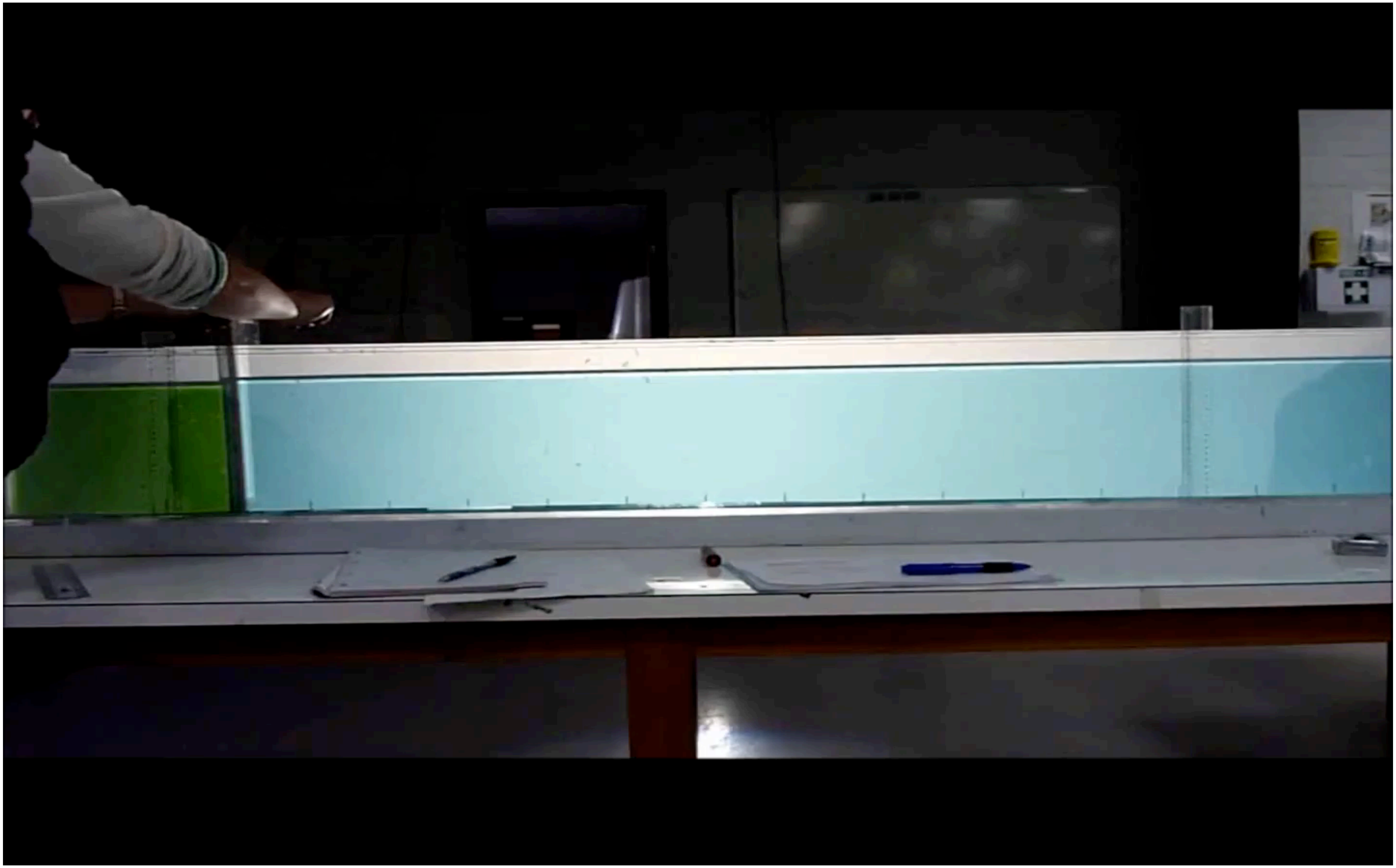
Gravity Currents: A Comparison of Analytical and Numerical Solutions

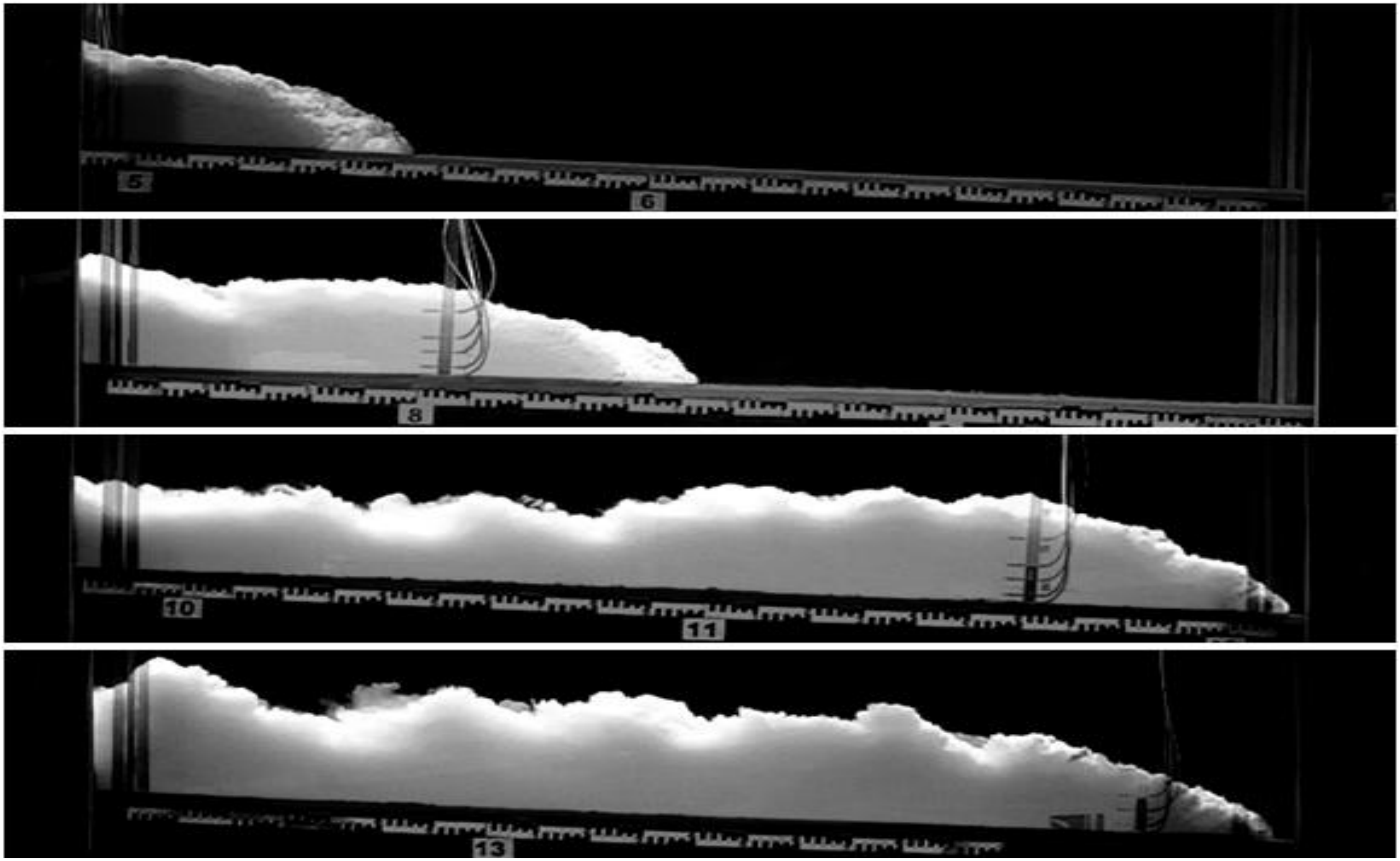
Condor Interns:
Jonah Lantaya
Lynn Nguyen
Glen Robinson
Magdiel Zuniga

