"Satellite-borne and Ground-based Total Ozone Column Concentration Measurements in the Philippines: Comparisons and Variations"

Atmospheric Unit Measurement Laboratory

BAGTASA Lab

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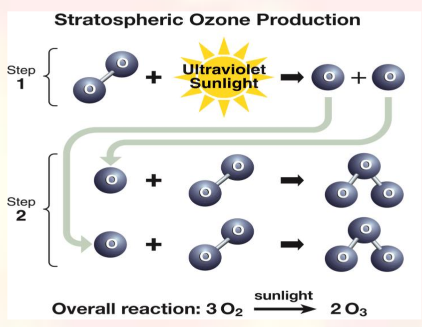
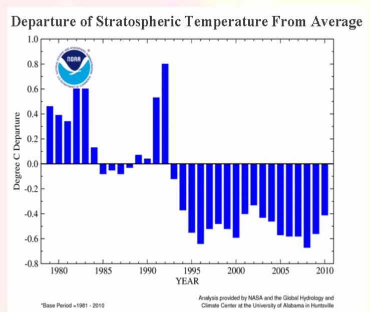
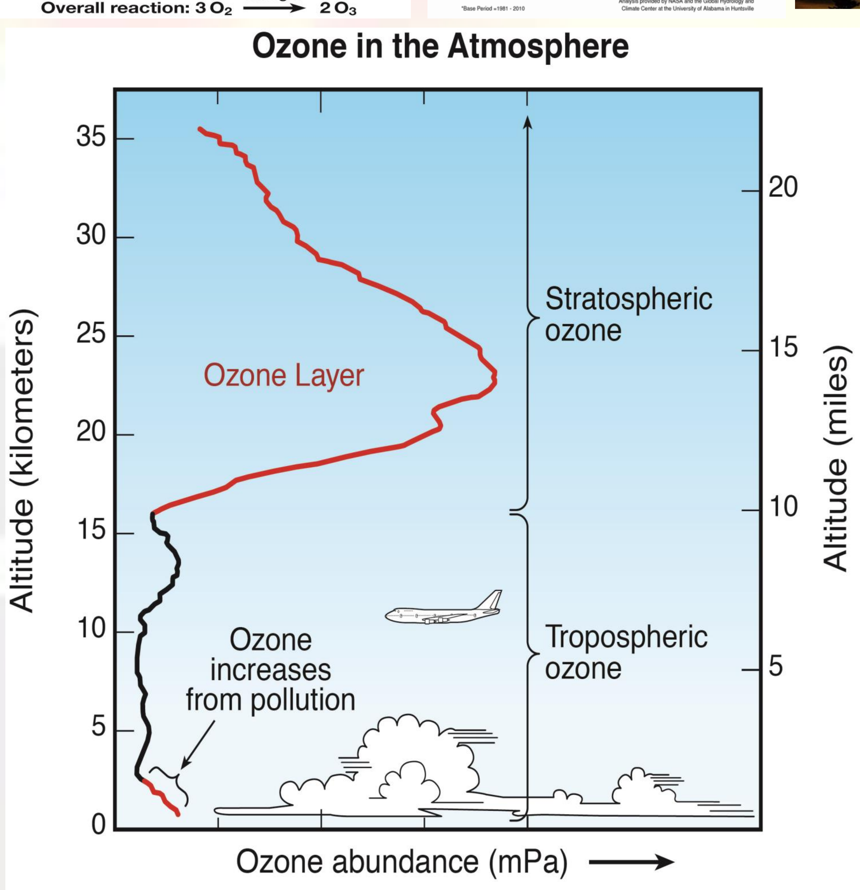
Abstract: *The ozone layer is under threat due to warming in the troposphere brought about by the increase in greenhouse gases (GHG) concentrations. Warming in the troposphere makes the stratosphere cooler, producing polar stratospheric clouds (PSCs) that support chemical reactions that produce active chlorine which destroys ozone. Ozone measurements and analyses with different instrument platforms (satellite-borne and ground-based) must still be performed as they remain essential even with the signing of the Montréal Protocol. The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) contributes to the Global Atmospheric Watch (GAW) Program of the World Meteorological Organization (WMO) [2006-2013] by measuring daily total ozone column using a Dobson spectrophotometer. Maximum amount of ozone was observed during the summer period and minimum throughout the winter due to unequal solar radiation which is a factor for ozone production. The differences between satellite-borne and ground-based ozone measuring instruments vary due to local weather events, solar zenith angle, sky conditions, and the relatively large footprint of the satellites. Comparing the ground-based Dobson spectrophotometer and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument on-board the ENVISAT satellite yielded a correlation coefficient and a root-mean-square error of 0.7261 and 12.45 DU, respectively. On the other hand, comparing the Dobson spectrophotometer and the Ozone Monitoring Instrument (OMI) on-board the Aura satellite produced a correlation coefficient and root-mean-square error of 0.5943 and 16.06 DU, respectively. The effects of water vapor intrusion in the Upper-Troposphere-Lower-Stratosphere (UTLS) to the total ozone column during tropical cyclones was also be quantified and investigated using the Weather Research and Forecasting (WRF) model.*

