Indonesia National Report
for the 12^{th} WMO/UNEP Ozone Research Managers Meeting
22-26 April 2024, Geneva, Switzerland

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INDONESIA

INTRODUCTION

The atmospheric structure of Indonesia is expected very complicated because of its dynamic effect. Strong convection significantly influences the composition of the atmosphere. Minor constituents that affect the atmospheric dynamics and thermal distributions are found in abundance. Particularly, the Indonesian Maritime Continent is the region where trace gas distributions in the troposphere are strongly influenced by deep convection, frequent lightning, and biomass burning. Quantitative studies of these processes have been very limited so far in this region due to the lack of simultaneous in situ measurements of key species, atmospheric ozone measurements, and research in the equatorial region. This is also to realize the importance of developing countries in the tropics to play a more important role in global initiatives to achieve a better understanding of atmospheric changes and the effects on the environment linked to ozone changes.

OBSERVATIONAL ACTIVITIES

To perform ozone observation, National Institute of Aeronautics and Space (LAPAN) works in collaboration with other National Institutions: NASA, NOAA, NASDA and Japanese University. In 2021, LAPAN joined the National Research and Innovation Agency (BRIN), since then research activities have continued under the coordination of BRIN

Surface ozone measurement

Surface Ozone measurement conducted at 4 (four) locations which are Bandung, Watukosek, Biak and Pontianak. The surface ozone monitor used in this observation is Dylec model 1006-AHJ and model 1150, produced under a license of Dasibi Inc. The air containing the ozone is pumped into sample cell where the measurement is done by using ultraviolet absorption technique. The result is represented in units of ppb with the resolution of 1 ppbv and recorded on a strip chart or sent directly to PC that is operated as data logger. The cycle time of measurement is about 12 seconds (Anonym, 1985). This instrument was operated automatically 24 hours every day.

The measurements are conducted in Bandung (6.9ºS, 107.5ºE) West Java, 740 m asl, representing polluted city. Biak (1º S,136ºE) Papua, 50 m asl, representing unpolluted area. Pontianak (0.05ºN,109.33°E), West Kalimantan, representing unpolluted area that sometimes influenced by pollution comes from biomass burning / forest fire. Watukosek (7.5ºS, 112.6ºE), East Java, 50 m asl representing growing urban area.

Column measurements of ozone and other gases/variables relevant to ozone loss

Brewer spectrophotometer MK-IV (#092) operated at Watukosek (1994-2000) data sent to NASDA. After 2000 Watukosek Brewer spectrophotometer was not operated.
In 1996, LAPAN installed Brewer spectrophotometer MK-IV (#116) in Bandung and operated until 1998. In 2006 Brewer in Bandung re operated after calibrated assistance by MWO in September 2006.

Variables relevant to ozone loss have also been studied and continue by analyzing the Ozone Depleting Substances (ODS) data derived from AURA-MLS satellites to investigate the condition and its trend in the Indonesian region (Komala N, Ambarsari N, 2015)

Profile measurements of ozone and other gases/variables relevant to ozone loss
Balloon-borne measurements take place at Watukosek, East Java (7.5°S, 112.6°E, 51 m a.s.l). Ozonesondes Since 1998, the Watukosek Ozonesonde station was officially accepted into the Southern Hemisphere Additional OZonesondes (SHADOZ) network. Ozonesonde soundings have been conducted every week, using ECC ozonesondes. Ozonosondes launches are a collaboration between NASA/NOAA, Kyoto University, and the Hokkaido University, Japan.

Vertical ozone measurement is conducted regularly at Watukosek by using balloon-borne equipment. The system is set up of an airborne system - ozonesonde payload type RSII-KC79D provided by Meisei Co., a ground observation system tracking telemetry signal automatically, and a data processing system (also data acquisition system) based on a personal computer. The important ozonesonde unit is made up of an ozone detector and dedicated electronics. Ozone data which is converted into an audio signal is sent sequentially with meteorological signals information, i.e. temperature, pressure, and references (Anonym, 1979). These payloads were carried aloft using a meteorological hydrogen-filled rubber balloon (usually 3000 grams) and a protective parachute.
The ozone detector is based on Komhyr's carbon iodine ozone sensor. The operating principle is based on the reaction of ozone to a potassium iodide solution wherein free iodine is liberated. The liberated iodine is measured quantitatively by a coulometrical method (Kobayashi and Toyama, 1966). According to Kobayashi, the error of the measurement is estimated to be within + 2%.

Water Vapor Measurements
Since 2001, together with ozone soundings also water vapor soundings have been taken place. Soundings have been conducted annually (usually in December or January) using cryogenic chilled-mirror hygrometers that are flown in combination with ozonesondes. Water vapor soundings or SOWER (Sounding Ozone and Water vapor in Equatorial Region) are a collaboration between LAPAN, Kyoto University, Hokkaido University, and CIRES-University of Colorado/NASA/NOAA.

