F. Box

# Sensitivity of the Transition to Turbulence In a Pipe


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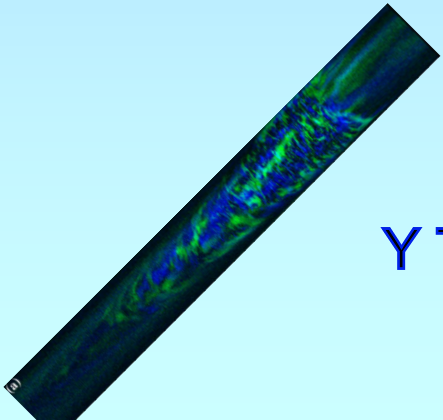
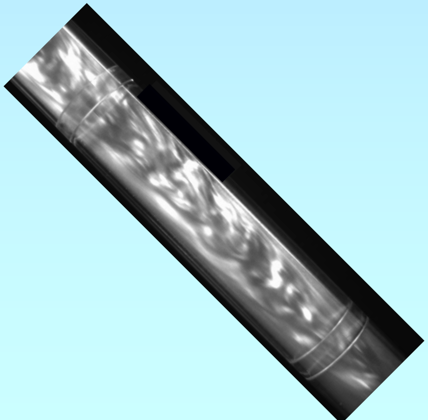



Joint work with:

Y Tasaka & J. Ohkubo

Sapporo

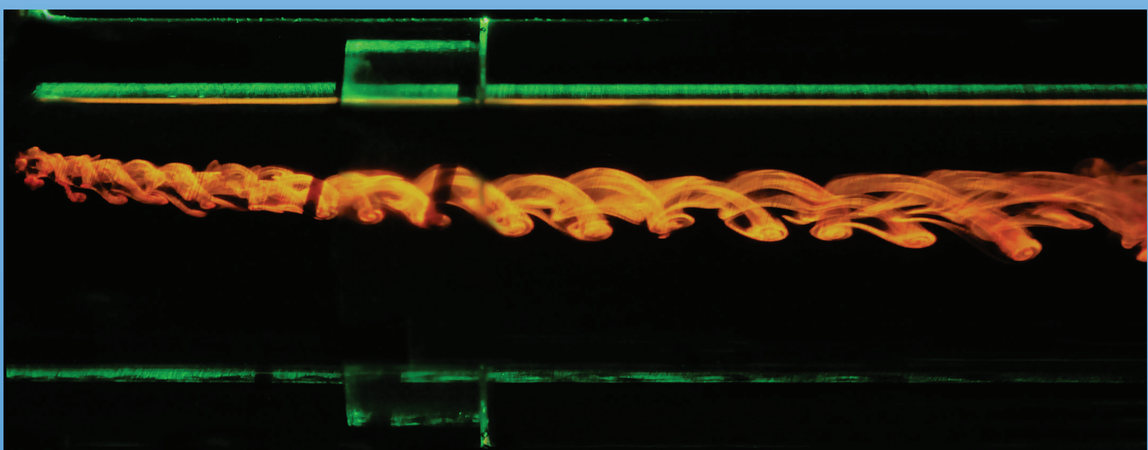



# Overview

1. The onset of disordered motion in pipe flow is abrupt “the sudden way in which eddies come into existence in the experiment with coloured bands” Reynolds 1883.

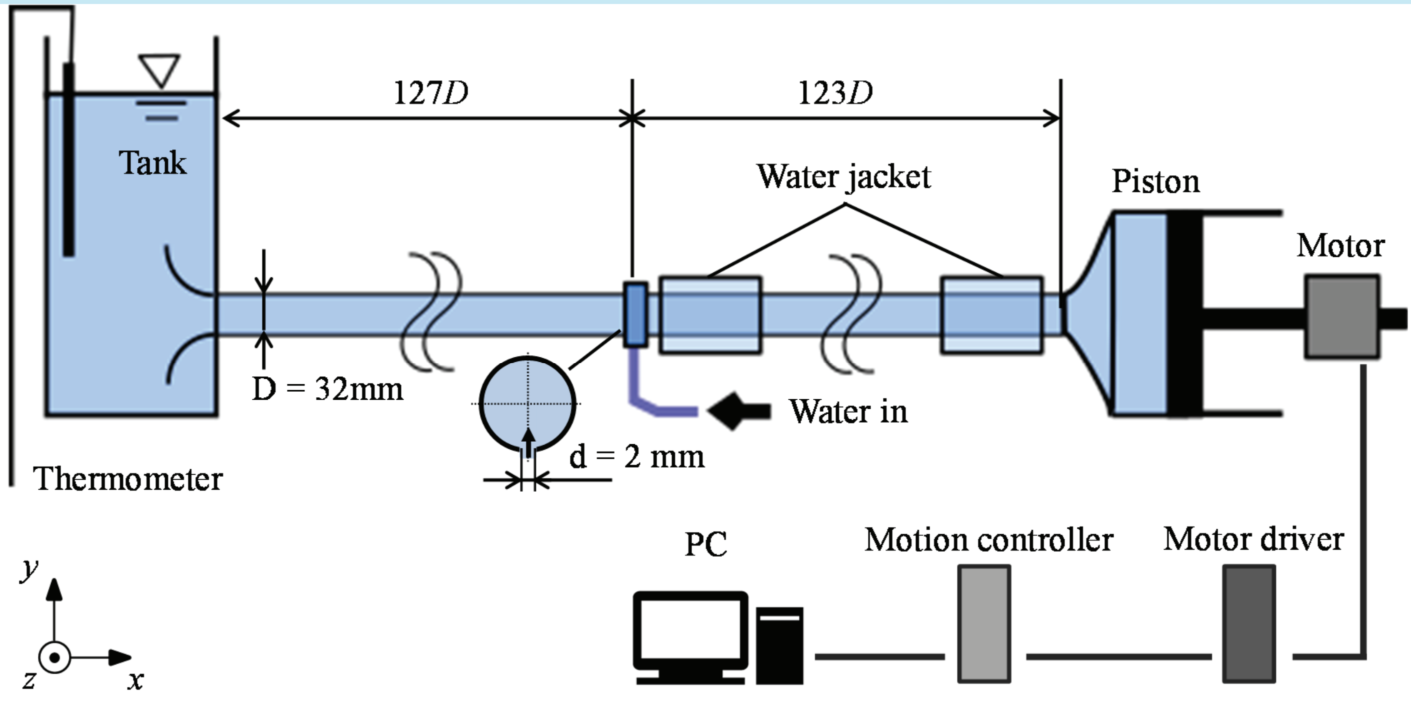
2. **Transition requires sufficiently large amplitude disturbance.**

