Challenges of GAW ozone and UV measurement programmes

Geir O. Braathen

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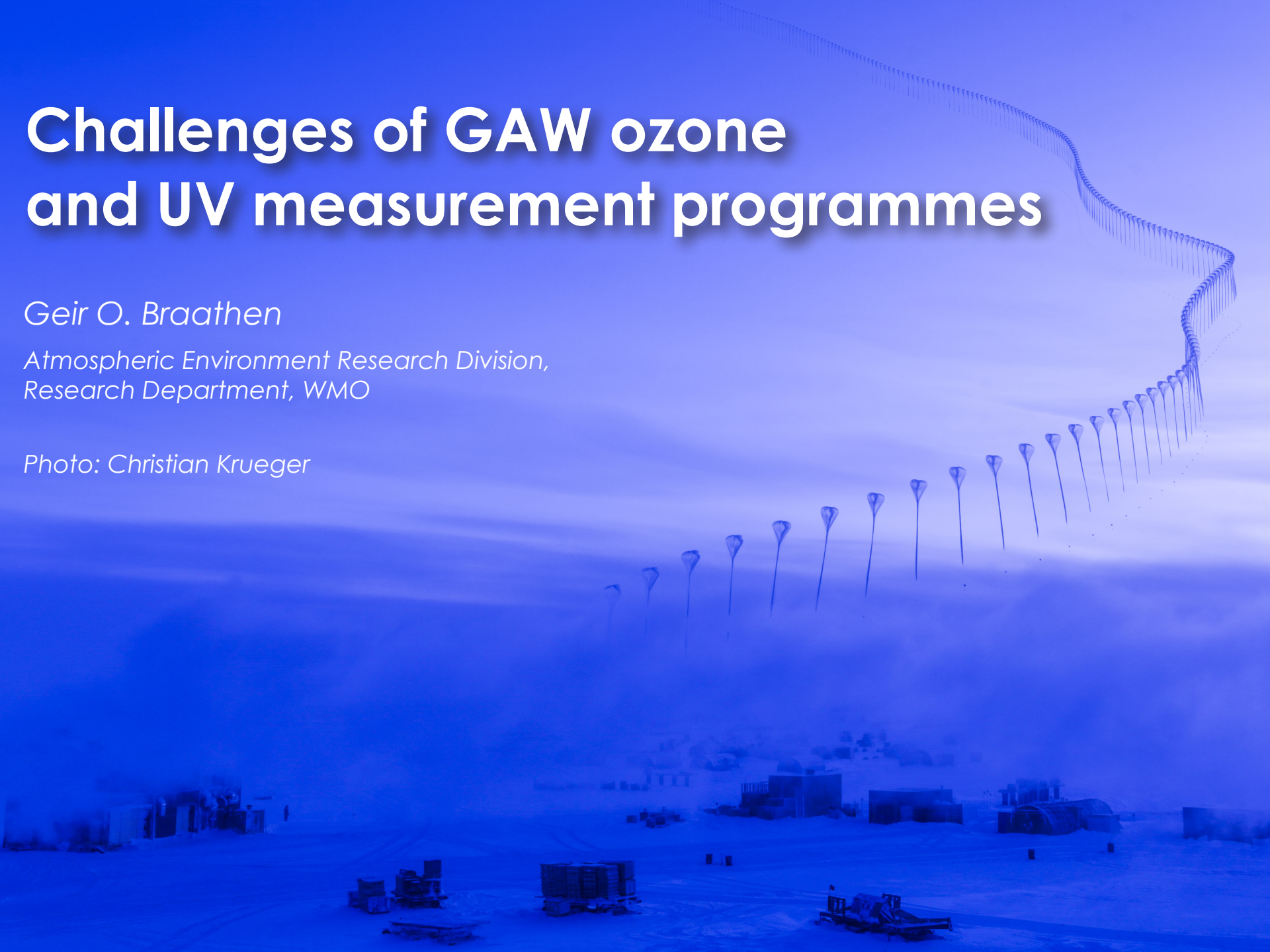
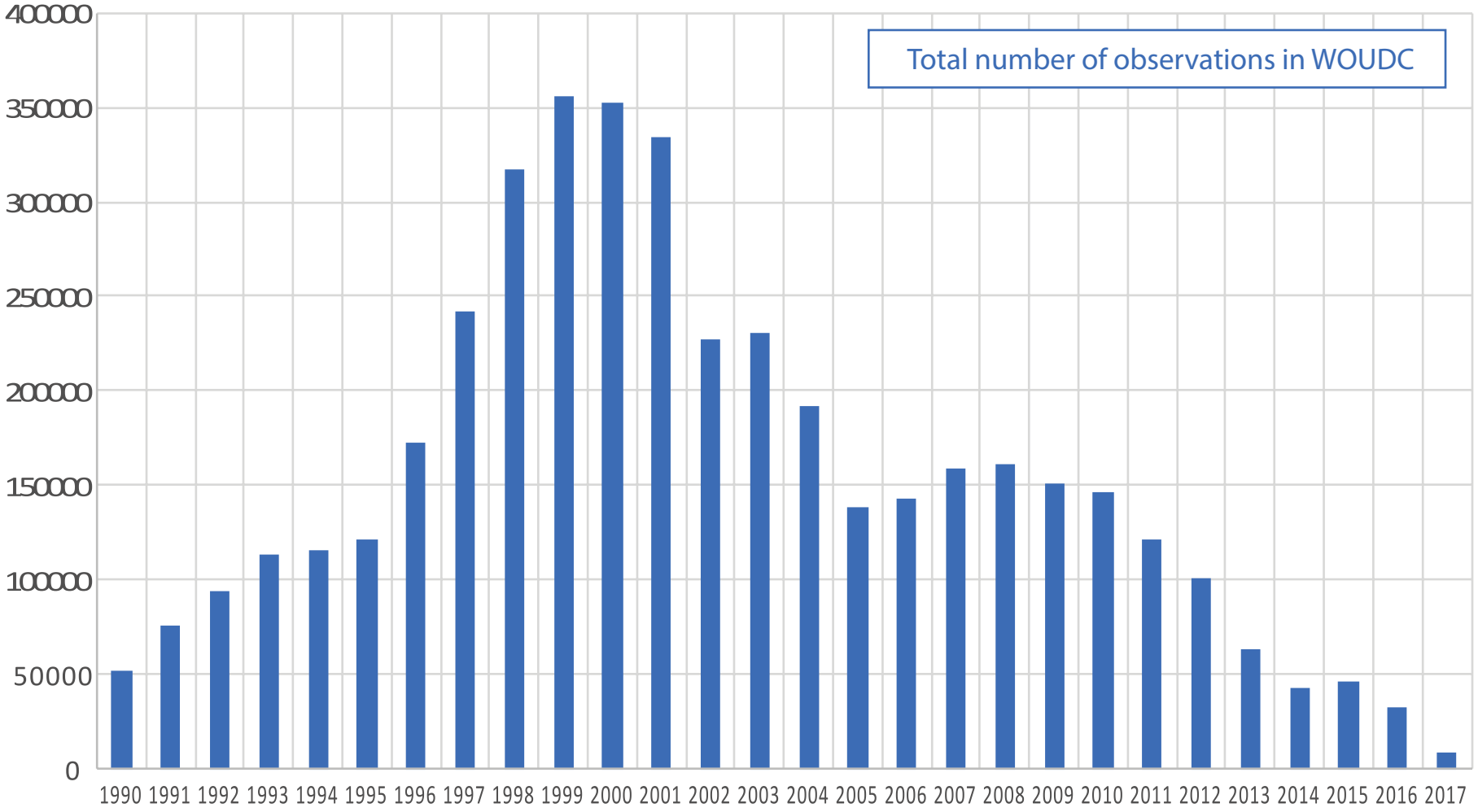
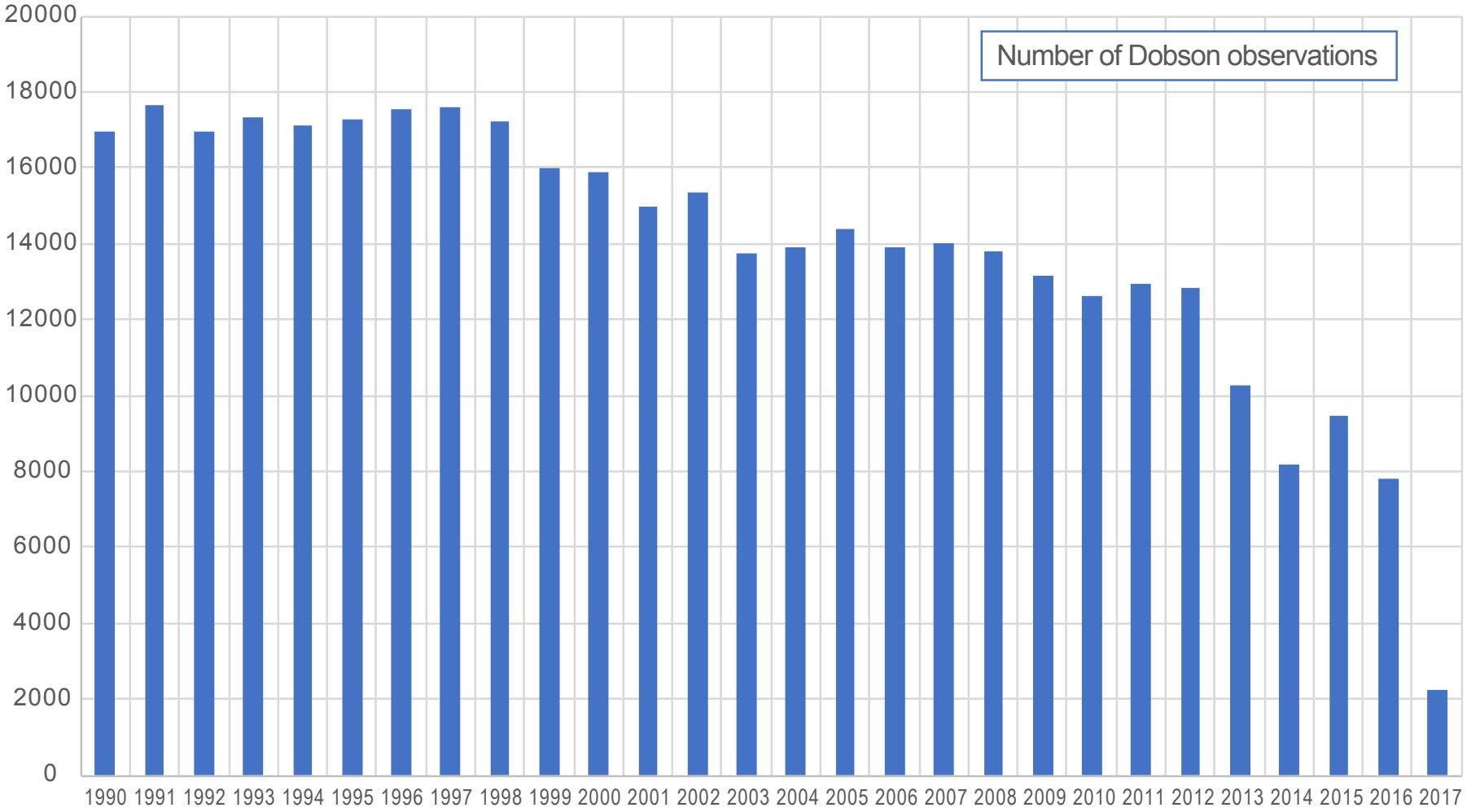
Photo: Christian Krueger



