Simulation and Experimental Study to Predict the Gas Emission from Porous Media

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Problem Description

- The rational for this study is to interpret and quantify for a specific location how soil produced carbon dioxide contributes to the green house effect.

- Respiration chambers can be used to quantify the soil efflux for certain locations whereby they come in different shapes and sizes depending on their use.

Thesis Objectives

- To derive several forms of efflux equations to link soil physical mechanisms, soil biological parameters and types of soil textures that affect soil efflux respiration.
- To Develop several chamber designs that measure biologically generated carbon dioxide effluxes from soils.
- To produce an innovative portable device that measures carbon dioxide efflux.
- To develop a software code within a MATLAB environment.
- To model the mass transport using CFD (ANSYS).
- To validate the software code through the use of experiments.

Design Process Stages

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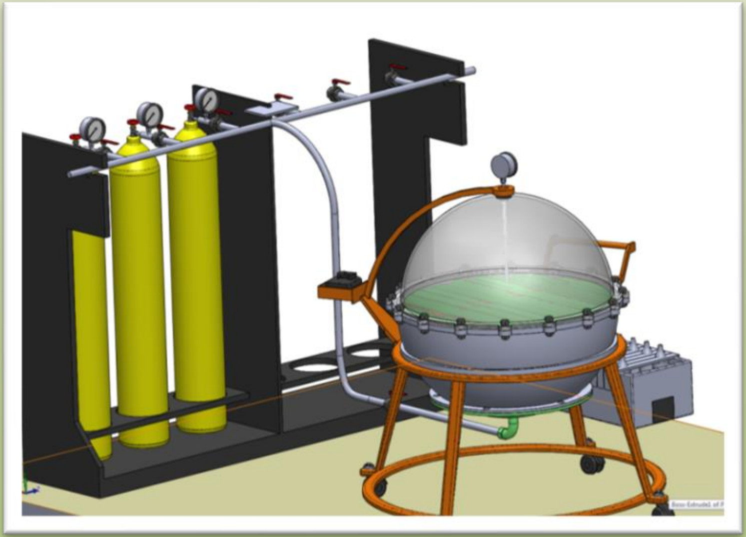

Design Stage 1

Design Stage 2

Design Stage 3

Final Design

The Experimental Setup and Part Description

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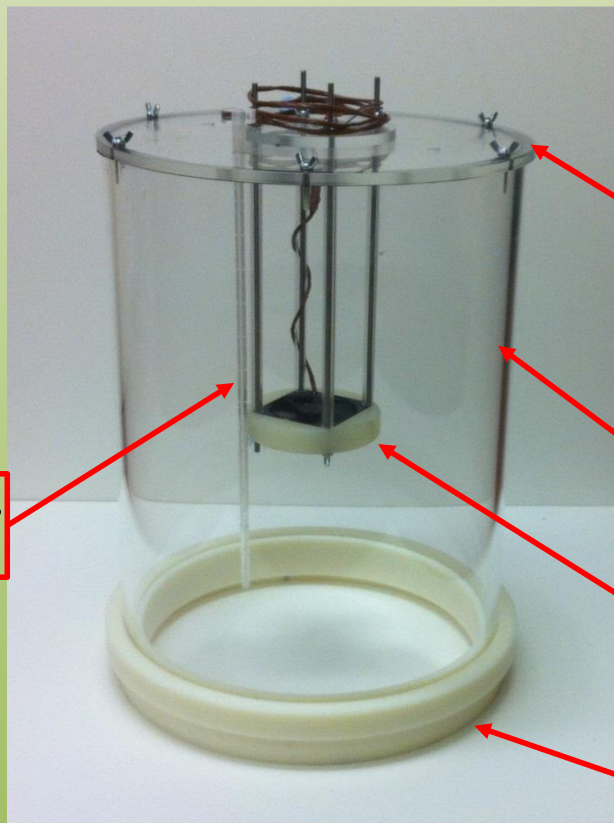
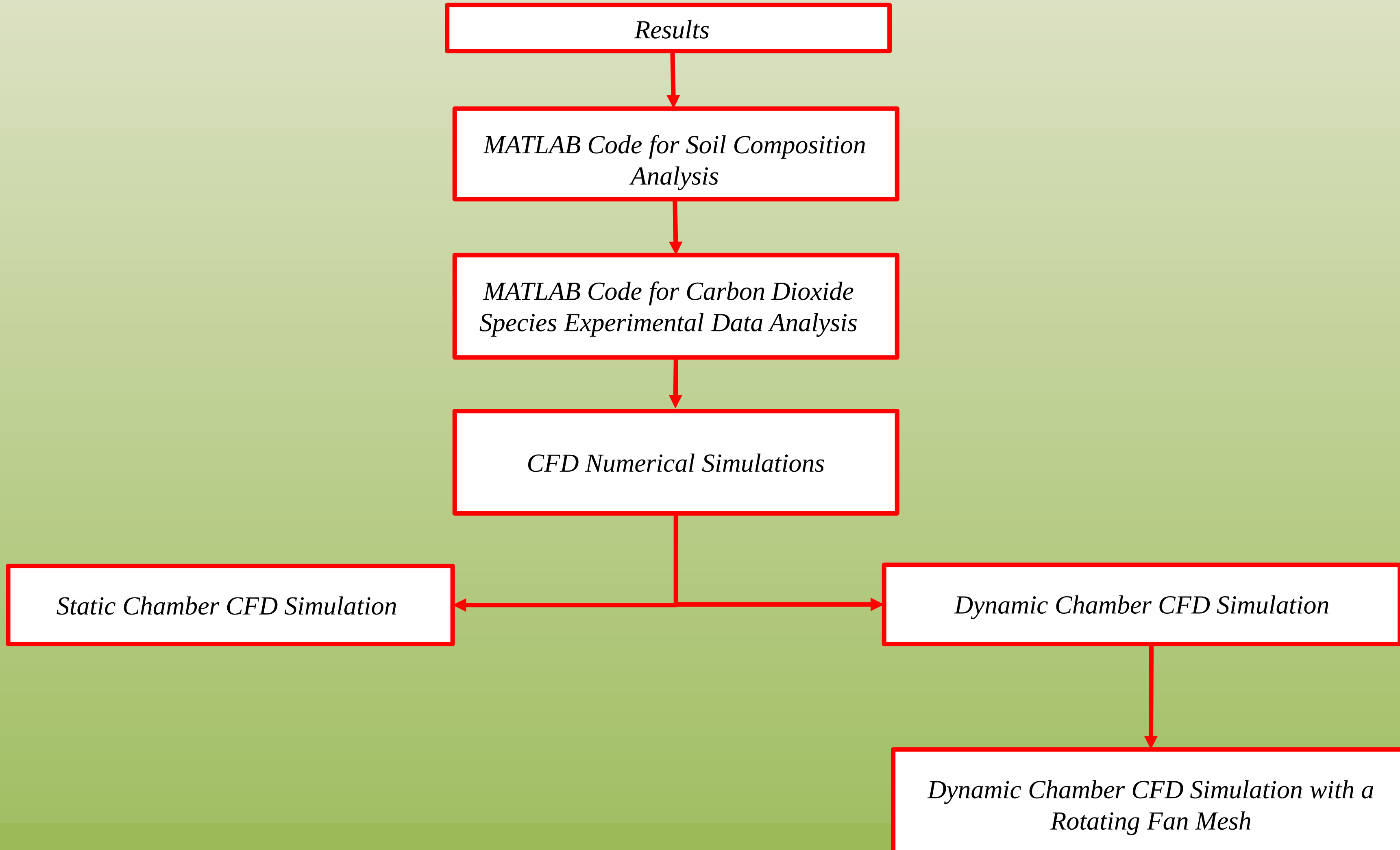
Chamber Parts Description



Chamber on Grass Land

Experimental and Numerical Results Flow Chart



MATLAB Software Interface for Soil Composition Analysis

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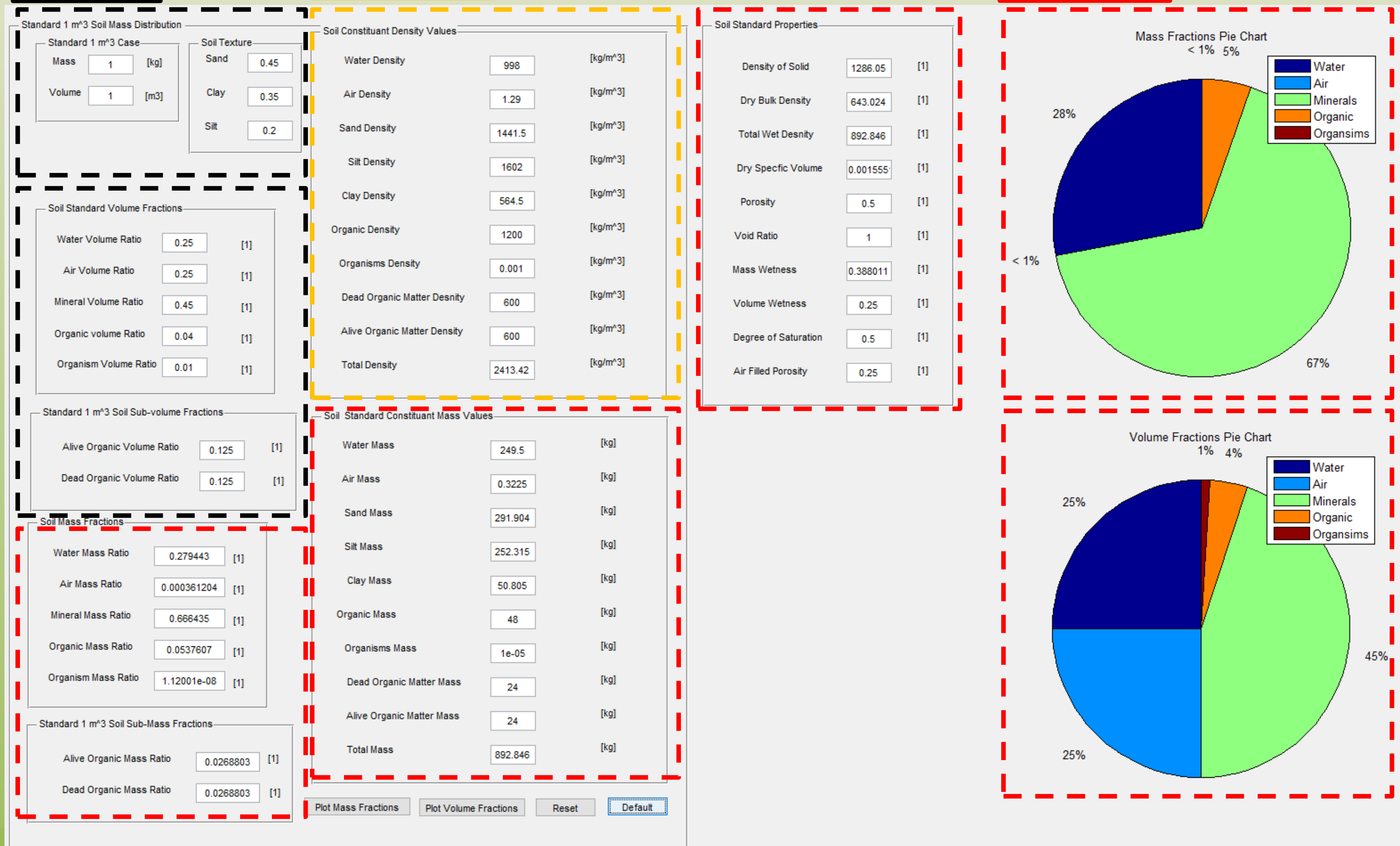
Data Input

Data Library

Data Output



MATLAB Software Interface for Soil Temperature Prediction in Relation to Depth and Physical Parameters

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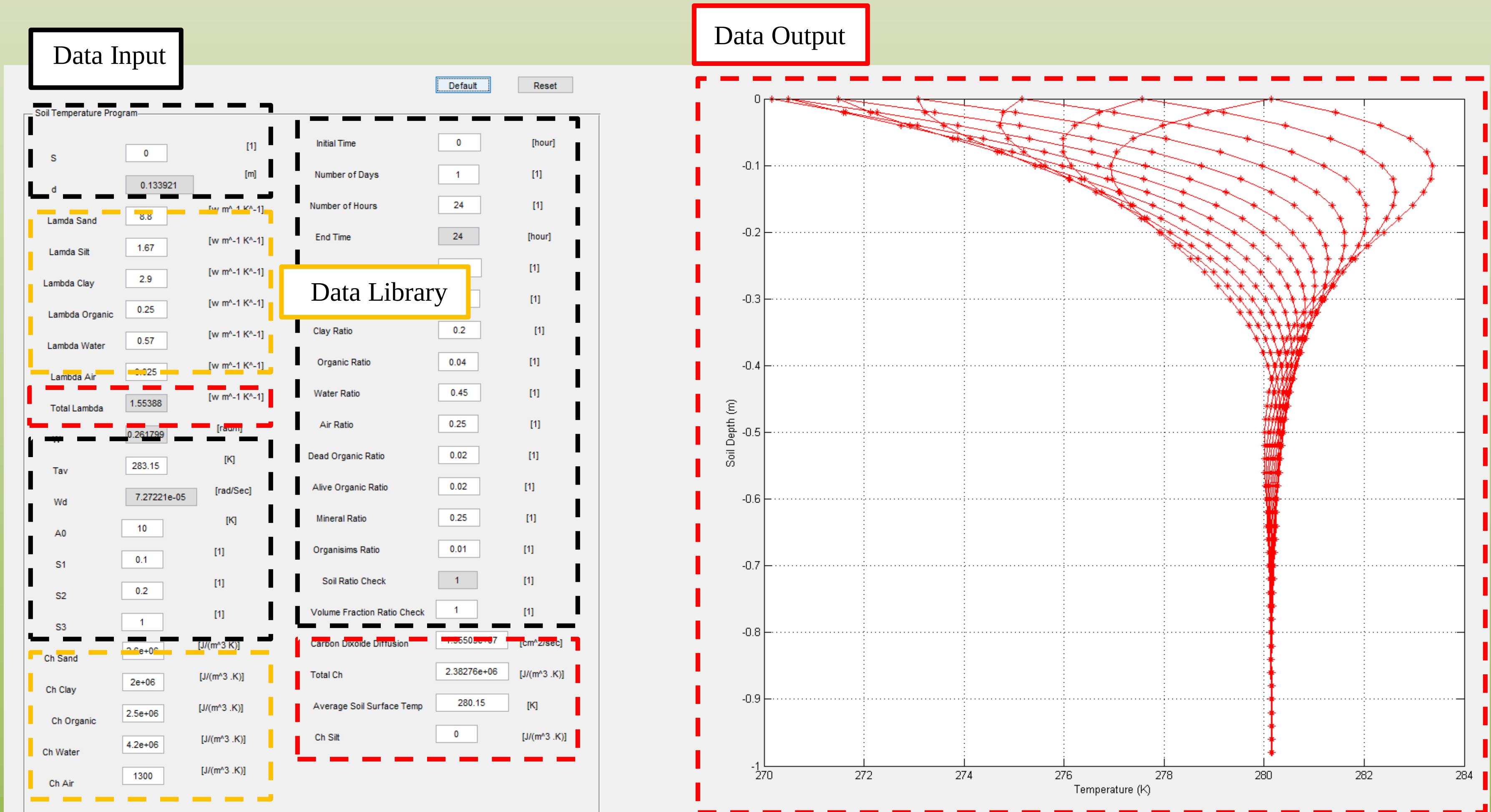
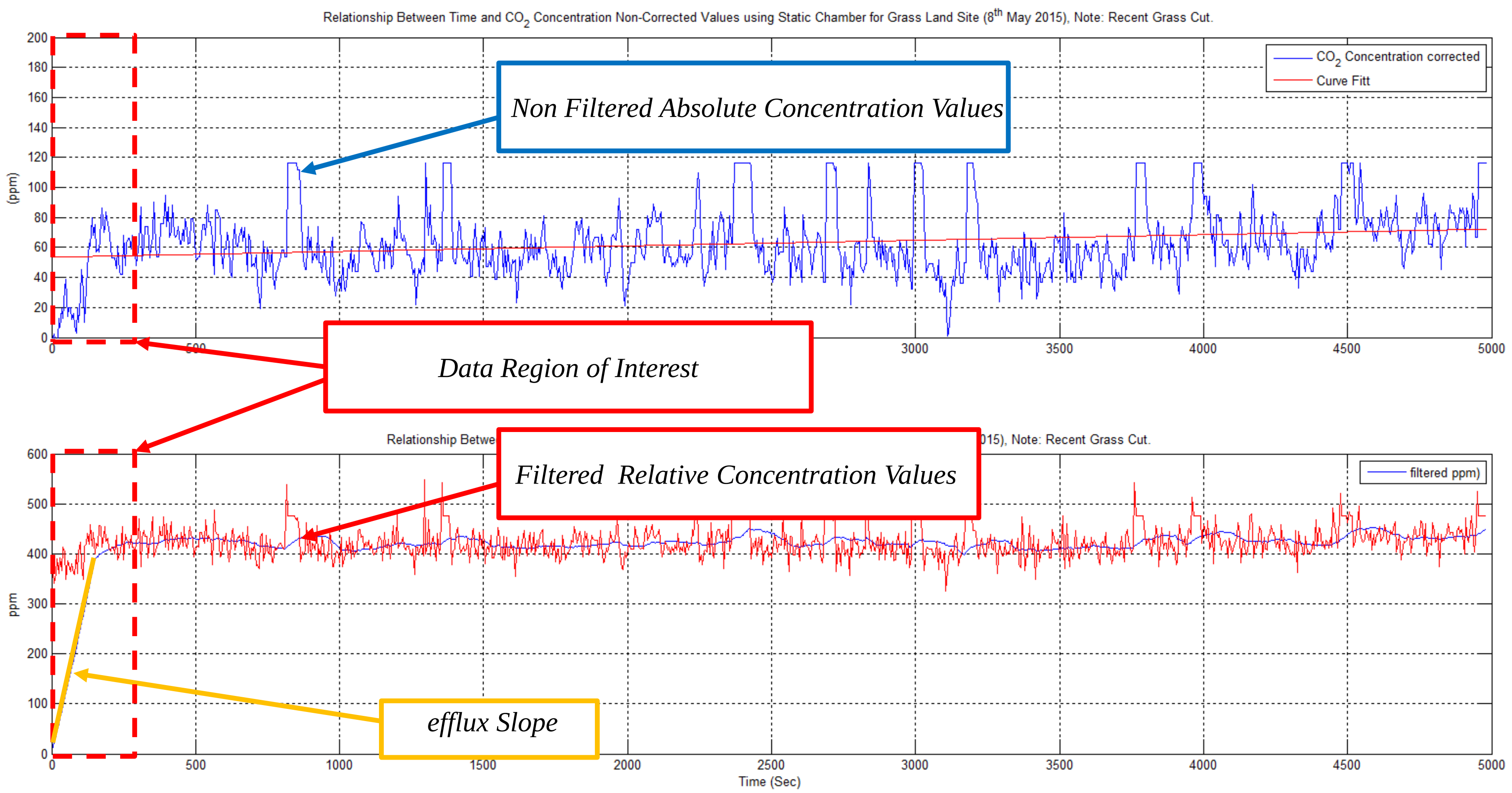


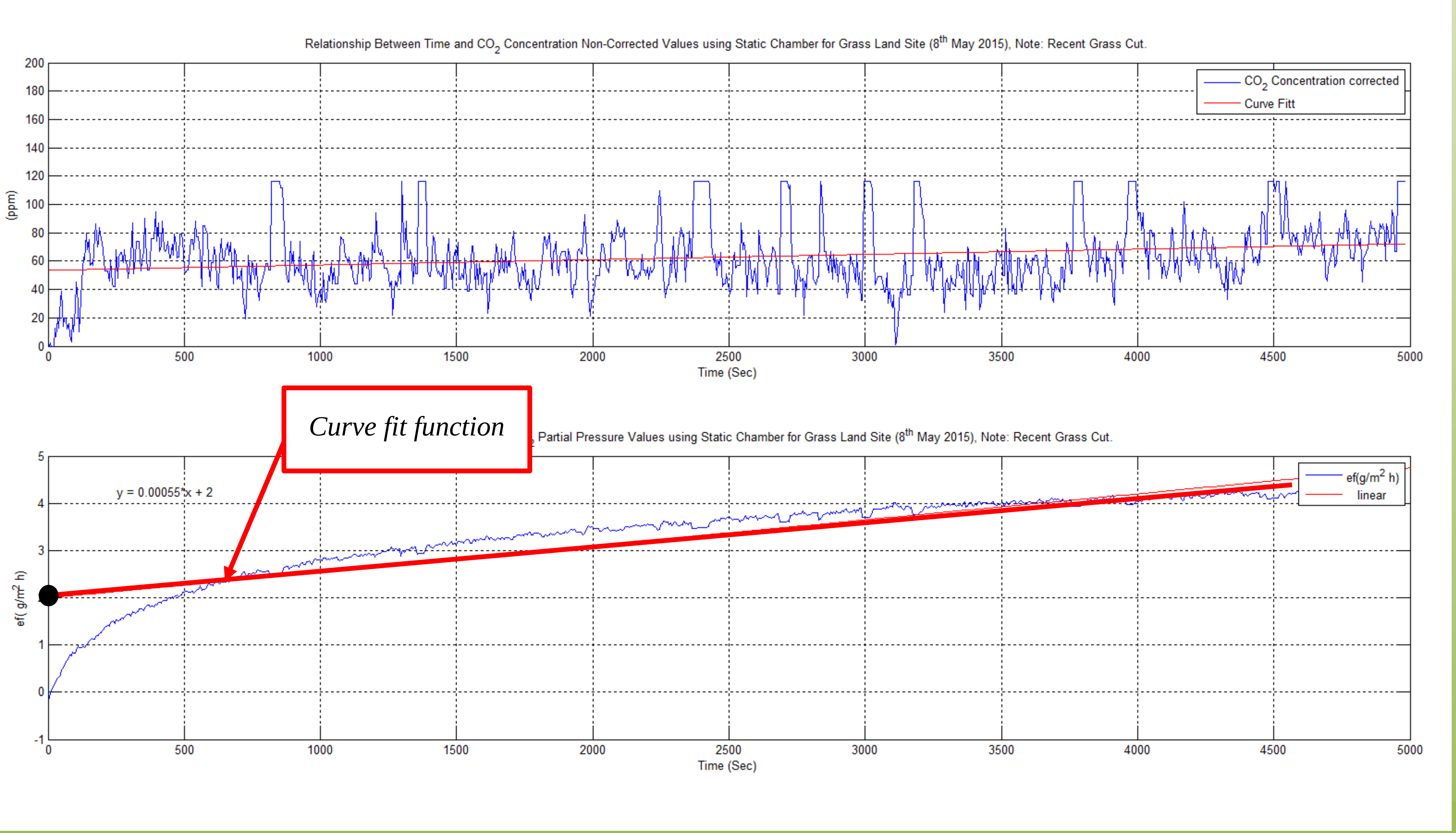
MATLAB Software Data Analysis

Absolute and relative species concentration values for carbon dioxide measured in experiments in relation to time.



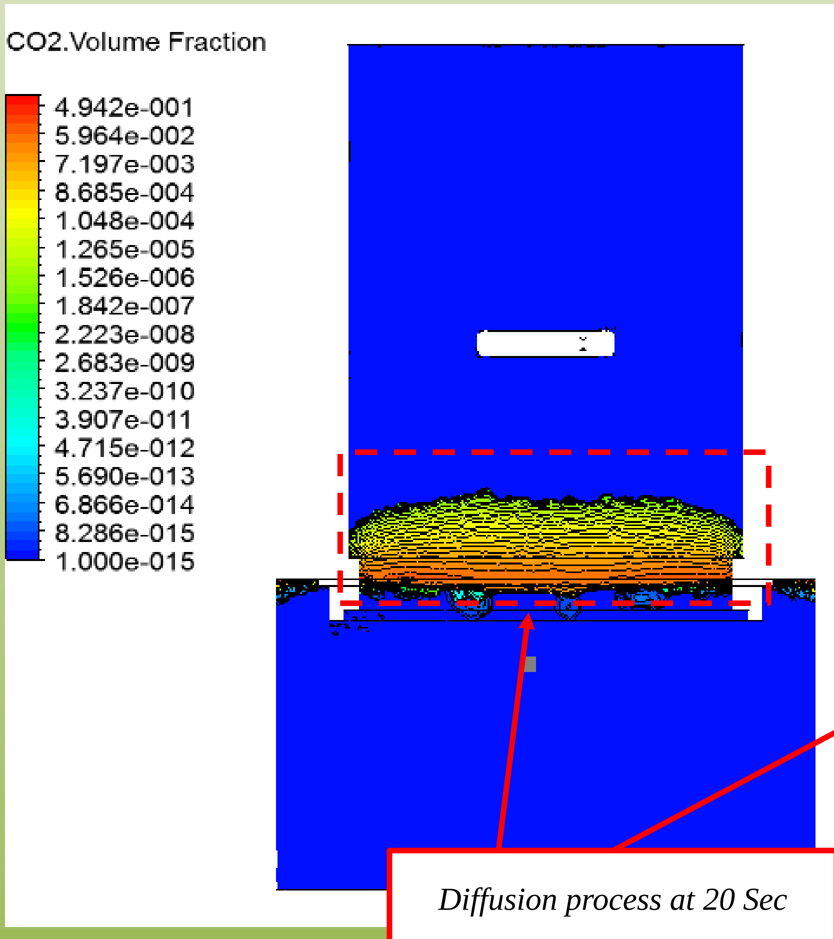
MATLAB Software Data Analysis

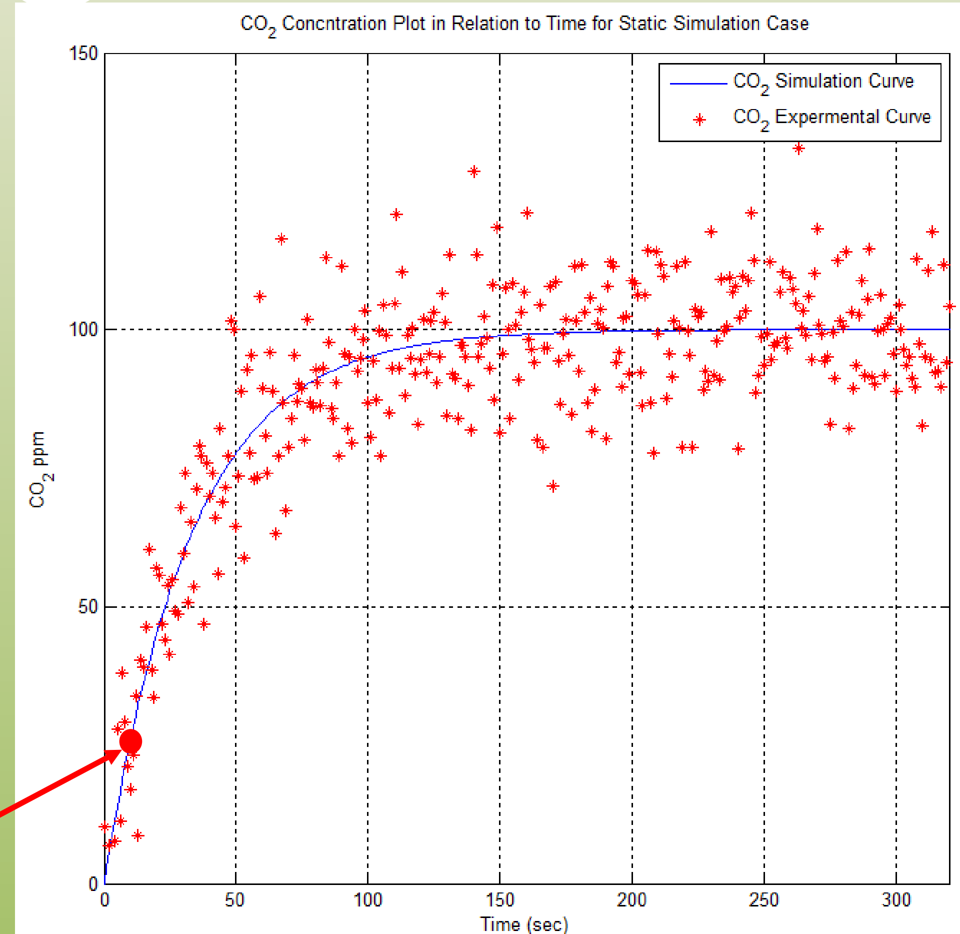
Absolute concentration values of carbon dioxide and measured efflux in relation to time



CFD Static Case Simulation

Capturing diffusion pattern within the chamber

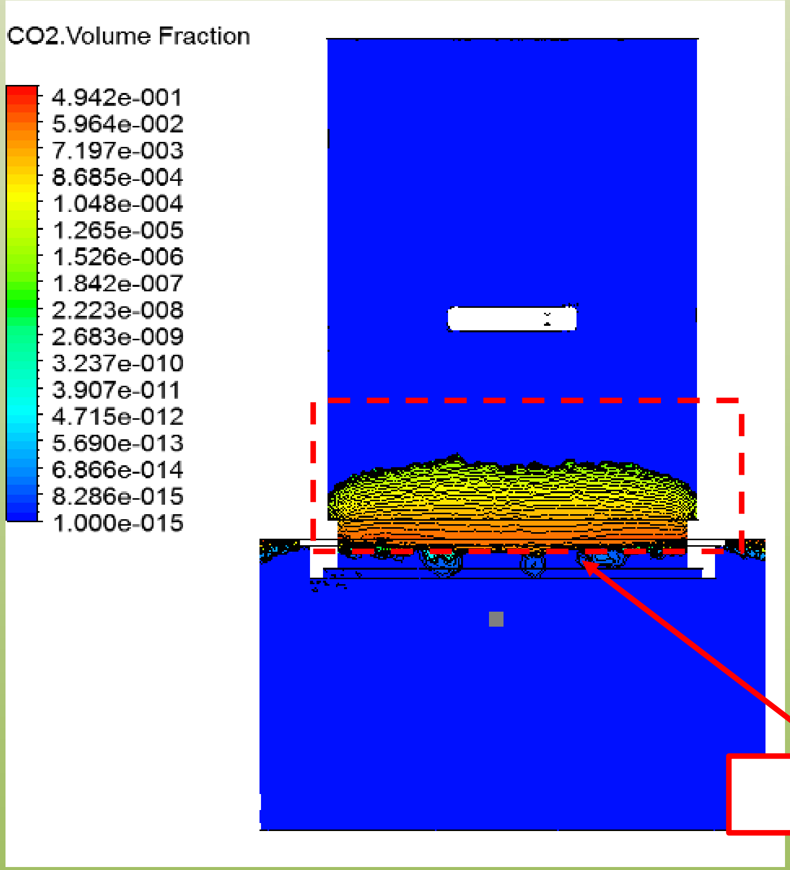




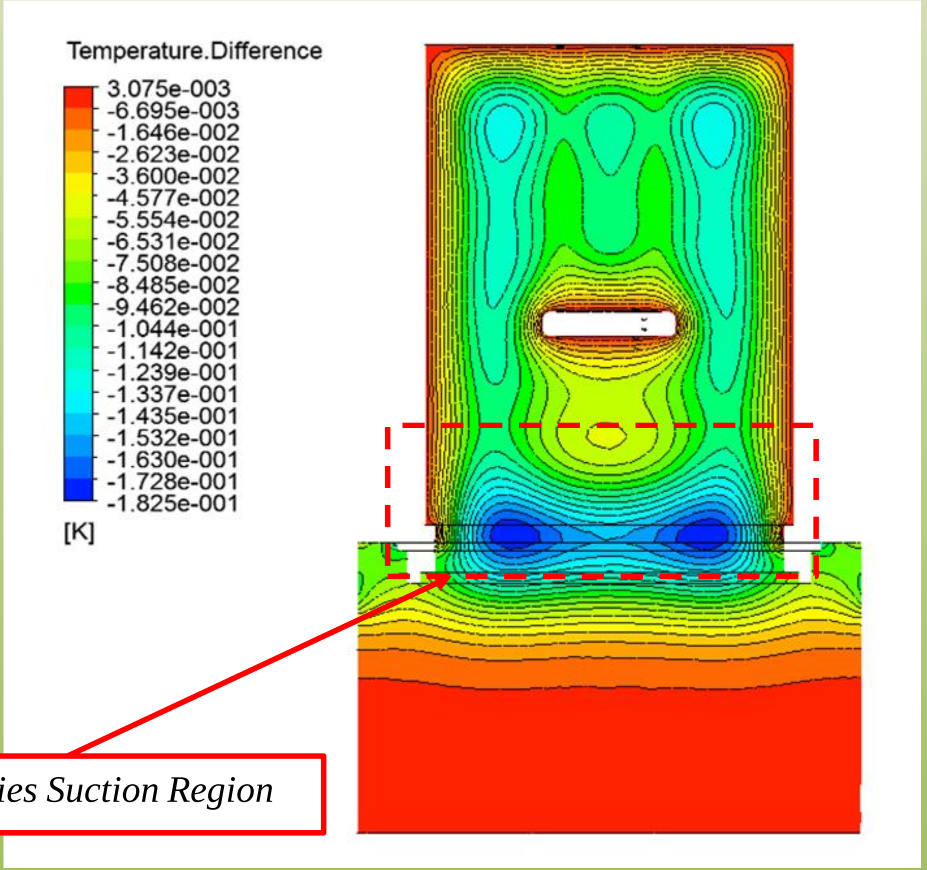
Comparison between experimental and numerical data for a static case

