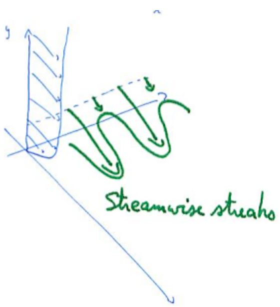
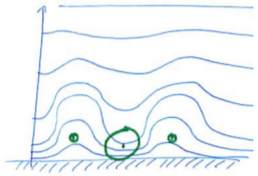
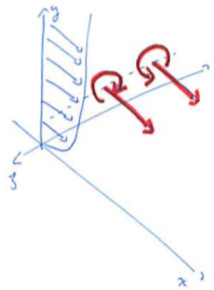
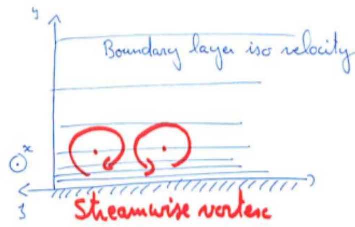
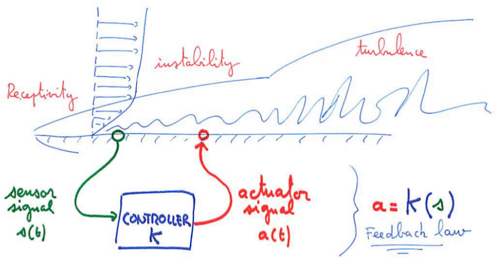
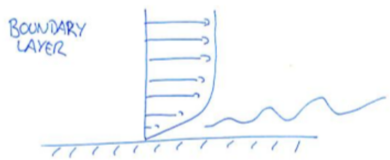


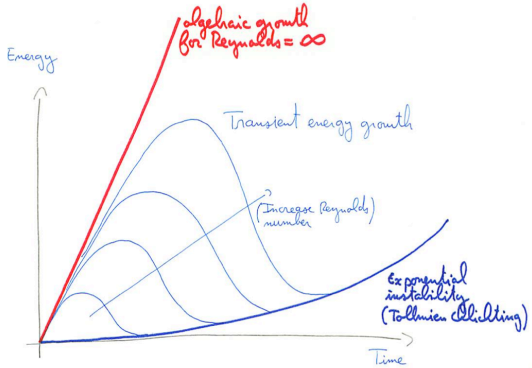




Transition to turbulence and flow control

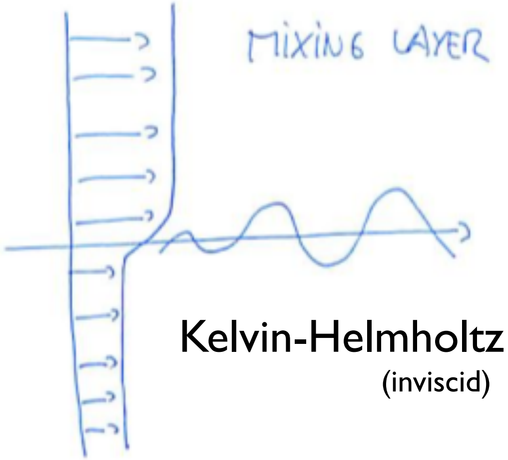
Jerome Hoepffner
Fukagata lab



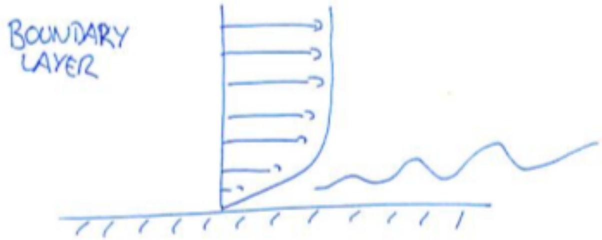




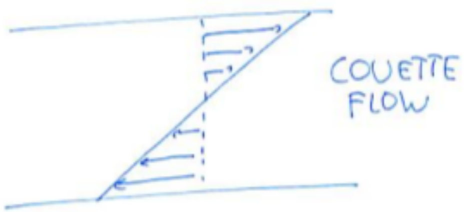
Instability mechanisms

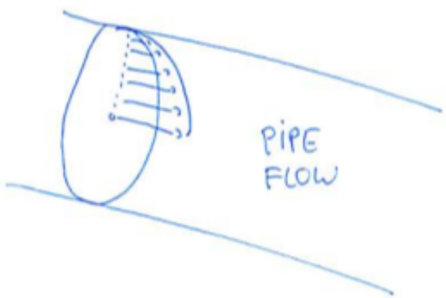


Kelvin-Helmholtz instability
(inviscid)



