

Preferential diffusion behavior of turbulent premixed hydrogen combustion

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Preferential diffusion behavior of turbulent premixed hydrogen combustion

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Hydrogen as alternative fuel

- Simplest fuel to produce from renewable electricity.
- Carbon-free.
- High burning velocity → Stabilization problems.
- High diffusivity ($Le \approx 0.3$).
- Strong preferential diffusion effects.

Lean ($\phi = 0.7$) premixed hydrogen-air mixtures are studied in order to understand its combustion properties.

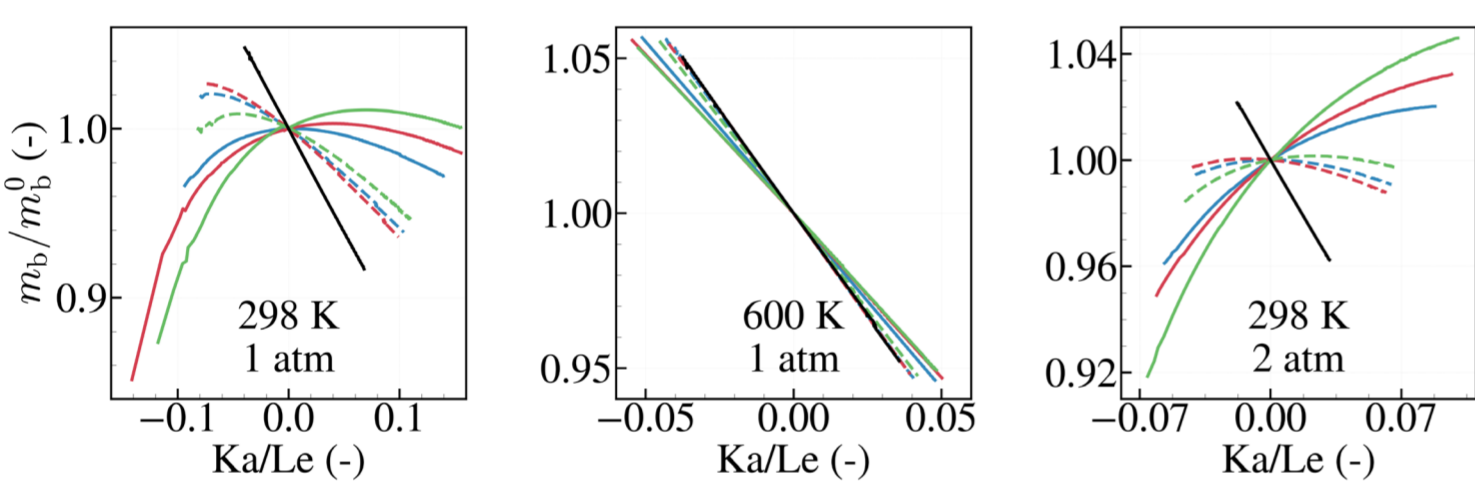
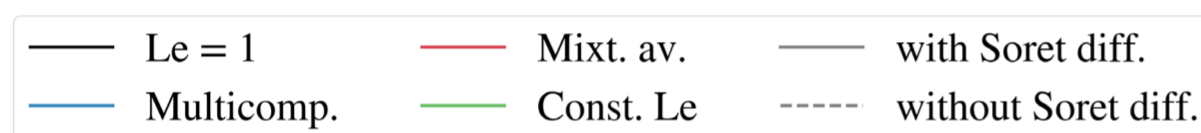
1-D stretched flamelets

Mass burning rate m_b of stretched flames [1]

$$\frac{m_b}{m_b^0} = 1 - \frac{Ka_i}{Le_i} + \Delta h_b \frac{\partial}{\partial h_b^0} (\ln m_b^0) + \sum_{j=1}^{N_e} Z_{j,b} \frac{\partial}{\partial Z_{j,b}^0} (\ln m_b^0)$$

