UBL/CLU-Escompte, a validation experiment for urban scale models

A contribution to subproject SATURN

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Summary

The main objective of the UBL/CLU-Escompte was to construct a data base allowing to test and validate urban energy exchange schemes and high resolution meteorological and chemistry-transport models. The project construction aimed at applying the model validation concepts developed within SATURN, in harmony with the objectives of the regional photochemical experimental campaign ESCOMPTE over the Berre-Marseilles area (http://medias.obs-mip.fr/escompte). UBL/CLU is an "associated project" of ESCOMPTE, focusing on the urban atmosphere of the city of Marseille, and taking advantage of the large experimental set-up of ESCOMPTE especially as concerns remote sensing from ground, airborne measurements, and the intense documentation of the regional meteorology. UBL/CLU additional experimental set-up aimed at documenting the fine scale dynamics and thermodynamics of the urban atmosphere over the Marseille area : the four-dimensional structure of the urban boundary layer and the associated urban canopy thermodynamics, during a summer period of low wind and breeze conditions. The experiments lasted from June 5 to July 15, 2001.

Data analyses include comparisons of ground-based micro-meteorology, radiative and turbulent fluxes, surface temperature and humidity obtained at several locations over the urban area, 1-D to 3-D sodar, radar and lidar soundings, airborne measurements, and satellite observations. The experimental data will be included within the ESCOMPTE Data Base. Further analyses include urban schemes validation, numerical simulations of the urban boundary layer within breeze systems, and chemistry-transport numerical simulations at several nested scales from the city quarter to the regional domain.

Aim of the research

The main objective of our contribution to SATURN is the development and the validation of models for the urban atmosphere and the urban canopy, allowing to predict the pollutant distribution close to the ground level, within the canopy, and in the urban boundary layer - and the air quality of the different quarters of a city. This new generation of models will allow to describe source-receptor relationships within the urban area, taking into account the pollutant transfers and transformation processes within the urban canopy. After validation, these improved canopy-accounting models may be included in air quality management systems to evaluate statistical or targeted impacts.

The group co-ordinated the urban boundary layer experiment UBL/CLU-Escompte over Marseille during the regional photochemical experimental campaign ESCOMPTE. As a SATURN-inspired model validation experiment and an "associated project" of ESCOMPTE, the experiment had 3 objectives:

(1) to validate the urban canopy thermodynamic schemes which are the basis of high resolution numerical simulations of the urban atmosphere with "obstacle accounting" atmospheric boundary layer models;
(2) to validate high resolution simulation modelling methods, including domain nesting, and to run sensitivity studies of urban air quality simulations to high resolution;
(3) to provide data allowing to develop and/or validate satellite data analysis methods allowing to provide the input data to the urban scale models.

To fulfil these objectives the UBL/CLU experimental set-up (embedded within that of ESCOMPTE) aimed at :
(a) documenting the 3D structure of the urban boundary layer over a large city, within coastal breeze systems and low wind sunny conditions, and its diurnal variations; this was obtained with two 3D scanning lidars and a sodar/RASS, based at the city outskirts, two sodars and an UHF radar within the city, a tethered balloon and a few radio-soundings from downtown, and a few flights of research aircrafts equipped with turbulence sensors or a downwards wind radar.
(b) documenting the radiation and energy budget over the urban canopy; this was obtained by deploying, at 4 different sites within the city, instrumentation for micrometeorology, turbulent fluxes, and radiation budget components on masts two times higher than the canopy. In addition, scintillometers measured the integrated heat flux along 2 km long paths over the city center.
(c) comparing ground-based measurements and satellite remote sensing of surface temperature; this was done with an array of 20 temperature-humidity sensor-recorders, an instrumented car, and a dense array of IR thermo-radiometers concentrated around 2 sites. During 4 days series of flights with a Piper 28 equipped with an infrared camera mapped the thermal infrared (TIR) response of the city for comparison with NOAA/AVHRR and ASTER thermal infrared data. Repetitive flights with several orientations over selected quarters also documented the orientation influence on surface temperature remote sensing.
Individual and co-operative programs have been structured for analysing the wealth of data obtained during this successful experiment. The first priority consists in providing reliable data sets to the ESCOMPTE data base.