Mentor: Amin Khodkar
P.I. : Eckart Meiburg
Dept. of Mechanical Engineering
Computational Fluid Dynamics Lab

Flow of Gravity Current

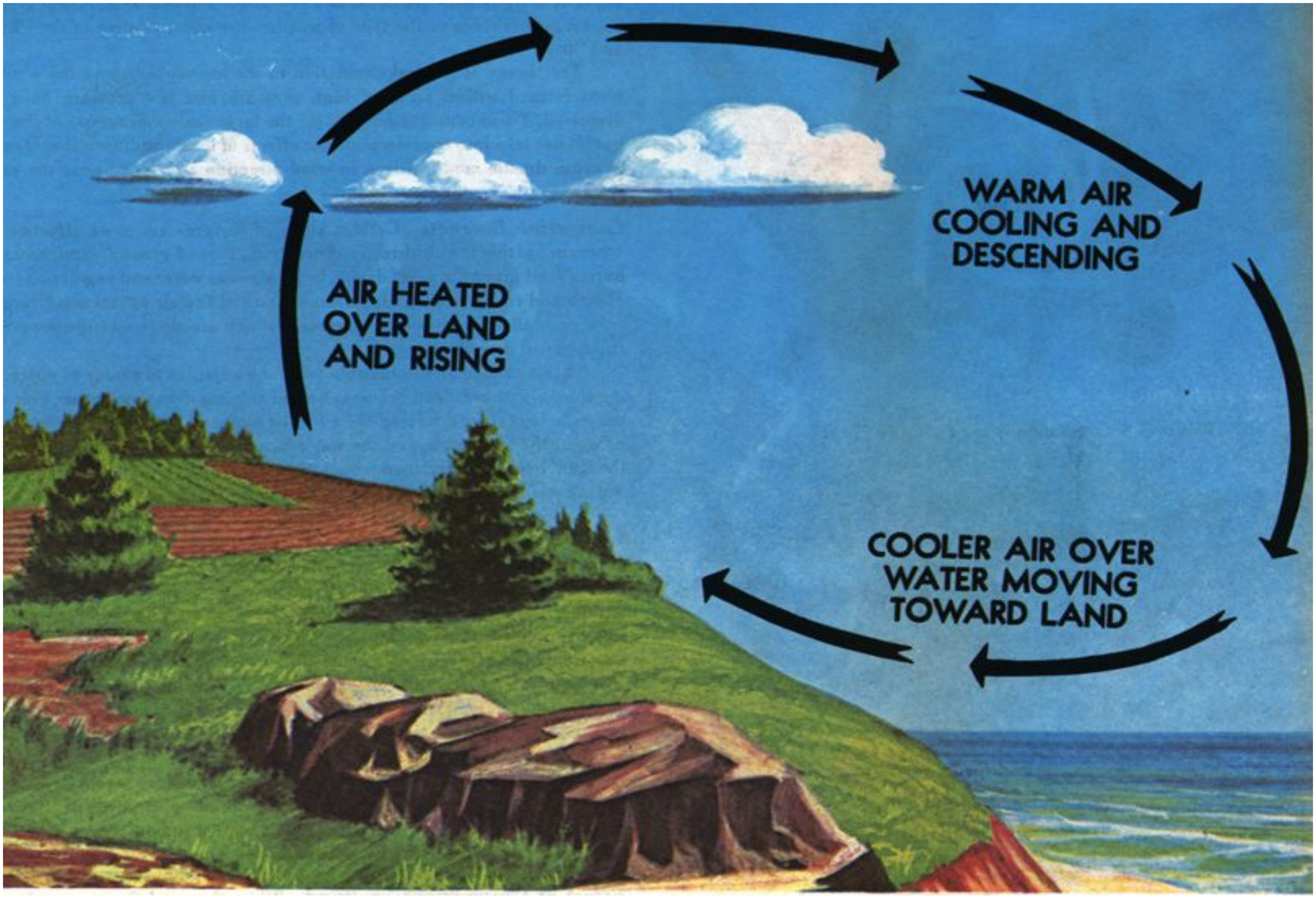


Gravity Current as Turbidity Current



Gravity Current as Dangerous Dust Storm

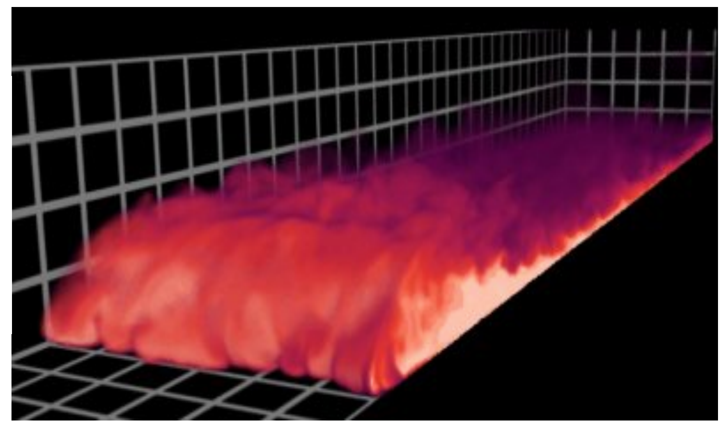