CFD Static Case Simulation

Species concentration distribution within the chamber



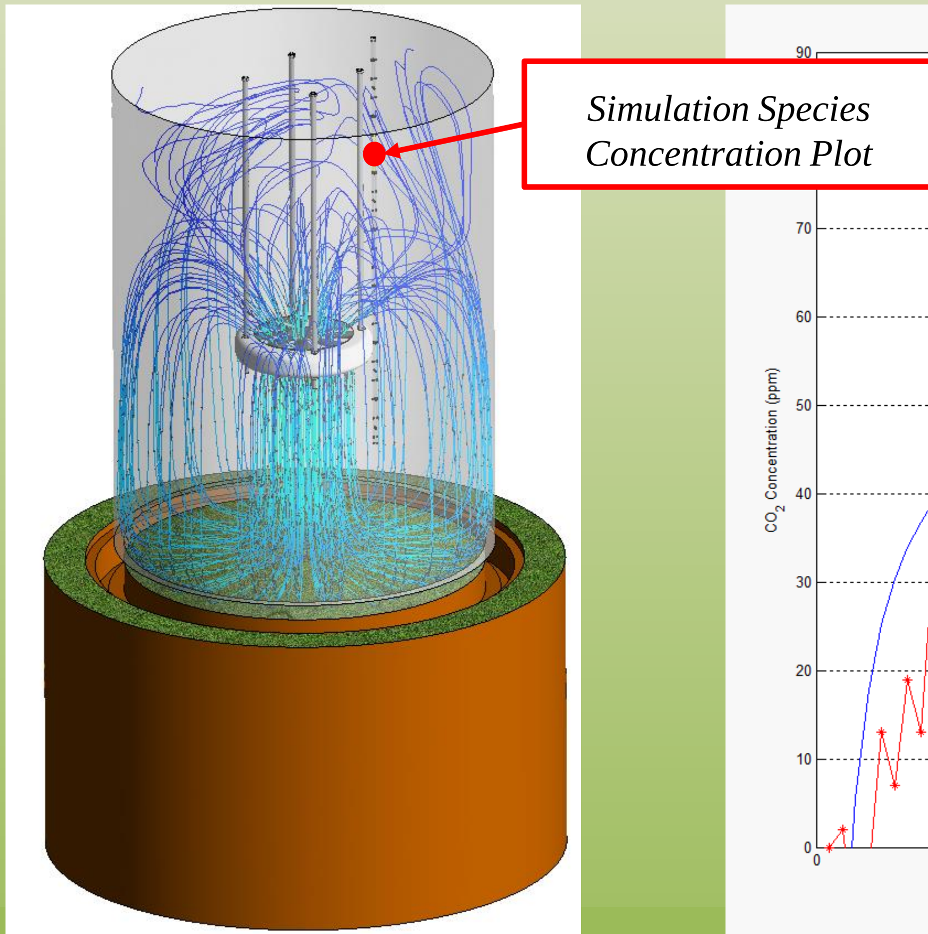
Temperature difference contour plot



Species Suction Region

CFD Dynamic Case Simulation with a Non Rotating Mesh Simulation

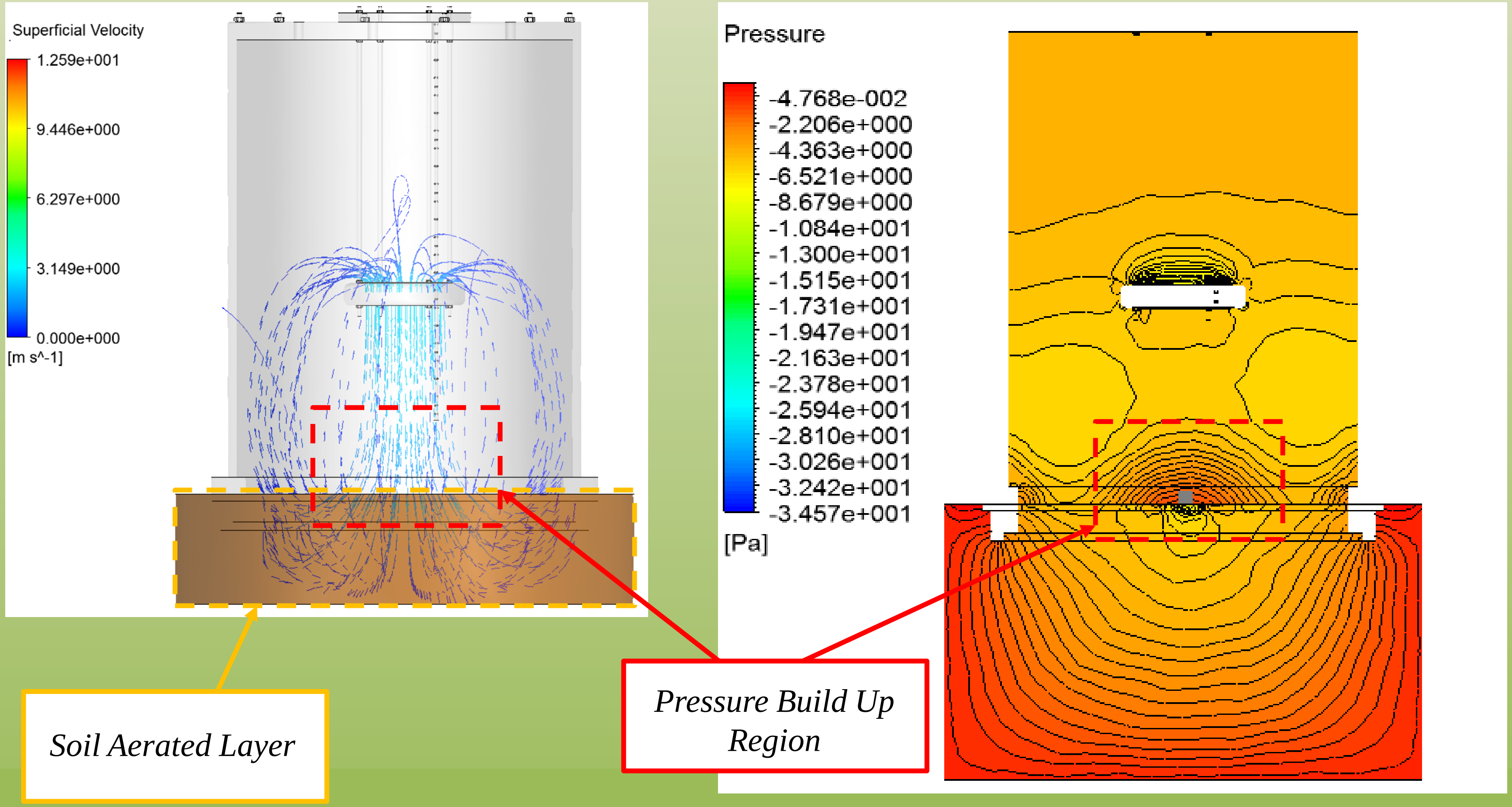
Capturing the flow pattern within the chamber



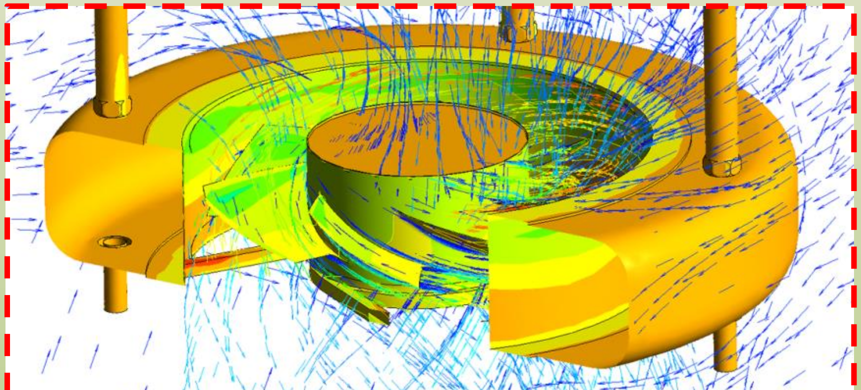
Comparison between experimental and numerical data for a dynamic case

