BLLAST

Boundary-Layer Late Afternoon and Sunset Turbulence

2011 Experimental Plans

Part I – Introduction

Objectives

Growth of the convective planetary boundary layer (CBL) over land in the middle of the day due to solar heating of the Earth's surface has been extensively observed and relatively successfully modelled. But the early morning transition—when the CBL emerges from the nocturnal boundary layer—and **the late afternoon transition (LAT)**—when the CBL decays to an intermittently turbulent residual layer overlying a stably-stratified boundary layer—are difficult to observe and model due to turbulence intermittency and anisotropy, horizontal heterogeneity, and rapid time changes. Even the definition of the boundary layer during these transitional periods is fuzzy, since there is no consensus on what criteria to use and no simple scaling laws to apply. Yet they play an important role in such diverse atmospheric phenomena as transport and diffusion of trace constituents, wind energy production, and convective storm initiation. The residual layer can be incorporated into the overlying free troposphere, so that water vapour and pollutants emitted at the surface and diffused throughout the CBL during the day can become isolated from the boundary layer and may be transported over long distances with no interaction with the surface.

At some point in the afternoon, the surface buoyancy flux is not large enough to maintain turbulent mixing throughout the CBL, especially for a deep CBL. Yet, vertical motions of up to 1 m s^{-1} extending horizontally over several km have been observed. The reason for this large-scale uplift is unclear; possibilities include surface variability and orography that can induce mesoscale circulations. The scale of these updrafts during the transition seems to be larger than the turbulent scales of vertical transfer during the middle of the day. Previous large-eddy simulation (LES) studies showed that during that period of the day, a decoupled residual layer, within which turbulence is still active, develops above the stably-stratified surface layer and is characterised by larger-scale updrafts than the mid-day eddies.

Quantitative observational evidence for this circulation is lacking, partly due to the difficulty of measuring weak turbulence and mean circulations in transitory conditions and at larger scales. Thus this phase of the diurnal cycle remains largely unexplored, from both modelling and observational perspectives.

The objective of the Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST) 2011 field experiment is to make more and better observations of the LAT, so as to better understand the physical processes that control it, and elucidate the role of the LAT on

mesoscale and turbulence scale motions, and on species transport. This implies the study of entrainment across the CBL top, surface heterogeneity, baroclinicity, horizontal advection, clouds, radiation and gravity waves.

Area and time frame

The 2011 BLLAST field campaign is planned in early summer**, from 14 June to 8 July 2011 in France, near the Pyrénées Mountains**. The site is called "**Plateau de Lannemezan**", a plateau of about 200 km² area, nearby the Pyrénées foothills, at equal distance from the Mediterranean sea and from the Atlantic ocean (about 200 km), and aligned with a main S-N oriented valley which starts to the south ("Vallée d'Aure"). The surface is covered by heterogeneous vegetation: grasslands, meadows, crops, forest.

The most favourable situations for the experiment correspond to either anticyclonic conditions, or dry post-frontal conditions. In the first case, the low troposphere is governed by the mountain-plain circulation, with a north-easterly flow over the Plateau. The CBL is either clear, or with a few rare cumulus clouds. Post-frontal conditions correspond to north-westerly winds (wind direction ranges from W to N, depending on the importance of the valley-wind relatively to the meteorological wind). They are associated with more cumulus clouds, from nicely paved (cloud streets) sky to more active post-frontal situations (with more and/or deeper clouds). Fair weather can also be encountered in foehn situation (south-westerly flow over the Pyrénées mountains), but this situation is more complex and less favourable than the two other typical situations.

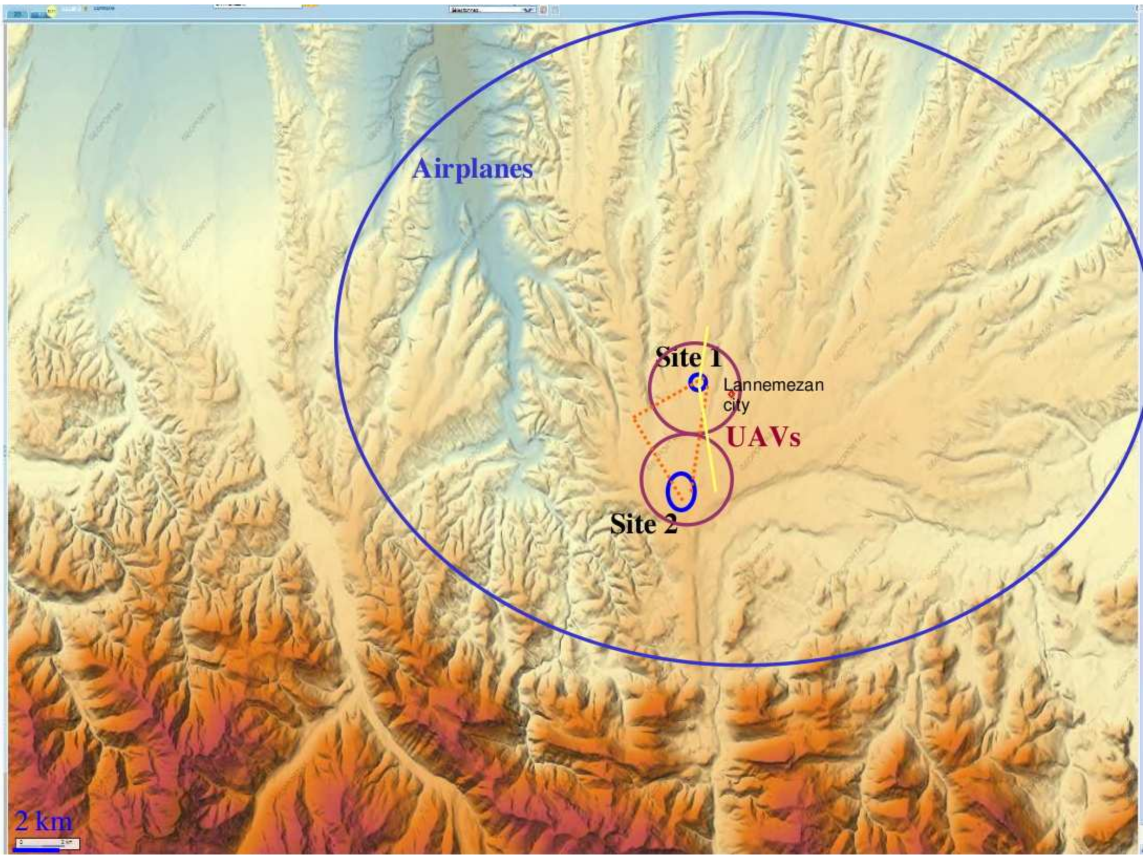


Figure 1: Relief of the experimental area, with Piémont mountains to the south, and the Plateau de Lannemezan in the north (blue circled area). Super-sites 1 and 2 are indicated, as well as the flying area probed by the manned airplanes and unmanned aerial vehicles.

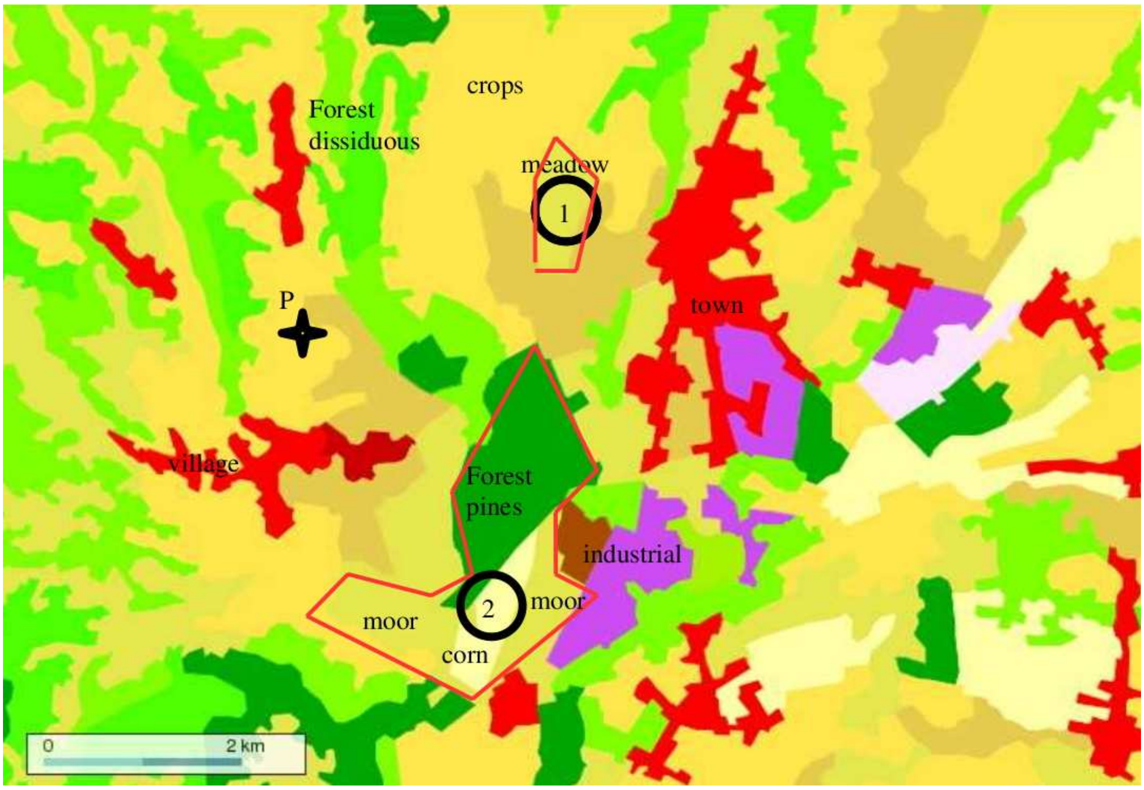


Figure 2: Land use (according to Corine classification) around the supersites.

General Strategy

The campaign will combine in situ measurements made with towers, balloons and airplanes with the remote sensing capability. The measurements will be intensified during the late afternoon transition.

Two sites (hereafter "super-site 1 and 2") will concentrate the ground-based instruments and intensive flying over operations. They are associated with two different observational strategies: **(1) vertical structure and (2) spatial heterogeneity,** respectively.

(1) In super-site 1, a sodar, UHF & VHF wind profilers, a microwave radiometer, a ceilometer, a backscatter lidar and radiosoundings will give a complete view of the mean vertical structure of the troposphere. In addition, a vertically-pointing Doppler lidar will give the structure of the vertical wind, with a resolution in time and space high enough for turbulence statistics studies and entrainment zone exploration. In situ measurement of turbulence will be made on the 60-m high tower and with a tethered-balloon-borne probe. The radiation divergence in the surface layer will be estimated on another 10-m high tower.

(2) In super-site 2, several sonic anemometers will be deployed over three adjacent surfaces (a moorland, a maize field and a forest), in order to measure the differences in the structure and evolution of the transition among different vegetated surfaces. The surface layer above the moorland and the maize field will be extensively probed by two tethered balloons, while UASs will fly low over the three surfaces.

A network of two UHF radars and one sodar wind profilers (located on super sites 1 and 2, and on a third position (site 3) that makes a triangle, see Fig. 3) will give continuous profiles of the mean wind for the study of the 3D atmospheric circulation.

Airplanes and unmanned aerial vehicles (UASs) will probe the atmosphere over both super-sites, focusing on either vertical structure or spatial variability. The two airplanes (Piper Aztec and Sky Arrow) will probe an area of a few tens of kilometres across centred around the super-sites (Fig. 1), with horizontal legs at different levels within and just above the CBL. UASs will also fly over both super-sites, at low levels when combined with the manned airplanes, and up to 2 km height otherwise.

Figure 3: Satellite picture (source: Google Earth – 2006 image) of the site.

Over the 3.5 planned weeks, we expect 10 days during which the aircraft, the UASs and the balloons (tethered and radiosoundings) will be deployed intensively, while other instruments will work continuously during the whole period. Those richly documented days will constitute real cases on which the numerical simulation will be based.

Part II – Continuous observations

Table 1 below summaries the in situ and remote sensing deployed during BLLAST over the 3 sites, for continuous observation from 14 June to 8 July.
We describe here the deployment of those instruments for the observation of (1) the surface layer processes, (2) boundary layer profiling, (3) sky monitoring, and (4) Aerosol content.

	Super site 1	Super site 2	Site 3
Instrumented Towers			
60 m tower 5 levels HR, LR wind HR, LR temperature HR, LR humidity HR, LR O_3 HR, LR CO_2 Radiation Soil moisture IR Camera	X		
Radiation Divergence 10 m tower 5 levels - radiation	X		
Skin flow 4 levels HR wind HR temperature	X		
2 m towers (*#*) 1 level Soil moisture	X		
30 m tower HR, LR wind HR, LR temperature HR, LR humidity Radiation		X	
Surface temperature probes network	X	X	
Wind profilers			
VHF wind profiler	X		
UHF wind profiler	X	X	
sodar	X		X
Lidars			
Aerosol Lidar	X	X	
Doppler Lidar	X		
Humidity Profilers			
Radiometer	X		
Scintillometry	X		
Ceilometery	X	X	
Full Sky Imagery	X		
Microbarometry	X		
Aerosols	X		

Table 1 : distribution of the continuous observation over the three sites.

The map below shows the position of the two surface super sites 1&2. Super-site 1 was especially dedicated to a thorough monitoring of the vertical structure, and super-site 2 to the surface heterogeneity study.

Figure 4: Super sites 1 and 2

- Super site 1: Thorough vertical monitoring of the first 3 km of the atmosphere
    - "Vertical monitoring" site
    - "60-m tower" site
    - "Divergence" site
    - "Edge effect" site
    - "Micro-scale surface heterogeneity" site

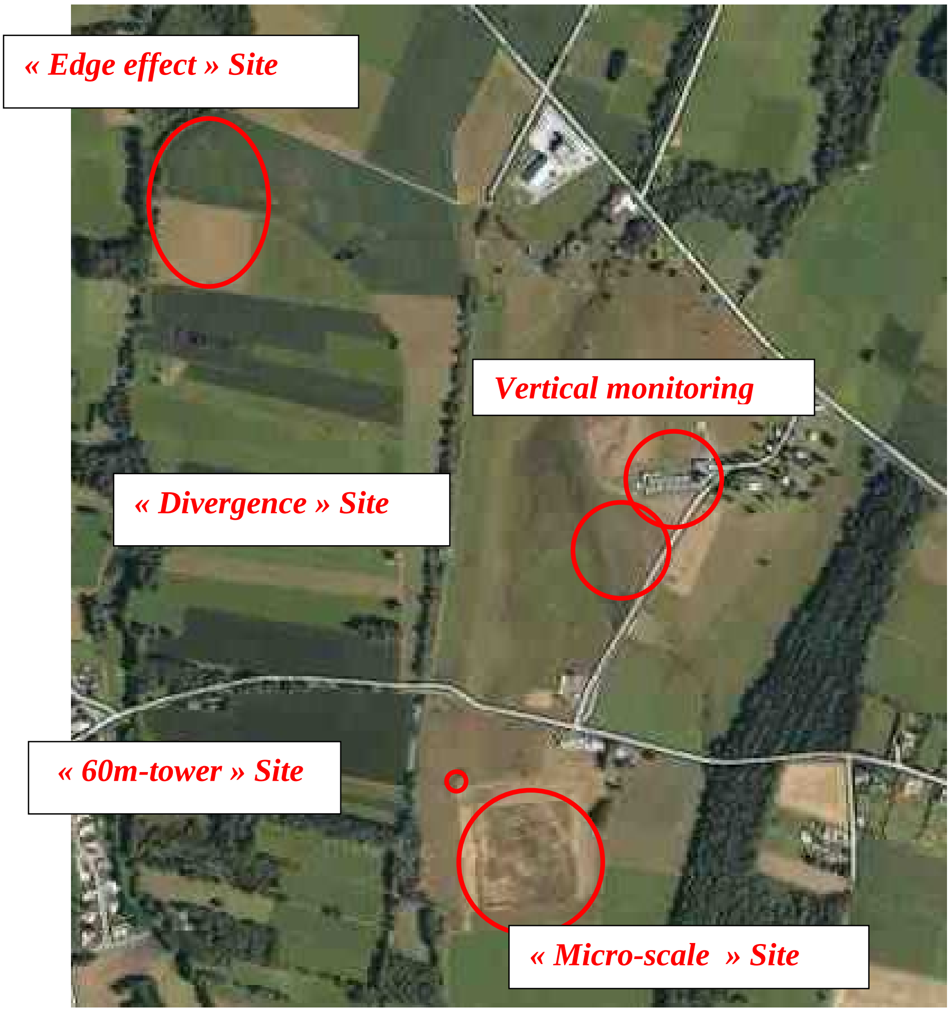


Figure 5: Location of "Edge effect", "divergence", "60-m tower" and Micro-scale surface heterogeneity sites on super site 1.

- Super site 2: Impact of the surface heterogeneity.
    - "Corn" site
    - "Moor" site
    - "Forest" site

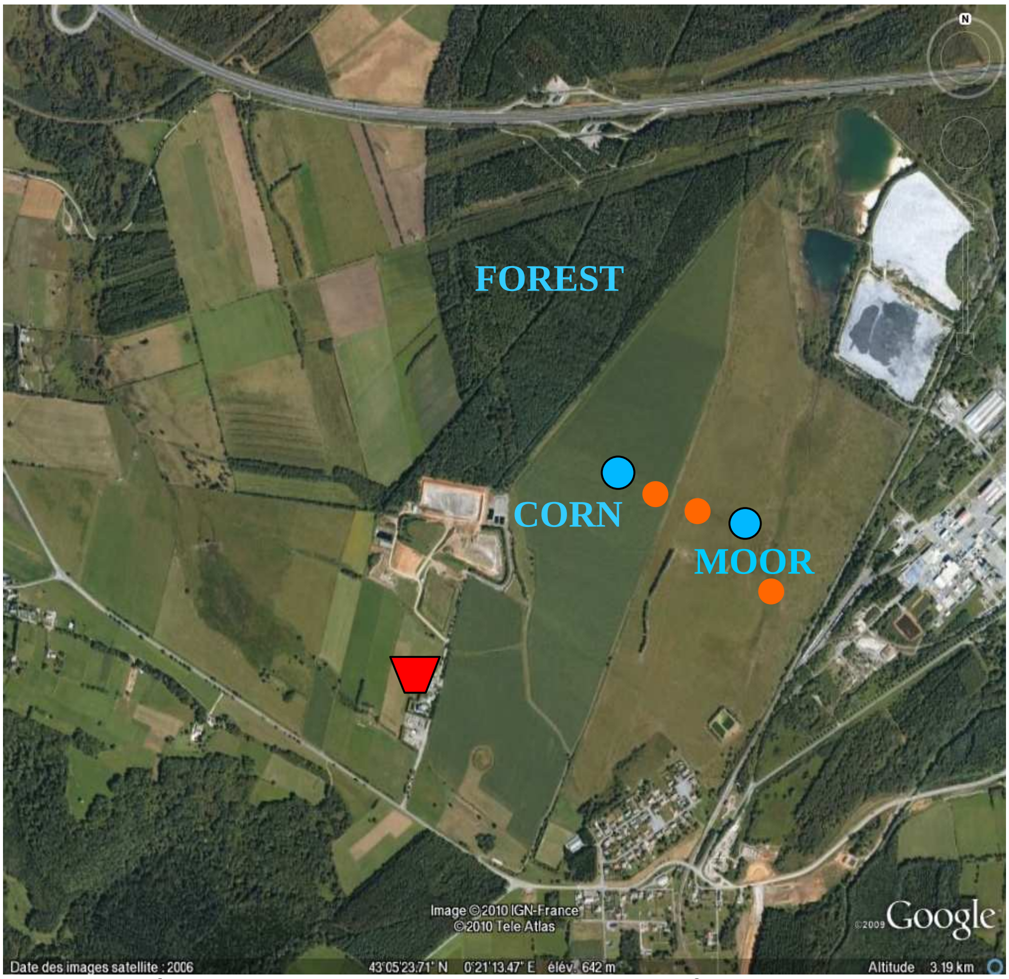


Figure 6: Surface cover types on super site 2, positioning of EC station, remote sensing and extra ground temperature probes.

EC Surface station

Remote sensing vertical monitoring

Surface Soil temperature sensors

Surface layer

- Turbulence and mean meteorological parameters

In the BLLAST experiment, 9 masts will be equipped with a total of 26 instruments measuring turbulence. Measured properties are: wind, temperature, CO_2 concentration and water vapour concentration. The first aim of all the stations is to get a clearer picture of the fluxes in the diverse landscape that is the BLLAST experimental site and integrated in the airborne measurements. Beyond this purpose, most of the surface stations are implemented to also deal with other objectives.

- The southern Corn, moor and forest EC-stations will sample three contiguous large areas with relatively homogeneous vegetation . The moor site has some heterogeneity in the vegetation, but this is uniform throughout the field. These three sites are devoted to study the impact of surface heterogeneities on the late afternoon transition. The surface energy balance time-shift between the different vegetation cover and the secondary circulation between the fields during this phase of the day will be investigated. The EC-data here are complemented with tethered balloons and unmanned aircraft data. In addition, the forest site tower will be instrumented at two levels, just above the canopy and 5 meters above, to study the flow near the canopy.

- The Micro-site main focus is the small surface heterogeneities study. Over a 100m square flat surface, bare soil, small bushes, grass, and small puddles constitute a very heterogeneous surface whose soil characteristics (temperature, humidity) will be extensively mapped. Added to the Ec-station, the temperature vertical profile up to 1.5m will be measured.

- The 60m mast is equipped with quick (10Hz) sensors at three levels. With this mast, a vertical profile can be made in and above the surface layer. This mast is a permanent platform at the CRA and provides year-round flux-data.

- The Skinflow-mast is a 10m high mast equipped with a total of 6 sonic anemometers. The aim of this set-up is to investigate near-surface divergence of the sensible heat flux. The lowest sonics are at a height of less than one meter. Complimentary to the sonic anemometers is a set of fast thermocouples, close to the ground. A twin tower will be settled near the skinflow-mast to measure the radiative divergence.

- At the edge site, a set-up of three masts, all equipped with sonic anemometers and fast water vapour and CO_2 sensors, is used to validate a flux-footprint model. Two stations will be set up in a grass and wheat field respectively and one station will be located at the edge. With a model that includes the land-uses in the surrounding area, representative fluxes can be reconstructed.

The following table presents the vegetation cover, the site latitude, longitude and height above the sea level and the properties measured at all EC-station.