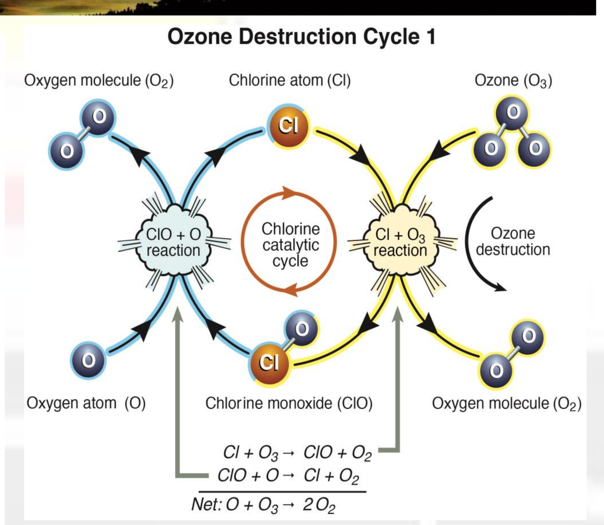
Why is total ozone column measurement important?

Ozone (O_3) is formed from oxygen gas in the atmosphere that serves as a protecting layer from the sun's harmful UV rays. The increase in GHG concentrations in the troposphere is causing a cooling in the stratosphere. This depletes ozone due to the formation of polar stratospheric clouds (PSCs) that support chemical reactions that produce active chlorine. Ozone monitoring is therefore still essential even with the signing of the Montréal Protocol.



