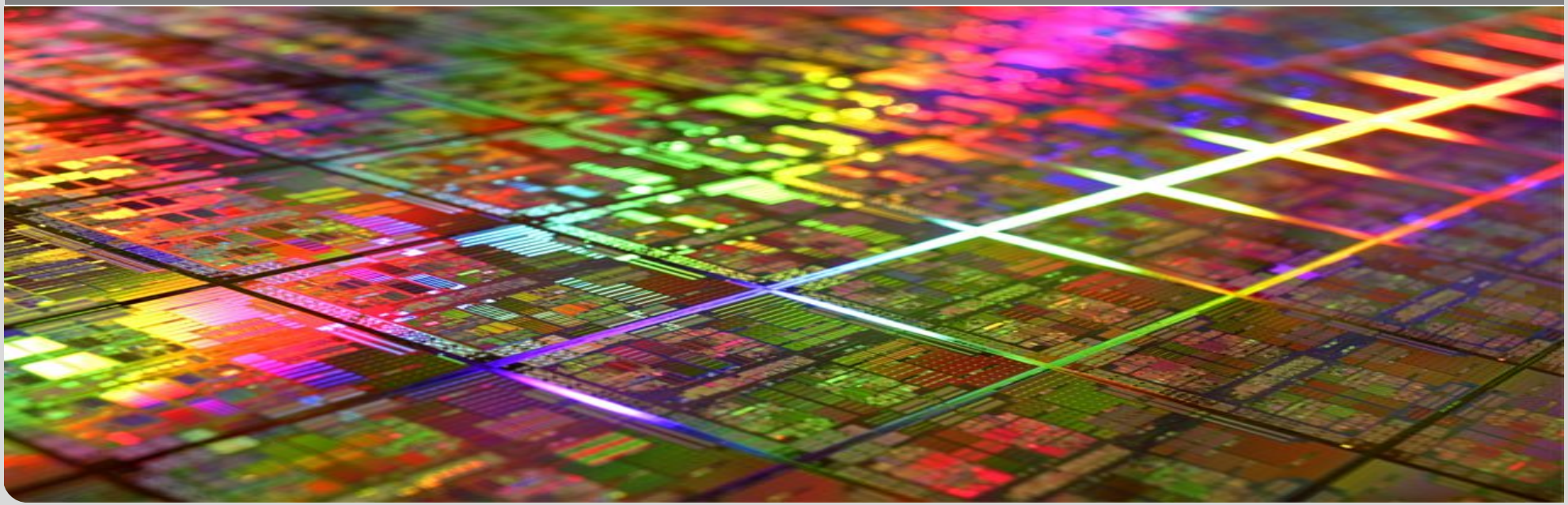
# Towards Bringing Together Numerical Methods for Partial Differential Equation and Deep Neural Networks

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.

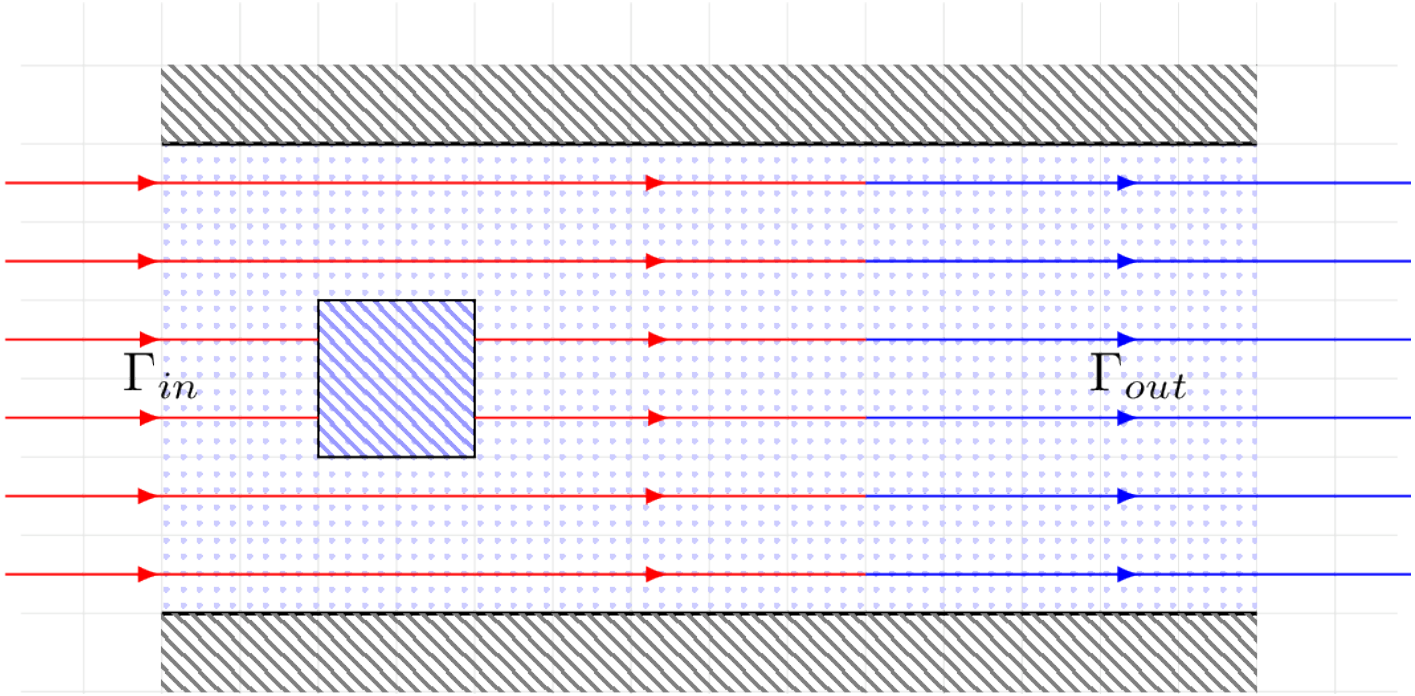



Figure: Simulation Setup

# Project description

**Basic idea:** Perform numerical simulation with ML-models

- Solutions of the simulation can be represented as images.

