WMO-CIMO Testbed for Aerosols and Water Vapour Remote Sensing Instruments (Izaña, Spain)

General Site Information

The Izaña testbed is a high mountain observatory affiliated to the Izaña Atmospheric Research Centre (IARC) from the State Meteorological Agency of Spain (AEMET). The Izaña Observatory celebrates the 100-year anniversary in 2016. AEMET-IARC participates in several observational networks including:

- SYNOP (surface synoptic observations) and radio/ozone sonde networks (since 1916)
- WMO-GAW (Global Atmospheric Watch)
- NDACC (Network for Detection of Atmospheric Composition Change)
- TCCON (Total Carbon Column Observing Network)
- BSRN (Baseline Surface Radiation Network)
- AERONET (AErosol RObotic NETwork)
- MPLNET (Micropulse Lidar NETwork)
- E-GVAP (EUMETNET EIG GNSS water vapour programme)
- PANDORA-PANDONIA

Izaña Observatory hosts the WMO Regional Brewer Calibration Centre (RBCC) for Europe and Africa, is an absolute calibration site for AERONET, AERONET-Europe, CARSNET (China), PHOTONS (*PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire*, France) and RIMA (*Red Ibérica de Medida Fotométrica de Aerosoles*, Iberia) photometer networks, and an absolute calibration site of the *Physicalisch-Meteorologisches Observatorium Davos* World Radiation Centre (PMOD-WRC). The IARC is also actively involved in the co-management of the WMO Sand and Dust Storm Warning Advisory and Assessment Regional Centre for Northern Africa, Middle East and Europe, hosted by AEMET and the Barcelona Supercomputing Centre (BSC). The Izaña Observatory has a long experience in hosting intensive instrument field campaigns and runs comprehensive programmes for monitoring and investigation of greenhouse gases, the ozone layer and related ozone depleting substances, reactive gases, solar radiation, and chemical and physical properties of atmospheric aerosols. Izaña also constitutes an international platform where specific measurements are used to assess observations made on board satellites and simulations from chemical transport models.

Testbed location:	28.309°N, 16.499°W, 2,373 m ASL
Climate type:	Cbs (Temperate dry summer climate)
Contact person:	Dr Emilio Cuevas
Email:	ecuevasa@aemet.es
Address:	C/ La Marina, 20, Planta 6, 38071, Santa Cruz de Tenerife, Spain
Tel:	+34 92 215 1718
Fax:	+34 92 257 4475
Website:	http://izana.aemet.es

Main activities

Areas of research

The Izaña Atmospheric Research Centre conducts monitoring and research activities related to atmospheric constituents that are capable of forcing change in the climate of the Earth (greenhouse gases and aerosols), that may cause depletion of the ozone layer, and that play key roles in air quality on a local to global scale.

The IARC is also involved in numerous evaluation activities of both ground based and satellite-borne atmospheric sensors. The centre also collaborates with different institutions in the development of new systems for monitoring the atmosphere.

The main areas of research are:

- Long-range transport of reactive gases and aerosols,
- Mineral dust transport and characterization of the Saharan Air Layer,
- Aerosols radiative forcing,
- Impacts of mineral dust on ocean and human health,
- Decadal variations of aerosols/dust and meteorological patterns,
- Physicochemical processes of the upper troposphere and stratosphere,
- Spatial distribution of sources and sinks of greenhouse gases,
- Development and validation of total ozone quality assurance methodologies in order to obtain high quality measurements, on a global scale, to validate satellite observations, feed and verify the prediction models,
- Satellite data validation.

Capabilities

The Izaña Observatory (IZO) is managed by the Izaña Atmospheric Research Center (IARC), from the State Meteorological Agency of Spain (AEMET), Environment Ministry.

IARC has been officially acknowledged as a Joint Research Unit of the *Consejo Superior de Investigaciones Científicas* (the National Research Council, CSIC) through the Institute of Environmental Assessment and Water Research (IDÆA-CSIC), Unit for the Study of Air Pollution. This Unit was created in February 2005, at that time through the Institute of Earth Sciences Jaume Almera, and has been extended until today.

IARC has been monitoring a large variety of atmospheric constituents for many years. It has a status of a Global Atmospheric Watch (GAW) station since 1984 and it has actively contributed to international networks and databases such as World Ozone and Ultraviolet Radiation Data Centre (WOUDC), Network for the Detection of Atmospheric Composition Change (NDACC), Aerosol Robotic Network (AERONET), Baseline Surface Radiation Network (BSRN), Micropulse lidar Network (MPLNET), and Total Carbon Column Observing Network (TCCON). Since 2003 this research centre represents the Regional Brewer spectrophotometer Calibration Centre for Europe (RBCC-E) designated by the World Meteorological Organization (WMO) and it is a reference for Fourier Transform Spectrometry (FTS) community.

Monitoring and studies of aerosol optical properties with remote sensing techniques were initiated at IZO in 2004. IZO has been a master-sun calibration site for PHOTONS (*PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire*) network since June 2004. This network is part of the AERONET (AErosol RObotic NETwork; http://aeronet.gsfc.nasa.gov/) Cimel sunphotometer network. IZO is also the sun-calibration centre of the Spanish RIMA (*Red Ibérica de Medida Fotométrica de Aerosoles*) Cimel sunphotometer network (http://www.rima.uva.es/RIMA/) managed by the Group of Atmospheric Optics from the Valladolid University (GOA-UVA), in collaboration with the IARC. RIMA is an associated network of PHOTONS/AERONET. IZO is an ad-hoc calibration site for nocturnal aerosols observations with the new Triple CE318-T photometer within the ACTRIS AERONET-Europe Central Facility. IZO is an absolute calibration site of the PMOD-WRC calibrating PFR instruments of the world triad reference.

