JOSIE-2000

Jülich Ozone Sonde Intercomparison Experiment 2000

The 2000 WMO international intercomparison of operating procedures for ECC-ozone sondes at the environmental simulation facility at Jülich
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Prepared by
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WMO TD No. 1225
EXECUTIVE SUMMARY

During September 2000, a World Meteorological Organization (WMO) international ozone sonde intercomparison campaign was conducted using the environmental simulation facility (http://www.fz-juelich.de/icg/icg-ii/esf/) of the World Calibration Center of Ozone Sondes (WCCOS) at the Research Centre Julich, Germany. It was a continuation of the assessment of the performance of ozonesondes used in the WMO Global Atmosphere Watch (GAW) programme under the Julich Ozone Sonde Intercomparison Experiment (JOSIE: http://www.fz-juelich.de/icg/icg-ii/josie/) which began in 1996. The JOSIE experiments in 1996, 1998, 2000 followed a step-by-step approach to accomplish the different quality assurance (QA) tasks for ozonesondes of the WCCOS. While the first two JOSIE campaigns were focused on the QA associated with the various types and manufacturers of sondes, the 2000 campaign was dedicated to support the assessment of standard operating procedures (SOPs) for the different sonde types presently operating in the GAW network. The task was to conduct intercomparison experiments in the simulation chamber which address uncertainties in the instrument preparation (sensing solution, background signal, pump efficiency) and data reduction procedures.

JOSIE 2000 brought together 7 participating ECC sounding stations of the GAW global network operating 2 different ECC-sonde types: SPC-6A & ENSCI-Z with 3 different sensing solution types (SST's): (i) SST-1A:1% KI, Full Buffer; (ii) SST-2B:0.5% KI, Half Buffer; (iii) SST-3A:2% KI, No Buffer. In addition, JOSIE 2000 was attended by the Japan Meteorological Agency (JMA) to test the profiling capabilities of their new sonde version KC-96 of the older version KC-79 which was tested during JOSIE 1996. The participating laboratories were split into two groups of four teams. Both groups attended the campaign for a 10 days period: 4-13 September 2000 (Campaign C-I) and 18-27 September 2000 (Campaign C-II). Participation from USA (NOAA/CMDL and NASA/WFF), Canada (MSC), New Zealand (NIWA), Germany (FZJ), Switzerland (SAP) France (URI), and Japan (JMA). The results of the different simulation experiments were compared, analysed and evaluated by the participants during the campaign.

For each combination of ECC-sonde type (SPC-6A and ENSCI-Z) and sensing solution type (SST-1A, SST-2B, and SST-3A), a total of six simulation experiments were conducted using different simulation profiles (2x Mid-Latitude, 2x Sub-Tropical & 2x Tropical). All sonde data were processed according the guidelines of Komhyr (1986). A summary of the results is shown in the Figure below. The experiments have shown that the characteristics of the two ECC-sonde types are not always the same. Even when operated under the same conditions, they can have significant differences. Particularly above 20 km the ENSCI-Z sonde tends to measure 5-10 % more ozone than the SPC-6A sonde. Below 20 km, the differences are 5 % or less but can differ from year to year. Furthermore, there is a significant difference in the ozone readings when sondes of the same type are operated with different cathode sensing solutions. For each ECC-type the use of 1% KI (full buffer) will give 5% larger ozone values compared with the use of 0.5%KI (half buffer), and even 10% larger values compared with 2% KI (no buffer). For ozone sounding stations doing long term measurements of ozone this means that in case of a change of sensing solution type or ECC-sonde type this can easily introduce a change of ±5% or even larger in their long term ozone records. This can have a significant impact on the trends derived from such records. The observed features for both ECC-sonde types using different sensing solutions are very consistent throughout the entire troposphere and lower/middle stratosphere up to 35 km altitude. For the SPC-6A sonde, the best quantitative results are obtained if operated with 1% KI & full buffer (SST-1A). In contrast, the ENSCI sonde performs best with 0.5%KI & half buffer (SST-2B).
Overview of the comparison of two different ECC-sonde types (SPC-6A and ENSCI-Z) with an UV-photometer. Both ECC-sonde types were operated with three different sensing solutions. Presented are the averages (± one standard deviation) of the individual sonde readings of each ensemble of sondes.

All JOSIE activities showed clearly that the standardisation of the operation procedures (including preparation and data correcting methods) is of crucial importance. As a consequence, under the auspices of WMO/GAW, an Assessment of Operating Procedures for Ozone Sondes (ASOPOS) has been initiated with the intent of defining easy to follow operating procedures that can be consistently implemented and will provide data of high quality that are comparable between ozone sounding stations.

Based on the JOSIE-results provisional standard operating procedures (SOPs) for ECC-sondes were unanimously established at a WMO Meeting of Ozone Sonde Experts in Geneva at 1-3 May 2001. Further, it was decided that the preliminary SOPs recommended by JOSIE had to be tested through an intercomparison in the real atmosphere for quality assurance and suitability before the procedures are applied to sondes launched at GAW stations. Therefore in April 2004 the Balloon Experiment on Standards for Ozone Sondes (BESOS) field campaign at the University of Wyoming at Laramie, USA, was conducted to test the provisional SOP's for ECC-ozonesondes. In a next step ASOPOS will evaluate JOSIE- and BESOS-results in order finally to establish WMO-recommended SOP's, for the different major types of ozone sondes used in the GAW-ozone sounding network.
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1. INTRODUCTION

Up to an altitude of about 20 km, ozone sondes constitute the most important data source with long term data coverage for the derivation of ozone trends, particularly in the important altitude region around the tropopause [SPARC-IOC-GAW Assessment of Trends in the Vertical Distribution of Ozone, 1998, WMO-Scientific Assessment of Ozone Depletion 1998, 2002]. This region and also the lower/middle stratosphere above up to 30-35 km altitude, ozone sondes are of crucial importance to validate and evaluate satellite measurements, particularly for their long term stability. Ozone sondes are also used extensively in process dedicated studies such as in the SHADOZ (South Hemispheric ADDitional Ozonesondes)-project in the tropical region [Thompson et al., 2003] or in the polar regions [Rex et al., 1998] where sounding data made from several different stations are compared with each other.

Ozone sondes are small, lightweight and compact balloon borne instruments, developed for measuring the vertical distribution of atmospheric ozone up to an altitude of about 30-35 km [e.g. Smit, 2002]. The sensing device is interfaced to a standard meteorological radiosonde for data transmission to the ground station and can be flown on a small rubber weather balloon (Figure 1).

Each ozone sounding is made with a new instrument, which has therefore to be characterized well prior to flight. To achieve consistent data sets, quality assurance of ozone sonde performance is a pre-requisite. As part of the quality assurance (QA) plan for ozone sondes that are in routine use in the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO), the environmental simulation facility at the Research Centre Juelich (Germany) was established as World Calibration Centre for Ozone Sondes (WCCOS). The simulation chamber of the facility enables control of pressure, temperature and ozone concentration and can simulate flight conditions of ozone soundings up to an altitude of 35 km, whereby an accurate UV-photometer serves as a reference [Smit et al., 2000, http://www.fz-juelich.de/icg/icg-ii/esf]

Figure 1: Ozone sounding at launch.
The longterm objective of WCCOS is the establishment and maintenance of a facility for quality assurance (QA) of ozonesondes operated in the WMO/GAW-Programme with three major tasks:

1. **QA-Manufacturers**: Quality check of the instrumental performance of sondes from different manufacturers
2. **QA-Operation**: Test of individual sonde profiling capabilities of different sounding laboratories
3. **QA-Procedures**: Establishment and up-date of Standard Operating Procedures (SOPs) of different sonde types

In the scope of this QA-plan for ozone sondes several Juelich Ozone Sonde Intercomparison Experiment (JOSIE) activities [http://www.fz-juelich.de/icg/icg-ii/josie] since 1996 have been conducted at the calibration facility to assess the performance of ozone sondes of different types and manufacturers [Smit and Kley, 1998, Smit and Straeter, 2003, 2004]. JOSIE 1996 [Smit et al., 1998] was a WMO international intercomparison campaign, attended by eight ozone sounding laboratories from seven countries representing the major types of ozone sondes. These include the Electrochemical Concentration Cell (ECC) made by two manufacturers, as well as Brewer/Mast (BM-original), Indian (modified BM-type) and Japanese (KC79). JOSIE campaigns yielded important information about the performance of the different ozone sonde types and the influence of the operating procedures for preparation and data correction applied by the participating laboratories. JOSIE showed also that there is a need to validate ozone sondes on a routine basis. Ozone sondes have gone through several modifications since they were first manufactured, which adds uncertainty to trend analysis. Routine testing of newly manufactured ozone sondes on a regular basis and establishing standard operating procedures for different sonde types will help to ensure more confidence in observed trends in the future.

More than 80 percent of the GAW ozone sounding network use ECC sondes (Figure 2) developed by Komhyr [1969]. In an electrochemical cell the reaction of ozone with potassium iodide in aqueous solution is used to measure the ozone concentration continuously. A small electrically-driven gas-sampling pump forces ambient air through a cell containing the sensing solution such that an electrical current is generated which is proportional to the amount of ozone forced through the cell. By knowing the gas flow rate, its temperature and pressure, the measured electrical current can be converted to ozone concentration. The ECC-sensor consists of two cells, made of Teflon, which serve as cathode and anode chamber, respectively. Both cells contain a platinum mesh, serving as electrodes. They are immersed in a KI-solution of known concentration. The two chambers are linked together by an ion bridge in order to provide an electron-pathway and to prevent mixing of the cathode and anode electrolytes.

At present the ECC-ozone sondes: are manufactured by Science Pump Corporation (Model type: SPC-6A) or Environmental Science Corporation (Model type: ENSCI-Z). JOSIE-1998 focused primarily on the quality checking of the instrumental performance of ECC-sondes from these two manufacturers (QA-manufacturer task). A sample of 26 randomly selected ECC-sondes (13 SPC-6A and 13 ENSCI-Z), which were provided by the different ECC-sonde users in the GAW ozone sounding network, were tested in the environmental simulation chamber at mid-latitude conditions between surface and 35 km altitude. An important result of JOSIE 1998 is that the performance characteristics of the two ECC-sonde types are in agreement up to an altitude of 20 km but differ significantly in the middle stratosphere above 25 km. The origin of the observed differences is not really understood.
JOSIE-1996 and 1998 clearly demonstrated that with regard to the sonde performance and hence the interpretation of ozone trends caution has to be exercised in making instrumental changes or in preparing/operating procedures. However, during the last decade several changes of operating procedures for ozone sondes were introduced such that at present, a variety of preparatory and corrective methods are applied by the different sounding stations. This introduces station to station ozone variability, which may have a dramatic impact on the derivation of long term ozone trends. It is obvious, that there is a strong need for the homogenization of the operating procedures for pre-launch preparation and post-flight data processing. Therefore, under the auspices of WMO/GAW an assessment of operating procedures for ozone sondes (ASOPOS) was initiated in 2000 to define easy-to-follow operating procedures, that can be consistently implemented and thus provide high quality data, that are comparable between ozone sounding stations.

While JOSIE-1998 was exclusively focused on the QA-Manufacturers task, JOSIE-2000 was dedicated to support the assessment of standard operating procedures (SOPs) for the different ozone sonde types operational in the GAW-network. JOSIE-2000 is a WMO international ozone sonde intercomparison campaign involving 7 ozone sounding laboratories using ECC sondes and one laboratory deploying the Japanese KC96 (Table 1). The participating laboratories were split into two groups of four teams. Both groups attended the campaign for a 10 day period: 4-13 September 2000 (Campaign C-I) and 18-27 September 2000 (Campaign C-II). The ECC-ozone sonde operating laboratories had brought together a pool of ECC sondes from two different manufacturers (Type SPC-6A of Science Pump Corporation and Type ENSCI-1/2Z of Environmental Science Corporation) which will be operated according different procedures of preparation and data reduction.
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Participating Group Code</th>
<th>Participating Sounding Laboratory</th>
<th>JOSIE Campaign Period</th>
<th>Participating Persons</th>
<th>Ozone Sonde Type</th>
<th>SST Nr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>JS_PG1 (CMDL)</td>
<td>NOAA/CMDL (Boulder, CO, USA)</td>
<td>C-I</td>
<td>Bryan Johnson (PI), Sam Oltmans</td>
<td>ECC ENSCI-Z &amp; SPC-6A</td>
<td>3A</td>
</tr>
<tr>
<td>2</td>
<td>JS_PG2 (AES)</td>
<td>AES (Ontario, Canada)</td>
<td>C-I</td>
<td>Jonathan Davies (PI),</td>
<td>ECC SPC-6A</td>
<td>3A</td>
</tr>
<tr>
<td>3</td>
<td>JS_PG3 (NIWA)</td>
<td>NIWA (Lauder, New Zealand)</td>
<td>C-I</td>
<td>Greg Bodeker (PI), Ian Boyd, Alan Thomas</td>
<td>ECC ENSCI-Z</td>
<td>2B</td>
</tr>
<tr>
<td>4</td>
<td>JS_PG4 (FZJ)</td>
<td>FZJ/ICG2 (Jülich, Germany)</td>
<td>C-I</td>
<td>Manfred Helten (PI), Marcel Berg</td>
<td>ECC SPC-6A</td>
<td>2B</td>
</tr>
<tr>
<td>5</td>
<td>JS_PG5 (WFF)</td>
<td>NASA/WFF (Wallops Island, Virginia, USA)</td>
<td>C-II</td>
<td>Frank Schmidlin (PI), E. David Ross, E Thomas Northam</td>
<td>ECC SPC-6A</td>
<td>1A</td>
</tr>
<tr>
<td>6</td>
<td>JS_PG6 (SAP)</td>
<td>MS/SAP (Payerne, Switzerland)</td>
<td>C-II</td>
<td>Bruno Hoegger (PI), Rene Stubi, Gilbert Levrat</td>
<td>ECC ENSCI-Z</td>
<td>1A</td>
</tr>
<tr>
<td>7</td>
<td>JS_PG7 (URI)</td>
<td>URI (Reunion Island, France)</td>
<td>C-II</td>
<td>Francoise Posny (PI), Jean-Marc Metzger</td>
<td>ECC ENSCI-Z</td>
<td>2B/3A</td>
</tr>
<tr>
<td>8</td>
<td>JS_PG8 (JMA)</td>
<td>JMA (Tokyo, Japan)</td>
<td>C-II</td>
<td>Toshifumi Fujimoto (PI), Takahiro Sato</td>
<td>KC96</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 1:** List of ozone sounding laboratories participating in JOSIE-2000 campaign and associated sonde types and sensing solution types used (SST= Sensing Solution Type), PI=Principal Investigator, Campaign C-I: 4-13 Sept. 2000 and Campaign C-II: 18-27 Sept. 2000.

