7A.2 IDEALIZED STUDIES WITH THE NEW URBAN SCHEME OF THE MET OFFICE UNIFIED MODEL

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1. INTRODUCTION

With the majority of the world's population currently living in urban areas, the understanding of the urban climate has become a major multi-disciplinary research topic. In contrast to the rural climate, the urban climate threatens human health, biodiversity and environment. Urban impacts on our society forces government and planning institutions to obtain quantitative predictions of the diverse perturbations associated with the urban climate. One of the main characteristics of the urban climate is the urban heat island (UHI), related to the occurrence of more frequent higher temperatures over urban areas than over surrounding rural areas. To be able to quantify the UHI within a NWP model, a good representation of the urban processes needs to be implemented. For this reason, we implemented a new urban scheme into the NWP MetUM (Met Office Unified Model) surface exchange scheme (Essery et al., 2001). This new scheme, MORUSES (Met Office Reading Urban Surface Exchange Scheme), will allow us to include a physical background and understanding of the urban processes as well as to capture more flexibility in the representation of urban material properties.

Idealized studies are undertaken to evaluate the new scheme against observational data. In a first attempt MORUSES is applied to study the impact of sub-grid scale urban fractions on the surface energy balance.

This paper is organized into three main sections:

- motivation and documentation of implementation and validation of MORUSES within the MetUM
- idealized sensitivity study of the surface energy balance fluxes to the urban fraction within a NWP grid boxes.
- Outline on the LUCID project (Local Urban Climate Model and its Application to the Intelligent Design of Cities) and preliminary results on future applications

2. IMPLEMENTATION OF THE NEW URBAN SCHEME

2.1 Motivation and Implementation

Over the last decade, research in meteorology has focused on the development of parameterizations for urban canopy models. Among these studies, Best (2005) introduced a radiative urban canopy model into the MetUM. In his model, the urban canopy consists of a thick slab layer with high thermal inertia and a weak coupling to the underlying ground. This combination allows the Best canopy to store and release heat within the urban fabric. The inclusion of the Best urban canopy within the NWP MetUM improves the operational forecasts of screen-level temperatures over urban areas (Best, 2005). However, as previously mentioned, the Best scheme does not allow for any physically-based sensitivity studies to urban material properties. Additionally, Best et al. (2006) and Porson et al. (2008 a) have shown that urban canopy models with two facets (roof and canyon) perform better than single facet models as the Best canopy. For these reasons, we implemented a new urban scheme into the MetUM which consists of two facets and which includes a physical dependence on urban material properties.

MORUSES is based on the radiation and heat transfer studies of Harman et al. (2004 a) and b). A full description of the scheme will be given in Porson et al. (2008 b). For the canyon facet, MORUSES computes bulk albedo and emissivity values following the exchange of radiation between the road and the walls (Harman et al. 2004b). Heat transfer is computed accounting for different wind regimes as flow recirculation and ventilation (Harnan et al. 2004 a). Thermal inertia and coupling between the urban facets and underlying soil depend on the facet thermal properties (Porson et al. 2008 b) and are hence computed separately for roof and canyon.

2.2 Idealized Simulations and Validation against Observations

Idealized sensitivity studies with MORUSES and the Best scheme were carried out to estimate the respective impact of both schemes on the surface energy balance flux densities. As shown in the talk and in further details in Porson et al. (2008 b), the impact of MORUSES on the surface energy balance fluxes is qualitatively and quantitatively similar to the impact of the Best scheme.

A comparison to observations of surface flux densities from Mexico City data (Oke et al., 1999) was also carried out for MORUSES and the Best scheme. The results show that MORUSES performs as well against observations as the Best scheme. MORUSES performance against observations depends directly on urban properties. As further detailed in the talk and in Porson et al. (2008 c), MORUSES performance against observations is highly sensitive to thermal properties of the urban facets.

Now that MORUSES performance is assessed in idealized conditions and against observations, our next goal is to investigate the impact of the urban canopy on the UHI using the MetUM.

3. IMPACT OF URBAN FRACTION ON SURFACE ENERGY BALANCE (SEB)

When applying the new urban scheme to more realistic case studies urban areas tend to cover only a certain sub-grid fraction of the land-use within each grid box (see Table 1 for London example).

