Solving Engineering Problems: Deep Learning (DL) for Computational Fluid Dynamics (CFD)

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n.g.

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Overview

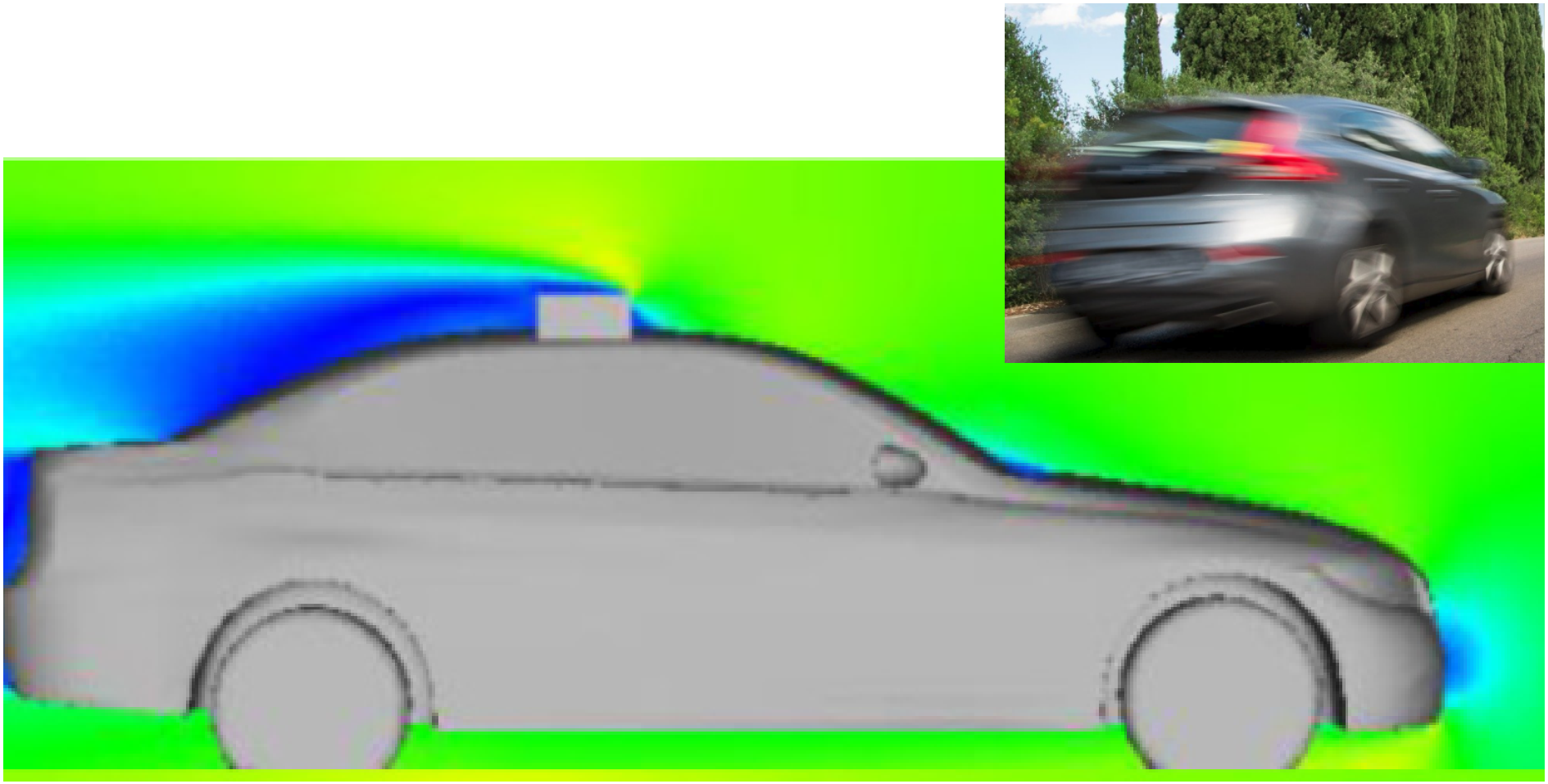
(*Image by Kiu Trung from Pixabay*)

- Visual Cortex (Hubel and Wiesel, 1959)

(*Image by Free-Photos from Pixabay*)

- AlexNet & ImageNet (Krizhevsky, Sutskever, and Hinton, 2012)
- CNN for object classification: cats vs. dogs

Engineering Tasks



(*Image by Free-Photos from Pixabay*)

Engineering Tasks

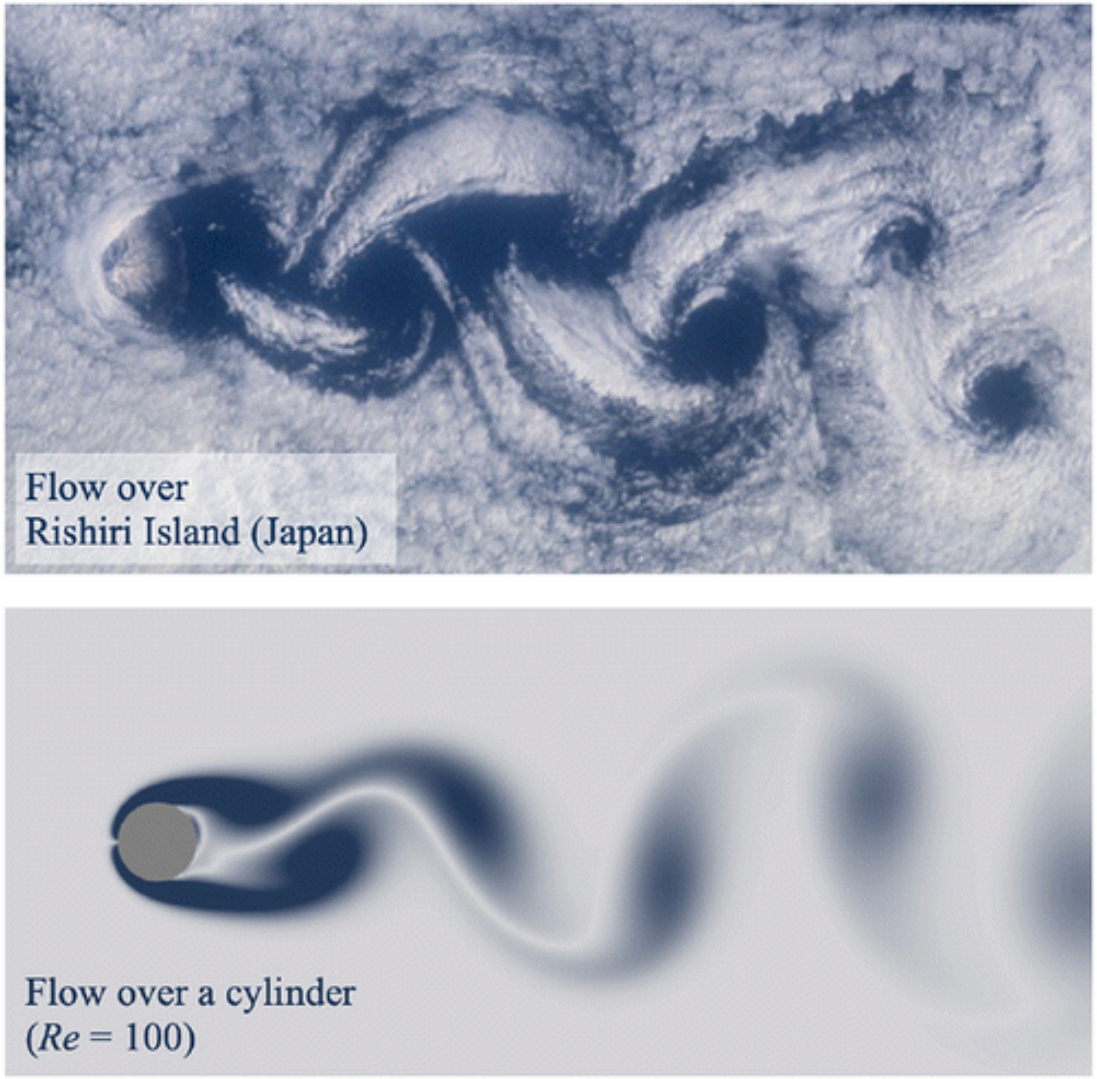
(*Image by Free-Photos from Pixabay*)

