Deep learning based forecasting and classification of aerosol

MANCHESTER 1824 The University of Manchester

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Motivation

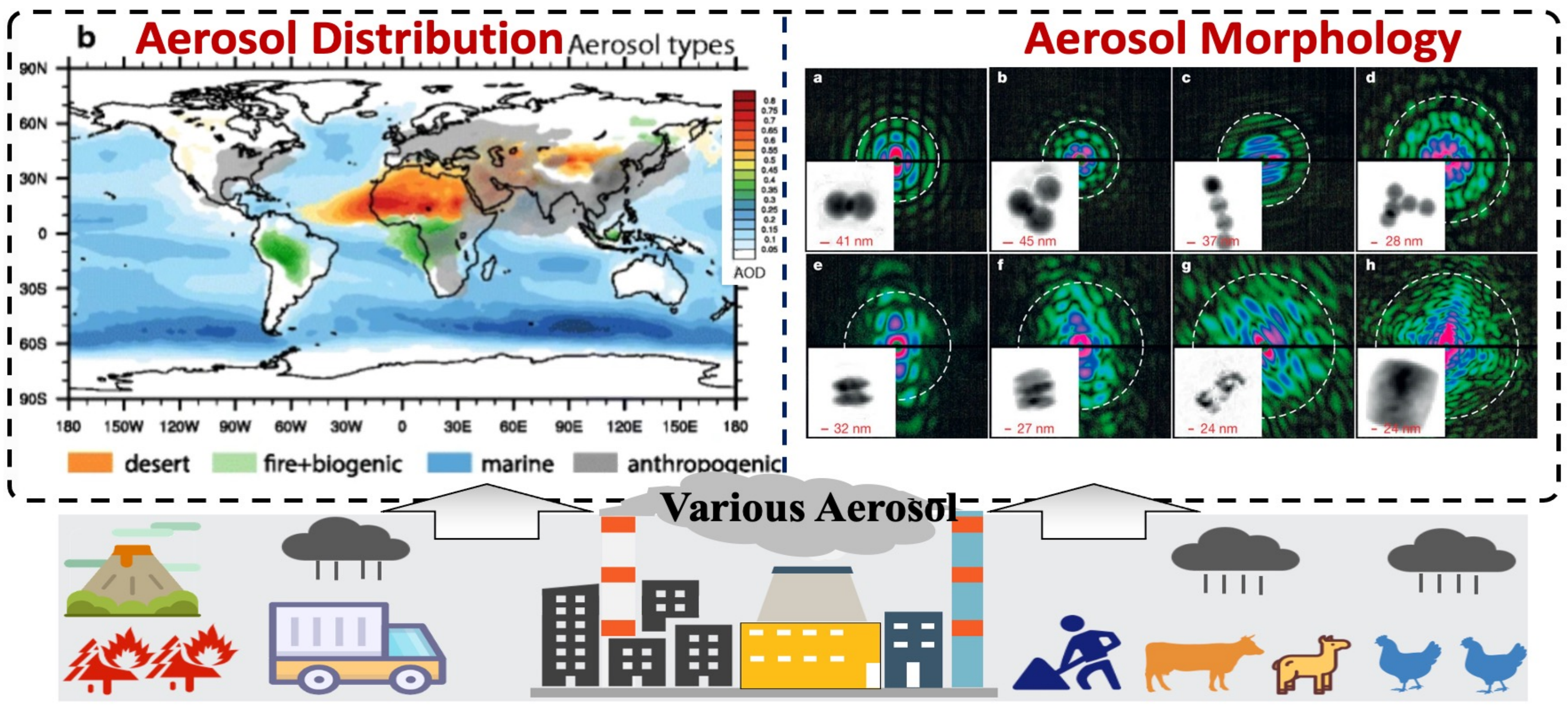


Fig 1. Distribution and morphology of different types of aerosols

Objectives

- Different concentration distribution for different aerosols.
- Different morphologies and sizes for different aerosols.
- Aerosol effects vary depending on type and distribution.

Objective 1: Build up a database of different types of aerosol morphology and concentrations distribution.

Objective 2: Develop an accurate classifier.

