Visualisation within School of Engineering Sciences SCI

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Linné Flow Centre

KTH Mechanics, Stockholm, Sweden

VIC Workshop, March 21, 2007

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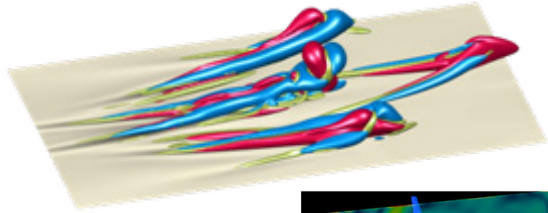
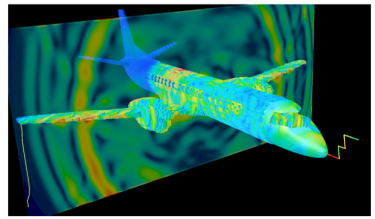
School of Engineering Sciences, SCI

Research groups with interest for visualisations

- **Mechanics**
  Fluids: Dan Henningson
  Solids: Anders Eriksson



- **Physics**
  Bengt Lund-Jensen
  Theoretical Physics: Mats Wallin



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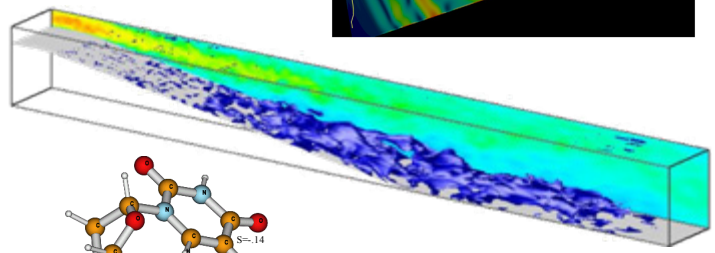
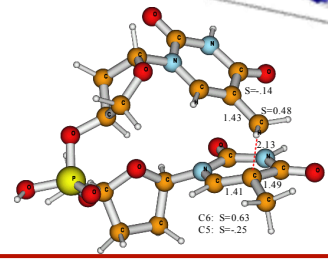
- **Vehicle Engineering**
  Gunilla Efraimsson
  Art Rizzi



- **Mathematics/Optimisation**
  Anders Lindquist



- **KCSE**: KTH Computational Science & Engineering Centre, Director: Olof Runborg

Vision/Needs for SCI

- Applications:
  - Computational Mechanics (incl. CFD)
  - 4D insight into motion/interaction of structures
- Status:
  - Very localised solutions (areas, persons)
  - "unsophisticated" software (Matlab, homegrown, …)
- Needs:
  - more centralised knowledge on visualisation techniques, capabilities, tools etc.
  - dedicated machines, i.e. with large memory, scratch disks, graphic cards
  - software availability, specialised tools e.g. for CFD
  - steep learning curve → specialists? (area-specific)
  - huge amounts of data (1 velocity field ~5GB)
- Vision:
  - Introduce Visualisation as a daily tool for students and researchers
  - focus on time-dependent 3D visualisations