IARC manages the AERONET sites of Izaña (IZO), Santa Cruz de Tenerife (SCO) and Tamanrasset (Algeria). A project funded by the International Cooperation Agency of Spain (AECID) and support from WMO Trust Fund deployed three new AERONET instruments in Northern Africa (Egypt, Tunisia and Morocco). This unique network provides dust information near dust sources over the Sahara and is a key observational facility, within the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) Northern Africa, Middle East and Europe Regional Centre, for dust modelling and aerosol satellite-based verification and validation activities.

The IARC and the Spanish Institute for Aerospace Technology (*Instituto Nacional de Tecnica Aeroespacial*, INTAl) co-manage the MPL routine observation management and started a long-term measurement program in 2005. The instrument is part of the NASA MPLNET worldwide aerosol lidar network (http://mplnet.gsfc.nasa.gov). This instrument, operated at Santa Cruz de Tenerife, is the unique aerosol lidar in Northern Africa that provides information about the vertical structure of the Saharan Air Layer over the North Atlantic.

Infrastructure

The Izaña Atmospheric Observatory (IZO) facilities consist of three separate buildings: the main building, inaugurated in 1916; the aerosols lab (PARTILAB), a small nearby building of the same period; and the technical tower, completely rebuilt in early 2000, which hosts most of the instruments. Details of the IZO measurement programme are given in Table 1.

The main building is a two-storey building with a total area of 1,420 m^2, which hosts the following facilities: office space, dining room, kitchen, library, conference hall with audio-visual system, meeting room, engine rooms, a mechanical workshop, and an electronics workshop. In addition, there is residential accommodation available for visiting scientists (seven double en-suite rooms).

The technical tower is a seven-storey building with a total area of 900 m^2. It includes 20 laboratories distributed among the different floors. All the laboratories are temperature-controlled. Details of the IZO Technical Tower facilities are given in Table 2.

Image of Izaña Atmospheric Observatory (IZO)

Izaña Atmospheric Observatory (2,373 m) with the volcano Teide (3,718 m) to the left of the image.

On the ground floor of the technical tower, there are two storage spaces, one of them for pressured cylinders (tested and certified at the Canary Islands Regional Council for Industry) and the other one for cylinder filling using oil-free air compressors. This floor also includes the central system for supplying high purity gases (H_2, N_2, Ar/CH_4) and synthetic air to the different laboratories. On the second floor, there is a dark-room with the necessary calibration set-ups for the IZO radiation instruments. On the top of the technical tower there is a 160 m^2 flat horizon-free terrace for the installation of outdoor scientific instruments that need sun or moon radiation. It also has the East and West sample-inlets which supply the ambient air needed by in-situ trace gas analysers set up in different laboratories.

The PARTILAB is a 40 m^2 building used as an on-site aerosol measurement laboratory. It has four sample-inlets connected to aerosol analysers. Outside Izaña Atmospheric Observatory there are the following facilities: 1) a 160 m^2 flat horizon-free platform with communications and UPS used for measurement field campaigns; 2) the meteorological garden containing two fully-automatic meteorological stations (one of them the SYNOP station and the second one for meteorological research), manual meteorological gauges, a total sky camera, a GPS/GLONAS receiver, a lightning detector, and an electric field mill sensor; and 3) the Sky watch cabin hosting four cameras for cloud observations with corresponding servers.

The optical calibration facility at IZO has been developed within the framework of the Specific Agreement of Collaboration between the University of Valladolid and the IARC-AEMET: "To establish methodologies and quality assurance systems for programs of photometry, radiometry, atmospheric ozone and aerosols within the atmospheric monitoring programme of the World Meteorological Organization". The main objective of the optical calibration facility is to perform Quality Assurance & Quality Control (QA/QC) assessment of the solar radiation instruments involved in the ozone, aerosols, radiation, and water vapour programs of the IARC. The seven set-ups available are the following:

1) Set-up for the absolute irradiance calibration by calibrated standard lamps in a horizontally oriented position suitable for small radiometers. The basis of the absolute irradiance scale consists of a set of FEL-type 1000 W lamps traceable to the primary irradiance standard of the *Physikalisch-Technische Bundesanstalt* (PTB).
2) Set-up for the absolute irradiance calibration by calibrated standard lamps in a vertical oriented position suitable for relatively large spectrophotometers. The basis of the absolute irradiance scale consists of a set of DXW-type 1000 W lamps traceable to the primary irradiance standard of the PTB.
3) Set-up for the absolute radiance calibration by calibrated integrating sphere. The system is traceable to the AERONET standard at Goddard Space Flight Center (Washington, USA). This set-up is mainly used by Cimel sun-photometers, but other instruments are also calibrated.
4) Set-up for the angular response calibration. It is used to quantify the deviations of the radiometer's angular response from an ideal cosine response. The relative angular response function is measured by rotating the mechanical arm where the seasoned DXW-type 1000 W lamp is located. The rotation over ±90° is controlled by a stepper motor with a precision of 0.01° while the instrument is illuminated by the uniform and parallel light beam of the lamp.
5) Set-up for the spectral response calibration. It is used to quantify the spectral response of the radiometer. The light is scattered by an Optronic double monochromator OL 750 within the range 200 to 1100 nm with a precision of 0.1 nm. An OL 740-20 light source positioned in front of the entrance slit acts as radiation source and two lamps, UV (200-400 nm) and Tungsten (250-2500 nm) are available.
6) Set-up for the slit function determination. The characterization of the slit function is performed illuminating the entrance slit of the spectrophotometer with the monochromatic light of a VM-TIM He-Cd laser. The nominal wavelength of the laser is 325 nm, its power is 6 mW, and its beam diameter is 1.8 mm.
7) Set-up for the alignment of the Brewer spectrophotometer optics. It is suitable to perform adjustments of the optics without sending the instrument to the manufacturer.