Gravity Current as a Sea Breeze



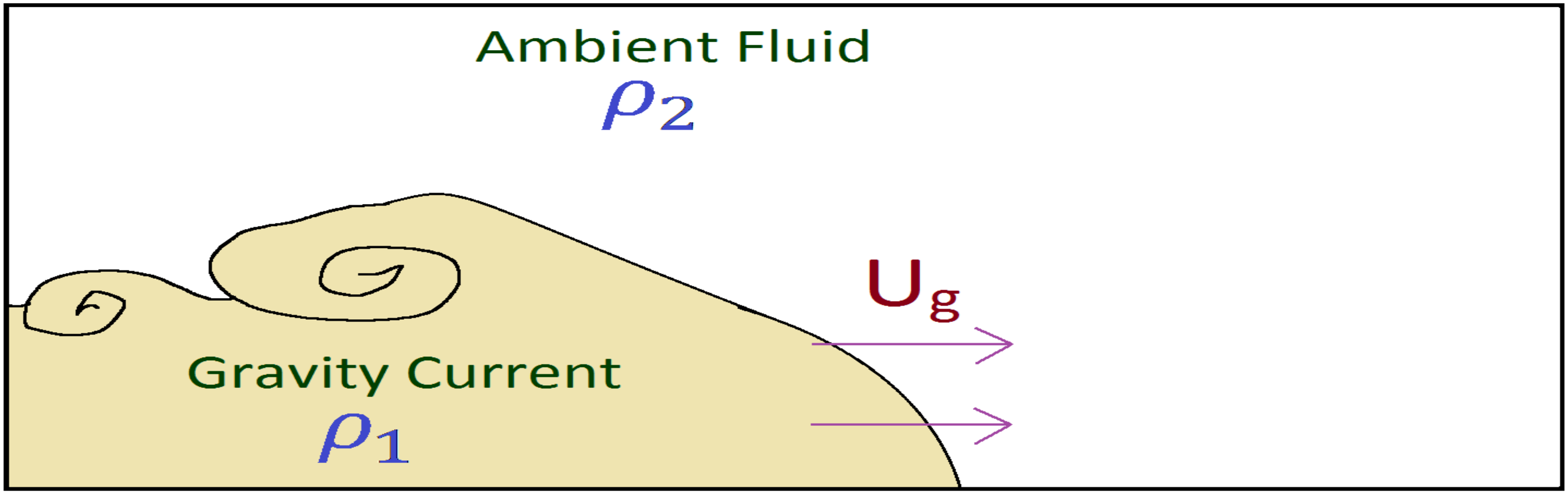
Modeling vs. Real World

Mathematical Model

$\stackrel{?}{=}$



Key Assumptions of Gravity Current System

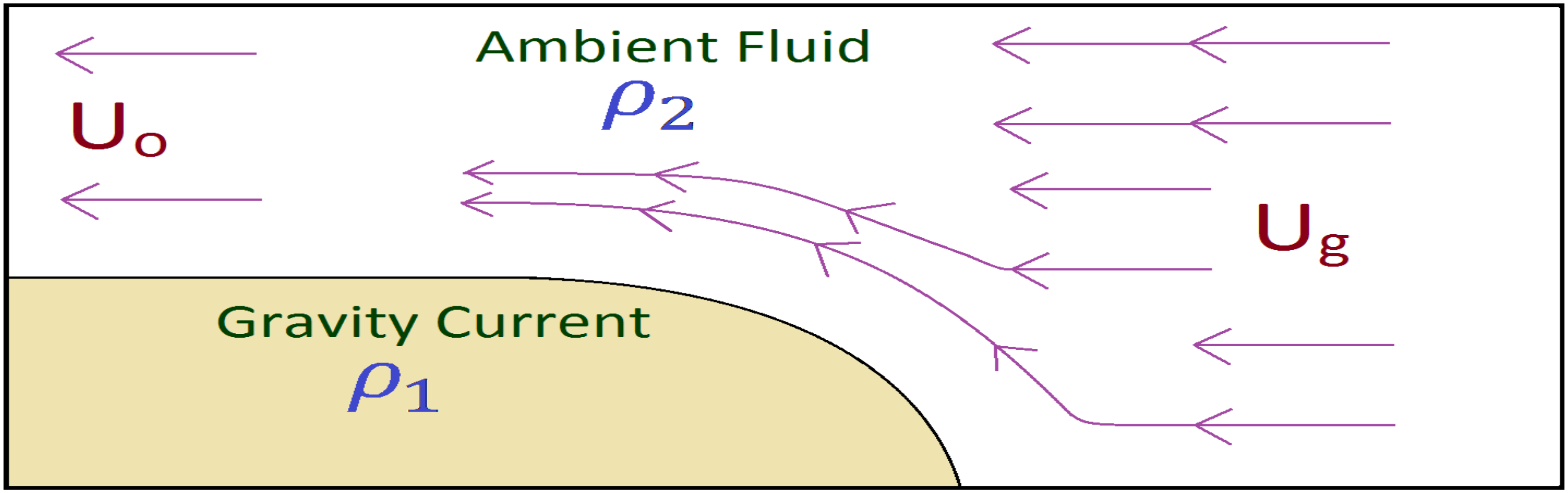


Gravity Current:

Moves with constant unknown speed, U_g.