Activities during the year, principal results and main conclusions

The instrumentation was deployed at 5 main sites, along the North-South axis of the city, roughly parallel to the shoreline. Four urban sites were equipped with micrometeorological masts raising some 12 to 20 m above the urban canopy, where all the aerodynamic and radiative fluxes necessary to monitor the canopy surface energy budget were continuously measured. The central site, located in the rather uniform, 18-19th Century, dense part of the city, was also equipped with an array of IR radio-thermometers, either fixed to monitor the surface temperature of selected elementary surfaces, or hand-held to evaluate surface temperature distributions during some periods of intense observation. IR radio-thermometers were also operated at the North site located in a suburban area of mixed constructions. The two sub-urban sites were equipped with mini-SODARs sounding the atmospheric surface layer while a fourth site, close to the city center was equipped with a wind profiler UHF radar and a tethered balloon occasionally measuring thermodynamic and ozone profiles from 20 to 300 m. Two scintillometers were set to measure the heat flux over the city center, with 2 km optical paths oriented N-

S and E-W. At the hilly northern borderline of the city, a "reference" site hosted a RASS-SODAR sounder, and two 3-D scanning LIDARS measuring O3 concentration, particle concentration, and wind, over a range of 5 to 10 km. The set-up also included an array of 20 T-RH continuous recorders at a 6 m height over the ground, while transect T-RH measurements were occasionally made from the "T-RH car".

Most measurements were recorded continuously. Two types of intensive observation periods were more densely documented : the ESCOMPTE IOPs, generally during breeze situations, with a few airplane flights documenting the turbulent fields within or at the top of the boundary layer ; the TIR IOPs, when the thermal infrared mapping camera on board of the Piper 28 scanned the urban canopy from different directions with respect to the sun, and at different times in the day.
While 11 groups participated in the field experiment, more than 17 groups participate in the data analyses, from at least 3 points of view : surface temperature and heat flux remote sensing from satellite visible and IR channels ; structure of the urban boundary-layer ; numerical simulation of urban air quality with high resolution chemistry-transport models. (Mestayer and Durand, 2002)

The ECN group operated the North sub-urban site with turbulence flux instrumentation on a 12 m high mast on the roof of a 12 m high building, a complete set of radiation sensors, a sodar, and a set of solid-surface temperature sensors and IR radio-thermometers. The group also operated the equipped "T-RH car".

This year, the group also worked actively to strengthen the links between the SATURN and ESCOMPTE projects, and between their steering groups, in the prospect of the organisation of air quality model validation exercises. We effectively supported the MESOCOM initiative to conduct a preliminary simulation exercise with the data obtained during the pre-ESCOMPTE campaign of June 2000.

The group also further developed numerical tools allowing to simulate the urban atmosphere at very high spatial resolution.
(1) A special software, called ASTUCE/DFMap, and specific methods using MapInfo were developed to analyse the urban geographical/elevation data bases, and satellite high resolution images and to produce high resolution sets of input data for the urban models. (Long et al., 2002)
(2) The urban soil/canopy model SM2-U has been achieved and tested against data obtained over a small urban catchment of the Nantes conurbation. (Dupont et al., 2000; Dupont, 2001; Berthier et al., 2001)
(3) Grid refinement and grid nesting methods for the urban boundary layer model SUBMESO have been achieved. (Pénelon et al., 2001)

Aims for the coming year

-1- The micrometeorological, radiation, and turbulence measurements obtained at the North sub-urban site during the Marseille UBL/CLU experiment will be analysed to test/validate the urban soil/canopy model SM2-U.

-2- The high resolution maps of the land uses and building parameters of Marseille will be constructed from the urban data bases, and aerodynamic and thermodynamic input parameters for SM2-U and SUBMESO will be computed on an hectometric grid.
-3- Methods for coupling SUBMESO with the regional scale model RAMS on the one hand, and the fine resolution chemistry-transport model TRANSCHIM on the other hand, will be developed.
-4- High spatial resolution simulations of the UBL/CLU and ESCOMPTE intense observation periods will be launched in view of a sensitivity analysis of the air quality simulations to high resolution in orography, canopy modeling, and source inventory.
-5- Participation in the ESCOMPTE and/or MESOCOM numerical model inter-comparison exercises will be prepared.

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