2-D Physical Model for the Buncefield Gas Cloud Formation
A Progress Report

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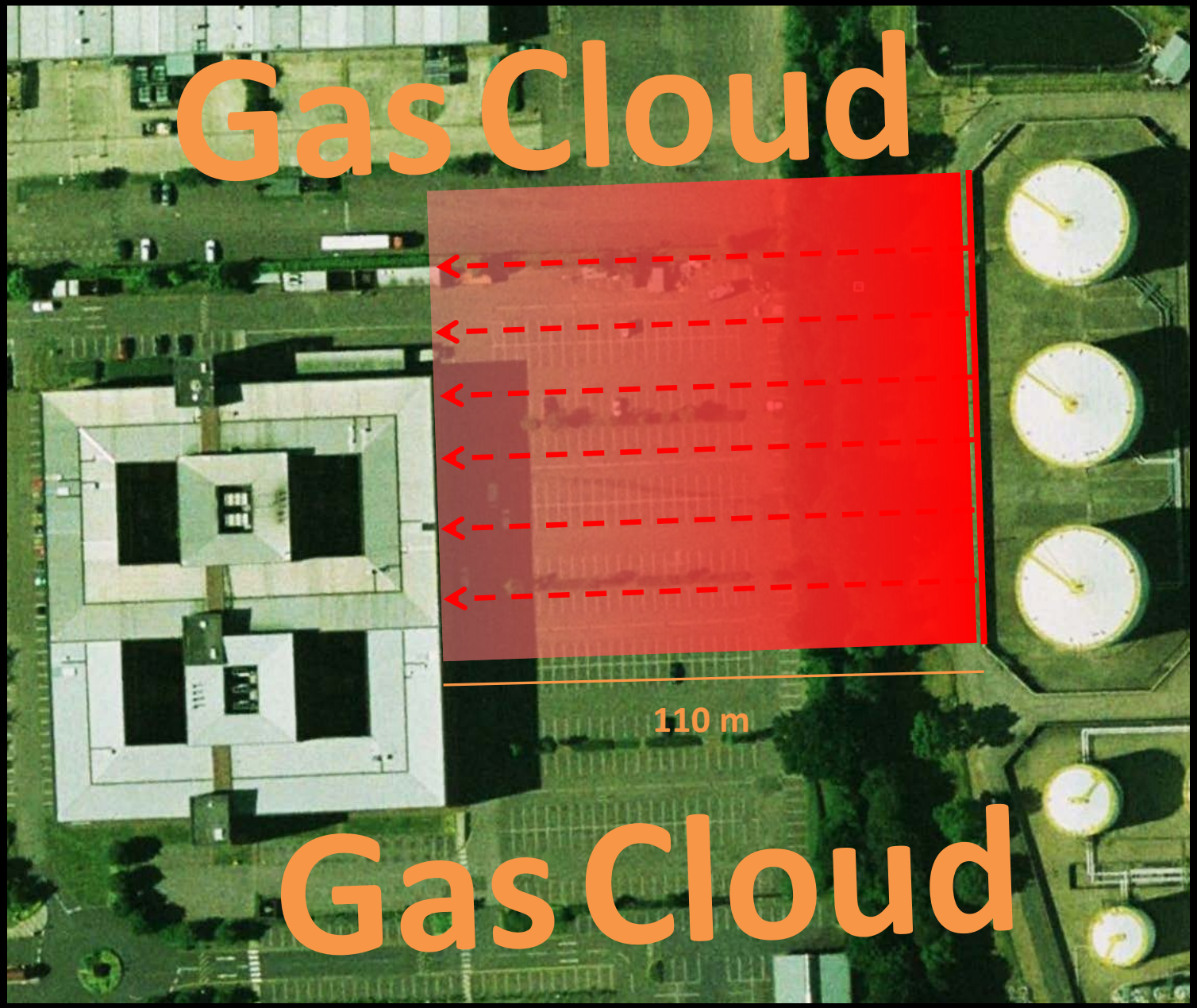
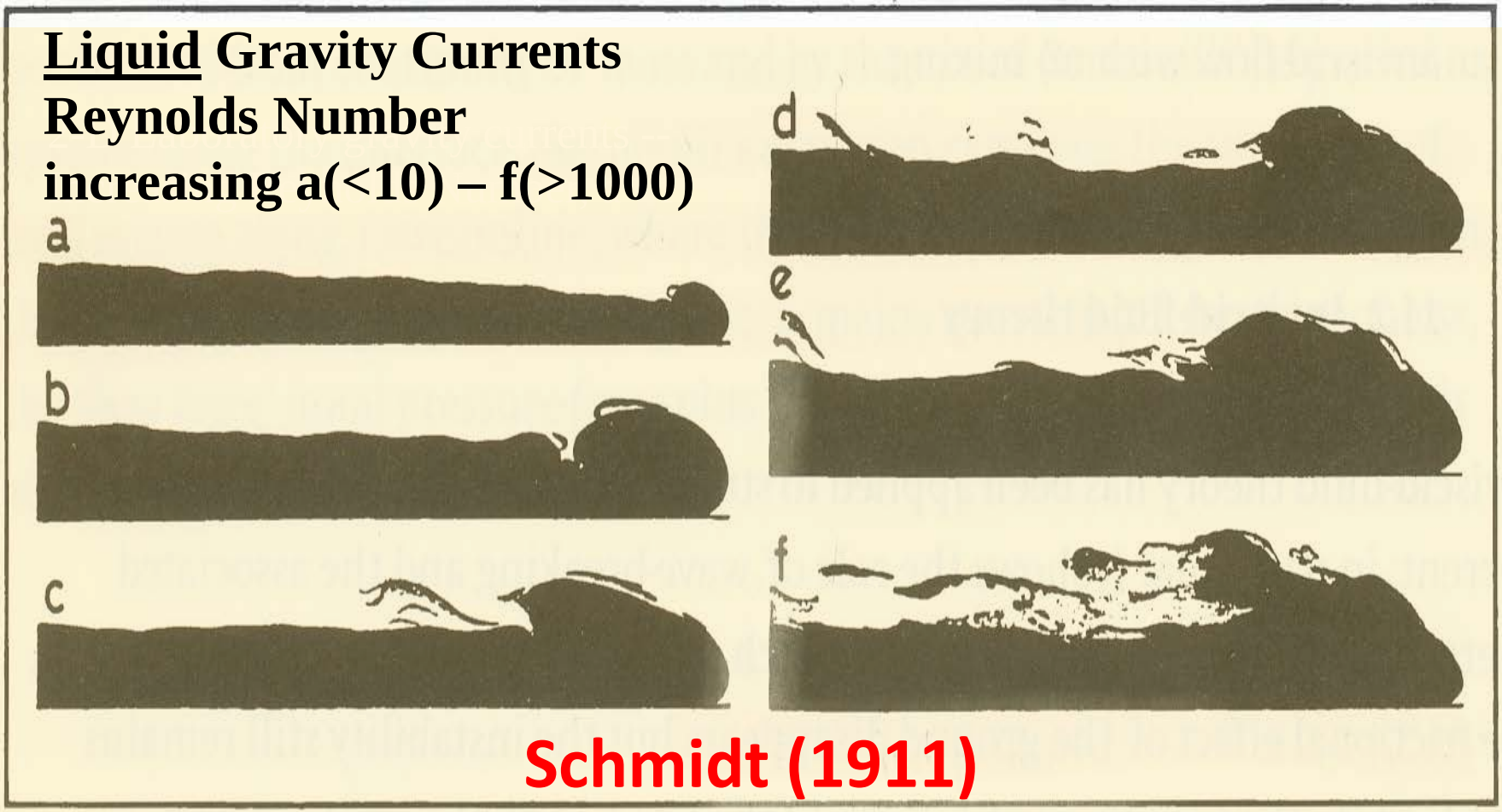
Assumed 2D Flow Area – Concentration Decreasing Right to Left



- Model as steady-feed 2-D Gas Gravity Current (zero wind)
- Primary goal: measure gas concentration in the flow field
- Secondary goal: model a 2-D section of the Buncefield gas flow



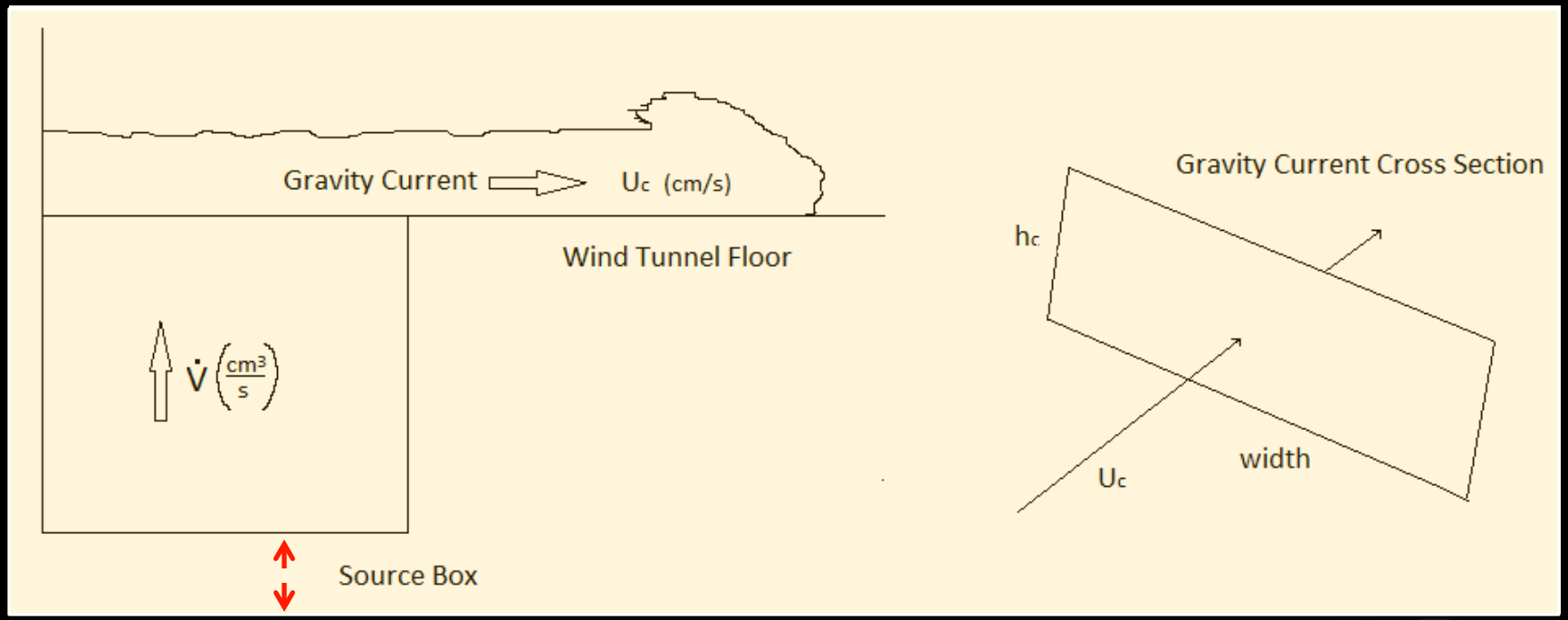
Purpose

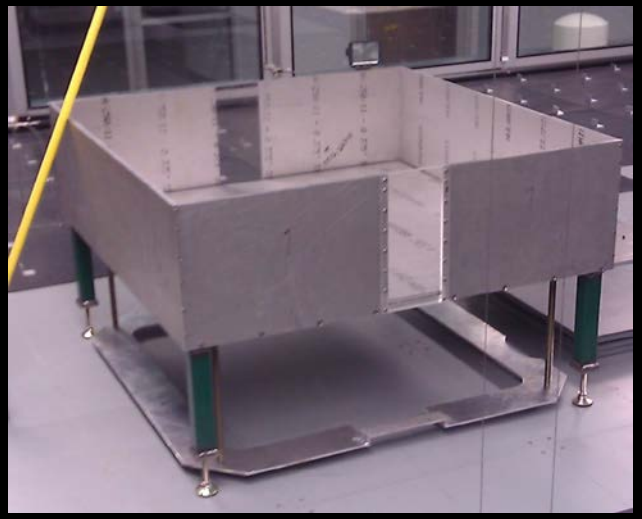
- Determine the magnitude and uniqueness (constancy) of the Froude number for a steady-feed 2-dimensional gas gravity current – Reported N_{Fr} range ~ 1.0 to $2^{1/2}$

- Determine the Reynolds number required for N_{Re} independence and verify independence with concentration measurements.

- Measure the resulting non-dimensional concentration distribution in the “indicated” section of the Buncefield flow.

