

Model and observation for surface atmosphere interactions

Experimental Plan
for P2OA EOP & SOP

Part I – Objectives and general strategy
- Main objective
- Heterogeneity around the 60 m tower
- Strategy
  - Enhanced Observing Period (EOP)
  - Special Observing Period (SOP)

Part II – Instrumental sheets of continuous observations
- Eddy-covariance stations
- Soil conditions
- Boundary layer dynamics
- Cloud base height & cloud fraction

Part III – Instrumental sheets of intensive observations
- Atmosphere profiling
- Turbulence measurements over a forest-maize transition
- Meteorological measurements over a forest-maize transition
- Vegetation
- Soil

Part IV – Forecasts

Part V – Database
- Web site
- Data base
- Data policy

Part VI – Participants
- List of participants, role and coordinates

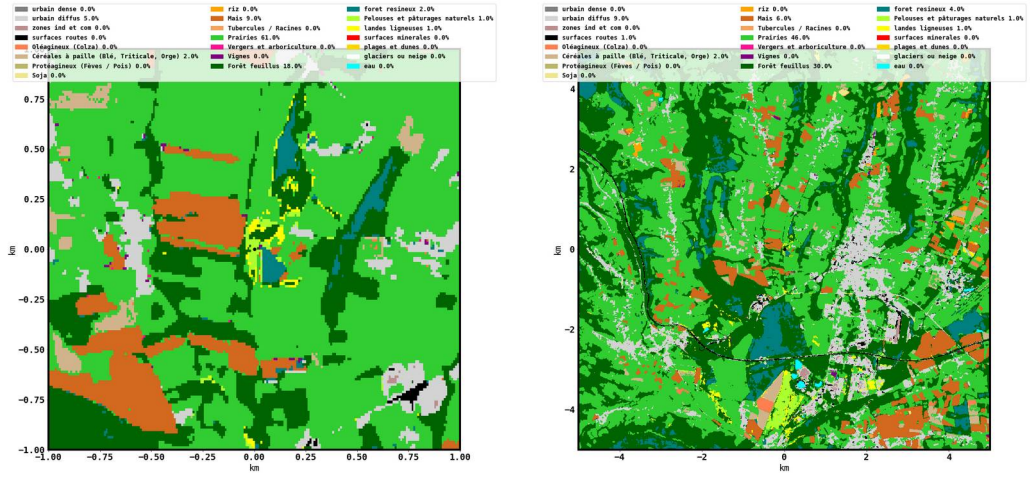
Part I – Objectives and general strategy

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. A third objective, also specific to this EOP and site, is to document the thermally-driven flows and their impact on the surface fluxes.

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.



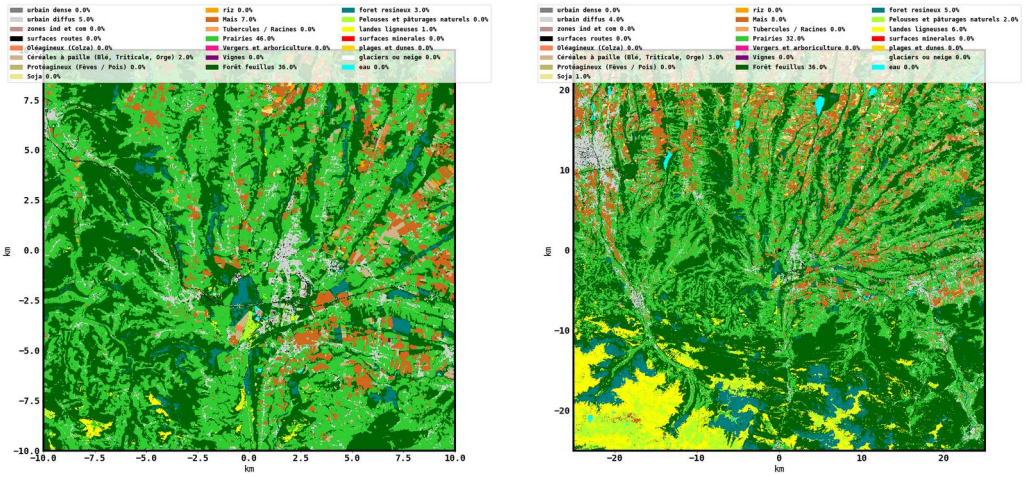


Figure 1 : Land-Use Map from CESBIO, THEIA OSO 2020 product, at 1, 2, 10, 20 km and 50km scale centred at P2OA 60 m tower. Ligher greens and Yellow: Prairies, Dark green: Deciduous trees, Blue-grey: Conifer trees, Orange: Summer crops (mainly maize), Light brown: Cereals (mainly triticale), Grey: diffuse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

	Area horizontal scale				
	1 km	**2 km**	**10 km**	**20 km**	**50 km**
Pastures and moors	55^{+}%	62^{+}%	48%	47%	40%
Deciduous forest	27%	18%	30%	36%	36%
Conifer forest	3^{-}%	2^{-}%	4%	3%	5%
Summer crops	14%	9%	6%	7%	9%
Winter crops	0%	2%	2%	2%	3%
Diffuse urban and road	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 pastures 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.

[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.*

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



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

Strategy

Enhanced Observing Period (EOP)

For the documentation of the surface heterogeneity, several flux stations and scintillometers were 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 covered 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 was continuously described all along the EOP by a UHF wind profiler, several Doppler lidars, a ceilometer, a sky imager.

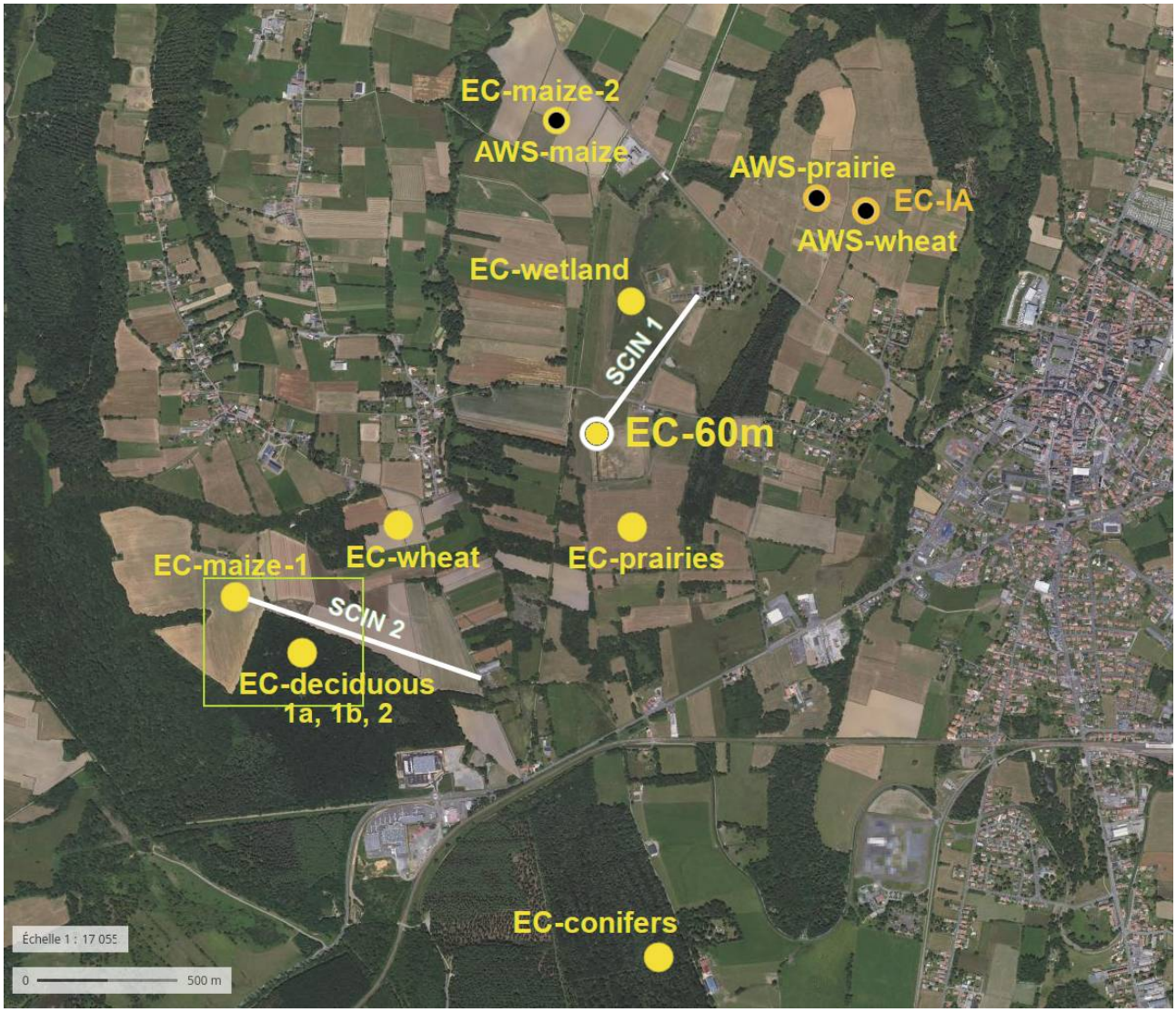


Figure 3 : Overview of the EOP deployment for fluxes and turbulence (see Table 2).
Yellow dots: EC stations,
White dots: MTO standard meteorological stations,
Orange circling: Alternating mobile EC-station.

/home/lotm/White line: Scintillometer path

Measured parameters	Instrumentation	Site
Surface-atmosphere interactions over different surface covers	**Eddy-Covariance stations**	**EC sites:** - EC-60m - EC-prairies - EC-wetland - EC-deciduous-1a - EC-deciduous-1b - EC-deciduous-2 - EC-conifers - EC-maize-1 - EC-maize-2 - EC-wheat - EC-town - EC-valley-exit - EC-IA / mobile Prairie/wheat
	Standard meteorological stations	**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

