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Daily distribution Map of Ozone (O_3) from AIRS over Southeast Asia

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Abstract: Problem statement: Daily retrieved Ozone (O_3) column data for 12 day for periods varying (11-18 August) 2005 and 2003 and (12-19 February) 2005, obtained from the Atmospheric Infrared Sounder AIRS, are utilized to investigate the ozone distribution over the Southeast Asia. **Approach:** AIRS included on the Earth Observing System (EOS) Aqua satellite launched on 4 May 2002. Ozone (O_3) is the gas that naturally present in our atmosphere and is a critical atmospheric trace species in the stratosphere and troposphere. Most ozone resides in the stratosphere. Ozone can be "good" or "bad" for your health and the environment. Closer to Earth, in the air we breathe, Ozone is a harmful pollutant that causes damage to lung tissue and plants; it is a major constituent of smog. **Results:** The aim of this study was to investigate Daily Distribution map and Indonesia forest fires influences on O_3 over Peninsular Malaysia and Thailand. The land use map of the study area was conducted by using total column O_3 obtained from AIRS/Aqua Level 3 Daily (AIRX3STD) 1×1° spatial resolution ascending Standard, are used to study the O_3 distribution and the impact of Indonesia forest fire. Considerable variations demonstrate annual changes in rainfall and drought patterns in various seasons (dry and wet season). Note such variations in the Ozone emissions over study area, while highest O_3 occurs over Industrial, congested urban zones and existence of Swamps and lakes during dry season and a greater draw down of O_3 occurs in the pristine marine environment over Surat Thani during wet seasons. **Conclusion/Recommendations:** In particular, we observe a quasi-biennial variation in O_3 emissions from study area with two contrary cases, the higher concentrations around the equatorial regions at dry season and less at wet season. Examining satellite measurements, we find the enhanced O_3 emission correlates with occasions of less rainfall during dry season.

Key words: AIRS, ozone, peninsular Malaysia, AMSU, Indonesia forest fires

INTRODUCTION

Many gases occur naturally in the atmosphere while others are synthetic, due to the industrial revolution began in the mid 1700s, both the natural and man-made Atmospheric concentrations gases have been raising over the last few centuries. Tropospheric ozone is central and highly reactive to many chemical transformations. Stratospheric ozone forms a protective shield that absorbs enough solar ultraviolet radiations to make life possible on the surface of the earth (Bian *et al*., 2007). Ozone (O_3) is the gas that naturally present in our atmosphere and because of its good absorption of infrared radiation it considered an important and essential greenhouse gases. In the presence of sunlight when emissions of Nitrogen Oxides (NOx) combined with emissions of Hydrocarbons (HC), including volatile organic compounds (VOCs), react to form ozone (O_3) (Morris *et al*., 2006). There, about 90% of atmospheric ozone is contained in the "Ozone layer," which shields us from harmful ultraviolet radiation from the Sun (Stephen, NASA) Stratospheric ozone is considered good for humans and other life forms because it absorbs Ultraviolet (UV)-B radiation from the Sun. In humans, increased exposure to UV radiation can lead to more cases of skin cancer, cataracts and impaired immune systems. Excessive UV exposure also can damage terrestrial plant life, single-cell organisms and aquatic ecosystems. Other UV radiation, UV-A, which is not absorbed significantly by ozone, causes premature aging of the skin (Fahey, 2007). In the Earth's lower atmosphere, near ground level, ozone is formed when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants and other sources react chemically in the presence of sunlight, which led to increases in the concentrations of chlorine, bromine, nitrogen and hydrogen radicals in the stratosphere (Clerbaux *et al*., 2003). Ozone at ground level is a harmful pollutant that causes damage to lung tissue and plants and other living systems because

