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Title: Modeling Kelvin-Helmholtz and Rayleigh-Taylor driven Mixing Layers using the BHR model

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Modeling Kelvin-Helmholtz and Rayleigh-Taylor driven Mixing Layers using the BHR model

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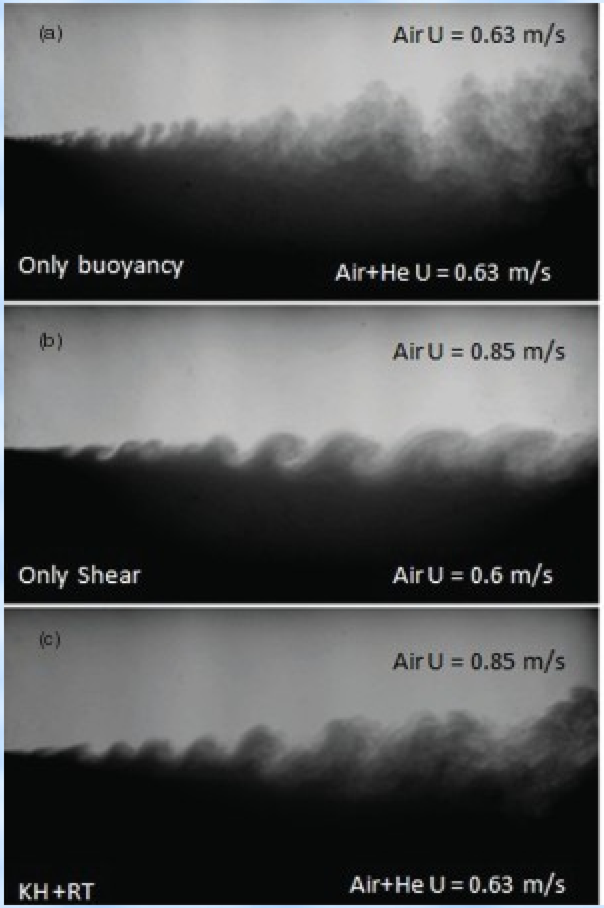
Hello! My name is Sasha Tan-Torres

- **From Philadelphia, PA**
- **B.S RPI : Mechanical and Nuclear Engineering**
- **M.S/PhD MIT: Nuclear Science and Engineering**
  - **CFD Group: working on modeling turbulent flow and Fluid Structure Interactions in a reactor core**

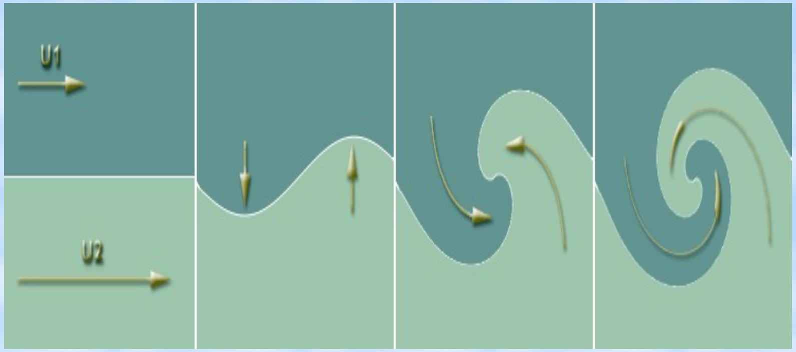
What are we doing?

- Studying coupled buoyancy and shear driven mixing layers (Rayleigh-Taylor and Kelvin-Helmholtz Instabilities)
- Calibrating and validating the BHR-3 model by comparison to experimental data from Texas A&M
- Why we care?
  - atmosphere/oceans, mixing in combustion chambers/chemical reactors, ICF and more



Background

- Buoyancy mixing
  - Rayleigh-Taylor Instability
  - Heavy fluid overlays a light fluid, unstable thermal interface
  - Leads to self-similar state
- Shear mixing
  - Kelvin-Helmholtz instability
  - Parallel streams of unequal velocity cause the two fluids to mix
  - Leads to self-similar state
- Combined Shear and Buoyancy
  - Does not have a self-similar state



