



A research institute
of the ETH Domain

From Gap-Filling to Virtual Trees

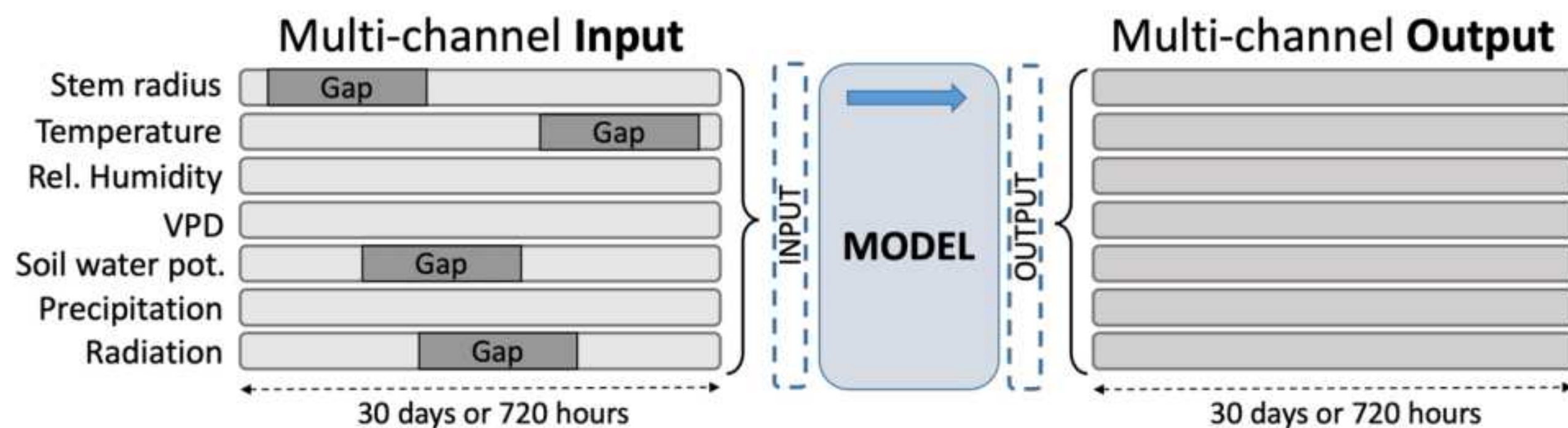
Mirko Lukovic, Roman, Sophia, Jan, William

WSL Swiss Federal Institute for Forest, Snow and Landscape Research

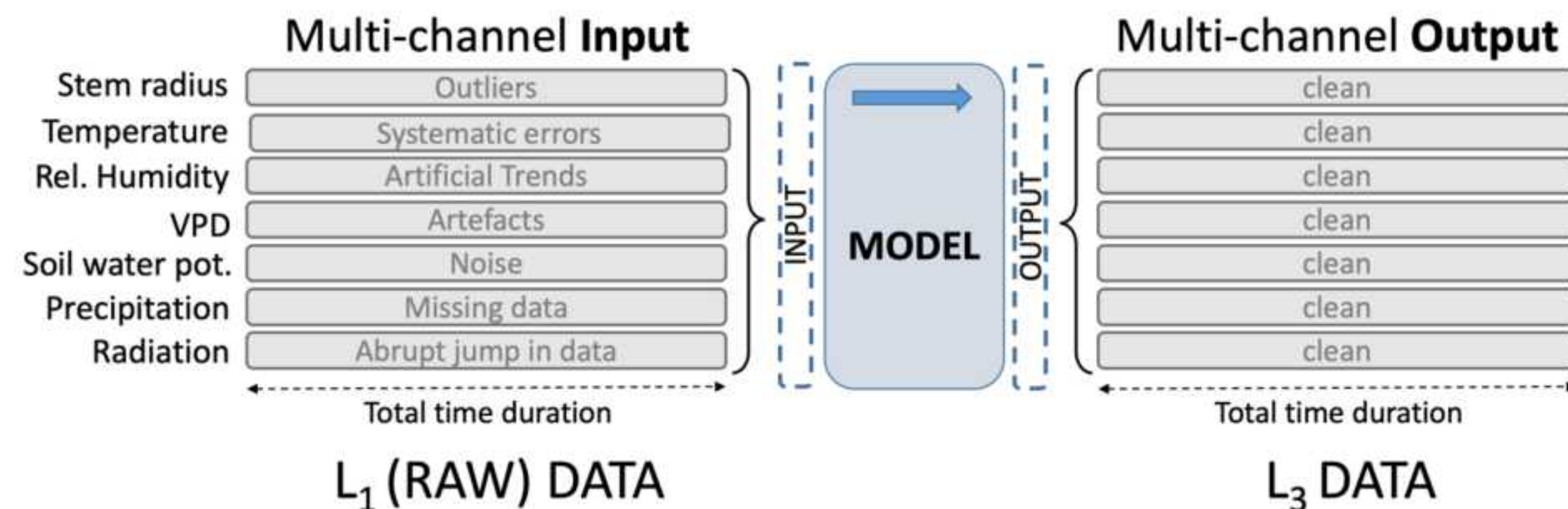
July 10, 2025 – **Fore[st]cast Annual Meeting, Zurich**



