Model and observation for surface atmosphere interactions

Experimental Plan
for P2OA EOP & SOP

Part I – Objectives and general strategy

Main Objective

This third MOSAI EOP aims at documenting the heterogeneity of the surface-atmosphere interactions around the permanent Eddy-Covariance flux measurements made on the 60 m tower of the P2OA ACTRIS-Fr site. A secondary objective, specific to this EOP, is to finely focus on the impact of a single heterogeneity transition on the lower troposphere, from a vertical and horizontal point of view.

Heterogeneity around the 60 m tower

This experiment is built to document the surface heterogeneity in a grid at the scale of the NWP and/or climate models. The first one is around 1.5 km and the second one is 50 km. Figure 1 shows the land-use around the 60 m tower at different scales, from CESBIO satellite-based data, and table 1 gives the corresponding percentages of each cover among the most representative ones.

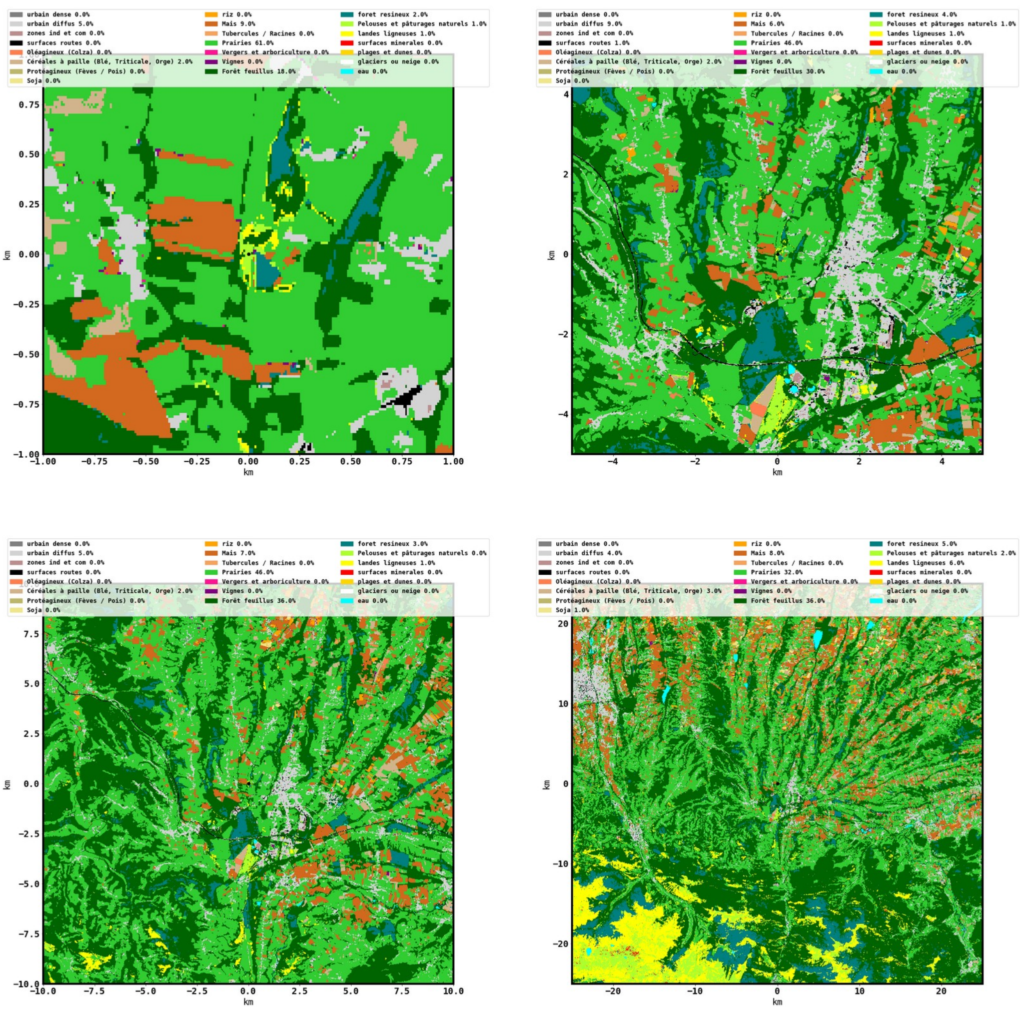

Figure 1 : Land-Use Map from CESBIO, THEIA OSO 2020 product, at 1, 2, 10, 20 km and 50km scale centred at P2OA 60 m tower. Ligher greens and Yellow: Prairies, Dark green: Deciduous trees, Blue-grey: Conifer trees, Orange: Summer crops (mainly maize), Light brown: Cereals (mainly triticale), Grey: diffuse urban, villages.

	Area horizontal scale				
	1 km	**2 km**	**10 km**	**20 km**	**50 km**
Prairies et landes	55^{+}%	62^{+}%	48%	47%	40%
Forêt de Feuillus	27%	18%	30%	36%	36%
Forêt de Conifères	3^{-}%	2^{-}%	4%	3%	5%
Cultures d’été	14%	9%	6%	7%	9%
Cultures d’hiver	0%	2%	2%	2%	3%
Urbain diffus et routes	1%	5%	10%	5%	4%

*Table 1 : Vegetable cover percentages from CESBIO, THEIA OSO 2020 land-use map product, in 5 different areas (1*1 km^2,5*5 km^2,10*10 km^2, 25*25 km^2) all centred at the P2OA 60 m tower.*

Prairies always dominate the landscape (mainly grazing land of grassland), with forest at second rank. At small scale around the 60 m tower (1 and 2 km), the prairies dominates more significantly, especially at 2 km, where it reaches more than 60%[1]. As we get to a larger domain, the forest part progressively grows closer to the prairie part, around 40%. At 50 km, Forest remains significant due to the woody foothills to the south, which compensate the growth of crops to the north. The forest is mostly deciduous, and present on the slopes.
Within the crops, the maize is the most present this year, but covers usually less than 10%. Note that the agricultural use of the land varies from one year to the other. Especially, maize and wheat often alternate. Grazing prairies can also alternate with crop.
The diffuse urban corresponds to the market town of Lannemezan and small villages around. Lannemezan covers a significant portion at 10 km, otherwise, diffuse urban generally has a small contribution, and includes a lot of lawns, even Lannemezan.

The choice of the cover over which the EC-stations are installed is guided by this land-use analysis.

