JOSIE 2017-SHADOZ at WCCOS:

Jülich Ozone Sonde Intercomparison Experiment

Herman G.J. Smit & Anne Thompson & JOSIE-SHADOZ Team
Quality Assurance (QA) of Ozone Sonde (O3S) 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

Standard operating procedures (SOP’s) and Homogenisation of O3S data records can improve precision & uncertainty better ±5%

3. Mai 2018

JOSIE 2017-SHADOZ:
GRUAN ICM10-AWI/Potsdam 23-27 April 2018
JOSIE 1996: QA-Operation
>> Small changes/differences of instruments or operating procedures can have significant impact on data quality!!!!

JOSIE 1998: QA-Manufacturers
>> Differences between manufacturers

JOSIE 2000: QA-Procedures
>> Differences between sensing solutions

>> Definition of provisional SOP’s

BESOS 2004: Testing of provisional SOP’s in the field

ASOPOS 2004: Evaluation JOSIE & BESOS
>> Unanimous agreement on SOP’s

ASOPOS 2009: Approval SOP’s by WMO
>> GAW Report #201

JOSIE 2009-2011: QA-Manufacturers

O3S-DQA Activity 2011-2017:
>> Homogenisation long term O3S records

JOSIE 2017/SHADOZ:
>> QA-Tropical profiling capabilities

ASOPOS 2.0 (2018-2019): Upgrade of SOP’s

The facility enables control of pressure, temperature and ozone concentration and can simulate quasi realistic flight conditions of ozone soundings from surface to Z=35 km. A dual beam UV-photometer serves as a reference (uncertainty better than ±5 %).
The SHADOZ project coordinated by Anne Thompson (NASA/GSFC) began in 1998 as a coordinated effort among NASA, NOAA and international partners to coordinate an operational network of tropical and remote ozone sounding sites. **To date, more than 7000 sets of ozone and P-T-U radiosonde measurements have been collected.**

[http://tropo.gsfc.nasa.gov/shadoz]
Objectives:

- Tropical Profiling Capabilities
- Critical instrumental issues: Background Current, Pump flow Corrections and Sensing Solution Type
- Capacity building (support from UNEP-Vienna Convention Trust Fund (Montreal Protocol) )
- Testing to upgrade SOP’s: ASOPOS 2.0 (Reload)

Week 1: Present Status SHADOZ : Inhomogeneity in SOP’s
Week 2: Future more homogeneity in SOP’s

Goal: Through better standardization of ground equipment and preparation procedures and instructions to achieve uncertainty better than 5%
### JOSIE 2017-SHADOZ: Participants

#### Session 1: 09-20 October 2017

![Participants of Session 1](image1.jpg)

**VTCF-Funded Operators**

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#### Session 2: 23 October-03 November 2017

![Participants of Session 2](image2.jpg)
### JOSIE 2017-SHADOZ: Session Schedule for 2 Weeks.

<table>
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<tr>
<th>Day (Day#)</th>
<th>Lecture</th>
<th>Tutorial</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Sunday (Day#01)</td>
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<td>Arrival</td>
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<tr>
<td>Monday (Day#02)</td>
<td>Principles of an ozone sounding</td>
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<td>Installation Ground Equipment 3-5 days preparation of O3S</td>
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<tr>
<td>Tuesday (Day#03)</td>
<td>Standard Operating Procedures (SOPs)</td>
<td>Preparation of an ozone sonde in practice</td>
<td>Test of O3S-simulation run</td>
</tr>
<tr>
<td>Wednesday (Day#04)</td>
<td>Post-flight data processing</td>
<td>Post-flight data processing in practice</td>
<td>First O3S simulation run Evaluation of first results</td>
</tr>
<tr>
<td>Thursday (Day#05)</td>
<td>Chemistry of O3+KI</td>
<td></td>
<td>Two O3S simulation runs</td>
</tr>
<tr>
<td>Friday (Day#06)</td>
<td>Pumpflow efficiency</td>
<td></td>
<td>Two O3S simulation runs</td>
</tr>
<tr>
<td>Saturday (Day#07)</td>
<td>Uncertainty analysis</td>
<td>Uncertainty analysis in practice</td>
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<tr>
<td>Sunday (Day#08)</td>
<td></td>
<td></td>
<td>Sight seeing</td>
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<tr>
<td>Monday (Day#09)</td>
<td>Radiosonde-PTU &amp; GPS/Wind/Altitude</td>
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<td>Mid-term evaluation meeting on the results of O3S</td>
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<tr>
<td>Tuesday (Day#10)</td>
<td>Background current</td>
<td></td>
<td>Two O3S simulation runs</td>
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<tr>
<td>Wednesday (Day#11)</td>
<td>Total ozone column/normalisation</td>
<td></td>
<td>Two O3S simulation runs</td>
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<tr>
<td>Thursday (Day#12)</td>
<td>QA/QC-evaluation</td>
<td>QA/QC-evaluation in practice</td>
<td>Last O3S simulation run</td>
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<tr>
<td>Friday (Day#13)</td>
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<td></td>
<td>Final evaluation meeting Packing Departure</td>
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<tr>
<td>Saturday (Day#14)</td>
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**Present Status:**
- Inhomogeneity in SOP’s