Within each campaign, a total of seven simulation experiments of vertical ozone soundings have been performed in the simulation chamber. Different types of vertical profiles of ozone were simulated up to an altitude of about 35 km. JOSIE-2000 was designed to evaluate the sensitivity, precision and accuracy of each sonde type at different pressure, altitude and ozone level. Special attention was paid to the influence of instrumental factors such as background signal, pumpflow efficiency, sensing solutions and their uncertainties on the data quality of ozone soundings. Important aspect is to test recent instrumental/procedural developments of the ECC and KC96 (former KC79) sonde types since JOSIE 1996. A crucial issue for ECC-sondes is that from laboratory investigations [Johnson et al., 1998, 2002], it appears that a change of the chemical composition of sensing solution will prevent the increase of sensitivity of the ECC-sensor caused by evaporation during flight which might be an improvement. However, this change of operating procedure should not be undertaken until the full implications of such a change is evaluated and its impact on the interpretation of ozone trends is well understood. This is a key issue for the ECC-sondes that has been addressed in the JOSIE-2000 campaign.
2. ENVIRONMENTAL SIMULATION FACILITY FOR OZONE SOUNDINGS

As part of the World Calibration Centre for Ozone Sondes (WCCOS) the environmental simulation facility (Figure 3) for ozone soundings at Jülich is for testing, calibrating and comparing different types of balloon borne ozone sondes which are used world wide for measuring the vertical distribution of ozone in the troposphere and lower/middle stratosphere.

Figure 3: Environmental Simulation Facility for Ozone Soundings

The facility is described in detail by Smit et al., [2000] and at http://www.fz-juelich.de/icg/icg-ii/esf/. The experimental set up of the simulation facility shown in Figure 4 consists of the following major components:

1. Temperature controlled vacuum chamber as environmental simulation chamber.
2. Fast response dual-beam UV-photometer (OPM) as ozone reference [Proffitt et al., 1983]. The instrument had been flown several times during BOIC missions in 1983/1984 [Hilsenrath et al., 1986]. The OPM is installed in a separate vacuum vessel which is connected to the simulation chamber such that the instrument has the same pressure conditions as the test room.
3. Ozone profile simulator (OPS), a gas flowing system to provide simultaneously four ozone sondes plus UV-photometer with ozone concentrations according simulated vertical ozone profiles. The OPS can simulate vertical profiles with ozone pressures varying between 0.1 and 35 mPa corresponding to altitudes from the Earth’s surface to 35 km. In addition, different types of ozone step functions can be applied in order to investigate the response time and background characteristics of the ozone sondes.
4. Computer controlled data acquisition system (DAS) for automatic control of the simulation process, on-line integration of sonde data, and post-flight data processing.

**Figure 4:** Set up for the simulation of vertical ozone soundings.

Four ozone sondes can be "flown" simultaneously and compared to the UV-photometer, whereby different types of vertical profiles of pressure, temperature and ozone concentrations versus time according vertical soundings with ascent velocities of about 5 m/s can be simulated. The simulation process as well as the post-flight data processing are completely computer controlled. The ECC-sondes are coupled with the data acquisition system via a special electronic interface (JOSIE/ECC-interface). The interface measures cathode cell current, pump temperature, pump motor current and supplies a voltage of 12V for the pump motor. Optionally, there is a small variable electrical heater (0-10W) to adjust temperatures inside the styrofoam box of the sonde to values similar to temperatures usually obtained at the sounding sites. This ozone sounding simulation facility enables us to investigate the performance of different types of ozonesondes under quasi flight conditions. The technical specifications of the facility are summarized in Table 2.
Test room volume is 500 litre (80x80x80 cm) capable of testing 4 sondes simultaneously.

Computer controlled simulation of "real" atmospheric conditions:

a.) **Pressure:** 10-1000 hPa

b.) **Temperature:** 200-300 K
   - dynamic: Rate = ± 2 K/min
   - static: Fluctuations < 0.1-0.2 K

c.) **Ozone:** 5-10000 ppbv (0.1-30 mPa)

Ozone Reference:

Dual Beam UV-photometer:
- response: 1 s
- precision: ±0.025mPa
- accuracy: ± 2 % (0-25 km), ±3.5% (30-35km)

**Table 2:** Specifications of environmental simulation facility (ESF) of World Calibration Centre of Ozone Sondes (WCCOS).

3. **EXPERIMENTAL DESIGN OF JOSIE 2000**

3.1 **Sensing Solution Type (SST)**

With regard to the development of SOP’s for ECC-sondes, one of the key issues to be addressed by JOSIE-2000 is the sensitivity of the two ECC-sonde types (SPC-6A and ENSCI-Z) to different sensing solutions. Three different sensing solution types (SST) were investigated during JOSIE 2000, which are listed in Table 3. The first sensing solution type, SST 1A, is the conventional type based on the guidelines described by Komhyr [1986] and is most widely used for the ozone sonde types (SPC-4A, -5A, and -6A) manufactured by Science Pump Corporation, USA. After the introduction of the ENSCI-Z, a new type of ECC ozone sonde manufactured by Environmental Science Corporation, the manufacturer recommended in 1997 to use the SST 2A for the ENSCI-Z sonde type. Based on laboratory and field investigations, [Johnson et al., 1996, 2002] recommended the use of a non-buffered, no KBr, but with 2.0% KI containing cathode solution. This was in order to avoid any increase of the stoichoimetry of the sensing reaction of ozone with KI, which appeared to be caused by the buffer due to evaporation of the sensing solution during ascent. SST 2A is beyond the scope of JOSIE 2000, because simulation experiments prior to JOSIE 2000 indicated that the ECC-response with SST-2A is rather similar to SST-1A. Laboratory experiments made by Johnson [private communications] indicated that the different sonde performance characteristics are probably caused by the addition of the buffer solution and its concentration.
### Table 3: Different Sensing Solution Types (SST) for ECC-ozone sondes. The SST 1A, 2B and -3A have been used during JOSIE 2000.

<table>
<thead>
<tr>
<th>SST</th>
<th>Description of Sensing Solution Type (SST)</th>
</tr>
</thead>
</table>
| 1A  | Conventional solution type according guidelines by Komhyr, 1986  
Cathode: 1% KI + Full buffer & full KBr, as described by Komhyr, 1986  
Anode: Cathode solution with saturated KI |
| 2A  | Solution type beyond the scope of JOSIE  
Cathode: 0.5% KI + full buffer & full KBr, as described by Komhyr, 1986  
Anode: Cathode solution with saturated KI |
| 2B  | New solution type introduced by Komhyr, 1997 for ENSCI-ozone sonde type  
Cathode: 0.5% KI + half of the amounts of buffer & KBr as described by Komhyr, 1986  
Anode: Cathode solution with saturated KI |
| 3A  | New solution type introduced by Johnson et al, 1998, 2002:  
Cathode: 2.0% KI + No buffer & No KBr  
Anode: Cathode solution with saturated KI (No buffer & No Kbr) |

3.2 Simulated Profiles of Pressure, Temperature and Ozone

The design of the JOSIE 2000 simulation experiments was strongly influenced by investigations of the performance of ozone sondes under quasi flight conditions conducted during JOSIE-1996 [Smit and Kley, 1998] and JOSIE 1998 [Smit and Straeter, 2004]. For example, during JOSIE-1996 two types of profiles were simulated (Figure 5). The first type of profile was a typical mid-latitude profile taken from the US Standard Atmosphere (1976) for 40-50 °N with a tropopause height of 12 km. The second type of profile related to typical tropical conditions of a high tropopause at 18 km, a low tropopause temperature and extremely low ozone values in the middle and upper troposphere due to high convective activity [Kley et al, 1996]. Because of these extreme tropospheric conditions, particularly the extremely low ozone pressures of about 0.1 mPa, makes the second type of profiles very suitable to investigate and to compare the performance of the different ozone sondes with regard to the influence of any “background”. In JOSIE 2000, in addition to the mid-latitude and tropical type of profile, a third type of profile related to typical subtropical conditions were simulated.
Figure 5: Vertical profiles of the simulation of ozone pressure and temperature at mid latitude and tropical conditions.

For each profile type, two simulation experiments of vertical ozone soundings were performed during JOSIE 2000. During the simulation runs two response tests (ozone set to zero for a short period of 3 to 4 minutes) were included in order to investigate instrumental aspects like response time and background characteristics of the different ozone sondes, once in the troposphere and once in the stratosphere. The pressure and temperature were changed according to ascent velocities of 5 m/s up to a burst altitude corresponding to 35 km.

3.3 Strategy of JOSIE-2000

The major objective of JOSIE-2000 was to focus on the instrumental performance of the ECC and the Japanese KC96-ozone sonde types. While addressing specific questions in support of the Assessment for SOP’s of Ozone Sondes (ASOPOS), a WMO-initiative that started in the course of 2000. The JOSIE operating principles were as follows:

1. Under the Global Atmosphere Watch programme of the World Meteorological Organization, JOSIE-2000 has the goal of providing ozone profile simulations useful in determining standard operating procedures (SOPs) for ozone sondes.

2. The JOSIE steering committee will make recommendations that result from the JOSIE-2000 intercomparisons, and the WMO will arbitrate on issues only if requested by the steering committee.

3. Each participating team of JOSIE-2000 must represent an ozone sounding station that routinely deploys one of the major types of ozone sondes used within the global network of GAW.
4. Each participating team is responsible for its own profiling capabilities including sonde preparation procedures and data reduction algorithms. These algorithms will be provided to FZ-Jülich and WMO prior to commencement of the campaign.

5. All pre-launch procedures for each ozone sonde must be performed by the responsible field operator using ground-check equipment provided by his station.

6. The simulated profile data will be directly integrated and stored in the data acquisition system (DAS) of the simulation facility. This will result in Raw Sounding Simulation (RSS) data for each sonde profile.

7. After each simulation run, the ozone data will be processed centrally by following the data analysis algorithms provided to FZ-Jülich prior to the campaign. The resulting data will constitute the Normal Corrected Sounding (NCS) data for each sonde profile.

8. The NCS-data set is the primary standard of JOSIE-2000 which is fixed and will not be subject to any modification. Revisions to the NCS data can be reported in addition to the NCS-data if identified as revised, why the revisions were made, and how the revisions were made.

9. The set of NCS-data will be considered representative of chamber simulations of these ozone sondes under normal operating procedures and compared with the simultaneously measured data from the ozone reference photometer.

10. The set of uncorrected RSS-data in combination with the reduced NCS-data will be used to evaluate the effects of the data analysis procedures (e.g. background signal correction and total ozone column normalization) on final reduced data.

11. The intercomparison will be blind. This means that during the campaign, participating teams will not have access to the RSS and NCS-data of other teams. The reference data will also not be available before completion the end of the campaign.

12. After the campaign, each Principle Investigator of JOSIE-2000 will have access to the entire database. The database will be exclusively used by the participants of JOSIE-2000 and by the steering committee for SOP evaluation, unless otherwise approved by the concerned participants and the steering committee.

13. During the campaign, a preliminary evaluation of the simulation results may be made to assure nominal operation of the sondes has been achieved.

14. Workshop sessions are planned to discuss and develop SOPs for the sonde types tested. JOSIE-2000 is organized under the auspice of the Environmental Division of the World Meteorological Organization (WMO).

This list of operating principles was part of the formal agreement of JOSIE 2000 (Annex D) that each participating laboratory had signed prior to the JOSIE 2000 campaign. In addition, each laboratory had signed the JOSIE 2000 data protocol (Annex E) describing the rights and obligations of data usage by the participants of JOSIE 2000.
4. EXPERIMENTAL DETAILS

4.1 Introduction

The ECC-ozone sonde operating laboratories have brought together a pool of ECC sondes from two different manufacturers (Type SPC-6A of Science Pump Corporation and Type ENSCI-Z of Environmental Science Corporation), which have been operated according to different procedures of preparation and data reduction. In Table 1, the specific type of ozone sonde and sensing solution used by each of the participating laboratories are listed. For each of the sensing solution types, respectively SST-1A, SST-2B, and SST-3A, a similar number of SPC-6A sondes and ENSCI-Z sondes have been tested. The pre-launch procedures of each ozone sonde prior to a simulation run were performed by the field operator of the participating sounding station using their own ground check equipment. During the simulation experiments, the measured data of each participating ozone sonde was integrated on-line in the data acquisition system of the facility. Each participating laboratory was responsible for his own ozone sonde profiling capabilities up to the JOSIE/ECC-interface connection to the data acquisition system of the facility (See Chapter 3).

4.2 Simulation Experiments

The participating laboratories were split into two groups of four teams (Table 1). Each group attended the campaign for a two week period, either from 4 to 13 September (Campaign C-I) or from 18 to 27 September 2000 (Campaign C-II). The different simulation experiments are specified in Table 4. For each campaign, C-I and C-II, a total of seven simulation experiments were conducted: (i) 2 runs using the mid-latitude profile, (ii) 2 runs using the sub-tropical profile, (iii) 2 runs using the tropical profile and (iv) one run using the step up/down profile. The subtropical profiles were modulated with a sinus wave to explore the response characteristics of the different sondes. Two times during each of the mid-latitude, sub-tropical and tropical simulation runs ozone was temporarily (3 to 5 minutes time period) set to zero level to investigate the response time and background characteristics of the different ozone sondes in the troposphere as well as in the stratosphere. The step up/down experiment consisted of a series of upwards and downwards steps of different ozone levels at discrete air pressures between 100 and 5 hPa. Corresponding air temperatures were associated with mid latitude pressure conditions.

4.3 Time Scale: System and Simulation Time

An independent and common time scale, the system time of the data acquisition system (DAS) was used for the processing of the JOSIE-2000 simulation data. Simultaneously to the system time, there was the simulation time which is set to zero at the start of the simulation experiment. The data were made equidistant in time (system time) with a time step of 2.5 seconds.