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Ozone reacts strongly to destroy or alter many other molecules. The first instrument for routine monitoring of total ozone was developed by Gordon M.B. Dobson in the 1920s. The instrument, now called a Dobson spectrophotometer, measures the intensity of sunlight at two ultraviolet wavelengths: one Dobson Unit (DU) is defined to be 0.01 mm thickness at STP (standard temperature and pressure).Ozone layer thickness is expressed in terms of Dobson units, which measure what its physical thickness would be if compressed in the Earth's atmosphere (Fahey, 2007). In Southeast Asia many social, economic and environmental impacts caused by forest and land fires. Tropical haze from peat fires has serious negative impacts on the human health and regional economy and peat land fires affect global carbon dynamics (De Groot *et al*., 2007) Fires considered one of the largest anthropogenic influences on terrestrial ecosystems after agricultural activities and urban and its indeed critical elements in the Earth System, vegetation, linking climate and land use (Lavorel *et al*., 2007).

The AIRS instrument is included among several instruments mounted on the (EOS) Earth Observing System Aqua satellite launched on 4 May 2002, with its partner, Advanced Microwave Sounding Unit (AMSU-A) are characterizing and observing the entire atmospheric column from the surface to the top of the atmosphere in terms of temperature and surface emissivity, cloud amount and height, atmospheric temperature and humidity profiles and the spectral outgoing infrared radiation. The science objectives of AIRS is to determination of the factors that control the global energy and water cycles (Chahine *et al*., 2006), investigation of atmosphere-surface interactions, improving numerical weather prediction, assessing climate variations and feedbacks and detection of the effects of increased carbon dioxide, methane, ozone and other greenhouse gases (Marshall *et al*., 2006). The AIRS instrument, includes 2378 infrared spectral channels provides spectral coverage in the 3.74-4.61, 6.20-8.22 and 8.8-15.4 μm infrared wavebands at a nominal spectral resolution of $\lambda/\Delta\lambda$ = 1200. The term "sounder" in the instrument's name refers to the fact that water vapor and temperature are measured as functions of height. The AIRS instrument also contains four Visible/Near-IR (Vis/NIR) channels between 0.40 and 0.94 μm, with a 2.3 km FOV.

This study is based on O_3 retrievals from a research version of the current AIRS operational physical algorithm, used Standard Level-3 Daily gridded product (AIRX3STD) 1×1º spatial resolution, Version 5 data, using AIRS IR and AMSU, without-HSB, to investigate Daily Distribution map of Ozone and the impact of Indonesia forest fire over peninsular Malaysia and Thailand. By using Retrieved O_3 total column, the land use map of the study area was conducted, map was processed and analyzed by using Photoshop CS and SigmaPlot 11.0 software to assess the effect of Indonesia forest fire August on atmosphere Ozone distribution.

Study area and data: An area (Fig. 1), covering 2.15×10^6 km^2, with a center at Thailand Gulf (101.5°E and 11.5°N) was selected for this study. The extent of the domain was chosen so that it was sufficiently large to contain O_3 plumes from severe fires in the area. The central dimensions of the study domain are 1000 E-W and 2150 km N-S. The time period from (12-18 August 2005 and 2003) was selected to study the O_3 distribution and cover the development of fires in the area mid-August was the period with the most fires.

Fig. 1: Study area (Source; Google Earth)

The data used for this study include O_3 data from AIRS; they were extracted for the study area and were processed to match in space and time. The O_3 data were derived from Atmospheric Infrared Sounder (AIRS) Version 5 Level 3 data available at http://disc.sci.gsfc.nasa.gov/data/datapool/AIRS_DP/, as well as auxiliary data including the corresponding location and time along the satellite track in a HDF (Hierarchical Data Format) format on Daily basis. Using the location information, O_3 data were gridded Daily at Geospatial Resolution: 1×1° (lat × long).

