Abstract: During the first portion of this seminar, extensive PIV data collected from a scaled down 3 blade, 3 x 5 turbine array is shown. In order to understand how large scale motions play a role in providing mean kinetic energy (MKE) to the array, low dimensional tools based on a proper orthogonal decomposition (POD) are used to analyze the spatially developing velocity field inside the scaled array. From this analysis, modal decomposition of the Reynolds stresses and fluxes of the MKE are constructed. Thus, from these modal expansions it is established that low order modes have large contributions to Reynolds shear stress regardless of analysis domain. In addition, it will be shown that mean kinetic energy transport resulting from Reynolds shear stress typically serves to bring energy into the array while transport terms associated with Reynolds wall-normal stress typically removes energy from the array. Furthermore, it will be shown that the sum of the first 13 modes for the mean fluxes contributes 75% of the total Reynolds shear stress in the domain.

The concept of coherent transfers of energy is employed here as means to uncover the scales responsible for the entrainment of mean kinetic energy into the array. The major contributions to the MKE entrainment are achieved by large-scale motions associated with sums of the Reynolds shear stress/(idosyncratic) modes (see figure 1). Thus, the sum of the first 9 modes yield 54% of the total energy entrainment, with scales given by L ~ 13D associated with this sum. It is expected that given a longer experimental setup, the lengths of these large-scale contributions would have been observed to be even bigger. Moreover, a major result from the modal length-scale analysis is that large scale motions or the idiosyncratic modes contain most of the MKE and that the low mode numbers are associated with the small scales. These high order POD modes in the inhomogeneous flow direction (x-coordinate) correspond to the Fourier-like modes and decay as 1/n where n is the mode number (see fig. 1 right). This observation is consistent with studies of wall-bounded flows by Baltzer & Adrian (PoF, 2011).

From these results, it is clear that scales of the order of the total wind farm size are those which are critical in determining how much power can be extracted from the atmospheric boundary layer. In addition, during this seminar it will be shown that dispersive stresses are also important in the energy entrainment and dissipation in wind arrays with complex topography and where proximity between turbines exists.

During the second part of the seminar, preliminary PIV results from scaled down experiments of 2 blades versus 3 blades arrays subject to similar conditions in a wind tunnel will be presented. Of primary importance from this data are the differences which exist in the entrainment patterns between 2 and 3 bladed turbine arrays. Finally, a prototype of a wind farm will be shown as means for future collaborations between UMN and TTU. In general, this seminar will stress the importance of understanding turbulence in wind energy.