UV measurements
The UV measurements are performed by LAPAN, by using in situ measurement and analyzing data derived from satellite. According to simulations from the 2010 Scientific Assessment of Ozone Depletion indicate future increases in UV levels in the tropics, for humans, this poses the risk of more skin cancer in the tropics, therefore UV measurement and spreading the information to the public is really important. Recently AWS (Automatic Weather Station) was also used to measure the UV Index. More detailed research has been carried out by adding the location of the research and analysis data derived from AURA-OMI to determine UV conditions in general and in certain regions of Indonesia.

Broadband measurements

Narrowband filter instruments

Bandung and Watukosek station is used to measure UV. The UV Sensor measures UV-B irradiances of the UV spectrum (280 nm - 315 nm).

Spectroradiometers

Calibration activities

Pre-launch calibration of ozonesonde takes place on a regular basis. Vaisala is calibrated at NOAA/CIRES University of Colorado/NASA.

Brewer instrument was installed by LAPAN in Bandung (Brewer spectrophotometer MK-IV #116). The instrument was installed in early 1995 and last visited in 2001, but had been out of service for the past 4-5 years. The instrument was found to need a new power supply, micro-board, and UV filter in front of the photomultiplier tube to get it back into service. This calibration was completed in September 2006 at the LAPAN site in Bandung, Indonesia by Ken Lamb, (IOS) with support from the Vienna Convention Trust Fund through the World Meteorological Organization (WMO). In November 2010 calibration and maintenance of Brewer #116, Bandung, and Brewer #092, Watukosek also has been done. Total ozone data at Bandung and Watukosek then continue to observed using OMI AURA satellite data.

RESULTS FROM OBSERVATIONS AND ANALYSIS

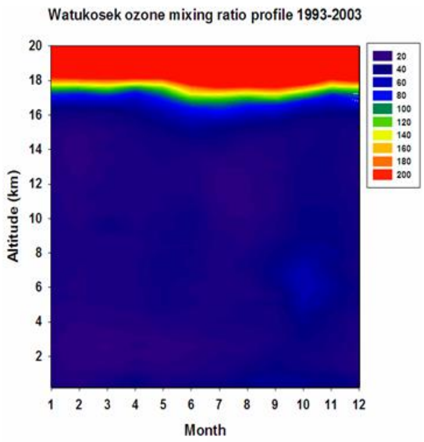


Fig.1. Profiles of ozone concentration observed at Watukosek derived from ten years observation.

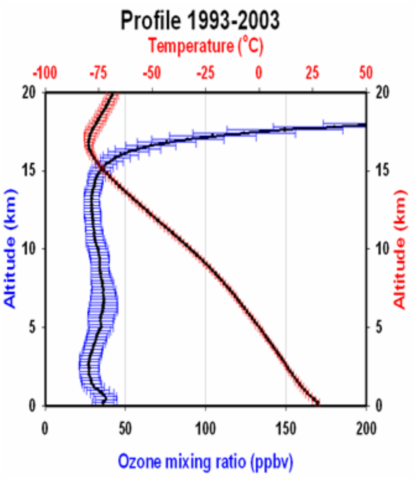


Fig.2. The compilation data from 1993 to 2003. These profiles are used as standard profiles for vertical ozone concentration and temperature

Profiles of ozone concentration and temperature observed at Watukosek in figure 1 and figure 2 has used as standard profile, (Komala, N. et al, 2006).

Since the end of 2020, the ozone launch in Watukosek in collaboration with NASA has been reactivated. Since the end of 2020, the ozone launch in Watukosek in collaboration with NASA has been reactivated. Below are the ozone results in Watukosek in 2022.

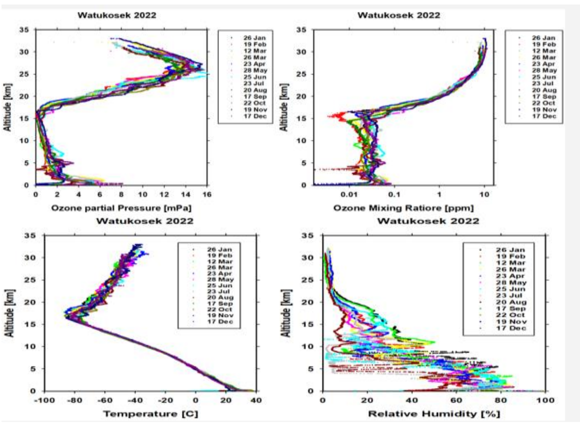
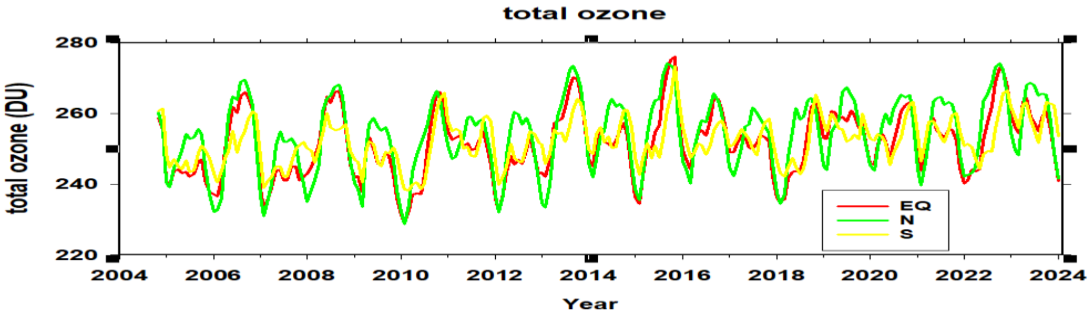