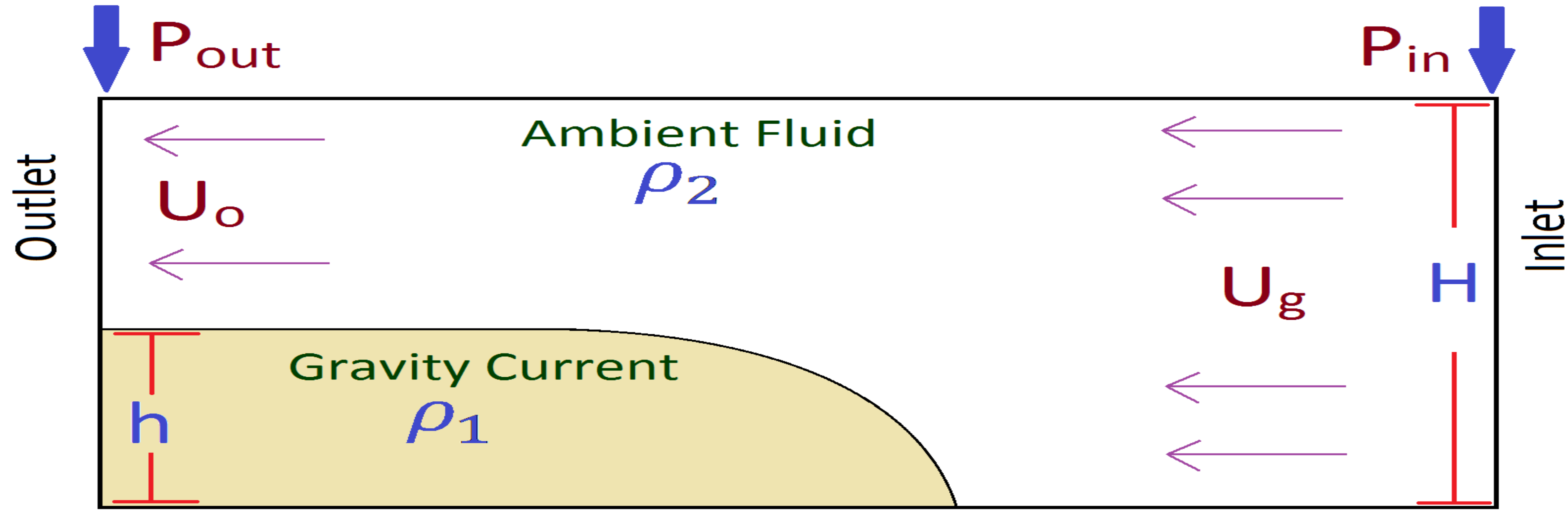
Higher density than Ambient Fluid, $\rho_1 > \rho_2$.

Key Assumptions of Gravity Current System



- Reference Frame changed
- Gravity Current is ideally shaped
- Steady state flow
- Internal friction is neglected

Analyzing Gravity Current System



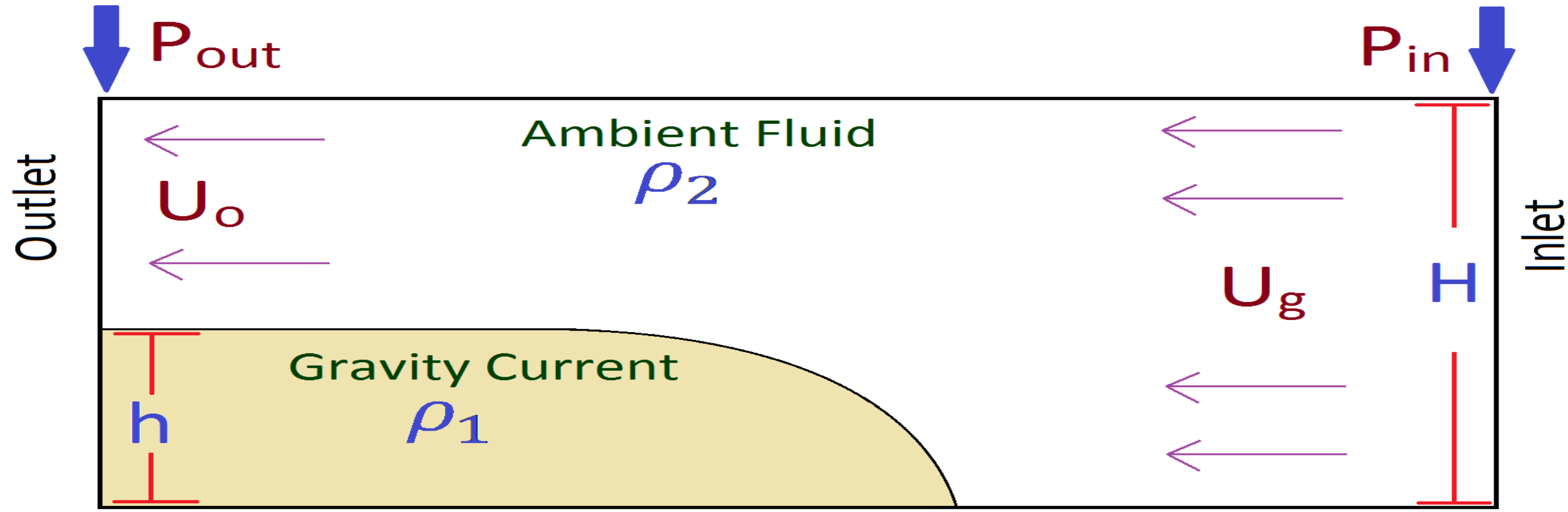
Known parameters:

- g
- h and H
- ρ_1 and ρ_2

Unknown parameters:

- U_g and U_o
- P_{in} and P_{out}

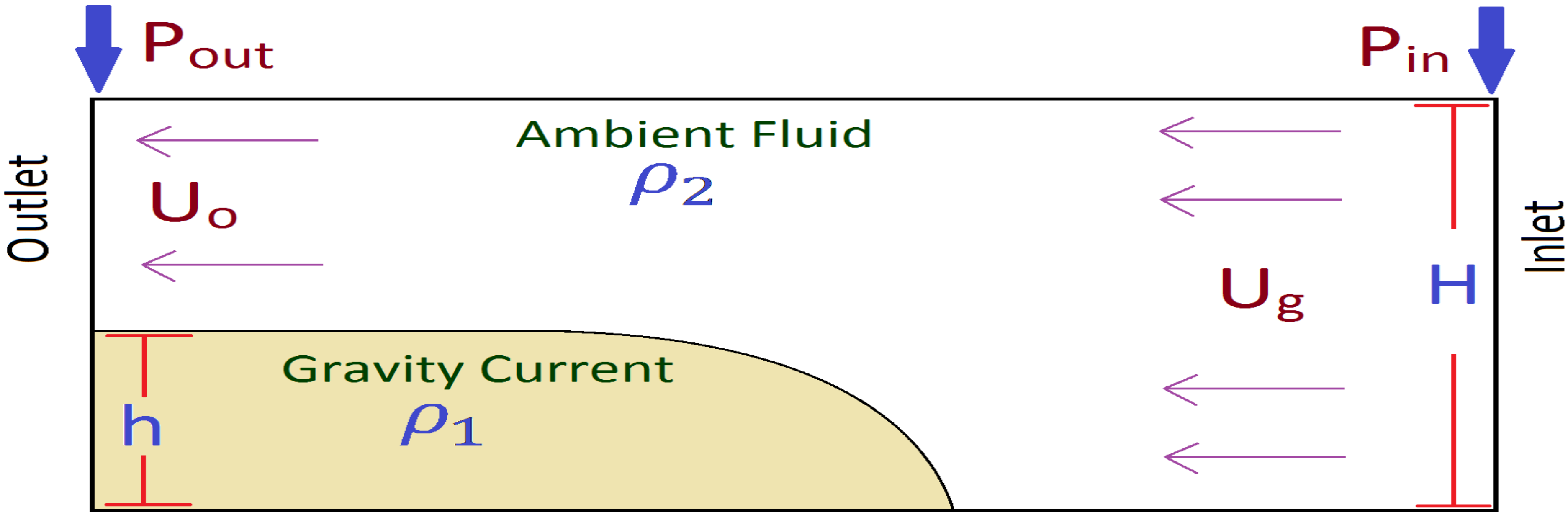
Derived Relationships from Conservation Laws



Continuity Equation from Mass Conservation

$$U_o(H - h) = U_g H$$

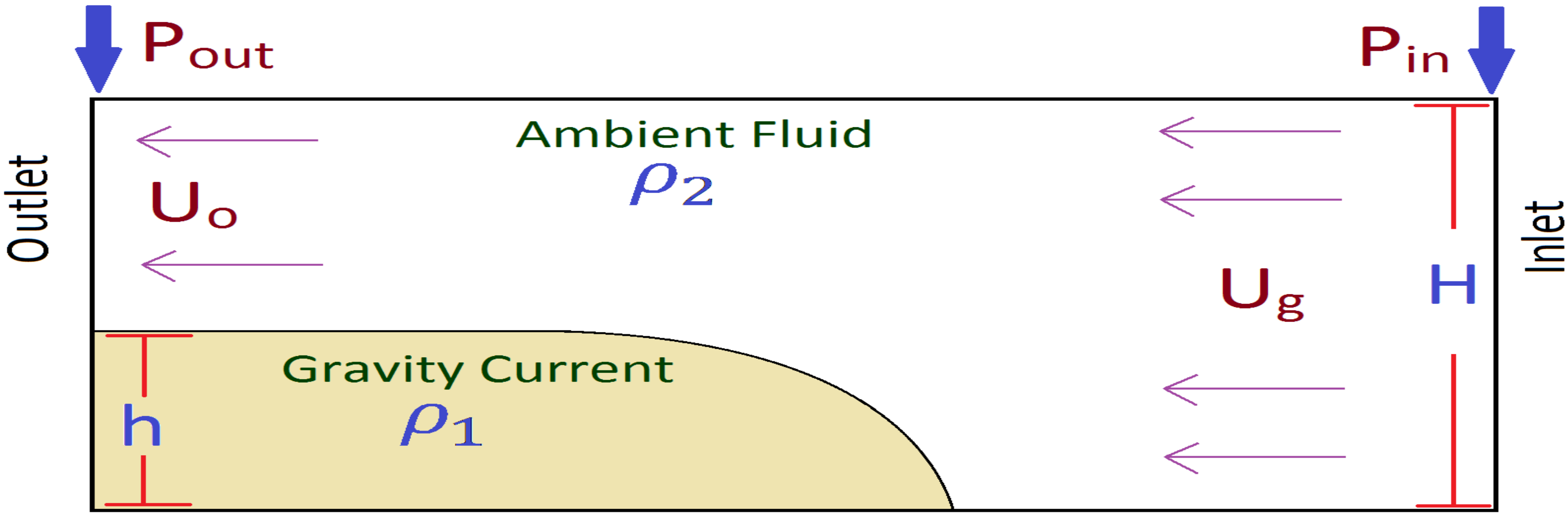
Derived Relationships from Conservation Laws



