HIGH FREQUENCY PATTERNS IN URBAN SURFACE TEMPERATURES

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Surface temperature T_s is a key parameter in urban climatology. Satellite, aerial and ground-based remote-sensing approaches addressing the urban surface energy exchange measure the spatial distribution and discuss T_s in the context of relative sun position, urban morphometry, material properties, storage, and radiation anisotropy. However, little is known on high-frequency (< 1°h) dynamics of T_s and its linkage to atmospheric turbulent exchange processes, especially under diabatic conditions. Large coherent structures dominate turbulent exchange in the atmosphere above a rough surface, such as a city. As a consequence, characteristic ramp structures in air temperature are observed close to the surface. It is unknown to which extent these air temperature patterns also affect T_s. The present study has the goal (a) to quantify the magnitude of high-frequency and small-scale fluctuations in T_s (b) to detect patterns in the temporal and spatial domains, and (c) couple fluctuations in T_s and turbulent exchange in the atmosphere aloft.

Embedded into the experimental framework of EXCUSE (Energy Exchange of Urban Structures and Environments), a thermal IR scanner located on a 120 m high-rise building in Berlin (Steglitzer Kreisel) continuously observes and records long-wave radiation flux densities Q_L of an urban neighbourhood. The instrument ('Variocam Heat', Infratec) measures T_s for 320 by 240 pixels at 50 Hz, which are subsequently resampled to 2 Hz and converted to absolute values for T_s by applying a detailed atmospheric correction and calibration procedure. The field of view (FOV) of the instrument approximately covers 0.1 km^2 in oblique view (-15 to -70° angle of inclination). It incorporates representative objects of the 3d structured urban surface (roofs, walls, streets, including urban vegetation). The setup is complemented by two ultrasonic anemometers: one at camera level and one within the urban canopy inside the scanner's FOV.

By using two averaging operators, a temporal average denoted by an overbar $\overline{T_s}$, and a spatial average denoted by angle brackets $\langle T_s \rangle$, 3d-stacks (x_i,t) of high-frequency time series are decomposed into fluctuating parts according two schemes, namely

The inner-temporal-outer-spatial decomposition: $T_s(x_i,t) = T_s'(x_i,t) + \overline{T_s}''(x_i) + \langle \overline{T_s} \rangle$

The inner-spatial-outer-temporal decomposition: $T_s(x_i,t) = T_s''(x_i,t) + \langle T_s \rangle'(t) + \overline{\langle T_s \rangle}$

A prime denotes a departure from the temporal average whereas a double prime indicates a departure from the spatial average. As a consequence of the large area covered in the FOV, for stationary time series $\partial \langle T_s \rangle / \partial t$ vanishes. Hence, temporal variations in the term $\langle T_s \rangle'(t)$ are supposed to be an effect of sensor noise, large scale trends and atmospheric processes close to the lens only. Together with the shift-difference method, this allows estimating an upper limit of the background and instrumental noise.

The remaining fluctuations are statistically analyzed to identify the magnitude at different locations (T_s') and in different time steps (T_s''). Further, with the use of wavelet-transforms and cross-correlations, characteristic patterns are detected, quantified and their frequency of occurrence is extracted from the time series.