3. Small disturbances provide interesting insights.

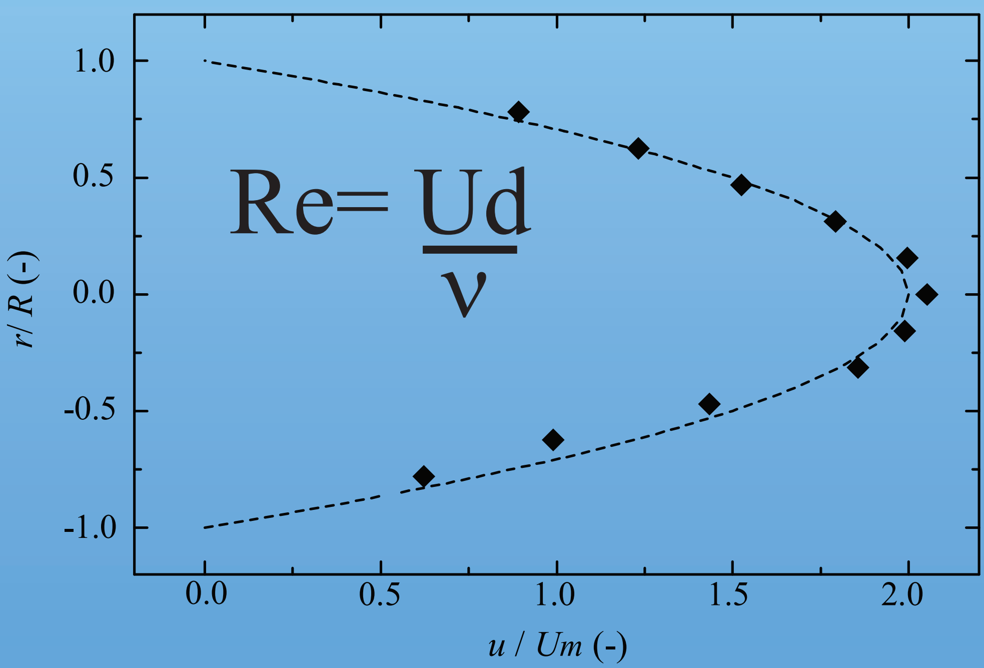


F.Box

# Constant Mass Flux Pipe Facility in Sapporo

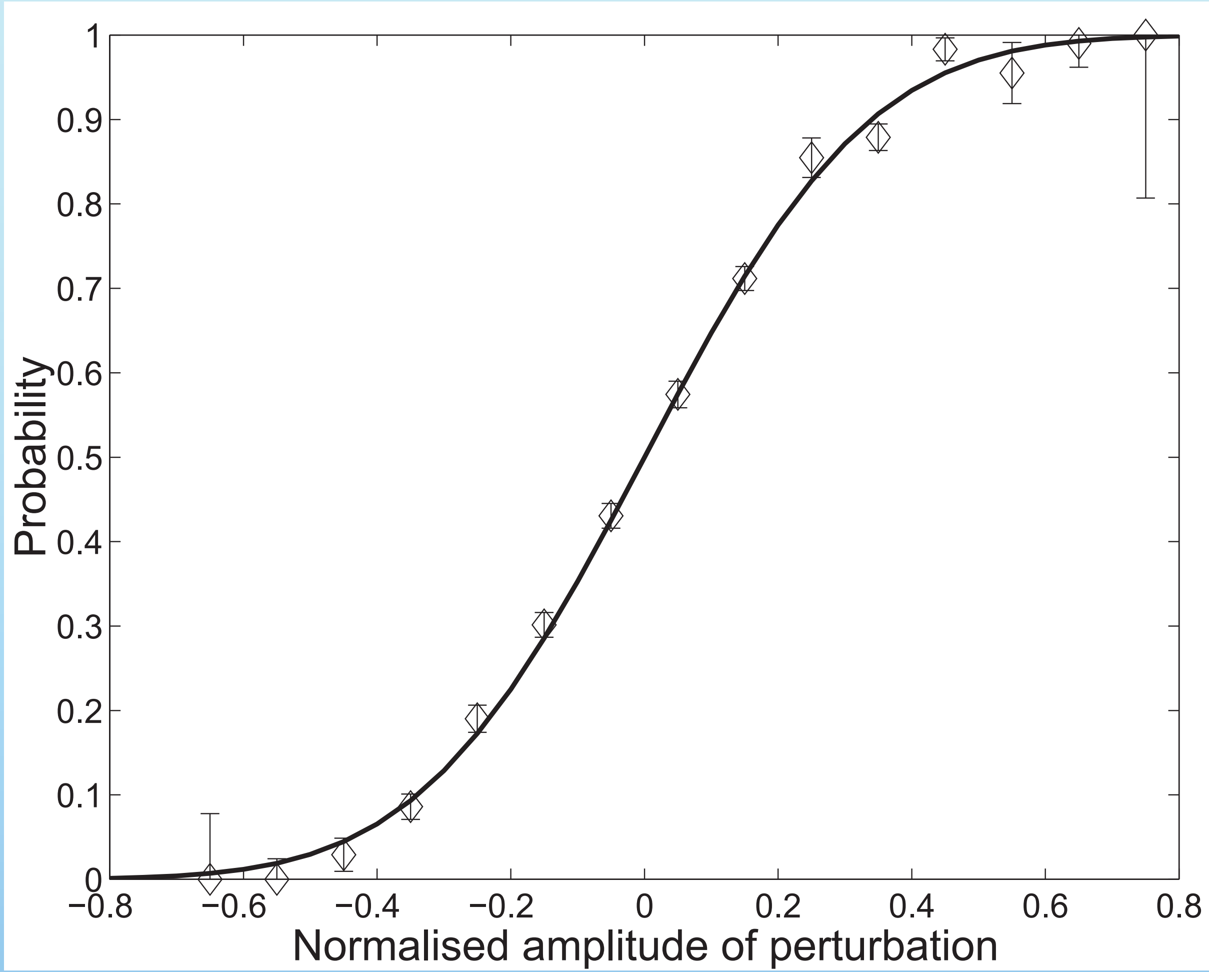



# Measured Poiseuille profile at Re =2,000




$$Re = \frac{Ud}{\nu}$$

# Transition probability



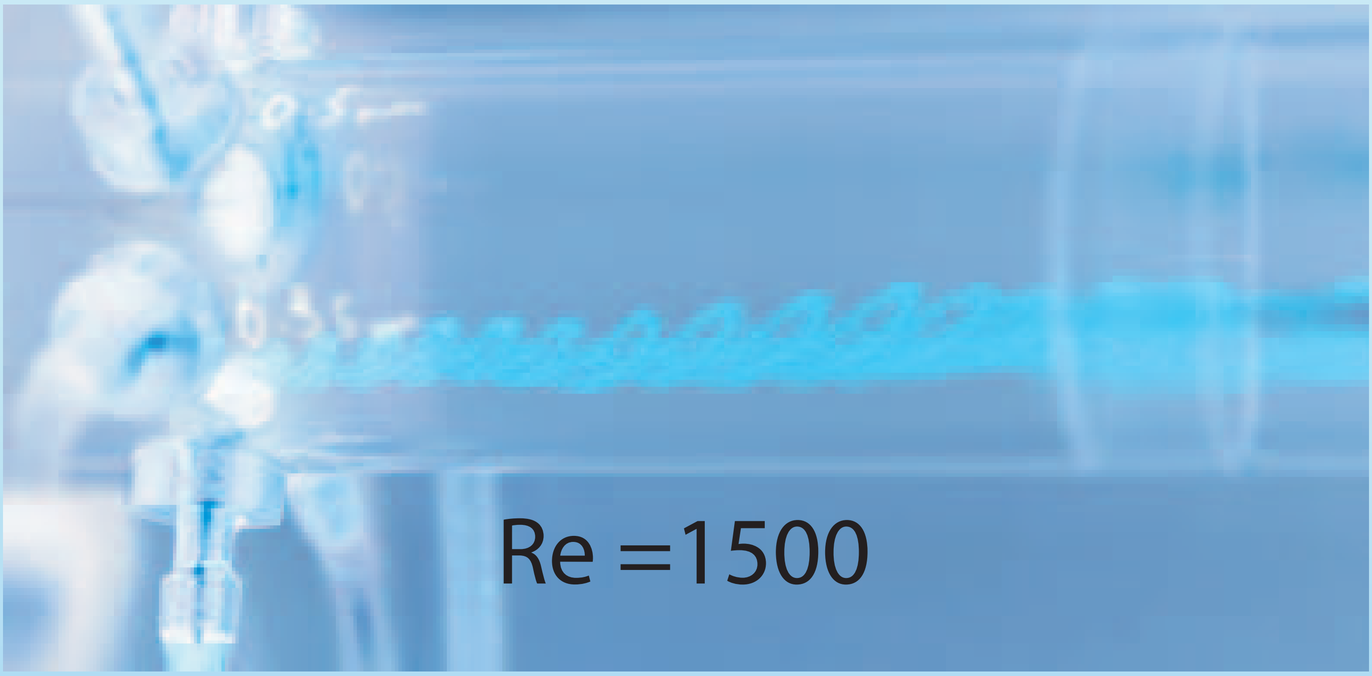

- Error function fit.
- Plot obtained from normalised data of 5000 experiments:

  1. Reynolds numbers of 2170, 3000 and 4000,
  2. Different location of perturbation along the developing flow.

- Threshold process?