Experimental Design



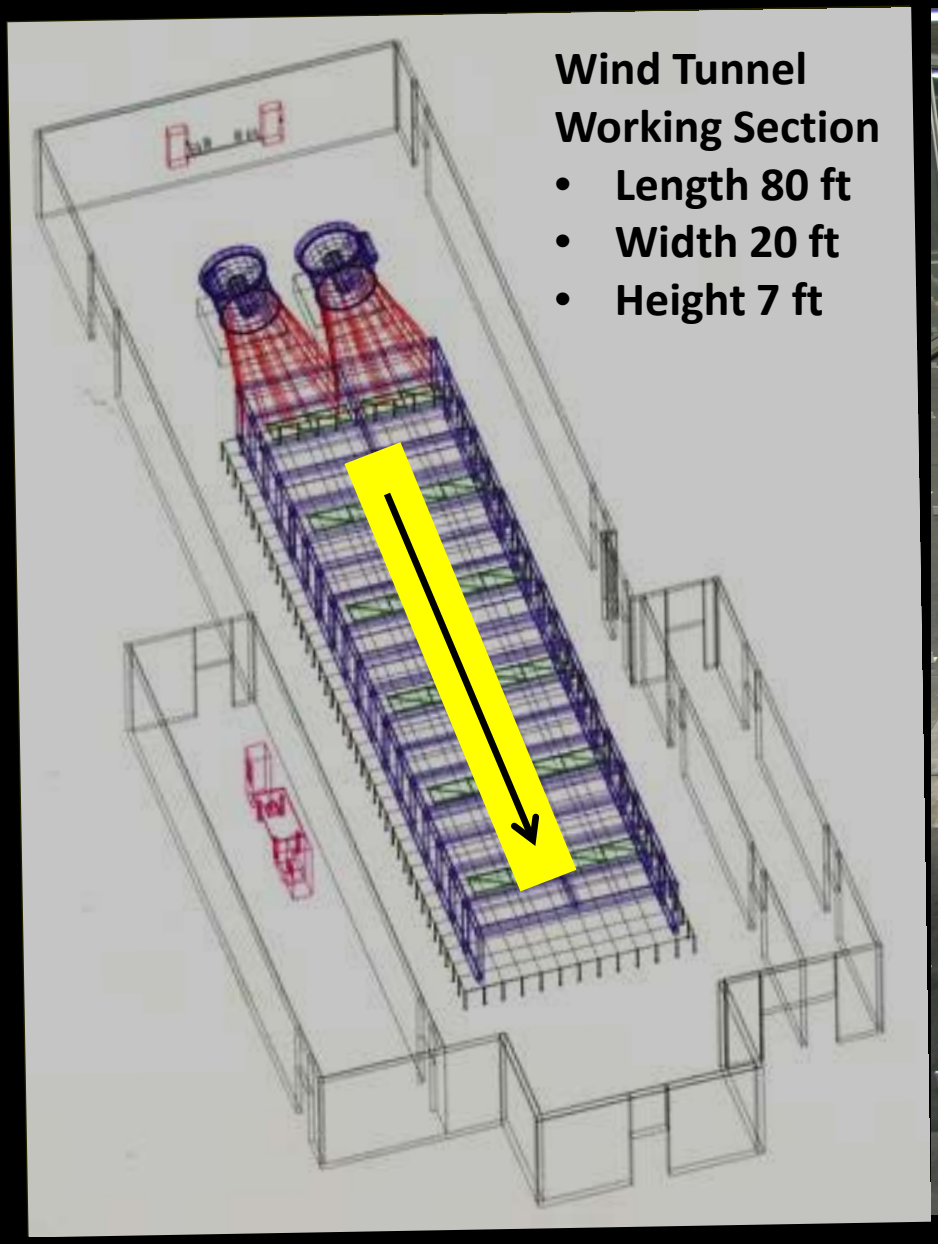


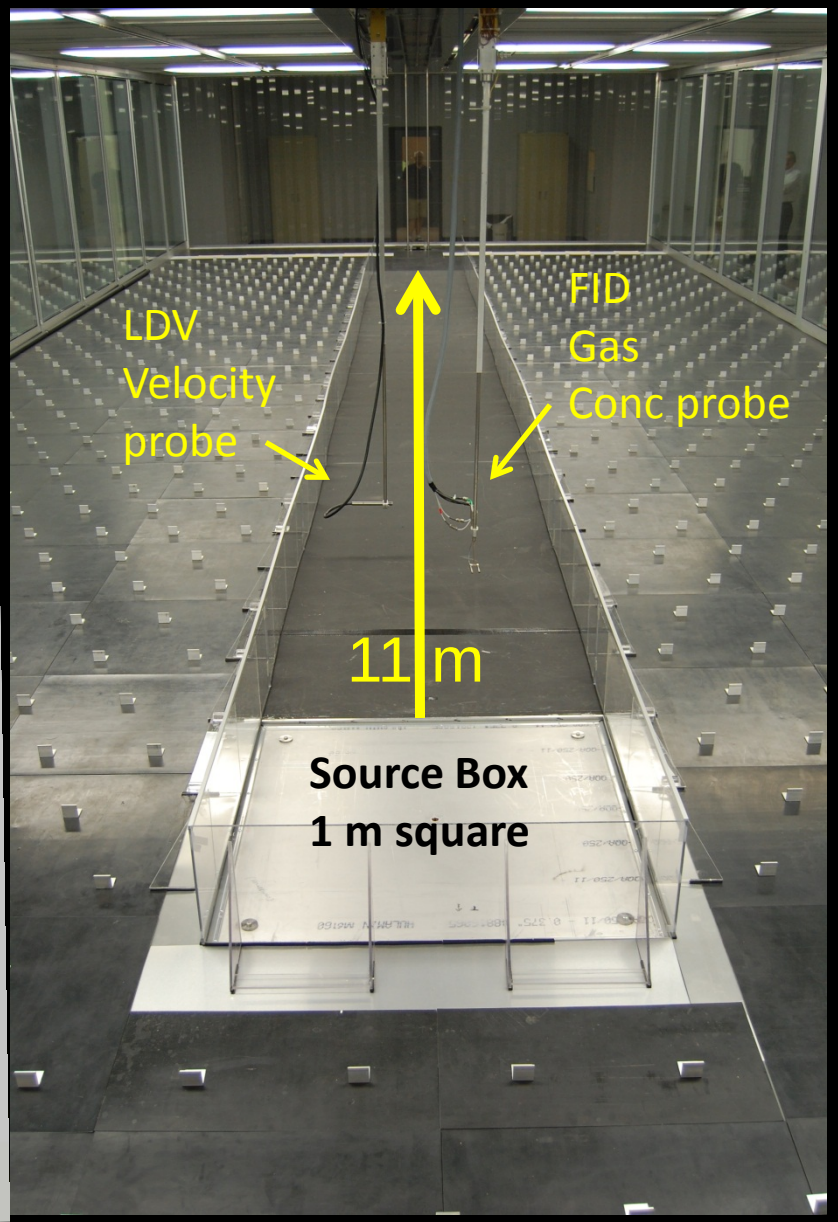
- Reynolds Number $\frac{U_c h_c}{\nu}$
- Froude Number $\frac{U_c^2}{g' h_c}$

