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Overview of the performance of ozone sondes and their uncertainties

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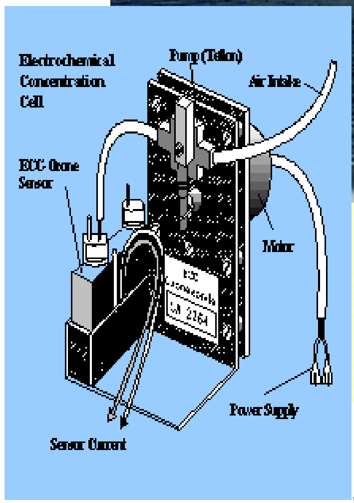
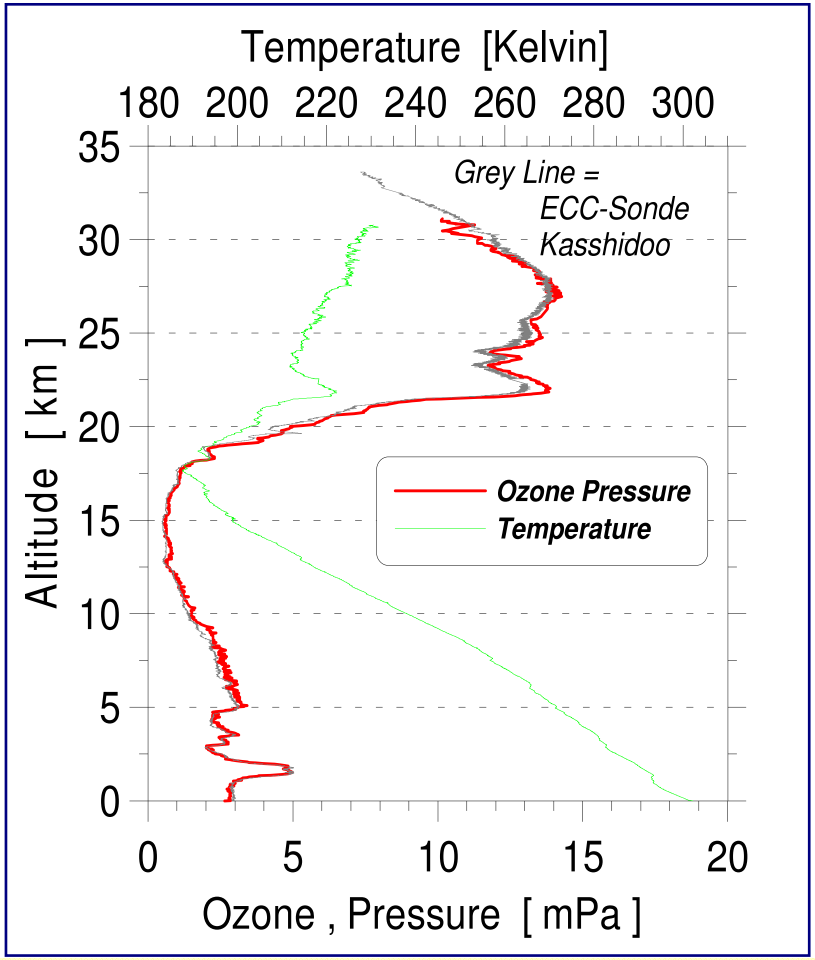
SPARC/IOC/WMO-IGACO Workshop on
Past Changes in the Vertical Distribution of Ozone
Geneva, January 25-27 2011