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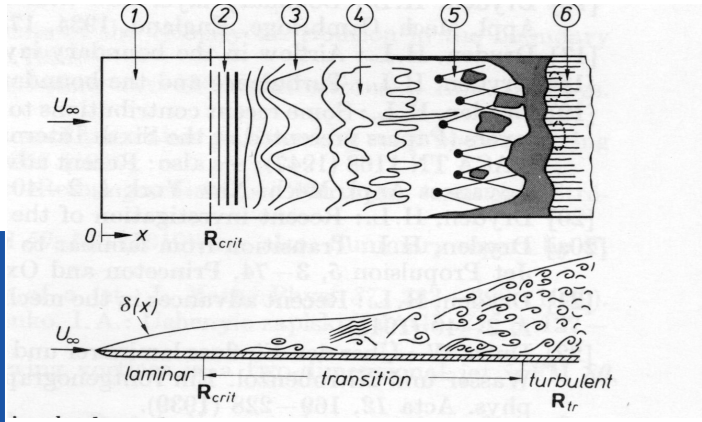
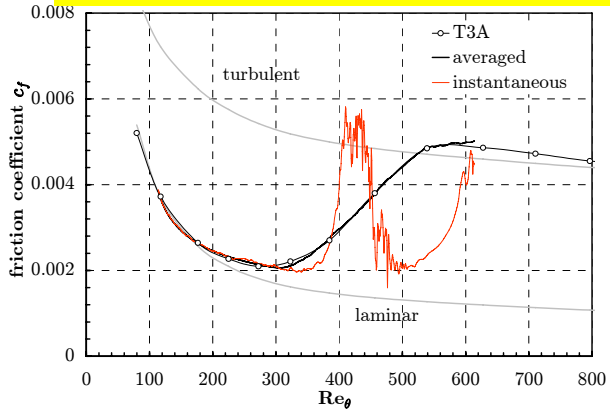
Workflow of Visualisation in CFD

1. Theory/Experiments



2. Simulation → Statistics



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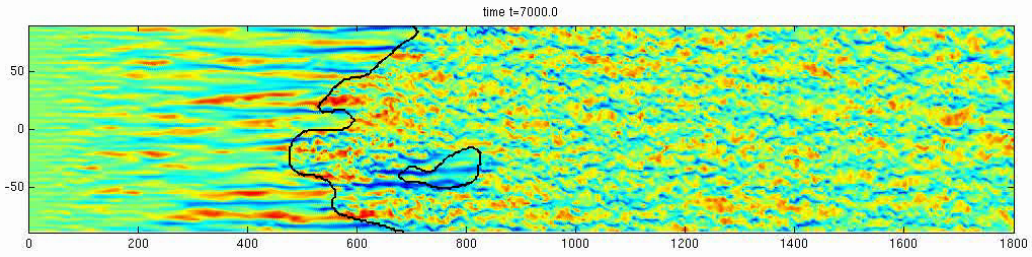
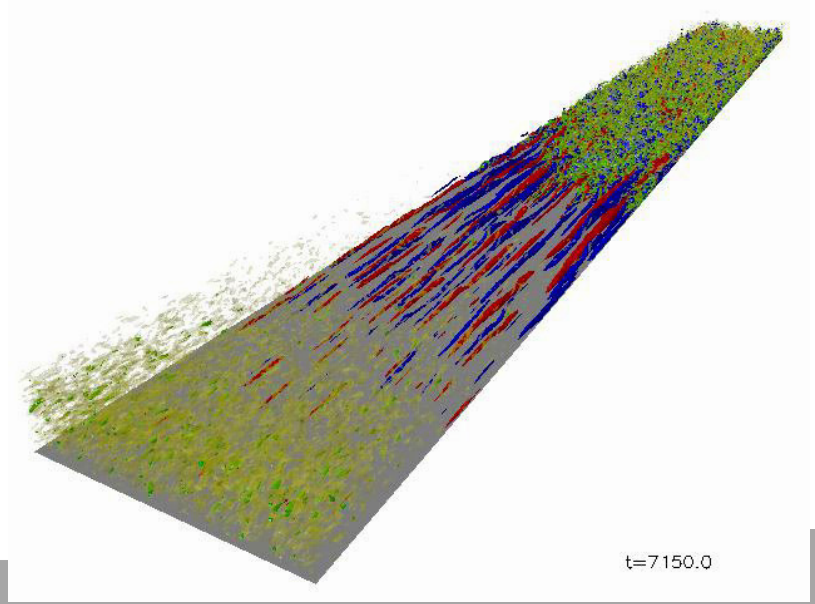
3. 2D-Visualisation