Pressure Difference from Momentum Conservation

$$P_{in} - P_{out} = \frac{g\left(\rho_1 - \rho_2\right)h^2}{2H} + \frac{\rho_2\left(H - h\right)h^2}{H}U_o^2 - \rho_2 U_g^2$$

Derived Relationships from Conservation Laws

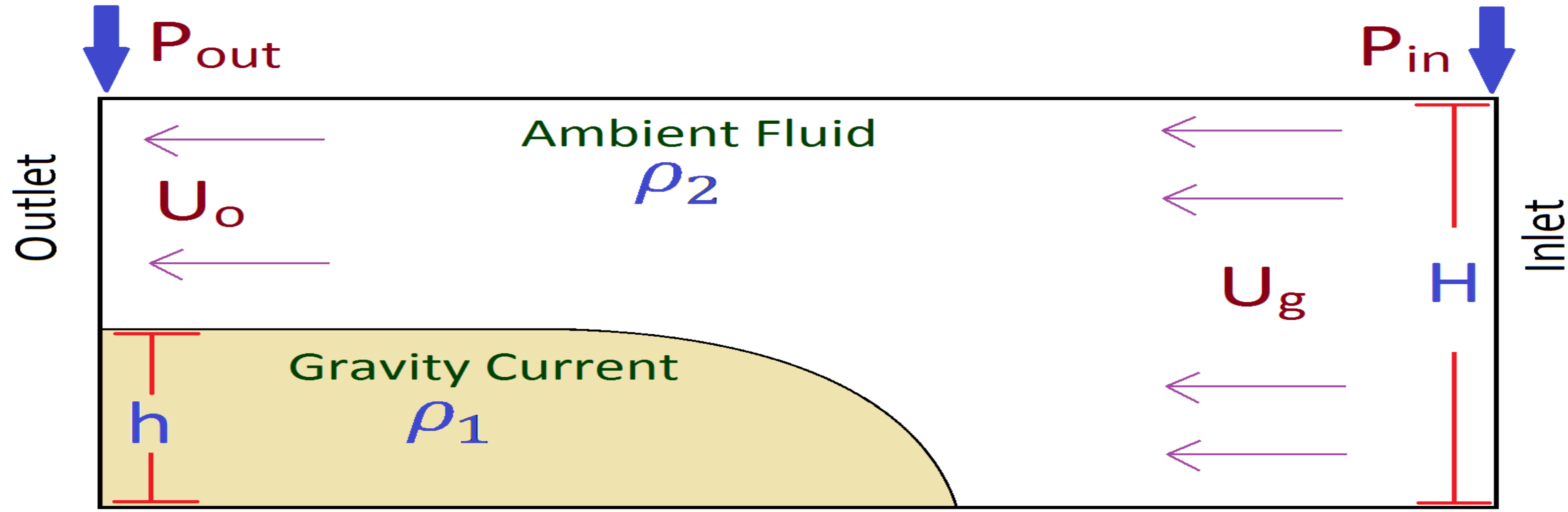


Bernoulli's Equation from Energy Conservation

$$\left(\frac{U^2}{2} + g\,\square + \frac{P}{\square}\right)_{inlet} = \left(\frac{U^2}{2} + g\,\square + \frac{P}{\square}\right)_{outlet} + \Delta$$

Where Δ is the Energy Loss due to assumptions and must be ≥ 0.

Derived Relationships from Conservation Laws



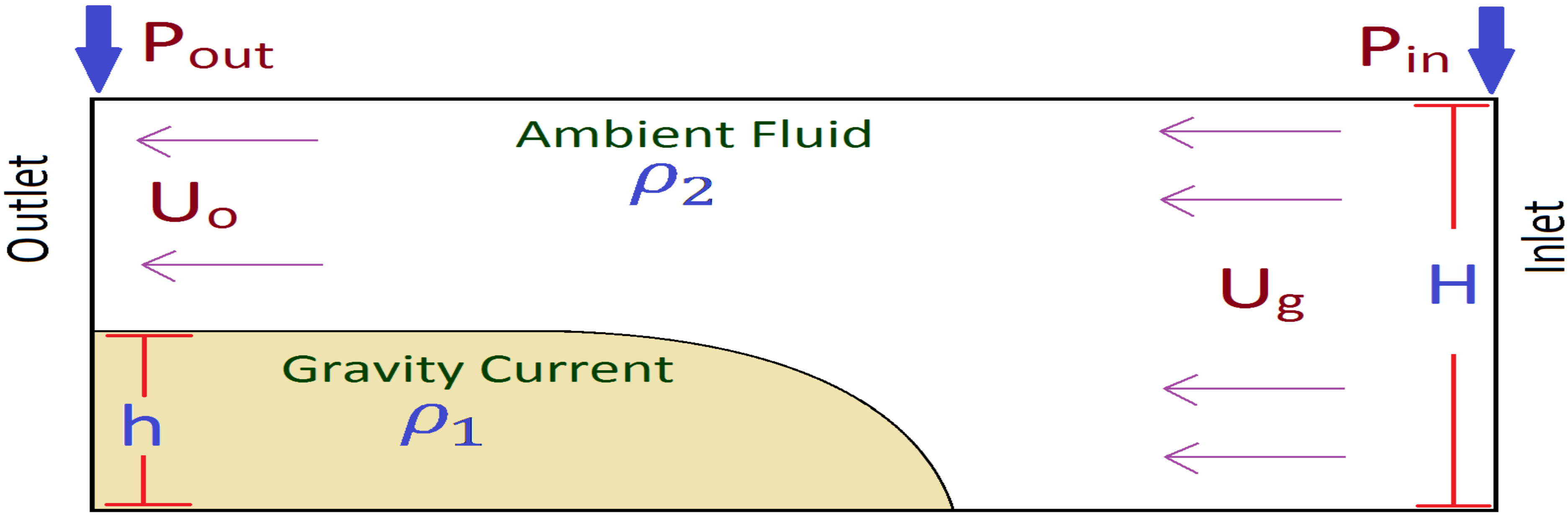
Inlet and Outlet Speeds from Circulation Conservation