Performance ECC-Ozone Sounding: Intercomparison

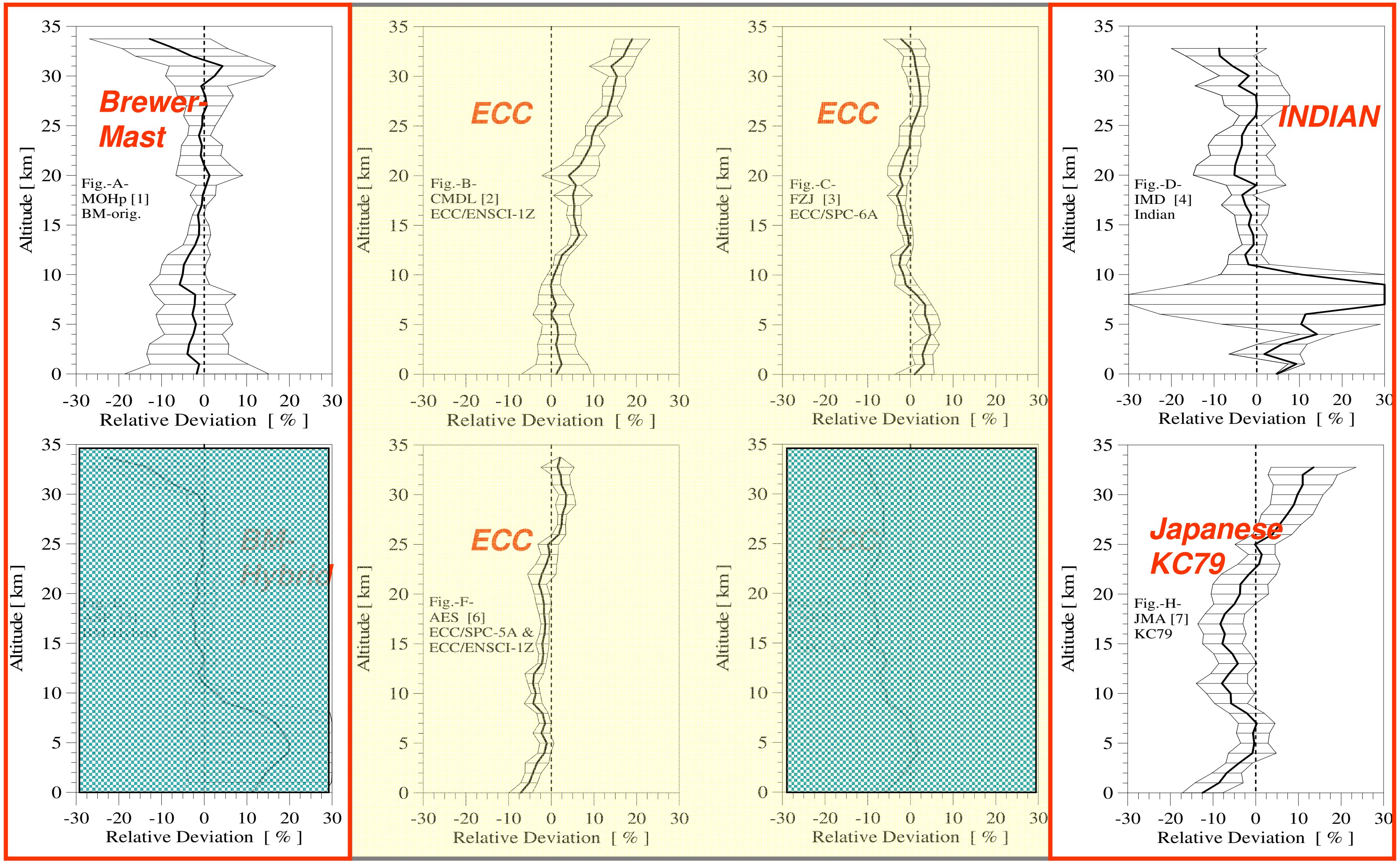




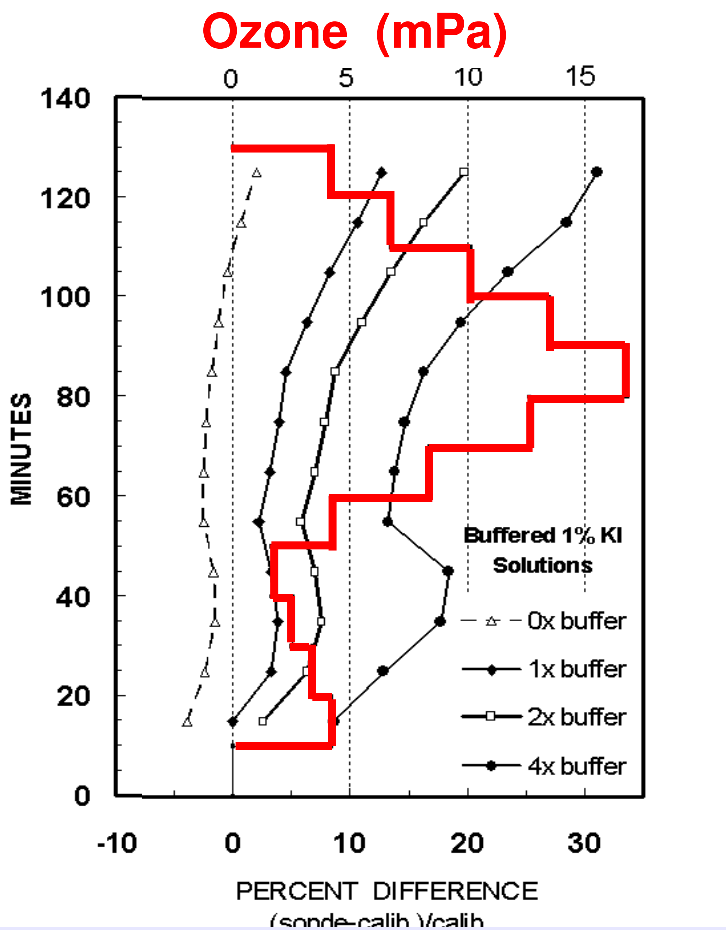
ECC-Ozone sensor converts sampled ozone flow into electrical current:

- In aqueous KI-solution Ozone is converted into Iodine molecules
- In electrochemical cell Iodine is converted at Pt-Cathode into Iodide-ions

JOSIE-1996:
Juelich Ozone Sonde Intercomparison Experiment



Conversion Efficiency ECC-Sonde:
Influence of Sensing Solutions (KI & Buffer)



Johnson, et al, J. Geophys. Res., 2002

Stoichiometry (O_3 + KI) Reaction yielding I_2 at 1% KI, full Buffer:

- At launch stoichiometry is unity
- During flight evaporation of H_2O
- Increase concentrations of KI & Buffer
- Increase of stoichiometry
- Majorly due to increase of buffer

Controversy ECC-sondes since Mid 1990's:

Two Manufacturers and 3 Different Sensing Solution Types

Manufacturer	Model Type	Years Manufactured.
Science Pump	SPC-6A	1995- present
EN-SCI	ENSCI-Z	1997 –present

Sensing Solution Type (SST)	KI [g/L]	P_H-Buffer		KBr [g/L]
		$NaH_2PO_4.H_2O$ [g/L]	$Na_2HPO_4.12H_2O$ [g/L]	
SST1.0: 1.0% KI & full buffer [(a)]	10	1.250	5.0	25
SST0.5: 0.5% KI & half buffer [(b)]	5	0.625	2.5	12.5
SST2.0: 2.0% KI & no buffer [(c)]	20	0	0	0

