Analyzing features and impacts of mountain breezes at three different mountainous sites

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EMS
04 September 2018
Budapest

Project context and objectives

ATMOUNT II project

- **Obj. 1:** Characterization of mountain breezes
  - **- Guadarrama Mountains (Herrería) (Spain)**
  - - Pyrenees (France)
  - - Salt Lake Valley (US)
- **Obj. 2:** Impacts of mountain breezes in CO_2 (micro-mesoscale interactions)

Mountain breezes detection

* Based on criteria in Arrillaga et al. 2018 (QJRMS)

DETECTION ALGORITHM*

LA HERRERIA (Guadarrama Mountains)

(2017 Example)

- **<u>LARGE SCALE</u>: Synoptic conditions** - NCEP: u, v, T, RH

			→ 365 days analised
- Filter 1: Wind at 700 hPa	<	9-10 m/s	→ 201 days pass Filter 1
- Filter 2: Fronts passage; $\Delta\theta_e$	>	-1.45 K/6 hours	→ 193 days pass Filter 1 and 2
- Filter 3: Rainfall	<	0.2 mm/day	→ 188 days pass Filter 1, 2 and 3

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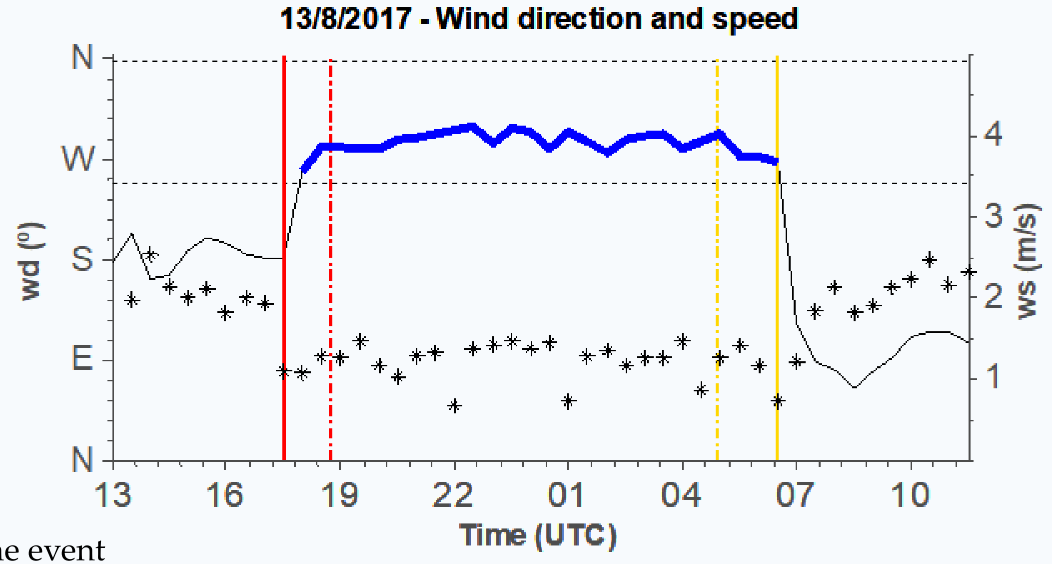
- **SMALL SCALE: Local conditions** - Wind Direction (WD) from tower

  - Ranges of WD for down (nighttime) / up (daytime) events
  - WD persistence (80% of event) in the appropriate range → **177 nighttime & 136 daytime events**
  - Minimum duration of events (3 hours min)

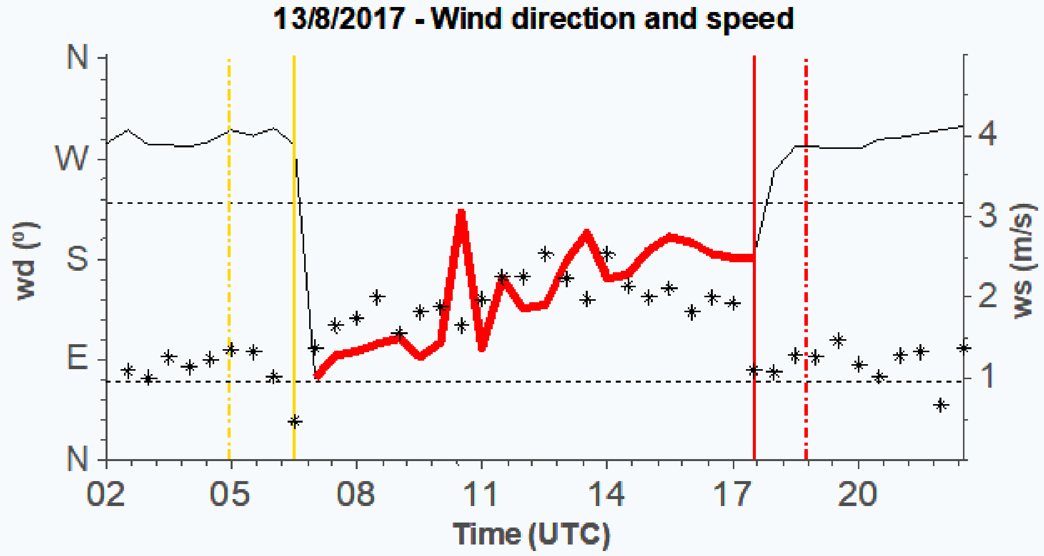
Mountain breezes events (examples)

Guadarrama example

Nighttime event



Daytime event

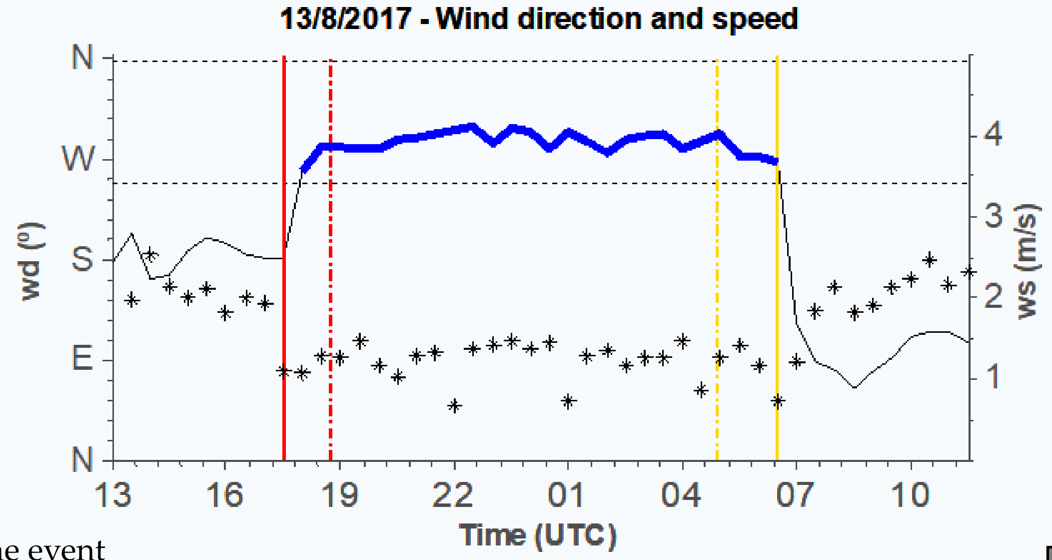


wd
Nighttime event
Daytime event
* ws
SH sign change (+ to -) (- to +)
Sunset / Sunrise

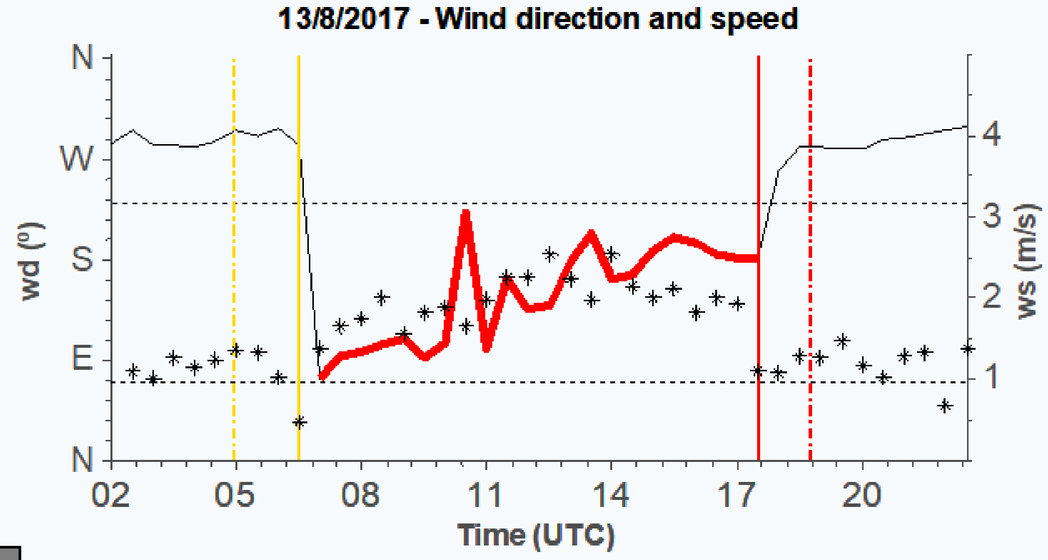
Mountain breezes events (examples)

Guadarrama example

Nighttime event



Daytime event



— wd
Nighttime event
Daytime event
* ws
SH sign change (+ to -) (- to +)
Sunset / Sunrise

With all events…

Mountain breezes statistics

Timing / duration of events.

Wind speed & Wind direction (mean and variability).

