Low Frequency Contributions to Heat, Water Vapor and Carbon Dioxide Fluxes Measured over Boreal Forest and Rice Paddy Field in Japan

*M. Saito[1], J. Asanuma[2] and A. Miyata[3]
1) Graduate school of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8577, Japan
2) Terrestrial Environment research center, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8577, Japan
3) Ecosystem Gas Exchange Team, National Institute for Agro-Environmental Sciences, Kannon-dai, 3-1-3, Tsukuba, Ibaraki, 305-8604, Japan
msaito@suiri.tsukuba.ac.jp

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Introduction: The improvements in sonic anemometer (SAT) and infrared gas analyzer (IRGA) enables us to use the eddy covariance method for long-term turbulent fluxes measurements with higher accuracy and less uncertainties. These long-term monitoring has revealed that scalar exchange rates are consistently smaller than those predicted by models and those expected from the budget equation of the scalar. It has been argued by many authors that this underestimation can be caused by various factors, observational and analysis problems, the biased the selection of a measurement location, and surface. Among them, attention is being paid to the contribution of the low frequency motions to the scalar exchanges. This component is usually ignored in the ordinary flux calculations. For example, to incorporate this low frequency flux components into flux estimates some of recent studies proposed analytical methods, so-called modified eddy covariance calculations. The goal of this study is to investigate the nature of low frequency components of heat, water vapor and carbon dioxide flux. In order to reveal the scale dependency of these fluxes especially at the scale of 10 minutes and larger, the wavelet transform is used in the analysis of the data obtained at two measurement sites with different landscapes.

Data: The data analyzed in this study comprises two data sets. One is the boreal forest dataset (TMK) that were collected over uniform Japanese larch canopy at the Tomakomai flux research site, Hokkaido, Japan. The flux measurements were conducted on a flux research tower (42 m), and eddy covariance data were collected with a SAT (DA-600, Kaijo) and an open-path IRGA (LI-7500, Li-cor) at two heights, 27 m and 42 m above ground over a 15 m canopy. The wind components, virtual temperature, water vapor density and CO_2 density were recorded at 10 samples per second. This study analyzes the dataset during 23 May to 6 August 2002.

The other, hereafter called MSE were collected over irrigated flat rice fields at the Mase paddy flux site, Ibaraki, Japan. The flux measurements were conducted at two heights, 3 m and 6 m above ground with a SAT (DA-600, Kaijo) and an open-path IRGA (LI-7500, Li-cor), from which the wind components, virtual temperature, water vapor density and CO_2 density were recorded at 10 samples per second. During the experiment, rice plant canopy height varied between 20 cm and 120 cm along with plant growth. This study analyzes the dataset during 1 June to 30 September 2004.

Result: First, heat and water vapor fluxes computed over two averaging periods, namely 15 minutes and 2 hours were compared with each other. At the MSE site, it was found with some data runs that heat flux with 2-hrs average significantly larger than 15-mins average, while other data runs show no significant difference between. Water vapor flux did not show such differences. At the TMK site, on the other hand, heat flux showed consistent increase with longer averaging period. In contrast, 2-hrs and 15-mins averages for water vapor flux differ when its magnitude is small or large. 2-hrs flux increased the magnitude when 15-mins water vapor flux was comparatively large, but on the contrary reduced when 15-mins flux was small. These results suggest that the contribution of atmospheric motions at the scale between 15 minutes and 2 hours varies with different measurements sites and for different scalars. The heat flux at the MSE site and the water vapor flux at the TMK site were investigated to see whether the fluxes component at the large scale have a dependency on the micrometeorological conditions. This large scale component showed a rough tendency to be large with weaker wind or with more convective stratification.

To further investigate the scale dependency of surface fluxes and the contribution of large scale motion to scalar transport, wavelet cospectra were calculated through wavelet transform from 2-hrs time series data. In this study, the multiresolution analysis, or equivalently wavelet transform with Haar wavelet, was used to decompose a time series into orthogonal modes of variations, and these modes were integrated to give a wavelet cospectrum. Wavelet analysis is a powerful tool to analyze non-stationary time series. All of computed wavelet cospectra showed an universal dependency on frequency in the energy-containing range and at higher frequencies regardless of their frequency dependencies at lower frequencies. On the other hand, wavelet cospectra at lower frequencies showed large run-to-run variation as well as 'intra-run' variation. A remarkable observation is that these run-to-run variations were limited to some of the analyzed runs, the runs which had shown differences between 15-mins and 2-hrs fluxes. These observations indicate that flux component at low frequencies between 15-mins and 2-hrs, or approximately 1 to 10 km in the horizontal length scale, is generated in only limited time. It was also found that these low frequency components significantly differ in their magnitude and in their scale dependence between the two sites and the two scalars.

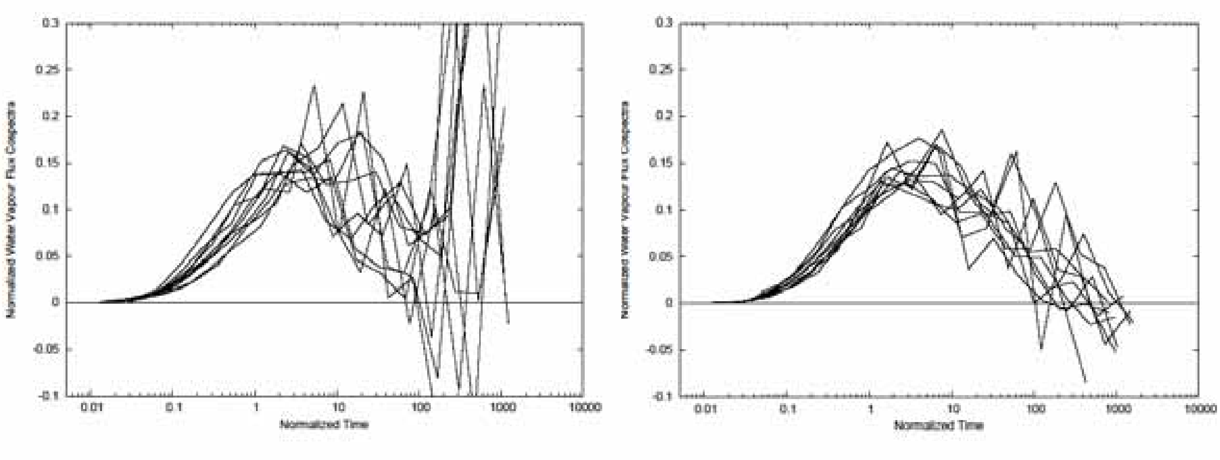

Figure. Normalized timescale dependency of normalized water vapor flux at the TMK site 42 m SAT data for 2-hrs average water vapor flux lager than 15-mins average (left) and no significant difference between (right).