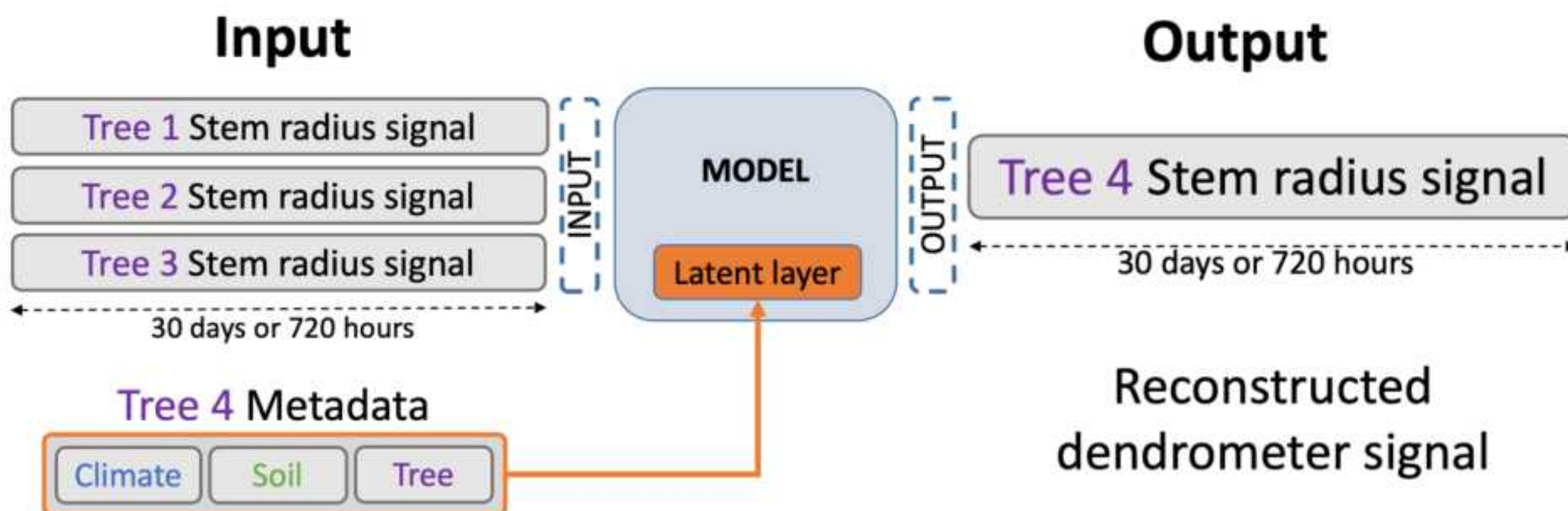
Gap-Filling



Automated Data Cleaning



Signal Reconstruction

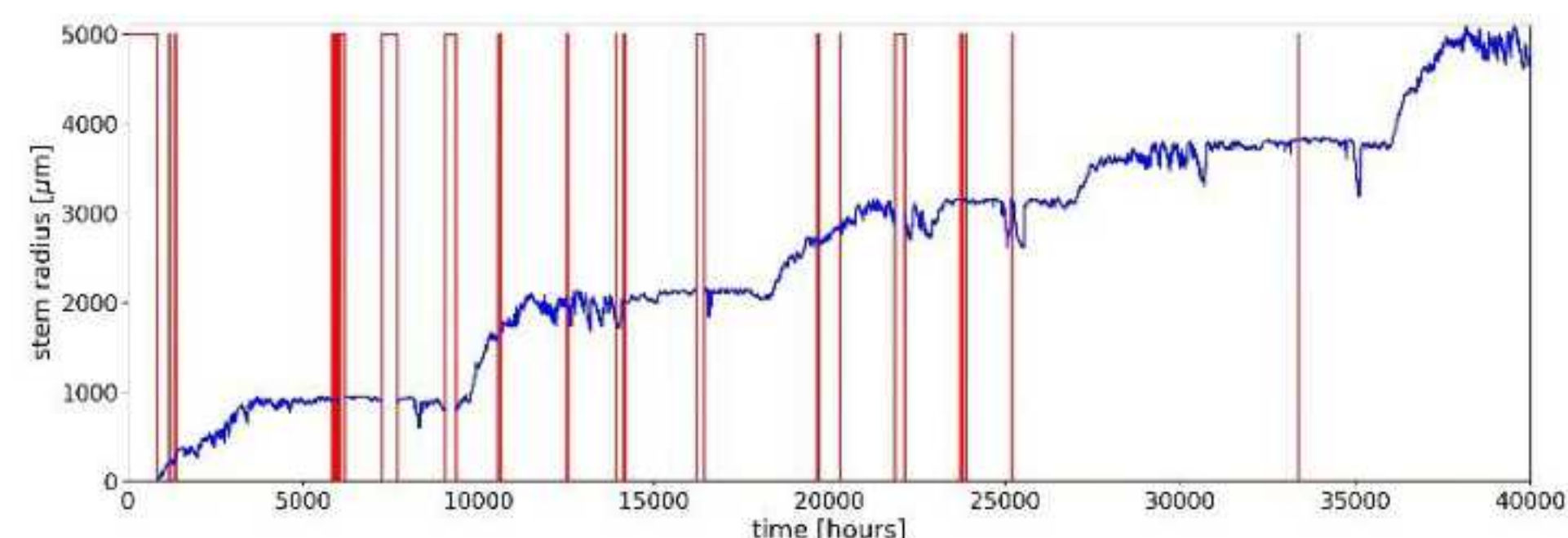


Correlations with Soil Water

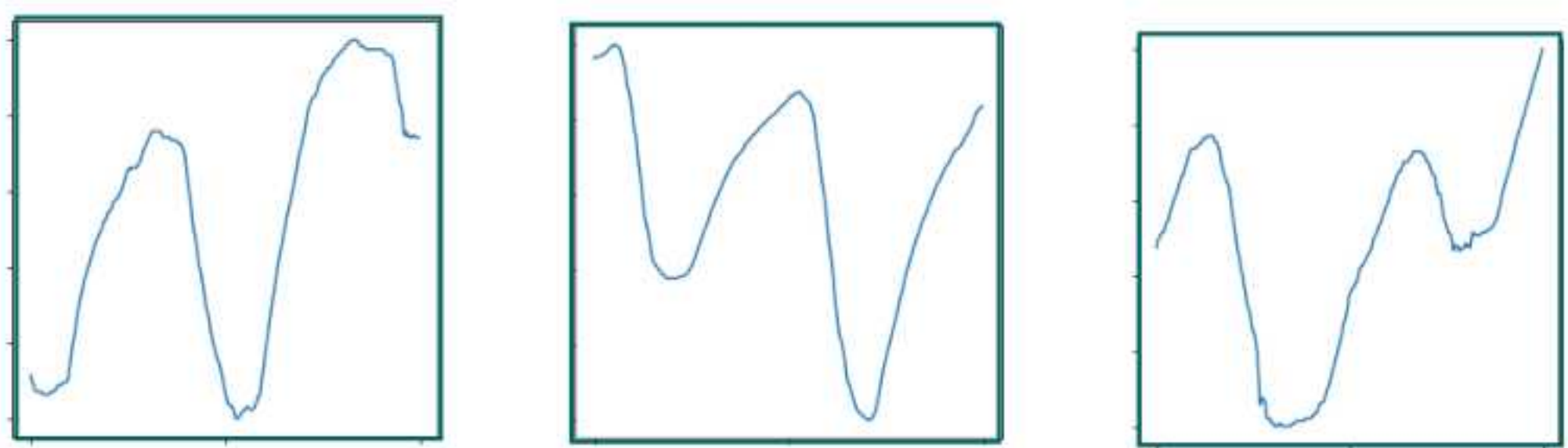
Work in progress

Data pre-processing

168 stem radius time series samples



Divided into many **30-day gap-free** segments

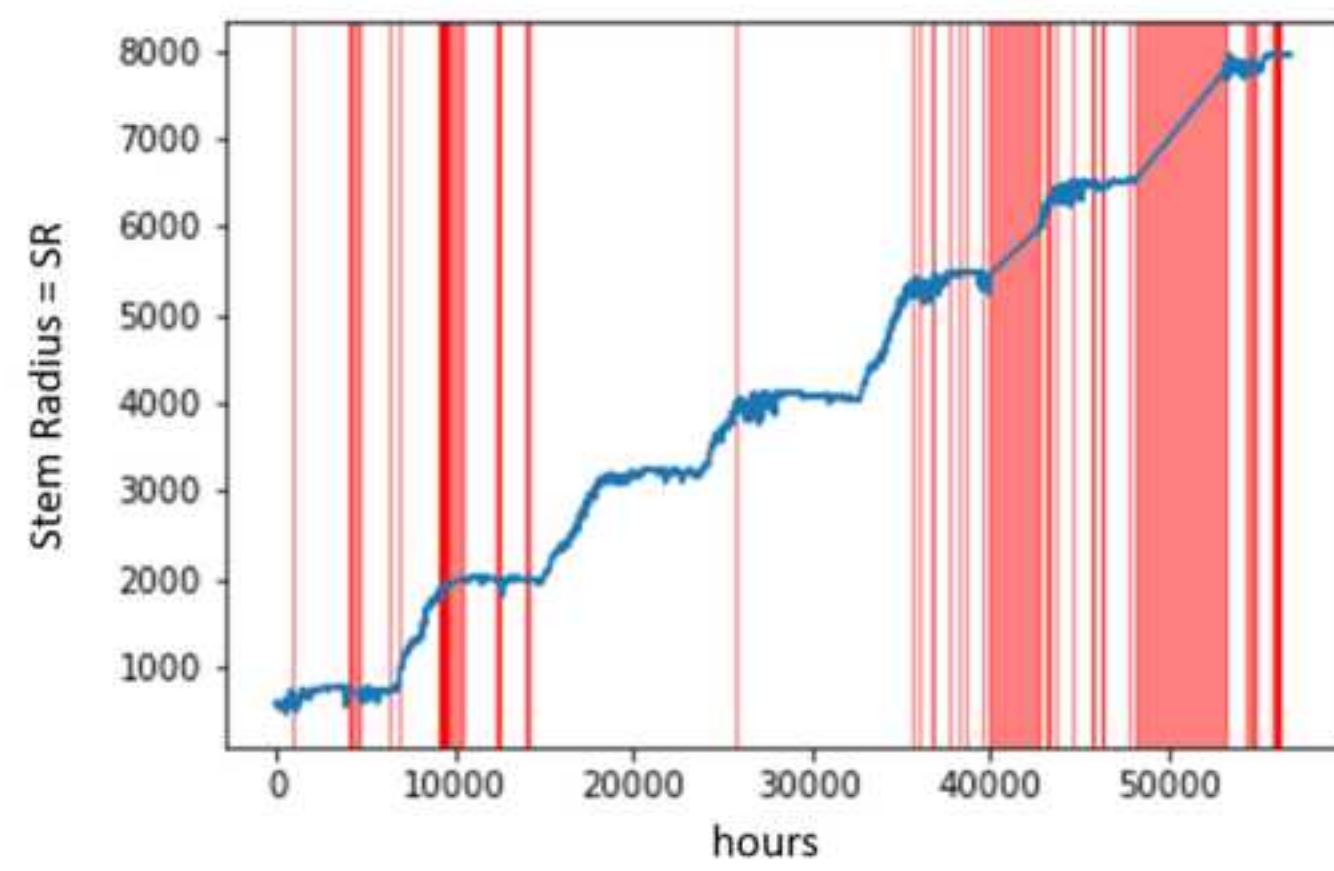


Missing data points	Percentage of total	Feature combination
303,595	53.46	SR, swp
134,210	23.63	swp
124,438	21.91	SR
3374	0.59	total precip
1770	0.31	SR, rad, swp

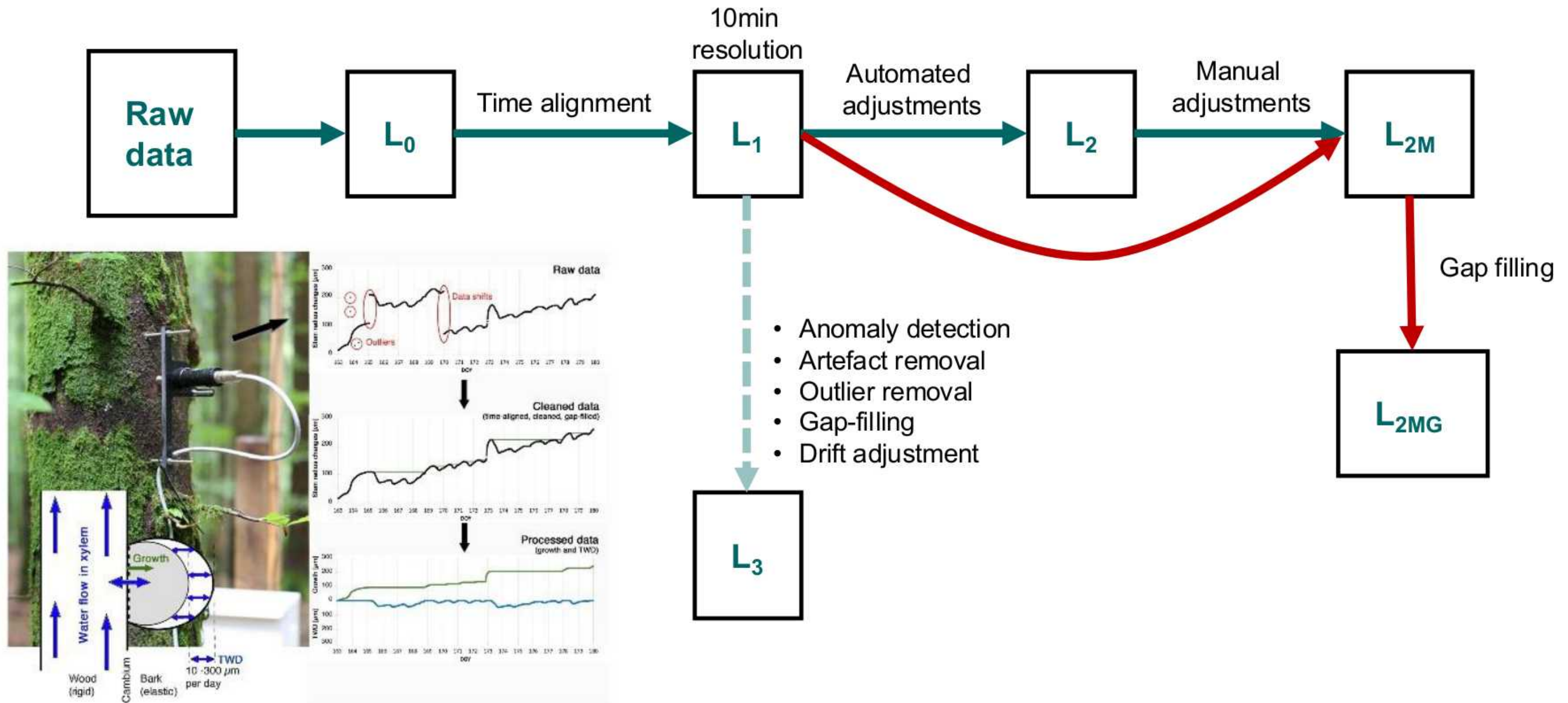
Tree species	Tree Samples	Segments w/o repair	segments w repair	Species label
Pinus sylvestris	24	1086	1325	0
Fagus sylvatica	42	1389	1939	1
Picea abies	53	2233	2783	2
Abies alba	10	415	525	3
Quercus petraea	10	396	535	4
Quercus pubescens	12	609	655	5
Fraxinus excelsior	7	284	351	6
Quercus cerris	10	250	303	7



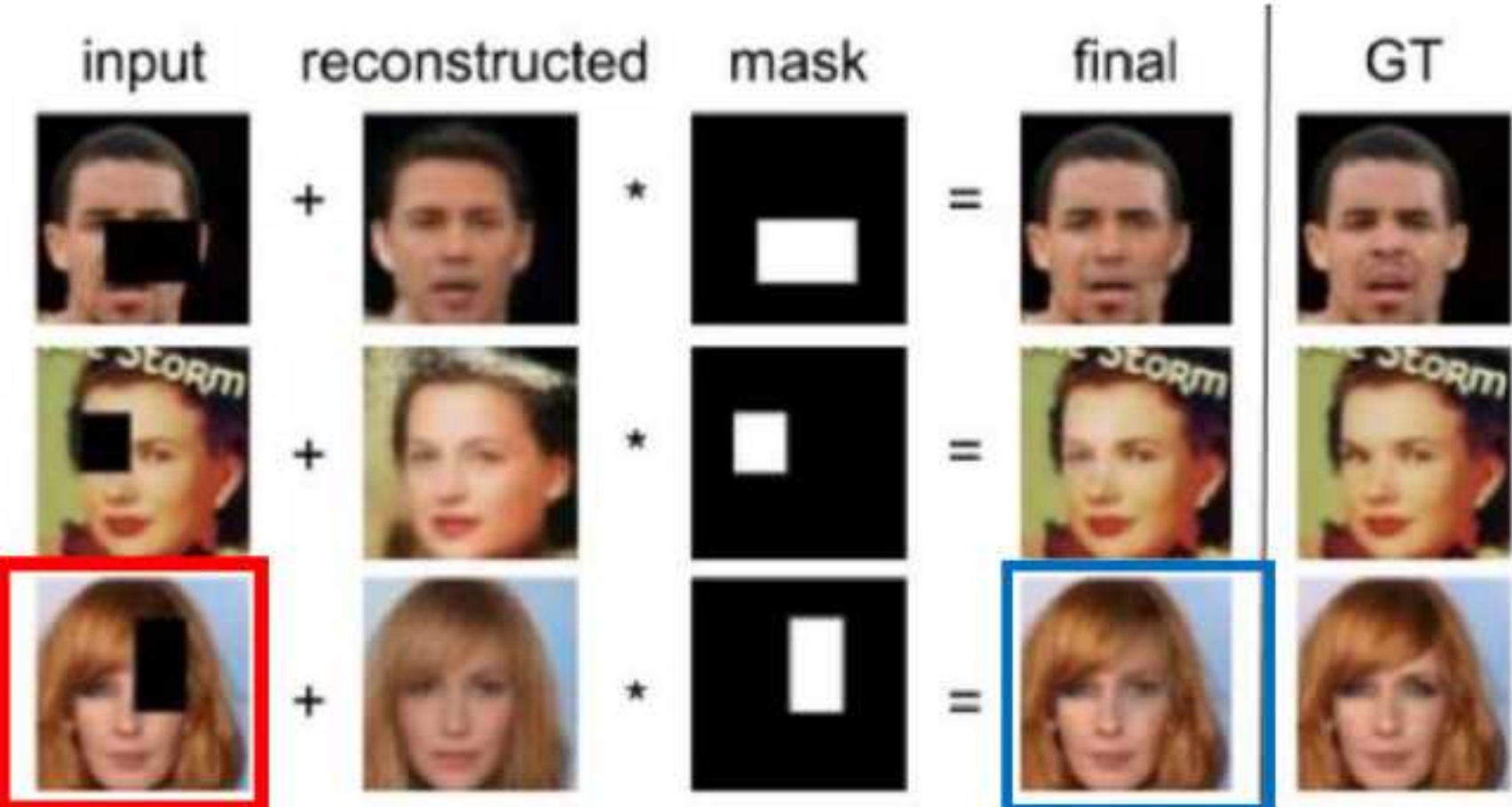
The dendrometers communicate wirelessly over LoRaWAN®