Impacts on → greenhouse gases concentration, fluxes, turbulence and stability…

La Herrería (Guadarrama) - HER

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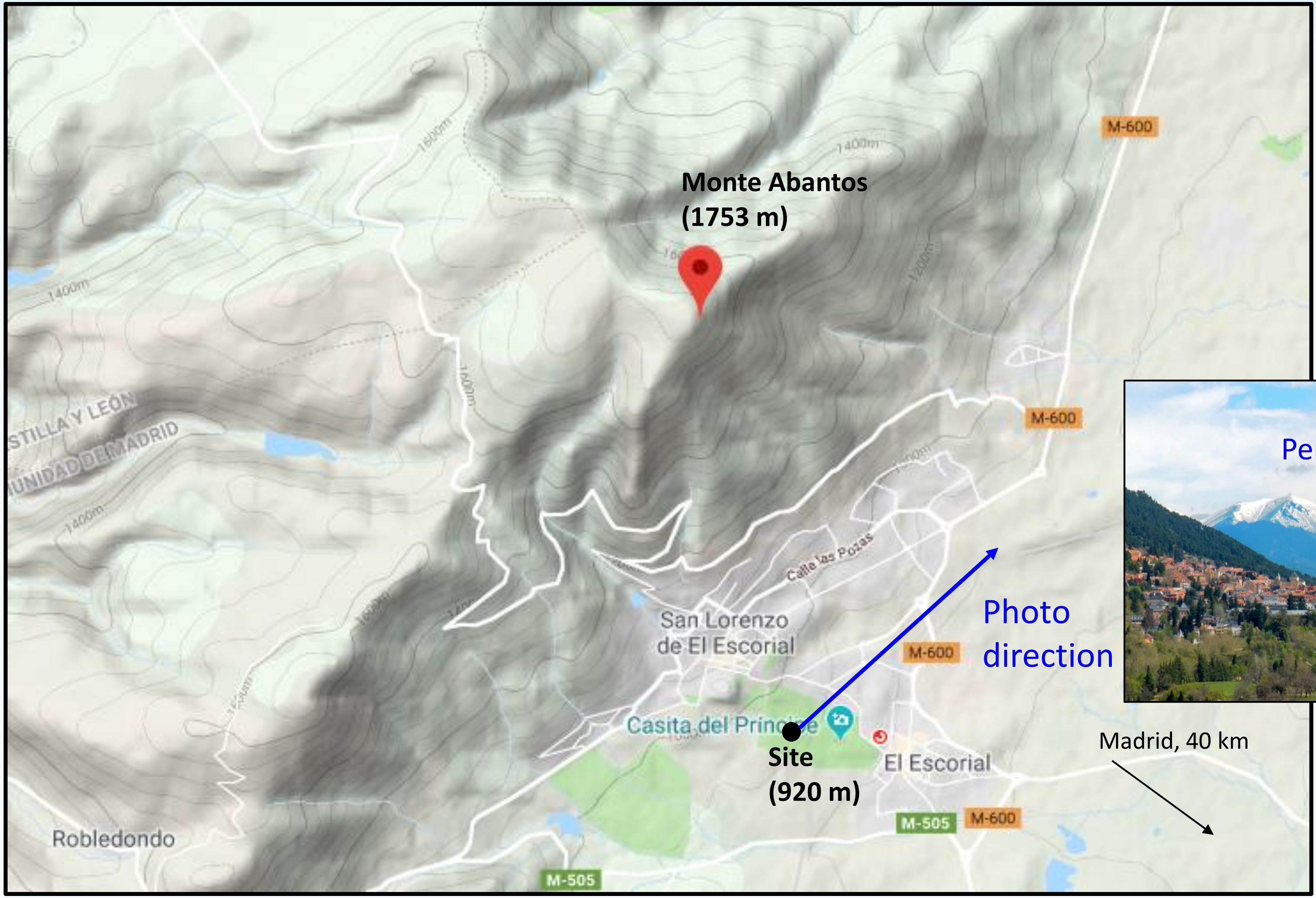
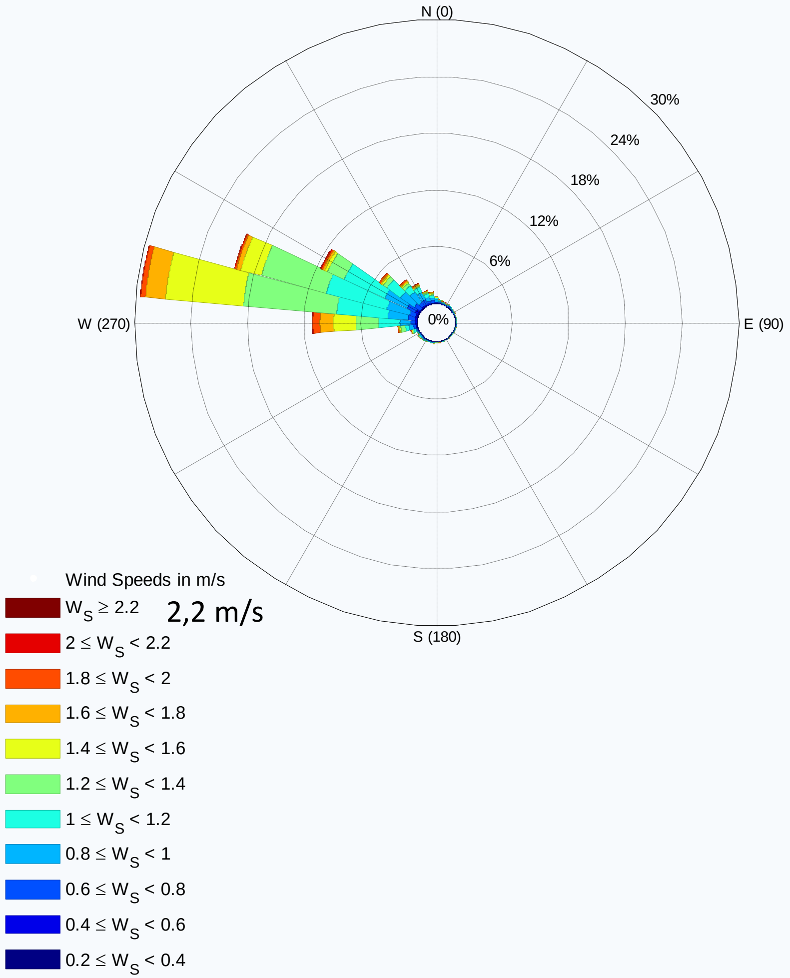
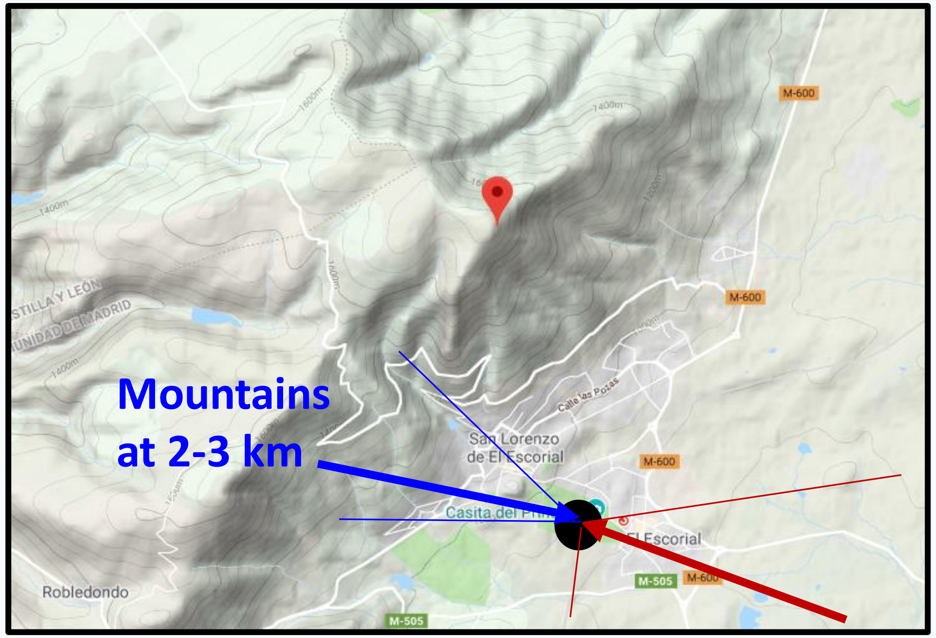


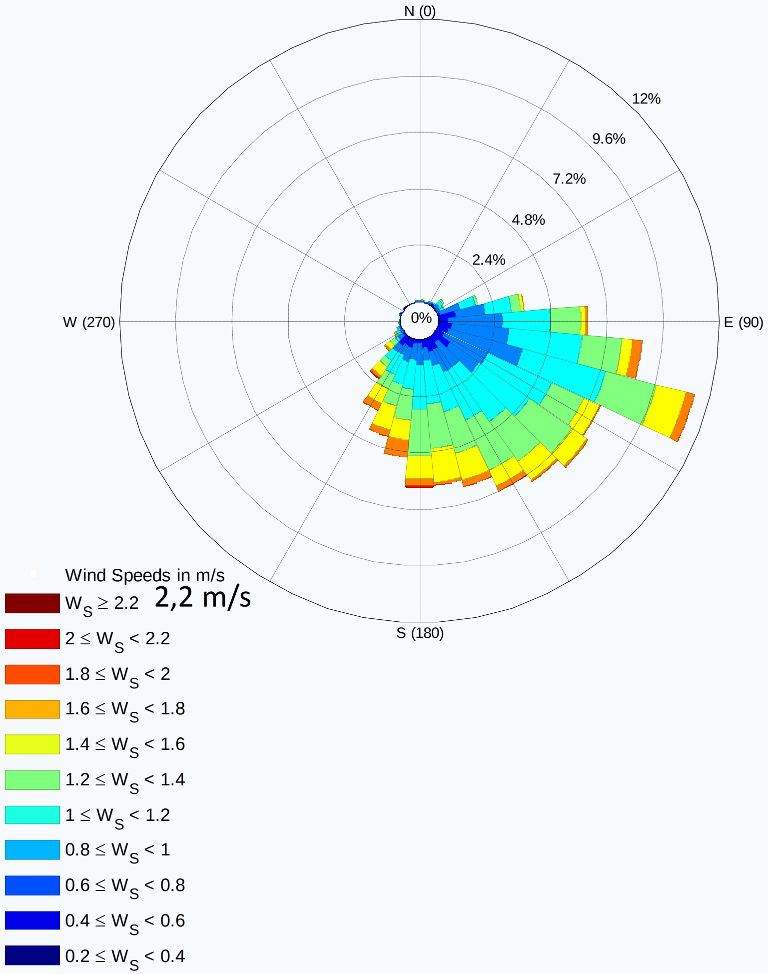
La Herrería (Guadarrama) - HER

Downslope





Upslope



EVENTS NUMBERS:

365 days analysed

177 downslope

136 upslope

CRA (Pyrenees)