Patterns

(*The Starry Night by Vincent van Gogh*)

Neural Style Transfer (Gatys, Ecker, and Bethge, 2016)

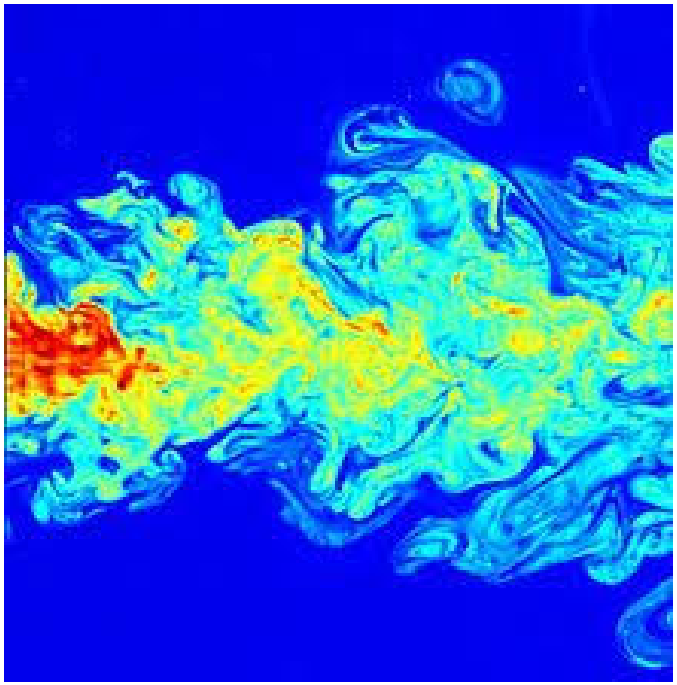
Patterns in Turbulent Flows



(Taira et al., 2020)

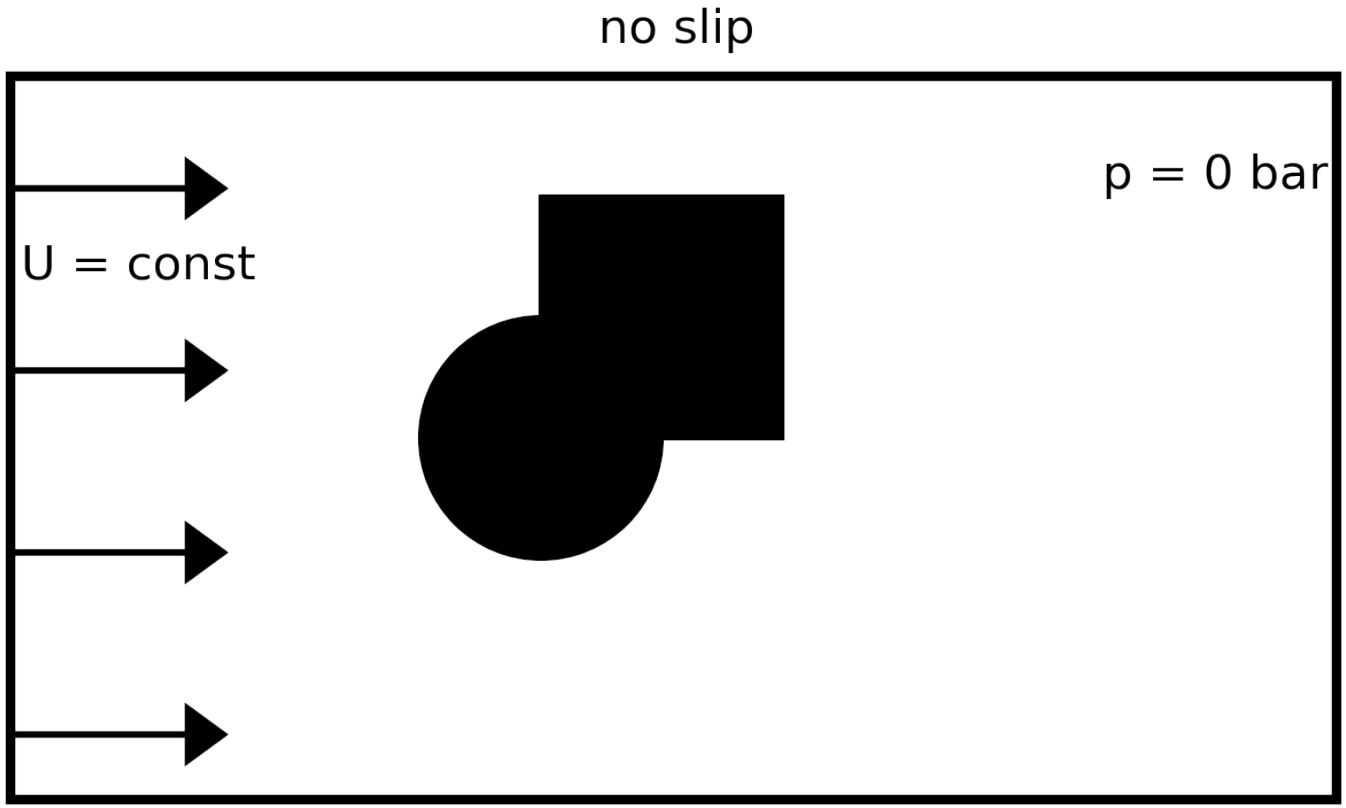
Patterns in Turbulent Flows

Turbulent luminance in impassioned van Gogh paintings (Aragón et al., 2008)

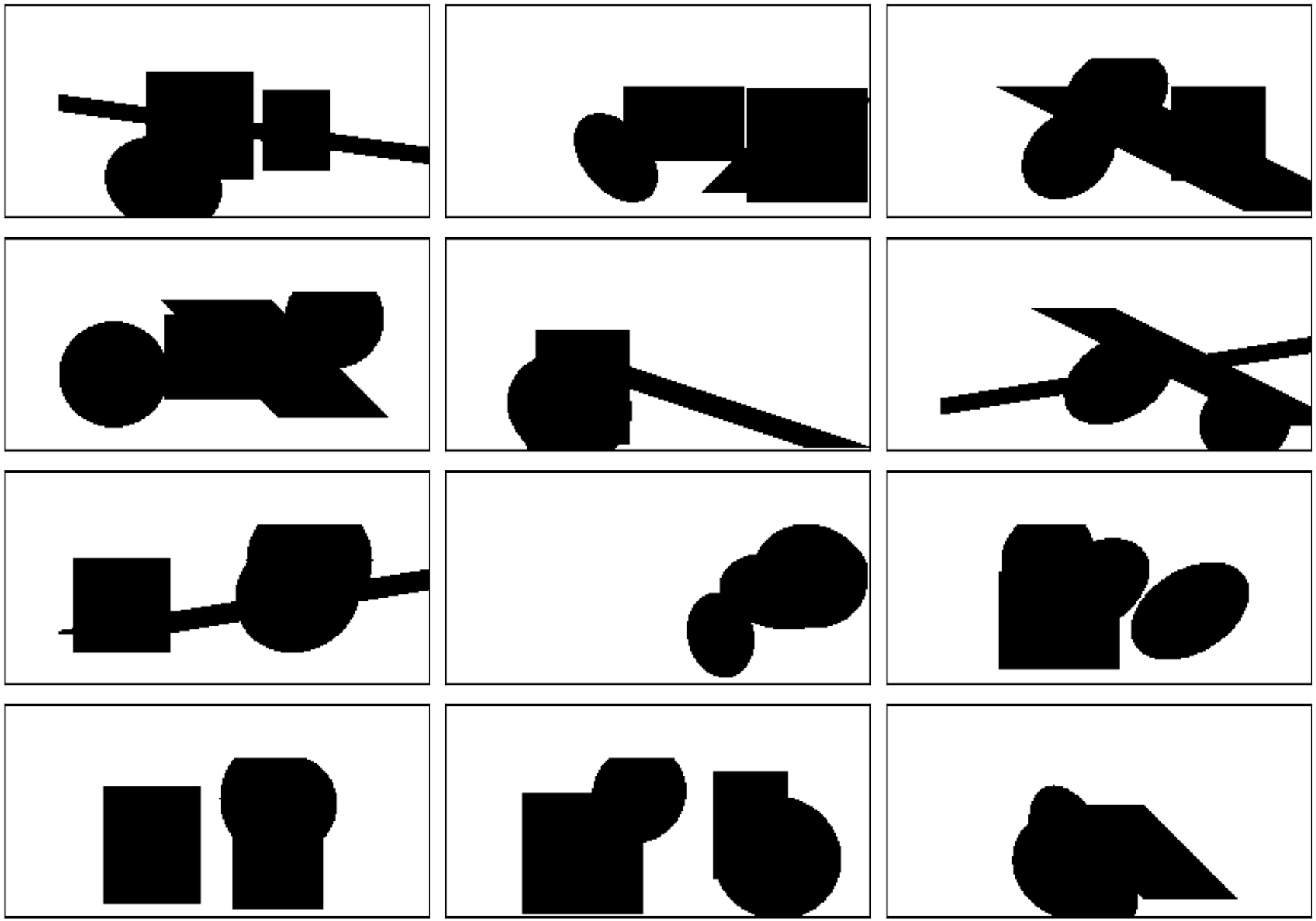


Turbulence jet with wide range of length scales, (*Energy Cascade*)

