



VAE-based Replication and Ensemble Methods for Enhanced Time Series Prediction

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1. Abstract

Motivation

- Because time series data often have trend and seasonal components, a large amount of data is required for effective analysis.
- However, time series data are difficult to collect due to the high cost and substantial time required, thereby limiting model training and reducing predictive performance.

Approach

- This study develops a variational autoencoder with a latent space that incorporates seasonal patterns.
- The proposed method produces replication/reconstruction time series data that well capture the seasonal patterns of the original time series data.
- Additionally, this study provides predictive modeling using the replication/reconstruction time series data to examine the effectiveness of the proposed method.

2. Application

2-1. Data

- North Extent & South Extent
 - Sea ice extent data from Arctic and Antarctic between 1989-01-01 and 2024-09-07.
(Source : National Snow & Ice Data Center)
- Nitric Dioxide (NO2) & Particulate Matter 2.5-micrometer (PM2.5)
 - NO2 and PM2.5 concentrations in Delhi of India between 2015-01-01 01:00 and 2020-07-01 00:00.
(Source : <https://www.kaggle.com/datasets/rohanrao/air-quality-data-in-india>)

2-2. Replication/Reconstruction

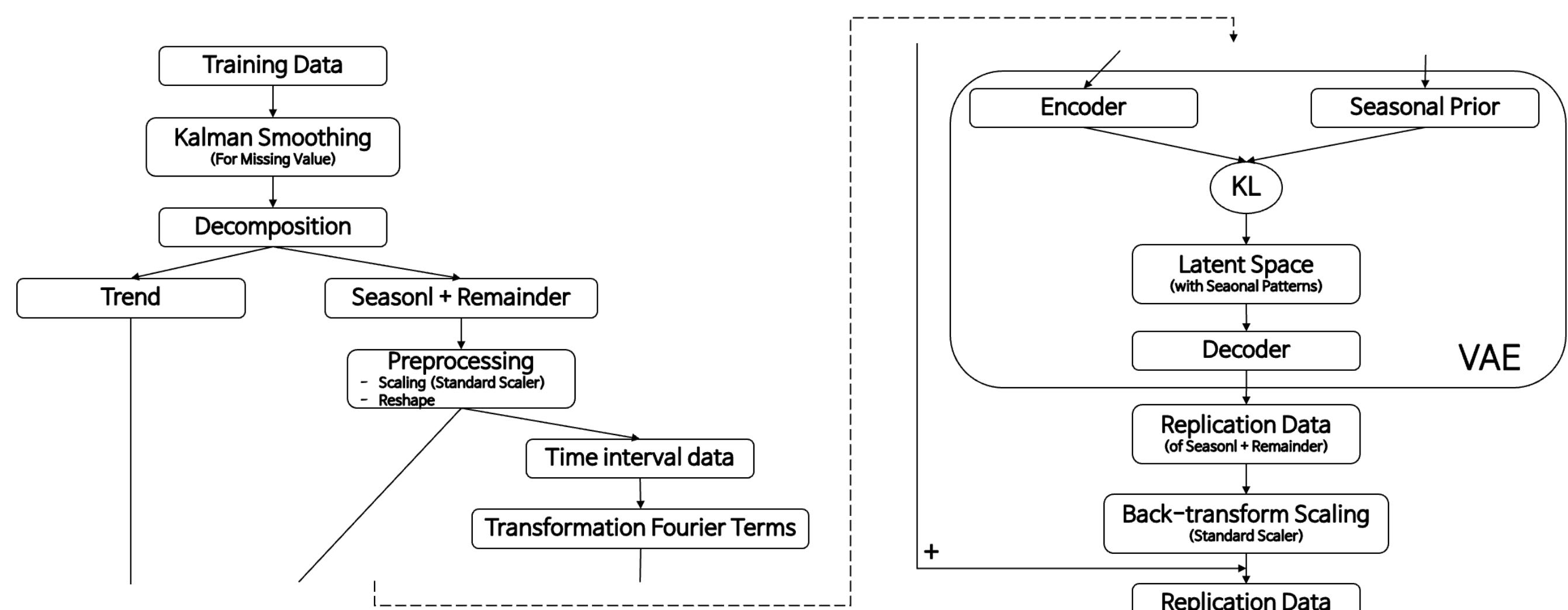
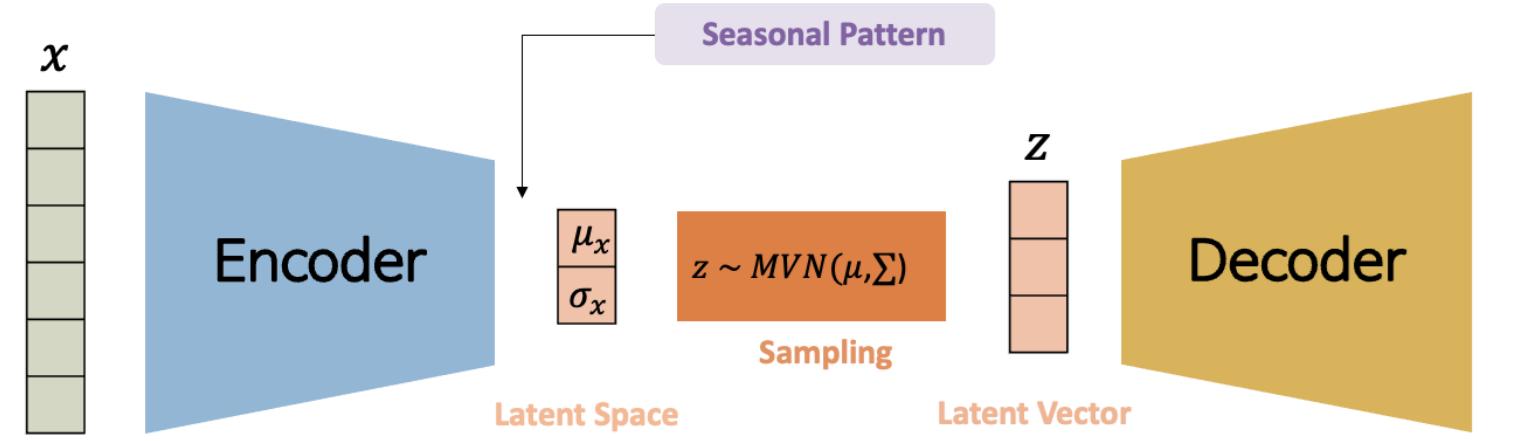