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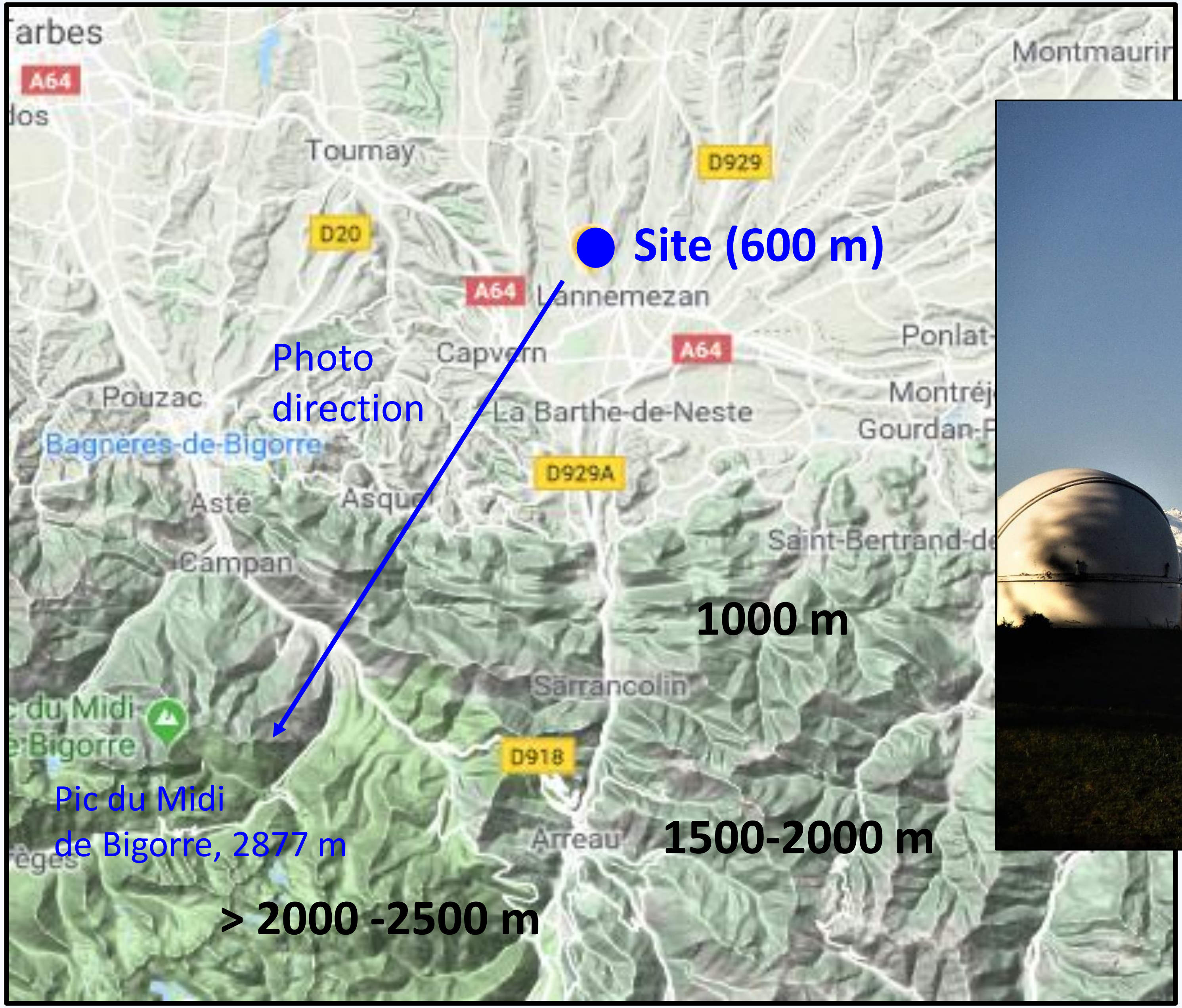
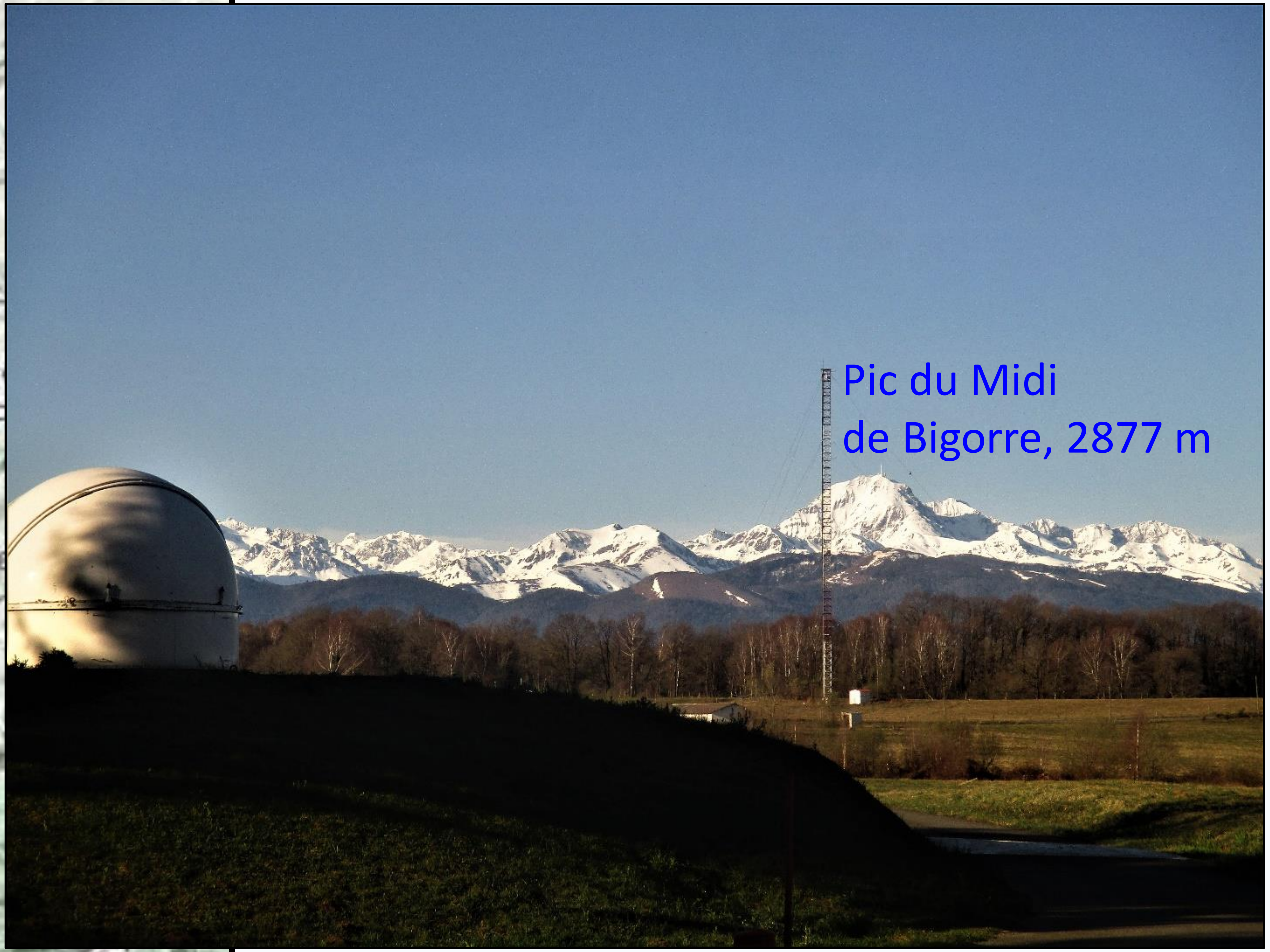
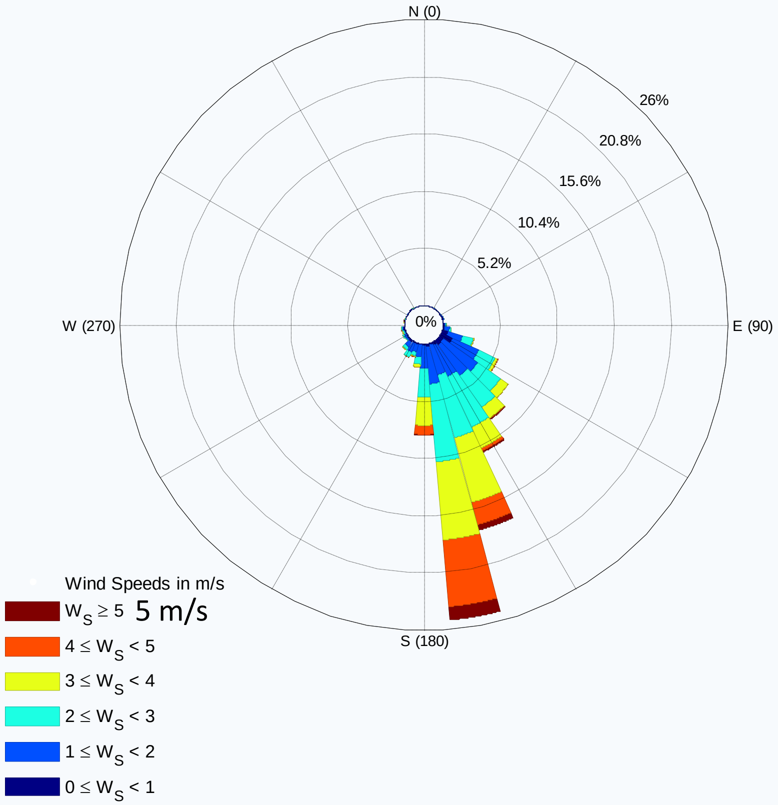
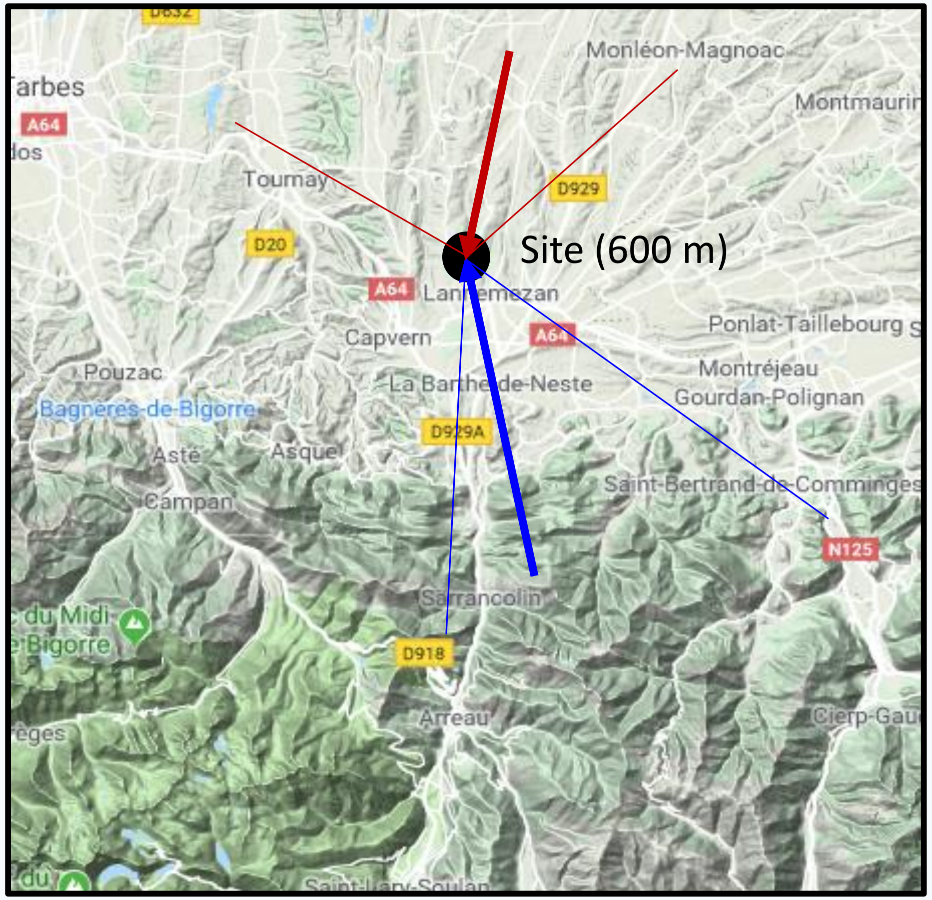




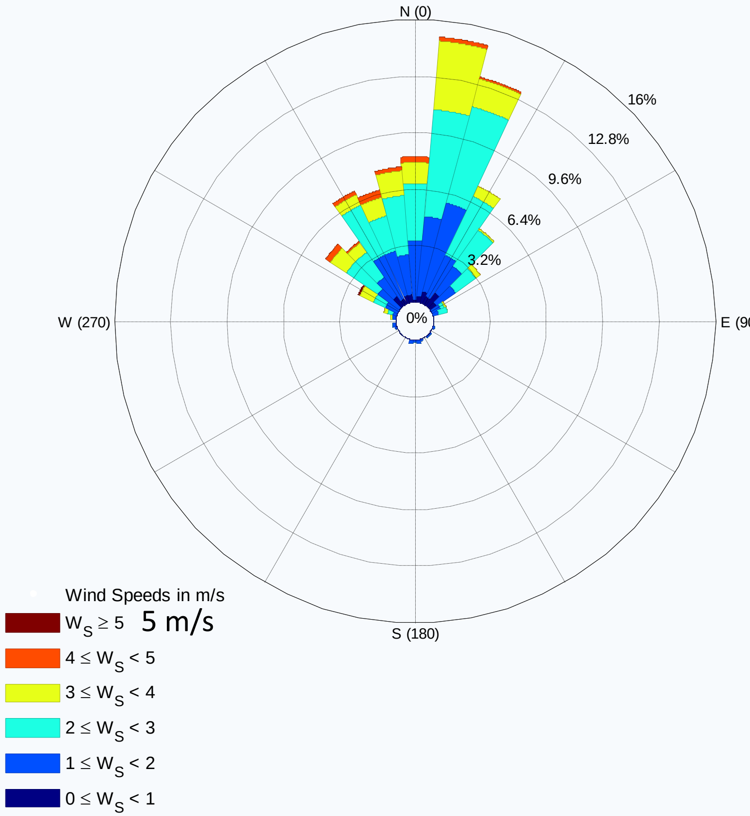
CRA (Pyrenees)

Downslope





Upslope



EVENTS NUMBERS:

365 days analysed

112 downslope

56 upslope

Salt Lake Valley (Rocky Mountains) - SLV

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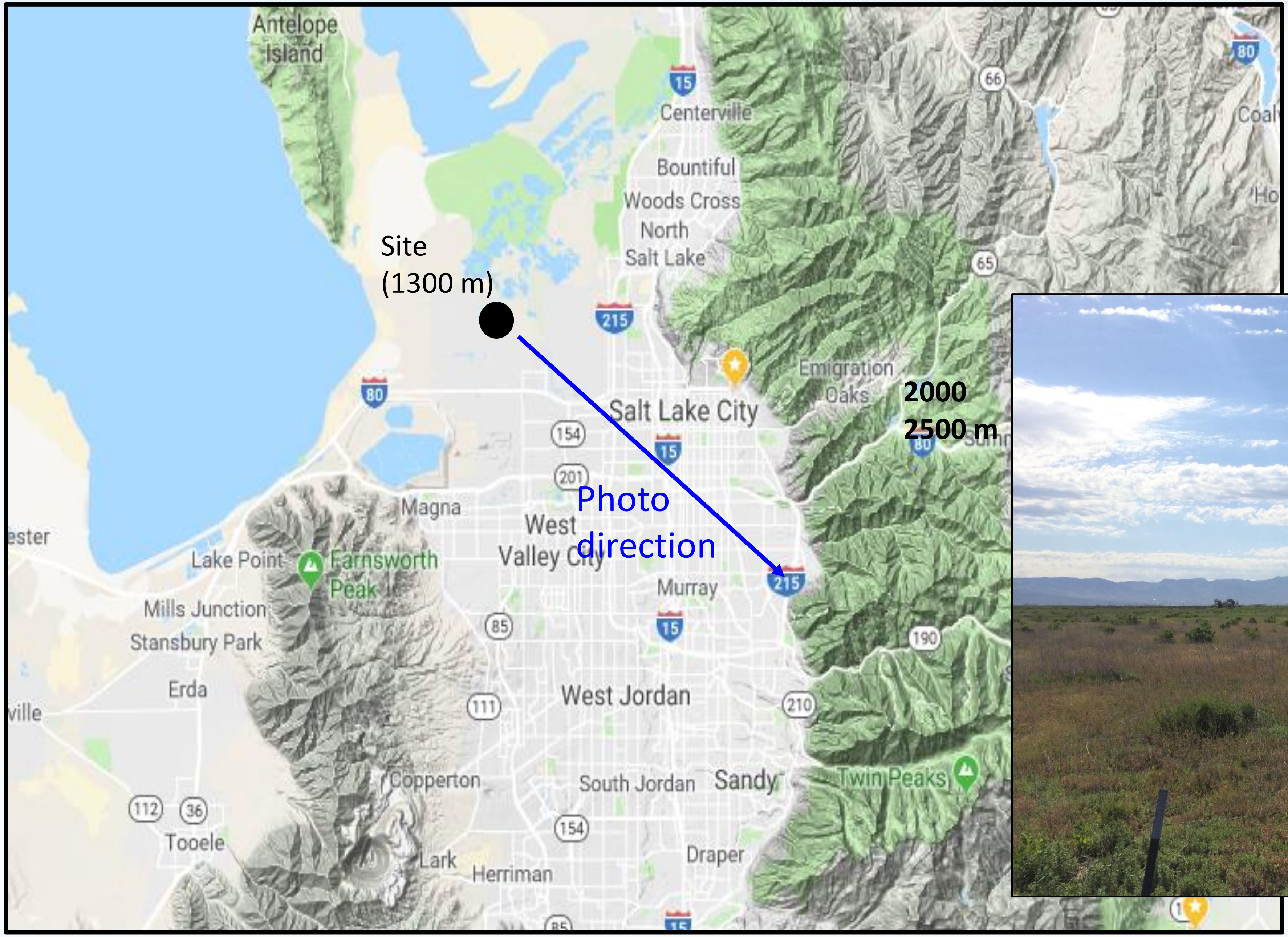
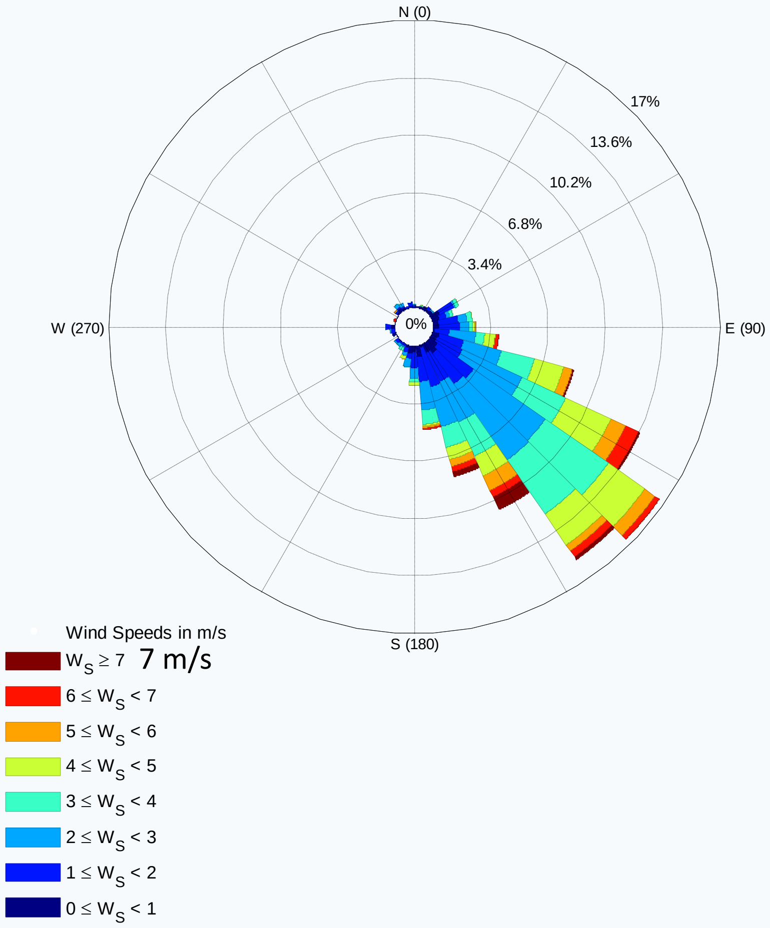
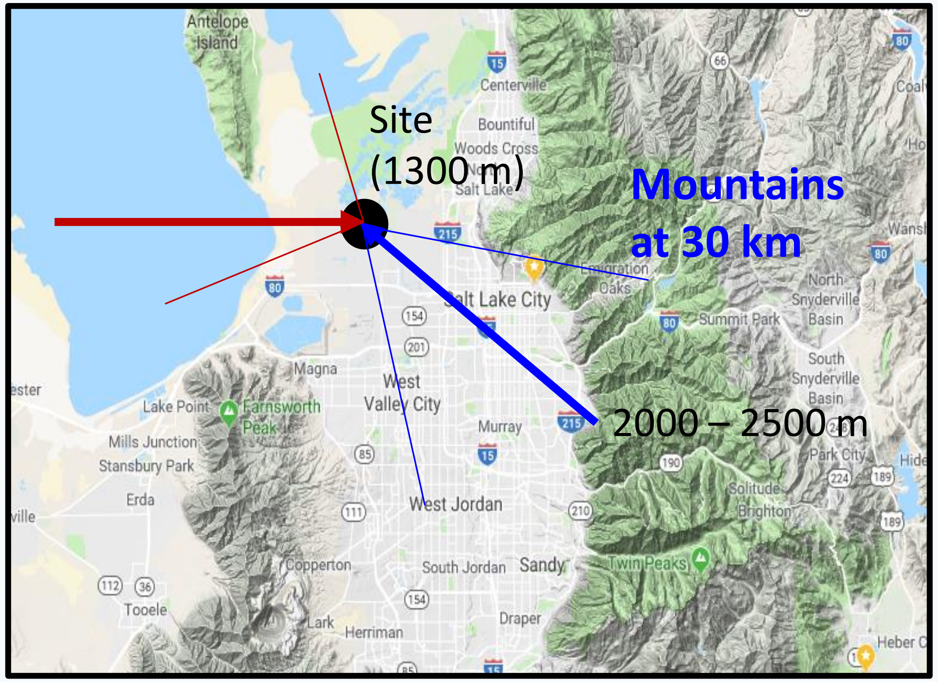


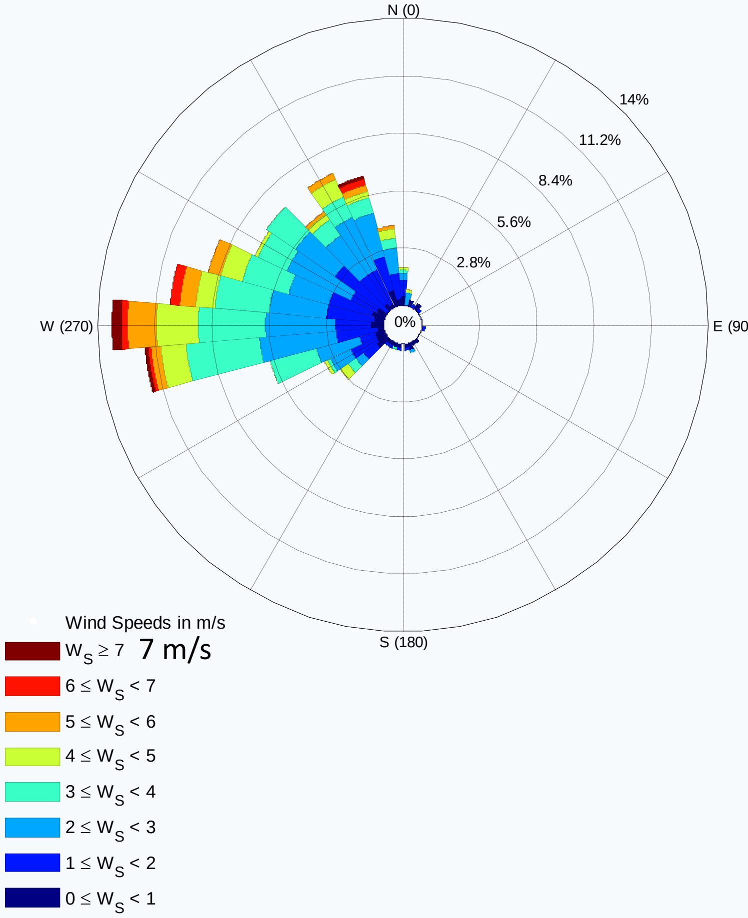
Salt Lake Valley (Rocky Mountains) – SLV

Downslope





Upslope



EVENTS NUMBERS:

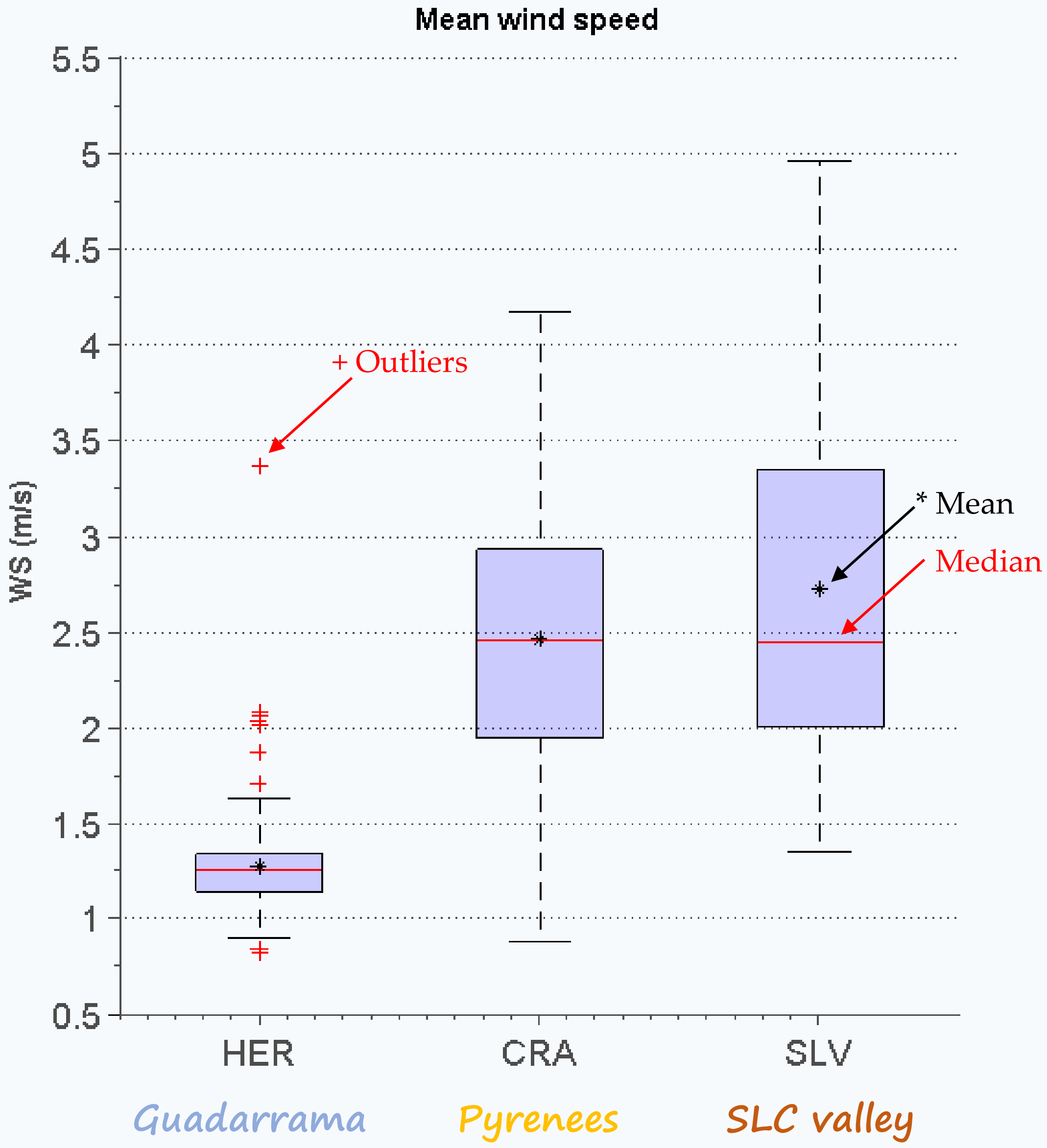
201 days analysed

30 downslope

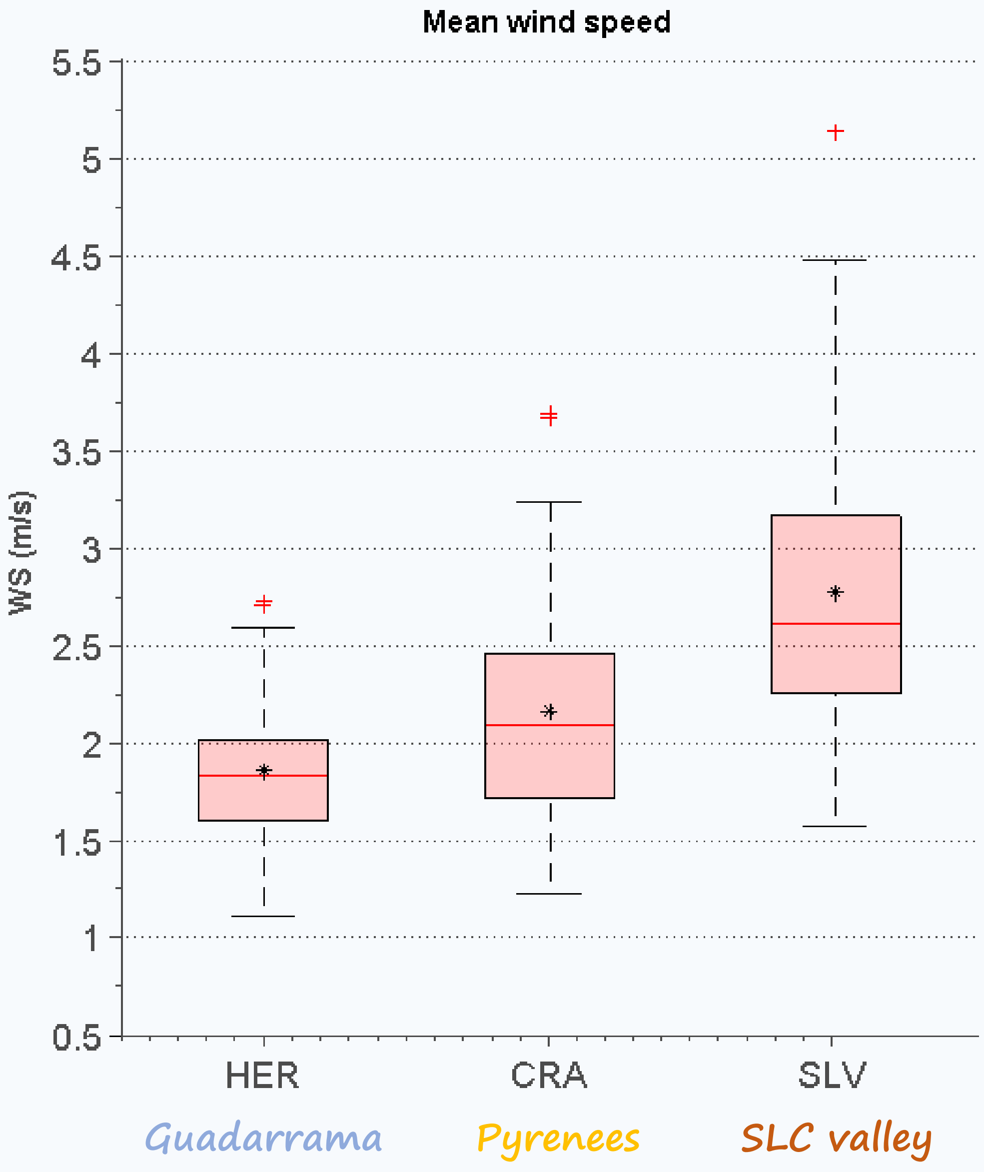
31 upslope

Mean WIND SPEED

Nighttime events



Daytime events

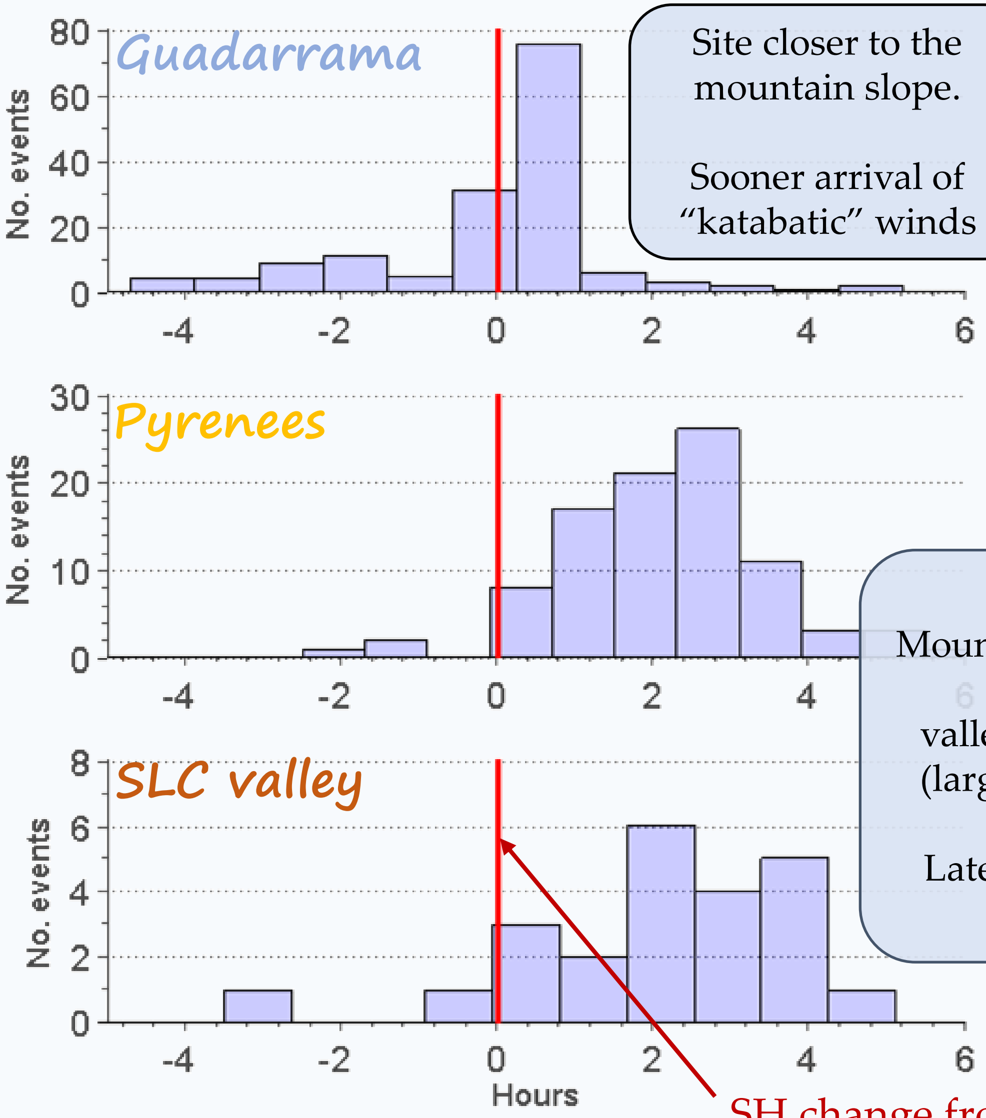


Mountain breezes arrival time (regarding sunset)

Nighttime events

Daytime events

Number of events



Site closer to the mountain slope.

Sooner arrival of "katabatic" winds

Mountain-plain and valley winds (larger scale)

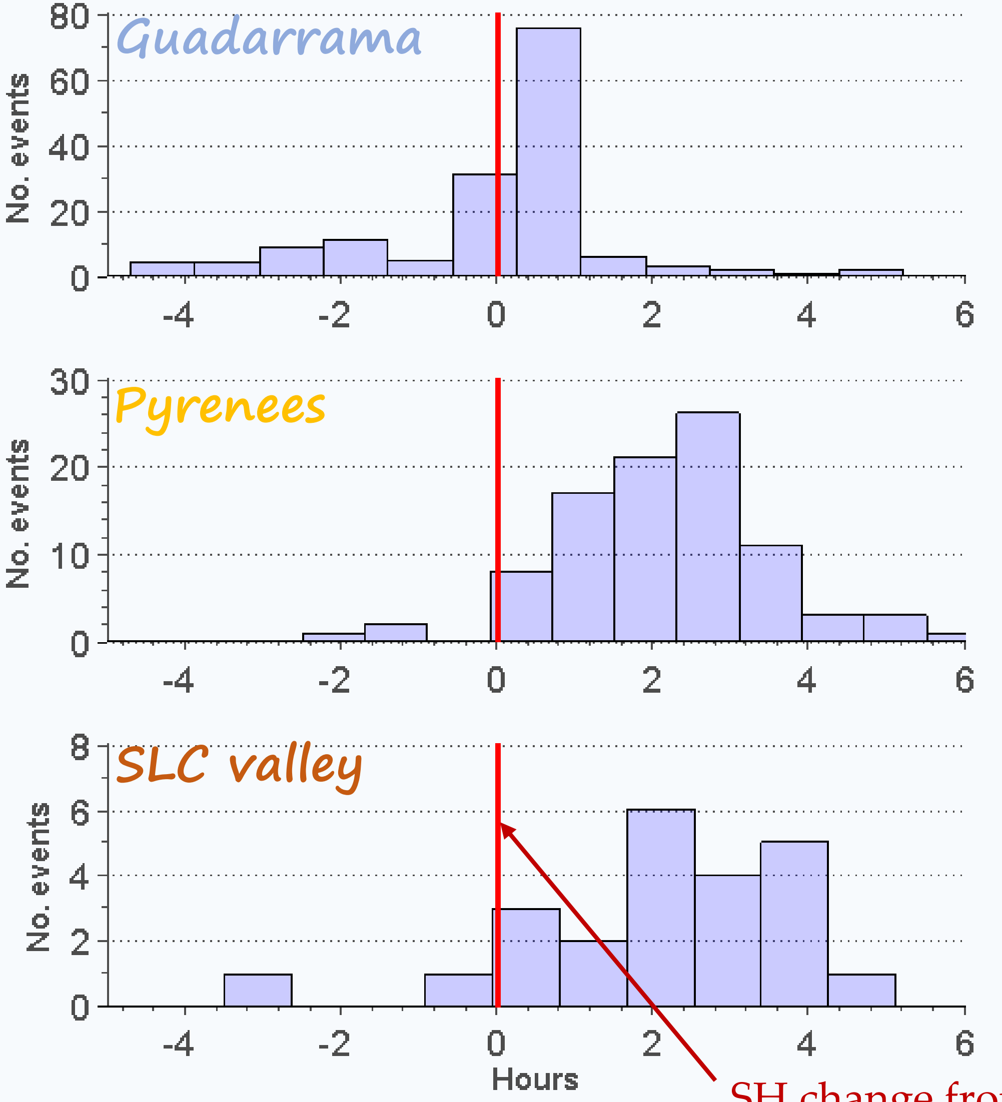
Later arrival

SH change from + to -

Mountain breezes arrival time (regarding sunset)

