Atmospheric Pollution Research 5 (2014) 179-188

Atmospheric Pollution Research

www.atmospolres.com

Ambient carbon dioxide concentrations in industrial park areas: A monitoring and modeling study

Kuo–Ying Wang [1], Jia–Lin Wang [2], Wen–Tzu Liu [2]

[1] *Department of Atmospheric Sciences, National Central University, Chung–Li, Taiwan*
[2] *Department of Chemistry, National Central University, Chung–Li, Taiwan*

ABSTRACT

Industrial parks are main sources for the fossil–fuel burning carbon dioxide (CO_2) emissions. In this work we describe a monitoring and modeling study of ambient CO_2 concentrations in two industrial park areas in Taiwan in 2011 and 2012. We used 1–minute high time resolution measurements to help better resolve time–varying plumes of air abundant in CO_2 than the traditional one–hour average data. The inclusion of span–one and span–two CO_2 calibration air traced back to the World Meteorological Organization (WMO) primary standards in the measurement system enabled us to persistently produce consistently calibrated CO_2 measurements over various industrial parks. We use a small scale Lagrangian model and two–dimensional (2D) observational winds to associate ambient CO_2 measurements with local emission sources. Given the closeness of our monitoring sites to the industrial parks, our 2D Lagrangian calculation can genuinely represent direction of pollution dispersion from the emission source. We focused on cases when vertical transport is weak and the emissions from the industrial parks are kept close to the surface. These much polluted cases were the targets of our 2D Lagrangian calculations. The model simulations with emissions from industrial park areas showed close resemblance between peak modeled results and observed CO_2 levels at measurement sites. These comparisons revealed both the local and non–local effects on the dispersion of CO_2 from industrial park areas. Our results vindicate the values of deploying high time–resolution CO_2 analyzers combined with high resolution modeling to determine the relative importance of local and long–distance sources of CO_2 emissions.

Keywords: *Carbon dioxide, industrial park, monitoring, modeling, emissions*

Corresponding Author:
Kuo–Ying Wang
☎ : *+886-3-280-4420*
🖷 : *+886-3-280-4420*
✉ : *kuoying@mail.atm.ncu.edu.tw*

Article History:
Received: 17 September 2013
Revised: 26 November 2013
Accepted: 27 November 2013

doi: 10.5094/APR.2014.022

1. Introduction

An industrial park is a designated area where industrial factories are concentrated for the purpose of efficient industrial manufacturing and production of goods for commercial purpose (Hsu and Chiang, 2001; Saxenian, 2002; Guerrieri and Pietrobelli, 2004). As such, industrial parks are hallmarks for the fossil–fuel burning based economy.

Most of previous works on CO_2 monitoring and modeling studies concern about unpolluted background atmosphere (e.g., Miles et al., 2012). However, in the context of climate change, monitoring and modeling atmospheric CO_2 levels around the industrial areas are important steps in quantifying and validating amount of CO_2 emissions from these industrial activities (Worrell et al., 2009). This is indeed a highly desirable goal if we are able to quantify CO_2 emitted from these industrial areas each year based on the use of monitoring data from a network of CO_2 monitoring sites (e.g., Miles et al., 2012; Sloop and Novakovskia, 2012). A step toward realizing that goal is to actually conduct CO_2 measurements in the industrial park areas, and to develop model to understand what the measurements tell us about the sources of emissions (Vine and Sathaye, 1997; Vine and Sathaye, 2000; Nisbet and Weiss, 2010; NRC, 2010; Duren and Miller, 2011). Monitoring and modelling are also important methods to help verifying effectiveness of intensive industrial CO_2 emission capture (e.g., Gale, 2004; EPA, 2013).

