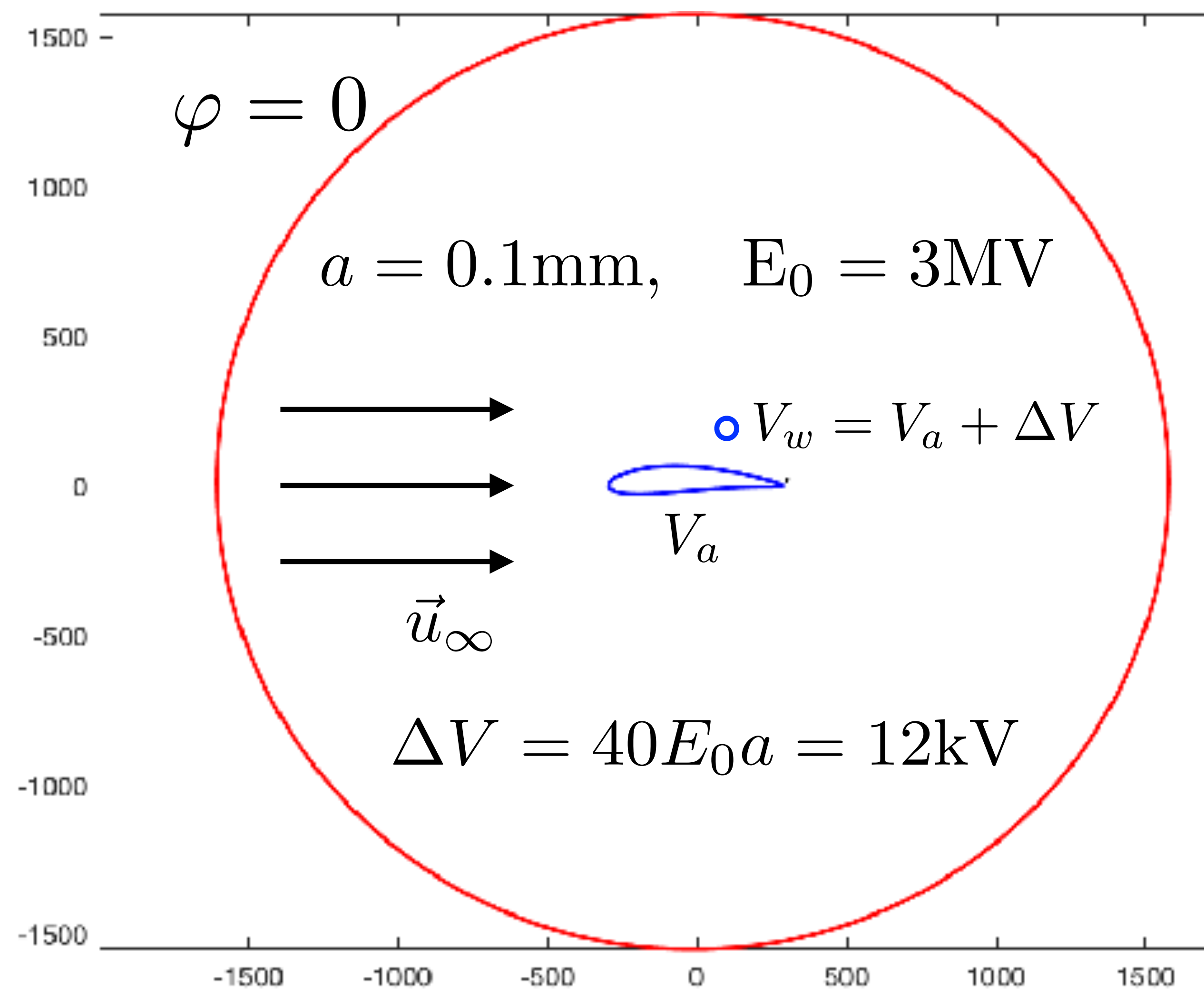
Steady-State Glow Corona Charging

Cylindrical pulsating corona: Ion charges are released at the anode and travel towards the cathode. The main interest is in the glow regime, in which the charges remain constant as they drifts, but since, under a rising potential or external field, ionization may be at some point be initiated in the bulk.



The following definitions are adopted for the various dimensionless quantities:

$$\eta = \frac{r}{a}; \quad \tau = \frac{\mu E_0}{a} t; \quad \varphi = \frac{\phi}{E_0 a}; \quad e = \frac{E}{E_0}$$

$$v = \frac{V}{E_0 a}; \quad q_k = \frac{Q_k}{2\pi\varepsilon_0 a E_0}; \quad i = \frac{I}{2\pi\varepsilon_0 \mu E_0^2}.$$

Here, μ is the mobility of positive ions, and *I* is the current per unit length in the external circuit feeding the corona.

Our goal is to determine the charge density due to the ion emission from the wire and the airfoil potential V_a.

Steady-State Glow Corona Model

The model consists of the Poisson equation and the charge conservation equation:

$$
\begin{aligned}
\nabla \cdot \vec{e} &= \rho, & (1) \\
\vec{e} &= -\nabla \phi, & (2) \\
\nabla \cdot \rho(\vec{e} + \vec{u}) &= 0 & (3)
\end{aligned}
$$

together with boundary conditions on the potential

$$\phi = V_a \text{ on airfoil}, \quad \phi = V_w \text{ on wire}, \quad \phi = 0 \quad \text{on cathode}$$

and boundary conditions on the charge density

$$\rho = \rho_w \text{ on wire}, \quad \rho = 0 \quad \text{on cathode}$$

Our goal is to determine the charge density on the wire ρ_w and the airfoil potential V_a.

Peek Condition

The charge density is calculated by imposing that the number of electrons created by an avalanche that starts at E(r)=E_0 (at which attachment to Oxygen molecules happens at the same rate as ionization) reaches a critical value N_e (of order 10):

$$\int_a^{r_0} (\alpha - \eta)\, dr = N_e$$

where α(E) and η(E) are the first and second Townsend coefficients, for ionization and attachment, respectively.

Assuming a linear approximation $\alpha(E) - \eta(E) = K(E - E_0)$, the above equation becomes

$$\int_a^{r_0} \left(\frac{E(r')}{E_0} - 1\right) d\left(\frac{r'}{a}\right) = \frac{N_e}{KE_0 a} \approx \frac{4.13\times 10^{-4}}{a(m)}$$

or, in non-dimensional terms,

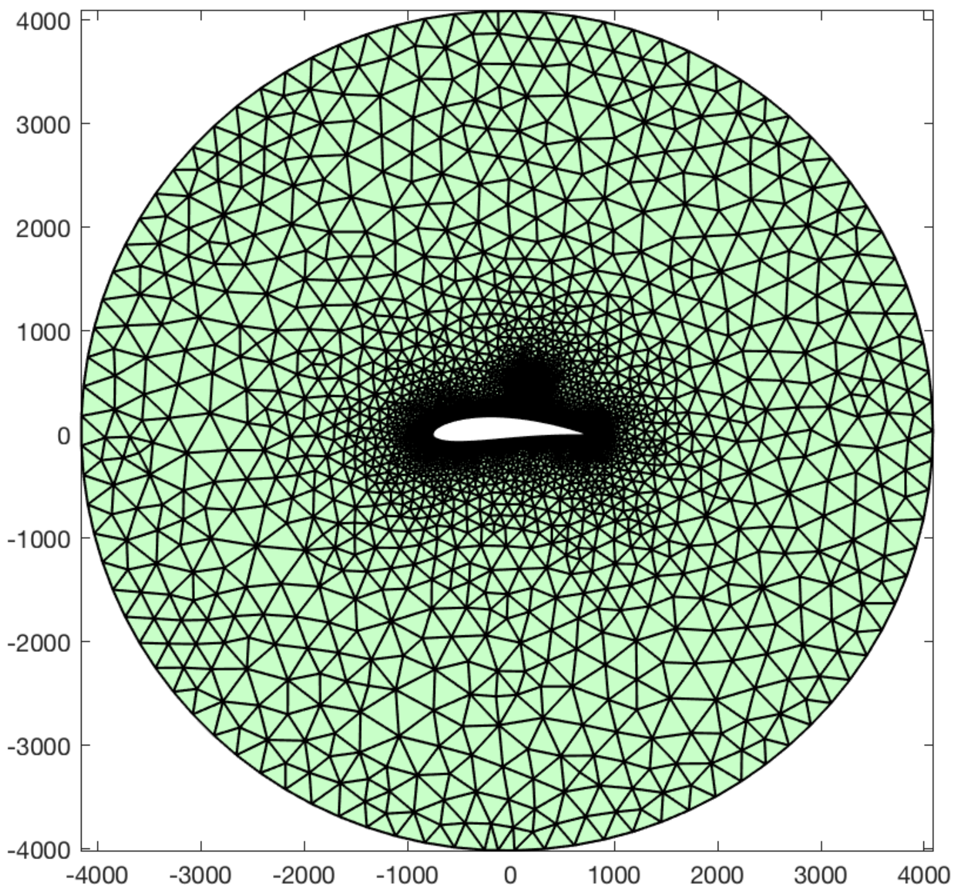
$$\int_1^{\eta_0} [e(\eta') - 1]\, d\eta' = R = \frac{4.13\times 10^{-4}}{a(m)}$$

The Peek condition is used to determined the charge density on the wire ρ_w.

