.)	Petitcol/Lacarrère	0,5-1	0-2

II.5 QC/QA operation

Contents	Author(s)	Nr. Pages	Nr Illust.
Description of QC/QA operations (summary of calibrations/intercomparisons; detailed operations in the appendix)	TBD	0,5-1	0

III FIELD ACTIVITIES: IOP MEASUREMENTS

III.1 Radiosondes

During IOP days, radiosondes will be launched at the site « La Cape Sud » (CS). The system measures the profiles of wind, temperature and moisture up to an altitude of about 20km. The Vaisala Digicora III sounding system, with RS92SGP sondes, uses the GPS to measure the balloon position from which the horizontal wind is computed. The sonde carries a barometer from which the altitude is computed, a thermistor and a twin capacitive, humidity sensor. It climbs at a rate of about 5m/s.

The vertical resolution of the profiles could be chosen in order to allow a good description of the boundary layer while avoiding noisy data resulting from a too-high resolution. 5sec. (i.e. about 25m) would be a good compromise.

During the campaign, the reduced profiles (as "TEMP" and "PILOT" files, containing the characteristic as well as standard levels) will be sent on the GTS, immediately after the end of the sounding, in order to be incorporated in the data assimilation system of the operational, limited area forecast model (ALADIN). This will improve the quality of the 1-2day forecasts and the operational analyses during the experiment.

It is planned to launch 4 to 5 sondes every IOP day. Few extra-soundings will be performed at CNRM in Toulouse, for some chosen days.

The operational met. station of Bordeaux-Merignac performs two radiosonde soundings on every day (at 00 and 12 UTC). The device used is the Vaisala "autosonde". The data of the IOP days (at least characteristic and standard levels) will be incorporated into the CarboEurope data set.

figure III.1-a ***: Preparation and release of a radiosonde balloon***

III.2 Aircraft

III.2.1 General overview of aircraft operations

Aircraft will play a key role during the CarboEurope Regional Experiment campaign.
The objectives of aircraft flights will be :

- to document the advection of CO2 within the domain (Piper Aztec)
- to monitor the vertical structure of the boundary layer and the CO2 concentrations at different locations of the experimental area (Dimona, Piper).
- to estimate turbulent fluxes and CO2 at low level in order to compare with the surface network and thus to upscale local measurements (Sky Arrow)
- to estimate by remote sensing the properties of the vegetation simultaneously with the flux estimate (Sky Arrow).

Four aircraft (see Figure below), described in the following Table, will be available during the field campaign:

table III.2.1-a ***: available aircrafts***

Aircraft	Institute	Measurements
PIPER AZTEC	CNRM / METEO FRANCE	Meteorological parameters, CO_2, CO, flasks sampling, surface temperature
SKY ARROW (in situ)	IBIMET / CNR	Meteorological parameters, turbulence, gas concentrations (H_2O, CO_2)
SKY ARROW (teledetection)	ISAFOM / CNR	Remote sensing apparatus to provide observations of land cover, surface albedo, surface temperature, NDVI
DIMONA	METAIR	Meteorological parameters, turbulence, O_3, NOx, NOy, HNO_3, PAN, Ox, CO, CO_2, H_2O, particle counter

<u>figure III.2.1-a</u> ***: The four research aircrafts available during the campaign***

During an IOP, the 4 planes will be able to flight simultaneously with the trajectory illustrated in the Figure below.

figure III.2.1-b ***: Flight plans of the 4 aircrafts flying simultaneously : -1- Piper; -2- Dimona; -3- the two Sky Arrow***

III.2.2 Piper-Aztec

III.2.2.1 Equipment

Succinct description of measures

On the Piper there are 2 kinds of measurement, on one hand basic measurements owing to the aircraft center, and on the other hand, specific measurements by means of instruments supplied by external laboratories. The airplane is equipped with a nose boom on the tip of which the airflow is measured. For the regional campaign of CarboEurope program, the instrumentation will be as follows:

Basic measurements :

Meteorological parameters:	Pressure, temperature, humidity (dew point & capacitive sensor).
Other parameters:	Position (lat, lon, alt (GPS and height), speed), aircraft velocity (Doppler radar), true heaging, true airspeed, attack and sideslip angles, CO, radiometric surface temperature.
Specific measurements :	CO_2 Infrared absorption (CONDOR system developed by LSCE), and flask sampling system for postpone analysis of carboneous compounds.

Measurements are acquired with the data acquisition system of the PIPER AZTEC at frequencies of 1 to 200Hz, according to the performances of the sensors. Time series, profiles and airplaine trajectory can be available about 2 hours after the landing of the aircraft if landing is at Francazal military airport.

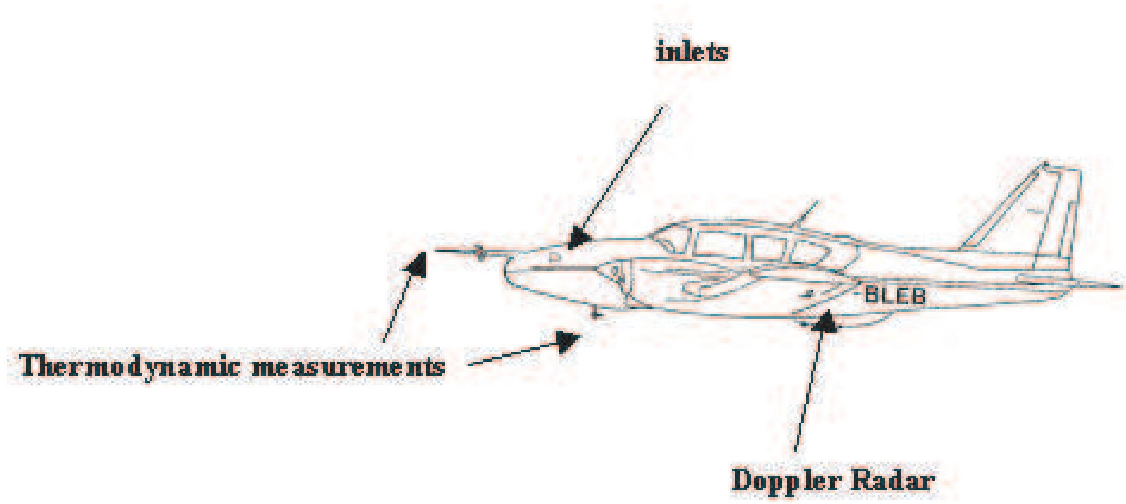


figure III.2.2.1-a ***: Piper measurements***

III.2.2.2 Flight plans

The flights are all in VFR by very good weather conditions. 4 types of flight are suggested and can be complementary. The flights will proceed starting from Toulouse-Francazal. This represents a 100 hours time volume in flight.

Plan "Landes"

It consists of three vertical profiles between 300 ft (surface) and 8500 ft and a main leg of 25 NM oriented North-South, 80 NM east from the first upstream vertical profile. This leg can slip towards North or South, according to the wind.

To save time, this profile will be only on the ascending or downward part of the figure. The other part will be used as transit.

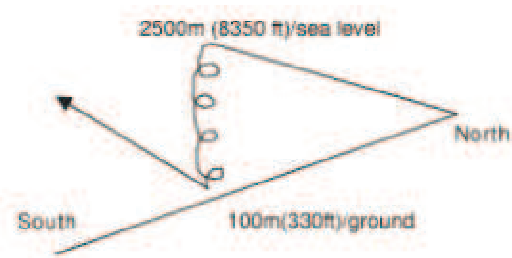


figure III.2.2.2-a ***: plan "Landes"***

Then transit between the vertical profiles is regarded as a flight measurement. The height of the flight will be 1000 ft (300 m) for a morning flight (take off at 0900 LT) and 3200 ft (800 m) for a flight during the afternoon (take off at 1430LT).
The duration of the flight is approximately 3h30 to 3h45. A technical landing in Saucats airport is possible before to be back in Francazal (Toulouse).
When two flights of this type are envisaged in the same day (5 times), there will not be more than 2 days of measurements consecutive. In the case of 2 daily flights, an intermediate halt will be envisaged in Bordeaux-Saucats where a team on the ground will ensure the conditioning of the plane during the stage.

figure III.2.2.2-b***: The « Landes » flight plan***

Plan "Landes-Toulouse"

It consists of 3 legs of 40 Nm (74 km) directed NS. The leg East will fly over the sites of "Beaumont de Lomagne" (N43 53,70 E0001 06,73) and the "Fauga" (N43 23,17 E001 17,67). This pattern is planned for a wind of the North-West. The height of flight will be 2700 ft (800 m) and takeoff is envisaged at 1000 LT. 2 profiles are envisaged between 8350 ft (2500 m) QNH and 330 ft (100 m) ground. The duration of measurement is about 2h30, plus a flight return of Biarritz (technical stopover) towards Francazal of 1h15.

figure III.2.2.2-c *: The « Landes-Toulouse » flight plan*

Plan "Toulouse"

It consists of a square of 4 legs of 40 Nm (74 km) around Toulouse, with 2 heights: in first 8350 ft (2500 m)/ground, then 2700 ft (800 m)/ground. The time of takeoff is 1400 LT. The duration of flight is about 3 hours.

figure III.2.2.2-d *: The « Toulouse » flight plan*

Plan "Lagrangien"

Used by wind of West and composed of 2 legs NS. The leg "upwind" makes 27 Nm (50 km) length and is carried out in the morning on 3 heights: 1000 ft (300 m), 2700 ft (800 m) and 5000 ft (1500 m). A profile at 8350 ft (2500 m) is envisaged.

The branch "down-wind" begins 2h00 after the landing of the first branch. It makes 54 Nm (100 km) and 3 heights are also envisaged: 1000 ft (300 m), 2700 ft (800 m) and 8350 ft (2500 m). A profile at 8350 ft (2500 m) will be placed in the medium of the leg.

figure III.2.2.2-e ***: The « Lagrangian » flight plan***

III.2.3 Sky Arrow (in situ)

III.2.3.1 Equipment

The Sky Arrow 650 ERA (Environmental Research Aircraft) is a commercially produced, certified small aircraft equipped with sensors to measure three dimensional wind and turbulence together with gas concentrations (H2O and CO2) and other atmospheric parameters (like temperature, surface radiometric temperature, net and UV radiation) at high frequency. The aircraft has a cruise flight speed of 45 m s^{-1} with an endurance of 3.5 h, allowing it to cover flight distances of up to 500 km. Operating altitudes can range from 10 m above ground level to more than 3500 m above sea level. The aircraft position, groundspeed and attitude angles are continuously measured.

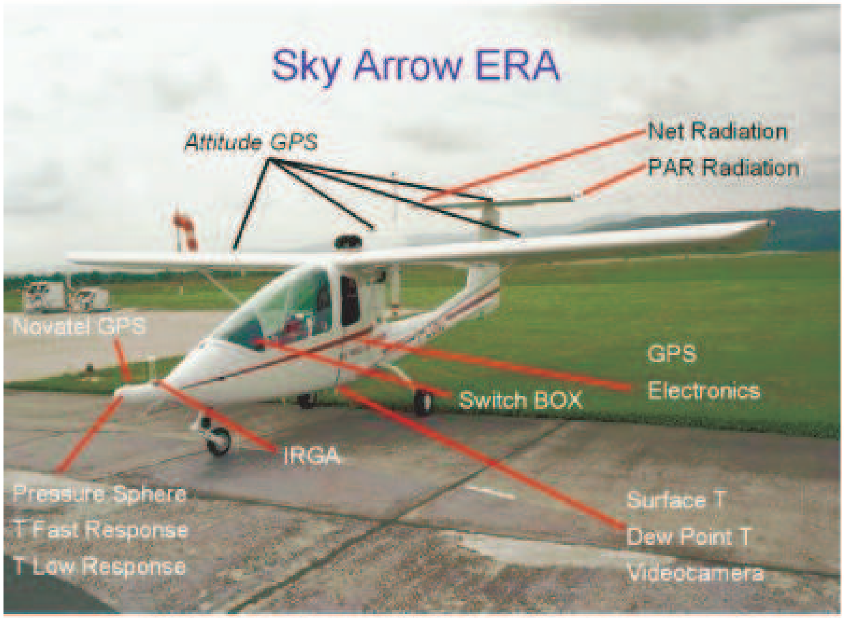


figure III.2.3-a ***: Photograph of the SkyArrow ERA showing the exact location of the sensors and instruments mounted onboard.***

The flux calculation procedure requires the wind components to be derived from the 50 Hz raw data out of the MFP. The subsequent calculation of carbon dioxide, water vapour, sensible and latent heat and momentum fluxes are made using conventional eddy covariance technique taking into account all the necessary corrections for open-path gas analysers (Webb et al., 1980). The complete computation procedure software has been developed by IBIMET in the last years.
The main difference between airborne and ground-based eddy covariance is in the averaging technique. It has been found that there is a correlation between vertical air motion and aircraft ground speed, causing some type of turbulent structures being sampled more densely than others (Crawford et al., 1993); this can introduce bias up to 20% in the fluxes computed simply by using a time average. Hence, turbulent fluctuations (wind and associated scalars) are calculated using averages calculated over space (per meter) rather than over time (per second). This "spatial average" is defined, for instance for the vertical wind component *w*, by the following equation (Crawford et al., 1993):

$$\overline{w} = \frac{1}{\overline{S}T}\sum_i w_i S_i \Delta t \qquad (1)$$

Where S is the instantaneous ground speed of the aircraft, $\overline{S}$ is the mean speed, Δt the time increment, and T the total time. A similar averaging procedure is applied to all the variables involved in the covariance calculation.
The definition of a proper averaging length is critical to ensure that all significant flux-carrying wavelengths are taken into account. Such a length depends on the flying altitude, on the surface roughness, and on atmospheric stability, and can be determined with cospectral analysis techniques (Desjardins et al. 1989). Using such an approach, proper averaging lengths ranging from 3000 m to 4500 m have been found in the different conditions encountered in the RECAB campaigns (Gioli et al. 2004).
The ability of eddy covariance to resolve the higher frequencies carrying flux is limited by a number of factors, including the insufficient dynamic frequency response of the sensors and the length of the scalar path averaging. The dynamic response time of each sensor can be, in fact, not fast enough to adequately resolve the measurements up to the measured frequency, introducing some loss in the fluxes. Hence, proper correction factors must be applied as a function of the flying altitude, the wind speed, and the atmospheric stability.
Vertical profile measurements will also performed in the CarboEurope IP experimental campaign, providing vertical distribution data of scalar concentrations of CO2, water vapour, temperature, wind magnitude and direction, and turbulence. High frequency data will be distributed at 5 - 10 cm over the vertical.

III.2.3.2 Flight plans

Flights will be performed in the area North of the Landes, overflying instrumented sites from Bordeaux-Saucats airfield. A total of 80 measurement flight hours has been planned:

- 60 hours of surface flux measurements
- 20 hours for vertical profiles measurements and flux divergence studies.

Three different types of surface flux measurements flights will be performed, in order to cover the most important areas and land use classes of the domain:

- a transect across the forest areas of Landes (blue track)
- a transect across the vineyard areas in the northern area of the domain (green track)
- a transect across forest and agriculture areas (mainly maize, black track)

Vertical profiles will be performed in different points of the domain, to be determined on the basis of logistic and scientific requirements.

Flux divergence studies will be performed occasionally in order to characterize the flux behaviour at different heights within and above the PBL. Such flights will consist of a transect flown repeatedly at different altitudes in the PBL, from the bottom level (approx. 100 m AGL) to the entrainment zone.

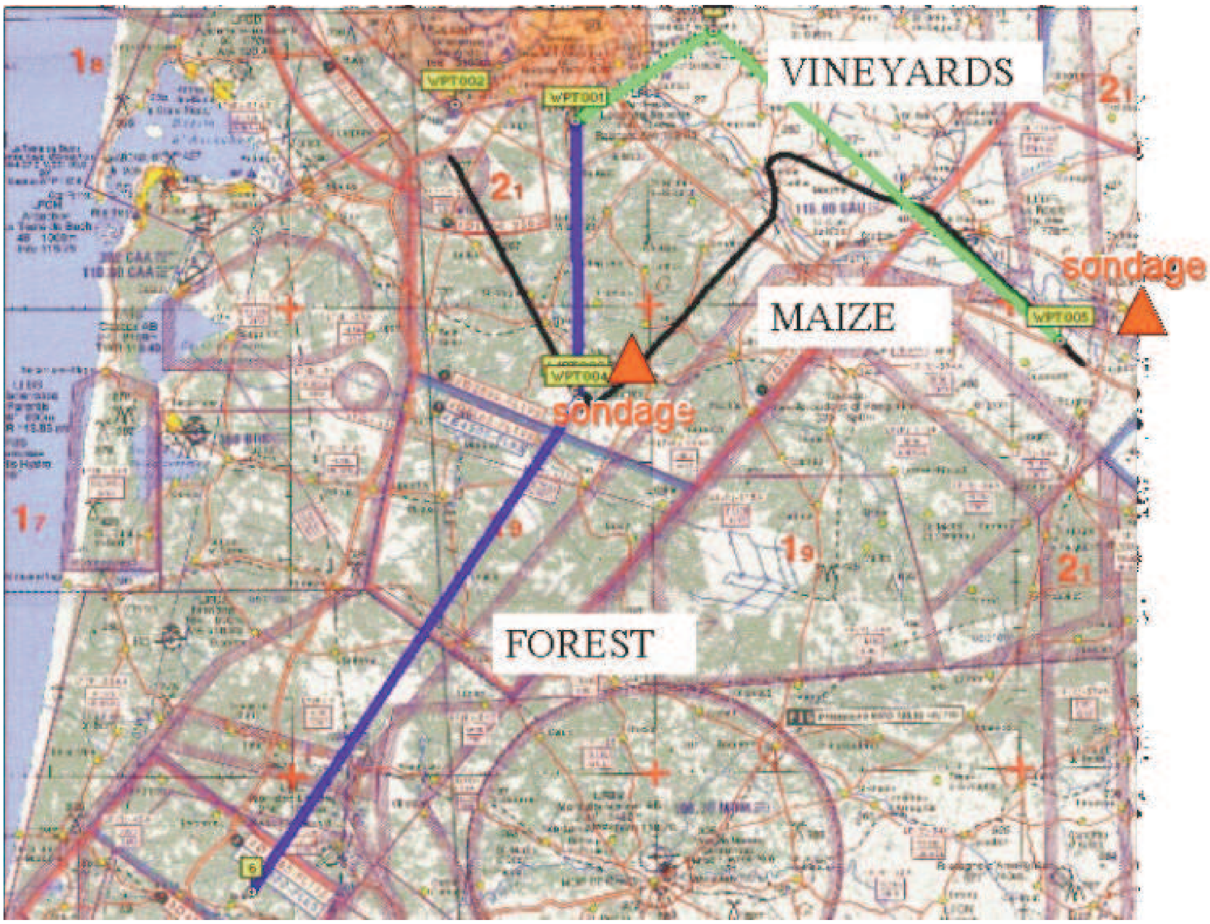


figure III.2.3-b ***: Flight tracks for surface flux measurements.***

III.2.4 Sky Arrow (teledetection)

III.2.4.1 Equipment

figure III.2.4-a ***: ISAFoM Sky Arrow ERA aircrafts***

One out of the two ISAFoM Sky Arrow 650 TCNS ERA research aircraft (see opposite picture) will be stationed at Saucats airport early in May. The aircraft will be equipped with a remote sensing apparatus (see details in VI.1.3) to provide high spatial resolution thermal and multispectral images of the instrumented study areas and the various land cover types of Les Landes region. The system will provide the following observations: 1) land cover; 2) surface albedo; 3) surface temperature 4) NDVI.

The acquisition device system (see VI.1.3) is based on a PC104 architecture and is made of two Duncantech 4100 multispectral and a FLIR M40 thermal cameras (sample images in figures below). Two small hyperspectral cameras in the visible and thermal infrared range may also be added to the setup.
These measurements can be combined to compute maps of evaporative fraction (Surface Energy Balance Index) and NDVI of underlying vegetation. The cameras need prior calibration and the accuracy of measurements is improved by concurrent radiometric observations on the ground.
As detailed thereafter, typical flight height is 3000 m. Optics presently fitted to multispectral and thermal cameras, provide a swath width of about 3 km and a target resolution of a few m. These figures allow for an adequate representation of optical properties of land patches included in the downwind footprint of study areas, measured by ground towers and flux aircraft.

figure III.2.4-b ***: true colour image of a cropland area***

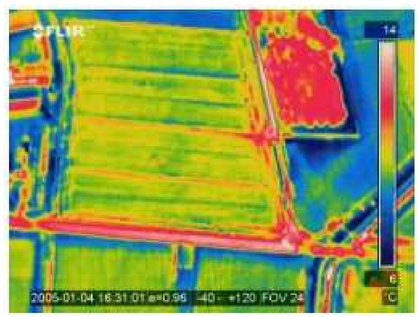


figure III.2.4-c ***: temperature mapping of a cropland area***

Coordinates, attitude and environmental parameters needed for the correction of images will be provided by the on board MFP apparatus for the measurement of turbulent fluxes, installed on both aircraft.
For added reliability, the entire setup has backups and spare parts: a second identical aircraft also equipped with the MFP may be brought in, at the extra cost of a few ferry flight hours; an early fully tested version of the acquisition device is available; an extra RGB camera is borrowed by a collaborating university; extra multi-spectral and thermal cameras were booked for renting from Duncantech and FLIR. A second pilot with technical skills will also stay at Bordeaux for the duration of the experiment.

