New insights from the Jülich Ozone-Sonde Intercomparison Experiments (JOSIE): calibration functions traceable to one ozone reference instrument

1 New Insights From The Jülich Ozone-Sonde Intercomparison
2 Experiments: Calibration Functions Traceable To One Ozone Reference
3 Instrument

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+ all results for 4 other sonde type – sensing solution combinations, relative contributions of the different components of the TRCC method, uncertainty estimation of the TRCC method
• Introduction
• Principles of “new” method
• Data
• Time Responses Correction (TRC) Method
• Application on JOSIE data
• Application on sounding data
• Conclusions and outlook
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1. improper Komhyr pump efficiency corrections $\eta_P$
2. a constant background current $I_B$
3. a constant conversion efficiency $\eta_C$ of the (main) chemical reaction equal to 1

However, we know...

1. measured pump efficiency factors, consistent between different labs in several decades
   $\rightarrow$ Johnson et al. (2002), Nakano & Morofuji (2023)
2.
3.
4.

$$P_{O3} = 0.043085 \frac{T_P}{(\eta_P \eta_A \eta_C \Phi_{P0})} (I_M - I_B)$$
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4. the primary chemical reaction (95%) has a fast time response with time constant $20-25$ s $\rightarrow$ corrections proposed in Imai et al. (2013), Huang et al. (2015)
Principles of “new” method

Pre-launch procedure at Uccle (N = 365-840)

a) 10 min @ 150-200 ppb → 10 min @ no O₃ → switch pump off

b) no O₃ @ 60 min, 120 min (pump on again)

Findings:

- fast time response (t = 20-25 sec) dominates when switching to no O₃
- almost no contribution of fast component to $I_M$ after 4 minutes
- slow time response (t = 20-25 min) of signal takes it over afterwards

$I_{\text{B0}} = 0.011 \pm 0.010 \mu\text{A} (N = 841)$

$I_{\text{B1}} = 0.045 \pm 0.034 \mu\text{A} (N = 841)$
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- at 60 min & 120 min: excess current w.r.t. slow response: $I_{B0}$ (current measured before O₃ exposure)

$\rightarrow I_M = I_F + I_S + I_{B0}$
JOSIE measurements in Environmental Simulation Facility in Jülich

- response test (RT) intervals in JOSIE 2009/2010
- 2 manufacturers (ENSCI, SPC), two solution strengths
- reference photometer in chamber

- I ECC: original ECC current
- I OPM: current measured by reference photometer in Jülich
- I slow conv.: convolved “slow” part of the signal
- iB0: background current before O₃ exposure

➔ contribution $S_s$ of slow component?
Contribution $S_S$ of slow component?

- contribution ranges between 1.7 and 5%
- similar solutions = similar contributions
- larger contributions for higher KI concentration and **higher buffer strength**
- independent of sonde manufacturer
- independent of response test interval used (atmospheric conditions)
In practice: \( (I_M = I_F + I_S + I_{B0}) \)

- subtract \( I_{B0} \) from measured currents \( I_M \) 
  \( (I_A = I_M - I_{B0}) \)
- determine slow component \( I_S \),
  - calculated as 25 minute (exponential) delayed signal, multiplied with its relative contribution \( S_S \)
  - subtract from the ECC current ("background current", but time/ozone exposure dependent)
- remaining fast component (\( = I_A - I_S \)) can be corrected for 20-25 s time response (\( I_{F,D} \)).

=> TRC method, see also Vömel et al. (2020)
<> role of \( I_{B0} \), smaller \( S_S \)
Application on JOSIE

Application on JOSIE 2009/2010 (mid-latitude) data

- Large reduction of rel. differences around response time (RT) intervals
- Major improvement with TRC: independent on ozone profile or pressure
- Slightly linearly increasing bias with decreasing pressure

2 recommended standards in the network
Application on JOSIE

Application on JOSIE 2017 (tropical) data

- 2 recommended standards in the network

- Large reduction of rel. differences UT!
- Major improvement with TRC: independent on ozone profile or pressure
- Slightly linearly increasing bias with decreasing pressure
Determination of calibration functions

- remaining linear regression lines are very similar for both campaigns (mid-lat vs. tropical)
- calculate those for the entire samples, for every sonde type – SST combination
- “calibration functions” to the OPM (conversion efficiency)

- After applying the TRC + calibration functions (“TRCC”): differences are within ±1% for almost the entire pressure range (except the lowest pressures)
- Now referenced to the OPM
Application on sounding data

Conventional vs TRCC:

- Remarkably improved agreement between ascent and descent profiles (→ correction for fast time response component) with TRCC.
- Also better agreement in ascent/descent profile shapes with TRCC.
- Lower UT ozone concentrations in tropical Samoa and ozone hole at South Pole.
- Amplification of features in TRCC profiles after correcting for the fast time constant (>< increased noise?)
Application on sounding data

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- Amplification of features in TRCC profiles after correcting for the fast time constant (> < increased noise?)
Conclusions and outlook

• Time Responses Correction method as described/illustrated by Tarasick et al. (2021) & Vömel et al. (2020) further developed with all available JOSIE data

• Time Responses Correction method looks very promising, implementing all the (real pump efficiency) measurements and (chemical) knowledge we have
  ✓ role for $I_{B0}$
  ✓ relative contribution of slow component (= signal convolved with $t= 25$ min exponential delay) varies between 1.5 and 5%
  ✓ correction for fast time response (= deconvolved $I_M - I_{B0} - I_S$ with $t=20-25$ s exponential delay) improves ozone gradient and amplifies features (smoothing!)

• but: need for calibration functions (“conversion efficiency”) to trace observations back to the photometer in Jülich → related to fast primary chemical reaction???

• still a lot to be learned about (the chemistry of) the ozonesonde

• implementation in the global ozonesonde network is envisioned.
References


