



Modelling pollution in the urban environment using neural networks

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CONTENTS

1 Introduction

4 Results

2 Literature Review

5 Conclusion

3 Methodology

INTRODUCTION

Topic

Air Pollution

Public Health Concern

Question

Prediction Accuracy

Limitations of Traditional
Methods

Answer

Comprehensive
Framework incorporating

- Neural Networks
- Computational Fluid Dynamic
- Data Assimilation

LITERATURE REVIEW

1

Neural Networks & Computational Fluid Dynamics

- NN-based Solver for PDEs
- Potential and Performance

Using ai libraries for incompressible computational fluid dynamics (Chen et al.)

2

Traditional Modelling v.s. Convolutional VAE

- Generation of Predictions
- Computational Resources
- Reducing Dimensionality

Bridging observations, theory and numerical simulation of the ocean using machine learning (Sonnewald et al.)

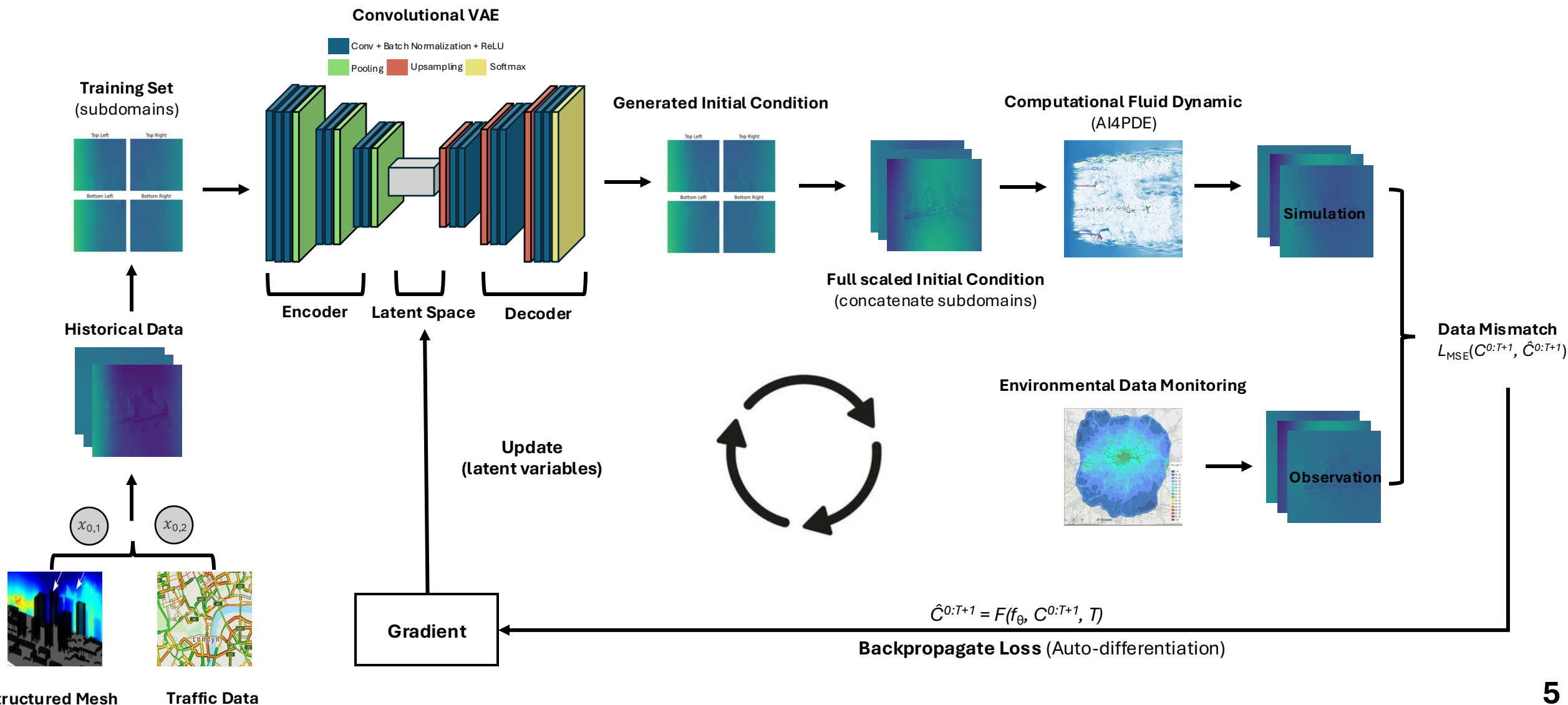
3

Assimilation with Observational Data

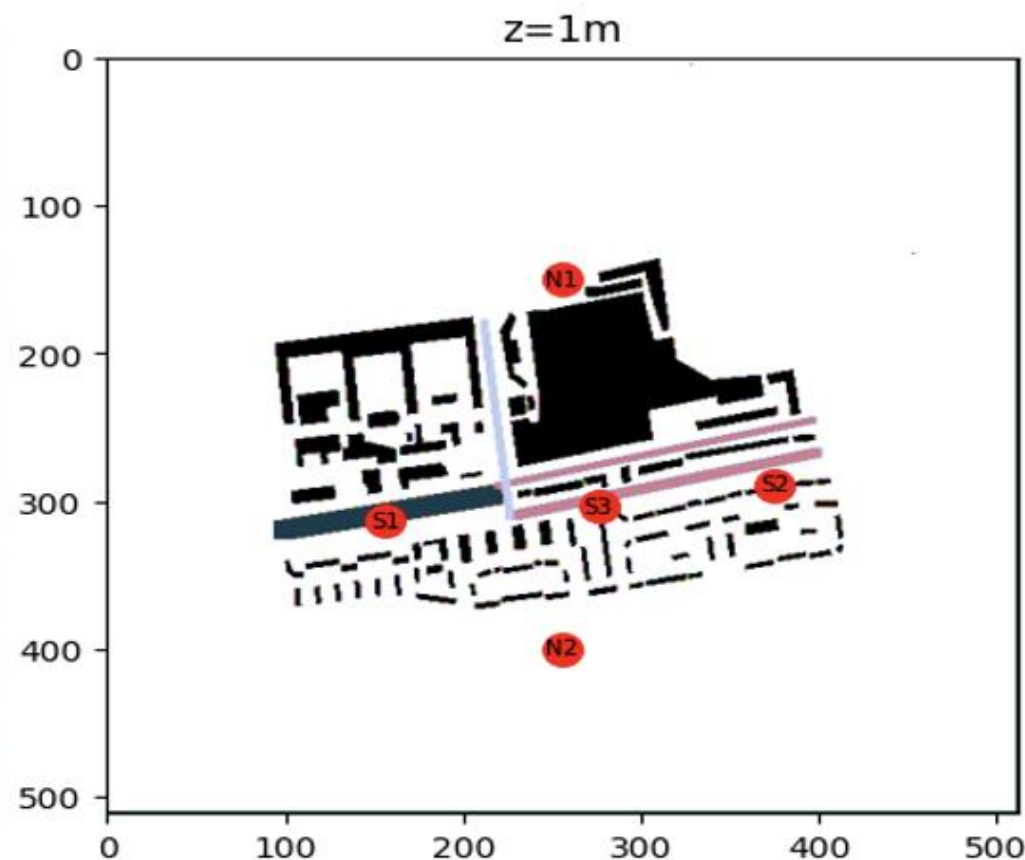
- Refining the Model
- Adjusting to Realistic Environment
- Accuracy of Predictions

Data assimilation in the latent space of a neural network (Amendola et al.)

