# Transnational Access project
# BLLATE1

## 1. General information

**Project acronym** BLLATE1

**Project title** Boundary Layer Late Afternoon Transition Experiment 1

**Type** Scientific project

**Scientific theme** To observe and understand the dynamics of the atmospheric boundary layer during the transition from convective to stable conditions

**Main scientific field and Specific discipline** Earth Sciences & Environment / Other - Earth Sciences

**Participants undertaking research**

| Name + link to id card | Research status | Email | Institution | Institution country | CV | Letter of reference | Publication |
|---|---|---|---|---|---|---|---|
| PINO David (lead scientist) | Post-doctoral researcher | david.pino@upc.edu | Technical University of Catalonia | Spain | CV | | |
| BLAY Estel | Post-Graduate | estel.blay@upc.edu | Universitat Politècnica de Catalunya | Spain | | | |
| DURAND Pierre | Experienced researcher | pierre.durand@aero.obs-mip.fr | CNRS | France | | | |
| LOTHON Marie | Experienced researcher | lotm@aero.obs-mip.fr | Laboratoire d\\' Aerologie | France | CV | | |
| VILA GUERAU DE ARELLANO Jordi | Experienced researcher | jordi.vila@wur.nl | Wageningen University | Netherlands | | | Publication (3) |

**Lead scientist's background**
*(scientific and aircraft measurements background and experience, English level)*My research during the last year has been focused on the different physical mechanisms that influence entrainment during the evolution of the boundary layer in convective conditions (see Pino et al. 2003, 2006a, 2008) and how the dynamics affects the concentration of some trace gases, mainly CO2.
Lately, I was also interested in study the evolution of the boundary layer during the afternoon decay.

**Recent relevant publications by application group in last 5 years (up to 5)**

- casso_etal_2008
- gorska_etal_2008
- pino_etal_2006
- pino_etal_2010
- Project BLLATE2
- vanheerwaarden_etal_2010

**Scientific problems being addressed by the experiments to be performed. Brief summary of the experiments** One of the current open issues that remain not yet well understood in the planetary boundary layer studies is the afternoon transition between the diurnal to nocturnal conditions.

To deepen in our understanding of the afternoon transition, the Boundary-Layer Late Afternoon and Sunset Turbulence (BLLAST; Pino et al., 2010) project started two years ago to study the transition that occurs in late afternoon. The main scientific questions to be investigated are, among others:

-What are the relevant spatial/temporal scales during this phase?
- Does the mixing height decrease in the afternoon? What are the specific roles played by subsidence, radiative divergence and entrainment, if it's still active?
- What is the role of shear, stability, and large-scale subsidence at the top of the mixed layer/residual layer?

To address these issues, an intensive observational campaign is planned for the summer 2011. During the campaign it is crucial to obtain information of the upper atmospheric conditions by means of two aircraft (one asked here and the other in BLLATE2, PI Jordi Vilà). By having two planes, detailed simultaneous measurements in the entrainment zone and near the surface layer could be performed.

The experiments will consist in flying simultaneously with the two aircraft platforms during the afternoon and evening (between 3-4 hours each day). Temperature, humidity, wind and carbon dioxide will be measured with a high frequency rate to determine the role played by dynamics in the transport of greenhouse gases. The total flying time will be 20 hours (for each platform).

**Aircraft** PIPER AZTEC - SAFIRE

**Why this aircraft best suits the experiments? Proposed alternative aircraft** The selected aircraft is able to fly slow and low, while they can still probe all the turbulence scales that we expect during the late afternoon transition.
We considered the PIPER AZTEC operated by SAFIRE at Toulouse, close to the experimental site and in a similar project the ERA Skyarrow operated by IBIMET. Both have to include instrumentation to measure turbulence, T, humidity at high frequency. Moreover, CO2 measurements have to be performed at least by the Skyarrow in order to analyze the scalar transport during the transition. By combining the observations made by the two aircrafts in the proposed flight plan we will be able to have a clear picture of the transition at the lowest levels but also at the entrainment zone.

In addition, UAVs will fly over smaller areas, at a still lower height than the manned aircraft, and will be in charge of probing smaller turbulence scales (ex: UAV Carolo) and also able to make very frequent soundings (ex: UAV SUMO).

## 2. Description of the experiments

**Scientific objectives / Proposed work / Anticipated output** First of all, it is important to notice that the whole experiment is designed by including two planes. As a consequence there are two identical projects with different PIs. The present project will mainly deal with questions regarding the boundary layer dynamics during sunset decay. In the other project, coordinated by Jordi Vilà-Guerau de Arellano, who has already experience in analyzing data collected with one of the EUFAR planes, the Skyarrow, will be devoted to study the scalar transport. However, the flight research strategy will be strongly coordinated.

