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The 2000 WMO international intercomparison of operating procedures for ECC-ozone sondes at the environmental simulation facility at Jülich

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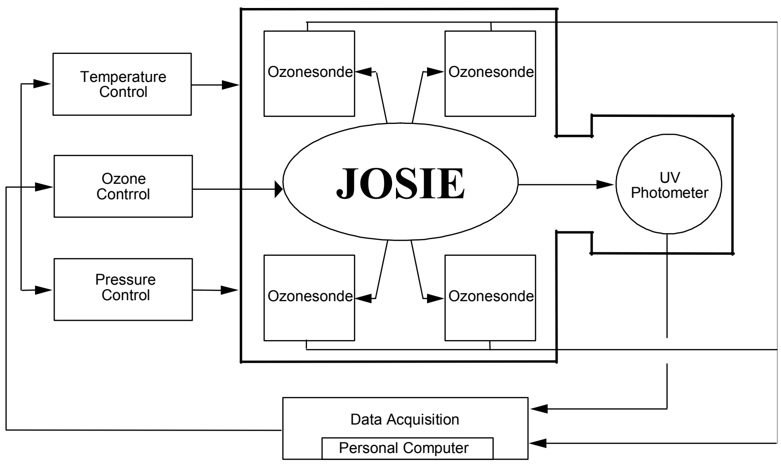

Jülich Ozone Sonde Intercomparison Experiment 2000

The 2000 WMO international intercomparison of operating procedures for ECC-ozone sondes at the environmental simulation facility at Jülich

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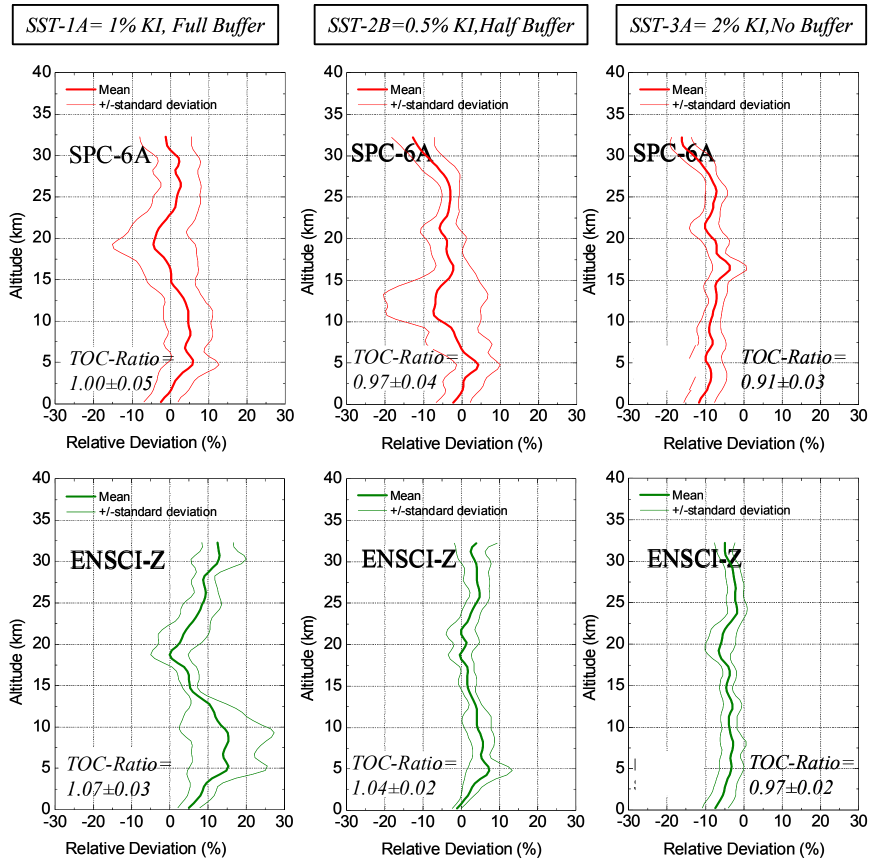
WMO TD No. 1225

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-sondes 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).



[TOC-Ratio = Ratio Total Ozone Column of Sonde to Ref.]

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

Table of Contents

1. INTRODUCTION

Up to an altitude of about 20 km, ozone sondes constitute the most important data source with longterm 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).

Figure 1: *Ozone sounding at launch.*

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]

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 platinium 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.

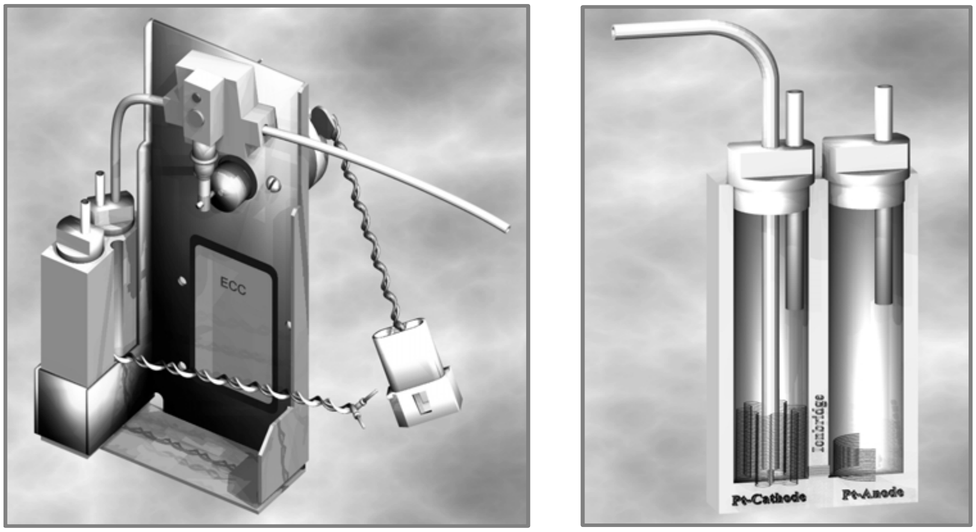


Figure 2: *Scheme of ECC-Sonde (left) with cross-sectional view of ECC-sensor.*

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.

Nr.	Participating Group Code	Participating Sounding Laboratory	JOSIE Campaign Period	Participating Persons	Ozone Sonde Type	SST Nr.
1	JS_PG1 (CMDL)	NOAA/CMDL *(Boulder, CO, USA)*	C-I	*Bryan Johnson (PI), Sam Oltmans*	ECC *ENSCI-Z & SPC-6A*	3A
2	JS_PG2 (AES)	AES *(Ontario,Canada)*	C-I	*Jonathan Davies (PI),*	ECC *SPC-6A*	3A
3	JS_PG3 (NIWA)	NIWA *(Lauder, New Zealand)*	C-I	*Greg Bodeker (PI), Ian Boyd Alan Thomas*	ECC *ENSCI-Z*	2B
4	JS_PG4 (FZJ)	FZJ/ICG2 *(Jülich, Germany)*	C-I	*Manfred Helten (PI) Marcel Berg*	ECC *SPC-6A*	2B
5	JS_PG5 (WFF)	NASA/WFF *(Wallops Island, Virginia, USA)*	C-II	*Frank Schmidlin (PI), E. David Ross E Thomas Northam*	ECC *SPC-6A*	1A
6	JS_PG6 (SAP)	MS/SAP *(Payerne, Switzerland)*	C-II	*Bruno Hoegger (PI) Rene Stubi, Gilbert Levrat*	ECC *ENSCI-Z*	1A
7	JS_PG7 (URI)	URI *(Reunion Island, France)*	C-II	*Francoise Posny (PI), Jean-Marc Metzger*	ECC *ENSCI-Z*	2B/3A
8	JS_PG8 (JMA)	JMA *(Tokyo, Japan)*	C-II	*Toshifumi Fujimoto (PI), Takahiro Sato*	KC96	-

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.

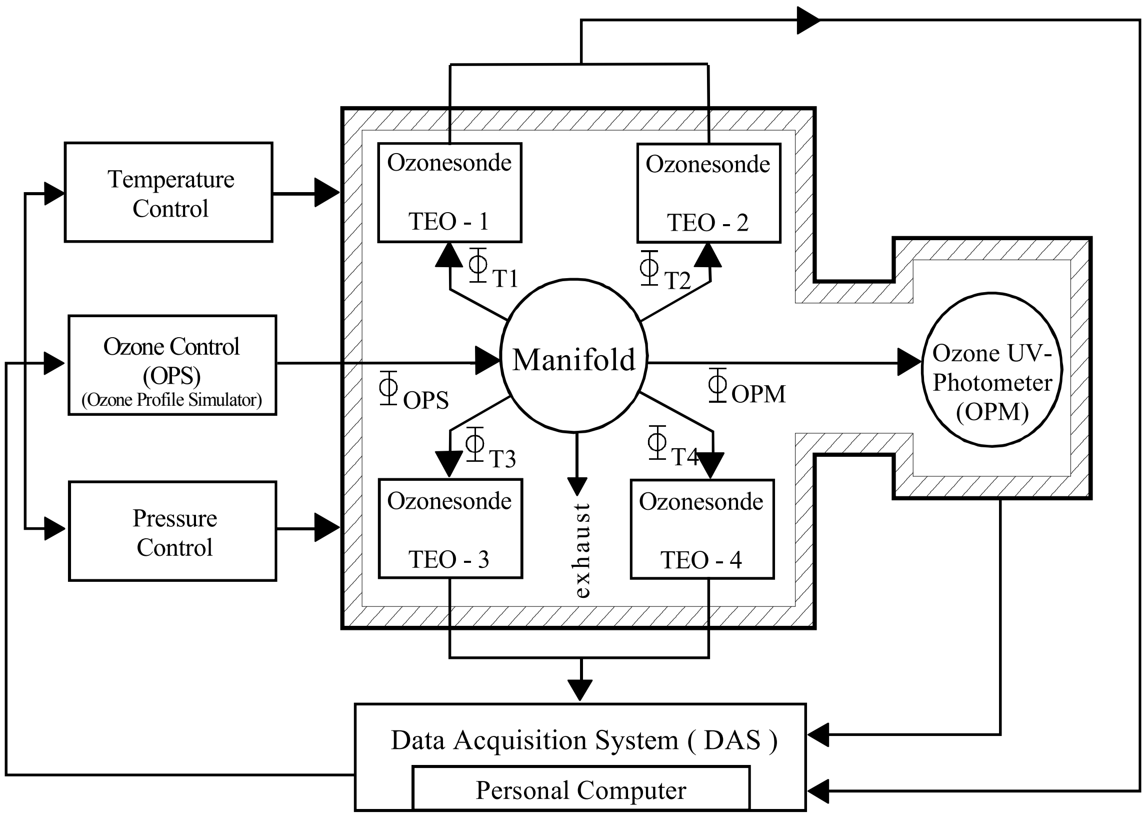


Figure 4: *Set up for the simulation of vertical ozone soundings.*

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.

SST	Description of Sensing Solution Type (SST)
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)

Table 3: *Different sensing solution types (SST) for ECC-ozone sondes. The SST 1A, 2B and -3A have been used during JOSIE 2000.*

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 sub-tropical conditions were simulated.

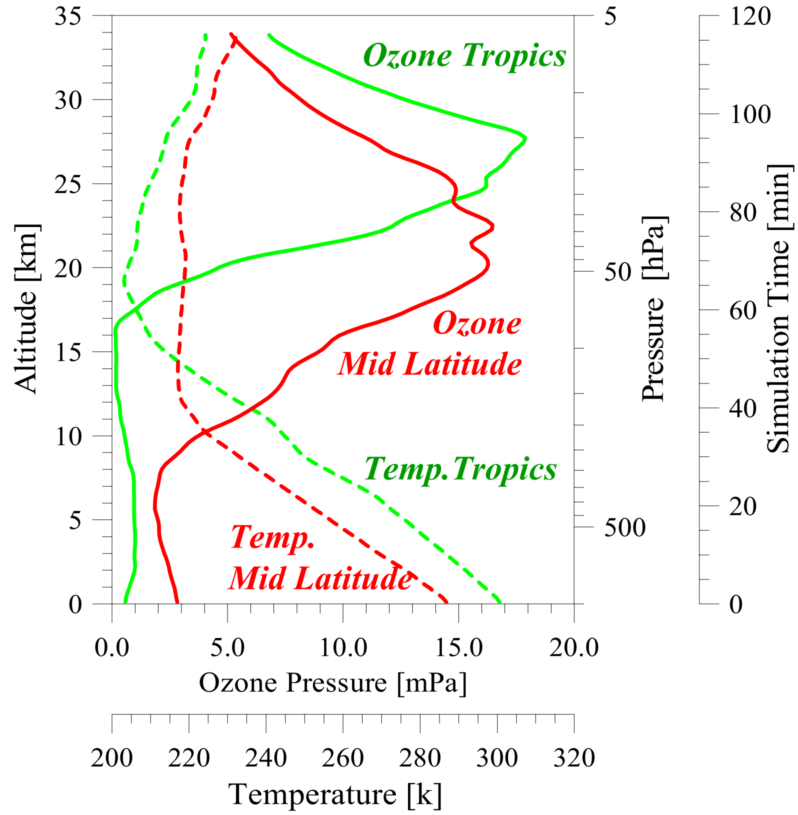


Figure 5: *Vertical profiles of the simulation of ozone pressure and temperature at mid latitude and tropical conditions.*

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 a 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-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 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 from18 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.

Sim. Exp. Nr.	Profile Type	Profile Type Index	Specifications	Step-Response (Down & Up)	Comments
89	Mid-Latitude	I-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
90	Mid-Latitude	I-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
91	Tropical	II-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
92	Tropical	II-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
93	Step Up/Down	IV-A	Different O_3-levels at discrete Pressures (1000 hPa-5 hPa)	-	
94	Sub-Tropical	III-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	Sinus Wave Modulation
95	Sub-Tropical	III-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	Sinus Wave Modulation
96	Mid-Latitude	I-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
97	Mid-Latitude	I-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
98	Tropical	II-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
99	Tropical	II-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	
100	Sub-Tropical	III-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	Sinus Wave Modulation
101	Step Up/Down	IV-A	Different O_3-levels at discrete Pressures (1000 hPa-5 hPa)	-	
102	Sub-Tropical	III-A	Ascent v=5m/s, Z=0-35 km	MT at Z≈5km LS at Z≈20km (O_3=0 for 3 min)	Sinus Wave Modulation

Table 4: *Specifications of JOSIE-2000 simulation experiments. MT = Mid Troposphere ; LS = Lower Stratosphere; v= ascent velocity ; Z = altitude*

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:

[E-1] $$\Delta Z = \frac{R}{g} * \frac{T_{i+1} + T_i}{2} * Ln\left(\frac{P_i}{P_{i+1}}\right)$$, 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-ozonesondes 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.

Sim. Exp. Nr.	PG Nr.1: CMDL		PG Nr.2: AES		PG Nr.3: NIWA		PG Nr.4: FZJ	
	Temp.Int.	Temp.Ext	Temp.Int	Temp.Ext	Temp.Int	Temp.Ext	Temp.Int	Temp.Ext
89	∆Tp-CMDL	DAS	∆Tp-WFF	DAS	∆Tp-NIWA	DAS	∆Tp-WFF	DAS
90	∆Tp-NIWA	DAS	∆Tp-WFF	DAS	∆Tp-NIWA	DAS	∆Tp-WFF	DAS
91	∆Tp-CMDL	DAS	∆Tp-WFF	DAS	∆Tp-NIWA	DAS	∆Tp-WFF	DAS
92	∆Tp-NIWA	DAS	∆Tp-WFF	DAS	∆Tp-NIWA	DAS	∆Tp-WFF	DAS
93	∆Tp-NIWA	DAS	∆Tp-WFF	DAS	∆Tp-NIWA	DAS	∆Tp-WFF	DAS
94	∆Tp-NIWA	DAS	∆Tp-WFF	DAS	DVM	DAS	DVM	DAS **(1)**
95	DVM **(2)**	DAS**(2)**	∆Tp-WFF	DAS	DVM	DAS	∆Tp-WFF	DAS
Sim. Exp. Nr.	**PG Nr.5: WFF**		**PG Nr.6: SAP**		**PG Nr.7: URI**		**PG Nr.8: JMA**	
	Temp.Int.	Temp.Ext	Temp.Int	Temp.Ext	Temp.Int	Temp.Ext	Temp.Int	Temp.Ext
96	DVM	DAS	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
97	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
98	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
99	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
100	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
101	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---
102	DAS	DVM	DAS	∆Tp-NIWA	∆Tp-NIWA	DAS	---	---

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 ∆Tp-CMDL for SPC-6A by CMDL, or ∆Tp-WFF for SPC-6A by WFF, and ∆Tp-NIWA for ENSCI-Z by NIWA (see text and figure 4)*

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.

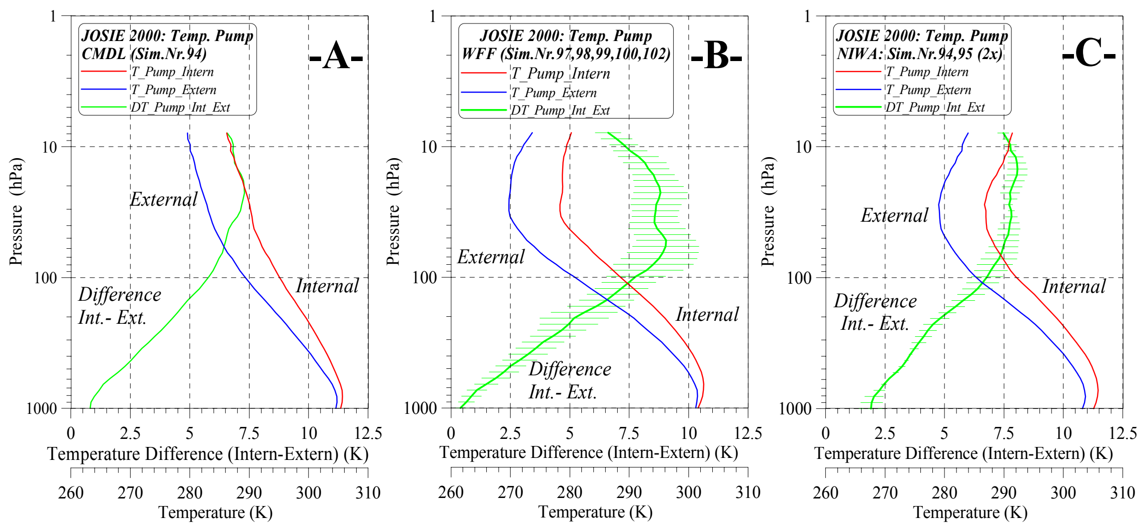


__Figure 6:__ Internal (red curve) and external (blue curve) pump temperature and their differences (green curve) as a function of simulated air pressure as measured for: (i) SPC-6A sonde operated by CMDL during Sim.Nr.94 (Diagram A), (ii) three ENSCI-Z sondes operated by NIWA during Sim.Nr.94 &95 (Diagram 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, ΔTp-CMDL (over one CMDL-sounding in Sim.Nr.94) and ΔTp-WFF (averaged over 5 WFF-soundings in Sim.Nr.97, 98, 99, 100, &102), and one characteristic for the ENSCI-Z sonde, ΔTp-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 ΔTp-CMDL characteristic is assumed to be only representative for the SPC-6A-sondes operated by CMDL. For all other SPC-6A sondes, the ΔTp-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^{o}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] $$P_{O3,Sonde} = C_{Sonde} * I_{O3,Sonde}$$

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

[E-3] $$\mathbf{C_{Sonde} = 0.04307 * \eta_{Sonde} * \frac{T_{Pump}}{\Phi_{V,Pump}}}$$

$P_{O3,Sonde}$ = 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, [μA]
η_{Sonde} = Conversion efficiency of the ozone sensor

The conversion efficiency η_{Sonde} is the overall result of the influences of several different parameters, such as absorption efficiency of O_3 into the sensing solution, stoichoimetry 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] $$\mathbf{I_{O3,Sonde} = I_{M,Sonde} - I_{B,Sonde}}$$

$I_{M,Sonde}$ = 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.

.Background Correction	Temperature Pump	Pumpflow Corrections
Before Exposure to Ozone Pressure Dependent	External	Pump Efficiency: Komhyr 1986 (2.5 cm3 of sensing solution in cathode cell).

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).

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

[E5] $$\Phi_{\mathrm{Pump,Actual}} = \Phi_{\mathrm{Meas}} * \left[\frac{\left(P_{\mathrm{Lab}} - \Delta P_{H_2O}\right)}{P_{\mathrm{Lab}}} \right]$$

[E6] $$\Delta P_{H_2O}\left(T_{\mathrm{Lab}}\right) = \left[1 - \frac{RH_{\mathrm{Air}}}{100} \right] * P_{H_2O,\mathrm{Sat}}\left(T_{\mathrm{Lab}}\right)$$

[E7] $$\Phi_{\mathrm{Pump,Actual}} = \Phi_{\mathrm{Meas}} * \left[1 - \left[1 - \frac{RH_{\mathrm{Air}}}{100} \right] * \frac{P_{H_2O,\mathrm{Sat}}\left(T_{\mathrm{Lab}}\right)}{P_{\mathrm{Lab}}} \right]$$

Whereby:

Φ_{Meas}	=	Pump flow rate measured with bubble flow meter.
$\Phi_{\mathrm{Pump,\ Actual}}$	=	Actual pump flow rate after correction for "moistening effect".
P_{Lab}	=	Pressure laboratory
T_{Lab}	=	Temperature laboratory
$\Delta P_{H2O}(T_{\mathrm{Lab}})$	=	Water vapour contribution due to evaporation in the sampling air at T_{Lab}.
RH_{Air}	=	Relative Humidity of the sampled air at the intake of the pump [%]
$P_{H2O,\mathrm{Sat}}(T_{\mathrm{Lab}})$	=	Saturated water vapour pressure at T_{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 $RH_{\mathrm{Air}}= RH_{\mathrm{Lab}}$. The other participants (FZJ, WFF, ASP, and JMA) used dry air (RH_{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 [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.

Pressure (hPa)	Correction after Komhyr 1986 (Handbook) (2.5 cm3 cathode solution)	Correction after Komhyr 1995 (STOIC-1989) (2.5 cm3 cathode solution)	Correction after ENSCI-Z Handbook (Komhyr, 1997)	Correction after Torres et al. (1981)
1000	1.000	1.000	1.000	1.000
200	1.007	1.000	1.000	1.000
150	1.008	1.002	1.002	1.000
100	1.010	1.007	1.007	1.000
70	1.012	1.012	1.013	1.007
50	1.015	1.018	1.018	1.013
30	1.024	1.029	1.029	1.025
20	1.033	1.041	1.041	1.035
15	1.041	1.048	1.048	1.046
10	1.054	1.066	1.066	1.063
7	1.070	1.087	1.087	1.085
5	1.087	1.124	1.124	1.105
3	1.124	1.240	1.240	---

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).*

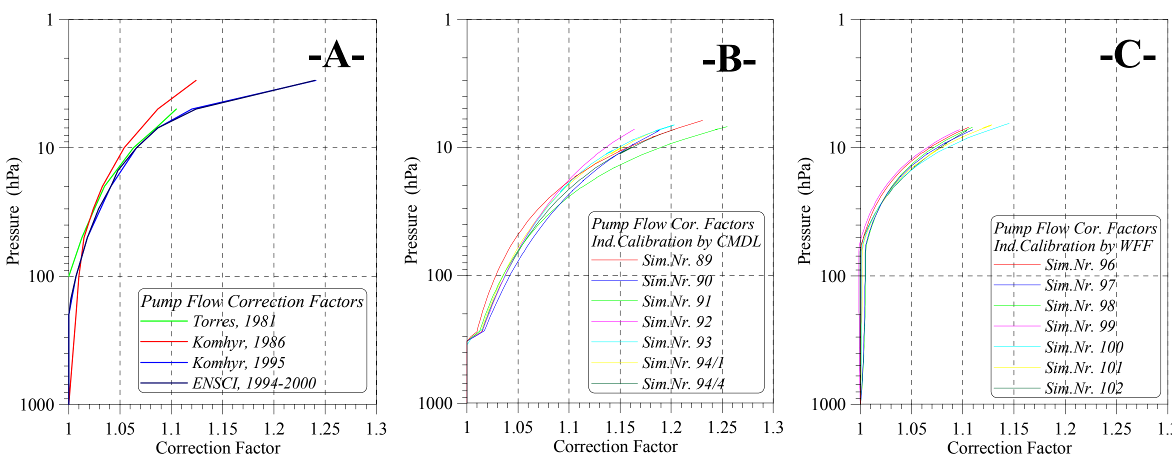


Figure 7: *Pump flow correction factors as a function of pressure used in JOSIE 2000. Diagram A: Factors reported by Torres (1981), Komhyr (1986), Komhyr et al.(1995), and Komhyr, (1997), Diagram B and C: Factors from individual pump flow calibrations of each „flown“ sonde made by CMDL (PG-Nr.1) and WFF (PG-Nr.5) respectively.*

CMDL PG-Nr.1	Sim.Nr.89	Sim.Nr.90	Sim.Nr.91	Sim.Nr.92	Sim.Nr.93	Sim.Nr.94/1	Sim.Nr.94/4
Pressure (hPa)	6A9992	2Z1860	6A8885	2Z1567	2Z1600	2Z1610	6A8839
1000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	1.015	1.024	1.018	1.022	1.021	1.020	1.021
150	1.020	1.031	1.025	1.028	1.028	1.026	1.027
100	1.028	1.042	1.036	1.038	1.038	1.036	1.038
70	1.038	1.054	1.047	1.047	1.048	1.046	1.048
50	1.049	1.066	1.060	1.058	1.058	1.057	1.060
30	1.070	1.087	1.086	1.076	1.078	1.077	1.081
20	1.094	1.108	1.114	1.095	1.097	1.098	1.104
15	1.116	1.126	1.140	1.110	1.115	1.117	1.124
10	1.158	1.158	1.190	1.136	1.148	1.151	1.161
7	1.209	1.195	1.252	1.167	1.195	1.193	1.208
5	1.274	1.246	1.335	1.211	1.278	1.250	1.277
3	1.380	1.424	1.525	1.382	1.701	1.425	1.527

WFF PG-Nr.5	**Sim.Nr.96**	**Sim.Nr.97**	**Sim.Nr.98**	**Sim.Nr.99**	**Sim.Nr.100**	**Sim.Nr.101**	**Sim.Nr.102**
Pressure (hPa)	**6A9774**	**6A9775**	**6A9776**	**6A9777**	**6A9778**	**Z05381**	**6A9779**
1000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	1.000	1.004	1.005	0.999	1.001	1.002	1.000
150	1.000	1.004	1.005	0.999	1.001	1.002	1.000
100	1.001	1.005	1.005	0.999	1.001	1.002	1.000
70	1.001	1.005	1.005	0.998	1.001	1.002	1.000
50	1.003	1.007	1.008	1.001	1.004	1.005	1.003
30	1.014	1.018	1.018	1.011	1.017	1.017	1.017
20	1.027	1.031	1.031	1.025	1.033	1.032	1.033
15	1.040	1.045	1.044	1.038	1.049	1.048	1.049
10	1.068	1.074	1.071	1.065	1.084	1.079	1.077
7	1.105	1.114	1.108	1.100	1.132	1.121	1.109
5	1.156	1.172	1.160	1.149	1.201	1.179	1.141
3	1.287	1.326	1.295	1.268	1.386	1.323	1.177

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

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[1] The response time τ_{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 $S(t) = S(0) * Exp[-t/\tau_{Res}]$

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.

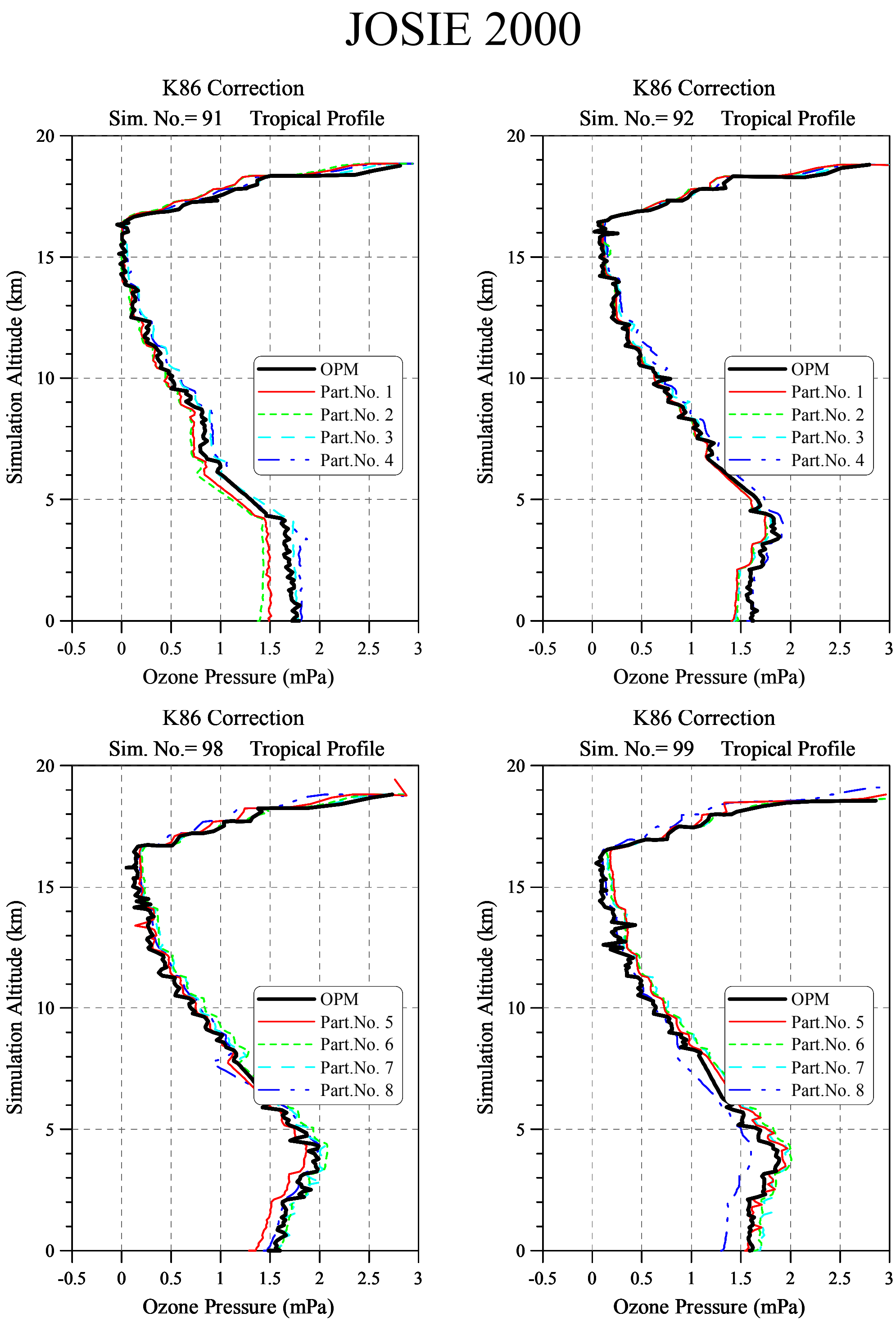

Figure 8: *Vertical profiles measured by the different sondes (thin lines) and the UV-photometer (fat line) for the tropospheric parts of the tropical type of profiles.*

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 $\pm$(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 $\Rightarrow$ SST-2B $\Rightarrow$ 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 $\pm$0.02) is significantly smaller than for SPC-6A (standard deviation of $\pm$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$\pm$0.02. This is a significant improvement compared to normalization factors (0.91$\pm$0.1) obtained for the KC79-sonde (predecessor of KC96) during JOSIE 1996.

Sim. Nr.	**Part. Nr**	**Sonde Code**	**Sens.Sol. Type SST**	Total Ozone Norm. Factor RAW-Data	**Total Ozone Norm. Factor K86-Data**	Total Ozone Norm. Factor PSC-Data
94	2	6A6939	1A	0,982	**0,958**	0,946
95	2	6A7093	1A	0,962	**0,937**	0,925
96	5	6A9774	1A	0,968	**0,949**	0,952
97	5	6A9775	1A	1,009	**0,990**	0,968
98	5	6A9776	1A	1,084	**1,056**	1,041
99	5	6A9777	1A	1,058	**1,029**	1,013
100	5	6A9778	1A	1,043	**1,018**	0,996
102	5	6A9779	1A	1,093	**1,066**	1,042
Average over 8 SPC-6A Sondes (±σ) For Sens.Sol.Type = 1A				1.025±0.050	**1.000±0.050**	0.985±0.044
89	4	6A7015	2B	1,030	**1,009**	1,007
90	4	6A7091	2B	1,017	**0,995**	0,980
91	4	6A7092	2B	1,085	**1,049**	1,030
92	4	6A7094	2B	1,042	**1,012**	1,011
95	4	6A7099	2B	1,122	**1,093**	1,070
Average over 5 SPC-6A Sondes (±σ) For Sens.Sol.Type = 2B				1.059±0.043	**1.032±0.040**	1.020±0.033
89	1	6A9992	3A	1,075	**1,053**	1,025
91	1	6A8885	3A	1,140	**1,108**	1,065
94	1	6A8839	3A	1,132	**1,106**	1,065
89	2	6A7089	3A	1,075	**1,053**	1,028
90	2	6A7098	3A	1,109	**1,086**	1,078
91	2	6A7090	3A	1,158	**1,127**	1,125
92	2	6A7012	3A	1,126	**1,097**	1,107
Average over 7 SPC-6A Sondes (±σ) For Sens.Sol.Type = 3A				1.116±0.032	**1.090±0.028**	1.070±0.037

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.*

Sim. Nr.	Part. Nr	Sonde Code	Sens.Sol. Type SST	Total Ozone Norm. Factor RAW-Data	**Total Ozone Norm. Factor K86-Data**	Total Ozone Norm. Factor PSC-Data
94	3	1Z1758	1A	0,927	**0,905**	0,889
95	3	1Z1757	1A	0,929	**0,914**	0,938
96	6	Z03716	1A	0,999	**0,978**	0,962
97	6	Z03709	1A	0,946	**0,926**	0,911
98	6	Z03746	1A	0,979	**0,952**	0,939
99	6	Z03763	1A	0,975	**0,948**	0,935
100	6	Z05420	1A	0,929	**0,905**	0,9
102	6	Z03749	1A	0,941	**0,916**	0,905
Average over 8 ENSCI-Z Sondes (±σ) For Sens.Sol.Type = 1A				0.953±0.027	**0.931±0.026**	0.922±0.025
89	3	1Z1741	2B	0,982	**0,962**	0,964
90	3	1Z1742	2B	0,946	**0,926**	0,914
91	3	1Z1744	2B	0,980	**0,952**	0,938
92	3	1Z1745	2B	0,990	**0,966**	0,948
95	3	1Z1756	2B	0,993	**0,970**	0,954
98	7	Z05416	2B	1.000	**0,972**	0,948
99	7	Z05417	2B	0,999	**0,970**	0,946
100	7	Z05421	2B	0,998	**0,973**	0,949
101	7	Z05418	2B	-	**-**	-
Average over 8 ENSCI-Z Sondes (±σ) For Sens.Sol.Type = 2B				0.986±0.018	**0.961±0.016**	0.945±0.015
90	1	2Z1860	3A	1,032	**1,012**	0,948
92	1	2Z1567	3A	1,073	**1,044**	0,999
94	1	2Z1610	3A	1,057	**1,032**	1,011
96	7	Z05414	3A	1,069	**1,050**	1,025
97	7	Z05415	3A	1,052	**1,030**	1,006
102	7	Z05419	3A	1,042	**1,015**	0,991
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.*

Sim. Nr.	Part. Nr	Sonde Code KC96	Sens.Sol. Type SST	Total Ozone Norm. Factor RAW-Data	Total Ozone Norm. Factor K86-Data	Total Ozone Norm. Factor PSC-Data
96	8	99306	4A	0,976	0,906	0,934
97	8	99314	4A	1,002	0,935	0,960
98	8	99307	4A	1,014	0,920	0,956
99	8	99309	4A	1,078	0,974	0,997
100	8	99310	4A	1,025	0,935	0,959
101	8	99315	4A	-	-	-
102	8	99312	4A	1,011	0,924	0,942
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.*

	Total Ozone Normalization Factor K86 Corrected Data			
Campaign	**Sensing Solution Type**	**SPC-6A**	**ENSCI-Z**	**Difference SPC-6A minus ENSCI**
JOSIE-2000	SST-1A	1.00±0.05 *(N=8)*	0.93±0.03 *(N=8)*	0.07
JOSIE-2000	SST-2B	1.03±0.04 *(N=5*	0.96±0.02 *(N=8)*	0.07
JOSIE-2000	SST-3A	1.09±0.03 *(N=7)*	1.03±0.02 *(N=6)*	0.06
JOSIE-1998	SST-1A	0.97±0.05 *(N=13)*	0.93±0.01 *(N=13)*	0.04
JOSIE-1996	SST-1A	1.00±0.05 *(N=6)*	0.95±0.02 *(N=6)*	0.05

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.

JOSIE-2000

K86 Correction

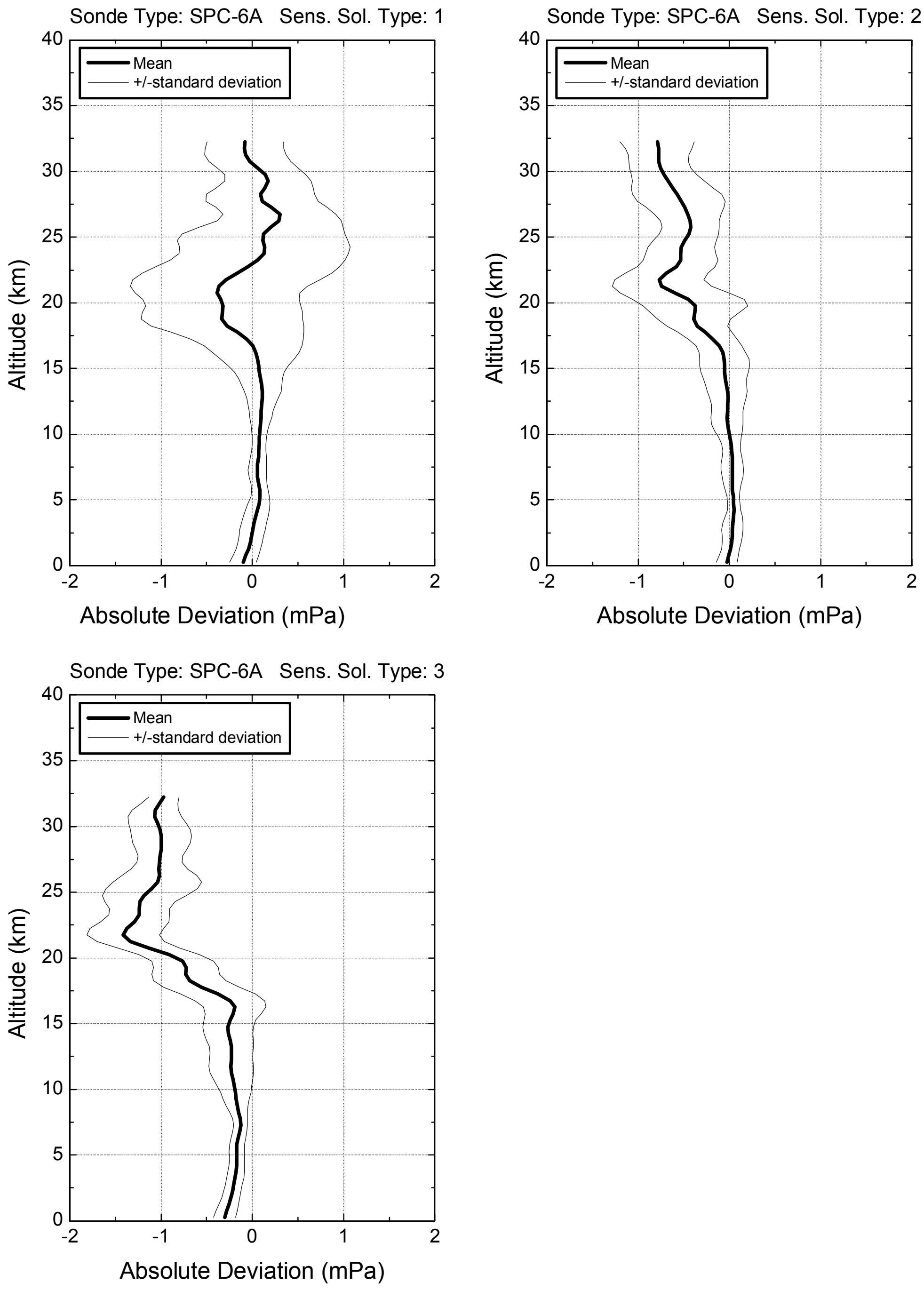

Figure 9-A: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual K86-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.*

JOSIE-2000

K86 Correction

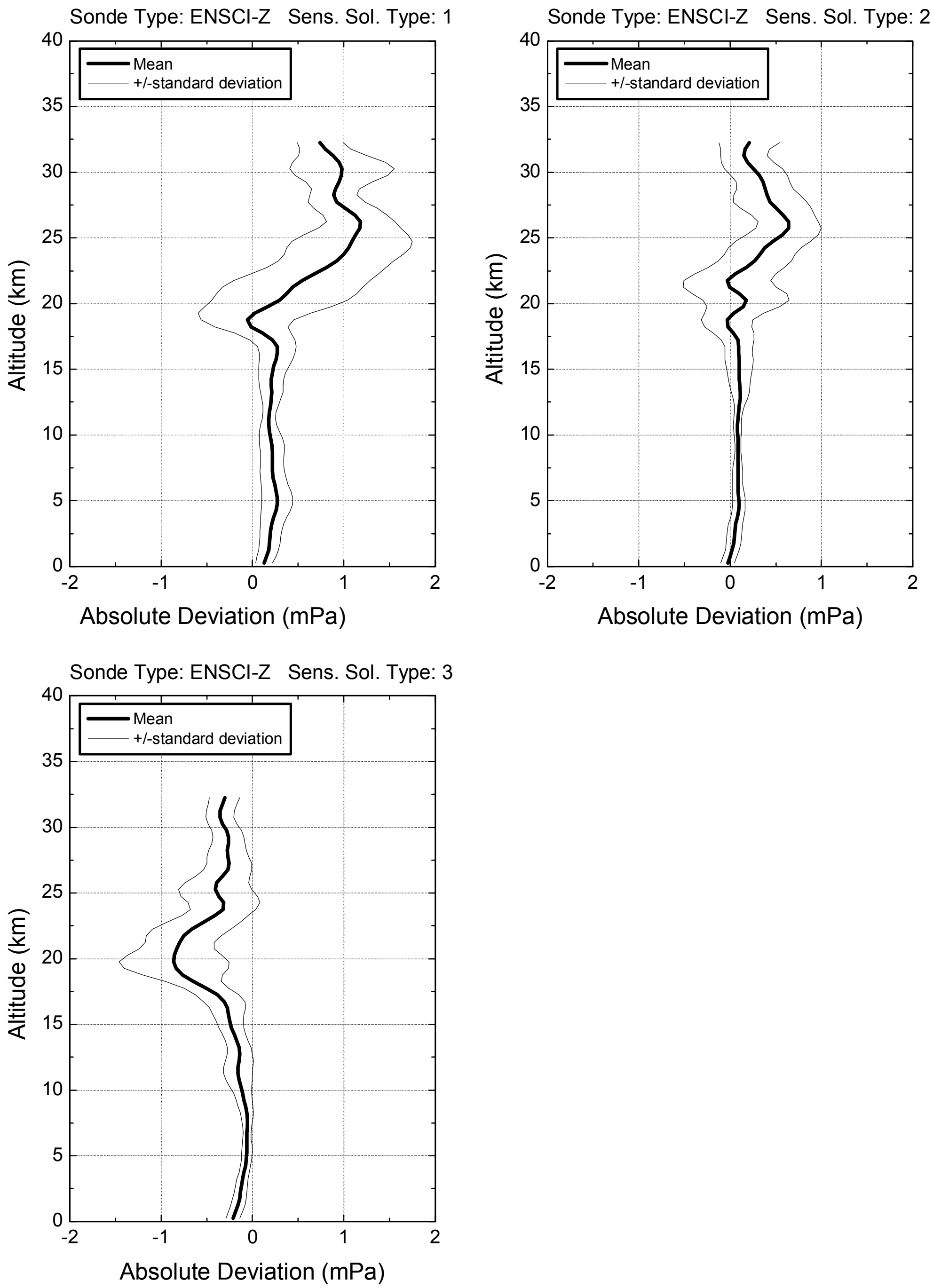

Figure 9-B: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual K86-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.*

