Geophysical Research Abstracts
Vol. 13, EGU2011-11391, 2011
EGU General Assembly 2011

The energy budget of the urban surface: Two locations in Dublin

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The energy budget is a statement of the principle of the conservation of energy. Applied to a surface it describes the magnitude and types of surface-air energy exchanges that give rise to distinctive near-surface climates. Traditionally observation programmes to measure its terms were conducted over ideal surfaces that could be described as flat and extensively homogenous. Hence, a measurement system located above the vegetative canopy at sufficient distance from the edge of the surface could be assured of a suitable fetch. Thus the energy fluxes acquired were substantially invariant with wind direction and could be clearly linked to the underlying surface. Conducting energy budget observations in an urban setting is more complex owing to the nature of the urban canopy, the heterogeneous nature of the urban surface and the presence of additional terms. Consequently, there are relatively few observations of urban energy budgets in different urban environments. However, this information is needed to improve our understanding of urban climate processes and to aid in the development of urban climate models.

A statement of the urban energy budget is as follows:

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

Which states that net radiation (Q^*) plus anthropogenic heat (Q_F) is partitioned into the vertical exchange of sensible and latent heat (Q_H+Q_E) via turbulence, the storage of heat in the system under study (ΔQ_S) and the horizontal transport of energy through the system (ΔQ_A) by advection. Each term is expressed as a flux density, the flow of energy (Watts, W) per unit surface area (m^2). Observing each of these terms is difficult in an urban setting and experimental designs have employed both measurements and estimates to partition energy exchanges. To acquire information on distinctive urban surface types requires careful placement of the instruments both vertically and horizontally. The vertical placement of instruments should be within the constant flux layer located above the urban 'surface'. The available evidence suggests that this layer is located a considerable distance above the urban roughness elements (H) at a height $\geq$1.5H. The horizontal placement within the settlement should be such as to ensure a suitable fetch over a 'homogenous' urban surface (so that ΔQ_A can be ignored). This requires careful site selection to ensure that instruments are located within a neighbourhood that has consistent properties (street widths, building heights, vegetative cover, etc.).

This paper presents the results of an energy budget measurement programme within Dublin. Two sites were selected to represent two urban subtypes:

1. A sub-urban location consisting of extensive semi-detached, two storey houses with private gardens and large, mature trees.
2. A densely built city centre site with little vegetation.

At both sites instrumented masts have been observing energy exchanges for approximately one year. These exchanges include net radiation (and the individual short- and long-wave terms) and turbulent sensible and latent heat fluxes. The nature of the urban surface cover at each site has been captured and is used to interpret the results. The paper will present the results from each site and compare these with comparable measurement programmes in other cities.