BHR-3 Model

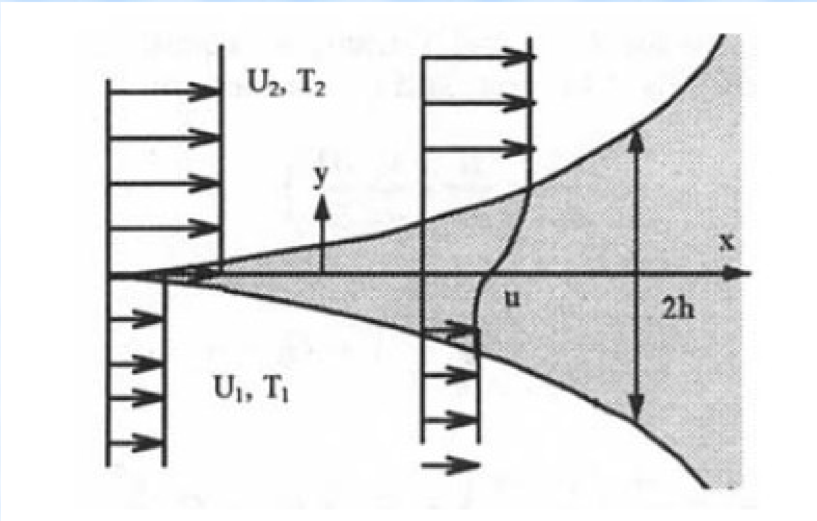
$$\frac{\partial\left(\bar{\rho}\tilde{R}_{ij}\right)}{\partial t}+\frac{\partial}{\partial x_k}\left(\bar{\rho}\check{u}_k\tilde{R}_{ij}\right)=(1-C_{r1})\left[a_i\frac{\partial\bar{P}}{\partial x_j}+a_j\frac{\partial\bar{P}}{\partial x_i}\right]+\bar{\rho}(C_{r2}-1)\left[\tilde{R}_{ik}\frac{\partial\tilde{u}_j}{\partial x_k}+\tilde{R}_{jk}\frac{\partial\tilde{u}_i}{\partial x_k}\right]$$
$$+C_{r3}\frac{\partial}{\partial x_k}\left(\frac{S}{\sqrt{K}}\bar{\rho}\tilde{R}_{km}\frac{\partial\tilde{R}_{ij}}{\partial x_m}\right)-C_{r4}\bar{\rho}\frac{\sqrt{K}}{S}\left(\tilde{R}_{ij}-\frac{1}{3}\tilde{R}_{kk}\delta_{ij}\right)-C_{r2}\frac{2}{3}\bar{\rho}\tilde{R}_{mk}\frac{\partial\tilde{u}_m}{\partial x_k}\delta_{ij}+C_{r1}\frac{2}{3}a_k\frac{\partial\bar{P}}{\partial x_k}\delta_{ij}-\bar{\rho}\frac{2}{3}\frac{K\sqrt{K}}{S}\delta_{ij}, \quad (1)$$

$$\frac{\partial\left(\bar{\rho}a_i\right)}{\partial t}+\frac{\partial}{\partial x_k}\left(\bar{\rho}\tilde{u}_k a_i\right)=b\frac{\partial\bar{\rho}}{\partial x_i}-\tilde{R_{ik}}\frac{\partial\bar{\rho}}{\partial x_k}-\bar{\rho}a_k\frac{\partial\left(\tilde{u}_i-a_i\right)}{\partial x_k}+\bar{\rho}\frac{\partial}{\partial x_k}(a_k a_i)+C_a\bar{\rho}\frac{\partial}{\partial x_m}\left(\frac{S}{\sqrt{K}}R_{mn}\frac{\partial a_i}{\partial x_n}\right)-C_{a1}\bar{\rho}\frac{\sqrt{K}}{S}a_i, \quad (2)$$