Tollmien-Schlichting instability
(viscous)





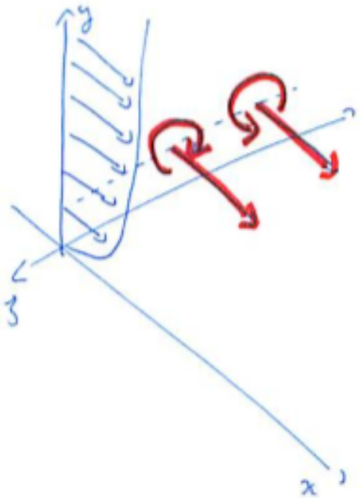
Couette and pipe are stable for all Reynolds.

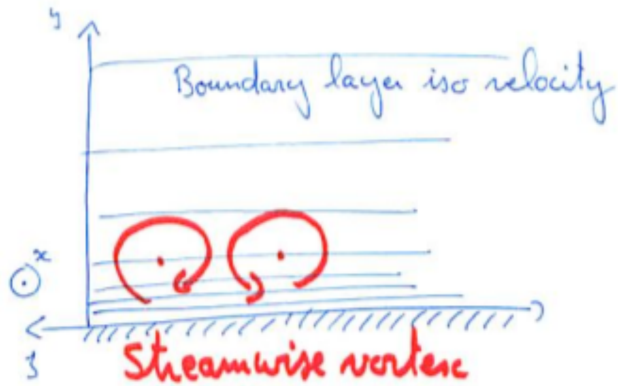
+

For boundary layers, transition to turbulence is observed before critical Reynolds number

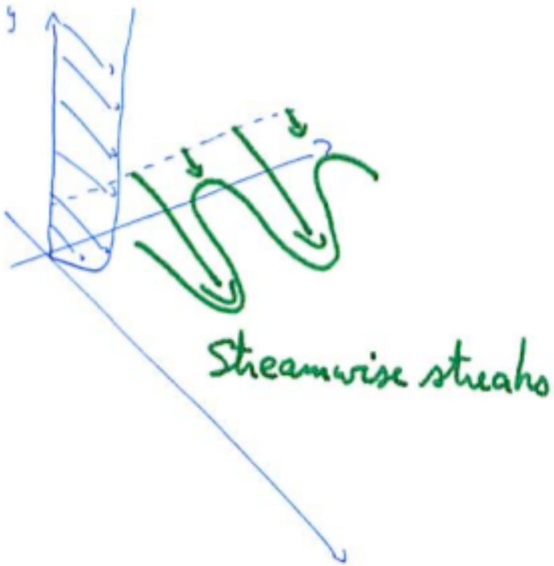
... what is the mechanism?