METHODOLOGY – Overview of the Workflow

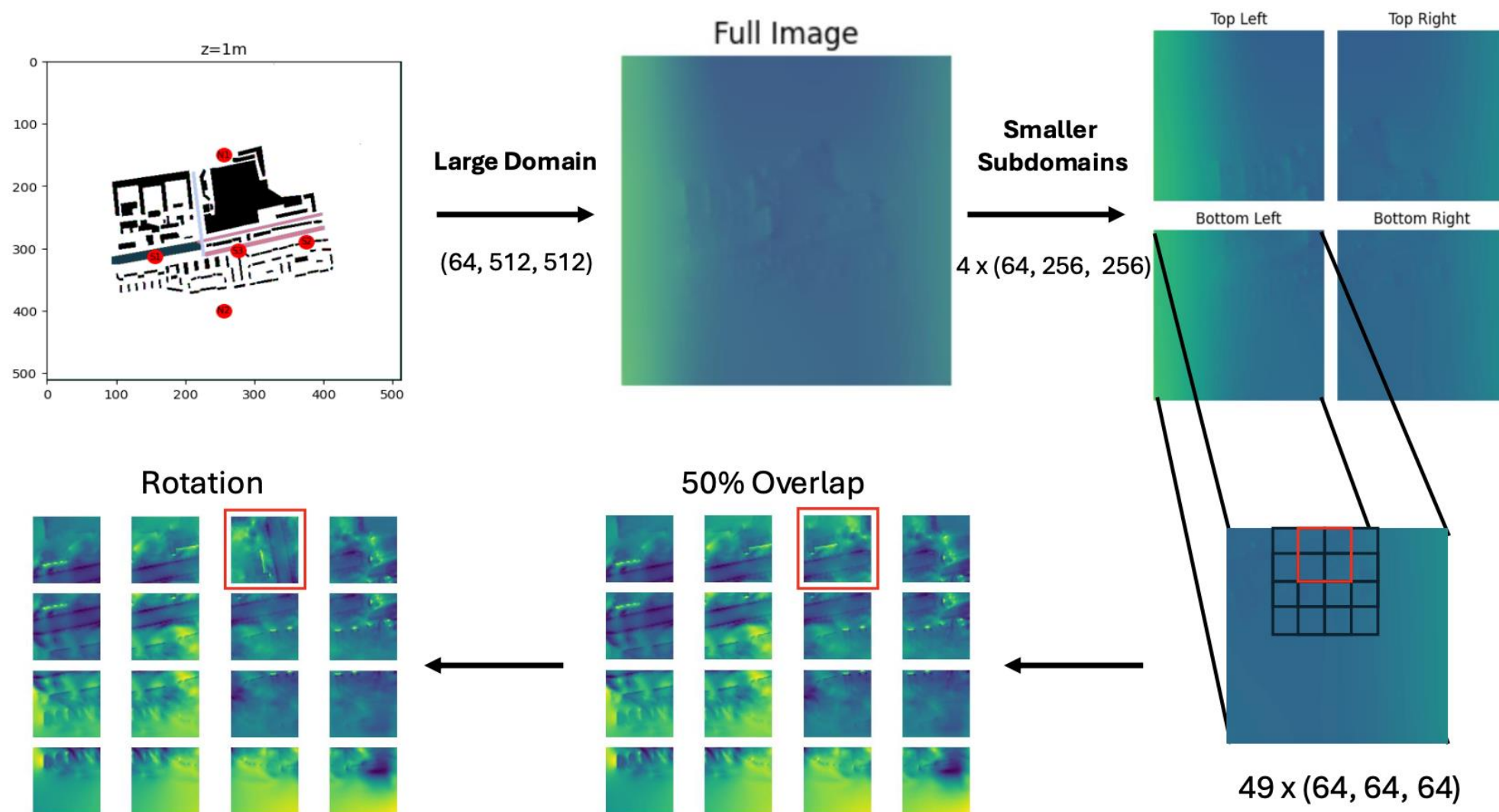


METHODOLOGY - Setup of a Test Case



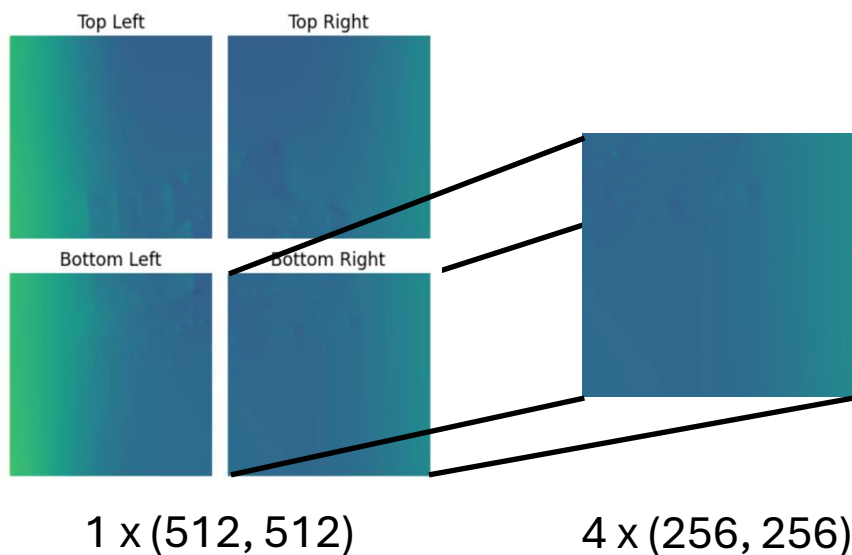
Sensor locations: Optimising sensor location using neural networks applied to air pollution (Zhan Xuan & Hong Xuan)

METHODOLOGY – Data Preprocessing

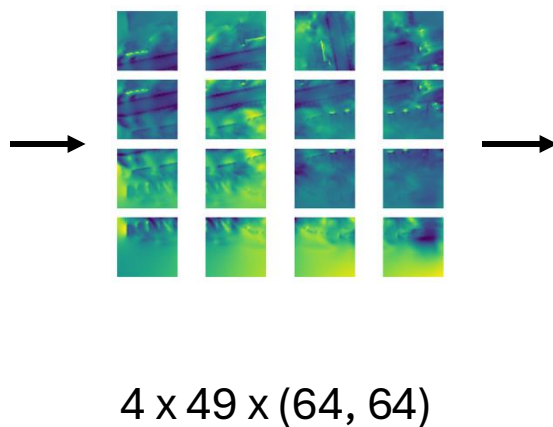


METHODOLOGY – Convolutional VAE

For Each Subdomain
(4 in total)



