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Analysis of total column ozone in Peninsular Malaysia retrieved from SCIAMACHY

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ABSTRACT

Due to lack of observational studies on greenhouse gases in Malaysia, most studies in this field were carried out based on ground station data. These studies did not utilize satellite data from the equatorial area. Satellite remote sensing is one of the most effective approaches for greenhouse gas distribution monitoring on a global scale. As such, satellite remote sensing exhibits a very high spatial and temporal resolution. Variations of ozone concentrations in Peninsular Malaysia were observed and investigated by means of data retrieved from the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY). The aim of this study was to determine the monthly and seasonal ozone concentrations in Peninsular Malaysia from January 2003 to December 2009. We utilized total column ozone at level 2 of the WFMD version 1.0. A spatial resolution value of 1°x1.25° was used. Analysis indicated that the five selected sites exhibited strong seasonal atmospheric ozone concentration variations. These variations resulted from the significant differences between the northeast monsoon (NEM) and the southwest monsoon (SWM). As the NEM prevails, cold air breaks out from Siberia and spreads to the equatorial region in the form of northeasterly cold surge winds. These winds manifest in low–level anticyclones over Southeast Asia. Inversely, the air masses from the southwest contribute to long–range air pollution. During SWM, the transport of atmospheric ozone by wind is associated with biomass burning in Sumatra, Indonesia. HYSPLIT was also utilized to identify the air pollutant transport between NEM and SWM toward Peninsular Malaysia. Comparisons were made between the ozone data from five sites in 2009. Data were retrieved from SCIAMACHY and the Atmospheric Infrared Sounder (AIRS). The relative difference average of the ozone data measured by SCIAMACHY and AIRS was approximately 6%.

Keywords: *Ozone, Peninsular Malaysia, SCIAMACHY, AIRS*

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1. Introduction

Increasing tropospheric ozone concentrations have received much attention because of their inherent capability of degrading air quality and causing hazardous human health and ecosystem effects (Freijer et al., 2002; Kim et al., 2004; Karnosky et al., 2007). Ozone is the most important indicator of photochemical smog; it is a secondary pollutant that is formed in the presence of precursor compounds [volatile organic compounds (VOCs) and nitrogen oxides (NO_X)] and sunlight (Pulikesi et al., 2006). Most of VOCs are anthropogenic and the biogenic sources of VOCs are at least as important as anthropogenic ones. VOCs are emitted from various sources such as motor vehicles and other industrial sources. Ozone is also the most abundant photochemical oxidant in the troposphere (Solomon et al., 2000). Ozone has the capability to oxidize other gases present in the atmosphere after the process of photolysis because of its very nature (Duenas et al., 2004). Thus, many factors affect atmospheric ozone concentrations. These factors pertain to meteorological parameters (temperature, wind speed, humidity, solar radiation, wind direction, and precipitation), atmospheric chemistry, precursor emission concentrations, dry deposition, and turbulent mixing (Chatterton et al., 2000).

Ozone at the ground level is a harmful pollutant. In this state, ozone can damage human health, vegetation, and other living organisms. Ozone alters molecules and gradually destroys these entities (Shan et al., 2008). Inversely, stratospheric ozone is considered good for humans and other living forms because it protects the biosphere from harmful ultraviolet radiation (Bracher et al., 2005). Approximately 90% of atmospheric ozone is contained in the "ozone layer". This layer protects us from the harmful ultraviolet radiation resulting from sunlight. Stratospheric ozone absorbs all of the UV–C, and a large amount of UV–B (Bian et al., 2007). The resulting increase of ultraviolet radiation on the Earth's surface is largely from ozone layer depletion. The depletion of ozone in this layer may cause high rates of skin cancer and eye cataracts. These diseases stem from the induction of chemical reactions between high–energy photons and exposed surfaces. In addition, excessive exposure to ultraviolet radiation can damage single–cell organisms, aquatic ecosystems, and terrestrial plant life (Jasim et al., 2010). Hence, the ozone can be considered as a form of beneficial ultraviolet protection in the stratosphere; however, it remains harmful to human beings at the ground level (Lu and Wang, 2006).

Climate change has become a hot issue of discussion. The abrupt shift in atmospheric global greenhouse gases influences climate change. Stratospheric ozone and tropospheric ozone have opposite effects on climate change. Stratospheric ozone can significantly enhance greenhouse effect with relatively small concentration shifts. This potential outcome results from the fact that ozone absorbs infrared radiation in the atmosphere (Shan et al., 2008). Solar irradiation, aerosols, and greenhouse gases in the atmosphere are important climate control variables (Lau et al., 2009). Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O). Ozone in the Earth's atmosphere contributes for 3–7% to greenhouse effect. Results from numerous previous research and investigations showed that the ozone concentration in the Earth's atmosphere is changing. A consensus was reached based on the increase of background levels. However, in recent decades, observations

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showed that a divergent global tropospheric ozone trend has emerged, and is most evident in the north hemisphere (Vingarzan, 2004; Zouzoulas et al., 2009).

Southeast Asia is one of the most heavily populated regions in the world. This region has a vibrant mixture of cultures. Aside from this fact, Southeast Asia greatly contributes to regional and global pollution (Jasim et al., 2011). Anthropogenic emissions and biogenic emissions from large tropical forests increase pollution. Malaysia, a tropical Southeast Asian country, has undergone rapid economic development and urban expansion. In addition, transportation facilities have increased fossil fuel consumption in the past few decades. As such, the establishment of these facilities has resulted in an increase in air pollutant emissions. The situation is most evident in industrial areas and cities. Malaysia is located in the equatorial region, so the country experiences humid tropical weather with heavy rainfall and high temperatures (Tangang et al., 2007; Mahmud and Kumar, 2008). Thus, during the rainy season, cloud conditions become an obstacle in acquiring high–resolution satellite data.