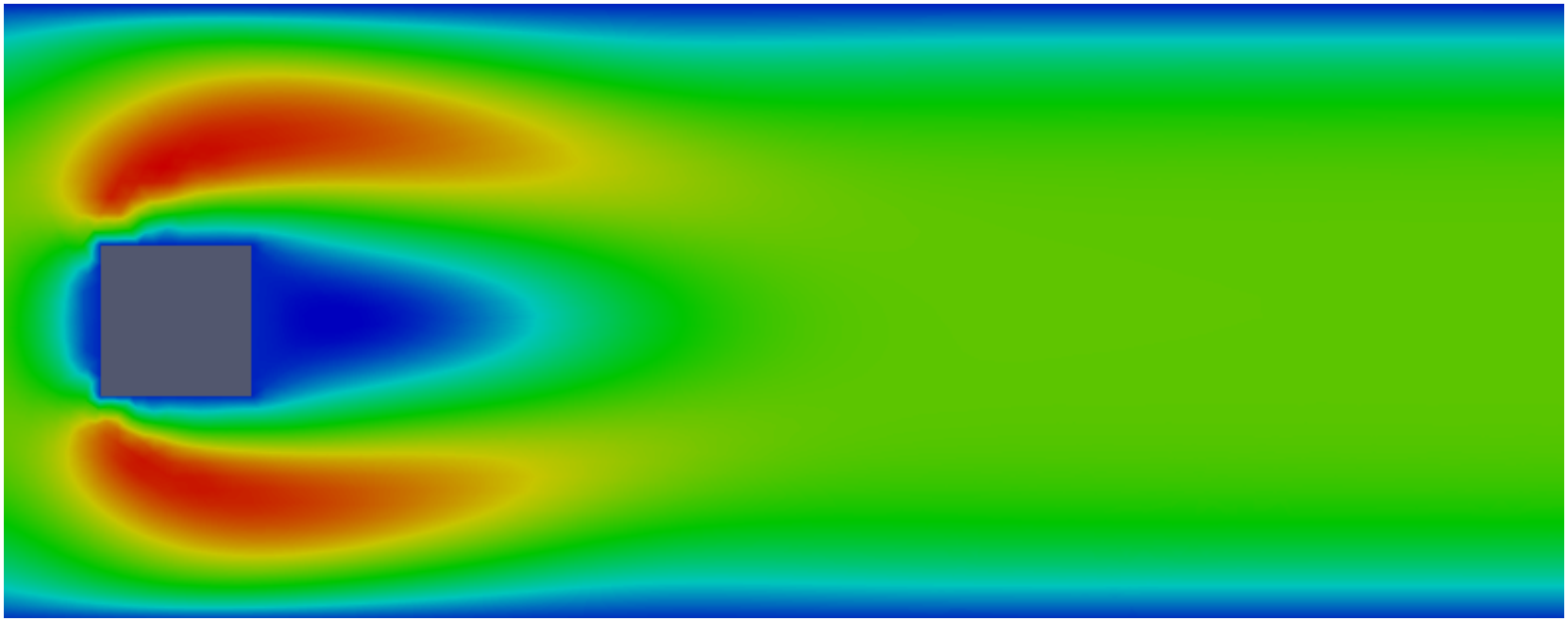
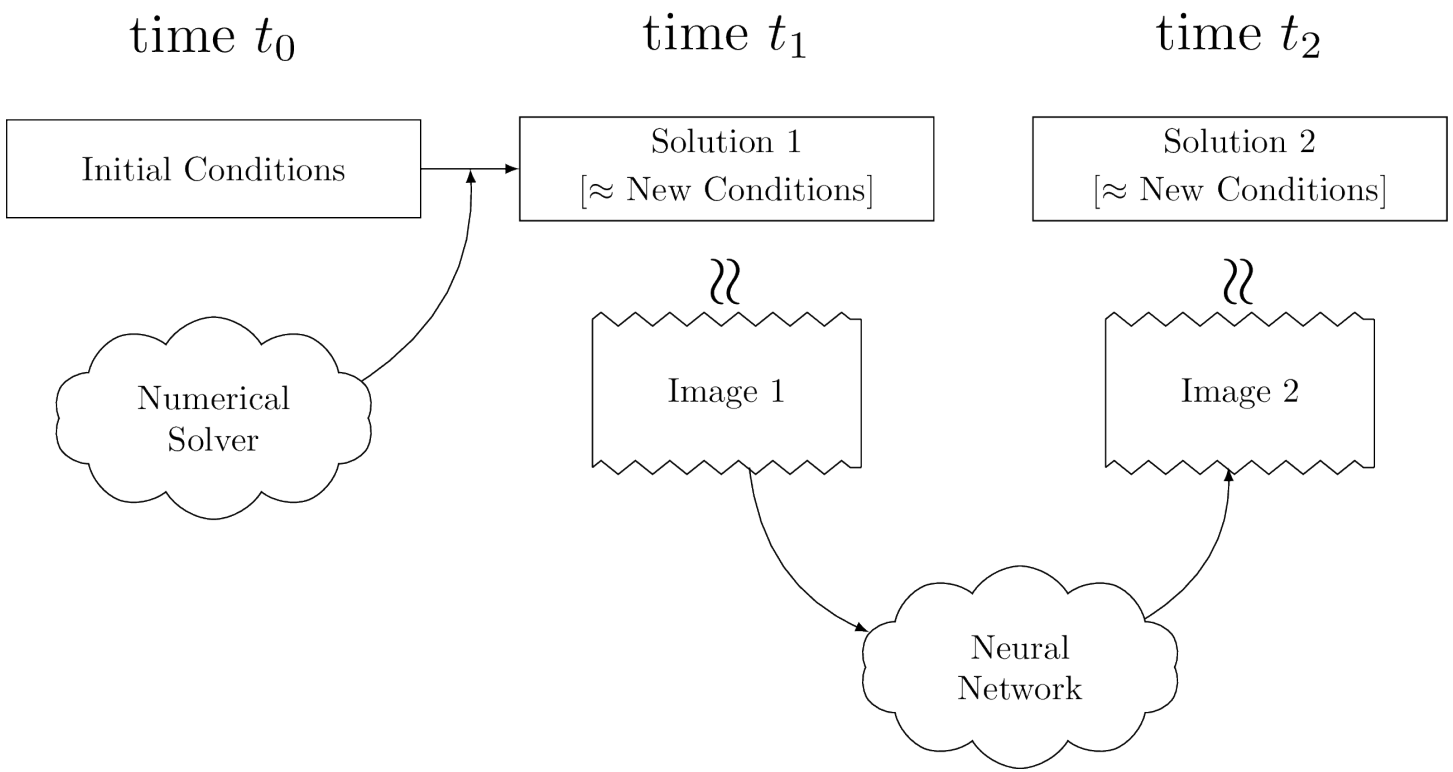


Figure: Simulation Image

# 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.

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- The simulation has several adjustable parameters
  - inflow speed
  - fluid viscosity
  - fluid density