JOSIE-2000

K86 Correction

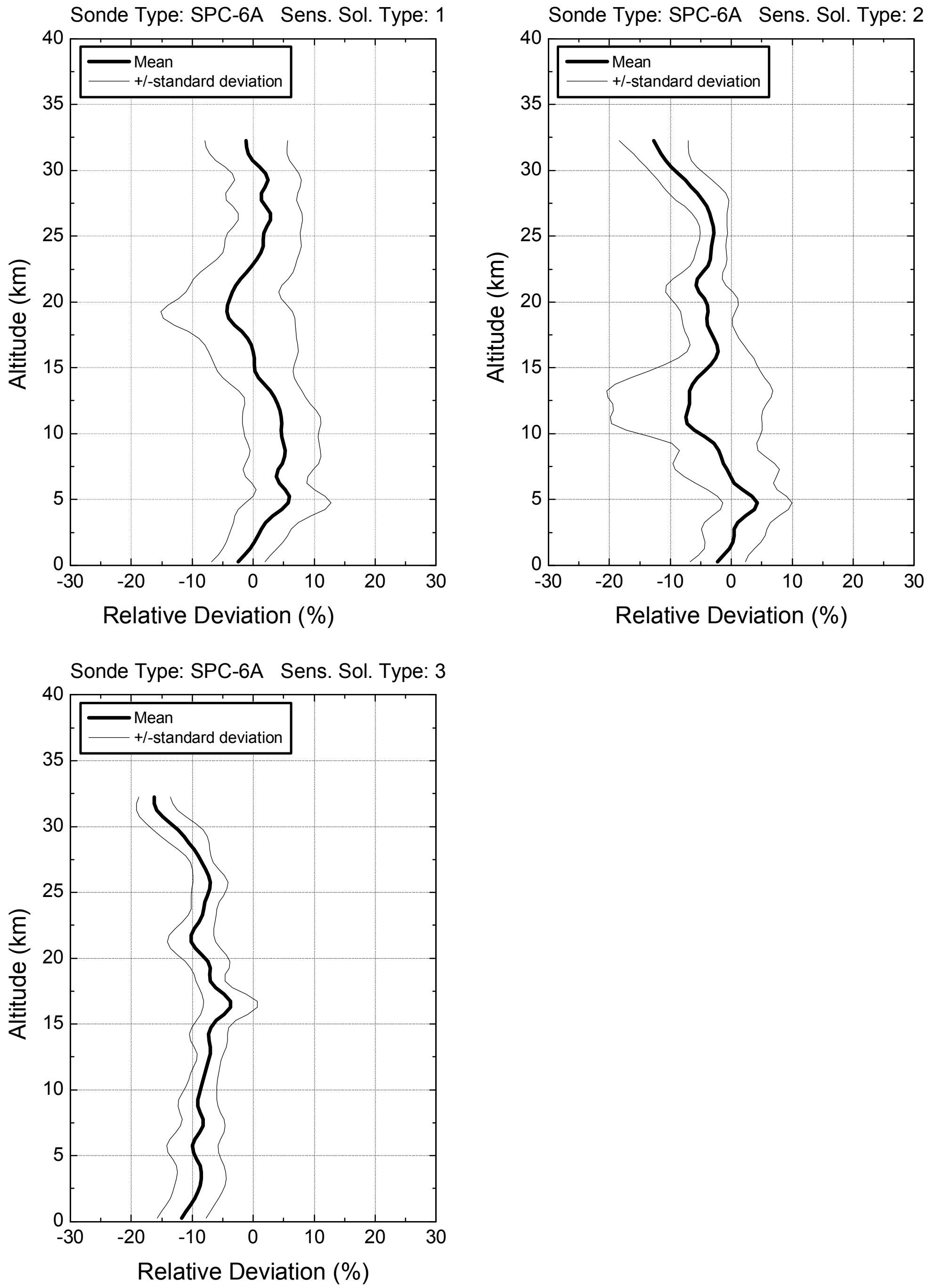

Figure 10-A: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual K86-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.*

JOSIE-2000

K86 Correction

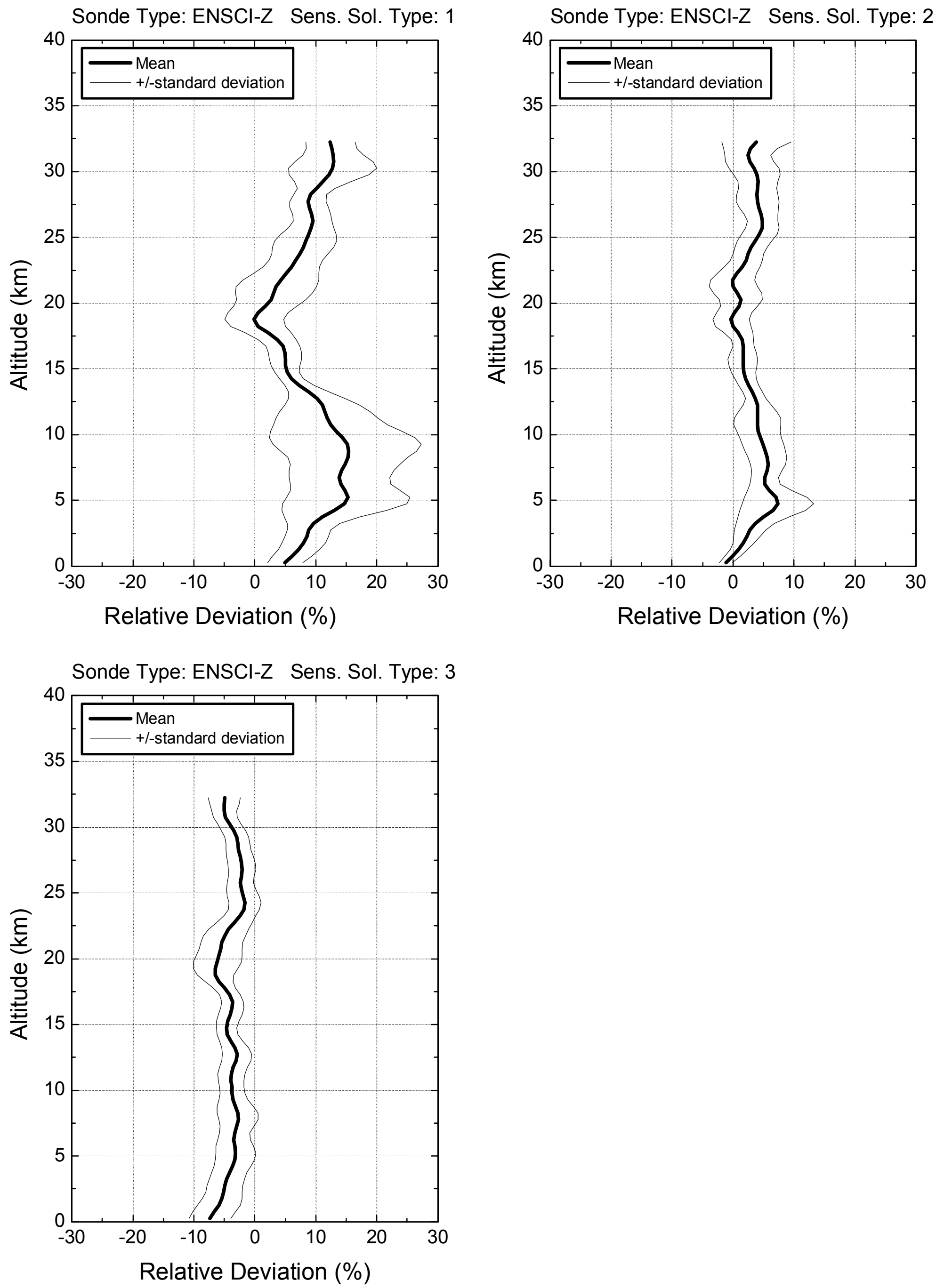

Figure 10-B: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual K86-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.*

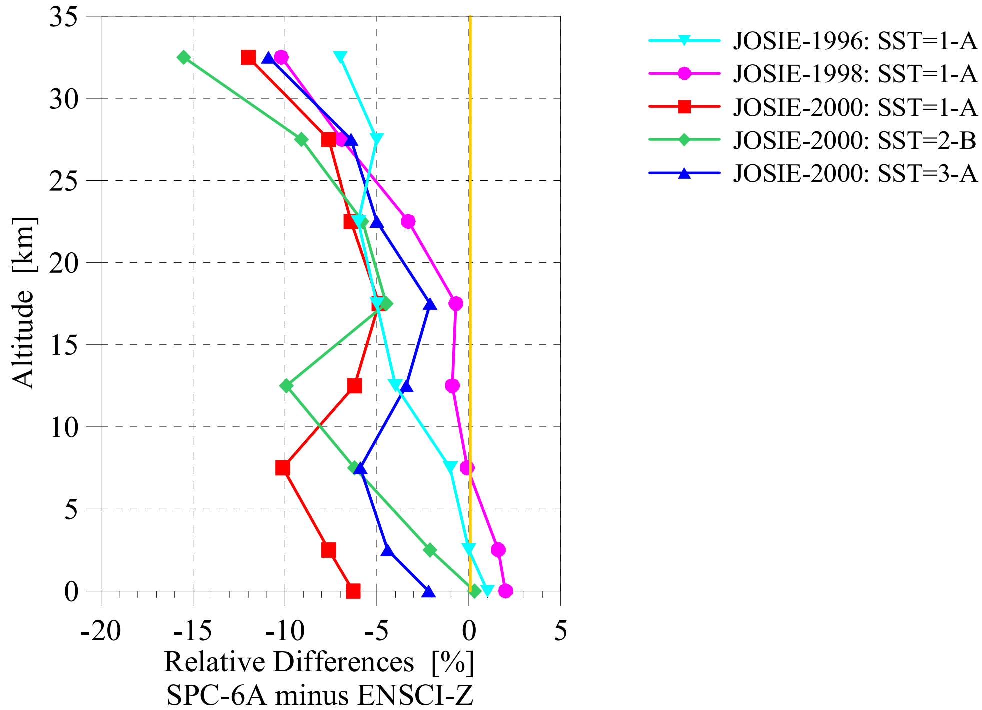

Figure 11: *Comparison of the relative differences between SPC-6A and ENSCI sonde types derived from the differences of the average relative deviations of the SPC-6A and ENSCI-Z sondes with the UV-photometer as presented in the Figure 8 for each of the sensing solution types. Included are the results of comparisons between SPC6A and ENSCI obtained during JOSIE 1996 and 1998 where both sondes were operated with SST-1A.*

Altitude Range Km	Relative Difference (SPC6A – ENSCI) / ENSCI x 100%				
	JOSIE 1996 SST=1A	JOSIE 1998 SST=1A	JOSIE 2000 SST=1A	JOSIE 2000 SST=2B	JOSIE 2000 SST=3A
30-35	-7	-10,2	-12	-15,5	-10,9
25-30	-5	-6,9	-7,6	-9,1	-6,4
20-25	-6	-3,3	-6,4	-5,8	-5
15-20	-5	-0,7	-4,9	-4,5	-2,1
10-15	-4	-0,9	-6,2	-9,9	-3,4
05-10	-1	-0,1	-10,1	-6,2	-5,9
00-05	0	1,6	-7,6	-2,1	-4,4

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 < 20km) 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, respectively. 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.

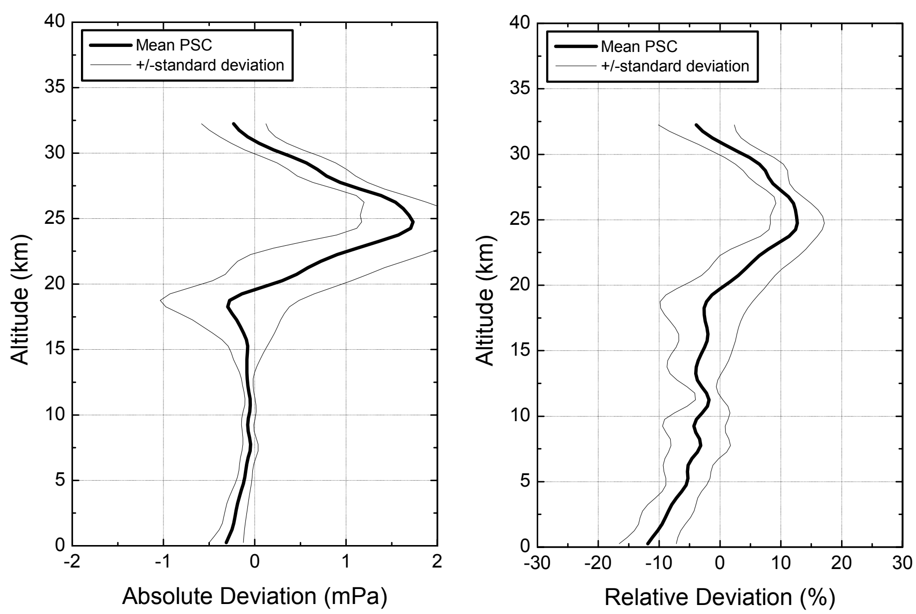

Figure 12: *JOSIE 2000-Comparison of KC96 sonde versus UV-Photometer: Averages (± one standard deviation) of the ozone pressure deviations (left diagram) and relative deviations (right panel) of the individual PSC corrected sonde data from the UV-photometer for the KC96 ozone sonde.*

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.

Mean Ozone Pressure Deviation (in mPa) ± Standard Deviation (in mPa) = Bias±Precision						
Altitude Range (km)	**K86-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa) (±Accuracy)**					
	SPC-6A Sonde			**ENSCI-Z Sonde**		
	SST-1A	**SST-2B**	**SST-3A**	**SST-1A**	**SST-2B**	**SST-3A**
30-35	-0.10 ± 0.45 (±0.55)	-0.76 ± 0.43 (±1.19)	-0.99 ± 0.28 (±1.27)	0.70 ± 0.64 (±1.34)	0.25 ± 0.45 (±0.70)	-0.30 ± 0.25 (±0.55)
25-30	0.22 ± 0.85 (±1.07)	-0.41 ± 0.55 (±0.96)	-0.94 ± 0.43 (±1.37)	1.10 ± 0.67 (±1.77)	0.61 ± 0.52 (±1.23)	-0.24 ± 0.52 (±0.76)
20-25	-0.02 ± 1.18 (±1.20)	-0.38 ± 0.78 (±1.16)	-1.07 ± 0.69 (±1.76)	0.85 ± 0.99 (±1.84)	0.40 ± 0.83 (±1.23)	-0.43 ± 0.75 (±1.18)
15-20	-0.11 ± 0.67 (±0.78)	-0.19 ± 0.39 (±0.58)	-0.48 ± 0.38 (±0.86)	0.18 ± 0.49 (±0.67)	0.08 ± 0.27 (±0.35)	-0.44 ± 0.43 (±0.87)
10-15	0.09 ± 0.19 (±0.28)	-0.02 ± 0.22 (±0.24)	-0.23 ± 0.24 (±0.47)	0.19 ± 0.13 (±0.32)	0.10 ± 0.10 (±0.20)	-0.16 ± 0.15 (±0.31)
5-10	0.08 ± 0.10 (±0.18)	0.03 ± 0.12 (±0.15)	-0.15 ± 0.10 (±0.25)	0.23 ± 0.15 (±0.38)	0.09 ± 0.06 (±0.15)	-0.07 ± 0.08 (±0.15)
0-5	-0.01 ± 0.14 (±0.15)	0.02 ± 0.11 (±0.13)	-0.22 ± 0.10 (±0.32)	0.20 ± 0.13 (±0.33)	0.05 ± 0.08 (±0.13)	-0.13 ± 0.08 (±0.21)

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.

Mean Relative Deviation (in %) ± Standard Deviation (in %) = Bias±Precision						
Altitude Range (km)	**K86-Data: Mean Relative Deviation (in %) ± Std Deviation (in %) (±Accuracy)**					
	SPC-6A			**ENSCI-Z**		
	SST-1A	**SST-2B**	**SST-3A**	**SST-1A**	**SST-2B**	**SST-3A**
30-35	-1.6 ± 6.7 (±8.3)	-11.5 ± 5.7 (±16.2)	-15.3 ± 3.9 (±19.2)	10.4 ± 9.9 (±20.3)	4.0 ± 7.1 (±11.1)	-4.4 ± 3.7 (±8.1)
25-30	2.5 ± 7.1 (±9.6)	-3.8 ± 4.7 (±8.5)	-8.3 ± 3.5 (±11.8)	10.1 ± 6.0 (±16.1)	5.3 ± 4.6 (±9.9)	-1.9 ± 4.1 (±6.0)
20-25	-0.1 ± 8.6 (±8.7)	-2.9 ± 5.6 (±8.5)	-7.7 ± 4.8 (±12.5)	6.5 ± 7.5 (±14.0)	2.9 ± 6.0 (±8.9)	-2.7 ± 5.1 (±7.8)
15-20	-1.7 ± 8.2 (±9.9)	-3.4 ± 5.3 (±8.7)	-6.6 ± 4.0 (±10.6)	3.2 ± 4.9 (±8.1)	1.1 ± 2.8 (±3.9)	-4.5 ± 3.6 (±8.1)
10-15	3.0 ± 6.9 (±12.9)	-6.6 ± 12.5 (±19.1)	-7.4 ± 3.0 (±10.4)	9.2 ± 6.3 (±15.5)	3.3 ± 3.7 (±7.0)	-4.0 ± 2.8 (±6.8)
5-10	5.3 ± 6.5 (±11.8)	-0.2 ± 8.3 (±8.5)	-9.0 ± 3.9 (±12.9)	15.4 ± 10.9 (±26.3)	6.0 ± 4.7 (±10.7)	-3.1 ± 3.6 (±6.7)
0-5	1.1 ± 5.2 (±6.3)	0.2 ± 5.1 (±5.3)	-9.5 ± 4.1 (±13.6)	8.7 ± 4.3 (±13.0)	2.3 ± 2.4 (±4.7)	-5.1 ± 3.6 (±8.7)

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.

Mean Deviation ± Standard Deviation = Bias±Precision (±Accuracy)		
Altitude Range (km)	**KC-96 Sonde *(Part.No. 8 = JMA)***	
	Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)	**Mean Relative Deviation (in %) ± Std Deviation (in %)**
30-35	-0.07 ± 0.40 (±0.47)	-1.4 ± 6.2 (±7.6)
25-30	1.16 ± 0.69 (±1.85)	10.2 ± 6.2 (±16.4)
20-25	1.20 ± 1.12 (±2.32)	8.5 ± 8.6 (±17.1)
15-20	-0.15 ± 0.55 (±0.70)	-3.0 ± 6.8 (±9.8)
10-15	-0.06 ± 0.12 (±0.18)	-2.8 ± 5.2 (±8.0)
5-10	-0.07 ± 0.08 (±0.15)	-4.3 ± 4.9 (±9.2)
0-5	-0.21 ± 0.13 (±0.34)	-8.7 ± 4.0 (±12.7)

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 O_3 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 $\pm$(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 $\pm$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 sonde 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

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ANNEX A

Results

of

Individual Tested ECC-Ozone Sondes

JOSIE-2000

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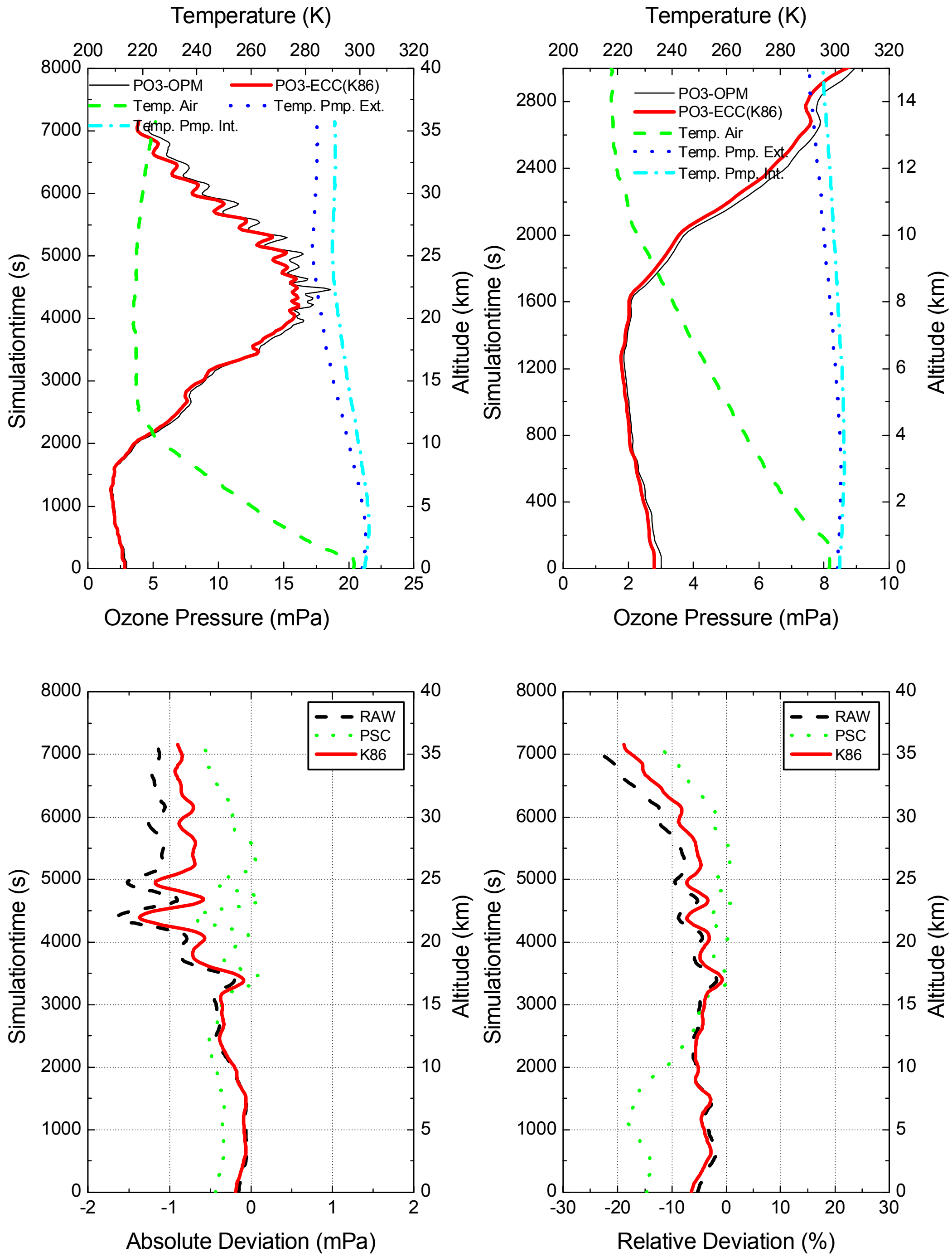

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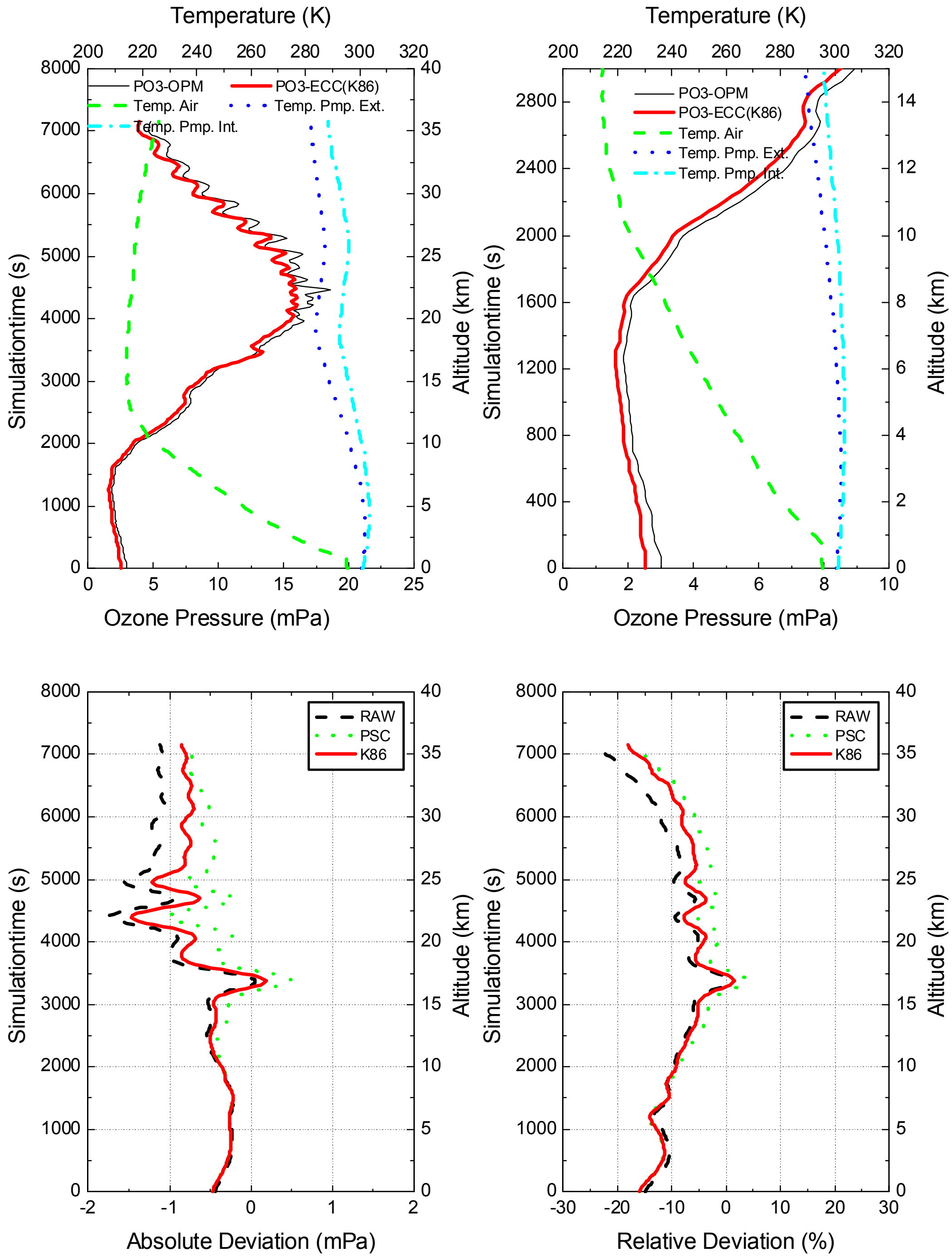

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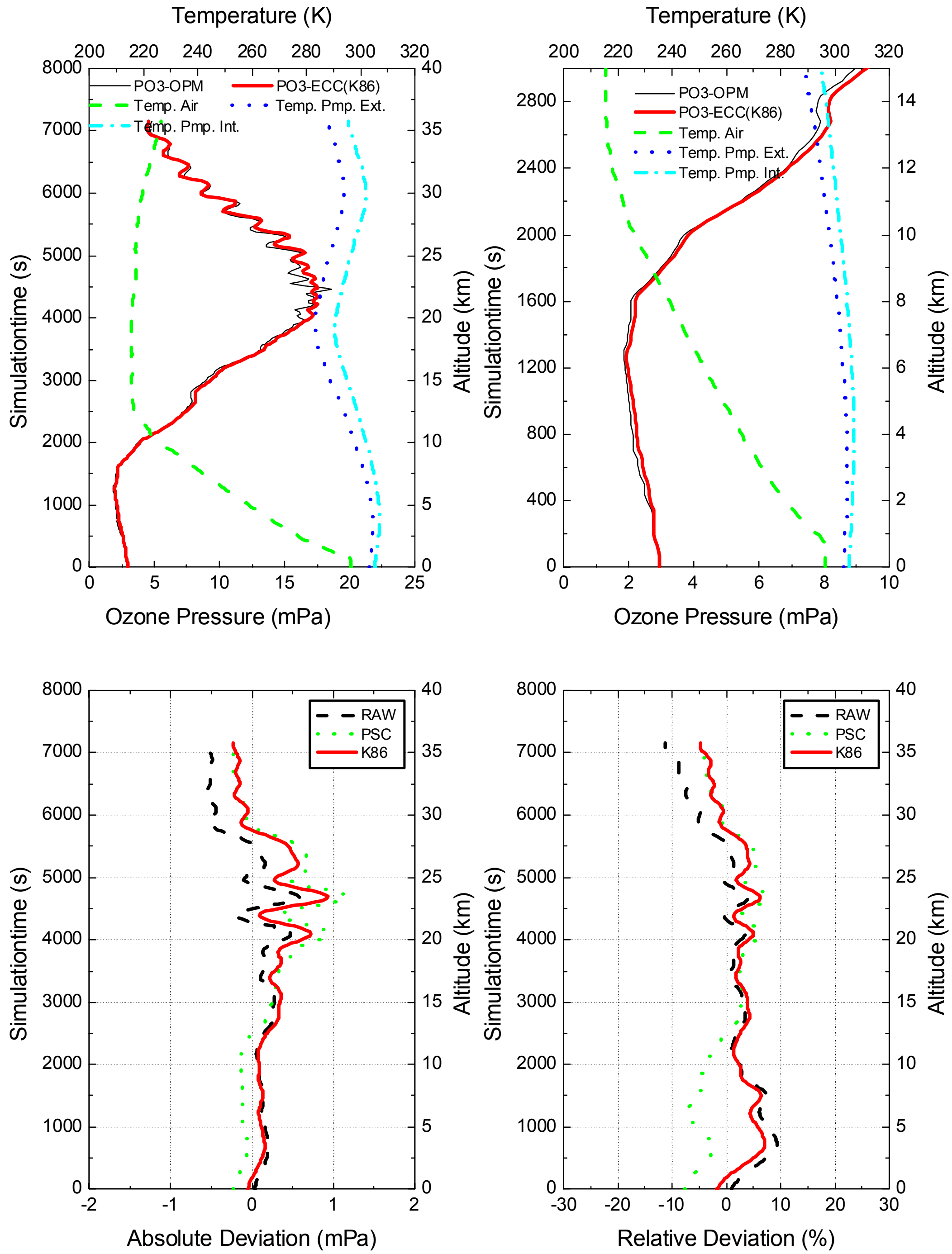

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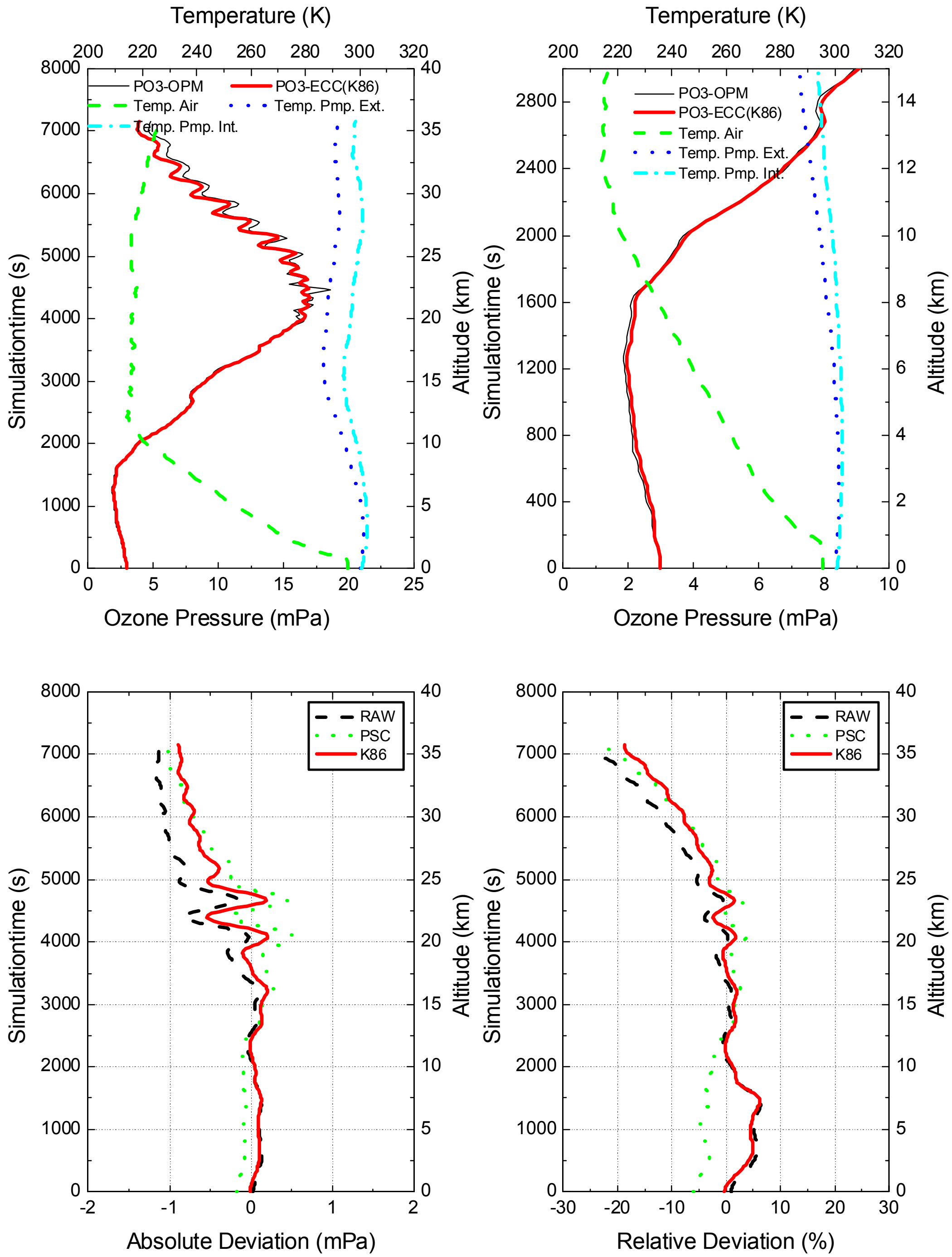

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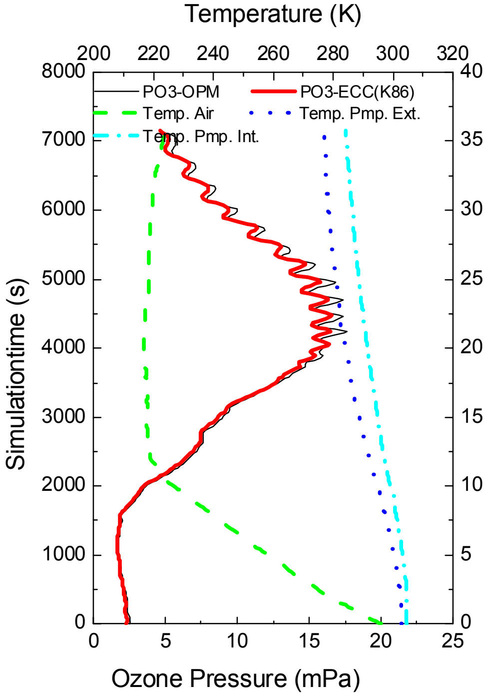

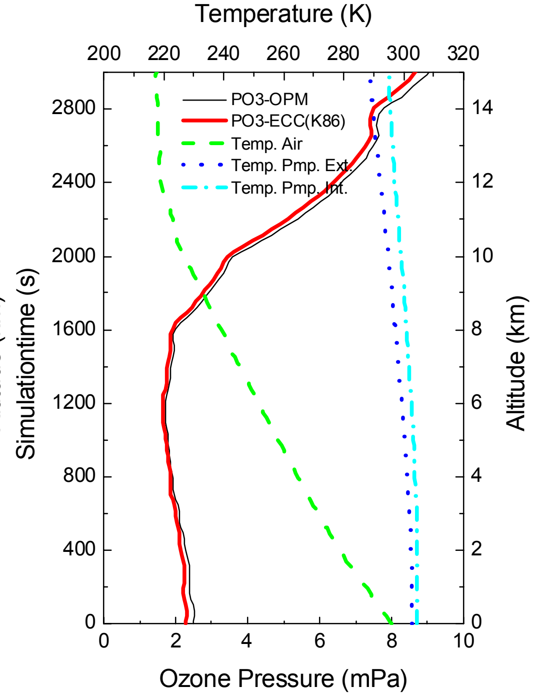

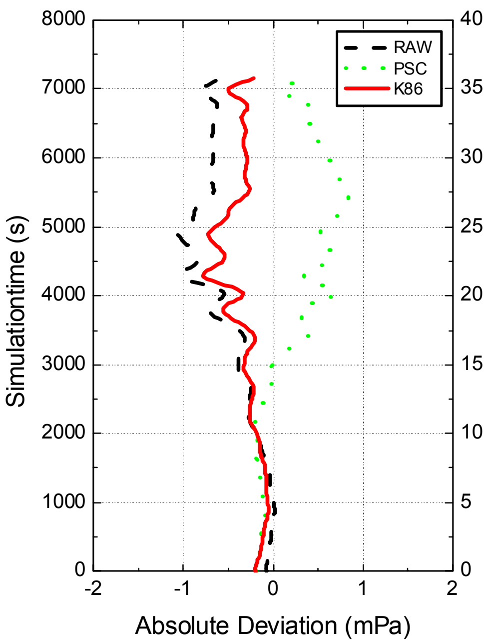

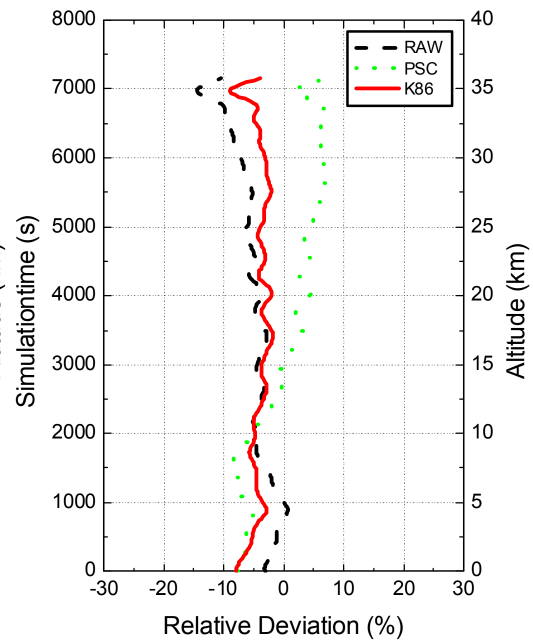

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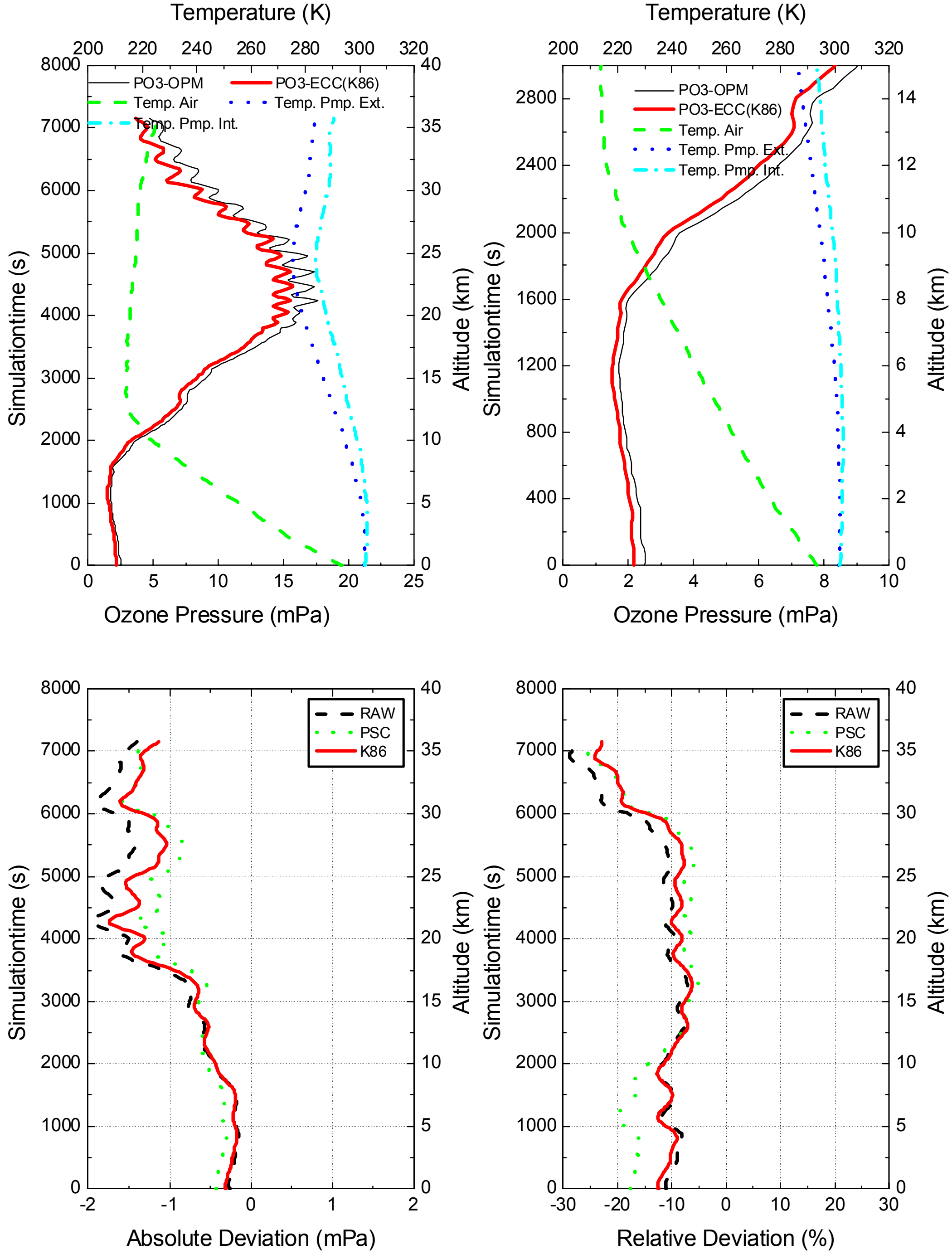

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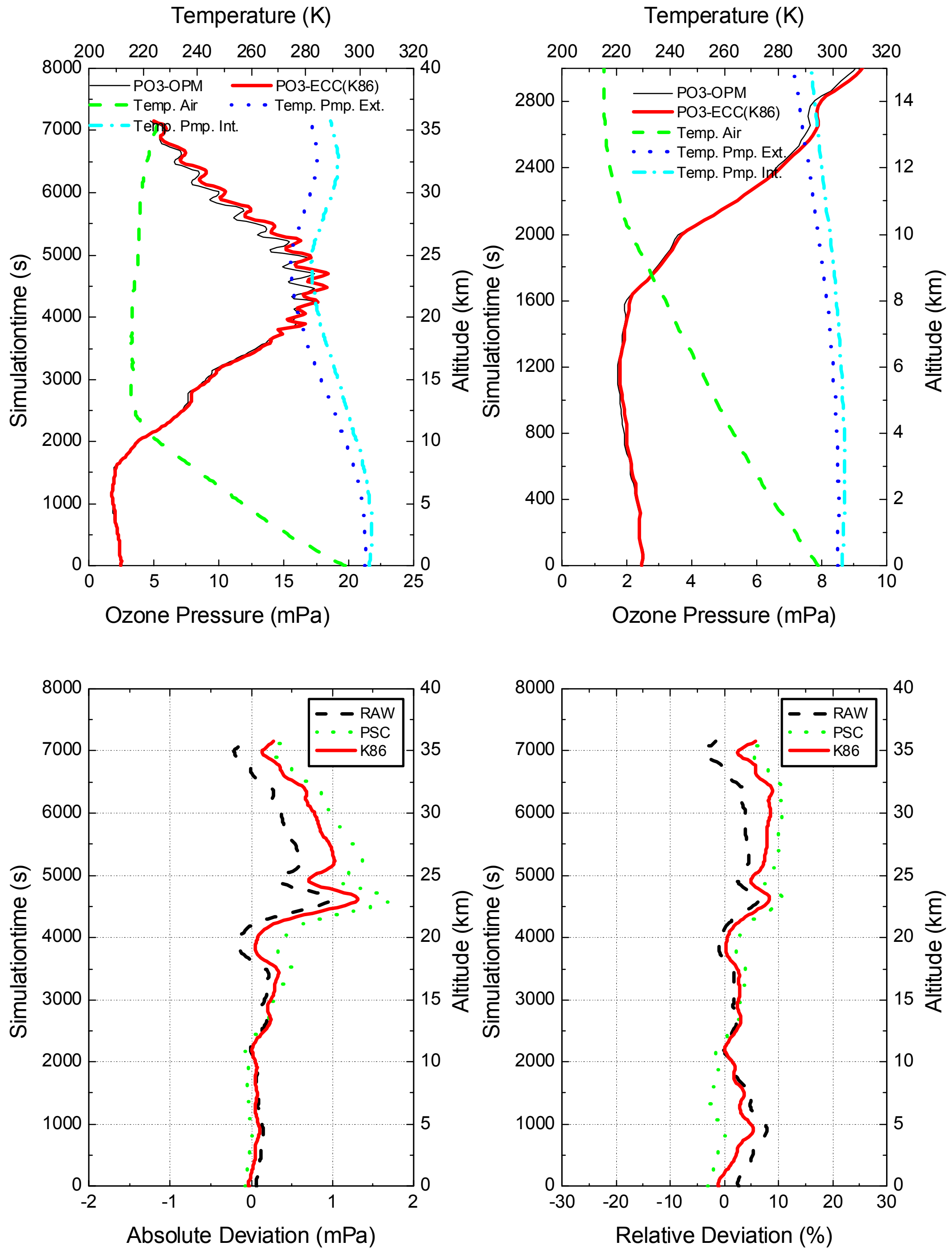

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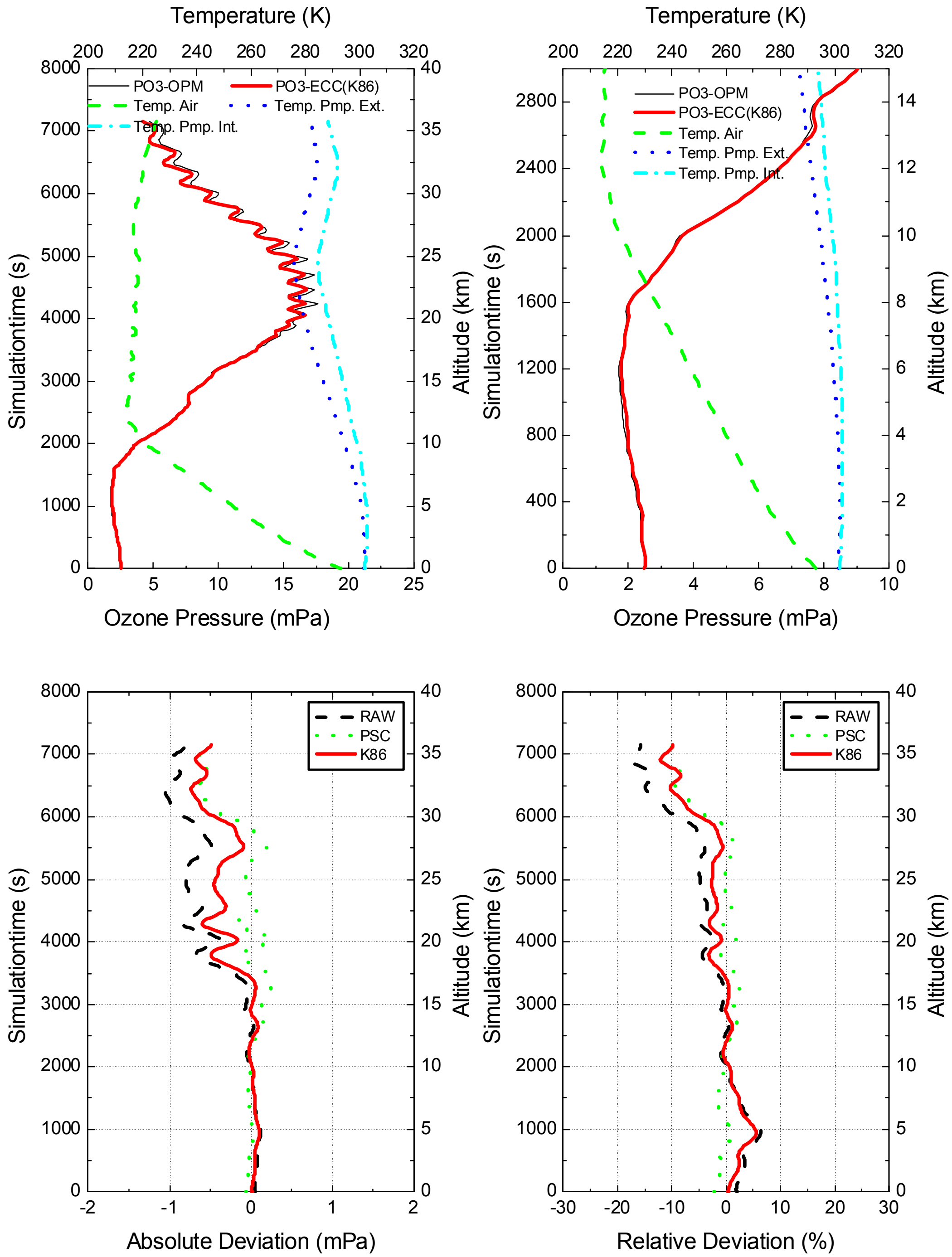

