Observational Study of Valley Breezes in Heterogeneous Terrain: Vertical and horizontal characterization in the Aure Valley (Pyrenees)

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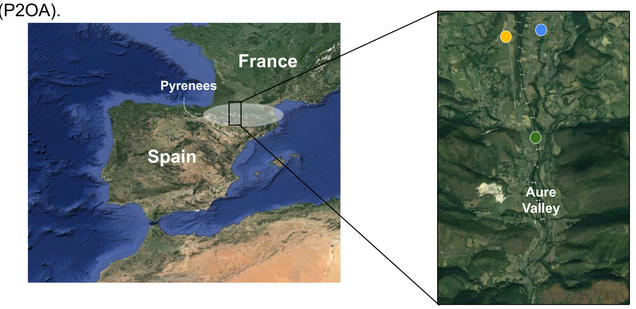
1. Objectives

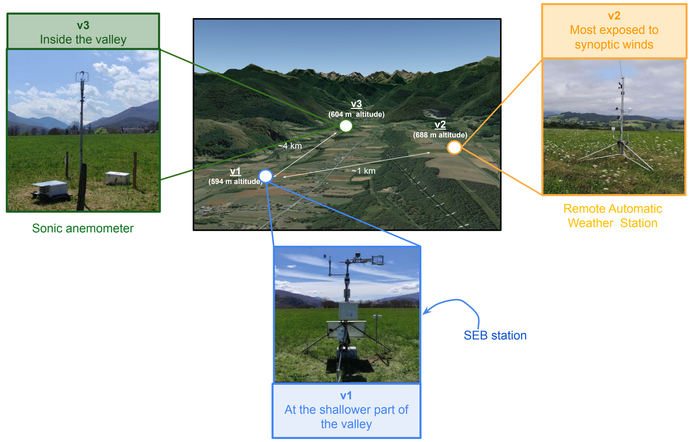
- Analyse spatial heterogeneity of Thermally-Driven Flows (TDF) within a Valley in the Pyrenees.
- Understanding turbulence and stability characteristics of the downvalley flow and associated interactions.

2. OBSERVATIONS

A field campaign was carried out from **April 2023 to April 2024** in the **Aure Valley** (French Pyrenees). This campaign is part of a larger project: **MOSAI** (Model and Observation for Surface-Atmosphere Interactions). Specifically the EOP (Enhanced Observing Period) of the Pyrenean Platform for Observation of the Atmosphere (P2OA).



Three measurement stations (v1, v2 and v3) were placed in different points of the valley and radiosondes were launched during the nights of 17-24 August from the v1 station:



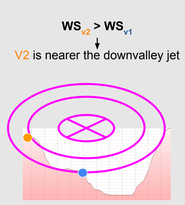
3. Results: 18th-19th of August →Fight of scales

Surface measurements: Wind and Turbulent Kinetic Energy (TKE) data

1st part of the event: clear down-valley flow

$WS_{v2} > WS_{v1}$

V2 is nearer the downvalley jet



*Vertical E-W transect intersecting **v1** and **v2**. Down-valley flow is represented with pink lines*

$TKE_{v1} > TKE_{v3}$

Possible explanation:
Different elevation of the jet inside *vs.* outside the valley

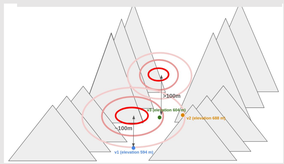
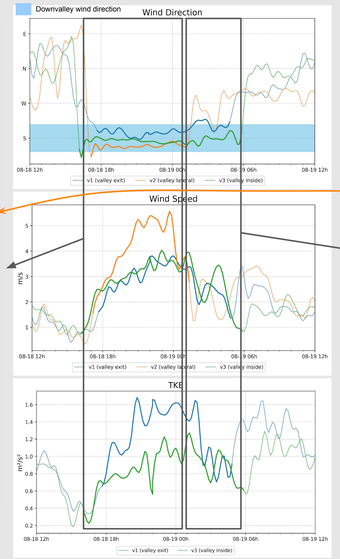
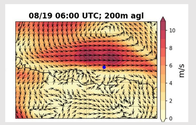


Diagram of the evolution of the downvalley structure as it moves from the narrow part of the valley to the wider part.