**Future Status:**
- More homogeneity in SOP’s
JOSIE 2017-SHADOZ: First Results of 2 Simulation Flights

Session 1, Simulation 171

- Participant 1, 302 DU
- Participant 2, 308 DU
- Participant 3, 290 DU
- Participant 4, 285 DU
- Photometer, 282 DU

Session 2, Simulation 189

- Participant 5, 302 DU
- Participant 6, 296 DU
- Participant 7, 302 DU
- Participant 8, 283 DU
- Photometer, 299 DU
Individual mean deviations to OPM in partial pressure (mPa) (left) and relative (%) (right) for SHADOZ SOP’s for both sessions. Based on 5 runs of each station.
JOSIE 2017-SHADOZ: Comparison Sondes to UV-Photometer (OPM) using JOSIE-SOP’s (Slightly Revised WMO/GAW SOP’s)

Individual mean deviations to OPM in partial pressure (mPa) (left) and relative (%) (right) for SHADOZ SOP’s for both sessions. Based on 5 runs of each station.
JOSIE 2017-SHADOZ: SHADOZ SOP’s versus JOSIE-SOP’

**A**

EN-SCI/SPC Standard Solutions Comparison

- **EN-SCI 0.5%, 0.5B, N = 20**
- **SPC 1.0%, 1.0B, N = 15**

**B**

Session 1: SHADOZ SOPs vs. JOSIE SOPs

- **SHADOZ SOPs, N = 20**
- **JOSIE SOPs, N = 20**

**C**

Session 2: 1.0% KI, 0.1B vs. 2.0% KI, 0.1B Solution

- **1.0% 0.1B, N = 10**
- **2.0% 0.1B, N = 10**

**D**

EN-SCI and SPC 1.0% 0.1B Comparison

- **EN-SCI, N = 25**
- **SPC, N = 10**
JOSIE 2017-SHADOZ: Achievements

• 2 x 2-Weeks-sessions with 2x4 SHADOZ stations
• 2 x 10-Simulation experiments of tropical profiles
• 2 x 40-Ozonesonde-profiles versus UV-Photometer for further investigations!
• Requirement for more standardization of ground equipment and preparational procedures
• Capacity building: Intensive training of station operators plus lectures by coaches and referees
JOSIE 2017-SHADOZ: Preliminary Findings

- The SPC / ENSCI offsets seen in JOSIE-2000 (Smit et al., 2007) & BESOS-2004 (Deshler et al., 2008) are confirmed in JOSIE-2017.

- With uniform preparation procedures, SHADOZ profiles agree within 5% with the UV photometer.

- Reducing the buffer in the sensing solution improves O₃ accuracy near the tropopause.

- ……….. Results Under Investigations……….
JOSIE 2017-SHADOZ: Outlook

- “The JOSIE-SHADOZ Experience”: BAMS-Paper
- Evaluation of JOSIE 2017 results
- Evaluation existing SOP‘s:
  >>> Start of ASOPOS 2.0 Reload
  *[Assessment of Standard Operating Procedures for Ozone Sondes]*

JOSIE-SHADOZ & ASOPOS Workshop 17-19 Sept. 2018 in Switzerland (Geneva area) after the NDACC-Annual SSC Meeting

Outcome of ASOPOS 2.0 Reload in 2019/2020:

1. More strict SOP’s
2. Standardization of ground equipment for preparation of O3-sondes
JOSIE 2017/SHADOZ: Acknowledgements

- JOSIE-SHADOZ support comes from FZ-Jülich, NASA and NOAA with special travel support from the UNEP Vienna Convention Trust Fund.

- Ozone sondes (more than 100) were supplied by NOAA, NASA, Environmental Canada, FMI, Meteo Suisse, KMI, KNMI, NIWA

- Participating organizations:

- Last but least now 4 minutes of 4 weeks of JOSIE 2017/SHADOZ campaign: https://vimeo.com/240986625 by Patrick Cullis (NOAA, Boulder)
Very important QA/QC factor to achieve the best data quality starts at the launch site:

1. Good quality of preparation equipment, which is well maintained

2. Well trained and motivated sonde operator & scientist

3. Good & regular communication between scientist & sonde operator
Presently elaborating the feasibility to submit a proposal for an EU COST action on the harmonisation of ozone profiling data from different ground based platforms.

