ModelFLOWs APP

MODAL DECOMPOSITION

Pattern detection

- HOSVD
- HODMD

Reconstruction

- Data Repairing
- Superresolution

Prediction

- HODMD

DEEP LEARNING

Pattern detection

- Autoencoders

Reconstruction

- Superresolution

Prediction

- Full DL
- Hybrid

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MODAL DECOMPOSITION

- **Pattern detection**
  - HOSVD
  - HODMD
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  - Data Repairing
  - Superresolution
- **Prediction**
  - HODMD

DEEP LEARNING

- **Pattern detection**
  - Autoencoders
- **Reconstruction**
  - Superresolution
- **Prediction**
  - Full DL
  - Hybrid

Motivation

Hybrid

A predictive physics-aware hybrid reduced order model for reacting flows

A. Corrochano[1,*] , R.S.M. Freitas[2,3],
A. Parente[2,3] and S. Le Clainche[1]

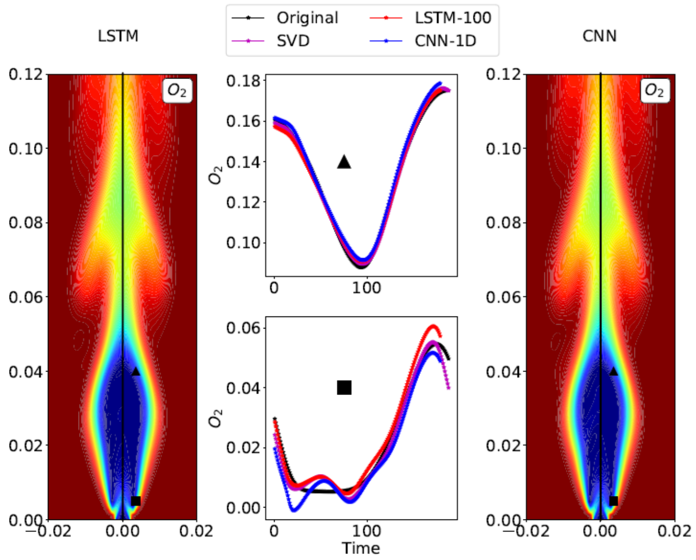
[1] *E.T.S.I. Aeronáutica y del Espacio, Universidad Politécnica de Madrid, Spain*

[2] *Université Libre de Bruxelles, École polytechnique de Bruxelles, Aero-Thermo-Mechanics Laboratory, Brussels, Belgium*

[3] *Université Libre de Bruxelles and Vrije Universiteit Brussel, Brussels Institute for Thermal-Fluid Systems and Clean Energy (BRITE), Brussels, Belgium*