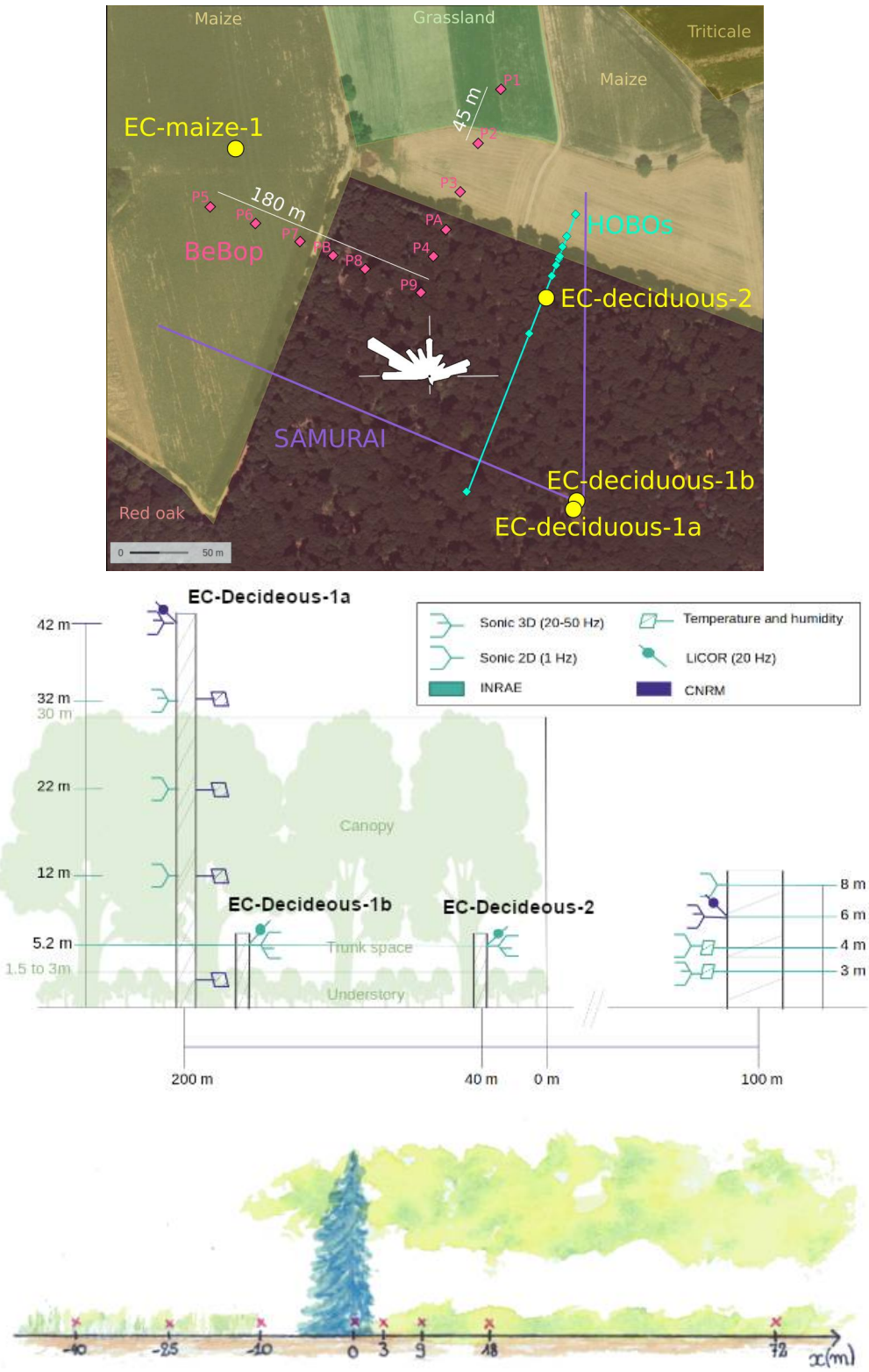


Figure 4 : (a) Zoom from Fig. 3 on the transition site. (b) W-E Cross section from Maize to Forest with instrumentation of the EC-Decideous stations (yellow dashed line), (c) Positioning of the HOBO stations along the N-S transect (white dashed line on (a). After Grulois et al 2026.

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 were deployed at the exit of the valley. (See Appendix A for more details on the connected UCM-UCA project.)

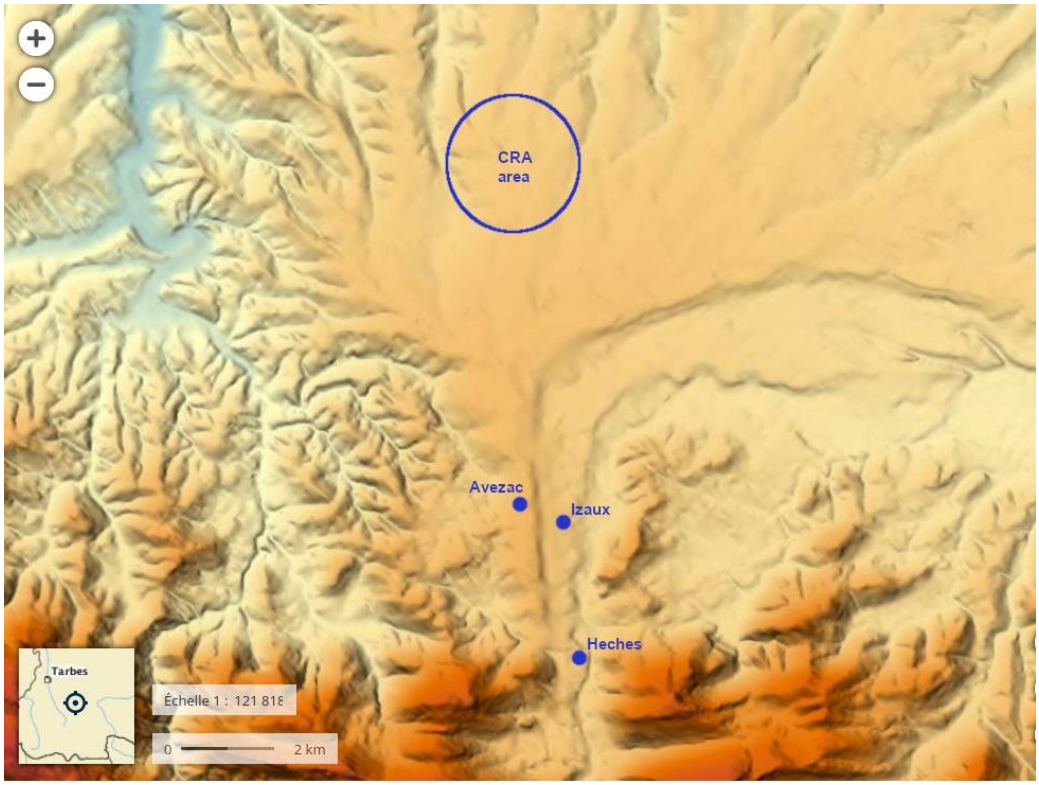


Figure 5 : Topography in the area, from the exit of the Aure valley to the CRA area. The blue circle locates Figure 3 frame.

Special Observing Period (SOP)

During three periods within the EOP, three SOP in April, August and December enabled us to intensify the exploration of the boundary layer structure: Re-usable radiosondes were launched on chosen IOP days (Intensive Observing Periods).

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

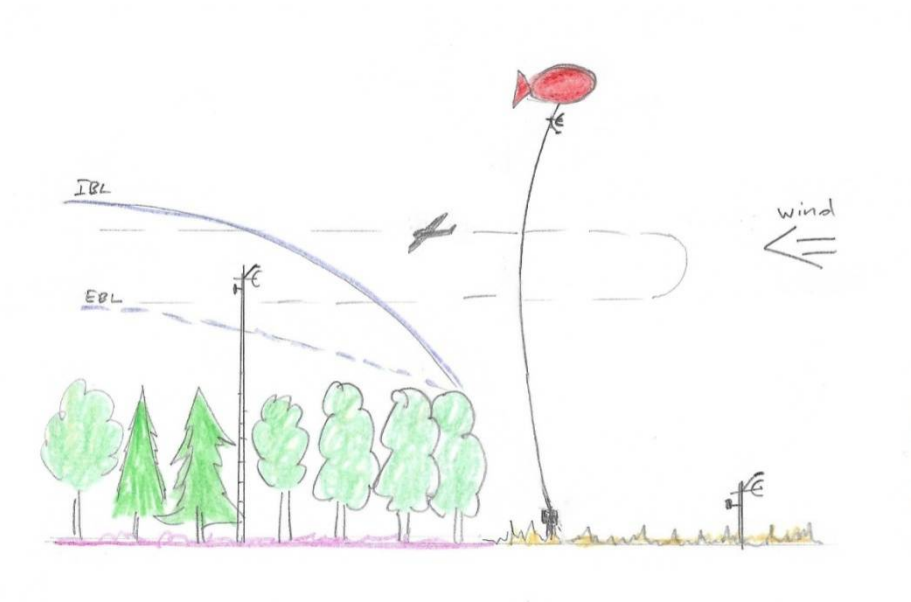


Figure 6: Scheme of the intensive observations over the transition

Measured parameters	Instrumentation	Site
Atmosphere profiling	Re-usable and standard Radiosondes SUMO RPAS	CRA CRA
Turbulence measurements within transition cross-section	SAMURAI RPAS Tethered-balloon-borne turbulence probe	Transition
Meteorological variables within transition cross-section	Multicopter Bebop2Met	Transition
Surface temperature	Multicopter DJITherm	
Vegetation : Leaf Aera Index	Network of Photosynthesis Active Radiation (PAR) sensors placed under the canopy	Forest Maize

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

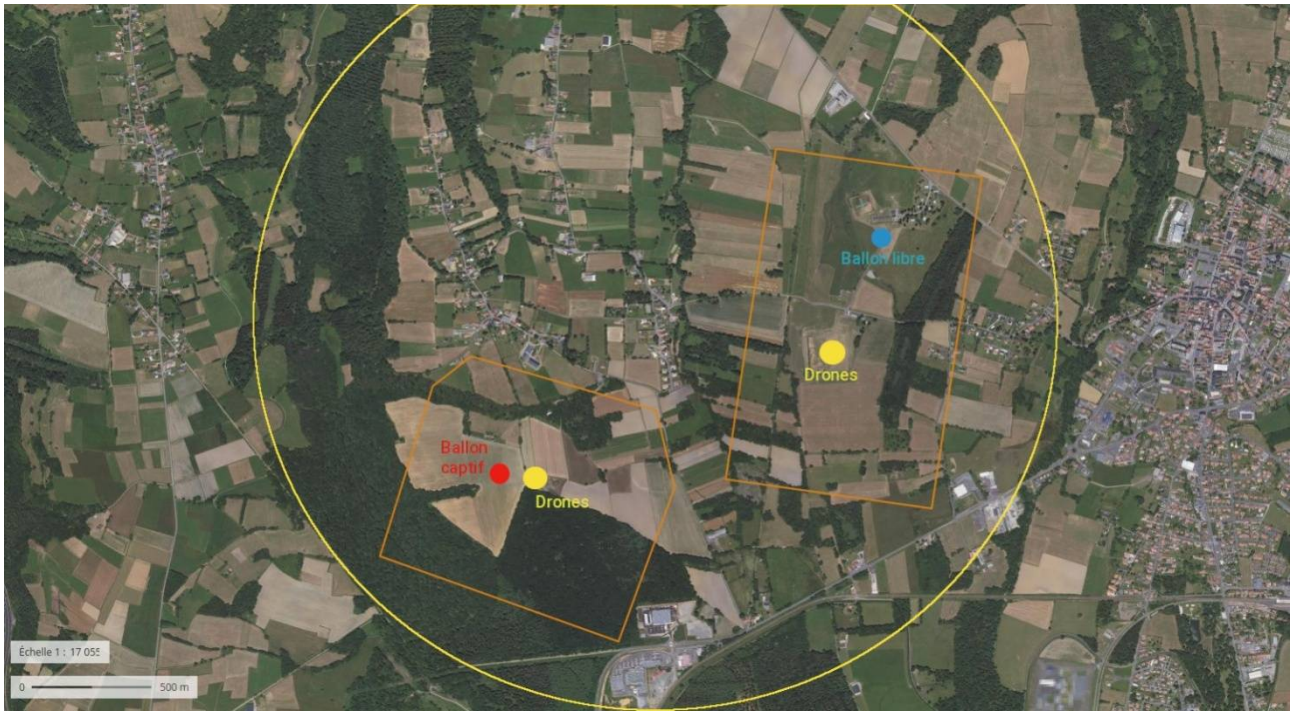


Figure 7 : TRA (yellow contour), flying area (orange contour) and localisation of tethered balloon (red), radio-soundings (blue) and RPAS (yellow).

