(a) $\mathcal{M}_1 = 10$

Turbulent kinetic energy, K

Thermochemically frozen gas

Thermal equilibrium $\diamond$

1D-DNS using HTR solver [1]

sea level

5 km

10 km

20 km

30 km

Pressure, atm

10^{-4} 10^{-3} 10^{-2} 10^{-1}

Relaxation length, m

Temperature, K

4000

3000

2000

1000

0

10 km

0 2 4 6 8

Relaxation length, mm

Pre-shock Mach number, $\mathcal{M}_1$

(b) Pressure, atm

0 0.25 0.5 0.75 1

Altitude, km

300 275 250 225 200

Temperature, K

[1] Di Renzo, M., Fu, L., and Urzay, J., "HTR solver: An open-source exascale-oriented task-based multi-GPU high-order code for hypersonic aerothermodynamics," Comput. Phys. Commun., Vol. 255, 2020, p. 107262.