https://arxiv.org/abs/2301.09860

A predictive physics-aware hybrid reduced order model for reacting flows



ModelFLOWs

Motivation

Hybrid

A predictive physics-aware hybrid reduced order model for reacting flows

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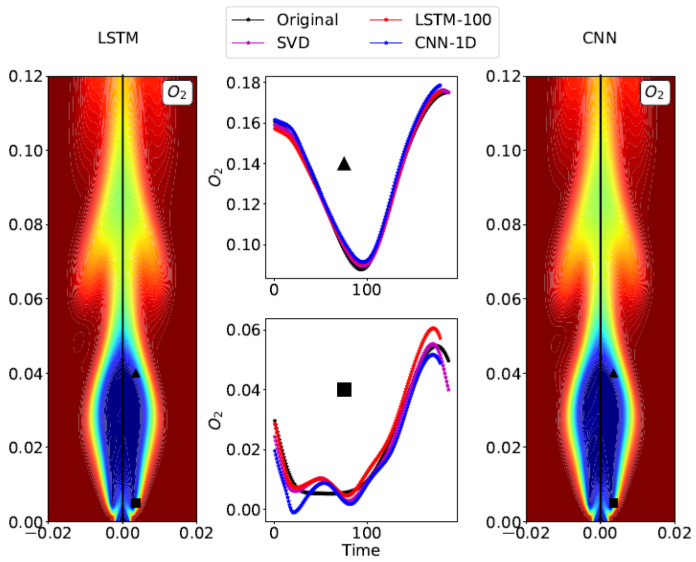
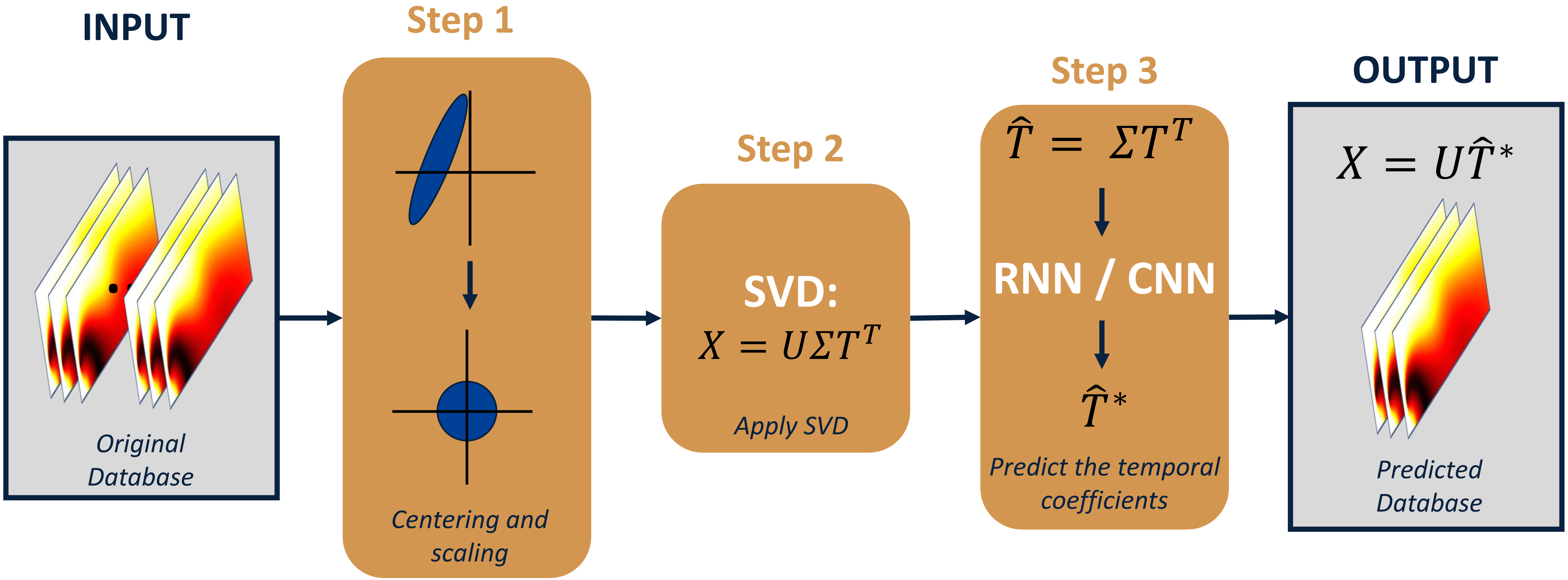


A predictive physics-aware hybrid reduced order model for reacting flows

- In this work we proposed two predictive models for reacting flows.
- We combine dimensionality reduction techniques (SVD) with deep learning architectures, in contrast with other works based only on deep learning.
- We also show the influence of the key hyperparameters on the model, as well as the ability of the model to predict a laminar flame under new conditions (transfer learning).

