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Scalar dissipation statistics in turbulent swirling flows

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1. INTRODUCTION

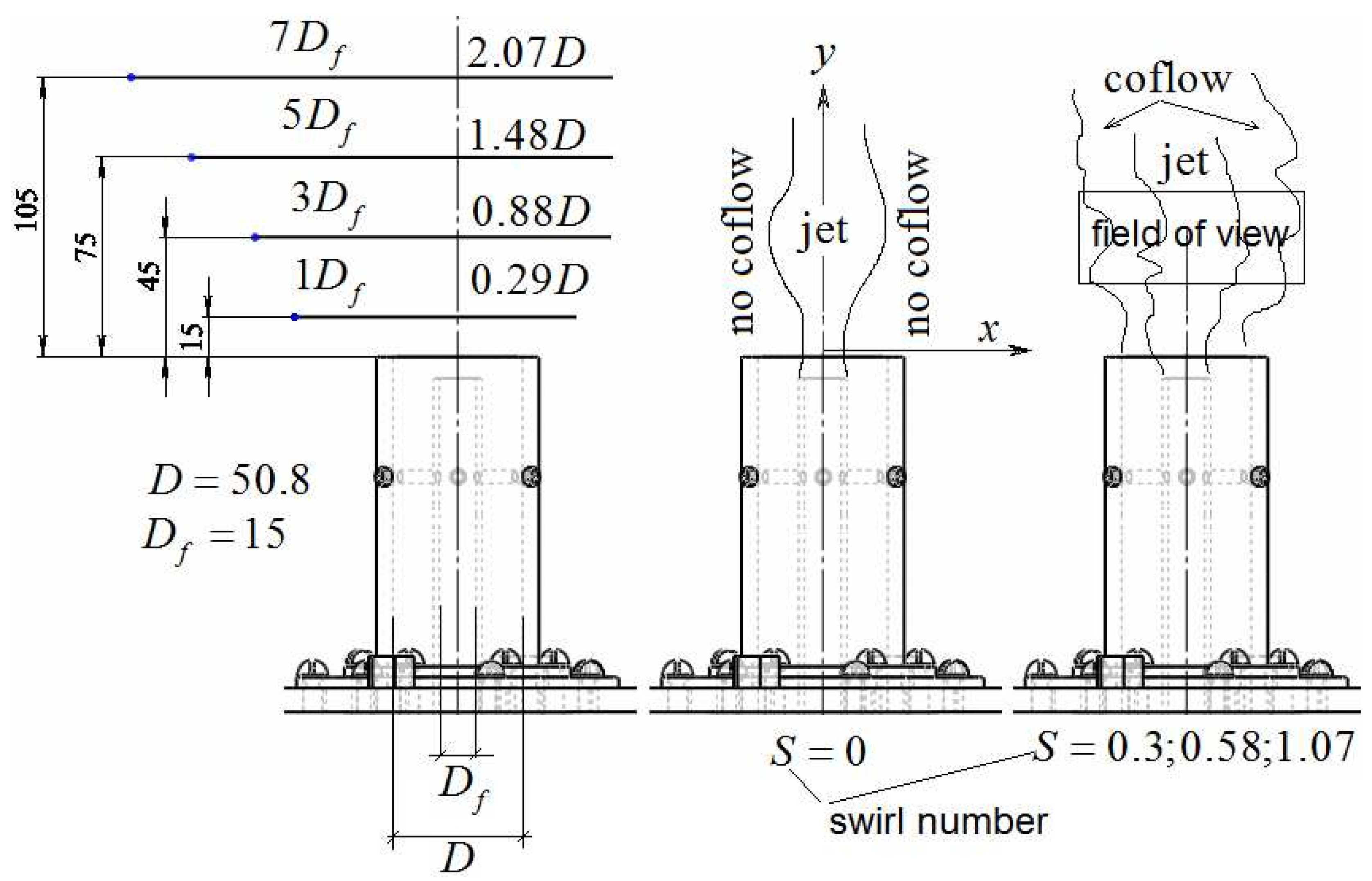
The dissipation rate $\chi \equiv D\nabla z \nabla z$ (z denotes mixture fraction, D is diffusivity) requires modeling in essentially all models for non-premixed combustion. The scalar dissipation rate can be used for instance in a pdf-flamelet approach in which species mass fraction and mean reaction rate are pre-calculated as a function of two variables namely mixture fraction and the scalar dissipation rate. Peters (1983) identified the scalar dissipation rate as a characteristic diffusion time scale, imposed by the mixing field.

