Investigate the Air Pollution Problem in Mountain Area of Taiwan Using Fine Scale Air Quality Simulation

Chia-Ying Lin and Fang-Yi Cheng
Department of Atmospheric Sciences, National Central University, Taoyuan, Taiwan

Introduction

Taiwan often suffers from severe air pollution problem under the weak influence of the synoptic weather system. The second and forth highest $PM_{2.5}$ concentrations from the year 2014-2015 were recorded at Puli and Zhushan station that is located in the mountainous area of central Taiwan (Hsu and Cheng 2016). Air pollutants are mainly produced in western coastal region and transported into inland area by the sea breeze during the day, which cause the bad air quality in the mountainous place. Local circulations such as land–sea breeze and mountain flow circulations have a great impact on air pollutant dispersion. However, few studies investigated the detailed structures of the flow patterns over the mountainous region and their impacts on air pollutants dispersion. Therefore, this study focus on central Taiwan to investigate the air pollution problem in mountain area through a case study.

Objectives

- To examine the characteristics of the land-sea breeze and mountain flow circulations over central Taiwan.
- To study the structure and evaluation of boundary layer in mountain area.
- To investigate the subsequent impact on the air pollutants dispersions

An overview of the study episode

High $PM_{2.5}$ concentration was observed in Puli basin on 25-27 Oct., 2016. The synoptic forcing was weak. Wind speed near the surface was lower than 5 m/s. The meteorological condition was favorable to the development of thermally driven circulation. Air pollutants dispersion is strongly related to local circulations as shown in Fig.1.

