

# RBCC-E 2003-2025

**RBCC-E (2003–2025): dos décadas de calibración Brewer y retos para el futuro de la medida de ozono.**

*A. Redondas, V. Carreño, A. Berjón, F. Parra*

*-22 years calibrating brewer-*



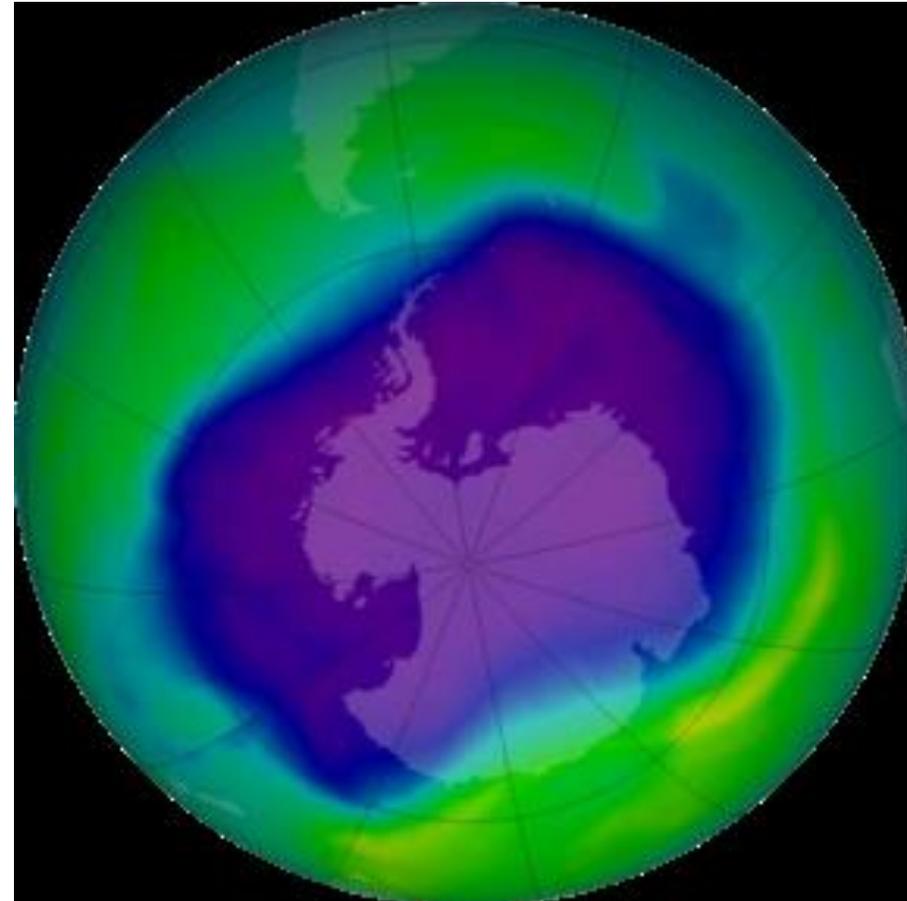
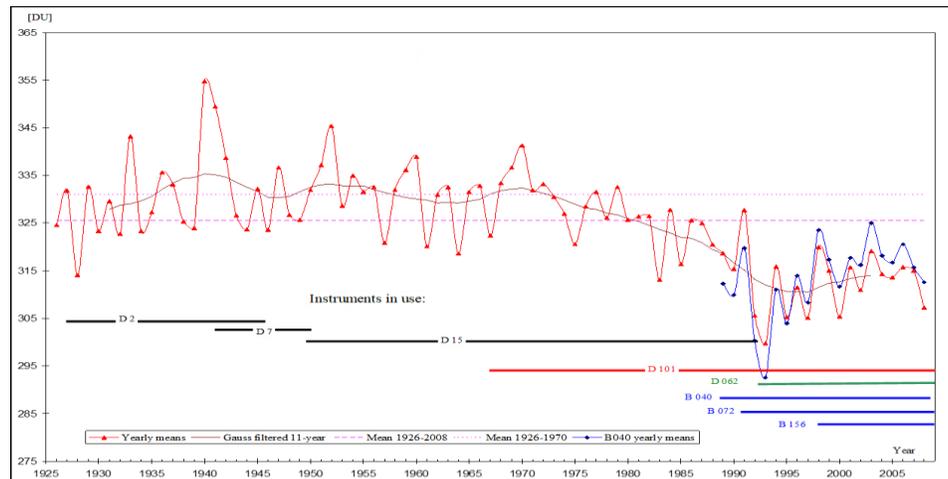
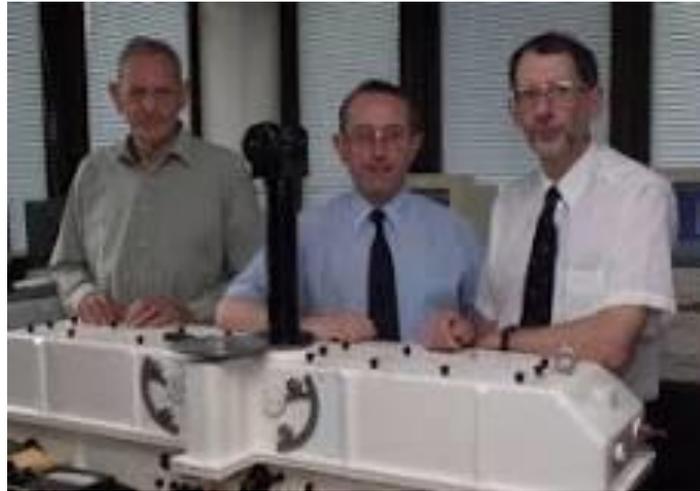
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Y EL RETO DEMOGRÁFICO

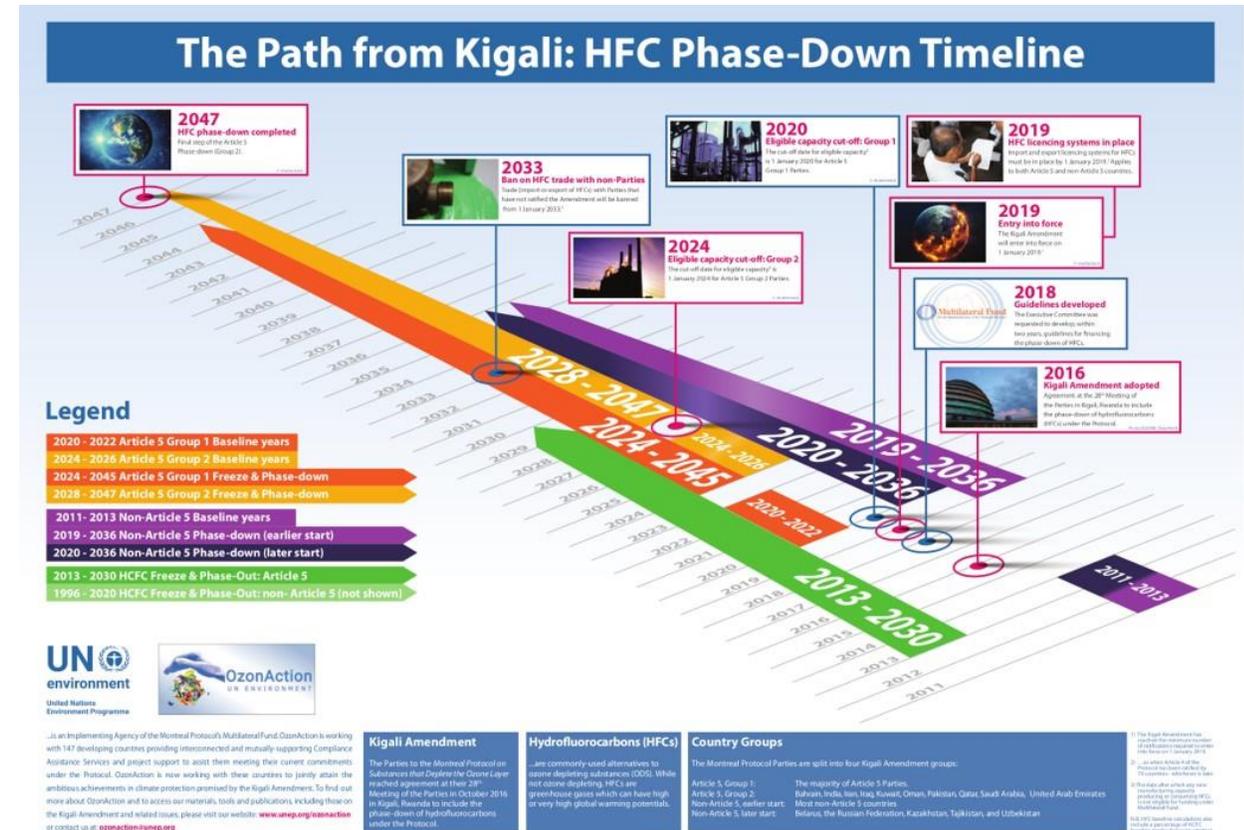


# The Ozone Problem



# The Ozone Solution

Vienna Convention 1985  
 Montreal Protocol 1987  
 Kigali Amendment (2016) in force since 1<sup>st</sup> Jan 2019



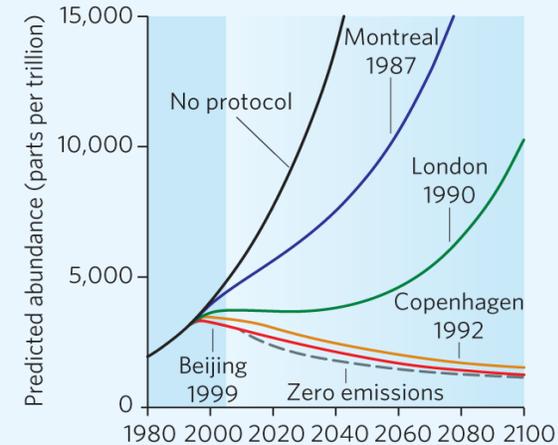
# Model Predictions

- Need confidence in our predictions
- Models can only be judged on how effectively they predict.
- 32 yrs since Montreal – only a small fraction on the scale of prediction.
- Still no definitive answer on ozone.

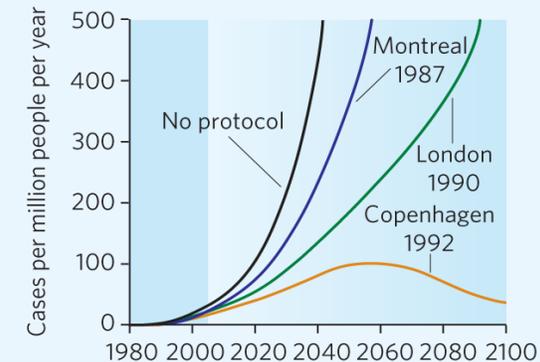
## THE TREATY THAT WORKED

Without the Montreal Protocol and its amendments, the amount of ozone-destroying compounds would continue to rise, driving up skin-cancer rates.