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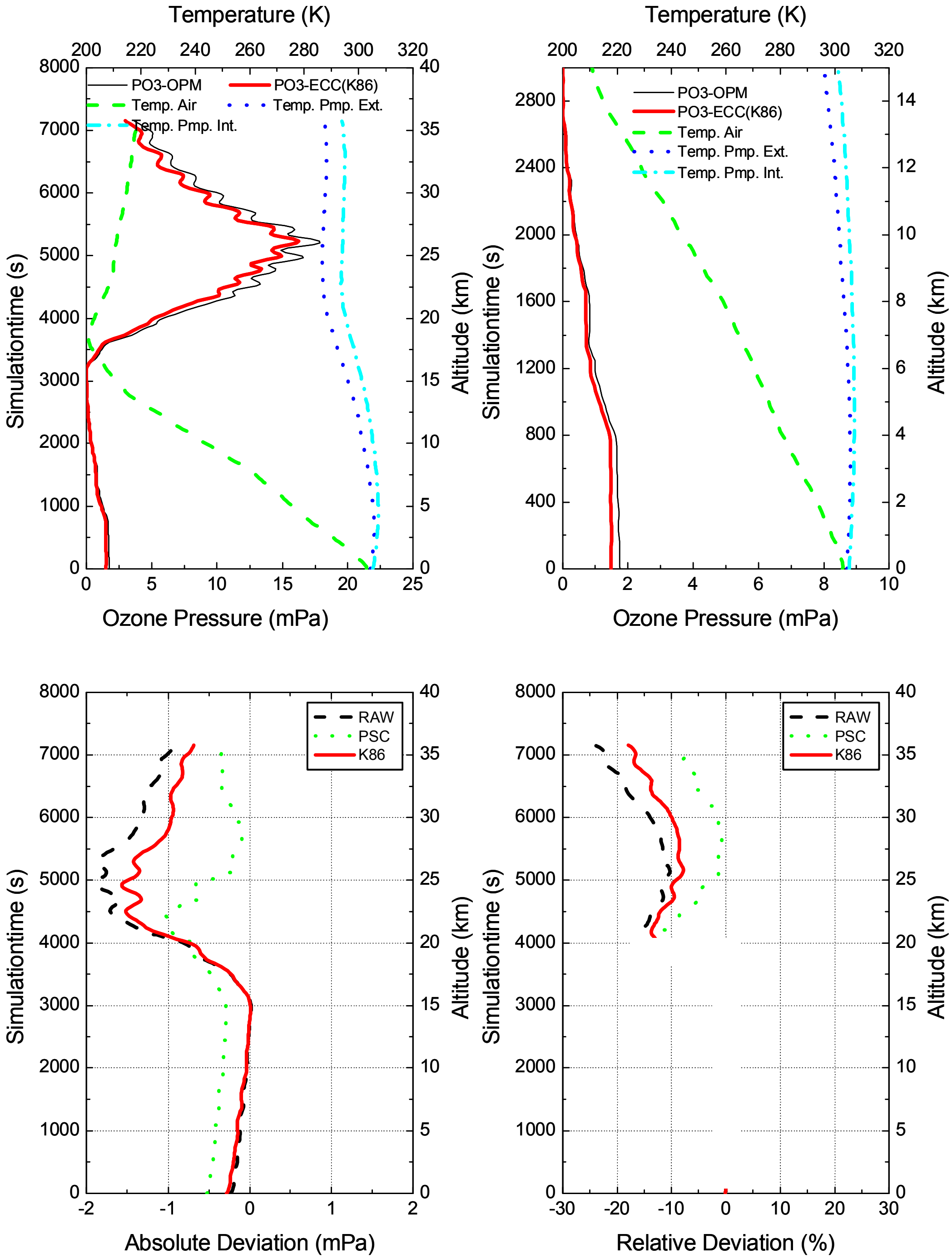

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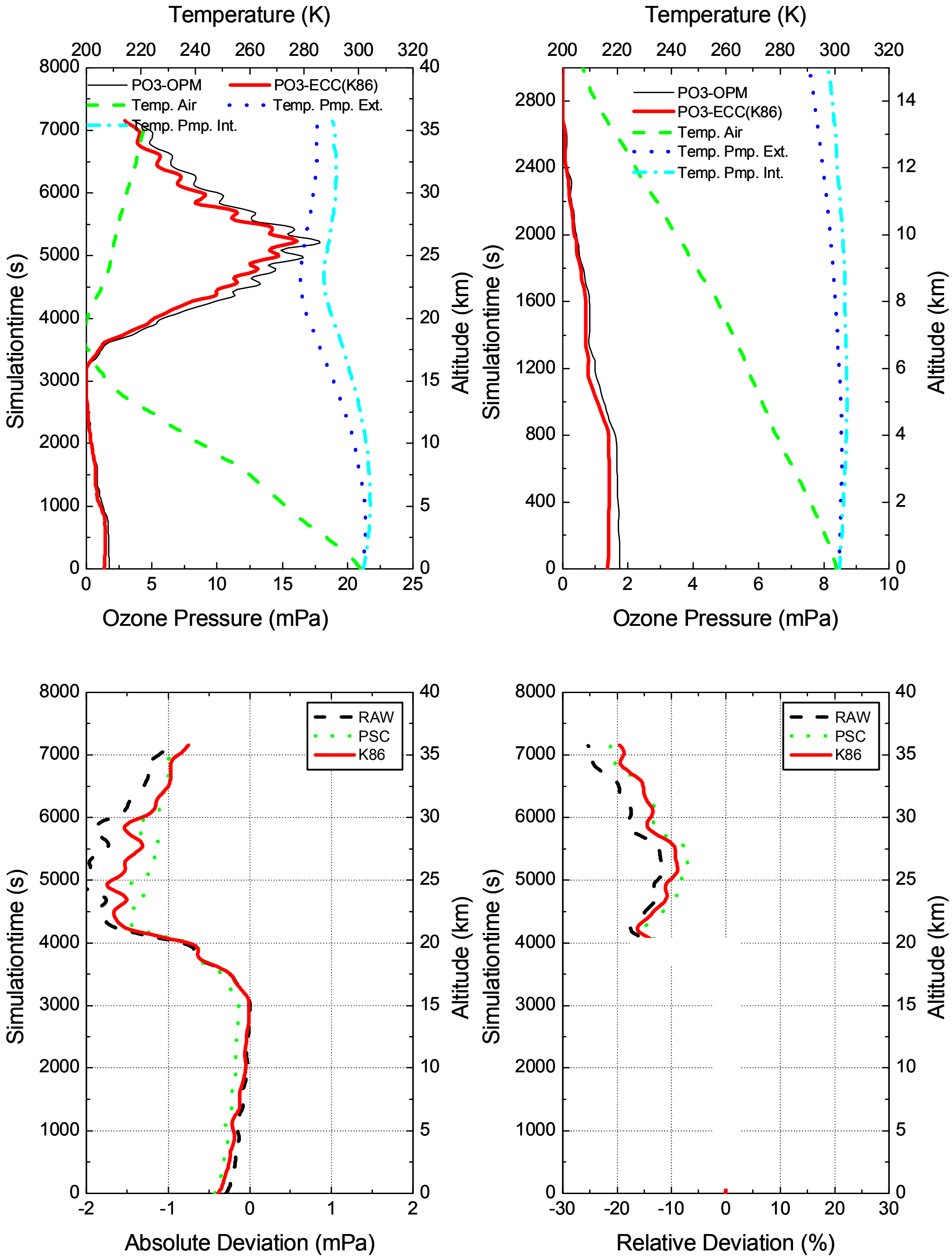

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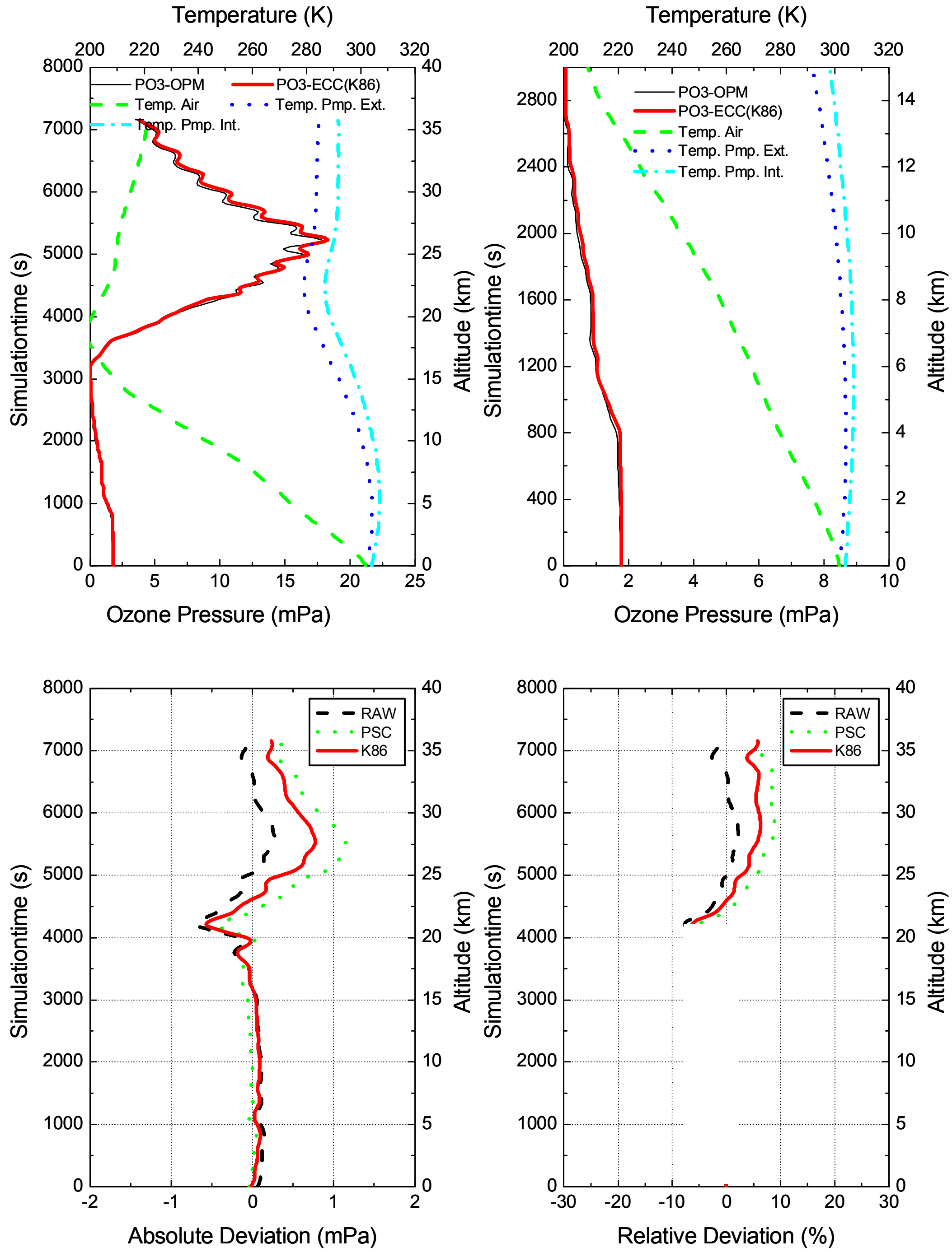

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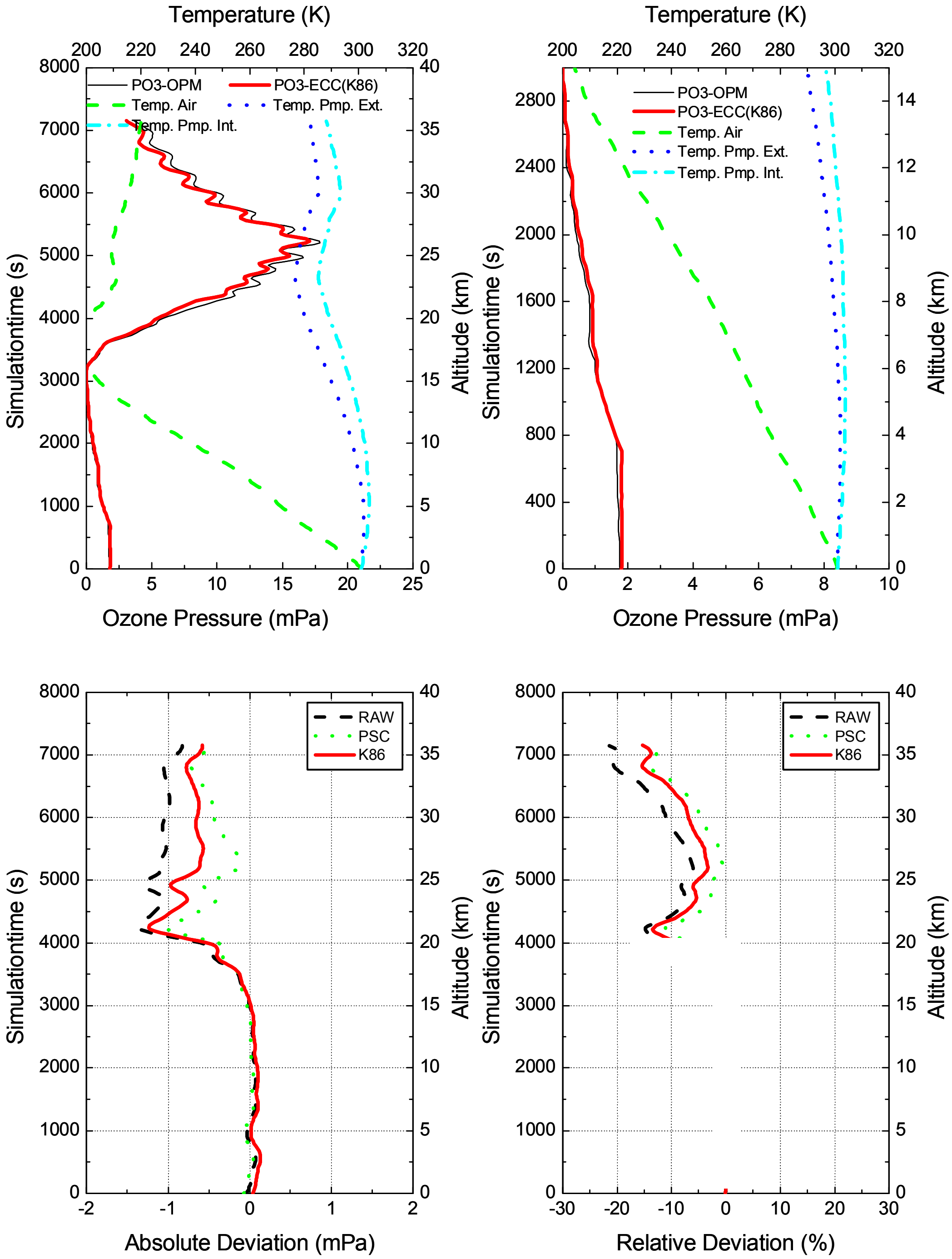

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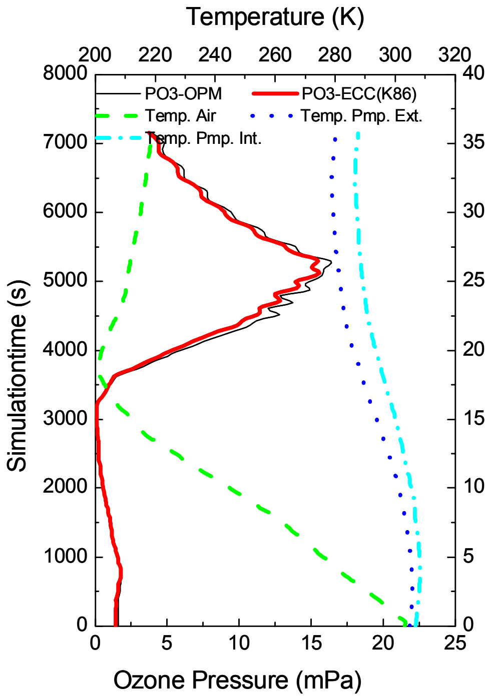

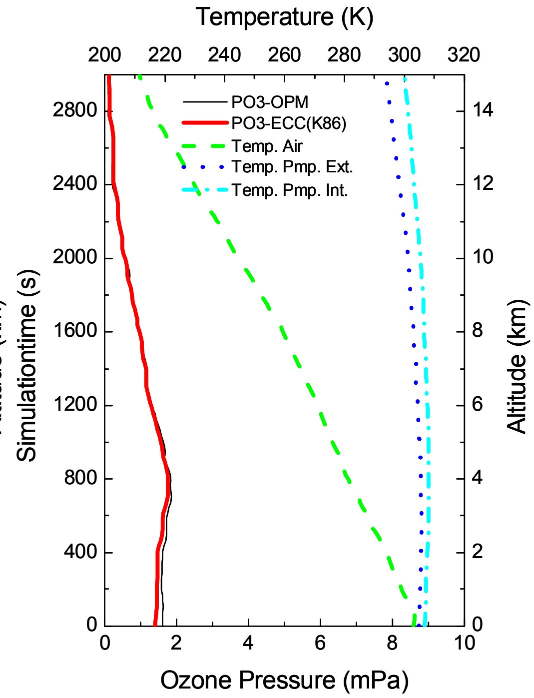

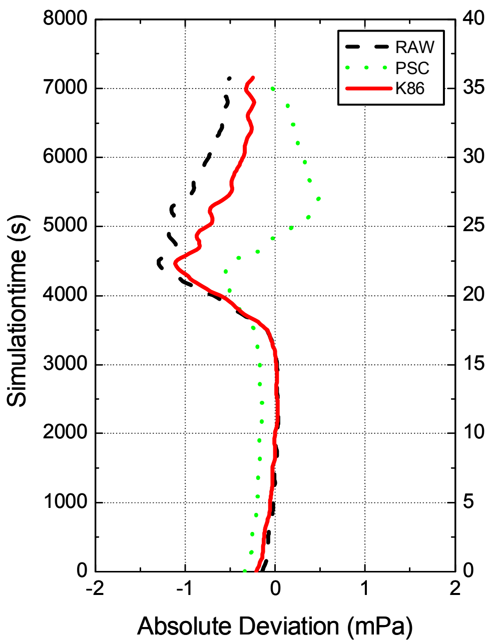

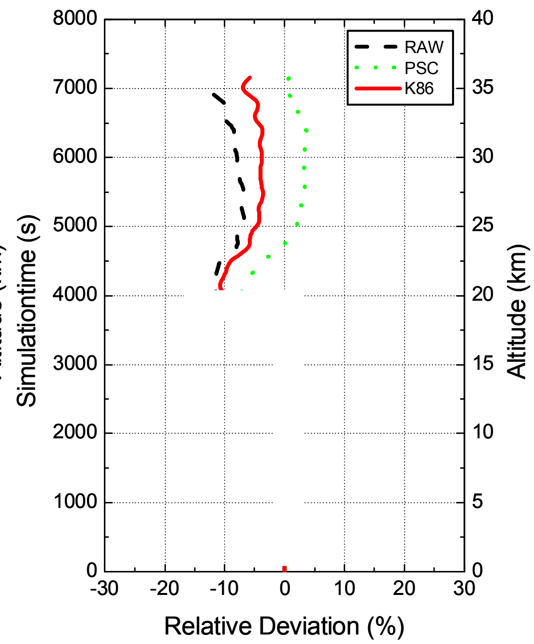

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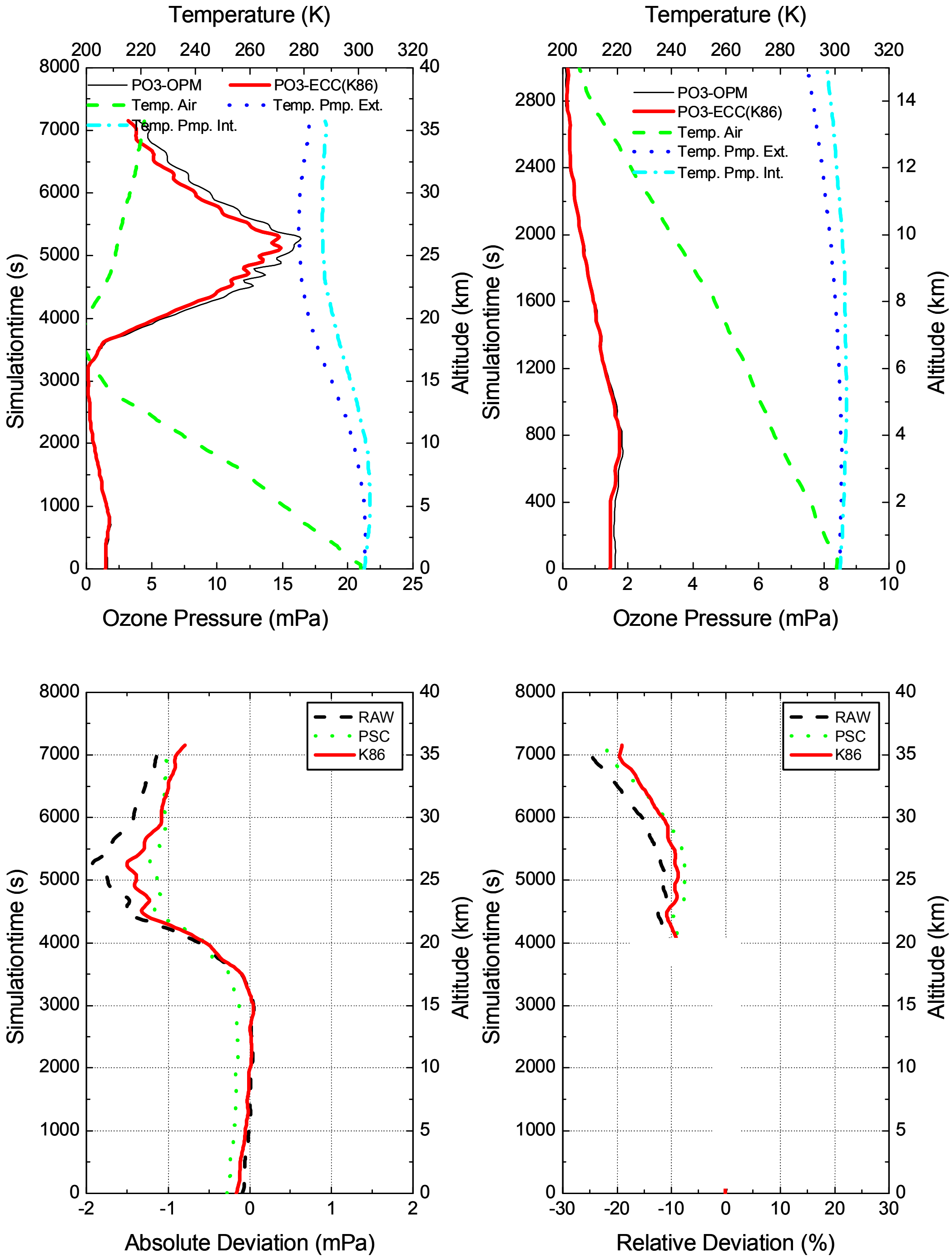

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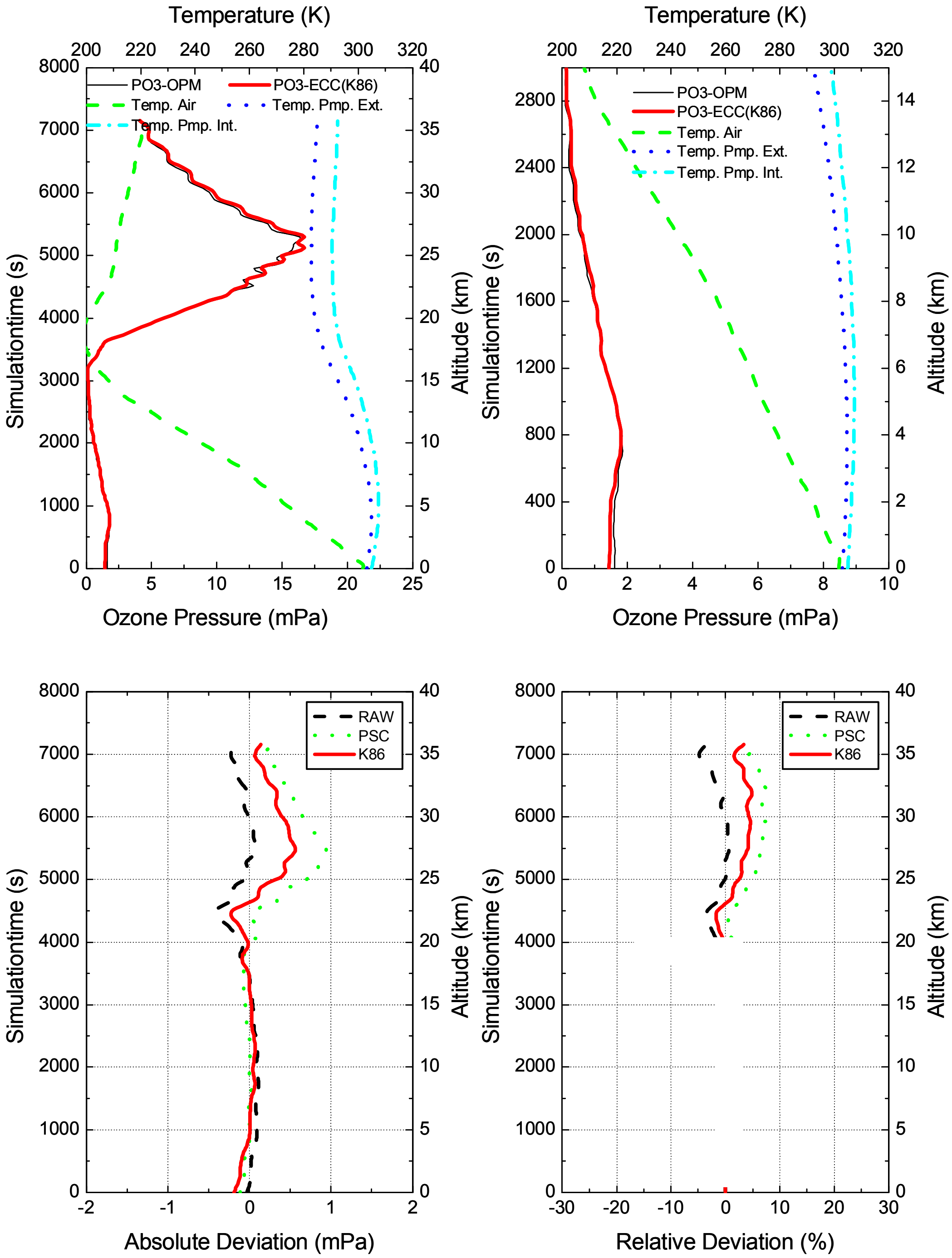

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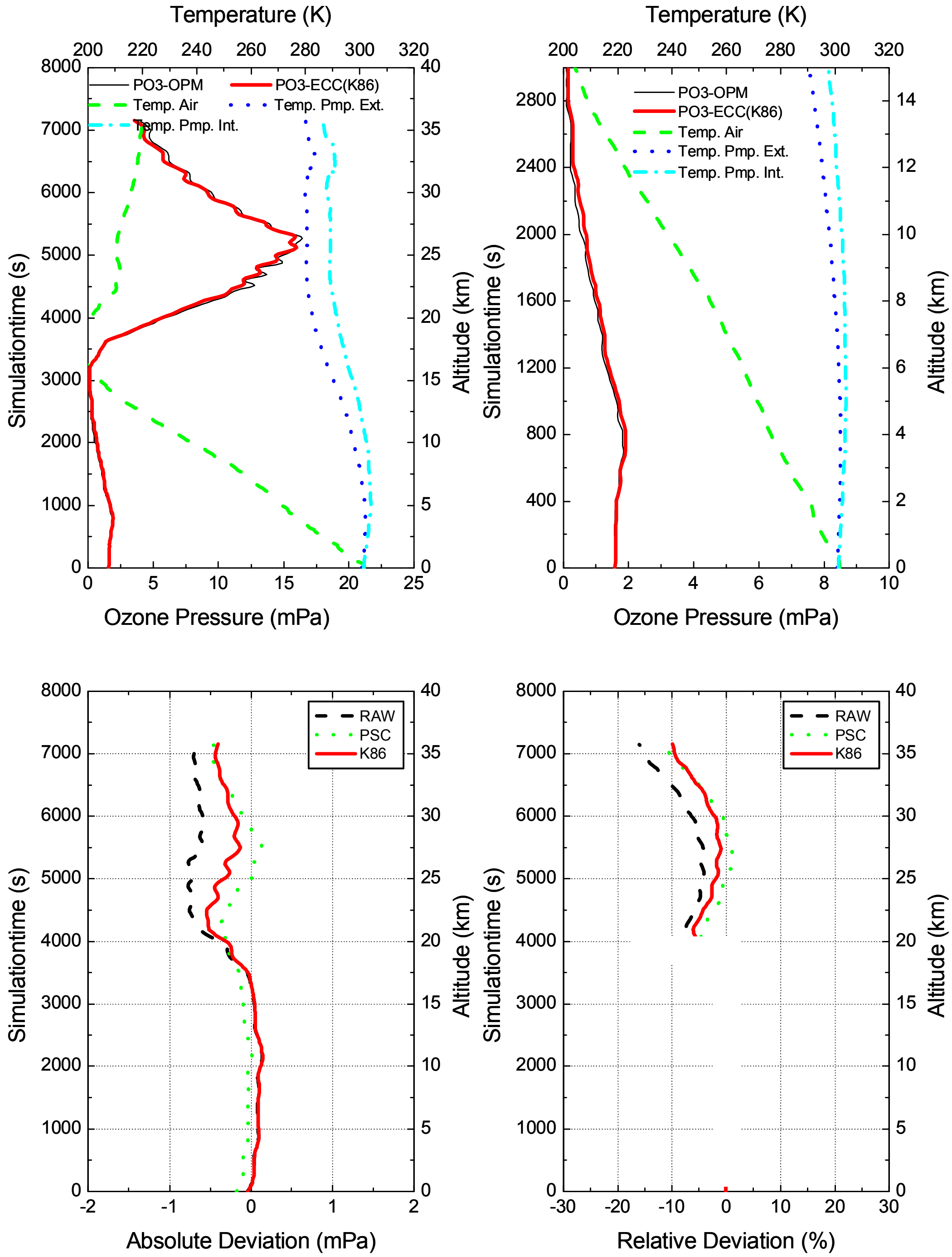

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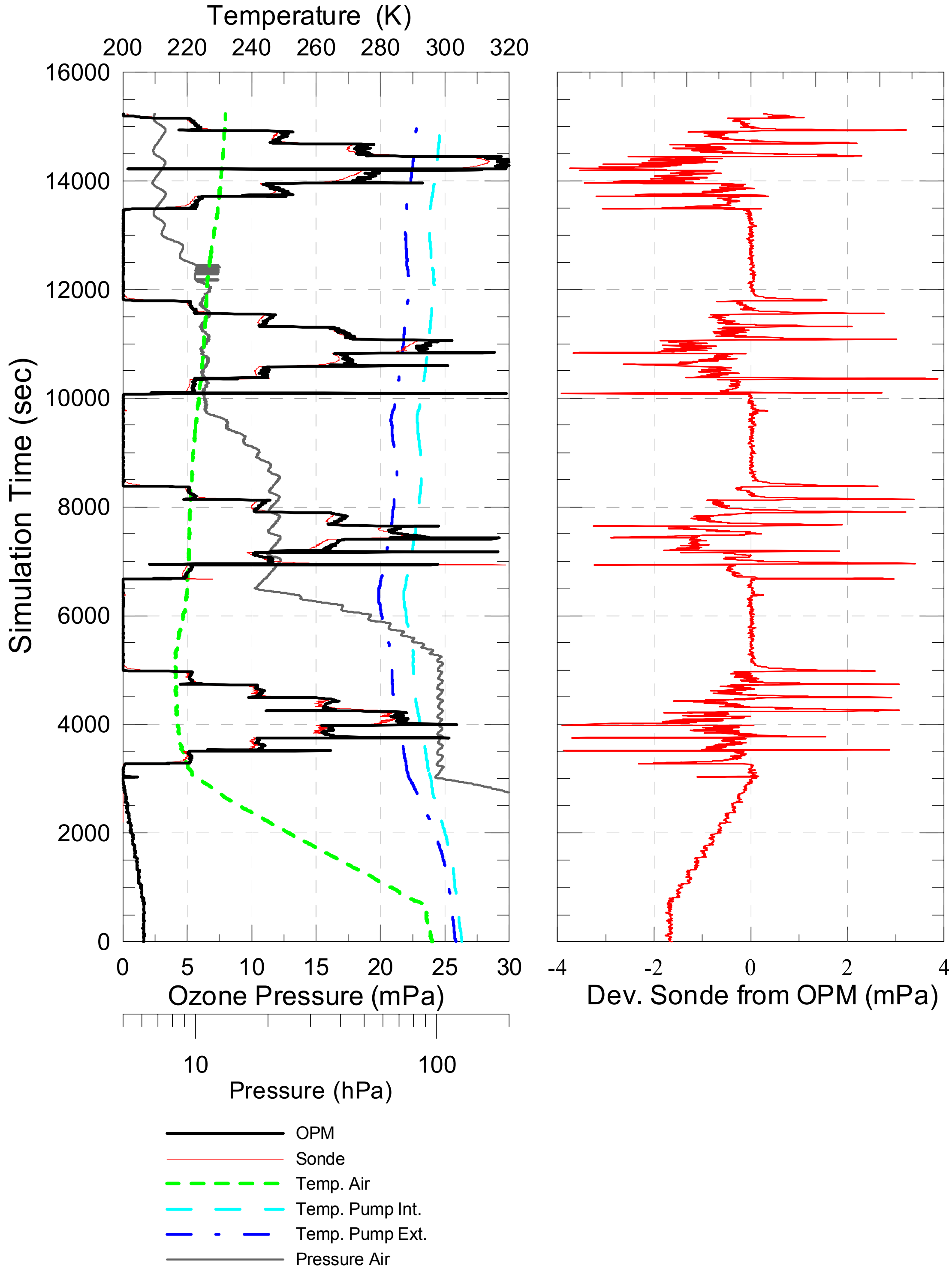
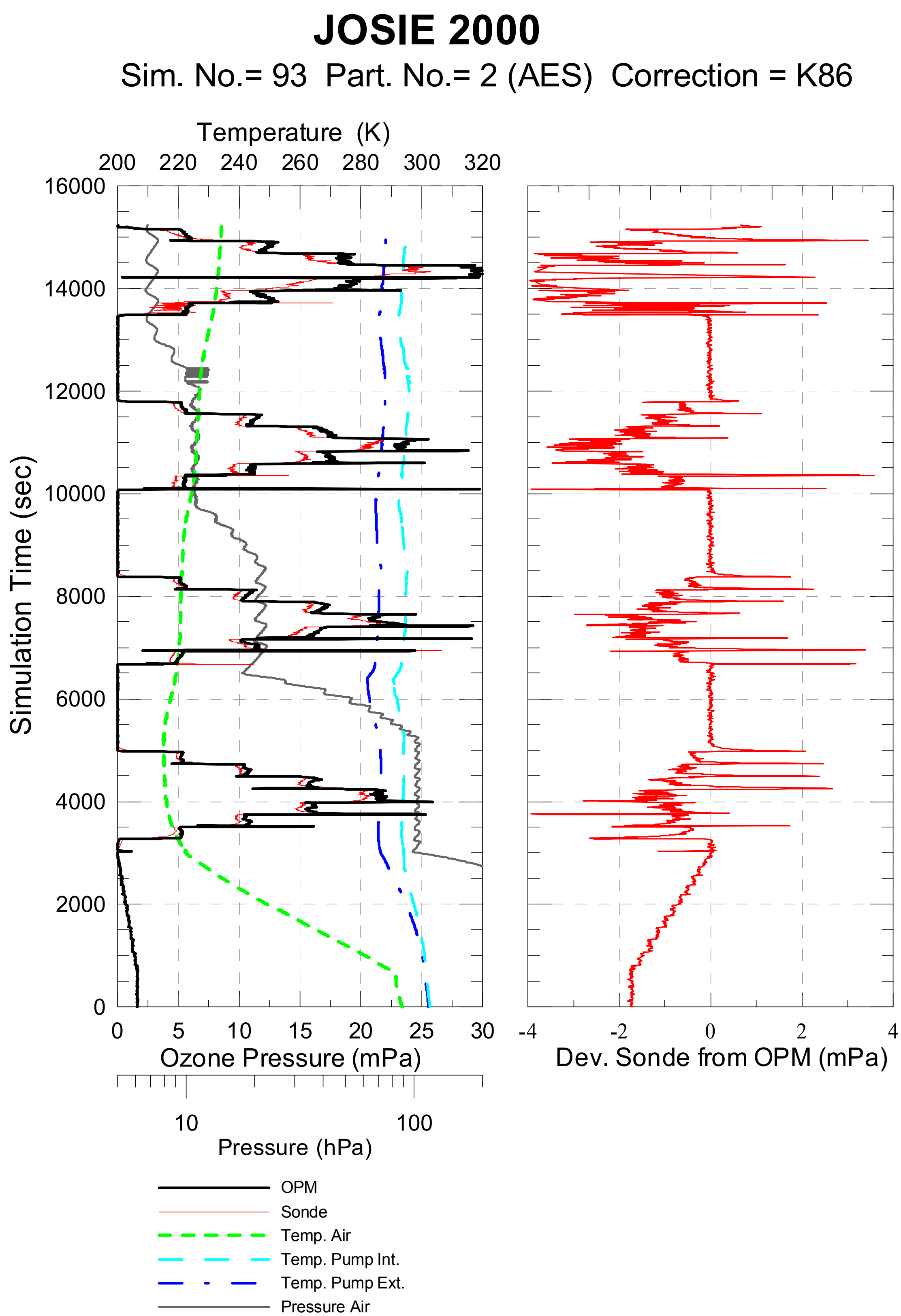
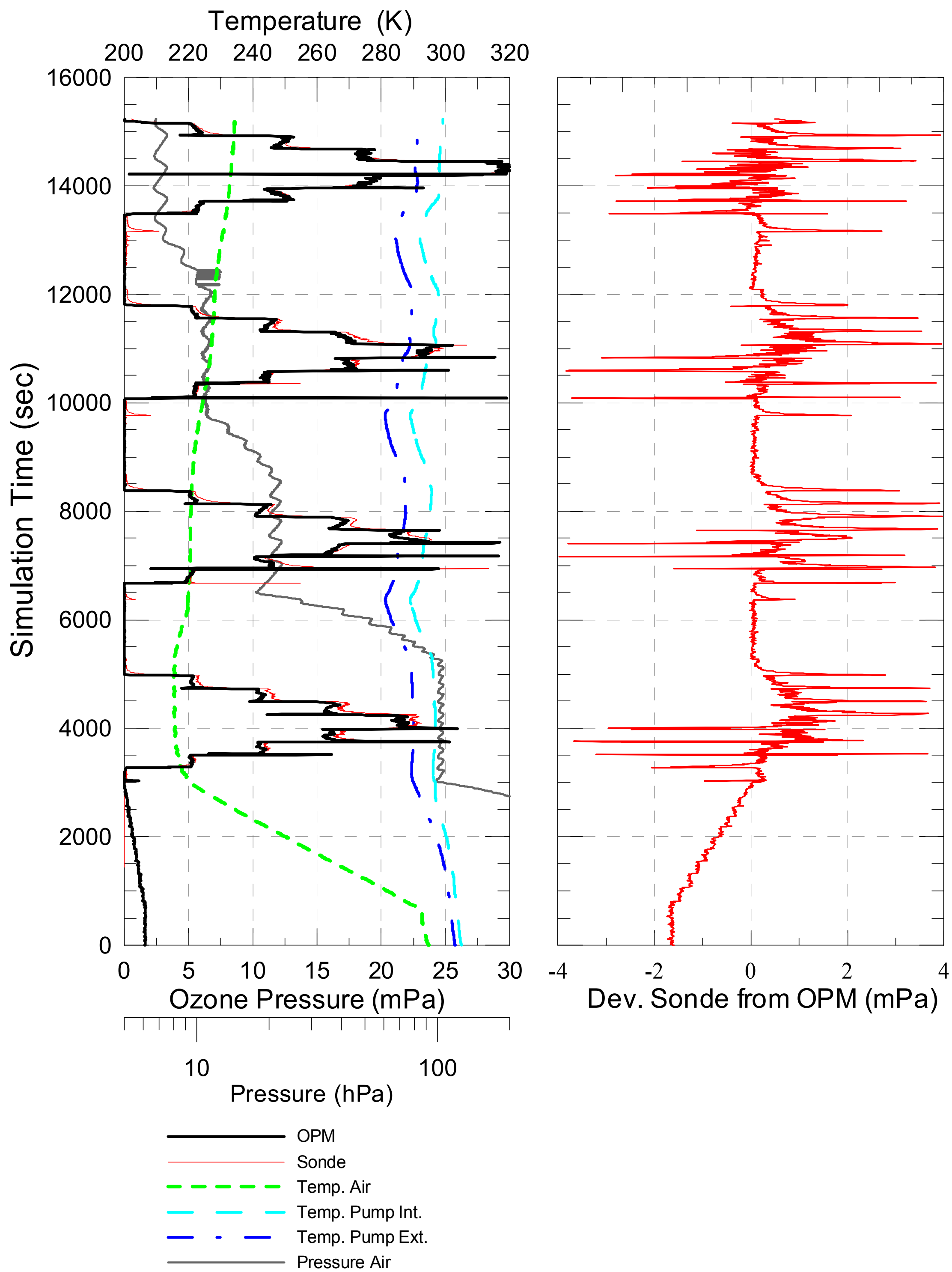



JOSIE 2000
Sim. No.= 93 Part. No.= 2 (AES) Correction = K86
Temperature (K)
200 220 240 260 280 300 320
16000
14000
12000
10000
8000
6000
4000
2000
0
Simulation Time (sec)
0 5 10 15 20 25 30
Ozone Pressure (mPa)
-4 -2 0 2 4
Dev. Sonde from OPM (mPa)
10 100
Pressure (hPa)
OPM
Sonde
Temp. Air
Temp. Pump Int.
Temp. Pump Ext.
Pressure Air