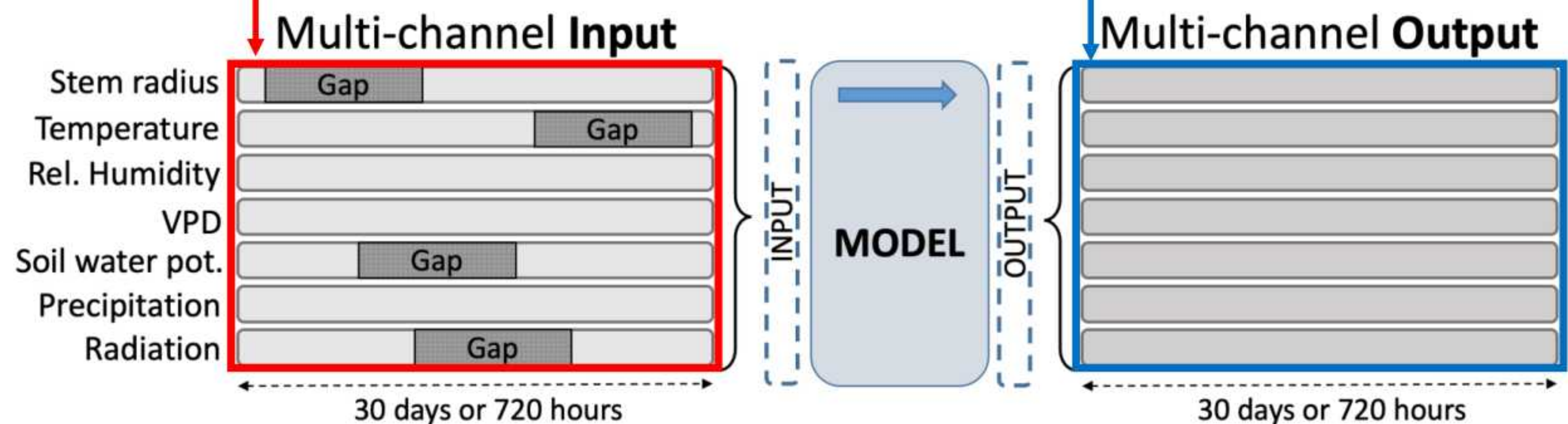
Data pre-processing



Gap Filling

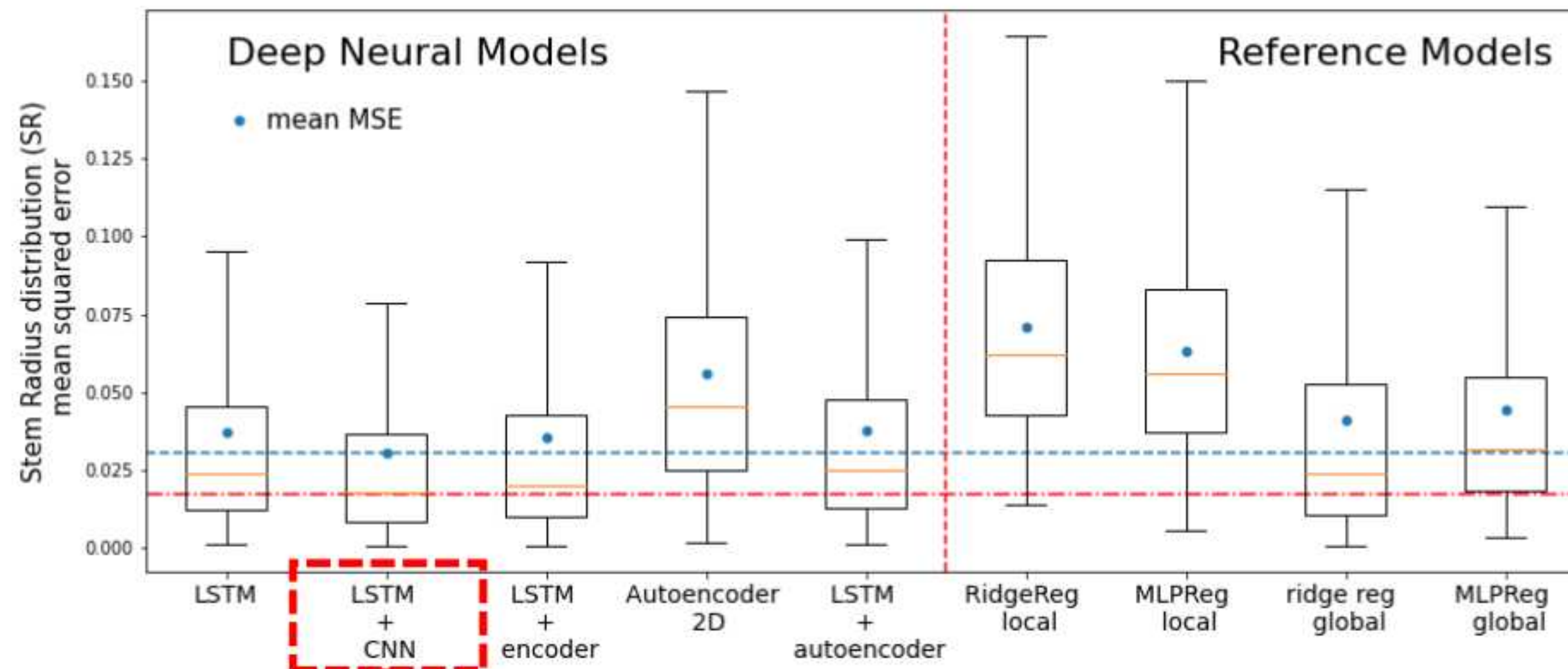


Feature	Abbreviation
Stem Radius [μm]	<i>SR</i>
Temperature [$^{\circ}C$]	<i>temp</i>
Relative humidity [%]	<i>rh</i>
Vapor pressure deficit [kPa]	<i>vpd</i>
Solar radiation [W/m^2]	<i>rad</i>
Soil water potential [kPa]	<i>swp</i>
Total precipitations [mm]	<i>total precip</i>

