

# Time series analysis

Jiří Materna



Machine  
Learning  
College

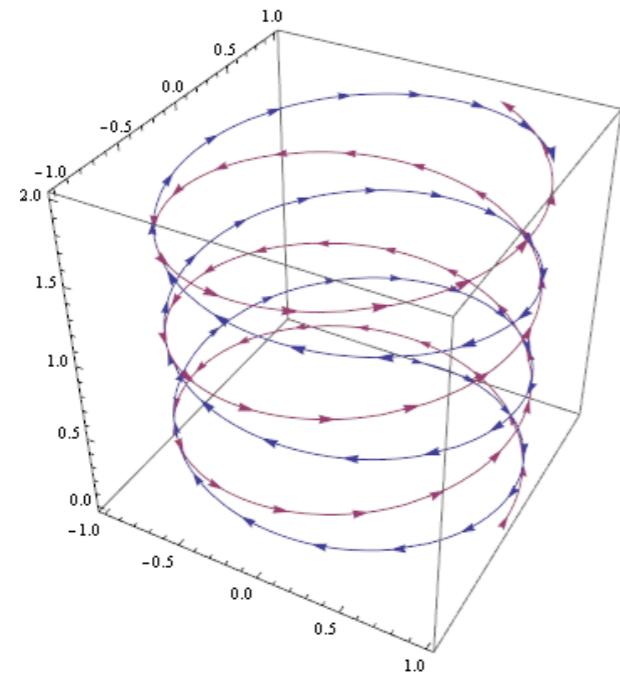
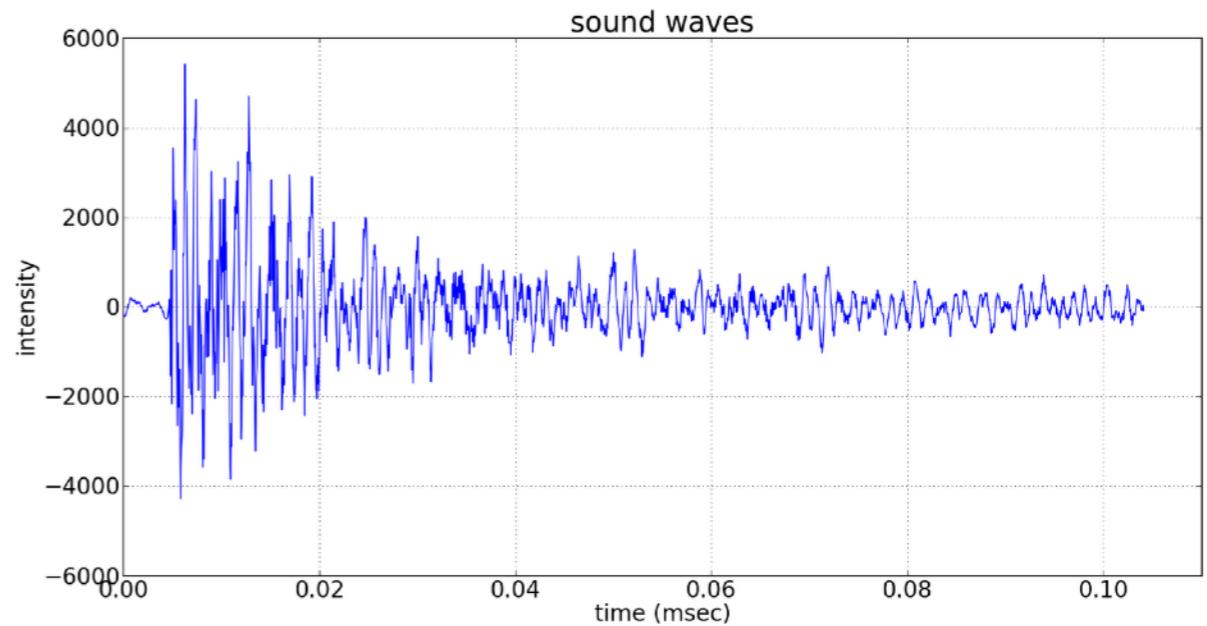
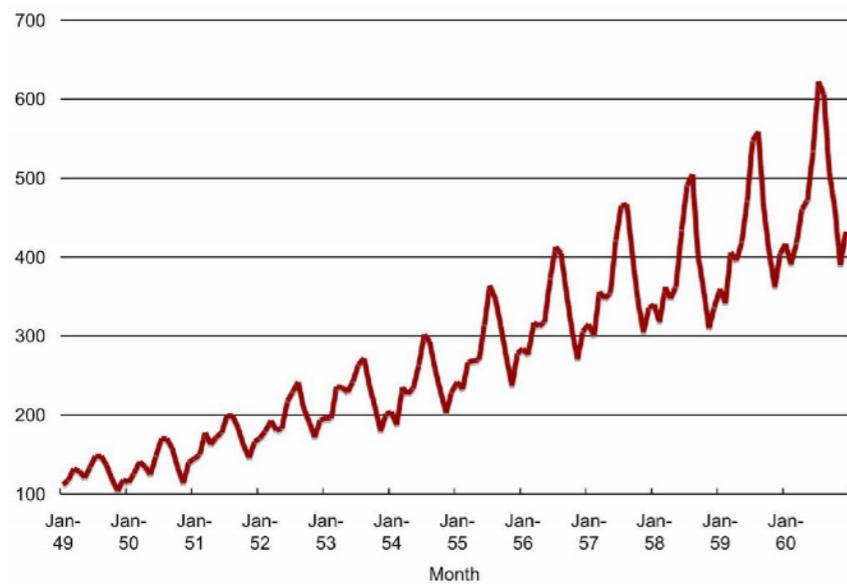
# About me

- Ph.D. in Natural Language Processing and Artificial Intelligence at Masaryk University
- 10 years at Seznam.cz (last 8 years as Head Of Research)
- Founder and lecturer at ML College
- Founder and co-organizer of ML Prague
- ML Freelance and consultant

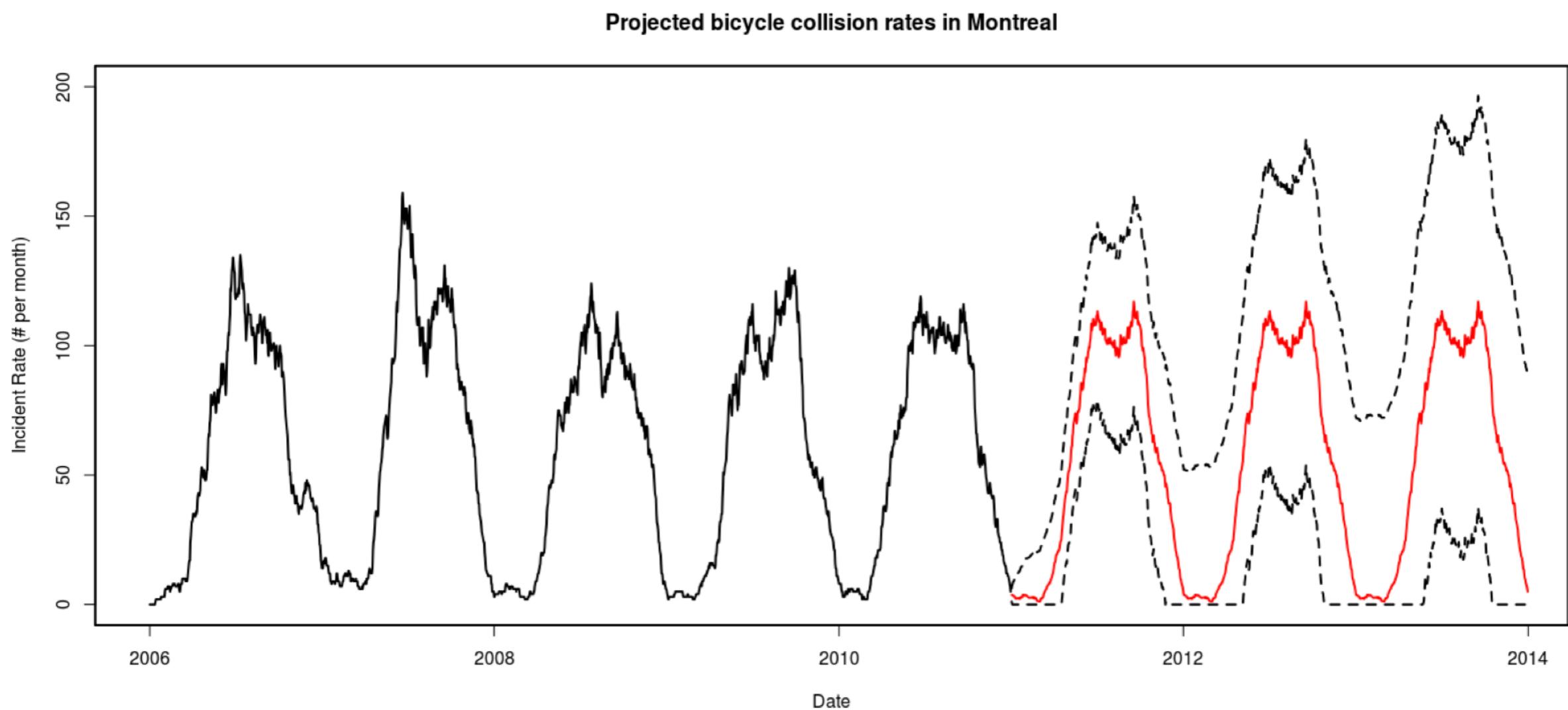
# Outline

- Introduction to time series analysis
- Analysis by decomposition
- ARIMA family models
- Time series prediction with Feed forward networks
- Recurrent neural networks
- Long short-term memory
- Forecasting
- Heating plant assignment