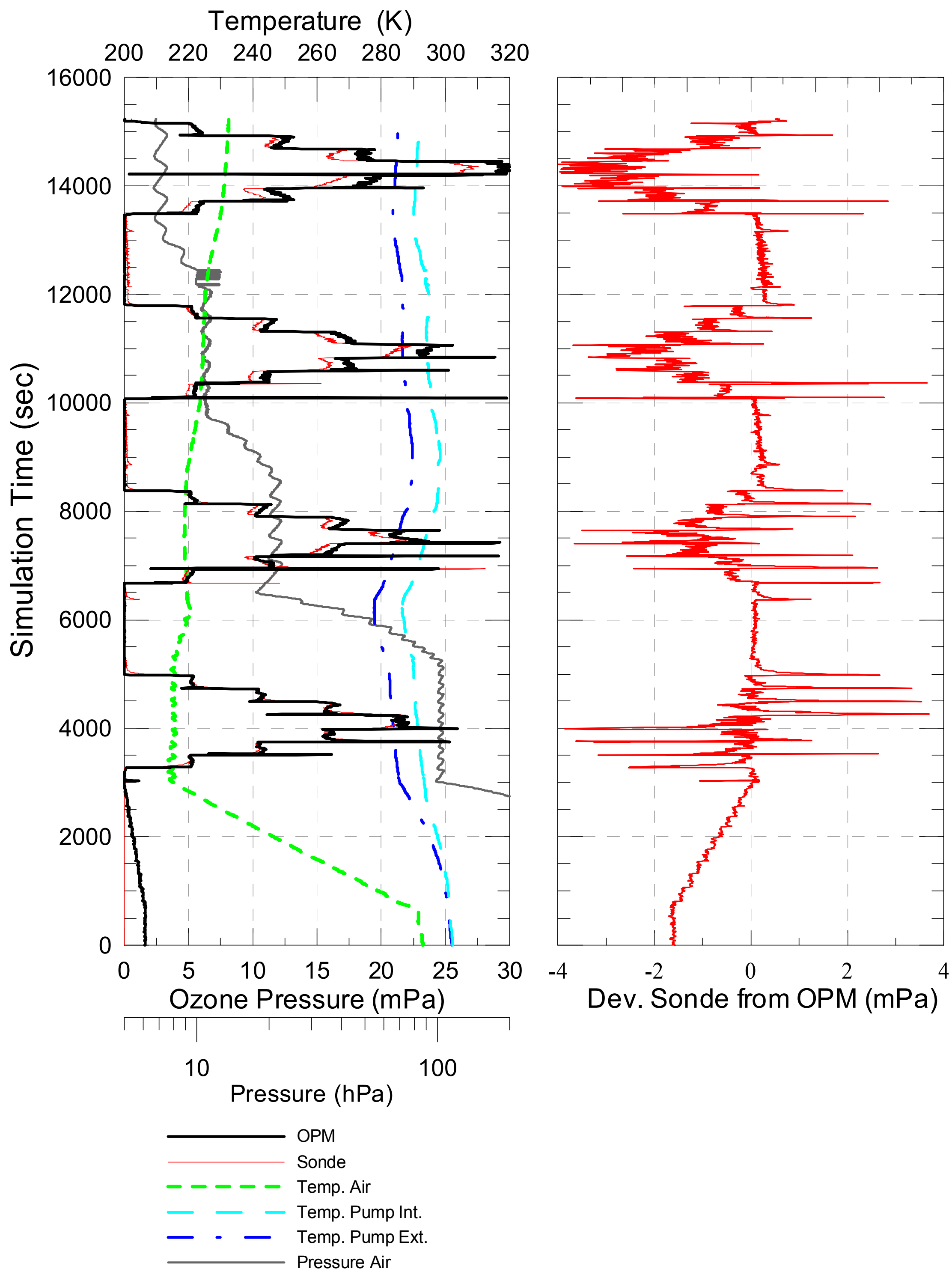
JOSIE 2000

Sim. No.= 93 Part. No.= 3 (NIWA) Correction = K86



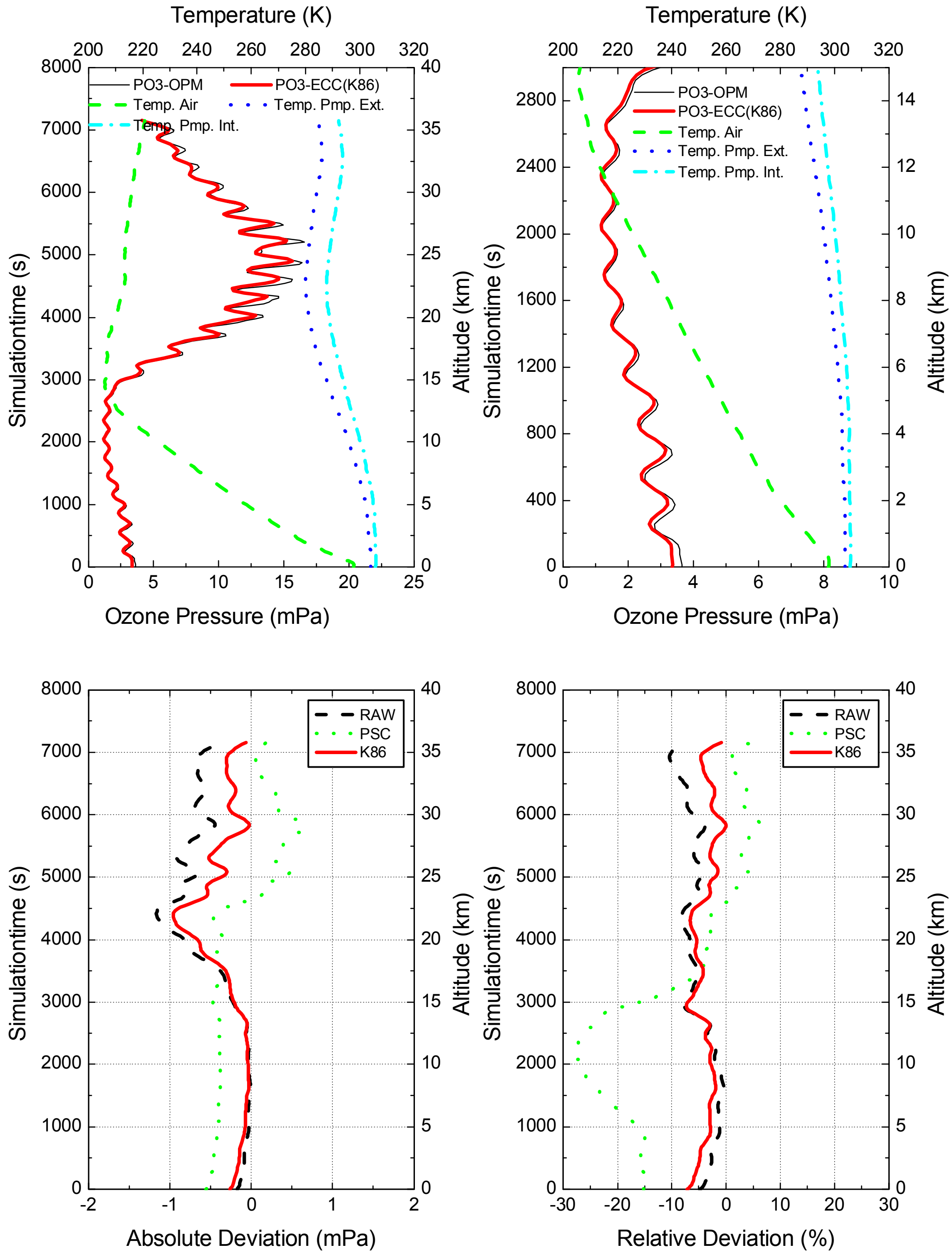
JOSIE 2000

Sim. No.= 93 Part. No.= 4 (FZJ) Correction = K86



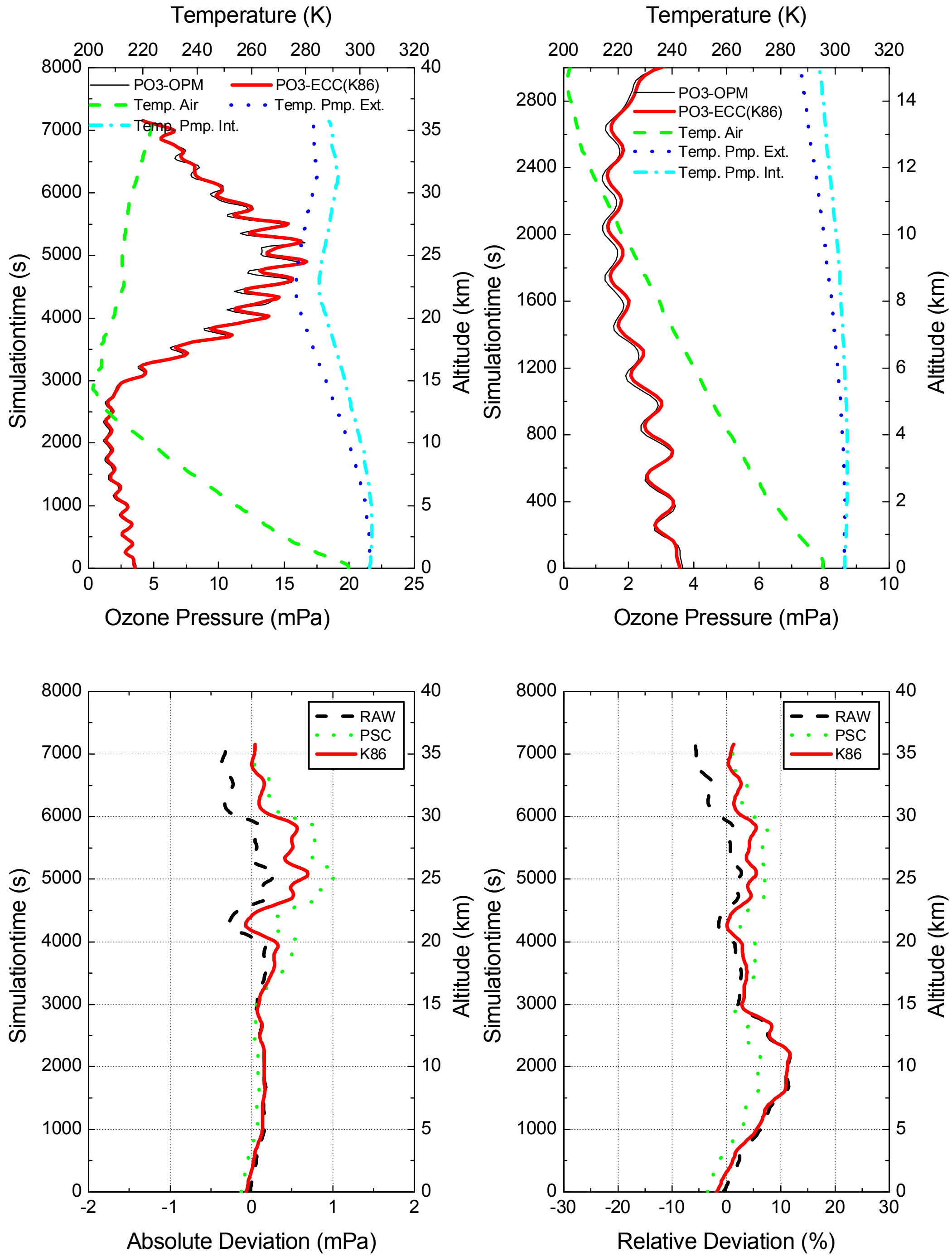
JOSIE-2000

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



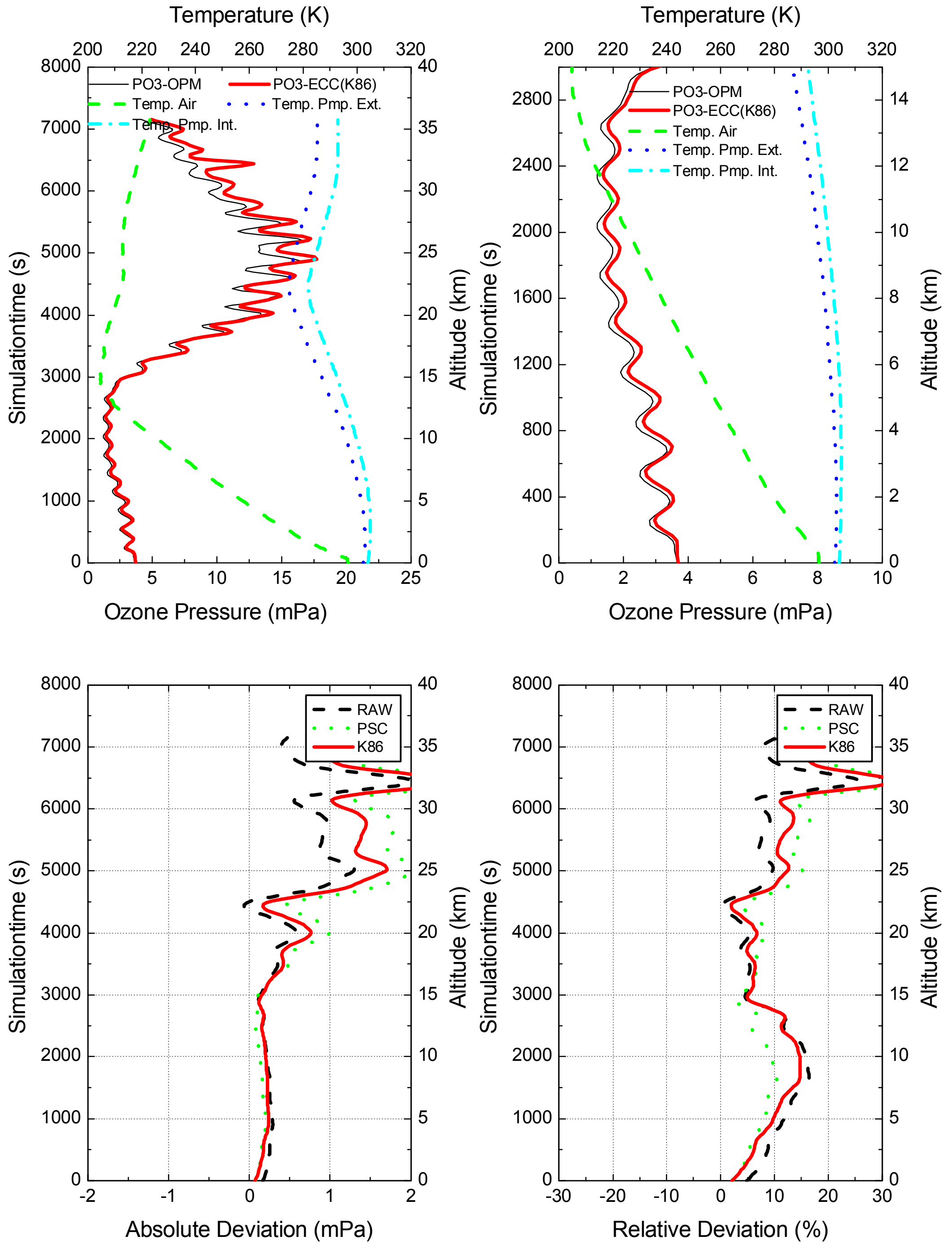
JOSIE-2000

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



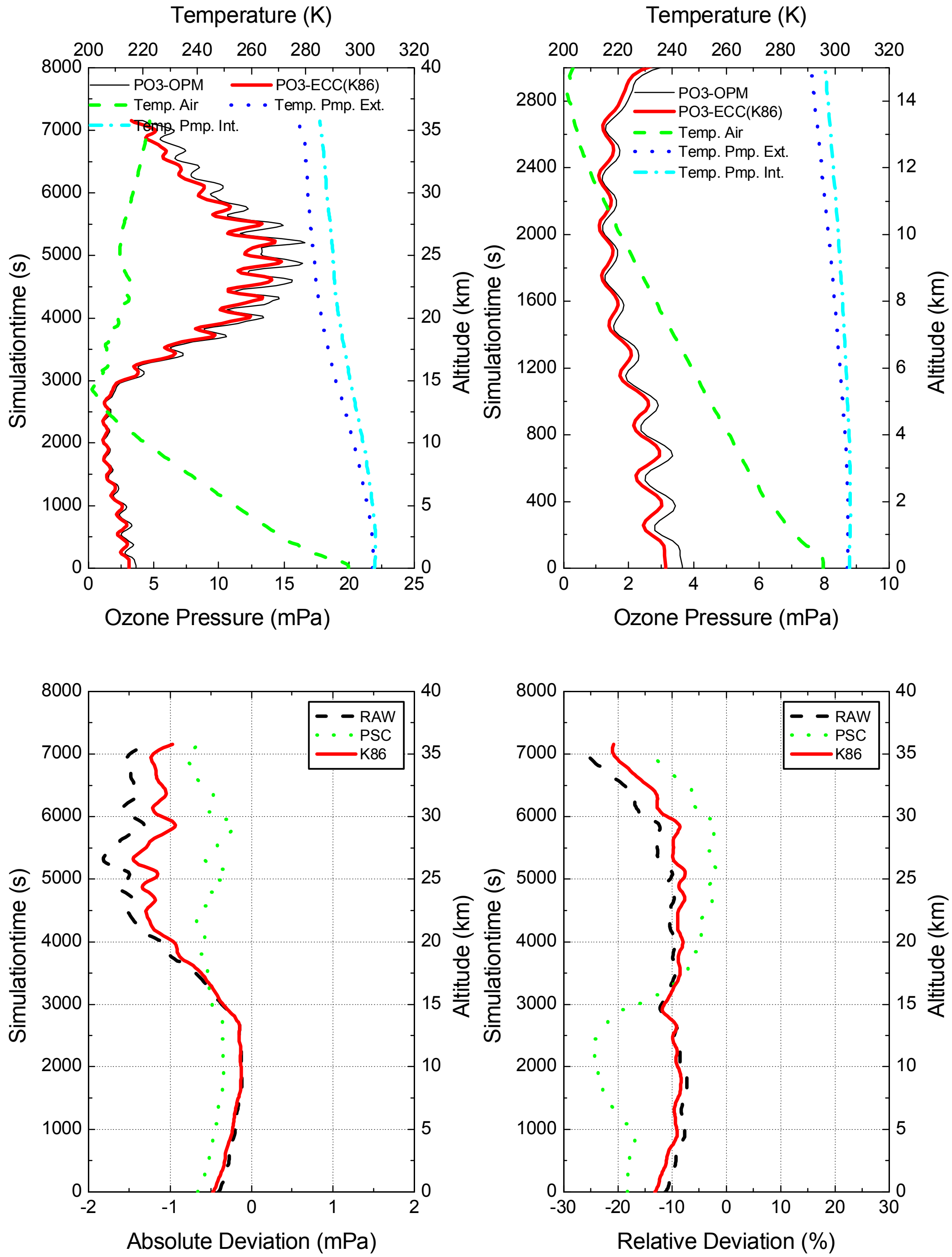
JOSIE-2000

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



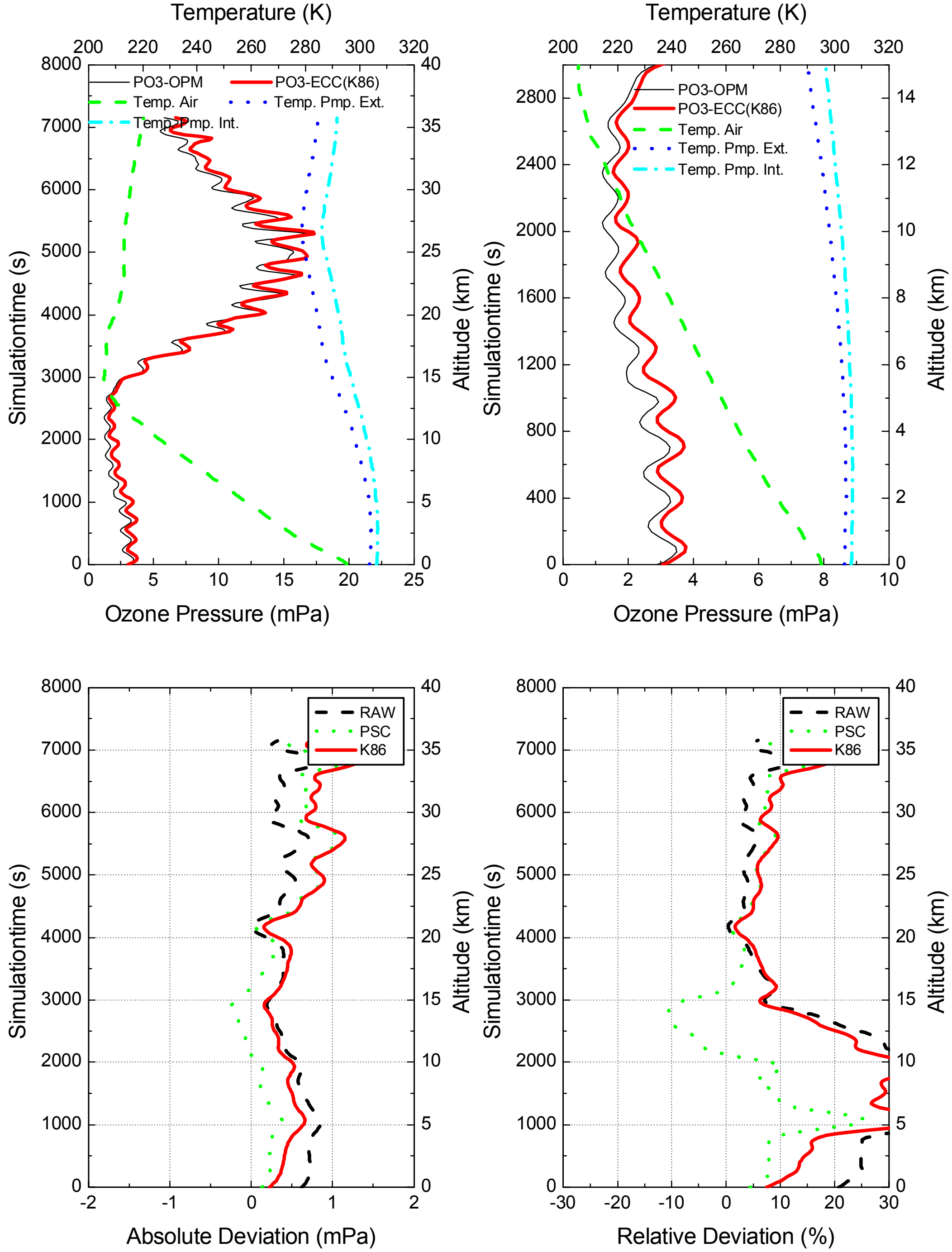
JOSIE-2000

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



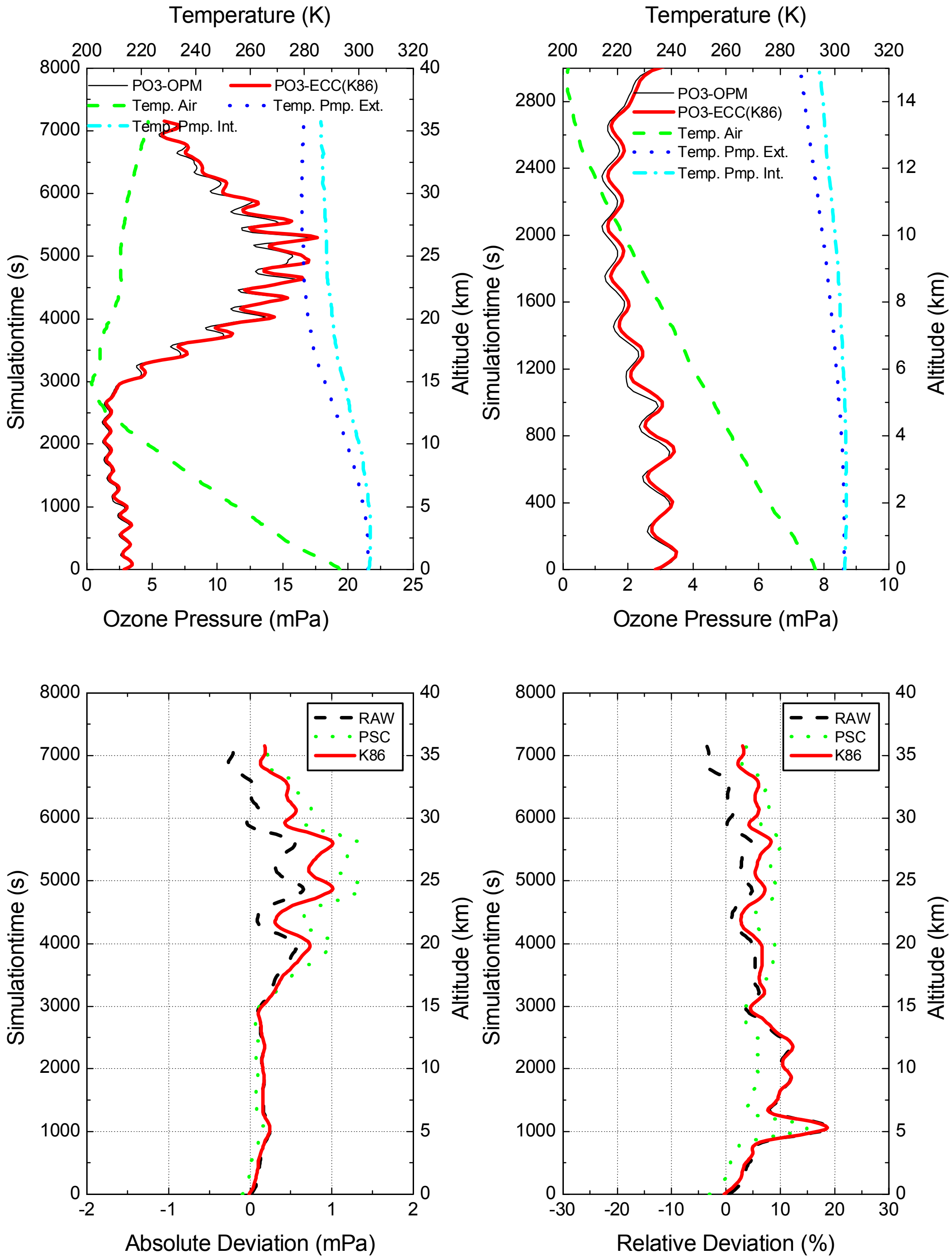
JOSIE-2000

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



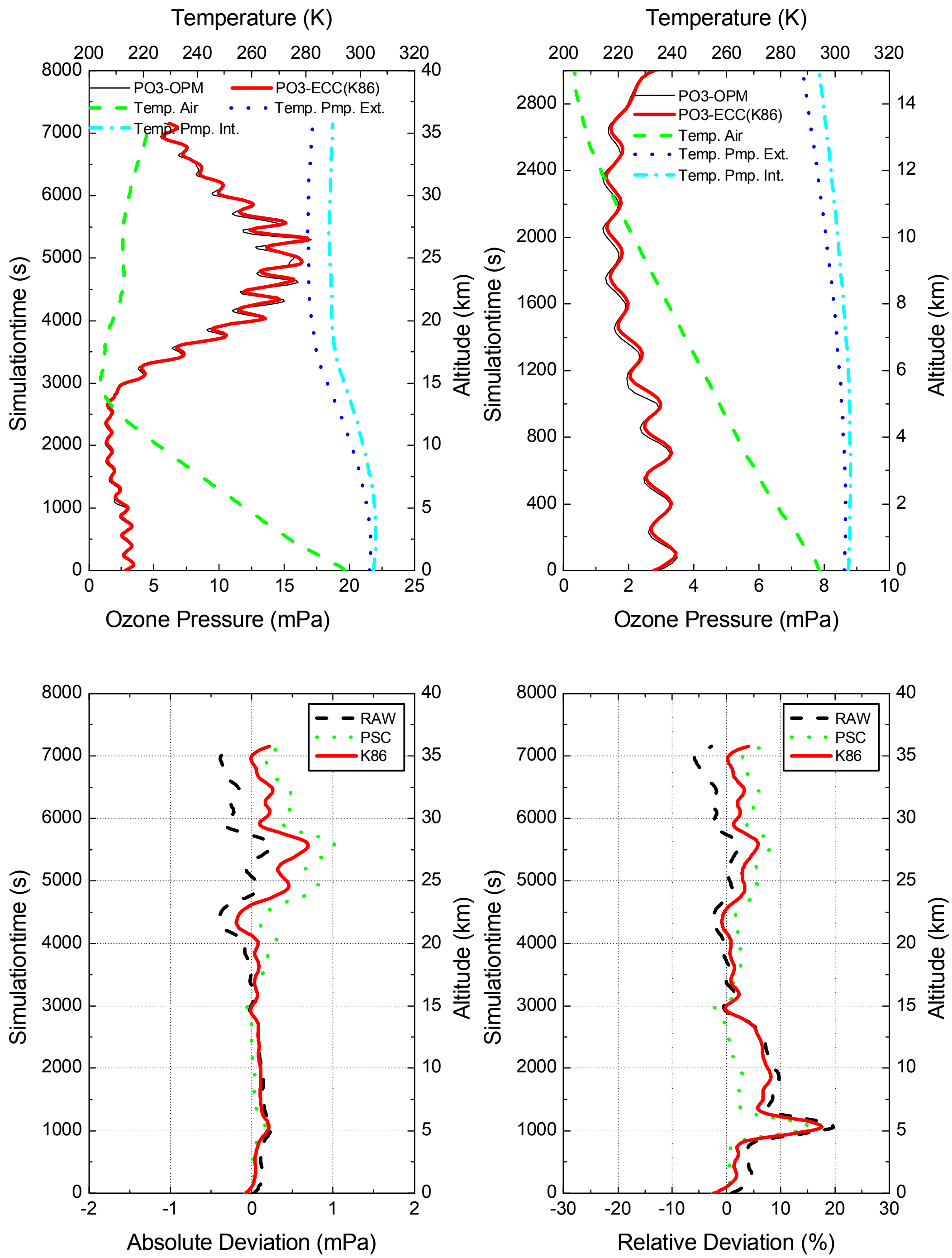
JOSIE-2000

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



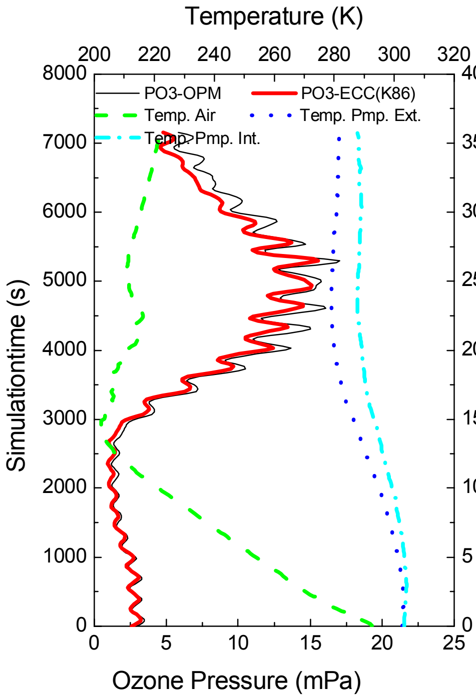
JOSIE-2000

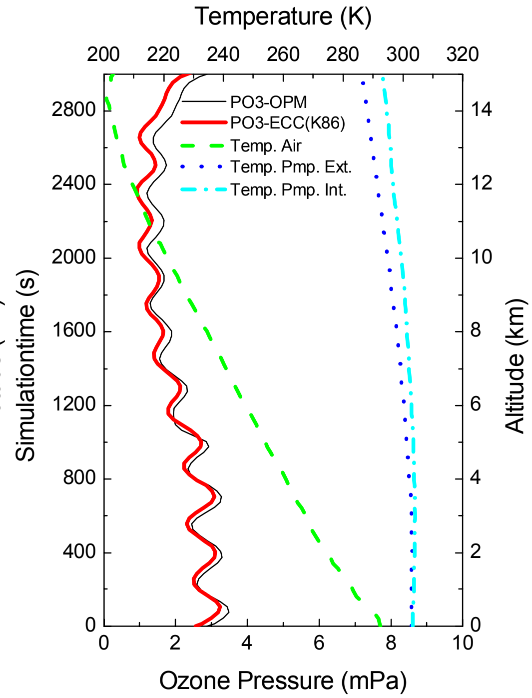
Participant=3   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=95

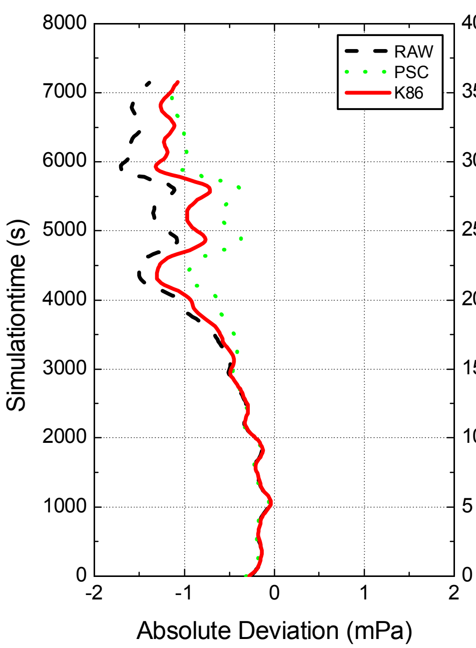


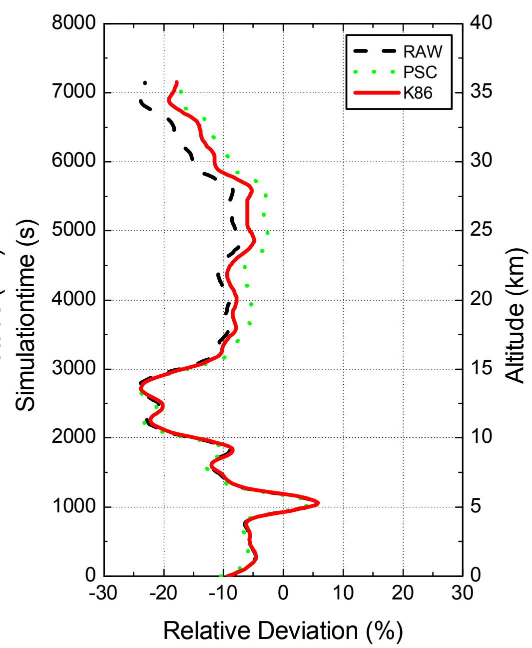
JOSIE-2000

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



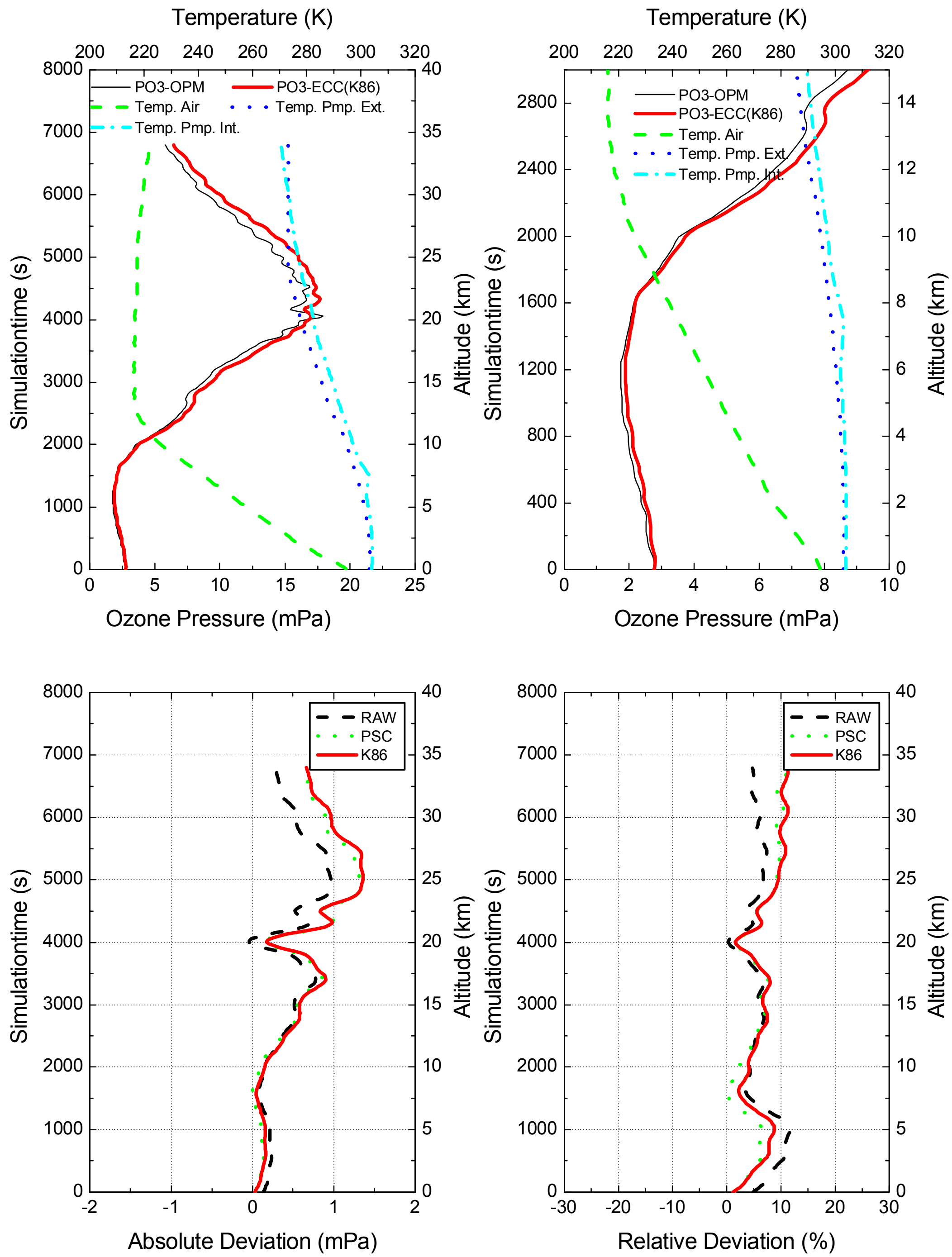






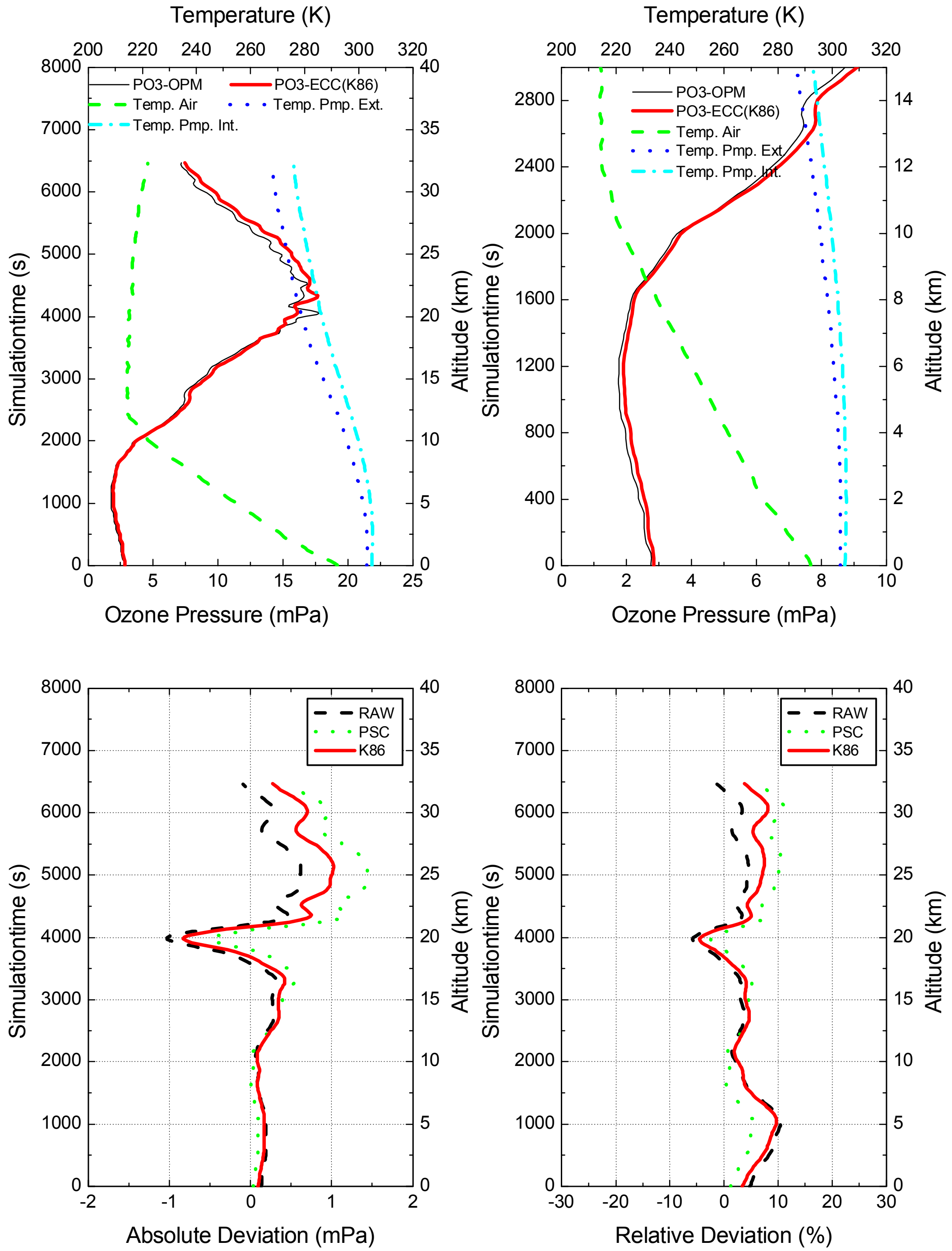
JOSIE-2000

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



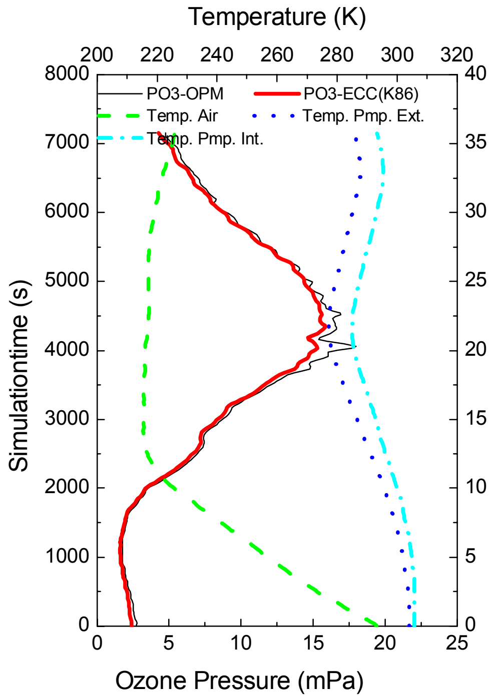
JOSIE-2000

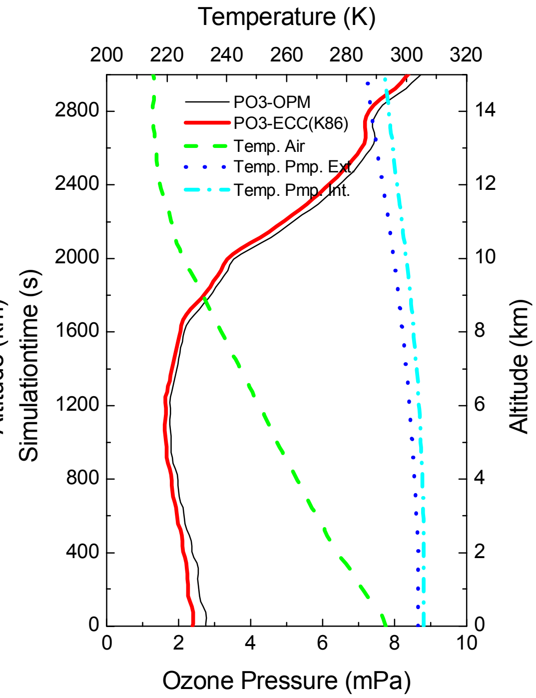
Participant=6   Sonde Type=ENSCI-Z   Sol.Type=1A   Sim.No.=96

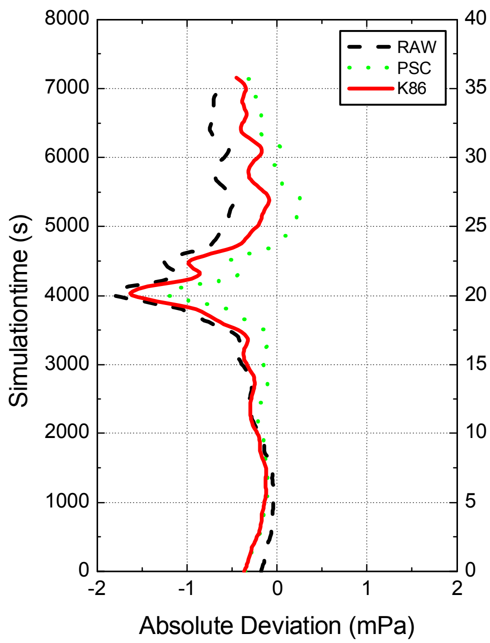


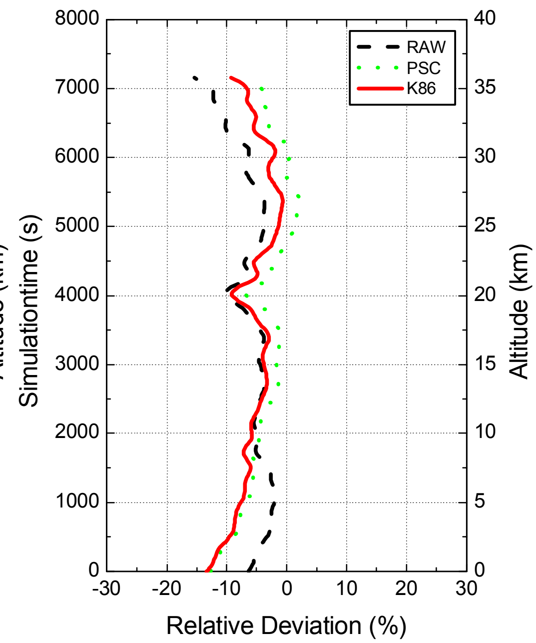
JOSIE-2000

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



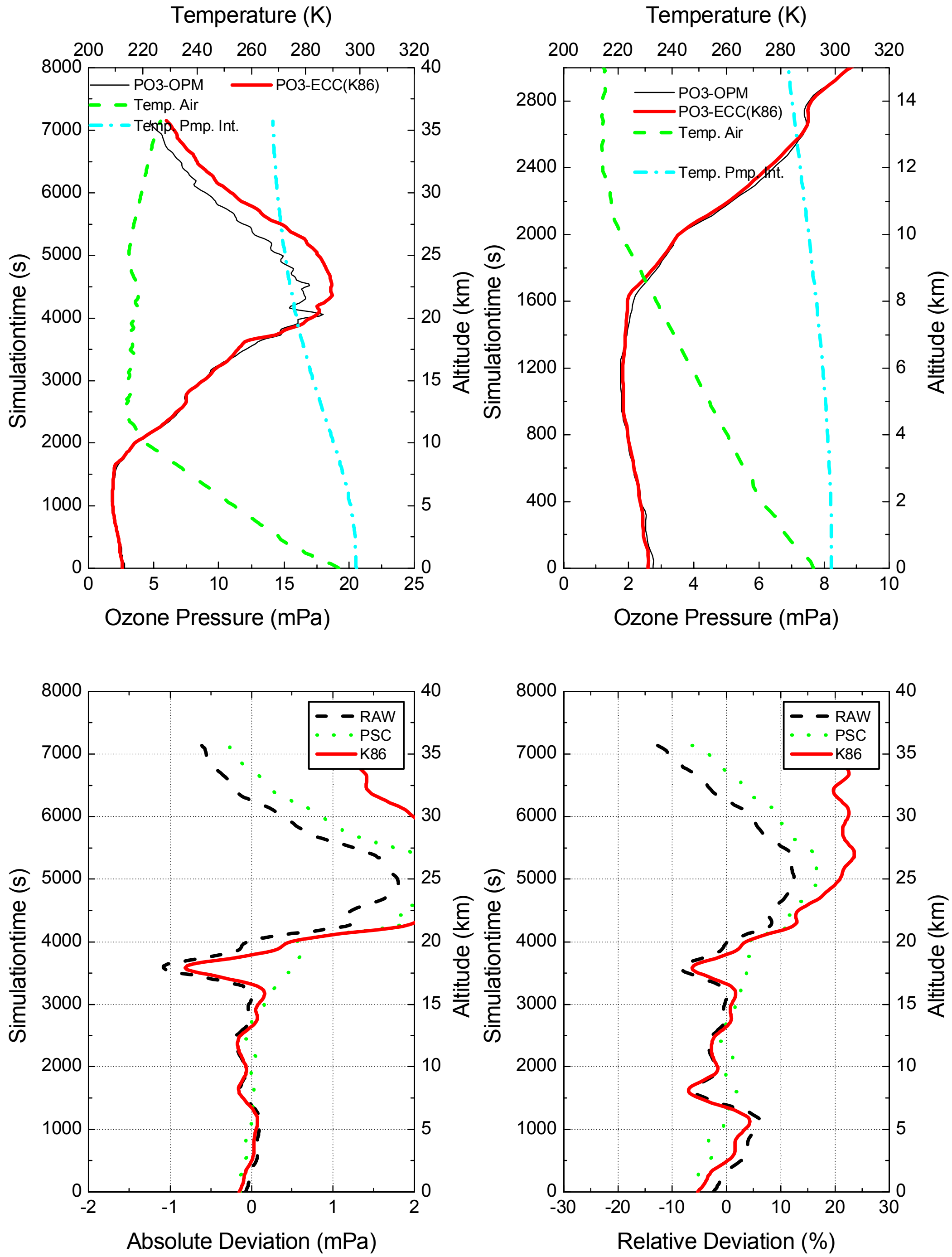






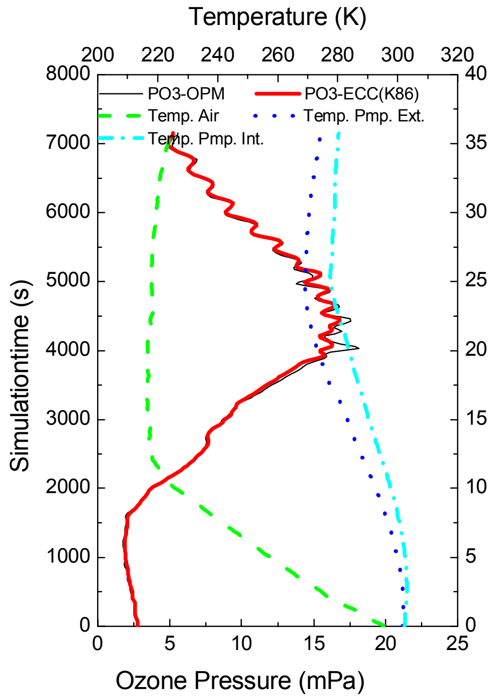
JOSIE-2000

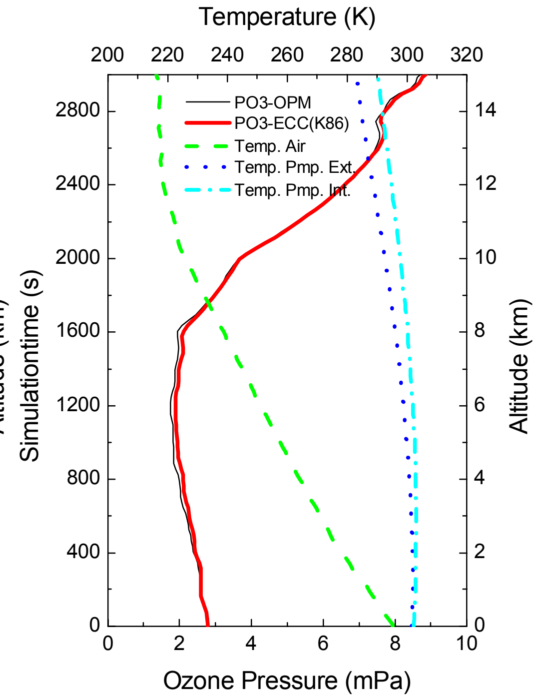
Participant=8   Sonde Type=KC96   Sol.Type=4A   Sim.No.=96