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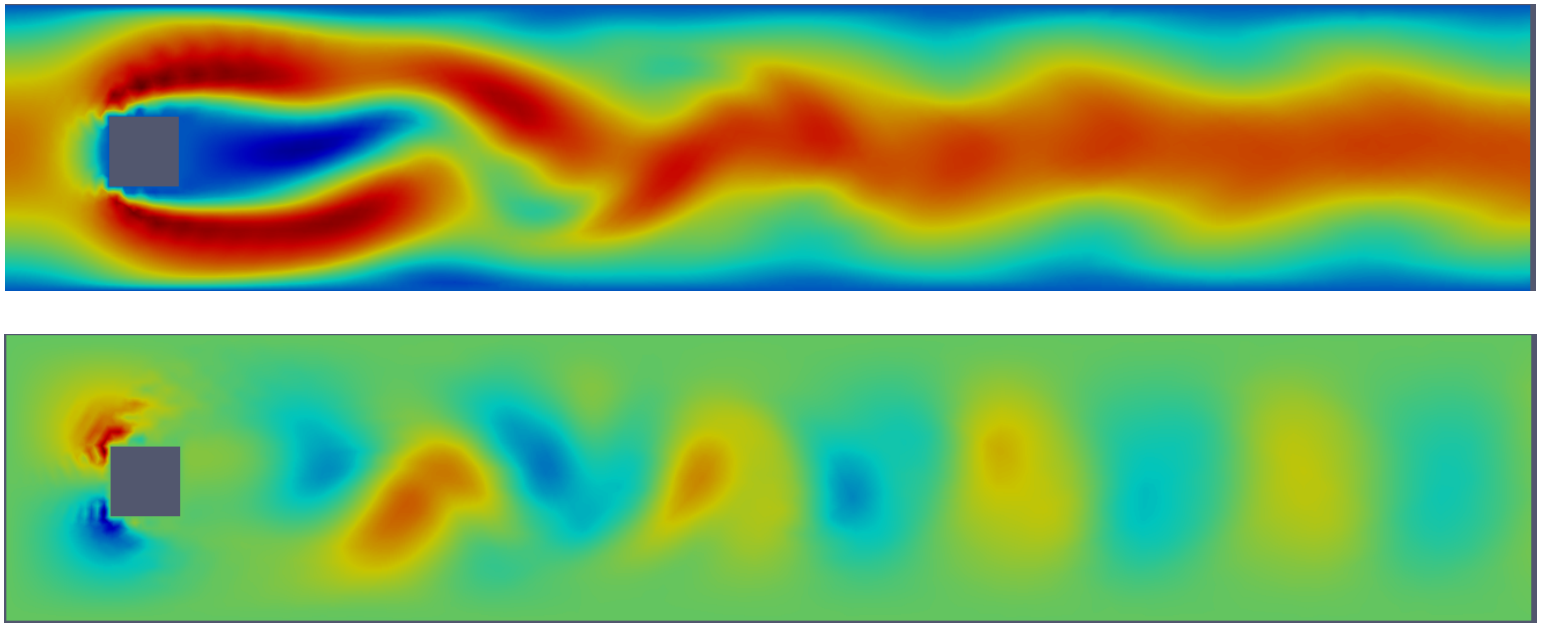
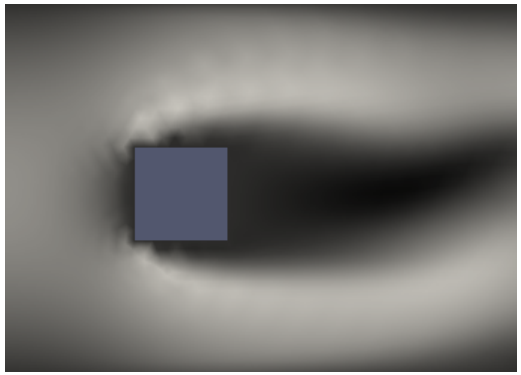
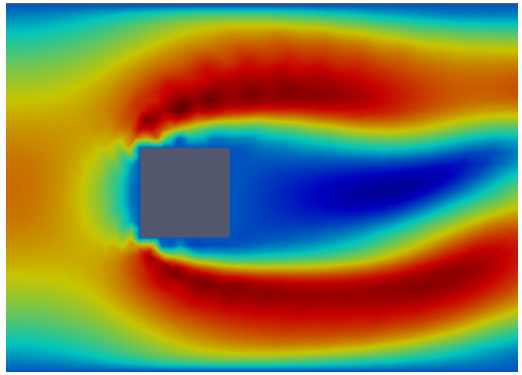
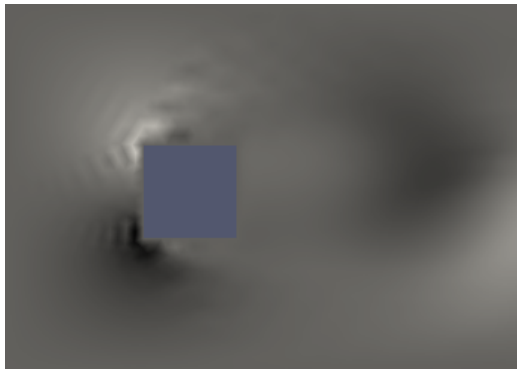
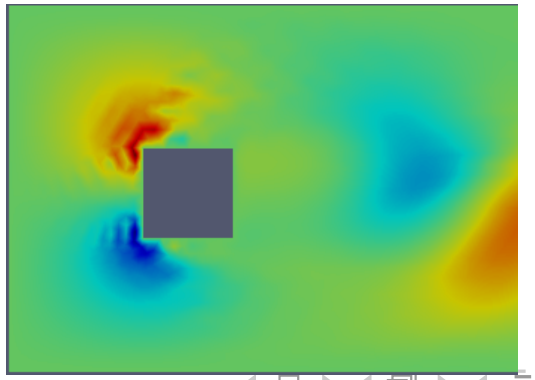


Figure: Karman vortex street

# 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

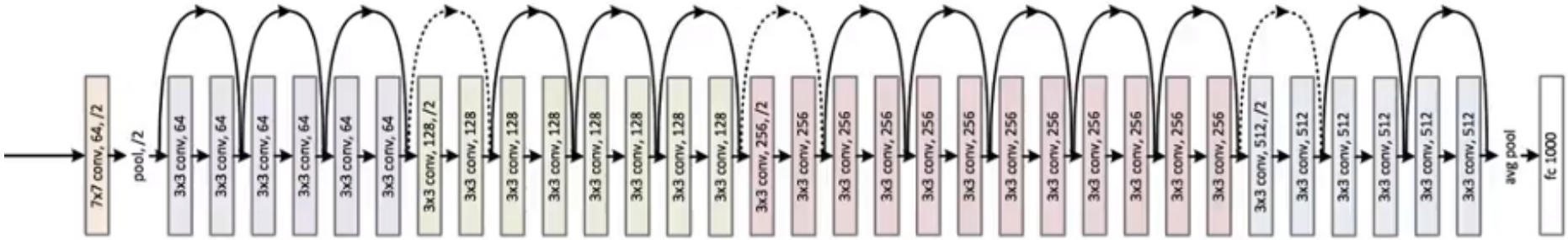





# Models

- Two types of architectures based on our preliminary research:

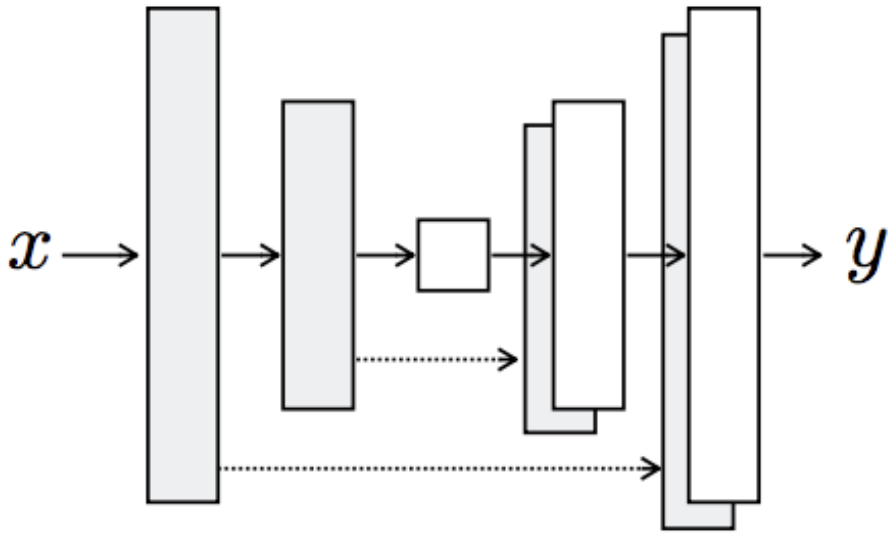
# Models

- 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.