Within a 9 or 15-day SOP, only about 5 IOP days were selected, for intensive observations by the platforms listed in Table 3. The selection depended on the meteorological conditions: we searched 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 helped us to choose the IOP days.

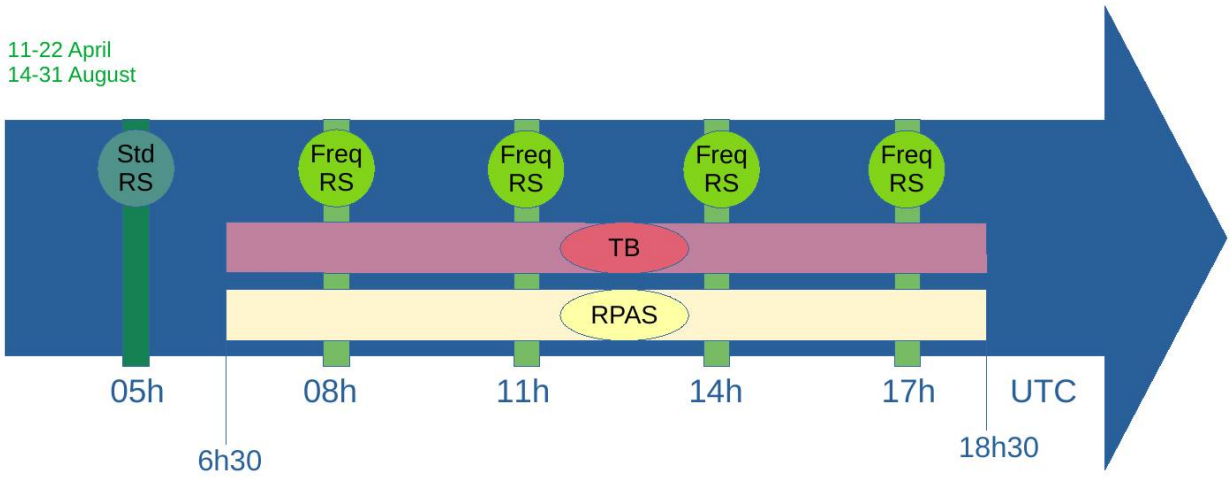


Figure 8a : Time schedule of and IOP day, with radiosondes launches, RPAS flights and TB operations. Case of SOP1 and SOP2.

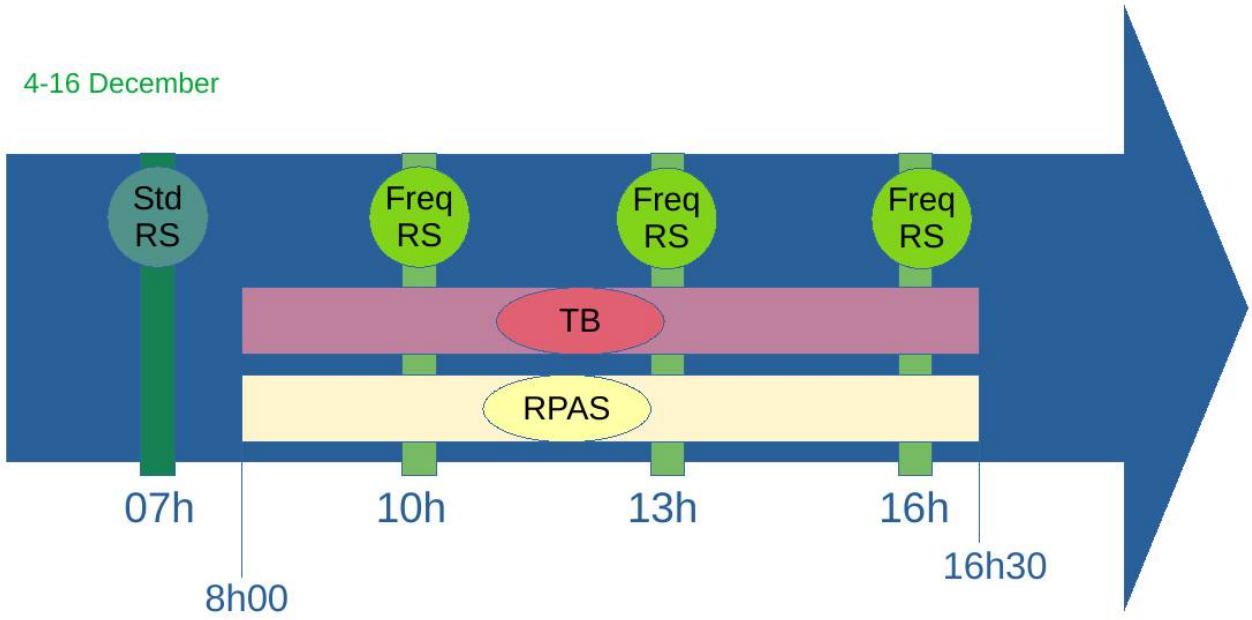


Figure 8b : Time schedule of and IOP day, with radiosondes launches, RPAS flights and TB operations. Case of SOP3.

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

Part II – Instrumental sheets of continuous observations

****
Eddy-covariance stations
****

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		6	U, V, W, T, H2O, CO2
EC-Deciduous-2	INRAE	Deciduous trees		6	U, V, W, T, H2O, CO2
EC-Conifer	LAERO	Conifer trees		42	U, V, W, T, H2O, CO2 SWup, SWdown, LWup, LWdown
EC-Maize-1	CNRM	Maize	43,11866°N 0,34714°E 594m	8	
EC-Wheat	Univ. Bergen LAERO	wheat, then prairie	43.120514°N 0.354586°E 603 m		
EC-PMP	LAERO	Prairie	43.121211°N 0.364225°E 603.4 m		
EC-wetland	IGE	wetland	43,1284″ N 0,3643″ E	2.5	U, V, T, H20, CO2 SWup, SWdown, LWup, LWdown, Ground flux Tair, Hair, wind
EC-Izaux	UMC	Prairie			
EC-Hèches	UMC	Prairie			
EC-IA (mobile)	LAERO	alternatively prairie / wheat		3	U, V, W, T, H2O, CO2 SWup, SWdown, LWup, LWdown Ground flux
EC-Maize-2	LAERO	Maize		5	U, V, W, T, H2O, CO2 SWup, SWdown, LWup, LWdown Ground flux

EC-60
60 m tower

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



Configuration of the station

Altitude		*603 m*
Longitude		0°21'45.33" E
Latitude		43°07'27.15" N
Temperature and humidity	*Height above ground*	*2m, 15m, 30m, 45m, 60m*
Rain gauge		*1.4 m*
4 components radiometer		*60m*
	Direction	*180°*
Anemometer	*Height above ground*	*15m, 45m*
	North direction	*0 °*
Ultrasonic anemometer	*North direction*	*270 ° (1)*
	Height above ground	*30m, 60m*
Infra red gas analyzer	*Position / anemometer*	*East of sonic head which is pointing to west*
	Distance / sonic	*12 cm*
radiometer	*Direction*	*180 ° (2)*
	Height above ground	*60 m*
	Angle / surface	*a circular surface with a radius of about 10 times the height*
Soil fluxes sensors	*Depth*	*- 5 cm*
Barometer	*Height above ground*	*1.4 m*

(1) *angle between the ultrasonic probe and north (positive angle in a clockwise direction)*

(2) *180°, which means that the sensor is facing south*

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	10 Hz	30m, 60m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500A	10 Hz	30m
CO2 concentration			
Atmospheric pressure from Licor sensor			
Temperature	Rotronic HC2-S3	5 sec.	2m, 15m, 30m, 45m, 60m
Relative Humidity			
Outgoing global radiation	Kipp & Zonen CNR1		60m
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Wind speed	Vector Instruments A100L2		15m
Wind direction	Vector Instruments W200P		15m
Atmospheric pressure	PTB101B		1.4 m
Wind speed and direction	Young 05103		45m
Soil heat flux	Hukseflux HFP01		- 5 cm
Rainfall	EML (Environmental Measurement Ltd) ARG100		0.4 m

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

Data access: https://doi.org/10.25326/506

EC-Conifer station

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



Configuration of the stations

Altitude		*622 m*
Longitude		*0.365833° E*
Latitude		*43.107222° N*
Temperature and humidity	*Height above ground*	*41 m*
4 components radiometer		*41 m*
	Direction	*180 °*
Ultrasonic anemometer	*North direction*	*327 °*
	Height above ground	*41m*
Infra red gas analyzer	*Position / anemometer*	*East of sonic head which is pointing to west*
	Distance / sonique	*14 cm*
radiometer	*Direction*	*180 °*
	Height above ground	*41 m*
	Angle / surface	*a circular surface with a radius of about 10 times the height*
Barometer	*Height above ground*	*30m*

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	10 Hz	41 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	41 m
CO2 concentration			
Atmospheric pressure			
Temperature	HMP155	5 sec	41 m
Relative Humidity			
Outgoing global radiation	Kipp & Zonen CNR4		41 m
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Pressure	Vaisala PTB110		30 m

EC-Deciduous-1a station

Laboratory in charge : CNRM

Persons in charge : O. Garrouste, G. Canut



Configuration of the stations

Altitude		*607 ± 3 m*
Longitude		*0° 21’ 02.1”*
Latitude		*43° 06’ 57.2”*
Temperature and humidity	*Height above ground*	*2, 12, 22, 32 and 40 m*
4 components radiometer		*60 cm*
	Direction	*180 °*
Gill R3ultrasonique anemometer	*North direction*	*0 °*
	Height above ground	*42 m*
Infra red gas analyzer	*Position / anemometer*	*160 ° / North sonique*
	Distance / sonique	*15 cm*
CSAT3B ultrasonique anemometer	*North direction*	*305 °*
	Height above ground	*32 m*
Gill WindSonic sonique anemometer	*North direction*	*305 °*
	Height above ground	*12 and 22 m*
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*

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			
Wind component U	Campbell CSAT 3B	50 Hz	32 m
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	GILL WindSonic 2D	1 Hz	12 and 22 m
Wind component V			
Specific humidity	LICOR 7500	20 Hz	42 m
CO2 concentration			
Atmospheric pressure			
Temperature	PT100	10 sec.	2, 12 , 22, 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

EC-Maize-1 station

Laboratory in charge : CNRM

Persons in charge : O. Garrouste, G. Canut



Configuration of the stations

Altitude		*594 ± 3 m*
Longitude		*0° 20’ 49.7”*
Latitude		*43° 07’ 07.18”*
Temperature and humidity	*Height above ground*	*200, 425, 600 and 810 cm*
Rain gauge		*100 cm*
4 components radiometer		*60 cm*
	Direction	*180 °*
Anemometer	*Height above ground*	*1000 cm*
	North direction	*0 °*
Metek ultrasonique anemometer	*North direction*	*300 °*
	Height above ground	*600 cm*
Infra red gas analyzer	*Position / anemometer*	*300 ° / North sonique*
	Distance / sonique	*15 cm*
Campbell ultrasonique anemometer	*North direction*	*356°*
	Height above ground	*300 cm*
Gill sonique anemometer	*North direction*	*345°*
	Height above ground	*425 and 810 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*

