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An investigation of the failure of flux gradient theory during the evening transition period

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During fair weather conditions there are typically two periods during the day in which the atmospheric boundary layer (ABL) undergoes major transitions. In the early morning, the ABL changes from a Stable Boundary Layer (SBL) to a Convective Boundary Layer (CBL), and from CBL to SBL in the afternoon. The Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST, [1]) project was developed to characterize the evolution of the atmospheric boundary layer during the late afternoon transition (LAT). The main objectives of this project are to better understand both the importance of terrain heterogeneity on the LAT as well as the vertical structure of the boundary layer during this period of the day.

During the evening transition, local gradient theory predicts that the sensible heat flux ceases to introduce heat into the ABL at the same time the gradient of the potential temperature becomes positive. Some investigations, such as Grimsdell and Angevin [2], reflect a continuation of heating after the sensible heat flux becomes negative from the upper part of the atmosphere via entrainment process. By using data collected during several days of the BLLAST campaign at a tower instrumented with 16 sensors (thermocouples and sonic anemometers), it will be shown that a delay (30 to 60 minutes) exists between the time when sensible heat flux goes to zero, and the change of sign in the local virtual potential temperature gradient. Additionally, by using fluid mechanics theory, we postulate an explanation for the time delay. Specifically, when the last eddy formed at the ground surface (which is associated with a positive sensible heat fluxes) is decelerated through the presence of viscosity and thermal diffusivity a delay time results that is greater than the classical convective time scale.

Finally, it is important to highlight that including the presence of this delay in atmospheric simulation models through parameterizations could help to improve the accuracy of near surface flux and variance computations.

References:
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[2] Grimsdell, A. W., Angevine, W. M., (2002): "Observations Of The Afternoon Transition Of The Convective Boundary Layer". J. Appl. Meteor., 41, 3–11.