The Canopy and Aerosol Particles Interaction in Toulouse Urban Layer (CAPITOUL) experiment: first results

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1.2 THE CANOPY AND AEROSOL PARTICLES INTERACTION IN TOULOUSE URBAN LAYER (CAPITOUL) EXPERIMENT : FIRST RESULTS

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1. ABSTRACT

The CAPITOUL (Canopy and Aerosol Particles Interaction in TOulouse Urban Layer) field observation program takes place over the city of Toulouse, France, from February 2004 to March 2005. There are five primary objectives: (i) to study the response of the urban surface and atmosphere to a wide range of atmospheric conditions with a focus on the urban surface energy balance (SEB) (ii) to quantify the response of the boundary layer to the characteristics of the urban surface, e.g., urban breezes, urban (thermodynamical) plumes, urban fog formation and dissipation, and to continuously observe trends in the urban heat island (UHI). (iii) to measure the transformation of the properties (physical, chemical and radiative) of urban aerosols, including urban emission characteristics (and turbulent fluxes of aerosols and their transport to rural areas up to 50 km downwind of the city. (iv) to study the dispersion of passive tracer in the atmosphere in suburban environment. (v) to measure the thermal signature of the urban surface.

Instrumentation includes a 30 m tower located in city center for the measurement of turbulent fluxes and the surface energy balance, 20 stations for observing the canopy layer UHI, surface radiative temperature measurements, scintillometers for turbulent heat fluxes, rural stations, including flux and aerosol measurement equipment, wind profilers, radiosonde launches and an aerosol profiler. Specialized aircraft flights were also conducted to sample the boundary layer and surface characteristics using flight paths at various altitudes that include both urban and rural boundary layers.

2. OBJECTIVES

The objectives of the campaign focus on the study of the diverse interactions between a city and the atmosphere. The surface characteristics of the city of Toulouse (500,000 inhabitants), located far from oceanic and orographic influences, can have a significant impact on the atmospheric boundary layer. In the Toulouse region, the prevailing winds are from NW or SE. Furthermore, due to the absence of extensive industrial zones, the primary source of particulate emissions is considered to be vehicular traffic. The objectives encompass 5 topics, and the overall program incorporates both observational and modeling components. The modeling aspects of CAPITOUL has been included from the start to the experiment design. The details of the objectives are described as follows.

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a) *Urban surface energy budget*

In order to develop our understanding of the SEB for a densely developed urban region, a one year observation program, covering a wide range of meteorological conditions (winter, summer, anticyclonic conditions, showers, rain, fog, wind…), is conducted.

The SEB data set is intended to provide calibration data for testing urban parameterization schemes such as TEB (Masson 2000).

b) *Impact of the city on the atmosphere*

Urban Boundary Layer effects and their causes will be quantified under anticyclonic conditions, during spring, summer and winter Intensive Observing Periods (IOPs) with a particular focus on three specific features:

- the Urban Heat Island
- urban breezes
- the Urban Plume

The observations will be used to validate the future numerical weather forecasting model of Meteo-France at the urban scale (2 km resolution).

3) **Urban aerosols**

A main focus of CAPITOUL is the study of urban aerosols. The aerosol study includes:

- observations of the formation and transformation of aerosols between 1 km and 50 km from the sources
- radiative interactions
- turbulent fluxes of aerosols in a city
- modeling of the chemical and physical transformations of urban aerosols

4) **Simulation of industrial hazard release**

CAPITOUL includes a tracer experiment in which a release of SF_6 is accompanied by

- ground and airborne measurements
- study of dispersion under different stability conditions
- modeling of dispersion plumes

5) **Thermal signature of cities**
Ground and aircraft-based measurements will be used to study the distribution of temperature in the city, as a function of season and time of day (including nighttime). The data set will then provide input and validation data for 3D canopy models as well as simplified SEB schemes.

3. DATES

The long term campaign, encompassing all ground measurements, extends from 1 March 2004 to 8 February 2005. Measurements within the urban boundary layer (UBL) are made during IOPs, in spring (March 2004), summer (21 June - 13 July 2004) and winter (15 November 2004 – 25 February 2005). During these periods, aircraft, balloon and SF_6 measurements are made during anticyclonic conditions as well as additional measurements of urban aerosols. Airborne Infra-red measurements will be made in July, September and December.