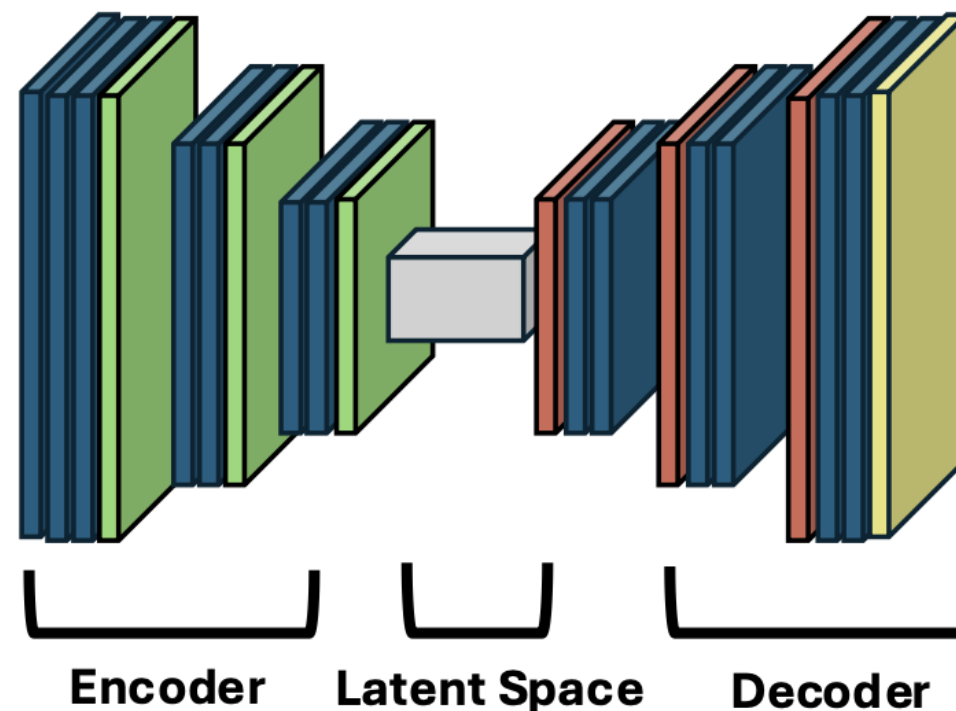
Priors
(Overlap, Rotation)



$$3 \times 64 \times 64 \times 64 = \underline{786,432}$$

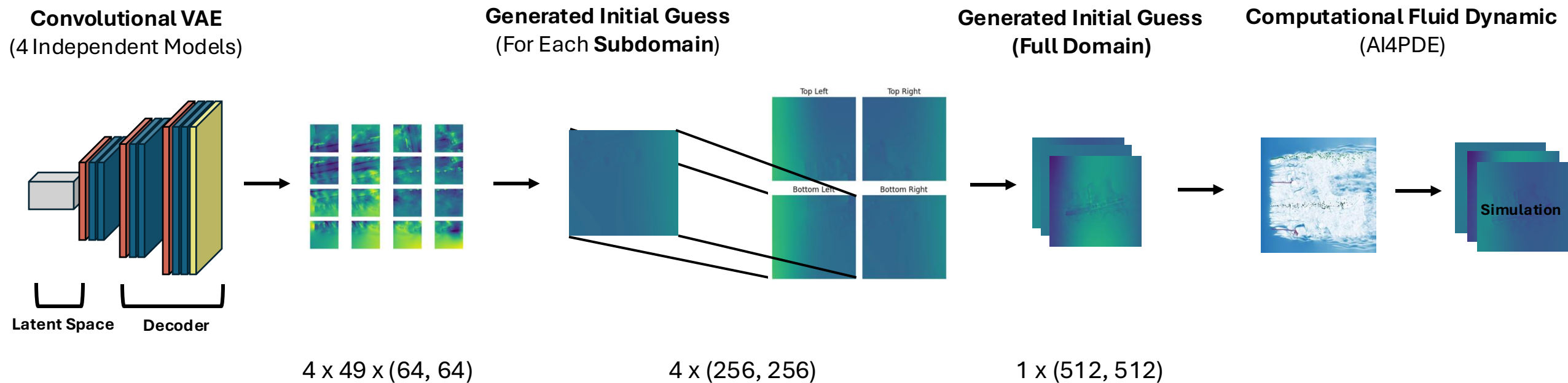
Convolutional VAE

Conv + Batch Normalization + ReLU
Pooling Upsampling Softmax



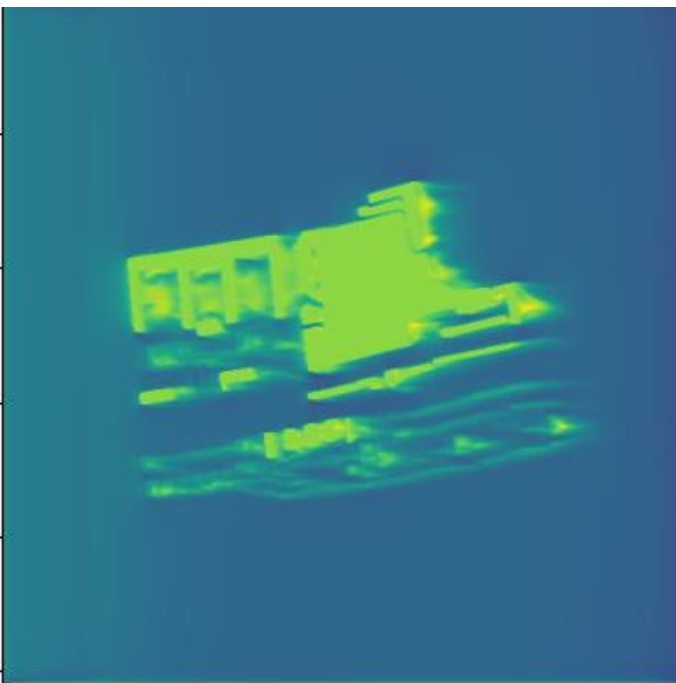
$$64 \times 8 \times 8 \times 8 = \underline{32,768}$$