4.4 Pressure and Temperature Inside the Simulation Chamber

The pressure inside the test room of the simulation chamber has been measured with three capacitive manometers with ranges of 1 - 1000 hPa, 0-100 hPa, and 0.1-12.5 hPa whereby, the accuracy of each manometer is better than +/-0.5 % of their reading. After the JOSIE 2000 campaign, the three manometers were re-calibrated resulting in small pressure corrections compared to the pressure measured during the campaign. The final pressure inside the chamber was selected from the manometer with the most accurate range of measurement.
Table 4: Specifications of JOSIE-2000 simulation experiments. MT = Mid Troposphere; LS = Lower Stratosphere; v= ascent velocity; Z = altitude

<table>
<thead>
<tr>
<th>Sim. Exp. Nr.</th>
<th>Profile Type</th>
<th>Profile Type Index</th>
<th>Specifications</th>
<th>Step-Response (Down &amp; Up)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>Mid-Latitude</td>
<td>I-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Mid-Latitude</td>
<td>I-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>Tropical</td>
<td>II-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>Tropical</td>
<td>II-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Step Up/Down</td>
<td>IV-A</td>
<td>Different O₃-levels at discrete Pressures (1000 hPa-5 hPa)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>Sub-Tropical</td>
<td>III-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td>Sinus Wave Modulation</td>
</tr>
<tr>
<td>95</td>
<td>Sub-Tropical</td>
<td>III-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td>Sinus Wave Modulation</td>
</tr>
<tr>
<td>96</td>
<td>Mid-Latitude</td>
<td>I-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>Mid-Latitude</td>
<td>I-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>Tropical</td>
<td>II-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>Tropical</td>
<td>II-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Sub-Tropical</td>
<td>III-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td>Sinus Wave Modulation</td>
</tr>
<tr>
<td>101</td>
<td>Step Up/Down</td>
<td>IV-A</td>
<td>Different O₃-levels at discrete Pressures (1000 hPa-5 hPa)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Sub-Tropical</td>
<td>III-A</td>
<td>Ascent v=5m/s, Z=0-35 km</td>
<td>MT at Z=5km LS at Z=20km (O₃=0 for 3 min)</td>
<td>Sinus Wave Modulation</td>
</tr>
</tbody>
</table>

Depending on the air pressure spatial temperature variations of about 2-5 Kelvin inside the test room were expected. Therefore, two different air temperatures, measured inside the environmental simulation chamber, were recorded for each sonde: the temperature inside chamber measured with a Pt100 located at ozone manifold and the actual temperature measured by Pt-100 at the individual air intake of each sonde, just exterior the styrofoam box.
4.5 Simulated Altitude

The simulated altitude was calculated step by step as the cumulative sum of the height difference between two successive pressure levels (i and i+1) using the hydrostatic equation:

\[
\Delta Z = \frac{R}{g} \left( T_{i+1} + T_i \right) \frac{2}{L \ln \left( \frac{P_i}{P_{i+1}} \right)}, \text{ whereby}
\]

- \( R \) = gas constant,
- \( g \) = gravity constant,
- \( T \) = temperature,
- \( P \) = pressure

and indices \( i \) and \( i+1 \) are representing the two succeeding pressure levels.

It is to be noted that due to an oscillating pressure effect caused by the pressure controller of the simulator, the simulated altitude is not always monotonically increasing but slightly oscillating.

4.6 Pump Temperature: Internal and External

4.6.1 Introduction

The standard procedure adopted for measuring the pump temperature during JOSIE-2000 was to tape a UUA 41J1 (10.000 KΩ at 298.15 K) thermistor to the outside of the teflon block of the pump near to and at the same height as the tube outlet from the block (going to the cathode cell) - henceforth known as the ‘external pump temperature’ (Temp_PmpExt). However, both ECC-sonde manufacturers (Science Pump Corporation and En-Sci Corporation) provide their ECC-ozone sondes with a hole drilled into the teflon block to allow the thermistor to be positioned close to the piston - henceforth known as the ‘internal pump temperature’ (Temp_PmpInt), although the entry point for the thermistor is different for each manufacturer. For the ENSCI-Z sonde the entry point is above the pump motor directly behind the piston and extends for about 8mm into the teflon block. For the SPC-6A sonde the entry point is below the tube outlet and also extends for about 8mm into the teflon block. Slight differences could therefore exist in the final positioning of the thermistor within the block.

4.6.2 Extra Pump Temperature Measurement

Most of the JOSIE 2000 participants typically used the internal temperature position to monitor pump temperature when performing sounding. Thus during several simulation runs the external and internal pump temperature of some ENSCI-Z and SPC-6A sondes were recorded to observe the differences in temperature measured at the two different positions. The extra temperature measurement (either internal or external) was made with a second UUA 41J1 thermistor by recording the thermistor resistance with a DVM (Digital Volt Meter) outside the simulation chamber at regular intervals (every 5-10 minutes after the start of a simulation).

In the first campaign period, the internal pump temperature was additionally measured with a DVM for one SPC-6A sonde operated by CMDL (Sim.Nr.94) and three ENSCI-Z sondes operated by NIWA (Sim.Nr.94 &95). During the second campaign period, the internal pump temperature of WFF and SAP were directly monitored by the DAS while for WFF the external pump temperature and for SAP the external cathode cell temperature were extra measured with DVM’s. Table 5 summarizes for each simulation experiment and participating laboratory the configuration for the measurement or determination of the internal and external pump temperature.
### Table 5: Configuration for the measurement or determination of the internal and external pump temperature by (i) DAS (=Data Acquisition System) of the simulation chamber, or by (ii) DVM (Digital Volt Meter) or (iii) derived from the empirical characteristics of the differences between internal and external pump temperature as a function of air pressure according $\Delta T_p$-CMDL for SPC-6A by CMDL, or $\Delta T_p$-WFF for SPC-6A by WFF, and $\Delta T_p$-NIWA for ENSCI-Z by NIWA (see text and figure 4)

<table>
<thead>
<tr>
<th>Sim. Exp. Nr.</th>
<th>PG Nr.1: CMDL</th>
<th>PG Nr.2: AES</th>
<th>PG Nr.3: NIWA</th>
<th>PG Nr.4: FZJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>$\Delta T_p$-CMDL</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>90</td>
<td>$\Delta T_p$-NIWA</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>91</td>
<td>$\Delta T_p$-CMDL</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>92</td>
<td>$\Delta T_p$-NIWA</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>93</td>
<td>$\Delta T_p$-NIWA</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>94</td>
<td>$\Delta T_p$-NIWA</td>
<td>DAS</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
<tr>
<td>95</td>
<td>DVM (2)</td>
<td>DAS(2)</td>
<td>$\Delta T_p$-WFF</td>
<td>DAS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sim. Exp. Nr.</th>
<th>PG Nr.5: WFF</th>
<th>PG Nr.6: SAP</th>
<th>PG Nr.7: URI</th>
<th>PG Nr.8: JMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>DVM</td>
<td>DAS</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
<tr>
<td>97</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
<tr>
<td>98</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
<tr>
<td>99</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
<tr>
<td>100</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
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<td>101</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
<tr>
<td>102</td>
<td>DAS</td>
<td>DVM</td>
<td>DAS</td>
<td>$\Delta T_p$-NIWA</td>
</tr>
</tbody>
</table>

Notes: (1) FZJ not participating but instead CMDL with SPC-6A sonde  
(2) CMDL not participating but instead NIWA with ENSCI-Z sonde

The results of the combined internal and external pump temperature measurements are summarized in the three diagrams of Figure 6 displaying the results of respectively: (A) SPC-6A sonde operated by CMDL during Sim.Nr.94, (B) average over 3 three ENSCI-Z sondes operated by NIWA during Sim.Nr.94 &95, and (C) average over 5 SPC-6A sondes operated by WFF during Sim.Nr. 97, 98, 99, 100, and 102.

The profiles of the differences of internal minus external pump temperature for all of the experiments are rather similar. In all cases, the internal pump temperatures are higher than the
external pump temperatures. At the start of the simulations the differences were between about 0.5 and 2 Kelvin, progressively increasing to about 7 to 10 Kelvin by about 65 minutes into the simulation (≈50 hPa pressure, i.e. 20 km altitude). The temperature differences then remaining relatively constant with a slight decreasing to the end of the simulation. The observed differences would result in retrieved ozone differences of between 2 and 3% for much of the profile.

Figure 6: Internal (red curve) and external (blue curve) pump temperature and their differences (green curve) as a function of simulated air pressure as measured for: (i) SPC-6A sonde operated by CMDL during Sim.Nr.94 (Diagram A), (ii) three ENSCI-Z sondes operated by NIWA during Sim.Nr.94 &95 (Diagram B), and (iii) five SPC-6A sondes operated by WFF during Sim.Nr. 97,98,99,100, &102 (Diagram C). Horizontal bars (green) are ± one standard deviation of the corresponding averages of the differences of the internal and external pump temperature.

4.6.3 Determination Internal Pump Temperature

The incidentally measured internal and external pump temperature profiles obtained as a function of pressure were used to derive empirical characteristics of the differences between both temperatures as a function of pressure (Figure 4). This finally yields two characteristics for the SPC-6A sonde, ∆Tp-CMDL (over one CMDL-sounding in Sim.Nr.94) and ∆Tp-WFF (averaged over 5 WFF-soundings in Sim.Nr.97, 98, 99, 100, &102), and one characteristic for the ENSCI-Z sonde, ∆Tp-NIWA (over 3 NIWA-soundings in Sim.Nr.94,&95). These characteristics were used to derive the internal or external pump temperature in case both temperatures were not measured during the simulation runs. Thus, it is assumed that the characteristics of the differences between internal and external pump temperatures is mainly a function of pressure.

The deviations in the pump temperature characteristics of the SPC-6A sonde operated by CMDL compared with the SPC-6A sonde operated by WFF are probably due to the moderating effect of the small metal can filled with about 100 ml of water that CMDL is using as extra heat capacity in order to avoid freezing of the sensing solutions. Therefore, the ∆Tp-CMDL characteristic is assumed to be only representative for the SPC-6A-sondes operated by CMDL. For all other SPC-6A sondes, the ∆Tp-WFF characteristics were applied to derive the missing extra pump temperature.

It is to be noted that the estimates of missing internal pump temperatures are preliminary. More work is required to establish correct procedures for measuring pump temperature, as well as determining differences in measured internal and external pump temperatures depending on the position of the thermistor inside or outside the pump. By using the thermistor positions provided by the manufacturers, it is most likely that consistent results are obtained. This may not be the case when a thermistor is either glued or taped to the teflon block or within the ozonesonde.
compartment where the same location may not be chosen every time. However, more experimental evidence is required to determine which temperature is most representative of the actual temperature inside the pump-piston volume to be used in equation E2. In the past, instead of pump temperature the concept of box temperature was applied [Komhyr, 1986].

4.7 Prevention of Freezing of Cathode Sensing Solution

One of the “flown” sondes showed at high altitudes (above 25 km) the problem of freezing of the sensing solution in the cathode cell. This premature freezing of the solution is probably due to the fact that during JOSIE 2000 the temperatures in the flightbox are about 5 to 10°C lower than during field operation. This seems to be caused by missing solar radiation (i.e. heating of the sonde box) in the simulation chamber. Therefore, precautions have been taken to prevent the freezing problem by adding either a small electrical resistance heater (1-2 W) or a small water bag as a heat capacity in the compartment of the styrofoam flight box of the sonde.

5. DATA PROCESSING

5.1 Basic Operating Formulas

Basically all sondes have in common that in principle each molecule of ozone forced through the sensing solution in the electrochemical cell generates an electrical current of approximately two electron in the external circuit. In other words, the electrical current generated in the electrochemical cell is directly related to the uptake rate of ozone in the sensing solution and is determined by the relation:

\[ E-2 \quad P_{O3,Sonde} = C_{Sonde} \cdot I_{O3,Sonde} \]

By knowing the gas volume rate and its temperature the conversion coefficient \( C_{Sonde} \) is determined by:

\[ E-3 \quad C_{Sonde} = 0.04307 \cdot \eta_{Sonde} \cdot \frac{T_{Pump}}{\Phi_{V,Pump}} \]

\( P_{O3,Sonde} \) = pressure of ozone, [mPa]
\( T_{Pump} \) = temperature of air sampling pump, [K]
\( \Phi_{V,Pump} \) = Volumetric flow rate of air sampling pump, [ml/s]
\( I_{O3,Sonde} \) = Electrical current due to sampled ozone, [\( \mu \)A]
\( \eta_{Sonde} \) = Conversion efficiency of the ozone sensor

The conversion efficiency \( \eta_{Sonde} \) is the overall result of the influences of several different parameters, such as absorption efficiency of \( O_3 \) into the sensing solution, stoichioemtry of the conversion of \( O_3 \) into \( I_2 \) etc. In practice the conversion efficiency is assumed to be 1.00.

The overall electrical current, \( I_{M,Sonde} \), measured by the sonde may be a superposition of the ozone current, \( I_{O3,Sonde} \) and the background current, \( I_{B,Sonde} \):

\[ E-4 \quad I_{O3,Sonde} = I_{M,Sonde} - I_{B,Sonde} \]

\( I_{M,Sonde} \) = Overall electrical current measured by ozone sensor due to ozone
\( I_{O3,Sonde} \) = Electrical current measured by ozone sensor due to ozone
\( I_{B,Sonde} \) = Electrical current measured by ozone sensor due to background

The equations E-2, E-3 and E-4 are the basic operating formulas for the data processing of the electrochemical ozone sensor.
5.2 Corrections of Simulation Data

Despite the basic operating formulas given in equations E-2, E-3, and E-4, there are significant differences in data reduction and correction methods applied by the different sounding teams with regard to temperature of gas sampling, degrading pump efficiency at lower pressure, background correction and total ozone normalization.

5.2.1 K86-Data: Corrections According Komhyr 1986

All raw ECC-sonde data were processed and corrected according the operating procedures specified by Komhyr [1986], summarized in Table 6 and indicated as K86-ozone data.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Background Correction</th>
<th>Temperature Pump</th>
<th>Pumpflow Corrections</th>
</tr>
</thead>
</table>
| [1] NOAA/CMDL       | After Exposure to Ozone | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}
|                     | Not Pressure Dependent |                  | Moisture Correction by Participant
|                     |                       |                  | Individual Pump Efficiency (P_{Air}).                      |
| [2] AES             | After Exposure to Ozone | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Pressure Dependent    |                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
| [3] NIWA            | At Launch (Zero O3)   | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): STOIC 1989 (2.5 cm3)           |
| [4] FZJ/ICG-2       | After Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=0.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
|                     | Not Pressure Dependent|                  | Moisture Correction by Participant
|                     |                       |                  | Individual Pump Efficiency (P_{Air})                      |
| [6] SAP             | After Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=0.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): STOIC 1989 (2.5 cm3)           |
| [7] URI             | Before Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Pressure Dependent    |                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
| [8] JMA             | -                     | -                | -                                                         |

Table 6: K86 data corrections used for the processing of the raw ECC-ozone sonde data according Komhyr, 1986.