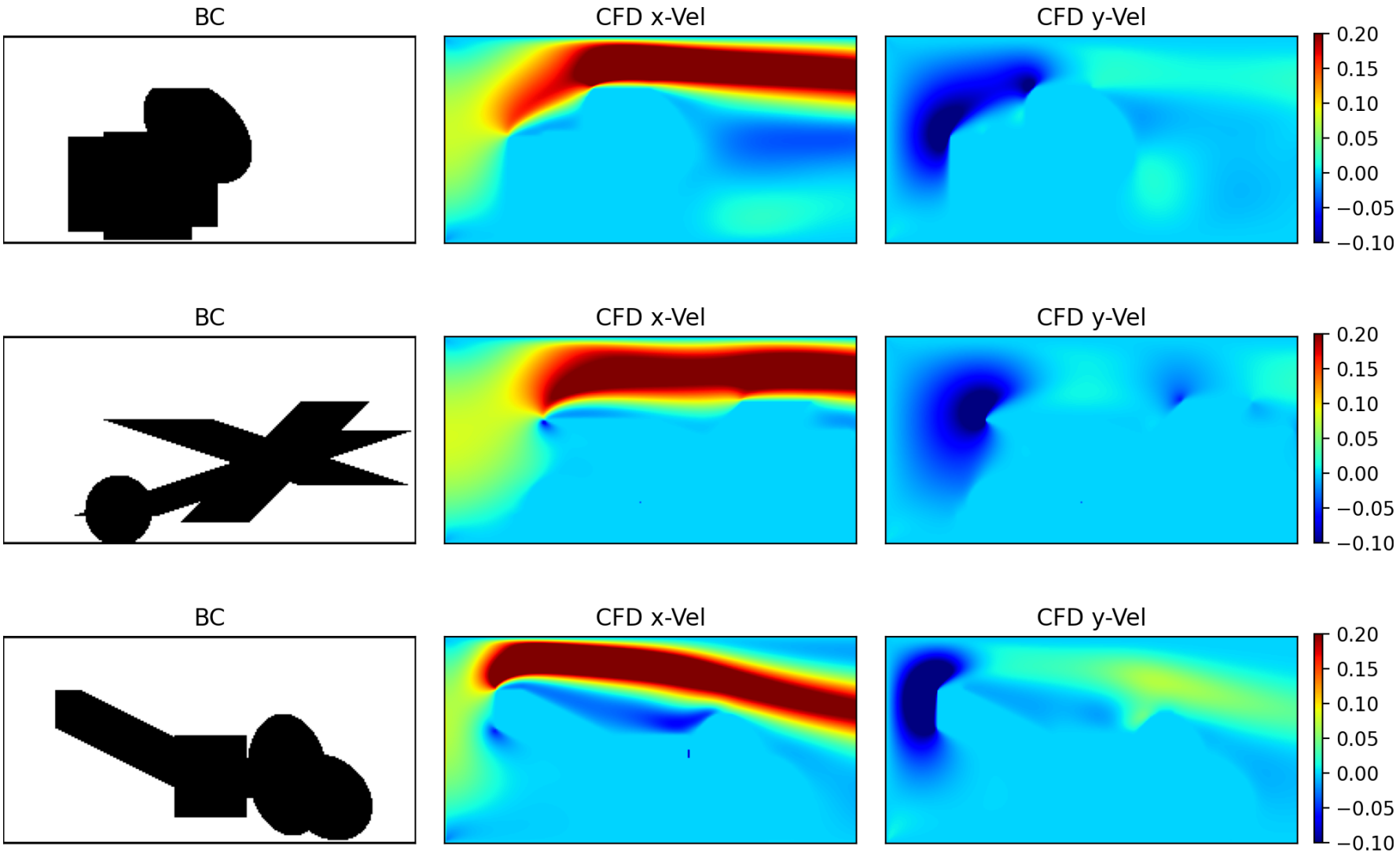
CFD Problem



Train Data: random shape variations



Training Data: CFD



BCs, CFD Results

Training Data

This slide contains a movie

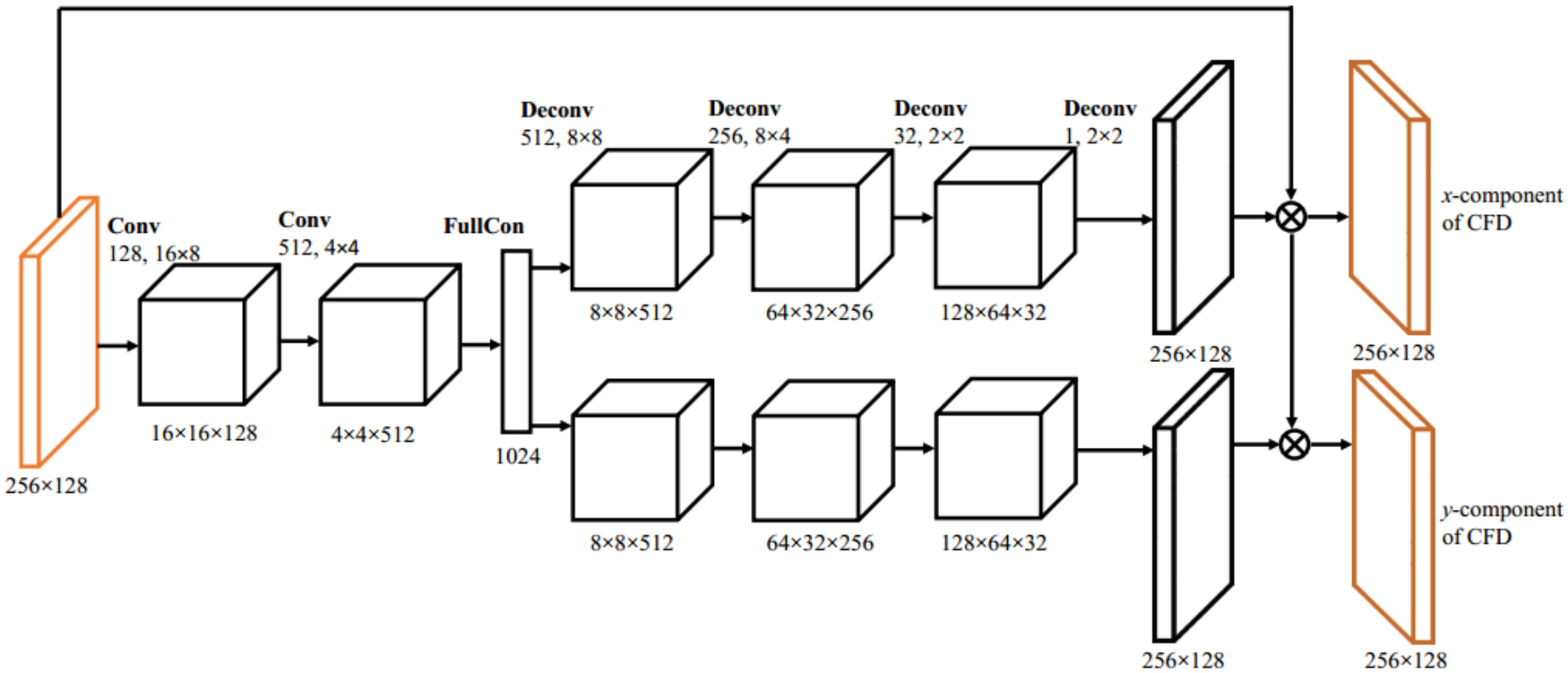
DL Approach Overview

- Training Data (*Hennigh 0., 2019*)
- Model Architectures
- Image Loss and Metrics
- Train Model
- Prediction on Unseen Data