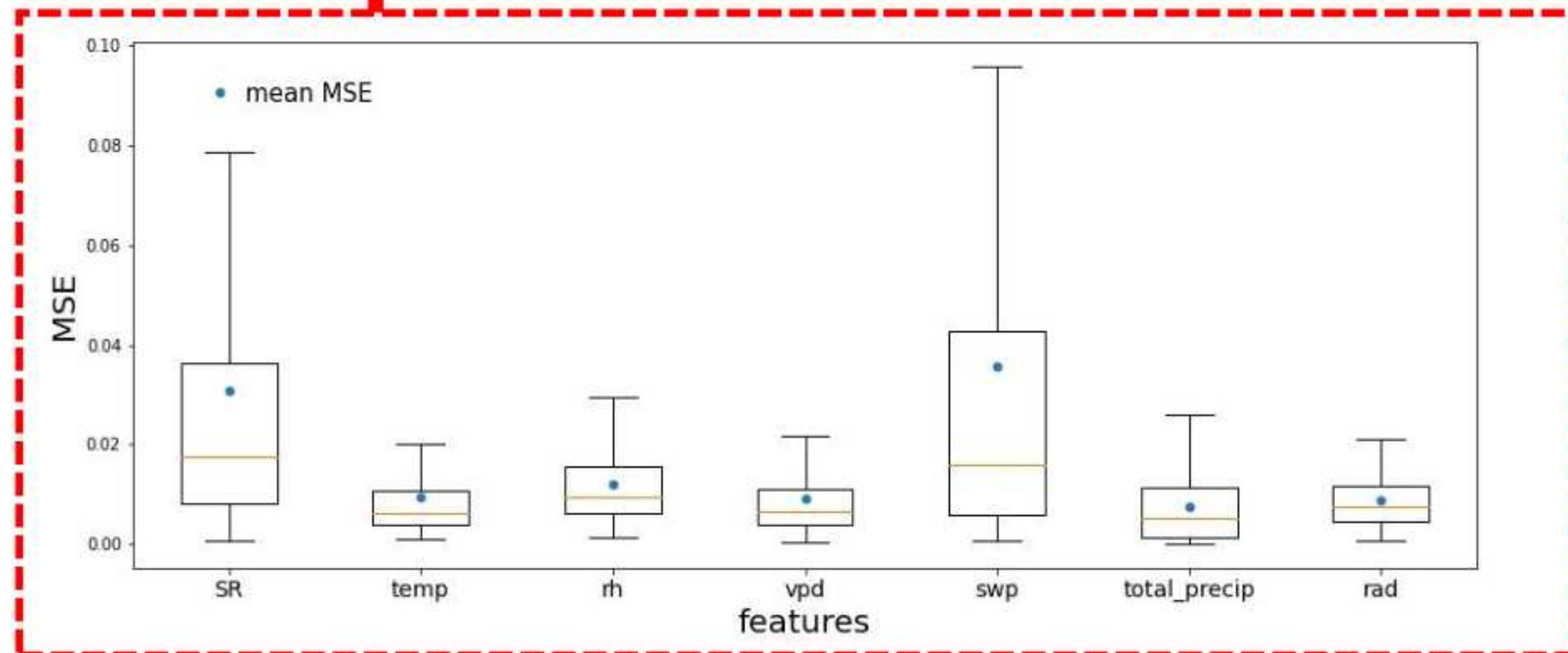


Model Performance – old results

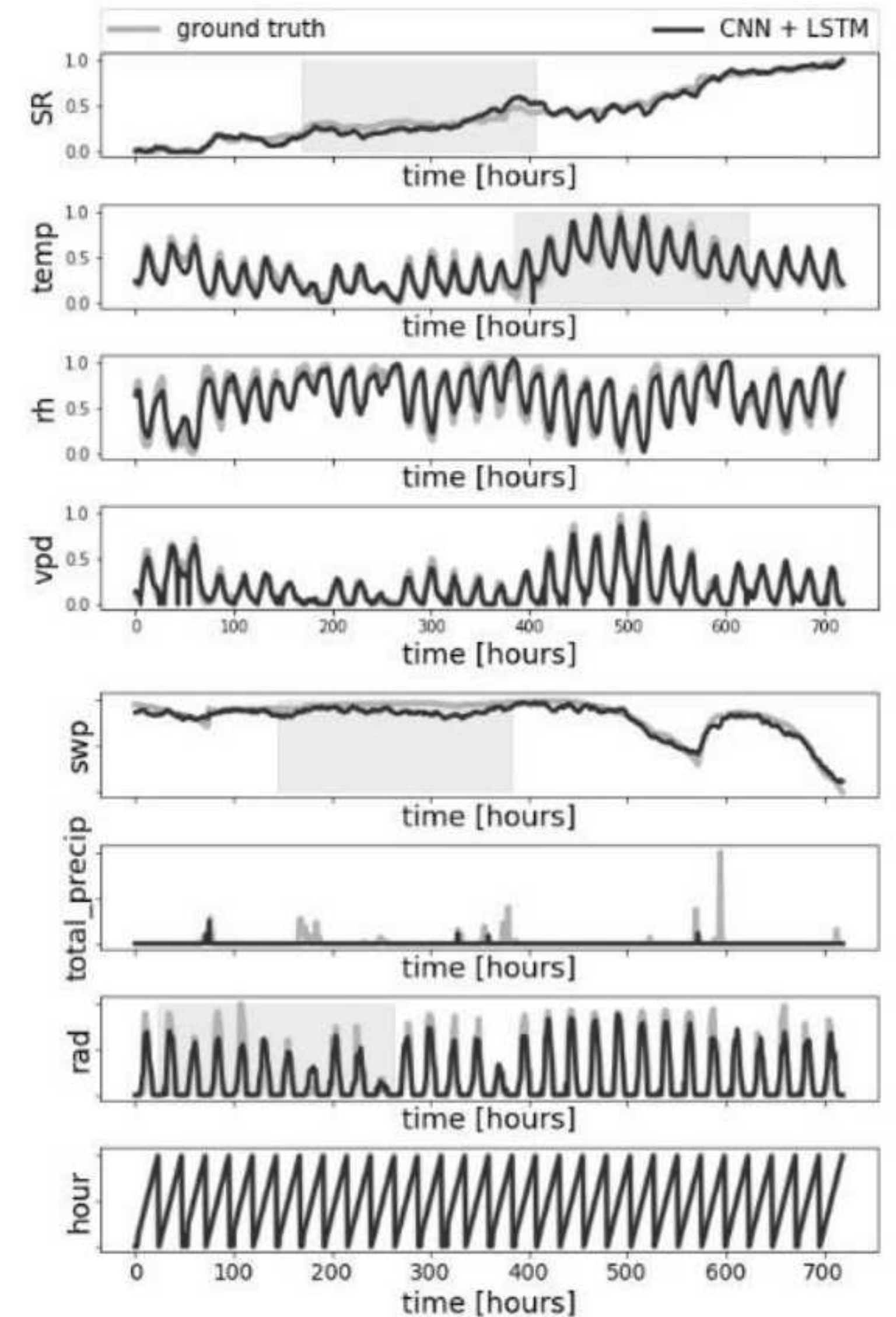
Mean squared error



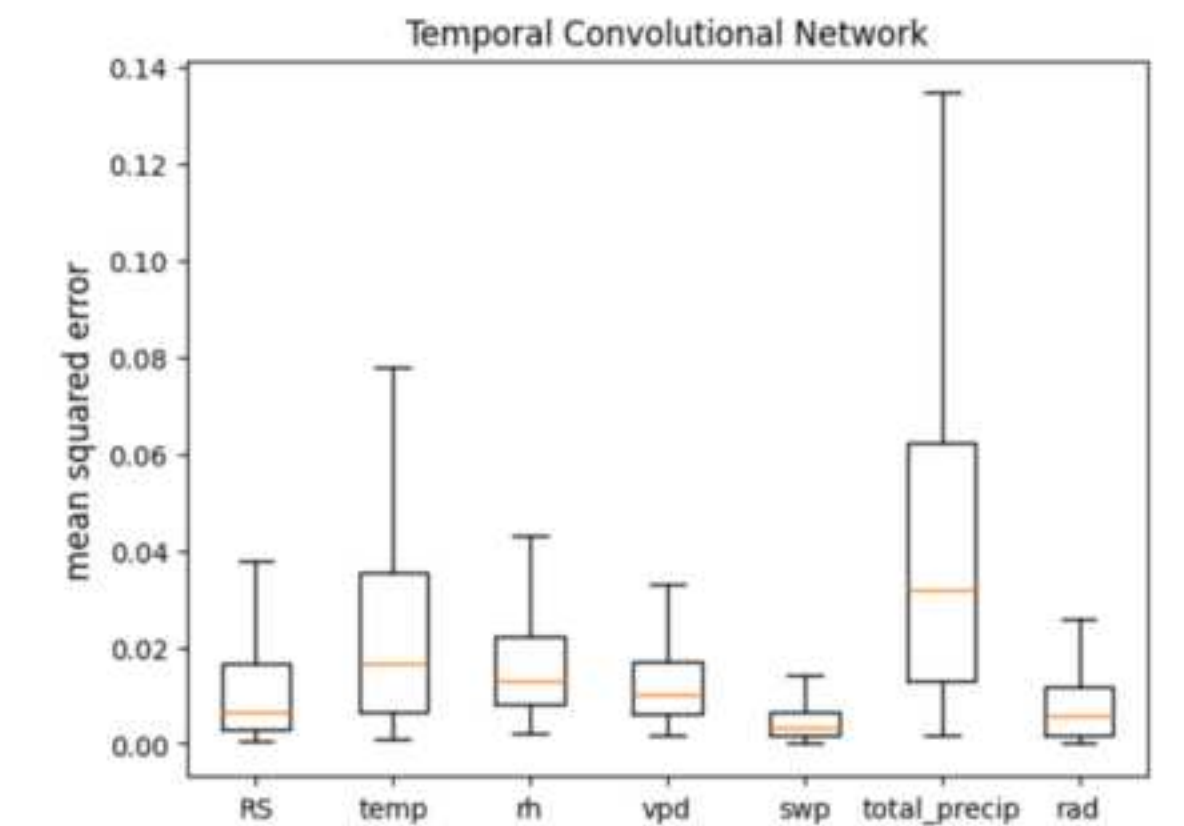
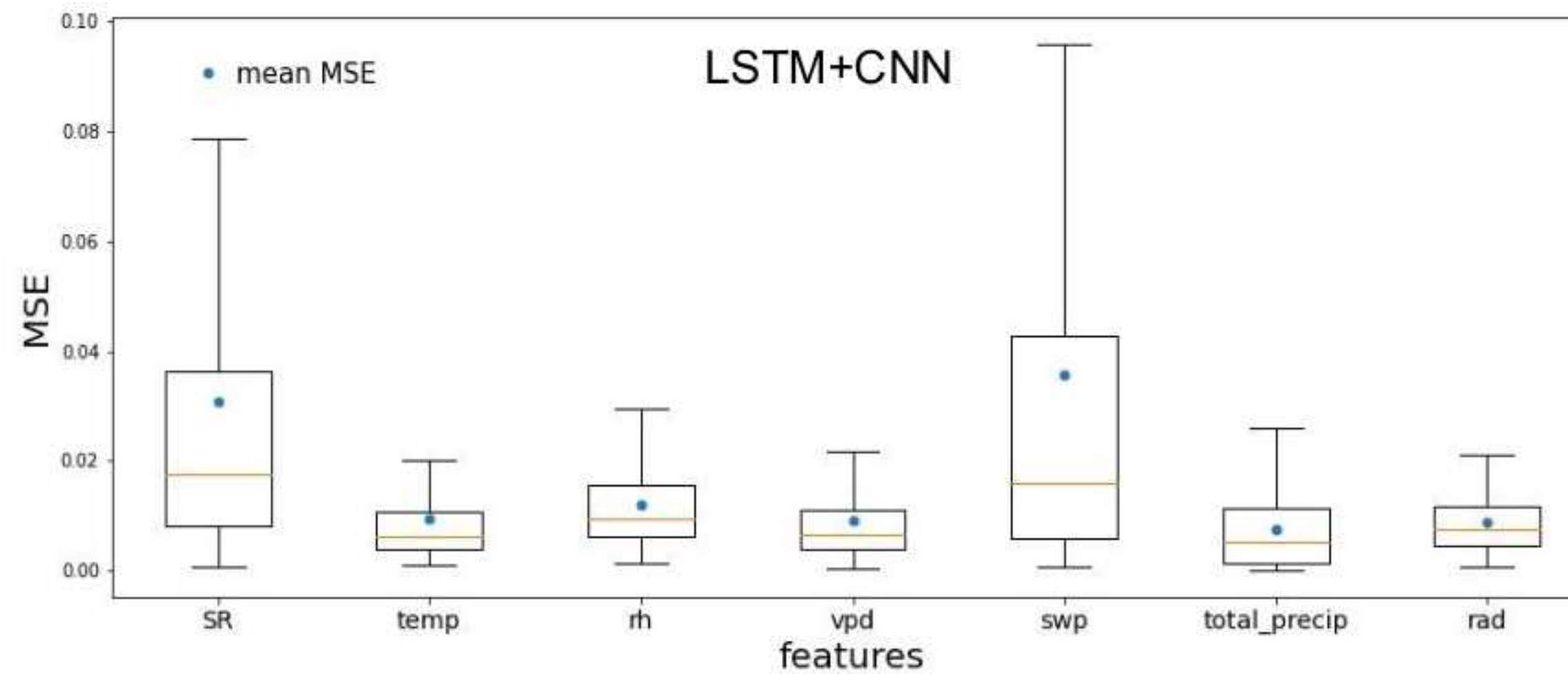
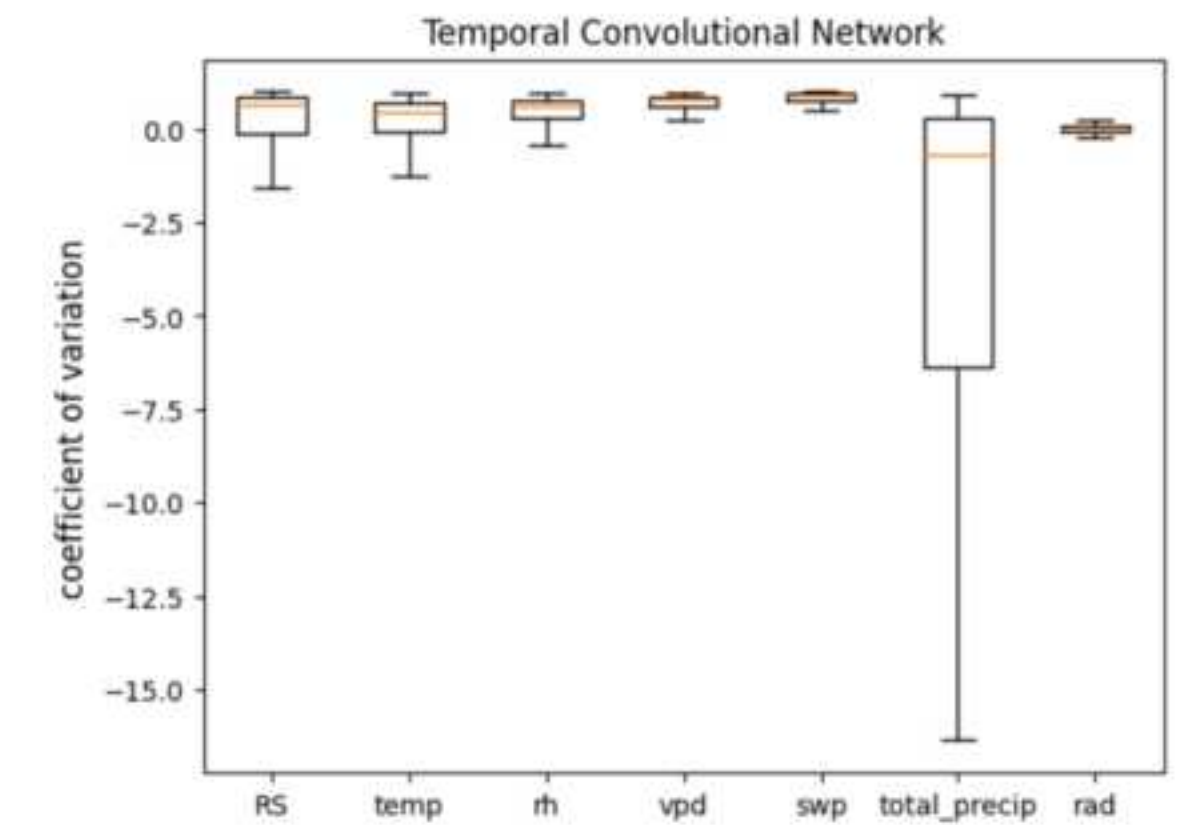
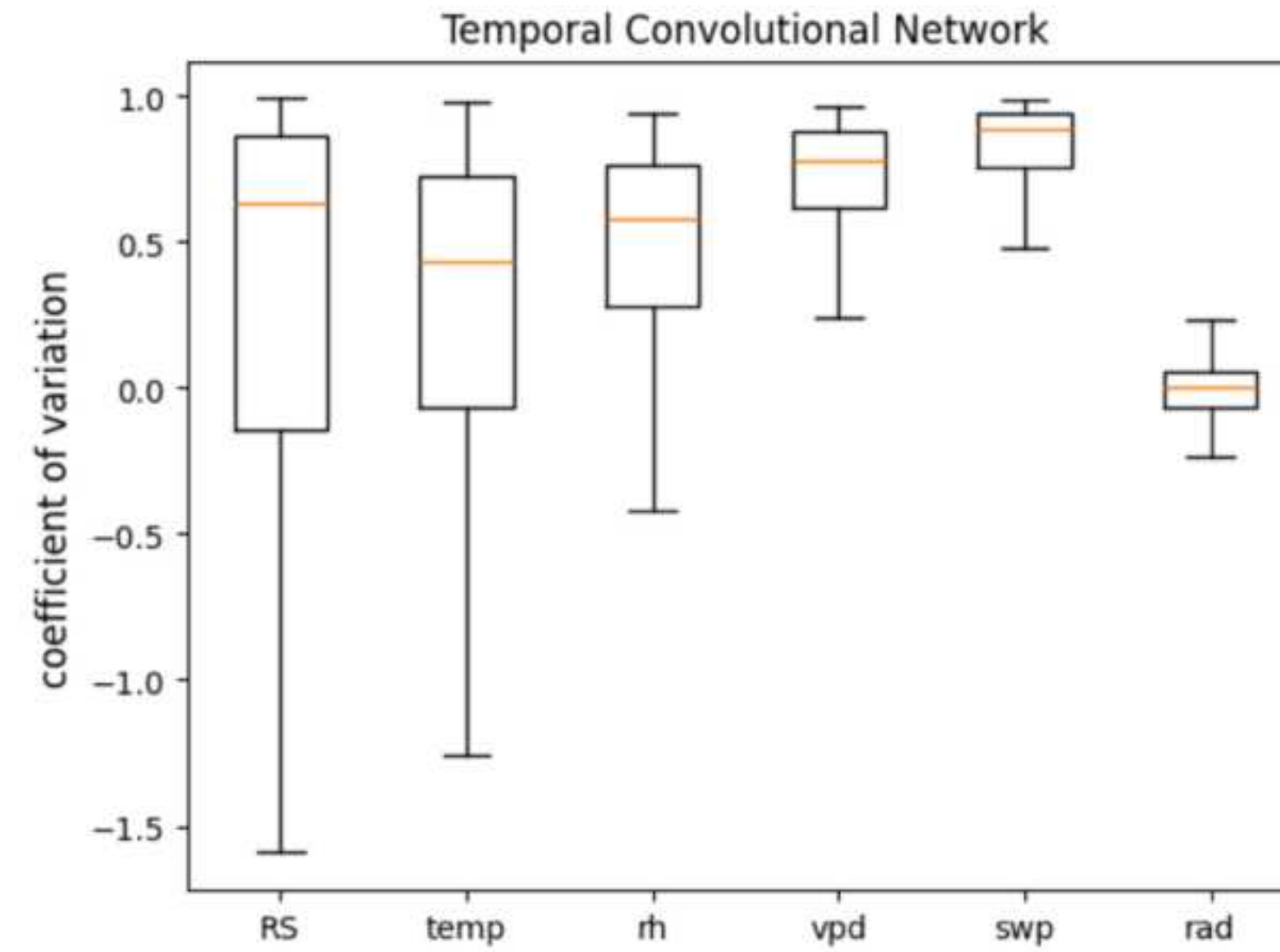
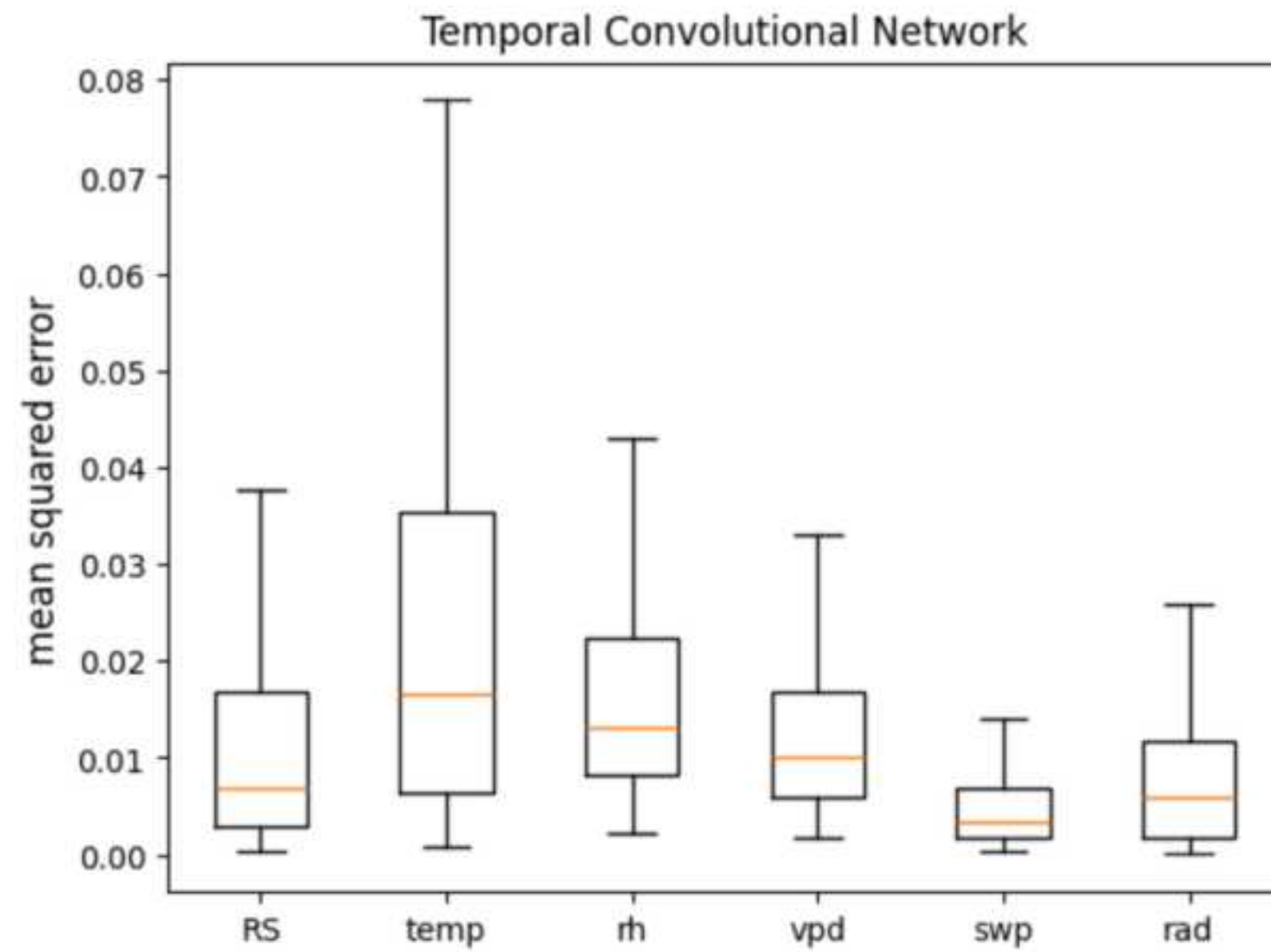
Minimisation