The amount of ozone in the atmosphere is measured by instruments on the ground level (sparsely distributed measurement sites). These instruments are thereafter set aloft on balloons, aircrafts, and/or satellites. Through ground and aircraft measurements, observations are only limited to the surface. As such, measurements are more sensitive to sources and sinks. However, these same instruments are unable to make evaluations based on daily global variations (Clerbaux et al., 2003). Satellite data acquired from remote sensing techniques have good spatial and temporal resolutions, as well as global area coverage (Tan et al., 2010; Tan et al., 2012). Through this means of measurement, we enhance our ability to investigate the influence of human activities on atmospheric chemistry and climate change (Dousset and Gourmelon, 2003).

2. Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) Instrument

SCIAMACHY is the first satellite instrument that can obtain measurements which are precise and sensitive to all greenhouse gases. This imaging means allows for the observation of altitude levels down to the Earth's surface (Schneising et al., 2008). ENVISAT is involved in SCIAMACHY as part of the atmospheric chemistry payload of the third European Space Agency (ESA) Earth observation. ENVISAT flies at an altitude of 795 km above the surface of the Earth. The satellite is synchronous to the polar orbit and passes by the equator with a descending node at 10:00 am local time. One orbit takes about 100 min, for a total of 14.3 orbits per day. SCIAMACHY is a passive remote sensing instrument that measures reflected, scattered, and transmitted solar radiation in the atmosphere. SCIAMACHY comprises eight spectral channels between 240 and 2 380 nm at a moderate spectral resolution with values between 0.2 and 1.5 nm (Bracher et al., 2005). Total ozone retrieval exists between 325 and 335 nm at a spectral resolution of approximately 0.2 nm. The extraordinary of SCIAMACHY as compared with other satellites is based on the spectroscopic observations that alternate between nadir and limb viewing geometries. In terms of the total column ozone retrieved from SCIAMACHY, the effective spatial resolution varies from 30 km along track and from 30 km to 240 km across the track (Bovensmann et al., 1999).

At the Institute of Environmental Physics (IUP) of the University of Bremen, Germany, scientists developed an algorithm called weighting function modified differential optical absorption spectroscopy (WFM–DOAS). This technology was developed to retrieve total column ozone SCIAMACHY nadir spectra (Stephens et al., 2007). WFM–DOAS can directly retrieve vertical column ozone largely due to its vertically integrated ozone weighting functions. These functions are compared with ozone cross–sections of sun–normalized radiances (Coldewey–Egbers et al., 2005). In addition, WFM–DOAS also considers slant column path length modulation as a wavelength function. The standard DOAS algorithm generally ignores this consideration.

3. Study Area and Methods

The study area of Peninsular Malaysia is located within latitudes 1° to 7° North and longitudes 99° to 105° East. Malaysia is located in Southeast Asia (south of Thailand, north of Singapore, and east of the Indonesian island of Sumatra). The area of Peninsular Malaysia is approximately 131 587 km^2, with an estimated population of 21 million (Tan et al., 2010) (Figure 1). The five selected sites are presented in Table 1.

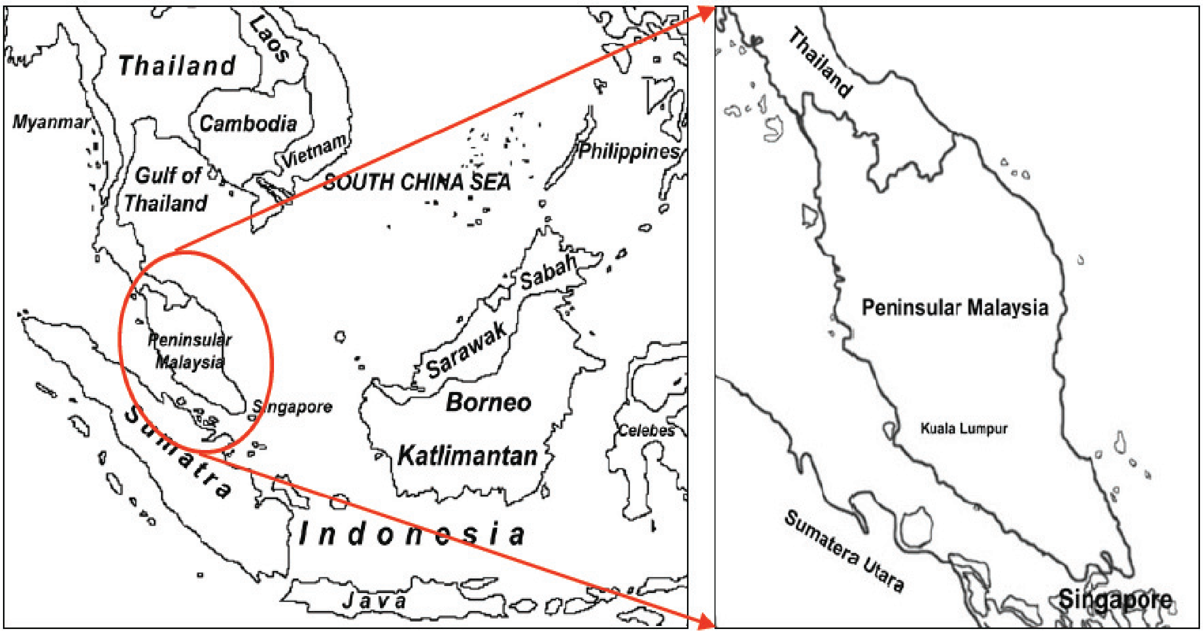

Figure 1. *Geographical features of the study area.*

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