10.3 SENSIBLE HEAT FLUX MODELLING OF URBAN AREAS USING RADIOMETRIC SURFACE TEMPERATURE

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1. INTRODUCTION

Variations of solar elevation and sensor view angle that together influence the apparent anisotropy of the upwelling longwave flux over rough surfaces have been suggested as possible causes in temporally varying z_{0h} or derived kB^{-1} values for these surfaces (e.g. Sugita and Brutsaert 1996, Voogt and Grimmond 2000), although not all rough surface types have been observed to yield these effects (Jacobs and Brutsaert 1998). The model of Brutsaert and Sugita (1996) [BS96] accounts for these factors through a specification of an exponential canopy temperature profile and model coefficients that indicate the degree of sparseness of the canopy. These assumptions and parameters are optimized for vegetated canopies and have been shown to be consistent with measurements (Qualls and Yates 2001). The application of BS96 in urban environments, however, is more problematic.

Here we use a model that estimates urban thermal anisotropy (S3mod; Soux et al. 2000) to generate radiometric surface temperatures for a range of sensor view orientations to further examine the influence of sensor position, solar elevation, and surface temperature structure on derived values of z_{0h} and kB^{-1} over a simple urban surface largely devoid of vegetation.

2. MODELLING ANISOTROPIC DISTRIBUTIONS OF URBAN SURFACE TEMPERATURE

Modelled radiometric temperatures are generated using the S3mod model (Soux et al. 2000). The model generates estimates of the view factors for elements of the urban surface seen by a remote sensor with given specifications (including instrument field of view, height, off-nadir angle, and sensor orientation) over a simple urban surface. The urban surface is modeled as a series of rectangular, equal height buildings arranged in "street block" units where blocks are separated by streets in two directions, and buildings are separated by alleyways in one direction and a specified inter-building spacing in the other. This surface geometry conforms to the primary scales of urban surface structural variability that controls surface temperature variability (Schmid and Oke 1992). The study area is characterized by a very regular arrangement of flat roofed buildings and low amounts of vegetation. The surface dimensions used in S3mod are set to preserve the ratio of complete building area to plan area that was calculated from a GIS of the actual building outlines.

The modelled view factors are used with measured temperatures of building walls and the ground surface from vehicle traverses, and roof temperatures from a roof-mounted IRT. A total of 13 traverses were carried out on Year/ Day 92/228 in the study area. Details of the study site are presented in Voogt and Grimmond (2000).

3. kB^{-1} CALCULATIONS

The modelled radiometric temperatures are used with measured values of sensible heat flux to estimate values of kB^{-1} using direct back calculation and the BS96 approach that has been developed and applied to account for anisothermal effects over homgeneous plant canopies. To apply the BS96 method we solve for estimates of the weighting factor w using

$$T_{rad} = w\, T_{rf} + (1-w)\, T_g \qquad (1)$$

where T_{rf} is a measured roof temperature and T_g is a ground temperature calculated from weighted sunlit and shaded ground surfaces seen within the sensor FOV. The w coefficient in (1) as used in the BS96 approach implicitly includes the effects of canopy density, architecture and shape of the canopy temperature profile, as well as sensor viewing geometry.

4. RESULTS

Results of the back-calculated (observed) and BS96 kB^{-1} values are shown in Figure 1. These illustrate the strong diurnal variability in the observed kB^{-1} for this study site.

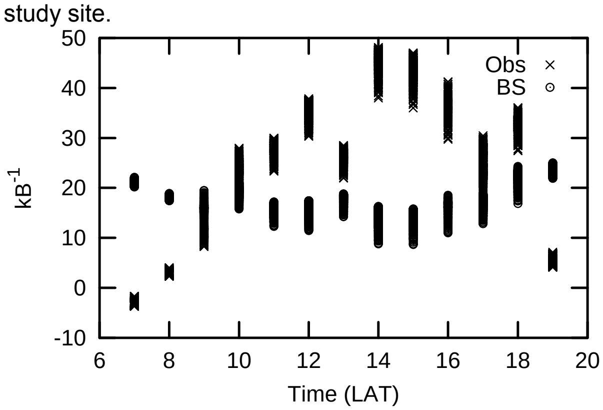

Figure 1. Diurnal variability of back-calculated (observed) and BS96 kB^{-1} for a light industrial study area in Vancouver BC.

