Ozone Sondes in GAW:

Future Collaboration Between GAW-WCCOS and GRUAN on Ozone Sondes QA

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Research Centre Jülich (IEK-8), Germany

GRUAN ICM#09 Annual Meeting

12-16 June 2017, Helsinki Finland

Outline

1.) O3S-Experts-Meeting 1-3 September 2016 at University of Edinburgh:

- in front of the QOS 2016
- 35 Participants, mostly O3S experts but also from industry (SPC, ENSCI (2), Vaisala (2), Modem)

Agenda:

Day#1: Instrumental Issues: Outstanding issues

Day#2: Reprocessing and Homogenisation

Day#3: JOSIE 2017-SHADOZ (Scheduled for Fall 2017)

2.) Harmonisation O3S-QA of GAW-NDACC-SHADOZ (WCCOS) with GRUAN/O3S

Ozone Experts Meeting 2017
University of Edinburgh, UK, 1-3 Sept. 2017

O3SEM 2016 Day#1: Key Outstanding Issues

JÜLICH
FORSCHUNGSZENTRUM

Pump Temperature [K]

Background Current [µA]

Ozone Pressure [mPa]

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

Conversion Efficiency

Pump Flow [cm3/s]

Measured Current [µA]

1. **Different sensing solutions and sonde type: Stoichiometry O3+KI larger than one and increasing in course of sounding**
2. **Uniform background current corrections (IB0, IB1, IB2)**
3. **Uniform pump flow efficiency correction at lower pressures**
4. **Pressure bias (radiosonde) : Large impact on height above 20 km**

New Pump Flow Efficiencies: New Conversion Efficiencies (1)

$$P_{O3} = C \cdot \frac{1}{\eta_T} \cdot \frac{T_P}{\Phi_P} \cdot (I_M - I_B)$$

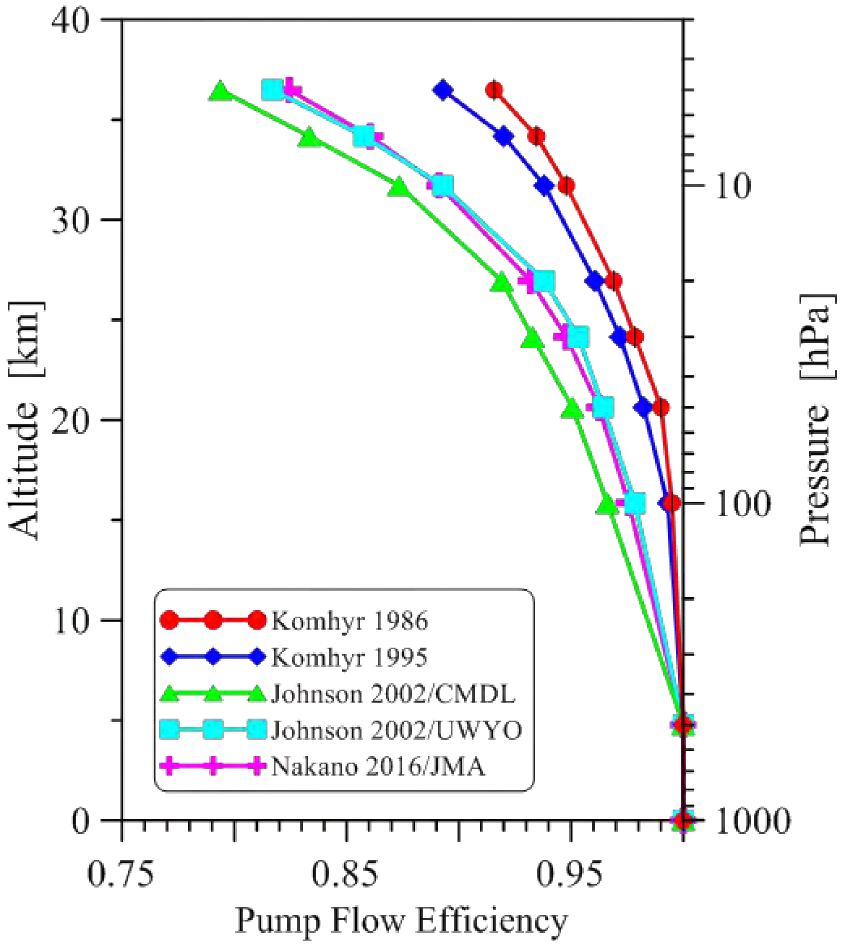
$$\eta_T = \eta_{Th} \cdot \eta_A \cdot \eta_C \cdot \eta_P \cdot \eta_X$$

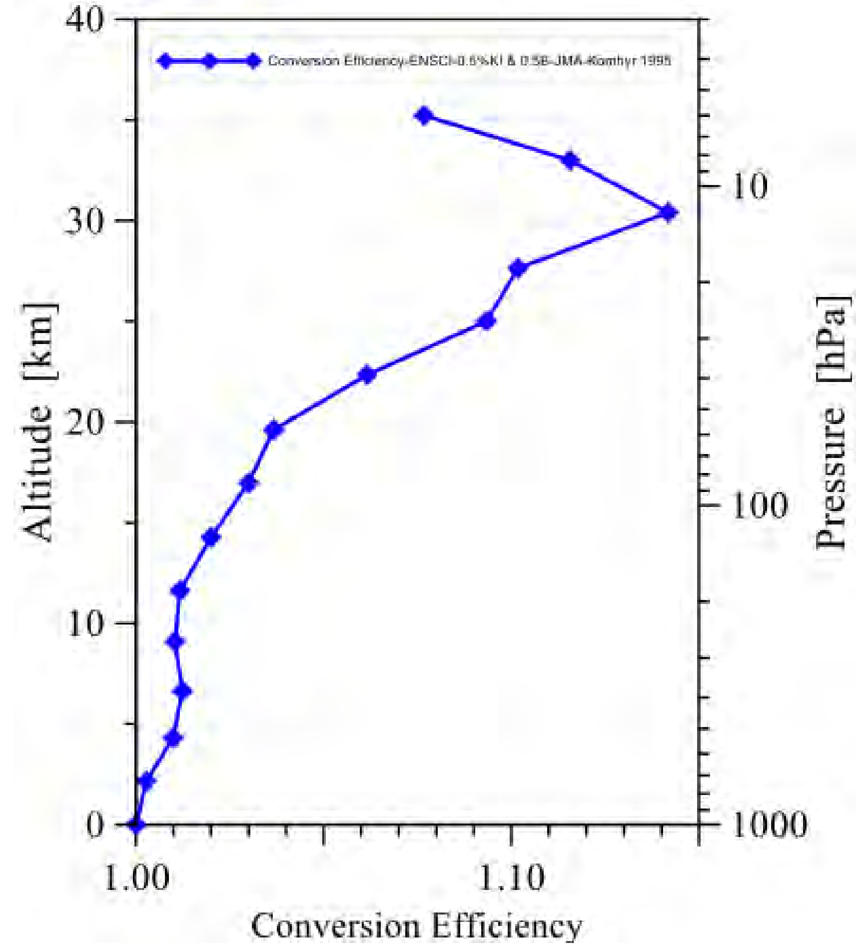
I. Present SOP's (See GAW-Report#201) recommend to use SPC sondes with SST1.0%/full buffer and ENSCI sondes with 0.5%/Half buffer

II. Since JOSIE 1996 we know that we have a counter balancing effect of:
   a) Pump flow efficiency η_P too high: modern laboratory measurements by NOAA and JMA show significant lower pump flow efficiencies than existing old tables still in use.
   b) Conversion efficiency η_C set to one is actually too low: Stoichiometry O3+KI larger than one

- **Present State: By doing it two times wrong one gets the right answer.**
- **New: Revise the concept and give the different terms in above equation also the real physical means they should have.**

New Pump Efficiencies:
New Conversion Efficiencies (2)

