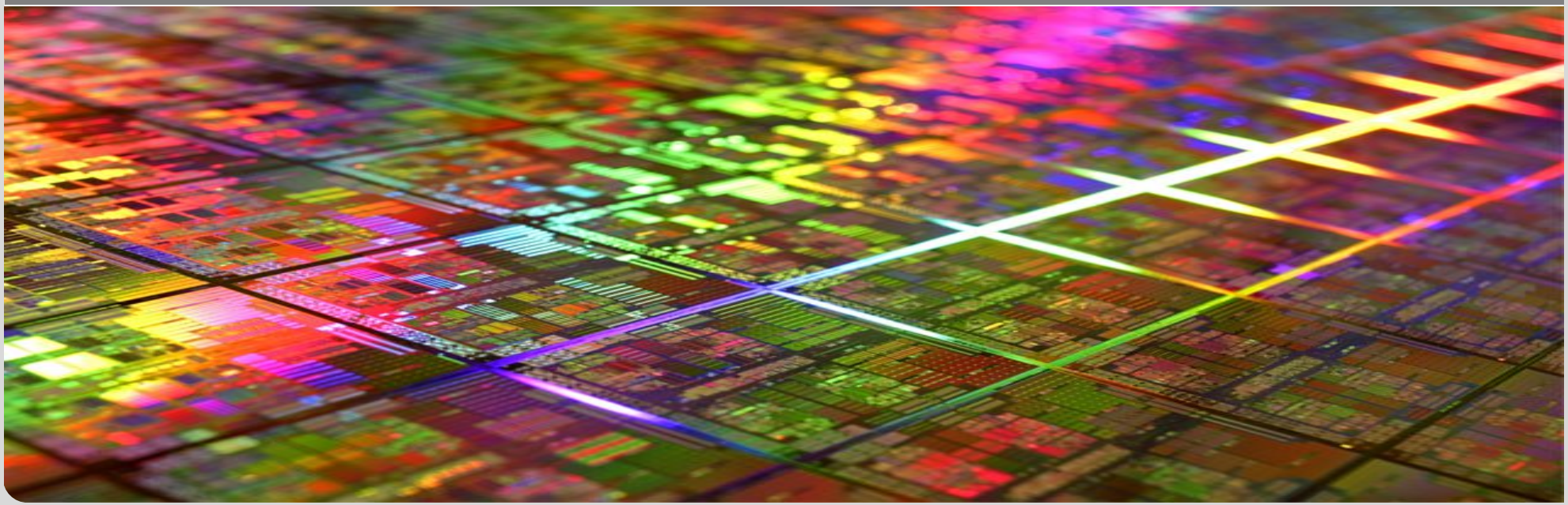
Towards Bringing Together Numerical Methods for Partial Differential Equation and Deep Neural Networks

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.

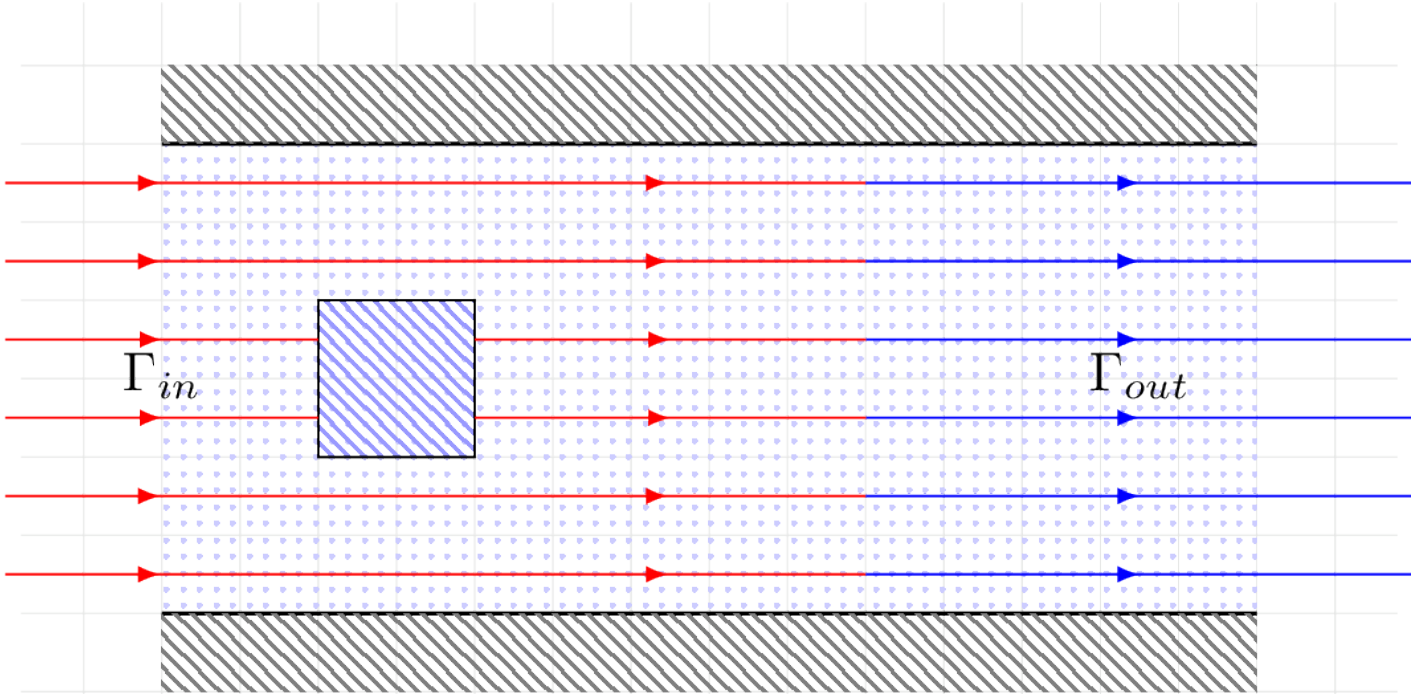


Figure: Simulation Setup

Project description

Basic idea: Perform numerical simulation with ML-models

- Solutions of the simulation can be represented as images.