III.2.4.2 Flight plans

Flight routes will overlap towers and low flying flux aircraft footprint areas, at a nominal height of 3000 m. Different paths and flight elevations might be chosen, taking into account the aeronautic restrictions to flight.
The actual swath widths and target resolutions are detailed in the table below. These figures could be increased linearly with flight height, since the theoretical ceiling of the aircraft is 4200 m. However, it is more feasible to increase swath by oversampling the area while performing the return path.

camera	swath (m)	resolution (m)
FLIR M40 thermal	2544	7.9
Duncantech 4100 RGB & CIR	3042	1.6
Sony xc-st70ce Hyper visible	6420	8.3
SU128-1.7RT-V Hyper NIR	4800	37.5

table III.2.4-a ***: swath widths and target resolutions***

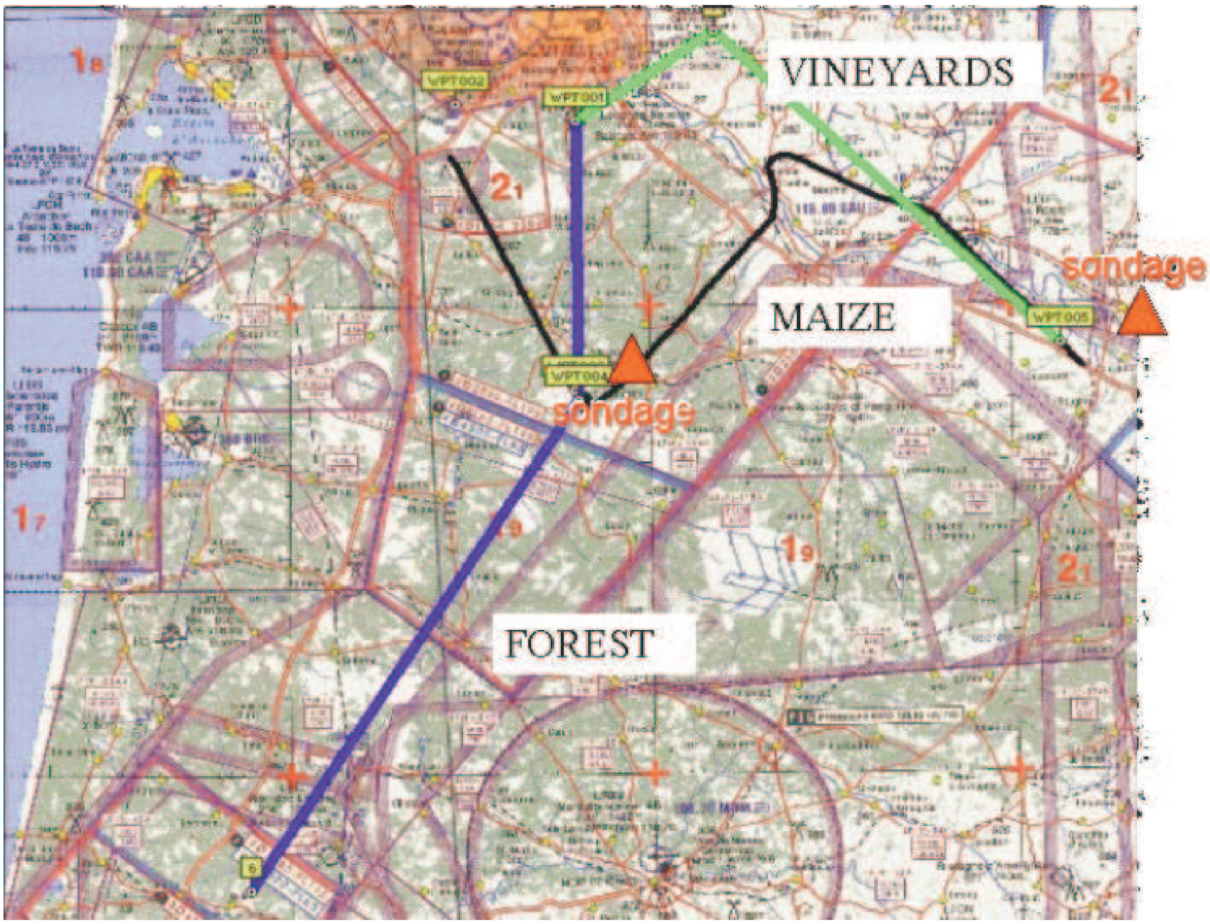


figure III.2.4-d ***: flight plans of skyarrow***

The flights will proceed on the north of the Landes, since the aerodrome of Bordeaux-Saucats. Skyarrows will fly over the instrumented sites with a height lower than 300 ft for the first and from 1500 ft to 2500 ft for the second.
The layouts ground are represented in blue and green on the chart attached. It is envisaged 2 flights of 3 hours per week (clear sky) for a total of about 30 hours.

III.2.5 ECO-Dimona

III.2.5.1 Equipment

MetAir's "Dimona HB-2335" is both an advanced, and ecologically sound airborne measuring platform. It is a two seated, self-launching powered glider (Dimona HK-36 TTC ECO) silent, low fuel consumption, but 150...200 km/h cruising speed / 5 h endurance. Underwing-pods with two times 50 kg for equipment (scientific instruments) contain state of the art sensors for meteorology, and chemistry, position, 3-d-wind, temperature, dewpoint, in turbulent resolution (10 Hz), for eddy fluxes with H2O, CO2, CO, NO2, heat and momentum.

The MetAir standard equipment includes sensors for:

- fast response and high accuracy air temperature and humidity;
- flow and attitude angles resulting in a fast 3-d wind and turbulence measurements;
- ozone (two methods; one accurate, one fast);
- NO_2, NO_x, NO_y, HNO_3, PAN, O_x;
- CO (5 Hz with a precision of 2 ppb);
- CO_2 and H_2O (open- and closed cell IRGA - one fast, the other accurate to 0.2 ppm);
- particle counter for 0.3 and 0.5 micrometer aerosols;
- many "housekeeping parameters", including GPS-position and distance to ground (radar).
- Remote sensing with Hyperspectral Scanner.

figure III.2.5.1-a ***: The Dimona at Saucats airland during the COCA 2001 campaign.***

III.2.5.2 Flight plans

Dimona will contribute to 5 to 6 days of measurements, with one or two flights per day (3 to 4.5 hours each). With two flights per day, they will be from about 9 to 12 h, and 14 to 18 h LT, or with one extended flight per day between 11 and 16 h LT.

In the following, the basic flight pattern is discussed with different aspects on different graphics.

figure III.2.5.2-a ***: MetAir's basic flight legs MA1 through MA5 shown together with the existing design of the pattern "Landes" for the Aztec***

MA1 is the ferry flight to some "center point, MA2+MA3 are the transsect for westerly winds, and MA2+MA4 for southwesterly winds. They are not not necessarily flown together with the Aztec, but, taking the same tracks might ease the permission, and there might be occasions, where the flights are quasi-synchronous. The same is true for the leg MA1, which is on one of the "SkyArrow tracks" (not shown here).

However, in contrast to Aztec and SkyArrows which fly on different constant altitudes, our task can only be fulfilled, when we can change altitude on these legs between near surface (minimum save flight altitude, see below), and about 2500 m AMSL (8000 ft) quite frequently. The ascents will be made in 8-shaped turns perpendicular to the wind, with the turns against the wind (see details on the last figure below).

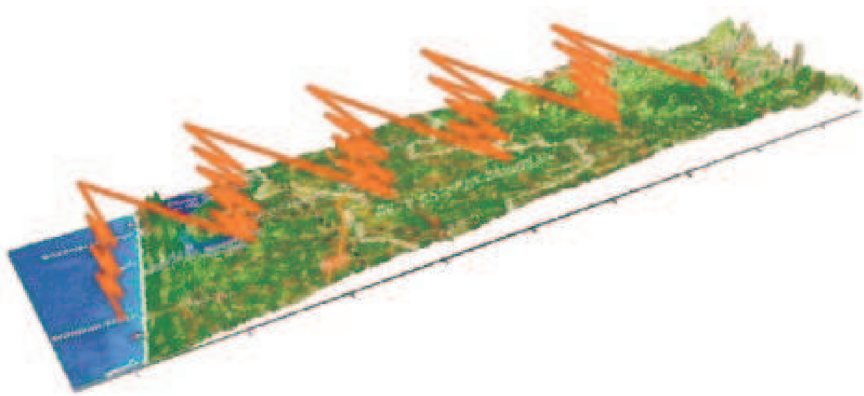


figure III.2.5.2-b ***: Perspective view of a west-to-east-strip with the desired flight pattern***

Then, we descend to the lowest point of the next profile. The separation between the profiles is depending from the wind speed. We try to move with the air mass (lagrangian measurement). Since ascents are made with about 2 to 3 m/s vertical speed (130 km/h horizontal speed), and descents with about –4 m/s (200 km/h), one ascent/descent cycle over 2500 m takes about half an hour. With an average wind speed of 10 m/s (20 kt or 36 km/h) in the boundary layer, this would result in distances between profiles of about 20 km (or less with lower wind speed as in figure III.2.5.2-d). Also the top of the profiles could be adjusted according to the actual height of the boundary layer. Especially during flights before noon, 1500 m MSL might be enough.

Considering the limitations of the air spaces with their complex vertical structure and temporal activity (see figure III.2.5.2-c), not every profile might be possible to the desired altitude at any time. However, we hope, that for the benefit of the project, most will be possible. Before each ascent, we will request the clearance from the relevant ATC. It is no problem to wait a few minutes when the actual traffic situation does not allow to continue, but, it's possible later (a delay or a divert to another position is less a problem than a "no go"). Our altitude is always visible on the radars, since we have Transponder-C, which is encoding height. Perhaps it would be practical, when we could get a "squawk" (transponder code) for each active measuring day, or even for the campaign?

When flying from LFCS via WP1 to the coast, we will fly on constant altitude about 300 m GND (which is about on 1000 ft MSL). In principle, each of these legs could be flown on this altitude for flights in parallel with the SkyArrows, or for transfers.

<u>figure III.2.5.2-c</u> ***: Air spaces on the map, and in a vertical cross section (altitude in feet) along the track (from Jeppesen FliteStar)***

The dark blue air spaces on the bottom graph are Aquitaine TMA Sectors 2 and 4 (class D and E), and the red ones are all special use (restricted) air spaces from Cazaux, Biscarosse, Landes West, Captieux, Mont-de-Marsan. We will have to find out, under what conditions we will be allowed to enter them. The blue flight tracks on the map are as in figure III.2.5.2-a (MA1 to MA5). In the vertical cross section (bottom graph), the black track is the upper envelope (top of the profiles).

We do not know yet, if MA3 will be possible (the leg from WP1 in figure III.2.5.2-c to the east, and back to WP3), because it crosses several restricted air spaces (see also figure III.2.5.2-d). Especially during days with southwesterly winds, MA4 (from WP1 to the NE) might be an alternative which crosses less restricted air spaces. However, for wind directions between 260 and 300°, it would be most desirable to use MA3.

Technical remark:

In principle, this map (and others) are available during the flight in the cockpit on the 12"-screen of the measuring system, with the actual position of the DIMO on it (moving map display), and – redundantly and independent – on the hand held GPS "Garmin GPSMAP 195" which also has an actual data base of air spaces. However, these are comfortable helps only, and the basic navigation will be made by classical means (VFR chart on paper, supported by VOR).

Safety remark:

During the campaign, we will find out, how possible emergency landing fields for lowaltitude single engine operation are distributed. Since the glide ratio also with the underwing pods is better than 1:20, and we gain about 50 m extra height when reducing from cruising speed to best glide speed, the "escape radius" on 300 mGND is about 5 km. The risk of engine failure is very low (fully certified double ignition aircraft engine "Rotax 914F" and all maintenance and procedures according to known best practice), but, we know from the terrain inspection in 2001, that the forest is unlandable, and also the clearings will have to be inspected. The lowest points of the profiles (50 to 150 mGND) will be positioned near suitable clearings. From the higher parts of the flight pattern (about 50% of the time), even airfields would be available in case of emergency.

figure III.2.5.2-d ***: details of the pattern for westerly winds (MA2+MA3)***

On this map, more details of the pattern for westerly winds (MA2+MA3) are shown, together with a better identification of the air spaces. The cross-legs (short north-south-legs of 3 to 5 km length) are the vertical profiles as discussed with figure III.2.5.2-b, with an average horizontal separation of 15 km in this example (suitable for a wind speed of about 30 km/h). These cross legs will be flown as 8-shaped ascending "zig-zag" perpendicular to the wind, with all the turns against the wind (this is to avoid crossing the own exhaust gases which could happen when circling).

III.3 Constant volume balloons

Constant volume balloons (CVBs) are cylindrical and overpressurized. This excess of pressure ensures that their volume remains quite constant, whatever their vertical displacement in the atmosphere. Given that their mass is also constant, it results that CVBs fly at a constant density level. Strictly speaking, they are therefore not Lagrangian: when the balloon departs from its density-equilibrium level (as occurring when it enters an updraft or a downdraft), its buoyancy brings it back to its density level. They can thus be considered as horizontally-Lagrangian vectors.

The CVBs are operated by the Space French Agency (Centre National d'Etudes Spatiales – CNES). Their ballast is computed in order they fly at the chosen density level: for CarboEurope experiment, this will correspond to an altitude of 800 to 1000m. CVBs embark a radiosonde, from which their position, as well as temperature and moisture along the trajectory, are recorded via telemetry by a ground station.

CVBs will be launched and tracked from the site "La Cape Sud" (CS), at the same location as for the radiosonde launches. It is expected to track the balloons for horizontal distances larger than 50km.

CVBs will be used in conjunction to airplanes Lagrangian missions, in order to help to the monitoring of the airmass trajectories during the flights. About 4 days with CVBs could be planned during the campaign.

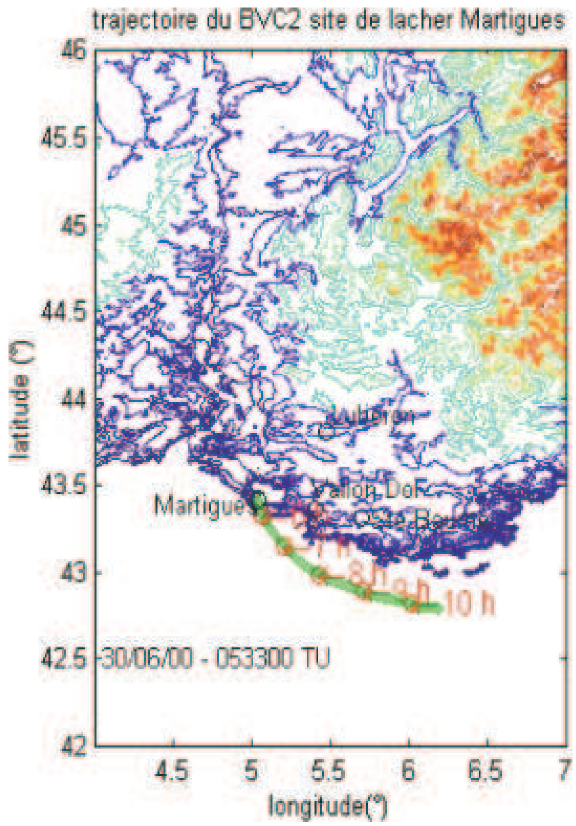


figure III.3-a ***: Example of CVB trajectory observed during the ESCOMPTE campaign. The balloon was launched from a site close to the shoreline in south-east of France, and tracked over the Mediterranean sea during about five hours***

IV FIELD ACTIVITIES: COORDINATION

IV.1 Headquarters

IV.1.1 Toulouse (CNRM)

The headquarter at Toulouse (HQT) is situated on the 2nd floor at CNRM. The room is equipped with Phone, Fax and a Windows PC.
Up to ~20 people could attend the daily briefing(s). Among them, there will be at least the PI and the scientific secretary (except for the periods they will be at Bordeaux HQ), the 'forecaster' from the operational weather service and a pilot or engineer of the Piper Aztec aircraft (based at the Francazal military airport).
The first briefing will be held on May 13th in in order to be able to launch the 1st IOP day on May 16th (would the conditions be favourable) with a 3-day alert time.

The meteorological situation as well as the forecast for short- (1-2 days) and long-range (up to 5 days) periods will be presented once daily by a person of the operational meteo. office during the morning briefing.
A short vocal message, indicating the status of the experiment, and summarizing the daily operations, will be registered on the answer-phone after each briefing. This message will be heard when calling the phone number indicated below, in the absence of people in the HQT room.

Phone : 05 61 07 97 10
Fax : 05 61 07 97 05
Headquarter coordination email : hq-carboeurope@cnrm.meteo.fr
Mailing list : carbo@medias.cnes.fr

IV.1.2 Bordeaux (INRA)

The headquarter at Bordeaux (HQ2) is situated in Ephyse building at INRA La Grande Ferrade. The room is equipped with a soundstation console, a Windows PC and a so-called "RETIM" station giving access to the main meteorological products of the weather forecasting service of Meteo-France.

From 23 to 29 May, the PI (Pierre Durand) and the scientific secretary (Nathalie Jarosz) will be at HQ2.

The first briefing will be held on 13 May in order to be able to lauch the 1st IOP day on 16 May 16 (would the conditions be favourable) with a 3-day alert time.

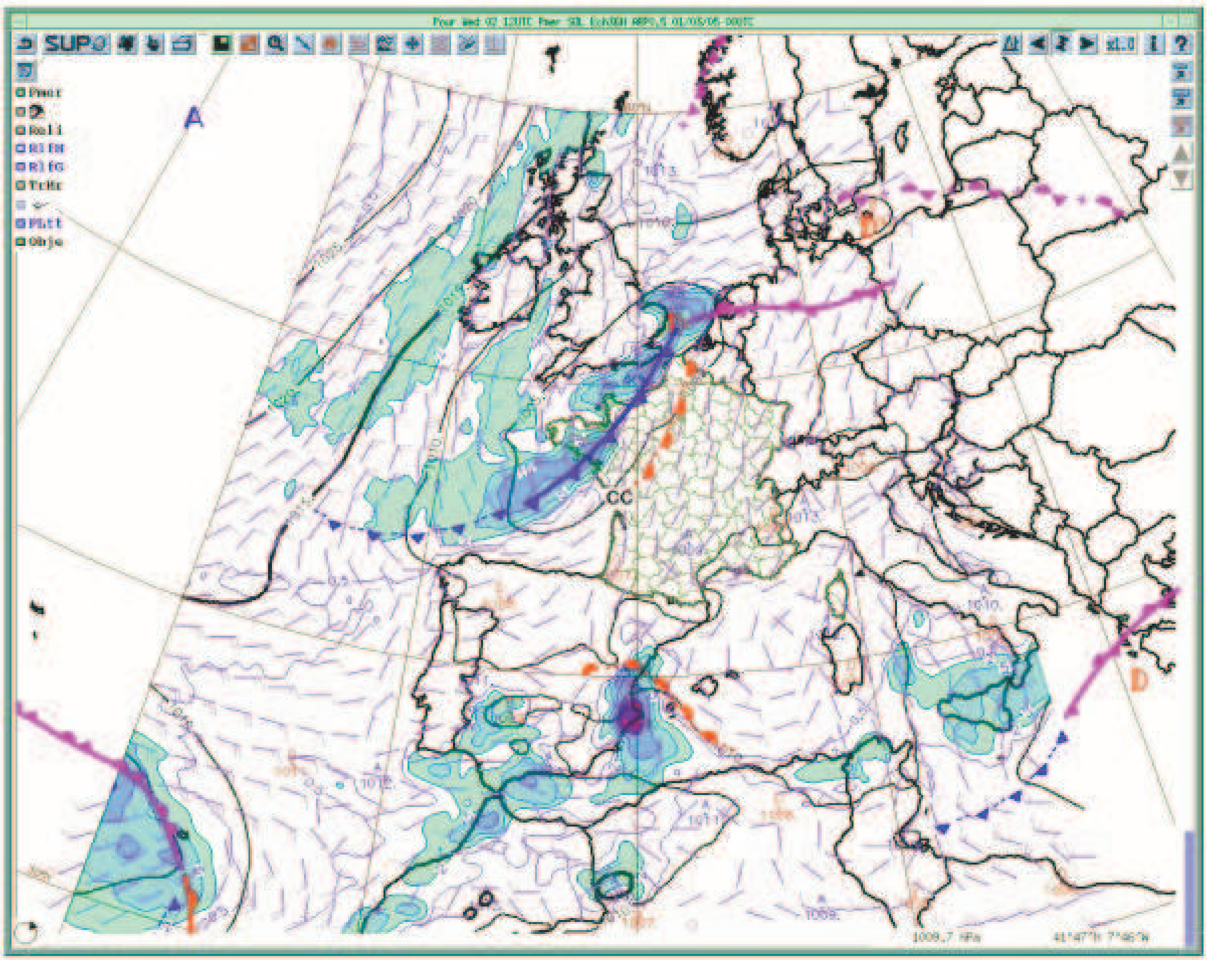
Phone : 05 57 12 24 13
Fax : 05 57 12 24 20

IV.2 Modeling activities

Météo-France products

Various operational NWP model output will be available to help the decision during the field campaign as well as the interpretation of measures. At Météo-France, the new operational assimilation system at mesoscale (3D Var Aladin with a 10 km resolution, run every 6 hours) will be in operation during the field campaign. The radiososonde soundings taken during the Intense Observing Periods (IOPs) at synoptic hours will enter the 3D Var system in real time. The objective is here to improve the mesoscale

weather analysis which could be used as initial and lateral conditions for high-resolution mesoscale modelling (e.g. with Meso-NH model).
Forecast products from ECMWF, Arpege and Aladin will be of course available at the headquarter of the campaign, as well as plots of back- and direct Aladin-forecasted trajectories (up to 2-day forecast), routinely computed for CaroboEurope every 6 hours at the sites of Biscarrosse, Marmande and Toulouse (i.e. at the entrance, middle and exit parts of the domain) at 500 and 2000m altitude, to help the decision to start an IOP and choice the aircraft flight plans. Among the Arpege/Aladin output, a large-scale map will be available once a day from the actual up to three days in advance, to illustrate the synoptic winds, surface fronts, and rainfall (see an example below).