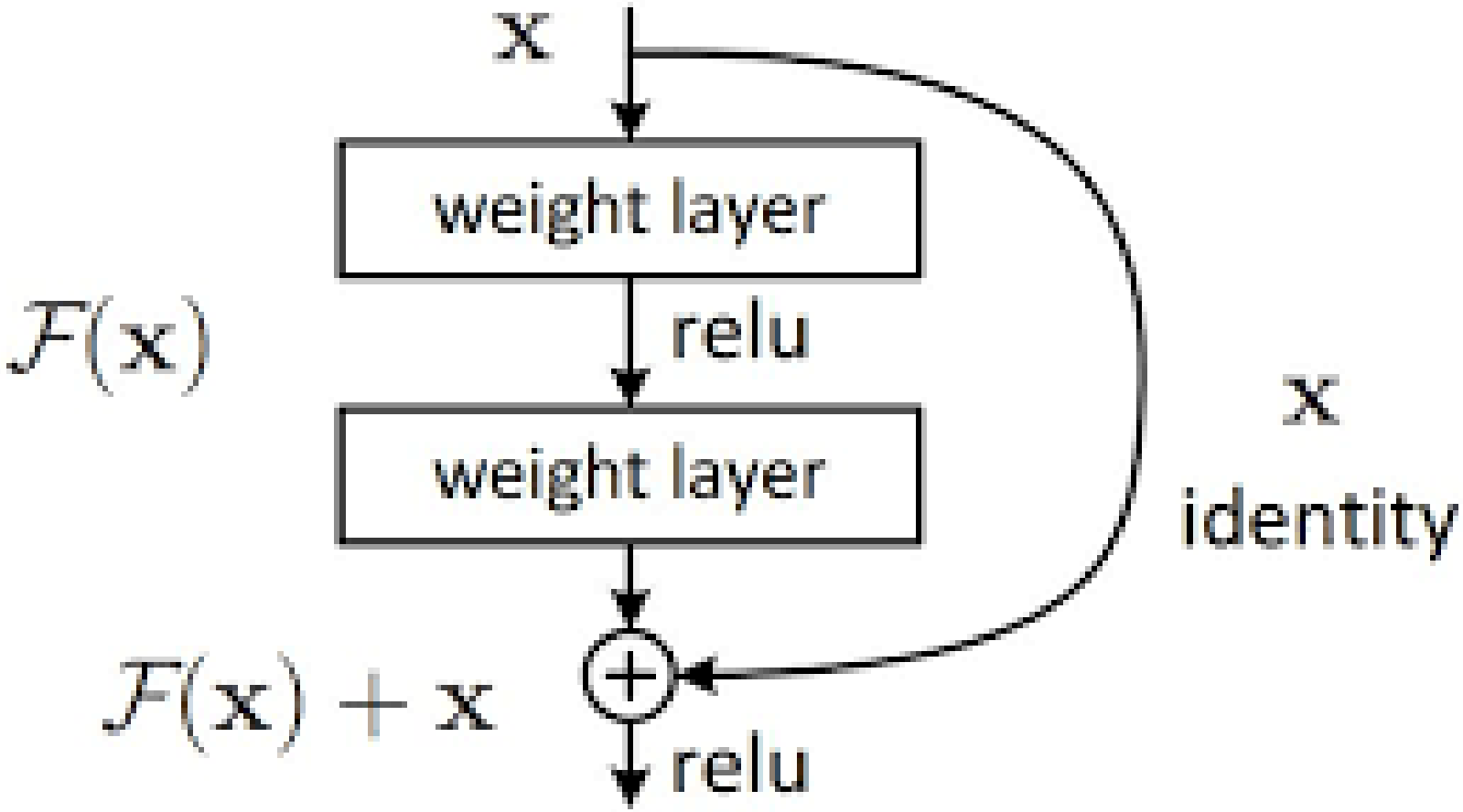
Training Data

- How complex is the problem you are trying to solve? Is training data representative from the problem we are trying to solve?
- Generate 50,000 $\Longrightarrow$ 10,000 $\Longrightarrow$ 5,000 records
- Training and test records drawn from same distribution (idd)

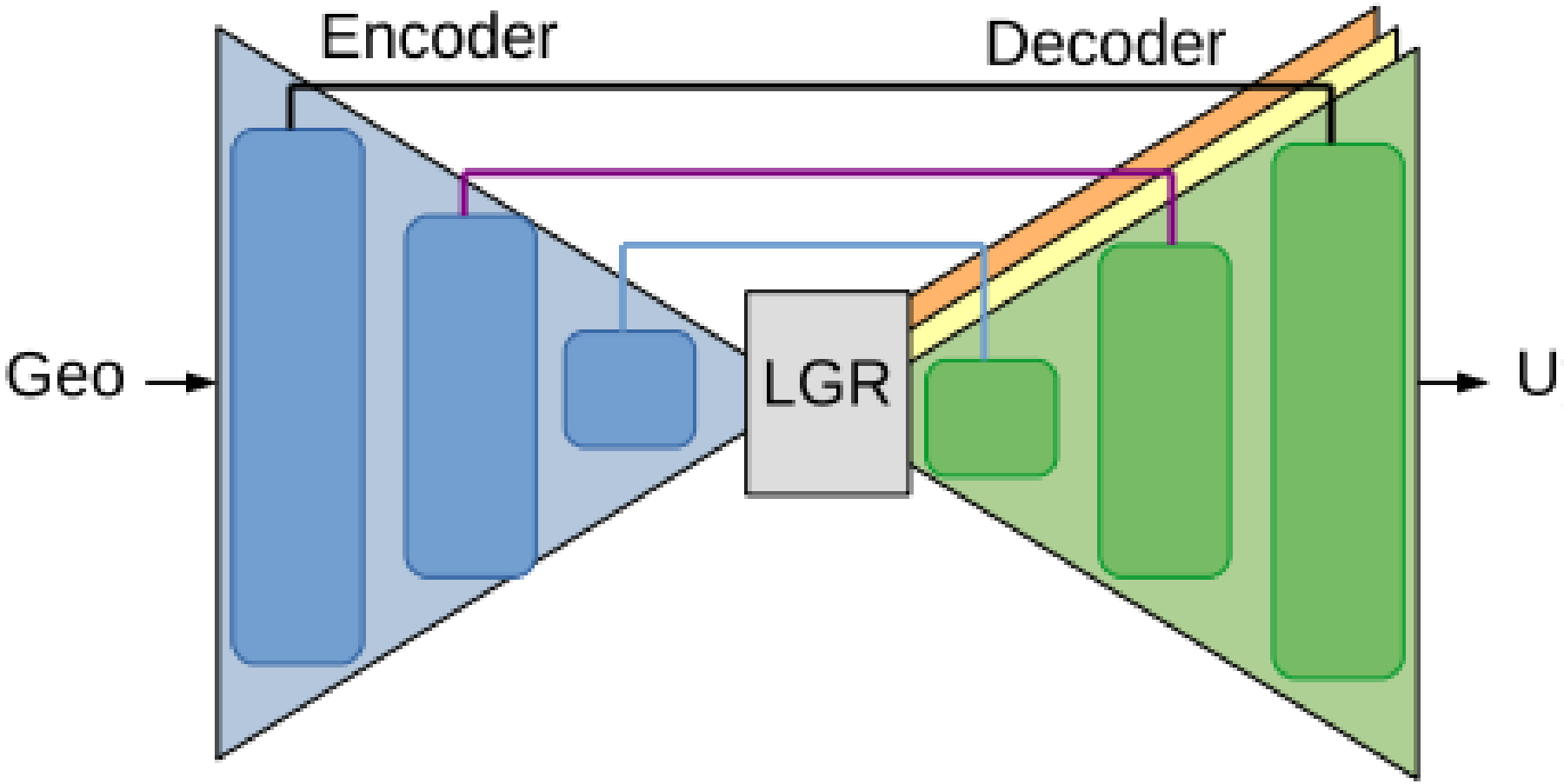
Architectures: CNNs (Guo, Li, and Iorio, 2016)