Fig.3. Profiles of ozone concentration observed at Watukosek in 2022.

Total ozone in the North of Indonesia (2N-12N), at the equator (2N-2S) and South (12S-2S) with latitudes 94E-146E in 2005 until 2023.



In Fig 4, total column ozone in North, equator and south of Indonesia in 2005-2023. In 2015 and 2022 total ozone show higher due to the El Nino and forest fire effect.

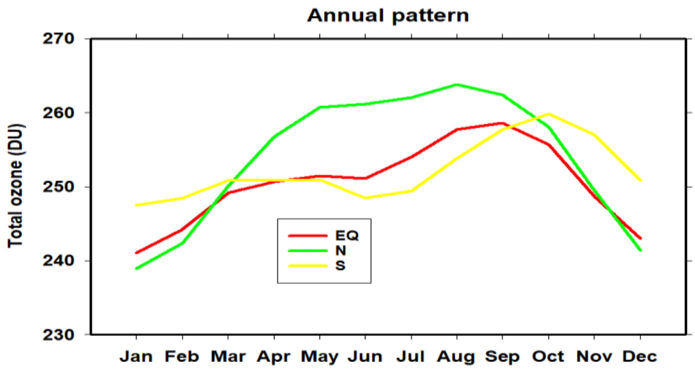


Fig. 5. Annual variation pattern of ozone in in the northern, equatorial, and southern regions of Indonesia

There are differences in the annual ozone pattern in the northern, equatorial, and southern regions of Indonesia. In the North the maximum is in August, the minimum is in January, at the Equator the maximum is in September, the minimum is in January, and in the South, the maximum is in October and the minimum is in January.

UV measurements

The UV measurements located at Bandung and Watukosek. The UV Sensor measures UV-B irradiances of the UV spectrum in the wavelength of 280 nm ~ 315 nm. The UV Index measurement also conducted in Bandung by using AWS (Automatic Weather Station).

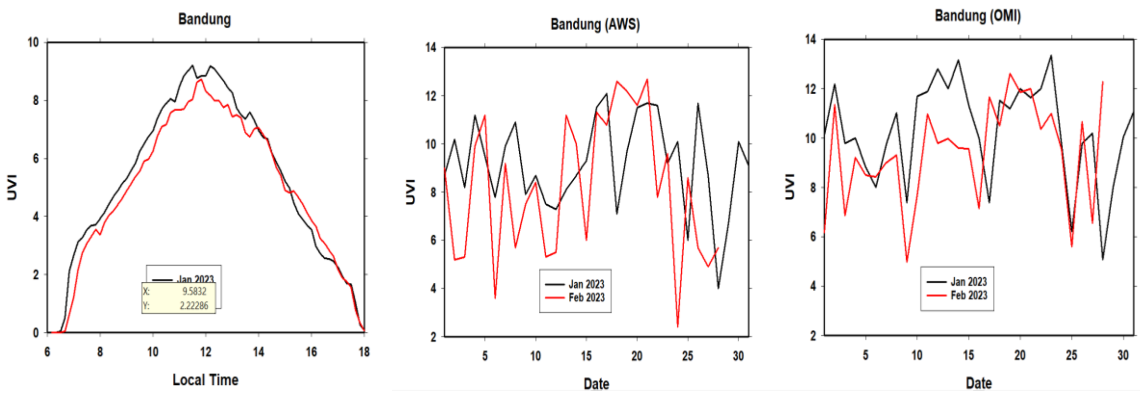


Fig 6. Diurnal variation of UV index in Bandung (left), daily variation from AWS (middle) and daily variation derived from AURA-OMI (right).

In Fig 6, the diurnal variation of UV index in Bandung in January and February 2023 shows that a peak of diurnal variation of UVI was detected in noon time with UVI of higher than 9. Daily variation of UVI from AWS shows between 3 to 13 and from AURA-OMI shows that the UVI annual variation varied between 5 to 13.