<u>figure IV.2-a</u> ***: Values of surface atmospheric pressure, ground track of atmopsheric fronts, synoptic wind and rainfall at 12 UTC***

At regional scale, the horizontal wind fields will be available at 500 and 1500m altitude, at 09, 12 and 15h UTC the day after, together with the forecasted "radiosonde" profiles above the "La Cape Sud" (CS) site, as illustrated below.

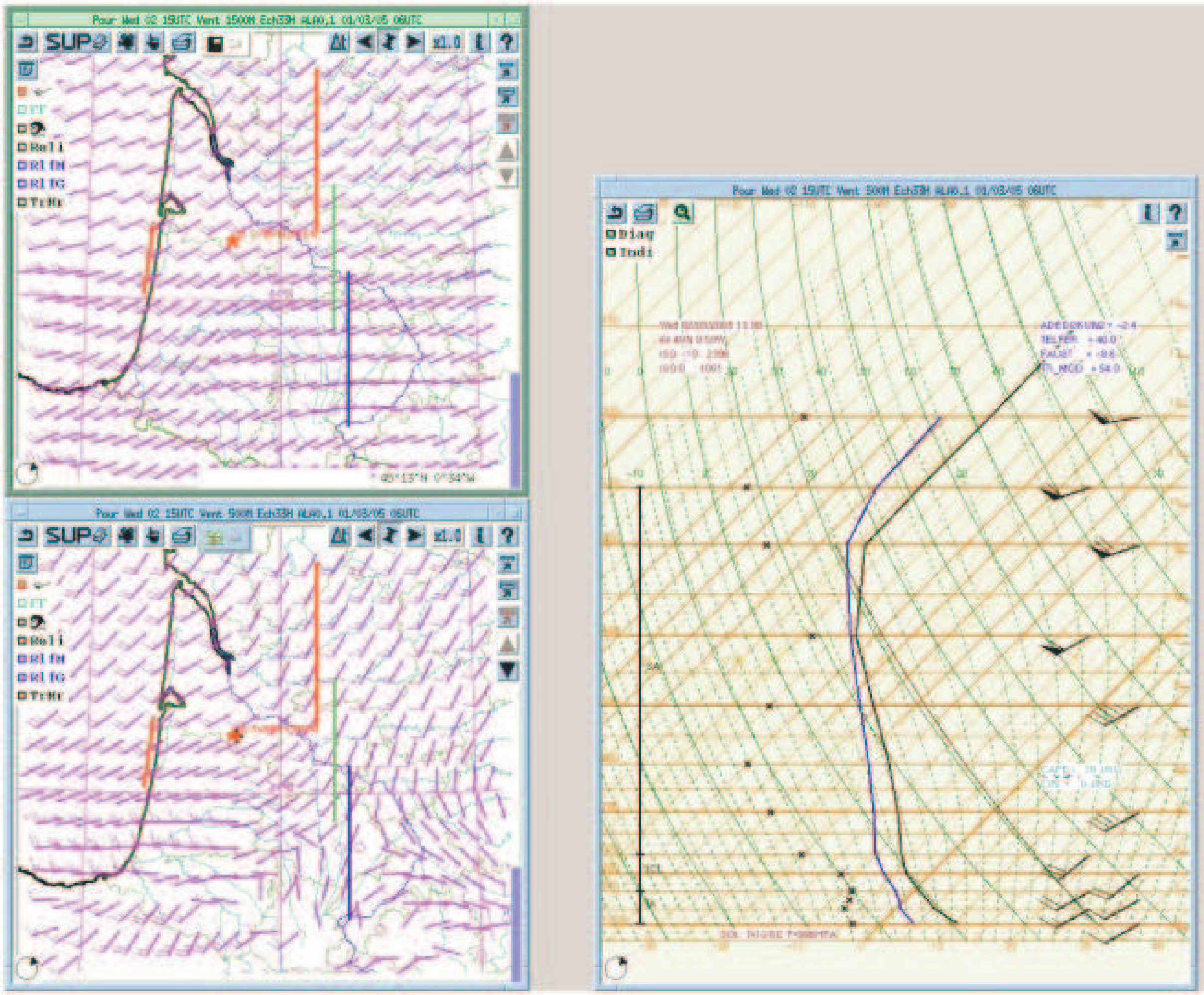


figure IV.1.2-b ***: Example of horizontal wind fields at 500 (bottom) and 1500m (top), and "adiosonde" profiles, forecasted by Aladin for the day after***

Max-Plank Institute (Jena) products

MPG-BGC will provide forecasts of the airmass history for a number of receptors in the experiment region. For this it is planned during the IOP to implement an operational system. This system will enable to plan airborne sampling in a way that can optimally constrain the exchange between biosphere and atmosphere. Such a system has been successfully used for the COBRA experiments [*Lin et al.*, 2004], see also <http://www.deas.harvard.edu/cobra/Fltplan/>. A recent update was made for the COBRA-Maine experiment in summer 2004, and this version has been transferred to workstations at the MPI-BGC. It will run on a newly purchased Workstation (4 processors, 8 GB RAM).

The forecasting system involves the Stochastic Time-Inverted Lagrangian Transport model (STILT), that is driven by forecasted meteorological fields, and that represents airmasses as individual Lagrangian particles. These particles are released at a given receptor location, and are moved backward in time by mean and turbulent winds [*Lin et al.*, 2003], [*Gerbig et al.*, 2003]. The density of these particles at a given time and location then describe the influence of that location to mixing ratios at the receptor location. That way measurements at different times can be located such that they observe the same airmass, i.e. they are made in a Lagrangian (airmass following) way. The system also suggests flight paths to characterize airmasses at a given time, and picks out nearby airports for missed approaches (missed approaches are "fake" landings at small airports, that allow to profile down to very low altitudes unreachable over other areas).

Modifications to this system will include adaptation of meteorological forecast fields not used before. The only met fields currently used that covering the intensive operational area, are generated by the gobal NCEP (US National Centers for Environmental Prediction) AVN model (now called GFS model). It is planned to add forecasted fields from the ECMWF model at 50 km resolution, and a file converter/pre-

processor is currently being written. It is further planned to use high-resolution output from Aladin, a mesoscale operational forecasting system by Météo-France. Further modifications of the forecasting system involve extension of the airport database to Europe, so that the detailed planning of flights can be done in a nearly automated way.
It is planned to have the forecasting system operational and web-accessible to project partners well before start of the IOP, to ensure a high quality during the campaign, but also to allow for a period of getting used to using the information.

Gerbig, C., J.C. Lin, S.C. Wofsy, B.C. Daube, A.E. Andrews, B.B. Stephens, P.S. Bakwin, and C.A. Grainger, Toward constraining regional-scale fluxes of CO2 with atmospheric observations over a continent: 2. Analysis of COBRA data using a receptor-oriented framework, *Journal of Geophysical Research-Atmospheres, 108* (D24), 4757, doi:10.1029/2003JD003770, 2003.
Lin, J.C., C. Gerbig, S.C. Wofsy, A.E. Andrews, B.C. Daube, K.J. Davis, and C.A. Grainger, A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model, *Journal of Geophysical Research-Atmospheres, 108* (D16), 4493, doi:10.1029/2002JD003161, 2003.
Lin, J.C., C. Gerbig, S.C. Wofsy, A.E. Andrews, B.C. Daube, C.A. Grainger, B.B. Stephens, P.S. Bakwin, and D.Y. Hollinger, Measuring fluxes of trace gases at regional scales by Lagrangian observations: Application to the CO2 Budget and Rectification Airborne (COBRA) study, *Journal of Geophysical Research-Atmospheres, 109*, D15304, doi:10.1029/2004JD004754, 2004.

An example of the graphical product generated by the flight planning tool. The receptor is Howland, Maine, which is the center of the downwind (0-hr) cross-section from where particles are simulated backward in time in STILT. The release time is on May 28th, 1300UT, and in this example the STILT particles are driven with meteorological fields from the AVN model updated on May 25th, 0600UT. The different components of the figure are tagged with numbers that are linked to explanations on the side

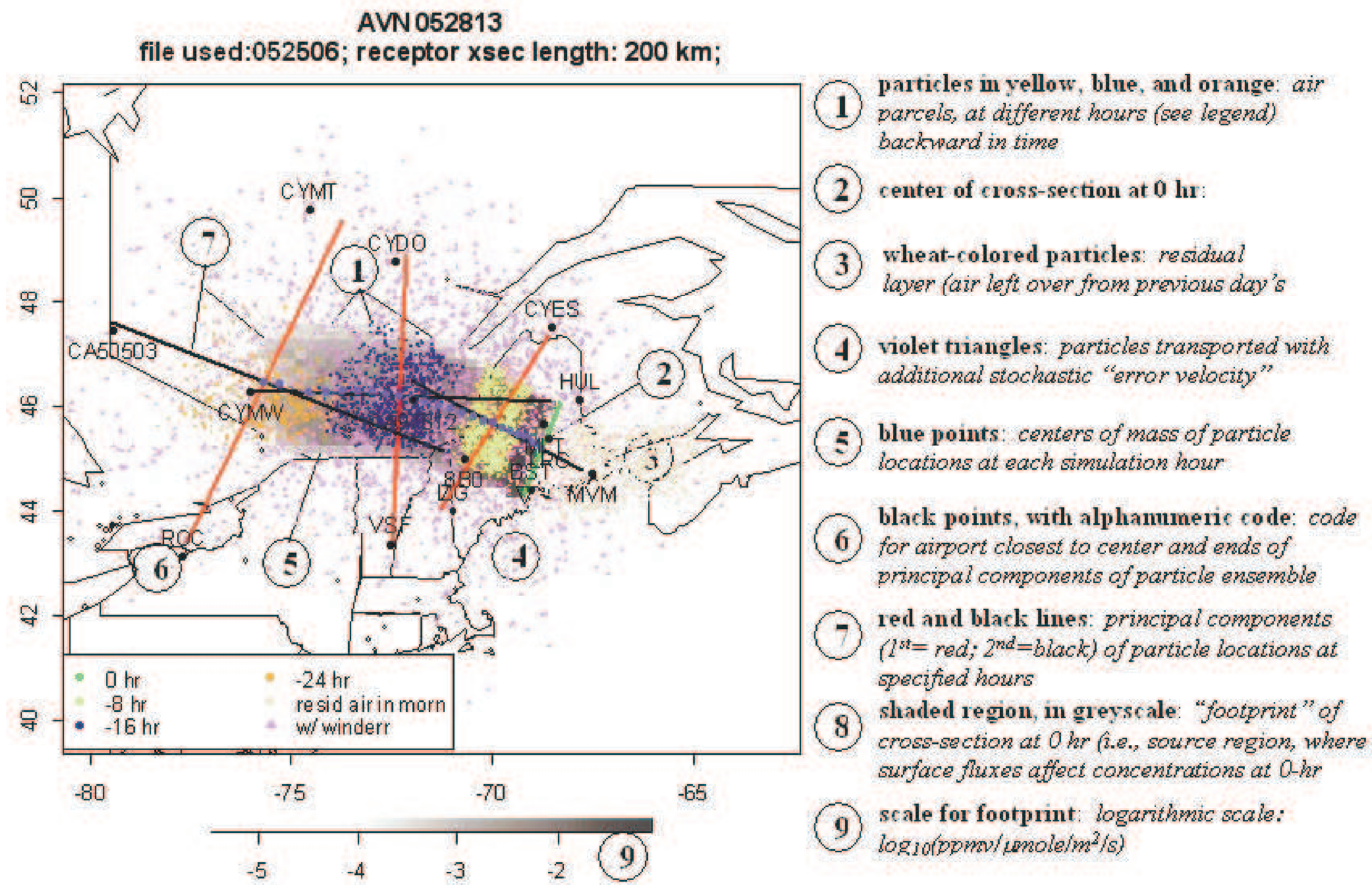


figure IV.1.2-c ***: AVN model***

IV.3 IOP trigerring and follow-up

During the whole experiment, a scientist (PI) is responsible and takes the decisions (i.e., IOP triggering, flight operations, radio sonde launches, etc.). He/she is assisted by a scientific secretary. Each of these two functions will be ideally assumed by 4-5 persons, i.e. with a turnover of 1.5 to 2 weeks.

On each day from May 13th to June 25th, there will be a morning briefing (at ~10.30 LT). The briefing will be held simultaneously at HQ1 (Toulouse, CNRM) and HQ2 (Bordeaux-Villenave d'Ornon, INRA), which will be connected by phone. The briefing is led by the responsible scientist, who could be either at HQ1 or HQ2. This briefing involves:

- A presentation (in the briefing room at Toulouse) of the present meteorological situation, as well as the short- and long-term forecasts, by the operational weather service with a particular focus on the Landes area.
- This presentation is completed by the dedicated meteorological tools: back- and direct trajectories computed from Aladin and Arpege forecast (2 and 4 day forecasts, respectively); STILT forecasts.
- An information on the status of the CoSMOS experiment, and on the operations planned for the next days by this programme.
- A check of the status (in order/out of order) of the various platforms (ground stations and aircraft) involved in the CarboEurope experiment.
- A report of the operations of the previous day, if this was an IOP day.
- A discussion on the opportunity to 1) continue or stop a current IOP; 2) trigger or confirm an alert for a possible IOP in one (D-1), two (D-2), or three (D-3) days; 3) to cancel an alert or maintain the no-alert status.
- A decision on the status of the experiment. This decision is accompanied by the following elements:
    - No alert or D-3alert: no elements required
    - D-2 alert: choice of the flight plans for D-day. This 2-day time delay is imposed by the air traffic control. Several flight plans can be considered, since there is no problem to cancel a planned flight. On the contrary, it is much more difficult to add a flight plan for less than 2 days.
    - D-1 alert: confirm the flight plans; if a several days IOP is envisaged, choice of flight plans for D+1; define the times of the radiosondes launches.
    - D: if the IOP lasts for more than 1 day, confirm the flight plans for D+1; define the times of the radiosondes launches for D+1. If an IOP of more than 2 days is envisaged, choice of flight plans for D+2.

From D-1 and to the end of the IOP, a second daily briefing will be held in the afternoon. This briefing has the following goals:

- to actualize the meteorological situation. Informations will be found at the operational meteo center in Toulouse (CDM31), and/or on the meteo receiver ("RETIM") in Bordeaux/INRA
- to report on the operations of the day (if IOP day)
- if the next day is an IOP day, to decide the "go-no go" for the operations (airplanes and radiosondes).

The minutes of each briefing will be written by the scientific secretary, and approved by the PI. They will be sent to the e-mail list (participants and interested people), and a summary recorded on the answer phone at Toulouse HQ.

The meteorological conditions favoured for IOP triggering are those of moderate westerlies, corresponding to a progressive modification of CO2 concentration of the air mass when travelling from the ocean through the experimental area. Other conditions could also be documented, like weak winds, or moderate SW synoptic flows, giving rise to SE local winds in the eastern part of the experimental area

(Toulouse region.) Cloudless or broken clouds conditions have to be preferred, because they favour the photosynthetic activity of vegetation; however, few more cloudy situations could also be analysed, in order to evaluate the impact of clouds on CO_2 budget on the domain. Conditions with well established and moderate westerly flow have to be carefully selected for the planning of Lagrangian flights. In these conditions, a particular information on the wind speed in the boundary layer in near real time will be required (e.g. from wind profiling systems) since it will determine the timing for the downwind flight agenda.

V DATA MANAGEMENT AND WEB SITE

V.1 Web site

The CarboEurope Regional Experiment dedicated web site will allow the data management and provide access to the relevant informations for all the teams involved in the project.

As a commitment in the European "Regional Experiment" programme, CNRM is in charge of the Database management. The various tools relative to this Database, as well as the corresponding web site are developed and maintained by Medias-France, a French company under the umbrella of public Institutes (the French space agency (CNES), Météo-France, CNRS and IRD). The principal objectives of these tools are :

- To collect, structure and standardize the various data sets, in a hierarchical way and metadata bank
- To build simple, ergonomics and distributed interfaces to facilitate datasets and metadatasets access
- To archive and secure datasets
- To provide technical support to CarboEurope Regional Experiment (Hardware and Software)

The web site (URL : http://carboregional.mediasfrance.org/) dedicated to CarboEurope Component 3 provides data access, data and metadata upload, focus point for community (news, documents), advertising (partners, organisations) for a simple and fast access to datasets, centralized in a single site.

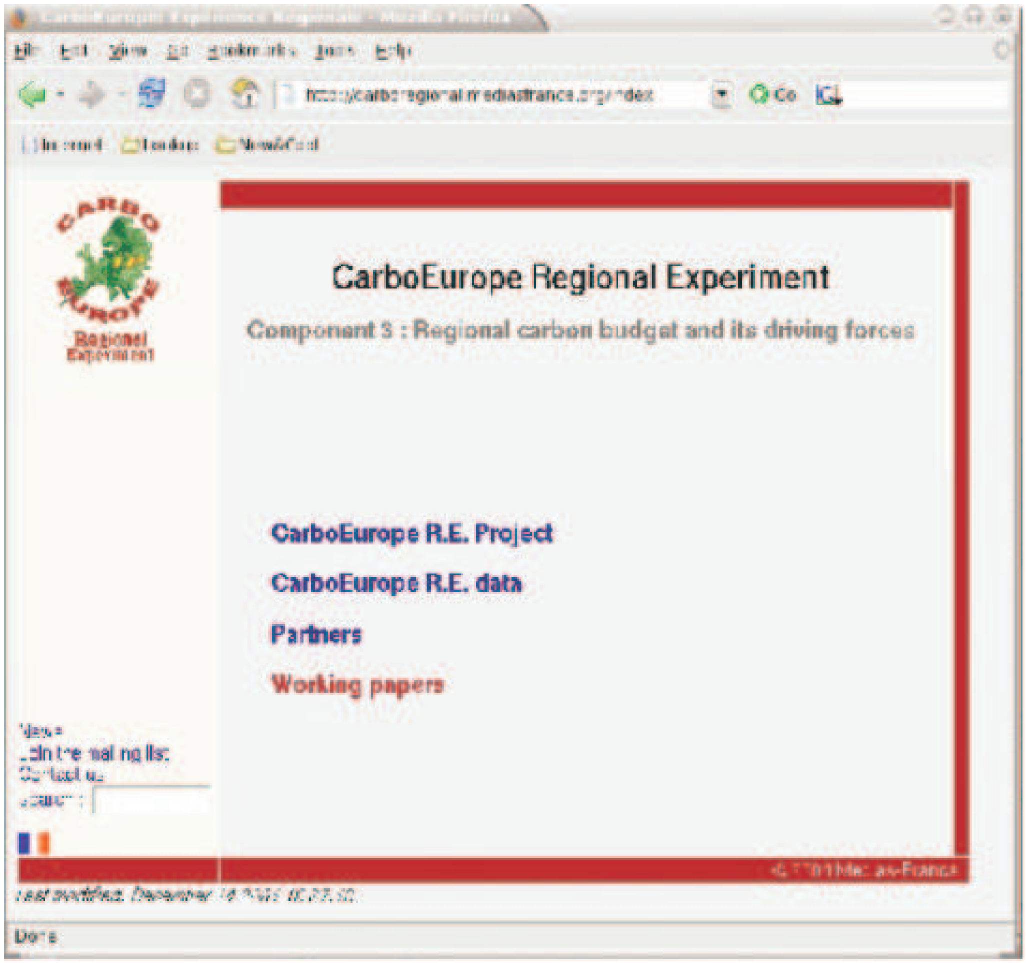
To upload and download data, two secured ftp sites are available (with login/password) :

- One uploading site: http://carboregional.mediasfrance.org//data/depot/ (Upload data files in specified directory + README file + welcome message, metadata input using specific forms, E-mail to boichard@medias.cnes.fr after downloading)
- Access site : http://carboregional.mediasfrance.org//data/acces/index

A dedicated mailing list : carbo@medias.cnes.fr, archived, secured (Virus), classified (Spam). This is an open mailing-list (without administrator). To subscribe, http://carboregional.mediasfrance.org/mailinglist/index.en.php .All e-mails are archived.

A special web page is dedicated to the field campaign (http://carboregional.mediasfrance.org/campagne/index) containing all information of a given day :

- Weather forecasting
- Forecast trajectories of STILT model
- Forecast trajectories of ALADIN model
- Quick look of measurements of the previous days (time series of meteorological parameters, CO2, fluxes for surface stations, aircraft measurements, etc.
- A message sent by the scientific secretary of the Head Quarter on the news of the campaign (information about the status of the campaign: stand-by, alert, IOP day; the operations planned for the present and next days; etc.



<u>figure V.1-a</u> ***: Home page of CarboEurope Regional Experiment***

V.2 Data policy

The CarboEurope Regional Experiment data policy is in agreement with the general policy of CarboEurope IP.

- **Quality control** : deliverable data are given with a quality level (table 6 Annex 1 Carboeurope IP) :

- Level-0 version : raw data (no IU needed) and metadata described .
- Level-1 version: raw data expressed in physically meaning in IUS i.e. physical units.
- Level-2 version : data corrected with standard procedures

The description level of metadata for all the database has to be defined in agreement for the CarboEurope IP database manager (R. Krause).

- **Access to data** : data and metadata are accessible to all CarboEurope regional partners. However, their access requires a login and password which have to be asked to the database manager (see on the web site).

- **Deliverable data** : For the Regional Experiment, data must be available on the web site 6 months after the end of the campaign (i.e. March 2006) for level-1 version, and 12 months after (i.e. June 2006) for level-2 version, except for aircraft data, for which level-1 will be available only 12 months after the campaign.

VI INSTRUMENTAL/TECHNICAL DETAILS

VI.1 Aircraft

VI.1.1 Piper-Aztec

The Piper Aztec (PA23-250, see figure VI.1.1-a) belongs to CNRM (National Centre of Meteorological Research)/CAM (Weather Center of Aviation) of Météo-France. The CAM is installed in Toulouse (Francazal military airport) since September 2003 and will form integral part of SAFIRE, a shared structure currently in the course of creation which will gather the French fleet of instrumented planes and will be driven jointly by the CNRS-INSU, the CNES (French space agency) and Météo-France.

figure VI.1.1-a : ***Piper Aztec***

Characteristics of Piper Aztec

The Piper Aztec can be flown in non-frosting, day or night conditions (VFR and IFR).