$$\frac{\partial(\bar{\rho}b)}{\partial t}+\frac{\partial(\bar{\rho}b\tilde{u}_k a_i)}{\partial x_k}=2\bar{\rho}a_k\frac{\partial b}{\partial x_k}-2(b+1)a_k\frac{\partial\bar{\rho}}{\partial x_k}+C_b\bar{\rho}^2\frac{\partial}{\partial x_m}\left(\frac{S}{\bar{\rho}\sqrt{K}}R_{mn}\frac{\partial b}{\partial x_n}\right)-C_{b2}\bar{\rho}\frac{\sqrt{K}}{S}b, \quad (3)$$

$$\frac{\partial\bar{\rho}S}{\partial t}+\frac{\partial}{\partial x_j}(\bar{\rho}\tilde{u}_j S)=\frac{S}{K}\left(\frac{3}{2}-C_4\right)a_j\frac{\partial\bar{P}}{\partial x_j}-\frac{S}{K}\left(\frac{3}{2}-C_1\right)\bar{\rho}\tilde{R}_{ij}\frac{\partial\tilde{u}_{ij}}{\partial x_j}-\left(\frac{3}{2}-C_2\right)\bar{\rho}\sqrt{K}-C_3\bar{\rho}S\frac{\partial\bar{u}_j}{\partial x_J}$$
$$+C_s\frac{\partial}{\partial x_m}\left(\frac{S}{\sqrt{K}}\bar{\rho}\tilde{R}_{mn}\frac{\partial S}{\partial x_n}\right) \quad (4)$$