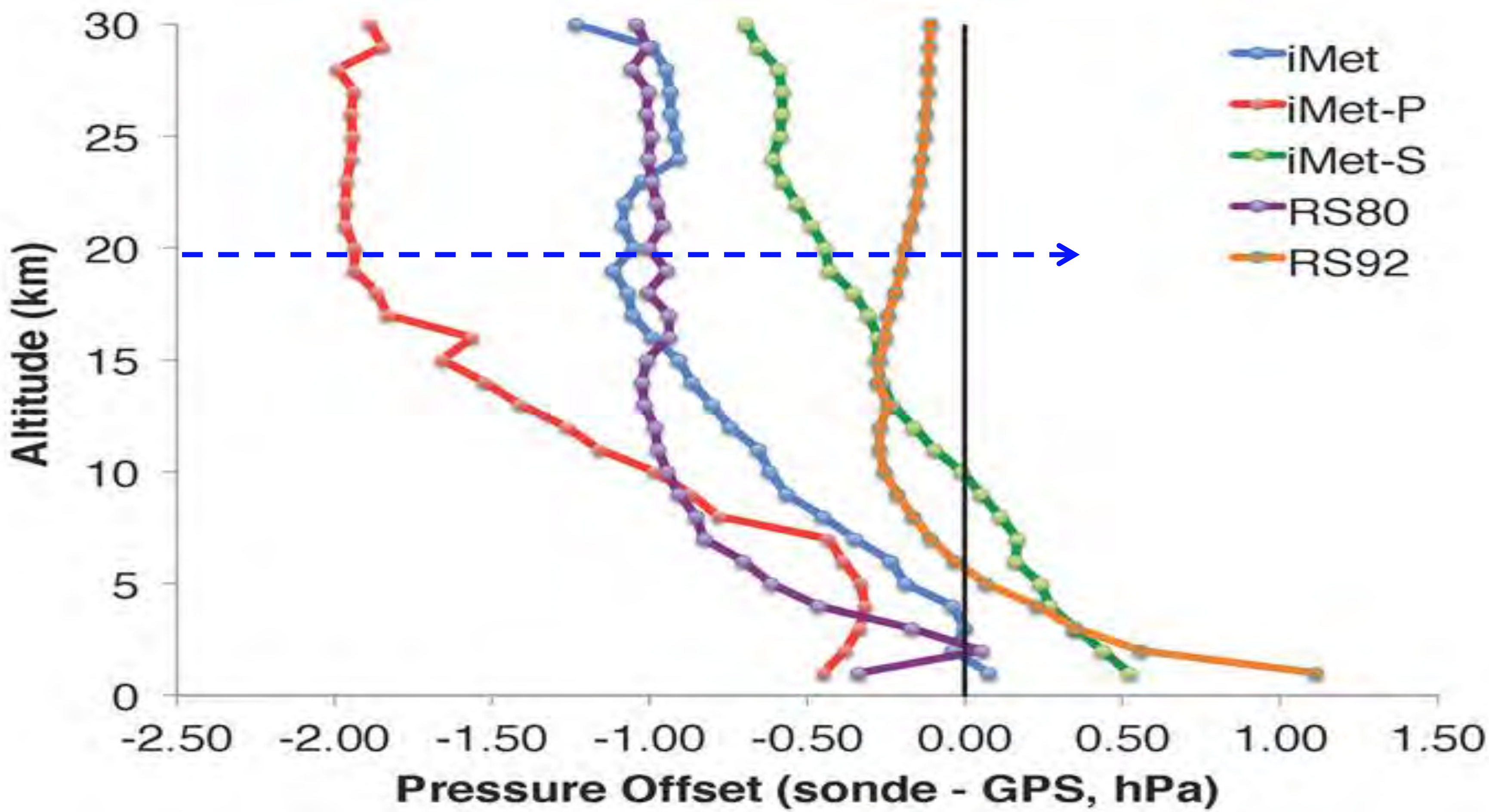




Pump flow efficiencies (ηP) as a function of air pressure for ECC-ozone sondes reported by (i) Komhyr, 1986; (ii) Komhyr et al., 1995; (iii) Johnson et al. 2002: GMD & UWYO; (iv) Nakano: JMA, private communication, 2017.

Conversion Efficiencies for ENSCI-Z with SST0.5% KI+0.5 Buffer estimated from JOSIE 2009 using average pump flow efficiencies of JMA/Nakano 2016

Radiosonde: Pressure Offset
Source: Stauffer et al., AMT, 2014



The pressure offset is significant but can be corrected for:
Significant improvement for altitude scale of the vertical ozone sonde profile

Estimation Overall Uncertainty P_{O3}

$$P_{O3} = 0.043085 \cdot \frac{T_P}{\left(\eta_T \cdot \Phi_P\right)} \cdot \left(I_M - I_B\right)$$

Assumption in O3S-DQA:

After all corrections have been done to resolve the different inhomogenities (bias effects) in the long term O3S-records all remaining individual uncertainties are random and following Gaussian statistics, then applying Gaussian law of error propagation can be applied:

$$\frac{\Delta P_{O3}}{P_{O3}} = \sqrt{\frac{(\Delta I_M)^2 + (\Delta I_B)^2}{(I_M - I_B)^2} + \left(\frac{\Delta \eta_T}{\eta_T}\right)^2 + \left(\frac{\Delta \Phi_P}{\Phi_P}\right)^2 + \left(\frac{\Delta T_P}{T_P}\right)^2}$$

O3S-DQA Homogenisation: Objectives

"Ozone Sonde Data Quality Assessment (O3S-DQA)" activity started in 2011 has following three major objectives:

1. Homogenization of a selected ozone sonde data set with the **goal to reduce uncertainty from 10-20% down to 5-10%** **(focus on SST-transfer functions, but also other instrumental aspects).** **Traceability to ozone reference** **(WCCOS-UV phoiometer)**

2. **Documentation** of the homogenization process and quality of ozonesonde measurements including **quantification of the uncertainty of each ozone sonde measurement.** *Prepare "WMO Guidelines to determine ozone sonde uncertainties, incl. storage in O3S-archives"*

3. Storage of additional **raw data of O3S** and the **overall uncertainty of each O3S-measurement**

O3S-DQA: Status of Re-processing

→ March 2017: Total of 28 Stations records have been re-processed, 4 papers published and 4 in preparation and several planned for 2018

→ Homogenised & Non-Homogenised data temporaly on password protected data server Juelich. Later (2018/2019) moved to the data centers (WOUDC, NDACC & SHADOZ)

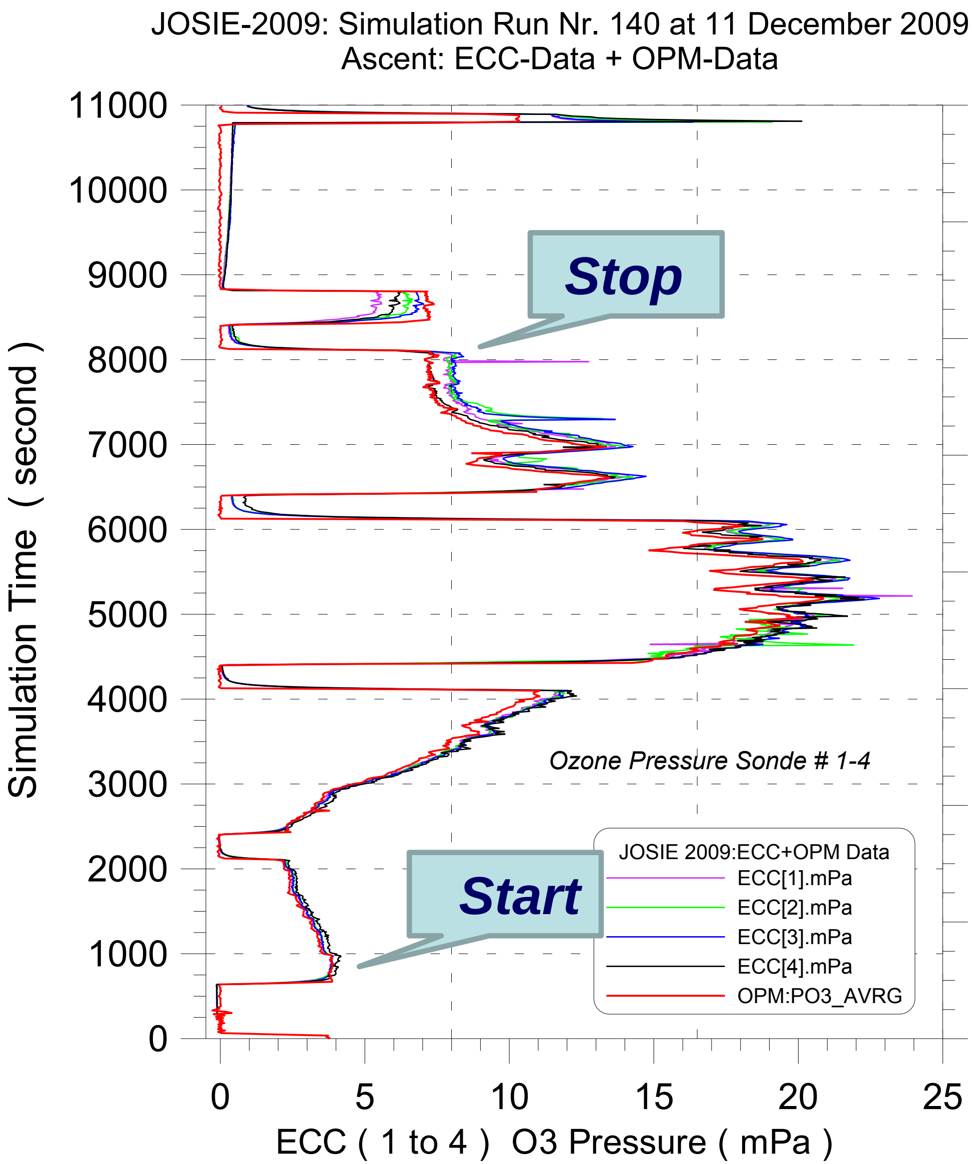
Goal for Summer-Fall 2017:

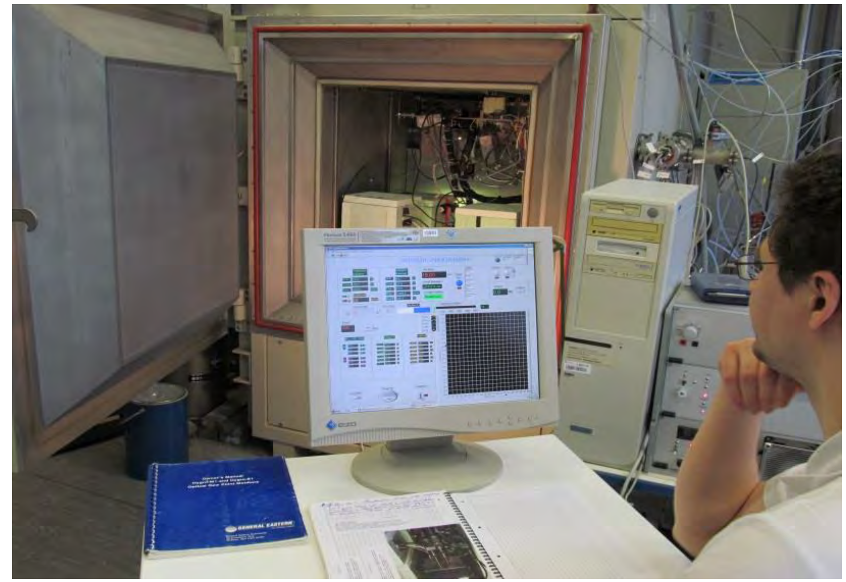
A. >30 Stations being homogenised (Re-processed data incl. RAW-Data, Overall Uncertainty, Documentation).
B. First Analysis on Validation → Evaluation can start
C. Key papers ready for publications: about 7
D. Provide part of homogenised data set to LOTUS , i.e. UNEP-Assessment on Ozone Depletion 2018