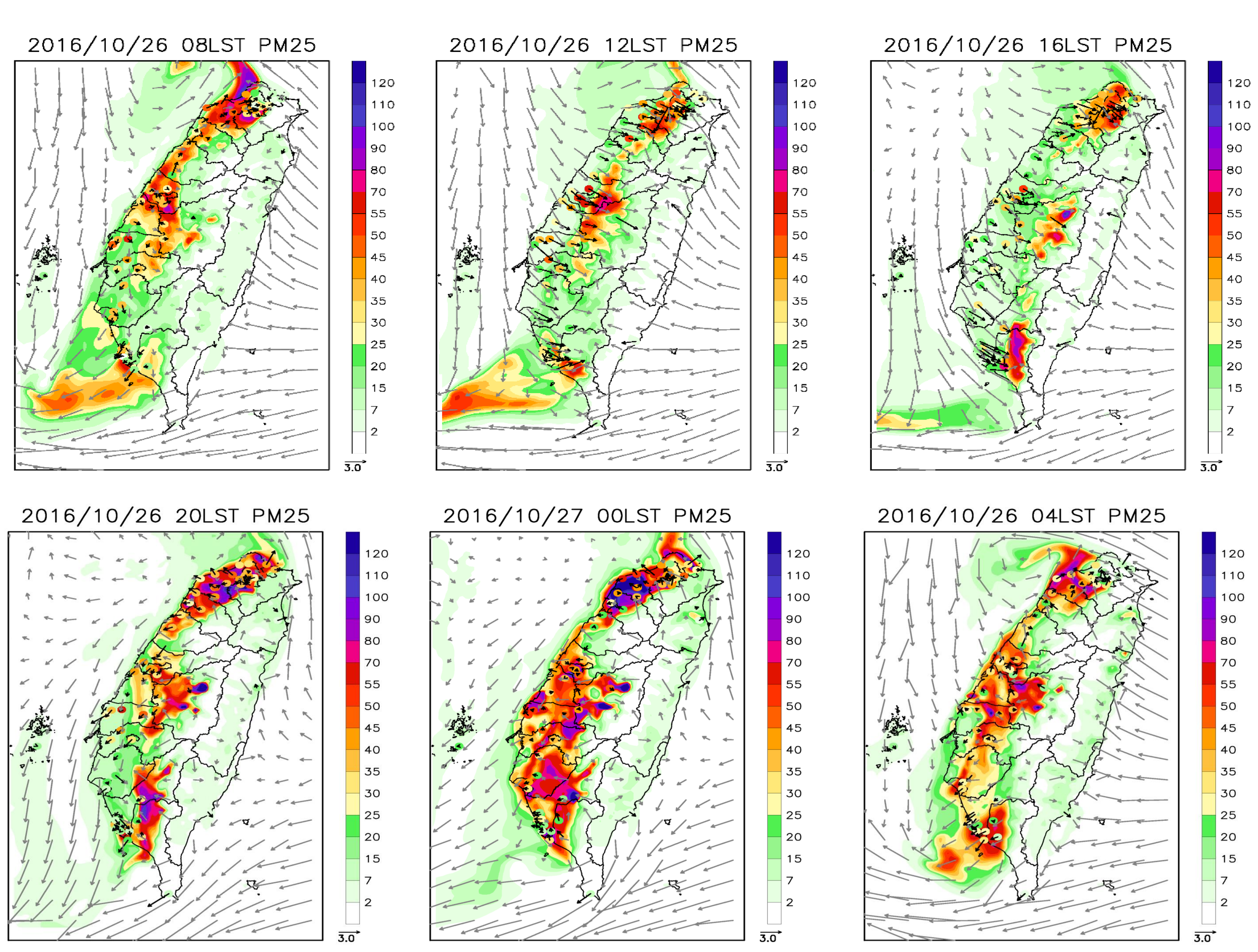

FIG.1. The distribution of $PM_{2.5}$ concentration. EPA station data (color dot) and model results (shaded) are included. Red circle points out the location of Puli basin

Numerical model

- Model: the Weather Research and Forecasting (WRF), version 3.7.1
- Simulation time: Oct. 25-27, 2016
- Horizontal resolution: 81, 27, 9, 3, 1 and 0.333 km
- Initial and boundary condition: NCEP FNL (Final) Operational Global Analysis data (1˚x1˚)

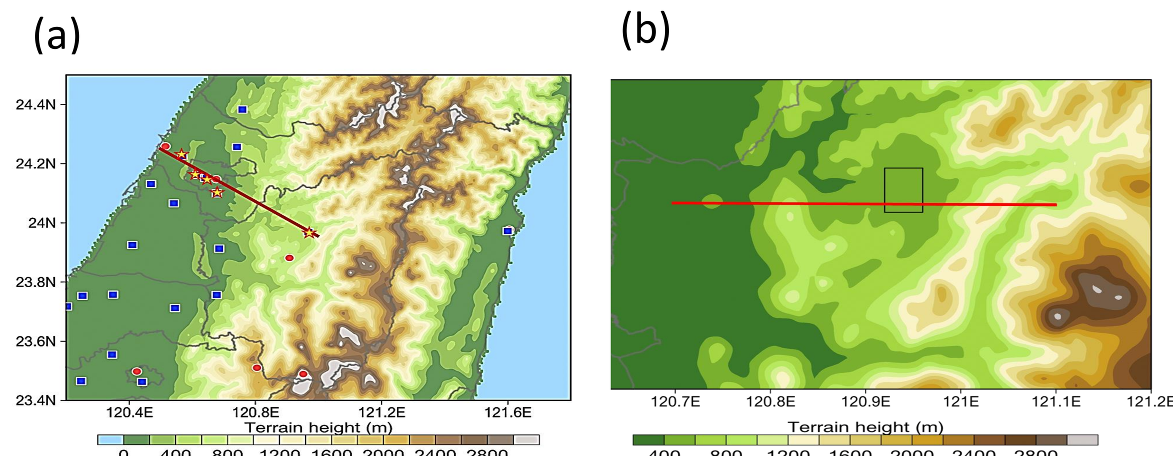

FIG.2. (a) The finest domain in WRF simulation with terrain height (shaded) and the station sites (dot) and (b) the location of Puli basin.

- Model: Community Multiscale Air Quality (CMAQ) model
- Horizontal resolution: 3 km

