SURFACE OZONE VARIATIONS AT THE GREAT WALL STATION, ANTARCTICA DURING AUSTRAL SUMMMER

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FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITI MALAYSIA SABAH

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I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a master's degree in science. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

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ABSTRACT

Surface Ozone (O_3) is a secondary pollutant which toxic to human health, and a greenhouse gas which is one of the prime climate forcers. Due to the clean atmospheric environment of the Antarctic region and given the complexity of O_3 chemistry, the observation of surface O_3 variability in this region is necessary in the quest to better understand the potential sources and sink of polar surface O_3. This study highlights the observation on surface O_3 variability at the Great Wall Station (GWS) during austral summer in December 2018 and January 2019. The continuous in-situ surface O_3 measurement at the GWS, Antarctica was carried out using the EcoTech Ozone analyzer while meteorological data was obtained from the conventional auto-observational station operated at the GWS. To have a better understanding of surface O_3 latitudinal distribution, the spatial and temporal of surface O_3 data obtained online from the World Meteorology Organization of World Data Centre for greenhouse gases (WMO WDCGG) were then compared to give an indications of its spatial and temporal characteristic. The HYSPLIT model (Hybrid Single-Particle Lagrangian back-trajectory) was employed to have a better picture on the overall impact of air mass transport toward the surface O_3 formation over the region. Lastly, to have a better discernment on the potential impact of meteorology to the surface O_3 formation, statistical principal analysis (PCA) was employed to give a confidence measure over which meteorological parameter play more pivotal role on affecting surface O_3 background level. The results show that despite being characterised as stable surface O_3 concentration with standard deviation value of 0.24 ppbv throughout the entire period of observation, though the hourly summer surface O_3 distribution at GWS varies from 4.45 ppbv to 7.81 ppbv. The online dataset from WDCGG showed that the summer characteristic of surface O_3 at GWS are one-to-three times lower than what been observed at other research station. The unique characteristic of surface O_3 of GWS can temporarily emphasized by its synoptic marine air mass characteristic with coefficient correlation value of 0.17, significant at value of 0.1. The statistical result of PCA shows that three principal components factors with eigenvalues cut-off unity value of 70%, and only atmospheric pressure as well surface temperature in factor 1 shows significant positive correlation with surface O_3 with coefficient value of 0.667 and 0.563, respectively. While wind speed and wind direction in factor 3 which significant at 0.701 and 0.748 respectively, have more pivotal role to cause residual change in diurnal surface O_3 concentration. To put something into perspective, the surface O_3 variability at the GWS suggesting that the marine air mass could be important source of low surface O_3 level, and the temporal characteristic controlled by combined local photochemical process and air mass transport subjected to the availability of its precursor, or halogen species and its weather condition.

Keywords: surface Ozone, meteorological conditions, Great Wall, austral summer, HYSPLIT

ABSTRAK

VARIASI OZONE PERMUKAAN DI STESEN GREAT WALL, ANTARTIKA PADA MUSIM PANAS AUSTRAL

Ozone (O_3) permukaan adalah bahan pencemar sekunder yang berbahaya bagi kesihatan manusia, dan gas rumah hijau yang merupakan salah satu punca utama perubahan iklim. Oleh kerana persekitaran atmosfera yang bersih di wilayah Antartika dan kerumitan tindakbalas kimia O_3, pemerhatian terhadap variasi O_3 di rantau ini diperlukan dalam usaha untuk lebih memahami proses dan sumber-sumber yang berpotensi dalam penghasilankan atau pemusnahan O_3. Fokus kajian ini adalah pemerhatian terhadap variasi O_3 di Stesen Great Wall pada musim panas Austral iaitu sekitar bulan Disember 2018 sehingga Januari 2019. Persampelan gas permukaan O_3 secara in-situ dilakukan secara berterusan di stesen ini dengan menggunakan EcoTech Ozone Analyzer sementara data meteorologi diperolehi daripada stesen pemerhatian automatik konvensional yang dikendalikan di GWS. Untuk lebih memahami variasi berkaitan taburan variasi permukaan O_3 di kawasan-kawasan sekitar wilayah Antartika, data dalam talian daripada World Meteorology Organization of World Data Centre for greenhouse gases (WMO WDCGG) diproses dan kemudianya dibandingkan untuk memberikan perbandingan secara spasial dan temporal terhadap variasi permukaan O_3. Model HYSPLIT (Hybrid Single-Particle Lagrangian back-trajectory) pula digunakan untuk memberikan gambaran keseluruhan terhadap kesan daripada peredaran jisim udara keatas penghasilan permukaan O_3 dikawasan ini. Untuk mengunjurkan analisa yang lebih baik berkaitan dengan potensi kesan perubahan meteorologi terhadap penghasilan permukaan O_3, statistikal analisis melalui kaedah Principal Component Analysis (PCA) digunapakai dalam menilai tiap-tiap parameter meteorologi dan pengaruhnya terhadap paras penghasilan permukaan O_3. Hasil kajian mendapati bahawa permukaan O_3 selama masa persampelan dilakukan di kawasan ini adalah bersifat stabil dengan nilai sisihan piawai 0.24 ppbv walaupun paras kepekatanya berbeza dari 4.45 ppbv sehingga 7.81 ppbv. Analisa perbandingan data yang diperolehi secara dalam talian dari WDCGG menunjukkan bahawa permukaan O_3 disepanjang musim panas Austral adalah satu sehingga tiga kali lebih rendah daripada stesen-stesen penyelidikan lain di rantau Antartika ini. Keunikan variasi permukaan O_3 dikawasan ini ada kalanya dikesankan oleh peredaran jisim udara marin dengan korelasi 0.17 pada nilai unjuran 0.1. Hasil