ν = kinematic viscosity, m^2/s

$g' = g((\rho - \rho_{air})/ \rho_{air})$, m/s^2

Experimental Design

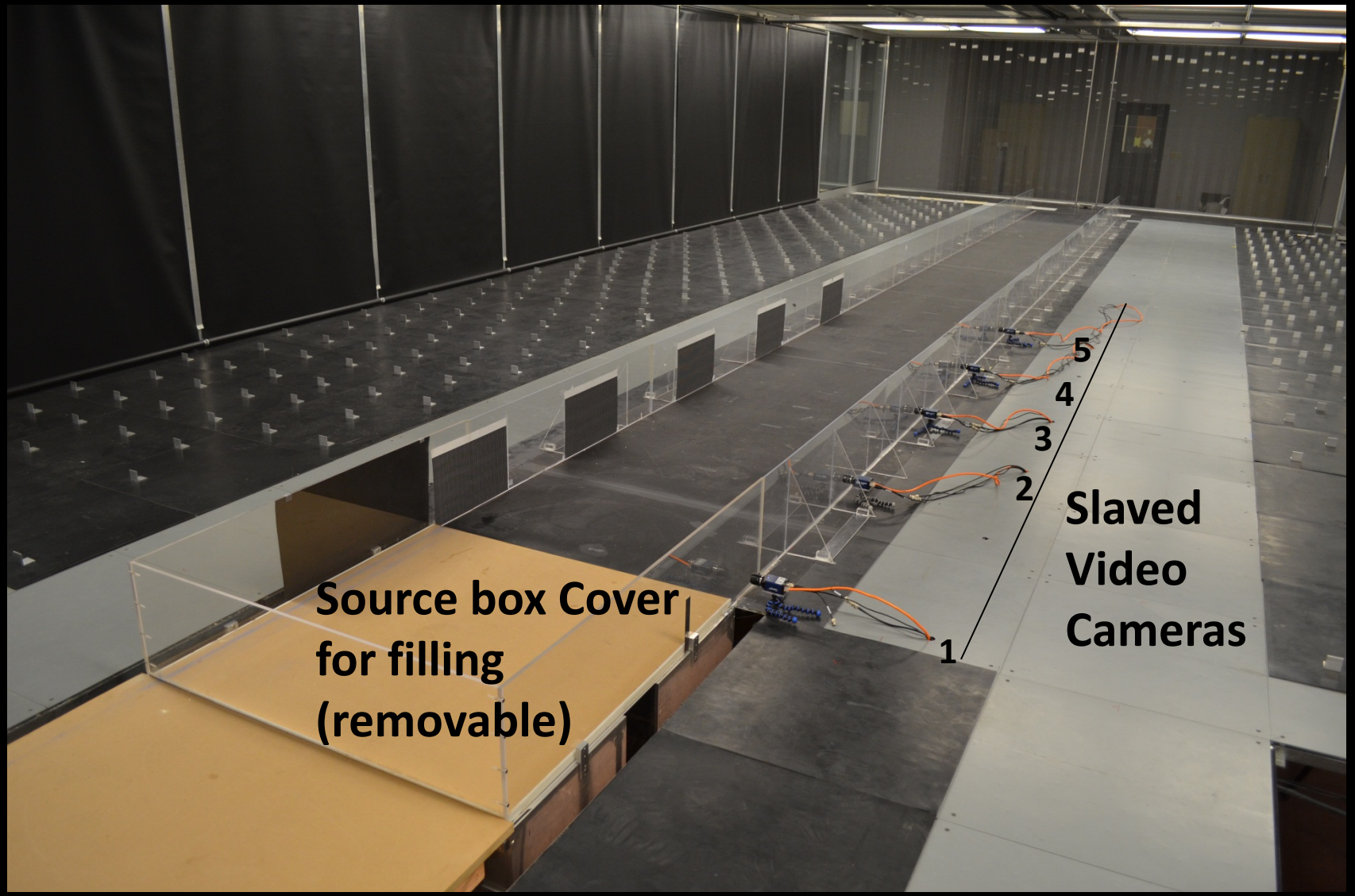




Video Recording

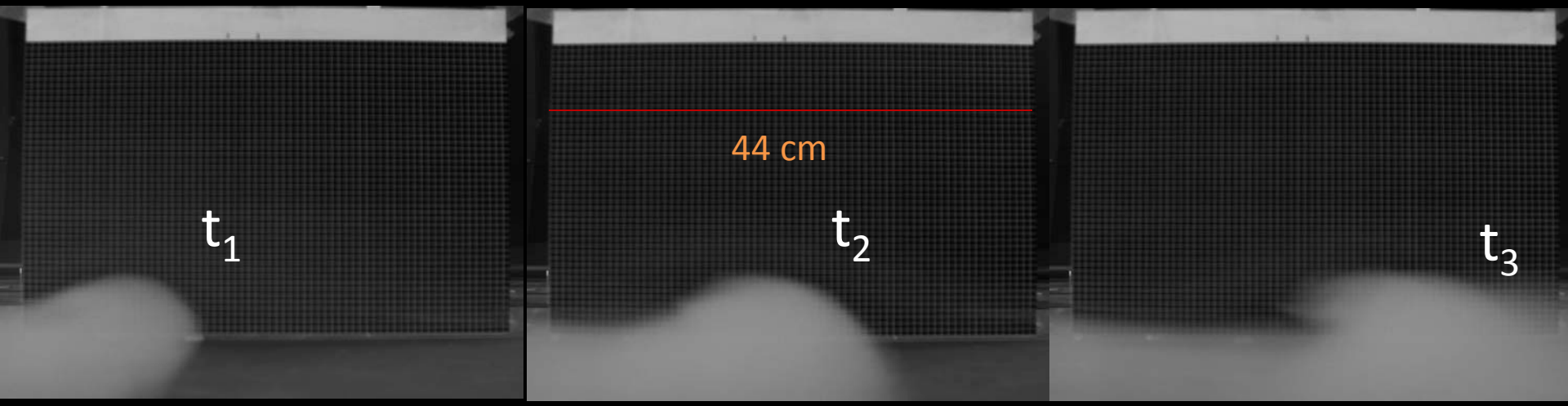
- Synchronized digital video capture of about 45 cm wide side-on views of flow (visualized with smoke) at 5 stations, starting from release edge
- Use timed video to measure gravity current height and velocity as function of down-current position and time
- Test Fr = 1 (and constancy) assumption
- Use video to determine rough measurements of entrainment from cloud height measurements as function of distance traveled – these measurements used to assist estimation of approach to N_{Re} independence