Experiment



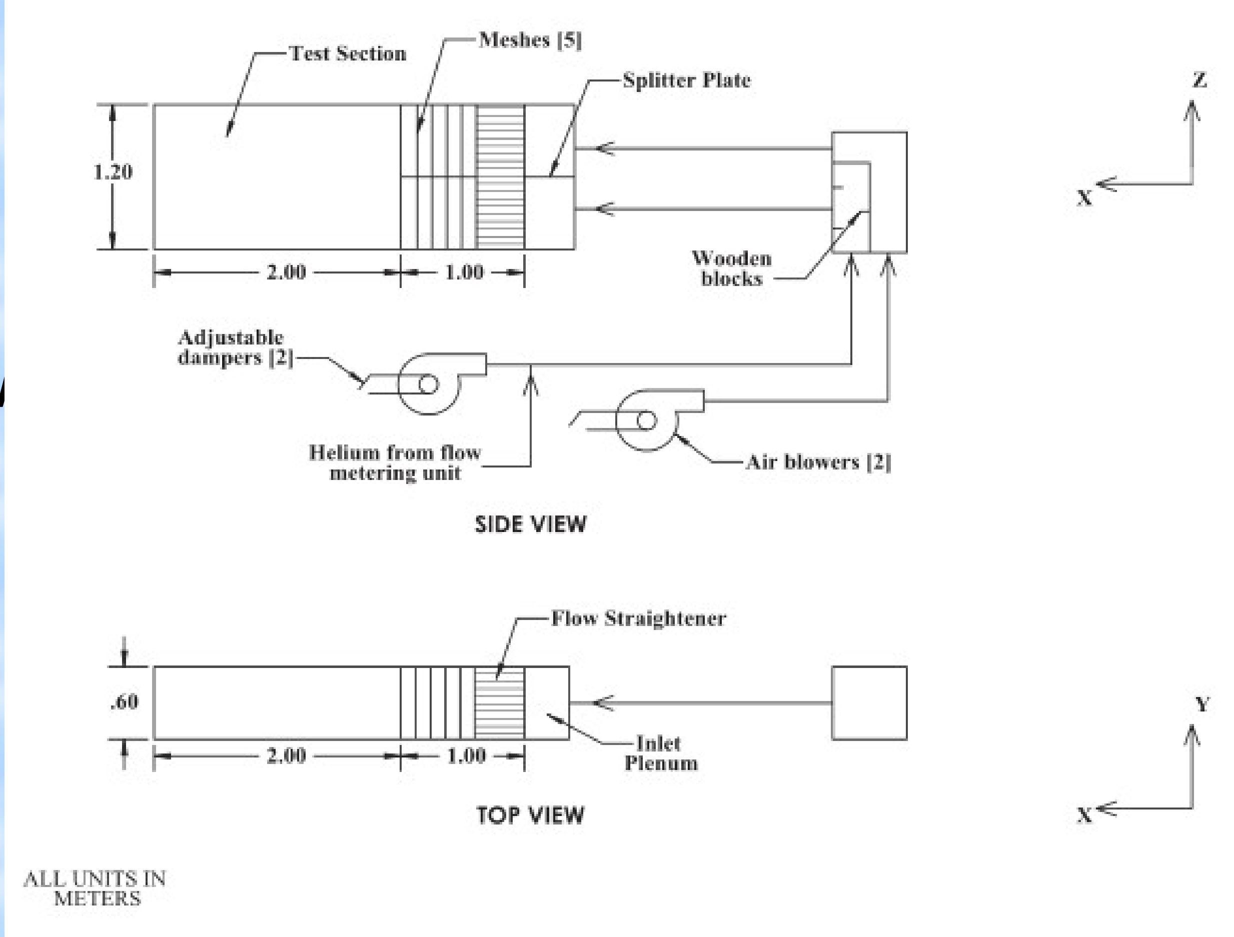
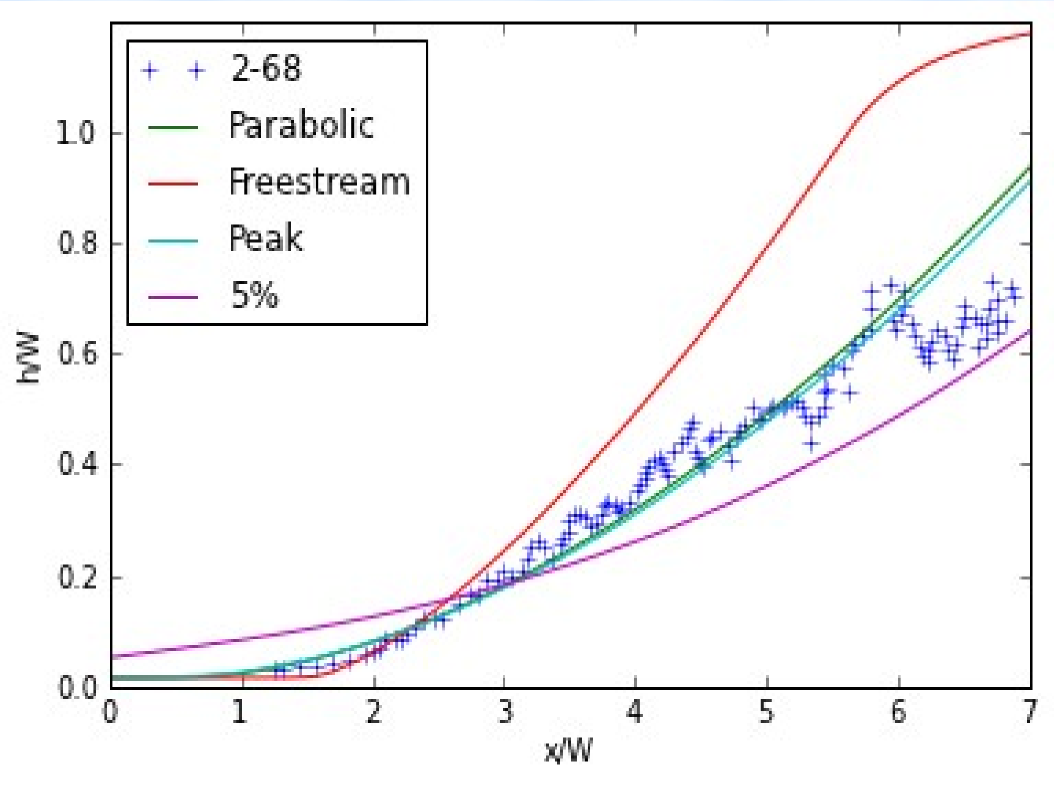


Table 2: Experimental Cases

Case	Bottom Stream Velocity, m/s (U_2)	Top Stream Velocity, m/s (U_1)	$U_{average}$, m/s	A_t	Maximum Ri number
RT	0.63	0.63	0.63	0.035	
KHRT1	0.63	0.86	0.75	0.035	-6.9
KHRT2	0.63	1.03	0.83	0.035	-1.8