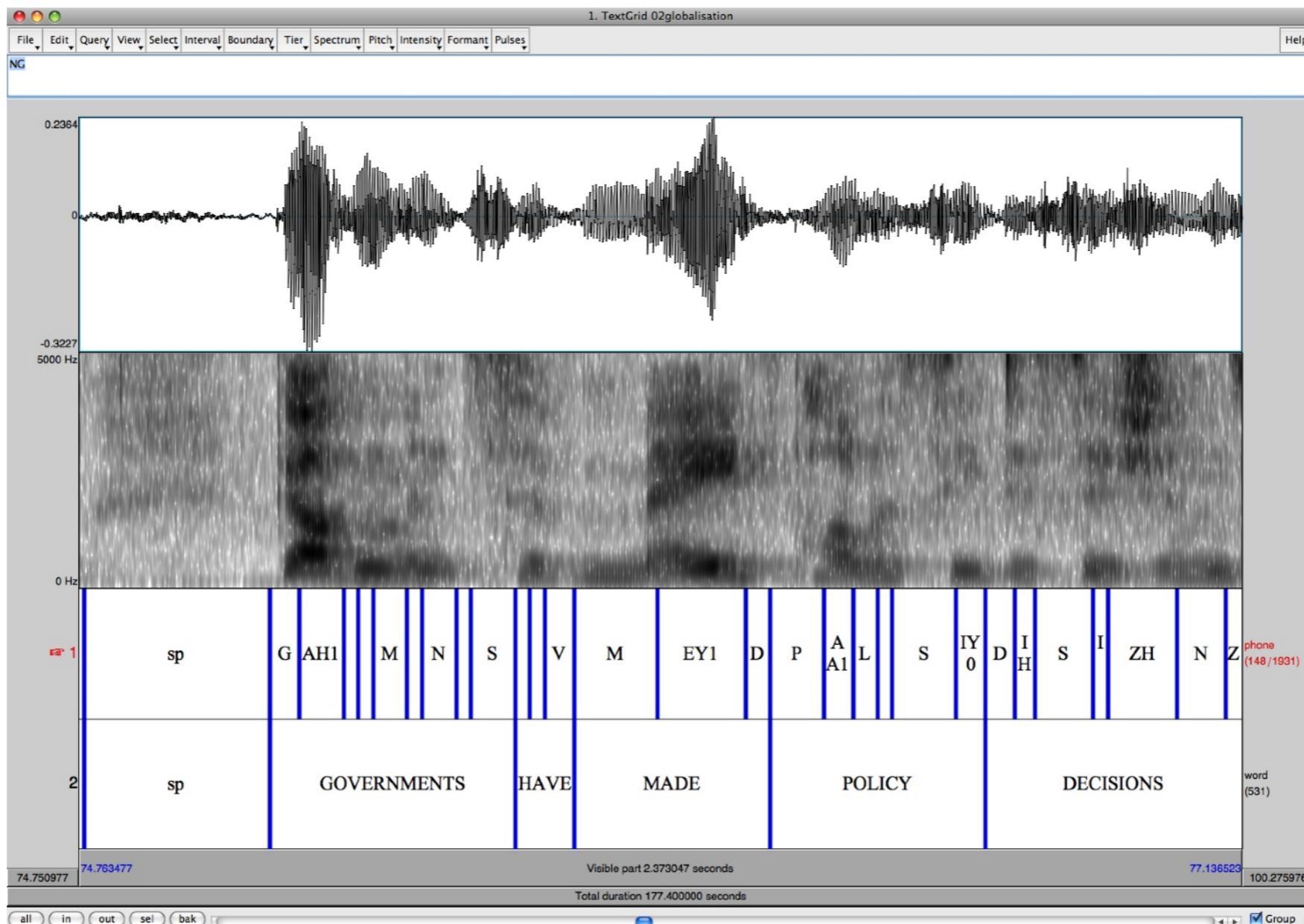
# Time series data types



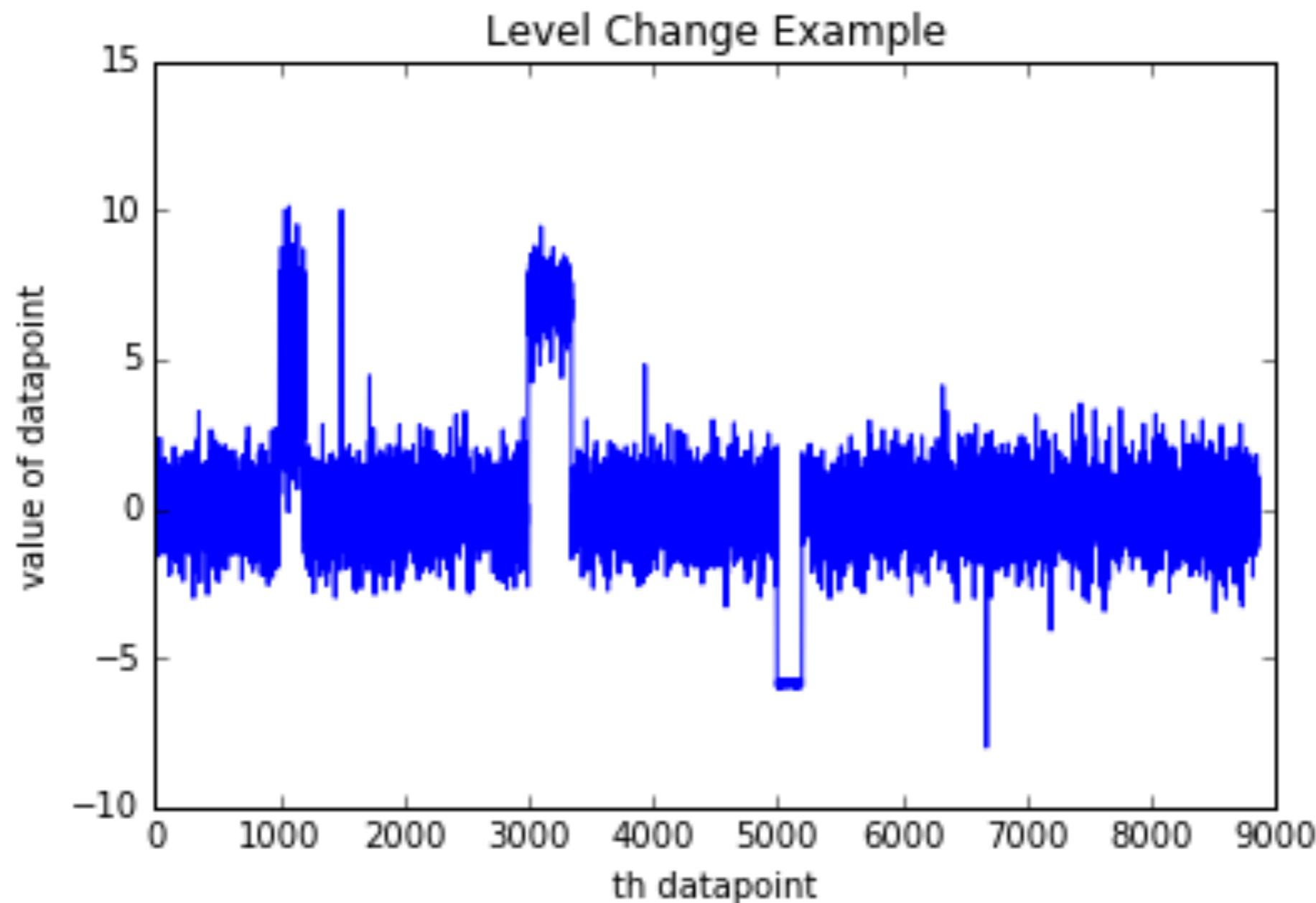
# Time series tasks - forecasting



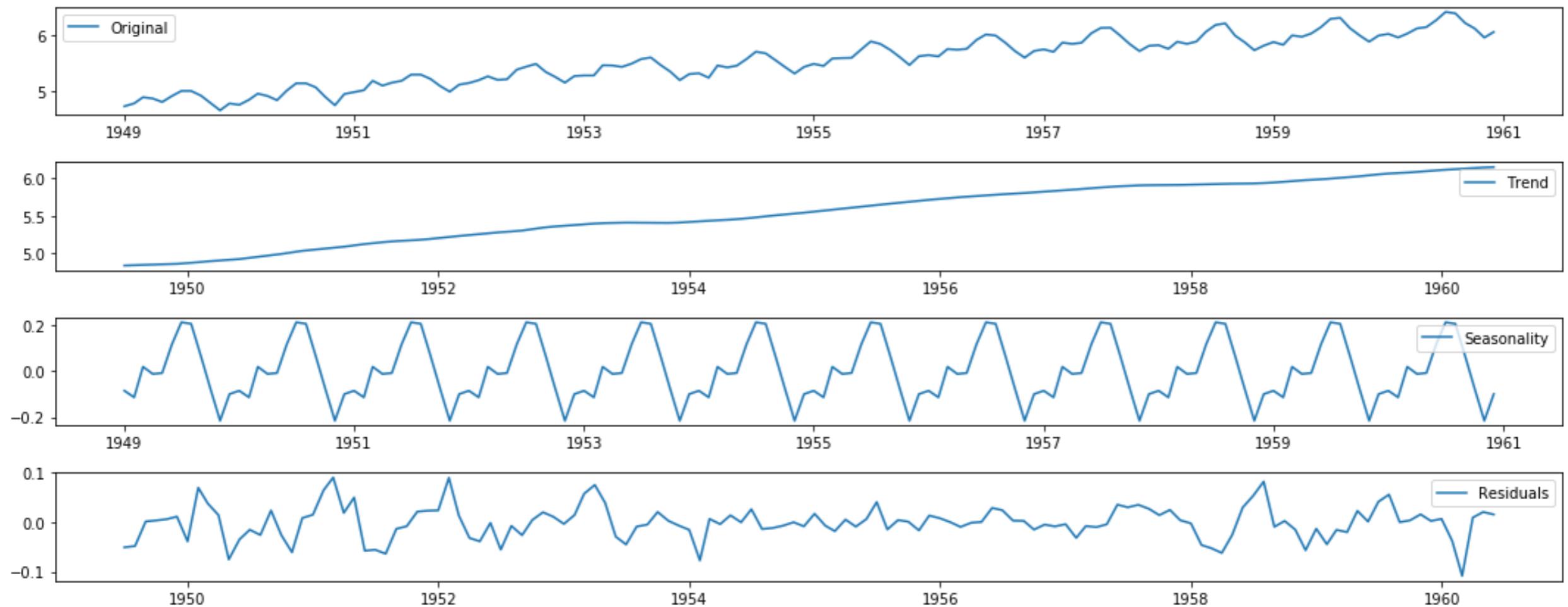
# Time series tasks - classification



# Time series tasks - anomaly detection



# Classical analysis - decomposition



# TS Decomposition tutorial

[\*\*01-Decomposition\\_tutorial.ipynb\*\*](#)

# ARIMA model

**Auto Regressive Integrated Moving Average**

**Auto Regression (AR)**

$$Y_t = \beta_1 + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \dots + \Phi_p Y_{t-p}$$

**Integration (I)**

$$Z_t = Y_{t+1} - Y_t \quad \dots d = 1$$

$$Q_t = Z_{t+1} - Z_t \quad \dots d = 2$$

...

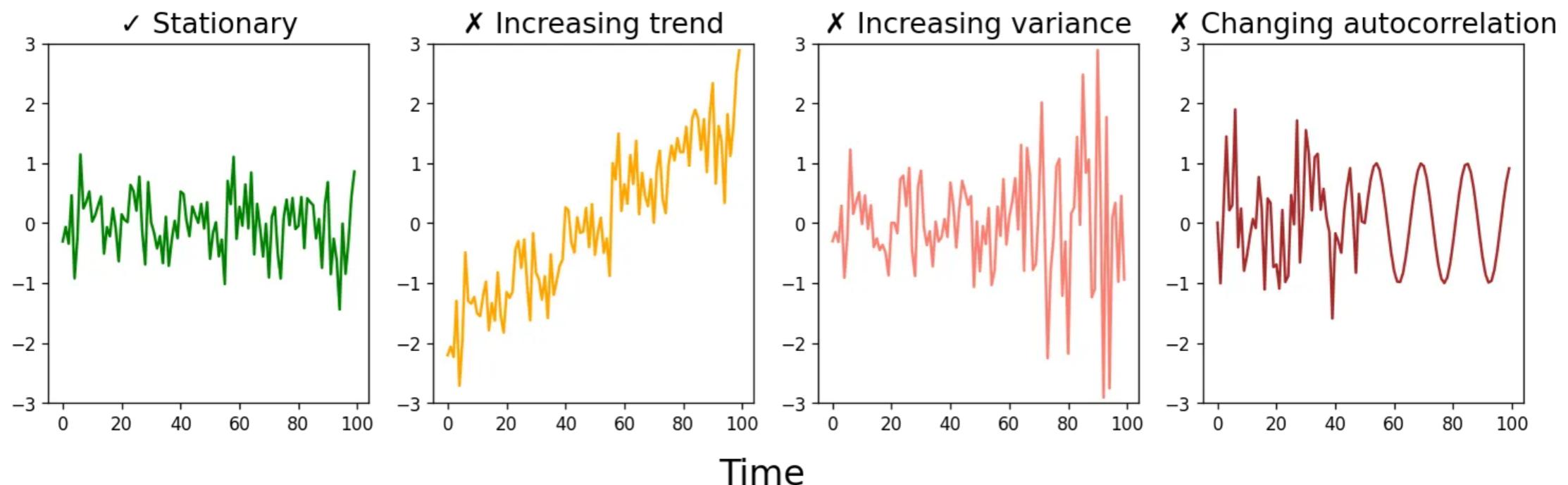
**Moving Average (MA)**

$$Y_t = \beta_2 + \omega_1 \varepsilon_{t-1} + \omega_2 \varepsilon_{t-2} + \dots + \omega_q \varepsilon_{t-q} + \varepsilon_t$$

**ARIMA(p, d, q)**

# Stationarity

- 1. Constant mean:** The mean of the time series remains constant over time.
- 2. Constant variance:** The variance of the time series remains constant over time.
- 3. Constant covariance:** The covariance between two observations at different time points is constant over time.



# SARIMA model

**Seasonal Auto Regressive Integrated Moving Average**

**ARIMA(p, d, q)(P, D, Q)m**

P: Seasonal autoregressive order.

D: Seasonal difference order.

Q: Seasonal moving average order.

m: The number of time steps for a single seasonal period.