5.2.2 PSC-Data: Participant Specific Corrections

The raw ECC sonde data of each participating sounding laboratory were processed according to the operating procedures specific for the station, which were submitted by the different laboratories prior to the JOSIE-2000 campaign in September 2001 (Table 7).

<table>
<thead>
<tr>
<th>Participant</th>
<th>Background Correction</th>
<th>Temperature Pump</th>
<th>Pumpflow Corrections</th>
</tr>
</thead>
</table>
| [1] NOAA/CMDL       | After Exposure to Ozone | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Not Pressure Dependent |                  | Moisture Correction by Participant
|                     |                       |                  | Individual Pump Efficiency (P_{Air}).
| [2] AES             | After Exposure to Ozone | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Pressure Dependent    |                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
| [3] NIWA            | At Launch (Zero O3)   | Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): STOIC 1989 (2.5 cm3)           |
| [4] FZJ/ICG-2       | After Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=0.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
|                     | Not Pressure Dependent|                  | Moisture Correction by Participant
|                     |                       |                  | Individual Pump Efficiency (P_{Air})                      |
| [6] SAP             | After Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=0.
|                     | Not Pressure Dependent|                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): STOIC 1989 (2.5 cm3)           |
| [7] URI             | Before Exposure to Ozone| Internal         | GC: Pump inlet air: RH_{Air}=RH_{Lab}.
|                     | Pressure Dependent    |                  | Moisture Correction by WCCOS
|                     |                       |                  | Pump Efficiency (P_{Air}): Komhyr 1986 (2.5 cm3)          |
| [8] JMA             | -                     | -                | -                                                         |

Table 7: PSC data corrections used for the processing of the raw ECC-ozone sonde data according to the operating procedures specific for the station, which were submitted by the different laboratories prior to the JOSIE-2000 campaign in September 2001. GC= Ground Check; RH = Relative Humidity.
5.2.3 Correction of Pump Flow Rate for “Moistening Effect”

The pump flow rate of the sonde is measured with a bubble flow meter at the gas outlet of the sensing cell. Before the sampling air is forced through the sensing solution and entering the bubble flow meter, it is generally “dry” (RH=0%) or “non-saturated”: (RH<100%). Due to evaporation of water in the sensing solution or in the bubble flow meter, the measured flow rate is larger than the actual sampled flow rate forced by the pump. Therefore, the measured flow rate has to be corrected for this “moistening effect” to yield the actual pump flow rate according to the following formulas:

\[
\Phi_{\text{Pump, Actual}} = \Phi_{\text{Meas}} \times \left[ \frac{P_{\text{Lab}} - \Delta P_{H_2O}}{P_{\text{Lab}}} \right]
\]

\[
\Delta P_{H_2O}(T_{\text{Lab}}) = \left[ 1 - \frac{\text{RH}_{\text{Air}}}{100} \right] \times P_{\text{H}_2\text{O, Sat}}(T_{\text{Lab}})
\]

\[
\Phi_{\text{Pump, Actual}} = \Phi_{\text{Meas}} \times \left[ 1 - \left( 1 - \frac{\text{RH}_{\text{Air}}}{100} \right) \times \frac{P_{\text{H}_2\text{O, Sat}}(T_{\text{Lab}})}{P_{\text{Lab}}} \right]
\]

Whereby:

- \( \Phi_{\text{Meas}} \) = Pump flow rate measured with bubble flow meter.
- \( \Phi_{\text{Pump, Actual}} \) = Actual pump flow rate after correction for “moistening effect”.
- \( P_{\text{Lab}} \) = Pressure laboratory
- \( T_{\text{Lab}} \) = Temperature laboratory
- \( \Delta P_{H_2O}(T_{\text{Lab}}) \) = Water vapour contribution due to evaporation in the sampling air at \( T_{\text{Lab}} \).
- \( \text{RH}_{\text{Air}} \) = Relative Humidity of the sampled air at the intake of the pump [%]
- \( P_{\text{H}_2\text{O, Sat}}(T_{\text{Lab}}) \) = Saturated water vapour pressure at \( T_{\text{Lab}} \).

CMDL, AES, NIWA, and URI supplied “filtered” laboratory air to the sonde. Laboratory tests made during the campaign showed that the supplied air contains the same humidity as the ambient air in the laboratory. This means that in these cases \( \text{RH}_{\text{Air}} = \text{RH}_{\text{Lab}} \). The other participants (FZJ, WFF, ASP, and JMA) used dry air (\( \text{RH}_{\text{Air}}=0\% \)). During the preparations of the sonde, the ambient laboratory conditions of pressure, temperature, and relative humidity have been recorded such that the actual pump flow rate has been corrected for any contribution of moistening according to equation \([\text{E7}]\).

5.2.4 Pump Flow Corrections at Low Pressures

The volumetric flow of the gas sampling pump of each sonde was individually measured before flight as part of the pre-flight preparation procedure. At ambient air pressures below about 100 hPa the efficiency of the gas sampling pump degrades, which is corrected for by applying a pump efficiency correction table as function of ambient pressure specific for each sonde type. Most of the correction tables are based on averages obtained from rather old pump flow efficiency measurements made in the past (Table 8). The exceptions were the pump flow corrections applied by NOAA/CMDL and NASA/WFF which were obtained from individual pump flow calibrations made in their laboratory prior to the JOSIE-2000 campaign (Table 9). Science Pump Corporation (SPC-6A sonde) recommend the Komhyr [1986] correction table while ENSCI recommend for the ENSCI-Z sonde the Komhyr, [1995] (STOIC-1989) correction table. Figure 7 displays a graphical overview of the different pumpflow corrections as a function of pressure as given in Tables 8 and 9.
### Table 8: Pumpflow corrections at low pressures according to different investigators: Komhyr, (1986), Komhyr et al. (1995), ENSCI-Z Handbook (Komhyr, 1997), and Torres et al. (1981).

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### Figure 7: Pump flow correction factors as a function of pressure used in JOSIE 2000. Diagram A: Factors reported by Torres (1981), Komhyr (1986), Komhyr et al.(1995), and Komhyr; (1997), Diagram B and C: Factors from individual pump flow calibrations of each „flown“ sonde made by CMDL (PG-Nr.1) and WFF (PG-Nr.5) respectively.
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Table 9: Individual pump flow corrections applied by NOAA/CMDL (upper part of table) and NASA/WFF (lower part of table) which were based on individual pump flow calibrations made in their laboratory prior to the JOSIE-2000 campaign.
5.2.5 **Background Correction**

When no ozone is present, the background signal of each ozone sonde was individually determined in the laboratory as part of the sonde preparation just prior to the simulation flight. The background of the ECC ozone sensors is not well understood. Laboratory experiments have shown that the background signal can depend on exposure to ozone. During the pre-flight laboratory check the background signals before and after exposure to ozone were measured and additionally, the background was measured in the simulation chamber just before the start of a simulation run. The background is treated as an offset of the measured signal (see also equation E-4). The pressure dependent background correction applied by AES (PG-Nr.2) and JMA (PG-Nr.8) assumes an oxygen dependence such that this offset gradually declines with decreasing pressure and is negligibly small in the upper troposphere and stratosphere [Komhyr, 1986]. All other laboratories have used the non-pressure dependent correction, (i.e. full subtraction of the background current throughout the entire profile). The different methods of background correction applied by the individual participants are listed in Table 7.

5.2.6 **Total Ozone Column and Total Ozone Normalization**

The integrated column of ozone measured by the UV-photometer during the simulation of the ascent of a sounding experiment serves as a reference for the total ozone normalization. The total ozone normalization factor is defined as the ratio of the integrated columns of ozone obtained from the UV-photometer and the sonde respectively. The total ozone normalization factor of a sounding can serve as a criterion to evaluate the quality of the ozone profile measured by the sonde.

For each individual sonde, the integrated column of ozone by the UV-photometer was determined using the air temperature measured at the air intake of the sonde. Parts of erratic or missing data in the vertical profile measured by the sonde and/or the UV-photometer were discarded for the ozone column integrations. No residuals of ozone above the maximum simulation altitude were calculated.

For all ECC-sonde data, no total ozone normalization was applied. Whilst, the KC96-sonde data of JMA are normalized by multiplying the measured sonde data with the corresponding total ozone normalization factor.

For the simulation experiments nr. 93 and 101, both ozone step-up and step-down simulation experiments, no total ozone columns and no corresponding normalization factors have been calculated.

6. **RESULTS AND DISCUSSION**

6.1 **Individual Simulation Runs**

6.1.1 **Introduction**

In 14 simulation runs, a total of 49 ECC-sondes (22 x SPC-6A and 27 ENSCI-Z) and 7 KC96 sondes were “flown” in the simulation chamber. The results of each of the tested ozone sondes are presented in Annex A of this report in the form of a panel of four diagrams for each sonde. The upper left diagram displays the complete individual vertical profiles of measured ozone by sonde (K86-correction) & UV-photometer, air temperature and internal and external pump temperature (indicated as Temp.Pmp.Int and Temp.Pmp.Ext., respectively) while the upper right diagram presents the tropospheric part of the profile in more detail. The lower left and right diagrams show the corresponding vertical profiles of the absolute deviations and relative deviations of ozone measured by the sonde compared with the UV-photometer as reference, respectively. The sonde deviations are displayed for RAW-, K86-, and PSC-sonde data. Relative deviations in
the tropospheric part of the tropical simulation runs (#91, 92, 98 and 99) are not displayed because the ozone pressures below 20 km altitude are too low and would blow up for any small deviation of the sonde readings with the UV-photometer. Also excluded are the time-response parts (one in troposphere) and (one in stratosphere) which are replaced by linear interpolation between the begin and end values of the individual reported parameters. The time response parts are reported separately in section 6.3.

It is to be noted that in this report for the ECC-sondes in the first stage, the performance of both ECC-sonde types operated with the three different sensing solution types will be compared and discussed by applying the conventional K86-correction scheme (Table 6) described in Komhyr 1986 and also here referred as standard corrected data.

The results of the individual profiles show that in general the tested sondes track the simulated ozone profiles very well and are in good agreement with the readings of the UV-photometer. This is particularly demonstrated by the subtropical simulation runs No. 94, 95, 100, and 102 with the modulated sinus wave (period length about 1-2 km). Even for the tropical profiles (simulation runs #91, 92, 98 and 99), the performance in the troposphere at the very low ozone pressures (0.3-1 mPa) is still rather good for both ECC sonde types as well as for the KC96-sonde. It is seen (Figure 8) that under these extreme conditions small structures (scale lengths ≥ 1 km) of the simulated vertical ozone profile are tracked rather well by all sondes flown. Most of the different types of sondes show for the tropical simulation runs a more or less systematic difference from the reference. The systematic deviations indicate that a more detailed analysis with a better procedure to determine and correct the background signal of the sondes may improve the accuracy of the different sondes. The tropical ozone profiles in the troposphere obtained in JOSIE-2000 are in good agreement with the tropical ozone profiles measured in JOSIE-1996.

6.1.2 In-Flight Time Response

To investigate the in-flight response time and background characteristics of the ozone sondes for different sensing solutions during each simulation run, ozone was temporarily (3-5 minutes period) set to zero level, once in the troposphere and once in the stratosphere. The individual time response profiles of the four simultaneously tested sondes are in Annex B for each in-flight response test. The ozone sonde data have been processed according to the K86-correction scheme. From the individual response curves, the response time\(^1\) and the observed offset at zero ozone of each sonde has been estimated. For the sake of clarity, the presented sonde data were corrected according to the K86-scheme (Table 6).

In general, the time response in upward as well as in downward flights is rather good for all tested sondes. The response time of both ECC-sonde types is within 20-30 seconds, which corresponds at an ascent velocity of 5m/s to an altitude resolution of about 100-150 m. During the 200 to 300 second period of zero ozone, none of the tested sondes returned to zero. Typical offset values of 0.10 mPa in tropospheric part A and 0.30 mPa in stratospheric part B respectively were observed. Based on the relatively short response time of 20 to 30 seconds, the ozone sensor signal should give values far below the observed offset-values. For both sonde types the offset of each sonde is even substantial larger in the stratospheric part than in the tropospheric part. This may indicate to an offset which depends on the exposure to ozone of the ECC-ozone sensor. However, at present the origin of these offset signals is not understood [Johnson et al., 2002]. This time response behaviour for both ECC-sonde types is for all three sensing solution types similar with no significant differences. The time response of the KC96 ozone sonde is about 40 seconds which corresponds to an altitude resolution of about 200 m while the offset is about 0.1 mPa in the troposphere and about 0.4 mPa in the stratosphere, respectively. In general, the observed offset

\(^1\) The response time \(\tau_{Res}\) on a downward response is defined as the time required, that the signal \(S(t)\) decayed by a factor 1/e of its initial value \(S(0)\), whereby \(S(t) = S(0) \times \exp[-t/\tau_{Res}]\)
response times and offsets are very similar to the corresponding results obtained during the previous JOSIE campaigns in 1996 and 1998. It can be concluded that the response time and offset are not significantly dependent on the type of sensing solution.

**JOSIE 2000**

*Figure 8:* Vertical profiles measured by the different sondes (thin lines) and the UV-photometer (fat line) for the tropospheric parts of the tropical type of profiles.
6.1.3 **Total Ozone Normalization as Screening Test**

Although the total ozone normalization factor is not used to correct the ECC-sondes profile, it provides a good screening test for unreliable soundings using the criterion that in field operation, the normalization factor should not deviate more than about 10 to 20 percent from unity. However, the normalization factor is not a guarantee that the profile is correct. Tables 10-A and 10-B display the total ozone column normalization factors calculated for all tested SPC-6A and ENSCI-sondes, respectively, for each of the three different sensing solution types used. In addition, Table 10-C shows the total ozone normalization factors for all tested KC96-ozone sonde type of the JMA. The total ozone normalization factors are calculated for uncorrected (RAW) data and corrected data according to K86 (Table 6) and PSC (Table 7). Table 11 gives a summary of the average total ozone normalization factors for the different combinations of ECC-sonde types and sensing solution types as obtained during JOSIE 2000 while comparable results obtained during JOSIE 1996 and JOSIE 1998 have been included.

