Analysis of a Continental Aerosol Outflow Event in East Asia: A Case in Taiwan

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Introduction

Taiwan is geographically situated in the downwind region of the Northeast monsoon during the winter and spring months. The island frequently experienced long-range transport (LRT) of pollutants from Northern China around this period as Taiwan is located at the periphery of the Siberian high-pressure system. Such atmospheric dynamics can lead to significant episodes of air quality deterioration in Taiwan, posing health risks to the population.

In this research, we focus on an episode of air quality deterioration that was associated with LRT between 02 March and 04 March 2022 (**Fig 1**). Our study primarily focuses on two critical aspects: firstly, identifying the sources of the pollutants and understanding their transportation mechanisms. Secondly, examine how the pollutants interact with the weather system and the terrain of Taiwan.

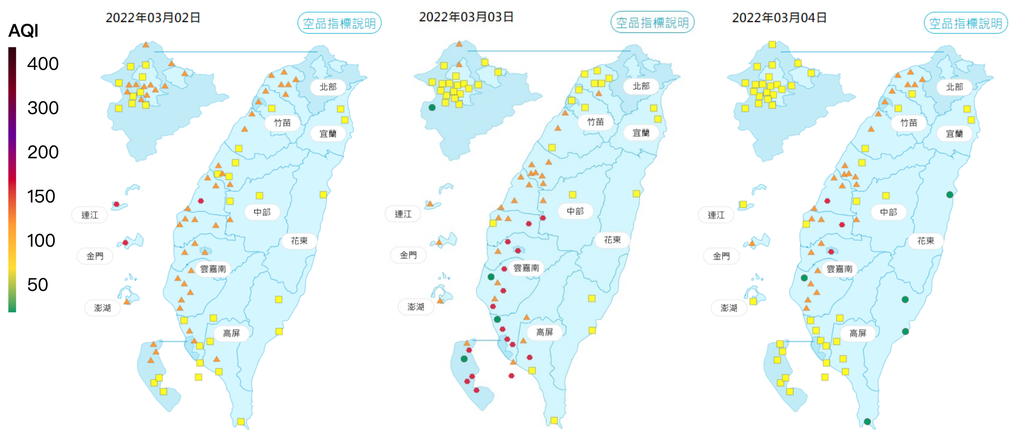

Fig 1. Daily Air Quality Index over Taiwan from 02 March to 04 March 2022.

Methods

This research employs several approaches. HYSPLIT, an atmospheric transport and dispersion model simulates the movement and spread of pollutants to predict their origin. Aerosol Optical Depth (AOD) data from satellite measurements (MERRA-2) helps trace pollutants on a larger scale.

Data from continuous monitoring stations around Taiwan provide higher-resolution insights into the pollution event on a local scale. Cape Fugui, Yangming, Hualien and Magong stations are specifically examined (**Fig 2**). Although Yangming station is located in Taipei, the elevation is 613m. These stations are minimally influenced by local pollution sources, making them ideal for monitoring pollutants from distant sources.

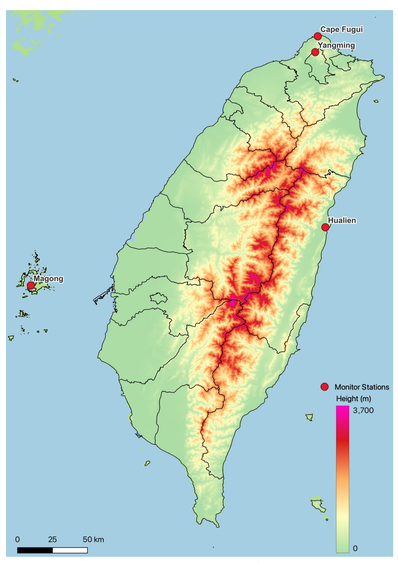

Fig 2. The location of three monitored stations.

Source

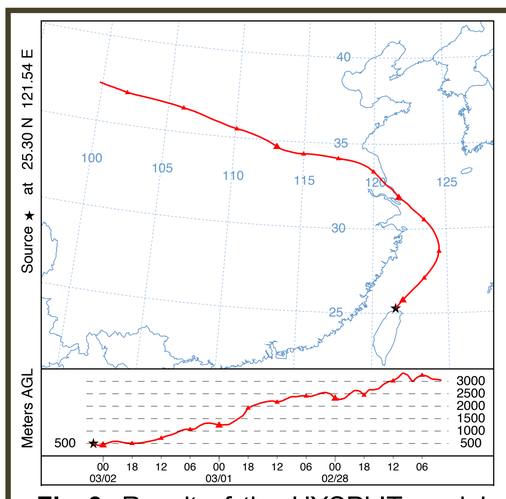

Fig 3. Result of the HYSPLIT model 72 hours backward trajectory at altitude of 500 m starting from UTC 0200 02 March at Fugui Cape station.