2. AIMS AND OBJECTIVES

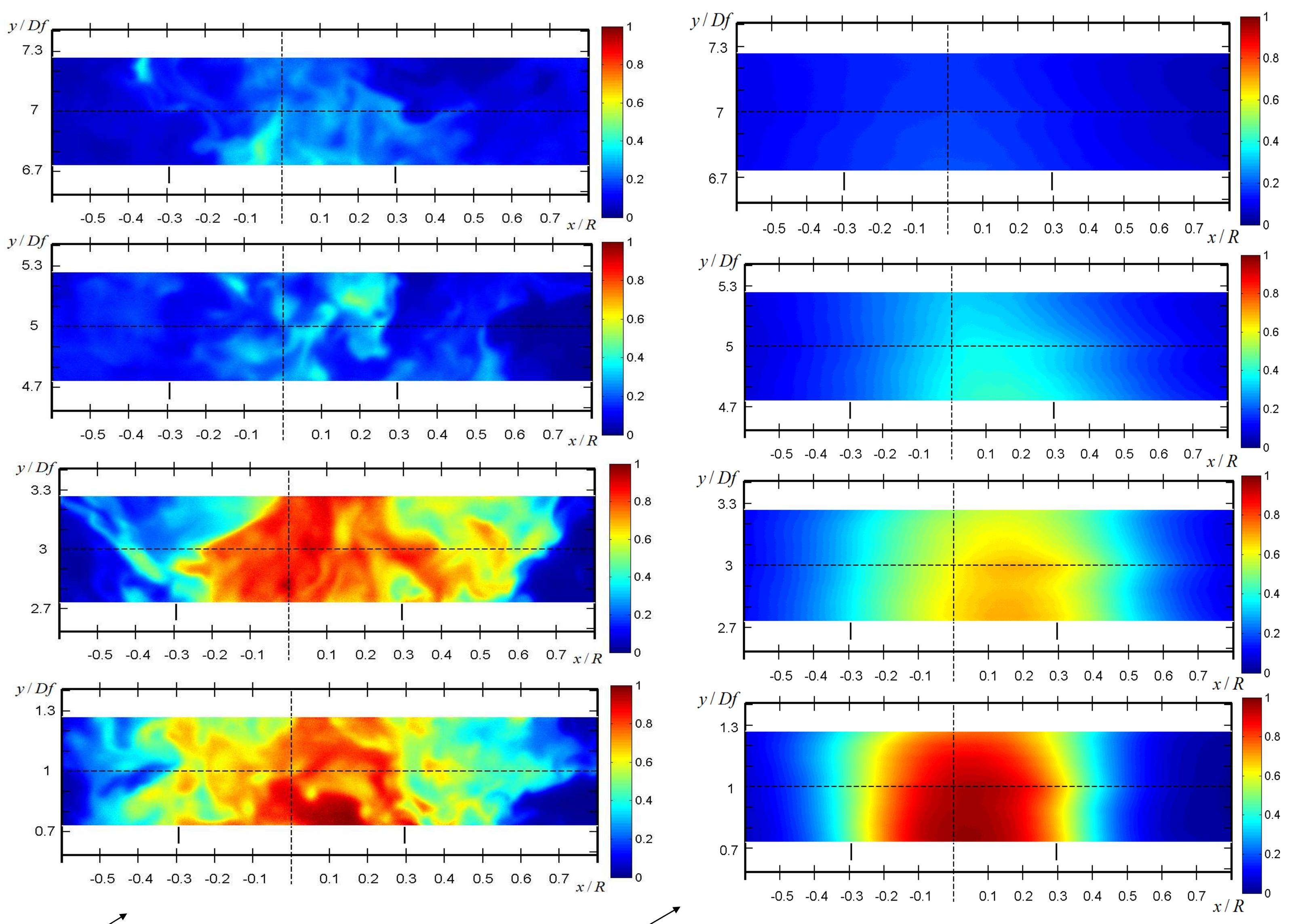
- measurements of scalar dissipation in turbulent non-premixed, non-reacting swirling jets in order to provide unconditional and conditional statistics for combustion modeling