S. Williams PhD Thesis

# Jet Through Small Hole



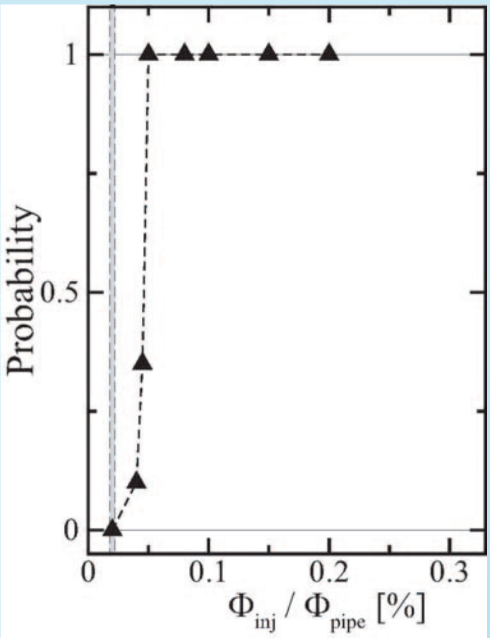

0.3mm diameter hole: Amp. 0.1%

0.3mm diameter hole: Amp. 0.1%

Re =1900

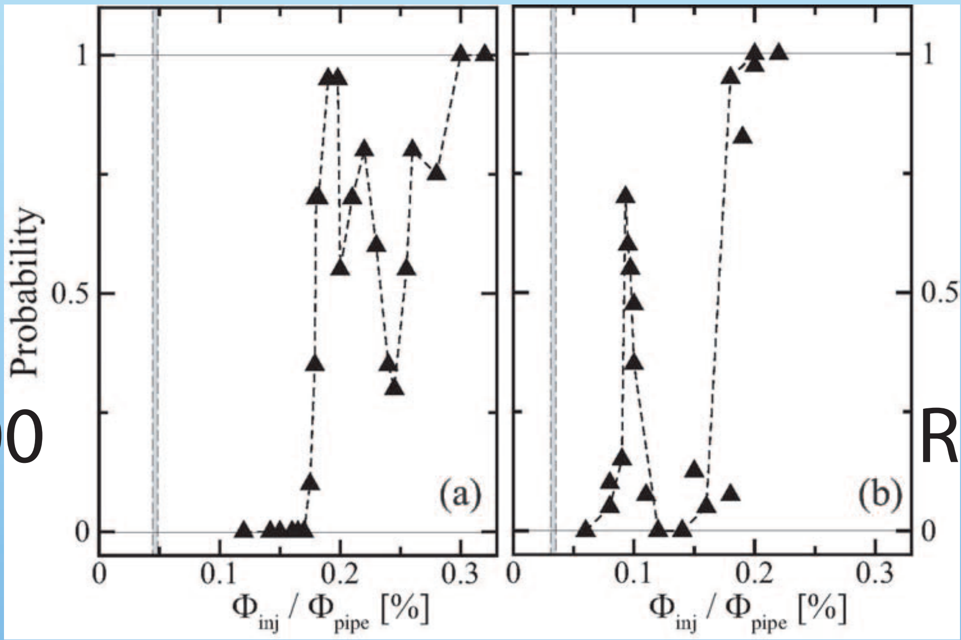
0.3mm diameter hole: Amp. 0.18%

# Transition Probabilities:



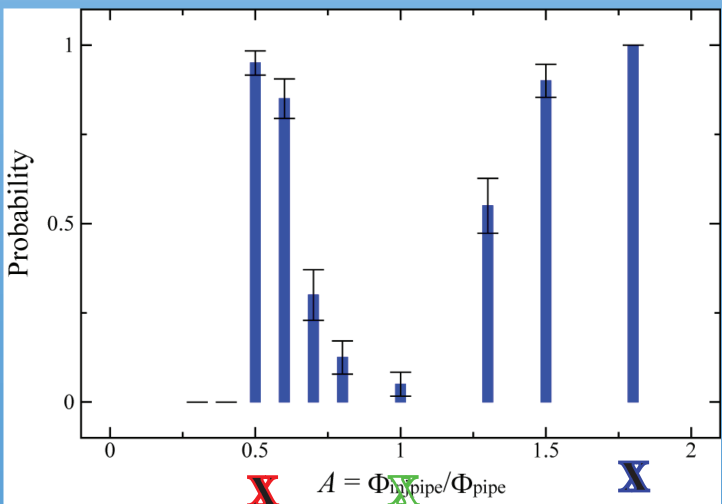

Re=3,000

Re=1900




Re=2100

Y. Tasaka, T. M. Schneider, and T. M.
PRL 105, 174502 (2010)



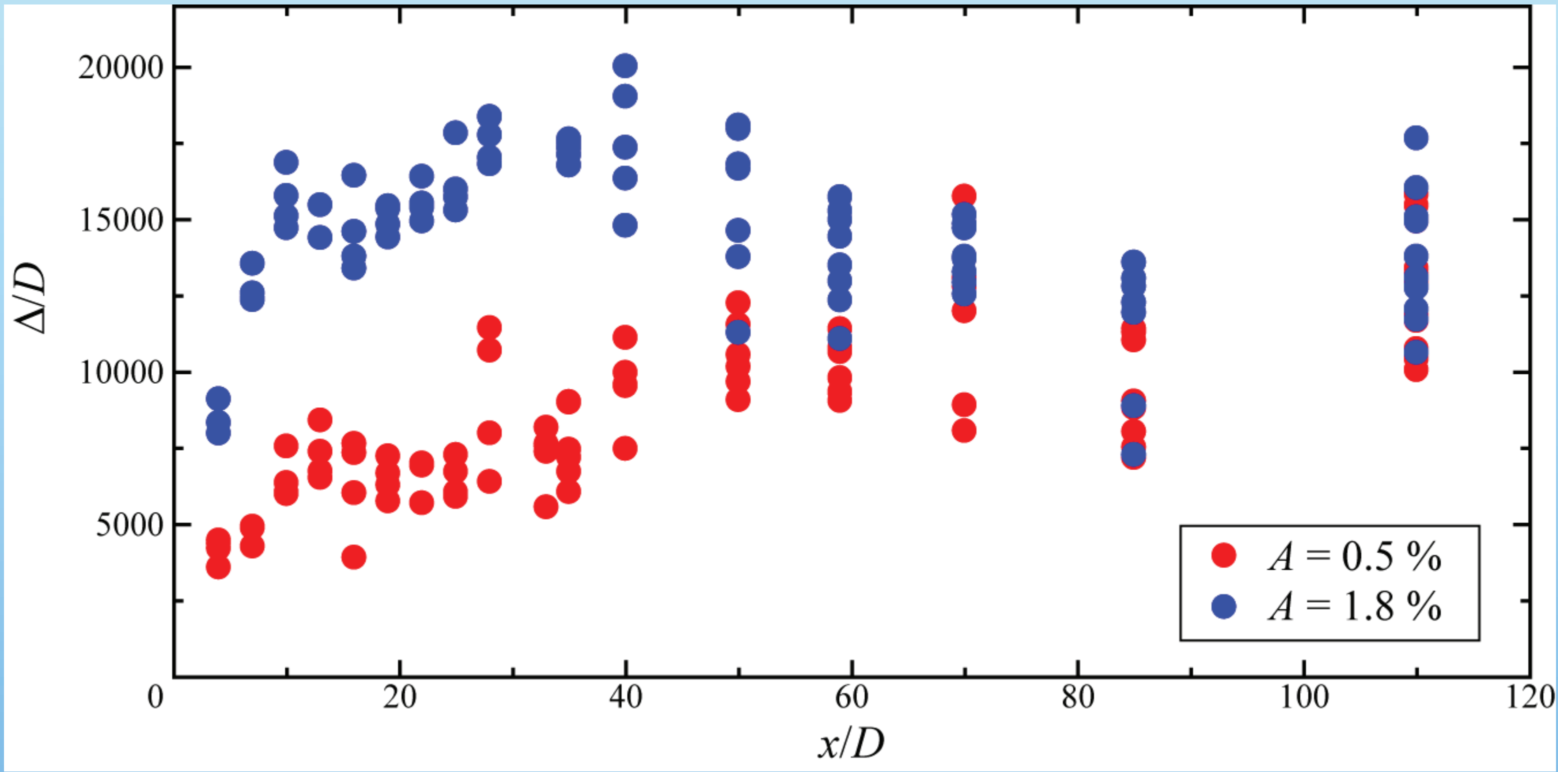

Repeat Saporro
(2015/6)

