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URBAN CLIMATE & ENERGY DEMAND IN BUILDINGS

Jahresbericht 2009

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BFE Projekt-/Vertrag-Nummer	154 143
BFE-Projektleiter	Dr. Ch. Filleux
Dauer des Projekts (von – bis)	1.07.2009 bis 31.12.2012
Datum	15.12.2009

ZUSAMMENFASSUNG

The project deals with the modelling of urban microclimate in street canyons and urban neighbourhoods taking in particular combined effects of wind and solar radiation into account. Modelling and simulation will be performed using computational fluid dynamics techniques. Validation experiments in selected isothermal and non-isothermal cases will be undertaken (air flow patterns, temperature distributions) in the new atmospheric boundary layer wind tunnel at Empa. With the enhanced understanding of the flow and heat transfer phenomena and the respective models developed, the impact of the urban climate on daytime and night-time (passive cooling) ventilation potentials as well as on heating and cooling demand of buildings shall be investigated.

In the present start up phase of the project the work to set up a methodology for the definition of situation cases on street canyon and urban neighbourhood scale was started. Flow and heat transfer phenomena in the urban canopy and respective available models and tools were studied. Knowledge of Large Eddy Simulation (LES) techniques in Computational Fluid Dynamics (CFD) was gained and first street canyon cases were simulated. First concepts for the envisaged experimental evaluations have been discussed, considering the scaling laws and the respective limitations in wind tunnel testing. Finally we started to define criteria and parameters suitable for the evaluation of time resolved flow fields and for the energy impact analysis.

In the year 2010 physical processes relevant for the interaction building – urban micro climate are to be described and the respective models to be developed. Situation cases will be defined and then simulated using CFD-LES. The methodology for the energy impact assessment will be developed and criteria and parameters defined for the evaluation of time resolved flow fields and the energy impact analysis. Street canyon experiments will start as soon as the new atmospheric boundary layer wind tunnel at Empa is operational.

Projektziele

The project aims at further developing the basic knowledge of physical processes, which are relevant for urban microclimates. On the street canyon and on the urban neighbourhood level microclimatic processes shall be analyzed from the point of view of energy demand in buildings (Fig. 1).

Modelling and simulation knowledge as well as prediction capabilities of computer models shall be enhanced in regard to predicting consequences of planned buildings and urban development on the microclimate. The impact of urban climate on daytime and night-time (passive cooling) ventilation potentials as well as on heating and cooling demand of buildings shall be investigated and quantified.

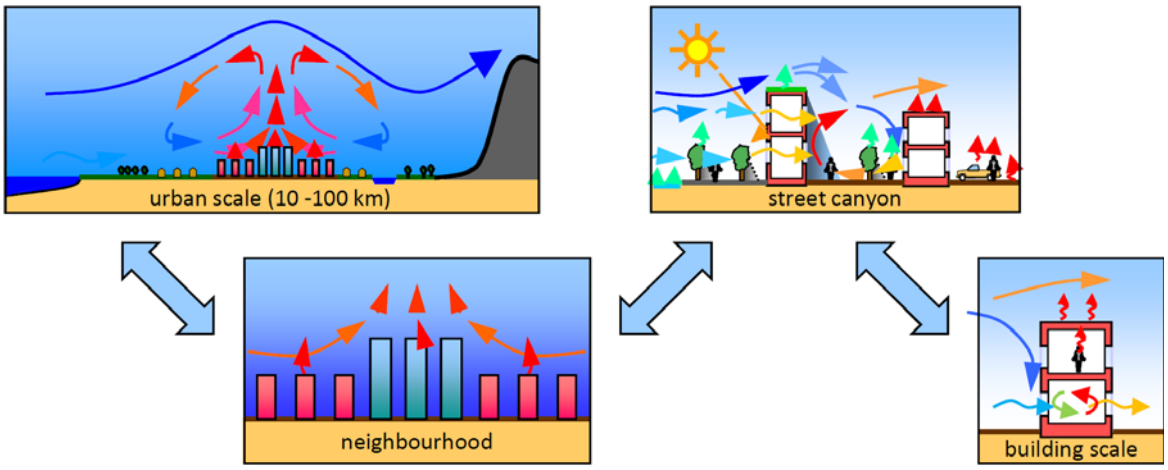

Fig. 1: The multi-scale aspects of urban climate modelling.

The following milestones are set:

(i) Definition of case study situations: street canyon and urban area models

(ii) Heat transfer modelling and CFD simulation: microclimate in street canyons and urban areas

(iii) Wind tunnel experiments: selective empirical validation

(iv) Impact assessment: urban climate and building energy demand

The results of the project are a methodology and the respective models to assess the impact of urban morphology and physical properties on the urban microclimate. Additionally, a more profound insight in the mechanisms and the impacts of the urban climate on the energy demand in buildings shall be given. Key topics in this respect are: decreasing heating demand, increasing cooling demand, daytime natural ventilation, passive cooling by night-time ventilation.