The normalization factor for each combination of ECC sonde type and sensing solution type give a rather robust behaviour with the following the striking features:

- For the standard corrected data nearly all normalization factors fall in the range 0.95 and 1.05 with a small variability of about ±(0.02-0.05).

- For each type of ECC-sonde, there is a systematic trend of the normalization factor towards higher values in case of a change of the use of the sensing solution type from SST-A ⇒ SST-2B ⇒ SST-3A.

- For each of sensing solution types, the normalization factors for ENSCI-Z sondes are 6-7 percent lower than for SPC-6A sondes while its variability (standard deviation of ±0.02) is significantly smaller than for SPC-6A (standard deviation of ±0.04).

The observed features are in good agreement with the results obtained from JOSIE 1996 & 1998 (See also Table 11).

The total ozone normalization factor of the KC96-ozone sonde for the PSC-data vary between 0.91 and 1.00 with an average value of 0.96±0.02. This is a significant improvement compared to normalization factors (0.91±0.1) obtained for the KC79-sonde (predecessor of KC96) during JOSIE 1996.
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**Average over 8 SPC-6A Sondes (±σ)**

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</tr>
<tr>
<td>90</td>
<td>4</td>
<td>6A7091</td>
<td>2B</td>
<td>1.017</td>
<td>0.995</td>
</tr>
<tr>
<td>91</td>
<td>4</td>
<td>6A7092</td>
<td>2B</td>
<td>1.085</td>
<td>1.049</td>
</tr>
<tr>
<td>92</td>
<td>4</td>
<td>6A7094</td>
<td>2B</td>
<td>1.042</td>
<td>1.012</td>
</tr>
<tr>
<td>95</td>
<td>4</td>
<td>6A7099</td>
<td>2B</td>
<td>1.122</td>
<td>1.093</td>
</tr>
</tbody>
</table>

**Average over 5 SPC-6A Sondes (±σ)**

For Sens.Sol.Type = 2B

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th>Total Ozone Norm. Factor</th>
<th>Total Ozone Norm. Factor</th>
<th>Total Ozone Norm. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>1</td>
<td>6A9992</td>
<td>3A</td>
<td>1.075</td>
<td>1.053</td>
</tr>
<tr>
<td>91</td>
<td>1</td>
<td>6A8885</td>
<td>3A</td>
<td>1.140</td>
<td>1.108</td>
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<tr>
<td>94</td>
<td>1</td>
<td>6A8839</td>
<td>3A</td>
<td>1.132</td>
<td>1.106</td>
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<tr>
<td>89</td>
<td>2</td>
<td>6A7089</td>
<td>3A</td>
<td>1.075</td>
<td>1.053</td>
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<tr>
<td>90</td>
<td>2</td>
<td>6A7098</td>
<td>3A</td>
<td>1.109</td>
<td>1.086</td>
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<tr>
<td>91</td>
<td>2</td>
<td>6A7090</td>
<td>3A</td>
<td>1.158</td>
<td>1.127</td>
</tr>
<tr>
<td>92</td>
<td>2</td>
<td>6A7012</td>
<td>3A</td>
<td>1.126</td>
<td>1.097</td>
</tr>
</tbody>
</table>

**Average over 7 SPC-6A Sondes (±σ)**

For Sens.Sol.Type = 3A

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th>Total Ozone Norm. Factor</th>
<th>Total Ozone Norm. Factor</th>
<th>Total Ozone Norm. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.116±0.032</td>
<td>1.090±0.028</td>
<td>1.070±0.037</td>
</tr>
</tbody>
</table>

**Table 10-A:** Total ozone normalization factors derived for the tested SPC-6A sondes for each of the three different sensing solution types used, respectively. The factors are calculated for uncorrected (RAW) data and corrected data according K86 (Table 6) and PSC (Table 7), respectively.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>94</td>
<td>3</td>
<td>1Z1758</td>
<td>1A</td>
<td>0.927</td>
<td>0.905</td>
<td>0.889</td>
</tr>
<tr>
<td>95</td>
<td>3</td>
<td>1Z1757</td>
<td>1A</td>
<td>0.929</td>
<td>0.914</td>
<td>0.938</td>
</tr>
<tr>
<td>96</td>
<td>6</td>
<td>Z03716</td>
<td>1A</td>
<td>0.999</td>
<td>0.978</td>
<td>0.962</td>
</tr>
<tr>
<td>97</td>
<td>6</td>
<td>Z03709</td>
<td>1A</td>
<td>0.946</td>
<td>0.926</td>
<td>0.911</td>
</tr>
<tr>
<td>98</td>
<td>6</td>
<td>Z03466</td>
<td>1A</td>
<td>0.979</td>
<td>0.952</td>
<td>0.939</td>
</tr>
<tr>
<td>99</td>
<td>6</td>
<td>Z03763</td>
<td>1A</td>
<td>0.975</td>
<td>0.948</td>
<td>0.935</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>Z05420</td>
<td>1A</td>
<td>0.929</td>
<td>0.905</td>
<td>0.9</td>
</tr>
<tr>
<td>102</td>
<td>6</td>
<td>Z03749</td>
<td>1A</td>
<td>0.941</td>
<td>0.916</td>
<td>0.905</td>
</tr>
</tbody>
</table>

Average over 8 ENSCI-Z Sondes (±σ) For Sens.Sol.Type = 1A

<table>
<thead>
<tr>
<th></th>
<th>89</th>
<th>1Z1741</th>
<th>2B</th>
<th>0.982</th>
<th>0.962</th>
<th>0.964</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90</td>
<td>1Z1742</td>
<td>2B</td>
<td>0.946</td>
<td>0.926</td>
<td>0.914</td>
</tr>
<tr>
<td></td>
<td>91</td>
<td>1Z1744</td>
<td>2B</td>
<td>0.980</td>
<td>0.952</td>
<td>0.938</td>
</tr>
<tr>
<td></td>
<td>92</td>
<td>1Z1745</td>
<td>2B</td>
<td>0.990</td>
<td>0.966</td>
<td>0.948</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>1Z1756</td>
<td>2B</td>
<td>0.993</td>
<td>0.970</td>
<td>0.954</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>Z05416</td>
<td>2B</td>
<td>1.000</td>
<td>0.972</td>
<td>0.948</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>Z05417</td>
<td>2B</td>
<td>0.999</td>
<td>0.970</td>
<td>0.946</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Z05421</td>
<td>2B</td>
<td>0.998</td>
<td>0.973</td>
<td>0.949</td>
</tr>
<tr>
<td></td>
<td>101</td>
<td>Z05418</td>
<td>2B</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Average over 8 ENSCI-Z Sondes (±σ) For Sens.Sol.Type = 2B

<table>
<thead>
<tr>
<th></th>
<th>90</th>
<th>2Z1860</th>
<th>3A</th>
<th>1.032</th>
<th>1.012</th>
<th>0.948</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>92</td>
<td>2Z1567</td>
<td>3A</td>
<td>1.073</td>
<td>1.044</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>94</td>
<td>2Z1610</td>
<td>3A</td>
<td>1.057</td>
<td>1.032</td>
<td>1.011</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>Z05414</td>
<td>3A</td>
<td>1.069</td>
<td>1.050</td>
<td>1.025</td>
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<tr>
<td></td>
<td>97</td>
<td>Z05415</td>
<td>3A</td>
<td>1.052</td>
<td>1.030</td>
<td>1.006</td>
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<tr>
<td></td>
<td>102</td>
<td>Z05419</td>
<td>3A</td>
<td>1.042</td>
<td>1.015</td>
<td>0.991</td>
</tr>
</tbody>
</table>

Average over 6 ENSCI-Z Sondes (±σ) For Sens.Sol.Type = 3A

|    | 1.054±0.016 | 1.031±0.015 | 0.997±0.027 |

Table 10-B: Total ozone normalization factors derived for the tested ENSCI-Z sondes for each of the three different sensing solution types used. The factors are calculated for uncorrected (RAW) data and corrected data according K86 (Table 6) and PSC (Table 7), respectively.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>8</td>
<td>99306</td>
<td>4A</td>
<td>0.976</td>
<td>0.906</td>
<td>0.934</td>
</tr>
<tr>
<td>97</td>
<td>8</td>
<td>99314</td>
<td>4A</td>
<td>1.002</td>
<td>0.935</td>
<td>0.960</td>
</tr>
<tr>
<td>98</td>
<td>8</td>
<td>99307</td>
<td>4A</td>
<td>1.014</td>
<td>0.920</td>
<td>0.956</td>
</tr>
<tr>
<td>99</td>
<td>8</td>
<td>99309</td>
<td>4A</td>
<td>1.078</td>
<td>0.974</td>
<td>0.997</td>
</tr>
<tr>
<td>100</td>
<td>8</td>
<td>99310</td>
<td>4A</td>
<td>1.025</td>
<td>0.935</td>
<td>0.959</td>
</tr>
<tr>
<td>101</td>
<td>8</td>
<td>99315</td>
<td>4A</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>102</td>
<td>8</td>
<td>99312</td>
<td>4A</td>
<td>1.011</td>
<td>0.924</td>
<td>0.942</td>
</tr>
</tbody>
</table>

Average over 6 KC96-Sondes (±σ): 1.018±0.034 0.932±0.023 0.958±0.022

**Table 10-C:** Total ozone normalization factors derived for the tested KC96 sondes. The factors are calculated for uncorrected (RAW) data and corrected data according K86 (Table 6) and PSC (Table 7), respectively.

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Sensing Solution Type</th>
<th>SPC-6A</th>
<th>ENSCI-Z</th>
<th>Difference SPC-6A minus ENSCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOSIE-2000</td>
<td>SST-1A</td>
<td>1.00±0.05 (N=8)</td>
<td>0.93±0.03 (N=8)</td>
<td>0.07</td>
</tr>
<tr>
<td>JOSIE-2000</td>
<td>SST-2B</td>
<td>1.03±0.04 (N=5)</td>
<td>0.96±0.02 (N=8)</td>
<td>0.07</td>
</tr>
<tr>
<td>JOSIE-2000</td>
<td>SST-3A</td>
<td>1.09±0.03 (N=7)</td>
<td>1.03±0.02 (N=6)</td>
<td>0.06</td>
</tr>
<tr>
<td>JOSIE-1998</td>
<td>SST-1A</td>
<td>0.97±0.05 (N=13)</td>
<td>0.93±0.01 (N=13)</td>
<td>0.04</td>
</tr>
<tr>
<td>JOSIE-1996</td>
<td>SST-1A</td>
<td>1.00±0.05 (N=6)</td>
<td>0.95±0.02 (N=6)</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**Table 11:** Summary of the average total ozone normalization factors obtained for each combination of ECC sonde type and sensing solution type. The factors are calculated for standard corrected data according K86-scheme (Table 6). Comparable results obtained during JOSIE-1996 and JOSIE-1998 are included. N= number of samples.
6.2 Comparison Sondes with UV-photometer

6.2.1 Introduction

For each combination of ECC-ozone sonde type and sensing solution type, the quantitative results of the sonde comparisons with the UV-photometer are presented in the Figures 9 and 10. The comparisons are presented as ozone pressure deviations (Figure 9) and as relative deviations (Figure 7) of the sonde readings from the UV-photometer, respectively. The deviations are presented as averages (± one standard deviation) over the individual sonde readings of each of the ensembles of tested sondes. The presented ECC-sonde data have been corrected according the K86-scheme (Table 6) while the corresponding results for RAW (uncorrected) and PSC-data are shown in Annex C. The KC96 sonde data have been processed according the PSC-scheme submitted by the JMA-participating laboratory. The results for RAW- and K86-data of the KC96-sonde are presented in Annex C. The tropospheric parts of the tropical simulations up to an altitude of 20 km are not included in the presentations of the relative deviations.

For the tropospheric as well as for the stratospheric part of the profiles, the tested ECC-sondes agree rather well with the UV-photometer. Relative deviations are typically within ±(5-10) % and occasionally ±(10-15) %. However, some systematic features are observed between the SPC-6A and ENSCI-sonde type if operated with the same sensing solution type:

- Throughout the entire vertical ozone profile, the ENSCI-Z sonde readings are about 5-10% higher than the SPC-6A sonde in case both sonde types are operated with the same sensing solution type.

- For the SPC-6A as well as the ENSCI-Z sonde, there is a systematic trend throughout the entire profile to a change of the ozone sonde readings of about 5-10% in case of a change of the sensing solution type. A change from SST-A ⇒ SST-2B or from SST-2B ⇒ SST-3A will produce in both cases a change in the ozone sonde readings of about +5%. This means that a maximum difference between sonde readings of about 10% can be expected when changing between SST-1A and SST-3A.

- The variability of each tested ensemble of ozone sonde type and sensing solution type is for both sonde type small, although, the ENSCI-Z sonde type tends to inhibit a smaller variability than the SPC-6A type of sondes.

Figure 11 shows the observed differences between SPC-6A and ENSCI-Z type of sondes for each of the sensing solution types. Included are thereby the differences between both ECC-sonde types (operated with SST-1A) as observed during JOSIE 1996 and 1998. In addition, the results are summarized in Table 12.
Figure 9-A: JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual K86-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
Figure 9-B: JOSIE-2000—Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual K86-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
Figure 10-A: JOSIE-2000—Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual K86-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
JOSIE-2000
K86 Correction

**Figure 10-B:** JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual K86-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
Figure 11: Comparison of the relative differences between SPC-6A and ENSCI sonde types derived from the differences of the average relative deviations of the SPC-6A and ENSCI-Z sondes with the UV-photometer as presented in the Figure 8 for each of the sensing solution types. Included are the results of comparisons between SPC6A and ENSCI obtained during JOSIE 1996 and 1998 where both sondes were operated with SST-1A.