## OZONE-DESTROYING COMPOUNDS



## EXTRA SKIN-CANCER CASES



# Ozone Monitoring



# Brewer Ozone Spectrophotometer

Total ozone column

Ozone profiles (umkehr)

Spectral UV

Aerosol optical depth in the UV

Sulphur dioxide



# RBCC-E 2003-2025

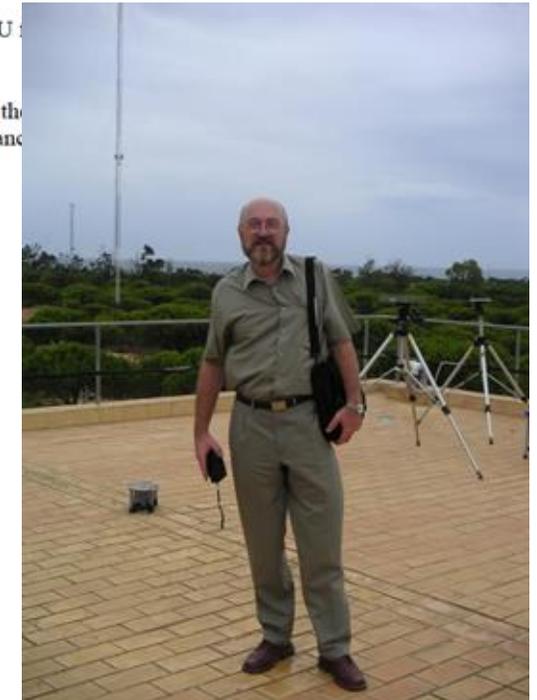
The idea was the creation of an internationally structured Brewer calibration system, under GAW program, with Quality Assurance (QA) procedures similar to those of the Dobson system

IZO had been recommended to become a Regional Brewer Calibration Center for WMO Region VI (Europe) at the WMO/GAW SAG-Ozone meeting in Toronto, September 2002

## Recommendations of the Scientific Advisory Group for Ozone of WMO-GAW

(Prepared at the SAG-O3 meeting in Toronto, September 09-10, 2002)

1. WMO GAW should seek support for Dobson calibrations in developing countries. Otherwise calibrations in developing countries will fall behind schedule.
2. A plan must be made to augment and extend the existing system of calibration and maintenance of Brewer instruments, which is presently being performed by private companies. An evaluation of the history and efficiency of the existing Dobson calibration system, which is operated through cooperation between the individual users and WMO-GAW oversight, would be useful in forming this plan.
3. Calibration histories of the Dobson, Brewer and FSU instruments should be maintained by WMO-GAW or WOUDC as assistance to the data users.
4. Creation of a regional Brewer calibration system in the Mediterranean region, including maintenance and calibration activities.

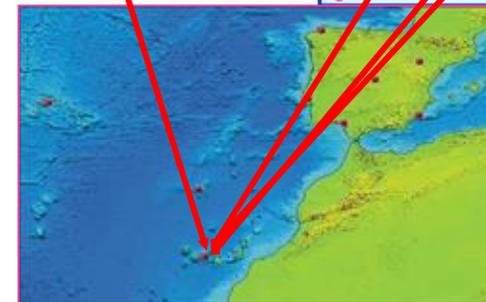


# RBCC-E 2003-2025

- Brewer Ozone Observations since 1992, since 2002 is a NDACC (NDSC) total ozone station.
  - Trained personnel , experienced on instruments and campaigns (Nordic 93, 97, Dobson 94, Arenosillo 1999, 2001 )
  - A good set of complementary measurements including NDAC DOAS and FTIR and UV calibration laboratory.
  - The station has the conditions to perform Absolute Langley Calibrations, high altitude, clear atmosphere and stable tropical ozone during major part of the year
- Maintain the Brewer #157 as the reference and buy a new spectrometer as travelling instrument.
  - Maintain the link with the World Reference Triad through regular calibration with the #017 and independently through Absolute calibrations of the instruments.
  - Organize a yearly calibration to transfer the calibration one on the south of Europe (Huelva, Spain) and a second one in Arosa.
  - Scientist is dedicated to the project a phd student and 50% of technical observer.

# Regional Brewer Calibration Center - Europe

- In November 2003, the WMO/GAW Regional Brewer Calibration Centre for RA-VI region (RBCC-E) was established at the Observatory Izaña of AEMET, Canary Islands (IZO).
- IZO is located in subtropical region (28°N) on top of the Izaña Mountain (2370 m.a.s.l.) with clear sky and small ozone variability. This allows routine absolute calibrations of the references similar to the **MLO site on Hawaii**.
- The IZO Triad were linked to the Environment Canada (EC) Triad by yearly calibrations towards the travelling reference BR 017.
- Because of doubts about the support of the world triad by EC, the WMO SAG Ozone authorizes at the meeting of 2011, that the **RBCC-E transfers its own calibration** based on Langley at Izaña Station. Since Arosa 2012 campaign the RBCC-E transfer his own Langley calibration
- Nowadays RBCC-E share the CCL with the WRC (ECC-Canadá), with common procedures and regular intercomparisons between the references



# RBCC-E 20 years 2003-2025



2003  
Start



2005  
RBCC-E



2006  
SALINA



2011  
Langley

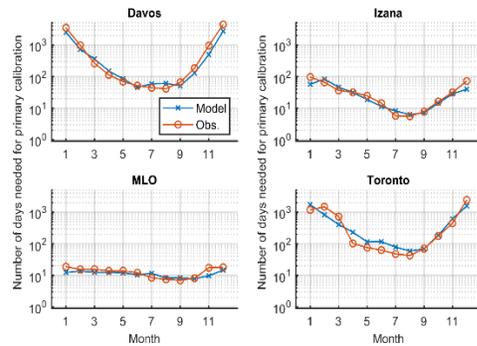


2022  
CCI

Brewer CCL working group have four Brewer research papers planned. We are aiming to have the papers published in 2022-2026, in the following order below:



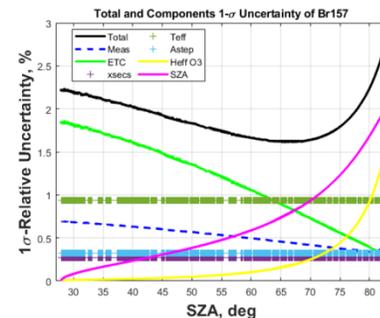
- 1. Brewer Primary Calibration condition paper** (journal submission by December 31, 2023): Is led by ECCC (Xiaoyi Zhao). This work focus on **evaluating the environmental conditions** for different Brewer calibration sites globally. This work addresses a key scientific question: What is needed to make sure that the primary calibration performed at different sites (e.g., Mauna Loa Observatory (MLO) in Hawaii and Izana in Spain) can be of the sam



- How many days we need to finish high-quality primary calibration at different sites?

- 2. Brewer Total Ozone Uncertainty Budget paper** (journal submission by December 31, 2025): Is led by Spain's State Meteorological Agency – AEMET (Francisco Parra-Rojas and Alberto Redondas). This work will also introduce a **new Brewer uncertainty budget model** to provide detailed uncertainties of Brewer observations (i.e., precision and ac

- Detailed Brewer total ozone uncertainty budget



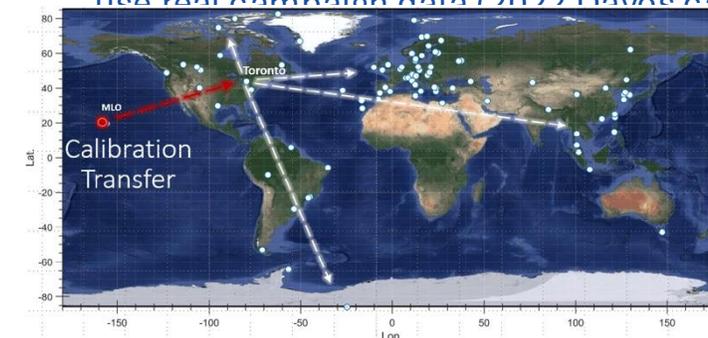
- 3. 1<sup>st</sup> Brewer Central Calibration Laboratory (CCL) paper** (journal submission by Spring, 2026): Is led by AEMET (Alberto Redondas). This work describes the **primary calibration theory and technical details** (e.g., the difference between the Canadian and Spanish's primary calibrations of their Brewer

The calibration methodology of the Brewer Triads, and their uncertainty budget.

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<sup>4</sup>Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, Switzerland  
<sup>5</sup>Scientist emeritus at Environment and Climate Change Canada, Canada  
 Correspondence: Alberto Redondas (arcondas@aemet.es)

- primary calibration theory and technical details

- 4. 2nd Brewer CCL paper** (to be published after 1<sup>st</sup> CCL paper; mid-2027): Is led by ECCC (Xiaoyi Zhao). This work focus on **how the primary calibration is transferred to field Brewer instruments** worldwide. In the context of having two CCLs instead of the current one CCL, this work will evaluate the transfer results from ECCC and AEMET primary calibrations to see if the calibration qualities are equivalent. This work will use real campaign data (2022 Davos campaign) to examine the



- Brewer calibration transfer map



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# Absolute Calibration of Reference Photometers and Total Ozone Spectroradiometers at Izaña July 31 - August 21, 2023

## START DATE

31 July 2023

## END DATE

22 August 2023

## LOCATION

Safari Izaña, Tenerife

The Izaña Atmospheric Research Center (IARC) in Tenerife, a branch of the Spanish State Meteorological Agency (AEMET) under the Ministry for Ecological Transition and Demographic Challenge (MITECO), has announced that it will serve as a calibration centre for the reference photometers of total ozone spectroradiometers and the AERONET network since the volcanic eruption at the Mauna Loa Observatory on Hawaii Island.

The eruption, which started on November 27, 2022, has severely damaged the infrastructure of the observatory operated by the National Oceanic and Atmospheric Administration (NOAA). As a result, IARC will temporarily take over the role of the global calibration centre for the standard

**The Washington Post**  
*Democracy Dies in Darkness*

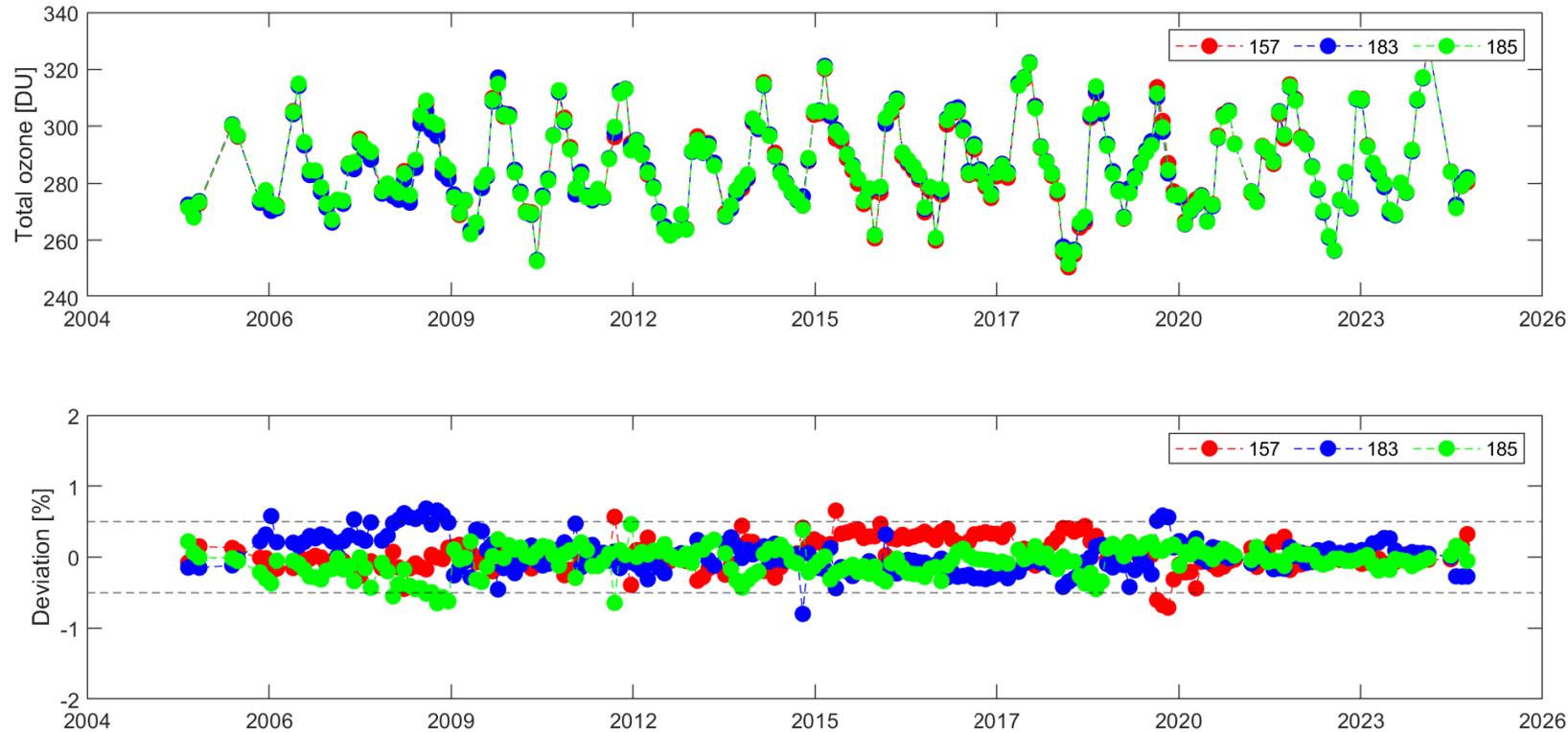
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## Trump moves to close facility that helps track planet-warming pollution

The lab is connected to the Mauna Loa Observatory, where scientists gather data to produce the Keeling Curve, a chart on the daily status of atmospheric carbon dioxide concentrations.

Updated March 14, 2025

# Reference Maintenance



Monthl  
Relative deviation of each Brewer from the monthly mean of the RBCC-E Triad during the 2005-2024 period. The standard deviation of the relative deviations from the RBCC-E Triad monthly mean have values of 0.21%, 0.24% and 0.19% (Brewer#157, Brewer#183 and Brewer#185) for the period 2005-2024) iad and b)

# New Triad

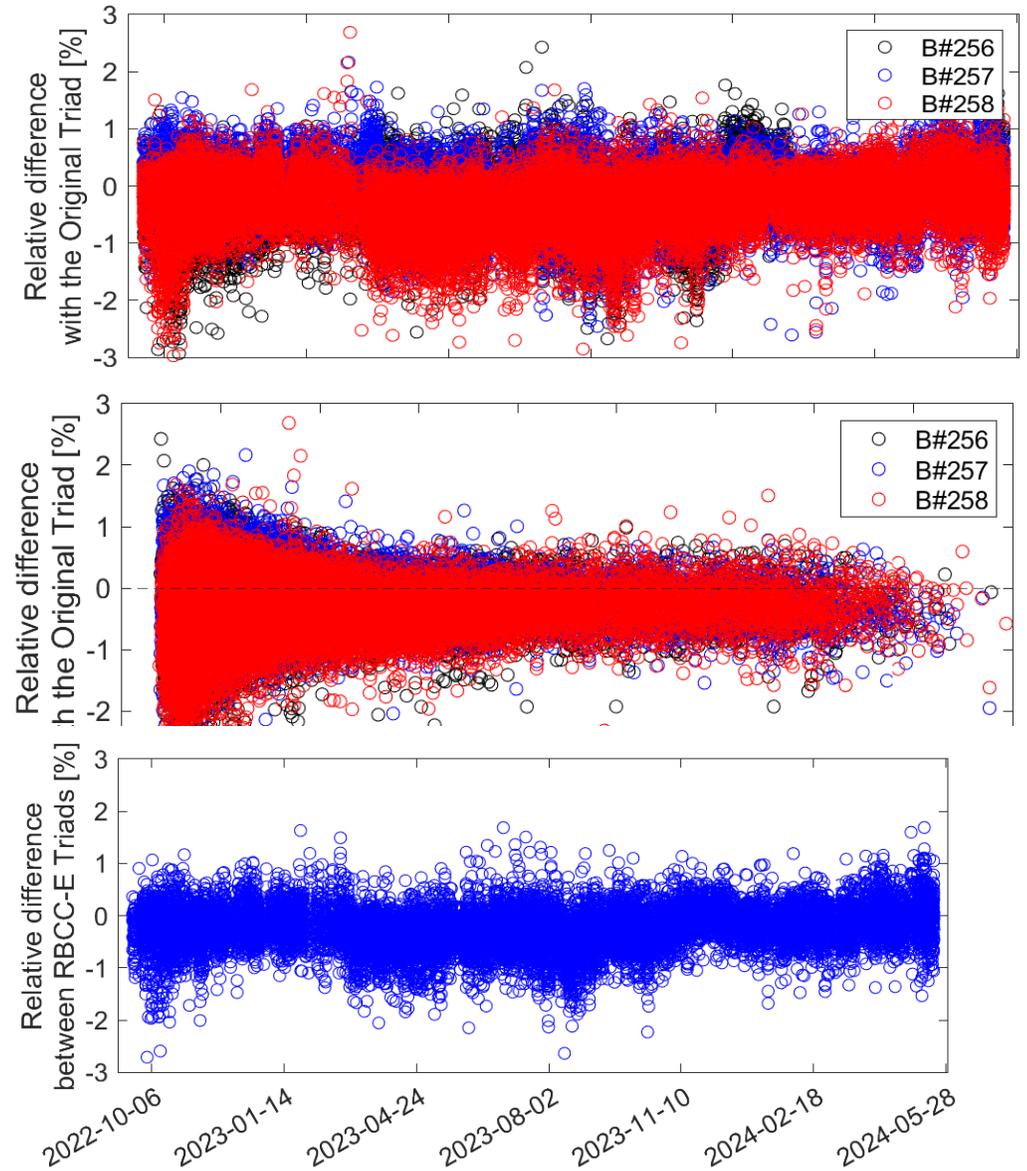
The New Triad instruments (#256, #257 and #258) have been operational since September 2022.

The average relative differences are between 0.03% and 0.10%, with standard deviations around 0.3%.

