Appendix V – Ozonesonde Instruments

Balloon-borne ozonesondes first became practical for atmospheric monitoring in the 1960s when it was recognized that the neutral buffered potassium iodide (NBKI) method worked well as the ozone sensor. The instrument was inexpensive, lightweight, and only needed a small pump to bubble ambient air into a buffered KI solution thereby producing an electrical current proportional to ozone, and a weather radiosonde to transmit the data to a ground station [Brewer and Milford, 1960; Komhyr, 1964, 1967, 1969]. These "in situ" instruments are unique in providing high-resolution (100 to 150 m) ozone profiles from ground level to the lower stratosphere, with maximum altitudes at balloon burst near 30-35 km. Over the last 40-50 years, ozonesonde development and improvement has been the result of many intercomparison projects involving different ozonesonde types and reference instruments [Attmannspacher and Dütsch, 1970; 1981; Barnes et al., 1985; Hilsenrath et al., 1986; Kerr et al., 1994; Beekmann et al.,1994; Komhyr et al., 1995a; 1995b; Reid et al., 1996; Smit and Kley, 1998, Johnson et al., 2002; Smit and Straeter, 2004a; 2004b; Smit et al., 2007; Deshler et al., 2008; Stübi et al. 2008; Deshler et al., 2017].

The most recent laboratory experiments [Thompson et al., 2019; Smit et al., 2024] have shown that ozonesondes provide very reproducible and consistent results when the Standard Operating Procedures (SOPs) are strictly followed. The variability (precision) between sondes is estimated to be ~3-5% throughout most of the profile below 28 km [Tarasick et al., 2021; Smit, Thompson, and the ASOPOS 2.0 Panel 2021 WMO/GAW Report no. 268]. Comparisons with Aura OMI Total Column Ozone (TCO) averaged across the network of 60 stations are stable within about ±2% over the past 18 years. Sonde TCO has similar stability compared to three other TCO satellite instruments, and the stratospheric ozone measurements average to within ±5% of MLS from 50 to 10 hPa [Stauffer et al., 2022]. Therefore, the ozonesonde has been accepted and proven as a reliable NDACC instrument suitable for long-term measurements of ozone vertical profiles.

Under the WMO umbrella, there is a network of approximately 60 global ozone sounding stations, which partially overlaps the NDACC network. The WMO has assigned the role of the World Calibration Center for Ozonesondes (WCCOS) to Forschungszentrum Jülich (FZJ) in Germany, encompassing the Central Calibration Laboratory (CCL) in Jülich and the Quality Assurance Science Activity Centre (QA/SAC) at the Royal Meteorological Institute (RMI) of Belgium. The primary goals of the WCCOS are to promote understanding of the instrument, to establish well-documented SOPs, and to assess differences in instrument manufacturers and in variations of SOPs in use. The WCCOS along with NDACC investigators were instrumental in establishing and updating the guidelines behind the presently recommended SOPs in a document that is cross-linked from the NDACC Ozonesonde Working Group (WG) web site: https://tropo.gsfc.nasa.gov/shadoz/NDACC_SondeWorkingGroup.html

The peculiarity of ozonesondes is that every instrument is new and flown only once, although some stations do re-use recovered sondes after a careful cleaning and laboratory performance checks. Therefore, the notion of a reference/standard instrument has to be interpreted differently than for other types of instruments. In

the case of ozonesondes, the main emphasis is on the (SOPs) for preparing the instruments for flight, on the data processing, and traceability to the WCCOS reference ozone photometer [Smit et al., 2024].

Quality Criteria for the Evaluation of New Ozone Sounding Station

Long term monitoring networks of ozone sounding stations as well as project-dedicated networks have developed optimal practices over the years. Within these networks two different types of ozonesondes are still employed: electrochemical concentration cell (ECC) and Brewer Mast (BM).

ECC ozonesondes are now by far the most widely used ozonesonde type. Presently only one station (Hohenpeissenberg in Germany) is still using BM ozonesondes operationally. The SOPs for BM sondes have been summarized in (Smit and the ASOPOS Panel, 2014). The Japanese sonde KC92 [Kobayashi et al., 1966; Fujimoto et al., 2004] has been replaced by ECC sondes by the Japanese Meteorological Agency. No other stations have used KC sondes. To be complete, we note that since, 2014, a modified ECC-type ozonesonde manufactured at the Institute of Atmospheric Physics (IAP), Beijing, has been produced (Zhang et al., 2014a, b), but to date, few comparisons of this Chinese instrument with the other well-characterized ECC types (see below) have been carried out.

Two companies produce ECC sondes, Science Pump Corporation (SPC) and EN-SCI Corporation. The two manufacturers each recommend slightly different SOPs. These recommendations have been improved using the expertise gained in the operational ozonesonde networks, such as NDACC and by comparisons organized by the WMO, particularly at the WCCOS. WCCOS continues to periodically test the quality of ECC ozonesondes provided by the two manufacturers. The NDACC ozonesonde working group endorses the role of the WCCOS and there is a good collaboration between NDACC and WCCOS.

Ozonesonde SOPs are described in detail in the GAW report no 268 available at: https://library.wmo.int/records/item/57720-ozonesonde-measurement-principles-and-best-operational-practices

For stations that have not followed the SPC and EN-SCI recommendations regarding the KI solution concentration, Deshler et al. (2017) describe a method to correct the systematic bias. This publication is also an important contribution to the Ozonesonde Data Quality Assessment activity that prescribed guidelines for the global homogenization and uncertainty estimation of the ozonesonde time records [Smit et al., 2012].

The manufacturers of ozonesondes produce a consistent product with well-established characteristics. Therefore, the evaluation of candidate ozonesonde stations to be accepted into the NDACC network will be primarily based on their compliance with recommended standards for instrument operation and data analysis. These recommended standards are available in the SOPs for BM or ECC sondes. These guidelines are not meant to discourage new experimental work through which important scientific contributions to our understanding of ozonesonde characteristics can be made. However, in cases where a station wishes to deviate from the SOPs for either practical or scientific reasons, the NDACC requires that the station PI(s) document such changes to the Ozonesonde

Working Group representatives and in the NDACC data archive, and provide results showing the consequences of the change compared to standard ECC ozonesonde operation as defined in the SOPs.

Data File format for the ozonesonde NDACC Archive

At its 2009 meeting in Jülich, Germany, the NDACC Ozonesonde WG decided on a data file format to be used when submitting data to the NDACC Data Host Facility. The format was based on the NASA/AMES 2160 format and efforts have been taken to standardize this format among all NDACC stations in order to avoid the need for a multiplicity of readers to access NDACC ozonesonde data. Thus, NDACC investigators are encouraged to submit all their data using this format, and, although not required, to consider resubmitting any earlier data that may have been submitted under a different format. At the time of this publication, the Ozonesonde WG is exploring a transition from NASA/AMES 2160 to the Generic Earth Observation Metadata Standard Hierarchical Data Format (GEOMS HDF).

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