Table 1: Izaña Atmospheric Observatory measurement programme

Parameter	Since	Present Instrument	Frequency
Greenhouse Gases and Carbon Cycle			
CO_2	Jun 1984	NDIR Licor 7000 (Primary instrument) NDIR Licor 6252 (Secondary instrument)	Continuous (30″) Continuous (30″)
CH_4	Jul 1984	GC-FID Dani 3800 GC-FID Varian 3800	2 samples/hour 4 samples/hour
N_2O	Jun 2007	GC-ECD Varian 3800	4 samples/hour
SF_6	Jun 2007	GC-ECD Varian 3800	4 samples/hour
CO	Jan 2008	GC-RGD Trace Analytical RGA-3	3 samples/hour
In-situ Reactive Gases			
O_3	Jan 1987	UV Photometry TECO 49-C (Primary instrument) TECO 49-C (Secondary instrument)	 Continuous (1′) Continuous (1′)
CO	Nov 2004	Non-dispersive IR abs. Thermo 48C-TL	Continuous (1′)
SO_2	Jun 2006	UV fluorescence Thermo 43C-TL	Continuous (1′)
$NO\text{-}NO_2\text{-}NO_x$	Jun 2006	Chemiluminescence Thermo 42C-TL	Continuous (1′)
Total Ozone Column and UV			
Column O_3	May 1991	Brewer Mark-III #157 (Primary Reference) Brewer Mark-III #183 (for developments) Brewer Mark-III #185 (Travelling Reference)	~100/day ~100/day ~100/day
Spectral UV: 290-365 nm	May 1991	Brewer Mark-III #157 (Primary Reference) Brewer Mark-III # 183 (for developments) Brewer Mark-III #185 (Travelling Reference	~30′ ~30′ ~30′
Spectral UV: 290-450 nm	May 1998	Bentham DM 150	Campaigns
Column SO_2	May 1991	Brewer Mark-III #157 (Primary Reference) Brewer Mark-III # 183 (for developments) Brewer Mark-III #185 (Travelling Reference)	~100/day ~100/day ~100/day
Column SO_2	Oct 2011	Pandora#101	10′
Column HCNO	Oct 2011	Pandora#101	10′

Parameter	Since	Present Instrument	Frequency
Fourier Transform Infrared Spectroscopy (FTIR)			
Greenhouse gases, reactive gases, and O_3 depleting substances (O_3, HF, HCN, HCl, $ClONO_2$, C_2H_6, HNO_3, CH_4, CO, CO_2, N_2O, NO, NO_2, H_2O, HDO, OCS)	Jan 1999 May 2007	Fourier Transform Infrared Spectroscopy Bruker IFS 120/5HR (co-managed with KIT) Middle infrared (MIR) solar absorption spectra Near infrared (NIR) solar absorption spectra	3 days/week (weather permitting)
Water vapour isotopologues (δD and δ18O)	Mar 2012	Picarro L2120-I δD and δ18O Analyser	Continuous (2″)
In-situ aerosols			
Chemical composition of total particulate matter (PM_T)	Jul 1987	High-volume sampler custom built/MVC™/MCZ™ Concentrations of soluble species by ion chromatography (Cl^-, NO_3^- and SO_4^{2-}) and FIA colorimetry (NH_4^+), major elements (Al, Ca, K, Na, Mg and Fe) and trace elements by ICP-AES and ICP-MS were determined at the Research Council of Spain (CSIC) in Barcelona (http://www.idaea.csic.es/)	8h sampling at night
Chemical composition of particulate matter < 2.5 µm ($PM_{2.5}$)	Apr 2002	High-volume sampler custom built/MVC™/MCZ™ Concentrations determined at CSIC	8h sampling at night
Chemical composition of particulate matter < 10 µm (PM_{10})	Jan 2005	High-volume sampler custom built/MVC™/MCZ™ Concentrations determined at CSIC	8h sampling at night
Number of particles > 3 nm	Nov 2006	TSI™, UCPC 3025A	1′
Number of particles > 2.5 nm	Dec 2012	TSI™, UCPC 3776	1′
Number of particles > 10 nm	Dec 2012	TSI™, UCPC 3772	1′
Size distribution of 10-400 nm	Nov 2006	TSI™, class 3080 + CPC 3010	5′
Size distribution of 0.7-20 µm	Nov 2006	TSI™, APS 3321	10′
Absorption coefficient 1λ	Nov 2006	Thermo™, MAAP 5012	1′
Attenuation 7λ	Jul 2012	Magee™, Aethalometer AE31-HS	1′
Scattering coefficient 3λ	Jun 2000	TSI™, Integration Nephelometer 3563	1′

