Measurements of atmospheric CO_2 concentrations along a transect

Introduction

Catalonia is situated in the north east of Spain, on the Mediterranean coastline. It is characterized by three main morphological features: the Pyrenees (in the north), the coast mountain ranges (with south-west to north-east direction) and the central depression valley. The distribution of valleys and canyons, and the local breezes mark the paths and modify the direction of synoptic winds. The interaction of sea and land breezes [*Sarrat et al.,* 2009], local topography, and katabatic winds on CO_2 concentration distribution are not well characterised [*Riley et al.,* 2005].

The main sources of CO_2 in Catalonia are cities, industrialized areas and large transport highways. Conversely, the main CO_2 sinks are forests and natural vegetated areas. The distribution of atmospheric CO_2 mixing ratios are influenced by the distribution of sources and sinks associated to land and human uses and by CO_2 transport (wind and local breezes).

Aims

- To become familiar with near infrared techniques for measuring atmospheric CO_2 mixing ratios
- To understand CO_2 distribution along a horizontal transect

Educational benefits

Geography

- Knowledge of the topography and the distribution of land uses in the students' local area
- Knowledge of the development of the local breezes: sea-land breezes, katabatic winds, etc.
- Get in touch with georeference technologies (GPS; Google Earth)

Technology

- Get in touch with the technologies which measure atmospheric CO_2 mixing ratios (near-infrared technique)

Meteorology

- Measurement of meteorological parameters, like wind direction and speed, temperature, dew point temperature, ambient pressure (real and reduced to the sea level) and humidity
- Knowledge of the synoptic situation under which measurements are carried out: interpretation of synoptic maps

Computer skills / Mathematics

- work with spreadsheets: statistics and graphs

Material

- Portable atmospheric CO_2-meter (i.e. Vaisala CARBOCAP with the MPI console)

- CO_2-meter support (in our case, a photographic tripod) and a solar radiation protection device (in our case, an umbrella)
- Portable meteorological station which measures ambient temperature, dew point temperature and humidity (Ref. TESTO)
- Portable anemometer to measure wind direction and speed and (Ref. Skywatch)
- GPS (which measures latitude, longitude and altitude)
- Pencil and worksheet (see annex)

Preparation for the experimental survey

Determine the measurement sites. The choice of these sites will depend on the answers to the following questions:

- Is there any CO_2 mixing ratio gradient related to the land use (city-rural)?
- Is there any CO_2 mixing ratio gradient related to the development of local breezes (sea/land, katabatic winds)?
- Is there any CO_2 mixing ratio gradient related to the altitude (i.e. is there any decrease/increase when measurements are taken higher in altitude?)

Furthermore, open and ventilated areas should be chosen.

During the experimental survey

Students should be responsible for one of the provided meters, that is, to carry them during the whole survey and make sure that they are not forgotten at the measurement sites.

Vaisala CARBOCAP should be powered on at least 30 minutes before the first measurement and should be switched on during the entire survey.

It could be organized in such a way that two students take the measurement of one variable (CO_2, temperature, wind, etc.); and at each measurement site, the roles are shifted so that all students get to use all instruments.

All parameters should be measured in equal conditions (i.e. the temperature and humidity measurements should be taken in the shade), and they should be noted in a worksheet (see below). Humidity and ambient pressure values should be entered in the CO_2-meter to correct the CO_2 measurements according to environmental conditions.

CO_2 measurements should be taken for a minimum of 6 minutes: the first 4 minute for meter stabilisation and the last 2 minutes are the actual measurements used to calculate the mean CO_2 concentration (plus minimum and maximum concentration).

In addition to the measurements, a description of the site (i.e. number of cars, urban/rural site, etc) should be noted (see worksheet).

Figure 1. Experimental set up for taking CO_2 measurements along a transect

After the experimental survey

The CO_2 measurements are compiled in a spreadsheet (for example, an Excel document). Students are asked to calculate the mean CO_2 concentration and the standard deviation for all sites measured from the last 2 minutes of measurements (or other statistical describers depending on their level on Statistics).

The mean CO_2 concentrations and the errors bars are plotted in a graph in function of altitude, distance from the sea, etc.

The CO_2 measurements obtained in the survey should be compared with other available CO_2 measurements, for example, measurements from other schools available at the SchoolCO2web webpage (http://www.carboschools.org/), or scientific measurement sites, for example those reported daily at https://ramces.lsce.ipsl.fr/.

When CO_2 measurements are done at different altitudes, the vertical structure of the CO_2 measurements could be compared with radiosonde data (vertical profiles of temperature, humidity, etc.), that can be found at:
http://weather.uwyo.edu/upperair/sounding.html.

Example

The city of Barcelona is situated on the Mediterranean coastline, delimitated by the sea in the east, and the Collserola mountain range in the west (up to 500 m), and the Besós and the Llobregat rivers in the south and in the north, respectively.

From the east to the west, a clear distribution of the population is observed. Close to the coastline, the city is highly populated and dense traffic is observed. As we move to the west, more spacious and less dense areas, mixed with urban green parks characterizes this part of city. In the top of the mountain, green natural Mediterranean forests are encountered. Along the path, there is an increase in altitude, from 0 to 500 m.

A horizontal transect is defined from east to west along the city, from the high dense populated area to the forest region (see Figure 2). Along the transect, a change of land use (urban, semi-urban, forest) and an increase in altitude (0 up to 500 m) is observed.