Strategy

Figure 2 : Time schedule of the EOP and SOP over an entire year

Enhanced Observing Period (EOP)

For the documentation of the surface heterogeneity, several flux stations and scintillometers

[1] *Note on the 1 and 2 km scale maps of Fig. 1, that the two blue-grey coloured areas north and south of the 60 m tower actually correspond to wetlands, and not conifer trees. This is a bias of the satellite imagery interpretation.*

will be installed over various vegetation covers representative of the area, at a scale of about 10 km, close to that of a NWP meshgrid scale. For P2OA site, those surfaces are prairies, deciduous forest, conifer forest, maize, wheat, and Lannemezan small city. Flux stations include Eddy-Covariance stations, and standard meteorological stations from which the flux can be estimated through Artificial Neural Network training (Lohou et al.).

Those measurements will cover an entire EOP year, in order to study and consider the seasonal variability of meteorological conditions and surface characteristics.

The description of the boundary layer structure will be continuously described all along the EOP by a UHF wind profiler, several Doppler lidars, a ceilometer, a sky imager.

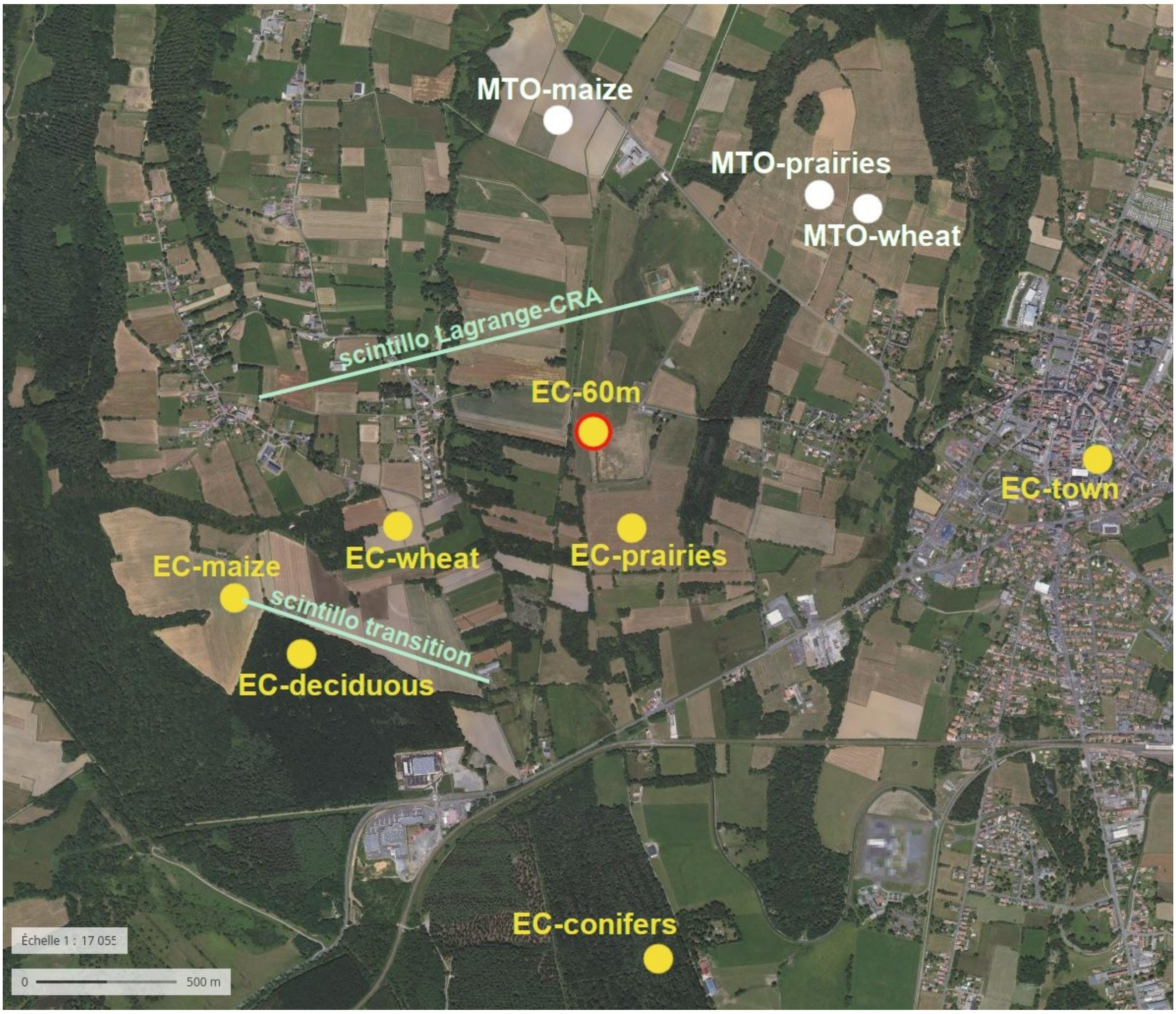

Figure 3 : Overview of the EOP (see Table 2).
Yellow dots: EC stations,
White dots: MTO standard meteorological stations,
White line: Scintillometer path

Measured parameters	Instrumentation	Site
Surface-atmosphere interactions over different surface covers	**Eddy-Covariance stations**	**9 EC sites:** - EC-60m - EC-prairies - EC-deciduous-1 - EC-deciduous-2 - EC-conifers - EC-maize-1 - EC-wheat - EC-town - EC-valley-exit - EC-mobile Prairie/wheat - EC-maize-2
	Standard meteorological stations	**3 MTO sites:** - MTO-prairies - MTO-maize - MTO-wheat - MTO-Heches - MTO-Avezac
	MW and IR Scintillometers	**2 paths:** - Along transition - Lagrange-to-CRA
Radiation at surface	**Eddy-Covariance stations**	**9 EC sites (cf above)**
Soils conditions	**Soil temperature and humidity close to surface**	**1 pit at CRA**
Boundary layer characteristics	**UHF, ceilometer, Doppler lidars**	**CRA**
Cloud base height and cloud fraction	**Ceilometer and sky camera**	**CRA**