Parameter	Since	Present Instrument	Frequency
Column aerosols			
AOD and Angstrom at 415, 499, 614, 670, 868, and 936 nm	Feb 1996	YES Multi Filter-7 Rotating Shadow-Band Radiometer (MFRSR)	1′
AOD and Angstrom at 340, 380, 440, 500, 675, 870, 936, 1020 nm	Mar 2003	Cimel CE318 sun photometer	~ 15′
Fine/Coarse AOD Fine mode fraction	Mar 2003	Cimel CE318 sun photometer	~ 15′
Optical properties	Mar 2003	Cimel CE318 sun photometer	~ 1h
AOD and Angstrom during night period	July 2012	Cimel CE318T sun photometer	~ 15′ during moon phases
AOD and Angstrom at 368, 412, 500 and 862 nm	July 2001	WRC Precision Filter Radiometer (PFR)	1′
AOD at 769.9 nm	July 1976	MARK-I (at the IAC)	AOD at 769.9 nm
Radiation			
Global Radiation 285-2600 nm	Jan 1977	2 CM-21 and CM-11 Kipp & Zonen pyranometers (in parallel) and YES MFRSR	Continuous (1′)
Estimated Direct Radiation	Feb 1996	YES MFRSR	Continuous (1′)
Direct Radiation 200-4000 nm	Aug 2005	2 CH-1 Kipp & Zonen pyrheliometers	Continuous (1′)
Direct Radiation 200-4000 nm	Jun 2014	Absolute cavity pyrheliometer PMO6	Calibration campaigns (1′)
Radiation			
Diffuse radiation	Feb 1996	YES MFRSR	Continuous (1′)
Diffuse radiation 285-2600 nm	Aug 2005	2 CM-21 Kipp & Zonen pyranometers (in parallel)	Continuous (1′)
Downward long-wave radiation 4.5-42μm	Mar 2009	2 CG-4 Kipp & Zonen pyrgeometers (in parallel)	Continuous (1′)
UVB radiation 315-400 nm	Aug 2005	2 Yankee YES UVB-1 pyranometer (in parallel)	Continuous (1′)
UVA radiation 280-400 nm	Mar 2009	Radiometers UVS-A-T	Continuous (1′)
PAR 400-700 nm	Aug 2005	Pyranometer Kipp & Zonen PQS1	Continuous (1′)

Parameter	Since	Present Instrument	Frequency
DOAS (managed by the Spanish National Institute for Aerospace Technology, INTA)			
Column NO_2	May 1993	UV-VIS DOAS EVA and MAXDOAS RASAS II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Column O_3	Jan 2000	UV-VIS MAXDOAS RASAS II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Column BrO	Jan 2002	UV-VIS MAXDOAS ARTIST-II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Tropospheric O_3	May 2010	UV-VIS MAXDOAS RASAS II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Tropospheric NO_2	May 2010	UV-VIS MAXDOAS RASAS II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Tropospheric IO	May 2010	UV-VIS MAXDOAS RASAS II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Column HCHO	Jan 2015	UV-VIS MAXDOAS ARTIST II (INTA's homemade; www.inta.es)	Every ~3′ during twilight
Column Water Vapour			
Precipitable Water Vapour (PWV)	Feb 1996	YES MFRSR-7 radiometer (941 nm)	1′
PWV	Jul 2008	GPS-GLONASS LEICA receiver	15′ (ultra-rapid orbits) and 1h (precise orbits)
Vertical relative humidity	Dec 1963	Vaisala RS-92	Daily at 00 and 12 UTC
PWV	Mar 2003	Cimel CE318 sun photometer	~ 15′
PWV	Jan 1999	Fourier Transform Infrared Spectroscopy	3 days/week when cloud-free conditions

Parameter	Since	Present Instrument	Frequency
Meteorology			
Temperature	Jan 1916	Thies Clima 1.1005.54.700 3 Vaisala HMP45C (in parallel) Vaisala PTU300 Thies Clima 1.0620.00.000 (thermo-hygrograph) Campbell Scientific CS215 (tower top)	1′ 1′ 1′ Continuous 1′
Relative humidity	Jan 1916	Thies Clima 1.1005.54.700 3 Vaisala HMP45C (in parallel) Vaisala PTU300 Thies Clima 1.0620.00.000 (thermo-hygrograph) Campbell Scientific CS215 (tower top)	1′ 1′ 1′ Continuous 1′
Wind direction and speed	Jan 1916	RM Young Sonic 3D 81000 Thies Clima Sonic 2D Thies Clima Sonic 2D Thies Clima Sonic 2D (tower top)	1′ 1′ 1′ 1′
Pressure	Jan 1916	Setra 470 Vaisala PTU 300 BELFORT 5/800AM/1 (Barograph) Setra 470 (tower top)	1′ 1′ Continuous 1′
Rainfall	Jan 1916	Thies Clima tipping bucket Thies Clima tipping bucket Hellman rain gauge Hellman pluviograph	1′ 1′ Daily Continuous
Sunshine duration	Aug 1916	Kipp & Zonen CSD3 Campbell-Stokes sunshine recorder	10′ Continuous
Present weather and visibility	Jul 1941	Thies Clima disdrometer Biral 10HVJS	10′ 10′
Vertical profiles of T, RH, P, wind direction and speed, from sea level to ~30 km altitude	Dec 1963	RS92+GPS radiosondes launched at Güimar automatic radiosonde station (WMO GUAN station #60018, managed by the Meteorological Centre of Santa Cruz de Tenerife)	Daily at 00 and 12 UTC

