INFERRING CO_2 SOURCE REGIONS USING A LAGRANGIAN TRANSPORT MODEL AND GOSAT RETRIEVED PROFILES

Ronald Macatangay[1*,2], Florian Schwandner[3], Voltaire Velazco[4], Christoph Gerbig[5], Thiranan Sonkaew[6] and Tatsuya Yokota[7]
[1]Institute of Environmental Science and Meteorology, University of the Philippines, Diliman, Quezon City, Philippines
[2]Natural Sciences Research Institute, University of the Philippines, Diliman, Quezon City, Philippines
[3]Atmospheric Observations Group, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California, USA
[4]Centre for Atmospheric Chemistry, University of Wollongong, Northfields Ave., Wollongong, New South Wales, Australia
[5]Max Planck Institute for Biogeochemistry, Hans-Knoell-Str., Jena, Germany
[6]Science Faculty, Lampang Rajabhat University, Lampang, Thailand
[7]Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan

Email: ronmcdo@gmail.com

KEY WORDS: carbon dioxide, satellite, back-trajectories, surface and volume influences, source regions.

ABSTRACT: Retrieved atmospheric carbon dioxide profiles from the Greenhouse gases Observing SATellite (GOSAT) were used in synergy with 3-day back-trajectories of surface and volume influences from the Stochastic Time-Inverted Lagrangian Transport (STILT) model. In this study, terrestrial soundings from GOSAT on the Philippine archipelago as well as on the eastern portion of Malaysia were utilized. Initial results show that potential CO_2 sources maybe identified by aggregating surface and volume influences at different altitude levels. Volume influences also indicate that the measurements maybe impacted by sources from different locations depending upon the wind speeds and directions occurring at the lower and at the upper vertical altitude levels. However, uncertainties are produced when no overlapping influences occur. This makes interpretation of possible source regions difficult.

1. INTRODUCTION

With the advent of the recent floods and typhoons that affected tropical Asia, particularly the Philippines, the need for assessing drivers for these climatic events is now imminent. One of these drivers are the concentrations of greenhouse gases (GHGs) in the atmosphere. Its continued increase has shifted the climate into a new norm, hence its continuous monitoring is essential. GHG concentrations can be measured in situ as well as it can be remotely sensed. This study focuses on the second technique.

Remote sensing of GHGs has the advantage of determining a more general picture of the trace gas concentrations in a particular region. It measures the total column concentration of GHGs. The Greenhouse gases Observing SATellite (GOSAT), launched in January 2009, monitors the global distribution of carbon dioxide (CO_2) from space. It is a joint project of Japan Aerospace Exploration Agency (JAXA), the Ministry of Environment (MOE), and the National Institute for Environmental Studies (NIES). The objective of the undertaking is in response to COP3 (Kyoto Protocol): Observation of Greenhouse Gases, including CO_2, with 1% relative accuracy in sub-continental spatial resolution and to identify GHG sources and sinks from the data obtained by GOSAT in synergy with ground-based data and with model simulations.

Monitoring GHG concentrations from space in the tropics, particularly in tropical Asia, is a very challenging task due to the persistence of clouds and aerosols. However, this is a very important region because sources and sinks of carbon are very strong, and it is the preeminent region for troposphere-stratosphere exchange as part of the general atmospheric circulation. Most water vapor enters the stratosphere through this region. The effective chemical equator, separating northern hemisphere air from southern hemisphere air, travels north to south over this region annually. With the limited data available, this study derives meaningful information on the distribution, sources and sinks of atmospheric carbon dioxide in tropical Asia.

2. METHODOLOGY

In this study, GOSAT retrieved CO_2 profiles over the Philippines and east Malaysia from July 2009 to March 2013 were utilized. However, in this paper, only the July 2, 23 and 24, 2009 soundings (southern Philippines and eastern

Malaysia) are presented. For a particular sounding, the Mauna Loa surface concentration was subtracted from the profile. The profiles were then weighted by the surface and volume influences produced by the Stochastic Time-Inverted Lagrangian Transport (STILT) model to come up with *CO_2 source attributions*. Surface and volume influences, $f(x_i, y_j, t_m)$ in units of ppm μmol^{-1} m^2 s (Gerbig et al., 2003; Lin et al., 2003), relate surface fluxes, $F\left(x_i, y_j, t_m\right)$ (in units of μmol m^{-2} s^{-1}) to changes in concentration, $\Delta c\left(t_m\right) = c\left(t_m\right) - c_o\left(t_m\right)$ (in ppm), at the measurement location or receptor, where $c_o\left(t_m\right)$ is the background concentration. The STILT model was driven by the meteorological fields of the Global Data Assimilation System (GDAS) model (1^O x 1^O) and ran at a horizontal downscaled to a resolution of ~200 km x 300 km for surface influences and at ~20 km x 30 km for volume influences. Three-day backtrajectories were also calculated for both surface and volume influences.