Table 2 List of continuous measurement along the entire EOP

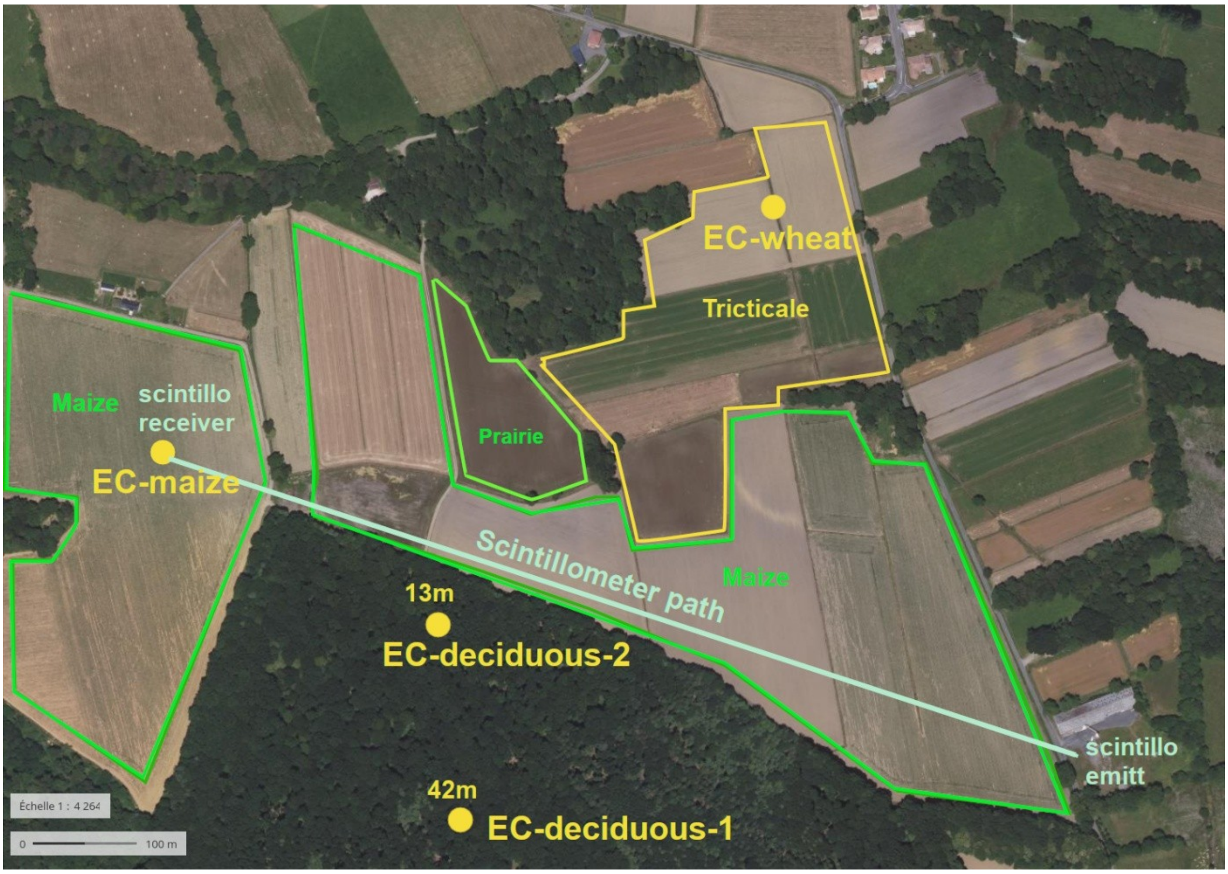

Figure 4 : Zoom on the forest-maize transition

In order to connect the dynamics observed on the Lannemezan Plateau with the valley winds coming from of blowing to the Aure Valley, several stations will be deployed at the exit of the valley.

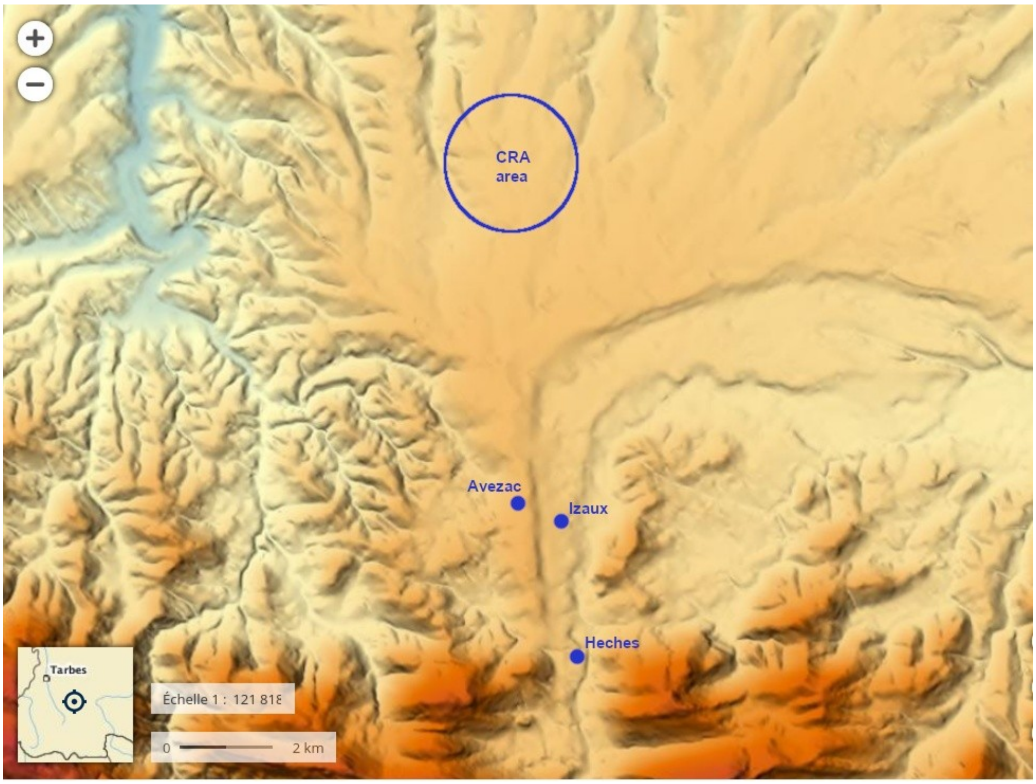

Figure 5 : Topography in the area, from the exit of the Aure valley to the CRA area. The blue circle locates Figure 3 frame.

Special Observing Period (SOP)

During three periods within the EOP, three SOP in April, August and December will enable to intensify the exploration of the boundary layer structure: Re-usable radiosondes will be launched on chosen IOP days (Intensive Observing Periods), and there may be RPAS profiling too.

The maize-forest transition will also be more intensively explored: a tethered balloon with turbulent probe onboard and several RPAS will be operated around and over the transition. The latter will measure either turbulence, surface temperature, or mean meteorological variables.

