Mountain breezes at three different sites: Salt Lake Valley, The Pyrenees and Guadarrama mountain range

C. Román-Cascón[1, 2], C. Yagüe[1], JA. Arrillaga[1], M. Lothon[2], F. Lohou[2], E. Pardyjak[3], M. Sastre[1], G. Maqueda[1] and RM. Inclán[4]

BLT-AMS
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Oklahoma City

1 UNIVERSIDAD COMPLUTENSE MADRID
2 LA LABORATOIRE D'AÉROLOGIE
3 THE UNIVERSITY OF UTAH
4 Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Project context and objectives

ATMOUNT II project

- **Obj. 1:** Characterization of mountain breezes
  - **- Guadarrama Mountains (Spain)***
  - - Pyrenees (France)
  - - Salt Lake Valley (US)

- **Obj. 2:** Impacts of mountain breezes in CO_2 (micro-mesoscale interactions)

Mountain breezes detection

Breezes detection → Algorithm* prepared to work in 3 sites

- **LARGE SCALE: Synoptic conditions** (NCEP: u, v, T, RH)
  - Filter 1: Wind at 700 hPa (< 9-10 m/s)
  - Filter 2: Fronts passage ($\Delta\theta_e$ < -1.45 K)
  - Filter 3: Rainfall < 0.2 mm/day
- **SMALL SCALE: Local conditions** (ws, wd from tower)
  - Ranges of wind direction for up/downslope
  - Wind direction persistence (80% of event) in the range
  - Minimum duration of events (3 hours min)

* Based on criteria in Arrillaga et al. 2018

LARGE SCALE (NCEP reanalysis)
365 days analysed
201 days have passed filter 1 (synoptic wind speed)
193 days have passed filter 2 (fronts passage)
188 days have passed filter 3 (in situ rainfall)

SMALL SCALE (tower *in situ*)
346 possible downslope events
312 downslope events with minimum persistence of 3 hour(s)
230 events with 80 percentage of time with the same wind direction

LARGE SCALE AND SMALL SCALE (downslope)
177 downslope events according to small scale & large scale

LA HERRERIA

(Guadarrama Mountains)
2017 analysis

Example mountain breezes detection algorithm

Mountain breezes statistics

Breezes analysis → Statistics

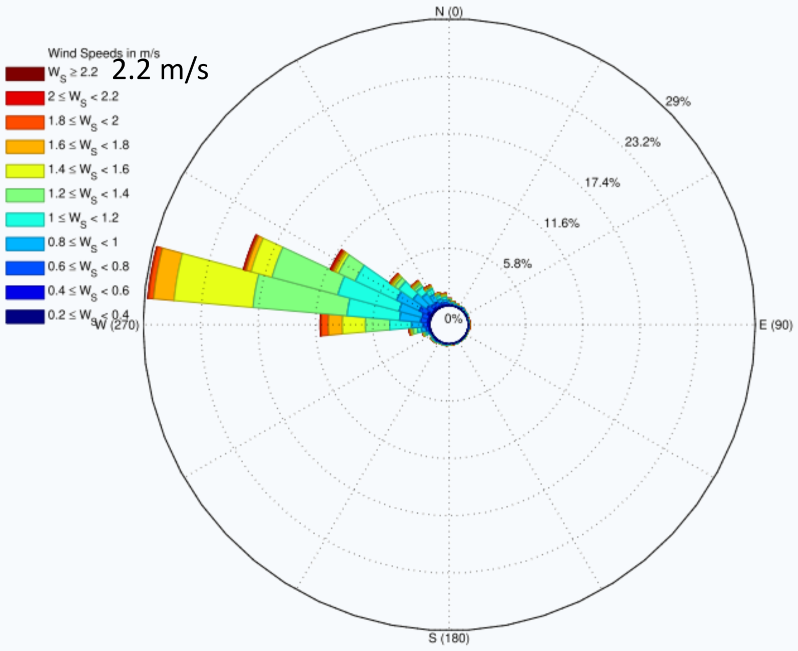
- **Timing** (related to sunrise/sunset) and **duration**.
- **Wind speed** intensity (and variability)
- **Wind direction** (and variability)
- Relation with → synoptic conditions, temperature, season, soil moisture…
- Impacts on → greenhouse gases concentration, fluxes, turbulence and stability…

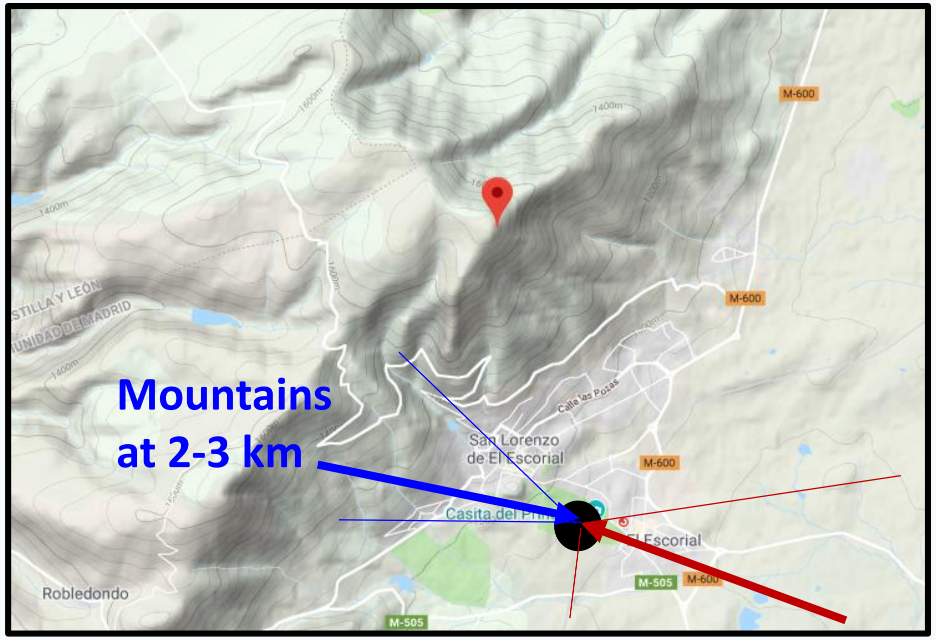
La Herrería (Guadarrama)

La Herrería (Guadarrama)

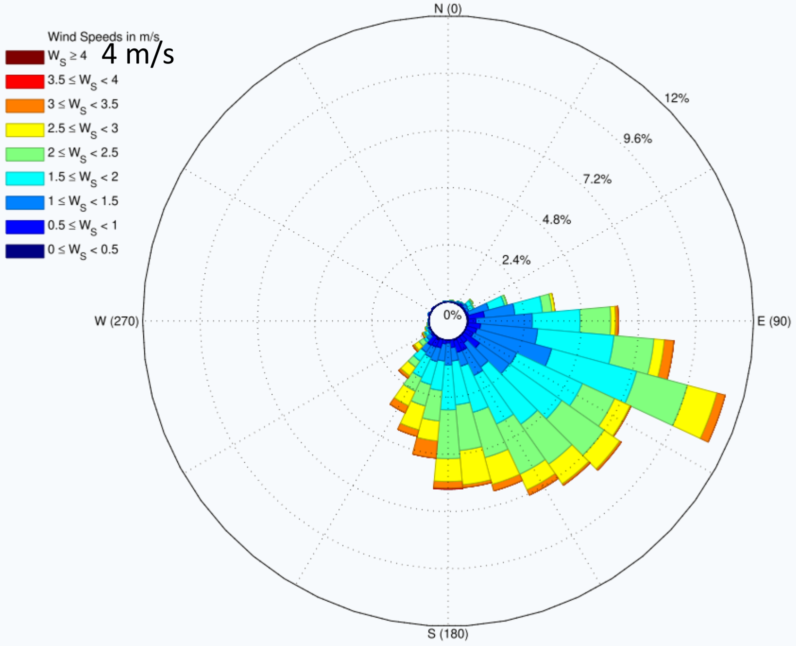
La Herrería (Guadarrama)

Downslope





Upslope



EVENTS NUMBERS:

365 days analysed
177 downslope
136 upslope

CRA (Pyrenees)

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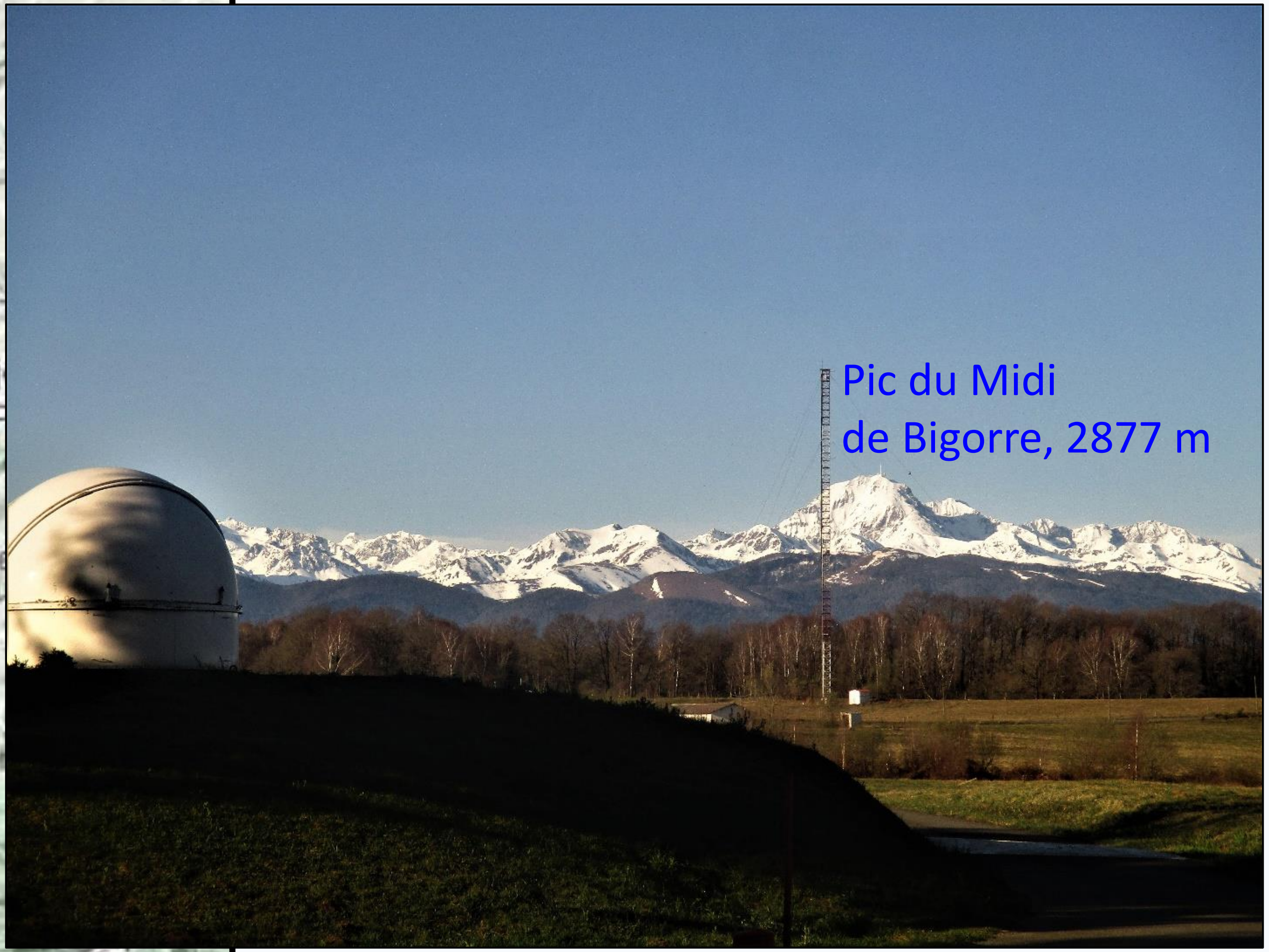
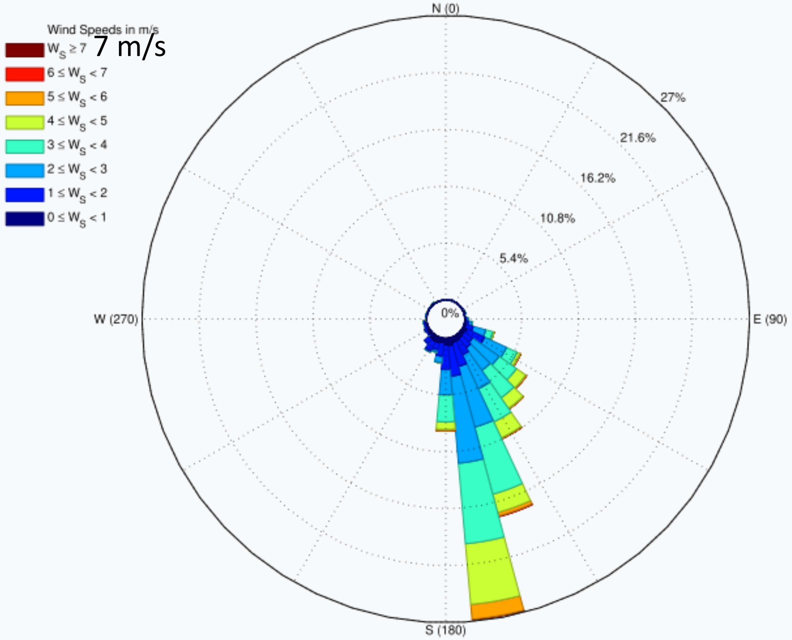
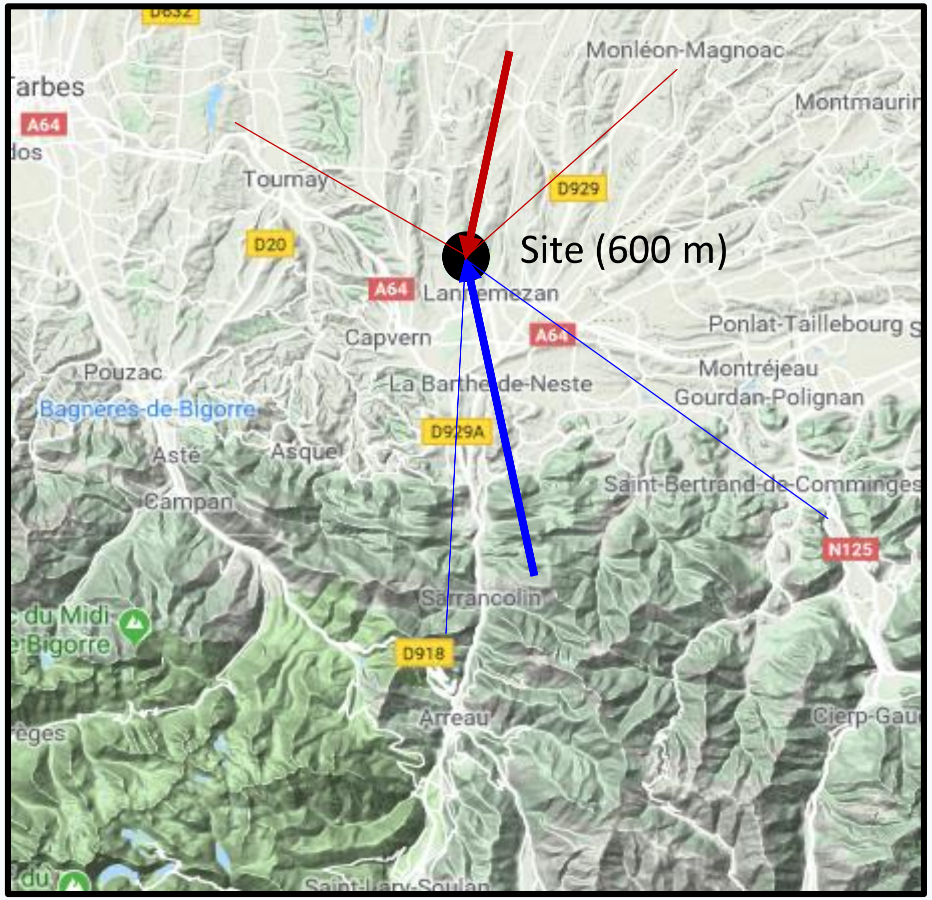