Re=1900

$\Delta$ is the time integral of the centreline velocity 'defect' where the integration is carried out over the measurement time $T$ such that,

$$\frac{\Delta}{D} = \frac{1}{D}\int_0^T [U(r=0) - u(r=0)dt$$

where U is the parabolic velocity profile of H-P flow and thius $U(r=0)$ is $2U_{mean}$.

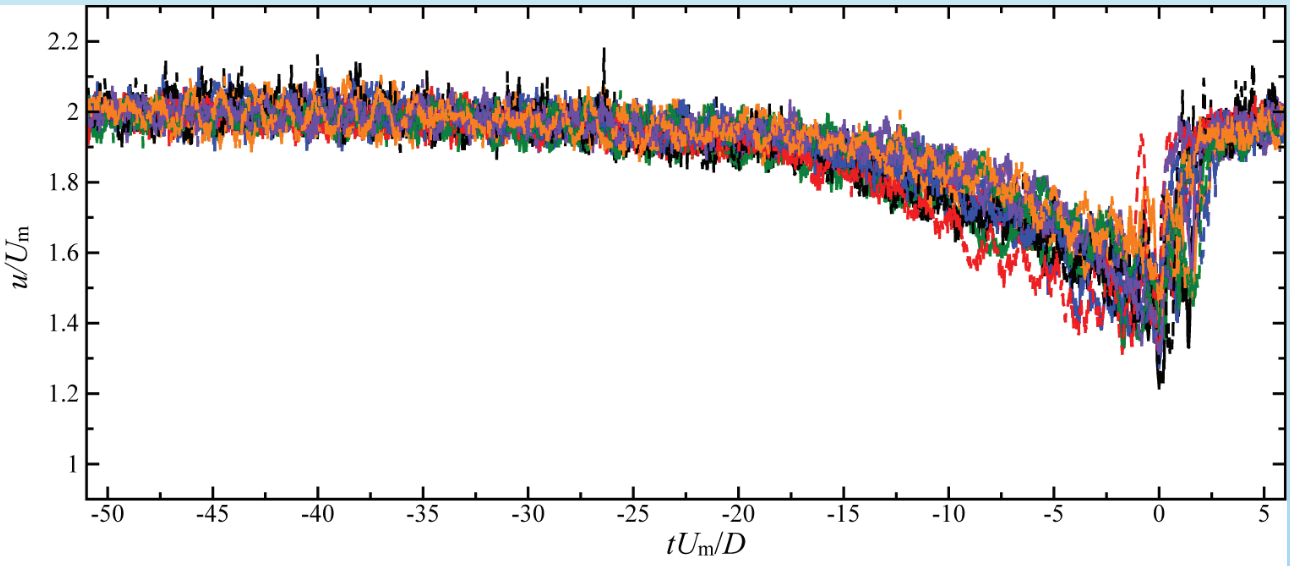



Evolution of velocity 'defect' as disturbance travels downstream.

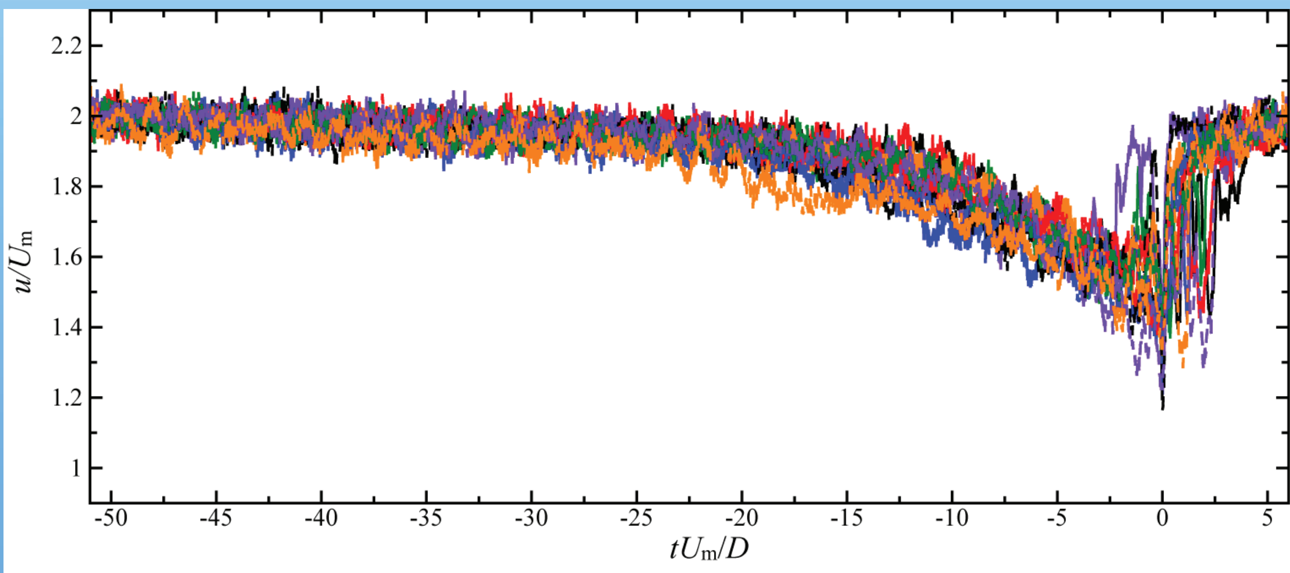
LDV used to measure on-axis vel. at 16 spatial locations plus one fixed pos. downstream (~200 runs of exp.)