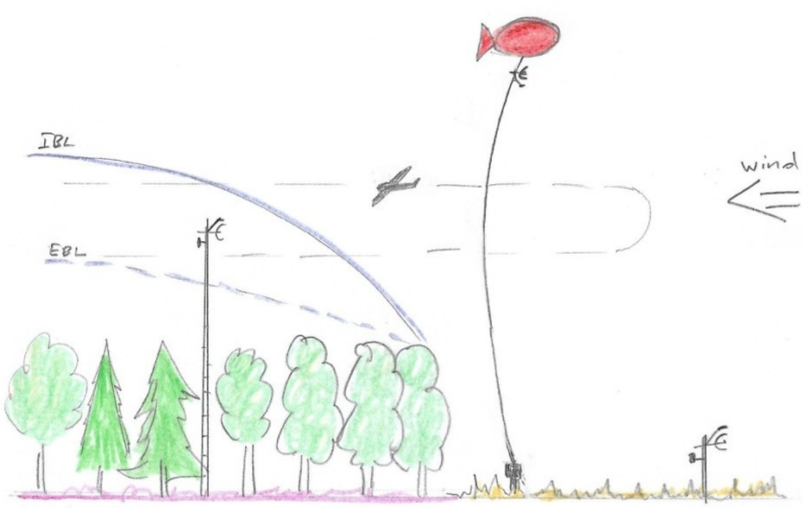

Figure 6: Scheme of the intensive observations over the transition

Measured parameters	Instrumentation	Site
Atmosphere profiling	Re-usable and standard Radiosondes SUMO RPAS	CRA CRA
Turbulence measurements within transition cross-section	SAMOURAI RPAS Tethered-balloon-borne turbulence probe	Transition
Meteorological variables within transition cross-section	Multicopter BeBopMet	Transition
Surface temperature	Multicopter DJITherm	
Vegetation : Leaf Aera Index	***	Forest Maize

Table 3: List of casual measurement platforms used during the SOP

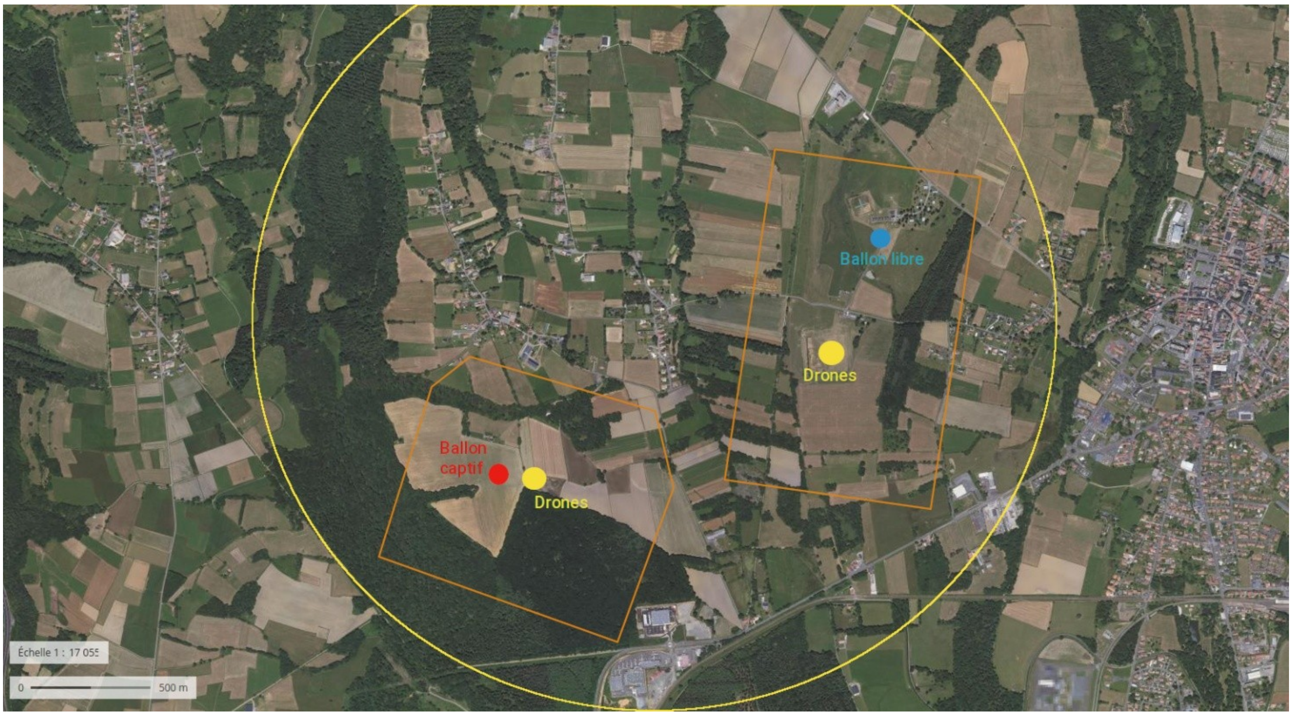

Figure 7 : TRA (yellow contour), flying area (orange contour) and localisation of tethered balloon (red), radio-soundings (blue) and RPAS (yellow).

Within a 9 or 15-day SOP, only about 5 IOP days will be selected, for intensive observations by the platforms listed in Table 3. The selection will depend on the meteorological conditions: we search for non-rainy rather sunny days, with predominant westerly or north-westerly winds or with plain-to-mountain wind (clearer days). WNW and ENE are the two flows perpendicular to one or the other ridge of the deciduous forest, at the forest-maize transition (cf Fig. 4), which will be preferentially studied. The daily forecast will help us to choose the IOP days.

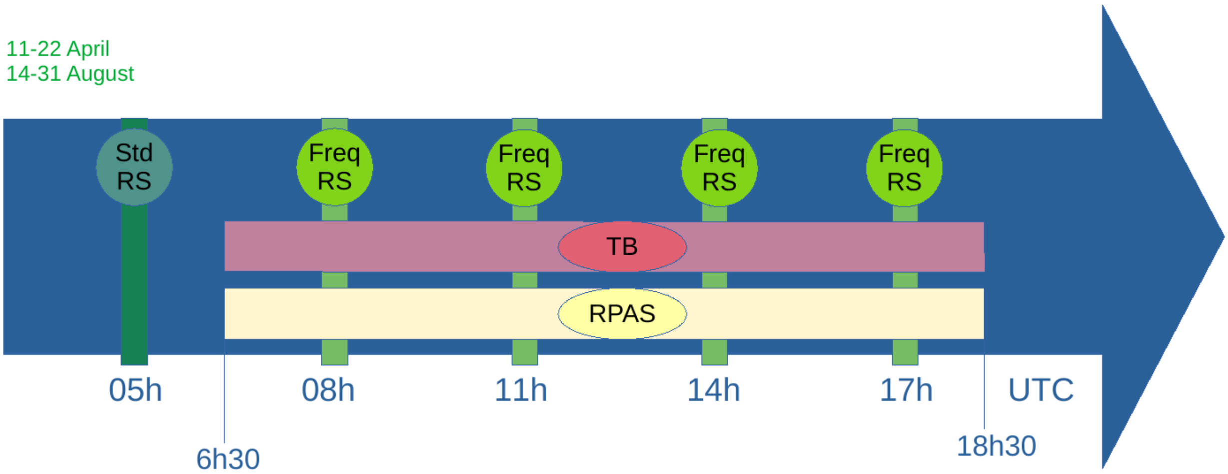

Figure 8a : Time schedule of and IOP day, with radiosondes launches, RPAS flights and TB operations. Case of SOP1 and SOP2.