JOSIE – ASOPOS - BESOS

WCCOS

World
Calibration
Centre for
Ozone
Sondes

At Juelich, Germany

JOSIE ⟷ **ASOPOS** ⟷ **BESOS**

JOSIE
Jülich
Ozone
Sonde
Intercomparison
Experiment

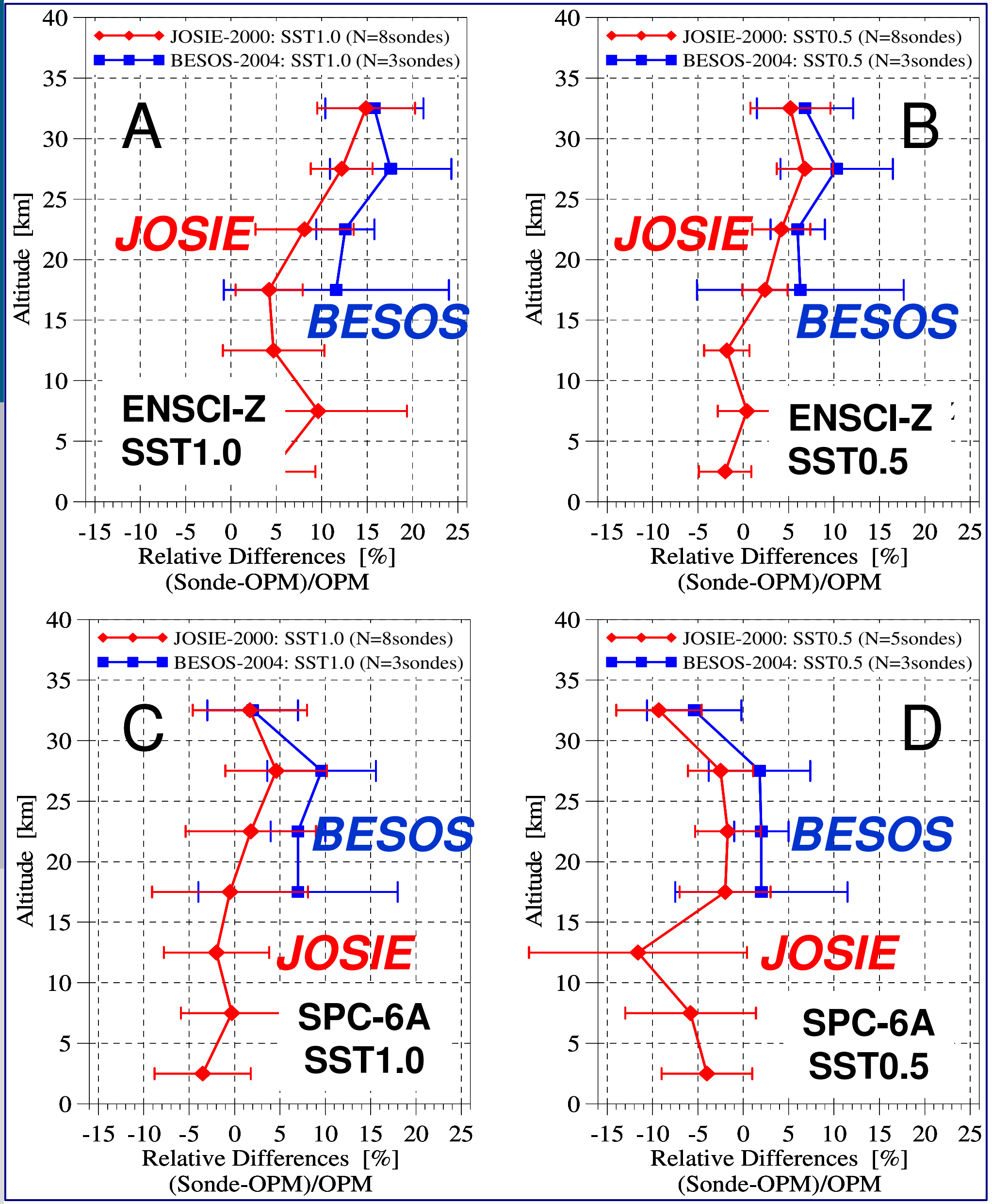
Since 1996

ASOPOS
Assessment for
Standard
Operating
Procedures for
Ozone
Sondes

BESOS
Balloon
Experiment on
Standards for
Ozone
Sondes

April 2004, at Laramie, USA

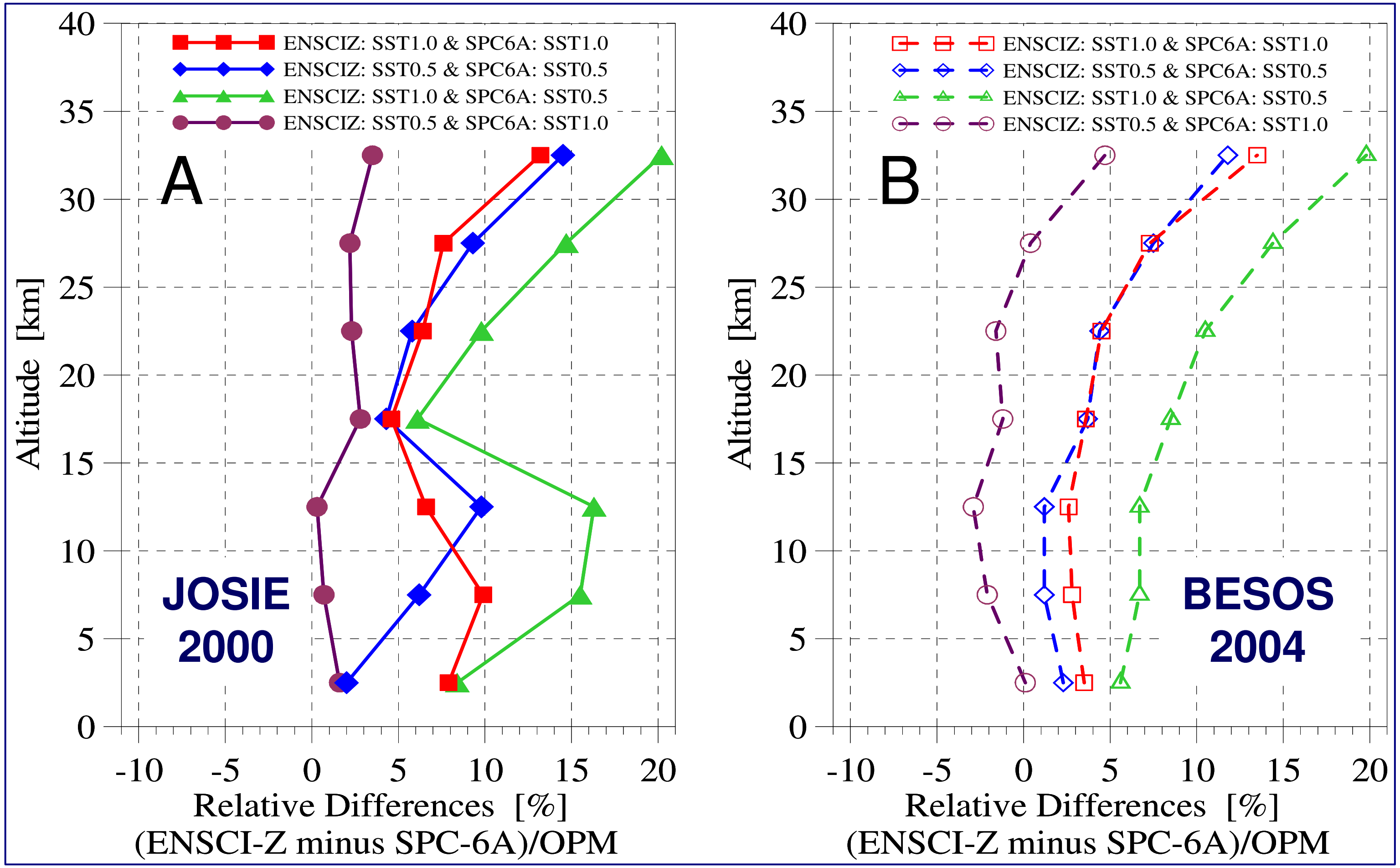
Sources: JOSIE [Smit et al., J.Geophys.Res., 2007]
BESOS [Deshler et al., J.Geophys.Res., 2008]



Sondes versus OPM : BESOS versus JOSIE

1. Systematic difference of 3-6%
2. Compared to sondes: OPM in BESOS about 3-6 % lower than in JOSIE.
3. Limited performance OPM during BESOS
4. Behaviour of sondes in stratosphere very consistent during JOSIE 1996, 1998, 2000 and BESOS

Sondes versus Sondes : BESOS versus JOSIE



JOSIE 2000 & BESOS 2004:

Comparison SPC-6A&ENSCI-Z @ Different Sensing Solutions

SST1.0 (1.0%KI,Full Buffer), SST0.5 (0.5%KI,Half Buffer), SST2.0 (2.0%KI, No Buffer)

[Data processed after Komhyr 1986, IB0 (PO2), No Total O3 Normalization]

Each sonde type (ENSCI or SPC):

- SST1.0 ≈ 5% larger than SST0.5
- SST0.5 ≈ 5% larger than SST2.0
- SST1 ≈ 10% larger than SST2.0

For each Sensing Solution Type (SST1.0 , SST0.5, and SST2.0) :

- ENSCI 5-10 % higher than SPC
- Precision about 3-6 %

ECC-Ozone Sonde Performance: What we learned from JOSIE and BESOS

1.) Small changes of
   a. ozone sonde instrument (e.g. manufacturers)
   b. operating procedures (e.g. sensing solutions)
   can have large impact on sonde data quality

2.) Non-uniformity in data processing

3.) Establishment of Standard of Operating Procedures (SOP) for ozone sondes by ASOPOS recomendations

4.) After standardization and homogenization improvement of precision and accuracy by about factor 2 can be expected