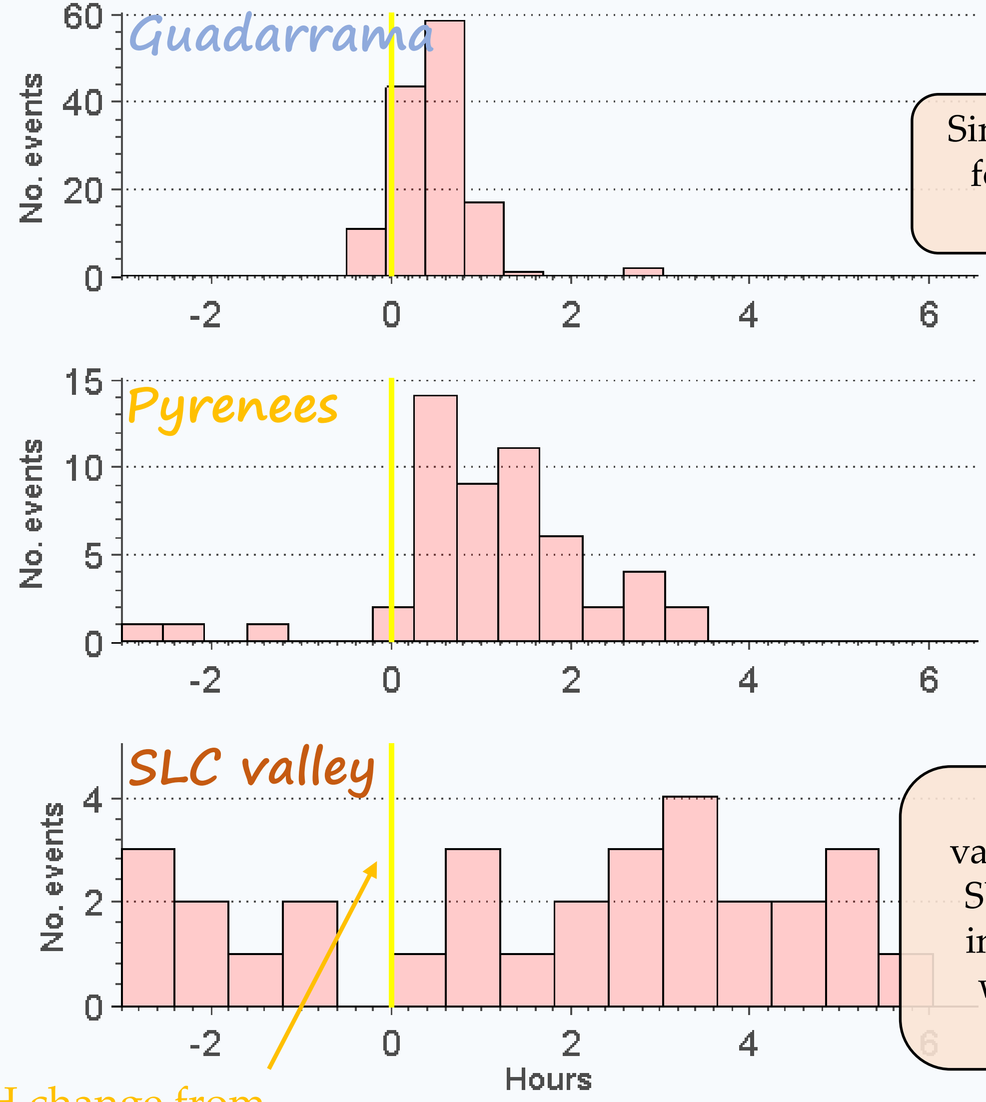
Nighttime events

Number of events



SH change from + to -

Daytime events



Similar results for daytime breezes

Large variability at SLV due to interaction with lake breezes

SH change from - to +

Objective 2. CO_2 & mountain breezes

- CO_2 diurnal cycle. What is the influence of the mountain breezes?

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

* Potentially influenced by mountain breezes

Objective 2. CO_2 & mountain breezes

CO_2 jump

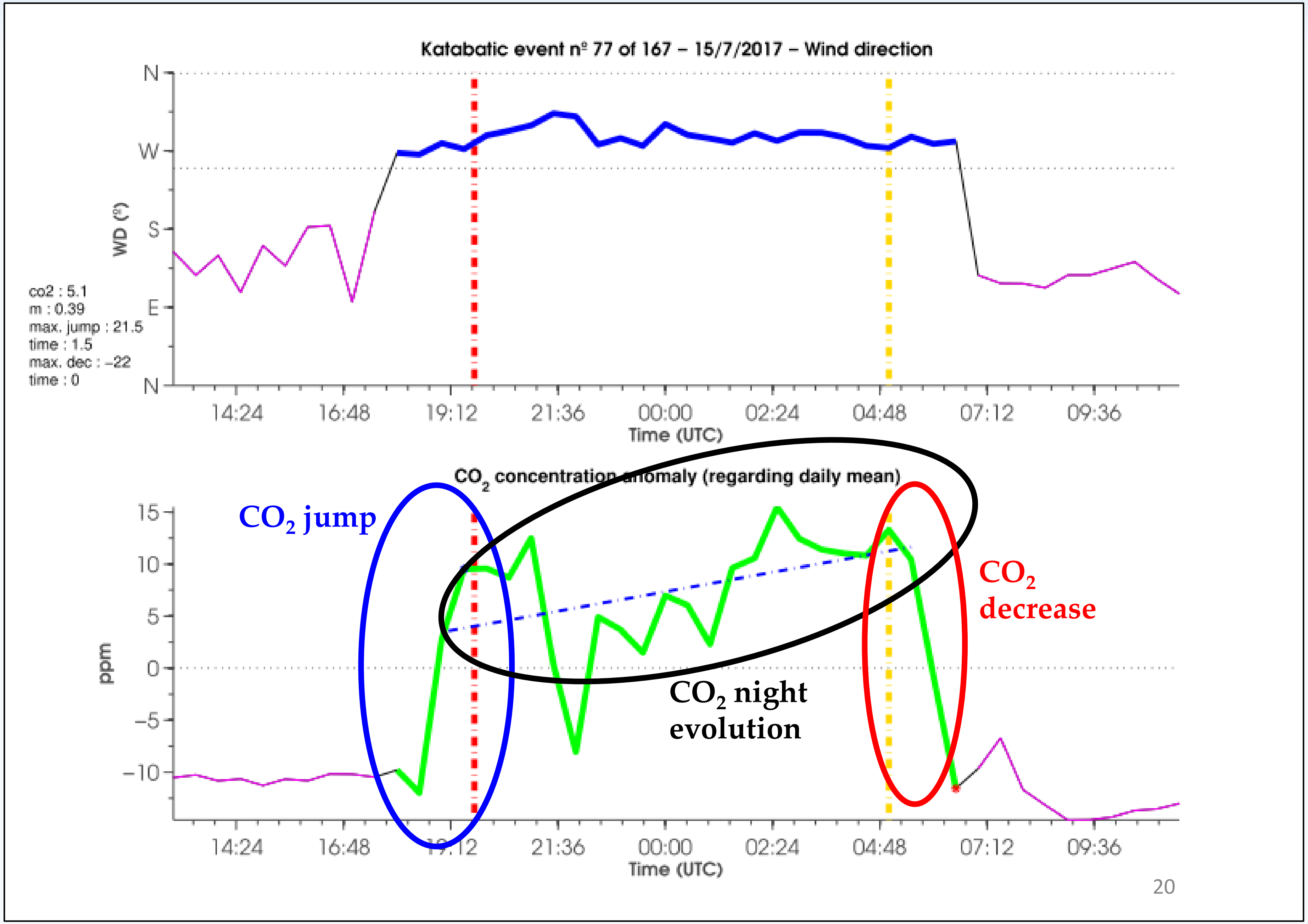
Katabatic onset?

CO_2 night evolution (slope)

TKE?

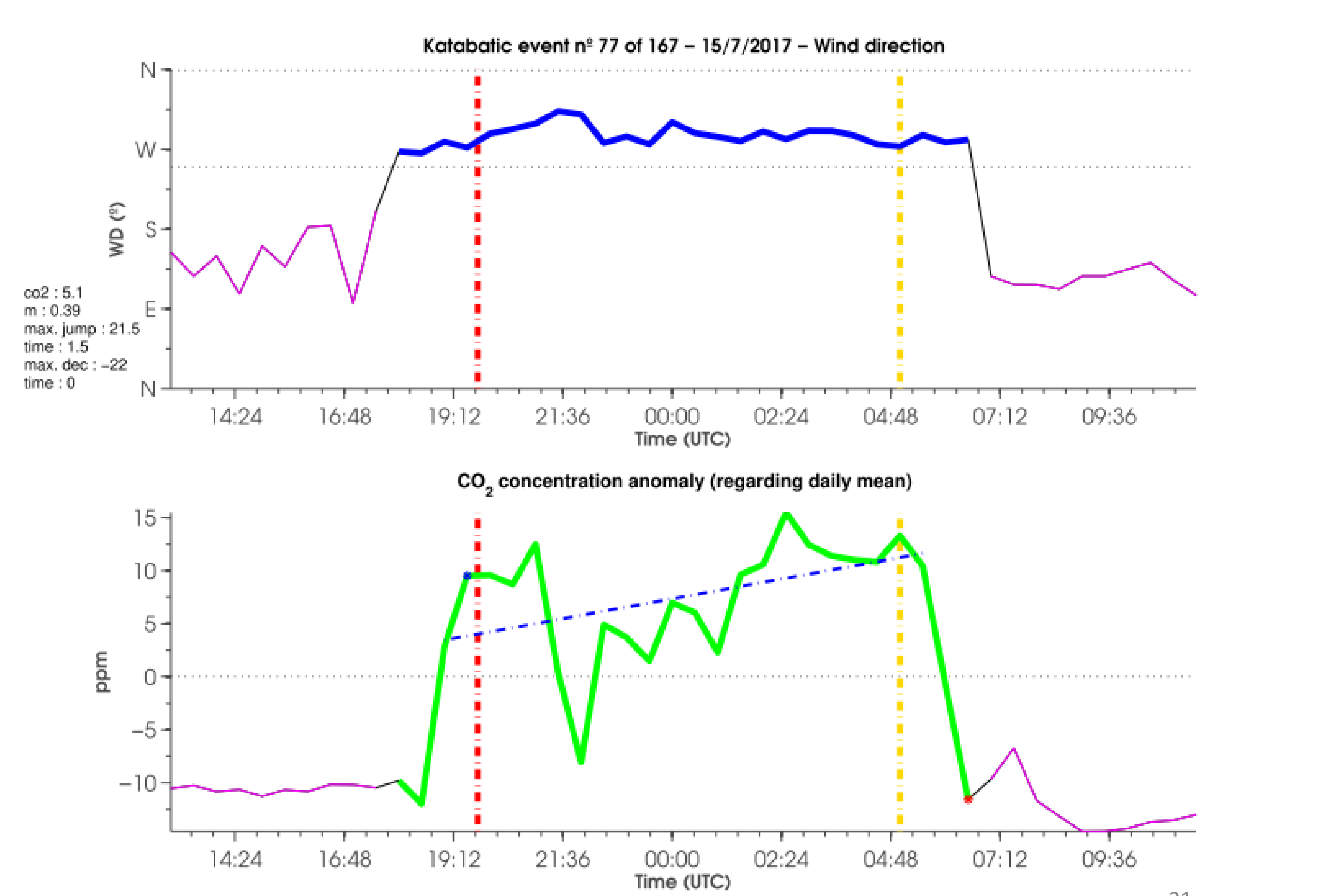
CO_2 decrease

Anabatic onset?



Mean CO_2 concentration* during events

MEAN CO_2 during the events??



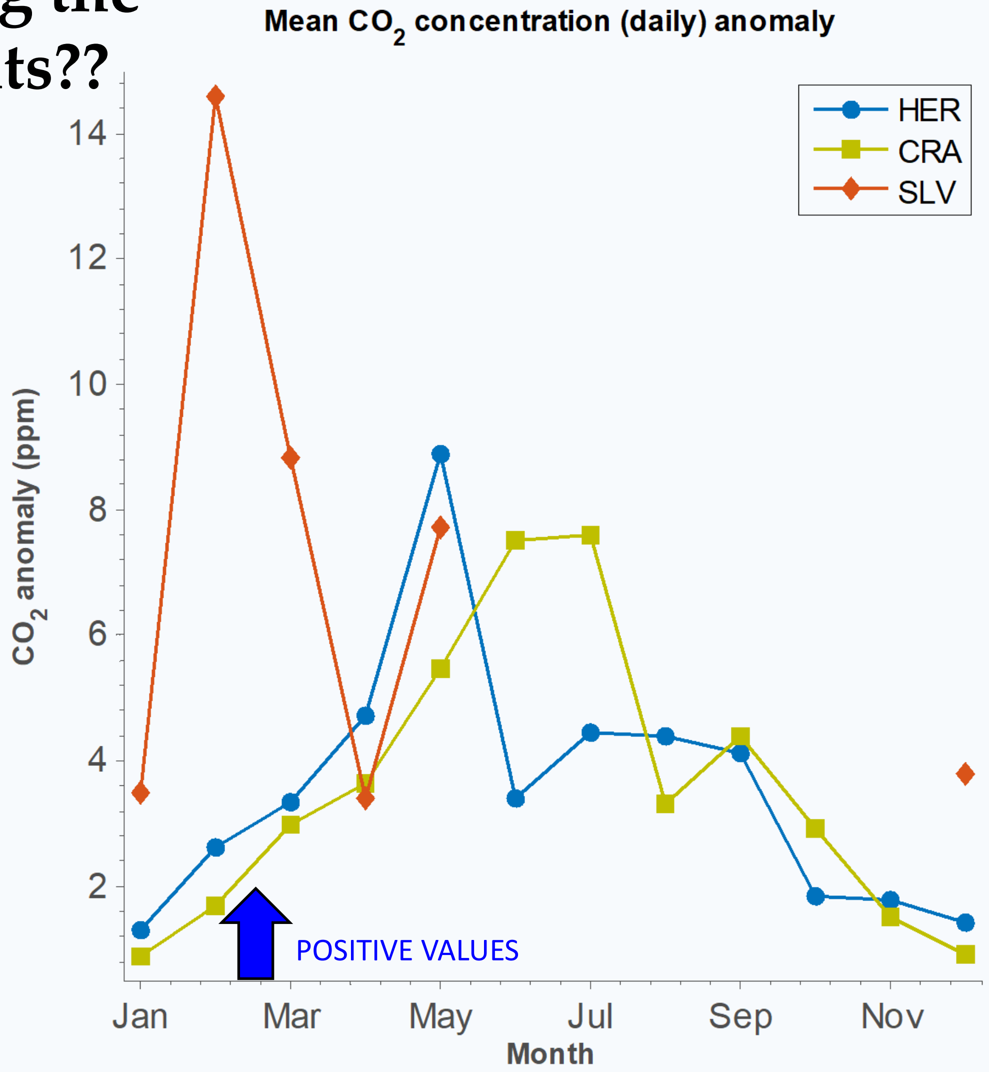
Mean CO_2 concentration* during events

* Minus daily mean (anomaly)

MEAN CO_2 during the events??

