Atmospheric remote sensing Exercise 3
Ozone Retrieval

Mathis

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Ozone plays a critical role in the atmosphere of the earth. It protects the ground from harmful ultraviolet radiation, it acts as a greenhouse gas and alters the lifetime of numerous other gases trough chemical reactions[1]. The UV index[2] serves as a crucial measurement tool that quantifies the intensity of solar ultraviolet radiation reaching the Earth's surface. When the ozone layer is compromised, higher levels of UV radiation can penetrate the atmosphere, leading to increased risks of skin cancer, eye damage, and potential disruptions to life on land.

Ozone concentration varies significantly across different latitudes due to complex atmospheric dynamics, including solar radiation, atmospheric circulation patterns, and anthropogenic influences. Factors such as temperature, air currents, and chemical interactions play crucial roles in determining total column ozone levels.

In this essay, remote sensing data of Ozone and the UV index are discussed. The used data was collected by the OMI instrument[4] onboard the Aura satellite, part of the A-train. The A-train is a multinational project currently consisting of three satellites in a sun synchronous orbit. They follow each other closely and observe in the afternoon, giving the constellation the name. OMI is a nadir looking hyperspectral imager. Its spectral range extends from 270 nm to 504 nm. With a swat of 2600 km it offers daily global coverage at a spacial resolution of 13 km along across track and 24 km along track (48 km between 270 nm and 310 nm).

For this analysis, seven sites at different latitudes were chosen. These sites are: Svalbard at 78°N, Switzerland at 47°N,Abu sari in the Nile valley in Sudan at 20°N, Lake Victoria at the equator, Eswatini at 26°S, Ile de la Possession at 47°S, Concordia station in the Antarctic at 73°S. For each site, a 3° by 3° field was averaged. For missing values, no interpolation was conducted. The temporal resolution was reduced from one day to one month to give more expressive figures. All data was downloaded from NASA giovanni[3].

1 Ozone analysis

The time series data of the Ozone concentration in figure 1 is difficult to interpret directly, as the annual variations are large and the data of different measurement locations overlaps. The annual ozone variability in figure 2 and evolution of the average ozone concentration in figure 3 offer more insights. We notice first that for both high latitude stations, we have missing data for the winter months. This is to be expected. As a passive instrument, OMI relies on the Sun to provide photons for its spectrometers. In the polar night, can not measure anything. This missing data skews the yearly averages. The effect is especially large for the South Pole, as it covers the peak of its ozone column. For the North Pole, the effect is lower, as its peak is later in the year. This is an interesting finding, hinting on the ozone hole over the South Pole. The effect of the ozone hole can clearly be seen in the yearly averages. For all other measurement stations, the Ozone content increases with their latitude.

All measured locations show yearly fluctuations of the ozone content. The peak of the ozone content is not consistent for the measured locations. For most locations, the peak is in the early spring. Interesting exceptions are Abu Sari, Lake Victoria and the South Pole. The peak in Abu Sari is