Parameter	Since	Present Instrument	Frequency
Meteorology			
Soil surface temperature	Jan 1953	2 Thies Clima Pt100 (in parallel)	10′
Soil temperature (20 cm)	Jan 2003	2 Thies Clima Pt100 (in parallel)	10′
Soil temperature (40 cm)	Jan 2003	2 Thies Clima Pt100 (in parallel)	10′
Atmospheric electric field	Apr 2004	Electric Field Mill PREVISTORM-INGESCO	10″
Lightning discharges	Apr 2004	Boltek LD-350 Lightning Detector	1′
Cloud cover	Sep 2008	Sieltec Canarias S.L. SONA total sky camera	5′
Fog-rainfall	Nov 2009	Thies Clima Tipping Bucket with 20 cm^2 mesh Hellman rain gauge with 20 cm^2 mesh	1′ Daily
Sea-cloud cover	Nov 2010	AXIS Camera: West View (Orotava Valley) AXIS Camera: South View (Meteo Garden) AXIS Camera: North View AXIS Camera: East View (Güimar Valley)	5′ 5′ 5′ 5′
Drop size distribution and velocity of falling hydrometeors	May 2011	OTT Messtechnik OTT Parsivel	1′
Aerobiology			
Pollens and spores	Jun 2006	Hirst, 7-day recorder VPPS 2000 spore trap (Lanzoni S.r.l.). Analysis performed with a Light microscope, 600 X at the *Laboratori d'Anàlisis Palinològiques, Universitat Autònoma de Barcelona.*	Continuous (1 h resolution) from April to October
Phenology			
Emergence of the inflorescence, the appearance of flower buds, flowering, and fruit development according to the BBCH code of 7 taxa	Jan 2014	Visual inspection/counting	Weekly during growing season, and monthly the rest of the year

Table 2: Izaña Atmospheric Observatory Technical Tower facilities

Floor	Facilities	Description
Ground Floor	Mechanical workshop	33 m^2 room with the necessary tools to carry out first-step mechanical repairs.
	Electronics workshop	25 m^2 room equipped with oscilloscopes, power supplies, multimeters, soldering systems, etc. to carry out first-step electronic repairs.
	Heating system	Central heating and hot water 90 kW system.
	Air conditioning system	Central air conditioning system for labs.
	Engine room: Backup generators	General electrical panel and two automatic start-up backup generators (400 kVA and 100 kVA, respectively).
	UPS room	Observatory's main UPS (40 kVA redundant) used for assuring the power of the equipment inside the building and an additional UPS (10 kVA) for the outside equipment.
	Compressor room	Room with clean oil-free air compressors used for calibration cylinders filling. It also contains the general pumps for the East and West sample inlets.
	Warehouse / Central gas supply system	30 m^2 warehouse authorized for pressure cylinders. Central system for high purity gas (H_2, N_2, Ar/CH_4) and synthetic air supply.
	Lift	6-floors. No lift access to roof terrace.
First Floor	Archive room	Archive of bands and historical records.
	Technical equipment warehouse	Spare parts for the Observatory's technical equipment.
	Meeting room	8 person meeting room
Second Floor	Optical calibration facility	30 m^2 dark room hosting vertical and horizontal absolute irradiance, absolute radiance, angular response, and spectral response calibration set ups.
	T2.1 Laboratory	10 m^2 lab with access to West sample inlet.
	T2.2 Laboratory	9 m^2 lab with access to East sample inlet.
	T2.3 Laboratory	13 m^2 lab hosting Picarro L2120-I δD and δ18O analyser with access to East sample inlet
Third Floor	Greenhouse gases laboratories	70 m^2 shared in two labs hosting CO_2, CH_4, N_2O, SF_6 and CO analysers with access to the East and West sample inlets.
Fourth Floor	All-purpose laboratories	Three labs with access to the East and West sample inlets.

Floor	Facilities	Description
Fifth Floor	Reactive gases laboratory	10 m^2 lab hosting NO-NO_2, CO, and SO_2 analysers with access to West sample inlet.
	Communications room	Server room and WIFI connection with Santa Cruz de Tenerife headquarters.
	Brewer laboratory	20 m^2 lab for Brewer campaigns.
Sixth Floor	Surface ozone laboratory	10 m^2 laboratory hosting surface O_3 analysers with access to West sample inlet.
	Solar photometry laboratory	10 m^2 maintenance workshop for solar photometers.
	Spectroradiometer laboratory	25 m^2 laboratory hosting two MAXDOAS and two spectroradiometers connected with optical fibre.
Roof	Instrument terrace	160 m^2 flat horizon-free terrace hosting outdoor instruments, East and West sample-inlets, wind, pressure, temperature and humidity gauges.

The main facilities at IZO are complemented with the following "satellite" facilities:

1) The Santa Cruz de Tenerife Observatory (SCO)

SCO is located on the roof of the IARC headquarters at 52 m ASL in the capital of the island (Santa Cruz de Tenerife), close by the city harbour. Details of the SCO measurement programme are given in Table 3.

Image of Santa Cruz Observatory

This observatory has two main objectives: 1) to provide information of background urban pollution for atmospheric research and interactions with long-range pollution transport driven by trade winds or Saharan dust outbreaks, and 2) to perform complementary measurement programmes to those performed at IZO.

The IARC headquarters include the following facilities:

- A laboratory for reactive gases (surface O_3, NO-NO_2, CO and SO_2),
- A laboratory for micro pulse lidar (MPL), 2-wavelenght lidar, and ceilometer VL-51,
- A laboratory to dry and weigh filters of high and low volume aerosol samplers,
- A laboratory for the preparation of ozonesondes,
- A 25 m^2 flat horizon-free terrace for radiation instruments and air intakes.

The Aerosol Filters Laboratory

The Aerosol Filters Laboratory is equipped with an auto-calibration microbalance (Mettler Toledo, XS105DU) with a resolution of 0.01 mg, a set of standard weights, and an oven that reaches 300 °C. Filters are weighed after temperature and humidity conditioning following the requirements of the EN-14907 standards. This filter weighing procedure is used for determining the concentrations of TSP, PM10, PM2.5 and PM1 by means of the standardized methods. Filters are conditioned to 20 °C and a fixed relative humidity (50 % RH for air quality studies and 30 % RH for research studies) within a methacrylate chamber, which also contains the balance used for weighing the filters.