Fig 4 is the time series maps of aerosol optical depth and wind & pressure data, respectively. Matching with the trajectory of **Fig 3**, it is noticeable that there was a high-pressure system in Siberia and a low-pressure system in Inner Mongolia between 27 and 28 February 2022. As a result, a strong air pressure gradient formed that generated strong surface winds that transported dust from the Gobi Desert. These dust particles were later carried towards Eastern China by the movement of the Siberian High. Between 28 February and 1 March, the dust particles combined with pollutants from Central China and the Yangtze River Delta and eventually carried the pollutants to Taiwan on 02 March 2022.

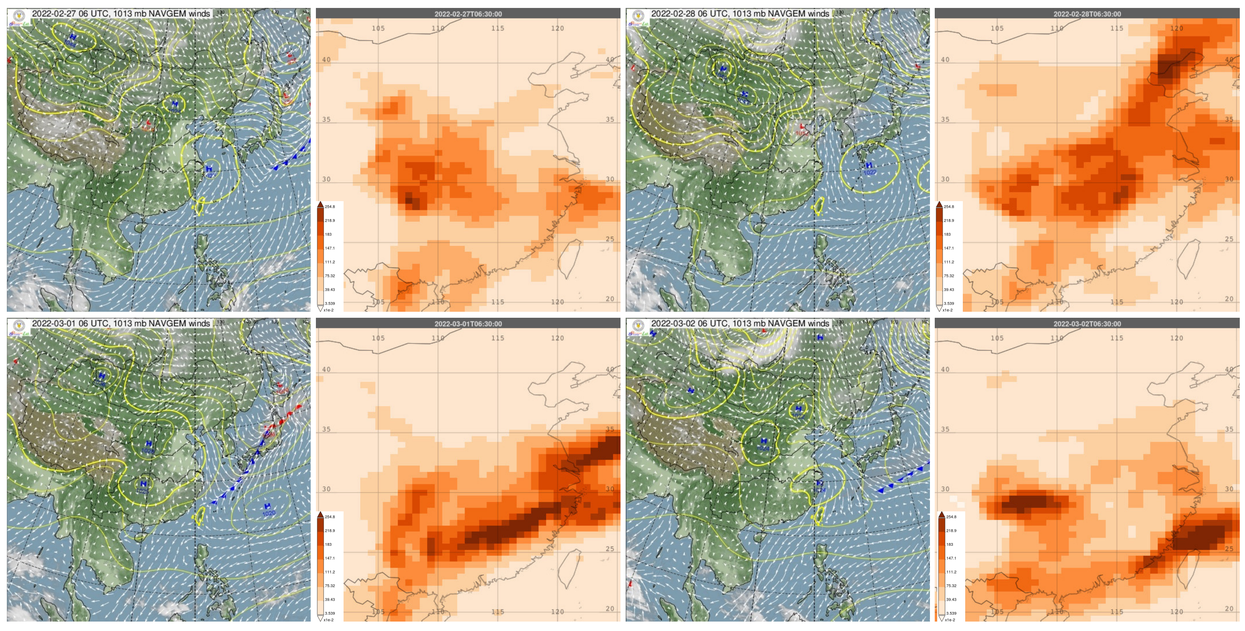

Fig 4. East Asia wind and weather map from UTC 0600 27 February to 0600 02 March 2022. Combined with Total Aerosol Scattering 550 nm from UTC 0630 27 February to UTC 0630 02 March. Data from Merra-2 reanalysis. One-day interval between each frame.