Architectures: ResNet (He et al., 2016)

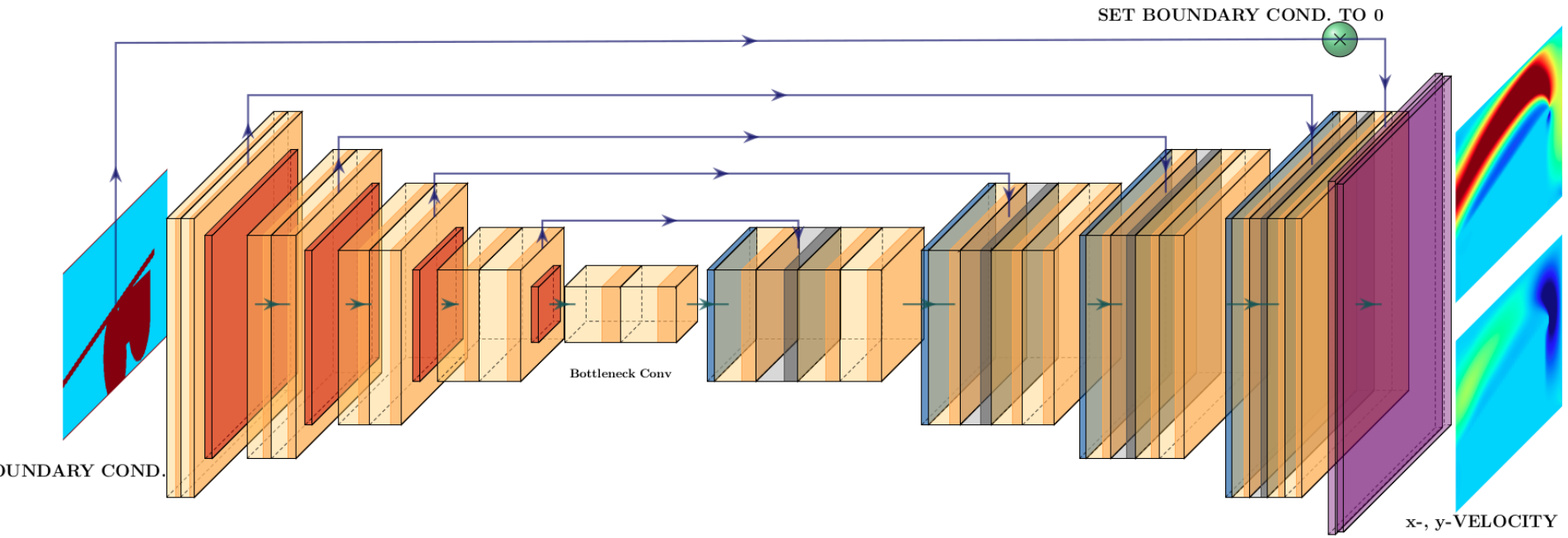


Architectures: U-Net (Ronneberger, Fischer, and Brox, 2015)

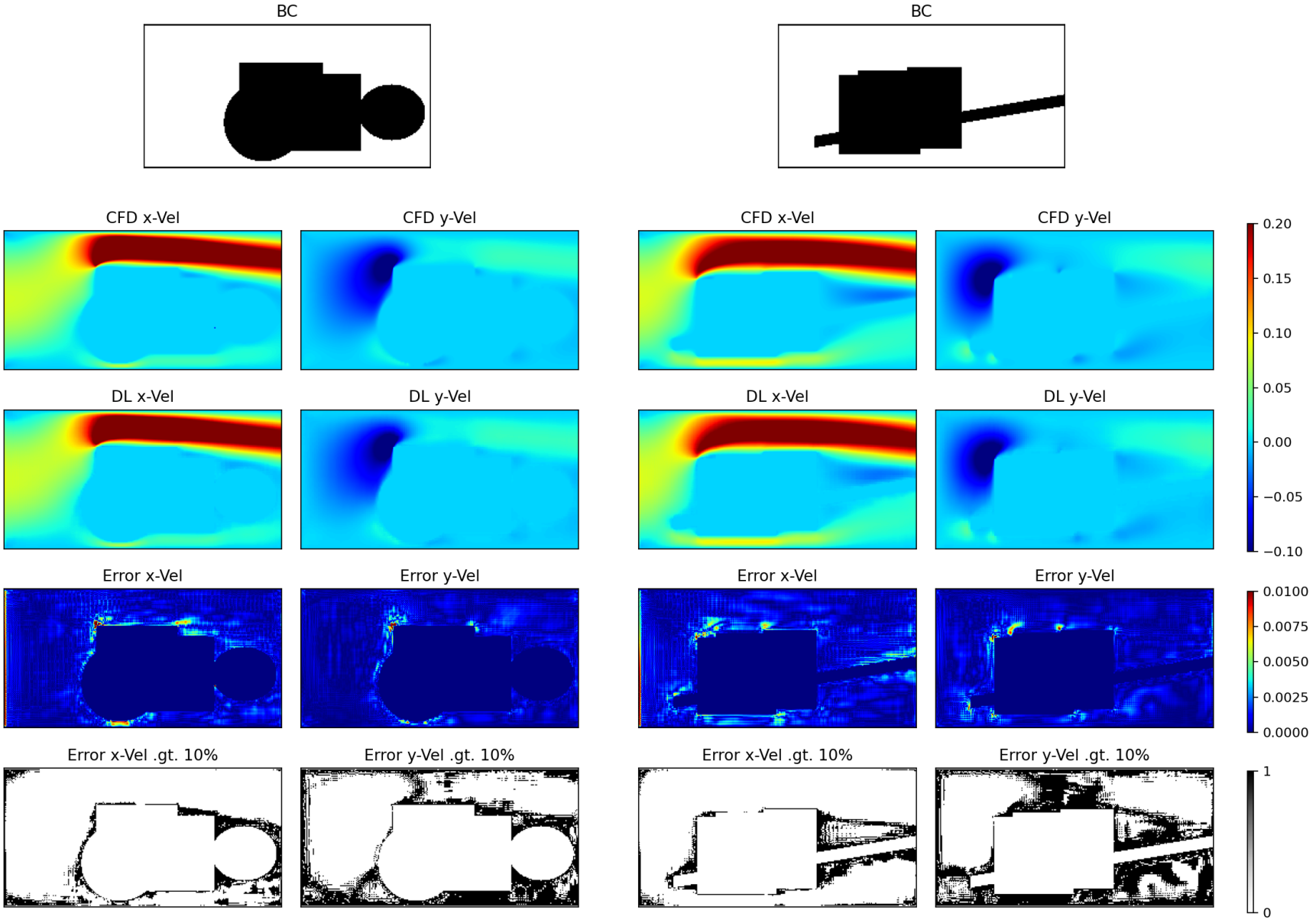


(Ribeiro et al., 2020)