Figure 1. Framework for Replication/Reconstruction

2-3. Variational Autoencoder (VAE)



- Unlike the latent space in a general VAE, this study structures a latent space that incorporates seasonal patterns to produce replication/reconstruction time series data with seasonal patterns of original time series data.

2-4. Replication/Reconstruction Results

2-4-1. North Extent

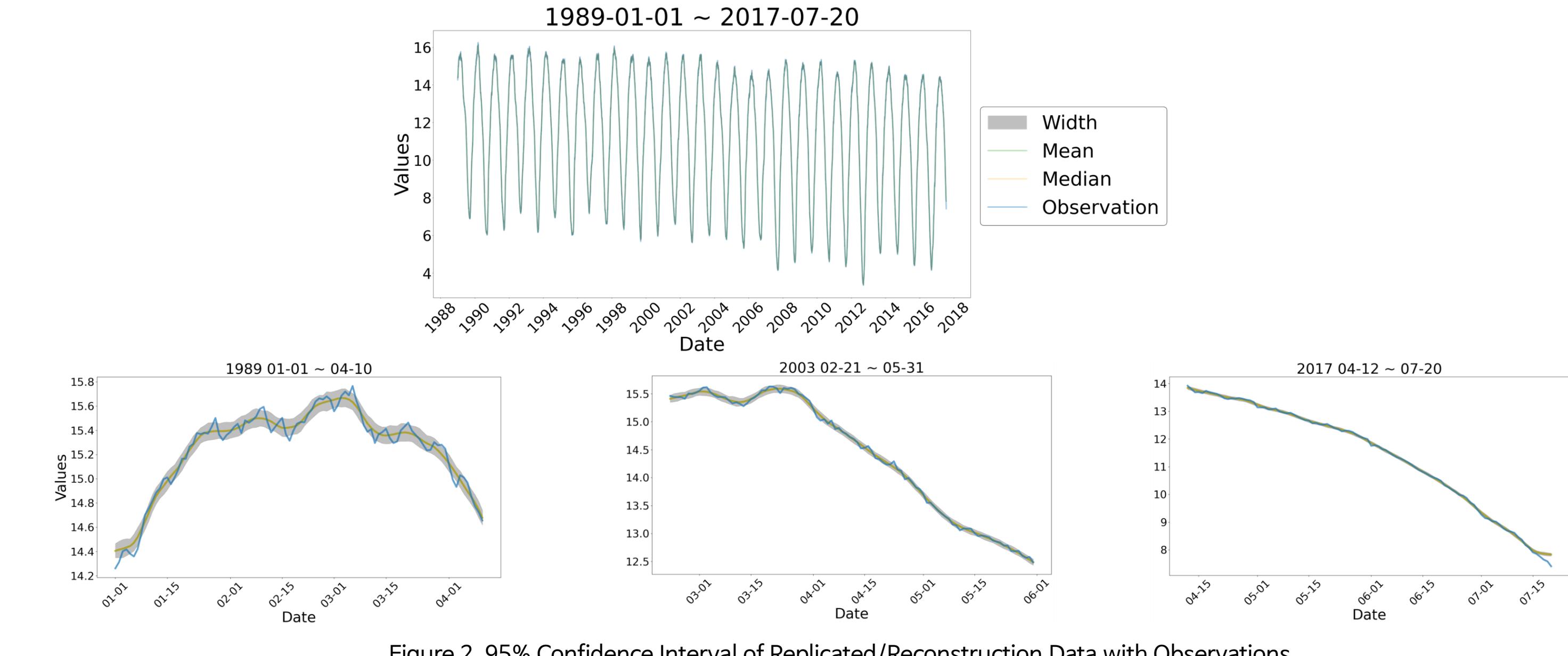


Figure 2. 95% Confidence Interval of Replicated/Reconstruction Data with Observations