Minimal Potential Condition

The potential on the airfoil is determined as a the minimum value that conserves the space charge between the wire and the airfoil. In other words, there is no charge leakage to free space.

First Case



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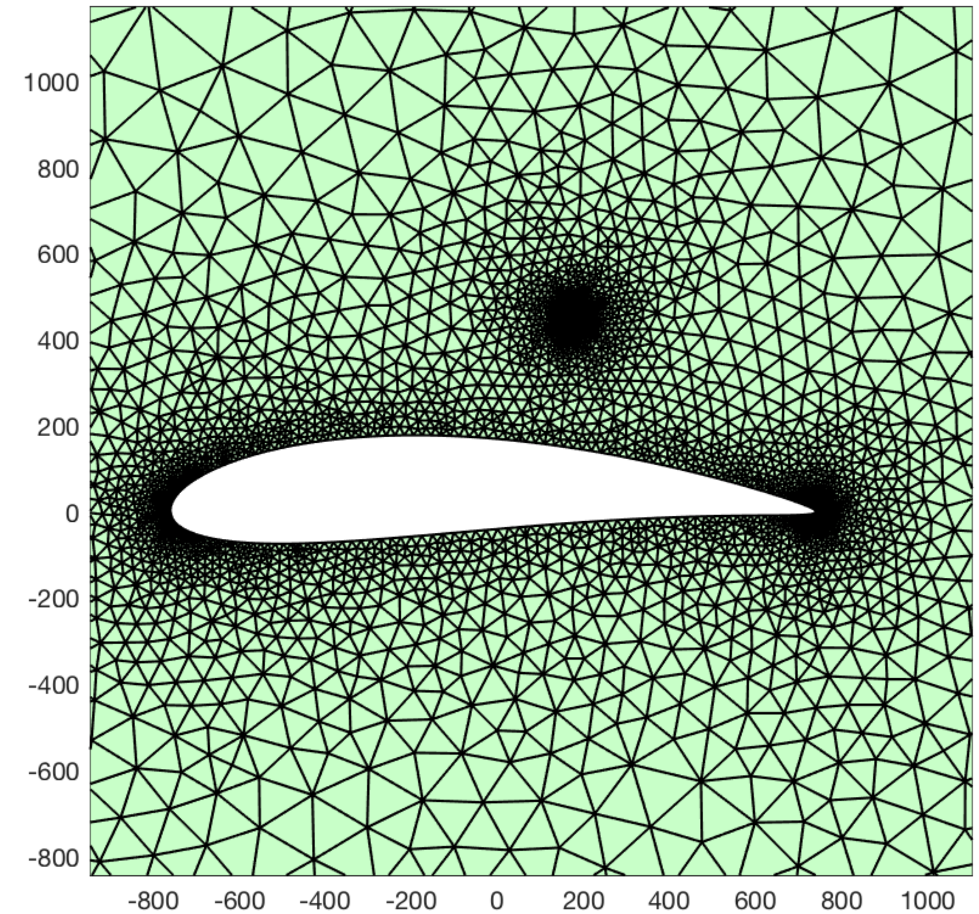

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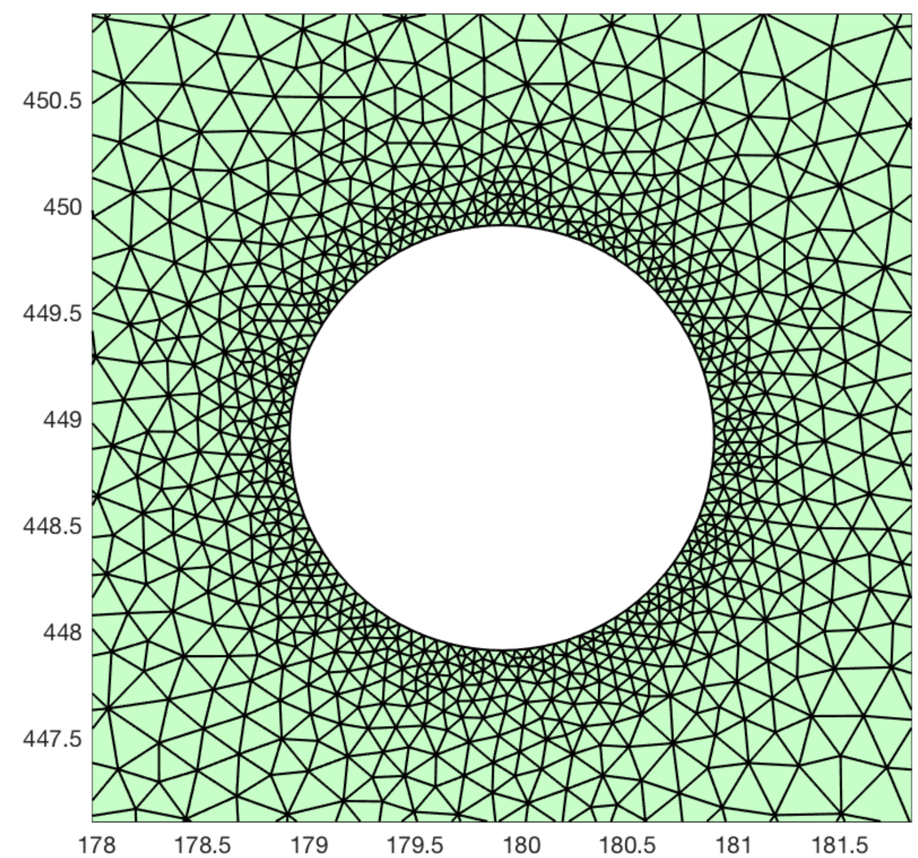