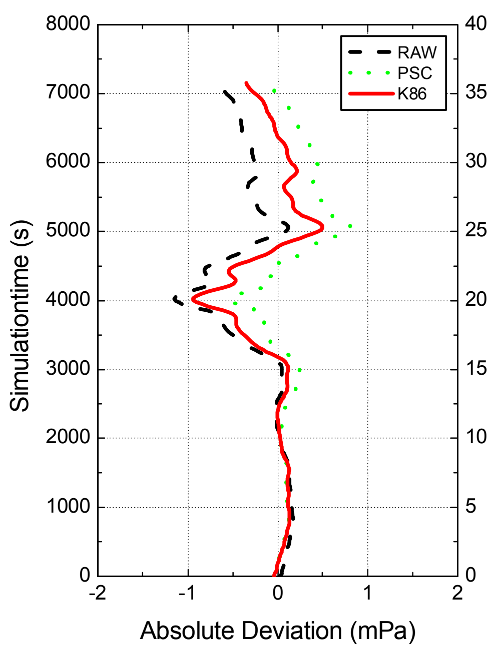


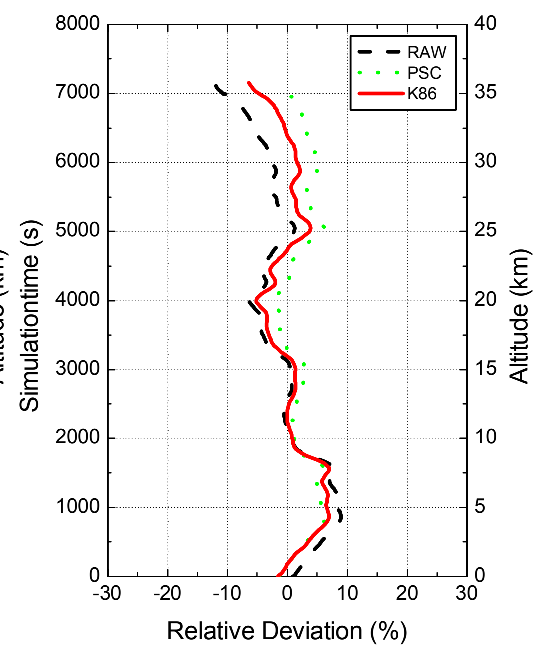
JOSIE-2000

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



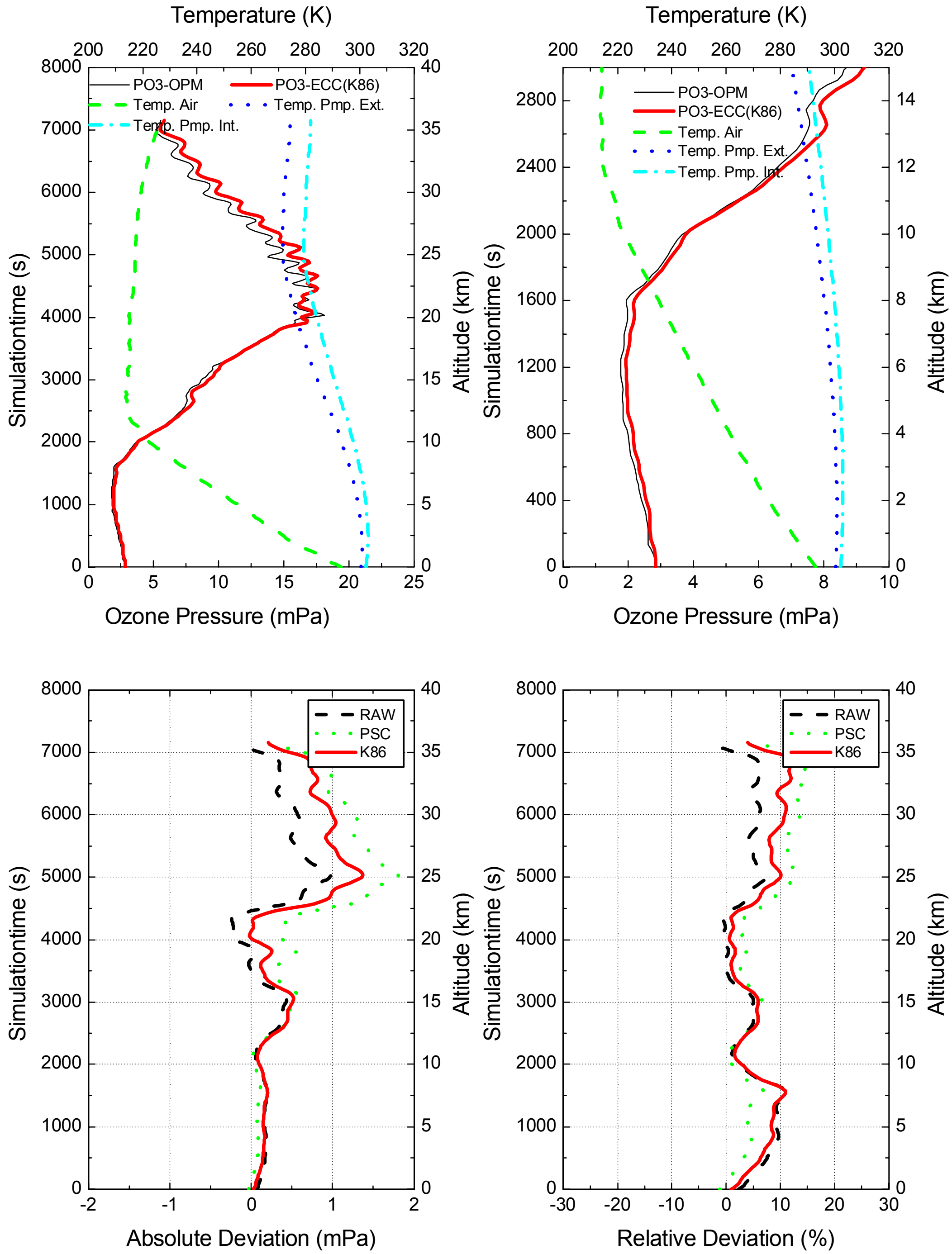






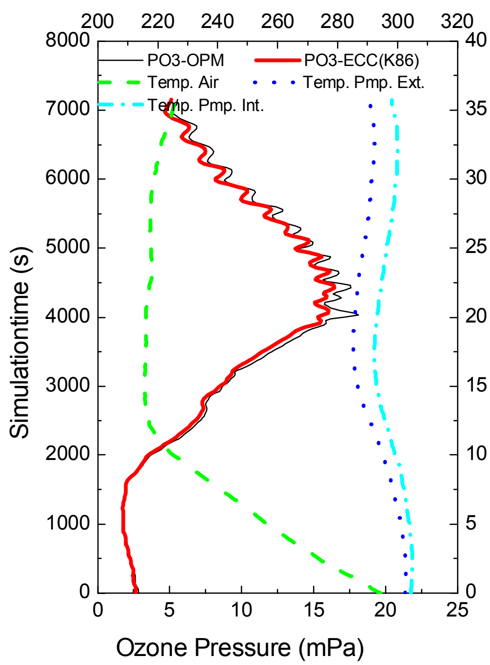
JOSIE-2000

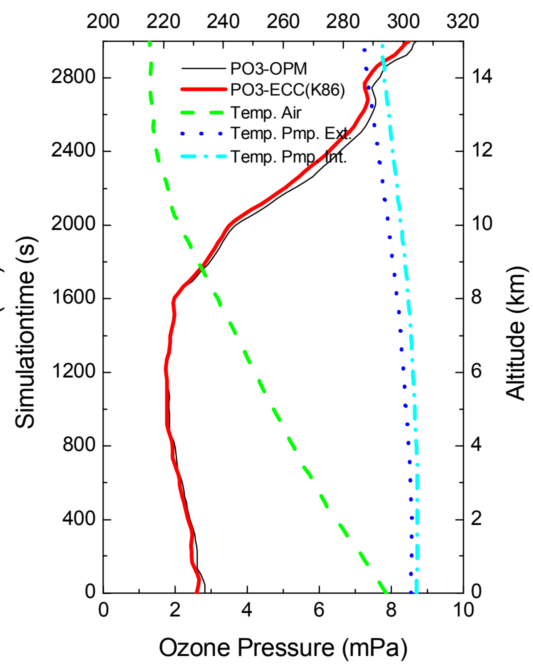
Participant=6 Sonde Type=ENSCI-Z Sol.Type=1A Sim.No.=97

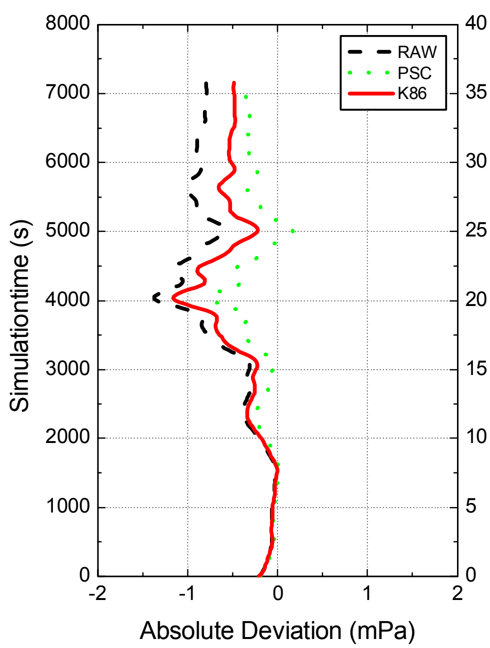


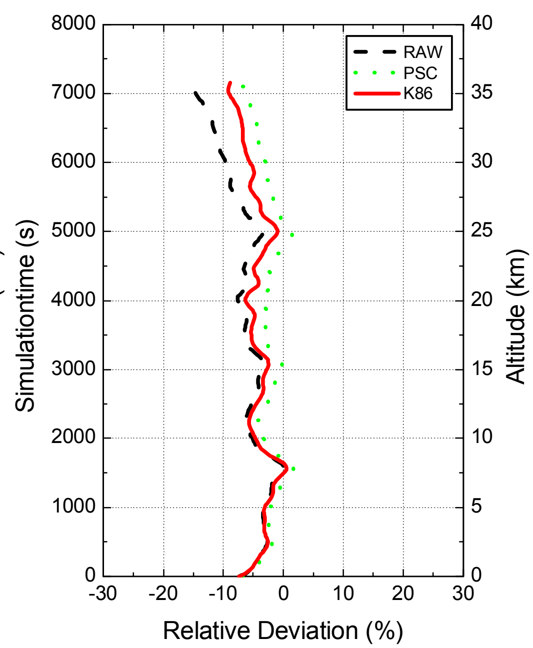
JOSIE-2000

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



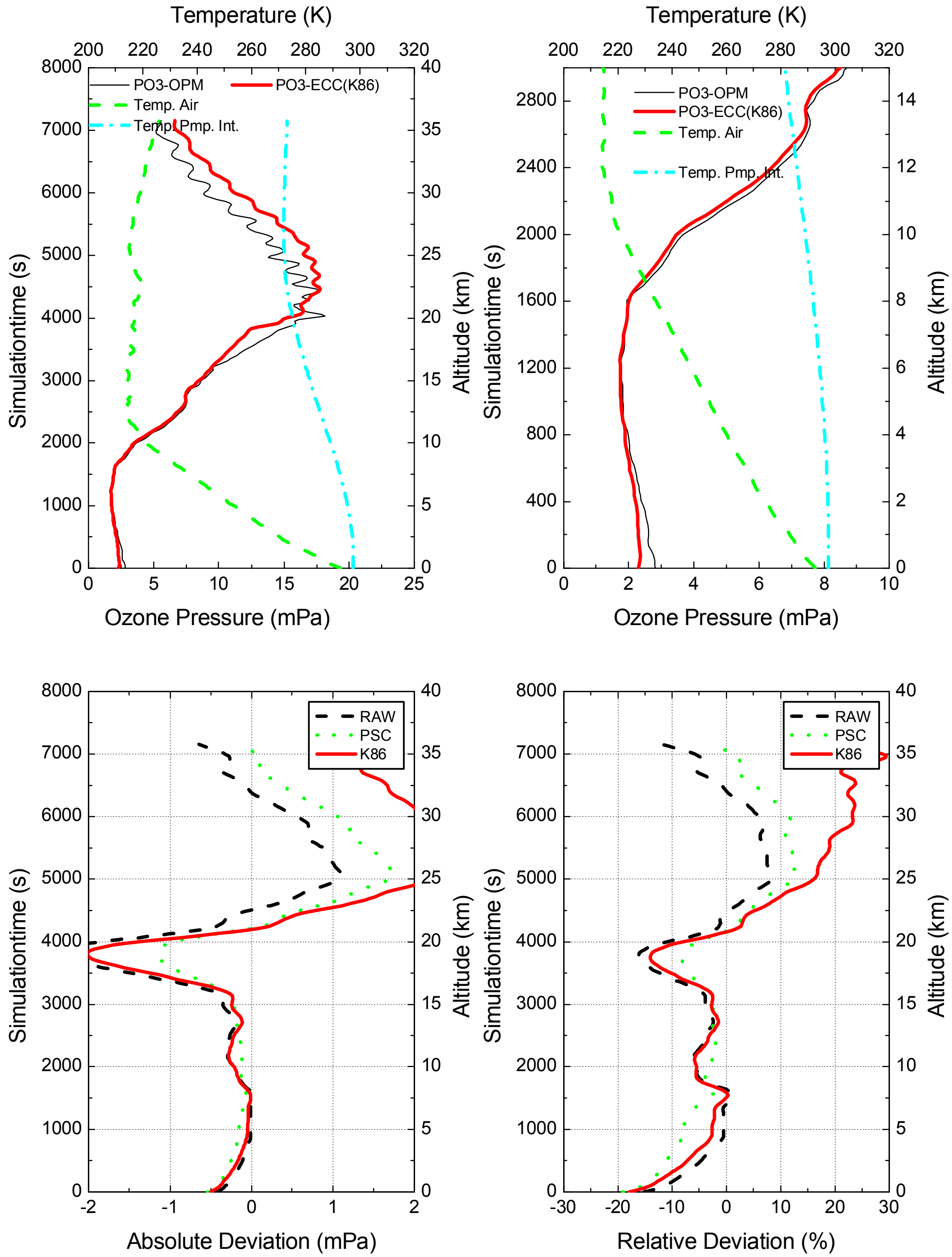






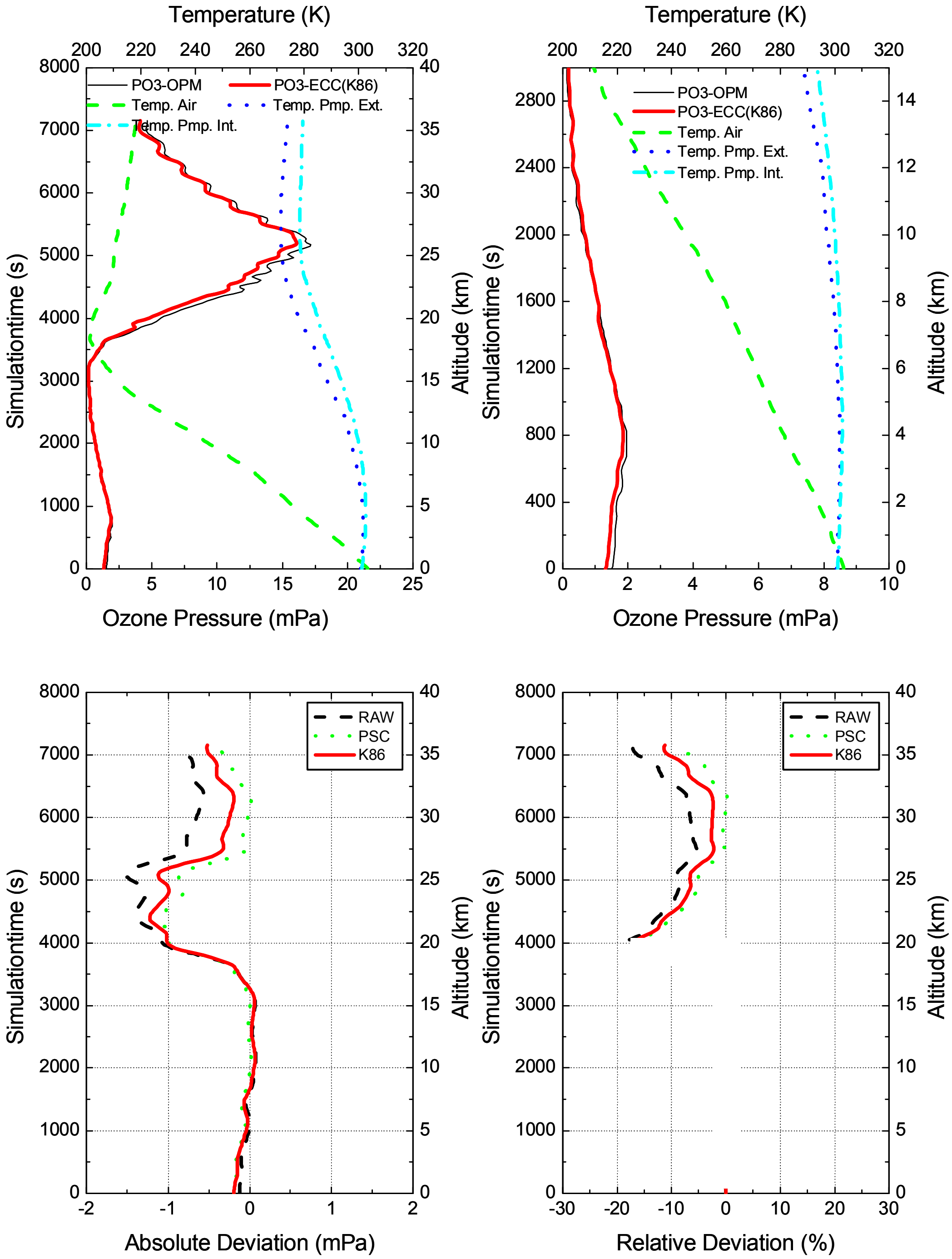
JOSIE-2000

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



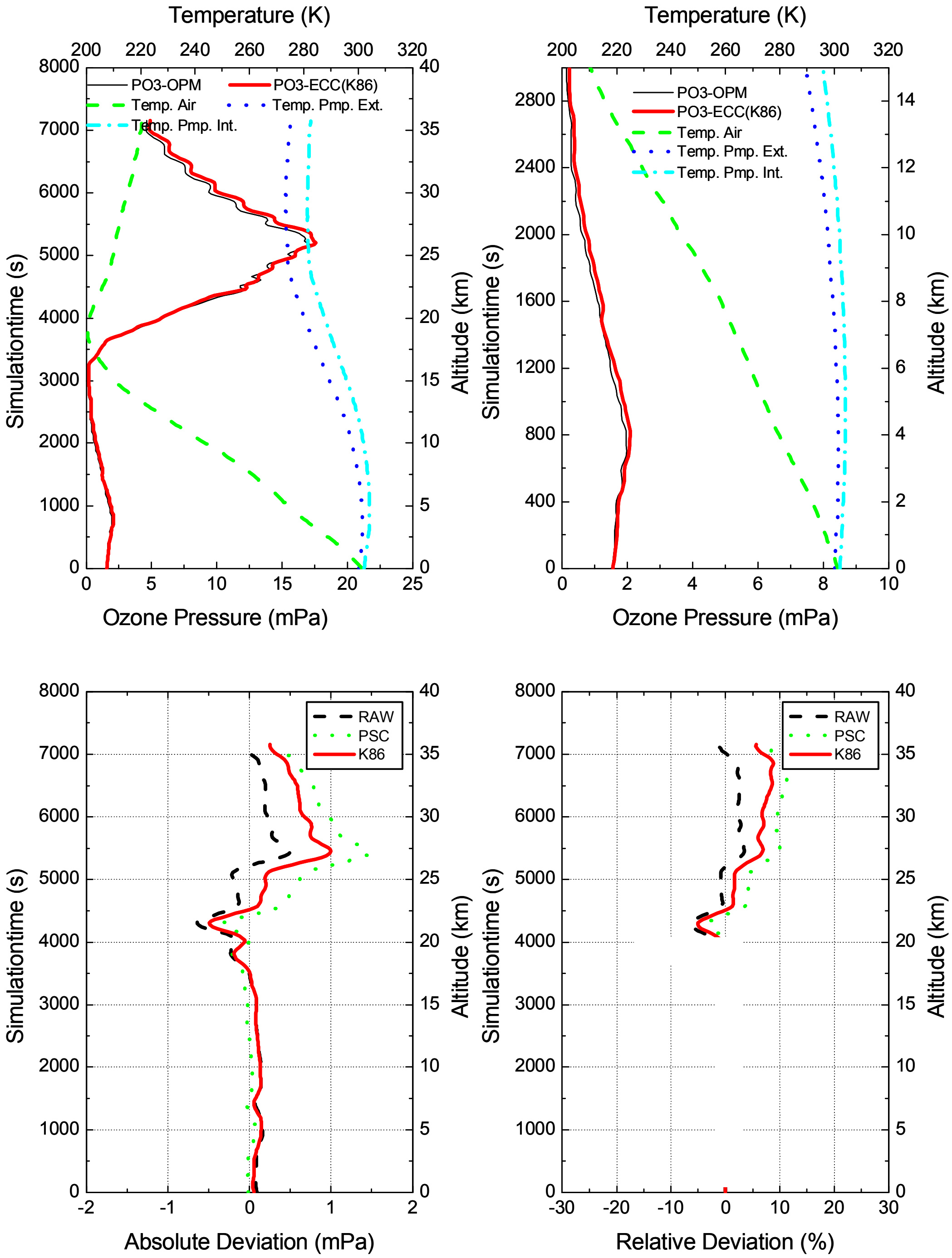
JOSIE-2000

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



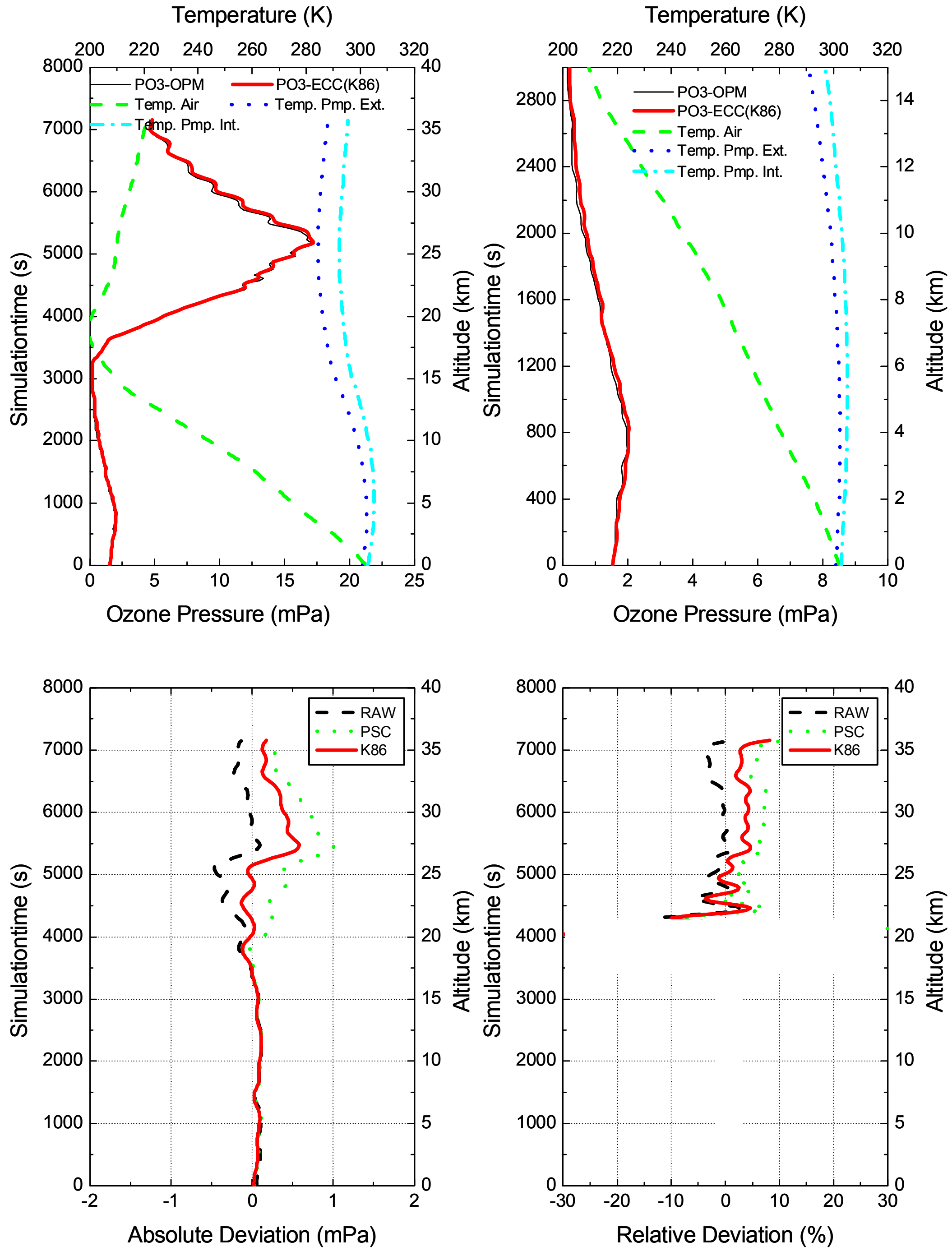
JOSIE-2000

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



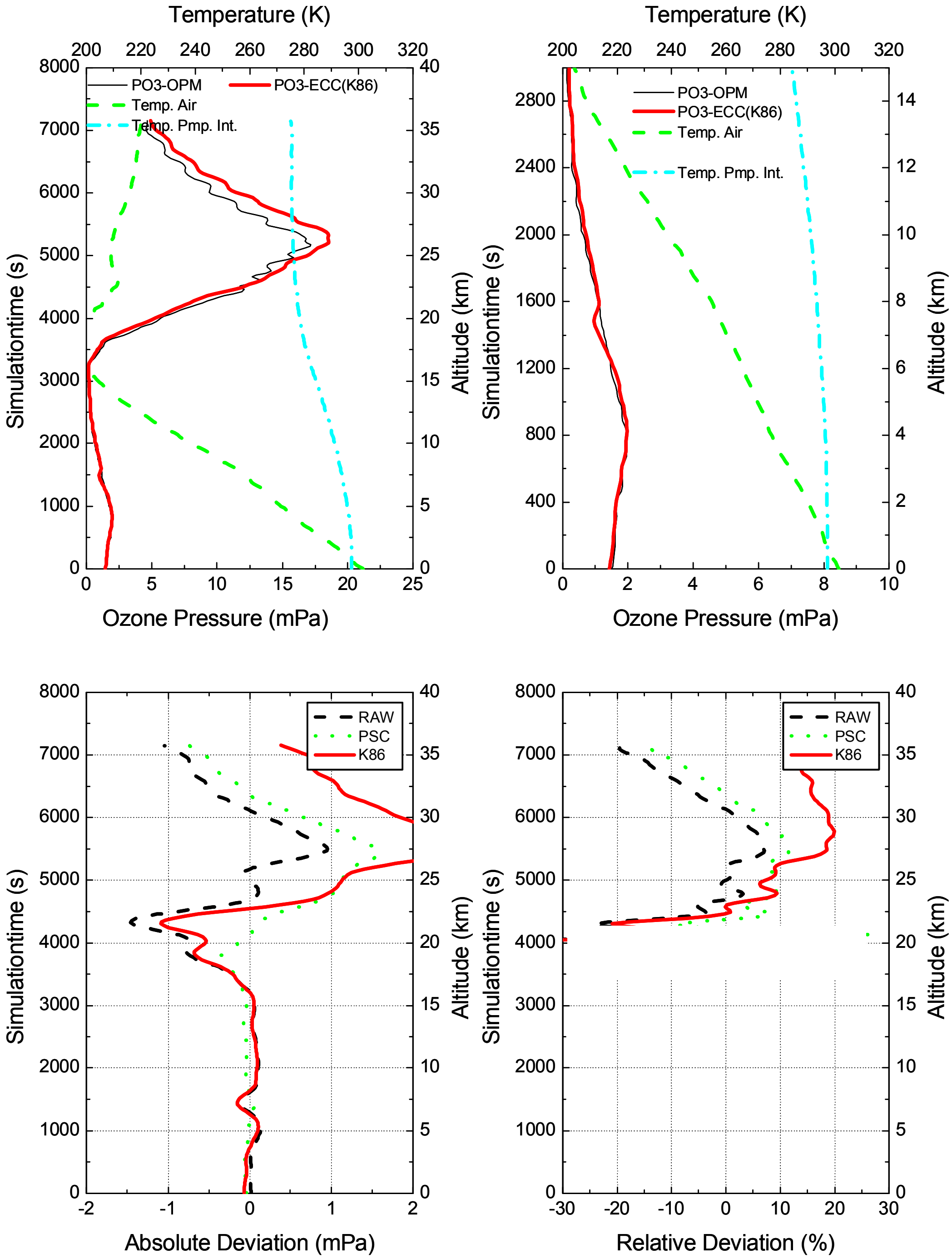
JOSIE-2000

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



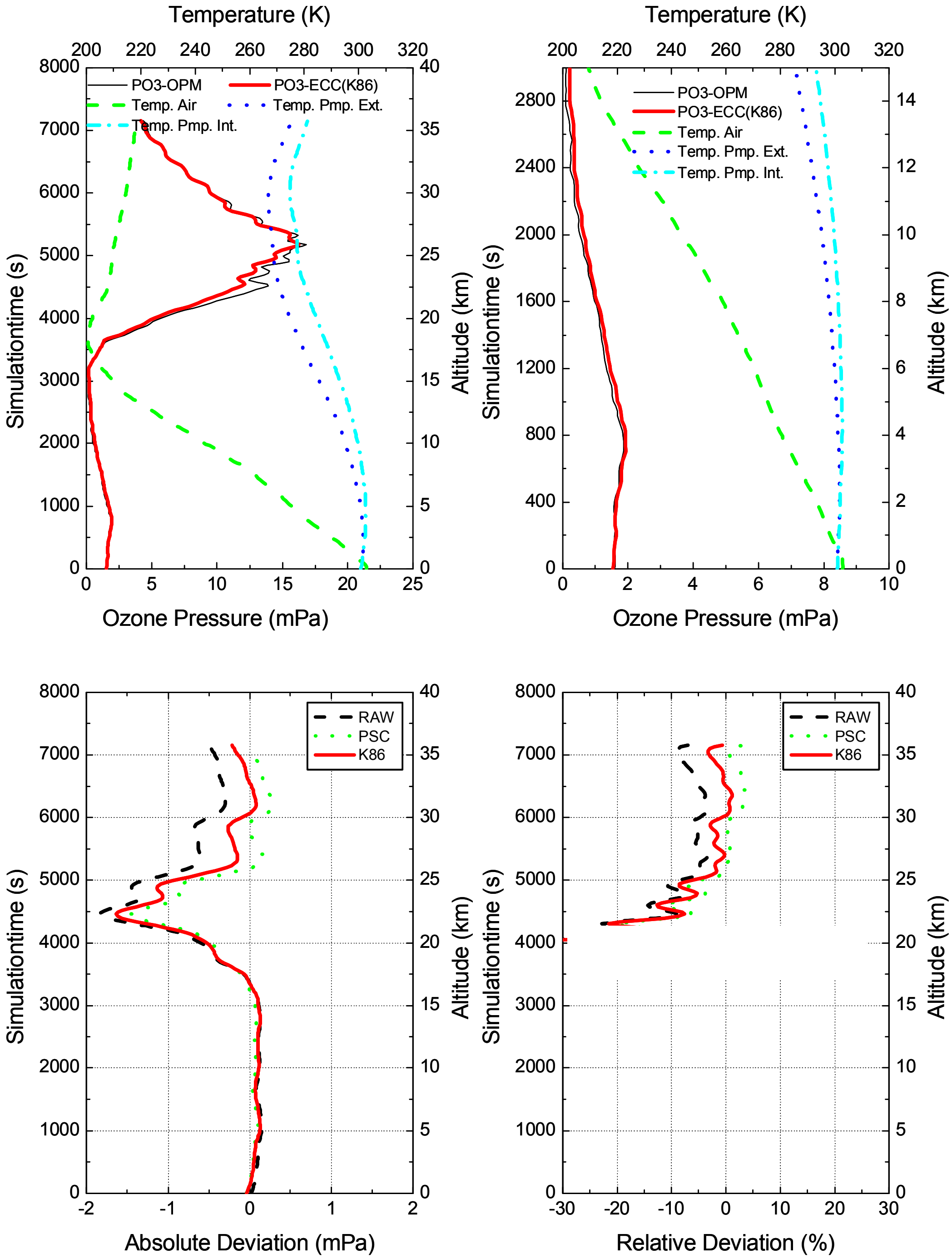
JOSIE-2000

Participant=8 Sonde Type=KC96 Sol.Type=4A Sim.No.=98



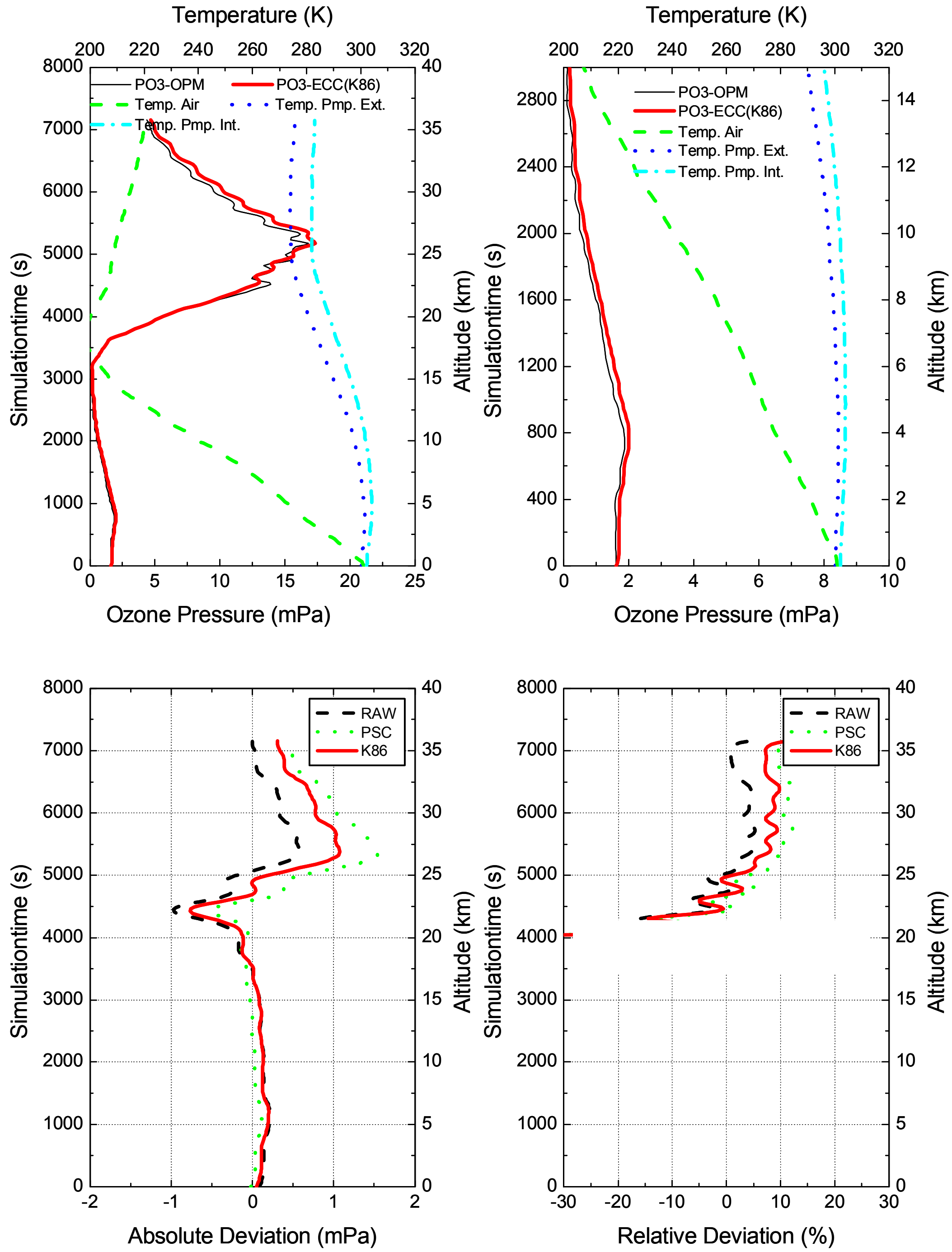
JOSIE-2000

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



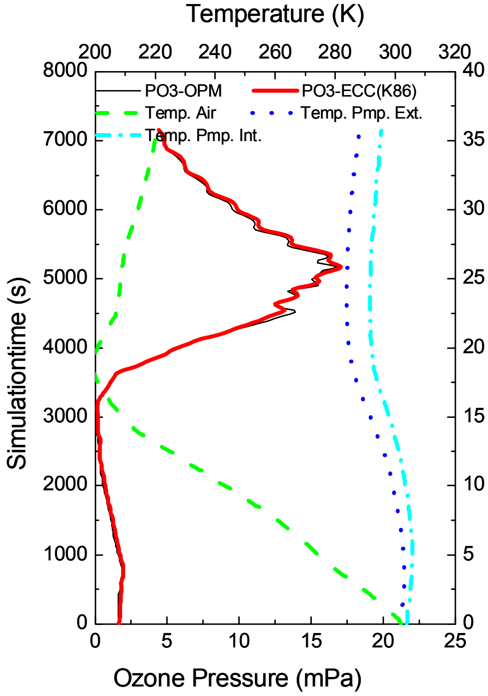
JOSIE-2000

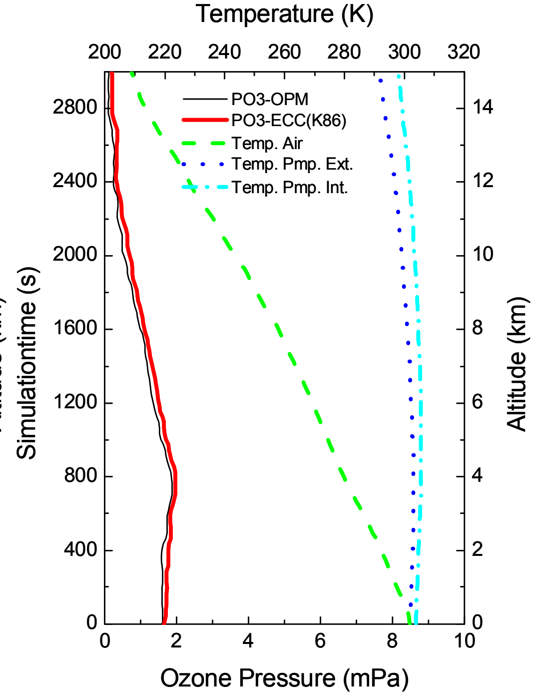
Participant=6   Sonde Type=ENSCI-Z   Sol.Type=1A   Sim.No.=99