Aerosol Filters laboratory: temperature and relative humidity controlled chamber

The Ozonesonde Laboratory

Advanced preparation of the Science Pump Corporation (SPC) ECC ozone sensor (Model ECC-6A), together with digital Vaisala RS92 radiosonde and digital interface, is performed at the Ozonesonde Lab at SCO. Expendables such as radiosondes, interfaces, ozonesondes, ozone solution chemicals, syringes, needles, protection gloves, and triple distilled water are stored in this lab. A Science Pump Corporation Model TSC-1 Ozonizer/Test Unit is used for ozonesonde preparation. This unit has been designed for conditioning ECC ozonesondes with ozone and for checking the performance of the sondes prior to balloon release. The Ozonizer/Test Unit is installed inside a hood in which ambient air is passed through an active charcoal filter to destroy ozone and other pollutants (ozone-free air).

Table 3: Santa Cruz Observatory (SCO) measurement programme

Parameter	Since	Present Instrument	Frequency
In-situ Reactive Gases			
O_3	Nov 2004	UV Photometry TECO 49-C	Continuous (1′)
CO	Mar 2006	Non-dispersive IR abs. Thermo 48C-TL	Continuous (1′)
SO_2	Mar 2006	UV fluorescence Thermo 43C-TL	Continuous (1′)
NO-NO_2-NO_x	Mar 2006	Chemiluminescence Thermo 42C-TL	Continuous (1′)
Ozone and UV (managed by the AEMET's Special Networks Service at the nearby Met Centre)			
Column O_3	Oct 2000	Brewer Mark-II#033	> ~20/day
Spectral UV	Oct 2000	Brewer Mark-II#033	~30′
SO_2	Oct 2000	Brewer Mark-II#033	~30′
Column aerosols			
AOD and Angstrom at 340, 380, 440, 500, 675, 870, 936, 1020 nm	Jul 2004	Cimel CE318 sun photometer	~ 15′
Fine/Coarse AOD	Jul 2004	Cimel CE318 sun photometer	~ 15′
Vertical Backscatter-extinction @523 nm, clouds alt. and thickness	Nov 2005	Micropulse Lidar MPL-3, SES Inc., USA (co-managed with INTA (www.inta.es))	1′
Vertical backscatter-extinction @910 nm, cloud alt. and thickness	Jan 2011	Vaisala CL-51 Ceilometer	1′
Radiation			
Global radiation	Feb 2006	Pyranometer CM-11 Kipp & Zonen	Continuous (1′)
Direct radiation	Feb 2006	Pyrheliometer Eppley	Continuous (1′)
Diffuse radiation	Feb 2006	Pyranometer CM-11 Kipp & Zonen	1′
UV-B radiation	Aug 2011	Yankee YES UVB-1 pyranometer (managed by the AEMET's Special Networks Service at the nearby Met Centre)	1′

Parameter	Since	Present Instrument	Frequency
Column Water Vapour			
Vertical relative humidity	Dec 1963	Vaisala RS-92	Daily at 00 and 12 UTC
Precipitable Water Vapour (PWV)	Mar 2003	Cimel CE318 sun photometer	~ 15′
PWV	Jan 2009	GPS/GLONASS GRX1200PRO receiver	15′ (ultra-rapid orbits) and 1 h (precise orbits)
PWV (total column) over SCO when cloudless skies Cloud base heights when cloudy skies over SCO	Jun 2014	1 SIELTEC Sky Temperature Sensor (infrared thermometer prototype)	Every 30″ during the complete day
Meteorology			
Vertical profiles of T, RH, P, wind direction and speed, from sea level to ~30 km altitude	Dec 1963	RS92+GPS radiosondes launched at Güimar automatic radiosonde station (WMO GUAN station #60018) (managed by the Meteorological Centre of Santa Cruz de Tenerife)	Daily at 00 and 12 UTC
Temperature	Jan 2002	Vaisala HMP45C	1′
Relative humidity	Jan 2002	Vaisala HMP45C	1′
Wind Direction and speed	Jan 2002	RM Young wind sentry 03002	1′
Pressure	Jan 2002	Vaisala PTB100A	1′
Rainfall	Jan 2002	Thies Clima Tipping Bucket	1′
Aerobiology			
Pollens and spores	Oct 2004	Hirst, 7-day recorder VPPS 2000 spore trap (Lanzoni S.r.l.)	Continuous (1 h resolution)

2) The Botanic Observatory (BTO)

The Botanic Observatory is located 13 km north-east of IZO at 114 m ASL in the Botanical Garden of Puerto de la Cruz. BTO is hosted by the Canary Institute of Agricultural Research (ICIA) and includes the following facilities:

- Ozone Sounding Monitoring Laboratory: equipped with a Digicora MW31 receiver with Vaisala METGRAPH data acquisition and processing software and a surface ozone analyser
- Launch container: equipped with a helium supply system used for ozonesonde balloons filling.

In addition to the ozonesonde measurements, there is a fully equipped automatic weather station (temperature, relative humidity, pressure, precipitation, wind speed and direction), a global irradiance pyranometer and a surface ozone analyser (also used for additional ECC electrochemical sondes ground checking). For details of the BTO measurement programme, see Table 4.

Image of Botanic Observatory (BTO)

Table 4 Botanic Observatory measurement programme.

