TOAR-II HEGIFTOM: Description of homogenized ozonesonde free-tropospheric ozone time series

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v1	Roeland Van Malderen	RMI	roeland.vanmalderen@meteo.be	26/10/2022
v2	Roeland Van Malderen	RMI	roeland.vanmalderen@meteo.be	26/01/2023
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Availability

The homogenized ozonesonde time series for 43 sites are available on the ftp-server “ftp-me.oma.be”, accessible with account name “ozonesondes” and password “OzonFeb2021:”. In the “ozonesondes” directory, every station has a directory with its name. In case of problems with connecting to the ftp-server, you can contact roeland.vanmalderen@meteo.be. The data is in any of the existing database formats:

- WOUDC (https://woudc.org/home.php, https://guide.woudc.org/en/#334-category-ozonesonde, https://woudc.org/archive/Documentation/Examples-extCSV/Ozonesonde.csv, with Python library code available on https://github.com/woudc/woudc-extcsv),
- NASA-AMES (from NDACC http://www.ndacc.org, see https://ndacc.larc.nasa.gov/data/formats) and,
- SHADOZ (https://tropo.gsfc.nasa.gov/shadoz/)

Data field description

- The minimum data fields that are/should be available are time (s), pressure (hPa), geopotential height (m), temperature (°C), relative humidity (%), pump temperature (°C), ozone partial pressure (mPa), relative uncertainty in ozone partial pressure, wind speed (m/s), and wind direction (degrees), and ozone current (µA). Additional fields possibly available nowadays are GPS height (m), latitude, longitude, pump motor current (mA), and pump motor voltage (V).
- Metadata are available in the headers of the data files and describe the site location, identify the hardware used (manufacturer, model and number of radiosonde, interface, ozonesonde), describe most aspects of the ozonesonde pre-flight preparation and its behaviour during preparation (e.g. background current, pump flow rate, ozonesonde response time), and give details about the processing used (e.g. pump efficiency correction table used). Data quality indicators (e.g. total ozone normalization factor compared to co-

located Brewer/Dobson/SAOZ spectrophotometer) might also be present in the metadata header.

Description of homogenization procedure

The aim of the homogenization is twofold: (i) to correct for biases related to instrumental (such as sonde type or sensing solution strength) or processing changes to reduce the uncertainty (from 10–20% down to 5–10 %), and (ii) provide an uncertainty estimate for every single ozone partial pressure measurement in the profile. The homogenization procedure and guidelines can be found in Annexes C and D of GAW Report No. 268, 2021: Smit, H.G.J., and Thompson, A.M., and the ASOPOS 2.0 Panel, "Ozonesonde Measurement Principles and Best Operational Practices. ASOPOS 2.0 (Assessment of Standard Operating Procedures for Ozonesondes)", WMO Global Atmosphere Watch Report Series, No. 268, World Meteorological Organization, Geneva, https://library.wmo.int/index.php?lvl=notice_display&id=21986#.YbI0xCYo_Ra. The first edition of the guidelines (Dated January 2012) can be found at https://www.wccos-josie.org/en/o3s-dqa, and a Python code that can be used for the homogenization is available at https://github.com/denizpoyraz/o3s-dqa-homogenization/.

Data management

Flagging

- Data cleaning like outlier removal is not systematically applied by every ozonesonde PI; some guidelines exist, but have not been generally implemented across the ozonesonde network.
- A data flagging scheme is proposed on pages 67-68 of GAW Report No. 268, but has not been systematically implemented in the archived data files.
- The total ozone normalization factor w.r.t. a co-located total ozone measuring instrument, if present, is included in the data file header as data quality indicator.

Uncertainties

- Every ozone partial pressure measurement P_{O3} in the ozone profile has an associated relative uncertainty $\Delta P_{O3}/P_{O3}$, following the homogenization guidelines as referred to here above (to be more specific: formula E-3-1 on page 39 in the GAW Report No. 268).
- As the homogenization should have removed all known systematic biases in the ozonesonde time series, the resulting uncertainty should represent only the contribution from random errors.

Traceability

Implementing the homogenization scheme ensures that the processed ozonesonde time series are traceable to the reference ozone photometer OPM (a fast dual-beam UV photometer, Proffitt and McLaughlin, 1983) in the simulation chamber of the World Calibration Centre for Ozonesondes (WCCOS) at FZ-Jülich, with a 1-s response, precision = 0.025 mPa, and uncertainty = 2% – 3%. Since 1996, activities to improve the quality of balloon-borne ozone soundings have been conducted at WCCOS through Jülich OzoneSonde Intercomparison Experiment (JOSIE) campaigns (https://www.wccos-josie.org/en/josie) [Smit et al., 2007; Thompson et al., 2019] and in the WMO/BESOS (Balloon Experiment on Standards for Ozonesondes) campaign [Deshler et al., 2008], in which traceability to the OPM instrument could be established, under the condition of applying the Standard Operating Procedures (SOPs) at the station.

Internal consistency

As the homogenized ozonesonde time series are traceable to the reference ozone photometer OPM, they should be internally consistent within the network. Several publications (see next section) have shown that the homogenization increased the consistency among different networks of ozonesondes with respect to the non-homogenized datasets.

External consistency

In publications describing the homogenization at ozonesonde sites, e.g. the Southern Hemispheric Additional Ozonesondes (SHADOZ) network [1,2,3,4], the Canadian network [5], the US network [4], and some individual sites [6, 7, 8], a comparison with other techniques (mainly measuring total ozone amounts) is made to assess the improvement of the homogenization.

1. Witte, J. C., et al., First reprocessing of Southern Hemisphere ADditional OZonesondes (SHADOZ) profile records (1998-2015) 1: Methodology and evaluation, J. Geophys. Res., 122, doi: 10.1002/2016JD026403 (2017).
2. Thompson, A. M., et al., First reprocessing of Southern Hemisphere ADditional OZonesondes (SHADOZ) Ozone Profiles (1998-2016). 2. Comparisons with satellites and ground-based instruments, J. Geophys. Res., 122, doi: 10.1002/2017JD027406 (2017).
3. Witte, J. C., et al., First reprocessing of Southern Hemisphere Additional Ozonesondes (SHADOZ) Profile Records. 3. Uncertainty in ozone profile and total column, J. Geophys. Res., 123(6), 3243-3268, doi: 10.1002/2017JD027791 (2018).
4. Sterling, C. W., et al., Homogenizing and estimating the uncertainty in NOAA's long-term vertical ozone profile records measured with the electrochemical concentration cell ozonesonde, Atmos. Meas. Tech., 11, 3661–3687, doi: 10.5194/amt-11-3661-2018 (2018).
5. Tarasick, D. W., et al., A re-evaluated Canadian ozonesonde record: measurements of the vertical distribution of ozone over Canada from 1966 to 2013, Atmos. Meas. Tech., 9, 195–214, doi: 10.5194/amt-9-195-2016 (2016).
6. Van Malderen, R., et al., On instrumental errors and related correction strategies of ozonesondes: possible effect on calculated ozone trends for the nearby sites Uccle and De Bilt, Atmos. Meas. Tech., 9, 3793–3816, doi: 10.5194/amt-9-3793-2016 (2016).
7. Witte, J. C., et al., The NASA Wallops Flight Facility digital ozonesonde record: Reprocessing, uncertainties, and dual launches. J. Geophys. Res., 124, 3565–3582, doi:10.1029/2018JD030098 (2019).
8. Ancellet, G., et al., Homogenization of the Observatoire de Haute Provence electrochemical concentration cell (ECC) ozonesonde data record: comparison with lidar and satellite observations, Atmos. Meas. Tech., 15, 3105–3120, doi:10.5194/amt-15-3105-2022 (2022).

Data quality indicators

In the GAW Report No. 268, on page 71, the following table 5.1 with some data quality indicators based on the available (meta)data of the ozonesonde is presented.

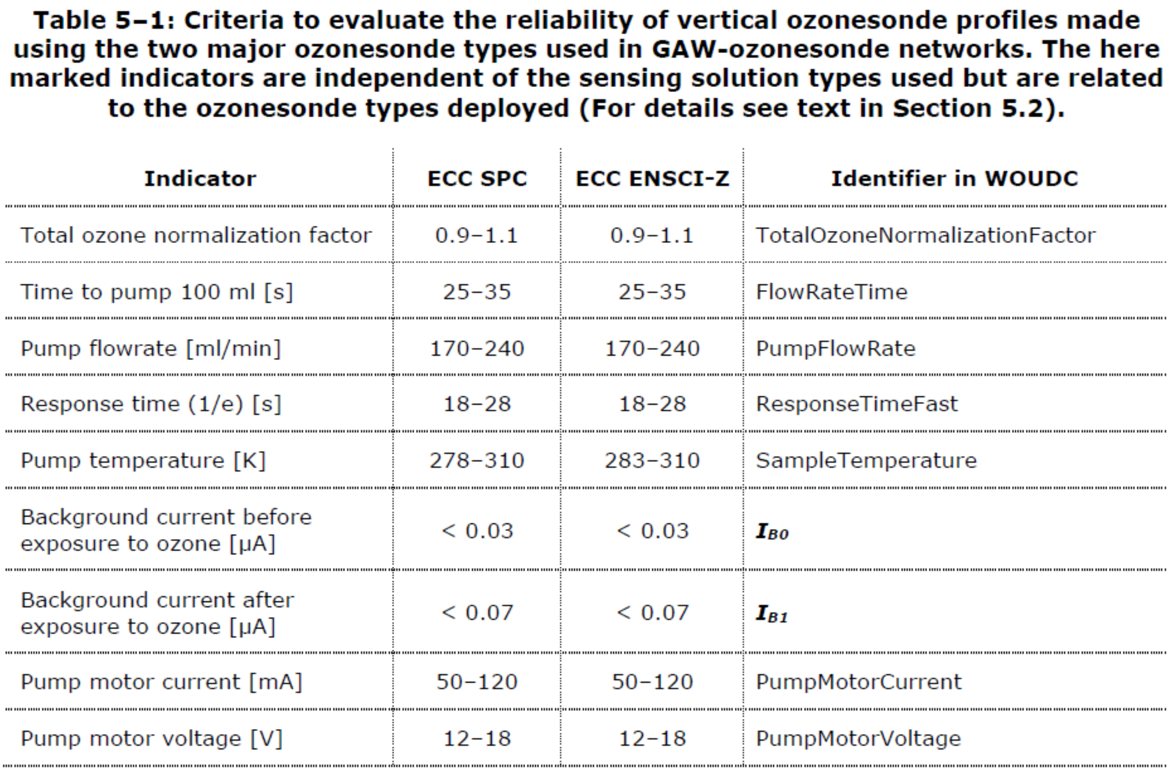

Table 5–1: Criteria to evaluate the reliability of vertical ozonesonde profiles made using the two major ozonesonde types used in GAW-ozonesonde networks. The here marked indicators are independent of the sensing solution types used but are related to the ozonesonde types deployed (For details see text in Section 5.2).

Indicator	ECC SPC	ECC ENSCI-Z	Identifier in WOUDC
Total ozone normalization factor	0.9–1.1	0.9–1.1	TotalOzoneNormalizationFactor
Time to pump 100 ml [s]	25–35	25–35	FlowRateTime
Pump flowrate [ml/min]	170–240	170–240	PumpFlowRate
Response time (1/e) [s]	18–28	18–28	ResponseTimeFast
Pump temperature [K]	278–310	283–310	SampleTemperature
Background current before exposure to ozone [µA]	< 0.03	< 0.03	I_{B0}
Background current after exposure to ozone [µA]	< 0.07	< 0.07	I_{B1}
Pump motor current [mA]	50–120	50–120	PumpMotorCurrent
Pump motor voltage [V]	12–18	12–18	PumpMotorVoltage

The overall performance of the ozonesonde (see section 3.2 in GAW Report No. 268) can be summarized as

	Precision	Uncertainty
Troposphere	3%-5%	5% (in Tropics: 5-10%)
Stratosphere (< 28 km)	3%-5%	5%-10%

List of homogenized sites (name, geographical location, period of observations)

Site	Lat	Lon	Time range	#	Instrument	Homogenized?	Instrument PI	Contact
Alert, Canada	82.49	-62.34	1987 – Apr 2020	1587	ECC	Yes	David Tarasick	david.tarasick@canada.ca
Eureka, Canada	79.98	-85.94	1992 – Mar 2021	1873	ECC	Yes	David Tarasick	david.tarasick@canada.ca
Ny-Ålesund, Norway	78.92	11.93	1992 - 2022	2670	ECC	Yes	Peter von der Gathen	peter.von.der.gathen@awi.de
Thule, Greenland	76.53	-68.74	1992 - 2015	0	ECC	No	Nis Jepsen	nje@dmi.dk
Resolute, Canada	74.7	-94.96	1966/1979 – Mar 2021	2190	BM/ECC	Yes	David Tarasick	david.tarasick@canada.ca
Summit, Greenland	72.34	-38.29	2006 - 2018?	0	ECC	No	Bryan Johnson	bryan.johnson@noaa.gov
Scoresbysund, Greenland	70.48	-21.97	1989 - 2022	1611	ECC	Yes	Nis Jepsen	nje@dmi.dk
Sodankylä, Finland	67.37	26.65	1994 - 2022	1446	ECC	Yes	Rigel Kivi	rigel.kivi@fmi.fi
Lerwick, United Kingdom	60.13	-1.18	1992 - 2022	1637	ECC	Yes	Norrie Lyall	norrie.lyall@metoffice.gov.uk
Churchill, Canada	58.74	-94.07	1973/1979 – Mar 2021	1790	BM/ECC	Yes	David Tarasick	david.tarasick@canada.ca
Edmonton, Canada	53.54	-114.1	1970/1979 – Mar 2021	2175	BM/ECC	Yes	David Tarasick	david.tarasick@canada.ca

Goose Bay, Canada	53.31	-60.36	1969/1980 – Mar 2021	2358	BM/ECC	Yes	David Tarasick	david.tarasick@canada.ca
Legionowo, Poland	52.4	20.97	1979/1993 - 2022	1749	OS/ECC	Yes	Bogumil Kois	Bogumil.Kois@imgw.pl
Lindenberg, Germany	52.21	14.12	1974/1992 - present	0	OS/ECC	No	Peter Oelsner	Peter.Oelsner@dwd.de
De Bilt, Netherlands	52.1	5.18	1992 - 2020	1489	ECC	Yes	Ankie Piters	Ankie.piters@knmi.nl
Valentia, Ireland	51.94	-10.25	1994 - 2022	790	ECC	Yes	Michael Gill	michael.gill@met.ie
Uccle, Belgium	50.8	4.35	1969/1997 - 2022	3748	BM/ECC	Yes	Roeland Van Malderen	roeland.vanmalderen@meteo.be
Port Hardy	50.69	-127.38	2018 – Mar 2021	110	ECC	Yes	David Tarasick	david.tarasick@canada.ca
Bratt's Lake, Canada	50.2	-104.7	2003 - 2011	0	ECC	No	David Tarasick	david.tarasick@canada.ca
Praha, Czech Republic	50.01	14.45	1994 - present	0	ECC	No, in progress	Pavla Skrivankova	pavla.skrivankova@chmi.cz
Kelowna, Canada	49.93	-119.4	2003 – Jun 2017	700	ECC	Yes	David Tarasick	david.tarasick@canada.ca
Hohenpeissenberg, Germany	47.8	11.01	1967 – Sep 2023	6452	BM	Yes	Wolfgang Steinbrecht	Wolfgang.Steinbrecht@dwd.de
Payerne, Switzerland	46.49	6.57	1968/2002 - 2022	3114	BM/ECC	Yes	Eliane Maillard-Barras	Eliane.MaillardBarras@meteoswiss.ch
Egbert, Canada	44.23	-79.78	2003 - 2011	0	ECC	No	David Tarasick	david.tarasick@canada.ca
Haute Provence, France	43.94	5.71	1991 – Sep 2023	1497	ECC	Yes	Gerard Ancellet	gerard.ancellet@latmos.ipsl.fr
Yarmouth, Canada	43.87	-66.11	2003 – Mar 2021	795	ECC	Yes	David Tarasick	david.tarasick@canada.ca
Sapporo, Japan	43.06	141.33	1990/2010 - ???	0	KC/ECC	No	Masamichi Nakamura	mnakamura@met.kishou.go.jp
L'Aquila, Italy	42.3	13.31	1994 – May 2023	340	ECC	Yes	Vincenzo Rizi	vincenzo.rizi@aquila.infn.it
Trinidad Head, California, USA	40.8	-124.16	1997 – Aug 2023	1354	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Madrid, Spain	40.47	-3.58	1994 - 2022	1180	ECC	Yes	Ana Diaz Rodriguez	adiazr@aemet.es
Boulder, Colorado, USA	40	-105.25	1967 – Sep 2023	2043	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Wallops Island, Virginia, USA	37.93	-75.48	1995 – Nov 2020	1477	ECC	Yes	Ryan Stauffer	ryan.m.stauffer@nasa.gov
Tateno (Tsukuba), Japan	36.06	140.13	1990/2010 - present	0	KC/ECC	No	Masamichi Nakamura	mnakamura@met.kishou.go.jp
Huntsville, Alabama, USA	34.72	-86.64	1999 - present	0	ECC	No	Bryan Johnson	bryan.johnson@noaa.gov
Izana, Tenerife, Spain	28.3	-16.5	1995 - 2022	1412	ECC	Yes	Carlos J. Torres García	ctorresg@aemet.es
Naha, Japan	26.21	127.69	1990/2009 - ???	0	KC/ECC	No	Masamichi Nakamura	mnakamura@met.kishou.go.jp
Hong Kong, China	22.31	114.17	2000 - present	0	?	No	?	
Hanoi, Vietnam	21.01	105.8	2004 – Nov 2021	350	ECC	Yes	Ryan Stauffer	ryan.m.stauffer@nasa.gov
Hilo, Hawaii, USA	19.43	-155.04	1982 – Sep 2023	1885	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Costa Rica	9.94	-84.04	2005 – Mar 2023	687	ECC	Yes	Holger Vömel	voemel@ucar.edu
Paramaribo, Suriname	5.8	-55.21	1999 - 2022	880	ECC	Yes	Ankie Piters	ankie.piters@knmi.nl
Kuala Lumpur, Malaysia	2.73	101.27	1998 - 2022	501	ECC	Yes	Ryan Stauffer	ryan.m.stauffer@nasa.gov
San Cristobal, Ecuador	-0.92	-89.62	1998-2022	468	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Nairobi, Kenya	-1.27	36.8	1998 – May 2022	968	ECC	Yes	Eliane Maillard Barras	Eliane.MaillardBarras@meteoswiss.ch
Natal, Brazil	-5.42	-35.38	1998 - 2022	724	ECC	Yes	Ryan Stauffer	ryan.m.stauffer@nasa.gov
Watukosek, Java, Indonesia	-7.5	112.6	1998 - 2022	370	ECC	Yes	Masatomo Fujiwara	fuji@ees.hokudai.ac.jp
Ascension Island, United Kingdom	-7.58	-14.24	1998 – Sep 2022	379	ECC	Yes	Ryan Stauffer	francis.j.schmidlin@nasa.gov
Pago Pago, American Samoa	-14.23	-170.56	1986 – Sep 2023	1149	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Suva, Fiji	-18.13	178.4	1997 – Jun 2023	517	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov
Réunion Island, France	-21.06	55.48	1998 - 2022	805	ECC	Yes	Jérome Brioude	jerome.brioude@univ-reunion.fr
Irene, South Africa	-25.9	28.22	1998 – Mar 2023	415	ECC	Yes	Gerrie Coetzee	gerrie.coetzee@weathersa.co.za

