Enhancing Spatio-Temporal PM2.5 Forecasting via Modified iTransformer and Wavelet Coherence Analysis

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This presentation participates in OSPP
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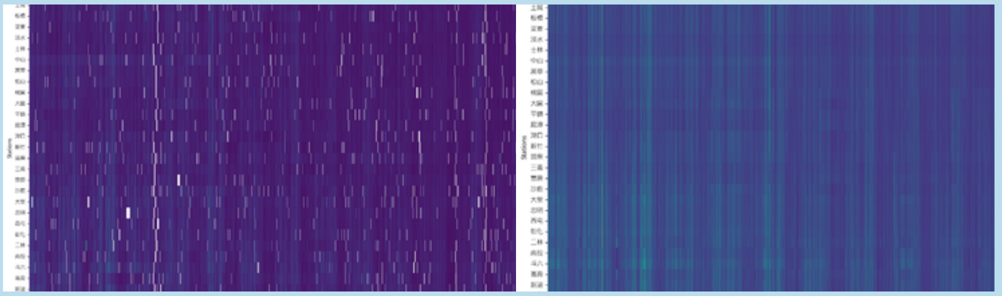
Outstanding Student & PhD candidate Presentation contest

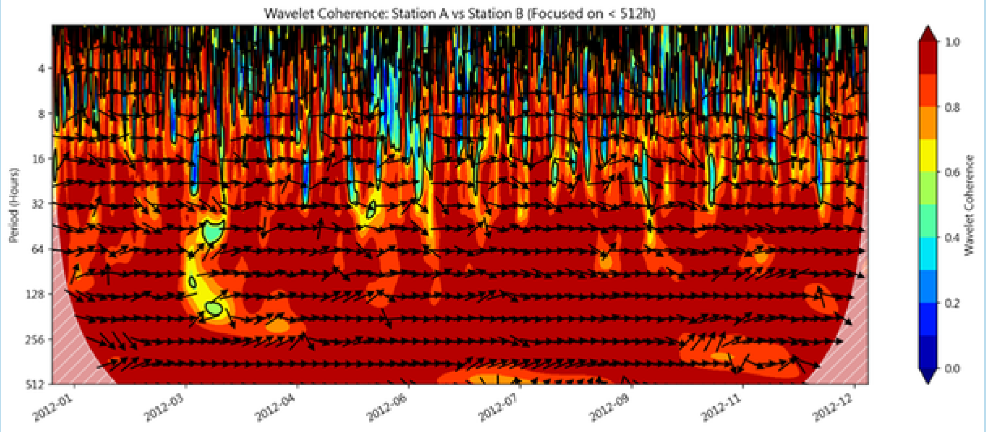
I introduction

- **Motivation:** WHO reports over 7 million annual premature deaths and 29% of lung cancer fatalities linked to PM2.5. However, precise forecasting in complex terrains remains challenging due to data sparsity and intricate spatio-temporal dynamics.
- **Multi-Source Variables:** This research integrates CEMS Data, Pressure Field, O3 and historical PM2.5 concentrations, Local wind speed.
- **Objectives:** To develop a robust imputation-prediction framework that enhances PM2.5 spatial estimation and identifies regional transmission pathways.

