QOS 2021

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Online Meeting

QUADRENNIAL OZONE SYMPOSIUM

# [E_252] Evaluating long-term changes in atmospheric ozone


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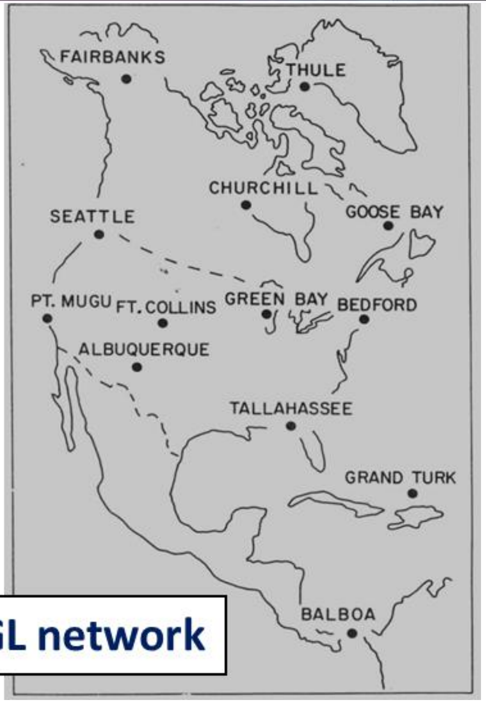
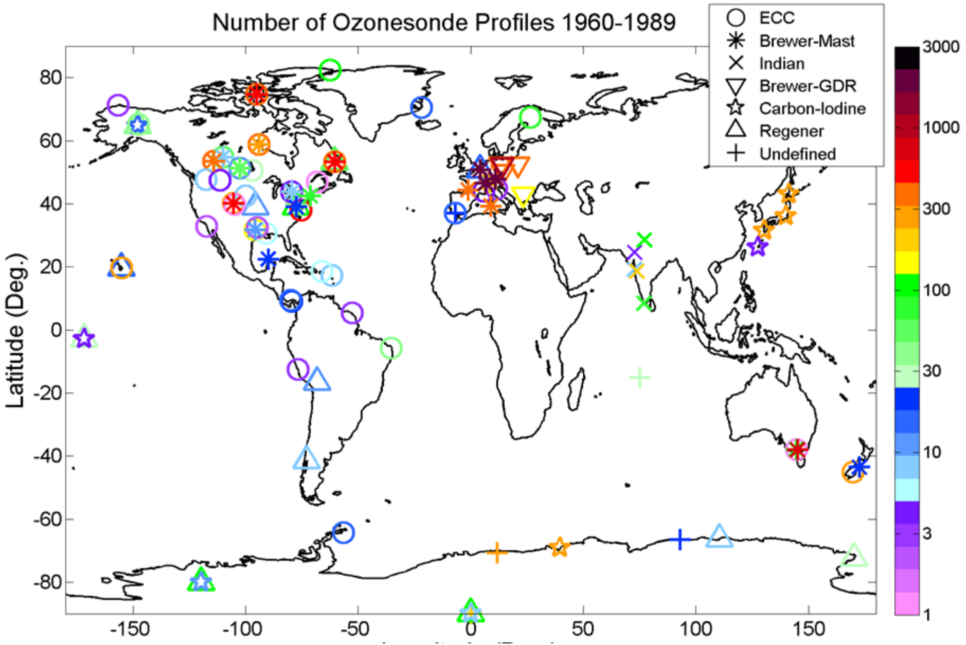
## Early measurements of the vertical profile of ozone