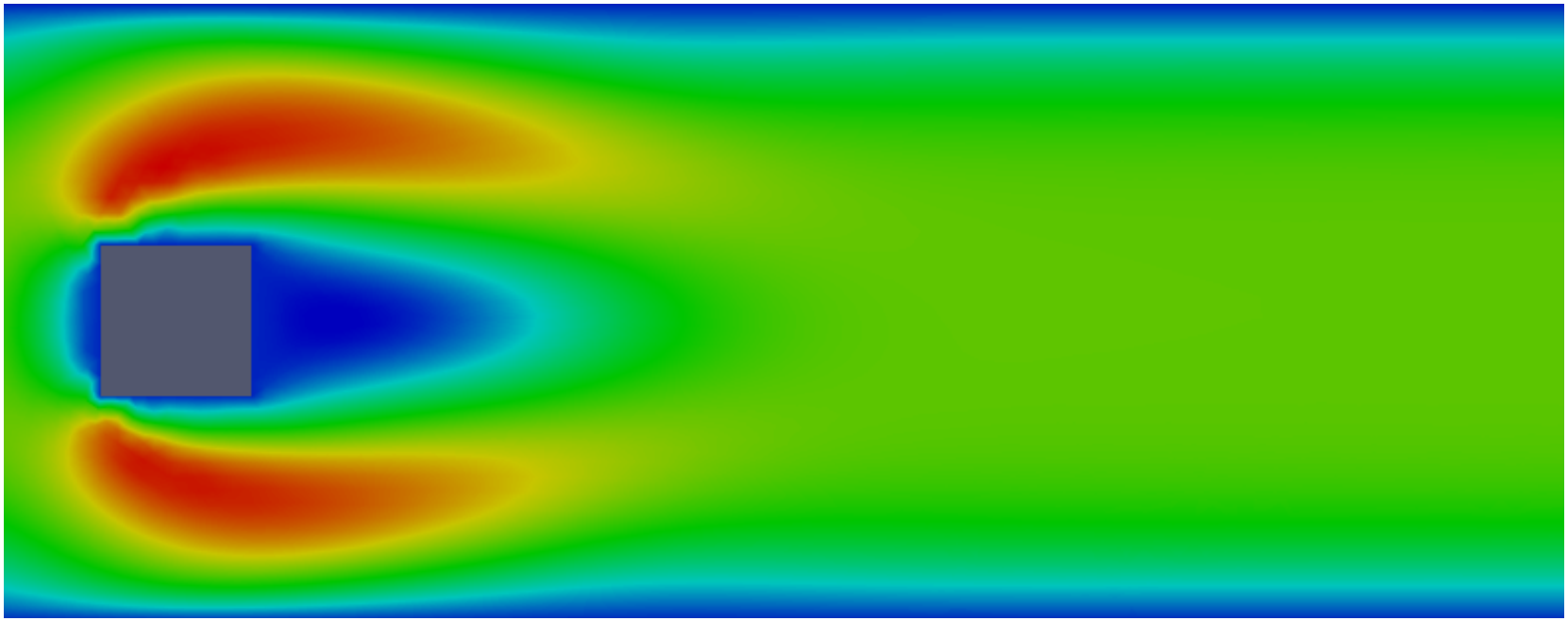
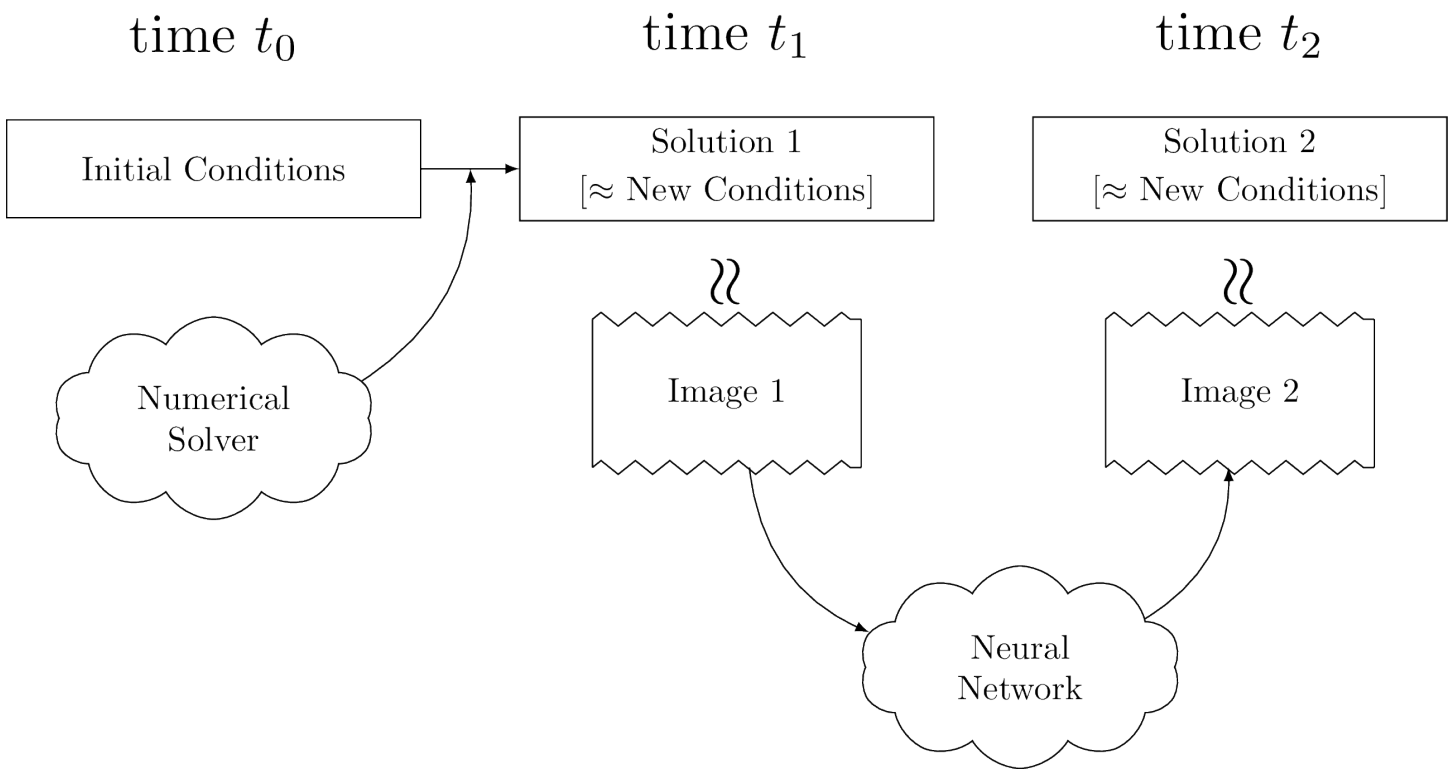


Figure: Simulation Image

Project description

Basic idea: Perform numerical simulation with ML-models

- Our ML-models 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.

Data Generation

- Use of numerical solver for real simulation data generation.
- The simulation has several adjustable parameters
  - inflow speed
  - fluid viscosity
  - fluid density

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- Reynold's number in the range of [90, 350]