analisa PCA menunjukkan bahawa terdapat 3 kelas faktor dengan total nilai varians yang diterangkan sebanyak 70%, akan tetapi hanya tekanan udara dan suhu sahaja dalam faktor 1 menunjukkan korelasi positif bersama permukaan O_3 dengan nilai korelasi 0.667 dan 0.563. Manakala kelajuan dan arah mata angin dalam faktor 3 dengan nilai unjuran korelasi 0.701 dan 0.748 dilihat memainkan peranan yang lebih penting dalam pembentukan permukaan O_3. Dapat disimpulkan bahawa sumber utama variasi permukaan O_3 yang rendah di GWS adalah bersumberkan daripada export peredaran jisim udara daripada kawasan marin, dan ciri-ciri temporalnya dipengaruhi oleh gabungan proses fotokimia dan pergerakan jisim udara, tertakluk pada ketersediaan prekursor atau halogen spesis dan keadaan cuaca.

Kata kunci: Ozon permukaan, keadaan meteorologi, Tembok Besar, musim panas austral, HYSPLIT

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LIST OF UNITS

^{o}	-	Degree
^{o}C	-	Degree Celsius
cm	-	Centimetre
hPa	-	hectopascals
kPa	-	kilopascal
km	-	Kilometre
ppbv	-	part per billion by volume
pptv	-	part per thousand by volume
m	-	meter
m mg^{-1}	-	meter per milligram
mb	-	millibar
mg m^{-3}	-	milligram per meter cube
MJ m^{2}	-	Megajoule per meter square
ms^{-1}	-	meter per second
mW m^{-2}	-	milliwatt per meter square
nm	-	nanometre
µm	-	micrometre
V	-	Volt

LIST OF SYMBOLS

+	-	Plus, positive
-	-	Minus, Negative
±	-	Plus, minus
%	-	Percentage
>	-	Greater than
<	-	Lower than
hv	-	Sun light
x	-	Times with
^{2}	-	Power of two, square
^{3}	-	Power of three, cube

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

ACC	-	Antarctic Circumpolar Current
a.g.l	-	Above ground level
a.s.l	-	Above sea level
ARL	-	Air Resource Laboratory
AWS	-	Automatic weather station
Br_2	-	Bromine
BrCl	-	Bromine monochloride
BrO	-	Bromine oxide
CCGG	-	Carbon cycle and greenhouse gases
$CHBr_3$	-	Bromoform
CH_4	-	Methane
Cl	-	Chloride
CO	-	Carbon monoxide
CRV	-	Coefficient of relative variation
E	-	East
ECMWF	-	European Centre for Medium-Range Weather Forecasting
GAW	-	Global Atmospheric Watch
GCM	-	Global Circulation Model
GDAS	-	Global Dataset Assimilation Process
GHGs	-	Greenhouse gases
GMD	-	Global Monitoring Division

G-RAD	-	Global radiation
GWS	-	Great Wall Station
H	-	Hydrogen
HATS	-	Halocarbons and other atmospheric trace gases
HC	-	Hydrocarbon
HNO_3	-	Nitric acid
HO_2	-	Water vapour
HYSPLIT	-	Hybrid Single-Particle Lagrangian Integrated Trajectory Model
hr	-	Hour
I	-	Iodine
IR	-	Infrared radiation
LT	-	Local Time
MBL	-	Marine boundary layer
N_2	-	Nitrogen
NetCDF	-	Network Common Data Form
NMHC	-	Non-Methane Hydrocarbon
NO_X	-	Nitrogen oxides
NO_2	-	Nitrogen dioxide
NOAA	-	National Oceanographic and Atmosphere Administration
O_2	-	Oxygen
O_3	-	Ozone
$O(^1D)$	-	Excite Oxygen

ODEs	-	Ozone depletion events
OEEs	-	Ozone enhance events
OH	-	Hydroxyl
OZWV	-	Ozone and water vapour
PBL	-	Planetary boundary layer
PCA	-	Principal component analysis
PC	-	Principal Component
PRT	-	Platinum resistance thermometer
RH	-	Relative humidity
S	-	South
SD	-	Standard deviation
SLGHGs	-	Short-lived greenhouse gases
SPO	-	South Pacific Ocean
SO	-	Southern Ocean
SOA	-	Secondary organic aerosol
SO_2	-	Sulphur dioxide
STT	-	Stratosphere-to-troposphere transport
SZA	-	Solar Zenith Angle
TCO	-	Total column ozone
UV	-	Ultraviolet
VOCs	-	Volatile organic compounds
W	-	West

WDCGG	-	World Data Centre for Greenhouse Gases
WMO	-	World Meteorological Organisation

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