Experimental Design



"CO_2" Timing Camera #2 Frames

Showing Head Development

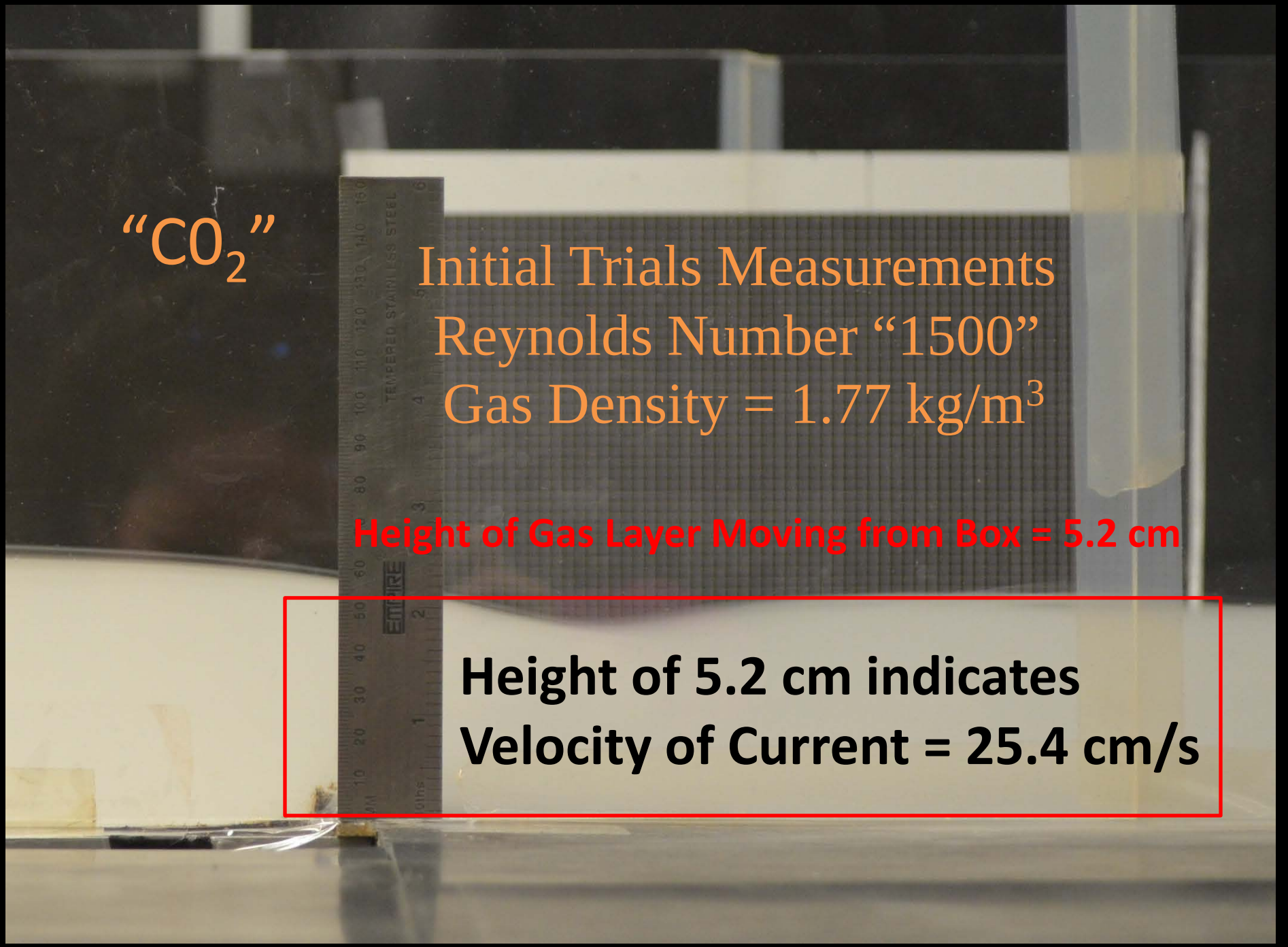


Gas Concentration Measurements

- Measure gas concentrations with FID at specific heights and down-channel locations for different flow rates (different N_{Re})
- Compare concentrations at identical dimensionless times and locations, emphasizing "steady" part of the flow
- If flows are N_{Re} independent, the concentrations at identical scaled values should approach equality

Initial Trials Measurements

- Density = 1.77 kg/m^3 "CO_2" ($g' = 4.87$ m/s^2)
- Density = 1.35 kg/m^3 "Buncefield" ($g' = 1.40$ m/s^2)