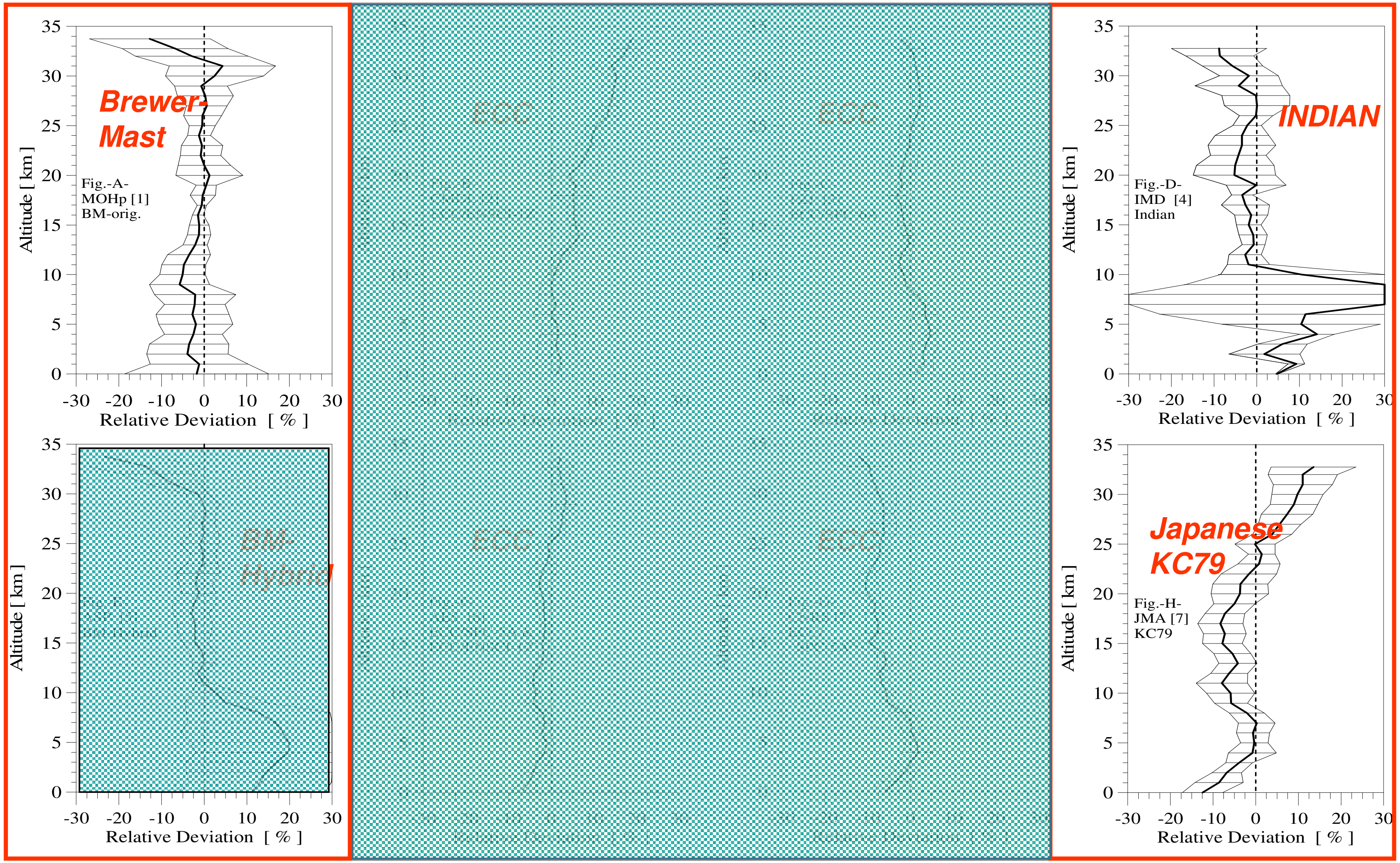
Task force group:
Transfer functions to homogenize ozone sonde records

Established with following plan:

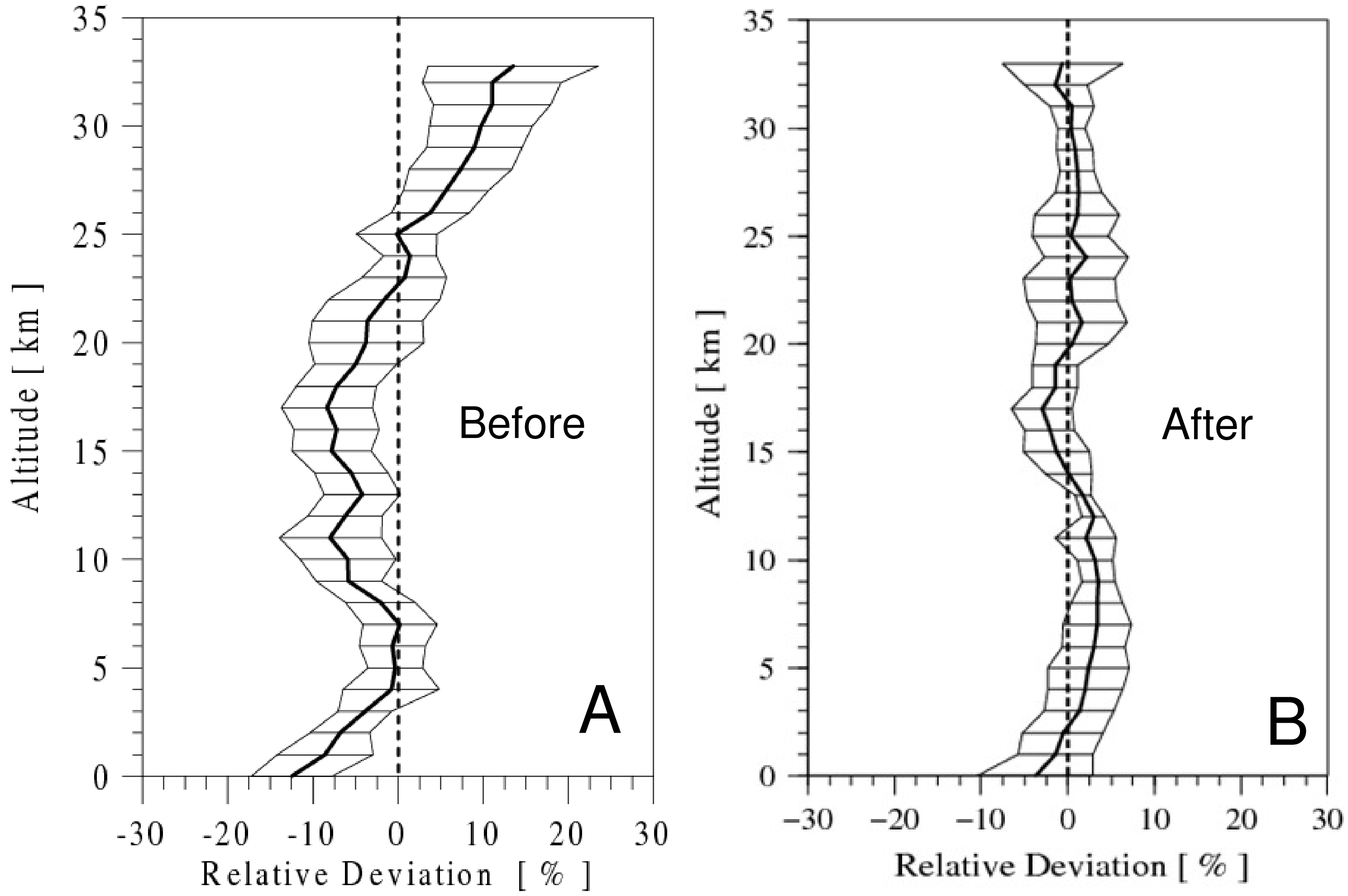
1) Construct/derive empirical transfer functions from existing data:
   - Relative Diffference PO3 (Z)
   - Absolute Difference PO3 (Z)
   - Absolute Difference PO3 (PO3)
2) Evaluate transfer functions: testing a set of homogenized O3S data on consistency (e.g. use MATCH, satellites, MOZAIC).
3) Recommendations on the methodology to homogenize data
4) Review by independent panel of scientists (O3S data users)
5) Approval of recommendations by WMO/GAW-O3-SAG and NDACC-SSC

