O3S-DQA (Ozone Sonde Data Quality Assessment)

Homogenisation of O3S-Records

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State of the Art of Ozone Sondes (O3S):

- Longest time series of vertical ozone distribution up to 30 km
- Important to validate satellites on their long term stability (O3S provide a-priori profiles)
- Cost efficient for process studies (e.g. MATCH, and many more.....)
- Small changes of instrument or operating procedures can have large impact on data quality (e.g. JOSIE & BESOS)
- Trend assessments and satellite validations show the need for more homogenity of data

JOSIE 1996, 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
- ❖SST1.0 ≈ 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 %

O3S-DQA: Objectives

"Ozone Sonde Data Quality Assessment (O3S-DQA)" activity started in 2011 has following two 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 transfer functions, including instrumental aspects)**

2. **Documentation** of the homogenization process and the quality of ozonesonde measurements including **quantification of the uncertainty of each ozone sonde measurement**

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

O3S-Homogenization: Guidelines For Reprocessing

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]

Guidelines for reprocessing O3S records:

1. Different sensing solutions and sonde type: Transfer functions
2. Background current corrections (Ib0, Ib1, Ib2)
3. Pump flowrate: humidity correction
4. Pump flow efficiency correction at lower pressures
5. Pump temperature (internal-, external-, box-)
6. Total ozone normalization factor
7. Determination of residual ozone
8. Determine overall uncertainties of ozone measurement
9. Coaching by O3S-DQA-expert

O3S-DQA: Estimation Overall Uncertainty P_{O3}

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

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 assumed to be random and following Gaussian statistics, then applying Gaussian law of error propagation can be applied:

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

O3S-DQA Coaching

O3S-Station PI

Prepatory Work I:
Collection of Meta Data
A. "Table Log Book O3S-Station Data"
B. "Time Series O3S-Parameters"

Prepatory Work II:
Prepare Station Specific Guidelines
To Process Long Term O3S Data

Reprocessing O3S-Data

Validation O3S-Data
A. Internal &External Consistency
B. Quantify Uncertainty PO3

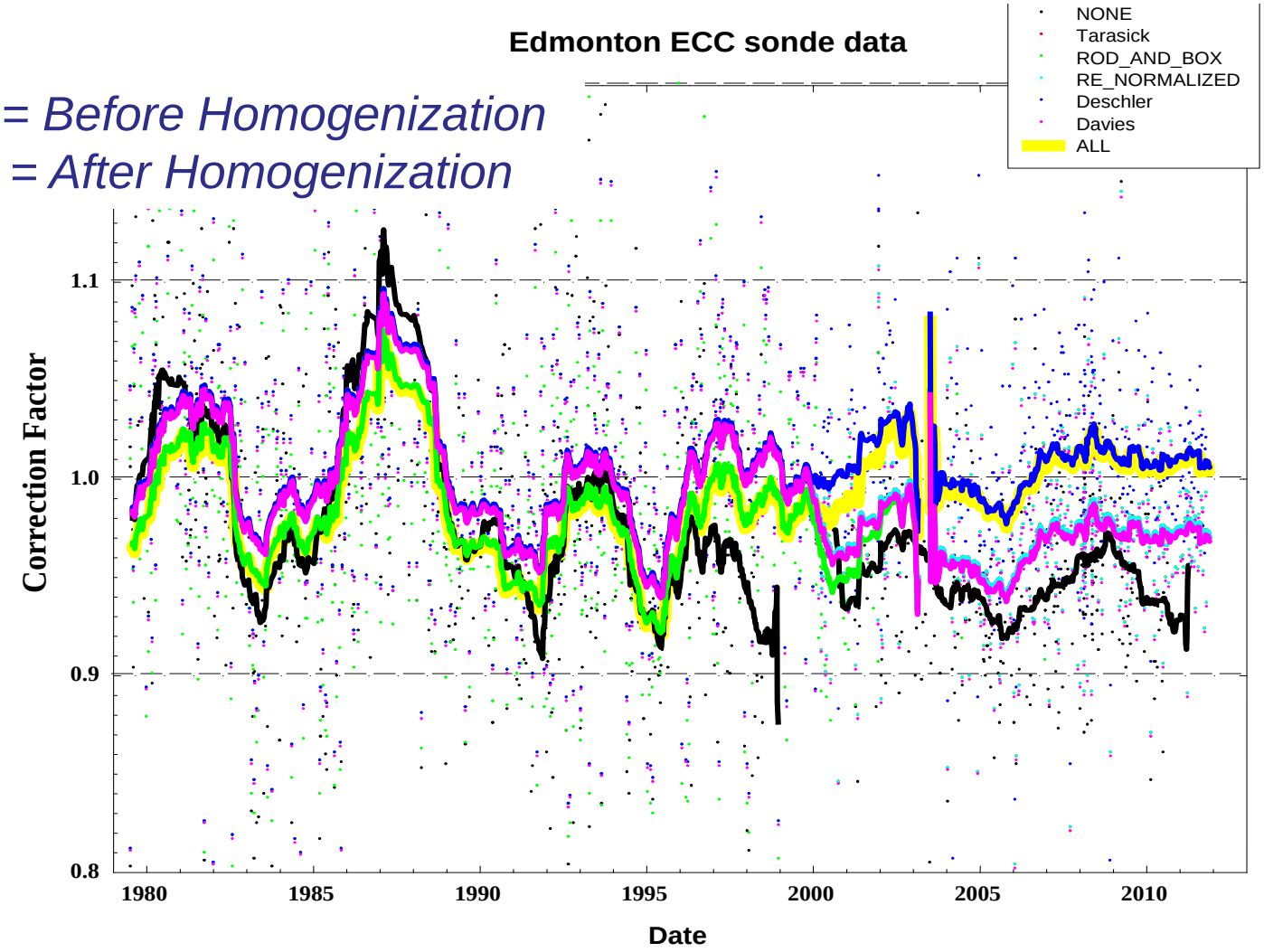
Submission O3S-Data
SPARC Assessment
O3-Trend Use