3. EXPERIMENTAL SETUP

A central fuel nozzle is surrounded by a concentric swirling air flow. The "fuel" used was air seeded with acetone and planar laser-induced fluorescence (PLIF) of acetone is used to obtain the concentration field in the swirling, isothermal flow, with swirl numbers S= 0.3, 0.58 and 1.07. The spatial resolution is 0.0263 mm/pixel and the Kolmogorov scale is circa 0.15 mm. The Reynolds number of swirling and jet fuel flow are 28662 and 3770 respectively.



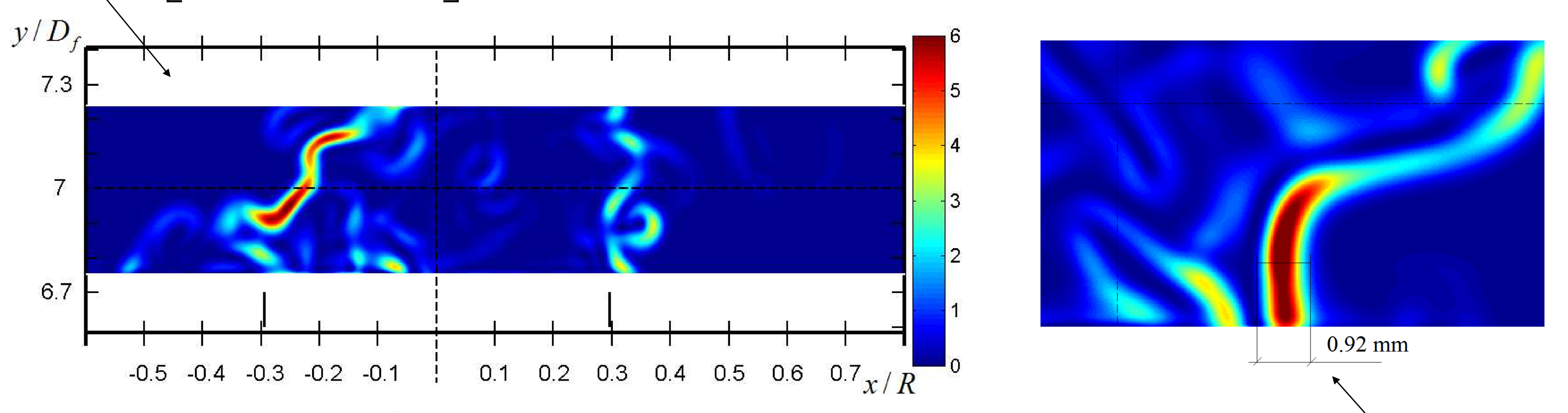
4. RESULTS



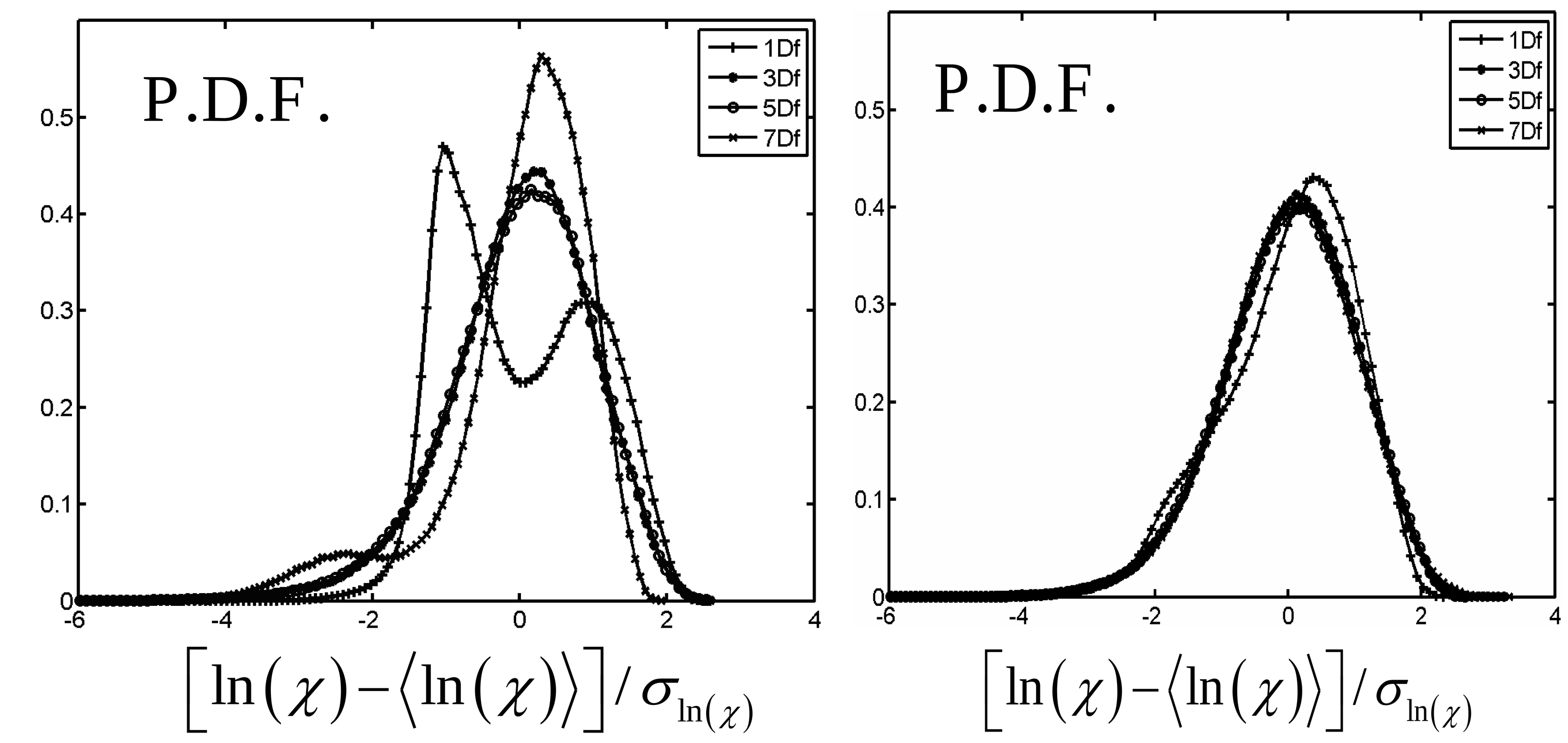
Instantaneous and Mean mixture fraction fields for S=0.58

$$\chi = 2D\left[\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2\right] \longleftarrow$$