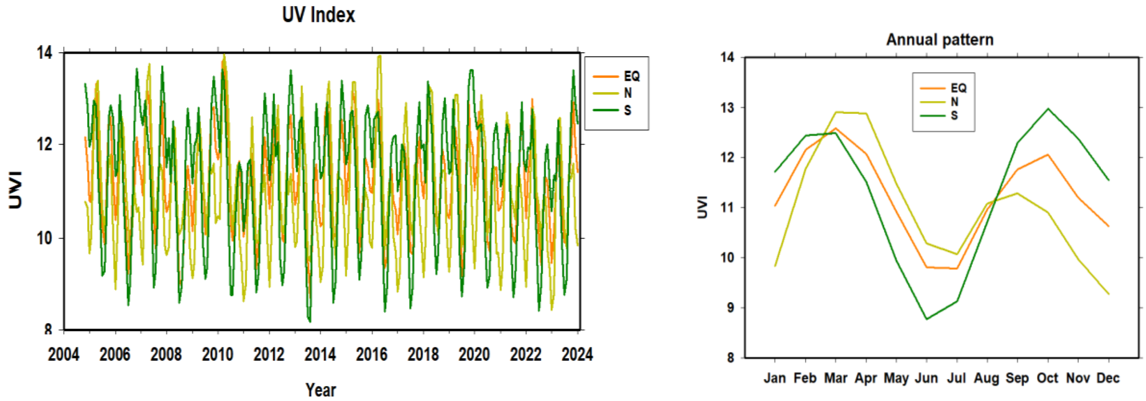


Fig 7. Time series of UVI In Indonesia from 2005 to 2023 and its annual variation pattern

The time series of UVI In the North, Equator, and southern of Indonesia derived from OMI_AURA data in 2005-2013 indicates that UVI shows 8 to 14 which indicates a higher and extreme value. The annual variation of UVI in North, Equator, and Southern Indonesia shows a different pattern. North shows maximum UVI in March and September and a minimum in June. Equatorial shows maximum in March and October and minimum in June and July. The range of the UV index is between 9 to 13.

THEORY, MODELLING, AND OTHER RESEARCH

The Ozone Standard Profile was constructed by using the long-term observation data of the ozonesonde launchings from Watukosek (surface ~ 20 km). This Watukosek standard profile is a result of a statistical model of Watukosek ozone and temperature.

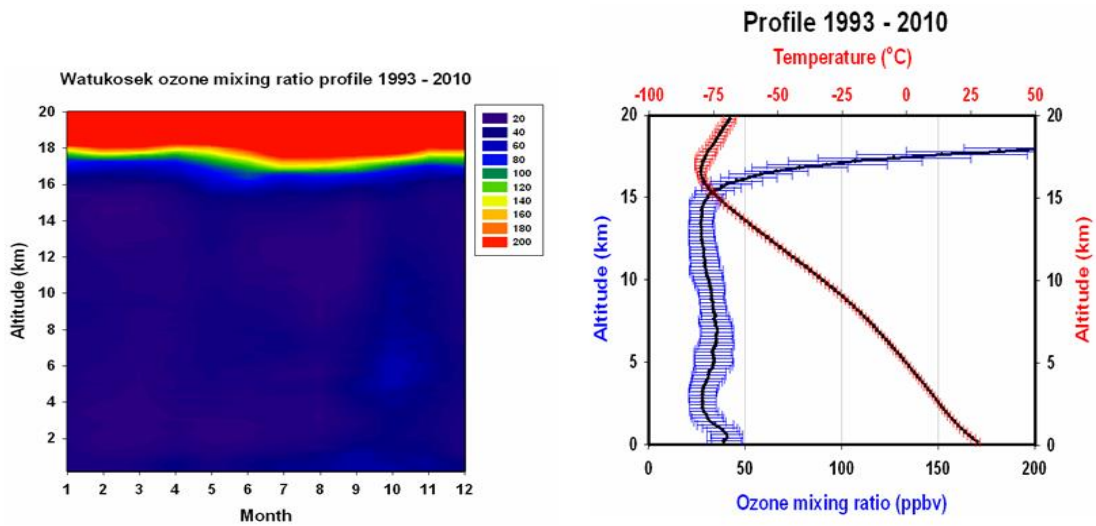
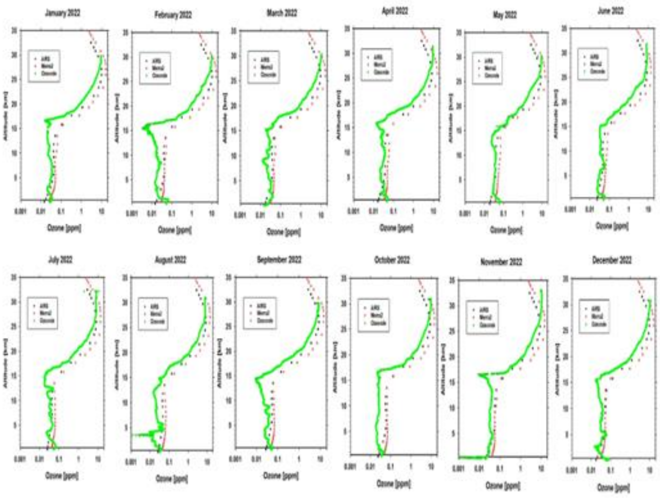


Fig 8, Contour of Watukosek Ozone Mixing Ratio profile 1993~2010 (left) and Watukosek OMR and temperature profile 1993~2010 with standard deviation (right), as a result of a statistical model of Watukosek ozone and temperature.