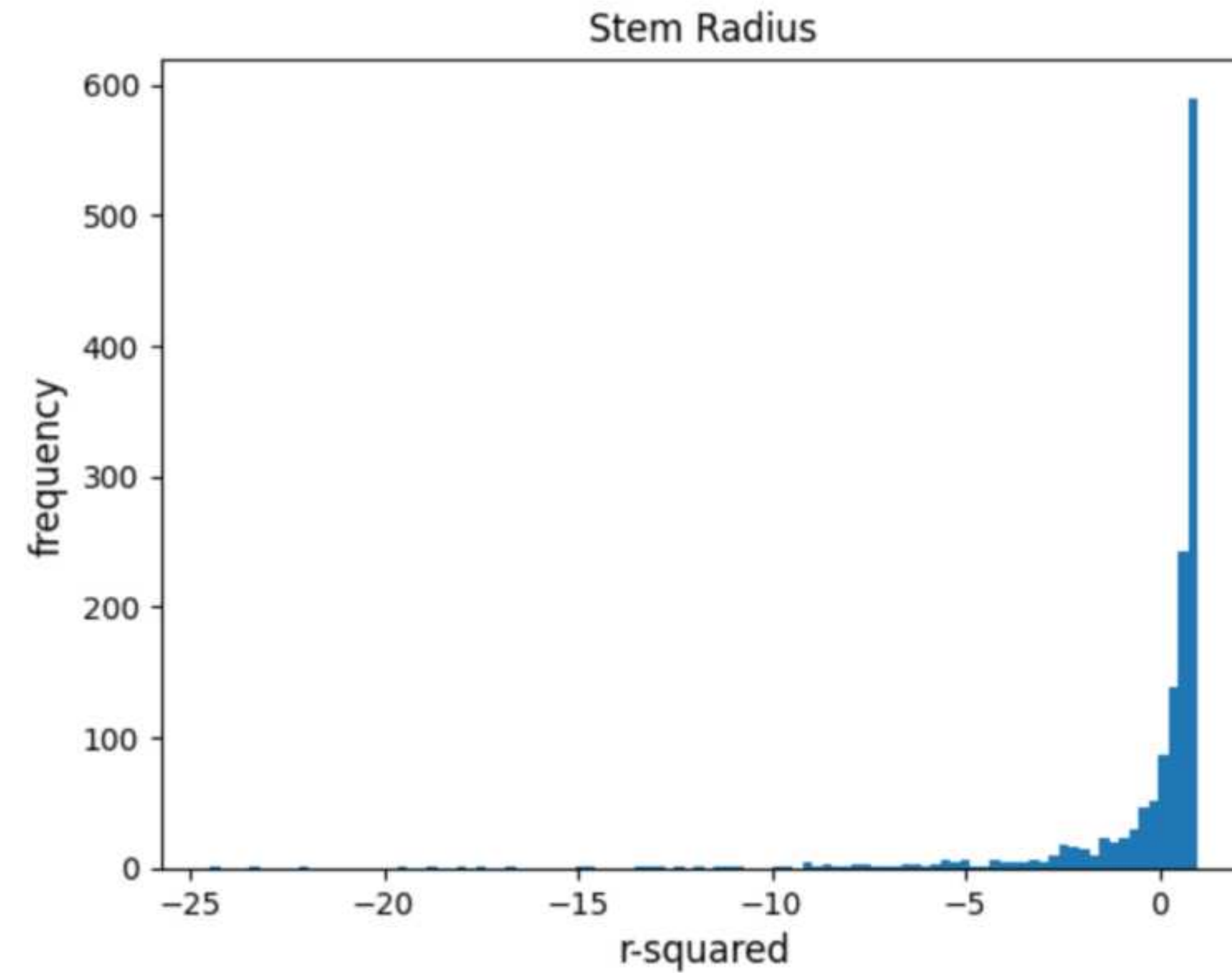
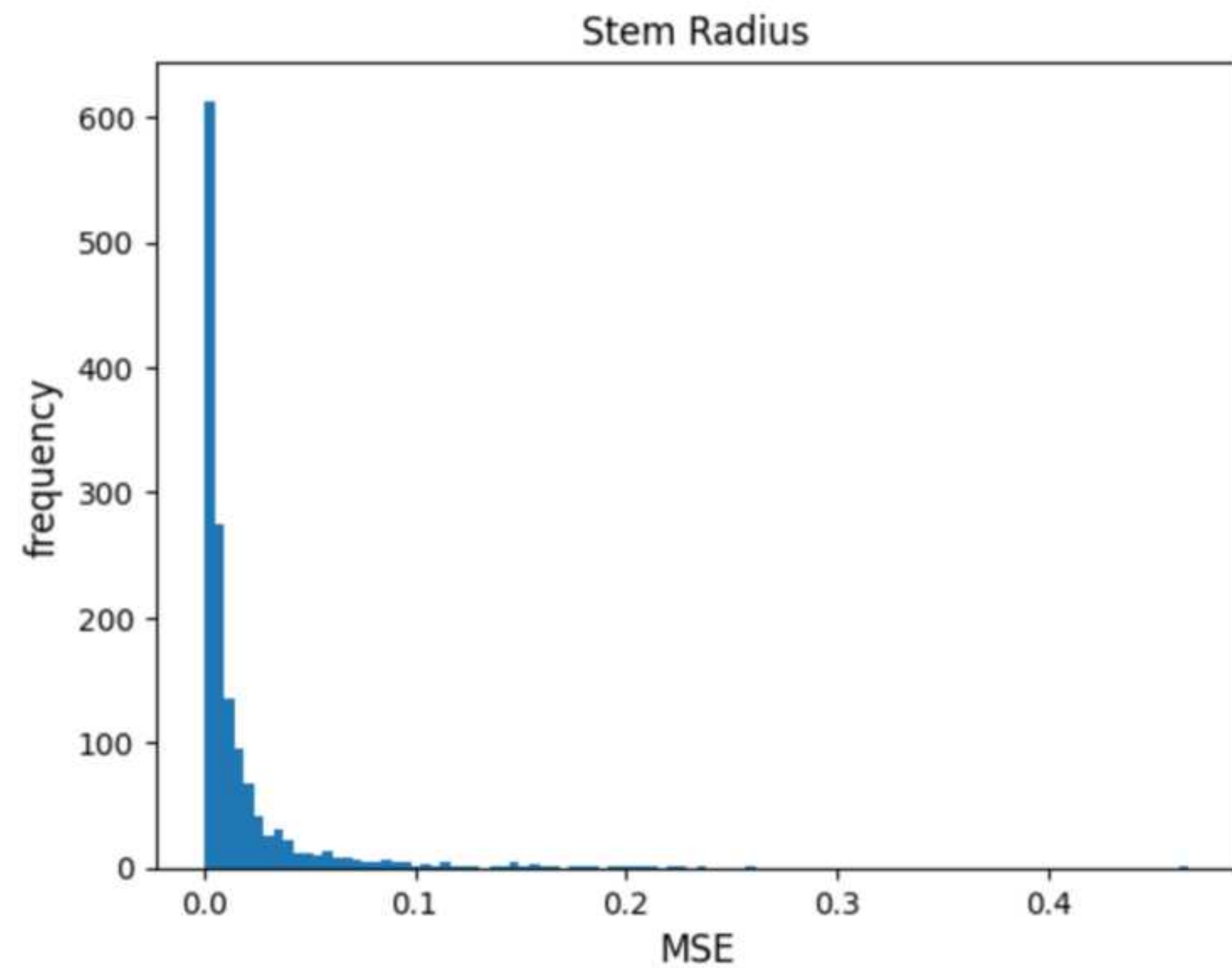
Lukovic, Zweifel, et al. (2022)