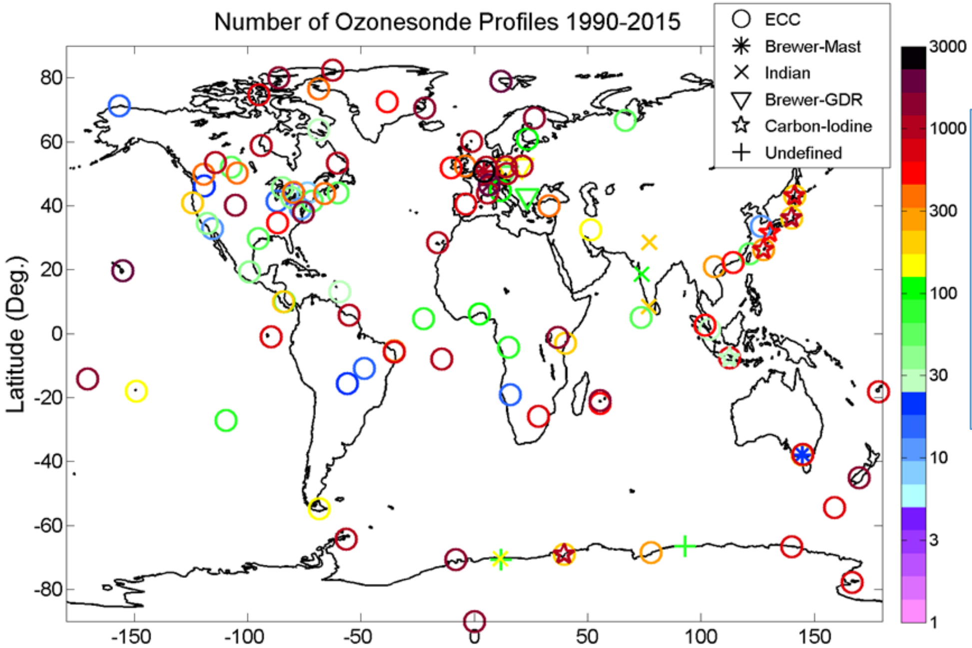
- Earliest profile measurements (*Regener and Regener*, 1934; *O'Brien et al.,* 1936; *Regener* 1938) were spectrophotometric (long-path)
- Filter-based optical sondes (*Coblentz and Stair*, 1939; 1941; *Paetzold*, 1955; *Fabian*, 1967)
- Chemiluminescent sondes (*Regener*, 1960) used briefly
- US ESSA and AFGL networks 1962-1966 launched 2000 Regener, Brewer-Mast and carbon-iodine sondes
- All “modern” sondes are electrochemical (KI)
- Regular soundings began in 1966. Now more than 50 years of data at some sites.






**AFGL network**



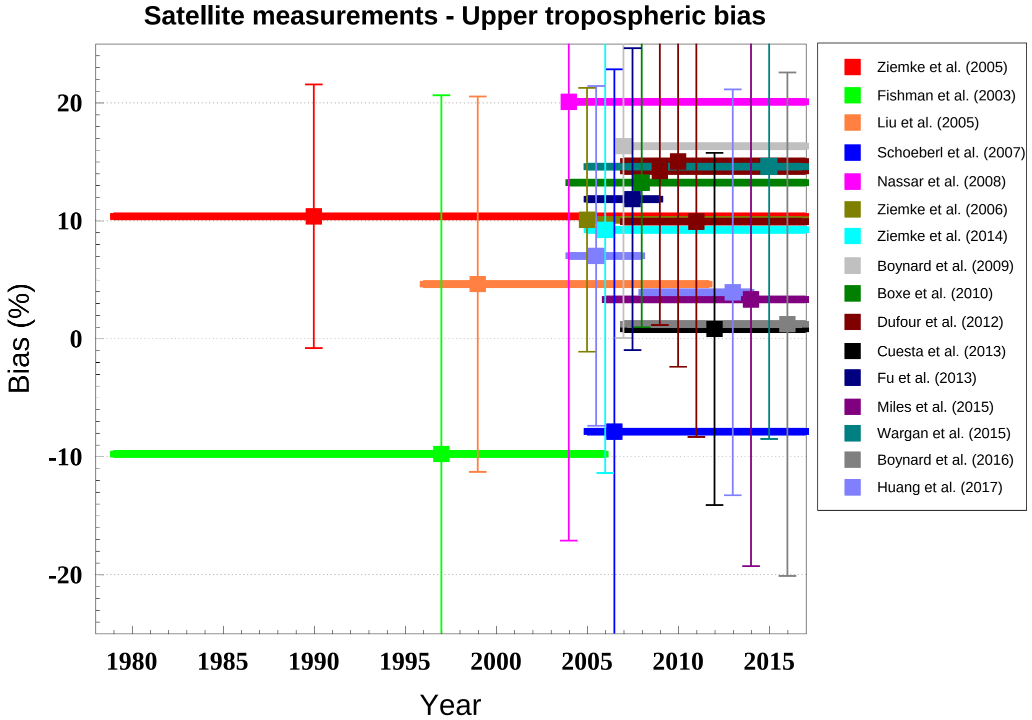

- Many different types in early years.
- Addition of SHADOZ network in late 1990s
- Gradual shift to ECC sondes.