Figure 2 depicts the variability of the two kB^{-1} estimates with sensor viewing geometry. Panels in the left hand column represent back-calculated kB^{-1} estimates; the

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right hand column presents estimates using the BS96 approach. Values are plotted as the difference from the mean kB^{-1} value for the data set. Points represent calculations made for sensor orientations 0 – 345° in 15° steps, and viewing angle from 0 – 50° plotted in Cartesian coordinates converted from the sensor polar geometry. These results (and those in Figure 1) show that the BS96 method removes some of the diurnal variability due to surface anisotropy. However, as can be seen from the remaining diurnal trend in Figure 1 it is not completely removed. The 3-dimensional plots suggest lower kB^{-1} values occur when viewing azimuths towards the sun, and higher values when viewing in the down-sun direction, and this pattern is retained after application of BS96.

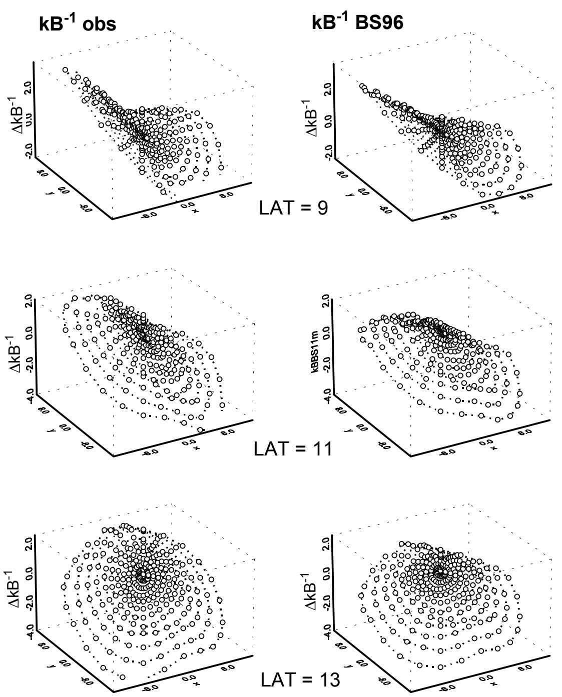

Figure 2. ΔkB^{-1} from the mean value plotted for all sensor viewing positions (converted to rectangular coordinates) at 9, 11 and 13 LAT. Left-hand side are observed (back-calculated values); RHS use BS96 approach.

When the BS96 kB^{-1} values are used to model Q_H, some periods are poorly modelled (Figure 3). In particular the period (14,15 h) which have the greatest observed kB^{-1} values (Figure 1) show the greatest departure from observed Q_H. At these times the BS96 method produces kB^{-1} values that show a minimum, falling below 20, the lower bound of the estimate suggested in Voogt and Grimmond (2000) for this site. The range of values plotted for each observed Q_H correspond to the range of sensor orientation and off nadir angle. It can be seen at the times of poorest performance the impact of this will also be the greatest on the calculated Q_H.

Further assessment of the BS96 method and determination of suitable input parameters for application of the method over urban areas is under way.

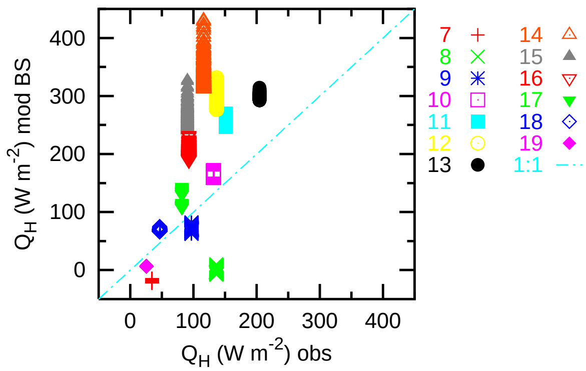

Figure 3. Observed versus modelled Q_H values using the BS96 approach. Plotting symbols vary with time of observation.

5. ACKNOWLEDGEMENTS

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