Linear Stability Analysis of Turbulent Flows

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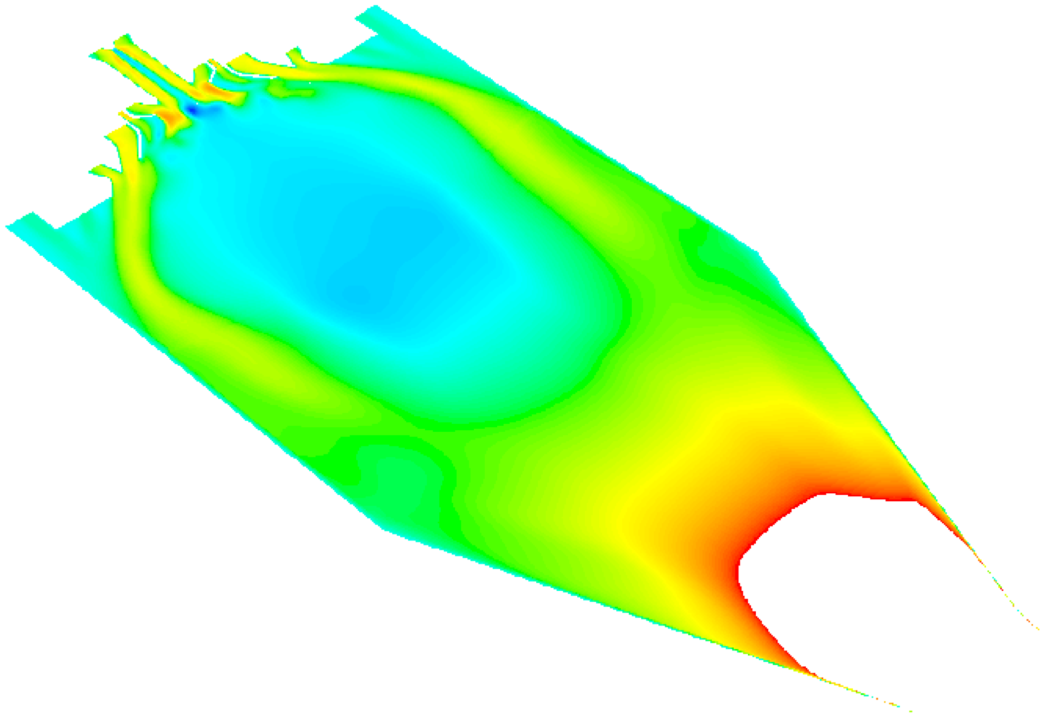
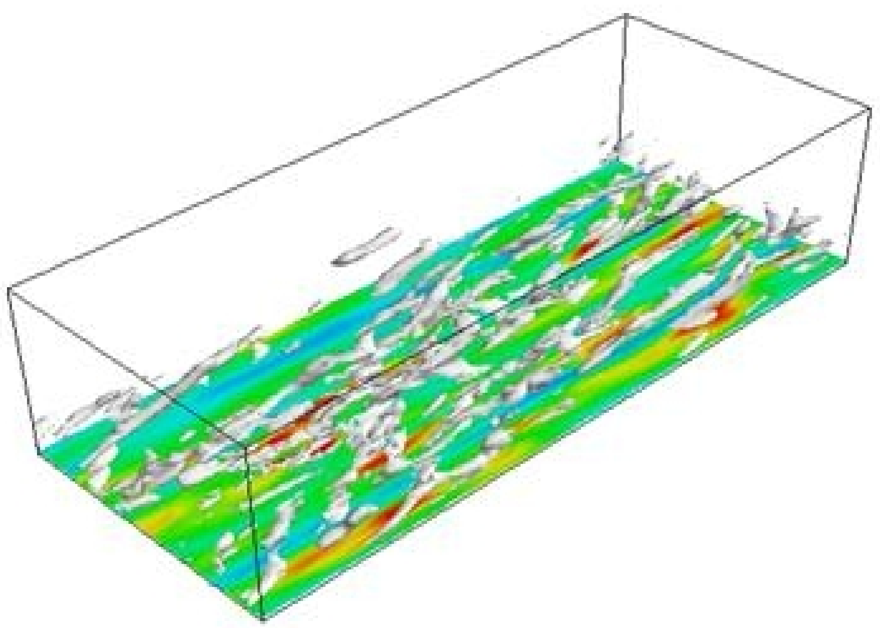
Challenges & Approximations in Linear Stability Analysis of Turbulent Flows

