A Machine Learning Approach to Unraveling the Complex Relationship between Air Pollution and Weather

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◆ Objective

In this study, we are aiming at unraveling the complex the complex interaction between air pollution in Taiwan and the synoptic weather in boreal winter through the Autoencoder and propose the concept of air pollution weather, which is a distinct meteorological condition that encapsulates intricate interactions between various weather systems operating across multiple scales.

◆ A typical air pollution weather case: 20081130-1206

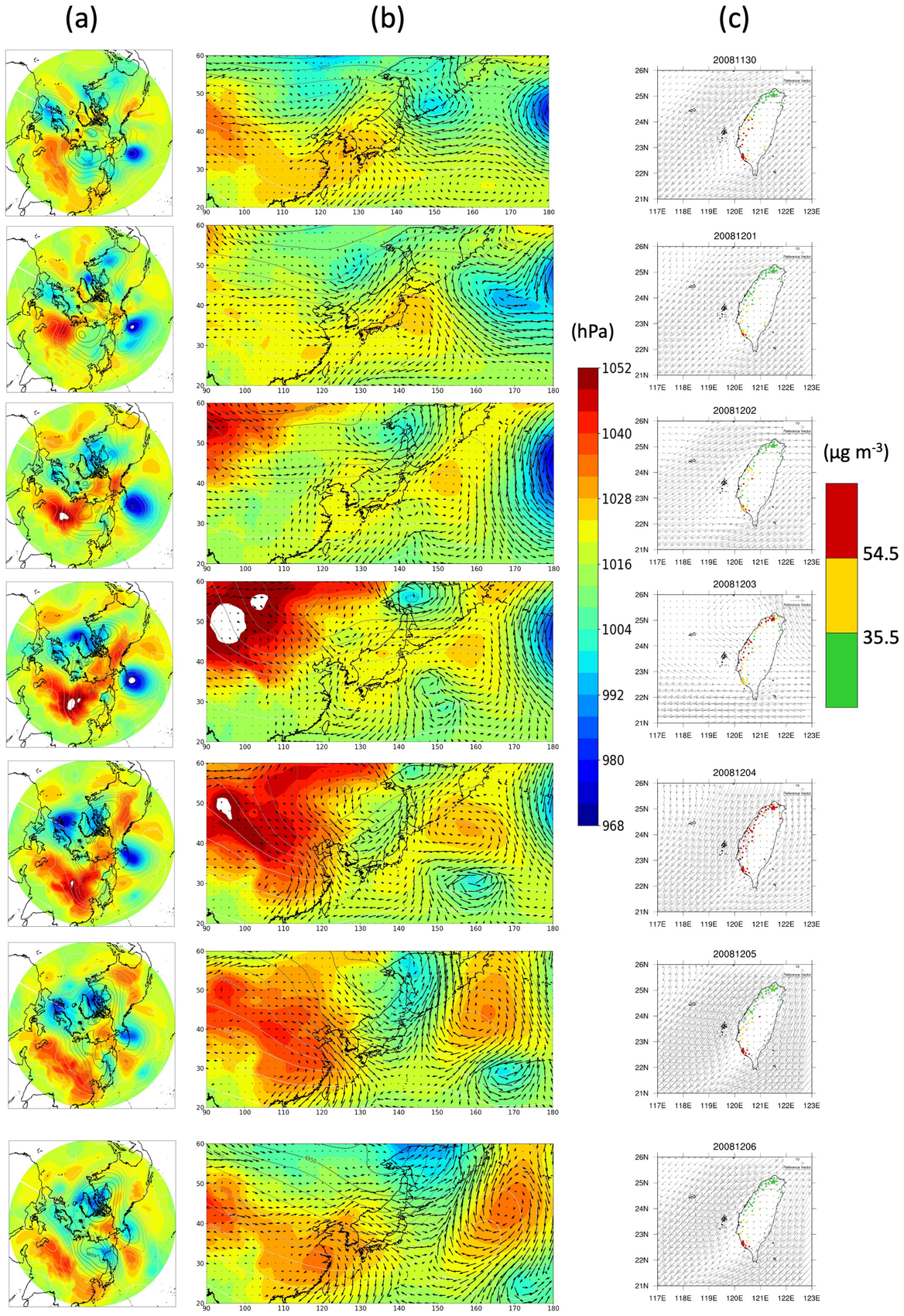
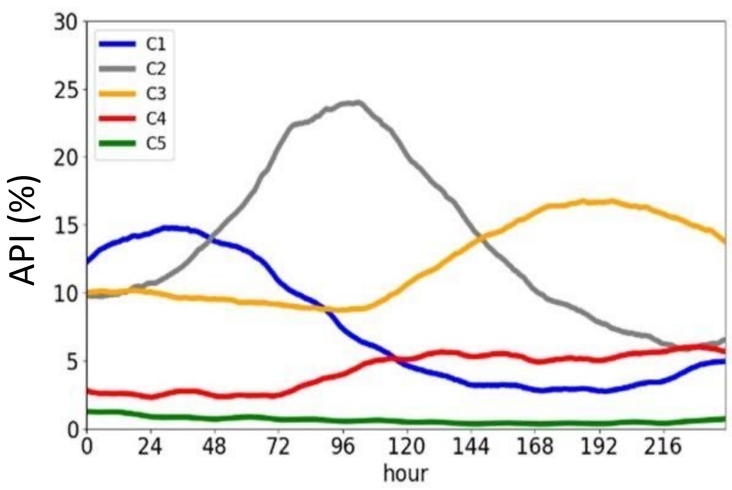