4. 3D-Visualisation



Detailed Insight through Visualisation: laminar-turbulent Transition

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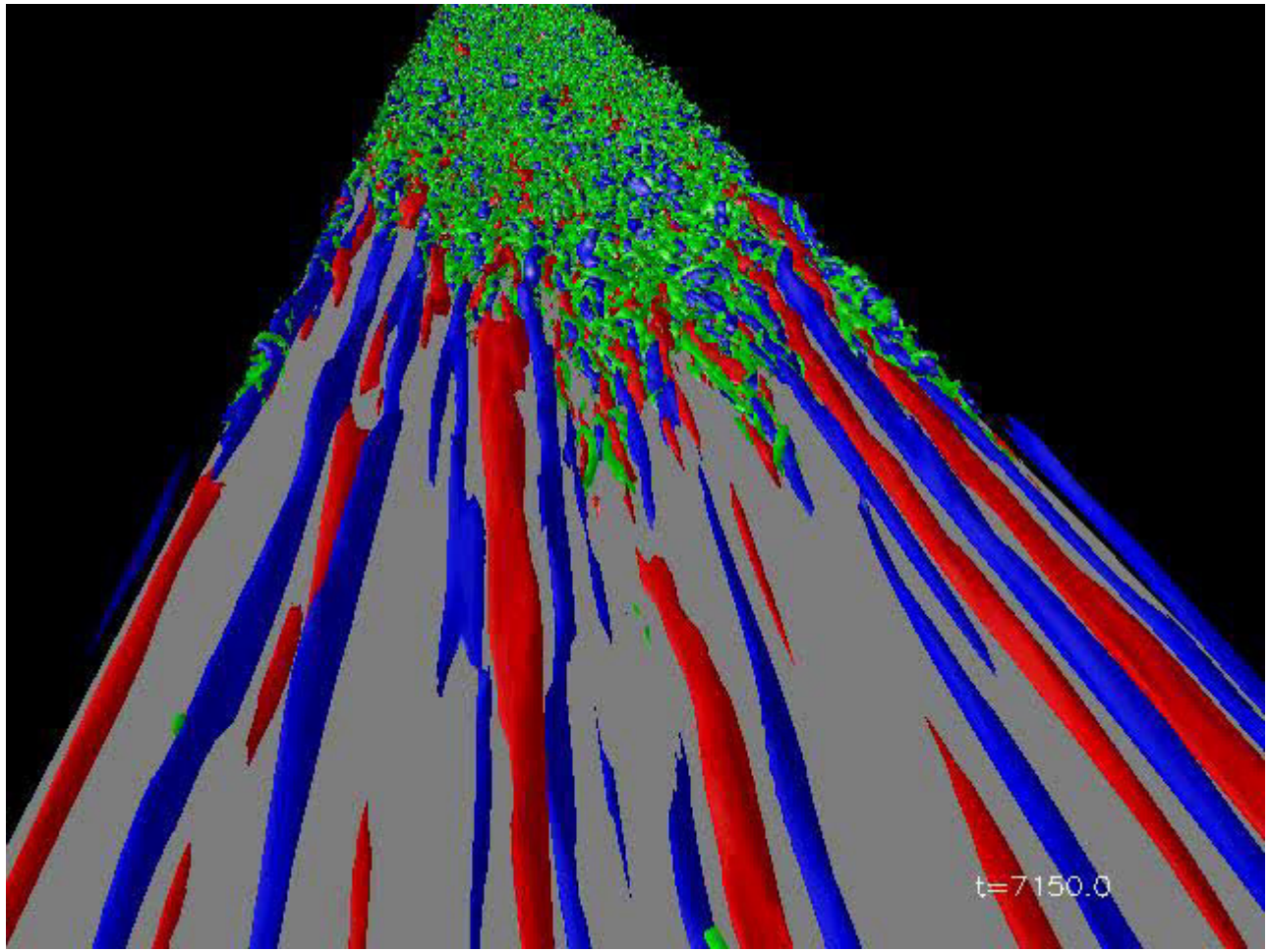
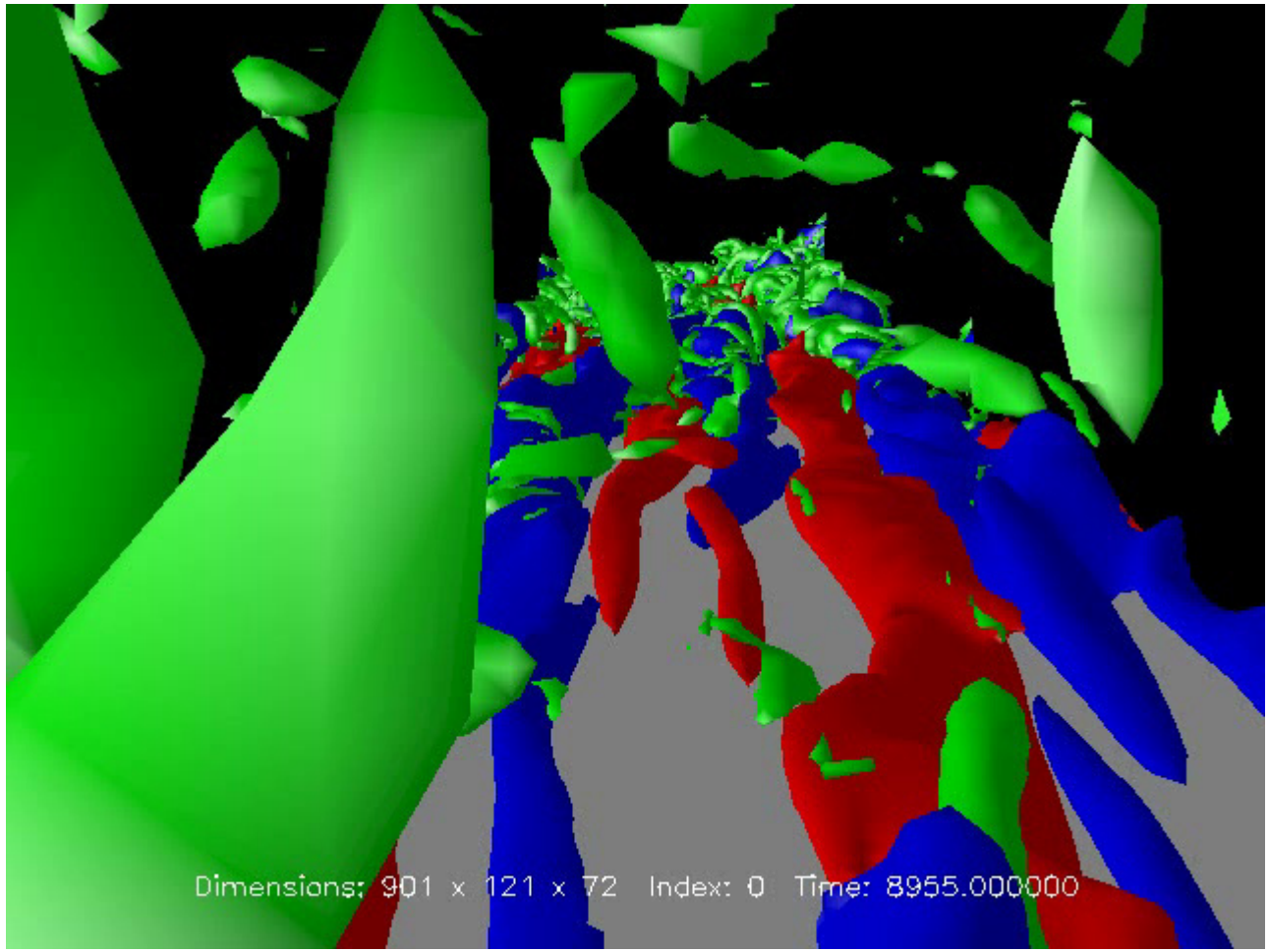