Develop a method for cheap hydrodynamic stability analysis of turbulent flows in industrial flows.



- Local linear stability analysis for turbulent flow.
- Implementation of Reynolds Stress Model to obtain linear perturbation equations.



First step: Check the method on fully developed turbulent channel flow.

Requirements for Linear Stability Analysis

Linear stability analysis is well developed for laminar flows however the same is not true for turbulent flows

Challenges:

- Linear stability analysis requires a base flow.
- It also requires to derive perturbation equations.
- Turbulence is considered as highly nonlinear process.

Approximations:

- Turbulent mean velocity can be used as base flow velocity
- A turbulent model is required to derive equations?

Background on Linear Stability Analysis of Turbulent Flows

Earlier linear stability analysis found that turbulent mean flows are linearly stable (Reynolds & Hussain (1972)).

The role of transient growth was recognized in laminar flows and thus similar non-modal stability analysis was performed for turbulent flows (Butler & Farrel (1992)).

The analysis is improved by using Eddy Viscosity Model to derive perturbation equations (Del Alamo & Jiminez (2006), Pujals et al. (2009)).

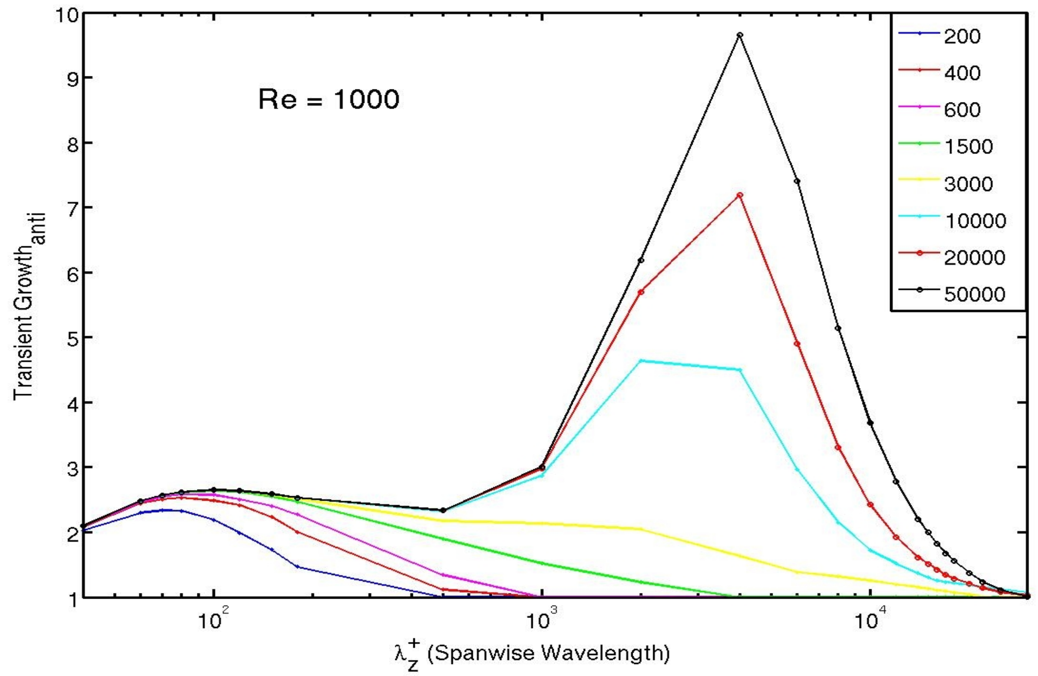
Application in Delaying transition to turbulence in a boundary layer flow (Fransson et al. (2006)).