2-4-2. NO2

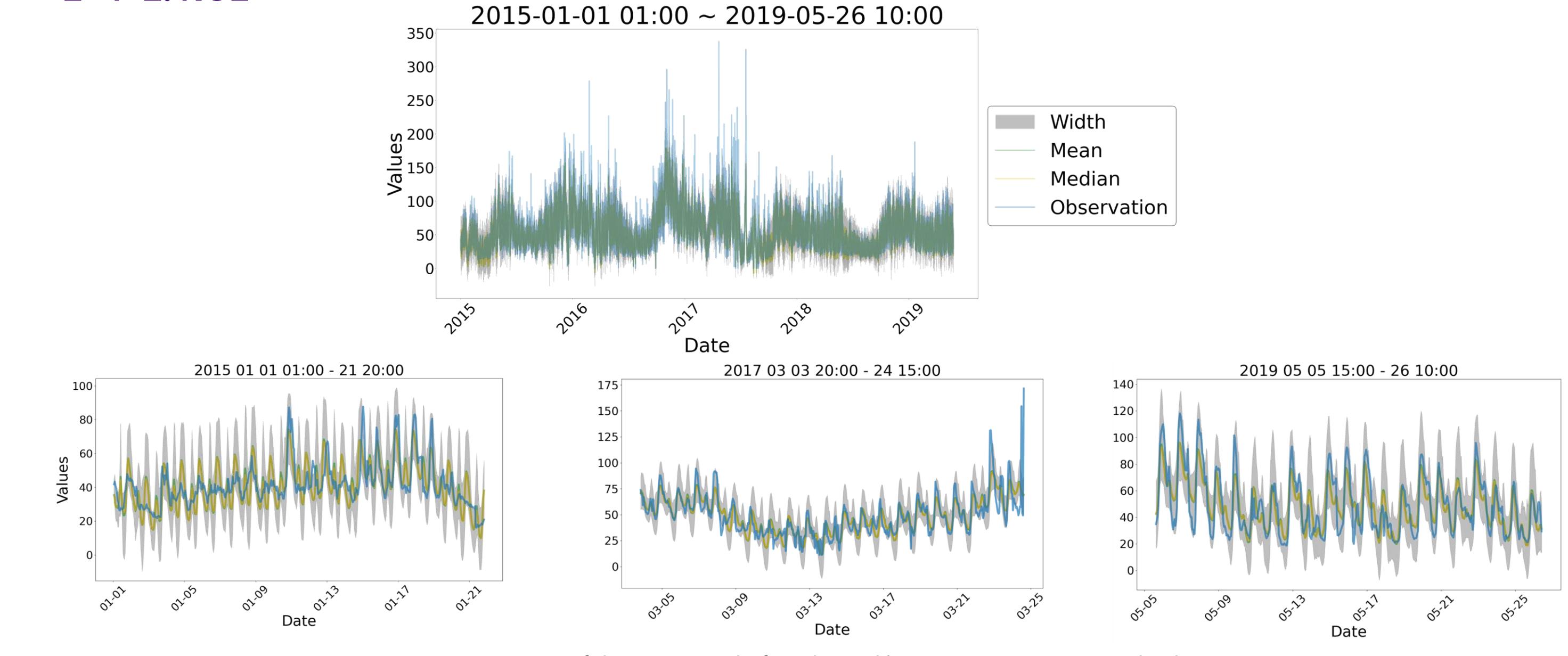


Figure 3. 95% Confidence Interval of Replicated/Reconstruction Data with Observations