Documentation
A. Data Processing
B. Uncertainty PO3

O3S-DQA: Homogenization Process of Long Term O3S-Data per Station As prescribed in „Guidelines for Homogenisation of Ozone Sonde Data"

O3S-DQA:Total Ozone Normalisation Before and After Homogenization

Black = Before Homogenization
Yellow = After Homogenization



O3S-DQA in 2016/2017:

1. Finishing prepatory work & reprocessing O3S-data
2. Reprocessed data stored on data server for testing on consistency:
    a. *Satellites, e.g. by Daan Huberts validation tools*
    b. *Comparison with other O3 profiling instruments @ O3S-site*
    c. *Troposphere-UTLS: MOZAIC-O3*
    d. *Stratosphere: MATCH-approach*
3. After O3S-DQA reprocessed data moved to data centers

- **Re-processed data will include raw data and uncertainty for each measured ozone value**
- **All reprocessed O3S-Data set will be documented**
- **The O3S-DQA homogenization process, including error analysis, will be published in peer reviewed journal (ACP/AMT)**

O3S Experts Workshop

Schedule: 1-3 September 2017 (3 days workshop)
Location: University at Edinburgh
Participants: O3S experts & O3S-DQA associates

Objectives:

1. **Critical Instrumental Issues**: Focus on integral approach of what is the best combination of sensing solution type (SST), pumpflow efficiency correction, and method of background correction
2. **O3S-DQA Interim Review**: Evaluation O3S-Homogenisation Stability of homogenized long term O3S-records
   - Where we are and what we have achieved?
   - Where we want to go to?
   - Practical guidelines to derive uncertainty for each measured ozone data point of the O3S-profile
3. **JOSIE 2017/2018**: Design & Preparation
   - JOSIE-SHADOZ: Tropical Profiling Capabilities
   - JOSIE-Instrumental: Pumpflow Corrections and SST
   - JOSIE-Manufacturer: New ECC-China, Transfer DMT to EnSci

Strategy of the O3S Experts Workshop

- The meeting should not finish with open ends like the one we had in January 2009 at Jülich but with a clear action plan with what to do and assigned with names of people who will do the job.
- This is a challenging task to go for.
- Constitution of a small executive team of experts to prepare the meeting.
- This also means that prior to the meeting this team of experts should sort out the major issues to be “solved” and 1-2 months before the meeting ask the participants on which issues they can or should contribute
- Regular (monthly) telecons to discuss progress made.

If people in the GRUAN-audience are interested we can meet off-line to discuss in developing more focused ideas

Reserve Slides

O3S-DQA:
Guide Lines For Homogenization

SI2N/O3S-DQA Activity:

Guide Lines for Homogenization of Ozone Sonde Data

(Version 2.0: 09 January 2013)

Prepared
by
O3S-DQA panel members on homogenization of O3S-data

(Herman Smit, Sam Oltmans, Terry Deshler, David Tarasick, Bryan Johnson, Frank Schmidlin, Rene Stuebi, Jonathan Davies)

Activity as part of

SPARC-IGACO-IOC Assessment

(SI2N)

"Past Changes in the Vertical Distribution of Ozone"