Task force group established as WMO/GAW-IGACO activity in collaboration with the NDACC and SHADOZ ozone sounding networks.

JOSIE-1996: Overview Comparison Ozone Sondes

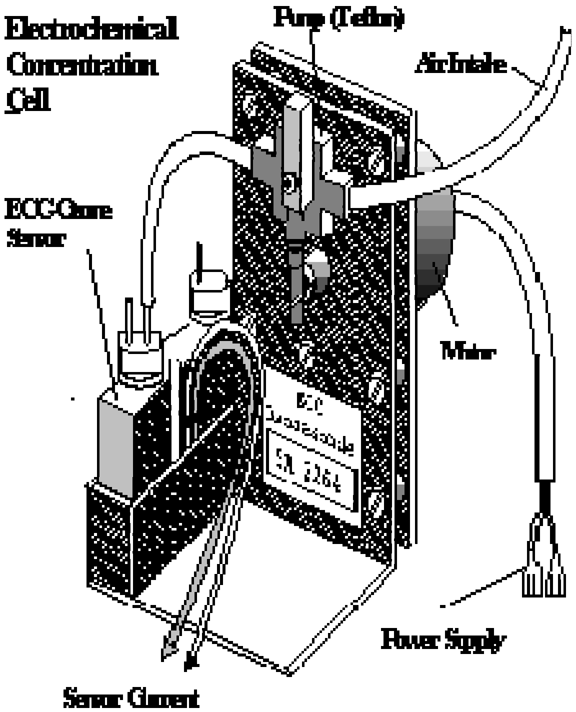


JOSIE-BESOS: Improvement KC96-Ozone Sonde



Electrochemical Ozone Sonde: Introduction

JÜLICH FORSCHUNGSZENTRUM



In an electrochemical cell:

- A small pump forces ambient air through a KI-solution
- Ozone is converted into iodine by the reaction:

$$2KI + O_3 + H_2O \rightarrow I_2 + O_2 + 2KOH$$

- At a Platinium cathode the Iodine is converted to Iodide: $I_2 + 2e \xrightarrow{Pt} 2I^-$
- In external electrical circuit a current is generated directly related to the uptake rate of ozone in the sensing solution

$$P_{O3} = 0.04307 \cdot \eta_C \cdot \frac{T_P}{\Phi_P} \cdot (I_M - I_B)$$

Ozone Pressure [mPa]

Pump Temperature [K]

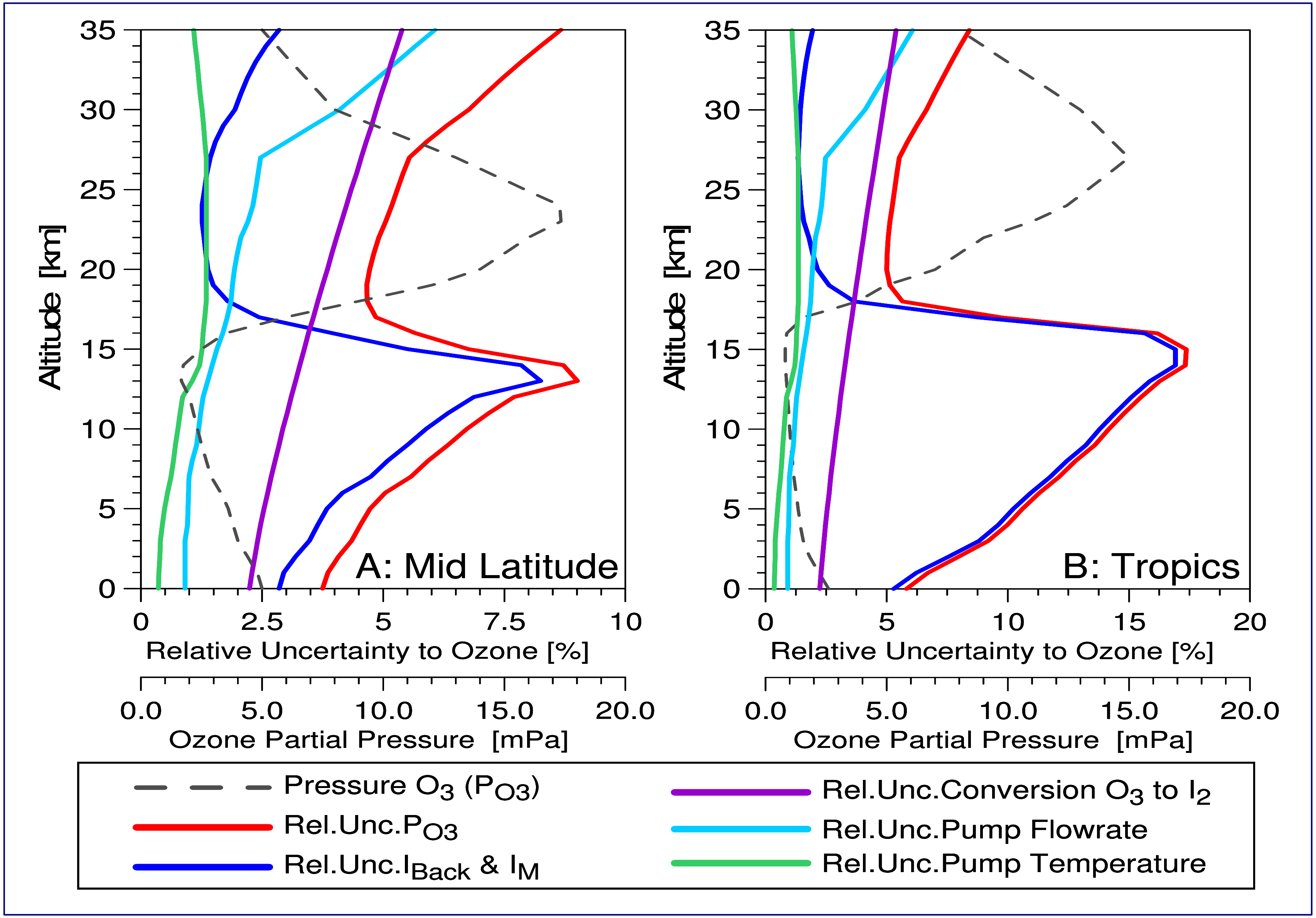
Conversion Efficiency

Pump Flow [cm3/s]