Structure of upslope wind

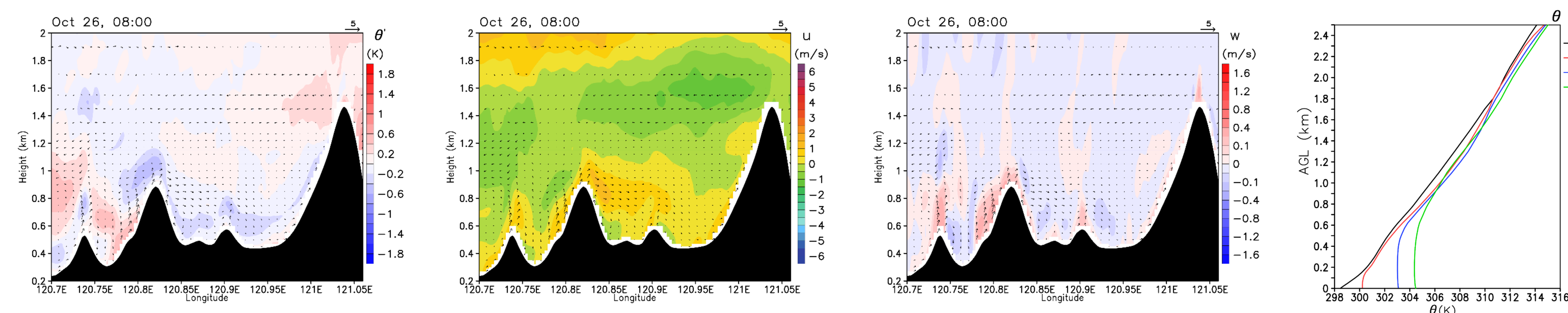

FIG.3. Vertical cross sections of (a)potential temperature anomaly, (b) horizontal velocity in the east-west direction and (c) vertical velocity along the red line in FIG.2(b). (d) Profile of potential temperature averaged over the rectangular area in FIG.2 (b)

Movement of sea breeze front and structure of circulation

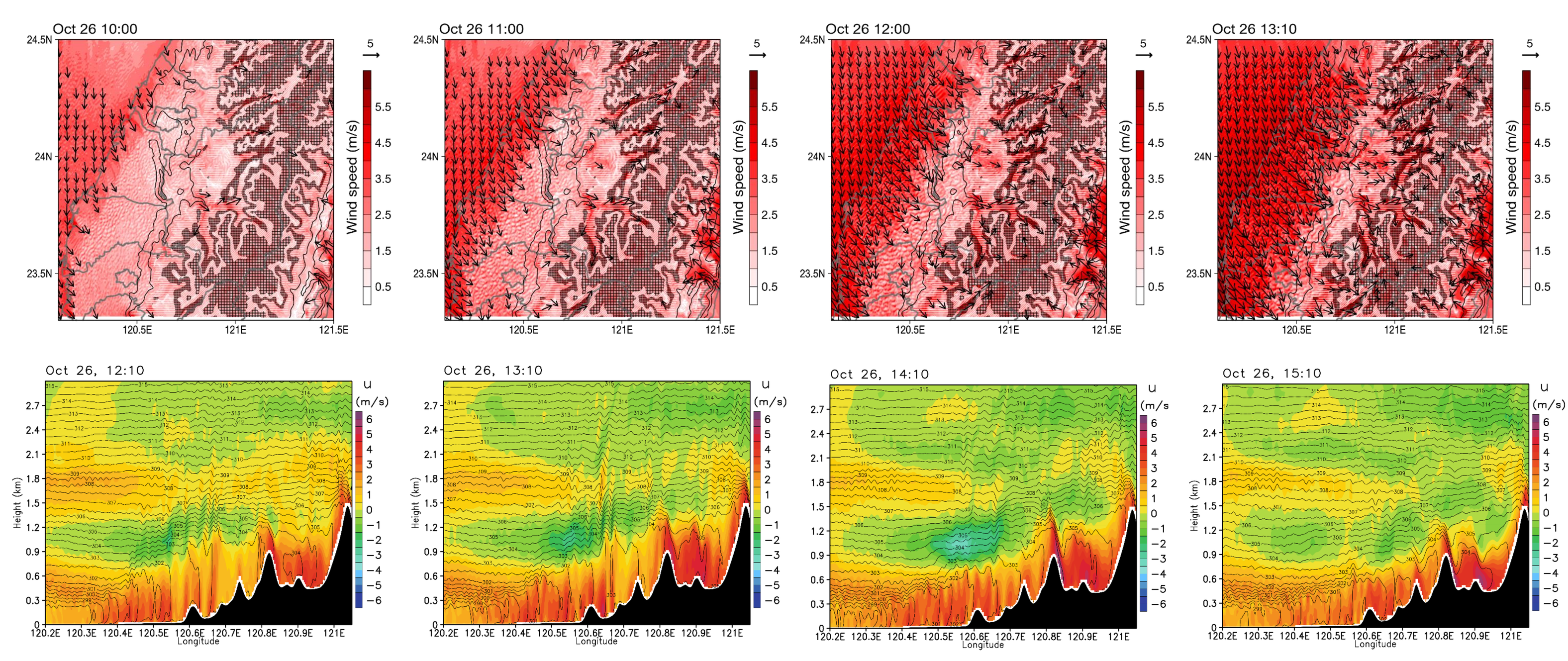

FIG. 4. Vertical cross section of horizontal wind velocity in the east-west direction (shaded) and potential temperature (black line) along the red line in FIG.2(b)