Objective 3: Establish a high-adaptability prediction method for aerosol concentration changes.

Methodology

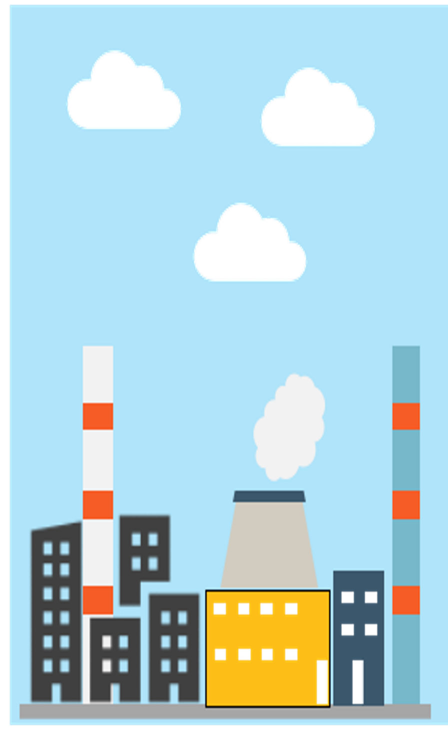
How to distinguish different types of aerosols?

How to predict concentration distribution?

Morphology dataset → Develop classifiers for different targets → Get the different clusters and optimize the classifiers → Deploy classifiers in different environment to test performance

Aerosol Types

Concentration dataset → Analyze data (WRF-Chem, CESM, etc.) → Get the key factors and reason that affect concentration → Predict changes in aerosol and its subsequent impacts



1. Type Classification

Classifier Framework

1. Reconstruct images and group aerosol to different clusters and types or directly predict the aerosol types.

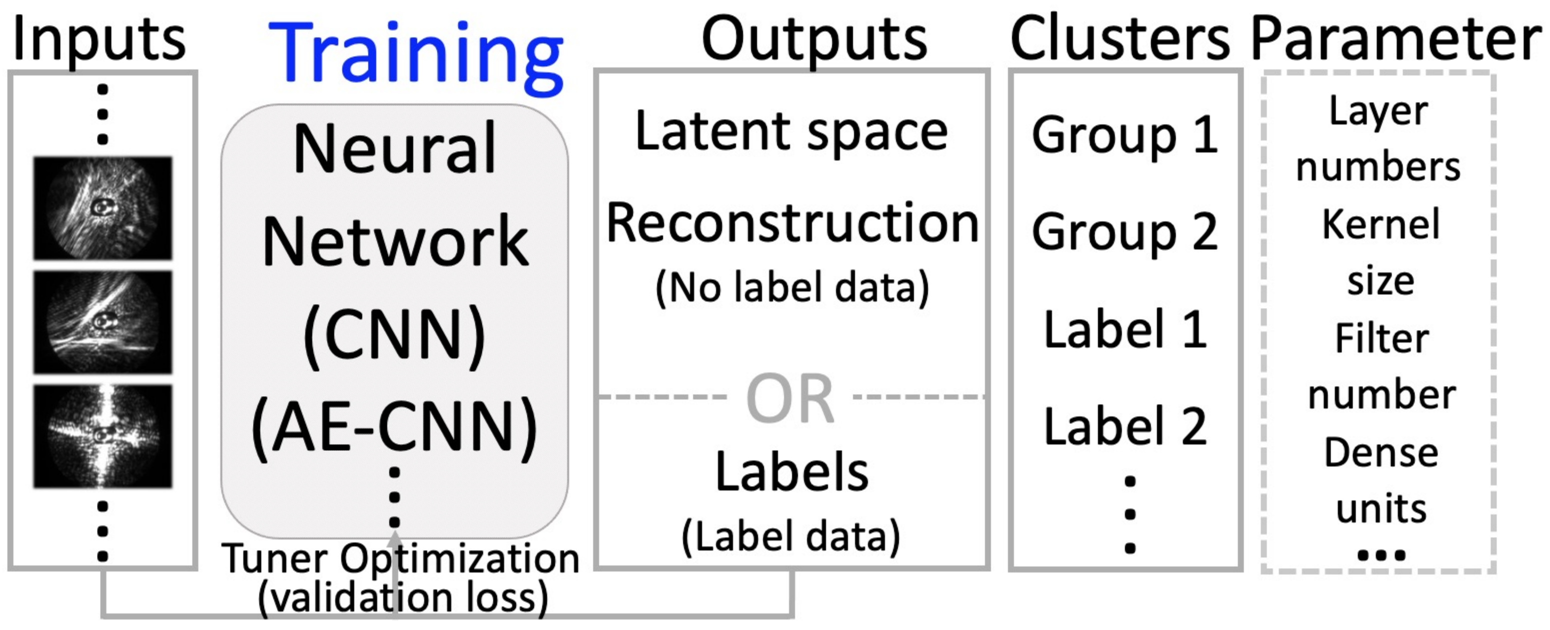
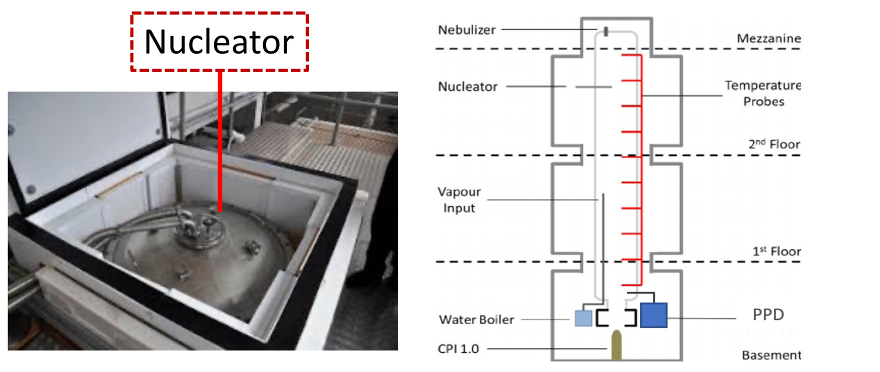