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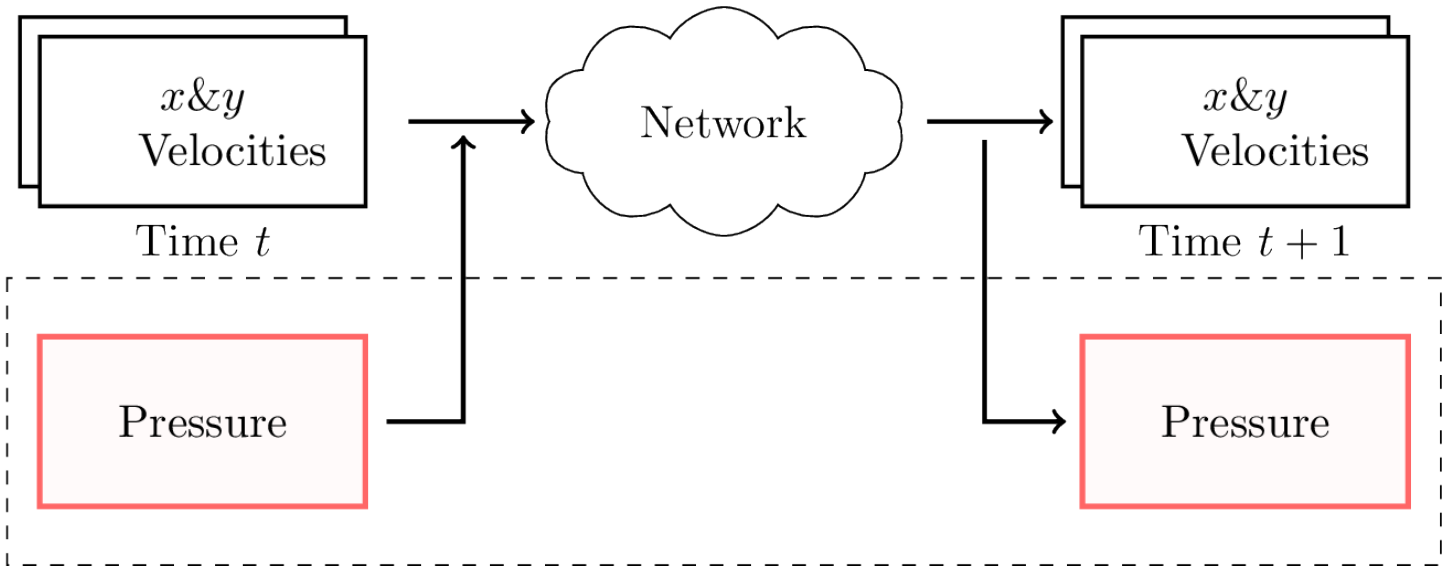
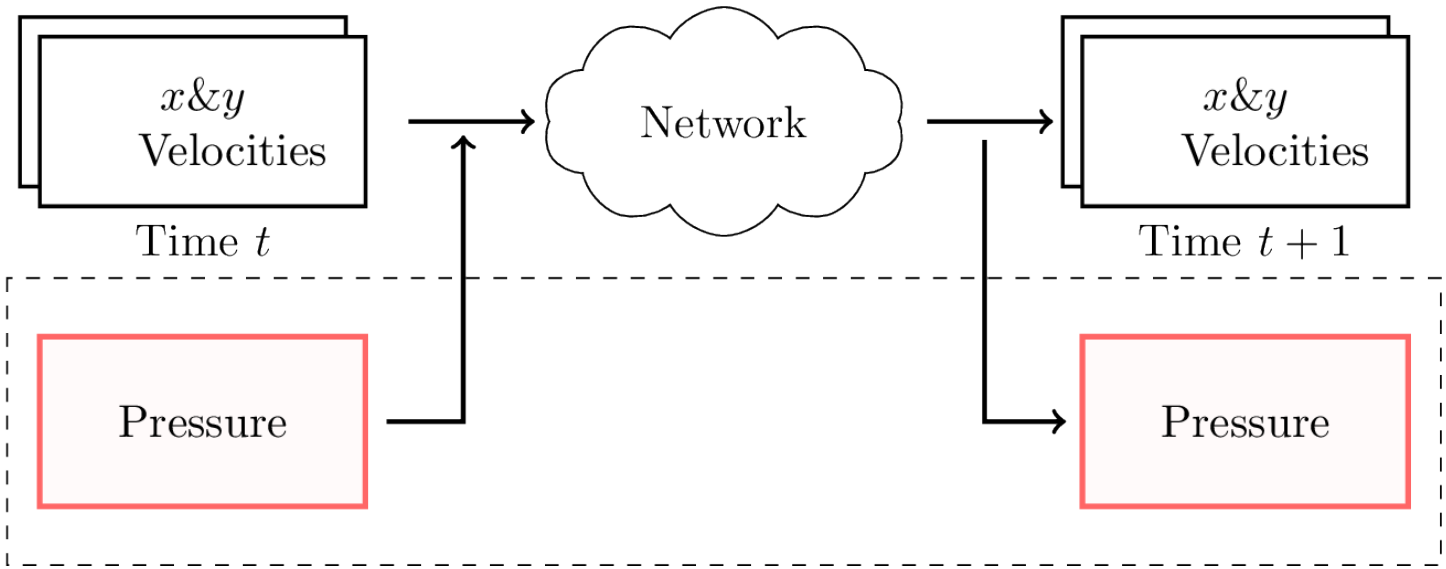
- Data being used by the network.
  - Usage of pressure field