# Centreline Vel.-Time Traces from 12 Runs at 110D

## 0.5% Disturbance Re= 1900

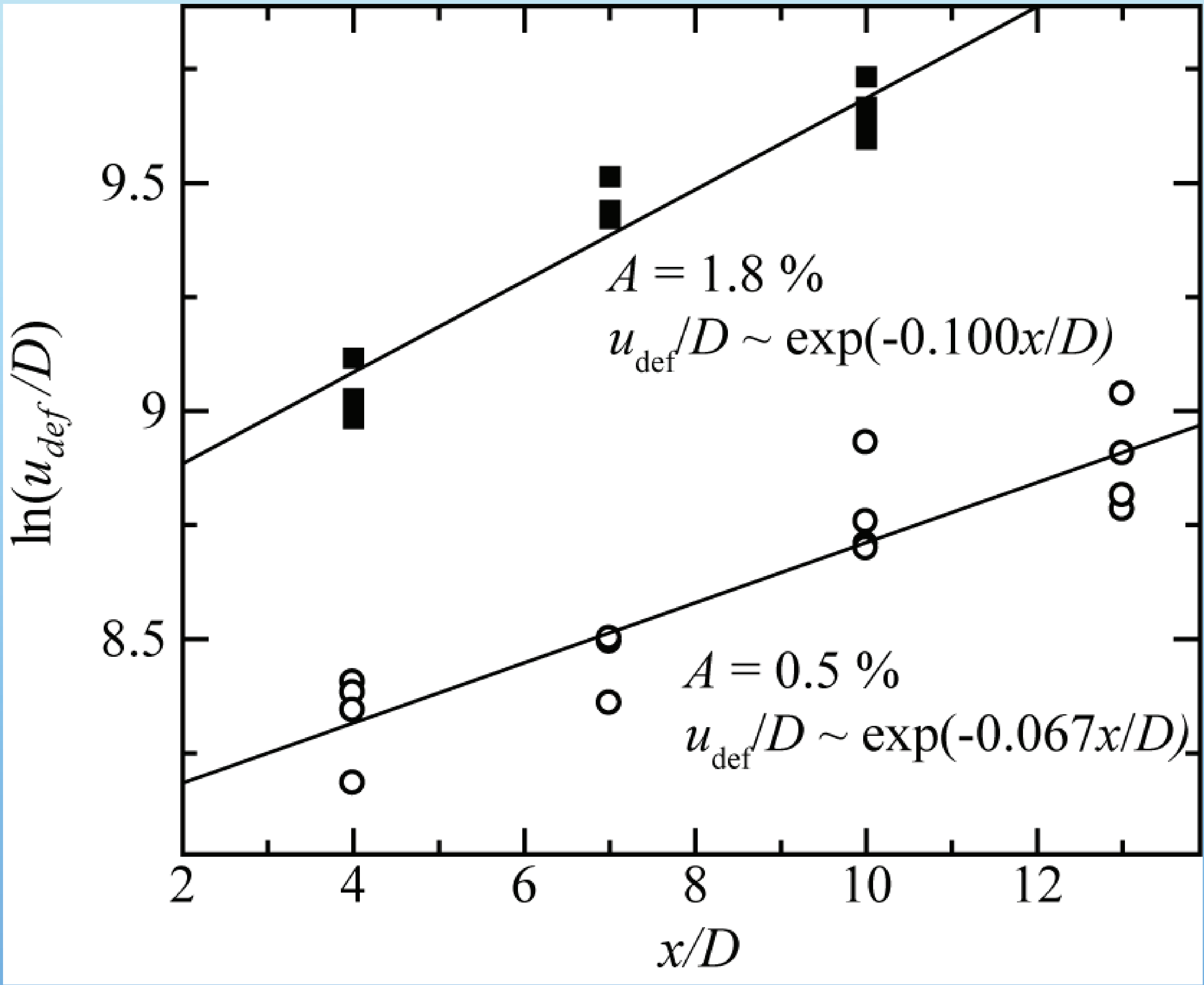



## 1.8% Disturbance Re+1900

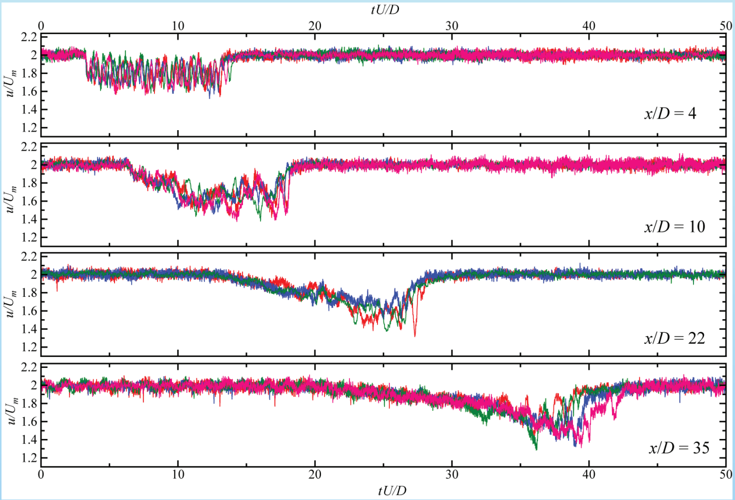


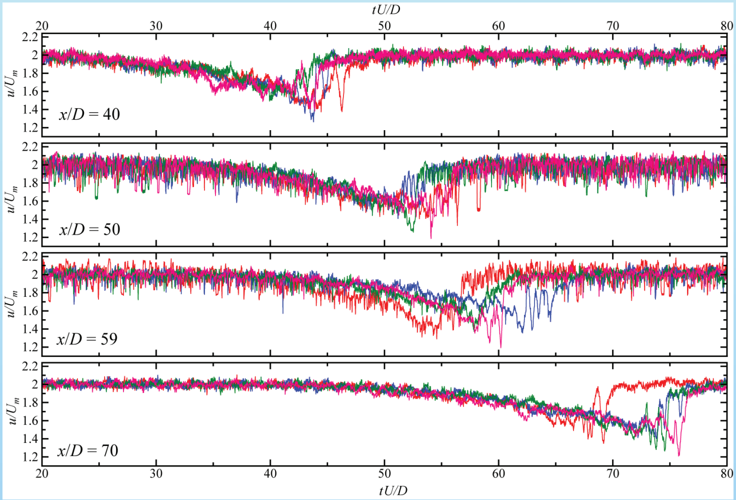
# Initial Downstream Growth of Velocity Defect