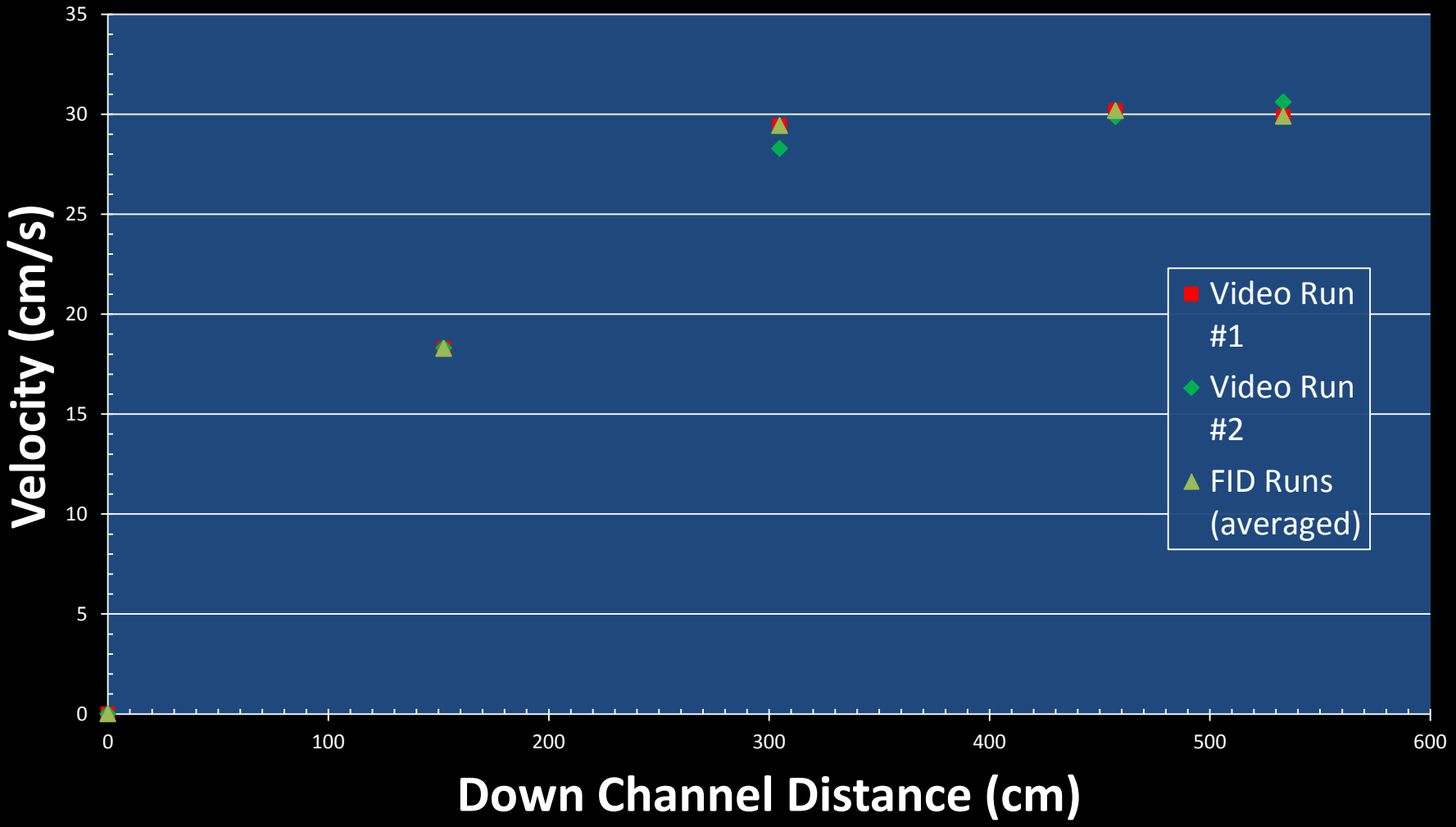

"CO_2"
Initial Trials Measurements
Reynolds Number "1500"
Gas Density = 1.77 kg/m^3
Height of Gas Layer Moving from Box = 5.2 cm
Height of 5.2 cm indicates
Velocity of Current = 25.4 cm/s

Reynolds Number "1500"
"CO_2" - 1.77 kg/m^3

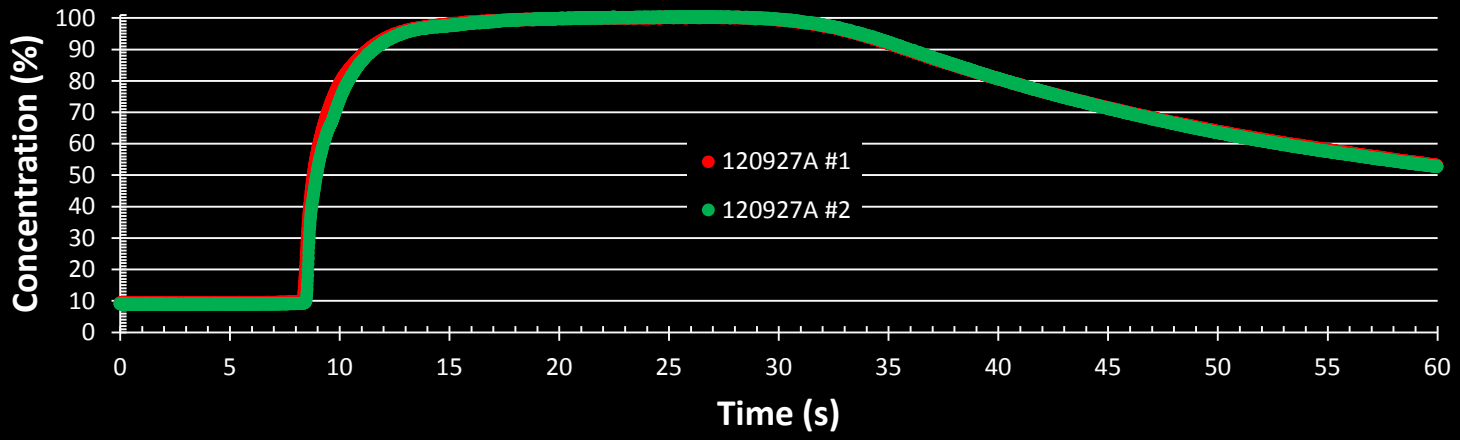
Reduced Gravity m/s^2	(upward) Floor Velocity cm/s	Calculated Horizontal Velocity (quasi steady) cm/s	Measured Cloud Height (initial) cm
4.87	1.31	25.4	5.2

"Measured" Reynolds Number = 1605

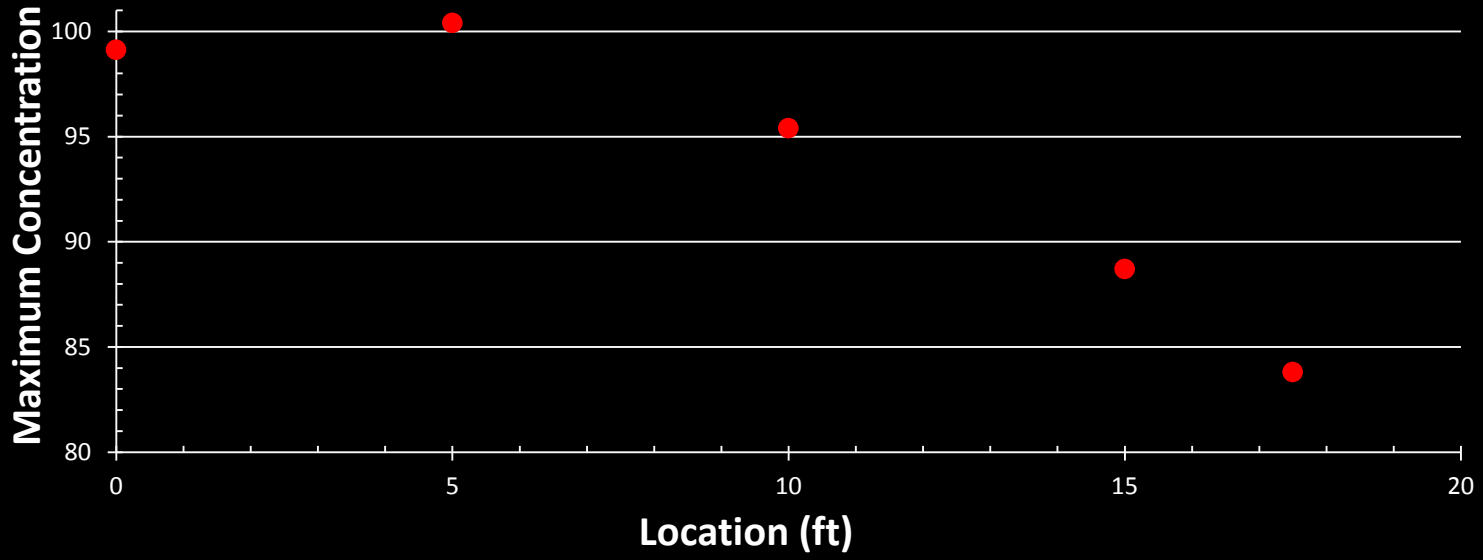
Reynolds Number "1500" – "CO_2" 1.77 g/m^3