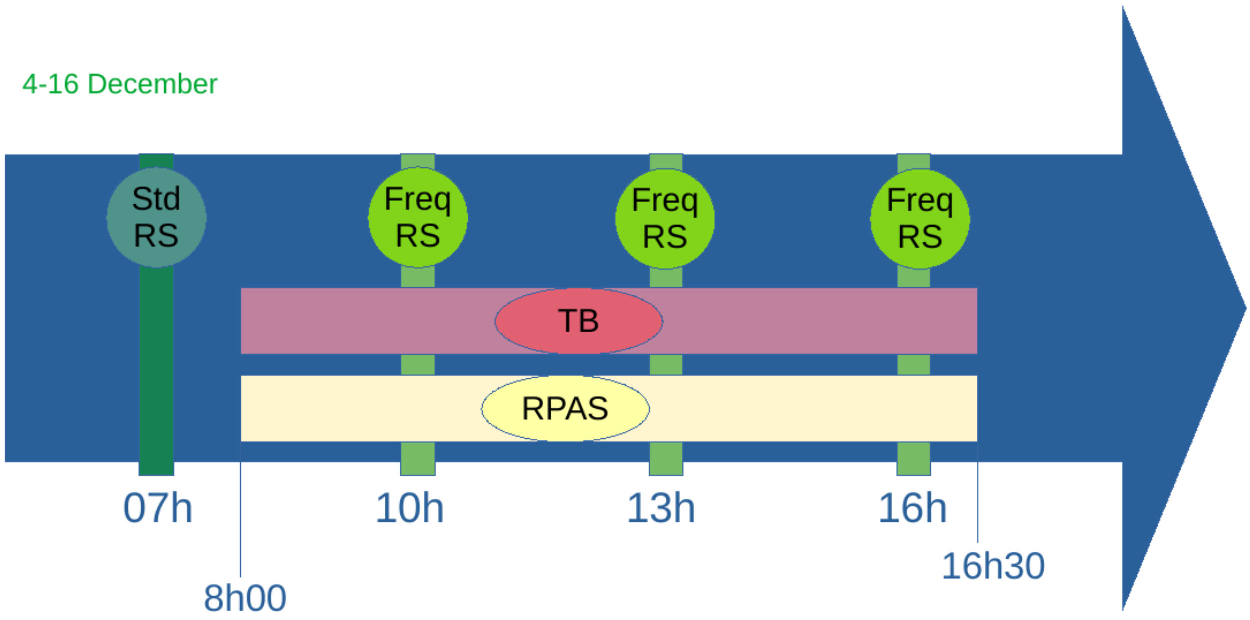

Figure 8b : Time schedule of and IOP day, with radiosondes launches, RPAS flights and TB operations. Case of SOP3.

The schedule of an IOP day is shown in Fig. 8. Radiosoundings will be launched all along the day from sunrise to sunset every 3h. Tethered ballon and RPAS will be operated from 7 UTC to 19 UTC.
A more detailed strategy of the tethered balloon and the RPAS are detailed in Part III.

Part II – Instrumental sheets of continuous observations

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Eddy-covariance stations

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

Station name	Lab	Land use	Latitude (N) Longitude (E) Heights ASL [m]	Tower height (m)	Measured Variables
EC-60m	LAERO	Heterogeneous	43.124208°N 0.362592°E 603 m	60	
EC-Deciduous-1a	CNRM	Deciduous trees	43,11582°N 0,35081°E 625m	42	
EC-Deciduous-1b	INRAE	Deciduous trees		9	U, V, W, T, H2O, CO2
EC-Deciduous-2	INRAE	Deciduous trees		9	U, V, W, T, H2O, CO2
EC-Conifer	LAERO	Conifer trees		42	
EC-Maize	CNRM	Maize	43,11866°N 0,34714°E 594m	8	
EC-Wheat	Univ. Bergen				
EC-PMP	LAERO	Prairie			
EC-Lanz	LAERO	Mixed Urban			
EC-Izaux	UMC	Prairie			

60 m tower

Laboratory in charge : Laboratoire d’Aérologie
Persons in charge : S. Derrien, A. Vial, F. Lohou

More info here:
https://p2oa.aeris-data.fr/sedoo_instruments/mat-instrumente-de-60-metres/

Conifer station

Laboratory in charge : Laboratoire d’Aérologie
Persons in charge : S. Derrien, A. Vial, F. Lohou

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	10 Hz	590 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	590 cm
CO2 concentration			
Atmospheric pressure			
Temperature	Rotronic HC2-S3		211 cm

Relative Humidity		5 sec.	
Outgoing global radiation	Kipp & Zonen CNR4		220 cm
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Pressure	Vaisala RPT410F-3143		*40 cm*
Soil heat flux	Hukseflux HFP01		4 cm
Soil temperature	Campbell T107		de -2.5cm à -12.5 cm
Soil water content	Campbell CS616		de la surface à -15 cm
Rainfall	EML (Environmental Measurement Ltd) ARG100		133 cm

Data provided to database

Geophysical parameter	Unit	Period - Frequency
temperature	°C	5 sec
relative humidity	%	
rain	mm	
soil temperature	°C	
soil volumic water content signal	sec	
soil volumic water content	unitless	
pressure	mbar	
soil heat flux #1	W/m2	
soil heat flux #2	W/m2	
shortwave upward radiation	W/m2	
shortwave downward radiation	W/m2	
longwave upward uncorrected radiation	W/m2	
longwave downward uncorrected radiation	W/m2	
longwave upward corrected radiation	W/m2	
longwave downward corrected radiation	W/m2	
radiation sensor temperature	K	
u wind component	m/s	10 Hz
v wind component		
w wind component		
Sonic temperature	°C	
CO_2 concentration	mmol/m3	
H_2O concentration		
pressure	kPa	

Configuration of the stations

Altitude		*641 🎙 3 m*
Longitude		*0° 21′ 42″*
Latitude		*43° 05′ 24″*
Temperature and humidity	*Height above ground*	*220 cm*
Rain gauge		*100 cm*
4 components radiometer		*200 cm*
	Direction	*180 °*
Anemometer	*Height above ground*	*223 cm*
	North direction	*0 °*