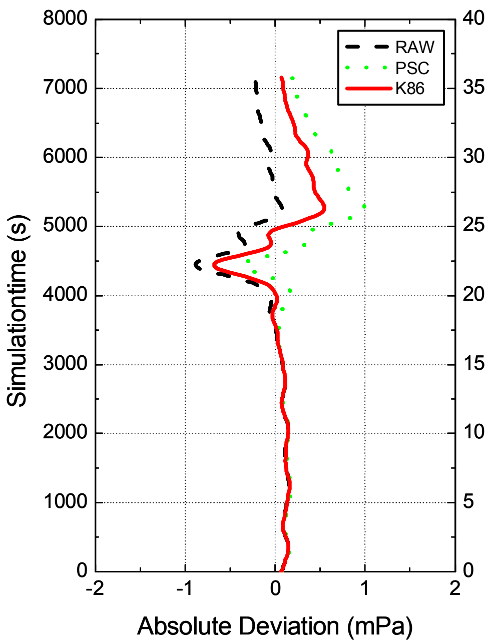


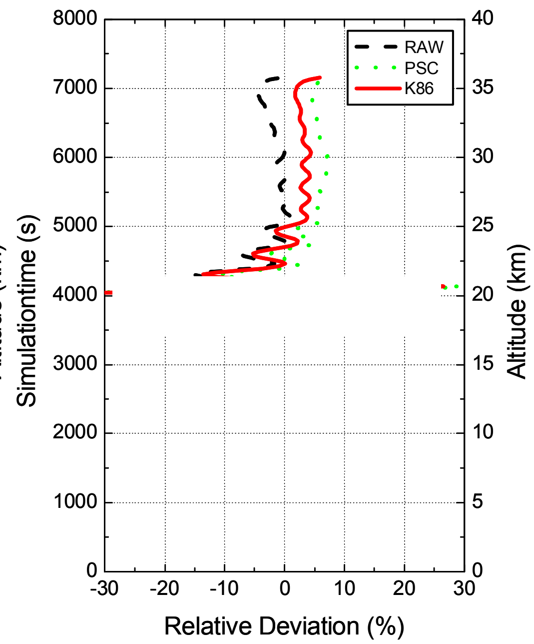
JOSIE-2000

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



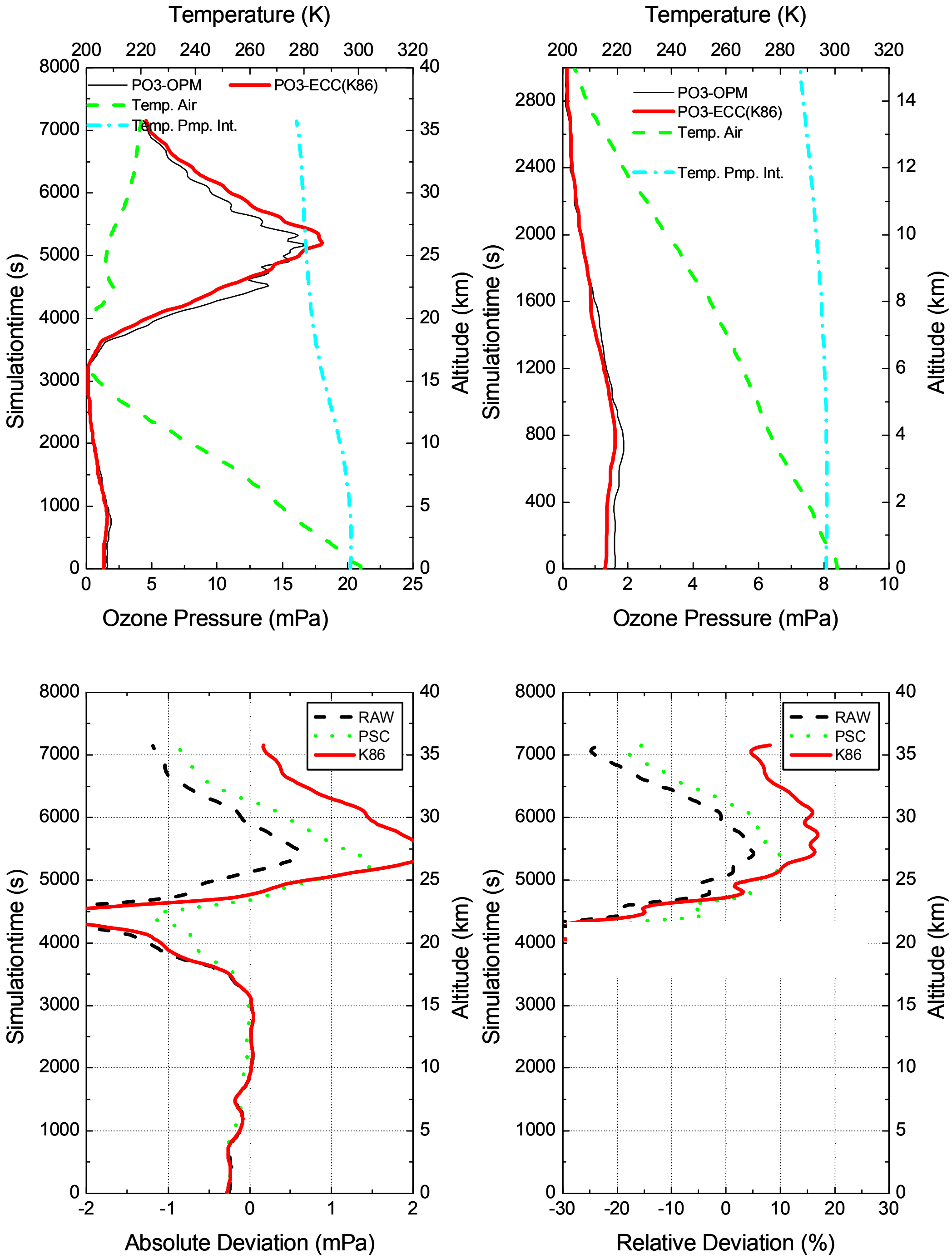






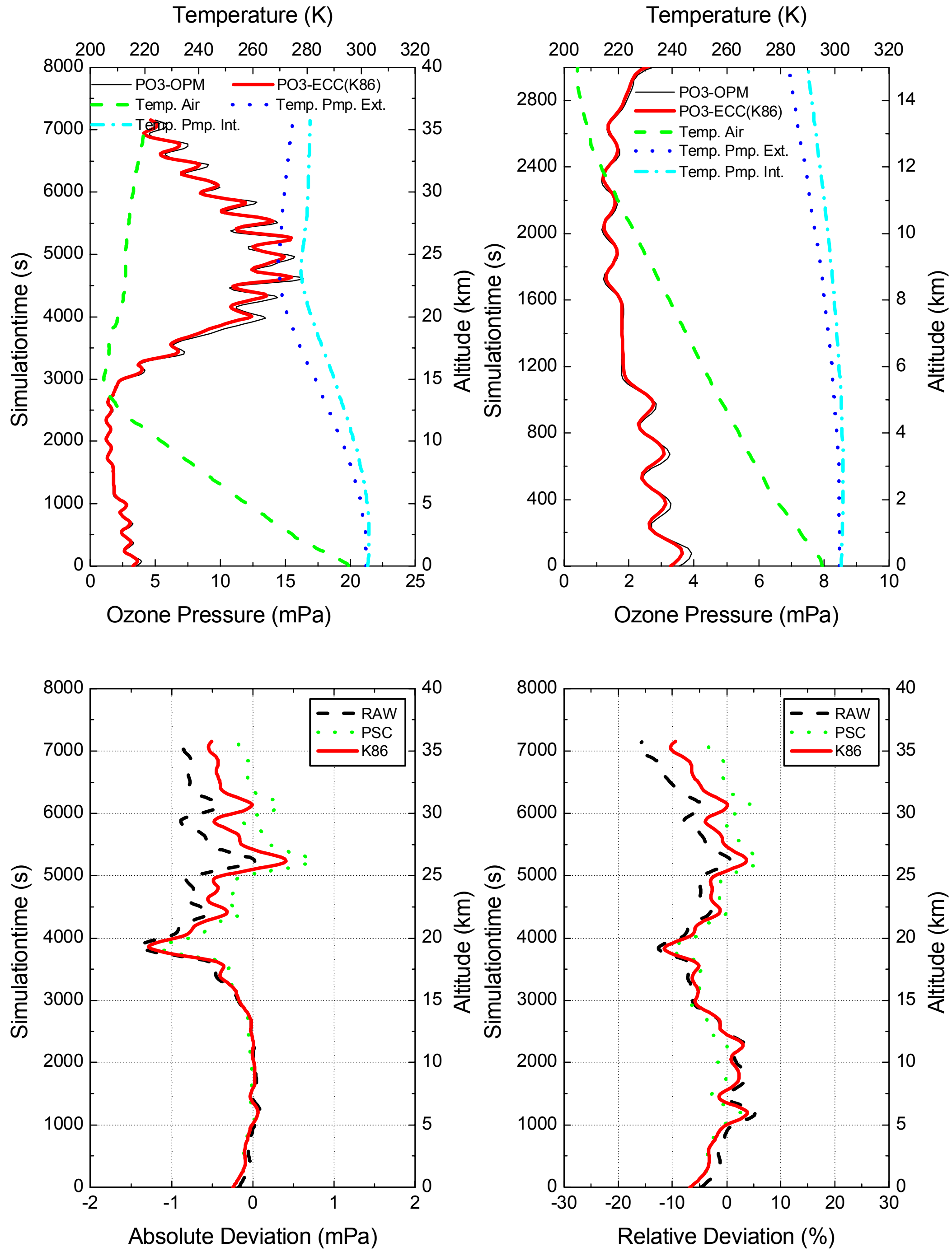
JOSIE-2000

Participant=8   Sonde Type=KC96   Sol.Type=4A   Sim.No.=99



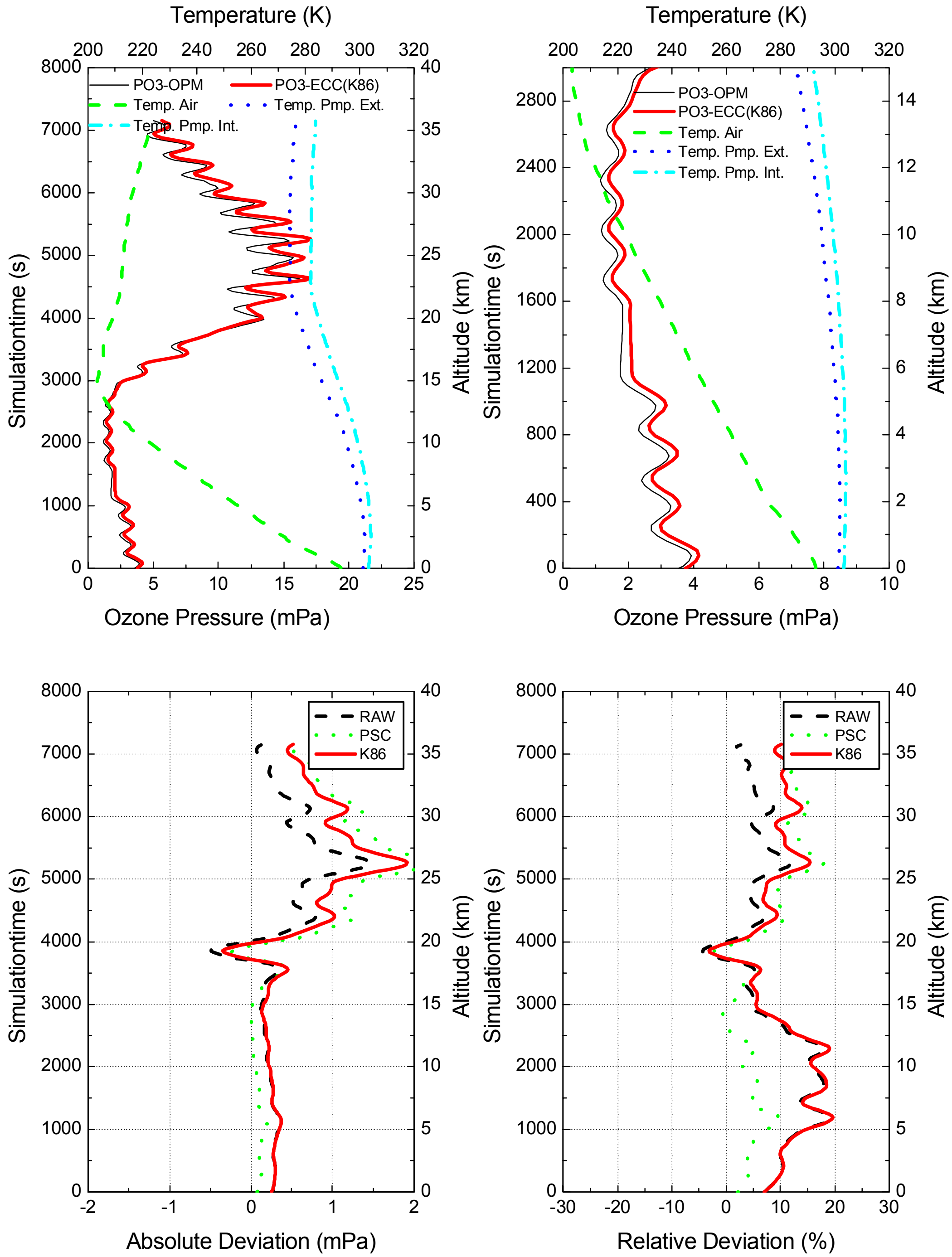
JOSIE-2000

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



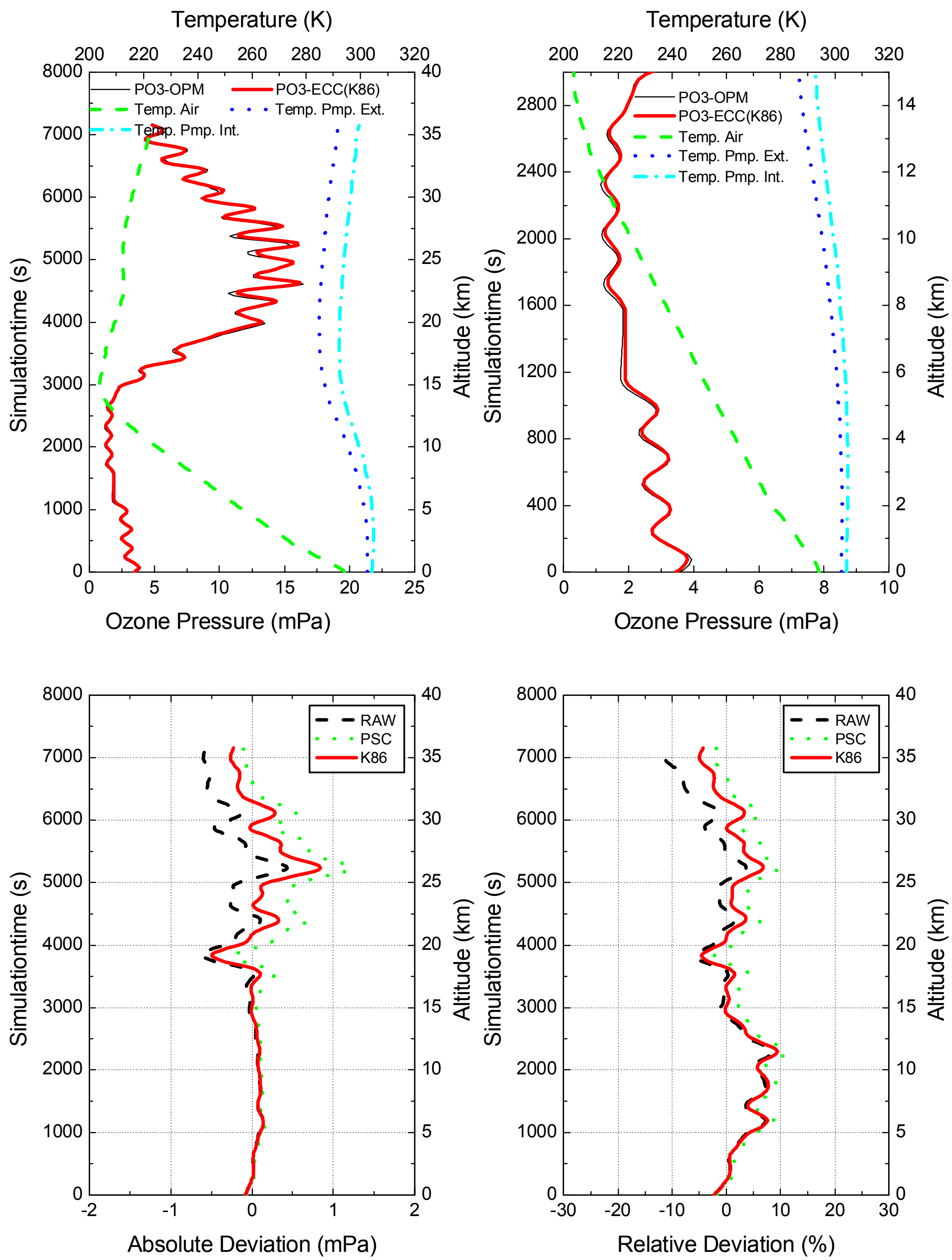
JOSIE-2000

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



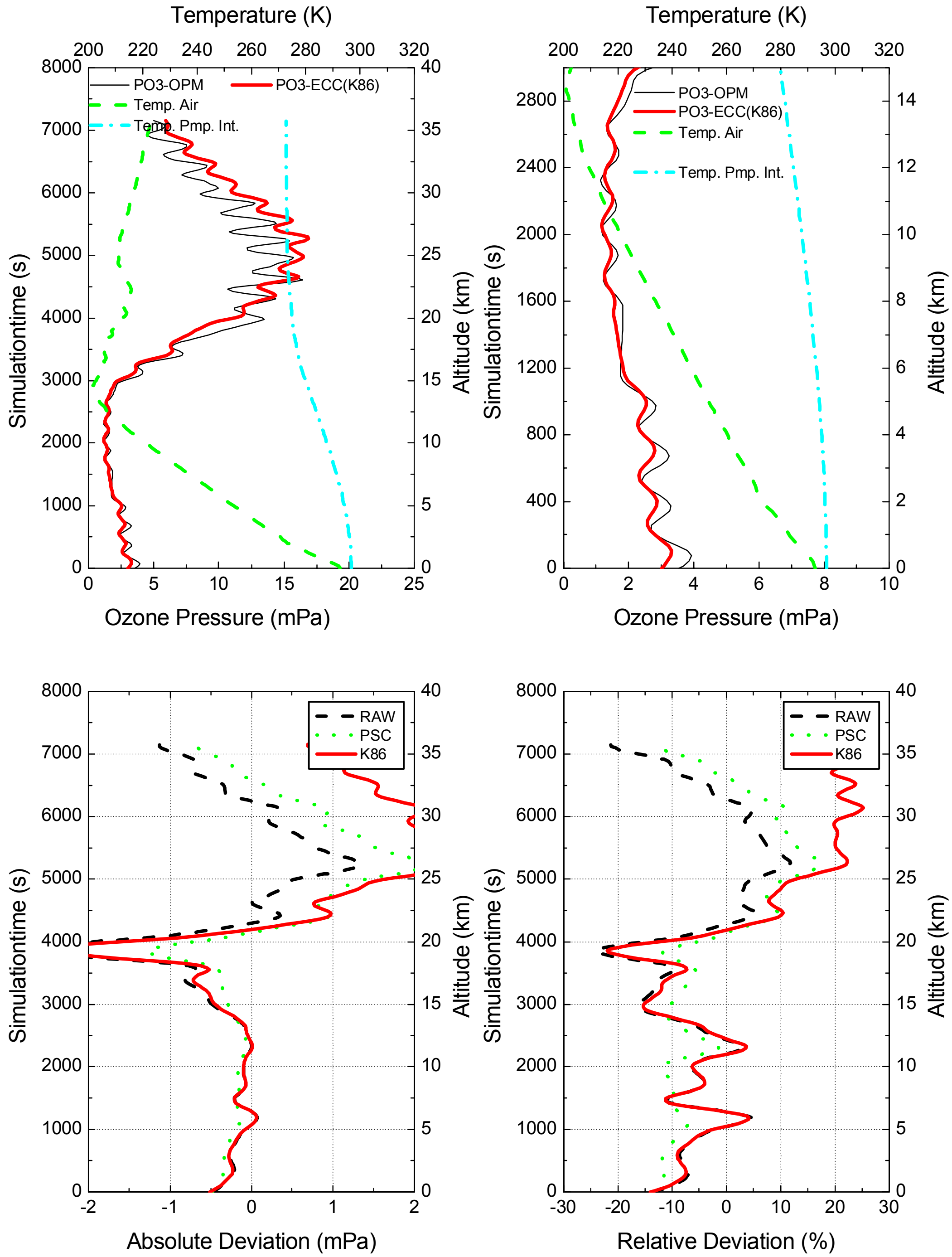
JOSIE-2000

Participant=7   Sonde Type=ENSCI-Z   Sol.Type=2B   Sim.No.=100



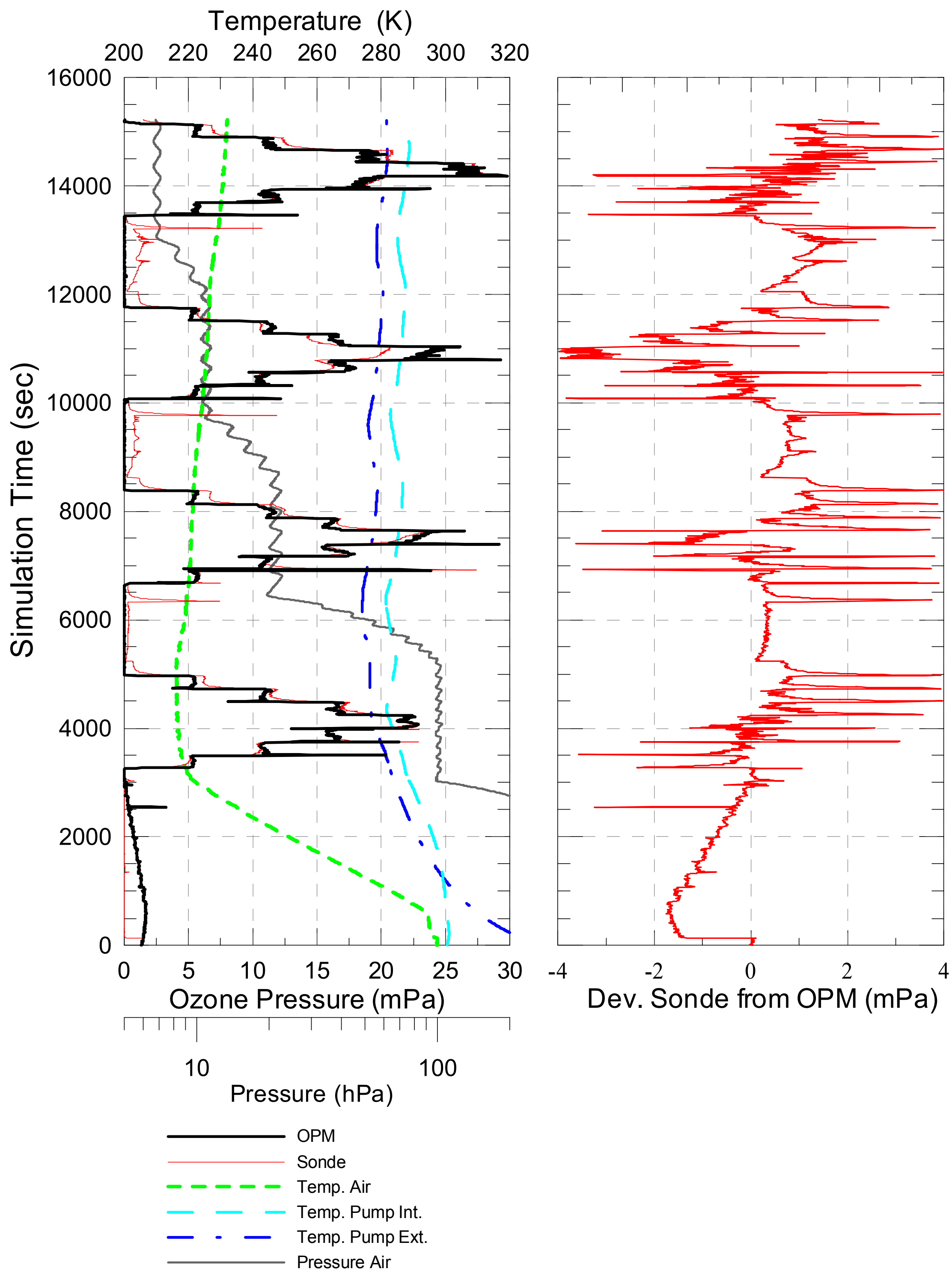
JOSIE-2000

Participant=8 Sonde Type=KC96 Sol.Type=4A Sim.No.=100



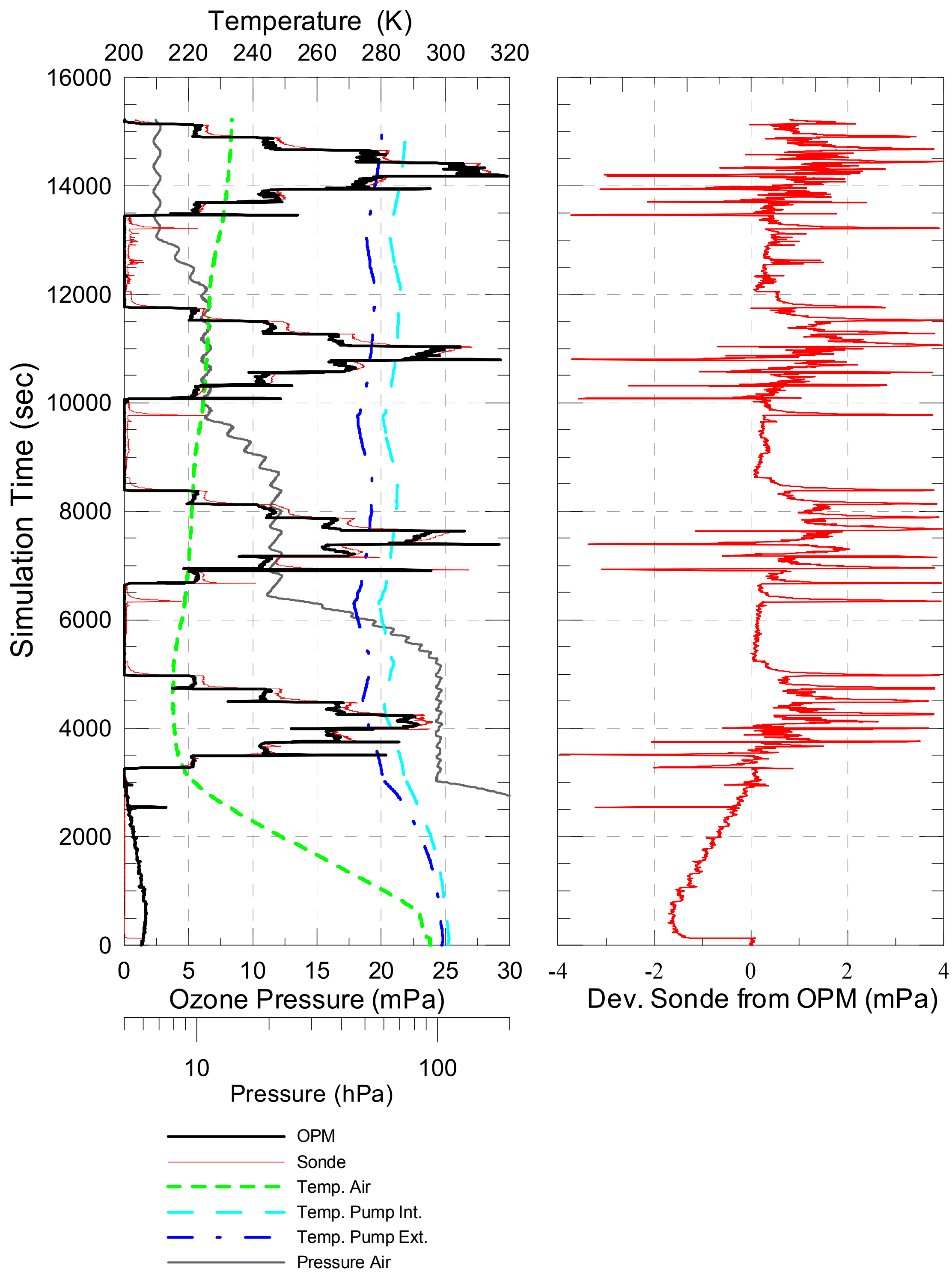
JOSIE 2000

Sim. No.= 101 Part. No.= 5 (WFF) Correction = K86



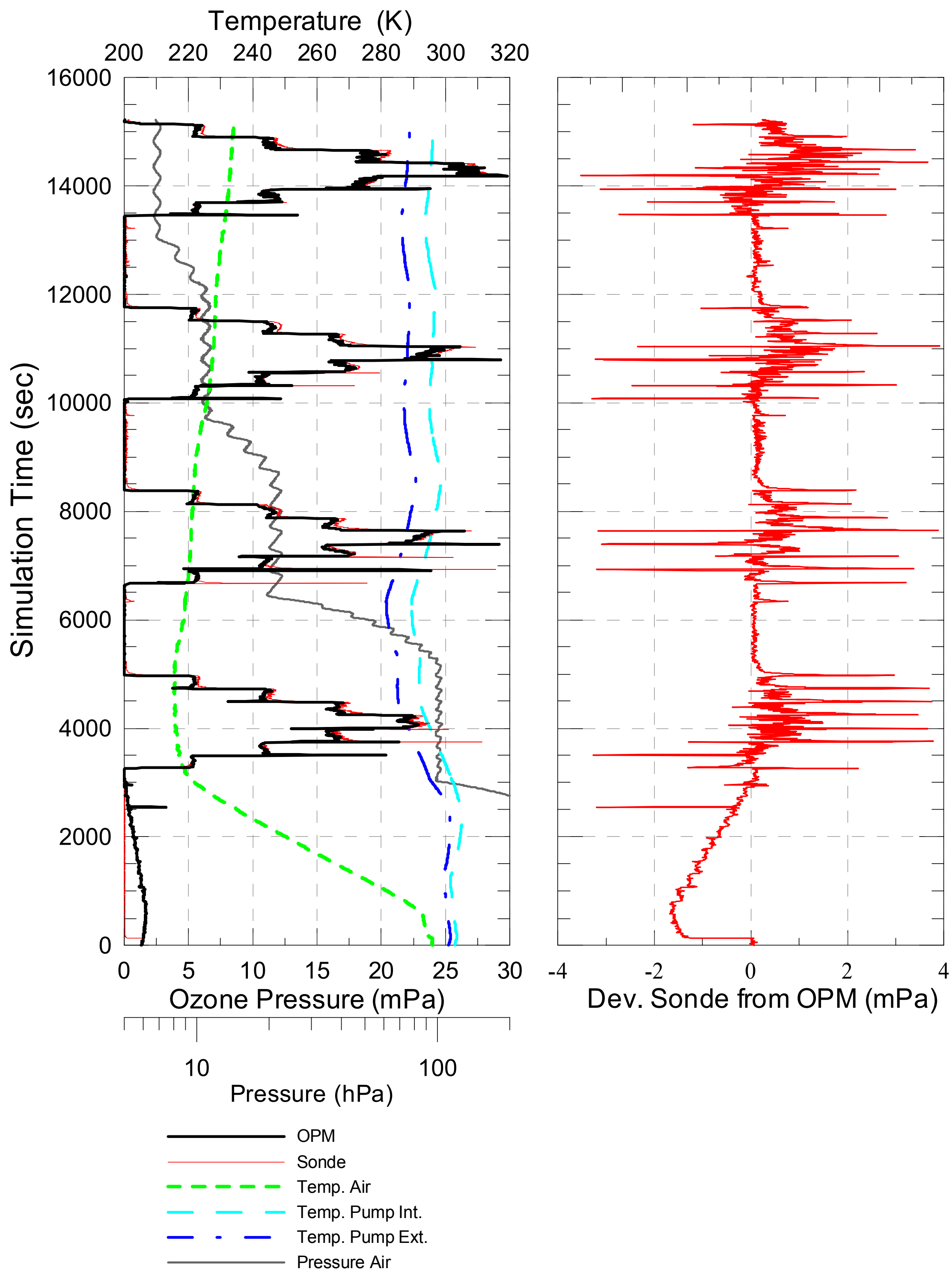
JOSIE 2000

Sim. No.= 101 Part. No.= 6 (SAP) Correction = K86



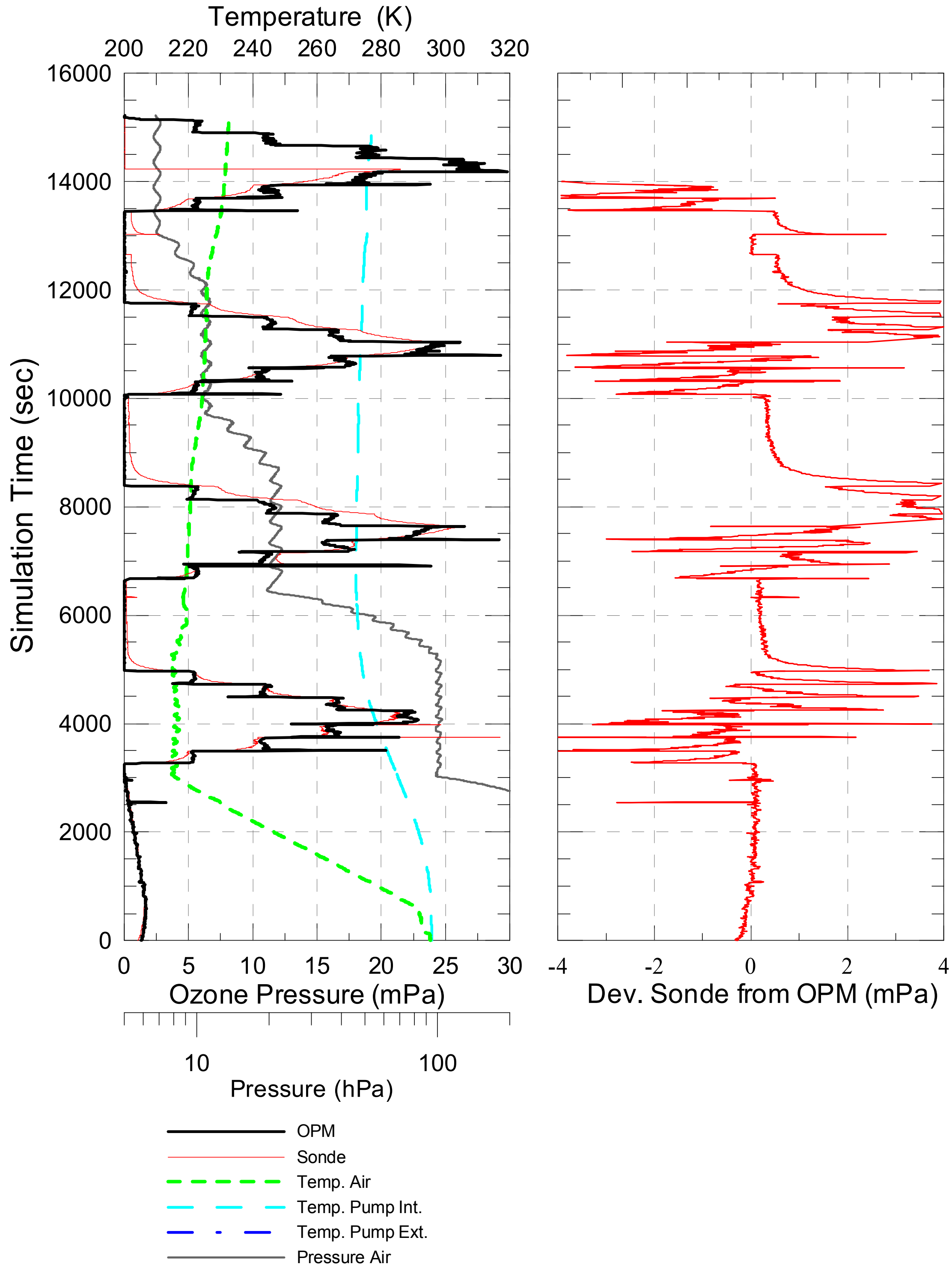
JOSIE 2000

Sim. No.= 101 Part. No.= 7 (URI) Correction = K86



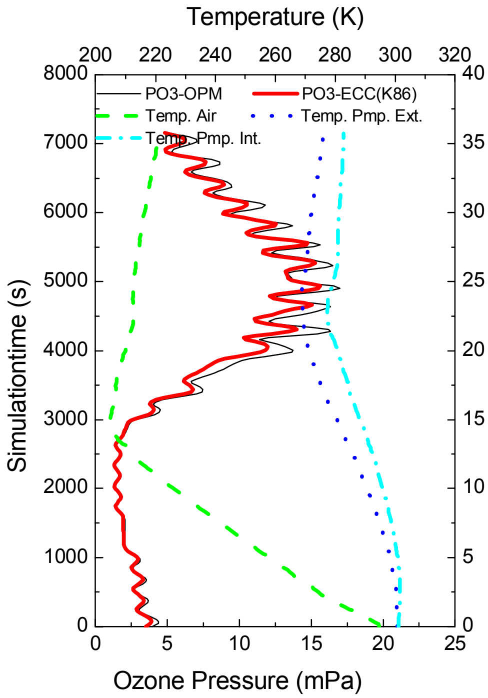
JOSIE 2000

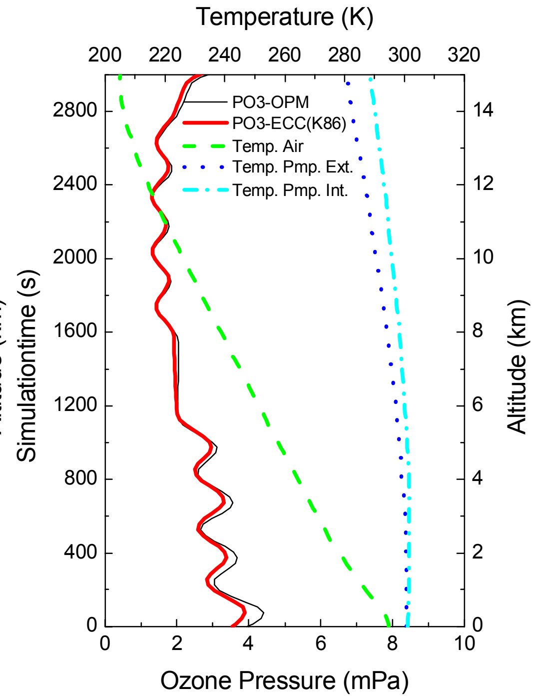
Sim. No.= 101 Part. No.= 8 (JMA) Correction = K86

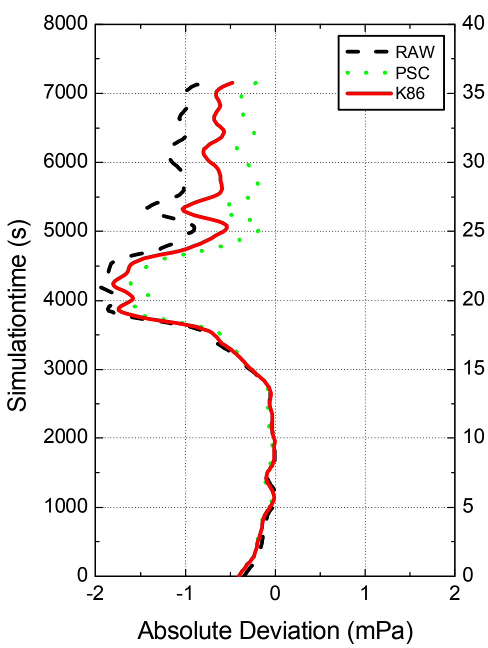


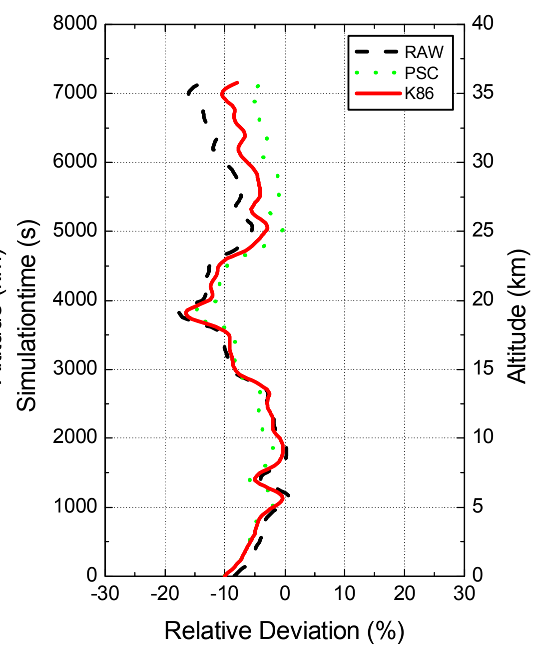
JOSIE-2000

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



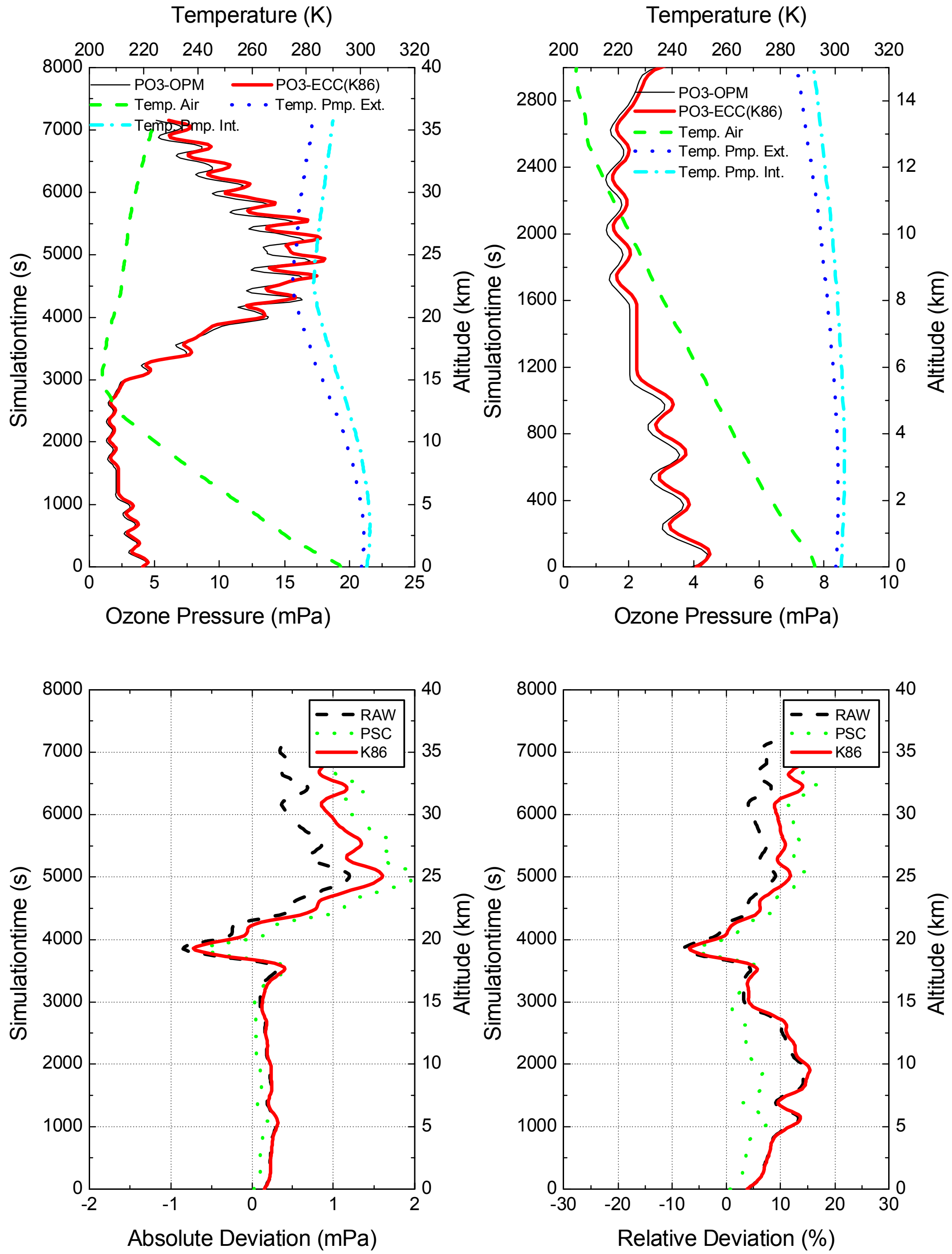






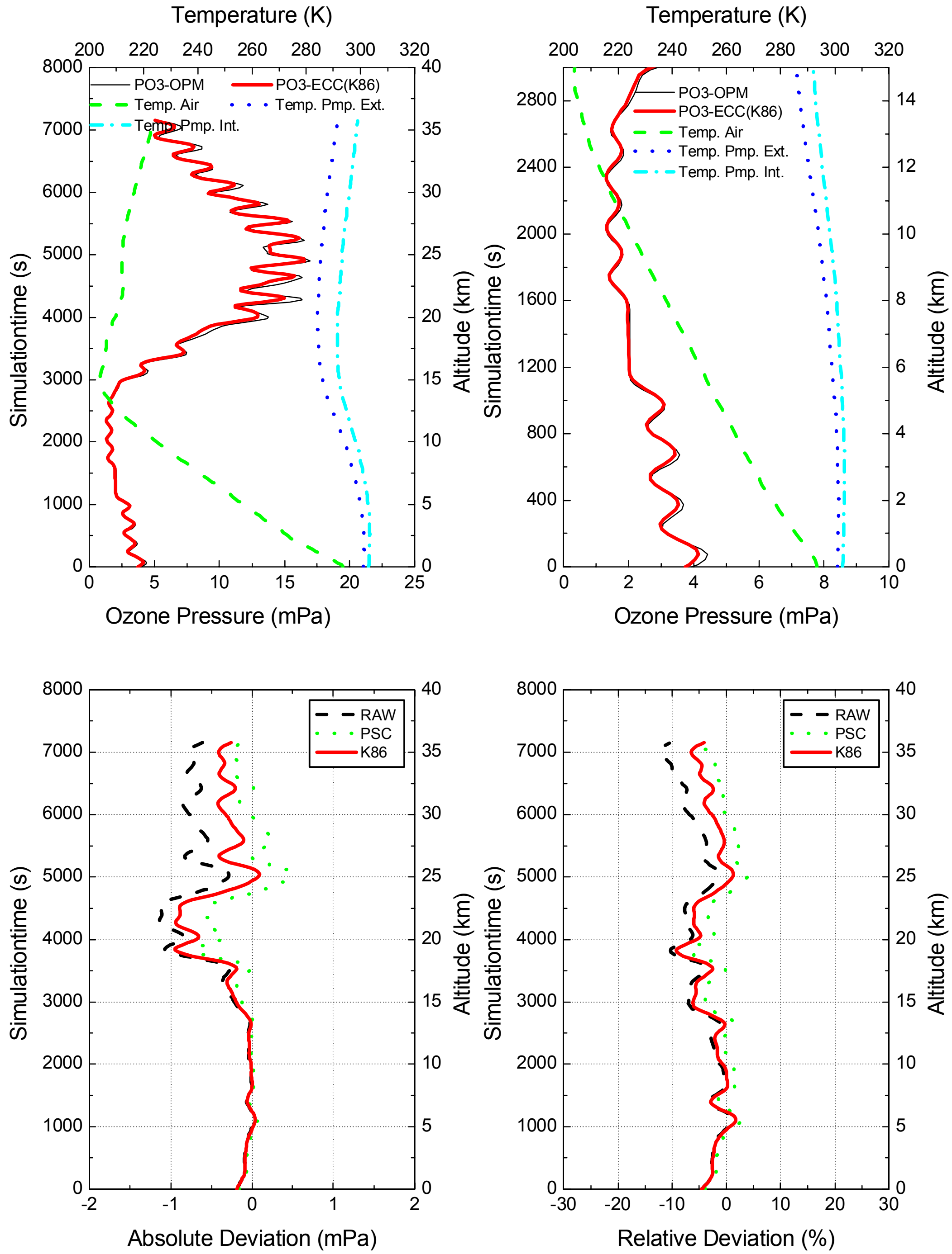
JOSIE-2000

Participant=6   Sonde Type=ENSCI-Z   Sol.Type=1A   Sim.No.=102



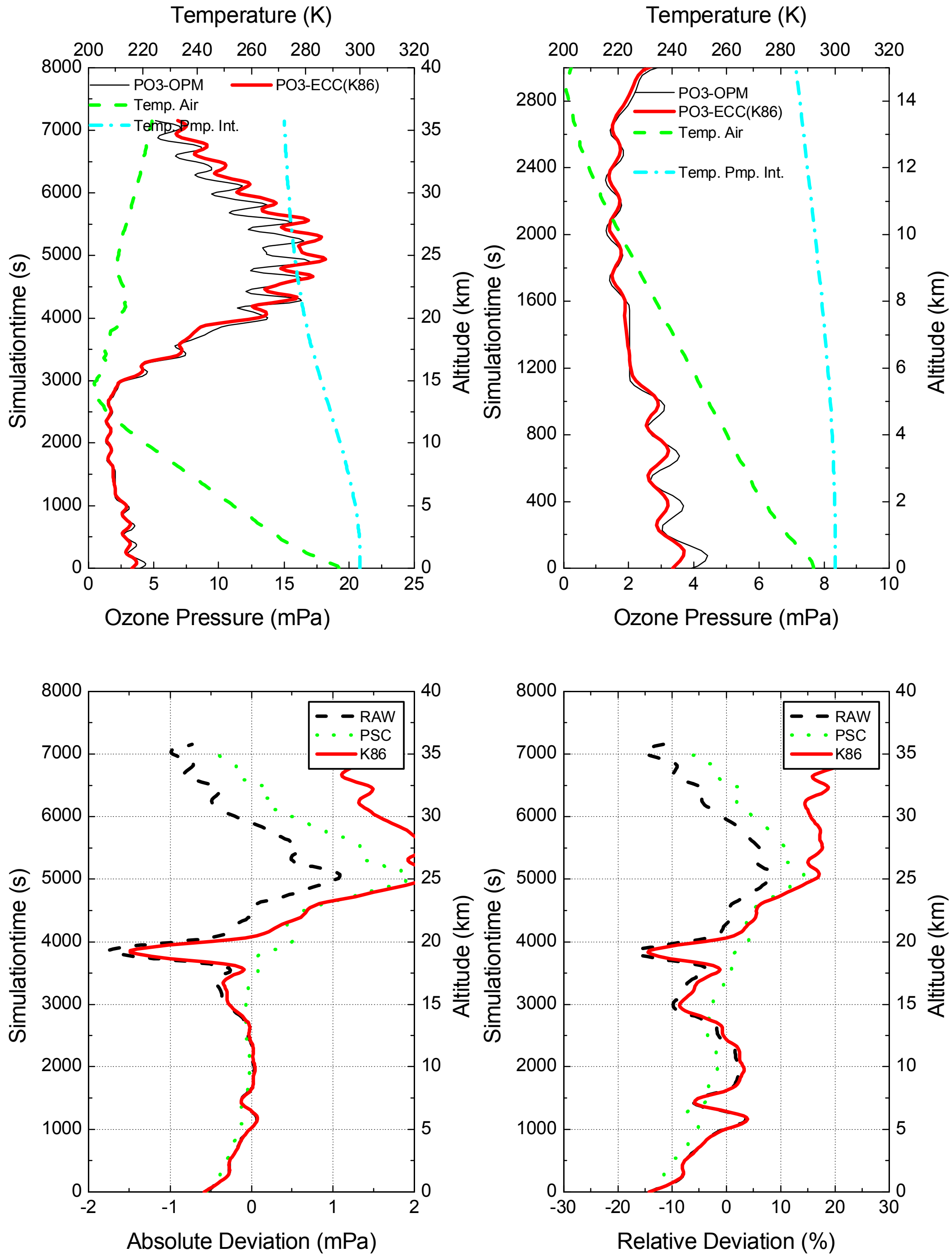
JOSIE-2000

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



JOSIE-2000

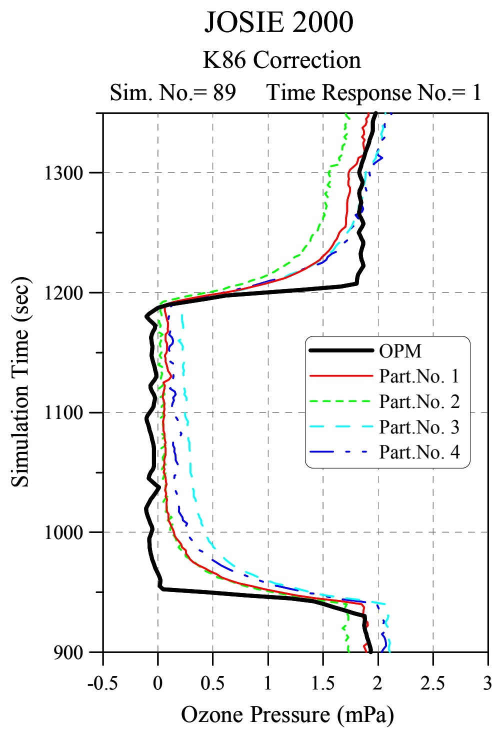
Participant=8   Sonde Type=KC96   Sol.Type=4A   Sim.No.=102