$U_o (H-h) = U_g H$

$$U_o = \sqrt{\frac{(\rho_1 - \rho_2)}{\rho_2} g h}$$

$$U_g = \left(1 - \frac{h}{H}\right)\sqrt{\frac{(\rho_1 - \rho_2)}{\rho_2} g h}$$

Equations Used from Conservation Laws



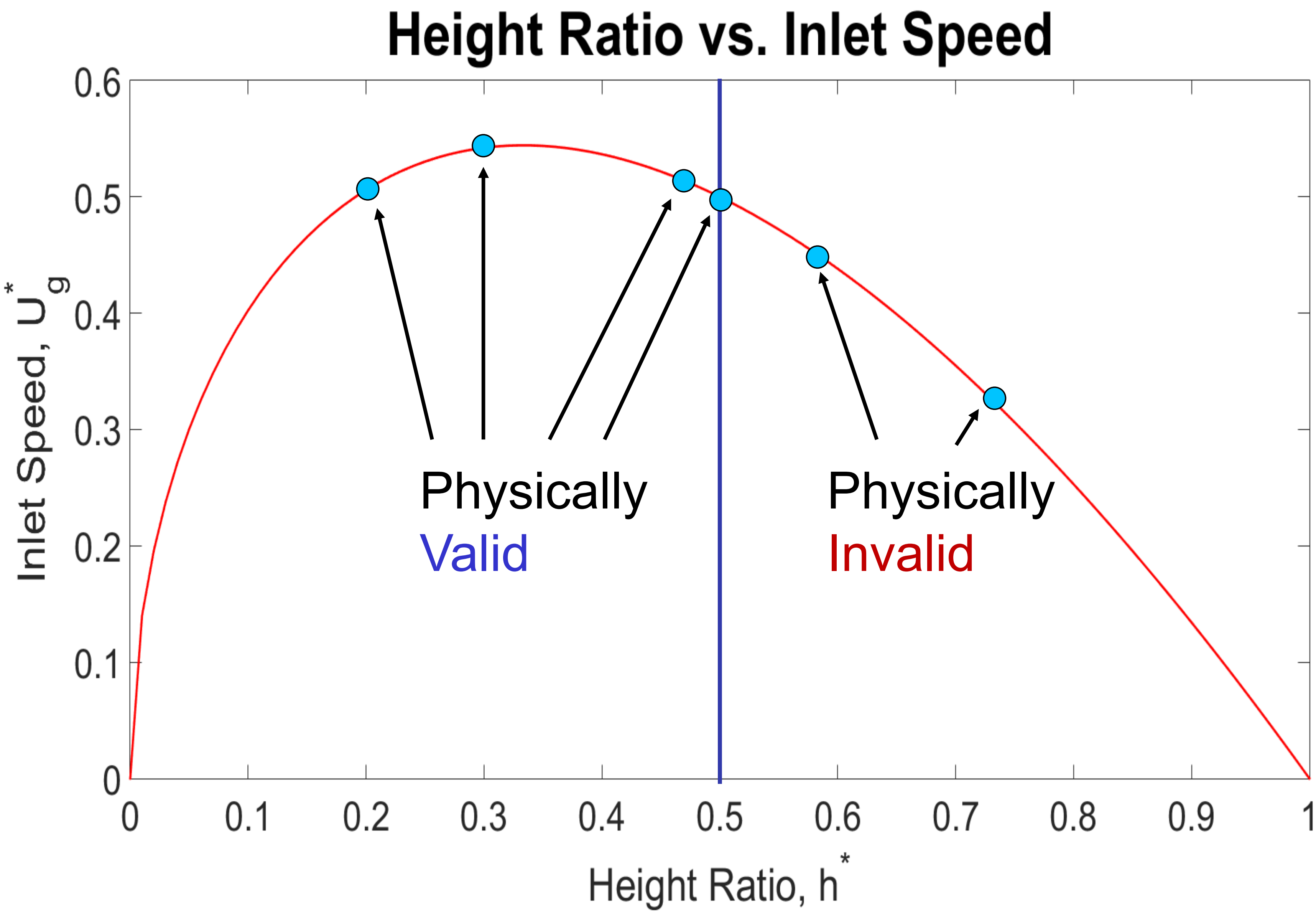
Height Ratio: $h^* = \frac{h}{H} = \frac{\text{Height of Gravity Current}}{\text{Total Height of System}}$