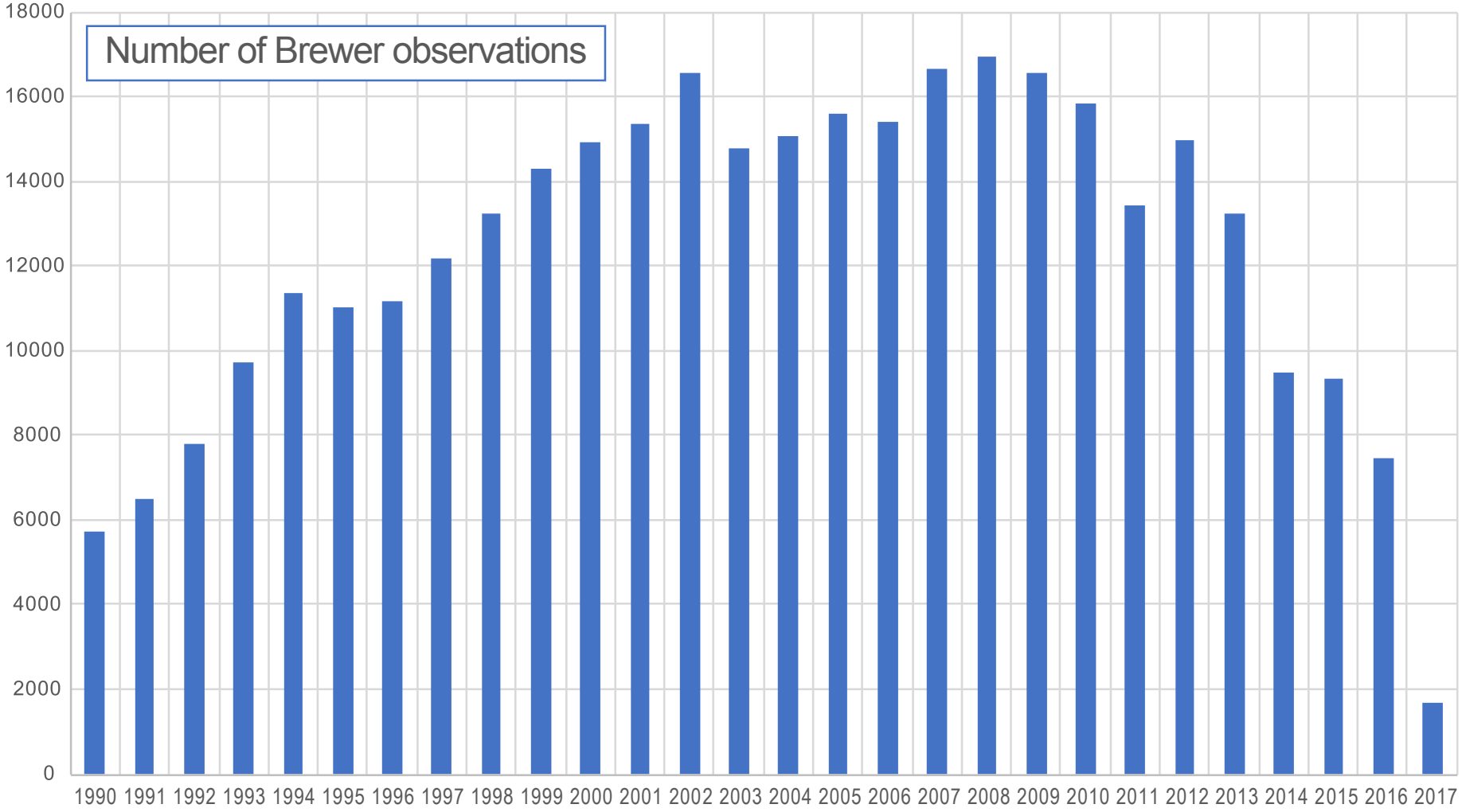
Dwindling number of observations



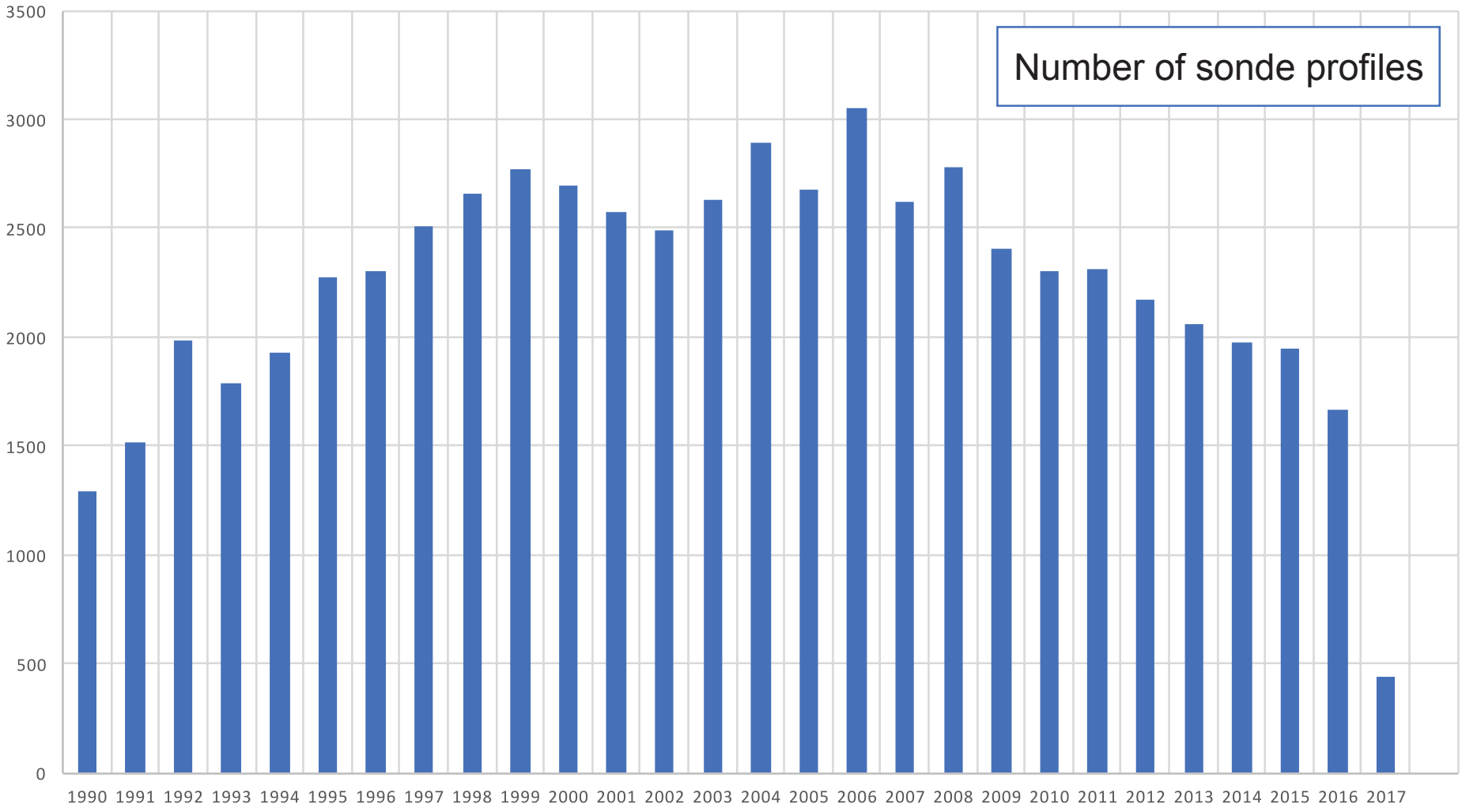
Dwindling number of observations



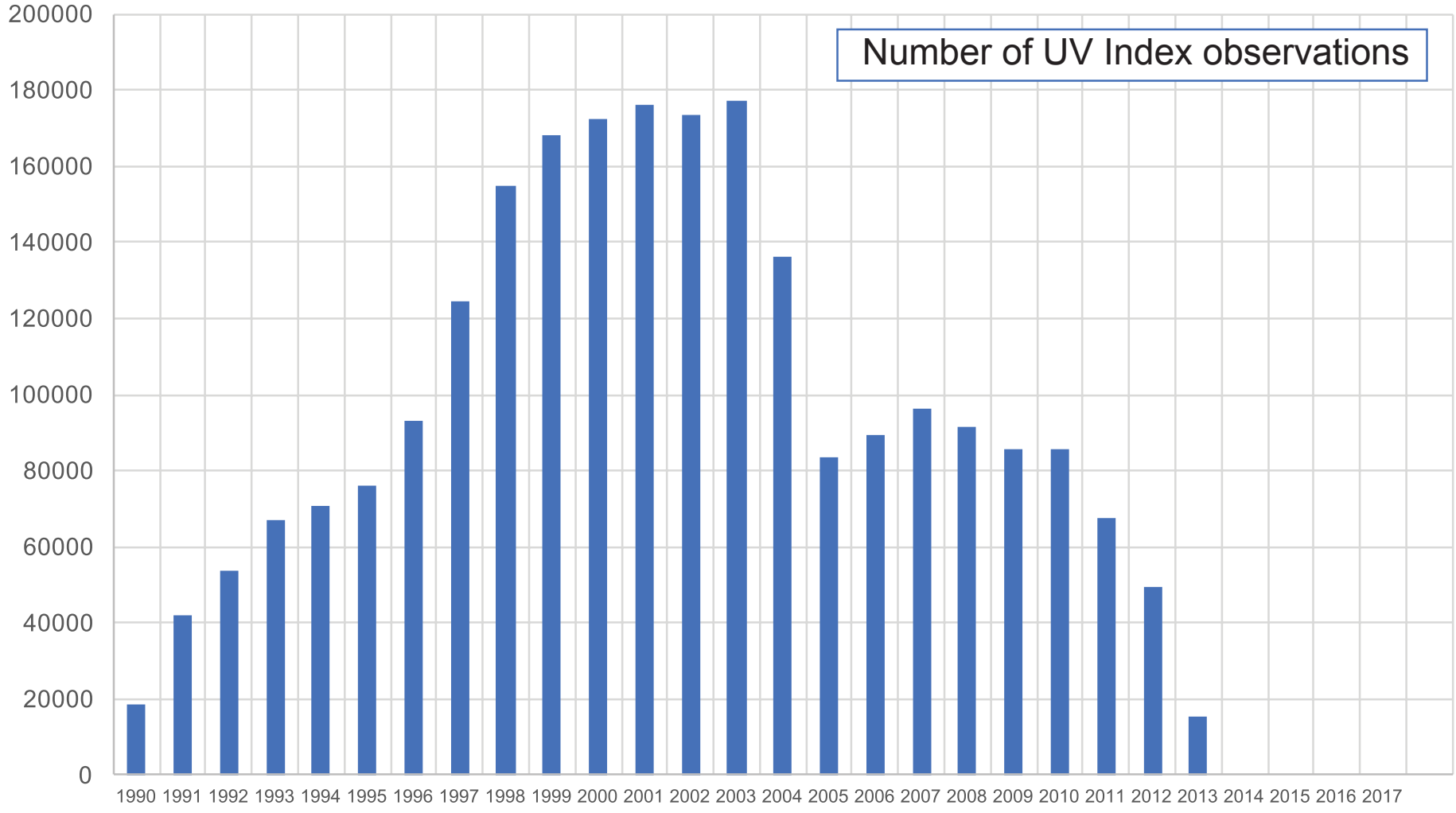
Dwindling number of observations



Dwindling number of observations



Dwindling number of observations



Brewer calibrations by IOS

II-Asia												
Brewer	**Model**	**Current home**	**Region**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
#023	MKIV	Taipei	II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#049	MKIV	Tomsk	II	✓				✓					
#054	MKII	Mt_Waliguan	II	✓		✓		✓		✓			
#061	MKIV	Chengkung	II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#076	MKII	Longfengshan	II	✓				✓		✓			
#077	MKII	Linan	II	✓		✓		✓		✓			
#092	MKIV	Bandung	II			✓							
#095	MKII	Pohang	II		✓		✓		✓				
#115	MKIVe	Hong_Kong	II	✓	✓	✓	✓		✓	✓		✓	
#120	MKIVe	Songkhla	II	✓	✓					✓			
#121	MKIVe	Bangkok	II	✓	✓					✓			
#129	MKIII	Taipei	II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#148	MKIVe	Seoul	II		✓		✓		✓				
#160	MKIV	Isfahan	II	✓									
#161	MKIVe	Pohang	II		✓		✓		✓				
Brewer	**Model**	**Current home**	**Region**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
#177	MKIV	Lhasa	II							✓			
#196	MKIII	Jeju_Gosan	II						✓				✓
#197	MKIII	Beijing	II					✓		✓			
#213	MKIII	Anmyeondo	II										✓
#216	MKIII	Beijing	II							✓			

Brewer calibrations by IOS

III-S.America												
Brewer	Model	Current home	Region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
#056	MKII	La_Paz	III		✓								
#073	MKIV	Natal	III		✓								
#081	MKII	Cuiaba	III		✓								