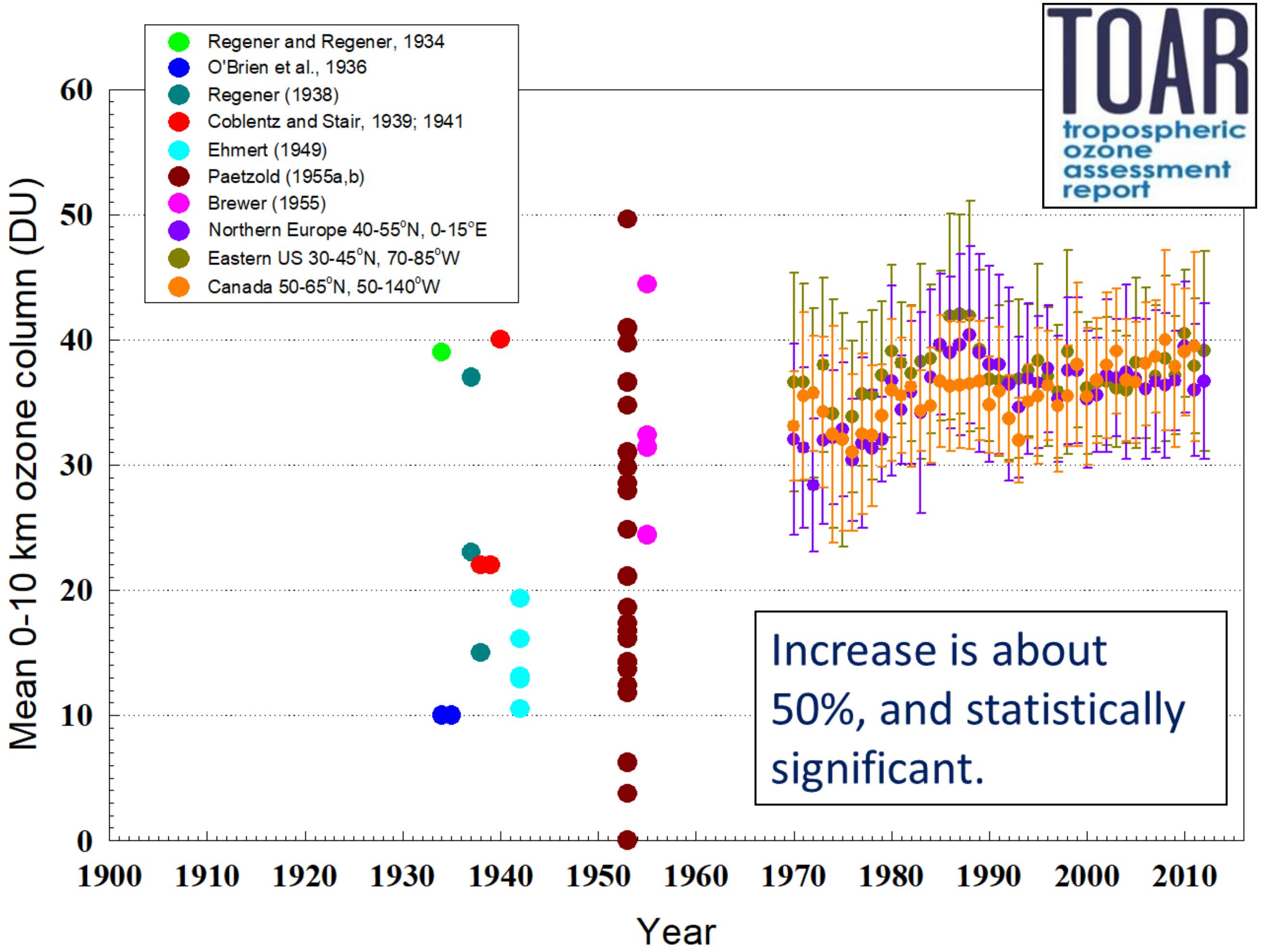
# Why are ozone soundings important?