Broadmeadows, Australia	-37.69	144.95	1965/1989 - present	0	BM/ECC	No	Matt Tully	matt.tully@bom.gov.au
Lauder, New Zealand	-45	169.68	1986 – Jun 2021	1973	ECC	Yes	Richard Querel	Richard.Querel@niwa.co.nz
Macquarie Island, Australia	-54.5	158.95	1994 - present	0	ECC	No	Matt Tully	matt.tully@bom.gov.au
Marambio, Antarctica	-64.24	-56.62	1988 - present	0	ECC	No	Rigel Kivi	rigel.kivi@fmi.fi
Dumont d'Urville, Antarctica	-66.7	140	1991 - present	0	ECC	No	Julien Jumelet	jumelet@latmos.ipsl.fr
Davis, Antarctica	-68.58	77.97	2003 - present	0		No	Matt Tully	matt.tully@bom.gov.au
Syowa, Antarctica	-69	39.58	1966 - present	0		No	Masamichi Nakamura	mnakamura@met.kishou.go.jp
Neumayer, Antarctica	-70.62	-8.37	1992 - present	0	ECC	No, TBD	Peter von der Gathen	peter.von.der.gathen@awi.de
McMurdo, Antarctica	-77.85	166.67	1986- Oct 2010	822	ECC	Yes	Terry Deshler	Richard.Querel@niwa.co.nz
Belgrano, Antarctica	-77.87	-34.63	2016 - present	0	ECC	No	Margarita Yela	yelam@inta.es
South Pole, Antarctica	-90	169.68	1967 – Sep 2023	2360	ECC	Yes	Bryan Johnson	bryan.johnson@noaa.gov

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