Simulation of Aircraft Cargo Hold Fires Using a High-Order Accurate Discontinuous Galerkin Method

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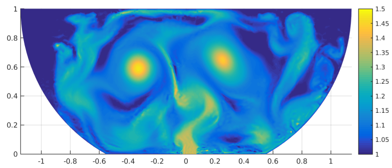
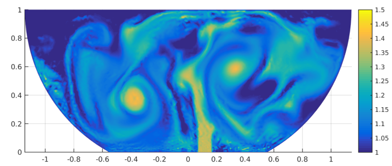
Accurate prediction of heat and particulate transfer in fire-induced flow is necessary for predicting the performance of aircraft cargo hold fire detection systems. Past investigations of cargo hold fires include full-scale experiments and simulations using traditional 2nd order accurate finite volume CFD methods. These traditional methods have several inadequacies when simulating the turbulent, vorticity-dominated fluid dynamics seen in the buoyancy-driven flows of aircraft cargo hold fires.

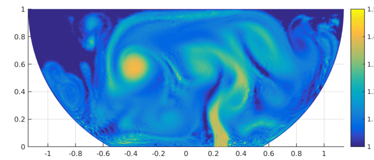
As a result, we are developing a new flow solver using the discontinuous Galerkin (DG) method for spatial discretization using unstructured grids, which allows for arbitrarily high order accuracy and geometric flexibility. In this talk, we present the current state of development of this new tool. Buoyancy driven flow simulations will be demonstrated in cargo hold geometries with varying order of accuracy. Validation case studies will be presented with a quantitative comparison between our code and publicly available experimental and numerical results for a B707 cargo hold fire. We will also summarize our work utilizing these simulation methods within an uncertainty quantification (UQ) framework to predict flow features of interest, such as near-ceiling temperature fields, in response to uncertainty in the location and strength of a given fire source. Figures 1, 2, and 3 show sample calculations from our past work using a 3^{rd} order accurate DG scheme for a 2D cross-section of the B707 cargo hold geometry, where the heat sources are modeled as simple fixed-temperature isothermal walls.



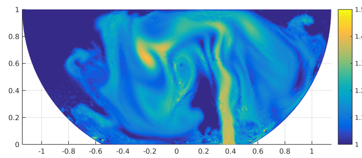
(a) $x_s = 0.024m$.



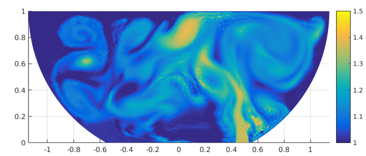
(b) $x_s = 0.116m$.



(c) $x_s = 0.262m$.

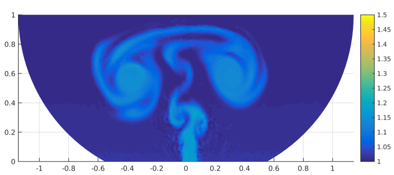


(d) $x_s = 0.387m$.

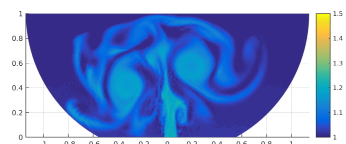


(e) $x_s = 0.480m$.

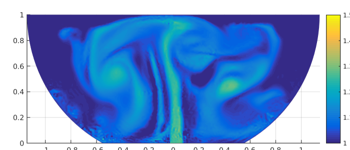
Figure 1: Temperature fields for $T_{source} = 1.486T_{wall}$ source at the 5 source locations, time $t = 10s$ after startup.



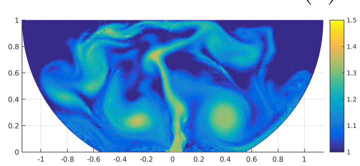
(a) $T_s = 1.214$.



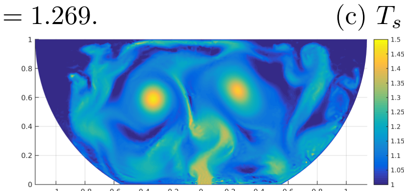
(b) $T_s = 1.269$.



(c) $T_s = 1.350$.

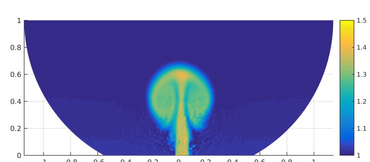


(d) $T_s = 1.431$.

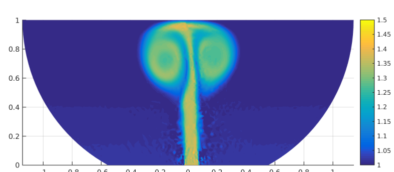


(e) $T_s = 1.486$.

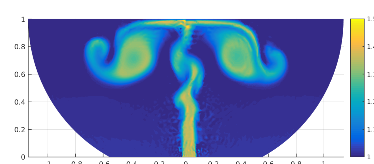
Figure 2: Temperature fields at $x_s = 0.024m$ for the 5 values of temperature source, time $t = 10s$ after startup.



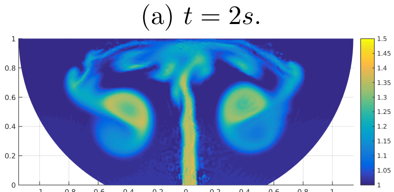
(a) $t = 2s$.



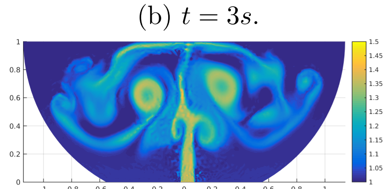
(b) $t = 3s$.



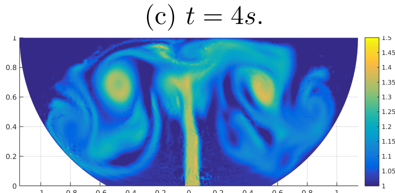
(c) $t = 4s$.



(d) $t = 5s$.



(e) $t = 6s$.



(f) $t = 7s$.

Figure 3: Temperature field time evolution for $T_{source} = 1.486T_{wall}$, $x_s = 0.024$ case.