Why Explicit Algebraic Reynolds Stress Model?

Problems with Eddy Viscosity Models:

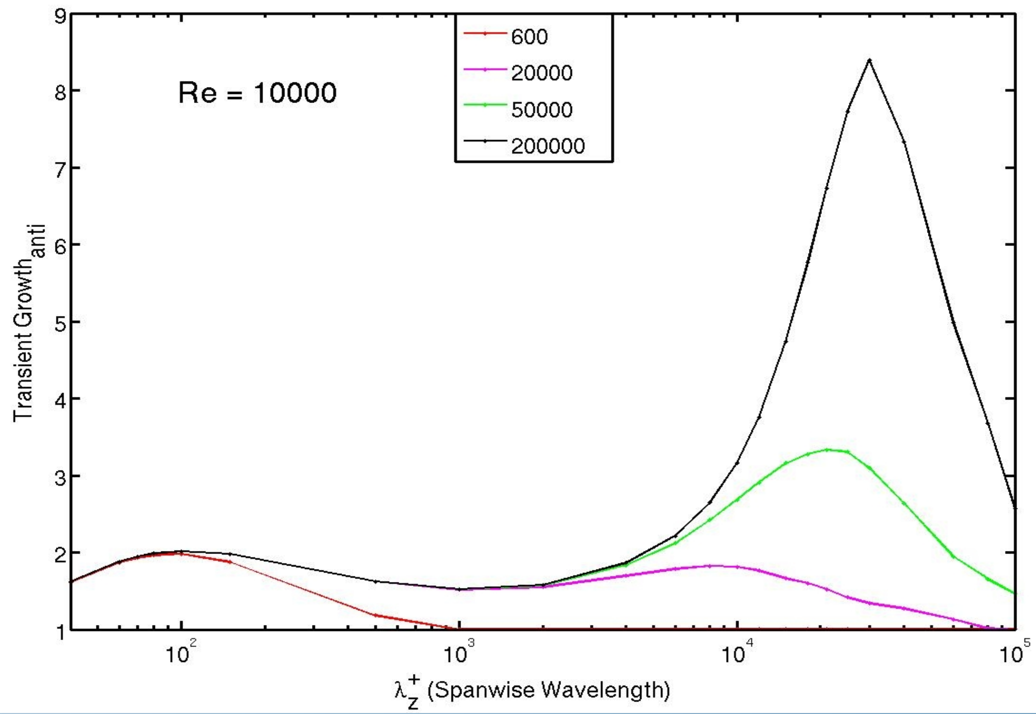
- Although useful the results are not very impressive.

- They are not applicable for many practical flows.



Reynolds Stress Model is the next level but it is more convenient to have algebraic relations for linear stability analysis.

A compromise can be made by using EARSM.



Results by Applying EARSM

Good Part:

- Unstable modes

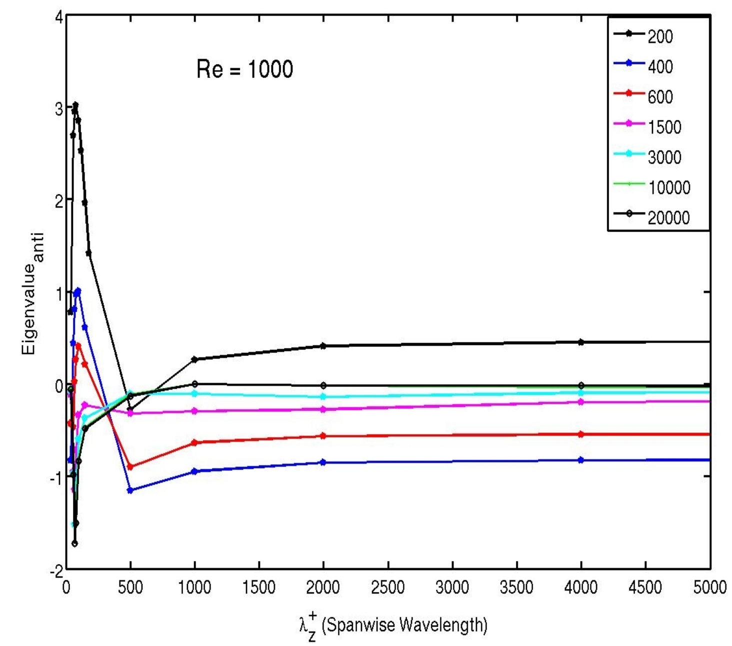
- Better sensitivity with streamwise wavelength.