Methodology

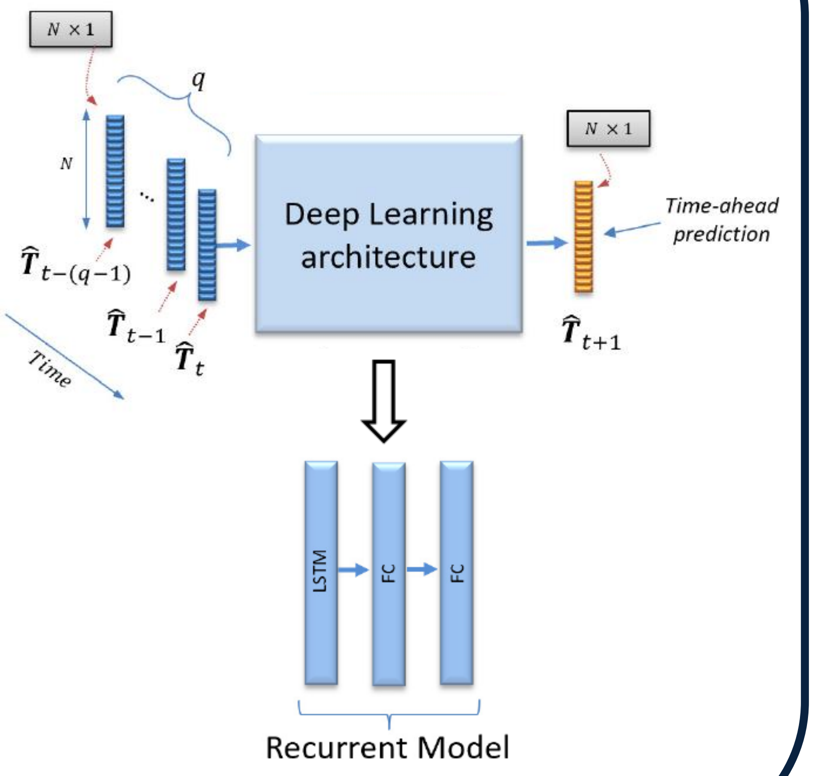
Hybrid



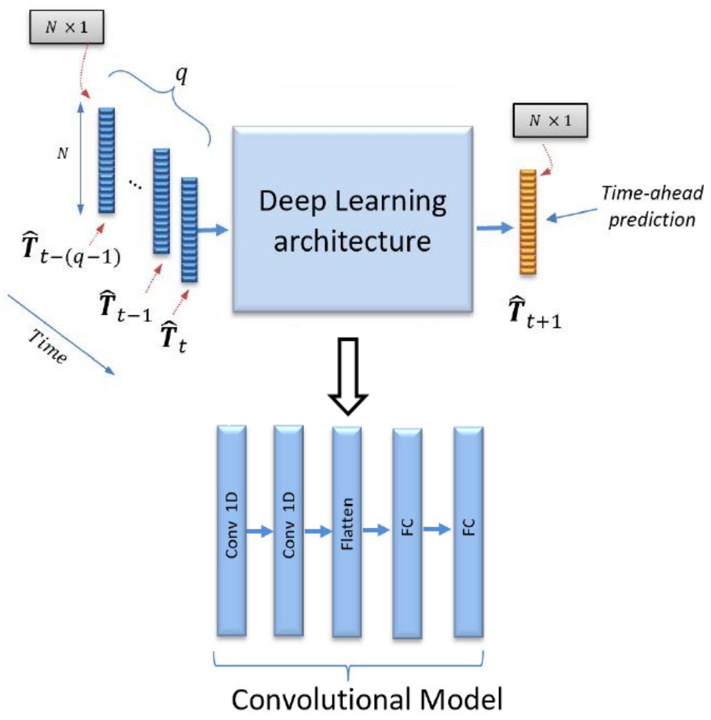
Methodology

Hybrid

RNN Model



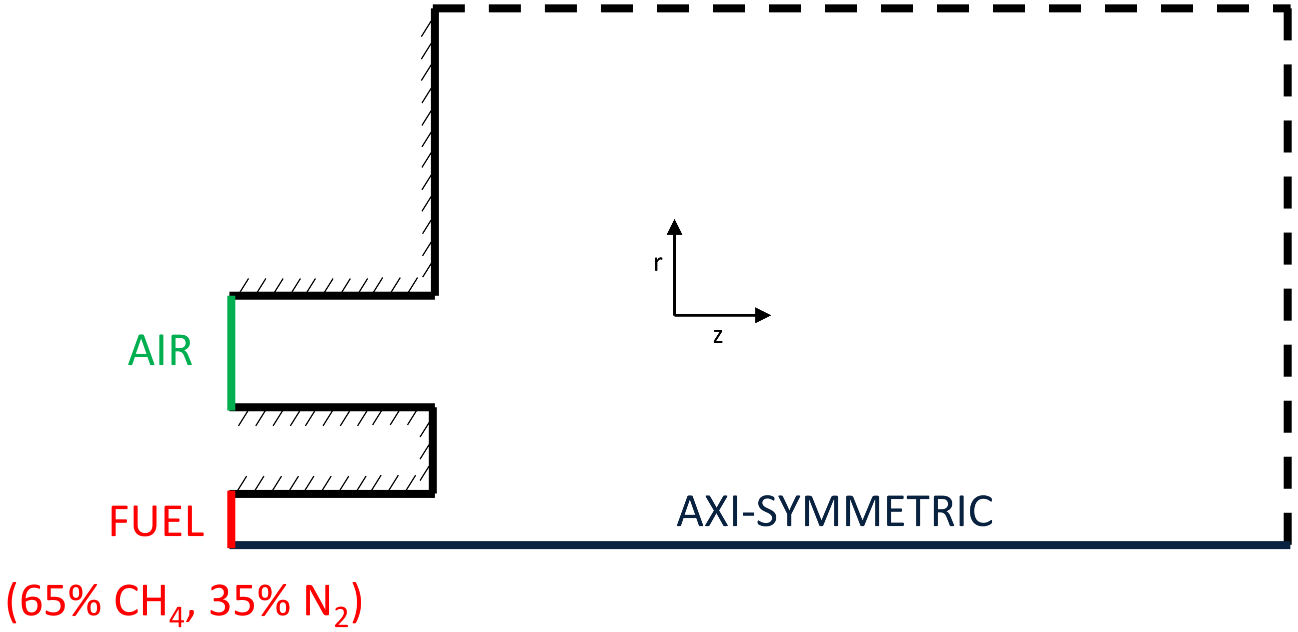
CNN Model



Database & Data preparation

Hybrid

Axisymmetric, time varying, non-premixed laminar co-flow flame



$$\text{Snapshots Tensor} = \{\underbrace{N_v}_{\text{Variables}}, \overbrace{N_z, N_r}^{\text{Spatial dimensions}}, \underbrace{N_t}_{\text{Temporal dimensions}}\}$$

Database & Data preparation

Hybrid

Snapshots Tensor = $\{N_v, N_z, N_r, N_t\}$

- N_v =10 (9 chemical species + temperature)
- $N_z = 100$
- $N_r = 75$