4. LONG-TERM GROUND MEASUREMENTS

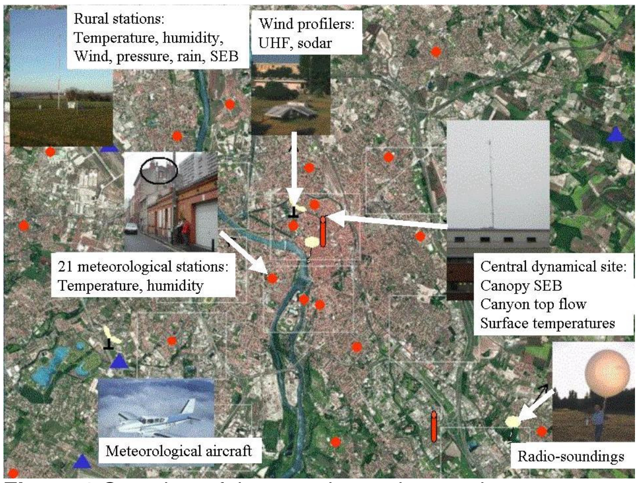

Figure 1 Overview of the experimental network

City centre site

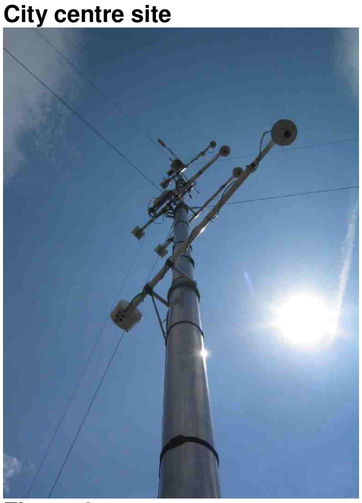
Figure 2 30m mast

A 30 m telescopic mast (Figure 2) was installed on a roof (20 m above street level) in the central city area for the year long SEB observations. All four radiative terms (incoming solar and infra-red, outgoing solar and infra-red), turbulent sensible and latent heat fluxes are measured. In addition, CO_2 and, for the first time, particulate turbulent fluxes, are also observed at the top of the mast.

A vertical temperature profile is also recorded using ventilated thermometers from the top of the mast to street level. The surface temperatures of streets, walls and roofs are continuously recorded using infra-red radiometers.

Turbulent fluxes of sensible and latent heat, carbon dioxide and particulate matter are also measured near the top of two street canyons. The data will provide insight into the vertical exchange processes operating between the urban canopy layer and urban boundary layer.


Figure 3 Boom above street to measure canyon top processes

City centre urban aerosol site

A station for the complete measurement of urban aerosols is located on top of a building near the 30 m mast. The objective of this site is to characterize particles emitted from the street canyon to the atmosphere through assessment of their:

- physical properties (size, counts)
- chemical properties (organic, inorganic, composition every 30 min during IOPs, every week for other periods)
- radiative properties

Urban thermodynamical network

Twenty one stations for the measurement of temperature and humidity are installed in the urban areas (Figure 4) to document UHI and humidity patterns. The stations sites were selected according to distance from the city center and surface cover. Analysis of data from this network is presented in paper **5.1**

Figure 4

Rural stations

Two rural flux stations were installed 30 km from the city with the same instrumentation as the central mast. They will serve as reference sites to allow comparison with the urban SEB. In addition, 4 rural sites are located 10 km from the city to complete the description of the UHI, and 50 other stations are present in a radius of 100 km.

Figure 5 a rural station

Wind profilers, ceilometer

Two wind profilers and a sodar were located in a suburban area and a UHF radar was situated in the city center to continuously observe the wind profiles. In the city center, a modified ceilometer documents not only the cloud base, but also the boundary layer top (even in clear sky conditions) and the aerosol profile.

Scintillometer

Two large aperture scintillometers will be used to observe the sensible heat fluxes integrated over 1 km paths, one located above the dense city center and the second over a suburban area 5 km away from city center. The paths are approximately 20 m above mean roof level.

Chemistry network

Pollutants and urban aerosol measurements are made at several stations distributed throughout the Toulouse agglomeration by the ORAMIP air quality survey association. 10 chemical stations are located in the urban area of Toulouse, and others are located in the surrounding countryside.