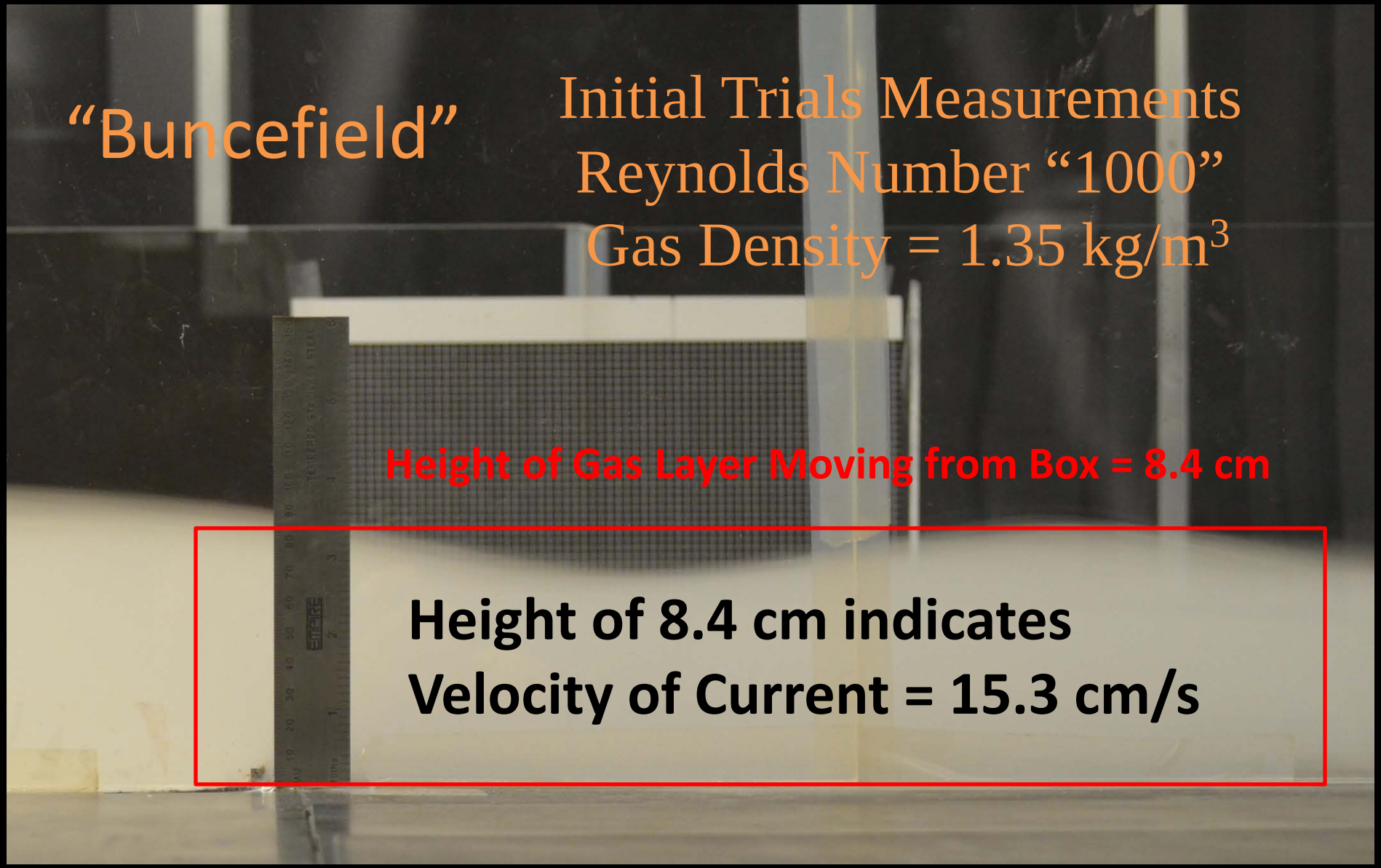
Reynolds Number "1500" - "CO_2" Concentration vs. Time – 5 ft down channel



Reynolds Number "1500" - "CO_2" Concentration vs. Distance



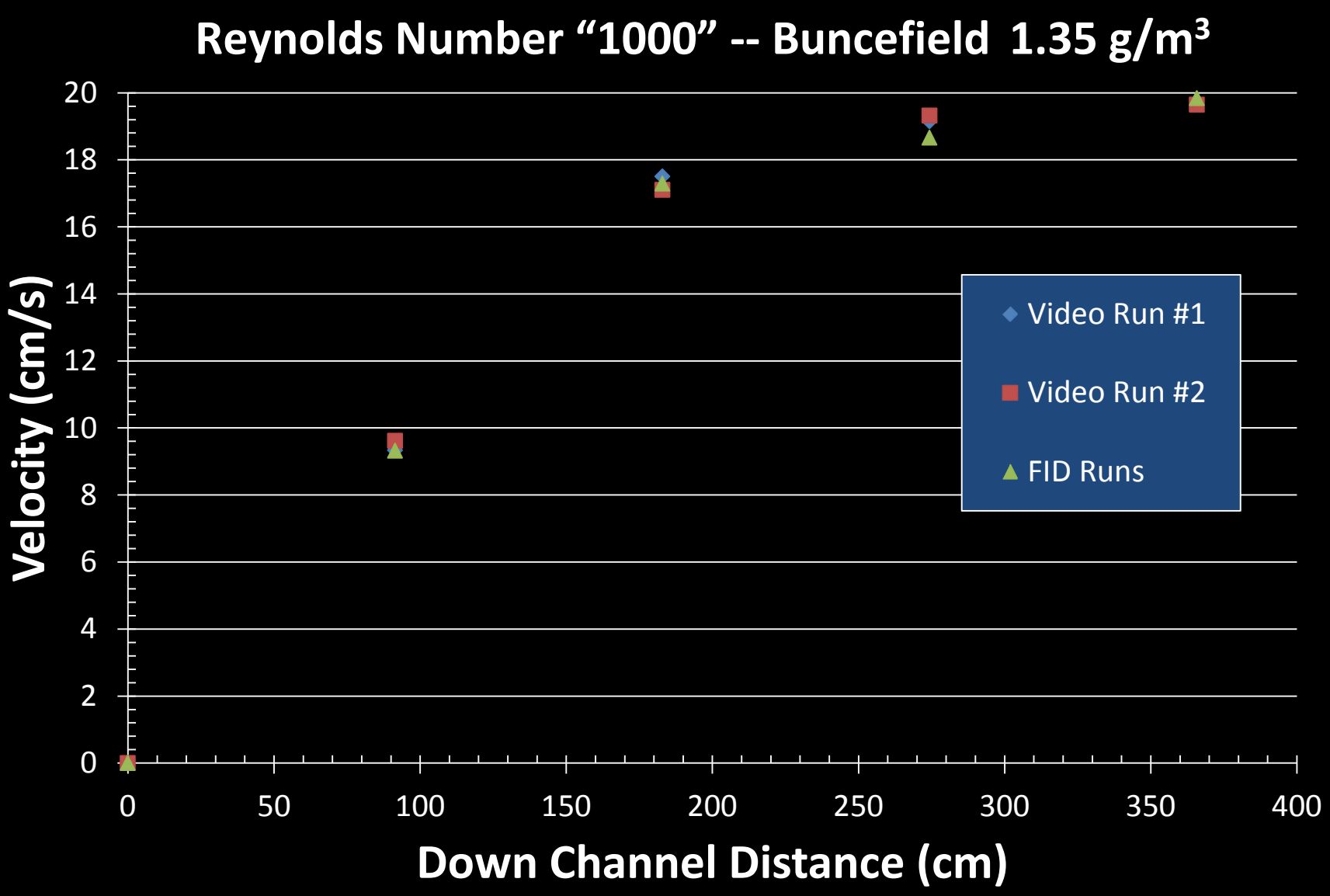
Front Structure


"Buncefield"
Initial Trials Measurements
Reynolds Number "1000"
Gas Density = 1.35 kg/m3
Height of Gas Layer Moving from Box = 8.4 cm
Height of 8.4 cm indicates
Velocity of Current = 15.3 cm/s

