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# COMPARISON OF GOME 2 METOP-A SATELLITE-BORNE TROPOSPHERIC $NO_2$ AND GROUND MEASUREMENTS

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## ABSTRACT

The growth of vehicles in Indonesia has been increasing to date, causing high concentration of pollutants. Nitrogen dioxide ($NO_2$) in the atmosphere is emitted by high volume of vehicle flow, it is therefore crucial to be able in identifying concentration pattern spatially. However, the presence of air quality monitoring in cities in Indonesia has been limited. Therefore, the use of satellite can help characterizing concentration pattern of $NO_2$ regionally. In this study, we apply GOME 2 (Global Ozone Monitoring Experiment 2) MetOp-A sattelite to identify $NO_2$ gas concentrations in the atmosphere. Images were obtained from GOME 2 MetOp-A satelliteand analyzed using ArcGIS applicationand were displayed in the form ofcolor intensity within pixels. Data (in $10^{15}$ molecules/$cm^2$units) of tropospheric $NO_2$were then validated using the ambient concentration values of $NO_2$from Air Quality Monitor Station (SPKU) located in Jakarta and Surabaya. Validation (119records) was done using linear regression model. The $R^2$ obtained from linear regression was quite low, 0.316, respectively, howeverthis technique shows promising alternative to capture $NO_2$ over Indonesia area.

*Keywords:* GOME 2 MetOp-A; Linier regression; NO2 (Nitrogen Dioxide)

## 1. INTRODUCTION

Air pollution is a problem that occurs continuously in urban areas around the world since the middle ages. Industrial activity development with limited regulations after the industrial revolution has aggravated air quality (Stern, 1973). Currently, the air pollution in large cities becomes a regular topic in the media. Lately, the World Health Organization (WHO) states that air pollution is a major cause of health problems that cause 7 million deaths every year worldwide (WHO, 2014). Currently, the major anthropogenic source of air pollution is traffic, power plants and industries (Beijk et al., 2010). Traffic air pollution occurs not only from fuel burning, but also from the use of brakes, and tire friction with the road surface. The emissions consist of various gases and particles such as carbon dioxide ($CO_2$), nitrogen oxides (Nox), and particulate matter (PM). Fischer et al (2000) suggests that $NO_2$ is often taken as an indicator that represents the mixture of these particles. Nitrogen dioxide is air pollutant produced duringcombustion process. When $NO_2$ is formed, the element of nitrogen oxide ($NO_X$) is also found; a collective combination of NO and $NO_2$refers to nitrogen oxides ($NO_2$).
Nitrogen dioxide ($NO_2$) is an anorganic gas that has reddish brown color and has strong smell. Itis formed by the oxidation of nitrogen oxide (NO), which is emitted from fuel burning at high temperatures. Below 21.15 degree Celsius, nitrogen dioxide changed

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into chocolate colored liquid state and at-11 degree Celsius, it becomes colorless solid state (Alberta, 2007). The characteristics of Nitrogen dioxide arecorrosive is high oxidizing ability, and not flammable. Pollutant $NO_2$ is very reactive and can combine with other atmospheric components to form nitric acid ($HNO_3$) that causes acid rain and particulatematter (PM) in the atmosphere. $NO_2$ is very corrosive to metal and the main emissions that compilethe ozone formations as well as one important components of the smoke (Srivastava, 2004).

Hoek, et al (2002) suggests that there is a correlation between mortality rates and the concentration levels of $NO_2$. In a study by Hoek, et al (2002), children in New York City who lives at 200 meters from the road with heavy traffic, would risks of developing asthma. Theyalso mentioned that the higher the levels of $NO_2$ that inhaled, the slower the lung will growth. The growth of the children's lung who lives in air polluted area is slower than in children who live in areas with little air pollution.