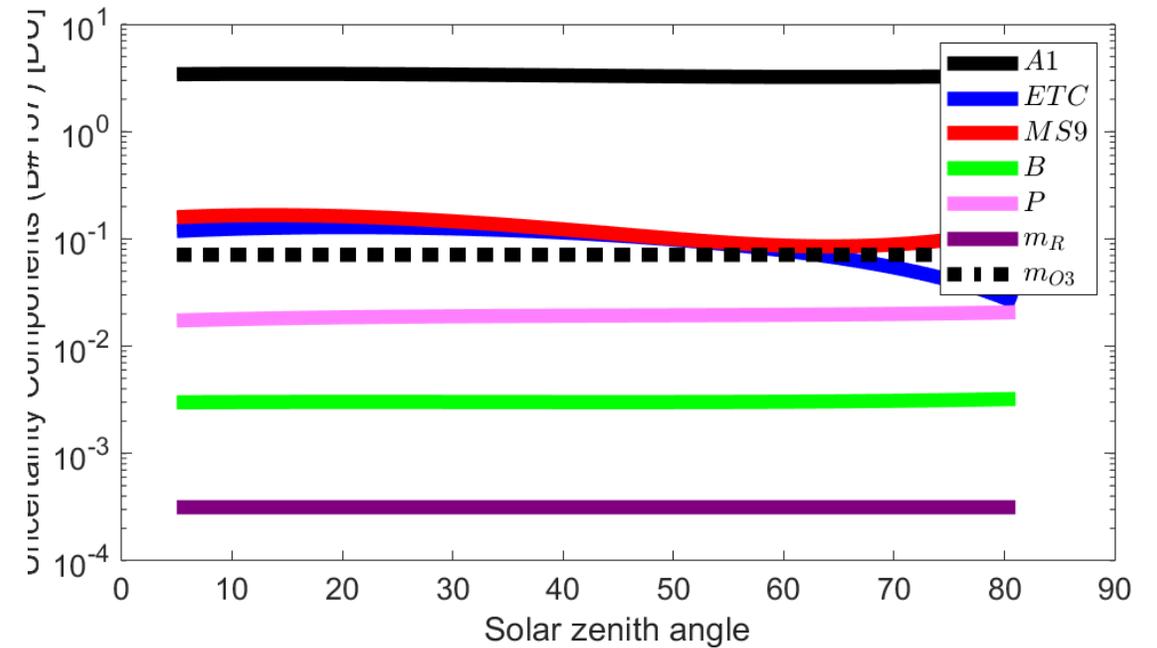
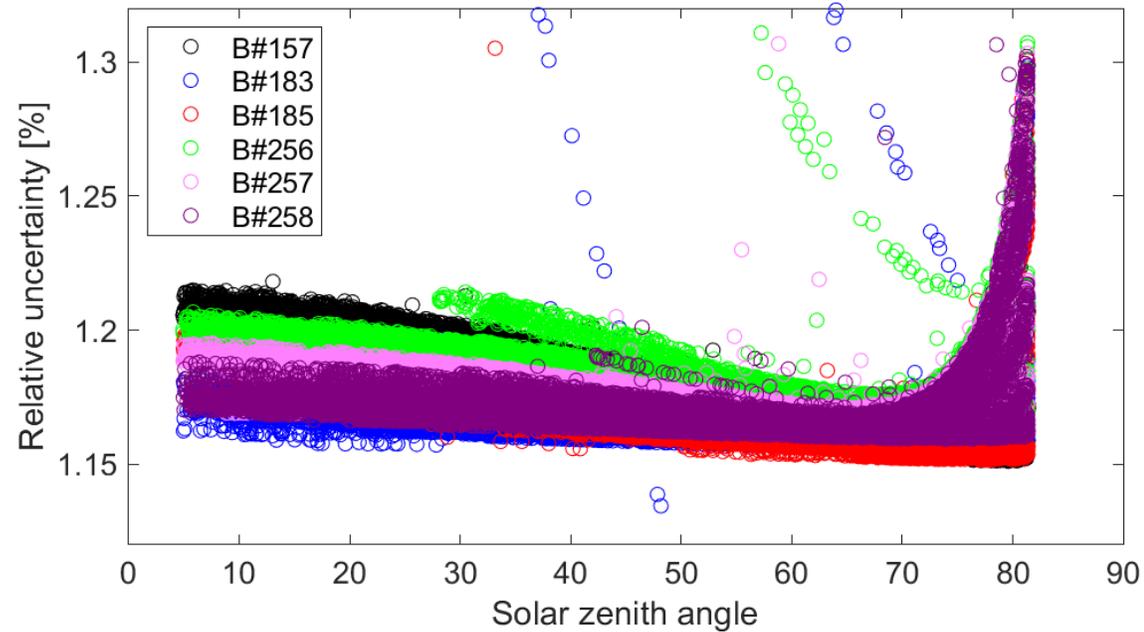
The cross-analysis shows the relative differences of each Brewer with respect to the other Triad. In this case, averages increase up to 0.37%, with standard deviations around 0.5%.

No significant dependencies are found in any case with the ozone slant column (OSC), although in the case of cross-analysis there is a slight deviation from zero.

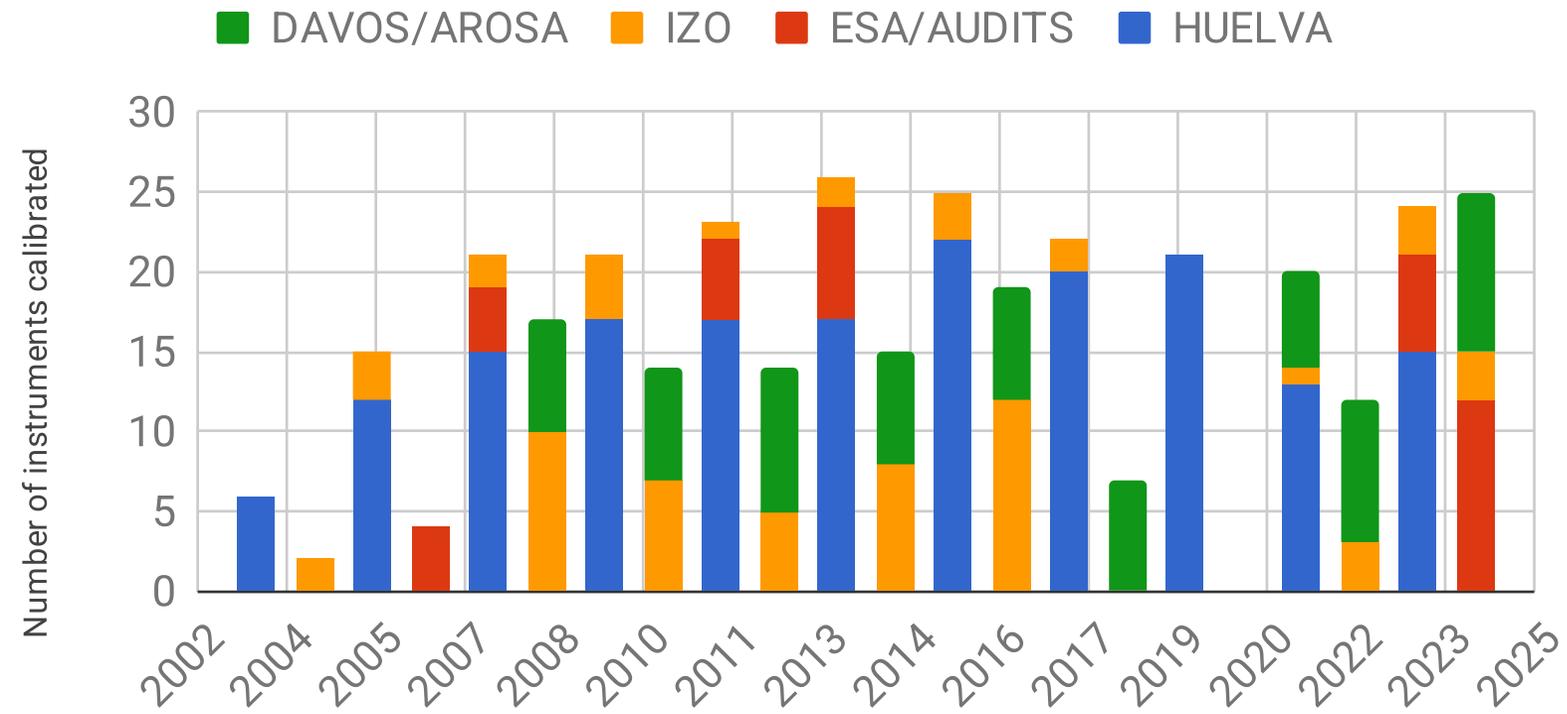
The comparison between the triads show a mean difference of 0.3% with a standard deviation of 0.4%.



# Triad uncertainty



# RBCC-E Campaigns



# Reference calibrations

Stie	Year	IOS	K&Z	ECCC	Japan	RBCCE	Reference
		#017 (*)	#158	#145/190	#174	#256	
Arosa	2008	-0,6					<a href="#">Redondas and Rodriguez-Franco, 2008</a>
Huelva	2009	-0,6	0,8	-0,1			<a href="#">Roozendael et al., 2012</a>
Arosa	2010	-0,6					<a href="#">Roozendael et al., 2013</a>
Huelva	2011	-0,1	-0,2	-0,6			<a href="#">Roozendael et al., 2014</a>
Arosa	2012		-0,1				<a href="#">Redondas et al., 2015</a>
Huelva	2013	-1,0	0,7				<a href="#">Redondas and Rodriguez-Franco, 2015a</a>
Izaña	2014			-2,2			<a href="#">Redondas et al., 2014</a>
Arosa	2014	-1,2	1,5				<a href="#">Redondas and Rodriguez-Franco, 2015b</a>
Huelva	2015	-0,5	-0,5				<a href="#">Redondas et al., 2018</a>
Arosa/Davos	2016						in preparation
Izaña	2016-1.6 (-3.5)						<a href="#">Cuevas et al., 2017</a>
Huelva	2017	-0,7					<a href="#">Redondas et. al, 2019</a>
Izaña	2017		1,0				<a href="#">Redondas et al., 2018</a>
Arosa	2018		0,7				<a href="#">Redondas et al., 2019</a>
Huelva	2019	-0,8		-0,9	-2,5	-2,5	<a href="#">Redondas et al., 2021</a>
Huelva	2021						<a href="#">Redondas et al., 2024</a>
Davos	2021		-1.4				<a href="#">Redondas et al., 2024</a>
Davos	2022		-0,6	-0,8			<a href="#">Redondas et al., 2025</a>
Izaña	2023						submitted
Huelva	2023		-1,1			0,5	<a href="#">Redondas et al., 2024</a>
Sta Maria	2024						submitted
Davos	2024						in preparation
Izaña	2024						in preparation

**Travelling standard & setup:** RBCC-E's travelling Brewer #185 is routinely compared against available reference instruments during intercomparison campaigns.

**Reference chain to WBT:** Key references include **IOS #017**, **ECCC Brewers #145 & #190**, **Kipp & Zonen #158**, and **JMA Brewer #174**. The first three provide a **direct link to the World Brewer Triad (WBT)**; see Redondas et al. (2018) for cross-reference results.

