Session IV: Boundary Layers

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Structure

- How are structures in transitional and fully-developed turbulent flows related?
  - Evidence from Parviz's recent DNS
  - Observation of similarity of conditioned statistics in turbulent spots

- What are the "elementary" structures
  - Near-wall cycle of streaks and vortices (with debated method of interaction
  - Hairpins/Townsend attached eddies
  - Townsend detached eddies +…?

- Are they identical between canonical (and non-canonical) flows?
- (How) do they change with increasing Reynolds number?
  - Fundamental change or do some simply not survive?

- Origin of the large scales?
  - Accumulations of smaller scales (LSM and/or VLSM) or vice versa?
  - Large scale pattern formation, e.g. Couette flow of Kawahara
  - Different dimensions in internal (>10h) and TBLs (6δ)?
  - Pitfalls of Taylor's hypothesis, particularly in this spectral range

Dynamics – linear and nonlinear processes

- Additional complexity of wall turbulence as compared to free shear flows
  - Non-modal vs. modal description

- But how useful are linear processes as a tool for investigating the dynamics of wall turbulence?
  - Progress with transient growth/RDT approaches
  - Nonlinear stability?
  - Removal of linear coupling term leads to turbulence decay

- Progress with dynamical systems approaches
  - Fixed points, edge states, exact cycles
  - How are these related to structure?

- Time for a reinvigoration of pattern formation techniques?
  - Insight into LSM and VLSMs?

Dynamics - structure

- What is the status of our understanding of the near-wall cycle?
  - What is driving it?
  - Relationship with the outer flow? Which direction of interaction, if any?

- Question was raised as to how the vorticity field is structured below the top layer of hairpin vortices

- How should we classify the VLSMs?
  - "Inactive" in the Townsend sense (certainly not true away from the wall
  - "Active", but "slosh" the small-scale, near-wall motion
  - Do they modulate the near-wall Reynolds shear stress as well as intensities?

- What happens as Reynolds number increases?
  - Top-down vs. bottom-up?
  - Dynamical importance of modulation of the small scales?
  - Relevant to control schemes or can we simply extrapolate the lower Reynolds number picture?

- Are we in a position to write down dynamical equations for the coherent structures to form low order models?
  - Previous POD efforts destined to identify only large scales
  - Newer approaches can include the smaller scales

Mean velocity profiles

- Comparison of flows
  - High precision of measurement (velocity and skin friction) possible in internal flow configurations, especially pipes
  - ZPG boundary layer varies because of spatial inhomogeneity and entrainment
  - Make the problem simpler: extend internal flow studies to those with more tunable parameters, e.g. Taylor-Couette flow
  - Make the problem harder: more practically relevant flows, e.g. APG boundary layers

- Form of the mean velocity
  - Is it a log law (with a universal Karman constant or a flow-dependent coefficient?)
  - Is it a power law?
  - Does it depend on the canonical flow (internal/external)?
  - What measurements are required to tell the difference?
  - Asymptotic composites, different scaling layers, universal profile? Must be applicable to additional flows.

Questions

1. How does collective organization of structure work in wall flows?
   - What are the elemental building blocks?
   - How do they interact?

2. What is the relative importance of linear processes and/or instabilities in the nonlinear problem of turbulence?
   - Foundations for control?
   - Dynamical equations for coherent structures?

3. What do we know/what don't we know about the large scale (outer) structures in wall flows? (Examples here in channels, TBLs, Couette flow)
   - Are there/what are the differences between flows?
   - How important are they for dynamics and control?
   - Theoretical and empirical description techniques
   - Entrainment through the turbulent/non-turbulent interface in the TBL
   - What is/is there a connection with free shear flows?
   - Does entrainment explain differences between internal and external flows (alongside spatial inhomogeneity)?