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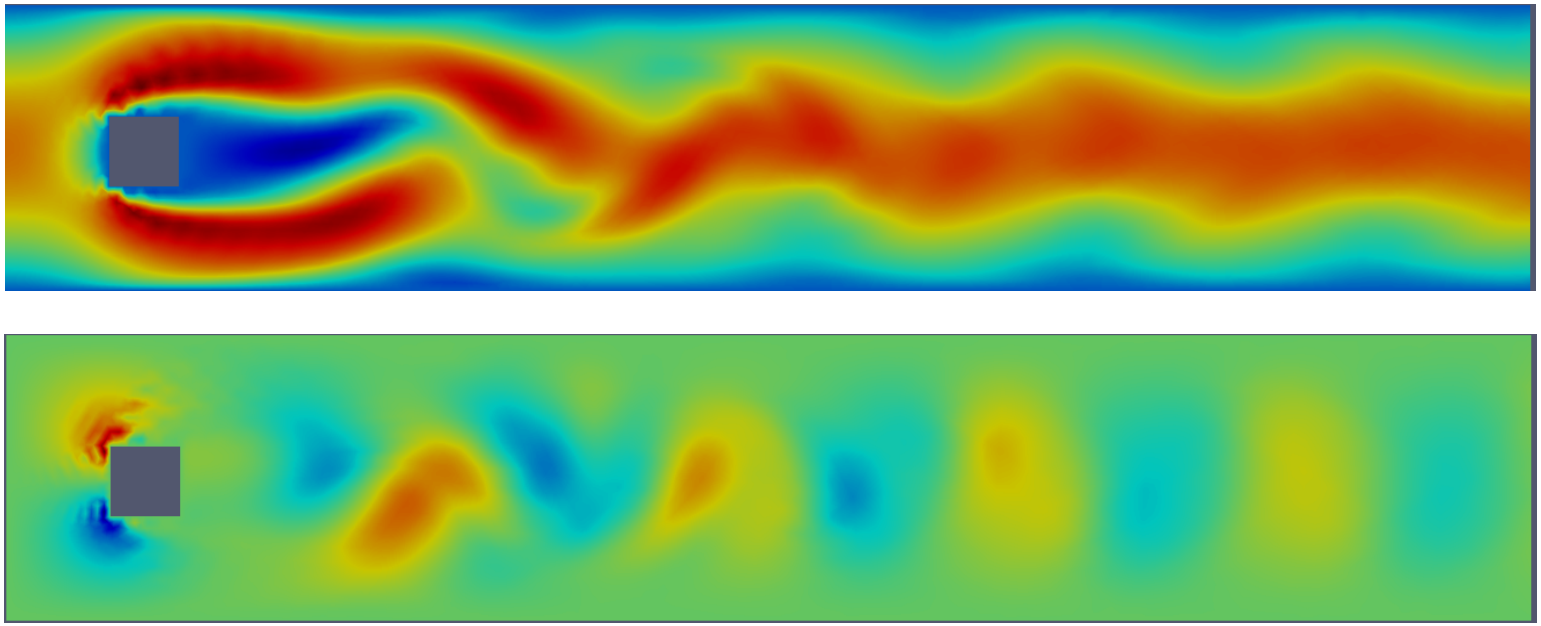
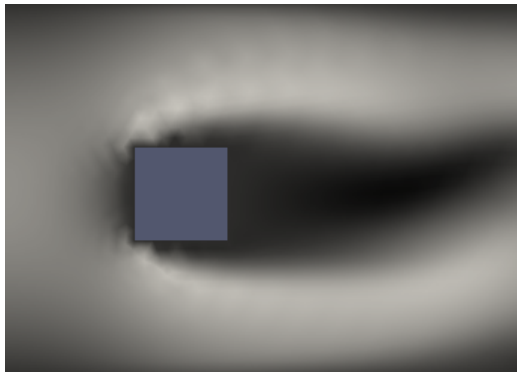
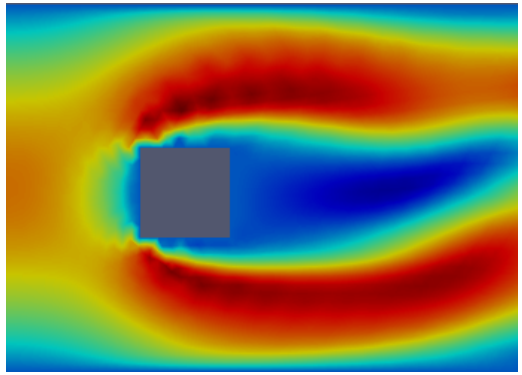
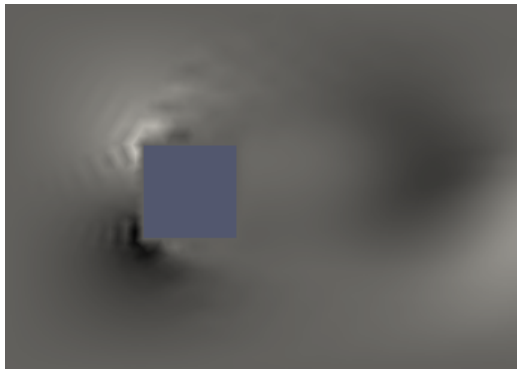
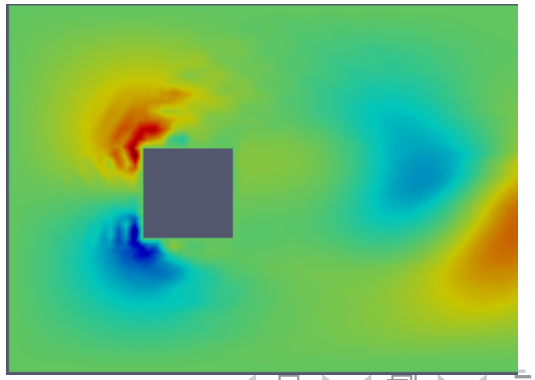


Figure: Karman vortex street

Data Generation

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

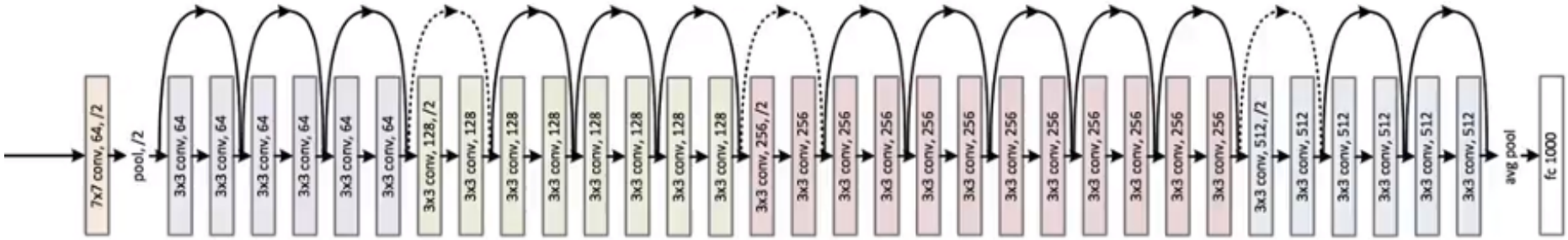





Models

- Two types of architectures based on our preliminary research:

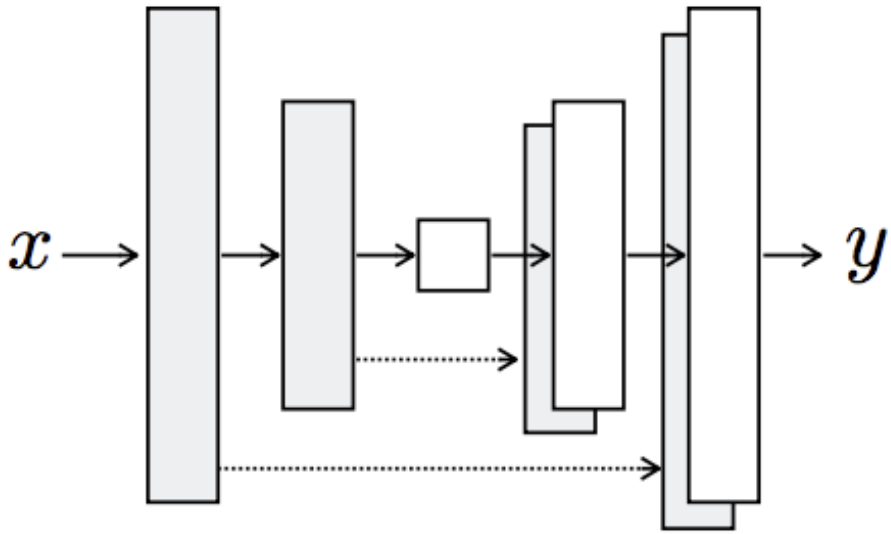
Models

- 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

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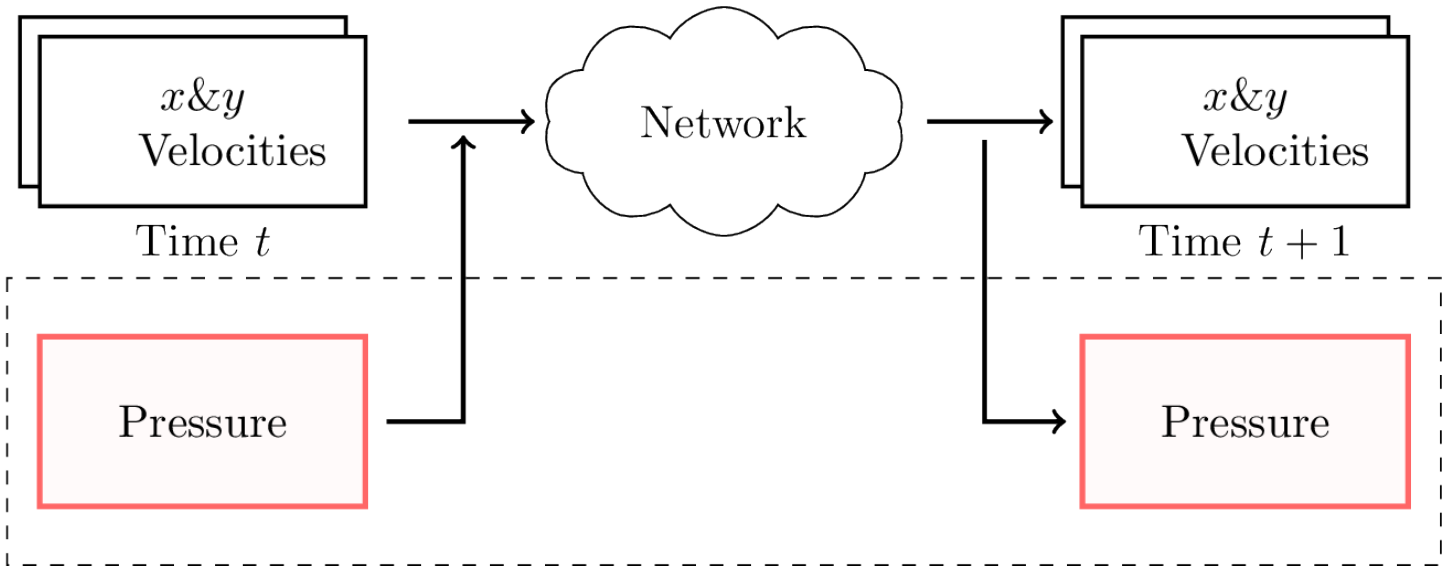
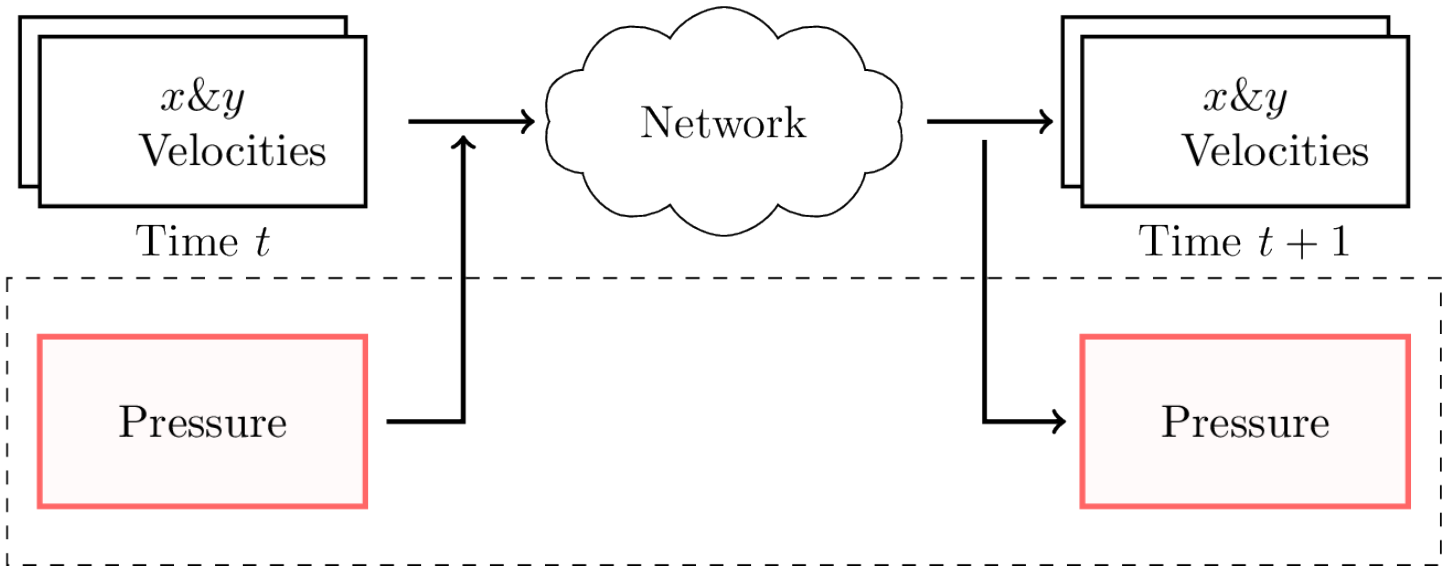
- Data being used by the network.
  - Usage of pressure field



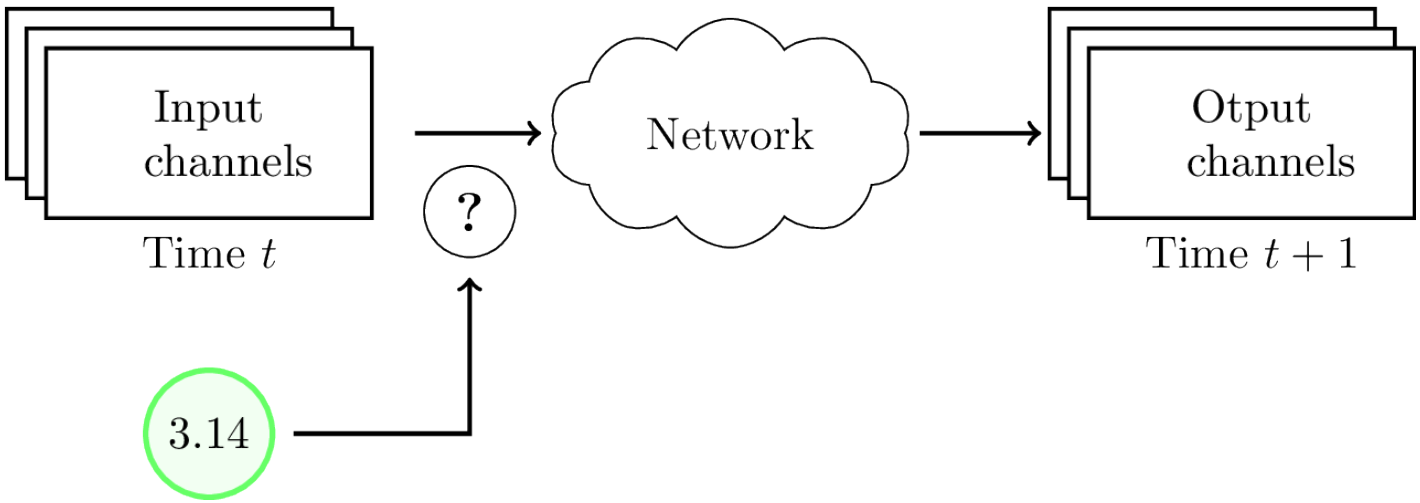
Models

- Two types of architectures based on our preliminary research:
- Data being used by the network.
  - Usage of pressure field $\rightarrow$ the pressure field turned out to be useful



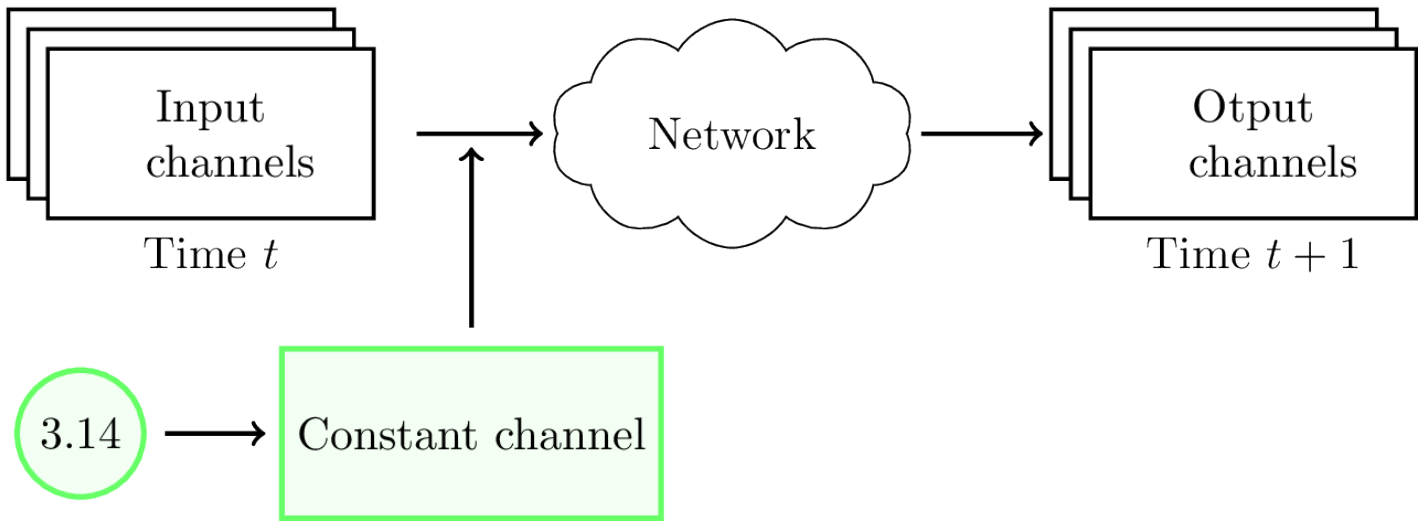
Models

- 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.
  - Processing of real values $\rightarrow$ extra image channel filled with the value



