Katabatic, anabatic winds and their impacts in CO$_2$

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BLLAST workshop
Palma de Mallorca
15 May 2018
• ATMOUNT project context

• Objective 1. Mountain breezes comparison in 3 sites

• Objective 2. Mountain breezes and their effects in CO₂

• Testing period: BLLAST (master students work)
  - CO₂ analyses over different surfaces
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**

- **ATMOUNT 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 CO₂ and water vapour concentration and fluxes

(among other objectives)
Mountain breezes comparison

- 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 (Δθn)
  - 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)

**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? +CO₂ and (H₂O)v

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* Based on criteria in Arrillaga et al. 2016

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

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 katabatic events have been detected with minimum persistence of 2 hours(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

(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

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

Anabatics

Anabatic formation +4 h  
Anabatic end -0.5 h
Salt Lake Valley (SLC)

Katabatics

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

Katabatic formation

Katabatic end

Anabatics

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

Anabatic formation

Anabatic end

Mountains at 30 km

2000 – 2500 m
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$_2$O not analysed yet! (and more complicated)
CO$_2$ analysis

Example
Katabatic event
15/07/2017
La Herrería
ASPECTS TO BE STUDIED

1. CO\textsubscript{2} jump
   - Is it related to the katabatic onset?
   - Which variables are controlling the strength of the CO\textsubscript{2} jump?
   - How does it change along the year?

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

3. CO\textsubscript{2} decrease
   - Speed of morning transition?

CO\textsubscript{2} dynamics more related to PBL dynamics (degree of turbulence) and biological activity

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

Example
Katabatic event
15/07/2017
La Herrería
CO$_2$ analysis

CO$_2$ jump and kat. onset

Katabatic CO$_2$ maximum jump TIME regarding kat. onset distribution -1h
CO\textsubscript{2} analysis

Mean CO\textsubscript{2} concentration during katabatics events

LA Herrería

Salt Lake Valley
Mean CO$_2$ concentration during katabatics events

CO$_2$ analysis
CO₂ analysis

CO₂ jump distribution

LA Herrería

CRA
CO$_2$ analysis

CO$_2$ slope during the event without initial and final hours

SUMMER

WINTER

CO$_2$ night evolution
CO$_2$ analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

HOW THE WIND DIRECTION IS INFLUENCING THE CO$_2$ CONCENTRATION?

LA Herrería
CO₂ analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

HOW THE WIND DIRECTION IS INFLUENCING THE CO₂ CONCENTRATION?

CRA
CO₂ analysis

ONLY KATABATIC, ONLY DURING NIGHTTIME,

HOW THE WIND DIRECTION IS INFLUENCING THE CO₂ CONCENTRATION?

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.

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

Does the mountain-breezes detection algorithm work during BLLAST? **YES!**
BLLAST. CO2 over different surfaces

BLLAST campaign statistics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nombre d’événements</td>
<td>11</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Horaire début (UTC)</td>
<td>9h13</td>
<td>19h41</td>
<td>20h02</td>
<td>8h28</td>
</tr>
<tr>
<td>Horaire fin (UTC)</td>
<td>18h41</td>
<td>20h53</td>
<td>09h01</td>
<td>8h51</td>
</tr>
<tr>
<td>Durée (h)</td>
<td>9h29</td>
<td>1h10</td>
<td>9,78</td>
<td>0h23</td>
</tr>
<tr>
<td>Persistance (%)</td>
<td>87.21</td>
<td>-</td>
<td>87.76</td>
<td>-</td>
</tr>
<tr>
<td>VV moyenne (m/s)</td>
<td>1,84</td>
<td>0,75</td>
<td>2,74</td>
<td>0,95</td>
</tr>
<tr>
<td>DV moyenne (°N)</td>
<td>2,34</td>
<td>-</td>
<td>157,24</td>
<td>-</td>
</tr>
</tbody>
</table>

ANABATICS

KATABATICS

2017
BLLAST. CO2 over different surfaces

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

Wheat – 3 m
Grass – 2,55 m
Tower – 30 m
Moor – 3 m
Corn – 3 m
AVERAGE
Interesting and particular period of transition, near-calm period, low turbulence... and high concentrations!
BLLAST. CO₂ over different surfaces

ΔCO₂ Vs TKE during katabatics

ΔCO₂ (ppm)

TKE (m²/s²) (ranges)
événements catabatiques : variation des concentrations en dioxyde de carbone en fonction de l'énergie cinétique turbulente

$\Delta CO_2$ Vs TKE during katabatics

BUT THIS DOES NOT HAPPEN AT 30 M!
BLLAST. CO₂ over different surfaces

At 30m, more turbulence means more CO₂ concentration due to the better mixing with CO₂-rich air from below.
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?

- CO₂ 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
Thanks!

Picture taken close to La Herrería site, looking North.

Courtesy of J. A. Arrillaga and Carlos Yagüe