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			
Wind component U	Campbell CSAT3B	50 Hz	300 cm
Wind component V			
Wind component W			
Sonic temperature			
Wind component U	GILL WindSonic 2D	1 Hz	425 and 810 cm
Wind component V			
Air temperature	Campbell CS215	0.5 Hz	425 and 810 cm
Relative humidity			
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		50cm
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

Ec-Deciduous-1b 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	Gill R3	20 Hz	535 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	535 cm
CO2 concentration			
Atmospheric pressure			

Configuration of the stations

Altitude		*607 ± 3 m*
Longitude		*0° 21′ 02.6″*
Latitude		*43° 06′ 57.8″*
Ultrasonique anemometer	*North direction*	*356 °*
	Height above ground	*535 cm*
Infra red gas analyzer	*Position / anemometer*	*180 ° / North sonique*
	Distance / sonique	*20 cm*

EC-Deciduous-2 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	Gill R3	20 Hz	515 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	512 cm
CO2 concentration			
Atmospheric pressure			

Configuration of the stations

Altitude		*606 ± 3 m*
Longitude		*0° 21′ 01.6″*
Latitude		*43° 07′ 03″*
Ultrasonique anemometer	*North direction*	*4 °*
	Height above ground	*515 cm*
Infra red gas analyzer	*Position / anemometer*	*180 ° / North sonique*
	Distance / sonique	*22 cm*

EC-Wheat station

Laboratory in charge : Univ. Bergen / LAERO

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	10 Hz	3.7 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500	10 Hz	3.7 m
CO2 concentration			
Atmospheric pressure from Licor sensor			
Outgoing global radiation	Kipp & Zonen CNR4	1 sec	1.5 m
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Soil heat flux x 2	Hukseflux HFP01	1 sec	- 5 cm

Configuration of the stations

Altitude		603 m
Longitude		0.354586°E
Latitude		43.120514°N
4 components radiometer	*Height above ground*	*1.5m*
	Direction	*260 °*
	Angle / surface	*a circular surface with a radius of about 10 times the height*
Ultrasonic anemometer	*North direction*	*359°*
	Height above ground	*3.7m*
Infra red gas analyzer	*Position / anemometer*	*South of sonic head which is pointing to north*
	Distance / sonic	*20 cm*

PMP station

Laboratory in charge : LAERO

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 Gill R3	20 Hz	260 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500-RS	20 Hz	260 cm
CO2 concentration			
Atmospheric pressure			
Net radiation	Kipp & Zonen NR lite	30 min	257 cm
Soil fluxes sensors	Kipp & Zonen HFP01	30 min	5 cm

Configuration of the stations

Altitude		*603 m*
Longitude		0°21'51.30" E
Latitude		43°07'16.40" N
Ultrasonic anemometer	*North direction*	*261°*
	Height above ground	260 cm
Infra red gas analyzer	*Position / anemometer*	*180 ° / North sonic*
	Distance / sonique	*11 cm*

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

Wetland station

Laboratory in charge : IGE

Persons in charge : JM Cohard, H. Barral, C. Coulaud

Daily monitoring : S. Derrien and A. Vial



Configuration of the stations

Altitude		587 m
Longitude		00°21′51.5″ E
Latitude		43°07′42.4″ N
Ultrasonique anemometer	*North direction*	*270°* cadran solaire = 14,5° à 9h14 TU le 14/03/2024 AZsoleil = 127.41° au même moment
	Height above ground	*250 cm*
Infra red gas analyzer	*Position / anemometer*	1ère mesure : --> orientation de l'axe entre le CSAT et le Licor = 338.0° à 9h17, le 14/03/2024 --> AZsoleil = 128.12° au même moment 2ème mesure : --> orientation de l'axe entre le CSAT et le Licor = 338.5° à 9h21, le 14/03/2024 --> AZsoleil = 129.07° au même moment
	Distance / sonique	*24 cm* *Axe y (barre sonic) 20cm* *Axe x 12 cm*

		relevé du 14/03/2024 : distance entre volumes CSAT et Li7500 = 26 cm (à vol d'oiseau)
4 components radiometer	*Height above ground*	*170 cm*
	Direction	*180 °*
Soil humidity sensor	*Depth*	*-13 cm*

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell CSAT 3	20 Hz	250 cm
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity	LICOR 7500A	20 Hz	250 cm
CO2 concentration			
Atmospheric pressure			
Temperature	Campbell CS215	Scan 10 sec. Moyennée sur 1 min	225 cm
Relative Humidity			
Horizontal wind speed	Gill Windsonic 4		230 cm
Wind direction			
Outgoing global radiation	Kipp & Zonen CNR1		170 cm
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Soil heat flux	Hukseflux HFP01		-5 cm
Soil temperature	Campbell thermocouples T105		-5 cm - 13 cm -30 cm
Soil water content	Campbell CS616		- 13cm

EC-mobile-station)
(Obs4Clim mobile station)

Laboratory in charge : LAERO

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell IRGASON	10 Hz	2.8 m (prairie) 3.1 m (wheat)
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity			
CO2 concentration			
Atmospheric pressure	Freescale MPXAZ6115A		
Temperature	BetaTherm 100K6A1A Thermistor	5 sec	2.8 m (prairie) 3.1 m (wheat)
Relative Humidity			
Outgoing global radiation	Kipp & Zonen CNR4		2.8 m (prairie) 3.1 m (wheat)
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Soil heat flux	Hukseflux HFP01		-5 cm

Configuration of the stations

Altitude		585 m (prairie and wheat)
Longitude		0° 22' 21.5" (prairie) 0°22'29.7" E (wheat)
Latitude		43°07’52.0” N (prairie) 43°07’56.9 N (wheat)
Ultrasonic anemometer	North direction	Around west, depending of periods and surfaces
	Height above ground	2.8 m (prairie) 3.1 m (wheat)
Infra red gas analyzer	Position / anemometer	Perfectly colocated
	Distance / sonique	0 cm
4 components radiometer	Height above ground	2.8 m (prairie) 3.1 m (wheat)
	Direction	180 °

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

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Campbell IRGASON	10 Hz	4.8 m
Wind component V			
Wind component W			
Sonic temperature			
Specific humidity			
CO2 concentration			
Atmospheric pressure	Freescale MPXAZ6115A		
Temperature	BetaTherm 100K6A1A Thermistor	5 sec	4.8 m
Relative Humidity			
Outgoing global radiation	Kipp & Zonen CNR4		5 m
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Ground heat flux	Hukseflux HFP01	5 sec	-0.05 m
	Hukseflux HFP01		
	Hukseflux HFP01		

Configuration of the stations

Altitude		584 m
Longitude		00°21’41” E
Latitude		43°08’02.2” N
Ultrasonic anemometer	North direction	308°
	Height above ground	4.8m
Infra red gas analyzer	Position / anemometer	Perfectly colocated
	Distance / sonique	0 cm
4 components radiometer	Height above ground	5 m
	Direction	180 °

EC-Valley-Exit (Izaux) station (prairie)

Laboratory in charge: University Complutense of Madrid (UCM)
Person in charge: Carlos Yagüe

Location: Izaux, prairie. 43.05707° N; 0.375019°E
Height above sea level: 595 m
Installation date: 12 April 2023 (some issues the first days).
Deinstallation date (possible): 25 August 2023

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	IRGASON (SON component, Campbell)	10 Hz	285 cm
Wind component V			
Wind component W			
Sonic temperature			
Temperature	IRGASON – BetaTherm 100K6A1A Thermistor (auxiliary sensor)	1 Hz	290 cm
Atmospheric pressure	IRGASON basic barometer (auxiliary sensor)	10 Hz	285 cm
Water vapor density	KH20 (Campbell)	10 Hz	285 cm
Atmospheric pressure			
Temperature	Campbell EE181 (with solar protection)		200 cm
Relative Humidity	Campbell EE181 (with solar protection)		
Outgoing global radiation	4-components radiometer Hukseflux NR01		200 cm
Incoming global radiation			
Outgoing longwave radiation			
Incoming longwave radiation			
Sensor temperature			
Soil heat flux	Heat flux plate Hukseflux HFP01SC	1 min.	- 5 cm
Soil temperature	TVAC	10 min.	-5 cm
Soil water content	CS616	10 min.	-5 cm
Wind direction	Vector W200P	1 s	285 cm

Site V3. Wind station – Héches (end of the narrow valley)

Laboratory in charge: University Complutense of Madrid (UCM) & University of Cádiz (UCA)
Persons in charge: Carlos Román Cascón & Carlos Yagüe

Location: Héches, prairie. 43.023581 ° N; 0.376768 °E
Height above sea level: 602 m
Installation date: 18 April 2023
Deinstallation data (possible): 25 August 2023

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind component U	Young 81000	10 Hz	285 cm
Wind component V			
Wind component W			
Sonic temperature			

This sensor was finally connected with a Campbell CR6 datalogger, sending data in remote with a router. Solar panel and mast courtesy of CRA.

****

Standard Meteorological Stations

****

Transect of HOBO meteorological stations

Laboratory in charge : INRAE

Person in charge : M. Grulois

Parameter	Sensor	Distance from edge	Sampling frequency (or period)	Height of measurement
Air temperature T	HOBO	0 m	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	3 m within Forest	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	9 m within Forest	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	18 m within Forest	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	72 m within Forest	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	180 m within Forest	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	10 m within Maize	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	25 m within Maize	5 min	150 cm
Relative Humidity RH				
Air temperature T	HOBO	40 m within Maize	5 min	150 cm
Relative Humidity RH				

AWS-prairie
(Obs4Clim mean meteorological station)

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



Configuration of the stations

Altitude	585m (prairie and wheat)
Longitude	0° 22' 21.5"
Latitude	43°07'52.0" N

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Incoming global radiation	CS320	0.033Hz	3.1 m
Temperature	Hygrovue	0.033Hz	2.92 m
Relative Humidity			
Wind component U	Wind sonic	10 Hz	3.37 m
Wind component V			
Soil moisture	CS650	0.033Hz	- 0.07 m

AWS-wheat
(Obs4Clim mean meteorological station)

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

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Incoming global radiation	CS320	0.033Hz	3.01 m
Temperature	Hygrovue	0.033Hz	2.92 m
Relative Humidity			
Wind component U	Wind sonic	10 Hz	3.26 m
Wind component V			
Soil moisture	CS650		- 0.06 m

Configuration of the stations

Altitude	585 m
Longitude	0°22'29.7" E
Latitude	43°07'56.9 N

AWS-maize
(Obs4Clim mean meteorological station)

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

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Incoming global radiation	CS320	0.033Hz	5.16 m
Temperature	Hygrovue	0.033Hz	4.5 m
Relative Humidity			
Wind component U	Wind sonic	10 Hz	4.9 m
Wind component V			
Soil moisture			- 0.06 m
Pressure ??			