Ozonesonde Correlation-2022 with		
	AIRS	Merra2
Jan	0.819	0.967
Feb	0.795	0.905
Mar	0.813	0.882
Apr	0.805	0.854
May	0.870	0.919
Jun	0.903	0.895
Jul	0.845	0.864
Aug	0.915	0.913
Sep	0.900	0.944
Oct	0.864	0.863
Nov	0.826	0.852
Dec	0.894	0.818

Fig. 9. Watukosek in situ ozone profile in 2022 based on ozonesonde, AIRS, and Merra2 model output, and correlation table of in situ ozone with AIRS and in situ ozone with Merra2 output

In 2023, the Watukosek ozone vertical profile data in 2022 is used to verify ozone vertical profile data from the Atmospheric Infrared Sounder (AIRS) and the output of the Merra2 model. Based on the comparison results, the ozone vertical profile suitability pattern was obtained. between the results of the AIRS and Merra2 models with the data from in situ observations. From the correlation values obtained, the results of the verification of the output of the Merra2 model are closer to the results of the observation data and the quality is better. (Komala, 2023).

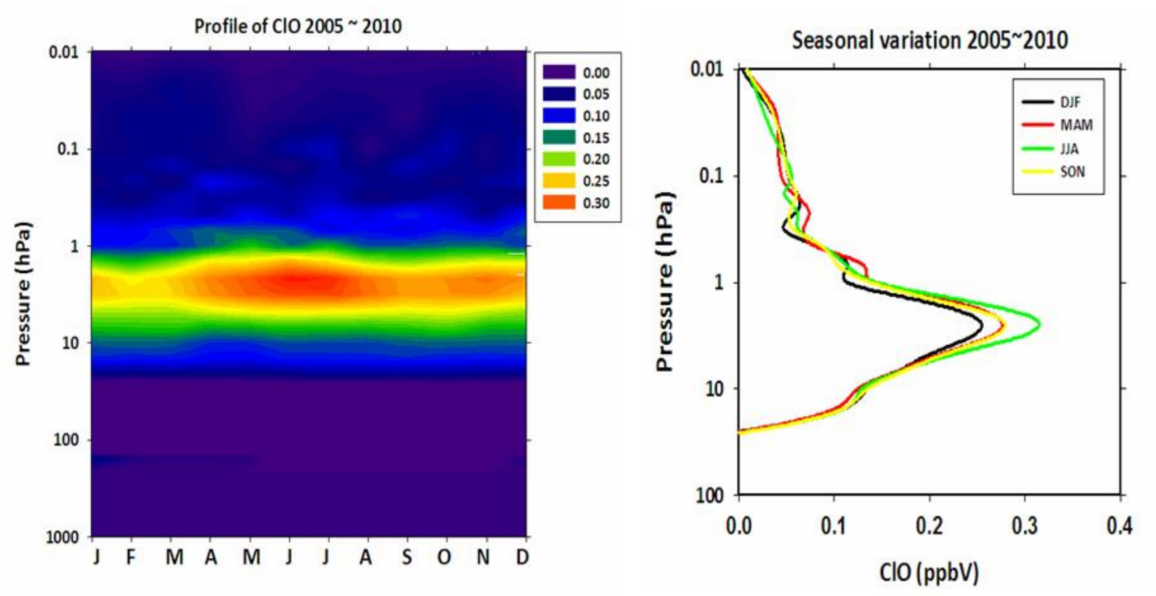


Fig 10. Annual pattern of ClO (left) and its seasonal profile in Indonesia for 2005 to 2010 (right).

A study of ClO in Indonesia indicates that the peak of the ClO profile in Indonesia was at 2.1 hPa (30.6 km) and ClO concentration varies between 0.20 ppb to 0.31 ppbv. Seasonal variation of the ClO profile shows a peak at 2.1 hPa (30.6 km) with a maximum concentration of 0.31 ppbV in June-July-August (JJA months), while a minimum concentration of 0.23 ppbV was detected in December-January-February (DJF months).

