Matched Monthly Mean Vertical Profiles of Ozone from Dobson (Optimized Umkehr), NOAA Cohesive Satellite Overpass, and Ozonesondes for trend analysis.

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Description:

This dataset was used in the trend analysis paper titled "Ozone trends in homogenized Umkehr, Ozonesonde, and COH overpass records" to be submitted for publication in 2024. Each file represents a monthly mean time series of the vertical profile of ozone from January 1980 (or the start of record for each instrument, whichever is later) to Dec 2020.

The filename format is MM_xxx_YYY_stn.txt where:

MM means Monthly Mean.
xxx is the instrument used (see table below)
YYY is the 'site' code. This is used to match the UMK/COH record to nearby SND record (for sites that do not have co-located ozonesonde record) into a single 'site' for comparison.
stn is the WOUDC station ID number (see third table below) where the instrument is located (UMK/SND) or the station the satellite overpasses (COH)

Instrument Code	Full Name	Reference
UMK	Dobson Umkehr	Petropavlovskikh 2022
COH	NOAA Cohesive Satellite Overpass	Wild 2016
SND	Ozonesonde	Sterling 2018, Ancellet 2022,

Table 1: Description of Instrument Codes with References for further descriptions.

UMK:

Vertical profiles from the Umkehr (UMK) inversion method are derived from Dobson spectrophotometer zenith sky measurements. The measurements are made during sunrise and sunset (12 nominal solar zenith angles ranging from 60-90 degrees). The time series has been

optimized for trend analysis by correcting for stray light effects and inhomogeneities rising from instrumental step changes (Petropavlovskikh et al., 2022).

COH:

The combined satellite ozone record of the Solar Backscatter Ultraviolet (SBUV version 8.6) and Ozone Mapping and Profiler Suite (OMPS version 4r1) instruments aboard NOAA and NASA satellites. Bias adjustments (with an ozone-dependent factor) are applied to reduce inhomogeneities between the different instruments/satellites (see table below). This dataset is called the NOAA Cohesive (COH) Ozone Dataset (Wild, 2016). The overpass record was created by using the profiles within a ±2/20 degree latitude/longitude box centered on each monitoring station. One to four profiles per day were found for each station. These are then inverse distance weighted and averaged providing one overpass profile per site per day. The overpass records can be found at: https://ftp.cpc.ncep.noaa.gov/SBUV_CDR/overpass. The COH layers and Umkehr layers use different pressure top and bottom values. The data in this paper is interpolated from the COH layer to the Umkehr layer. Further, COH data are matched to the Umkehr measurement dates, then averaged to create the monthly average datasets. The station zonal mean has been added as well. These are also interpolated to the Umkehr layers, and matched to Umkehr measurement dates. See Table 3 for zonal mean included for each station.

Satellite	Dates
Nimbus 07	10/1978 - 5/1989
NOAA 11	6/1989 - 12/1993
NOAA 09	1/1994 - 6/1997
NOAA 11	7/1997 - 12/2000
NOAA 16	1/2001 - 12/2003
NOAA 17	1/2004 - 12/2005
NOAA 18	1/2006 - 12/2010
NOAA 19	1/2011 - 12/2013
SUOMI - NPP	1/2014 - present

Table 2: List of Satellites that comprise the COH overpass record.

Site	Zonal Mean
MLO	17.5N

BLD	(37.5N+42.5N)/2
ARO	47.5N
OHP	42.5N
LAU	(47.5S+42.5S)/2

Table 3: Zonal Mean used for COH. Labels for the zones used indicate the center latitude of the 5° wide zone. BLD and LAU are on the border of two zones, so the average of the adjacent zones are used.