Fig 2. Deep learning classification framework

Current Results

1. Use PPD to capture ice crystal formed in MICC (-30 to -10 °C).



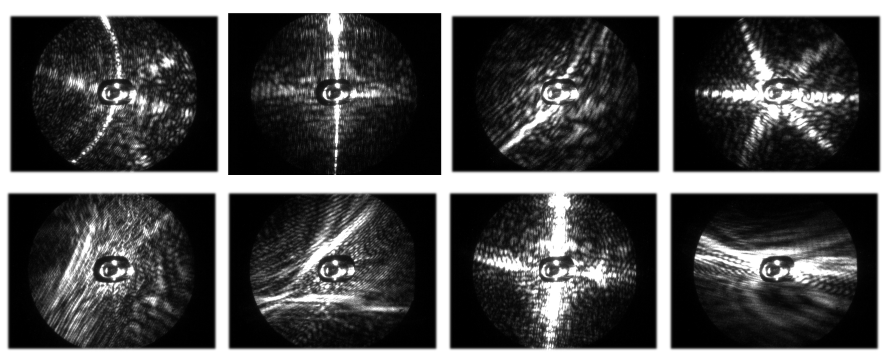


Fig 3. Diagram of experimental system Fig 4. Scattering pattern of ice crystals

2. Hyperparameter tuner and reconstruct morphology images.

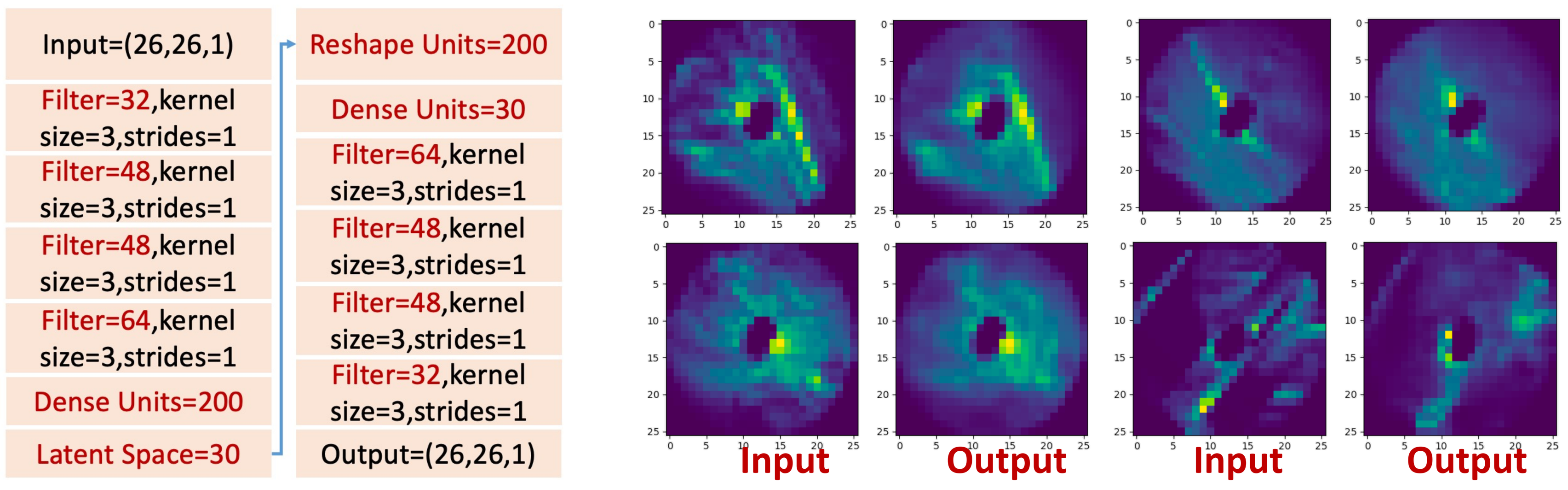


Fig 5. AE-CNN framework (left) and input and output images (right)

3. Hierarchical Cluster Analysis (HCA).

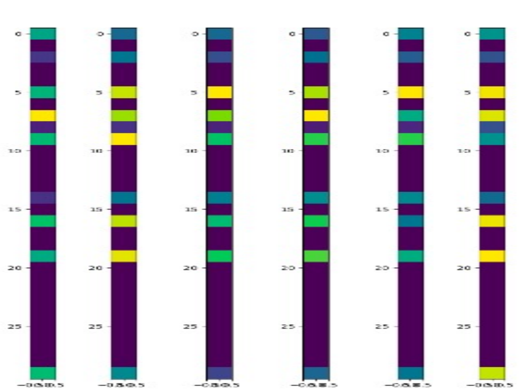


Fig 6. Latent spaces

$$CH(k) = \frac{B(k)/((k-1)}{W(k)/(n-k)}$$

Calinski-Harabasz index (CH index)

Tab.1. CH index scores

Cluster numbers	CH scores
2	1676.7
3	**1908.5**
4	1647.3
5	1575.8
6	1581.4
7	1597.6

2. Concentration Prediction

Concentration Distribution Data Source

1. Sites in different regions record concentration information and global or regional AOD data.

2. Supersites in Manchester supply data of the wider Manchester region with concentration of different particle types and other information.

Fig 7. Supersites in Manchester (left and middle) and example of AOD (right)

Concentration Analysis

1. Deep learning analyzes concentration changes relatively accurately, but input parameters are fixed (nearly 16 meteorology factors), and ignore physical and chemical processes, so it is less adaptable in different region.

2. Other methods like Chemical transport model (CTM) can describe complex physical and chemical processes, but not accurate enough to analyze concentration changes. However, it can help to find the main factors.

3. Add the analysis end and combine the CTM/Statistics and Deep learning can better analyze the changes in aerosols.

Data → **Data analysis end** → Reason / Key factors → **Deep learning end**

Meteorology factors:
Total cloud area fraction
Surface pressure
10 m specific humidity
Total precipitation
Tropopause pressure
Surface skin temperature
Eastward/northward wind
Potential evaporation
…

→

New factors:
EL Nino sea surface temperature
Antarctic Oscillation (for north India)
Boundary layer interaction (for east China)
Dewhethered (for covid effect)
…

Fig 8. Aerosol concentration analysis framework