LES Data, ca. 20 Mio. Grid Points, done with OpenDX

Views not obtainable from Experiments…



DNS Data, ca. 40 Mio. Grid Points, done with OpenDX

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Thank you!

Comparison: Simulation and Experiment

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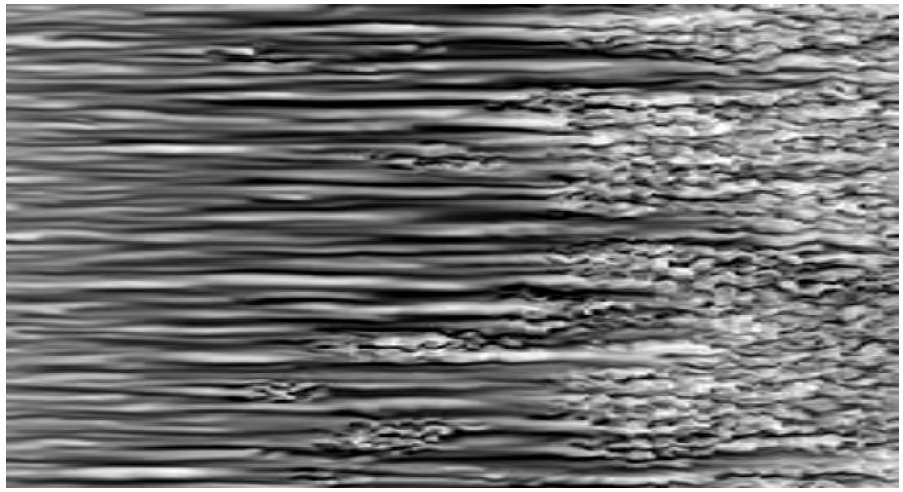
Experiment

KTH Windtunnel
Matsubara & Alfredsson (2001)

Simulation



LES (ADM-RT)
Schlatter, Brandt & Henningson (2006)

Transition Mechanism: Classical Transition

Low levels of background noise (<1%)

→ exponential modal growth

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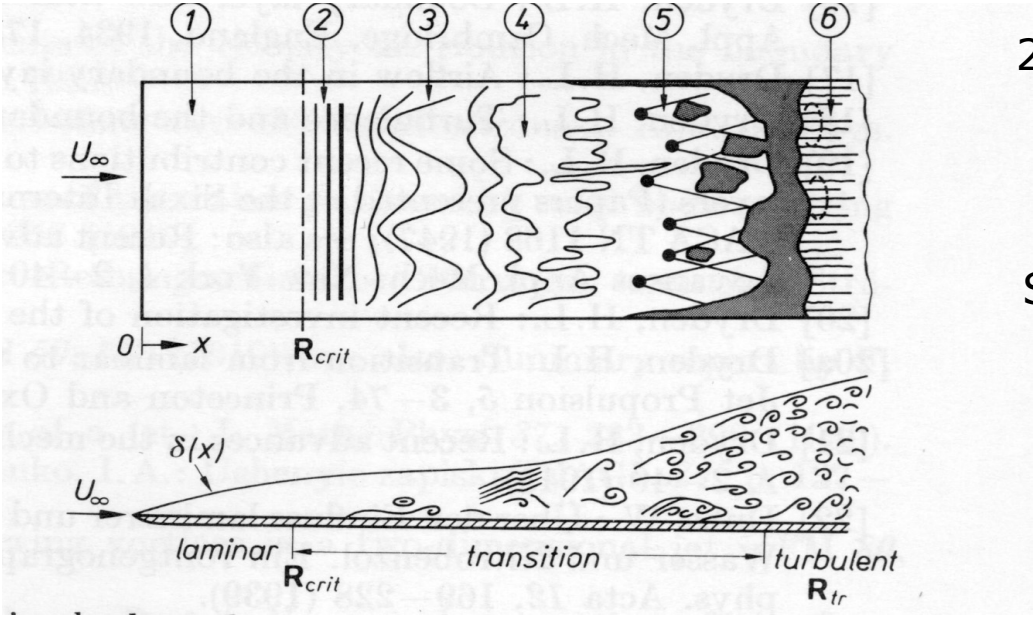

