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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**

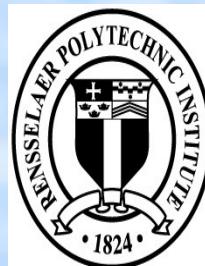
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**Computational Physics Program XCP-4  
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# Hello! My name is Sasha Tan-Torres

- From Philadelphia, PA
- B.S RPI : Mechanical and Nuclear Engineering



# Rensselaer

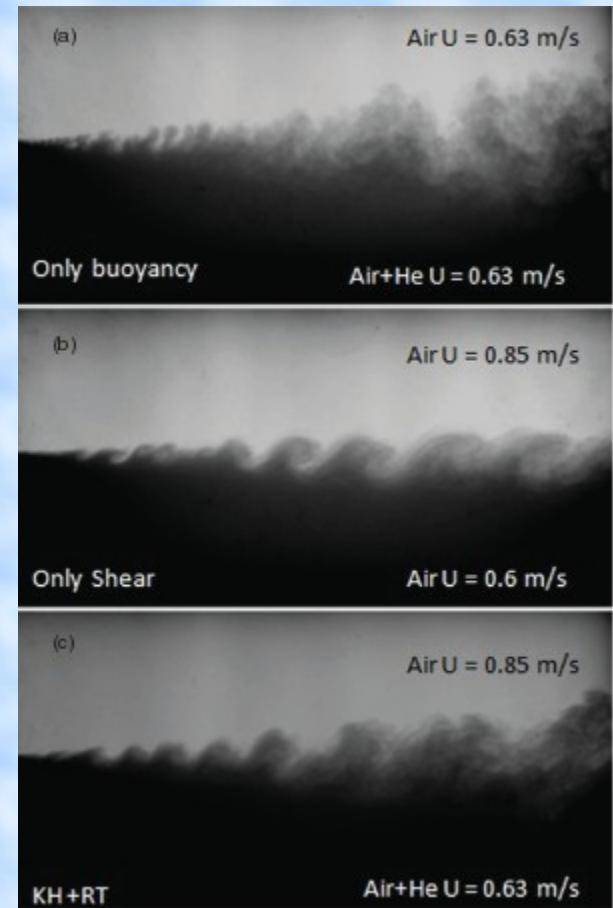
- M.S/PhD MIT: Nuclear Science and Engineering
  - CFD Group: working on modeling turbulent flow and Fluid Structure Interactions in a reactor core



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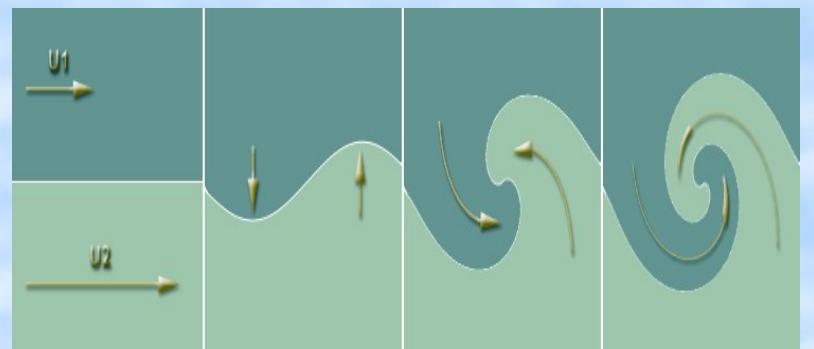
# What are we doing?

- 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

$$\frac{\partial(\bar{\rho}\tilde{R}_{ij})}{\partial t} + \frac{\partial}{\partial x_k}(\bar{\rho}\tilde{u}_k\tilde{R}_{ij}) = (1 - C_{r1}) \left[ a_i \frac{\partial \bar{P}}{\partial x_j} + a_j \frac{\partial \bar{P}}{\partial x_i} \right] + \bar{\rho}(C_{r2} - 1) \left[ \tilde{R}_{ik} \frac{\partial \tilde{u}_j}{\partial x_k} + \tilde{R}_{jk} \frac{\partial \tilde{u}_i}{\partial x_k} \right] \quad (1)$$

$$+ C_{r3} \frac{\partial}{\partial x_k} \left( \frac{S}{\sqrt{K}} \bar{\rho} \tilde{R}_{km} \frac{\partial \tilde{R}_{ij}}{\partial x_m} \right) - C_{r4} \bar{\rho} \frac{\sqrt{K}}{S} \left( \tilde{R}_{ij} - \frac{1}{3} \tilde{R}_{kk} \delta_{ij} \right) - C_{r2} \frac{2}{3} \bar{\rho} \tilde{R}_{mk} \frac{\partial \tilde{u}_m}{\partial x_k} \delta_{ij} + C_{r1} \frac{2}{3} a_k \frac{\partial \bar{P}}{\partial x_k} \delta_{ij} - \bar{\rho} \frac{2}{3} \frac{K \sqrt{K}}{S} \delta_{ij},$$