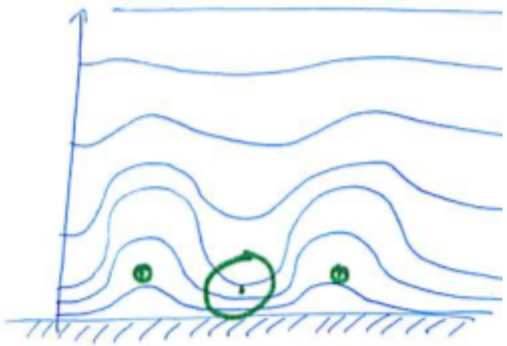
Transient growth in the boundary layer





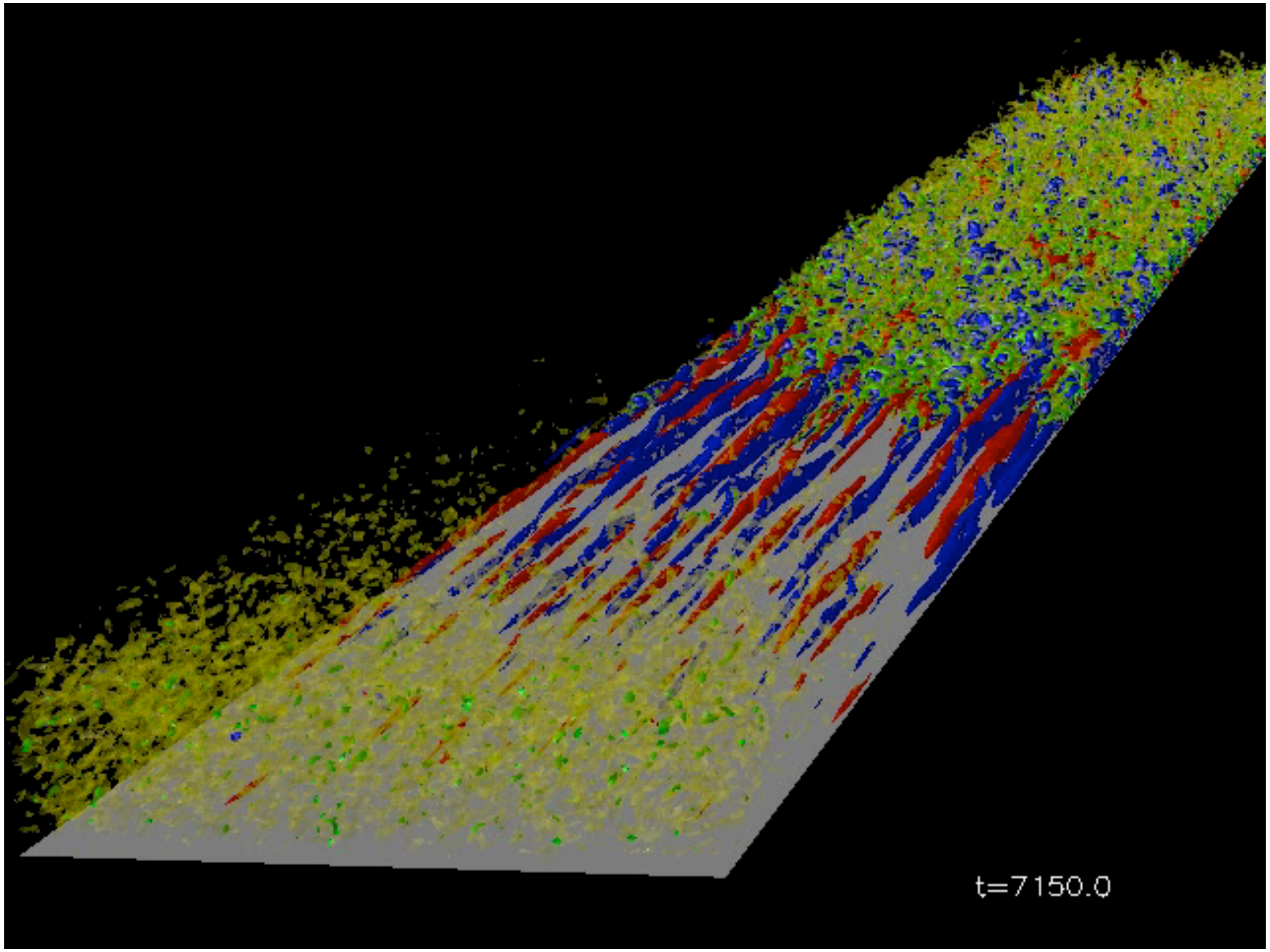
A pair of small streamwise vortices move the flow particles in the wall normal direction: deform the lines of streamwise velocity