#110	MKIVe	S_J_Campos	III		✓								
#159	MKIII	Paramaribo	III	✓						✓			
#180	MKIII	Punta_Arenas	III		✓						✓		

Brewer calibrations by IOS

VI-Europe												
Brewer	Model	Current home	Region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
#001	MKIV	Athens	VI			✓			✓				
#005	MKII	Thessaloniki	VI								✓		
#006	MKII	Vindeln	VI	✓					✓			✓	
#010	MKII	Hohenpeissenberg	VI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#016	MKII	Brussels	VI	✓									
#030	MKII	Lindenberg	VI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#037	MKII	Sodankyla	VI	✓	✓							✓	
#040	MKII	Arosa	VI	✓		✓		✓		✓			✓
#042	MKV	Oslo	VI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#043	MKII	Kislovodsk	VI	✓				✓					
#044	MKII	Obninsk	VI	✓				✓					
#050	MKIVe	Ny_Alesund	VI		✓						✓		
#053	MKII	Sondrestrom	VI		✓		✓						
#064	MKII	Belsk	VI	✓	✓	✓	✓	✓		✓	✓	✓	
#066	MKIV	Aosta	VI		✓		✓	✓	✓		✓		✓
Brewer	Model	Current home	Region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
#067	MKIV	UofRome	VI		✓		✓	✓	✓	✓	✓		✓
#070	MKIV	Madrid	VI		✓		✓		✓		✓		✓
#072	MKII	Davos	VI	✓		✓		✓		✓			✓
#075	MKIV	Reading	VI		✓		✓		✓		✓		
#078	MKIV	Lindenberg	VI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
#082	MKIVe	Copenhagen	VI		✓		✓						
#088	MKIV	Valentia	VI	✓		✓		✓		✓		✓	
#093	MKIV	Sonnblick	VI				✓				✓		

The European COST Action

EUBrewNet Goals:

- Automated data transfers to central database beginning Sept 2014.
- Calibration data stored in central data base.
- Site and instrument characterisation.
- Central data processing in addition to station processing.

