Three cruises of South China Sea observe pollutants and use the eddy covariance technique over sea to derive fluxes

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Abstract

We will apply this technique for our data over sea. We have conducted measurements over the South China Sea during 3 cruises (OR1-728, OR1-802 and OR3-1149). From the observations, the albedo and near-surface air pollutant concentrations were measured. These data can be used for meteorological model and air quality model as the lower boundary conditions over the South China Sea. During the OR1-728 cruise the calculated vertical flux derives from resistance dry deposition, and observation vertical flux is evaluated from concentration gradient. We define vertical flux plus in upward position. All of average pollutants' flux is negative. It tells us that pollutants on South China Sea have sink phenomenon. The ratios of fluxes between observation and calculation range from 0.13 to 1.5. Provided that we only take downward flux, observed CO_2 vertical flux can reach -0.26 mg m^{-2} s^{-1} as Table 1. On the other hand the standard deviation of CO_2 flux has greatest gap among pollutants. During the OR3-1149 cruise, the average atmosphere longwave radiation was 315 W m^{-2}, the average terrestrial longwave radiation was 364 W m^{-2}, and the peak solar shortwave radiation was about 960 W/m^2 at 11:30 am. During OR1-802 cruise, it's found that the concentration of CO_2 was between 370 ppm and 400 ppm as see Figure 1. The concentration of SO_2 was about 3 - 5 ppb at the harbor, but it decreased to 1 - 2 ppb over sea. On the other hand the standard deviation of CO_2 flux has greatest gap among pollutants. the concentration of O_3 was about 10 - 30 ppb, and the concentration at noon was slightly higher than the other time periods. It was obvious that NO and NO_2 concentration were much higher than those offshore which rose to 10 - 30 ppb, when the vessel was near dock. On the contrary the vessel cruised the SCS; NO and NO_2 was lower than 10 ppb.

Eddy Covariance System (ECS) was installed onboard as see Figure 2 and Figure 3, we define vertical flux plus in upward position. All of average pollutants' flux is negative. It tells us that pollutants on South China Sea have sink phenomenon. Compare with observation/ calculation flux, we get high relevant ratio on pollutant flux, which distribute between 0.13 and 1.5. Provided that we only take downward flux, observed CO_2 vertical flux can reach -0.26 mg m^{-2} s^{-1}. On the other hand the standard deviation of CO_2 flux has greatest gap among pollutants. Incidentally CO observed flux is smaller than calculated flux by one order.

Introduction

Ocean provides the largest surface area for air pollutants to sink. Observations of air pollutants over oceans provide background data of the boundary conditions for air quality models and for understanding the exchange rates of the pollutants between the atmosphere and oceans. Near-surface airborne pollutant (such as SO_2, CO, O_3, NO and NO_2) except for CO_2 observations over the South China Sea, to the authors' knowledge, is very few. In contrast, there were a few studies over the other oceans (Tokioka, 1995; Okita et al., 1996; Bazhanov et al., 1996; Tsutsumi et al., 1996; Streets, 1997; Bacastow et al., 1997; Wong et al., 1997; Brostrom, 2000; Leung et al., 2000; Saio et al., 2000; Kesgin et al., 2001; Kim et al., 2001; Sinha et al., 2003; Alvala et al., 2004; Marmer et al., 2005). This study tries to fill the gap.

Eddy Covariance System (ECS) was installed onboard during OR1-728, OR3-1149 and OR1-802 cruises. It was installed at 12.12 m above the sea surface during the OR1-802 cruise. Sensible heat flux, latent heat flux and CO_2 flux were measured. The ECS consists of 2 fast-response instruments: a 3-D ultrasonic anemometer (Young 81000 or CSAT3) and an open path infrared hygrometer/CO_2 sensor (LICOR 7500). The anemometer measures three orthogonal wind components (u, v, w) and the speed of sound. The open path infrared hygrometer/CO_2 sensor measures the concentrations of CO_2 and water vapor. In addition, Gyro enhanced Orientation sensor (3DM-G) was located close to the 3-D anemometer, used to measure the ship movements (roll, pitch, yaw), to covert anemometer to the earth reference frame. And all the data were sampled via a datalogger (CR5000), and then used a transmission line to connect with a computer for storage.

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Table 1. Measurement summary during the OR1-728 cruise.

		NO	*NO_2*	*SO_2*	*CO*	*O_3*	**CO_2**
Sc		0.93	1.03	1.01	0.93	1.04	1.02
D (m^2 s^{-1})		1.71E-05	1.53E-05	1.44E-05	1.71E-05	1.71E-05	1.54E-05
Kw (m s^{-1})		0.0051	0.0048	0.0047	0.0051	0.0048	0.0048
F***	calc	-0.014	-0.019	-0.0062	-0.0028	-0.056	-0.035
(g m^{-2} s^{-1})	obs**	-0.010	-0.020	-0.0063	-0.00035	-0.084	-0.014
Plus upward	obs /calc	0.71	1.05	1.02	0.13	1.5	0.4

*The averages of observation V_d only take plus values.
** The averages of observation F only take negative values.
***The unit of vertical flux in CO and CO_2 is mg m^{-2} s^{-1}.

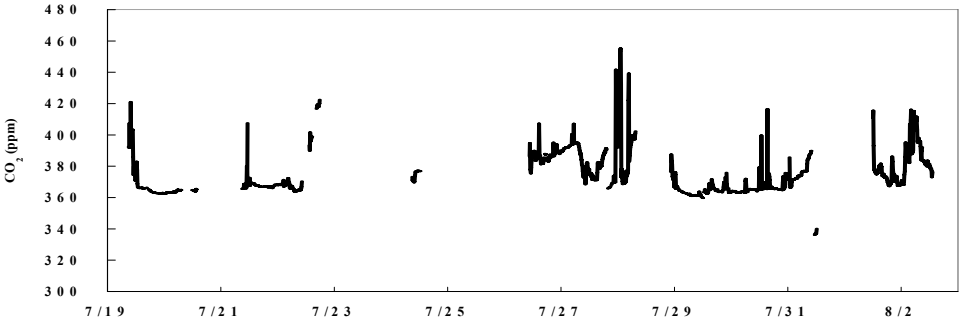

Figure 1. Time series of the observed concentrations of CO_2 during OR1-802 cruise in 2006.

Figure 2. (left) Eddy covariance system installed in OR1 during the OR1-802 cruise at the Kaoshiung Harbor on 18 July 2006. The flux was measured at 12.12 m above the ocean surface. The two boxes in the lower mast were the control box of infrared hygrometer and Datealogger (CR5000); (right) Three-axis sonic anemometer (Young 81000) and infrared hygrometer (LICOR 7500) used to measure the fluxes.

Figure 3. Short-wave and long-wave radiation measurements in OR1 during the OR1-802 cruise at the Kaoshiung Harbor on 18 July 2006.