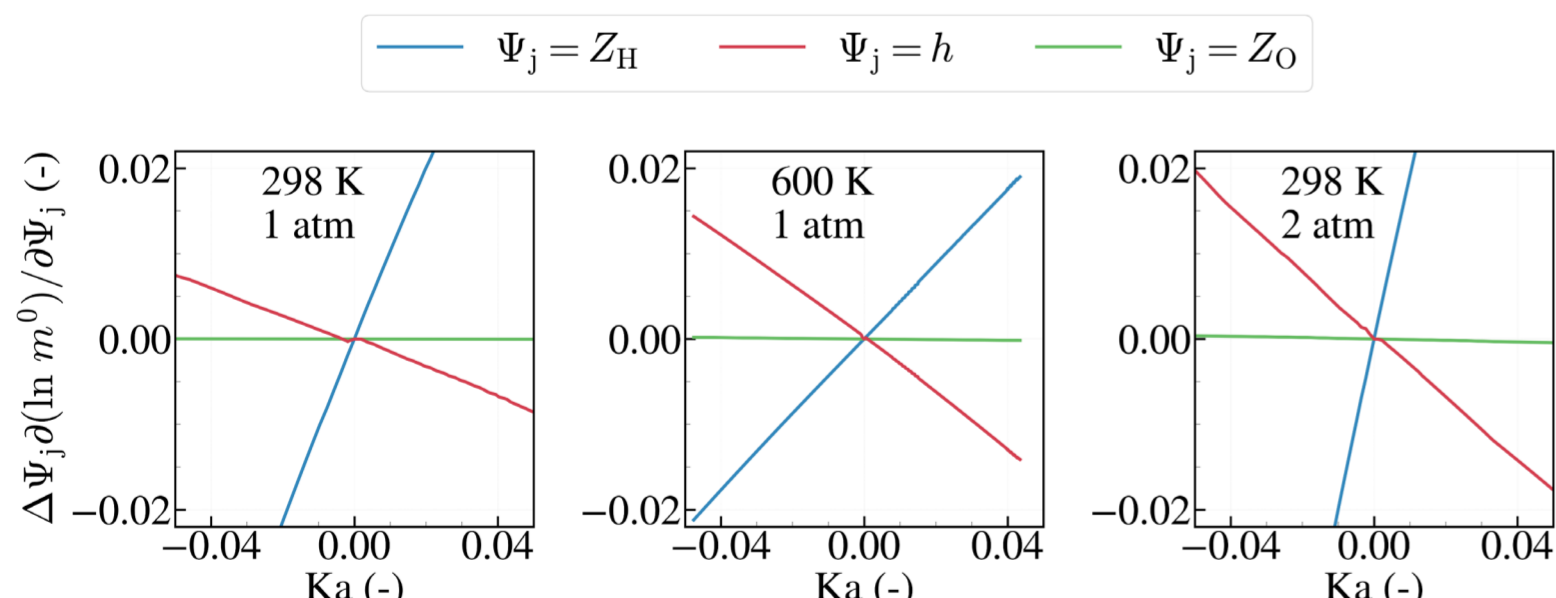
Direct stretch effect Non-unity Lewis numbers effect

Scaled mass burning rate of 1-D freely propagating flames vs. Karlovitz number Ka (dimensionless stretch rate), for different transport models:



- $Le = 1 \Rightarrow$ Direct stretch effect $\Rightarrow m_b$ decreases linearly with Ka
- $Le \neq 1 \Rightarrow$ Preferential diffusion effects $\Rightarrow m_b$ increases with respect to the unity Le case
- Constant Le model + Soret diffusion \Rightarrow Good approximation for lean H_2 flames

Contribution of changes hydrogen content Z_H , oxygen content Z_O and enthalpy h to the mass burning rate:



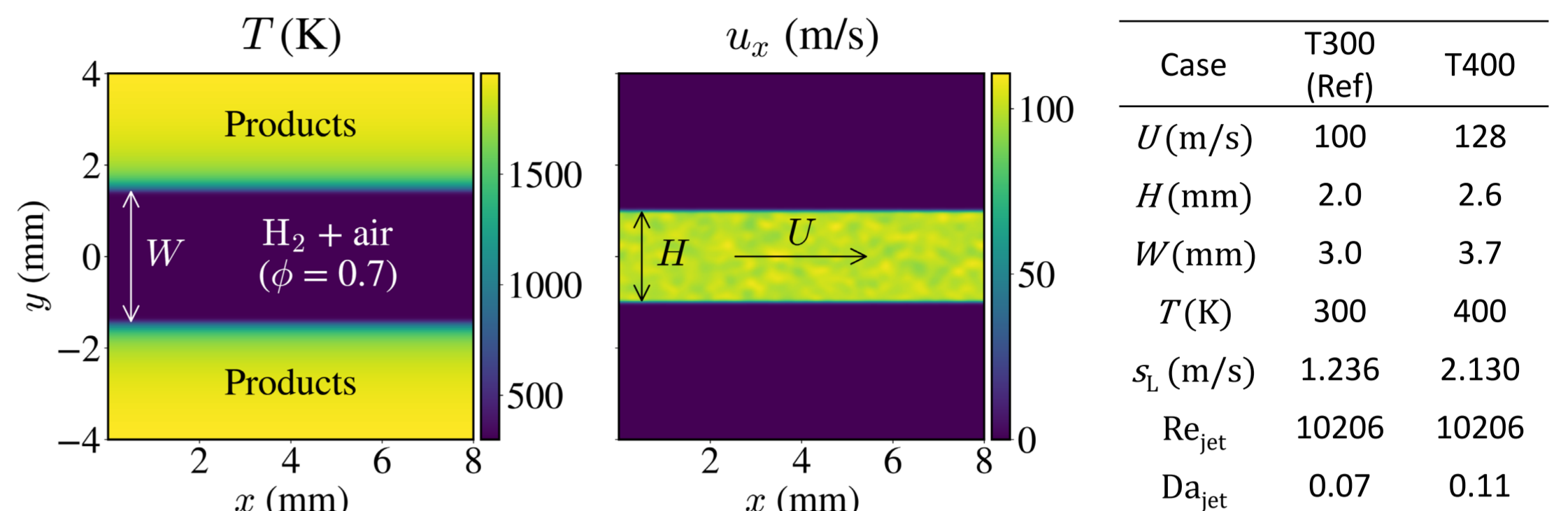
- 298 K 1 atm \Rightarrow Important contribution from ΔZ_H and lower influence of $\Delta h \Rightarrow$ High preferential diffusion
- 600 K 1 atm \Rightarrow Contribution of Δh increases, compensating that of $\Delta Z_H \Rightarrow$ Lowered preferential diffusion
- 298 K 2 atm \Rightarrow Contribution of ΔZ_H becomes more important than that of $\Delta h \Rightarrow$ Enhanced preferential diffusion