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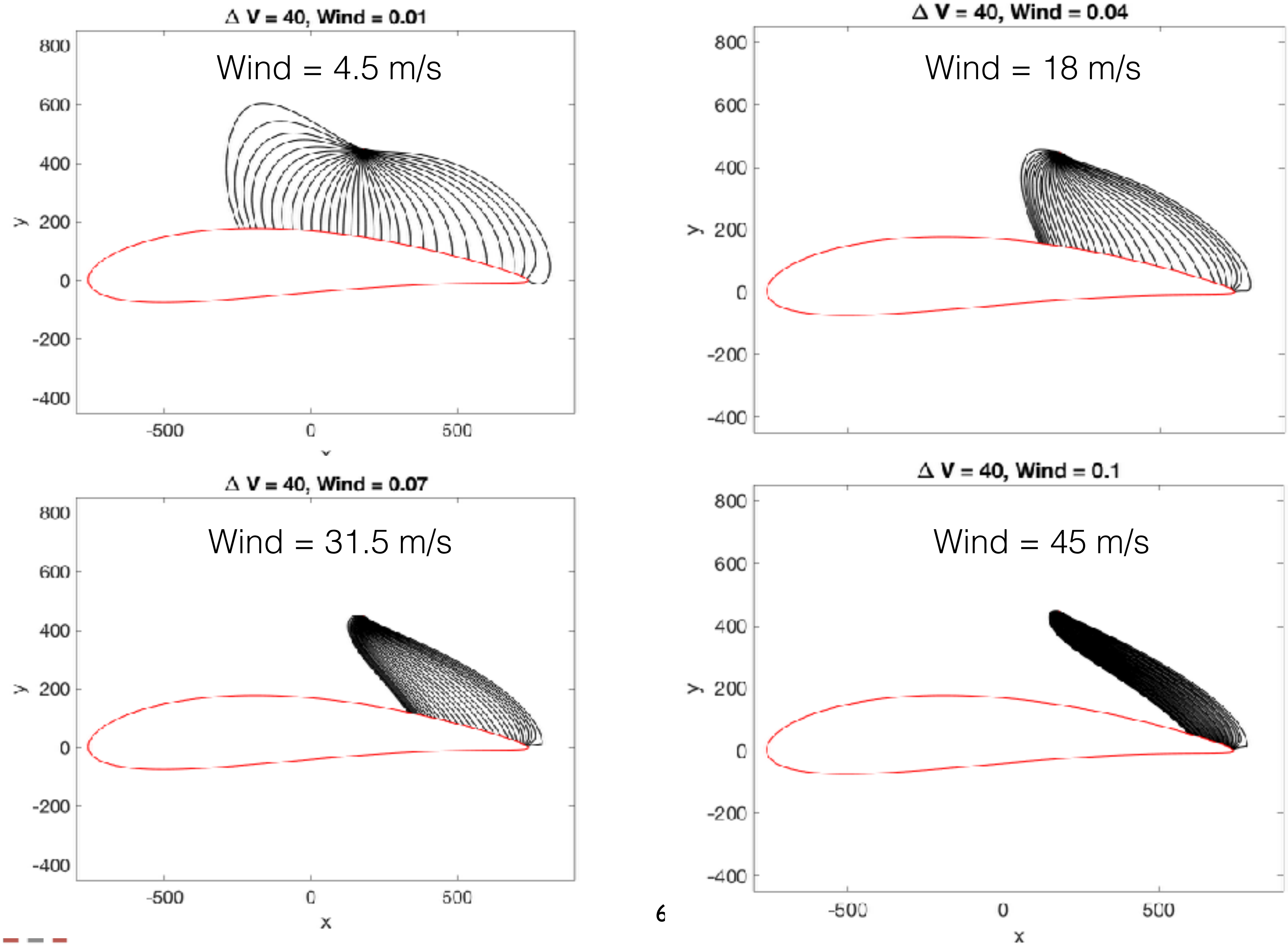
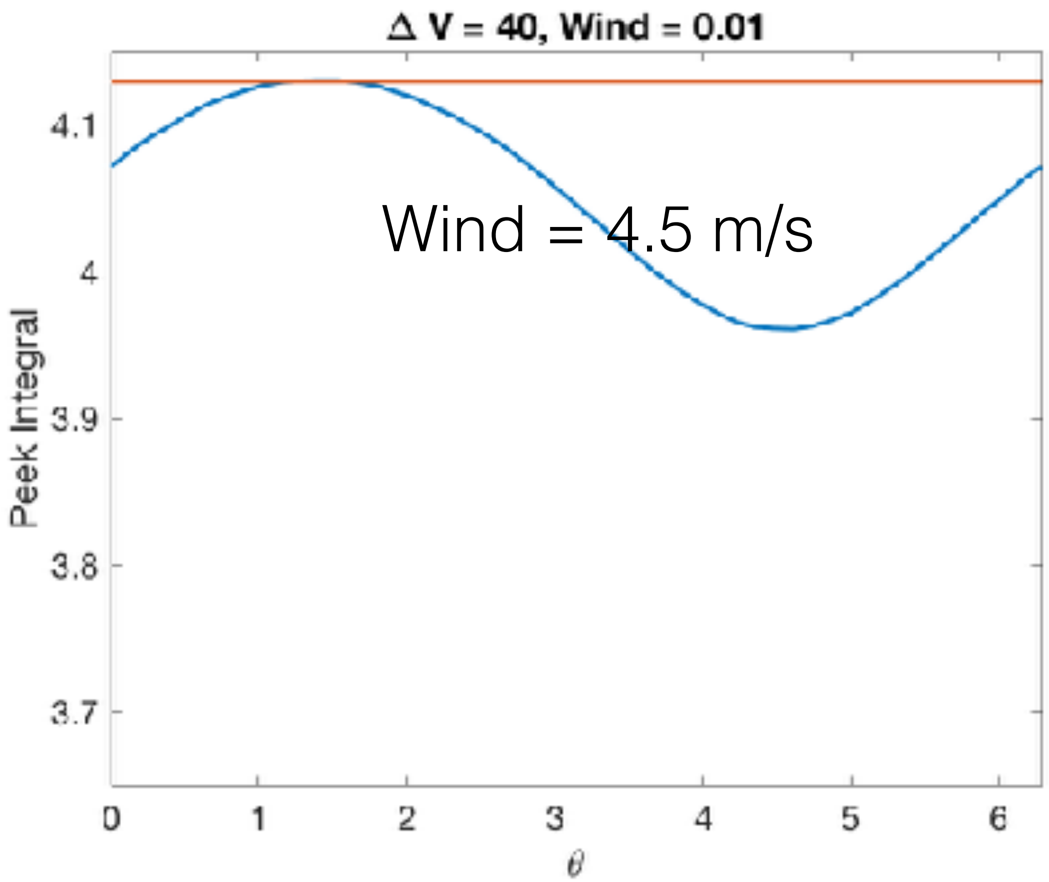
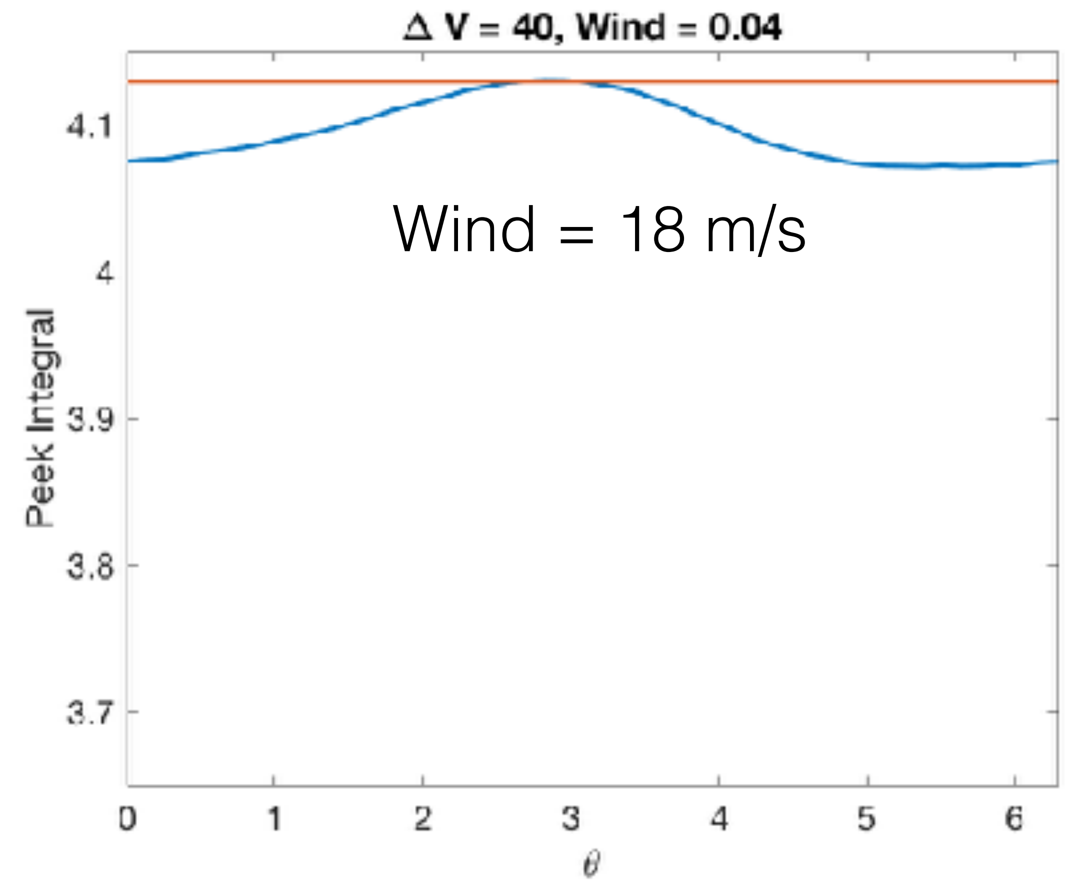
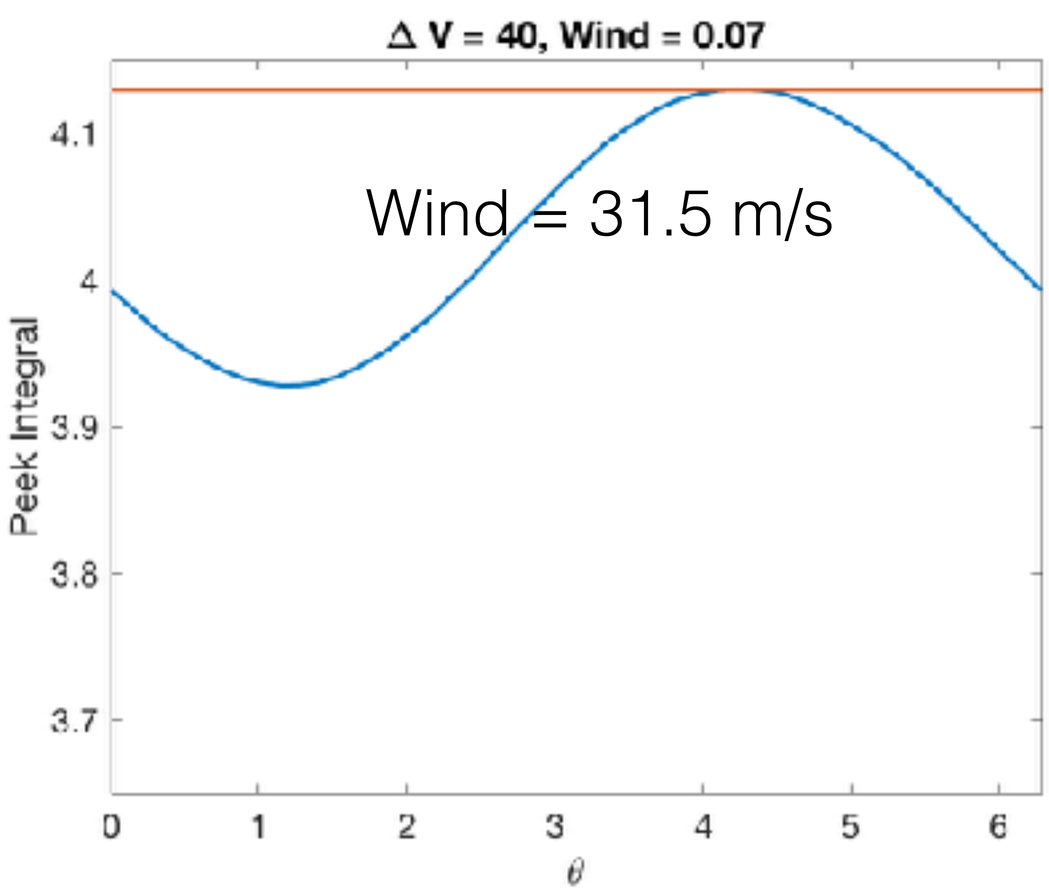
Effect of Wind on Space Charge