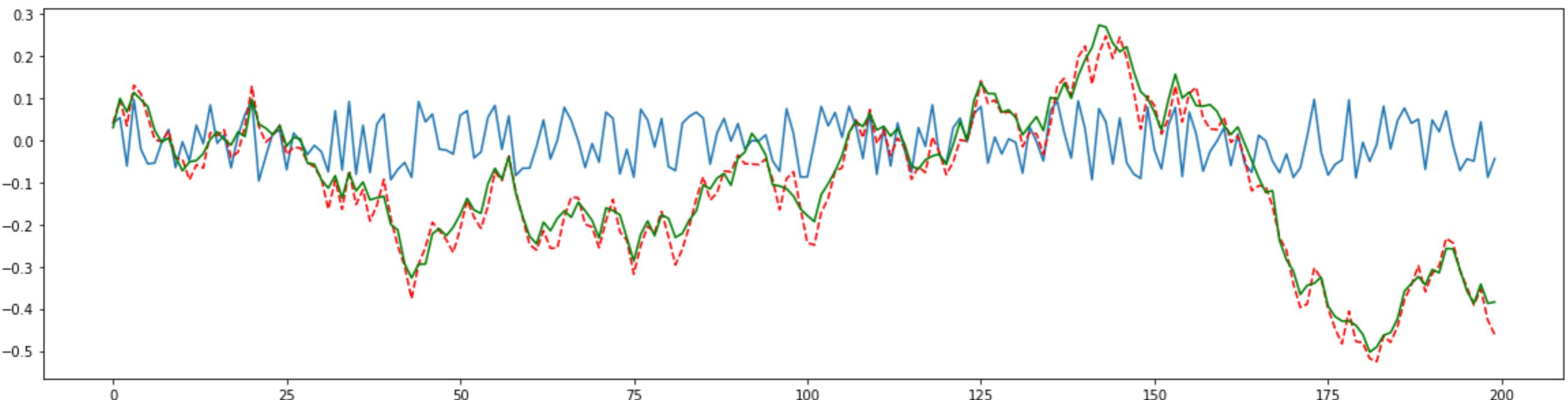
# SARIMAX model

Adds exogenous variables

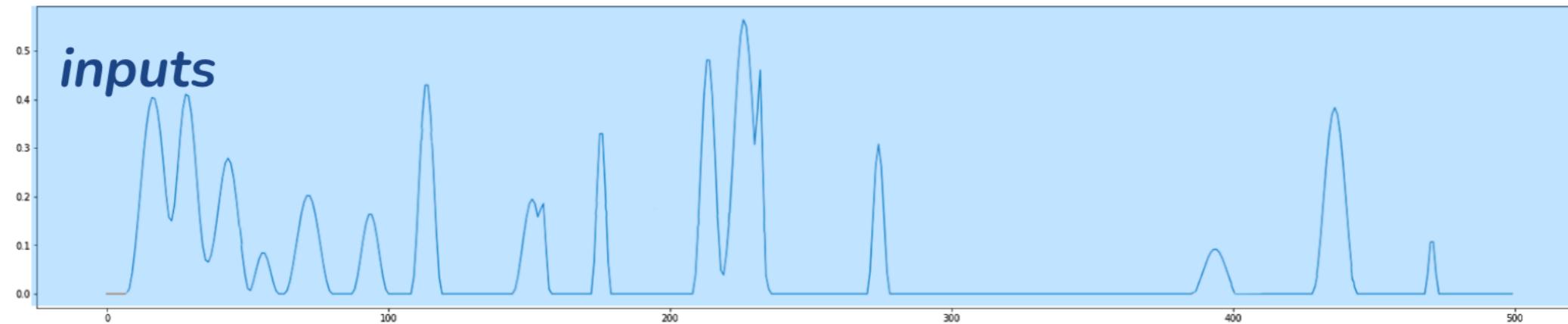
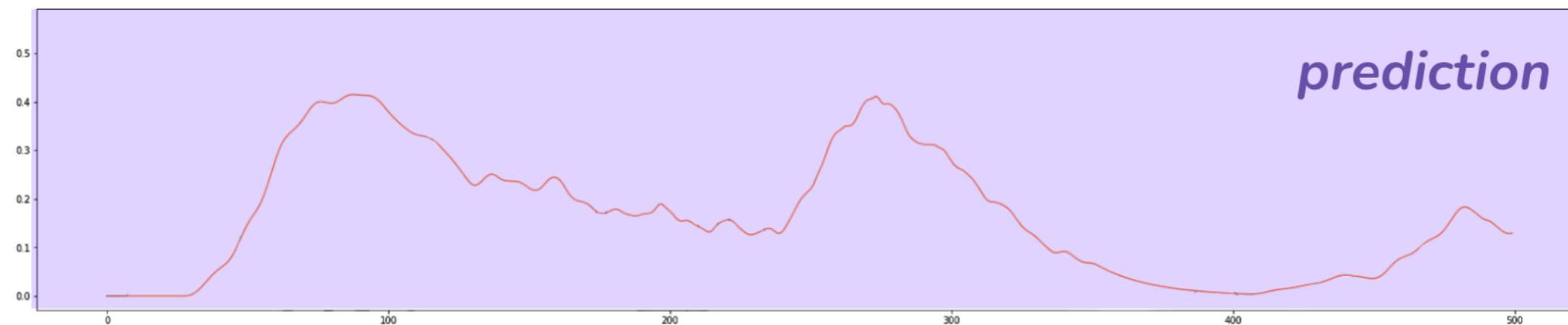
# ARIMA tutorial

[\*\*02-ARIMA tutorial.ipynb\*\*](#)

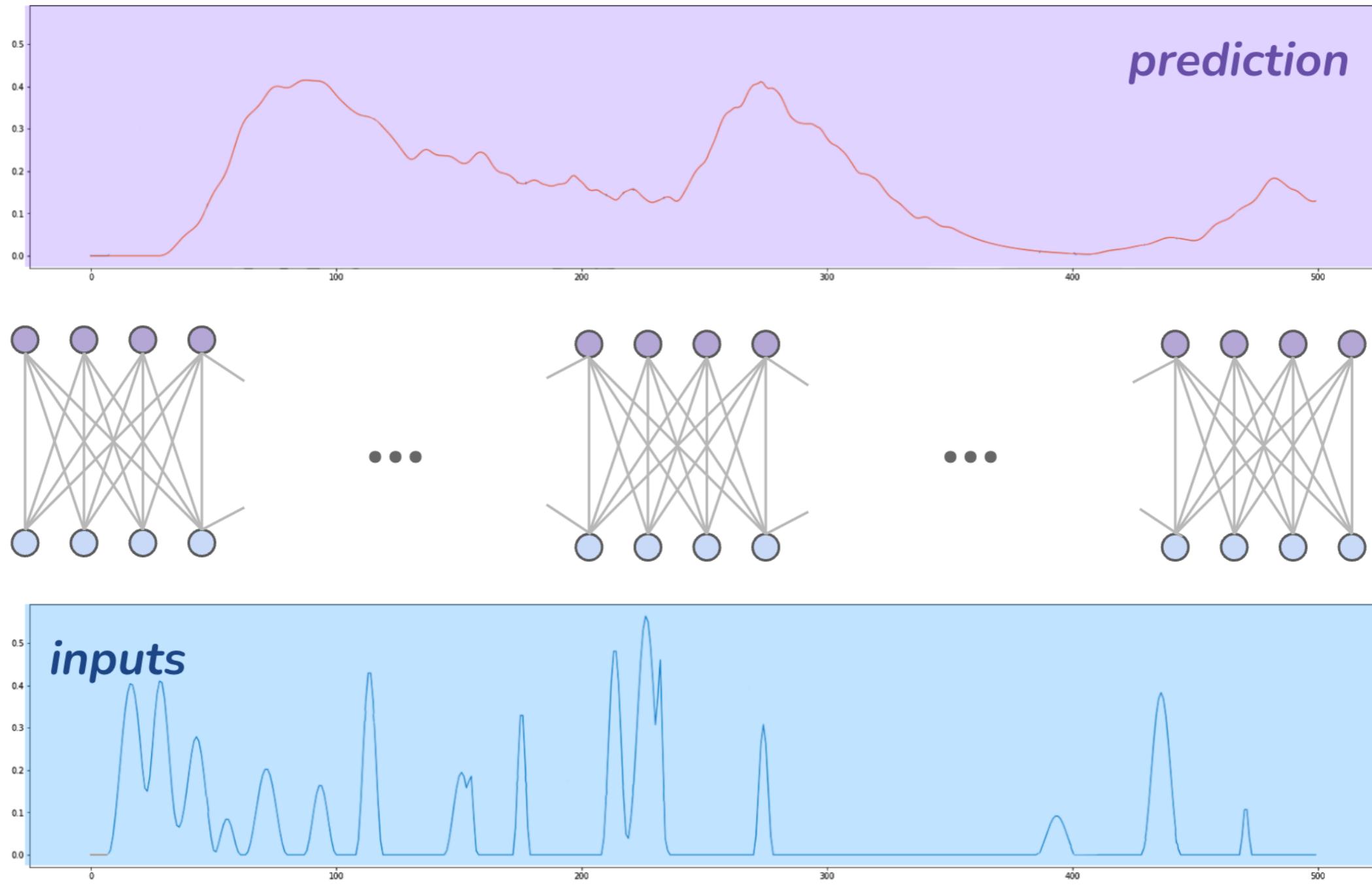
# Time series prediction with neural networks



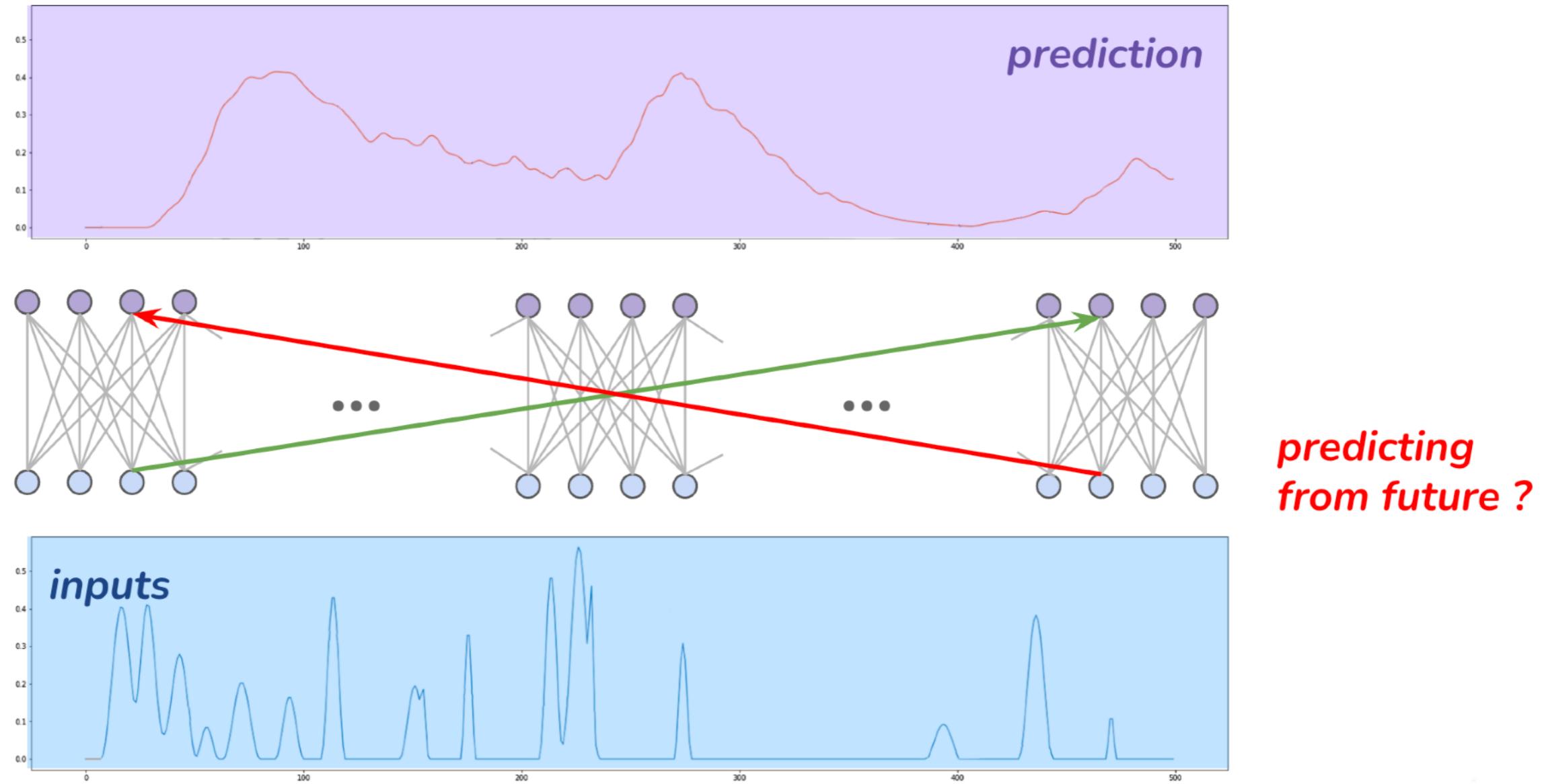
# Time series prediction with neural networks



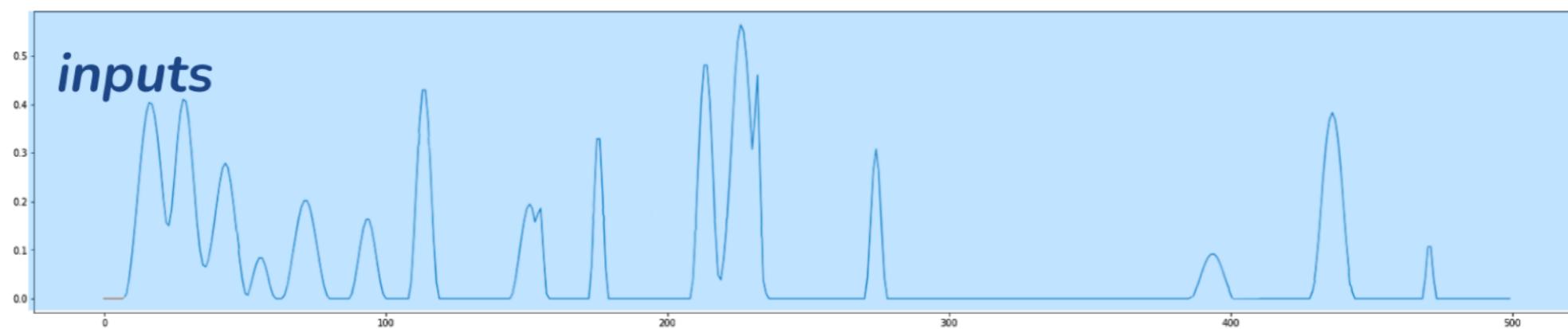
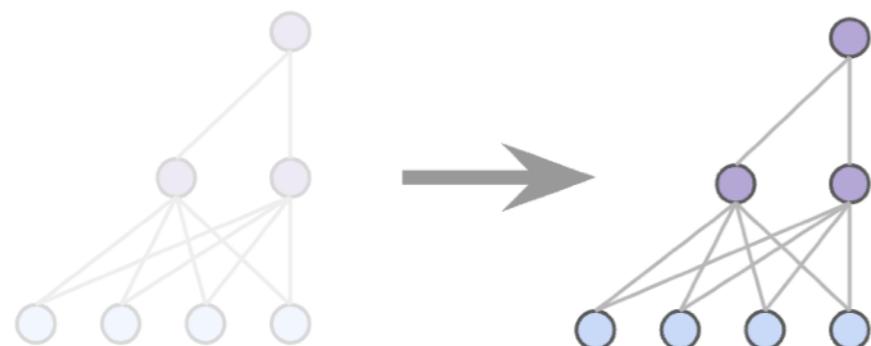
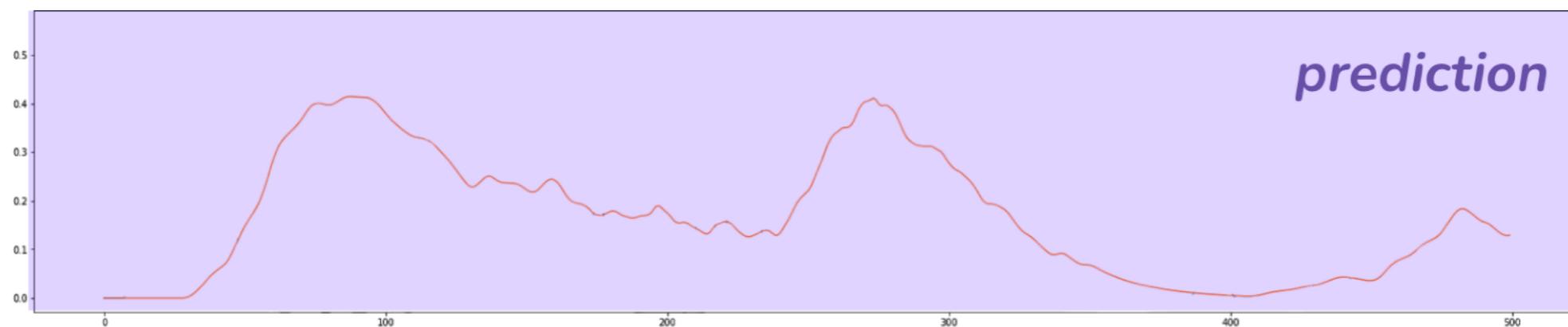
# Simple feed-forward network