Acquisition and specification: AIRS and its companion microwave sounder instruments (AMSU-A1, AMSU-A2) and HSB observe the entire atmospheric column from Earth's surface to the top of the atmosphere and designed to operate in synchronism, they provides both new and measurements improved of atmospheric temperature and humidity, cloud properties and land and ocean skin temperatures, with the accuracy, resolution and coverage required by numerical weather prediction and climate models (Aumann *et al*., 2003). AIRS infrared spectrometer acquires 2378 spectral samples at resolutions, $\lambda/\Delta\lambda$ ranging from 1086-1570, in three bands: 3.74-4.61, 6.20-8.22 and 8.8-15.4 µm, AIRS radiance data in the 9.6 µm band are used to retrieve column ozone and ozone profiles for both day and night (including the polar night). The V5 Level-3 gridded products are derived from the Level 2 standard swath products. The Level 2 quality indicators determine which of the Level-2 Standard Product data are combined to create the Level 3 Product. There are three AIRS Level 3 data products separately derived from MW-Only retrievals and combined IR/MW retrievals as summarized in (Table 1), we used Daily (AIRX3STD) 1×1° spatial resolution, for Level-3 ascending (day time), we used ($TotO_3$-A) Retrieved Total integrated column ozone burden (Dobson Units DU). The initial guess Ozone profiles are derived and given at 100 levels, uncertainty estimate (0-100% bias near tropopause ;< 20% above. These initial guess profiles are then used in the physical retrieval algorithm, which finds geophysical parameters that best match cloud cleared regression in a subset of the AIRS channels (41 channels) for O_3 (Bian *et al*., 2007).

Table 1: AIRS level 3 version 5 products

Data set	Short name	Granule size (MB)
Level 3 standard daily product	airx3std	~70
Level 3 8-day standard product	airx3st8	~103
Level 3 monthly standard product	airx3stm	~105

MATERIALS AND METHODS

For the purpose of investigate and analysis the ozone distribution over the equatorial Southeast Asian region, we have chosen Daily retrieved Ozone (O_3) data from AIRS for three different periods, ascending (11-18 August) 2005 and 2003 and (12-19 February) 2005. AIRS is one of several instruments inboard on EOS Aqua satellite, providing new insights into weather and climate for the 21st century (McMillan *et al*., 2005). The Aqua spacecraft orbit is polar sun-synchronous with an orbital period of 98.8 minutes and a nominal altitude of 705 km. The repeat cycle period is 233 orbits (16 days) with a ground track repeatability of +/- 20 km. Crossing over equatorial regions at local times 1:30 in the morning (descending) and 1:30 in the afternoon (ascending) (Olsen *et al*., 2005).The initial guess ozone profiles are obtained and given at 100 levels by (41) channels with uncertainty estimate 5% tropics and 5-40% poles. The V5 Level-3 gridded products are derived from the Level 2 standard swath products. Standard Level-3 Daily gridded product (AIRX3STD) 1×1° spatial resolution Version 5 data used to evaluate ozone distribution and impact of forest fires on study area for different periods at wet season (August) and dry season (February). Data including the corresponding location and time along the satellite track in a HDF (Hierarchical Data Format) format on Daily basis. Map of the study area was conducted by using Photoshop CS and SigmaPlot 11.0 software to analyzed the ozone data and assess the effect of Indonesia forest fire August on atmosphere Ozone distribution.

Ozone ground level measurements from ILP, Perai, P. Pinang station in Malaysia been observed for periods study, to observed and evaluate the variation of Ozone concentrations with different seasons.

RESULTS

The eight maps in Fig. 2a-d (12-18 August) 2005 (top) and Fig. 2e-h (11-18 August) 2003 (bottom), illustrate the extent of AIRS Daily coverage of Total integrated column ozone burden, the nominal peak of AIRS vertical sensitivity and the magnitude of the variations in atmospheric O_3 over peninsular Malaysia and Thailand.