The main scientific objective is to observe and analyze the atmospheric boundary layer during the transition from daytime convective conditions to evening stable conditions. To our knowledge this will be the first experiment specifically devoted to analyze the boundary layer during sunset over land. Previous experiments like FLATLAND and CASES-99 (Poulos et al. 2002) already provided some evidence of the specific characteristic of the afternoon transition. However, the novelty of the BLLAST objectives is to further understand the following processes:

• To study the diurnal cycle of CO2, from the vegetation uptake at day hours to the initial accumulation in the evening stable layer, passing through the afternoon transition phase.
• To study whether the mixed layer collapses or remains approximately at the same height: measuring of the boundary layer height and thermodynamic variables in the boundary layer and free troposphere.
• To analyze the formation of the residual layer: determination of ground inversion temporal evolution.
• To analyze how the turbulence decays: by observing the evolution of the turbulent kinetic energy, momentum fluxes (shear) and buoyancy heat flux when they are still strong to be measured. Afterwards, we will be able to estimate other turbulence characteristics: integral scales, dissipation, TKE.
• To study the evolution of the characteristics length scales of the main variables in order to elucidate how these variables evolve during the transition: to observe the velocity components to calculate autocorrelation functions for the thermodynamic variables,
• To analyze the influence of the entrainment fluxes (stratification aloft, inversion strength) in the decaying turbulence: measuring fluxes at the top of the decaying boundary layer.
• To determine the CO2-budget during the afternoon transition: measuring fluxes and (co-)variances.

The proposed work will consist in flying during several days (3) when the intensive campaign BLLAST (planned for approximately 15 days) will deploy several observational platforms at surface, with both in situ (ground stations, radiosoundings, tethered balloon) and remote sensing instruments (UHF, lidar) on the site.

Our suggestion is to select 2/3 days with the following sequence plan. As mentioned, the flight plan is designed for two planes (IBIMET-Sky Arrow and SAFIRE Piper Aztec)

a) Early afternoon (around 12-13 UTC). Approximately 120 minutes flying.
• Vertical profile upwards (plane 1)
• Double-stack pattern consisting of (3 or 4) vertical sequences of horizontal legs at the upwind and downwind of the area under study within and above the boundary layer. The length of the horizontal legs will be around 30 km (plane 1 and 2). The two planes will fly horizontal legs: plane 2 will fly as low as possible in the surface layer whereas plane 1 will begin to fly at higher altitudes in the CBL or residual layer, and above/below the entrainment zone. At one point, the two planes will fly at the same height to intercompare the measurements.
• Vertical profile downwards (plane 2)
b) Late afternoon (before sunset). Same pattern as before.

In addition to these aircraft measurements, it is also planned to observe the afternoon characteristics flying Unmanned Aerial Vehicles (UAV) to support and compare the measurements gathered with the other aircraft platforms (in coordination with COST-ES802). To our knowledge this is the first time that manned and unmanned aircraft measurements will be carried out simultaneously. However, it's important to note that the UAV data is not necessary to fulfill the objectives of the project written here.

With the observations taken during the experiment, the following studies are planned within the framework of BLLAST:

1. Determination of the boundary layer height evolution, mean, fluxes and (co-variances) of the thermodynamic quantities using different analysis techniques. Following the analysis techniques described at Gorska et al. (2008), we will treat the data using different averaging procedures and running means. By so doing, we will be able to determine the sensitivity of the data process to the raw data analysis to calculate the energy budget in the region.
2. Determination of the characteristic length scales of the thermodynamic variables during the transition by applying spectral analysis to the data.
3. Based on the BLATTE observations, designing numerical experiments using conceptual model, the large-eddy simulation model (DALES) and the mesoscale model WRF.

**Weather conditions** *(e.g. clouds, atmospheric stability, wind speed and direction, weather…)* We wish for clear skies or fair weather cumulus. Moreover, it would be convenient to have low winds to ensure convective conditions during the day.

**Time constraints** *(time of the day, pass(es) of satellites, weekends, season…)* The experiment will be done at the beginning of the summer (middle June first half of July). We are interested in having measurements from the beginning of the afternoon (13UTC) to the evening (18 UTC).

**Location(s) and reason for that choice**

Laboratoire d'Aerologie, Centre de Recherches Atmospheriques (CRA)

The CRA is established on the Plateau of Lannemezan at 600 meters of altitude, located thirty kilometers north of the Pyrenees.