Background Current [µA]

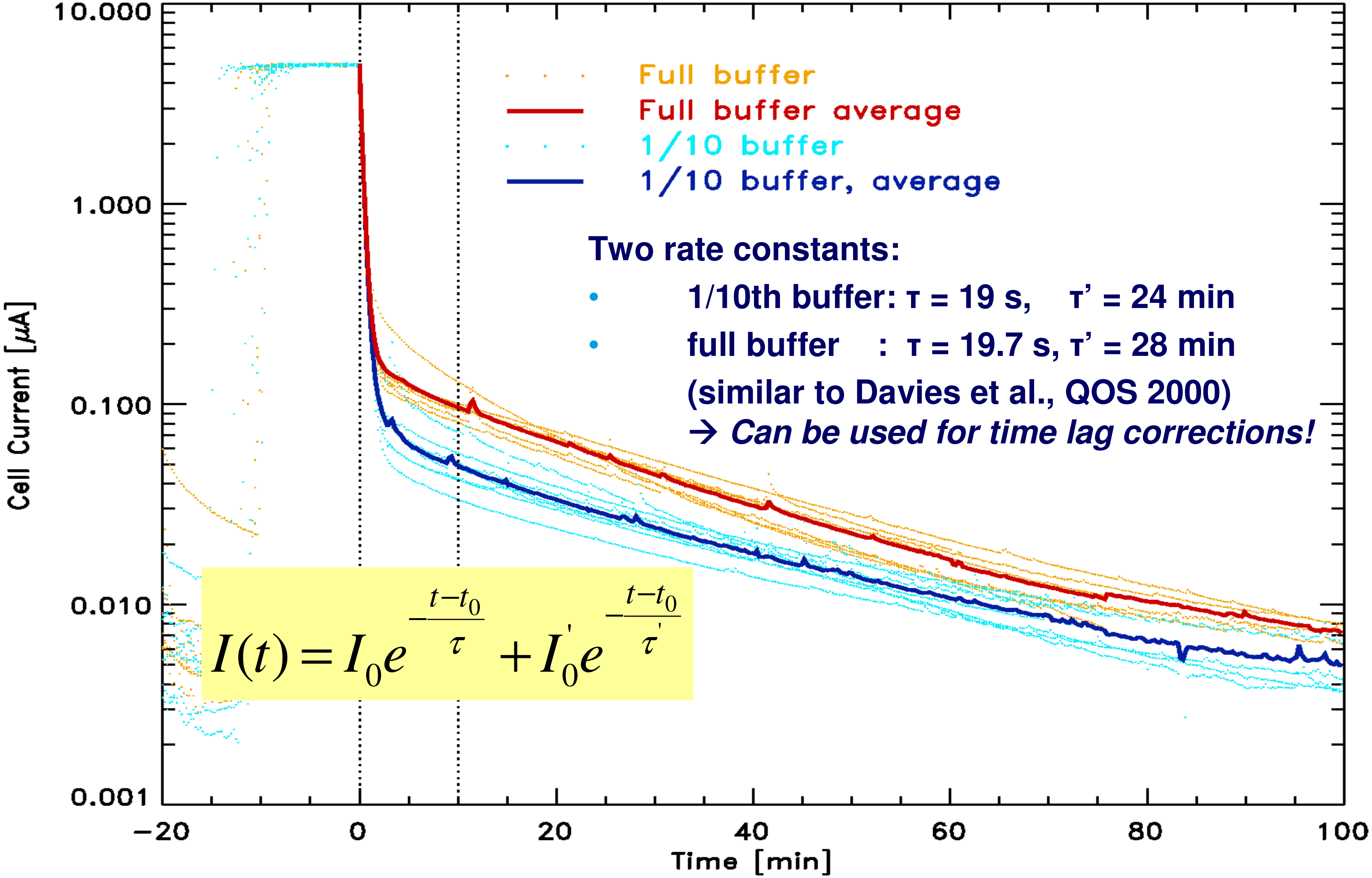
Measured Current [µA]

Instrumental Uncertainties of ECC-Ozone Sonde



ECC-Sonde: Downward Step Response

[Source: Voemel & Diaz, AMT 2010]



Two rate constants:

- 1/10th buffer: τ = 19 s, τ' = 24 min
- full buffer : τ = 19.7 s, τ' = 28 min

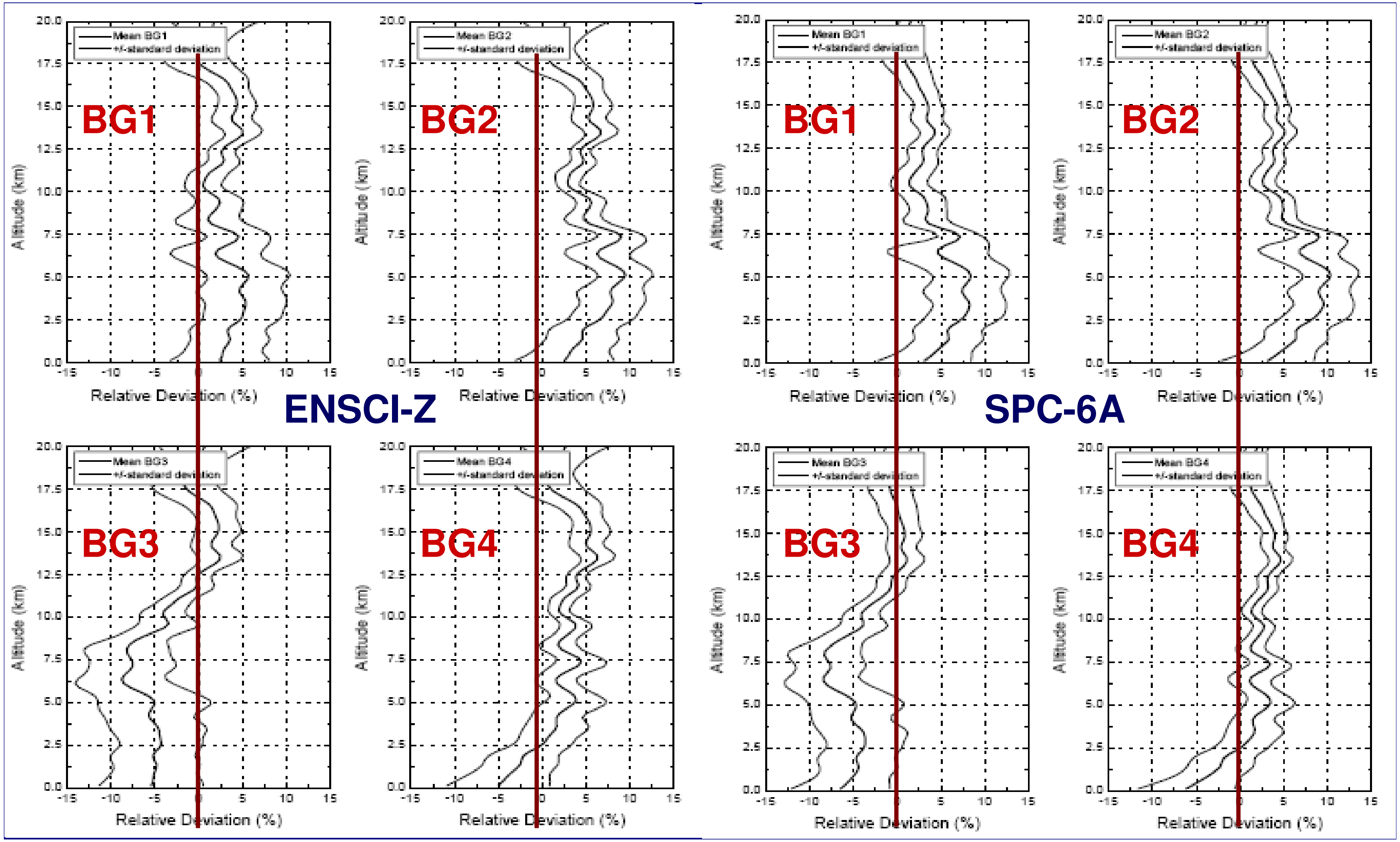
(similar to Davies et al., QOS 2000)