Given the factthatthe impact of $NO_2$pollution is quite dangerous, there should be an effort to manage the ambient air quality.One step is to install ambient air quality monitoring stations (SPKU). However, only a few cities have SPKU. Therefore it is necessary to havealternative in identifying $NO_2$ pattern over area that has no monitoring stations and that alternative is byusing satellite imagery. One of the satellites that can read traces of $NO_2$ is Satellite GOME 2 MetOp-A.

GOME 2 (Global Ozone Monitoring Experiment 2) is a remote sensing instrument on the ERS 2 (European Remote Sensing 2) Satellite which was launched by the European Space Agency on October 19, 2006. ERS 2 is a satellite that orbits based on the movement of the sun that located about 800 kilometers above the earth (European Space Agency, 1995). GOME 2 consists of two satellites, GOME 2 MetOp-A and GOME 2 MetOp-B. MetOp-A satellite was launched in October 2006, while MetOp-B was launched in September 2012. The two satellites are operated by EUMETSAT (the European Organisation for the Exploitation of Meteorological Satellite). MetOp-A fly in the sun's orbit (sun-synchronus) with repeated cycles for 29 days.

GOME 2 is designed to detect the reflected radiation from the soil and spread by an atmosphere that includes wavelengths ranging from 240-790 nm (Munro et al., 2006). GOME 2 satellite scanning process is using UV-VIS (Ultraviolet-Visible) spectrometer with a nadir-scanning process. One pixel at the Earth's surfacethat can be read in nadir condition by the GOME 2 Metop A is 40 x 40 $km^2$. The scanning distance covers 1920 km with timeframe for 1.5 days. Although the main target of GOME is ozone, but traces of other gases such as $NO_2$ can also be measured (Burrows, et al., 1999; J. Ma, et al., 2006).

## 2. METHODOLOGY/EXPERIMENTAL

*Satellite data*

Satellite data of GOME 2 MetOp-A is downloadable at www.temis.nl website. The data is from MetOp-A satellite scanning that has been processed by the KNMI (Royal Netherlands Meteorological Institute). The processed data covers the whole world scanning result with daily or monthly timeframe.Data aremonthly data from January 2012 to June 2015 and are pixel valuesof$NO_2$($10^{15}$ mol/$cm^2$) columndeliberately match with any monthly ground measurements from SPKU.

*GroundMonitoring stations (SPKU) Data*

Ground Monitoring stations (SPKU) are located in two cities, Surabaya and Jakarta. Records that were used are $NO_2$ concentration with units of ppm. We compare thisdata

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withthose from satellite. $NO_2$ columnscaptured by the satellite are in the troposphere. $NO_2$ concentrationsused were data from 2012 to 2015. Daily ground measurement information were then convertedinto monthly data.

There are 7 monitoring stations in the city of Surabaya, those are SUF1, SUF 2, SUF3, SUF4, SUF 5, SUF6 and SUF7. While in the Jakarta, there are 6 points of SPKU, those are DKI1, DKI2, DKI3, DKI4, DKI5, and JAF4. The location and the coordinates of each point SPKU in Surabaya and Jakarta can be seen in Table 1.