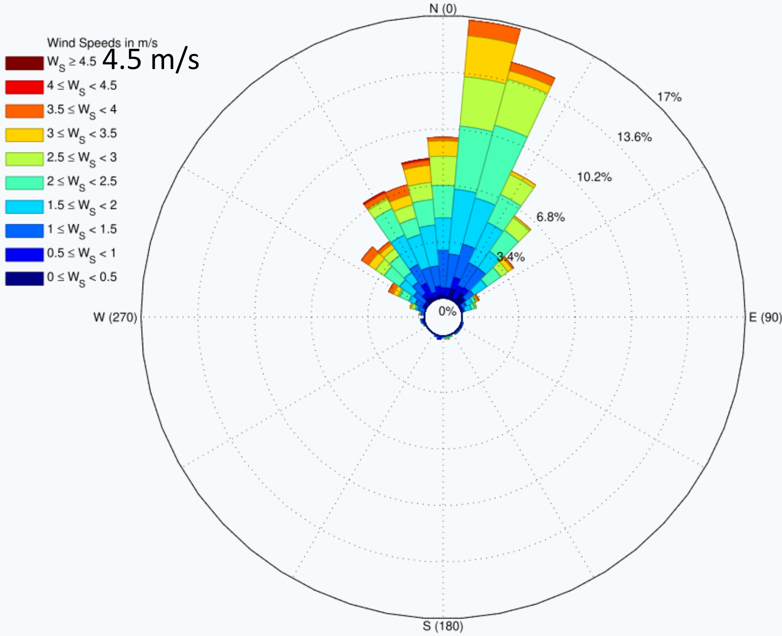
CRA (Pyrenees)

Downslope





Upslope



EVENTS NUMBERS:

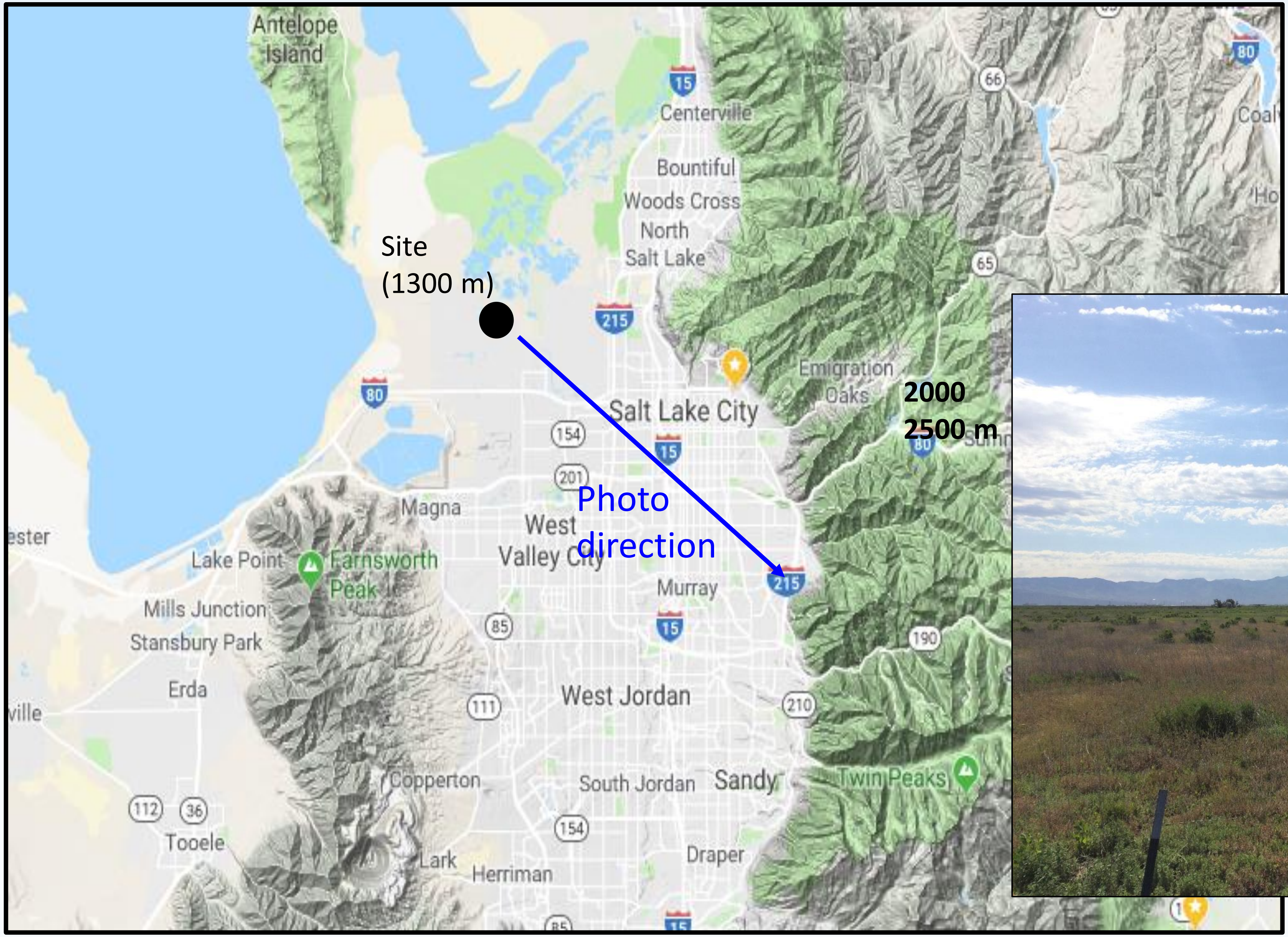
365 days analysed

112 downslope

56 upslope

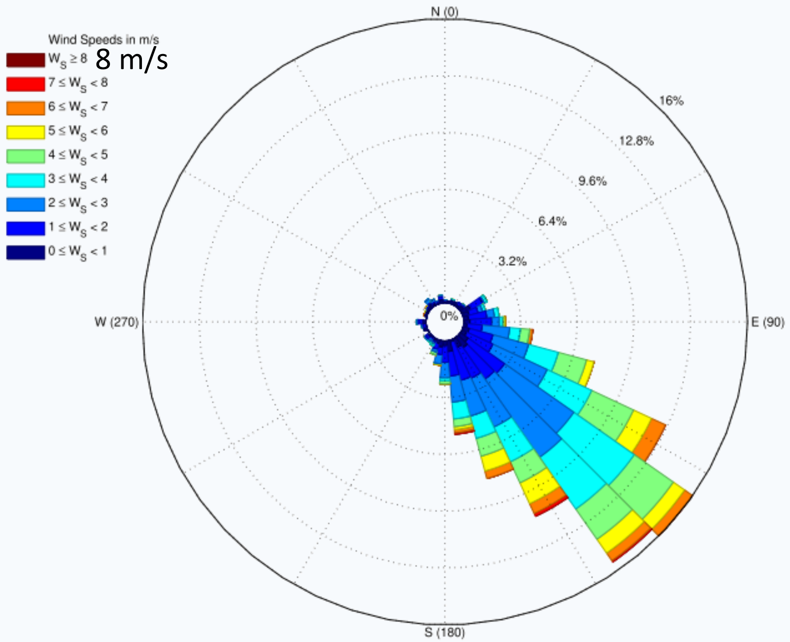
Salt Lake Valley (Rocky Mountains)

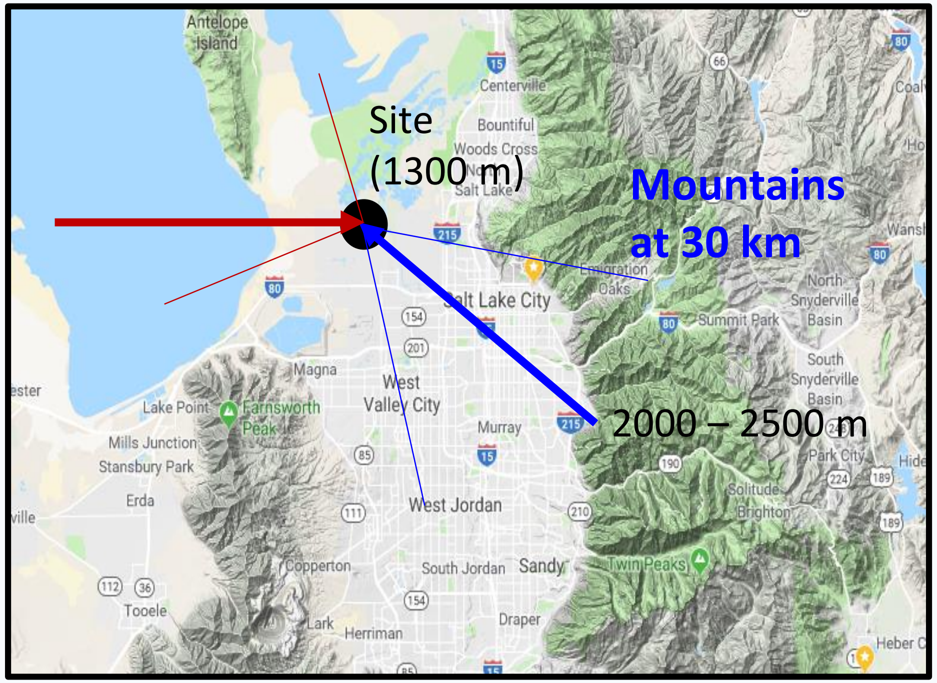
Salt Lake Valley (Rocky Mountains)



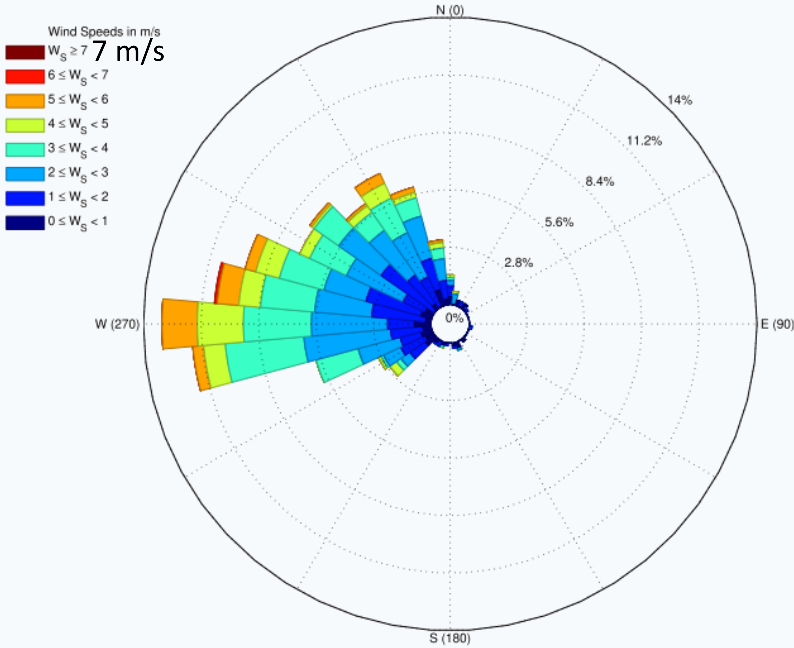
Salt Lake Valley (Rocky Mountains)