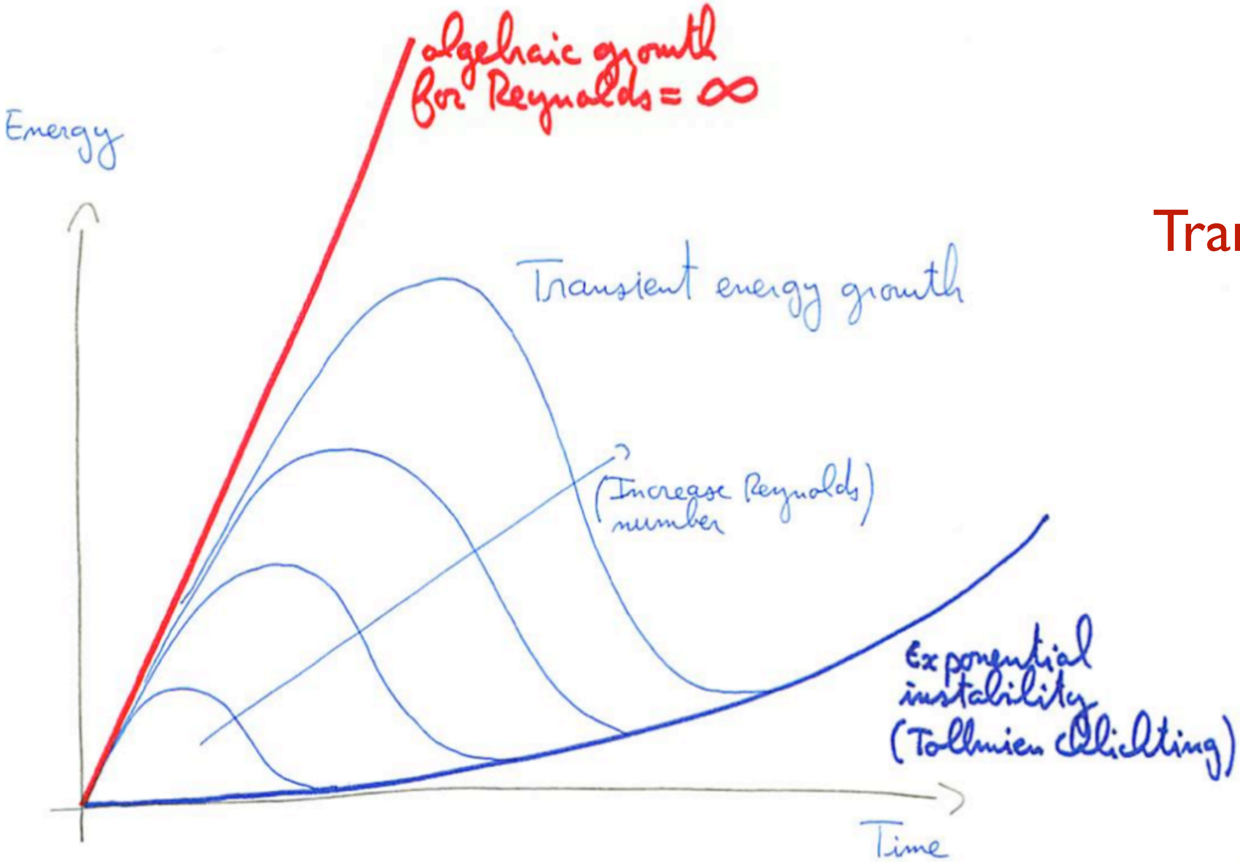
➜generates streaks of high and low streamwise velocity

Some special disturbance can have very large effect, even if the flow is stable



Boundary layer with incomming free-stream turbulence
(LES: Philipp Schlatter, KTH)