- Very important as **a transfer standard and stable reference for satellite validation.** → evaluate **sensor drift**
- Need in situ measurements to evaluate retrieval accuracy. **Most validation studies use ECC sondes**
- Satellites can monitor ozone changes in the middle and upper stratosphere, but ozonesondes are the **only source of trend-quality long-term records below ~18 km**
- **Radiative forcing by ozone is strongly altitude-dependent,** and largest in the upper troposphere and lower stratosphere
- **Process studies** (e.g. MATCH...)

Tarasick, Galbally et al. (2019), TOAR- Observations: Tropospheric ozone from 1877 to 2016, observed levels, trends and uncertainties, *Elem Sci Anth*, 7(1), p.39. http://doi.org/10.1525/elementa.376.



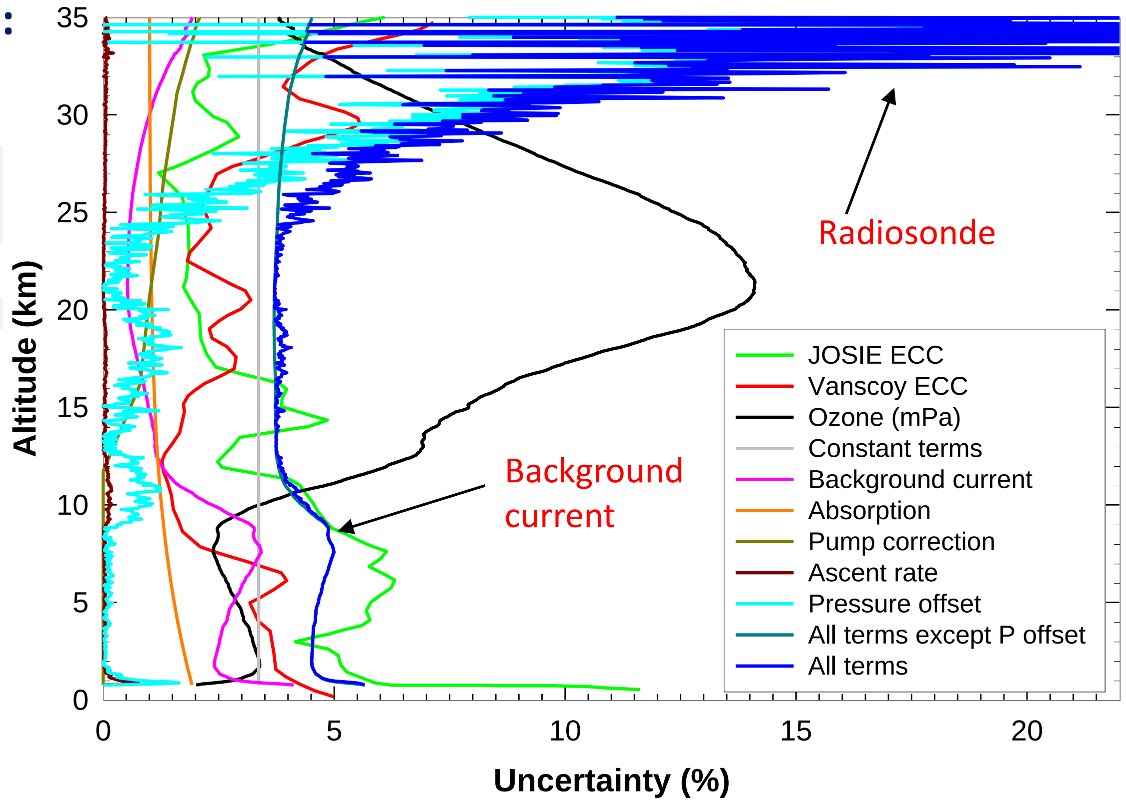
# But how accurate is this reference?