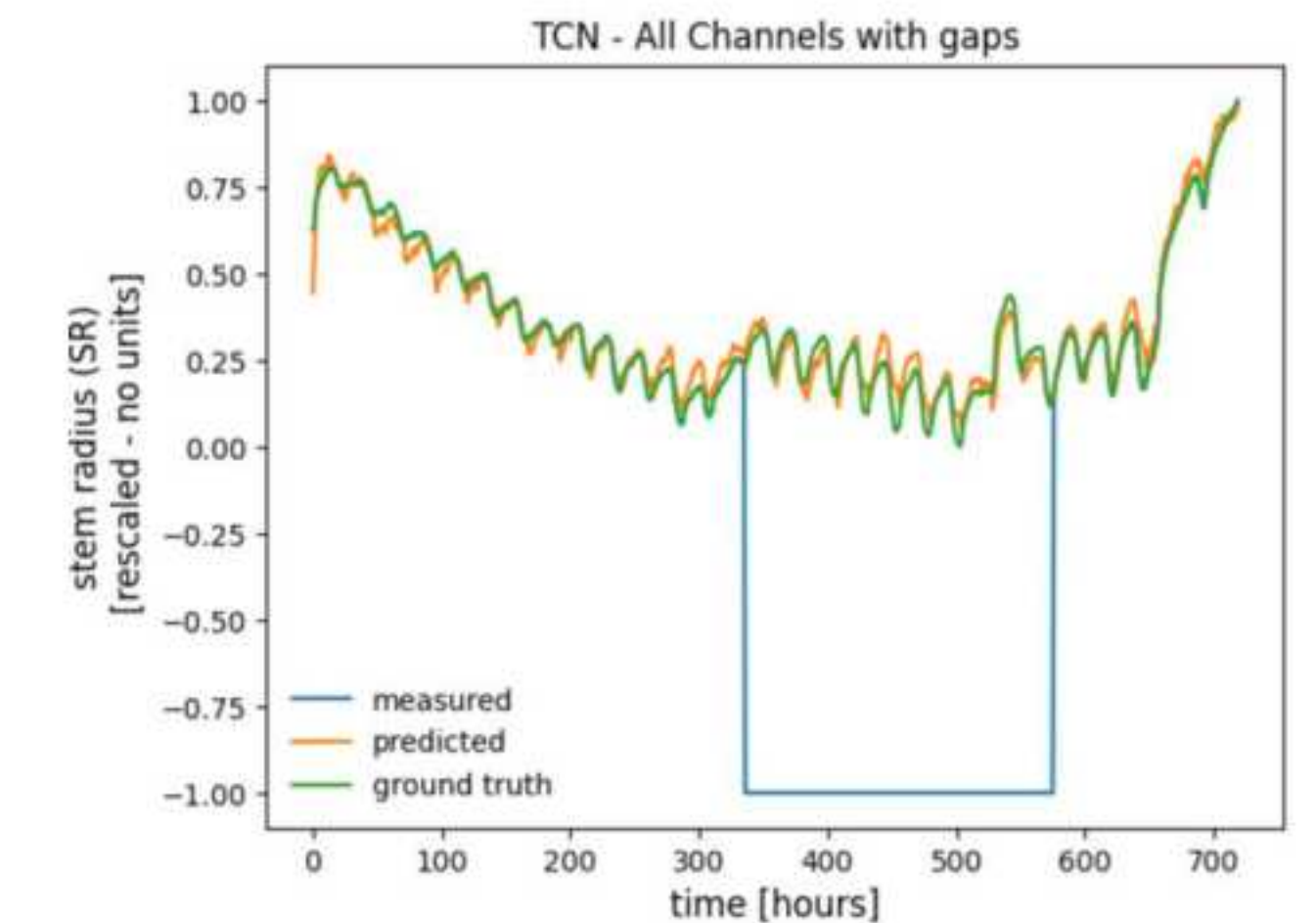
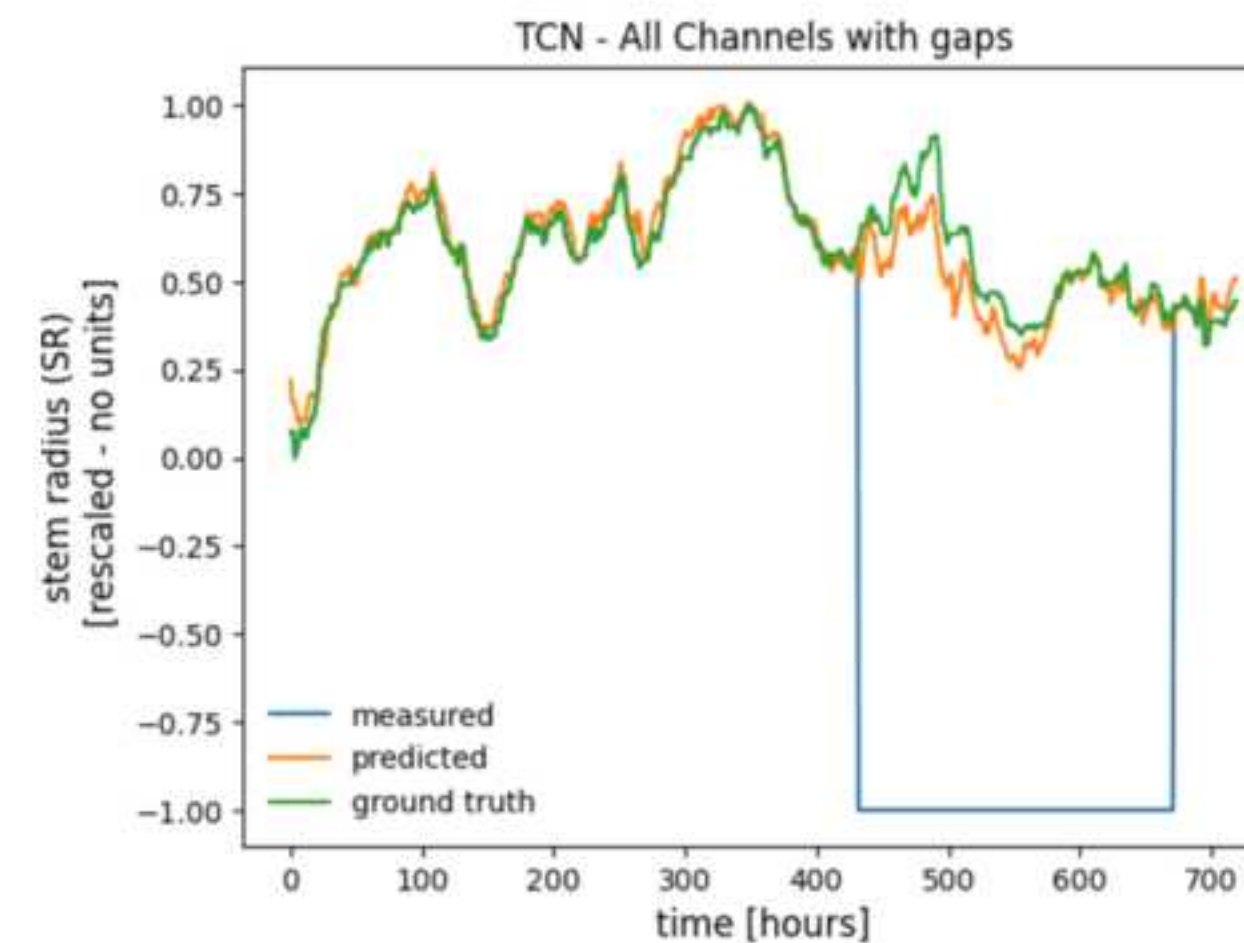
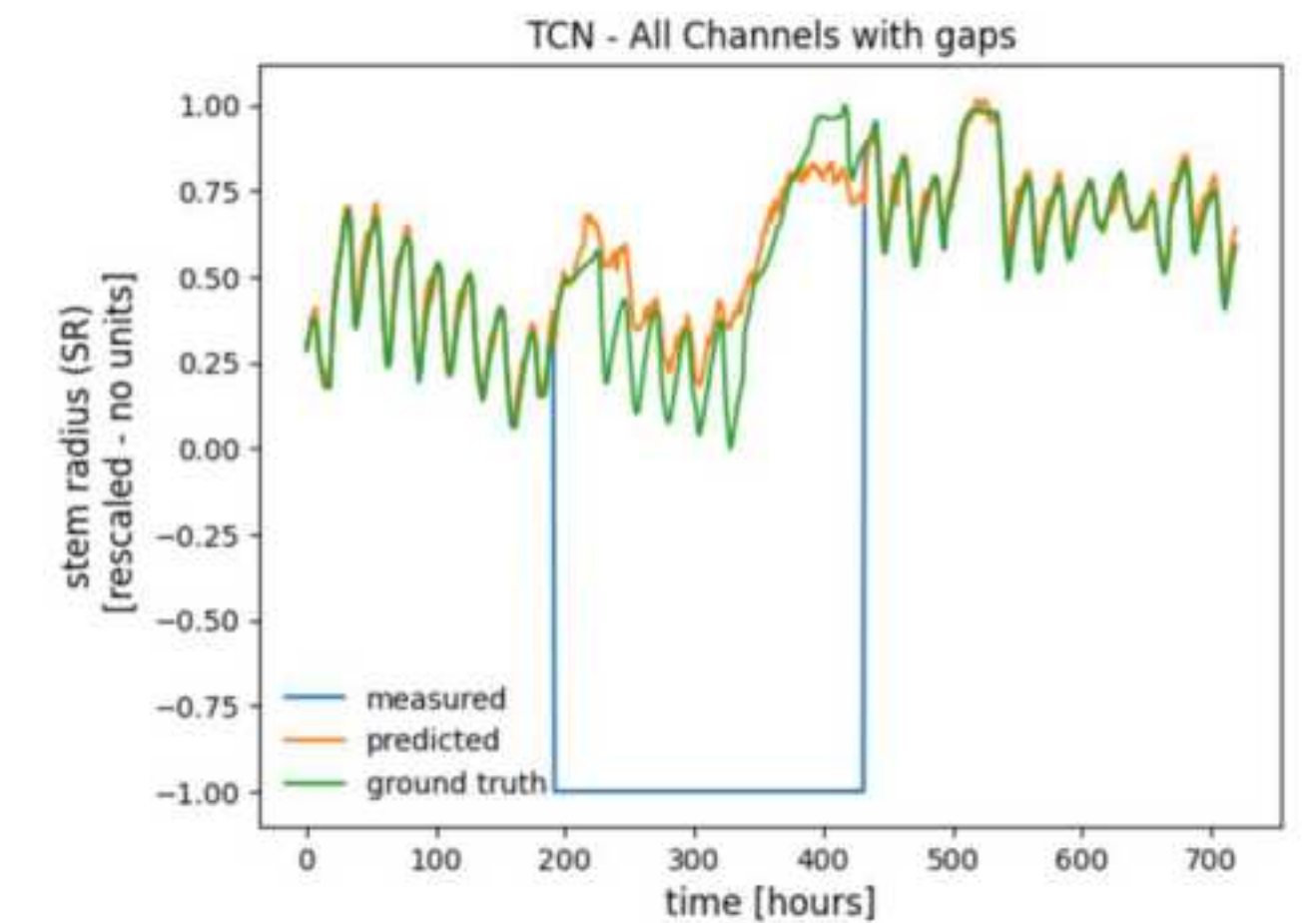
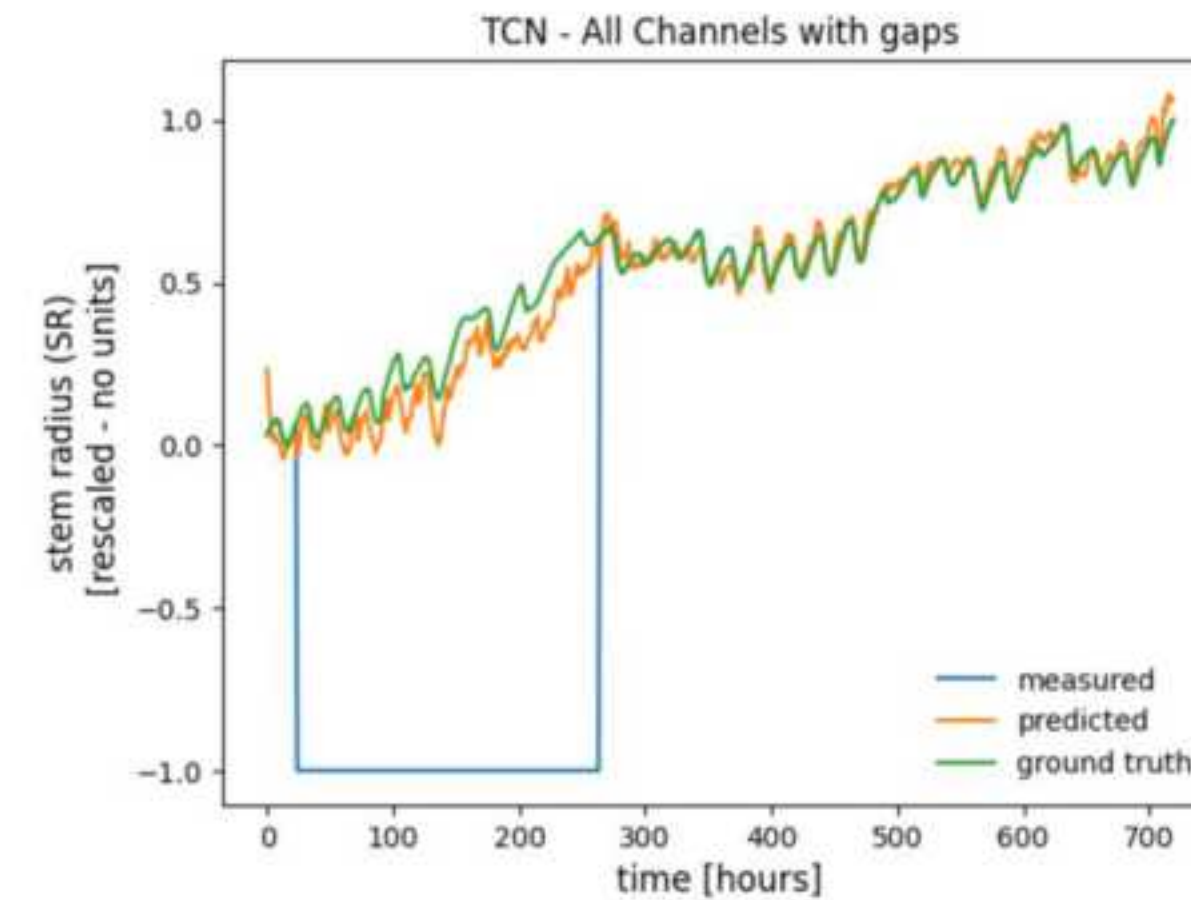
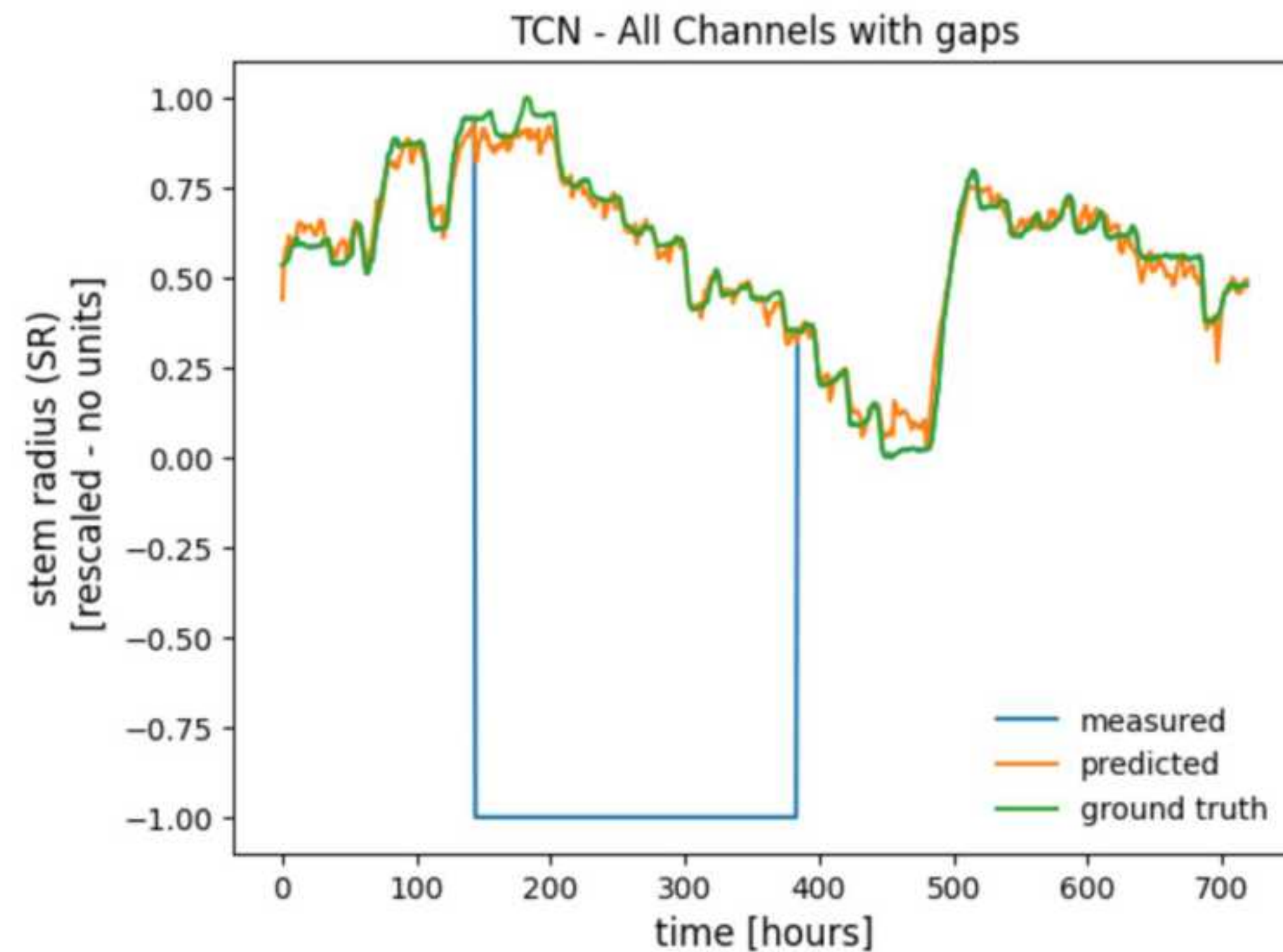
Temporal Convolutional Network