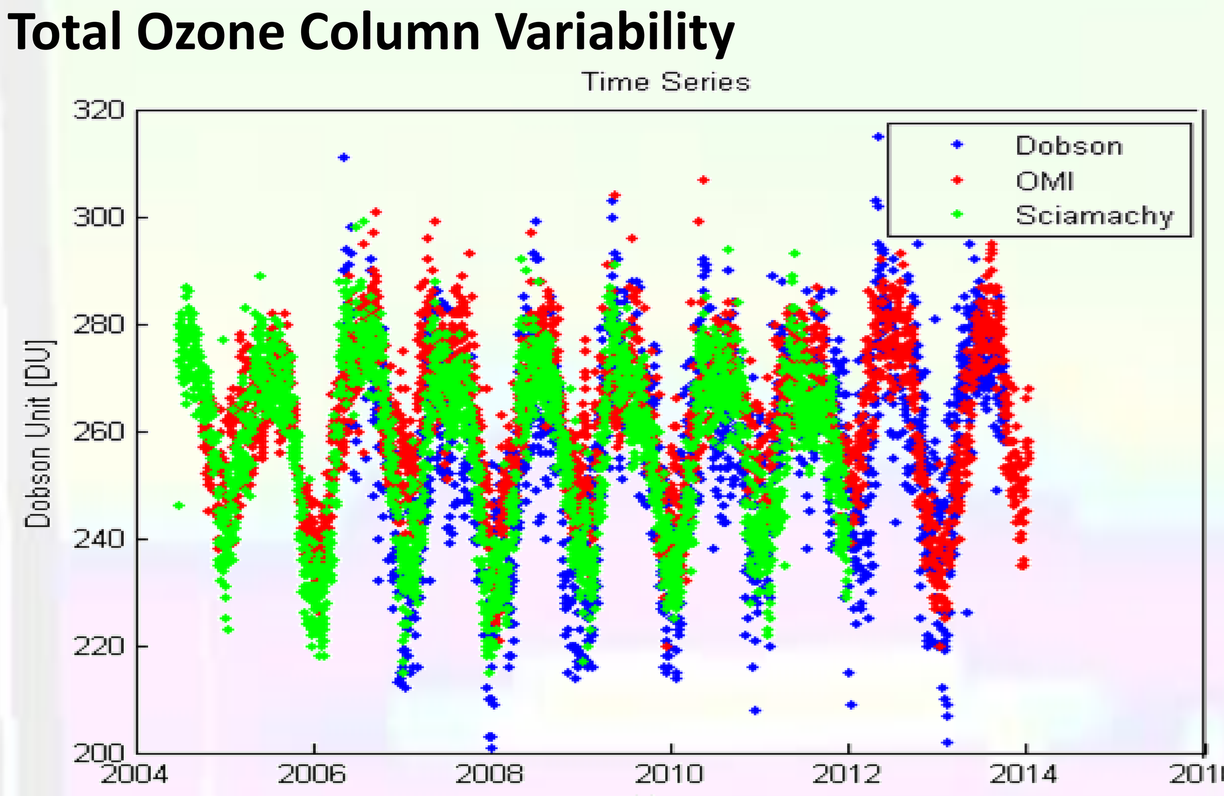




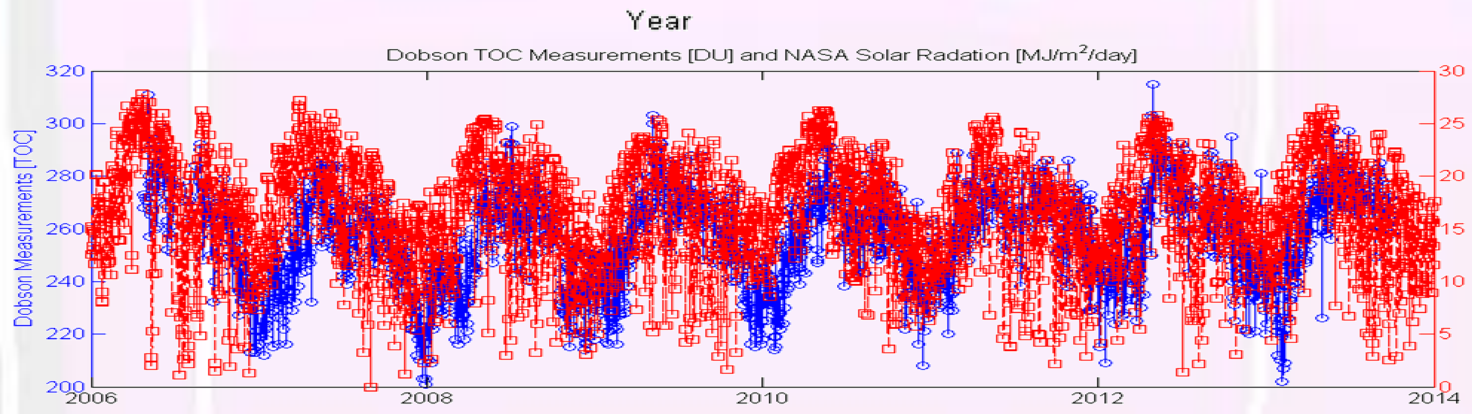


Total ozone column (TOC) is measured in Dobson units (DU) where 1 DU is equivalent to a 0.01 mm thick layer of ozone gas at STP. The highest amount of ozone in the atmosphere is located over the stratosphere (around 20-30km).