The European COST Action EUBrewNet Goals:

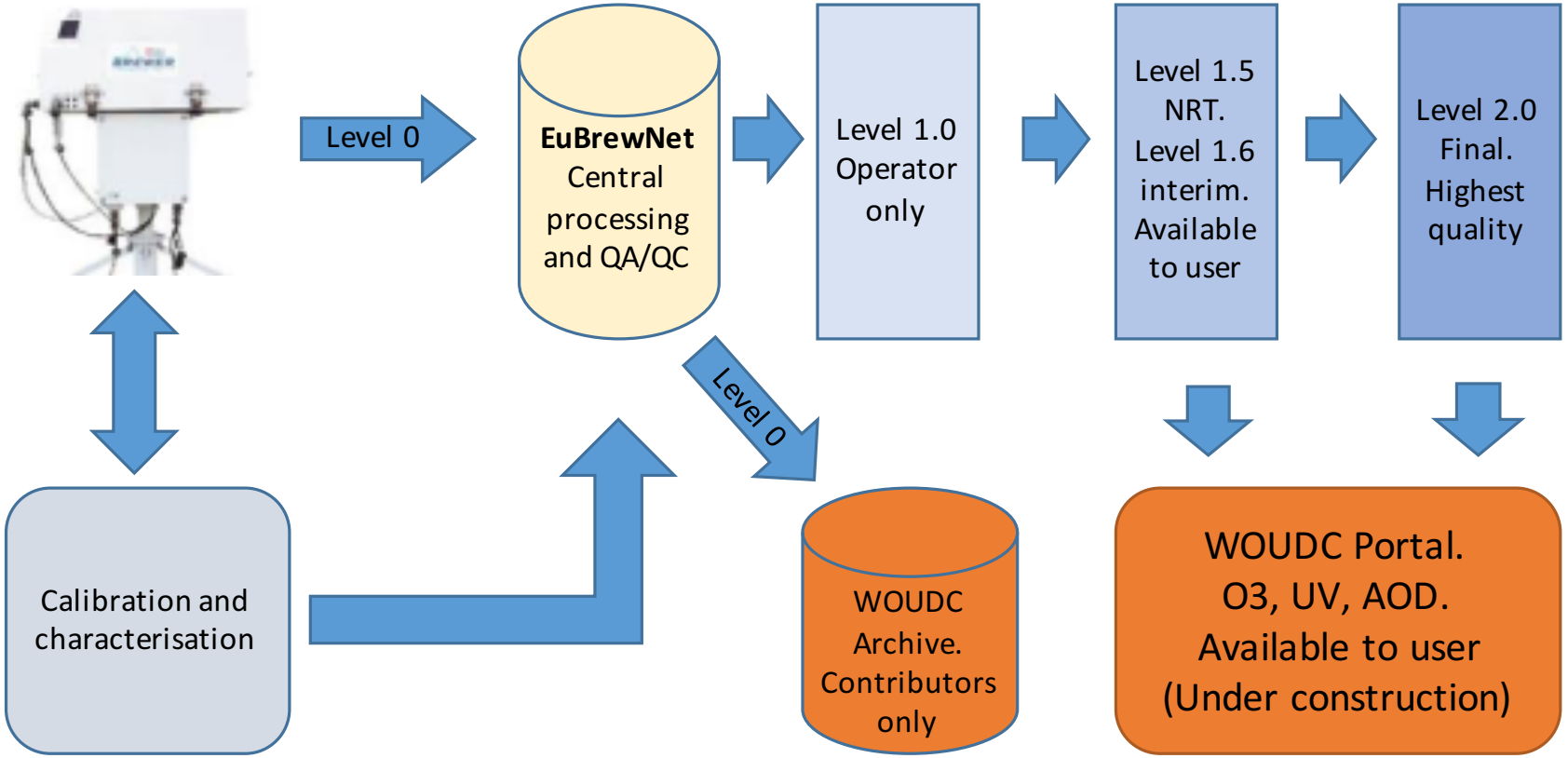
- Central re-processing.
- Central QA/QC systems.
- Near-real-time data.
- Link to WOUDC.

EUBrewNet


Canada
United States
Russia
China
India
Malaysia
Indonesia
Australia
North Atlantic Ocean
South Atlantic Ocean
Indian Ocean
South Pacific Ocean

What we have done.

(and it's all automated)



Operator Training Courses

- Tenerife, March 2014
- Huelva , June 2015
- Edinburgh, Sept 2016
- Sydney, Sept 2017

Vienna Convention Trust Fund

Recent and upcoming activities:

- Dobson intecomparison for Asia in Tsukuba, March 2016
- Dobson intercomparison for SW Pacific in Melbourne, Feb. 2017
- Dobson intercomparison for N-Africa in Huelva, Sep. 2017
- Brewer training course for Asia in Sydney (co-funded with Canadian Brewer Trust Fund), Sep. 2017
- JOSIE campaign in Jülich, Oct.-Nov. 2017
- Dobson intercomparison for Southern Africa, 2018
- Dobson intercomparison for South America, Feb. 2018

Balance on Trust Fund after this: USD 12’444

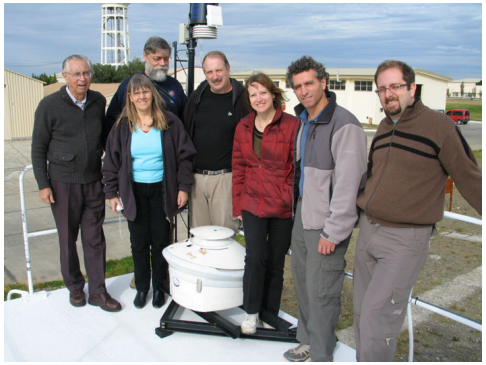
Dobson intercomparison, El Arenosillo, Spain

