Joint retrieval of $PM_{2.5}$ concentration and aerosol optical depth over China using multi-task learning on Fengyun-4A Advanced Geostationary Radiation Imager data

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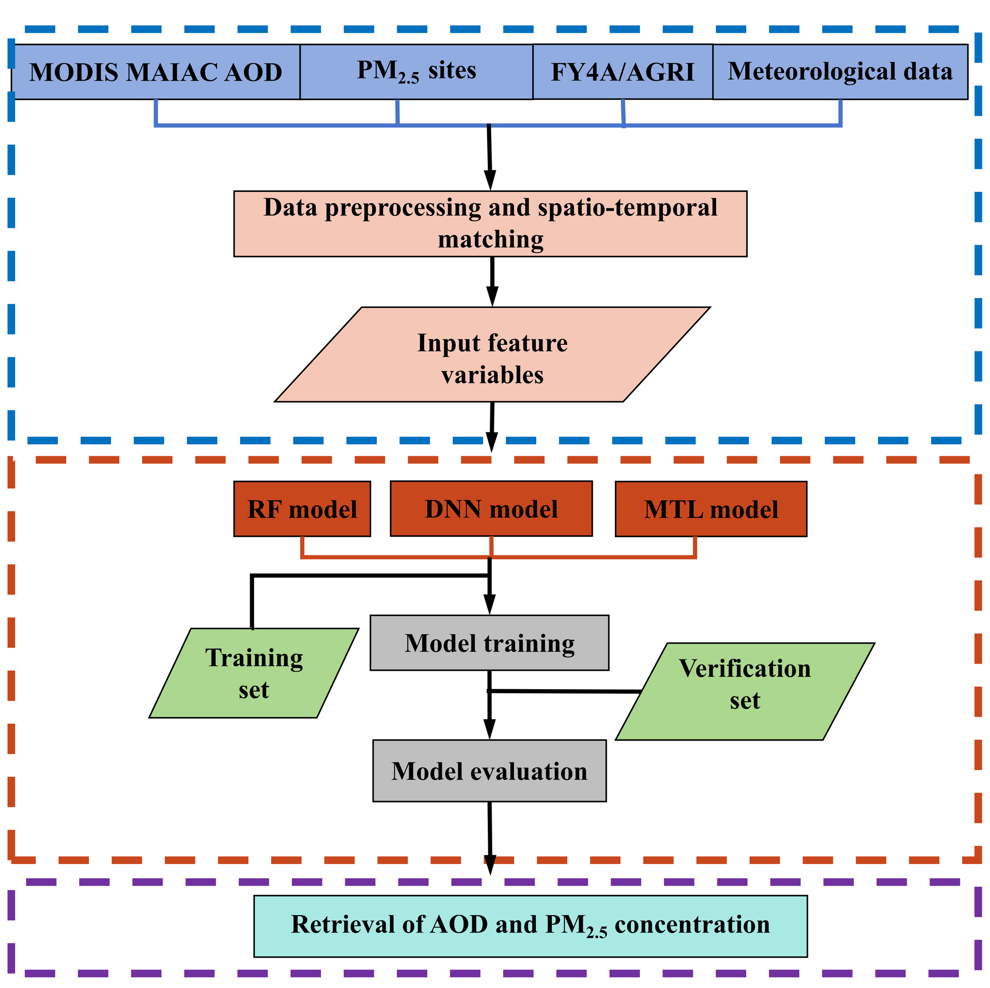
Abstract

In this paper, a DNN-based **joint retrieval** algorithm for AOD and $PM_{2.5}$ is proposed using **Multi-task learning techniques** and applied on the top-of-the-atmosphere reflectance(**TOAR**) data gathered by the **Fengyun-4A** Advanced Geosynchronous Radiation Imager.

Motivation:

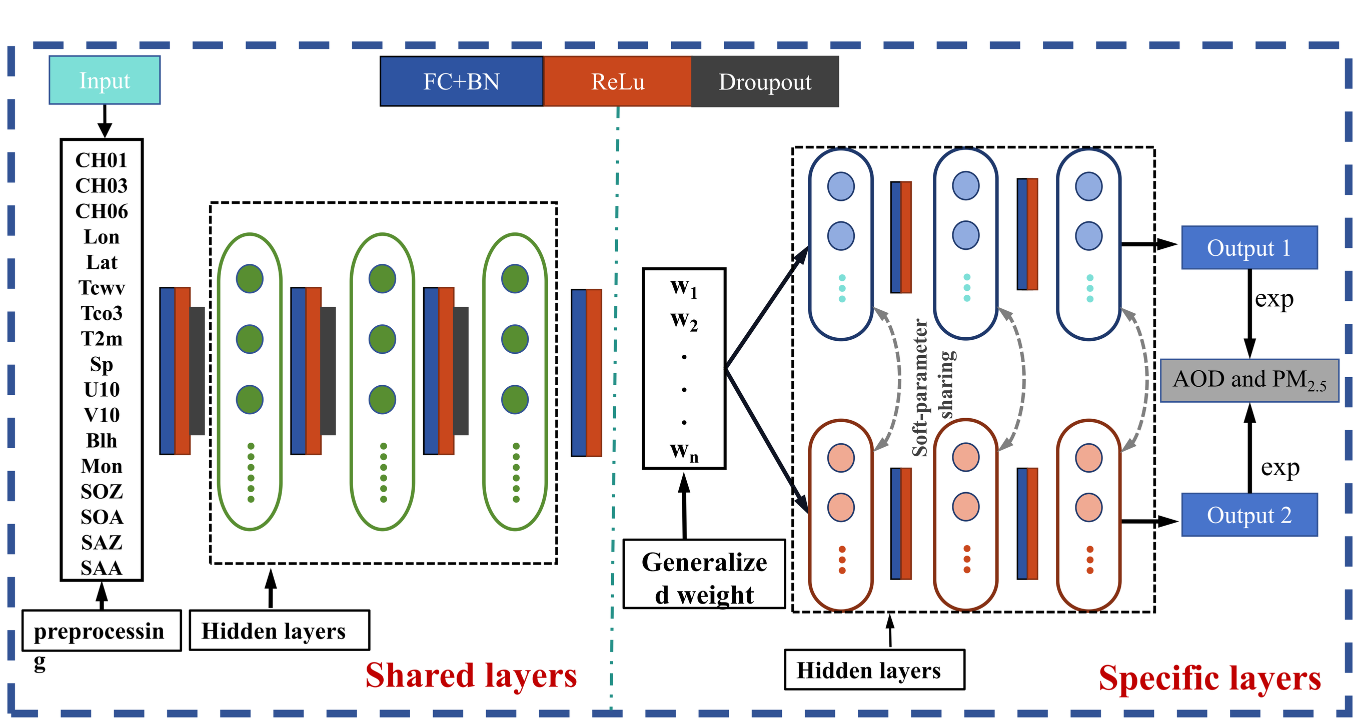
- ◆Overcoming the challenges of AOD and $PM_{2.5}$ retrieval;
- ◆Simultaneous high-precision retrieval of AOD and $PM_{2.5}$;
- ◆Provides a new perspective for efficient aerosol monitoring.

Data and method



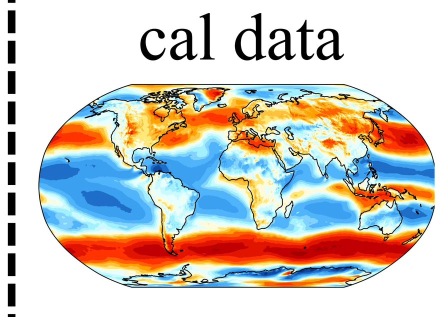
Two single-task learning (**STL**) models：**DNN and RF.**

- ◆17 features as inputs to the models.
- ◆Soft and hard sharing of parameters.
- ◆Comparison of MTL and STL performance.

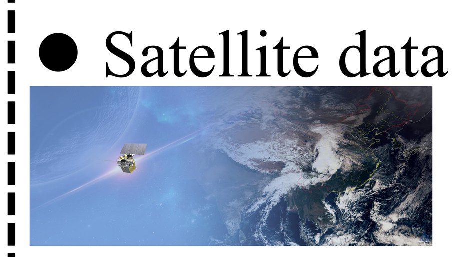


Input:

- Meteorological data



- Satellite data

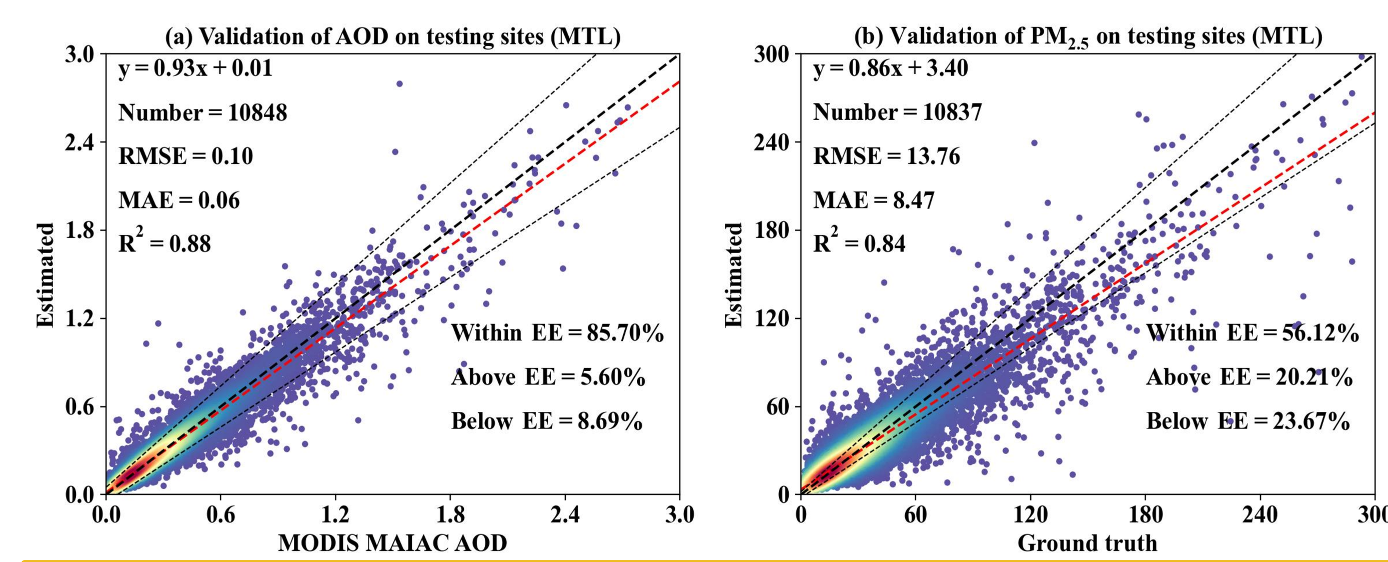


$$L_{(w,\sigma_1,\sigma_2)} = \frac{1}{2\sigma_1^2}L_1(w) + \frac{1}{2\sigma_2^2}L_2(w) + \log\sigma_1\sigma_2$$

In the above equation, the larger a is, the greater the **uncertainty** of the task, the smaller the weight of the task is, i.e., noisy and difficult to learn tasks will have a smaller weight.