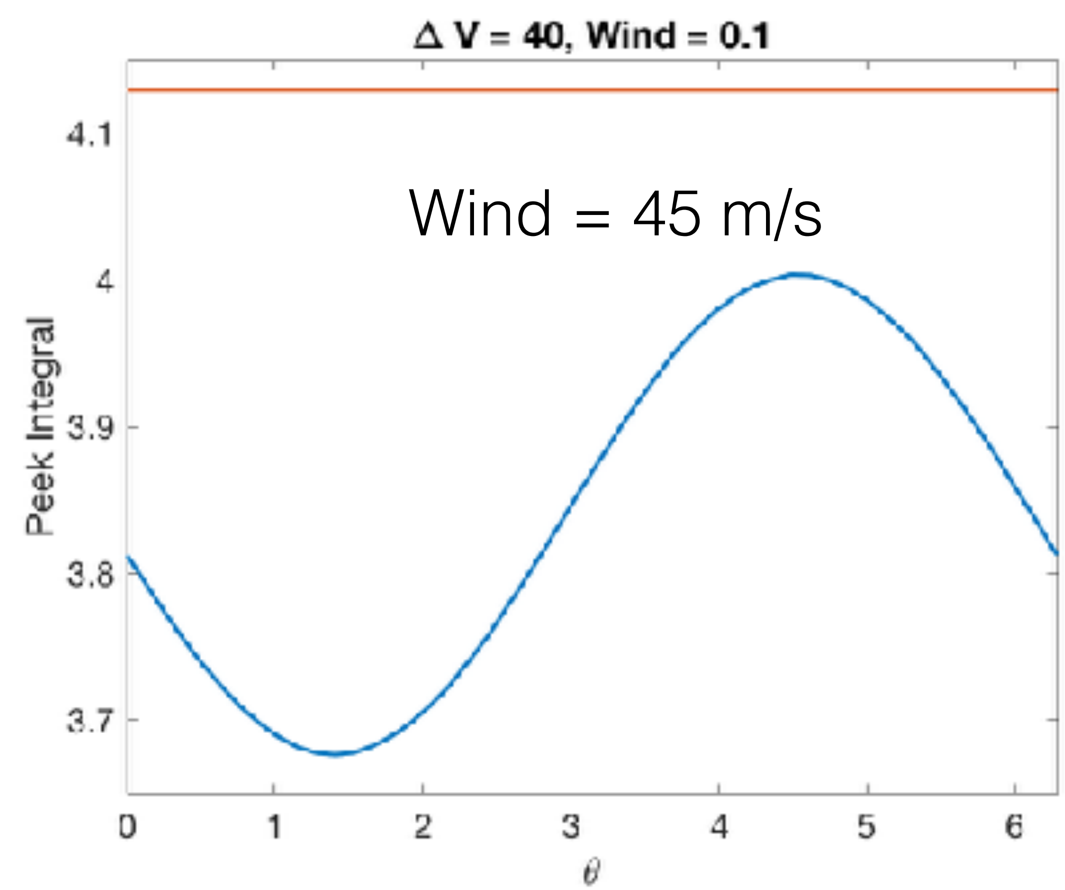


Peek Integral

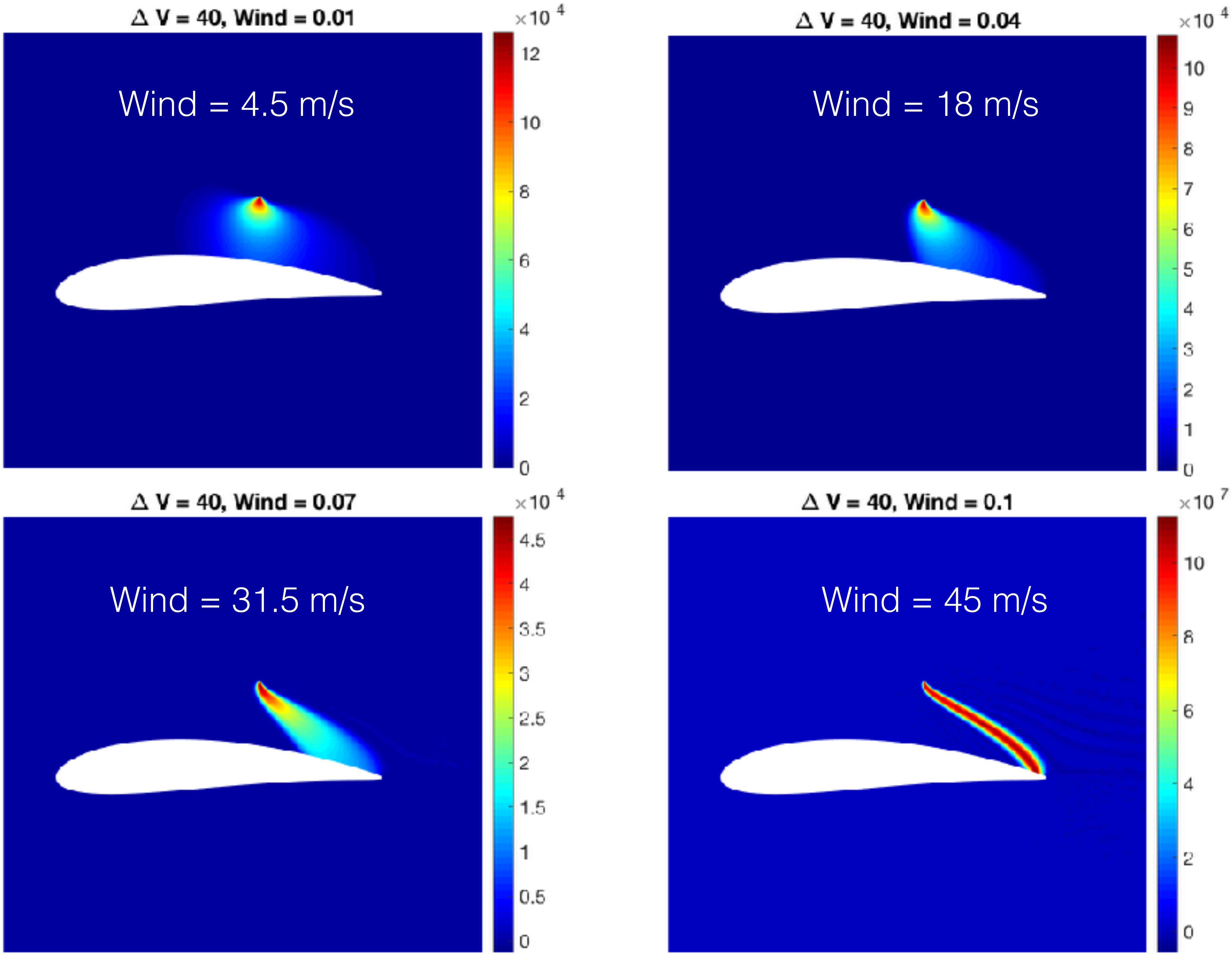




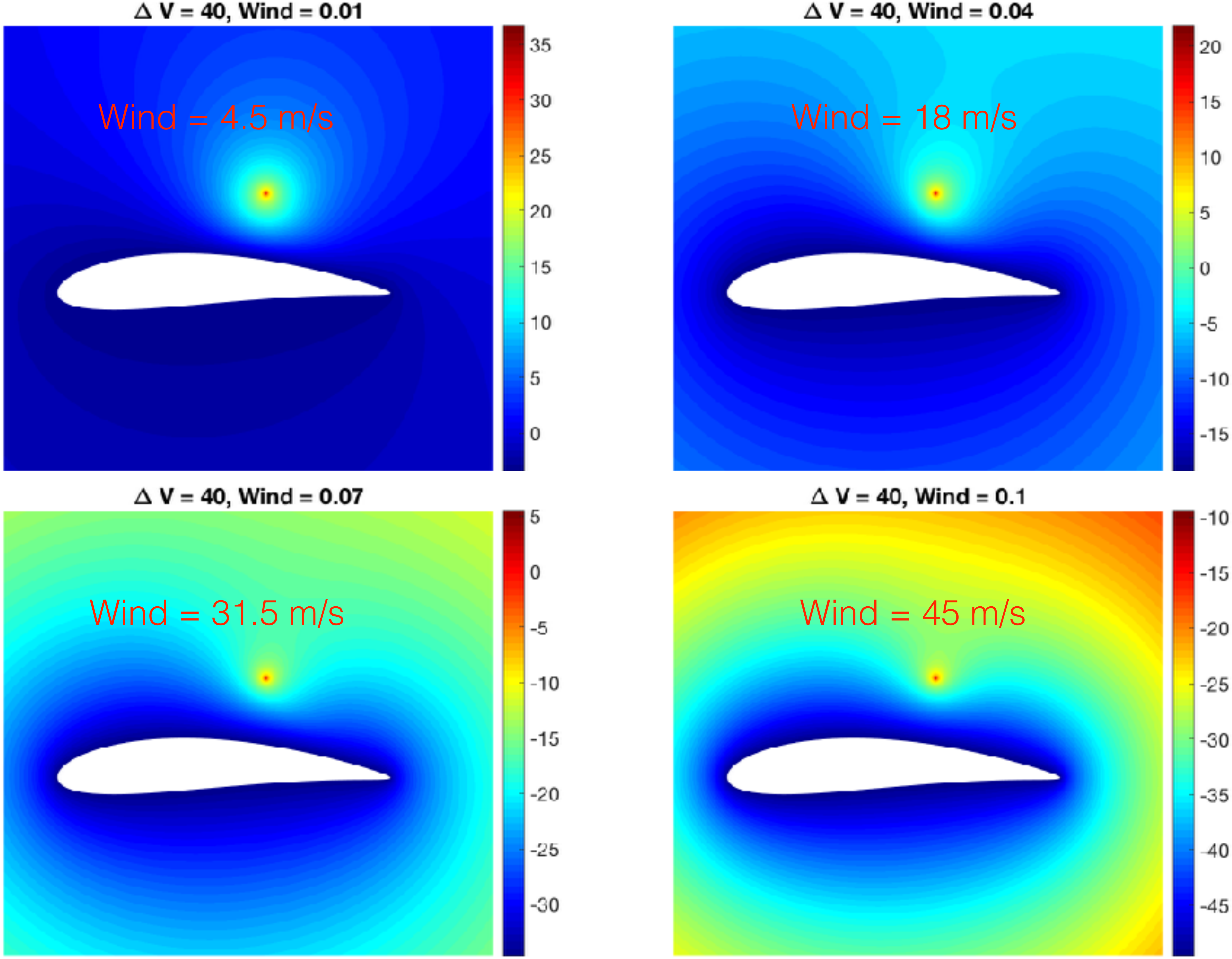




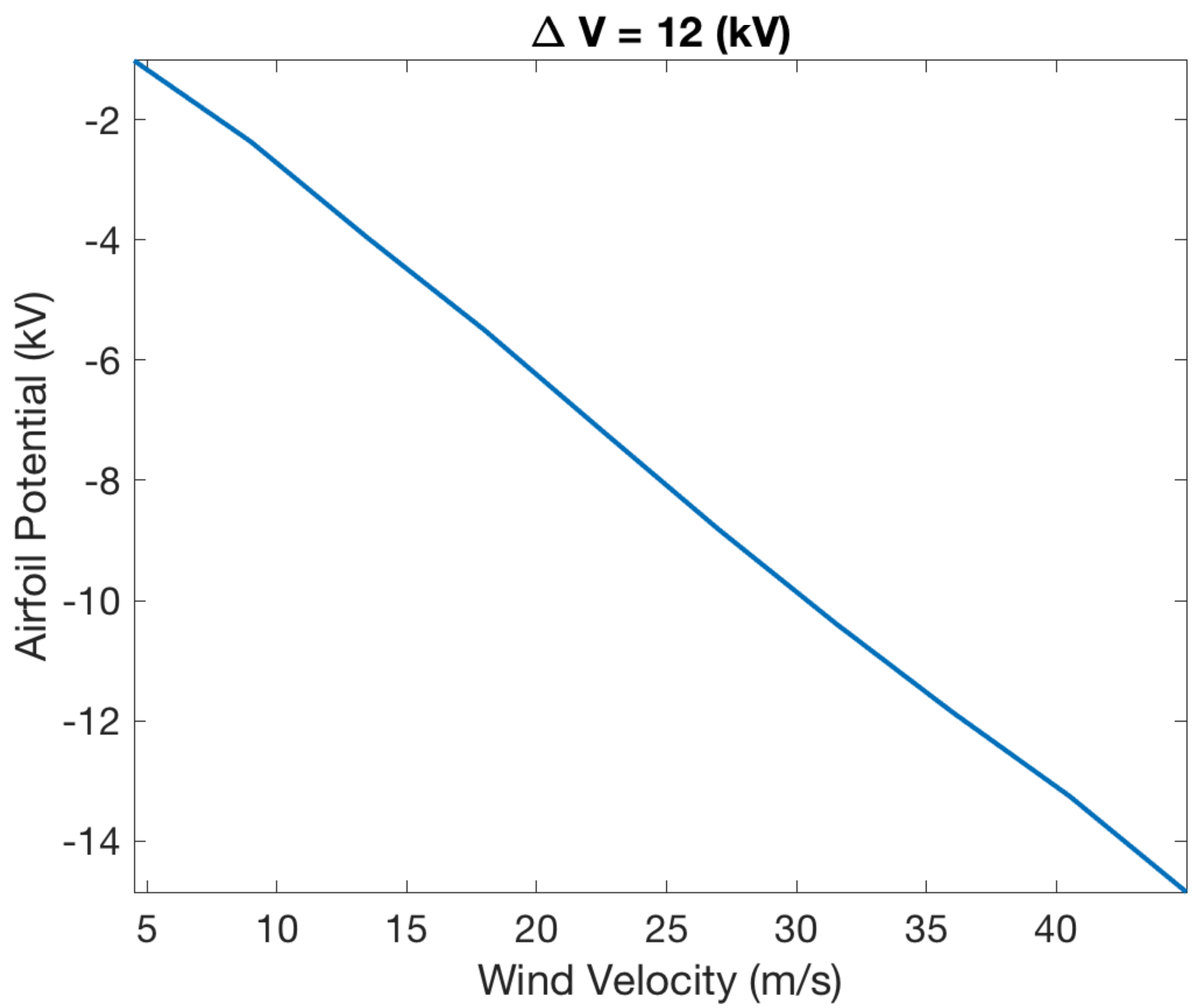