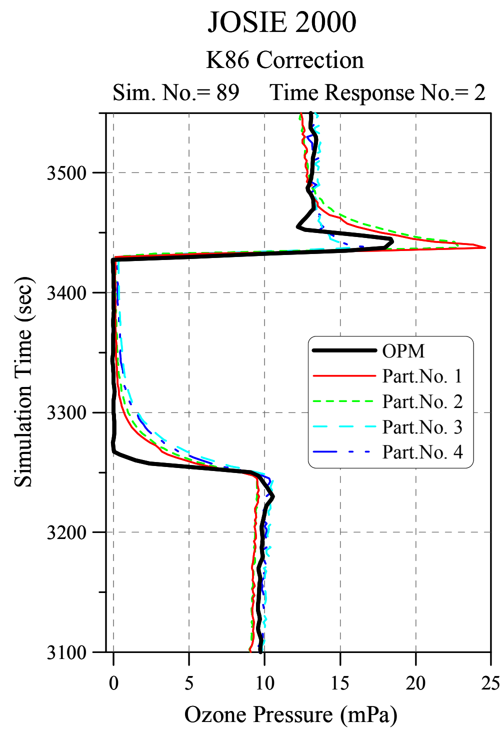


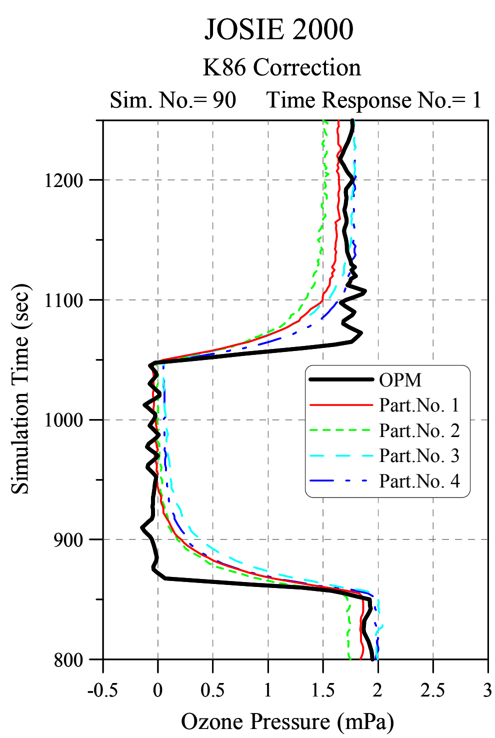
Results

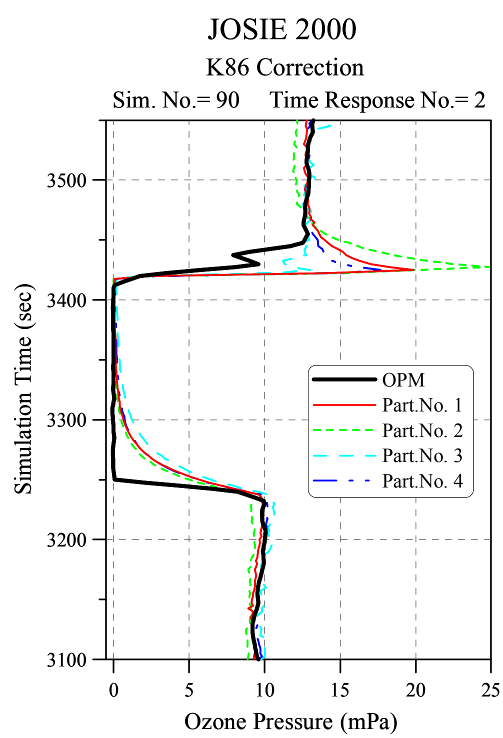
of

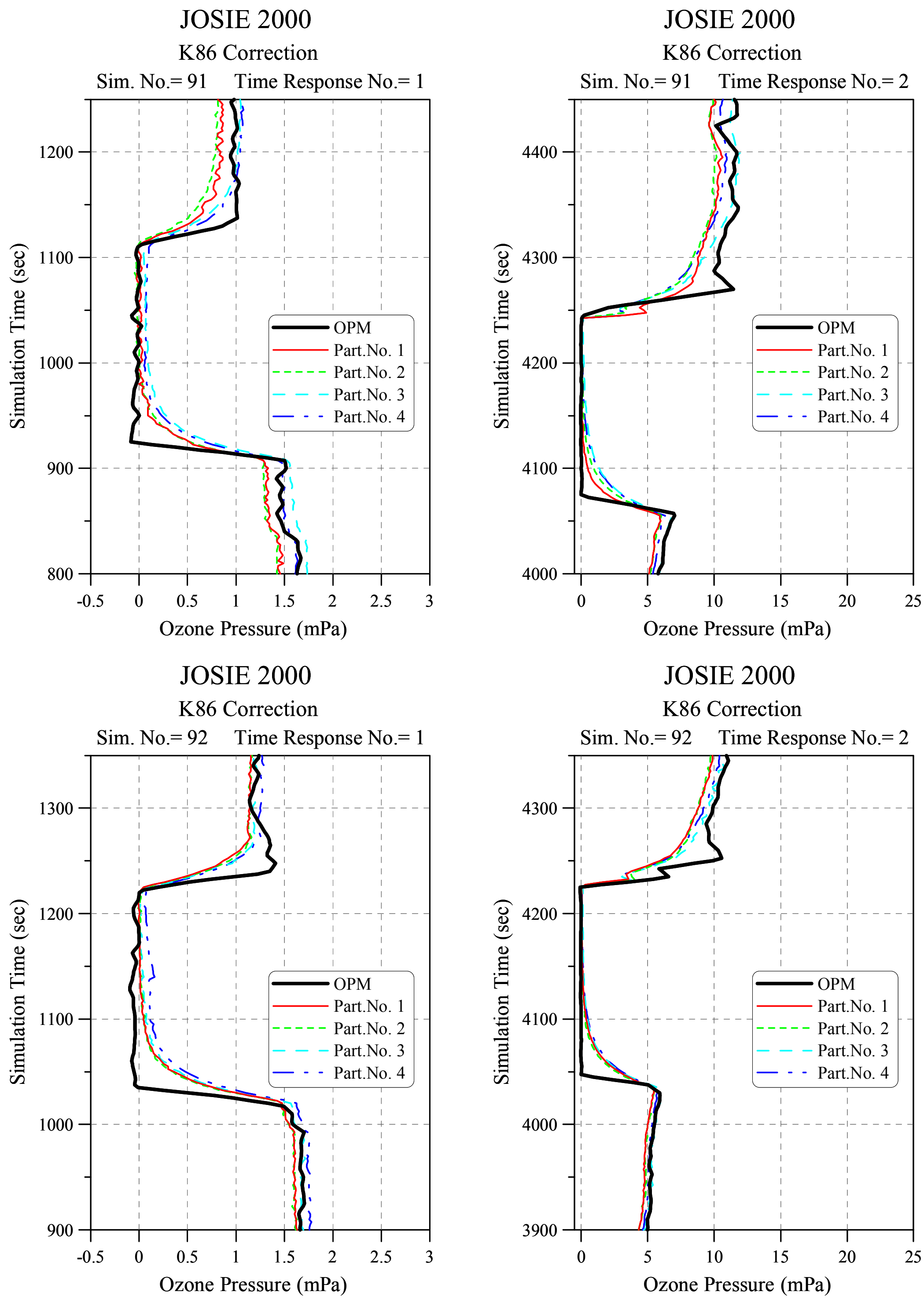
Individual Response Time Tests


JOSIE 2000
K86 Correction
Sim. No.= 89 Time Response No.= 1
Simulation Time (sec)
900
1000
1100
1200
1300
-0.5
0
0.5
1
1.5
2
2.5
3
Ozone Pressure (mPa)
OPM
Part.No. 1
Part.No. 2
Part.No. 3
Part.No. 4

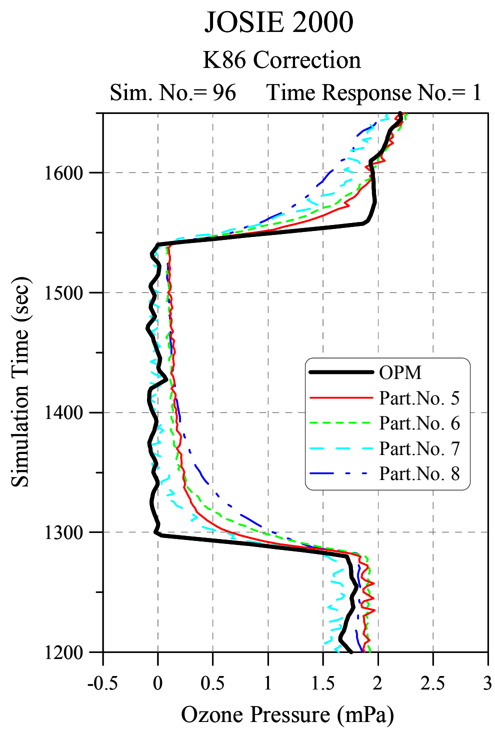

JOSIE 2000
K86 Correction
Sim. No.= 89 Time Response No.= 2
Simulation Time (sec)
3100
3200
3300
3400
3500
0
5
10
15
20
25
Ozone Pressure (mPa)
OPM
Part.No. 1
Part.No. 2
Part.No. 3
Part.No. 4

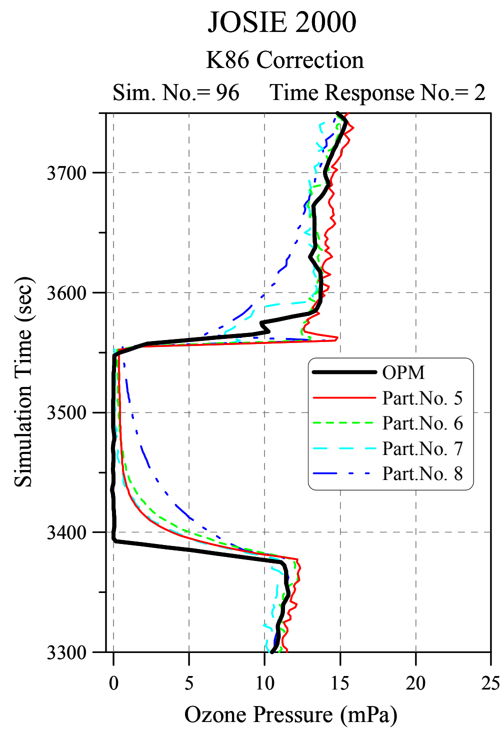

JOSIE 2000
K86 Correction
Sim. No.= 90 Time Response No.= 1
Simulation Time (sec)
800
900
1000
1100
1200
-0.5
0
0.5
1
1.5
2
2.5
3
Ozone Pressure (mPa)
OPM
Part.No. 1
Part.No. 2
Part.No. 3
Part.No. 4

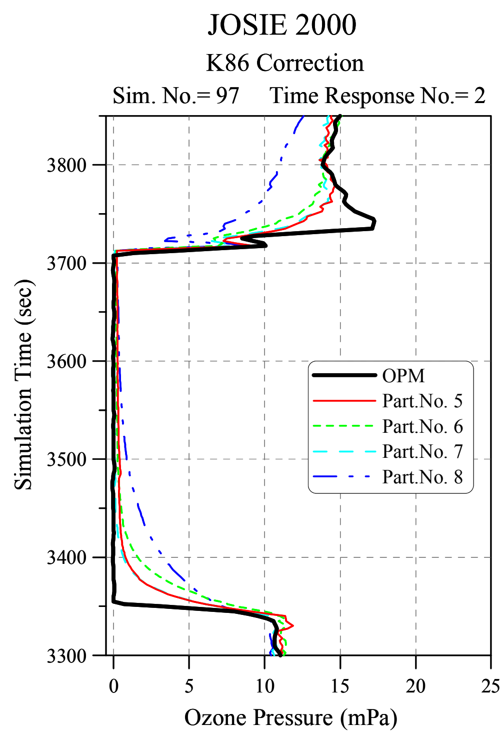

JOSIE 2000
K86 Correction
Sim. No.= 90 Time Response No.= 2
Simulation Time (sec)
3100
3200
3300
3400
3500
0
5
10
15
20
25
Ozone Pressure (mPa)
OPM
Part.No. 1
Part.No. 2
Part.No. 3
Part.No. 4

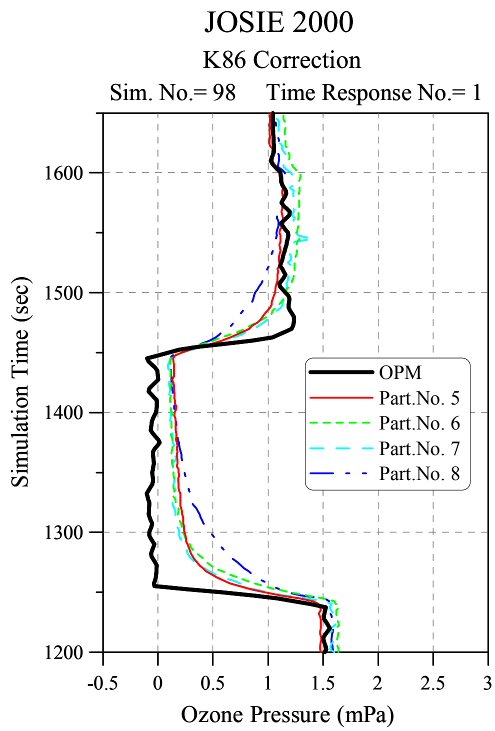


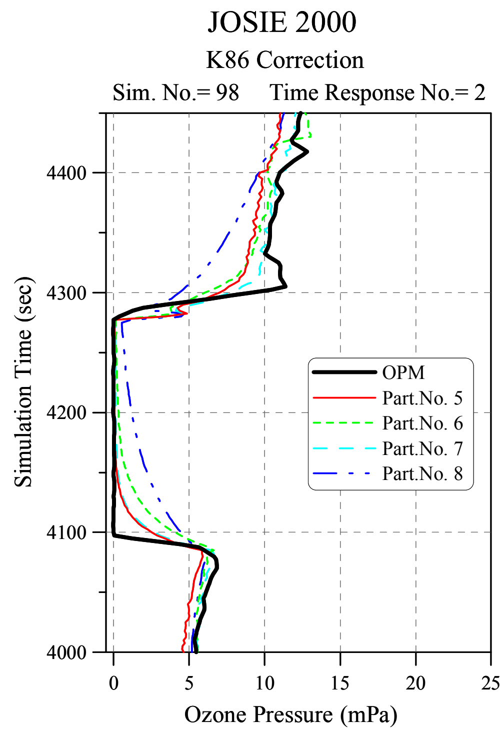
JOSIE 2000
K86 Correction
Sim. No.= 91 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 1
Part.No. 2
Part.No. 3
Part.No. 4
JOSIE 2000
K86 Correction
Sim. No.= 91 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
JOSIE 2000
K86 Correction
Sim. No.= 92 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
JOSIE 2000
K86 Correction
Sim. No.= 92 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)

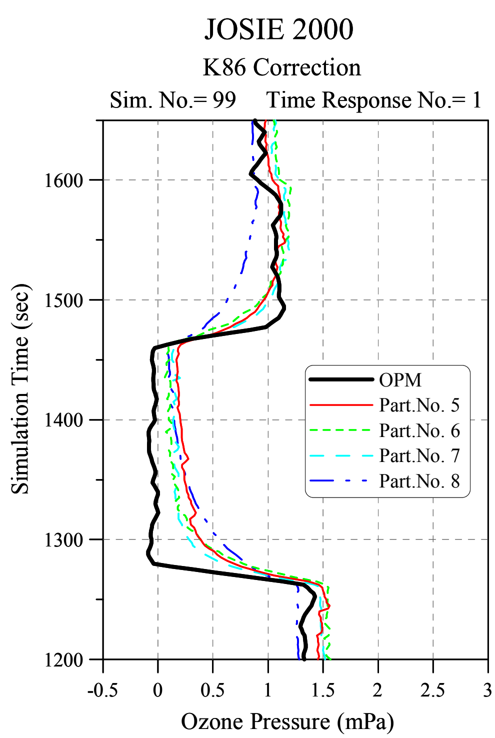

JOSIE 2000
K86 Correction
Sim. No.= 96 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
1200
1300
1400
1500
1600
-0.5
0
0.5
1
1.5
2
2.5
3

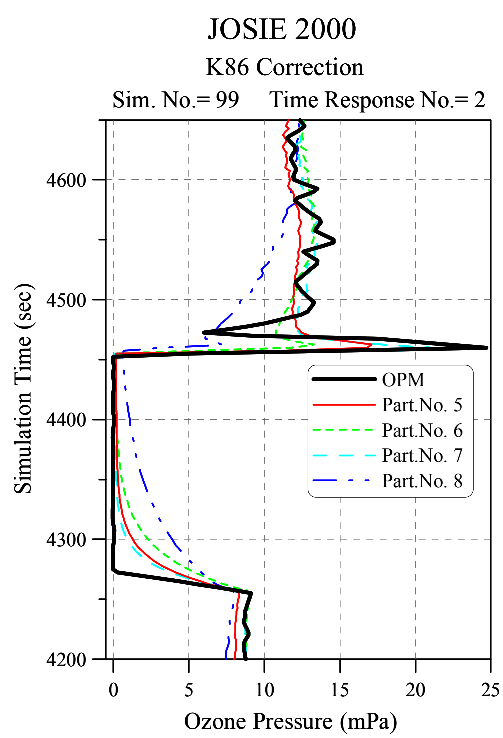

JOSIE 2000
K86 Correction
Sim. No.= 96 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
3300
3400
3500
3600
3700
0
5
10
15
20
25

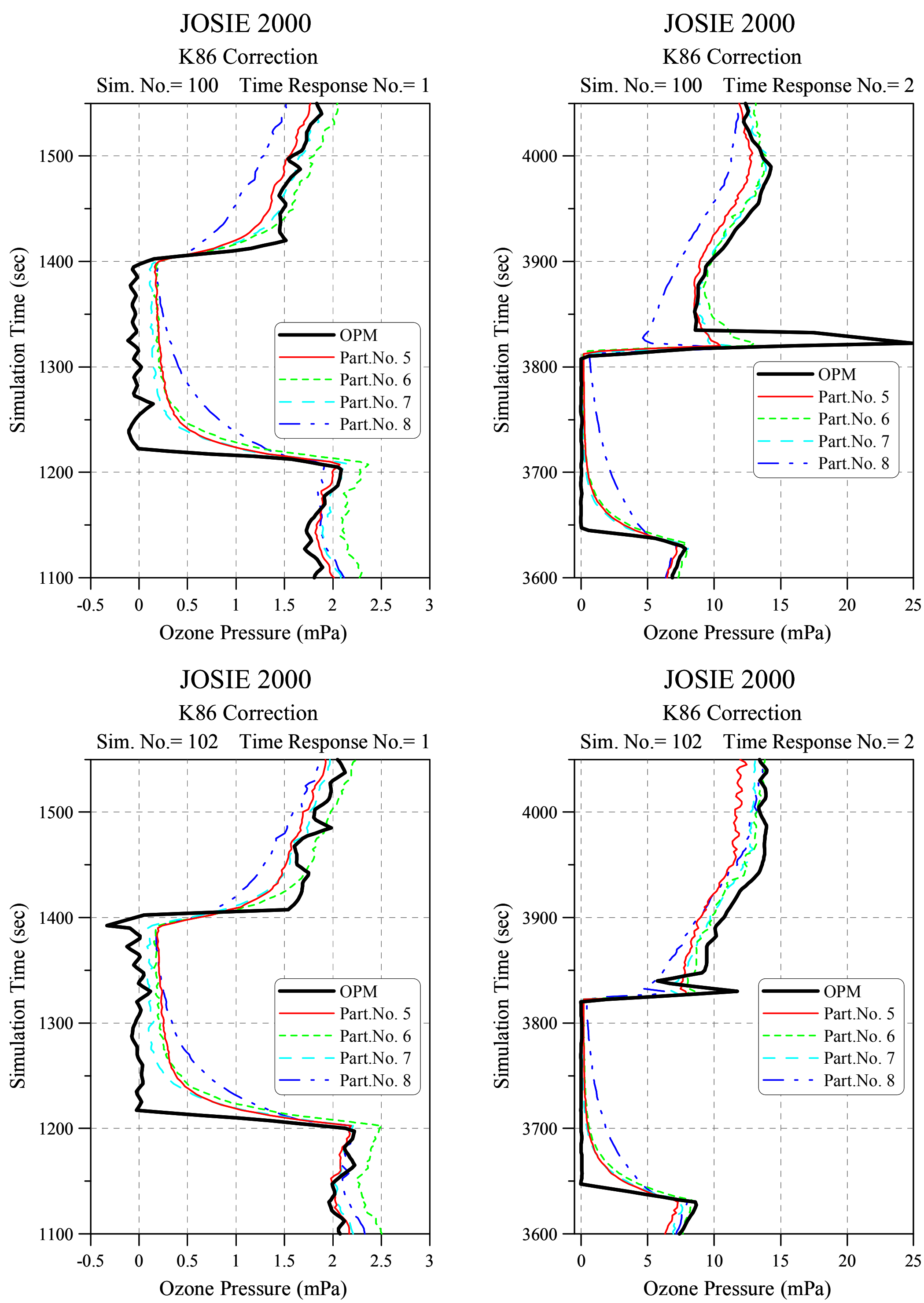

JOSIE 2000
K86 Correction
Sim. No.= 97 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
3300
3400
3500
3600
3700
3800
0
5
10
15
20
25


JOSIE 2000
K86 Correction
Sim. No.= 98 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8


JOSIE 2000
K86 Correction
Sim. No.= 98 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8


JOSIE 2000
K86 Correction
Sim. No.= 99 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8


JOSIE 2000
K86 Correction
Sim. No.= 99 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8


JOSIE 2000
K86 Correction
Sim. No.= 100 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
JOSIE 2000
K86 Correction
Sim. No.= 100 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
JOSIE 2000
K86 Correction
Sim. No.= 102 Time Response No.= 1
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8
JOSIE 2000
K86 Correction
Sim. No.= 102 Time Response No.= 2
Simulation Time (sec)
Ozone Pressure (mPa)
OPM
Part.No. 5
Part.No. 6
Part.No. 7
Part.No. 8

Average Deviations of Ozone Sondes from UV-photometer:
RAW- and PSC-Sonde Data (ECC-Sondes)
RAW- and K86-Sonde Data (KC96-Sondes)

JOSIE-2000

RAW Correction

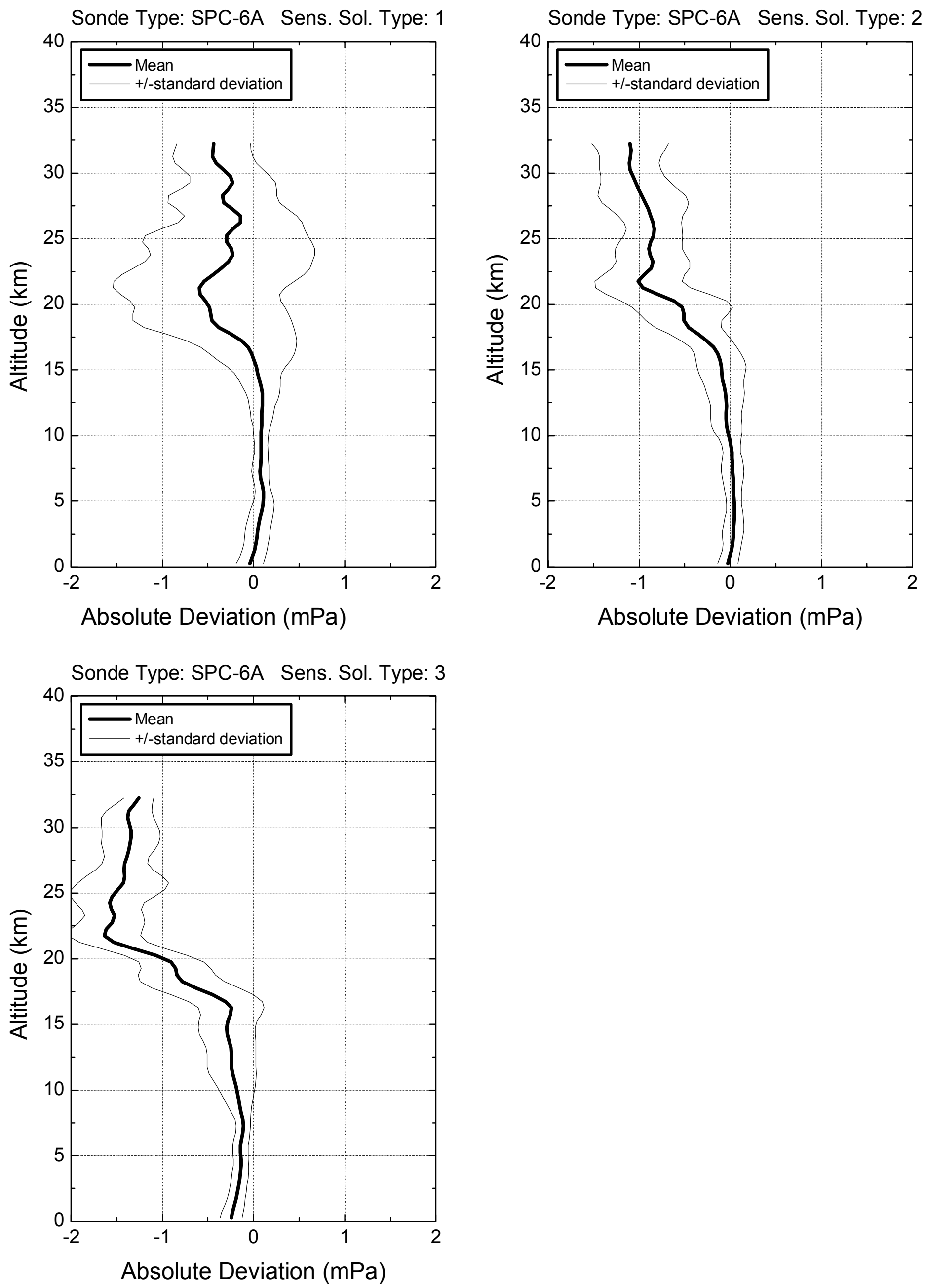


Figure Annex C-1: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution*.

JOSIE-2000

PSC Correction

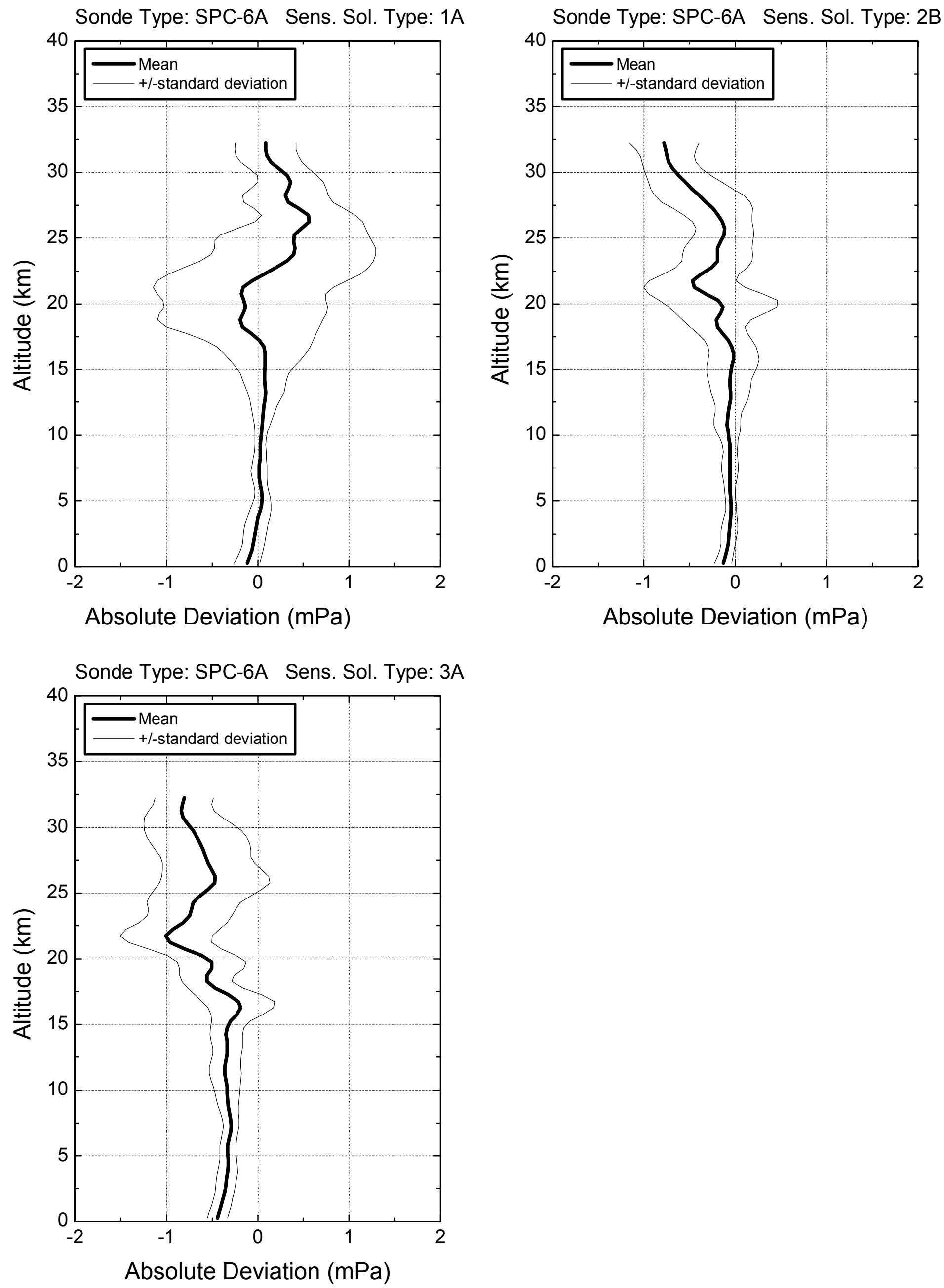
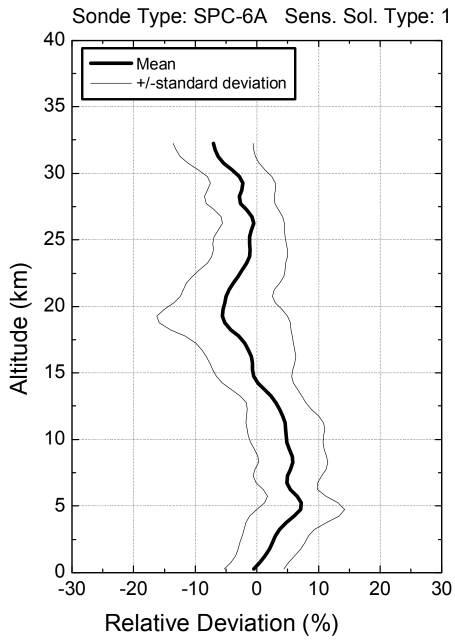
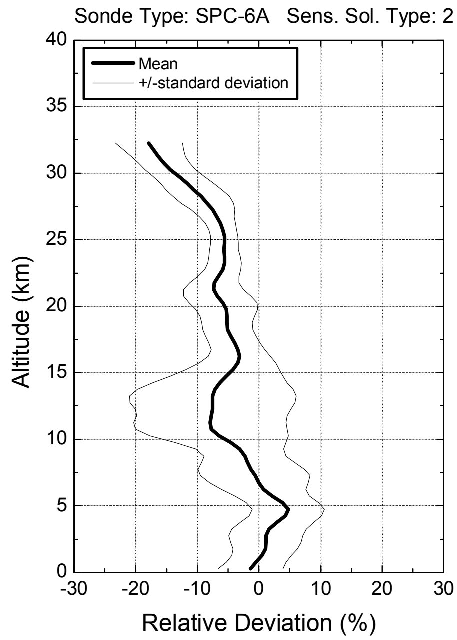


Figure Annex C-2: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual PSC-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution*.

JOSIE-2000

RAW Correction





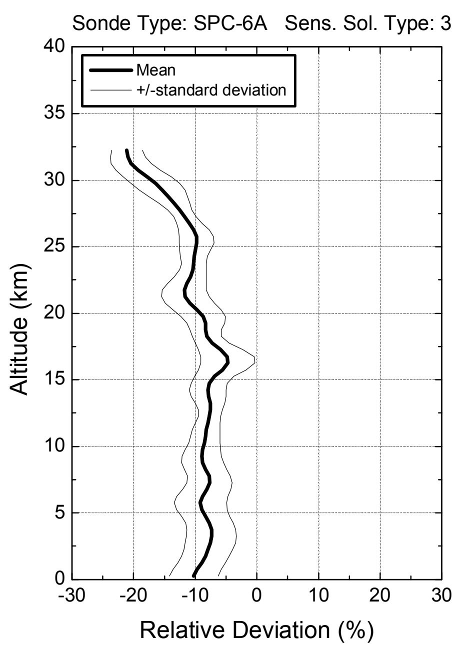


Figure Annex C-3: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution.*

JOSIE-2000

PSC Correction

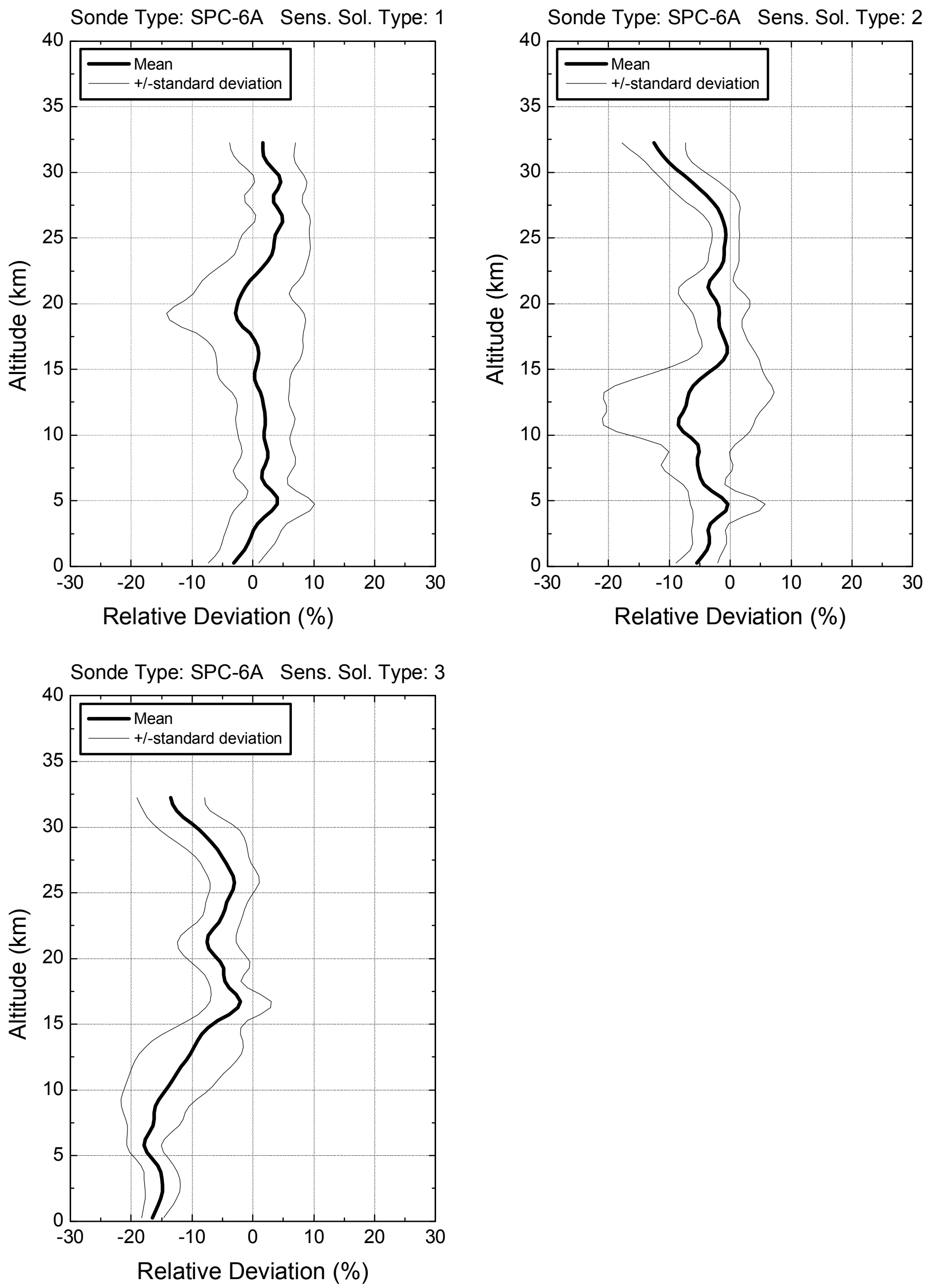
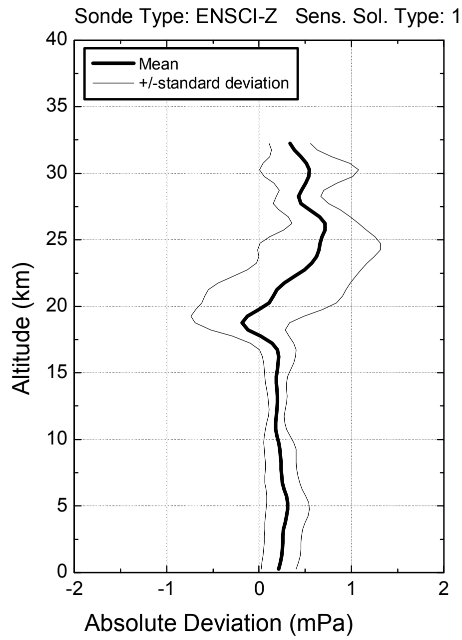
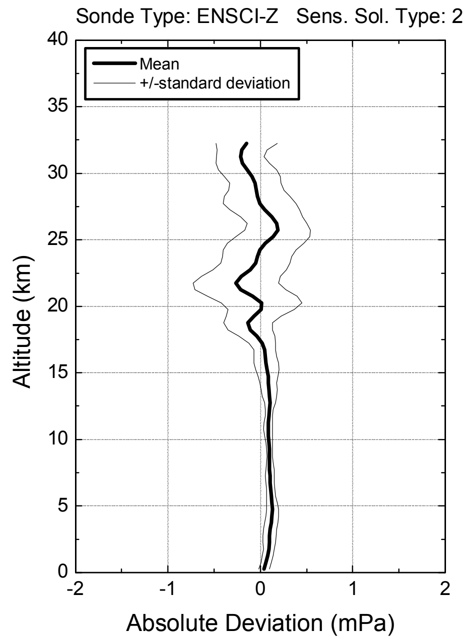


Figure Annex C-4: *JOSIE 2000-Comparison of SPC-6A versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual PSC-corrected sonde data from the UV-photometer for the SPC-6A sonde for each sensing solution***.**

JOSIE-2000

RAW Correction





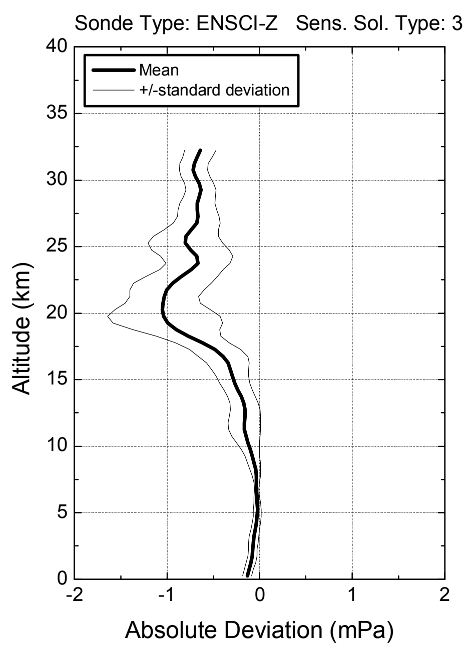


Figure Annex C-5: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution*.