Total Ozone Column Variability

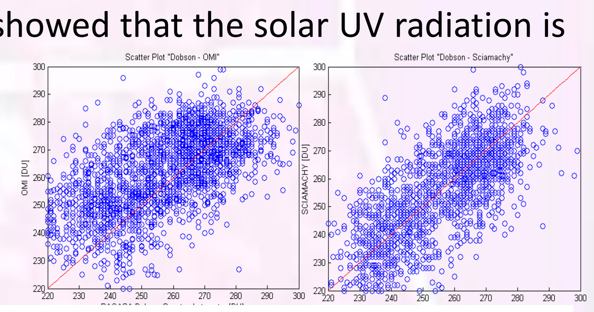


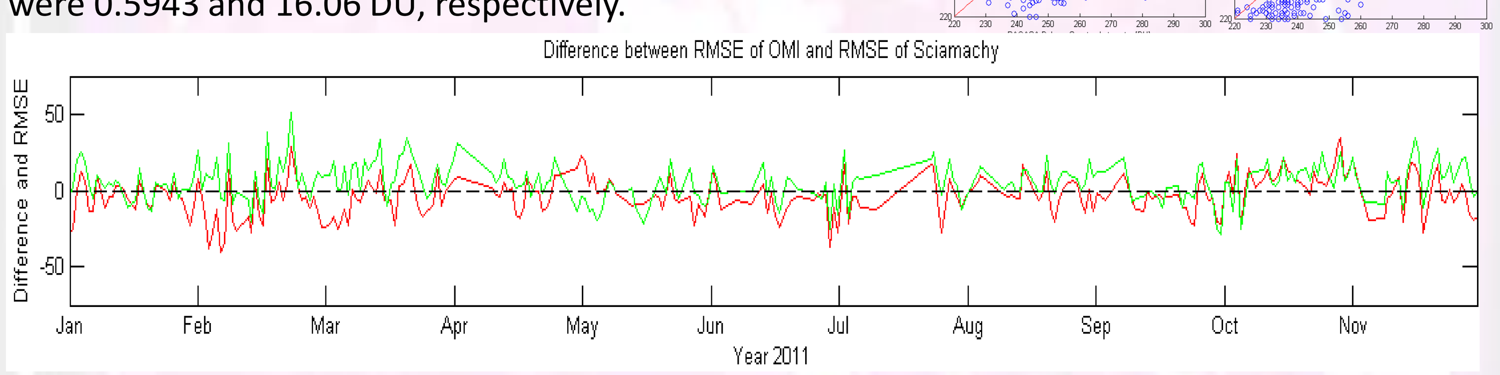
A see-saw pattern was observed, this pattern is partly caused by unequal solar radiation. Maximum amount of ozone was obtained during summer and minimum during winter.



Solar radiation (MJ/m^2 /day) data (2006–2013) from NASA plotted with the TOC (DU) measurements (above) from Dobson spectrophotometer showed that the solar UV radiation is one of the main drivers for stratospheric ozone variations.

Inter-comparison of Dobson-SCIAMACHY data from 2007-2011 yielded a correlation coefficient and RMSE of 0.7261 and 12.45 DU, respectively while those of Dobson-OMI were 0.5943 and 16.06 DU, respectively.

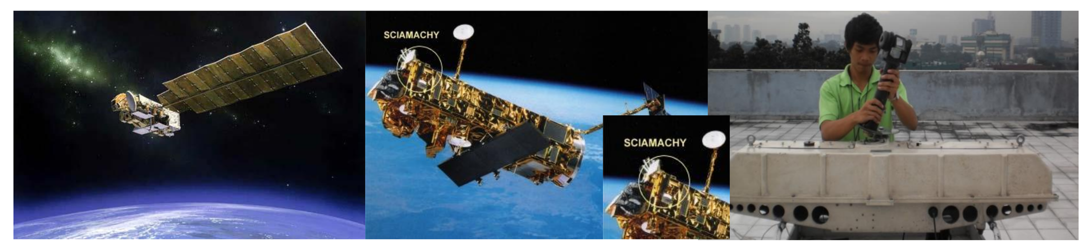




Instruments that Measure Total Ozone Column in the Philippines

Ground-Based Instrument

The Dobson spectrophotometer (extreme right) is the earliest ground-based instrument that measures total ozone column, designed by Gordon Dobson in the 1920's.