Space Charge Distribution

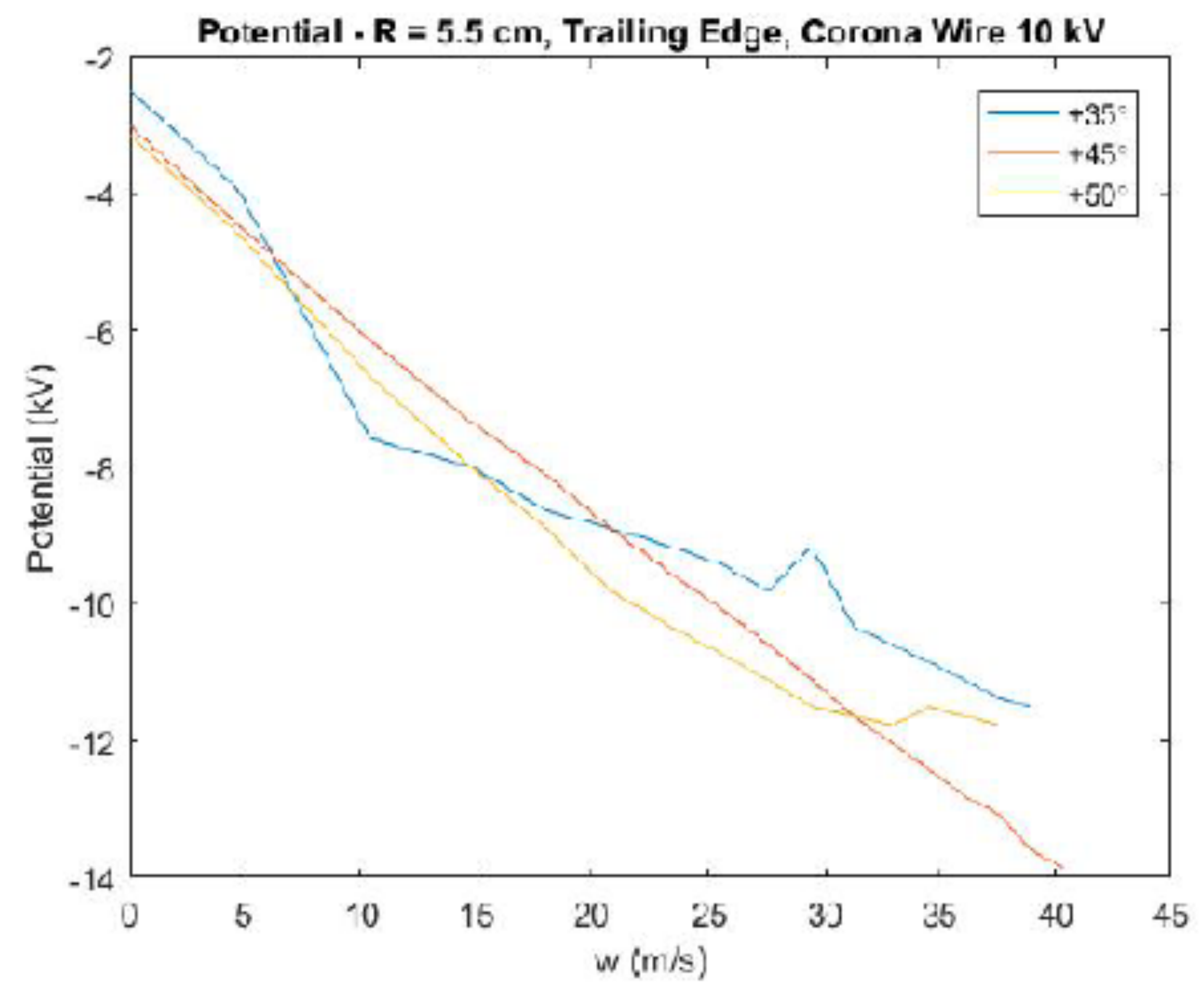


Potential Field

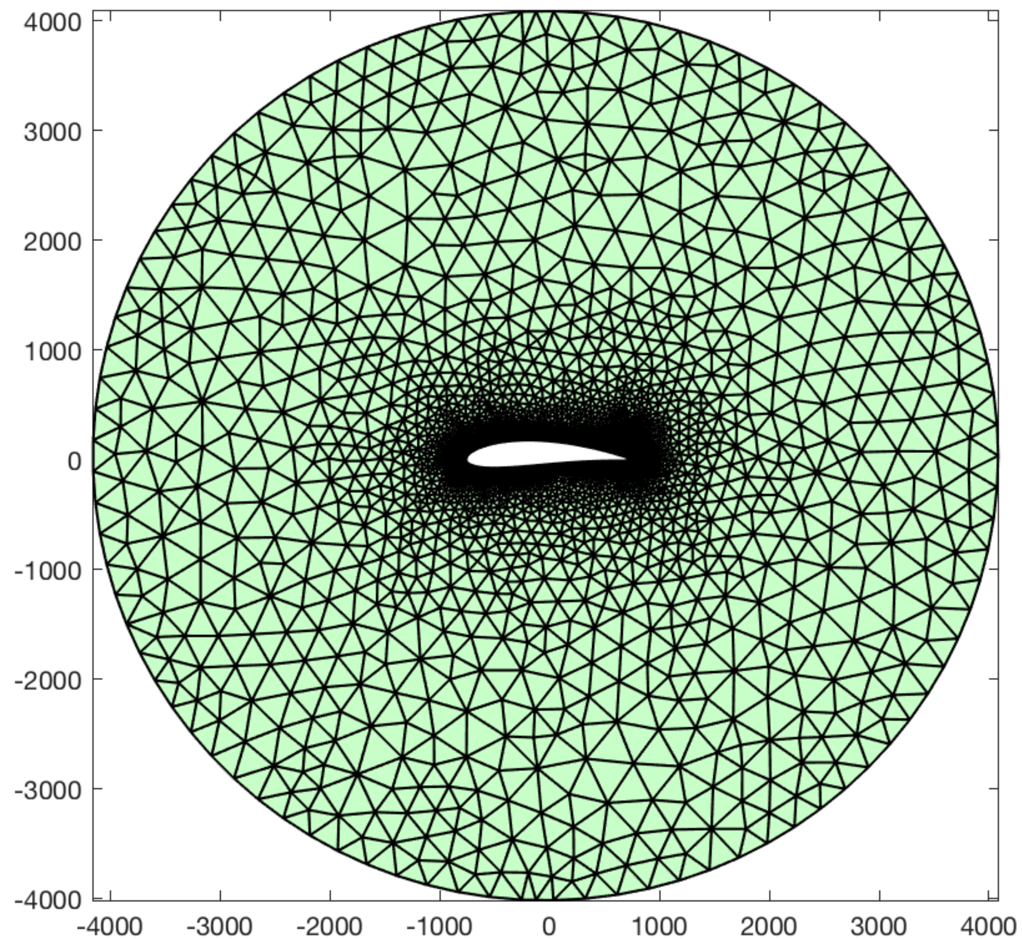


Airfoil Potential vs Wind Velocity