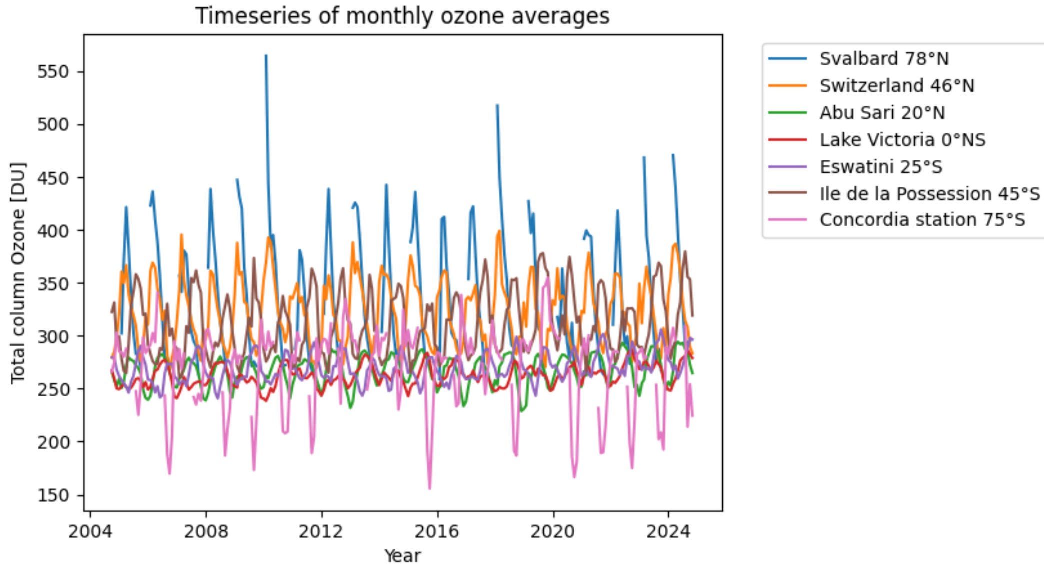

Figure 1: Time series of the total column Ozone content at different latitudes measured with OMI.

in summer, while its counterpart in the Southern Hemisphere follows the pattern, with the peak in spring. One reason for this could be the difference in ground albedo. An interesting observation at the equator is that the ozone content is not symmetric regarding summer in the Northern and Southern Hemisphere. This could be due to the larger landmass in the North, that affects air currents. The South Pole is the biggest deviation of the pattern we see in the other locations. As already mentioned, this is due to the ozone hole.

The variance of the measurements can be attributed to several factors. As an optical satellite is used for the acquisition, clouds have a significant influence on the quality of the extracted ozone columns. The data was not cleaned for cloud free days. How many gains this could offer is unclear. Looking at the evolution of the yearly averages, we can expect that the annual fluctuations account for large parts of the variability. While there seems to be a slight trend towards higher ozone concentrations, the effect is not significant.

If we compare the annual averages at similar latitudes, we can not see a correlation between Northern and Southern Hemisphere. This is to be expected as most of the ozone is located in the stratosphere. The air currents in the stratosphere flow from the equator to the poles, isolating effects[5]. There seems to be a correlation of the locations in the Northern Hemisphere.

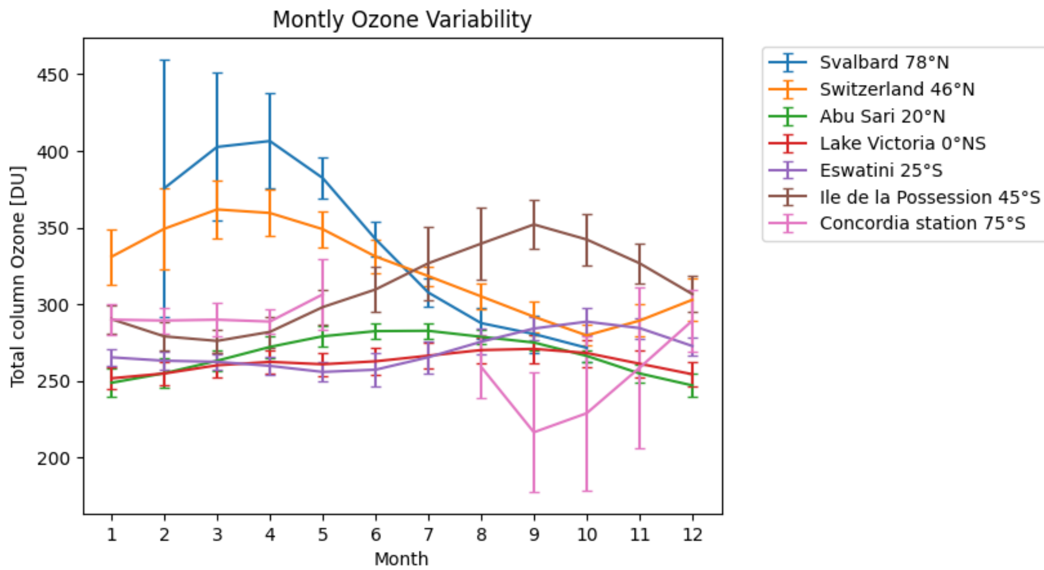

Figure 2: Annual variability of the total column Ozone content at different latitudes measured with OMI.