Schlichting (1977)

2D primary instability (TS waves)

↓

Secondary instability (K- & H-modes)

↓

Turbulent spots

↓

Turbulence

Transition Mechanism: Bypass Transition

High levels of free-stream turbulence (>1%)

→ exponential growth of TS waves is "bypassed"

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Matsubara & Alfredsson (2001)

U_∞

Non-modal growth of 3D streaks

↓

Secondary instability of streaks

↓

Turbulent spots

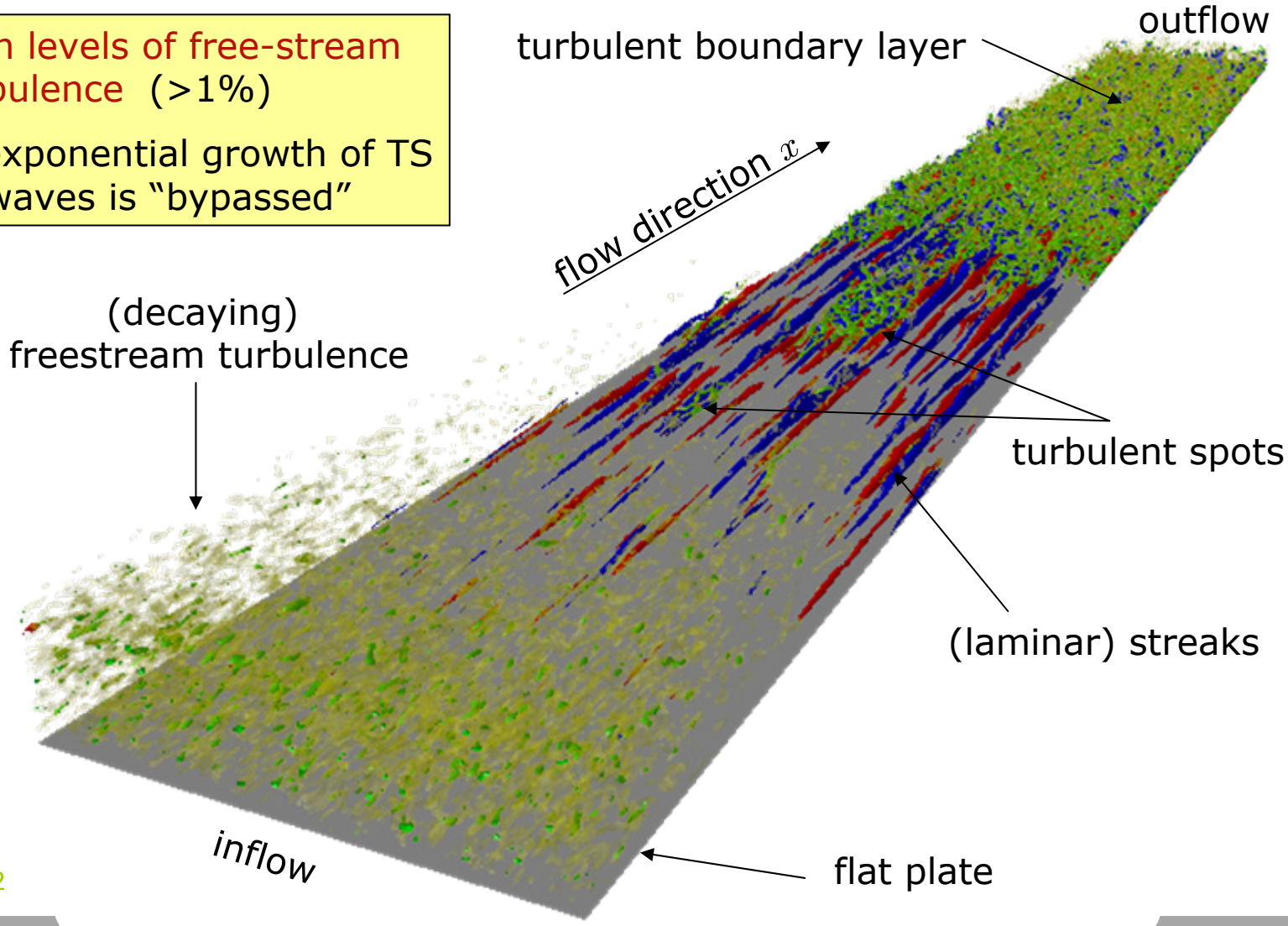
↓

Turbulence

Bypass Transition

High levels of free-stream turbulence (>1%)

→ exponential growth of TS waves is "bypassed"



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high velocity