**Maintaining traceability:** the WBT link is ensured via **joint Langley calibrations at Mauna Loa or Izaña**.

**Recent status:** The **last IOS–RBCC-E comparison dates to 2019** (no subsequent IOS data shared with RBCC-E).

**Latest WBT check:** The **WBT–RBCC-E Triad intercomparison was held at Izaña in September 2024**.

# Brewer Stop-Production

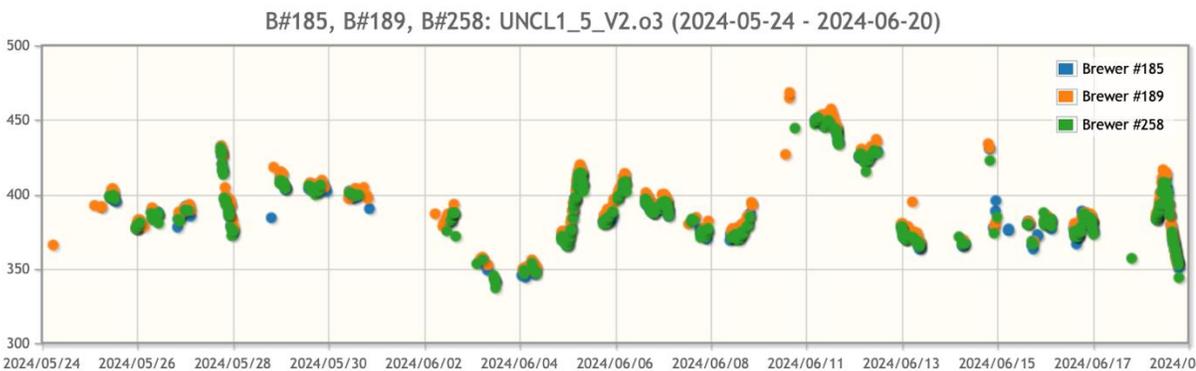
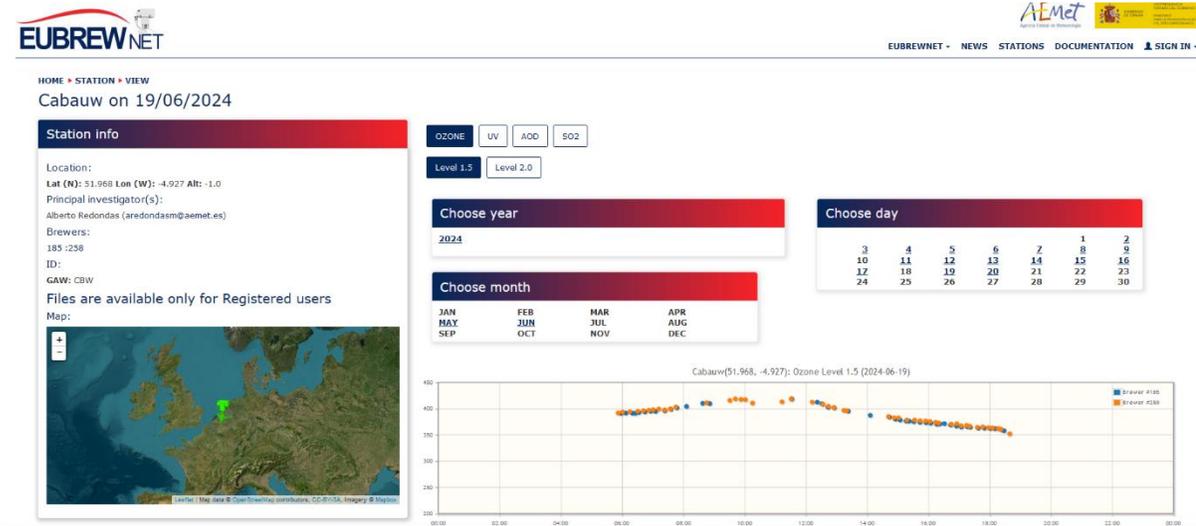
Possible alternatives are being discussed: **BTS and Pandora:**

- These alternatives do not match the quality of the double brewer.
- Their long-term stability has not been demonstrated.
- They have not been tested in polar latitudes or tropical environments.

**Regarding the maintenance of existing brewers:**

- The old electronics (multi-board) are supported by IOS for most components.
- There are no alternatives for the new electronics (single board) brewers.
- There is a problem with recently acquired brewers: There are no spare parts available for the electronics, despite the equipment being under warranty and legal requirements to provide spare parts for 10 years.
- Establishing a Brewer spare parts warehouse managed by WMO calibration centers is recommended. Collect spare parts from brewers that are currently out of service.
- The Canadian service is redesigning the brewer, but this is not a short-term solution.
- IOS does not appear to support the new electronics.
- **Campaigns to evaluate new instruments include Dobson, Brewer, BTS, and Pandora will be desirable on the future.**

# CINDI3 – V2 updated algorithm



Source	Standard (V1)	Update (V2) – CINDI-3
Absorption Cross Section	Bass and Paur, 1984	Serdyuchenko et al., 2013 Weber(2016)
Ozone Effective Temperature	-45 °C	TOMS Climatology
Ozone Effective Altitude	22 km	TOMS Climatology
Rayleigh Coefficients	fixed/hard-coded	Calculated for every Brewer
Rayleigh Coefficients Source	Bates (Kerr, 2010)	Bodhaine et al., 1999
Station Altitude	Not considered	Considered



Show 10 entries

Station	Country	GAW ID	WOUDC	Latitude	Longitude
Abu Dhabi	United Arab Emirates	ADB	397	24.3387	-54.6402
Academy of Athens	Greece		449	37.99	-23.78
Andoya	Norway	ARR	476	69.279	-16.009
Ankara	Turkey	TRA	348	39.95	-32.88

# CINDI3 - Pandora

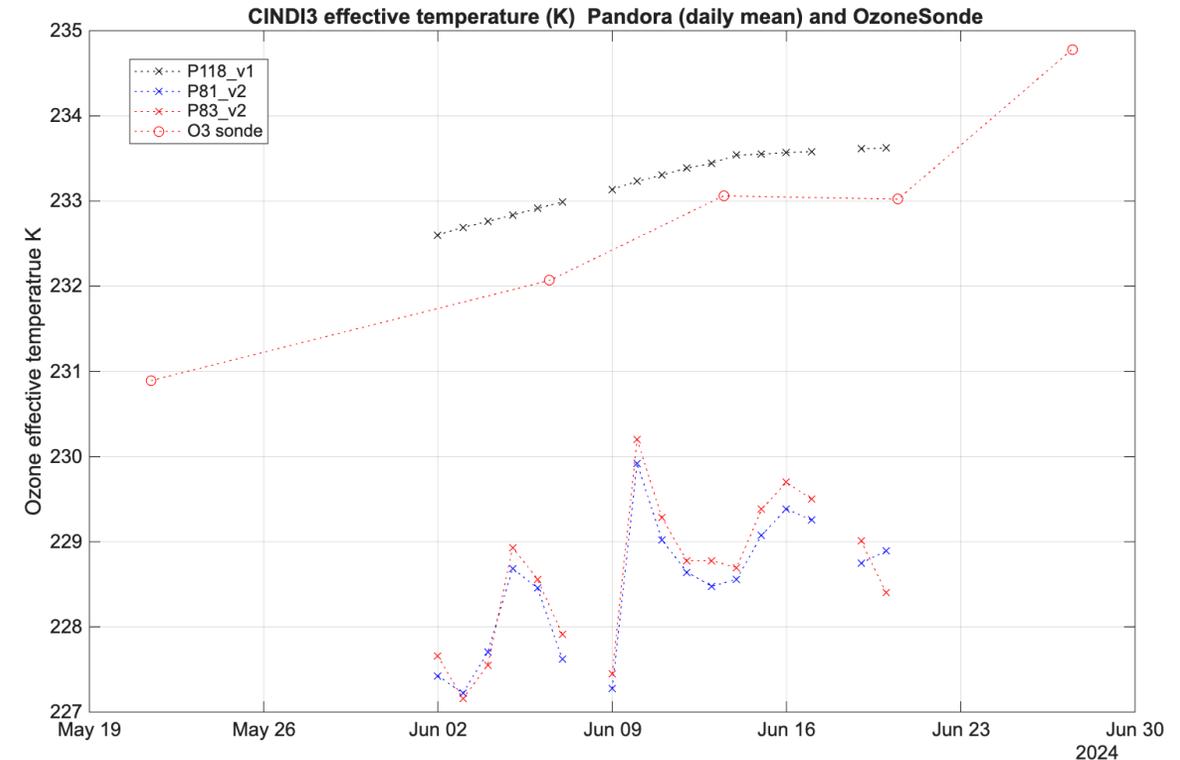
**Datasets compared:** Operational **V1** vs updated **V2** for Brewer and Pandora.

## Cross-sections & Teff:

Brewer: **V1 = Bass & Paur**, **V2 = Serdyuchenko** (as in DOAS participants).

Pandora: both **V1/V2** use **Serdyuchenko**; **V1** uses a **climatological Teff**, **V2 fits Teff** (see Cede et al., 2025).

**Pandora V2** needs dedicated calibration (straylight) and is only available for pandoras. **P81** and **P83**.



# CINDI3 - Pandora

**Brewer V2** is ~2% higher than the operational (V1).

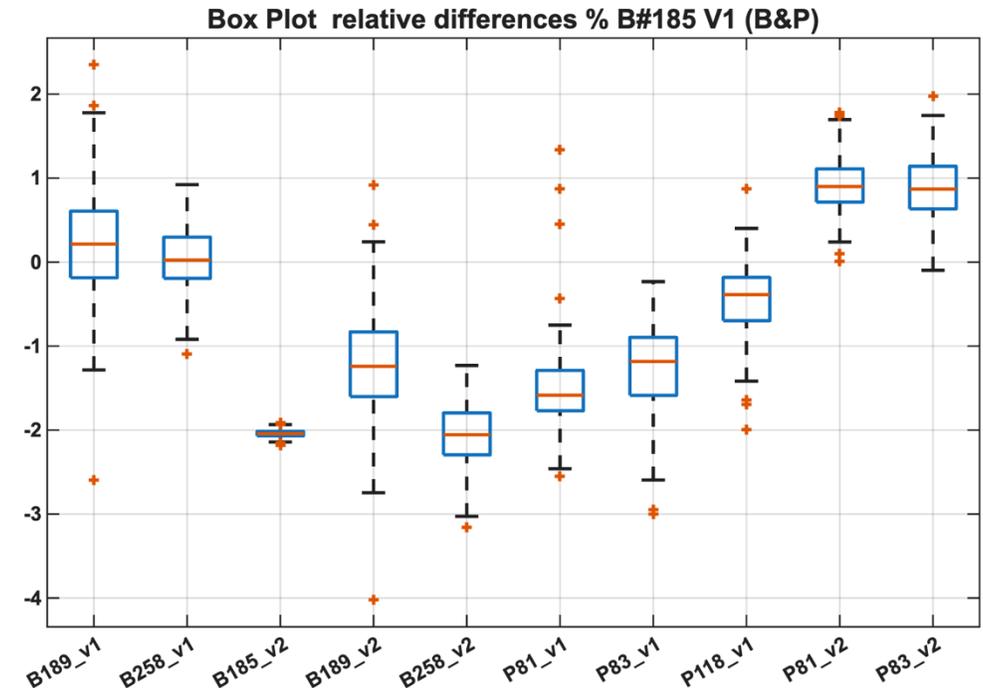
**Internal Brewer consistency:** Agreement to Brewer\_V2 is **0.2%** for #258 and **0.8% mean** for the De Bilt instrument (85 km from Cabauw); similar performance with V1.