- Ozonesondes utilize electrochemical detection methods that were developed originally for surface monitoring (*Paneth and Glückauf*, 1941; *Glückauf et al.*, 1944; *Ehmert*, 1951; *Bowen and Regener*, 1951; *Vassy*, 1949; *Brewer and Milford*, 1960).
- While these generally gave good results, there are many examples of field instruments that suffered low biases (the Mast Ozone Meter; the Pruchniewicz instrument; the Cauer method) as well as examples of very high values (*Dauvillier* (1934); *Wilson et al*. (1952); *Kelley* (1970))
- **Controversy re stoichiometry of neutral-buffered KI in the 1970s:**
- *Dietz et al*. (1973): 1.00 ±0.03 at pH 7 & 0.1 to 0.4 ppm
- *Pitts et al*. (1976): 1.23 ±0.06 @ 50% RH & 0.1 to 1 ppm; 1.14 ±0.04 at 3% RH
- Some authors note that rigorous procedures, cleaning, were important.
- Chemical methods for $O_3$ abandoned by 1980s, except for ozonesondes

Given this, the accuracy of ozonesondes is impressive…

**Rigorous standard operating procedures** can improve random uncertainty to better than ±5%

- Pressure offset uncertainty largely resolved with GPS sondes
- Low confidence in uncertainty estimates for stoichiometry, background current ($i_B$)



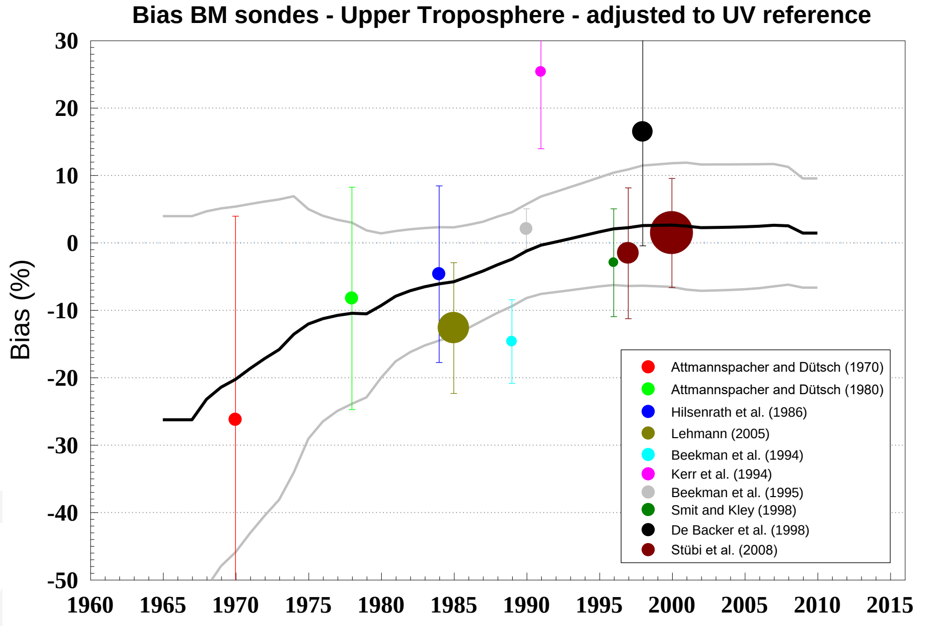

Uncertainty analysis for a midlatitude site (Edmonton, Canada)