Site name	Land use	Latitude (N) Longitude (E)	Height ASL [m]	Properties measured
Corn (Site 2)	Corn	43° 05′ 24″ 0° 21′ 30 ″	645±5	Temperature, wind, H_2O, CO_2, pressure, radiation, rain, soil temperature, soil humidity, soil heat flux
Moor (Site 2)	Mixed moor-like vegetation	43° 05′ 24″ 0° 21′ 42″	641±3	Temperature, wind, H_2O, CO_2, pressure, radiation, rain, soil temperature, soil humidity, soil heat flux
Forest (Site 2)	Douglas Spruce		620	Temperature, wind, H_2O, CO_2, pressure
60-m tower (Site 1)	Mixed	43°07'27.15" 0°21'45.33"	602	Temperature, wind, H_2O, CO_2, pressure, radiation
Micro (Site 1)	Grass and shrubs	43° 07′ 26″ 0° 21′ 51.3″	601	Temperature, wind, H_2O, CO_2, pressure, radiation
Skinflow (Site 1)	Grass	43°07′39.2″ 0°21′57.4″	591±5	Temperature, wind

Edge (Site 1)	Wheat, rhye and peas	43°07’56.0” 0°21’37.3”	582	Temperature,wind,H_2O, CO_2, pressure, wet-bulb-temperature, soil temperature, soil humidity, soil heat flux
	Grass	43°07’52.5” 0°21’33.9”	581	Temperature,wind,H_2O, CO_2, pressure, wet-bulb-temperature, soil temperature, soil humidity, soil heat flux
	Mixed	43°07’53.4” 0°21’35.2”	581	Temperature, wind, H_2O, CO_2, pressure

- Radiation 10 m tower

The BLLAST field campaign focuses on the improved understanding of evening transition of the atmospheric boundary layer. During the transition, the radiation balance, defined as follows (*K* being the shortwave and *L* being the longwave part of the spectrum in Wm^{-2}),

$$Q = K^{\downarrow} - K^{\uparrow} + L^{\downarrow} - L^{\uparrow} \quad ,$$

changes drastically, and net radiation is most negative just after the transition.

In addition, a series of recent studies has shown that apart from turbulent flux divergence, the divergence of longwave radiation is a substantial contributor to the heat budget ($\frac{\partial \theta}{\partial t}$) close to the ground during the evening transition (Ha and Mahrt, 2003; Savijarvi, 2006; Steeneveld et al, 2010),

$$\frac{\partial \theta}{\partial t} = -\frac{\partial \overline{w\theta}}{\partial z} - \frac{1}{\rho C_p}\frac{\partial L_{net}}{\partial z}$$

Some of these studies report even up to 3 Kh^{-1} of radiative cooling during transitions after clear skies calm summer days. At the same time, it is realised that atmospheric models have limited skill in the transition during low winds. In order to get a complete overview of the boundary layer heat budget, longwave radiation divergence need to be observed. Also, model skill of operational mesoscale models for longwave radiation divergence can be aiming at identifying model biases.

Objectives

-To measure the radiation balance at the surface.

-To measure radiation divergence, and examine its relative contribution in the heat budget.

Field activities

The field activities consist of two contributions, one by Wageningen Univ. (Netherlands, WUR from now on) and one by the Physikalisch-Meteorologisches Observatorium in Davos, World Radiation Center (PMOD/WRC, Switzerland.

WUR will deploy a tower instrumented by 5 levels of up- and downwelling longwave radiation. Instruments, Hukseflux IR02 pyrgeometers, will be installed at 8, 5, 2, 1, 0.5 m. This instrument has the advantage that it is equipped with heating, avoiding effects of dew deposition at night. Grass below the instruments should be kept relative constant and short (~3-10 cm). Research has shown that in order to measure flux differences between different levels, the radiometers need to be calibrated relative to each other. Therefore, the instruments will be installed for at least one month at the same height. This will be done before or after the BLLAST experiment at the Wageningen observatory.

➢Microbarometers-Sonic

During the BLLAST field campaign (14 June to 8 July), three microbarometers PAROSCIENTIFIC (Model 6000-16B) will be deployed in supersite 1 (See Fig. 7). The configuration will be forming a triangular array of 150m aprox. and at 1m a.g.l.. In order to avoid contamination from wind speed, static pressure ports (GILL 230-61002) are connected to the microbarometers, so that almost all the dynamic perturbation produced by the wind is filtered. These high precision digital instruments can detect very small pressure perturbations, of the order of thousandths of hPa. During BLLAST, a sampling rate of 2Hz is chosen as a compromise between having a good temporal resolution and registering small enough pressure perturbations (with this sampling rate the resolution is around 0.002 hPa).

The objective is to study the small scale static pressure fluctuations produced in the atmospheric boundary layer. These fluctuations can be due to turbulent motions (high frequency) and also to the propagation of waves of different types (gravity waves, Kelvin-Helmholtz instabilities, etc), produced by different mechanisms such as orographic forcing, fronts, convective forcing, geostrophic adjustment, shear instability, etc. The typical amplitudes of the pressure fluctuations related to waves is in the range of 0.01-0.1 hPa with a periodicity ranging from 1 to 40 minutes, although some episodes of intense mesoscale gravity waves with amplitudes up to 2-3 hPa have been reported.

The array configuration of the three microbarometers can be used during specific periods of the field campaigns, to detect and characterize wave events by means of lag analysis, cross-correlation or methods based on wavelets decompositions (wavelength, phase speed and direction of propagation of these waves can be evaluated).

Additionally, an Ultrasonic Wind Sensor, uSonic-3 Scientific (previously USA-1) (METEK) will be deployed above the Microbarometer A, at z=2.4m agl measuring the 3 velocity components (u, v and w) and sonic temperature (T) at 20 Hz sampling rate.

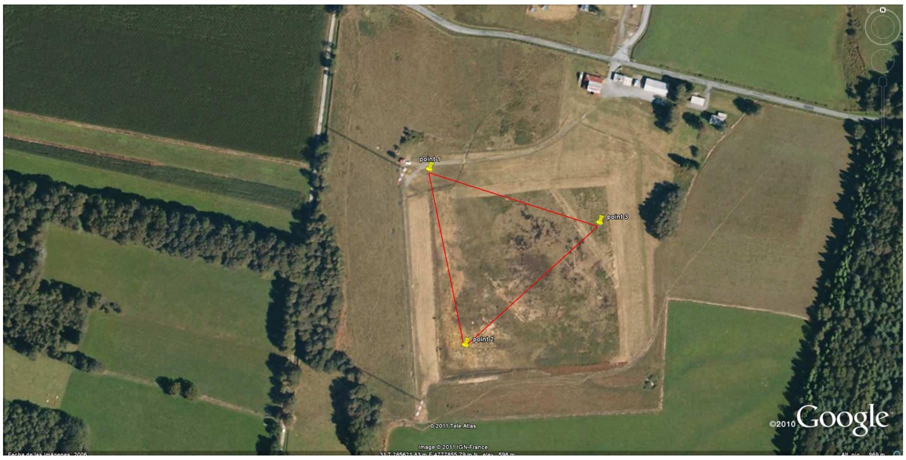


Fig. 7: Deployment of the microbarometers array in BLLAST (site 1)

➢Scintillometers

Scintillometers allow us to measure heat fluxes along a path which separates the emitter from the receiving telescope. The fluxes result from eddies which are crossing the path along a given time window. Thus, it is an integrated measurement of surface fluxes.

Three scintillometers will be settled during BLLAST:
1/ On the "edge site" at site 1, a mini-scintillometer from MAQ (University of Wageningen), installed from one field to the other, with a 40 m path across the edge.

2/ Another 3 km path scintillometer from MAQ was installed between the top of the church of Campistrous and the roof of site 1 main building.

3/ A large aperture scintillometer will be installed by Météo-France GAME/GMEI, between the cheminée of the KNOF industry company and the roof of site 1 main building, 4 km apart one from the other.

Boundary layer profiling

Wind profilers (sodar, UHF, VHF)

At site 1, the combinaison of a sodar (MAG, measuring the wind from 10 m to 300 m a.g.l), UHF profiler (LA, measuring the wind from 200 m to 3000 m a.g.l) and a VHF profiler (LA, measuring the wind from 1.5 km to 16 km a.g.l) is covering the whole atmospheric column.
The sodar is mobile, and will potentially be moved for some IOPs at the entrance of the main valley nearby, for the knowledge of the wind reversal in this valley.

A network of 3 profilers (LA UHF in site 1, CNRM UHF in site 2, and LPCA sodar in site 3 at Capvern) will enable to estimate the 3D wind at the scale of the Plateau. Both the UHF and the sodar profiling systems can also measure some characteristics of the atmospheric turbulence. The UHF wind profiler also gives estimates of the height of boundary layer top inversion, or of other strong vertical gradients in the atmosphere.

Doppler lidar

In collaboration with LMD-IPSL, a LEOSPHERE Doppler lidar (Windcube 200) has been operated in site 1 during the BLLAST experiment. It measured the vertical velocity of the wind at high temporal (5 s) and vertical (50 m) resolutions. This enables us to make wind vertical velocity statistics, to analyse the structure of the thermals and calculate the vertical velocity integral scales and the intensity of turbulence during the afternoon transition.

Aerosol lidar

There will be one aerosol lidar on each of site 1 (LPCA) and site 2 (CNRM/GAME), monitoring the aerosol backscatter structure continuously during BLLAST.

Sky monitoring

Total sky

A full sky camera in site 1 (LA, RAPACE instrument) will take pictures of the entire sky every one min, for qualitative monitoring of the cloud cover.

Ceilometer

A ceilometer from CRM/GAME will be collocated with the full sky camera, for a quantitative monitoring of the cloud base.

Aerosol Size Measurements

An Optical Particle Counter and a Scanning Mobility Particle Sizer (SMPS) will be installed on super-site 1 (from 15/06 to 08/07) by LPCA-ULCO. They provide the particle-size distribution and number of particles per air cubic meter, from 10 nm to 20 µm.

Part III – Intensive observations

When the conditions are favorable, intensive observations will be made with manned aircraft, unmanned aerial systems (UAS), tethered and radiosounding balloons, and in situ aerosol measuring system. The airplanes (Piper Aztec and Sky Arrow) and UAS will probe an extended area, with horizontal legs at different levels for the measurement of turbulence intensity and scales.

The potential favorable conditions are fair weather, dry convection during the day, expected clear sky or fair weather cumulus during the afternoon and evening transitions, with light to moderate winds. Those correspond to anti-cyclonic conditions (mountain-plain breeze regime), post-frontal conditions, low pressure gradient conditions, … Frontal systems and strong foehn events are unfavorable.

Over the 3.5 planned weeks of field campaign, we expect/hope for 10 days of good conditions, during which the aircraft, the UASs and the balloons will be deployed intensively. Those days will be classically called Intensive Observing Periods (IOP).

Balloons

	SITE 1	SITE 2
Radiosoundings		
Standard radiosoundings – max 20 km	X	
Frequent radiosoundings – max 2 km		X
Tethered balloons		
Univ. of Utah Balloon 1 / 5 levels LR wind, temperature, humidity		X
LA Balloon 2 / 5 levels LR wind, temperature, humidity		X
CNRM/GAME Balloon 3 / 1 level HR wind, temperature, humidity	X	

Radiosoundings

The radiosoundings remain the reference for an absolute measurements of the wind, humidity and temperature along a vertical profile of the atmosphere. They give the mean structure of the atmosphere.

Standard radiosoundings

Standard MODEM (LA) and GS-H (UC Davis) radiosoundings will be launched during the IOP days at least, and potentially more days 4 times per day at 6, 12, 18, 24 UTC, and assimilated by the Météo-France forecast models. During the first week, the University of Bonn will help in the operations of the radiosoundings in site 1 (GRAW radiosondes).
Those standard radiosoundings will give the mean structure of the entire troposphere (up to 20 km height) along an entire diurnal cycle. If the number of radiosondes allows it, more than four soundings per day will be launched. On some events, an attempt of estimating the sub-mesoscale divergence will be done by launching simultaneously 3 balloons on three sites (the three sommits of the profiler triangle, super-site 1, super-site 2 and site 3).

Frequent radiosoundings

A new technique used by Météo-France/GAME/GMEI will be used for frequent soundings of the lower troposphere only, during the late afternoon transition. By use of 2 balloons, those are ascending up to about 2 km height, and then go back down to the ground. A model allows to predict the landing area, and helps the decision of release. The probe, protected by a structure, is re-used after a sounding for a future sounding. The time interval planned is 1 hour or 1.5 h between two soundings.

Tethered balloons

Tethered balloons are used with similar probes than with radiosoundings, except that the probes also have a cup-anemometer for the wind measurements. Those probes are hanged to the wire that keeps the balloon linked to the ground. There will be 3 tethered balloons operating during the late afternoon of IOP days, from 14h to 21 UTC.

The CNRM balloon will be equipped with one newly developed turbulence probe, and operated at site 1. The probe will be fixed at a given height, slight above the 60 m tower, or in the vicinity of the inversion and entrainment zone, when the boundary layer depth and the wind allow it.

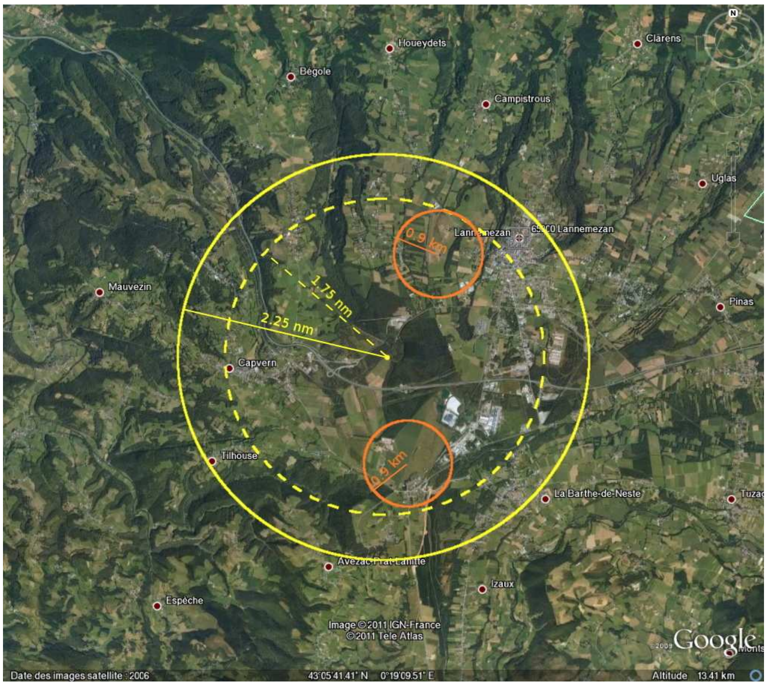
Two other tethered-balloons (from LA and the University of Utah, also with help of the University of Bonn for the first week) will be operated on site 2, over 2 different surfaces (the maize field and the moor field), with 5 to 6 usual TTS probes below them, hanged at 5-6 different levels. They measure the mean meteorological variables at 1 s interval when they are single, and about 8 s time interval if 6 probes are used.
Most of the time, the balloon will be alternatively fixed at a low height (about 150 m a.g.l), or sounding vertical profiles if the wind allows it.
The goal is to evaluate the impact of the surface heterogeneity on the surface layer vertical structure.

Unmanned Aerial Vehicles

Introduction

The UASs have shown in the recent years their ability to probe the Atmospheric Boundary Layer. Some scientific teams have a relatively long experience and some others are coming now into this fastly growing field of activity. In BLLAST experienced and new teams will participate either during the whole campaign or in the special period at the end of the campaign.

The restriction of flying in sight limits the horizontal range of operation of the UASs. The Temporary Restricted Airspace (TRA) reserved for BLLAST covers Sites 1 and 2 and has a vertical extend of 7500 feet (see Figure below). The area is a 2.25 nm radius cylinder, centred on N 43°6′18′′, E 0°21′6′′, and of 7500 ft height a.g.l. However the maximum height that a UAS system can reach depends on the authorization provided by the French aviation authority and is a function mainly of the previous expertise of the operating team and of the flight hours of the platform. Besides, when aircrafts will be in operation over the area, UASs will be restricted to fly below 2500 ft QNH feet and the aircratf above 3000 ft QNH. A coordinator of UASs operations will be in charge of organizing the flight schedule of UASs.



Three teams will operate during the whole campaign, those of the Universities of Tübingen (Bange/Kroonenberg), Braunschweig (Martin/Aschenbrenner) and Bergen (Reuder/Jonassen). The first two are suited for flying relatively long well levelled legs, allowing for the computation of means and fluctuations, from which estimation of turbulent covariances can be obtained. The latter uses the small

UAS SUMO, mainly used for profiling up to some thousands of meters, but lately also for flying legs at lower heights than the other two systems.

The last days of BLLAST comprise a special period for UASs testing and inter-comparison. The participating teams may contribute to the general objectives of the experiment. They will be centered in Site 1. A small multicopter and a fixed wing plane will be operated by the University of Lippe (HSOWL). The University of Bremen will use a fixed wing and may bring a multicopter. The University of Heidelberg will test their new plane intended to measure surface properties. Finally the Technical University of Zurich will test their new UMARS which will measure atmospheric variables and gases.

Below is a complete list of the UAS which will fly during BLLAST:

	institute	Contact PI	airframes	max. tow
1	University of Bergen Geophysical Instiyute	Joachim Reuder joachim.reuder@gfi.uib.no ++47 47381397	3 SUMO	0.6 kg
2	Technical University Braunschweig Institute of Aerospace Systems	Sabrina Martin sabrina.martin@tu-bs.de	1 M^2AV	5 kg
3	University of Tübingen Environmental Physics	Aline van den Kroonenberg aline.van-den-kroonenberg@uni-tuebingen.de	1 MASC	5 kg
4	University of Applied Sciences Ostwestfalen-Lippe Department of Environmental Engineering and Applied Computer Sciences	Burkhard Wrenger burkhard.wrenger@hs-owl.de	octocopter	1 kg
5	University of Applied Sciences Bremen	Heinrich Warmers hwarmers@hs-bremen.de	1 Fun-Jet	0.6 kg
6	ENAC	Catherine Ronfle-Nadaud catherine.ronfle-nadaud@enac.fr	1 quadrotor	0.45 kg
7	University of Heidelberg Institute of Environmental Physics	Cornelius Claussen cornelius.claussen@mavinci.eu +49 175 6944518	1 SiriusII or 1 Multiplex Mentor	<5kg

Flying strategy:

Depending on the situation, several UASs may fly simultaneously, or one after the other. The flying strategy will also depend on the aircraft strategy, as both airplanes have to be combined securely in space and time. We can divide the flight strategy into three kinds: (1) horizontal exploration, (2) vertical structure exploration and (3) soundings. Repeated legs at same height and on same axis by the same UAS will give a very interesting information about the evolution of turbulence along this leg. So repeated missions along the day will be favoured.

(1) Vertical structure exploration

Corresponding to (and possibly simultaneously with) the aircraft vertical structure mission, there will be one mission with stacked legs: 2 to 3 UASs will fly together the same axis, one on top of each other. When the aircraft will be flying above, the 3 UASs will focus on the lowest atmosphere, below 2500 ft QNH, and will be able to extend their vertical exploration the rest of the time.

(2) Horizontal Exploration

Corresponding to (and possibly simultaneously with) the aircraft horizontal variability, there will be a second mission with parallel axis flown by 2 to 3 UASs together.

The SUMO can make dense horizontal exploration 60 above ground, with measurements of the surface temperature, allowing the mapping of surface temperature above the two super sites. SIRUS II, with the same kind of flight, will make very high resolution visible images of the surface from above.

Multicopters will have similar flight strategy at smaller scale, flying a few m only above the ground. At the small scale heterogeneity site especially, the multicopter operated by the team of the University of Lippe (HSWOL) will fly transects over the square at selected levels (starting at 2m) and provide profiles below 100 m above ground level. The information that will be provided will be air temperature and humidity and surface temperature. This team will operate from June 27 to July 8.

(3) Sounding

SUMO UAS is able to make soundings up to the top of the TRA within 15-30 min. It will be one of the missions of the SUMO to make frequent soundings of the atmosphere.

<u>The UAS COST campaign</u>

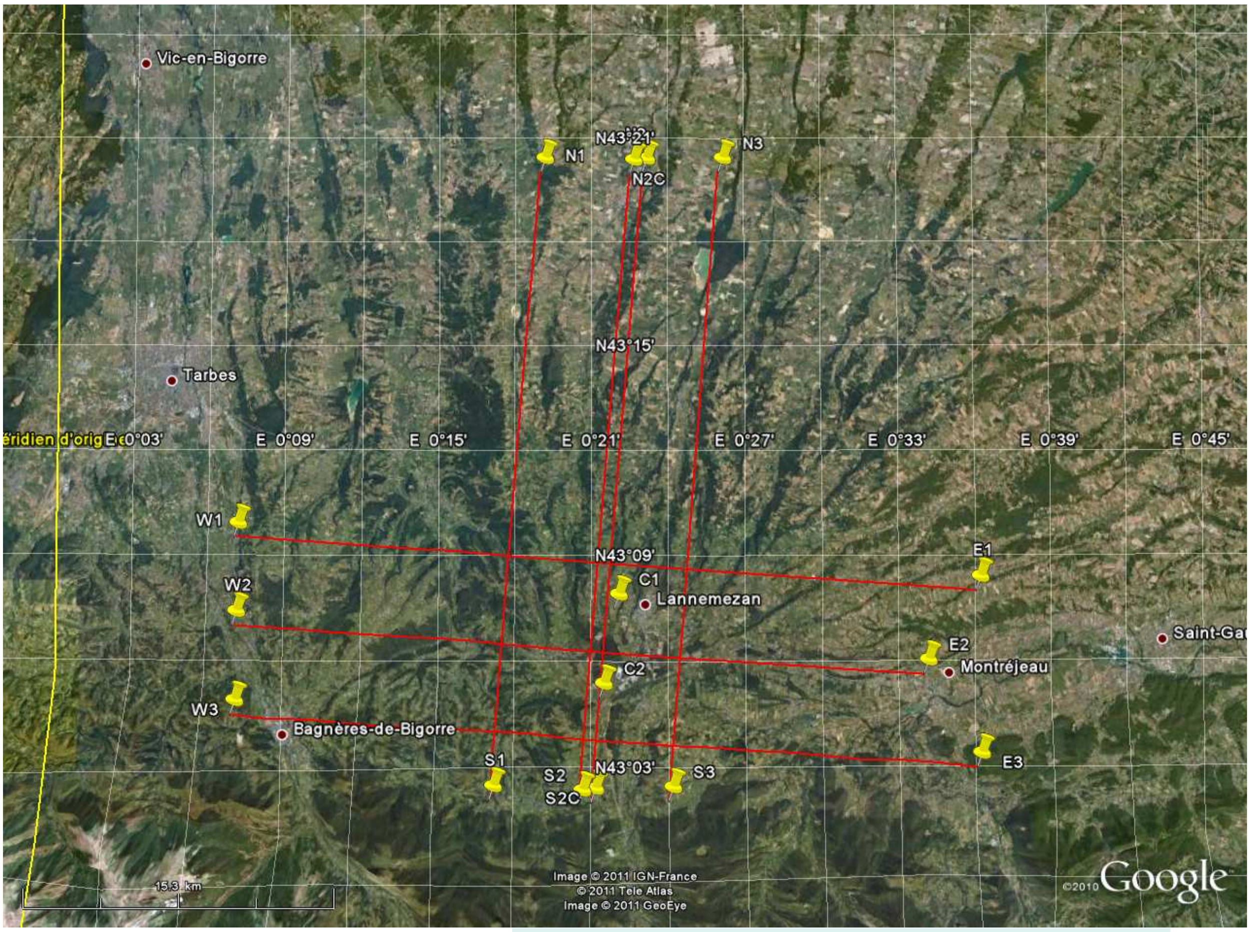
From July 1 to 8, the morning hours before BLLAST IOPs (which will start at 14h official local time) are free time to proceed to special tests devoted to UASs operation. Intercomparison flights between drones, special flight strategies of one or more systems, testing instrumentation using other reference data (ballon, tower, profilers, surface instrumentation). The interaction between teams is expected to be very beneficial for all.