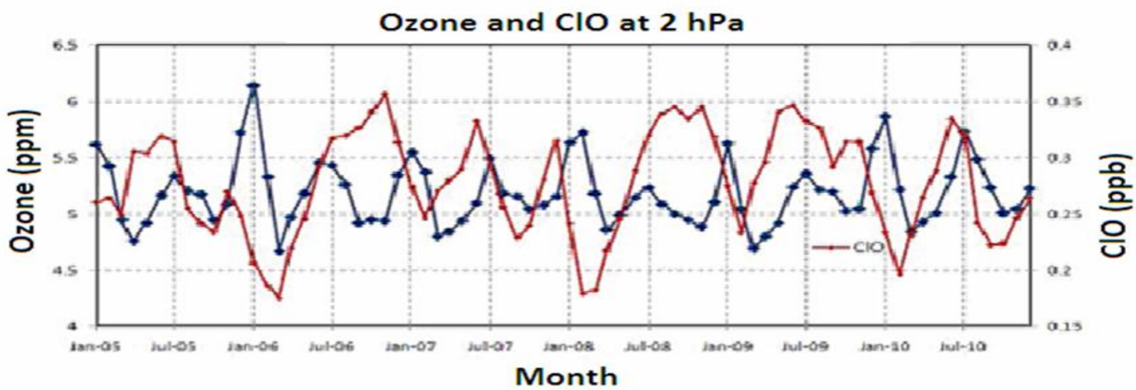


Fig 11. Time series of ClO and ozone in Indonesia at 2.1 hPa where ClO concentration reach maximum.

Time series of ClO and ozone at 2.1 hPa (30. km) where ClO concentration reaches maximum. At this altitude, ozone in Indonesia showed 4 to 6.2 ppmV and ClO ranged between 0.15 to 0.35 ppbV. We can find the tendency of ozone minimum when ClO reaches a maximum, especially in January and July each year.

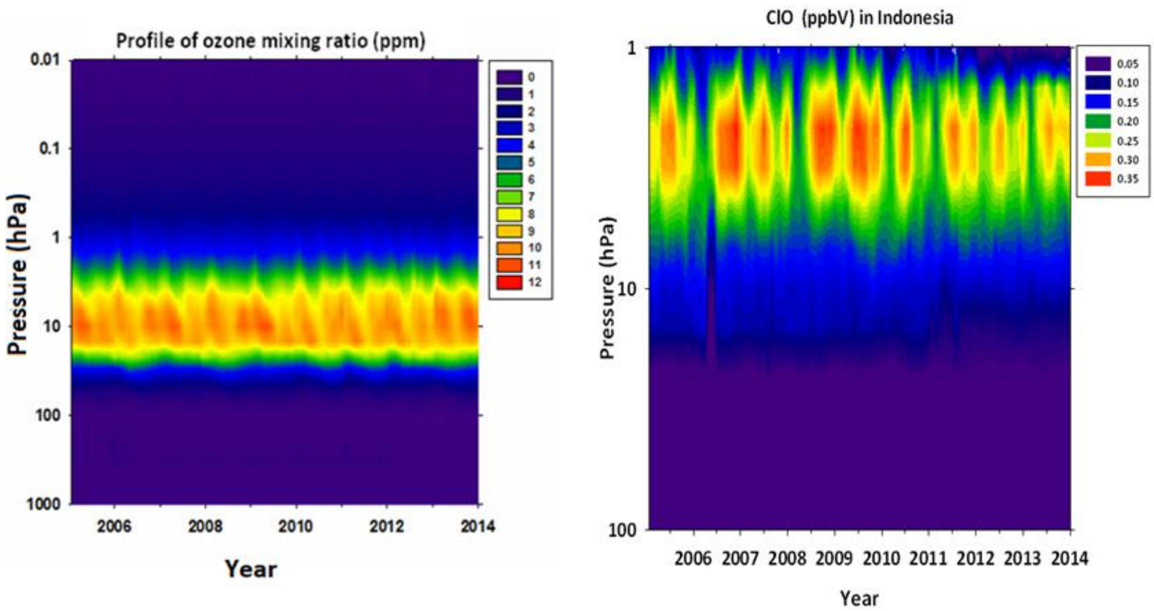


Fig 12. Timeseries of ozone (left) and ClO profile in Indonesia for 2005 to 2013 (right) derived from MLS-AURA.

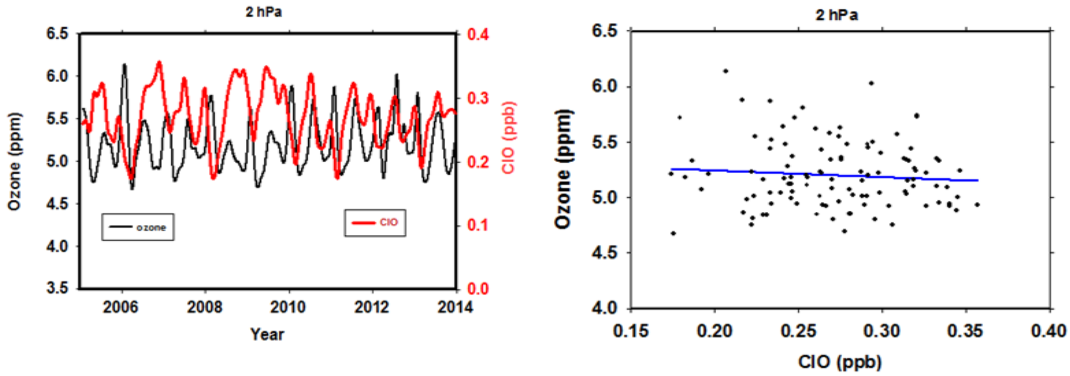


Fig. 13 The relationship between ozone and ODS (ClO)

