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The superposition of a rotating wake with the atmospheric Ekman spiral

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Stably stratified atmospheric boundary layers are often characterized by a veering wind profile, in which the wind direction changes clockwise (counterclockwise) with height in the Northern Hemisphere (Southern Hemisphere). Wind-turbine wakes respond to this veer in the incoming wind by stretching from a circular shape into an ellipsoid. Englberger, Dörnbrack and Lundquist (2020) investigate the relationship between this stretching and the direction of the turbine rotation by means of large-eddy simulations (LESs).

The basic physics underlying the interaction process of a rotating wake with a veering inflow can be described with the superposition of a Rankine vortex as representation of the wind-turbine wake with the characteristic hemispheric-dependent nighttime Ekman spiral of the atmospheric wind. In dependence of the rotational direction and the hemisphere, this superposition results in an amplification of the spanwise flow component if a counterclockwise rotating rotor interacts with a northern hemispheric Ekman spiral (a clockwise rotating rotor interacts with a southern hemispheric Ekman spiral). In case of a clockwise rotating rotor interacting with a northern hemispheric Ekman spiral (a counterclockwise rotating rotor interacting with a southern hemispheric Ekman spiral), the superposition leads to a weakening of the spanwise flow component. In case of no veering inflow, the magnitude of the spanwise flow component is independent of the rotational direction.

These theoretical superposition effect of the Ekman layer with the wake vortex occur in nighttime LESs, where the rotational direction dependent magintude of the spanwise flow component further impacts the streamwise flow component in the wake. In particular, there is a rotational direction dependent difference in the wake strength, the extension of the wake, the wake width, and the wake deflection angle. In more detail, a northern hemispheric veering wind in combination with a counterclockwise rotating actuator results in a larger streamwise velocity output, a larger spanwise wake width, and a larger wake deflection angle at the same downwind distance in comparison to a clockwise rotating turbine.

Englberger, Dörnbrack and Lundquist, 2020, Does the rotational direction of a wind turbine impact the wake in a stably stratified atmospheric boundary layer? *Wind Energ. Sci.* **5**, 1359-1374.