Table 12: Relative differences between SPC-6A and ENSCI sonde types for each sensing solution types. Included are the results of comparisons between SPC6A and ENSCI obtained during JOSIE 1996 and 1998 where both sondes were operated with SST-1A.
It is obvious that above 20 km altitude the performance characteristics of the two ECC-sonde types are significantly different. With increasing altitude ENSCI-Z measures 5-10% more than SPC-6A in case of deploying same sensing solution and pump flow correction table. Below an altitude of 20 km (Z < 20 km) the results are not consistent every year:

- **JOSIE 1996**: ENSCI-Z tends to measure 1-5% more than SPC-6A at Z=0-20 km
- **JOSIE 1998**: Within ±(0-2)% good agreement between ENSCI-Z and SPC-6A
- **JOSIE 2000**: ENSCI-Z measures about 5-10% more than SPC-6A at Z=0-20 km

An overview of the quantitative results of the sonde comparison with the UV-photometer for the KC96-sonde is shown in Figure 12, displaying the average (± one standard deviation) of the ozone pressure deviations (left diagram) and relative deviations (right panel) of the individual PSC corrected sonde data from the UV-photometer. The KC96-sonde tends to underestimate ozone in the troposphere and overestimate ozone in the middle stratosphere (above 25 km altitude) compared with the UV-photometer. A similar behaviour was observed during JOSIE 1996 with the KC79 sonde (predecessor of KC96). However, in the upper troposphere and lower stratosphere there is good agreement with the UV-photometer, while the variability of the performance of the sonde by sonde has improved since JOSIE 1996.

![Figure 12](image-url)

**Figure 12**: JOSIE 2000-Comparison of KC96 sonde versus UV-Photometer: Averages (± one standard deviation) of the ozone pressure deviations (left diagram) and relative deviations (right panel) of the individual PSC corrected sonde data from the UV-photometer for the KC96 ozone sonde.
6.2.2 Precision, Bias and Accuracy

The precision is determined by the standard deviation of the average of the sonde deviations (= bias) with the UV-photometer, while the accuracy is determined as the sum of sonde precision and the absolute value of its bias with the UV-photometer. For each combination of ECC-sonde type and sensing solution type a survey of the sonde bias and its precision are listed in Table 13 and 14 in altitude bins of 5 km on the ozone pressure scale and on the relative scale with regard to the UV-photometer, respectively. Table 15 contains a survey of bias and precision of the KC96-sonde for PSC-data. The surveys including all three levels of data processing like RAW-, K86- and PSC-data are shown in Annex C.

<table>
<thead>
<tr>
<th>Mean Ozone Pressure Deviation (in mPa) ± Standard Deviation (in mPa) = Bias±Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altitude Range (km)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>30-35</td>
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<tr>
<td>25-30</td>
</tr>
<tr>
<td>20-25</td>
</tr>
<tr>
<td>15-20</td>
</tr>
<tr>
<td>10-15</td>
</tr>
<tr>
<td>5-10</td>
</tr>
<tr>
<td>0-5</td>
</tr>
</tbody>
</table>

Table 13: Survey of the bias (systematic deviation) and precision of the SPC-6A and ENSCI ozone sondes for each sensing solution type and K86-corrected ozone sonde data. Between brackets the accuracy is determined by the sum of the precision and the absolute value of the bias. For details see text.
**SPC-6A and ENSCI-Z Sondes:**

Both ECC-sonde types show in the troposphere and lower/middle troposphere a relative precision of about ±(3-6)% with some outliers up to 12%. The best precision for both sonde types had been achieved with the SST-3A sensing solution type. However, the SPC-6A sonde show for SST-3A a large negative relative bias which varies between -(7-10)% in the troposphere as well as in the stratosphere up to 30 km altitude while above the bias is strongly increasing up to –15% at 35 km altitude. For the ENSCI-Z sonde the relative bias for SST-3A is smaller with values varying between –3% and –8%. Therefore the ENSCI-Z sonde show for SST-1A a large positive relative bias of about 10% in the troposphere, +(3-6)% in the lower stratosphere and about +10% in the middle stratosphere. The best relative accuracy of about ±(5-10)% was achieved for the SPC-6A sonde with SST-1A while the ENSCI-Z sonde show the best accuracy with SST-2B.

<table>
<thead>
<tr>
<th>Altitude Range (km)</th>
<th>K86-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)</th>
<th>±Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPC-6A</td>
<td>SST-2B</td>
</tr>
<tr>
<td>30-35</td>
<td>-1.6 ± 6.7</td>
<td>-11.5 ± 5.7</td>
</tr>
<tr>
<td></td>
<td>(±8.3)</td>
<td>(±16.2)</td>
</tr>
<tr>
<td>25-30</td>
<td>2.5 ± 7.1</td>
<td>-3.8 ± 4.7</td>
</tr>
<tr>
<td></td>
<td>(±9.6)</td>
<td>(±8.5)</td>
</tr>
<tr>
<td>20-25</td>
<td>-0.1 ± 8.6</td>
<td>-2.9 ± 5.6</td>
</tr>
<tr>
<td></td>
<td>(±8.7)</td>
<td>(±8.5)</td>
</tr>
<tr>
<td>15-20</td>
<td>-1.7 ± 8.2</td>
<td>-3.4 ± 5.3</td>
</tr>
<tr>
<td></td>
<td>(±9.9)</td>
<td>(±8.7)</td>
</tr>
<tr>
<td>10-15</td>
<td>3.0 ± 6.9</td>
<td>-6.6 ± 12.5</td>
</tr>
<tr>
<td></td>
<td>(±12.9)</td>
<td>(±19.1)</td>
</tr>
<tr>
<td>5-10</td>
<td>5.3 ± 6.5</td>
<td>-0.2 ± 8.3</td>
</tr>
<tr>
<td></td>
<td>(±11.8)</td>
<td>(±8.5)</td>
</tr>
<tr>
<td>0-5</td>
<td>1.1 ± 5.2</td>
<td>0.2 ± 5.1</td>
</tr>
<tr>
<td></td>
<td>(±6.3)</td>
<td>(±5.3)</td>
</tr>
</tbody>
</table>

**Table 14:** Survey of the relative bias (systematic deviation) and relative precision of the SPC-6A and ENSCI ozone sondes for each sensing solution type and for K86-corrected ozone sonde data. Between brackets the relative accuracy which is determined by the sum of the relative precision and the absolute value of the relative bias. For details see text.
**KC-96 Sondes:**

The relative precision of the KC-96 sonde is about ±5% in the troposphere and about ±(6-8)% in the stratosphere. In the troposphere, the sonde show a negative relative bias which is turning into a positive bias in the lower stratosphere and increasing with altitude. The relative accuracy of the KC-96 sonde varies between ±8 and 15% in the troposphere and stratosphere.

<table>
<thead>
<tr>
<th>Altitude Range (km)</th>
<th>Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)</th>
<th>Mean Relative Deviation (in %) ± Std Deviation (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-35</td>
<td>-0.07 ± 0.40</td>
<td>-1.4 ± 6.2</td>
</tr>
<tr>
<td></td>
<td>(±0.47)</td>
<td>(±7.6)</td>
</tr>
<tr>
<td>25-30</td>
<td>1.16 ± 0.69</td>
<td>10.2 ± 6.2</td>
</tr>
<tr>
<td></td>
<td>(±1.85)</td>
<td>(±16.4)</td>
</tr>
<tr>
<td>20-25</td>
<td>1.20 ± 1.12</td>
<td>8.5 ± 8.6</td>
</tr>
<tr>
<td></td>
<td>(±2.32)</td>
<td>(±17.1)</td>
</tr>
<tr>
<td>15-20</td>
<td>-0.15 ± 0.55</td>
<td>-3.0 ± 6.8</td>
</tr>
<tr>
<td></td>
<td>(±0.70)</td>
<td>(±9.8)</td>
</tr>
<tr>
<td>10-15</td>
<td>-0.06 ± 0.12</td>
<td>-2.8 ± 5.2</td>
</tr>
<tr>
<td></td>
<td>(±0.18)</td>
<td>(±8.0)</td>
</tr>
<tr>
<td>5-10</td>
<td>-0.07 ± 0.08</td>
<td>-4.3 ± 4.9</td>
</tr>
<tr>
<td></td>
<td>(±0.15)</td>
<td>(±9.2)</td>
</tr>
<tr>
<td>0-5</td>
<td>-0.21 ± 0.13</td>
<td>-8.7 ± 4.0</td>
</tr>
<tr>
<td></td>
<td>(±0.34)</td>
<td>(±12.7)</td>
</tr>
</tbody>
</table>

**Table 15:** Survey of the absolute and relative bias (systematic deviation) and absolute and relative precision of the KC96 ozone sonde for PSC-ozone sonde data. Between brackets the accuracy which is determined by the sum of the precision and the absolute value of the bias. For details see text.
7. SUMMARY AND CONCLUSIONS

JOSIE 2000 was the second WMO international ozone sonde intercomparison campaign at the WCCOS in Jülich. It was a continuation of the assessment of the performance of ozonesondes used in GAW which begun in 1996 as the Julich Ozone Sonde Intercomparison Experiment (JOSIE). The concept of the JOSIE experiments in 1996, 1998, and 2000 has followed a step by step approach to accomplish the different QA-tasks for ozonesondes of the WCCOS. While the earlier JOSIEs were focused on the QA associated with the various types and manufacturers of sondes, JOSIE 2000 was dedicated to support the assessment of standard operating procedures (SOPs) for the different sonde types presently operating in the GAW network. JOSIE 2000 focused on the controversial issue of the sensitivity to the chemical sensing solution of the ECC (Electrochemical Concentration Cell) type ozone sonde. The task was to conduct intercomparison experiments in the simulation chamber which address uncertainties in the instrument preparation (sensing solution, background signal, pump efficiency) and data reduction procedures.

JOSIE 2000 brought together operators from seven ECC sounding stations of the GAW-network, operating two different sonde types (SPC-6A & ENSCI-Z) with three different sensing solutions (SST-1A: 1% KI, full buffer; SST-2B: 0.5% KI, half buffer; SST-3A: 2% KI, no buffer). For each combination of ECC-sonde and sensing solution, a total of six simulation experiments were performed. All data were processed according the guidelines of Komhyr, 1986. An overview of the results is shown in Figure 1 [Smit and Straeter, 2004-B]. When operated with the same sensing solution, ENSCI-Z sondes give about 5-10% higher O₃ concentrations than SPC-6A sondes throughout the vertical profile. In addition, both sonde types exhibit a systematic sensitivity to changes in the sensing solution. Going from SST-1A to SST-2B and SST-3A will produce each time a change in the sensitivity of about +5% over the entire profile. Therefore, a difference of up to 10% can be expected for different sonde types operated with different sensing solutions.

The differences in performance between the SPC6A and ENSCI-Z sonde types as observed since JOSIE 1996 are summarized in Figure 2. It is obvious that above 20 km altitude the performance characteristics of the two ECC-sonde types are significantly different. With increasing altitude ENSCI-Z measures 5-10% more than SPC-6A in case of deploying the sensing solution and pump flow correction table. Below an altitude of 20 km (Z < 20km), the results are not consistent every year:

- JOSIE 1996: ENSCI-Z tends to measure 1-5% more than SPC-6A
- JOSIE 1998: Within ±(0-2)% good agreement between ENSCI-Z and SPC-6A
- JOSIE 2000: ENSCI-Z measures 5-10% more than SPC-6A

A key conclusion is that the characteristics of the two ECC-sonde types is not always the same when operated under the same conditions and can have significant differences. Particularly above 20 km, the ENSCI-Z sonde tends to measure 5-10% more ozone than the SPC-6A sonde. Below 20 km, the differences are 5% or less, but can differ from year to year. Furthermore, there is a significant difference in the ozone readings when even sondes of the same type are operated with different sensing solutions. For each ECC-type the use of SST-1A will give 5% larger ozone values compared with the use of SST-2B, and even 10% larger values compared with SST-3A. For ozone sounding stations doing long term measurements of ozone, this means that in case of a change of sensing solution type or ECC-sonde type this can easily introduce a change of ±5% or even larger in the longterm ozone record.

The observed features for both ECC-sonde types using different sensing solutions are very consistent throughout the entire troposphere and lower/middle stratosphere up to 35 km altitude. The best quantitative results are obtained for the SPC-6A sonde if operated with SST-1A and for the ENSCI sonde operated with SST-2B. While the origin of the observed differences is not fully understood, the results clearly demonstrate that small differences in the instrumental layout of both ECC-sonde types or the use of different sensing solutions can have a significant influence on
the measurement accuracy and thus, may influence the trends derived from such records. JOSIE demonstrates the urgent need for regular validation of ozone sondes and homogenisation of the standard operating procedures (SOP’s), particularly with regard to proper choice of the chemical composition of the sensing solution is of crucial importance. From the experience of JOSIE 1996-2000, the following major recommendations are made:

a. There is an urgent need for WMO to establish Standard Operating Procedures (SOP’s) for ozone sondes;
b. There is a need of regular quality assured manufacturing;
c. There is a need for further research into ECC-sonde pumpflow efficiency at lower pressures and particularly of the different experimental methods available to determine the pump flow efficiency at low pressures.

The standardisation of the operation procedures including preparation and data correcting methods is of crucial importance. As a consequence, under the auspices of WMO/GAW, an Assessment of Operating Procedures for Ozone Sondes (ASOPOS) has been initiated with the intent of defining easy to follow operating procedures that can be consistently implemented and will provide data of high quality that are comparable between ozone sounding networks within the GAW global network.

Based on the JOSIE results, provisional SOPs for ECC-sondes were unanimously established at a WMO Meeting of Ozone Sonde Experts in Geneva, 1-3 May 2001. It was further decided that the preliminary SOPs recommended by JOSIE had to be tested through an intercomparison in the real atmosphere for quality assurance and suitability before the procedures are applied to sondes launched in various GAW stations. In April 2004, the Balloon Experiment on Standards for Ozone Sondes (BESOS) field campaign at the University of Wyoming at Laramie, USA, was conducted to test the provisional SOP’s for ECC-and KC96-ozonesondes. In a next step ASOPOS will evaluate JOSIE- and BESOS-results in order to establish WMO-recommended SOP’s, for the different major types of ozone sondes used in the GAW-ozone sounding network.