Our Architecture: CNN + U-Net + ResNet



Test Data ☺


BC
BC
CFD x-Vel
CFD y-Vel
CFD x-Vel
CFD y-Vel
DL x-Vel
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DL x-Vel
DL y-Vel
Error x-Vel
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Error x-Vel .gt. 10%
Error y-Vel .gt. 10%
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0.10
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0.00
−0.05
−0.10
0.0100
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0.0050
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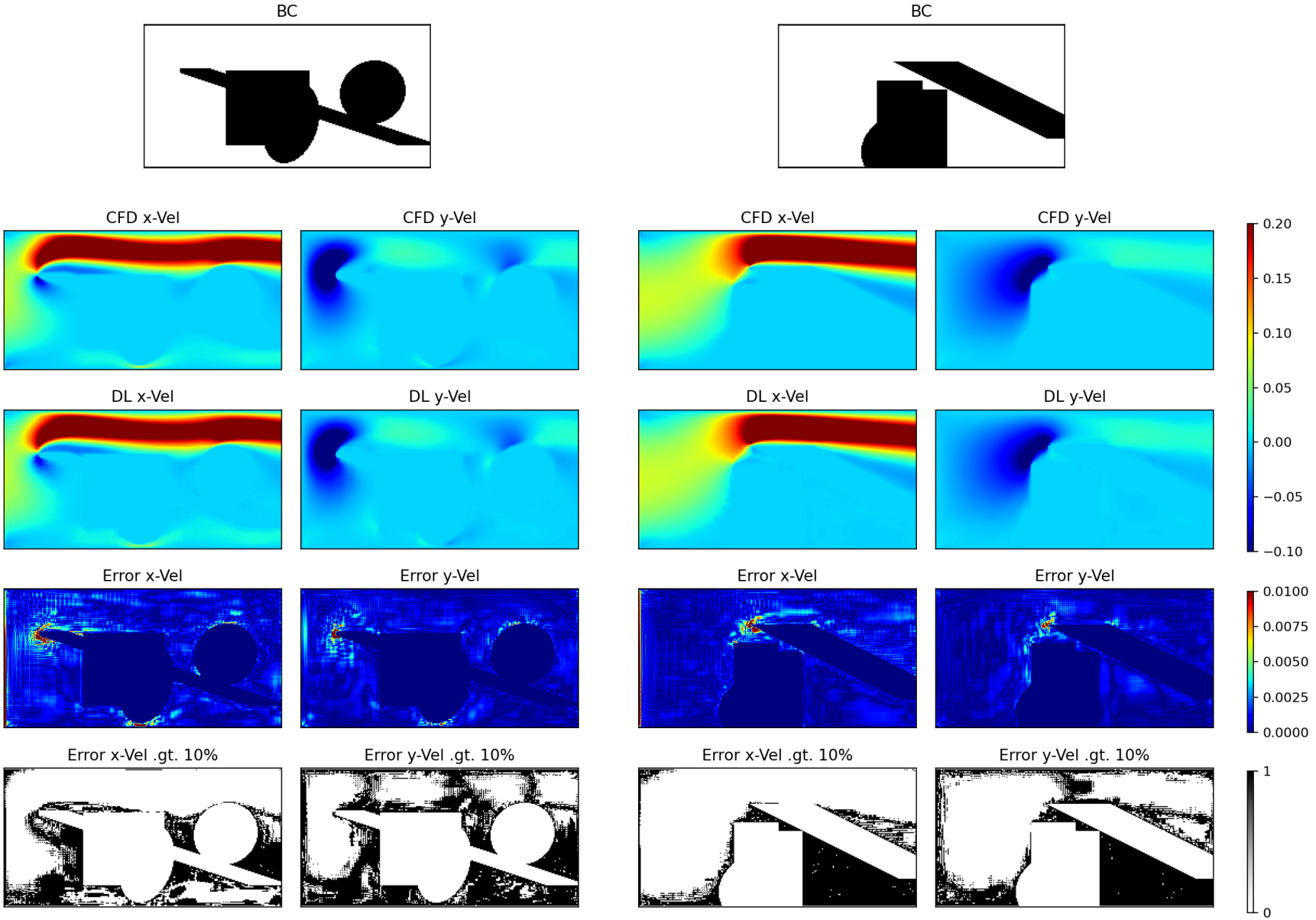
Test Data ☹


BC
BC
CFD x-Vel
CFD y-Vel
CFD x-Vel
CFD y-Vel
DL x-Vel
DL y-Vel
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0.0075
0.0050
0.0025
0.0000
1
0

Test Data

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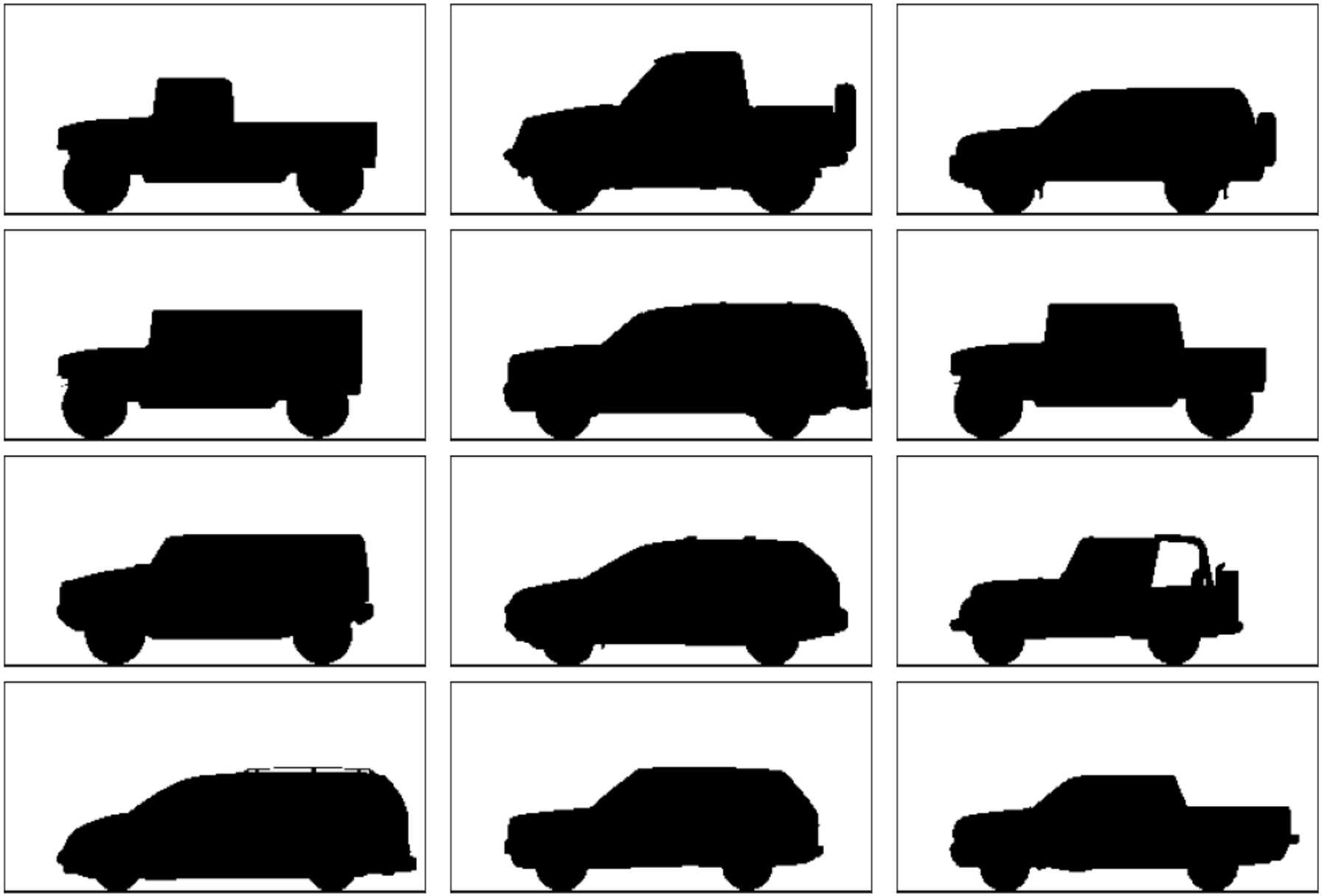
Train vs. Validation Data