For August 2003, where normal circumstances in the absence of any event, can observed, as further we move from the equator to the north, the greater concentration of ozone, the less values of O_3 total column are found on 18 August at south Thailand over west coasts of Phang Nga and east coasts of Surat Thani (213 DU) at latitude 8.5°, while the higher values over Industrial and congested urban zones on 11 August at north Thailand over Lao Tang Kam (288 DU)at latitude 17.5°, where existence a number of Swamps and lakes.

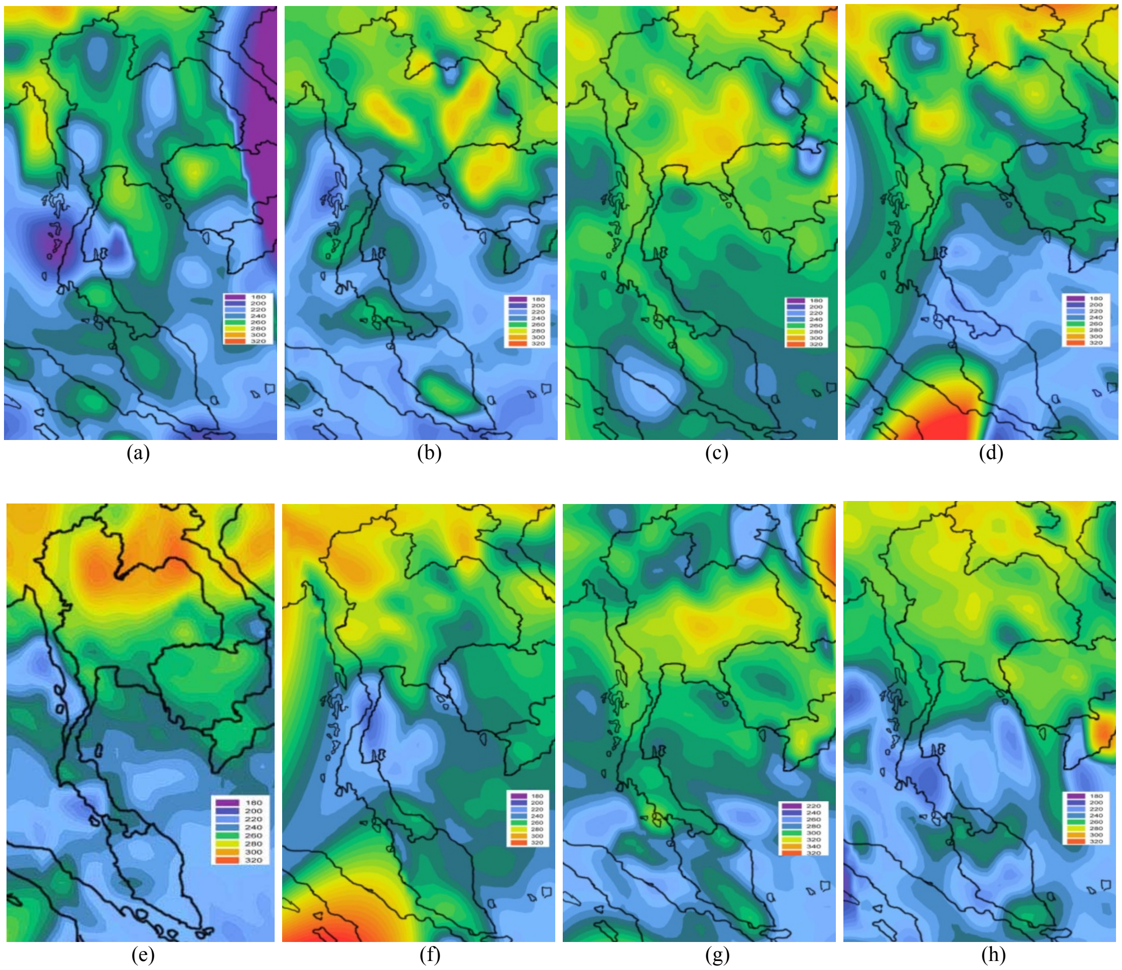

Fig. 2: AIRS Total integrated column ozone burden (DU), (a-d) (12-18 August) 2005 (top) and (e-h) (11-18 August) 2003 (bottom)