Jülich Ozone Sonde Intercomparison Experiment: JOSIE 2017/SHADOZ

- Tropical Profiling Capabilities
- Instrumental issues: Background Current, Pumpflow Corrections and Sensing Solution Type
- Capacity building (support from UNEP-Vienna Convention Trust Fund (Montreal Protocol)
- Where: WCCOS, FZJ-Jülich
- When: 09 Oct. - 03 Nov. 2017
- JOSIE-2017 will test combinations which represents all current ECC operational systems

JOSIE-2009: Simulation Run





Ozone Reference

Dual Beam UV-Photometer:

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

JOSIE-2017 (Fall) together with SHADOZ

Addressing tropical profiling capabilities & capacity building

	SHADOZ sites represented	Radiosonde / ECC / Solution	Station PI/Data Provider
1	Reunion	MODEM / ENSCI / 0.5%	F. Posny (CNRS)
2	Natal, Punta Arenas	LMS / SPC / 1%	E. T. Northam (Wallops) Claudio Casiccia (UMAG)
3	Irene, Paramaribo	Vaisala / SPC / 1%	GJR Coetzee (SAWS) A. Piters (KNMI)
4	Costa Rica, Fiji, Samoa, Hilo	IMET / ENSCI / 1% 1/10th & 2% Unbuffered	R. Selkirk (USRA) B. Johnson (NOAA)
5	Nairobi	Vaisala / ENSCI / 1%	R. Stuebi (MeteoSwiss)
6	Hanoi, Lauder	Vaisala / ENSCI / 0.5%	Shin-Ya Ogino (JAMSTEC), R. Querel (NIWA)
7	Ascension	IMET / ENSCI / 0.5%	A.M. Thompson (NASA)
8	Kuala Lumpur	Changfeng / ENSCI / 0.5%	Maznorizan Mohamad (MMD)

JOSIE-2017 Session Schedule for 2 Weeks. Session 1: 9-20 Oct. Session 2: 23 Oct-3 Nov. 2017

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

JOSIE-2017 Organizational Aspects

Coaches (2-3) x 2weeks:
1. Bryan Johnson (NOAA)
2. Anne Thompson (NASA)
3. Rene Stuebi (MeteoSwiss)
4. Jacquelyn Witte (SSAI/NASA)
5. Rigel Kivi

Referees:
1. Jonathan Davies (EC)
2. Roeland van Malderen (IRM)
3. Peter von der Gathen (AWI)

Alternate Coaches/Referees
1. Gary Morris (St. Edwards U.)
2. Masatomo Fujiwara (Hokkaido U.)

- **JOSIE-2017:** Two Groups each work two weeks 9-20 Oct 2017 (4 Types/stations) or 23 Oct – 3 Nov 2017 (4 Types/stations)
- **Handbook and Protocol for JOSIE-2017 is in preparation**
- **Followup Participant Workshop: Summer 2018 combined with experts workshop to address some SOP's to be revised: ASOPOS 2.0 Reload**

Ozone Sondes: GAW-NDACC-SHADOZ versus GRUAN (1)

Preamble: Ozone sondes of GAW-NDACC-SHADOZ are already since about 2010 part of the GCOS observing system

- GRUAN's strict philosophy of central processing of raw data takes away the identity of the ozone sounding site and the risc to take their long term scientific motivation, involvement and responsibility. The O3S network is still a research based network with strong PI's involvement..
- In contrast: the philosophy of WOUDC, NDACC and SHADOZ O3S-data centers is to store and archive O3S-data as being processed and validated by the PI's of the O3S-sites. New since 2015: Raw-data and extended meta data are stored to enable any scientist to do an in-dependent reprocessing of the O3S-data. Also included are the uncertainties of the measured ozone sonde data

Good Communication Between Data Centers that O3S data of GRUAN-O3S sites also get archived in other data bases

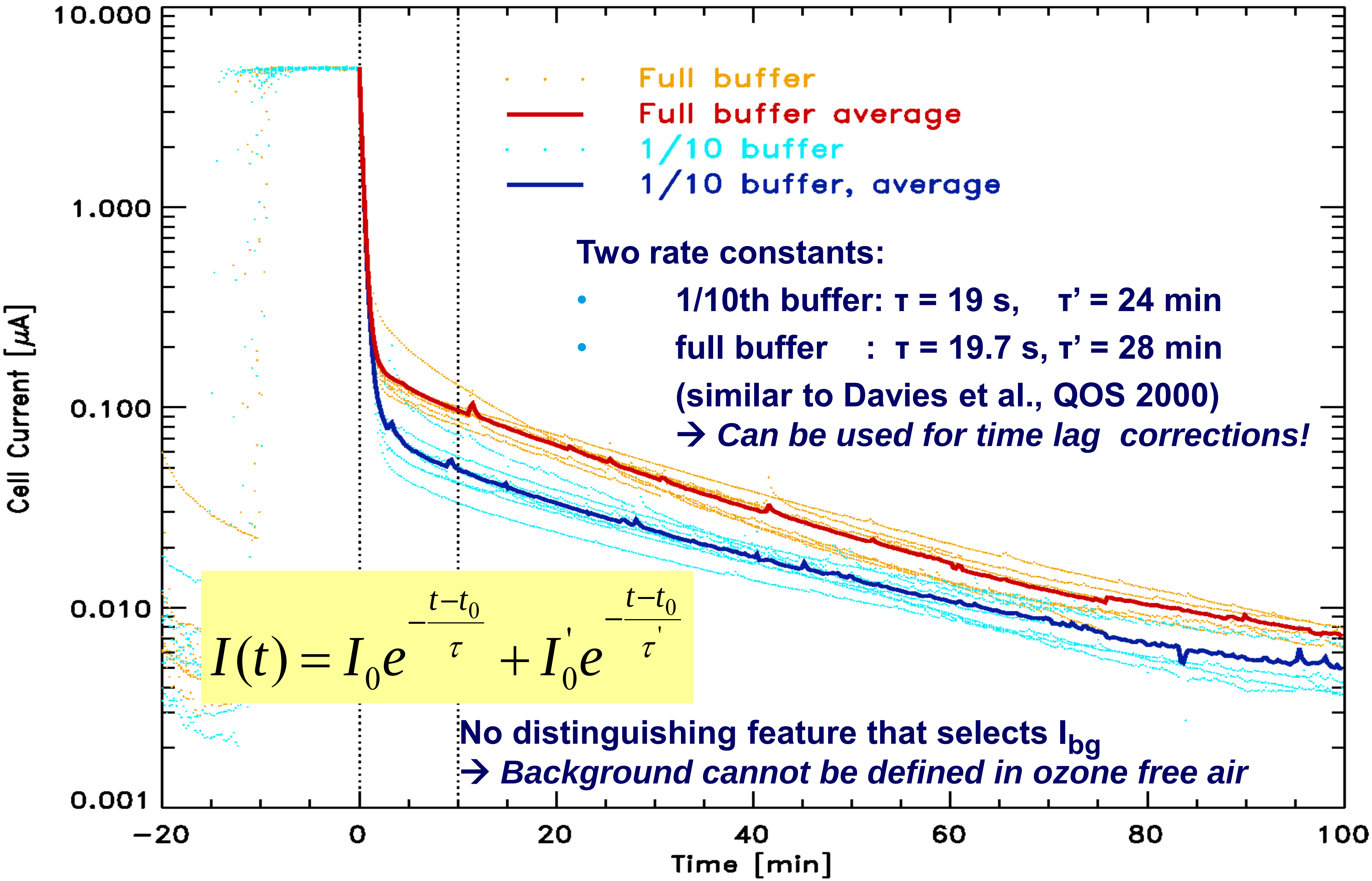
QA for Ozone Sondes: GAW-NDACC-SHADOZ versus GRUAN (2)

- QA Plan of O3S should be kept the same for the different ozone networks (GAW-NDACC-SHADOZ & GRUAN) and based on the principle of learning from each other instead of solo-actings by one of the networks. Go for one common SOP.
- The O3S-Experts meeting in Edinburgh in September 2016 has been shown a first step to consolidate a common QA-Plan of O3S for GAW-NDACC-SHADOZ included GRUAN
- JOSIE 2017/SHADOZ that runs under umbrella of GAW-NDACC-SHADOZ should include GRUAN

Extra Slides

ECC-Sonde: Downward Step Response

[Source: Voemel & Diaz, AMT 2010]



Ozone Profiling: Role in Atmospheric and Climate Research

- **Ozone climatologies and trends** on regional and global scales (WMO/GAW-Network): **Long term changes**
- **Validation of satellite and other vertical profiling techniques** (e.g. CCVal, SI2N): **O3S are the back bone of remote sensing techniques**
- **Process studies** (e.g. MATCH, and many more ....)
- **Tracer for mapping atmospheric dynamics** for weather forecasting (e.g. ECMWF) or identification origin of air masses (moist convection versus large scale subsidence)
- Ozone as chemical component for air quality forecastings