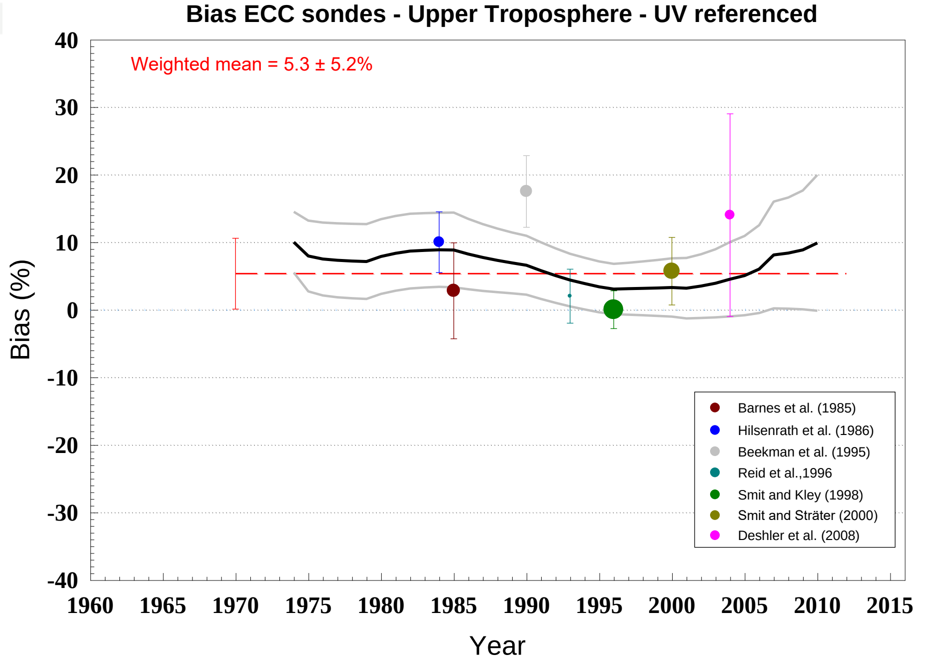
# And how stable is this "stable reference"?

- There have been changes in sonde type (ECC, Brewer-Mast, Indian, KC, Brewer-GDR…) and in standard operating procedures
- International intercomparisons can give us information about sonde response changes with time
- lab experiments characterize effects of hardware & SOP changes: the JOSIE campaigns have been of critical importance

  **Homogenization of older ozonesonde data records** – accounting for these effects – can improve systematic uncertainty to about ±5%

- BM sonde tropospheric response seems to have changed with time (see top right)
- Japanese KC sonde response also appears to have increased, by ~5% since 1970
- Early intercomparisons did not have a UV photometer (reliable benchtop UV photometers appear in the late 1970s). When these data are corrected, ECC appears stable within about +/- 5%.
- **Stratosphere: No discernable trends in total ozone normalization factors (in general)**



