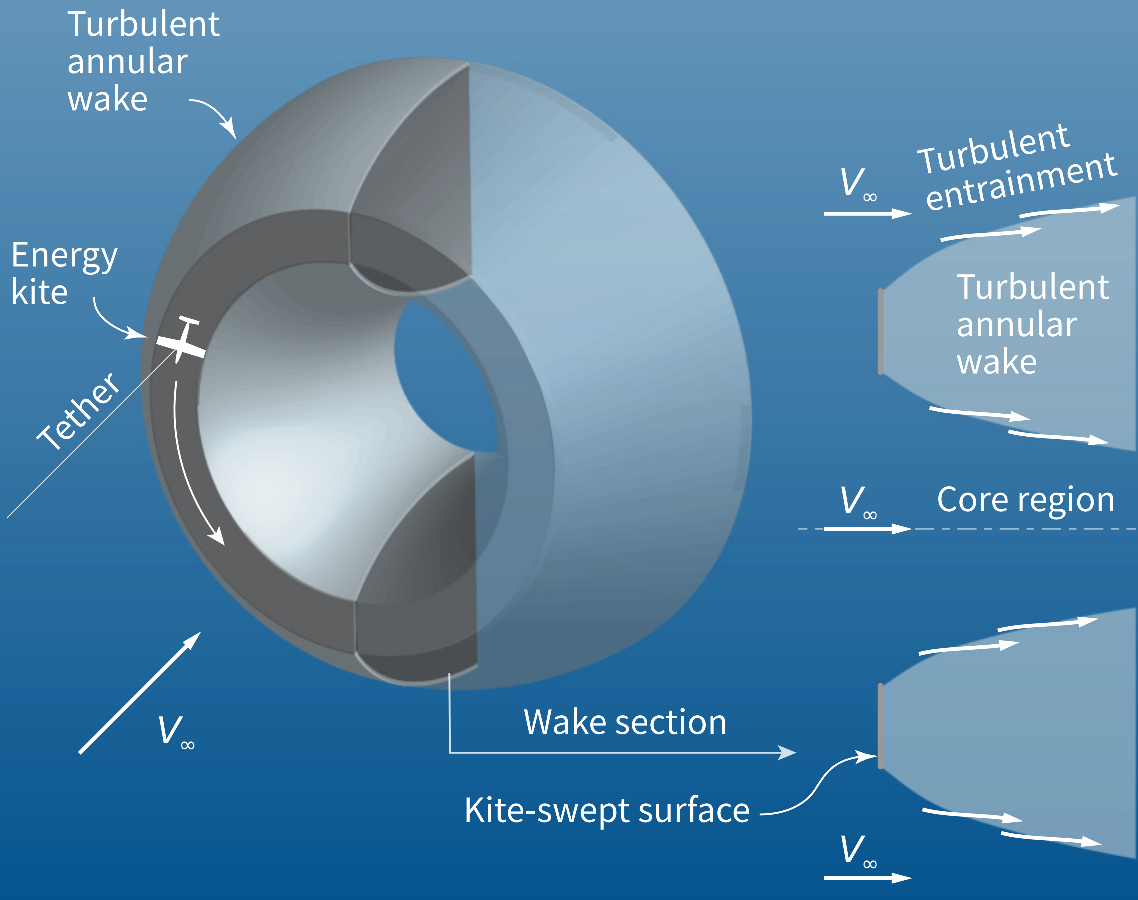


Turbulent annular wake
Energy kite
Tether
V_∞
Wake section
Kite-swept surface
V_∞
Turbulent entrainment
Turbulent annular wake
V_∞
Core region
V_∞

Sam Kaufman-Martin

Doctoral Candidate
University of California, Santa Barbara
Department of Mechanical Engineering
Fluid Energy Science Laboratory
Engineering II, UCSB

Santa Barbara, California 93106
United States

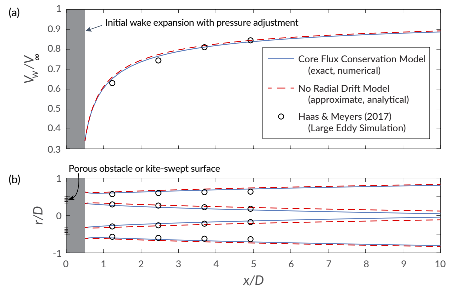
s_kaufman-martin@ucsb.edu
feslab.me.ucsb.edu

An Entrainment-Based Model for Annular Wakes, with Applications to Airborne Wind Energy

Sam Kaufman-Martin, Nicholas Naclerio, Pedro May, Paolo Luzzatto-Fegiz
University of California, Santa Barbara

Several novel wind energy systems produce wakes with annular cross-sections (as illustrated the figure on the opposite page), which are qualitatively different from the wakes with circular cross-sections commonly generated by conventional horizontal-axis wind turbines and by compact obstacles. Since wind farms use arrays of tens or hundreds of turbines, good analytical wake models are essential for efficient wind farm planning. Several models already exist for circular wakes; however, none have previously been published for annular wakes, making it impossible to quickly estimate their array performance across a variety of configurations.

To address this challenge, we use the turbulent entrainment hypothesis to develop a reduced-order model for the shape and flow velocity of an annular wake behind a generic annular obstacle. Our model consists of a set of three ordinary differential equations, which we solve numerically. In addition, by assuming that the annular wake does not drift radially, we further reduce the problem to a model comprising only two differential equations, which we solve analytically. Both of our models are in good agreement with previously published large eddy simulation results, as shown in the following figure.



Comparison of our entrainment wake models with the simulation of Haas & Meyers [1] for the laminar inflow case. Similar agreement is found for turbulent inflow [2]. (a) Wake velocity. (b) Wake cross section.

References:

[1] Haas, T., Meyers, J.: Comparison Study between Wind Turbine and Power Kite Wakes. J. Phys. Conf. Ser. 854, 012019 (2017). doi:10.1088/1742-6596/854/1/012019

[2] Kaufman-Martin, S., Naclerio, N., May, P., Luzzatto-Fegiz, P.: An Entrainment-Based Model for Annular Wakes, with Applications to Airborne Wind Energy. Wind Energy 25(3), 419-431 (2021). doi:10.1002/we.2679