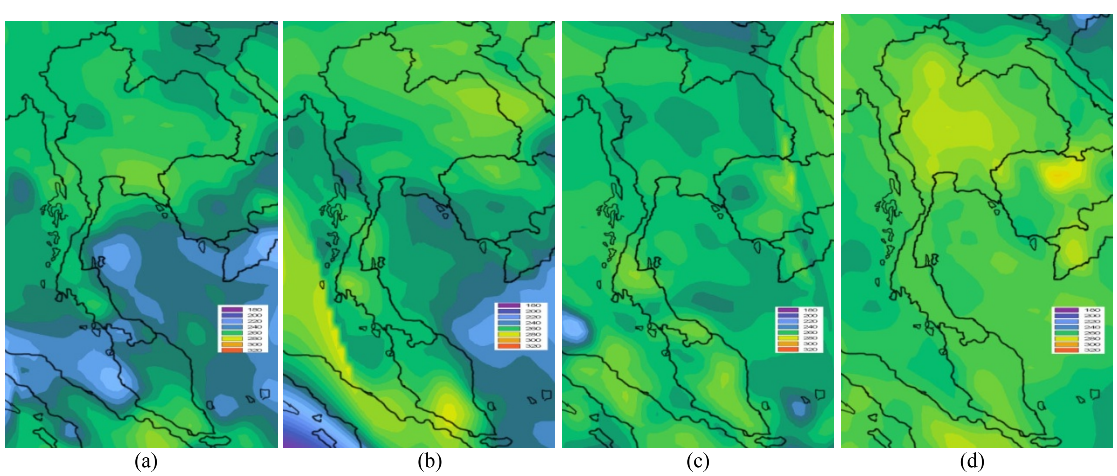

Fig. 3: AIRS Total integrated column ozone burden (DU), (a-d) (12-19 February) 2005

While for August 2005, note the plainly evident of Indonesia forest fire on O_3 total column concentration over Peninsular Malaysia and south Thailand, the higher values in the study area was on 16 August at north Thailand over Burirum (288 DU) at latitude 15.5° and the greater draw down of O_3 occurs on 12 August over Surat Thani (210 DU) at latitude 8.5°.

The Four maps in Fig. 3a-d (12-19 February) 2005, illustrate the extent of AIRS Daily coverage of Total integrated column ozone burden, these sequences of daily maps reveal that O_3 concentrations has moderate values over most of the study areas, ranging (249-278 DU) and higher around the equatorial regions than other regions. The higher values in the study area was on 14 February at south Peninsular Malaysia over Johor (278 DU) at latitude 2.5°, while the greater draw down of O_3 occurs on 17 February at middle of Thailand over Srithan (249 DU) at latitude 16.5°.

Observed an elevation in the O_3 measurements higher than the normal rates from ILP, Perai, P. Pinang station in Malaysia during the period from mid-June to mid-August 2005, with the relative decline for the month of August 2003 on average annual. The average values of August 2005 (0.017 ppm) and (0.016 ppm) for August 2003, the highest value was on 15 August 2005 (0.030 ppm), while for February 2005 the average value was (0.027 ppm) and the higher value on 6 February (0.033 ppm).

DISCUSSION

The Southeast Asia is dominated by a strong monsoon; seasons are not as distinct as in more temperate zones, only wet and dry seasons can be clearly distinguished. This region experiences a wet seasons, summer monsoon for about six months (May-October). The prevailing wind flow is generally southwesterly and light, below 15 knots. Winter monsoon prevails during the subsequent dry season (November-April), steady easterly or northeasterly winds of 10 to 20 knots prevail (Juneng *et al*., 2007). East coast states of Peninsular Malaysia are the more severely affected areas where the wind may reach 30 knots during periods of intense surge of cold air from the north.

