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# Turbulent flux of conserved scalar in transverse jet in cross-flow


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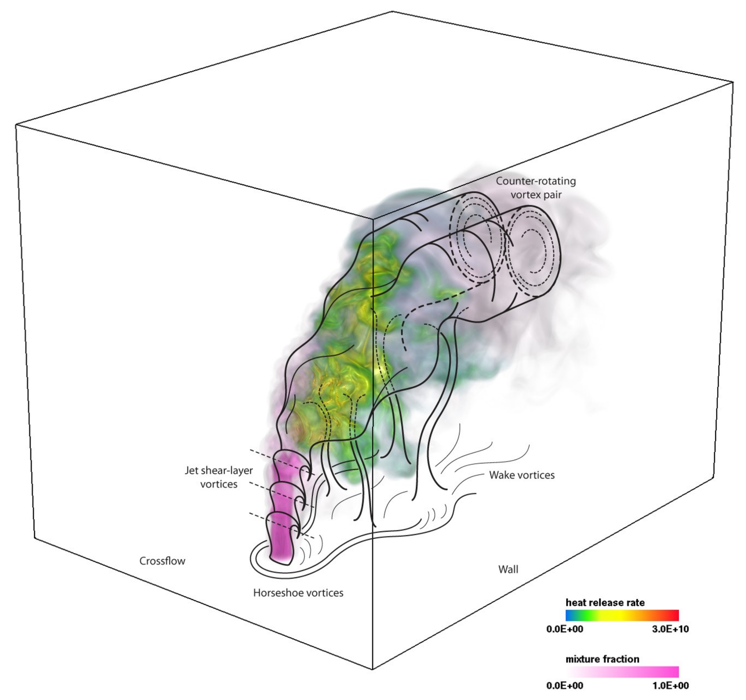
## Transverse JICF



## Relevance:

- Prevalent in many systems (flares, boilers, scramjets, GT combustors etc.).
- Rapid fuel-air mixing in small volume.
- Our focus: optimal fuel injection in lean pre-mixed stationary gas-turbine combustors.

## Challenges:

- Complex 3D turbulent flow field
- Inhomogeneous, anisotropic.
- Near field flame stabilization in premixed/partially-premixed mode [1].
- Turbulent fuel-air mixing critical for near field flame characteristics.
- Evidence of counter-gradient diffusion of scalar flux [2].

**Objective:** *Study turbulent flux of mixture fraction in RANS context.*

## Methodology:

- Fully compressible 3D DNS of inert and reacting JICF [3].
- DNS performed with in-house code S3D.
- Detailed chemical kinetics and transport properties.

## Configuration:

- Round $H_2/N_2$ (7:3) jet (1mm dia) in turbulent BL cross-flow of air.
- $T_J$=420K, $T_{CF}$=750K, $u_J$=250m/s, $u_{CF}$=55m/s, $R_m$=3.4.
- BCs: inflow-outflow (X), wall-outflow (Y), periodic (Z)

## Analysis: Favre mean scalar flux

$$\frac{\partial \bar{\rho}\widetilde{u_i''\xi''}}{\partial t} + \frac{\partial \bar{\rho}\tilde{u}_j\widetilde{u_i''\xi''}}{\partial x_j} = \underbrace{-\frac{\partial \overline{\rho u_j'' u_i'' \xi''}}{\partial x_j}}_{\text{I}} \underbrace{-\overline{\rho u_j'' u_i''}\frac{\partial \tilde{\xi}}{\partial x_j}}_{\text{II}}$$
$$\underbrace{-\overline{\rho u_j'' \xi''}\frac{\partial \tilde{u}_i}{\partial x_j}}_{\text{III}} \underbrace{-\overline{\xi''}\frac{\partial \bar{p}}{\partial x_i}}_{\text{IV}} \underbrace{-\overline{\xi''\frac{\partial p'}{\partial x_i}}}_{\text{V}} \underbrace{-\overline{u_i''\frac{\partial J_k}{\partial x_k}}}_{\text{VI}}$$
$$\underbrace{+\overline{\xi''\frac{\partial \tau_{ik}}{\partial x_k}}}_{\text{VII}} \underbrace{-\overline{u_i''\frac{\partial J_{diff,k}}{\partial x_k}}}_{\text{VIII}}, \quad i,j,k = 1,2,3$$