→ ***Can be used for time lag corrections!***

$$I(t) = I_0 e^{-\frac{t-t_0}{\tau}} + I_0^{'} e^{-\frac{t-t_0}{\tau^{'}}}$$

ECC-Background Current Correction @JOSIE 1998

JÜLICH
FORSCHUNGSZENTRUM



BG1 = Before O3 Exposure (IB0) , No F(PO2)
BG2 = Before O3 Exposure (IB0) , F(PO2)
No F(PO2) = Constant

BG3 = After O3 Exposure (IB1) , No F(PO2)
BG4 = After O3 Exposure (IB1) , F(PO2)
F(PO2) = O2-pres. dependent

JOSIE 1998: Downward Response Tests ECC-Sondes (13xSPC6A and 13xENSCI-Z-)

Sonde Type	Sonde Nr.	Response Time (s)		Offset (mPa) (@t=5min)	
		Troposphere	Stratosphere	Troposphere	Stratosphere
SPC-6A	Average	24.0±1.7	21.5±2.9	0.16±0.07	0.52±0.15
ENSCI-Z	Average	27.7±2.9	28.6±3.2	0.10±0.05	0.52±0.10

ECC-Sonde: Background measurement with O3

[Source: Voemel & Diaz, AMT 2010]

$$I_{cell} - I_{TEI} = \alpha \cdot I_{cell} + \beta$$

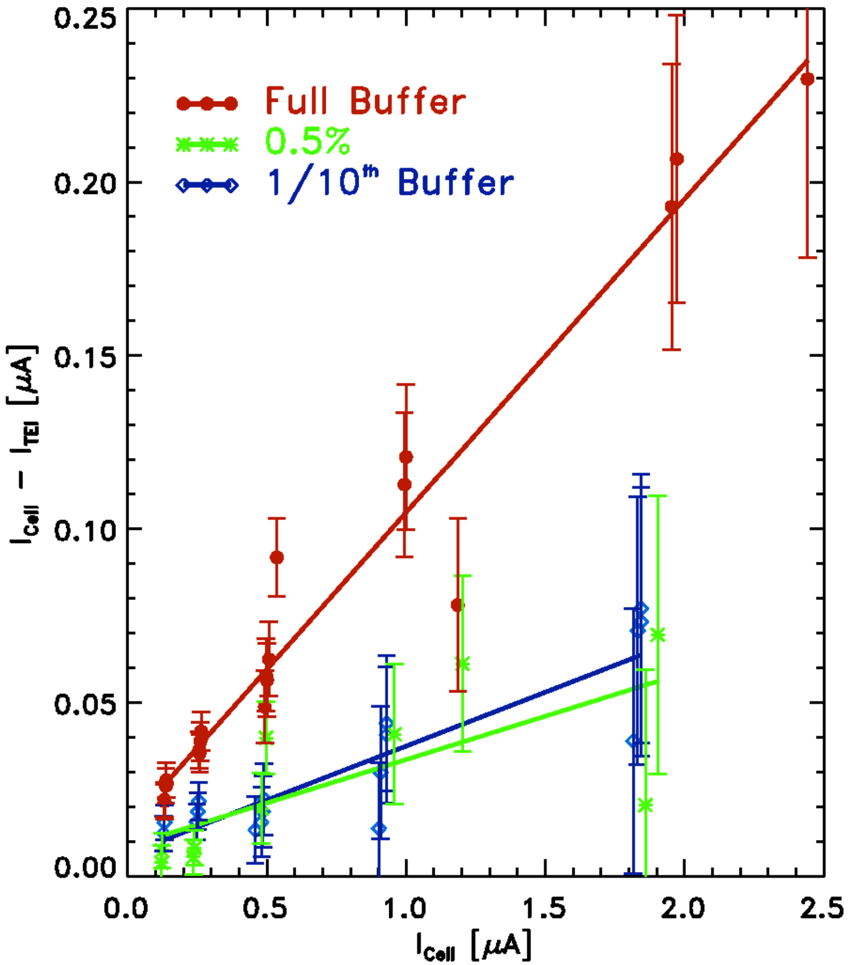
Offset parameter β:
Modified background
Slope parameter α:
Correction for stoichiometry