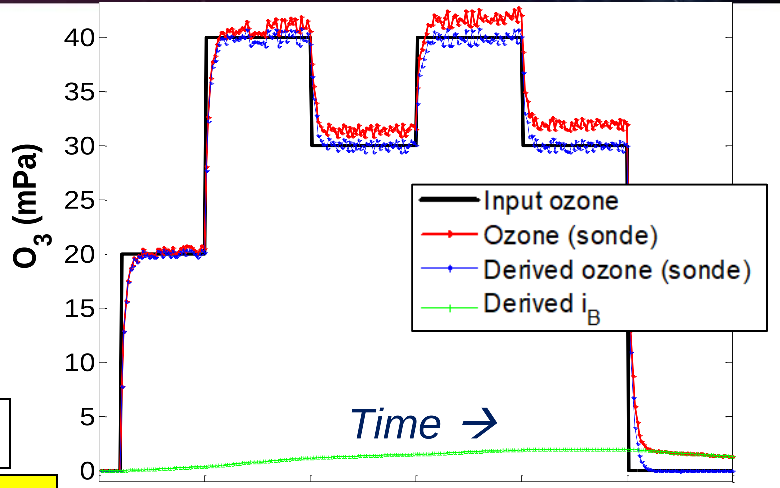



# Stoichiometry and Response Time



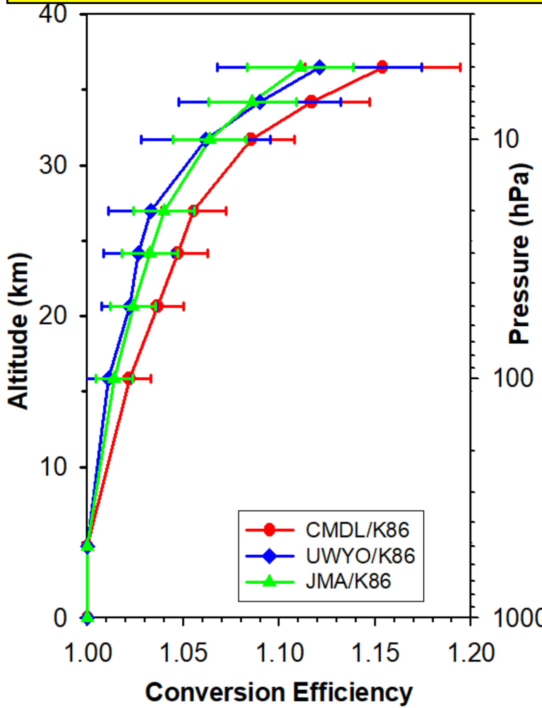
- *Saltzman and Gilbert* (1959): reaction stoichiometry varies with pH, but is 1.00 at pH = 7; second slow response up to 20%; *Flamm* (1977): stoichiometry increases with time, by 15-30%; Johnson et al. (2002): increase of 7% in ECC cell
- This suggests that the background current ($i_B$) is due to previous ozone exposure. A cell in equilibrium will have $i_B = 0$
- ECC sonde integrated columns agree well with total ozone measurements, but measured pump corrections (NOAA, U. Wyoming) are much larger than the operational standard (*Komhyr,* 1986)

⇨ The low Komhyr86 "pump corrections" compensate the increase in stoichiometry (on average)

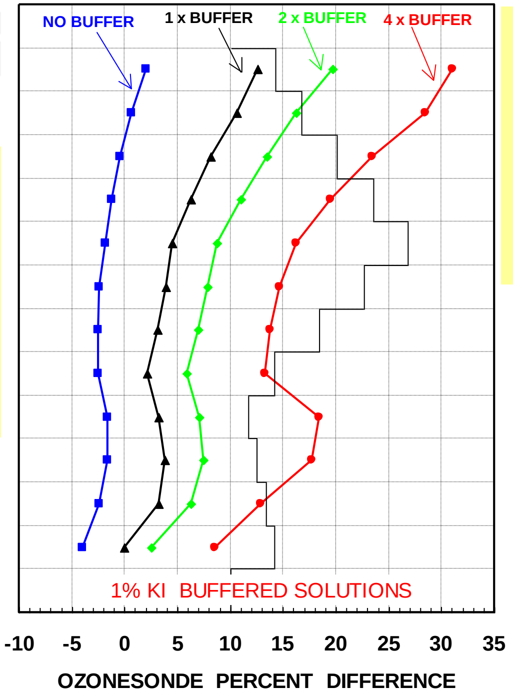



⇨ Model $i_B$ as 2nd order time response: $O_3^{sonde}(t) = O_3(1-e^{-t/\tau}) + 0.07*O_3(1-e^{-t/\zeta})$

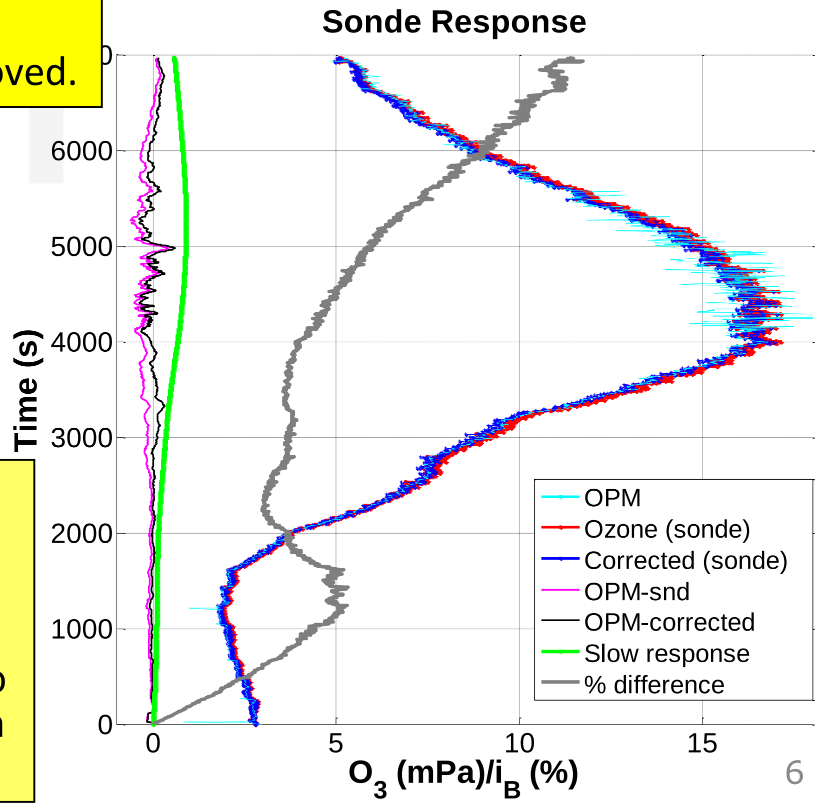
Use real pump corrections. Agreement with chamber ozone photometer (OPM) significantly improved.