At larger scale, the proximity of the Pyrenees, distant solid mass of a score of kilometers, generates orographical circulations (valley winds for example) interesting for the studies of atmospheric dynamics, of the cycle of water and the clouds, and the transport of pollution on different scale. The afternoon transition plays a specific role in the transition from one regime to the other in this context.

There is a 65 m tower with sonic anemometers and fast measurements of T, and q at three different heights, and measurements of mean meteorological variables, chemistry (CO2 and Ozone) and radiation at 2 other levels. A 2 m surface weather station, UHF and VHF wind profilers work continuously.

For the campaign additional ground-based instruments will be deployed over different surfaces in the surrounding area, to measure the differences in the structure and evolution of the transition among different vegetated surfaces, and the role of the surface heterogeneity in the new circulations establishing during the transition.

Four sites have therefore been considered for the deployment of ground station, tethered balloon and remote sensing together on each site. UHF and sodar wind profilers will give continuous profiles of the mean wind and CBL depth, and Doppler lidar(s) will give the fine-scale structure of the radial velocity component, with high resolution in time and space for turbulence statistics studies and entrainment zone exploration. Additionally, two or three tethered balloons will probe the surface layer and entrainment zone if possible. Radiosoundings will be conducted throughout the day, with increased density of launches during the late afternoon transition (with a specific technique to make fast-sounding of the lower troposphere).

Finally, during the campaign several UAVs are expected to be flying, in the context of a joint COST action ES0802 field campaign, for validation, calibration of the UAVs, and for the participation of the process studies in BLLAST. Consequently, if the proposal is approved BLLAST/BLLATE will be the first boundary layer field campaign which joins UAVs and manned aircrafts. Obviously, this point depends on the funding of the UAV project and the necessary permissions for flying UAVs and manned aircraft simultaneously.

**Number of flights / flight hours and flight patterns** Once the different remote sensing instruments have provided the boundary layer depth, the plane will perform a spiral sounding to reach this depth. Therefore several horizontal legs below and above this height during 1.5 hours will be done. By doing this we will have observations of the entrainment fluxes during the transition. Finally, a vertical profile will be performed.

**Other constraints or requirements**

## 3. Key measurements required to achieve science aims

**Parameter / measurement required** High frequency (100 Hz) measurements of the three components of the wind speed, temperature and humidity and carbon dioxide are required.

**If applicable, specify TA instrument required** None

**Instruments to be provided by hosting aircraft operator** *(basic instrumentation owned by the aircraft operator described on EUFAR website only)* PIPER AZTEC
• Dew/Frost-point hygrometer 1011C SAFIRE Dew Point
• Additional instruments to measure turbulence, T and humidity at a high frequency rate are needed: INS, a rosemount fast temperature sensor and a Licor sensor ( CO2 / H20 IRGA (Licor7500))

**Instruments to be provided by scientific group** *(Have already been flown. On which aircraft? Do the instruments have their own data acquisition system?)* No instruments provided by the scientific group

**Instrument operators onboard (in addition to those provided by the aircraft operator). If so, how many?**

**If applicable, plans for simultaneous field work plans / ground equipment to be used**

## 4. Data processing and analysis

**Methodology for handling the data and analysis of output** *(airborne data acquisition, ground-truthing / observations, data processing and interpretation)* Several methods will be sued to analyze the aircraft data. The methods are based on the work of Gorska et al. (2008).

Because of the challenge to measure turbulence in transitory conditions, we plan not to use the standard methods to estimate turbulence fluxes (Desjardins et al., 1989), but rather use new method to study the fundamental turbulent processes occurring during the decay. The documented scales will strongly depend on the scales that will be sampled with a large statistics, which is on the considered aircraft. Third-order structure function and autocorrelation functions will be a useful tool to make those studies, and access to dissipation rate, turbulent kinetic energy and possibly varying cascades.

**Resources available to support the project beyond the flying/data acquisition period** *(funding, cooperation with other projects, manpower for analysis of results and preparation of user report, availability of laboratory facilities…)* Projects by the Spanish Ministry of Science and Innovation (MICINN, CGL2009-08609) and by the European project INTERREG FLUXPYR EFA 34/08.

Several of the researchers involved in the BLLAST campaign are applying or have applied in their countries to obtain resources:
• Marie Lothon (France): LEFE program, BQR
• Erick Pardyjak (USA): NSF
• Frank Beyrich/Jens Bange (Germany): DFG

All the data analysis and numerical experiments will be done at the Applied Physics Department (DFA, Technical University of Catalonia) and at the Meteorology and Air Quality Section (MAQ, Wageningen University). As mentioned, it is planned that the data will be intensively used by the lead investigator and as a part of the PhD research conducted by Estel Blay. In addition, it is planned that several MSc students will work as part of the MSc thesis.