Second Case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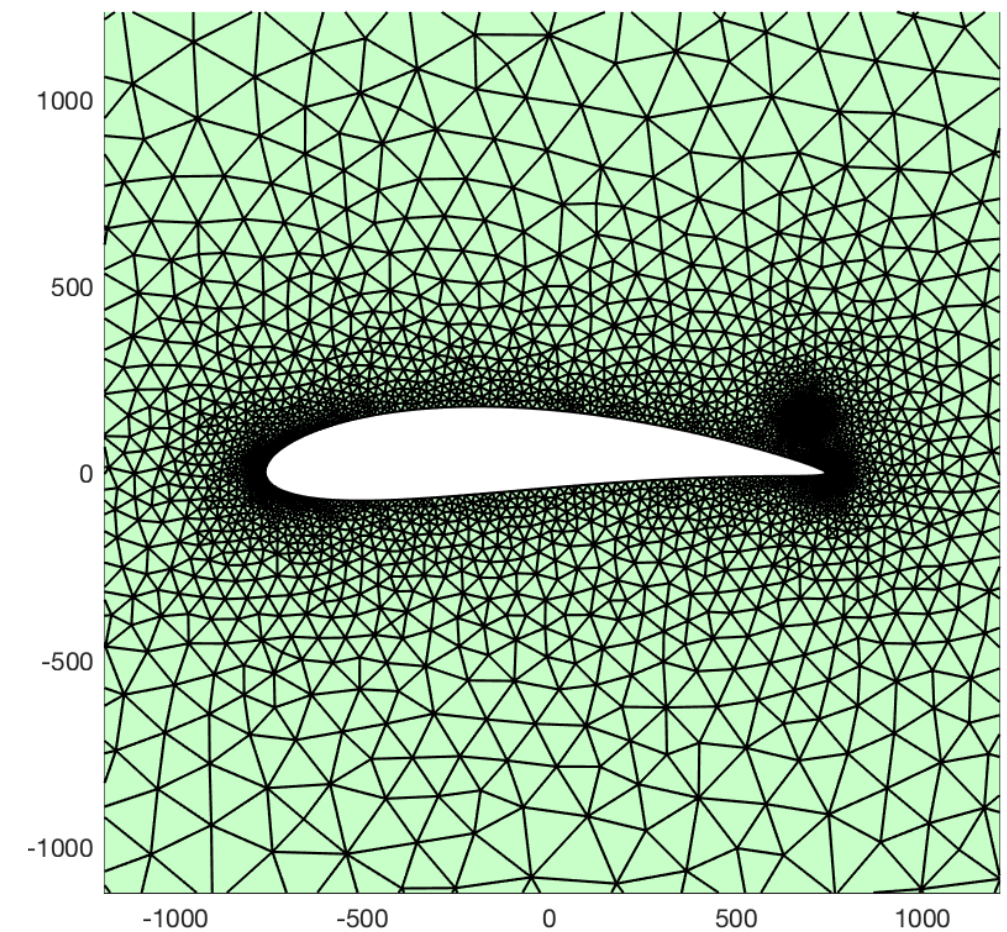
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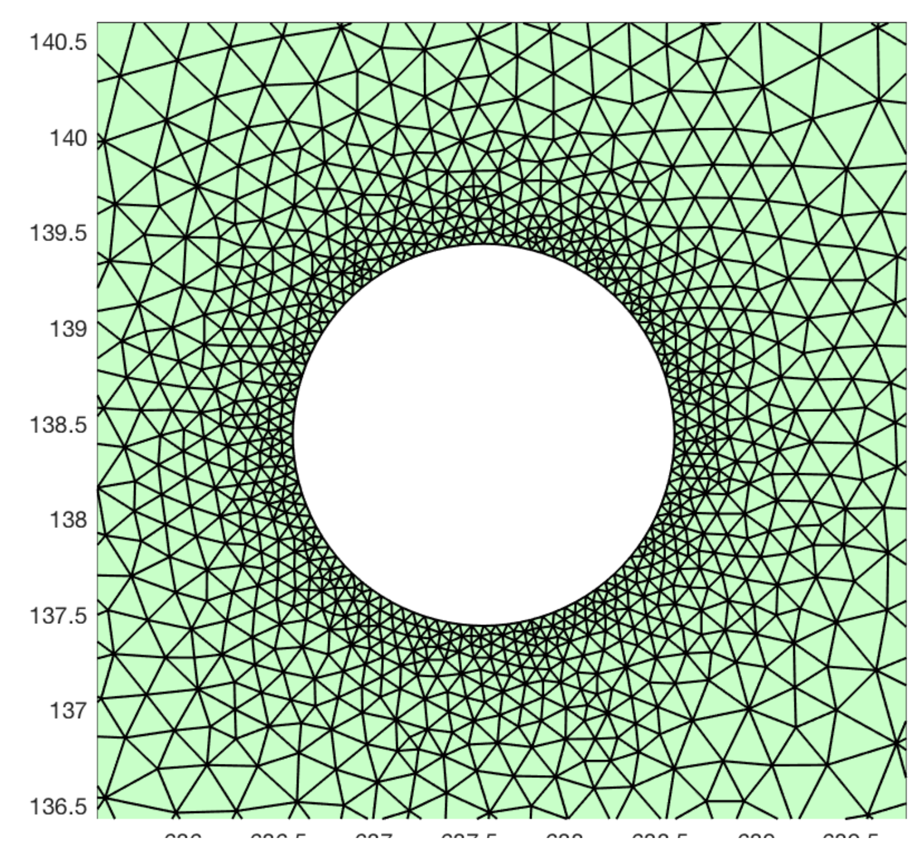