Downslope





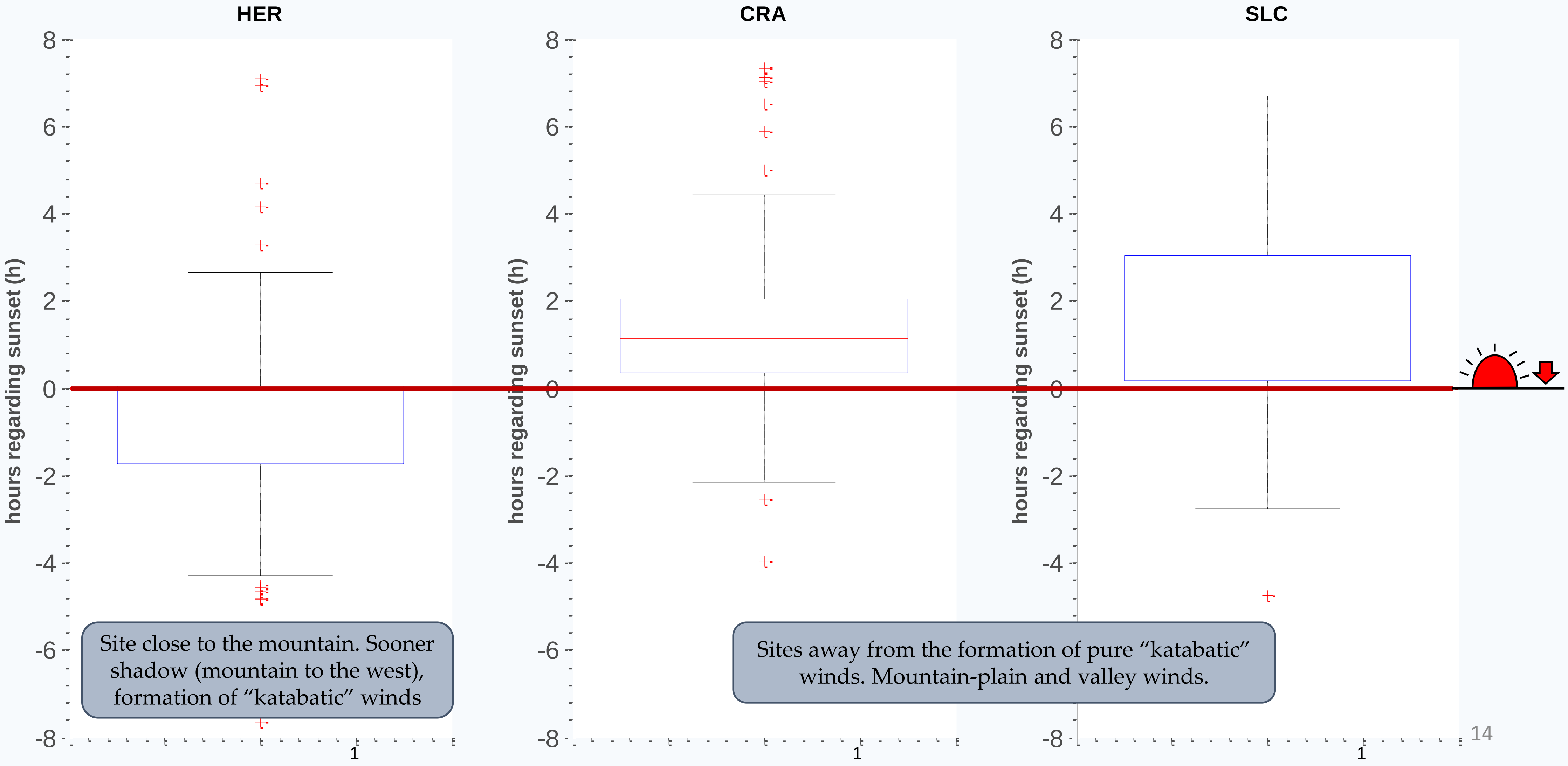
Upslope



201 days analysed
36 downslope
38 upslope

Downslope flows ONSET time (regarding sunset)

Guadarrama | Pyrenees | SLC valley

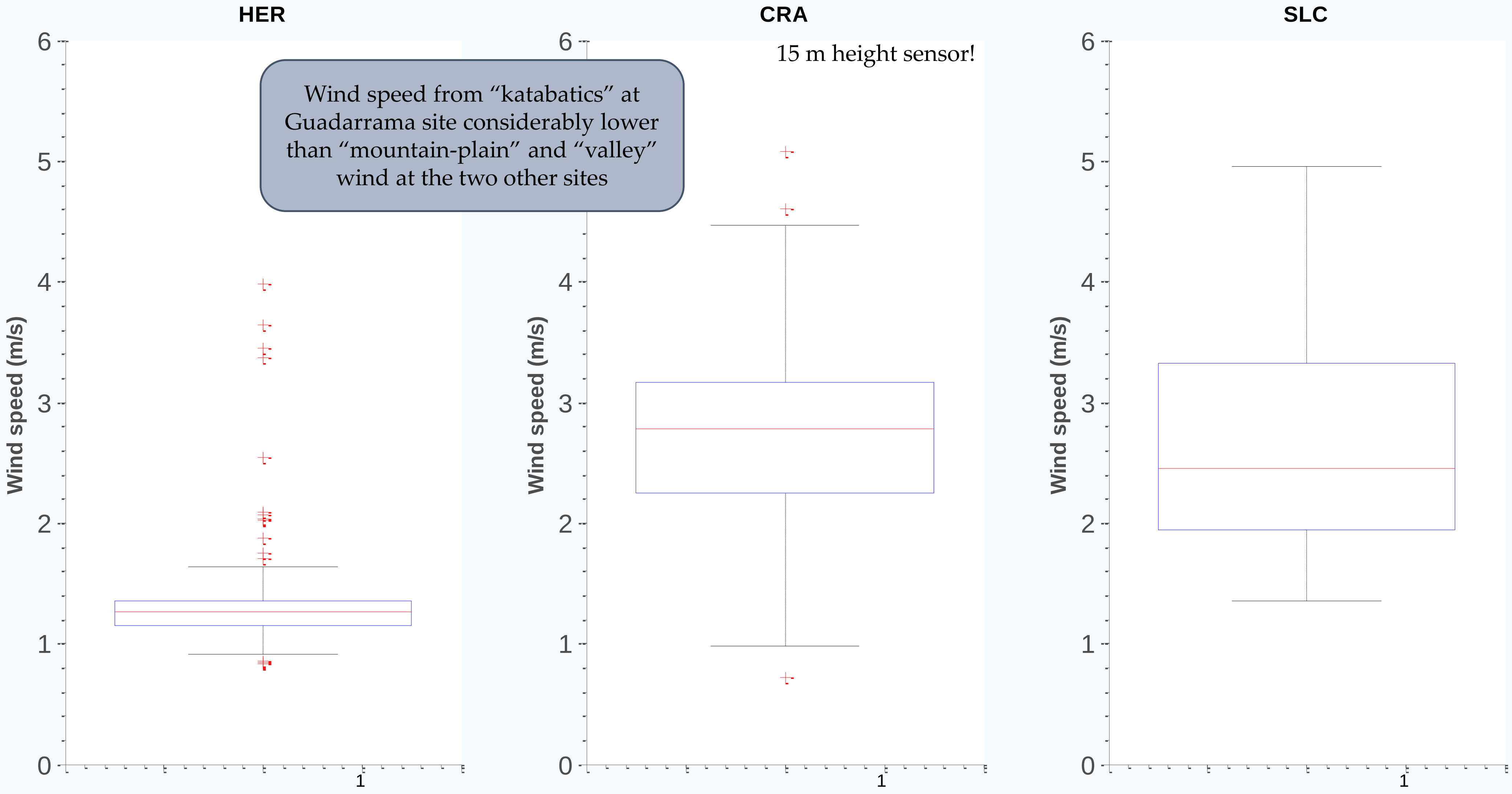


Site close to the mountain. Sooner shadow (mountain to the west), formation of "katabatic" winds

Sites away from the formation of pure "katabatic" winds. Mountain-plain and valley winds.

Downslope flows mean WIND SPEED

Guadarrama | Pyrenees | SLC valley



Wind speed from “katabatics” at Guadarrama site considerably lower than “mountain-plain” and “valley” wind at the two other sites

Objective 2. CO_2 & mountain breezes

- **OBJ. 2 - Analysis of impacts in CO_2/water vapour concentrations and fluxes:**

- CO_2 diurnal cycle. What is the influence of the mountain breezes?
- H_2O not analysed yet! (and more complicated)

CO_2 evolution:
- PBL dynamics*
- Degree of turbulence*
- Advection*
- Mixing from "above"*
- Plant activity
- "Soil" respiration

I WILL SHOW RESULTS ONLY FOR DOWNSLOPE FLOWS

* Potentially influenced by mountain breezes

Objective 2. CO_2 & mountain breezes

Example

Impacts in CO_2

CO_2 jump

- Related to the katabatic onset? (advection)
- Variables controlling the jump?

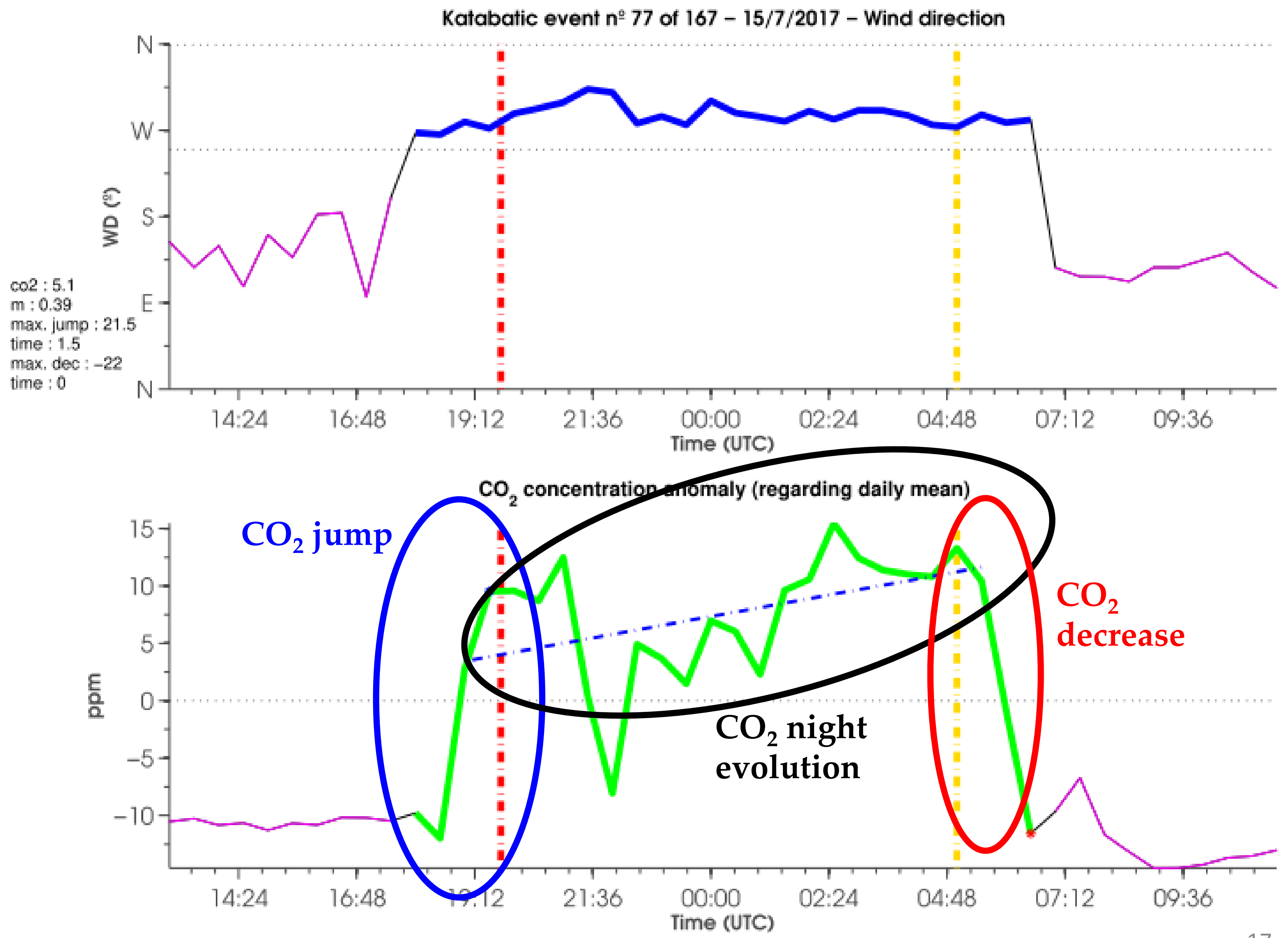
 stability? turbulence? PBL height?

CO_2 night evolution (slope)

- Seasonal variability?
  - >0 in summer?
  - ~0 in winter?
- Turbulence → CO_2 diffusion?

CO_2 decrease

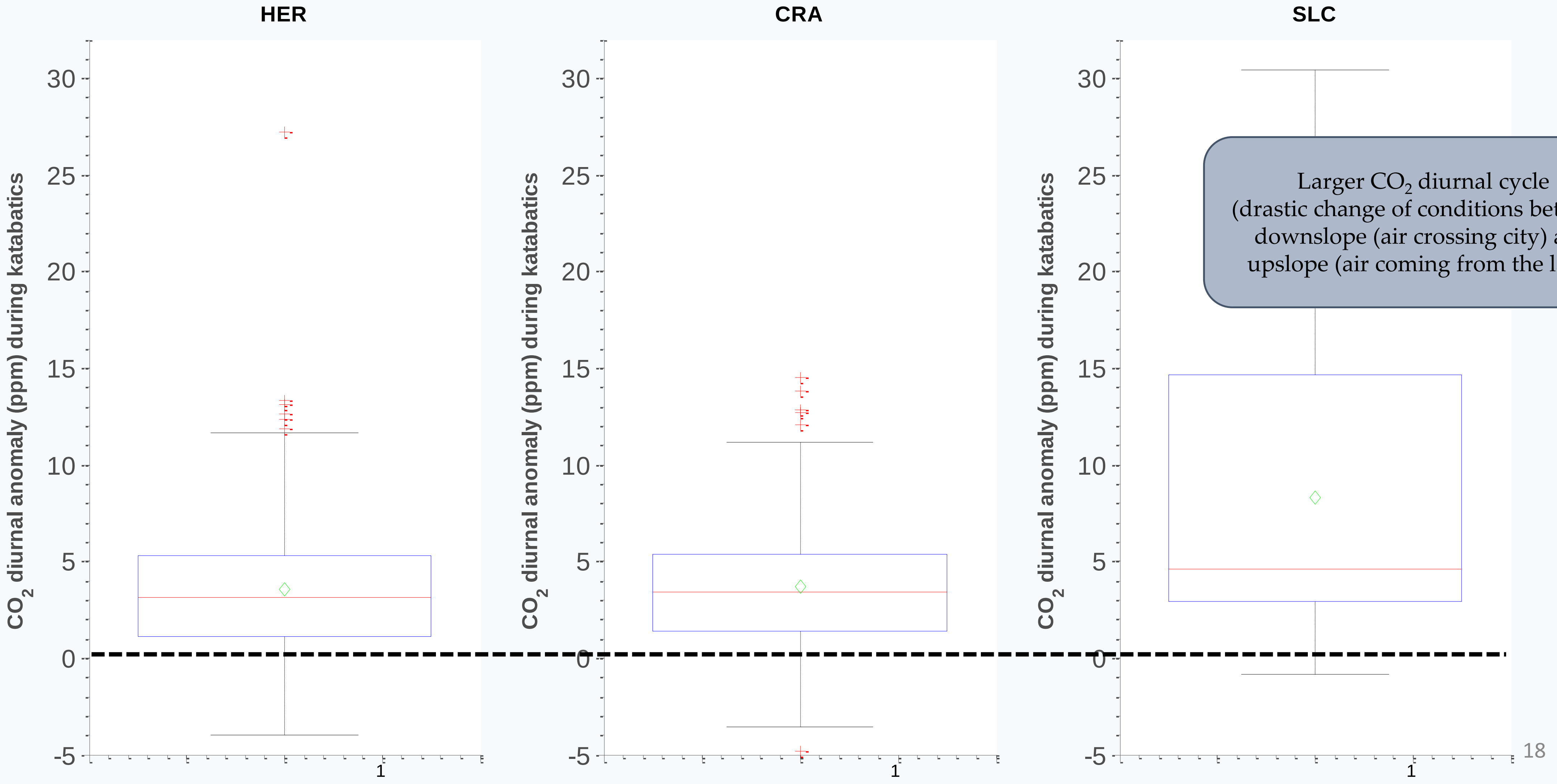
- Related to speed of transition?