METHODOLOGY – Convolutional VAE

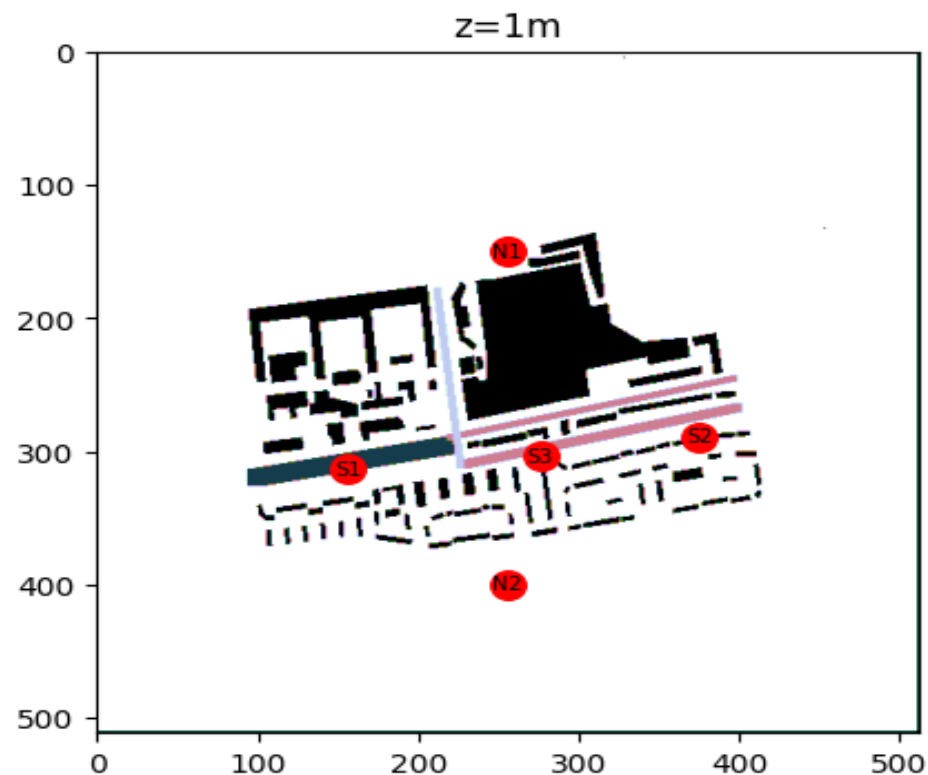


METHODOLOGY – CFD Simulation

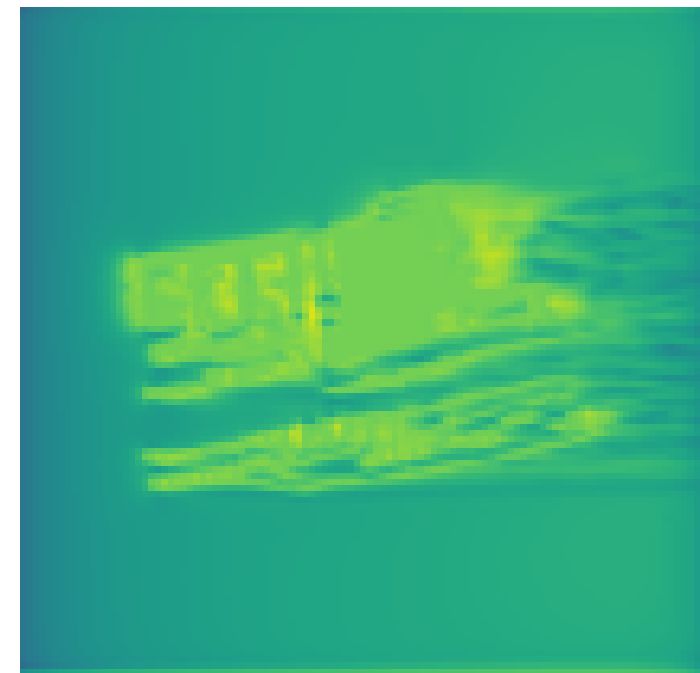
Generated Initial Condition



Computational Fluid Dynamic Model
(10000 timesteps)



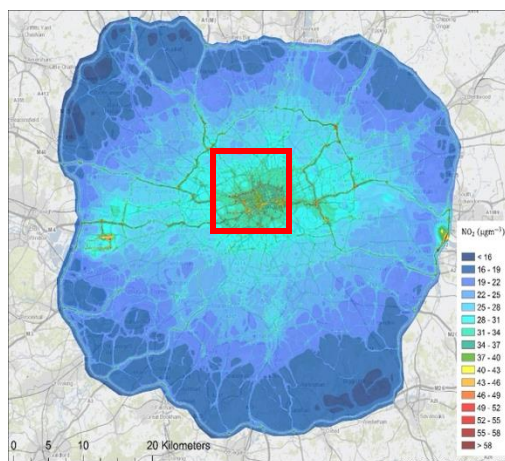
Simulation Result



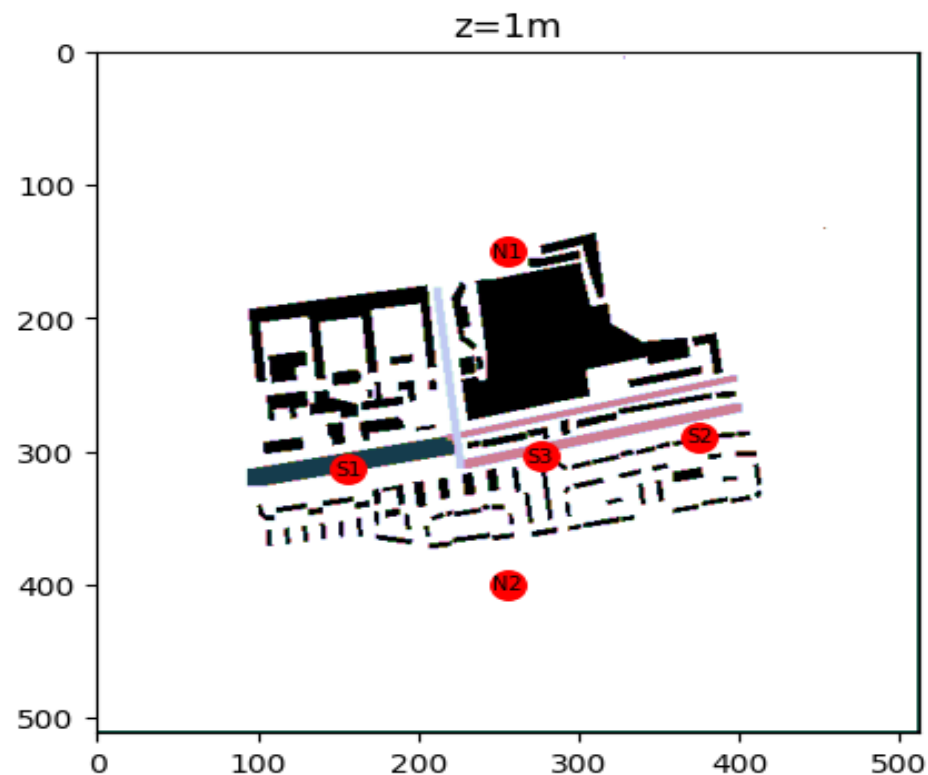
METHODOLOGY – Observational Data

Raw Data
(cleansing, missing values)

A4636	131	37	21	28		45
A2524	86	20	24	21	1	20
A3713	75	17	13	18		27
A4452	73	5	33	17		18
A4088	72	14	16	12	2	28
A2103	68	14	13	14	1	26
A2156	68	16	13	19	2	18
A3681	66	12	16	9	1	28
A1366	50	11	15	12		12
A2610	39	5	7	12		15