$$I_{O3} = (1-\alpha) \cdot I_{Cell} - \beta$$

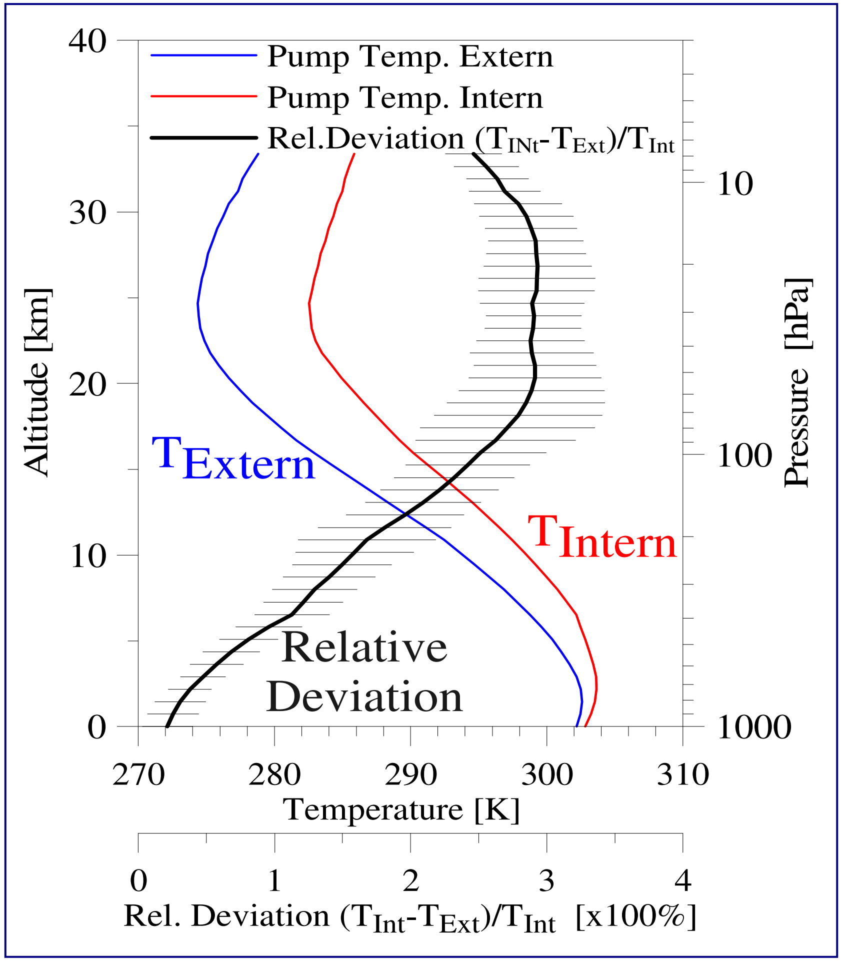
full buffer :
α = 0.090, β = 0.014μA

1/10th buffer :
α = 0.031, β = 0.007μA

0.5% :
α = 0.024, β = 0.009μA



Pump Temperature: Internally or Externally Measured



Internal pump temperature:

- inside the Teflon block of the pump

External pump temperature:

- outside the Teflon block of the pump
- corresponds to box temperature

Ozone Sonde:

Total Ozone Column and Normalization Factor (NF)

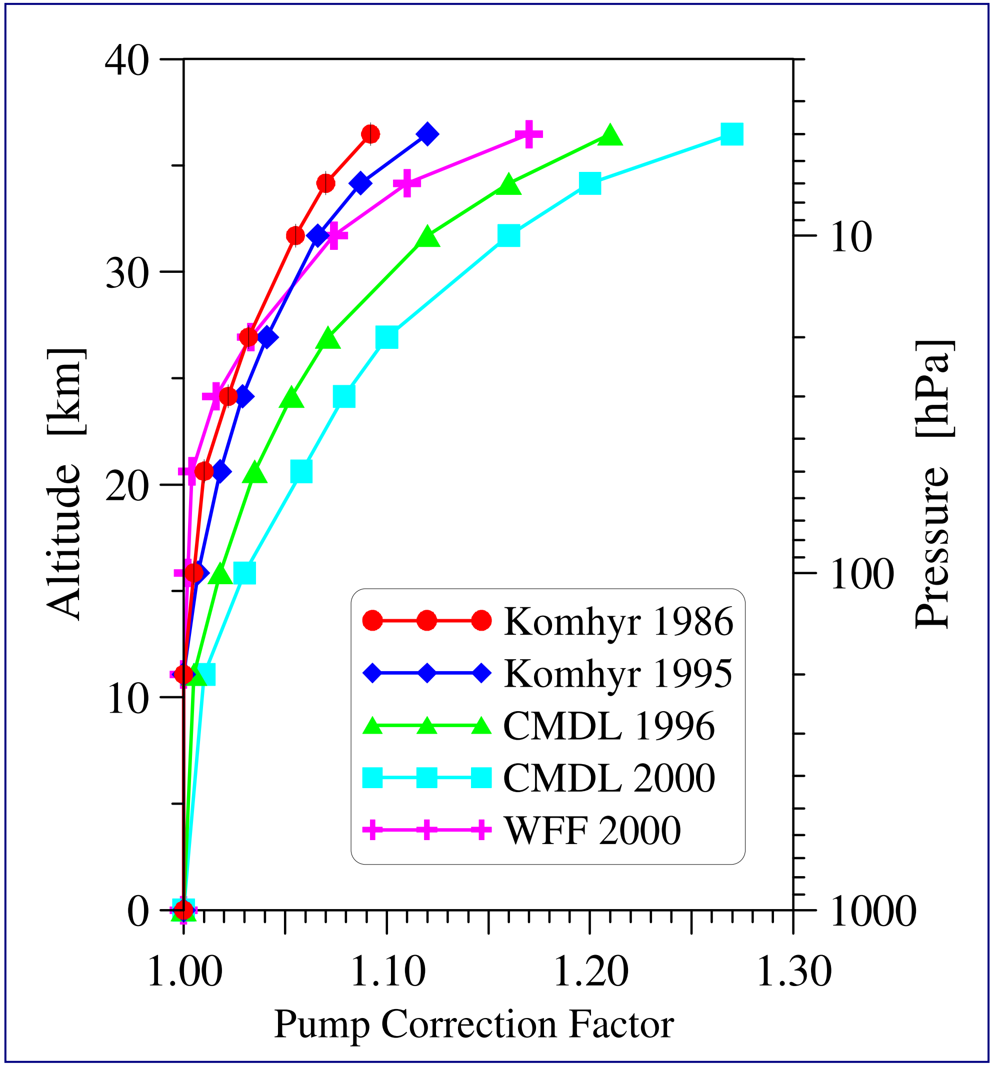
TOC = TOS + ROC

TOC = Total Ozone Column between surface and top of atmosphere (TOA)
TOS = Total Ozone Column between surface and burst point (PB, ZB)
ROC = Residual Ozone Clumn above burst point (PB, ZB)

TOS : Dependent on Accuracy of Z, P
ROC : Dependent on Accuracy of ZB, PB
CMR-Method OR SBUV-Method
TO3 = Total Ozone Column measured by Dobson or Brewer Or Satellite

NF = TO3 / TOC

Pump Flowrate Correction at Low Pressures



JOSIE :

[CMDL(NOAA) and WFF(NASA) are averages from about 6 individually calibrated pumps]

Task force group "O3S-Pump Flow Correction"

1) Review different laboratory methods by "experts"

2) Intercomparison of existing methods by ring-experiment of a set of SPC6A and ENSCI pumps by testing laboratories (NOAA, UWY, WFF, KMI & JMA) [Blind & Referee].

3) Evaluation

4) Implications

5) Recommendations

6) Approval by WMO/SAG-O3 to include as recommendation into the SOP's

Time schedule: 2010-2012
IGACO-O3 activity

In how far O3-Sondes usable for trend analysis?

Altitude:

ECC : 0- 30 km (uncert. 5-10%)

BM: 0- 25 km (uncert. 10%) ; KC79/96: 0-25 km (uncert.10%)

Long term stability:

Only for limited number of stations after selection on „objective“ criteria to be defined by panel of experts.

Level of confidence:

Limited with respect to poor coverage in space and time

Yes, but depends on stations, sonde type , and length of record

Internal consistency of single station

External consistency: Intercomparison excercises like JOSIE, BESOS and other field activities (e.g. dual-soundings)