2-5. Predictive Modeling

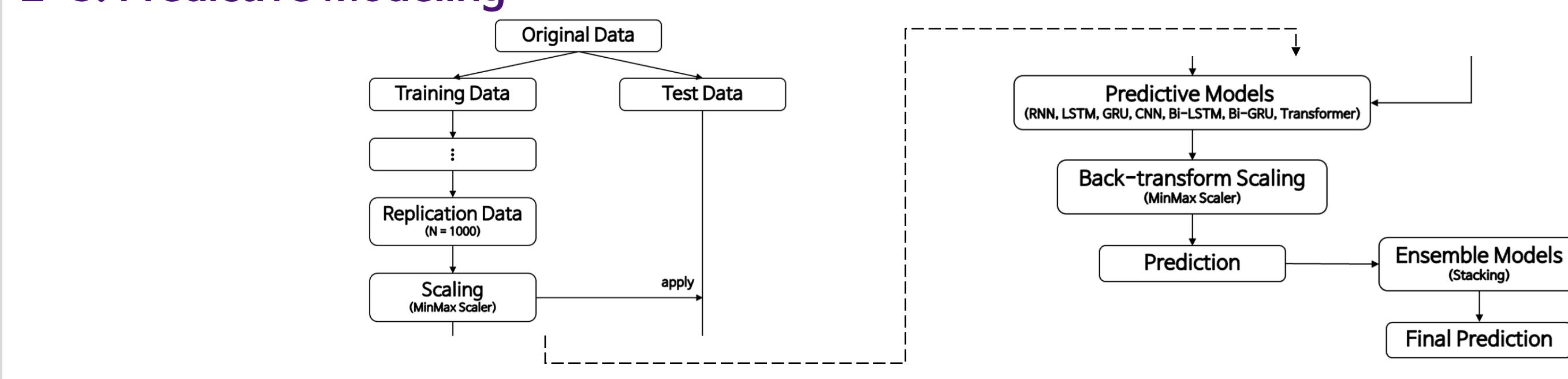
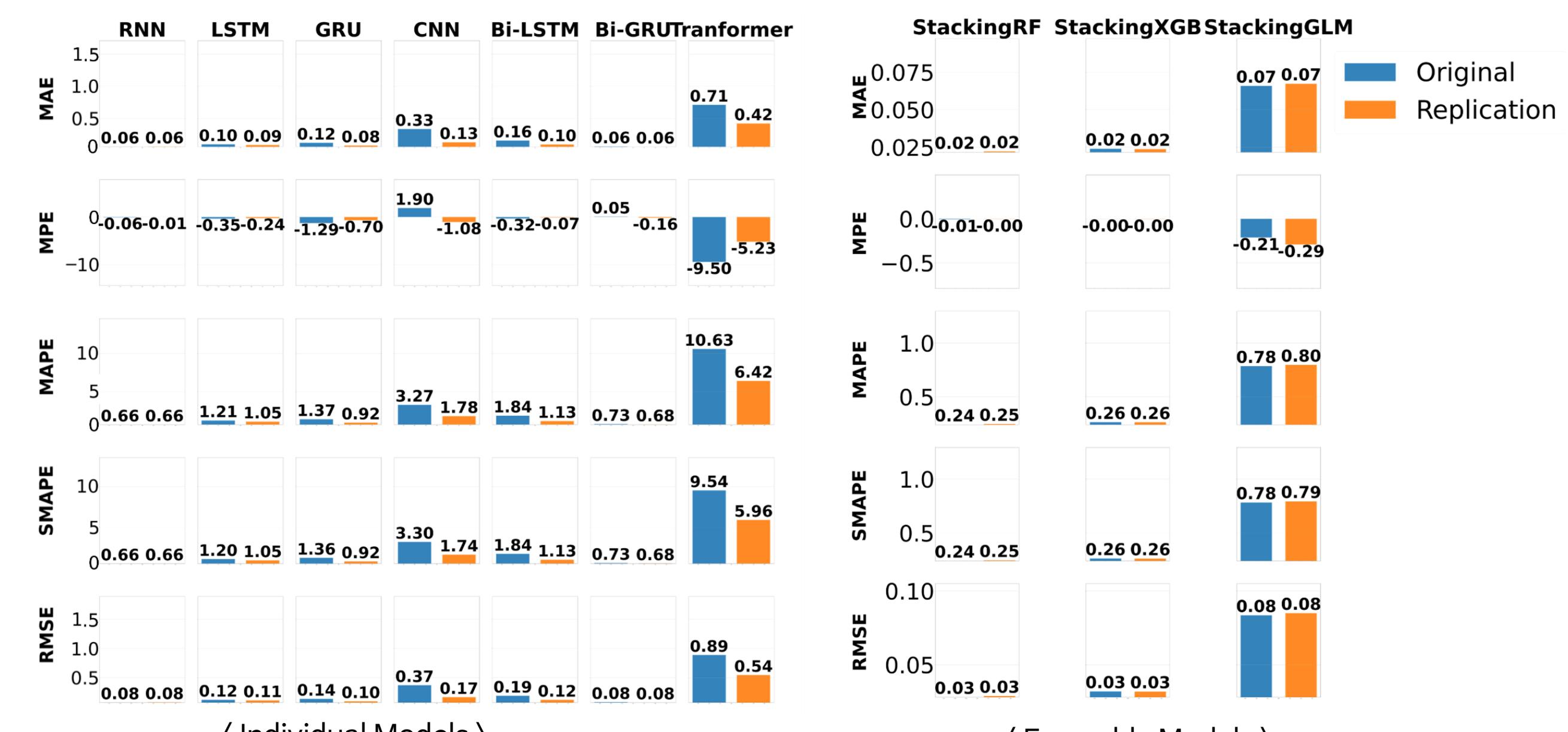