During the IOP time, the participating teams can join the common effort and participate in the different aspects of the BLLAST.

Aircrafts

Aircraft are invaluable tools in atmospheric measurement campaigns since they are able to capture high-rate fluctuations as well as horizontal and vertical variation of mean parameters, like temperature, moisture and wind. Given the BLLAST objectives, the aircraft will mainly fly in the middle-to-late afternoon, in close coordination with ground-based instruments (flux stations and remote sensing devices), tethered balloons, and, when possible, unmanned airborne systems. Two aircraft were chosen to contribute to BLLAST: The French Piper Aztec from SAFIRE, and the Italian Sky Arrow from Ibimet and Isafom. Both are equipped for turbulence measurements, and offer a good cost-performance compromise. A part of their operation is funded by the European EUFAR programme, in the frame of two BLLAST side-projects: BLLATE1 for the Piper Aztec, coordinated by D. Pino (Barcelona Tech, SP), and BLLATE2 for the Sky Arrow, coordinated par J. Vila (University of Wageningen, NL). The remaining part is funded by French scientific research agency (CNRS) and the University of Toulouse (France).

Different flight strategies have been elaborated, according to the objectives and the aircraft availability: The Sky Arrow will participate to the campaign from June 14 to June 26, whereas the Piper Aztec will be on filed for the whole period (up to July 8). Furthermore, the two aircraft present some differences, the Piper Aztec flying at 70 m/s, i.e. ~ 30 m/s faster than the Sky Arrow. For an identical time of flight, the former thus explores an area larger than the latter does, but offers a coarser resolution (assuming an identical instrumental performance), and a poorer maneuverability for the evolutions at the lowest heights. The flight plans are drawn to capture horizontal heterogeneity, vertical structure, size of the (coherent) eddies and their (non-) isotropy, and time evolution. The levels of horizontal runs are often dependent on the thickness of the boundary layer, which in general will be determined from a vertical sounding at the beginning of the flight.



The main flight axes are represented in the figure above. The coordinates of the axes extremities are given in the opposite. S2C-N2C axis crosses the two supersites, whereas S3-N2 axis is equally distant from the two other S-N axes.

N1	N2	N2C**	N3
43°20' N	43°20' N	43°20' N	43°20' N
00°19' E	00°22.5' E	00°23' E	00°26' E

BLLAST waypoints

W1	43°09.5' N, 00°07' E
W2	43°07' N, 00°07' E
W3	43°04.5' N, 00°07' E

E1	43°08' N, 00°36' E
E2*	43°05.6' N, 00°34' E
E3	43°03' N, 00°36' E

S1	S2	S2C**	S3
43°02' N	43°02' N	43°02' N	43°02' N
00°17' E	00°20.5' E	00°21' E	00°24' E

* *E2 has been shifted by 2 nm to the west to avoid the « Saint-Gaudens – Montréjeau » airfield area*

** *S2C-N2C axis crosses the supersites C1 and C2*

The use of combined data from the two aircraft requires they are able to give same values if they measure the same parameters at the same place and time. This requires calibration and intercomparison maneuvers. As often as it could be done, a run on the same track, at the same altitude and at close times will be done by the two aircraft somewhere between the airport/airfield area and the BLLAST flight area. Furthermore, one dedicated intercomparison flight can be envisaged during the campaign, with common figures at close times (spiraling sounding, few straight and level runs in two orthogonal directions). However, wing-to-wing maneuvers cannot be realized due to the airspeed difference between the two aircraft.

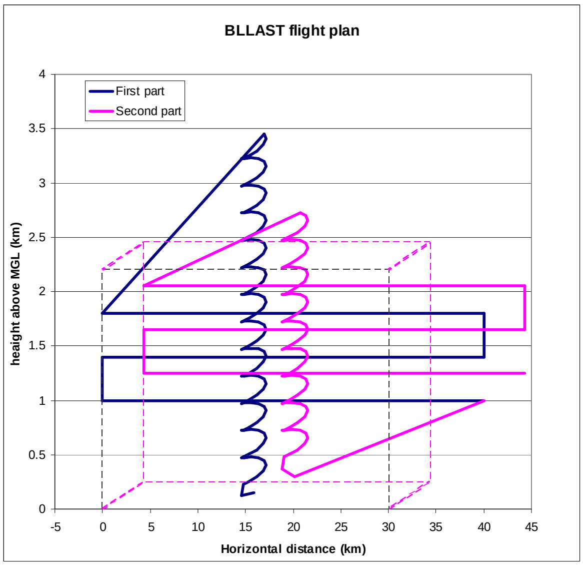
The flight plans are presented in the sections below. They are generally built on stacked runs in vertical planes and spiraling profiles. In addition, simpler patterns like flying a single repeated track for a large number of passes to maximize the sample size, and then examine the sampling problem and better isolate the influence of surface heterogeneity, are also envisaged.

Piper Aztec

The Piper Aztec owns to Météo-France and is operated by the service SAFIRE. It measures along its flight track the pressure, temperature, moisture, CO_2 concentration and 3-D wind with a spatial resolution of few meters. Its endurance is 2.5 hours (see the detailed description in Part VIII). During BLLAST, it will be based at the Tarbes-Lourdes international airport (LFBT). A time of flight of up to 2 hours can be devoted to measures in the domain of interest for BLLAST. All the flights will be realized under the visual flight rules (VFR), but LFBT is equipped for VFR landing after sunset, which is an advantage given the interest of BLLAST for the evening period. Below are the Piper Aztec flight plans.

Flight plan Nr 1 – « parallel » - Piper Aztec
FP1par.-PA

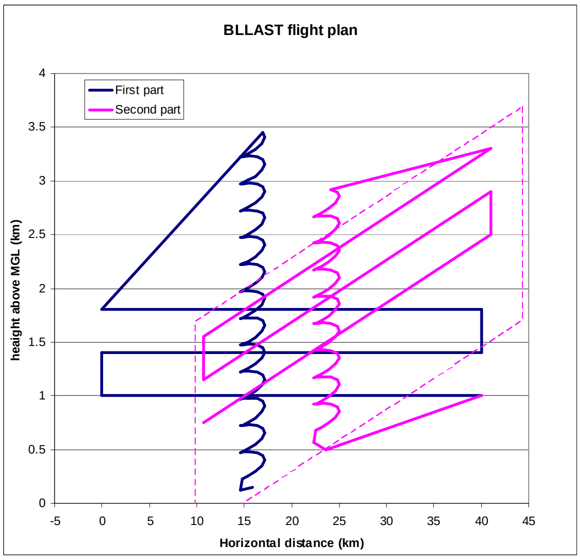
In two vertical (W-E or S-N) plans
In plan P1:
vertical sounding up to FL 100
3 stacked level runs (35-40 km length) in the upper half of the boundary layer, the level of which depending on the inversion height
In plan P2:
same pattern (sounding and stacked runs) in a second parallel vertical plan
Simultaneous Sky Arrow flight (FP1par.-SA)



Flight plan Nr 1 – « perpendicular » - Piper Aztec

FP1per.-PA

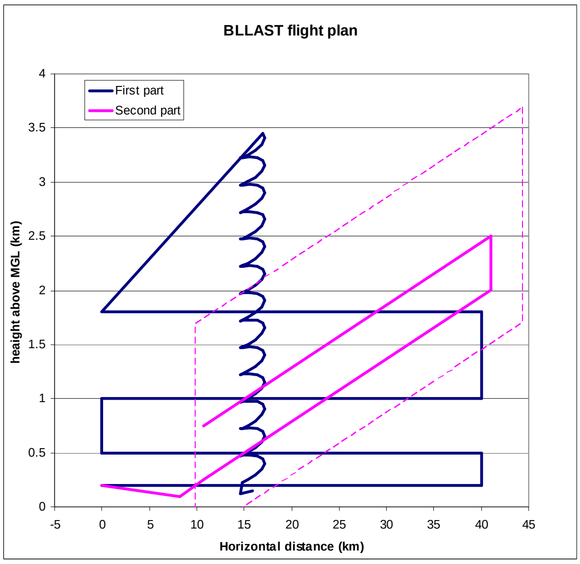
In two vertical and perpendicular plans
In plan P1:
vertical sounding up to FL 100
3 stacked level runs (35-40 km length) in the upper half of the boundary layer, the level of which depending on the inversion height
In plan P2:
same pattern (sounding and stacked runs) in a second perpendicular vertical plan
Simultaneous Sky Arrow flight (FP1per.-SA)



Flight plan Nr 2 – Piper Aztec

FP2-PA

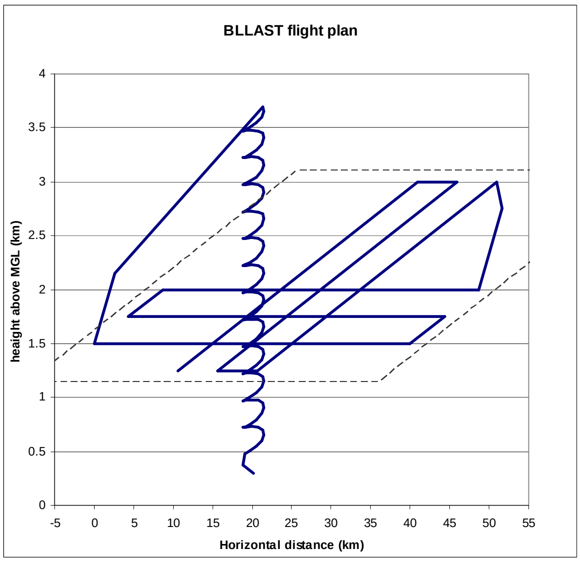
In two vertical and perpendicular plans
In plan P1:
vertical sounding up to FL 100
4 stacked level runs (35-40 km length), the uppermost close to the inversion level
In plan P2:
2 stacked level runs (35-40 km length)
The Sky Arrow does not fly in the same time



Flight plan Nr 3 – Piper Aztec

FP3-PA

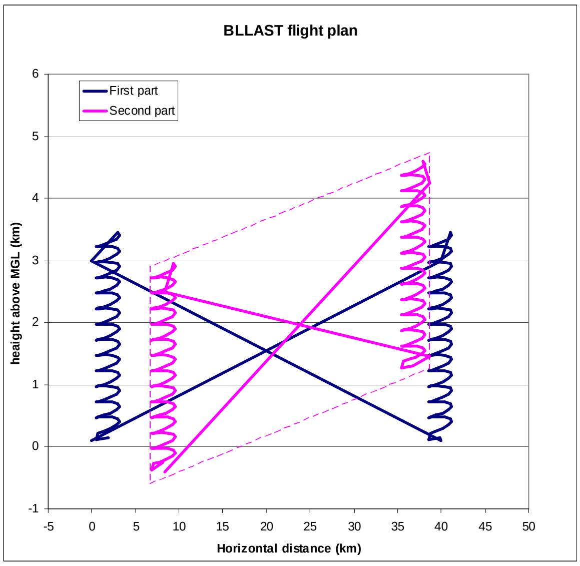
Vertical sounding up to FL 100
In a horizontal plan in the middle of the boundary layer:
3 parallel straight runs (35-40 km length)
3 straight runs (35-40 km length) in the perpendicular direction
Possible simultaneous Sky Arrow flight (FP3-SA)



Flight plan Nr 4 – Piper Aztec

FP4-PA

In two vertical and perpendicular plans
In plan P1:
Vertical sounding up to FL 100 at one extremity of the plan
Straight descent towards the lowest level at the other extremity of the plan (35-40 km apart)
At this point, vertical sounding up to FL 100
Straight descent towards the lowest level at the other extremity of the plan
The same sequence is repeated in a the second, perpendicular plan P2
The Sky Arrow does not fly.



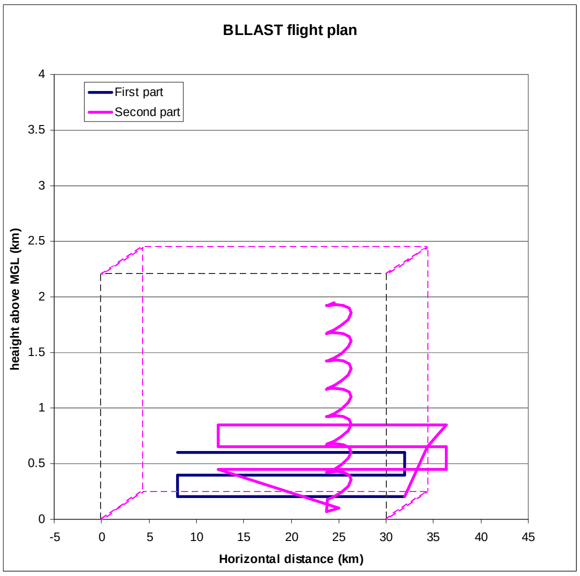
Sky Arrow

The Sky Arrow owns to Ibimet and Isafom and is operated by VALAR company. It measures along its flight track the pressure, temperature, moisture, CO2 concentration and 3-D wind with a spatial resolution of ~ 1 m. Its endurance is 2.5 hours (see the detailed description in Part VIII). During BLLAST, it will be based at the Tarbes-Laloubère airfield (LFDT). A time of flight of up to 2 hours can be devoted to measures in the domain of interest for BLLAST. All the flights will be realized under the visual flight rules (VFR), LFDT being not equipped for VFR landing after sunset. Below are the Sky Arrow flight plans.

Flight plan Nr 1 – « parallel » - Sky Arrow

FP1par.-SA

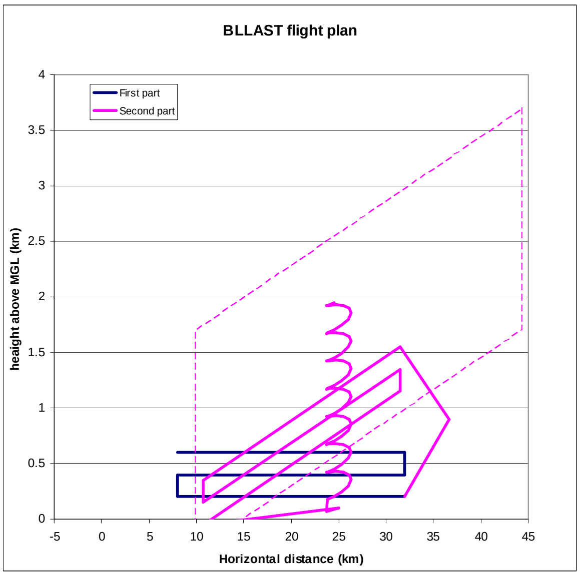
In two vertical (W-E or S-N) plans
In plan P1:
3 stacked level runs (~ 25 km length) in the lower half of the boundary layer
In plan P2:
same pattern (stacked runs) in a second parallel vertical plan, followed by a vertical sounding up to ~ FL 60
Simultaneous Aztec flight (FP1par.-PA)



Flight plan Nr 1 – « perpendicular » - Sky Arrow

FP1per.-SA

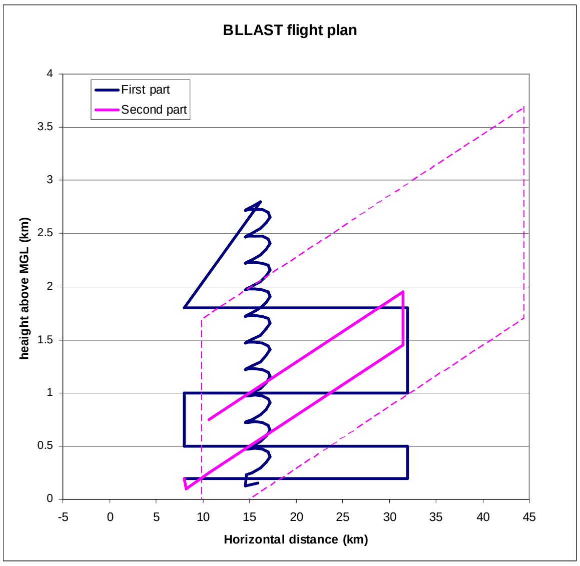
In two vertical and perpendicular plans
In plan P1:
3 stacked level runs (~25 km length) in the lower half of the boundary layer
In plan P2:
same pattern (sounding and stacked runs) in a second perpendicular vertical plan, followed by a vertical sounding up to ~ FL 60
Simultaneous Aztec flight (FP1per.-PA)



Flight plan Nr 2 – Sky Arrow

FP2-SA

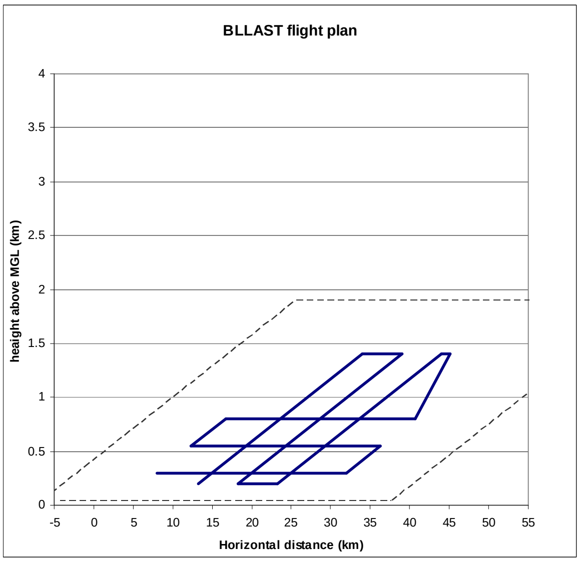
In two vertical and perpendicular plans
In plan P1:
vertical sounding up to ~ FL 70 (overpassing the inversion level)
4 stacked level runs (~25 km length), the uppermost close to the inversion level
In plan P2:
2 stacked level runs (~25 km length)
The Piper Aztec does not fly in the same time



Flight plan Nr 3 – Sky Arrow

FP3-SA

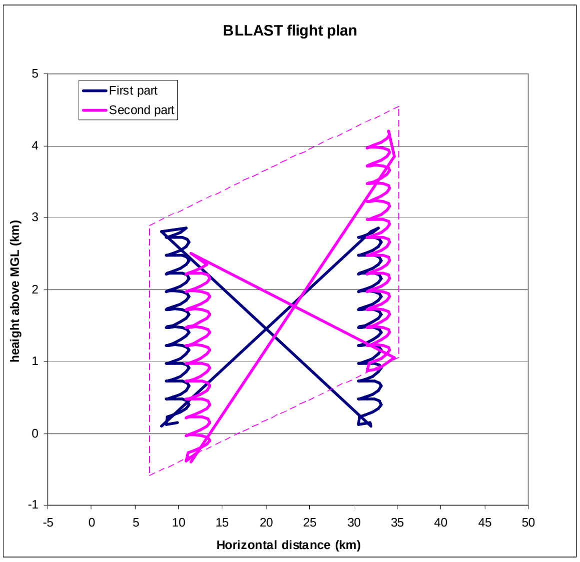
In a horizontal plan in the lower half of the boundary layer:
3 parallel straight runs (~25 km length)
3 straight runs (~25 km length) in the perpendicular direction
Possible simultaneous Aztec flight (FP3-PA)



Flight plan Nr 4 – Sky Arrow

FP4-SA

In two vertical and perpendicular plans
In plan P1:
Vertical sounding up to ~ FL 70 (overpassing the inversion level) at one extremity of the plan
Straight descent towards the lowest level at the other extremity of the plan (~ 25 km apart)
At this point, vertical sounding up to ~ FL 70
Straight descent towards the lowest level at the other extremity of the plan
The same sequence is repeated in a the second, perpendicular plan P2
The Piper Aztec does not fly



Aerosol Size Measurements during IOPs (LPCA – ULCO)

Atmospheric particles will be collected at the top of the 12 meters high mast (CRA, site 1), during IOPs between 30/06 and 07/07, using a cascade impactor (DekatiTM PM10) operating with a flow rate of 30L/min. This impactor has three consecutive stages to separate coarse and fine fractions with cut-off diameters of 10 µm, 100 nm and 30nm (equivalent aerodynamic diameters at 50% of collection efficiency). The impactor is equipped with a PM2 head that discard all particles with an aerodynamic diameter higher than 2 µm by a cyclone technology.

Table 1 summarizes the sampling strategy during IOP.

	Starting time (UTC)	Ending time (UTC)
Sample 1	14H00	15H00
Sample 2	15H30	16H30
Sample 3	17H00	18H00
Sample 4	18H30	19H30
Sample 5	20H00	21H00

Table 1: Starting and ending time of aerosol sampling by cascade impactor during IOP.

Part IV – Forecasts

During the field campaign, a forecast secretary will analyse and report the meteorological situation for the operations. The task consists in:

- Using the BOC (http://boc.sedoo.fr/) to analyze all interesting outputs (forecasts and observations): analyses, forecasts from ARPEGE and AROME, satellite images, radar images, early morning sounding, etc...
- Calling the French local forecaster from Tarbes Meteorological Center. There will be a call in the evening to discuss the situation for the following days and sometimes, when needed, another call just before the morning briefing.
- Summarizing the info in a PPT file
- Discussing with the secretary and coordinator if time allows
- Presenting the forecast in the morning briefing
- Making a pdf forecast report to be put on the BOC
- Updating the forecast for the evening briefing

A synergy station will also be available for the forecast secretary to look at other products than available on the BOC if needed.

AROME and ARPEGE :

The models:

During the field campaign, specific outputs from two French operational Numerical Weather Prediction models will be saved.