Taiwan contains 100 dedicated industrial parks (see MOEAIDB, 2013). Ambient air monitoring stations have been set up around Taiwan to help provide continuous measurements of air quality (Fang and Chen, 1996; Yang, 2002). These monitoring data are very valuable for providing real–time air quality information to help protect public health (Jacobson, 2008). However, these ambient air monitoring stations are not located in the close vicinity of industrial parks. Also, CO_2 is not regularly monitored as other air pollutants such as carbon monoxide, ozone, nitrogen oxide, sulfur dioxide, methane, non–methane hydrocarbons, PM_{10}, $PM_{2.5}$, and total suspended particles (Fang et al., 2002; Lin et al., 2004; Yang et al., 2005). In this work we describe a methodology of monitoring and modeling of ambient CO_2 concentrations in two industrial park areas in Taiwan in 2011 and 2012. The purpose of this methodology is that it can be used to quantify ambient CO_2 concentrations in the industrial areas, and to identify the sources of immense CO_2 emissions.

2. Data and Methods

2.1. Monitoring sites and periods

Two industrial park areas were used in the setup of continuous monitoring of ambient CO_2 concentrations. The Formosa Industrial Park area (120.21°E and 23.81°N) (Lin et al., 2008; see also FHI, 2013) is located in Mailiao area in the central south Taiwan (Figure 1). A monitoring site 15–km northeast of the industrial park was set up during the period 20 May–22 June 2011 at the Meifong elementary school. The Formosa industrial park contains 61 plants and a port, covering Taiwan's upstream oil refining to downstream petro–chemical products (e.g., phenol, polycarbonate, etc.) (Hu and Chen, 2012). The power plants in

Mailiao ranked 6th in the world in 2007, emitted around 29 million tones of CO_2 per year (Tollefson, 2007).

The second monitoring site is set up in the Hsinchu Industrial Park area (121.01°E and 24.87°N; Figure 2; see also HSP, 2013), located in the central north Taiwan. The Hsinchu monitoring site is located in the service center of the industrial park during the period 6 June–8 July 2012. Hsinchu Industrial Park contains 450 factories, and is a major industrial park in northern Taiwan (MOEAIDB, 2013).

2.2. Ambient CO_2 monitoring

CO_2 analyzers. The method used for ambient CO_2 monitoring is described in details in Wang et al. (2010a; 2010b) and Wang et al. (2011a; 2011b). Here we briefly outline the procedures for setting up a CO_2 monitoring site for this work. In this work we used an updated version of gas filter correlation non–dispersive infrared analyzer (EC9820T, ECOTECH) (Wang et al., 2011a). The analyzer used in this work has a lower detectable limit of 2 ppmv (parts per million by volume) or 0.2% of concentration reading, whichever is greater. The precision is 10 ppmv or 1% of reading (whichever is greater). The noise (root–mean–square) during the measurement process is 1 ppmv or 0.1% of concentration reading (whichever is greater). The EC9820T CO_2 analyzers that we have operated since 2010 contain two–span capability, one in low CO_2 concentration (350–375 ppmv) and the other in high CO_2 concentration (550–575 ppmv). To the best of our knowledge, the updated EC9820T is now the only commercially available CO_2 analyzers of the world that are capable of performing the tasks of measuring zero, 2–span CO_2 calibration gases, and air samples (see Figure S1) all in a self–contained unit. No external units such as a data logger are needed. Two methods are mostly applied to monitoring CO_2 in the atmosphere: the infrared (IR) based non–dispersive IR method (NDIR; ECOTECH, 2007), and the laser–based cavity ring–down spectroscopy method (Picarro, 2011; Richardson et al., 2012). The NDIR analyzers does not cost as much as the laser analyzers. Hence, we have used NDIR analyzers as the main instruments for a network of CO_2 monitoring over industrial park areas (as described in this work), and laser analyzer in the laboratory for calibrating CO_2 working standards and for comparison with the NDIR analyzers.