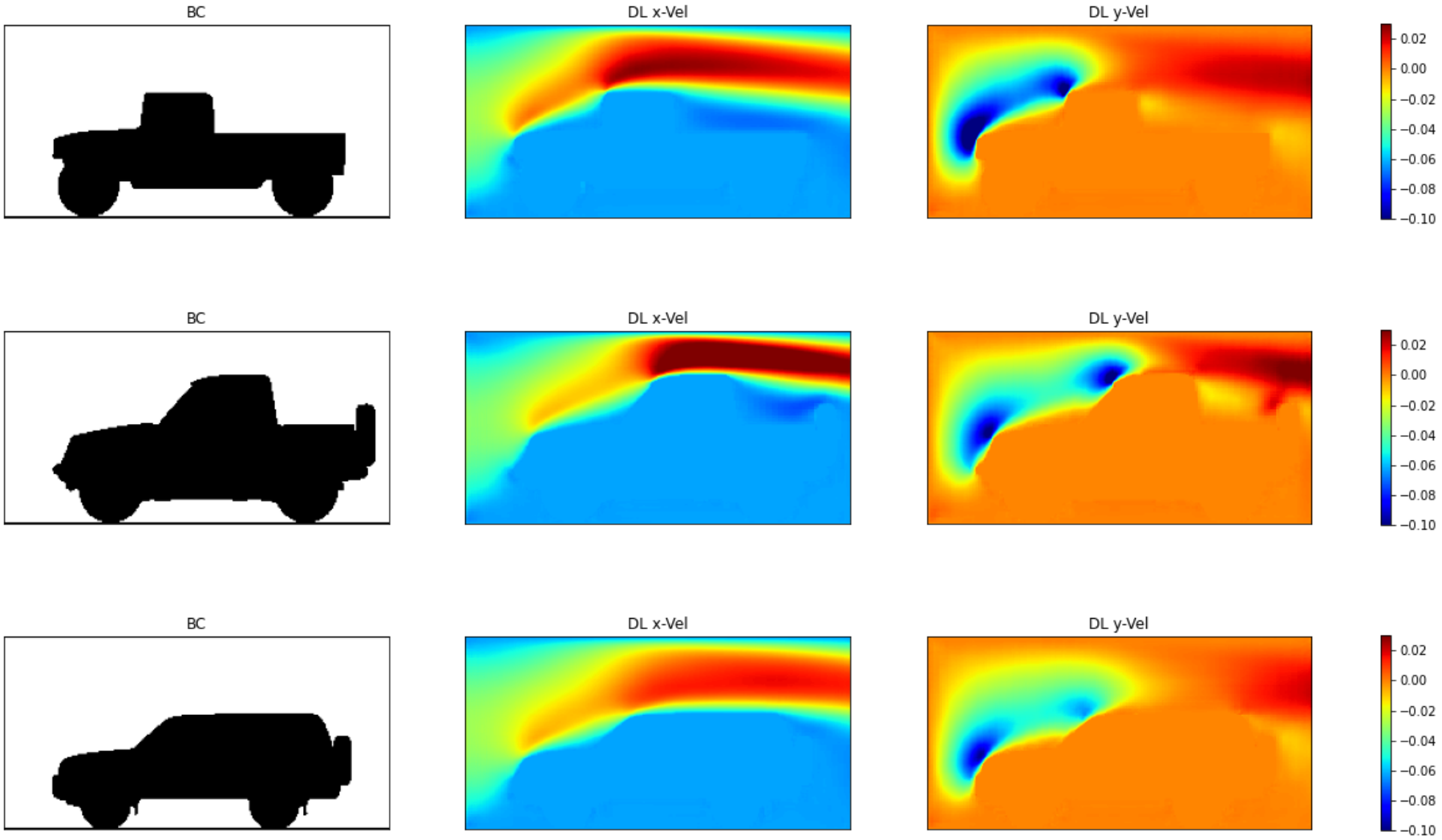
- Train/Test Data: random geometrical shapes
- Validation Data: cars designs

iid?