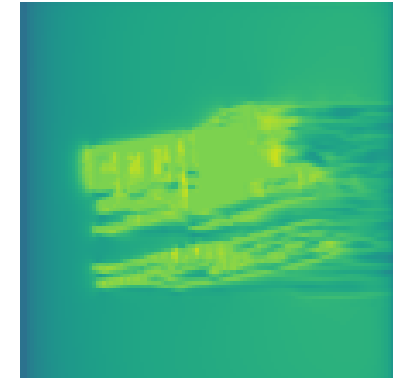
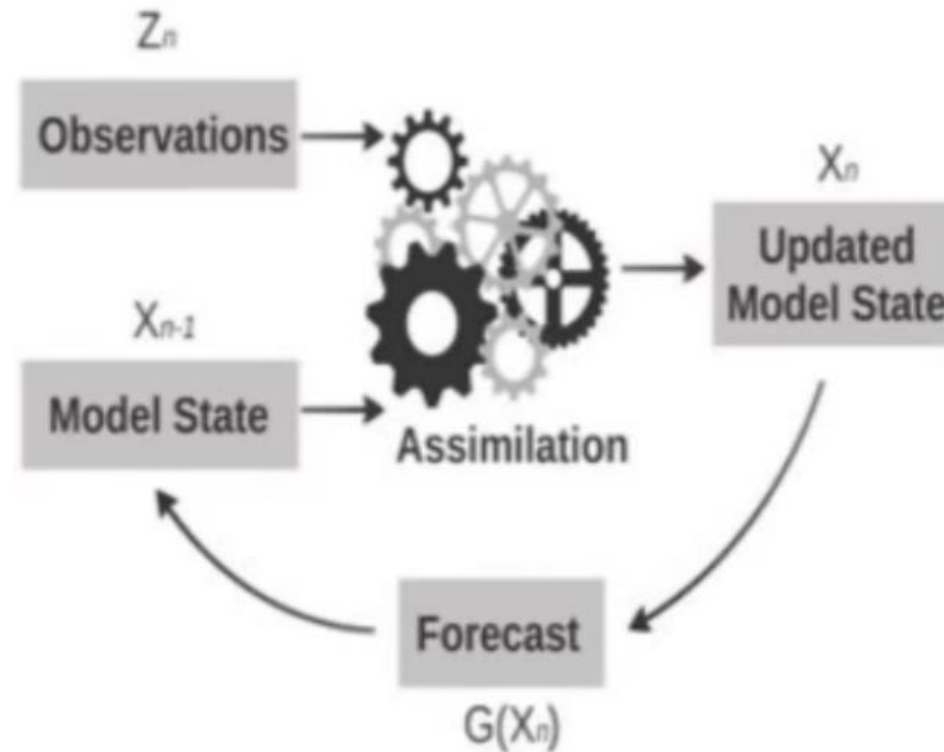
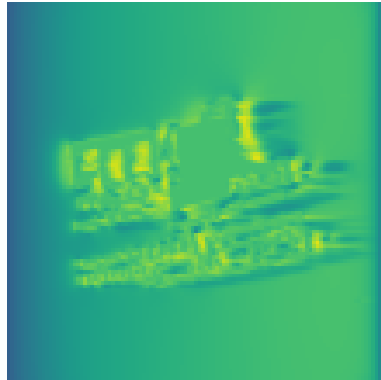
Computational Fluid Dynamic Model
(1 timesteps to create structured mesh)



