

Numerical simulations of low-level jets with land-sea transition

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Duration : 6 months, start in April 2024
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Requirements :

- Knowledge of fluid mechanics and numerical simulations (theory) at Master level.
- Basic knowledge of a programming language (C++ and/or python or julia are best but not mandatory).
- Knowledge of atmospheric boundary layer not required.

Low-level jets are atmospheric structures appearing mostly during the night in a stable atmospheric boundary layer. The jet is best described as a pronounced wind speed less than a km over the surface, a sharp change to the classical logarithm profile expected from boundary layer, developing during sunset in cloud-free conditions. The wind speed often reaches a peak in the early morning before decaying after dawn with the onset of convective mixing.

There has been numerous observations over the Great Plains in the USA and several theoretical models have been developed as early as 1957 (see [Shapiro 2016] and references herein. For an easier conceptual approach, see [Van De Wiel, 2010]).

Nowadays, several realistic approaches have been made to simulate low-level jets over specific areas, supported by improved on-site measurement methods. This spark of interest results from offshore wind-farm. Low-level jets were seen to developed over land-sea interface, with thus a potential resource for wind energy. If these studies offer great insight on the local behavior of a jet, they, unfortunately, cannot grant a deep understanding of a more general view of this kind of specific structure. For example, what are the difference between a land jet and a land-sea jet ? A recent direct numerical simulation by [Fedorovitch, 2017] had shown noticeable differences between a jet over a plane surface and a slow-slope. What happens with the thermal difference between land and sea, which is known to sharply change the boundary layer? What happens to the turbulence? These questions remain with little to no answer. Even with a simple jet over a plan, the turbulence behavior over such a stratified boundary layer is still an open question.

Preliminary organization of the work :

The intern will thus realized numerical simulations (DNS or LES) with the microHH code (<https://microhh.github.io/>), starting from what was done in [Fedorovitch, 2017], without the slow-slope. This first simulation will serve as the groundwork for comparison with low-level jets going over a thermally changing surface (mimicking a land-sea transition). The intern will be expected to compare the wind and temperature profiles of the different jets. The turbulent kinetic energy will also be compared and, if the time allows it, spectral analysis of the turbulent cascade will be carried on.

Bibliography :

[Fedorovitch, 2017] : Fedorovich, E., J. A. Gibbs, and A. Shapiro, 2017: Numerical Study of Nocturnal Low-Level Jets over Gently Sloping Terrain. *J. Atmos. Sci.*, 74, 2813–2834, <https://doi.org/10.1175/JAS-D-17-0013.1>.
 [Shapiro 2016] : Shapiro, A., E. Fedorovich, and S. Rahimi, 2016: A Unified Theory for the Great Plains Nocturnal Low-Level Jet. *J. Atmos. Sci.*, 73, 3037–3057, <https://doi.org/10.1175/JAS-D-15-0307.1>.
 [Van De Wiel, 2010] : Van de Wiel, B. J. H., A. F. Moene, G. J. Steeneveld, P. Baas, F. C. Bosveld, and A. A. M. Holtslag, 2010: A Conceptual View on Inertial Oscillations and Nocturnal Low-Level Jets. *J. Atmos. Sci.*, 67, 2679–2689, <https://doi.org/10.1175/2010JAS3289.1>