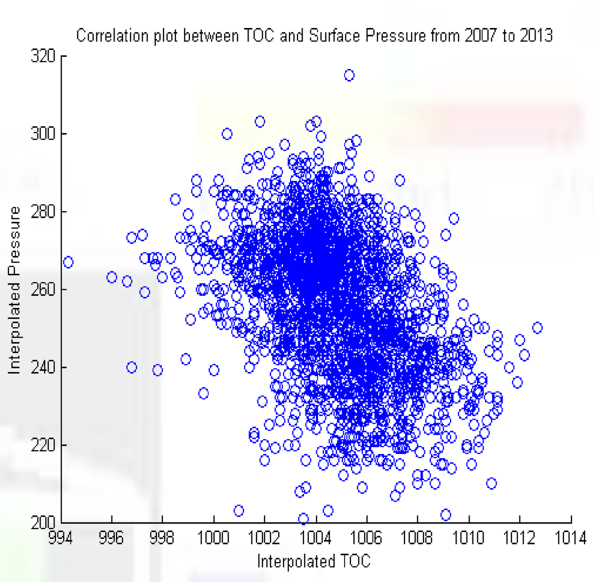


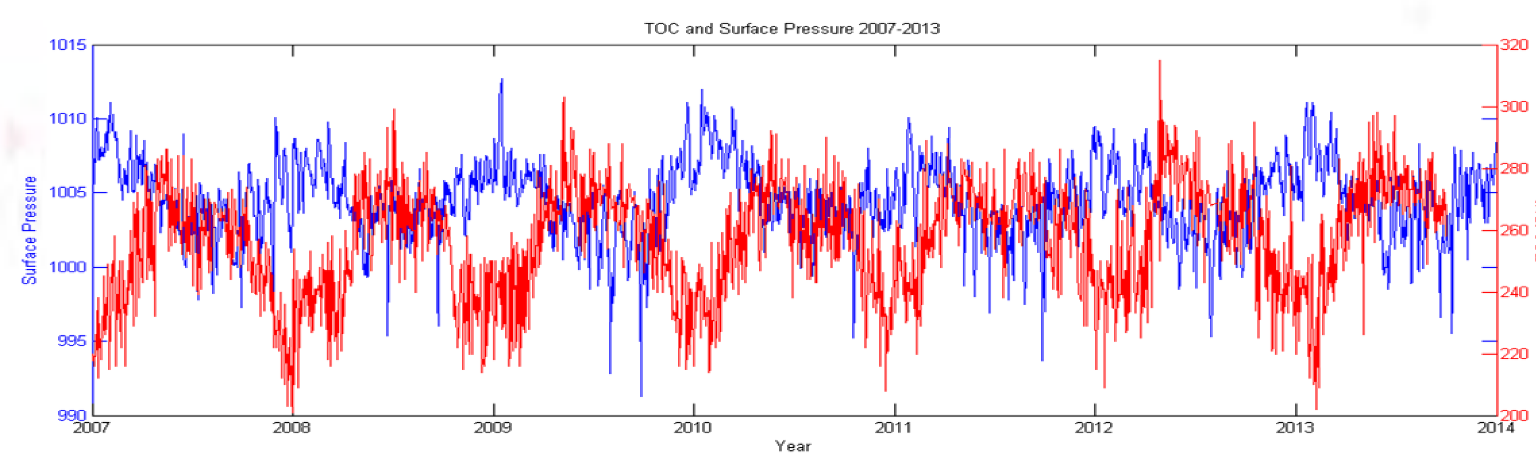
Satellite-Borne Instruments:

OMI (left above) is a contribution of the Netherlands Agency for Aerospace Programs (NIVR) in collaboration with the Finnish Meteorological Institute (FMI) to the EOS Aura mission.

SCIAMACHY (center above) is a passive remote sensing moderate-resolution imaging UV-Vis-NIR spectrometer on board the European Space Agency's (ESA) Environmental Satellite (ENVISAT), launched in March 2002 in Kourou, French Guiana.