SND:

Ozonesondes (SND) are launched at the same facility as three of the Umkehr stations (BDR, OHP, and LAU). At the other two sites (ARO and MLO), the ozonesonde record closest to the Umkehr monitoring station was chosen. Ozonesondes are launched on a weekly or biweekly basis and are reported at their sampling rate or averaged in 100-meter intervals. Typically, the balloons burst around 30 km (Umkehr layer 5 or 6). The ozonesonde record has been homogenized to reduce instrumental step changes by several efforts. The NOAA ozonesonde record (BDR, MLO) homogenization information can be found in Sterling 2018. OHP's homogenization technique is described in Ancellet et al. (2022).

Site	WOUDC Site ID	Full Name	Instrument	Lat,Lon	Source
MLO	031	Mauna Loa Observatory, Hawaii	UMK	19.5°N, 155.6°W	NOAA GML
	109	Hilo, Hawaii	SND	19.7°N, 155.1°W	NOAA GML
ARO	035	Arosa, Switzerland Davos, Switzerland	UMK	46.8°N, 9.7°E 46.8°N, 9.8°E	NOAA GML
	099	Hohenpeißenberg, Germany	SND	47.8°N, 11.0°E	NDACC
BDR	067	Boulder, Colorado	UMK	40.0°N, 105.3°W	NOAA GML
			SND	40.0°N, 105.3°W	NOAA GML
OHP	040	Observatoire de Haute-Provence, France	UMK	43.9°N, 5.8°E	NOAA GML
			SND	43.9°N, 5.8°E	NDACC
LAU	256	Lauder, New Zealand	UMK	45.0°S, 169.7°E	NOAA GML
			SND	45.0°S, 169.7°E	NDACC

Table 4: Original Datasets for the Umkehr and Ozonesonde profiles where:
NOAA GML: NOAA Global Monitoring Laboratory FTP
Umkehr: (https://gml.noaa.gov/aftp/data/ozwv/Dobson/AC4/Umkehr/Optimized/)
Ozonesonde: https://gml.noaa.gov/aftp/ozwv/Ozonesonde/
NDACC: Network for the Detection of Atmospheric Composition Change (www.ndacc.org)

Vertical Coordinate System:

All data have been converted to the 16 pressure layer system of the Umkehr method. The Umkehr vertical layer grid resolution is referenced to the standard atmospheric pressure at the surface of the Earth (nominally 1013.26 mb), the pressure at the bottom of each successive layer is half of the pressure of the layer below. Only levels that are used in the trend analysis paper are included in the files. For the trend analysis in the body of the companion paper, the fine vertical resolution of the Sonde data is smoothed by application of the Umkehr AK. The COH data is already of similar vertical resolution to the Umkehr, but with different pressures, so it is simply interpolated and integrated to the Umkehr layers.

10 Layer Umkehr Data					
Layer Number	Bottom	Top	UMK	SND	COH
10	0.99	Note 2	Excluded: See note 4	Excluded: See note 5	Excluded: See note 6
9	1.98	0.99			
8	3.96	1.98			
7	7.91	3.96			
6	15.83	7.91			
5	31.66	15.83			
4	63.31	31.66			Excluded: See note 6
3	126.63	63.31			
2	253.25	126.63	Excluded: See note 3		
0+1	Note 1	253.25			

Table 5: Shows which layers are included for the three instrument types. Pressures are in hPa.

Note 1: Bottom pressure of the Bottom layer extends to the surface
Note 2: Top layer extends to top of the atmosphere
Note 3: As the paper focuses on Stratospheric ozone trends, layers that are representative of the troposphere are not included
Note 4: Averaging Kernels from the Umkehr retrieval method do not allow for much independent information to be retrieved in layers 9 and 10 and are excluded from the trend analysis.
Note 5: The ozonesonde balloons usually burst around 30 km which is almost always within layer 6 and therefore profile cannot be integrated to the top of the layer 6 pressure level. Also, there is often missing information above layer 6 to meet the requirements of the averaging kernel applications. Therefore, the ozonesonde data in layer 6 and above are excluded from this study.
Note 6: There is little independent profile information below 30 hPa in the SBUV and OMPS nadir profiler datasets, so layers 1 to 4 are not included in the COH dataset in this study (Kramarova, 2013).