Table 1 Coordinate of SPKU location

| City | Monitoring point | Location Name | x y Coordinate | Coordinate |
|---|---|---|---|---|
| Surabaya | SUF 1 | Taman Prestasi | -7.262016, 112.746425 | 112° 44' 47.130" E and 7° 15' 43.258" S |
| | SUF 2 | Perak Timur | -7.223738, 112.733968 | 112° 44' 2.285" E and 7° 13' 25.457" S |
| | SUF 3 | Sukomanunggal | -7.248917, 112.647734 | 112° 38' 51.842" E and 7° 14' 56.101" S |
| | SUF 4 | Gayungan | -7.333790, 112.707853 | 112° 42' 28.271" E and 7° 20' 1.644" S |
| | SUF 5 | Gebang Putih | -7.290515, 112.793565 | 112° 47' 36.834" E and 7° 17' 25.854" S |
| | SUF 6 | Wonorejo | -7.313076, 112.785212 | 112° 47' 6.763" E and 7° 18' 47.074" S |
| | SUF 7 | Kebon sari | -7.327922, 112.713241 | 112° 42' 47.668" E and 7° 19' 40.519" S |
| Jakarta | DKI1 | Bunderan HI | -6.1949571, 106.82306 | 106° 49' 23.016" E and 6° 11' 41.846" S |
| | DKI2 | Kelapa Gading | -6.1604549, 106.90546 | 106° 54' 19.660" E and 6° 9' 37.638" S |
| | DKI3 | Jagakarsa | -6.334917, 106.823737 | 106° 49' 25.453" E and 6° 20' 5.701" S |
| | DKI4 | Lubang Buaya | -6.2939072, 106.90339 | 106° 54' 12.233" E and 6° 17' 38.066" S |
| | DKI5 | East Jakarta | -6.2069444, 106.75222 | 106° 45' 7.999" E and 6° 12' 25.000" S |
| | JAF4 | West Jakarta | -6.1683295, 106.75884 | 106° 45' 31.856" E and 6° 10' 5.986" S |

*Model and Data Input System*

The Daily data from GOME 2 MetOp-A satellite is in the form of hdf format, while the monthly data is data with grd format. In this study, the required data is monthly data. The monthly data can be read using ArcGIS applications. Monthly data that has been downloaded by grd format must be converted into ASCII format so it can be read using ArcGIS applications.

The data analysis from satellites and SPKU are validated using linear regression models. Linear regression has an equations that called a regression equation. The regression equation expressing the linear relationship between the dependent variable / variable criteria by the symbol Y and one or more independent variables / predictor by the symbol X if there is only one predictor and X1, X2 up to Xk, if there is more than one predictor (Crammer & Howitt, 2006). The independent variable is $NO_2$ ground measurements in ppm and the dependent variable is trpospheric $NO_2$ density column.

## 3. RESULTS AND DISCUSSION

*Analysis of data from ground station (SPKU)*

From 2012 to 2015, there were only five monitoring stations fully functional in reading $NO_2$. They were SUF1, SUF3, SUF4, SUF6 and SUF7. SUF2 monitoring station of the year 2014 could not read the concentration of $NO_2$ due to sensor failure. SUF5 monitoring station could only capture the concentration of $NO_2$ for 3 months in early 2014, so the data from SUF2 and SUF5 were not used in the analysis. In Jakarta, the $NO_2$ concentration records at all SPKU were reported until 2014, except SPKU in DKI5

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and JAF4. DKI5 monitoring station began taking measurements in January 2013 and JAF4 monitoring station took measurements until December 2012.
The number of data from SPKU in Surabaya and Jakarta during 2012 and 2015 is 225. Summary $NO_2$ concentration data at each point SPKU in Surabaya and Jakarta can be seen in Table 2. The data in these tables is the data in the monthly period which have been processed from daily data.