Acknowledgements

We want to thank Dr Michael Proffitt, Dr John Miller, Dr Volker Mohnen and Dr Anne Thompson for their personal engagement, contributions and arranging financial support to JOSIE. Many thanks to Dr Dieter Kley for his encouraging support to establish JOSIE from the very beginning as a platform for quality assurance for ozone sondes. Also, many thanks to Dr Manfred Helten and Marcel Berg for assistance to organize and conduct the JOSIE 2000 campaign. Further thanks to Sabine Schroeder for the quasi-on line post flight processing of the simulation data and thanks to Thomas Heil for setting up and maintain all computer facilities during the campaign. Dr Karin Thomas of KT-Consulting many thanks for data analysis and preparing most of the graphics. Further we are grateful to all participants and people involved in JOSIE 2000 (Annex A) for their encouraging support and fruitful discussions during the campaign and afterwards. JOSIE 2000 was sponsored by WMO/GAW and FZJ.

References


Results of Individual Tested ECC-Ozone Sondes
JOSIE-2000

Participant=1  Sonde Type=SPC-6A  Sol. Type=3A  Sim. No.=89

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Relative Deviation (%)

Absolute Deviation (mPa)

Altitude (km)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)
Participant=2  Sonde Type=SPC-6A  Sol.Type=3A  Sim.No.=89
JOSIE-2000

Participant=4  Sonde Type=SPC-6A  Sol.Type=2B  Sim.No.=89

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Relative Deviation (%)

Absolute Deviation (mPa)

Simulation time (s)

Relative Deviation (%)

Absolute Deviation (mPa)
JOSIE-2000

Participant=1  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=90

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Absolute Deviation (mPa)

Simulation time (s)

Relative Deviation (%)

Simulation time (s)
JOSIE-2000

Participant=2  Sonde Type=SPC-6A  Sol.Type=3A  Sim.No.=90

![Graphs showing temperature and ozone pressure simulations with absolute and relative deviations.](image-url)
JOSIE-2000

Participant=3  Sonde Type=ENSCI-Z  Sol.Type=2B  Sim.No.=90
JOSIE-2000

Participant=4  Sonde Type=SPC-6A  Sol.Type=2B  Sim.No.=90
JOSIE-2000

Participant=1  Sonde Type=SPC-6A  Sol.Type=3A  Sim.No.=91

Temperature (K)

Ozone Pressure (mPa)

Absolute Deviation (mPa)

Relative Deviation (%)

Altitude (km)

Simulation time (s)
JOSIE-2000

Participant=2   Sonde Type=SPC-6A   Sol.Type=3A   Sim.No.=91
JOSIE-2000

Participant=3   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=91

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Absolute Deviation (mPa)

Relative Deviation (%)

Participant=3   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=91

JOSIE-2000
JOSIE-2000

Participant=4  Sonde Type=SPC-6A  Sol.Type=2B  Sim.No.=91

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Absolute Deviation (mPa)

Simulation time (s)

Relative Deviation (%)

Simulation time (s)
JOSIE-2000

Participant=1  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=92

Simulation Time (s)

Temperature (K)

Ozone Pressure (mPa)

Altitude (km)

Absolute Deviation (mPa)

Relative Deviation (%)

Participant=1  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=92

JOSIE-2000
JOSIE-2000

Participant=2  Sonde Type=SPC-6A  Sol.Type=3A  Sim.No.=92

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Absolute Deviation (mPa)

Relative Deviation (%)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Absolute Deviation (mPa)

Relative Deviation (%)

Simulation time (s)
JOSIE-2000

Participant=3  Sonde Type=ENSCI-Z  Sol.Type=2B  Sim.No.=92

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Absolute Deviation (mPa)

Relative Deviation (%)

Simulation time (s)

Altitude (km)

Participant=3   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=92

JOSIE-2000
JOSIE 2000
Sim. No. = 93 Part. No. = 1 (CMDL) Correction = K86

Temperature (K)

Ozone Pressure (mPa)

Pressure (hPa)

Dev. Sonde from OPM (mPa)

Legend:
- OPM
- Sonde
- Temp. Air
- Temp. Pump Int.
- Temp. Pump Ext.
- Pressure Air
JOSIE 2000
Sim. No.= 93 Part. No.= 2 (AES) Correction = K86

![Graph showing temperature and simulated data over time and pressure levels.](graph)

- Temperature (K)
- Simulation Time (sec)
- Ozone Pressure (mPa)
- Dev. Sonde from OPM (mPa)

Legend:
- OPM
- Sonde
- Temp. Air
- Temp. Pump Int.
- Temp. Pump Ext.
- Pressure Air
JOSIE 2000
Sim. No.= 93  Part. No.= 3 (NIWA)  Correction = K86
JOSIE-2000

Participant=1  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=94
JOSIE-2000

Participant=2  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=94

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Relative Deviation (%)

Absolute Deviation (mPa)

Simulation time (s)

Altitude (km)

Simulation time (s)

Altitude (km)
JOSIE-2000

Participant=3   Sonde Type=ENSCI-Z   Sol.Type=1A   Sim.No.=94
JOSIE-2000

Participant=4  Sonde Type=SPC-6A  Sol.Type=3A  Sim.No.=94

![Simulation results for various parameters including Ozone Pressure, Temperature, Absolute Deviation, and Relative Deviation.](image)
JOSIE-2000

Participant=1  Sonde Type=ENSCI-Z  Sol.Type=1A  Sim.No.=95
JOSIE-2000

Participant=2   Sonde Type=SPC-6A   Sol.Type=1A   Sim.No.=95
JOSIE-2000

Participant=3  Sonde Type=ENSCI-Z  Sol.Type=2B  Sim.No.=95

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Absolute Deviation (mPa)

Relative Deviation (%)

Simulation time (s)

Altitude (km)

Simulation time (s)

Altitude (km)
JOSIE-2000

Participant=4   Sonde Type=SPC-6A   Sol.Type=2B   Sim.No.=95

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Absolute Deviation (mPa)

Relative Deviation (%)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=96

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Absolute Deviation (mPa)

Relative Deviation (%)

Altitude (km)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)
JOSIE-2000

Participant=7   Sonde Type=ENSCI-Z   Sol.Type=3A   Sim.No.=96

Temperature (K)

![Graph of Temperature (K) over Simulation Time (s) and Ozone Pressure (mPa)]

Temperature (K)

![Graph of Temperature (K) over Simulation Time (s) and Ozone Pressure (mPa)]

Absolute Deviation (mPa)

![Graph of Absolute Deviation (mPa) over Simulation Time (s) and Altitude (km)]

Relative Deviation (%)

![Graph of Relative Deviation (%) over Simulation Time (s) and Altitude (km)]
JOSIE-2000

Participant=8  Sonde Type=KC96  Sol.Type=4A  Sim.No.=96

Temperature (K)

Ozone Pressure (mPa)

Simulationtime (s)

Altitude (km)

Absolute Deviation (mPa)

Relative Deviation (%)

Simulationtime (s)

Altitude (km)
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=97
JOSIE-2000

Participant=7  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=97

Temperature (K)

Ozone Pressure (mPa)

Simulationtime (s)

Altitude (km)

Relative Deviation (%)

Absolute Deviation (mPa)

Simulationtime (s)

Altitude (km)
JOSIE-2000

Participant=8  Sonde Type=KC96  Sol.Type=4A  Sim.No.=97
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=98
JOSIE-2000

Participant=6  Sonde Type=ENSCI-Z  Sol.Type=1A  Sim.No.=98
JOSIE-2000

Participant=7  Sonde Type=ENSCI-Z  Sol.Type=2B  Sim.No.=98
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=99

Temperature (K)

Ozone Pressure (mPa)

Absolute Deviation (mPa)

Relative Deviation (%)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Altitude (km)

Simulation time (s)

Altitude (km)

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=99

JOSIE-2000
Participant=6   Sonde Type=ENSCI-Z   Sol.Type=1A   Sim.No.=99
JOSIE-2000

Participant=7   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=99
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=100

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Relative Deviation (%)

Absolute Deviation (mPa)

Simulation time (s)

Altitude (km)

Altitude (km)

PO3-OPM
PO3-ECC(K86)
Temp. Air
Temp. Pmp. Int.

PO3-OPM
PO3-ECC(K86)
Temp. Air
Temp. Pmp. Int.

RAW
PSC
K86

RAW
PSC
K86
JOSIE-2000

Participant=6  Sonde Type=ENSCI-Z  Sol.Type=1A  Sim.No.=100

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Absolute Deviation (mPa)

Relative Deviation (%)
Participant=7  Sonde Type=ENSCI-Z  Sol.Type=2B  Sim.No.=100

JOSIE-2000
Participant=8  Sonde Type=KC96  Sol.Type=4A  Sim.No.=100
JOSIE 2000
Sim. No.= 101  Part. No.= 5 (WFF)  Correction = K86

Temperature (K)

Pressure (hPa)

Ozone Pressure (mPa)

Simulation Time (sec)

Dev. Sonde from OPM (mPa)

- OPM
- Sonde
- Temp. Air
- Temp. Pump Int.
- Temp. Pump Ext.
- Pressure Air
JOSIE 2000
Sim. No.= 101  Part. No.= 6 (SAP)  Correction = K86
JOSIE 2000
Sim. No.= 101  Part. No.= 7 (URI)  Correction = K86
JOSIE 2000
Sim. No.= 101  Part. No.= 8 (JMA)  Correction = K86
JOSIE-2000

Participant=5  Sonde Type=SPC-6A  Sol.Type=1A  Sim.No.=102

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Temperature (K)

Simulation time (s)

Ozone Pressure (mPa)

Absolute Deviation (mPa)

Simulation time (s)

Relative Deviation (%)

Simulation time (s)
Participant=6  Sonde Type=ENSCI-Z  Sol.Type=1A  Sim.No.=102

JOSIE-2000
JOSIE-2000

Participant=7  Sonde Type=ENSCI-Z  Sol.Type=3A  Sim.No.=102

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Temperature (K)

Ozone Pressure (mPa)

Simulation time (s)

Absolute Deviation (mPa)

Relative Deviation (%)
JOSIE-2000

Participant=8  Sonde Type=KC96  Sol.Type=4A  Sim.No.=102
Results of Individual Response Time Tests
Average Deviations of Ozone Sondes from UV-photometer:
RAW- and PSC-Sonde Data (ECC-Sondes)
RAW- and K86-Sonde Data (KC96-Sondes)
Figure Annex C-1: JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages ($\pm$ one standard deviation) of the ozone pressure deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
Figure Annex C-2: JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual PSC-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
Figure Annex C-3: JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
Figure Annex C-4: JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual PSC-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.
Figure Annex C-5: JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
Figure Annex C-6: JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual PSC-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
Figure Annex C-7: JOSIE-2000 — Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
Figure Annex C-8: JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual PSC-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.
JOSIE-2000

Participant: 8

Figure Annex C-9: JOSIE 2000-Comparison of KC96 sonde versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations and the relative deviations of the individual RAW- and K86-data from the UV-photometer for KC96-sonde.
### Table Annex C-1

Survey of the bias (systematic deviation) and precision of the SPC-6A and ENSCI ozone sondes for each sensing solution type and for RAW, K86- and PSC-ozone sonde data. The accuracy is determined by the sum of the precision and the absolute value of the bias.

<table>
<thead>
<tr>
<th>Altitude Range (km)</th>
<th>RAW-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)</th>
<th>K86-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)</th>
<th>PSC-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPC-6A Sonde</td>
<td>ENSCI-Z Sonde</td>
<td>SPC-6A Sonde</td>
</tr>
<tr>
<td></td>
<td>SST-1A</td>
<td>SST-2B</td>
<td>SST-3A</td>
</tr>
<tr>
<td>30-35</td>
<td>-0.47 ± 0.45</td>
<td>-1.08 ± 0.43</td>
<td>-1.29 ± 0.28</td>
</tr>
<tr>
<td>25-30</td>
<td>-0.21 ± 0.85</td>
<td>-0.81 ± 0.54</td>
<td>-1.33 ± 0.43</td>
</tr>
<tr>
<td>20-25</td>
<td>-0.31 ± 1.16</td>
<td>-0.67 ± 0.77</td>
<td>-1.33 ± 0.69</td>
</tr>
<tr>
<td>15-20</td>
<td>-0.20 ± 0.66</td>
<td>-0.28 ± 0.39</td>
<td>-0.56 ± 0.42</td>
</tr>
<tr>
<td>10-15</td>
<td>0.08 ± 0.18</td>
<td>-0.05 ± 0.21</td>
<td>-0.24 ± 0.27</td>
</tr>
<tr>
<td>5-10</td>
<td>0.09 ± 0.09</td>
<td>0.02 ± 0.12</td>
<td>-0.14 ± 0.11</td>
</tr>
<tr>
<td>0-5</td>
<td>0.04 ± 0.14</td>
<td>0.02 ± 0.11</td>
<td>-0.18 ± 0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-35</td>
<td>0.08 ± 0.40</td>
<td>-0.76 ± 0.43</td>
<td>-0.99 ± 0.28</td>
</tr>
<tr>
<td>25-30</td>
<td>0.22 ± 0.85</td>
<td>-0.41 ± 0.55</td>
<td>-0.94 ± 0.43</td>
</tr>
<tr>
<td>20-25</td>
<td>-0.02 ± 1.18</td>
<td>-0.38 ± 0.78</td>
<td>-1.07 ± 0.69</td>
</tr>
<tr>
<td>15-20</td>
<td>-0.11 ± 0.67</td>
<td>-0.19 ± 0.39</td>
<td>-0.48 ± 0.38</td>
</tr>
<tr>
<td>10-15</td>
<td>0.09 ± 0.19</td>
<td>-0.02 ± 0.22</td>
<td>-0.23 ± 0.24</td>
</tr>
<tr>
<td>5-10</td>
<td>0.08 ± 0.10</td>
<td>0.03 ± 0.12</td>
<td>-0.15 ± 0.10</td>
</tr>
<tr>
<td>0-5</td>
<td>-0.01 ± 0.14</td>
<td>0.02 ± 0.11</td>
<td>-0.22 ± 0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-35</td>
<td>0.08 ± 0.40</td>
<td>-0.73 ± 0.41</td>
<td>-0.76 ± 0.41</td>
</tr>
<tr>
<td>25-30</td>
<td>0.47 ± 0.77</td>
<td>-0.18 ± 0.55</td>
<td>-0.49 ± 0.61</td>
</tr>
<tr>
<td>20-25</td>
<td>0.23 ± 1.18</td>
<td>-0.07 ± 0.78</td>
<td>-0.61 ± 0.77</td>
</tr>
<tr>
<td>15-20</td>
<td>-0.02 ± 0.68</td>
<td>-0.07 ± 0.40</td>
<td>-0.39 ± 0.33</td>
</tr>
<tr>
<td>10-15</td>
<td>0.07 ± 0.19</td>
<td>-0.06 ± 0.21</td>
<td>-0.34 ± 0.17</td>
</tr>
<tr>
<td>5-10</td>
<td>0.03 ± 0.09</td>
<td>-0.06 ± 0.09</td>
<td>-0.31 ± 0.10</td>
</tr>
<tr>
<td>0-5</td>
<td>-0.03 ± 0.13</td>
<td>-0.08 ± 0.09</td>
<td>-0.37 ± 0.11</td>
</tr>
</tbody>
</table>
## Table Annex C-2: Survey of the relative bias (systematic deviation) and relative precision of the SPC-6A and ENSCI ozone sondes for each sensing solution type and for uncorrected, K86- and PSC-ozone sonde data. The relative accuracy is determined by the sum of the relative precision and the absolute value of the relative bias.

