Updated Trends of the Stratospheric Ozone Vertical Distribution at Select NOAA Global Monitoring Laboratory Dobson Monitoring Stations Based on the LOTUS Regression Model

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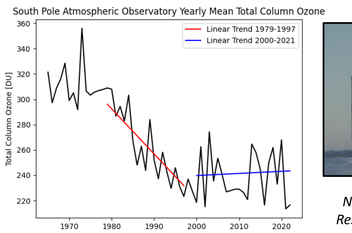
INTRODUCTION

This study presents an updated evaluation of stratospheric ozone profile trends at Boulder, Haute Provence, Lauder, and Mauna Loa, with a focus on the 2000-2020 (recovery) period. Stratospheric Ozone Depletion was first detected in 1985 and linked to the anthropogenic emissions of ozone depleting substances. After the Montreal Protocol was signed in 1987, emissions continued until they peaked around 2000. (Newman et. al. 2007). Since 2000s, many studies have confirmed that Stratospheric ozone is recovering (Godin-Beekmann et. al. 2022). However, the recovery is not uniform and questions remain, especially in the lower stratosphere. Multilinear Regression Models with dynamical proxies are often used to determine the trend in ozone.

The Long-Term Trends and Uncertainties in the Stratosphere (LOTUS) project was formed in part to improve the understanding of the sources of uncertainties in the trends. Here the updated trends and uncertainties are provided, along with an investigation into using the equivalent latitude as an additional dynamical proxy.



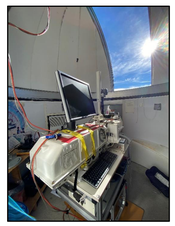
NOAA/NSF South Pole Atmospheric Research Observatory (Credit: NOAA)

OBJECTIVES

- This project, along with other LOTUS activities are meant to estimate the trend of ozone by fitting the record to a linear trend and dynamical proxies. We use the LOTUS multilinear regression model on the Dobson Umkehr Records at four sites.
- We compare the trends in the Umkehr record with trends derived from ozonesondes and one satellite for intercomparing and confirmation of trends.
- Use of Equivalent Latitude as a proxy in the multi-linear regression model is investigated. Equivalent Latitude is based on Potential Vorticity contours and is defined as the latitude a contour enclosing he same area would have, if it would be circular and centered around the pole.
- Equivalent latitude can be a representative proxy for short-term dynamical variability which influences the ozone concentrations. By fitting the ozone record with the Equivalent latitude, we had hoped to reduce the uncertainties in the trend estimation.
- The following four NOAA Dobson sites where chosen as they perform the Umkehr measurements and launched ozonesondes:
    - Boulder, Colorado (40.0N, 105.3W),
    - Haute Provence, France (43.9N, 5.8E),
    - Lauder, New Zealand (45.04S, 169.68E),
    - Mauna Loa, Hawaii (19.5N, 155.58W)