- $N_t = 999$

Training data set

65% Training snapshots

15% Validation snapshots

Testing data set

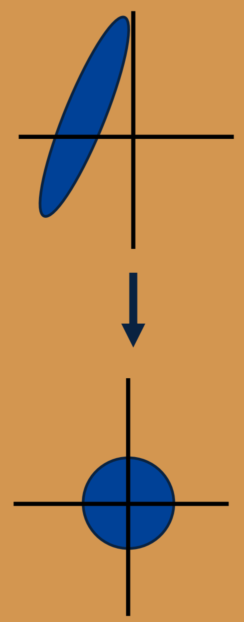
20% Testing snapshots

ModelFLOWs

Calibration

Hybrid

Step 1



Centering and scaling

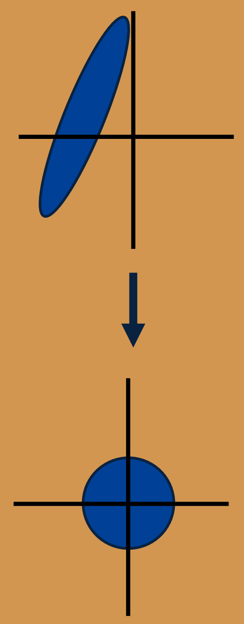
Step 1:

- Scaling method: Auto scaling
  - Implemented: No scaling, Range, Pareto

Calibration

Hybrid

Step 1



Centering and scaling

Step 1:

- ❑ Scaling method: Auto scaling
  - ❑ Implemented: No scaling, Range, Pareto

Step 2:

- ❑ Number of selected modes: 18
- ❑ Scaling method: MaxPerMode
  - ❑ Implemented: No scaling, Range, Auto