- Change in behavior with Reynolds number.

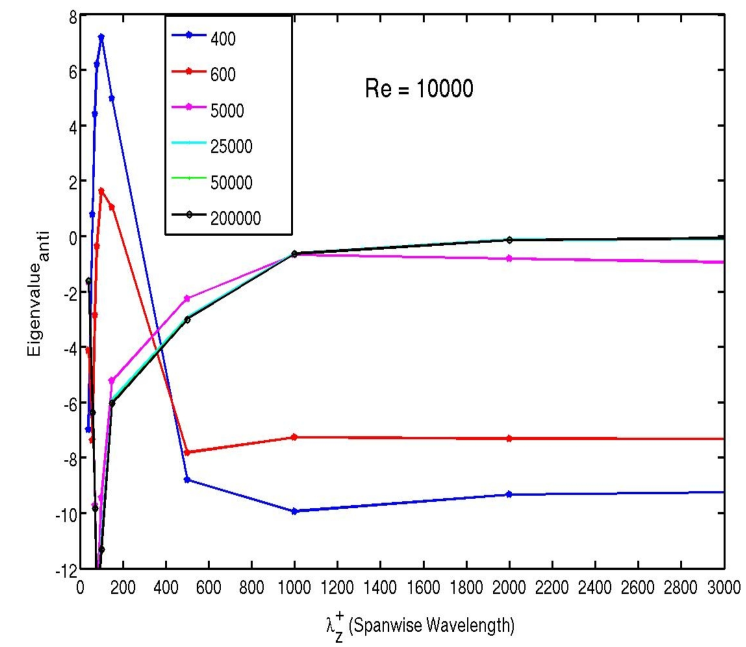
Bad Part:

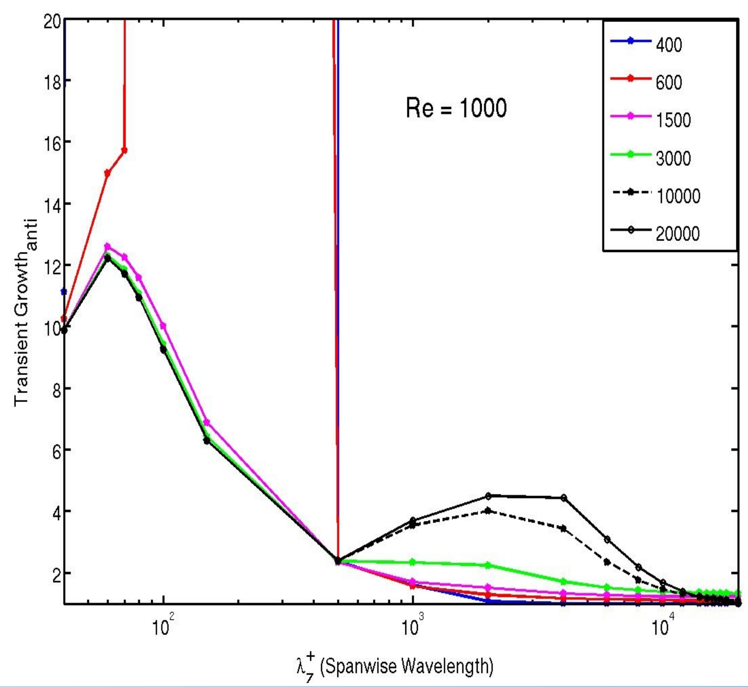
- Smaller the streamwise wavelength → more unstable the mode is.