**Brewer- Pandora comparison:**

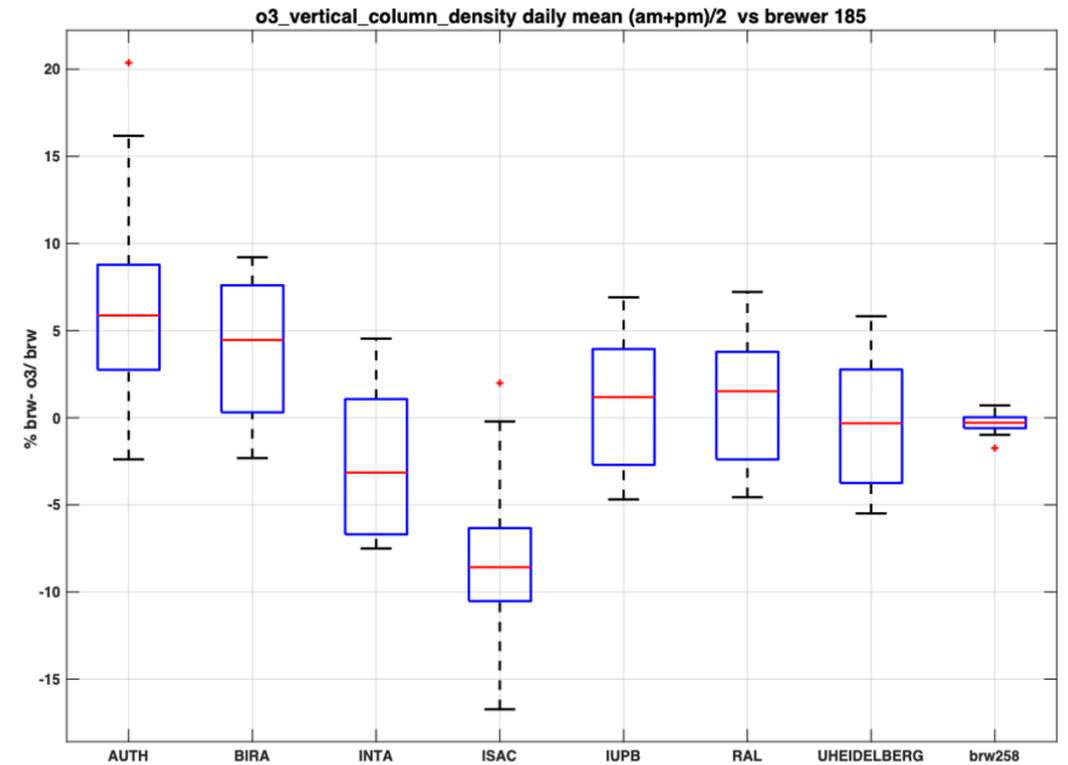
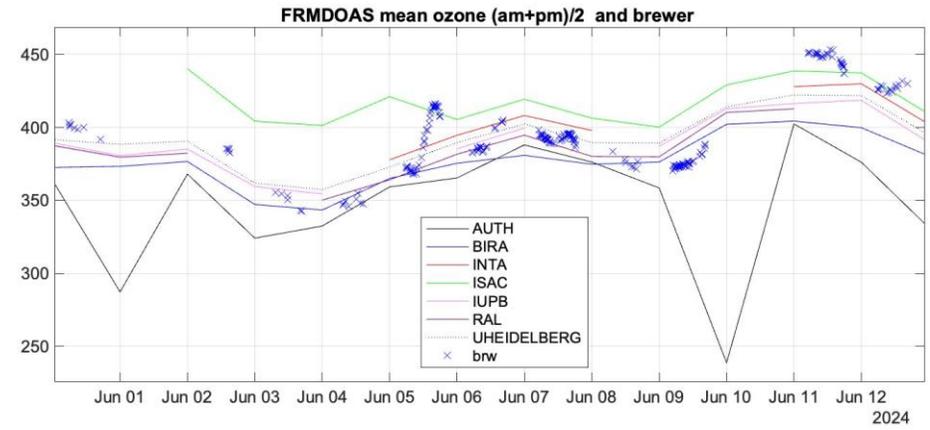
**Pandora V1 (operational):** differences ~1%

**Pandora V2:** differences increase to ~3%.

The ~3% Brewer–Pandora V2 discrepancy (despite differing cross-sections) is **under investigation**.

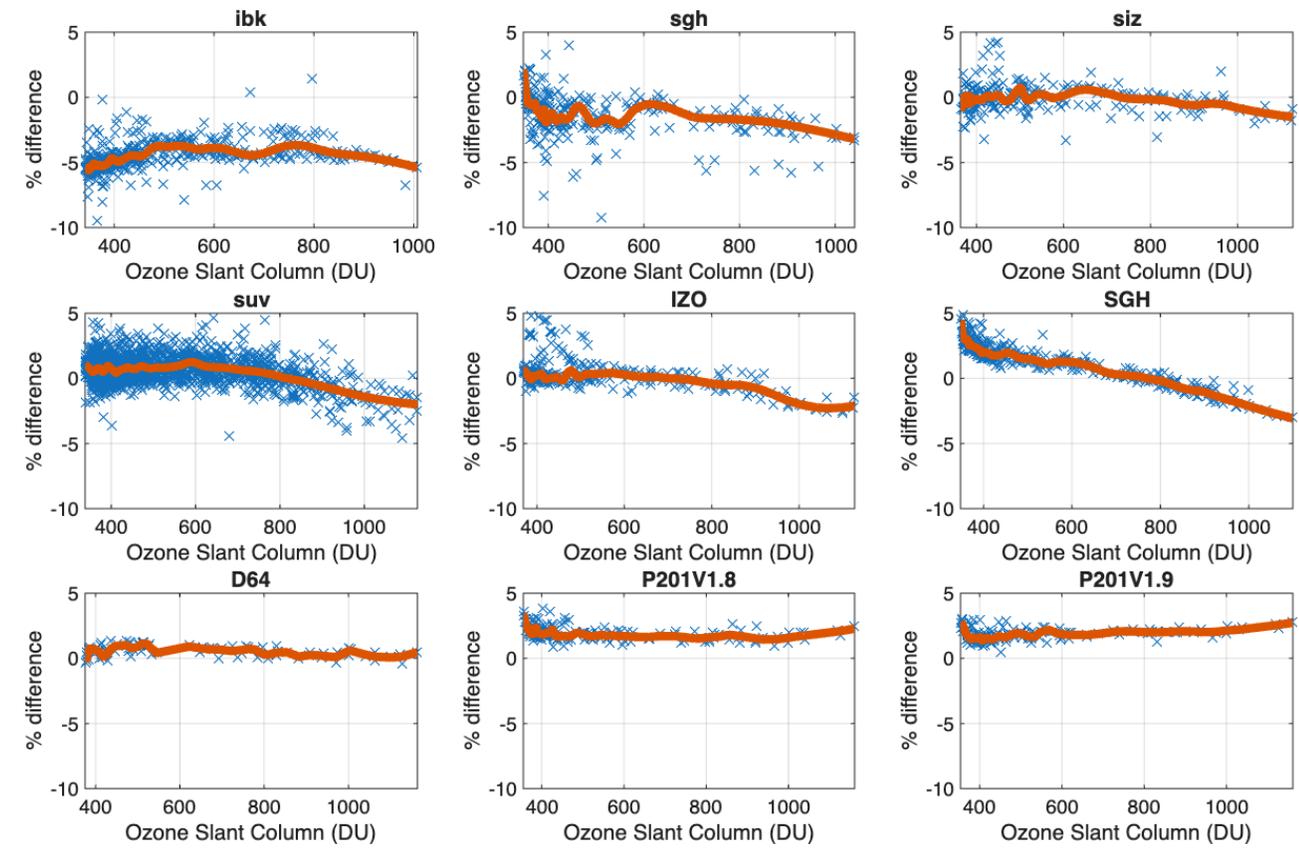
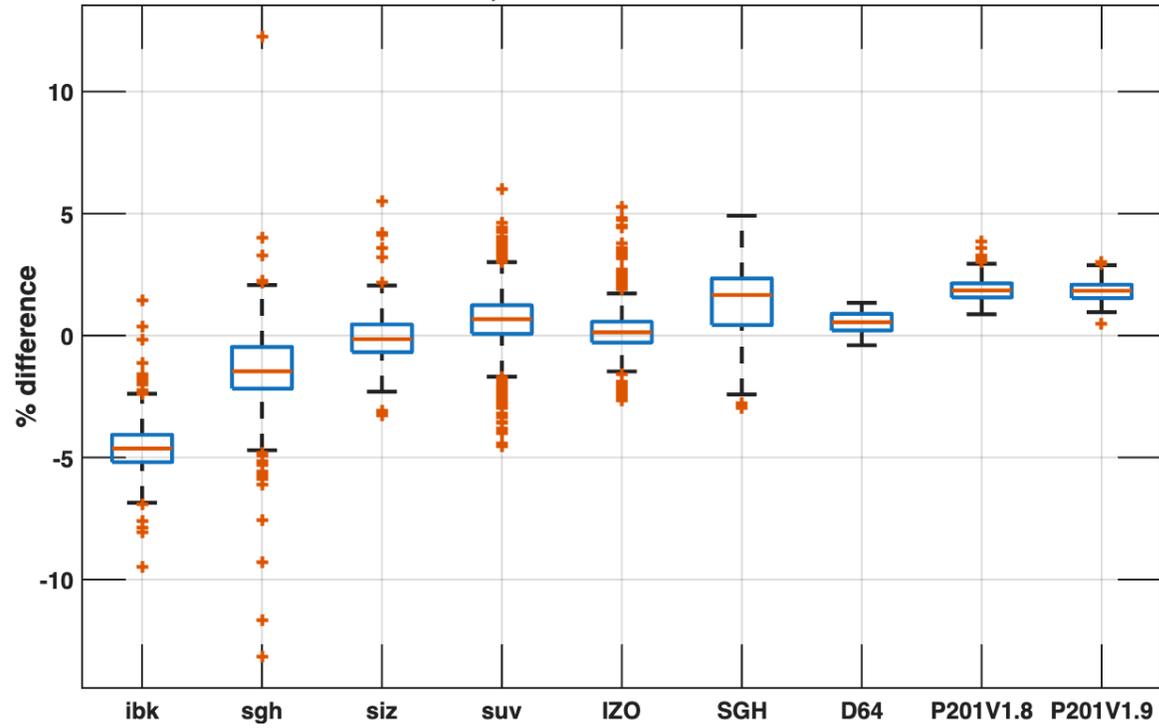