Step 2

SVD:

$$X = U\Sigma T^T$$

Apply SVD

ModelFLOWs

Calibration

Hybrid

Step 3

$$\hat{T} = \Sigma T^T$$

↓

RNN / CNN

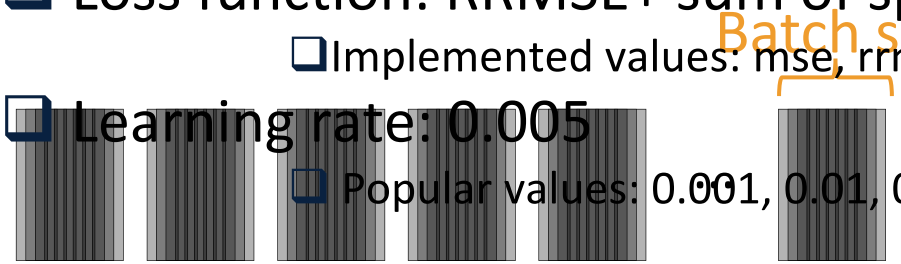
↓

$$\hat{T}^*$$

Predict the temporal coefficients

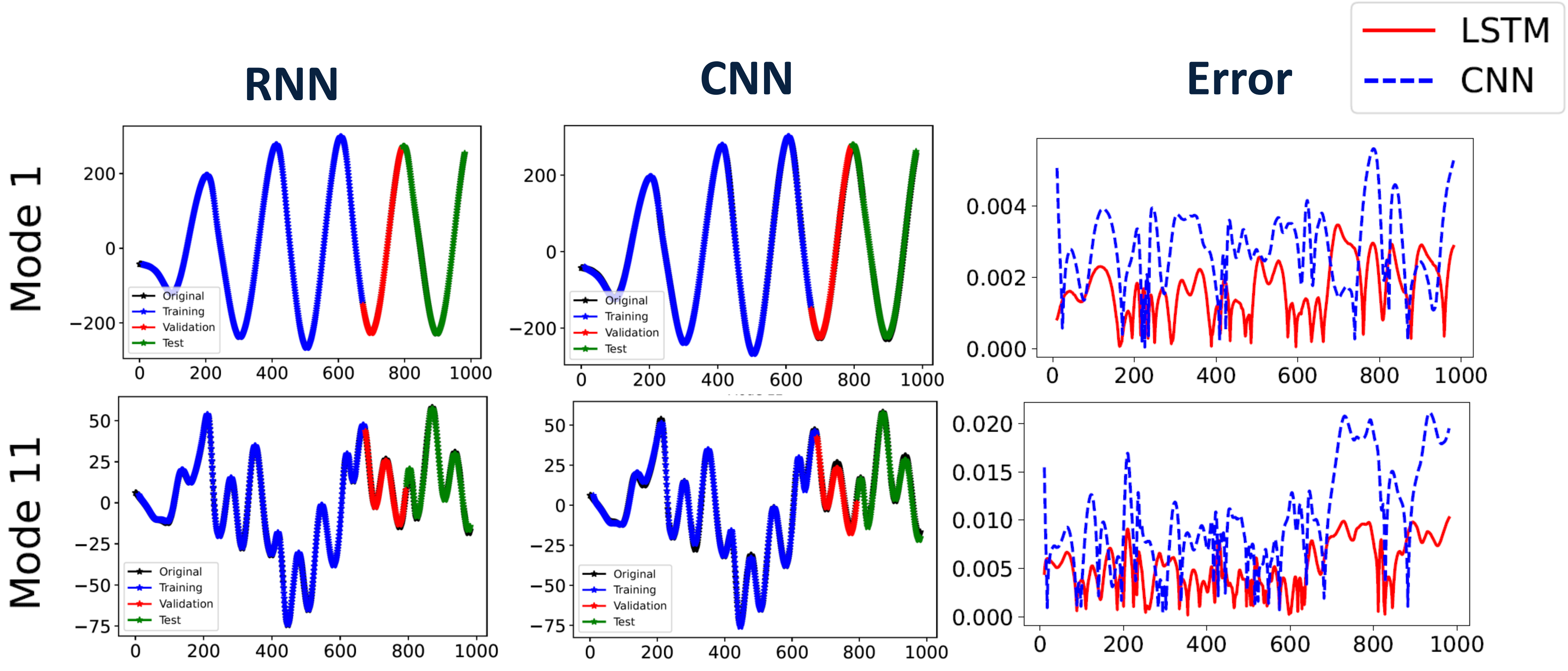
Step 3 (Hyperparameters):

- ❑ Batch size: 12
  - ❑ Popular values: 5, 8, 16, 32, 64, and 128 samples.
- ❑ Activation function for the hidden layer: relu
  - ❑ Popular values: linear, elu, tanh, sigmoid.
- ❑ Activation function for the output layer: tanh
  - ❑ Popular values: linear, elu, tanh, sigmoid.
- ❑ Loss function: RRMSE+ sum of species = 1
  - ❑ Implemented values: mse, rrmse.
- ❑ Learning rate: 0.005
  - ❑ Popular values: 0.001, 0.01, 0.003.