New instrumentation

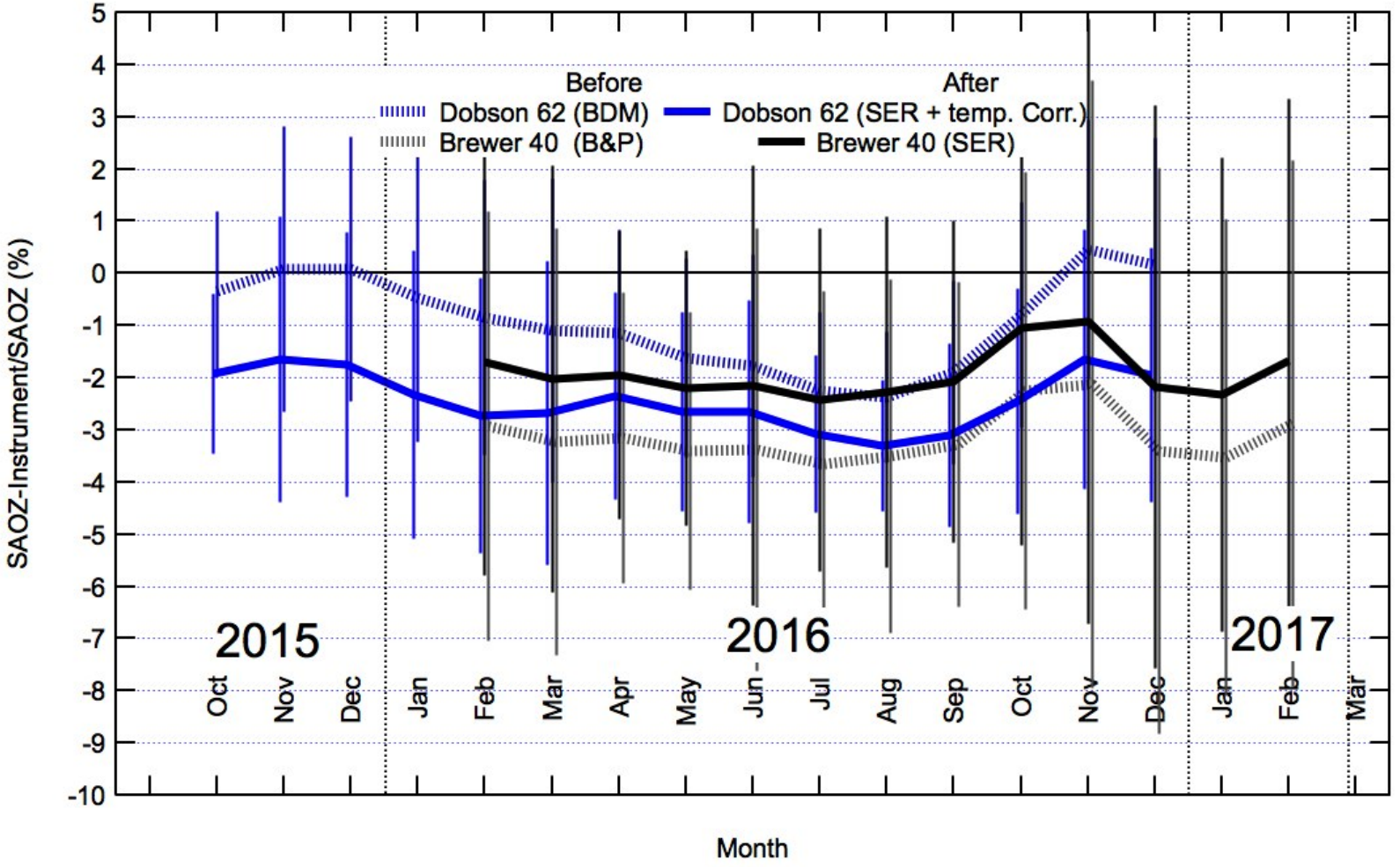
- **Dobson spectrophotometer: Invented in 1924**
- **Brewer spectrophotometer: In production from 1981**
- **New instruments are now available or becoming available:**
  SAOZ (used in NDACC) and miniSAOZ at many sites

GPS Location of the SAOZ instruments (see Table)

Name	N°	Location	Country	Lat.	Long.	Start	End	Owner	Collab.
SAOZ	8	NY-Alesund	Spitzberg	78N	12E	1991	---	NILU	
SAOZ	7	Thule	Groenland	76N	69W	1991	---	DMI	
SAOZ	4	ScoresbySund	Groenland	71N	22W	1991	---	CNRS	DMI
SAOZ	18	Kiruna	Campaigns	68N	21E	1988	1990	CNRS	
SAOZ	17	Sodankyla	Finland	67N	27E	1990	---	CNRS	FMI
SAOZ	12	Zhigansk	Russie	67N	123E	1992	---	CNRS	CAO
SAOZ	5	Salekhard	Russie	67N	67E	1998	---	CNRS	CAO
SAOZ	9	Aberyswyth	Wales	52N	4W	1991	---	Uni.Wales	
SAOZ	11	Jungfraujoch	Suisse	47N	8E	1990	---	IASB	CNRS
SAOZ	13	OHP	France	44N	6E	1992	---	CNRS	
SAOZ	2	Tarawa	Kiribati	1N	173E	1992	1999	CNRS	NIWA
SAOZ	15	Saint Denis	Reunion	21S	55E	1993	---	CNRS	U. Reu
SAOZ	1	Bauru	Brésil	22S	49W	1995	---	CNRS	UNESP
SAOZ	14	Durban	South. Af	30S	31E	1992	1998	Uni. Durb.	
SAOZ	10	Sanae	South. Af	30S	31E	1991	---	Uni. Durb.	
SAOZ	3	Kerguelen	Sub Antarc	49S	70E	1995	---	CNRS	
SAOZ	26	Rio Gallegos	Argentina	52S	69W	2008	---	CNRS	
SAOZ	6	Faraday	Antarc UK	65S	64W	1990	1996	BAS	
SAOZ	6	Rothera	Antarc UK	67S	68W	1997	---	BAS	
SAOZ	16	Dumont	Terre Adélie	67S	140E	1988	---	CNRS	
SAOZ	27	Concordia	DomeC	75S	123E	2007	---	CNRS	