Evaluating the results

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Two views of the results

Image processing

Numerical Simulation

Evaluating the results

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Image processing

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

Numerical Simulation

Evaluating the results

Two views of the results

Image processing

- Perceived qualities of the image results
- Metrics:
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Numerical Simulation

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

Evaluation cases

Two evaluation cases

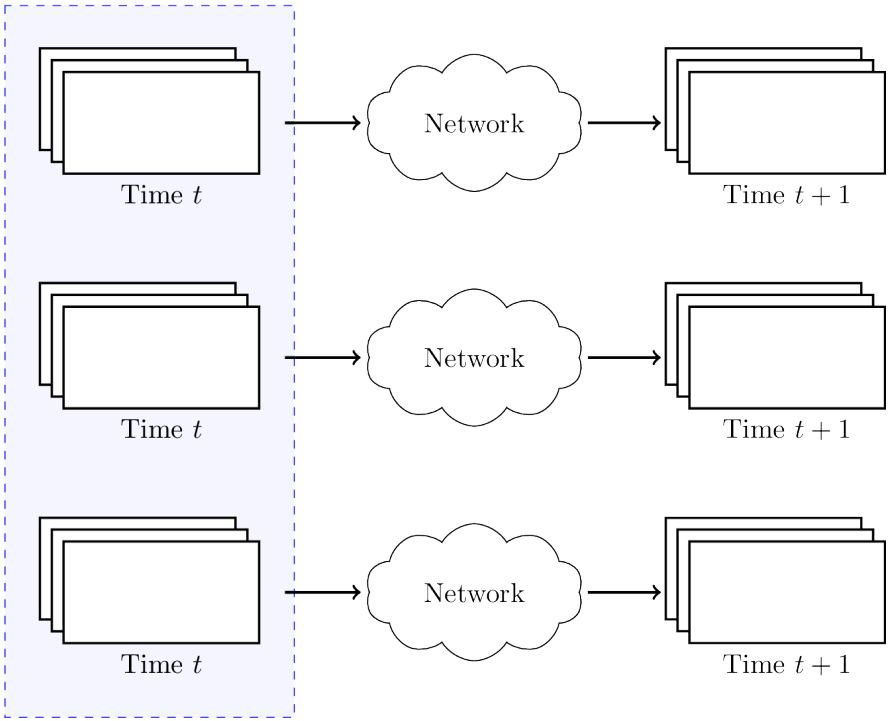
Individual Images

Recursive Application

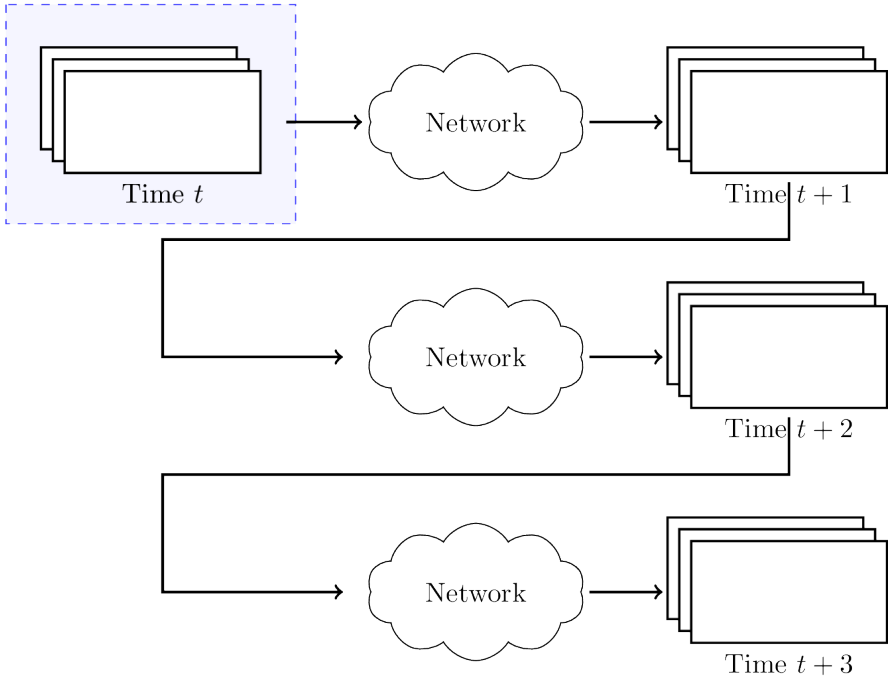
Evaluation cases

Two evaluation cases

Individual Images



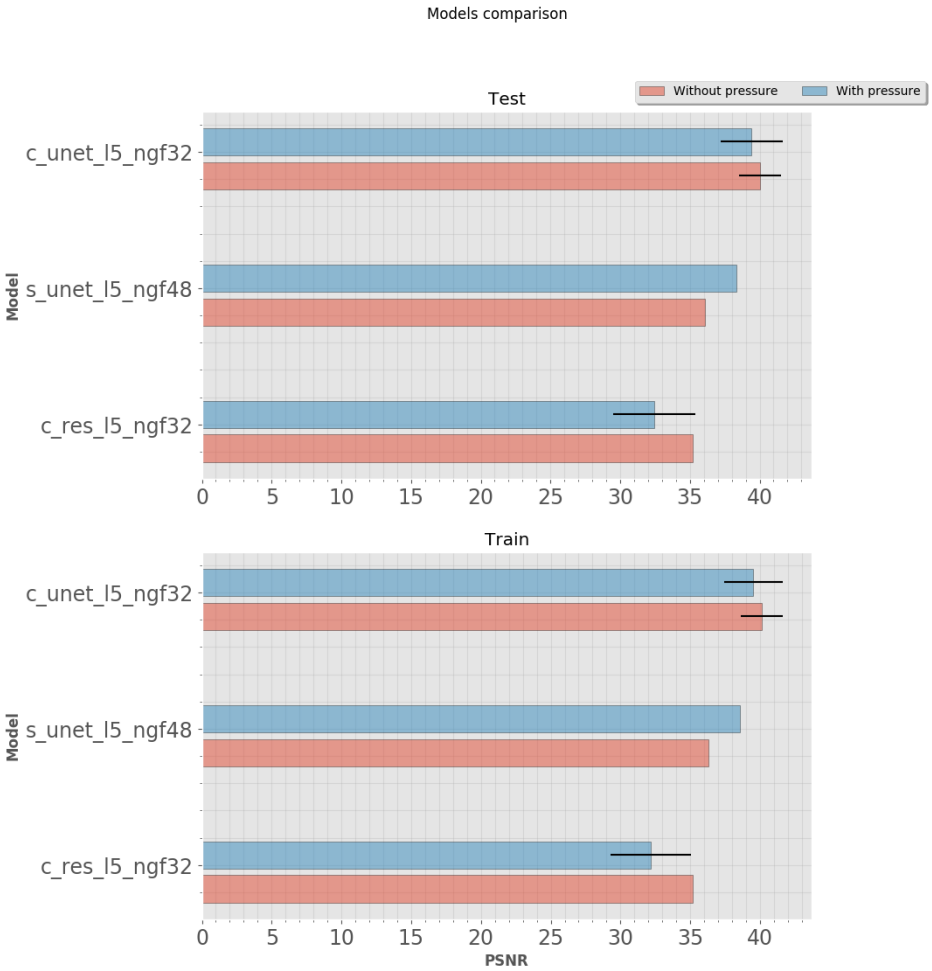
Recursive Application

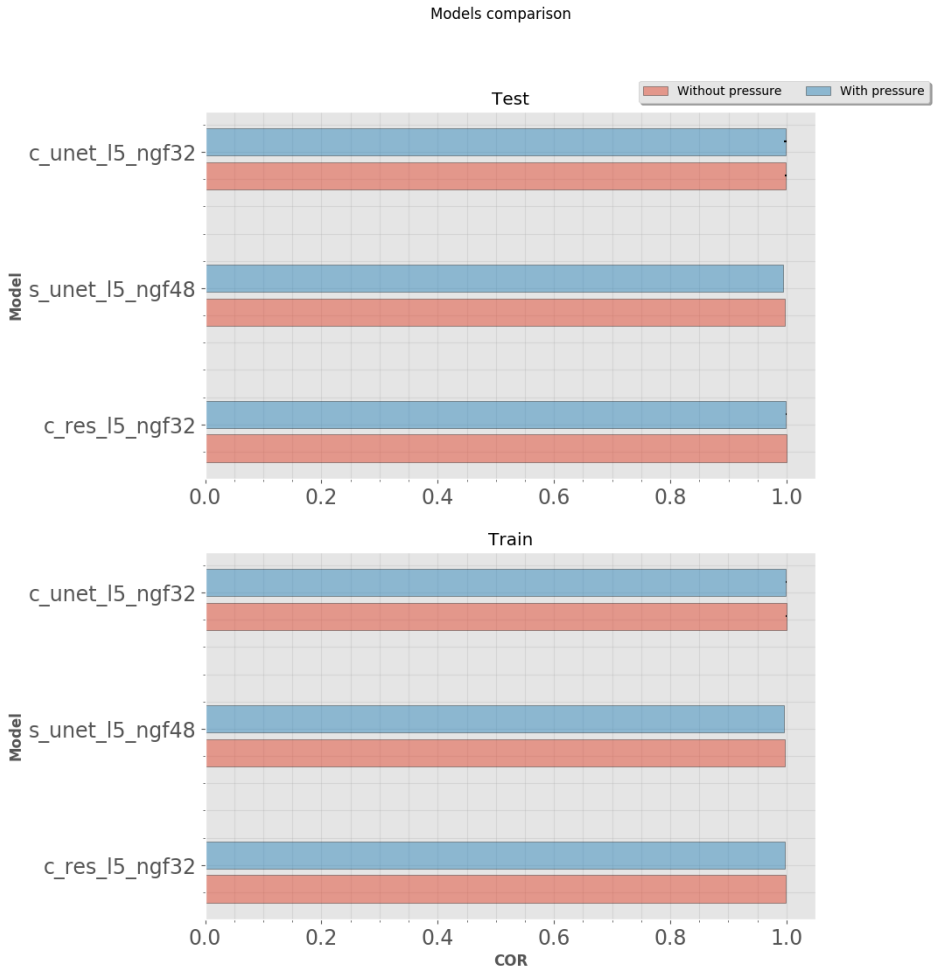


Results

Individual Images

Cor. and PSNR:

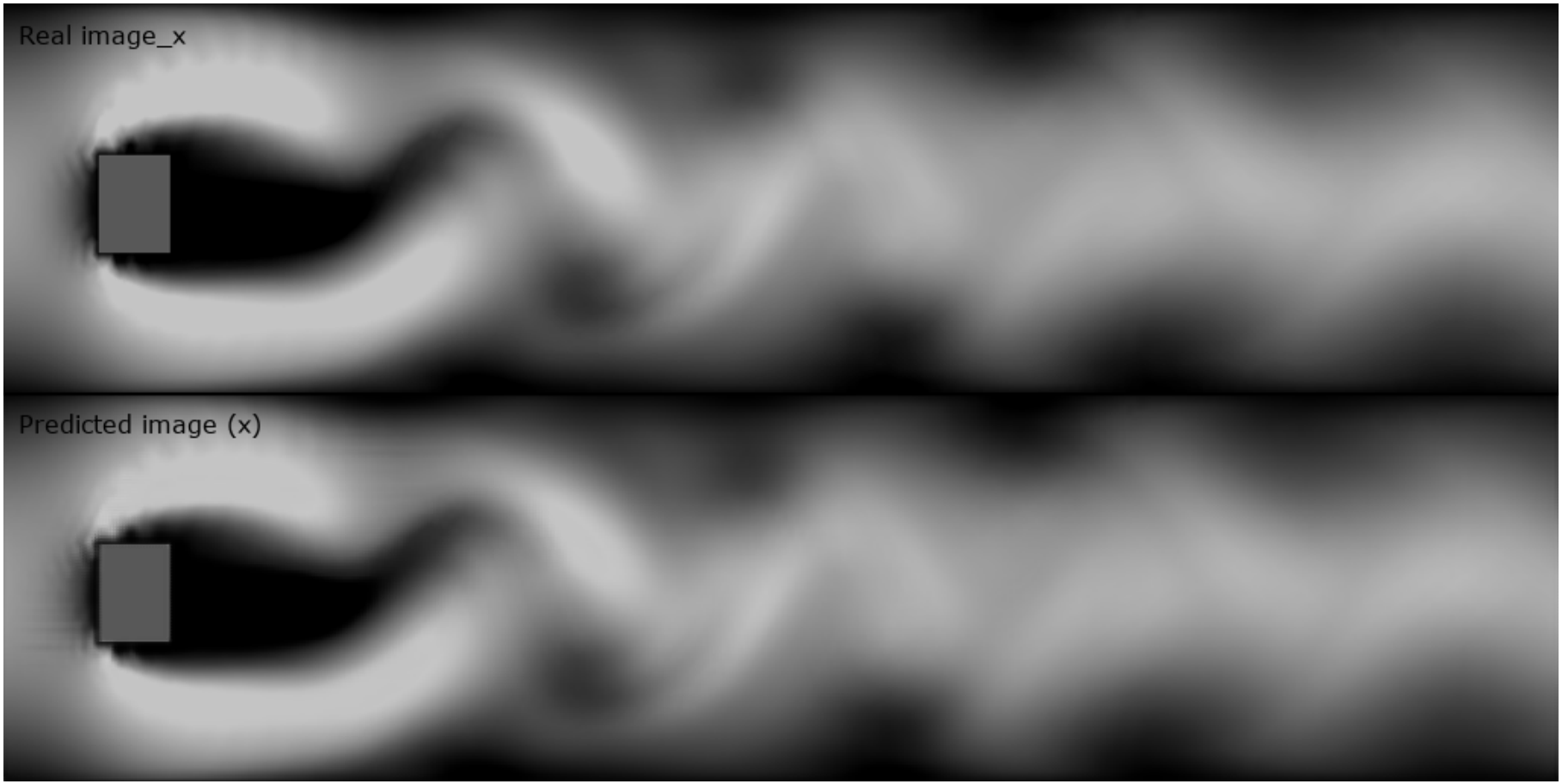




Results

Individual Images

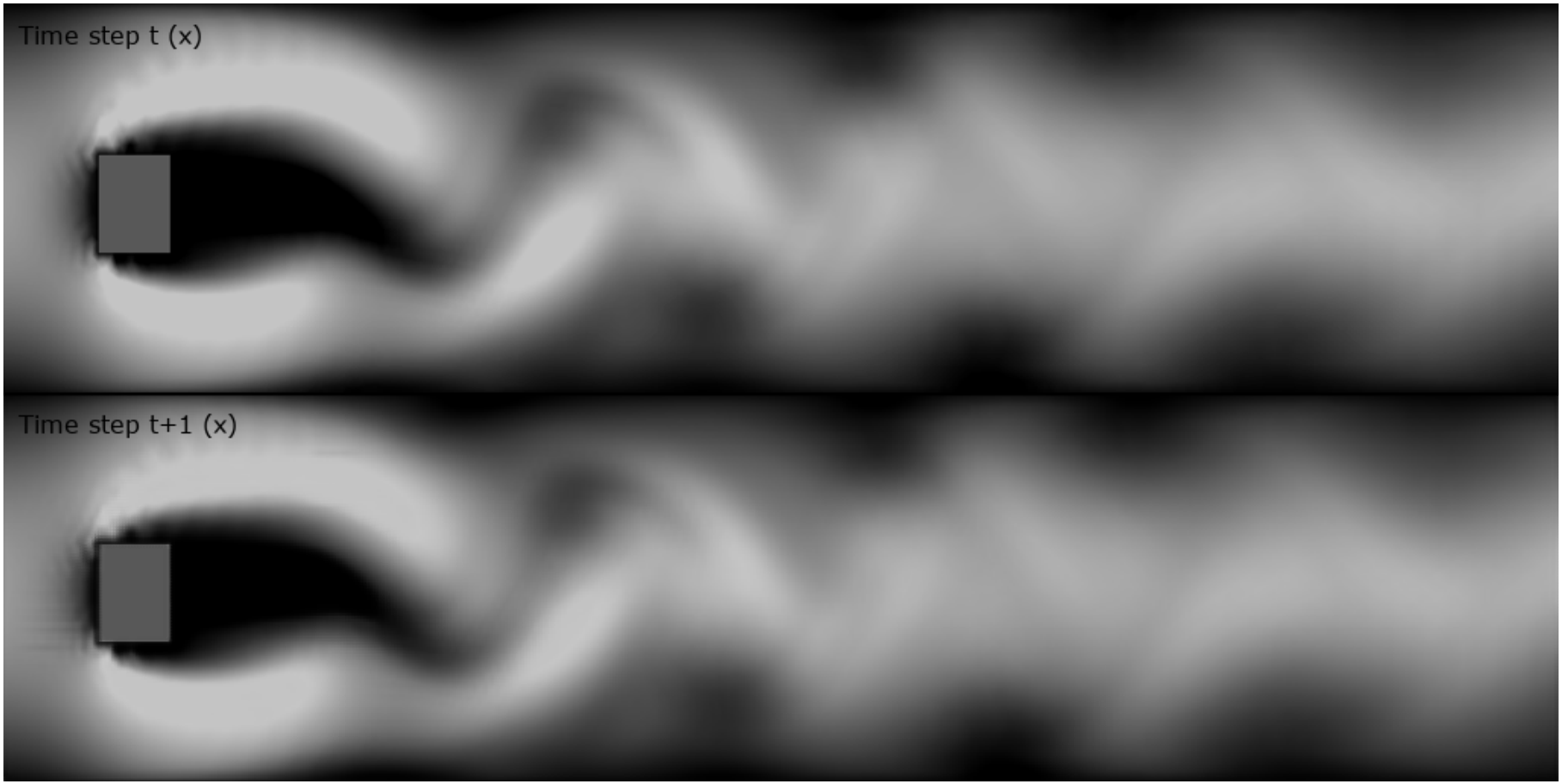
Prediction image:



Results

Individual Images