# 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



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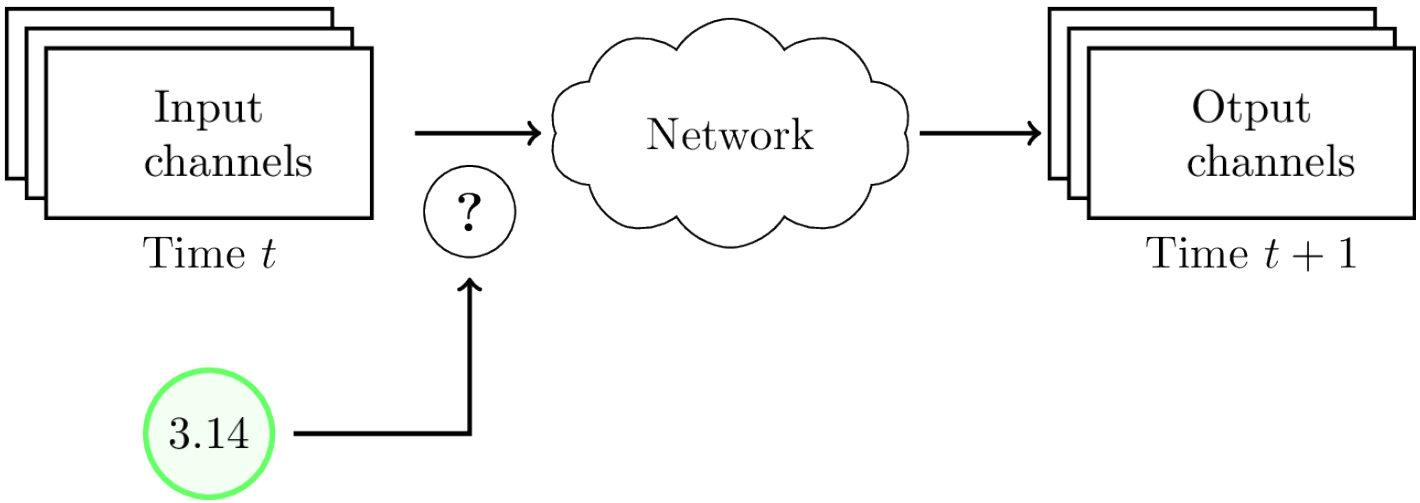
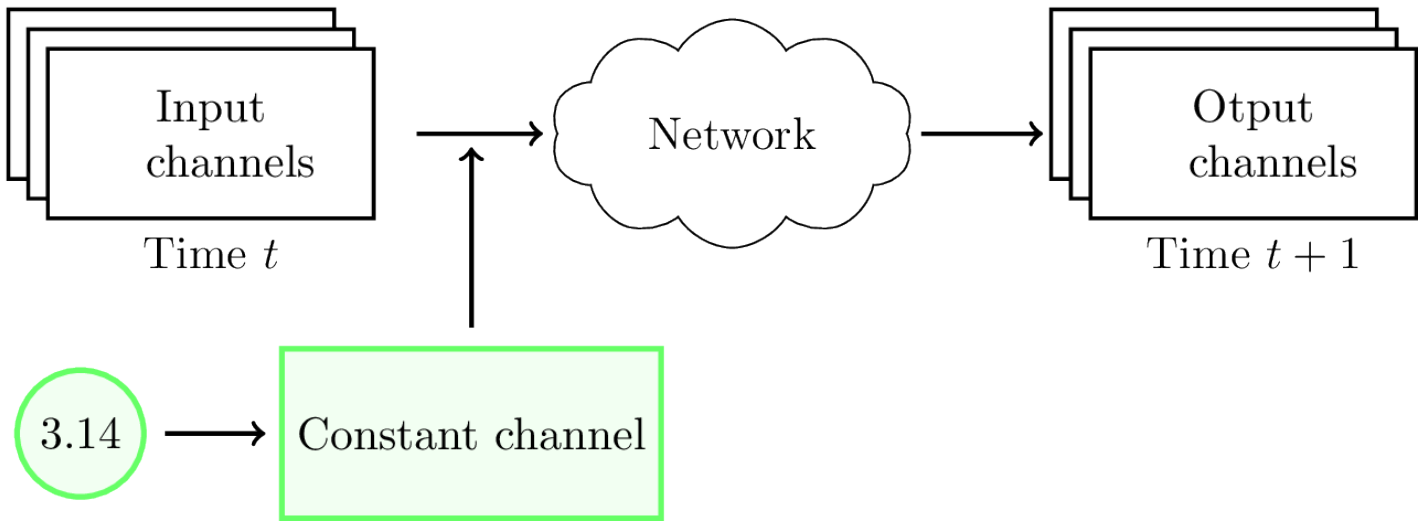
- Two types of architectures based on our preliminary research:
- Data being used by the network.
  - Processing of real values



# 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

## Two views of the results

### 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:
  - 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

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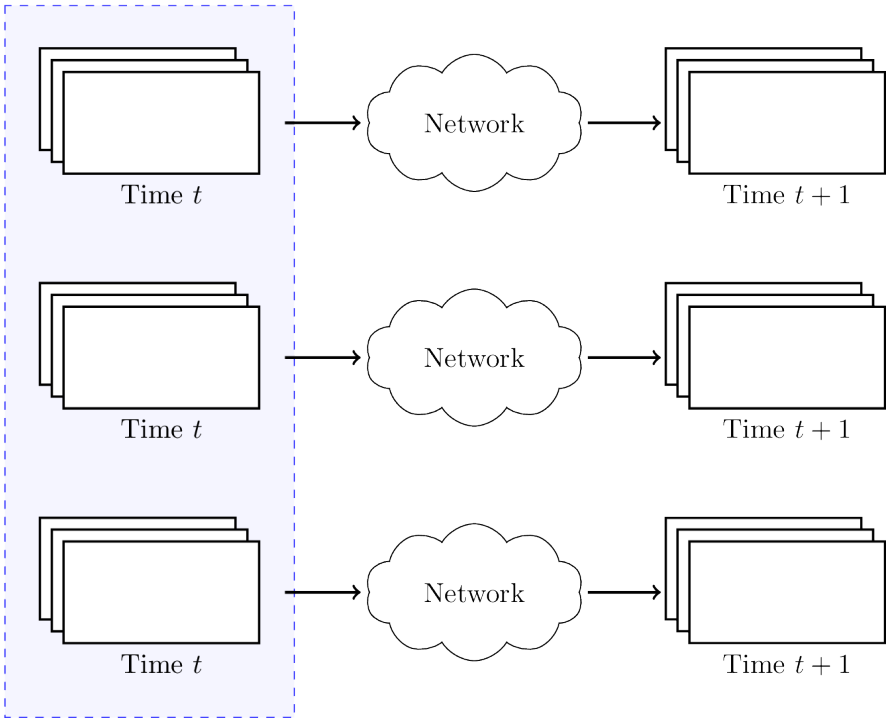
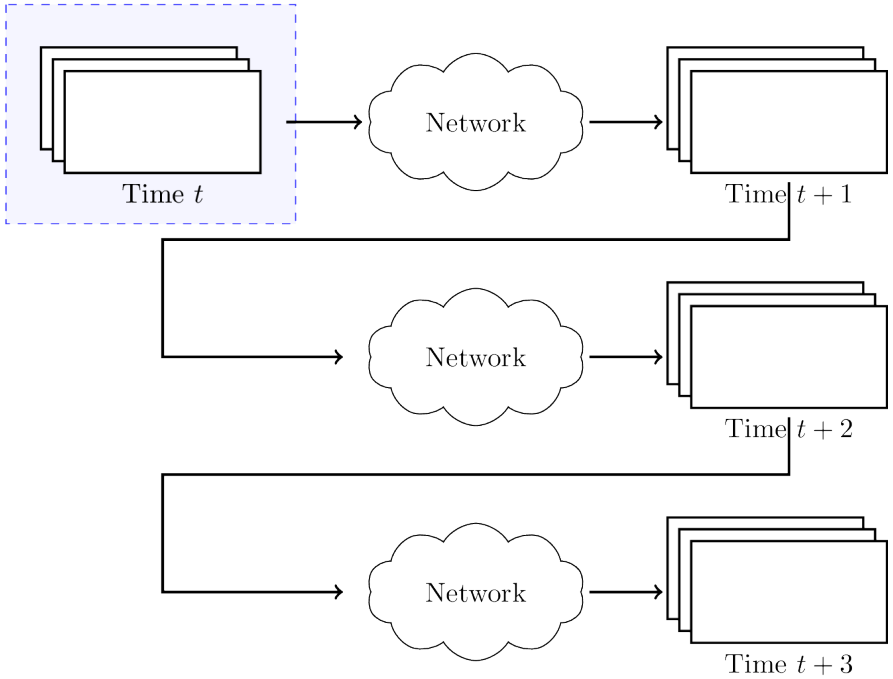
## Two evaluation cases