Validation Data: cars designs

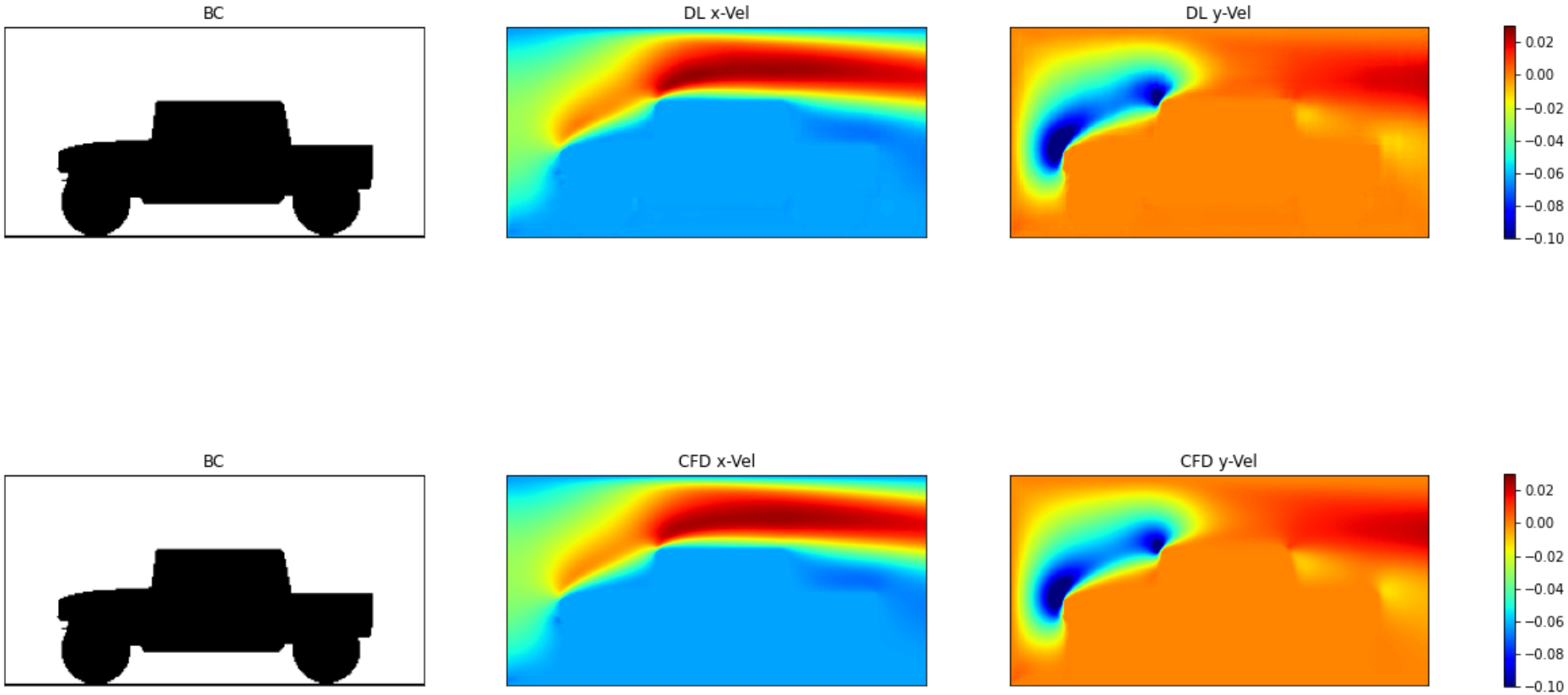


Validation Data



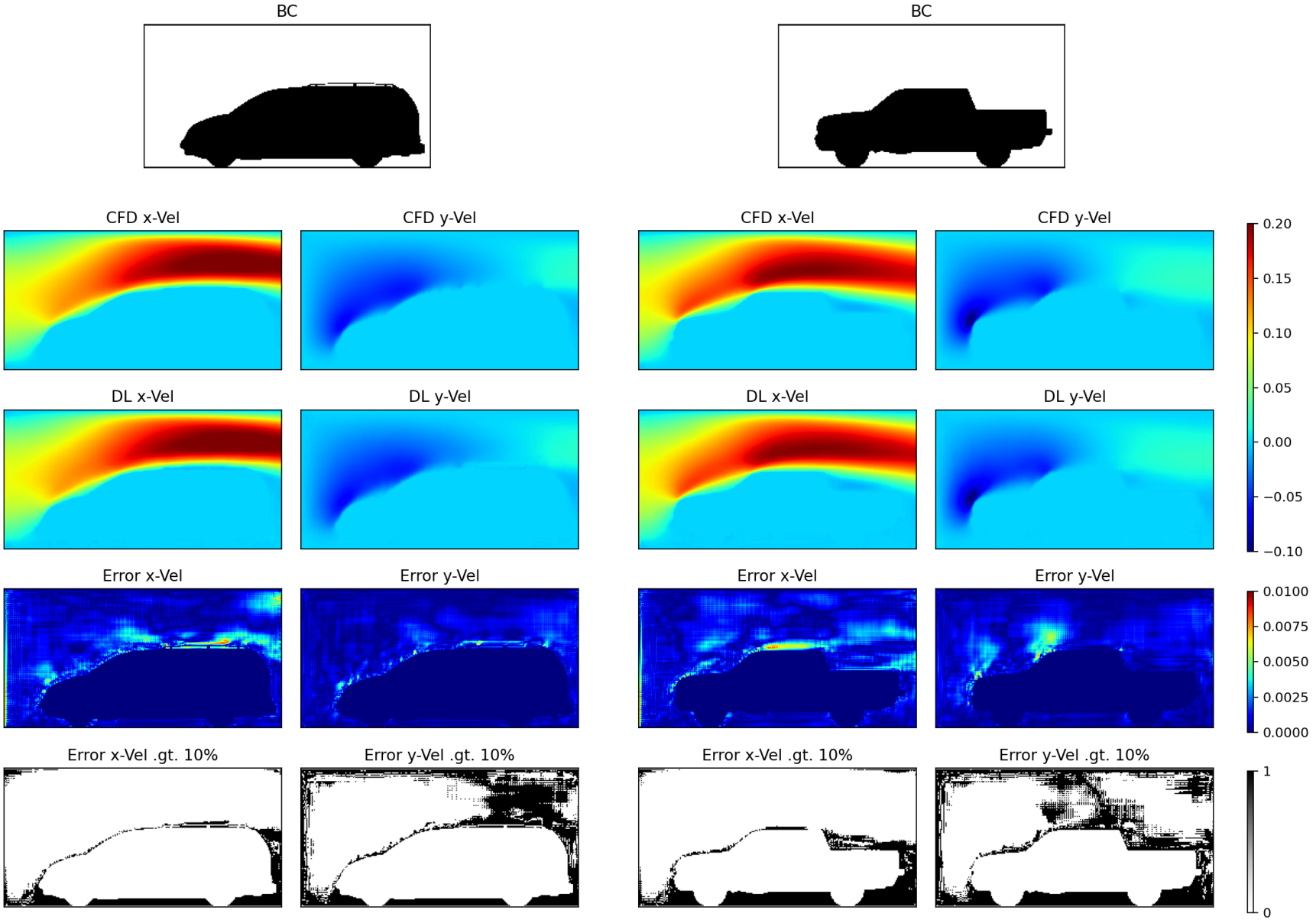
BCs & DL predictions

Validation Data

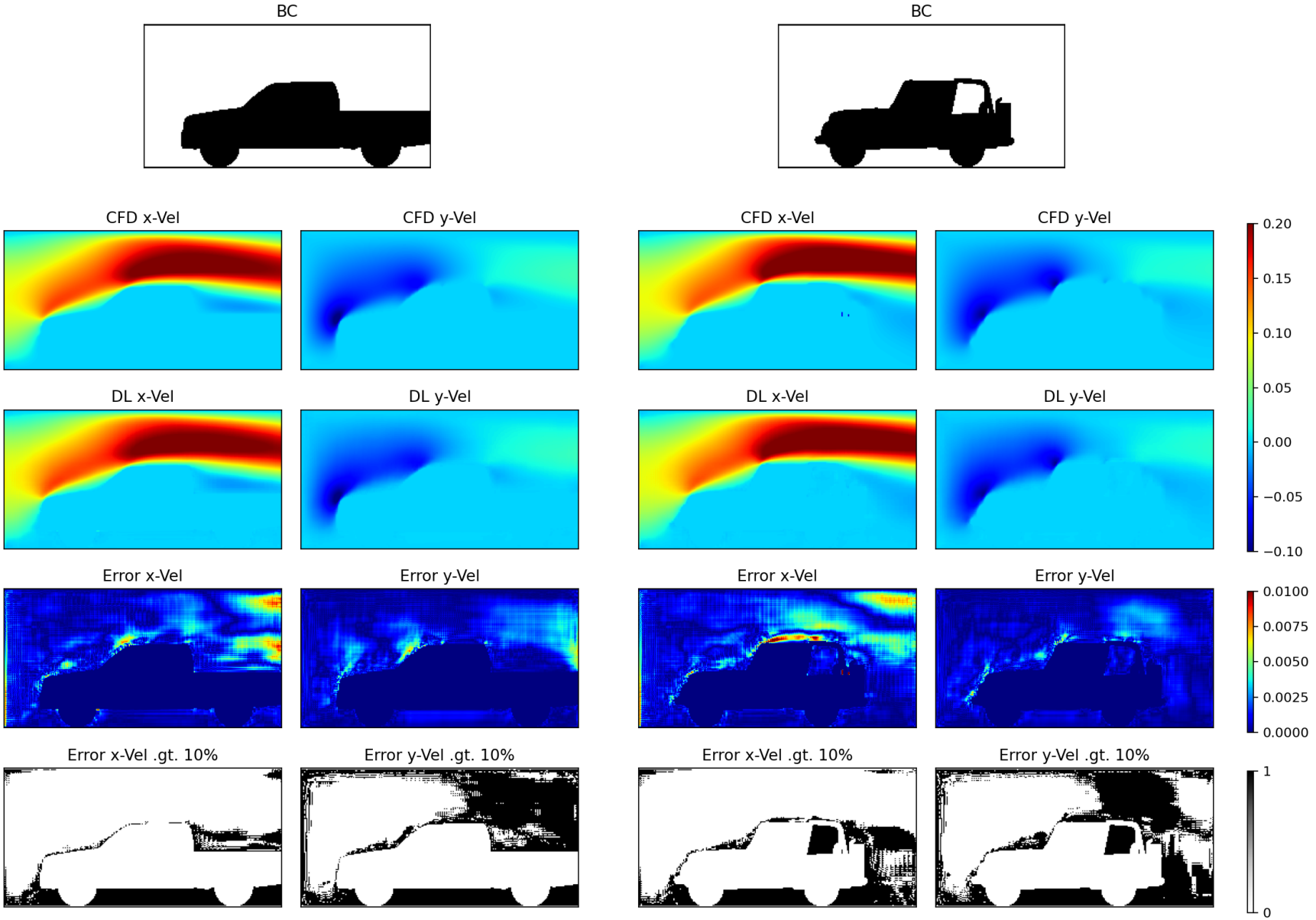


DL vs. CFD

Validation Data ☺



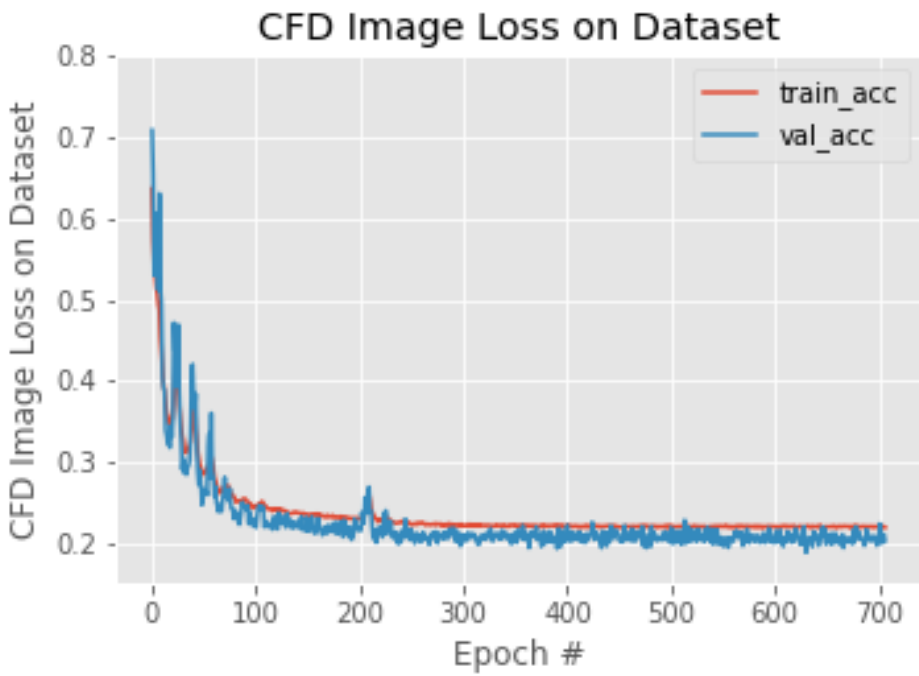
Validation Data ☹



Validation Data

This slide contains a movie

Training Loss



Further Work

- Better Loss/Metrics Function
- More Training Data
- Increase Training Time
- Improve architecture

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