3. RESULTS AND DISCUSSION

Figure 1 shows the CO_2 surface attributions for the July 2, 2009 sounding. For this particular case, only the surface and the 1 km level had surface influences. These two surface influences (the surface and 1 km surface influence) were then averaged. Regions where the surface influences overlap represent potential CO_2 source regions. On the other hand, regions with no surface influence overlap get smeared out.

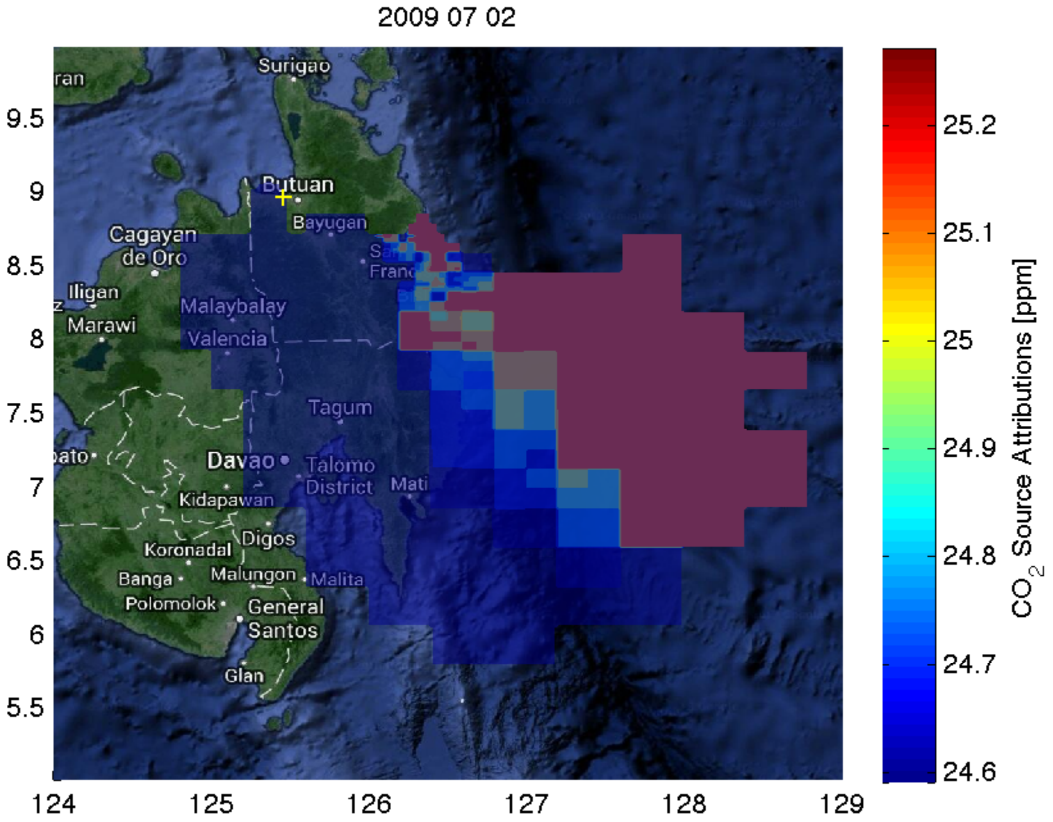

Figure 1. Surface CO_2 Source Attributions for July 2, 2009. The cross (+) represents the sounding location. Surface influences from the surface and 1 km level were averaged (other levels had no surface influence). The colorbar values represent the CO_2 source attributions after the Mauna Loa concentration for July 2009 (July 2009 background) has been subtracted.

Figure 2 shows the CO_2 source attributions for July 23, 2009. It primarily shows a smeared source attribution indicating no overlapping regions for the surface influence (surface and 1 km level). Zooming in to a particular section though, one can see a distinct probable CO_2 source.