Outlet Speed: $U_o^* = \sqrt{2h^*}$

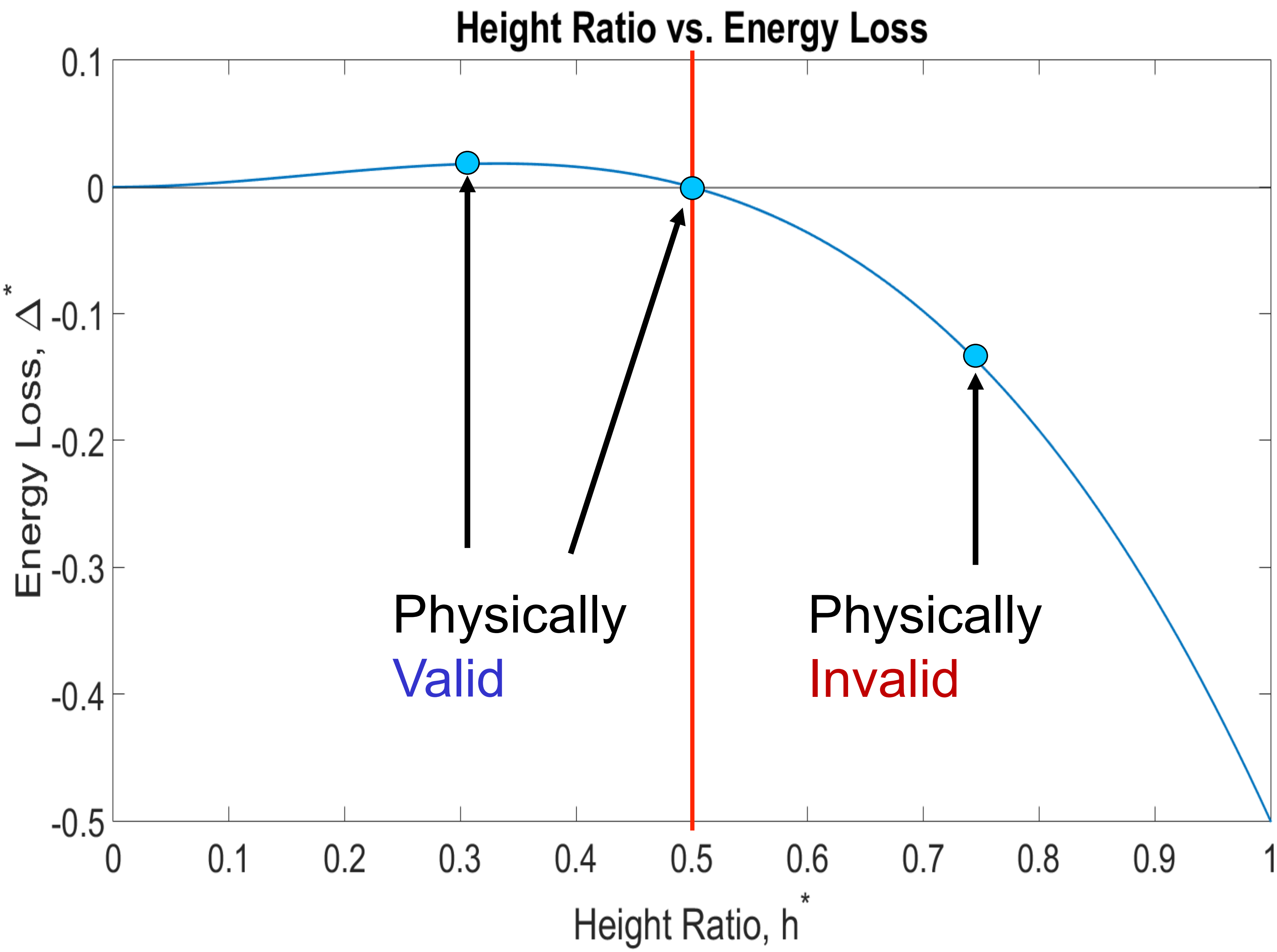
Inlet Speed: $U_g^* = (1 - h^*)\sqrt{2h^*}$

Energy Loss: $\Delta^* = h^{*2}\left(\frac{1}{2} - h^*\right)$, *where* $\Delta^* \geq 0$

Obtaining Data for Simulation



Looking at the Energy Loss

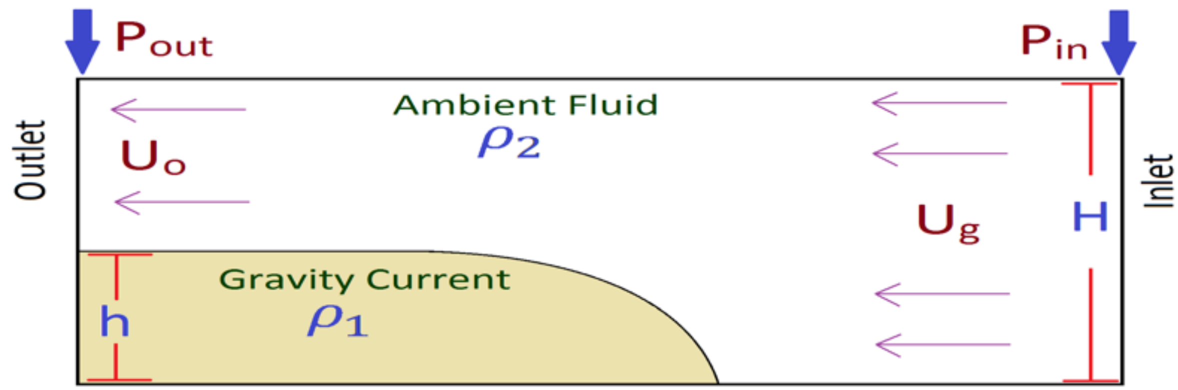


Simulation: h^*= 0.50

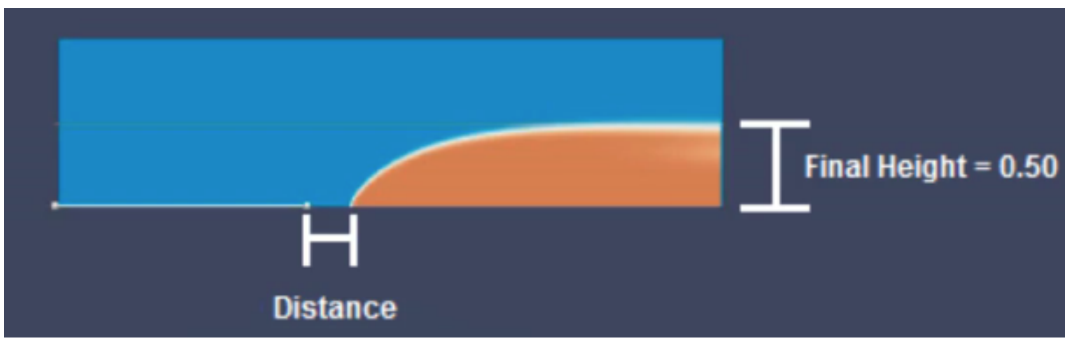
Simulation: h^*= 0.30

Simulation: h^*= 0.72

Knowledge Gained from the Project



This model can make complex real world problems simpler.



Computer Science can make the world's problems easier to solve.

Thank You!

Dean Morales
Dr. Jens-Uwe Kuhn
Wendy Ibsen
All condor interns

Special Thanks

Our mentor: Amin Khodkar
P.I. : Eckhart Meiburg
CFD Lab
Dept. of Mechanical Engineering