in the Fig 13, it can be seen that every additional 0.01 ppb of ClO will reduce 5.83 ppb of ozone (Komala, 2015).

A detailed study of chemistry and dynamic processes affecting the ClO concentration in the atmosphere and its influence on ozone variation is still urgently needed.

DISSEMINATION OF RESULTS

Data reporting

The ozone profile data collected in Watukosek is sent to Hokkaido University, in Sapporo, Japan. The data from Hokkaido University is then transferred to the SHADOZ (Southern Hemispheric Additional OZonesondes) archives data: http://croc.gsfc.nasa.gov/shadoz/java.html.

Bandung Brewer Spectrophotometer data is sent to WOUDC, Canada, ftp://ftp.tor.ec.gc.ca

Information to the public

Vertical ozone profile data is made available after every launch on the SHADOZ website for the scientific community.

Relevant scientific papers

- Vömel, H., J. E. Barnes, R. N. Forno, M. Fujiwara, F. Hasebe, S. Iwasaki, R. Kivi, N. Komala, E. Kyrö, T. Leblanc, B. Morel, S.-Y.Ogino, W. G. Read, S. C. Ryan, S. Saraspriya, H. Selkirk, M. Shiotani, J. Valverde Canossa, and D. N. Whiteman (2007), **Validation of Aura Microwave Limb Sounder water vapor by balloon-borne Cryogenic Frost point Hygrometer measurements**, *Journal of Geophysical Research, 112*, D24S37, doi:10.1029/2007JD008698.
- Hasebe, F., M. Fujiwara, N. Nishi, M. Shiotani, H. Vömel, S. Oltmans, H. Takashima, S. Saraspriya, N. Komala, and Y. Inai (2007), **In situ observations of dehydrated air parcels advected horizontally in the Tropical Tropopause Layer of the western Pacific**, *Atmospheric Chemistry and Physics, 7*, 803-813
- Fujiwara, M., Y. Tomikawa, K. Kita, Y. Kondo, N. Komala, S. Saraspriya, T. Manik, A. Suripto, S. Kawakami, T. Ogawa, E. Kelana, B. Suhardi, S. W. B. Harijono, M. Kudsy, T. Sribimawati, and M. D. Yamanaka (2003), **Ozonesonde observations in the Indonesian maritime continent: A case study on ozone rich layer in the equatorial upper troposphere**, *Atmospheric Environment, 37*, Issue 3, 353-362.