Figure 1. The synoptic configuration and the daily averaged PM2.5 concentration in Taiwan. (a) Mean sea level pressure (shading, units: hPa) and the geopotential height (contour) on 500 hPa (Z500, unit: gpm) in the Northern Hemisphere. (b) Mean sea level pressure (shading) and 925 hPa wind in East Asia. (c) Daily averaged PM2.5 concentration station data (unit: μg m^{-3})

◆ Air pollution episodes



- API: the percentage of stations impact by severe air pollution.
- There were five clusters of air pollution episodes in cold seasons identified by hierarchical clustering.

Figure 2. The composite API within every 10 days in each cluster. (Modified from Su et al., 2020)

Reference: Su, S. H., Chang, C. W., Chen, W. T., 2020: The Temporal Evolution of PM2.5 Pollution Events in Taiwan: Clustering and the Association with Synoptic Weather. Atmosphere, 11, 1265. doi:10.3390/atmos11111265.
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◆ Autoencoder

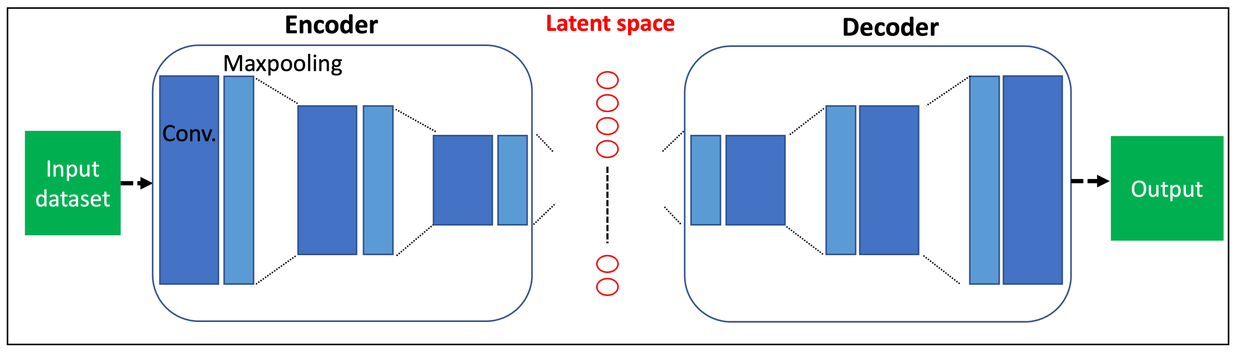


Figure 3. The structure of autoencoder

The autoencoder is constructed with the input dataset comprised of normalized ERA-Interim MSLP and Z500 from 2006-2010, with the latent space containing 20 neurons.

◆ Image reconstructed by Autoencoder resembles the input

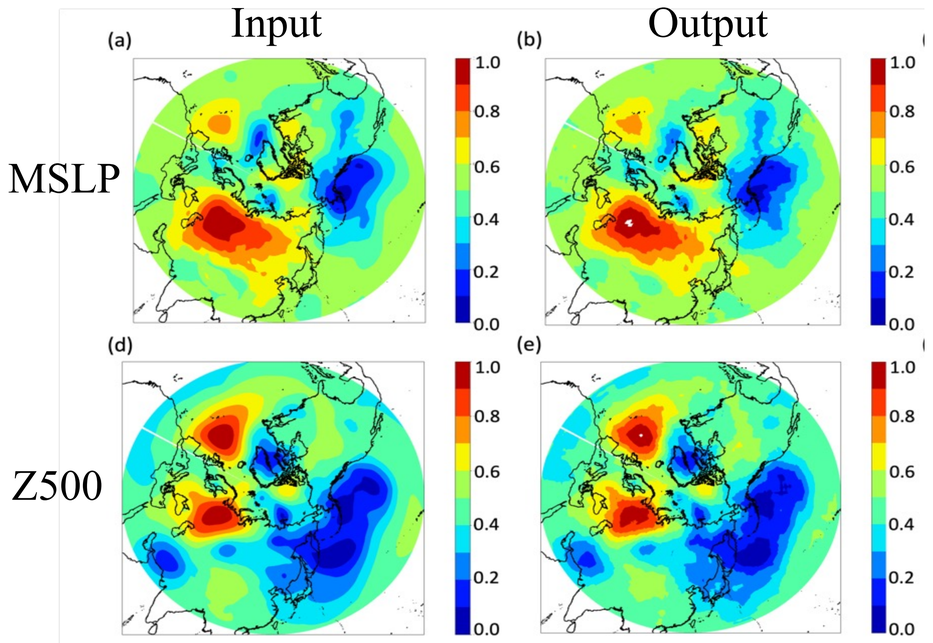
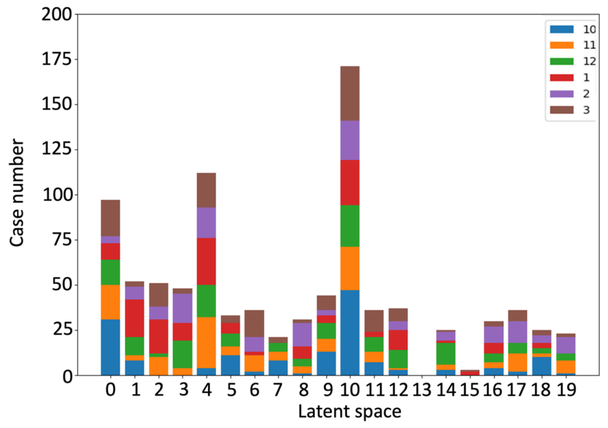