JOSIE-2000

PSC Correction

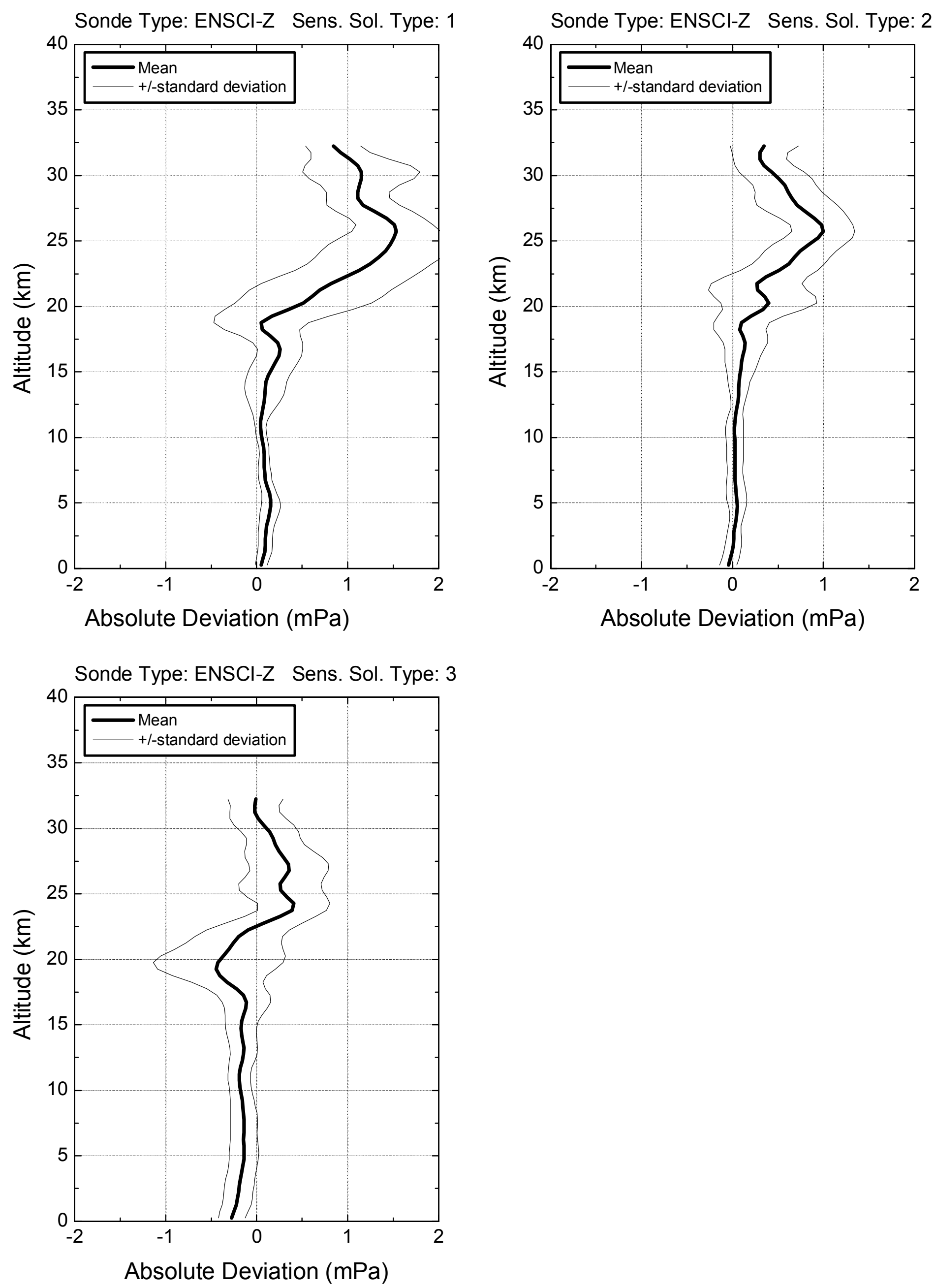


Figure Annex C-6: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations of the individual PSC-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.*

JOSIE-2000

RAW Correction

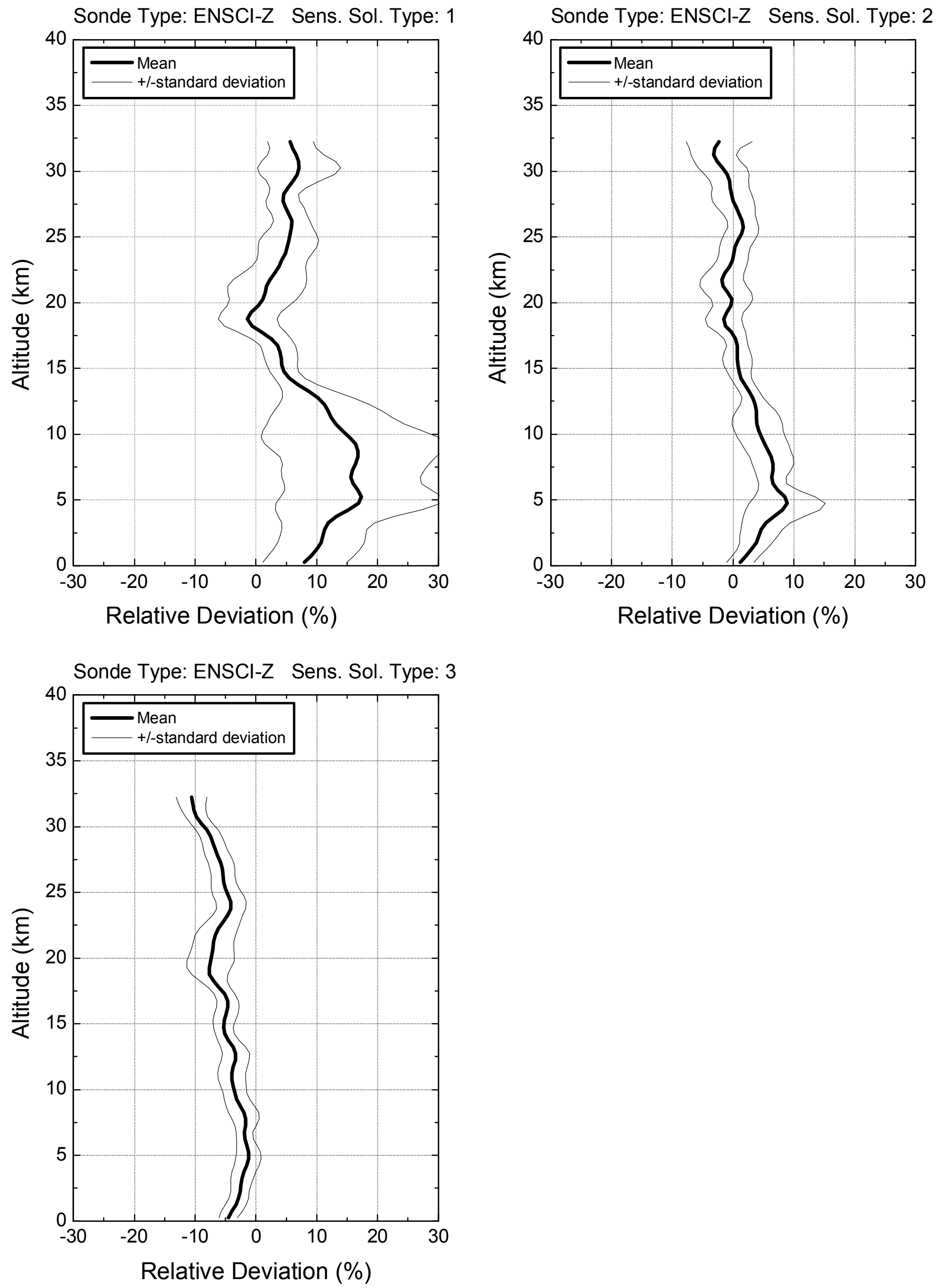


Figure Annex C-7: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual uncorrected (RAW) sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution*.

JOSIE-2000

PSC Correction

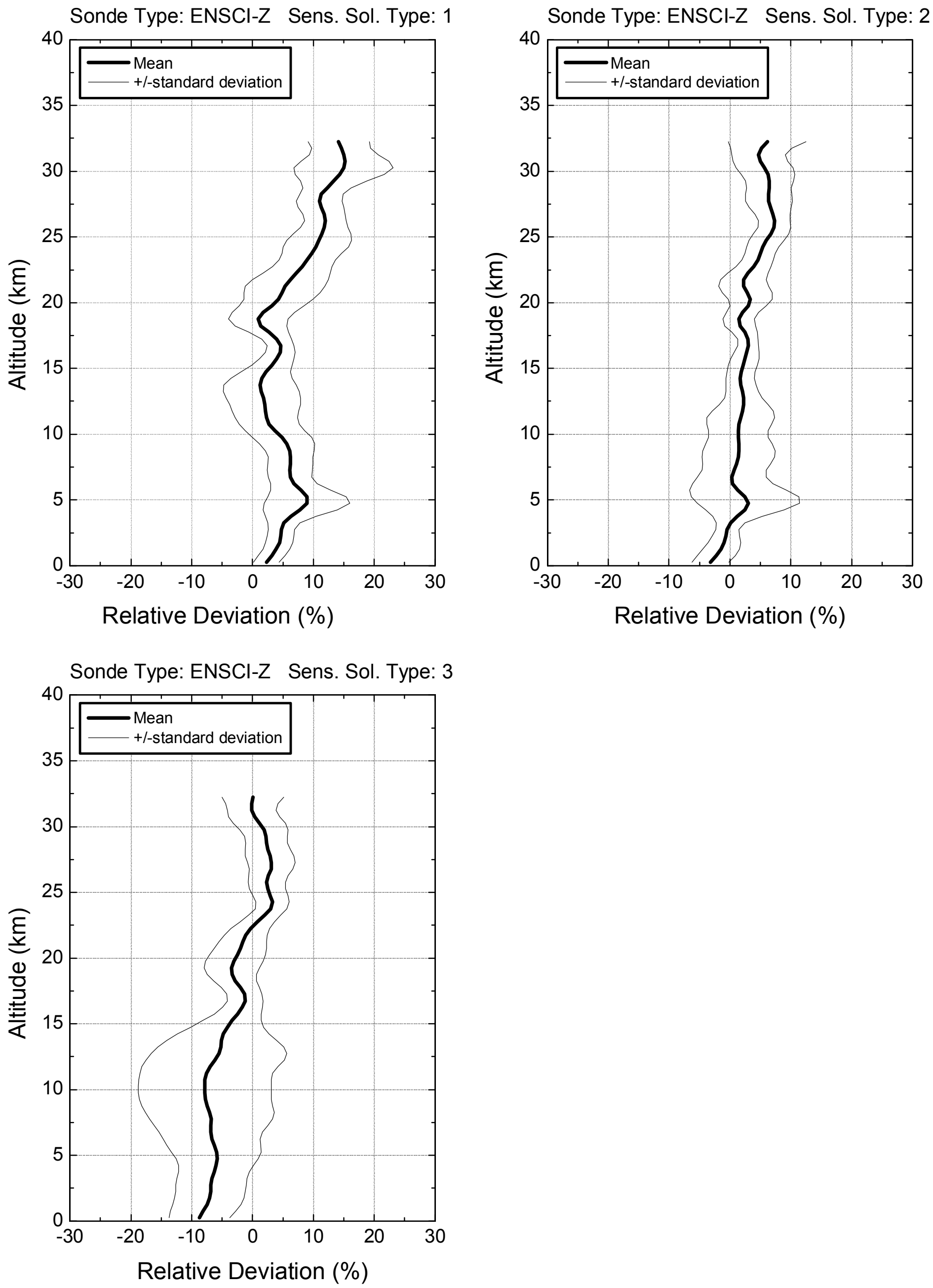


Figure Annex C-8: *JOSIE 2000-Comparison of ENSCI-Z versus UV-photometer: Averages (± one standard deviation) of the relative deviations of the individual PSC-corrected sonde data from the UV-photometer for the ENSCI-Z sonde for each sensing solution.*

JOSIE-2000

Participant: 8

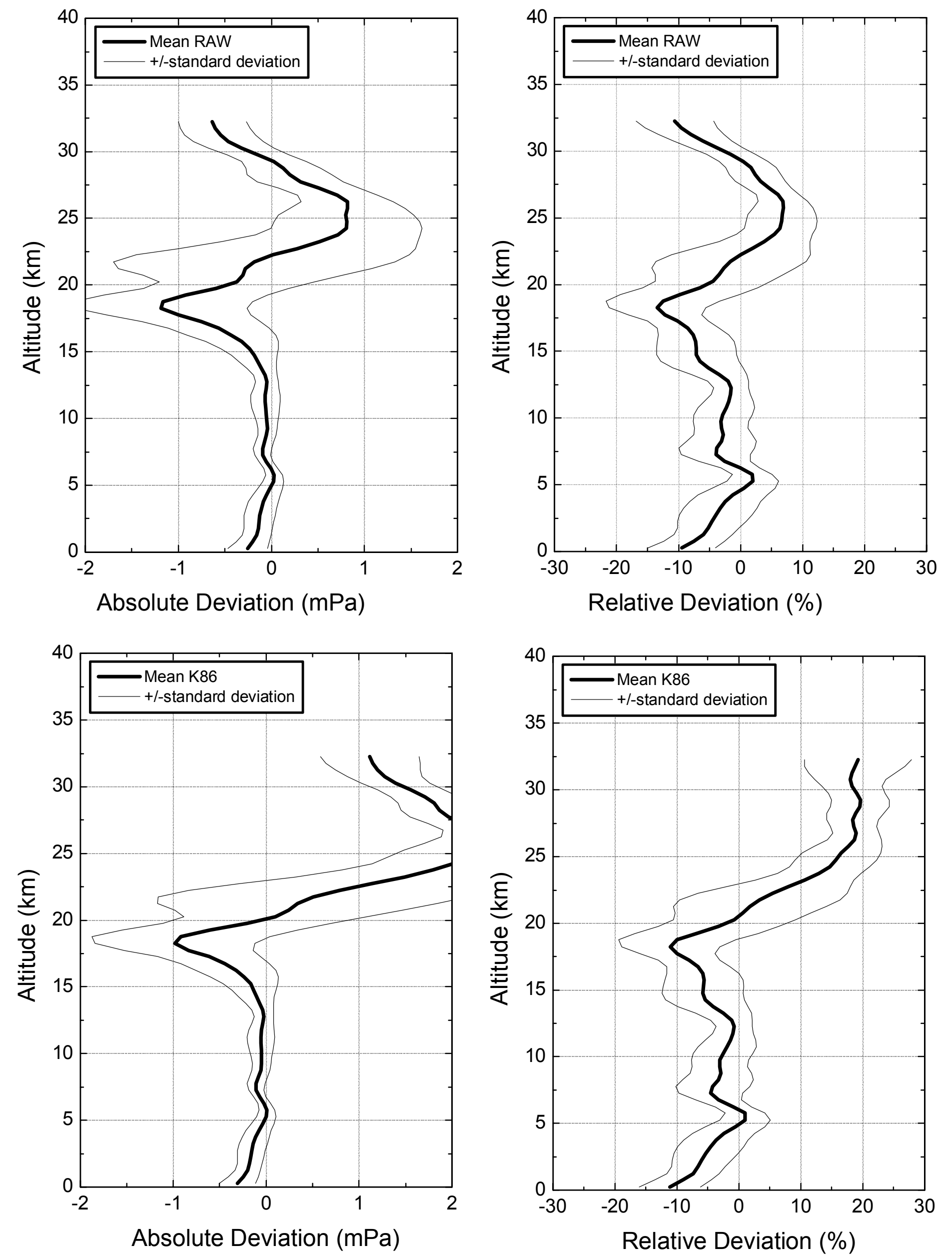


Figure Annex C-9: *JOSIE 2000-Comparison of KC96 sonde versus UV-photometer: Averages (± one standard deviation) of the ozone pressure deviations and the relative deviations of the individual RAW- and K86-data from the UV-photometer for KC96- sonde.*

Mean Ozone Pressure Deviation (in mPa) ± Standard Deviation (in mPa) = Bias±Precision						
Altitude Range (km)	**RAW-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)**					
	SPC-6A Sonde			**ENSCI-Z Sonde**		
	SST-1A	**SST-2B**	**SST-3A**	**SST-1A**	**SST-2B**	**SST-3A**
30-35	-0.47 ± 0.45	-1.08 ± 0.43	-1.29 ± 0.28	0.29 ± 0.59	-0.12 ± 0.44	-0.65 ± 0.25
25-30	-0.21 ± 0.85	-0.81 ± 0.54	-1.33 ± 0.43	0.63 ± 0.66	0.16 ± 0.52	-0.65 ± 0.51
20-25	-0.31 ± 1.16	-0.67 ± 0.77	-1.33 ± 0.69	0.54 ± 0.98	0.11 ± 0.81	-0.72 ± 0.75
15-20	-0.20 ± 0.66	-0.28 ± 0.39	-0.56 ± 0.42	0.09 ± 0.48	0.01 ± 0.25	-0.55 ± 0.46
10-15	0.08 ± 0.18	-0.05 ± 0.21	-0.24 ± 0.27	0.18 ± 0.13	0.09 ± 0.09	-0.18 ± 0.17
5-10	0.09 ± 0.09	0.02 ± 0.12	-0.14 ± 0.11	0.26 ± 0.19	0.11 ± 0.06	-0.04 ± 0.07
0-5	0.04 ± 0.14	0.02 ± 0.11	-0.18 ± 0.10	0.26 ± 0.21	0.09 ± 0.07	-0.07 ± 0.07
Altitude Range (km)	**K86-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)**					
	SPC-6A Sonde			**ENSCI-Z Sonde**		
	SST-1A	**SST-2B**	**SST-3A**	**SST-1A**	**SST-2B**	**SST-3A**
30-35	-0.10 ± 0.45	-0.76 ± 0.43	-0.99 ± 0.28	0.70 ± 0.64	0.25 ± 0.45	-0.30 ± 0.25
25-30	0.22 ± 0.85	-0.41 ± 0.55	-0.94 ± 0.43	1.10 ± 0.67	0.61 ± 0.52	-0.24 ± 0.52
20-25	-0.02 ± 1.18	-0.38 ± 0.78	-1.07 ± 0.69	0.85 ± 0.99	0.40 ± 0.83	-0.43 ± 0.75
15-20	-0.11 ± 0.67	-0.19 ± 0.39	-0.48 ± 0.38	0.18 ± 0.49	0.08 ± 0.27	-0.44 ± 0.43
10-15	0.09 ± 0.19	-0.02 ± 0.22	-0.23 ± 0.24	0.19 ± 0.13	0.10 ± 0.10	-0.16 ± 0.15
5-10	0.08 ± 0.10	0.03 ± 0.12	-0.15 ± 0.10	0.23 ± 0.15	0.09 ± 0.06	-0.07 ± 0.08
0-5	-0.01 ± 0.14	0.02 ± 0.11	-0.22 ± 0.10	0.20 ± 0.13	0.05 ± 0.08	-0.13 ± 0.08
Altitude Range (km)	**PSC-Data: Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)**					
	SPC-6A Sonde			**ENSCI-Z Sonde**		
	SST-1A	**SST-2B**	**SST-3A**	**SST-1A**	**SST-2B**	**SST-3A**
30-35	0.08 ± 0.40	-0.73 ± 0.41	-0.76 ± 0.41	0.83 ± 0.67	0.40 ± 0.48	0.05 ± 0.38
25-30	0.47 ± 0.77	-0.18 ± 0.55	-0.49 ± 0.61	1.37 ± 0.70	0.91 ± 0.53	0.34 ± 0.64
20-25	0.23 ± 1.18	-0.07 ± 0.78	-0.61 ± 0.77	1.16 ± 1.00	0.71 ± 0.84	0.19 ± 0.79
15-20	-0.02 ± 0.68	-0.07 ± 0.40	-0.39 ± 0.33	0.22 ± 0.52	0.16 ± 0.31	-0.18 ± 0.50
10-15	0.07 ± 0.19	-0.06 ± 0.21	-0.34 ± 0.17	0.07 ± 0.17	0.05 ± 0.12	-0.17 ± 0.16
5-10	0.03 ± 0.09	-0.06 ± 0.09	-0.31 ± 0.10	0.10 ± 0.08	0.03 ± 0.11	-0.14 ± 0.15
0-5	-0.03 ± 0.13	-0.08 ± 0.09	-0.37 ± 0.11	0.10 ± 0.09	0.01 ± 0.09	-0.20 ± 0.16

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.*

Mean Relative Deviation (in %) ± Standard Deviation (in %) = Bias±Precision						
Altitude Range (km)	RAW-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)					
	SPC-6A			ENSCI-Z		
	SST-1A	SST-2B	SST-3A	SST-1A	SST-2B	SST-3A
30-35	-7.1 ± 6.3	-16.4 ± 5.5	-20.0 ± 3.8	4.1 ± 9.3	-1.8 ± 6.7	-9.8 ± 3.5
25-30	-1.4 ± 6.9	-7.4 ± 4.6	-11.7 ± 3.4	5.9 ± 5.7	1.4 ± 4.5	-5.7 ± 3.9
20-25	-2.2 ± 8.4	-4.8 ± 5.5	-9.5 ± 4.7	4.2 ± 7.3	0.8 ± 5.8	-4.7 ± 5.0
15-20	-2.8 ± 8.0	-4.5 ± 5.3	-7.6 ± 3.9	2.1 ± 4.9	0.0 ± 2.8	-5.5 ± 3.5
10-15	2.6 ± 6.7	-7.2 ± 12.5	-7.9 ± 2.9	9.3 ± 7.4	2.9 ± 3.8	-4.4 ± 2.8
5-10	6.2 ± 6.4	-0.2 ± 8.6	-8.5 ± 4.0	17.1 ± 13.8	6.9 ± 4.7	-1.9 ± 2.9
0-5	2.8 ± 5.6	0.9 ± 5.7	-8.3 ± 4.0	11.2 ± 7.5	4.3 ± 3.2	-2.7 ± 2.5
Altitude Range (km)	K86-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)					
	SPC-6A			ENSCI-Z		
	SST-1A	SST-2B	SST-3A	SST-1A	SST-2B	SST-3A
30-35	-1.6 ± 6.7	-11.5 ± 5.7	-15.3 ± 3.9	10.4 ± 9.9	4.0 ± 7.1	-4.4 ± 3.7
25-30	2.5 ± 7.1	-3.8 ± 4.7	-8.3 ± 3.5	10.1 ± 6.0	5.3 ± 4.6	-1.9 ± 4.1
20-25	-0.1 ± 8.6	-2.9 ± 5.6	-7.7 ± 4.8	6.5 ± 7.5	2.9 ± 6.0	-2.7 ± 5.1
15-20	-1.7 ± 8.2	-3.4 ± 5.3	-6.6 ± 4.0	3.2 ± 4.9	1.1 ± 2.8	-4.5 ± 3.6
10-15	3.0 ± 6.9	-6.6 ± 12.5	-7.4 ± 3.0	9.2 ± 6.3	3.3 ± 3.7	-4.0 ± 2.8
5-10	5.3 ± 6.5	-0.2 ± 8.3	-9.0 ± 3.9	15.4 ± 10.9	6.0 ± 4.7	-3.1 ± 3.6
0-5	1.1 ± 5.2	0.2 ± 5.1	-9.5 ± 4.1	8.7 ± 4.3	2.3 ± 2.4	-5.1 ± 3.6
Altitude Range (km)	PSC-Data: Mean Relative Deviation (in %) ± Std Deviation (in %)					
	SPC-6A			ENSCI-Z		
	SST-1A	SST-2B	SST-3A	SST-1A	SST-2B	SST-3A
30-35	1.2 ± 6.0	-11.0 ± 5.5	-12.0 ± 6.4	12.4 ± 10.5	6.4 ± 7.6	0.9 ± 5.9
25-30	4.6 ± 6.5	-2.0 ± 4.8	-4.4 ± 5.3	12.5 ± 6.4	7.8 ± 4.8	3.2 ± 5.3
20-25	1.7 ± 8.7	-0.6 ± 5.6	-4.6 ± 5.5	8.6 ± 7.6	5.2 ± 6.1	1.5 ± 5.4
15-20	-0.7 ± 8.4	-1.9 ± 5.4	-5.8 ± 5.5	3.3 ± 5.0	2.3 ± 3.1	-2.2 ± 5.0
10-15	1.2 ± 6.2	-6.9 ± 12.7	-10.6 ± 7.7	1.6 ± 6.2	1.8 ± 4.4	-6.3 ± 10.1
5-10	2.8 ± 5.4	-4.1 ± 6.4	-16.6 ± 4.7	7.1 ± 5.8	1.7 ± 7.6	-6.9 ± 9.8
0-5	-0.1 ± 4.8	-3.7 ± 3.4	-15.5 ± 2.7	4.7 ± 3.1	-0.7 ± 3.1	-7.0 ± 6.0

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.*

Mean Deviation ± Standard Deviation = Bias±Precision						
Altitude Range (km)	**KC-96 Sonde** ***(Part.No. 8 = JMA)***					
	Mean O3 Pressure Deviation (in mPa) ± Std Deviation (in mPa)			**Mean Relative Deviation (in %) ± Std Deviation (in %)**		
	RAW	**K86**	**PSC**	**RAW**	**K86**	**PSC**
30-35	-0.53 ± 0.47	1.25 ± 0.58	-0.07 ± 0.40	-8.1 ± 6.8	19.5 ± 9.2	-1.4 ± 6.2
25-30	0.43 ± 0.83	2.06 ± 0.81	1.16 ± 0.69	3.9 ± 7.1	18.8 ± 7.9	10.2 ± 6.2
20-25	0.25 ± 1.40	1.10 ± 1.51	1.20 ± 1.12	1.5 ± 11.1	7.5 ± 11.9	8.5 ± 8.6
15-20	-0.72 ± 0.73	-0.54 ± 0.70	-0.15 ± 0.55	-10.2 ± 7.4	-8.0 ± 7.6	-3.0 ± 6.8
10-15	-0.10 ± 0.18	-0.07 ± 0.17	-0.06 ± 0.12	-4.0 ± 6.1	-3.2 ± 6.2	-2.8 ± 5.2
5-10	-0.03 ± 0.10	-0.04 ± 0.10	-0.07 ± 0.08	-1.1 ± 5.1	-1.5 ± 5.1	-4.3 ± 4.9
0-5	-0.13 ± 0.18	-0.16 ± 0.16	-0.21 ± 0.13	-4.4 ± 5.7	-5.7 ± 5.1	-8.7 ± 4.0

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.*

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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)

Participating Laboratory Nr.1: CMDL (*ECC-ozone sonde Type: ENSCI-Z & SPC-6A)*

NOAA Climate Monitoring & Diagnostic Laboratory (NOAA/CMDL)
325 Broadway
Boulder, CO 80303-3328, USA

Participant:
Bryan Johnson (Principal Investigator)
Tel: (+)-1-303-4976842 Fax: (+)-1-303-4976290 Email: bjohnson@cmdl.noaa.gov

Participating Laboratory Nr.2: AES (*ECC-ozone sonde Type: SPC-6A)*

Atmospheric Environment Service (AES) / Experimental Studies Division
4905 Dufferin Street
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Participant:
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Tel: (+)-1-416-739-4210 Fax: (+)-1-416-739-4281 Email:jonathan.davies@ec.gc.ca

Participating Laboratory Nr.3: NIWA (*ECC-ozone sonde Type: ENSCI-Z)*

National Institute of Water and Atmospheric Research (NIWA)
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Private Bag 50061
Omakau, Central Otago , New Zealand

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Ian Boyd
Alan Thomas

Participating Laboratory Nr.4: FZJ (*ECC-ozone sonde Type : SPC-6A)*

Research Center Jülich GmbH (FZJ)
Institute for Chemistry and Dynamics of the Geosphere: Troposphere (ICG-II)
P.O. Box 1913
D-52425 Jülich , Germany

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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)***
NASA/GSFC-Wallops Flight Facility (WFF)
Code 972, NASA/GSFC/Wallops Flight Facility
Wallops Island, Virginia 23337, USA

Participants:
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David Ross
Thomas Northam
Jacquelyn Witte

Participating Laboratory Nr.6: SAP **(*ECC-ozone sonde Type: ENSCI-Z)***
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Bruno Hoegger (Principal Investigator at the site, retired)
Gilbert Levrat

Participating Laboratory Nr.7: URI (*ECC-ozone sonde Type: ENSCI-Z)*
University of La Reunion Island
15 avenue Rene Cassin - BP 7151
97715 Saint Denis Messag Cedex 9
La Reunion , France

Participants:
Francoise Posny (Principal Investigator)
Tel: (+)-262-93-8226 Fax: (+)-262-93-8665/8217 Email: posny@univ-reunion.fr
Jean-Marc Metzger

Participating Laboratory Nr.8: JMA **(J*apanese KC96 Sonde)***
Japan Meteorological Agency (JMA)
Ozone Layer Monitoring Office
Aerological Division
Observations Department
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Tokyo, 100-8122 , Japan

Participants:
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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)

ANNEX

Formal Agreement JOSIE-2000: Strategy of JOSIE-2000

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 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

JOSIE-2000

Jülich Ozone Sonde Intercomparison Experiment

4-13 September 2000 and 18–27 September 2000

(Sponsors: FZ-Jülich, WMO/GAW)

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

JOSIE-2000

Jülich Ozone Sonde Intercomparison Experiment

4-13 September 2000 and 18–27 September 2000

(Sponsors: FZ-Jülich, WMO/GAW)

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):

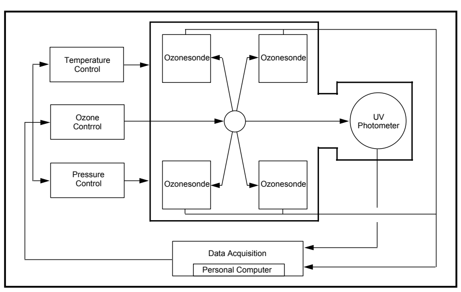
Stamp of Institution:

Please return to:

JOSIE-Site:
c/o Herman G.J. Smit
Research Centre Juelich
ICG-2
P.O. Box 1913
D-52428 Juelich
Germany

Send copy to:

WMO
c/o Mike Proffitt
Environment Division
41 Giuseppe Motta
Case Postal No. 2300
CH-1211 Geneva 2
Switzerland



GLOBAL ATMOSPHERE WATCH REPORT SERIES

1. Final Report of the Expert Meeting on the Operation of Integrated Monitoring Programmes, Geneva, 2-5 September 1980.

2. Report of the Third Session of the GESAMP Working Group on the Interchange of Pollutants Between the Atmosphere and the Oceans (INTERPOLL-III), Miami, USA, 27-31 October 1980.

3. Report of the Expert Meeting on the Assessment of the Meteorological Aspects of the First Phase of EMEP, Shinfield Park, U.K., 30 March - 2 April 1981.

4. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at April 1981.

5. Report of the WMO/UNEP/ICSU Meeting on Instruments, Standardization and Measurements Techniques for Atmospheric CO_2, Geneva, 8-11; September 1981.

6. Report of the Meeting of Experts on BAPMoN Station Operation, Geneva, 23-26 November, 1981.

7. Fourth Analysis on Reference Precipitation Samples by the Participating World Meteorological Organization Laboratories by Robert L. Lampe and John C. Puzak, December 1981.

8. Review of the Chemical Composition of Precipitation as Measured by the WMO BAPMoN by Prof. Dr. Hans-Walter Georgii, February 1982.

9. An Assessment of BAPMoN Data Currently Available on the Concentration of CO_2 in the Atmosphere by M.R. Manning, February 1982.

10. Report of the Meeting of Experts on Meteorological Aspects of Long-range Transport of Pollutants, Toronto, Canada, 30 November - 4 December 1981.

11. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1982.

12. Report on the Mount Kenya Baseline Station Feasibility Study edited by Dr. Russell C. Schnell.

13. Report of the Executive Committee Panel of Experts on Environmental Pollution, Fourth Session, Geneva, 27 September - 1 October 1982.

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

15. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1981, May 1983.

16. Report of the Expert Meeting on Quality Assurance in BAPMoN, Research Triangle Park, North Carolina, USA, 17-21 January 1983.

17. General Consideration and Examples of Data Evaluation and Quality Assurance Procedures Applicable to BAPMoN Precipitation Chemistry Observations by Dr. Charles Hakkarinen, July 1983.

18. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1983.

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

20. Extended Abstracts of Papers to be Presented at the WMO Technical Conference on Observation and Measurement of Atmospheric Contaminants (TECOMAC), Vienna, 17-21 October 1983.

21. Fifth Analysis on Reference Precipitation Samples by the Participating World Meteorological Organization Laboratories by Robert L. Lampe and William J. Mitchell, November 1983.

22. Report of the Fifth Session of the WMO Executive Council Panel of Experts on Environmental Pollution, Garmisch-Partenkirchen, Federal Republic of Germany, 30 April - 4 May 1984 (WMO TD No. 10).

23. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1982. November 1984 (WMO TD No. 12).

24. Final Report of the Expert Meeting on the Assessment of the Meteorological Aspects of the Second Phase of EMEP, Friedrichshafen, Federal Republic of Germany, 7-10 December 1983. October 1984 (WMO TD No. 11).

25. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at May 1984. November 1984 (WMO TD No. 13).

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).

27. Report on a Study of the Transport of Sahelian Particulate Matter Using Sunphotometer Observations by Dr. Guillaume A. d'Almeida. July 1985 (WMO TD No. 45).

28. Report of the Meeting of Experts on the Eastern Atlantic and Mediterranean Transport Experiment ("EAMTEX"), Madrid and Salamanca, Spain, 6-8 November 1984.

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).

30. Report of the Ad-hoc Consultation on Quality Assurance Procedures for Inclusion in the BAPMoN Manual, Geneva, 29-31 May 1985.

31. Implications of Visibility Reduction by Man-Made Aerosols (Annex to No. 14) by R.M. Hoff and L.A. Barrie. October 1985 (WMO TD No. 59).

32. Manual for BAPMoN Station Operators by E. Meszaros and D.M. Whelpdale. October 1985 (WMO TD No. 66).

33. Man and the Composition of the Atmosphere: BAPMoN - An international programme of national needs, responsibility and benefits by R.F. Pueschel, 1986.

34. Practical Guide for Estimating Atmospheric Pollution Potential by Dr. L.E. Niemeyer. August 1986 (WMO TD No. 134).

35. Provisional Daily Atmospheric CO_2 Concentrations as Measured at BAPMoN Sites for the Year 1983. December 1985 (WMO TD No. 77).

36. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1984. Volume I: Atmospheric Aerosol Optical Depth. October 1985 (WMO TD No. 96).

37. Air-Sea Interchange of Pollutants by R.A. Duce. September 1986 (WMO TD No. 126).

38. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at 31 December 1985. September 1986 (WMO TD No. 136).

39. Report of the Third WMO Expert Meeting on Atmospheric Carbon Dioxide Measurement Techniques, Lake Arrowhead, California, USA, 4-8 November 1985. October 1986.

40. Report of the Fourth Session of the CAS Working Group on Atmospheric Chemistry and Air Pollution, Helsinki, Finland, 18-22 November 1985. January 1987.

41. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1982, Volume II: Precipitation chemistry, continuous atmospheric carbon dioxide and suspended particulate matter. June 1986 (WMO TD No. 116).

42. Scripps reference gas calibration system for carbon dioxide-in-air standards: revision of 1985 by C.D. Keeling, P.R. Guenther and D.J. Moss. September 1986 (WMO TD No. 125).

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

44. Report of the Sixth Session of the WMO Executive Council Panel of Experts on Environmental Pollution, Geneva, 5-9 May 1986. March 1987.

45. Proceedings of the International Symposium on Integrated Global Monitoring of the State of the Biosphere (Volumes I-IV), Tashkent, USSR, 14-19 October 1985. December 1986 (WMO TD No. 151).

46. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1984. December 1986 (WMO TD No. 158).

47. Procedures and Methods for Integrated Global Background Monitoring of Environmental Pollution by F.Ya. Rovinsky, USSR and G.B. Wiersma, USA. August 1987 (WMO TD No. 178).

48. Meeting on the Assessment of the Meteorological Aspects of the Third Phase of EMEP IIASA, Laxenburg, Austria, 30 March - 2 April 1987. February 1988.

49. Proceedings of the WMO Conference on Air Pollution Modelling and its Application (Volumes I-III), Leningrad, USSR, 19-24 May 1986. November 1987 (WMO TD No. 187).

50. Provisional Daily Atmospheric Carbon Dioxide Concentrations as Measured at BAPMoN Sites for the Year 1985. December 1987 (WMO TD No. 198).

51. Report of the NBS/WMO Expert Meeting on Atmospheric CO_2 Measurement Techniques, Gaithersburg, USA, 15-17 June 1987. December 1987.

52. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1985. Volume I: Atmospheric Aerosol Optical Depth. September 1987.

53. WMO Meeting of Experts on Strategy for the Monitoring of Suspended Particulate Matter in BAPMoN - Reports and papers presented at the meeting, Xiamen, China, 13-17 October 1986. October 1988.

54. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1983, Volume II: Precipitation chemistry, continuous atmospheric carbon dioxide and suspended particulate matter (WMO TD No. 283).

55. Summary Report on the Status of the WMO Background Air Pollution Monitoring Network as at 31 December 1987 (WMO TD No. 284).

56. Report of the First Session of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Hilo, Hawaii, 27-31 March 1988. June 1988.

57. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1986, Volume I: Atmospheric Aerosol Optical Depth. July 1988.

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

59. Extended Abstracts of Papers Presented at the Third International Conference on Analysis and Evaluation of Atmospheric CO_2 Data - Present and Past, Hinterzarten, Federal Republic of Germany, 16-20 October 1989 (WMO TD No. 340).

60. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1984 and 1985, Volume II: Precipitation chemistry, continuous atmospheric carbon dioxide and suspended particulate matter.

61. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data for 1987 and 1988, Volume I: Atmospheric Aerosol Optical Depth.

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

63. Report of the Informal Session of the Executive Council Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Sofia, Bulgaria, 26 and 28 October 1989.

64. Report of the consultation to consider desirable locations and observational practices for BAPMoN stations of global importance, Bermuda Research Station, 27-30 November 1989.

65. Report of the Meeting on the Assessment of the Meteorological Aspects of the Fourth Phase of EMEP, Sofia, Bulgaria, 27 and 31 October 1989.

66. Summary Report on the Status of the WMO Global Atmosphere Watch Stations as at 31 December 1990 (WMO TD No. 419).

67. Report of the Meeting of Experts on Modelling of Continental, Hemispheric and Global Range Transport, Transformation and Exchange Processes, Geneva, 5-7 November 1990.

68. Global Atmospheric Background Monitoring for Selected Environmental Parameters. BAPMoN Data For 1989, Volume I: Atmospheric Aerosol Optical Depth.

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

70. Report of the Second Session of EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Santiago, Chile, 9-15 January 1991 (WMO TD No. 633).

71. Report of the Consultation of Experts to Consider Desirable Observational Practices and Distribution of GAW Regional Stations, Halkidiki, Greece, 9-13 April 1991 (WMO TD No. 433).

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

73. Report of the Experts Meeting on Global Aerosol Data System (GADS), Hampton, Virginia, 11 to 12 September 1990 (WMO TD No. 438).

74. Report of the Experts Meeting on Aerosol Physics and Chemistry, Hampton, Virginia, 30 to 31 May 1991 (WMO TD No. 439).

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

76. The International Global Aerosol Programme (IGAP) Plan: Overview (WMO TD No. 445).

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

78. Global Atmospheric Background Monitoring for Selected Environmental Parameters BAPMoN Data for 1990, Volume I: Atmospheric Aerosol Optical Depth (WMO TD No. 446).

79. Report of the Meeting of Experts to Consider the Aerosol Component of GAW, Boulder, 16 to 19 December 1991 (WMO TD No. 485).

80. Report of the WMO Meeting of Experts on the Quality Assurance Plan for the GAW, Garmisch-Partenkirchen, Germany, 26-30 March 1992 (WMO TD No. 513).

81. Report of the Second Meeting of Experts to Assess the Response to and Atmospheric Effects of the Kuwait Oil Fires, Geneva, Switzerland, 25-29 May 1992 (WMO TD No. 512).

82. Global Atmospheric Background Monitoring for Selected Environmental Parameters BAPMoN Data for 1991, Volume I: Atmospheric Aerosol Optical Depth (WMO TD No. 518).

83. Report on the Global Precipitation Chemistry Programme of BAPMoN (WMO TD No. 526).

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).

86. The Global Atmosphere Watch Guide, 1993 (WMO TD No. 553).

87. Report of the Third Session of EC Panel/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, Geneva, 8-11 March 1993 (WMO TD No. 555).

88. Report of the Seventh WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques, Rome, Italy, 7 - 10 September 1993, (edited by Graeme I. Pearman and James T. Peterson) (WMO TD No. 669).

89. 4th International Conference on CO_2 (Carqueiranne, France, 13-17 September 1993) (WMO TD No. 561).

90. Global Atmospheric Background Monitoring for Selected Environmental Parameters GAW Data for 1992, Volume I: Atmospheric Aerosol Optical Depth (WMO TD No. 562).

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).

92. Report of the Second WMO Meeting of Experts on the Quality Assurance/Science Activity Centres of the Global Atmosphere Watch, Garmisch-Partenkirchen, 7-11 December 1992 (WMO TD No. 580).

93. Report of the Third WMO Meeting of Experts on the Quality Assurance/Science Activity Centres of the Global Atmosphere Watch, Garmisch-Partenkirchen, 5-9 July 1993 (WMO TD No. 581).

94. Report on the Measurements of Atmospheric Turbidity in BAPMoN (WMO TD No. 603).

95. Report of the WMO Meeting of Experts on UV-B Measurements, Data Quality and Standardization of UV Indices, Les Diablerets, Switzerland, 25-28 July 1994 (WMO TD No. 625).

96. Global Atmospheric Background Monitoring for Selected Environmental Parameters WMO GAW Data for 1993, Volume I: Atmospheric Aerosol Optical Depth.

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

98. Report of the WMO Meeting of Experts on Global Carbon Monoxide Measurements, Boulder, USA, 7-11 February 1994 (WMO TD No. 645).

99. Status of the WMO Global Atmosphere Watch Programme as at 31 December 1993 (WMO TD No. 636).

100. Report of the Workshop on UV-B for the Americas, Buenos Aires, Argentina, 22-26 August 1994.

101. Report of the WMO Workshop on the Measurement of Atmospheric Optical Depth and Turbidity, Silver Spring, USA, 6-10 December 1993, (edited by Bruce Hicks) (WMO TD No. 659).

102. Report of the Workshop on Precipitation Chemistry Laboratory Techniques, Hradec Kralove, Czech Republic, 17-21 October 1994 (WMO TD No. 658).

103. Report of the Meeting of Experts on the WMO World Data Centres, Toronto, Canada, 17-18 February 1995, (prepared by Edward Hare) (WMO TD No. 679).

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).

105. Report of the Fourth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Garmisch, Germany, 6-11 March 1995) (WMO TD No. 718).

106. Report of the Global Acid Deposition Assessment (edited by D.M. Whelpdale and M-S. Kaiser) (WMO TD No. 777).

107. Extended Abstracts of Papers Presented at the WMO-IGAC Conference on the Measurement and Assessment of Atmospheric Composition Change (Beijing, China, 9-14 October 1995) (WMO TD No. 710).

108. Report of the Tenth WMO International Comparison of Dobson Spectrophotometers (Arosa, Switzerland, 24 July - 4 August 1995).

109. Report of an Expert Consultation on 85Kr and 222Rn: Measurements, Effects and Applications (Freiburg, Germany, 28-31 March 1995) (WMO TD No. 733).

110. Report of the WMO-NOAA Expert Meeting on GAW Data Acquisition and Archiving (Asheville, NC, USA, 4-8 November 1995) (WMO TD No. 755).

111. Report of the WMO-BMBF Workshop on VOC Establishment of a “World Calibration/Instrument Intercomparison Facility for VOC” to Serve the WMO Global Atmosphere Watch (GAW) Programme (Garmisch-Partenkirchen, Germany, 17-21 December 1995) (WMO TD No. 756).

112. Report of the WMO/STUK Intercomparison of Erythemally-Weighted Solar UV Radiometers, Spring/Summer 1995, Helsinki, Finland (WMO TD No. 781).

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

114. Report of the Fifth WMO Meeting of Experts on the Quality Assurance/Science Activity Centres (QA/SACs) of the Global Atmosphere Watch, jointly held with the Second Meeting of the Coordinating Committees of IGAC-GLONET and IGAC-ACE[Ed], Garmisch-Partenkirchen, Germany, 15-19 July 1996 (WMO TD No. 787).

115. Report of the Meeting of Experts on Atmospheric Urban Pollution and the Role of NMSs (Geneva, 7-11 October 1996) (WMO TD No. 801).

116. Expert Meeting on Chemistry of Aerosols, Clouds and Atmospheric Precipitation in the Former USSR (Saint Petersburg, Russian Federation, 13-15 November 1995).

117. Report and Proceedings of the Workshop on the Assessment of EMEP Activities Concerning Heavy Metals and Persistent Organic Pollutants and their Further Development (Moscow, Russian Federation, 24-26 September 1996) (Volumes I and II) (WMO TD No. 806).

118. Report of the International Workshops on Ozone Observation in Asia and the Pacific Region (IWOAP, IWOAP-II), (IWOAP, 27 February-26 March 1996 and IWOAP-II, 20 August-18 September 1996) (WMO TD No. 827).

119. Report on BoM/NOAA/WMO International Comparison of the Dobson Spectrophotometers (Perth Airport, Perth, Australia, 3-14 February 1997), (prepared by Robert Evans and James Easson) (WMO TD No. 828).

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

121. Report of the Eighth WMO Meeting of Experts on Carbon Dioxide Concentration and Isotopic Measurement Techniques (prepared by Thomas Conway) (Boulder, CO, 6-11 July 1995) (WMO TD No. 821).

122. Report of Passive Samplers for Atmospheric Chemistry Measurements and their Role in GAW (prepared by Greg Carmichael) (WMO TD No. 829).

123. Report of WMO Meeting of Experts on GAW Regional Network in RA VI, Budapest, Hungary, 5 to 9 May 1997.

124. Fifth Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry, (Geneva, Switzerland, 7-10 April 1997) (WMO TD No. 898)

125. Instruments to Measure Solar Ultraviolet Radiation, Part 1: Spectral Instruments (lead author G. Seckmeyer) (WMO TD No. 1066)

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

127. Report of the WMO-WHO Meeting of Experts on Standardization of UV Indices and their Dissemination to the Public (Les Diablerets, Switzerland, 21-25 July 1997) (WMO TD No. 921).

128. The Fourth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting, (Rome, Italy, 22-25 September 1996) (WMO TD No. 918).

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

130. Jülich Ozone Sonde Intercomparison Experiment (JOSIE, 5 February to 8 March 1996), (H.G.J. Smit and D. Kley) (WMO TD No. 926).

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

132. Report of the Ninth WMO Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques (Edited by Roger Francey), (Aspendale, Vic., Australia).

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

134. Guide on Sampling and Analysis Techniques for Chemical Constituents and Physical Properties in Air and Precipitation as Applied at Stations of the Global Atmosphere Watch. Carbon Dioxide (WMO TD No. 980).

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).

136. WMO/EMEP/UNEP Workshop on Modelling of Atmospheric Transport and Deposition of Persistent Organic Pollutants and Heavy Metals (Geneva, Switzerland, 16-19 November 1999) (Volumes I and II) (WMO TD No. 1008).

137. Report and Proceedings of the WMO RA II/RA V GAW Workshop on Urban Environment (Beijing, China, 1-4 November 1999) (WMO-TD. 1014) (Prepared by Greg Carmichael).

138. Reports on WMO International Comparisons of Dobson Spectrophotometers, Parts I – Arosa, Switzerland, 19-31 July 1999, Part II – Buenos Aires, Argentina (29 Nov. – 12 Dec. 1999 and Part III – Pretoria, South Africa (18 March – 10 April 2000) (WMO TD No. 1016).

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).

140. WMO/CEOS Report on a Strategy for Integrating Satellite and Ground-based Observations of Ozone (WMO TD No. 1046).

141. Report of the LAP/COST/WMO Intercomparison of Erythemal Radiometers (Thessaloniki, Greece, 13-23 September 1999) (WMO TD No. 1051).

142. Strategy for the Implementation of the Global Atmosphere Watch Programme (2001-2007), A Contribution to the Implementation of the Long-Term Plan (WMO TD No.1077).

143. Global Atmosphere Watch Measurements Guide (WMO TD No. 1073).

144. Report of the Seventh Session of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the GAW 2001 Workshop (Geneva, Switzerland, 2 to 5 April 2001) (WMO TD No. 1104).

145. WMO GAW International Comparisons of Dobson Spectrophotometers at the Meteorological Observatory Hohenpeissenberg, Germany (21 May – 10 June 2000, MOHp2000-1), 23 July – 5 August 2000, MOHp2000-2), (10 – 23 June 2001, MOHp2001-1) and (8 to 21 July 2001, MOHp2001-2). Prepared by Ulf Köhler (WMO TD No. 1114).

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).

148. Report of the Eleventh WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques (Tokyo, Japan, 25-28 September 2001) (WMO TD No 1138).

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).

150. Updated Guidelines for Atmospheric Trace Gas Data Management (Prepared by Ken Maserie and Pieter Tans) (WMO TD No. 1149).

151. Report of the First CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 18-19 March 2003) (WMO TD No. 1181).

152. Current Activities of the Global Atmosphere Watch Programme (as presented at the 14th World Meteorological Congress, May 2003). (WMO TD No. 1168).

153. WMO/GAW Aerosol Measurement Procedures: Guidelines and Recommendations. (WMO TD No. 1178).

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

155. 1st International Expert Meeting on Sources and Measurements of Natural Radionuclides Applied to Climate and Air Quality Studies (Gif sur Yvette, France, 3-5 June 2003) (WMO TD No. 1201).

156. Addendum for the Period 2005-2007 to the Strategy for the Implementation of the Global Atmosphere Watch Programme (2001-2007), GAW Report No. 142 (WMO TD No. 1209).

157. JOSIE-1998 Performance of ECC Ozone Sondes of SPC-6A and ENSCI-Z Type (Prepared by Herman G.J. Smit and Wolfgang Straeter) (WMO TD No. 1218).