Configuration of the stations

Altitude	584 m
Longitude	00°21′41″ E
Latitude	43°08′02.2″ N

Site V2. Avezac-Prat-Lahitte – edge of the wider valley (RAWS station)

Laboratory in charge: University of Cádiz (UCA)
Person in charge: Carlos Román Cascón

Location: Labastide, prairie. 43.052469° N; 0.360765° E
Height above sea level: 686 m
Installation date: 12 April 2023
Deinstallation data (possible): 25 August 2023

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Wind direction	Davis 6410	1 s	285 cm
Wind speed	Davis 6410	1 s	285 cm
Temperature	Holfuy	1 s	200 cm
Relative Humidity	Holfuy	1 s	200 cm
Pressure	Holfuy	1 s	200 cm
Solar radiation	Davis 6450	1 s	100 cm
Rain	Holfuy	1 s	100 cm
Soil moisture	SMT50 truebner	1 s	-5 cm
Soil temperature	SMT50 truebner	1 s	-5 cm

****
Scintillometers
****

SCIN2 Scintillometer

Laboratory in charge : CESBIO
Persons in charge : Aurore Brut, Franck Granouillac, Clément Remont

Transmitter location: Lagrange, sawmill, 43.116121°N, 0.358121°E
Receiver Location : Maize field, 43.119405°N, 0.344550°E like the EC-Maize-1 station
Measurement Height: 6 m
Installation date: 12 April 2023
Deinstallation data : 22 novembre 2023

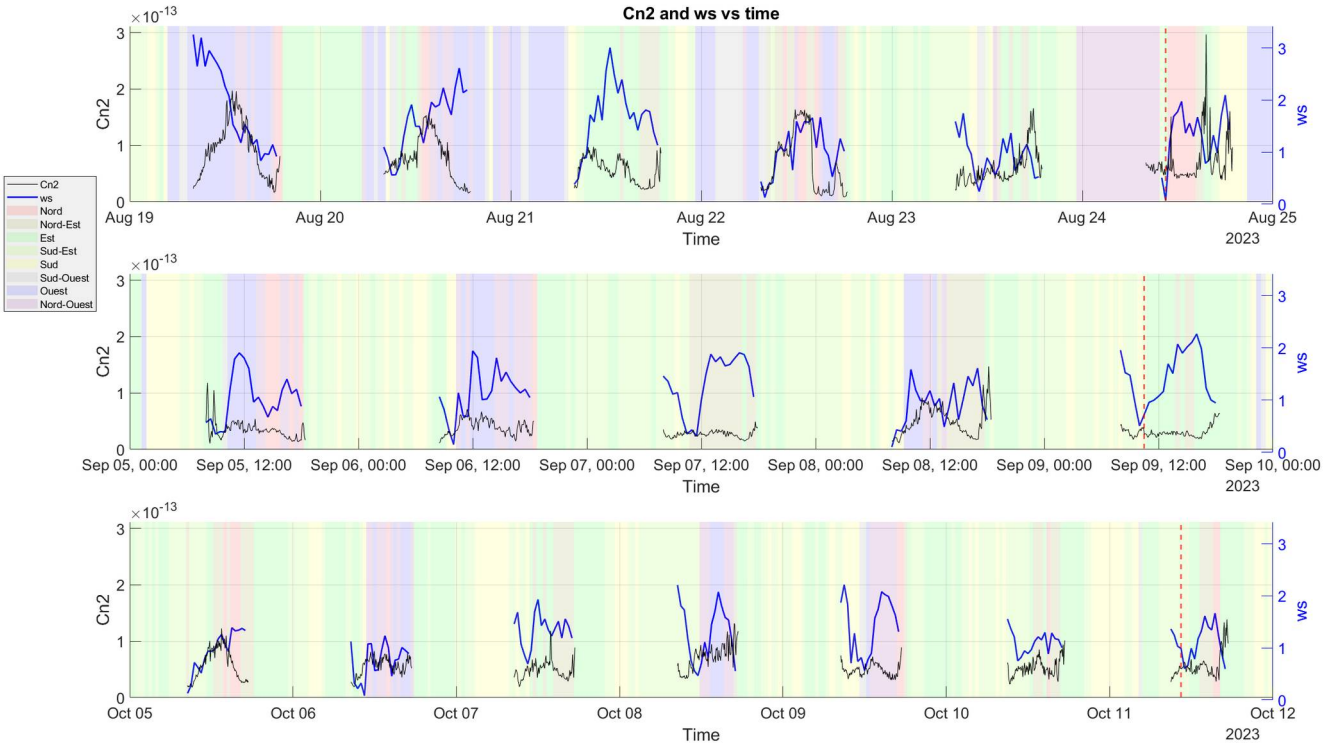


Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Structure coefficient of the Refraction index (Cn2)	Kipp&Zonen LAS	5 min	6 m
Wind direction	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Wind speed	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Temperature	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Relative Humidity	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Pressure	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Solar radiation	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Rain	ClimaVUE50 (Campbell Scientific)	30 min	200 cm
Soil moisture	SoilVUE (Campbell Scientific)	30 min	-5, -10, -20, -30, -40, -50 cm
Soil temperature	SoilVUE (Campbell Scientific)	30 min	-5, -10, -20, -30, -40, -50 cm
Soil heat flux	Heat flux plate Hukseflux HFP01S	30 min	- 5 cm

The scintillometer measurements are recorded at a 5 min frequency and the recording file contains the signal intensity at the receiver, the demod signal, and the Cn^2 value.

Then, the data (Cn^2) are filtered according to the net radiation values and the values are considered only for daytime periods (Rn >50 W/m²). On the following figure, the Cn^2 are presented conjointly with the wind speed (right axis) and wind direction (colors), for 3 golden periods in August, September and October (clear sky with high incoming radiation).



SCIN1 Scintillometer

Laboratory in charge : IGE

Persons in charge : JM Cohard, H. Barral, Davy Régneau



Transmitters location: EC60, 43°07’27.11” N, 0°21’45.33” E
Receivers Location : CRA, 43°07’42.83” N, 0°22’02.43” E
Measurement Height: 19.6 m
Installation date: 16 April 2023
Deinstallation data : 02 May 2024

Sensors and sampling

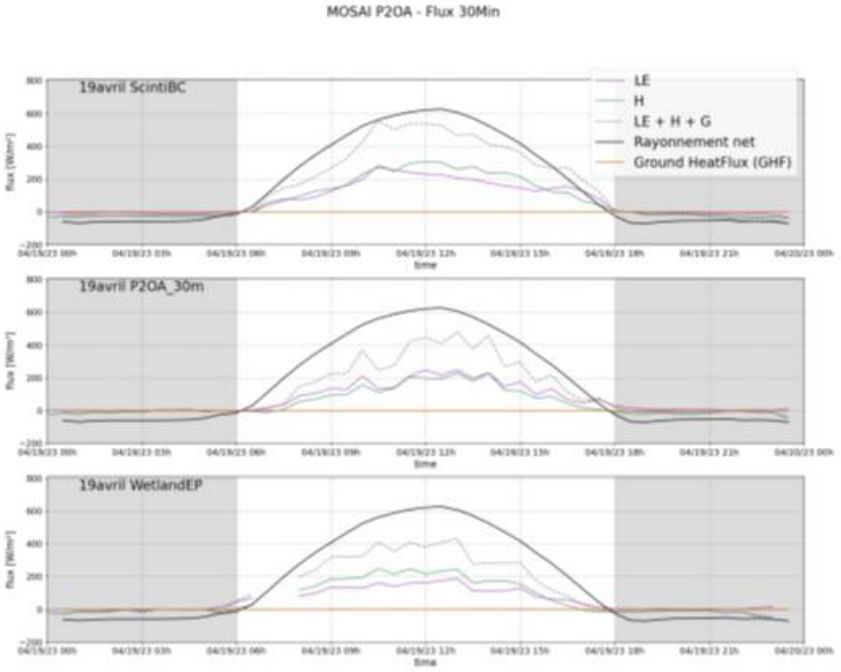
Parameter	Sensor	Sampling frequency (or period)	Height of measurement
IR Refraction index scintillation structure parameter	Kipp&Zonen LAS (apertture diameter : 14.5 cm)	1 kHz	19.6 m
MW Refraction index structure parameter	RAL/IGE 94GHz Microwave Scintillometer prototype (aperture diameter 29cm)	1 kHz	19.6m

Data processing :

The scintillometer measurements are sampled at 1 kHz and recorded in hourly binary files. These files contain the received signal intensity for IR and the amplitude of the signal measured by the two detectors—linear and logarithmic—of the microwave receiver, MW_{lin} and MW_{log}. Due to a software error, the raw data was sometimes oversampled. This was corrected to create a homogeneous dataset at 1 kHz. The data was then cleaned with a despiking process.

The signals were then filtered using a high-pass filter (HPF) and a low-pass filter (LPF). The filter settings were defined independently for the C^2_n MW (LPF: 300 Hz) and IR (LPF: 50 Hz) calculations, and a specific setting was defined for the CnIRnMW (LPF: 50 Hz).

For the first analysis, no high-pass filter was applied for the calculation of the 1-minute C^2_n.
The microwave scintillation spectra also reveal a bump in the power-law region (Kolmogorov). This anomaly is not due to external sources and appears to be associated with the Hill Bump (Hill and Clifford 1978).
The C_T^2, C_q^2, and C_{Tq} values, followed by the sensible (H) and latent (LE) heat fluxes, were then calculated using the bichromatic method proposed by Ward et al. 2015a and b.
The results are quite satisfactory, as shown in the figure below for April 19, 2023.



Hill, R. J., et S. F. Clifford. « Modified spectrum of atmospheric temperature fluctuations and its application to optical propagation ». *Journal of the Optical Society of America* 68, n° 7 (1978): 892-99. https://doi.org/10.1364/josa.68.000892.

Ward, H. C., J. G. Evans, et C. S. B. Grimmond. « Infrared and millimetre-wave scintillometry in the suburban environment - Part 2: Large-area sensible and latent heat fluxes ». *Atmos. Meas. Tech.* 8, n° 3 (2015): 1407-24. https://doi.org/10.5194/amt-8-1407-2015.

Ward, H. C., J. G. Evans, C. S. B. Grimmond, et J. Bradford. « Infrared and millimetre-wave scintillometry in the suburban environment - Part 1: Structure parameters ». *Atmos. Meas. Tech.* 8, n° 3 (2015): 1385-405. https://doi.org/10.5194/amt-8-1385-2015.

****
Soil conditions down to 2 m
****

Pit

Laboratory in charge : LAERO

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

Pit of 1.2 m depth with 6 levels, each with two soil temperature and three soil water content sensors, not far from the 60 m tower, over a representative soil covered with prairies.