2nd part of the event: presence of sinoptic W wind

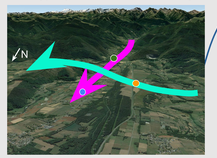
Before sunrise, synoptic W wind is advected:



Wind Direction (arrows) and Wind Speed (shaded) from ECMWF IFS model (analysis; 10 km horizontal resolution) at 6:00 UTC. Blue dot indicates the location of the valley

"Fight" of scales (Meso *vs.* synoptic)

Under the presence of synoptic W wind (green arrow), the down-valley flow (pink arroy) is present within the valley



Schematic figure of the wind field over the valley during the presence of synoptic W wind

Event averages

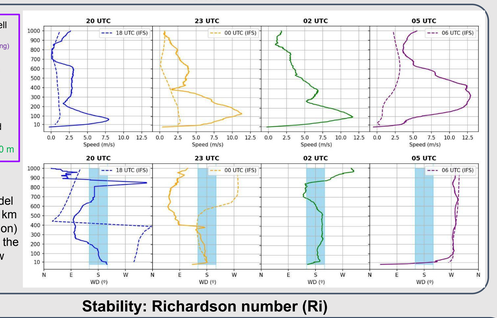
	v1	v2	v3
Sunset (UTC)		18:55	
Event initialization (UTC)	17:30	17:00	16:00
Event end (UTC)	05:00	01:30	06:00
Event duration (h)	11.5	8.5	14
WD (°)	200	160	173
WS (m/s)	2.68	3.96	2.72
Temperature (°C)	22.41	24.03	22.29
TKE (m^2/s^2)	1.25	-	0.84
U^* (m/s)	0.37	-	0.22
SH (W/m^2)	-55.64	-	-44.63

Longer event duration in v3 due to its location in the valley (protected by the mountains)

Radiosoundings:

Wind

Downvalley jet well observed (except in the last sounding) (05 UTC = 07 LT)
↓
Arrival of westerlies
↓
Max jet height 400 m
Maximum speed height: 80 m – 120 m – 100 m

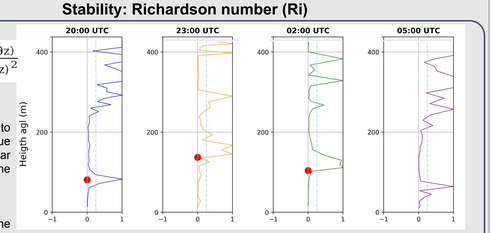


ECMWF IFS model (dashed lines; 10 km horizontal resolution) fails in performing the downvalley flow

Stability: Richardson number (Ri)

$$Ri = \frac{\frac{g}{\theta}\,(\partial\theta/\partial z)}{(\partial\bar{u}/\partial z)^2}$$

- subcritical values closer to the ground due to surface shear created by the downvalley
- supercritical values near the wind maxima



Red dot indicates the height of the jet agl. Dashed line indicates Richardson critical number (Ri_c = 0.25)

4. FUTURE WORK

* Can a high-resolution model see the valley breeze and its characteristics? → WRF model (1K km or less)
* Comparison with the other cases under different background synoptic conditions

Valley IOP	Sounding time (UTC)	Jet height (m)	Jet magnitude (m/s)	Down-valley depth (m)	Inversion height (m)	Inversion magnitude (ºC)	Mixing layer (m)
v-IOP-a	20	71	6		160	2,9	136
17-18 August 2023	23	No	No		234	2,6	52
	2	200	5		74	0,92	143
	5	100	4		150	4,7	92
v-IOP-b	20	81	8	200	208	3,9	182
18-19 August 2023	23	137	11	400	331	4,9	262
	2	104	11	900	280	7,3	228
	5	No	No	No	65	0,4	431

⋮

Analysis of the interaction between jet-driven and surface-driven turbulence
* Can we separate the dynamical and the thermal contributions to total turbulence?
Long-term statistical analysis (1-year data)

Work in progress is shown with a * symbol

5. TAKE-HOME MESSAGES

- **6 Nighttime events detected with different synoptic conditions**
- **Analysis of 1 case (with synoptic conditions changing throughout the night):**
  - The downvalley flow is present within the valley under moderate synoptic forcing→ "Fight of scales: Meso *vs.* Synoptic"
  - Interesting horizontal heterogeneity (duration, wind speed, turbulence) → downvalley flow estructure changes within the valley
  - Radiosoundings show a jet structure within the first 400 m
  - 10 km model resolution (ECMWF IFS) cannot see the valley breeze due to its insuficient resolution → can WRF (1 km or less) model provide better results?

6. ACKNOWLEDGEMENTS

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More info about the **MOSAI** and WINDABL projects: