Katabatic, anabatic winds and their impacts in CO_2

C. Román-Cascón, I. Turki, P. Camparguez, M. Lothon, F. Lohou, C. Yagüe, J. A. Arrillaga and E. Pardyjak

BLLAST workshop
Palma de Mallorca
15 May 2018

Outline

- **ATMOUNT** project context
- **Objective 1.** Mountain breezes comparison in 3 sites
- **Objective 2.** Mountain breezes and their effects in CO_2
- **Testing period:** BLLAST (master students work)
  - CO_2 analyses over different surfaces

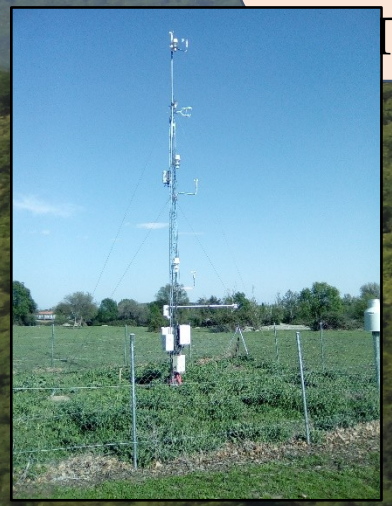
Project context

ATMOUNT

Land-atmosphere interactions in mountains analysis and impacts on global change

- ATMOUNT I – *Surface/atmosphere interactions in mountains and soil-vegetation-atmosphere transfer processes (obs+mod).* Univ. Islas Baleares
- **ATMOUNT II – *Micro-mesometeorological flows around Sierra de Guadarrama: Influences on fluxes of greenhouse gases and energy.* Univ. Complutense Madrid**

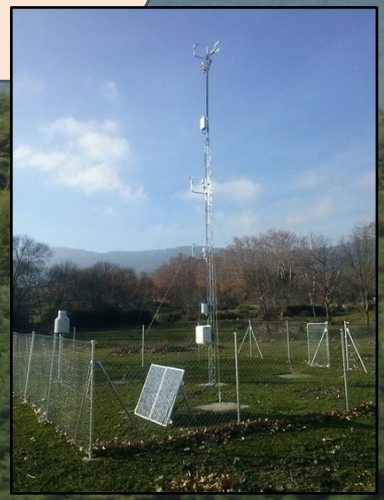
TMOUNT III – *Gravity waves, orographic rainfall.* Univ. Barcelona



ATMOUNT II

- OBJECTIVE 1: To compare mountain breezes in other sites.
- OBJECTIVE 2: To analyse the impacts of mountain breezes in CO_2 and water vapour concentration and fluxes

(among other objectives)



Mountain breezes comparison

1. **La Herrería** (Guadarrama Mountains)
2. **CRA** (Pyrenees)
3. **Salt Lake Valley** (Rocky Mountains)

- OBJ. 1 - Comparison of mountain breezes features in 3 sites:

Breezes detection → Algorithm* prepared to work in 3 sites

- Synoptic conditions (NCEP: u, v, T, RH)
  - Wind at 700 hPa (< 10-11 m/s)
  - Fronts passage ($\Delta\theta_e$)
  - Rainfall
- Local conditions
  - Range (kata/ana) of wind direction at specific timing
  - Wind direction persistence (80% of time)
  - Minimum duration of events (2 hours min)

* Based on criteria in Arrillaga et al. 2016

Breezes analysis → Statistics

- Formation and end times (related to sunrise/sunset)
- Duration
- Wind speed intensity and variability
- Wind direction variability
- Events relation with other variables (synoptic conditions, temperature, season, soil humidity…)
- IMPACTS: on fluxes, turbulence, stability, PBL behavior, transitions? +CO_2 and $(H_2O)_v$

Objective 1. Breezes detection and statistics

- La Herrería (almost 2 available years) → Analysis for all 2017
- CRA (several available years) → Analysis for all 2017
- Salt Lake Valley → Jan-July 2015 (MATERHORN)

+ TESTING PERIOD… **BLLAST!**

LA HERRERIA (El Escorial) - 2017

LARGE SCALE CRITERIA KATABATICS

201 days from a total of 365 have passed filter 1 (synoptic wind speed)
193 days have passed ALSO filter 2 (fronts passage)
183 days have passed ALSO filter 3 (in situ rainfall (stormy days))

SMALL SCALE CRITERIA KATABATICS

290 possible katabatic events
276 katabatics events have been detected with minumum persistence of 2 hour(s)
132 events also passed the criteria of 80 percentage of time with the same wd

----- LARGE SCALE AND IN SITU KATABATIC DETECTION -----

Number of kat. events according to small scale & large scale = 107

CONFIGURATION	
Synoptical height	700
Synoptic wind speed threshold (m/s)	9
Synoptic theta threshold (K/6h)	-1,45
Rainfall threshold (mm/day)	0,5
Katabatic range min	250
Katabatic range max	340
Anabatic range min	70
Anabatic range max	230
Data time resolution	10
Katabatic ini time regarding sunrise	-5
Katabatic end time regarding sunrise	+18
Anabatic ini time regarding sunset	-2
Anabatic end time regarding sunset	+18
Katabatic minimum time persistence (h)	2
Anabatic minimum time persistence (h)	2
% of kat/anab continuity	80

(same type of analysis and criteria for anabatics)

Objective 1. Breezes detection and statistics

Example

Katabatic event

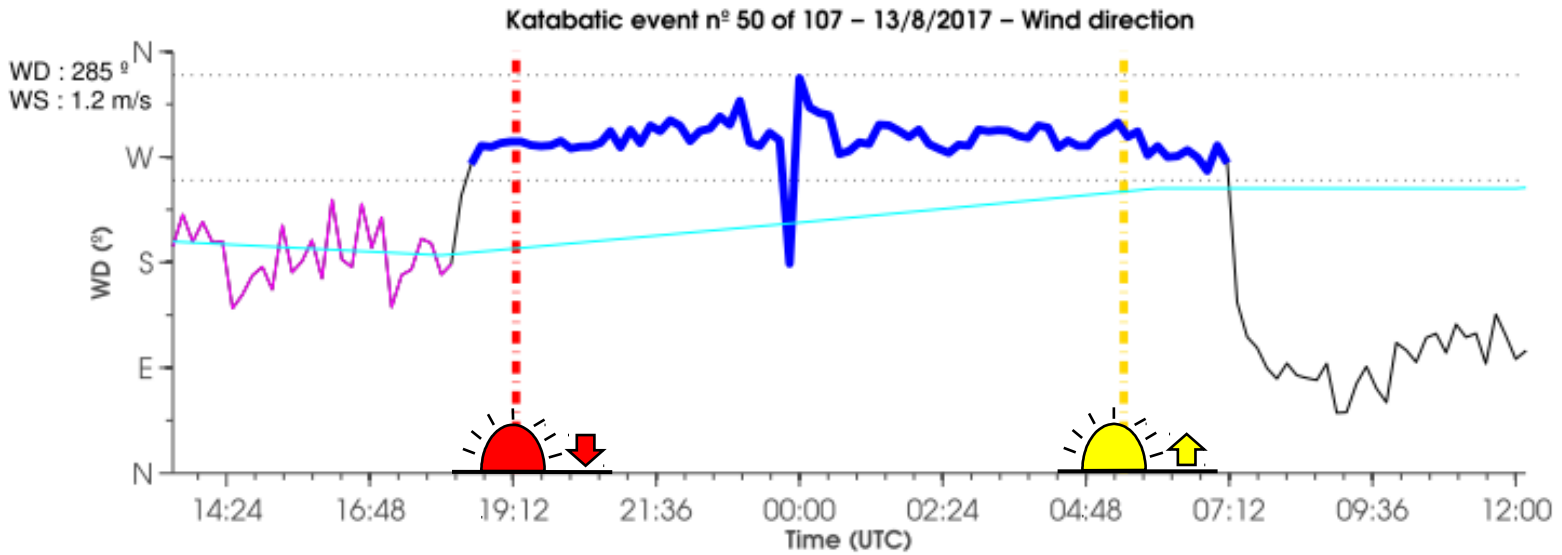
15/07/2017

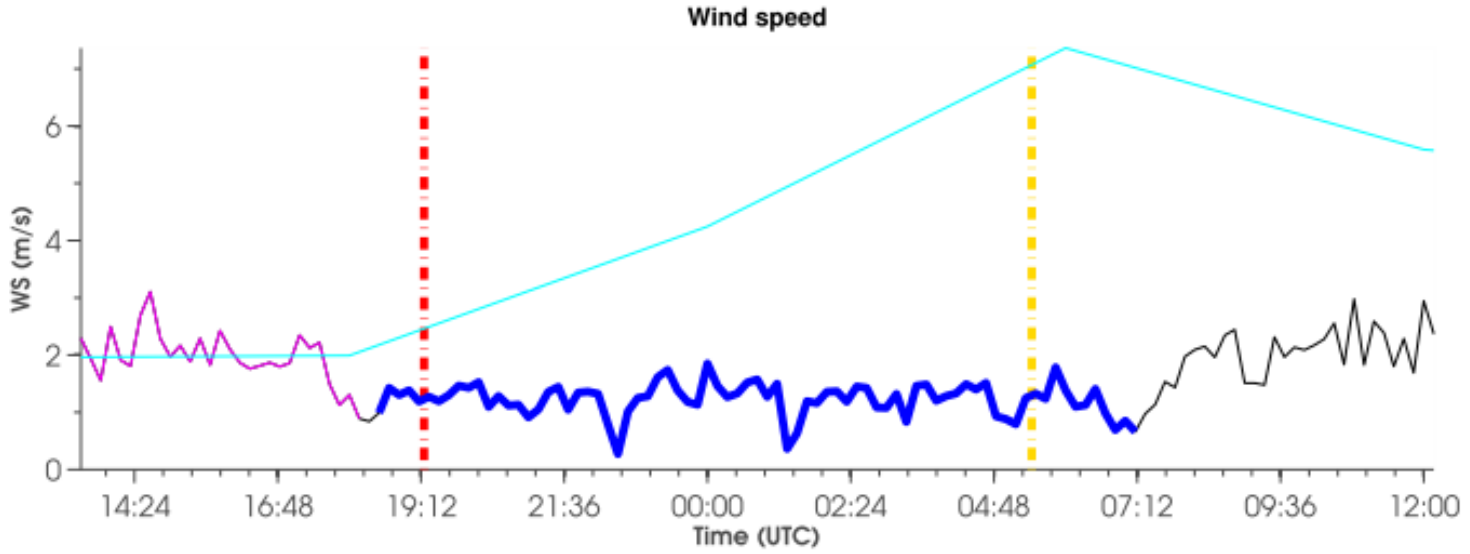
La Herrería

Typical case

Cases very similar and constant

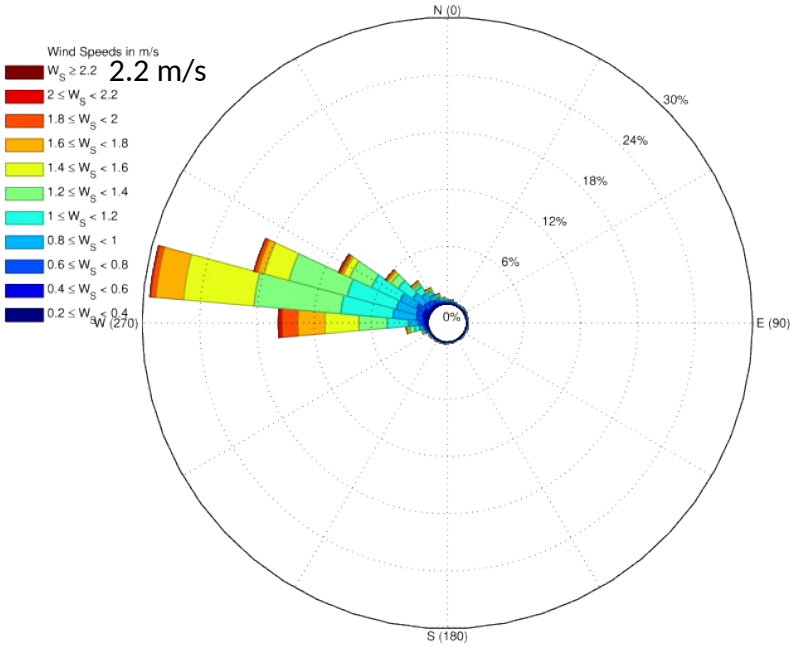
POSSIBILITY OF REMOVING UNCLEAR CASES

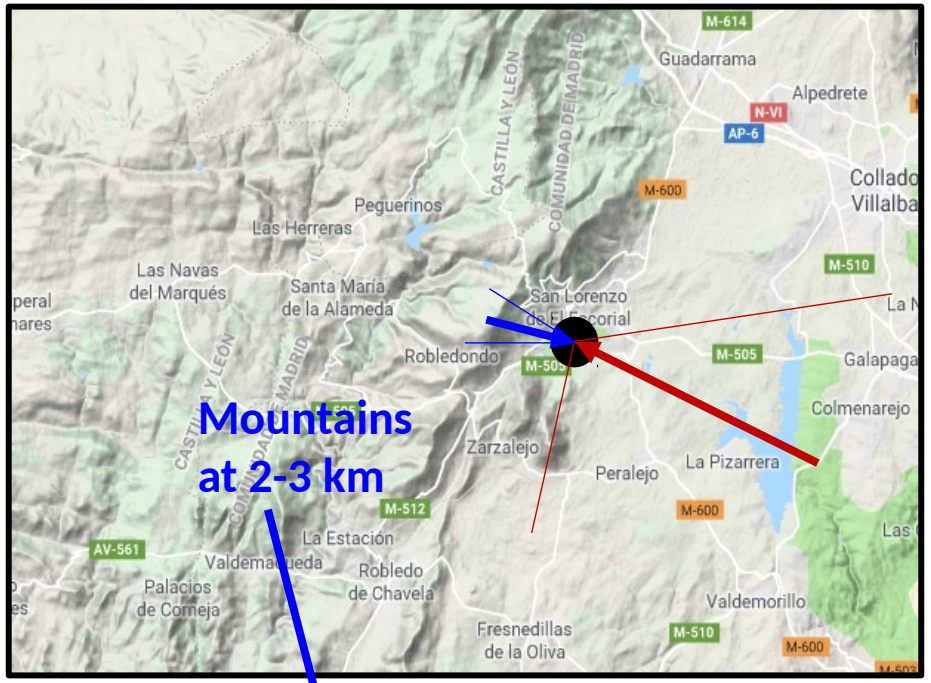


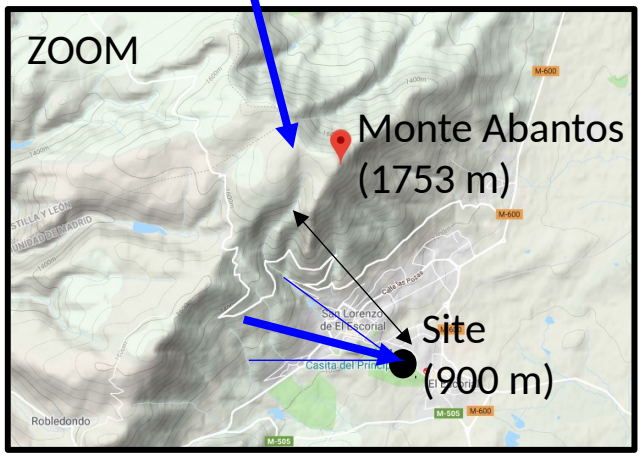


La Herrería (San Lorenzo de El Escorial)

Katabatics





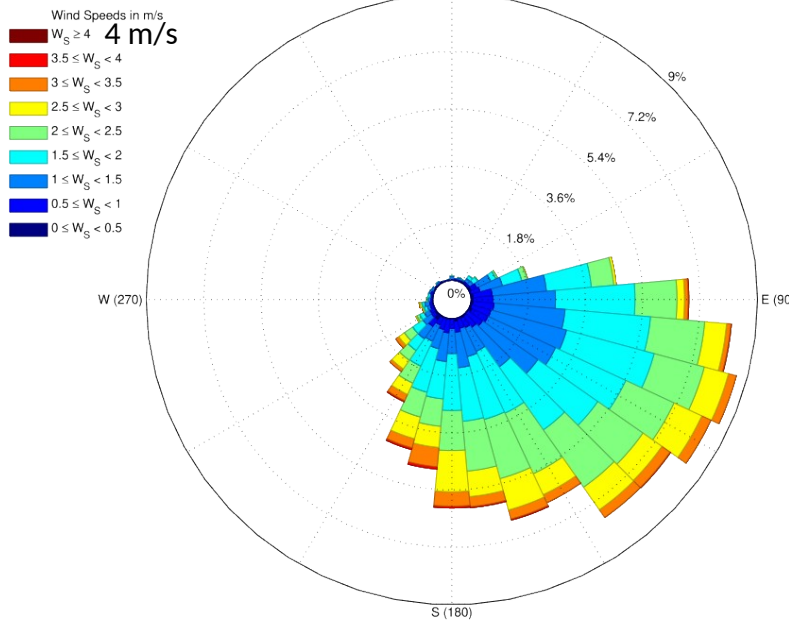


Mean wind speed = 1.2 m/s
(range 1 to 1.5 m/s)

Katabatic formation  **-0.5 h**

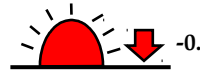
Katabatic end  **+1.5 h**

Anabatics



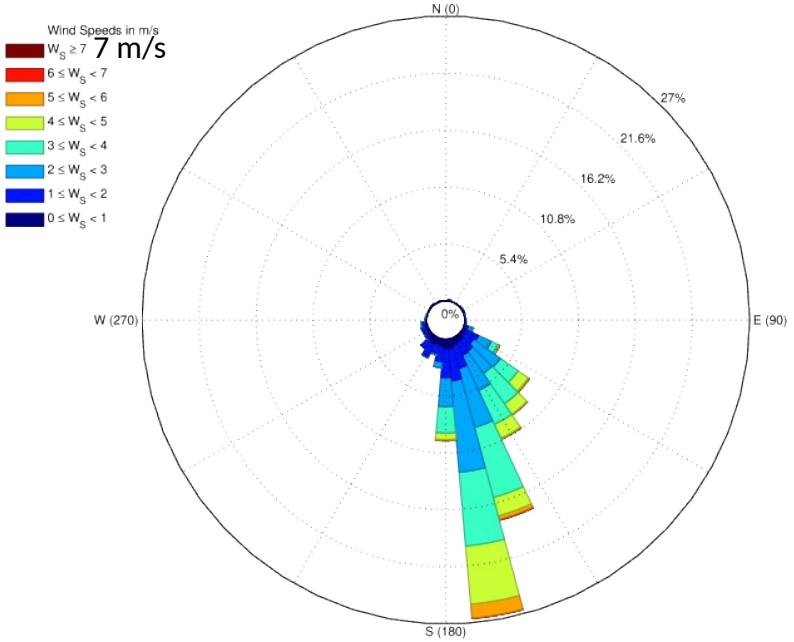
Mean wind speed = 1.7 m/s
(range 1.1 – 2.5 m/s)

Anabatic formation  **+1.5 h**

Anabatic end  **-0.75 h**

CRA (Lannemezan)

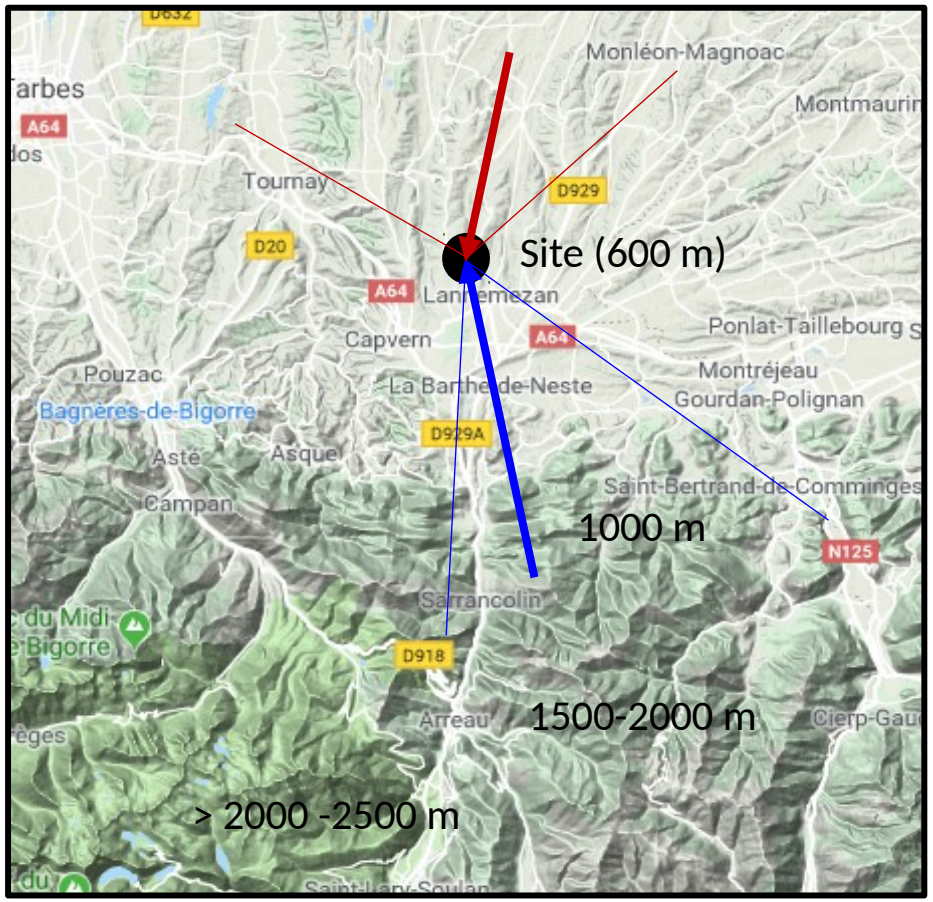
Katabatics



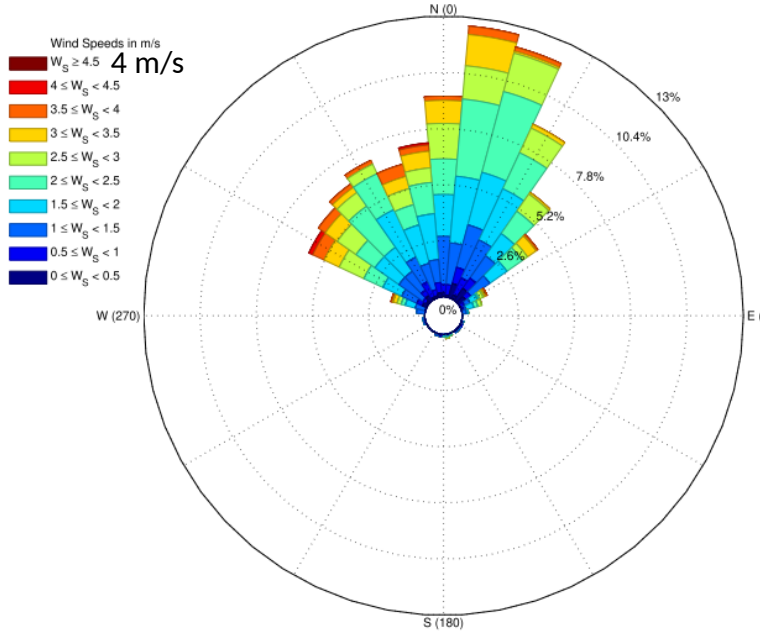
Mean wind speed = 2.6 m/s
(range 0.5 to 4.5 m/s)

Katabatic formation  **+1 h**

Katabatic end  **+2.5 h**

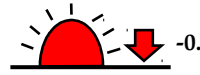


Anabatics



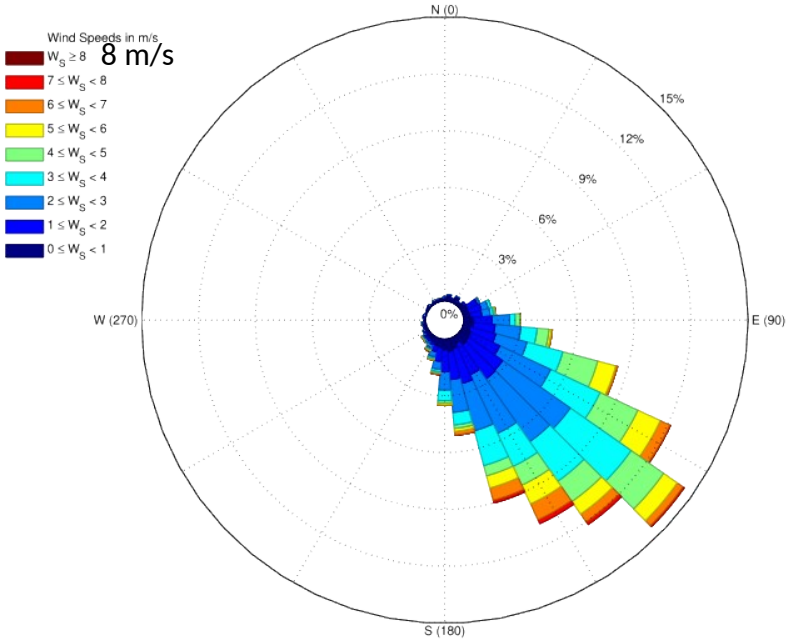
Mean wind speed = 1.7 m/s
(range 1 – 3.2 m/s)

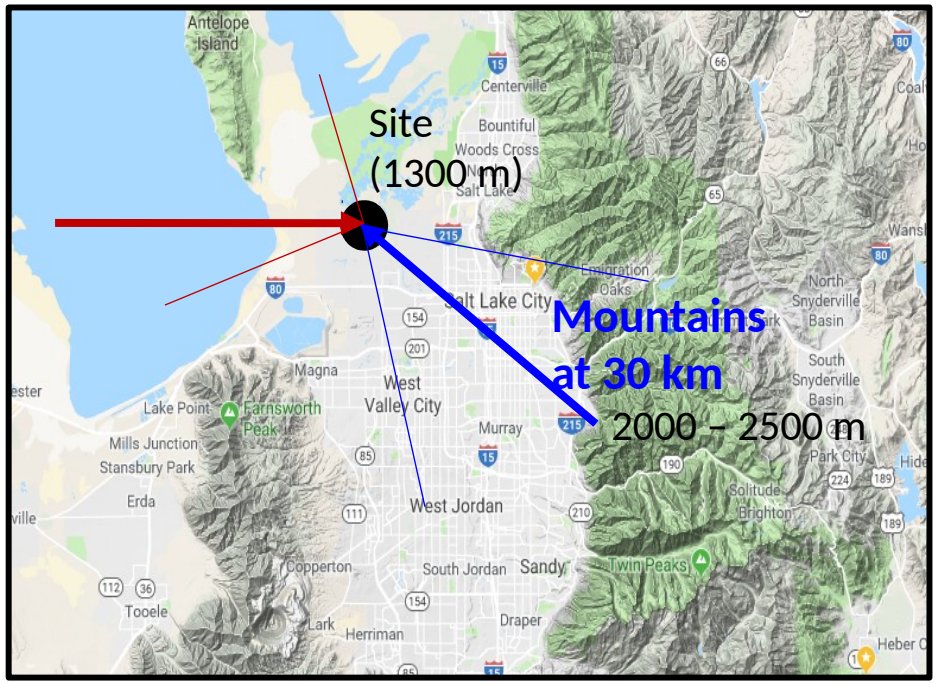
Anabatic formation  **+4 h**

Anabatic end  **-0.5 h**

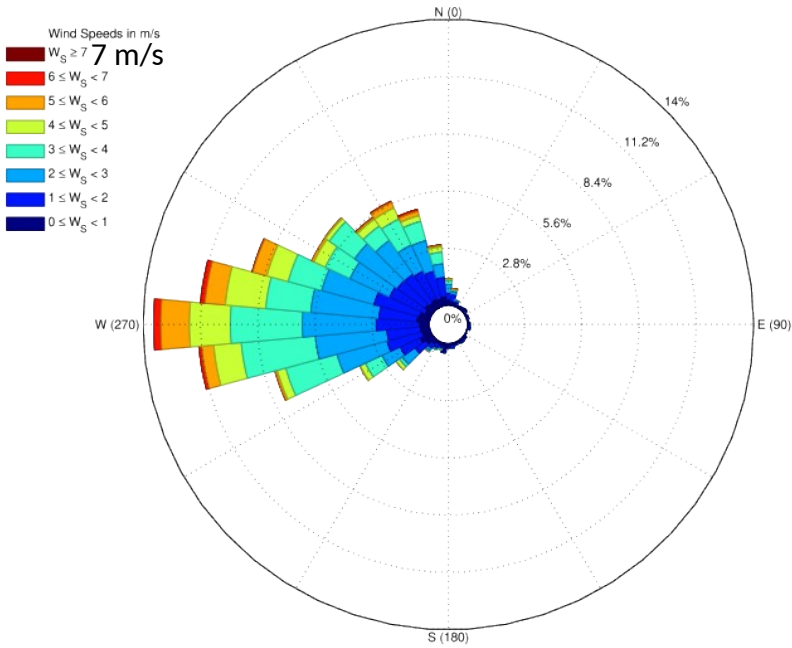
Salt Lake Valley (SLC)

Katabatics





Anabatics



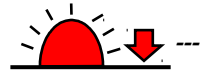
Mean wind speed = 2.7 m/s
(range 1.5 to 3.5 m/s)

Katabatic formation  **+1 h**

Katabatic end  **-1 h**

Mean wind speed = 2.7 m/s
(range 1 – 5.5 m/s)

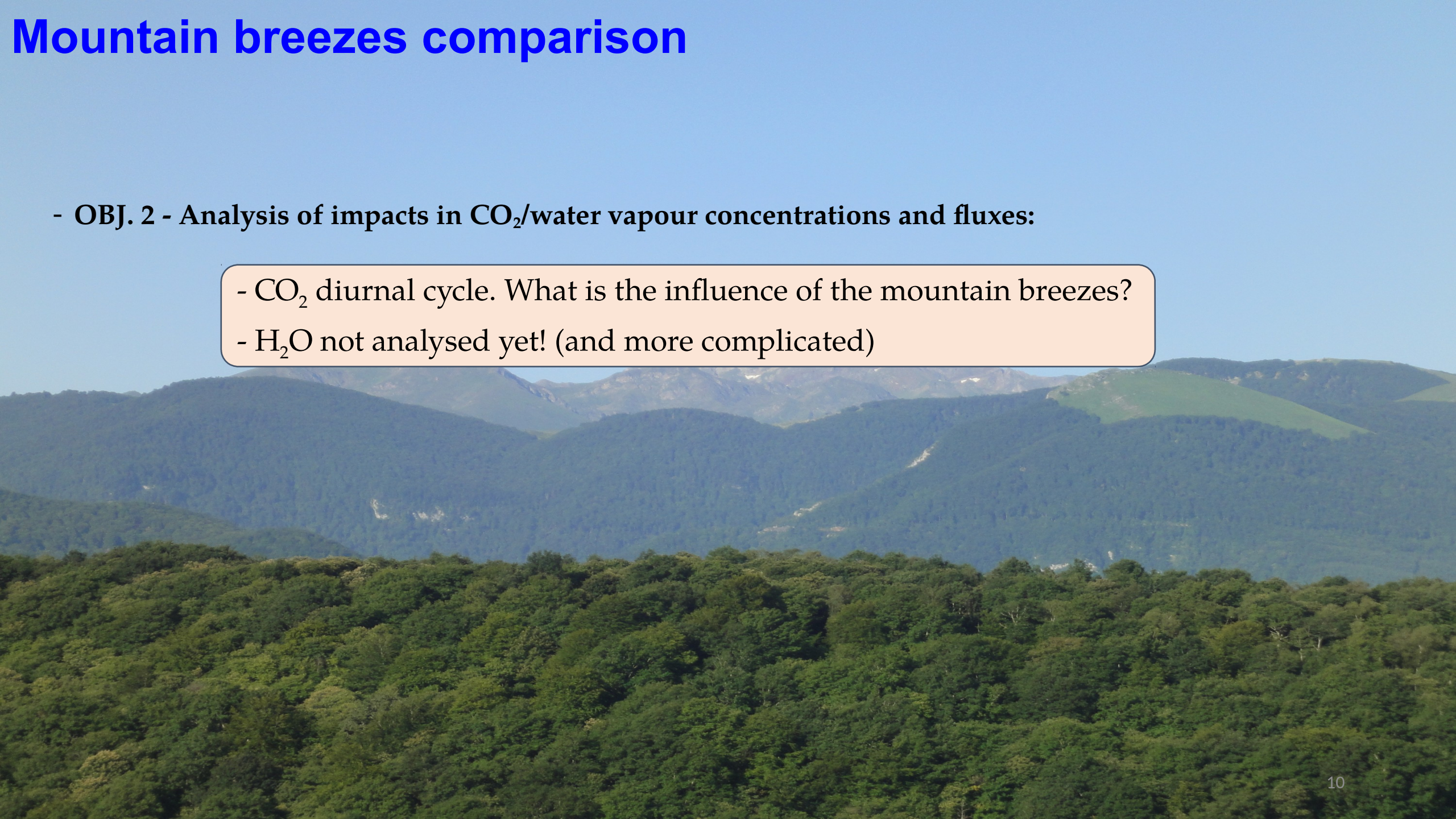
Anabatic formation  **+2.5 h**

Anabatic end  **--- h**

Mountain breezes comparison

- **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)



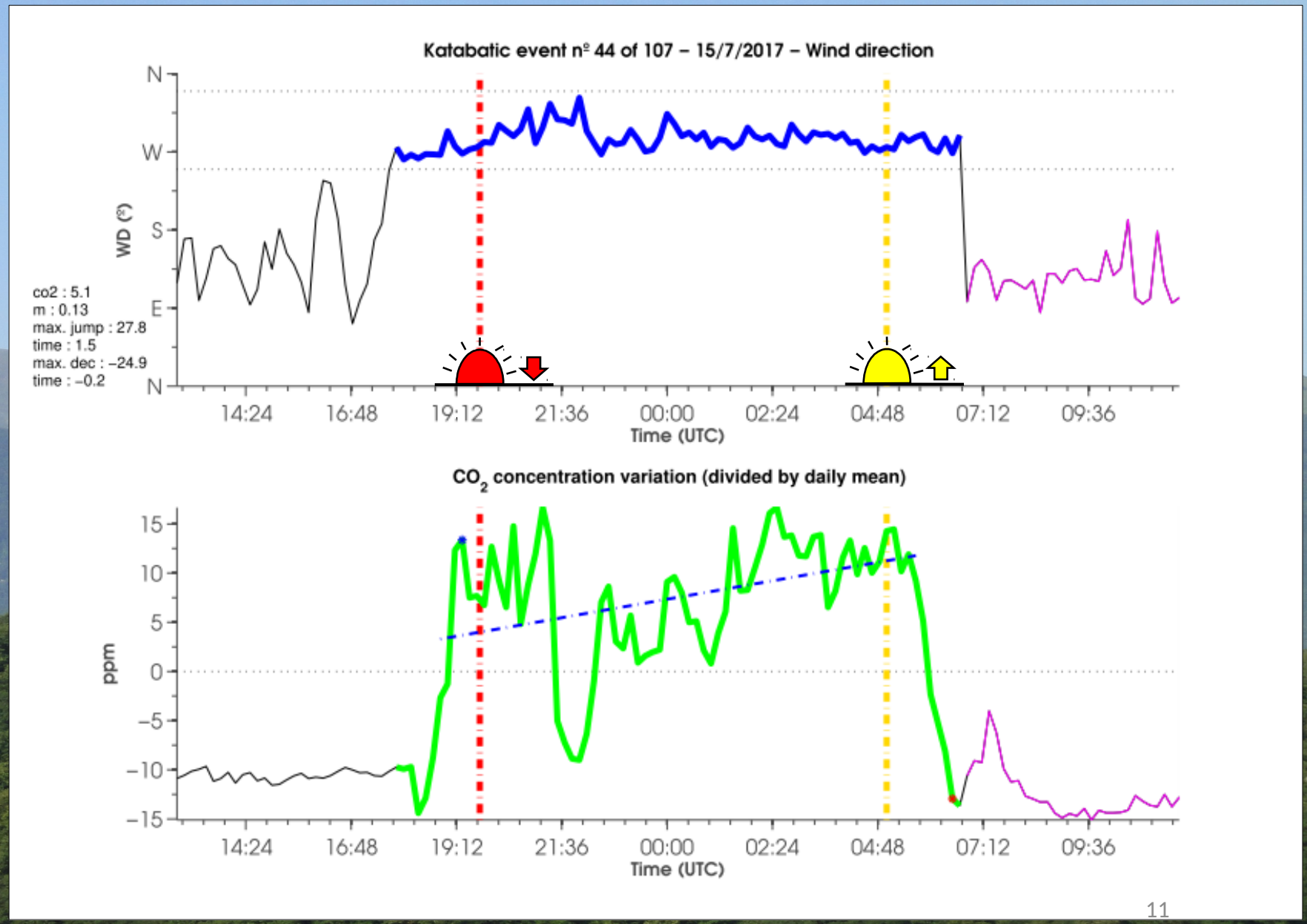
CO_2 analysis

Example

Katabatic event

15/07/2017

La Herrería



CO_2 analysis

Example

Katabatic event

15/07/2017

La Herrería

ASPECTS TO BE STUDIED

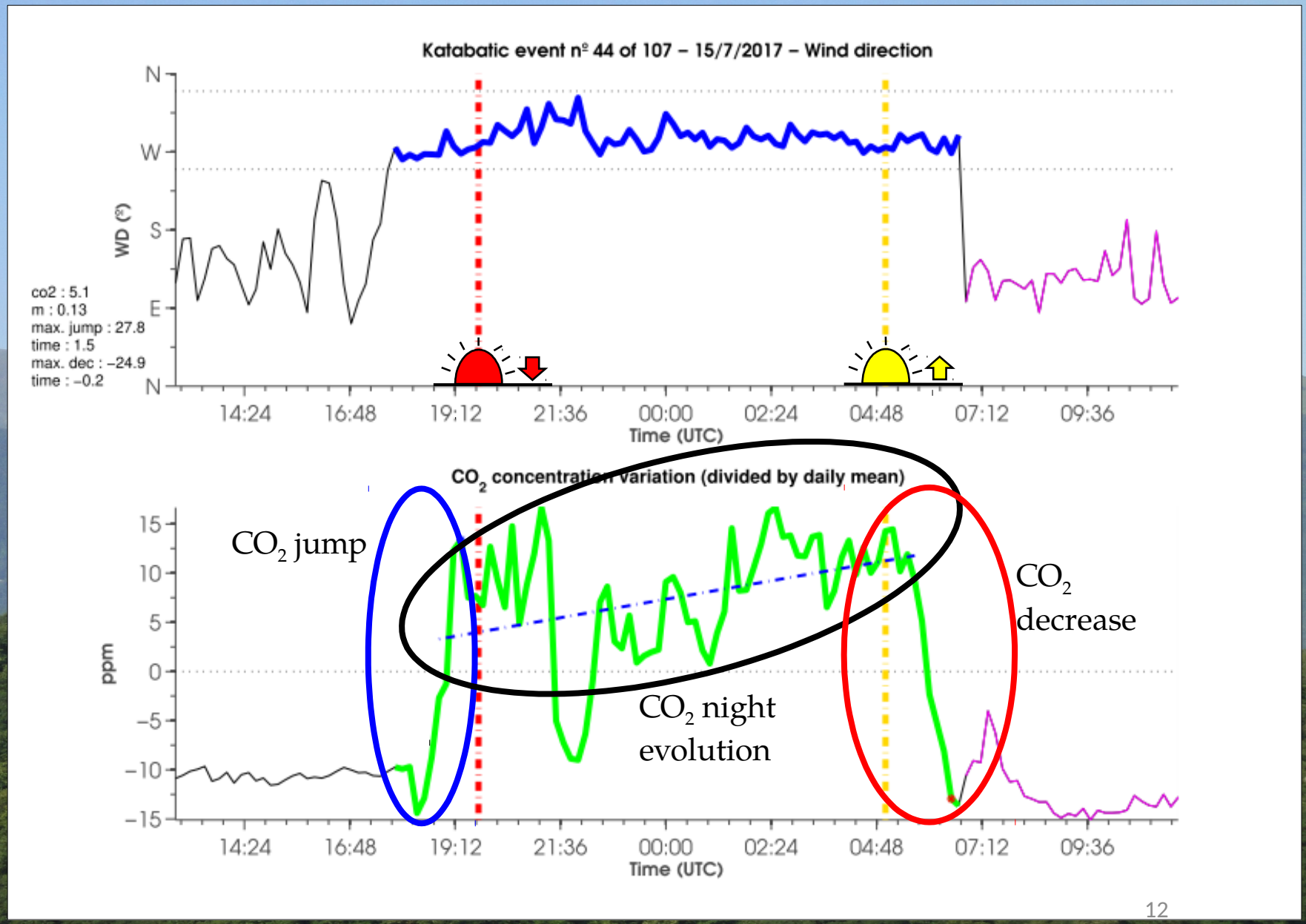
1. CO_2 jump
   - Is it related to the katabatic onset?
   - Which variables are controlling the strength of the CO_2 jump?
   - How does it change along the year?

2. CO_2 night evolution (slope)
   - Positive during summer?
   - Negative during winter?
   - Annual evolution?
   - CO_2 pic always at the beginning of the SBL related to very low turbulence

3. CO_2 decrease
   - Speed of morning transition?

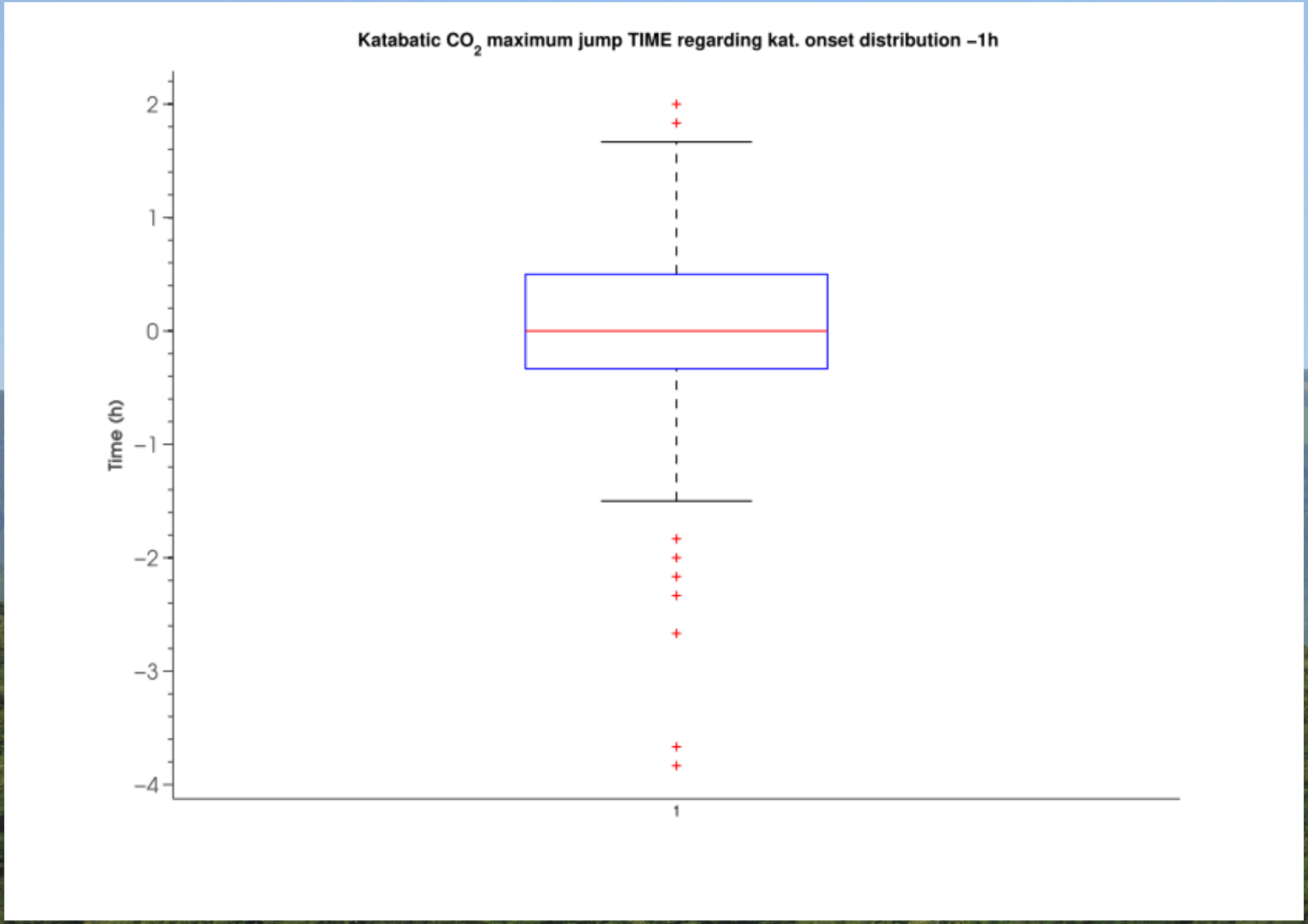
CO_2 dynamics more related to PBL dynamics (degree of turbulence) and biological activity

THERE IS NO EFFECT OF LOCAL ADVECTIONS DUE TO KATABATIC/ANABATIC?



CO_2 analysis

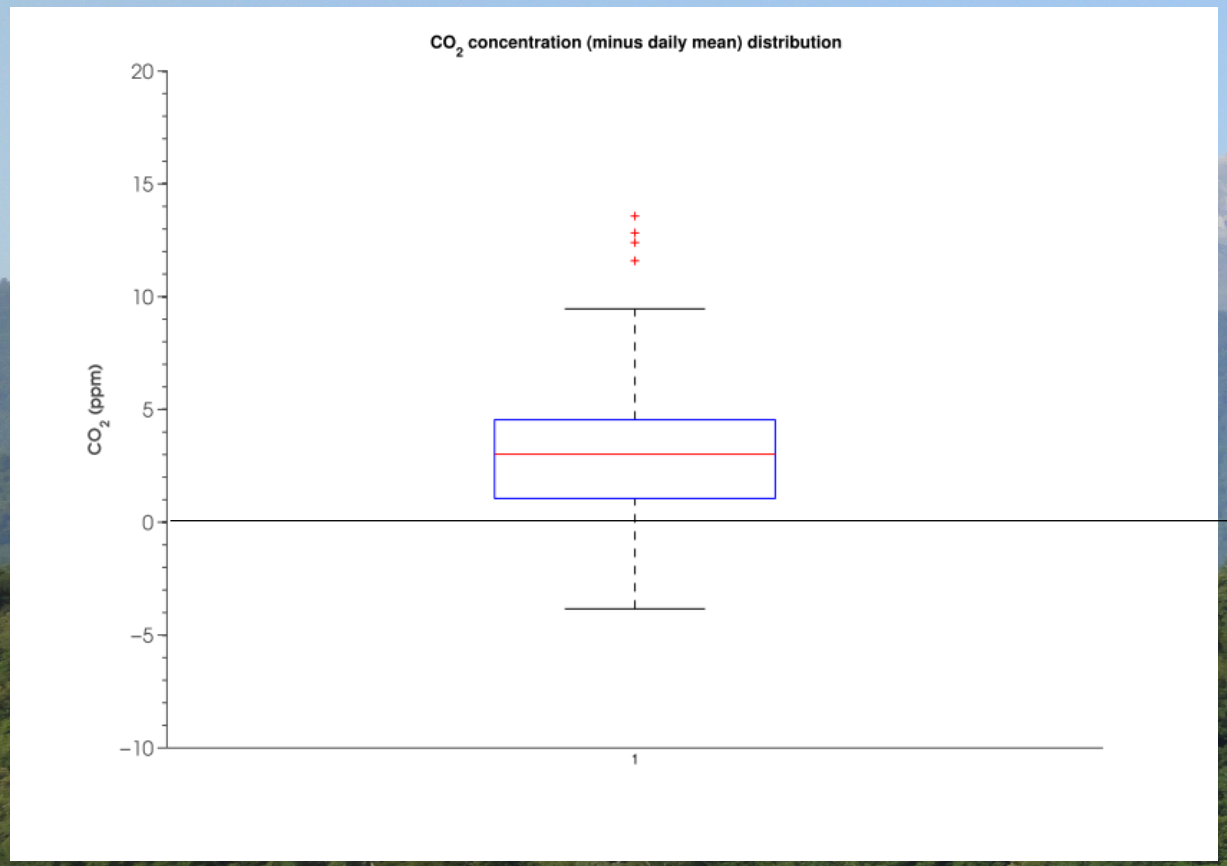
CO_2 jump and kat. onset



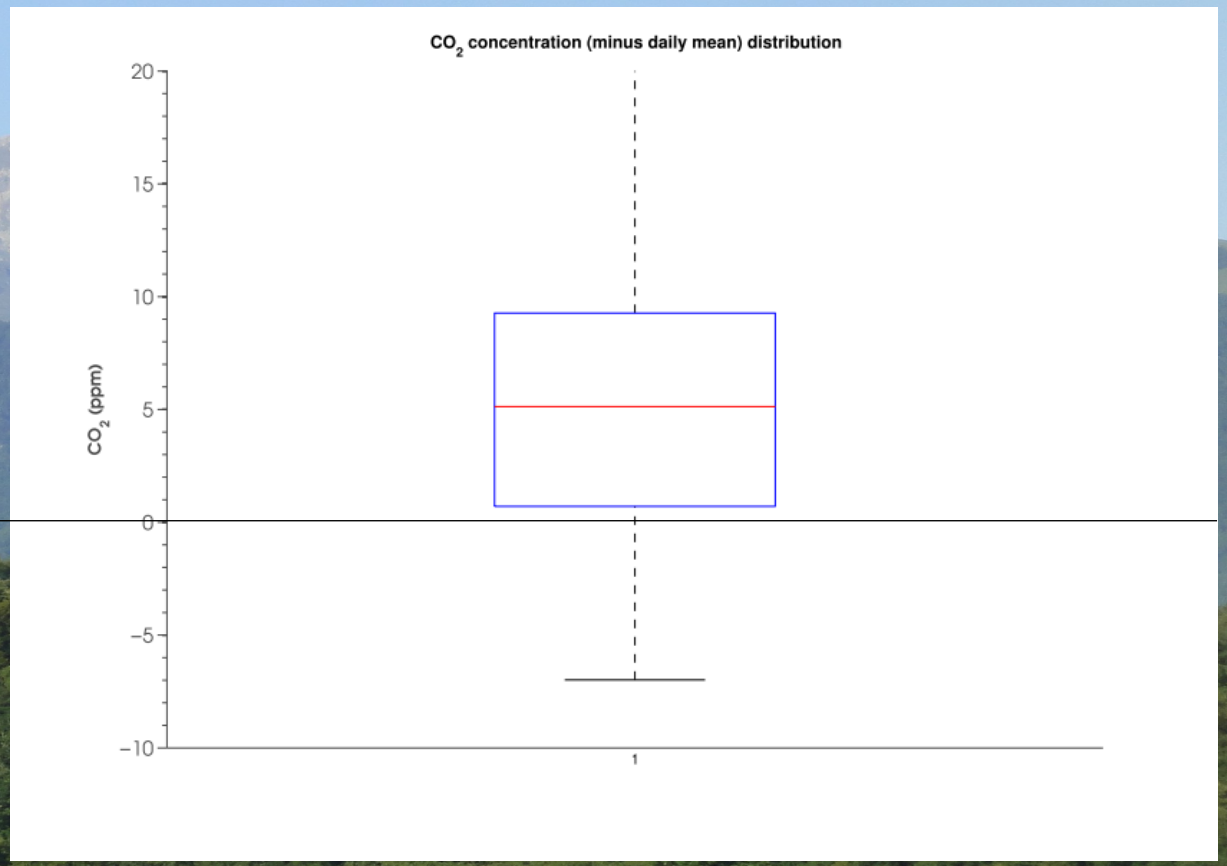
CO_2 analysis

Mean CO_2 concentration during katabatics events

LA Herrería



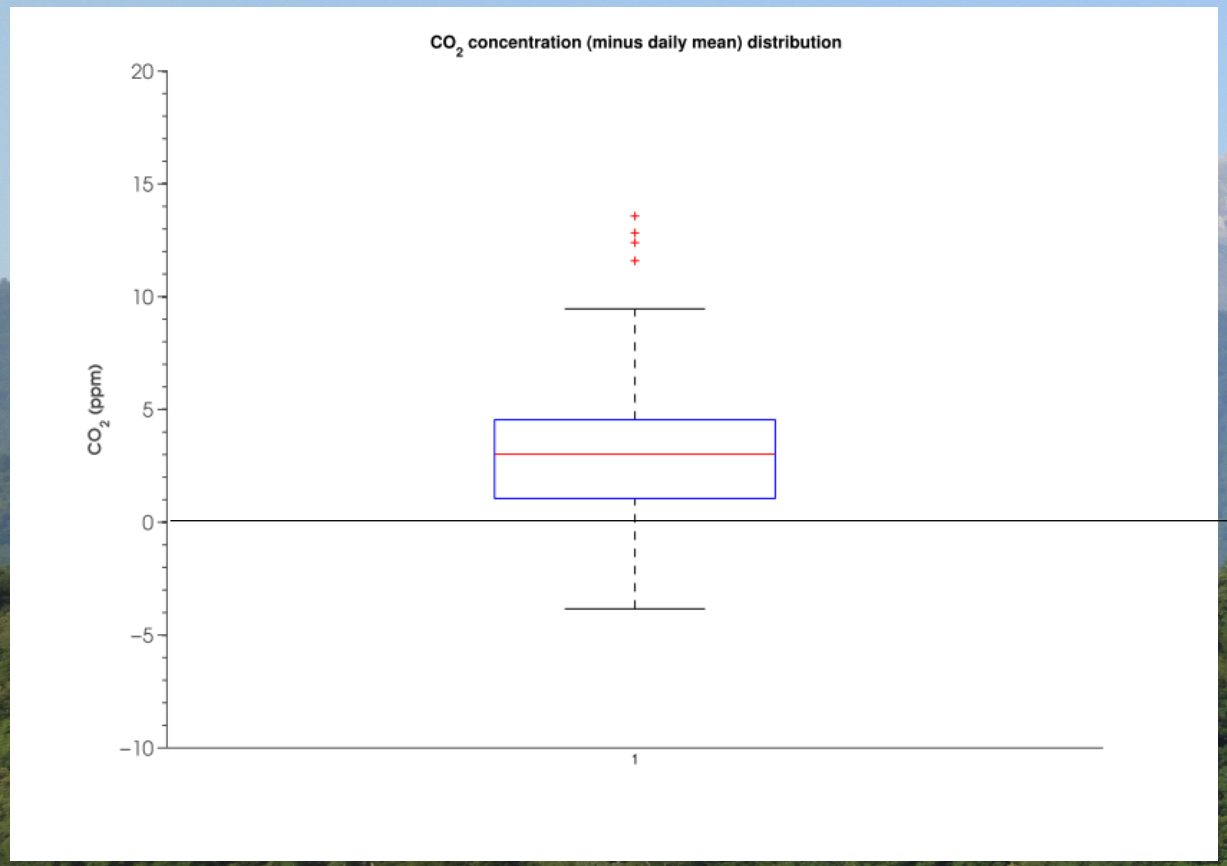
Salt Lake Valley



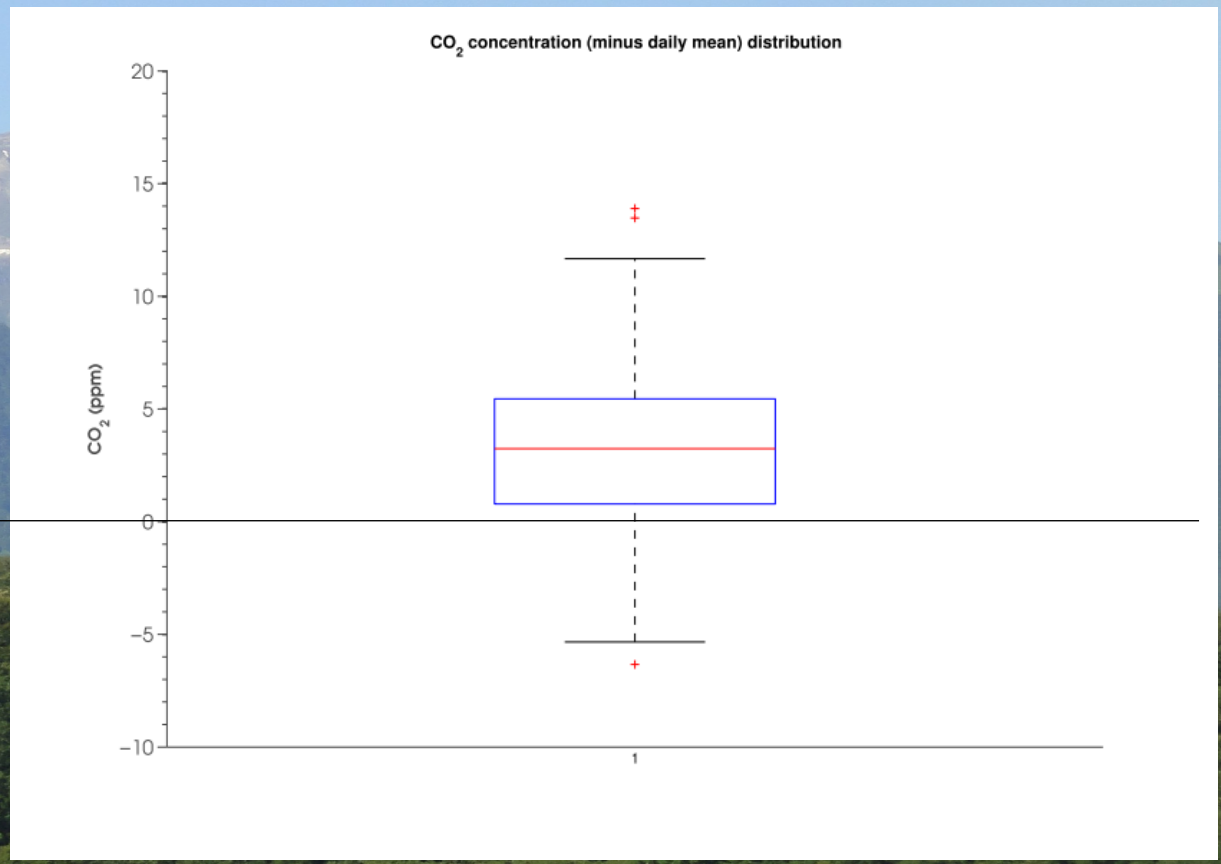
CO_2 analysis

Mean CO_2 concentration during katabatics events

LA Herrería

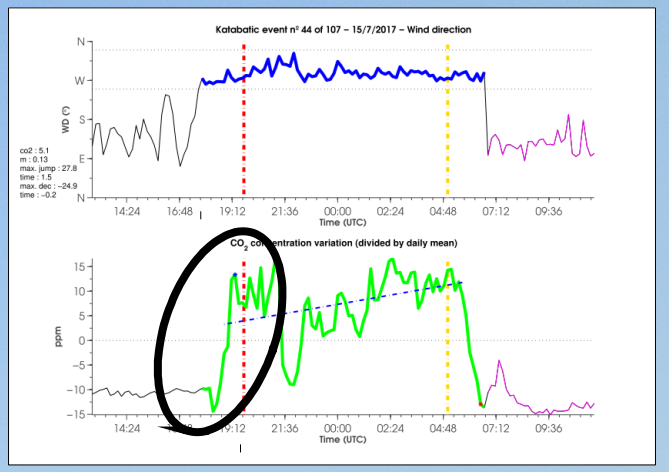


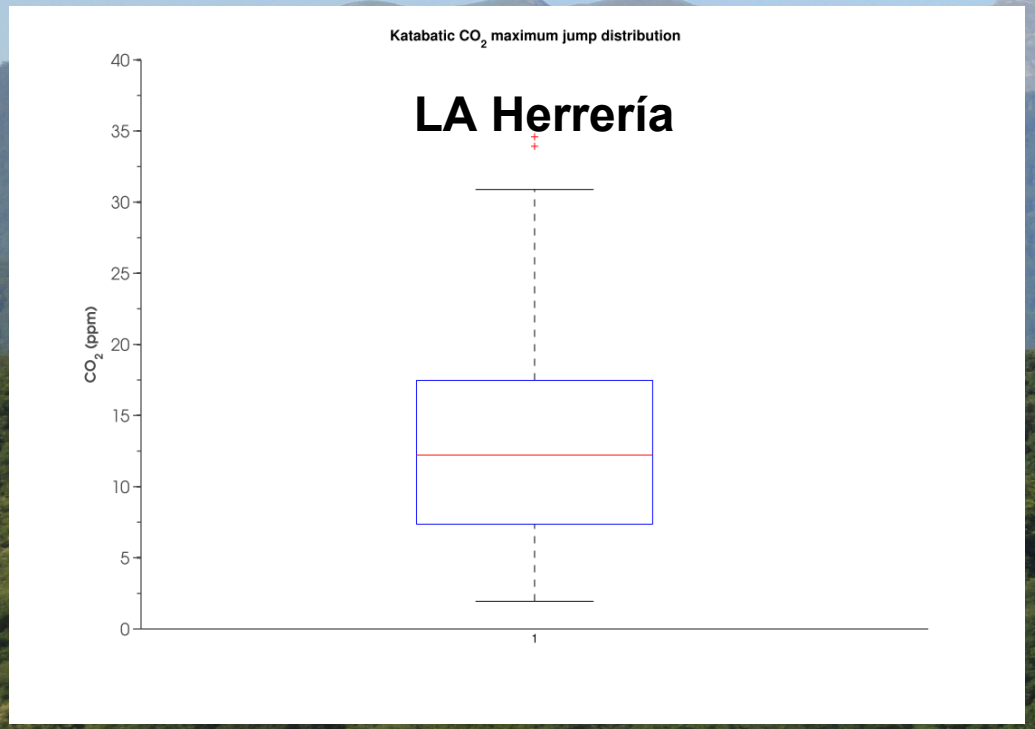
CRA

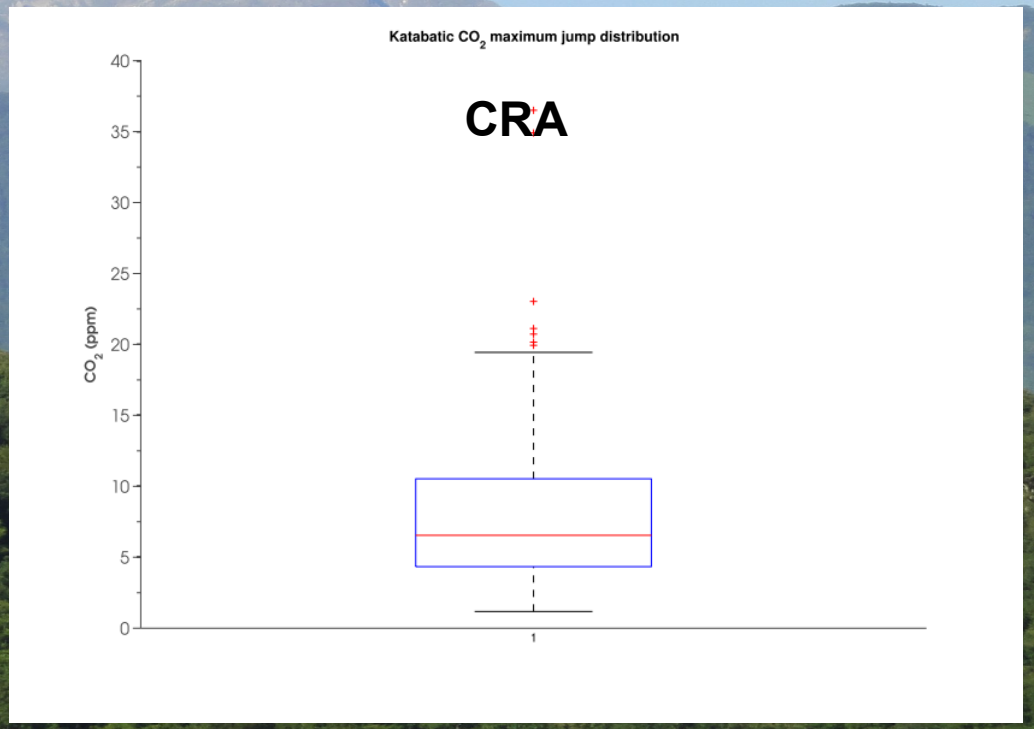


CO_2 analysis

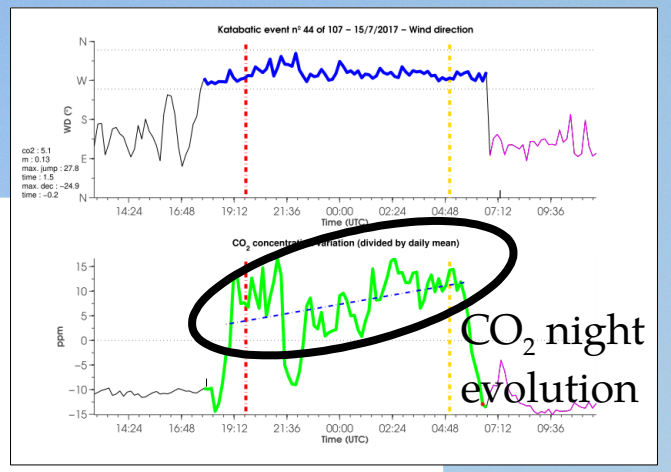
CO_2 jump distribution







CO_2 analysis

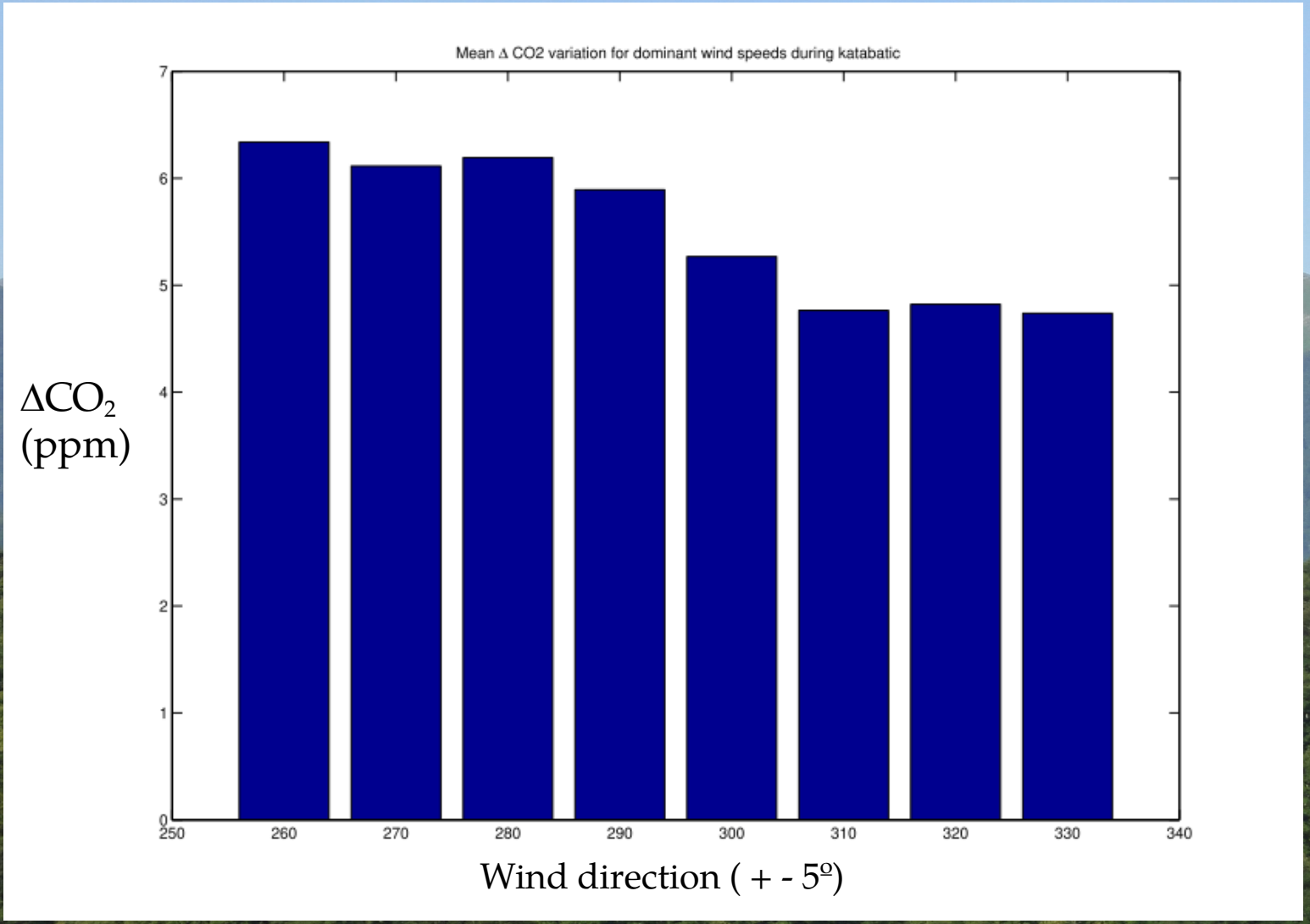


CO_2 analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

HOW THE WIND DIRECTION IS INFLUENCING THE CO_2 CONCENTRATION?

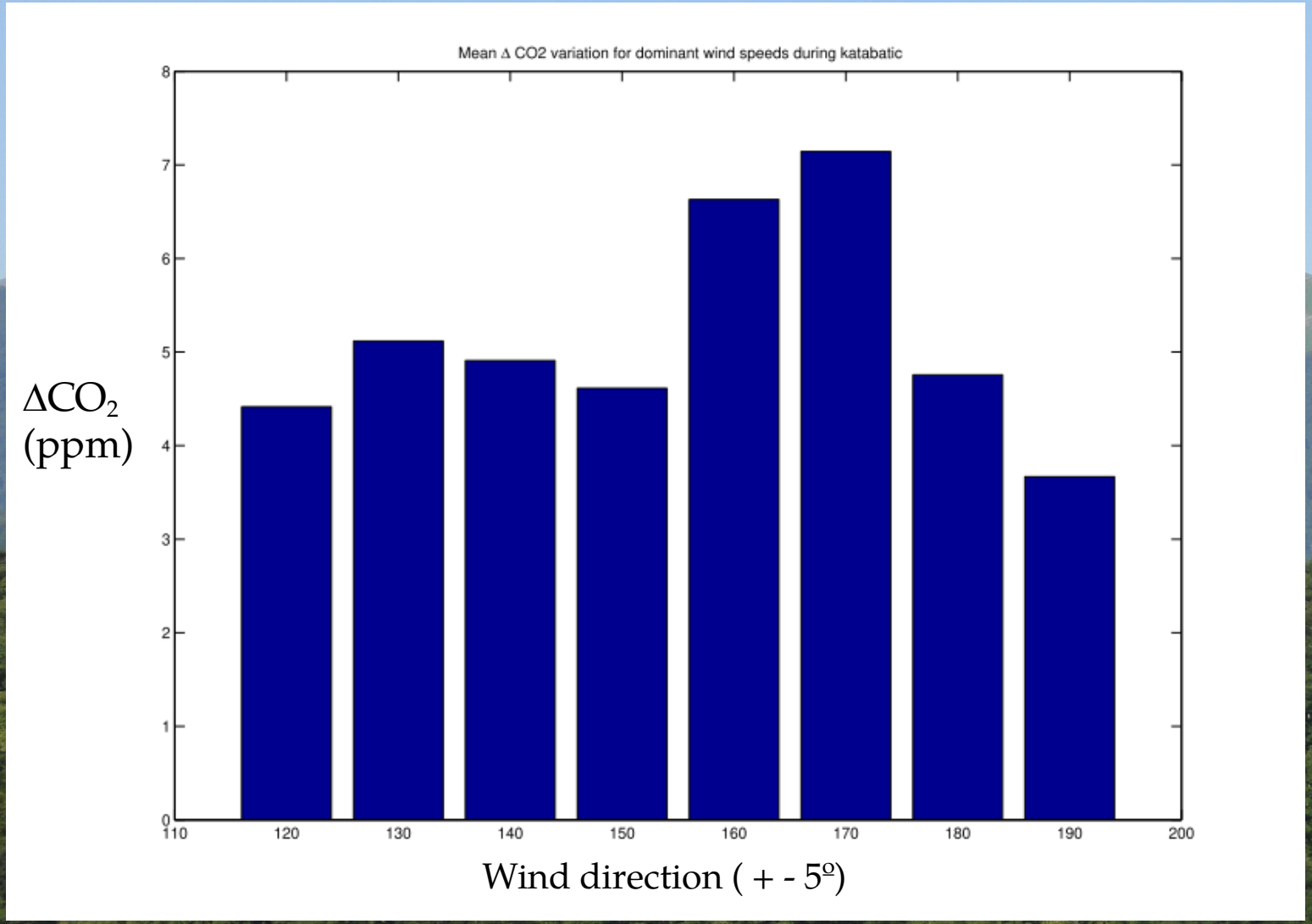
LA Herrería



CO_2 analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

HOW THE WIND DIRECTION IS INFLUENCING THE CO_2 CONCENTRATION? **CRA**

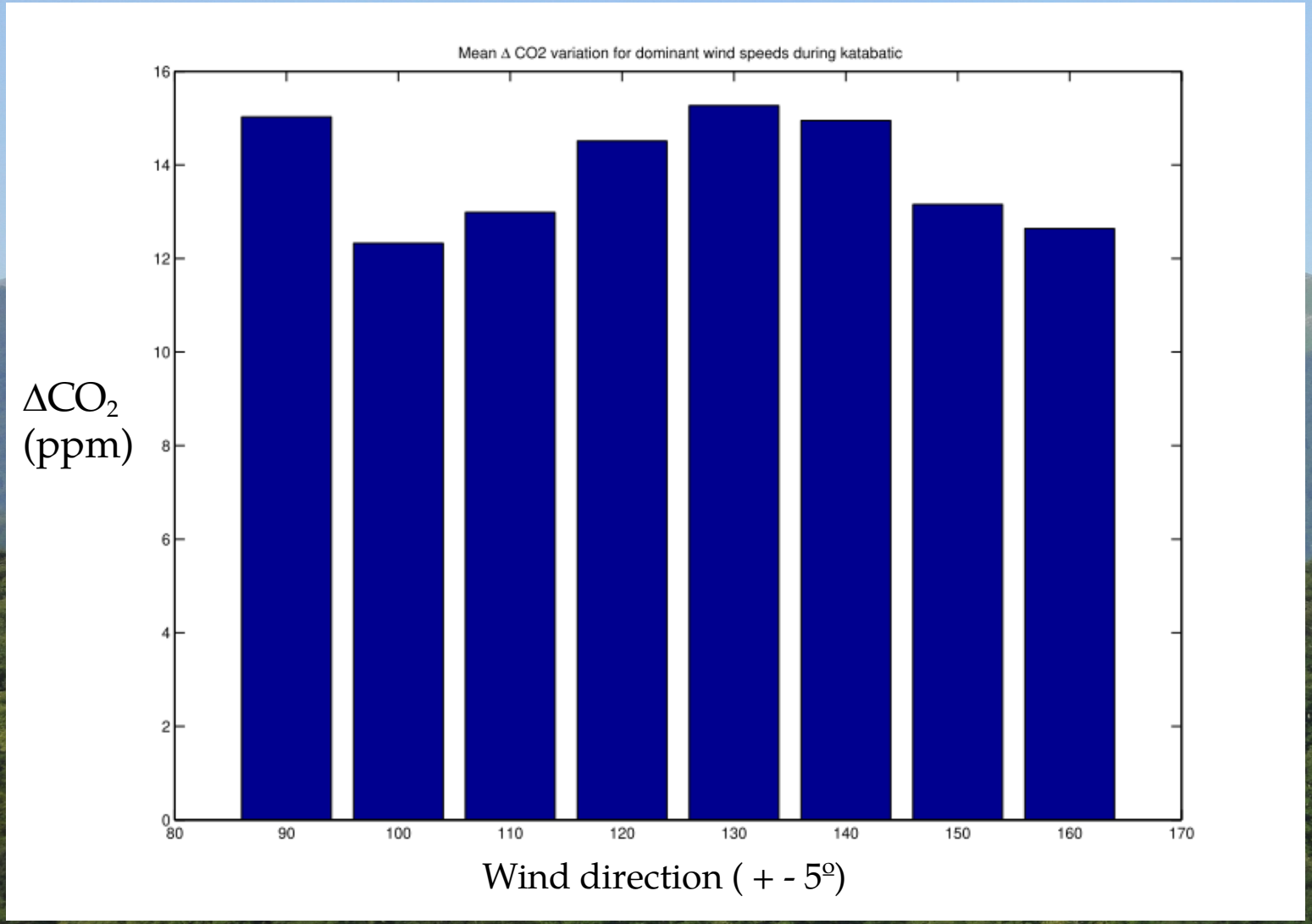


CO_2 analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

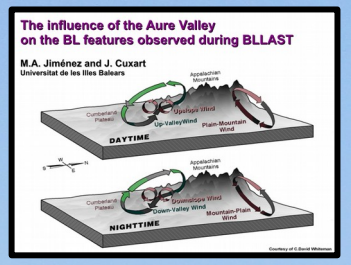
HOW THE WIND DIRECTION IS INFLUENCING THE CO_2 CONCENTRATION? **SLC**

Still preliminary
Needs to be analyzed and discussed.



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!

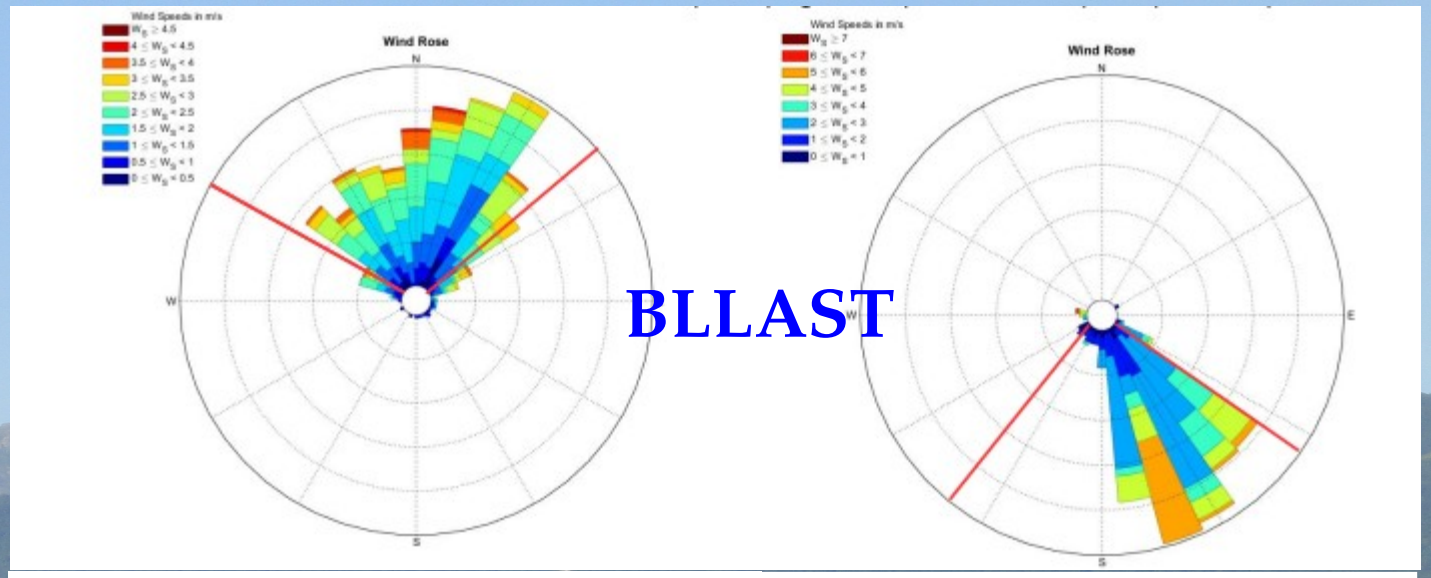
BLLAST. CO2 over different surfaces

BLLAST campaign statistics

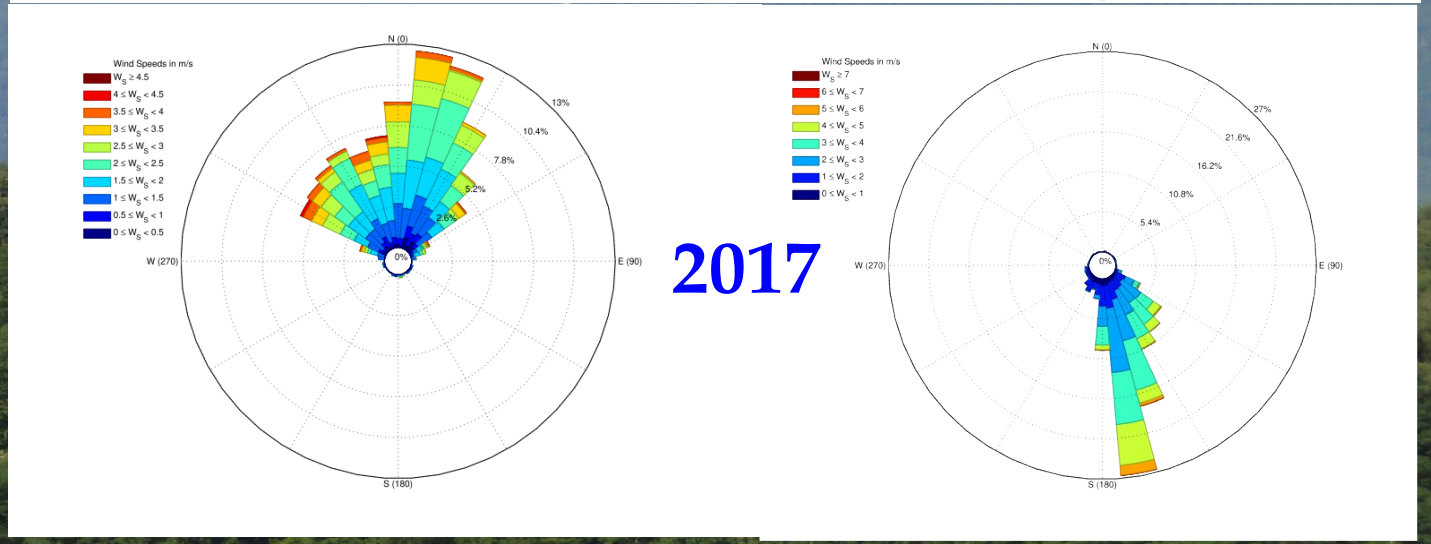
	Ana.	Phase transition post-cata.	Cata.	Phase transition post-ana.
Nombre d'événements	11	5	8	3
Horaire début (UTC)	9h13	19h41	20h02	8h28
Horaire fin (UTC)	18h41	20h53	09h01	8h51
Durée (h)	9h29	1h10	9,78	0h23
Persistance (%)	87,21	-	87,76	-
VV moyenne (m/s)	1,84	0,75	2,74	0,95
DV moyenne (°N)	2,34	-	157,24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

ANABATICS

KATABATICS



BLLAST



2017

BLLAST. CO2 over different surfaces

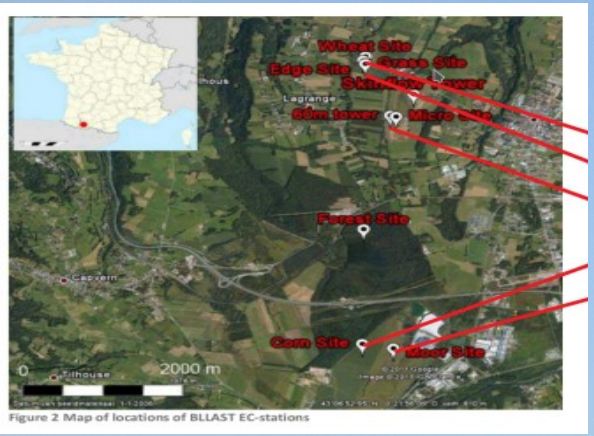
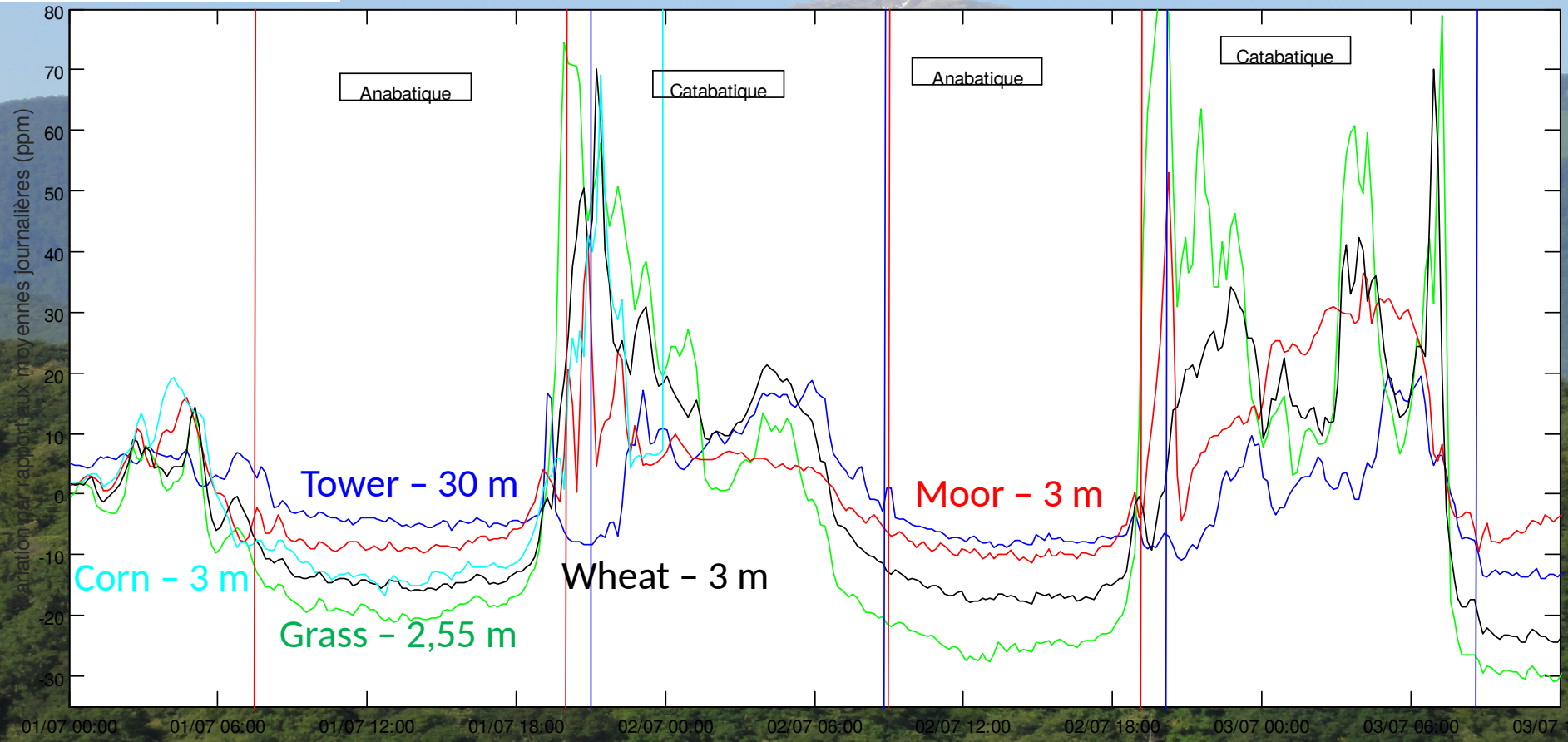


Figure 2 Map of locations of BLLAST EC-stations

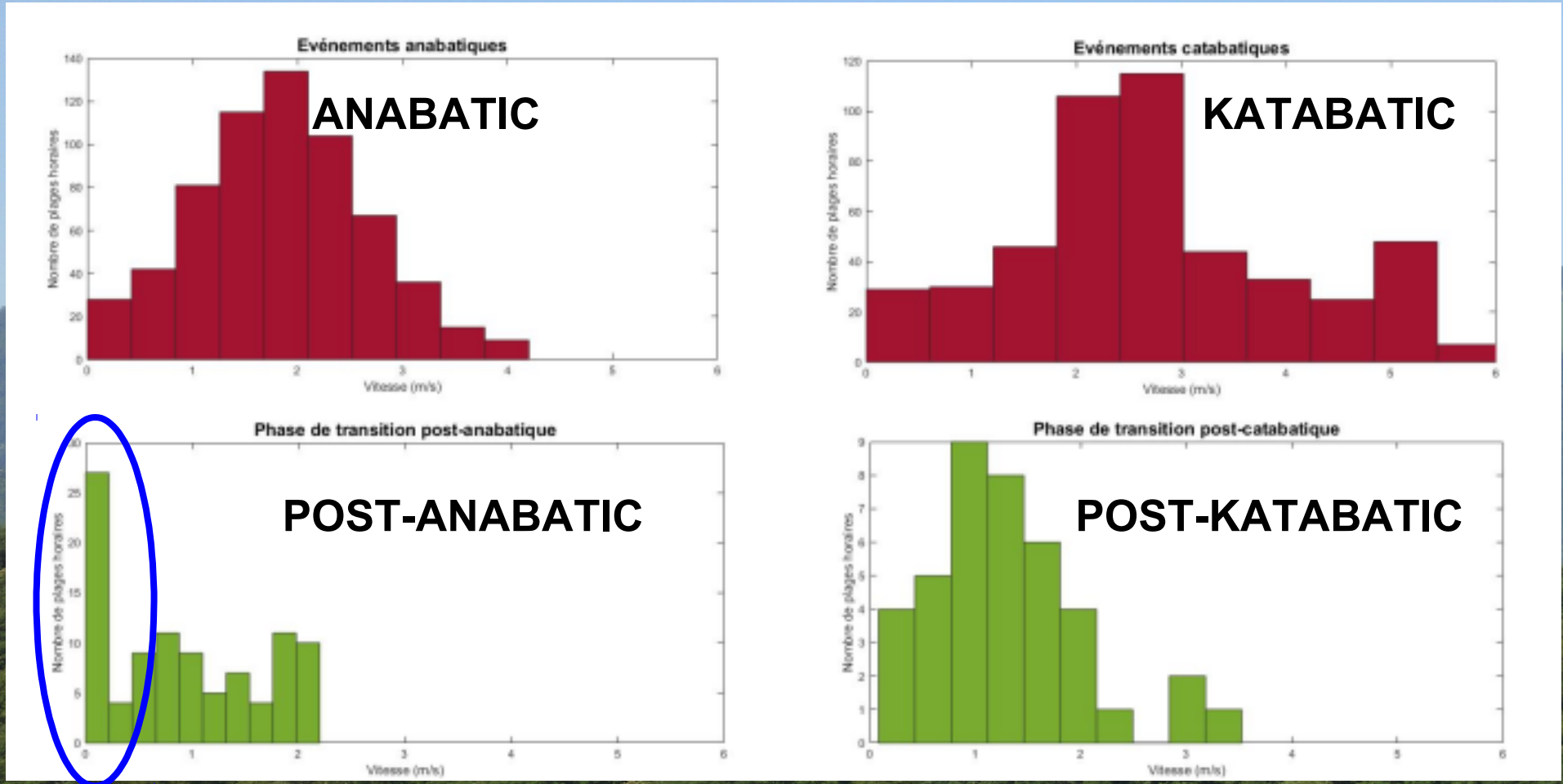
Wheat – 3 m
Grass – 2,55 m
Tower – 30 m
Moor – 3 m
Corn – 3 m
AVERAGE

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)**



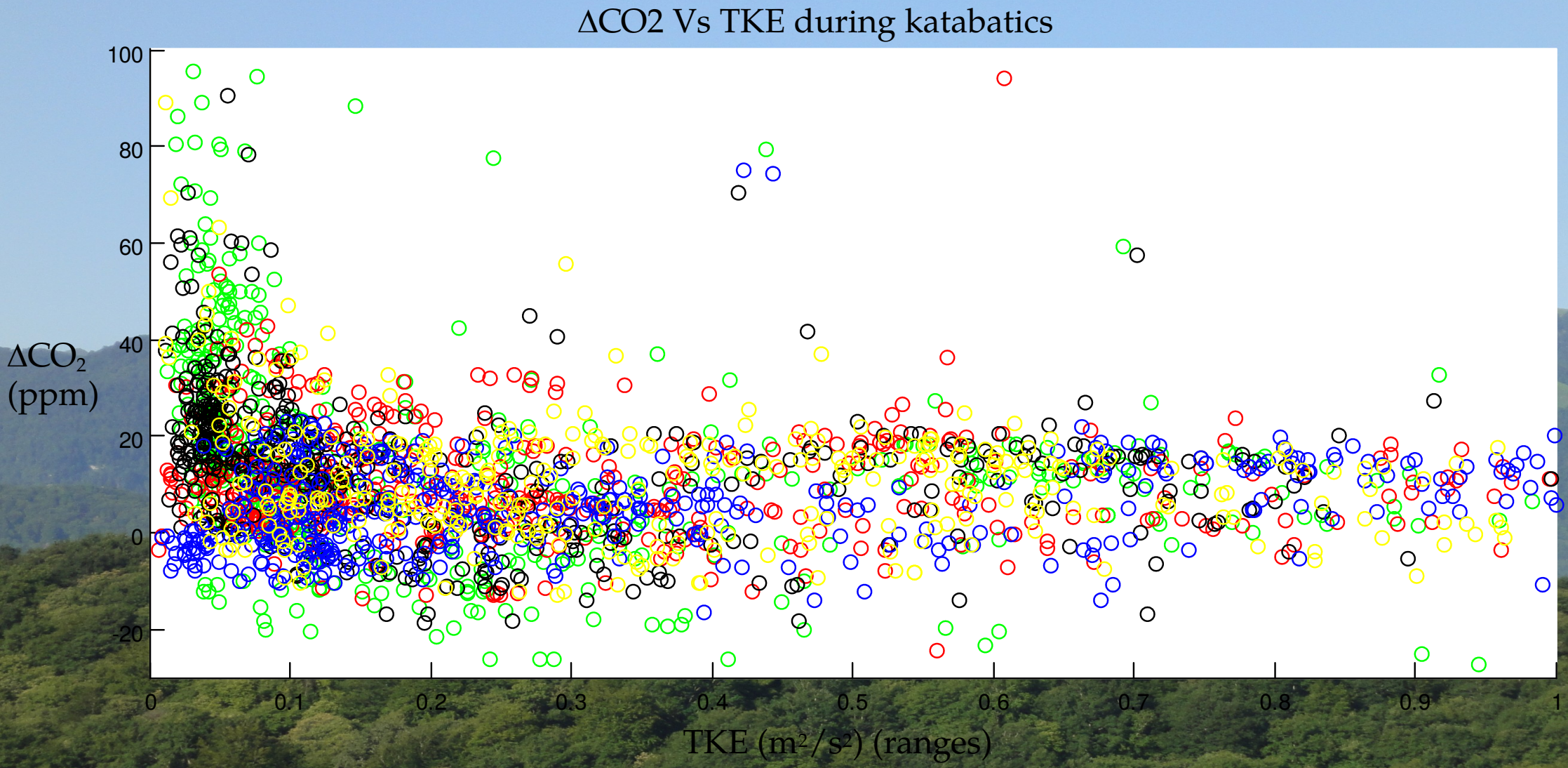
BLLAST. Katabatic and anabatic wind distributions

Wind distributions

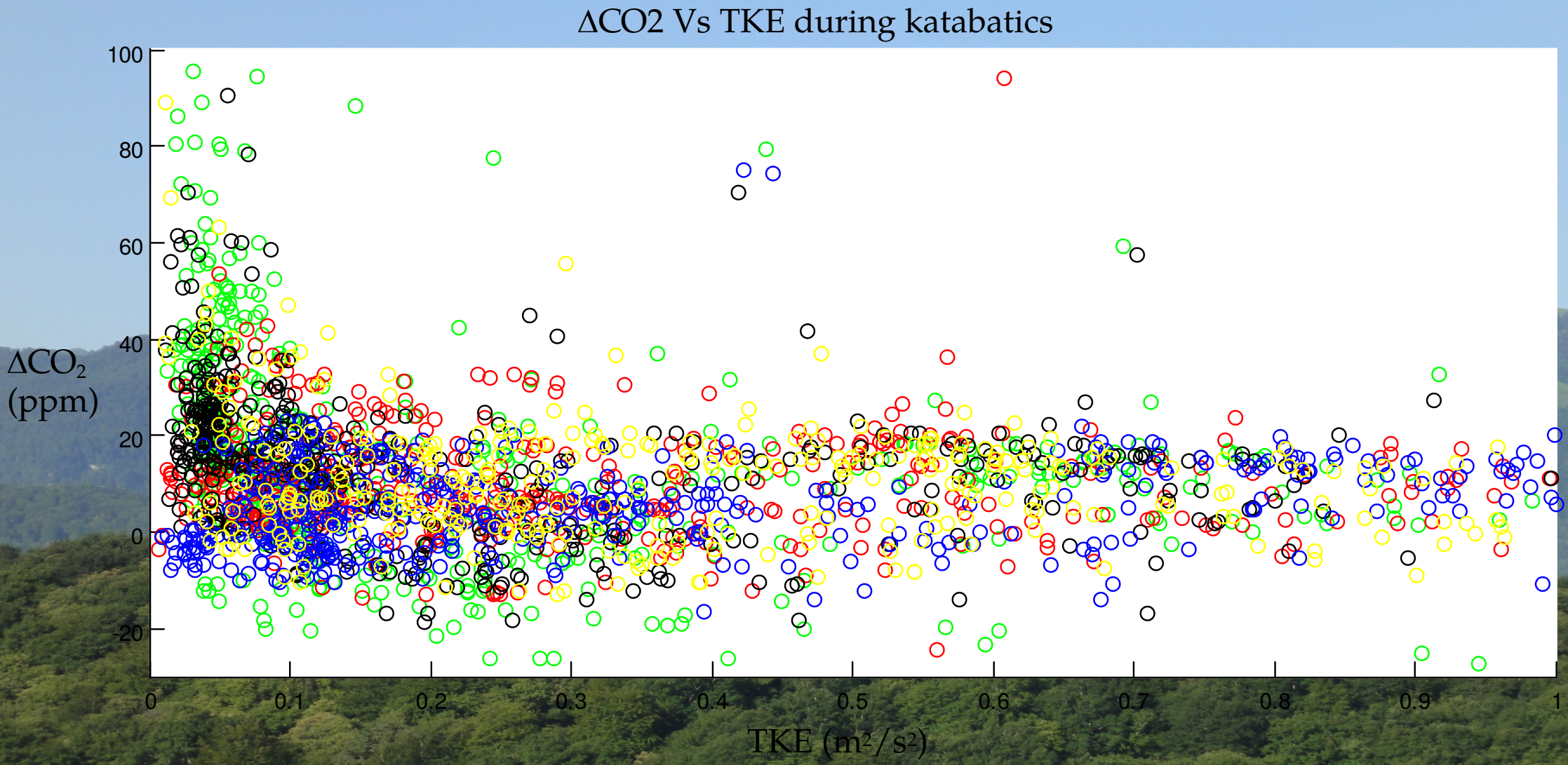


Interesting and particular period of transition, near-calm period, low turbulence… and high concentrations!

BLLAST. CO_2 over different surfaces



BLLAST. CO_2 over different surfaces

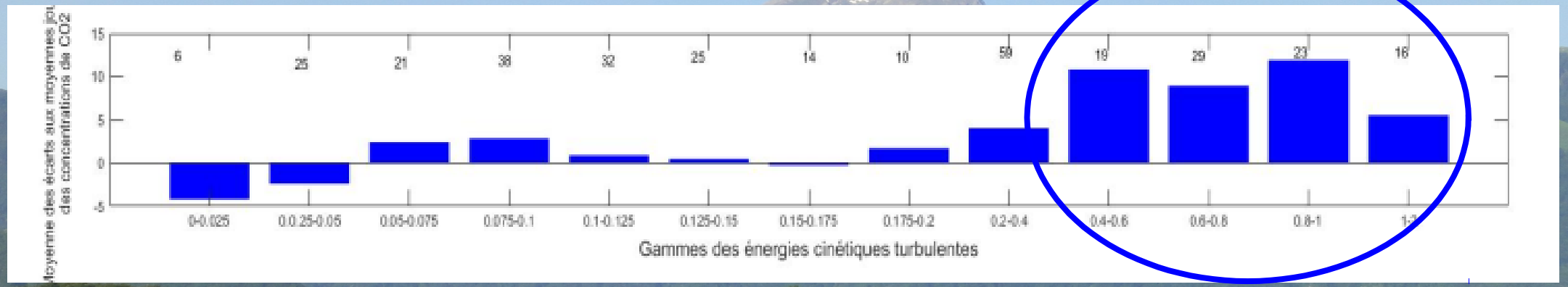


BUT THIS DOES NOT HAPPEN AT 30 M!!

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)

Conclusions

- A lot of statistics can be performed –> Many variables available in the same prepared matrix

- Deep analysis of results still pending More in BLT-AMS?

- CO_2 seems more linked to diurnal cycle of PBL height, turbulence and… biological activity?

- Difficult to study similar cases without mountain breezes (modelling?) CLASS?

- Pending to analyse effect of changes in fluxes (through changes in wind speed?)

- Pending to analyse q, LH

Picture taken close to La Herrería site, looking North.

Courtesy of J. A. Arrillaga and Carlos Yagüe

Thanks!