Base for a flyer:„The Many Faces of Ozone“

SHADOZ-Network:
"Transfer Function" Permits Technique-Independent Construction of a Station Time-series

Station	Solution(s) *= Current	ECC
Ascension	1% Full Buffer, 0.5% Half Buffer*	SPC, ENSCI*
Costa Rica (various loc)	0.5% Half Buffer, 1% $1/10^{th}$*	ENSCI
Fiji (Suva)	1% Full Buffer, 2% Unbuffered, 1% $1/10^{th}$ Buffer*	ENSCI
Hanoi	1% Full Buffer, 2% Unbuffered, 1% $1/10^{th}$ Buffer 0.5% Half Buffer*	SPC, ENSCI*
Hilo	2% Unbuffered, 1% $1/10^{th}$ Buffer*	ENSCI
Irene	1% Full Buffer	SPC
Kuala Lumpur	1% Full Buffer , 0.5% Half Buffer*	SPC, ENSCI*
Lauder	0.5% Half Buffer	ENSCI
Nairobi	1% Full Buffer	ENSCI
Natal	1% Full Buffer	ENSCI, SPC*
Paramaribo	1% Full Buffer	SPC
Reunion	0.5% Half Buffer	SPC, ENSCI*
Samoa (Pago Pago)	1% Full Buffer, 2% Unbuffered, 1% $1/10^{th}$ Buffer*	ENSCI
San Cristobal	2% Unbuffered, 1% $1/10^{th}$ Buffer*	ENSCI
Watukosek-Java	2% Unbuffered	ENSCI

Combinations listed are used in SHADOZ; also represent all current ECC operational systems

JOSIE-2017/SHADOZ:
Configuration Proposed with Tropical Site Capacity Building. Each Group inOne Session, 9-20 Oct. or 23 Oct-3 Nov 2017

	SHADOZ sites represented	Radiosonde / ECC / Solution	Station PI/Data Provider
1	Reunion	MODEM / ENSCI / 0.5%	F. Posny (CNRS)
2	Natal, Punta Arenas	LMS / SPC / 1%	E. T. Northam (Wallops) Claudio Casiccia (UMAG)
3	Irene, Paramaribo	Vaisala / SPC / 1%	GJR Coetzee (SAWS) A. Piters & M. Allaart (KNMI)
4	Costa Rica, Fiji, Samoa, San Cristobal, Hilo	IMET / ENSCI / 1% 1/10th & 2% Unbuffered	R. Selkirk (USRA) B. Johnson (NOAA)
5	Nairobi	Vaisala / ENSCI / 1%	R. Stuebi (MeteoSwiss)
6	Hanoi, Lauder	Vaisala / ENSCI / 0.5%	Shin-Ya Ogino (JAMSTEC), R. Querel (NIWA)
7	Ascension	IMET / ENSCI / 0.5%	A.M. Thompson (NASA)
8	Kuala Lumpur	Changfeng / ENSCI / 0.5%	Maznorizan Mohamad (MMD)

** Proposed to Vienna Convention Trust Fund for Travel.
Balance of JOSIE expenses cost-share with FZ-Jülich, NASA, NOAA

SHADOZ Radiosonde Types

Ascension	LMS, IMET*
Costa Rica (various loc)	Vaisala/Strato
Fiji (Suva)	Vaisala/Strato, IMET*
Hanoi	MEISEI, Vaisala/Strato, Vaisala*
Hilo	Strato/Vaisala, IMET*
Irene	Vaisala
Kuala Lumpur	Vaisala, MODEM, ChangFeng*
Lauder	Vaisala
Nairobi	Vaisala
Natal	LMS
Paramaribo	Vaisala
Reunion	Vaisala/Strato, MODEM*
Samoa (Pago Pago)	Vaisala/Strato, IMET*
San Cristobal	Vaisala/Strato, Vaisala*
Watukosek-Java	MEISEI, Strato/Vaisala*

LMS = Lockheed Martin Sippican
Strato = NOAA/H. Vömel Processing Software.
NOAA/SkySonde has replaced Strato. for IMETs except for CR.

WCCOS: Activities

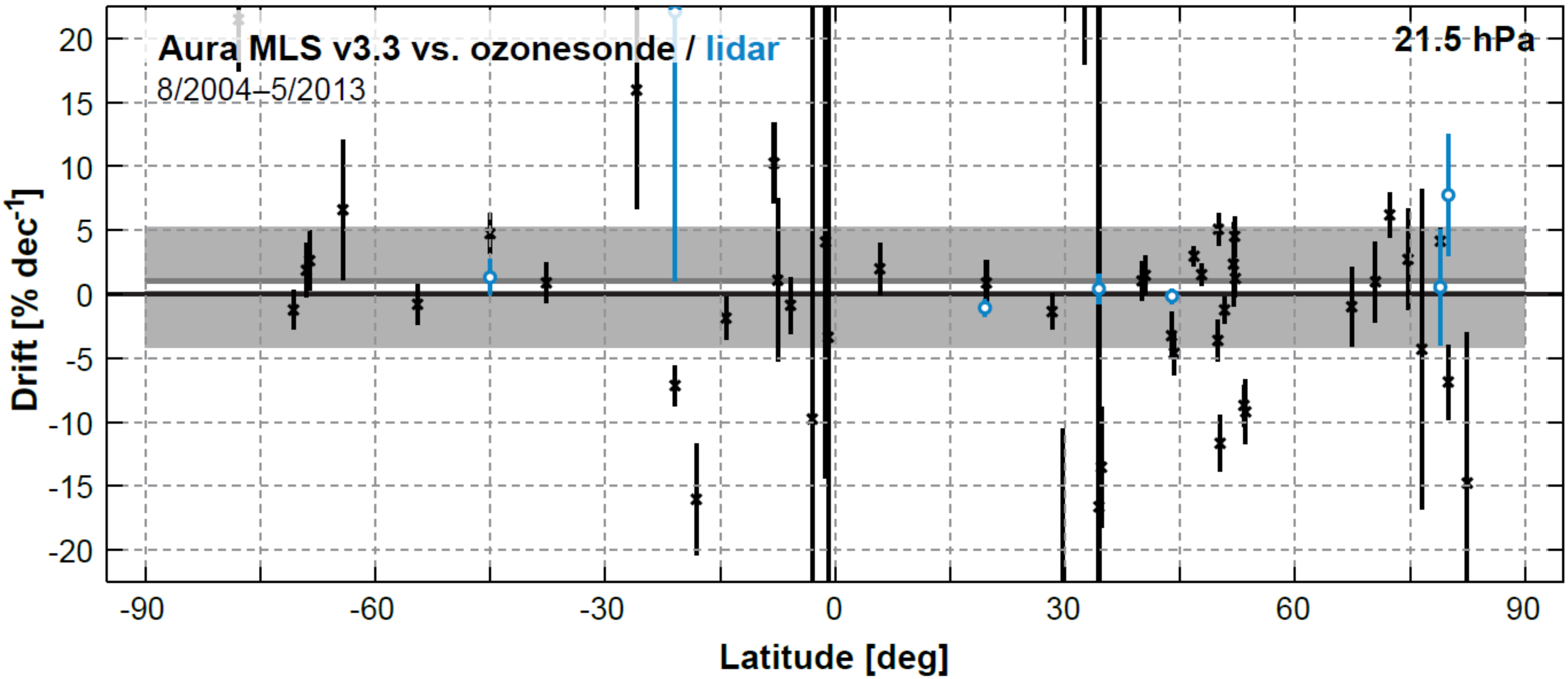
1996:	*JOSIE-96*	QA-Operation
1997:	*SPARC/OTA*	Co-Chair Chapter 2: „Data quality“
1998:	*JOSIE-98*	QA-Manufacturer
2000:	*JOSIE-2000*	QA-Standard Operating Procedures)
2004:	*BESOS*	Balloon Experiment on Standards for O3S
2004/10:	*ASOPOS*	Assessment of Standard Operating Procedures for O3S
2009	*JOSIE-2009*	QA-Manufacturer: brand-new sondes
2010	*JOSIE-2010*	Like JOSIE-2009, but now refurbished sondes
2012/17	*O3S-DQA*	O3S-Data Quality Assessment: Homogenization
2017	*JOSIE-SHADOZ*	Addressing tropical soundings

2017/19 Research Activities to determine the best combination of:

- ❖ Sensing Solution Type
- ❖ Pump Efficiency Correction
- ❖ Background Current Correction

O3S-DQA: Where are we nowadays?