Table 2.SummarySPKU Data

| Period | Concentrationof $NO_2$(ppm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surabaya | | | | | Jakarta | | | | | |
| | SUF 1 | SUF 3 | SUF 4 | SUF 6 | SUF7 | DKI1 | DKI2 | DKI3 | DKI4 | DKI 5 | JAF4 |
| 2012 | | | | | | | | | | | |
| January | 0.00248- | - | - | - | | 0.01746 | 0.01748 | 0.00633 | 0.01206- | | 0.00481 |
| February | 0.00268 | 0.03886- | - | - | | 0.01896 | 0.02148 | 0.01132 | 0.02003- | | 0.00260 |
| March | 0.00656 | 0.04434 | 0.00795- | - | | 0.01493 | 0.01730 | 0.00715 | 0.01389- | | 0.00918 |
| April | 0.00613 | 0.04580 | 0.00498- | - | | 0.02997 | 0.02178 | 0.01420 | 0.01853- | | 0.01948 |
| May | 0.00434 | 0.04520 | 0.00210- | - | | 0.03042 | 0.02096 | 0.01488 | 0.01958- | | 0.02183 |
| June | 0.00724- | - | - | - | | 0.02984 | 0.01957 | 0.01605 | 0.01878- | | 0.02166 |
| July | 0.00825- | | 0.00886- | - | | 0.03787 | 0.02494 | 0.01517 | 0.02017- | | 0.02011 |
| August | 0.00615- | | 0.00397- | - | | 0.02987 | 0.01825 | 0.01243 | 0.01602- | | 0.01811 |
| September | 0.00718- | - | - | - | | 0.03590 | 0.02065 | 0.01408 | 0.02168- | | 0.01868 |
| October | 0.00513- | | 0.00389- | - | | 0.03301 | 0.02217 | 0.01294 | 0.01830- | | 0.02017 |
| November | 0.00411- | - | | 0.01277- | | 0.03472 | 0.02936 | 0.01302 | 0.02215- | - | |
| December | 0.00954 | 0.04648 | 0.00791 | 0.01492- | | 0.02283 | 0.02040 | 0.00887 | 0.01531- | | 0.01572 |
| 2013 | | | | | | | | | | | |
| January | 0.00159 | 0.00346 | 0.00466 | 0.00993- | | 0.02068 | 0.01778 | 0.00688 | 0.01281 | 0.01193- | |
| February | 0.00183 | 0.00098- | | 0.01138- | | 0.02507 | 0.02127 | 0.00902 | 0.01524 | 0.01413- | |
| March | 0.00177 | 0.00113- | | 0.01155- | | 0.02706 | 0.02288 | 0.00950 | 0.01538 | 0.01589- | |
| April | - | 0.00072- | | 0.00274- | | 0.02490 | 0.02025 | 0.01100 | 0.01459 | 0.01730- | |
| May | - | 0.00002- | | 0.00806- | | 0.02929 | 0.02242 | 0.01256 | 0.01692 | 0.01899- | |
| June | - | - | 0.00376 | 0.01081- | | 0.02744 | 0.02167 | 0.01207 | 0.01642 | 0.01770- | |
| July | - | - | 0.00883 | 0.00809- | | 0.02905 | 0.02098 | 0.01307 | 0.01692 | 0.02067- | |
| August | - | - | 0.00327 | 0.00303- | | 0.02327 | 0.01686 | 0.01110 | 0.01385 | 0.01587- | |
| September | - | - | 0.00657 | 0.00674- | | 0.03036 | 0.02253 | 0.01108 | 0.01540 | 0.01664- | |
| October | - | - | - | 0.00618- | | 0.03188 | 0.02657 | 0.01186 | 0.01479 | 0.01777- | |
| November | - | - | - | 0.00847- | | 0.02762 | 0.02770 | 0.01005 | 0.01280 | 0.01676- | |
| December | - | - | - | - | | 0.02422 | 0.02413 | 0.00870 | 0.01107 | 0.01141- | |
| 2014 | | | | | | | | | | | |
| January | - | - | - | 0.00895 | 0.01210 | 0.02323 | 0.02053 | 0.00547 | 0.00899 | 0.01237- | |
| February | - | - | - | 0.01142 | 0.01184 | 0.02787 | 0.02576 | 0.00862 | 0.01163 | 0.01634- | |
| March | - | - | - | 0.01060 | 0.01787 | 0.03319 | 0.02858 | 0.01299 | 0.01978 | 0.01832- | |
| April | - | - | - | 0.01067 | 0.02263 | 0.02440 | 0.02281 | 0.00899 | 0.01357 | 0.01227- | |
| May | - | - | - | 0.00660 | 0.01879- | - | - | - | - | - | |
| June | - | - | - | 0.00566 | 0.02045- | - | - | - | - | - | |
| July | - | - | - | 0.00534 | 0.01797- | - | - | - | - | - | |
| August | - | - | - | 0.00592 | 0.01942- | - | - | - | - | - | |
| September | - | - | - | 0.00736 | 0.02312- | - | - | - | - | - | |
| October | - | - | - | 0.00656 | 0.02128- | - | - | - | - | - | |
| November | - | - | - | 0.00824 | 0.02230- | - | - | - | - | - | |
| December | - | - | - | 0.01135 | 0.01175- | - | - | - | - | - | |
| 2015 | | | | | | | | | | | |
| January | - | - | - | 0.00965 | 0.00311- | - | - | - | - | - | |
| February | - | - | - | 0.01113 | 0.00423- | - | - | - | - | - | |
| March | - | - | - | 0.00905 | 0.00365- | - | - | - | - | - | |
| April | - | - | - | 0.00998 | 0.00476- | - | - | - | - | - | |
| May | - | - | - | 0.00509 | 0.00536- | - | - | - | - | - | |
| June | - | - | - | 0.00462 | 0.00842- | - | - | - | - | - | |