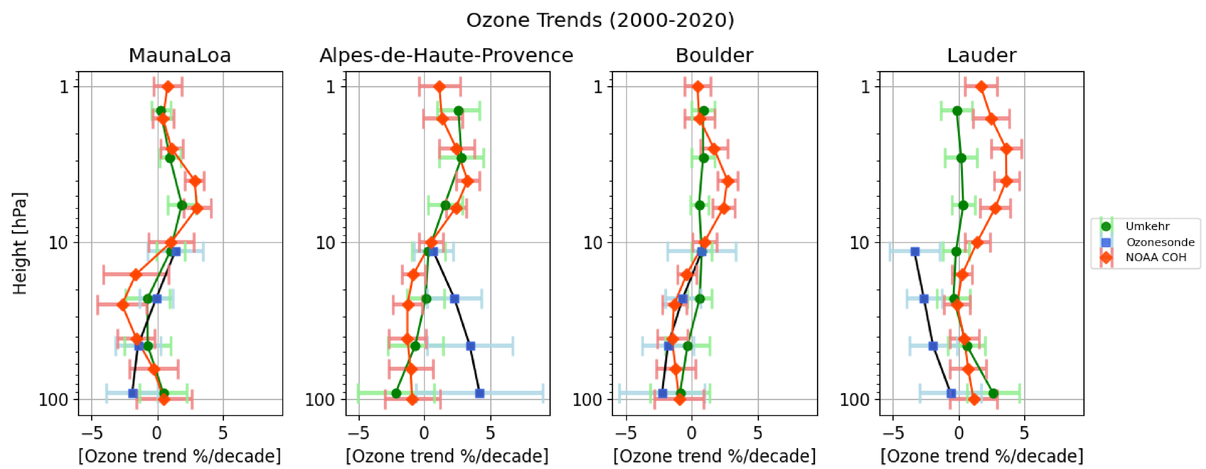
METHOD

- Long-Term Trends and Uncertainties in the Stratosphere (LOTUS) Independent Linear Regression Model v0.8.0[1] was used to derive trends at four sites.
- The model was run with the following proxies: El Niño /Southern Oscillation (enso), Solar Cycle, and Quasi-Biennial Oscillation (QBO).
- Additionally, the model was run again for the years 2000-2020 with the Equivalent Latitude integrated as a proxy on the Umkher record.
- Equivalent Latitude was based on the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2)
- Data Used:
    - Optimized Umkehr vertical ozone profiles which are retrieved from the difference in the intensity of light measured with a Dobson ozone spectrophotometer zenith sky measurements at two pairs of wavelengths: (311.5, 332.4 nm) and (317.5, 339.9 nm). Ozone strongly absorbs at the shorter wavelengths.
    - Optimized Ozonesondes which are launched weekly from each site. The monthly averaged profiles are interpolated into the Umkehr layers. Typically they burst around 30-35km.
    - NOAA 'cohesive' (COH) dataset: NOAA's homogenized satellite record from SBUV, SBUV/2 and OMPS satellite instruments.
- Optimization: Ozonesondes and Umkehr profiles have been optimized for long-term trend analysis (Petropavlovskikh 2022)

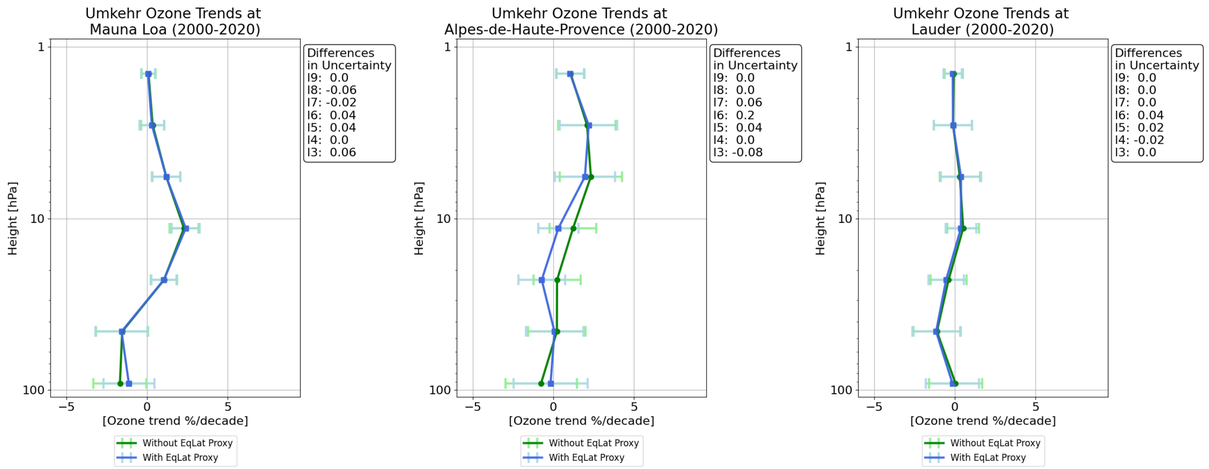


Dobson Spectrophotometer at NOAA ESRL - Boulder, CO (credit: Peter Effertz)

RESULTS: TRENDS



RESULTS: EQUIVELENT LATITUDE AS A PROXY



CONCLUSIONS

- Generally, the three methods agree on the trends of Stratospheric Ozone recovery.
- The Northern Hemispheric sites of Haute Provence, and Mauna Loa show positive trends in the mid to upper Stratosphere with trends peaking at ~2%/decade in the Umkehr record.
- Umkehr trends in the upper stratosphere at Boulder and Lauder are positive, but not statistically significant. However, the trends in the COH record
- In the lower stratosphere, trends are mostly negative. Significant trends were found at Mauna Loa and Lauder.
- However, the lower stratospheric trend uncertainties are quite large.
- Optimization technique improves the trend analysis, especially at Lauder. Trends in Umkehr record come into much closer agreement to the trends in the COH record.
- However, Adding Equivalent Latitude as a proxy did not change the overall trends and uncertainties significantly.
- There is a slight change to the trends at Haute-Provence, but not statistically different.
- At Mauna Loa, Lauder, and Boulder the changes in the uncertainty are very small.
- At Haute-Provence, there is a slightly larger, but still overall very small reduction in the uncertainty.

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[1]https://arg.usask.ca/docs/lotus_regression/