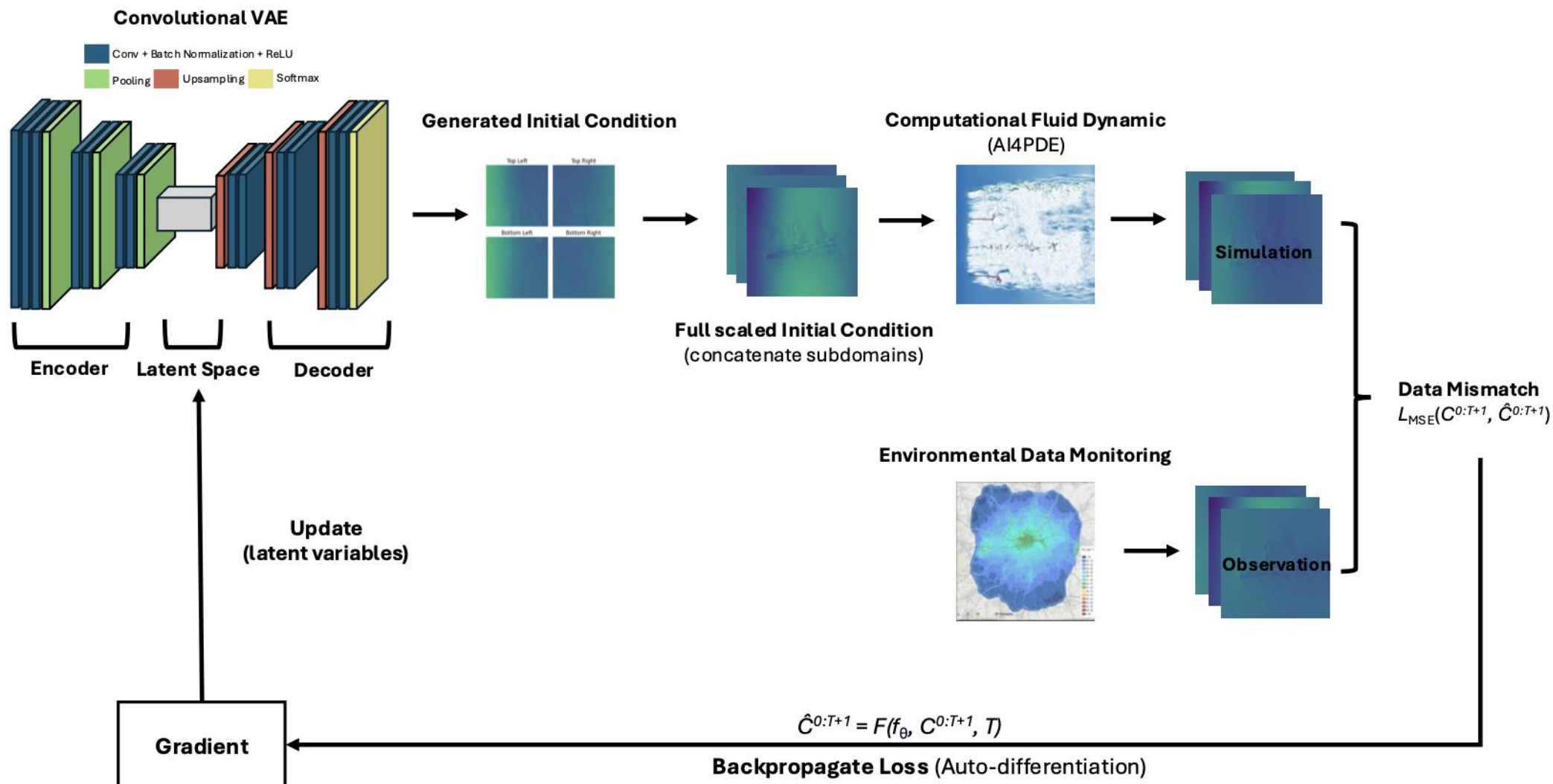
Observational Data



METHODOLOGY – Data Assimilation



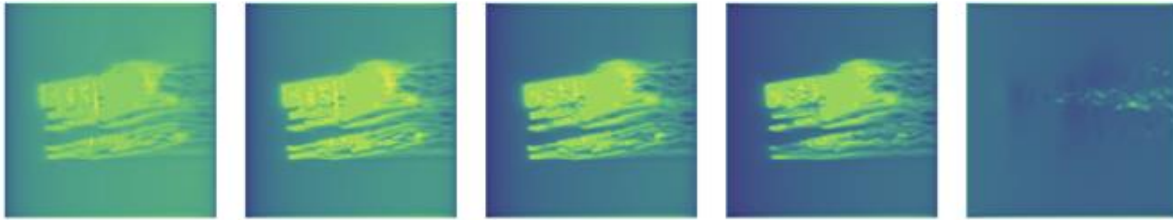
METHODOLOGY – Data Assimilation Loop



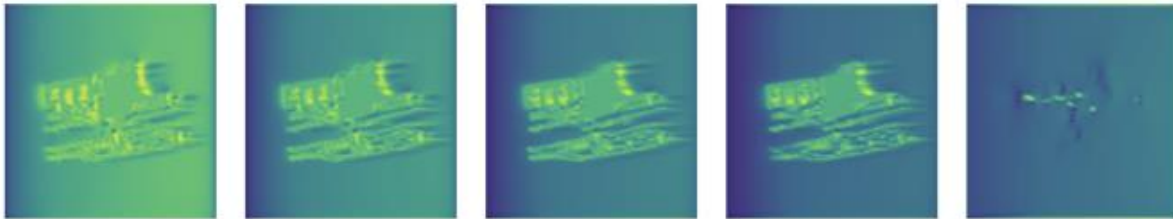
RESULTS - Velocity and Pollution Field

Wind Velocity in X-Direction

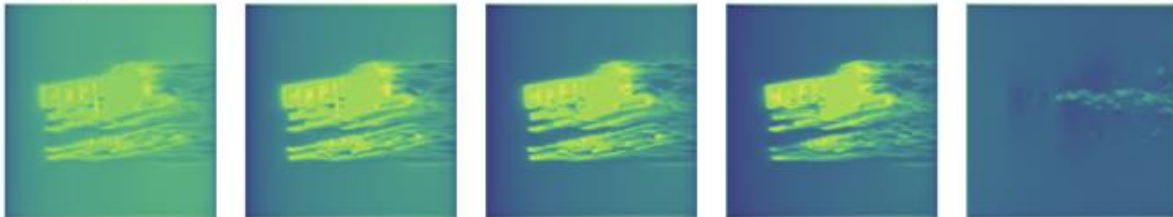
Simulation



Observation



Updated



Pollution Concentration Field

Simulation



Observation



Updated



RESULTS - Velocity and Pollution Field