*Note: (-) SPKU fails to capture$NO_2$*

*Analysis of data from GOME 2 MetOP-A satellite*

Data of GOME-2 MetOp-A satellite is taken from the monthly data which is processed by KNMI. The data is read using ArcGIS application and presented in the form of pixel colors. Results of data visualization can be seen in Figure 1.
Figure 1 shows the results of visualization of tropospheric $NO_2$ column in the area of Indonesia extracted from the KNMI data in January 2012. The figure describes the

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column values of $NO_2$(with units of $10^{15}$ mol/ $cm^2$) in the range of low value at -469 x $10^{15}$ mol / $cm^2$as indicated by the orange color pixel and the highest range is 9999 x $10^{15}$ mol/ $cm^2$ indicated with a blue color pixel. It appears that blue color pixels in Indonesia are in urban regionswith high level of activities and population.Some areasare in the island of Java and Sumatra, and some areas in East Kalimantan. It also shows the corresponding correlation between satellite imagery to conditions in areas with a high density of activities that could potentially produce excessive $NO_2$ emission.

The location was determined based on the point of monitoring stations in Surabaya and Jakarta. From the results of satellite image GOME 2 MetOp-A, the location of SPKU in Surabaya is located at 4 pixel points. In Jakarta, there are only 2 pixels that encompass the location of SPKU. The SPKU locations are shown in Table 1 and Figure 2.

SPKU in Jakarta are covered by 2 point pixel (pixel A and pixel B). "A" pixel includes SPKU DKI1, DKI2, DKI5 and JAF4. Pixel B includes DKI3 and DKI4. Surabaya regions are covered by 4 pixel point. However the location SPKU only cover in 3-point pixel (ie pixel C, D pixel and pixel E). Pixel C includes SUF3. Pixel D includes SUF1, SUF4, and SUF 7. Pixel E only covers SUF6.