Downslope flows mean CO_2 concentration*

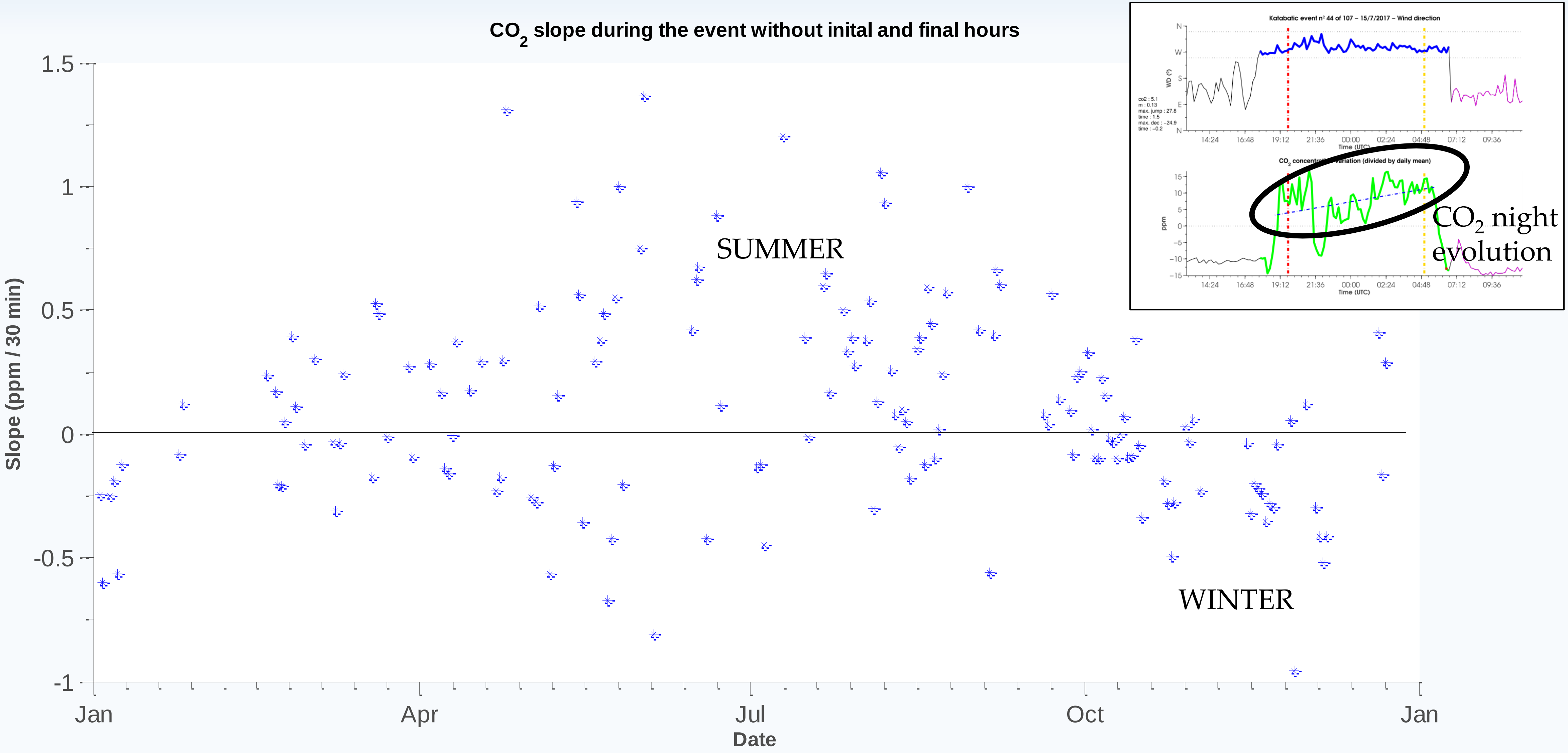
** Minus daily mean*

Guadarrama   Pyrenees   SLC valley



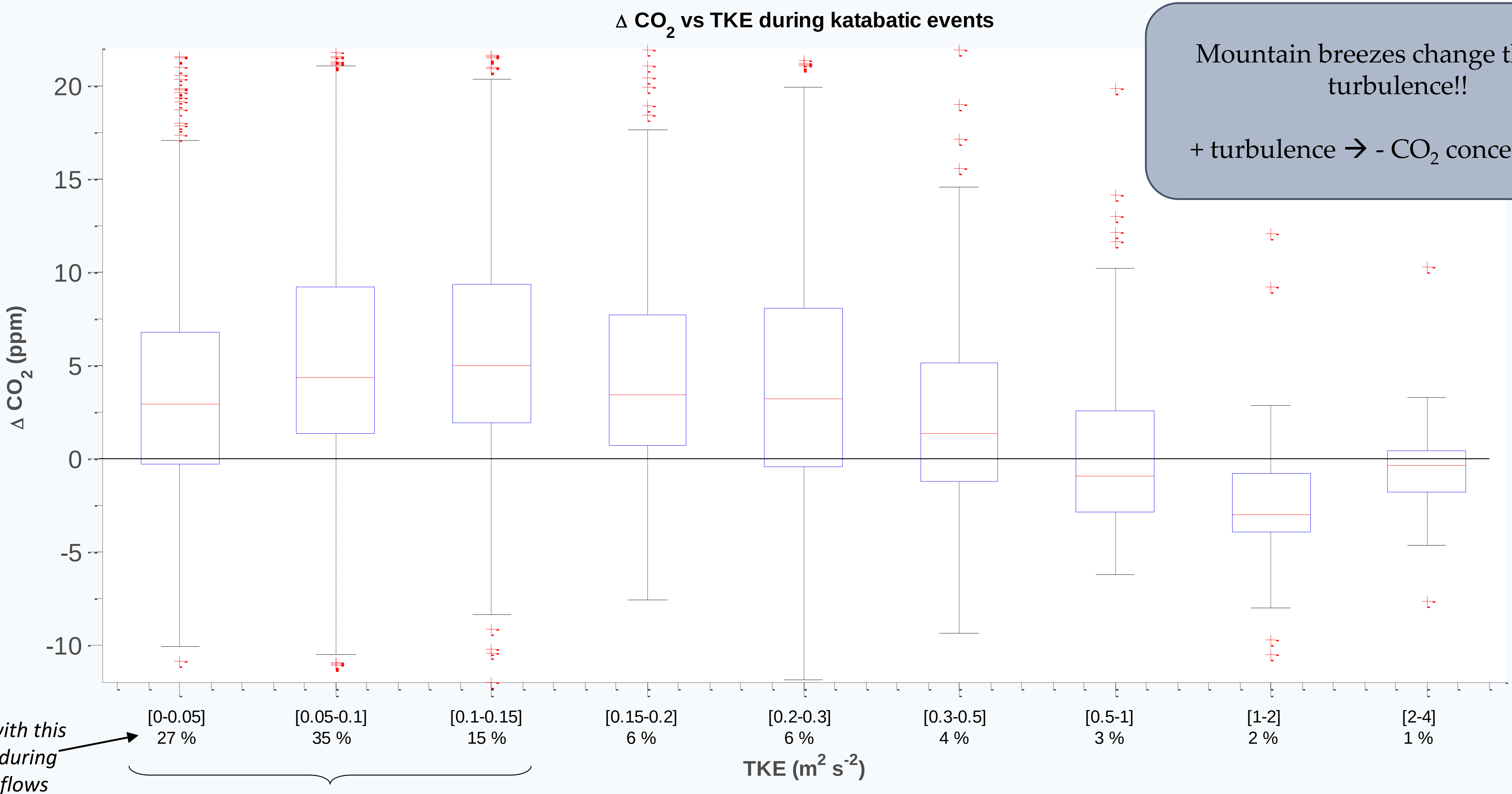
Larger CO_2 diurnal cycle
(drastic change of conditions between downslope (air crossing city) and upslope (air coming from the lake)

CO_2 night-evolution slope



CO_2 vs TKE during downslope flows

GUADARRAMA SITE
8-m sensor



Mountain breezes change the local turbulence!!

+ turbulence → - CO_2 concentration

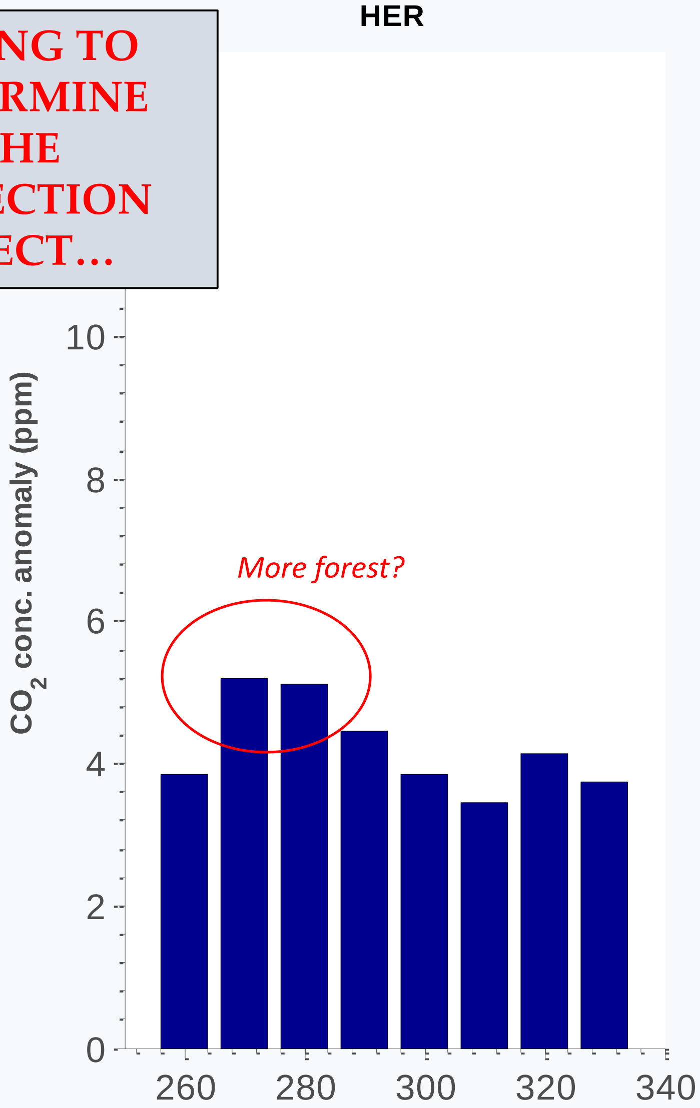
% of time with this TKE values during downslope flows

Most of data during downslope

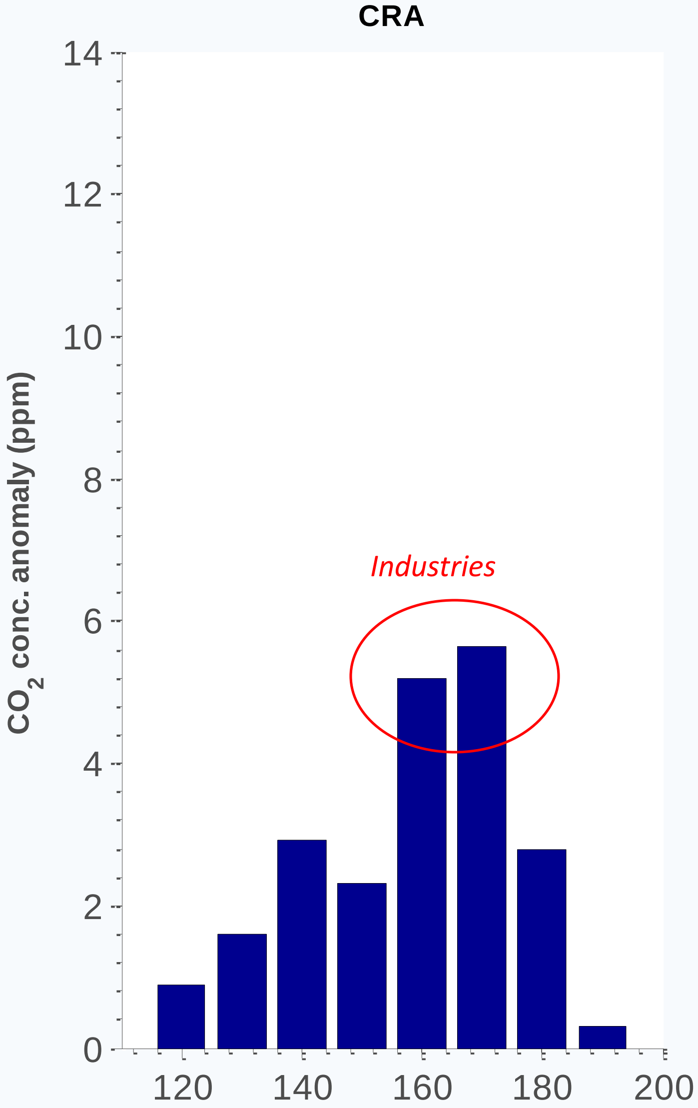
Downslope flows CO_2 concentration for different WD

Guadarrama

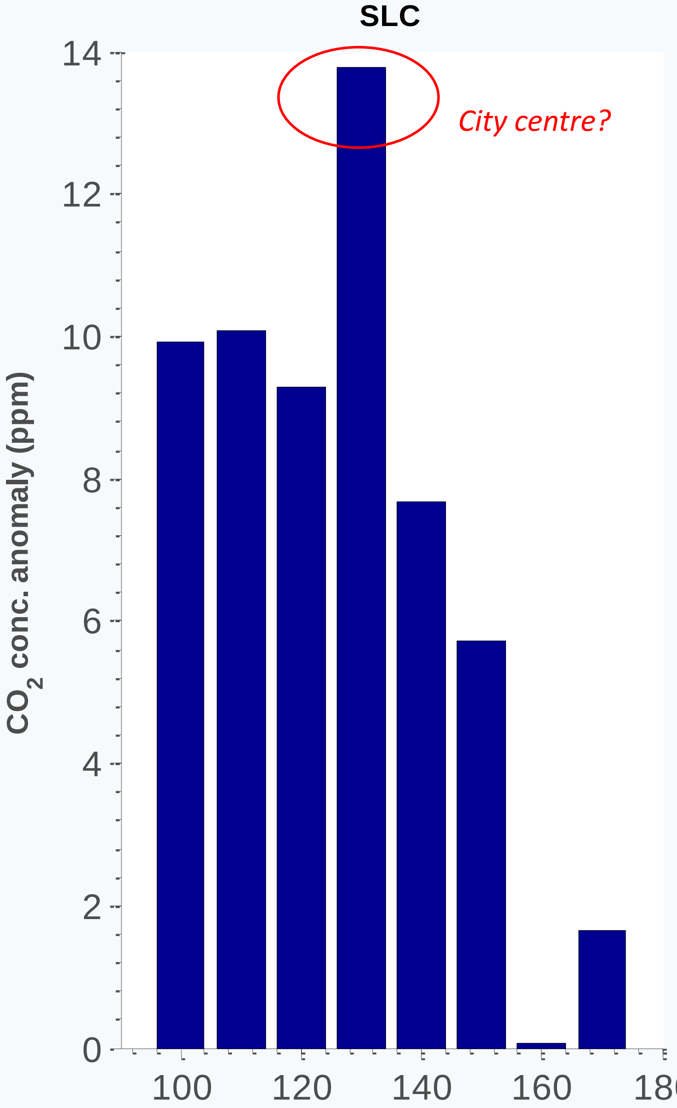
TRYING TO DETERMINE THE ADVECTION EFFECT…



Pyrenees



SLC valley



Conclusions

- Different features due to:
  - Type of phenomena (katabatic, mountain-plain, valley channelled flows)
  - Distance to the mountains, tower location…

- CO_2 modulated by:
  - **PBL dynamics (stability conditions) & "mixing" height**
  - Turbulence (but not only)
  - Some influence of wind direction (advection)…
  - Plant activity? (affecting slope night evolution)
  - Mixing from "above" in SBL (Gravity waves? Residual eddies?)
  - Soil respiration??

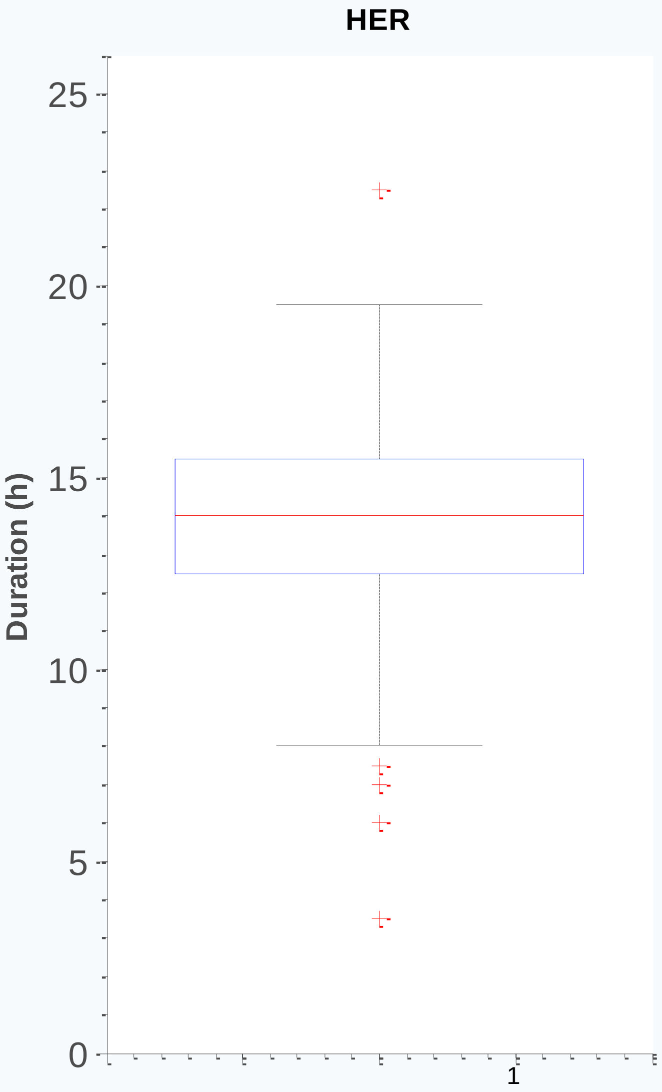
Mountain breezes influence CO_2 concentrations

Picture taken close to La Herrería site, looking North.
Photo by Jon Ander Arrillaga.

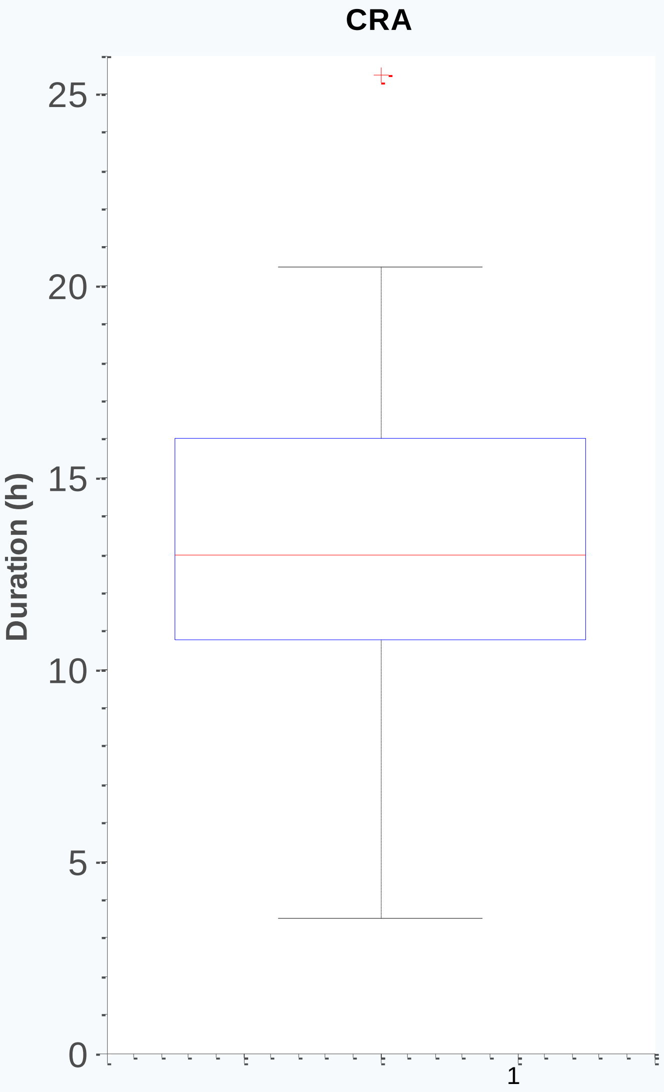
Thanks!