## Results

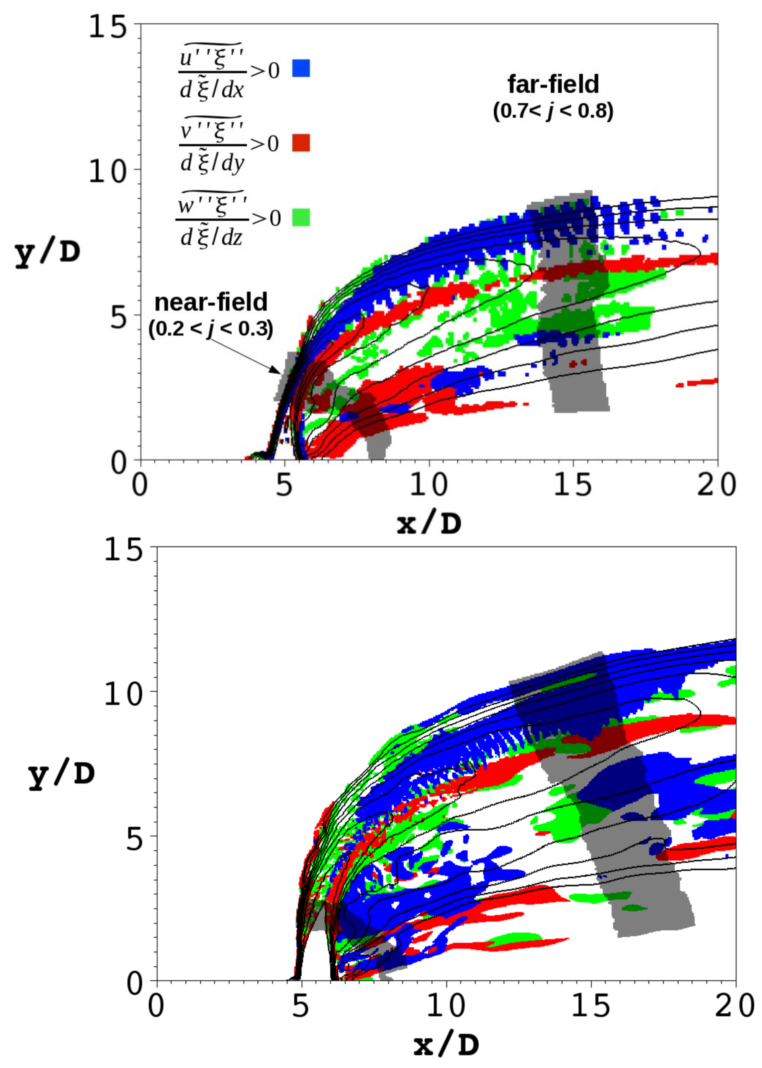



Fig.1. Regions of CGD on spanwise midplane shown for the inert (top) and reacting (bottom) JICF