Durchgeführte Arbeiten und erreichte Ergebnisse

Case study situations: A first overview on existing work regarding urban morphology in relation to numerical and experimental urban climate studies was made.

Modelling: Considering the multi-scale aspects of urban climate modelling [1,2], the different levels of detail and sophistication of existing flows and radiation models were investigated and contrasted both to the needs of urban climate modelling and to the capabilities of existing whole-building energy simulation and CFD codes.

Concerning CFD modelling, a parameterized model for CFD street canyon modelling was developed. First simulations employing Large Eddy Simulation (LES) techniques have been performed [3]. As an example, Fig.2. shows three snapshots of a standing vortex inside a 20x10 m street canyon with a three second time interval. The turbulent character of the wind flow pattern has a direct impact on the comfort and health of pedestrians, and an indirect effect on the energy consumption of the buildings.

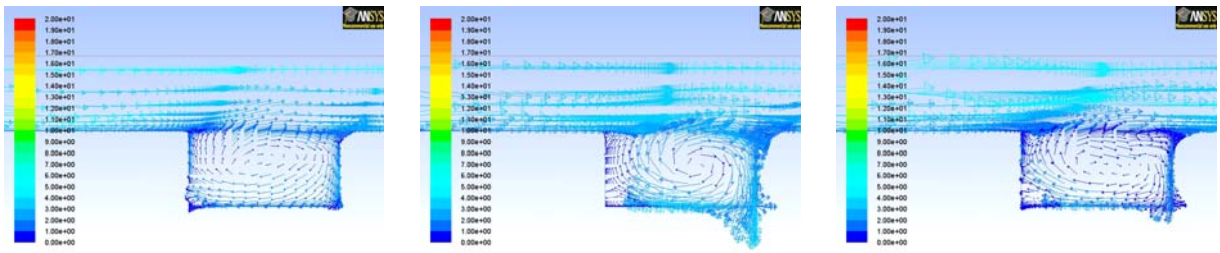

Fig. 2: Typical result of CFD-LES street canyon simulation: evolution of a vortex over time. Arrows represent (magnified) velocity vectors, coloured by velocity magnitude.

Experimental evaluation: The installation of the new atmospheric boundary layer wind tunnel at Empa is progressing as planned. First conceptual studies were made for the planned street canyon experiments on the interactions between canopy flow and buoyancy driven flow along heated surfaces, considering (i) the limitations in regard to scaling parameters (especially Richardson number) [4], (ii) transitional laminar/turbulent flow aspects and (iii) the requirements and possibilities for time resolved Particle Image Velocimetry.

Nationale Zusammenarbeit

Inherently, a close collaboration is established with the Chair of Building Physics at ETHZ. Links exist also to research institutions working in the fields of energy as well as urban planning, urban morphology and building typology (e.g. EPFL-LESO, HSLU T&A CCTP).

Internationale Zusammenarbeit

Collaboration with University of Cyprus (Prof. Marina Neophytou) was established in regard to experimental and CFD validation. The establishment of collaborations with other institutions in the field of urban climate modelling is in progress.

Bewertung 2009 und Ausblick 2010

The project had to be adapted to organisational changes. *Basler & Hofmann AG* is now included as project partner, focussing on the methodologies for the case definitions and for the energy impact, and contributing also to the modelling task.

Case study situations: Most work on the definition of cases has been shifted to 2010. Existing work on the effects of urban morphology and building typology cases will be considered wherever possible (e.g. results of COST Action 732 [5], or [6]). In the project, generic cases of increasing geometric complexity will be considered, from simple street canyon geometries to structures reflecting typical urban neighbourhood morphologies.

Modelling: Modelling work in the frame of the PhD thesis has already started in October 2009. This work will continue, supplement by input from additional work at Empa on pollutants dispersion and on combined heat, moisture and plant evaporation modelling in urban street canyon and neighbourhood situations. On short term, the focus is on boundary conditions and radiation modelling. Physical processes relevant for the interaction building – urban micro climate are to be described and the respective models to be developed. Then, suitable evaluation criteria and parameters are to be defined for the evaluation of time resolved flow fields, considering on the one hand transient and intermittent effects such as vortex shedding and sweep and ejections flows, and on the other hand the need for more integral values, meaningful for the energy impact analysis. The CFD-LES work is continued with the simulation and analysis of the situation cases specified.

Experimental evaluation: Street canyon experiments will start as soon as the new atmospheric boundary layer wind tunnel and the Particle Image Velocimetry system are operational. Comparisons are also planned with results provided by the University of Cyprus (water channel experiments and CFD).

Impact assessment: In 2010, the methodology for the energy impact assessment will be specified.

Referenzen

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[6] Han J., Sandberg M., Li Y. ***Effect of urban morphology on wind condition in idealized city models***. Atmospheric Environment 43 (2009) 869–878.