CFD Dynamic Case Simulation with a Non Rotating Mesh Simulation

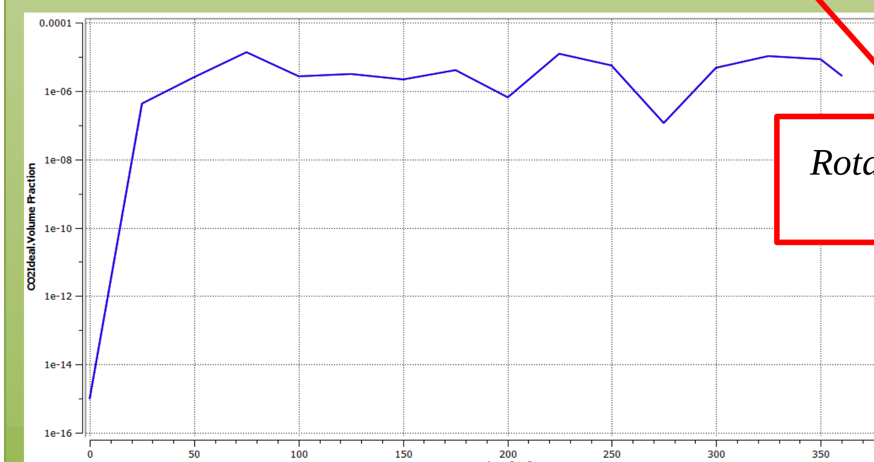
Pressure effects on the active part of the soil



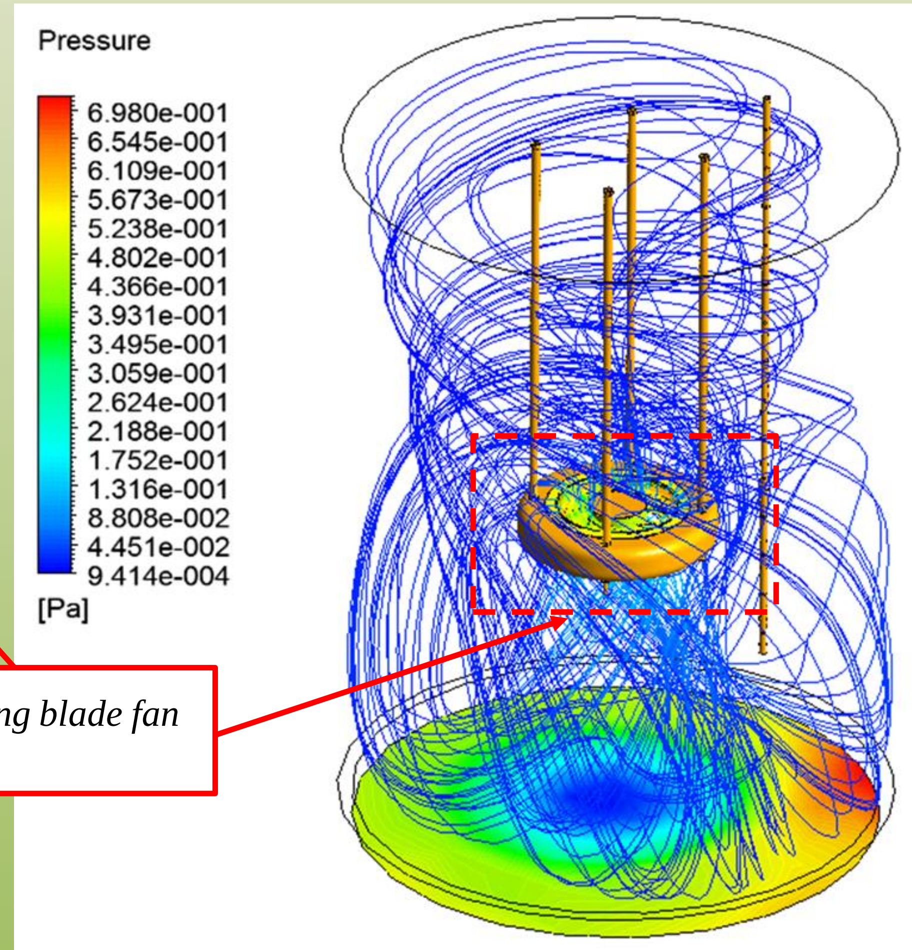
CFD Dynamic Case Simulation with a Rotating Mesh