The first model is ARPEGE, this is a global model with a stretched horizontal resolution varying from 10 km over France up to 55 km over Australia. It is run every 6 hours for 96h. There is a 4D var data assimilation system.

The second model is AROME, this is a non-hydrostatic model with a regular horizontal resolution of 2.5km. It is also run every 6 hours for 30 hours. There is an assimilation system for the surface (optimal interpolation) and for the atmosphere (3D var assimilation system with mesoscale data assimilation, Doppler radar reflectivities and winds). This model is forced at the lateral boundaries by the forecast of ARPEGE. During the campaign, this model will be rerun on a smaller domain covering the South-West of France with lateral boundaries from the operational AROME model. This will allow the computation of diagnostics. This run will be used for the real-time and time-delay outputs.

The real-time outputs:

During the field campaign, specific outputs from those two operational Numerical Weather Prediction models will be available on the BOC. These will concern model runs from 00h and 12h.They consist of horizontal map of cloud cover (low, medium, high and total), wind, temperature and humidity at 2/10m, 100m, 500m 1000m and 4000m, the boundary-layer height diagnosed as the first level where the turbulent kinetic energy gets lower than 10^{-2} m^2/s^2 and hourly cumulated rainfall. The principal area covers a zone from 41°N to 46.5°N and from 2.5°W to 4° E. A zoom on a domain of 1°x1° centered over Lannemezan will also be available for the AROME outputs as well as temporal series of vertical profiles of cloud cover and relative humidity at Lannemezan and Toulouse.

The time-delayed model products:

Supplementary products will be available after the field campaign. This includes :

- vertical profiles of prognostic variables (t, q, ,u, v, tke) and their budgets
- horizontal cross-section of tke
- u*, w*
- surface fluxes, surface variables and soil variables
- horizontal variability on a box of $10x10km^2$ (5x5 points in AROME)
- very high-frequent outputs (every timestep): for T,q, u, v to compare with tower observations (-> 65m), tethered ballons, lidar…

Tarbes CDM local forecast

During the field campaign, the forecasters from Tarbes CDM will provide forecast report for up to 5 days that will be posted on the BOC at about 6 UTC. Moreover, they can be called directly (05 62 32 65 01) in the evening to get an overview of the situation for the following days, and discuss it. If needed, when the situation is really delicate, another call could be made just before the morning briefing.

Part V – Coordination & organization

Time schedule

There will be one briefing per day during IOP days, at 8 UTC.

Assuming an IOP day D.

- At D-2, we may foresee a good window for D day, and be in pre-warning.
- At D-1, an IOP during D day is planned (warning for D day).
- The IOP day D starts with the launch of a radiosounding at 6h UTC (launched at 5h15 UTC) from site 1.
- Between 6 and 8 UTC, products available on the BOC are used to make the forecast for the day, and next 3 days (see previous section part IV about forecast).
- At 8 UTC, the briefing is taking place at site 1.

The briefing starts with a forecast, and continues with the report on the functioning of the continuous observations. Discussions follow on the planned IOP. The decision is confirmed (from the night before) to operate intensive observations during this day D. The flight missions for aircraft, UAS and tethered-balloons are defined, with an accurate time schedule for all of them. This defines the time and space area of exploration of each type of spaceship, and separate them in time and/or space.

- from 9 UTC to 10 UTC, the aircraft, UAS and tethered-balloons are separately defining more accurately their flight plan, given the mission defined during the briefing.
- from 10 to 13 UTC: lunch and preparation of the afternoon operations

Overall Coordinators

The coordinators for all operations in general (starting with the entire preparation of the experiment) are listed below:

General coordination	M. Lothon
Surface	F. Lohou
Aircraft operation	P. Durand
Tethered Balloons	E. Pardyjak
Radiosoundings	D. Legain
Radiation	G-.J Steeneveld
Microbarographs	C. Yagüe
Lidar coordination	A. Dabas
UAS coordination	J. Cuxart and J. Reuder
Modelling Forecast	F. Couvreux
Field catalog web site	J. L. Boichard
Web site	L. Mastrorillo
Data policy and database	L. Fleury
Computing	E. Bargain
Logistic	Y. Bezombes

Headquarter

As explained before, there will be continuous observations and intensive observations (IOPs). The latter depend on the weather, and are triggered during the morning briefings depending on the forecast.
During the campaign, coordinators of the IOP will be designated for the aircraft, UAS, radiosoundings, and tethered balloons operations for each period of successive IOP days. Those, with the help pf the secretary, will work together for the coordination of the operations and the communication.
People involved in the IOP coordination are:

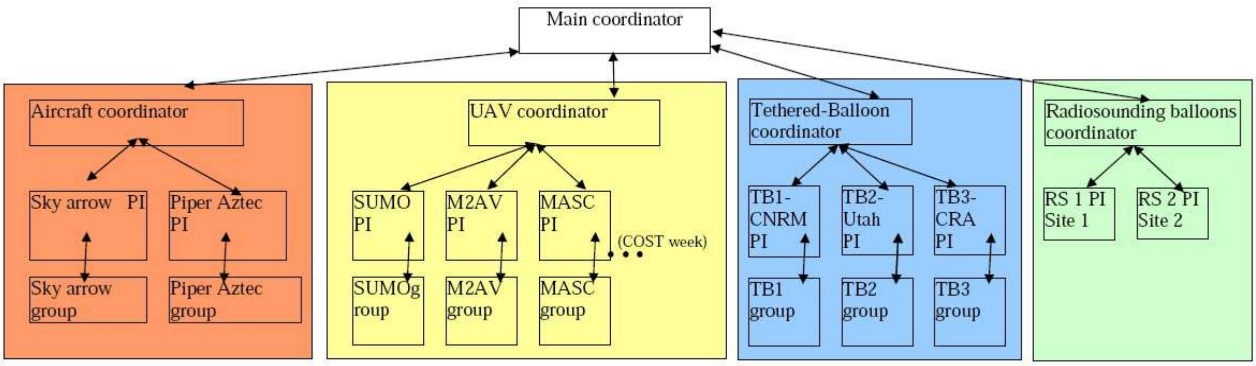
General coordination	M. Lothon, P. Durand, F. Lohou, E. Pardyjak, F. Couvreux, J. Reuder
Scientific secretary	F. Couvreux, D. Pino, C. Darbieu, F. Guichard
Aircraft operation	P. Durand, D. Pino, J. Vila Guerau de Arellano
Tethered Balloons	E. Pardyjak, F. Lohou, M. Lothon
Radiosoundings	D. Legain, F. Couvreux, F. Lohou, M. Lothon
UAS	J. Reuder , A. van Kroonenberg, S. Martin
Forecast	J. Cuxart, M. Jonassen, F. Guichard, F. Couvreux, A. Moene, G. J. Steeneveld

The scientific secretary has a key role: (1) collecting the info from the PIs about the functioning of the instruments, and about the operations made during the day, (2) reporting the info, (3) taking notes during the briefing about the forecast, the decision and plans made, etc…

All those people will turn approximately every week according to a planning set in advance. The following planning is not the definite planning, as it will probably be adjusted according to the IOPs dates, the meteorological conditions, the needs in operations of instruments, etc….

Communication during the IOP

For IOP operations, the following diagram explains how the communication is transmitted among the aircraft, UAS and balloon operating groups:



Each group airplane/UAS/tethered-balloons/Radiosounding-balloons have their own (non aviation) frequency to work internally.

Communication on the civil aviation 123.45 MHz frequency:
The 123.45 MHz is a civil aviation frequency used by airplanes to communicate together. The 2 BLLAST airplanes will use it to communicate together, but also other external airplanes and gliders flying around.

This frequency will be used by:
- the Sky Arrow and Piper Aztec airplanes to communicate together
- the Sky Arrow and Piper Aztec airplanes to inform UASs and balloons operators each time they are about

to penetrate the TRA.
- the UAS coordinator, the tethered balloon and the radiosounding balloon coordinators, to receive the information by the manned aircraft and to inform about any major problem (loss of control of a UAS, loss of tethered balloon, or impossibility of drawing down the tethered balloon, etc…).

Remarks:
UAS and balloon coordinators do not need to inform the 123.45 MHz frequency about their operations (launches/landings, soundings up and down…).
This frequency should be used only for the emergency situations described above, but be let free the rest of the time, for the airplanes flying in the area.
It needs to be listened to carefully during the entire duration of the respective operations.

A white board in the hall will display on a daily basis: the local forecast from the Tarbes Meteorological Center, the designated coordinators of the current IOP, some of the experimental maps (flying areas), important phone numbers for emergency, the list of participants and their phone number, and some information on coming meetings or events.
In the back of this board, people will register for lunch booking.

Part VI – Database

SEDOO – SErvice de DOnnées OMP, Toulouse – is in charge of developing the BLLAST website and the data archive and distribution system. All the tools described here need to be supplied by BLLAST participants (documents, metadata information, datasets…)

Web site

The BLLAST website - http://bllast.sedoo.fr/ - aims at gathering together all the documents and information useful to describe and manage the project. Scientific plans, newsletter and workshops documents are made available as soon as possible and the download procedure is unrestricted.

The BLLAST website includes the Bllast Operational Center (BOC) pages. This quick look and reports archive associated with display PhP scripts is set up to meet the operational needs for the airborne and ground-based observation teams during the 2011 field campaign. In particular, BOC pages provide maps and indexes issued from weather forecasts to help to plan aircraft operations and from nowcasts to guide the aircrafts missions in real time. After the campaign, BOC pages will provide a testimonial view on the campaign and an investigation tool through the different situations.
The displayed products are operational observations (radiosonde profiles, satellite images …), numerical weather products issued from different global or regional forecasts models, and research forecasts or diagnostics designed to meet the field campaign purposes. BLLAST observations either ground based or airborne, together with field or flight reports are displayed. Briefings and bulletins will also be posted on the BOC archive. Displayed quick looks are automatically fetched from operational centres or provided by individual scientists using a ftp deposit system.
During the field campaign, the BOC website - http://boc.sedoo.fr/ - will be operational and several persons will be involved to maintain it on a best effort basis. A backup of the website has been set up by SEDOO and Laboratoire d'Aérologie teams and will be hosted by the Centre de Recherche Atmosphérique (CRA) in Lannemezan during the campaign. The CRA server holds the same functionalities than the SEDOO one and could be used as BOC website main host in case the SEDOO server fails.

Data base

SEDOO is setting up a data management system composed of three components:

- The meta database contains the information needed to characterize the datasets. The metadata fields are defined following the INSPIRE directive and stored in xml files. Instrument types and topics are referenced according to the GCMD thesaurus keywords. Principal investigators are invited to provide metadata as early as possible (doc or pdf file). The metadata will be captured in xml files. Forms will be online in July 2011 and allow to add, complete or correct metadata information.

- A dataset archive stores the data files. Principal investigators are advised to provide dataset files written in NetCDF format respecting CF conventions. But ASCII column or excel files provided along with a file describing the format will be accepted. Many different versions of a dataset can be stored and the provision of raw data is encouraged. Quality-controlled data should be provided within 4 months after data acquisition. A http data files deposit and retrieval system procedure will be online in September 2011.

- A browsing system through the metadata will allow users to select datasets according different criteria (location, time, instrument type and parameter) and to download the corresponding data files.

- A user database will store dataset users name, organization and address. Any access to a dataset will automatically trigger an e-mail to the dataset PI and indicate him/her the user information.

Data policy

The data policy aims at defining mutual rights and obligations of data producers / owners and data users. The text has been written by SEDOO, together with BLLAST participants and leaders. It will be amended

and endorsed by the project participants.
The final version will be published online at http://sedoo.fr/database.

Part VII – People

List of participants, role and coordinates

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Part VIII – Instruments

List of platforms and instruments, technical details

CONTINUOUS OBSERVATIONS		
Surface-layer		
	MTO-station / EC-stations	60 m tower site 1
		Divergence tower s1
		Skin flow tower s1
		Micro-site (site 1)
		Edge site
		30 m tower - forest
		6 m tower Maize s2
		6 m tower Moor s2
	Scintillometers	Scintillometer Edge-site
		Scintillometer Church
		Scintillometer KNOF
	Temperature heterogeneity	IR camera site 1
	Radiation reference	Radiation Budget (PMOD/WRC) s1
	Barometer network	Microbarometers s1
Boundary layer profiling		
		VHF site 1
		UHF site 1
		UHF site 2
		sodar Capvern
		mini-sodar site 1
		Aerosol lidar site 1
		Aerosol lidar site 2
		Ceilometer site 1
		Doppler Lidar
		HATPRO Radiometer s1
sky monitoring		Full Sky Imagery s1
INTENSIVE OBSERVATIONS		
	Unmaned platforms	SUMO profiles
		SUMO surveys
		UAV M2AV site 1
	Aircraft	Piper PA23
		Sky Arrow
	Radio-sounding	RS MODEM site 1
		RS GRAW-Davis site 1-3
		RS GRAW-Bonn site 1
		Frequent-RS site 2
	Tethered balloons	Turbulent sensor (site 1)
		Mean measurements (site 2)
	Atmospheric Chemistry	Aerosols chemistry site 1
		Aerosol size measurements s1

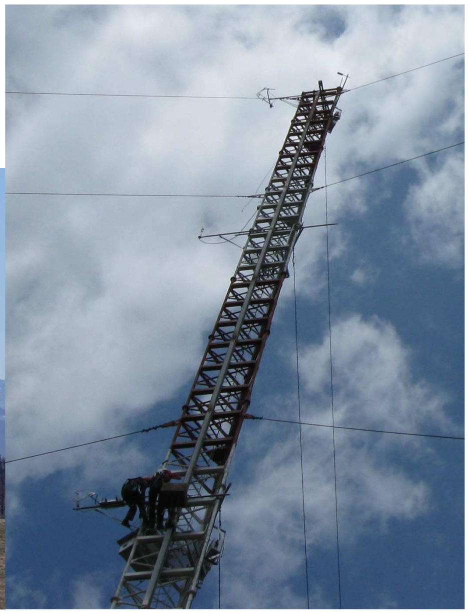
CONTINUOUS MEASUREMENTS
Surface layer
EC-Station / MTO-stations

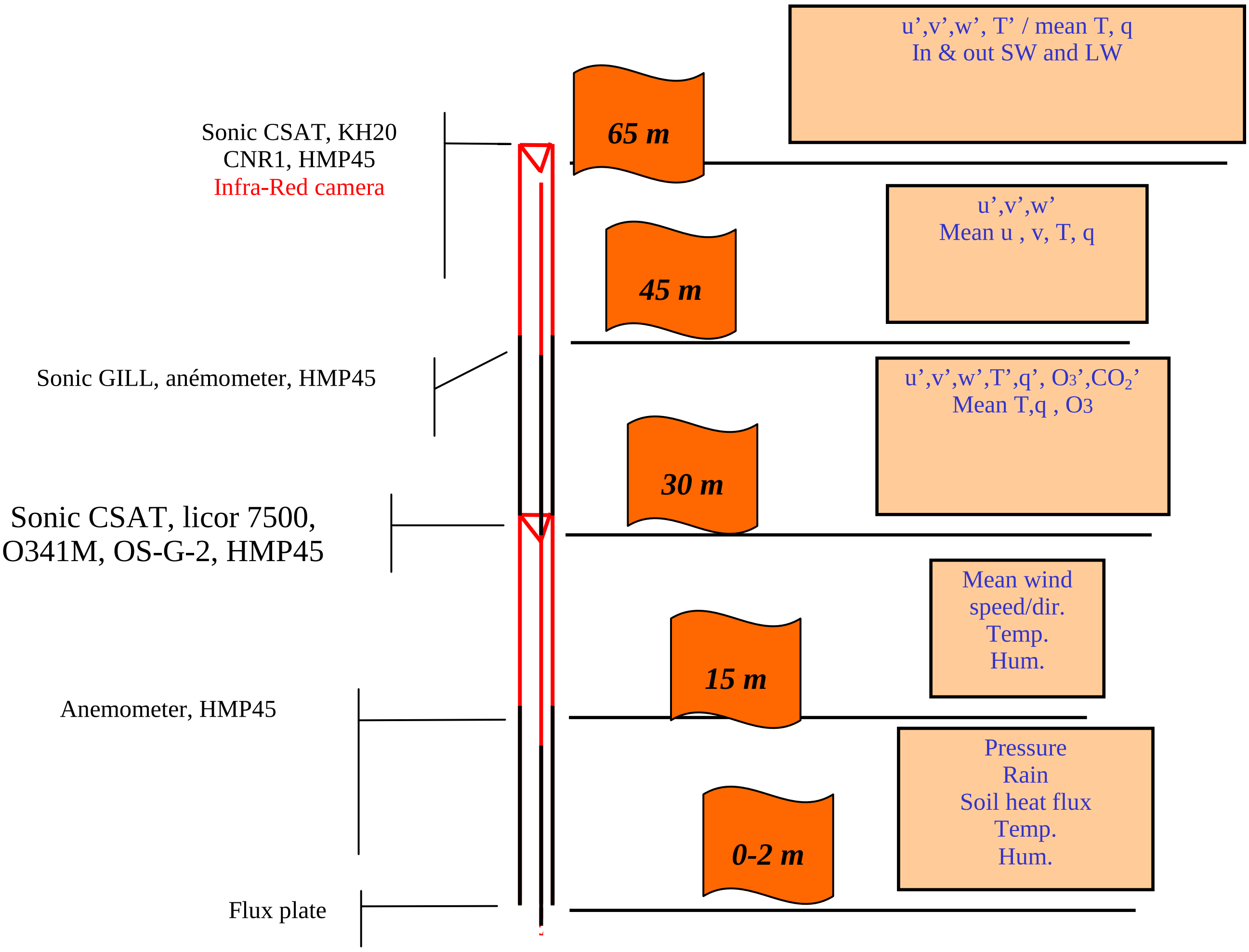
LA

60-m tower

(F. Saïd, S. Derrien)

SITE 1: 60-m tower





Sensors and sampling

Level	Measured parameters	Unit	Frequency	Sensor
2 m	Temperature	°C	0.1 HZ	Campbell HMP45
2 m	Relative humidity	%	0.1 HZ	Campbell HMP45
1.2 m	Pressure	hPa	0.1 HZ	Barometer vaïssala PTB101B
0 m	Rainfall	mm	0.1 HZ	Rain Gauge ARG100
-0.05 m	Ground flux 1	Wm-2	0.1 HZ	Hukseflux HFP01
-0.05 m	Ground flux 2	Wm-2	0.1 HZ	Hukseflux HFP01
-0.05 m	Ground flux 3	Wm-2	0.1 HZ	Hukseflux HFP01
14.8 m	Wind speed	ms-1	0.1 HZ	Switching anemometer A100L2
14.8 m	Wind direction	deg	0.1 HZ	Vector instrument W200P wind vane
14.8 m	Temperature	°C	0.1 HZ	Campbell HMP45
14.8 m	Relative Humidity	%	0.1 HZ	Campbell HMP45
29.4 m	Temperature	°C	1 HZ	Campbell HMP45
29.4 m	Relative humidity	%	1 HZ	Campbell HMP45
27.6 m	Ozone concentration	ppbv	1 Hz	Environnement SA O341M
29.3 m	Temperature	°C	10 HZ	Campbell Csat 3D Sonic anemometer
29.3 m	3 wind components	ms-1	10 Hz	Campbell Csat 3D Sonic anemometer
29.3 m	Water vapour mixing ratio	mmole m-3	10 Hz	Licor 7500A CO2/H2O analyser
29.3 m	CO2 mixing ratio	mmole m-3	10 Hz	Licor 7500A CO2/H2O analyser
29.3 m	pressure	kPa	10 Hz	Licor 7500A CO2/H2O analyser
45.6 m	Temperature	°C	1 HZ	Campbell HMP45
45.6 m	Relative humidity	%	1 HZ	Campbell HMP45
45.3 m	Wind speed	ms-1	1 Hz	Wind monitor Young 05103
45.3 m	Wind direction	deg	1 Hz	Wind monitor Young 05103
45.8 m	Temperature	°C	10 Hz	Gill master pro 3D sonic anemometer
45.8 m	3 wind components	ms-1	10 Hz	Gill master pro 3D sonic anemometer
61.6 m	Temperature	°C	1 HZ	Campbell HMP45
61.6 m	Relative humidity	%	1 HZ	Campbell HMP45
61.7 m	4 radiative components	Wm-2	1 Hz	CNR1 Kipp Zonen
61.4 m	Temperature	°C	10 Hz	Campbell Csat 3D Sonic anemometer
61.4 m	3 wind components	ms-1	10 Hz	Campbell Csat 3D Sonic anemometer
61.4 m	Water vapour fluctuations	mV	10 Hz	Campbell KH20 hygrometer

WUR/ UTAH Univ./ PMOD- WRC

Radiation mast

(GJ Steeneveld, E. Pardyjak, J. Gröbner)

SITE 1: Divergence site

Instrumental/technical details

Instruments by WUR

WUR will utilize 5 sets of Hukseflux IR02 radiometers, of which the technical specifications are listed in Table 1 below.

Table 1: technical specifications Hukseflux IR02 radiometers.

IR02 specifications:

Sensitivity (nominal)	15 μV/ Wm^{-2}
Temperature range	-40 - +80 °C
Range	-1000 - +1000 Wm^{-2}
Temperature dependence	< 0.1%/°C
Temperature sensor	Pt100
Spectral range	4500 - 50000 nm
Calibration traceability	ITS 90
Window heating offset	<15 Wm-2 @ 1000 Wm^{-2}
Heating power	1.6 Watt @12VDC

Instruments by PMOD/WRC

PMOD/WRC will deploy two net radiation systems consisting of pyranometers and pyrgeometers measuring the upwelling and downwelling shortwave and longwave radiation respectively (see instrumental sheet further). The radiometers will be calibrated relative to the World Standard Groups operated at PMOD/WRC for shortwave and longwave radiation respectively.
One system (ARBEX) has its own structure for holding the up and down welling instruments. The second system (TURAC) requires a post to fix the instrumentation which measures alternatively the up and downwelling radiation components using the same radiometers mounted in a rotation unit. In addition PMOD/WRC will operate a pyrgeometer with sensitivity in the 8-14 m range which gives information on the effective temperature of the lower atmosphere (Gröbner et al., 2010). The measurements will be acquired as one minute averages continuously during the whole campaign.

Data Policy

WUR will make available the individual components of the surface radiation budget as soon as possible after the BLLAST campaign. Observations of the radiation divergence will become available one year after the end of BLLAST campaign. Both will be on request by email.
PMOD/WRC will provide preliminary up and downwelling radiation components during the BBLAST campaign and quality assured data 6 month after the end of the campaign. The total surface radiation budget will be determined from the measurements made by PMOD/WRC for the two locations at which the systems will be installed.

WUR/ UTAH Univ.