**Re = 1900**

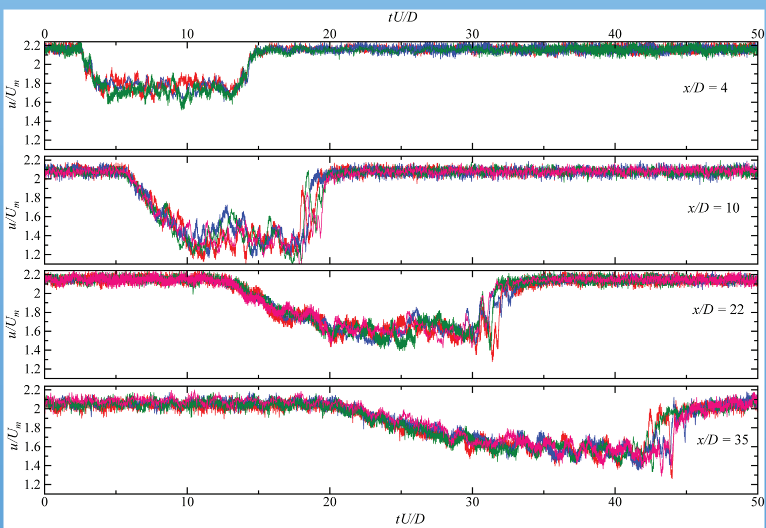


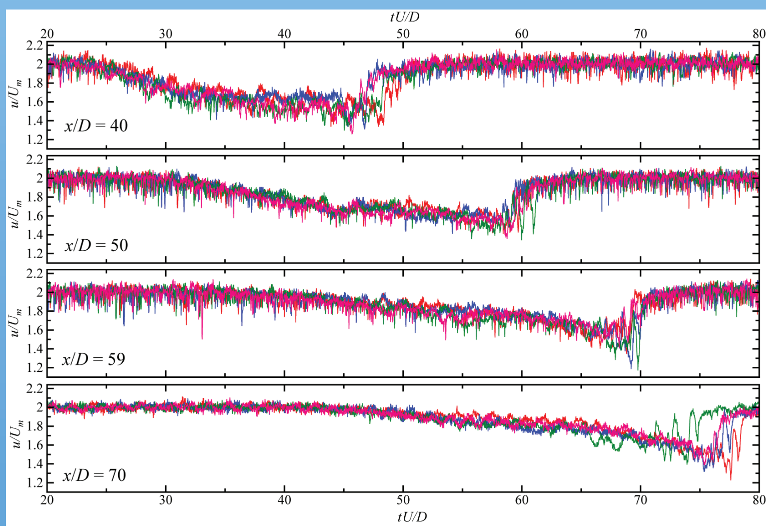
# Evolution of 0.5% disturbance



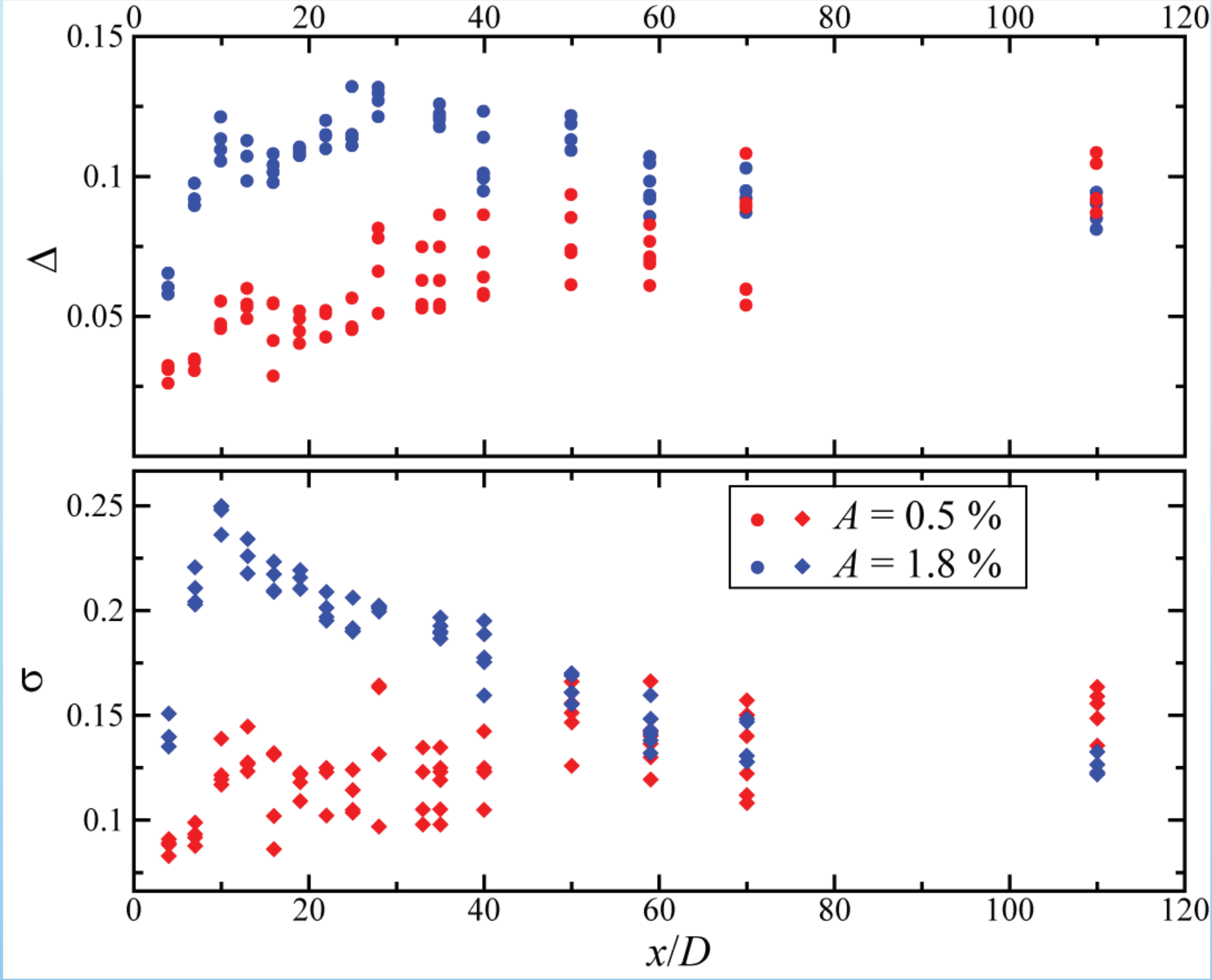




# Evolution of 1.8% Disturbance



# Defect




# Variance

$\Delta$ represents averaged velocity defect at the center of pipe for a measurement time $T = N\delta t$ ($N$ and $\delta t$ mean number of data and sampling period of the velocity fluctuation) as

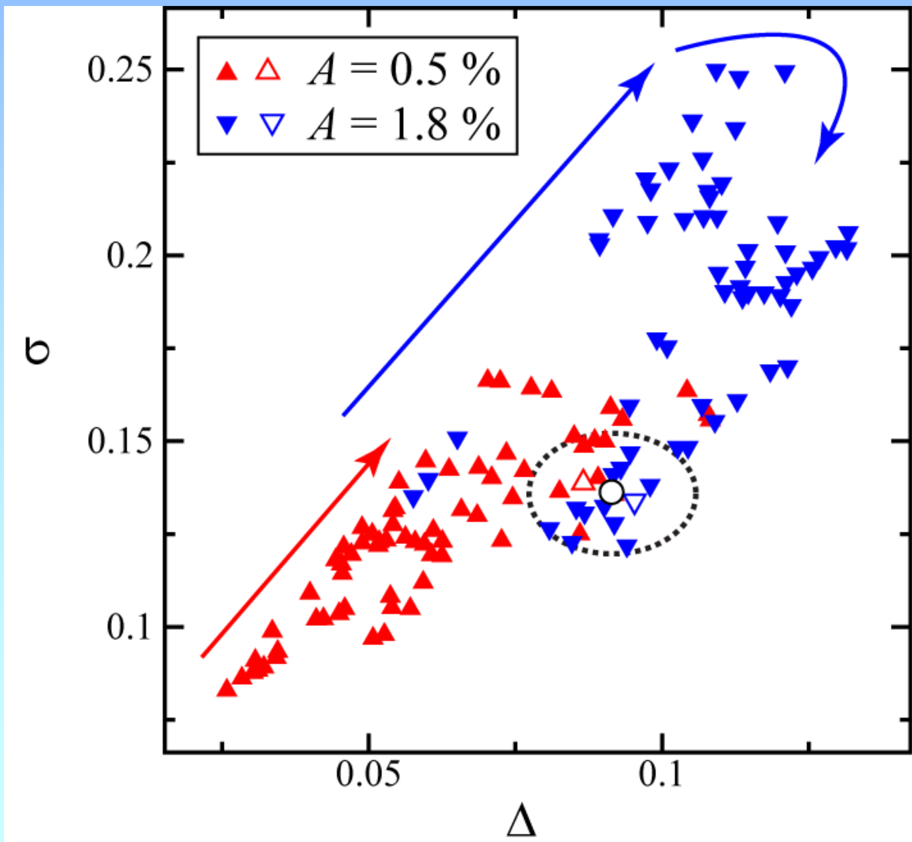
$$\Delta = \frac{1}{N}\sum_{i=0}^{N-1}\frac{U(r=0) - u_i(r=0)}{U_{mean}},$$

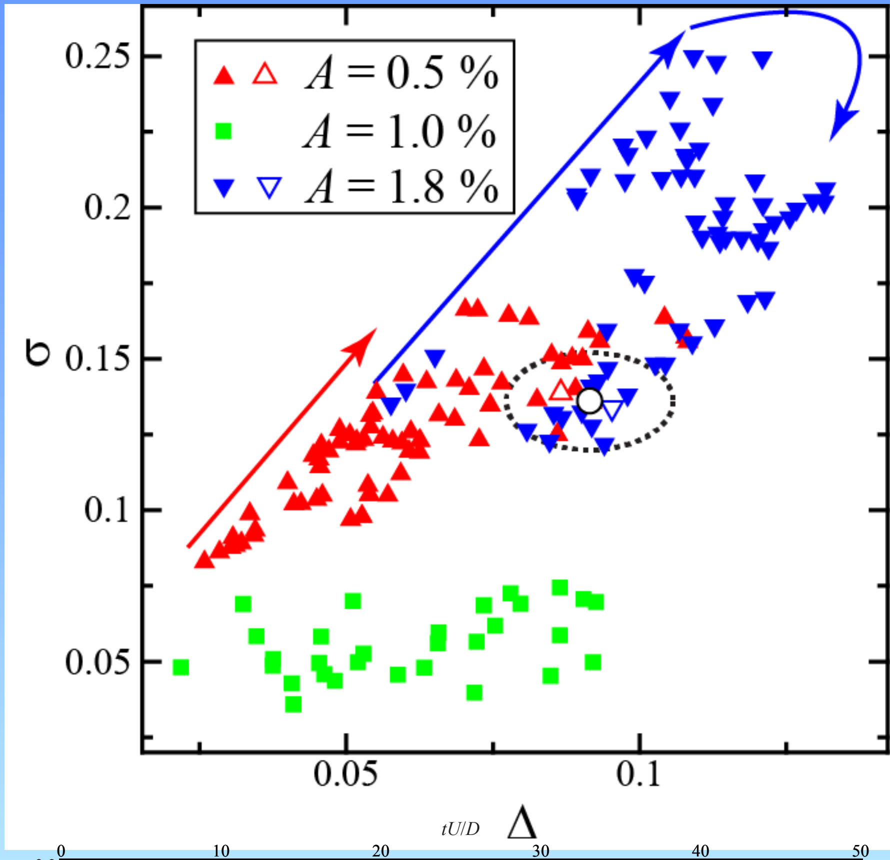
where $U$ represents parabolic velocity profile of Hagen-Poiseuille flow, and thus $U(r=0)$ corresponds to $2U_{mean}$. $\sigma$ means standard deviation defined as