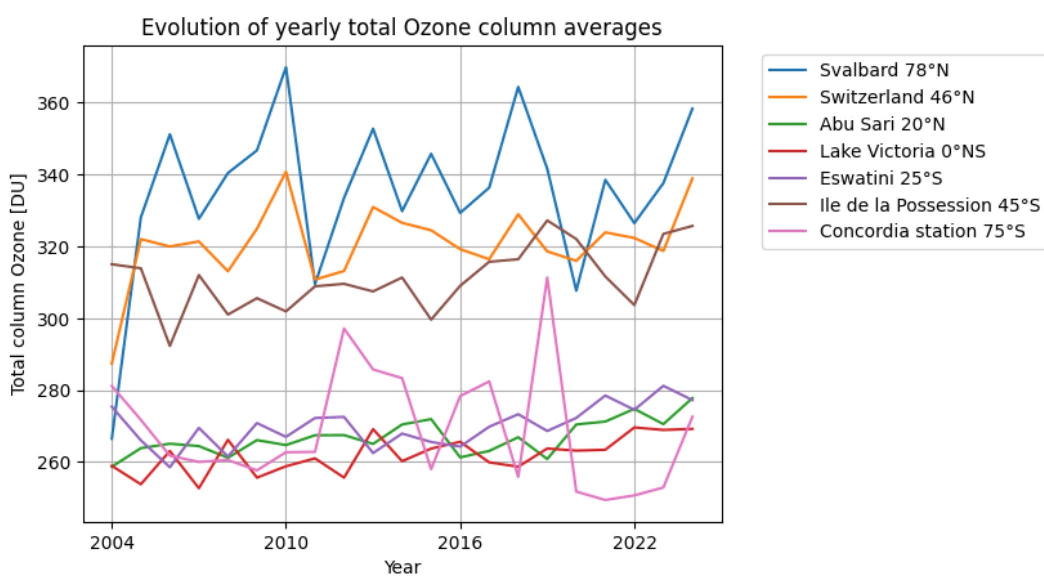

Figure 3: Evolution of the yearly average of the ozone concentration at different latitudes measured by OMI.

2 UV index

The UV index is directly correlated to the UV radiation that reaches the ground, and therefore strongly correlated to the Ozone content of the atmosphere. It is an erythema-weighed average of UV radiation[2].

In figure 4 we can clearly see the annual fluctuations due to the varying zenith angle of the Sun. This effect dominates the fluctuations in Ozone concentrations. The peak of the ozone concentration in spring does not lead to a minimum in UV index in spring. While comparing the locations from its UV-index directly is difficult, we can get insights from its variability. Looking at Abu Sari we see a shift in the weather in early summer until the end of the year. The variability of UV index decreases, while the variability of the ozone does not change over the year. This indicates that the variability in UV index is dominated by weather changes. More insights can be gained looking at figure 5. The yearly average UV index does not change significantly. The full time series is not shown intentionally, as the plot is too cramped to gain meaningful insights. Although being strongly correlated to the Ozone content of the atmosphere, the figure shows clearly that other factors play a significant role in the UV index. Probably clouds or surface albedo play a significant role. Only the difference between the Arctic and the Antarctic can be explained by the differences in ozone, as both locations show little clouds and the ozone content difference is large. An interesting observation is that despite the difference, the mountainous Switzerland and the maritime Ile de la Possession show a very similar annual UV index. The difference between Eswatini and Abu sari is remarkable and probably attributable to the desert environment of the latter.

We have seen that the connection of ozone and the UV index are not straight forward and needs further study. With an evolving climate, understanding of the ultraviolet radiation that reaches the ground is important, not only for human skincare, but also for its effects it has on the plants we grow and the animals we keep.