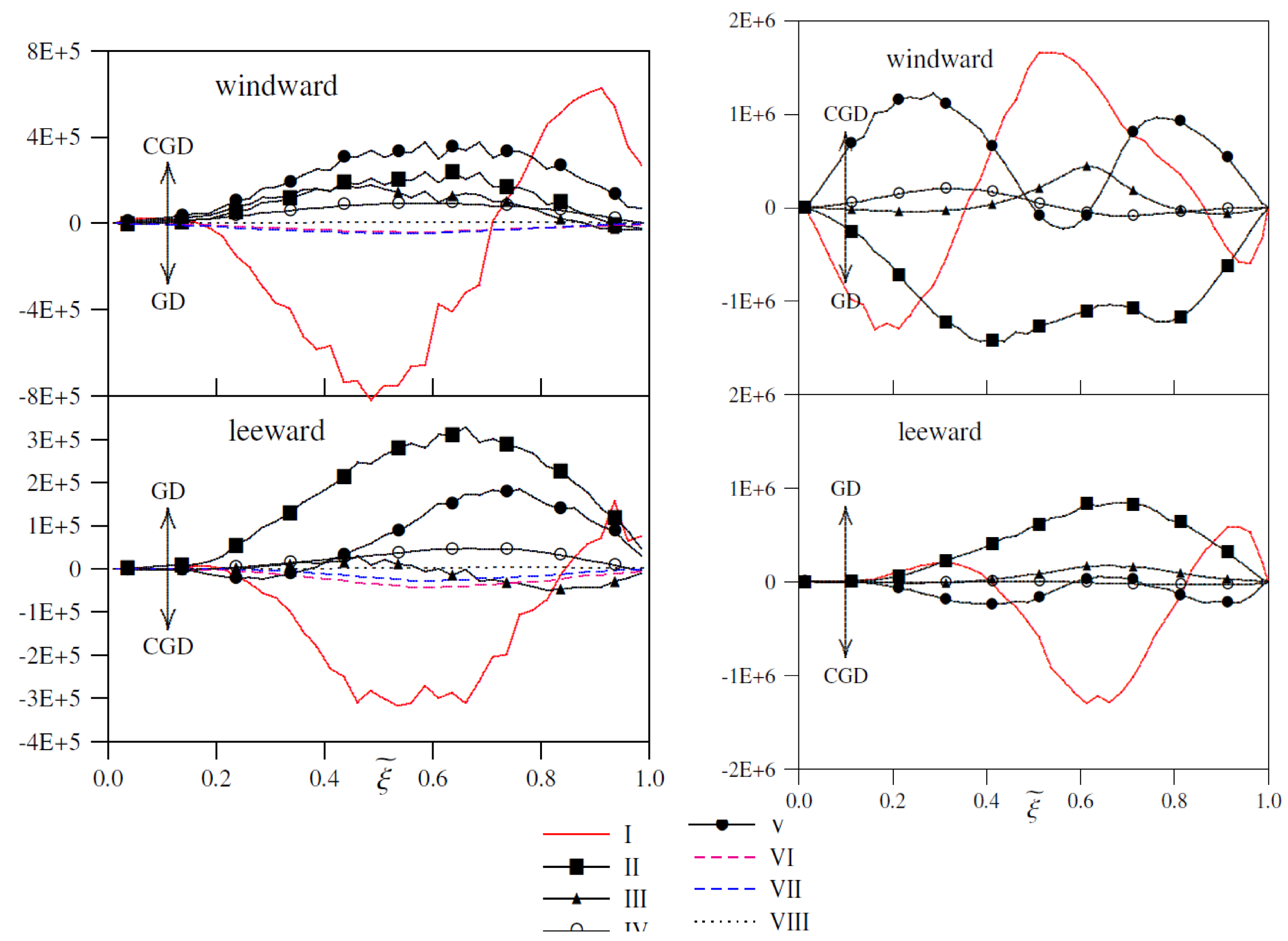



Fig.2. Balance of various terms in the budget of stream wise turbulent flux of mixture fraction for the inert (left) and reacting (right) cases.

## Key Conclusions

- Significant CGD in both inert and reactive cases.
- Behaviour different for windward leeward sides.
- Driven mainly by pressure (V) and anisotropy (I, II) terms.
- Pressure contribution attributed to preferential acceleration by mean pressure gradient (similar to premixed flames).

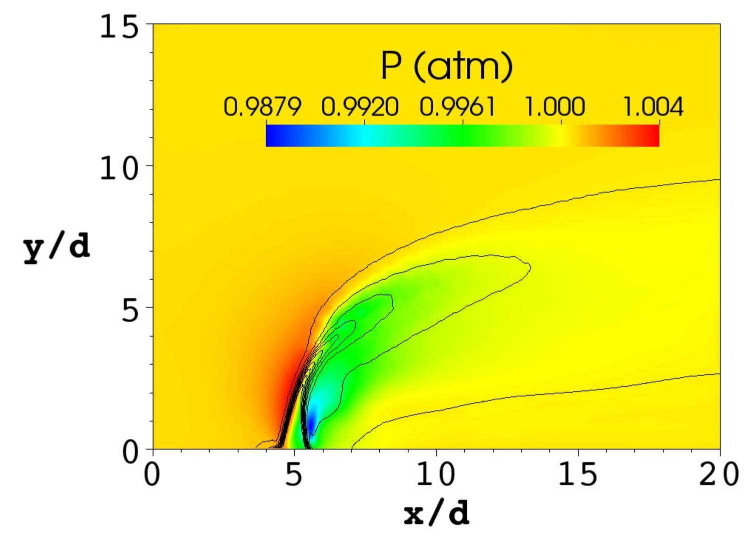



Fig.3. Contours of mean pressure from the inert case are shown for the spanwise midplane along with iso-lines of Favre mean mixture fraction.


## References

[1] R.W. Grout *etal.*, ***Proc. Comb. Inst.***, 33, 2010.

[2] S. Muppidi, K. Mahesh, ***J. Flu. Mech.***, 598, 2008

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