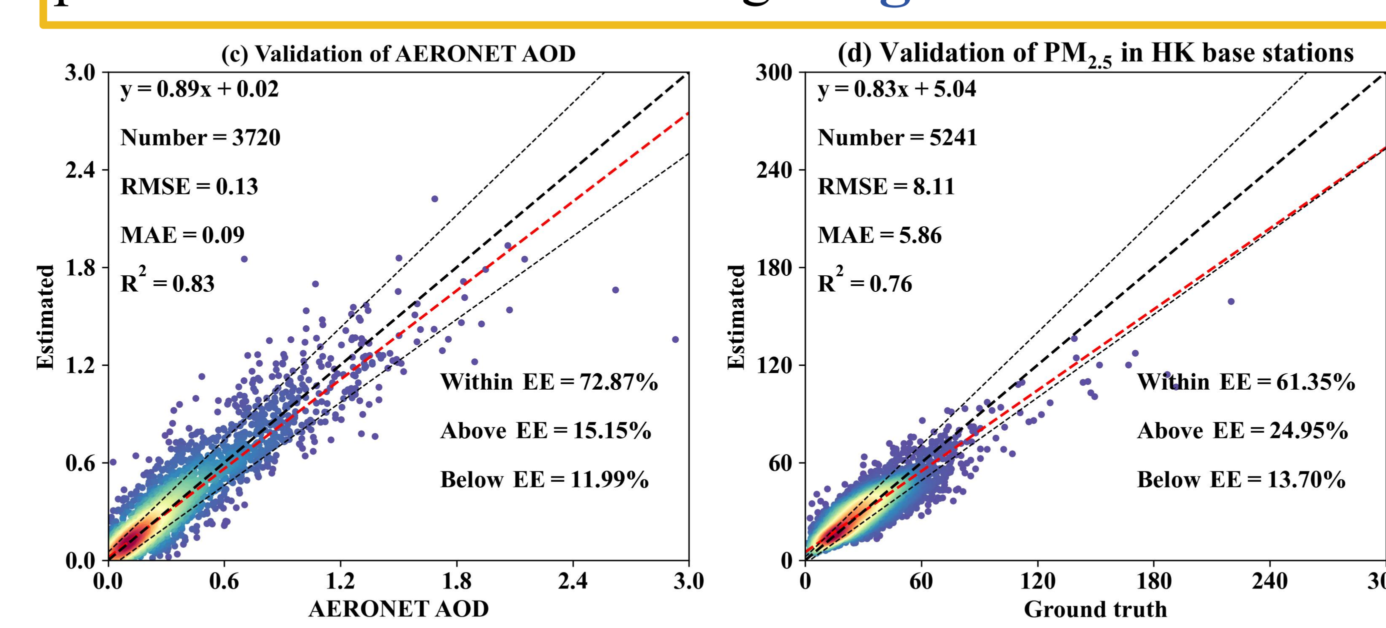
Results and discussion

Comparing with DNN STL model, the R^2 of the MTL model for estimating AOD and $PM_{2.5}$ increased by 0.01 and 0.05, respectively. This indicates that the MTL model is better optimized for $PM_{2.5}$.



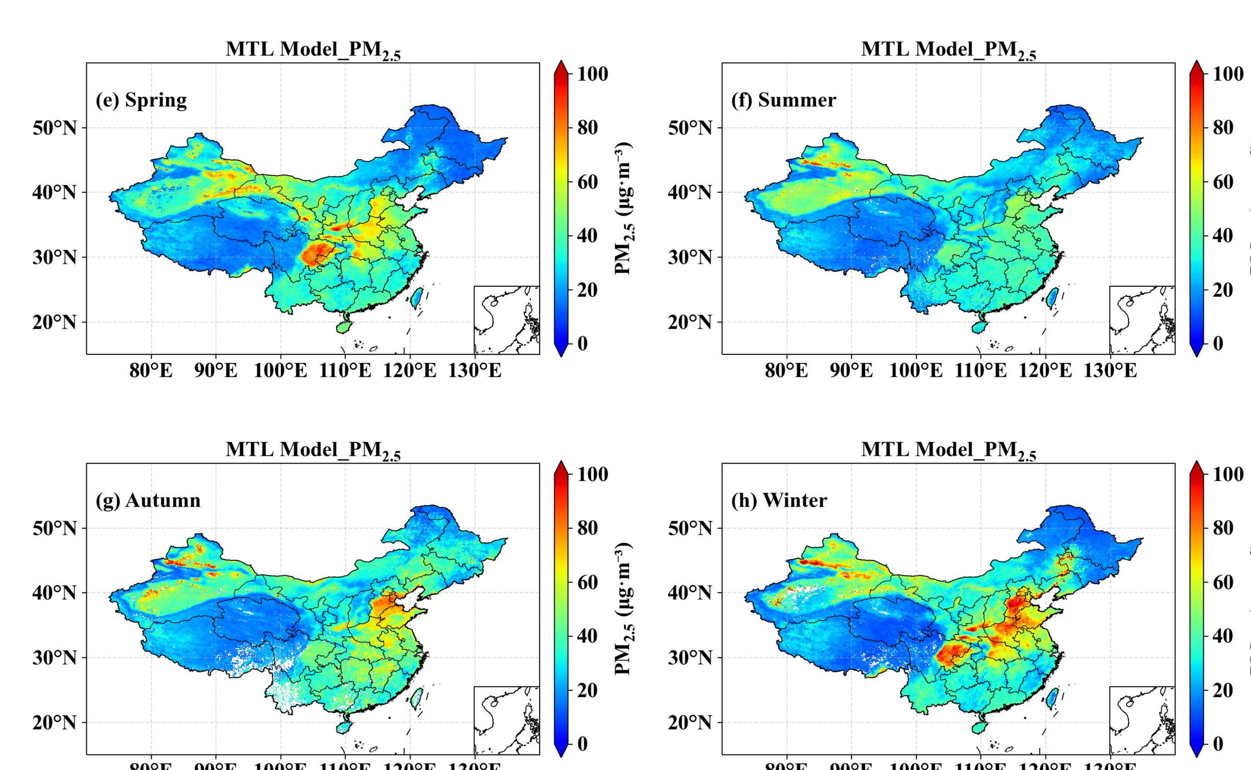
Validation results on 159 testing sites.