Sensors and sampling

Parameter	Sensor	Sampling frequency (or period)	Height of measurement
Skin temperature	APOGEE	2 sec	1.5 m
Soil temperature	Campbell T107	2 sec	-5 cm, -10 cm
Soil temperature	Campbell T107	1min	-20 cm, -30 cm
Soil temperature	Campbell T107	1h	-60 cm, -120 cm
Soil water content	Campbell CS616	2 sec	-5 cm, -10 cm
Soil water content	Campbell CS616	1min	-20 cm, -30 cm
Soil water content	Campbell CS616	1h	-60 cm, -120 cm

Configuration of the stations

Altitude	591 m
Longitude	00°21′59.94″ E
Latitude	43°07′40.7″ N

****
Boundary layer dynamics
****

UHF wind profiler

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



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

Laboratory in charge : CNRM

Persons in charge : G. Canut, A. Riandet

The WLS7 windcube lidar manufactured by Leosphere provides information on the atmospheric dynamics at meso and small scale in the first two hundred metres of the planetary boundary layer. It supplies vertical profile of the three components of the wind, in clear or cloudly air, at 20 m vertical resolution, from 40 m to 220 m a.g.l, and every 3s or 10 minutes.

Technical characteristics :

Radial resolution	20m
beams geometry	4 inclined beams at 28° + 1 vertical beam
Elevation of the oblique beams	68
Vertical cover	40220 m to m a.g.l
Radial sampling	20 m
Temporal resolution	3s or 10 min

****
Cloud base height and cloud fraction
****

CL 61 Ceilometer

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



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.

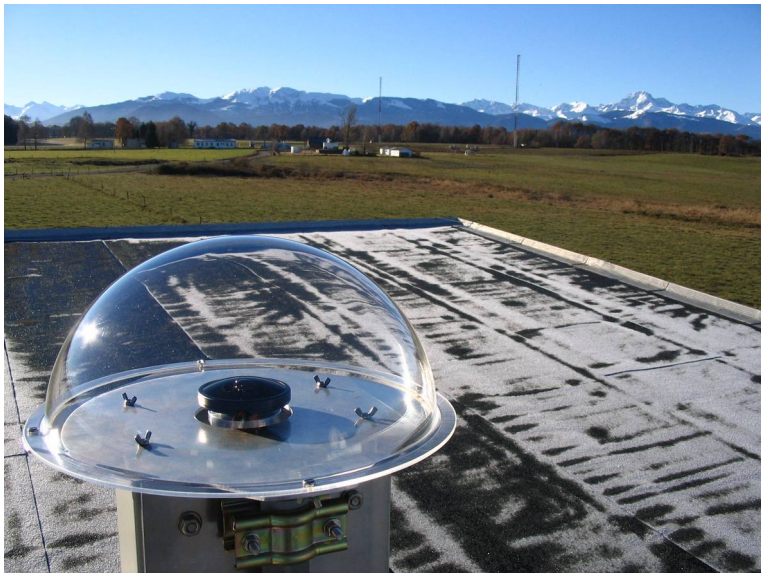
In case of heavy precipitation or fog, the ceilometer software reports vertical visibility.

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, with images every 5 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

****
Atmosphere profiling
****

MODEM – Standard Radiosoundings

Laboratory in charge : LAERO
Persons in charge : A. Philibert, 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.

Radiosounding launching from Aure Valley

The group is also interested in launching low-atmosphere (~2 km) Sparv radiosoundings at the valley exit, especially during nighttime flows (downvalley flows). This complements the radiosoundings launched at CRA, being interesting for the comparison of the vertical structure of the atmosphere in both regions. The purpose is the observation of the jet structure before it has a more important interaction with larger-scale winds (CRA).

Due to the technical difficulties a the beginning of the participation, during the April SOP1, the group performed an intercomparison exercise at CRA with the normal and recurrent radiosoundings launched by LAERO, to check differences between the widely used MODEM radiosoundings and the Sparv ones (http://sparvembedded.com/products/windsond/).

The following SPARV radiosoundings were launched (test ones) at CRA, that was compared to others launched at similar times by the CRA team.

2023 04 18 19:00 LT
2023 04 19 07:00 LT
2023 04 19 13:30 LT
2023 04 19 19:30 LT

The group aims at launching radiosoundings each 3 hours at the valley during IOPs of the SOP2 in August 2023.

****

Turbulence measurements over the transition

****

SAMURAI RPAS

Laboratory in charge: University of Bergen
Persons in charge: J. Reuder, S. Kral, A. Seeling





RMYoung 81000 sonic anemeometer
SBG Ellipse-D INS

Atmospheric u, v, w, Ts @20 Hz
Payload's lat, lon, alt, pitch, roll, yaw, u, v, w @ 50Hz

The SAMURAI system consists of a heavy lifting multicopter carrying a scientific payload suspended by 19 m. The payload consists of a sonic anemometer and inertia navigation system (INS) and is designed to obtain atmospheric turbulence measurements that corrected for the payload's orientation and motion, from which turbulent properties such as the turbulent fluxes of heat (buoyancy flux) and momentum and the specific turbulent kinetic energy as well as other turbulent statistics can be obtained.

The SAMURAI system was used to capture turbulence characteristics above the forest and the maize-forest transition adding additional observations at levels above the near and within canopy measurements provided by the mast-mounted EC systems within and above the forest canopy.
The SAMURAI system was operated by two people between roughly 07:00 and 17:00 UTC, with up to 13 flights per IOP day (see Appendix Table C1 in manuscript). Turbulence data

where collected from around 15 min hovering periods above the forest and ~400 m transects crossing the maize forest transition.

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 were 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 was 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	*from 0 to 300 m agl maximum*
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		

3 flights per day at 6:30UTC, 10:30UTC and 14:30UTC. About 30 min (minimum 20 min) to change batteries and replace SD card

Probe height	100m												Vol 3	
	60 m													
	42 m													
	0 m												V1 et 2	Vol 3
Flight #1	LT	8h29	8h30	8h51	9h12	9h33	9h54	10h15	10h36	10h57	11h18	11h39	12h01-12h29	/
	UTC	6:29	6:30	6:51	7:12	7:33	7:54	8:15	8:36	8:57	9:18	9:39	10:01-10:29	/
Flight #2	LT	12h29	12h30	12h51	13h12	13h33	13h54	14h15	14h36	14h57	15h18	15h39	16h01-16h29	/
	UTC	10:29	10:30	10:51	11:12	11:33	11:54	12:15	12:36	12:57	13:18	13:39	14:01-14:29	/
Flight #3	LT	16h29	16h30	16h51	17h12	17h33	17h54	18h15	18h36	18h57	19h18	19h39	20h01	20h23
	UTC	14:29	14:30	14:51	15:12	15:33	15:54	16:15	16:36	16:57	17:18	17:39	18:01	18:23

: 20 min sample (including height change)
: at ground, 28 min
: changement batterie treuil
: changement batterie FAMOUS et treuil
: changement batterie FAMOUS et treuil + carte SD acquisition FAMOUS
: fin de journée (protection du ballon, récupération données, rechargement des batteries)

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.

****

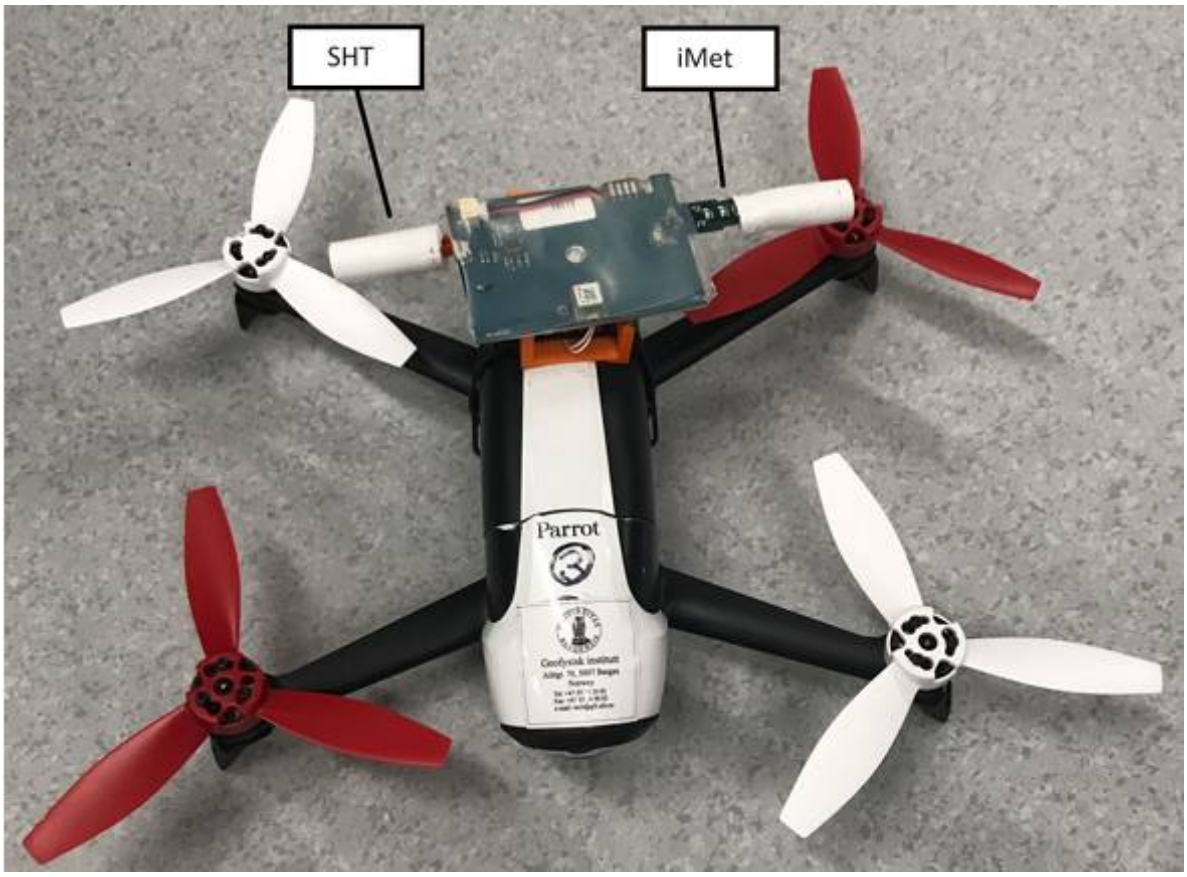
Meteorological measurements over the transition

****

Bebop2Met RPAS

Laboratory in charge: University of Bergen
Persons in charge: J. Reuder, S. Kral, A. Seeling

The Bebop2Met system (Kral et al. 2018, 2021) was used to collect vertical profiles of temperature, humidity, and wind across the maize-forest transition. It consists of a lightweight quadcopter (Parrot Bebop2, ca. 30 cm, 500 g) equipped with the Paparazzi autopilot and a combined temperature-humidity sensor (Sensirion SHT75) and an iMet-XQ2 mounted near a rear propeller for optimal ventilation (Kral et al. 2018; Greene et al. 2019). Wind direction was inferred from the drone's orientation (wind-vane mode), and wind speed from its pitch angle (Palomaki et al. 2017). Flights followed a vertical profiling strategy up to 120 m along a roughly N-S or E-W 180 m transect perpendicular to the forest edge (see Fig. 6). Profiles were spaced 45 m apart, with additional points (PA, PB) added during IOP2. Altitude ranged from 5 m to 110 m outside and 42 m to 110 m above the forest, with ascent rates of 0.5 m/s (first 15 m) and 1.0 m/s thereafter. A total of 443 profiles were collected across the three SOPs (see Table D1 in Appendix D).