### Individual Images



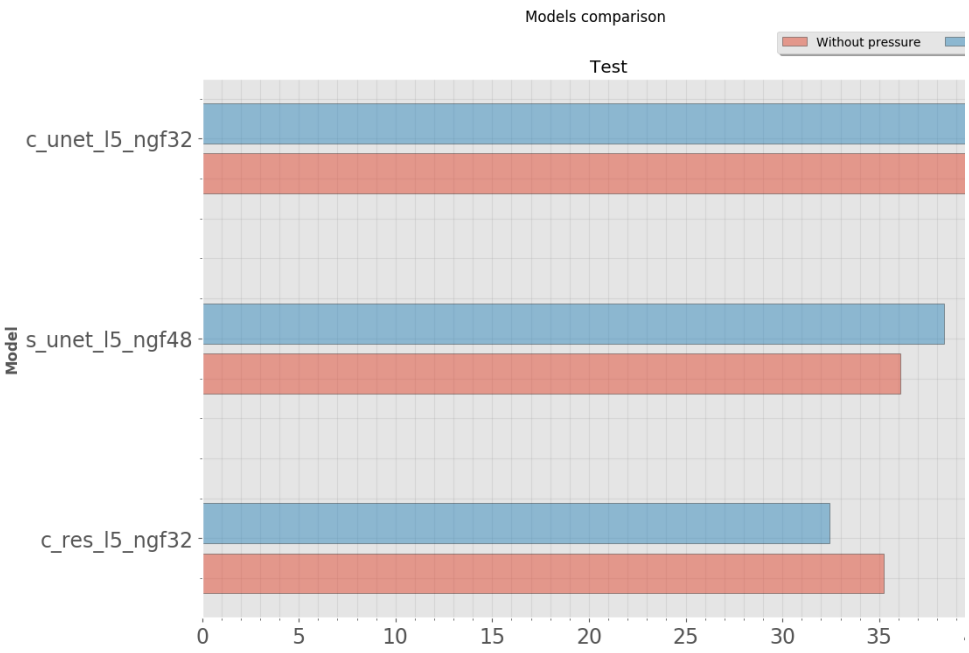

### Recursive Application

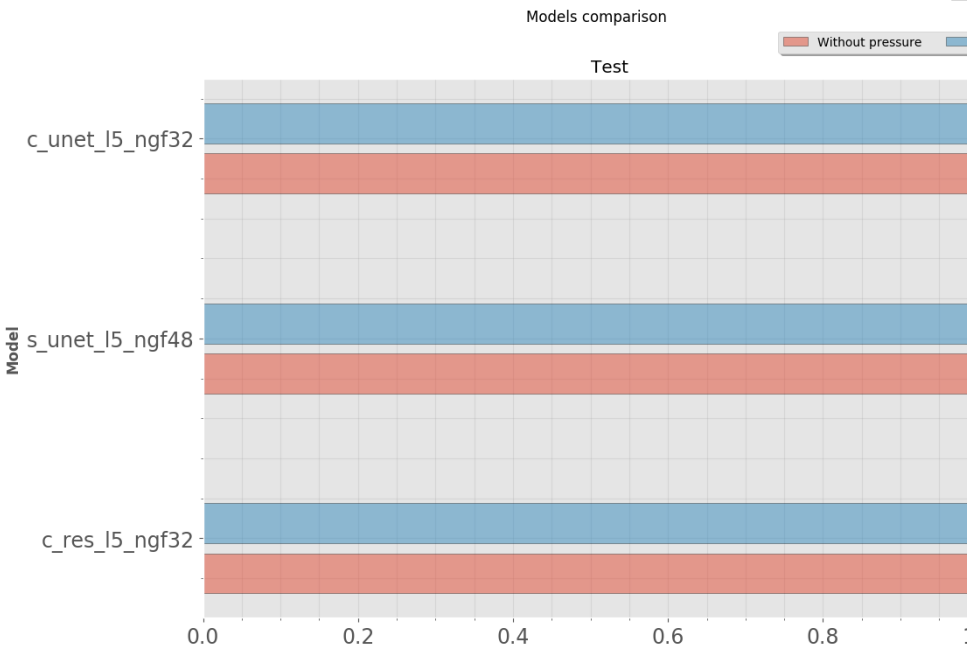


# Results

## Individual