Comparison AURA-MLS versus OzoneSonde from Daan Hubert et al., AMT, 2016



Ozone sondes have presently relative uncertainty ±(5-10-20)% (incl. bias)

Targeting for 2020:

Relative uncertainty better than ±5% , no bias , and traceable to one reference

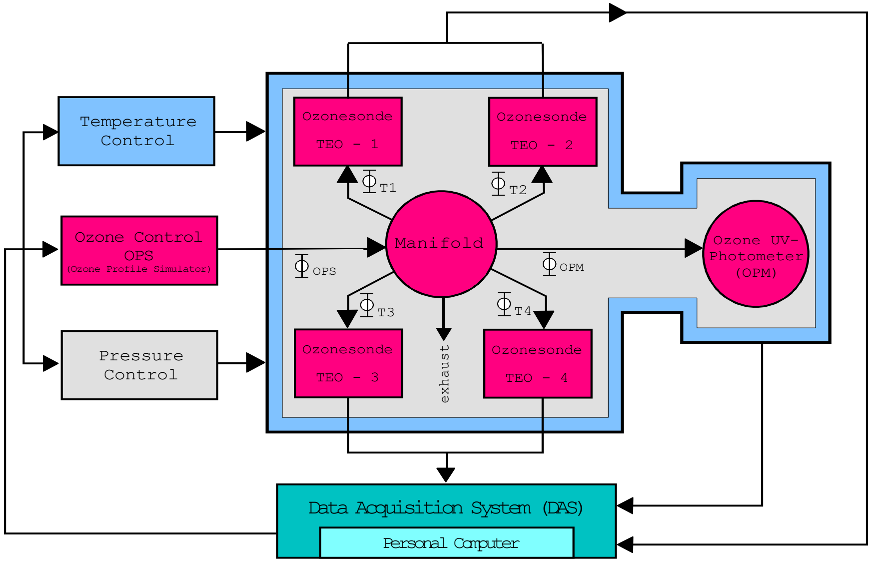
ASOPOS: Status 2010
(Assessment for Standard Operating Procedures for Ozone Sondes)

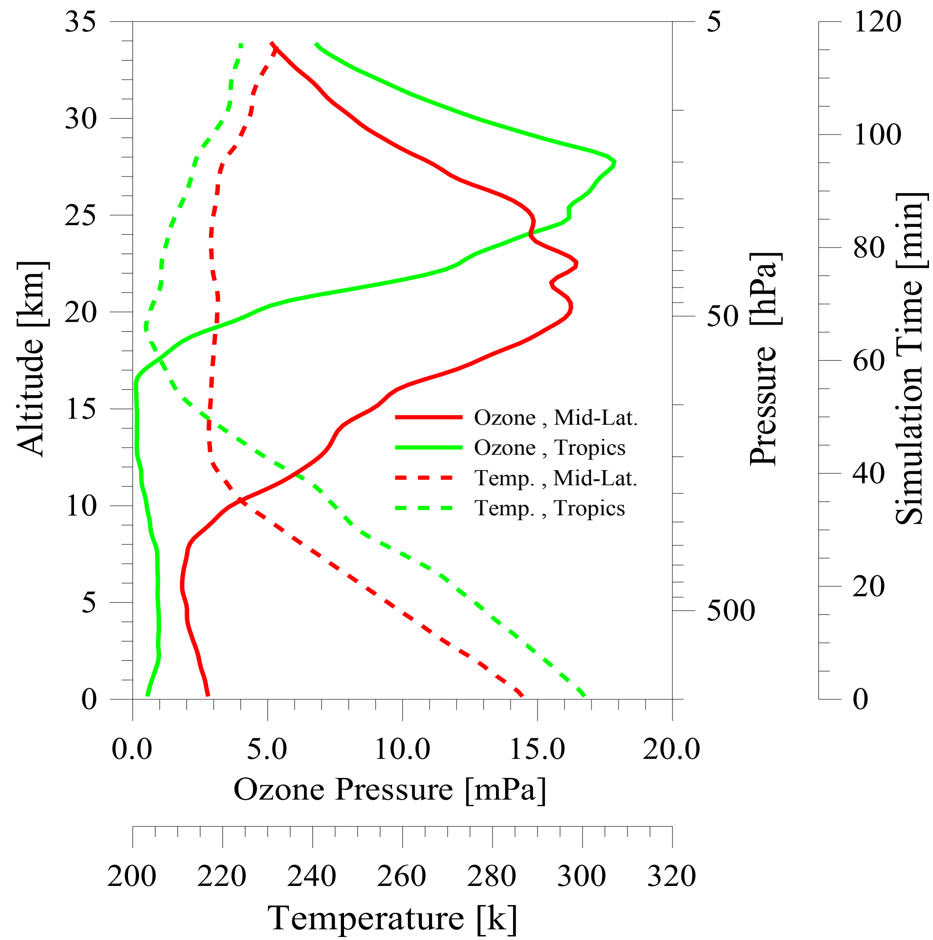
- ASOPOS-Report: QA/QC and SOP 's for O3S (GAW-report#201)
- Recommendations on use of sensing solution type (SST):
  - SPC6A: 1.0% KI, full buffer (SST1.0)
  - ENSCI : 0.5% KI, half buffer (SST0.5)

  Note: These two SST's very close agreement with OPM (Ozone Photo Meter) at WCCOS
- Standardization of SOP 's leads to the best precision of 3-5 %
- Non uniformity in ozone sonde types or operating procedures can introduce "inhomogenities" in sonde data records of each of the stations or between different stations of 5-20 %
- Need for transfer functions to homogenize sonde data records
- After homogenization accuracy can be better than 5-10 %

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

WCCOS: Simulation of Ozone Soundings
Under Quasi Realistic Atmospheric Conditions of Pressure, Temperature and Ozone





Ozone Reference

Dual Beam UV-Photometer:

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

WCCOS 2009/2010

JOSIE 2009 (Dec. 2009): MidLatitude

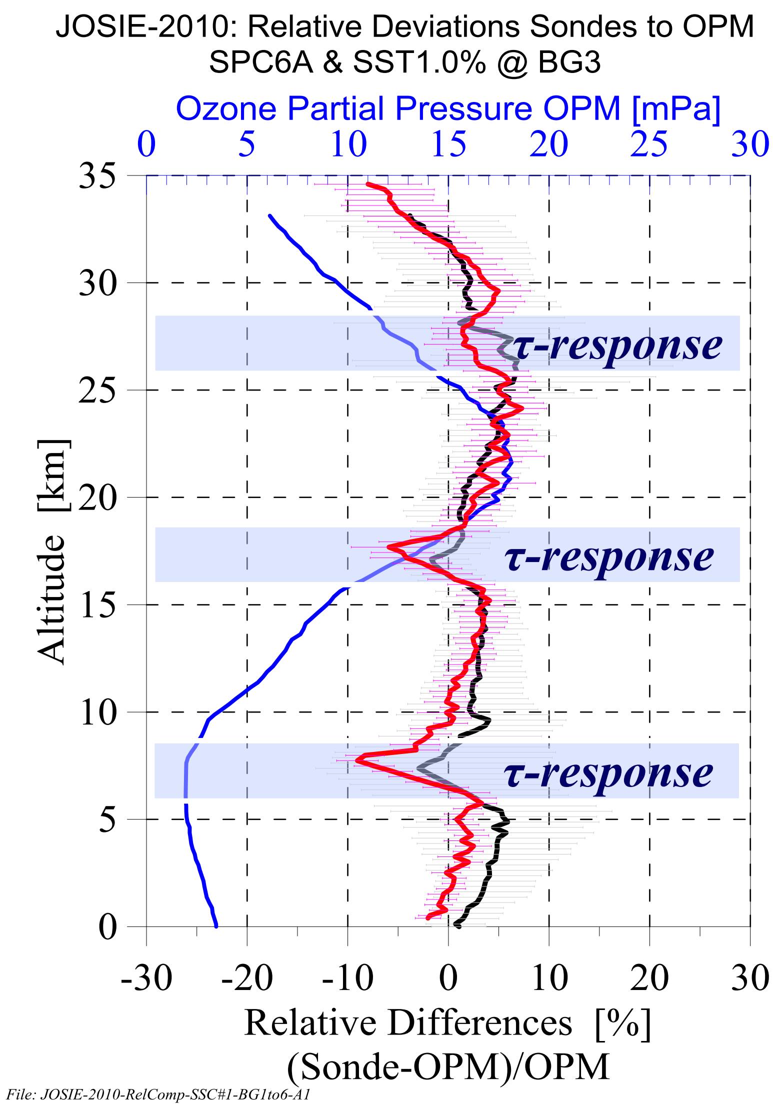
QA-manufacturing + Transfer functions

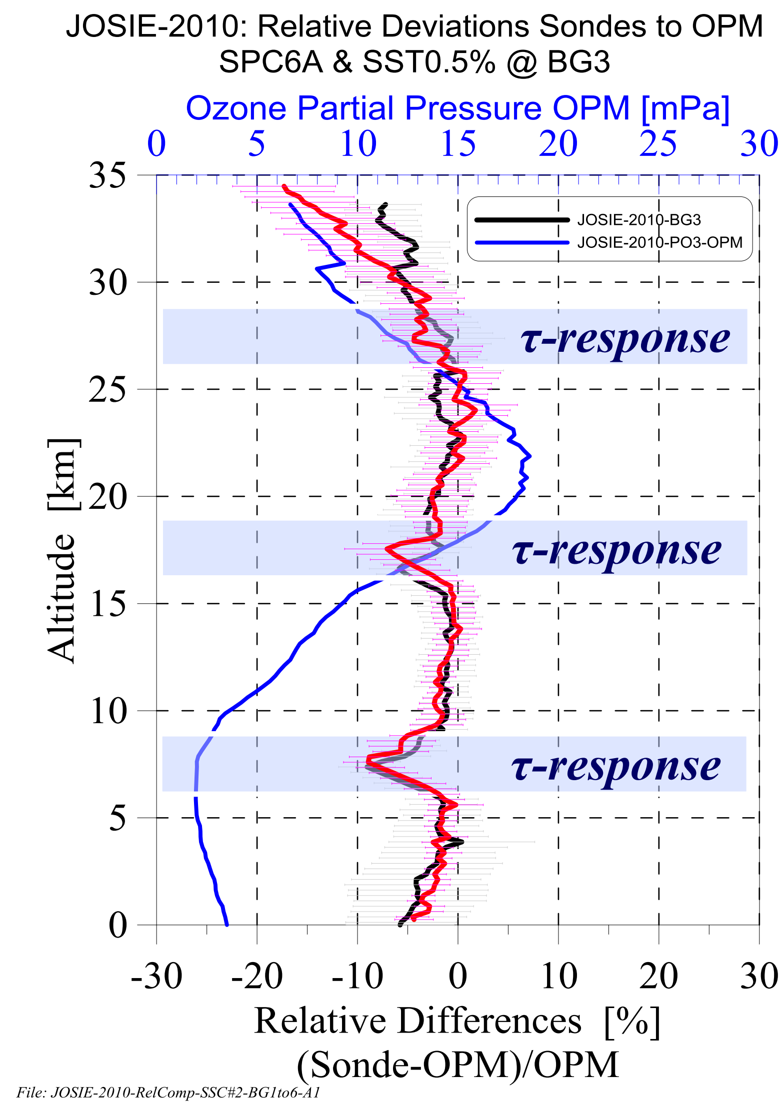
- Design similar as JOSIE 1998 , whereby:
  - 9xSPC6A & 9xENSCI (1.0% KI, full buffer)
  - 9xSPC6A & 9xENSCI (0.5% KI, half buffer)
  - new sondes provided by the O_3S-network
  - randomly picked from the shelf
  - mid-latitude profiling
- Prepared and processed according SOP ‘s

JOSIE 2010 (August 2010): Re-Used, Mid Lat.