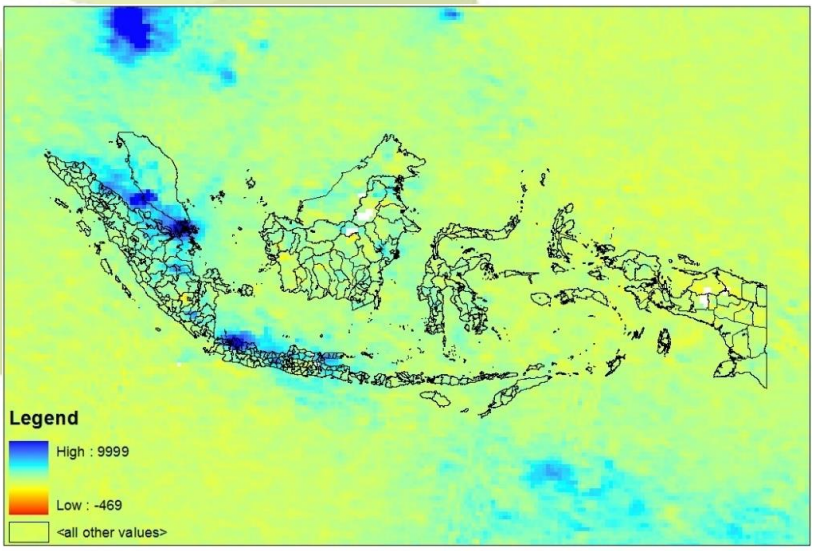
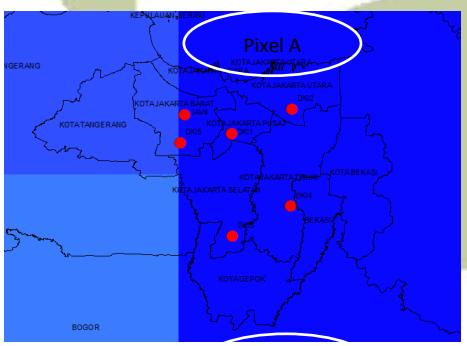
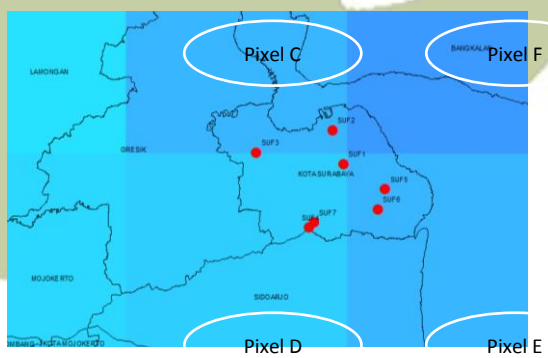



Figure 1 Visualization column $NO_2$in Indonesia on January 2012 (Copyright © TEMIS/ ESA; http://www.temis.nl/)




SPKU in Jakarta




SPKU in Surabaya

Figure 2 Location of SPKU in Jakarta and Surabaya (Copyright © TEMIS/ ESA; http://www.temis.nl/)

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*Regression Model*

The regression model was conducted using data from SPKU (Table 2) and data from GOME 2 MetOp-A satellite. Records are classified based on pixels (figure 2). Table 2 shows the amount of $NO_2$ concentration data obtained from SPKU which there are 225 of data, but the $NO_2$ data column obtained from the satellite are based on pixel area. So the $NO_2$ daily concentrations from SPKU that located in the same pixels were averaged. Recapitulation process produces 119 pairs of data. Summary data from SPKU and satellite is shown in Table 3.