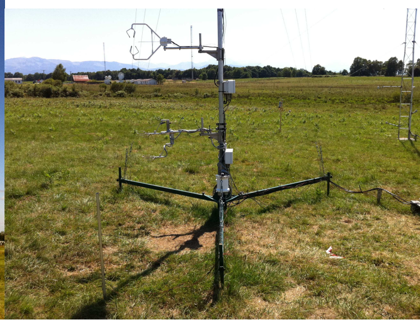
Skin flow mast

(E. Pardyjak, O. Hartogensis)

SITE 1: Divergence site

The University of Utah deployed a Skin Flow Tower collaboratively with the Meteorology and Air Quality Group from Wageningen University at Site 1 from 19.06.2011 10:11:59 through 06.07.2011 07:23:54.45 UTC. The GPS coordinates of the site were: N43° 07′ 39.3′′; E00° 21′ 57.9′′. All instruments were oriented toward 117 degrees. The heights of the sonic anemometers and FW thermo-couples were selected to reasonably match the heights of the long-wave radiation sensors on the Divergence Tower that was located just adjacent to the Skin Flow Tower at Site 1. The station consisted of:

- A 10-m meteorological mast was deployed with 4-Campbell Scientific CSAT3 sonic anemometers fit with Campbell Scientific E-TYPE model FW05 thermocouples for direct determination of momentum fluxes and sensible heat fluxes. Four additional FW05 thermocouples were deployed at locations close to the ground to investigate the growth of the stable surface layer.
- From 19.06.2011- 23.06.2011 one Kaio Denki mini-sonic with a 5cm path distance was deployed at 1.12 m with a Campbell Scientific E-TYPE model FW05 thermocouples. From 23.06.2011, two Kaios Denkis were deployed. Only the sensor at 1.12 m was fit with a fine wire thermocouple.
- A Campbell CR5000 data logger was used for data storage (20 Hz).


Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Measurement height
Wind component U	Kaio Denki 1*	20 Hz	0.85 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Kaio Denki 2	20 Hz	1.12 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Campbell Scientific CSAT3	20 Hz	2.23 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Campbell Scientific CSAT3	20 Hz	3.23 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Campbell Scientific CSAT3	20 Hz	5.27 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	Campbell Scientific CSAT3	20 Hz	8.22 m
Wind component V			
Wind component W			
Sonic temperature			
Air temperature++	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	0.091 m
Air temperature++	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	0.131 m
Air temperature++	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	0.191 m
Air temperature++	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	0.569 m
Air temperature**	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	1.12 m
Air temperature	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	2.23 m
Air temperature	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	3.23 m
Air temperature	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	5.27 m
Air temperature	Campbell Thermocouple E-TYPE FW05 (0.0127 mm)	20 Hz	8.22 m

++These sensors were only deployed during IOPs, this measurement was retaken for each deployment and was measured to the *hard-packed* soil surface. Hence, the lowest thermocouple was just at the top of the "grass canopy" (See image above). *Only operated from 23.06.2011- 17:01:24.5 UTC through 06.07.2011 07:23:54.45 UTC **Note that the thermocouple cable for this fine-wire thermocouple was likely bad resulting in bad temperature readings.

WGFI/ UoB

Eddy-covariance station

(J. Reuder)

SITE 1: micro-site

The Geophysical Institute, University of Bergen, Norway (GFI/UoB) has deployed a complete surface energy balance station at the small-scale heterogeneity field of site 1 from 15.06.-07.07.2011.

The stations consists of :

- an eddy correlation system (Campbell CSAT, LICOR 7500) for direct determination of turbulent fluxes
- a 9-m meteorological mast for standard meteorological parameters at 3 levels
- a 4-component radiation balance measurement (Kipp&Zonen CR1)
- two heat flux plates in 10 cm and 20 m below the surface
- a Campbell CR5000 data logger for data storage (20 Hz for turbulence, 1 minute for standard meteorology)

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Measurement height
wind component U	Campbell CSAT3 sonic anemometer	20 Hz	1.95 m
wind component V			
wind component W			
sonic temperature			
specific humidity	LICOR 7500	20 Hz	1.95 m
CO2 concentration			
pressure			
black body temperature of radiometer	CNR1 Kipp&Zonen	1 min.	0.95 m
outgoing global radiation			
incoming global radiation			
outgoing longwave radiation			
incoming longwave radiation			
air temperature		1 min.	1.8 m
air temperature		1 min.	4.8 m
air temperature		1 min.	8.3 m

relative humidity		1 min.	1.8 m
relative humidity		1 min.	4.8 m
relative humidity		1 min.	8.3 m
temperature	Campbell Thermocouple ASP TC	1 min.	1.8 m
temperature difference	Campbell Thermocouple ASP TC	1 min.	4.8 m
temperature difference	Campbell Thermocouple ASP TC	1 min.	8.3 m
wind speed	Vector Instruments A100LK	1 min.	2.1 m
wind speed	Vector Instruments A100LK	1 min.	5.1 m
wind speed	Vector Instruments A100LK	1 min.	8.6 m
wind direction	Vector Instruments W200P	1 min.	2.1 m
wind direction	Vector Instruments W200P	1 min.	5.1 m
wind direction	Vector Instruments W200P	1 min.	8.6 m
ground heat flux		1 min.	-0.1 m
ground heat flux		1 min.	-0.2 m

WUR / fz-juelich

Three Eddy-covariance stations

(A.van de Boer, O. de Coster, A. Graf, O. Hartogensis, M. Lennefer, H. Pietersen,)

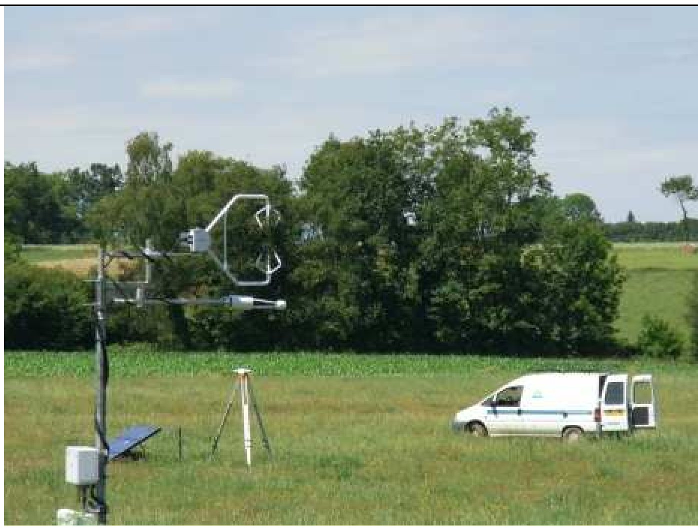
SITE 1: Edge site

Two complete surface energy balance stations with eddy covariance, profile measurements up to 6m, radiance balance and soil temperature and heat flux and were installed in the grass and the wheat field. One station with only eddy covariance measurements was installed at the edge of those fields.
The two comprehensive stations include two measurement systems:
- a low frequency datalogger (CR7 Campbell Scientific) which samples wet and dry bulb temperature, wind speed, soil temperature, wind direction and stores data every minute.
- a high frequency datalogger (CR3000 Campbell Scientific) which samples and synchronizes 20Hz turbulence data from a sonic anemometer, an infrared gas analyzer and four radiometers.

The small station includes a high frequency datalogger (CR1000 Campbell Scientific) which samples 20Hz turbulence data from a sonic anemometer and an infrared gas analyzer.
Energy is provided by solar cells and battery; one 150W solar cell was used for the small station, two sets of each 300W were used for the comprehensive stations (12V 65A.h).

GRASS:

PARAMETER	SENSOR	FREQUENCY/PERIOD	HEIGHT FROM SURFACE
Wind direction	Vane	10 sec --> 1 min	6.0m
Wind speed	Cup anemometers	10 sec --> 1 min	0.5;1.0;2.0;4.0;5.8 m
Temperature	Psychrometers	10 sec --> 1 min	0.5;1.0;2.0;4.0;5.8 m
Wind u	3D sonic anemometer (Campbell Scientific CSAT3)	20Hz	2.55m
Wind v			
Wind w			
Temperature sonic			
Specific humidity	LiCor7500	20Hz	2.55m
CO2 concentration			
Outgoing shortwave	Pyranometer	10 sec --> 1 min	1.68m
Incoming shortwave			
Outgoing longwave	Pyrgeometer		
Incoming longwave			
Pressure	Vaisala PTB 100A	10 sec --> 1 min	0.5m
Temperature soil	Custom-built Pt100	10 sec --> 1 min	2;5;10;20;50cm
Soil heat flux	Hukseflux HFP01	10 sec --> 1 min	3cm



WHEAT:

PARAMETER	SENSOR	FREQUENCY/PERIOD	HEIGHT FROM SURFACE
Wind speed	Cup anemometers	10 sec --> 1 min	1.0;1.5;2.0;4.0;5.8 m
Temperature	Psychrometers	10 sec --> 1 min	0.5;1.0;2.0;4.0;5.8 m
Wind u	3D sonic anemometer (Campbell Scientific CSAT3)	20Hz	3.00m
Wind v			
Wind w			
Temperature sonic			
Specific humidity	Li-Cor Li-7500	20Hz	3.00m
CO2 concentration			
Outgoing shortwave	Pyranometer	10 sec --> 1 min	1.68m
Incoming shortwave			
Outgoing longwave	Pyrgeometer		
Incoming longwave			
Pressure	Vaisala PTB 100A	10 sec --> 1 min	0.5m
Temperature soil	Custom-built Pt100	10 sec --> 1 min	2;5;10;20;50cm
Soil heat flux	Hukseflux HFP01	10 sec --> 1 min	3cm

EDGE:

PARAMETER	SENSOR	FREQUENCY/PERIOD	HEIGHT FROM SURFACE
Wind u	3D sonic anemometer(Campbell Scientific CSAT3)	20Hz	2.89m
Wind v			
Wind w			
Temperature sonic			
Specific humidity	Li-Cor Li-7500	20Hz	2.60m
CO2 concentration			
Pressure	Vaisala PTB 100A	10 sec --> 1 min	1m

Some additional soil temperature, moisture and soil heat flux measurements were done manually during most of the IOP's at different locations on the edge fields.

Data provided to database:

- Sensible and latent heat fluxes (W/m2, 30min)
- 3D-wind, Temperature, H2O and CO2 (20Hz)
- four radiation components (W/m2, 1min)
- wind and temperature profiles (m/s, degC, 1min)

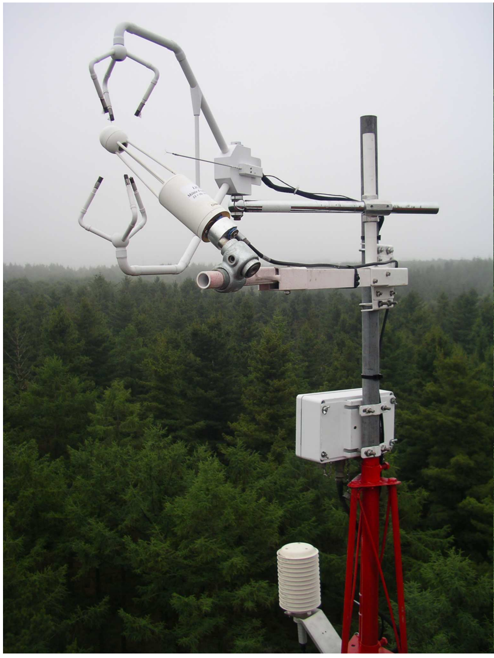
UTAH university/ LA/ CNRM

Forest-mast

(Eric Pardyjak)

SITE 2

This mast has been implemented in the pine forest in site 2, devoted to the surface heterogeneity. The forest vegetation coverage constitutes the third extended coverage, with the moor and the corn. The canopy top varies between 20 to 25m.




Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	CSAT Campbell sonic anemometer (UTAH)	10 Hz	31.55 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity CO2 concentration	LICOR 7500 (LA)	10 Hz	
Black body temperature of radiometer	CNR1 KIPP & ZONEN (LA)	1 Hz	28.69 m
Outgoing global radiation			
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Temperature	Campbell HMP45 (LA)	1 Hz	29.02 m
Relative humidity			
Wind component U	CSAT Campbell sonic anemometer (UTAH)	10 Hz	21.84 m
Wind component V			
Wind component W			
Sonic temperature			

CNRM/GAME

Surface energy Balance station

(D. Legain, G. Bouhours, O. Traullé, E. Moulin, D. Suquia)

SITE 2: MOOR and CORN

CNRM will deploy two complete surface energy balance stations based on well known eddy correlation technique.

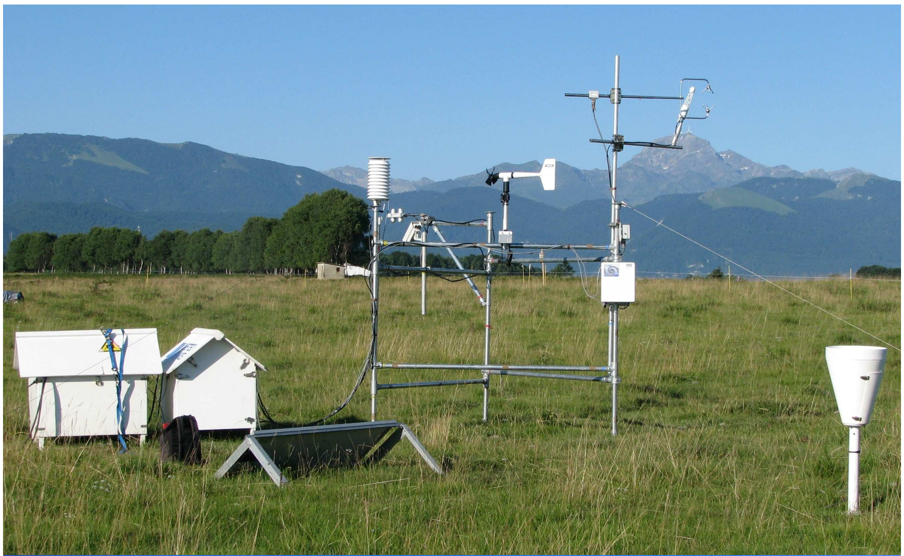
These stations include two measurement systems :

- a low frequency datalogger (CR23X Campbell Scientific and multiplexer) sample all meteorological sensors and store data at a one minute step.
- a Linux PC sample and synchronize high frequency turbulent data (Sonic anemometer and infra red gas analyzer).

Fluxes are computed with two way

- a on board low level fluxes computation permit to have a real time fluxes quick look. Quick look may be sent on request by GSM way
- a high quality eddy correlation fluxes computation, in delayed time

Energy is provided by solar cells and battery, allowing easy deployment without energy infrastructures.
For BLLAST conditions, four 75 W solar cells (60 cm x 120 cm) and four 12 V 65 A.h battery.
Low frequency data will send with GSM way, and turbulence data are stored on a amovible USB hard-disk for



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Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind direction	YOUNG 05103 (3)	1 min.	TBD according vegetation
Wind speed			
Wind component U	Solent Gill sonic anemometer (3) (“horizontal” research device HS50)	25 Hz	
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500 (2)	20 Hz	
CO2 concentration			
Temperature	ATEXIS PT1000 Classe A (1)	1 min.	
Relative Humidity	HMP45 VAISALA (1)		
Black body temperature of radiometer	CNR1 KIPP & ZONEN (1) Météo-France calibration		
Outgoing global radiation			
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Pressure	PTB210 VAISALA (1)		TBD m
Surface temperature	Infrared thermometer Campbell Scientific IR100		TBD according vegetation
Soil water content	Delta Devices THETA PROBE ML2X	15 min.	Surface
Soil temperature	ATEXIS PT1000 Classe A (1)	1 min.	-1 cm
Rainfall	QUALIMETRICS	1 min.	0.3 m TBD
	SPIEA, Météo-France manual raingauge	daily	0.3 m TBD
Soil heat flux	HUSKEFLUX HFP01 (3) 3 sensors in a large area for better sampling	1 min.	-1 cm

(1) Météo-France calibration
(2) Calibrated with CO2 reference gaz 400 ppm +-1% and chilled mirror dew point hygrometer.
(3) Factory calibration.

Data provided to database

	Unit	Period - Frequency
Sensible heat flux	W/m2	30 min
Latent heat flux		
4 radiations components		
Soil heat flux		
Slow meteorological parameters		1 – 30 min TBD
Turbulence parameters (Wind 3D, Temperature, H2O and CO2)		10 – 25 Hz TBD

Configuration of the stations

		Moor	Corn
Altitude		641 ± 3 m	645 ± 5 m
Longitude		0° 21′ 42′′	0 ° 21 ′ 30 ′′
Latitude		43° 05′ 24′′	43° 05′ 24′′
Temperature and humidity	Height above ground	220 cm	345 cm
Rain gauge	Height above ground	100 cm	305 cm
4 components radiometer	Height above ground	200 cm	280 cm
4 components radiometer	Direction	180 °	
Anemometer	Height above ground	223 cm	430 cm
Anemometer	North direction	0 °	
Ultrasonique anemometer	North direction	305 °	
Ultrasonique anemometer / Infra red gas analyzer	Height above ground	293 cm	480 cm
Infra red gas analyzer	Position / anemometer	270 ° / North sonique	
Infra red gas analyzer	Distance / sonique	20 cm	
Infrared radiometer	Direction	180 °	
Infrared radiometer	Height above ground	175 cm	230 cm
Infrared radiometer	Angle / surface	45 °	
Soil fluxes sensors	Depth	- 3 cm	
Soil humidity sensor	Depth	– 5 to 0 cm	
Soil thermometer	Depth	- 1 cm	
Barometer	Height above ground	40 cm	

CONTINUOUS OBSERVATIONS
Surface measurements
Scintillometers

WUR

Laser scintillometer

(A. van de Boer, O. de Coster, O. Hartogensis, H. Pietersen)

SITE 1: Edge site

One Scintec AG dual beam laser scintillometer (SLS-20) was installed perpendicular to the edge between the grass and the wheat field mentioned above, with a path length of 109.6m.

A solar panel of 150W was used as power supply for the Scintec receiver (2.10m above surface in the grass field) and a pc.

A solar panel of 50W was used for the Scintec sender (2.79m above surface in the wheat field).

Data was collected at the pc every 6 seconds.

Wavelength=670nm

Data provided to database:
30 minutes averages from 6 second raw data:

- Structure parameter(Cn2) [*10^-12 m^-2/3]
- Inner scale of turbulence (l0) [m]
- Dissipation rate of TKE [m^2/s^3]
- Sensible heat fluxes (H) [W/m2]
- Friction Velocity (U*)[m/s]

CNRM/GAME

Kipp et Zonen LAS Scintillometer

(D. Legain, J. Barrié, E. Moulin)

Scintillometer XLAS Kipp and Zonen
Wave length = 880 nm

Path length 4 Km

	Site	Latitude	Longitude	Z XLAS AGL
Receiver (1)	North site, CRA	43°7'42.16 N	0°22'02.30 E	# 20 m TBC
Emitter (2)	South site, Knauf factory	43°5'38.02 N	0°22'44.51 E	# 60 m TBC

Additional data (P,T,HU and wind) for heat sensible flux computation gift by CRA mast (65 m)

Sampling

	Unit	Period - Frequency
Structure parameter of the refractive index of air along path length CN2	m-2/3	1 s

Data provided to database

	Unit	Period - Frequency
Sensible heat flux	W/m2	10 min

CONTINUOUS OBSERVATIONS
Surface measurements
IR camera, reference radiation measurements,
Barometer network

University of California, San Diego

Thermal Infra-red (IR) Camera

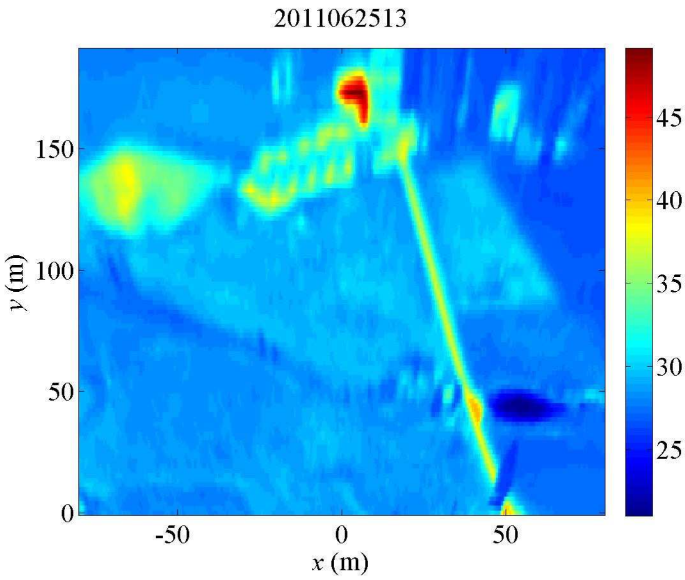
(A. Garai, J. Kleissl)

A FLIR A320 IR camera was mounted at the top of the 60 m tower during BLLAST campaign, in order to measure surface temperature. The IR camera measures and images the received long-wave radiation from the scene which is a function of temperature and emissivity ε. If the emissivity is less than 1, the IR radiation measured by the camera includes radiation from surroundings which is reflected by the object and weighted by 1-ε. The radiation from the object and the reflected radiation is scattered and absorbed by the numerous gases and aerosols in the atmosphere before reaching the camera. These reductions in radiation are quantified by the atmospheric transmittance. The magnitude of transmittance depends on path length and atmospheric constituents. Since the atmospheric constituents are at ambient temperature they also radiate energy. Thus the radiance accumulated in the line of sight is known as atmospheric path radiance. Considering above mentioned phenomena the voltages measured by the detector in the camera can be expressed as

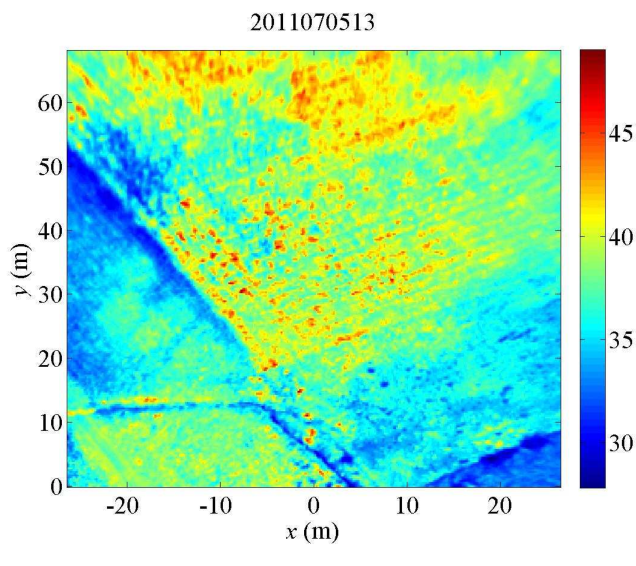
$$V_{detector} = Tr(\varepsilon\sigma T_{object}^4 + (1-\varepsilon)\sigma T_{amb}^4) + (1-Tr)\sigma T_{amb}^4$$

where Tr, ε, σ, T_{object}, T_{amb}, $V_{detector}$ is transmittance, emissivity, Stefan-Boltzmann constant, object temperature, ambient temperature and total radiance.