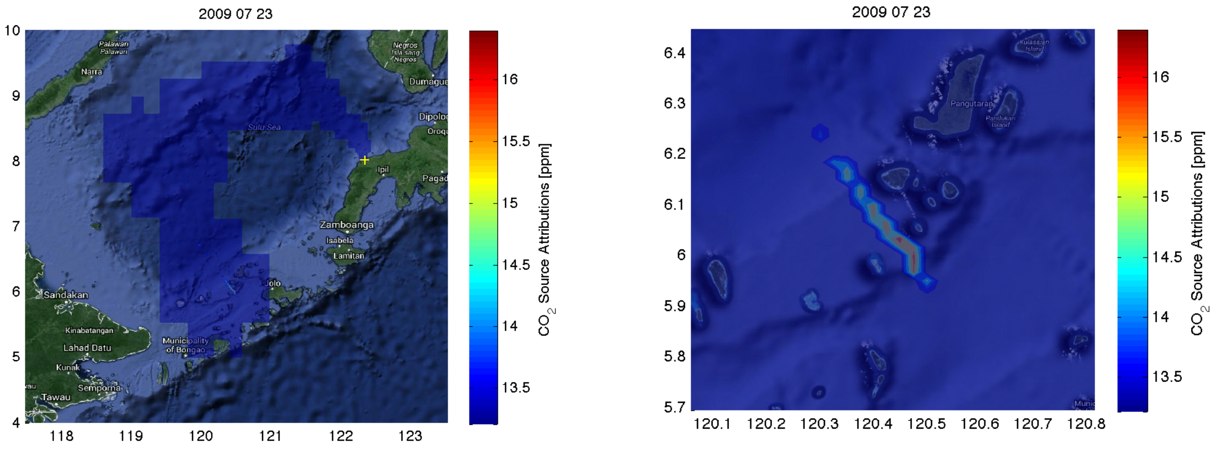

Figure 2. Surface CO$_2$ Source Attributions for July 23, 2009 (left). A zoomed view of the region at around 6^o N and 120.5^o E.

Figure 3 shows the CO$_2$ source attributions for July 24, 2009. For this sounding, surface influences exist from the surface, the 1 km level, the 2 km level, the 3 km level and the 4 km level.

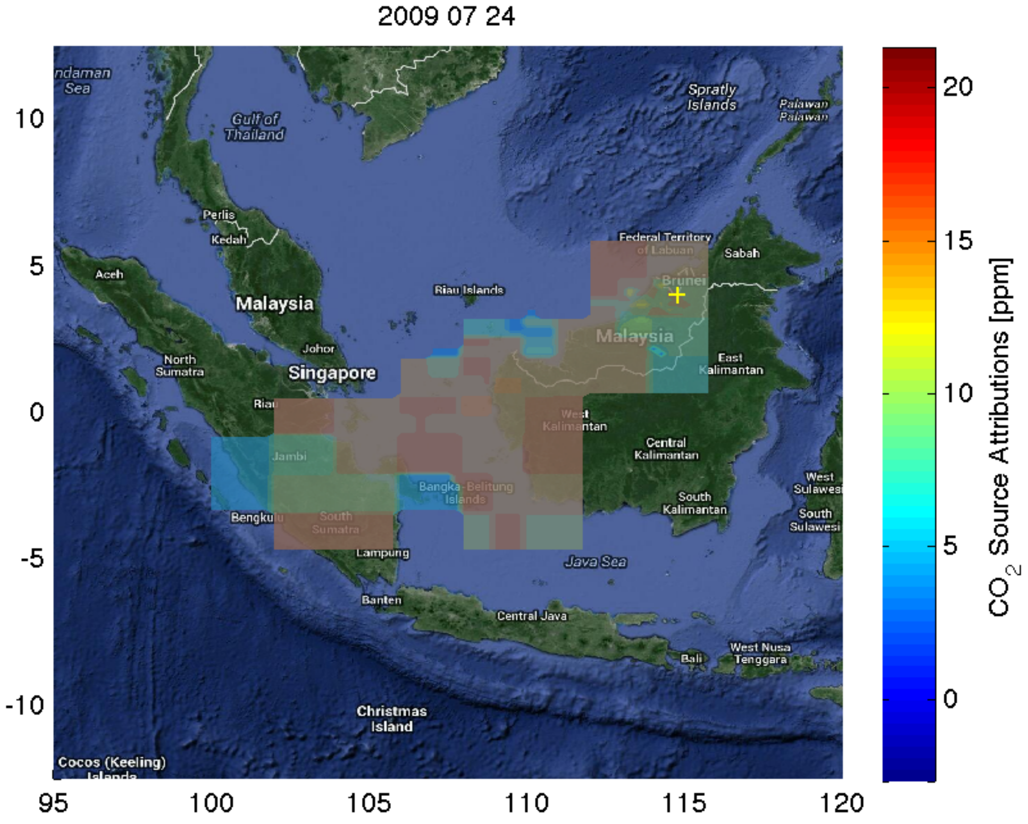

Figure 3. Surface CO$_2$ Source Attributions for July 24, 2009.

Figure 4 shows the CO$_2$ source attributions for July 2, 23 and 24, 2009, this time taking into consideration the volume influences. In these cases, volume influences were averaged from the surface up to 20 km at 1 km intervals. For the July 2, 2009 case, winds at different levels come uniformly from the same easterly direction, which are mostly oceanic influences producing low or sinks of atmospheric carbon dioxide. For the July 23 and 24, 2009 cases, winds come from different directions for different levels. For the lower levels, the winds generally come from the southwest giving out terrestrial sources. For the upper levels, the winds predominantly come from the east, producing oceanic sinks.