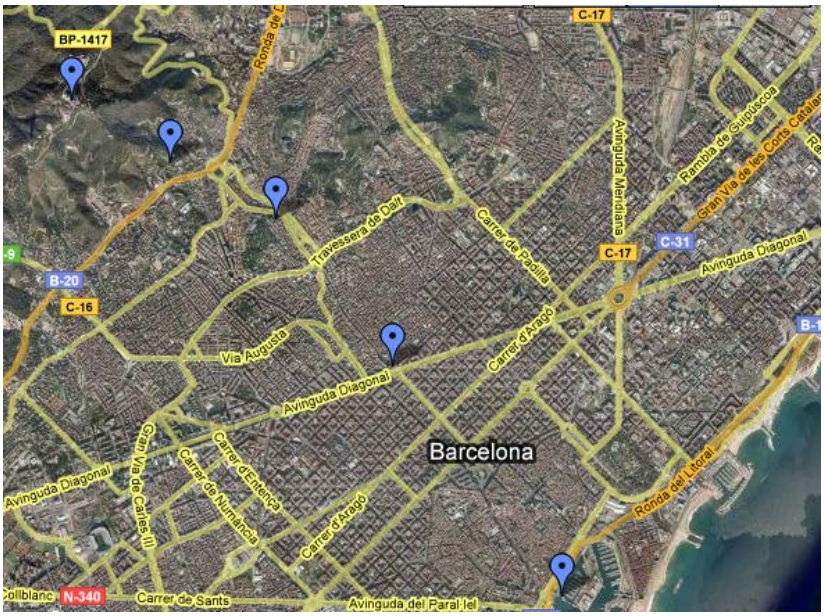


Figure 2. Horizontal transect defined in Barcelona. Blue marks points the measurement sites where CO_2 mixing ratios are measured.

References

Riley, W. J., J. T. Randerson, P. N. Foster, and T. J. Lueker (2005), Influence of terrestrial ecosystems and topography on coastal CO_2 measurements: A case study at Trinidad Head, California, *J. Geophys. Res., 110,* G01005, doi: 10.1020/2004JG000007

Sarrat, C., J. Noilhan, P. Lacarrère, V. Masson, E. Cheschia, P. Ciais, A. Dolman, J. Elbers, C. Gerbig, and N. Jarosz (2009), CO_2 budgeting at the regional scale using a Lagrangian experimental and meso-scale modelling, *Biogeosciences, 6,* 113-127.

Annexes

Worksheet

VAISALA REFERENCE NUMBER:

Date: Samplers:

Name	Center:

Weather	**Sky**	Cloudy	Partially cloudy	Misty	Clear
	Precipitation	Non	Light rain	Showers	

Site (localization):

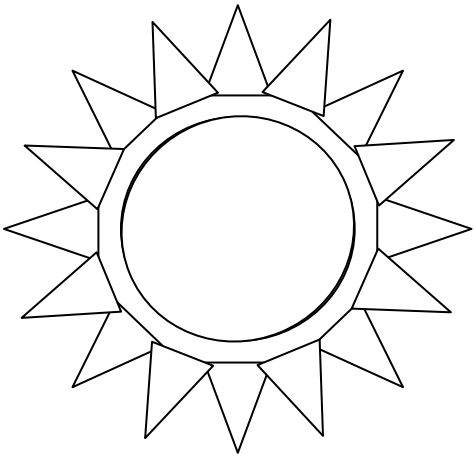
	Instrumentation	**UNITY**	**VALUE**	**CALI**
Time (UT)		**hh:mm**		
Latitude	**GPS**			
Longitude	**GPS**			
Altitude (masl)	**GPS** **Topographic map**	**m**		
QNH **Pressure reduced to the sea level**	**Skywatch – Xplorer4**	**hPa**		
QFE **Real pressure at the site**	**Skywatch – Xplorer4**	**hPa**		
Relative Humidity	**Higròmetre TESTO**	**(%)**		
Dewpoint temperature	**Higròmetre TESTO**	**ºC**		
Ambient temperature	**Higròmetre TESTO**	**ºC**		
Wind speed	**Skywatch – Xplorer4**	**m/s**		
Wind direction	**Skywatch – Xplorer4**	**º**		
Traffic index: **(number of lanes)/(distance, in meters, between two cars)**				
F (freely) x<0.1 (ex:1 lane, 10 m) **N (normal) 0.1<x<1 (3 lanes, 3 m)** **H (heavy) 1<x**				

Sun/shadow **Suntrap/Shady**				
RECORDED COMPROVATION				
Starting minute		**mm:ss**		
Recording interval		**s**		
Ending minute		**mm:ss**		
Minimum CO_2 concentration ppmv last 2 minutes (minus 30 seconds)	**Vaisala CarboCap**	**ppmv**		
Mean CO_2 concentration ppmv last 2 minutes (minus 30 seconds)	**Vaisala CarboCap**	**ppmv**		
Maximum CO_2 concentration ppmv last 2 minutes (minus 30 seconds)	**Vaisala CarboCap**	**ppmv**		

Comments, other interesting points:

Description of the site:

Compass rose:



Make sure that before leaving you have all following instruments:

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Vaisala CarboCap	
Skywatch – Xplorer4	
TESTO	
GPS	