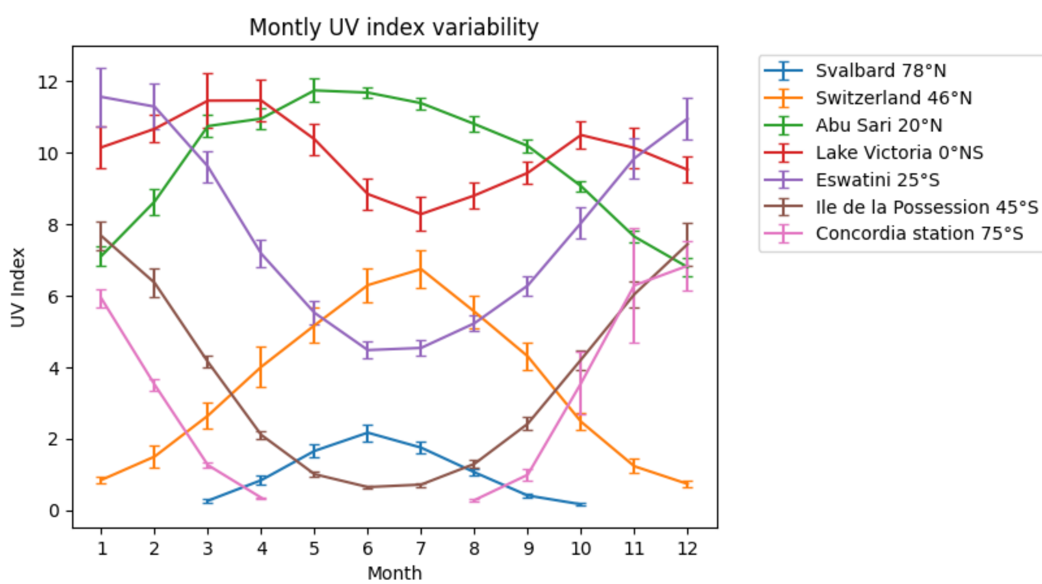

Figure 4: Monthly variability of the UV index.

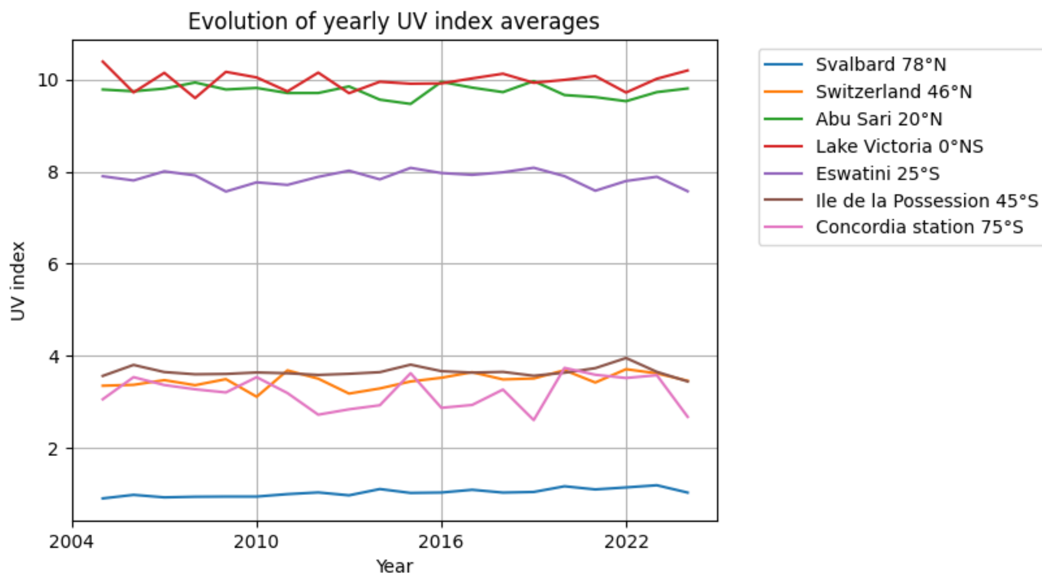

Figure 5: Evolution of the yearly average of the UV index.

References

[1] D. Ehhalt et al. "Atmospheric Chemistry and Greenhouse Gases". In: *Climate change 2001: the scientific basis, Intergovernmental panel on climate change*. 2001. URL: https://hal.science/hal-03333922.

[2] Vitali Fioletov, James B Kerr, and Angus Fergusson. "The UV index: definition, distribution and factors affecting it". In: *Canadian journal of public health* 101 (2010), pp. I5–I9.

[3] *Giovanni NASA*. URL: https://giovanni.gsfc.nasa.gov/giovanni/.

[4] P.F. Levelt et al. "The ozone monitoring instrument". In: *IEEE Transactions on Geoscience and Remote Sensing* 44.5 (2006), pp. 1093–1101. DOI: 10.1109/TGRS.2006.872333.

[5] Charles R. Trepte and Matthew H. Hitchman. "Tropical stratospheric circulation deduced from satellite aerosol data". In: *Nature* 355 (1992), pp. 626–628. URL: https://api.semanticscholar.org/CorpusID:4273960.