$$\sigma = \sqrt{\frac{\sum_{i=0}^{N-1}[U(r=0) - u_i(r=0)]^2}{U_{mean}^2 N}}.$$

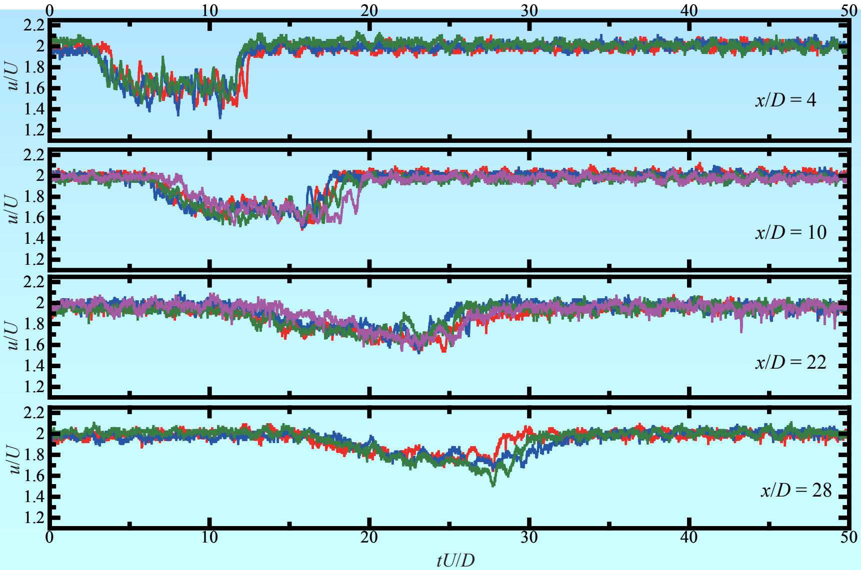
Defect/Variance Correlation for A= 0.5% and A = 1.8 %

'Puff' final state in both cases






Defect/Variance Correlation including decay

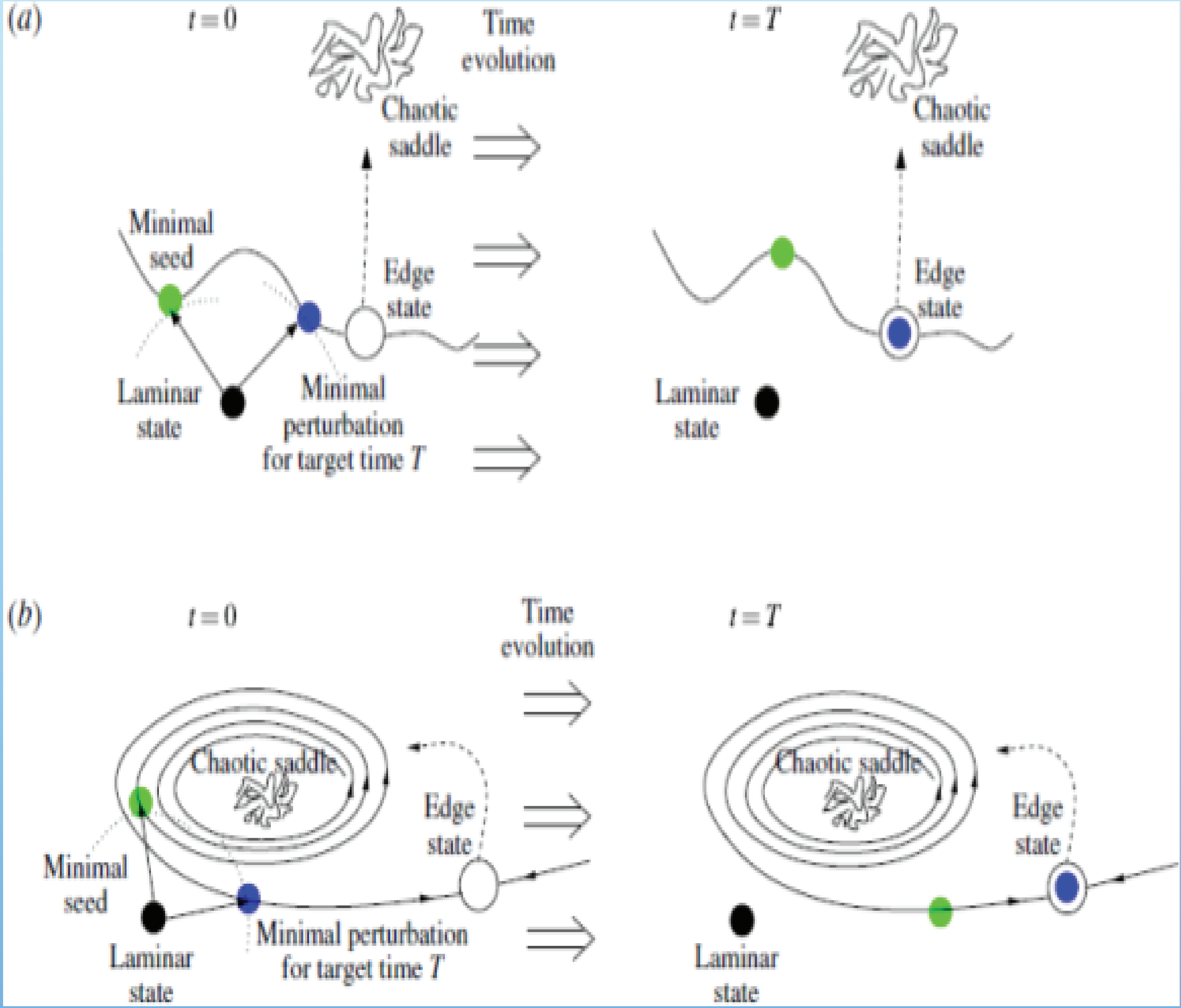



Decay at 1% disturbance

# Conclusions

## Are we probing the 'edge' state?

## Local




## Global

Rep. Prog. Phys. 77 (2014) 085901
R R Kerswell, C C T Pringle and A P Willis

J. Fluid Mech. (2010), vol. 645, pp. 529–539.

# Quantitative measurement of the lifetime oflocalized turbulence in pipe flow

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Laboratory for Aero & Hydrodynamics, Delft University of Technology, Mekelweg 2,
2628 CD Delft, The Netherlands