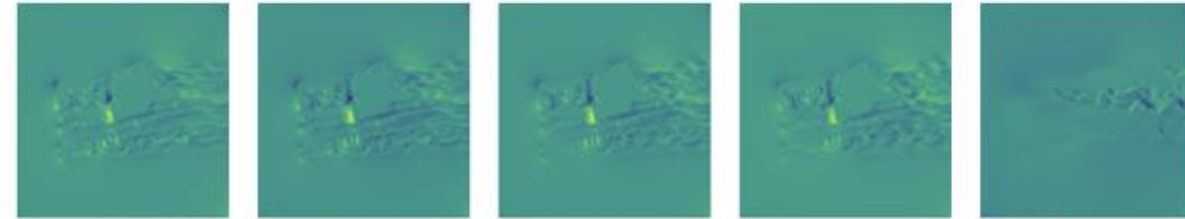
Wind Velocity in Z-Direction

Wind Velocity in Y-Direction

Simulation



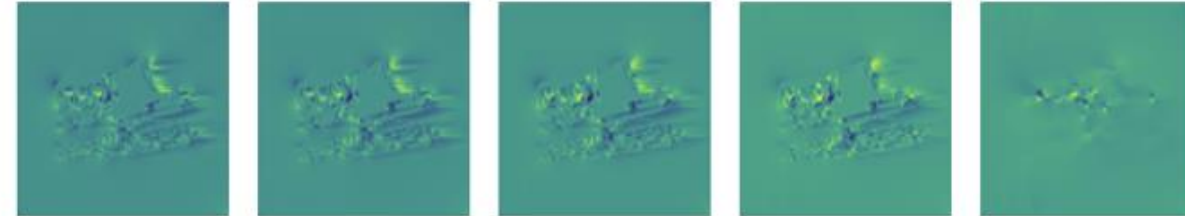
Simulation



Observation



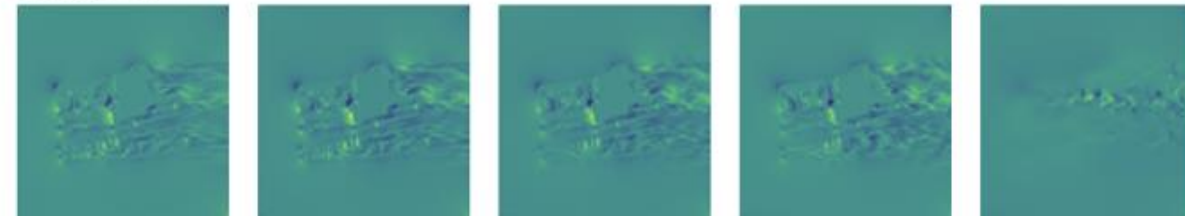
Observation



Updated



Updated



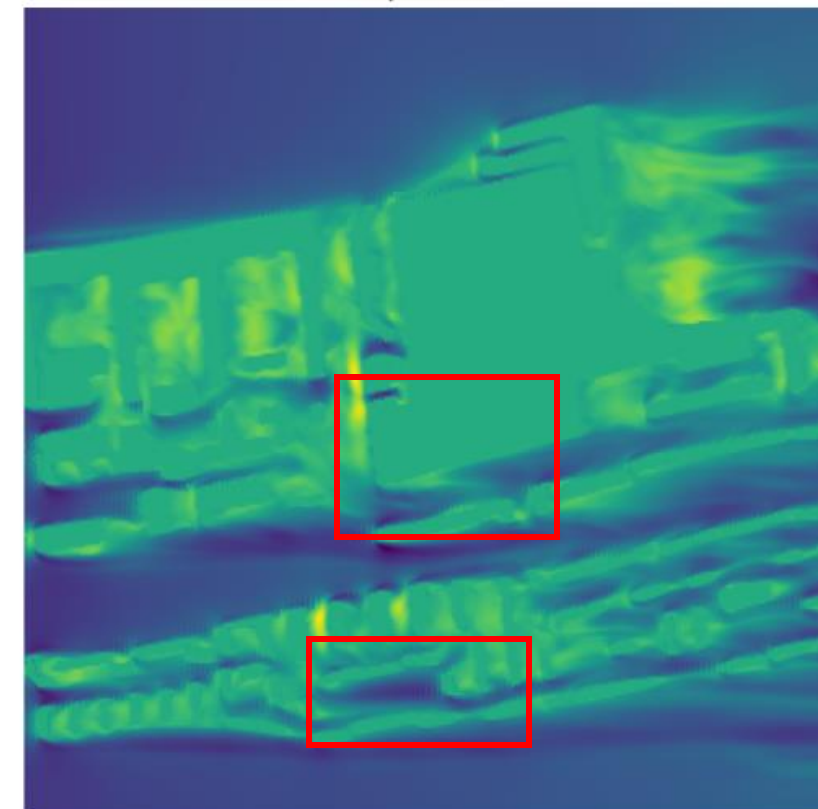
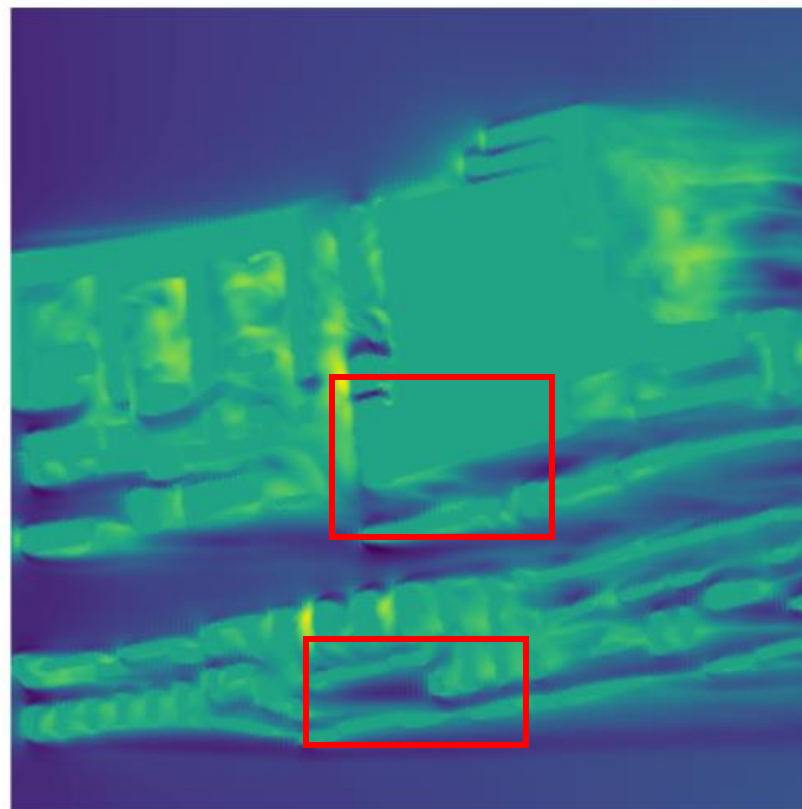
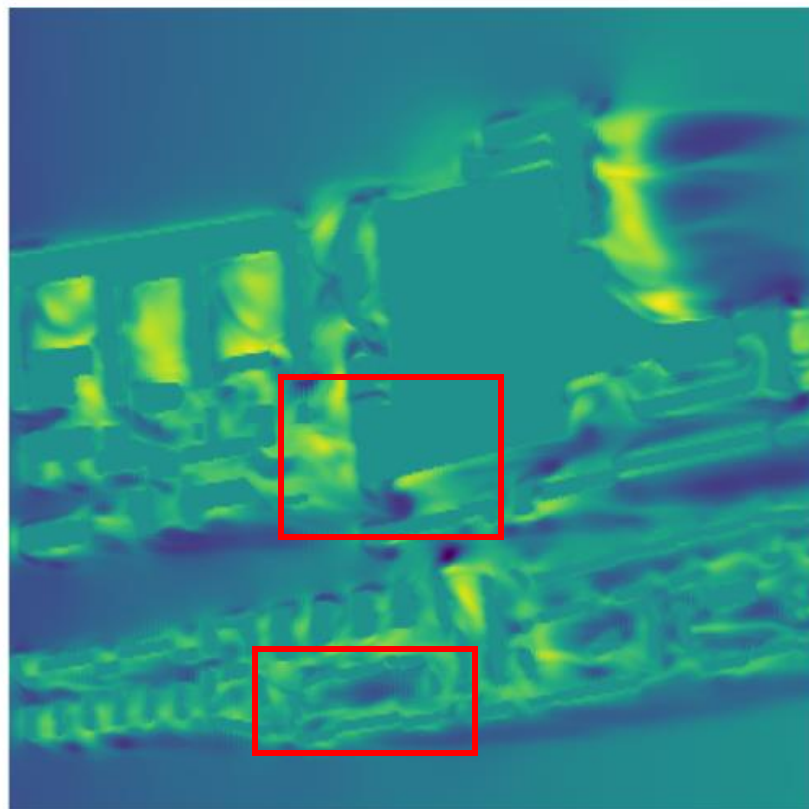
RESULTS - Detailed Analysis

(Velocity Field in x-direction at 1-Meter Height)