Ultrasonique anemometer	*North direction*	*305 °*
	Height above ground	*293 cm*
Infra red gas analyzer	*Position / anemometer*	*270 ° / North sonique*
	Distance / sonique	*20 cm*
Infrared radiometer	*Direction*	*180 °*
	Height above ground	*175 cm*
	Angle / surface	*45 °*
Soil fluxes sensors	*Depth*	*- 3 cm*
Soil humidity sensor		*– 5 to 0 cm*
Soil thermometer		*- 1 cm*
Barometer	*Height above ground*	*40 cm*

Lanz station

Laboratory in charge : Laboratoire d'Aérologie
Persons in charge : S. Derrien, A. Vial, F. Lohou

EC-deciduous-1a station

Laboratory in charge : CNRM
Persons in charge : O; Garrouste, G. Canut

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Gill - R3-50 1210-PK-085	50 Hz	42 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	20 Hz	42 m
CO2 concentration			
Atmospheric pressure			
Temperature	PT100	10 sec.	2, 10 , 20, 32 and 40m
Relative Humidity	Vaisala HMP110		
Outgoing global radiation	Kipp & Zonen CNR4		42 m
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Pressure	Vaisala PTB210		*40 cm*
Soil heat flux	Hukseflux HFP01		3 cm
Soil temperature	PT100		-5, -10 and -30 cm
Soil water content	Delta T - thetaprobe ML2x	1 min.	-5, -10 and -30 cm

Data provided to database

Geophysical parameter	**Unit**	**Period - Frequency**
temperature	°C	1min
relative humidity	%	

soil temperature	°C	1min
soil volumic water content signal	mV	1 min.
soil volumic water content	unitless	
pressure	mbar	1min
soil heat flux #1	W/m2	
soil heat flux #2	W/m2	
shortwave upward radiation	W/m2	
shortwave downward radiation	W/m2	
longwave upward uncorrected radiation	W/m2	
longwave downward uncorrected radiation	W/m2	
longwave upward corrected radiation	W/m2	
longwave downward corrected radiation	W/m2	
u wind component	m/s	20 Hz
v wind component		
w wind component		
Sonic temperature	°C	
CO2 concentration	mmol/m3	20 Hz
H2O concentration		
pressure	kPa	1min

Configuration of the stations

Altitude		*641 🎙 3 m*
Longitude		*0° 21′ 42″*
Latitude		*43° 05′ 24″*
Temperature and humidity	*Height above ground*	*2, 10, 20, 32 and 40 m*
4 components radiometer		*60 cm*
	Direction	*180 °*
Ultrasonique anemometer	*North direction*	*0 °*
	Height above ground	*42 m*
Infra red gas analyzer	*Position / anemometer*	*160 ° / North sonique*
	Distance / sonique	*15 cm*
Soil fluxes sensors	*Depth*	*- 3 cm*
Soil humidity sensor		*– 5, -10 and -30 cm*
Soil thermometer		*– 5, -10 and -30 cm*
Barometer	*Height above ground*	*40 cm*

Maize-1 station

Laboratory in charge : CNRM

Persons in charge : O. Garrouste, G. Canut

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	METEK - 3 class A H	50 Hz	600 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	20 Hz	600 cm
CO2 concentration			
Atmospheric pressure			
Temperature	PT100	10 sec.	200 and 600 cm
Relative Humidity	Vaisala HMP110		
Outgoing global radiation	Kipp & Zonen CNR4		60 cm

Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Pressure	Vaisala PTB210		*à renseigner*
Soil heat flux	Hukseflux HFP01		3 cm
Soil temperature	PT100		-5, -10 and -30 cm
Soil water content	Delta T - thetaprobe ML2x	1 min.	-5, -10 and -30 cm
Rainfall	Précis Mécanique - 3039	1 sec.	100 cm

Data provided to database

Geophysical parameter	**Unit**	**Period - Frequency**
temperature	°C	1min
relative humidity	%	
rain	mm	1 min.
soil temperature	°C	1min
soil volumic water content signal	mV	1 min.
soil volumic water content	unitless	
pressure	mbar	1min
soil heat flux #1	W/m2	
soil heat flux #2	W/m2	
shortwave upward radiation	W/m2	
shortwave downward radiation	W/m2	
longwave upward uncorrected radiation	W/m2	
longwave downward uncorrected radiation	W/m2	
longwave upward corrected radiation	W/m2	
longwave downward corrected radiation	W/m2	
u wind component	m/s	20 Hz
v wind component		
w wind component		
Sonic temperature	°C	
CO2 concentration	mmol/m3	20 Hz
H2O concentration		
pressure	kPa	1min

Configuration of the stations

Altitude		*641 🎙 3 m*
Longitude		*0° 21′ 42″*
Latitude		*43° 05′ 24″*
Temperature and humidity	*Height above ground*	*200 and 600 cm*
Rain gauge		*100 cm*
4 components radiometer		*60 cm*
	Direction	*180 °*
Anemometer	*Height above ground*	*1000 cm*
	North direction	*0 °*
Ultrasonique anemometer	*North direction*	*300 °*
	Height above ground	*600 cm*

Infra red gas analyzer	*Position / anemometer*	*300 ° / North sonique*
	Distance / sonique	*15 cm*
Soil fluxes sensors	*Depth*	*- 3 cm*
Soil humidity sensor		*– 5, -10 and -30 cm*
Soil thermometer		*– 5, -10 and -30 cm*
Barometer	*Height above ground*	*40 cm*

Deciduous-1bis station

Laboratory in charge : INRAE

Persons in charge : M. Grulois, J-M. Bonnefond, M. Irvine

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	50 Hz	800 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	800 cm
CO2 concentration			
Atmospheric pressure			

Data provided to database

Geophysical parameter	**Unit**	**Period - Frequency**
u wind component	m/s	50 Hz
v wind component		
w wind component		
Sonic temperature	°C	
CO2 concentration	mmol/m3	10 Hz
H2O concentration		
pressure	kPa	

Configuration of the stations

Altitude		*641 🎙 3 m*
Longitude		*0° 21′ 42″*
Latitude		*43° 05′ 24″*
Ultrasonique anemometer	*North direction*	*305 °*
	Height above ground	*293 cm*
Infra red gas analyzer		
	Position / anemometer	*270 ° / North sonique*
	Distance / sonique	*20 cm*

Deciduous-2 station

Laboratory in charge : INRAE

Persons in charge : M. Grulois, J-M. Bonnefond, M. Irvine

Sensors and sampling

Parameter	Sensor	Sampling frequency	Height of measurement

		(or period)	
Wind component U	Campbell CSAT 3	50 Hz	800 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	800 cm
CO2 concentration			
Atmospheric pressure			