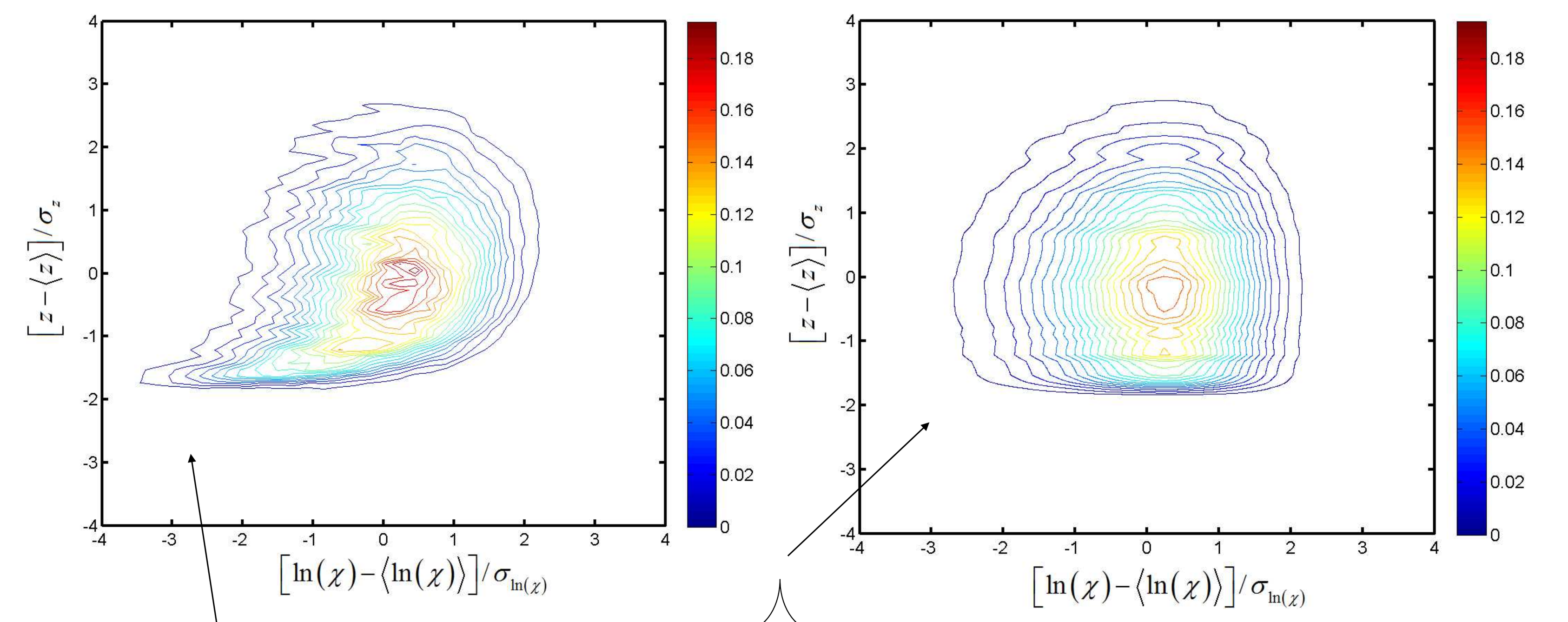
Measured scalar dissipation (squared gradient of mixture fraction field)



An instantaneous scalar dissipation rate and its layer



P.D.F. of scalar dissipation fluctuation



$$pdf(z,\chi) = pdf(z)\, pdf(\chi) \rightarrow \text{Usually assumed}$$

Joint P.D.F. of the scalar and its dissipation

5. CONCLUSIONS

- The maximum of instantaneous scalar dissipation rate was found to be up to 35 s^{-1} while mean values were circa 3 s^{-1}.
- The dissipation layer was defined as 1% of maximum scalar dissipation value across the layer and was computed to be approximately 0.92mm tick.
- The P.D.F of the scalar dissipation was found to be slightly negatively skewed at low swirl number (0.3) and almost symmetrical when swirl number increased to 0.58-1.07.
- Statistical independence between scalar and its dissipation was validated and did hold for high swirl numbers.
- P.D.F. of the scalar dissipation was log-normal.