# CINDI3 - FRMDOAS



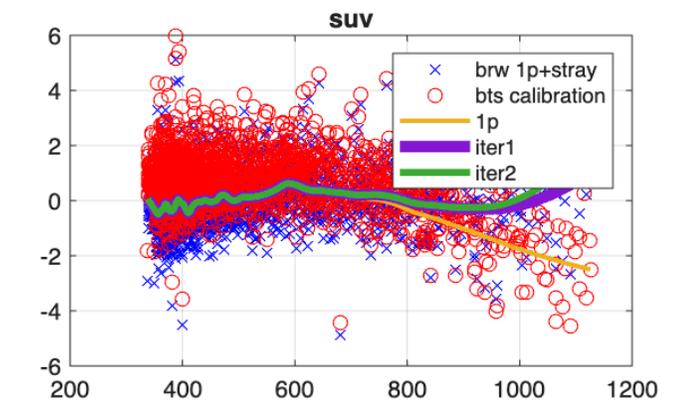
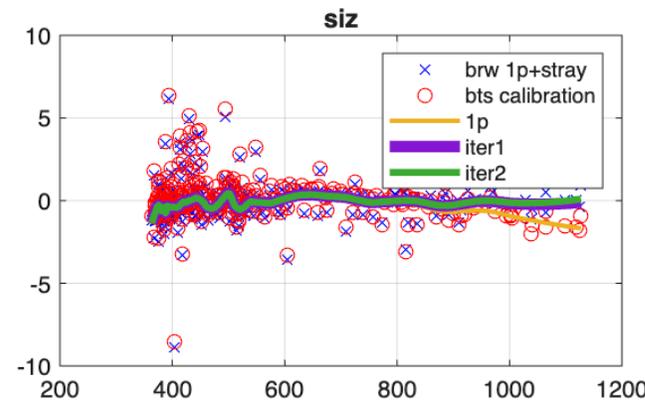
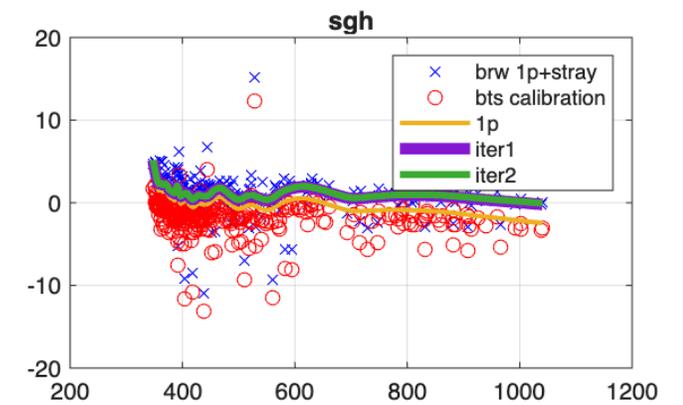
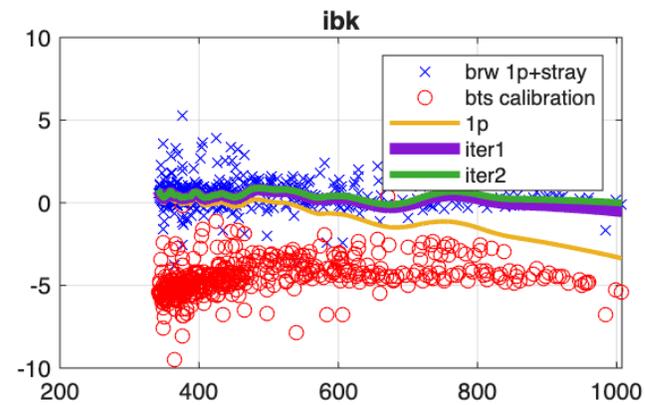
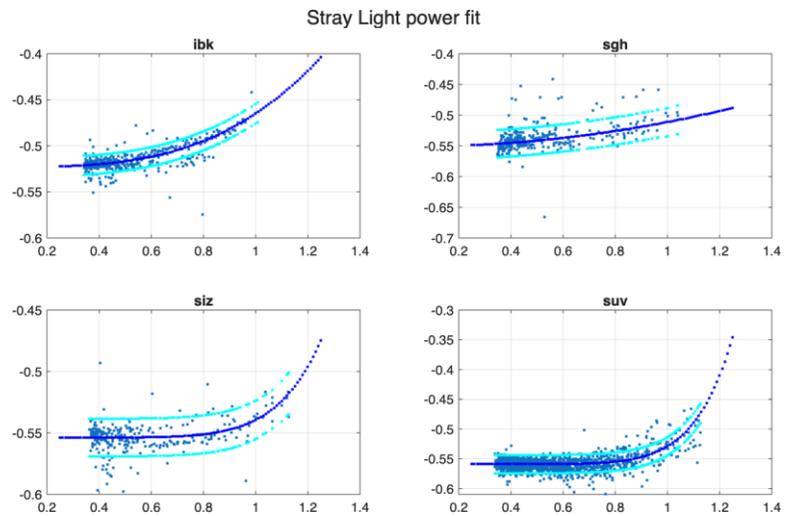
# DAV2024

Ratio to B185, SDK XIX RBCC-E Davos 2024



# DAV 2024 - CDR

## 1P + Stray Light calibration



## 20th Brewer Calibration Campaign

**Location & Organization** • El Arenosillo Atmospheric Sounding Station (INTA), Huelva, Spain • Co-organized by AEMET & INTA • Supported by the World Meteorological Organization (WMO) and UNEP

**Global Participation** • 50+ participants from 16 countries • 9 Dobson, 20 Brewer, and 6 BTS instruments calibrated

**Scientific Traceability** • Calibration references by: – Dobson DWD (Germany)  
– Brewer :AEMET-Izaña (Spain) –UV : PMOD-WRC Davos (Switzerland)

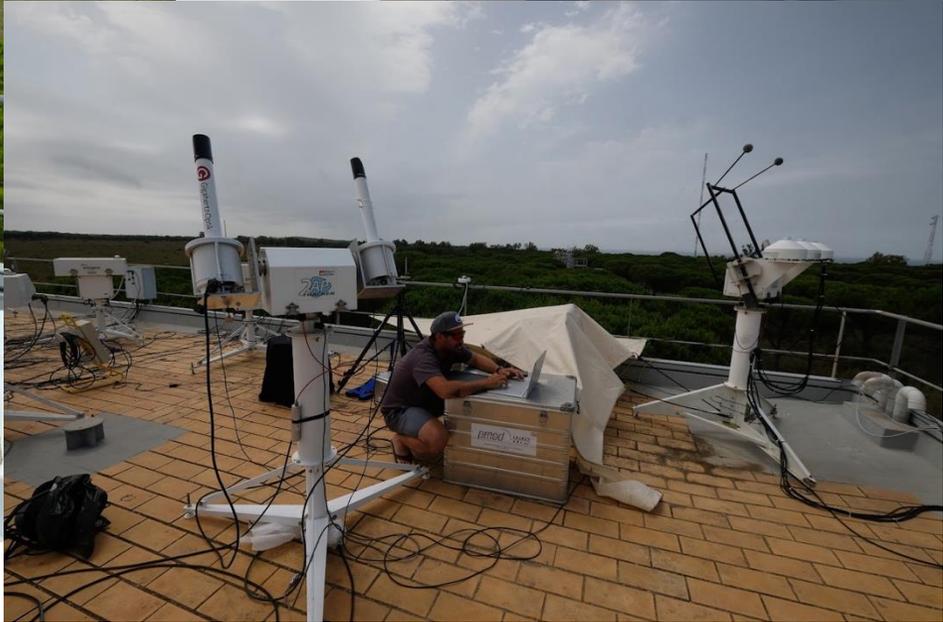
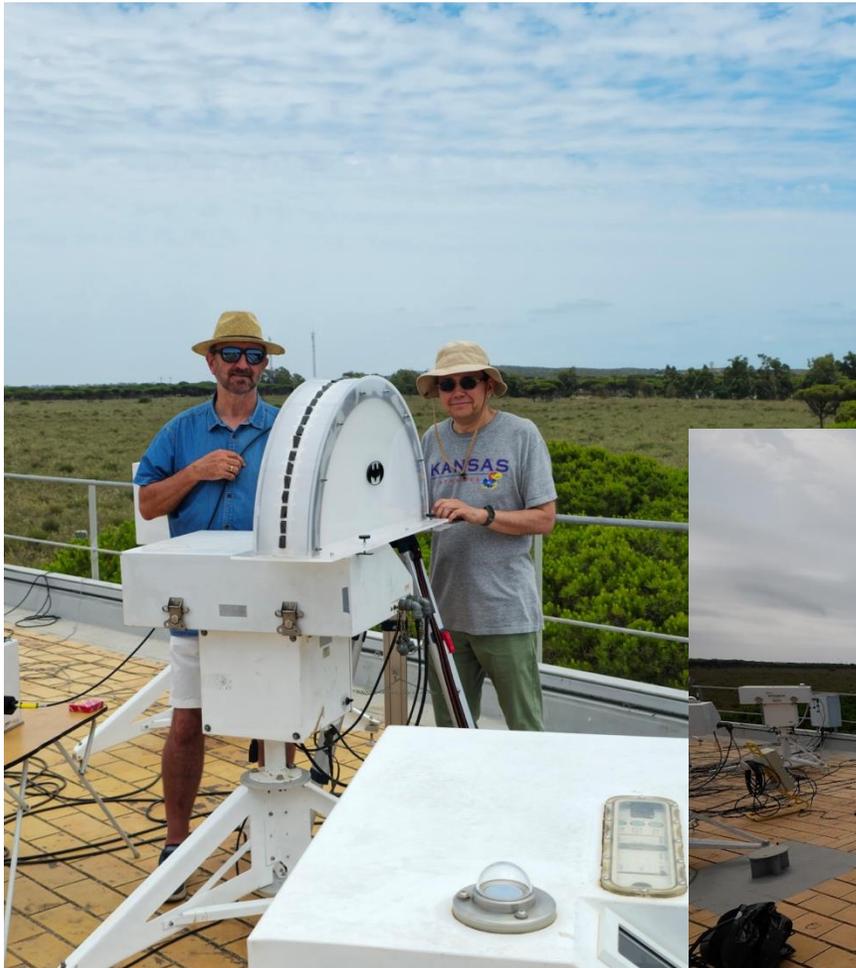
**Innovation & Training** • BTS devices under evaluation as Brewer replacements • WMO team testing BTS performance • First campaign fully operated through Eubrewnet (real-time data) • Technical training course for ozone instrument operators

# RBCC-E data protocol



## RBCC-E Calibration campaign

1. For Brewer instruments, it is essential to record raw observations, which must be submitted to the EUBREWNET services in real-time and from there. This includes the results from the characterization tests conducted during the maintenance period.
2. Prior to the commencement of the campaign, it is required to submit the Brewer operative software, instrument configuration, and data from past calibrations, along with observations from the previous year. (see observations table)
3. During the 'blind days' of the campaign, no adjustments or interventions will be made to the operational instruments to ensure an unbiased assessment of the instrument calibration.
4. The outcome of your participation in the campaign will be published in a GAW (Global Atmosphere Watch) report, similar to previous campaigns.
5. All the participating teams are requested to participate on the daily briefings, this participation could be telematic.
6. For the UV calibration with QASUME unit, the EUBREWNET processing will be used for the outcome