Field of view	45^0 x 34^0
Wavelength	8-13 μm
Image frequency	1 Hz
Thermal sensitivity	50mK @ 30^0 C
Camera size	170 x 70 x 70 mm, 0.7 kg
ε, Tr	0.95, 1



One-hr average of surface temperature at divergence site on 25th June at 13 UTC



One-hr average of surface temperature at micro site on 5th July at 13 UTC

The IR camera was mounted on 60 m tower at 59.02 m above the ground level, looking downward at an angle 6^0 from 13th June (1158 UTC) to 29th June (1618 UTC) towards divergence site and at 59.9 m above the ground level looking downward at an angle 49.2^0 from 29th June (1738 UTC) to rest of the campaign towards micro-site. A coordinate transformation and interpolation was performed to bird's eye view resulting in uniform spatial resolution to get about 160 x 190 m and 60 x 70 m camera footprint for first and second part of the experiment. Figure 1 and 2 shows sample of one hour average surface temperature at divergence and micro site. With this high frequency surface temperature data set one can study the heat transport process and coherent structures in the convective boundary layer.

PMOD/WRC

Surface Radiation budget

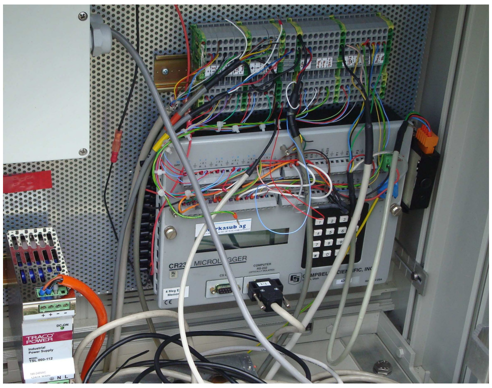
(J. Gröbner, S.Wacker, L.Maag)

PMOD/WRC will deploy an instrumental set-up to determine the surface radiation balance by measuring the down-welling and up-welling components of the short-wave and long-wave irradiance. The setup features a Kipp&Zonen CM22 and CM21 pyranometer to measure the short-wave radiation and an Eppley-PIR and Kipp&Zonen CG4 pyrgeometer to measure the long-wave components. All radiometers have been recently calibrated against the respective World standard groups hosted by the World Radiation Center (WRC) at Davos in order to guarantee high quality measurements.

The setup will be equipped with a modified CGR3 pyrgeometer from Kipp&Zonen which is only sensitive to the 8-14 micrometer band. In combination with the measurements of the broadband pyrgeometer, it is possible to derive the effective radiative temperature of the boundary layer with high temporal resolution (1 min data) (Gröbner et al., 2009). Thus, the early morning and the late afternoon transition can be precisely observed.

Furthermore, the measurements of broadband long-wave and short-wave up- and down-welling irradiance will be used to validate the radiation measurements by other participating groups. The set-up will be placed close to these instruments for a short period to provide simultaneous measurements.

Instrumental set-up to measure the surface radiation budget.



Data acquisition with Campbell CR23X logger.

Parameter	Sensor	Sensitivity
Down-welling short-wave radiation	Kipp&Zonen CM21 920091 pyranometer	$10.66*10^{-6}$ V/(Wm^{-2})
Up-welling short-wave radiation	Kipp&Zonen CM22 010031 pyranometer	$8.96*10^{-6}$ V/(Wm^{-2})
Down-welling long-wave radiation	Kipp&Zonen CG4 FT005 pyrgeometer	$9.48*10^{-6}$ V/(Wm^{-2}) [1.)]
Up-welling long-wave radiation	Eppley PIR 29435F3 pyrgeometer	$3.59*10^{-6}$ V/(Wm^{-2}) [2.)]
Down-welling long-wave radiation (8-14 microns)	Kipp&Zonen CGR3 070103 pyrgeometer	$8.98*10^{-6}$ V/(Wm^{-2}) [3.)]
Screen-level temperature	Rotronic PT-100 temperature sensor	
Relative humidity	Rotronic hygromer humidity sensor	

1.) k_1=0.035; k_2=0.9984; k_3=0
2.) k_1=0.02; k_2=1; k_3=3.7
3.) k_1=0.01; k_2=0.9994; k_3=0

Reference:

Gröbner, J., S. Wacker, L. Vuilleumier, and N. Kämpfer (2009), Effective atmospheric boundary layer temperature from longwave radiation measurements, *J. Geophys. Res., 114*, D19116, doi:10.1029/2009JD012274.

Universidad Complutense de Madrid

Microbarometers

(C. Yagüe, G. Maqueda, C. Román-Cascón, M. Sastre)

The working principle of a microbarometer is based on the dependence of the vibrational frequency of a quartz crystal with temperature and applied pressure. A pressure transducer produces two square wave signals whose period is proportional to applied pressure and internal transducer temperature. The internal electronics of these devices integrates these signals for a certain time, to measure the periods of the pressure and temperature signals. From these periods the absolute pressure measurement is computed using the calibration formulas which are specific for each PAROSCIENTIFIC unit. The resolution of these instruments depends on the precision with which the temperature and pressure periods are determined (i.e., the integration time of the pressure and temperature signals). Therefore, higher sample rates mean less precise measurements.

- 3 PAROSCIENTIFIC model 6000-16B microbarometers are available (Fig. 1a).
- Its working principle is based on the dependence of the vibration frequency of a quartz crystal with pressure.
- High precision digital instruments that can detect very small pressure perturbations, of the order of thousandths of hPa.
- GILL static pressure ports are used to avoid data contamination by dynamic pressure fluctuations (see Fig. 1b).
- The 3 microbarometers can be connected to an industrial computer, equipped with a multiplexer card for connecting the microbarometers to 3 independent serial ports, using RS-485 connections. Data-logging software is installed for saving the pressure records into daily files.
- A sampling rate of 2Hz is usually chosen as a compromise between having a good temporal resolution and registering small enough pressure perturbations (with this sampling rate the resolution is around 0.002 hPa). These values are quite suitable for a proper registration of any kind of wave event produced, as the typical amplitudes of the pressure fluctuations related to waves is in the range of 0.01-0.1 hPa with a periodicity ranging from 1 to 40 minutes.
- From pressure series registered at different positions at the surface, it is possible to observe the propagation of coherent structures (waves) along the site, and calculate the wave parameters (wavelength, phase speed, direction) using wavelet methods. We have used a triangular array around 150m side.

A PAROSCIENTIFIC model 6000-16B microbarometer

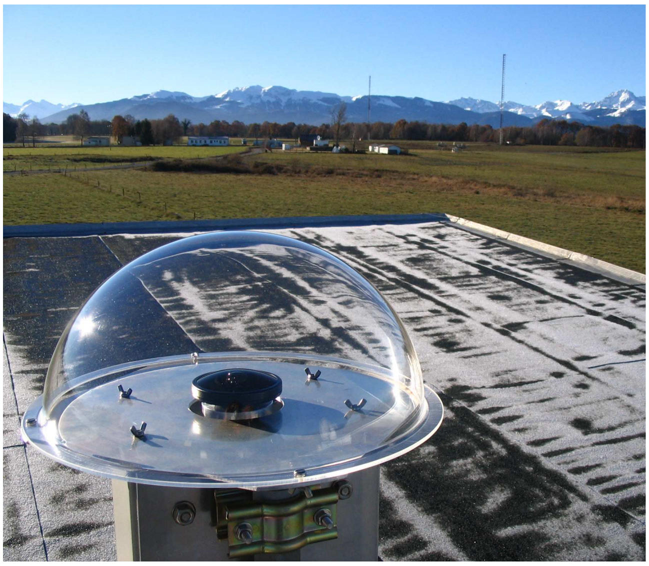
GILL static pressure ports

CONTINUOUS OBSERVATIONS
Surface measurements
Sky monitoring

Laboratoire d'Aérologie

RAPACE - Full Sky imagery

(M. Lothon, S. Derrien, E. Bargain, S. Rondi)



RAPACE on the CRA roof

Example of observation.
Fair weather cumulus clouds, 02/20/2006

Objective:

RAPACE (Récepteur Automatique Pour l'Acquisition du Ciel Entier) is a full sky imagery system that enables to visualize the total sky (2π steradians) above the CRA site. It stores routinely the cloud cover above the site.

Principe :

A digital camera is associated with a fish-eye objective. The latter is protected by a Plexiglas dome and controlled by a thermostat which maintains the temperature within the dome at 10°C to avoid condensation. RAPACE is installed on the roof of the CRA main lab building.

Operation :

RAPACE has been operated continuously at CRA since 2006, with the storage of one image every hour. A 10 s pause is used during the night, for application in astronomy. The frequency of acquisition can be increased for field campaigns and specific applications, with the possibility of generating movies. For certain days, the time interval was set to 10 min, 1 min and down to 30 s. During BLLAST, the time interval between pictures will be set to 1 min.

CONTINUOUS BSERVATIONS
Boundary layer profiling

CNRM/GAME
Degreane PCL 1300 UHF radar
(O. Garrouste, T. Douffet, J-M Donier)

SITE 2

Degreane wind profiler mobil PCL1300 is a pulsed Doppler radar. It uses as tracer of wind the variations of the air's refractive index created by the atmospheric turbulence. The measurement of the Doppler associated to the moving turbulences furnishes the wind speed in the direction of the RADAR antenna's main lobe. A set of measurements in three different directions is necessary to reconstruct the three dimensional wind. The range of altitudes covered by the instrument is variable, depending on atmospheric conditions and electronic parameters. The profile of the horizontal wind is valid between 500 and 5 000m. Other parameters could be deduced (vertical wind, Cn^2, dissipation rate…)

Technical characteristics:	
Equip. Size (Lenght/Width/Height)	*15 x 15 x 3 m*
Weight	*2250 Kg*
Power supply	*220 V (AC/DC) 50 Hz, 10 A, 2 kW*
Env. Conditions	*-30°C to +50°C, 0..100%HU*
Cooling Constraint (Air-conditioning)	*yes*
Safety Area	*2 m around sensor*
Equipment Compatibilty & Safety Issues	*EM compatibility*
Data Recording system	*yes in the PCAcquisition (sensor) and in the PCTraitement*
Com Links	
Data link	*electric wire with GSHDSL (Ethernet Report)*
Com protocol	*IP*
Com Rate	*2M bit/s*
Daily Human operation	data *control 1 h/day*
Remote Control Capability	*yes by 3G router*
Maintenance	*no*

CNRM/GAME
Ceilometer
(O. Garrouste, F. Lavie)

SITE 1

CT25K has been modified in order to retrieve the height of the atmospheric boundary layer. It uses a Laser diode at a wavelength of 905 nm to measure the height of cloud bases about 7600 m. The backscattered light is analyzed on the first 4 000 m with a vertical resolution of 7,5 m and a profile can be obtained every 15 s.

Technical characteristics:	
Equip. Size (Length/Width/Height)	*1 x 1 x 1,5 m*
Weight	*35 Kg*
Power supply	*220 V (AC/DC) 50 Hz, 400W*
Env. Conditions	*-50°C to +60°C, 0..100%HU*
Cooling Constraint (Air-conditioning)	*no*
Safety Area	*2 m around sensor*
Equipment Compatibility & Safety Issues	
Class 1M EN60825	
CLASS 1 21 CFR1040	
Data Recording system	Remote *PC with graphic PC display software*
Com Links	Data link : serial line
Daily Human operation	data *control 1 h/day*
Remote Control Capability	*yes by 3G router*
Maintenance	*no*

CNRM/GAME
Retrodiffusion lidar
(O. Garrouste, F. Lavie)

SITE 2

The Leosphère aerosol lidar used by CNRM is a Bistatic backscatter Lidar. Its emitting wavelength is 354.7 nm (UV). It measures backscattered light from clouds, aerosols and plumes, and is able to measure low diameter aerosols (diameter < 0.3 μm).

Technical characteristics

Size (Lenght/Width/Height):	
Optical head	0,3 x 0,3 x 1 m
Laser power / control unit 8U rackable	0,3 x 0,4 x 0,5 m
Weight	*16 + 20 Kg*
Power supply	*220 V (AC/DC) 50 Hz, 700W*
Env. Conditions	*+5°C to +60°C, 0..100%HU*
Cooling Constraint (Air-conditioning)	*no*
Safety Area	*2 m around sensor*
Equipment Compatibilty & Safety Issues	EN/IEC 60825-1
Data Recording system	*PC/lase power with graphic PC display software*
Daily Human operation	data *control 1 h/day*
Remote Control Capability	*yes by 3G router*
Maintenance	*yes, flashlamp* replaced every 50 million shots

LEOSPHERE, LMD-IPSL

LEOSPHERE Aerosol Doppler Lidar WINDCUBE200

(L. Thobois, F. Gibert)

SITE 1

LIDAR (Light Detection And Ranging, also LADAR) is an optical remote sensing technology that uses pulses from a laser to measure the radial velocity and properties of the illuminated target. In the atmosphere, it gives access to the air aerosol content, and to a wind velocity component. Pointed upward, sit measures the vertical velocity of the air, at 50 m vertical resolution, and every 5 s.

Performances of WINDCUBE200 during BLLAST:

Wavelength	1.54 µm
Laser Pulse energy/ PRF	100 µJ / 10 kHz
Power supply/ consumption	240V AC 50-60 Hz / 370W
Size/ weight	800×650×550 mm / 65 kg
Operation during BLLAST	Continuous vertical measurements
Output data	- Range-resolved vertical velocity - Signal-to-Noise Ratio (atmospheric reflectivity)
Maximum range	Boundary Layer / Tropospheric clouds
Range/ Temporal resolutions	50 m / 5 s

For further details on WINDCUBE200, see LEOSPHERE website: http://www.leosphere.com/

LPCA – ULCO
Aerosol lidar

(P. Augustin, M. Fourmentin, H. Delbarre)

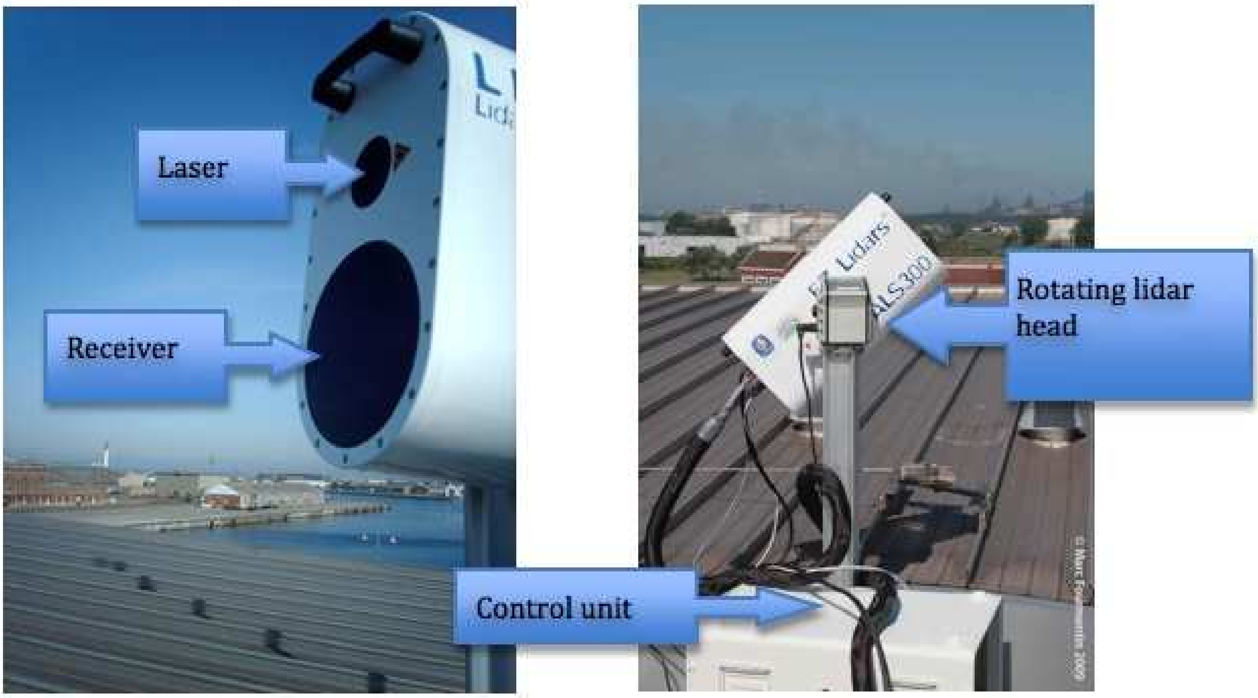
SITE 1

During the campaign, the angular aerosol lidar operates with a third harmonic of a Nd-YAG laser (355 nm) with an energy pulse of about 16 mJ at a repetition rate of 20 Hz. High temporal/spatial resolutions continuous monitoring vertical scanning is performed to deduce the vertical fine structure and evolution of the lower troposphere aerosol stratification. Lidar signals provide qualitative information on the structure and the dynamics of the lower troposphere and the extraction of the extinction coefficient from the lidar signals will give us an estimation of the spatial distribution of aerosols. This lidar is installed on the super-site 1 (from 12/06 to 08/07) and each vertical scanning is performed whithin 10 min (500 shots per profile) with an increment of 2° from 37° to 87° (zenithal angle) toward south (175,6°//North). The lidar blind distance for optimal near-field overlap is 250 m and the spatial resolution is 15 m along each beam.


Aerosol lidar during BLLAST campaign at CRA

Technical characteristics

Laser	Nd-YAG pumped by lampe flash
Wavelength	355 nm
Pulse energy	16 mJ
Maximum range	15 km to 20 km
Spatial resolution	15 m
Angular resolution	0.2°
Eye safety	IEC 60825-1 2001
Lidar head weight	16 kg
Lidar head size	650x356x190 mm
Control unit weight	45 kg
Unit control size	820x620x550 mm
Transfert et pilotage	Réseau (local/Ethernet)
Power supply	230 VAC/50Hz
Total power consumption	2 kW



Rotating lidar head for vertical and horizontal scans

Parameter	Range, Unit	Time sampling	Accuracy
Pr2	3 - 5 km, a.u.	25 s/ profile	
logPr2	3 - 5 km, a.u.	25 s/ profile	
NLSV	3 - 5 km, a.u.	25 s/ profile	
Extinction coefficient	m^{-1}	30 s to 60 s	± 10%

LPCA – ULCO
Accoustic Doppler Sodar

(P. Augustin, M. Fourmentin, H. Delbarre)

SITE 3

The PA2 REMTECH monostatic Doppler Sodar system uses four antennas to deduce the horizontal component of wind velocity. It provides information on the vertical wind profile (wind speed, wind direction, turbulence, vertical motion) from 25 m up to 500 m a.g.l, and also on the vertical structure of the atmosphere thanks to the echo and the variance of the vertical wind velocity.

Technical characteristics

Nominal central operating frequency	2250 Hz
Antenna size	1,30 m x 1,30 m
Antenna weight including supporting structure	100 kg
Acoustic Power	10 W
Maximal range	500 m
Spatial resolution	25 m
Power supply	230 VAC/50Hz
Total power consumption	50 W

Sampling characteristics and accuracy

Measured variable	Range, Unit	Time sampling	Accuracy
Horizontal wind speed	0 to 3000, cm/s	15 min (2 min to 1h)	± 3%
Horizontal wind direction	0 to 360, °	15 min (2 min to 1h)	± 1%
Vertical wind speed	-400 to 400, cm/s	15 min (2 min to 1h)	± 1%
Echo strength	a.u.	15 min (2 min to 1h)	
u’, v’, w’	cm/s	15 min (2 min to 1h)	

Remtech Sodar PA2 on site 3, Capvern, during BLLAST campaign

Laboratoire d'Aérologie (LA)

UHF (Ultra High Frequency) wind profiler

(F. Saïd, B. Campistron, Y. Bezombes, S. Derrien)

SITE 1

Objective :

The UHF (Ultra High Frequency) wind profiler provides information on the atmospheric dynamics at meso and small scale in the lower troposphere. It supplies vertical profile of the three components of the wind, in both clear air and cloudy air or rain, at 75 m vertical resolution, from 150 m to 3000 m a.g.l, and every 5 or 15 minutes.
It also allows the study of the atmospheric boundary layer, with estimates of the boundary layer top inversions, of the kinetic energy dissipation rate. The momentum flux can be estimated with some hypotheses.

Principle :

The principle is based on active remote sensing : a 1270 MHz electromagnetic wave is emitted with pulses in the atmosphere in five different directions alternatively, and backscattered by the fluctuations of the refractive index of the air, by biological fragments, large dust particles, insects or precipitations. The received power is related to the atmospheric turbulence or to the drop size distribution of the backscattering particles. The Doppler velocity measured along each beam allows the measurement of the three component of the mean wind. The Doppler spectral width enables to estimate the intensity of turbulence or some characteristics of the precipitation, depending on the source of the received echo.

Technical characteristics :

Emitted frequency	1270 MHz
Wavelengh	23.6 cm
Peak power	4 kW
Repetition frequency	20 k Hz
Pulse length	150 m
Radial resolution	75 m
Number of antenna beams	5
Elevation of the oblique beams	75°
Type of antenna	Coaxial-Colinear
Antenna area	2 x 2 m^2
Beamwidth	8.5°
Vertical cover	200 m to 3000 m a.g.l
Radial sampling	75 m
Temporal resolution	~ 5 minutes

Operation :

This UHF wind profiler has been acquired by the Laboratoire d'Aérologie in 2010. It works continuously at CRA site, except during external field campaigns or maintenance.

Real-time observations of this profiler can be seen at http://www.aero.obs-mip.fr/specials/images_uhf.html

NB: This type of wind profiler has been operated at CRA site for about 10 years between 1996 and 2006 in collaboration with EDF (Electricité de France, electrical power company) and Degréane-Horizon. It has also worked continuously on this site, or punctually been used for field campaigns elsewhere during this period.

Laboratoire d'Aérologie (LA)

VHF (Very High Frequency) wind profiler

(F. Saïd, B. Campistron, Y. Bezombes, S. Derrien)

SITE 1

Objectives :

Measurements made by the ST (Stratosphere-Troposphere) VHF (Very High Frequency) wind profiler allow us to study the atmospheric dynamics at the meso and large scales within the column of the troposphere located above the radar. It especially enables the study of the frontal systems, the impact of the mountain on the flow, the wind profiles associated with storms, the variability of the tropopause, etc...

