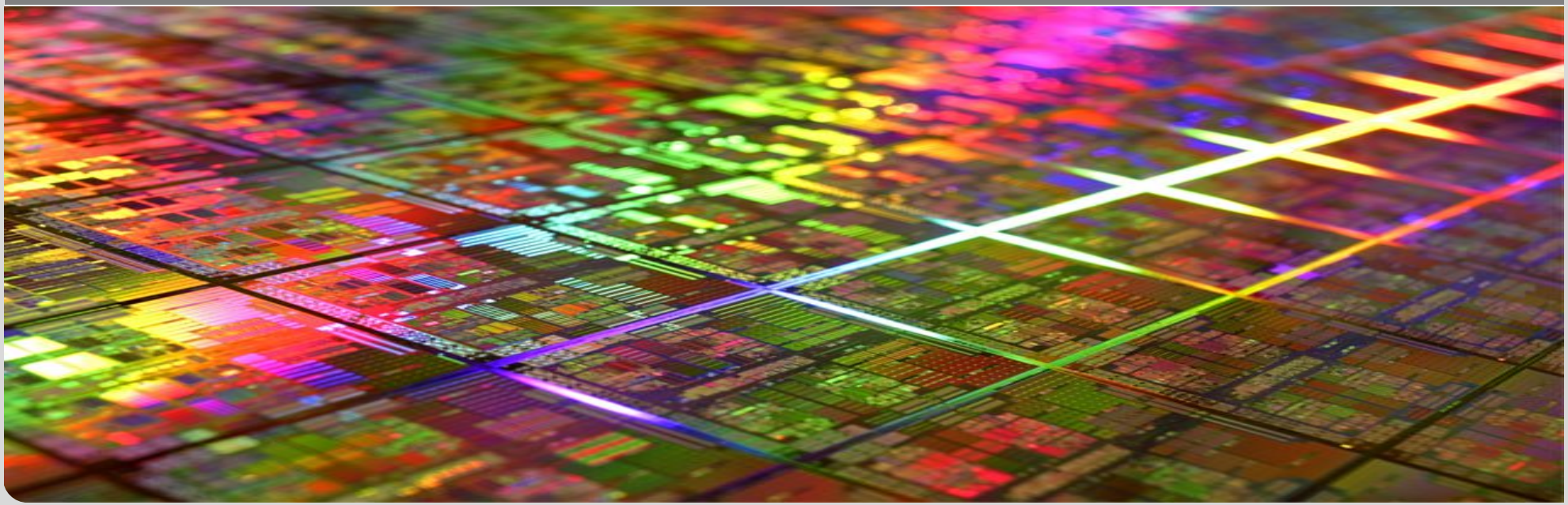
Towards Bringing Together Numerical Methods for Partial Differential Equation and Deep Neural Networks

Progress Update, Supervisor - Markus Hoffmann

Stanislav Arnaudov | September 26, 2019

CHAIR FOR COMPUTER ARCHITECTURE AND PARALLEL PROCESSING



Project description

Basic idea: Perform numerical simulation with ML-models

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- Concrete problem: Flow around an object according to the Navier–Stokes equations.

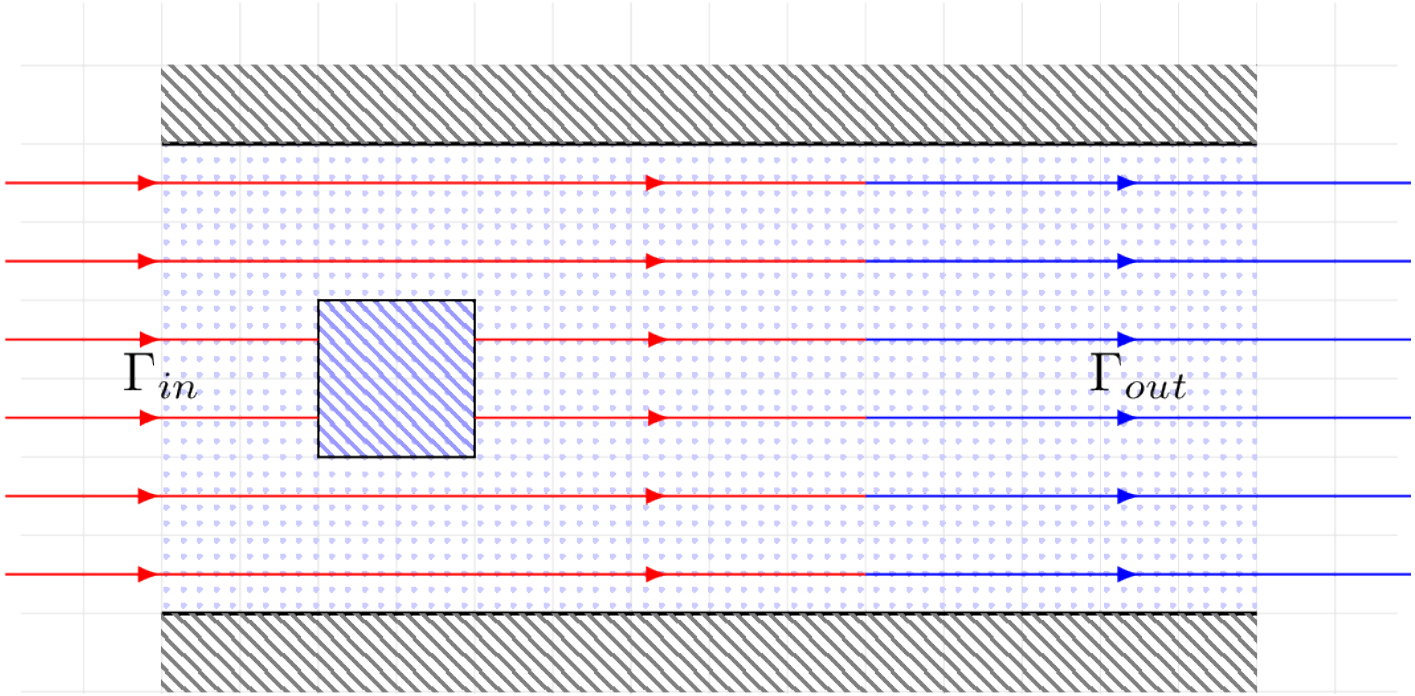


Figure: Simulation Setup

Project description

Basic idea: Perform numerical simulation with ML-models

- Solutions of the simulation can be represented as images.