Table 3 Summary Data from SPKU and GOME 2 MetOP-A satellite based on pixel area

| Period | Pixel A (DKI1, DKI2, DKI5 and JAF4) | | Pixel B (DKI3 and DKI4) | | Pixel C (SUF3) | | Pixel D (SUF1, SUF4, and SUF 7) | | Pixel E (SUF6) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column |
| 2012 | | | | | | | | | | |
| January | 0.03974 | 515 | 0.01839 | 496 | - | - | 0.00248 | 238 | - | - |
| February | 0.04304 | 624 | 0.03135 | 700 | 0.03886 | 408 | 0.00268 | 372 | - | - |
| March | 0.04141 | 590 | 0.02104 | 524 | 0.04434 | 304 | 0.01451 | 307 | - | - |
| April | 0.07123 | 629 | 0.03273 | 658 | 0.04580 | 367 | 0.01111 | 365 | - | - |
| May | 0.07321 | 765 | 0.03445 | 629 | 0.04520 | 325 | 0.00644 | 357 | - | - |
| June | 0.07108 | 781 | 0.03484 | 678 | - | - | 0.00724 | 322 | - | - |
| July | 0.08292 | 783 | 0.03534 | 682 | - | - | 0.01711 | 405 | - | - |
| August | 0.06623 | 610 | 0.02845 | 487 | - | - | 0.01012 | 335 | - | - |
| September | 0.07523 | 783 | 0.03576 | 782 | - | - | 0.00718 | 408 | - | - |
| October | 0.07535 | 697 | 0.03124 | 562 | - | - | 0.00902 | 377 | - | - |
| November | 0.06407 | 674 | 0.03517 | 705 | - | - | 0.00411 | 378 | 0.01277 | 335 |
| December | 0.05895 | 507 | 0.02418 | 252 | 0.04648 | 409 | 0.01745 | 366 | 0.01492 | 365 |
| 2013 | | | | | | | | | | |
| January | 0.05039 | 170 | 0.01969 | 172 | 0.00346 | 336 | 0.00625 | 285 | 0.00993 | 295 |
| February | 0.06047 | 910 | 0.02426 | 962 | 0.00098 | 418 | 0.00183 | 374 | 0.01138 | 320 |
| March | 0.06583 | 849 | 0.02488 | 676 | 0.00113 | 336 | 0.00177 | 324 | 0.01155 | 306 |
| April | 0.06245 | 1001 | 0.02559 | 857 | 0.00072 | 363 | - | - | 0.00274 | 302 |
| May | 0.07070 | 733 | 0.02948 | 666 | 0.00002 | 361 | - | - | 0.00806 | 306 |
| June | 0.06680 | 678 | 0.02850 | 666 | - | - | 0.00376 | 372 | 0.01081 | 351 |
| July | 0.07069 | 727 | 0.02999 | 535 | - | - | 0.00883 | 272 | 0.00809 | 354 |
| August | 0.05599 | 1019 | 0.02495 | 812 | - | - | 0.00327 | 481 | 0.00303 | 415 |
| September | 0.06952 | 1052 | 0.02648 | 806 | - | - | 0.00657 | 597 | 0.00674 | 466 |
| October | - | - | - | - | - | - | - | - | - | - |
| November | 0.07208 | 1389 | 0.02285 | 1283 | - | - | - | - | - | - |
| December | 0.05975 | 969 | - | - | - | - | - | - | - | - |
| 2014 | | | | | | | | | | |
| January | 0.05613 | 1522 | 0.01446 | 1186 | - | - | 0.01210 | 507 | 0.00895 | 460 |
| February | 0.06998 | 1412 | 0.02026 | 1256 | - | - | 0.01184 | 316 | 0.01142 | 422 |
| March | 0.08009 | 1879 | 0.03277 | 1814 | - | - | 0.01787 | 691 | 0.01060 | 502 |
| April | 0.05948 | 995 | 0.02256 | 909 | - | - | 0.02263 | 611 | 0.01067 | 451 |
| May | - | - | - | - | - | - | 0.01879 | 648 | 0.00660 | 430 |
| June | - | - | - | - | - | - | 0.02045 | 485 | 0.00566 | 573 |
| July | - | - | - | - | - | - | 0.01797 | 546 | 0.00534 | 377 |
| August | - | - | - | - | - | - | - | - | - | - |
| September | - | - | - | - | - | - | - | - | - | - |
| October | - | - | - | - | - | - | - | - | - | - |
| November | - | - | - | - | - | - | - | - | - | - |
| December | - | - | - | - | - | - | - | - | - | - |

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| Period | Pixel A (DKI1, DKI2, DKI5 and JAF4) | | Pixel B (DKI3 and DKI4) | | Pixel C (SUF3) | | Pixel D (SUF1, SUF4, and SUF 7) | | Pixel E (SUF6) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column | SPKU (ppm) | $NO_2$ Total Column |
| 2015 | | | | | | | | | | |
| January | - | - | - | - | - | - | 0.00311 | 515 | 0.00965 | 478 |
| February | - | - | - | - | - | - | 0.00423 | 347 | 0.01113 | 349 |
| March | - | - | - | - | - | - | 0.00365 | 493 | 0.00905 | 402 |
| April | - | - | - | - | - | - | 0.00476 | 683 | 0.00998 | 559 |
| May | - | - | - | - | - | - | 0.00536 | 678 | 0.00509 | 593 |
| June | - | - | - | - | - | - | 0.00842 | 546 | 0.00462 | 471 |

*Note: (-) SPKU could not read $NO_2$ concentrations*

The data in Table 3 were used in the regression model with value of 'x' is the total $NO_2$ data column ($10^{15}$ mol/ $cm^2$) from GOME 2 MetOp-A satellite and the value of 'y' is a the concentration of $NO_2$(ppm) from SPKU. The regression graph can be seen in Figure 3.