Manufacturer	Piper Aircraft Corp.
Type	PA23-250
Length	9.2 m
Wing span	11.3 m
Standard crew	1 pilot, 1 engineer

table VI.1.1-a : ***general information on Piper Aztec***

Performances

Maximum altitude	4 000 m
Maximum take-off weight	2177 kg
Maximum landing weight	2177 kg
Endurance	5 hours
Range	1400 km
Speed of Work	70 m/s (250 km/h)
Payload	300 Kg

table VI.1.1-b : ***performances of Piper Aztec***

Specifications

Engines	2 Lycoming IO 540 C1B5 of 250 HP
Propellers	2 blades, constant speed
Electrical power supply	Alternators 28 V of 60 A each one. The electric installation was modified to also provide 115 V/400 Hz and 220 V 50 Hz from inverters.

table VI.1.1-c ***: specifications of the Piper Aztec***

Measurements

table VI.1.1-d ***: Pressure***

Parameter	**Sensor**	**Range**	**Accuracy**	**Acquisition frequency**	**spatial resolution**
angle of attack	Rosemount 1221	+/- 35 hPa	+/-0,2 hPa	200 Hz	0.35 m
slide slip	Rosemount 1221	+/- 7 hPa	+/-0,2 hPa	200 Hz	0.35 m
Static	Rosemount 1201	300 à 1100 hPa	+/-0,5 hPa	200 Hz	0.35 m

table VI.1.1-e ***: Temperature***

Parameter	**Sensor**	**Range**	**Accuracy**	**Acquisition frequency**	**Spatial resolution**
impact tempe.	Rosemount E102	- 60 à +50°C	+/-0,5 °C	200 Hz	0.35 m
Radiometric temperature	Barnes	-20°C à +20°C	+/-1 °C	50 Hz	1.4 m
Reverse flow tempe.	SFIM T4113	+/- 70°C	+/-0,5 °C	200 Hz	0.35 m

table VI.1.1-f ***: Humidity***

Parameter	**Sensor**	**Range**	**Accuracy**	**Acquisition frequency**	**Spatial resolution**
Relative humidity	capacitive sensor ; CORECI Humicor 5000	2 à 98%	5% (variable evolution)	50 Hz	1.4 m
dew point temperature	Buck Research 1011B	- 75 à +50°C	+/-0,5 °C	25 Hz	3 m

table VI.1.1-g ***: other parameters***

Other Parameters	**Instruments**	**Accuracy**	**Acquisition frequency**	**Spatial resolution**
Altitude	GPS + computing	~meter	1 Hz	70 m
Height (/ground)	Radar altimeter till 2500ft	50 m	1 Hz	70 m
Wind speed and direction (mean and turbulence)	Gust probe + Doppler radar + True heading	2 m/s	25 Hz	18 m
Latitude	GPS Bancomm	+/- 100 m	1 Hz	70 m
Longitude	GPS Bancomm	+/- 100 m	1 Hz	70 m
Angle of attack (from differential pressure)	Rosemount 1221	1°	50 Hz	1.4 m
Angle of sideslip (from differential pressure)	Rosemount 1221	1°	50 Hz	1.4 m
Groundspeed	Doppler radar	+/- 3%	1 Hz	70 m
Accelerations along 3 axes	SFIM		50 Hz	1.4 m
Heading	Navigation compass		1 Hz	70 m

The other specific instruments described below will be installed in the PIPER AZTEC for the CARBOEUROPE experiment:

The flask sampling consists in filling flask during a flight. The analysis of the samples is made afterwards at he Max-Planck-Institut at Jena. During a flight it is planed that about 12 flasks will be filled up. The time required to fill a flask is about 30 seconds. It is obvious that these data can't be viewed on the quick-look output.

The CO measurement will be made by a Thermo Environment inc. type 48CTL. The measurement is based on the IR absorption. The threshold is 10ppbv and the time response is 30s. This parameter is recorded as the other basic parameter on the real-time acquisition sytem.

The Non Dispersive Infra Red CONDOR fast CO2 analyzer (Figure 1) was developed in 2001 as part of the European project AEROCARB (Airborne European Regional Observations of the Carbon Balance). The instrument was used in the DLR Falcon-10 jet for two CAATER campaigns, and is now regularly flying on board a Piper Aztec over the Orléans Forest. The CONDOR is based on a commercial Non Dispersive Infra Red Analyser (Li-COR 6262) doted with a fast response detector and a high acquisition frequency (1 Hz) that make it a dedicated tool for airborne measurements. The performances of the initial commercial analyzer have been improved for bearing temperature and pressure variations encountered during flights, by controlling the temperature, the pressure and the flow rates of gas analyzed by the LI-COR at constant values (Table 1). Atmospheric air is pumped and dried at the entrance of the instrument by a magnesium perchlorate cartridge before being injected into the sample cell.

table VI.1.1-h ***: Characteristics of the CONDOR analyzer.***

Precision	≤ 0.20 ppm
Calibration gas	1 reference tank; 2 calibration tanks
Sampling frequency	1 Hz
Power supply	18-32VDC / 15A max
Cells pressure	1080 ± 0.1 hPa
Flow rates	50±0.2 sccm (Reference) and 400±0.5 sccm (Sample)
Temperature	35±0.6°C
Calibrations	With 2 standards (3 mn each), every 40 mn or manual
Volume	95 x 55 x 40 cm^3 (analyzer and standard gases)
Weight	80 kg

In order to be useful for atmospheric research purposes, airborne CO_2 measurements must have a precision better than 0.5 ppm [Gloor et al., 2000]. Frequent calibrations allow ground instrumentation to get a precision of 0.1 ppm. However, flight constraints do not allow to use gas bottles of high volume, therefore calibration is carried out only every 40 minutes and last 6 minutes. In order to take into account slow drifts of the CONDOR analyzer due to changes in surrounding physical parameters such as pressure and temperature, regular calibrations of the instrument have to be done during each flight. This step consists in injecting two standard gases in the analyzer, respectively called the high standard and the low one. Standard bottles were filled in with synthetic air of CO_2 concentration chosen to bracket the atmospheric range for this compound. The low and high standards concentrations have measured in our laboratory on the NOAA scale and are equal to 365.922±0.045 ppm and 401.292±0045 ppm, respectively. Each standard is run during 3 minutes in the analyzer, and only the last minute is kept. The mean and standard deviation are computed to estimate the quality of the instrument. During the CAATER1 campaign, there has been 32 calibrations done, total. The precision of the instrument was always below than 0.18 ppm. This result is highly satisfying, since it confirms that the regulations done on the CONDOR allow to obtain a reproductibility much higher than 0.5 ppm.

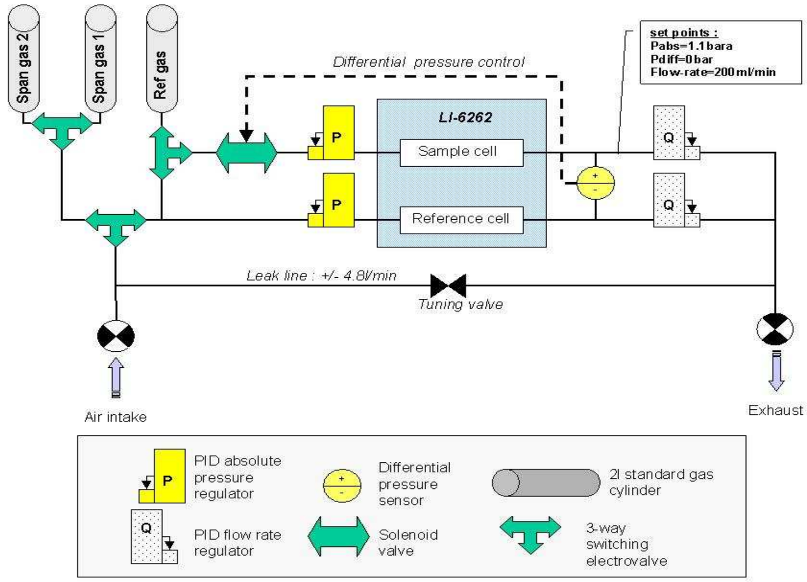


figure VI.1.1-b ***: Schematic of the CONDOR analyzer.***

The data from CONDOR system are stored on a dedicated acquisition system.

System of acquisition and processing of data

The computing system for acquisition and processing of data embarked onboard the Piper Aztec consists of:
· 1 system of basic acquisition
· 1 scientific station, terminal type X
The main part of Piper Aztec acquisition system is based on a VME bus, and a real time, blade HP processor, functioning under HP-RT system. A lot of charts of acquisition slaves makes it possible to acquire analog signals, frequencies, signals digitized by a CCE box, ARINC data bus, or RS232. Measurements are acquired at frequencies from 1 to 200 Hz. This system is controlled, and supervised from the scientific station, by an engineer of Météo-France. Real-time data are controlled through graphs which allow to control the functioning of the measuring equipment. On board, the data are recorded on extractable hard disk, with copy on magnetic tape (DAT).

Post-flight control

Time series, profiles and airplane trajectory can be available about 2 hours after the landing of the aircraft if landing is at Francazal military airport. These "quick-look" only involve parameters recorded on the basic acquisition system of the airplane.

VI.1.2 Sky arrow (in situ)

The aerial platform that will be used within CarboEurope IP is based on the technology developed within the previous project RECAB, and it is based on the certified aircraft Sky Arrow 650 ERA (Environmental Research Aircraft). The SkyArrow is a commercially produced, certified small aircraft equipped with sensors to measure three dimensional wind and turbulence together with gas concentrations and other atmospheric parameters at high frequency. It is a two seat aircraft made of carbon fibre and epoxy resin, powered by 75 kW engine. It has a wingspan of 9.6 m, a length of 8.2 m, a wing area of 13.1 m2, and a maximum takeoff mass of 648.6 kg (figure VI.1.2-a). The aircraft has a cruise flight speed of 45 m s-1 with an endurance of 3.5 h, allowing it to cover flight distances of up to 500 km. Operating altitudes can range from 10 m above ground level to more than 3500 m above sea level.

figure VI.1.2-a ***: Photograph of the SkyArrow ERA showing the exact location of the sensors and instruments mounted onboard.***

The aircraft was re-engineered in 1999 to host the Mobile Flux Platform (MFP), which consists of a set of sensors for atmospheric measurements. The installation was certified to operate under both FAA (Federal Aviation Administration, USA) and JAR (Joint Aviation Regulations, EU) aeronautical regulations. Atmospheric turbulence measurements are made with the "Best Aircraft Turbulence" (BAT) probe, developed by NOAA-ATDD and ARA Australia (see figure below). In brief, the BAT probe measures the velocity of air with respect to aircraft using a hemispheric 9-hole pressure sphere that records static and dynamic pressures by means of four differential pressure transducers (Crawford and Dobosy, 1992).

figure VI.1.2-b ***: The BAT Probe***

The Sky Arrow engine is mounted in a pusher configuration, allowing the BAT probe to be installed directly on the aircraft's nose, thus reducing most of airflow contamination due to upwash and sidewash generated by the wing (Crawford et al. 1996). The actual wind components (horizontal U, V and vertical W) relative to the ground are calculated introducing corrections for three-dimensional velocity, pitch, roll and heading of the aircraft. Those corrections are made using a combination of GPS velocity measurements and data from two sets of three orthogonal accelerometers mounted at the centre of gravity of the aircraft and in the centre of the hemisphere. Aircraft velocity relative to the ground is measured by means of a conventional differential GPS (RT20, Novatel USA) at 10 Hz.

An additional 4-antenna GPS system (AT4, Javad, USA) is used to measure aircraft attitude angles at frequencies up to 20 Hz (figure VI.1.2-c). Finally, the GPS and accelerometer signals are blended to obtain attitude and velocity data at frequencies up to 50 Hz. Accordingly, atmospheric turbulence is actually measured at a frequency of 50 Hz and since the aircraft can fly at relatively slow speed (35 m s-1), a horizontal spacing of 0.7 m between 50 Hz measurements in no-wind conditions can be achieved. In this way, eddies of wavelengths larger than 1.4 m can be detected. The probe is equipped with a fast thermocouple to measure air temperature with a response time of 0.02 s. A platinum resistance thermometer is used for a mean air temperature reference.

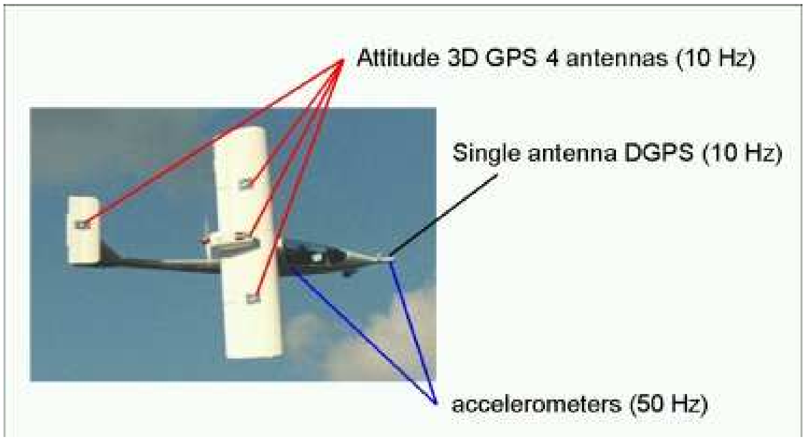


figure VI.1.2-c ***: Altitude measuring system***

A net radiometer (Q*7, REBS USA) and upward and downward looking PAR radiometers (200s, LiCor USA) are mounted on the aircraft's horizontal stabilizer. Low frequency air moisture measurements are made using a chilled mirror dew point sensor (EdgeTech, USA). Surface temperature is measured using an infrared thermometer (4000.4GH, Everest USA). Atmospheric densities of carbon dioxide and water vapour are sampled and recorded at 50 Hz by a LiCor 7500 (LiCor, Lincoln, Nebraska) open path infrared gas analyser installed on the aircraft nose (see figure above). All the digitally converted signals from the BAT Probe and the sensors are stored on a PC located on-board. Additional details of underlying theory and the technical implementation of flux aircraft can be found in Crawford and Dobosy (1992) and Crawford and Hacker (2001), Dumas et al. (2001).

table VI.1.2-a ***: Equipment installed on board the Skyrrow ERA***

PARAMETER	SENSOR(S)	ACCURACY and Notes
Time	GPS (Novatel RT 20, single freq.) Differentially corrected	All data syncronized with GPS clock
Position (lat, long & alt)	Extended to 50Hz with probe accelerometer	10 cm accuracy
Velocity (u,v,w)		±1 cm/s accuracy
Attitude (pitch, roll & heading)	Javad AT4 (extended to 50 Hz with differential accelerometers)	±0.05° extended to 50Hz with diff. acceleration
Humidity (abs. Humidity and dew point)	EdgeTech Model 200 Chilled Mirror	accuracy ±0.5°C
Winds (u, v, & w)	Best Aircraft Turbulence (BAT) probe	Turbulence acc. ±2 cm/s Mean wind acc. ±0.5 m/s
Temperature	- Reference thermocouple - High frequency thermocouple	Combined to obtain high frequency referenced temperature signal.
Surface temperature	Everest 4000.4GL infrared radiometer	15° viewing angle, 8-14µ, ±0.5°C accuracy
Radiation	- Licor PAR up and down-welling - REBS Q*7.1 net radiometer	
CO_2 concentration	Licor 7500 open-path gas analyzer	50 Hz flux sensor
H_2O concentration	Licor 7500 open-path gas analyzer	50 Hz flux sensor

VI.1.3 Sky arrow (teledetection)

Details about the Remote Sensing setup are given below.

The MFP apparatus for the measurement of turbulent fluxes is also described thereafter. Three such systems were purchased from NOAA in 2003. Two are installed on board ISAFoM ERA aircraft, while a third one is available at IBIMET for the purposes of Carboeurope regional experiment.

figure VI.1.3-a ***: ISAFoM Sky Arrow ERA aircraft***

figure VI.1.3-b ***: the camera mounting plate***

figure VI.1.3-c ***: the MFP and image grabbing PCs***

Remote sensing apparatus

The acquisition device features a PC104 architecture and a Matrox Imaging 01-MET2-CL+/32 frame grabber, capable of digitizing two 10 bits taps on each channel, allowing for collecting information simultaneously from both the Duncantech 4100 RGB and the CIR cameras at full resolution. A single Labview executable running under Windows XP operating system, featuring multiple VIs pilots the multispectral as well as the FLIR A40M thermal cameras.
An early hybrid version of such apparatus, also based on a PC104 mother board but featuring a backplane board hosting a PCI NI frame-grabber, will serve as a backup during the intensive campaign in case of failure. For extra security, FLIR and Duncantech will provide spare rental cameras, while a backup 4100 RGB is provided by Federico II University of Napoli.
All cameras are triggered by the 500 Hz TTL signal provided by the Novatel GPS, part of the onboard MFP system, which will also provide environmental parameters required for atmospheric corrections, position and attitude data.
Details and specifications of the cameras are to be found at the following URLs:

- Duncantech 4100 Multispectral RGB and CIR :
<http://www.redlake.com/spectral/mega_MS4100.html>
- ThermoVision® A40M Infrared Camera :
<http://www.flirthermography.com/cameras/camera.asp?camera_id=1040&

MFP

The MFP on the Italian Sky Arrow ERAs system consists of three major pieces of equipment, the MFP computer, the Auxiliary box, and the BAT probe assembly.

MFP Computer:

The MFP computer consists of a single-board computer and industrial chassis from American Portwell Technologies (Chassis: <http://www.portwell.com/irc-306.htm>;
Motherboard: <http://www.portwell.com/robo-698.htm>:
Backplane: <http://www.portwell.com/backplane.htm>).
Two PCI serial cards from Quatech and a custom ISA card finish the system.

Auxiliary Box:

The Auxiliary box is custom built at NOAA/ATDD. It contains circuit boards for signal conditioning of the auxiliary REM A/D module, power distribution to the assorted discrete instruments, switching circuits for master power control, a pilot-controlled switch box, a set of orthogonal 3-D accelerometers, and a REM A/D module. The pilot-controlled switchbox provides switches for the pilot to control data file write, markers, and events.

The orthogonal 3-D accelerometer board, contains a set of 3-D orthogonal accelerometers used to measure the motion of the center of gravity of the aircraft. These are used differentially with the 3-D orthogonal accelerometers in the BAT probe assembly to measure high-frequency pitch, roll, and heading angles.

REM Module is a data acquisition module produced by Airborne Research Australia and is capable of digitizing 16 analog channels with 16-bit resolution and providing the data via serial stream to the host MFP computer. (<http://ara.es.flinders.edu.au/; <http://www.noaa.inel.gov/Capabilities/Bat)

BAT Probe Assembly:

The BAT probe assembly is a system of circuit boards and electronic hardware encased in a weatherproof fiberglass/carbon fiber housing that is mounted on the nose of an aircraft. The probe assembly consists of a pressure sphere with 9 holes used to measure the magnitude and direction of the incident wind vector on the hemisphere. A tapered cone afterbody houses a BAT-REM module that is used for digitizing the analog signals and providing a serial data stream to the host MFP computer, much like the BAT-REM module in the auxiliary box. In addition to pressure measurements, a set of three orthogonal accelerometers is also installed in the pressure sphere to measure high frequency motion of the hemisphere in three dimensions. High and low frequency air temperature measurements are made utilizing a PRT probe and a micro-bead thermistor. Static pressure measurements from the pressure sphere round out the BAT probe instrument suite.

BAT-REM Module – This is a data acquisition module produced by Airborne Research Australia and is capable of digitizing 16 analog channels with 16-bit resolution and providing the data via serial stream to the host MFP computer.

The hard disk is used for primary onboard data storage. The Zip drive with IDE interface is used for secondary data storage. The pilot's switch box contains an instrument power switch, a computer power switch, a file write switch, an event button, and a marker switch. In addition, two LED's are used to indicate power and system status. The pilot's display is a color flat panel VGA display (640x480 resolution) that interfaces to a standard ISA VGA card in the computer box. The normal mode of operation of the BATSTORE program is an 80-column by 25-row text screen.

Discrete MFP Components:

Several instruments are added to the basic system to enhance measurement capabilities. The following are a list of instruments added to the Italian Sky Arrow ERA aircraft. Each is interfaced either through the analog A/D BAT-REM module in the auxiliary box, or directly to the Quatech ESC-100-D9 eight-port serial card in the MFP computer.