Images

## Cor. and PSNR:

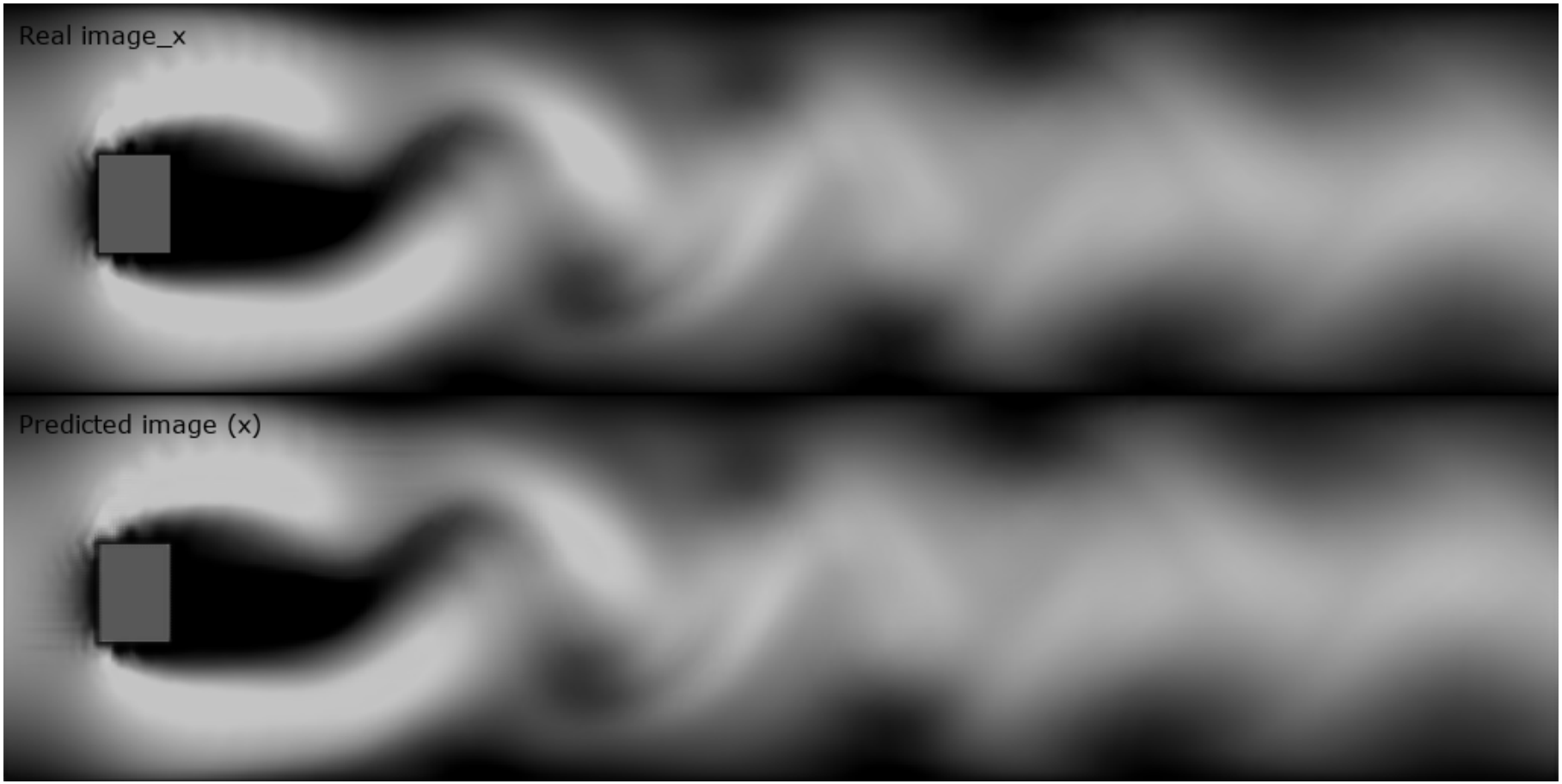


# Results

## Individual Images

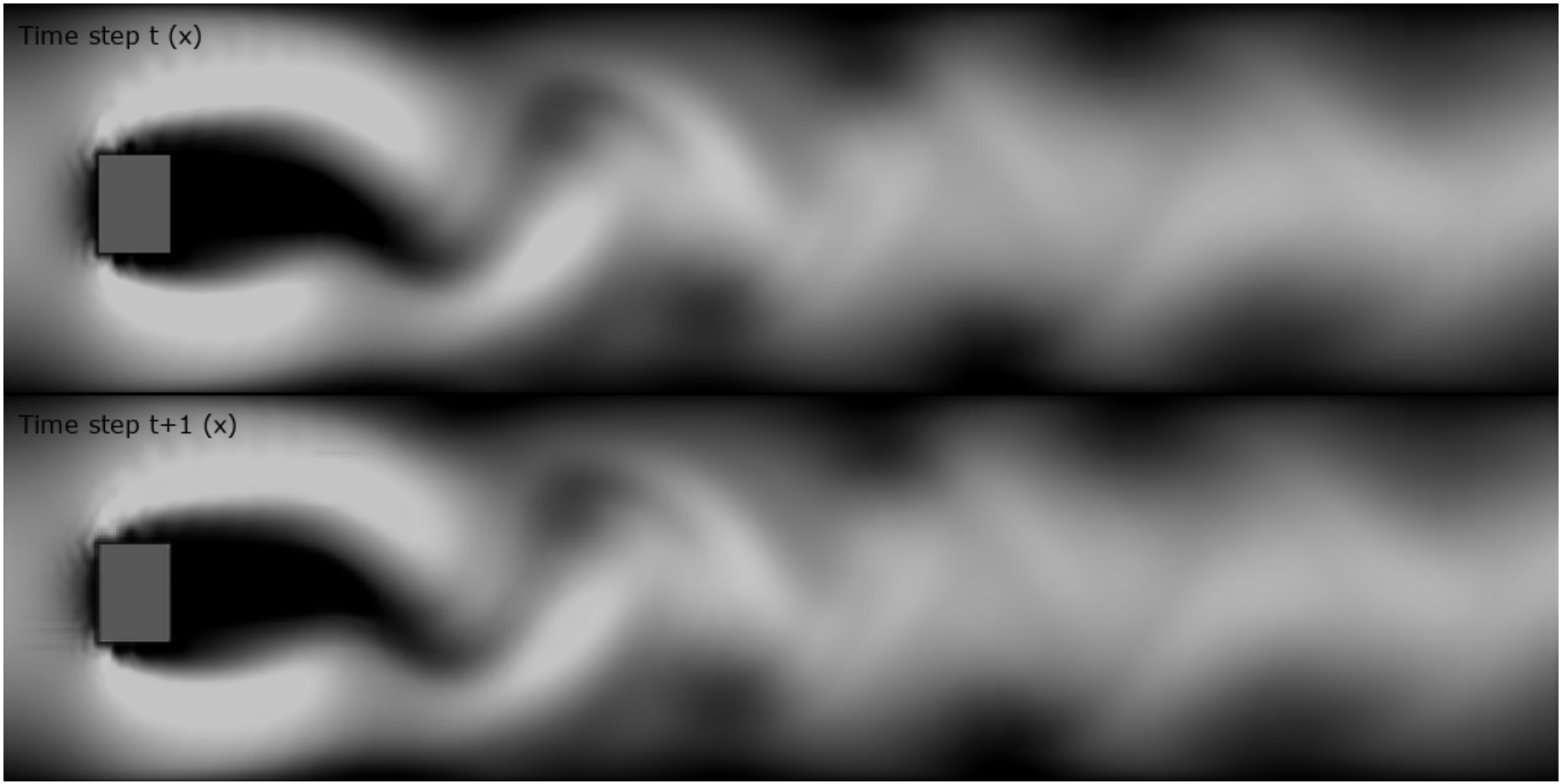
### Prediction image:



# Results

## Individual Images

### Timestep image:

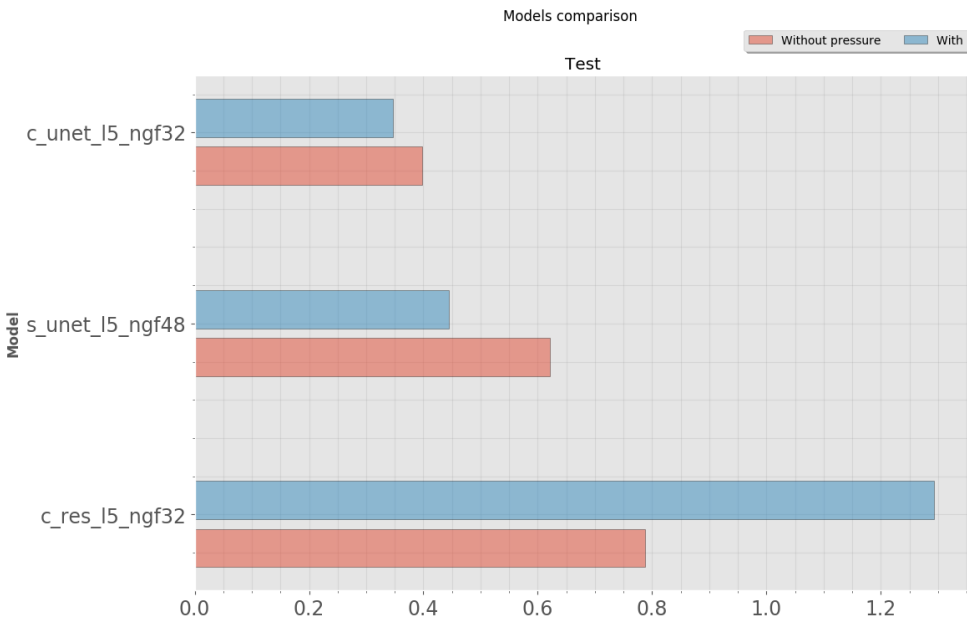


# Results

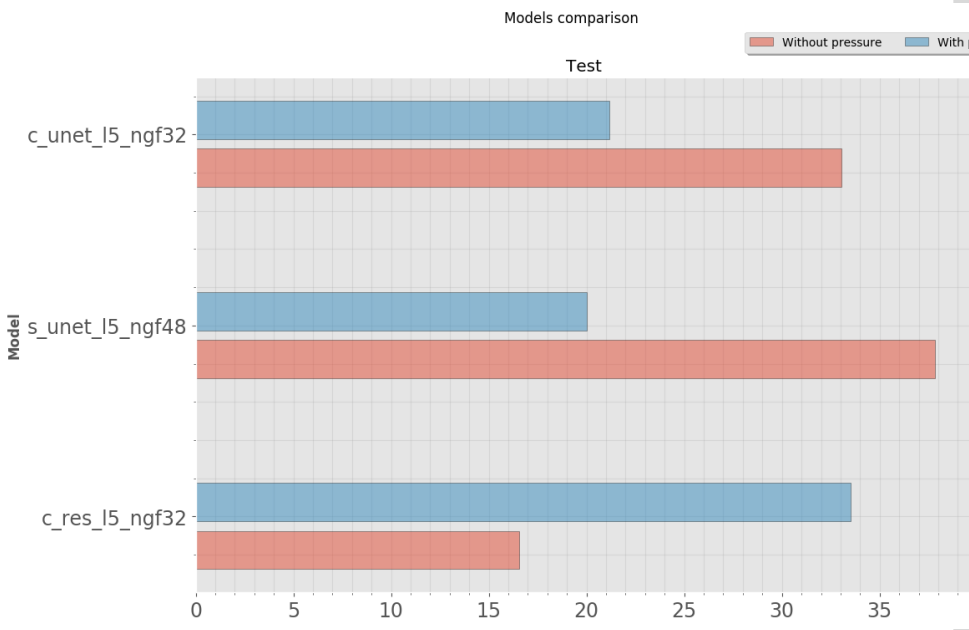
## Individual Images

## Numerical view:

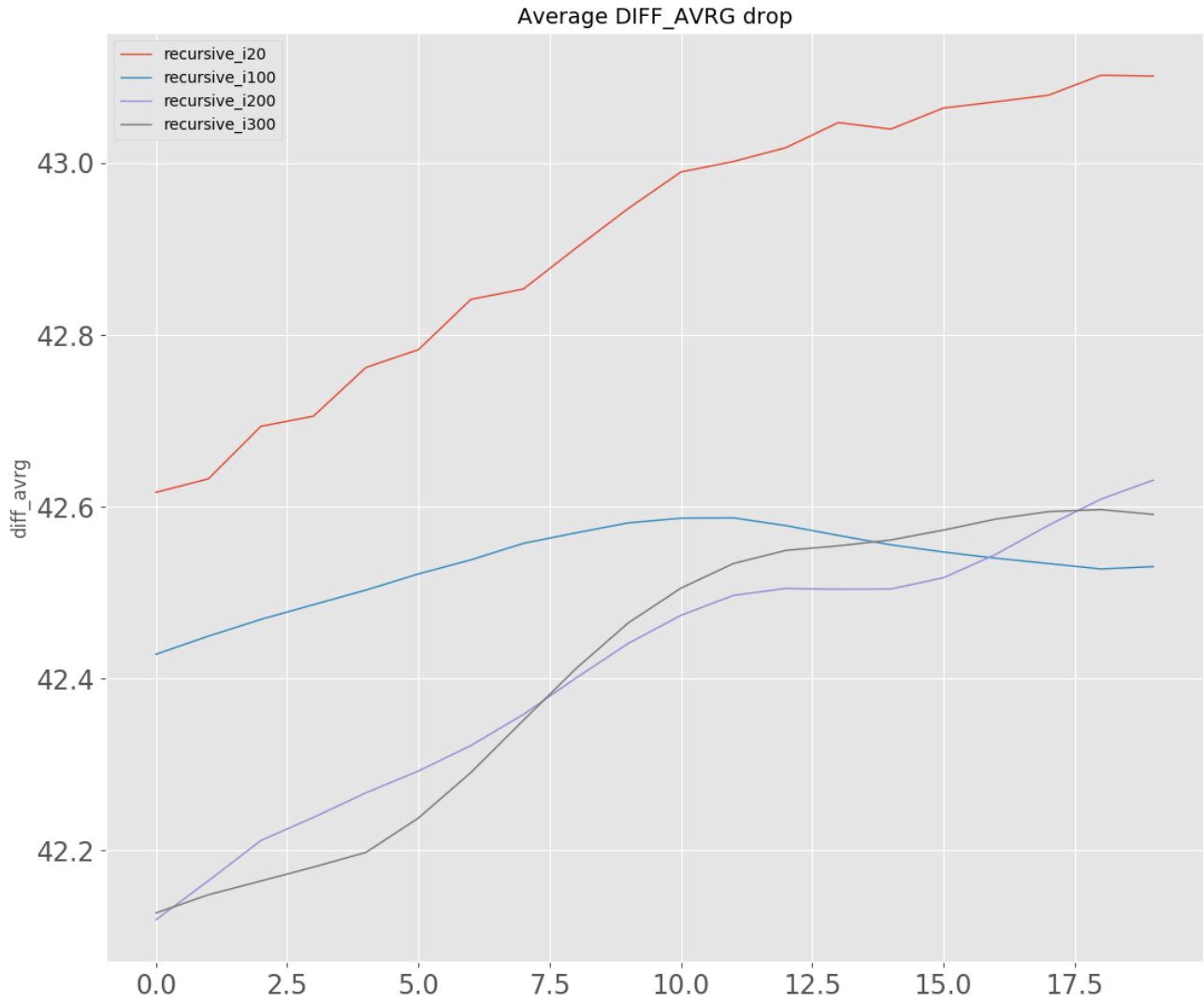
### Avrg. difference




### Max difference



# Recursive application – constant model



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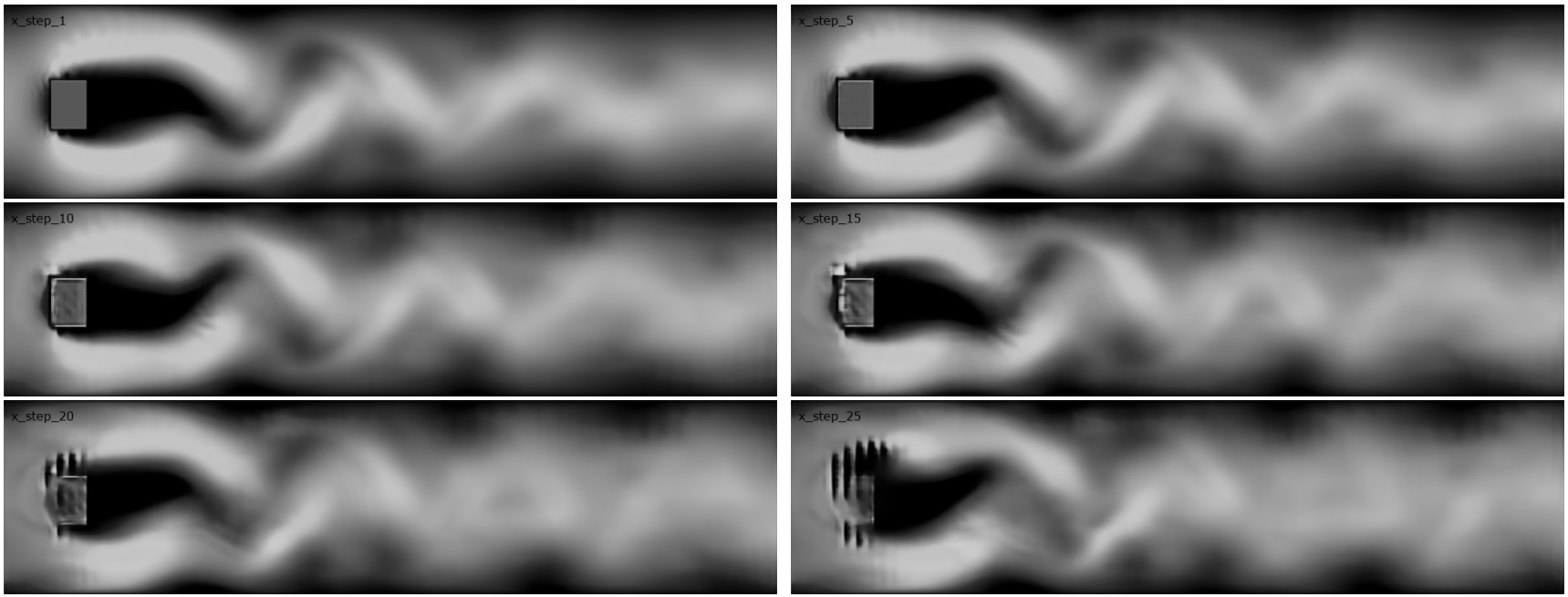

Thank you for your attention.

# Questions?