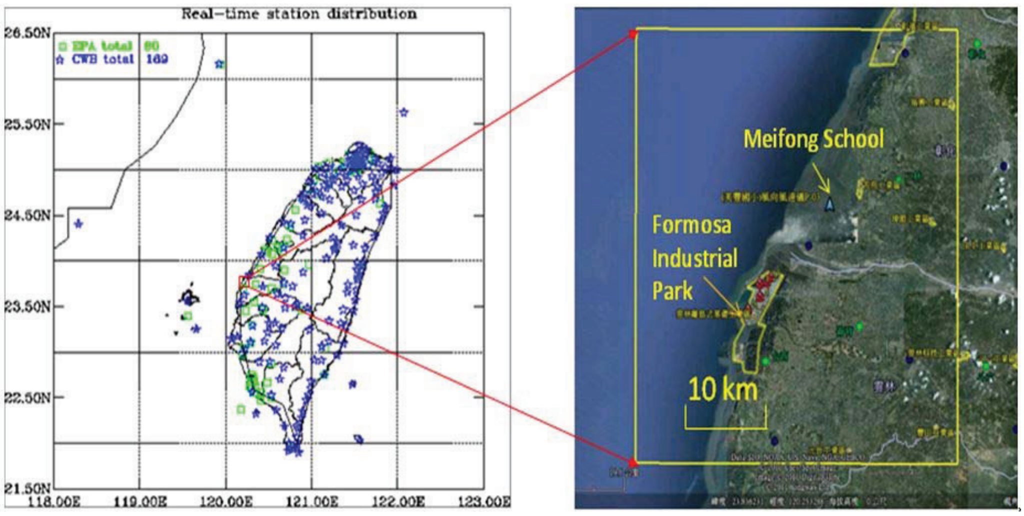

Figure 1. The Formosa industrial park area (right panel), and the distribution of wind stations (left panel). Red symbols in the industrial park area indicate locations for model particle emissions.

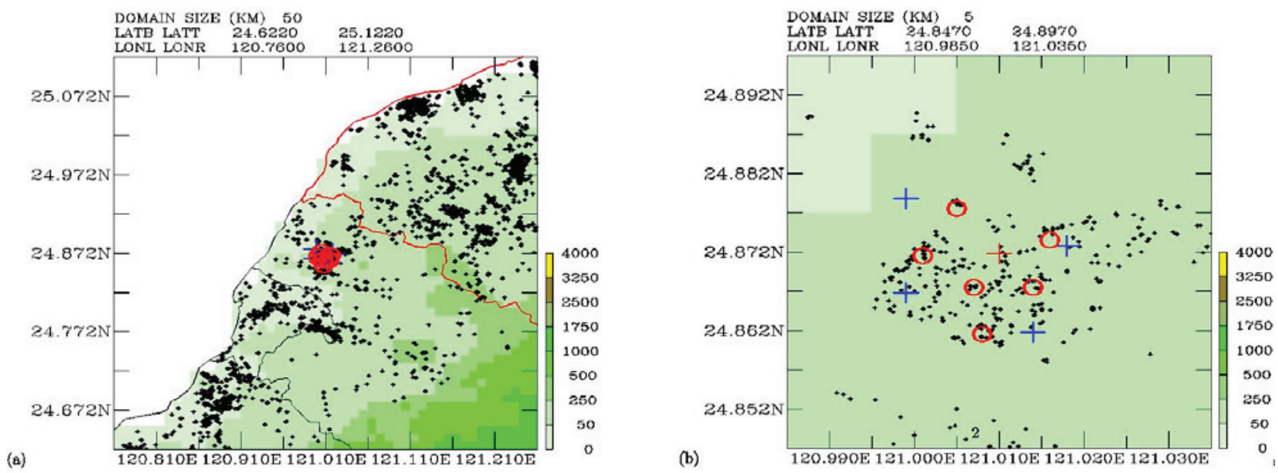

*Figure 2. Location of the Hsinchu Industrial Park area (indicated by blue crosses and red circles) in **(a)** a 50×50 km domain size of the central north Taiwan, and **(b)** an enlarged 5×5 km domain. Blue crosses represent sites with wind sensors, red crosses represent the industrial service center where both a CO_2 analyzer and a wind sensor were installed. Red circles indicate sites for model emissions. Major point sources are shown as small black crosses. Shaded colors indicate terrain height (m).*