- Fujiwara, M., K. Kita, T. Ogawa, S. Kawakami, T. Sano, N. Komala, S. Saraspriya, and A. Suripto (2000), **Seasonal variation of tropospheric ozone in Indonesia revealed by 5-year ground-based observations** , *Journal of Geophysical Research, 105*, No. D2, 1879-1888.
- Fujiwara, M., K. Kita, S. Kawakami, T. Ogawa, N. Komala, S. Saraspriya, and A. Suripto (1999), **Tropospheric ozone enhancements during the Indonesian forest fire events in 1994 and in 1997 as revealed by ground-based observations**, *Geophysical Research Letters, 26*, No. 16, 2417-2420.
- Fujiwara, M., K. Kita, T. Ogawa, N. Komala, S. Saraspriya, A. Suripto, and T. Sano (1998), **Total ozone enhancement in September and October 1994 in Indonesia**, in *Atmospheric Ozone*, Vol. 1, (Proceedings of the XVIII Quadrennial Ozone Symposium, L'Aquila, Italy, September 12-21, 1996), edited by R. D. Bojkov and G. Visconti, pp. 363-366.
- Komala, N., S. Saraspriya, K. Kita, and T. Ogawa, **Tropospheric ozone behavior observed in Indonesia**, *Atmospheric Environment, 30, 1851-1856, 1996.*
- Martin G Schultz, Sabine Schröder, Olga Lyapina, Owen R Cooper, Ian Galbally, Irina Petropavlovskikh, Erika Von Schneidemesser, Hiroshi Tanimoto, Yasin Elshorbany, Manish Naja, Rodrigo J Seguel, Ute Dauert, Paul Eckhardt, Stefan Feigenspan, Markus Fiebig, Anne-Gunn Hjellbrekke, You-Deog Hong, Peter Christian Kjeld, Hiroshi Koide, Gary Lear, David Tarasick, Mikio Ueno, Markus Wallasch, Darrel Baumgardner, Ming-Tung Chuang, Robert Gillett, Meehye Lee, Suzie Molloy, Raeesa Moolla, Tao Wang, Katrina Sharps, Jose A Adame, Gerard Ancellet, Francesco Apadula, Paulo Artaxo, Maria E Barlasina, Magdalena Bogucka, Paolo Bonasoni, Limseok Chang, Aurelie Colomb, Emilio Cuevas-Agulló, Manuel Cupeiro, Anna Degorska, Aijun Ding, Marina Fröhlich, Marina Frolova, Harish Gadhavi, Francois Gheusi, Stefan Gilge, Margarita Y Gonzalez, Valerie Gros, Samera H Hamad, Detlev Helmig, Diamantino Henriques, Ove Hermansen, Robert Holla, Jacques Hueber, Ulas Im, Daniel A Jaffe, Ninong Komala, Dagmar Kubistin, Ka-Se Lam, Tuomas Laurila, Haeyoung Lee, Ilan Levy, Claudio Mazzoleni, Lynn R Mazzoleni, Audra McClure-Begley, Maznorizan Mohamad, Marijana Murovec, Monica Navarro-Comas, Florin Nicodim, David Parrish, Katie A Read, Nick Reid, Ludwig Ries, Pallavi Saxena, James J Schwab, Yvonne Scorgie, Irina Senik, Peter Simmonds, Vinayak Sinha, Andrey I Skorokhod, Gerard Spain, Wolfgang Spangl, Ronald Spoor, Stephen R Springston, Kelvyn Steer, Martin Steinbacher, Eka Suharguniyawan, Paul Torre, Thomas Trickl, Lin Weili, Rolf Weller, Xu Xiaobin, Likun Xue, Ma Zhiqiang, ***Tropospheric Ozone Assessment Report: Database and metrics data of global surface ozone observations***, *Elementa: Science of the Anthropocene* (2017) 5: 58. https://doi.org/10.1525/elementa.244
- Ninong Komala and Novita Ambarsari, Ozone Variability and Ozone Depleting Substances (ODS) in Indonesia based on MLS-AURA Data, *International Journal of Remote Sensing and Earth Sciences Vol.12 No.2 December 2015: 125 – 134.*
- Komala, N., **Analysis of Java Island's ozone layer and ultra violet index variability based on satellite data, *E3S Web of Conferences***, 2019, 76, 04001.

PROJECTS AND COLLABORATION

The major international collaborations are with Hokkaido University, Kyoto University, CIRES-University of Colorado-NOAA/NASA.

LAPAN has participated in projects:

Sounding of Ozone and Water vapor at Equatorial Region (SOWER), financed by Hokkaido University, Kyoto University, CIRES-University of Colorado-NOAA/NASA, through this project, we launch regularly ozone and water vapor sondes at Biak (the campaign is conducted every January). This project was conducted from January 2004 until 2015.

Southern Hemisphere ADditional OZonosondes, SHADOZ, financed by NASA, from January 1998 and still ongoing. (reactivated in 2020).

FUTURE PLANS

Future research activities will be a continuation and extension of current investigations such as:

- Continue monitoring vertical ozone profiles under the SHADOZ program, to obtain ozone climatology,
- Continue to monitor the ozone total with Brewer and start with a UV network in Indonesia (measurement of UV Index).
- Evolution of the total ozone column over the Indonesia region, which can determine trends of ozone and UV levels.
- Start to measure ODS and improve its analysis data derived from satellite and plan to measure ODS in situ.
- Collaboration research concerning ozone modeling and impact of higher UV-B radiation and ozone layer in Indonesia, dynamics, chemistry, and inter-annual variation of equatorial ozone,
- Continuing and improving the surface ozone measurements,
- To improve dissemination of the data on ozone, UV Index and its impact on human health, and the impact of ODS in saving the ozone layer to the Indonesian community by spreading the information and establishing an integrated Indonesia web page.

NEEDS AND RECOMMENDATION

- Permanent ground-based and satellite-based instruments are an essential complement to this research.
- The current monitoring networks must be continued and maintained in qualified operation. The long-term research is necessary to determine the future evolution of ozone
- Requires strong support in capacity building at the technician and research levels to continue both with monitoring and relevant research
- The new monitoring activities of ODS in the Indonesian region to provide relevant information including long-term monitoring
- Needed financial support for travel to meetings, seminars, and workshops abroad.
- The ozone and UV (measurement of UV index) network in Indonesia must be continued and maintained.
- Since the tropical region where we stand, UV levels are high, collaboration research concerning ozone modeling and the impact of higher UV-B radiation and the ozone layer in Indonesia are also needed as a consequence of the equatorial region country.
- Still needed assistance for calibration and maintenance of instrumentations which cannot be done in Indonesia due to the lack of budget spare parts and experts.