Initial Conditions

- **Importance**
  - **Initial conditions may dominate behavior**
  - **When matching model to experiment, we must take initial conditions into account**
  - **Using the wrong Initial conditions can look like a model error**
  - **Flow for shear and buoyancy is not self-similar**

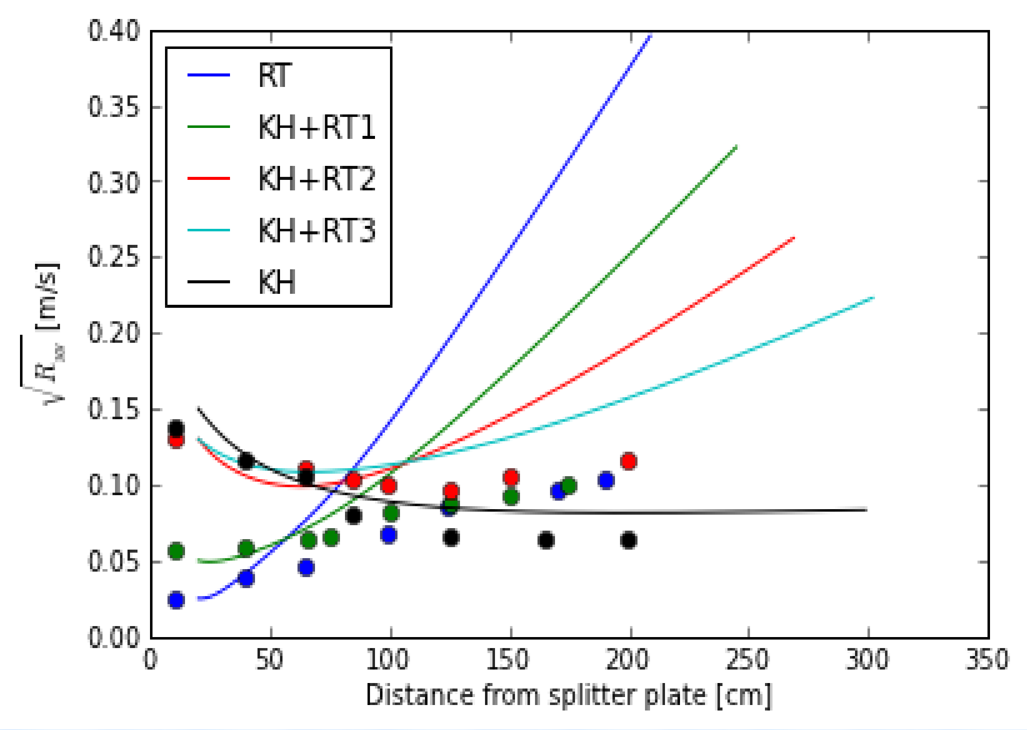


Initial Conditions

- What we did
  - Used a linear profile for velocity and density
  - Assumed parabolic profile for all turbulent quantities (data is approximately parabolic)
  - Set width based on experimental width data
  - Set amplitude based on experimental center line data
  - IC: Rxy, Ryy, k, ax, ay, b, epsilon
    - Scaled epsilon based on the width

Results and Analysis

- **Texas A&M data**
- **BHR-3 model**
- **Initial conditions set based on Ryy**
- **ax, ay, and b were set to 0**
- **Shows correct trend, but we hoped that by setting the other initial conditions from experimental values we could achieve a better agreement**



Results and Analysis

- Thus far, we have not achieved better agreement
- Possible Explanations
  - Epsilon scaling is wrong. There is no measured data for epsilon.
  - Error in post-processing experimental data
  - BHR-3 needs further calibration in the transient regime
  - Bug in the code

Conclusions and Future Work

- **Results are very sensitive to initial conditions**
- **Most calibration is done in a self-similar regime. Calibration for a transient problem is very difficult**
- **Resolve the lack of agreement**
- **Get complete TAMU initial condition profiles, instead of only center line data**
- **Error analysis**

Questions?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UNCLEAR
PERPLEXED
DISORIENTED
BEWILDERED