Like JOSIE 2009, but now Re-used sondes

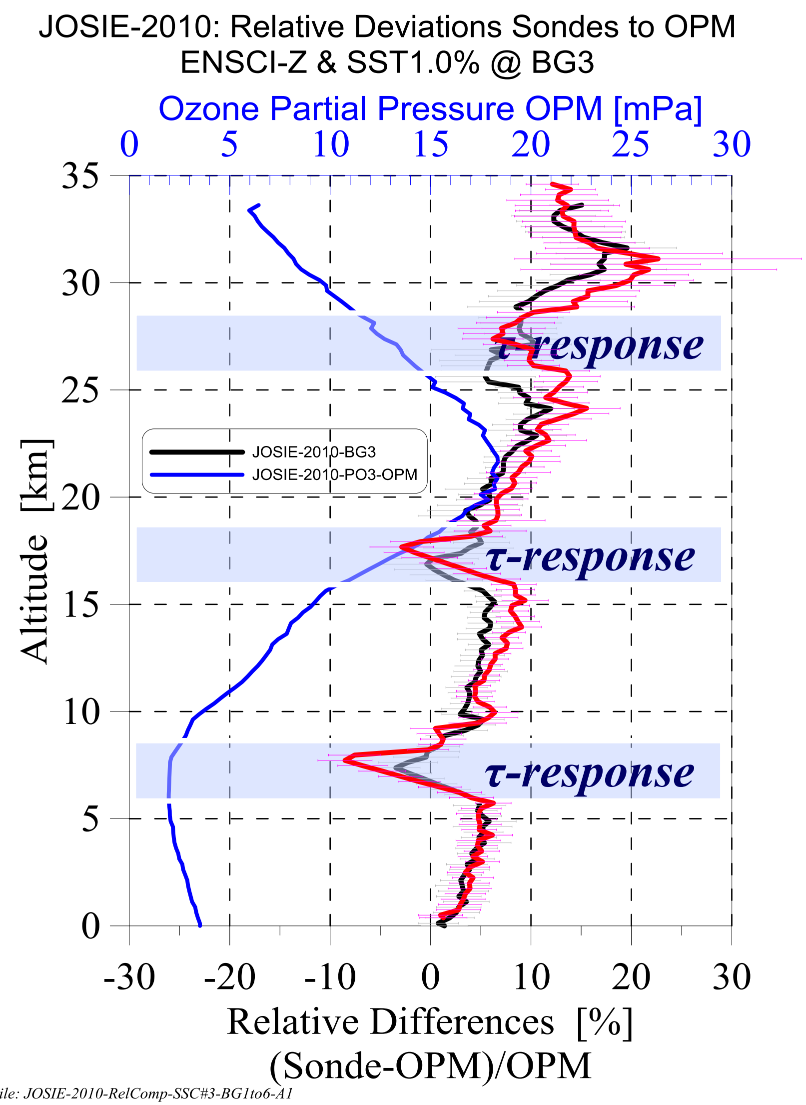
JOSIE-2009/2010: SPC-6A Sondes
Relative Deviations to OPM @ SST1.0% & SST0.5% (BG3)

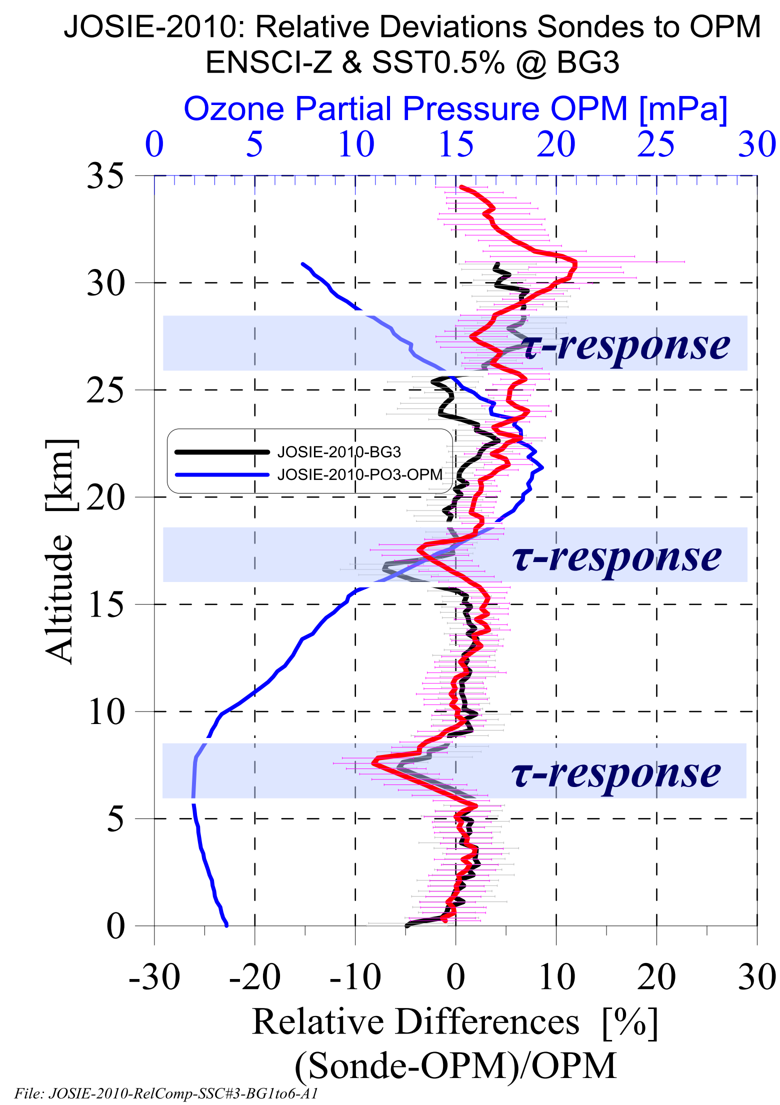




JOSIE-2009/2010: ENSCI-Sondes

Relative Deviations to OPM @ SST1.0% & SST0.5% (BG3)





O3S-DQA
Strategy O3S-Homogenization Process

1. **In Time (O3-trends @ individual stations)**
   Each station will homogenize his O3S-record individually
   a. Following guidelines prescribed by O3S-DQA panel
   b. Using transfer functions based on dual soundings & JOSIE 2009
   c. Coaching by O3S-DQA-expert.

2. **In Space (Validation: e.g. satellites)**
   All individual O3S station records using JOSIE 2009 based transfer functions to refer the homogenized O3S to one standard (OPM= UV-Photometer @ WCCOS-JOSIE, Juelich, Germany)

3. **Testing on Consistency**
   a. Comparison with other O3 profiling instrument @ O3S-site
   b. Troposphere-UTLS: MOZAIC-O3
   c. Satellites: e.g. Daan Huberts approach (AMT, 2016)
   d. Stratosphere: MATCH-approach