The Bebop2Met drone equipeed with its meteorological payload

Parameter	Sensor	Sampling frequency
Air temperature Relative Humidity Pressure	Sensirion SHT75	4 Hz
Air temperature Relative Humidity Pressure	iMet-XQ2	1 Hz
Position, lat, lon, alt Attitude angles	GNSS IMU	4 Hz 4 Hz

Greene, B., Segales, A., Bell, T., Pillar-Little, E., & Chilson, P. (2019). Environmental and Sensor Integration Influences on Temperature Measurements by Rotary-Wing Unmanned Aircraft Systems. Sensors, 19(6), 1470. https://doi.org/10.3390/s19061470

Kral, S. T., Reuder, J., Vihma, T., Suomi, I., O'Connor, E., Kouznetsov, R., Wrenger, B., Rautenberg, A., Urbancic, G., Jonassen, M. O., Båserud, L., Maronga, B., Mayer, S., Lorenz, T., Holtslag, A. A. M., Steeneveld, G.-J., Seidl, A., Müller, M., Lindenberg, C., … Schygulla, M. (2018). Innovative Strategies for Observations in the Arctic Atmospheric Boundary Layer (ISOBAR)—The Hailuoto 2017 Campaign. Atmosphere, 9(7), 268. https://doi.org/10.3390/atmos9070268

Kral, S. T., Reuder, J., Vihma, T., Suomi, I., Haualand, K. F., Urbancic, G. H., Greene, B. R., Steeneveld, G., Lorenz, T., Maronga, B., Jonassen, M. O., Ajosenpää, H., Båserud, L., Chilson, P. B., Holtslag, A. A. M., Jenkins, A. D., Kouznetsov, R., Mayer, S., Pillar-Little, E. A., … Wrenger, B. (2021). The Innovative Strategies for Observations in the Arctic Atmospheric Boundary Layer Project (ISOBAR): Unique Finescale Observations under Stable and Very Stable Conditions. Bulletin of the American Meteorological Society, 102(2), E218–E243. https://doi.org/10.1175/BAMS-D-19-0212.1

Palomaki, R. T., Rose, N. T., van den Bossche, M., Sherman, T. J., & De Wekker, S. F. J. (2017). Wind estimation in the lower atmosphere using multirotor aircraft. Journal of Atmospheric and Oceanic Technology, 34(5), 1183–1191. https://doi.org/10.1175/JTECH-D-16-0177.1

Seeling, A. (2024). Addressing the observational gap over heterogeneous land surfaces in the lower atmospheric boundary layer by multi-copter temperature and humidity profile measurements. Master's thesis, Geophysical Institute, University of Bergen

****
Surface temperature
****

DJITherm RPAS

Laboratory in charge : INRAE
Persons in charge : M. Irvine

The DJI Thermal 3 (DJI Shenzhen CN) UAV was used to collect thermal images at different positions ranging from the maize to the forest transition to within the forest. The UAV is equipped with a long wave thermal sensor of 640 by 512 pixels and an NEDT of 50mK. The FOV is 61°. Flights were made along the transition Maize-Forest with fixed positions along the transition to acquire high frequency (0.5 Hz) image data for 5 minute periods at fixed positions. To maximize surface area, flights were made between 90 and 120m altitude. Flights were made at different times of the day during 3 days of SOP 2.



****

Vegetation Phenology

****

Hemispherical pictures and light sensors PASTiS-57

Laboratory in charge : INRAE ISPA

Persons in charge : S. Lafont

The objective of this part is to document the phenology of the oak forest.

Low cost light transmittance sensors (called PASTiS-57) have been developed for the monitoring of phenology of crops and forest. A detailed description and evaluation can be found in (Brede et al., 2018).The development/fall of leaves in the forest is observed by performing the ratio of the incoming radiation above the canopy and below the canopy.

The set up was a network of 5 PASTiS-57 light sensors (Brede et al., 2018), randomly placed under the forest canopy and 2 reference sensors outside the forest (representing the above canopy sensor), in order to monitor the canopy development. They measured the absorption of blue and green light by the canopy to quantify the evolution of the leaf area index of the forest. The light measurement was performed every minute. During the post processing (coded in R) daily transmittance are computed.

The sensors experienced multiple breakdowns at the end of 2023, maybe due to cold temperatures. Consequently, no data were collected during SOP3.

The measurement are available from the 15-03-2023 to mid-december 2023 covering, a short period without leaves, the leaves development, the leaf-on period, and the beginning of the leaf-fall. Some low-quality data are available beginning of 2024.

These continuous measurements were complemented by 3 campaigns of hemispherical photographs. The photographs taken were processed with the CAN-EYE software (available at https://can-eye.paca.hub.inrae.fr/)

DHP campaigns summary :

- 19-04-2023, 15 pictures, sunset conditions
- 20-04-2023, 10 pictures, sunrise conditions

- 20-08-2023 17 pictures, sunset conditions
- 05-12-2023, 5 pictures, cloudy conditions

Part IV – Forecasts

For each SOP, there was 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 and role

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 14-18/08	logistic
Fabienne Guesdon	LAERO		logistic	logistic	Logistic ?	logistic
Mathilde Jomé	LAERO			RS	Secretary 21-25/08	support
Fabienne Lohou	LAERO		Coord.	secretary	Coord.	RS
Marie Lothon	LAERO		Coord.	Coord.	secretary 14-20/08 Logistic 19-25/08	forecast
Alban Philibert	LAERO		UHF CL61	RS	RS	support
Eric Pique	LAERO		EC-Towers mechanics			
Felix Starck	LAERO		Power supply			
Antoine Vial	LAERO		MTO, EC UHF	EC, MTO CL61	RS or support	support
Gaspard Simonet				Forecast	RS Aure	
Eric Bazile	CNRM/GMAP		SOP 1, 3			RS
Fleur Couvreux	CNRM/GMME		SOP 2, 3		RS 14-23/08	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				Forecast tbc	
Stephan Kral	Univ. Bergen		EC	RPAS	RPAS	RPAS
Mauro Ghirardelli	Univ. Bergen		EC	RPAS	RPAS	RPAS
Joachim Reuder	Univ. Bergen		EC	RPAS	RPAS	RPAS
Alexander Seeling	Univ. Bergen		EC	RPAS	RPAS	RPAS
Carlos Roman-Cascon	Univ. Cadiz		EC, MTO		RS Aure	
Pablo Ortiz Corral	Univ. C. Madrid		EC, MTO		RS Aure	
Juan Jiménez Rincón	Univ. Cadiz		EC, MTO		RS Aure	
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?**
Myrtille Grulois	**INRAE**		**EC, MTO**			
Jean-Marc Bonnefond	**INRAE**		**EC, MTO**			
José Darrozes	**GET**			**Soil**	**Soil**	**Soil**
	GET					

Appendix A

UCM/UCA experimental plan in MOSAI – P2OA

Carlos Román-Cascón[1]; Carlos Yagüe[2]; Pablo Ortiz-Corral[2]; Juan Jiménez-Rincón[1]
1. University of Cádiz (UCA), Spain.
2. University Complutense of Madrid (UCM), Spain.

The UCA and UCM scientific groups participated in the MOSAI field campaign with the installation of several towers in the *Vallée d'Aure,* in the frame of the related LATMOS-i[1] and WINDABL[2] projects.

The main objective of LATMOS-i and WINDABL in this participation is to improve the understanding of the diurnal mountain wind systems developed in the region, as well as to investigate how the land-atmosphere-interaction processes affect these phenomena. To reach this objective, three towers were deployed around the area (Figure A1 and Figure A2) to compare differences between the winds observed at different points of the valley and to be able to characterise related processes. For simplification, the whole area of study has been divided into three main parts.

- Narrow valley. Covering from Sarrancolin to Arreau and finishing at Héches. This part of the valley has a slightly descending slope from the highest point (Sarrancolin, around 700 m asl) to the lowest one (Hèches, around 600 m asl) in ~4 km. The bottom of the valley is relatively narrow (100-700 m wide) and surrounded by high mountains (1000-1500 m asl). The last part of the valley is oriented in the south-north direction.

- Wider valley. Covering from Héches to La Barthe de Neste, this part of the valley slightly descends until Izaux and then increases again. This part of the valley is well defined but with much lower elevations in the edges and with a characteristic shape shown in Figure A3. At the northernmost part, the orientation tends to veer slightly from the S-N to the SW-NE direction.

- Plateau. The plateau of Lannemezan is at a higher altitude than the wider valley, being a larger and relatively flat area. A statistical characterization of breezes at CRA (plateau) can be found in Román-Cascón et al., 2019 (see Figure A4).

1. LATMOS-i (Land-ATMOSphere interactions in a changing environment: How do they impact on atmospheric-boundary-layer processes at the meso, sub-meso and local scales in mountainous and coastal areas? Grant PID2020-115321RB-I00 funded by MCIN/AEI/ 10.13039/501100011033

2. WINDABL. How are the surface thermally driven WINDs influenced by the vertical and horizontal structure of the Atmospheric Boundary Layer? UCA project funded by the University of Cádiz (Plan Propio 2022-2023). Ref. PR2022-055

The three specific observational sites (V-sites (for "valley")) are strategically selected to investigate the horizontal differences of the daytime and nighttime breezes; the sites are indicated in Figure A1 and Figure A2, and listed below:

- Site V1. ***Izaux – middle of the wider valley.*** This emplacement is in the middle of the wider part of the valley, not exactly at the bottom part, but in a quite flat and open region with good "view" of the nocturnal and diurnal breezes (see Figure A3). This site was the reference one, with a complete surface energy balance (SEB) tower (GuMNet-Portátil, UCM) that was installed to obtain all the SEB components over a surface composed by grass. *(See instrumental sheet in Part II.)*

- Site V2. ***Avezac-Prat-Lahitte (Labastide) – edge of the wider valley.*** This emplacement is at the edge of the valley, around 100 m higher than site 1 (see Figure A3). A Remote Automatic Weather Station (RAWS, UCA) was installed at this point, to observe meteorological differences with the site 1. *(See instrumental sheet in Part II.)*

- Site V3. Hèches – end of the narrow valley. This emplacement is just at the area where the narrower part of the valley finishes. A sonic anemometer was installed at this site, to mainly focus on the wind and turbulence characteristics at this point, that could be compared to those measured at site V1. *(See instrumental sheet in Part II.)*