**Left:** Estimated change in stoichiometry based on pump correction differences




**Left:** Response of unbuffered versus buffered cathode solutions (*Johnson et al., JGR*, 2002).




**Right:** Note similarity of grey curve to plot at left. Sonde column integrated ozone is reduced from 350.7 to 344.3 DU, agrees with OPM at 344.5 DU

# Conclusions

- **The detection of artifacts in ozonesonde time series should be a priority for the global network.**
- **Regular comparison with multiple satellite sensors will be a valuable tool for detection of such artifacts.**
- **We need more "housekeeping" data, such as pump motor current, speed, and cell temperature**
- **Regular sonde intercomparisons, using UV standard instruments traceable to the modern UV-absorption standard (the WCCOS facility)**
- **Need to detect and quantify any systematic changes in response (biases) that could affect the reliability of ozonesonde time series for merging shorter satellite data sets and for evaluation of satellite sensor drift.**

➢ *Hubert et al.* (2016): using ozonesonde profiles for satellite drift detection requires bias and precision of 3-5%

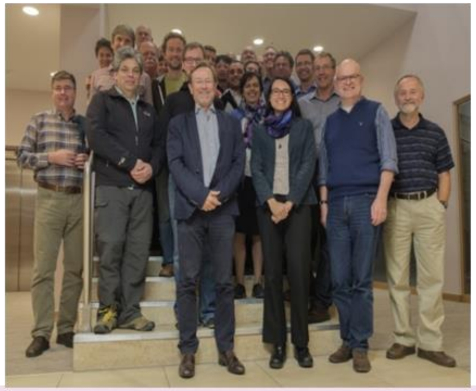
## Quality Assurance (QA) of Ozone Sonde ($O_3S$) Data

**ASOPOS**
Assessment for Standard Operating Procedures for Ozone Sondes

**JOSIE**
Jülich Ozone Sonde Intercomparison Experiment
*Since 1996*

**O3S-DQA**
Ozone Sonde Data Quality Assurance





Rigorous standard operating procedures, homogenization of ozonesonde data records can improve precision & uncertainty to ±5% or better

# See also:

- Tarasick, D.W., H.G.J. Smit, A.M. Thompson G.A. Morris, J.C. Witte, J. Davies, T. Nakano, R. van Malderen, R.M. Stauffer, T. Deshler, B.J. Johnson, R. Stübi, S.J. Oltmans and H. Vömel (2021), Improving ECC Ozonesonde Data Quality: Assessment of Current Methods and Outstanding Issues, *Earth and Space Science*, https://doi.org/10.1029/2019EA000914
- ASOPOS (Assessment of Standard Operating Procedures for Ozone Sondes) 2.0 Report: Updated Guidelines for Global Ozonesonde Operations (WMO - GAW Report, in press)
- Poster SAT2_20: ASOPOS (Assessment of Standard Operating Procedures (SOPs) for OzoneSondes) 2.0: Ozonesonde Measurement Principles and Best Operational Practices
- Poster SAT2_23: New Insights From The Jülich Ozone-Sonde Intercomparison Experiments: Calibration Functions Traceable To One Ozone Reference Instrument
- THU2_6: The 25th Anniversary Of The Juelich Ozone Sonde Intercomparison Experiment (JOSIE): 25 Years Of Ozonesonde QA/QC And Data Quality Improvements
- FRI1_2: An Updated Examination of the Post-2013 Ozonesonde Total Column Ozone "Dropoff“
- FRI1_1: The Importance Of Correcting The Time Response Of The Electrochemical Concentration Cell (ECC) Ozonesonde