Monitored data

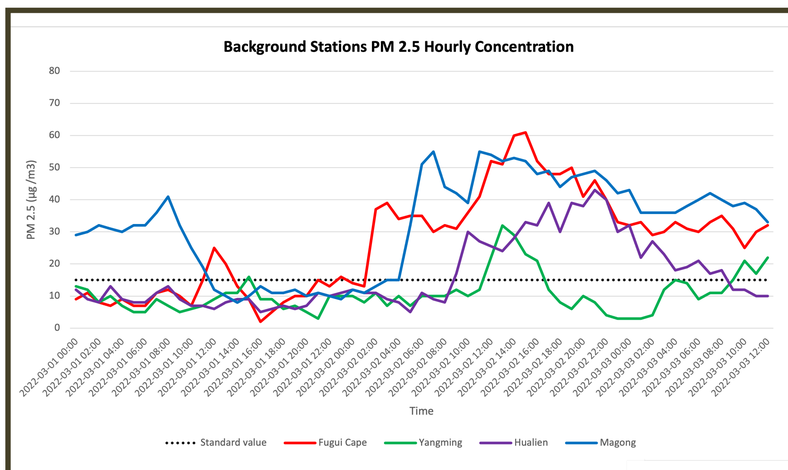

Fig 5. $PM_{2.5}$ Hourly concentration of background stations from local time 0000 01 March to 1200 03 March. Cape Fugui experienced the earliest surge in $PM_{2.5}$ levels, while Yangming recorded the latest surge and the lowest concentration overall. Although Hualian is closer to Cape Fugui, its $PM_{2.5}$ concentration increased four hours later than at Magong station.

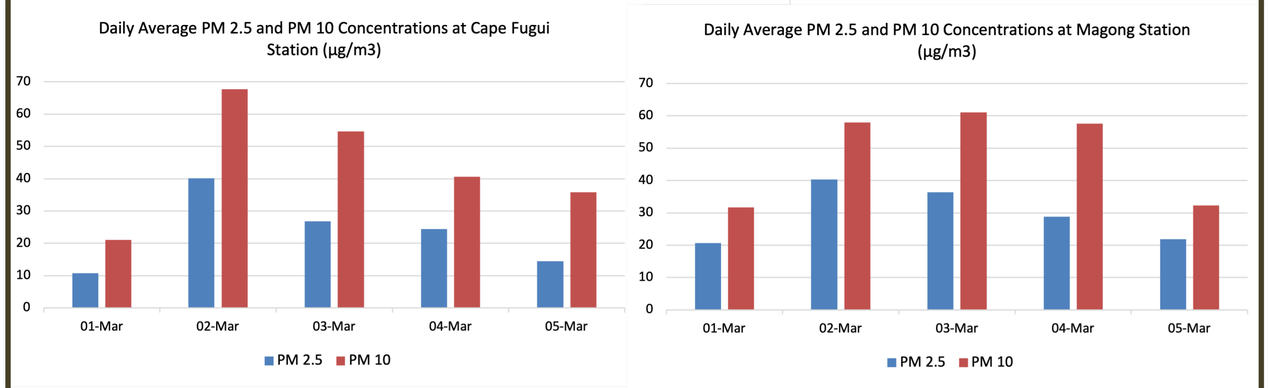

Fig 6. Daily average concentrations of $PM_{2.5}$ and PM_{10} at the Cape Fugui and Magong stations between local time 01 and 05 March 2022. During this episode, $PM_{2.5}$ levels were slightly higher than PM_{10}, suggesting that the pollutants were predominantly anthropogenic. Magong is located approximately 200 km from Cape Fugui. Hence, the station exhibited a delayed trend.

Channel Effect

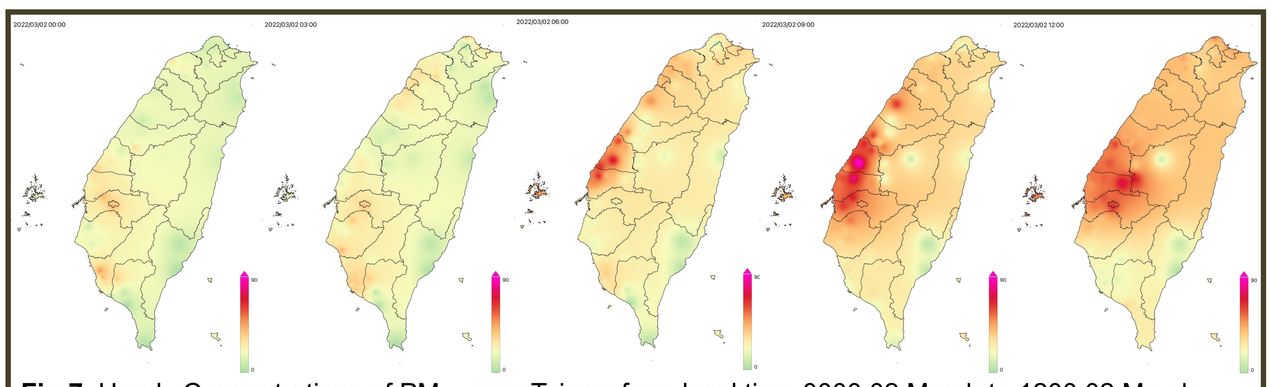

Fig 7. Hourly Concentrations of $PM_{2.5}$ over Taiwan from local time 0000 02 March to 1200 02 March 2022. The 3-hour interval between each frame.