Data provided to database

Geophysical parameter	**Unit**	**Period - Frequency**
u wind component	m/s	50 Hz
v wind component		
w wind component		
Sonic temperature	°C	
CO2 concentration	mmol/m3	10 Hz
H2O concentration		
pressure	kPa	

Configuration of the stations

Altitude		*641 🎙 3 m*
Longitude		*0° 21′ 42″*
Latitude		*43° 05′ 24″*
Ultrasonique anemometer	*North direction*	*305 °*
	Height above ground	*293 cm*
Infra red gas analyzer	*Position / anemometer*	*270 ° / North sonique*
	Distance / sonique	*20 cm*

Wheat station

Laboratory in charge : Univ. Bergen

Persons in charge : TBC

PMP station

Laboratory in charge : LAERO

Persons in charge : S. Derrien, A. Vial, F. Lohou

More info here:

https://p2oa.aeris-data.fr/sedoo_instruments/mat-instrumente-de-60-metres/

EC-mobile-station)
(Obs4Clim fixed station)

Laboratory in charge : LAERO

Maize-2 station
(Obs4Clim fixed station)
Laboratory in charge : LAERO

EC-Valley-Exit (Izaux) station (prairie)
Laboratory in charge : UMC

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Standard Meteorological Stations
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Standard Meteorological stations
(Obs4Clim project)
Laboratory in charge : LAERO
Persons in charge : F. Lohou, A. Vial, S. Derrien

Avezac station (prairie)
Laboratory in charge : Univ. Cadiz

Hèches station (prairie)
Laboratory in charge : Univ. Cadiz

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Scintillometers
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XXX Scintillometer
Laboratory in charge : CESBIO
Persons in charge : A. Brut, Franck Grenouillac, Clément Remont…

XXX Scintillometer
Laboratory in charge : IGE
Persons in charge : JM Cohard,…

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Soil conditions down to 2 m
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Pit

Laboratory in charge : LAERO
Persons in charge : S. Derrien, A. Vial, F. Lohou

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Boundary layer dynamics

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UHF wind profiler

Laboratory in charge : LAERO
Persons in charge : Y. Bezombes, A. Vial, A. Philibert

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 2, 5 or 15 minutes.
It also allows the study of the atmospheric boundary layer, with estimates of the boundary layer top inversions (Philibert et al. 2023), and of the kinetic energy dissipation rate (Jacoby-Koaly et al . 2000).

Technical characteristics :

Emitted frequency	1274 MHz
Wavelengh	23.5 cm
Peak power	3.5 kW
Repetition frequency	20 k Hz
Pulse length	150 m
Radial resolution	75 m
Number of antenna beams	5
Elevation of the oblique beams	73°
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

More info here:
https://p2oa.aeris-data.fr/sedoo_instruments/profileur-de-vent-uhf/

Doppler Lidar(s)

Laboratory in charge : CNRM

Persons in charge : à compléter

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Cloud base height and cloud fraction

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CL 61 Ceilometer

Laboratory in charge : LAERO

Persons in charge : S. Derrien, A. Philibert, A. Vial

Vaisala Lidar Ceilometer CL61 is a light detection and ranging (LiDAR) instrument with depolarization measurement. It enables to estimate cloud base height, and explore the stratification of the atmosphere.

The depolarization measurement capability enables clear liquid/solid or dissymmetrical/spherical differentiation for particles and clouds.

Profiles are measured initially every 5 s, but averaged every 30 s.
Radial resolution is 5 m, with an effective resolution of 48 m.
The CL61 ceilometer can measure up to 16 km. Up to 5 cloud layers may be detected, depending of the characteristics of the clouds.

In case of heavy precipitation or fog, the ceilometer software reports vertical visibility.

More info here:
https://p2oa.aeris-data.fr/sedoo_instruments/cl61-ceilometer/.

RAPACE Sky imager

Laboratory in charge : LAERO

Persons in charge : S. Derrien, M. Lothon, A. Vial

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.

During MOSAI, the time interval between pictures will be set to 1 min.
ELIFAN algorithm enables to estimate the cloud fraction and cloud masks from the acquired images.

More info here:
https://p2oa.aeris-data.fr/sedoo_instruments/rapace-imagerie-de-ciel-total/

Part III – Instrumental sheets of intensive observations

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Atmosphere profiling

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MODEM – Normal Radiosoundings

Laboratory in charge : LAERO

Persons in charge : S. Derrien, M. Lothon, F. Lohou

Objective :

MODEM radio sounding system allows to acquire a profile of thermodynamic parameters such as temperature, humidity, wind speed and wind direction. The system of the Centre de Recherches Atmosphériques (LA) is a SR2K2-P from MODEM Company, used with M10 radiosondes.

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 M10 model with a temperature sensor, a humidity sensor, a GPS card, a radio card and batteries for power supply.

Figure 8: MODEM Radiosounding System

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 speed 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. 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 in 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 eventual interferences .

Ground pressure is measured by a pressure sensor in the bench, and is calibrated each year. Pressure is calculated from ground pressure, 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 excellent 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.

Reusable Radiosondes

Laboratory in charge : LAERO
Persons in charge : A. Philibert, S. Derrien, M. Lothon, F. Lohou

A MODEM sounding system radiosonde (see Normal Radiosounding System) is used with one ballon for the ascent (white one in the picture) and one balloon for the descent (red one in the pictre). The first balloon is separated after a preset time of ascent. The second balloon set the falling rate. Ascent and fall rates can be preset with the volume of helium used to inflate the balloons.

A team of two persons is needed to search the sonde with a radio-reciever antenna. The GPS coordinates of the last point recorded fix the location from where the search starts. The red balloon also helps to locate the sonde.

SUMO RPAS

Laboratory in charge : Univ. Bergen

Persons in charge : J. Reuder, S. Kral, A. Seeling

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Turbulence measurements over the transition

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SAMOURAI RPAS

Laboratory in charge : Univ. Bergen

Persons in charge : J. Reuder, S. Kral, A. Seeling

Tethered balloon

Laboratory in charge : CNRM

Persons in charge : J. Capo, G. Canut, O. Garrouste

Sonde Turbulence *20Hz*

A sonic anemometer, a rapid humidity sensor and an inertial motion sensor will be suspended below the tethered balloon. This system measures temperature, specific humidity and horizontal and vertical wind at high frequency and allows the estimation of heat and momentum fluxes as well as turbulent kinetic energy in the lower part of the boundary layer. The tethered balloon and measurements are described in detail with figure 9 and in the table below.