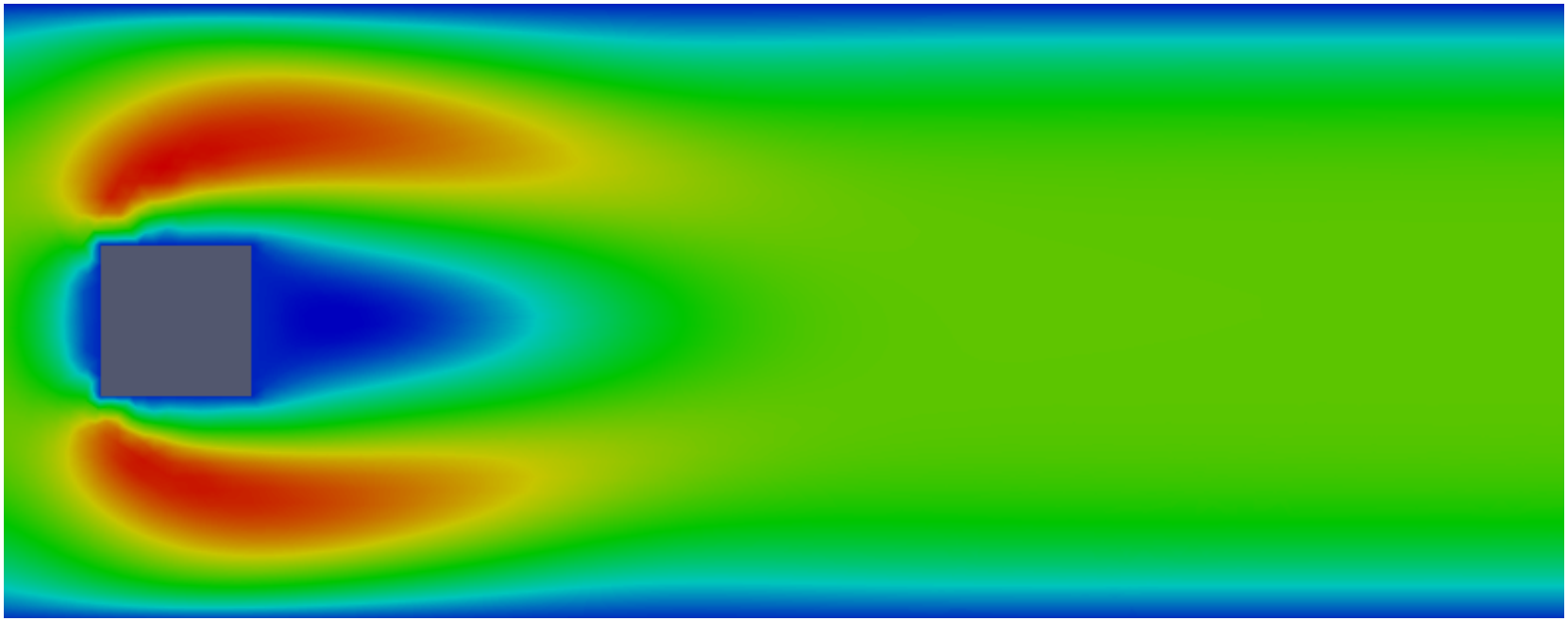
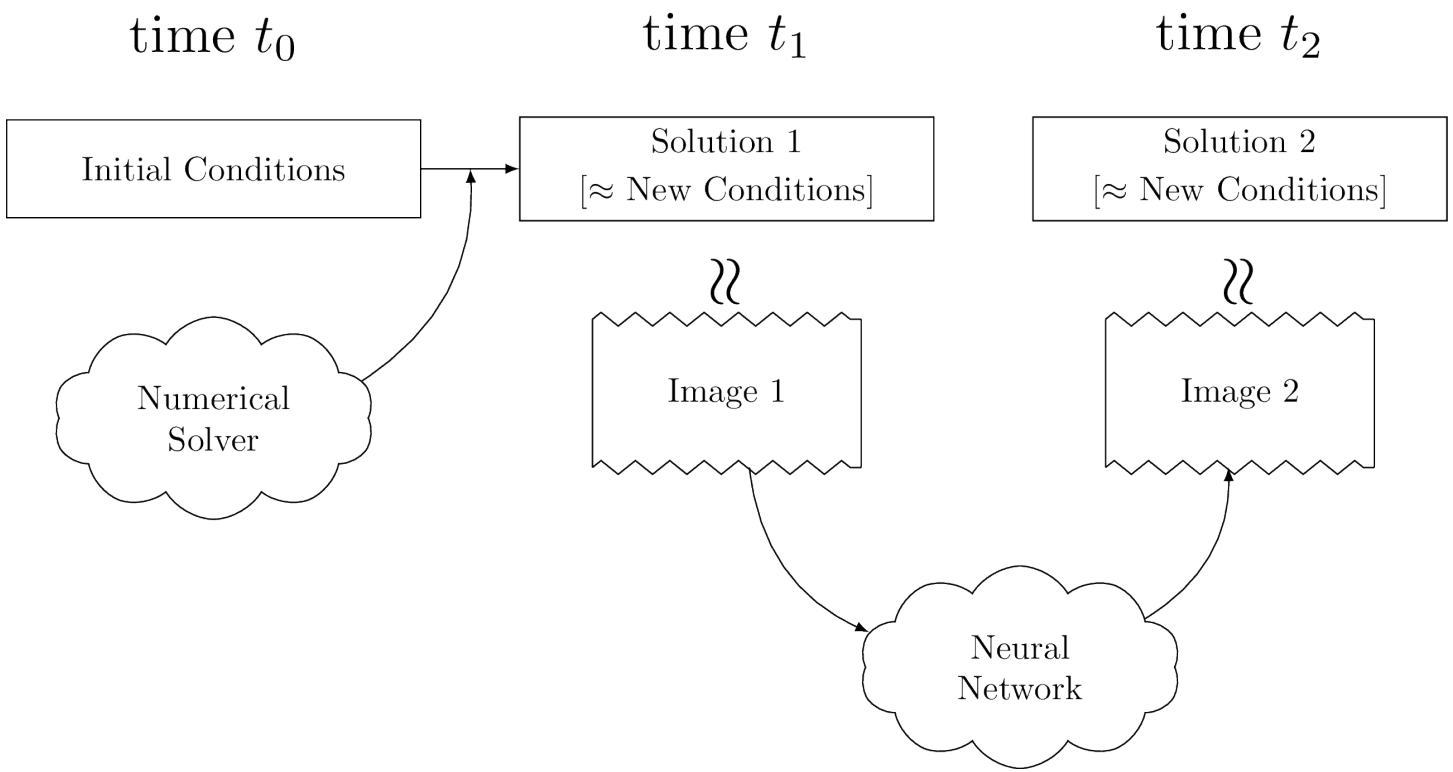


Figure: Simulation Image

Project description

Basic idea: Perform numerical simulation with ML-models

- Or ML-model primarily use images as input and output.



Project description

Several cases to investigate

- Constant model
- Fluid speed model
- Fluid viscosity and density model
- Object in space model

Data Generation

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
  - inflow speed
  - fluid viscosity
  - fluid density
- Reynolds Number in the range of [90, 350]