Downslope flows DURATION

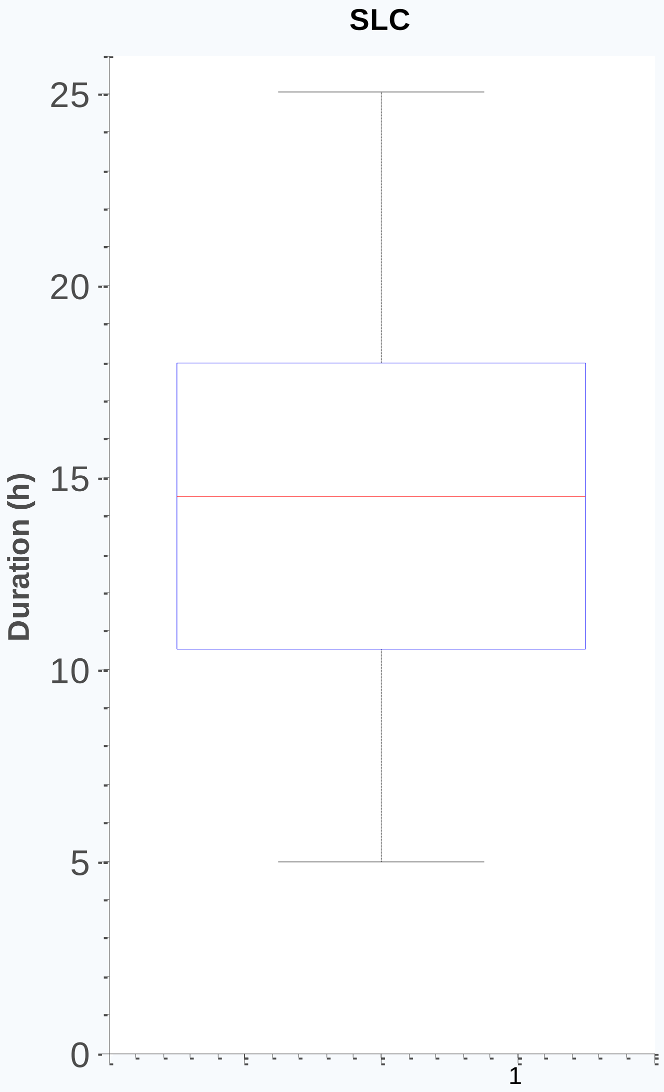
Guadarrama



Pyrenees

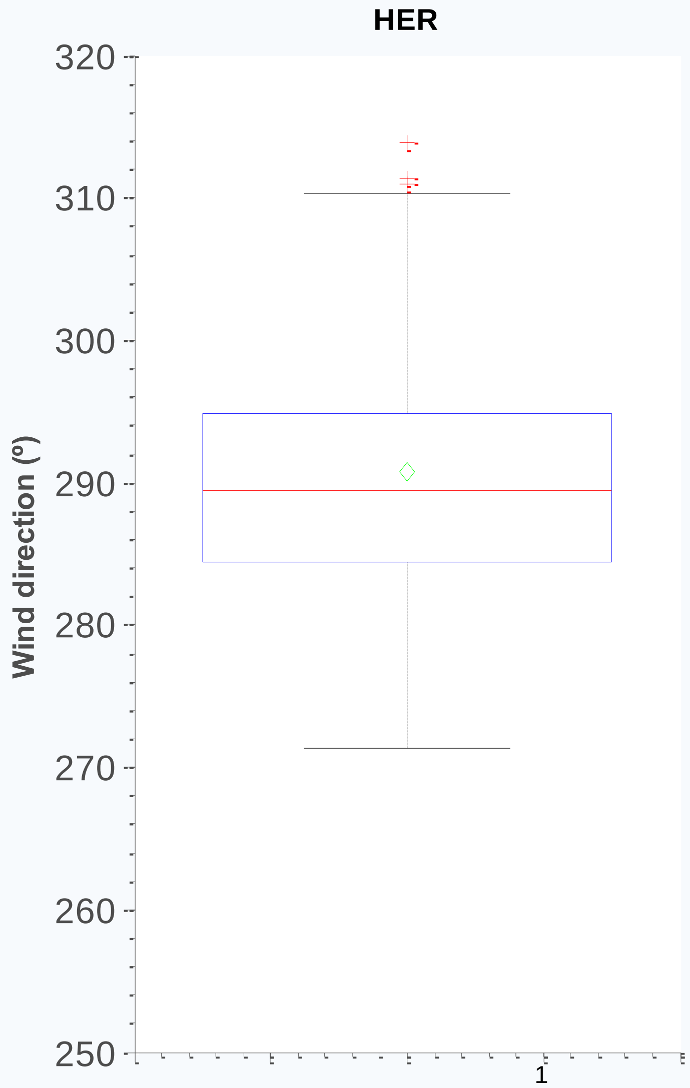


SLC valley

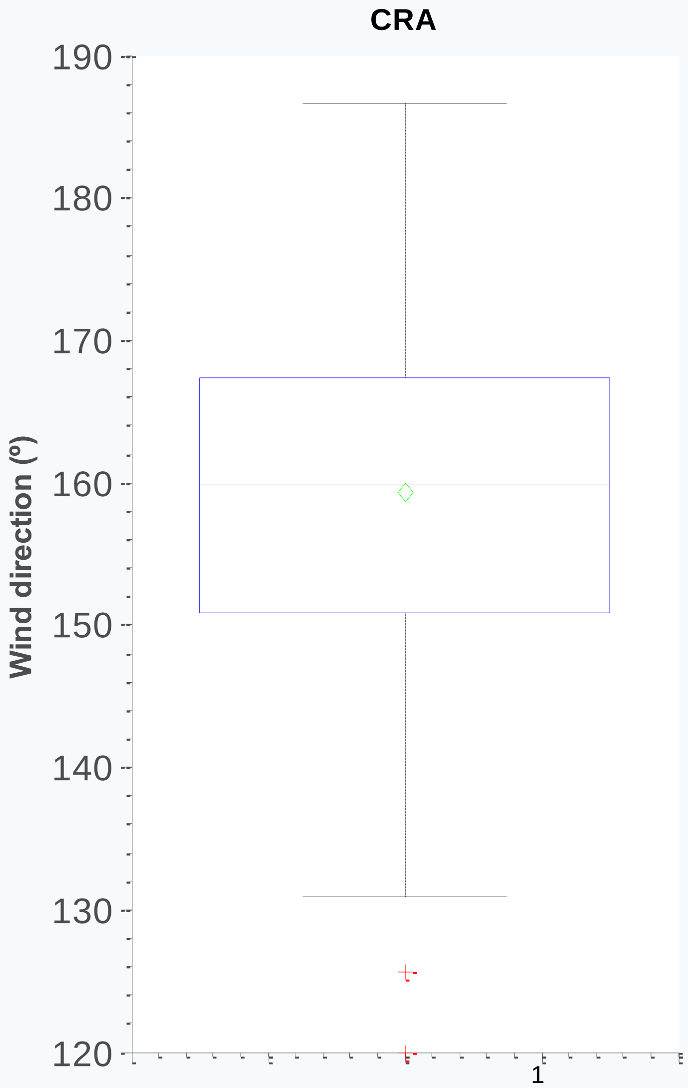


Downslope flows mean WIND DIRECTION

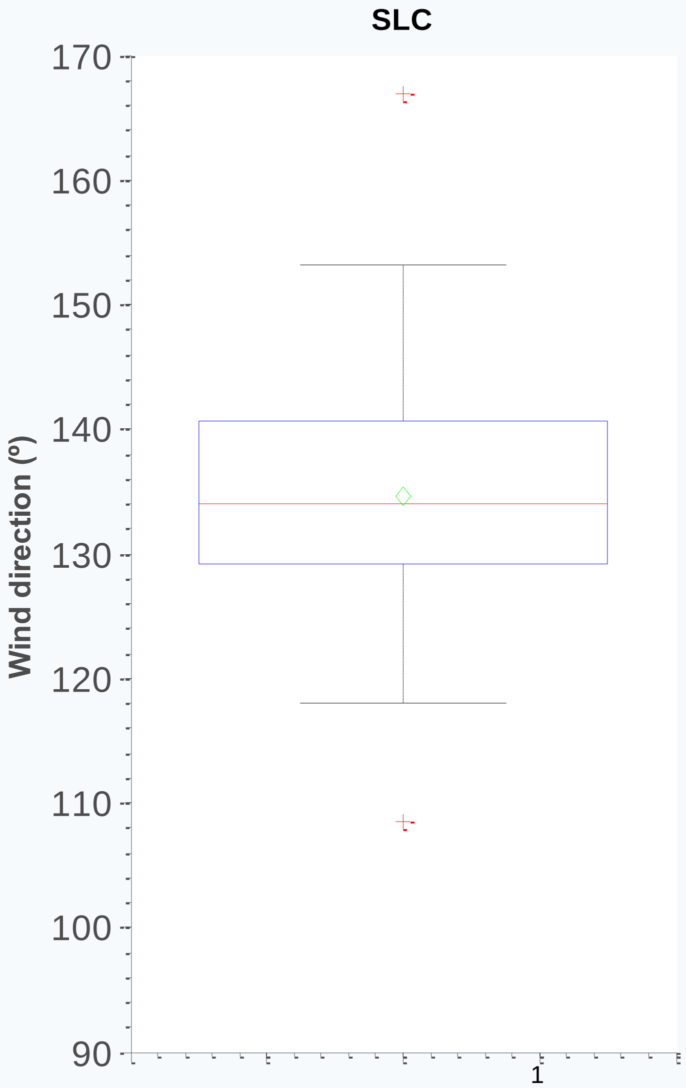
Guadarrama



Pyrenees

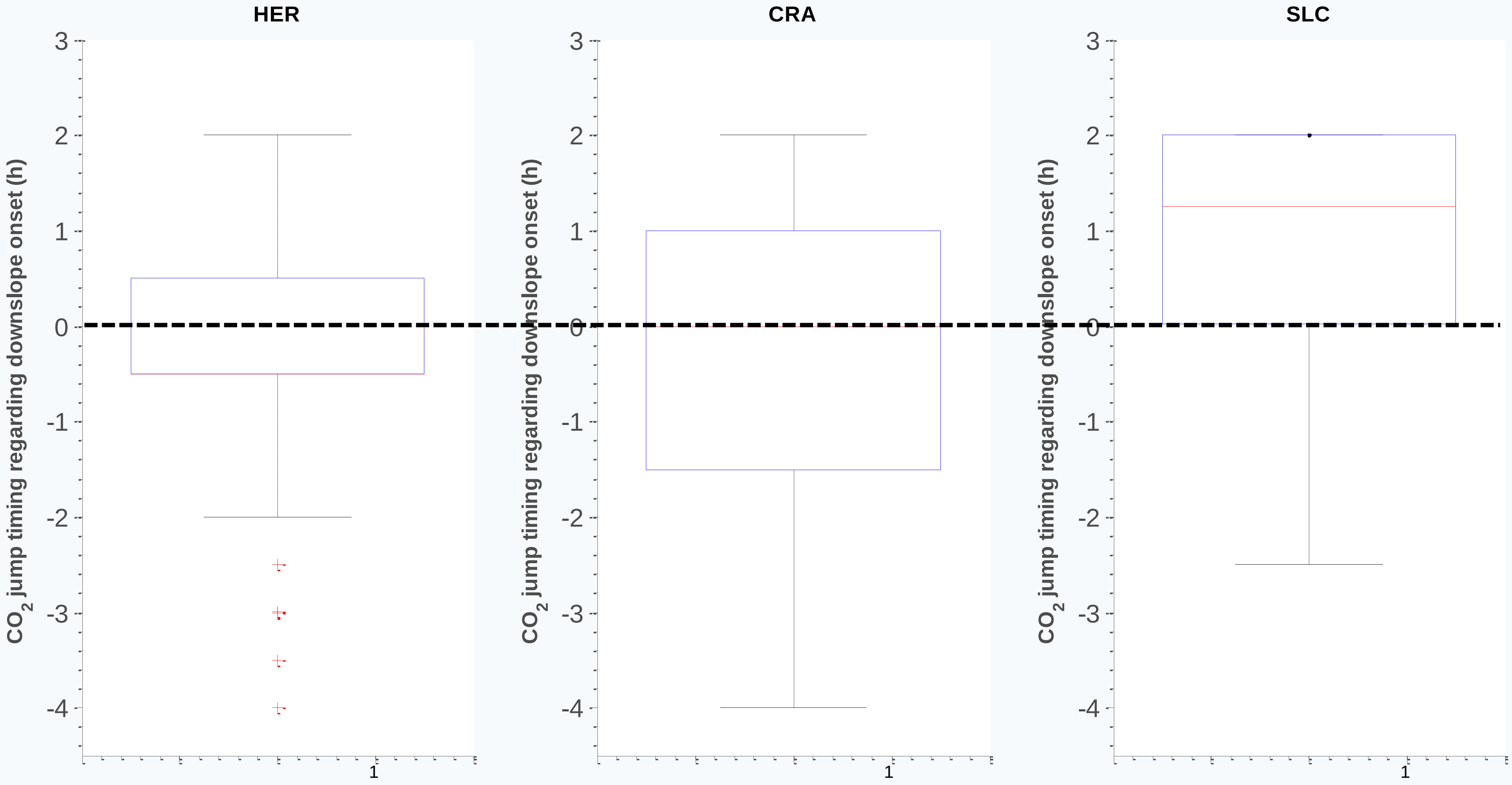


SLC valley



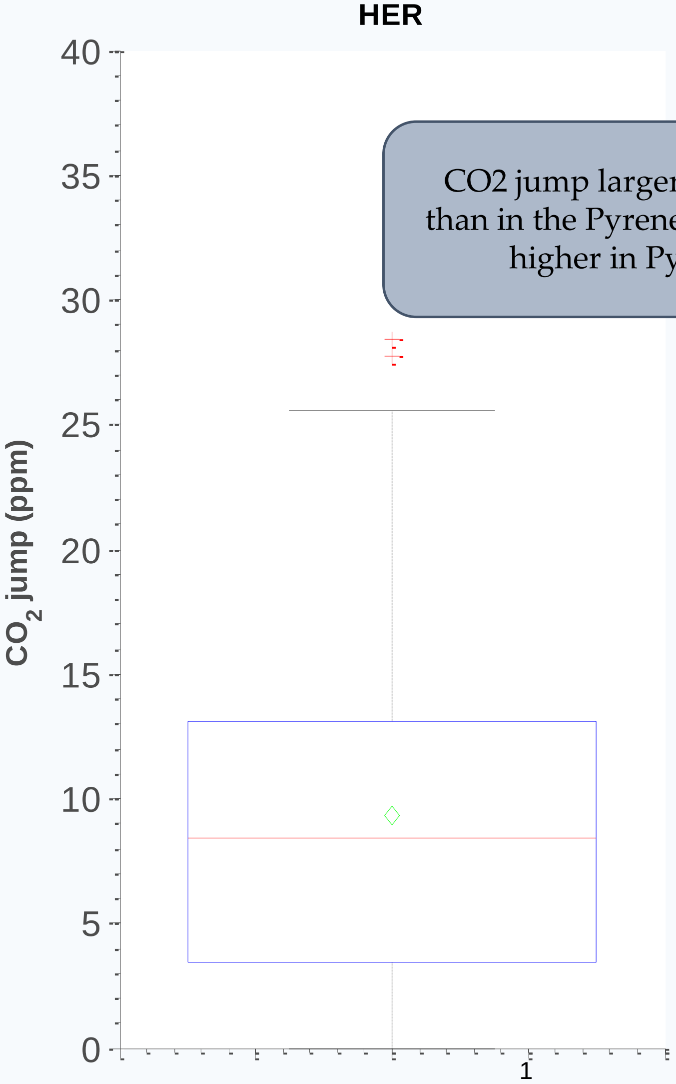
Downslope flows CO_2 jump timing (regarding katabatic onset)

Guadarrama | Pyrenees | SLC valley



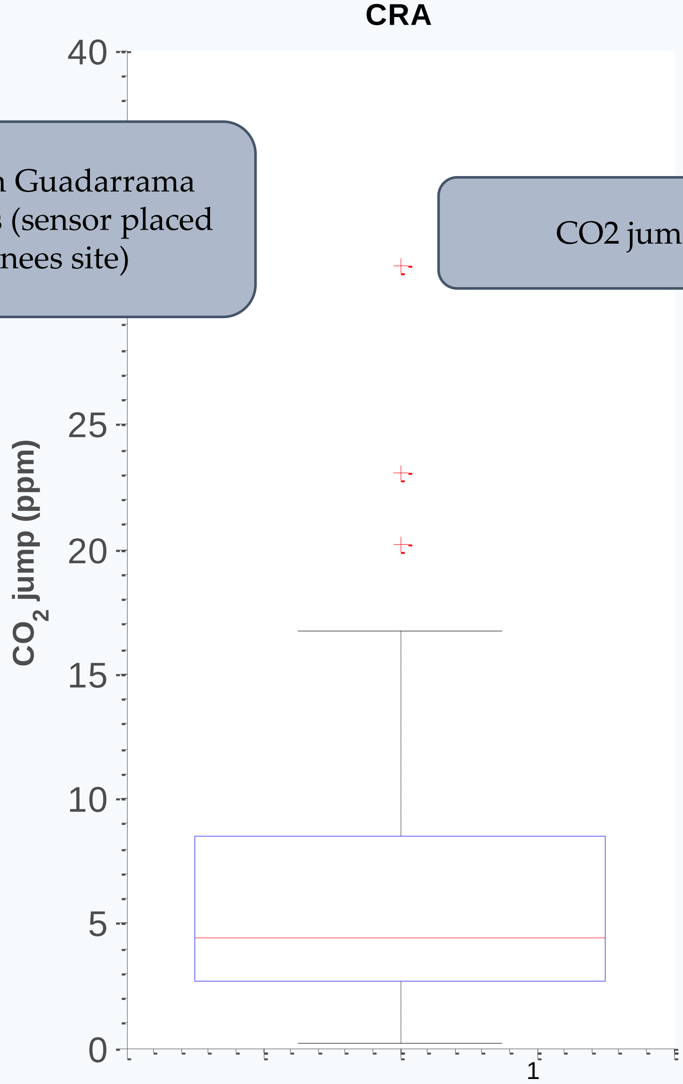
Downslope flows mean CO_2 jump

Guadarrama



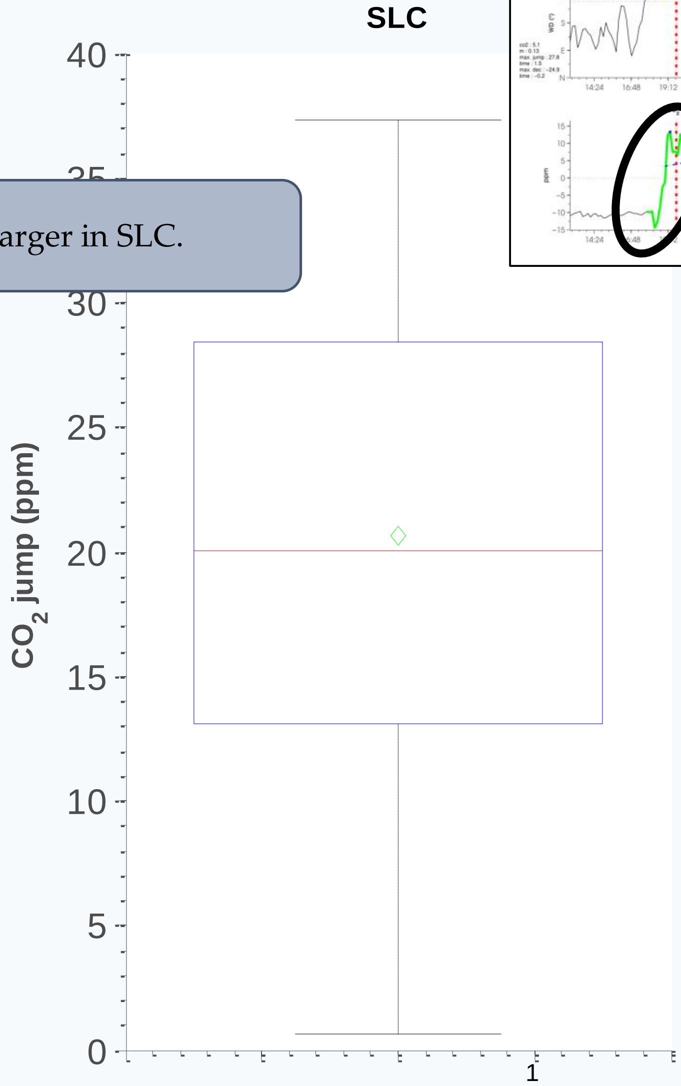
CO2 jump larger in Guadarrama than in the Pyrenees (sensor placed higher in Pyrenees site)

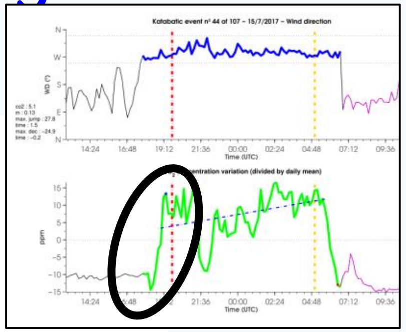
Pyrenees



CO2 jump larger in SLC.

SLC valley

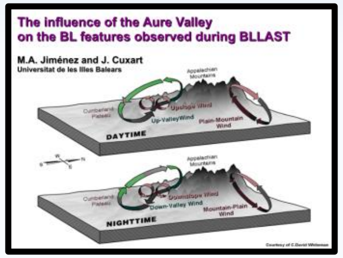




BLLAST testing period (Pablo and Imen)

BLLAST. Testing the detection algorithm (Pablo and Imen)…

Comparison with Jimenez et al. work on *Vallée d'Aure*.



IOP	Up/Down slope in Lannemezan	Up/Down slope exit Aure valley	Interaction Aure-Lann (Day/Night)	REASONS
3 20-21 june	NO / YES	YES / YES	NO / NO	LS wind
5 25-26 june	NO / YES (late)	YES /YES	NO / YES	When LS wind weakens, the exit valley jet reaches Lannemezan
6 26-27 june	NO / YES	YES / YES	NO / YES	Aure valley and Lannemezan linked during the whole night
9 1-2 july	YES / YES	YES / YES	YES / YES	LS winds are weak. Local winds present
11 5-6 july	YES / NO	YES / NO	YES / YES	LS winds from S and W. No local slope winds present. Foehn?