Effect of Tropical Cyclones to Total Ozone Column

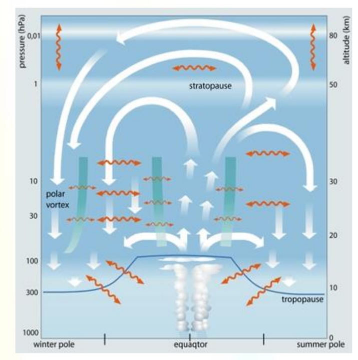




Daily surface pressure recorded from PAGASA weather bureau plotted together with Dobson TOC measurement (figure above) shows that they are negatively correlated with correlation coefficient equivalent to -0.4299 which was statistically significant as shown in the scatter plot (on left).

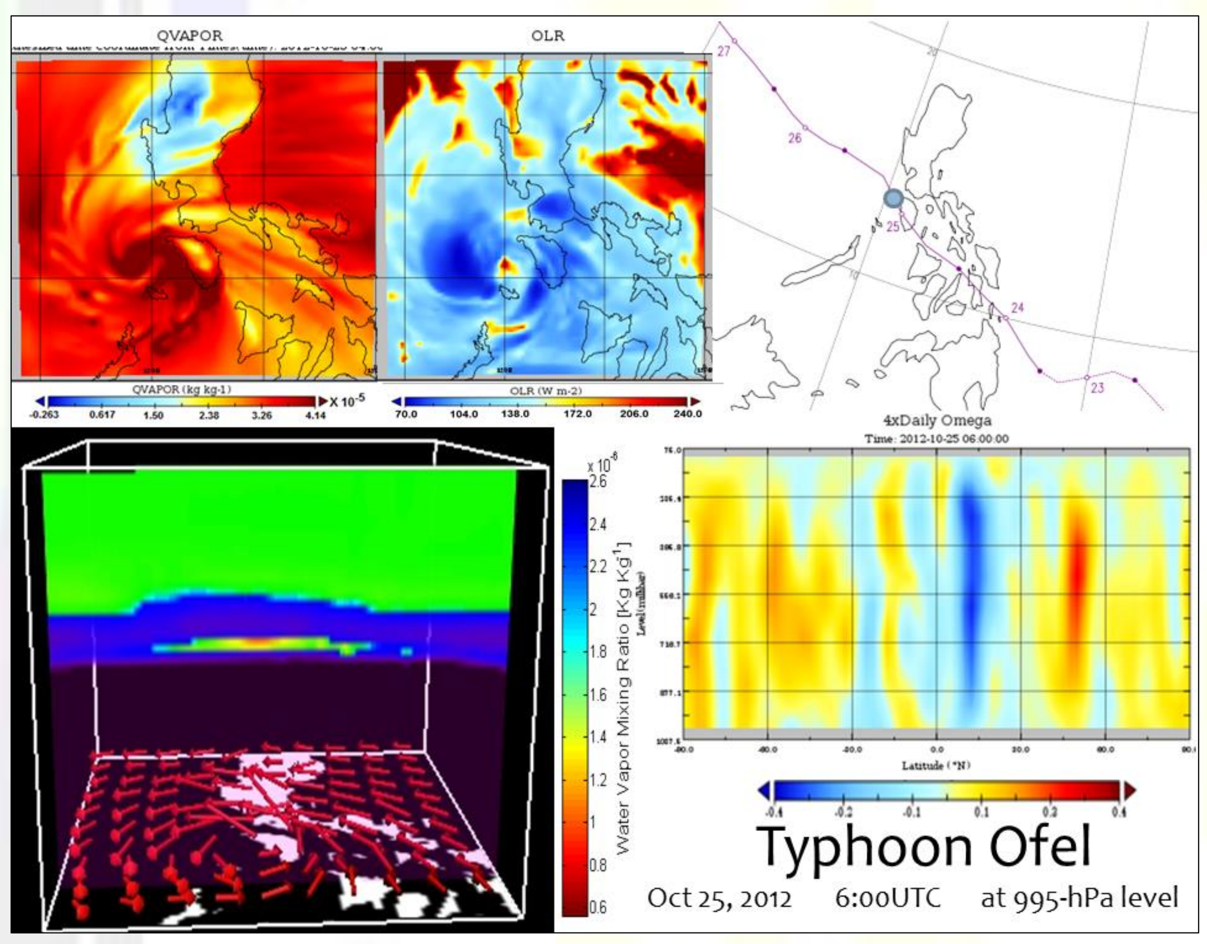
Chemical reaction of water vapor to ozone [Midya et. Al.,2012] :