Mini-SAOZ in Arosa

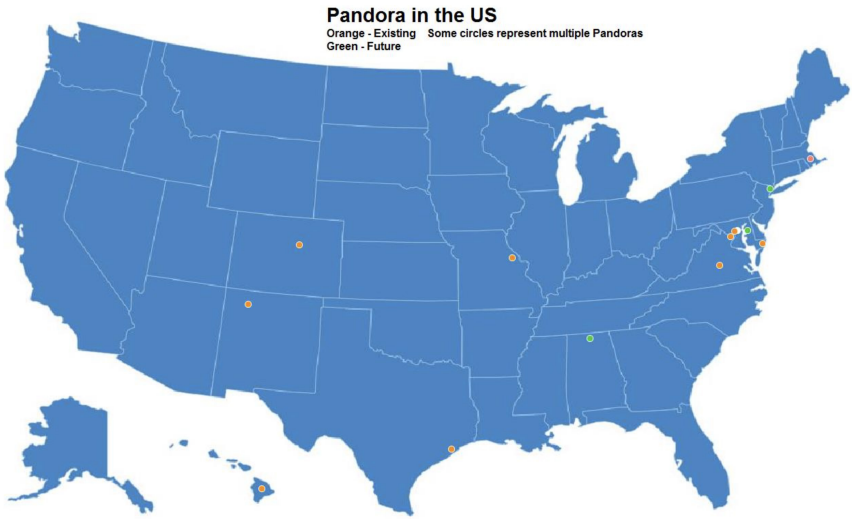


- ✔ **Pommereau et al., in prep.**

Pandora and the Pandonia network

Pandora at Izaña

Pandora-2S in Innsbruck



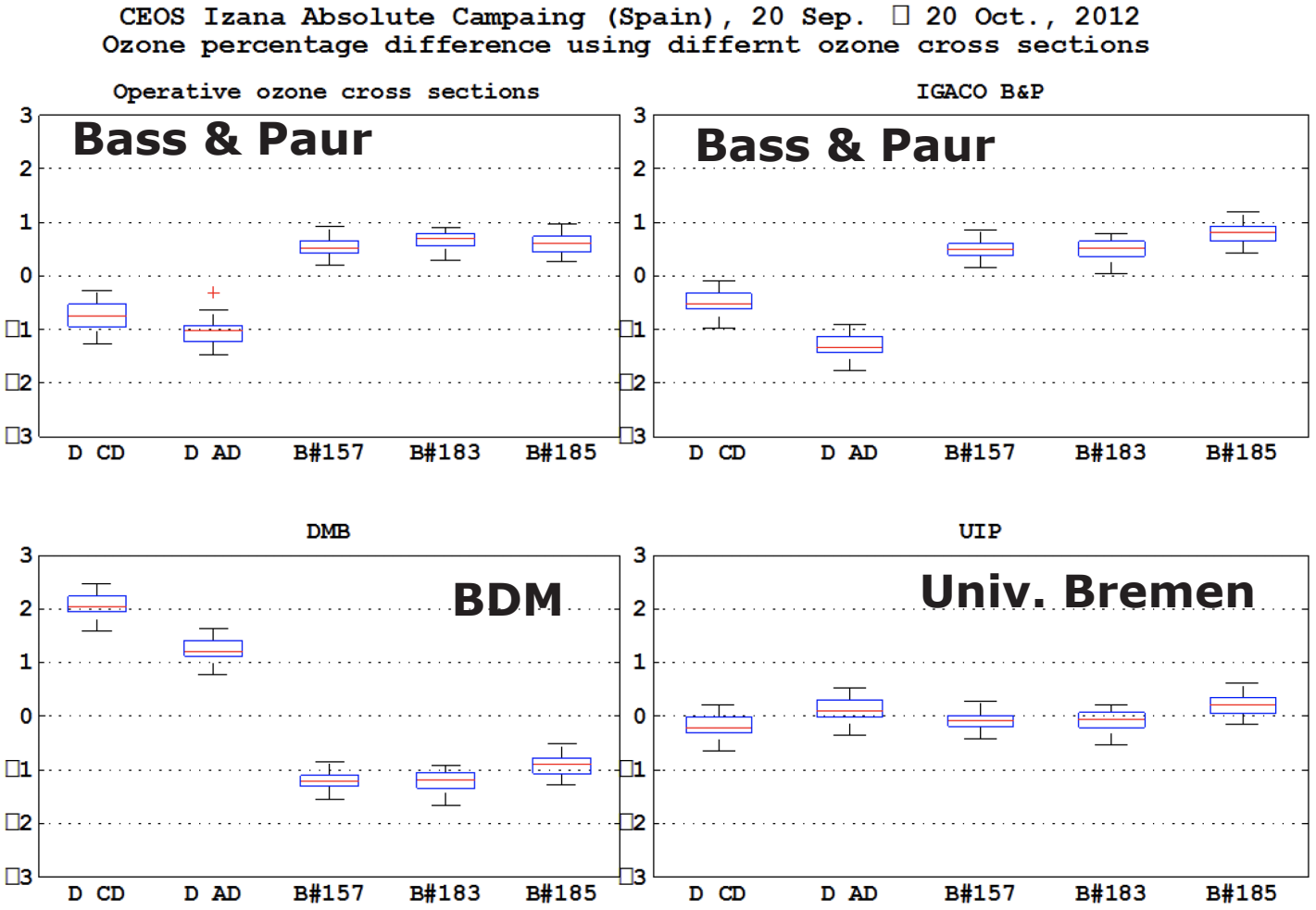
X. Zhao et al., AMT, 2016; J. Herman et al., AMT, 2017.

http://pandonia.net

Ozone Absorption Cross Sections (ACSO)

- **The activity "Absorption Cross-Sections of Ozone" (ACSO) started in 2008 as a joint initiative of the International Ozone Commission (IO_3C), the World Meteorological Organization (WMO) and the IGACO-O_3/UV ("Integrated Global Atmospheric Chemistry Observations") subgroup to study, evaluate, and recommend the most suitable ozone absorption cross-section laboratory data to be used in atmospheric ozone measurements.**
  - **J. Orphal et al., J. Mol. Spec., Volume 327, September 2016, Pages 105-121**
  - **GAW Report no. 218. http://library.wmo.int/opac/index.php?lvl=notice_display&id=19466**
- **Based on the ACSO work, the GAW Scientific Advisory Group recommends the use of the Bremen (Serdyuchenko) cross sections for Dobson and Brewer observations.**

Ozone Absorption Cross Sections (ACSO)



Ozone Absorption Cross Sections (ACSO)

Letter of 28 Feb. 2017

International Association of Meteorology and Atmospheric Sciences (IAMAS)

International Ozone Commission (IO_3C)

President	Secretary	Vice President
Dr. Sophie Godin-Beekmann	Dr. Irina Petropavlovskikh	Dr. Paul Newman
Tel: +33 1 80 28 54 99	Tel. +1 303 497 62 79	Tel: +1 301 614 59 85
Fax: +33 1 80 28 53 30	Fax: +1 303 497 55 90	Fax: +1 301 614 59 03
sophie.godin-beekmann@latmos.ipsl.fr	Irina.petro@noaa.gov	paul.a.newman@nasa.gov

Paris, February 28th 2017

Dear Members of the WMO Scientific Advisory Group for Ozone,

At the last meeting of the International Ozone Commission, held during the 2016 Quadrennial Ozone symposium in Edinburg, UK on 6 September 2016, the Commission members discussed the results of the "ACSO" ("Absorption Cross Sections of Ozone") committee investigation. This committee was established to evaluate the sensitivity of various measurement types (ground-based or satellite) to a change in ozone absorption cross-section (http://igaco-o3.fmi.fi/ACSO/index.html). Results of the assessment were summarized in the GAW final report # 218 (2015) and the recent paper lead by J. Orphal:
http://dx.doi.org/10.1016/j.jms.2016.07.007

In ACSO, different sets of laboratory ozone absorption cross-section data (including their dependence on temperature) of the group of Reims (France) (Brion et al., 1993, 1998, 1992, 1995, abbreviated as BDM, 1995) and those of Serdyuchenko et al. (2014), and Gorshelev et al. (2014), (abbreviated as SER, 2014) were examined for use in atmospheric ozone measurements in the Huggins band. Several recommendations were made for different categories of ozone measurements.

In particular, for retrieval of ground-based instruments of total ozone and ozone profile measurements by the Umkehr method performed by Brewer and Dobson instruments, data of SER (2014) are recommended to be used. When SER (2014) is used, the difference between total ozone measurements of Brewer and Dobson instruments are very small and the difference between Dobson measurements at AD and CD wavelength pairs are diminished.

The IO3C agreed with this recommendation. Consequently, the Commission voted for the use of the SER(2014) cross-sections in the Dobson and Brewer ozone retrieval and for the consideration of the temperature dependence of ozone absorption cross-sections into the retrieval, in order to improve the seasonal bias relative to other ozone data sets.

The IO3C is now asking the Ozone SAG to design a plan for (1) implementing the conversion of Dobson and Brewer total ozone historical records to the new SER(2014) ozone cross-sections; and (2) taking into account the temperature dependence of ozone absorption cross-section into the retrieval.