Ozone sondes, Lidars, In Service-Aircraft and others.

Focus on Troposphere + Tropopause region until Z= 20 km.

EU-COST action is a networking activity.

Funded by the European Commission for 4 years.

Majorly covering the costs of meetings, trainings, summer schools, short scientific missions (< 1-2 weeks).

Call for proposals in Fall 2018.

Oversigned by factor 5-10.

Several administrative thresholds/obstacles to be taken.

Realism: Limited chances of success.

JOSIE-Fun: [https://vimeo.com/240986625](https://vimeo.com/240986625) by Patrick Cullis (NOAA, Boulder)
Reserve Slides
Ozone Sonde (O3S) in Global Networks

- Longest time series of vertical ozone distribution
- Cost efficient for process studies (e.g. MATCH, SHADOZ)
- Backbone of satellites: Provide a-priori profiles for satellite retrievals and important to validate satellites on their long-term stability
- Small changes of instrument or operating procedures can have large impact on data quality
- Trend assessments show need for more homogeneity of data
WCCOS:
World Calibration Centre for Ozone Sondes

Part of Quality Assurance (QA) plan of WMO/GAW
(World Meteorological Organization / Global Atmosphere Watch)

Tasks:
- QA-Manufacturers
- QA-Operation
- QA-Procedures

Activities:
- ASOPOS & O3S-DQA
What Is An Ozone Sounding?

![Image of ozone sounding instrument and chart showing altitude, temperature, and pressure data.]

**Temperature [Kelvin]**

- 180 200 220 240 260 280 300

**Altitude [km]**

- 0 5 10 15 20 25 30

**Ozone, Pressure [mPa]**

Grey Line = ECC-Sonde Kasshidoo

---

**What Is An Ozone Sounding?**

- INDOEX-1999

**INDOEX-1999**

- JOSIE 2017-SHADOZ:
  - GRUAN ICM10-AWI/Potsdam 23-27 April 2018
Electrochemical Ozone Sonde: Introduction

In an electrochemical cell:
- A small pump forces ambient air through a KI-solution.
- Ozone is converted into iodine by the reaction:
  \[ 2\text{KI} + \text{O}_3 + \text{H}_2\text{O} \rightarrow \text{I}_2 + \text{O}_2 + 2\text{KOH} \]
- At a Platinium cathode the Iodine is converted to Iodide:
  \[ \text{I}_2 + 2e^{-} \xrightarrow{\text{Pt}} 2\text{I}^- \]
- In external electrical circuit a current is generated directly related to the uptake rate of ozone in the sensing solution.

\[ P_{\text{O}_3} = 0.04307 \cdot \eta_C \cdot \frac{TP}{\Phi_P} \cdot (I_M - I_B) \]

**Variables:**
- \( P_{\text{O}_3} \): Ozone Pressure [mPa]
- \( \eta_C \): Conversion Efficiency
- \( TP \): Pump Temperature [K]
- \( \Phi_P \): Pump Flow [cm3/s]
- \( I_M \): Measured Current [µA]
- \( I_B \): Background Current [µA]
Global Ozone Sonde Network (GAW-NDACC-SHADOZ-GRUAN)
The overall objective of JOSIE (Jülich Ozone Sonde Intercomparison Experiment) is to establish **quality assurance guidance** for the global ozone sonde community.

- To assess the performance of the various ozone sonde instrument types the environmental simulation chamber at the Forschungszentrum Jülich was established as the World Calibration Center for Ozone Sondes (WCCOS) in 1996.

- The chamber simulates flight conditions of ozone sonde soundings up to 35 km. This controlled environment allows for accurate comparisons of ozonesonde profiles to the reference UV-photometer.
Environmental Simulation Facility for O3S:
Simulation of Ozone Soundings Under Quasi Realistic
Atmospheric Conditions of Pressure, Temperature and Ozone

Ozone Reference
Dual Beam UV-Photometer:
- response: 1 s
- precision: \( \pm 0.025 \text{mPa} \)
- accuracy: \( \pm 2 \% \) (0-25 km),
  \( \pm 3.5 \% \) (30-35km)
## JOSIE 2017/SHADOZ: Participating Stations

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<th>SHADOZ-Site</th>
<th>ECC–O3S / Sensing Solution</th>
<th>Station Principal Investigator</th>
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<tbody>
<tr>
<td>Irene, South Africa</td>
<td>SPC-6A / SST1.0%-Full Buffer</td>
<td>G. Coetzee (SAWS)</td>
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<td>Natal, Brasil</td>
<td>SPC-6A / SST1.0%-Full Buffer</td>
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<td>A.M. Thompson (NASA)</td>
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For each Sensing Solution Type

(SST1.0, SST0.5, and SST2.0):

- ENSCI 5-10 % higher than SPC
- Precision about 3-6 %
Summary of Unbuffered Versus Buffered Cathode Solution Tests (Source: Johnson et al., JGR, 2002):
Tests were done at room pressure and temperature.