The VHF wind profiler in Lannemezan enables us to retrieve the three components of the wind in clear air or precipitations between 1.5 and 16 km height with a vertical resolution of 375 m and temporal interval of about 15 min. It is possible to estimate the height of the tropopause or other stable layers that indicate the intrusion of air from the stratosphere, by use of the vertical profiles of the measured backscatter power.

Principle :

The principle is that of active remote sensing: a 45 MHz wave is pulse emitted in the atmosphere in five distinct directions (5 beams) and backscattered by the fluctuations of the air refractive index along its path. The power received is thus linked with the turbulence of the air and also with humidity and temperature gradients. The Doppler velocity measured on every beam enables to retrieve the three components of the wind. Interestingly, the observed noise can even be used to estimate the sky temperature associated with cosmic radiation...

Technical characteristics :

Emitted frequency	45 MHZ
Wavelength	6.66 m
Peak to peak power	6 kW
Repetition frequency	6400 Hz
Pulse length	6000 m
Effective radial resolution	375 m
Antenna beams	5 beams, one vertical beam and four oblique beams at 75° site angle
Antenna type	Coaxial-Colinear
Antenna area	60 x 60 m2

Vertical range	1.5 km to 16 km
Radial sampling	375 m
Temporal resolution (Duration of one cycle over the five beams)	15 min

Operation :

The VHF wind profiler has been set up at the CRA site since 1993. It is part of a wind profiler network of INSU-MétéoFrance. Since 2001 the profileur at CRA has been functionning continuously in the context of the European CWINDE network. Its hourly observations are assimilated by operational forecast models used in UK and France.

Real-time observations of this profiler can be seen at http://www.aero.obs-mip.fr/specials/images_st.html

Radiometer, Laboratoire d'Aérologie

(J.F. Georgis, F. Mesnard, O. Pujol, H. Sauvageot)

Detailed description of the RPG-HATPRO radiometer

The radiometer (RPG-HATPRO) belongs to Laboratoire d'aérologie, Université Paul Sabatier (Toulouse III), CNRS.

The HATPRO is capable of performing fast LWP (Liquid Water Path) sampling with 1 second time resolution while simultaneously measuring full troposphere profiles of temperature and humidity. The instrument supports two different scanning modes to achieve a maximum accuracy and vertical resolution for temperature profiling in the full troposphere (< 10000 m, vertical resolution 150 – 250 m) and boundary layer (< 1000 m, vertical resolution 50 m).
In zenith observation mode the radiometer only measures in the vertical direction while scanning the water vapour and oxygen lines in Fig.1 continuously. Atmospheric quantities like LWP, IWV, Wet/Dry delay and absolute / relative humidity profiles are retrieved from the water vapour line shape and a window channel at 31.4 GHz. The oxygen line complex is only used for temperature profiling of the troposphere.
The RPG-HATPRO radiometer comprises 7 channels on the water vapour line / window and 7 channels on the oxygen line.
In boundary layer mode the radiometer scans the atmosphere in elevation to acquire more information about the lower atmospheric layer (<1000 m). For the retrieval of boundary layer temperature profiles only the upper four channels are used which show the highest absorption below 1000 m. The variation of brightness temperature in a scan is typically in the order of 1 to 4 K. Thus a sensitive receiver and long integration times are required for the method to achieve the required accuracy. The RPGHATPRO uses integration times of 20-60 seconds per angle (user selectable) with a total scan time of 2-6 minutes. During this time the zenith observation mode is disabled.
Characteristics of the RPG-HATPRO

Manufacturer	Radiometer Physics GmbH (RPG)
Type	HATPRO
Channels number	14

Channel center frequencies and corresponding bandwiths

fc (GHz)	22,24	23,04	23,84	25,44	26,24	27,84	31,4	51,26	52,28	53,86	54,94	56,66	57,3	58
b (MHz)	230	230	230	230	230	230	230	230	230	230	230	600	1000	2000

Parameter	**Specification**
Humidity profile performance	Vertical resolution: 200m (range 0-2000m) 400m (range 2000-5000m) 800m (range 5000-10000m) Accuracy: 0.4g/m3 RMS (abslute humidity) 5% RMS (rel. humidity)
Temperature profile performance	Vertical resolution: BL-Mode: 50m (range 0-1200m) Z-Mode: 200m (range 1200-5000m) 400m (range 5000-10000m) Accuracy: 0.25 K RMS (range 0-500m) 0.50 K RMS (range 500-1200m) 0,75 K RMS (range 1200-4000m) 1,00 K RMS (range 4000-10000m)
Liquid Water Path	Accuracy: +/-20 g/m² Noise: 2 g/m² RMS
Integrated Water Vapor	Accuracy: +/-0.2 kg/m² RMS Noise: 0.05 kg/m² RMS
Radiometric resolution	K-Band: 0.10 K RMS V-Band: 0.20K RMS @ 1.0 sec integration time
Absolute brightness temperature accuracy	0.5 K
Radiometric range	0-800 K
Optical resolution	HPBW: 3.5° for water vapor 1.8° for temperature profiler
Sidelobe level	<-30dBc
Power consumption	<120 Watts average, 350 Watts peak for warming-up (without dew blower heater), blower: 130 Watts max.
Input voltage	90-230 V AC, 50 to 60 Hz
Weight	60 kg (without dew blower)
Dimensions	63x36x90 cm3

CONTINUOUS OBSERVATIONS
In situ aerosols

LPCA – ULCO

Optical Particle Counter (OPC)

(P. Flament, K. Deboudt, C. Rufin-Soler)

SITE 1

OPC General Principles of Operations:

The OPCs use a light-scattering technology for single-particle counts, whereby a semiconductor-laser serves as the light-source. The scattered signal from the particle passing through the laser beam and is collected at approximately 90° by a mirror and transferred to a recipient-diode. The signal of the diode passes, after a corresponding reinforcement, a multi-channel size classifier. A pulse height analyzer then classifies the signal transmitted in each channel. These counts can be displayed and are also stored in the data storage card and may be transferred via the RS 232 for further analysis.
The ambient-air, to be analyzed, is drawn into the unit via an internal volume-controlled pump at a rate of 1.2 liters/minute. The sample passes through the sample cell, past the laser diode detector and is collected onto a 47-mm PTFE filter which can then be analyzed gravimetrically for verification of the reported aerosol's mass. The data are available in intervals of every 60 seconds and reported as number of particles per liter in 15 granulometric classes between 0.3 and 20 µm.

OPC Main Technical Characteristics

Sample flow rate	1.2 l/min ±5%
Data interface	ASCII: RS-232 (9600 baud, 8 bit, no par parity, 1 stop-bit, protocol: Xon/Xoff)
Power supply	AC 95-250V, 47-63Hz or battery (12V/2,3Ah)
Operation temperature range	0...+40 °C, r.H. < 95 %

GRIMM Optical Particle Counter Model 1.108
(Courtesy of GRIMM Gmbh)

LPCA – ULCO

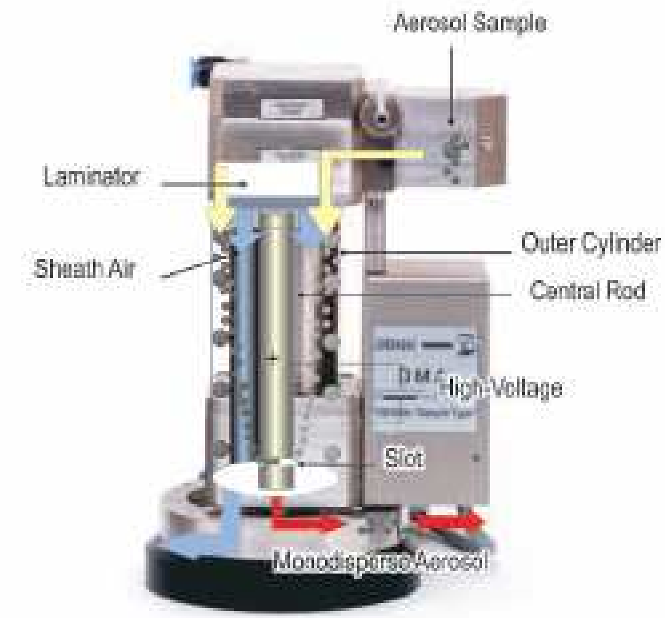
Scanning Mobility Particle Sizer (SMPS)

(P. Flament, K. Deboudt, C. Rufin-Soler)

SITE 1

SMPS General Principles of Operations:

Fine and ultrafine particles are classified with a Differential Electrical Mobility Analyser (DMA). Larger particles (size > 10 µm) are removed by an impactor at the inlet of the DMA. A bipolar charger serves to establish a well defined charge distribution on the particles. The classification (i.e. the selection of a well defined fraction from a broad size distribution) occurs in the electrostatic electric field in the annulus between inner and outer electrode of the DMA. When a positive voltage is applied to the inner electrode, negatively charged particles in the sample air (yellow arrows in Fig.1) drift through the initially particle free sheath air (blue arrows) towards the inner electrode, this drift is superimposed to the downward movement of the air flow. Because small particles drift faster than large particles (they feature a higher "mobility"), only particles of a certain size reach a narrow slit at the bottom of the inner electrode and thus a downstream detection system (Condensation Particle Counter).



Principle of Differential Electrical Mobility Analyze (Courtesy of GRIMM Gmbh)

GRIM and C System Main Characteristics:	
Size Range	11 – 1110 nm
Size Resolution	44 channels
Flow Rate of Sample Air	0.3 L/min
Flow Rate of Sheath Air	3.0 L/min
Working Fluid for CPC	1-Butanol (Reagent-grade)
Operating Conditions:	
Ambient Temperature Ambient Humidity	10 to 35°C 0 to 95% RH

INTENSIVE OBSERVATIONS
Aircraft / Unmaned platfrom

SAFIRE, Laboratoire d'Aérologie, CNRM/GAME, Univ. Cataluña

Piper Aztec research aircraft

(A. Butet, P. Durand, B. Piguet, D. Pino)

Detailed description of Piper Aztec instrumentation

The Piper Aztec (PA23-250, see Figure 1) belongs to Météo-France and is operated by the French service of atmospheric research aircraft SAFIRE, a joint structure of CNES (French Space Agency), CNRS (French Research Agency) and Météo-France.

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

Performances

Maximum altitude	4 000 m
Maximum take-off weight	2177 kg
Maximum landing weight	2177 kg
Endurance	2.5 to 5 hours, depending on the mass
Range	700 to 1400 km
Speed of Work	70 m/s (250 km/h)
Payload	300 Kg

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.

Measurements

Pressure:

Parameter	Sensor	Range	Accuracy	Acquisition frequency	spatial resolution
Attack pressure	Rosemount 1221	+/- 35 hPa	+/-0,2 hPa	200 Hz	0.35 m
Sideslip pressure	Rosemount 1221	+/- 7 hPa	+/-0,2 hPa	200 Hz	0.35 m
Static pressure	Rosemount 1201	300 à 1100 hPa	+/-0,5 hPa	200 Hz	0.35 m

Temperature:

Parameter	Sensor	Range	Accuracy	Acquisition frequency	Spatial resolution
Impact temperature	Rosemount E102	- 60 à +50°C	+/-0,5 °C	200 Hz	0.35 m

Gaz concentration :

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
Water vapour density	Licor 7500	??	??	??	??
CO_2 concentration	Licor 7500	??	??	??	??

Other Parameters	Instruments	Accuracy	Acquisition frequency	Spatial resolution
Altitude	GPS + INS	~ 1 m	1 Hz	70 m
Height (/ground)	Radar altimeter till 2500ft	50 m	1 Hz	70 m
Attitude angles (roll, pitch, true heading)	IXSEA	??	??	??
3-D ground-speed	IXSEA	??	??	??
3-D wind (mean and turbulence)	Gust probe + IXSEA attitude and inertial platform	2 m/s (resol. XX m/s)	25 Hz	18 m
Latitude	GPS Bancomm	+/- 100 m	1 Hz	70 m
Longitude	GPS Bancomm	+/- 100 m	1 Hz	70 m

Post-flight control

Time series, profiles and airplaine trajectory can be available XX hours after landing. These “quick-look” only involve parameters recorded on the basic acquisition system of the airplane.

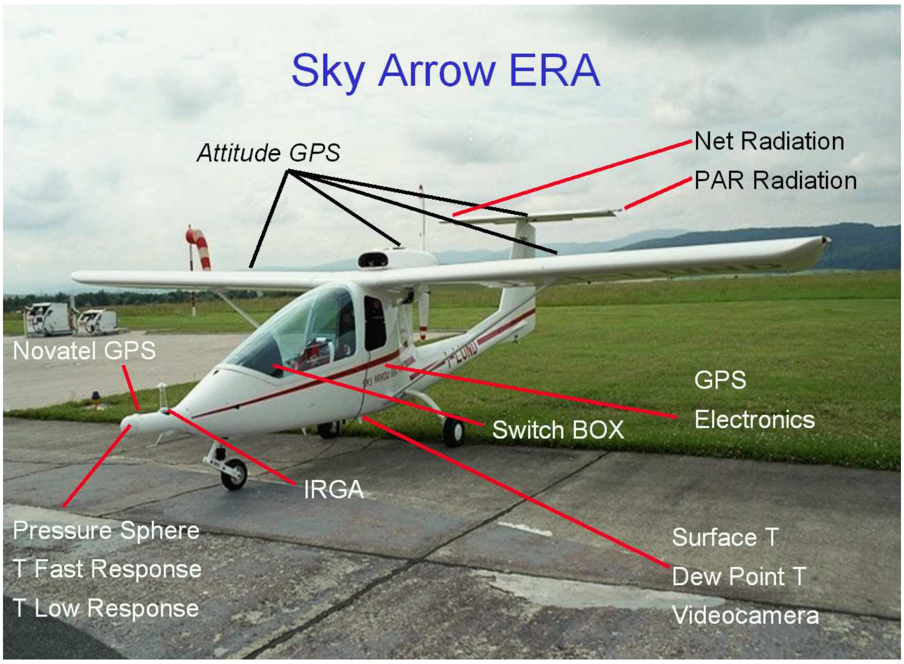
CNR - Ibimet

Sky arrow research aircraft

(B. Gioli,A. Zaldei, E. Magliulo)

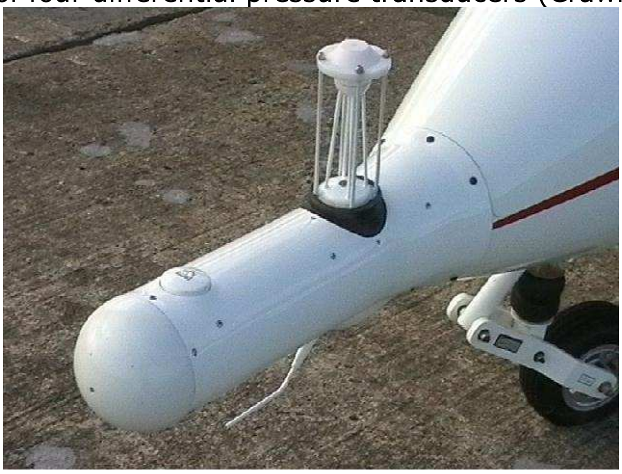
The Sky Arrow

The aerial platform that will be used 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 (Fig.1). 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.



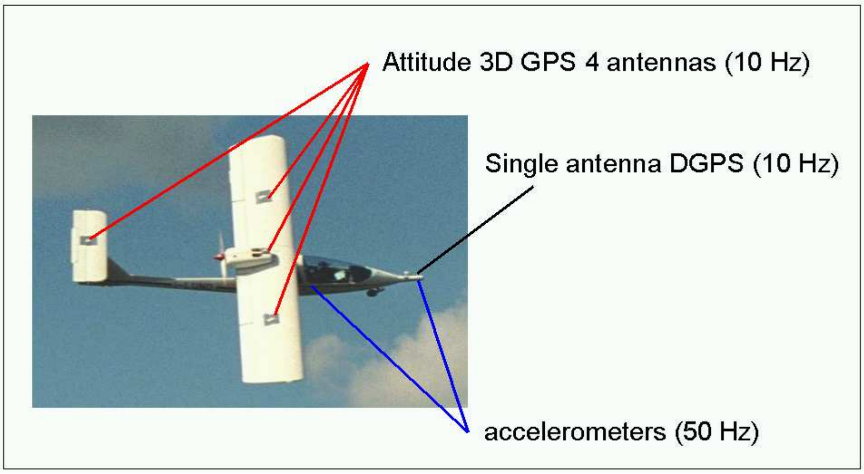
Photograph of the SkyArrow ERA showing the exact location of the sensors and instruments mounted onboard.

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).



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 (Fig. 3). 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.



Attitude 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).

INSTRUMENTATION AND SYSTEMS - SkyArrow ERA		
PARAMETER	SENSOR(S)	ACCURACY and Notes
Time	GPS (Novatel RT 20, single freq.) Differentially corrected Extended to 50Hz with probe accelerometer	All data syncronized with GPS clock
Position (lat, long & alt)		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

Equipment installed on board the Sky Arrow

University of Bergen, Geophysical Institute

UAS SUMO (Small Unmanned Meteorological Observer)

(J. Reuder, M. Jonassen, C. Lindenberg, M. Müller)

Detailed description of SUMO and its instrumentation

The UAS SUMO is based on a commercially available model construction kit (FunJet by Multiplex) made from EPP foam material. With its overall take-off weight of 580 g, the system is comparable to the mass of the routinely used radiosondes. There is no dense material exposed to the outside so that even in the case of a crash the impact is low. The propeller and motor are installed in the back of the aircraft, therefore additionally reducing the risk of damage or injury in the case of impact.
SUMO is equipped with the open source autopilot system Paparazzi, mainly developed and maintained by the École Nationale de l'Aviation Civile (ENAC), Toulouse, France. This autopilot is used by several hundreds of educational and scientific users all over the world. It enables the aircraft to be flown autonomously under the supervision of an experienced RC pilot and the ground control station (GCS) operator.
SUMO has been developed in cooperation between the Geophysical Institute, University of Bergen, Norway and Martin Müller Engineering, Hildesheim, Germany. Up to now the system has been performed more than 300 scientific meteorological missions. Operations are intended both during day and night. For night time operations, that have been successfully performed in the past, SUMO is equipped with colored LEDs (green=steerboard wingtip, red=backboard wingtip, white=fuselage/nose). For increased visibility during day and night operation, SUMO is equipped with flashing high-power LEDs at the rear.
SUMO is intended to be operated as controllable and recoverable radiosonde for boundary layer research. During BLLAST the main scientific missions will be atmospheric profiling in a helical flight pattern up to 7000 ft a.s.l., horizontal survey flights for surface temperature monitoring and straight transects for the determination of atmospheric turbulence.

Characteristics of SUMO

SUMO technical specifications	
vehicle type	fixed wing UAS

DIMENSIONS	
Wingspan	0.80 m
Length	0.75 m
Height	0.23 m
propeller diameter	227 mm (9x6)
take off weight	580 g (including battery)
PROPULSION	
Motor	electric brushless
motor type	AXI2212/26
motor power	120 W
battery type	Lithium-Polymer
battery capacity	2.1 Ah / 11.1 V
SPEED	
minimum speed	29 km/h
maximum speed	151 km/h
cruise speed	54 km/h
RANGE/ENDURANCE	
Horizontal	< 5 km
Vertical	3 km
Duration	< 30 min
SENSORS	
attitude control	IMU and infrared thermopiles
Navigation	GPS
basic meteorology	Pressure, temperature, humidity

SUMO operation	
mode of control, mode 1	autopilot (AUTO2)
mode of control, mode 2	stabilized manual (AUTO1)
mode of control, mode 3	manual (MAN)
launch method	hand launch
landing method 1	belly landing, manual
landing method 2	belly landing automatic
personell during start/landing	2, operator and pilot
personell in flight	2, GCS operator and safety pilot in stand-by
ground station	PC with 2.4 GHz radio modem + remote control for manual take-off and landing

Ground control station (GCS)	
Type	Paparazzi GCS
computer hardware	Panasonic Toughbook CF19
joystick interface	No
simulator for mission planning and operator training	yes
replay possible	yes
multiple UAV profiles	yes
user definable holding patterns	Yes
in-flight mission reprogramming	Yes
change waypoints in flight	Yes
in-flight gain adjustment	Yes
track all in-flight data live	Yes
telemetry logs indexed by time	Yes
telemetry data of battery power and system status	Yes
telemetry data of pressure	Yes

Measurements

Basic meteorology (all 3 SUMO aircrafts, #10, 11, and 12), operational during the BLLAST campaign:

Parameter	**Sensor**	**Range**	**Accuracy**	**Acquisition frequency**	**Sensor time constant**
temperature	Sensirion SHT 75	-40/+124 °C	+/-0.3 K	2 Hz	5-30 s
humidity	Sensirion SHT 75	+/- 7 hPa	+/-0,2 hPa	2 Hz	ca. 8 s
temperature	Pt 1000 Heraeus M222	-32/+96 °C	+/-0.2 K	4 Hz	ca. 3 s
pressure	VTI SCP1000	300-1200 hPa		2 hZ	
surface temperature (IR emission)	MLX90247			2 Hz	

Turbulent flow vector (only SUMO #12), prototype and test operation during the BLLAST campaign:

Parameter	**Sensor**	**Range**	**Accuracy**	**Acquisition frequency**	**Spatial resolution**
3D flow vector	5 hole probe, Aeroprobe Air data probe with data logging unit	11-35 m/s		100 Hz	0.25 m

Institute of Aerospace Systems, Technische Universität Braunschweig
Meteorological Mini Aerial Vehicle (M²AV)

(G. Lohmann, S. Martin, A. Lampert)

The automatically operating Meteorological Mini Aerial Vehicle (M²AV) is based on the Carolo T200 unmanned aerial vehicle (UAV) developed at the Institute of Aerospace Systems (ILR), Technische Universität Braunschweig. It is an electrical twin-engine aircraft with a special meteorological sensor package mounted on the nose that consists of a 5-hole probe for measuring the three-dimensional wind vector, a Vaisala HMP 50 for temperature and humidity measurements, and a thermocouple for measuring fast temperature fluctuations. All sensor inputs are recorded with a temporal resolution of 100 Hz, regardless of the individual sensor's response time.
The unmanned aircraft is launched either by convenient bungee start, or by hand, which requires a certain skill and experience from the ground staff. The M²AV is controlled by the miniature integrated navigation and control (MINC) autopilot system, which includes a 3-axis inertia measurement unit (TrIMU) and a satellite navigation receiver. This combination ensures precise and long-term stable determination of position, velocity, attitude, and true heading.
The Mini-UAV system is completed by a ground antenna and the UAV Control Desktop software (MAVCDesk) running on a common laptop computer. This software is the main user interface, allowing mission planning before take-off and mission supervision in-flight, including changing of the flight trajectory as long as the aircraft is within telemetry range. A remote control receiver on board can be used for back-up manual remote control of the aircraft.