The IO3C also discussed the timing of the calibration of Dobson spectrophotometers. Following the recommendation by the WMO Scientific Advisory Group for Ozone, the Commission has agreed to extend the original 4-year calibration of Dobson spectrophotometers cycle to 5 or 6 years.

Cordially,

Dr. Sophie Godin-Beekman
President

Dr. Paul Newman
Vice-President

Dr. Irina Petropavloskikh
Secretary

Ozone Commission website: https://ioc.atmos.illinois.edu/

The IO3C agreed with this recommendation. Consequently, the Commission voted for the use of the SER(2014) cross-sections in the Dobson and Brewer ozone retrieval and for the consideration of the temperature dependence of ozone absorption cross-sections into the retrieval, in order to improve the seasonal bias relative to other ozone data sets. The IO3C is now asking the Ozone SAG to design a plan for (1) implementing the conversion of Dobso and Brewer total ozone historical records to the new SER(2014) ozone cross-sections; and (2) taking into account the temperature dependence of ozone absorption cross-section into the retrieval.

The ATMOZ Project

Coordinartor: Julian Gröbner
PMOD, Davos

Traceable Ozone Measurements

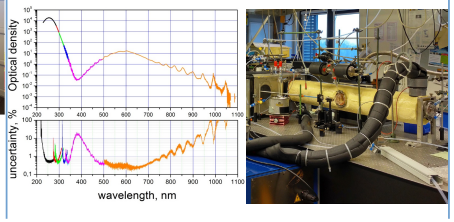
Radiometry | **Atmospheric Model**

Solar Measurement → **Total Column Retrieval Method** → **O_3 Value**

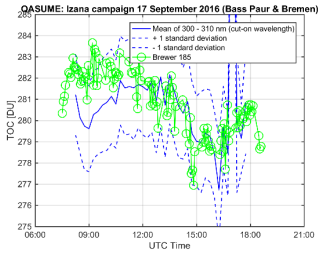
Uncertainty of **measurement:** + Uncertainty of **model:** = Uncertainty of **O_3 value**

Measurements & Characterizations:
- Field campaigns
- Laboratory characterisations

Benchmark Datasets:
- New ozone cross-sections
- New extraterrestrial solar spectrum



Uncertainty Budget:
- Monte-Carlo-Model approach



EMRP European Metrology Research Programme ▸ Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Universidad de La Laguna · Universität Bremen* · KIPP & ZONEN SINCE 1830 · VSL Dutch Metrology Institute · EURAMET

The ATMOZ Project: Outcome

- **The spectral characterisation of the Dobson spectroradiometers has for the first time allowed to calculate the ozone absorption coefficients for individual Dobsons, increasing the consistency between different wavelength pairs and also between Dobsons.**
- **The quantitative improvements are still being determined. See Köhler et al., 2017 and Redondas et al., 2017, both in preparation.**
- **We have shown that an independently calibrated spectroradiometer can retrieve total column ozone based on an absolute radiometric calibration without needing Langley-plots, with an uncertainty in TOC of around 1.5% or better (to be confirmed). This would allow such an instrument to act as independent reference instrument for TOC. See Egli et al., 2017 in preparation.**

Ground-based data for the Multi-Sensor Reanalysis

Assumption:

- ✔ **The ground observations are on average a good approximation for the true values.**

Procedure:

- ✔ **All UV-VIS satellite data in the period 1970-2012 is used.**
- ✔ **Step 1 : Correct satellite data to avoid biases. The reference data that is chosen are ground data observations from reliable WOUDC stations.**
- ✔ **Step 2 : Satellite data is assimilated in a chemical-transport model to achieve complete global and temporal coverage.**

Availability:

- ✔ **Multi Sensor Re-analysis (MSR) data available at http://www.temis.nl**

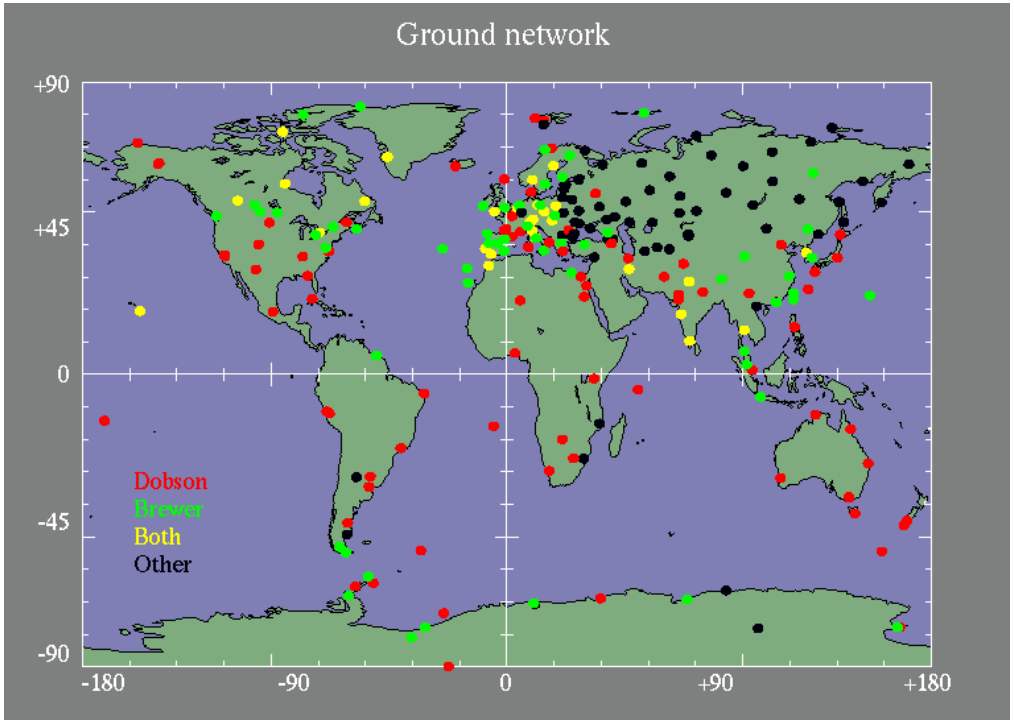
Published in:

- ✔ **R.J. van der A , Allaart, M. A. F., and Eskes, H. J.: Extended and refined multi-sensor reanalysis of total ozone for the period 1970–2012, Atmos. Meas. Tech., 2015.**

Ground-based data for MSR

Reference data set:

- ✔ From WOUDC 91 ground stations are selected with a long and reliable dataset (Fioletov et al., 2008)
- ✔ Dobson & Brewer instruments
- ✔ Dobson data corrected for temperature dependence (Kerr et al., 2002)



World Meteorological Organization

Working together in weather, climate and water

Thank you for your attention!

GLOBAL ATMOSPHERE WATCH

Geir O. Braathen, WMO, Research Department