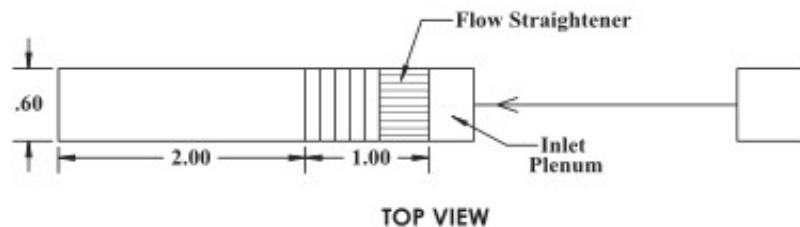
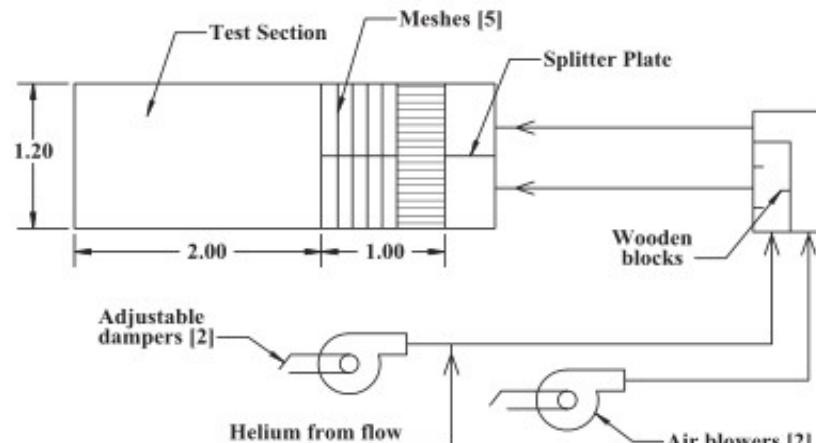
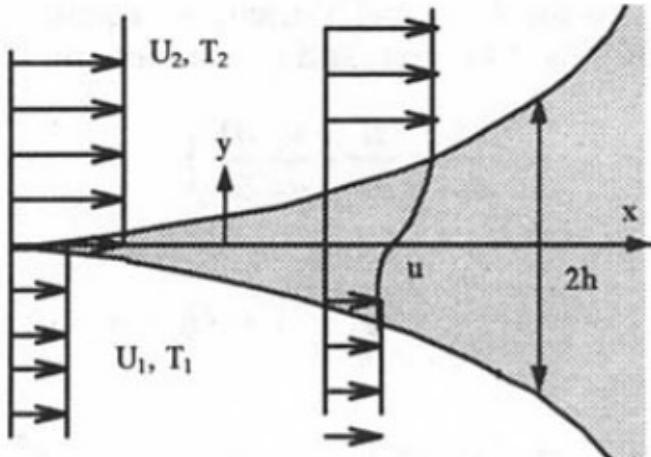
$$\frac{\partial(\bar{\rho}a_i)}{\partial t} + \frac{\partial}{\partial x_k}(\bar{\rho}\tilde{u}_k a_i) = b \frac{\partial \bar{\rho}}{\partial x_i} - \tilde{R}_{ik} \frac{\partial \bar{\rho}}{\partial x_k} - \bar{\rho} a_k \frac{\partial(\tilde{u}_i - a_i)}{\partial x_k} + \bar{\rho} \frac{\partial}{\partial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

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

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

$$+ C_s \frac{\partial}{\partial x_m} \left( \frac{S}{\sqrt{K}} \bar{\rho} \tilde{R}_{mn} \frac{\partial S}{\partial x_n} \right)$$