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
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Europe	Germany-Lindenberg	DWD	Holger Voemel	holger.voemel@dwd.de	Yes
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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
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Japan	Japan-Sapporo	JMA	Takashi Koide	takashi.koide@gmail.com	
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Africa	Kenya-Nairobi-	MeteoSuisse	Rene Stuebi	rene.stubi@meteoswiss.ch	Yes
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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
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Australia	Australia-Macquarie Island	BOM	Matt Tully	m.tully@bom.gov.au	Yes
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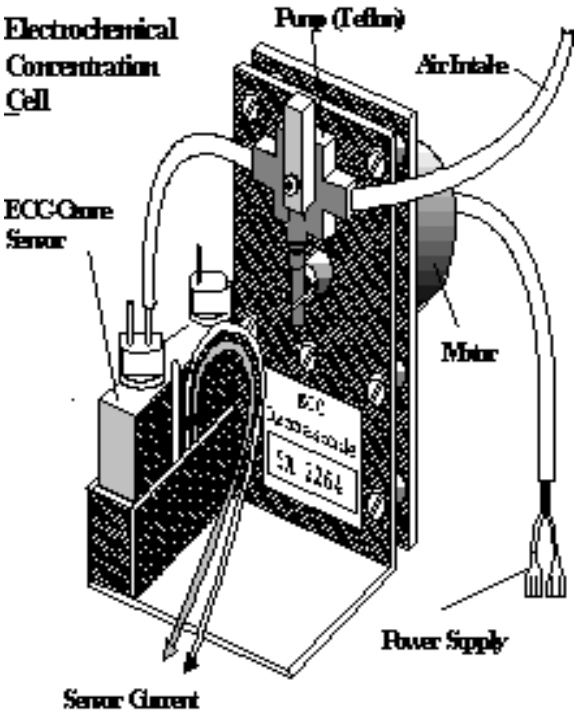
Antarctica	Neumayer	AWI	Gert Koenig-Langlo	gert.koenig-langlo@awi.de	Yes
Antarctica	McMurdo	University Wyoming	Terry Deshler	deshler@uwyo.edu	Yes
Antarctica	South Pole	NOAA	Bryan Johnson	bryan.johnson@noaa.gov	Yes

Electrochemical Ozone Sonde: Introduction



In an electrochemical cell:

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

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

- 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

Ozone Pressure [mPa]

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

Pump Temperature [K]

Background Current [μA]

Conversion Efficiency

Pump Flow [cm3/s]

Measured Current [μA]

Global O3S-Records: State of the Art

Four types of ozone sondes:

1. ECC (Electrochemical Concentration Cell) (nowadays 90% fly ECC)
2. BM (Brewer Mast: original) (since 1970: specially elder stations
3. KC 79/96 (Japanese network: long term records since 1970's)
4. IMD (BM-type produced and flown by Indian Meterological Department): ??