5. EXTRA MEASUREMENTS DURING IOPs

Aircraft measurements

In order to document the structure of the Urban Boundary Layer, both in space and time, the Piper Aztec aircraft from Météo-France (Figure 6) will fly above and near the city when meteorological conditions are favorable for observing a strong urban influence on the BL. Two flights a day are planned: a morning flight followed by an afternoon flight. The flight pattern has been specifically designed to document the urban plume and breezes. It consists of a long leg parallel to the wind direction (both upwind and downwind of the city), and a short leg perpendicular to the wind direction crossing above the city centre. A further short perpendicular flight leg will also be flown 40 km downwind to document the urban plume.

Instrumentation is composed of classical meteorological parameters, fast wind sensors and aerosol observations: a particle counter and an aethalometer, which measures the radiative absorption of aerosols, indicating the concentration of black carbon.

Figure 6 The Piper-Aztec instrumented aircraft

Radio-soundings

Radiosondes are launched from 3 sites, one in the city center and the others 15 km upwind and downwind of the city. Radiosondes are released simultaneously, to document the differences in the boundary layer between the city center and the countryside.

Rural aerosol site

An instrumented lab truck is installed during the summer IOP 20 km downwind of the city. It measures the characteristics of the transformed urban aerosols as completely as the aerosol site in the city center. Comparison between the two sites will enhance our understanding of the transformations of aerosols between their emission zone and the rural area.

SF6 dispersion study

During each of the spring, summer and winter IOPs, SF_6 is released by IRSN (Institute for Radiological Protection and Nuclear Safety) in a suburban area of the city. The releases occur during primarily anticyclonic conditions, and at several times of the day in order to document the effect of atmospheric stability. Concentration measurements are conducted at a distance between 300m and 3000m downwind of the discharging point with an instrumented truck, air samples located across the plume, and also with the Piper Aztec aircraft, at 100m and 200m above ground level.

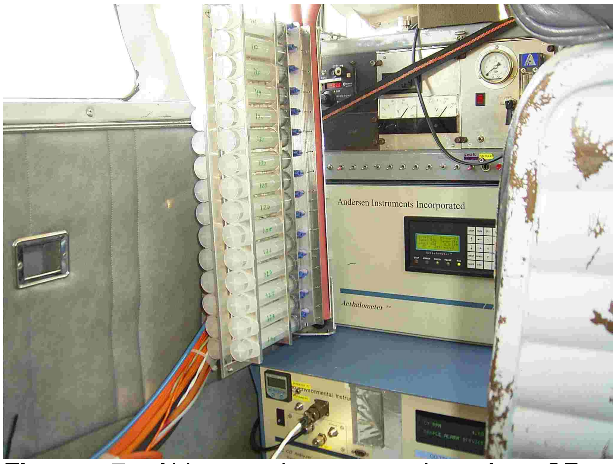

Figure 7 Airborne instrumentation for SF_6 measurements

Infra-red airborne measurement

In order to study the directional effect of the thermal pattern of the city surfaces, several flights above the city center will be made using an aircraft instrumented with an infra-red camera (spatial resolution 1 m). The flights will take place over several hours during the same day (morning, midday, afternoon) and also at several periods of the year. Select days will also incorporate night time flights.

During these periods, additional measurements by hand-held infra-red radiometers will complement the continuous infra-red thermometers installed in the city center, sampling several blocks in the city center. Measurements of the properties of the materials (especially emissivity) are also done in a laboratory.

6. FIRST RESULTS AND CONCLUSION

During march 2004, 2 IOPs of 2 days each have been sampled. In both cases, the weather was cold and dominated by a moderate synoptic wind (20 km h^{-1}). During these IOPs, the thermodynamic and aerosol characteristics of the urban plume were observed. Data from the first day of IOP2, the 9th March, is presented in paper **P1.5**.

The first results of the long-term measurement period focussed on the SEB in the urban area and on the structure of UHI and humidity from February to June are presented in paper **5.1**. Wavelet analysis of the turbulent fluctuations at the central and rural sites were also conducted (paper **JP1.8)**.

Modeling of the canopy energy exchanges, of the aerosol properties and of the 3D UBL will then be performed, for (i) validation and (ii) analyses purposes.