# Experiment



ALL UNITS IN  
METERS

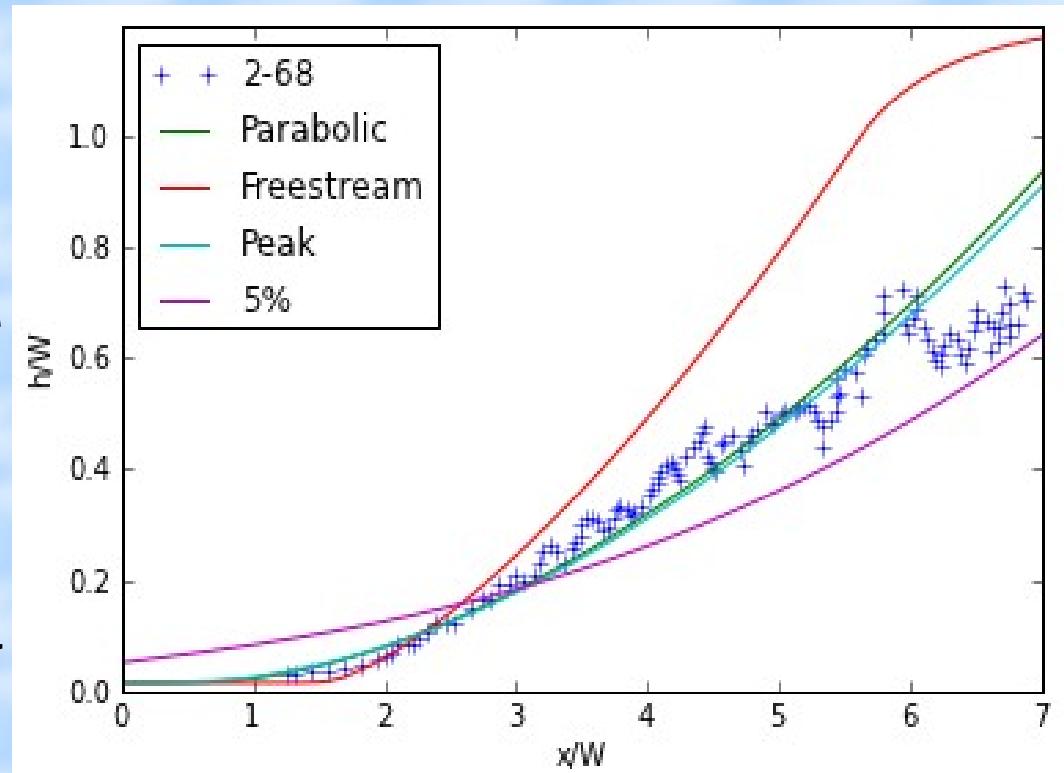
Table 2: Experimental Cases

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**

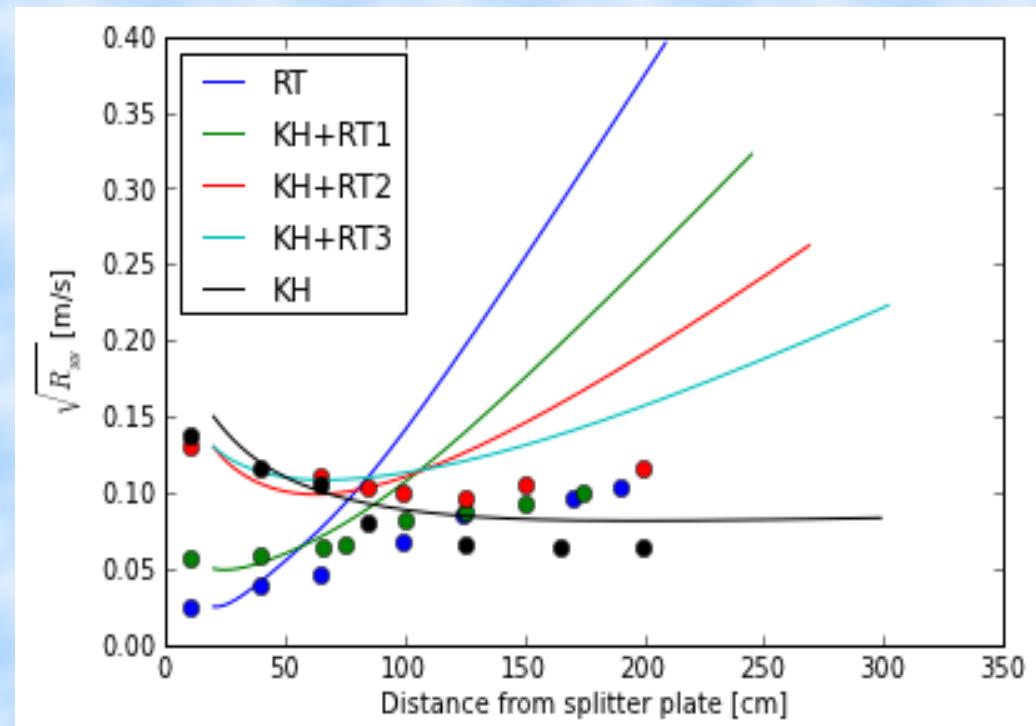


# Initial Conditions

- **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:  $R_{xy}$ ,  $R_{yy}$ ,  $k$ ,  $a_x$ ,  $a_y$ ,  $b$ ,  $\epsilon$ 
    - Scaled epsilon based on the width

# Results and Analysis

- Texas A&M data
- BHR-3 model
- Initial conditions set based on  $R_{yy}$
- $a_x$ ,  $a_y$ , 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?