Nocturnal local circulation in Puli basin

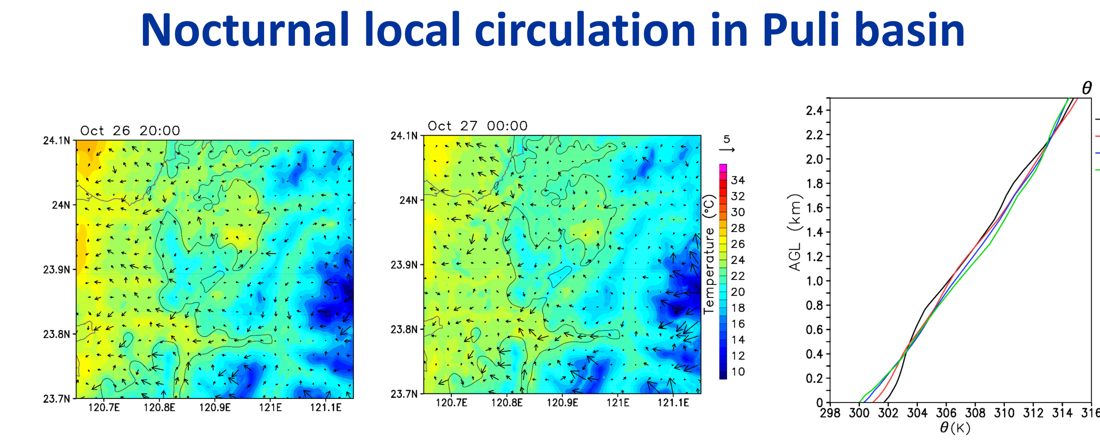

FIG.5. (a) Field of wind (vector) at 10 m and air temperature near the surface (shaded), and (b) profile of potential temperature averaged over the rectangular area in FIG.2.(b)

Evolution of PBL structures in Puli basin

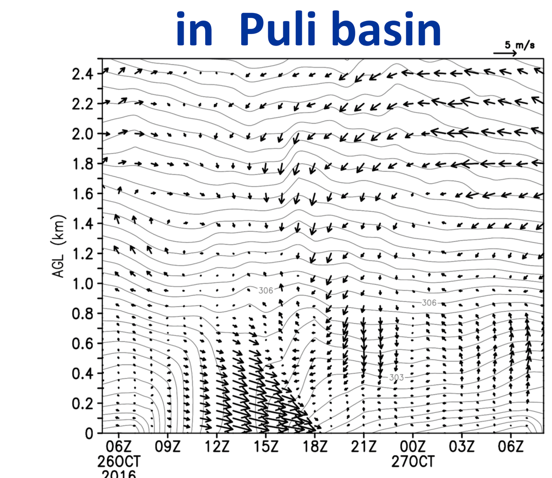

FIG.6. Time-height cross section of horizontal wind (vector) and potential temperature (grey line) averaged over the rectangular area FIG.2 (b). The contour interval of potential temperature is 1 K.

Influence of local circulations and boundary layer on air pollutants dispersion

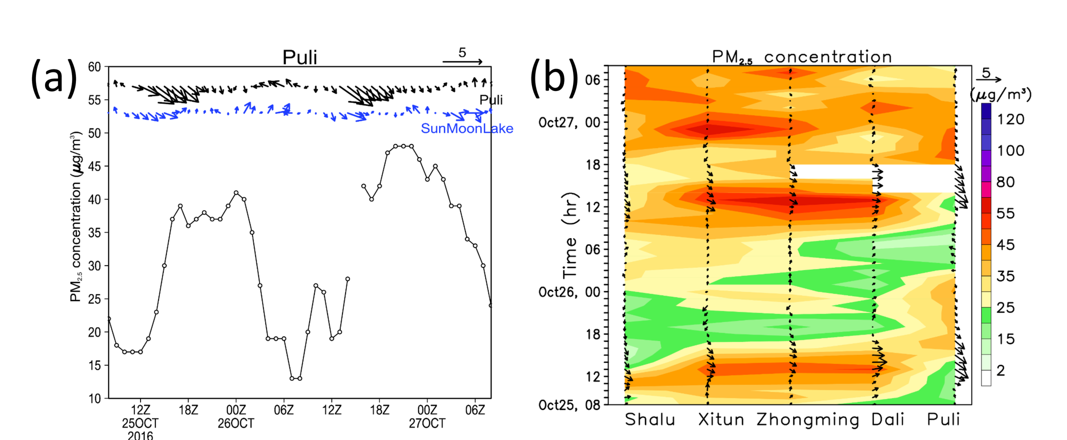

FIG.7. (a) Time series of $PM_{2.5}$ concentration (line) and surface wind (black vector) recorded by Puli station and wind at 10 m (blue vector) recorded by Sun Moon Lake station, and (b) the observed $PM_{2.5}$ distributions (shaded) and wind vector (m/s) from October 25-27, 2016 in Hovmoller diagram. The stations include Shalu, Xitun, Zhongming, Dali and Puli shown in FIG.2 (a).