Parameter	Since	Present Instrument	Frequency
Reactive gases and ozonesondes			
Vertical profiles of O_3, PTU, and wind direction and speed, from sea level to ~33 km altitude	Nov 1992	ECC-A6+RS92/GPS radiosondes	1/week (Wednesdays)
Surface O_3	May 2011	UV Photometry TECO 49-C	1′
Radiation			
Global radiation	May 2011	Pyranometer CM-11 Kipp & Zonen	1′
Column Water Vapour			
Precipitable Water Vapour (PWV)	Jan 2009	GPS/GLONASS GRX1200PRO receiver	15’ (ultra-rapid orbits) and 1h (precise orbits)
Parameter	**Since**	**Present Instrument**	**Frequency**
Meteorology			
Temperature	Oct 2010	Vaisala F1730001	1′
Relative humidity	Oct 2010	Vaisala F1730001	1′
Wind direction and speed	Oct 2010	VaisalaWMT700	1′
Pressure	Oct 2010	Vaisala PMT16A	1′
Rainfall	Oct 2010	Vaisala F21301	1′

3) The Teide Peak Observatory (TPO) is located at 3,555 m ASL at the Teide Cable Car terminal in the Teide National Park. TPO was established as a satellite station of IZO primarily for radiation and aerosol observations at very high altitude. TPO station, together with Jungfraujoch (3,454 m ASL) in Switzerland, are the highest permanent radiation observatories in Europe.

This measurement site provides radiation and aerosol information under extremely pristine conditions and in conjunction with measurements at SCO and IZO allows us to study the variation of global radiation, UV-B and aerosol optical depth from sea level to 3555 m ASL In addition to radiation and aerosol measurements, there is a meteorological station and a water vapour isotopologues analyser. Full details of the measurement programme are given in Table 5.

Measurements at Teide Peak Observatory (TPO)

Table 5. Teide Peak Observatory measurement programme

Parameter	Since	Present Instrument	Frequency
Column aerosols			
AOD and Angstrom at 340, 380, 440, 500, 675, 870, 936 and1020 nm	Jun 1997	Cimel CE318 sun photometer (Co-managed with the University of Valladolid Atmospheric Optics Group)	~ 15′ (during Apr-Oct)
Fine/Coarse AOD Fine mode fraction	Jun 1997	Cimel CE318 sun photometer (Co-managed with the University of Valladolid Atmospheric Optics Group)	~ 15′ (during Apr-Oct)
Radiation			
Global Radiation	Jul 2012	Pyranometer CM-11 Kipp & Zonen	1′
UVB Radiation	Jul 2012	Pyranometer Yankee YES UVB-1	1′
Water vapour			
Water vapour isotopologues (δD and δ18O)	June 2013	Picarro L2120-I δD and δ18O analyser	Continuous (2″)
Meteorology			
Wind direction and speed	Oct 2011	Thies Clima Sonic 2D	Wind direction and speed
Temperature	Aug 2012	Vaisala HMP45C	1′
Relative humidity	Aug 2012	Vaisala HMP45C	1′
Pressure	Aug 2012	Vaisala PTB100A	1′

Ongoing and planned projects

Completed projects are:

- Development of data processing and calibration methodology for nocturnal observations of the new AERONET CE318-T (triple) photometer, and corresponding validations of AOD, AE and water vapour against external references (AERONET, GAW-PFR, Excalibur stellar photometer, and EGVAP),
- Determination of long-term AOD series by using artificial neural networks,
- Course on sunphotometry to colleagues of Egypt, Tunisia, Algeria and Morocco, in 2014 and 2015, with visits to AERONET stations or other field stations of IARC.

Ongoing and planned projects are:

- Development of methodologies for improving night-time lidar observations by using AOD measured with lunar photometry,
- Development of a new low-cost, highly automated and easily maintained Sieltec DSCR device for deriving total column aerosols/dust from zenith sky radiation intensity measurements at five wavelengths, including calibration methods, algorithms to determine dust-AOD and external validation against AERONET and GAW-PFR,
- Continuation of testing of the new Precision Solar Spectroradiometer (PSR) developed at PMOD-WRC,
- Developing methodologies to obtain long-term AOD series by using sunshine records, and corresponding validation against GAW-PFR reference,
- Obtaining traceability of AERONET-Europe reference with PMOD-WRC reference,
- Development of new inversion methods for the new CE318-T Triple photometer by using GRASP to obtain day and night aerosol optical properties,
- Testing a new 2-wavelength (with polarization) lidar from Cimel Electronique
- Performing a comprehensive comparison assessment of vertical extinction profiles from a CL51 ceilometer and a micropulse lidar,
- A training course on Cimel sunphotometer at Izaña is planned for 2016 within ACTRIS project.
- Specific training courses on sunphotometry and color index radiometer for North Africa stations are scheduled for 2016.

Publication list

A total of 111 peer-reviewed scientific papers related to WMO/GAW Programme have been published in the period 2011-2016. Last peer-reviewed specific papers related with activities of the Izaña Testbed are the following:

- García, R. D., García, O. E., Cuevas, E., Cachorro, V. E., Barreto, A., Guirado-Fuentes, C., Kouremeti, N., Bustos, J. J., Romero-Campos, P. M., and de Frutos, A. M.: Aerosol optical depth retrievals at the Izaña Atmospheric Observatory from 1941 to 2013 by using artificial neural networks, Atmos. Meas. Tech., 9, 53-62, doi:10.5194/amt-9-53-2016, 2016.
- Schneider, M., Wiegele, A., Barthlott, S., González, Y., Christner, E., Dyroff, C., García, O. E., Hase, F., Blumenstock, T., Sepúlveda, E., Mengistu Tsidu, G., Takele Kenea, S., Rodríguez, S., and Andrey, J.: A framework for accurate, long-term, global and high resolution observations of tropospheric H2O-δD pairs – a MUSICA review, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-330, in review, 2016.
- Barreto, A., Cuevas, E., Granados-Muñoz, M. J., Alados-Arboledas, L., Romero, P. M., Gröbner, J., Kouremeti, N., Almansa, A. F., Stone, T., Sorokin, M., Holben, B., Canini, M., and Yela, M.: The new sun-sky-lunar Cimel CE318-T multiband photometer – a comprehensive performance evaluation , Atmos. Meas. Tech. Discuss., 8, 11077-11138, doi:10.5194/amtd-8-11077-2015, 2015.
- Dyroff, C., Sanati, S., Christner, E., Zahn, A., Balzer, M., Bouquet, H., McManus, J. B., González, Y., and Schneider, M., Airborne in situ vertical profiling of HDO/H216O in the subtropical troposphere during the MUSICA remote sensing validation campaign, Atmos. Meas. Tech., 8, 2037-2049, 2015, doi:10.5194/amt-8-2037-2015, 2015.
- González, Y., Schneider, M., Dyroff, C., Rodríguez, S., Christner, E., García, O. E.¸ Cuevas, E.¸ Bustos, J. J., Ramos, R., Guirado-Fuentes, C., Barthlott, S., Wiegele, A. and Sepúlveda, E.: Detecting moisture transport pathways to the subtropical North Atlantic free troposphere using paired H2O-δD in situ measurements, Atmos. Chem. Phys. Discuss., 15, 27219–27251, 2015.
- Román, R., M. Antón, V.E. Cachorro, D. Loyola, J.P. Ortiz de Galisteo, A. de Frutos, P.M. Romero-Campos, : Comparison of total water vapor column from GOME-2 on MetOp-A against ground-based GPS measurements at the Iberian Peninsula, Science of The Total Environment, Volume 533, 15 November 2015, Pages 317-328, ISSN 0048-9697, http://dx.doi.org/10.1016/j.scitotenv.2015.06.124, 2015.
- Scheepmaker, R. A., Frankenberg, C., Deutscher, N. M., Schneider, M., Barthlott, S., Blumenstock, T., Garcia, O. E., Hase, F., Jones, N., Mahieu, E., Notholt, J., Velazco, V., Landgraf, J., and Aben, I.: Validation of SCIAMACHY HDO/H2O measurements using the TCCON and NDACC-MUSICA networks, Atmos. Meas. Tech., 8, 1799-1818, doi:10.5194/amt-8-1799-2015, 2015.
- Schneider, M., González, Y., Dyroff, C., Christner, E., Wiegele, A., Barthlott, S., García, O. E., Sepúlveda, E., Hase, F., Andrey, J., Blumenstock, T., Guirado, C., Ramos, R., and Rodríguez, S.: Empirical validation and proof of added value of MUSICA's tropospheric δD remote sensing products, Atmos. Meas. Tech., 8, 483-503, doi:10.5194/amt-8-483-2015, 2015.
- Barreto, A., Cuevas, E., Pallé, P., Romero, P. M., Guirado, C., Wehrli, C. J., and Almansa, F.: Recovering long-term aerosol optical depth series (1976–2012) from an

astronomical potassium-based resonance scattering spectrometer, Atmos. Meas. Tech., 7, 4103-4116, doi:10.5194/amt-7-4103-2014, 2014.

- Barreto, A., Cuevas, E., Damiri, B., Romero, P. M., and Almansa, F.: Column water vapor determination in night period with a lunar photometer prototype, Atmos. Meas. Tech., 6, 2159-2167, doi:10.5194/amt-6-2159-2013, 2013. (http://www.atmos-meas-tech.net/6/2159/2013/amt-6-2159-2013.pdf).
- Barreto, A., Cuevas, E., Damiri, B., Guirado, C., Berkoff, T., Berjón, A. J., Hernández, Y., Almansa, F., and Gil, M.: A new method for nocturnal aerosol measurements with a lunar photometer prototype , Atmos. Meas. Tech., 6, 585-598, doi:10.5194/amt-6-585-2013, 2013. (http://www.atmos-meas-tech.net/6/585/2013/amt-6-585-2013.pdf).
- Guirado, C., R. Ramos, A. de Frutos, A. Berjón, A. Redondas, C López, V. Cachorro, E. Cuevas, R. González, S. González, M. Hernánez, Optical calibration facility at the Izaña Atmospheric Research Center, Opt. Pura Apl., 45 (1) 57-62, Special Section: 37th AMASOM Instrumentation and Techniques, 2012. (http://izana.aemet.es/images/stories/news/imgnews2012/OPA45-1-57.pdf).
- Mazzola, M., A. Lupi, V. Vitale, C. Tomasi, R. S. Stone, A. Herber, C. Toledano, V. E. Cachorro, B. Torres, A. Berjón, J. P. Ortiz, N. T. O. Neill, S. Masataka, K. Stebel, V. Aaltonen, T. Zielinski, T. Petelski, P. Goloub, L. Blarel, Z. Li, I. Abboud, E. Cuevas, M. Stock, K-H. Schulz, A. Virkkula, Evaluation of Sun photometer capabilities for retrievals of aerosol optical depth at high latitudes: the POLAR-AOD intercomparison campaigns, Atmos. Environ., 52, 4-17, (2012). (http://www.sciencedirect.com/science/article/pii/S1352231011007862).
- Schneider, M., P. M. Romero, F. Hase, T. Blumenstock, E. Cuevas, and R. Ramos: Continuous quality assessment of atmospheric water vapour measurement techniques: FTIR, Cimel, MFRSR, GPS, and Vaisala RS92, Atmos. Meas. Tech., 3, 323-338, 2010. (http://www.atmos-meas-tech.net/3/323/2010/amt-3-323-2010.pdf).