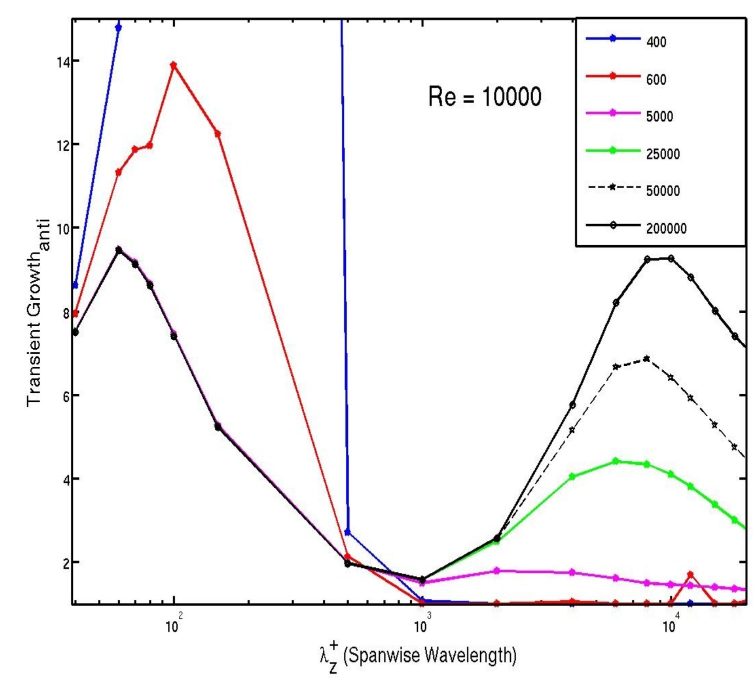
Re = 1000



Re = 10000







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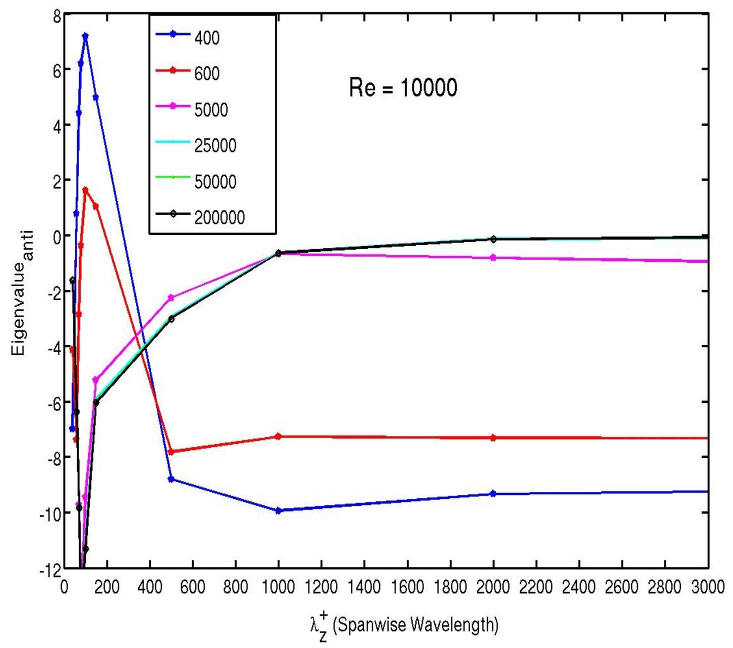
Summary and Future Work

Application of EARSM for linear stability analysis shows better match with experiments and DNS for turbulent channel flows.



Future work is to extend this analysis for more complicated flows and finally apply it in industrial situation.