- ATDD/FRD turbulence measurement probe (with internal REM module) (BAT-REM) (serial interface); <http://www.noaa.inel.gov/Capabilities/Bat
- Licor-7500 open-path Infrared Gas Analyzer (IRGA) CO_2/H_2O (analog interface); <http://env.licor.com/Products/GasAnalyzers/7500/7500.htm>
- Everest Interscience IR temperature sensor (analog interface); <http://www.everestinterscience.com/Products/4000.4ZLprod.htm>
- Riegl distance measuring laser (serial interface); <http://www.rieglusa.com/
- Edgetech dewpoint sensor (analog inteface): <http://www.edgetech.com/mh_200.htm>
- Novatel OEM-G2 RT20 GPS system (serial interface); <http://www.novatel.ca/Products/oem4g2.asp
- Javad AT-4 GPS attitude system (serial interface); <http://www.javad.com/
- UNITEC ETL2000 tick film gas analyzer CO/CH4/Nox/SO (analog interface) (only **I-NCOP** ISAFoM aircraft); <http://www.unitec-srl.com/StaticoUK/etl-busUK.htm>
- REBS Q*7 net radiometer (analog interface)
- Licor Quantum (PAR up/PAR down) (analog inteface)

VI.1.4 ECO-Dimona

DIMONA TECHNICAL SPECIFICATIONS:

Type of aircraft	TMG (Touring Motor Glider) Dimona HK36 TTC-ECO (two seated motorised aircraft with long endurance and good aerodynamic performance, with 16.5 m wing span);
Manufacturer	Diamond Aircraft, Wiener-Neustadt, Austria;
Modifications	2 underwing pods for instrumentation (wide enough for 19"/6HU instruments), enhanced MTOW, larger fuel tanks, door to baggage/instrument compartment behind the cockpit, second electrical system with 28V/1 kW generator;
Certification	BAZL (Swiss), after AustroControl, under JAR 22 in utility class;
Call sign	HB-2335;
MTOW	930 kg;
empty weight	610 kg (including basic installations);
crew	2 (pilot and operator), side by side, pilot only operation is possible;
maximum payloads	50 kg in each pod, 30 kg behind seats, 110 kg on each seat, 75 kg of fuel (total may not exceed 320 kg);
scientific payload	100 kg for maximum endurance with operator until about 200 kg with less endurance and short endurance;
fuel	70 kg (a bit less than the 110 litres which are specified in the manual);
endurance	5 hrs at 170 km/h (more if slower, less if faster, or with frequent changes of altitude, typical research flight is 2 to 4.5 hrs);

maximum distance without refueling: 800 km;

scientific payload	100 to 200 kg, depending on endurance and with or without operator;

cruising speed (minimum / typical / maximum during measurements): 110 / 170 / 200 km/h (IAS)

climb rate	3 m/s from GND to about 3000 mMSL;
ceiling	4000 mMSL (more with crew oxigen; due to turbo charged engine, the limit is not the engine, but other safety considerations such as icing, spread between minimum and maximum speed, etc.);
typical operation altitudes	150 mGND to 3000 mMSL, or less with special permission;
electrical power	primary 28 VDC unregulated (+/- 1 V) 1 kW (operationally tested up to 0.5 kW); 100 Watt 12 VDC regulated; 300 Watt 230 VAC;
other remarks	lowest noise class (among the most quiet aircraft with also a comfortable sound); very good view to the outside for pilot and operator; integrated 12" colour graphical data display in instrument panel;

list of both standard and optional instrumentation is in the proposal, and with more details, always updated on **www.metair.ch/SYSTEMS.htm**

figure VI.1.4-a *: **MetAir's "Dimona HB-2335"***

MetAir's "Dimona HB-2335" on a tri-national flight around Mont Blanc (regional study "Etude Mont Blanc" funded by Italy, France and Switzerland). Clearly visible are the underwing pods (figure VI.1.4-b) carrying the scientific instrumentation. On board is a crew with the pilot and an operator usually performing flights of 2 to 4.5 hours duration.

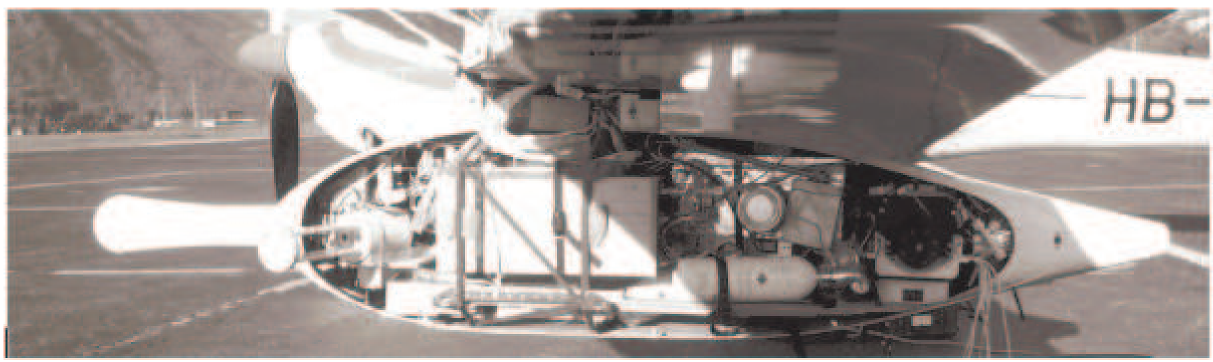


figure VI.1.4-b ***: One of the two pods densely packed with instrumentation***

One of the two pods densely packed with instrumentation (from front to back): Boom with pressure sensors and accelerometers for flow and altitude measurement, open path IRGA (infra-red gas analyser) for CO2 and H2O, CO-monitor and a six-channel instrument measuring nitrogen oxides (joint development MetAir/PSI). In the other pod (not visible here) the gaschromatography system for speciated VOC's and the closed cell IRGA are installed.

More details in the next section, on the MetAir web page www.metair.ch

table VI.1.4-a ***: Measured parameters on board of MetAir's aircraft "ECO-Dimona HB-2335"***

parameter	instrument/method	range from..to	resolution parameter / time	precision / accuracy	calibration or checks
position (x,y,z)	GPS TANS Vector	global	1 m / 1 s	5..20 m	fix points
ground speed (vx, vy)	GPS TANS Vector	global	0.1 m/s / 1 Hz	0.1..0.5 m/s [a]	zero and wind

parameter	instrument/method	range from..to	resolution parameter / time	precision / accuracy	calibration or checks
attitude (azi, pitch, roll)	GPS TANS Vector	0..360° / 60°	0.1° / 10 Hz	0.1 / 0.5°	fix and wind
acceleration (vert.+long.)	Kistler/DLR	-20..+30 m/s^2	0.01 m/s^2 / 10 Hz		
air temperature	Meteolabor thermocouple	-50..50 oC	0.1 oC / 10 Hz	0.1 / 0.5 oC	ice-water / mercury
dewpoint	Meteolabor dewopoint mirror	-50..50 oC	0.1 oC / 1 Hz	0.1 / 0.5 oC	psychrometer
5 pressures (1 absolute, 4 diff.) for ...	Keller capacitve sensors	300..1300; 0..50 hPa	0.02 hPa / 10 Hz	0.1 / 0.5 hPa	factory calibrated
...flow angles	differences of pairs (left/right, top/bottom)	-20..20°	0.1° / 0.1 s	0.1°/0.5°	wind residuals
...true airspeed,	calculated (p,T,u)	10..70 m/s	0.1 m/s / 10 Hz	0.2 / 0.5 m/s	wind residuals
...and pressure altitude	integrated (p,T,u)	0..7000 mMSL	1 m / 4 s	3 / 10 m	mountaintops
height above ground	radar altimeter TERRA	15..800 m	1 m / 1 s	1 / 5 m	against press. alt.
3-d-wind (x,y,z)	post flight processing from above parameters	0.5..30 m/s	0.5 m/s / 10 Hz	0.5 / 1.0 m/s	wind during maneuvers
aerosols (0.3 and 0.5 µm)	MetOne LASER particle counter	0..150 cm^{-3}	1 cm^{-3} / 1 s	1 / 10 cm^{-3}	factory calibration
aerosols (>10 nm) (*)	TSI condensation particle counter	0..1e^4 cm^{-3}	1 cm^{-3} / 1 s	1 / 10 cm^{-3}	fact.cal.+zero
O_3 (slow, accurate)	PSI / UV absorption	2 ppb .. 1 ppm	1 ppb / 4 s	1 / 2 ppb	cal. gas
O_3 (fast, but, drifting) (**)	Scintrex LOZ-3 (Eosin-Y chemilum.)	1 ppb..1 ppm	0.1 ppb / 10 Hz	10 ppb	against UV-photometer
speciated hydrocarbons (C_4..C_{10})	Gaschromatograph Airmotec HC-1010	10 ppt..10 ppb	10 ppt / 10'	10 ppt / 50 ppt or 20 %	cal.gas
NO_2, NO_x, NO_y, HNO_3, PAN, O_x	MetAir-NOxTOy: 6-channel Luminol-detector with CrO3- and Mo-converters	0.5..500 ppb	0.1 ppb / 1..5 s	0.1 /0.5 ppb	NO2 calibration gas
SO_2 (*)	FIAMS, Adelaide (Luminol with H_2O_2)	0.5..500 ppb	0.1 ppb / 1 Hz	0.1 / 1.0 ppb	cal. gas
Peroxides (H_2O_2 and organic) (*)	Aerolaser (enzymatic fluorometry)	0.1..20 ppb	50 ppt / 10 s	0.1 / 0.5 ppb	H2O2 in water
Formaldehyde (HCHO) (*)	similar as for H_2O_2 (above)				HCHO in water

parameter	instrument/method	range from..to	resolution parameter / time	precision / accuracy	calibration or checks
CO_2	NOAA-IRGA (open path IR-absorption)	200..500 ppm (adj.)	0.1 ppm/ 20 Hz	0.1 / 3 ppm	cal. gas / profiles
H_2O	NOAA-IRGA (open path IR-absorption)	0.5..30 g/kg (adj.)	0.05 g/kg / 20 Hz	0.01 / 0.1 g/kg	dew point mirror
CO_2 (***)	LICOR- IRGA (modified)	310..410 ppm (adj.)	0.05 ppm / 1 Hz	0.05 / 0.3 ppm	cal. gas
H_2O (***)	LICOR- IRGA (modified)	0..20 g/kg (adj.)	0.01 g/kg / 1 Hz	0.01 / 0.05 g/kg	dewpoint mirror
CO (***)	Aerolaser (vacuum UV-fluorescence)	2 ppb..5 ppm	10 Hz / 1 ppb	1 ppb / 2 ppb	cal. gas
manual sampling of up to 12 glass flasks for CO2, etc. (***)	MetAir				
automatic sampling units for VOC's, biog. VOC's, SF_6, etc. (*)	MetAir / FZJ				
IR-scanner (*)	AGEMA / Univ. Bâle				

*) optional, not installed in standard instrumentation; may be added or exchanged with another instrument/parameter.

**) now replaced by fast Ox-NO2 from NOxTOy, but, could be re-installed if necessary.

***) new since summer 2000 or 2001 (fast and precise carbon monoxide, and redundancy in CO2/H2O), now belonging to standard equipment

VI.2 Radiosonde systems

CNRM operates Vaisala DigiCORA®III sounding systems. It consists of a laptop, which is connected to a sounding processor subsystem via a network adapter. The passive sounding controller contains the processor cards for Temperature, Pressure, Humidity, GPS wind finding and appropriate connections to the required antennas (UHF Telemetry and GPS antennas).

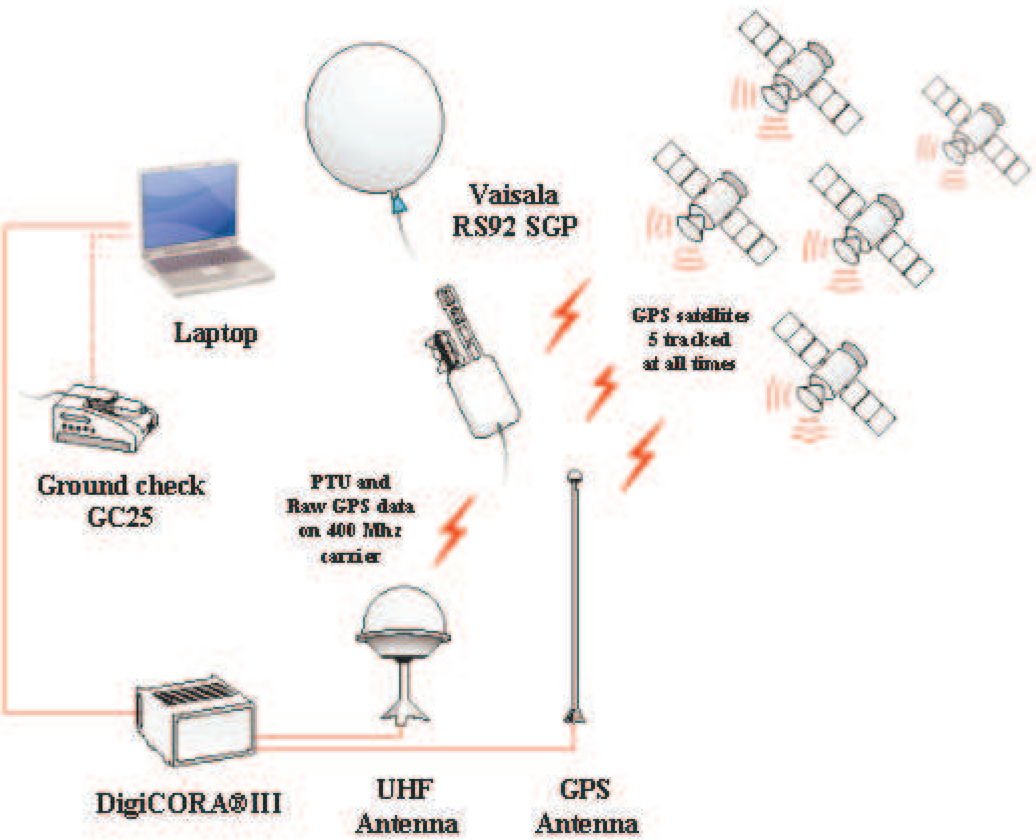


figure VI.2-a ***: radiosonde system***

Vaisala radiosonde RS92 SGP is used for measuring the thermodynamic parameters and the wind in the boundary layer and the upper atmosphere. It works in the 400 Mhz meteorological band. It is equipped with a capacitive thermistor, a silicon Pressure sensor and a heated twin Humidity sensor.

figure VI.2-b ***: the ballon launcher***

A balloon launcher is used for mobile operations. It is dimensioned for 300, 350 or 500 g balloon sizes.

The GC 25 Ground Check unit is used to check the functioning of the RS92 SGP and the sensor accuracy, as well as to set the frequency of radiosondes or pre-selected time from launch.

DigiCORA®III is configured to produce meteorological messages like TEMP.The archived soundings can be opened, simulated or exported from it. Sounding data can also be converted to another format at export. Converted EDT and STD data has the following format :

- Time from soundind start (sec)
- Scaled logarithmic pressure (ln)
- Temperature (K)
- Humidity (%)
- Wind speed, north component (m/s)
- Wind speed east compoment (m/s)
- Height (m)
- Pressure (hPa)
- Dew point temperature (K)
- Humidity mixing ratio (g/kg)
- Wind direction (dgr)
- Wind speed (m/s)
- Sonde azimuth (dgr)
- Sonde distance (m)
- Sonde longitude coordinate (dgr)
- Sonde latitude coordinate (dgr)

Temperature	**capacitive thermistor**
Measurement range	+60°C to -90°C
Resolution	0.1°C
Accuracy	0.5°C
Humidity	**thin film capacitor, heated twin sensor design**
Measurement range	0 to 100%
Resolution	1%
Accuracy	5%
Pressure	**silicon sensor**
Measurement range	1080hPa to 3hPa
Resolution	0.1hPa
Accuracy	0.5hPa
Battery	
Operation Time	135 min
Telemetry	
Transmitter type	Synthesized
Frequency band	403 Mhz
Turning range	400~406 Mhz
Code correlating GPS receiver	
Number of channels	12
Positioning accuracy	10m (horizontal), 20m (vertical)
Velocity	0,2m/s

table VI.2 a ***: meteorological sensors***

VI.3 Troposphere profiling systems

VI.3.1 VRIJE (Marmande)

RASS-Sodar system will be installed at the Marmande (MR) site, in the Garonne valley (coord. 0° 11.76 min. E ; 44° 27.84 min. N, alt. 21m).

The Scintec XFAS52 flat array sodar consists of one large, octogonal acoustic antenna with dimension of 1448 mm in both directions (see the left panel of figure below). This antenna houses both the transducers and switches and contains audio power drivers for emission and audio preamplifiers for reception mode. The number of elements is 52, and the same elements are used to translate electrical signals for emitting sound waves and to reconvert the received sound waves in electric signals that can be analyzed. The antenna is surrounded by an octagonal steel enclosure, which has a width of 3692 mm and an overall height of 1995 mm. The enclosure consists of 16 identical metal sheets that are coated by sound absorbing foam. The acoustic antenna is connected to the power supply and a processing unit by 9 m long coaxial cables. Both the processing unit and the power supply are contained in an aluminium box. The processing unit is connected to a terminal PC or laptop on which the FASRUN software is installed. The processing unit operates as a slave processor following the instructions from the terminal PC or laptop. The orientation of the antenna is such that it is horizontally leveled and the "North" sign is pointing to the north direction.

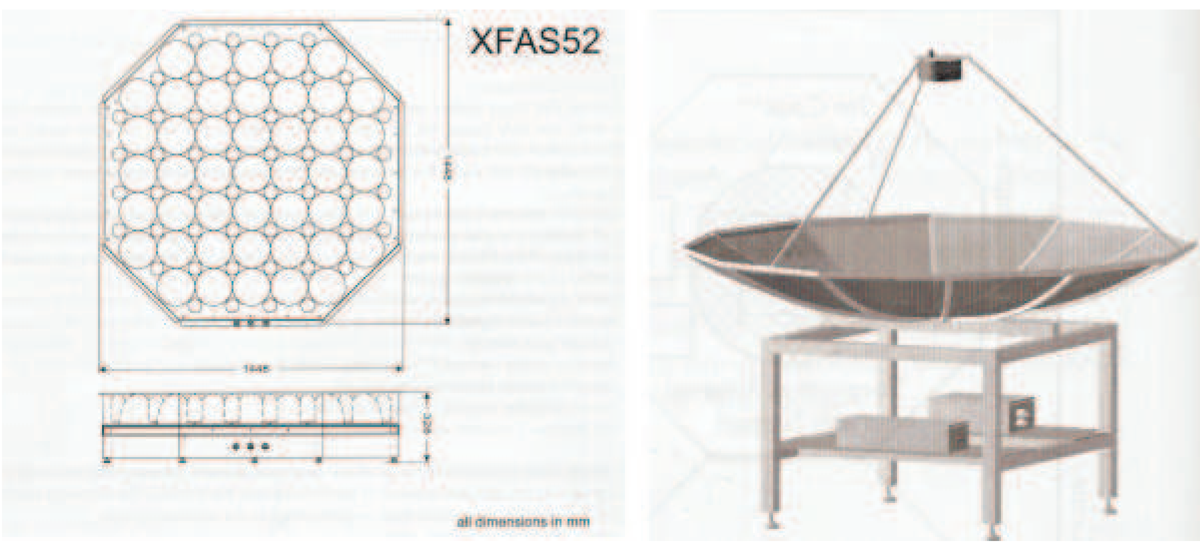


figure VI.3.1-a ***: Schematic picture including dimensions (in mm) of the Scintec Flat array sodar acoustic antenna of the XFAS52 (left panel); Schematic picture of RASS parabaolic antenna (right panel)***

The RASS extension consists of two parabolic antennas (see the right panel of figure above), one for transmission and one for receival of the electro-magnetic radio waves. The centers of the RASS antennas and the center of the sodar antenna have to stand in a straight line. The RASS receiver and transmitter antennas are situated at the end of this line with the sodar halfway between them (see Figure below). The distance between both RASS antennas is 8 m. Both the RASS transmitting antenna and receival antenna are enclosed by an enclosure the dimensions of which are equal to the dimensions of the sodar antenna enclosure. Both the RASS transmitter and receiver are connected to a RASS transceiver, which is subsequently connected to the central processing unit. The RASS transceiver shares its aluminium box with the processing unit. Within the enclosure of the RASS transmitter a power amplifier and a RASS power supply are installed. Also, these are contained in an aluminium box.

The sodar's frequency range is from 825 Hz to 1375 Hz. The electric acoustic output power is 500 W and beams are emitted vertically in in all four horizontal directions under angles of 19 °, 22 °, 24 ° and 29 °. Electric power requirement is about 600 W, but peak power requirement is about 1500 W.

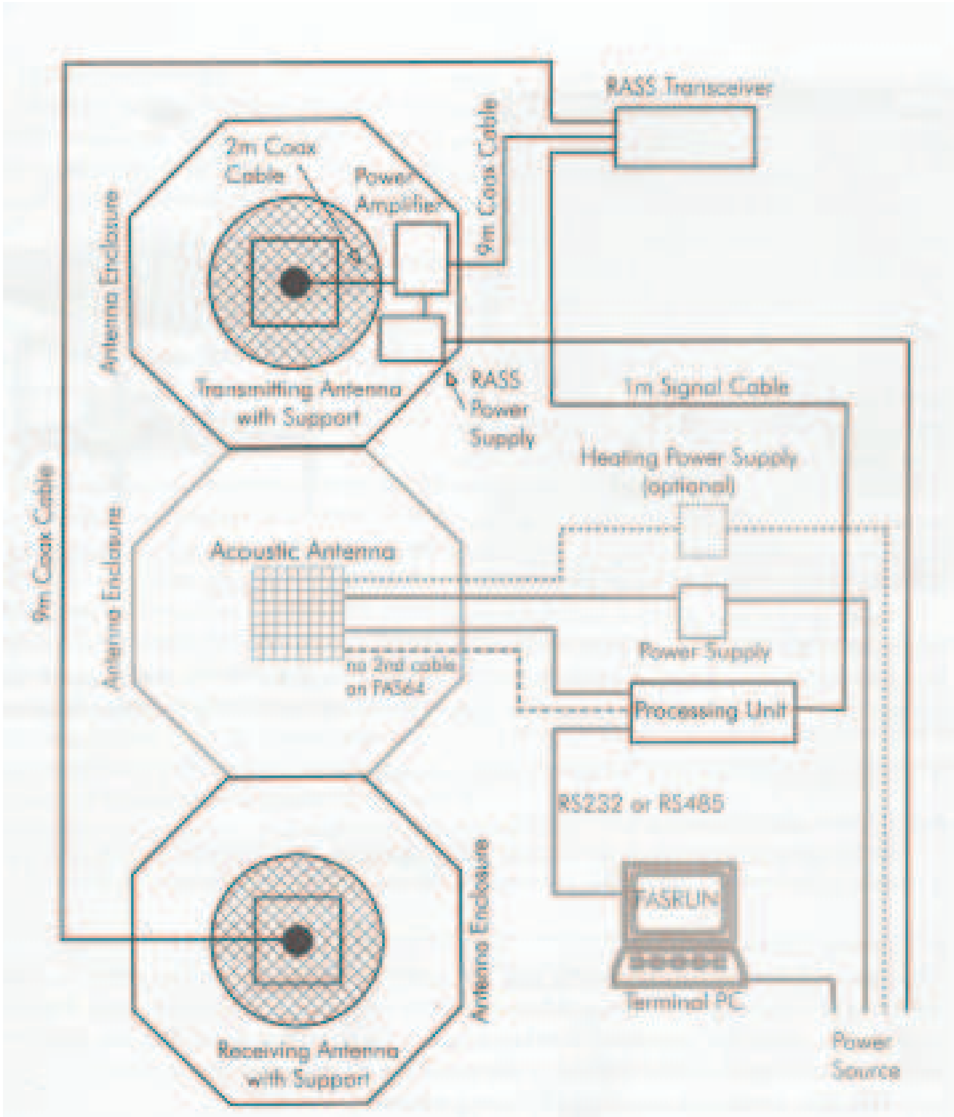


figure VI.3.1-b ***: Wiring scheme of a sodar with the RASS extension***

VI.3.2 CNRM (La Cape Sud)

At La Cape Sud (CS) site, CNRM will operate both a Doppler Sodar and a Doppler UHF radar. The measurements done by these two instruments are based on the same physical principle, i.e. the computation of three radial wind components from the Doppler shift recorded on the backscattered signal. The sodar uses acoustic waves, whereas the UHF radar radio-wave ones. Identical assumption, i.e. the homogeneity of the horizontal wind profile in the volume scanned by the three beams is required for the two instruments. This implies that zenital angles of the beams are small. As can be seen below on the technical characteristics of the instruments, they are complementary because the sodar is able to measure the profile of the horizontal wind U between 50 and 300-600m, with a resolution of 50m, whereas the UHF radar operates between 300 and 2000-3000m, with a resolution of either 75 or 375m, according to the mode chosen.

