Modelling of Urban Sensible Heat Flux at Multiple Spatial Scales: a Demonstration Using Airborne Hyperspectral Imagery of Shanghai and a Temperature-Emissivity Separation Approach

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Urbanization related alterations to the surface energy balance impacts urban warming ('heat islands'), the growth of the boundary layer, and many other biophysical processes. Traditionally, in situ heat flux measures have been used to quantify such processes, but these typically represent only a small local-scale area within the heterogeneous urban environment. For this reason, remote sensing approaches are very attractive for elucidating more spatially representative information. Here we use hyperspectral imagery from a new airborne sensor, the Operative Modular Imaging Spectrometer (OMIS), along with a survey map and meteorological data, to derive the land cover information and surface parameters required to map spatial variations in turbulent sensible heat flux (Q_H). The results from two spatially-explicit flux retrieval methods which use contrasting approaches and, to a large degree, different input data are compared for a central urban area of Shanghai, China: (1) the Local-scale Urban Meteorological Parameterization Scheme (LUMPS) and (2) an Aerodynamic Resistance Method (ARM). Sensible heat fluxes are determined at the full 6 m spatial resolution of the OMIS sensor, and at lower resolutions via pixel aggregation and spatial averaging. At the 6 m spatial resolution, the sensible heat flux of rooftop dominated pixels exceeds that of roads, water and vegetated areas, with values peaking at ~ 350 W m^{-2}, whilst the storage heat flux is greatest for road dominated pixels (peaking at around 420 W m^{-2}). We investigate the use of both OMIS-derived land surface temperatures made using a Temperature-Emissivity Separation (TES) approach, and land surface temperatures estimated from air temperature measures.

Sensible heat flux differences from the two approaches over the entire 2 x 2 km study area are less than 30 W m^{-2}, suggesting that methods employing either strategy maybe practica1 when operated using low spatial resolution (e.g. 1 km) data. Due to the differing methodologies, direct comparisons between results obtained with the LUMPS and ARM methods are most sensibly made at reduced spatial scales. At 30m spatial resolution, both approaches produce similar results, with the smallest difference being less than 15 W m^{-2} in mean Q_H averaged over the entire study area. This is encouraging given the differing architecture and data requirements of the LUMPS and ARM methods. Furthermore, in terms of mean study Q_H, the results obtained by averaging the original 6 m spatial resolution LUMPS-derived Q_H values to 30 and 90 m spatial resolution are within ~ 5 W m^{-2} of those derived from averaging the original surface parameter maps prior to input into LUMPS, suggesting that that use of much lower spatial resolution spaceborne imagery data, for example from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is likely to be a practical solution for heat flux determination in urban areas.