Concentration plot for the numerical simulation of a dynamic case



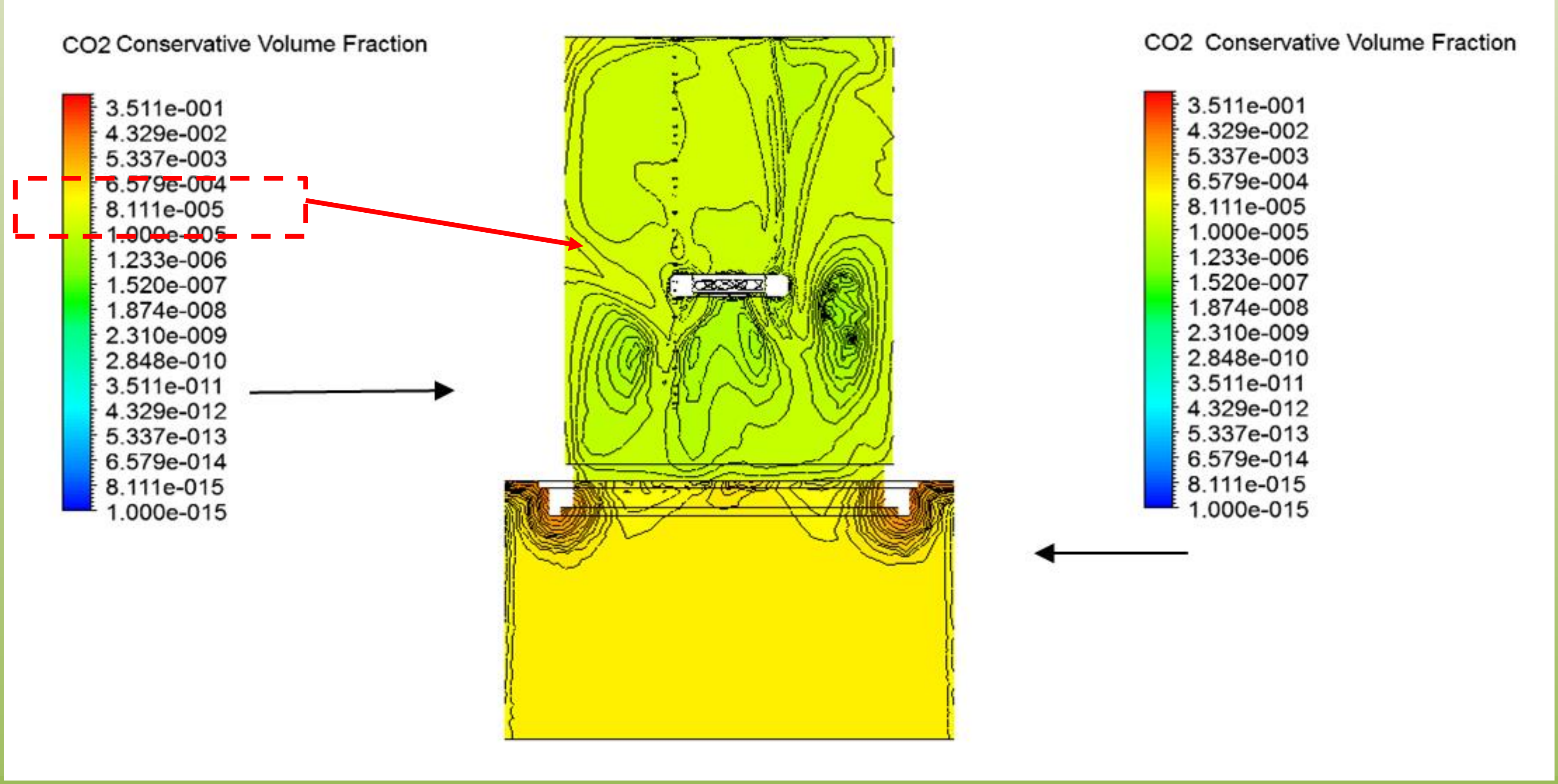
Rotating blade fan



Capturing the flow pattern within the chamber

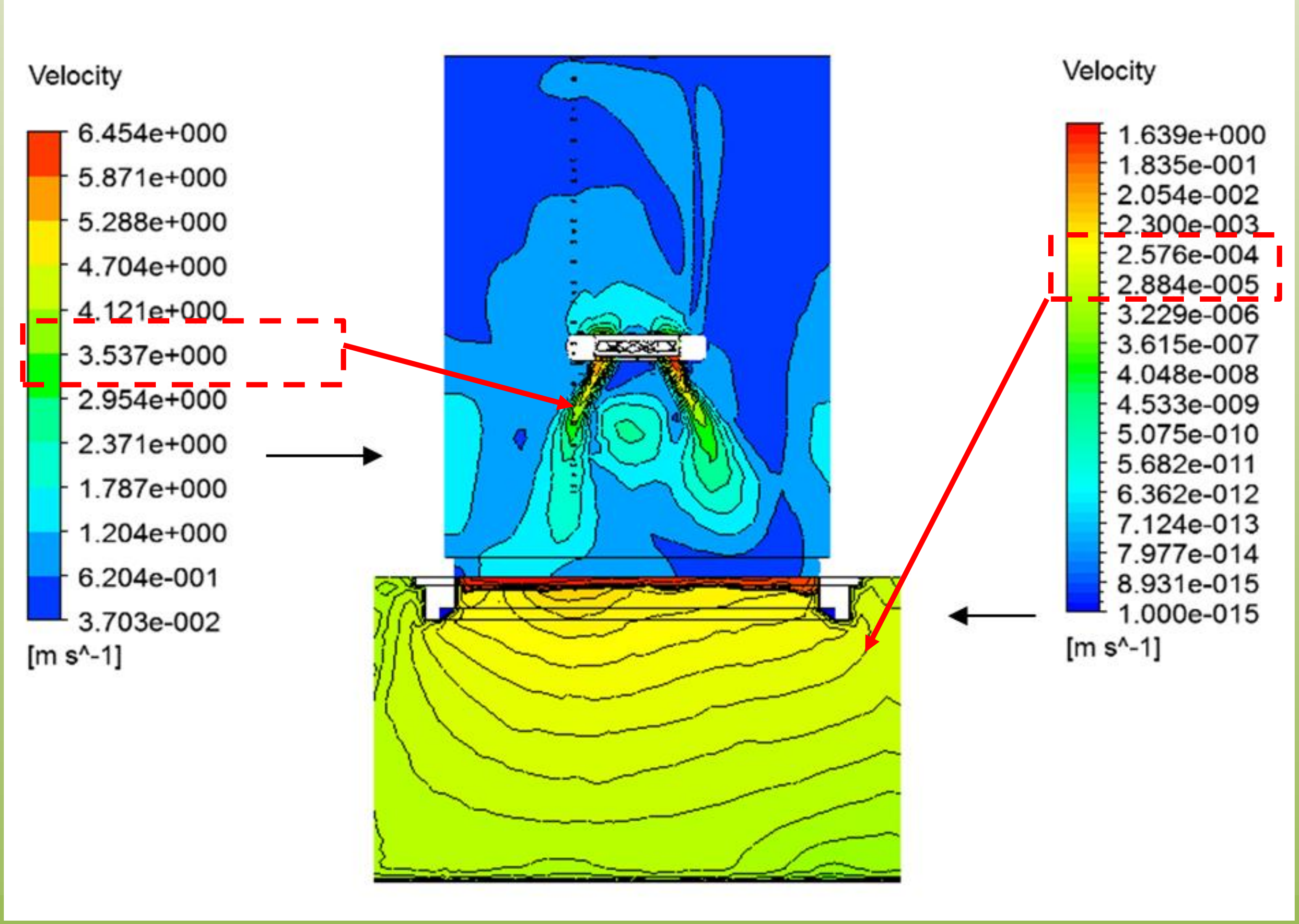
CFD Dynamic Case Simulation with a Rotating Mesh

Concentration plot for a numerical simulation of a dynamic case



CFD Dynamic Case Simulation with a Rotating Mesh

Velocity contour plot for a numerical simulation of a dynamic case



Thesis Conclusion

- Several forms of efflux equations where derived to link soil physical mechanisms, soil biological parameters and types of soil textures that affect soil biological efflux respiration.
- A new chamber design was made, tested and validated.
- The results of this project significantly contribute towards the growing research in this area. The innovations of the respiration chamber design in its operational mode whether static or dynamic delivered accurate concentration measurements to a level of ∓ 20 ppm for a frequency sampling period of 5 seconds by the used gas sensor.

Thesis Conclusion

- A software code using MATLAB was developed to incorporate interface windows that can assist in the data analysis stage of the project for the grass land location. Consequently this will help future testing and calibrating new sensor technologies compatibility with any developed chamber design.
- For both cases of a rotating fan mesh and without a fan mesh the K-Epslion turbulence model proved that it can be used to model flows in closed dynamic respiration chambers.
- The Laminar flow model can be applied to model the static flow case where mass diffusion is dominant.
- The Darcy equation proved to be applicable and can be used in porous media for a grassland location.

Publications

Conference Paper

- A NUMERICAL AND EXPERIMENTAL STUDY OF A NEW DESIGN OF CLOSED DYANMIC RESPIRATION CHAMBERS. Ahmed Al Makky, Olabi, Alaswad, Gibbson, and Shigeng Song.

Journal Paper (Submitted and Under Review)

- A NUMERICAL AND EXPERIMENTAL STUDY OF A NEW DESIGN OF CLOSED DYANMIC RESPIRATION CHAMBER Authors: Ahmed Al Makky; A. Alaswad; D. Gibson; A. G. Olabi. Article Type: Research Paper Environmental Pollution.
- DEVELOPMENTS ON SOIL EMISSION MEASUREMENTS PART I. Authors: Ahmed Al Makky; A. Alaswad; D. Gibson; A. G. Olabi. Article Type: Renewable & Sustainable Energy Reviews.
- DEVELOPMENTS ON SOIL EMISSION MEASUREMENTS PART II. Authors: Ahmed Al Makky; A. Alaswad; Des Gibson; A. G. Olabi. Article Type: Renewable & Sustainable Energy Reviews.

Thank You