UHF radar

The UHF radar is a PCL1300 system built up by Degreane company. It is composed of 5 beams, one pointing vertically and the 4 others with a 17 degrees zenital angle and azimuth aligned along the four main directions (W, N, E and S). The three wind components are thus computed from these 5 redundant radial velocities. On each beam direction, the Doppler spectrum is recorded, as well as reflectivity, radial velocity and the spectral width of the backscattered signals. These informations are available every 5 min. While a first-level version of the wind profile is available real-time, the storage of the raw data allow to process the Doppler spectra after the campaign again, in order to optimize the software parameters used to compute the wind profiles.

Specific software could allow to estimate turbulence parameters, like the structure parameter C_n^2 for the radio frequency used, or the dissipation rate of turbulent kinetic energy. This allows to estimate the height of the atmospheric boundary layer.

The system operates in two simultaneous configurations: in the first one, called "high", the vertical resolution of the wind profile is coarse (375m), which allows to reach higher altitudes (generally > 3km) ; in the other one, called "low", the vertical distance between to consecutive values can be reduced down to 50m, but, in this case, only the lowest atmosphere could be analysed (say, around 2 km on average). Wind profiles are available every 5 min.

The technical characteristics of the instrument are summarized in the table below.

Wavelength (l) : 24,2 cm
Emission frequency (F_e) : 1274 MHz
Max. power (crest) (P_t) : 4 kW
Pulse length (h) : (low mode : ~ 150 m ; high mode : ~ 750m)
Pulse repetition frequency (F_r) : (~ 20000 Hz)
Beam width (q) : 8.5°
Number of range gates (N_p) : (~ 50)
Minimum distance between consecutive levels (Δ r) : (~ 50m)
Number of FFT values (N_{fft}) : (128)
Number of non-coherent integrations (N_{inti}) : (10 to 20)
Number of coherent integrations (N_{intc}) : variable (~ 100)
Ambiguous distance ($D_a = c / 2F_r$) : (~ 6 km)
Non-ambiguous radial velocity ($\Delta V_a = \pm l F_r / 4 N_{intc}$) : variable (~ $\pm$ 6 ms^{-1} , tunable by real-time software)
Resolution of radial velocity ($\Delta v = 2 \Delta V_a / N_{fft}$) : variable (~0.1 ms^{-1})
Time required for one beam analysis ($T_f = N_{inti} N_{intc} N_{fft} / F_r$) : variable (~ 10 s)
Minimum value of a signal to be detected at 1 km: ~ -18.8 dBZ

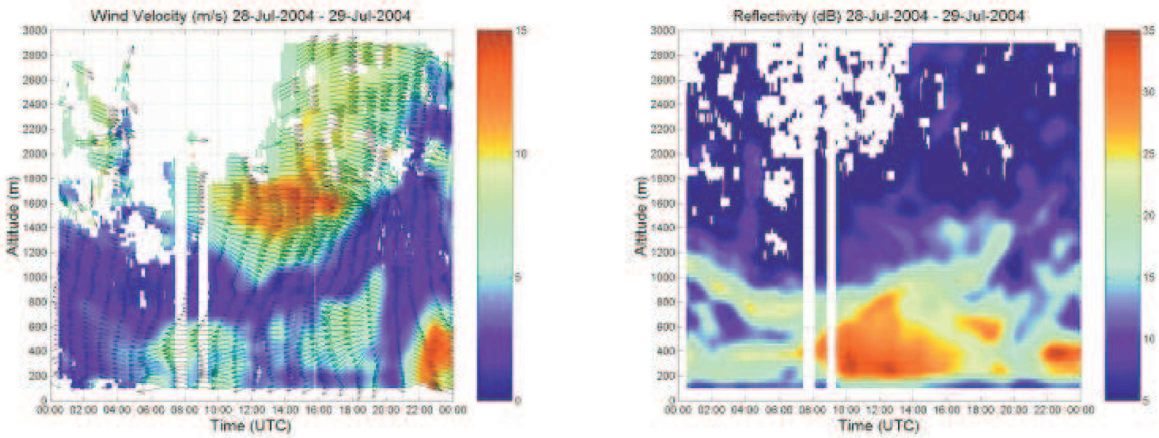


figure VI.3.2-a ***: Time-height cross-section of the horizontal wind (left) and the reflectivity (right) mesured by the UHF radar during a 24-hour period.*** *(courtesy of V. Puygrenier and B. Campistron, lab. Aérologie)*

Doppler sodar

The Doppler Sodar is a REMTECH PA1 instrument. Its antenna is composed by an array of loudspeakers. It contains audio power drivers for emission and audio preamplifiers for reception mode. The same elements are used to translate electrical signals for emitting sound waves and to reconvert the received sound waves in electric signals. The antenna unit is connected to a laptop on which the REMTECH software is installed.

Changes of phases between loudspeakers allows emission of sound waves along three directions, one of which being vertical and the two others with a zenital angle of 30 degrees. The three wind components are computed from the three radial velocities (deduced from the Doppler shift frequency). The wind retrieval is based on the assumption that the horizontal gradient of the wind profile is weak inside the volume sampled by the three beams. Other parameters related to atmospheric turbulence, like the structure parameter for the frequency of the instrument (close to the Ct^2 one), and the variance of vertical wind, are also computed by the software. The height of the boundary layer could thus be estimated provided that it does not overpass the max. height of measurements, which depends on atmospheric and ambient conditions : for moderate winds, it is generally of the order of 500m, whereas it becomes lower for higher windspeed, due to the wind-generated noise. Ambient non-atmospheric noise, like car traffic, also disturbs the measurements. The vertical resolution of the computed wind profile is 50m (see an illustration below).

The general characteristics of the instrument are summarized in the table below.

Average acoustic wavelength (λ) : 16 cm
Average acoustic emission frequency (F_e) : 2100 Hz
Acoustique power (P_t) : 10 W
Vertical resolution (Δ r) : 50 m
First measurement level (D_o) : 50 m
Ambiguous distance ($D_a = c / 2F_r$) :
Non-ambiguous interval ($\Delta V_a = \pm \lambda F_r / 4$)
Velocity resolution ($\Delta v = 2 \Delta V_a / N_{fft}$)

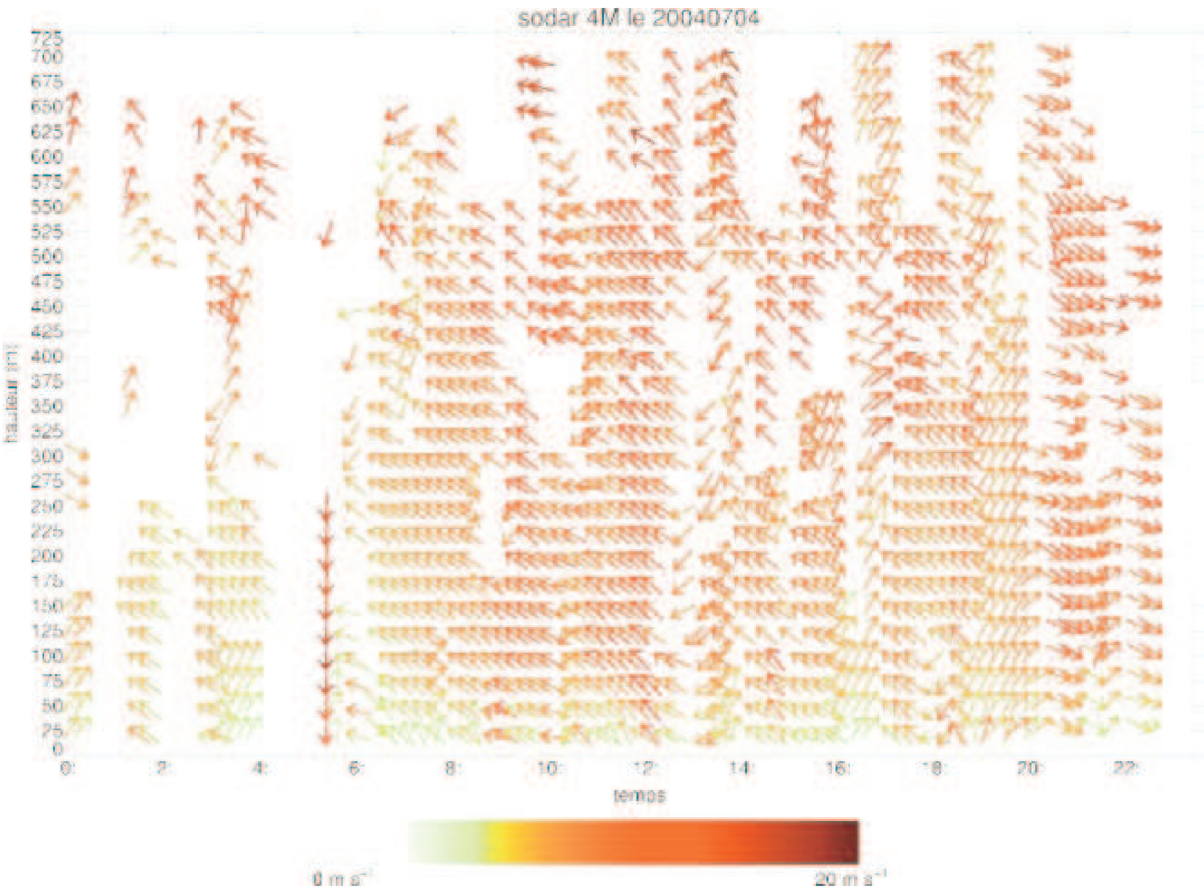


figure VI.3.2-b ***: Time-height cross-section of the horizontal wind measured by CNRM sodar during a whole day. Wind direction is aligned along the arrows, whereas windspeed is according the bottom colorscale. This situation illustrates a wind reverse, from SE ("Autan" wind) to the NW, which is quite common in the Toulouse region***

VI.4 CO2 concentration

VI.4.1 LSCE (Biscarrosse)

The CARIBOU system (M.Ramonet, Ph. Galdemard)

CARIBOU instrument, a Non Dispersive Infra-Red spectrometer developed at CEA will be installed on a high tower for the intensive campaign of spring 2005. The system is divided in two subsystems:

– The pumping compartment (figure VI.4.1-a left), which includes the pumps required to bring the air into the analyser, and a fridge for preliminary drying of the air.

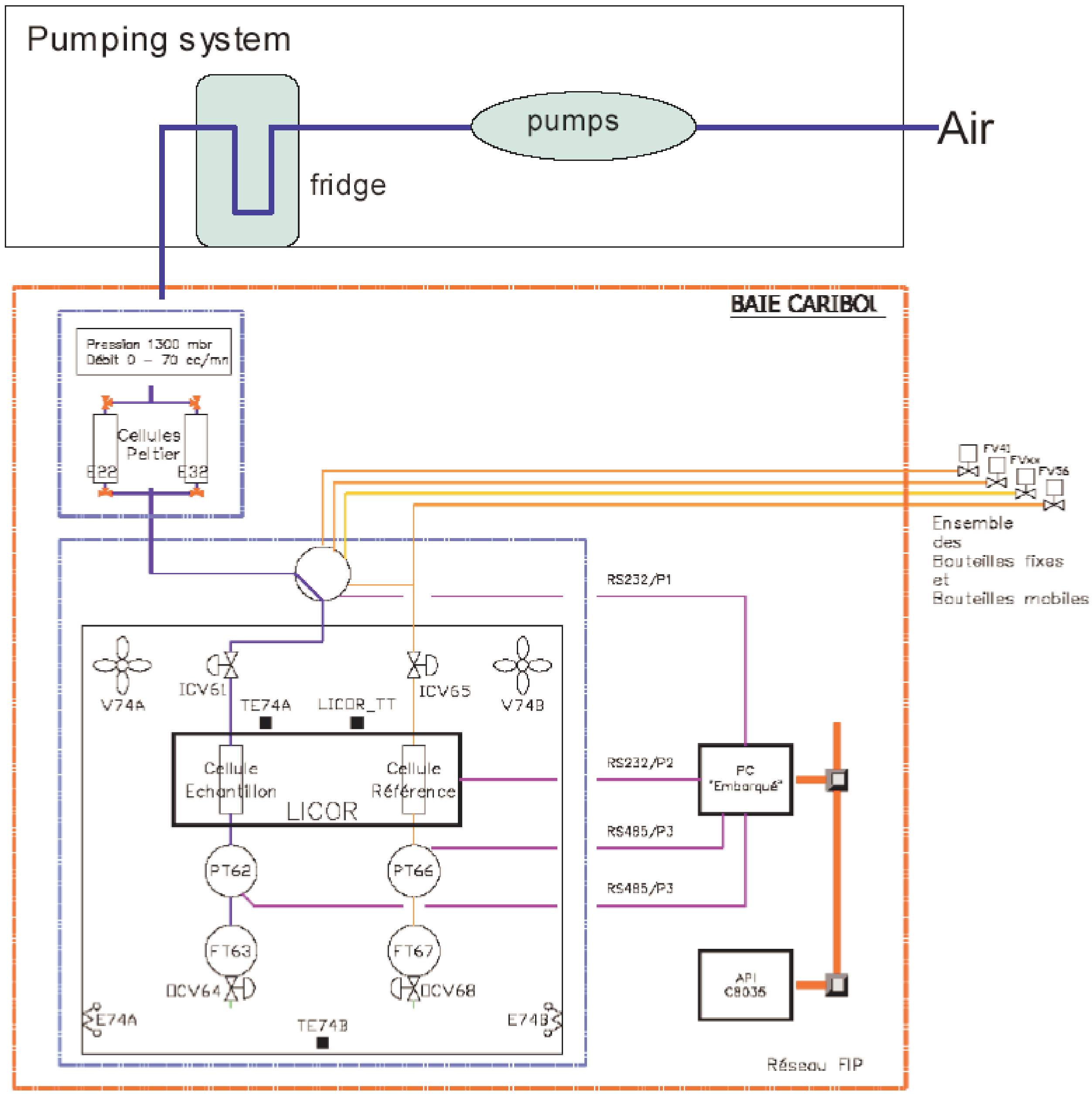
– The analysis and control compartment (figure VI.4.1-a right), which includes a Peltier-based cooling system to trap the remaining water vapour of the incoming air, a commercial LICOR-6252 analyser, pressure, flow and temperature regulators controlled by a PLC, and a PC used to configure and control the experiment. The rack containing the LICOR analyser and the hardware necessary to regulate the gas flow, the pressure and the temperature is shown open on figure VI.4.1-a middle.

figure VI.4.1-a ***: CARIBOU instrument : Pumping system (left), regulation & measurements system (middle) , Analysis and Control compartment (right)***

An overview of the Caribou design can be found below. The lower part of the figure shows the analysis compartment, which will includes a Peltier cooler to achieve an adequate dryness of the incoming air (the Peltier system is at the moment under manufacturing and could be replaced by a commercial cryocooler if not available). The pressure of the reference and sample cells are regulated individually and absolutely around 1080 mbar, and the test results show a relative pressure difference between them lower than 0.1 mbar.
The flows of both the reference and sample gas are regulated at 20 cm^3/min, which will allow very long lifetimes for the standard tanks (from half a year for the reference gas to several years for the other standards)

CARIBOU site requirements:

- The size of the control compartment is around 1m80 (height) X 70 cm X 70 cm.
- The air inlet will be located outside the tower, as high as possible.
- The air will be brought into the analyser via a DECABON 1300 tube (1.3 cm in diameter).
- The size of the pumping system is about 1m (height) x 60 cm X 70 cm
- There will be from 6 to 12 high pressure cylinders containing the various calibration gases.
- The total power supply requirement is lower than 1 kW (220 V, one phase)
- A phone line is needed to send the data.



<u>figure VI.4.1-b </u>***: CARIBOU CO2 analyser schematics***

The CARIBOU CO2 analyser is based on a commercial LICOR-6252 CO2 and H2O analyser, which uses the differential, Non Dispersive Infra Red (NDIR) technique. The CO2 spectrum includes a number of absorption features in the thermal Infra Red. The absorption band centered at 4,26 µm is chosen in the LICOR-6252 because this region of the spectrum is quite clear from other features of other atmospheric species.

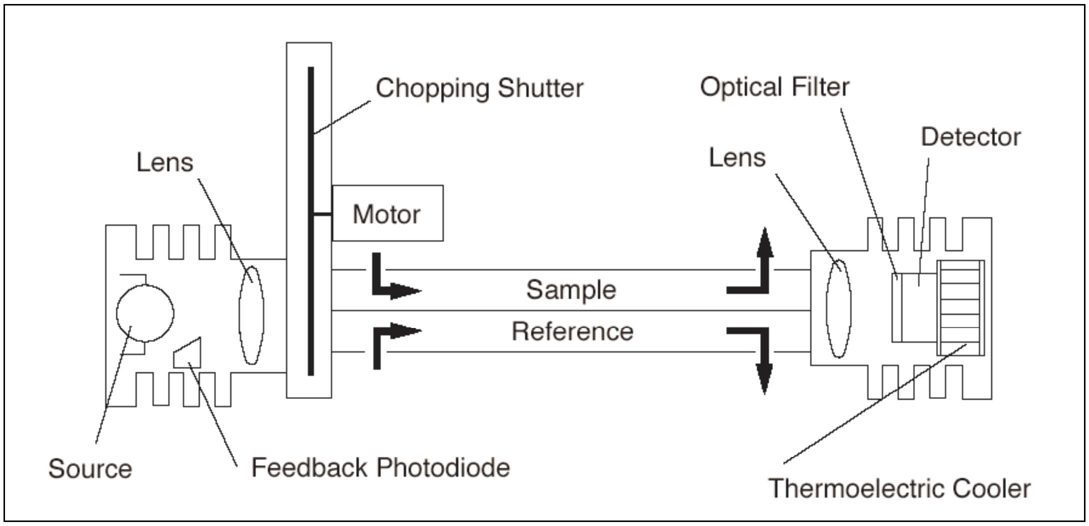


figure VI.4.1-c ***: Principle of the LI-6252 differential, non-dispersive (NDIR) CO2 analyser***

figure VI.4.1-c depicts the operation principle of the LI-6252: The CO2 measurement is inferred by measuring the difference in absorption of the infrared radiation passing through two gas sampling cells. The reference cell is continuously flushed with a gas of known CO2 concentration, and the sample cell is flushed by the air sample or standard gas to be measured. The rotating chopping shutter allows blocking alternatively the radiation entering the reference and the sample cell, so the single IR PbSe detector alternatively measures the IR intensity coming from the reference and the sample cells. The analyser output is simply proportional to the difference in absorption between both cells. After adequate calibrations of the instrument by known standard gases, the analyser output is converted in CO2 absolute concentrations. The required level of precision for the measurement of the CO2 concentration in the atmosphere, is lower than 0.1 ppm for the CARIBOU instrument. This is far better than what can be achieved using only a commercial LI-6252 from the shelf. To increase the level of precision, the CARIBOU includes the regulation of the physical parameters of the reference and sample gas:
regulation of the LICOR cell pressure at 1080 mbar +/- 0.05 mbar
regulation of the LICOR cells at 35°C +/- 0.03 °C.
Finally, in order to minimise the running cost of the CO2 station, both reference and sample gas flows are regulated at 20 cm3/min.
The typical repetability of the CARIBOU instrument is approximately 0.02 ppm rms (Note: this number is preliminary because CARIBOU is still being characterised in the lab). See figure VI.4.1-d.

figure VI.4.1-d ***: Typical repeatability of the CARIBOU analyser (preliminary results).***

The white curve corresponds to the raw, uncalibrated measurements of the same standard gaz, during 3 days. The orange curve is obtained by subtracting the varying offset measured regularly by feeding the sample cell with the reference gas. The standard deviation after offset correction is of the order of 0.02 ppm

VI.4.2 ALTERRA (Marmande)

CO_2 profiling system will be installed at the Marmande (MR) site, in the Garonne valley (coord. 0° 11.76 min. E ; 44° 27.84 min. N, alt. 21m).