Nighttime events

Daytime events



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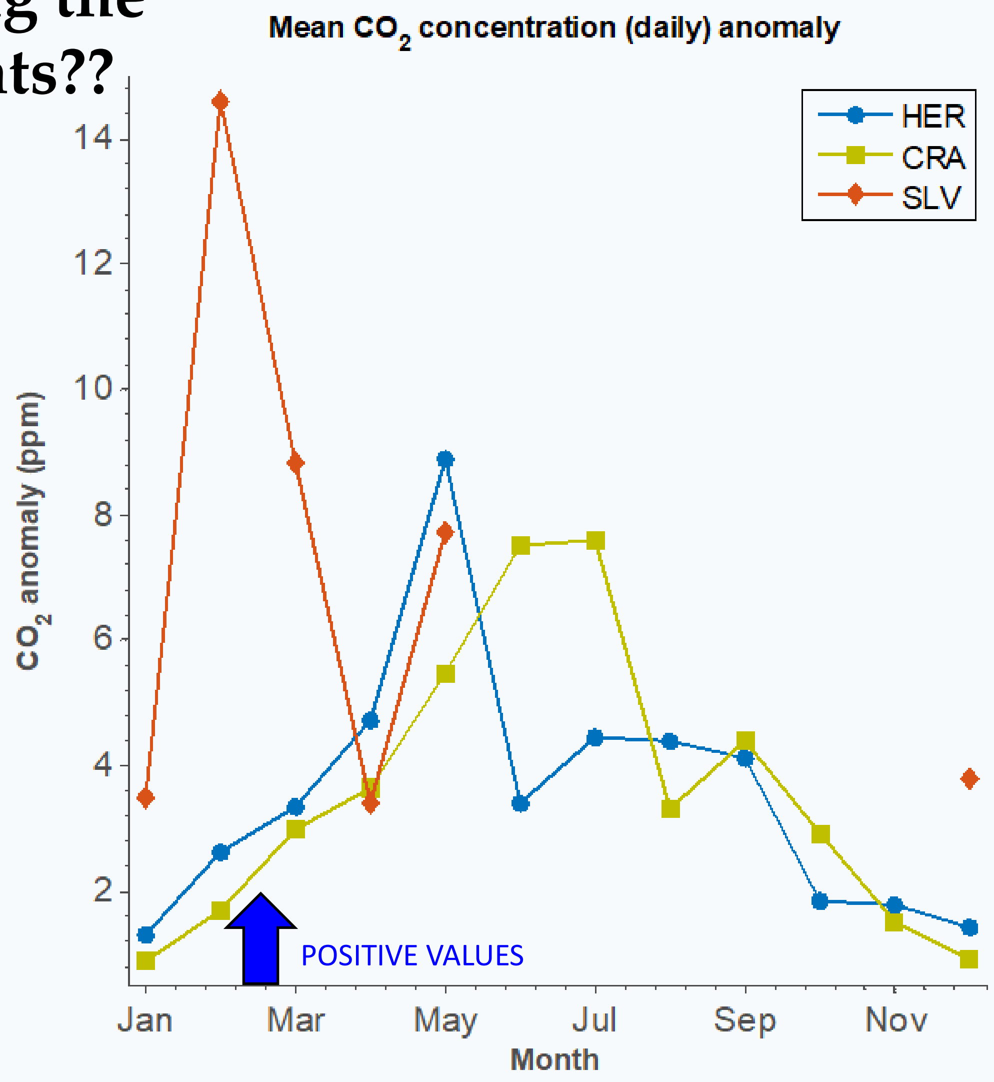
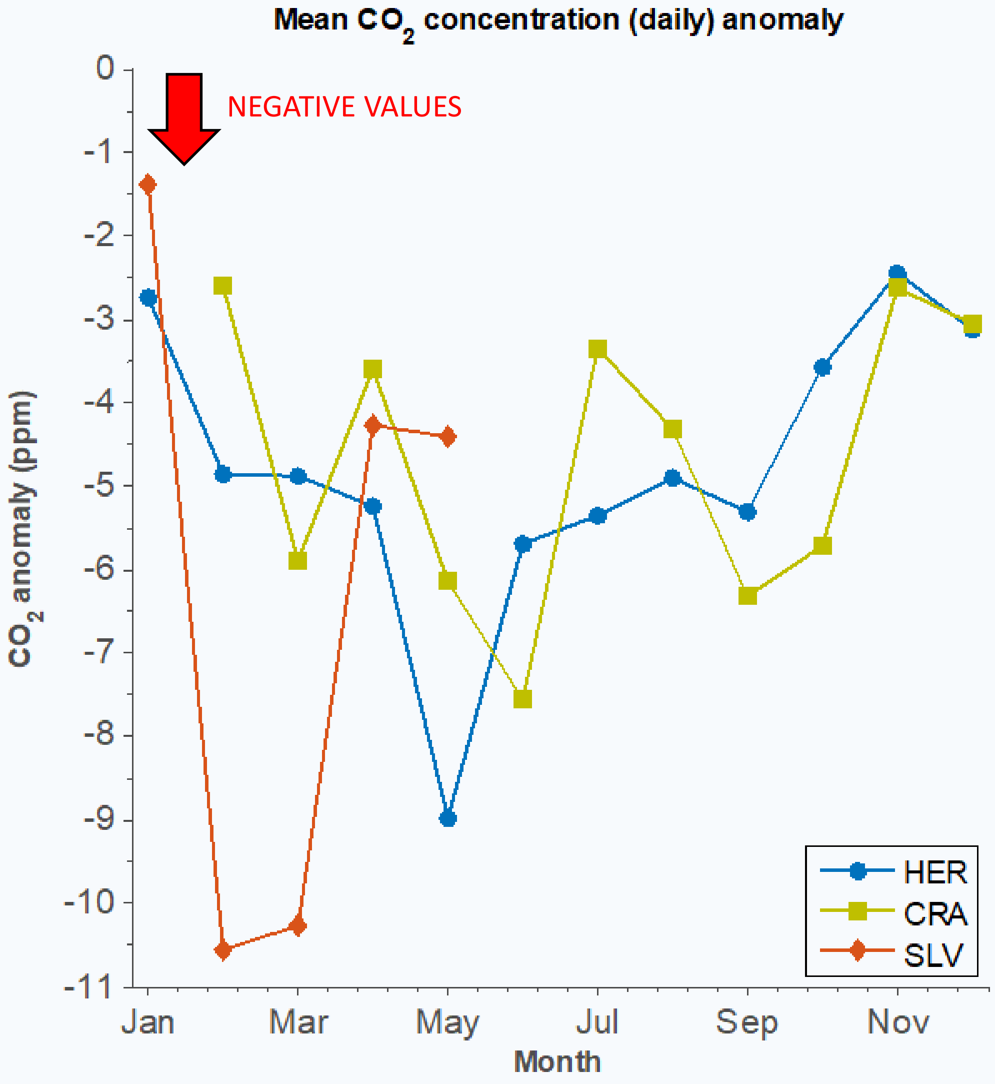
MEAN CO_2 during the events??

Nighttime events

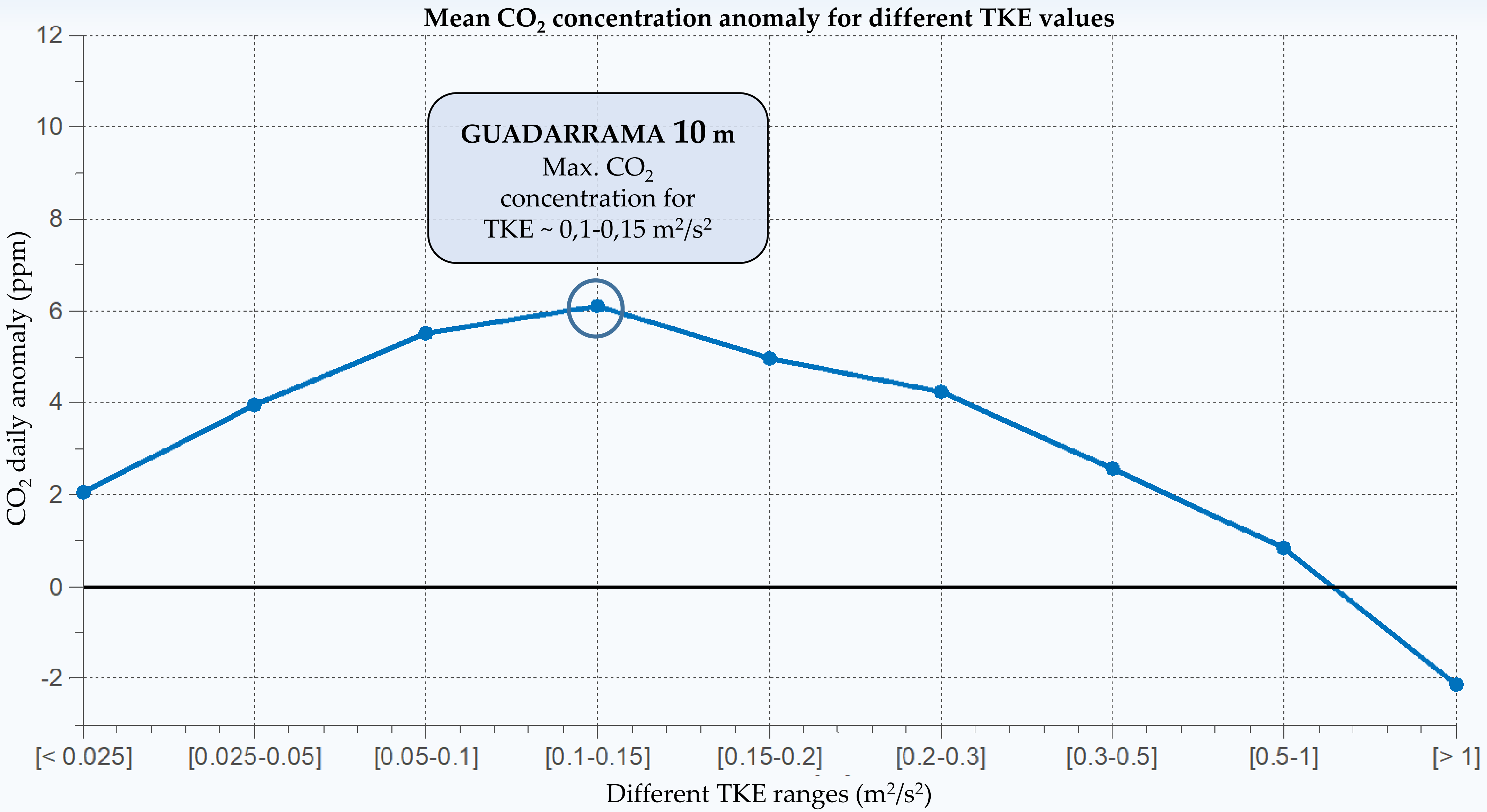


Daytime events



CO_2* vs TKE during downslope flows

* Minus daily mean (anomaly)