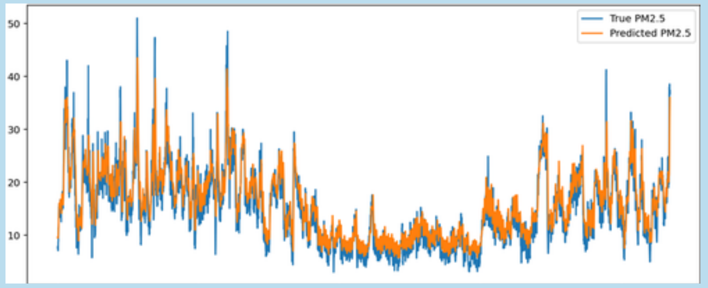
II Methodology



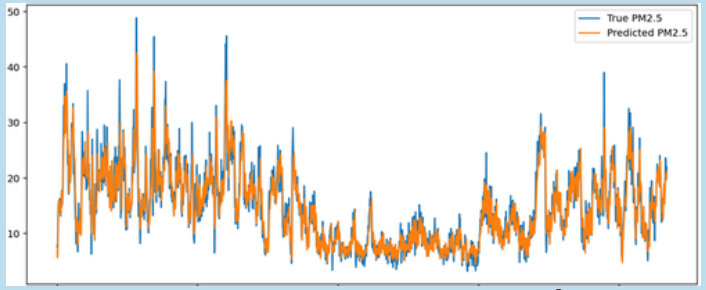
PCA reduces dimensionality while GRU-D performs temporal imputation, reconstructing missing data into continuous, high-quality sequences.



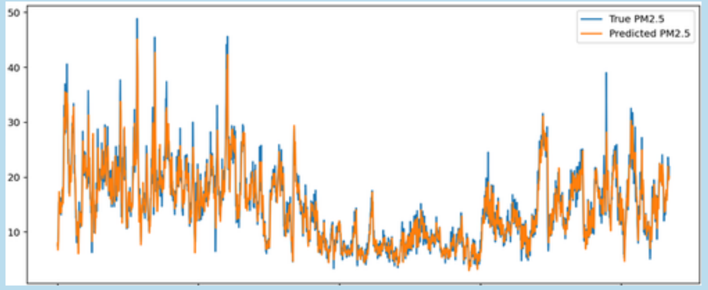
Wavelet Coherence extracts inter-station lead-lag priors. Filtered by national wind speeds, an 8–64h transmission window dynamically captures pollution transport.



LSTM+CNN: RMSE: 2.817, MAE: 2.145, R^2 =0.835



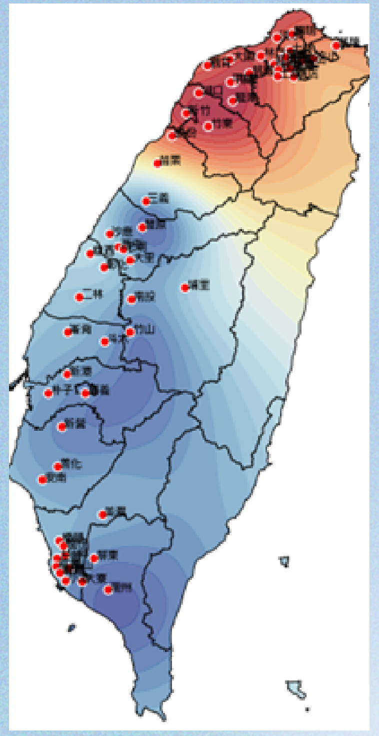
PatchTST: RMSE: 2.489, MAE: 1.762, R^2: 0.869



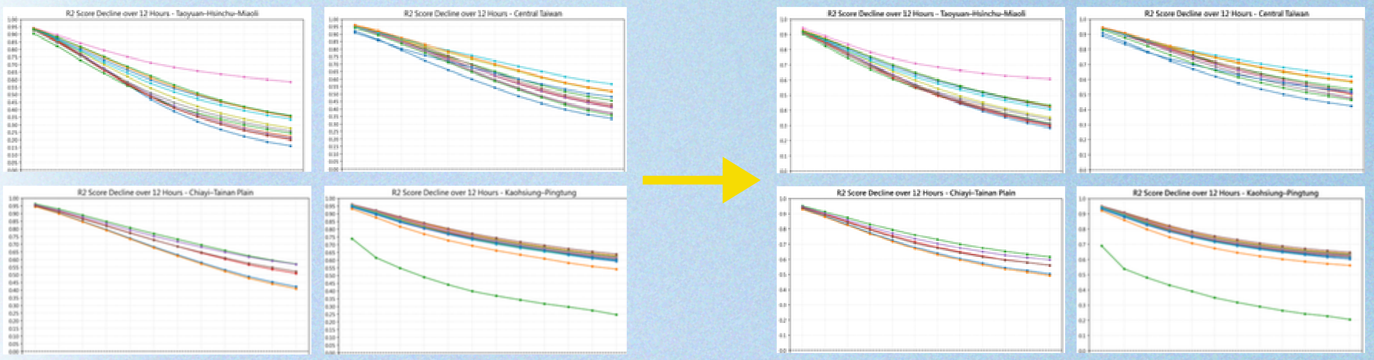
iTransformer: RMSE: 1.905, MAE: 1.315, R^2: 0.913 Significantly outperforming others in capturing complex inter-variable correlations.