Model Performance - TCN



Reconstruction examples - TCN



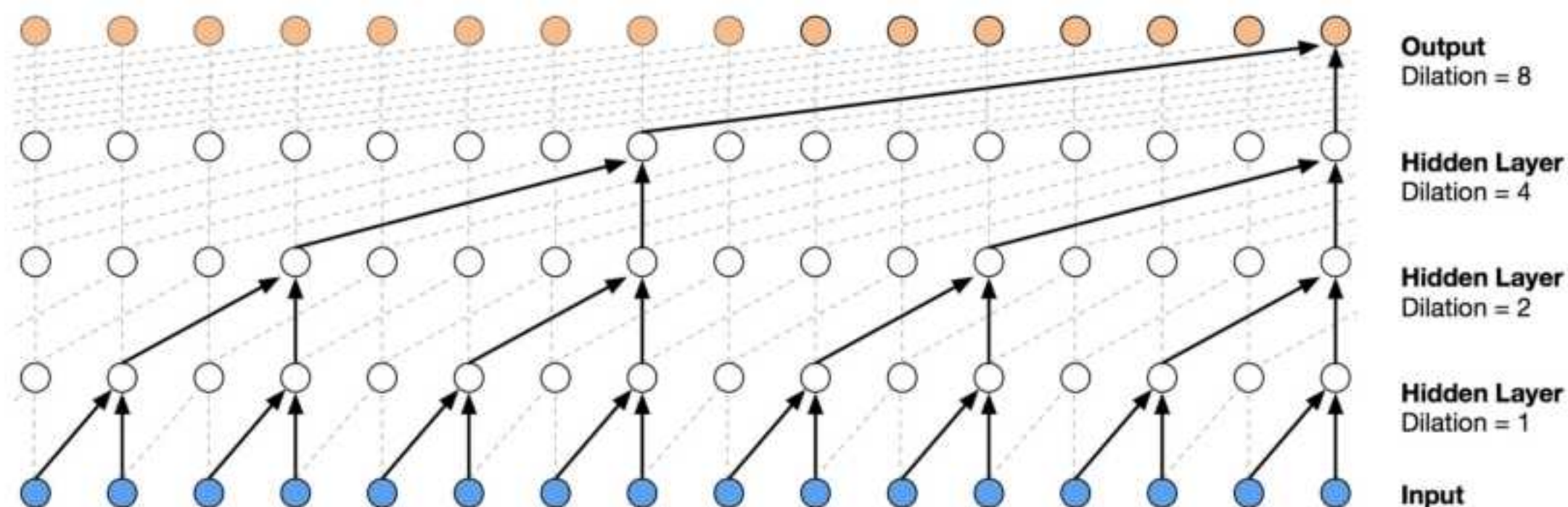
Temporal Convolution Network

*«We conclude that the common association between sequence modeling and recurrent networks should be reconsidered, and **convolutional networks should be regarded as a natural starting point for sequence modeling tasks.**»*

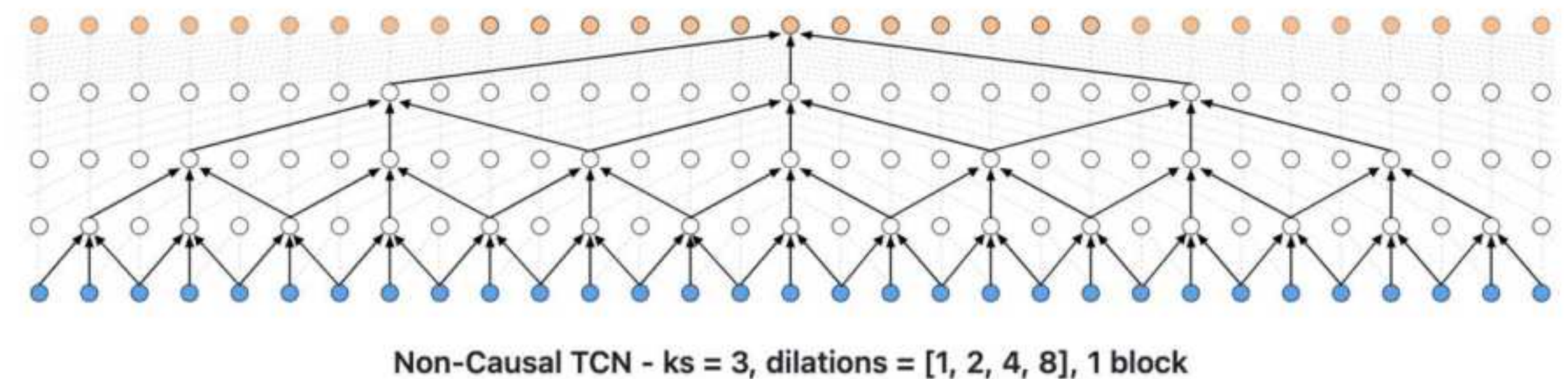
Bai, Kolter & Koltun, arXiv (2018).

Why TCN (Temporal Convolutional Network) instead of LSTM/GRU?

- TCNs exhibit longer memory than recurrent architectures with the same capacity.
- Performs better than LSTM/GRU on long time series (Seq. MNIST, Adding Problem, Copy Memory, Word-level PTB...).
- Parallelism (convolutional layers), flexible receptive field size (how far the model can see), stable gradients (compared to backpropagation through time, vanishing gradients)...

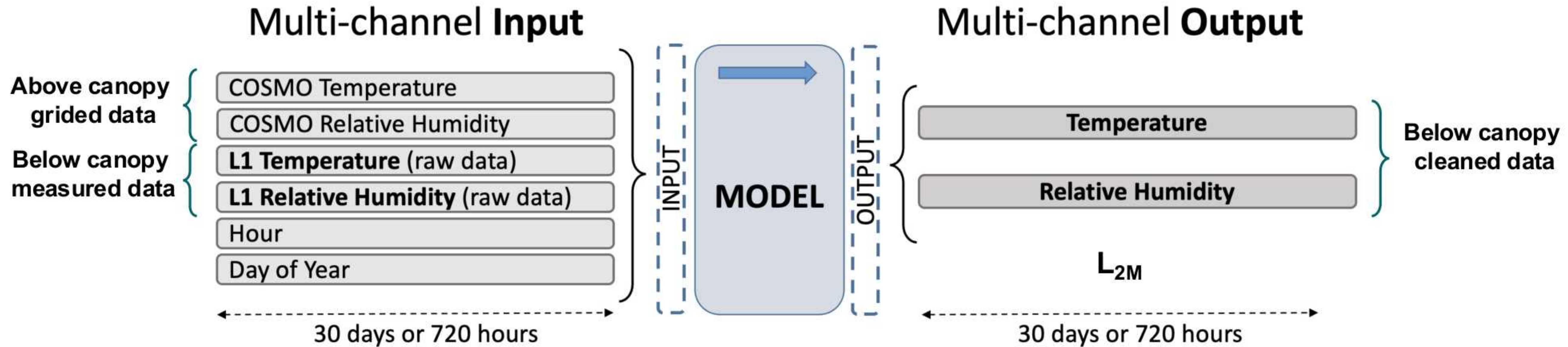


Visualization of a stack of dilated causal convolutional layers (Wavenet, 2016)



Philippe Remy, Temporal Convolutional Networks for Keras, GitHub (2020)

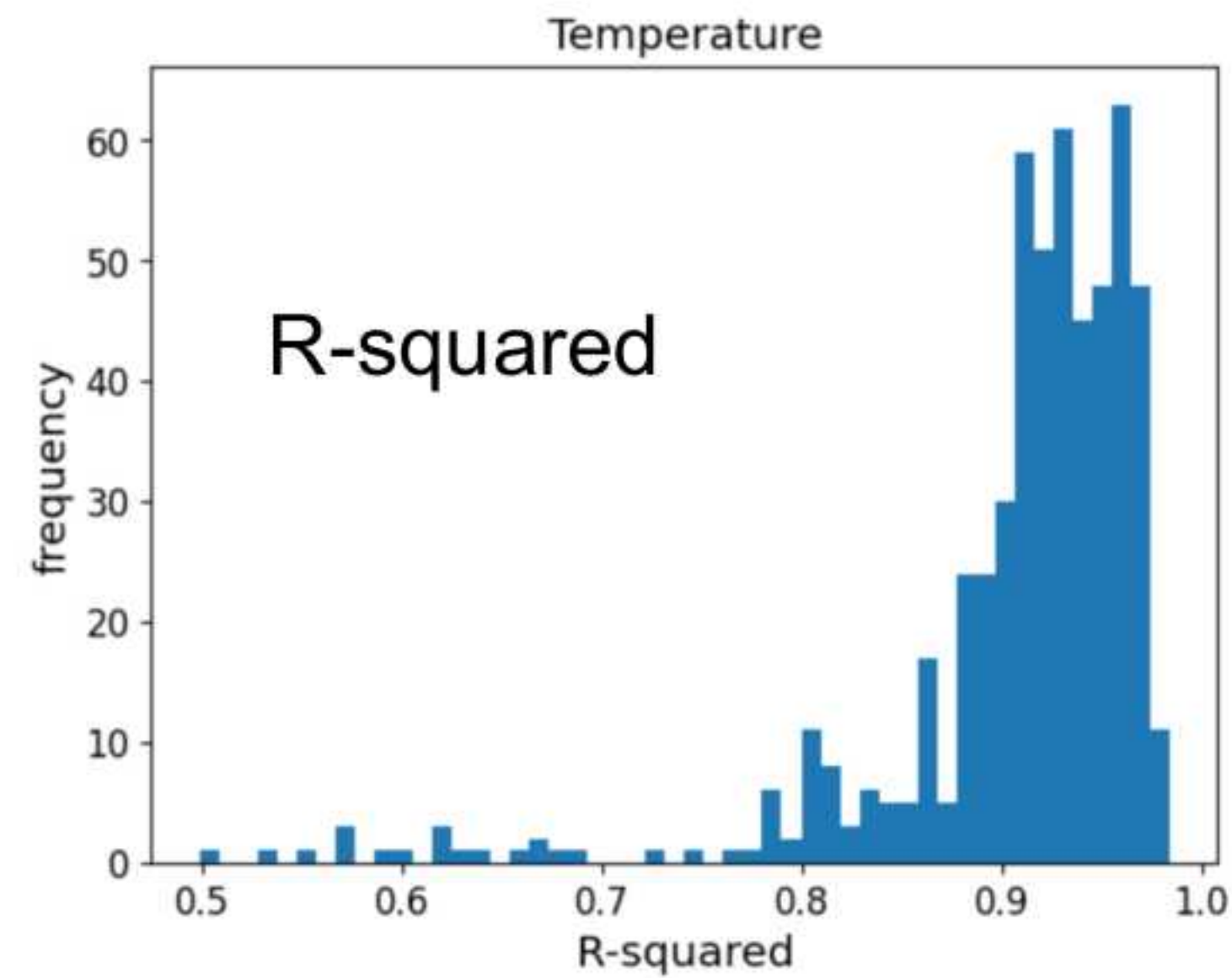
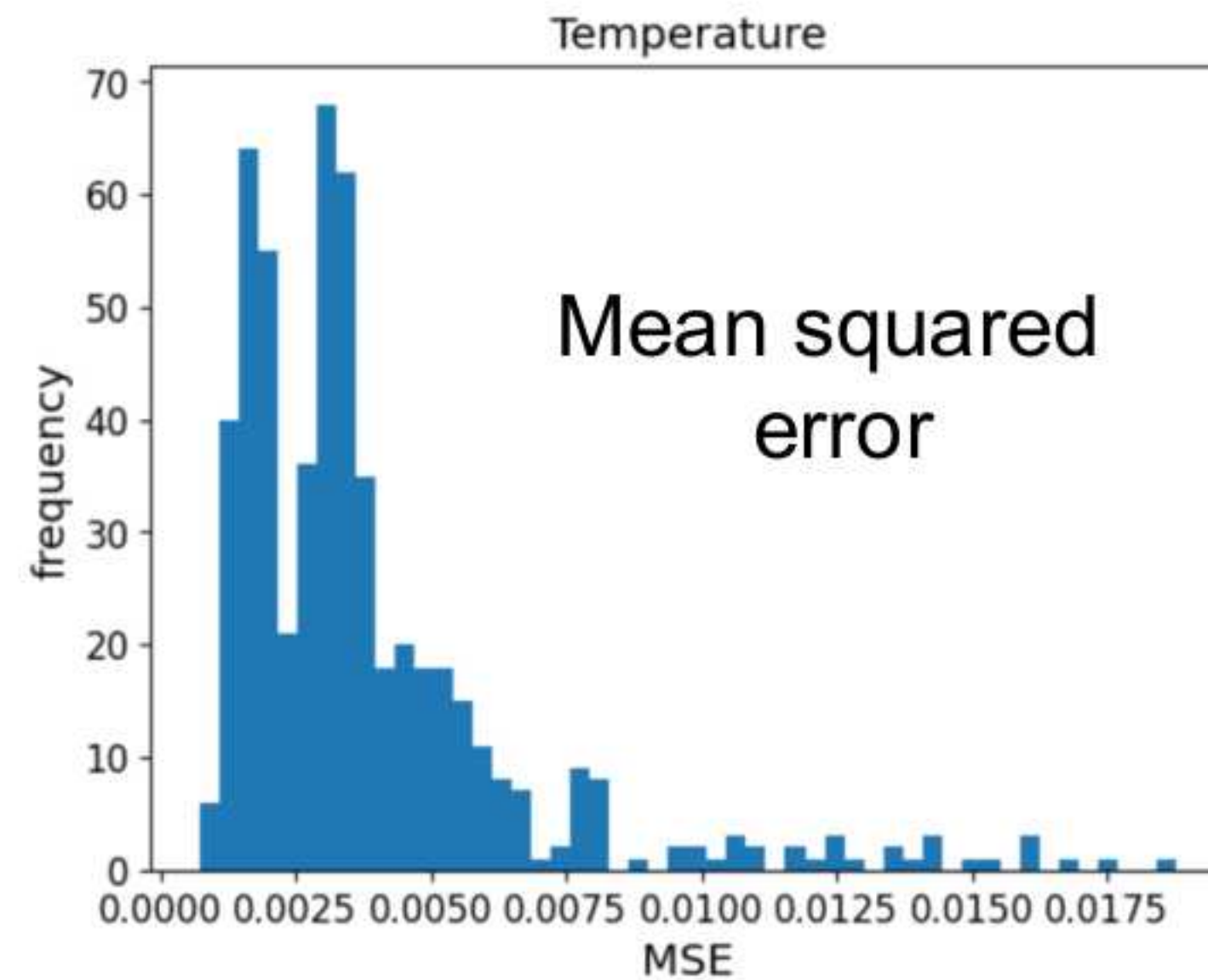
Climate Data Preprocessing (cleaning)