From Fig. 2 the combination of rich local sources of O_3 in study area along with the transport of additional O_3 and Ozone from remote forest fires in Indonesia led to the Ozone pollution event of August 2005 that was characterized increases Ozone by 5-25% in southern region, over peninsular Malaysia and south of Thailand because it's a regions experienced extensive to the intense Indonesia forest fire, while there is no clear observational evidence that there is a large differences in Ozone values over middle and northern regions, because it's far to raging wildfire.

For August 2003, northern regions higher than southern regions because in the tropical regions there are thick clouds at wet season which means little UV and so little formation of ozone. Also rain is a great cleanser of the atmosphere; Oxides of nitrogen that are another element in the ozone equation would also be removed by rain as well as the northeast monsoon prevails during wet season, when it moves northward it transport continental air masses from the Indian Ocean into Northern Hemisphere. Weather conditions can also cause considerable daily variations. The total column O_3 in the tropical atmosphere depends on both chemical and dynamical processes and has been extensively studied during the last few decades (Tian *et al*., 2007).

While for August 2005, observed that ozone concentrations influence by Indonesia forest fire especially over Peninsular Malaysia and southern Thailand. Higher value was at latitude 15.5º because maximum rainfall occurs during wet season (southern west monsoon) which influence of development and transport of moisture from the tropic and mid-latitude (Mahmud and Vijaya Kumar, 2008), rain is a great cleanser of the atmosphere so the (Hoskins, 2001), so the highest value of the Ozone occurred at lowest rainfall region.

Figure 3, February 2005, the higher ozone concentration were around equatorial regions it's completely different to what happened in August of same year, because Ozone needs ultraviolet light for its production, during dry season there are thin clouds (minimum rainfall season) which means much UV and so much formation of ozone, the emission from industrial facilities and electric utilities, motors vehicle exhaust, gasoline vapors and chemical solvents are some of the major sources of Nitrogen (NOx) and Volatile Organic Compounds (VOC) so that as soon as the sun shone the equation was complete and urban ozone was born along with its twin, smog (NOx + VOC + Heat and Sunlight = Ozone) (Hoskins, 2001), as well as the southwest monsoon prevails during dry season, which transport continental air masses from northeast Asia toward the Southern Hemisphere.

CONCLUSION

As demonstrated here, AIRS' Daily views of Total integrated column ozone burden (DU) across the study area enable detailed analyses of both the spatial and temporal variations in emissions; AIRS can successfully detect O_3 emission from large forest fires.

AIRS/Aqua Level 3 Daily gridded product (AIRX3STD) 1×1° spatial resolution, Version 5 data using AIRS IR and AMSU, without-HSB, to investigate Daily Distribution map of Ozone, exacerbate the Indonesia forest fires on O_3 contamination and quality of the satellite measurements.

During wet season for August 2005and 2003 the higher O_3 concentrations was over the northern regions of study area, while the less values around the equatorial regions and northern regions higher than southern regions as well as clear impact of Indonesia forest fire over Peninsular Malaysia and south Thailand. While for dry season (February 2005), contrary to what happened in wet season, O_3 concentrations on the southern regions higher than northern regions, moderate values over most of the study areas and higher concentrations around the equatorial regions. A greater draw down of O_3 occurs in the pristine marine environment over Surat Thani during wet seasons.

This study has provided evidence for the impact of remote O_3 emissions and forest fire on Ozone pollution levels above study area and enhanced our knowledge on AIRS detection of O_3 emission from forest fire, the utility and accuracy of remotely sensed atmospheric O_3 columns and abundances from AIRS.

Satellite measurements are able to measure the increase of atmospheric O_3 concentration over different regions of Southeast Asia, from AIRS data; we expect O_3 maps will lead to a more understanding of the O_3 budget. Further study will be extended to include assess the observation and measurement of the satellite (AIRS) to the effects of other pollutant and greenhouses gases.

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