Aircraft Specifications:

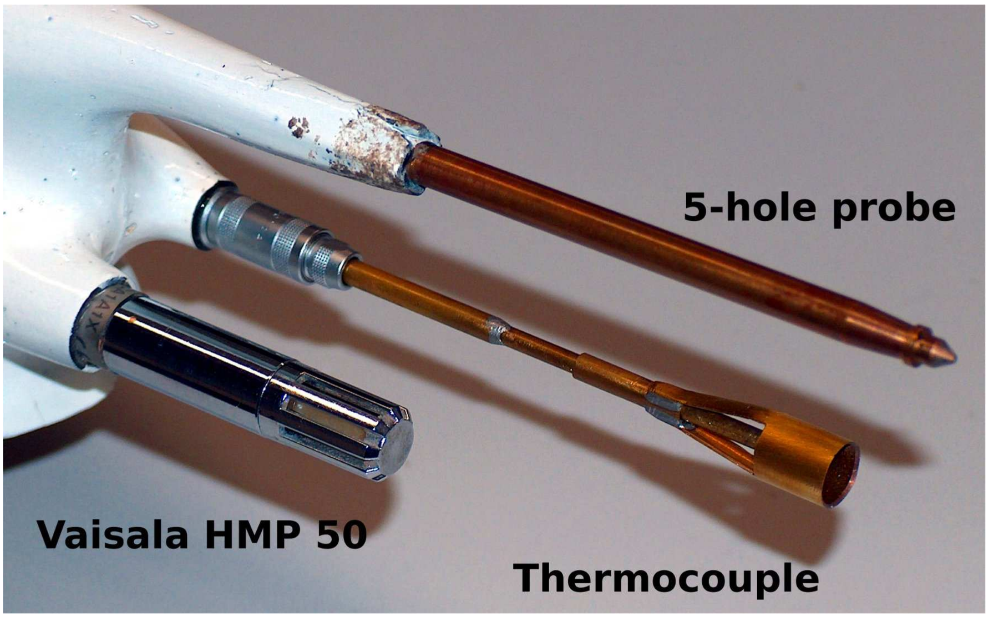
(1)maximum take-off weight: 6 kg
(2)meteorological payload: 1.5 kg
(3)wing span: 2.0 m
(4)length: 1.8 m
(5)typical cruise speed: 22 m/s
(6)endurance (level flight): 50 to 60 min.
(7)climb performance: 2000 m agl
(8)standard telemetry system: 868 MHz ISM band
(9)frequency of remote control: 2.4 GHz or 35 MHz
(10)operating wind speed: max. 10 m/s

Sensor Specfications:

- 5-hole probe for wind vector measurements
  - temporal resolution: 30 Hz
  - operating angles of attack and sideslip: -20° to +20°
  - wind speed accuracy: ± 0.8 m/s
  - wind direction accuracy: ± 15°

- Vaisala HMP 50 for temperature and humidity measurements
  - temporal resolution: 1 Hz
  - humidity accuracy: ± 2 %
  - temperature accuracy: ± 0.6 K

- Thermocouple for high resolution temperature measurements
  - temporal resolution: 10 Hz
  - coupled with HMP 50, thus offering the same accuracy of ± 0.6 K



University of Tübingen

Multi-purpose Automatic Sensor Carrier, MASC

(A. van Kroonenberg, N. Wildmann, J. Bange)

The research aircraft of type 'multi-purpose automatic sensor carrier' MASC are electrically powered twin-engined research UAV that operate automatically (i.e. without remote control) at 20 m/s mission airspeed. The new (open source) autopilot system allows for very low measurement heights and very precise flight paths. The altitude can be maintained with an accuracy of ±2 m which is not feasible for a human pilot but very important for safe and precise operation. MASC can at least climb up to 2000 m agl (above ground level) and thus is able to probe the entire ABL. The aircraft provide automatic take-off and 75 minutes total endurance, i.e., within a safety endurance of
60 minutes, a MASC can travel nearly 80 km.

The weight of a MASC is about 5 kg including a 1.5 kg scientific payload, that can easily be substituted by other sensor containers. The standard meteorological measurement container consists of fast in-situ sensors for temperature, humidity and wind vector, sampled by a board computer (named AMOC, in-house development) at 100 Hz, providing a 30 Hz resolution after anti-aliasing filtering (or a sub-metre resolution at 20 m/s airspeed). Position, ground speed and attitude of the aircraft are measured using GPS and several inertia sensors. The UAV is equipped with LEDs for better visibility during twilight and night.

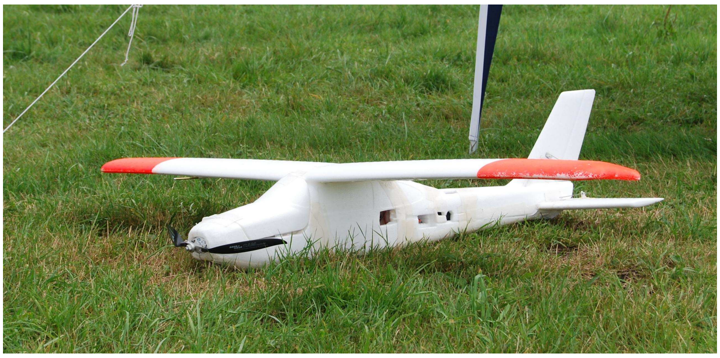
The autopilot used is Paparazzi and is an open source system for autonomous flight and for ground station mission planning and monitoring. The system was officially developed at Ecole Nationale de l'Aviation Civile (ENAC), the French National School of Civil Aviation. Due to the open source character the project is constantly growing and is now used and advanced by many teams around the world. All the source code and hardware schematics are available at the following website: http://paparazzi.enac.fr/wiki/Main Page.

Parameter	**Sensor**	**Accuracy**	**Resolution (estimated in flight)**
Relative humidity	P14-rapid	-	5 Hz / 4 m
Relative humidity	UPSI-f-tuta.34r	3 % RH	5 Hz / 4 m
Temperature	thermocouple	0.5 K	10 Hz / 2 m
Temperature	PT1000	0.15 K	< 1 Hz / 20 m
Airspeed and Airflow angles (wind)	5-hole probe with differential pressure sensors	-	30 Hz / 0.7 m
Groundspeed and position (wind)	GPS u-blox	Horiz. Pos.: typ. 7.5m Vert.Pos.: typ. 9m	5 Hz / 4 m
Attitude angles (wind)	IMU CHR-6dm	Static conditions: Roll and Pitch < 0.5° Yaw: < 1°	30 Hz / 0.7 m

University of Heidelberg, Institute of Environmental Physics

MAVinci SIRIUS I Unmanned Aerial System (UAS)

(C. Claussen, J. Born)



Technical Data

(11)Wingspan: 163 cm
(12)Length: 120 cm
(13)2,7 kg take off weight
(14)40 min flight time with 500 g payload and one battery
(15)Economic Airspeed: 65 km/h

Sensors

Temperature & Humidity

- SHT21 by Sensiron
- HTM-B71-H by TronSens
- DigiPicco by IST

Temperature

- PT1000 Din class A
- K-type thermocouple diameter: 0,25 mm

Other:

- Surface roughness (Hokuyo Laser scanner)
- Orthophotos (Panasonic Gf1, Camera for visible range)
- Surface Temperature (Thermopile)
- Air pressure (BMP085)

University of Applied Sciences Ostwestfalen-Lippe
BlackHat Multicopter with AMOR platform

(B. Wrenger, J. Duennermann)

The multicopter used by University of Applied Sciences Ostwestfalen-Lippe uses a 8-motor electric propulsion capable of carrying a payload of up to 1.5 kg for up to 40 min. flight time. It operates from hovering up to 10 m/s horizontal airspeed and climbs with up to 7 m/s. The autopilot allows different modes (manual, position hold, waypoint navigation) and has been operated during the BLLAST campaign in waypoint navigation mode supervised by a safety pilot. Due to the low altitude flights (5-10 m for horizontal survey flights and up to 120 m for vertical profile flights), the flight path could not be straight forward to give reasonable safety distance to all scientific instruments in the field. The weight of the the multicopter is about 1.5 kg including the battery pack (5.000 mAh). The standard measurement payload includes in-situ sensors for temperature, surface temperature, humidity and pressure. One of the temperature sensors is a fast thermocouple type temperature sensor developed by the University of Tübingen (DE). The AMOC data acquisition system jointly developed by University of Applied Sciences Ostwestfalen-Lippe and University of Tübingen measure a 100 Hz stores the data onboard and also sends them to a scientific ground station. Position, ground speed and attitude is measured by GPS and inertia sensors which are part of the AMOC system. Due to LED illumination bands, the multicopter is easily operated also in the night time making it easy to sample morning and evening transitions.
The BlackHat multicopter is operated by one safety pilot and one ground control station operator.

Parameter	**Sensor**	**Accuracy**
Relative humidity	Sensirion SHT75	3 % RH
Relative humidity	UPSI-f-tuta.34r	3 % RH
Temperature	Thermocouple (Tübingen type)	0.5 K
Temperature	Sensirion SHT75	0.3 K
Surface Temperature	Melexis MLX90614	0.1 K
Position	GPS u-blox	Horiz. Pos.: max. 7.5m Vert.Pos.: max. 9m
Attitude angles	AMOC	Static conditions: Roll and Pitch < 0.5° Yaw: < 1°

INTENSIVE OBSERVATIONS
Radiosoundings

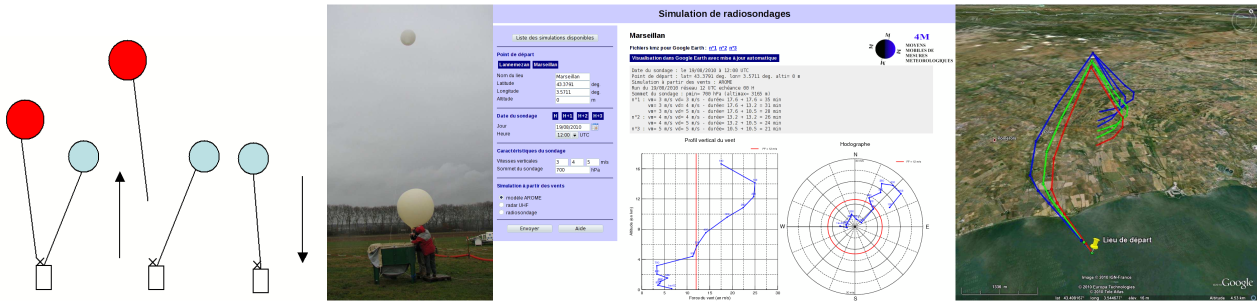
CNRM/GAME

Frequent and sonde-reusable radiosounding system

(D. Legain, D. Tzanos, E. Moulin, T. Douffet)

SITE 2

A Vaisala sounding system Digicora III with RS92 SGP radiosonde is used with two ascending balloons. The first balloon is separated at a preset height (controlled with a pressure sensor) above the boundary layer top. The second balloon set the falling rate. Ascent and fall rates can be preset with 3 values between 3 - 6 m/s according to balloons inflating.



A single tool, using Météo-France Arome model local wind profil forecasting, or real time radar UHF wind profil give 6 fall locations plotted on Google-Earth or IGN 1:25000 map. The operator chooses the best point to have better possibility to found the radiosonde and inflate the balloon according to the expected ascent and fall rates. Last transmitted GPS position and high visibility of the second balloon give two ways to found the radiosonde.

Radiosonde sensors are specifically protected against shocks to permit new launching. Radiosonde measurements are checked with ground station before new flight.

Logistics and operating constraints :

- Shield is needed for balloon inflating and balloon tare in still air.
- 220 V 300 W for data logger
- Antenna must be set to elevated point to have a good radio reception when balloon landing.

Laboratoire d'Aérologie (LA)
MODEM – standard radio soundings

(M. Lothon, S. Derrien, F. Lohou, F. Couvreux)

SITE 1

Objectives:

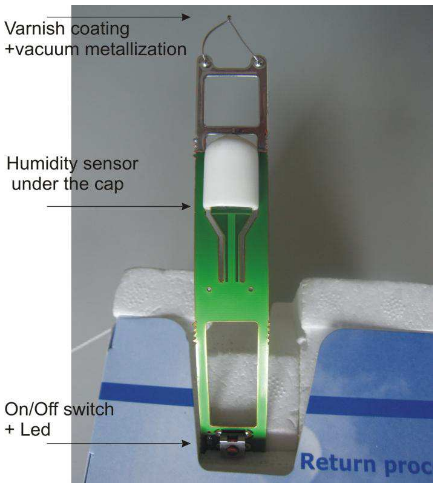
MODEM radio sounding system enables the profiling of thermodynamic parameters such as temperature, humidity, wind speed and wind direction. The system of the Centre de Recherches Atmosphériques (Laboratoire d'Aérologie) is a SR2K2-P from MODEM Company, used with M2K2-DC sondes. It has been operated during BLLAST field campaign with 4 soundings each IOP day minimum, and up to six soundings maximum.

As an in situ observation, radio sounding is still a reference measurement for atmospheric profiles in comparison to remote sensing.

MODEM SR2K2-P consists in:

- an acquisition bench (electronic and laptop)
- a ground check box (with reference sensors)
- radio and GPS antennas

The sondes are M2K2-DC model with a temperature sensor, a humidity sensor, a GPS card, a radio card and batteries for power supply.



Principle:

Usable radio frequencies are from 400 to 406 MHz (meteorological band). It allows the bench and the sondes to communicate together.

3D GPS module provides the position of the sonde (latitude, longitude, and altitude) as well as the velocity components (North-South, East–West and Z). These data are correlated to time. Position is calculated every second by triangulation method between 4 or more satellites.
The velocity is not calculated from the difference between 2 positions but directly issued from Doppler. On short time scales, velocity is more accurate than position when it becomes less accurate on large time scales. MODEM system takes into account both measurement methods in order to provide the most accurate data.
These data are compared to GPS reference station (Differential GPS) in order to clear satellites disturbances and potential interferences.

Ground pressure is measured by a pressure sensor in the bench, and is calibrated each year.
Pressure is calculated from GPS altitude, temperature and humidity according to barometric equation (Laplace law).

Temperature is measured by a thermistor chip wrapped into a glass ball. Its tiny size (0,9 x 2 mm) allows response time around 1 to 1.3 sec. Temperature sensor is led on a layer processed against humidity and solar radiations.
Boom end undergoes a special vacuum metallization process reducing both solar and infrared radiation effects. Solar radiation correction is less than 1.5°C at 23 hPa.

Humidity is measured by a capacitor of which value is directly proportional to relative humidity. It is composed of 3 primary components: (i) Basic layer as an electrode, (ii) A dielectric of which characteristics vary along relative humidity, (iii) A short response porous electrode as the second electrode of the capacitor.
A cap is protecting the sensor from rain and mechanical damage

Temperature and humidity are checked before launch thanks to reference sensors in the ground check box, containing a GPS repeater for indoor initialization.

Technical characteristics:

General features

Dimensions	Width : 92 mm Length : 107 mm Height: 160 mm
Weight	210g (including batteries)

Pressure

Method	Calculated from GPS altitude
Range	1100 to 3 hPa
Accuracy	±1 hPa at Surface ±0.1 hPa at 60 hPa

Temperature

Sensor	Thermistor
Range	+60° to –90°
Resolution	0.1°C
Accuracy	+/- 0.5°C
Response time	< 2s
Measurement rate	1 Hz
Calibration	Yes
Factory calibration	Stored on EPROM

Humidity

Sensor	Capacitor
Range	0% to 100%
Resolution	1%
Accuracy	+/-5%
Response time	< 2s
Measurement rate	1 Hz
Calibration	Yes
Factory Calibration	Stored on EPROM

Wind

3D GPS calculation	Differential
Altitude range	Unlimited
Position accuracy	10 m
Speed accuracy	0.15 m/s
Direction accuracy	2 °
Position resolution	0.01 m
Horiz. speed resolution	0.01 m/s
Direction resolution	0.1 °
Measurement rate	1 Hz

UC Davis, California

GRAW – standard radio soundings

(I. Faloona – UC Davis California, J. Mione – ENSEEIHT Toulouse)

SITE 1-3

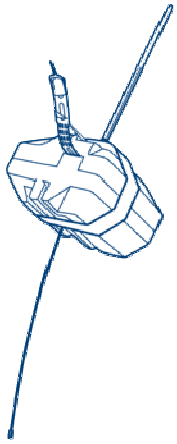
Principle

The DFM-06 is GRAW standard radiosonde for most applications. It is designed to measure the profile of atmospheric pressure, temperature, humidity, wind speed and direction, from the surface up to 40 km altitude. Continuous data sets of measurements are sent down to the groundstation by radio-telemetry link.

GRAW DFM-06 consists in:

portable ground station (GS-H Handheld)
a VHF radio
Radiosondes

Each radiosonde can transmit in a narrow channel anywhere within the meteorological band, which is 400 MHz to 406 MHz. The sonde uses an on-board frequency synthesiser, which is automatically set to the desired transmission channel during initialisation. It allows the bench and the sondes to communicate together.



Temperature and humidity sensors

All sensors on the radiosonde are factory calibrated; no additional ground calibration is necessary prior to launch.

(16)The temperature and humidity sensor boom ensures precise measurements during ascent, it is unaffected by any thermal influences of the sondes housing
(17)A mirrored surface reduces errors due to solar radiation
(18)A ceramic temperature sensor delivers a fast response due to its low mass and low thermal capacity
(19)Fast, capacitive polymer humidity sensor

Differential C/A-Code GPS for Wind measurements

The GRAW radiosonde has a standard on-board C/A code-correlated GPS receiver. The sonde's positional information is transmitted to the groundstation where it is corrected with the groundstation's differential GPS system. The resulting data is used to calculate the wind speed and direction of the sonde's ascent - at all heights. Fully coded GPS allows the groundstation to be used on the move.

Pressure Measurements
The pressure is calculated by the GPS height, the ground pressure and the vertical profile of temperature and humidity.

Technical characteristics:

General features			
Dimensions	94 x 94 x 60 mm		
Weight	90g		
Battery	Lithium		
Pressure		***Wind***	
Accuracy	±1 hPa	Position accuracy	10 m
Geopot. height accuracy	30 m	Speed accuracy Measurement rate	0.2 m/s 1 Hz
Temperature		***Humidity***	
Resolution	0.1°C	Resolution	1%
Accuracy	+/- 0.2°C	Accuracy	+/-5%

INTENSIVE OBSERVATIONS
Tethered balloons

CNRM –GAME

Tethered balloon and turbulence probe

(E. Moulin, D. Legain, D. Tzanos, J. Barrié)

SITE 1

Helium inflated balloon Vaisala 7 m^3
Payload 2 Kg
Dimensions l 2.6 x H 2.8 x p 6.2 m
Measurements from ground to 1000 m AGL if wind < 12 m/s
Air traffic control (DGAC in France) flight autorization

Two kind of instrumentation available :

A set of 4 tethersondes Vaisala TTS111 for 5 levels continous measurements with real time data transmission

	Resolution	Accuracy	Range	Response time
Temperature	0.1 °C	0.1 °C		0.2 s
Humidity	0.1 %	2 %	0 – 100 %	0.5 s
Pressure	0.1 hPa	0.4 hPa	500 – 1080 hPa	
Wind speed	0.1 m/s		0 – 20 m/s	
Wind direction	1 °		0 – 360 °	

5 to 10 s sampling
Frequency tunable from 400 to 406 MHz. Coordination with other systems needed.

CNRM Turbulence probe
Wind 3D and speed of sound and sonic temperature: Gill Windsonic 3D
XYZ speed, acceleration and position : Motion pack GPS MTI-G Xsens
Pressure sensor
Absolute air temperature : platinum fine wire with radiation shied
Raw data 10 Hz on SD memory card
Power supply autonomy : 5 h
Weight :2 Kg battery included
Vaisala TTS111 with real time data transmission for balloon safety
Frequency tunable from 400 to 406 MHz. Coordination with other systems needed.

Logistics and operating constraints :
- Safety shield is needed for night storage without deflating
- 220 V 500W for datalogger and electrical winch
- Ideally, the balloon should be operated at the same site that high frequency radiosoundings.

UTAH / LA

Two Tethered balloons

(E. Pardyjak, F. Lohou, M. Lothon, S. Derrien)

SITE 2: moor and corn

Helium inflated balloon Vaisala 7 m^3
Payload 2 Kg
Dimensions l 2.6 x H 2.8 x p 6.2 m
Measurements from ground to 1000 m AGL if wind < 12 m/s
Air traffic control (DGAC in France) flight authorization

A set of 5 tethersondes Vaisala TTS111 for 5 levels continuous measurements with real time data transmission

	Resolution	Accuracy	Range	Response time
Temperature	0.1 °C	0.1 °C		0.2 s
Humidity	0.1 %	2 %	0 – 100 %	0.5 s
Pressure	0.1 hPa	0.4 hPa	500 – 1080 hPa	
Wind speed	0.1 m/s		0 – 20 m/s	
Wind direction	1 °		0 – 360 °	

5 to 10 s sampling
Frequency tunable from 400 to 406 MHz. Coordination with other systems needed.

INTENSIVE OBSERVATIONS
Chemistry

LPCA – ULCO

Cascade Impaction Sampling for Chemical Analyses

(P. Flament, K. Deboudt, C. Rufin-Soler)

SITE 1

Atmospheric particles were collected at the top of the 12 meters high mast (CRA, site 1), from 30/06 to 07/07, using a cascade impactor (Dekati^{TM} PM10) operating with a flow rate of 30L/min. This impactor has three consecutive stages to separate coarse and fine fractions with cut-off diameters of 10 µm, 100 nm and 30nm (equivalent aerodynamic diameters at 50% of collection efficiency). The impactor is equipped with a PM2 head that discard all particles with an aerodynamic diameter higher than 2 µm by a cyclone technology.

Top of the 12-m mast implemented with the cascade impactor (in the red circle)

Detailed view of the cascade impactor with its cyclone PM2 head

Particles impacted onto cellulose filters. Analysis of hydrosoluble anions (Cl^-, PO_4^{3-}, NO_3^-, SO_4^{2-}) will be performed by Ion Chromatography (IC) after a dissolution of atmospheric aerosols in 20 mL of ultrapure water at 60°C during 1 hour in an ultrasonic bath. This analytical methodology is regularly checked on a certified simulated rain water sample (AES-05, National Water Research Institute, Canada).