## 5. Planning

Starting date: 14-06-2011
Ending date: 08-07-2011

**Preferred and acceptable dates** *(season / time windows)* Between 14 June and 8 July 2011.

**Agreement to share aircraft time** *(project clustering, cost sharing)* No

## 6. Other useful comments

**Training benefit of the project** *(e.g. spread potential of airborne research to a wide scientific community; training of research students in experimental planning, methodology, data analysis and applications, etc)* The students involved in the campaign will learn how to prepare an intensive campaign. Moreover, they will learn the fundamentals of the data analysis.

The PIs for proposals BLLATE 1 and BLLATE 2 are experts in modeling the boundary layer, with 1D-mixed layer model, large eddy simulation and mesoscale modeling. This EUFAR-TA will give them and their associated students a great opportunity to learn about airborne research, flight operations, sensors, flying strategy, and data analysis.

Beniamino Gioli, Pierre Durand and Marie Lothon will share their expertise on airborne research and teach the BLLATE 1 and 2 users.

**If possible, 3 scientific reviewers that EUFAR may contact** Ulrich Corsmeier, Norbert Kalthoff, and Michael Tjernstrom

**Sources of funding of the project and of related projects** *(if clustering with existing projects supported either by national or other EC funding, how the project add additional or complementary aims to the already funded experiments)* This experiment will help in the development of the Spanish project mentioned above because it will provide the necessary data to be used and compared with the ongoing Large-Eddy Simulations to analyze the boundary layer dynamics during the transition.

**Scientific training provided by lead scientist to other EUFAR sponsored scientists within the fields of the proposed experiments and analysis** Yes

**Number of students** 2

**Number of days recommended** 7

**Knowledge about EUFAR opportunities from** From your colleagues

**Related documents**
*You may need to login to the EUFAR Back Office to see all the documents.*

## Comments

From PINO David on 11/02/2011:
Application BLLATE1 and BLLATE2

Answer to the Reviewer A

We thank the referee's positive opinion about the scientific objectives of the project. Since the two projects are closely linked we provide a common response to the referee.

Regarding the technical questions, we agree with the referee that neither in the original application nor in the EUFAR web page appeared any turbulence instrument on board the SAFIRE Aztec. As the reviewer pointed out, without these instruments the aims of the project cannot be achieved. However, the suited instrumentation either is already installed on the aircraft (the nose boom with pressure ports and associated transducers for true airspeed, attack and sideslip angles measurements) or will be mounted on the aircraft before the campaign. The Piper Aztec capabilities and the feasibility of the instrumentation planning were checked with SAFIRE prior to the original submission of the proposal in September 2010.

Below we answer the specific comments of referee (quoted) criticizing the project:

• "The other proposed aircraft, the SAFIRE Aztec however, is in my opinion neither operationally suitable nor - to the best of my information (I tried to find it on the EUFAR website, but only some air chemistry sensors are listed there) - equipped with appropriate instrumentation for the task."

We contacted SAFIRE for this revision, to update the planning and confirm the feasibility of the turbulence instrumentation and calibration of

the Piper Aztec. SAFIRE will start to install the following instruments in the next weeks:
- Licor 7500 adapted for aircraft measurements (already tested on the ATR, we will use the same installation on the Piper).
-Airins iXsea inertial system. (see http://www.ixsea.com/en/mobile_mapping_airborne_survey/2/airins.html).
- Temperature will be measured by a thin wire (high frequency temperature provided by MeteoFrance) and by a Rosemont 102E2AL platinum resistance sensor.
- Airflow vector will be computed from pressure measurements (differential sensor dedicated for the dynamic pressure, and attack and sideslip angles already located at the nose boom.

The calibration flights are planned from March 28th to April 8th 2011. The other basic instrumentation is already installed (static pressure, temperature and humidity "slow" sensors). In addition, the software to treat and correct the aircraft data is also ready to be used.

• "Operationally, it will be necessary to make near instantaneous decisions on the flight strategy based on real-time data displays of the sampled data **while flying**. This requires an experienced atmospheric scientist to be part of the crew of each aircraft"

Both the Aztec and the SkyArrow are able to take a scientist and/or an operator on board, who can interact during the flight for real time flight plan adjustments.

In addition of the PIs of BLLATE1 (D. Pino) and BLLATE2 (J. Vilà), with large experience on boundary layer dynamics, the group of researchers involved in the projects include other experts on aircraft turbulence measurement and data processing, who have a significant experience on boundary layer aircraft field campaigns. A list of publications related to turbulence aircraft measurements is included at the end of this revision.