Ozone calibrator set to approximate typical profile.
Session 1: (1) George Brothers (NASA/WFF); (2) Kennedy Thiong’o (Kenya Met Dept.); (3) Francisco Raimundo da Silva (INPE Natal); (4) Ernesto Corrales (Univ. Costa Rica); (5) Peter von der Gathen (Alfred Wegener Institute); (6) Herman Smit (FZ Jülich); (7) Ryan Stauffer (NASA/GSFC); (8) Gary Morris (St. Edward’s Univ.); (9) Gabi Nork (FZ Jülich); (10) Anne Thompson (NASA/GSFC); (11) Bryan Johnson (NOAA ESRL); (12) Tshidi Machinini (South African Weather Service); (13) Nakano Tatsumi (Japan Met Agency); (14) Rhonie Wolff (NASA/WFF)
Session 2: (1) Gonzague Romanens (MeteoSwiss); (2) Torben Blomel (FZ Jülich); (3) Jennifer Gläser (FZ Jülich); (4) Nguyen Thi Hoang Ahn (National Hydro-Meteorological Service of Vietnam); (5) Anne Thompson (NASA/GSFC); (6) Jonathan Davies (Env. Climate Change Canada); (7) Zamuna Zainal (Met Malaysia); (8) Patrick Neis (FZ Jülich); (9) Gabi Nork (FZ Jülich); (10) Rigel Kivi (FMI); (11) Rene Stübi (MeteoSwiss); (12) Patrick Cullis (NOAA ESRL); (13) Herman Smit (FZ Jülich); (14) Marc Allaart (KNMI); (15) Roeland Van Malderen (Royal Meteorological Institute of Belgium); (16) Jacquelyn Witte (NASA/GSFC); (17) George Paiman (Met Dept. of Suriname); (18) Andreas Petzold (FZ Jülich); (19) Gilbert Levrat (MeteoSwiss); (20) Françoise Posny (Univ. of La Réunion)
BESOS 2004 versus JOSIE 2000: SPC-6A & ENSCI-Z @ SST1.0% & SST0.5%

3. Mai 2018

JOSIE 2000: Different Operating Procedures

JOSIE 2017/SHADOZ: Jülich Ozone Sonde Intercomparison Experiment

BESOS 2004: Standard Operating Procedures
JOSIE-2009/2010: SPC-6A Sondes
Relative Deviations to OPM @ SST1.0% & SST0.5% (BG3)

File: JOSIE-2010-RelComp-SSC#1-BG1to6-A1

File: JOSIE-2010-RelComp-SSC#2-BG1to6-A1

JOSIE 2017/SHADOZ:
Jülich Ozone Sonde Intercomparison Experiment
JOSIE-2009/2010: ENSCI-Sondes
Relative Deviations to OPM @ SST1.0% & SST0.5% (BG3)

JOSIE-2010: Relative Deviations Sondes to OPM
ENSCI-Z & SST1.0% @ BG3
Ozone Partial Pressure OPM [mPa]

JOSIE-2010: Relative Deviations Sondes to OPM
ENSCI-Z & SST0.5% @ BG3
Ozone Partial Pressure OPM [mPa]

Altitude [km]
Relative Differences [%]
(Sonde-OPM)/OPM

File: JOSIE-2010-RelComp-SSC#3-BG1to6-A1

JOSIE 2017/SHADOZ:
Jülich Ozone Sonde Intercomparison Experiment
### JOSIE 2017: Pump Flow Efficiencies (part 1)

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</table>
Ozone Reference

Dual Beam UV-Photometer:
- response: 1 s
- precision: ±0.025 mPa
- accuracy: ±2 % (0-25 km), ±3.5% (30-35 km)
Lessons We Learned With ECC's Again and Again

At the first sight it seems all fine and not to worry, because from Design, Components and Type all ECC Types look the Same

But:

Small changes of instrument or operating procedures or changing manufacturers can have large impact on data quality (e.g. JOSIE & BESOS)

Warning:

Cautious with regard to any changes

(Remind, that the devil is always hiding himself in the details)