The tethered balloon will be operated by 2 or 3 people from 6:30 UTC to 18:30 UTC in April and August and from 8 UTC to 16:30 UTC in December.
The floor heights are 50 and 150 m with a minimum of 20 minutes of stay on each floor.

Figure 9: The Skyhook Helikite 16m^3 tethered balloon and the turbulent probe

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Gill - Vertical Windmaster 1590-PK-020	20 Hz	flight height (floor at 50m and 150m)
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	FAMOUS		
Temperature	ROTRONIC Hygroclip2 HC2-S3		
Relative Humidity			
Pressure	NXP MPS4115A		
Motion tracker	Xsens Mti-G710		

April and August SOP: tethered balloon flights description

3 flights during the day at 6:30 UTC, 10:30 UTC and 14:30 UTC.

Level	150m											
	50 m										Flight 3	
	0 m										F1 & 2	Flight 3
Flight 1	UTC	6:29	6:30	6:57	7:24	7:51	8:18	8:45	9:12	9:39	10:07-10:29	/
Flight 2	UTC	10:29	10:30	10:57	11:24	11:51	12:18	12:45	13:12	13:39	14:07-14:29	/
Flight 3	UTC	14:29	14:30	14:57	15:24	15:51	16:18	16:45	17:12	17:39	18:06	18:32

: floor of 25 min

: At ground (period of 22 min between 2 flights)

December SOP: tethered balloon flights description

2 flights during the day at 8:00 UTC and 12:30 UTC

Level	150m											
	50 m										Flight 1 Flight 2	
	0 m											
Flight 1	UTC	07:59	8:00	8:27	8:54	9:21	9:58	10:25	10:52	11:19	11:46	12:07-12:29
Flight 2	UTC	12:29	12:30	12:57	13:24	13:51	14:18	14:45	15:12	15:39	16:06	16:32

: floor of 25 min

: floor of 25 min

: At ground (period of 22 min between 2 flights)

More information: Canut G., F. Couvreux, M. Lothon, D. Legain, B. Piguet, A. Lampert, W. Maurel, and E. Moulin : Turbulence fluxes and variances measured with a sonic anemometer

mounted on a tethered balloon, Atmos. Meas. Tech., 9, 4375-4386, doi:10.5194/amt-9-4375-2016, 2016.

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Meteorological measurements over the transition

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BeBopMet RPAS

Laboratory in charge : Univ. Bergen

Persons in charge : J. Reuder, S. Kral, A. Seeling

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Surface temperature

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DJITherm RPAS

Laboratory in charge : INRAE

Persons in charge : M. Irvine

A small UAV will be used to create a thermal of the transition zone during IOP periods. Thermal images will be collected at 2 second intervals and processed using Pix4D to produce thermal maps.

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Vegetation

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Leaf Aera Index

Laboratory in charge : CNRM

Persons in charge : à compléter

Part IV – Forecasts

For each SOP, there will be one person responsible for the everyday forecast.
He/she may be supported by a pair of students from the National Meteorological School (ENM).

Part V – Database

Link to MOSAI main website:	https://mosai.aeris-data.fr/
Link to MOSAI database:	https://mosai.aeris-data.fr/catalogue/
Link to MOSAI data policy:	https://mosai.aeris-data.fr/data-and-publication-policy/
Link to P2OA database:	https://p2oa.aeris-data.fr/data/

Part VI – Participants

List of participants, role and contact

Name	Lab	Phone	EOP	SOP1	SOP2	SOP3
Yannick Bezombes	LAERO		UHF	logistic	logistic	logistic
Solène Derrien	LAERO		EC, MTO CL61	EC, MTO CL61	support	support
Jean-Bernard Estrampes	LAERO		logistic	logistic	logistic	logistic
Fabienne Guesdon	LAERO		logistic	logistic	logistic	logistic
Mathilde Jomé	LAERO			RS	secretary	support
Fabienne Lohou	LAERO		Coord.	secretary	Coord.	RS
Marie Lothon	LAERO		Coord.	Coord.	RS	forecast
Alban Philibert	LAERO		UHF CL61	RS	support	support
Eric Pique	LAERO		EC-Towers mechanics			
Felix Starck	LAERO		Power supply			
Antoine Vial	LAERO		MTO, EC UHF	EC, MTO CL61	support	support
Gaspard Simonet				Forecast		
Eric Bazile	CNRM/GMAP		SOP 1, 3			RS
Fleur Couvreux	CNRM/GMME		SOP 2, 3		RS	TB
Joël Barrié	CNRM/GMEI		EC-stations			TB
Guylaine Canut	CNRM/GMEI		EC-stations	TB	TB	secretary
Julie Capo	CNRM/GMEI		EC-stations	TB - first 3 IOP / RS obs	TB	TB
Christophe Ciais	CNRM/GMEI		EC-stations	TB	TB	TB
Patrick Aressy	CNRM/GMEI		EC-stations	TB	TB	TB
Olivier Garrouste	CNRM/GMEI		EC-stations	TB	TB	TB
Eric Moulin	CNRM/GMEI		EC-stations	TB first 2 IOP		
Alexandre Paci	CNRM/GMEI		lidar			RS
Romain Roehrig	CNRM/GMAP				RS	Coord.
Emilie Bernard	CNRM/GMAP				TB	
ENM student 1	ENM				Forecast	Forecast
ENM student 2	ENM				Forecast	Forecast
Sophie Bastin	LATMOS			RS		RS
Maurin Zouzoua	LATMOS			RS		
Frédérique Cheruy	LMD				RS	
Pierre Tiengou	LMD				support	
Stephan Kral	Univ. Bergen		EC	RPAS	RPAS	
Joachim Reuder	Univ. Bergen		EC	RPAS	RPAS	
Alexander Seeling	Univ. Bergen		EC	RPAS	RPAS	
Carlos Roman-Cascon	Univ. Cadiz		EC, MTO		support	
Pablo Ortiz Corral	Univ. C. Madrid		EC, MTO		support	
Juan Jiménez Rincón	Univ. Cadiz		EC, MTO		support	
Aurore Brut	CESBIO		Scintillo			
Franck Granouillac	CESBIO		Scintillo			
Clément Remont	CESBIO		Scintillo			
Jean-Martial Cohard	IGE		Scintillo, EC			
Hélène Barral	IGE		Scintillo, EC			
Bernard Mercier	IGE		Scintillo, EC			
Catherine Couleau	IGE		Scintillo, EC			
Sébastien Lafont	INRAE		EC, MTO	LAI	LAI	LAI
Sylvain Dupont	INRAE		EC, MTO			
Mark Irvine	INRAE			RPAS	RPAS	RPAS
Myrtille Grulois	INRAE		EC, MTO			
José Darrozes	GET			Soil	Soil	Soil
***	GET					