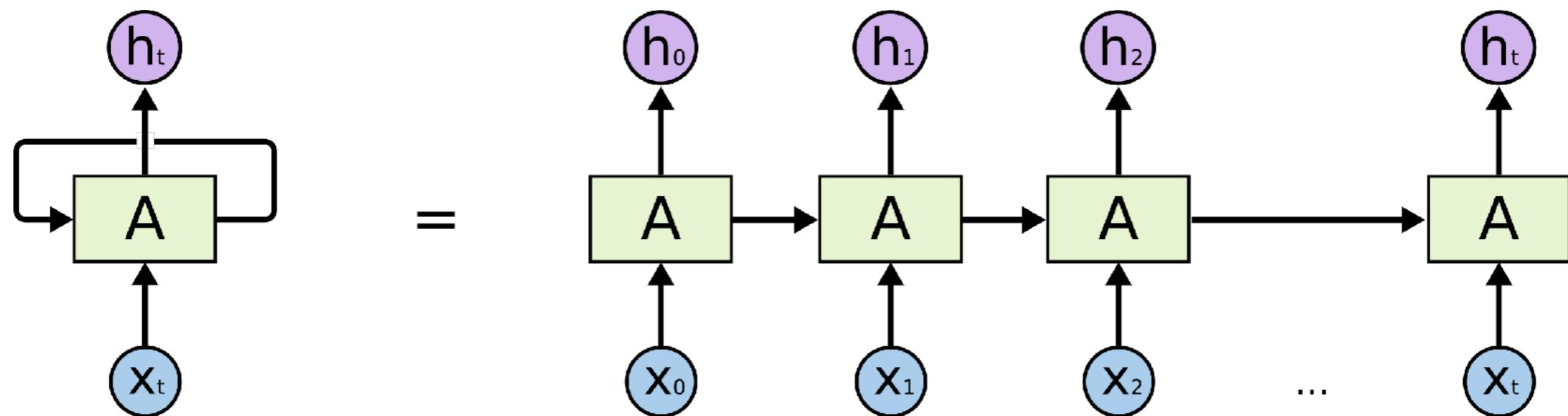
# Simple feed-forward network



# Sliding feed-forward network

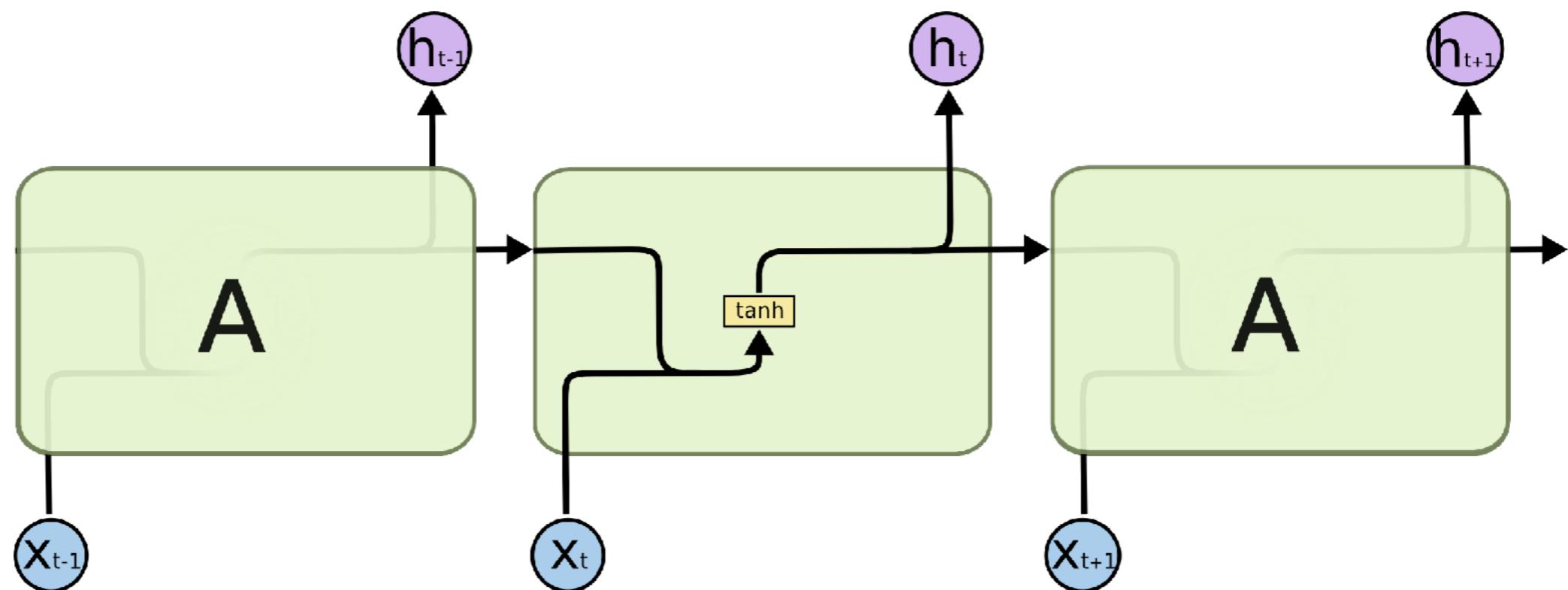


# Recurrent Neural networks

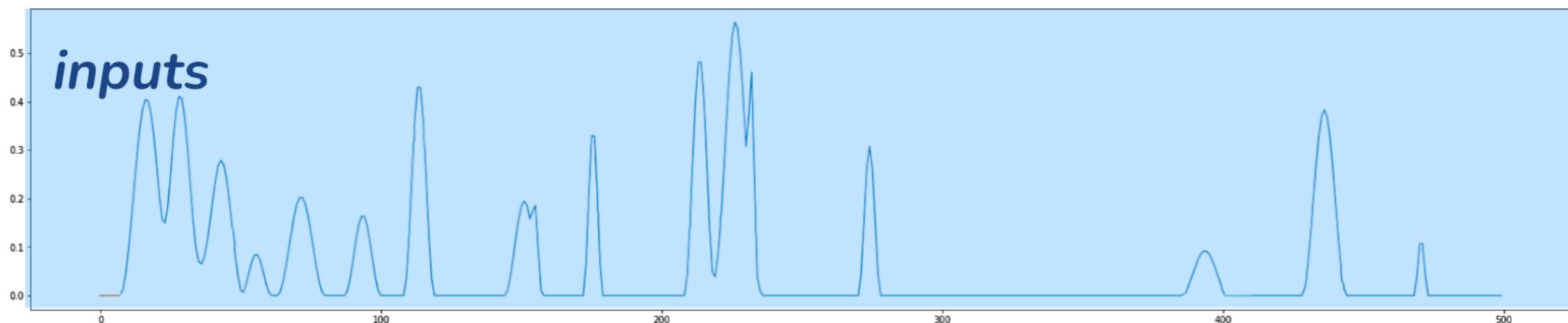
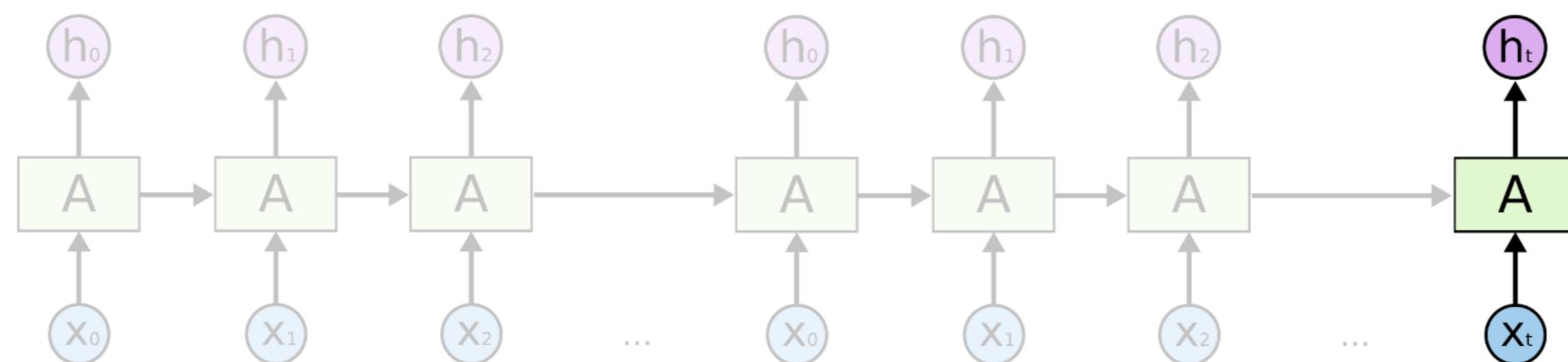