Figure 4. The input and the reconstructed (output) MSLP and Z500.

◆ The weather types can be identified by Latent Space



- The various synoptic weather in boreal winter can be contract to 19 types.

Figure 5. Cases identified by the node. (unit: day)

◆ Weather types identified in latent space could connect directly to air pollution episodes

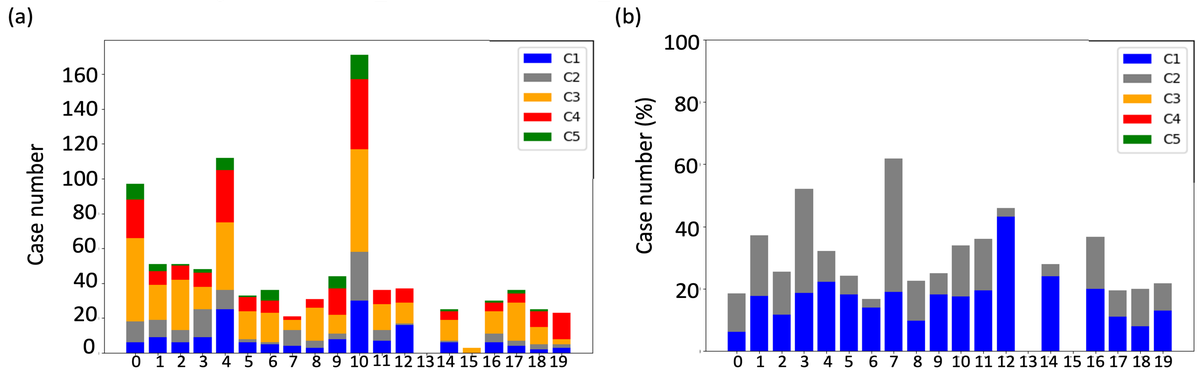
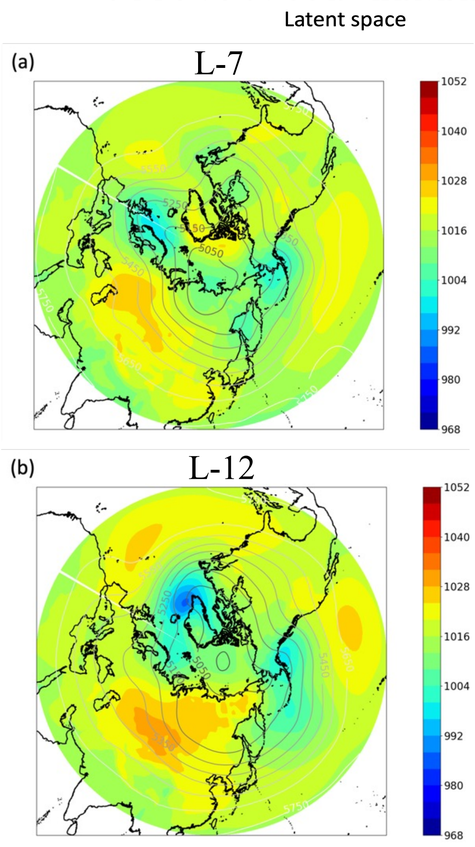


Figure 6. The case numbers and corresponding air pollution episode in the latent space. (a) The actual case numbers (unit: days) (b) In percentage.



◆ Remarks:

- Air pollution weather is a weather type that incorporates interplays of systems across multiple scales.
- The air pollution episodes could serve as an indicator of the boreal winter weather
- Air pollution episode C2 (C1) is more likely to occur under L-7 (L-12) condition.