$$H_2O + h\nu \rightarrow OH + H \quad (1)$$
$$OH + h\nu \rightarrow O + H \quad (2)$$
$$O + O + M \rightarrow O_2 + M \quad (3)$$
$$OH + O_3 \rightarrow HO_2 + O_2 \quad (4)$$
$$HO_2 + O \rightarrow OH + O_2 \quad (5)$$
$$O_3 + O \rightarrow 2O_2 \quad (net)$$

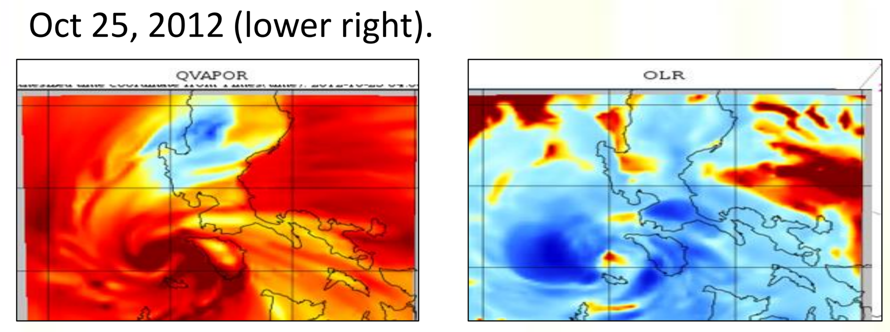


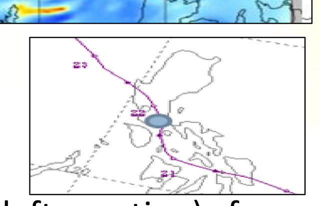
Nevertheless, in the lower stratosphere, ozone concentration is significantly being affected by the Brewer-Dobson Circulation (BDC) . The BDC (left image) transports energy from the tropics towards the poles.

Typhoon	Date	% Depletion
Son-Tinh(Ofel)	Oct 21-29, 2012	9.88
Conson(Basyang)	Jul 11-18, 2010	5.31
Fengshen(Frank)	Jun 17-27, 2008	-1.60
Nesat(Pedring)	Sep 23-30, 2011	-2.23



The track (upper right portion) of Typhoon Jangmi (Ofel local name) retrieved from Japan Meteorological Agency (JMA) together with the WRF model output of *Qvapor (lower left)*, amount of water vapor in Kg/Kg and OLR (outgoing longwave radiation) in W/m^2 at 995-hPa vertical level during Typhoon Frank at 06:00 UTC Oct 25, 2012 (lower right).