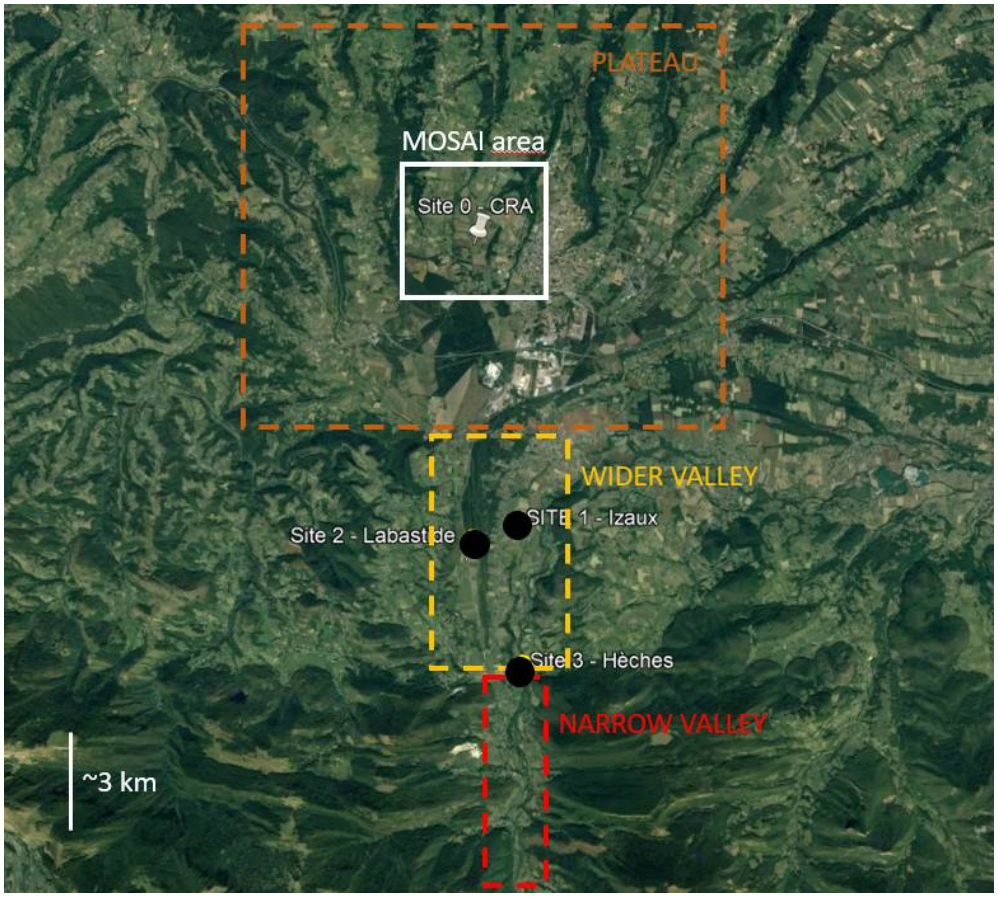


Figure A1. Area of interest, where the regions have been divided into three main regions (narrow valley, in red; wider valley, in orange; plateau, in brown). The three sites where the UCM/UCA towers were installed are indicated with black circles. The MOSAI area is indicated with a white box.

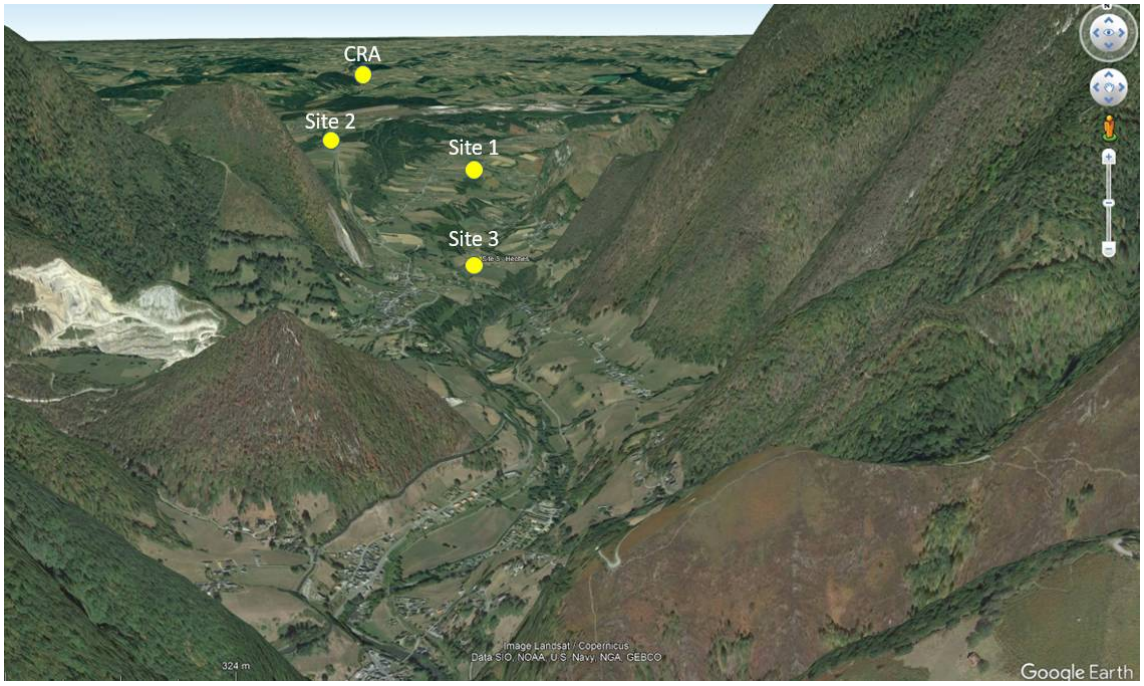


Figure A2. Area of interest in 3D.

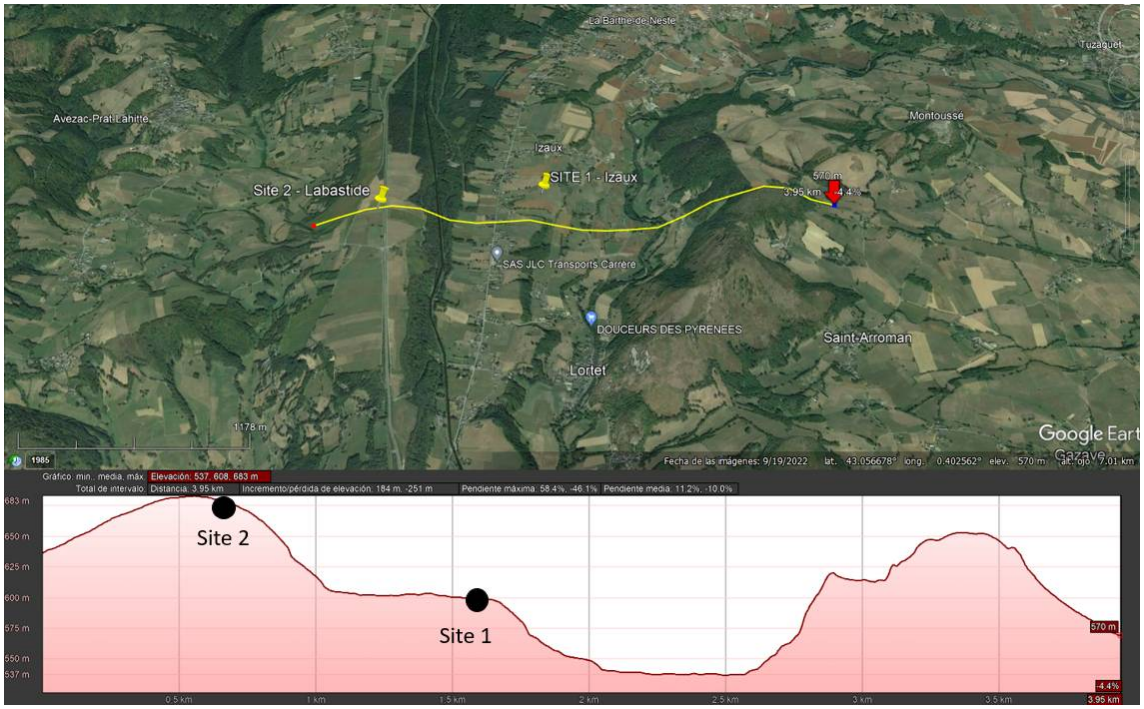


Figure A3. Elevation profile in the wider part of the valley, close to the sites 1 and 2.

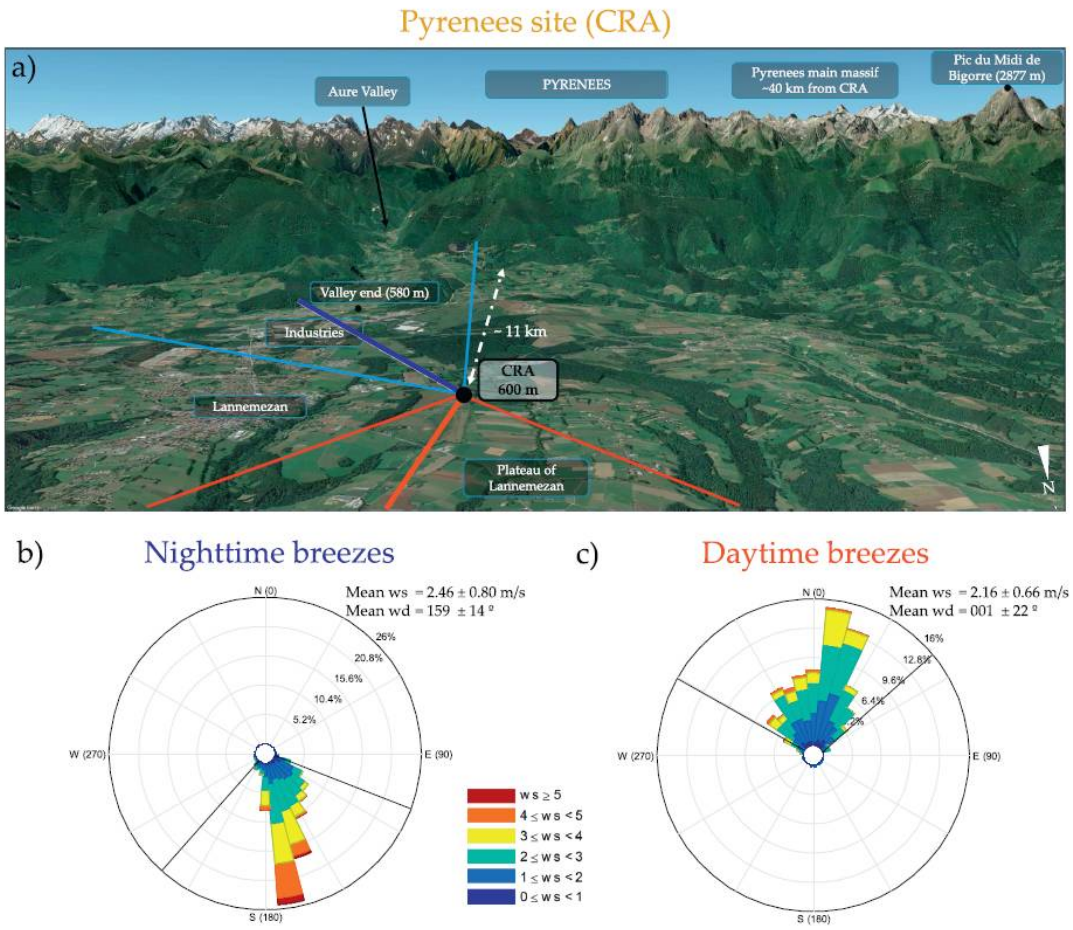


Figure A4. Statistical characterization of the breezes in the area, as observed from the CRA site (using data from the 60 m tower: Román-Cascón et al., 2019).