source: <http://colah.github.io/posts/2015-08-Understanding-LSTMs/>

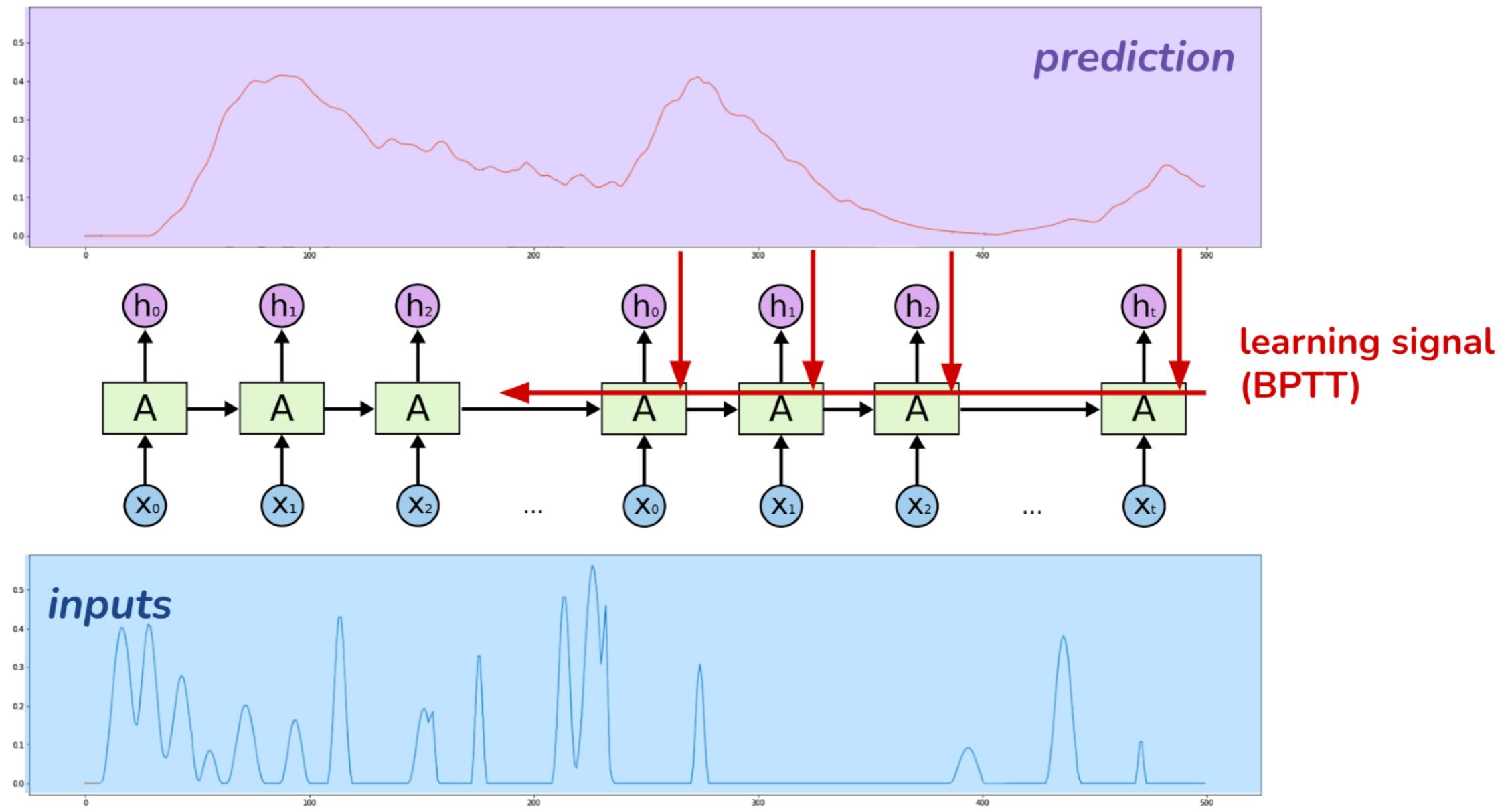
# Recurrent Neural Networks



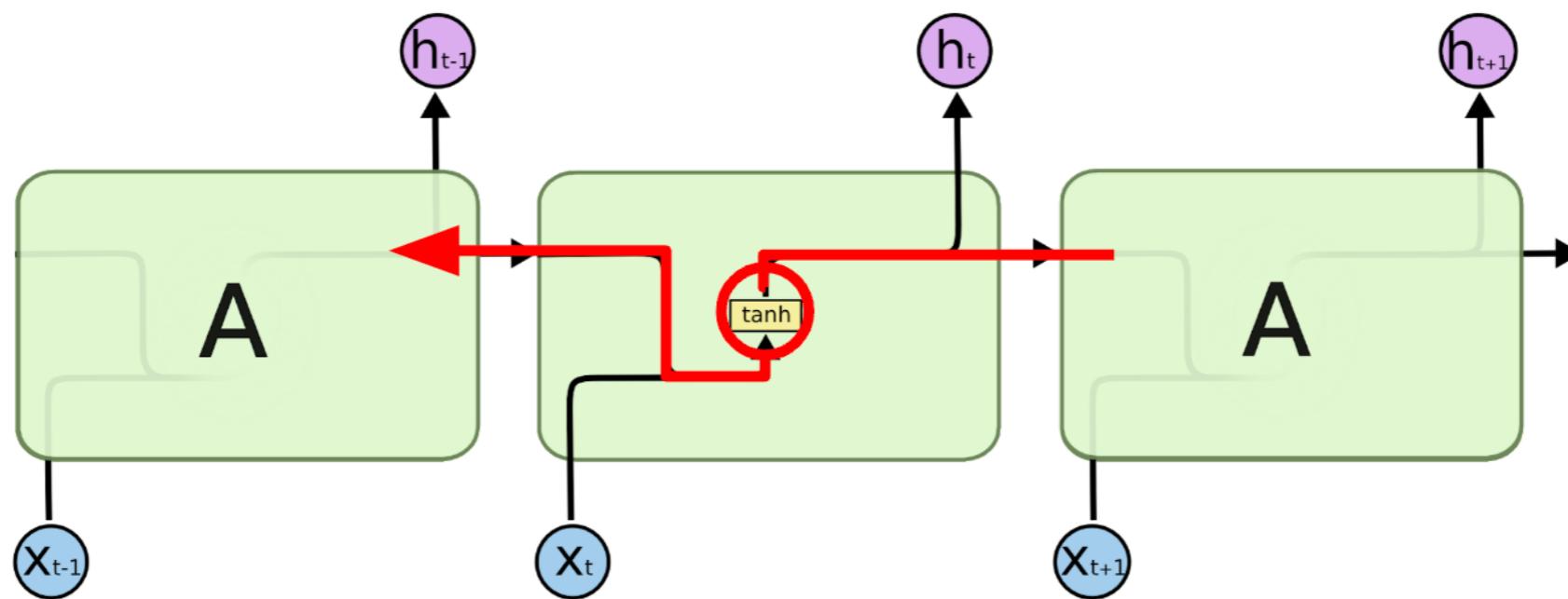
# Recurrent Neural Networks



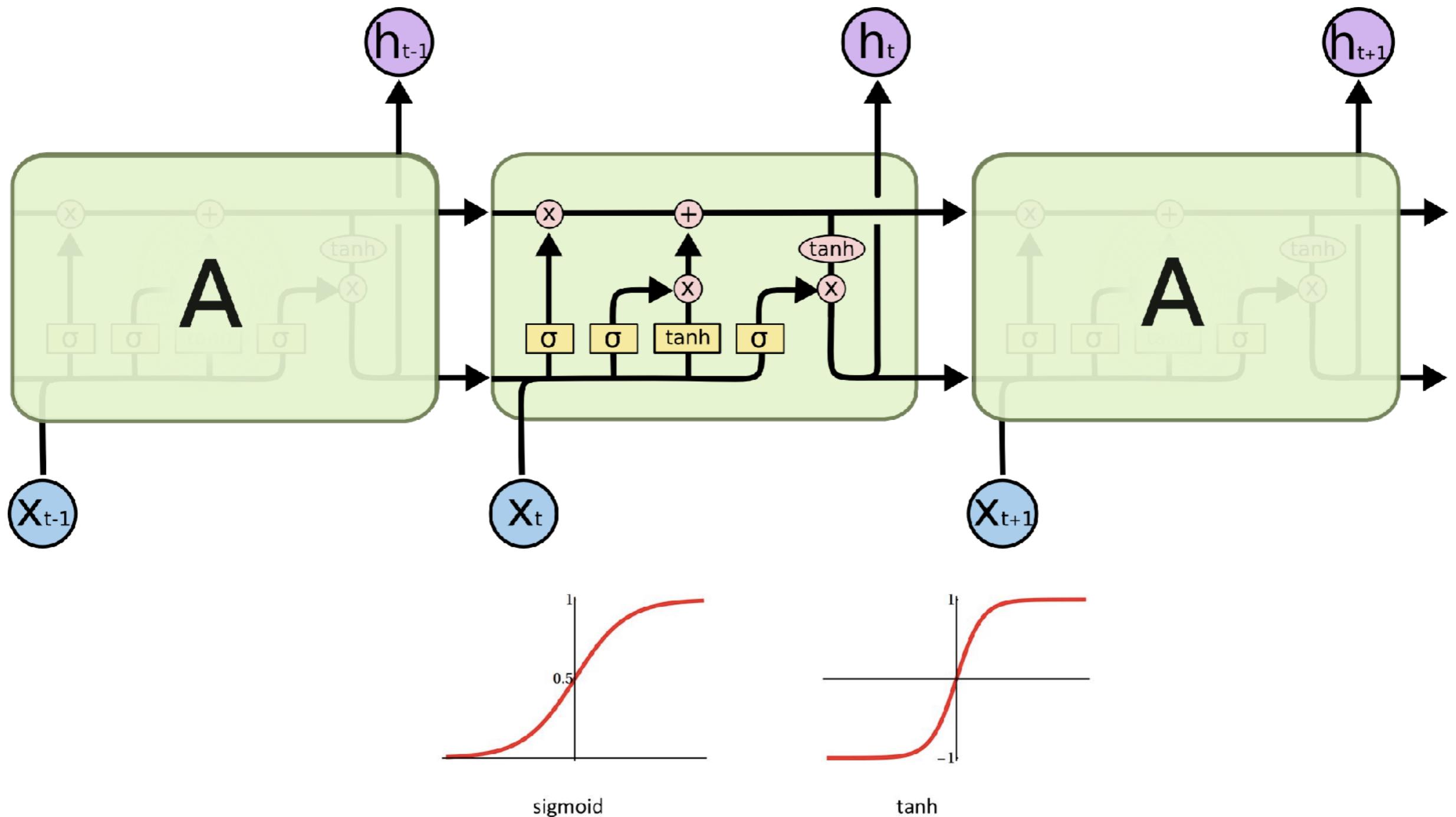
# Backpropagation Through Time



# Vanishing gradients

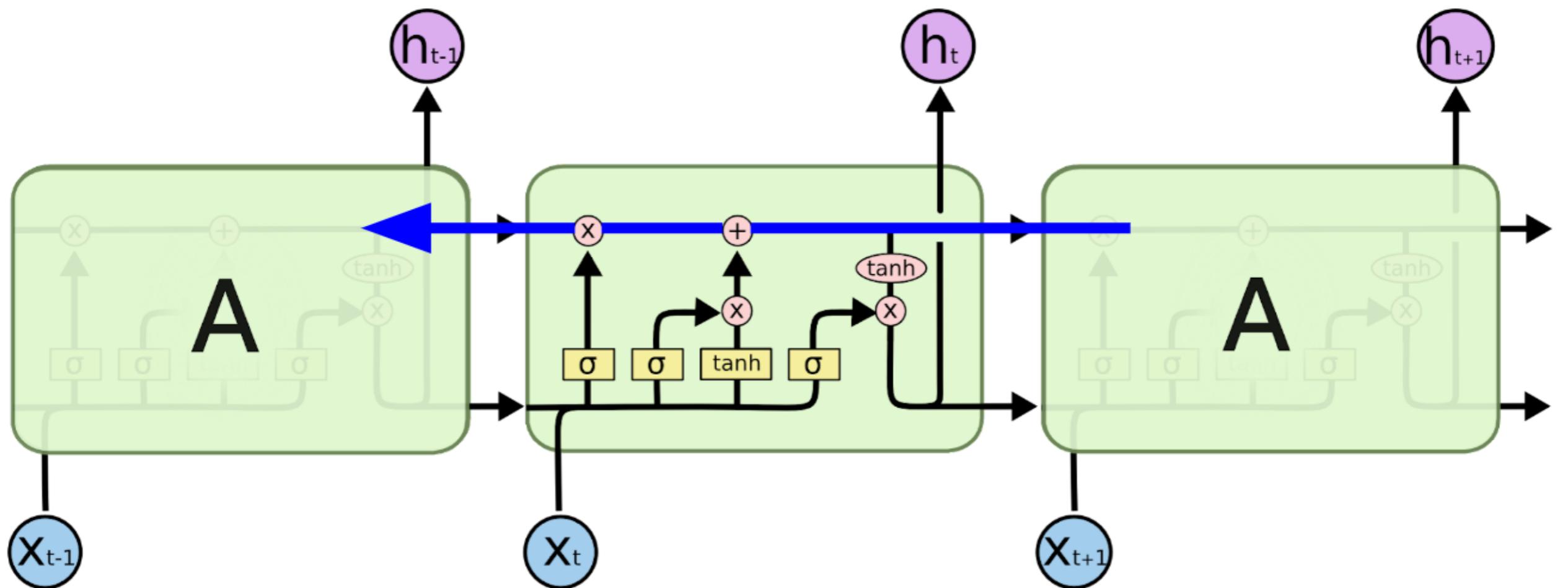


# Long Short-Term Memory

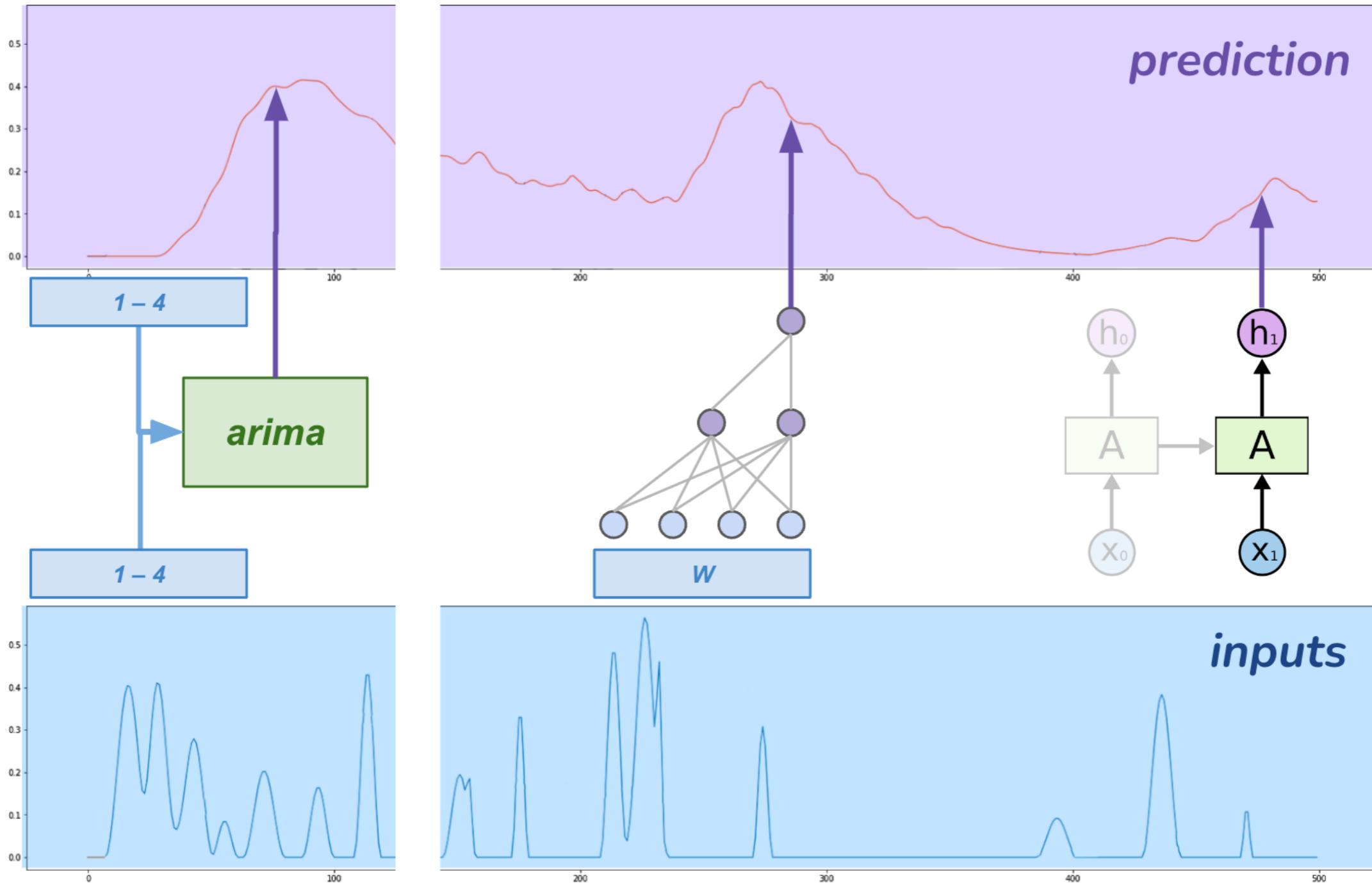