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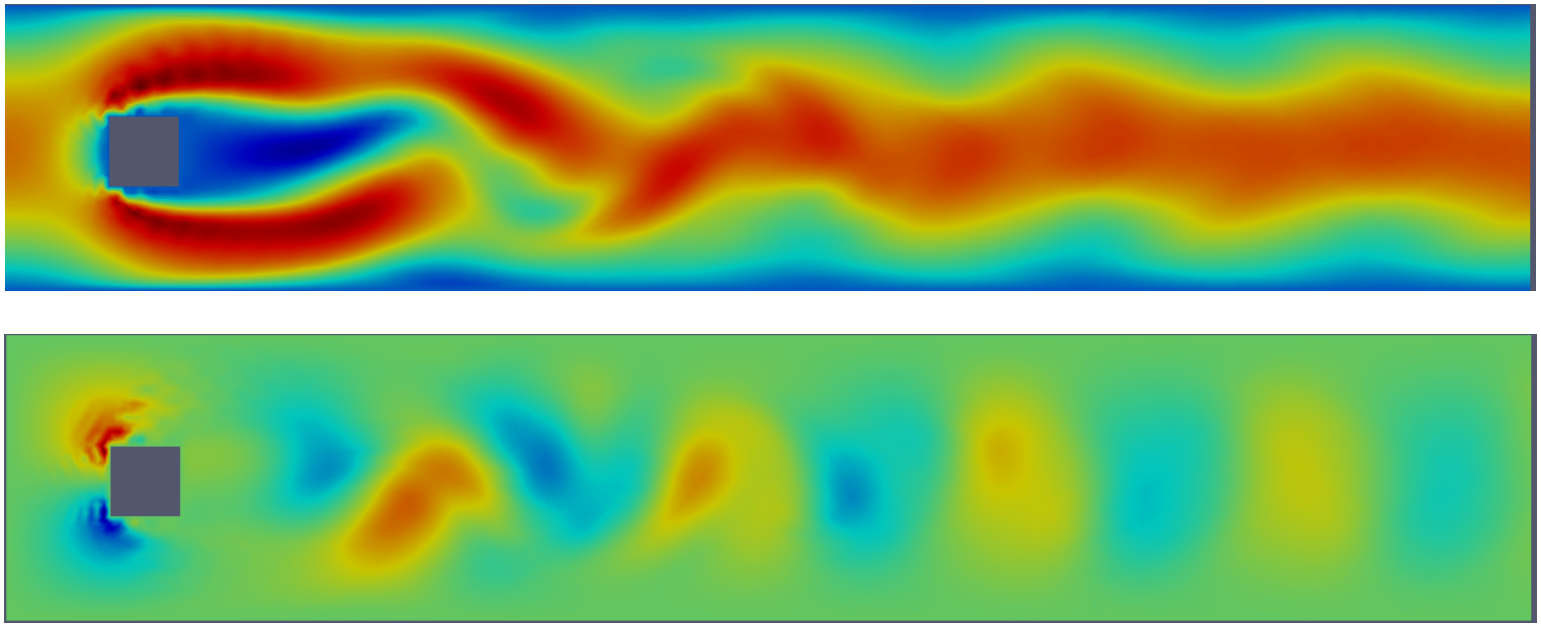
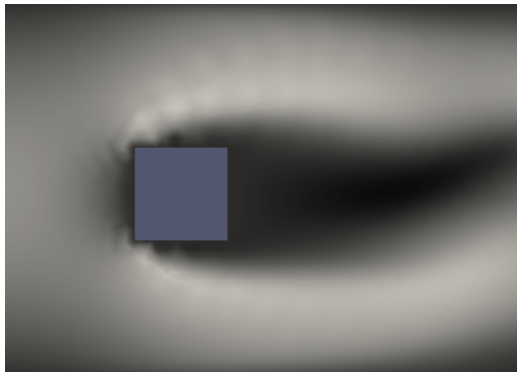
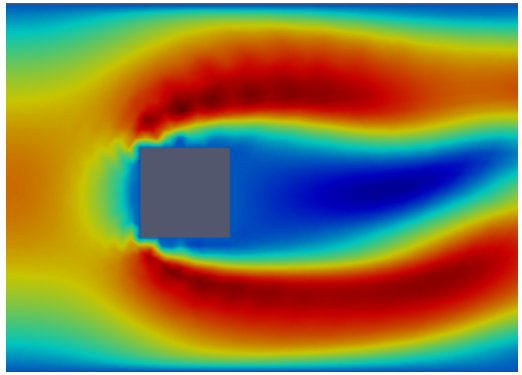
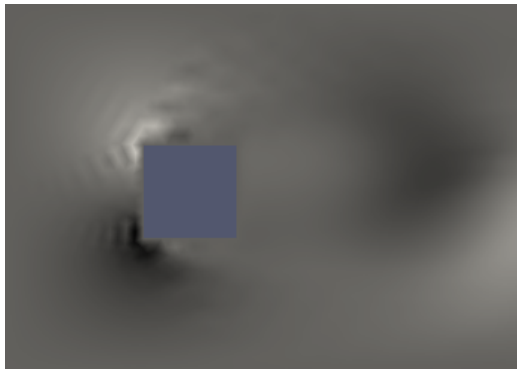
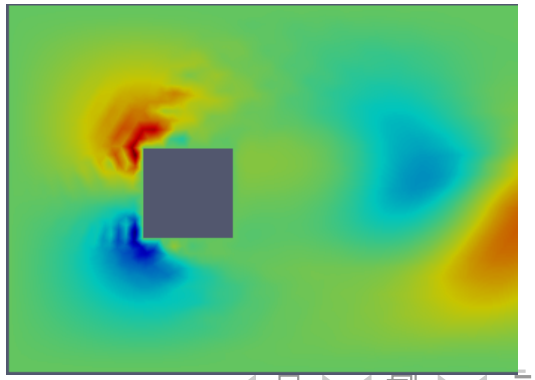


Figure: Karman vortex street

Data Generation

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
- Reynolds Number in the range of [90, 350]
- Choosing appropriate color space : Grayscale or RGB

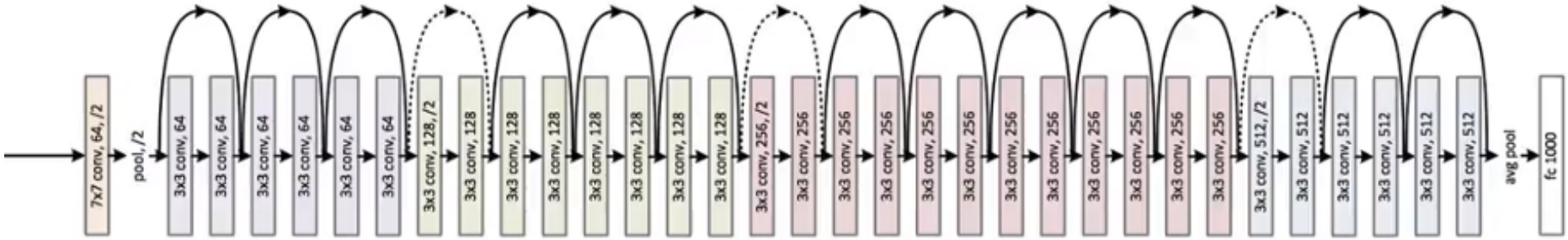





Models

- Two types of architectures based on our preliminary research:

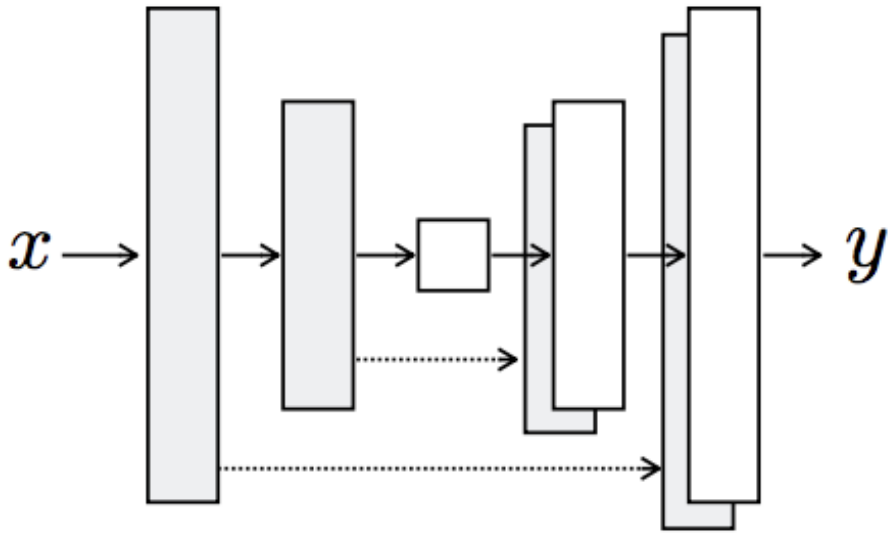
Models

- Two types of architectures based on our preliminary research:
  - ResNet



Models

- Two types of architectures based on our preliminary research:
  - UNet



Models

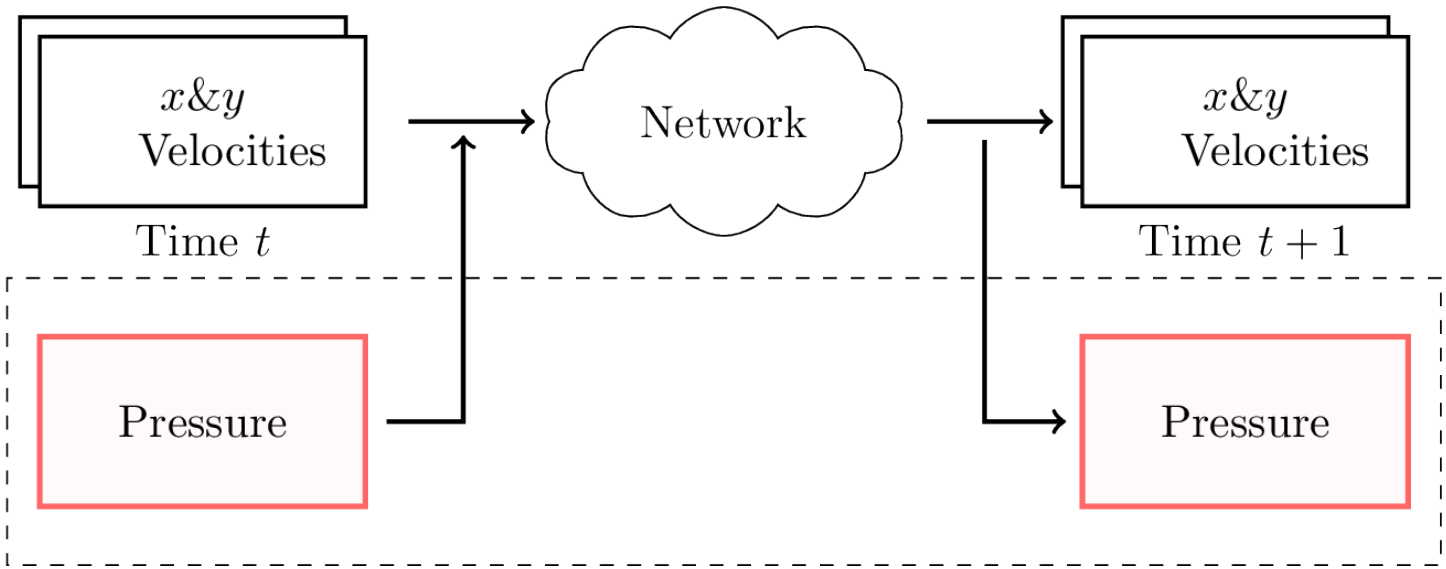
- Two types of architectures based on our preliminary research:
  - UNet turned out to perform better.

Models

- Two types of architectures based on our preliminary research:
- Data being used by the network.

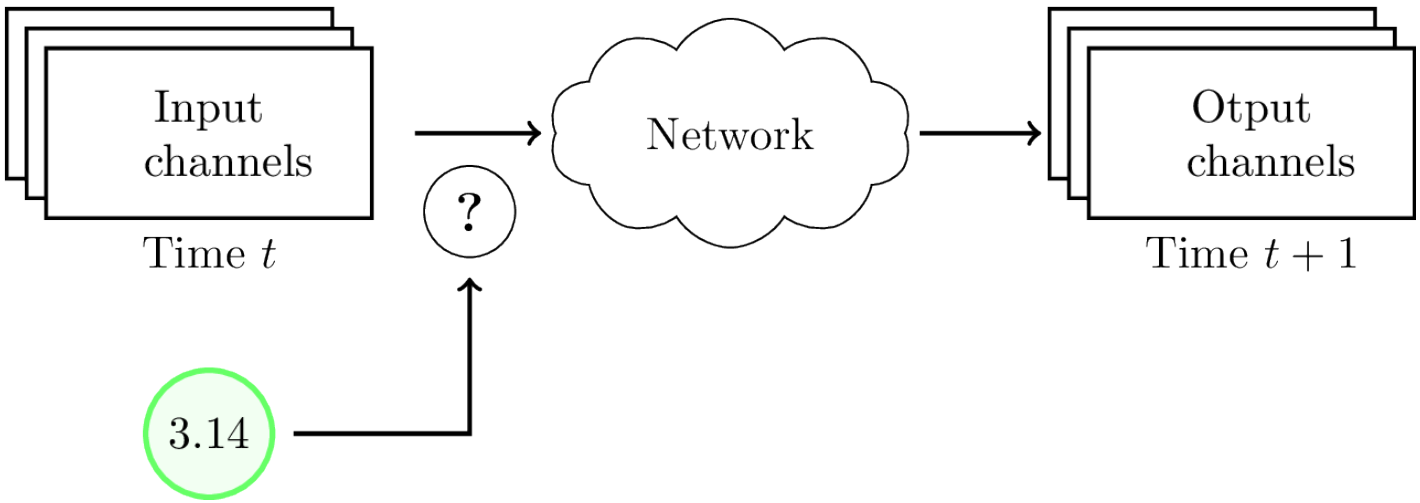
Models

- Two types of architectures based on our preliminary research:
- Data being used by the network.
  - Usage of pressure field



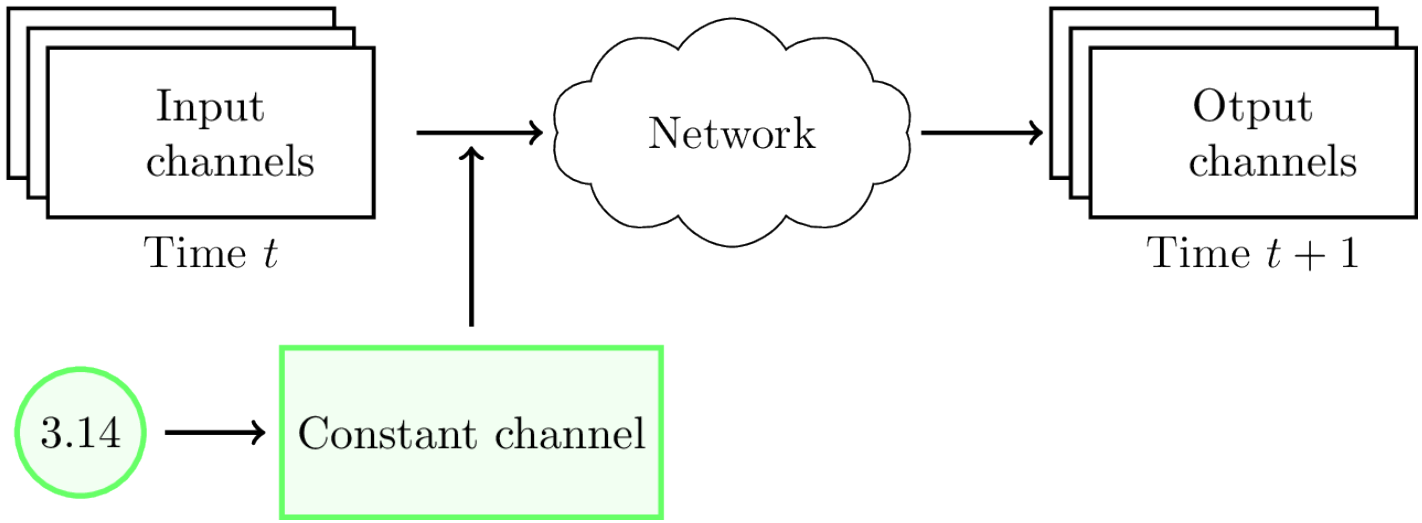
Models

- Two types of architectures based on our preliminary research:
- Data being used by the network.
  - Processing of real values