Figure 2. Framework for Predictive Modeling

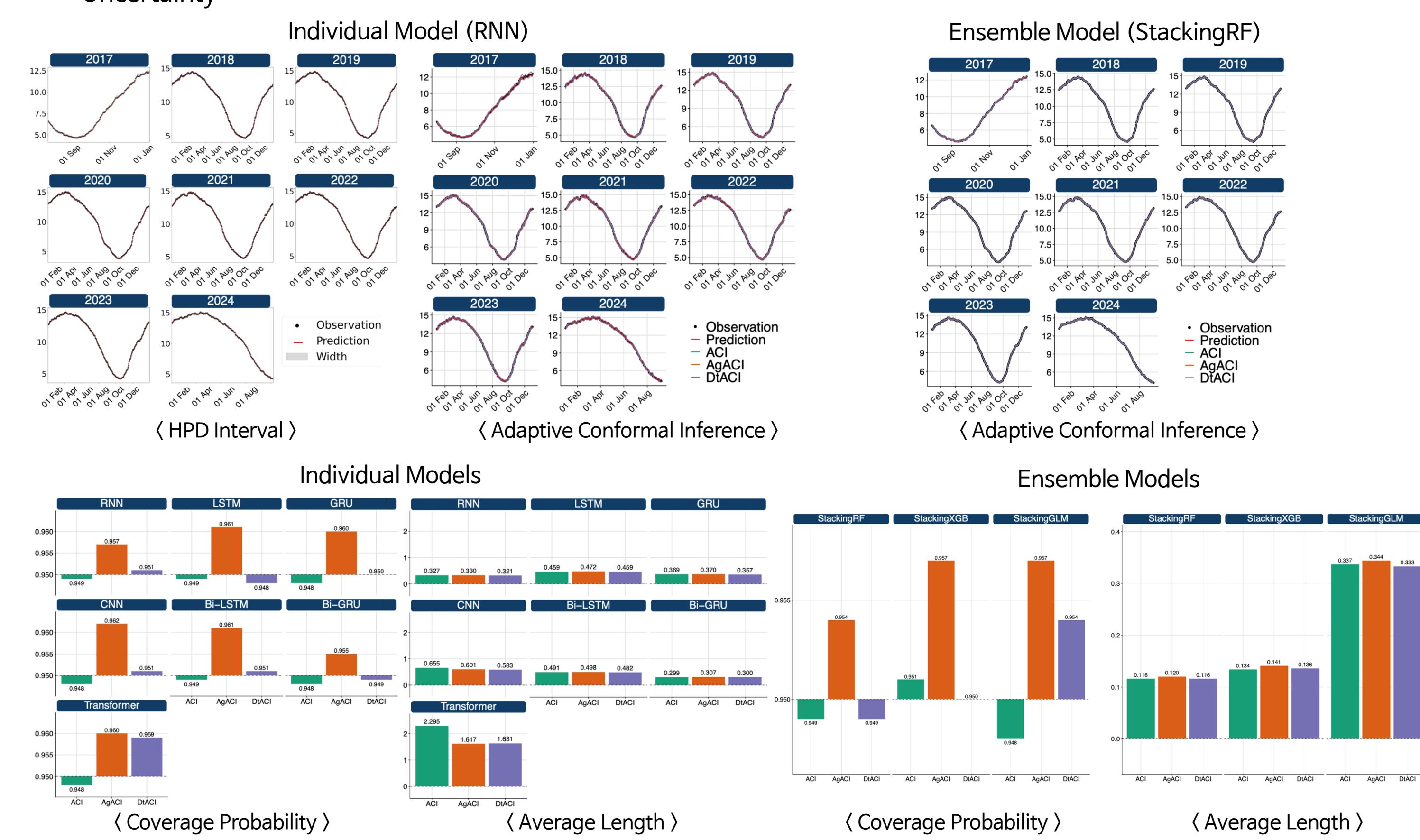
2-6. Predictive Modeling Results

2-6-1. North Extent

Evaluation

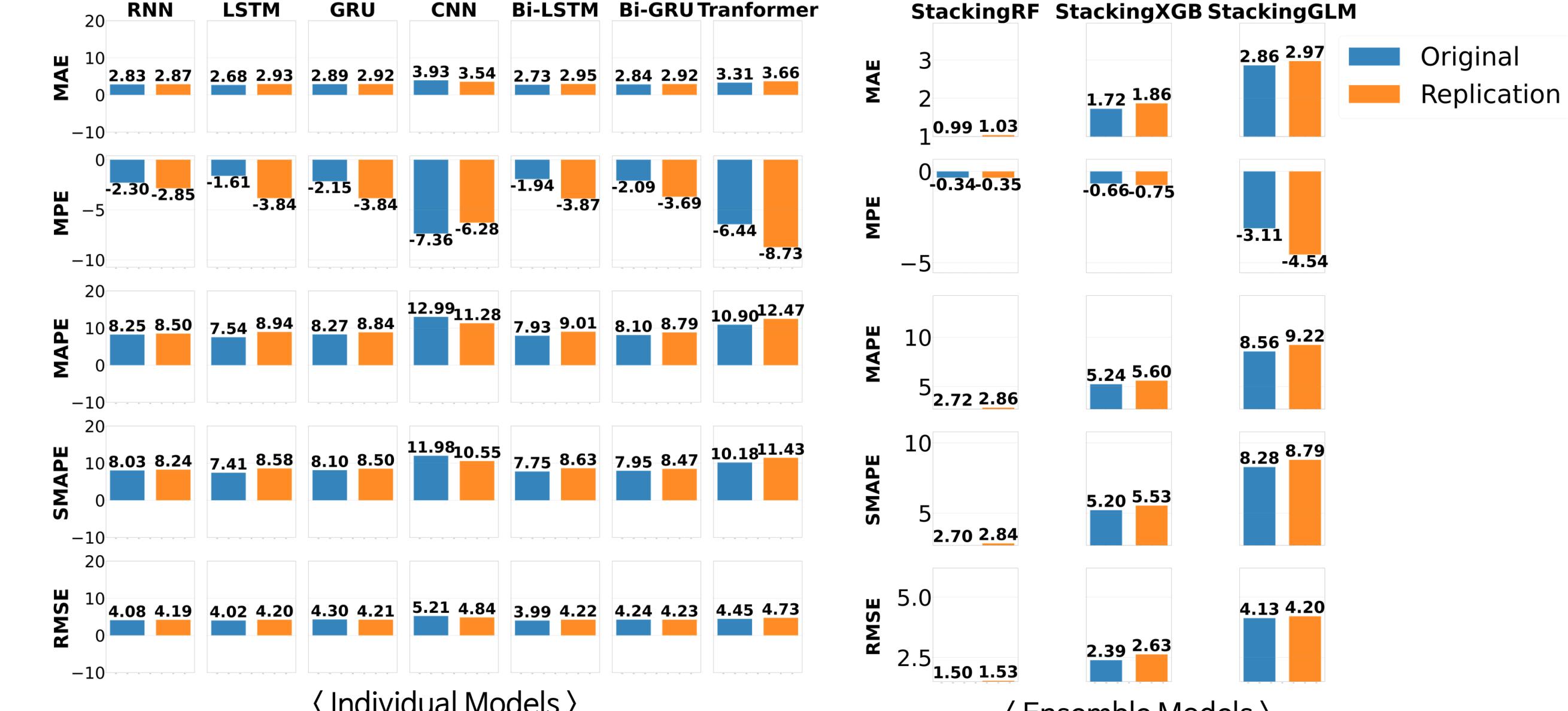


Uncertainty

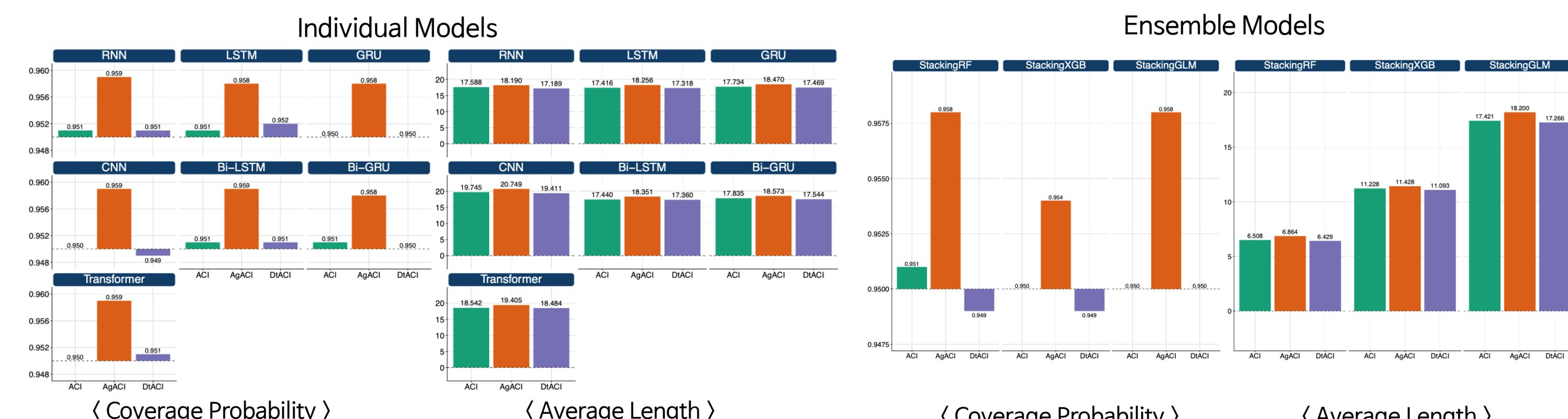


2-6-2. NO2

Evaluation and Comparison



Uncertainty



3. Conclusions

- From the results, we can see that the replication/reconstruction time series data well capture the seasonal patterns of the original data.
- Additionally, evaluation of uncertainty demonstrates the reliability of the prediction intervals.
- Based on these results, the proposed VAE can produce a substantial amount of time series data that capture the seasonal patterns of the original data.
- In the future, this study aims to extend to multivariate time series data and to incorporate trend patterns into the variational autoencoder, enabling the model to effectively handle a wider range of data types.