A PP Systems CIRAS-SC IRGA is used to analyse the sample air for H_2O and CO_2. This analyser uses a low flow internal pump (100 ml/min$_{-1}$), is thermostatted and compensates for cell pressure and temperature. All levels are pumped continuously at 0.4 L/min$_{-1}$ except one level that is sampled by the gas analyser. In a half-hour cycle up to 6 levels can be sampled.

Twice a day, at noon and midnight, a CO_2 calibration gas sample is measured by the analyser to allow a post-correction on the concentrations. The calibration gas is humidified using a nafion humidifier and the sample gas flow of level 1.

Accuracy, after calibration correction, is better than 1 ppm CO_2.

During the field campaign, the system will be installed on the Marmande (MR) site, close to Vrije RASS-Sodar system and to the ALTERRA eddy-flux station. CO_2 profiles will be measured up to 20m height.

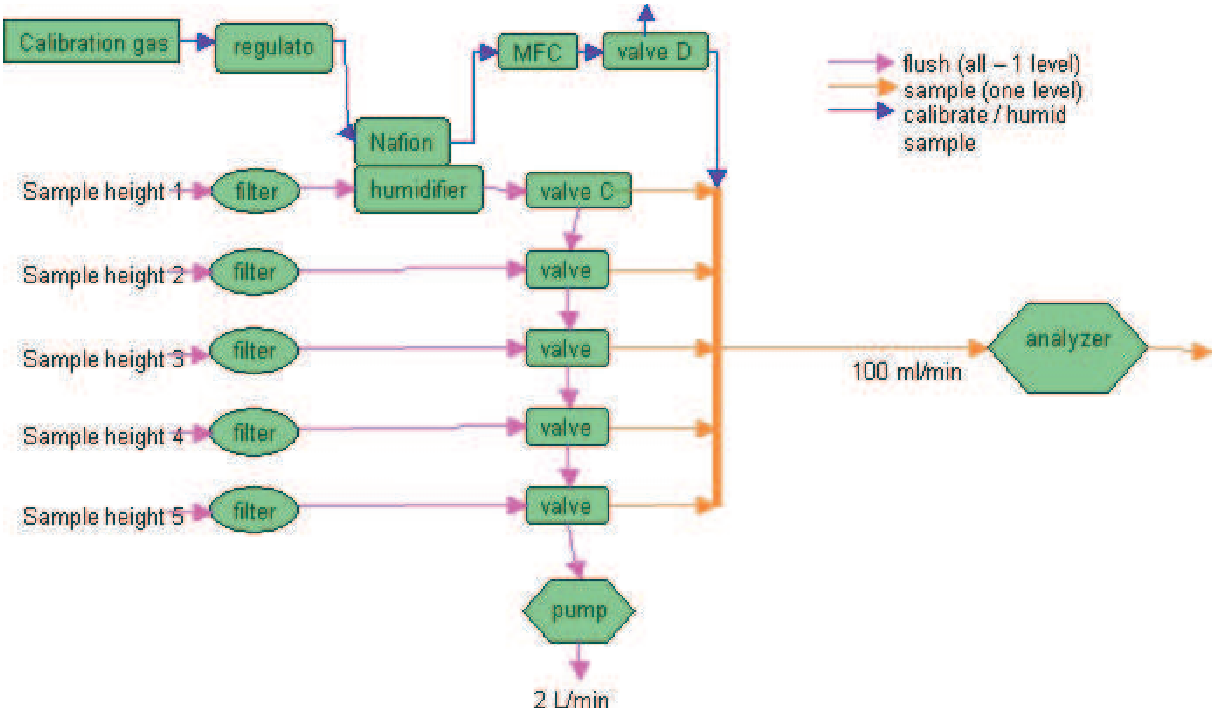


figure VI.4.2-a ***: CO2 profiling system***

VI.4.3 MPI Jena (Biscarosse)

Atmospheric trace gas observations by solar absorption Fourier transform infrared (FTIR) spectrometry

T. Warneke (U. Bremen) and C. Gerbig (MPI-BGC)

MPI-Jena in collaboration with University of Bremen is planning FTIR measurements of column abundances for a number of trace gases, including CO_2, at the Biscarosse site during the Intensive Operational Period (IOP) in May-June 2005.
The measurement principle is as follows: Each molecule in the atmosphere absorbs solar radiation at characteristic wavelengths. These characteristic absorption features are analysed by means of FTIR spectrometry. This allows retrieving column densities (total number of molecules above the observer) of several tropospheric and stratospheric gases. Tropospheric gases include CO_2, CH_4, CO, N_2O, C_2H_2, C_2H_6, CH_2O, OCS and various CFCs. Important measurable stratospheric species are O_3, HCl, HNO_3, NO, NO_2 and $ClONO_2$. For some species (e.g. CO, CH_4, HCl, HF, N_2O) a vertical profile can be determined from the pressure broadening of the spectral lines, however, the vertical resolution is limited to about 4 km.
The solar radiation is collected by the solar tracker and directed to FTIR-spectrometer (Michelson-Interferometer). Inside the spectrometer, the radiation is split into two beams, which travel on separate optical paths through the instrument and are then recombined. The length of one path is varied with respect to the other. At equal path length (ZPD = zero-path difference) constructive interference occurs and the highest intensity is measured. When the optical path difference is changed, interference causes the intensity to fluctuate. This interference-modulated signal as a function of optical path difference is an interferogram. This interferogram is the Fourier transform of the spectrum of the incoming radiation. The spectrum can be reconstructed from the recorded interferogram by inverse Fourier transformation. The information about the trace gases is retrieved by fitting a computer-simulated spectrum to the recorded one.

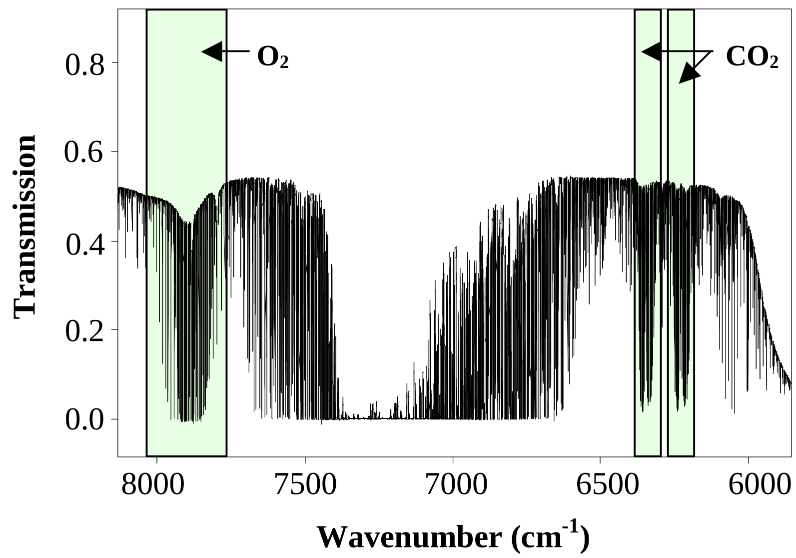


figure VI.4.3-a***: Spectral region used for the CO2-retrieval***

For the retrieval of carbon dioxide (and methane and carbon monoxide) transitions in the near-IR are used (figure VI.4.3-a). The main reason for choosing near infrared transitions is the fact that also O_2 has strong absorption features in this spectral region. Since the atmospheric volume-mixing ratio of O_2 is known to be highly constant (0.2095), it can be used as a reference gas. The column-averaged volume-mixing ratio of CO_2 (XCO_2) is obtained by scaling the (CO_2/O_2) column ratio by 0.2095. Due to cancellation of systematic errors the variations in the CO_2/O_2 ratio are substantially smaller than those in the CO_2 or O_2 individually. Currently precisions of about 0.5% can be achieved for CO_2, CH_4 and CO (figure VI.4.3-b).

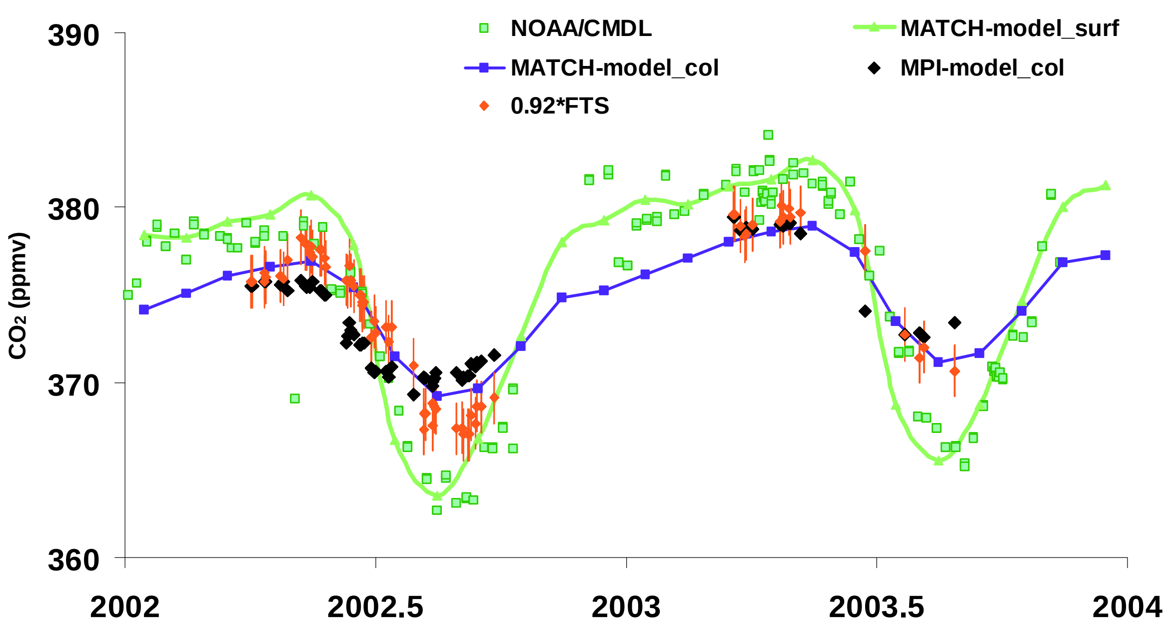


figure VI.4.3-b ***: Measurements of column CO2 (red) at Ny-Alesund (Spitsbergen) compared with nearby in situ observations (green squares) and model data***

The FTIR will be operated inside a Container (6,1x2,6x2,4m), which will be located next to the Biscarosse tower, just to the south in order to provide clear view to the sun. This co-location with in-situ measurements made by LSCE will provide ample opportunity for intercomparison and evaluation of the FTIR retrieval for CO_2. Frequent comparison with aircraft measurements made while profiling over the tower are essential for improving retrieval algorithms with respect to profile information (instead of just column abundance).

VI.5 Eddy-correlation units and meteorological stations

VI.5.1 INRA (Le Bray)

Le Bray (LB) is a mandatory site in the Ecosystem part of the project. The site is located approximately 20 km SW from Bordeaux (latitude 44°42' N, longitude 0°46' W, altitude 61 m) in a 16 ha maritime pine stand (*Pinus Pinaster* Ait.) planted in 1970. The trees are distributed in parallel rows along a northeast–southwest axis. The mean tree height is about 21 m. The inter-row spacing is 4 m and stand density is about 360 trees per hectare.

An equipped 40 m high scaffolding is set up in the middle of the stand (Figure below) surrounded by similar stands, except in the northwest direction where there had been a clear-cut at about 200 m from the tower following the storm of December 1999 (Figure below).

figure VI.5.1-a : ***Le Bray site equipped with a 40 m high scaffolding with EC and meteorological measurements***

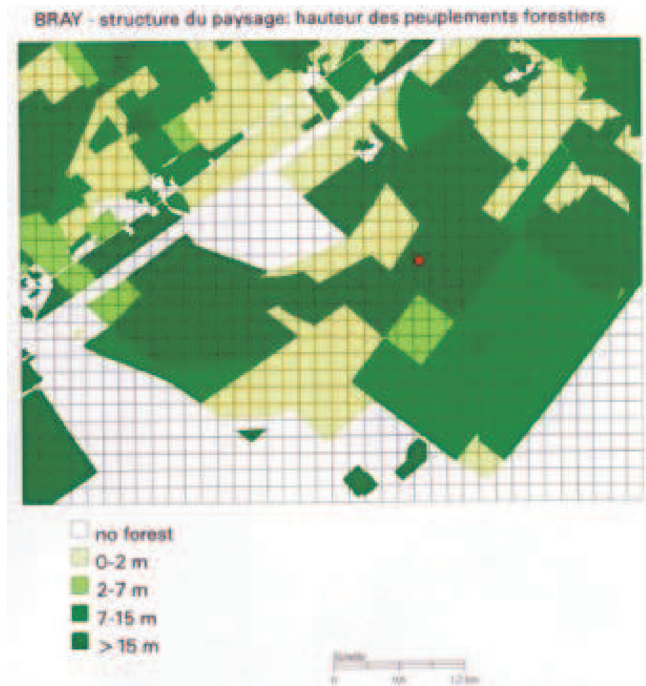


figure VI.5.1-b : ***Lansdcape structure around the tower (red dot) at Le Bray site***

The site is also remarkably flat. The understorey consists mostly of grass (mainly *Molinia coerulea* L. Moench). The clumps of grass are about 0.7 m high in early summer: they partly remain in winter, depending on frost. The soil is a sandy and hydromorphic podzol, with dark organic matter in the first 60 cm. A layer of compacted sand, barely penetrable by the roots, is located at a depth of about 80 cm. Inorganic sand lies below this layer. The water table level reaches the soil surface during most winters, and in summer it is generally from 120 to 200 cm depth.

The EC system consists of a 3D sonic anemometer (Solent R2, Gill Instruments, Lymington, Hampshire, UK) set up at 41.5 m, coupled with an Open Path CO_2/H_2O InfraRed Gas Analyzers (IRGA) LI-7500 (LICOR, Lincoln, NE, USA). Data acquisition is made at 20.8 Hz.

The CO_2 profile is also measured with a LI-800 (LICOR, Lincoln, NE, USA) at 0.06, 0.48, 1.60, 2.80, 4.80, 8, 15.40, 17, 19, 23, 30, 35 and 41 m and the temperature and moisture profile is measured using home-made psychrometers at 1.60, 2.80, 4.80, 8, 15.40, 19, 23 and 40 m.

At the tower top, meteorological measurements are taken every 10 s and averaged every half hour. Detailed instruments are summed up in the Table below. At the moment, net radiation is calculated but will be directly measured soon. Rainfall is measured at 24 m on another tower, just above the top of the trees. Soil temperature is measured at four different locations and eight depths: 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64 and 1 m using home-made thermocouples, i.e copper-constantan soldered joints coated with waterproof paint. Soil water content measurements are taken at 0.05, 0.23, 0.34 and 0.8 m depth. The data are recorded on CR10X, CR21X and CR23X Campbell dataloggers (Campbell Scientific, Logan Utah, USA).

table VI.5.1-a ***: Description of meteorological measurements done and instruments used at Le Bray site***

Parameter	Abbreviation	Instrument
Precipitation	P	rain jauge ARG 100 (Campbell Scientific, Logan, USA)
Global or short wave incoming radiation	Rg	CE180 pyranometers (Cimel Electronique, Paris, France)
Reflected or short wave outgoing radiation	Rr	CE180 pyranometers (Cimel Electronique, Paris, France)
Long wave incoming radiation	Lwin	CG2 Pyrgeometer (Kipp & Zonen, Delft, The Netherlands)
Long wave outgoing radiation	Lwout	CG2 Pyrgeometer (Kipp & Zonen, Delft, The Netherlands)
Photosynthetic photon flux density	PPFD	Sunshine sensor BF2 (Delta T Devives, Cambridge, UK)
Diffuse photosynthetic photon flux density	PPFDd	Sunshine sensor BF2 (Delta T Devives, Cambridge, UK)
Reflected photosynthetic photon flux density	PPFDr	Sunshine sensor (Skye Instruments Ltd, Llandrindod Wells Powys, UK)
Air temperature	Ta	HMP 45 (Vaisala, Helsinki, Finland)
Pressure	Pa	Vaisala (Helsinki, Finland)
Bole temperature	Tbole	Thermocouple Copper-Constantan
Soil water content		TDR Trase and Campbell CS615
Soil heat flux	G1	REBS (Radiation Energy Balance Systems, Seattle, USA)
Relative humidity	Rh	HMP 45 (Vaisala, Helsinki, Finland)
Wind direction	WD	wind vane anemometer (5103 Young, Traverse City, Michigan, USA)
Horizontal wind speed	WS	wind vane anemometer (5103 Young, Traverse City, Michigan, USA)

VI.5.2 INRA (Bilos)

Bilos is an associated site in the Ecosystem part of the project. The site is located approximately 50 km SW from Bordeaux (latitude 44° 30' N, longitude 0° 57' W, altitude 38 m) in a 1000 × 600 m clear-cut maritime pine stand. Pines were sown on half of the site in summer 2004. The inter-row spacing is 4 m.

A 6 m high mast is set up in the middle of the stand (Figure below), which is bordered to the North by maize crops (also carrots & flowers) and mature maritime pine forest either. The landscape is a coastal plain, very flat, with drainage ditches bordering the parcel. The soil is a sandy podzol lying over a hard iron pan at 70 cm. Groundwater depth usually is near the surface in winter, and below the pan during summer.

figure VI.5.2-a ***: EC measurements at Bilos site***

Flux and meteorological measurements are detailed in the table below.

table VI.5.2-a ***: Description of meteorological and flux measurements done and instruments used at Bilos site***

Parameter	Instrument
CO_2 & H_2O IRGA	LiCOR LI6262 (or LiCOR LI7500)
3D wind and Ts	Sonic anemometer Gill R3
MFC	Tylan FC2901
solar radiation (pyranometer)	Cimel CE180
net radiation	NR-Lite (Kipp and zonen, The Netherland)
PPFD	SKP 215 (Skye Instruments, Powys, UK)
Sunshine sensor (2m)	BF3 (Delta T, Cambridge, UK)
Water table depth	Depth & Level pressure sensors (PDCR 1830, Druck)
Precipitation (1m)	Rain gauge ARG 100 (Campbell Scientific, Logan, USA)
Thermohygrometer (4m)	HMP45C (Vaisala, Finland)
TDR (4 profiles)	CS615 (Campbell Sci, UK)
Soil heat flux	HFP01SC (Hukseflux,the Netherland)
Atmospheric pressure	Vaisala (PTB101B)
Thermocouple (2 soil profiles)	copper constantan
Wind speed	Vector Inst A100R
Wind direction	Vector inst W 200
Mean CO_2 concentration	LiCOR LI800

VI.5.3 INRA (Couhins)

Couhins will be set up especially for the Regional Experiment. However all the vegetative period will be covered from March to September. EC measurements use open path infra-red gas analyser system and sonic anemometer. Standard meteorological measurements will be taken during the experiment. Detailed instruments are given in the table below.

figure VI.5.3-a : ***View of the Couhins site***

table VI.5.3-a : ***Detailed instruments at Couhins site***

Parameter	Instrument
CO_2 & H_2O IRGA	Li-7500 (LICOR, Lincoln, NE, USA)
3D wind and Ts	Sonic Young 81000
Horizontal wind speed	Cup snemometer (Cimel)
Wind direction	Mobile vane (Campbell)
Air temperature and humidity	Vaisala
Net radiation	NR-Lite
Global radiation	Cimel CE 180
PPFD	Skye
Rainfall	

VI.5.4 INRA (La Cape Sud)

A tower will be set up above a maize crop from the sowing (probably at the end of April or beginning of May) to the pollinating period (end of July).

The site coordinates are :
Longitude : 0° 38.26 min. W
Latitude : 44° 24.16 min. N
Altitude : 65 m.

figure VI.5.4-a ***: View of the site (farmland "La Cape Sud") and flux tower location (red solid circle) above maize crops***

EC measurements use open path infra-red gas analyser system and sonic anemometer. Standard meteorological measurements will be taken during the experiment. Detailed instruments are given in the table below.

table VI.5.4-a ***: Detailed instruments at La Cape Sud site***

Parameter	Instrument
CO_2 & H_2O IRGA	Li-7500 (LICOR, Lincoln, NE, USA)
3D-wind	Sonic Young 81000
Horizontal wind speed	Cup anemometer (Cimel)
Wind direction	Campbell
Air temperature and humidity	Vaisala
Net radiation	NR-Lite
Global radiation	Cimel CE 180
PPFD	Skye
Precipitation/irrigation	Several Rain jauges (ARG100)
O_3	Fast and low response ozone analyzer

Additional measurements of LAI and biomass will be done twice a month. Maize height will be measured once a week.

VI.5.5 Eddy Correlation System description ALTERRA (Marmande)

The heart of the system is a Gill R3-50 3-dimensional ultrasonic anemometer, mounted on top of a mast, sending its digital output to a HP Palmtop computer located in a cabinet near the mast. The ultrasonic anemometer gives a 10 Hz output of the three vectors of wind speed and speed of sound. From this speed

virtual air temperature can be calculated. The mast is pneumatically erectable and can easily be set at different heights.
The ultrasonic anemometer has six 10 Hz analog inputs to which a Li-cor LI-7500 open path infrared gas analyser, detecting both CO_2 and H_2O, is connected.
Calibration of the CO_2 channel of the gas analyser takes place using dry compressed nitrogen gas and a CO_2 calibration gas (NOAA). The H_2O channel is calibrated using a dew point calibrator (Li-cor LI-610). The ultrasonic anemometer has fixed calibration factors.