low velocity
contours of λ_2

DNS Results: Streak Breakdown

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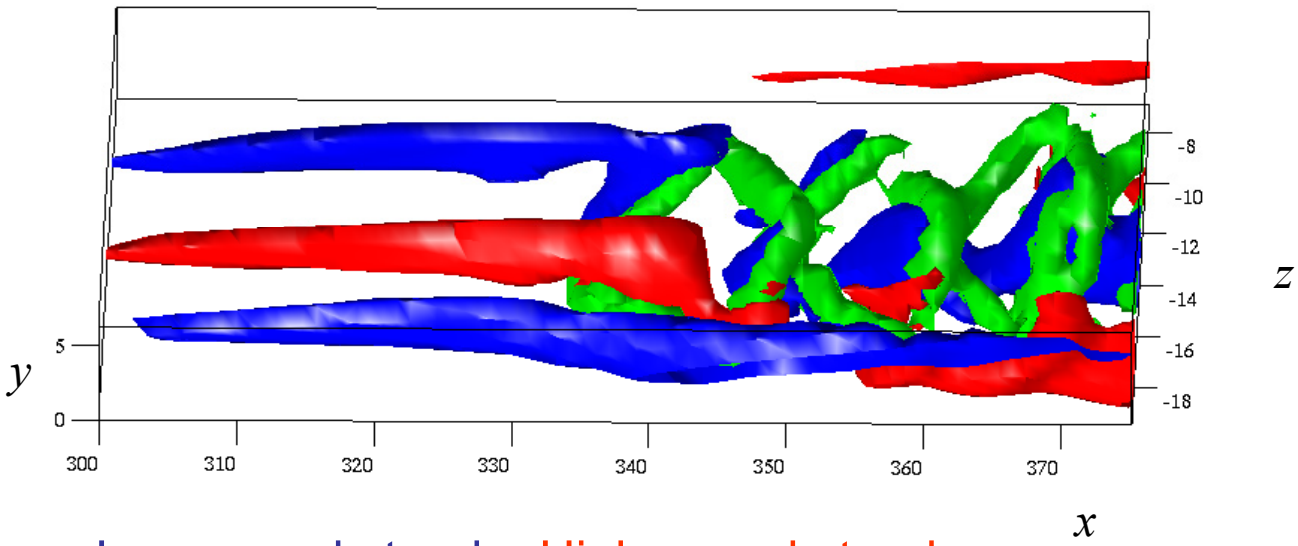

Low-speed streak High-speed streak

Vortical structures (negative λ_2)

✓ **horseshoe pattern (symmetric instability)**

Brandt, Schlatter & Henningson, *J. Fluid Mech.* (2004)

Visualisation of Bypass Transition

- Streamwise velocity component u obtained from LES with ADM-RT in a wall-parallel (x, z) plane at y=2 δ^*_0
  red: high velocity, blue: low velocity,
  black: spot detection criterion
  - Threshold for spanwise velocity variance
  - Median filters to smoothen boundaries