Timestep image:

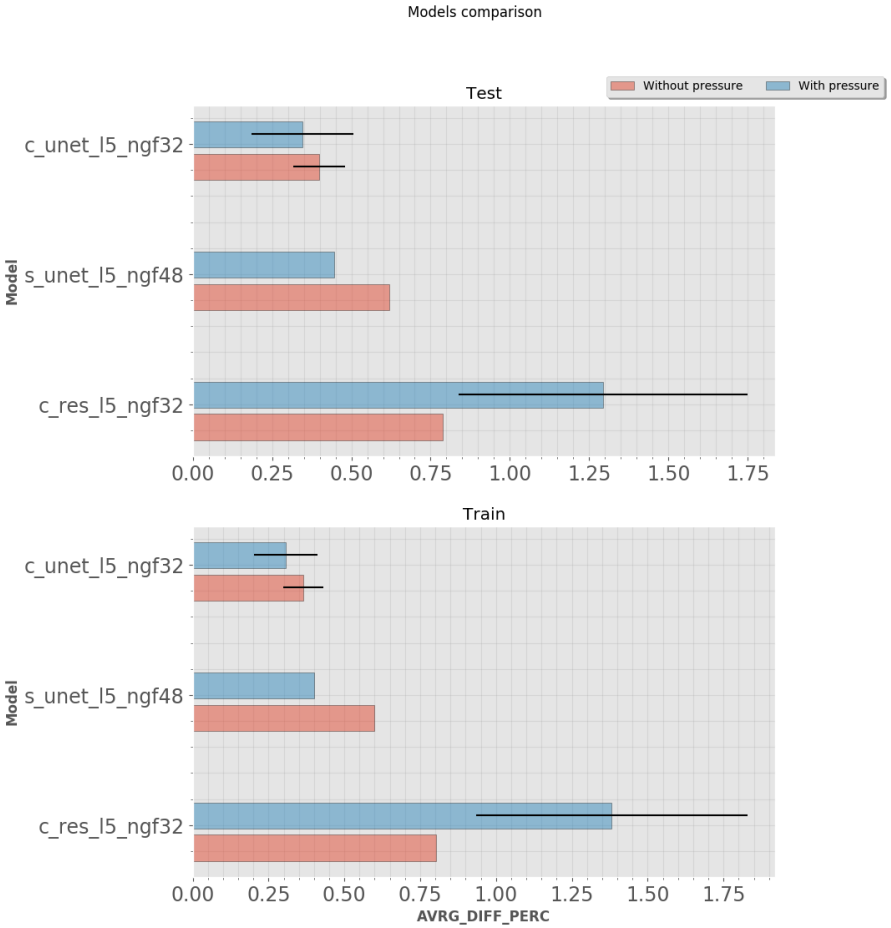


Results

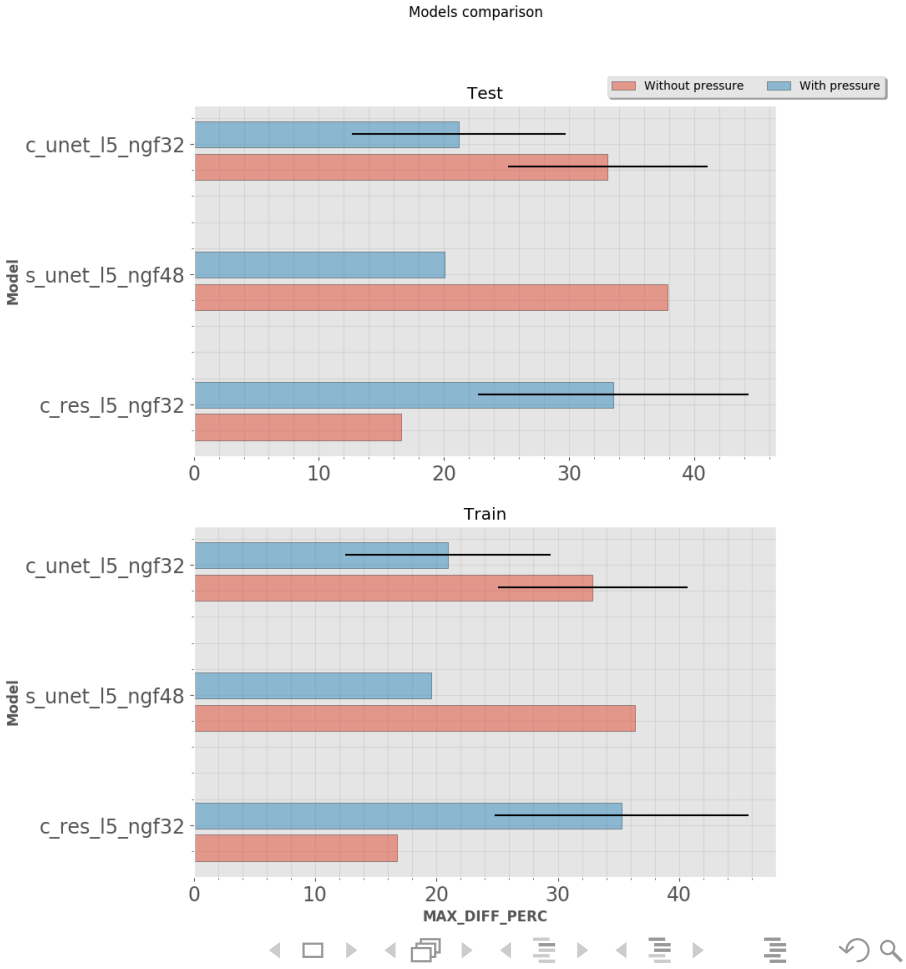
Individual Images

Numerical view:

Avrg. difference

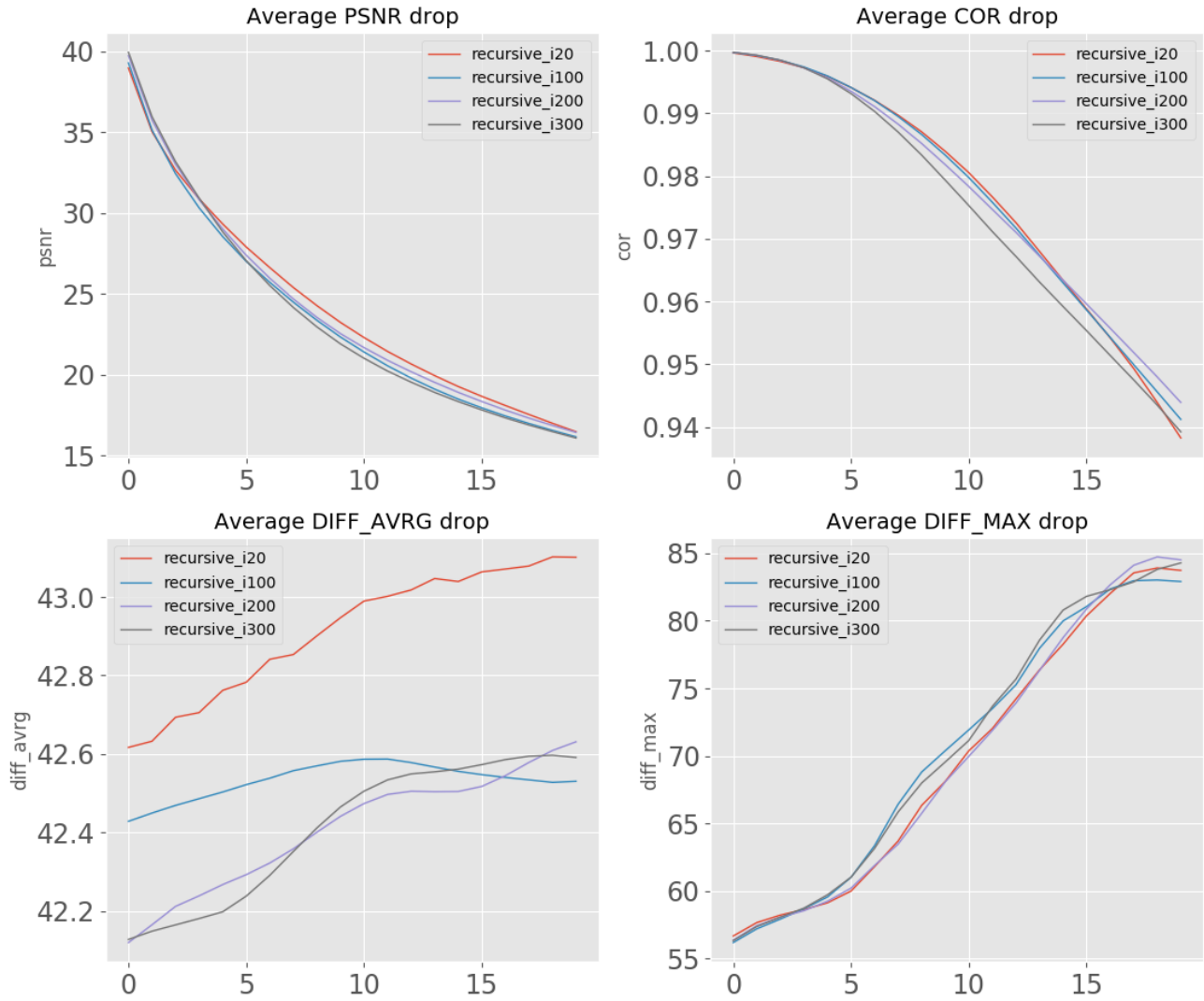


Max difference



Results

Recursive application – constant model



Results

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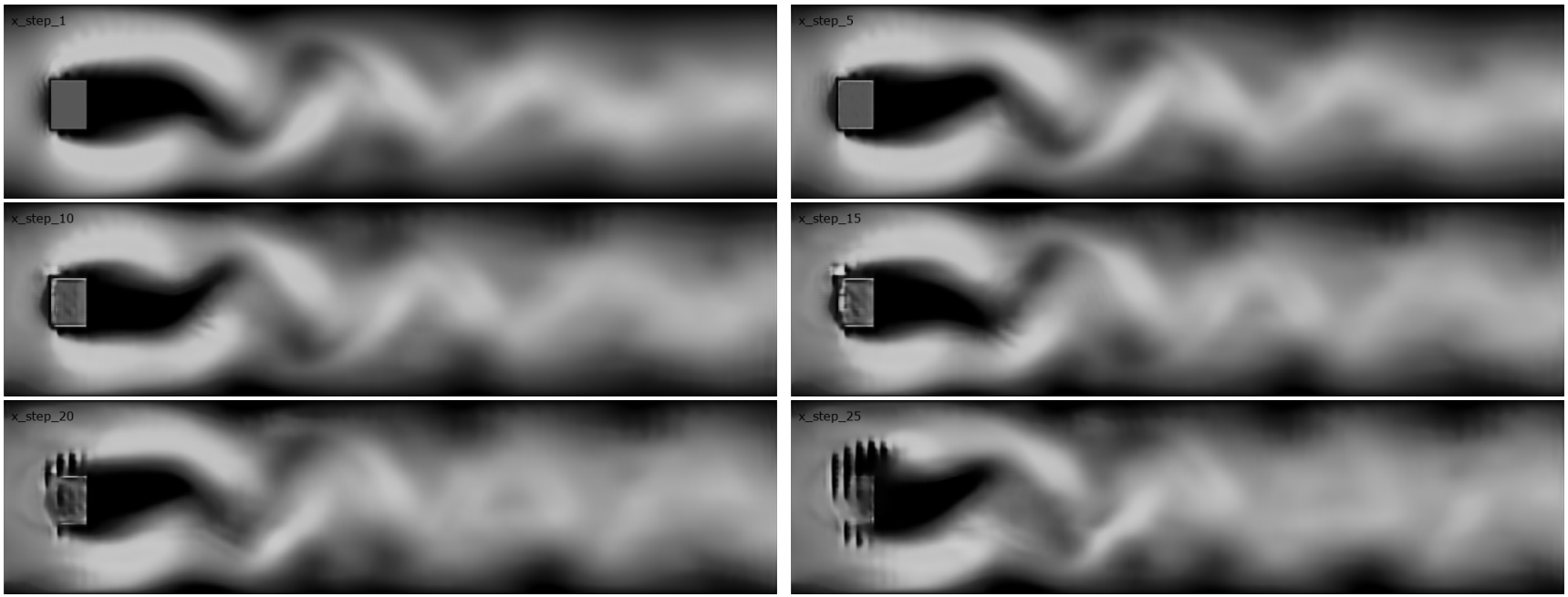

Thank you for your attention.

Questions?