Dates	IOPs	Événements ana. algo.	Modèles (M. Jimenez)	Évaluation qualitative ana.	Événements cata. algo.	Modèles (M. Jimenez)	Évaluation qualitative cata.	
14/06	x	x		x	.		.	
15/06	x	x		x	.		.	
16/06	.	.		.	.		.	
17/06	.	x		x	.		.	
18/06	.	.		.	.		.	
19/06	x	x		x	x		x	
20/06	x	x	.	x	x	x	?	
21/06	.	.		.	x		x	
22/06	.	.		.			.	
23/06	.	.		.			.	
24/06	x	x		x	x		x	
25/06	x	.	.	.	x	x	x	
26/06	x	.	.	.	x	x	x	
27/06	x	x		x	.		.	
28/06	.	.		.	.		.	
29/06	.	.		.	.		.	
30/06	x	.		.			.	
01/07	x	x	x	x	x	x	x	
02/07	x	x		x	x		x	
03/07	.	.		?	.		.	← précip. soir
04/07	.	.		.	.		.	
05/07	x	x	x	x	.	.	.	
06/07	.	.		.	.		?	← précip.
07/07	.	.		.	.		?	← précip.
08/07	.	.		.	.		.	

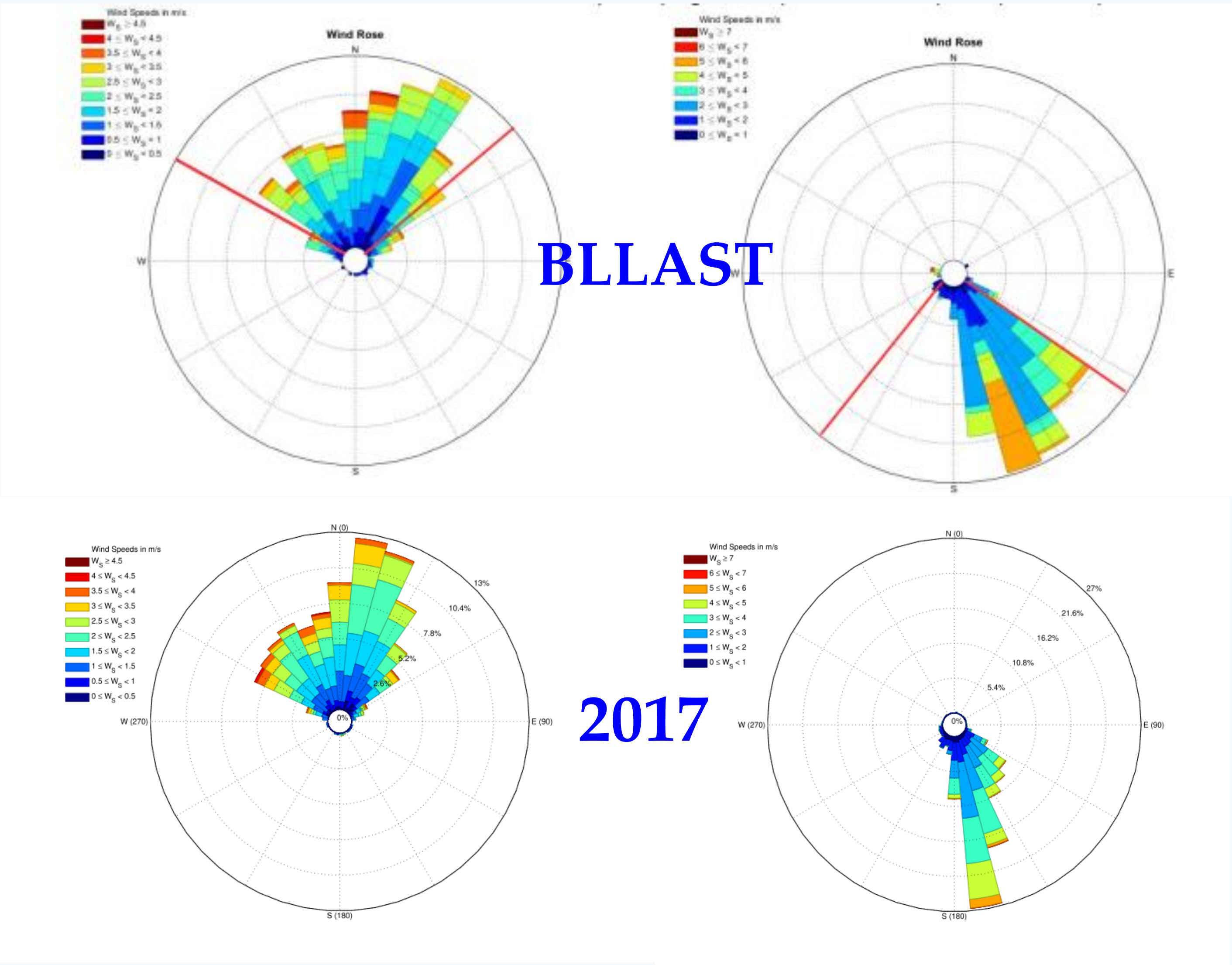
Does the mountain-breezes detection algorithm work during BLLAST? → YES!

BLLAST. CO_2 over different surfaces

BLLAST campaign statistics

	Ana.	Phase transition post-cata.	Cata.	Phase transition post-ana.
Nombre d'événements	11	5	8	3
Horaire début (UTC)	9h13	19h41	20h02	8h28
Horaire fin (UTC)	18h41	20h53	09h01	8h51
Durée (h)	9h29	1h10	9,78	0h23
Persistance (%)	87,21	-	87,76	-
VV moyenne (m/s)	1,84	0,75	2,74	0,95
DV moyenne (°N)	2,34	-	157,24	-

ANABATICS **KATABATICS**



BLLAST. CO2 over different surfaces

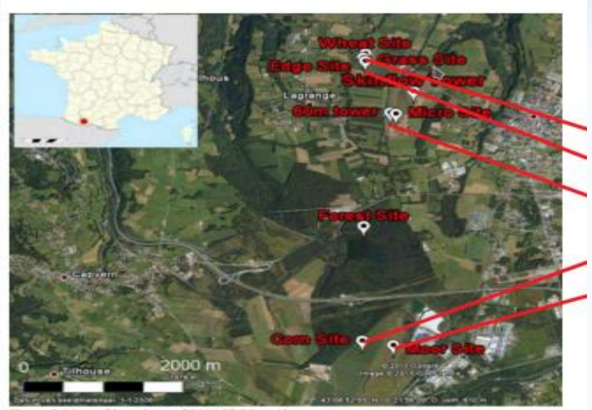
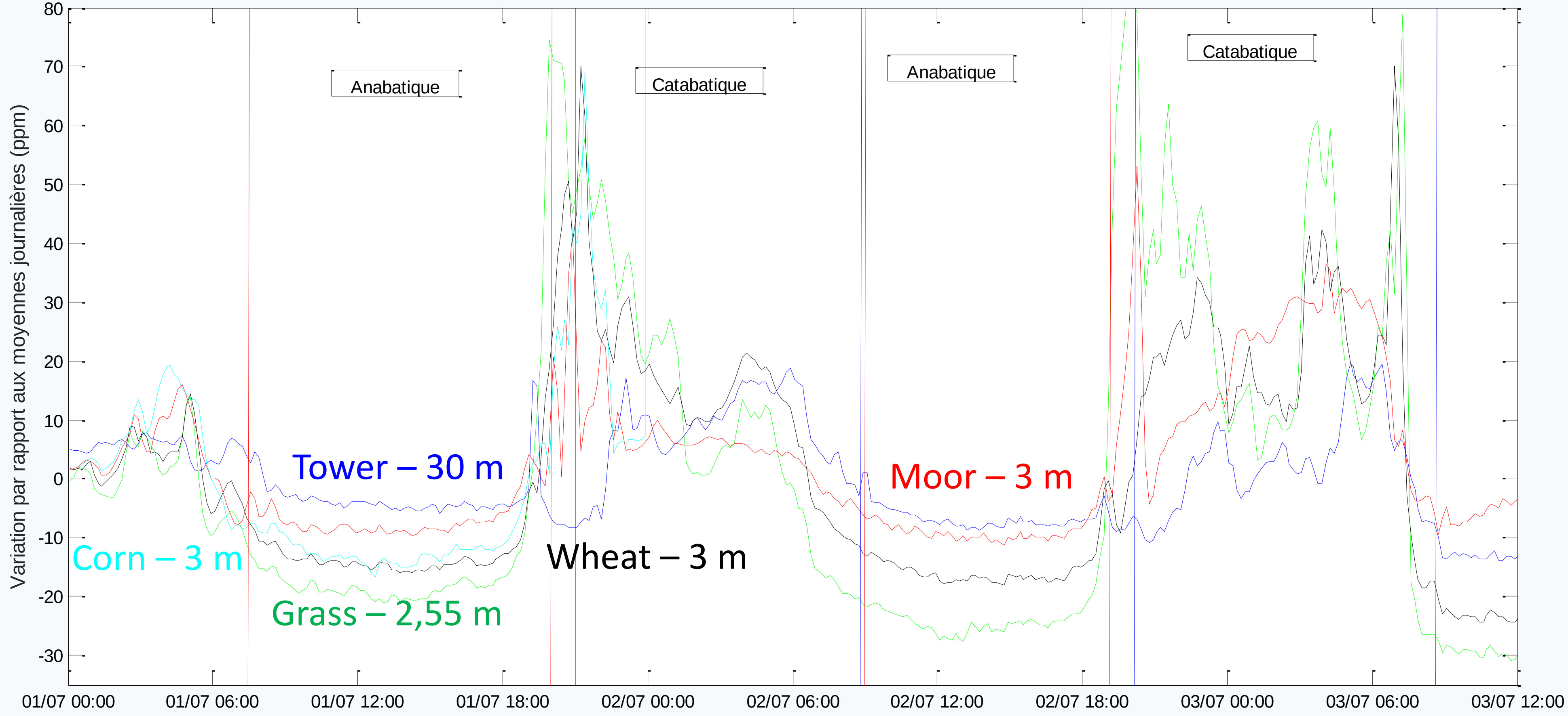


Figure 2 Map of locations of BLLAST EC-stations

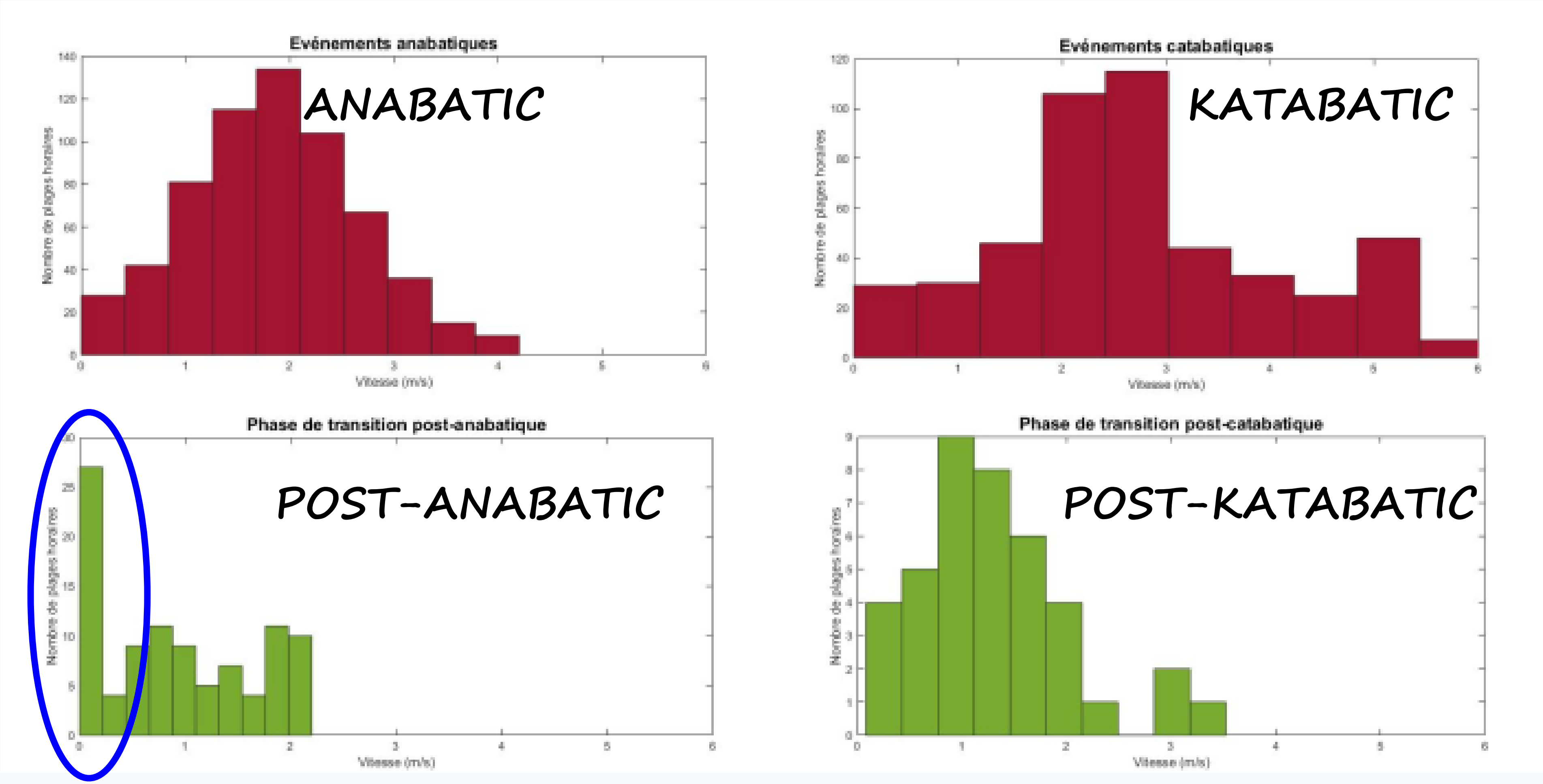
Wheat – 3 m
Grass – 2,55 m
Tower – 30 m
Moor – 3 m
Corn – 3 m
AVERAGE