Models

- Two types of architectures based on our preliminary research:
- Data being used by the network.
  - Usage of pressure field → the pressure field turned out to be useful
  - Processing of real values → extra image channel filled with the value



Evaluating the results

Evaluating the results

Two views of the results

Computer Vision

Numerical Simulation

Evaluating the results

Two views of the results

Computer Vision

- Perceived qualities of the image results
- Metrics:
  - Peak signal-to-noise ratio - PSNR
  - Correlation

Numerical Simulation

Evaluating the results

Two views of the results

Computer Vision

- Perceived qualities of the image results
- Metrics:
  - Peak signal-to-noise ratio - PSNR
  - Correlation

Numerical Simulation

- Real differences between the predicted and the actual values
- Metrics:
  - Average percentage difference
  - Max percentage difference

Evaluation cases

Two evaluation cases

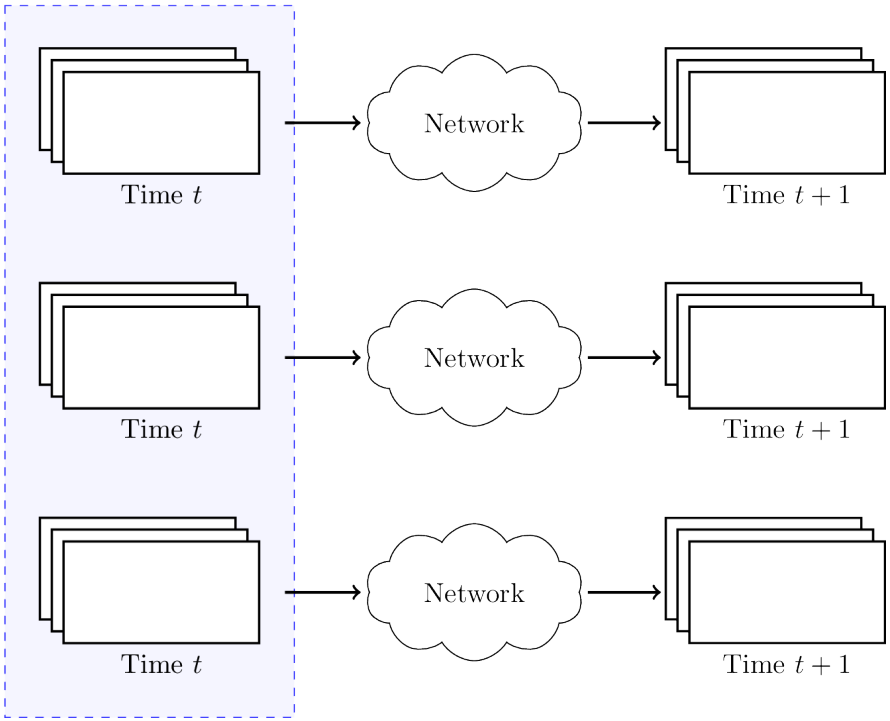
Individual Images

Recursive Application

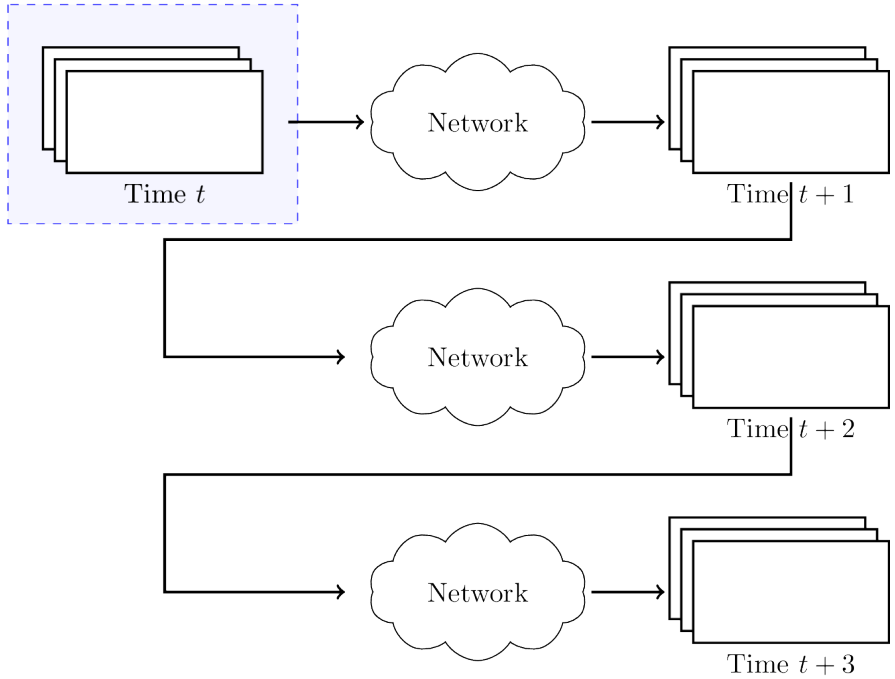
Evaluation cases

Two evaluation cases

Individual Images



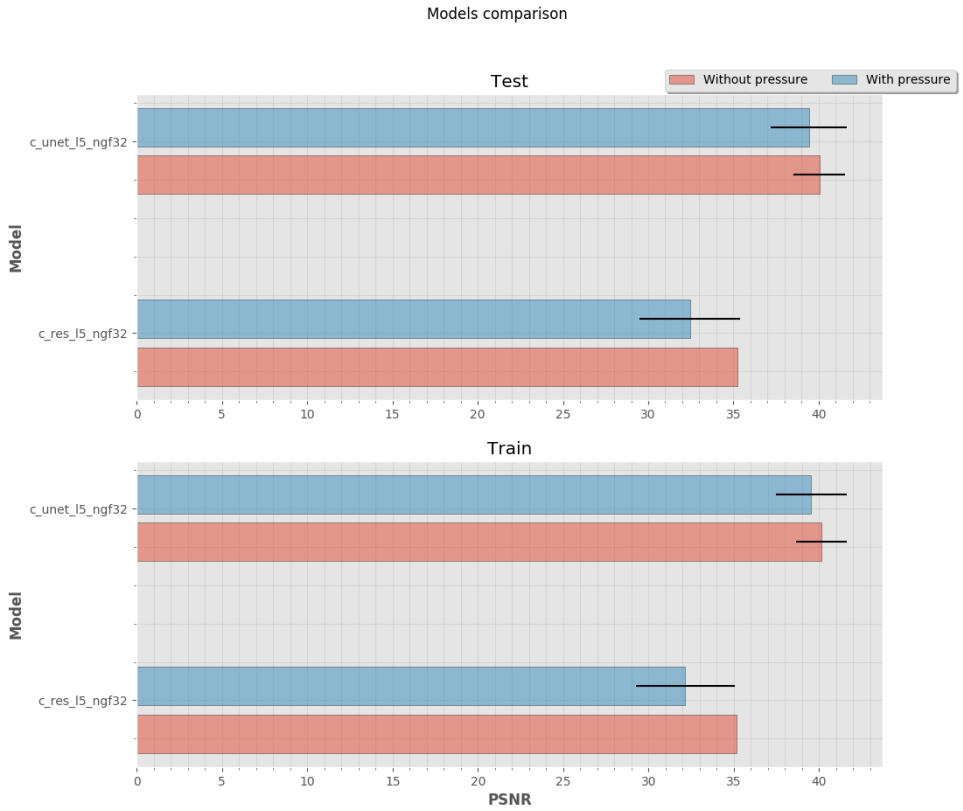
Recursive Application

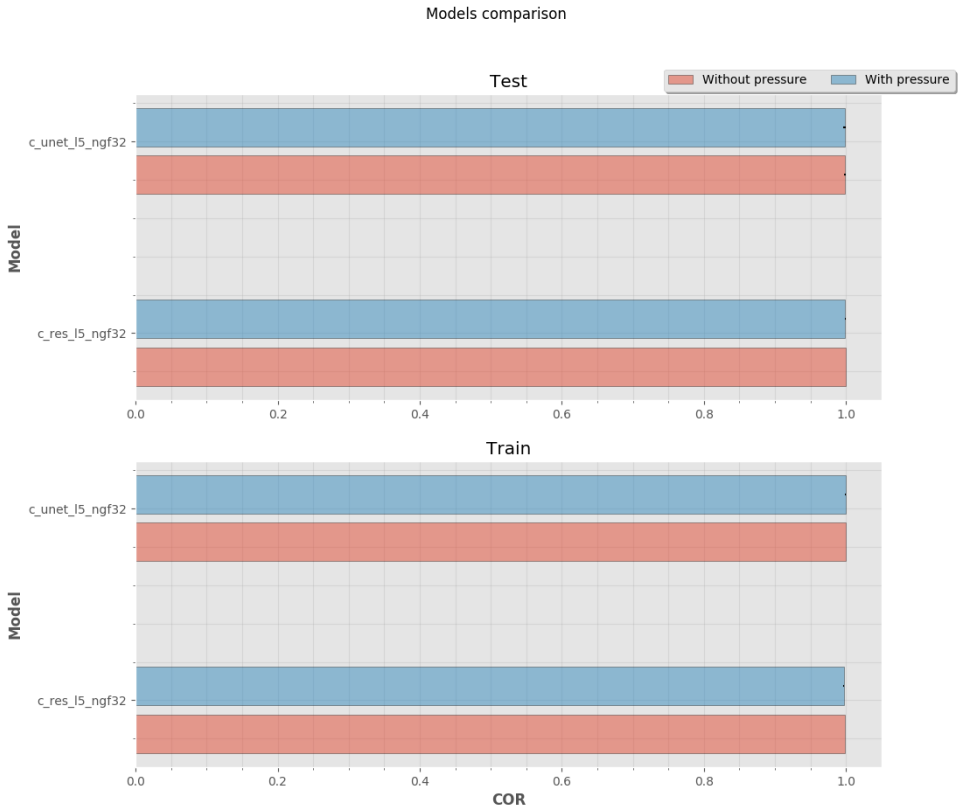


Results

Individual Images – constant model

Cor. and PSNR:

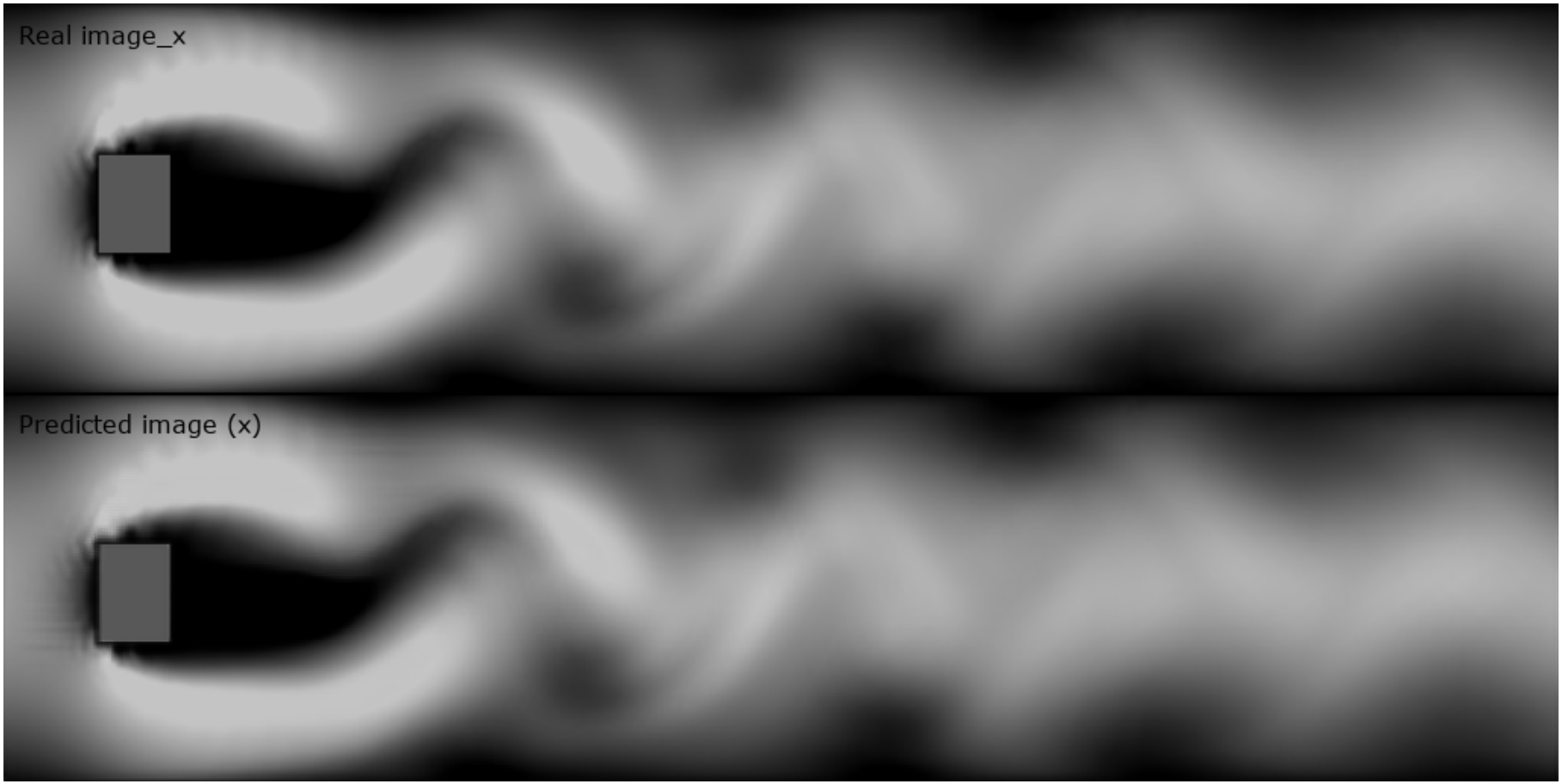




Results

Individual Images – constant model

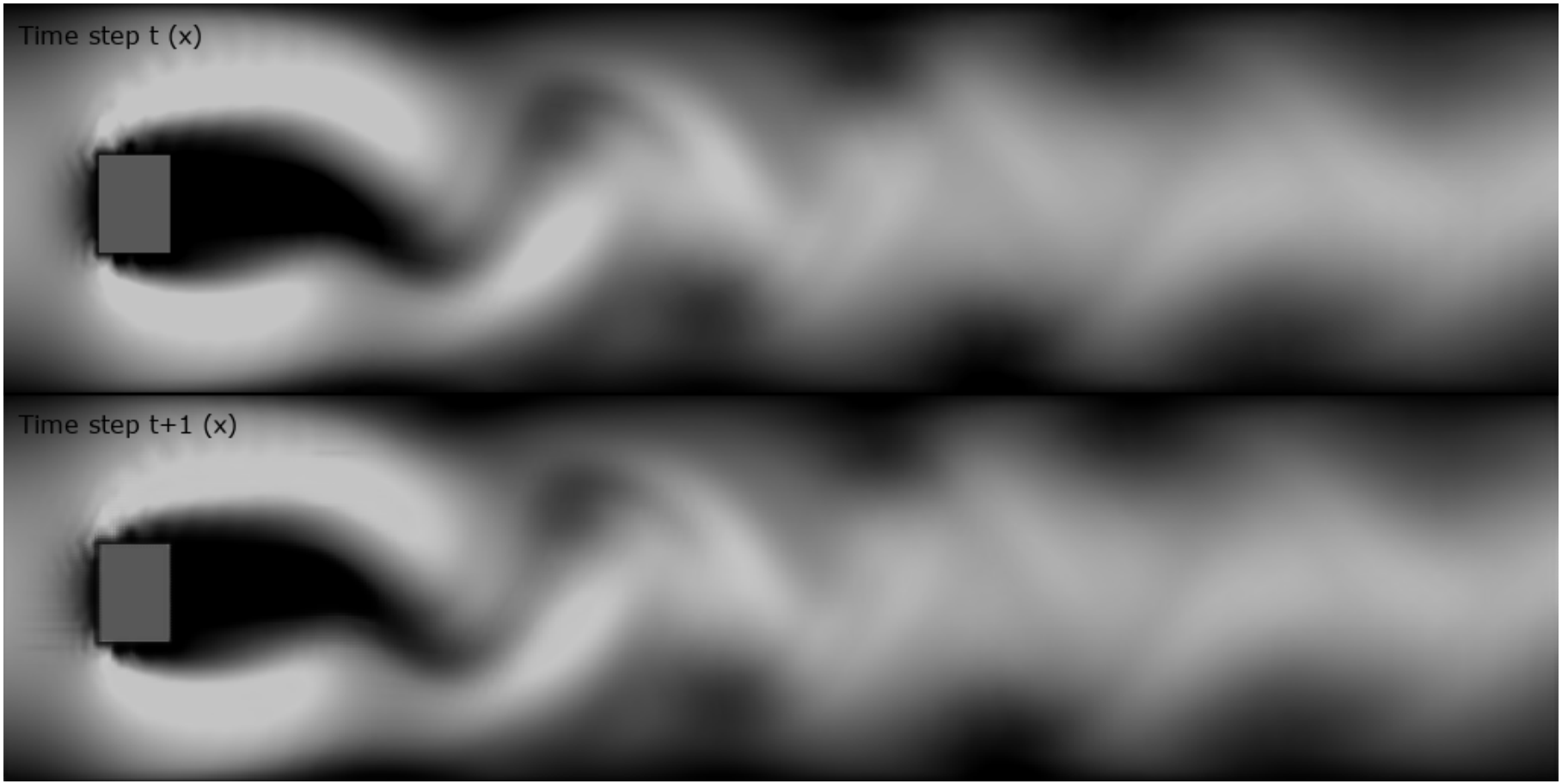
Prediction image:



Results

Individual Images – constant model

Timestep image:

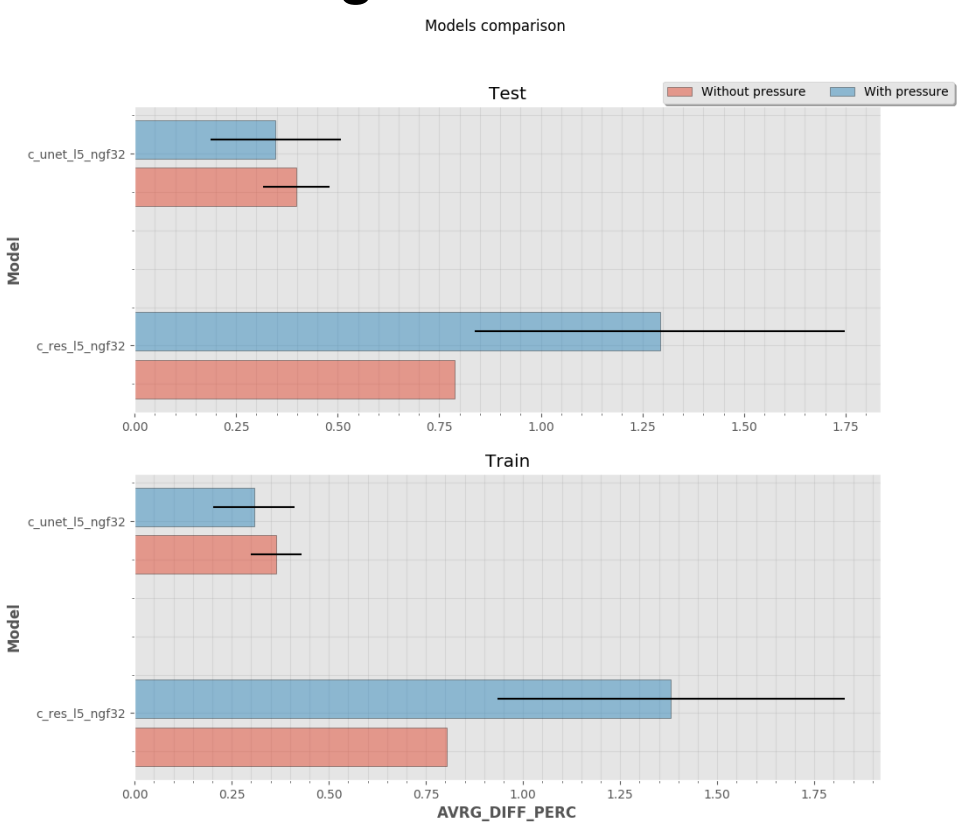


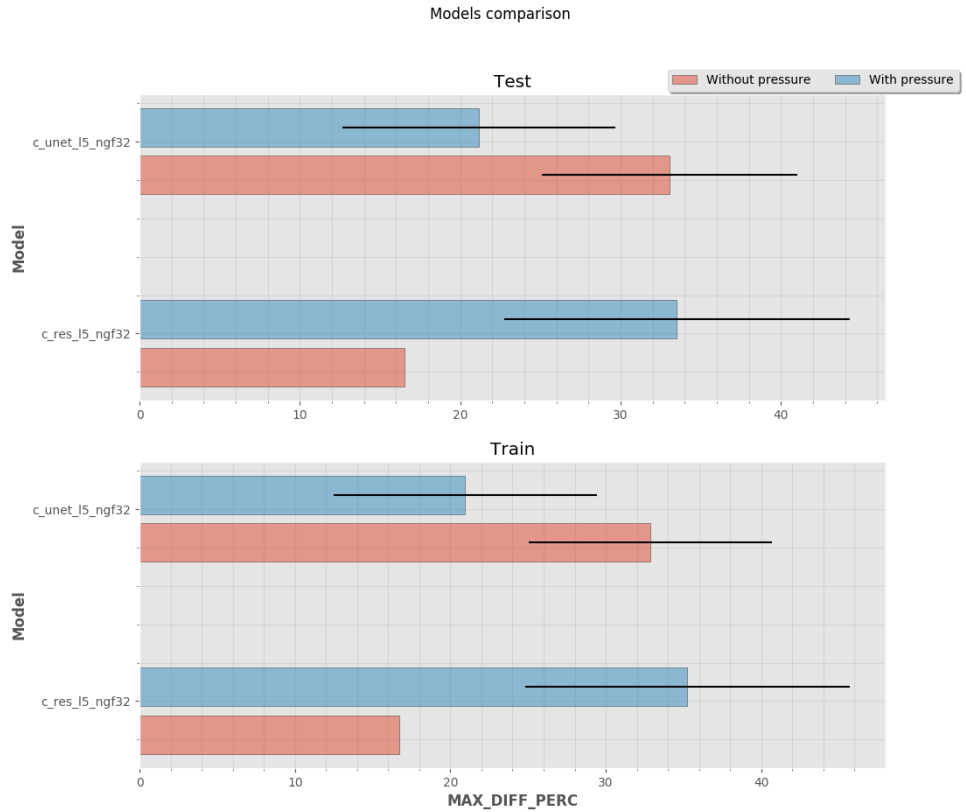
Results

Individual Images – constant model

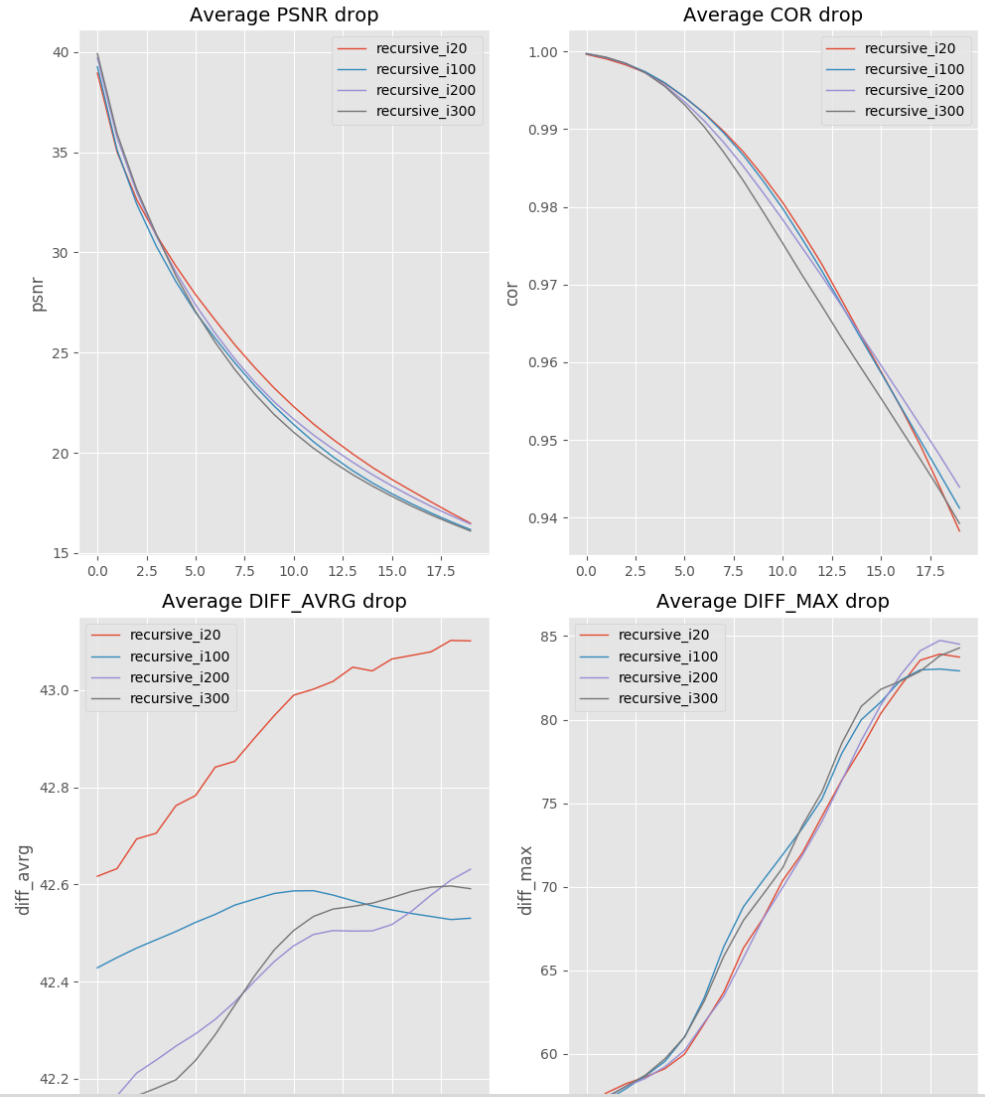
Numerical results: **Max difference**