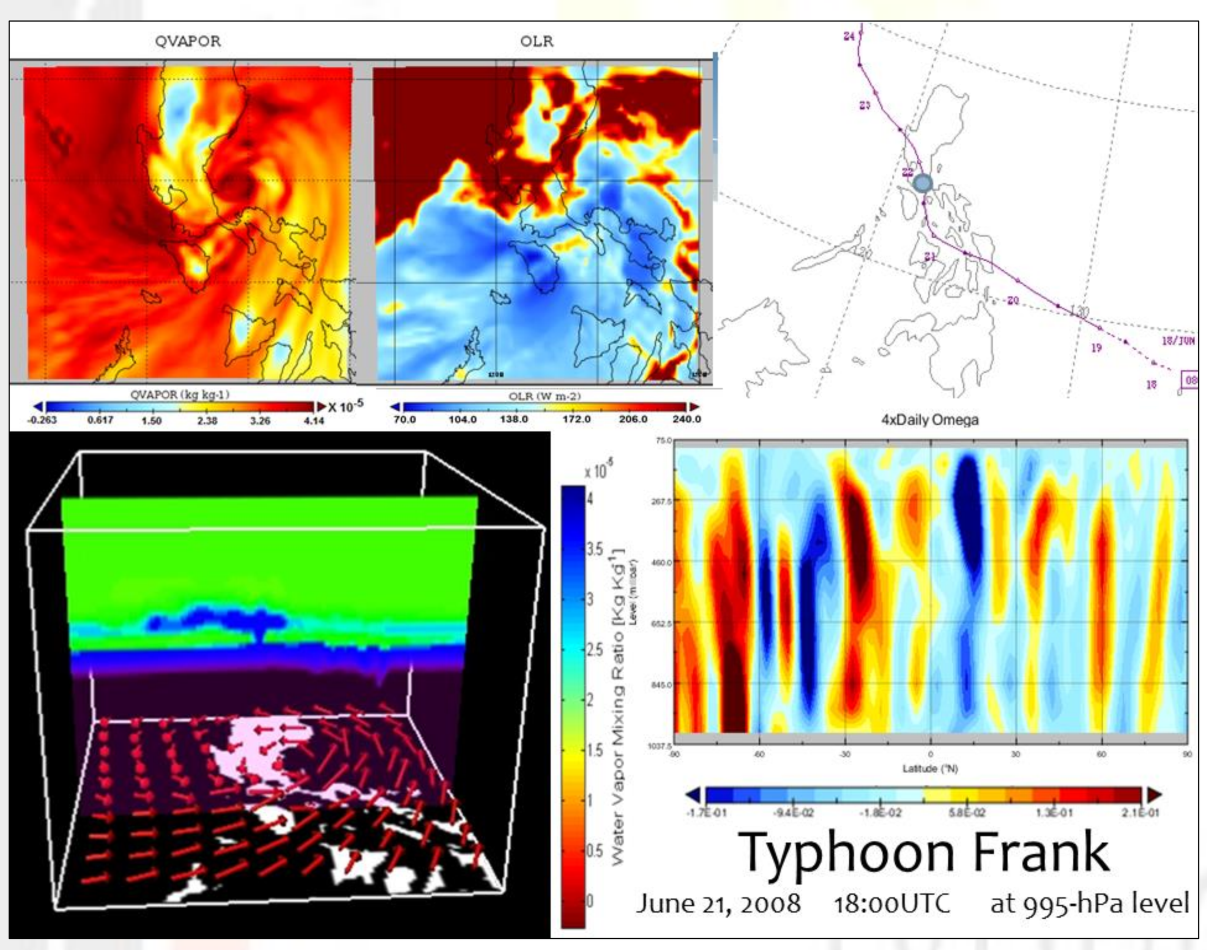




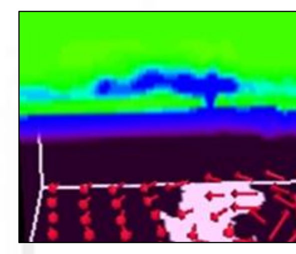
Blue dot on the typhoon track represents the location of the eye of typhoon.

Omega or vertical wind (lower left portion) from National Center for Environmental Prediction (NCEP) with 2.5 x 2.5 degree ground resolution with vertical levels up to 100hPa shows the upwelling during the tropical cyclone activity. Low values of omega indicates upward motion of vertical winds.

The 3-Dimentional image (lower left) represents the Qvapor at a certain latitude together with the wind barbs (red arrows) during the typhoon.



Simulation output of typhoon Fengshen (Frank local name) (on the left) shows a better representation for the water vapor intrusion.



Conclusions

- Least-squares linear regression shows that the annual trend for Dobson Spectrophotometer instrument has a value of 2.326 Dobson Unit per day (DU/day) and is statistically significant with the 95% confidence level from 2007-2011.
- The annual trend for OMI on the other hand was 0.109 (DU/day) which is statistically not significant and lastly, SCIAMACHY with annual trend of 0.998 (DU/day) and was statistically significant with 95% confidence levels respectively also from 2007-2011.
- Quantification for the effect of water vapor intrusion to TOC during tropical cyclone shows that typhoon Nesat has lowest percentage depletion with -2.23% and Jangmi (Ofel) with the highest percentage of ozone depletion equivalent to 9.88%.
- Results from typhoon Fengshen shows that water vapor intrusion in the UTLS can be simulated and visualized using WRF model and visualizer softwares.

Selected References

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