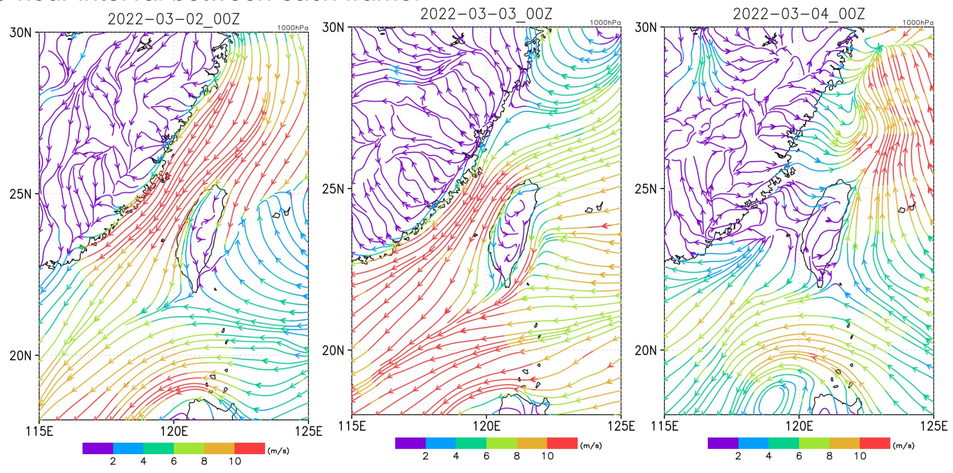

Fig 8. Wind speed simulation over Taiwan from UTC 02 March to 04 March 2022. One day interval between each frame.

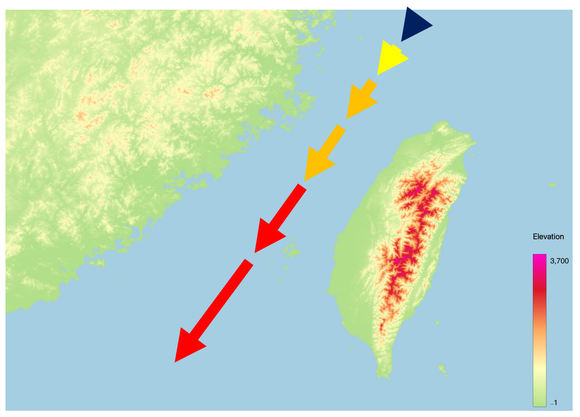

Fig 9. Illustration of the channel effect in the Taiwan Strait. The strait lies between the Wuyi Mountains in Fujian (2000m) and the Central Mountain Range (CMR) in Taiwan (3000m). As winds pass through the strait, they are funnelled between these two mountain ranges, which largely increases the speed of winds.

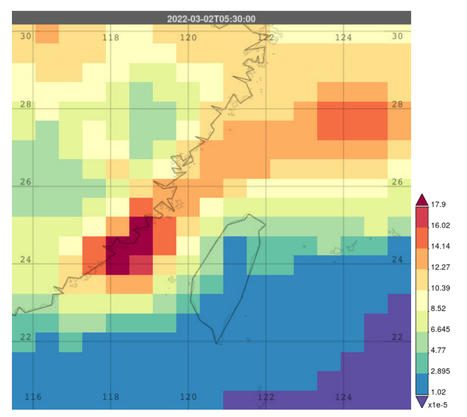

Fig 10. Total Column Mass Density of $PM_{2.5}$ (kg m^2) at UTC 05:30 02 March 2022. Data from Merra-2 reanalysis. The $PM_{2.5}$ density was the highest in Taiwan Strait.

Conclusion

- The air pollution event was primarily driven by anthropogenic pollutants from the Yangtze River Delta, which mixed with dust transported from the Gobi Desert and local pollutants.
- The uneven distribution of pollutants over Taiwan exhibited a complex interaction with the terrain of Taiwan.
- The Central Mountain Range plays a significant role in transporting pollutants. The mountain range blocks the easterly flow and funnels the winds that enter the strait.
- Long-range transport pollutants had little effect on the Southern tip and Eastern part of Taiwan.