Results

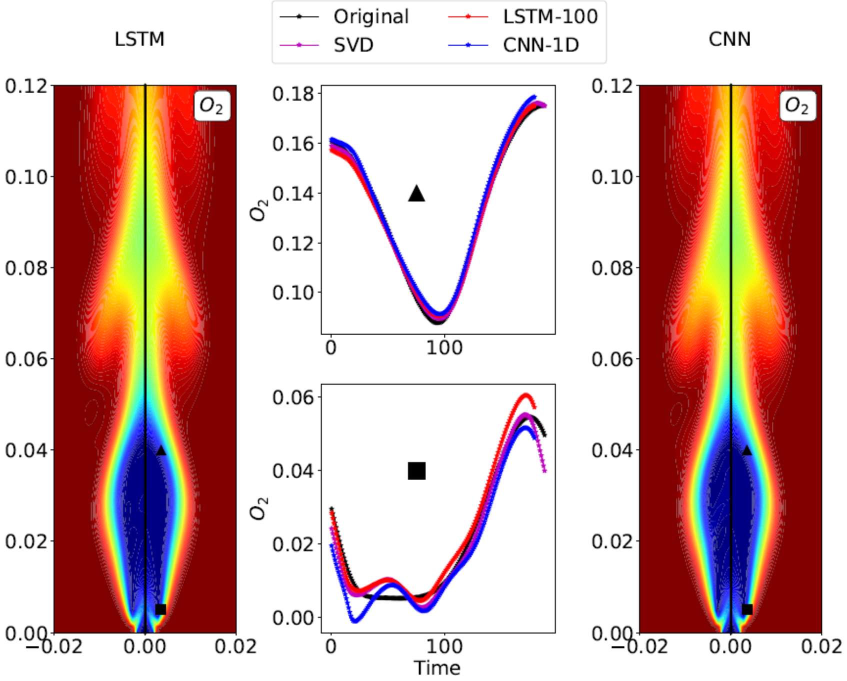
Hybrid



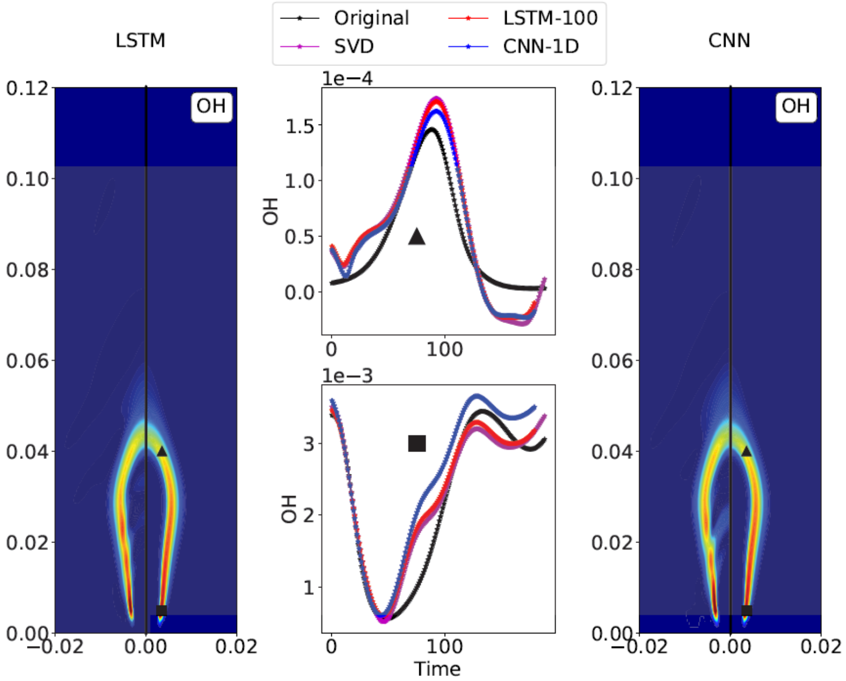
Results

Hybrid

Major species



Minor species



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