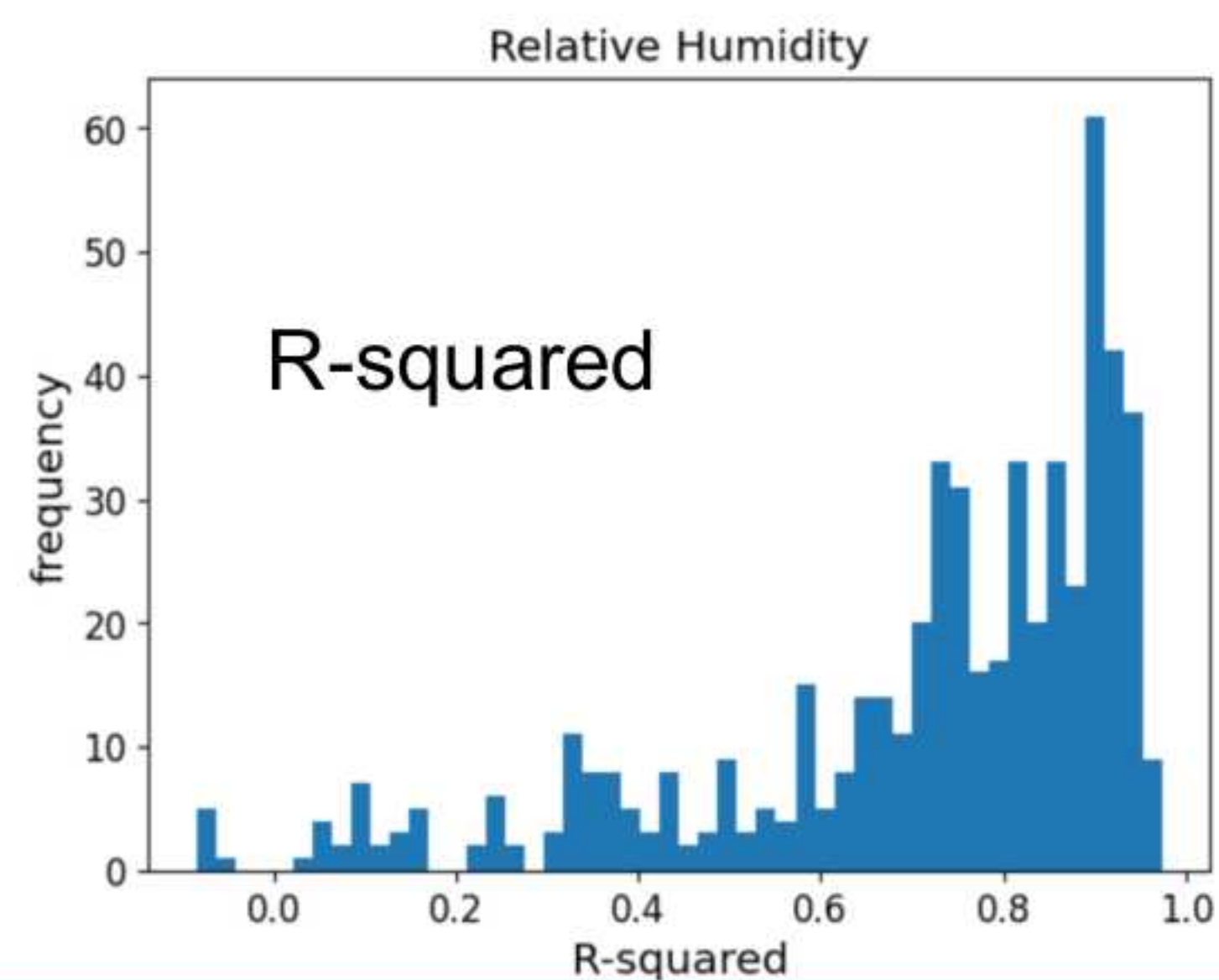
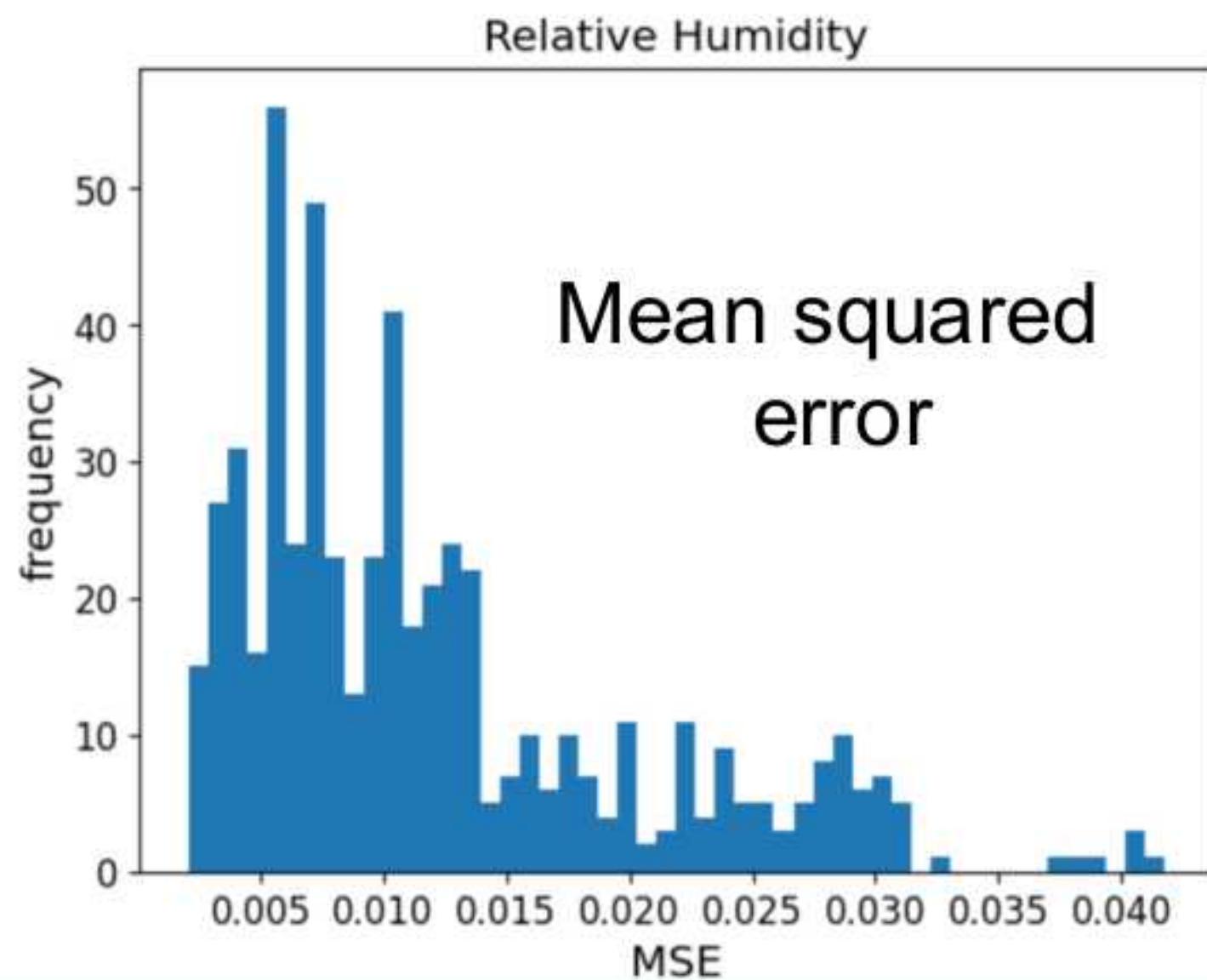
MODEL = Temporal Convolution Network

Goal – preprocess temperature and relative humidity using commercially available products such as COSMO.

Climate Data Preprocessing (cleaning)

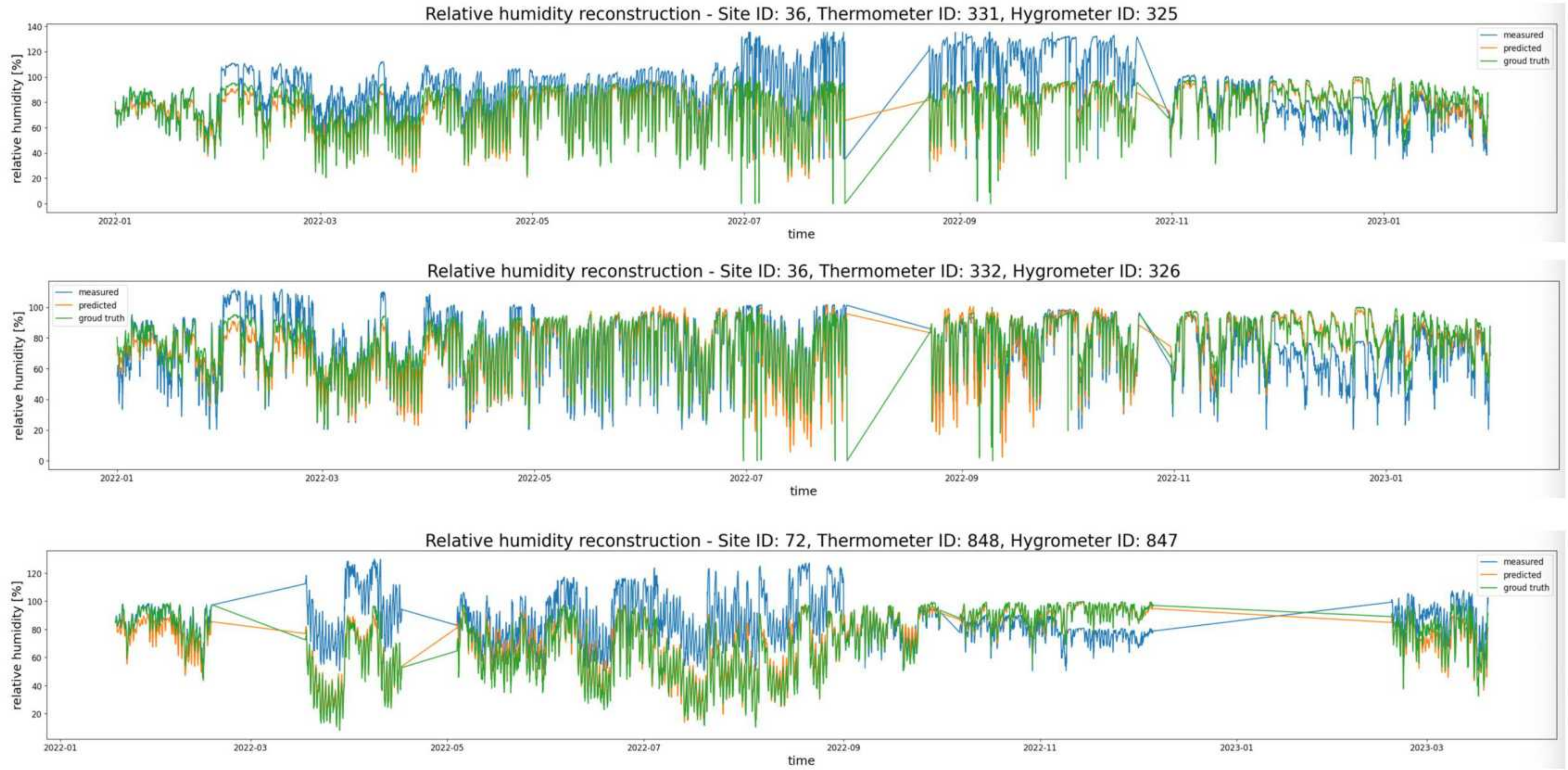


Temperature



Relative Humidity

Relative Humidity (cleaning) examples



GitHub Repository

github.com/treenet/treenetAI

Proton Account: Sig... Home - WSL Make your polls - n... Локална пореска а... eUprava Synonyms and Anto... Dictionary.com | Me... Microsoft Loop Microsoft Copilot Your AI Research A

files	readme update	4 months ago
images	readme update	4 months ago
models/templates	small changes	2 weeks ago
raw_data_elaboration	small changes	2 weeks ago
task_scripts	small changes	2 weeks ago
utils	Cosmo file ordering implemented	3 weeks ago
.gitignore	LSTM_CNN model works	last month
CITATION.cff	updated structure	4 months ago
LICENSE	Create LICENSE	5 months ago
README.md	raw data format as dictionary	4 months ago
config.py	Cosmo file ordering implemented	3 weeks ago
evaluation.py	Cosmo file ordering implemented	3 weeks ago
training.py	Cosmo file ordering implemented	3 weeks ago

README

GPL-3.0 license

TreeNetAI



treenet.info

forest growth drought time-series-analysis gap-filling treenet dendrometer stem-radius-changes stem-growth tree-water-deficit

Readme

GPL-3.0 license

Cite this repository

Activity

Custom properties

0 stars

1 watching

0 forks

Report repository

Releases

No releases published

Create a new release

Packages

No packages published

Publish your first package

Contributors 2

lukov

Mirko Lukovic

micahwilhelm

Micah

Languages

Python 91.0%

Shell 7.9%

TeX 1.1%