<table>
<thead>
<tr>
<th>Altitude Range (km)</th>
<th>RAW-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)</th>
<th>K86-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)</th>
<th>PSC-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPC-6A</td>
<td>ENSCI-Z</td>
<td>SPC-6A</td>
</tr>
<tr>
<td>30-35</td>
<td>-7.1 ± 6.3</td>
<td>-16.4 ± 5.5</td>
<td>-20.0 ± 3.8</td>
</tr>
<tr>
<td>25-30</td>
<td>-1.4 ± 6.9</td>
<td>-7.4 ± 4.6</td>
<td>-11.7 ± 3.4</td>
</tr>
<tr>
<td>20-25</td>
<td>-2.2 ± 8.4</td>
<td>-4.8 ± 5.5</td>
<td>-9.5 ± 4.7</td>
</tr>
<tr>
<td>15-20</td>
<td>-2.8 ± 8.0</td>
<td>-4.5 ± 5.3</td>
<td>-7.6 ± 3.9</td>
</tr>
<tr>
<td>10-15</td>
<td>2.6 ± 6.7</td>
<td>-7.2 ± 12.5</td>
<td>-7.9 ± 2.9</td>
</tr>
<tr>
<td>5-10</td>
<td>2.6 ± 6.7</td>
<td>-7.2 ± 12.5</td>
<td>-7.9 ± 2.9</td>
</tr>
<tr>
<td>0-5</td>
<td>2.6 ± 6.7</td>
<td>-7.2 ± 12.5</td>
<td>-7.9 ± 2.9</td>
</tr>
</tbody>
</table>
Table Annex C-3: Survey of the absolute and relative bias (systematic deviation) and absolute and relative precision of the KC96 ozone sonde for uncorrected, K86- and PSC-ozone sonde data. The accuracy is determined by the sum of the precision and the absolute value of the bias.
ANNEX D

List of people involved in JOSIE-2000
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JOSIE-2000 Organizing Team at WCCOS

Herman G.J. Smit (Coordinator, Principal Investigator)
Wolfgang Sträter (Simulation Chamber)
Manfred Helten (Logistics, Simulation Experiment)
Sabine Schroeder (Data Processing)
Thomas Heil (Computer Facilities)
Participating Ozone Sounding Laboratories

Campaign Period I (4-13 September 2000)

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Participant:
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Ian Boyd
Alan Thomas

Participating Laboratory Nr.4: FZJ (ECC-ozone sonde Type: SPC-6A)
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Marcel Berg
Participating Ozone Sounding Laboratories (continued)

Campaign Period II (18-27 September 2000)

Participating Laboratory Nr.5: WFF (ECC-ozone sonde Type: SPC-6A)
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Participating Laboratory Nr.6: SAP (ECC-ozone sonde Type: ENSCI-Z)
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Participating Laboratory Nr.7: URI (ECC-ozone sonde Type: ENSCI-Z)
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Jean-Marc Metzger

Participating Laboratory Nr.8: JMA (Japanese KC96 Sonde)
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Ozone Layer Monitoring Office
Aerological Division
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Sato, Takahiro
Formal Agreement of JOSIE-2000
JOSIE-2000, Jülich Ozone Sonde Intercomparison Experiment
4-13 September 2000 and 18–27 September 2000
(Sponsors: FZ-Jülich, WMO/GAW)

Formal Agreement

We, the principal investigator ................................................................................................................

and co-workers ..................................................................................................................................

..........................................................................................................................................................

sign this protocol for the JOSIE campaign. The principal investigator and all members of his or her group agree
♦ to participate in the campaign
♦ to abide by the rules, formulated in Strategy of JOSIE-2000 as Annex of this document, agreed by the group before the start of the campaign
♦ to adhere to general safety regulations for personnel, apparatus, materials, and motor vehicles which are established for the site and buildings or may be introduced by the organizer
♦ to have access to the entire database of JOSIE after signing a data protocol defining rights and duties of data usage

Location ...........................................

Date..................................................

.................................................................................................................
Signature (PI)

.................................................................................................................
Signature (Co-worker)

.................................................................................................................
Signature (Co-worker)

1. JOSIE-2000 is organized under the Global Atmosphere Watch programme of the World Meteorological Organization with the goal of providing ozone profile simulations useful in determining standard operating procedures (SOPs) for ozone sondes.

2. The JOSIE steering committee will make recommendations that result from the JOSIE-2000 intercomparisons, and the WMO will arbitrate on issues only if requested by the steering committee.

3. Each participating team of JOSIE-2000 must represent an ozone sounding station that routinely deploys one of the major types of ozone sondes used within GAW/GLONET.

4. Each participating team is responsible for its own profiling capabilities including sonde preparation procedures and data reduction algorithms. These algorithms will be provided to FZ-Julich and WMO prior to commencement of the campaign.

5. All pre-launch procedures for each ozone sonde must be performed by the responsible field operator using ground-check equipment provided by his station.

6. The simulated profile data will be directly integrated and stored in the data acquisition system (DAS) of the simulation facility. This will result in Raw Sounding Simulation (RSS) data for each sonde profile.

7. After each simulation run, the ozone data will be processed centrally by following the data analysis algorithms provided to FZ-Julich prior to the campaign. The resulting data will constitute the Normal Corrected Sounding (NCS) data for each sonde profile.

8. The NCS-data set is the primary standard of JOSIE-2000 which is fixed and will not be subject to any modification. Revisions to the NCS data can be reported in addition to the NCS-data if identified as revised, why the revisions were made, and how the revisions were made.

9. The set of NCS-data will be considered representative of chamber simulations of these ozone sondes under normal operating procedures and compared with the simultaneously measured data from the ozone reference photometer.

10. The set of uncorrected RSS-data in combination with the reduced NCS-data will be used to evaluate the effects of the data analysis procedures (e.g. background signal correction and total ozone column normalization) on final reduced data.

11. The intercomparison will be blind. This means that during the campaign, participating teams will not have access to the RSS and NCS-data of other teams. The reference data will also not be available before completion of the end of the campaign.

12. After the campaign, each Principle Investigator of JOSIE-2000 will have access to the entire database. The database will be exclusively used by the participants of JOSIE-2000 and by the steering committee for SOP evaluation, unless otherwise approved by the concerned participants and the steering committee.

13. During the campaign, preliminary evaluations of the simulation results may be made to assure nominal operation of the sondes has been achieved.

14. Workshop sessions are planned to discuss and develop SOPs for the sonde types tested. JOSIE-2000 is organized under the auspice of the Environmental Division of the World Meteorological Organization (WMO).
Data Protocol of JOSIE-2000
DATA PROTOCOL

The aims of the protocol are:

- to encourage rapid dissemination of the scientific results from JOSIE
- to uphold the rights of the individual scientists
- to have all involved researchers treated equitably.

These aims conflict at times, and it is hoped that the provisions of the protocol resolve these conflicts fairly. It is recognized that this cannot always be achieved to everyone's complete satisfaction; there are bound to be cases where individual interests clash with those of the programme. The two cases which we hope to avoid are the hoarding and poaching of data. To try to meet these aims, all Principal Investigators, in accordance with and on behalf of their co-investigators, must sign that they will abide the following conditions.

A. MEASUREMENTS

i) Data must be made available to other JOSIE-2000 scientists as soon as possible, as outlined in the JOSIE-2000 Planning Report (Version 2.0, 1 August 2000). There are 2 advantages to quick release: a) planning of the future development of the programme can be greatly improved, and b) scientific evaluation of the data can occur in a timely manner.

ii) Any corrections/amendments to the preliminary data should be announced as soon as possible.

iii) The Principal Investigators and their co-investigators agree to have access to the data contingent upon the following conditions: a) statement of scientific purpose from the party requesting the information; b) assurance of non-disclosure of data to other third parties; c) confirmation of use of the data for scientific information only.

B. GENERAL

i) Following the opening of the database to the scientific community, various co-investigators could associate with the JOSIE-2000 evaluation phase, working in connection with relevant PI’s. All scientists involved in JOSIE-2000 Programme are to have equal and complete access to measurements and model results produced during JOSIE-2000 Programme after signing this protocol.
ii) If measurements/model results from other research groups within JOSIE-2000 are used in a publication, joint authorship should be offered.

iii) The responsibility for the method with which data and model results are disseminated will rest with the central data bank (FZ-Jülich) and the JOSIE Steering Committee. Access to the data bank is granted only after having signed this protocol.

iv) Publication of results in the scientific literature is encouraged at any time during and after JOSIE-2000 Programme, as long as conditions ii) and iii) are met.

C. SCIENTIFIC STEERING COMMITTEE

Herman G.J. Smit   FZJ, Germany
Mike Proffitt       WMO, Switzerland
Samual J. Oltmans   NOAA/CMDL, USA
Anne Thompson      NASA/GSFC, USA
Pierre Viatte       Meteo Swiss, Switzerland

D. PRINCIPAL INVESTIGATORS

Herman G.J. Smit   FZJ, Germany
Bryan Johnson      NOAA/CMDL, USA
Jonathan Davies    AES, Canada
Greg Bodeker       NIWA, New Zealand
Manfred Helten     FZJ, Germany
Francis Schmidlin  NASA/GSFC, USA
Bruno Hoegger      Meteo Swiss/SAP, Switzerland
Francoise Posny    URI, France
Toshifumi Fujimoto JMA, Japan
The undersigned agrees to the conditions of this data protocol.

Institution:

Address:

Name(s) of scientist(s), acting as Co-investigator(s):

Associated to PI:

Date : Signature(s):

Stamp of Institution:

Please return to: Send copy to:

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**WMO**
c/o Mike Proffitt
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8. Review of the Chemical Composition of Precipitation as Measured by the WMO BAPMoN by Prof. Dr. Hans-Walter Georgii, February 1982.


14. Effects of Sulphur Compounds and Other Pollutants on Visibility by Dr. R.F. Pueschel, April 1983.


19. Forecasting of Air Pollution with Emphasis on Research in the USSR by M.E. Berlyand, August 1983.


26. Sulphur and Nitrogen in Precipitation: An Attempt to Use BAPMoN and Other Data to Show Regional and Global Distribution by Dr. C.C. Wallén. April 1986 (WMO TD No. 103).


29. Recommendations on Sunphotometer Measurements in BAPMoN Based on the Experience of a Dust Transport Study in Africa by Dr. Guillaume A. d'Almeida. September 1985 (WMO TD No. 67).


43. Recent progress in sunphotometry (determination of the aerosol optical depth). November 1986.


58. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the years 1986 and 1987 (WMO TD No. 306).


62. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at BAPMoN sites for the year 1988 (WMO TD No. 355).


69. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1989 (WMO TD No. 400).


72. Integrated Background Monitoring of Environmental Pollution in Mid-Latitude Eurasia by Yu.A. Izrael and F.Ya. Rovinsky, USSR (WMO TD No. 434).


75. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at Global Atmosphere Watch (GAW)-BAPMoN sites for the year 1990 (WMO TD No. 447).


77. Report of the WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques, Lake Arrowhead, California, 14-19 October 1990.


84. Provisional Daily Atmospheric Carbon Dioxide Concentrations as measured at GAW-BAPMoN sites for the year 1991 (WMO TD No. 543).

85. Chemical Analysis of Precipitation for GAW: Laboratory Analytical Methods and Sample Collection Standards by Dr Jaroslav Santroch (WMO TD No. 550).


89. 4th International Conference on CO₂ (Carqueiranne, France, 13-17 September 1993) (WMO TD No. 561).


91. Extended Abstracts of Papers Presented at the WMO Region VI Conference on the Measurement and Modelling of Atmospheric Composition Changes Including Pollution Transport, Sofia, 4 to 8 October 1993 (WMO TD No. 563).


97. Quality Assurance Project Plan (QAPjP) for Continuous Ground Based Ozone Measurements (WMO TD No. 634).


104. Report of the Fourth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the First Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE, Garmisch-Partenkirchen, Germany, 13 to 17 March 1995 (WMO TD No. 689).


113. The Strategic Plan of the Global Atmosphere Watch (GAW) (WMO TD No. 802).


120. WMO-UMAP Workshop on Broad-Band UV Radiometers (Garmisch-Partenkirchen, Germany, 22 to 23 April 1996) (WMO TD No. 894).


126. Guidelines for Site Quality Control of UV Monitoring (lead author A.R. Webb) (WMO TD No. 884).


129. Guidelines for Atmospheric Trace Gas Data Management (Ken Masarie and Pieter Tans), 1998 (WMO TD No. 907).


131. WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2 to 5 June 1998) (Gregory R. Carmichael). Two volumes.


133. Workshop on Advanced Statistical Methods and their Application to Air Quality Data Sets (Helsinki, 14-18 September 1998) (WMO TD No. 956).


135. Sixth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Zurich, Switzerland, 8-11 March 1999) (WMO TD No.1002).


139. The Fifth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Halkidiki, Greece, September 1998)(WMO TD No. 1019).


146. Quality Assurance in monitoring solar ultraviolet radiation: the state of the art. (WMO TD No. 1180).

147. Workshop on GAW in RA VI (Europe), Riga, Latvia, 27-30 May 2002 (WMO TD No. 1206).


149. Comparison of Total Ozone Measurements of Dobson and Brewer Spectrophotometers and Recommended Transfer Functions (prepared by J. Staehelin, J. Kerr, R. Evans and K. Vanicek) (WMO TD No. 1147).


154. WMO/IMEP-15 Trace Elements in Water Laboratory Intercomparison. (WMO TD No. 1195).