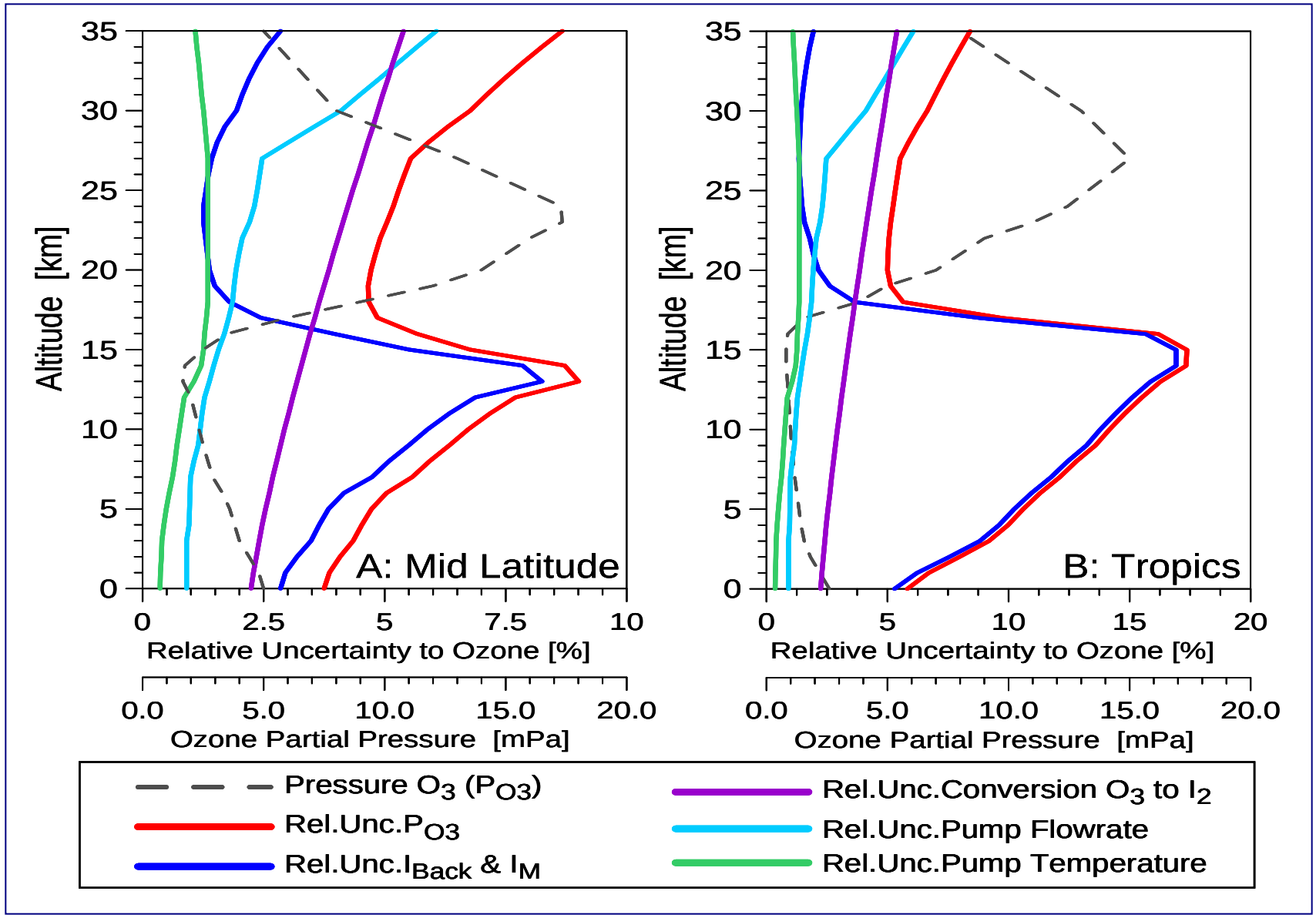
Ozone sounding records:

a) Short term: 5-10 years (Validation)
b) Middle term: 10-25 years (after 1985) (Validation + Trends)
c) Long term: 25-40 years (since 1970's) (Validation + Trends)

Inhomogenities in long term O3S-records:

Due to changes of instruments or operating procedures

Instrumental Uncertainties of ECC-Ozone Sonde



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

O3S-DQA:Example Canadian Network (2)

Canadian ozonesonde network – changes in ozonesondes and associated radiosondes

Year	Change	Possible Effect
1979	ECC 3A introduced	~15% increase in tropospheric response response relative to BM sondes. Sonde T measured via rod thermistor.
1984	ECC 4A introduced	redesigned pump; maximum change <1%, at 50-20 hPa. Sonde "box" T measured; new rod thermistor.
1993	ECC 5A introduced	New pump correction; maximum change ~1%, at 100 hPa.
1993	Vaisala RS-80, RSA-11 introduced	Older VIZ sonde: warm bias in daytime; pressure errors. May introduce altitude shifts in profile; ozone increases of up to ~2% at 20 hPa.
1996	ECC 6A	No differences below about 20-25 km [*Smit et al.*, 2000].
2000	ENSCI 1Z design change	High bias with 1% KI solution [*Smit et al.*, 2007].
2004	3cc solution (new sites)	Better ozone capture in troposphere
2006	Vaisala RS-92 introduced	RS80s low by ~20m in the troposphere, high by 100m at 10hPa (Steinbrecht et al., 2008)
2007	Thermistor in ECC pump	More accurate measurement of air volume

Environment Canada Environnement Canada

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O3S-DQA:Example Canadian Network (3)

Results: reduced uncertainty

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 6% before 1980, less below 25km. Increases of ~1% in 1980s, ~2-3% in 1990s; little change in 2000s.

	Mean K	Std Dev	Trend
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

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O3S-DQA: Time Table

1. **<u>July/August 2016:</u>**

   Homogenization O3S-data:

   – 17 Stations ready (6xCanadian Network, 6x NOAA, McMurdo, Lindenberg, Uccle, De Bilt, Paramaribo)

   – About 10-15 stations still in processing/verification process

   – Comparison with Satellites

3. **<u>September 2016:</u>**

   O3S-Experts Meeting: Mid Term Review

4. **<u>October-December 2016:</u>**

   ✧ Preparation key scientific papers (Homogenisation, Uncertainty, Transfer Functions & NOAA approach)