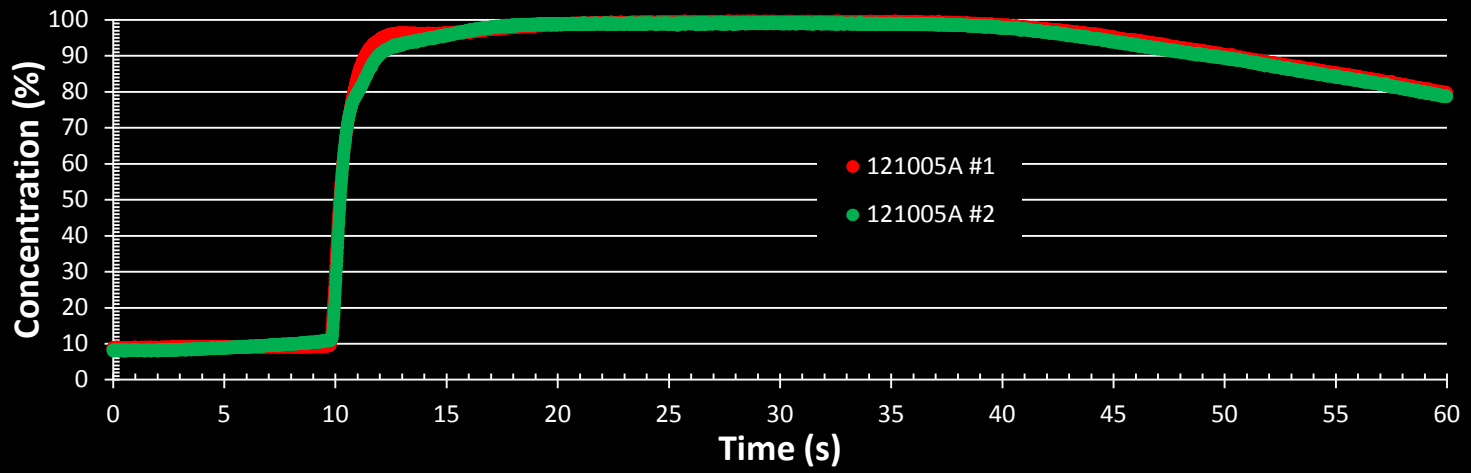
Reynolds Number "1000"
"Buncefield" – 1.35 kg/m^3

Reduced Gravity m/s^2	(upward) Floor Velocity cm/s	Calculated Horizontal Velocity (quasi steady) cm/s	Measured Cloud Height (initial) cm
1.40	1.28	15.3	8.4

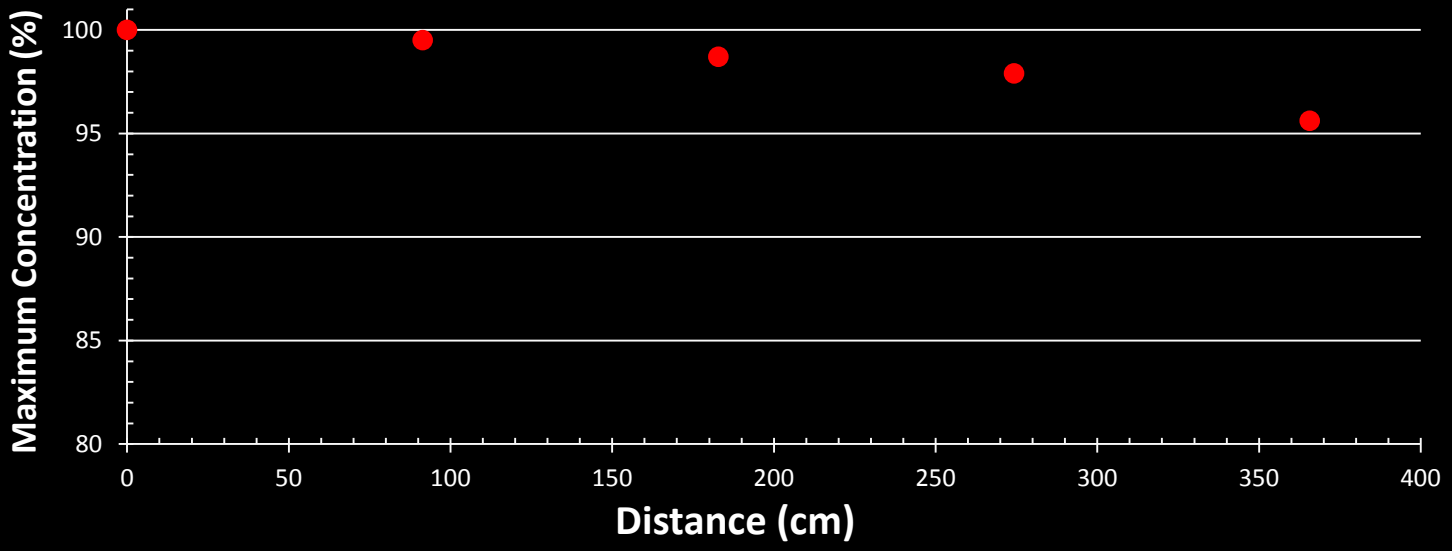
"Measured" Reynolds Number = 1020


Reynolds Number "1000" -- Buncefield 1.35 g/m3
Velocity (cm/s)
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
300
350
400
Down Channel Distance (cm)
Video Run #1
Video Run #2
FID Runs

Reynolds Number “1000” - “Buncefield”
Concentration vs. Time – 3 ft down channel



Reynolds Number “1000” - “Buncefield”
Concentration vs. Distance



Current Status

- Demonstrated experiment repeatability, including near-exact transient concentration repeatability
- Demonstrated consistent measurement of gravity current velocity by video records and FID gas concentration measurements
- Identified importance of transient phase of gravity current in these experiments

Immediate Plans

- Automate experiment plan/procedure
- Investigate vertical concentration distribution
- Investigate Reynolds Number Similarity
- Investigate scaling considerations for Buncefield

Questions?