SI2N/O3S-DQA: List of selected O3S station records to homogenize

Region	Location	Organization	Principal Investigator	E-Mail	Participate
Arctic	Canada-Resolute	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
Arctic	Canada-Alert	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
Arctic	Canada-Eureka	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
Arctic	Finland-Sondankyla	FMI	Rigel Kivi	rigel.kivi@fmi.fi	Yes
Arctic	Spitzbergen –Ny Alesund	AWI	Peter von der Gathen	peter.von.der.gathen@awi.de	Yes
Arctic	Greenland-Scoresbysund	DMI	Niels Larsen	nl@dmi.dk	
Arctic	Greenland-Summit	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
Europe	Germany-Hohenpeissenberg	DWD	Hans Claude	hans.claude@dwd.de	Yes
Europe	Germany-Lindenberg	DWD	Holger Voemel	holger.voemel@dwd.de	Yes
Europe	Switzerland–Payerne	MeteoSuisse	Rene Stuebi	rene.stubi@meteoswiss.ch	Yes
Europe	Belgium – Uccle	KMI	Hugo Debacker	hugo.debacker@meteo.be	Yes
Europe	Netherlands – De Bilt	KNMI	Marc Allaart	marc.allaart@knmi.nl	Yes
Europe	France – ObsHauteProvence	CNRS	Sophie Godin	sophie.godin@aero.jussieu.fr	Yes
Europe	UK-Lerwick	UKMO	David Moore??	david.moore@metoffice.gov.uk	
Europe	Iceland-Keflavik	INTA	M.Gil	gilm@inta.es	Yes
Europe	Spain–Izana(Canary Islands)	IMN	Alberto Redondas	aredondasm@aemet.es	Yes
North America	Canada-Churchill	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Edmonton	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Goose Bay	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Kelowna	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Bratts Lake	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Egbert	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	Canada-Yarmouth	EC-(Environmental Canada)	David Tarasick	david.tarasick@ec.gc.ca	Yes
North America	USA-Wallops Island	NASA	Frank Schmidlin	francis.j.schmidlin@nasa.gov	Yes
North America	USA-Narragansett, RI	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
North America	USA-Huntsville, AL	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
North America	USA-Boulder, CO	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
North America	USA-Trinidad, CA	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
Central Pacific	Hawaii–Hilo	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
Japan	Japan-Sapporo	JMA	Takashi Koide	takashi.koide@gmail.com	
Japan	Japan-Tsukuba/Tateno	JMA	Takashi Koide	takashi.koide@gmail.com	
Japan	Japan-Naha	JMA	Takashi Koide	takashi.koide@gmail.com	
China	China–Hong Kong	HKO	Y.K. Leung	jykleung@hko.gov.hk	
Africa	Kenya-Nairobi-	MeteoSuisse	Rene Stuebi	rene.stubi@meteoswiss.ch	Yes
Africa	SouthAfrica-Irene	SAWO	Gerrie Coetzee	gerrie.coetzee@weathersa.co.za	Not Yet
Africa	Reunion Island	CNRS	Francois Posny	posny@univ.reunion.fr	
Central Atlantic	Ascension Island	NASA	Frank Schmidlin	francis.j.schmidlin@nasa.gov	Yes
South America	Brazil-Natal	NASA	Frank Schmidlin	francis.j.schmidlin@nasa.gov	Yes
South America	Ecuador-Galapagos Islands	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
South Pacific	AmericanSamoa-Pago Pago,	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
South Pacific	Fiji-Suva	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes
Australia	New Zealand–Lauder	NIWA	Ghang Zeng	guang.zeng@niwa.co.nz	Yes
Australia	Australia-Melbourne	BOM	Matt Tully	m.tully@bom.gov.au	Yes
Australia	Australia-Macquarie Island	BOM	Matt Tully	m.tully@bom.gov.au	Yes
Central Pacific	Indonesia–Watukosek	Hokkaido University	Masatomo Fujiwara	fuji@ees.hokudai.ac.jp	Yes
Antarctica	Syowa	JMA???	Takashi Koide???	takashi.koide@gmail.com	
Antarctica	Marambio	FMI???	Rigel Kivi??	Rigel.Kivi@fmi.fi	Yes
Antarctica	Neumayer	AWI	Gert Koenig-Langlo	gert.koenig-langlo@awi.de	Yes
Antarctica	McMurdo	University Wyoming	Terry Deshler	deshler@uwyo.edu	Yes
Antarctica	South Pole	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes

Transfer Functions Different SST's

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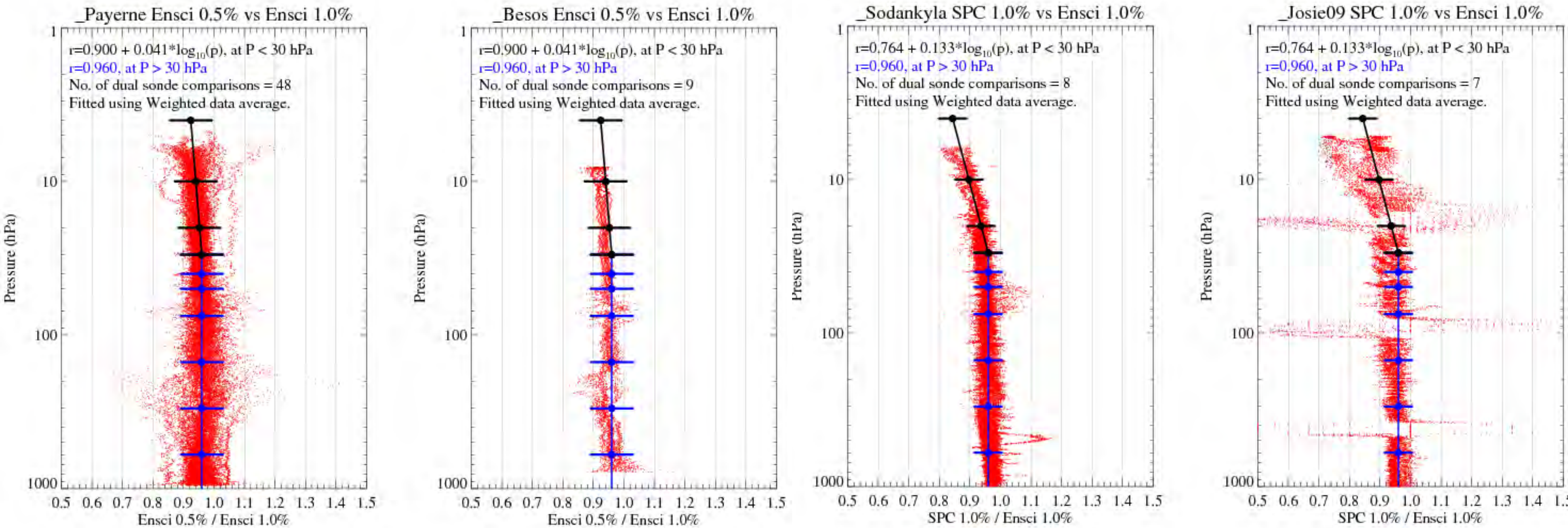
Deshler , Stuebi et al., AMT, published, 2017

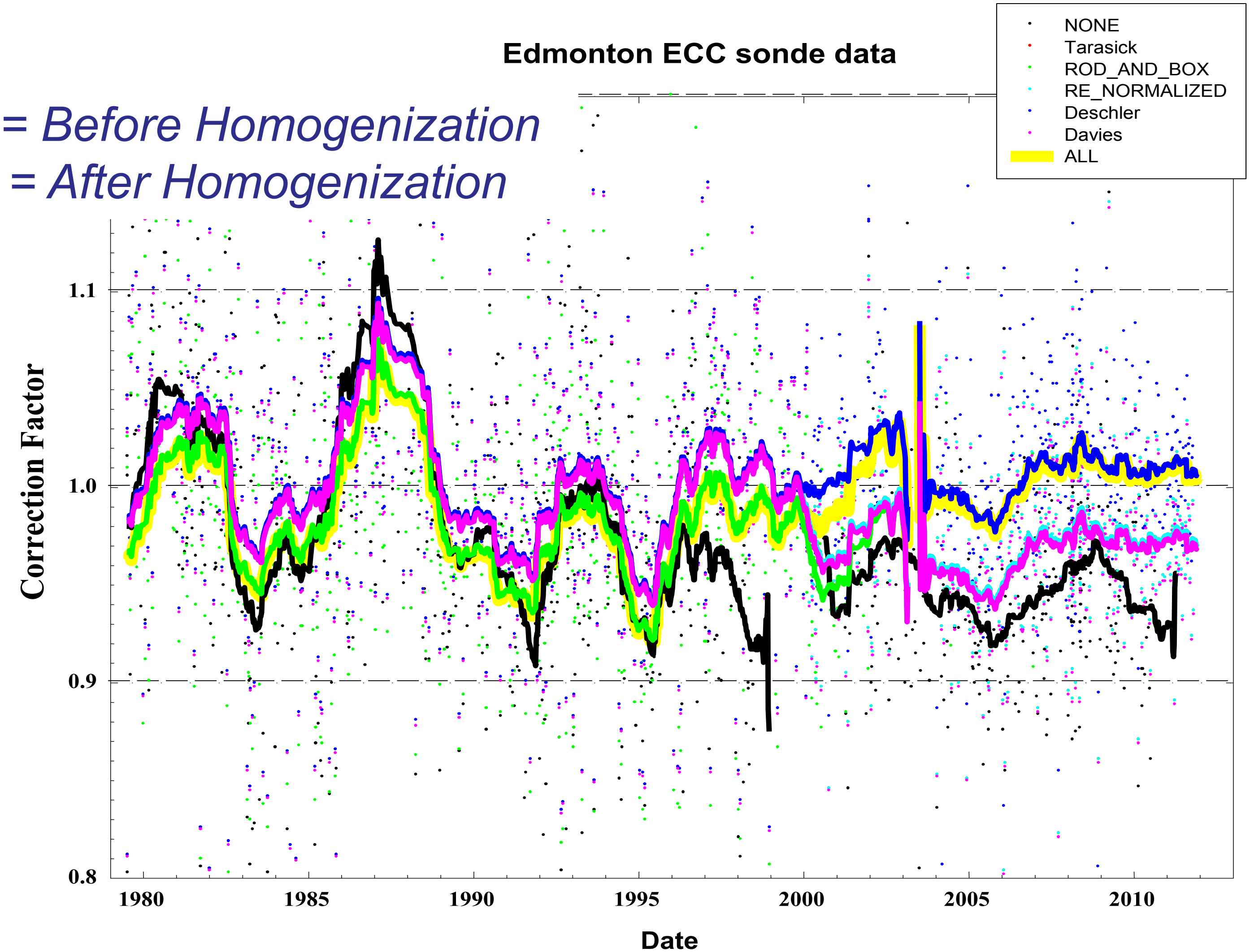
Derived from dual soundings, JOSIE & BESOS campaigns:



Equation	*Y dependent =*	*Ratio*	*X independent*	*Pressure*	*O3-sonde or SST*
Eq.7A	SST 0.5%	0.96	SST 1.0%	P ≥ 30 hPa	Both SPC & ENSCI
Eq.7B	SST 0.5%	$0.90+0.041*\log_{10}(p)$	SST 1.0%	P < 30 hPa	Both SPC & ENSCI
Eq.7C	SPC	0.96	ENSCI	**P ≥ 30 hPa**	0.5% & 1.0%
Eq.7D	SPC	$0.764+0.133*\log_{10}(p)$	ENSCI	**P < 30 hPa**	0.5% & 1.0%
Eq.7E	SPC-1.0%	1.01	ENSCI-0.5%	**P>0**	

O3S-DQA:Total Ozone Normalisation Before and After Homogenization

Black = Before Homogenization
Yellow = After Homogenization



O3S-DQA:Total Ozone Normalisation
Before and After Homogenization of Env.Canada-Stations

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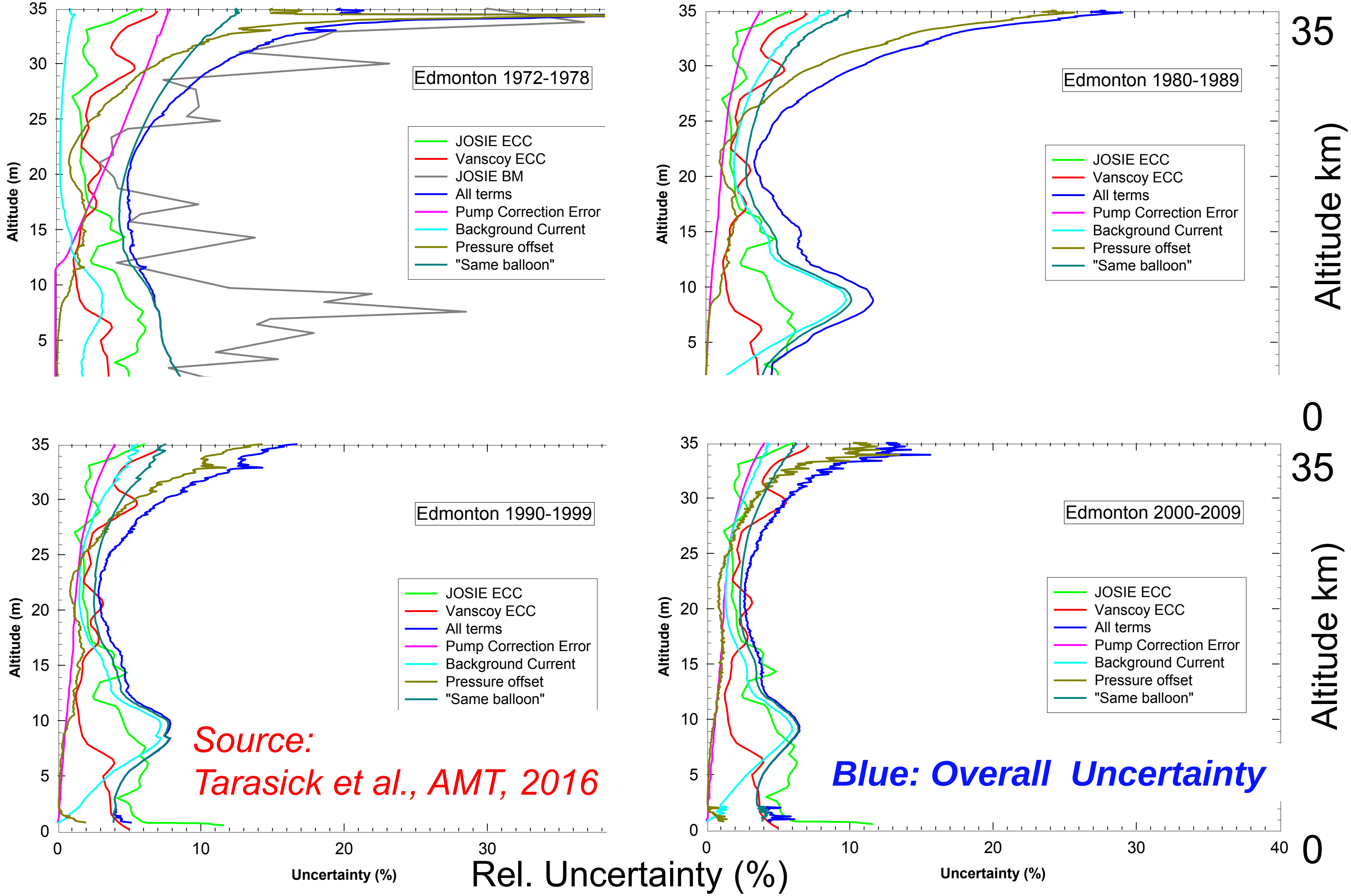
Tropospheric changes: increases of up to 5% after 1979; up to 20% before 1980 (Brewer-Mast sondes), reducing with altitude.

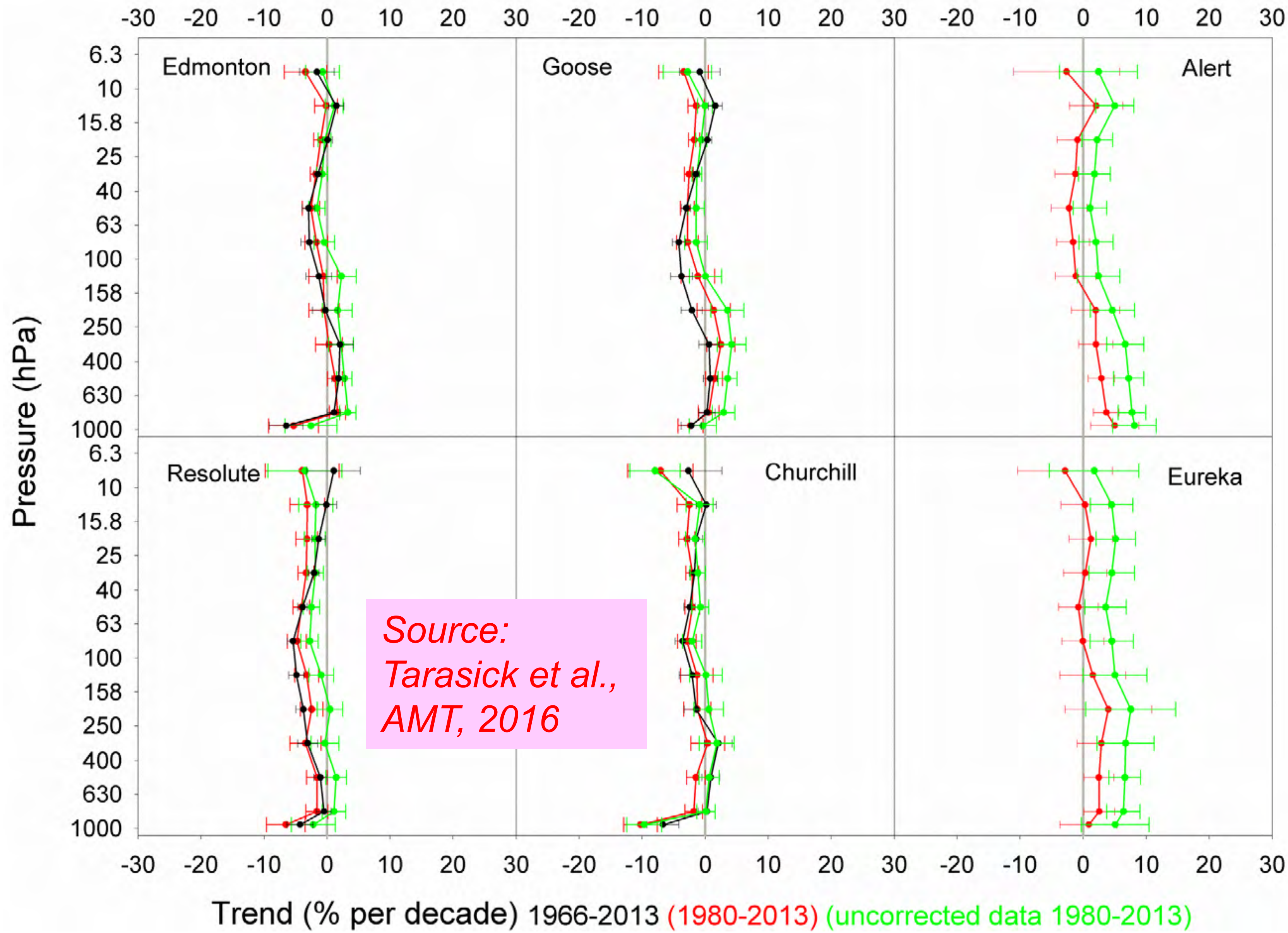
Stratospheric changes: decreases of up to 4% before 1980 at 25 km, smaller decreases above and below. . Increases of ~1% in 1980s, ~2-3% in 1990s; little change in 2000s.

	Mean K	Std Dev	Trend in K
BM data			
Original	1.27	0.303	2.7%/decade
Renormalized	1.20	0.198	
Response correction	1.03	0.179	2.2%/decade
ECC data			
Original	0.97	0.101	-2.6 +/- 0.6 %/decade
All corrections	0.99	0.087	0.6 +/- 0.5 %/decade

O3S-DQA: Uncertainty Budget



O3S-DQA: O3 Trends Before & After



Source: Tarasick et al., AMT, 2016