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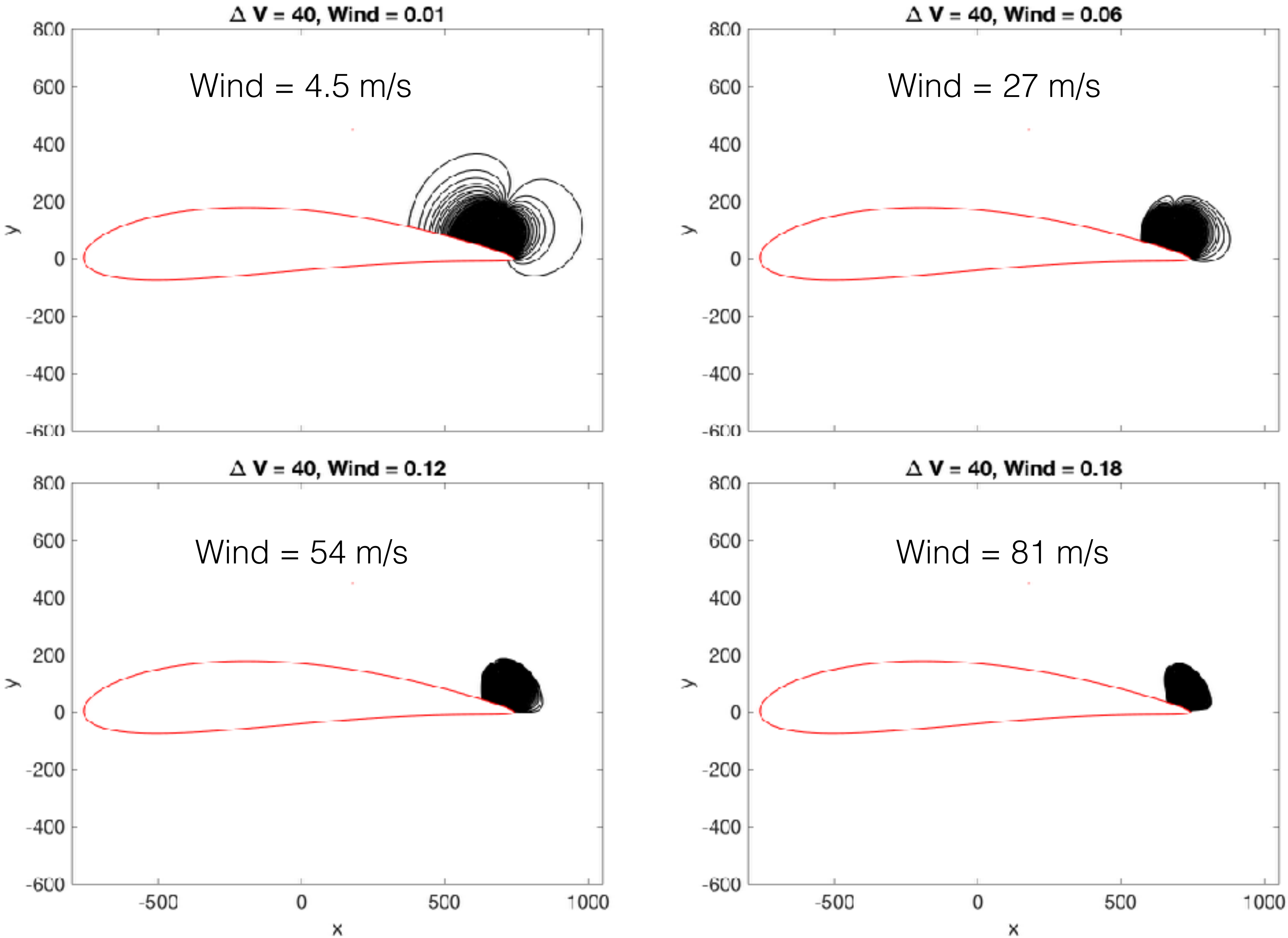
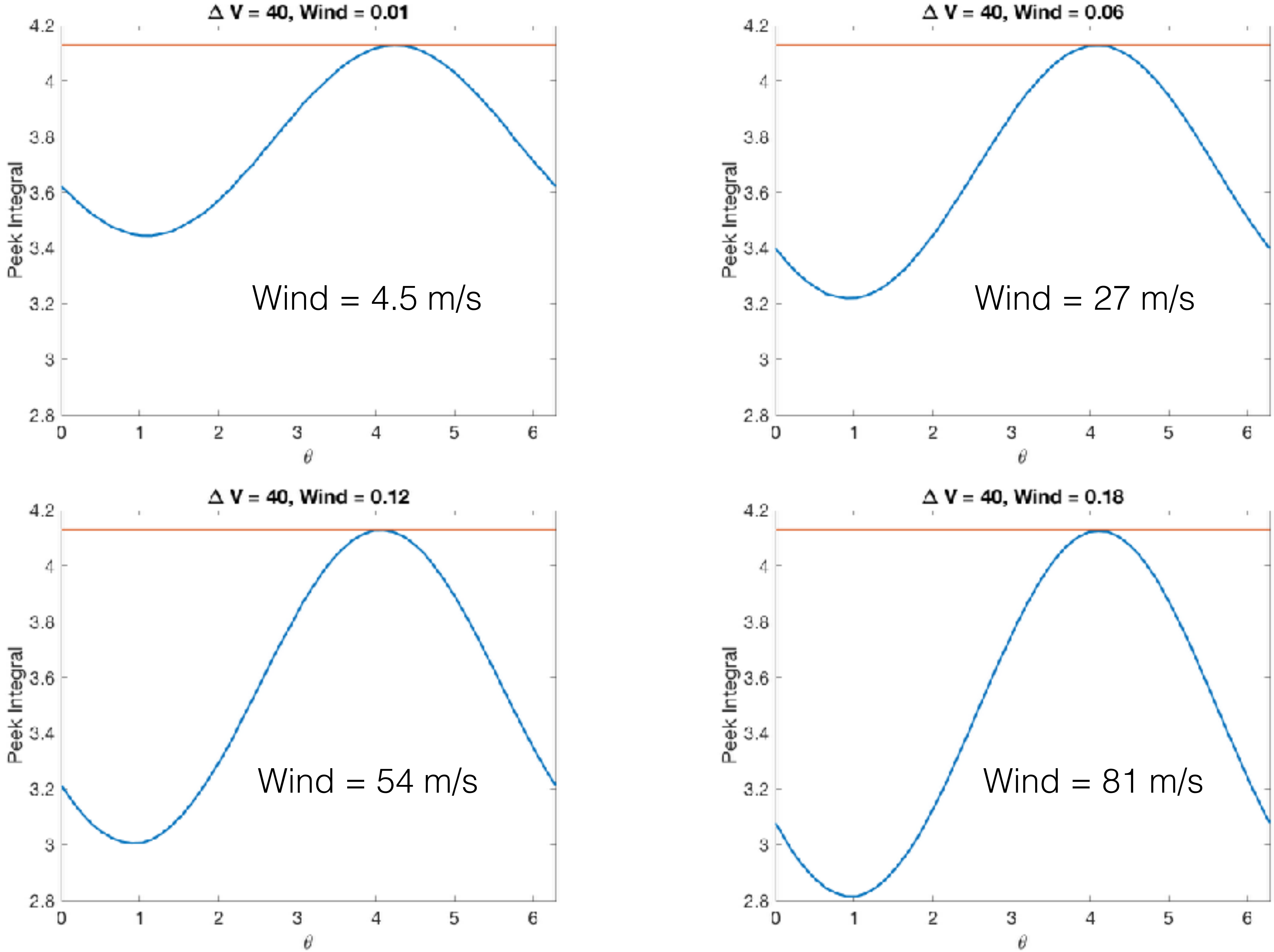
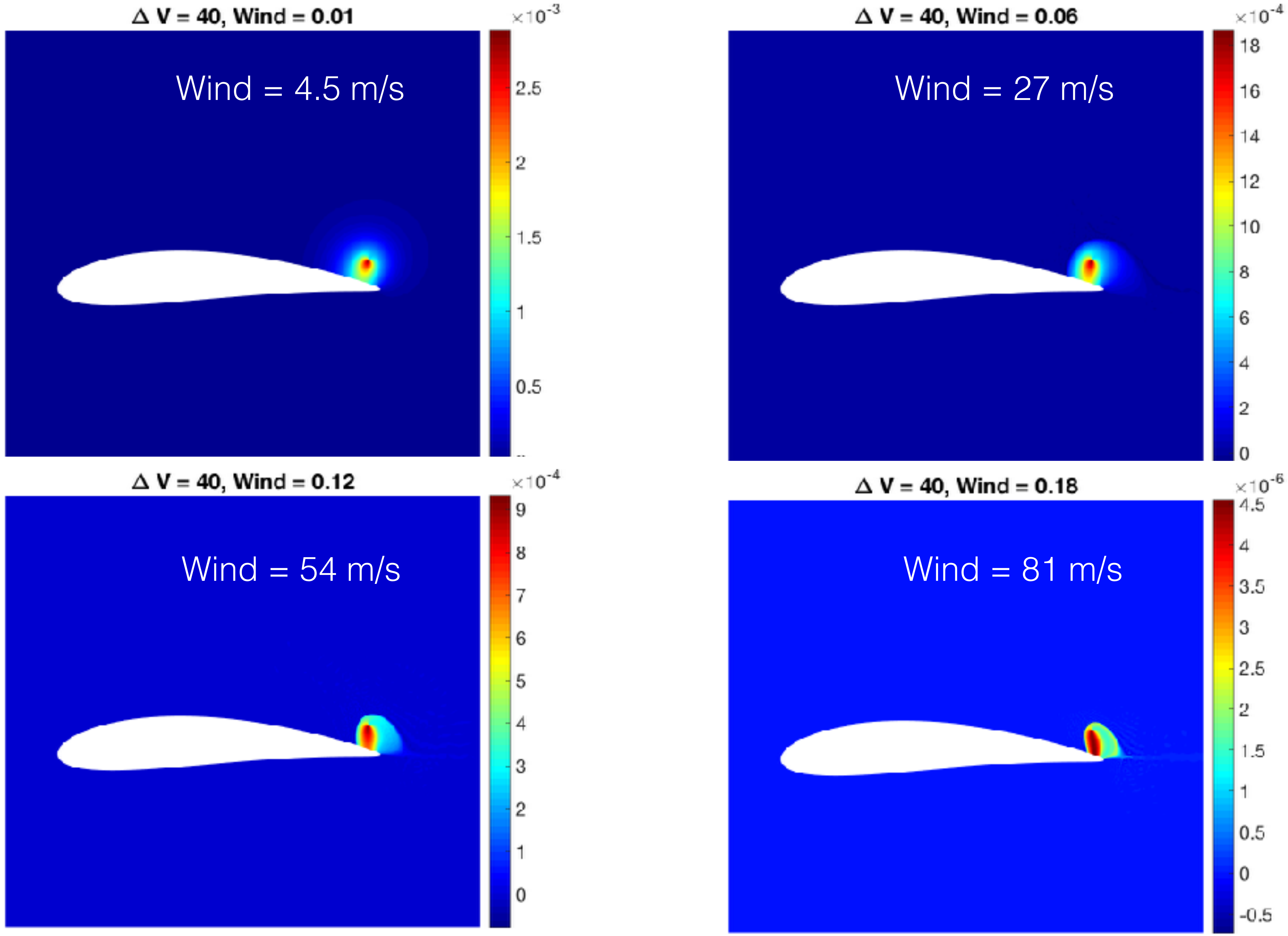
Effect of Wind on Space Charge