Zdroj: <http://colah.github.io/posts/2015-08-Understanding-LSTMs/>

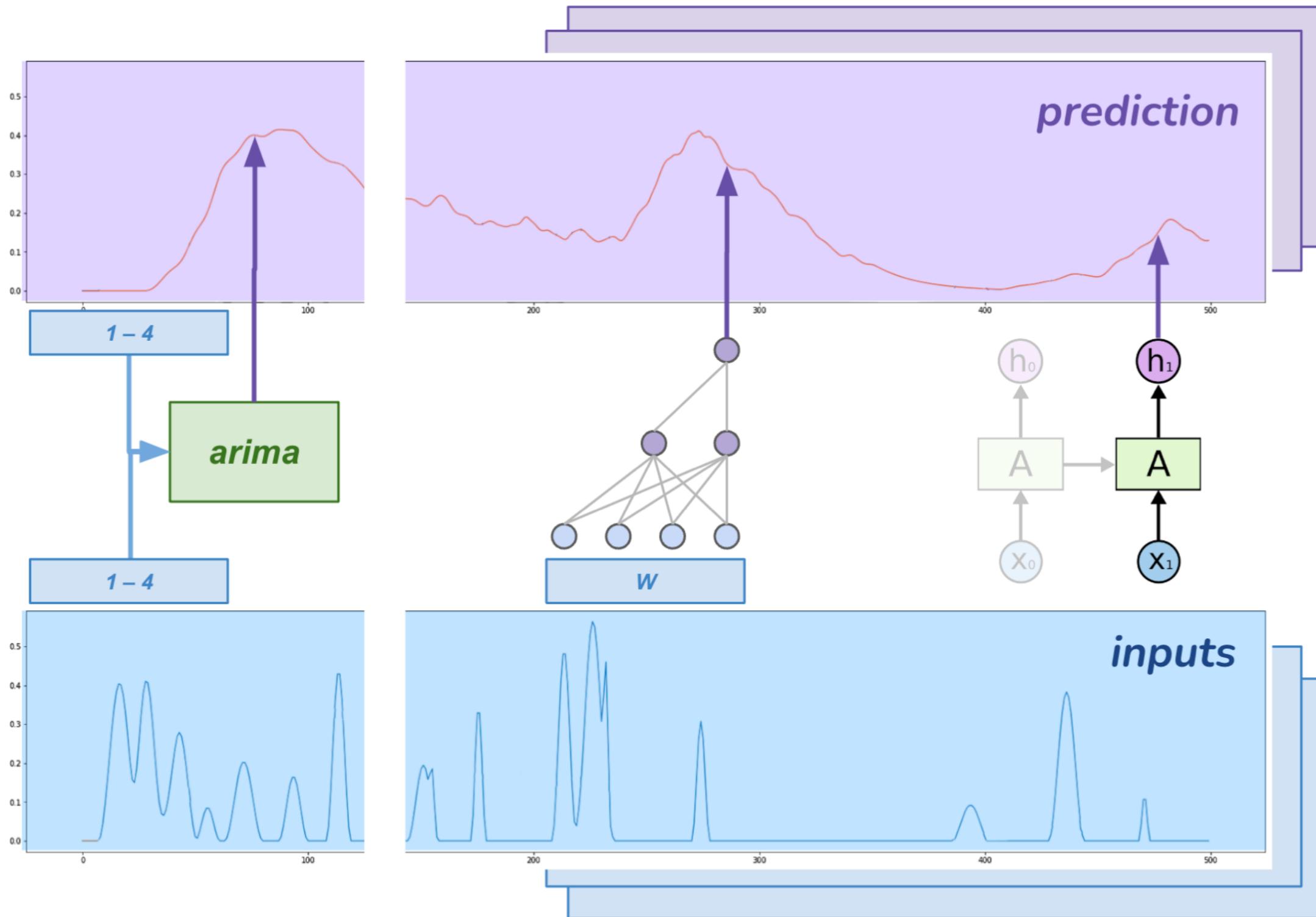
# Long Short-Term Memory



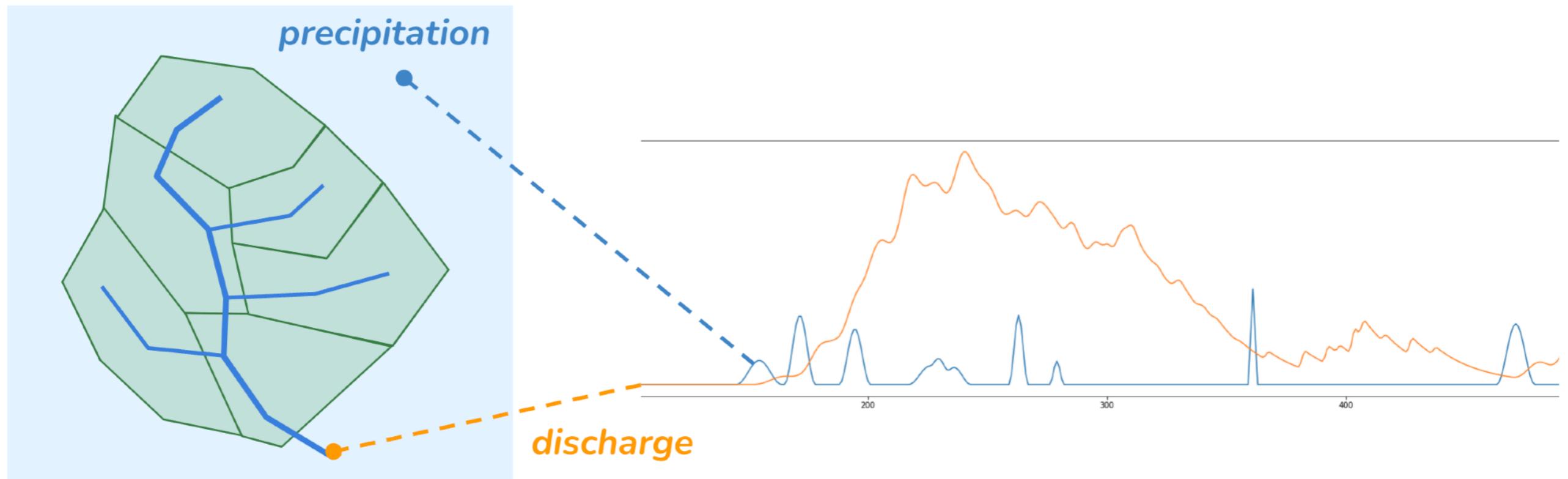
# Classical vs. neural network model



# Classical vs. neural network model

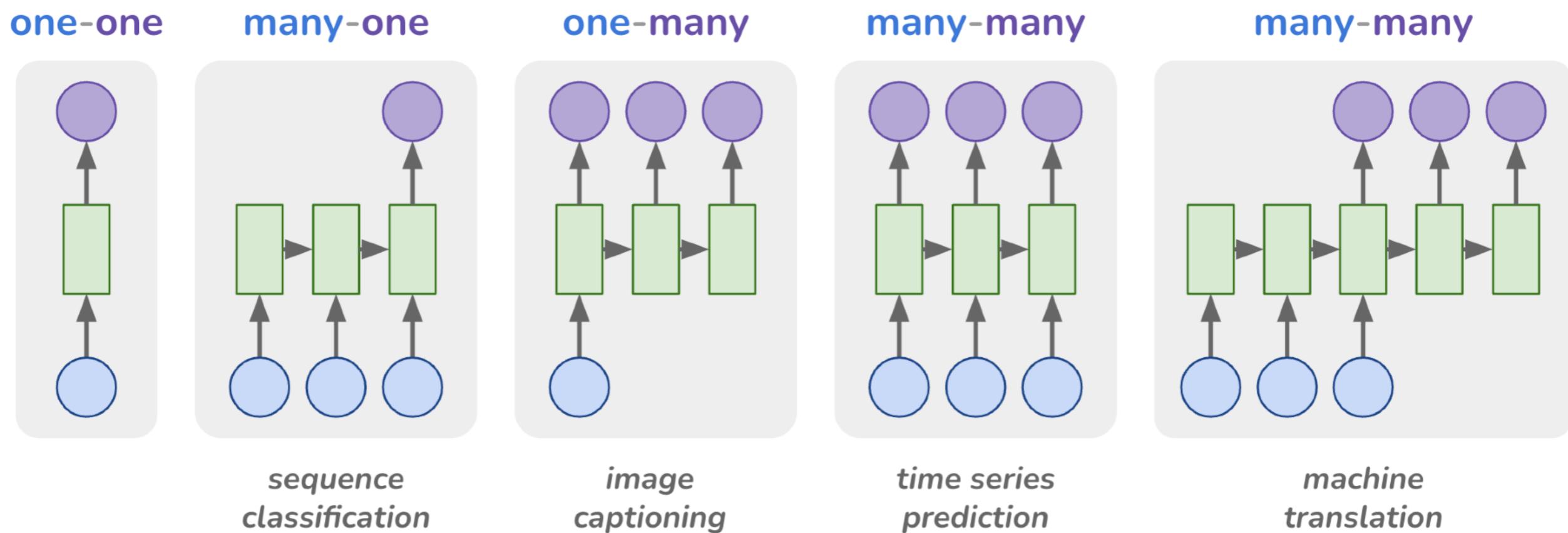


# Rainfall runoff example

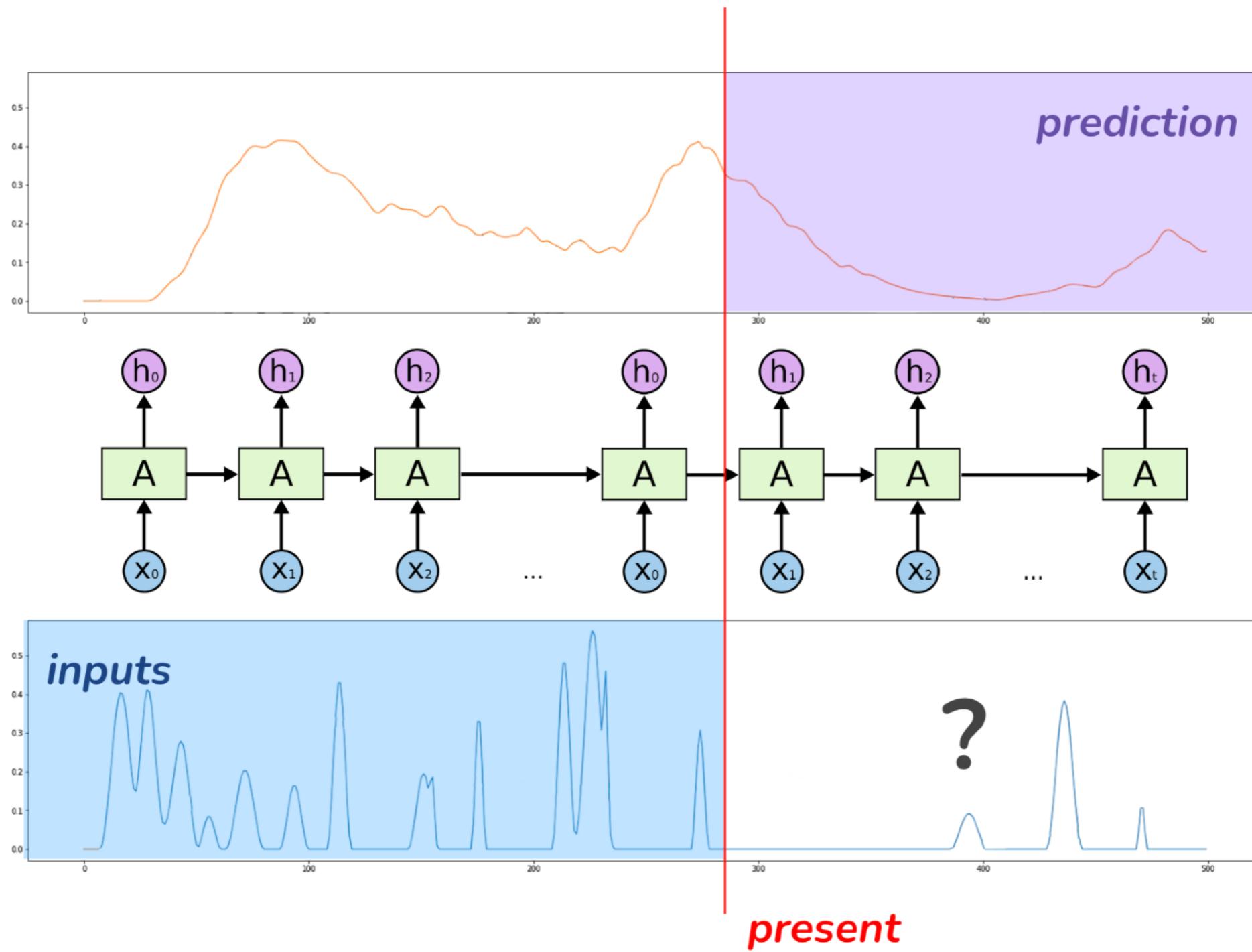


[03-rainfall runoff tutorial.ipynb](#)