Independently verified by AERONET AOD and HK $PM_{2.5}$.This proves that MTL model has good **generalization ability.**



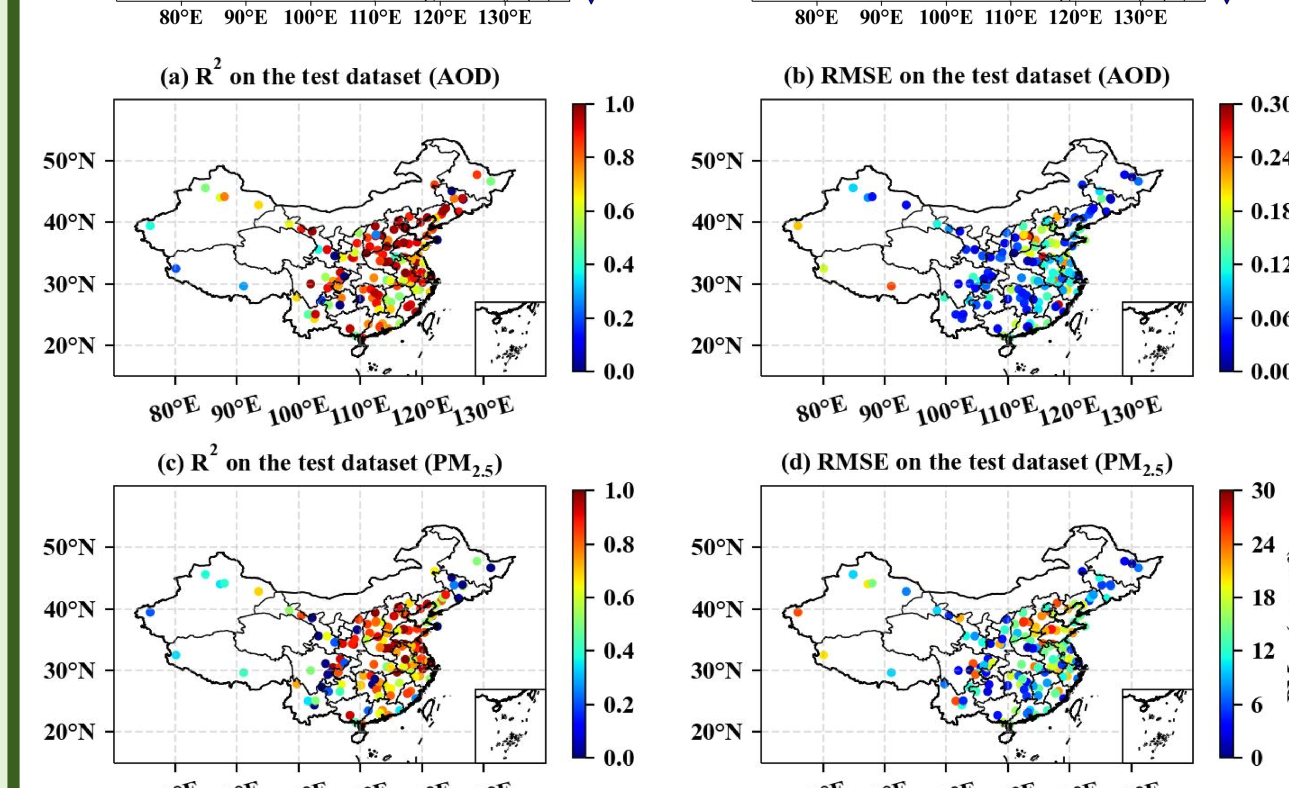
AERONET : Beijing-Tianjin-Hebei;

HK: 15 $PM_{2.5}$ sites



Seasonal average of $PM_{2.5}$ (μg·m⁻³):

- ➢ spring (37.67)
- ➢ summer (26.45)
- ➢ autumn (30.81)
- ➢ winter (41.51)



The performance of the MTL model is affected by the unevenness and scarcity of ground stations.

Conclusions

- ◆The MTL model achieves joint retrieval of two tasks (AOD and $PM_{2.5}$) with correlation, and the results outperform the STL model.
- ◆The problem of insufficient training samples and model overfitting can be solved to a certain extent, and it is applicable to places with fewer ground monitoring stations.
- ◆The seasonally averaged distributions of AOD and $PM_{2.5}$ are similar to previous findings and provide new insights for efficient monitoring of aerosol properties.