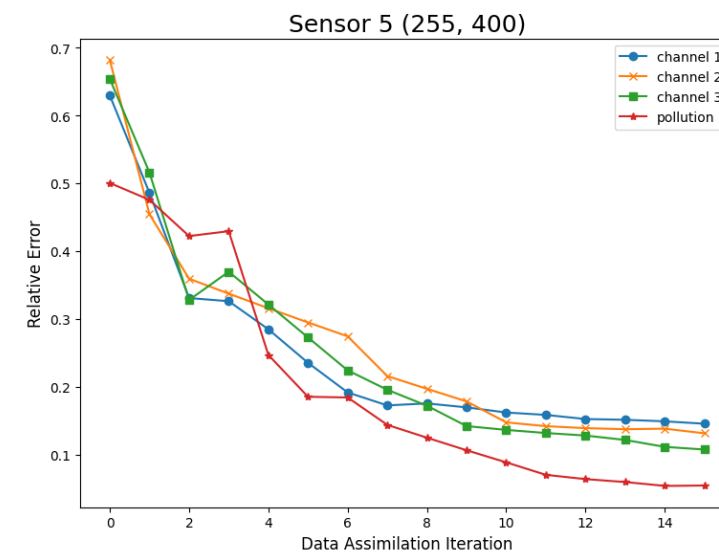
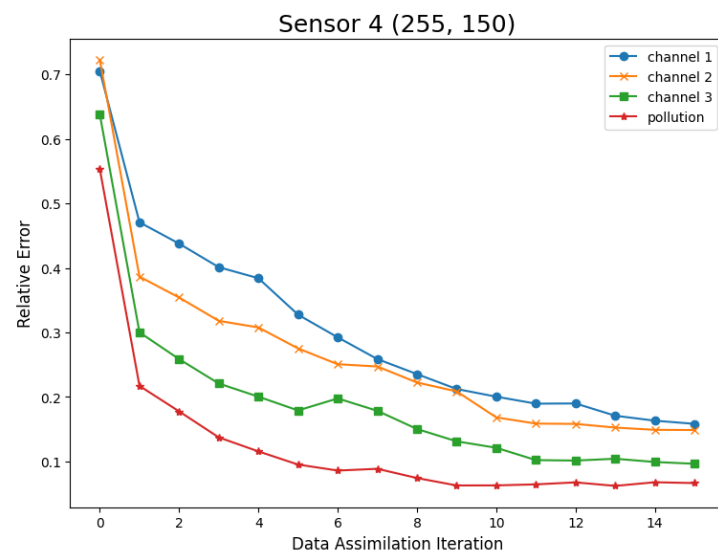
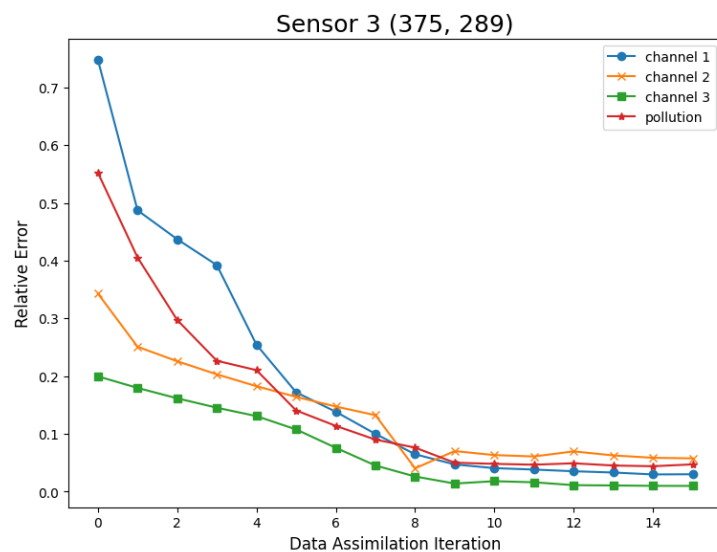
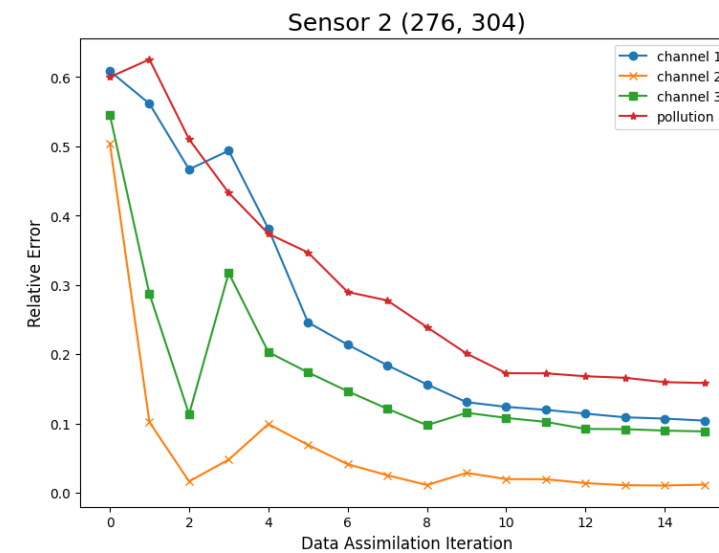
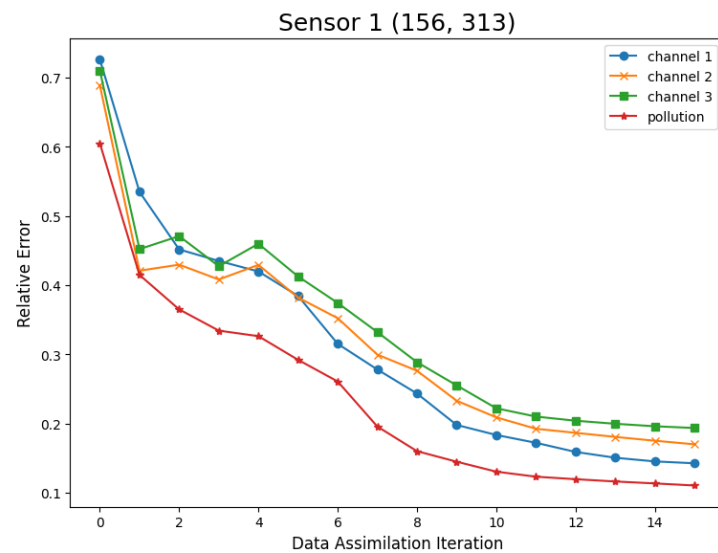
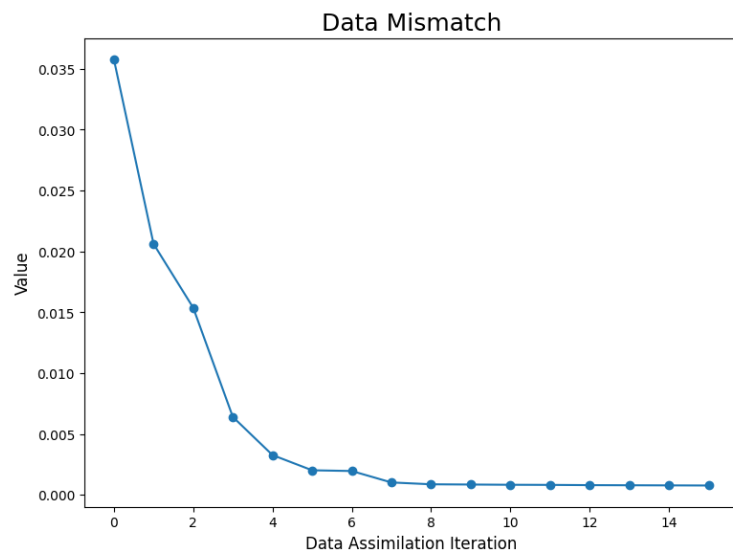
Simulation

Observation

Updated



RESULTS – Data Mismatch & Sensor Performance



CONCLUSION & DISCUSSION

1

Novel Framework

- Neural Networks
- Computational Fluid Dynamic
- Data Assimilation

2

Large-Scale Predictions

- Feasibility for a smaller domain
- Relative Error $< 10\%$
- Environmental Policy

3

Moving Window Strategy

- Memory Issue
- Stored and Reloaded
- In terms of Time



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