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Power and Flow
Department of Mechanical Engineering

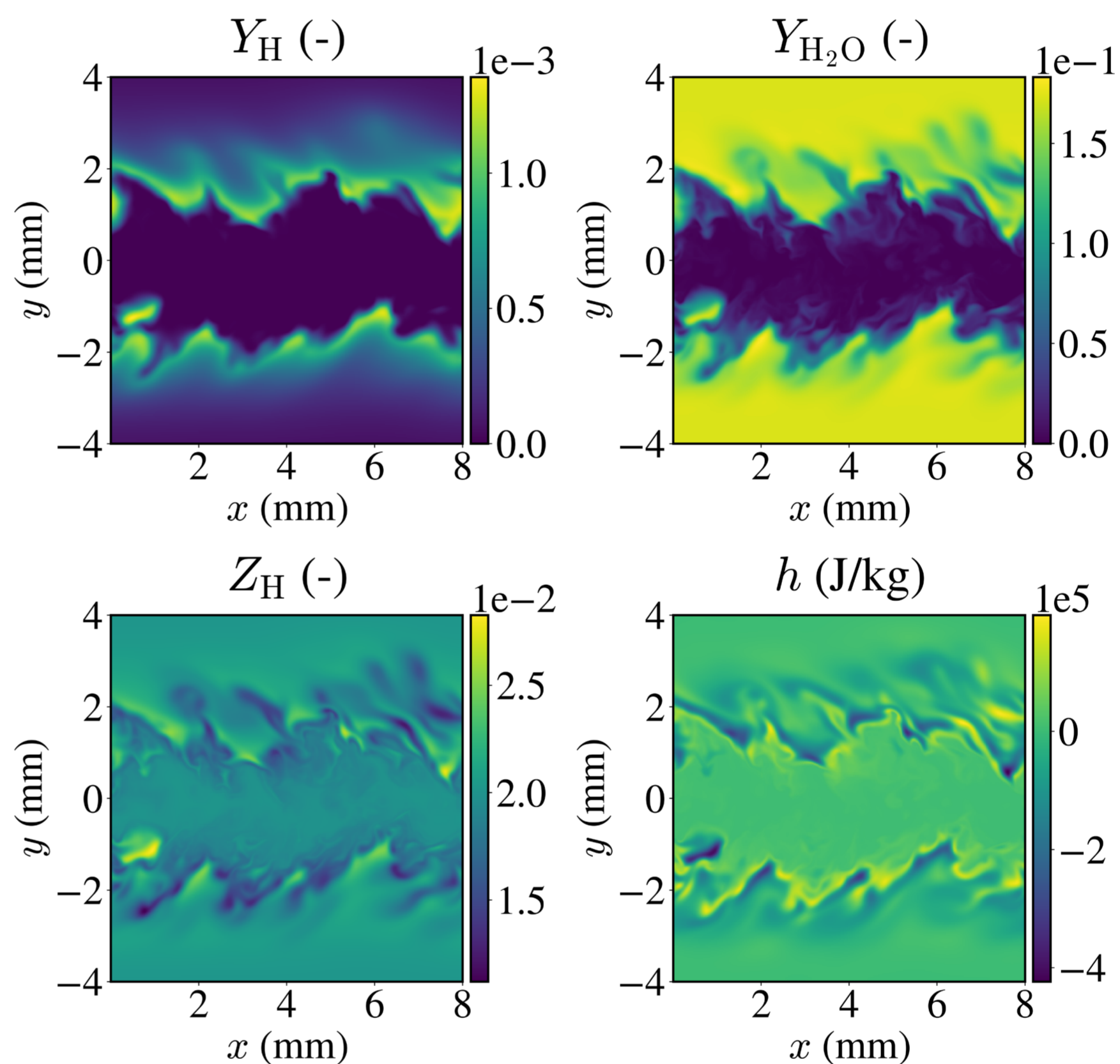
DNS of turbulent planar mixing layers



$\Delta x = 25 \mu m$

$\Delta t = 10 ns$

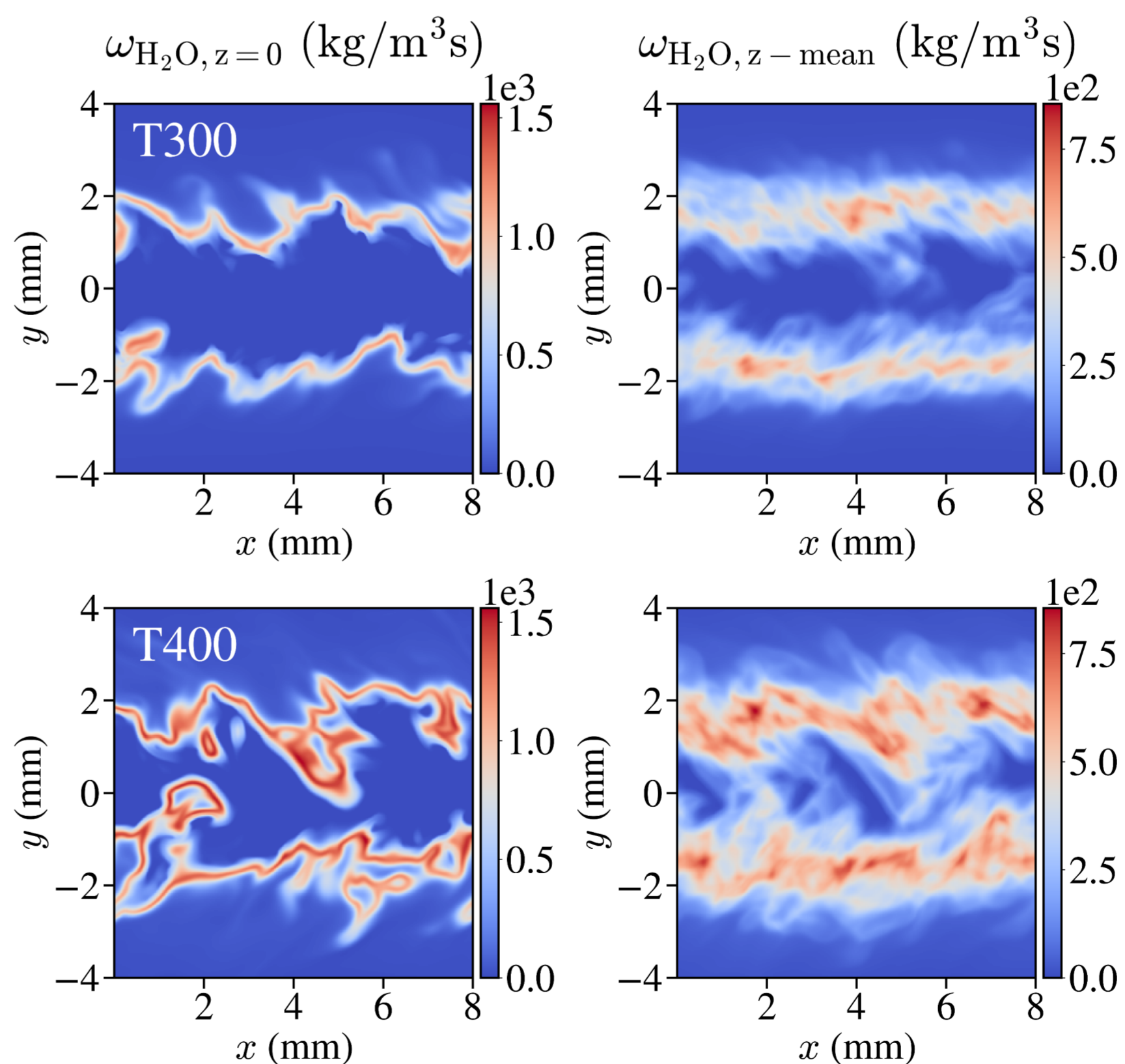
Reference case



Regions with fuel enrichment by diffusion and accumulation of products.

Variation of Z_H and h along the flame front due to stretch. This leads to higher burning rates.

Effect of increasing temperature



- Enhanced burning rates
- Larger scale structures
- More equal distribution of source terms along the flame front

References

[1] van Oijen et al. (2016). Prog. Energy Combust. Sci. 57, 30.

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