# Eubrewnet : real time and q/c

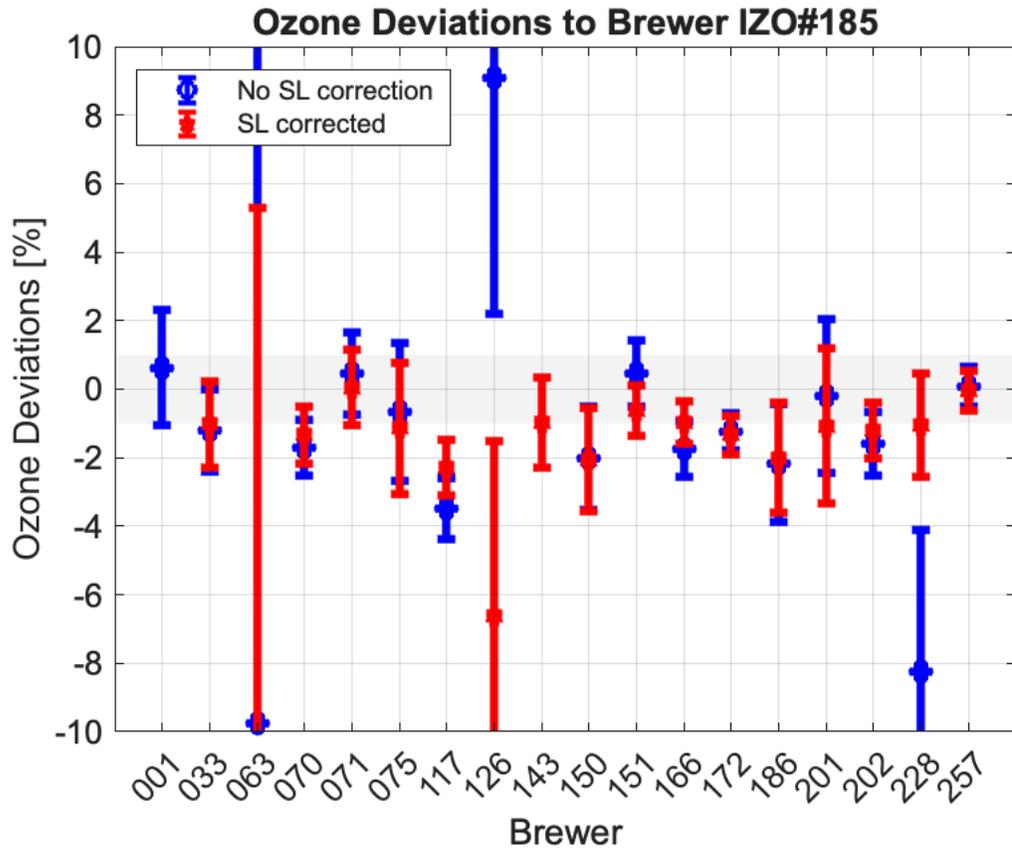


## Brewers close to #143

- Brewer #126
- Brewer #228
- Brewer #257
- Brewer #151
- Brewer #172
- Brewer #71
- Brewer #75
- Brewer #166
- Brewer #117
- Brewer #63
- Brewer #1
- Brewer #150
- Brewer #33
- Brewer #185
- Brewer #186
- Brewer #70
- Brewer #202
- Brewer #143

# 20<sup>th</sup> RBCC-E campaigning

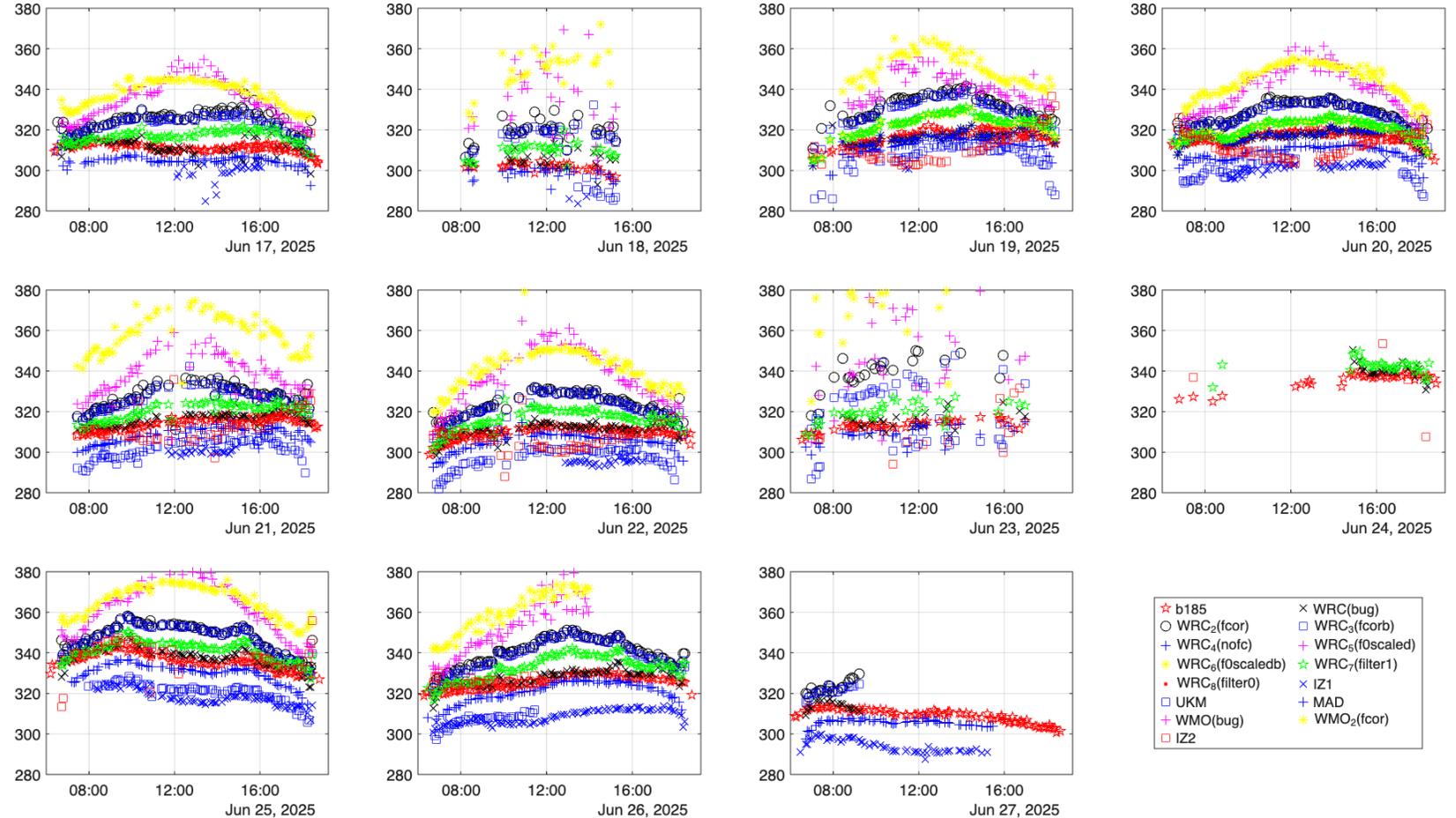
# El Arenosillo 2025



	<u>brw</u>	<u>mean</u>	<u>std</u>	<u>mean_slc</u>	<u>std_slc</u>	<u>SL_corr</u>
<b>IZO#185</b>	185	0	0	0	0.1	1
<b>ATN#001</b>	1	0.7	1.4	89.3	19.1	0
<b>MAD#033</b>	33	-1.1	1.2	-0.9	1.2	1
<b>ITA#063</b>	63	-5	18.7	-10.9	16.7	0
<b>COR#070</b>	70	-1.5	0.6	-1.1	0.6	1
<b>NAI#071</b>	71	0.7	0.8	0.2	0.7	1
<b>UK#075</b>	75	-0.8	1.9	-1.3	1.8	0
<b>MUR#117</b>	117	-3.5	0.9	-2.2	0.7	1
<b>UK#126</b>	126	10.1	6.6	-6.8	4.9	1
<b>EGY#143</b>	143	-22.5	5.3	-0.9	1.2	1
<b>ARE#150</b>	150	-2.5	1.3	-2.5	1.3	0
<b>SCO#151</b>	151	0.7	0.7	-0.5	0.6	1
<b>ZAR#166</b>	166	-1.8	0.8	-1	0.6	1
<b>UK#172</b>	172	-1.3	0.5	-1.4	0.5	1
<b>MAD#186</b>	186	-2.3	1.6	-2	1.6	1
<b>TAM#201</b>	201	0	2.5	-0.9	2.5	0
<b>DNK#202</b>	202	-1.7	0.9	-1.3	0.9	1
<b>DNK#228</b>	228	-9.3	3.8	-1.3	1.4	1
<b>IZO#257</b>	257	0	0.6	-0.1	0.6	0

# HUELVA 2025- BTS

XX RBCC-E , El Arenosillo Jun /2025 (cleaned observations)





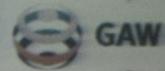
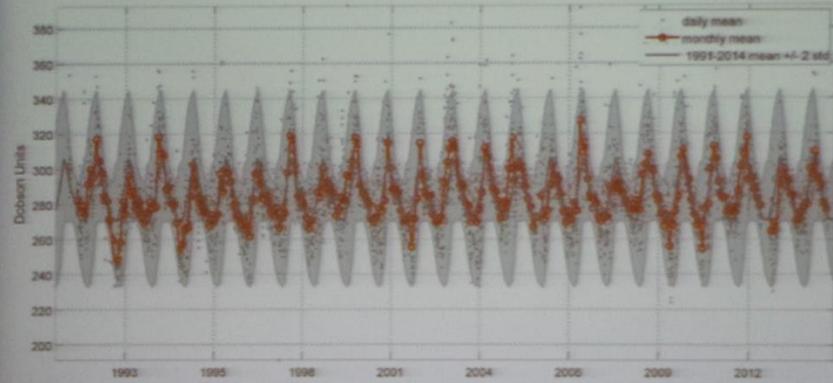








# Ozone and UV: Regional Brewer Calibration Center for Europe (RBCCE)



NOGIC campaigns



[www.rbcc-e.org](http://www.rbcc-e.org)

Close collaboration with the Dobson Calibration Centre Hohenpeissenberg (DWD)