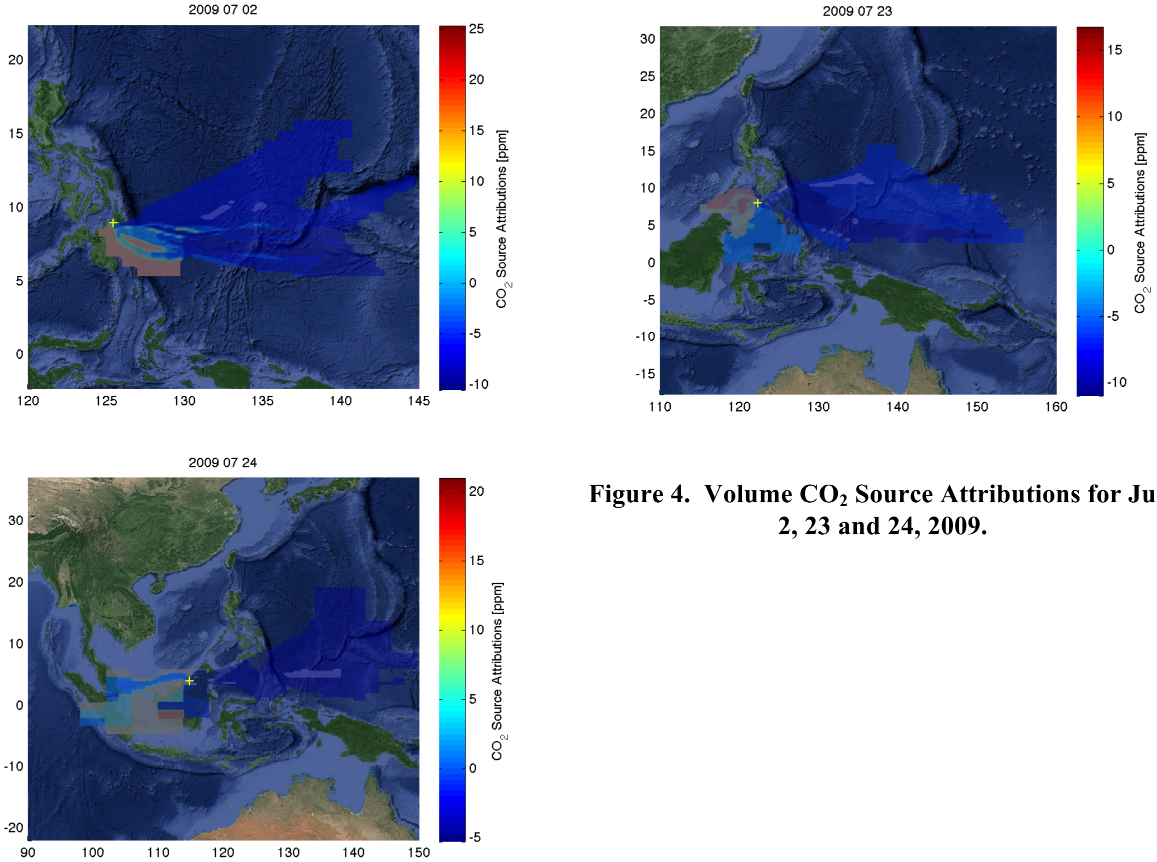

Figure 4. Volume CO$_2$ Source Attributions for July 2, 23 and 24, 2009.

4. CONCLUSIONS AND FURTHER WORK

In this paper, locations and intensities of potential sources and sinks of atmospheric carbon dioxide were inferred from a combination of GOSAT retrieved profiles and by the surface and volume influences derived from the STILT model. However, this method is only effective if the influences at different vertical levels overlap. Otherwise, the inferred *CO$_2$ source attributions* get smeared out. In order to validate the results, power plant, volcano, traffic, landfill, active fire products and brightness temperatures need be overlaid. To increase both the temporal and spatial information, GOSAT island mode data products would have to be considered.

5. REFERENCES

Gerbig, C., Lin, J. C., Wofsy, S. C., Daube, B. C., Andrews, A. E., Stephens, B. B., Bakwin P. S. and Grainger, C. A. (2003). Toward constraining regional-scale fluxes of CO$_2$ with atmospheric observations over a continent: 1. Observed spatial variability from airborne platforms. *Journal of Geophysical Research: Atmospheres*, *108*(D24), n/a–n/a. doi:10.1029/2002JD003018.

Lin, J. C., Gerbig, C., Wofsy, S. C., Andrews, A. E., Daube, B. C., Davis, K. J., & Grainger, C. A. (2003). A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model. *Journal of Geophysical Research*, *108*(D16), ACH 2-1–ACH 2-17. doi:10.1029/2002JD003161.