Avrg difference

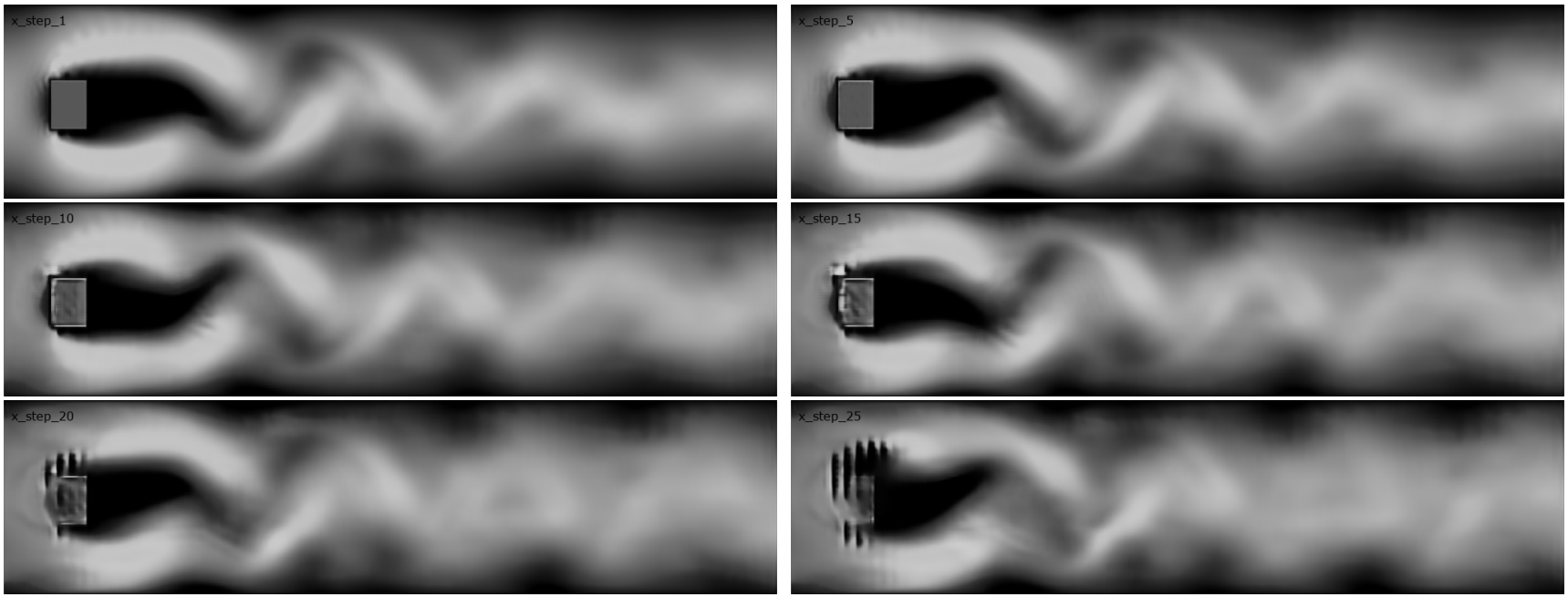




Recursive application – constant model



Recursive application – constant model



Thank you for your attention.

Questions?