• "Furthermore, it is unclear to me how the proponents envisage to follow the development of the CBL into the night, unless the research aircraft can continue their measurements into the hours of darkness as well. To only rely on ground- and tower-based measurements after sunset will limit the scientific outcomes of the study quite a bit."

For this type of flights, both the Sky Arrow and the Piper Aztec fly under VFR (visual flight rules), which allow flying until sunset, and even after sunset (nocturnal VFR – the possibility of such operations have already been checked with the pilots of SAFIRE). Furthermore, the afternoon transition (main research of the international experiment BLLAST) starts several hours before sunset. The study of this transition does not require flying during the core of the night.

We include a list of references to show the experience and skills of the scientists who are in support of the present applications in using aircraft data for the investigation of boundary layer dynamics and related subjects.

References

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## 7. Reporting

**Campaign dates:** From 14-06-2011 to 25-06-2011

**Participants**

| Name | First time flying this aircraft | Participation in the campaign | Number of visits to campaign | Duration of stay | T&S reimbursed | Additional information |
|---|---|---|---|---|---|---|
| PINO David | Yes | On site | 7 | 13 | Yes | Only one week will be asked for reimbursement |
| BLAY Estel | Yes | On site | 5 | 12 | Yes | Only one week will be asked for reimbursement |
| DURAND Pierre | No | On site | 7 | 13 | Yes | Only one week will be asked for reimbursement |
| LOTHON Marie | Yes | On site | 7 | 13 | No | |
| VILA GUERAU DE ARELLANO Jordi | Yes | On site | 4 | 6 | No | |

**Meetings**

| Start date | End date | Location | Title | Number of persons from the group attending the meeting | Overall number of attendees |
|---|---|---|---|---|---|
| 14-06-2011 | 14-06-2011 | Lannemezan (France) | Preparation of IOP1 | 5 | 10 |
| 15-06-2011 | 15-06-2011 | Lannemezan (France) | Preparation of IOP1 | 5 | 10 |
| 18-06-2011 | 18-06-2011 | Lannemezan (France) | Preparation of IOP2 | 5 | 10 |
| 19-06-2011 | 19-06-2011 | Lannemezan (France) | Preparation of IOP2 and IOP3 | 4 | 9 |
| 20-06-2011 | 20-06-2011 | Lannemezan (France) | Preparation of IOP3 | 4 | 8 |
| 24-06-2011 | 24-06-2011 | Lannemezan (France) | Preparation of IOP5 | 4 | 8 |
| 03-11-2011 | 04-11-2011 | Florence (Italy) | Presentation of the data processing | 5 | 8 |

**Confirmation of the user access (list of flights, number of flight hours) / Evaluation of the service provided by the operator: mark (1-Unsatisfactory, 2-Insufficient, 3-Satisfactory, 4-Good, 5-Excellent) and comments**

Flight number/IOP number Day Flight hours Evaluation 1/IOP 01 15-june 1.6 5 2/IOP01 15-june 1.4 5 3/IOP02 19-june 1.9 5 4/IOP02 19-june 2.0 5 5/IOP03 20-june 2.1 5 6/IOP03 20-june 2.1 5 7/IOP05 (intercomparison flight) 25-june 1.2 5 8/IOP05 25-june 2.0 5 9/IOP05 25-june 2.0 5 Total flights hours: 16.2 All the flights were done satisfactorily according the discussed flight plan.

**Quality of data and associated service**

**Main achievements / Further plans for analysis**

During the campaign we mainly processed vertical profiles of mean variables taken by the plain. They compared satisfactorily with the soundings launched from the ground at similar hours. We also processed some data taken during some flights at the inversion level. The variability of humidity at this level was clearly observed from the measured data. Regarding turbulence, we are planning to process in the next months and to meet before the end of the year to share the results.

**Difficulties encountered**

Weather conditions during several days with cloudy skies an some rain make that the campaign lasted more than one week. For this reason, some of the flights were done during the second week. However, we have only included in the EUFAR budget the costs of the first week. Regarding the flight operations, the main difficulty was related to the special characteristics of the campaign. Two planes were flying during the first ten IOP days: the Piper Aztec from Safire and the SkyArrow from IBIMET, which hours were obtained by a EUFAR companion project (see BLLATE2 project). The flight plan included the participation of both planes and at the beginning some difficulties existed regarding the communication between the pilots and with ground operations.

**Publications linked to the project**

**Website of the project** http://bllast.sedoo.fr/objectives/