Temporal matching:

For calculation of the monthly mean (MM) ozone data, the COH or SND files are matched temporally with Umkehr observation (within ± 24 hours centered on the date and averaged UTC time of Umkehr observation between 70 and 90 degrees SZA), and then the mean of all matched profiles is calculated (e.g. more than 2 profiles are needed). The MM of the matched Umkehr dataset (selected Umkehr profiles within a valid COH or SND profile temporal match criteria) is also provided in respective files.

File Structure

UMK

Year: Year
Month: Month of the year
Layer: Layer of the atmosphere (numbered 3-8).
B_Pres: Bottom pressure of the Layer (hPa).
T_Pres: Top pressure of the Layer (hPa).
UMK: Monthly Mean of Umkehr data. 9999.000 represents missing data.
Used in the trend analysis in the body of the companion paper.
UMK_N: Number of profiles used in the monthly mean.
UMK(COH_match): Monthly Mean of Umkehr data using only profiles that have a satellite overpass match (within ± 24 hours of the Umkehr profile).
Used in Appendix 3. Temporal Sampling and Impact on Trends.
UMK(COH_match)_N: Number of profiles used in the monthly mean.
UMK(SND_match): Monthly Mean of Umkehr data using only profiles that have a sonde overpass match (within ± 24 hours of the Umkehr profile).
Used in Appendix 3. Temporal Sampling and Impact on Trends.
UMK(SND_match)_N: Number of profiles used in the monthly mean.

COH

Year: Year
Month: Month of the year
Layer: Layer of the atmosphere (numbered 5-9).
B_Pres: Bottom pressure of the Layer (hPa).
T_Pres: Top pressure of the Layer (hPa).
COH: Monthly Mean of all available Cohesive satellite overpass data. 9999.000 represents missing data.
Used in Appendix 3. Temporal Sampling and Impact on Trends.COH_N: Number of profiles used in the monthly mean.
COH(UMK_match): Monthly Mean of Cohesive satellite overpass data using only profiles that have an Umkehr measurement match (within ± 24 hours of the satellite profile). Used in the trend analysis in the body of the companion paper.
COH(UMK_match)_N: Number of profiles used in the monthly mean.
COH(Zonal): Zonal mean of the station latitude using daily data with a matching Umkehr measurement. See Table 3 for the zonal means used.
Used in the body of the paper to show the relative difference between the trend, SE and adjusted R-squared results for station overpass and the zonal mean.
COH(Zonal)_N: Number of profiles used in the monthly mean.

SND

Year: Year
Month: Month of the year

Layer: Layer of the atmosphere (numbered 3-5).
B_Pres: Bottom pressure of the Layer (hPa).
T_Pres: Top pressure of the Layer (hPa).
SND: Monthly Mean of Ozonesonde data. 9999.000 represents missing data. No AK smoothing.
Used in Appendix 3. Temporal Sampling and Impact on Trends.
SND_N: Number of profiles used in the monthly mean.
SND(UMK_match): Monthly Mean of Ozonesonde data using only profiles that have an Umkehr measurement match (within ±24 hours of the sonde profile). No AK smoothing applied.
Used in Appendix 3. Temporal Sampling and Impact on Trends
SND(UMK_match)_N: Number of profiles used in the monthly mean. Note this number can be larger than the number of ozonesonde profiles without matching since the +/- 24 hours selection can pick up more than one Umkehr profile which is measured twice per day.
SND(UMK_match_AK): Monthly Mean of Ozonesonde data using only profiles that have an Umkehr measurement match (within ± 24 hours of the sonde profile) and have the Umkehr averaging kernel applied.
Used in the trend analysis in the body of the companion paper
Note the number of profiles in this are the same as SND(UMK_match)_N.

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