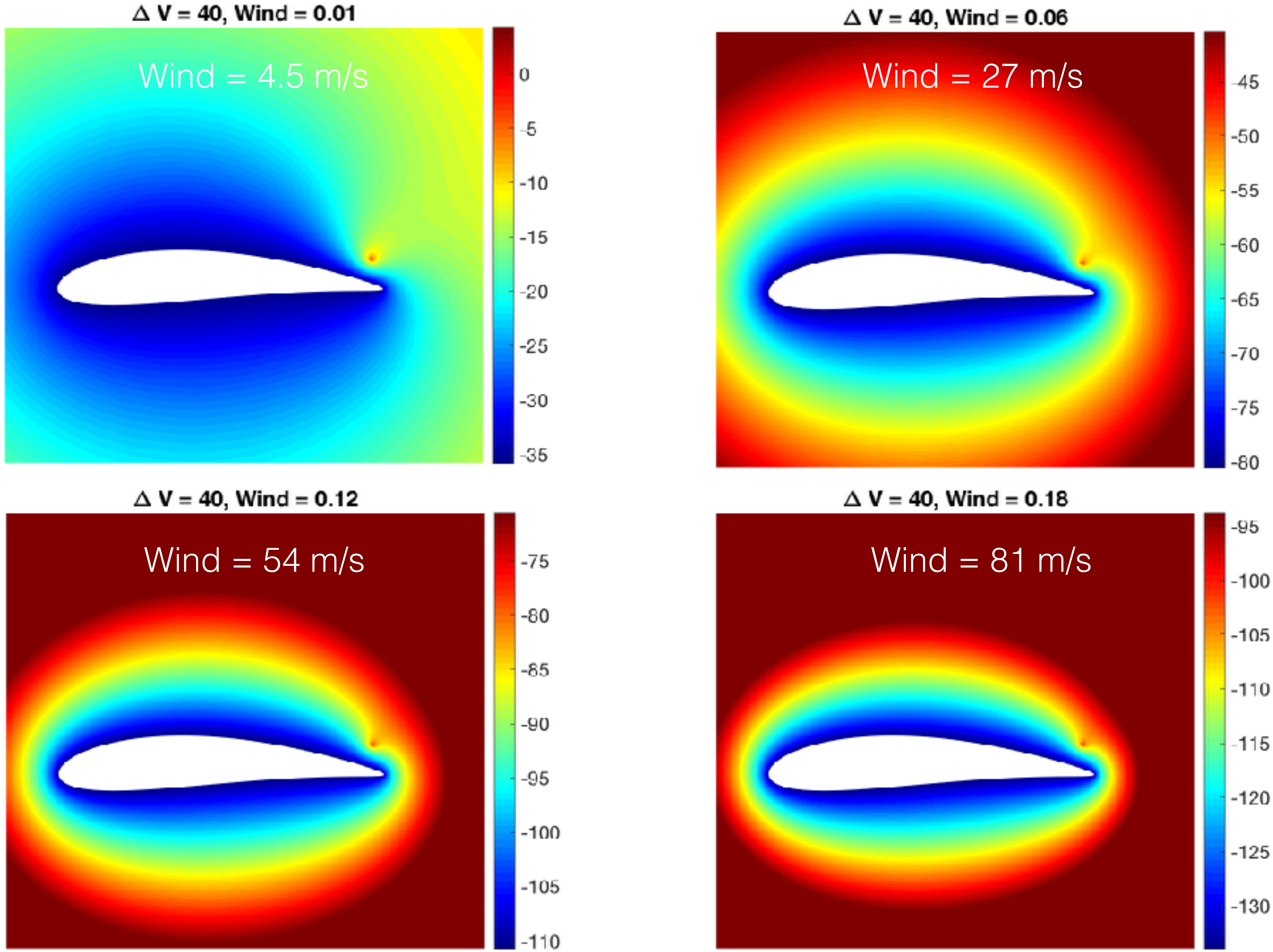
Peek Integral



Space Charge Distribution



Potential Field



Airfoil Potential vs Wind Velocity