Sites	Ev. anabatiques (jour seulement)	Phase transition vers Cata. (+2h)	Ev. catabatiques (nuit seulement)	Phase transition vers Ana. (+2h)
Blé	-12,44 (-13,79)	21,70 (18,73)	14,10 (18,65)	-10,05 (-9,59)
Herbe	-16,39 (-18,19)	52,27 (40,55)	14,54 (21,32)	-16,77 (-17,24)
Valimev	-4,39 (-4,43)	-4,81 (-3,97)	4,69 (3,68)	-0,84 (0,92)
Landes	-3,29 (-4,11)	11,92 (7,81)	10,11 (12,62)	3,03 (-2,93)
Maïs	-10,43 (-11,50)	9,32 (19,2)	9,75 (13,19)	-6,20 (-4,67)
Moyenne	**-9,39 (-10,4)**	**18,08 (16,48)**	**10,64 (13,9)**	**-7,38 (-6,70)**



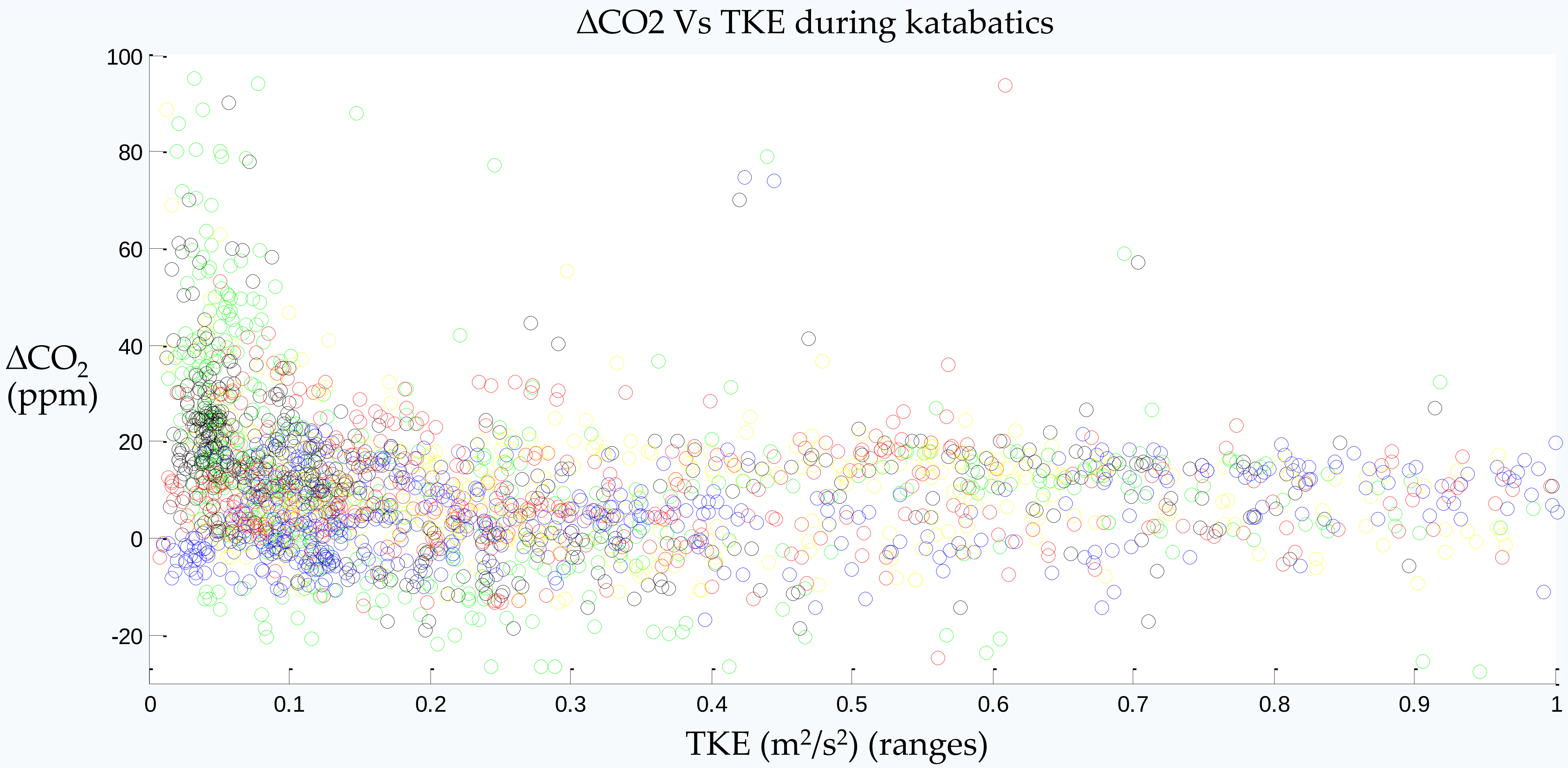
BLLAST. Katabatic and anabatic wind distributions

Wind distributions

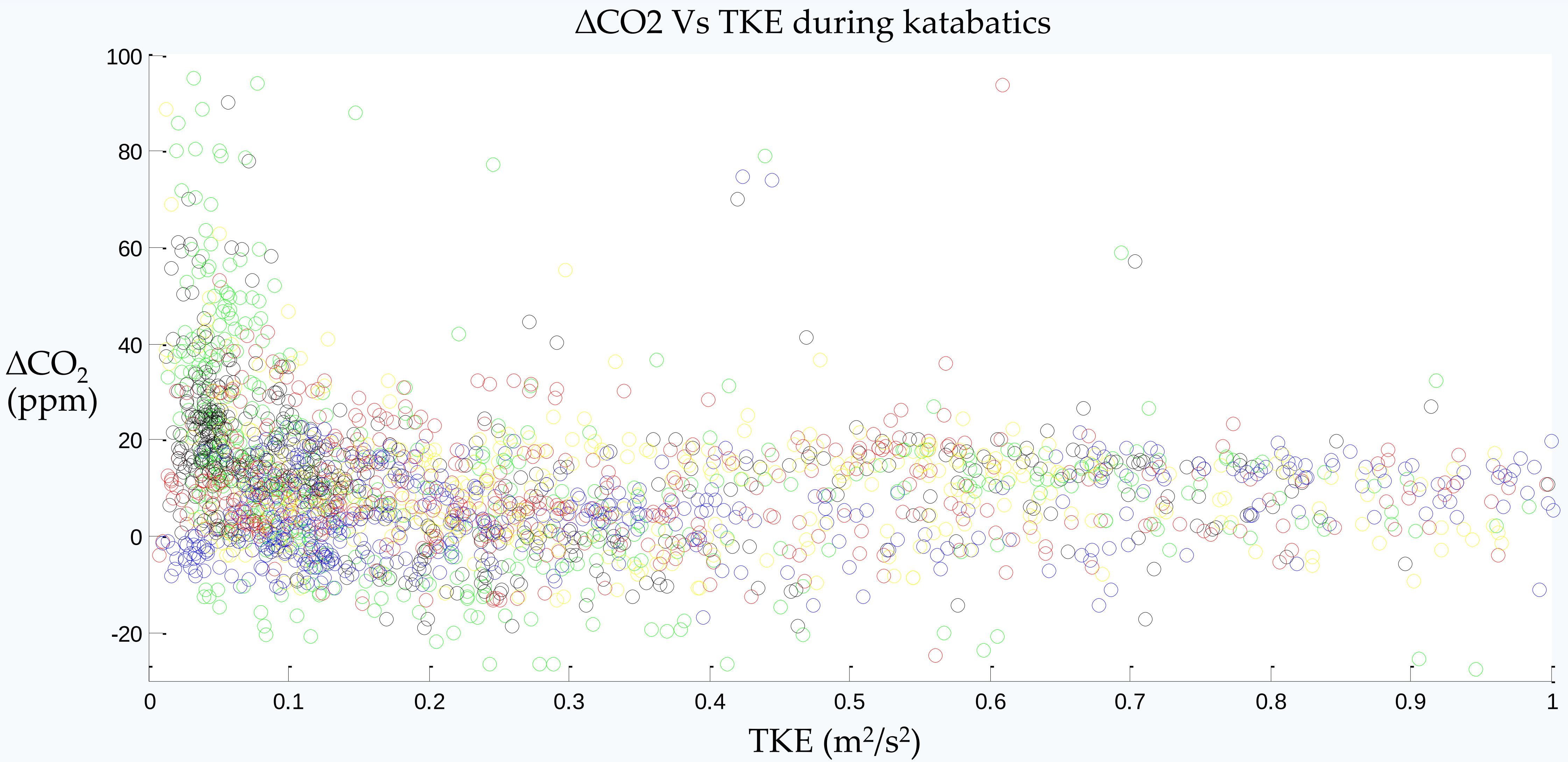


Interesting and particular period of transition, near-calm period, low turbulence… and high concentrations!

BLLAST. CO_2 over different surfaces



BLLAST. CO_2 over different surfaces

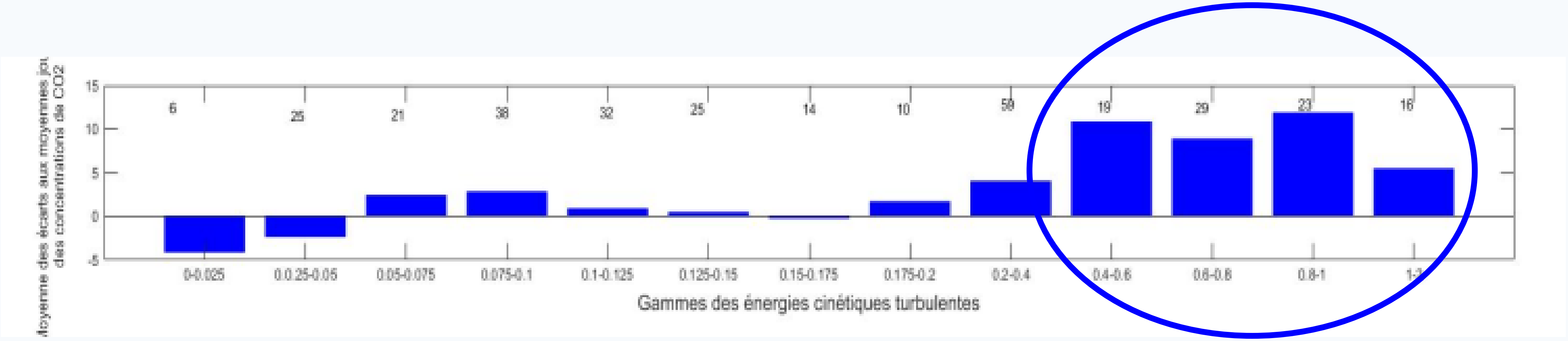


BUT THIS DOES NOT HAPPEN AT 30 M!!

BLLAST. CO_2 over different surfaces

At 30m, more turbulence means more CO_2 concentration due to the better mixing with CO_2-rich air from below

ΔCO_2 (ppm)



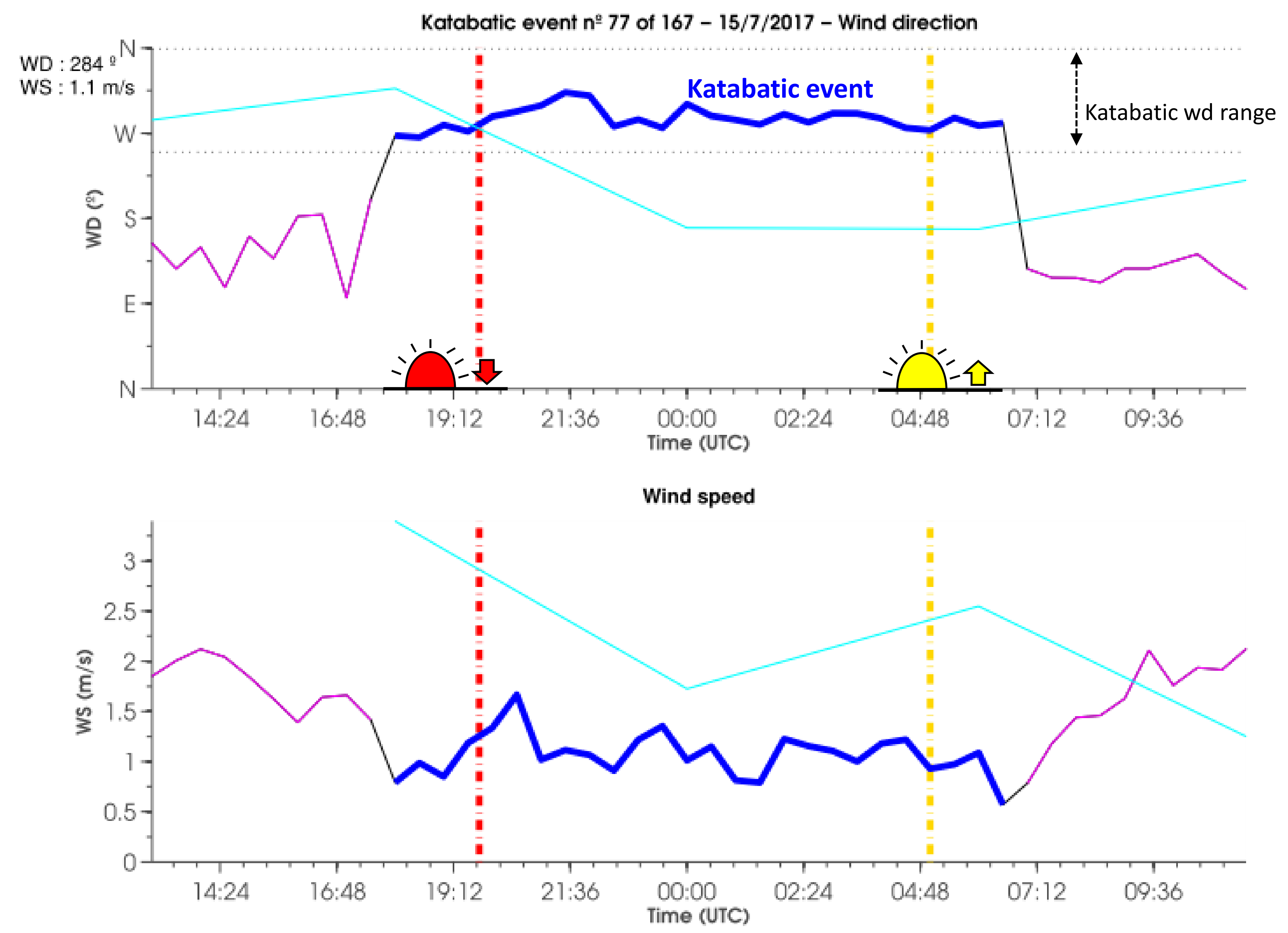
TKE (m^2/s^2) (ranges)

Mountain breezes detection

Example

Downslope winds

(10-m wind direction & 10-m wind speed)



(example)
Katabatic event
15/07/2017
La Herrería
(Guadarrama Mountains)