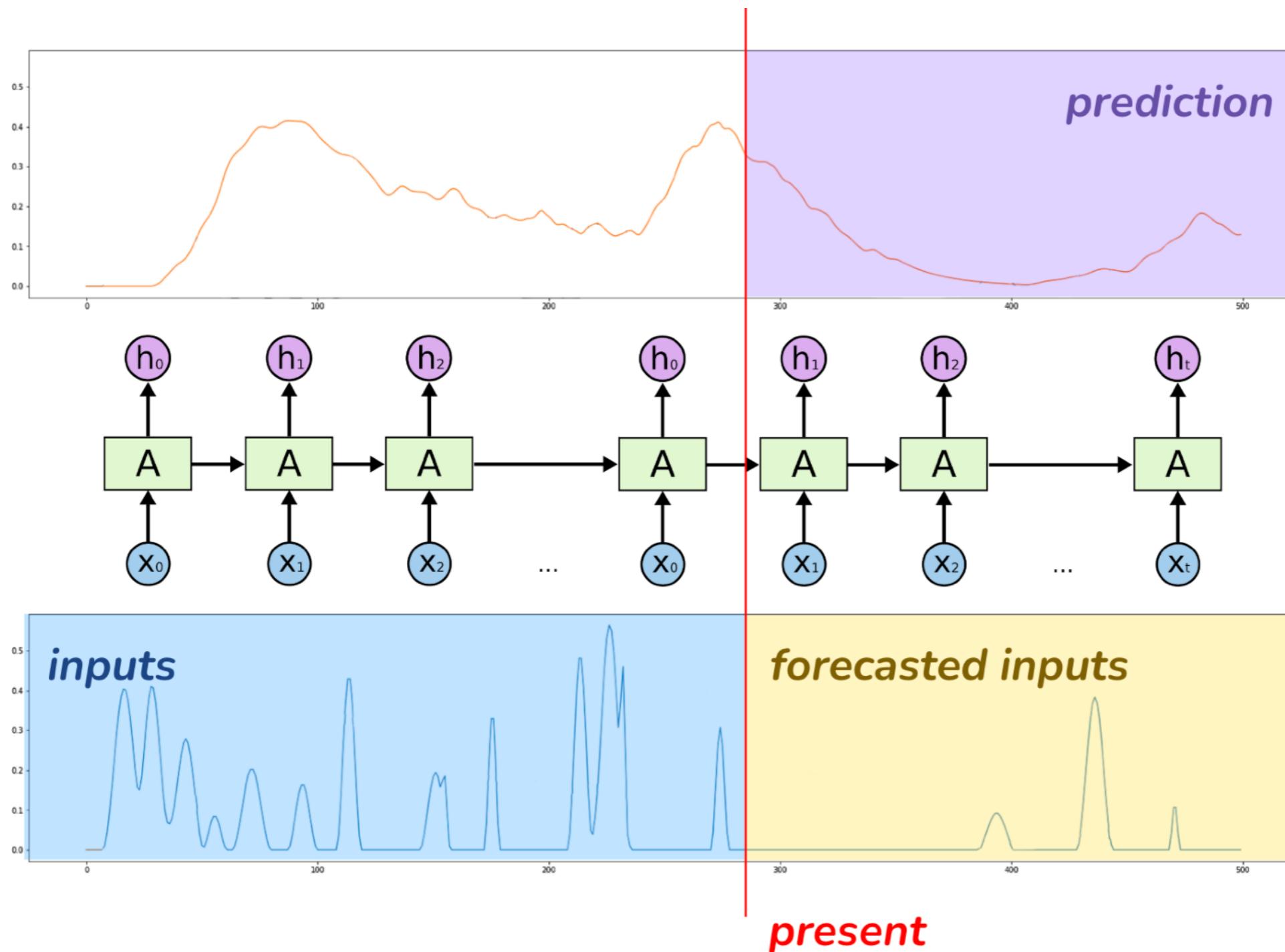
# Sequence data processing



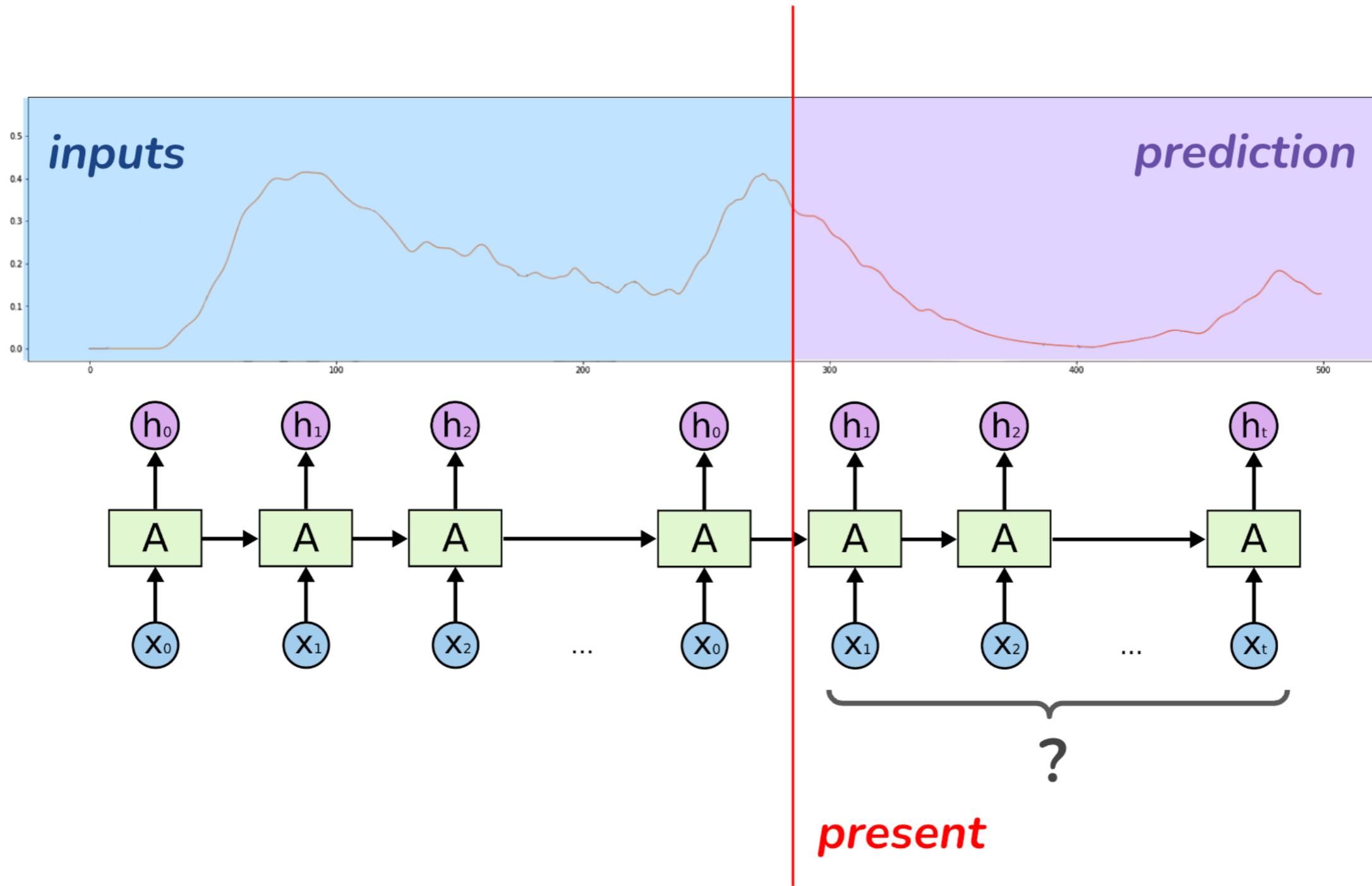
# Forecasting from input variables



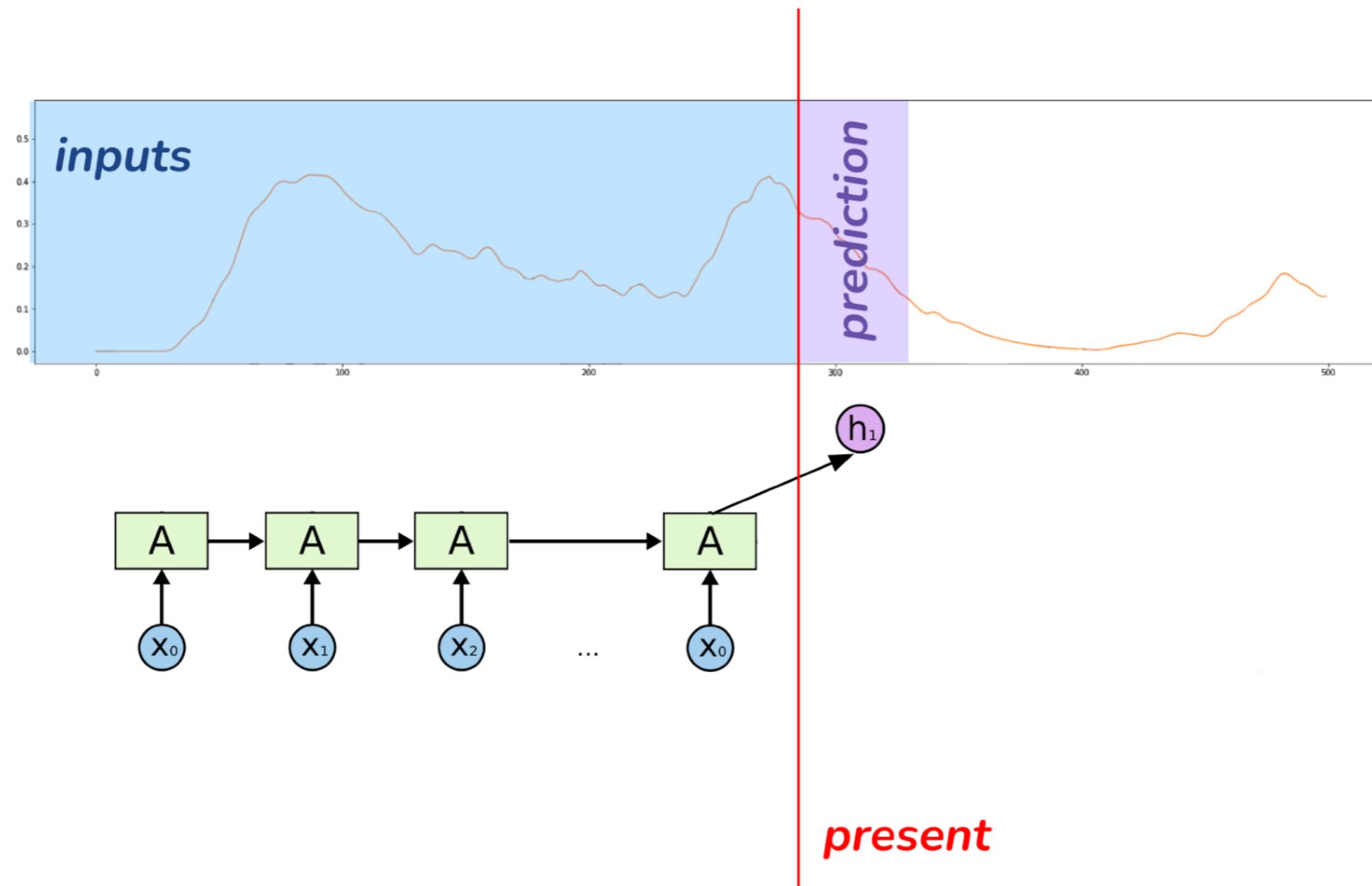
# Forecasting from input variables



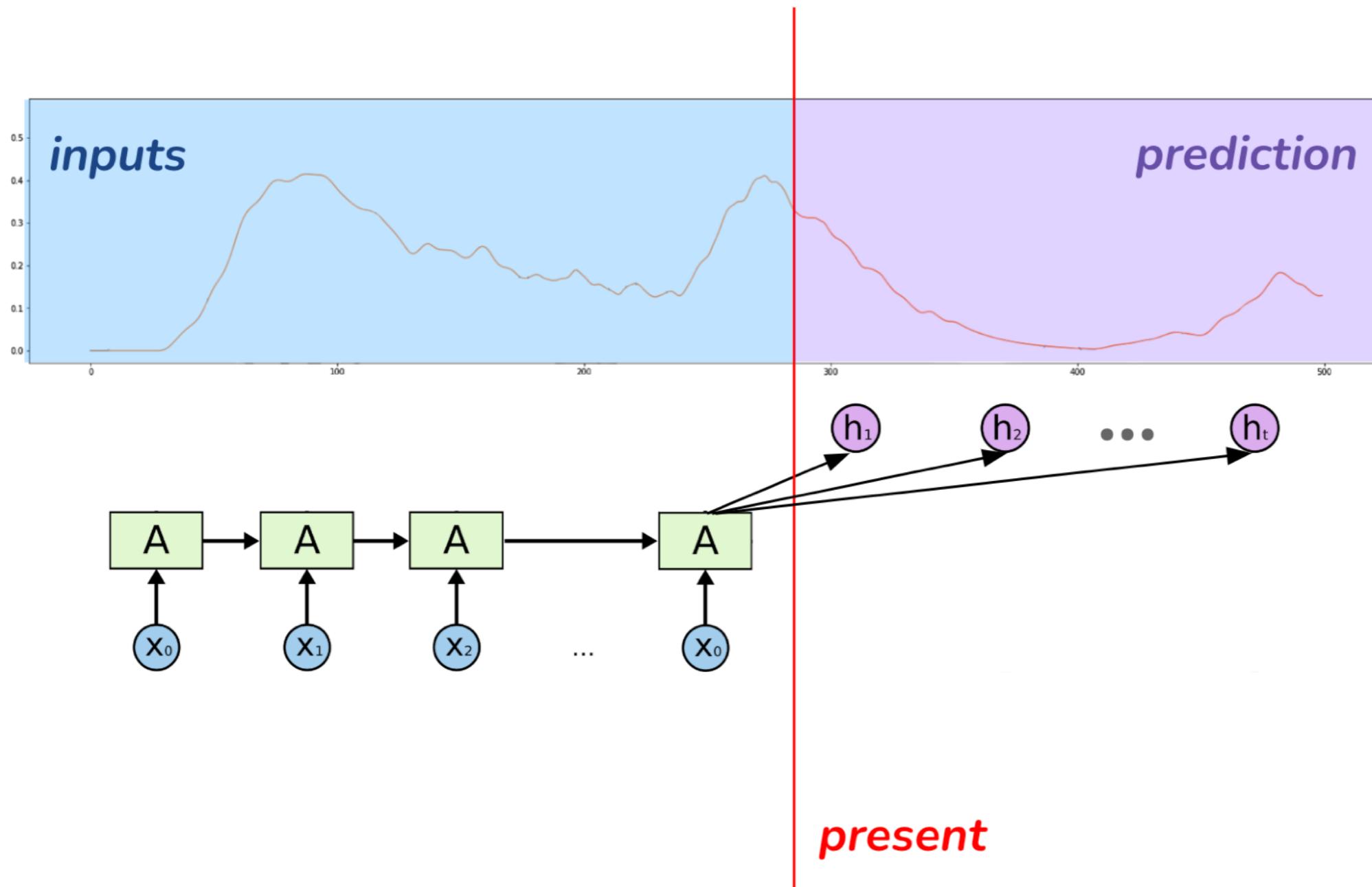
# Forecasting historical values



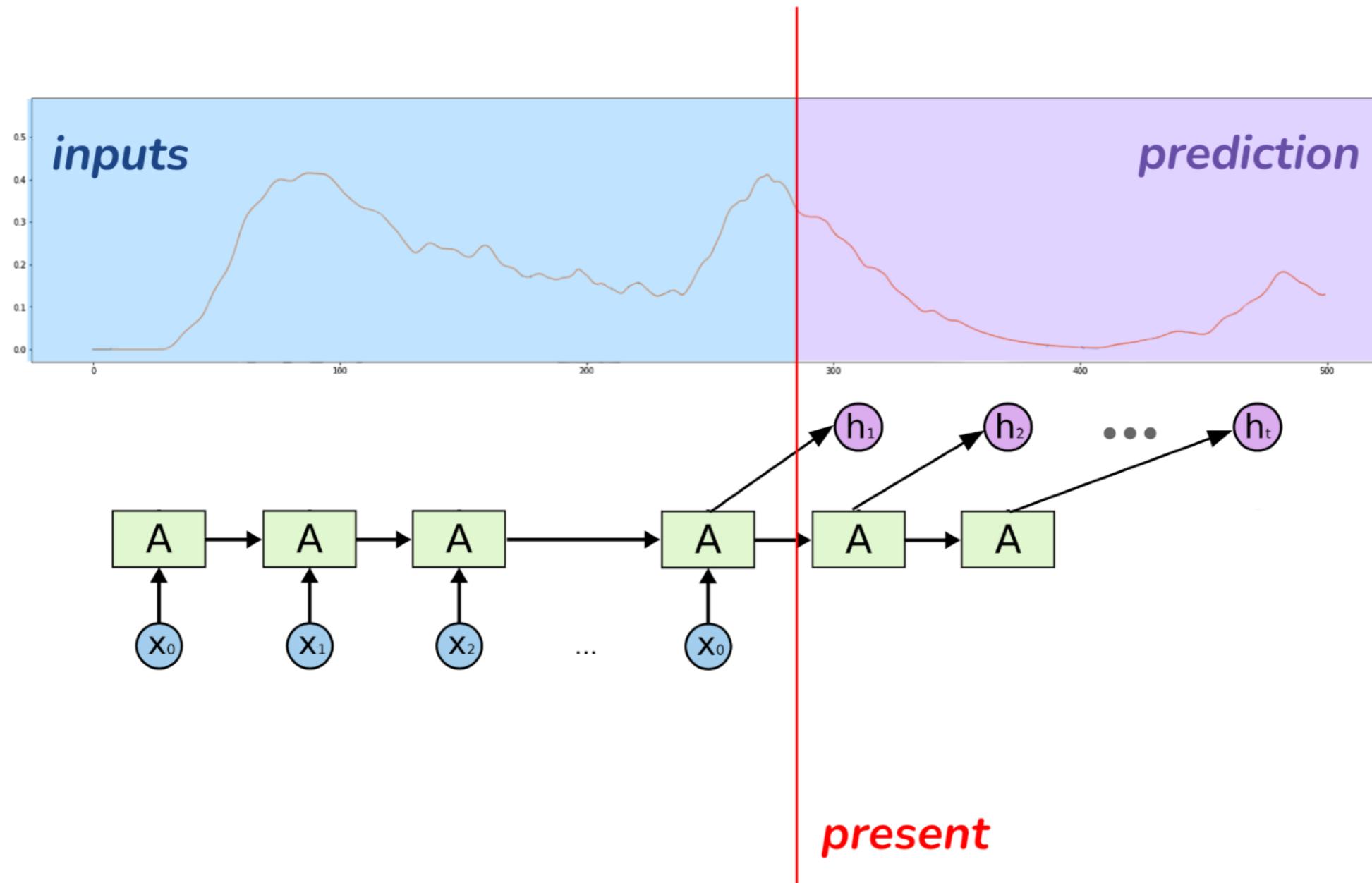
# Forecasting - one step ahead



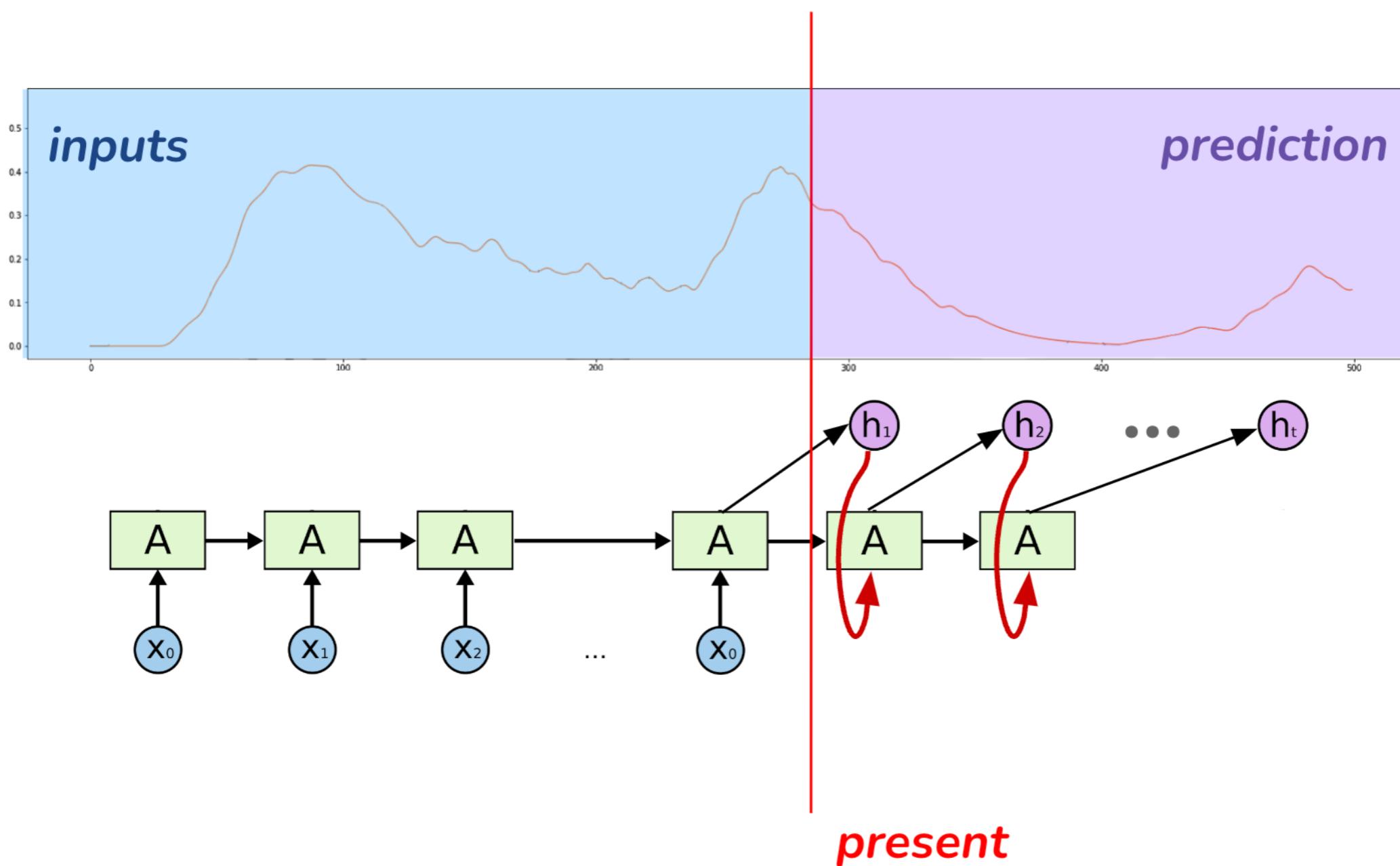
# Forecasting - flat multi-step prediction



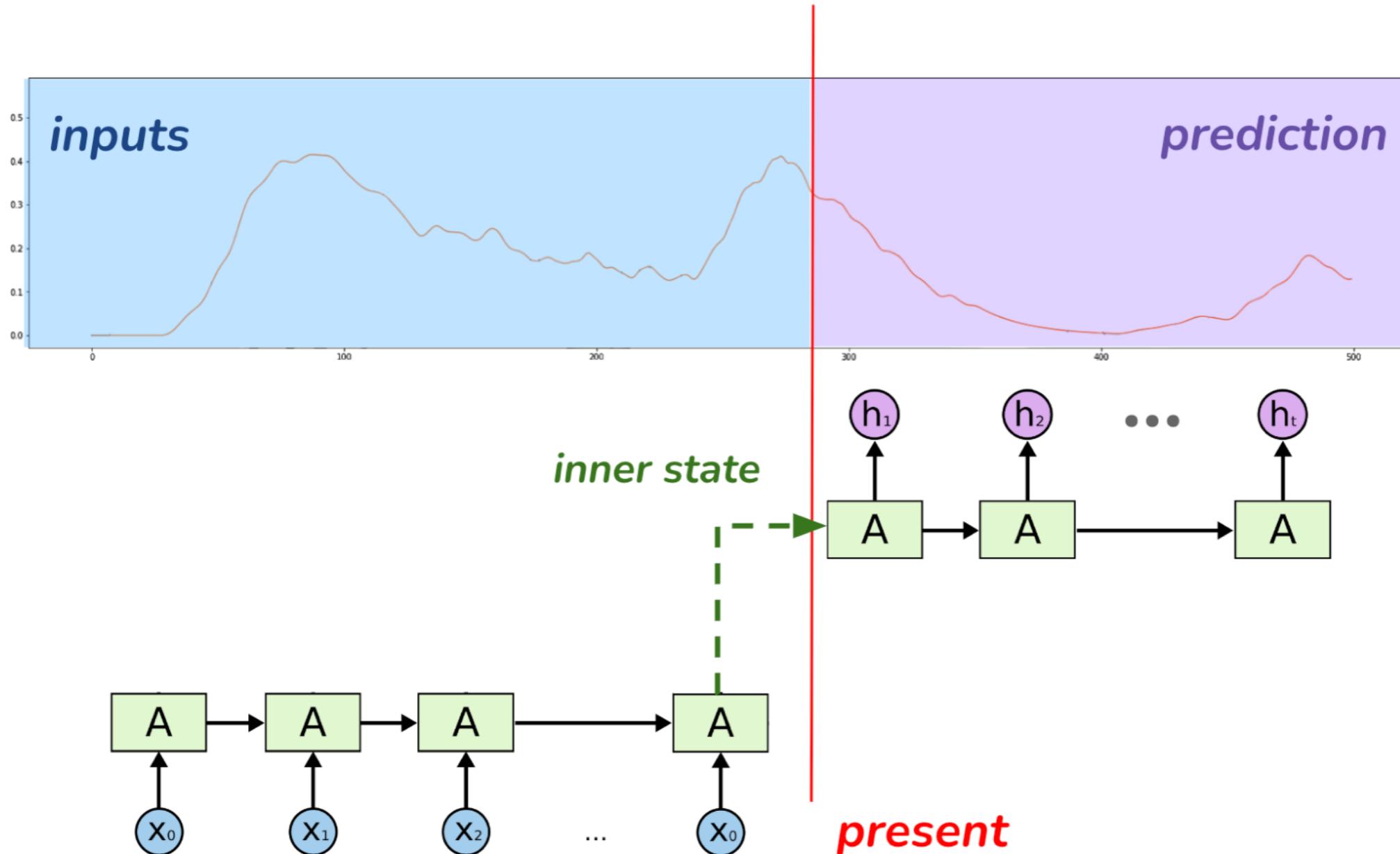
# Forecasting - developed multi-step prediction



# Forecasting - developed multi-step prediction



# Forecasting - encoder & decoder

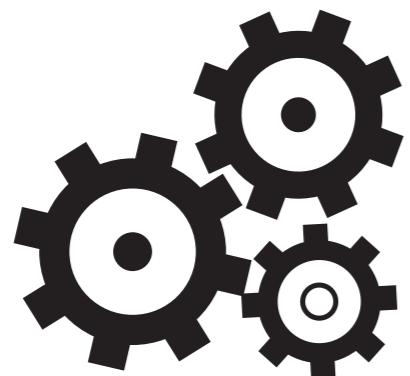


# Heating plants

[\*\*04-Heating plant assignment.ipynb\*\*](#)

# What next?

**<https://www.mlcollege.com/en/#courses>**



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# Thank you for your attention

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