CO_2* vs TKE during downslope flows

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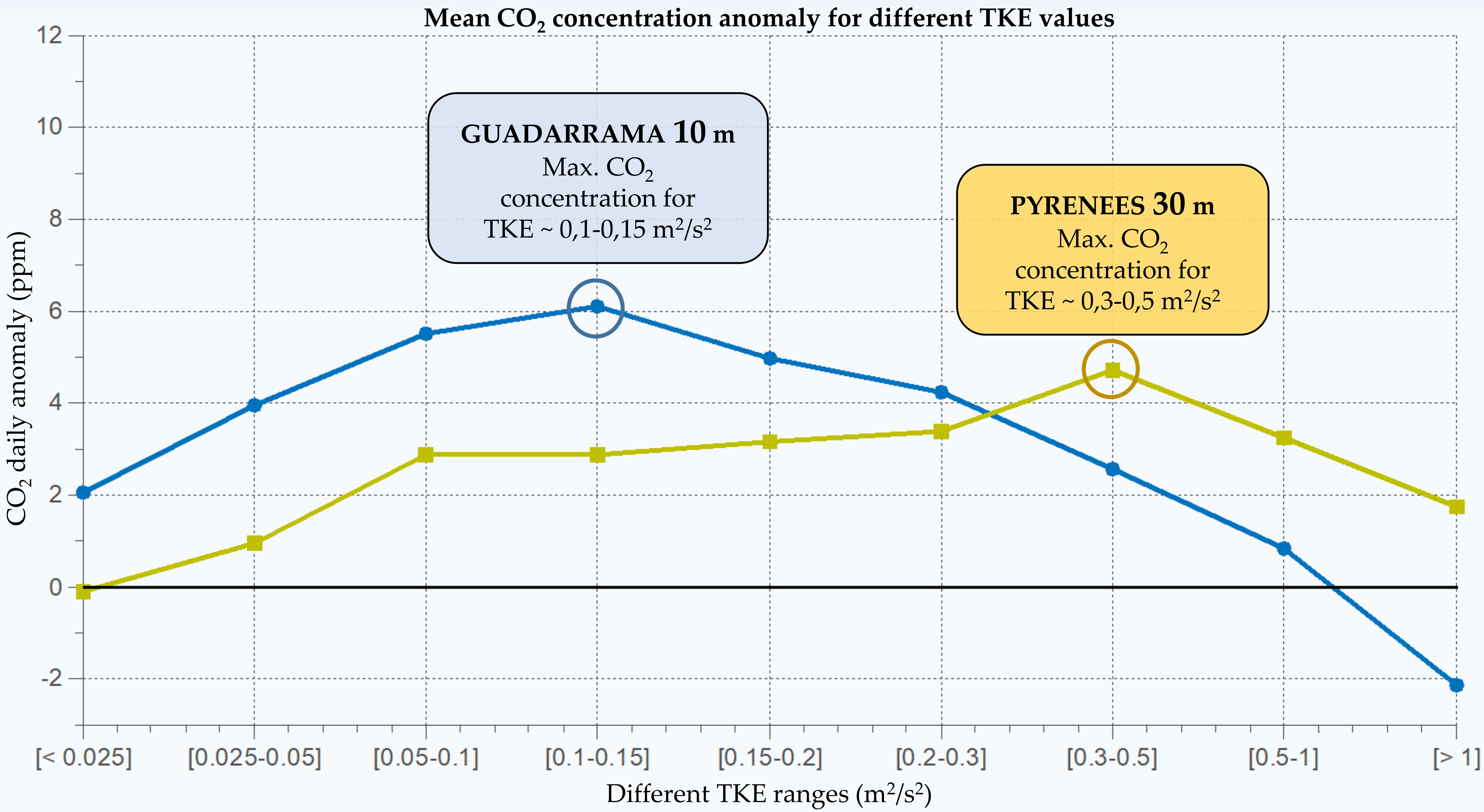


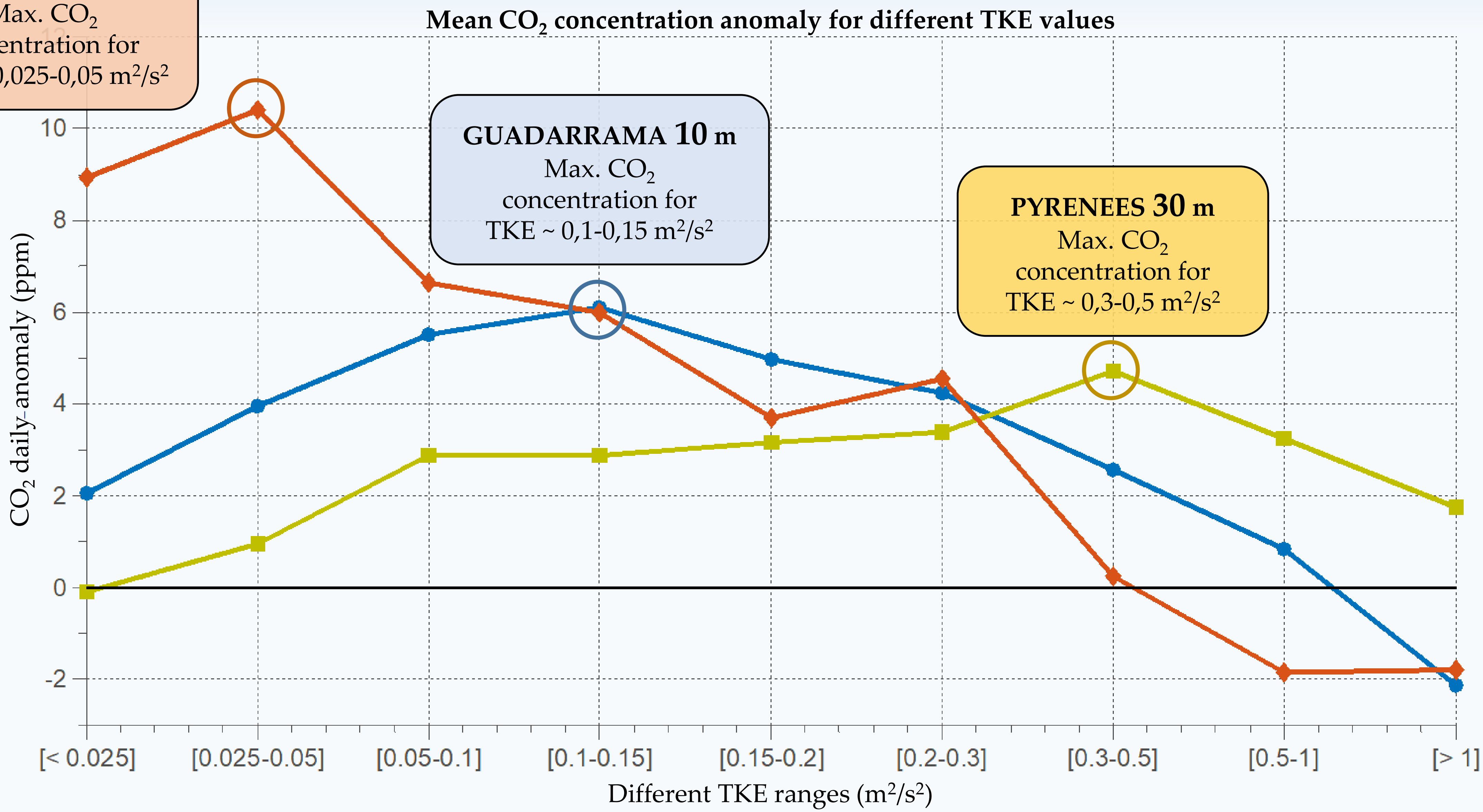
CO_2* vs TKE during downslope flows

* Minus daily mean (anomaly)

SLC 10 m
Max. CO_2 concentration for TKE ~ 0,025-0,05 m^2/s^2

GUADARRAMA 10 m
Max. CO_2 concentration for TKE ~ 0,1-0,15 m^2/s^2

PYRENEES 30 m
Max. CO_2 concentration for TKE ~ 0,3-0,5 m^2/s^2

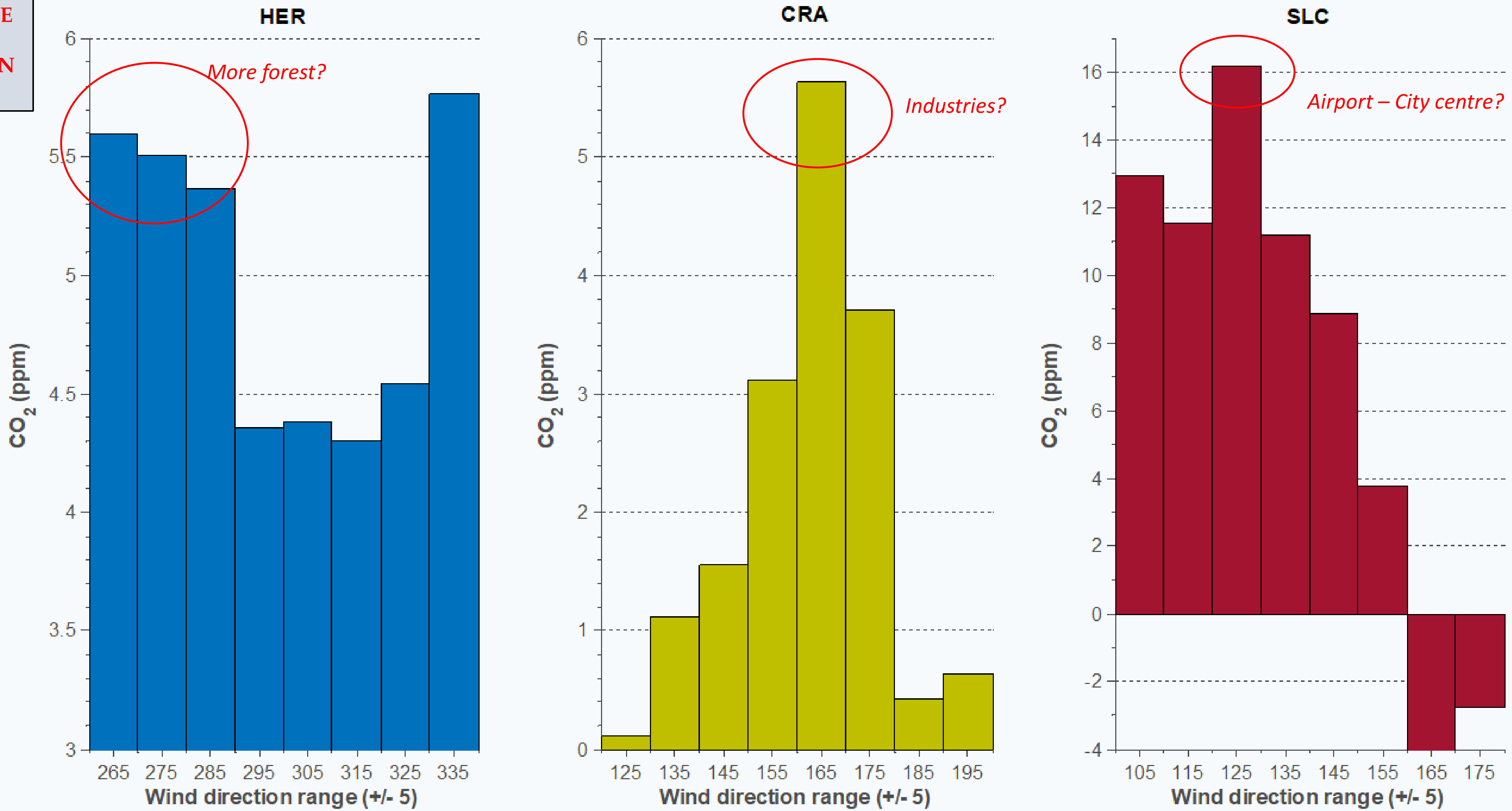


Downslope flows

CO_2* concentration for different WD

* Minus daily mean (anomaly)

TRYING TO DETERMINE THE ADVECTION EFFECT…



Guadarrama Pyrenees SLC valley

Conclusions

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

- CO_2 modulated by:
  - **PBL transitions: stable ⟷ convective**
  - **Turbulence**
  - **Wind direction (advection) in very heterogeneous sites (SLC)**

Mountain breezes influence CO_2 concentrations

and…

- Mixing from "above" in SBL (Gravity waves? Residual eddies?)
- Soil respiration??
- Plants activity??

Picture taken close to La Herrería site, looking North.
San Lorenzo del Escorial (Madrid, Spain)

Thanks!