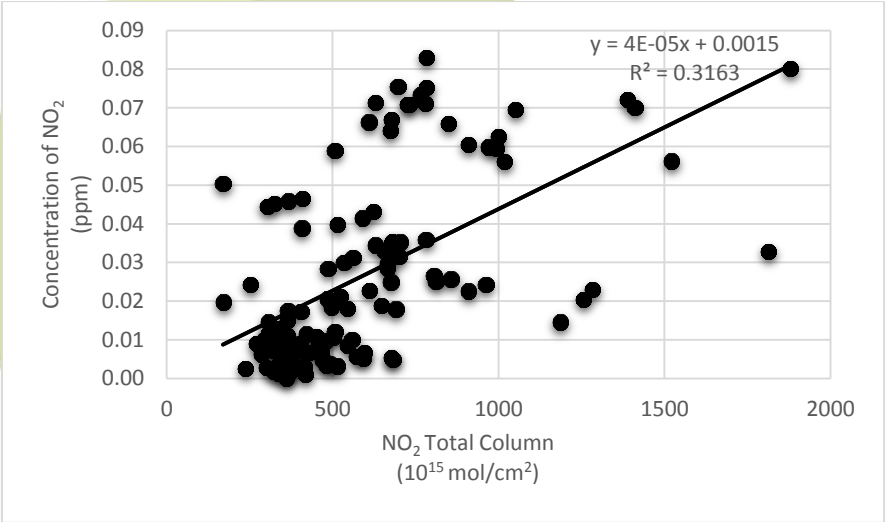


Figure 3 The result of linear regression

From the graph in Figure 3, the score of R square ($R^2$) determination is 0.3163 with a regression equation $y = 4.10^{-5}x + 0.0015$. The $R^2$ value describes the degree of accuracy in predicting the concentration of $NO_2$ on other areas is equal to 31.63%.The correlation shows weak correlation between two measurements which is probably due to limitation of data collection from GOME 2 MetOp-A satellite.

Satellite instrument integrates and combines both horizontal and vertical information of NO2 whereas ground measurements were captured as point only and not distributed across regions. Furthermore, the quality of tropospheric $NO_2$ column depends highly on large spatial resolution which is 40 x 40 km2 which causes high discrepancy with ground measurement. However, this drawback cannot diminish its indispensable value to acquire $NO_2$ concentration patterns over large coverage areas such as cities and province level.

## 4. CONCLUSION

$NO_2$ measurement data from monitoring stations in Jakarta and Surabaya is the monthly data from the years 2012 to 2015. There are some data that has an error, because the monitoring system on the SPKU tools are damaged or under maintenance. In addition, the small value of $NO_2$ concentration in the ground station's area can affect the process of monitoring, so that the resulting data can not be read.

$NO_2$ total column data of GOME 2 MetOp-A satellite that have been processed by the KNMI is also the monthly data from the years 2012 to 2015. The amount of concentration data and $NO_2$ total column data were used for analysis of each total 119 data. The data is used to form a linear regression model. The results of the regression model in the form of regression equation $y = 4.10^{-5}x + 0.0015$ with 'x' represents the $NO_2$ total data column(1015 mol / $cm^2$) of GOME 2 MetOp-A satellite and the value of 'y' is the concentration of $NO_2$(ppm). Despite its low correlation level, 31.63% respectively, the use of satellite has been demonstrated to be promising in the future to predict and to capture $NO_2$ information for large areas such as cities and their neighboring areas as well as provinces, especially for developing countries with very limited monitoring stations.

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