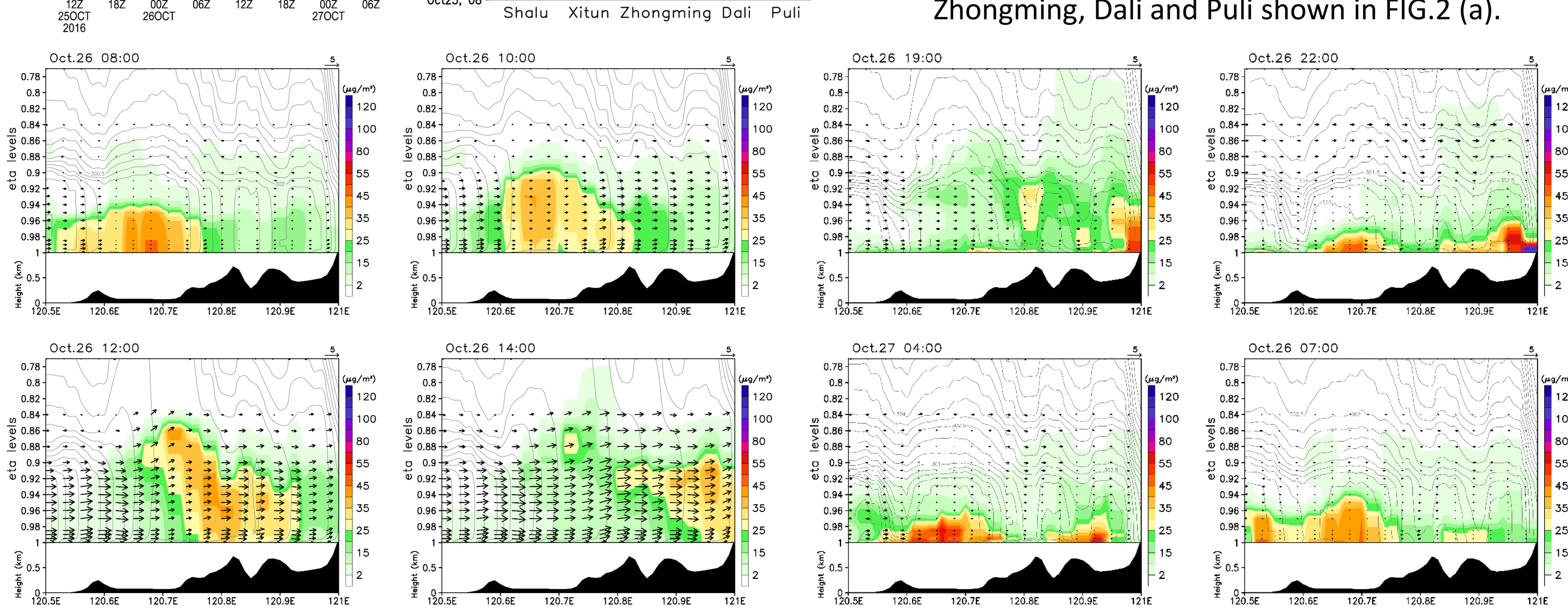

FIG.8. Vertical cross section of simulated PM2.5 concentrations (shaded), potential temperature (contour) and horizontal wind along the red line (vector) in FIG.2 (a).

- Air pollutants were transported into Puli by sea breeze and the $PM_{2.5}$ concentration increased rapidly in the afternoon.
- The $PM_{2.5}$ concentration remained high until midnight because the air pollutants were trapped by the inversion layer, but transported plainward with the onset of the mountain wind.
- After sunrise, with the development of convective boundary layer, the vertical mixing became strong and diluted the $PM_{2.5}$ concentration near the surface.

Summary

- With the weak synoptic forcing, local circulations and planetary boundary layer are two important factors influencing air pollutants dispersions.
- The sea breeze typically form and air pollutants are transported toward the inland mountain area.
- Air pollutants tend to be accumulated near the surface during the night because of the surface inversion layer associated with radiative cooling process and cool air advection.
- In the daytime, the solar heating and the subsiding warming induced by upslope winds above the basin bottom can increase the air temperature in the basin and break the inversion layer forming in the previous night.
- With development of convective boundary layer, strong vertical mixing can transport pollutants into higher level and dilute the $PM_{2.5}$ concentrations near the surface.