Energy evolution

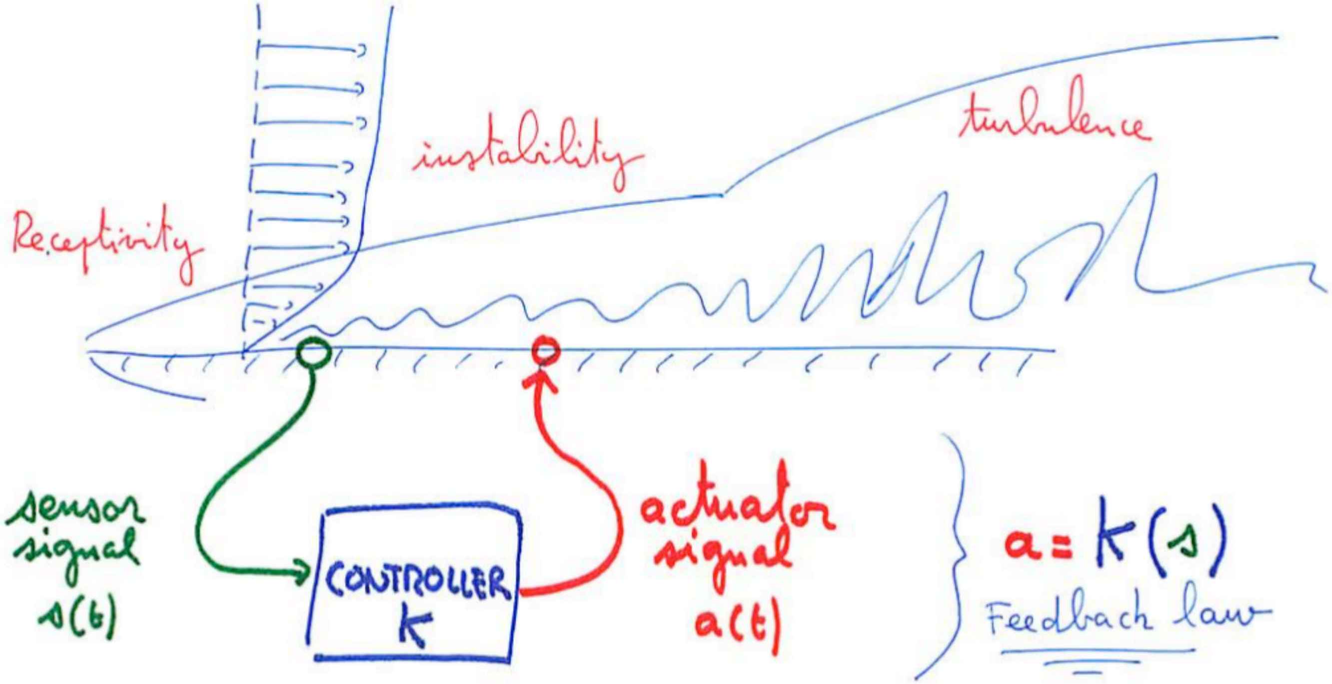


Transition to turbulence can be caused by transient growth

It is not allways enough to compute the unstable eigenmodes... also compute the "optimal disturbances"

➡Stability analysis using optimization

Flow control



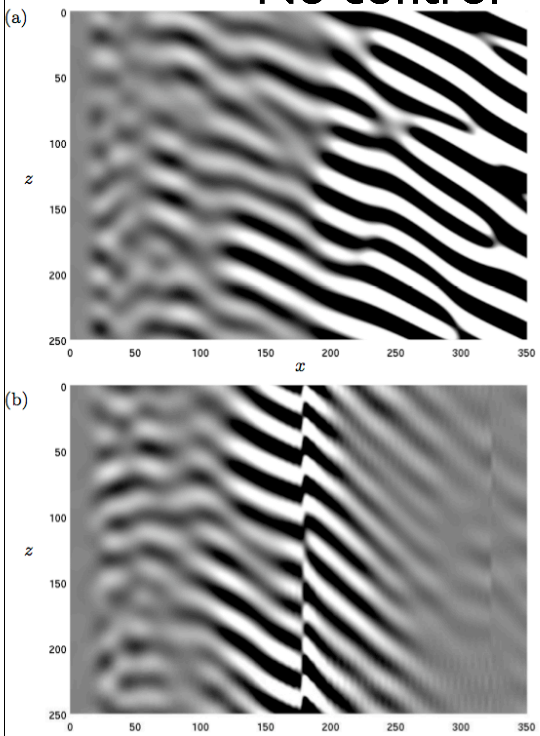
Sensor: measure skin friction/pressure
Actuator: blowing and suction
Controller: computes the feedback

How to compute the best controller K?

Examples:

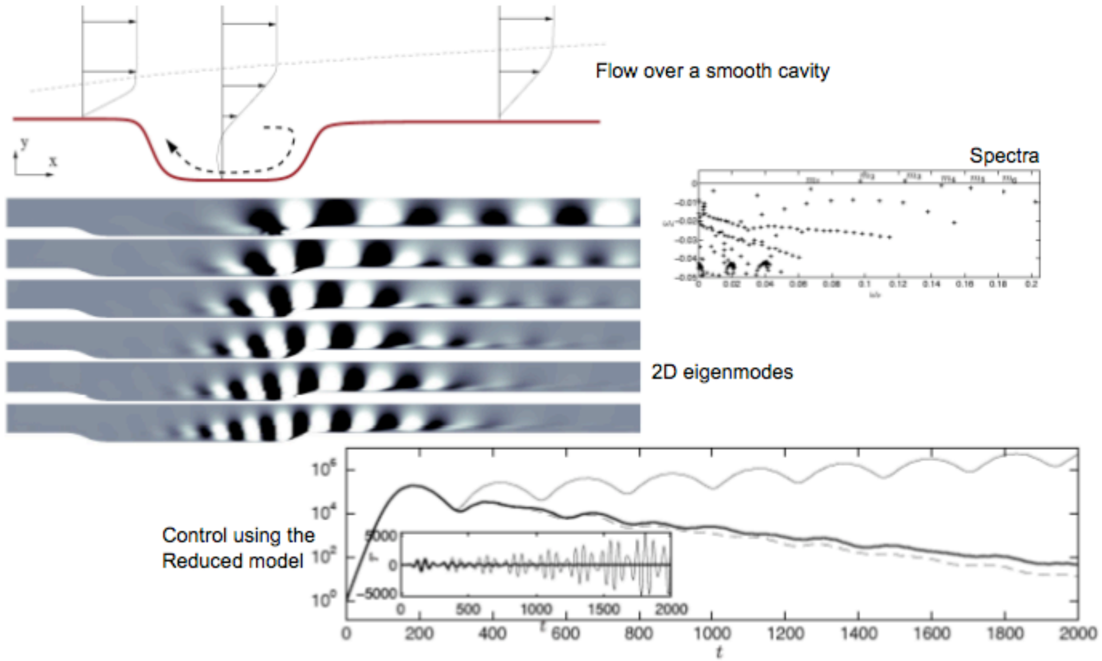
3D Swept-wing Boundary layer

No control

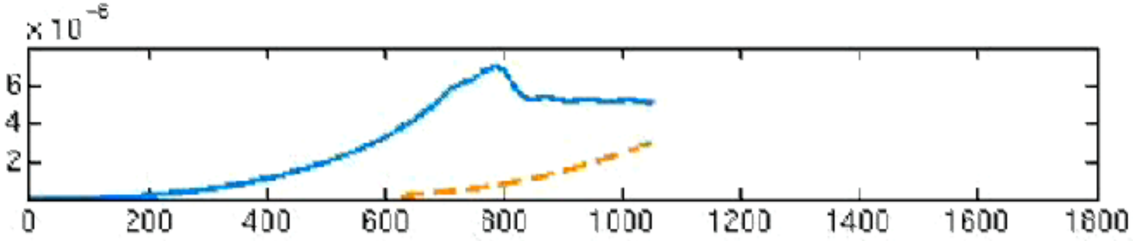


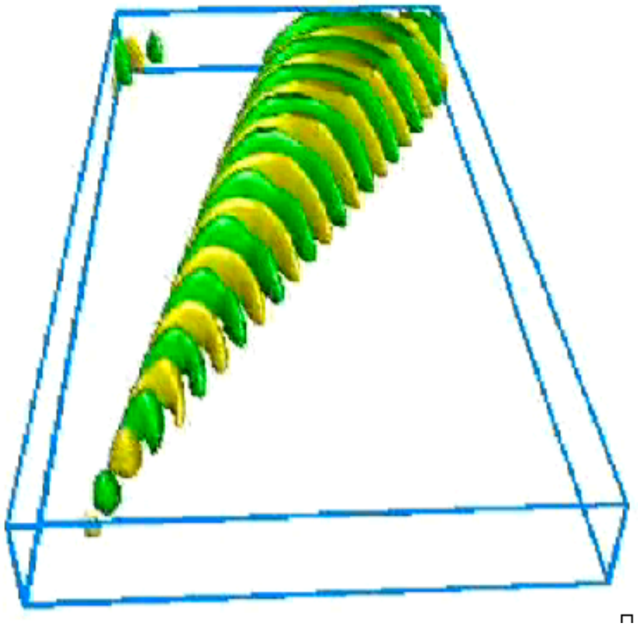
With control

2D Separated boundary layer

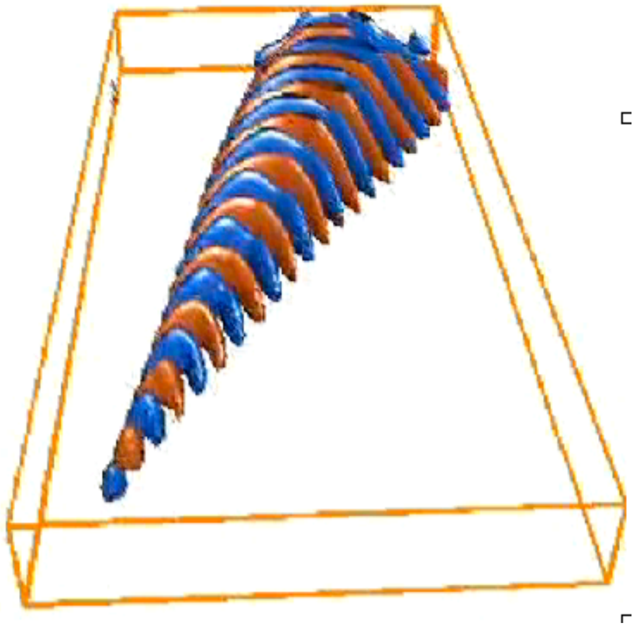


Swept-wing boundary layer with pointwise forcing





Real flow



Flow field reconstructed using sensors