Flow transition over surface gaps in 2D incompressible laminar boundary layers

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Motivation

Figure: Wing of a Boeing 737-800

Framework

- 2D Incompressible Navier-Stokes
- We linearize the flow around a steady baseflow:

$$\mathbf{u}(x, y, t) = \mathbf{U}(x, y) + \tilde{\mathbf{u}}(x, y, t)$$

- From LST we can obtain disturbances of the form:

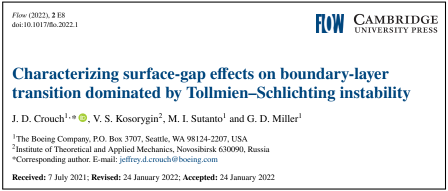
$$\tilde{\mathbf{u}} = \boldsymbol{\phi}(y)\mathrm{e}^{-\alpha_i x}\mathrm{e}^{\mathrm{i}(\alpha_r x - \omega t)}$$

- But this is a local representation! To account for streamwise growth in the BL we use the e^N method:

$$n(x, \omega) = -\int_{x_0}^{x} \alpha_i(s, \omega)\,\mathrm{d}s = \log\left(\frac{|\tilde{\mathbf{u}}(\omega)|}{|\tilde{\mathbf{u}}_0|}\right)$$
$$N(x) = \max_{\omega} n(x, \omega)$$

$\Longrightarrow$ Distrubances of amplitude A_0 satisfy $A(x) \leq A_0\mathrm{e}^{N(x)}$.

Previous Work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Characterizing surface-gap effects on boundary-layer transition dominated by Tollmien–Schlichting instability

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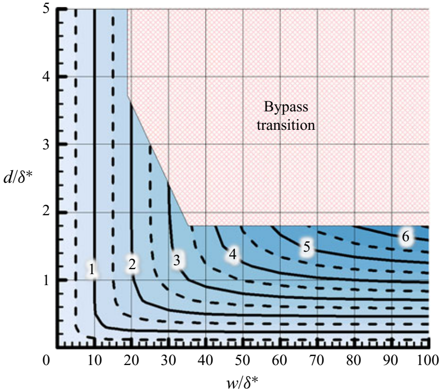

Figure: $\Delta N = N - N_{\text{ref}}$ for different gap dimensions

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Setup

PICTURE BL blasius + gap

- $\mathrm{Re}_{\delta^*} = 1000$

Results

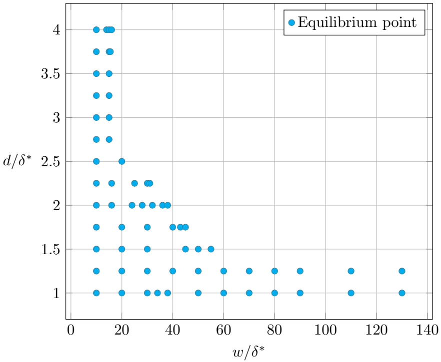
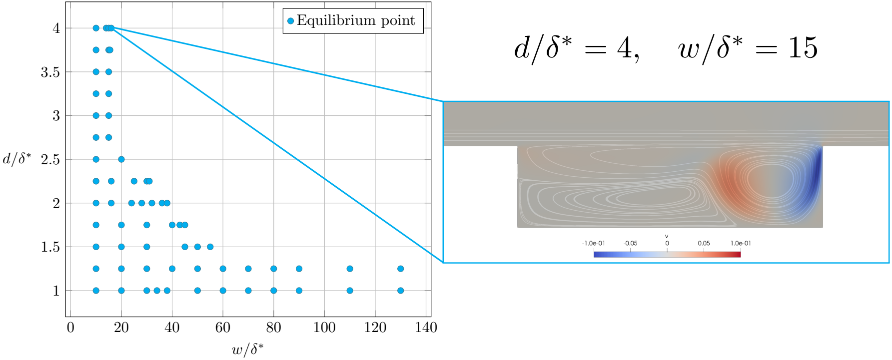


Figure: Classification of the topological behavior of points downstream the gap.

Results



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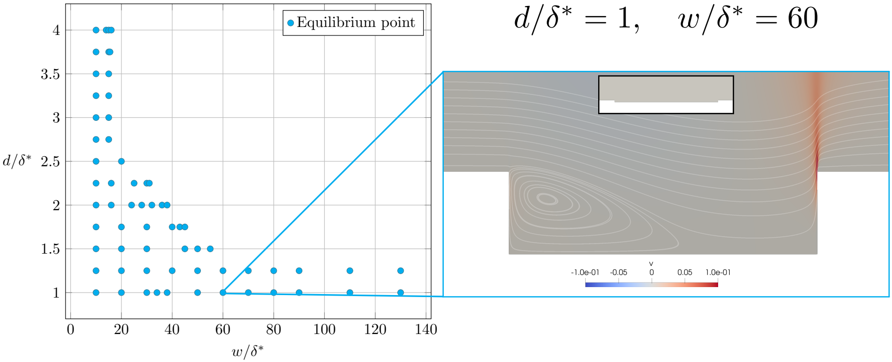

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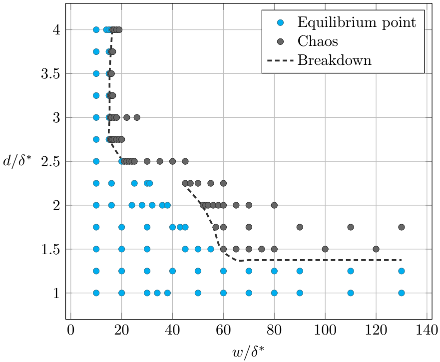

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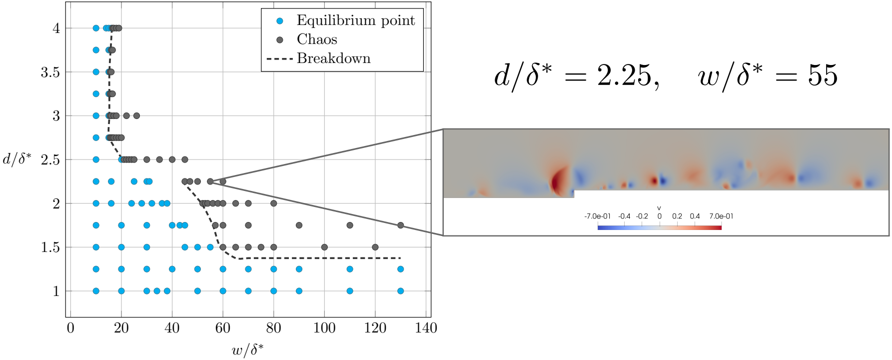

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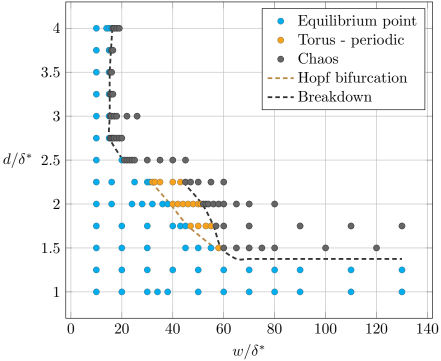

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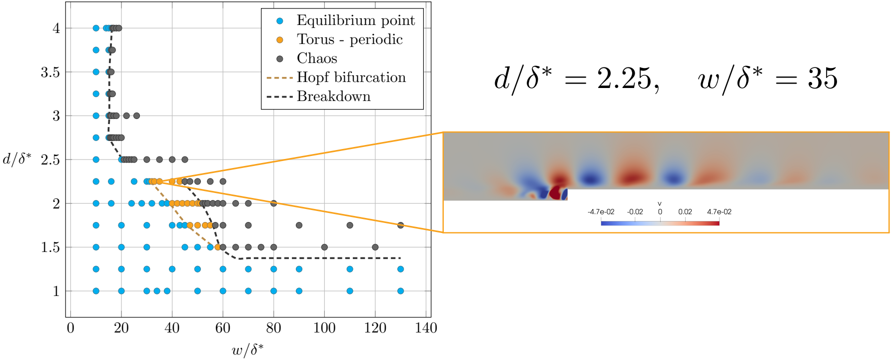

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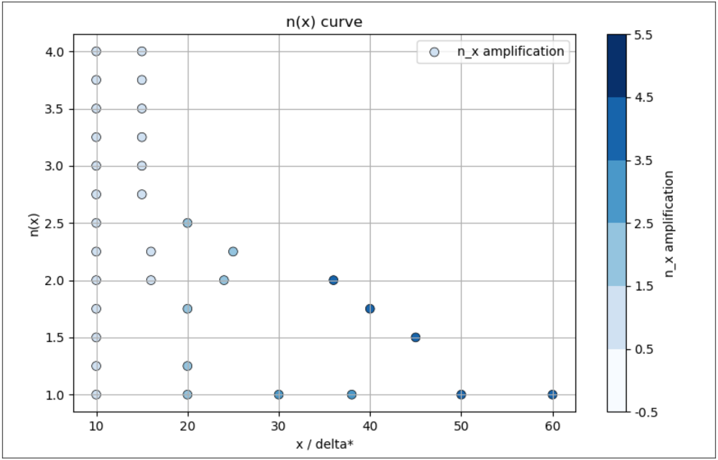

Figure

Future Work

- Go to higher Ma number (compressible regime)
- Account for spanwise effects (quasi-3d)