The program Eddylogp (developed at Alterra from Gill_wmp) running on the PC controls offloading of data from the ultrasonic anemometer and storage of the raw data on a PCMCIA card.
The entire system is battery powered, the battery being maintained by solar panels and a charge regulator, and is able to perform continuous measurements for extended periods. Power consumption is approximately 8 Watts.
The raw data are post-processed using Alterra software.

figure VI.5.5-a ***: Eddy Correlation System***

During the CarboEurope field campaign, the system will be installed close to Marmande city, on a flat maize field in the Garonne valley (coord. 0° 11.76 min. E ; 44° 27.84 min. N, alt. 21m).

VI.5.6 CNRM (La Cape Sud)

CNRM, INRA and Laboratoire d'Aérologie surface measurements will be installed on an irrigated, agricultural parcel covered by beans. This field is a part of the farmland called "La Cape Sud", which is a more than 6 km2 cultivated area inside the Landes forest. Individual fields cover an area of 0.30 to 1km2, and the region is completely flat, which allows good fetch conditions for surface flux measurements. In the same farmland, but about 3 km away from this bean field, INRA will install a flux station on a maize field.

figure VI.5.6-a ***: view of a bean field in the farmland of "La Cape Sud"***

The measured parameters are described in the table below. The main meteorological parameters (wind, radiation, temperature and moisture) are measured at 2m height, whereas atmospheric pressure is measured at 0.3m. Rainfall is measured by both a tipping bucket rain gauge and an optical ORG device. Below the surface, temperature and water content are measured at various depths (see table below).

Fluxes of momentum, sensible heat, latent heat and CO2 are computed with conventional eddy-correlation technique, on the basis of 20Hz measurements done by a sonic anemometer and an open-path gas analyser (Li7500).

Emission/deposition of Ozone and nitrogen oxides are also measured on this site: Ozone flux is computed with eddy-correlation technique by INRA, from the measurements performed by their fast-response analyser, calibrated against a slow-response TEI sensor. A relaxed eddy-accumulator (REA), built at CNRM, is set up with a second sonic anemometer, in order to measure the fluxes of CO2 and water vapor (using a Li 6262 closed-path IR gas analyser), and of NOx (using a TEI gas analyser). According to the well-known REA method, the system pumps the air at a constant rate as close as possible to the sonic anemometer sampling volume, and alternatively fills two bags according to the sign of the instantaneous vertical velocity. After the sampling period (20min.), the contents of the bags is analysed and the system is emptied in order to start the next 30 min. cycle. During the sampling phase, the analysers (of CO2, H2O, NO and NO2) are used to measure the ambient mean concentration of these gases. Details on the system can be found in Brut et al. (J. Atmos. Ocean. Tech., 2004). The REA will be installed close to the eddy-correlation station, so the CO2 and latent heat fluxes will be computed with two different techniques and therefore thoroughly compared.

During two or three weeks in the beginning of the campaign, NO soil emission will be measured by the Laboratoire d'Aérologie with the chamber technique. This value will be analysed jointly with the NOx flux measured by the REA, this latter flux being the difference between the NO soil emission and the NO2 deposition at the surface of the soil and the vegetation.

The site coordinates are :
Longitude : 0° 35.85 min. W
Latitude : 44° 24.00 min. N
Altitude : 70m

table VI.5.6-a ***: measured parameters***

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind direction	YOUNG 05103	1 min.	2 m

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind speed			
Wind component U	Solent Gill sonic anemometer ("vertical" research device)	21 Hz	
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Solent Gill sonic anemometer ("horizontal" research device HS50)	50 Hz	
Wind component V			
Wind component W			
Sonic temperature			
Ozone concentration (fast)	Chemiluminescence	50 Hz	
Specific humidity	LICOR 7500	20 Hz	
CO2 concentration			
Temperature	PT1000	1 min.	
Relative Humidity	HMP45 VAISALA		
Black body temperature of radiomenter	CNR1 KIPP & ZONEN		
Outgoing global radiation			
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Pressure	PTB210 VAISALA		0,3 m
Soil water content	THETA PROBE ML2X	15 min.	Surface
			-10 cm
			-20 cm
			-30 cm
			-40 cm
Soil temperature	PT1000	1 min.	-1 cm
			- 5 cm
			- 10 cm
			- 20 cm
			- 30 cm
Rainfall	QUALIMETRICS	1 min.	0.3 m
Instantaneous rainfall	ORG 115 SCTI	1 min.	1 m
Soil heat flux	HUSKEFLUX HFP01	15 min.	Surface
NO soil emission	Chamber with TEI 42 CTL	5min.	Surface
CO2 flux	REA (CNRM) withLICOR 6262 and Solent Gill sonic anemometer ("vertical" research device)	30 min.	2 m
Latent heat flux			
NOx flux	REA (CNRM) with TEI 42 CTL		
Ozone concentration	TEI 49C	10 s	
NO concentration	TEI 42 CTL	10 s (*)	
NO2 concentration			

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
NOx concentration			
CO2 concentration	LICOR 6262	1 s (*)	

(*) Not measured during the REA bag analysis period (10 min. every 30 min.)

VI.5.7 CNRM (St Sardos)

CNRM surface measurements will be installed on an irrigated, agricultural parcel covered by maize. This field is situated about 40km NNW of Toulouse, south to the valley of the Garonne river. The surroundings of the field are flat.

The measured parameters are described in the table below. Temperature and moisture are measured at 2m height, whereas atmospheric pressure is measured at 0.3 m. Rainfall is measured by a tipping bucket rain gauge. The four components of radiation are measured at 6m height. Below the surface, temperature and water content are measured at various depths (see table below).

Fluxes of momentum, sensible heat, latent heat and CO2 are computed with conventional eddy-correlation technique, on the basis of 20Hz measurements done by a sonic anemometer and an open-path gas analyser (Li7500).

figure VI.5.7-a ***: view of the maize field at the site of St-Sardos***

table VI.5.7-a ***: measured parameters***

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Solent Gill sonic anemometer ("vertical" research device)	21 Hz	6 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	20 Hz	
CO2 concentration			
Black body temperature of radiometer	CNR1 KIPP & ZONEN	1 min.	
Outgoing global radiation			
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Temperature	PT1000	1 min.	2 m
Relative Humidity	HMP45 VAISALA		
Pressure	PTB210 VAISALA		0,3 m

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Soil water content	THETA PROBE ML2X	5 min.	Surface
			-10 cm
			-20 cm
			-30 cm
			-40 cm
			-60 cm
			-90 cm
			-120 cm
Soil temperature	PT1000	1 min.	-1 cm
			- 5 cm
			- 20 cm
			- 50 cm
			- 90 cm
Rainfall	QUALIMETRICS	60 min.	0.3 m
Soil heat flux	HUSKEFLUX HFP01	1 min.	Surface

VI.5.8 CNRM (CoSMOS sites)

Contents	Author(s)	Nr. Pages	Nr Illust.
Detailed description of instrumentation (three/four sites)	Calvet	2-3	2-4

VI.5.9 CESBIO (Continental Biosphere sites)

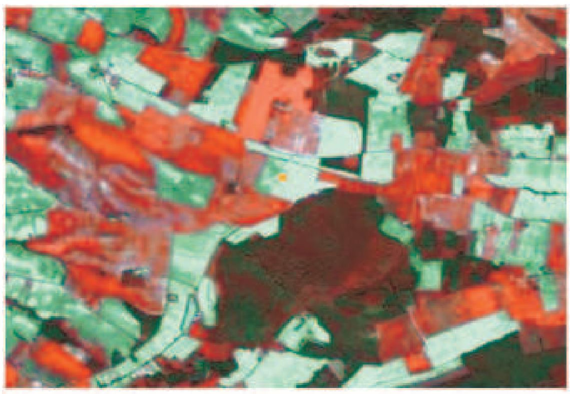
Lamasquère and Auradé crop sites: 2005 campaign of measurements

Participants : Eric Ceschia, Valerie Demarez, Valérie Le Dantec, Patrick Mordelet, Pierrette Gouaux, Sylvie Duthoit, Pierre Beziat, Lauren Fortabat and Gérard Dedieu.

Sites description

Most information concerning present and past management, detailed information concerning site location, former land cover, map, and satellite pictures have been collected in 2004. A data base is under construction. Detailed description of soil profile still has to be done. For more details see below.

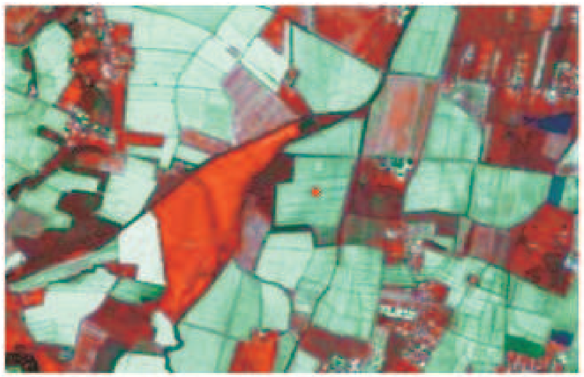
Auradé site :



- Altitude: 242.5 m
- Mean Annual T°C ≈ 13.3°C
- Mean Annual Precipitations ≈ 690 mm
- Coordinates: 43° 32' 58'' N
  01° 06' 28'' E
- Located on a plateau
- Surface area of the plot is 14 ha
- Land tenure: Private owner
- EC started in March 2004 (wheat)
- Crop type : rotation wheat-sunflower-wheat- rapeseed
- Management: tilled, fertilised
- Rapeseed in 2005

figure VI.5.9-a ***: Auradé site***

Lamasquère site :



- Altitude: 180 m
- Mean Annual T°C ≈ 13.3°C
- Mean Annual Precipitations ≈ 690 mm
- Coordinates: 43° 29' 36'' N
  01° 14' 14'' E
- Located in a flat large alluvial valley
- Surface area of the plot is 37 ha
- Land tenure: Private owner
- EC started in June 2004 (corn)
- Crop type: rotation wheat-corn-corn- sunflower
- Management: tilled, irrigated and fertilised

figure VI.5.9-b ***: Lamasquère site***

Set Up

- The Auradé and Lamasquère sites were equipped in March and July 2004, respectively, with meteorological and flux stations running on batteries and solar panels. Auradé site was equipped with a Campbell Csat3 sonic anemometer and a LiCor 7500 IRGA: data were collected on a Campbell CR5000 datalogger but power supply problems were encountered till June and in winter during cloudy days.

- The Lamasquère site was at first equipped with a Solent Gill R2 sonic anemometer and a LiCor 7500 IRGA : data were collected on a portable computer but persistent power supply problems forced us to switch to a similar setup as in Auradé. This was done in December. Power supply problems are also encountered during cloudy days.

A more powerful set of batteries and solar panels will be installed in early 2005 to ensure fulltime coverage of the measurement period.

Data analysis and datasets

Although data were collected regularly, only meteorological data have been processed so far. Flux data analysis will start in February 2005 using Edire software. All mandatory parameters have been recorded as well as a list of optional parameters (soil heat flux, light interception, canopy radiative temperature…). Concerning the footprint analysis data were sent to Mathias Goeckede for the standardised footprint analysis.

Vegetation

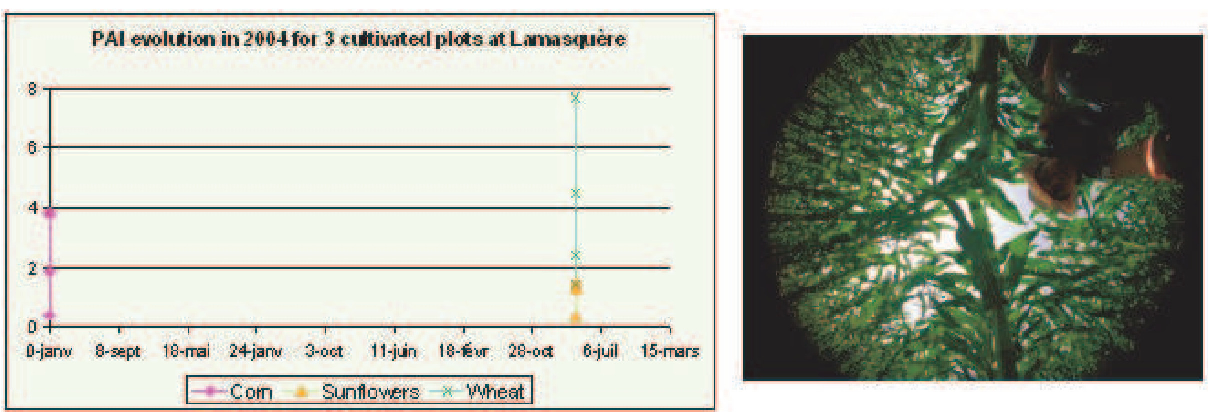


figure VI.5.9-c ***: Hemispherical picture of the corn stand at Lamasquère in 2004***

Phenology, leaf area index, plant area index biomass and height were measured regularly throughout the 2004 season. Biometric relationships were already obtained for several crops on our two plots and on surrounding plots in Lamasquère. LAI and PAI were also estimated using digital pictures from a fish-eye camera. Similar measurements will be done in 2005 on both sites.

Soil

Soil samples will be collected in February 2005 based on the former land cover. The will be used to estimate Carbon stocks in the ground at several depth in relation with former management practices. Soil texture, structure, density, humidity, N content, CEC will also be measured. Soil CO_2 flux measurements will start in the same period and will cover the whole year on a monthly basis.

Additional measurements

Depending on man power, we may complete our setup with atmospheric water, temperature and CO_2 vertical profiles (tethered balloon) and additional flux measurements (scintillometers and additional flux towers…) in order to assess fluxes at the landscape level.

VI.6 Constant volume balloons

Constant volume balloons (CVBs) are operated by the French Space Agency (Centre National d'Etudes Spatiales).

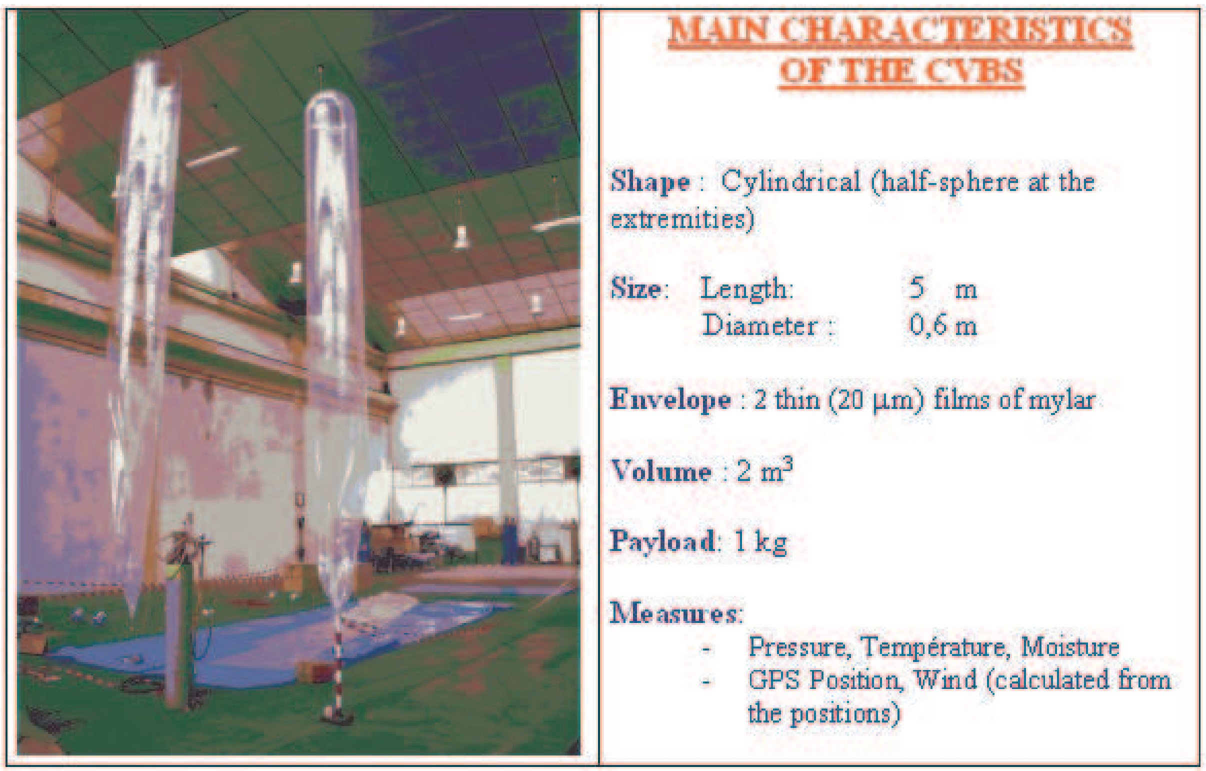


figure VI.6-a ***: Constant volume balloons***

They are vertical, cylindrical balloons, 5m in length and 0.6m in diameter, with half-spheres at the extremities. They are composed by two thin (20 µm) mylar envelopes, which are over-pressurized by up to 100hPa. The volume inside the envelope is about 2 m^3, filled by Helium (He). The maximum payload is about 1kg.

For Carbo-Europe experiment, CVBs will fly at altitudes of about 1000m. The excess of pressure inside the balloon would be 40hPa on average, which would allow vertical excursions of up to 500m above or below the the mean flight level without bursting of the balloon. For flight periods of some hours, the He leakage is weak (<1/1000).

The flight level is defined before the filling of the balloon, according to atmospheric profiles observed on radiosonde profiles. The air density at the flight level allows to compute the mass of the ballast below the balloon, and the He quantity inside the envelope in order to the internal pressure overpasses the atmospheric pressure by about 40hPa at the flight level.

The radiosondes are identical to those used for the profiles (soundings) : Vaisala RS92SGP. They measure atmospheric pressure, temperature and moisture along the balloon trajectory. In order to avoid spurious heating of the sensors because of the weakness of the wind relative to the balloon, the temperature and moisture sensors are put inside a small screen equipped with a fan. The position of the balloon is measured by GPS.

The balloons will be launched from the site "La Cape Sud (CS)", at the same location of the radiosonde soundings. Only one Vaisala system will be used to receive the balloon data via telemetry (403MHz). It is expected to track the balloon for at least 50km.

VI.7 QC/QA operations

VI.7.1 Aircraft

Contents	Author(s)	Nr. Pages	Nr Illust.
Description of QC/QA operations (intercomparison flights ; in flight calibration maneuvers; etc.)	Bourdinot/Magliulo/Miglietta/Neininger	0,5-1	0-2

VI.7.2 Ground-based systems

Contents	Author(s)	Nr. Pages	Nr Illust.
Description of QC/QA operations (instrumental protocol; intercomparisons; etc.)	TBD	0,5-1	0-2

VII COORDINATES

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VII.2 Site characteristics

Site	Label	Lat.	Lon.	Alt. (m)	Land use	Measurements/Platforms	PIs	Institutes	Experiment
HQ1					Toulouse headquarter	Coordination	J. Noilhan	CNRM	**CarboEurope**
HQ2					Bordeaux headquarter	Coordination	Y. Brunet	INRA	
Le Bray	LB	44° 43'	- 0° 46'	60	Pine forest	[CO_2], FCO2, meteorology, energy fluxes, soil parameters, biomass	Y. Brunet N. Jarosz	INRA	
Bilos	BL	44° 29'	- 0° 57'	40	Bare soil, recently soot with pine trees.				

Site	Label	Lat.	Lon.	Alt. (m)	Land use	Measurements/Platforms	PIs	Institutes	Experiment
Couhins	CO	44° 45.6'	- 0° 33.6'	25	Vineyard				
Marmande	MR	44° 26.9'	+ 0° 12.6'	21	Maïze	[CO_2], FCO2, meteorology, fluxes, RASS	R. Ronda R. Hutjes J. Elbers	VU ALTERRA	
La Cape Sud	CS	44° 25'	- 0° 37'	70	Beans	[CO_2], FCO2, meteorology, fluxes, soil parameters, biomass, O_3, NOx, FO_3, FNO_x, Radiosondes, drifting balloons, UHF radar, ceilometer	D. Legain N. Jarosz D. Serça G. Facon	CNRM INRA LA CNES	
Biscarosse	BS	44° 23.6'	- 1° 09.8'	70	Sand and pine forest	[CO_2], FTIR, meteorology, wind sodar	M. Ramonet T. Warneke	LSCE Bremen Univ. CEL	
Cazaux	CZ			25		UHF Radar, meteorology	P. Laborderie	DGA	
Saucats	SC	44° 39.2'	- 0° 35.7'	60		Aircraft basement (Sky arrows, DiMona)	F. Miglietta E. Magliulo B. Neininger	IBIMET ISAFOM METAIR	
CNRM Toulouse	TL	43° 34.5'	+ 1° 22.4'	160	Peri-urban	Radiosondes	D. Legain	CNRM	
Francazal	FR	43° 32'	+ 1° 22'	160		Aircraft basement (Piper-Aztec)	A. Butet	SAFIRE	
Le Fauga	LF	43° 23.1'	+ 1° 17.5'	186	Fallow	[CO_2], FCO2, meteorology, energy fluxes, soil parameters	J.-C. Calvet	CNRM	**CoSMOS**
Agre Forest	AF	43° 56.2'	+ 1° 16.6'	122	Deciduous forest	meteorology, soil parameters			
Montbartier	MB	43° 55.3'	+ 1° 17.9'	106	Barley	meteorology, soil parameters			
Fronton	FR	43° 51.3'	+ 1° 26.3'	105	Vineyard	meteorology, soil parameters			

Site	Label	Lat.	Lon.	Alt. (m)	Land use	Measurements/Platforms	PIs	Institutes	Experiment
St Sardos	SS	43° 53.7'	+ 1° 06.7'	189	Maïze	Meteorology, [CO_2], FCO2, fluxes, soil parameters, biomass	D. Legain	CNRM	**PNBC**
Auradé	AU	43° 33.0'	+ 1° 06.5'	245	Rapeseed	Meteorology, [CO_2], FCO2, fluxes, soil parameters, soil respiration, biomass	E. Ceschia	CESBIO	
Lamasquère	LM	43° 29.6'	+ 1° 14.2'	180	Wheat				