Urban fraction	all	0.1	0.2	0.3	0.4
N	9894	3505	2228	1548	1027
%	100	35	23	16	10
Urban fraction	0.5	0.6	0.7	0.8	0.9
N	671	424	261	121	19
%	7	4	3	1	1

Table 1 The percentage of grid boxes containing an urban fraction exceeding a critical threshold is calculated for all grid boxes containing urban fractions in the London area with N being the total amount of grid boxes.

Urban areas differ significantly from more vegetated surfaces in terms of the surface energy balance with a higher heat storage uptake, which leads to the UHI effect especially under low wind conditions. In a further step, the critical sub-grid urban fraction needed to obtain a significant urban perturbation in the overall averaged surface energy balance is determined.

Idealized simulations are carried out with the MetUM restricting the sub-grid land use to the two most representative tiles in and around London grass and urban areas, respectively. Bi-cyclic boundary conditions are applied to suppress horizontal advection and all grid boxes consist of the same grass/urban land-use fraction during each simulation. The urban fraction is increased stepwise from 0 % towards 60 %, while similar fractions for the roof and the canyon within the urban tile are ensured. For completeness a case with 100 % urban land use is included as well.

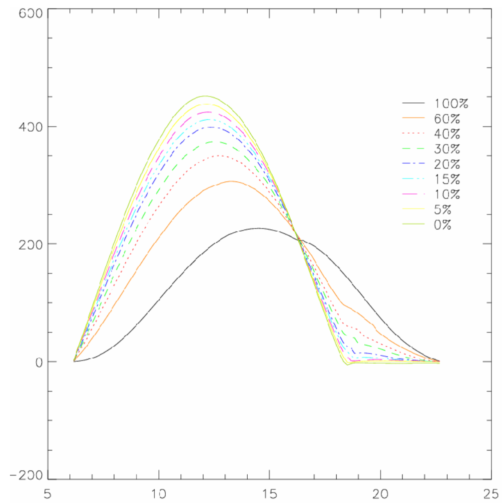

Figure 1 sensible heat fluxes averaged over the whole model domain for varying urban fractions.

The results show a phase shift of the sensible heat flux (Figure 1) with increasing urban fraction and a reduction in the amplitude due to the increased heat storage uptake by the urban area (Figure 2). Both depend in a non-linear way on the urban fraction.

When applying an urban fraction of 30 % it turns out to have already a significant impact on the overall surface energy balance with a reduction of about 20 % in the amplitude of the sensible heat flux, while the differences between 5 %, 10 % and 15 % are comparably small. Similar results are gained for the heat storage term of the energy balance (Figure 2). When comparing this with the urban land use for London (Table 1) those grid boxes with more than 30 % urban fraction contribute to about 16 % out of all urban grid boxes.

4. CONCLUSIONS

In this paper, we have documented the implementation of a new urban scheme, MORUSES into the MetUM (Met Office Unified Model). The impact of MORUSES on the surface energy balance flux densities is similar to the impact of the current scheme from Best (2005). MORUSES, however, includes a physical background and more flexibility in capturing the observations in response to varying urban material properties.

A first sensitivity study indicated that small sub-grid urban fractions have a marginal impact on the overall surface energy balance but 30 % turned out to be a critical fraction needed to affect the surface energy balance significantly.

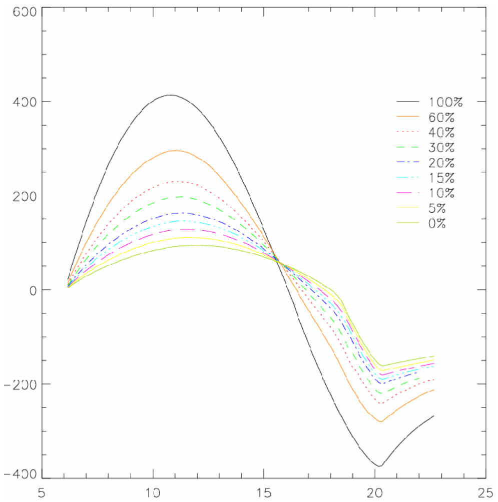

Figure 2 Like Figure 1 but for the heat storage term.

5. OUTLOOK

The improved urban scheme is currently applied to real case scenarios including sensitivity studies and long-term runs over London within the LUCID project to investigate the urban heat island effect and its sensitivity towards different urban built-up areas like commercial districts and more rural districts. High resolution urban building information is currently incorporated to represent London on the kilometre scale.

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