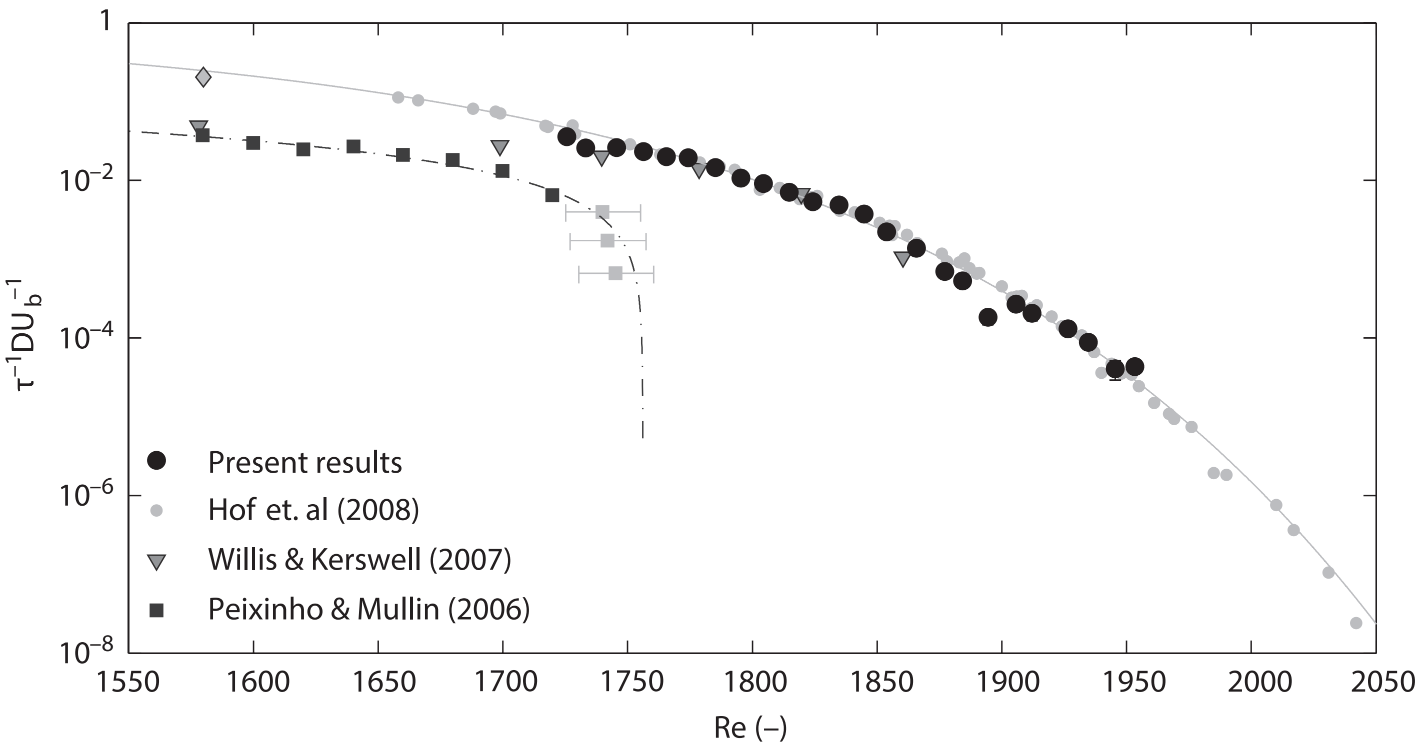
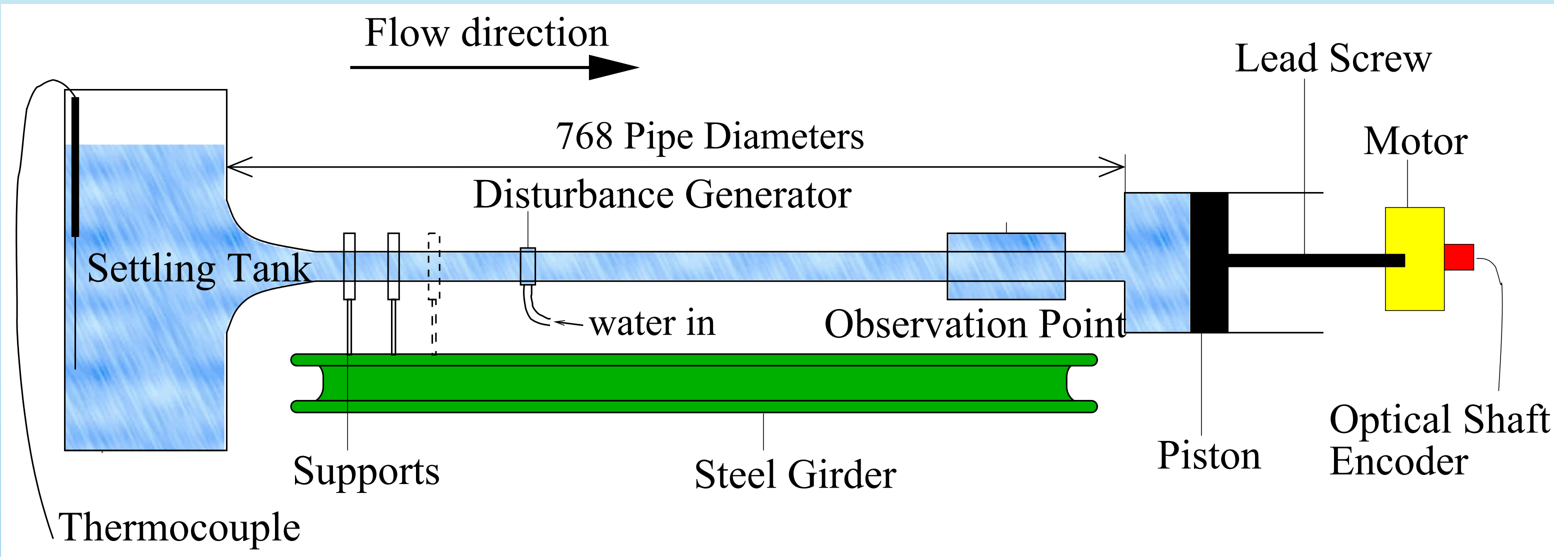
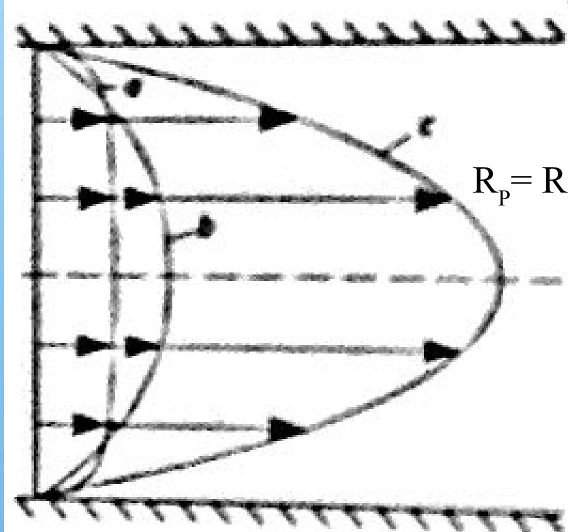



Figure 5. The inverse of the characteristic lifetime $\tau^{-1}$ as function of Reynolds ( Re ) number. Data from Peixinho & Mullin (2006) and Hof et al. (2008) are included, together with their linear and super-exponential scaling respectively. The data points of Peixinho & Mullin (2006) for Re $\geqslant$ 1740 are plotted in light grey since they are, considering the error estimates, measured at the same Reynolds number. The data of Willis & Kerswell (2007 a) is shown, in which the data point at Re = 1580 is reinterpreted (Hof et al. 2007; Willis & Kerswell 2007 b) (Hof et al. 2007, (◇), original ( ▼)).

# Drive the flow either by pressure gradient or constant mass flux.



Schlichting: Bound. Lay. Theory 8th ed. ch15 (2000)
B. L. Roxhdestvensky and I . N . Sirnakin JFM 147 (1984)

$R_P = R_Q = 5{,}000$

$$R_Q = \frac{3Q}{8\nu\rho_0 L},$$

$$R_p = \frac{|\nabla p|\, L^3}{2\rho_0 \nu^2}$$

Velocity distribution in a pipe
(a) turbulent
(b) laminar, same volume flux as a
(c) laminar, same pressure gradient as a