III Results & Future Outlook

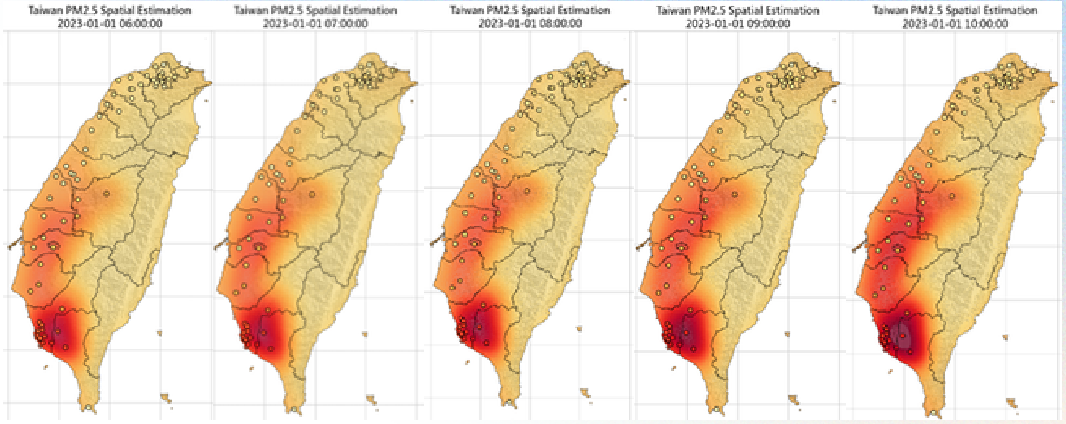
- **Source Identification:** Wavelet coherence calculates phase differences to map the "spatial lead" of pollution, effectively pinpointing critical transmission routes and regional sources.

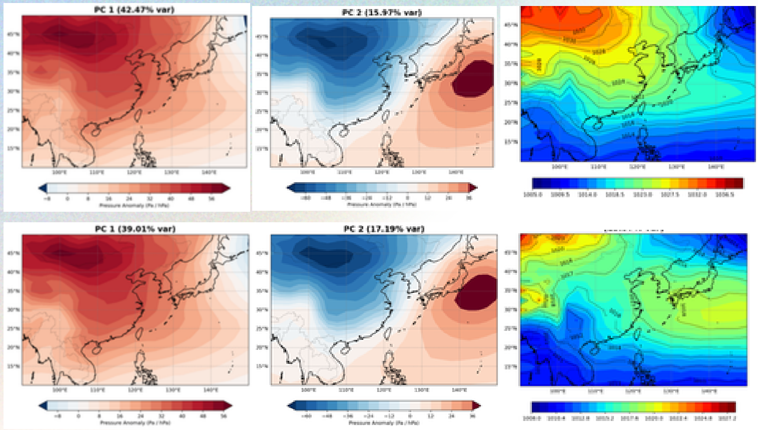


- **Feature Effectiveness:** Incorporating wavelet-derived spatio-temporal features significantly improves the model's capability to capture sudden PM2.5 peaks compared to baseline models.



- **Dynamic Spatial Tracking:** The 5-hour continuous prediction successfully visualizes the morning accumulation phase. It highlights a stagnant, high-concentration hot spot in southwestern Taiwan, alongside a gradual northward diffusion of pollutants across the western plains.





- **Future Work: Enhancing Northern Taiwan Forecasts:** Current predictions for Northern Taiwan are frequently impacted by transboundary pollution events. Future iterations will incorporate Long-range Dust Storm events as dynamic boundary parameters. This enhancement aims to mitigate the influence of winter monsoons and improve regional forecasting precision in coastal and northern areas.